

New Particle Physics Predicted by TGD: Part I

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Abstract

TGD predicts a lot of new physics and it is quite possible that this new physics becomes visible at LHC. Although the calculational formalism is still lacking, p-adic length scale hypothesis allows to make precise quantitative predictions for particle masses by using simple scaling arguments.

The basic elements of quantum TGD responsible for new physics are following.

1. The new view about particles relies on their identification as partonic 2-surfaces (plus 4-D tangent space data to be precise). This effective metric 2-dimensionality implies generalization of the notion of Feynman diagram and holography in strong sense. One implication is the notion of field identity or field body making sense also for elementary particles and the Lamb shift anomaly of muonic hydrogen could be explained in terms of field bodies of quarks.
2. The topological explanation for family replication phenomenon implies genus generation correspondence and predicts in principle infinite number of fermion families. One can however develop a rather general argument based on the notion of conformal symmetry known as hyper-ellipticity stating that only the genera $g = 0, 1, 2$ are light. What “light” means is however an open question. If light means something below CP_2 mass there is no hope of observing new fermion families at LHC. If it means weak mass scale situation changes.

For bosons the implications of family replication phenomenon can be understood from the fact that they can be regarded as pairs of fermion and antifermion assignable to the opposite wormhole throats of wormhole throat. This means that bosons formally belong to octet and singlet representations of dynamical $SU(3)$ for which 3 fermion families define 3-D representation. Singlet would correspond to ordinary gauge bosons. Also interacting fermions suffer topological condensation and correspond to wormhole contact. One can either assume that the resulting wormhole throat has the topology of sphere or that the genus is same for both throats.

3. The view about space-time supersymmetry differs from the standard view in many respects. First of all, the super symmetries are not associated with Majorana spinors. Super generators correspond to the fermionic oscillator operators assignable to leptonic and quark-like induced spinors and there is in principle infinite number of them so that formally one would have $\mathcal{N} = \infty$ SUSY. I have discussed the required modification of the formalism of SUSY theories and it turns out that effectively one obtains just $\mathcal{N} = 1$ SUSY required by experimental constraints. The reason is that the fermion states with higher fermion number define only short range interactions analogous to van der Waals forces. Right handed neutrino generates this super-symmetry broken by the mixing of the M^4 chiralities implied by the mixing of M^4 and CP_2 gamma matrices for induced gamma matrices. The simplest assumption is that particles and their superpartners obey the same mass formula but that the p-adic length scale can be different for them.
4. The new view about particle massivation based on p-adic thermodynamics raises the question about the role of Higgs field. The vacuum expectation value (VEV) of Higgs is not feasible in TGD since CP_2 does not allow covariantly constant holomorphic vector fields. The original too strong conclusion from this was that TGD does not allow Higgs. Higgs VEV is not needed for the selection of preferred electromagnetic direction in electro-weak gauge algebra (unitary gauge) since CP_2 geometry does that. p-Adic thermodynamics explains fermion masses but the masses of weak bosons cannot be understood on basis of p-adic thermodynamics alone giving extremely small second order contribution only and failing to explain W/Z mass ratio. Weak boson mass can be associated to the string tension of the strings connecting the throats of two wormhole contacts associated with elementary particle (two of them are needed since the monopole magnetic flux must have closed field lines).
5. One of the basic distinctions between TGD and standard model is the new view about color.
 - (a) The first implication is separate conservation of quark and lepton quantum numbers implying the stability of proton against the decay via the channels predicted by GUTs. This does not mean that proton would be absolutely stable. p-Adic and dark length scale hierarchies indeed predict the existence of scale variants of quarks and leptons and proton could decay to hadrons of some zoomed up copy of hadrons physics. These decays should be slow and presumably they would involve phase

transition changing the value of Planck constant characterizing proton. It might be that the simultaneous increase of Planck constant for all quarks occurs with very low rate.

- (b) Also color excitations of leptons and quarks are in principle possible. Detailed calculations would be required to see whether their mass scale is given by CP_2 mass scale. The so called leptohadron physics proposed to explain certain anomalies associated with both electron, muon, and τ lepton could be understood in terms of color octet excitations of leptons.
6. Fractal hierarchies of weak and hadronic physics labelled by p-adic primes and by the levels of dark matter hierarchy are highly suggestive. Ordinary hadron physics corresponds to $M_{107} = 2^{107} - 1$. One especially interesting candidate would be scaled up hadronic physics which would correspond to $M_{89} = 2^{89} - 1$ defining the p-adic prime of weak bosons. The corresponding string tension is about 512 GeV and it might be possible to see the first signatures of this physics at LHC. Nuclear string model in turn predicts that nuclei correspond to nuclear strings of nucleons connected by colored flux tubes having light quarks at their ends. The interpretation might be in terms of M_{127} hadron physics. In biologically most interesting length scale range 10 nm-2.5 μ m there are four Gaussian Mersennes and the conjecture is that these and other Gaussian Mersennes are associated with zoomed up variants of hadron physics relevant for living matter. Cosmic rays might also reveal copies of hadron physics corresponding to M_{61} and M_{31} .

The well-definedness of em charge for the modes of induced spinor fields localizes them at 2-D surfaces with vanishing W fields and also Z^0 field above weak scale. This allows to avoid undesirable parity breaking effects. It is quite possible that this localization is consistent with Kähler-Dirac equation only in the Minkowskian regions where the effective metric defined by Kähler-Dirac gamma matrices can be effectively 2-dimensional and parallel to string world sheet.

7. Weak form of electric magnetic duality implies that the fermions and antifermions associated with both leptons and bosons are Kähler magnetic monopoles accompanied by monopoles of opposite magnetic charge and with opposite weak isospin. For quarks Kähler magnetic charge need not cancel and cancellation might occur only in hadronic length scale. The magnetic flux tubes behave like string like objects and if the string tension is determined by weak length scale, these string aspects should become visible at LHC. If the string tension is 512 GeV the situation becomes less promising.

In this chapter some aspects of the predicted new physics and possible indications for it are discussed. The evolution of the TGD based view about possible existing Higgs like particle and about space-time SUSY are discussed in separate chapters.

1 Introduction

TGD predicts a lot of new physics and it is quite possible that this new physics becomes visible at LHC. Although calculational formalism is still lacking, p-adic length scale hypothesis allows to make precise quantitative predictions for particle masses by using simple scaling arguments. Actually there is already now evidence for effects providing further support for TGD based view about QCD and first rumors about super-symmetric particles have appeared.

Before detailed discussion it is good to summarize what elements of quantum TGD are responsible for new physics.

1. The new view about particles relies on their identification as partonic 2-surfaces (plus 4-D tangent space data to be precise). This effective metric 2-dimensionality implies generalization of the notion of Feynman diagram and holography in strong sense. One implication is the notion of field identity or field body making sense also for elementary particles and the Lamb shift anomaly of muonic hydrogen could be explained in terms of field bodies of quarks.
2. The topological explanation for family replication phenomenon implies genus generation correspondence and predicts in principle infinite number of fermion families. One can however develop a rather general argument based on the notion of conformal symmetry known as hyper-ellipticity stating that only the genera $g = 0, 1, 2$ are light [?] What "light" means is however an open question. If light means something below CP_2 mass there is no hope of observing new fermion families at LHC. If it means weak mass scale situation changes.

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3. The view about space-time supersymmetry differs from the standard view in many respects. First of all, the super symmetries are not associated with Majorana spinors. Super generators correspond to the fermionic oscillator operators assignable to leptonic and quark-like induced spinors and there is in principle infinite number of them so that formally one would have $\mathcal{N} = \infty$ SUSY. I have discussed the required modification of the formalism of SUSY theories in [?] and it turns out that effectively one obtains just $\mathcal{N} = 1$ SUSY required by experimental constraints. The reason is that the fermion states with higher fermion number define only short range interactions analogous to van der Waals forces. Right handed neutrino generates this super-symmetry broken by the mixing of the M^4 chiralities implied by the mixing of M^4 and CP_2 gamma matrices for induced gamma matrices. The simplest assumption is that particles and their superpartners obey the same mass formula but that the p-adic length scale can be different for them.
4. The new view about particle massivation based on p-adic thermodynamics raises the question about the role of Higgs field. The vacuum expectation value (VEV) of Higgs is not feasible in TGD since CP_2 does not allow covariantly constant holomorphic vector fields. The original too strong conclusion from this was that TGD does not allow Higgs. Higgs VEV is not needed for the selection of preferred electromagnetic direction in electro-weak gauge algebra (unitary gauge) since CP_2 geometry does that. p-Adic thermodynamics explains fermion masses but the masses of weak bosons cannot be understood on basis of p-adic thermodynamics alone giving extremely small second order contribution only and failing to explain W/Z mass ratio. Weak boson mass can be associated to the string tension of the strings connecting the throats of two wormhole contacts associated with elementary particle (two of them are needed since the monopole magnetic flux must have closed field lines).

At M^4 QFT limit Higgs VEV is the only possible description of massivation. Dimensional gradient coupling to Higgs field developing VEV explains fermion masses at this limit. The dimensional coupling is same for all fermions so that one avoids the loss of “naturalness” due to the huge variation of Higgs-fermion couplings in the usual description.

The stringy contribution to elementary particle mass cannot be calculated from the first principles. A generalization of p-adic thermodynamics based on the generalization of super-conformal algebra is highly suggestive. There would be two conformal weights corresponding the the conformal weight assignable to the radial light-like coordinate of light-cone boundary and to the stringy coordinate and third integer characterizing the poly-locality of the generator of Yangian associated with this algebra (n -local generator acts on n partonic 2-surfaces simultaneously).

5. One of the basic distinctions between TGD and standard model is the new view about color.
 - (a) The first implication is separate conservation of quark and lepton quantum numbers implying the stability of proton against the decay via the channels predicted by GUTs. This does not mean that proton would be absolutely stable. p-Adic and dark length scale hierarchies indeed predict the existence of scale variants of quarks and leptons and proton could decay to hadons of some zoomed up copy of hadrons physics. These decays should be slow and presumably they would involve phase transition changing the value of Planck constant characterizing proton. It might be that the simultaneous increase of Planck constant for all quarks occurs with very low rate.
 - (b) Also color excitations of leptons and quarks are in principle possible. Detailed calculations would be required to see whether their mass scale is given by CP_2 mass scale.

The so called lepto-hadron physics proposed to explain certain anomalies associated with both electron, muon, and τ lepton could be understood in terms of color octet excitations of leptons [?]

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In this chapter the predicted new elementary particle physics and possible indications for it are discussed. Second chapter is devoted to new hadron physics and scaled up variants of hadron physics in both quark and lepton sector.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at <http://tgdtheory.fi/tgdglossary.pdf> [L8].

2 Family Replication Phenomenon

2.1 Higher Gauge Boson Families

TGD predicts that also gauge bosons, with gravitons included, should be characterized by family replication phenomenon but not quite in the expected manner. The first expectation was that these gauge bosons would have at least 3 light generations just like quarks and leptons.

Only within last two years it has become clear that there is a deep difference between fermions and gauge bosons. Elementary fermions and particles super-conformally related to elementary fermions correspond to single throat of a wormhole contact assignable to a topologically condensed CP_2 type vacuum extremal whereas gauge bosons would correspond to a wormhole throat pair assignable to wormhole contact connecting two space-time sheets. Wormhole throats correspond to light-like partonic 3-surfaces at which the signature of the induced metric changes.

In the case of 3 generations gauge bosons can be arranged to octet and singlet representations of a dynamical $SU(3)$ and octet bosons for which wormhole throats have different genus could be massive and effectively absent from the spectrum.

Exotic gauge boson octet would induce particle reactions in which conserved handle number would be exchanged between incoming particles such that total handle number of boson would be difference of the handle numbers of positive and negative energy throat. These gauge bosons would induce flavor changing but genus conserving neutral current. There is no evidence for this kind of currents at low energies which suggests that octet mesons are heavy. Typical reaction would be $\mu + e \rightarrow e + \mu$ scattering by exchange of $\Delta g = 1$ exotic photon.

2.1.1 New view about interaction vertices and bosons

There are two options for the identification of particle vertices as topological vertices.

1. Option a)

The original assumption was that one can assign also to bosons a partonic 2-surface X^2 with more or less well defined genus g . The hypothesis is consistent with the view that particle reactions are described by smooth 4-surfaces with vertices being singular 3-surfaces intermediate between two three-topologies. The basic objection against this option is that it can induce too high rates for flavor changing currents. In particular $g > 0$ gluons could induce these currents. Second counter argument is that stable $n > 4$ -particle vertices are not possible.

2. Option b)

According to the new vision (option 2)), particle decays correspond to branchings of the partonic 2-surfaces in the same sense as the vertices of the ordinary Feynman diagrams do correspond to branchings of lines. The basic mathematical justification for this vision is the enormous simplification caused by the fact that vertices correspond to non-singular 2-manifolds. This option allows also $n > 3$ -vertices as stable vertices.

A consistency with the experimental facts is achieved if the observed gauge bosons have each value of $g(X^2)$ with the same probability. Hence the general boson state would correspond to a phase $\exp(in2\pi g/3)$, $n = 0, 1, 2$, in the discrete space of 3 lowest topologies $g = 0, 1, 2$. The observed bosons would correspond to $n = 0$ state and exotic higher states to $n = 1, 2$.

The nice feature of this option is that no flavor changing neutral electro-weak or color currents are predicted. This conforms with the fact that CKM mixing can be understood as electro-weak phenomenon described most naturally by causal determinants X_i^3 (appearing as lines of generalized Feynman diagram) connecting fermionic 2-surfaces of different genus.

Consider now objections against this scenario.

1. Since the modular contribution does not depend on the gradient of the elementary particle vacuum functional but only on its logarithm, all three boson states should have mass squared which is the average of the mass squared values $M^2(g)$ associated with three generations. The fact that modular contribution to the mass squared is due to the super-symplectic thermodynamics allows to circumvent this objection. If the super-symplectic p-adic temperature is small, say $T_p = 1/2$, then the modular contribution to the mass squared is completely negligible also for $g > 0$ and photon, graviton, and gluons could remain massless. The wiggling of the elementary particle vacuum functionals at the boundaries of the moduli spaces \mathcal{M}_g corresponding to 2-surfaces intermediate between different 2-topologies (say pinched torus and self-touching sphere) caused by the change of overall phase might relate to the higher p-adic temperature T_p for exotic bosons.
2. If photon states had a 3-fold degeneracy, the energy density of black body radiation would be three times higher than it is. This problem is avoided if the super-symplectic temperature for $n = 1, 2$ states is higher than for $n = 0$ states, and same as for fermions, say $T_p = 1$. In this case two mass degenerate bosons would be predicted with mass squared being the average over the three genera. In this kind of situation the factor $1/3$ could make the real mass squared very large, or order CP_2 mass squared, unless the sum of the modular contributions to the mass squared values $M_{mod}^2(g) \propto n(g)$ is divisible by 3. This would make also photon, graviton, and gluons massive. Fortunately, $n(g)$ is divisible by 3 as is clear from $n(0) = 0$, $n(1) = 9$, $n(2) = 60$.

2.1.2 Masses of genus-octet bosons

For option 1) ordinary bosons are accompanied by $g > 0$ massive partners. For option 2) both ordinary gauge bosons and their exotic partners have suffered maximal topological mixing in the case that they are singlets with respect to the dynamical $SU(3)$. There are good reasons to expect that Higgs mechanism for ordinary gauge bosons generalizes as such and that $1/T_p > 1$ means that the contribution of p-adic thermodynamics to the mass is negligible. The scale of Higgs boson expectation would be given by p-adic length scale and mass degeneracy of octet is expected. A

good guess is obtained by scaling the masses of electro-weak bosons by the factor $2^{(k-89)/2}$. Also the masses of genus-octet of gluons and photon should be non-vanishing and induced by a vacuum expectation of Higgs particle which is electro-weak singlet but genus-octet.

2.1.3 Indications for genus-generation correspondence for gauge bosons

Tommaso Dorigo is a highly inspiring blogger since he writes from the point of view of experimental physicist without the burden of theoretical dogmas. I share with him also the symptoms of splitting of personality to fluctuation-enthusiast and die-hard skeptic. This makes life interesting but not easy. This time Tommaso Dorigo told about the evidence for new neutral gauge boson states in $p\bar{p}$ collisions. The title of the posting was “A New Z' Boson at 240 GeV? No, Wait, at 720!?” [C1].

1. *The findings*

The title tells that the tentative interpretation of these states are as excited states of Z^0 boson and that the masses of the states are around 240 GeV and 720 GeV. The evidence for the new states comes from electron-positron pairs in relatively narrow energy interval produced by the decays of the might-be-there gauge boson. This kind of decay is an especially clean signature since strong interaction effects are not present and it appears at sharp energy.

240 GeV bump was reported by CDF last year [C30] CDF last year in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The probability that it is a fluctuation is 6 per cent. What is encouraging that also D0 found the same bump. If the particle in question is analogous to Z^0 , it should decay also to muons. CDF checked this and found a negative result. This made Tommaso Dorigo rather skeptic.

Also indications for 720 GeV resonance (720 GeV is just a nominal value, the mass could be somewhere between 700-800 GeV) was reported by D0 collaboration: the report is titled as “Search for high-mass narrow resonances in the di-electron channel at D0” [C45]. There are just 2 events above 700 GeV but background is small: just three events above 600 GeV. It is easy to guess what skeptic would say.

Before continuing I want to make clear that I refuse to be blind believer or die-hard skeptic and that I am unable to say anything serious about the experimental side. I am just interested to see whether these events might be interpreted in TGD framework. TGD indeed predicts -or should I say strongly suggests- a lot of new physics above intermediate boson length scale.

2. *Are exotic Z^0 bosons p-adically scaled up variants of ordinary Z^0 boson?*

p-Adic length scale hypothesis allows the p-adic length scale characterized by prime $p \simeq 2^k$ vary since k can have several integer values. The TGD counterpart of Gell-Mann-Okubo mass formula involves varying value of k for quark masses. Several anomalies reported by Tommaso Dorigo during years could be resolved if k can have several values. Last anomaly was the discovery that Ω_b baryon containing two strange quarks and bottom quark seems to appear with two masses differing by about 100 MeV. TGD explains the mass difference correctly by assuming that strange quark can have besides ordinary mass scale mass differing by factor of 2. The prediction is 105 MeV.

One can look whether p-adic length scale hypothesis could explain the masses of exotic Z^0 candidates as multiples of half octaves of Z^0 mass which is 91 GeV. $k=3$ would give 257 GeV, not too far from 240 GeV. $k=6$ would give 728 GeV consistent with the nominal value of the mass. Also other masses are predicted and this could serve as a test for the theory. This option does not however explain why muon pairs are not produced in the case of 240 GeV resonance.

3. *Support for topological explanation of family replication phenomenon?*

The improved explanation is based on TGD based view about family replication phenomenon [K11].

1. In TGD the explanation of family replication is in terms of genus of 2-dimensional partonic surface representing fermion. Fermions correspond to $SU(3)$ triplet of a dynamical symmetry assignable to the three lowest genera (sphere, torus, sphere with two handles). Bosons as wormhole contacts have two wormhole throats carrying fermion numbers and correspond to $SU(3)$ singlet and octet. Sooner or later the members of the octet - presumably heavier than singlet- should be observed (maybe this has been done now).

2. The exchange of these particles predicts also charged flavor changing currents respecting conservation of corresponding “isospin” and “hypercharge”. For instance, lepton quark scattering $e + s \rightarrow \mu + d$ would be possible. The most dramatic signature of these states is production of muon-positron pairs (for instance) via decays.
3. Since the Z^0 or photon like boson in question has vanishing “isospin” and “hypercharge”, it must be orthogonal to the ordinary Z^0 which couples identically to all families. There are two states of this kind and they correspond to superpositions of fermion pairs of different generations in TGD framework. The two bosons - very optimistically identified as 240 GeV and 720 GeV Z^0 , must be orthogonal to the ordinary Z^0 . This requires that the phase factors in superposition of pairs adjust themselves properly. Also mixing effects breaking color symmetry are possible and expected to occur since the SU(3) in question is not an exact symmetry. Hence the exotic Z^0 bosons *could* couple preferentially to some fermion generation. This kind of mixing might be used to explain the absence of muon pair signal in the case of 240 GeV resonance.
4. The prediction for the masses is same as for the first option if the octet and singlet bosons have identical masses for same p-adic mass scale so that mass splitting between different representations would take place via the choice of the mass scale alone.

4. *Could scaled up copy of hadron physics involved?*

One can also ask whether these particles could come from the decays of hadrons of a scaled up copy of hadron physics strongly suggested by p-adic length scale hypothesis.

1. Various hadron physics would correspond to Mersenne primes: standard hadron physics to M_{107} and new hadron physics to Mersenne prime $M_{89} = 2^{89} - 1$. The first guess for the mass scale of “light” M^{89} hadrons would be $2^{(107-89)/2} = 512$ times that for ordinary hadrons. The electron pairs might result in a decay of scaled up variant of pseudo-scalar mesons π , η , or of η' or spin one ρ and ω mesons with nearly the same mass. Only scaled up ρ and ω mesons remains under consideration if one assumes spin 1.
2. The scaling of pion mass about 140 MeV gives 72 GeV. This is three times smaller than 240 GeV but this is extremely rough estimate. Actually it is the p-adic mass scale of quarks involved which matters rather than that of hadronic space-time sheet characterized by M_{89} . The naïve scaling of the mass of η meson with mass 548 MeV would give about 281 GeV. η' would give 490 GeV. ρ meson with mass would give 396 GeV. The estimates are just order of magnitude estimates since the mass splitting between pseudo-scalar and corresponding vector meson is sensitive to quark mass scale.
3. This option does not provide any explanation for the lack of muon pairs in decays of 240 GeV resonance.

To conclude, family replication phenomenon for gauge bosons is consistent with the claimed masses and also absence of muon pairs might be understood and it remains to be seen whether only statistical fluctuations are in question.

2.1.4 First indications for the breaking of lepton universality due to the higher weak boson generations

Lepton and quark universality of weak interactions is a basic tenet of the standard model. Now the first indications for the breaking of this symmetry have been found.

1. Lubos (<http://tinyurl.com/nymddtq>) tells that LHCb has released a preprint with title “Measurement of the ratio of branching ratios $(B_0 \rightarrow D^* + \tau\nu)/(B_0 \rightarrow D^* + \mu\nu)$ ” [C55]. The news is that the measured branching ratio is about 33 per cent instead of 25 percent determined by mass ratios if standard model is correct. The outcome differs by 2.1 standard deviations from the prediction so that it might be a statistical fluke.

2. There are also indications for second B^0 anomaly discovered at LHCb (<http://tinyurl.com/n6525qs>). B mesons have to long and short-lived variants oscillating to their antiparticles and back - this relates to CP breaking. The surprise is that the second B meson - I could not figure out was it short- or long-lived - prefers to decay to $e\nu$ instead of $\mu\nu$.
3. There are also indications for the breaking of universality [C54] (<http://tinyurl.com/n7nbgrk>) from $B^+ \rightarrow K^+ e^+ e^-$ and $B^+ \rightarrow K^+ \mu^+ \mu^-$ decays.

In TGD framework my first - and wrong - guess for an explanation was CKM mixing for leptons [K11]. TGD predicts that also leptons should suffer CKM mixing induced by the different mixings of topologies of the partonic 2-surfaces assignable to charged and neutral leptons. The experimental result would give valuable information about the values of leptonic CKM matrix. What new this brings is that the decays of W bosons to lepton pairs involve the mixing matrix and CKM matrix whose deviation from unit matrix brings effects anomalous in standard model framework.

The origin of the mixing would be topological - usually it is postulated in completely ad hoc manner for fermion fields. Particles correspond to partonic 2-surfaces- actually several of them but in the case of fermions the standard model quantum numbers can be assigned to one of the partonic surfaces so that its topology becomes especially relevant. The topology of this partonic 2- surface at the end of causal diamond (CD) is characterized by its genus - the number of handles attached to sphere - and by its conformal equivalence class characterized by conformal moduli.

Electron and its muon correspond to spherical topology before mixing, muon and its neutrino to torus before mixing etc. Leptons are modelled assuming conformal invariance meaning that the leptons have wave functions - elementary particle vacuum functionals - in the moduli space of conformal equivalence classes known as Teichmueller space.

Contrary to the naïve expectation mixing alone does *not* explain the experimental finding. Taking into account mass corrections, the rates should be same to different charged leptons since neutrinos are *not* identified. That mixing does not have any implications follows from the unitarity of the CKM matrix.

The next trial is inspired by a recent very special di-electron event and involves higher generations of weak bosons predicted by TGD leading to a breaking of lepton universality. Both Tommaso Dorigo (<http://tinyurl.com/pfw7qqm>) and Lubos Motl (<http://tinyurl.com/hqzat92>) tell about a spectacular 2.9 TeV di-electron event not observed in previous LHC runs. Single event of this kind is of course most probably just a fluctuation but human mind is such that it tries to see something deeper in it - even if practically all trials of this kind are chasing of mirages.

Since the decay is leptonic, the typical question is whether the dreamed for state could be an exotic Z boson. This is also the reaction in TGD framework. The first question to ask is whether weak bosons assignable to Mersenne prime M_{89} have scaled up copies assignable to Gaussian Mersenne M_{79} . The scaling factor for mass would be $2^{(89-79)/2} = 32$. When applied to Z mass equal to about .09 TeV one obtains 2.88 TeV, not far from 2.9 TeV. Eureka!? Looks like a direct scaled up version of Z!? W should have similar variant around 2.6 TeV.

TGD indeed predicts exotic weak bosons and also gluons.

1. TGD based explanation of family replication phenomenon in terms of genus-generation correspondence forces to ask whether gauge bosons identifiable as pairs of fermion and antifermion at opposite throats of wormhole contact could have bosonic counterpart for family replication. Dynamical SU(3) assignable to three lowest fermion generations/genera labelled by the genus of partonic 2-surface (wormhole throat) means that fermions are combinatorially SU(3) triplets. Could 2.9 TeV state - if it exists - correspond to this kind of state in the tensor product of triplet and antitriplet? The mass of the state should depend besides p-adic mass scale also on the structure of SU(3) state so that the mass would be different. This difference should be very small.
2. Dynamical SU(3) could be broken so that wormhole contacts with different genera for the throats would be more massive than those with the same genera. This would give SU(3) singlet and two neutral states, which are analogs of η' and η and π^0 in Gell-Mann's quark model. The masses of the analogs of η and π^0 and the analog of η' , which I have identified as standard weak boson would have different masses. But how large is the mass difference?

3. These 3 states are expected to have identical mass for the same p-adic mass scale, if the mass comes mostly from the analog of hadronic string tension assignable to magnetic flux tube. connecting the two wormhole contacts associates with any elementary particle in TGD framework (this is forced by the condition that the flux tube carrying monopole flux is closed and makes a very flattened square shaped structure with the long sides of the square at different space-time sheets). p-Adic thermodynamics would give a very small contribution genus dependent contribution to mass if p-adic temperature is $T = 1/2$ as one must assume for gauge bosons ($T = 1$ for fermions). Hence 2.95 TeV state could indeed correspond to this kind of state.
4. Can one imagine any pattern for the Mersennes and Gaussian Mersennes involved? Charged leptons correspond to electron (M_{127}), muon ($M_{G,113}$) and tau (M_{107}): Mersenne- Gaussian Mersenne-Mersenne. Does one have similar pattern for gauge bosons too: $M_{89} - M_{G,79} - M_{61}$?

The orthogonality of the 3 weak bosons implies that their charge matrices are orthogonal. As a consequence, the higher generations of weak bosons do not have universal couplings to leptons and quarks. The breaking of universality implies a small breaking of universality in weak decays of hadrons due to the presence of virtual $M_{G,79}$ boson decaying to lepton pair. These anomalies should be seen both in the weak decays of hadrons producing $L\nu$ pairs via the decay of virtual W or its partner $W_{G,79}$ and via the decay of virtual Z of its partner $Z_{G,79}$ to L^+L^- . Also $\gamma_{G,79}$ could be involved.

This could explain the three anomalies associated with the neutral B mesons, which are analogs of neutral K mesons having long- and short-lived variants.

1. The two anomalies involving W bosons could be understood if some fraction of decays takes place via the decay $b \rightarrow c + W_{G,79}$ followed by $W_{G,79} \rightarrow L\nu$. The charge matrix of $W_{G,79}$ is not universal and CP breaking is involved. Hence one could have interference effects, which increase the branching fraction to $\tau\nu$ or $e\nu$ relative to $\mu\nu$ depending on whether the state is long- or short-lived B meson.
2. The anomaly in decays producing charged lepton pairs in decays of B^+ does not involve CP breaking and would be due to the non-universality of $Z_{G,79}$ charge matrix.

One expects that higher generation weak bosons are accompanied by a higher generation Higgses, which differ from SUSY Higgses in the sense that they all have only neutral component. The naïve scaling of the Higgs mass by $2^{(-89-79)/2}$ gives mass of 4 TeV. There are indications for a scalar with this mass!

Year or two after writing the first version of this text, I realized that also the puzzle of proton charge radius due to the observation that the proton radius determined from hydrogen and muonium atom are slightly different could be understood in terms of a second generation of Z boson breaking lepton universality [L22]. This article also explains in more detail the notion of family-SU(3) for gauge bosons. Also the anomaly of anomalous magnetic moment of muon might be understood in this manner.

I also learned (April 2017) about new data concerning B meson anomalies (see <http://tinyurl.com/m7gahup>). The analysis of data is explained at <http://tinyurl.com/m1335qf>. It is interesting to look at these results in more detail from TGD point of view using the data of the first link.

1. There is about 4.0σ deviation from τ/l universality ($l = \mu, e$) in $b \rightarrow c$ transitions. In terms of branching ratios one has:

$$R(D^*) = \frac{Br(B \rightarrow D^* \tau \nu_\tau)}{Br(B \rightarrow D^* l \nu_l)} = 0.316 \pm 0.016 \pm 0.010 \quad ,$$

$$R(D) = \frac{Br(B \rightarrow D \tau \nu_\tau)}{Br(B \rightarrow D l \nu_l)} = 0.397 \pm 0.040 \pm 0.028 \quad ,$$

The corresponding SM values are $R(D^*)_{SM} = 0.252 \pm 0.003$ and $R(D)_{SM} = .300 \pm .008$. My understanding is that the normalization factor in the ratio involves total rate to $D^* l \nu_l$,

$l = \mu, e$ involving only single neutrino in final state whereas the $\tau\nu$ decays involve 3 neutrinos due to the neutrino pair from τ implying broad distribution for the missing mass.

The decays to $\tau\nu_\tau$ are clearly preferred as if there were an exotic W boson preferring to decay $\tau\nu$ over $l\nu$, $l = e, \mu$. In TGD it could be second generation W boson. Note that CKM mixing of neutrinos could also affect the branching ratios.

2. Since these decays are mediated at tree level in the SM, relatively large new physics contributions are necessary to explain these deviations. Observation of 2.6 σ deviation of μ/e universality in the dilepton invariant mass bin $1 \text{ GeV}^2 \leq q^2 \leq 6 \text{ GeV}^2$ in $b \rightarrow s$ transitions:

$$R(K) = \frac{Br(B \rightarrow K\mu^+\mu^-)}{Br(B \rightarrow Ke^+e^-)} = 0.745^{+0.090}_{-0.074} \pm 0.038$$

deviate from the SM prediction $R(K)|_{SM} = 1.0003 \pm 0.0001$.

This suggests the existence of the analog of Z boson preferring to decay to e^+e^- rather than $\mu^+\mu^-$ pairs.

If the charge matrices acting on dynamical family-SU(3) fermion triplet do not depend on electroweak bosons and neutrino CKM mixing is neglected for the decays of second generation W , the data for branching ratios of D bosons implies that the decays to e^+e^- and $\tau^+\tau^-$ should be favored over the decays to $\mu^+\mu^-$. Orthogonality of the charge matrices plus the above data could allow to fix them rather precisely from data. It might be that one must take into account the CKM mixing.

3. CMS recently also searched for the decay $h \rightarrow \tau\mu$ and found a non-zero result of $Br(h \rightarrow \tau\mu) = 0.84^{+0.39}_{-0.37}$, which disagrees by about 2.4σ from 0, the SM value. I have proposed an explanation for this finding in terms of CKM mixing for leptons [L12]. h would decay to W^+W^- pair, which would exchange neutrino transforming to $\tau\mu$ pair by neutrino CKM mixing.
4. According to the reference, for Z' the lower bound for the mass is 2.9 TeV, just the TGD prediction if it corresponds to $M_{G,79}$ so that the mass would be 32 times the mass of ordinary Z boson!

TGD allows also to consider leptoquarks as pairs of leptons and quarks and there is some evidence for them too! I wrote about this an article [L11] (<http://tinyurl.com/m9sn8fm>). Also indications for M_{89} and $M_{G,79}$ hadron physics with scaled up mass scales is accumulating [L13] (<http://tinyurl.com/lkdov99>). It seems that TGD is really there and nothing can prevent it showing up, and QCD is shifting to the verge of revolution [L1] (<http://tinyurl.com/lcpp5z1>). I predict that next decades in physics will be a New Golden Age as colleagues finally wake up.

2.1.5 The latest piece in the story

The latest piece in the story emerged as I found in FB a link to a highly interesting popular article "Dark matter exists? Chinese satellite detects mysterious signals while measuring cosmic rays" (see <http://tinyurl.com/ycoyr6bm>). There is an article in Nature with title "*Direct detection of a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons*" (see <http://tinyurl.com/y8sm5v36>) by DAMPE collaboration [C50].

A Chinese satellite – Dark Matter Particle Explorer (DAMPE), also called Wukong or "Monkey King", is reported to have made a discovery. The energy spectrum of cosmic ray electrons and positrons is measured. The surprise was that there is a break at about .9 TeV and a strange spike at around 1.4 TeV. The conclusion is that the spike indicates a particle with a mass of about 1.4 TeV on the spectrum. To me a more natural conclusion would be that there is a particle with mass 2.8 TeV decaying to electron positron pair. Unfortunately, the popular article does not allow to conclude what is the precise finding.

In any case, TGD predicts scaled up variant of electroweak physics and there are several pieces of evidence for its existence coming from the violation of lepton and quark universality [L24, L13, L22]. The mass scale for this physics would correspond to Gaussian Mersenne prime $M_{G,79} = (1+i)^{79} - 1$

and is obtained by scaling the mass scale of electroweak physics by a factor 32. This predicts the mass of Z boson of this physics to be 2.9 TeV. It would decay to electron positron pairs with members having energy 1.45 TeV in cm system. Also gluons could have scaled up variants and there is some evidence for this too for the breaking of the quark universality (see

Cosmic ray electron and positron spectra are found to have peak at 1.4 TeV. Could they result in the decays of the second generation Z boson with mass 2.9 TeV? In TGD framework this boson would not however solve dark matter puzzle. In TGD Universe dark matter has explanation as $h_{eff}/h = n$ phases of ordinary matter. Could the "break" at about .9 TeV (I am not quite sure what "break" really means) relate to massive photon of $M_{G,79}$ physics.

Article also mentions that the cosmic ray positron flux is higher than predicted above 70 GeV. That this energy corresponds to the mass of M_{89} pion, might not be an accident. The decay to gamma pairs dominates and gives a peak but the rate for the decay to $\gamma + e^+e^-$ pair would be by factor of order $\alpha \sim 1/137$ lower and would give a break rather than peak since the energy spectrum of pairs is continuous. Therefore support for both M_{89} and $M_{G,79}$ physics emerges. Maybe the long-awaited breakthrough of TGD might not be in too far future.

2.2 A Slight Indication For The Exotic Octet Of Gauge Bosons From Forward-Backward Asymmetry In Top Pair Production

CDF has reported two anomalies related to the production of top quark pairs. The production rate for the pairs is too high and the forward backward asymmetry is also anomalously high. Both these anomalies could be understood as support for the octet of gauge bosons associated predicted by TGD based explanation of family replication phenomenon [K11]. The exchange of both gauge bosons would induce both charged and neutral flavour changing electroweak and color currents.

2.2.1 Two high production rate for top quark pairs

Both Jester (see <http://tinyurl.com/y7ybabsj>) and Lubos Motl (see <http://tinyurl.com/y8epcrmb>) tell about top quark related anomaly in proton-antiproton collisions at Tevatron reported by CDF collaboration. The anomaly has been actually reported already last summer but has gone un-noticed. More detailed data can be found in [C6] (see <http://tinyurl.com/ybvzrtpa>).

What has been found is that the production rate for jet pairs with jet mass around 170 GeV, which happens to correspond to top quark mass, the production cross section is about 3 times higher higher than QCD simulations predict. 3.44 sigma deviation is in question meaning that its probability is same as for the normalized random variable x/σ to be larger than 3.44 for Gaussian distribution $exp(-(x/\sigma)^2/2)/(2\pi\sigma^2)^{1/2}$. Recall that 5 sigma is regarded as so improbable fluctuation that one speaks about discovery. If top pairs are produced by some new particle, this deviation should be seen also when second top decays leptonically meaning a large missing energy of neutrino. There is however a slight deficit rather than excess of these events.

One can consider three interpretations.

1. The effect is a statistical fluke. But why just at the top quark mass?
2. The hadronic signal is real but there is a downwards fluctuation reducing the number of leptonic events slightly from the expected one. In the leptonic sector the measurement resolution is poorer so that this interpretation looks reasonable. In this case the decay of some exotic boson to top quark pair could explain the signal. Below this option will be considered in more detail in TGD framework and the nice thing is that it can be connected to the anomalously high forward backward asymmetry in top quark pair production (see <http://tinyurl.com/3y5hht7>) reported by CDF for few weeks ago [C31].
3. Both effects are real and the signal is due to R-parity violating 3-particle decays of gluinos with mass near to top quark mass. This is the explanation proposed in the paper of Perez and collabators (see <http://tinyurl.com/ydbo97sr>).

2.2.2 Too high forward backward asymmetry in the production rate for top quark pairs

There is also a second anomaly involved with top pair production. Jester (see <http://tinyurl.com/4b622rx>) reports new data [C94] about the strange top-pair forward-backward asymmetry in top pair production in p-pbar collisions already mentioned [C31]. In Europhysics 2011 conference D0 collaboration reported the same result. CMS collaboration found however no evidence for the asymmetry (see <http://tinyurl.com/ydxe5n8o>) in p-p collisions at LHC [C38]. For top pairs with invariant mass above 450 GeV the asymmetry is claimed by CDF to be stunningly large 48+/-11 per cent. 3 times more often top quarks produced in qqbar annihilation prefer to move in the direction of quark. Note that this experiment would have reduced the situation from the level of ppbar collisions to the level of quark-antiquark collisions and the negative result suggests that valence quarks might play an essential role in the anomaly.

The TGD based explanation for the finding would relation on the flavor octet of gluons and the new view about Feynman diagrams.

1. The identification of family replication phenomenon in terms of genus of the wormhole throats [K11] predicts that family replication corresponds to a dynamical SU(3) symmetry (having nothing to do with color SU(3) or Gell-Mann's SU(3)) with gauge bosons belonging to the octet and singlet representations. Ordinary gauge bosons would correspond besides the familiar singlet representation also to exotic octet representation for which the exchanges induce neutral flavor changing currents in the case of gluons and neutral weak bosons and charge changing ones in the case of charged gauge bosons. The exchanges of the octet representation for gluons could explain both the anomalously high production rate of top quark pairs and the anomalously large forward backward asymmetry! Also electroweak octet could of course contribute.
2. This argument requires a more detailed explanation for what happens in the exchange of gauge boson changing the genus. Particles correspond to wormhole contacts. For topologically condensed fermions the genus of the second throat is that of sphere created when the fermionic CP_2 vacuum extremal touches background space sheet. For bosons both wormhole throats are dynamical and the topologies of both throats matter. The exchange diagram corresponds to a situation in which $g = g_i$ fermionic wormhole throat from past turns back in time spending some time as second throat of virtual boson wormhole contact and $g = g_f$ from future turns back in time and defines the second throat of virtual boson wormhole contact. The turning corresponds to gauge boson exchange represented by a wormhole contact with $g = g_i$ and $g = g_f$ wormhole throats. Ordinary gauge bosons are quantum superpositions of (g, g) pairs transforming as SU(3) singlets and SU(3) charged octet bosons are of pairs (g_1, g_2) with $g_1 \neq g_2$. In the absence of topological mixing of fermions inducing CKM mixing the exchange is possible only between fermions of same generation. The mixing is however large and changes the situation.
3. One could say that top quark from the geometric future transforms at exchange line to space-like t-quark (genus $g = 2$) and returns to future. The quark from the geometric past does the same and returns back to the past as antiquark of antiproton. In the exchange line this quark combines with t-quark to form a virtual color octet gluon.

This mechanism could also give additional contributions to the mechanism generating CP breaking since new box diagrams involving two exchanges of flavor octet weak boson contribute to the mixings of quark pairs in mesons. The exchanges giving rise to an intermediate state of two top quarks are expected to give the largest contribution to the mixing of the neutral quark pairs making up the meson. This involves exchange of a member W boson flavor octet boson analogous to the usual exchange of the flavor singlet boson. This might relate to the reported anomalous like sign muon asymmetry in BBbar decay [C46] suggesting that the CP breaking in this system is roughly 50 times larger than predicted by CKM matrix. The new diagrams would only amplify the CP breaking associated with CKM matrix rather than bringing in any new source of CP breaking. This mechanism increases also the CP breaking in KKbar system known to be also anomalously high.

2.3 The Physics Of $M - \bar{M}$ Systems Forces The Identification Of Vertices As Branchings Of Partonic 2-Surfaces

For option 2) gluons are superpositions of $g = 0, 1, 2$ states with identical probabilities and vertices correspond to branchings of partonic 2-surfaces. Exotic gluons do not induce mixing of quark families and genus changing transitions correspond to light like 3-surfaces connecting partonic 2-surfaces with different genera. CKM mixing is induced by this topological mixing. The basic testable predictions relate to the physics of $M\bar{M}$ systems and are due to the contribution of exotic gluons and large direct CP breaking effects in $K - \bar{K}$ favor this option.

For option 1) vertices correspond to fusions rather than branchings of the partonic 2-surfaces. The prediction that quarks can exchange handle number by exchanging $g > 0$ gluons (to be denoted by G_g in the sequel) could be in conflict with the experimental facts.

1. *CP breaking in $K - \bar{K}$ as a basic test*

CP breaking physics in kaon-antikaon and other neutral pseudo-scalar meson systems is very sensitive to the new physics. What makes the situation especially interesting, is the recently reported high precision value for the parameter ϵ'/ϵ describing direct CP breaking in kaon-antikaon system [C76]. The value is almost by an order of magnitude larger than the standard model expectation. $K - \bar{K}$ mass difference predicted by perturbative standard model is 30 per cent smaller than the the experimental value and one cannot exclude the possibility that new physics instead of/besides non-perturbative QCD might be involved.

In standard model the low energy effective action is determined by box and penguin diagrams. $\Delta S = 2$ piece of the effective weak Lagrangian, which describes processes like $s\bar{d} \rightarrow d\bar{s}$, determines the value of the $K - \bar{K}$ mass difference Δm_K and since this piece determines $K \rightarrow \bar{K}$ amplitude it also contributes to the parameter ϵ characterizing indirect CP breaking. $\Delta S = 2$ part of the weak effective action corresponds to box diagrams involving two W boson exchanges.

2. *Δm_K kills option a*

For option 1) box diagrams involving Z and $g > 0$ exchanges are allowed provided exchanges correspond to exchange of both Z and $g > 0$ gluon. The most obvious objection is that the exchanges of $g > 0$ gluons make strong $\Delta S > 0$ decays of mesons possible: $K_S \rightarrow \pi\pi$ is a good example of this kind of decay. The enhancement of the decay rate would be of order $(\alpha_s(g = 1)/\alpha_{em})^2(m_W/m_G(g = 1))^2 \sim 10^3$. Also other $\Delta S = 1$ decay rates would be enhanced by this factor. The real killer prediction is a gigantic value of Δm_K for kaon-antikaon system resulting from the possibility of $\bar{s}d \rightarrow \bar{d}s$ decay by single $g = 1$ gluon exchange. This prediction alone excludes option 1).

3. *Option 2) could explain direct CP breaking*

For option 2) box diagrams are not affected in the lowest order by exotic gluons. The standard model contributions to Δm_K and indirect CP breaking are correct for the observed value of the top quark mass which results if top corresponds to a secondary padic length scale $L(2, k)$ associated with $k = 47$ (Appendix). Higher order gluonic contribution could increase the value of Δm_K predicted to be about 30 per cent too small by the standard model.

In standard model penguin diagrams contribute to $\Delta S = 1$ piece of the weak Lagrangian, which determines the direct CP breaking characterized by the parameter ϵ'/ϵ . Penguin diagrams, which describe processes like $s\bar{d} \rightarrow d\bar{d}$, are characterized by effective vertices dsB , where B denotes photon, gluon or Z boson. dsB vertices give the dominant contribution to direct CP breaking in standard model. The new penguin diagrams are obtained from ordinary penguin diagrams by replacing ordinary gluons with exotic gluons.

For option 2) the contributions predicted by the standard model are multiplied by a factor 3 in the approximation that exotic gluon mass is negligible in the mass scale of intermediate gauge boson. These diagrams affect the value of the parameter ϵ'/ϵ characterizing direct CP breaking in $K - \bar{K}$ system found experimentally to be almost order of magnitude larger than standard model expectation [C76].

2.4 How to describe family replication phenomenon gauge theoretically?

In TGD framework family replication phenomenon is described topologically [K11] (see <http://tinyurl.com/y7s8e1pc>). The problem is to modify the gauge theory approach of the standard model to model to describe family replication phenomenon at QFT limit.

2.4.1 Original picture about family replication phenomenon

The original view about family replication phenomenon assumed that fermions correspond to single boundary component of the space-time surface (liquid bubble is a good analogy) and thus characterized by genus g telling the number of handles attached to the sphere to obtain the bubble topology.

1. Ordinary bosons would correspond to $g = 0$ (spherical) topology and the absorption/emission of boson would correspond to 2-D topological sum in either time direction. This interpretation conforms with the universality of ordinary ew and color interactions.
2. The genera of particle and antiparticle would have formally opposite sign and the total genus would be conserved in the reaction vertices. This makes sense if the annihilation of fermion and anti-fermion to $g = 0$ boson means that fermion turns backwards in time emitting boson. The vertex is essentially 2-D topological sum at criticality between two manifold topologies. In the vertex 2-surface would be therefore singular manifold. The analogy to closed string emission in string model is obvious.

2.4.2 The recent vision

Later the original picture was replaced with a more complex identification.

1. Fundamental particles - partons - serving as building bricks of elementary particles are partonic 2-surfaces identified as throats of wormhole contacts at which the Euclidian signature of the induced metric of the wormhole contact changes to Minkowskian one. The orbit of partonic 2-surface corresponds to a light-like 3-surface at which the Minkowskian signature of the induced metric changes to Euclidian, and carries fermion lines defining of boundaries of string world sheets. Strings connect different wormhole throats and mean generalization of the notion of point like particle leading to the notion of tensor network [K19] (see <http://tinyurl.com/y9kwnqfa>).

Elementary particles are pairs of two wormhole contacts. Both fermions and bosons are pairs of string like flux tubes at parallel space-time sheets and connected at their ends by CP_2 sized wormhole contacts having Euclidian signature of induced metric. A non-vanishing monopole flux loop runs around the extremely flattened rectangle loop connecting wormhole throats at both space-time sheets and traverses through the contacts.

2. The throats of wormhole contacts are characterized by genus given by the number g of handles attached to sphere to get the topology. If the genera g_a, g_b of the opposite throats of given wormhole contact are same, one can assign genus to it : $g = g_a = g_b$. This can be defended by the fact, that the distance between the throats is given by CP_2 length scale and thus extremely short so that $g_a \neq g_b$ implies strong gradients and by Uncertainty Principle mass of order CP_2 mass.

If the genera of the two wormhole contacts are same: $g_1 = g_2$, one one can assign genus g to the particle. This assumption is more questionable if the distance between contacts is of order of Compton length of the particle. The most general assumption is that all genera can be different.

3. There is an argument for why only 3 lowest fermion generations are observed [K11] (see <http://tinyurl.com/y7s8e1pc>). Assume that the genus g for all 4 throats is same. For $g = 0, 1, 2$ the partonic 2-surfaces are always hyper-elliptic allowing thus a global conformal Z_2 symmetry. Only these 3 2-topologies would be realized as elementary particles whereas higher generations would be either very heavy or analogous to many-particle states with a continuum mass spectrum. For the latter option $g = 0$ and $g = 1$ state could be seen as

vacuum and single particle state whereas $g = 2$ state could be regarded as 2-particle bound state. The absence of bound n -particle state with $n > 2$ implies continuous mass spectrum.

4. Fundamental particles would wave function in the conformal moduli space associated with its genus (Teichmueller space) [K11]. For fundamental fermions the wave function would be strongly localized to single genus. For ordinary bosons one would have maximal mixing with the same amplitude for the appearance of wormhole throat topology for all genera $g = 0, 1, 2$. For the two other $u(3)_g$ neutral bosons in octet one would have different mixing amplitudes and charge matrices would be orthogonal and universality for the couplings to ordinary fermions would be broken for them. The evidence for the breaking of the universality [K25] (see <http://tinyurl.com/y7axat8j>) is indeed accumulating and exotic $u(3)_g$ neutral gauge bosons giving effectively rise to two additional boson families could explain this.

2.4.3 Two questions related to bosons and fermions

What about gauge bosons and Higgs, whose quantum numbers are carried by fermion and anti-fermion (or actually a superposition of fermion-anti-fermion pairs). There are two options.

1. **Option I:** The fermion and anti-fermion for elementary boson are located at opposite throats of wormhole contact as indeed assumed hitherto. This would explain the point-likeness of elementary bosons. $u(3)$ charged bosons having different genera at opposite throats would have vanishing couplings to ordinary fermions and bosons. Together with large mass of $g_a \neq g_b$ wormhole contacts this could explain why $g_a \neq g_b$ bosons and fermions are not observed and would put the Cartan algebra of $u(3)_g$ in physically preferred position. Ordinary fermions would effectively behave as $u(3)_g$ triplet.
2. **Option II:** The fermion and anti-fermion for elementary boson are located at throats of different wormhole contacts making them non-point like string like objects. For hadron like stringy objects, in particular graviton, the quantum numbers would necessarily reside at both ends of the wormhole contact if one assumes that single wormhole throats carries at most one fermion or anti-fermion. For this option also ordinary fermions could couple to (probably very massive) exotic bosons different genera at the second end of the flux tube.

There are also two options concerning the representation of $u(3)_g$ assignal to fermions corresponding to $su(3)_g$ triplet 3 and $8 \oplus 1$.

Option I: Since only the wormhole throat carrying fermionic quantum numbers is active and since fundamental fermions naturally correspond to $u(3)_g$ triplets, one can argue that the wormhole throat carrying fermion quantum number determines the fermionic $u(3)_g$ representation and should be therefore 3 for fermion and $\bar{3}$ anti-fermion.

At fundamental level also bosons would in the tensor products of these representations and many-sheeted description would use these representations. Also the description of graviton-like states involving fermions at all 4 wormhole throats would be natural in this framework. At gauge theory limit sheets would be identified and in the most general case one would need $U(3)_g \times U(3)_g \times U(3)_g \times U(3)_g$ with factors assignable to the 4 throats.

1. The description of weak massivation as weak confinement based on the neutralization of weak isospin requires a pair of left and right handed neutrino located with ν_L and $\bar{\nu}_R$ or their CP conjugates located at opposite throats of the passive wormhole contact associated with fermion. Already this in principle requires 4 throats at fundamental level. Right-handed neutrino however carries vanishing electro-weak quantum numbers so that it is effectively absent at QFT limit.
2. Why should fermions be localized and $su(3)_g$ neutral bosons delocalized with respect to genus? If g labels for states of color triplet 3 the localization of fermions looks natural, and the mixing for bosons occurs only in the Cartan algebra in $u(3)_g$ framework: only $u(3)_g$ neutral states are mix.

Option II: Also fermions belong to $8 + 1$. The simplest assumption is that both fermions and boson having $g_1 \neq g_2$ have large mass. In any case, $g_1 \neq g_2$ fermions would couple only to $u(3)_g$

charged bosons. Also for this option ordinary bosons with unit charge matrix for $u(3)_g$ would couple in a universal manner.

1. The model for CKM mixing [K30] (see <http://tinyurl.com/y7as5ed6>) would be modified in trivial manner. The mixing of ordinary fermions would correspond to different topological mixings of the three states $su(3)$ -neutral fermionic states for U and D type quarks and charged leptons and neutrinos. One could reduce the model to the original one by assuming that fermions do not correspond to generators Id , Y , and I_3 for $su(3)_g$ but their linear combinations giving localization to single valued of g in good approximation: they would correspond to diagonal elements e_{aa} , $a = 1, 2, 3$ corresponding to $g = 0, 1, 2$.
2. p-Adic mass calculations [K22] (see <http://tinyurl.com/y9cvb332>) assuming fixed genus for fermion predict an exponential sensitivity on the genus of fermion. In the general case this prediction would be lost since one would have weighted average over the masses of different genera with $g = 2$ dominating exponentially. The above recipe would cure also this problem. Therefore it seems that one cannot distinguish between the two options allowing $g_1 \neq g_2$. The differences emerge only when all 4 wormhole throats are dynamical and this is the case for graviton-like states (spin 2 requires all 4 throats to be active).

The conclusion seems to be that the two options are more or less equivalent for light fermions. In the case of exotic fermions expected to be extremely heavy the $8 + 1$ option looks more natural. At this limit however QFT limit need not make sense anymore.

2.4.4 Reaction vertices

Consider next the reaction vertices for the option in which particles correspond to string like objects identifiable as pairs of flux tubes at opposite space-time sheets and carrying monopole magnetic fluxes and with ends connected by wormhole contacts.

1. Reaction vertex looks like a simultaneous fusing of two open strings along their ends at given space-time sheets. The string ends correspond to wormhole contacts which fuse together completely. The vertex is a generalization of a Y-shaped 3-vertex of Feynman diagram. Also 3-surfaces assignable to particles meet in the same manner in the vertex. The partonic 2-surface at the vertex would be non-singular manifold whereas the partonic orbit would be singular manifold in analogy with Y shaped portion of Feynman diagram.
2. In the most general case the genera of all four throats involved can be different. Since the reaction vertex corresponds to a fusion of wormhole contacts characterized in the general case by (g_1, g_2) , one must have $(g_1, g_2) = (g_3, g_4)$. The rule would correspond in gauge theory description to the condition that the quark and antiquark $su(3)_g$ charges are opposite at both throats in order to guarantee charge conservation as the wormhole contact disappears.
3. One has effectively pairs of open string fusing along their and the situation is analogous to that in open string theory and described in terms of Chan-Paton factors. This suggests that gauge theory description makes sense at QFT limit.
 - (a) If g is same for all 4 throats, one can characterize the particle by its genus. The intuitive idea is that fermions form a triplet representation of $u(3)_g$ assignable to the family replication. In the bosonic sector one would have only. $u(3)_g$ neutral bosons. This approximation is expected to be excellent.
 - (b) One could allow $g_1 \neq g_2$ for the wormhole contacts but assume same g for opposite throats. In this case one would have $U(3)_g \times U(3)_g$ as dynamical gauge group with $U(3)_g$ associated with different wormhole contacts. String like bosonic objects (hadron like states) could be therefore seen as a nonet for $u(3)_g$. Fermions could be seen as a triplet.

Apart from topological mixing inducing CKM mixing fermions correspond in good approximation to single genus so that the neutral members of $u(3)_g$ nonet, which are superpositions over several genera must mix to produce states for which mixing of genera is small. One might perhaps say that the topological mixing of genera and mixing of $u_3(g)$ neutral bosons are anti-dual.

- (c) If all throats can have different genus one would have $U(3)_g \times U(3)_g \times U(3)_g \times U(3)_g$ as dynamical gauge group $U(3)_g$ associated with different wormhole throats. This option is probably rather academic. Also fermions could be seen as nonets.

2.4.5 What would the gauge theory description of family replication phenomenon look like?

For the most plausible option bosonic states would involve a pair of fermion and anti-fermion at opposite throats of wormhole contact. Bosons would be characterized by adjoint representation of $u(3)_g = su(3)_g \times u(1)_g$ obtained as the tensor product of fermionic triplet representations 3 and $\bar{3}$.

1. $u(1)_g$ would correspond to the ordinary gauge bosons coupling to ordinary fermion generations in the same universal manner giving rise to the universality of electroweak and color interactions.
2. The remaining gauge bosons would belong to the adjoint representation of $su(3)_g$. One indeed expects symmetry breaking: the two neutral gauge bosons would be light whereas charged bosons would be extremely heavy so that it is not clear whether QFT limit makes sense for them.

Their charge matrices Q_g^i would be orthogonal with each other ($Tr(Q_g^i Q_g^j) = 0, i \neq j$) and with the unit charge matrix $u(1)_g$ charge matrix $Q^0 \propto Id$ ($Tr(Q_g^i) = 0$) assignable to the ordinary gauge bosons. These charge matrices act on fermions and correspond to the fundamental representation of $su(3)_g$. They are expressible in terms of the Gell-Mann matrices λ_i (see <http://tinyurl.com/y7ukgf5m>).

How to describe family replication for gauge bosons in gauge theory framework? A minimal extension of the gauge group containing the product of standard model gauge group and $U(3)_g$ does not look promising since it would bring in additional generators and additional exotic bosons with no physical interpretation. This extension would be analogous to the extension of the product $SU(2) \times SU(3)$ of the spin group $SU(2)$ and Gell-Mann's $SU(3)$ to $SU(6)$. Same is true about the separate extensions of $U(2)_{ew}$ and $SU(3)_c$.

1. One could start from an algebra formed as a tensor product of standard model gauge algebra $g = su(3)_c \times u(2)_{ew}$ and algebraic structure formed somehow from the generators of $u(3)_g$. The generators would be

$$J_{i,a} = T_i \otimes T_a \quad , \quad (2.1)$$

where i labels the standard model Lie-algebra generators and a labels the generators of $u(3)_g$.

This algebra should be Lie-algebra and reduce to the same as associated with standard model gauge group with generators T^b replacing effectively complex numbers as coefficients. Mathematician would probably say, that standard model Lie algebra is extended to a module with coefficients given by $u(3)_g$ Lie algebra generators in fermionic representation but with Lie algebra product for $u(3)_g$ replaced with a product consistent with the standard model Lie-algebra structure, in particular with the Jacobi-identities.

2. By writing explicitly commutators and Jacobi identifies one obtains that the product must be symmetric: $T_a \circ T_b = T_b \circ T_a$ and must satisfy the conditions $T_a \circ (T_b \circ T_c) = T_b \circ (T_c \circ T_a) = T_c \circ (T_a \circ T_b)$ since these terms appear as coefficients of the double commutators appearing in Jacobi-identities

$$[J_{i,a}, [J_{j,b}, J_{k,c}]] + [J_{j,b}, [J_{k,c}, J_{i,a}]] + [J_{k,c}, [J_{i,a}, J_{j,b}]] = 0 \quad . \quad (2.2)$$

Commutativity reduces the conditions to associativity condition for the product \circ . For the sub-algebra $u(1)_g^3$ these conditions are trivially satisfied.

3. In order to understand the conditions in the fundamental representation of $su(3)$, one can consider the product the $su(3)_g$ product defined by the anti-commutator in the matrix representation provided by Gell-Mann matrices λ_a (see <http://tinyurl.com/y7ukgf5m> and <http://tinyurl.com/y8smg8fz>):

$$\{\lambda_a, \lambda_b\} = \frac{4}{3}\delta_{a,b}Id + 4d_{abc}\lambda^c, \quad Tr(\lambda_a\lambda_b) = 2\delta_{ab}, \quad d_{abc} = Tr(\lambda_a\{\lambda_b, \lambda_c\}). \quad (2.3)$$

d_{abc} is totally symmetric under exchange of any pair of indices so that the product defined by the anti-commutator is both commutative and associative. The product extends to $u(3)_g$ by defining the anti-commutator of Id with λ_a in terms of matrix product. The product is consistent with $su(3)_g$ symmetries so that these dynamical charges are conserved. For complexified generators this means that generator and its conjugate have non-vanishing coefficient of Id .

Remark: The direct sum $u(n) \oplus u(n)_s$ formed by Lie-algebra $u(n)$ and its copy $u(n)_s$ endowed with the anti-commutator product \circ defines super-algebra when one interprets anti-commutator of $u(n)_s$ elements as an element of $u(n)$.

4. Could $SU(3)$ associated with 3 fermion families be somehow special? This is not the case. The conditions can be satisfied for all groups $SU(n)$, $n \geq 3$ in the fundamental representation since they all allow completely symmetric structure constants d_{abc} as also higher completely symmetric higher structure constants $d_{abc\dots}$ up to n indices. This follows from the associativity of the symmetrized tensor product: $((Adj \otimes Adj)_S \otimes Adj)_S = (Adj \otimes (Adj \otimes Adj)_S)_S$ for the adjoint representation.

To sum up, the QFT description of family replication phenomenon with the extension of the standard model gauge group would bring to the theory the commutative and associative algebra of $u(3)_g$ as a new mathematical element. In case of ordinary fermions and bosons and also in the case of $u(3)_g$ neutral bosons the formalism would be however rather trivial modification of the intuitive picture.

2.4.6 New indications for third generation weak bosons

There are indications (see <http://tinyurl.com/y8cwb98b>) that electron neutrinos appear observed by ICECUBE more often than other neutrinos. In particular, the seems to be a deficit of τ neutrinos. The results are very preliminary. In any case, there seems to be an inconsistency between two methods observing the neutrinos. The discrepancy seems to come from higher energy end of the energy range [13 TeV, 7.9 PeV] from energies above 1 PeV.

The article “Invisible Neutrino Decay Could Resolve IceCube’s Track and Cascade Tension” by Peter Denton and Irene Tamborra tries to explain this problem by assuming that τ and μ neutrinos can decay to a superparticle called majoron [C110] (see <http://tinyurl.com/ycvwehmr>).

The standard model for the production of neutrinos is based on the decays of pions producing $e^+\nu_e$ and $\mu^+\nu_\mu$. Also μ^+ can travel to the direction of Earth and decay to $e^+\nu_e\bar{\nu}_\mu$ and double the electron neutrino fraction. The flavor ratio would be 2:1:0.

Remark: The article at (see <http://tinyurl.com/ycvwehmr>) claims that the flavor ratio is 1:2:0 in pion decays, which is wrong: the reason for the lapsus is left as an exercise for the reader.

Calculations taking into account also neutrino oscillations during the travel to Earth to be discussed below leads in good approximation to a predicted flavor ratio 1:1:1. The measurement teams suggest that measurements are consistent with this flavor ratio.

There are however big uncertainties involved. For instance, the energy range is rather wide [13 TeV, 7.9 PeV] and if neutrinos are produce in decay of third generation weak boson with mass about 1.5 PeV as TGD predicts, the averaging can destroy the information about branching fractions.

In TGD based model [L40] [K25] (see <http://tinyurl.com/y94zru7s>) third generation weak bosons - something new predicted by TGD - at mass around 1.5 TeV corresponding to mass scale assignable to Mersenne prime M_{61} (they can have also energies above this energy) would produce neutrinos in the decays to antilepton neutrino pairs.

1. The mass scale predicted by TGD for the third generation weak bosons is correct: it would differ by factor $2^{(89-61)/2} = 2^{14}$ from weak boson mass scale. LHC gives evidence also for the second generation: also now mass scale comes out correctly. Note that ordinary weak bosons would correspond to M_{89} .

2. The charge matrices of 3 generations must be orthogonal and this breaks the universality of weak interactions. The lowest generation has generation charge matrix proportional to (1,1,1) - this generation charge matrix describes couplings to different generations. Unit matrix codes for universality of ordinary electroweak and also color interactions. For higher generations of electro-weak bosons and also gluons universality is lost and the flavor ratio for the produced neutrinos in decays of higher generation weak bosons differs from 1:1:1.

One example of charge matrices would be $\sqrt{3}/2(0, 1, -1)$ for second generation and $(2, -1, -1)/\sqrt{2}$ for the third generation. In this case electron neutrinos would be produced 2 times more than muon and tau neutrinos altogether. The flavor ratio would be 0:1:1 for the second generation and 4:1:1 for the third generation in this particular case.

3. This changes the predictions of the pion decay mechanism. The neutrino energies are above the energy about 1.5 PeV in the range defined by the spectrum of energies for the decaying weak boson. If they are nearly at rest the energies are a peak around the rest mass of third generation weak boson. The experiments detect neutrinos at energy range [13 TeV, 7.9 PeV] having the energy of the neutrinos produced in the decay of third generation weak bosons in a range starting from 1.5 PeV and probably ending below 7.9 PeV. Therefore their experimental signature tends to be washed out if pion decays are responsible for the background.

These fractions are however not what is observed at Earth.

1. Suppose that $L + \nu_L$ pair is produced. It can also happen that L^+ , say μ^+ travels to the direction of Earth. It can decay to $e^+ \bar{\nu}_\mu \nu_e$. Therefore one obtains both ν_μ and ν_e . From the decay to $\tau^+ \nu_\tau$ one obtains all three neutrinos. If the fractions of the neutrinos from the generation charge matrix are (X^e, X^μ, X^τ) , the fractions travelling to each are proportional to

$$\{x^\alpha\} \leftrightarrow \{X^\alpha\} = (X^e, X^\mu, X^\tau) = (x^e + x^\mu + x^\tau, x^\mu + x^\tau, x^\tau) . \quad (2.4)$$

and the flavor ratio in the decays would be

$$X^e : X^\mu : X^\tau = x^e + x^\mu + x^\tau : x^\mu + x^\tau : x^\tau . \quad (2.5)$$

The decays to lower neutrino generations tend to increase the fraction of electronic and muonic neutrinos in the beam.

2. Also neutrino oscillations due to different masses of neutrinos (see <http://tinyurl.com/oov344k>) affect the situation. The analog of CKM matrix describing the mixing of neutrinos, the mass squared differences, and the distance to Earth determines the oscillation dynamics.

One can deduce the mixing probabilities from the analog of Schrödinger equation by using approximation $E = p + m^2/2p$ which is true for energies much larger than the rest mass of neutrinos. The masses of mass eigenstates, which are superpositions of flavour eigenstates, are different.

The leptonic analog of CKM matrix $U_{\alpha i}$ (having in TGD interpretation in terms of different mixings of topologies of partonic 2-surfaces associated with different charge states of various lepton families [K11]) allows to express the flavor eigenstates ν_α as superpositions of mass eigenstates ν_i . As a consequence, one obtains the probabilities that flavor eigenstate ν_α transforms to flavour eigenstate ν_β during the travel. In the recent case the distance is very large and the dependence on the mass squared differences and distance disappears in the averaging over the source region.

The matrix $P_{\alpha\beta}$ telling the transformation probabilities $\alpha \rightarrow \beta$ is given in Wikipedia article (see <http://tinyurl.com/ooV344k>) in the general case. It is easy to deduce the matrix at the limit of very long distances by taking average over source region to get expressions having no dependence

$$P_{\alpha\beta} = \delta_{\alpha\beta} - 2 \sum_{i>j} \text{Re}[U_{\beta i} U_{i\alpha}^\dagger U_{\alpha j} U_{j\beta}^\dagger] . \quad (2.6)$$

Note that $\sum_{\beta} P_{\alpha\beta} = 1$ holds true since in the summation second term vanishes due to unitary condition $U^\dagger U = 1$ and $i > j$ condition in the formula.

3. The observed flavor fraction is $Y_e : Y_\mu : Y_\tau$, where one has

$$Y_\alpha = P_{\alpha\beta} X^\beta . \quad (2.7)$$

It is clear that if the generation charge matrix is of the above form, the fraction of electron neutrinos increases both the decays of τ and μ and by this mechanism. Of course, the third generation could have different charge matrix, say $\sqrt{3/2}(0, 1, -1)$. In this case the effects would tend to cancel.

2.4.7 TGD view about ANITA anomalous events

I read an article [C86] (see <https://arxiv.org/pdf/1809.09615.pdf>) telling about 2 anomalous cosmic ray events detected by ANITA (The Antarctic Impulsive Transient Antenna) collaboration. Also ICECUBE collaboration has observed 3 events of this kind. What makes the events anomalous is that the cosmic ray shower emanates from Earth: standard model does not allow the generation of this kind of showers. The article proposes super-partner of tau lepton known as stau as a possible solution of the puzzle.

Before continuing it is good to summarize the basic differences between TGD and standard model at the level of elementary particle physics. TGD differs from standard model by three basic new elements: p-adic length scale hypothesis predicting a fractal hierarchy of hadron physics and electroweak physics; topological explanation of family replication phenomenon; and TGD view about dark matter.

1. p-Adic length scale hypothesis states that Mersenne primes M_n and Gaussian Mersennes $M_{G,n}$ give rise to scaled variants of ordinary hadron and electroweak physics with mass scale proportional to $\sqrt{M_n} = 2^{n/2}$. M_{127} would correspond to electron and possibly also to what I have called lepto-hadron physics [K47]. Muon and nuclear physics would correspond to $M_{G,113}$ and τ and hadron physics would correspond to M_{107} . Electroweak gauge bosons would correspond to M_{89} . $n_G = 73, 47, 29, 19, 11, 7, 5, 3, 2$ would correspond to Gaussian Mersennes and $n = 61, 31, 19, 17, 13, 7, 5, 3, 2$ to ordinary Mersennes. There are four Gaussian Mersennes corresponding to $n_G \in \{151, 157, 163, 167\}$ in biologically relevant length scale range 10 nm-2.5 μm (from cell membrane thickness to nucleus size): this can be said to be a number theoretical miracle.
2. The basic assumption is that the family replication phenomenon reduces to the topology of partonic 2-surfaces serving as geometric correlates of particles. Orientable topology is characterized by genus - the number of handles attached to sphere to obtain the topology. 3 lowest genera are assumed to give rise to elementary particles. This would be due to the Z_2 global conformal symmetry possible only for $g = 0, 1, 2$ [K11]. By this symmetry single handle behaves like particle and two handles like a bound state of 2 particles. Sphere corresponds to a ground state without particles. For the higher genera handles and handle pairs would behave like a many-particle states with mass continuum.

3. The model of family replication is based on $U(3)$ as dynamical “generation color” acts as a combinatorial dynamical symmetry assignable to the 3 generations so that fermions correspond to $SU(3)$ multiplet and gauge bosons to $U(3)$ octet with lowest generation associated with $U(1)$. Cartan algebra of $U(2)$ would correspond to two light generations with masses above intermediate boson mass scale.

3 “generation neutral” (g-neutral) weak bosons (Cartan algebra) are assigned with $n = 89$ (ordinary weak bosons), $n_G = 79$ and $n_G = 73$ correspond to mass scales $m(79) = 2.6$ TeV and $m(73) = 20.8$ TeV. I have earlier assigned third generation with $n = 61$. The reason is that the predicted mass scale is same as for a bump detected at LHC and allowing interpretation as g-neutral weak boson with $m(61) = 1.3$ PeV.

3+3 g-charged weak bosons could correspond to $n = 61$ with $m(61) = 1.3$ PeV (or $n_G = 73$ boson with $m(73) = 20.8$ TeV) and to $n_G = 47, 29, 19$ and $n = 31, 19$. The masses are $m(47) = .16$ EeV, $m(31) = 256 \times m(47) = 40$ EeV, $m(29) = 80$ EeV, $m(19) = 256$ EeV, $m(17) = .5 \times 10^3$ EeV, and $m(13) = 2 \times 10^3$ EeV. This corresponds to the upper limit for the energies of cosmic rays detected at ANITA.

In TGD framework the most natural identification of Planck length would be as CP_2 length R which is about $10^{3.5}$ times the Planck length as it is usually identified [L37]. Newton’s constant would have spectrum and its ordinary value would correspond to $G = R^2/\hbar_{eff}$ which $\hbar_{eff} \sim 10^7$. UHE cosmic rays would allow to get information about physics near Planck length scale in TGD sense!

4. TGD predicts also a hierarchy of Planck constants $h_{eff} = n \times h_0$, $h = 6h_0$, labelling phases of ordinary matter identified as dark matter. The phases with different values of n are dark matter relative to each other but phase transitions changing the value of n are possible. The hypothesis would realize quantum criticality with long length scale quantum fluctuations and it follows from what I call adelic physics [L28, L29].

n corresponds to the dimension of extension of rationals defining one level in the hierarchy of adelic physics defined by extensions of rationals inducing extensions of p-adic number fields serving as correlates for cognition in TGD inspired theory of consciousness [L31]. p-Adic physics would provide extremely simple but information rich cognitive representations of the real number based physics and the understanding of p-adic physics would be easy manner to understand the real physics. This idea was inspired by the amazing success of p-adic mass calculations [K29], which initiated the progress leading to adelic physics.

It is natural to ask what TGD could say about the Anita anomaly serving as very strong (5 sigma) evidence for new physics beyond standard model. Consider first the basic empirical constraints on the model.

1. According to the article [C86], there are 2 anomalous events detected by ANITA collaboration and 3 such events detected by ICECUBE collaboration. For these events there is cosmic ray shower coming Earth’s interior. Standard model does not allow this kind of events since the incoming particle - also neutrino - would dissipate its energy and never reach the detector.

This serves as a motivation for the SUSY inspired model of the article proposing that stau, super-partner of tau lepton, is created and could have so weak interactions with the ordinary matter that it is able to propagate through the Earth. There must be however sufficiently strong interaction to make the detection possible. The mass of stau is restricted to the range .5-1.0 TeV by the constraints posed by LHC data on SUSY.

2. The incoming cosmic rays associated with anomalous events have energies around $\epsilon_{cr} = .5 \times 10^{18}$ eV. A reasonable assumption is that the rest system of the source is at rest with respect to Earth in an energy resolution, which corresponds to a small energy EeV scale. No astrophysical mechanism producing higher energy cosmic rays about 10^{11} GeV based on standard physics is known, and here the p-adic hierarchy of hadron physics and electroweak physics suggests mechanisms.

In TGD framework the natural question is whether the energy scale correspond to some Mersenne or Gaussian Mersenne so that neutrino and corresponding lepton could have been produced in a decay of W boson labelled by this prime. By scaling of weak boson mass scale Gaussian

Mersenne $M_{G,47} = (1+i)^{47} - 1$ would correspond to a weak boson mass scale $m(47) = 2^{(89-47)/2} \times 80$ GeV = .16 EeV. This mass scale is about roughly a factor 1/3 below the energy scale of the incoming cosmic ray. This would require that the temperature of the source is at least $6 \times m(47)$ at source if neutrino is produced in the decay of $M_{G,47}$ W boson. This option does not look attractive to me.

Could cosmic rays be (possibly dark) protons of $M_{G,47}$ hadron physics?

1. The first objection is that if the proton moves with nearly light-velocity and that its rest mass must be much smaller than its energy. This cannot be the case. The proton should be non-relativistic to have the required mass.
2. The scaling of the mass of the ordinary proton about $m_p(107) \simeq 1$ GeV gives $m_p(47) = 2^{(107-47)/2}$ GeV $\simeq 1$ EeV! This is encouraging! Darkness in TGD sense could make for them possible to propagate through matter. In the interactions with matter neutrinos and leptons would be generated.

The article tells that the energy ϵ_{cr} of the cosmic ray showers is $\epsilon_{cr} \sim .6$ EeV, roughly 60 per cent the rest mass of the proposed cosmic ray proton. I do not know how precise the determination of the energy of the shower is. The production of dark particles during the generation of shower could explain the discrepancy.

3. What could one say about the interactions of dark $M(47)$ proton with ordinary matter? Does $p(47)$ transform to ordinary proton in stepwise manner as Mersenne prime is gradually reduced or in single step. What is the rate for the transformation to ordinary proton. The free path should be a considerable fraction of Earth radius by the argument used in [C86] for stau.

The transformation to ordinary proton would generate a shower containing also tau leptons and tau neutrinos coming pion decays producing muons and electrons and their neutrinos. Neutrino oscillations would produce tau neutrinos: standard model predicts flavor ratio about 1:1:1.

4. What could happen in the strong interactions of dark proton with nuclei? Suppose that dark proton is relativistic with $E_p = xM_p = x$ EeV, $x > 1$, say $x \sim 2$. The total cm energy E_{cm} in the rest system of ordinary proton is for a relativistic!) EeV dark proton + ordinary proton about $E_{cm} = (3/2)\sqrt{x}\sqrt{m_p M_p} = \sqrt{x} \times 5$ TeV, considerably above the rest energy $m_p(89) = 512m_p = .48$ TeV of M_{89} dark proton. The kinetic energy is transformed to rest energy of particles emanating from the collision of dark and ordinary proton.

If the collision takes place with a quark of ordinary proton with mass $m_q = 5$ MeV, E_{cm} is reduced by a factor of $\sqrt{5}10^{-3/2}$ giving $E = \sqrt{x}1.3$ TeV, which is still above for the threshold for transforming the cosmic ray dark proton to M_{89} dark proton.

This suggests that the interaction produce first dark relativistic M_{89} protons, which in further interactions transform to ordinary protons producing the shower and neutrinos. I have proposed already more than two decades ago that strange cosmic ray events such as Centauros generate hot spot involving M_{89} hadrons. At LHC quite a number of bumps with masses obtained by scaling from the masses of mesons of ordinary hadron physics are observed. I have proposed that they are associated with quantum critically assignable to a phase transition analogous to the generation of quark gluon plasma, and are dark in TGD sense having $h_{eff}/h = 512$ so that their Compton wavelengths are same as for ordinary hadrons [K25].

5. The free path of (possibly) dark $M_{G,47}$ proton in ordinary matter should be a considerable fraction of the Earth's radius since the process of tau regeneration based on standard physics cannot explain the findings. The interaction with ordinary matter possibly involving the transformation of the dark proton to ordinary one (or vice versa!) must be induced by the presence of ordinary matter rather than being spontaneous.

Also the flux of cosmic ray protons at EeV energies must be high enough. It is known that UHE cosmic rays very probably are not gamma rays. Besides neutrinos dark $M_{G,47}$ protons would be a natural candidate for them.

The peculiar feature of these cosmic rays is that they are upward going unlike the usual cosmic rays (see <http://tinyurl.com/y9wuub61>). This is what makes difficult the interpretation as high energy neutrinos - the cross section is too large for getting through the Earth. This brings in mind TGD view about formation of galaxies, stars, and even planets [L32, L33, L36, L39, L44]. All these objects would correspond to local tangles along magnetic flux tubes looking like field line pattern of dipole fields replaced with a loopy structure formed by the flux tube. Flux tube would be an outcome of a thickening of a cosmic string - a space-time surface in $H = M^4 \times CP_2$ having 2-D string world sheet as M^4 projection and carrying monopole flux.

Cosmic strings would dominate in primordial cosmology and during the counterpart of inflationary period would thicken and their magnetic and volume energy would start to decay to ordinary matter in analogy with the decay of inflaton vacuum energy to ordinary matter. These cosmic strings explain flat velocity spectrum of distant stars in galaxies with string tension serving as the only parameter of the model: galactic dark matter halo would be absent.

Cosmic rays would propagate along the flux tubes serving as kind of cosmic highways. The strange events at Antarctica could correspond to cosmic rays arriving along flux tubes connecting Earth and planets to Sun connected to other stars and arriving Earth at North pole.

2.4.8 Could second generation of weak bosons explain the reduction of proton charge radius?

The above proposed speculative model is not the only one that one can imagine. The observation could be explained also as breaking of the universality of weak interactions. Also other anomalies challenging the universality exists. The decays of neutral B-meson to lepton pairs should be same apart from corrections coming from different lepton masses by universality but this does not seem to be the case [K25]. There is also anomaly in muon's magnetic moment discussed briefly in [K39]. This leads to ask whether the breaking of universality could be due to the failure of universality of electroweak interactions.

The proposal for the explanation of the muon's anomalous magnetic moment and anomaly in the decays of B-meson is inspired by a recent very special di-electron event and involves higher generations of weak bosons predicted by TGD leading to a breaking of lepton universality. Both Tommaso Dorigo (<http://tinyurl.com/pfw7qqm>) and Lubos Motl (<http://tinyurl.com/hqzat92>) tell about a spectacular 2.9 TeV di-electron event not observed in previous LHC runs. Single event of this kind is of course most probably just a fluctuation but human mind is such that it tries to see something deeper in it - even if practically all trials of this kind are chasing of mirages.

Since the decay is leptonic, the typical question is whether the dreamed for state could be an exotic Z boson. This is also the reaction in TGD framework. The first question to ask is whether weak bosons assignable to Mersenne prime M_{89} have scaled up copies assignable to Gaussian Mersenne M_{79} . The scaling factor for mass would be $2^{(89-79)/2} = 32$. When applied to Z mass equal to about .09 TeV one obtains 2.88 TeV, not far from 2.9 TeV. Eureka!? Looks like a direct scaled up version of Z!? W should have similar variant around 2.6 TeV.

2.5 Mapping the Universe using cosmic neutrinos

The Quanta Magazine article "A New Map of the Universe, Painted With Cosmic Neutrinos" (rb.gy/0yd7g) tells about the findings suggesting that ultrahigh energy (UHE) neutrinos do not originate from a continuous diffuse source but from discrete sources, presumably active galactic nuclei (AGNs).

2.5.1 The findings IceCube related to Milky Way neutrinos

Consider first the most recent observations of the IceCube laboratory.

1. A mapping of the Milky Way is carried by the IceCube laboratory using high energy neutrinos. Diffuse haze of cosmic neutrinos is found to be emanating along the plane the Milky Way [E2]. Neutrinos could emanate from the inner region of Milky Way (rb.gy/kp611) [E7], or even from the galactic blackhole.

2. If the neutrinos were generated in the collisions of very high cosmic rays, accelerated in ultra strong magnetic fields in the galactic plane, perhaps magnetic fields prevailing near the galactic blackhole, their flux would be by a factor of 100 higher than the observed flux. This suggests that active galactic nuclei (AGN) are the sources of UHE neutrinos.
3. The neutrino flux from milky Way is by a fact or order 1/100 lower than from other galactic sources so that that Milky Way might be called neutrino desert [E6].

2.5.2 The findings IceCube related to discrete sources of cosmic neutrinos

IceCube studies have already earlier connected UHE cosmic neutrinos with individual sources.

1. IceCube found [E5] that the galaxy called TXS 0506+056 ([rb.gy/ypekf](#)), briefly TXS, was emitting UHE neutrinos and flares of X-rays and gamma rays simultaneously. The distance of TXS is 5.7 billion light years. TXS is a blazar ([rb.gy/468q7](#)), which means that there is a jet directed towards the Earth. The neutrinos and other high energy particles arrive along this jet.
2. IceCube has also found a second patch emitting UHE neutrinos [E4]. It has an active galaxy NGC 1068 (Messier 77) ([rb.gy/ngi3w](#)) in the center. It is located at a distance 47 million light years, which is by a factor of 1/100 smaller than the distance of the TSX. Gamma ray burst is absent in this case. One proposal is that the high energy neutrinos and gammas arrive along the galactic plane but there is an absorption of gamma rays by the matter at the galactic plane near the active galactic nucleus.

A possible explanation is that high energy neutrinos arise in the decays of cosmic rays, which have accelerated in very strong magnetic fields. These magnetic fields could be associated with the stars that become supernovas or when two neutron stars collide. they would be accompanied by gamma ray bursts and high energy neutrinos. The problem is that the flux of high energy neutrinos should be much higher. AGNs therefore remains the only viable candidate.

2.5.3 Could TGD allow to understand the findings of IceCube?

Could TGD (Topological GeometroDynamics) based view of astrophysics explain these findings? TGD predicts a lot of new physics. Geometrization and number theoretization of quantum physics provide complementary approaches to TGD.

Consider first an explanation for the origin of UHE neutrinos and for their huge energies.

1. Number theoretical vision predicts a hierarchy of p-adic physics, where p is the prime characterizes p-adic number field. Number theoretically p would correspond to a ramified prime for an extension of rationals assignable to a given space-time region. One of the basic conjectures is p-adic length (mass) scale hypothesis stating the existence of a a hierarchy $L_p = L(k) \propto 2^{k/2}$, $p \simeq 2^k$, k some integer, of p-adic length scales. This hypothesis is central in p-adic mass calculations, which replace the Higgs mechanism with p-adic thermodynamics [K22].
2. Family replication phenomenon is one of the mysteries of recent day particle physics. In the TGD Universe family replication phenomenon has topological origin [K11] [L40].

Elementary particles have as basic building bricks partonic 2-surfaces assignable to the wormhole contacts with Euclidean signature of the induced metric and connecting two space-time sheets with a Minkowskian signature of induced metric. Partonic 2-surfaces carry fermions as point-like particles at the ends of strings connecting partonic 2-surfaces to each other.

The partonic 2-surfaces are characterized by genus g identifiable as the number of handles attached to 2-sphere. The lowest 3 genera (with handle number $g = 0, 1, 2$) always allow global Z_2 conformal symmetry unlike the higher genera. The proposal is that this means that for these genera the g handles form a bound state (trivially for $g \leq 2$) whereas for $g \geq 2$ one has many-handle states with a mass continuum so that one does not obtain elementary particles. The 3 fermion genera are assumed to give rise to a combinatorial symmetry $U(3)_g$ and the 3 fermion generations correspond to the fundamental representation 3_g .

3. In TGD there are no bosons as fundamental particles. Bosons would correspond to fermion antifermion bound states of fundamental fermions. This suggests that gauge bosons and Higgs correspond to the tensor product of 3_g and its conjugate representation so that bosons would correspond to the $8_g + 1_g$, where $8+1=9$ is the dimension of the dynamically generated symmetry group $U(3)_g$.

Ordinary bosons would correspond to $SU(3)_g$ singlet 1_g . Besides this new exotic boson octet 8_g is predicted. The original proposal was that the 2 bosons of 8_g with vanishing $SU(3)_g$ quantum numbers in 8_g are light so that there would be 3 boson generations. This assumption is not necessary [L60].

4. The ultrahigh energy (UHE) neutrinos (energy range [13 TeV, 7.9 PeV]) would correspond to very large p-adic mass scales characterizing the massscales for the analogs of weak bosons decaying to charged lepton and neutrino/antineutrino.
5. The lepton-neutrino pairs could be created in the decays of exotic counterparts of W bosons in 8_g . From the energies of UHE neutrinos one can conclude that these exotic bosons could correspond to the p-adic length scale $L(k = 61)$, where $p = 2^{61} - 1$ is Mersenne prime. Higgs, would be associated with the p-adic length scale $L(89)$, $p = 2^{89} - 1$. W and Z could correspond to p-adic primes with $k = 91$.

These huge mass scales require an enormous temperature in [13 TeV, 7.9 PeV] range, possibly reached inside active galactic nuclei (AGNs). In standard physics it is difficult to imagine how high these temperatures could be achieved.

1. In the TGD Universe space-times are 4-D surfaces in $M^4 \times CP_2$. TGD predicts, besides Einsteinian space-time surfaces with 4-D M^4 projection, also space-time surfaces with 2-D M^4 projection. I have called them cosmic strings but they are not the cosmic strings of gauge theories. Cosmic strings have a huge string tension and energy identifiable as dark energy.
2. In TGD based view of galaxy formation, galaxies are formed as tangles along long cosmic strings with 2-D M^4 projection. They are unstable against the thickening of M^4 projection, which can be induced by the collision of cosmic strings inducing their intersection leading to the thickening. The thickening generates monopole flux tubes with a 4-D M^4 projection and since the string tension decreases, the dark energy decays in an explosive manner to ordinary matter and dark matter. This process would be the TGD counterpart of inflation. This would explain the needed huge temperature. Kind of a local mini big bang would be in question.
3. The TGD counterparts of the galactic blackholes can be associated with the decaying cosmic strings. The recent observations suggesting that dark energy is assignable to AGNs supports this view. The temperature in these regions can be huge and make possible p-adically scaled up versions of hadron physics and also the presence of 8_g bosons. Their decay to lepton-neutrino pairs would generate UHE neutrinos but they could be also generated in the collisions of UHE cosmic rays with matter.
4. Note that in the TGD Universe gravitational quantum coherence is possible in arbitrarily long length scales. This network could be analogous to a nervous system and make possible very intense highly targeted beams of cosmic rays. Diffraction in the tessellation of cosmic time=constant hyperboloid, having stars as analogs of unit cells of a lattice, could explain the recently observed gravitational hum difficult to understand in standard astrophysics [L62].

Two different production mechanisms are suggested as an explanation for the differences between UHE emissions from TXS and NGC 106. One should also explain why the Milky Way seems to be a neutrino desert.

1. The galaxies are accompanied by cosmic strings or flux tubes obtained as their thickenings, roughly orthogonal to the galactic plane. Galactic jets can be assigned to these flux tubes. The cosmic strings would form a fractal network connecting galactic blackhole-like objects and the stars inside them to each other. The channelling of high energy particles to jets

would be caused by the space-time topology (the cross section of the flux tube would be a closed 2-surface).

The huge magnetic fields associated with these flux tubes would accelerate cosmic rays to ultrahigh energies. Both gamma ray bursts and the UHE neutrinos and accompanying gamma rays from TXS could be assigned with these jets. UHE neutrinos could be created either in the galactic nucleus or produced in the collisions of UHE cosmic rays with matter.

2. Also the flux tube tangles in the galactic plane could give rise to analogous jets. TGD Universe is fractal and in TGD inspired quantum biology U-shaped flux tube tentacles play a key role in biocatalysis, in which the reconnection of them creates a flux tube pair between two objects. These tentacles could also appear in astrophysical scales and mediate gravitational interaction as gravitons, which propagate along them. In fact, the thin structures found to emanate from the center of the Milky Way could be associated with monopole flux tube pairs in the galactic plane. The view about the formation of astrophysical structures based on magnetic bubbles generated by monopole flux tubes is discussed in [?, L61].

For the thick flux tubes in the galactic plane, the string tension would be much lower than for the environment of the cosmic string parallel to the jets. The acceleration of cosmic rays in their much weaker magnetic fields would not allow them to reach ultra high energies as in the case of jets normal to the galactic plane and the collisions of cosmic rays with matter could not create UHE neutrinos. Also gamma ray bursts would be absent.

3. The UHE neutrinos created in the AGN propagating along these flux tubes should generate the observed signal. This would suggest that neutrino flux is the sum of the primary flux from AGN and the flux generated by the interactions of cosmic rays inside the flux tube. The latter generates most of the signal for the galactic jets with ultra-strong magnetic fields. In the case of NGC, the UHE neutrino flux would be in the galactic plane. It is by a factor of order 1/100 weaker than predicted by the model in which the neutrinos are created in the collisions of cosmic rays accelerated in ultra strong magnetic fields with matter.
4. What about the Milky Way neutrino desert? Since the flux tube normal to the plane of the Milky Way does not reach Earth, the high energy neutrino flux would be so low that one could speak of neutrino desert. Whether the UHE neutrino flux from AGN is consistent with the finding that the Milky Way is a neutrino desert, is not clear. One explanation is that the Milky Way blackhole-like object is not active. This could mean that the ultra-hot regions where the generation of UHE neutrinos is possible are not present.

2.6 Anomalous anomalous magnetic moment of muon as breaking of lepton universality

Lepton universality predicts that the magnetic moments of leptons should be the same apart from the corrections due to different masses. Leptons have besides the magnetic moment predicted by Dirac equation also anomalous magnetic moment which is predicted to come from various radiative corrections.

The standard model predictions for the anomalous magnetic moments of the electron are $a_e = (g_e - 2)/2 = .00115965218091$ and $a_\mu = (g_\mu - 2)/2 = .00116591804$.

The anomalous magnetic moments of electron and muon differ by .1 per cent. This breaking of universality is however due to the different masses of electron and muon rather than different interactions.

2.6.1 The finding of Fermilab

The breaking of universality could also come from interactions and the Fermilab experiment [C72] (<https://cutt.ly/svuyhww>) and earlier experiments suggest this. The experiment shows that in the case of muon the magnetic moment differs by from the predicted: the deviation from the standard model prediction is 2.5×10^{-4} per cent. The smallness of this number tells how accurate the calculations in standard model can be. The anomaly however indicates that there might be interactions violating the lepton universality.

Besides the problem with the muon's magnetic moment, which differs from that of the electron, there is also a second problem. The decays of B mesons seem to break universality of fermion interactions: indications for the breaking of universality have emerged during years so that this is not new.

The measurement result involves various sources of error and one can estimate the probability that the measurement outcome is due to this kind of random fluctuations. The number of standard deviations tells how far the measurement result is from the maximum of the probability distribution. The deviation is expressed using standard deviation as a unit. Standard deviation is essentially the width of the distribution. For instance, 4 standard deviations tells that the probability that the result is random fluctuation is .6 per cent. For 5 standard deviations from predicted is .0001 per cent and is regarded as the discovery limit.

2.6.2 Theoretical uncertainties

There are also theoretical uncertainties related to the calculation of magnetic moment. There are 3 contributions: electroweak, QCD, and hadronic contributions. The electroweak and QCD corrections are "easily" calculable. The hadronic contributions are difficult to estimate since perturbative QCD does not apply at the hadronic energies. There are groups which claim that their estimation of hadronic contributions produces a prediction consistent with the Fermilab finding and the earlier findings consistent with the Fermilab finding.

The prediction based on experimentally deduced R ratio characterizing the rate for the decay of a virtual photon to quark pair allows to estimate the hadronic contribution and gives a prediction for hadronic contributions which is in conflict with experimental findings. On the other hand, the calculations based on lattice QCD give a result consistent with the experimental value [B2]. Should one trust experiment or theory?

2.6.3 Is a wider perspective needed?

To my opinion, one should see the problem from a bigger perspective than a question about how accurate the standard model is.

1. Standard Model does not explain fermion families. Also GUTs fail in this respect: the mass ratios of fermions vary in the range spanned by 11 orders of magnitude. This is not a small gauge symmetry breaking but something totally different: mass scale is the appropriate notion and p-adic length scale hypothesis provides it.
2. One must also challenge the belief that lattice QCD can describe low energy hadron physics. There might be much deeper problems than the inability to compute hadronic contributions to $g - 2$. Perturbative QCD describes only high energy interactions and QCD might exist only in the perturbative sense. The fact is that low energy hadron physics is virtually existent. Saying this aloud of course irritates lattice QCD professionals but the reduction of QCD to thermodynamics in the Euclidian space-time looks to me implausible. There are deep problems with Wick rotation.

For instance, massless dispersion relation $E^2 - p^2 = 0$ in M^4 translates to $E^2 + p^2 = 0$ in E^4 : massless fields disappear completely since one has only $E = 0, p = 0$ zero mode. There are similar problems with the massless Dirac equation. For the massive case the situation is not so bad as this. There is the strong CP problem caused by instantons and a problem with multiplication of spinor degrees of freedom since the 4-D cube has the topology of 4-torus and allows 16 spinor structures.

Quarks explain only a few per cent of hadron mass just as ordinary matter explains only a few percent of mass in cosmology. Hadron physics might therefore involve something totally new and color interaction could differ from a genuine gauge interaction.

2.6.4 What TGD can say about family replication phenomenon?

In TGD framework, the topological explanation of family replication phenomenon identifying partonic 2-surfaces as fundamental building blocks of elementary particles provides the

needed understanding and predicts 3 different fermion generations corresponding to 3 lowest general: sphere, torus, and sphere with two handles [K11].

Conformal Z_2 symmetry for partonic 2-surfaces is present for the lowest 3 genera but not for the higher ones for which one must talk about many handle states with continuous mass spectrum. p-Adic thermodynamics allows to estimate the masses of new boson by simple scaling arguments and Mersenne prime hypothesis.

In the TGD framework the two findings can be seen as indications for the failure of lepton universality. Besides 3 light fermion generations TGD also predicts 3 light generations for electroweak bosons, gluons, and Higgs. These generations are more massive than weak bosons and p-adic length scale hypothesis also allows to estimate their masses.

The couplings of the lightest generations to the gauge bosons obey fermion universality (are identical) but the couplings of the 2 higher generations cannot do so since the charge matrices of 3 generations must be orthogonal to each other. This predicts breaking of fermion universality which in quantum field theory approximation comes from the loops coupling fermions to the 2 higher boson generations.

This prediction is a test for TGD based topological view about family replication phenomenon in terms of the genus of partonic 2-surface: partonic 2-surface can be sphere, torus or sphere with two handles. TGD also explains why higher generations are experimentally absent.

2.6.5 What does TGD say about low energy hadron physics?

There is also the question about whether QCD catches all aspects of strong interactions. In TGD color magnetic flux tubes carry Kähler magnetic energy and volume energy parametrized by length scale dependent cosmological constant so that every system is characterized cosmological constant defining the string tension of magnetic flux tube as basic parameter and a connection with cosmology indeed emerges [L41, L39, L43]. The reconnections of U-shaped flux tubes give rise to the TGD counterparts of meson exchanges of old-fashioned hadron physics [L55].

Color group need not be a gauge group but analogous to a Kac-Moody group or Yangian group (only non-negative conformal weights). In TGD framework $SU(3)$ at the level of $H = M^4 \times CP_2$ is not a gauge symmetry but acts as isometries of CP_2 and fermions do not carry color as an analog of spin but as angular momentum like quantum number. At the level of complexified M_8 $SU(3)$ is a subgroup of G_2 acting as octonion automorphisms and defines Yangian replacing the local gauge group [L47, L48].

2.7 W mass anomaly

Particle physicists at LHC have found a new anomaly [C35] <https://cutt.ly/rF1NLZ5>). The measured mass of the W boson is by .1 per cent higher than predicted by high precision calculation. For a layman .1 per cent does not sound like an earthquake but, in the accuracies achieved, it is. Weak interactions are indeed weak, this kind of accuracy is possible. Physics has become incredibly precise!

This makes every builder of TOE humble! Of course, a new theory cannot achieve the precision of the predictions of the standard model. What is needed is understanding at a qualitative level and despite its marvellous accuracy, standard model cannot provide this understanding.

This anomaly suggests new massive particles. Also the earlier earthquakes, the CP breaking anomaly of B mesons and g-2 anomaly for muon, suggest new massive particles. Using the language of quantum field theory (QFT), the new particles should appear in self-energy loops of the W boson. Also the QFT limit of TGD uses this language although it is replaced with something much more elegant at the fundamental level [L58, L59].

Can one understand these anomalies in the TGD framework. I have already discussed the earlier anomalies [K25].

- (a) In the TGD framework, the family replication phenomenon for fermions (one has three quark and lepton generations) is explained topologically and the CKM mixing of fermions as induced by their topological mixing [K11, K22]. This goes outside the standard model, which just assumes CKM mixing without any attempt to understand it. The new physics prediction is that also the gauge bosons and graviton have the analog of family replication [K25].
- (b) Fermions would have 3 generations, which correspond to 3 topologies for a 2-D wormhole throat characterized by the number of handles: sphere, torus as sphere with one handle, and sphere with two handles.

For the 3 lightest genera there is Z_2 conformal symmetry, - hyperellipticity - irrespective of conformal moduli. For higher genera this symmetry is possible only for preferred moduli. This symmetry allows a bound state of 2-handles. One can assign a dynamically generated symmetry group $SU(3)_g$ to these 3 fermion states (electron, muon, tau + plus neutrinos and 3 quark generations). Fermions of these 3 generations form a triplet.

For a higher number of handles, one would have analogs of many-particle states with handles regarded as particles moving around the sphere like free particles: mass spectrum would be continuous - one could talk about ur particles.

- (c) Elementary bosons would correspond to pairs of wormhole throats characterized by handle number and group theoretically to a tensor product $3 \otimes 3$ of fermion triplets [K25]. This would give a singlet and octet. Singlet would correspond to ordinary gauge bosons and gravitons. For singlet, that is ordinary gauge bosons, the couplings to fermions would be the same for all genera since 3×3 $SU(3)_g$ charge matrix is unit matrix.

Octet would contain 2 states with vanishing $SU(3)_g$ quantum numbers plus $3+3=6$ $SU(3)_g$ charged states. Let us refer to these 2 states as 2 "exotics". The 2 exotics are analogs of neutral pion π^0 and η in the good old hadron physics involving strong isospin and strangeness.

An intuitive guess is that the $3+3$ $SU(3)_g$ "charged" states are very heavy (analogous to kaon K and charged pions π^\pm in the old-fashioned quark model). This assumption is however not essential for what follows. Thus $2+6$ new states with the same standard model quantum numbers as the existing ones, are predicted, and the 2 exotics are expected to be light. Effectively this gives 4 gauge boson generations.

The exotics appear in various loop corrections at the QFT limit of TGD.

- (a) Exotics could explain the anomalous CP violation for neutral B mesons. The couplings to fermions specified by $SU(3)_g$ charge matrices, which are orthogonal for the 3 generations and therefore cannot be the same for all generations. One would have a violation of universality and this is at the core of CP violation anomaly.
- (b) The exotics could also explain the anomaly of g-2 anomaly of muon.

Could the exotics also explain the W mass anomaly? Could a mixing between ordinary gauge bosons and exotics give a positive contribution to the self-energy loops of W and increase the mass slightly? If the mass changes in this manner, it must increase. This is encouraging.

- (a) Fermionic generations mix topologically. For instance, a sphere becomes a quantum superposition of several topologies containing mostly sphere and a little bit of torus and also a sphere with two handles. CKM mixing is essentially the difference of the topological mixings for U and D type quarks.

Could also gauge bosons with the same $SU(3)_g$ quantum numbers belonging to singlet and octet mix? A pair of spherical wormhole throats would get a contribution from a pairs of $g = 1$ and $g = 2$ wormholes.

- (b) Could one find some support for the mixing idea from the existing hadron physics? Vector boson dominance of the good old hadron physics assumed that photons can mix with rho mesons. ρ mesons correspond to quark pairs completely analogous to the analog of the first $SU(3)_g$ singlet (analog of pion). This mixing would be caused by the decay of photons to a quark pair in turn forming a ρ meson.

Exactly the same could happen for $SU(3)_g$. An ordinary gauge boson would decay to a virtual quark pair, which would combine with a small amplitude also to an exotic gauge boson, which is actually a superposition of fermion pairs in TGD. This would be induced by the topological mixing.

- (c) What about self energy corrections from the intermediate gauge boson pairs appearing in self-energy loops? They are certainly very small but in the TGD framework, they do not appear at the fundamental level in the lowest order.

The reason is that in the TGD Universe also gauge bosons are quark and lepton pairs: there are no fundamental bosons in the TGD Universe since bosons emerge from fermions as fermion-antifermion pairs (two pairs for gravitons).

Also leptons, could emerge from quarks but that is another story [L54]. The fundamental particle physics reduces to that for quarks [L58, L59].

3 Dark Matter In TGD Universe

TGD based explanation of dark matter means one of the strongest departures of TGD from the more standard approaches. In standard approaches dark matter corresponds to some very weakly interaction exotic particles contributing to the mass density of the Universe a fraction considerably larger than the contributions of “visible” matter.

In TGD Universe dark matter corresponds to phases with non-standard value of Planck constant and also ordinary particles could be in dark phase.

3.1 Dark Matter And Energy In TGD Universe

In TGD framework the identification of dark matter comes from arguments which could start from the strange finding that ELF em fields in frequency range of EEG have quantal effects on vertebrate brain [K14]. This is impossible in standard physics since the energies of photons many orders of magnitude below the thermal energy.

The proposal is that Planck constant is dynamical having a discrete integer valued spectrum so that for a given frequency the energy of photon can be above thermal energy for sufficiently large value of Planck constant. Large values of Planck constant make possible macroscopic quantum coherence so that the hypothesis would explain how living matter manages to be quantum system in macroscopic scales. Particles characterized by different values of Planck constant cannot appear in same interaction vertices so that in this sense particles with different values of Planck constant are dark relative to each other. This however allows interactions by particle exchange involving phase transition changing the value of Planck constant and also the interaction via classical fields.

The observation of Nottale [E3] that planetary orbits could be understood as Bohr orbits with a gigantic value of gravitational Planck constant leads also to the same idea [K40, K32]. The expression $\hbar_{gr} = GMm/v_0$, where v_0 has dimensions of velocity, forces to identify the Planck constant as a characterizer of the space-time sheets mediating the gravitational interaction between Sun and planet. Quite generally, there is a strong temptation to assign dark matter with the field bodies (or magnetic bodies) of physical systems and this assumption is made in the model of living matter based on the notion of the magnetic body.

One must be cautious with the identification of galactic dark matter in terms of phases with large value of Planck constant. One explanation for the galactic dark matter would be in terms of string like objects containing galaxies like pearls in the necklace [K12]. The Newtonian gravitational potential of the long galactic string would give rise to constant velocity spectrum. It could of course be that dark matter in TGD sense resides as particles at the long strings which could also carry antimatter. At least part of dark matter could be in this form. One must also bear in mind that \hbar_{grav} has gigantic values and could have different origin as large \hbar assignable to living matter: this is discussed in [K40].

What can one the conclude about dark energy in this framework?

- (a) Dark energy might allow interpretation as dark matter at the space-time sheets mediating gravitational interaction and macroscopically quantum coherent in cosmological scales. The enormous Compton wave lengths would imply that the density of dark energy would be constant as required by the interpretation in terms of cosmological constant.
- (b) This is however not the only possible interpretation. The magnetic tension of the magnetic flux tubes gives rise to the negative “pressure” inducing the accelerated expansion of the Universe serving as the basic motivation for the dark energy [K41].
- (c) The Robertson-Walker cosmologies with critical or over-critical mass density imbeddable to the embedding space are characterized by their necessarily finite duration and possess a negative pressure. The interpretation as a constraint force due to the imbeddability to $M^2 \times CP_2$ might explain dark energy [K41].
- (d) The GRT limit of TGD based on Einstein-Maxwell system with cosmological constant assigned with Euclidian regions of space-time allowing to get CP_2 as a special solution of field equation suggests that cosmological constant equals to the cosmological constant of CP_2 multiplied by the fraction of 3-volume with Euclidian signature of metric [K48] and representing generalized Feynman graphs [K17].

Whether these explanations represent different ways to say one and the same thing is not clear.

One could add the hierarchy of Planck constants as a separate postulate to TGD but it has turned out that the vacuum degeneracy characterizing TGD could imply this hierarchy as an effective hierarchy so that at the fundamental level one would have just the standard value of Planck constant [K16]. For both options the geometric realization for the hierarchy of Planck constants comes in terms of local covering spaces of embedding space inducing covering space structure for the space-time surfaces.

- (a) If the hierarchy is postulated rather than derived, the coverings in questions would be those of the causal diamond $CD \times CP_2$ such that the number of sheets of the covering equals to the value of Planck constant. The coverings of both CD and CP_2 are possible so that Planck constant is product of integers.
- (b) The hierarchy of local coverings would follow from the fact that time derivatives of embedding space coordinates are in general many-valued functions of canonical momentum densities by the vacuum degeneracy of Kähler action. In this case the covering would be covering of H assignable to a regions of space-time sheet. Note that, for the vacuum extremals for which induced Kähler gauge field is pure gauge and CP_2 projection any 2-D Lagrangian of CP_2 , an infinite number of branches of the covering co-incide. The situation can be characterized in terms of a generalization of catastrophe theory [A1] to infinite-D context.
- (c) Constant torque as a dynamical mechanism necessitating the covering is discussed in [K20].,

An open question is whether dark matter phases can/must correspond to same p-adic length scale and therefore same mass. Dark matter would correspond to particles with non-standard values of Planck constant and also ordinary particles with standard values of masses could appear in dark phase and is assumed in TGD inspired quantum biology. Even quarks with Compton lengths scaled up to cell length scale appear in the model of DNA as topological quantum computer [K2]. The model of lepto-pions [K47] in terms of colored excitations of leptons would suggests that colored excitations of leptons have same mass as leptons or possibly p-adically scaled octave of it in the case of colored ta lepton. The colored excitation of lepton with ordinary value of Planck constant must have mass larger than one half of intermediate gauge boson mass scale. Same applies to possible colored excitations of quarks.

This picture modifies profoundly the ideas about how to detect dark matter.

- (a) For instance, it might be possible to photograph dark matter and it might be that Peter Gariaev and his group have actually achieved this. What they observe are strange flux tube like structures associated with DNA sample [I2]: a TGD based model for the findings is developed in [K1]. If dark matter is what TGD claims it to be, the experimental methods used to detect dark matter might be on wrong track.
- (b) One should try to find a situation in which the particles must be created in dark phase and in this respect colored excitations of leptons are a good candidate since the decay widths of intermediate gauge boson do not allow new light fermions so that if these excitations exist they must have non-standard value of Planck constant.
- (c) The recent results of DAMA and Cogent suggesting the existence of dark matter particles with mass around 7 GeV are in conflict with the findings of CDMS and Xenon100 experiments. It is encouraging that this conflict could be explained by using the fact that the detection criteria in these experiments are different and by assuming that the dark matter particles involved are tau-pions formed as bound states of colored excitations of tau-leptons.

3.2 Shy Positrons

The latest weird looking effect in atomic physics is the observation that positrium atoms consisting of positron and electron scatter particles almost as if they were lonely electrons [C102, C81]. The effect has been christened cloaking effect for positron.

The following arguments represent the first attempts to understand the cloaking of positron in terms of these notions.

- (a) Let us start with the erratic argument since it comes first in mind. If positron and electron correspond to different space-time sheets and if the scattered particles are at the space-time sheet of electron then they do not see positron's Coulombic field at all. The objection is obvious. If positron interacts with the electron with its full electromagnetic charge to form a bound state, the corresponding electric flux at electron's space-time sheet is expected to combine with the electric flux of electron so that positronium would look like neutral particle after all. Does the electric flux of positron return back to the space-time sheet of positronium at some distance larger than the radius of atom? Why should it do this? No obvious answer.
- (b) Assume that positron dark but still interacts classically with electron via Coulomb potential. In TGD Universe darkness means that positron has large \hbar and Compton size much larger than positronic wormhole throat (actually wormhole contact but this is a minor complication) would have more or less constant wave function in the volume of this larger space-time sheet characterized by zoomed up Compton length of electron. The scattering particle would see point-like electron plus background charge diffused in a much larger volume. If the value of \hbar is large enough, the effect of this constant charge density to the scattering is small and only electron would be seen.
- (c) As a matter fact, I have proposed this kind of mechanism to explain how the Coulomb wall, which is the basic argument against cold fusion could be overcome by the incoming deuteron nucleus [L2], [L2]. Some fraction of deuteron nuclei in the palladium target would be dark and have large size just as positron in the above example. It is also possible that only the protons of these nuclei are dark. I have also proposed that dark protons explain the effective chemical formula $H_{1.5}O$ of water in scattering by neutrons and electrons in atto-second time scale [L2], [L2]. The connection with cloaked positrons is highly suggestive.
- (d) Also one of TGD inspired proposals for the absence of antimatter is that antiparticles reside at different space-time sheets as dark matter and are apparently absent [K41]. Cloaking positrons (shy as also their discoverer Dirac!) might provide an experimental supports for these ideas.

The recent view about the detailed structure of elementary particles forces to consider the above proposal in more detail.

- (a) According to this view all particles are weak string like objects having wormhole contacts at its ends and magnetically charged wormhole throats (four altogether) at the ends of the string like objects with length given by the weak length scale connected by a magnetic flux tube at both space-time sheets. Topological condensation means that these structures in turn are glued to larger space-time sheets and this generates one or more wormhole contacts for which also particle interpretation is highly suggestive and could serve as space-time correlate for interactions described in terms of particle exchanges. As far electrodynamics is considered, the second ends of weak strings containing neutrino pairs are effectively non-existing. In the case of fermions also only the second wormhole throat carrying the fermion number is effectively present so that for practical purposes weak string is only responsible for the massivation of the fermions. In the case of photons both wormhole throats carry fermion number.
- (b) An interesting question is whether the formation of bound states of two charged particles at the same space-time sheet could involve magnetic flux tubes connecting magnetically charged wormhole throats associated with the two particles. If so, Kähler magnetic monopoles would be part of even atomic and molecular physics. I have proposed already earlier that gravitational interaction in astrophysical scales involves magnetic flux tubes. These flux tubes would have an interpretation as analogs of say photons responsible for bound state energy. In principle it is indeed possible that the energies of the two wormhole throats are of opposite sign for topological sum contact so that the net energy of the wormhole contact pair responsible for the interaction could be negative.
- (c) Also the interaction of positron and electron would be based on topological condensation at the same space-time sheet and the formation of wormhole contacts mediating the interaction. Also now bound states could be glued together by magnetically charged wormhole contacts. In the case of dark positron, the details of the interaction are rather intricate since dark positron would correspond to a multi-sheeted structure analogous to Riemann surface with different sheets identified in terms of the roots of the equation relating generalized velocities defined by the time derivatives of the embedding space coordinates to corresponding canonical momentum densities.

3.3 Dark Matter Puzzle

Sean Carroll has explained in Cosmic Variance (<http://tinyurl.com/c2r2cv>) the latest rather puzzling situation in dark matter searches. Some experiments support the existence of dark matter particles with mass of about 7 GeV, some experiments exclude them. The following arguments show that TGD based explanation might allow to understand the discrepancy.

3.3.1 How to detect dark matter and what's the problem?

Consider first the general idea behind the attempts to detect dark matter particles and how one ends up with the puzzling situation.

- (a) Galactic nucleus serves as a source of dark matter particles and these one should be able to detect. There is an intense cosmic ray flux of ordinary particles from galactic center which must be eliminated so that only dark matter particles interacting very weakly with matter remain in the flux. The elimination is achieved by going sufficiently deep underground so that ordinary cosmic rays are shielded but extremely weakly interacting dark matter particles remain in the flux. After this one can in the ideal situation record only the events in which dark matter particles scatter from nuclei provided one eliminates events such as neutrino scattering.
- (b) DAMA experiment does not detect dark matter events as such but annual variations in the rate of events which can include besides dark matter events and other kind of events. DAMA finds an annual variation interpreted as dark matter signal since other sources of events are not expected to have this kind of variation [C49]. Also CoGENT has

reported the annual variation with 2.8 sigma confidence level [C113]. The mass of the dark matter particle should be around 7 GeV rather than hundreds of GeVs as required by many models. An unidentified noise with annual variation having nothing to do with dark matter could of course be present and this is the weakness of this approach.

- (c) For a few weeks ago we learned that XENON100 experiment detects no dark matter [C64] (<http://tinyurl.com/y9t3gxxu>). Also CDMS has reported a negative result [C36]. According to Sean Carroll, the detection strategy used by XENON100 is different from that of DAMA: individual dark matter scatterings on nuclei are detected. This is a very significant difference which might explain the discrepancy since the theory laden prejudices about what dark matter particle scattering can look like, could eliminate the particles causing the annual variations. For instance, these prejudices are quite different for the habitants of the main stream Universe and TGD Universe.

3.3.2 TGD based explanation of the DAMA events and related anomalies

I have commented earlier the possible interpretation of DAMA events in terms of tau-pions (<http://tinyurl.com/ycgkvuy9>). The spirit is highly speculative.

- (a) Tau-pions would be identifiable as the particles claimed by Fermi Gamma Ray telescope with mass around 7 GeV and decaying into tau pairs so that one could cope with several independent observations instead of only single one.
- (b) Recall that the CDF anomaly gave for two and half years ago support for tau-pions whereas earlier anomalies dating back to seventies give support for electro-pions and mu-pions. The existence of these particles is purely TGD based phenomenon and due to the different view about the origin of color quantum numbers. In TGD colored states would be partial waves in CP_2 and spin like quantum numbers in standard theories so that leptons would not have colored excitations.
- (c) Tau-pions are of course highly unstable and would not come from the galactic center. Instead, they would be created in cosmic ray events at the surface of Earth and if they can penetrate the shielding eliminating ordinary cosmic rays they could produce events responsible for the annual variation caused by that for the cosmic ray flux from galactic center.

Can one regard tau-pion as dark matter in some sense? Or must one do so? The answer is affirmative to both questions on both theoretical and experimental grounds.

- (a) The existence of colored variants of leptons is excluded in standard physics by intermediate gauge boson decay widths. They could however appear as states with non-standard value of Planck constant and therefore not appearing in same vertices with ordinary gauge bosons so that they would not contribute to the decay widths of weak bosons. In this minimal sense they would be dark and this is what is required in order to understand what we know about dark matter.

Of course, all particles can in principle appear in states with non-standard value of Planck constant so that tau-pion would be one special instance of dark matter. For instance, in living matter the role of dark variants of electrons and possibly also other stable particles would be decisive. To put it bluntly: in mainstream approach dark matter is identified as some exotic particle with ad hoc properties whereas in TGD framework dark matter is outcome of a generalization of quantum theory itself.

- (b) DAMA experiment requires that the tau-pions behave like dark matter: otherwise they would never reach the strongly shielded detector. The interaction with the nuclei of detector would be preceded by a transformation to a particle-tau-pion or something else- with ordinary value of Planck constant.

3.3.3 TGD based explanation for the dark matter puzzle

The criteria used in experiments to eliminate events which definitely are not dark matter events - according to the prevailing wisdom of course - dictates to high degree what interactions of tau pions with solid matter detector are used as a signature of dark matter event. It could well be that the criteria used in XENON100 do not allow the scatterings of tau-pions with nuclei. This is indeed the case. The clue comes from the comments of Jester in Resonaances (see <http://tinyurl.com/yd3vs7x5>). From a comment of Jester one learns that CoGENT - and also DAMA utilizing the same detections strategy - “does not cut on ionization fraction”. Therefore, if dark matter mimics electron recoils (as Jester says) or if dark matter produced in the collisions of cosmic rays with the nuclei of the atmosphere decays to charged particles one can understand the discrepancy.

The TGD based model [K47] explaining the more than two years old CDF anomaly [C29, C87] indeed explains also the discrepancy between XENON100 and CDMS on one hand and DAMA and CoGENT on the other hand. The TGD based model for the CDF anomaly can be found in [K47].

- (a) To explain the observations of CDF [C29, C87] one had to assume that tau-pions and therefore also color excited tau-leptons inside them appear as several p-adically scaled up variants so that one would have several octaves of the ground state of tau-pion with masses in good approximation equal to 3.6 GeV (two times the tau-lepton mass), 7.2 GeV, 14.4 GeV. The 14.4 GeV tau-pion was assumed to decay in a cascade like manner via lepto-strong interactions to lighter tau-pions- both charged and neutral- which eventually decayed to ordinary charged leptons and neutrinos.
- (b) Also other decay modes -say the decay of neutral tau-pions to gamma pair and to a pair of ordinary leptons- are possible but the corresponding rates are much slower than the decay rates for cascade like decay via multi-tau-pion states proceeding via lepto-strong interactions.
- (c) Just this cascade would take place also now after the collision of the incoming cosmic ray with the nucleus of atmosphere. The mechanism producing the neutral tau-pions - perhaps a coherent state of them- would degenerate in the collision of charged cosmic ray with nucleus generating strong non-orthogonal electric and magnetic fields and the production amplitude would be essentially the Fourier transform of the “instanton density” $E \cdot B$. The decays of 14 GeV neutral tau-pions would produce 7 GeV charged tau-pions, which would scatter from the protons of nuclei and generate the events excluded by XENON100 but not by DAMA and Cogent.
- (d) In principle the model predicts to a high degree quantitatively the rate of the events. The scattering rates are proportional to an unknown parameter characterizing the transformation probability of tau-pion to a particle with ordinary value of Planck constant and this allows to perform some parameter tuning. This parameter would correspond to a mass insertion in the tau-pion line changing the value of Planck constant and have dimensions of mass squared.

The overall conclusion is that the discrepancy between DAMA and XENON100 might be interpreted as favoring TGD view about dark matter and it is fascinating to see how the situation develops. This confusion is not the only confusion in recent day particle physics. All believed-to-be almost-certainties are challenged.

3.3.4 Has Fermi observed dark matter?

Resonaances (<http://tinyurl.com/y79x4v3y>) reports about a possible dark matter signal at Fermi satellite [C19]. Also Lubos Motl (<http://tinyurl.com/yd7xsfxo1>) has a posting about the finding and mentions that the statistical significance is 3.3 sigma.

The proposed dark matter interpretation for the signal would be pair of monochromatic photons with second one detected at Earth. The interpretation would be that dark matter

particles with mass m nearly at rest in galactic center annihilate to a pair of photons so that one obtains a pair of photons with energy equal to the cm energy which is in a good approximation the sum $E = 2 \times m$ for the masses of the particles. The mass value would be around $m=130$ GeV if the final state involves only 2 photons.

In TGD framework I would consider as a first guess a pion like state decaying to two photons with standard coupling given by the coupling to the “instanton density” $E \cdot B$ of electromagnetic field. The mass of this particle would be 260 GeV, in reasonable approximation 2 times the mass $m=125$ GeV of the Higgs candidate.

- (a) Similar coupling was assumed to [K47]. The anomaly would have been produced by tau-pions, which are pionlike states formed by pairs of colored excitations of tau and its antiparticle (or possibly their super-partners). What was remarkable that the mass had three values coming as powers of two: $M = 2^k \times 2m(\tau;)$, $k = 0, 1, 2$. The interpretation in terms of p-adic length scale hypothesis would be obvious: also the octaves of the basic state are there. The constraint from intermediate gauge boson decay widths requires that these states are dark in TGD sense and therefore correspond to a non-standard value of Planck constant coming as an integer multiple of the standard value.
- (b) Also the explanation of the findings of PAMELA discussed in this chapter require octaves of tau-pion produced in Earth’s atmosphere.
- (c) Even ordinary pion should have 2-adic octaves. But doesn’t this kill the hypothesis? We “know” that pion does not have any octaves! Maybe not, there is recent evidence for satellites of ordinary pion with energy scale of 40 MeV interpreted in terms of IR Regge trajectories assignable to the color magnetic flux tubes assignable to pion. There has been several wrong alarms about Higgs: at 115 GeV and 155 GeV at least. Could it be that there there is something real behind these wrong alarms: the scale for IR Regge trajectories would be about 20 GeV now!

So: could the dark matter candidates with mass around 260 GeV correspond to the first octave of M_{89} pion with mass around 125 GeV, the particle that colleagues want to call Higgs boson although its decay signatures suggest something different?

- (a) In this case it does not seem necessary to assume that the Planck constant has non-standard value although this is possible.
- (b) This particle should be produced in M_{89} strong interactions in the galactic center. This would require the presence of matter consisting of M_{89} nucleons emitting these pions in strong interactions. Galactic center (<http://tinyurl.com/y9clyfs>) is very exotic place and believed to contain even super-massive black hole. Could this environment accommodate also a scaled up copy of hadron physics? Presumably this would require very high temperatures with thermal energy of order 5 TeV correspond to the mass of M_{89} proton to make possible the presence of M_{89} matter. Or could M_{89} pion be produced in ultrastrong non-orthogonal electric and magnetic fields in the galactic center by the coupling to the instanton density. The needed field strengths would be extremely high. I have indeed proposed long time ago an explanation of very high energy cosmic rays in terms of the decay products of scaled up hadron physics (see “Cosmic Rays and Mersenne primes” in this chapter).

One can of course imagine that the photon pair is produced in the annihilation of M_{89} pions with opposite charges via standard electromagnetic coupling. Also the annihilation of M_{89} spions consisting of squark pair can be considered in TGD framework where squarks could have same mass scale as quarks. In this case mass would be near 125 GeV identified as mass of neutral M_{89} pion. By scaling up the mass difference 139.570-134.976 MeV of the ordinary charged and neutral pion by the ratio of the pion M_{89} and M_{107} pion masses equal to $(125/140) \times 10^3$ one obtains that the charged M_{89} pion should have mass equal to 129.6 MeV to be compared with the 130 GeV mass suggested by experimental evidence.

The story did not end here as so often when observations cannot be replicated. The Estonian researchers Elmo Tempel, Andi Hektora and Martti Raidala have found a confirmation for

the 130 GeV Fermi excess in gamma radiation from galactic center discovered by Cristoph Weniger [E1]. An important conclusion of these researchers is that best fit is obtained if the dark matter candidates decay by two-body annihilation to photons and have mass 145 GeV. The reason for why the gamma peak is at 130 GeV rather than 145 GeV would be due to the emission light particle pairs by the photons. There are also indications for a peak at 111 GeV: this could be assigned to γZ final state of two-body decay.

In TGD framework the annihilating particles with mass about 145 GeV mass could be charged pion-like states of M_{89} hadron physics. They could be dark in the sense of having large value of Planck constant but it is not clear whether this is necessarily so. The TGD based on view about galactic dark matter locates in cosmic string like objects containing galaxies as pearls in necklace and no halo is needed to explain galactic rotation spectrum [K12]. An ultrahigh temperature would be needed to excite M_{89} hadron physics and if there is giant blackhole in galactic nucleus, there are hopes about this. M_{89} hadron physics could also produce ultrahigh energy cosmic rays as described in this chapter.

It is amusing that also CDF found for a couple of years ago evidence for a bump at the same 145 GeV energy (this has been forgotten long time ago by bloggers in 125 GeV Higgs hysteria). Estonians propose that also a particle with 290 GeV (mass would twice that of 145 GeV state) is needed. This brings further support for the idea about mass octaves of ground state of pionlike states needed to explain various anomalies (see this chapter and [K47]).

If one takes seriously the evidence for 125 GeV state and its identification as Euclidian pion together with the evidence for galactic pionlike state with mass of 145 GeV identified as M_{89} , one has a nice support for the overall TGD based view about situation described in this chapter. The small splitting between pionlike states has possible counterpart in the ordinary hadron physics: there is evidence for satellites of pion, mesons, and baryons in 20-40 MeV scale for mass splittings and in TGD framework they would correspond to IR Regge trajectories with the scale of 10-20 GeV mass splittings (see this chapter).

We are living exciting times!

3.3.5 Two different lifetimes for neutron as evidence for dark protons

I found a popular article (see <http://tinyurl.com/hqsaqok>) about very interesting finding related to neutron lifetime [L34] (see <http://tinyurl.com/h88n57j>). Neutron lifetime turns out to be by about 8 seconds shorter when measured by looking what fraction of neutrons disappears via decays in a box than by measuring the number of protons produced in beta decays for a neutron beam travelling through a given volume. The lifetime of neutron is about 15 minutes so that relative lifetime difference is about $8/(15 \times 60) \simeq .8$ per cent. The statistical significance is 4 sigma: 5 sigma is accepted as the significance for a finding acceptable as discovery.

How could one explain the finding? The difference between the methods is that the beam experiment measures only the disappearances of neutrons via beta decays producing protons whereas box measurement detects the outcome from all possible decay modes. The experiment suggests two alternative explanations.

- (a) Neutron has some other decay mode or modes, which are not detected in the box method since one measures the number of neutrons in initial and final state. For instance, in TGD framework one could think that the neutrons can transform to dark neutrons with some rate. But it is extremely improbable that the rate could be just about 1 per cent of the decay rate. Why not 1 millionth? Beta decay should be involved with the process. Could some fraction of neutrons decay to dark proton, electron, and neutrino so that dark protons would not be detected in beam experiment? No, if one takes seriously the basic assumption of TGD that particles with different value of $h_{eff}/h = n$ do not appear in the same vertex. Neutron should first transform to dark proton but then also the disappearance could take place also without the beta decay of dark proton and the discrepancy would be larger.

- (b) The proton produced in the ordinary beta decay of neutron can however transform to dark proton not detected in the beam experiment! This would automatically predict that the rate is some reasonable fraction of the beta decay rate. About 1 percent of the resulting protons would transform to dark protons. This makes sense and would give strong hold about the rate for ordinary-dark transition rate. The observation of decays of neutron to electron, and neutrino but not proton would provide a support for the hypothesis. Both neutrino and proton would represent missing mass!

Dark matter as hierarchy of phases of ordinary matter is now a basic prediction of adelic TGD and $h_{eff}/h = n$ has in terms of number theory and space-time topology [K50, ?]. What is so nice is that the transformation of protons to dark protons is indeed the basic mechanism of TGD inspired quantum biology [K33, ?]! For instance, it would occur in Pollack effect [I1] in with infrared irradiation of water bounded by gel phase generates so called exclusion zone (EZ), which is negatively charged, and creates what Pollack calls fourth phase of water. TGD explanation is that some fraction of protons transforms to dark protons at magnetic flux tubes outside the system. Negative charge of DNA and cell could be due to this mechanism. One also ends up to a model of genetic code with the analogs of DNA, RNA, tRNA and amino-acids represented as triplets of dark protons associated with magnetic flux tubes parallel to DNA strands [K49] [L14]. The model predicts correctly the numbers of DNAs coding a given amino-acid. Besides quantum biology, the model has applications to cold fusion [L9], and various phenomena referred to as “free energy phenomena” [K38, K6].

3.4 AMS Results About Dark Matter

The results of AMS-02 experiment are published. There is an article [C22] (see <http://tinyurl.com/mg8ksp91>) in live blog at (see <http://tinyurl.com/ycox8cbk>) from CERN. Also Lubos Motl has written a summary from the point of view of SUSY fan who wants to see the findings as support for the discovery of SUSY neutralino (see <http://tinyurl.com/y894fzt4>). More balanced and somewhat skeptic representations paying attention to the hype-like features of the announcement come from Jester at (see <http://tinyurl.com/y93g7g22>) and Matt Strassler at (see <http://tinyurl.com/yd66ub7e>).

The abstract of the article is here.

A precision measurement by the alpha Magnetic Spectrometer on the International Space Station of the positron fraction in primary cosmic rays in the energy range from 0.5 to 350 GeV based on 6.8×10^6 positron and electron events is presented. The very accurate data show that the positron fraction is steadily increasing from 10 to 250 GeV, but, from 20 to 250 GeV, the slope decreases by an order of magnitude. The positron fraction spectrum shows no fine structure, and the positron to electron ratio shows no observable anisotropy. Together, these features show the existence of new physical phenomena.

New physics has been observed. The findings confirm the earlier findings of Fermi and Pamela also showing positron excess. The experimenters do not give data above 350 GeV but say that the flux of electrons does not change. The press release (see <http://tinyurl.com/c5r5hot>) states that the data are consistent with dark matter particles annihilating to positron pairs. For instance, the flux of the particles is same everywhere, which does not favor supernovae in galactic plane as source of electron positron pairs. According to the press release, AMS should be able to tell within forthcoming months whether dark matter or something else is in question - this sounds rather hypeish statement.

3.4.1 About the neutralino interpretation

Lubos Motl (see <http://tinyurl.com/y894fzt4>) trusts on his mirror neurons and deduces from the body language of Samuel Ting that the flux drops abruptly above 350 GeV as neutralino interpretation predicts.

- (a) The neutralino interpretation (see <http://tinyurl.com/maq5>) assumes that the positron pairs result in the decays $\chi\chi \rightarrow e^+e^-$ and predicts a sharp cutoff above mass scale of

neutralino due to the reduction of the cosmic temperature below critical value determined by the mass of the neutralino.

- (b) According the press release and according to the figure 5 of the article (see <http://tinyurl.com/y894fzt4>) [C22] the positron fraction settles to small but constant fraction before 350 GeV. The dream of Lubos Motl is that abrupt cutoff takes place above 350 GeV: about this region we did not learn anything yet because the measurement uncertainties are too high. From Lubos Motl's dream I would intuit that neutralino mass should be of the order 350 GeV. The electron/positron flux is fitted as a sum of diffuse background proportional to $C_e^\pm E^{-\gamma_e^\pm}$ and a contribution resulting from decays and parametrized as $C_s E^{-\gamma_s} \exp(-E/E_s)$ - same for electron and positron. The cutoff E_s of order $E_s = 700$ GeV: error bars are rather large. The factor $\exp(-E/E_s)$ does not vary too much in the range 1-350 GeV so that the exponential is probably motivated by the possible interpretation as neutralino for which sharp cutoff is expected. The mass of neutralino should be of order E_s . The positron fraction represented in figure 5 of the article (see <http://tinyurl.com/mg8ksp91>) [C22] seems to approach constant near 350 GeV. The weight of the common source is only 1 per cent of the diffuse electron flux.
- (c) Lubos Motl notices that in neutralino scenario also a new interaction mediated by a particle with mass of order 1 GeV is needed to explain the decrease of the positron fraction above 1 GeV. It would seem that Lubos Motl is trying to force right leg to the shoe of the left leg. Maybe one could understand the low end of the spectrum solely in terms of particle or particles with mass of order 10 GeV and the upper end of the spectrum in terms of particles of M_{89} hadron physics.
- (d) Jester (see <http://tinyurl.com/y93g7g22>) lists several counter arguments against the interpretation of the observations in terms of dark matter. The needed annihilation cross section must be two orders of magnitude higher than required for the dark matter to be a cosmic thermal relic, this holds true also for the neutralino scenario. Second problem is that the annihilation of neutralinos to quark pairs predicts also antiproton excess, which has not been observed. One must tailor the couplings so that they favor leptons. It has been also argued that pulsars could explain the positron excess: the recent finding is that the flux is same from all directions.

3.4.2 What could TGD interpretation be?

What can one say about the results in TGD framework? The first idea that comes to mind is that electron-positron pairs result from single particle annihilations but it seems that this option is not realistic. Fermion-anti-fermion annihilations are more natural and brings in strong analogy with neutralinos, which would give rise to dark matter as a remnant remaining after annihilation in cold dark matter scenario. An analogous scenario is obtained in TGD Universe by replacing neutralinos with baryons of some dark and scaled up variant of ordinary hadron physics of lepto-hadron physics.

- (a) The positron fraction increases from 10 to 250 GeV with its slope decreasing between 20 GeV and 250 GeV by an order of magnitude. The observations suggest to my innocent mind a scale of order 10 GeV. The TGD inspired model (see <http://tinyurl.com/ybfkptns>) for already forgotten CDF anomaly [K47] suggests the existence of τ pions with masses coming as three first octaves of the basic mass which is two times the mass of τ lepton. For years ago I proposed interpretation of the Fermi and Pamela anomalies now confirmed by AMS in terms τ pions. The predicted mass of the three octaves of τ pion would be 3.6 GeV, 7.2 GeV, and 14.4 GeV. Could the octaves of τ pion could explain the increase of the production rate up to 20 GeV and its gradual drop after that?

There is a severe objection against this idea. The energy distribution of τ pions dictates the width of the energy interval in which their decays contribute to the electron spectrum and what suggests itself is that decays of τ pions yield almost monochromatic peaks

rather than the observed continuum extending to high energies. Any resonance should yield similar distribution and this suggests that the electron positron pairs must be produced in the two particle annihilations of some particles.

The annihilations of colored τ leptons and their antiparticles could however contribute to the spectrum of electron-positron pairs. Also the leptonic analogs of baryons could annihilate with their antiparticles to lepton pairs. For these two options the dark particles would be fermions as also neutralino is.

- (b) Could colored τ leptons and - hadrons and their muonic and electronic counterparts be really dark matter? These particles might be dark matter in TGD sense - that is particle with a non-standard value of effective Planck constant \hbar_{eff} coming as integer multiple of \hbar . The existence of colored excitations of leptons and pion like states with mass in good approximation twice the mass of lepton leads to difficulties with the decay widths of W and Z unless the colored leptons have non-standard value of effective Planck constant and therefore lack direct couplings to W and Z. A more general hypothesis would be that the hadrons of all scaled up variant of QCD like world (lepto-hadron physics and scaled variants of hadron physics) predicted by TGD correspond to non-standard value of effective Planck constant and dark matter in TGD sense. This would mean that these new scaled up hadron physics would couple only very weakly to the standard physics.
- (c) At the high energy end of the spectrum M_{89} hadron physics would be naturally involved and also now the hadrons could be dark in TGD sense. E_s might be interpreted as temperature, which is in the energy range assigned to M_{89} hadron physics and correspond to a mass of some M_{89} hadron. The annihilations nucleons and anti-nucleons of M_{89} hadron physics could contribute to the spectrum of leptons at higher energies. The direct scaling of M_{89} proton mass gives mass of order 500 GeV and this value is consistent with the limits 480 GeV and 1760 GeV for E_s .
- (d) There would be also a relation to the observations of Fermi suggesting annihilation of some bosonic states to gamma pairs with gamma energy around 135 GeV could be interpreted in terms of annihilations of a M_{89} pion with mass of 270 GeV (maybe octave of lepto-pion with mass 135 GeV in turn octave of pion with mass 67.5 GeV).

3.4.3 How to resolve the objections against dark matter as thermal relic?

The basic objection against dark matter scenarios is that dark matter particles as thermal relics annihilate also to quark pairs so that proton excess should be also observed. TGD based vision could also circumvent this objection.

- (a) Cosmic evolution would be a sequence of phase transitions between hadron physics characterized by Mersenne primes. The lowest Mersenne primes are $M_2 = 3$, $M_3 = 7$, $M_5 = 31$, $M_7 = 127$, M_{13} , M_{17} , M_{19} , M_{31} , M_{61} , M_{89} , and M_{107} assignable to the ordinary hadron physics are involved but it might be possible to have also M_{127} . There are also Gaussian Mersenne primes $M_{G,n} = (1 + i)^n - 1$. Those labelled by $n = 151, 157, 163, 167$ and spanning p-adic length scales in biologically relevant length scales 10 nm, ..., 2.5 μ m.
- (b) The key point is that at given period characterised by M_n the hadrons characterized by larger Mersenne primes would be absent. In particular, before the period of the ordinary hadrons only M_{89} hadrons were present and decayed to ordinary hadrons. Therefore no antiproton excess is expected - at least by the mechanism producing it in the standard dark matter scenarios where all dark and ordinary particles are present simultaneously.
- (c) Since M_{89} hadrons are strongly interacting one can hope that the cross section is indeed high enough to produce positron excess.
- (d) Second objection relates to the cross section, which must be two orders of magnitude larger than required by the cold dark matter scenarios. I am unable to say anything definite about this. The fact that both M_{89} hadrons and colored leptons are strongly interacting would increase corresponding annihilation cross section and lepto-hadrons could later decay to ordinary leptons.

3.4.4 Connection with strange cosmic ray events and strange observations at RHIC and LHC

The model allows also to understand the strange cosmic ray events (Centauros) suggesting a formation of a blob (“hot spot” of exotic matter in atmosphere and decaying to ordinary hadrons. In the center of mass system of atmospheric particle and incoming cosmic ray cm energies are indeed of order M_{89} mass scale. As suggested (see <http://tinyurl.com/y9ej3h8h>) [K25] already earlier, these hot spots would be hot in p-adic sense and correspond to p-adic temperature assignable to M_{89} . Also the strange events observed already at RHIC in heavy ion collisions and later at LHC in proton-heavy ion collisions), and in conflict with the perturbative QCD predicting the formation of quark gluon plasma could be understood as a formation of M_{89} hot spots. The basic finding was that there were strong correlations: two particles tended to move either parallel or antiparallel, as if they had resulted in a decay of string like objects. The AdS/CFT inspired explanation was in terms of higher dimensional blackholes. TGD explanation is more prosaic: string like objects (color magnetic flux tubes) dominating the low energy limit of M_{89} hadron physics were created.

The question whether M_{89} hadrons, or their cosmic relics are dark in TGD sense remains open. In the case of colored variants of the ordinary leptons the decay widths of weak bosons force this. In the case of colored variants of the ordinary quarks the decay widths of weak bosons force this. It however seems that a coherent story about the physics in TGD Universe is developing as more data emerges. This story is bound to remain to qualitative description: quantitative approach would require a lot of collective theoretical work.

3.4.5 Also CDMS claims dark matter

Also CDMS (Cryogenic Dark Matter Search) reports new indications for dark matter particles: see the Nature blog article “Another dark matter sign from a Minnesota mine” at <http://tinyurl.com/ycnrds4>. Experimenters have observed 3 events with expected background of 7 events and claim that the mass of the dark matter particle is 8.6 GeV. This mass is much lighter than what has been expected: something like 350 GeV was suggested as explanation of the AMS observations. The low mass is however consistent with the identification as first octave of tau-pion with mass about 7.2 GeV for which already forgotten CDF anomaly provided support for years ago (as explained above p-adic length scale hypothesis allows octaves of the basic mass for lepto-pion which is in good approximation 2 times the mass of the charged lepton, that is 3.6 GeV). The particle must be dark in TGD sense, in other words it must have non-standard value of effective Planck constant. Otherwise it would contribute to the decay widths of W and Z.

4 Scaled Variants Of Quarks And Leptons

4.1 Fractally Scaled Up Versions Of Quarks

The strange anomalies of neutrino oscillations [C105] suggesting that neutrino mass scale depends on environment can be understood if neutrinos can suffer topological condensation in several p-adic length scales [K22]. The obvious question whether this could occur also in the case of quarks led to a very fruitful developments leading to the understanding of hadronic mass spectrum in terms of scaled up variants of quarks. Also the mass distribution of top quark candidate exhibits structure which could be interpreted in terms of heavy variants of light quarks. The ALEPH anomaly [C14], which I first erratically explained in terms of a light top quark has a nice explanation in terms of b quark condensed at $k = 97$ level and having mass ~ 55 GeV. These points are discussed in detail in [K30].

The emergence of ALEPH results [C14] meant a an important twist in the development of ideas related to the identification of top quark. In the LEP 1.5 run with $E_{cm} = 130-140$ GeV, ALEPH found 14 e^+e^- annihilation events, which pass their 4-jet criteria whereas 7.1 events

are expected from standard model physics. Pairs of dijets with vanishing mass difference are in question and dijets could result from the decay of a new particle with mass about 55 GeV.

The data do not allow to conclude whether the new particle candidate is a fermion or boson. Top quark pairs produced in e^+e^- annihilation could produce 4-jets via gluon emission but this mechanism does not lead to an enhancement of 4-jet fraction. No $b\bar{b}b\bar{b}$ jets have been observed and only one event containing b has been identified so that the interpretation in terms of top quark is not possible unless there exists some new decay channel, which dominates in decays and leads to hadronic jets not initiated by b quarks. For option 2), which seems to be the only sensible option, this kind of decay channels are absent.

Super symmetrized standard model suggests the interpretation in terms of super partners of quarks or/and gauge bosons [C101]. It seems now safe to conclude that TGD does not predict sparticles. If the exotic particles are gluons their presence does not affect Z^0 and W decay widths. If the condensation level of gluons is $k = 97$ and mixing is absent the gluon masses are given by $m_g(0) = 0$, $m_g(1) = 19.2$ GeV and $m_g(2) = 49.5$ GeV for option 1) and assuming $k = 97$ and hadronic mass renormalization. It is however very difficult to understand how a pair of $g = 2$ gluons could be created in e^+e^- annihilation. Moreover, for option 2), which seems to be the only sensible option, the gluon masses are $m_g(0) = 0$, $m_g(1) = m_g(2) = 30.6$ GeV for $k = 97$. In this case also other values of k are possible since strong decays of quarks are not possible.

The strong variations in the order of magnitude of mass squared differences between neutrino families [C105] can be understood if they can suffer a topological condensation in several p-adic length scales. One can ask whether also t and b quark could do the same. In absence of mixing effects the masses of $k = 97$ t and b quarks would be given by $m_t \simeq 48.7$ GeV and $m_b \simeq 52.3$ GeV taking into account the hadronic mass renormalization. Topological mixing reduces the masses somewhat. The fact that b quarks are not observed in the final state leaves only $b(97)$ as a realistic option. Since Z^0 boson mass is ~ 94 GeV, $b(97)$ does not appreciably affect Z^0 boson decay width. The observed anomalies concentrate at cm energy about 105 GeV. This energy is 15 percent smaller than the total mass of top pair. The discrepancy could be understood as resulting from the binding energy of the $b(97)\bar{b}(97)$ bound states. Binding energy should be a fraction of order $\alpha_s \simeq .1$ of the total energy and about ten per cent so that consistency is achieved.

4.2 Toponium at 30.4 GeV?

Prof. Matt Strassler tells about a gem found from old data files of ALEPH experiment (see <http://tinyurl.com/ze615wr>) by Arno Heisner [C13](see <http://tinyurl.com/hy8ugf4>). The 3-sigma bump appears at 30.40 GeV and could be a statistical fluctuation and probably is so. It has been found to decay to muon pairs and b-quark pairs. The particle that Strassler christens V (V for vector) would have spin 1.

Years ago [K25] I have commented a candidate for scaled down top quark reported by Aleph: this had mass around 55 GeV and the proposal was that it corresponds to p-adically scaled up b quark with estimated mass of 52.3 GeV.

Could TGD allow to identify V as a scaled up variant of some spin 1 meson?

- (a) p-Adic length scale hypothesis states that particle mass scales correspond to certain primes $p \simeq 2^k$, $k > 0$ integer. Prime values of k are of special interest. Ordinary hadronic space-time sheets would correspond to hadronic space-time sheets labelled by Mersenne prime $p = M_{107} = 2^{107} - 1$ and quarks would be labelled by corresponding integers k .
- (b) For low mass mesons the contribution from color magnetic flux tubes to mass dominates whereas for higher mass mesons consisting of heavy quarks heavy quark contribution is dominant. This suggests that the large mass of V must result by an upwards scaling of some light quark mass or downwards scaling of top quark mass by a power of square root of 2.

- (c) The mass of b quark is around 4.2-4.6 GeV and Upsilon meson has mass about 9.5 GeV so that at most about 1.4 GeV from total mass would correspond to the non-perturbative color contribution partially from the magnetic body. Top quark mass is about 172.4 GeV and p-adic mass calculations suggest $k = 94$ (M_{89}) for top. If the masses for heavy quark mesons are additive as the example of Upsilon suggests, the non-existing top pair vector meson (toponium) (see <http://tinyurl.com/nfzhnej>) would have mass about $m(\text{toponium}) = 2 \times 172.4 \text{ GeV} = 344.8 \text{ GeV}$.
- (d) Could the observed bump correspond to p-adically scaled down version of toponium with $k = 94 + 7 = 101$, which is prime? The mass of toponium would be 30.47 GeV, which is consistent with the mass of the bump. If this picture is correct, V would be premature toponium able to exist for prime $k = 101$. Its decays to b quark pair are consistent with this.
- (e) Tommaso Dorigo (see <http://tinyurl.com/zhgyecd>) argues that the signal is spurious since the produced muons tend to be parallel to b quarks in cm system of Z^0 . Matt Strassler identifies the production mechanism as a direct decay of Z^0 and in this case Tommaso would be right: the direct 3-particle decay of $Z^0 \rightarrow b + \bar{b} + V$ would produce different angular distribution for V . One cannot of course exclude the possibility that the interpretation of Tommaso is that muon pairs are from decays of V in its own rest frame in which case they certainly cannot be parallel to b quarks. So elementary mistake from a professional particle physicist looks rather implausible. The challenge of the experiments was indeed to distinguish the muon pairs from muons resulting from b quarks decaying semileptonically and being highly parallel to b quarks.

A further objection of Tommaso is that the gluons should have roughly opposite momenta and fusion seems highly implausible classically since the gluons tend to be emitted in opposite directions. Quantally the argument does not look so lethal if one thinks in terms of plane waves rather than wave packets. Also fermion exchange is involved so that the fusion is not local process.

- (f) How the bump appearing in $Z^0 \rightarrow b + \bar{b} + V$ would be produced if toponium is in question? The mechanism would be essentially the same as in the production of Ψ/J meson by a $c + \bar{c}$ pair. The lowest order diagram would correspond to gluon fusion. Both b and \bar{b} emit gluon and these could annihilate to a top pair and these would form the bound state. Do virtual t and \bar{t} have ordinary masses 172 GeV or scaled down masses of about 15 GeV? The checking which option is correct would require numerical calculation and a model for the fusion of the pair to toponium.

That the momenta of muons are parallel to those of b and \bar{b} might be understood. One can approximate gluons with energy about 15 GeV as a brehmstrahlung almost parallel/antiparallel to the direction of b/\bar{b} both having energy about 45 GeV in the cm system of Z^0 . In cm they would combine to V with helicity in direction of axis nearly parallel to the direction defined by the opposite momenta of b and \bar{b} . The V with spin 1 would decay to a muon pair with helicities in the direction of this axis, and since relativistic muons are in question, the momenta would by helicity conservation tend to be in the direction of this axis as observed.

Are there other indications for scaled variants of quarks?

- (a) Tony Smith [C117] has talked about indications for several mass peaks for top quark. I have discussed this in [K30] in terms of p-adic length scale hypothesis. There is evidence for a sharp peak in the mass distribution of the top quark in 140-150 GeV range). There is also a peak slightly below 120 GeV, which could correspond to a p-adically scaled down variant t quark with $k = 93$ having mass 121.6 GeV for ($Y_e = 0, Y_t = 1$). There is also a small peak also around 265 GeV which could relate to $m(t(95)) = 243.2 \text{ GeV}$. Therefore top could appear at least at p-adic scales $k = 93, 94, 95$. This argument does not explain the peak in 140-150 GeV range rather near to top quark mass.
- (b) What about Aleph anomaly? The value of $k(b)$ in $p_b \simeq 2^{k_b}$ uncertain. $k(b) = 103$ is one possible value. In [K25]. I have considered the explanation of Aleph anomaly in terms

of $k = 96$ variant of b quark. The mass scaling would be by factor of $2^{7/2}$, which would assign to mass $m_b = 4.6$ GeV mass of about 52 GeV to be compared with 55 GeV.

To sum up, the objections of Tommaso Dorigo might well kill the toponium proposal and the bump is probably a statistical fluctuation. It is however amazing that its mass comes out correctly from p-adic length scale hypothesis which does not allow fitting.

4.2.1 Aleph anomaly just refuses to disappear

I learned about evidence for a bump around 28 GeV (see <https://arxiv.org/abs/1808.01890>). The title of the preprint is “*Search for resonances in the mass spectrum of muon pairs produced in association with b quark jets in proton-proton collisions at $\sqrt{s} = 8$ and 13 TeV*”. An excess of events above the background near a dimuon mass of 28 GeV is observed in the 8 TeV data, corresponding to local significances of 4.2 and 2.9 standard deviations for the first and second event categories, respectively. At 13 TeV data the excess is milder. This induced two *dejavu* experiences.

1. First *dejavu*

Last year (2018) came a report from Aleph titled “*Observation of an excess at 30 GeV in the opposite sign di-muon spectra of $Z \rightarrow b\bar{b} + X$ events recorded by the ALEPH experiment at LEP*” (see <https://arxiv.org/pdf/1610.06536.pdf>). The article represents re-analysis of data from 1991-1992. The energy brings strongly in mind 28 GeV bump.

TGD - or more precisely p-adic fractality - suggests the existence of p-adically scaled variants of quarks and leptons with masses coming as powers of 2 (or perhaps even $\sqrt{2}$). They would be like octaves of a fundamental tone represented by the particle. Neutrino physics is plagued by anomalies and octaves of neutrino could resolve these problems.

Could one understand 30 GeV bump - possibly same as 28 GeV bump in TGD framework? b quark has mass 4.12 GeV or 4.65 GeV depending on the scheme used to estimate it. b quark could correspond to p-adic length scale $L(k)$ for $k = 103$ but the identification of the p-adic scale is not quite clear. p-Adically scaling b -quark mass taken to be 4.12 GeV by factor 4 gives about 16.5 GeV ($k = 103 - 4 = 99$), which is one half of 32 GeV: could this correspond to the proposed 30 GeV resonance or even 28 GeV resonance? One must remember that these estimates are rough since already QCD estimates for b quark mass vary about 10 per cent.

28 GeV bump could correspond to p-adically scaled variant of b with $k = 99$. b quark would indeed appear as octaves. But how to understand the discrepancy: could one imagine that there are actually two mesons involved and analogous to pion and rho meson?

2. Second *dejavu*

Concerning quarks, I remember an old anomaly reported by Aleph at 56 GeV. This anomaly is mentioned in a preprint published last year (see <https://arxiv.org/pdf/hep-ph/9608264.pdf>) and there is reference to old paper: ALEPH Collaboration, D. Buskulic *et al.*, CERN preprint PPE/96-052.. What was observed was 4-jet events consisting of dijets with invariant mass around 55 GeV. What makes this interesting is that the mass of 28 GeV particle candidate would be one half of the mass of a particle with mass of mass of 56 GeV particle, quite near to 55 GeV.

My proposal for the identification of the 55 GeV bump was as a meson formed from scaled variants b and \bar{b} corresponding to p-adic prime $p \simeq 2^k$, $k = 96$. The above argument suggests $k = 99 - 2 = 97$. Note that the production of the 28 GeV bump decaying to muon pair is associated with production of b quark and second jet.

3. What the resonance are and how could they be produced?

The troubling question is why the two masses around 28 GeV and 30 GeV? Even worse: for 30 GeV candidate a dip is reported in at 28 GeV! Could the two candidates correspond to $\pi(28)$ and $\rho(30)$ having slightly different masses by color-magnetic spin-spin splitting?

The production mechanism should explain why the resonance is associated with b-quark and jet and also why two different mass values suggest themselves.

- (a) If one has 56 GeV pseudo-scalar resonance consisting mostly of $b\bar{b}$ - call it $\pi(56)$, it could couple to Z^0 by standard instanton density coupling, and one could have the decay $Z \rightarrow Z + \pi(56)$. The final state virtual Z would produce the b-tag in its decay.
- (b) $\pi(56)$ in turn would decay strongly to $\pi(28) + \rho(30)$ with spin 1 and analogous to the rho meson partner of ordinary pion. Masses would be naturally different for π and ρ .

It is easy to check that the observed spin-spin splitting is consistent with the simplest model for the spin-spin splitting obtained by extrapolating the for ordinary $\pi - \rho$ system.

- (a) At these mass scales the spin-spin splitting proportional to color magnetic moments and thus to inverses of the b quark masses should be small and indeed is.
- (b) Consider first ordinary $\pi - \rho$ system. The predicted masses due to spin-spin splitting are $m(\pi) = m - \Delta/2$ and $m(\rho) = m + 3\Delta/2$, where one has $m = (3m(\pi) + m(\rho))/4$ and $\Delta = (m(\rho) - m(\pi))/2$. For $\pi - \rho$ system one has $r_1 = \Delta m/m \simeq .5$. $\Delta m/m$ is due to the interaction of color magnetic moments and of form $xr, r\alpha_s^2 m^2(\pi)/m^2(d)$. The small masses of u and d quarks - $m(d) \simeq 4.8$ MeV (Wikipedia value, the estimate vary widely) - implies that $m(\pi)/m(d) \simeq 28.2$ is rather large. The value of α_s is larger than $\alpha_s = .1$ achieved at higher energies, which gives $r_2 = \alpha_s^2 m^2(\pi)/m^2(d) > .28$. One has $r_1/r_2 \simeq .57$.
- (c) For $\pi(28) - \rho(30)$ system the values of the parameters are $m \simeq 29$ GeV and $\Delta m = 2$ GeV and $r_1 = \Delta m/m \simeq .07$. The mass ratio is roughly $m(\pi)/m(b) = 2$ for heavy mesons for which quark mass dominates in the meson mass. For $\alpha_s = .1$ the order of magnitude for $r_2 = \alpha_s^2 m^2(\pi(28))/m^2(b)$ is $r_2 \simeq .04$ and one has $r_1/r_2 = .57$ to be compared with $r_1/r_2 = .56$ for ordinary $\pi(28) - \rho(30)$ system so that the model looks realistic.

Interestingly, the same value of α_s works in both cases: does this provide support for the TGD view about renormalization group invariance of coupling strengths [L38, L42]? This invariance is not global but implies discrete coupling constant evolution.

4.3 Could Neutrinos Appear In Several P-Adic Mass Scales?

There are some indications that neutrinos can appear in several mass scales from neutrino oscillations [C8]. These oscillations can be classified to vacuum oscillations and to solar neutrino oscillations believed to be due to the so called MSW effect in the dense matter of Sun. There are also indications that the mixing is different for neutrinos and antineutrinos [C67, C7].

In TGD framework p-adic length scale hypothesis might explain these findings. The basic vision is that the p-adic length scale of neutrino can vary so that the mass squared scale comes as octaves. Mixing matrices would be universal. The large discrepancy between LSND and MiniBoone results [C67] contra solar neutrino results could be understood if electron and muon neutrinos have same p-adic mass scale for solar neutrinos but for LSND and MiniBoone the mass scale of either neutrino type is scaled up. The existence of a sterile neutrino [C100] suggested as an explanation of the findings would be replaced by p-adically scaled up variant of ordinary neutrino having standard weak interactions. This scaling up can be different for neutrinos and antineutrinos as suggested by the fact that the anomaly is present only for antineutrinos.

The different values of Δm^2 for neutrinos and antineutrinos in MINOS experiment [C7] can be understood if the p-adic mass scale for neutrinos increases by one unit. The breaking of CP and CPT would be spontaneous and realized as a choice of different p-adic mass scales and could be understood in ZEO. Similar mechanism would break supersymmetry and explain

large differences between the mass scales of elementary fermions, which for same p-adic prime would have mass scales differing not too much.

4.3.1 Experimental results

There several different type of experimental approaches to study the oscillations. One can study the deficit of electron type solar electron neutrinos (Kamiokande, Super-Kamiokande); one can measure the deficit of muon to electron flux ratio measuring the rate for the transformation of ν_μ to ν_τ (super-Kamiokande); one can study directly the deficit of ν_e ($\bar{\nu}_e$) neutrinos due to transformation to ν_μ ν_μ coming from nuclear reactor with energies in the same range as for solar neutrinos (KamLAND); and one can also study neutrinos from particle accelerators in much higher energy range such as solar neutrino oscillations (K2K,LSND,Miniboone,Minos).

1. Solar neutrino experiments and atmospheric neutrino experiments

The rate of neutrino oscillations is sensitive to the mass squared differences Δm_{12}^2 , Δm_{13}^2 , Δm_{23}^2 and corresponding mixing angles θ_{12} , θ_{13} , θ_{23} between ν_e , ν_μ , and ν_τ (ordered in obvious manner). Solar neutrino experiments allow to determine $\sin^2(2\theta_{12})$ and Δm_{12}^2 . The experiments involving atmospheric neutrino oscillations allow to determine $\sin^2(2\theta_{23})$ and Δm_{23}^2 .

The estimates of the mixing parameters obtained from solar neutrino experiments and atmospheric neutrino experiments are $\sin^2(2\theta_{13}) = 0.08$, $\sin^2(2\theta_{23}) = 0.95$, and $\sin^2(2\theta_{12}) = 0.86$. The mixing between ν_e and ν_τ is very small. The mixing between ν_e and ν_μ , and ν_μ and ν_τ tends is rather near to maximal. The estimates for the mass squared differences are $\Delta m_{12}^2 = 8 \times 10^{-5} \text{ eV}^2$, $\Delta m_{23}^2 \simeq \Delta m_{13}^2 = 2.4 \times 10^{-3} \text{ eV}^2$. The mass squared differences have obviously very different scale but this need not means that the same is true for mass squared values.

2. The results of LSND and MiniBoone

LSND experiment measuring the transformation of $\bar{\nu}_\mu$ to $\bar{\nu}_e$ gave a totally different estimate for Δm_{12}^2 than solar neutrino experiments MiniBoone [C100]. If one assumes same value of $\sin^2(\theta_{12})^2 \simeq .86$ one obtains $\Delta m_{23}^2 \sim .1 \text{ eV}^2$ to be compared with $\Delta m_{12}^2 = 8 \times 10^{-5} \text{ eV}^2$. This result is known as LSND anomaly and led to the hypothesis that there exists a sterile neutrino having no weak interactions and mixing with the ordinary electron neutrino and inducing a rapid mixing caused by the large value of Δm^2 . The purpose of MiniBoone experiment [C67] was to test LSND anomaly.

- (a) It was found that the two-neutrino fit for the oscillations for $\nu_\mu \rightarrow \nu_e$ is not consistent with LSND results. There is an unexplained 3σ electron excess for $E < 475 \text{ MeV}$. For $E > 475 \text{ MeV}$ the two-neutrino fit is not consistent with LSND fit. The estimate for Δm^2 is in the range $.1 - 1 \text{ eV}^2$ and differs dramatically from the solar neutrino data.
- (b) For antineutrinos there is a small 1.3σ electron excess for $E < 475 \text{ MeV}$. For $E > 475 \text{ MeV}$ the excess is 3 per cent consistent with null. Two-neutrino oscillation fits are consistent with LSND. The best fit gives $(\Delta m_{12}^2, \sin^2(2\theta_{12})) = (0.064 \text{ eV}^2, 0.96)$. The value of Δm_{12}^2 is by a factor 800 larger than that estimated from solar neutrino experiments.

All other experiments (see the table of the summary of [C100] about sterile neutrino hypothesis) are consistent with the absence of $\nu_\mu \rightarrow n_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ mixing and only LSND and MiniBoone report an indication for a signal. If one however takes these findings seriously they suggest that neutrinos and antineutrinos behave differently in the experimental situations considered. Two-neutrino scenarios for the mixing (no sterile neutrinos) are consistent with data for either neutrinos or antineutrinos but not both [C100].

3. The results of MINOS group

The MINOS group at Fermi National Accelerator Laboratory has reported evidence that the mass squared differences between neutrinos are not same for neutrinos and antineutrinos [C7]. In this case one measures the disappearance of ν_μ and $\bar{\nu}_\mu$ neutrinos from high energy beam in the range .5-1 GeV and the dominating contribution comes from the transformation to τ neutrinos. Δm_{23}^2 is reported to be about 40 percent larger for antineutrinos than for neutrinos. There is 5 percent probability that the mass squared differences are same. The best fits for the basic parameters are ($\Delta m_{23}^2 = 2.35 \times 10^{-3}$, $\sin^2(2\theta_{23}) = 1$) for neutrinos with error margin for Δm^2 being about 5 per cent and ($\Delta m_{23}^2 = 3.36 \times 10^{-3}$, $\sin^2(2\theta_{23}) = .86$) for antineutrinos with errors margin around 10 per cent. The ratio of mass squared differences is $r \equiv \Delta m^2(\bar{\nu})/\Delta m^2(\nu) = 1.42$. If one assumes $\sin^2(2\theta_{23}) = 1$ in both cases the ratio comes as $r = 1.3$.

4.3.2 Explanation of findings in terms of p-adic length scale hypothesis

p-Adic length scale hypothesis predicts that fermions can correspond to several values of p-adic prime meaning that the mass squared comes as octaves (powers of two). The simplest model for the neutrino mixing assumes universal topological mixing matrices and therefore for CKM matrices so that the results should be understood in terms of different p-adic mass scales. Even CP breaking and CPT breaking at fundamental level is un-necessary although it would occur spontaneously in the experimental situation selecting different p-adic mass scales for neutrinos and antineutrinos. The expression for the mixing probability a function of neutrino energy in two-neutrino model for the mixing is of form

$$P(E) = \sin^2(2\theta)\sin^2(X) \ , \ X = k \times \Delta m^2 \times \frac{L}{E} \ .$$

Here k is a numerical constant, L is the length travelled, and E is neutrino energy.

1. LSND and MiniBoone results

LSND and MiniBoone results are inconsistent with solar neutrino data since the value of Δm_{12}^2 is by a factor 800 larger than that estimated from solar neutrino experiments. This could be understood if in solar neutrino experiments ν_μ and ν_w correspond to the same p-adic mass scale $k = k_0$ and have very nearly identical masses so that Δm^2 scale is much smaller than the mass squared scale. If either p-adic scale is changed from k_0 to $k_0 + k$, the mass squared difference increases dramatically. The counterpart of the sterile neutrino would be a p-adically scaled up version of the ordinary neutrino having standard electro-weak interactions. The p-adic mass scale would correspond to the mass scale defined by Δm^2 in LSND and MiniBoone experiments and therefore a mass scale in the range .3-1 eV. The electron Compton scale assignable to eV mass scale could correspond to $k = 167$, which corresponds to cell length scale of $2.5 \mu\text{m}$. $k = 167$ defines one of the Gaussian Mersennes $M_{G,k} = (1 + i)^k - 1$. $L_e(k) = \sqrt{5}L(k)$, $k = 151, 157, 163, 167$, varies in the range 10 nm (cell membrane thickness) and $2.5 \mu\text{m}$ defining the size of cell nucleus. These scales could be fundamental for the understanding of living matter [K14] .

2. MINOS results

One must assume also now that the p-adic mass scales for ν_τ and $\bar{\nu}_\tau$ are near to each other in the “normal” experimental situation. Assuming that the mass squared scales of ν_μ or $\bar{\nu}_\mu$ come as 2^{-k} powers of $m_{\nu_\mu}^2 = m_{\nu_\tau}^2 + \Delta m^2$, one obtains

$$m_{\nu_\tau}^2(k_0) - m_{\bar{\nu}_\mu}^2(k_0 + k) = (1 - 2^{-k})m_{\nu_\tau}^2 - 2^{-k}\Delta m_0^2 \ .$$

For $k = 1$ this gives

$$r = \frac{\Delta m^2(k=2)}{\Delta m^2(k=1)} = \frac{\frac{3}{2} - \frac{2r}{3}}{1 - r} \ , \ r = \frac{\Delta m_0^2}{m_{\nu_\tau}^2} \ . \quad (4.1)$$

One has $r \geq 3/2$ for $r > 0$ if one has $m_{\nu_\tau} > m_{\nu_\mu}$ for the same p-adic length scale. The experimental ratio $r \simeq 1.3$ could be understood for $r \simeq .31$. The experimental uncertainties certainly allow the value $r = 1.5$ for $k(\bar{\nu}_\mu) = 1$ and $k(\nu_\mu) = 2$.

This result implies that the mass scale of ν_μ and ν_τ differ by a factor $1/2$ in the “normal” situation so that mass squared scale of ν_τ would be of order $5 \times 10^{-3} \text{ eV}^2$. The mass scales for $\bar{\nu}_\tau$ and ν_τ would about $.07 \text{ eV}$ and $.05 \text{ eV}$. In the LSND and MiniBoone experiments the p-adic mass scale of other neutrino would be around $.1\text{-}1 \text{ eV}$ so that different p-adic mass scale large by a factor $2^{k/2}$, $2 \leq k \leq 7$ would be in question. The different results from various experiments could be perhaps understood in terms of the sensitivity of the p-adic mass scale to the experimental situation. Neutrino energy could serve as a control parameter.

CPT breaking [B1] requires the breaking of Lorentz invariance. ZEO could therefore allow a spontaneous breaking of CP and CPT. This might relate to matter antimatter asymmetry at the level of given CD.

There is some evidence that the mixing matrices for neutrinos and antineutrinos are different in the experimental situations considered [C7, C67]. This would require CPT breaking in the standard QFT framework. In TGD p-adic length scale hypothesis allowing neutrinos to reside in several p-adic mass scales. Hence one could have apparent CPT breaking if the measurement arrangements for neutrinos and antineutrinos select different p-adic length scales for them [K25].

4.3.3 Is CP and T breaking possible in ZEO?

The CKM matrices for quarks and possibly also leptons break CP and T. Could one understand the breaking of CP and T at fundamental level in TGD framework?

- (a) In standard QFT framework Chern-Simons term breaks CP and T. Kähler action indeed reduces to Chern-Simons terms for the proposed ansatz for preferred extremals assuming that weak form of electric-magnetic duality holds true.

In TGD framework one must however distinguish between space-time coordinates and embedding space coordinates. CP breaking occurs at the embedding space level but instanton term and Chern-Simons term are odd under P and T only at the space-time level and thus distinguish between different orientations of space-time surface. Only if one identifies P and T at space-time level with these transformations at embedding space level, one has hope of interpreting CP and T breaking as spontaneous breaking of these symmetries for Kähler action and basically due to the weak form of electric-magnetic duality and vanishing of $j \cdot A$ term for the preferred extremals. This identification is possible for space-time regions allowing representation as graphs of maps $M^4 \rightarrow CP_2$.

- (b) In order to obtain non-trivial fermion propagator one must add to Dirac action 1-D Dirac action in induced metric with the boundaries of string world sheets at the light-like parton orbits. Its bosonic counterpart is line-length in induced metric. Field equations imply that the boundaries are light-like geodesics and fermion has light-like 8-momentum. This suggests strongly a connection with quantum field theory and an 8-D generalization of twistor Grassmannian approach. By field equations the bosonic part of this action does not contribute to the Kähler action. Chern-Simons Dirac terms to which Kähler action reduces could be responsible for the breaking of CP and T symmetries as they appear in CKM matrix.
- (c) The GRT-QFT limit of TGD obtained by lumping together various space-time sheets to a region of Minkowski space with effective metric defined by the sum of Minkowski metric and deviations of the induced metrics of sheets from Minkowski metric. Gauge potentials for the effective space-time would identified as sums of gauge potentials for space-time sheets. At this limit the identification of P and T at space-time level and embedding space level would be natural. Could the resulting effective theory in Minkowski space or GRT space-time break CP and T slightly? If so, CKM matrices for quarks and fermions would emerge as a result of representing different topologies for wormhole throats with different topologies as single point like particle with additional genus quantum number.

- (d) Could the breaking of CP and T relate to the generation of the arrow of time? The arrow of time relates to the fact that state function reduction can occur at either boundary of CD [K4]. Zero energy states do not change at the boundary at which reduction occurs repeatedly but the change at the other boundary and also the wave function for the position of the second boundary of CD changes in each quantum jump so that the average temporal distance between the tips of CD increases. This gives to the arrow of psychological time, and in TGD inspired theory of consciousness “self” as a counterpart of observed can be identified as sequence of quantum jumps for which the state function reduction occurs at a fixed boundary of CD. The sequence of reductions at fixed boundary breaks T-invariance and has interpretation as irreversibility. The standard view is that the irreversibility has nothing to do with breaking of T-invariance but it might be that in elementary particle scales irreversibility might manifest as small breaking of T-invariance.

4.3.4 Is CPT breaking needed/possible?

Different values of Δm_{ij}^2 for neutrinos and antineutrinos would require in standard QFT framework not only the violation of CP but also CPT [B1] which is the cherished symmetry of quantum field theories. CPT symmetry states that when one reverses time’s arrow, reverses the signs of momenta and replaces particles with their antiparticles, the resulting Universe obeys the same laws as the original one. CPT invariance follows from Lorentz invariance, Lorentz invariance of vacuum state, and from the assumption that energy is bounded from below. On the other hand, CPT violation requires the breaking of Lorentz invariance.

In TGD framework this kind of violation does not seem to be necessary at fundamental level since p-adic scale hypothesis allowing neutrinos and also other fermions to have several mass scales coming as half-octaves of a basic mass scale for given quantum numbers. In fact, even in TGD inspired low energy hadron physics quarks appear in several mass scales. One could explain the different choice of the p-adic mass scales as being due to the experimental arrangement which selects different p-adic length scales for neutrinos and antineutrinos so that one could speak about spontaneous breaking of CP and possibly CPT. The CP breaking at the fundamental level which is however expected to be small in the case considered. The basic prediction of TGD and relates to the CP breaking of Chern-Simons action inducing CP breaking in the Kähler-Dirac action defining the fermionic propagator [L3]. For preferred extremals Kähler action would indeed reduce to Chern-Simons terms by weak form of electric-magnetic duality.

In TGD one has breaking of translational invariance and the symmetry group reduces to Lorentz group leaving the tip of CD invariant. Positive and negative energy parts of zero energy states correspond to different Lorentz groups and zero energy states are superpositions of state pairs with different values of mass squared. Is the breaking of Lorentz invariance in this sense enough for breaking of CPT is not clear.

One can indeed consider the possibility of a spontaneous breaking of CPT symmetry in TGD framework since for a given CD (causal diamond defined as the intersection of future and past directed light-cones whose size scales are assumed to come as octaves) the Lorentz invariance is broken due to the preferred time direction (rest system) defined by the time-like line connecting the tips of CD. Since the world of classical worlds is union of CDs with all boosts included the Lorentz invariance is not violated at the level of WCW. Spontaneous symmetry breaking would be analogous to that for the solutions of field equations possessing the symmetry themselves. The mechanism of breaking would be same as that for supersymmetry. For same p-adic length scale particles and their super-partners would have same masses and only the selection of the p-adic mass scale would induce the mass splitting.

4.3.5 Encountering the puzzle of inert neutrinos once again

Sabine Hossenfelder had an interesting link to Quanta Magazine article “*On a Hunt for a Ghost of a Particle*” telling about the plans of particle physicist Janet Conrad to find the inert neutrino (see <http://tinyurl.com/ybhcjwu6>).

The attribute “sterile” or “inert” (I prefer the latter since it is more respectful!) comes from the assumption this new kind of neutrino does not have even weak interactions and feels only gravitation. There are indications for the existence of inert neutrino from LSND experiments (see <http://tinyurl.com/y7ktyfrs>) and some Mini-Boone experiments (see <http://tinyurl.com/y74hmq7c>). In standard model it would be interpreted as fourth generation neutrino which would suggest also the existence of other fourth generation fermions. For this there is no experimental support.

The problem of inert neutrino is very interesting also from TGD point of view. TGD predicts also right handed neutrino with no electroweak couplings but mixes with left handed neutrino by a new interaction produced by the mixing of M^4 and CP_2 gamma matrices: this is a unique feature of induced spinor structure and serves as a signature of sub-manifold geometry and one signature distinguishing TGD from standard model. Only massive neutrino with both helicities remains and behaves in good approximation as a left handed neutrino.

There are indeed indications in both LSND and MiniBoone experiments for inert neutrino. But only in some of them. And not in the ICECUBE experiment (see <http://tinyurl.com/h79dyj3>) performed at was South Pole. Special circumstances are required. “Special circumstances” need not mean bad experimentation. Why this strange behavior?

- (a) The evidence for the existence of inert neutrino, call it $\bar{\nu}_I$, came from antineutrino mixing $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ manifesting as mass squared difference between muonic and electronic antineutrinos. This difference was $\Delta m^2(LSND) = 1 - 10 \text{ eV}^2$ in the LSND experiment. The other two mass squared differences deduced from solar neutrino mixing and atmospheric neutrino mixing were $\Delta m^2(sol) = 8 \times 10^{-5} \text{ eV}^2$ and $\Delta m^2(atm) = 2.5 \times 10^{-3} \text{ eV}^2$ respectively.
- (b) The inert neutrino interpretation would be that actually $\bar{\nu}_\mu \rightarrow \bar{\nu}_I$ takes place and the mass squared difference for $\bar{\nu}_\mu$ and $\bar{\nu}_I$ determines the mixing.

1. The explanation based on several p-adic mass scales for neutrinos

The first TGD inspired explanation proposed for a long time ago relies on p-adic length scale hypothesis predicting that neutrinos can exist in several p-adic length scales for which mass squared scale ratios come as powers of 2. Mass squared differences would also differ by a power of two. Indeed, the mass squared differences from solar and atmospheric experiments are in ratio 2^{-5} so that the model looks promising!

Writing $\Delta m^2(LSND) = x \text{ eV}^2$ the condition $m^2(LSND)/m^2(atm) = 2^k$ has 2 possible solutions corresponding to $k = 9$, or $k = 10$ and $x = 2.5$ and $x = 1.25$. The corresponding mass squared differences 2.5 eV^2 and 1.25 eV^2 .

The interpretation would be that the three measurement outcomes correspond to 3 neutrinos with nearly identical masses in given p-adic mass scale k but having different p-adic mass scales. The atmospheric and solar p-adic length scales would come as powers $(L(atm), L(sol)) = (2^{n/2}, 2^{(n+10)/2}) \times L(k(LSND))$, $n = 9$ or $n = 10$. For $n = 10$ the mass squared scales would come as powers of 2^{10} .

How to estimate the value of $k(LSND)$?

- (a) Empirical data and p-adic mass calculations suggest that neutrino mass is of order .1 eV. The most natural candidates for p-adic mass scales would correspond to $k = 163, 167$ or $k = 169$. The first primes $k = 163, 167$ correspond to Gaussian Mersenne primes $M_{G,n} = (1 + i)^n - 1$ and to p-adic length scales $L(163) = 640 \text{ nm}$ and $L(167) = 2.56 \mu\text{m}$.
- (b) p-Adic mass calculations [K22] predict that the ratio $x = \Delta m^2/m^2$ for $\mu - e$ system has upper bound $x \sim .4$. This does not take into account the mixing effects but should give upper bound for the mass squared difference affected by the mixing.
- (c) The condition $\Delta m^2/m^2 = .4 \times x$, where $x \leq 1$ parametrizes the mass difference assuming $\Delta m(LSND)^2 = 2.5 \text{ eV}^2$ gives $m^2(LSND) \sim 6.25 \text{ eV}^2/x$.

$x = 1/4$ would give $(k(LSND), k(atm), k(sol)) = (157, 167, 177)$. $k(LSND)$ and $k(atm)$ label two Gaussian Mersenne primes $M_{G,k} = (1+i)^k$ in the series $k = 151, 157, 163, 167$ of Gaussian Mersennes. The scale $L(151) = 10$ nm defines cell membrane thickness. All these scales could be relevant for DNA coiling. $k(sol) = 177$ is not Mersenne prime nor even prime. The corresponding p-adic length scale is $82 \mu\text{m}$ perhaps assignable to neuron. Note that $k = 179$ is prime.

This explanation looks rather nice because the mass squared difference ratios come as powers of two. What seems clear that the longer the path of neutrino travelled from the source to the detector, the smaller than mass squared: in other words one has $k(LSND) < k(atm) < k(sol)$. This suggest that neutrinos transform to lower mass neutrinos during the travel $k(LSND) \rightarrow k(atm) \rightarrow k(sol)$. The sequence could contains also other p-adic length scales.

What really happens when neutrino characterised by p-adic length scale $L(k_1)$ transforms to a neutrino characterized by p-adic length scale $L(k_2)$.

- (a) The simplest possibility would be that $k_1 \rightarrow k_2$ corresponds to a 2-particle vertex. The conservation of energy and momentum however prevent this process unless one has $\Delta m^2 = 0$. The emission of weak boson is not kinematically possible since Z^0 boson is so massive. For instance, solar neutrinos have energies in MeV range. The presence of classical Z^0 field could make the transformation possible and TGD indeed predicts classical Z^0 fields with long range. The simplest assumption is that all classical electroweak gauge fields except photon field vanish at string world sheets. This could in fact be guaranteed by gauge choice analogous to the unitary gauge.
- (b) The twistor lift of TGD however provides an alternative option. Twistor lift predicts that also M^4 has the analog of Kähler structure characterized by the Kähler form $J(M^4)$ which is covariantly constant and self-dual and thus corresponds to parallel electric and magnetic components of equal strength. One expects that this gives rise to both classical and quantum field coupling to fermion number, call this $U(1)$ gauge field U . The presence of $J(M^4)$ induces P, T, and CP breaking and could be responsible for CP breaking in both leptonic and quark sectors and also explain matter antimatter asymmetry [L19, L20] as well as large parity violation in living matter (chiral selection). The coupling constant strength α_1 is rather small due to the constraints coming from atomic physics (new $U(1)$ boson couples to fermion number and this causes a small scaling of the energy levels). One has $\alpha_1 \sim 10^{-9}$, which is also the number characterizing matter antimatter asymmetry as ratio of the baryon density to CMB photon density.

Already the classical long ranged U field could induce the neutrino transitions. $k_1 \rightarrow k_2$ transition could become allowed by conservation laws also by emission of U boson. The simplest situation corresponds to parallel momenta for neutrinos and U . Conservation laws of energy and momentum give $E_1 = \sqrt{p_1^2 + m_1^2} = E_2 + E(U) = \sqrt{p_2^2 + m_2^2} + E(U)$, $p_1 = p_2 + p(U)$. Masslessness gives $E(U) = p(U)$. This would give in good approximation $p_2/p_1 = m_1^2/m_2^2$ and $E(U) = p_1 - p_2 = p_1(1 - m_1^2/m_2^2)$.

One can ask whether CKM mixing for quarks could involve similar mechanism explaining the CP breaking. Also the transitions changing $h_{eff}/h = n$ could involve U boson emission.

2. The explanation based on several p-adic mass scales for neutrinos

Second TGD inspired interpretation would be as a transformation of ordinary neutrino to a dark variant of ordinary neutrino with $h_{eff}/h = n$ occurring only if the situation is quantum critical (what would this mean now?). Dark neutrino would behave like inert neutrino. One cannot exclude this option but it does not give quantitative predictions.

This proposal need not however be in conflict with the first one since the transition $k(LSND) \rightarrow k_1$ could produce dark neutrino with different value of $h_{eff}/h = 2^{\Delta k}$ scaling up the Compton scale by this factor. This transition could be followed by a transition back to a particle with p-adic length scale scaled up by 2^{2k} . I have proposed that p-adic phase transitions occurring at criticality requiring $h_{eff}/h > 1$ are important in biology [K21].

There is evidence for a similar effect in the case of neutron decays. Neutron lifetime is found to be considerably longer than predicted. The TGD explanation [K25] is that part of protons resulting in the beta decays of neutrino transform to dark protons and remain undetected so that lifetime looks longer than it really is [L34] (see <http://tinyurl.com/yc8d7sed>). Note however that also now conservation laws give constraints and the emission of U photon might be involved also in this case. As a matter of fact, one can consider the possibility that the phase transition changing $h_{eff}/h = n$ involve the emission of U photon too. The mere mixing of the ordinary and dark variants of particle would induce mass splitting and U photon would take care of energy momentum conservation.

4.3.6 LSND anomaly is here again!

MinibooNe collaboration published a highly interesting preprint [C58] “Observation of a Significant Excess of Electron-Like Events in the MiniBooNE Short-Baseline Neutrino Experiment” (see <https://arxiv.org/abs/1805.12028>).

The findings give strong support for old and forgotten LSND anomaly - forgotten because it is in so blatant conflict with the standard model wisdom. The significance level of the anomaly is 6.1 sigmas in the new experiment. 5 sigma is regarded as the threshold for a discovery. It is nice to see this fellow again: anomalies are the theoreticians best friends.

To me this seems like a very important event from the point of view of standard model and even theoretical particle physics: this anomaly together with other anomalies raises hopes that the patient could leave the sickbed after illness that has lasted for more than four decades after becoming a victim of the GUT infection.

LSND as also other experiments are consistent with neutrino mixing model. LSND however produces electron excess as compared to other neutrino experiments. Anomaly means that the parameters of the neutrino mixing matrix (masses, mixing angles, phases) are not enough to explain all experiments.

One manner to explain the anomaly would be fourth “inert” neutrino having no couplings to electroweak bosons. TGD predicts both right and left-handed neutrinos and right-handed ones would not couple electroweakly. In massivation they would however combine to single massive neutrino just like in Higgs massivation Higgs gives components for massive gauge bosons and only neutral Higgs having no coupling to photon remains. Therefore this line of thought does not look promising in TGD framework.

For many years ago I explained the LSND neutrino anomaly in TGD framework as being due to the fact that neutrinos can correspond to several p-adic mass scales. p-Adic mass scale coming as power of $2^{1/2}$ would bring in the needed additional parameter. The new particles could be ordinary neutrinos with different p-adic mass scales. The neutrinos used in experiment would have p-adic length scale depending on their origin. Lab, Earth’s atmosphere, Sun, ... It is possible that the neutrinos transform during their travel to less massive neutrinos.

What is intriguing that the p-adic length scale range that can be considered as candidates for neutrino Compton lengths is biologically extremely interesting. This range could correspond to the p-adic length scales $L(k) \sim 2^{(k-151)/2} L(151)$, $k = 151, 157, 163, 167$ varying from cell membrane thickness 10 nm to $2.5 \mu\text{m}$. These length scales correspond to Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$. The appearance of four of 4 Gaussian Mersennes in such a short length scale interval is a number theoretic miracle. Could neutrinos or their dark variants with $h_{eff} = n \times h_0$ together with dark variants weak bosons effectively massless below their Compton length have a fundamental role in quantum biology?

Remark: $h = 6 \times h_0$ is the most plausible option at this moment [L15, L35] (see <http://tinyurl.com/ybxlqqsj> and <http://tinyurl.com/yafndef9>).

5 Neutrinos and TGD

Neutrinos are problematic from the point of view of the standard model. It has become clear that neutrinos experience an analog of CKM mixing for quarks but there are anomalous findings related to the mixing. MiniBoone collaboration published 2018 findings [C57] (see <https://arxiv.org/abs/1805.12028>) related to the mixing between muon and electron neutrinos for incoming muon beam.

The transformation of electron neutrino to electron via charged current reaction was used as a signature for the electron neutrinos and the findings forced the conclusion that the number of electrons produced is too high to be consistent with the neutrino CKM matrix deduced from other experiments. The sterile neutrino was one of the many proposed explanations (see <https://cutt.ly/DRKPZYz>).

The recent experiment of Micro-Boone collaboration however shows no evidence for sterile neutrinos (<https://cutt.ly/QRKDsUA> and <https://cutt.ly/oRKS77W>). The only remaining anomaly is associated with the channel producing an electron but no hadrons in the final state. If this finding is taken seriously, it is difficult to avoid the conclusion that some new physics, which is not caught by the standard model, is involved. Could the transformation of neutrino to an electron occur in some unknown way?

As it often happens, this rather specific question led to a thorough reconsideration of the TGD view about particles and their massivation: what is really understood and what is really certain? The basic idea of the TGD based solution described at the end of the article, would not have required these considerations so that an impatient reader can directly skip to the last section.

5.1 Two problems related to neutrinos

The following considerations were motivated by two problems related to neutrinos.

5.1.1 What is the role of right handed neutrinos in TGD?

The new view led to the conclusion that the right-handed neutrino predicted by TGD and analogous to the inert neutrino solves some long-standing problems of TGD.

- (a) TGD in its recent form predicts an entire tower of color excitations as modes of second quantized $H = M^4 \times CP_2$ spinor field identified as a quark field. The mass scale determined by CP_2 length scale and these give rise to bound states of 3 antiquarks having quantum numbers of leptons if TGD view about color symmetry is accepted [L54]. In particular, covariantly constant right-handed neutrino ν_R in some respects analogous to a sterile neutrino is predicted.

It is intuitively clear that ν_R must have a very special physical role. The naive proposal that ν_R and ν_R could generate the analog $N = 2$ SUSY [L46] has not led to a breakthrough. Sparticles would have been created by adding zero momentum right-handed neutrinos and antineutrinos to the state: the problem is that the norm of these states vanishes if the only CP_2 Kähler form is present as in the formulation of TGD before the discovery of the twistor lift of TGD.

- (b) The twistor lift of TGD [L30] predicts that also M^4 has Kähler structure. This implies a breaking of Lorentz symmetry within causal diamond CD to $M^2 \subset M^4$ emerging also in the dual M^8 picture based on number theoretical view about physics [L47, L48, L56] as a prerequisite of $M^8 - H$ duality.

M^4 mass squared m^2 is replaced with M^2 mass squared as in the quark model of hadrons, in string models, and also in p-adic mass calculations [K22]. The M^2 mass squared spectrum for $H = M^4 \times CP_2$ spinor modes is very much like in conformal field theories and the two integers (n_1, n_2) characterizing analogs of cyclotron states are analogous to conformal weights.

The key point is that the massless ν_R transforms to a tachyon. This is due to the presence of spin term $J^{kl}(M^4)\Sigma_{kl}$ in $D^2(H)$ vanishing for left-handed leptons. On the other hand, p-adic mass calculations [K22] require a tachyon-like ground state: otherwise massless states are impossible. The origin of tachyonicity has remained a mystery. The tachyonic right-handed neutrinos could provide the long sought-for mechanism allowing to reduce the conformal weight of a given many-quark state to obtain a massless state.

- (c) The hard problem is that neutrinos are massive but only the left-handed neutrinos are observed. The problem is that the left-handed neutrinos mix with the right-handed ones if H Dirac operator $D(H)$ determines the time evolution operator. This should be seen in neutrino mixing experiments.

The proposed solution of the problem is based on the TGD view about time evolution in zero energy ontology (ZEO). It has become clear that the time evolution between "small" state function reductions (SSFRs) corresponds to a scaling rather than time translation, and is induced by Virasoro generator L_0 - essentially mass squared operator - rather than by Hamiltonian.

This suggests that for the spinor modes of H , the mass squared operator, that is the square $D^2(H)$ of Dirac operator $D(H)$ - or rather, its longitudinal M^2 part - should determine the time evolution operator rather than $D(H)$. Different M^4 chiralities would *not* mix.

- (d) This alone does not explain why only left-handed neutrinos are observed since different M^4 chiralities for leptons can appear as superpositions if left and right M^4 chiralities have the same value of $m^2(M^2)$. However, the $J^{kl}(M^4)\Sigma_{kl}$ term in $D^2(H)$ implies L-R splitting of mass squared eigenvalues. Degeneracy is possible if different values of $n_1 + n_2$ can compensate for this splitting.

Empirical facts require that R-L mixing is possible for charged leptons but not for neutrino states. Right-handed neutrinos would not mix with left-handed ones and would couple only to M^4 Kähler form but not to electroweak interactions. This could explain why they are not detected but also suggests that their detection might be possible.

5.1.2 Mini-Boone-Micro-Boone conflict and the TGD view about dark matter

This picture looks nice but does not explain the conflict between Mini-Boone and Micro-Boone experiments. Because Micro-Boone observes the anomaly for single electron final states only, it seems that neutrinos must scatter from some new form of matter.

TGD indeed predicts $h_{eff} > h$ phases of ordinary particles behaving like dark matter. The anomalous production of electrons by charged currents could be understood by the presence of dark protons or nuclei in the detector and having large enough h_{eff} . This could scale up weak interaction Compton length by h_{eff}/h above nuclear or even atomic length scale so that weak bosons would be effectively massless particles and the scattering cross section could be of the same order of magnitude as electroweak scattering cross section.

5.2 Some background about TGD

Some background about TGD is necessary in order to tackle the problems related to neutrinos.

5.2.1 Spinor fields in TGD

Spinor fields appear in TGD at three levels. At the level of embedding space $H = M^4 \times CP_2$, at the level of space-time surface $X^4 \subset H$, and at the level of "world of classical worlds" (WCW).

1. Spinor fields in H

Consider first spinor fields and their quantization at the level of H , which actually induces the spinor structure at the level of X^4 and WCW.

- (a) In the TGD Universe space-times are 4-surfaces X^4 in 8-D $H = M^4 \times CP_2$. The only fundamental fermions are quarks and the TGD view about color allows us to identify leptons as composites of 3 antiquarks in the scale of CP_2 : this is not possible in QCD [L46, L54]. In what follows a key assumption is that leptons behave effectively like H spinor field having a chirality opposite to that for quarks and have the same electroweak quantum numbers apart from em charge. Therefore the Dirac equation in H applies to them.
- (b) The quantization of spinors is carried out at the level of H and quantized quark fields in X^4 are induced, that is restricted, to X^4 so that one avoids all problems related to second quantization in curved background. One of them is the difficulty in defining what positive and negative energy solutions to the Dirac equation do really mean.
- (c) If the Kähler form of $J(M^4)$ of M^4 vanishes (the more general case will be discussed later on), the square $D^2(H)$ of the H Dirac operator $D(H) = D(M^4) + D(CP_2)$ allows solutions satisfying $D^2(H)\Psi = 0$ that is massless modes in 8-D sense. The solutions of $D(H)\Psi = 0$ are of form $D(M^4)\Psi_1 \otimes \Psi_2 + \Psi_1 \otimes D(CP_2)\Psi_2$. Ψ_1 is a plane wave and Ψ_2 is an eigenstate of $D^2(CP_2)$ with a quantized mass squared eigenvalue m^2 . Note that chiralities are mixed in accordance with the massivation in H .

Covariantly constant right-handed neutrino is the only massless solution of $D(H)\Psi = 0$ in the M^4 sense. Since it does not have electroweak couplings it satisfies $D(CP_2)\nu_R = 0$ and is covariantly constant in CP_2 . One can say that masslessness in 4-D sense is replaced with masslessness in 8-D sense and this is crucial also for why the twistor lift of TGD applies also to massive particles.

One can say that $D(CP_2)$ is the analog of $D(M^4) = \gamma^k p^k$ in M^4 degrees of freedom. However, it cannot be algebraized. One could also say that it acts as an analog of the Higgs field which is not a H scalar but a CP_2 vector.

2. Spinor fields in X^4

Consider next the spinor fields at the level of X^4 .

- (a) One can define modified Dirac operator [L56] at the level of X^4 in terms of the modified Gamma matrices determined as contractions of H gamma matrices Γ^k and the canonical momentum currents T_k^α determined by the action, which for twistor lift involves volume term (length scale dependent cosmological constant) and Kähler action analogous to Maxwell action. Preferred extremals are actually minimal surfaces which are also extremals of the Kähler action in the interior of X^4 [L57].
- (b) Modified Dirac equation cannot be satisfied generally as an operator equation. It could be however satisfied at the boundaries of causal diamond (CD) (one might say for external free quarks there) or possibly even in the interior of X^4 for the physical states but not generally. In any case the oscillator operator algebra for quarks in H would be used to construct quantum states.

The intuitive guess is that the inverse of D can appear as a propagator. Its construction looks however a horrible problem. Fortunately, the problem disappears since $D(H)$ naturally defines a propagator between points restricted to the space-time surface.

What is remarkable is that quite generally, the propagation between points with light-like distance is essentially like massless propagation. Particle-like entities are light-like orbits of partonic 2-surfaces so that the geometric character of particles forces massive modes effectively masslessness. A more precise formulation is discussed in [L56].

The induction procedure generalizes to the level of the isometry algebra (IA) and even super-symplectic algebra (SSA) [K35] [L51, L56].

- (a) One can construct the representations of IA and SSA in H for the Dirac action associated with $D(H)$ and construct the Noether currents of super symplectic algebra and project the currents to the space-time surface. A natural condition would be that these currents are equal to the corresponding currents assigned to the modified Dirac action for the physical states defined at the boundaries of CD.
- (b) An analogous condition for classical currents was proposed in [L56] and stated that the conserved classical current for given isometry with Killing vector j_A^k is proportional to its projection to the space-time surface.

$$\begin{aligned} T_B^{A\alpha} &= \Lambda(x)j_A^\alpha , \\ j_A^\alpha &= j_A^k \partial^\alpha h_k \equiv j_A^k h_{kl} g^{\alpha\beta} \partial_\beta h^l , \\ \partial_\alpha \Lambda j^{A\alpha} &= 0 . \end{aligned} \tag{5.1}$$

This condition could be true for the entire space-time surface or at the ends of X^4 at the boundaries of CD. The conserved bosonic current in H corresponds to j_A^k satisfying $D_k j_A^k = 0$. The conservation condition requires that Λ is constant along the flow lines of j_A^k .

Quantum classical correspondence suggests that the condition can be true only for Cartan algebra. For the volume part of the action the condition is identically true and $\Lambda(x)$ corresponds to length scale dependent cosmological constant in this case. For Kähler action, the condition is non-trivial.

- (c) In the fermionic case, the condition would state that the conserved second quantized quark current at the level of H projected to the space-time surface is equal to the conserved fermionic current for the Dirac action in X^4 . In the general case, this could hold true for the Cartan algebra and in the case of H isometries at the entire space-time surface. For the symplectic currents it could hold true at the 3-D ends of the space-time surface at boundaries of CD. The condition reads as

$$T_F^{A\alpha} = \bar{\Psi} \Gamma_k \partial_\alpha h^k \delta_A \Psi = k(x) \bar{\Psi} \Gamma_k T_B^{k\alpha} \delta_A \Psi . \tag{5.2}$$

If the bosonic condition for $T_B^{k\alpha}$ holds true, this condition and the conservation condition are trivially satisfied for $k(x) = \Lambda(x)$ as also the conservation condition. The condition also generalizes to super-currents obtained by replacing $\bar{\Psi}$ or Ψ by a mode of H spinor field in the expression of the fermionic current.

3. WCW spinors

The third realization is at the level of the "world of classical worlds" (WCW) assigned to H consisting of 4-surfaces as preferred extremals of the action. Gamma matrices of WCW are expressible as superpositions of quark oscillator operators so that anti-commutation relations are geometrized. WCW spinors are Fock states of quarks. The conditions stating super-symplectic symmetry are a generalization of super-Kac-Moody symmetry and of super-conformal symmetry and give rise to the WCW counterpart of the Dirac operator [K35] [L51, L56] as a non-hermitian super-Virasoro generator G which however carries fermion number.

Bosonic conditions and the fermionic condition implied by them have been already discussed and would dramatically simplify the construction of the quantum states as super-symplectic representations.

WCW gamma matrices would be simply SSA super charges for the induced spinor fields obtained by integrating the 3-D SSA super currents over 3-surfaces X^3 defining the ends of X^4 at the boundaries of CD. That they are projections of 8-D conserved currents in H would make life simple.

One could construct also WCW Kähler metric and in principle all related geometric entities in terms of SSA.

- (a) The matrix element of the WCW Kähler metric would be obtained as anticommutators

$$g_{\bar{A},B} = \frac{1}{2}\{Q_A^\dagger, Q_B\} \quad (5.3)$$

of the super symplectic charges. Super charge Q_A is obtained as a 3-D integral of super current J_A carrying quark number over the 3-surface X^3 :

$$Q_A = \int_{X^3} d^3x J_A . \quad (5.4)$$

The anticommutators of the fermionic oscillator operators for H spinors give Kronecker deltas for both momenta and color quantum numbers.

- (b) The localization at 3-surface implies that $g_{\bar{A}B}$ is given by an integral of form

$$\int_{X^3 \times X^3} d^3x_1 d^3x_2 \sum_{p,n} \bar{T}_{A_1}(p, n, x_1) T_{A_2}(p, n, x_2) . \quad (5.5)$$

The plane waves in the product give a factor $\exp[ip \cdot (m(x_1) - m(x_2))]$ giving rise to interference. CP_2 spinor harmonics give a product of $\bar{\Psi}_n(s(x_1))\Psi_n(s(x_2))$. The products of factors at different points give rise to interference effects and could save from infinities.

The replacement of point-like particles with 3-surfaces is essential since the 7-D equal-time anti-commutation relations for quark oscillator operators give a 7-D delta function in H . Indeed, for a point-like particle instead of a 3-surface, one would obtain a sum over terms $\bar{\Psi}_n(s(x_1))\Psi_n(s(x_1))$ multiplied by the volume of the corresponding mass shell.

- (c) More generally, the double 3-D integral over a particle like n -surface should compensate for the 7-D delta function divergence so that for $2n > 7$ divergences would be absent. For 3-D objects one has $2n = 6$, so that one cannot exclude logarithmic divergences typically present also in gauge theories. Does this mean that the divergence cancellation cannot rely on mere non-locality.
- (d) Could the preferred extremal property be crucial? As a matter of fact, the condition guaranteeing that SSA currents for the action are equal to the projections of SSA currents for H spinors (at least at boundary CD) has been already assumed.

Number theoretic holography fixes the space-time region in terms of roots of a polynomial with rational coefficients and is an extremely powerful condition also on 3-surfaces at the boundary of CD.

Also the geometry of $\delta CD = \delta cd \times CP_2$ might be relevant as also the precise definition of the integral. One has a 6-D integral over $\delta cd \times \delta cd$. It seems that this is the correct intuition.

The following argument indeed shows that the geometry of CD (and thus ZEO) is highly relevant.

- (a) For $m_1 - m_2 = 0$, the CP_2 anticommutator gives a 4-D delta function in CP_2 as a singularity for $s(m_1) = s(m_2)$. For $m_1 = m_2$, one also has a 3-D delta function corresponding to equal time anticommutation relations. This would give 7-D delta function and the integral would diverge and be ill-defined. This is the source of troubles and raises the question whether one should one define the integral as a limit in which the ill-defined 7-D delta function contribution is avoided.

- (b) Denote by D the diagonal set $Diag(\delta cd \times \delta cd)$ of points $m_1 = m_2$ of $\delta cd \times \delta cd$. Assign to D a thin 3-D layer $D \times L$ with L having a thickness l and define the integral over the volume $cd \times cd \setminus D \times L$ and take the limit $l \rightarrow 0$. This removes the problematic 7-D delta function singularity and leaves only the 1-D light-ray singularity at δcd [L53, L52] under consideration so that the anticommutator is well-defined and finite.
- (c) Irrespective of mass, fermion anticommutator has 1-D delta function type singularity as a 1-D delta function $\delta(a)$, $a^2 = (m_1 - m_2)^2$. Now both m_1 and m_2 are points at δcd , and the delta function defines light-like geodesic rays from origin connecting m_1 and m_2 . This delta function eliminates 1 integration variable from 6 integration variables in the integration measure $dV = d^3 m_1 d^3 m_2$ associated with $\delta cd \times \delta cd$.
 $d^3 m$ is determined by the determinant of the induced metric and if the CP_2 coordinates are not constant, the determinant is manifestly non-trivial even if one uses radial light-like coordinate r and angle coordinates Ω of $R_+ \times S^2$ as coordinates. This leaves a 5-D integration volume $X^5 \subset \delta cd \times \delta cd$. Note that for canonically embedded M^4 as a minimal surface extremal the integration measure is trivial so that the 3-surfaces do not belong to WCW.
- (d) The geometry of δcd would be highly relevant. If one had E^3 as time= constant slice instead of M^4 , the same definition of the integral would give a vanishing result since light-like radial rays as singularities would be lost. This picture supports the importance of light-cone boundary as a basic notion but strictly speaking does not force CD.

One could worry for the somewhat ad hoc elimination of 7-D delta function singularity and perhaps take it as a signal telling that something important is still missing. There indeed exists a variant of gamma matrices with which I ended up from the cancellation of fermionic divergences in ZEO. This option is inspired by the multi-locality of the Yangian variants of the super symplectic algebra and isometry algebra for H .

- (a) The fermionic creation and annihilation operators appearing as building bricks of super symplectic (SSA) charges defining the gamma matrices would be at the opposite boundaries of CD and 3-D states at the opposite boundaries would relate like bras and kets. Annihilation operators would act like creation operators at the opposite boundary of CD.

The conserved isometry currents in H would be replaced by bilocals with Ψ and $\bar{\Psi}$ and opposite boundaries of CD and remain conserved currents thanks to the (covariant) constancy of M^4 gamma matrices. Note that although SSA currents are not conserved, the Noether charges at the boundaries of CD are well-defined.

- (b) Can one apply this recipe to the WCW gamma matrices as bi-local entities having 3-surfaces at opposite boundaries as arguments? For supersymmetry generators associated with H isometries, the conservation laws hold and one can calculate the anticommutators. They are non-vanishing and the dominating contributions come from pairs of points with light-like separations. One can use the same CP_2 and S^2 coordinates at both light-like boundaries and only the radial light-like coordinates are different. The 3-D delta function singularity does not appear at all. This would justify the notion of CD rather than only light-cone boundary.
- (c) The commutators of SSA charges associated with 3-surfaces at different boundaries of CDs or even at boundaries of different CDs generate a poly-local algebra, which could have an interpretation as the Yangian algebra of SSA acting as isometries for WCW.

5.2.2 Twistor lift predicts M^4 Kähler force

The twistor lift of TGD suggests also a modification of the neutral weak forces.

- (a) The twistor lift of TGD requires that there is a covariantly constant self-dual Kähler form also in M^4 . This would contribute to the electromagnetic and Z^0 fields an additional coupling analogous to that of electroweak hypercharge to $U(1)$ gauge potential.

- (b) M^4 Kähler form contributes to the Kähler action an additional term. The M^4 contribution is fixed by the condition that the M^4 metric is the square of the Kähler form. Also H -spinors couple to M^4 Kähler gauge potential defining a self-dual Abelian field: essentially constant electric and magnetic fields, which are orthogonal and have the same strength, is in question.

The scale of the M^4 metric defines the normalization of $J(M^4)$. Here one however encounters a problem since M^4 does not have any inherent scale in its geometry. The size scale L causal diamond ($CD = cd \times CP_2$), where cd is the intersection of light-cones with opposite direction, serves as a natural scale allowing to identify dimensionless coordinates for M^4 in such a way that the range of variation for the dimensionless coordinates does not depend on the size of CD .

In these coordinates the self-dual Kähler form scales $E = B = k/L^2$, k a constant near unity. At the limit of long length scales $E = B$ would approach zero. The identification of L as a length scale determined by the cosmological constant is attractive. The breaking of Lorentz symmetry to that of M^4 for the Dirac operator $D(H)$ would be small in long length scales. In very short length scales associated with quarks, the breaking would be large.

Remark: One cannot completely exclude the alternative option $E = B = k/R^2$, where R is CP_2 scale for which the breaking of Lorentz invariance would be large in all scales.

The presence of M^4 Kähler structure has non-trivial implications also at the level of particle physics.

- (a) In particular, M^4 Kähler gauge potential $A(M^4)$ couples also to neutrinos unlike $A(CP_2)$, where the net coupling vanishes. The effects are expected to be small in the TGD view about space-time sheets at particle level.
- (b) The prediction is that all particles have an additional M^4 contribution in their Z^0 and em force and also right-handed neutrinos couple to M^4 Kähler gauge potential.

Remark: The Kähler gauge potential A does not correspond to a genuine gauge invariance and each choice defines a different physics. The proposal is that the so-called Hamilton-Jacobi structures could correspond to different choices of A .

- (c) At the level of H the square $D^2(H)$ of the modified Dirac operator would allow spinors to be eigen states of energy and single momentum component. Self duality and co-variant constancy imply that $D^2(H)$ contains a term proportional to charge matrix $J^{kl}(M^4)\Sigma_{kl} \propto (\sigma_{03} + \Sigma_{12})$, which vanishes for the second M^4 chirality.
- (d) 2 components of the 3-momentum would correspond to harmonic oscillator states so that the states would be confined to a finite transversal volume to a harmonic oscillator state characterized by transversal momenta of order magnetic length $\sqrt{B_K}$.

Suppose that for the transversal degrees of freedom in E^2 with signature $(-1,-1)$, Kähler gauge potential can be chosen to be $A_x = B_K y$. For an eigenstate of p_x , one obtains for the square of the E^2 part of the square D^2 of the Dirac operator,

$$D^2(E^2) = -(\partial_x - B_K y)^2 - \partial_y^2 = p_x^2 + \partial_y^2 - B_K y^2 - 2ip_x B_K y .$$

The sign of the harmonic oscillator term is correct and the complex shift does not produce problems if the notion of hermiticity is generalized so that PT replaces complex conjugation. Eigenvalues of $p_y^2 + ..$ are essentially the eigenvalues of energy in harmonic oscillator potential and proportional to $2nB_K$ with $n = 1$ assignable to the ground state.

- (e) In the longitudinal degrees of freedom M^2 , the signature of the metric is $(1,-1)$. If A is given by $A_t = B_K z$, the M^2 part of the square of the Dirac operator for an energy eigenstate reduces to $D^2(M^2) = (iE - iB_K z)^2 - \partial_z^2 = -E^2 - \partial_z^2 - B_K^2 z^2 - 2EB_K z$. One obtains a harmonic oscillator potential with a wrong sign and has suffered a complex shift by $z \rightarrow z + iE/B_K$. Harmonic oscillator Gaussian would be replaced with an imaginary exponential - this is of course familiar from free quantum field theories based on path integral defined by Gaussian. The size scale of CD would bring to the theory an arbitrarily long p-adic length scale as a fundamental level scale but expressible in terms of CP_2 radius.

Some physics inspired comments are in order.

- (a) This picture brings strongly in mind the parton model of hadrons. If cosmological constant Λ characterizes the size scale L , it must correspond to the scale which is essentially geometric mean of Planck length and the p-adic length scaled defining the length scale dependent cosmological constant Λ (of order Hubble scale). In the TGD framework, cosmological constant is length scale dependent, and the value of Λ assignable to cosmology would correspond to length L of order 10^{-4} meters assignable to a large neuron.
- (b) The spectrum of the M^2 mass squared operator is integer valued using B as a unit. The mass squared spectrum is similar to the spectrum in string models. This picture also conforms with the idea that the transversal Kac-Moody modes in $M^2 \times E^2$ are dynamical. Also transversality of polarizations in gauge theories conforms with this picture. Also the properties of "massless external" support this picture.
- (c) What comes to mind is that the values of integers n_i characterizing harmonic oscillator states are analogous to fermionic conformal weights. One has conformal weight for both the light-like radial coordinate of super symplectic representations and for the Kac-Moody type representations associated with light-like orbits of partons: the light-likeness of the partonic 2-surfaces and of light-cone boundary make them metrically 2-D and implies a generalization of conformal invariance.

This conforms with the notion of induction. The fermion super symplectic charges should be constructible in terms of the quark oscillator operators for the second quantized quark fields of H .

5.2.3 How can massless particles exist at all and how do they become massive?

One must understand why there are light particles at all and what makes them massive.

- (a) The mass scale for CP_2 is about 10^{-4} Planck masses and the only massless particle is a right-handed neutrino of only $J(CP_2)$ is present. Also the color quantum numbers depend on the em charge. Therefore physical elementary particles cannot correspond to the quarks as such. The situation remains essentially the same if $J(M^4)$ is present. The proposal has been that H spinor modes define ground states for super-symplectic representations and operators carrying conformal weight contribute to mass squared additively create the physical states. The lowest states have vanishing mass squared. The introduction of $J(M^4)$ suggests that the quark oscillator operators labelled by two integers could actually be interpreted as conformal weights and that M^2 momentum would take the role of M^4 momentum. The number of ground states of super-symplectic representations could be much smaller.
- (b) p-Adic thermodynamics however mixes these states with states of higher conformal weight and this gives rise to the mass of the light particles. One must assume that there is a negative tachyonic contribution to the ground state conformal weight since only the right-handed neutrino is massless in 4-D sense. The origin of this negative conformal weight has remained a mystery.
- (c) $M^8 - H$ duality provides a possible insight to the mystery of the tachyonic conformal weight. The map of 4-surfaces in M_c^8 (complexified octonions) by $M^8 - H$ duality involves selection of M^4 as a 4-D linear subspace in M^8 . This choice is not unique. Momenta and color quantum numbers in H correspond to 8-momenta in M^8 such that 8-D mass squared vanishes at both sides and M^4 momenta are identical. For a suitable choice of $M^4 \subset M^8$, the 8-momentum is parallel to M^4 and the state is massless!

Could the introduction of negative tachyonic conformal weight provide an alternative description of this choice? This choice can be made only for a single, naturally dominant contribution of the state, and the remaining contributions to mass squared coming from higher conformal weights give rise to massivation described by p-adic thermodynamics.

- (d) Here the twistor lift comes to rescue. Twistor lift of TGD requires that also M^4 has Kähler structure defined by a self-dual Kähler form $J_{kl}(M^4)$ (constant E and B with $\text{vert}B| = |E|$ orthogonal to each other). Depending on the selected correlation between M^4 and CP_2 chiralities guaranteeing that quarks correspond to a fixed H chirality, $D^2(H)$ contains for either left- or right-handed M^4 modes a nonvanishing spin term $J^{kl}(M^4)\Sigma_{kl}$. The reason is that for left-/right-handed mode the eigenvalues of Σ_{03} and Σ_{12} have the same/opposite sign or vice versa.

This would give a mass splitting between left- and right-handed modes and also spin splitting for left- or right-handed modes. The spin-splitting could give rise to a negative contribution to the mass squared in the case of right-handed neutrinos. Could the tachyonic state of the right-handed neutrino give rise to the mysterious tachyonic ground states required by p-adic mass calculations? Could a suitable number of tachyonic right-handed neutrinos allow to nullify arbitrarily high conformal weight of ground state?

5.2.4 How to describe the unitary time evolution of quantum states in the TGD Universe?

The first question is how to describe the time evolution of quantum states in general. The time evolution at the single particle level is involved with the mixing of neutrinos.

Remark: One must remember that physical particles are multi-quark composites: even leptons are local composites of 3 antiquarks). Therefore the description in terms of H -spinors applied in the sequel can be criticized.

- (a) In the TGD framework the standard 4-D approach based on the Hamiltonian picture can be only an approximate description since it neglects masslessness in the 8-D sense and is not relativistically invariant.
- (b) The empirical fact is that neutrinos are massive but always left-handed. The trivial explanation could be that right-handed neutrinos have only gravitational interaction so that their detection is not possible. The mixing of left-handed neutrinos with right-handed ones should however be visible in neutrino mixing experiments.

In the TGD framework Dirac equation in H forces the mixing of quark chiralities for the modes of H -spinors. The covariantly constant right-handed neutrino is an exception. Induction as a mere restriction to the space-time surface respects this property! This implies that left-handed neutrino modes mix with right-handed ones and this could make itself visible in the neutrino beam experiments like Mini-Boone and Micro-Boone. The problem can be avoided if it is possible to have massive neutrinos with well-defined M^4 chirality and a time evolution which does not mix the chiralities. Could this kind of time evolution allow a realization?

- (c) Certainly, if the Dirac operator in H , or equivalently, the modified Dirac operator in X^4 defines the phenomenological Hamiltonian operator, the chirality mixing seems unavoidable. There is however no deep reason why $D(H)$ or $D(X^4)$ should define the propagation.
- (d) To get some guidance, one can also consider the level of "world of classical worlds" (WCW). The gamma matrices of WCW are constructed in terms of anticommuting oscillator operators of H -spinors and at that level the analog of the Dirac operator is a generator G of super-conformal algebra whereas the scaling generator L_0 is essentially GG^\dagger . However, G carries a quark number and therefore it does not make sense to talk about a propagator defined by G or an analog of Hamiltonian.

The only reasonable unitary time evolution operator at WCW level is defined by the exponent of L_0 , which is essentially mass squared operator obtained as "square" of WCW Dirac operator and has at the level of H counterpart of mass squared operator $D^2(H)$.

In fact, in superstring models, the time evolution operator for the string world sheet is defined by L_0 so that this idea is not new. Also p-adic thermodynamics is defined by

the exponent of L_0 , at this time real, and its existence in the p-adic sense is responsible for the predictive power of p-adic thermodynamics.

Here one must be more precise. Entire L_0 cannot be in question if it annihilates the physical states. In p-adic mass calculations L_0 is identified as the vibrational part $L_{0,vib}$ and for physical states in the string model satisfy $L_0\Psi = (p^2 - kL_{0,vib})\Psi = 0$. One could say that one has thermodynamics for states with different values of mass squared but satisfying the Virasoro condition. p^2 could also correspond to the longitudinal M^2 momentum and transversal momentum would be absorbed to $L_{0,vib}$. Both p-adic mass calculations and M^4 Kähler form favor this option and this picture conforms also with the stringy picture with M^2 effectively replacing the string world sheet.

Also the TGD based quantum measurement theory [L45] [K52] leads to the conclusion that the unitary time evolutions between "small" state function reductions (SSFRs) correspond to the exponential of L_0 . Unitary time evolution as a time translation is replaced with a scaling which is a Lorenz invariant notion and better suited for relativistic purposes.

- (e) L_0 does not mix chiralities! If the initial state of a neutrino is left-handed, it remains left-handed. But how can the initial state of a neutrino be left-handed if spinor modes at the level of H are mixtures of left and right-handed modes as $D(H)\Psi = 0$ demands? Massless Dirac equation cannot be satisfied at the level of X^4 and at the level of WCW it does not make sense. Could one consider the radical possibility of giving it up altogether so that at the level of H one would require only that $D^2(H)\Psi = 0$ is satisfied and $D^2(H)$ would define counterpart of fermionic L_0 and time evolution.

If so, the number of modes is doubled except for the right-handed neutrino. This implies mirror neutrinos. Could left and right-handed charged leptons and quarks be interpreted in terms of the mirror modes? Mirror neutrino hypothesis does not however have empirical support at available energies. One explanation is that the right-handed neutrino modes are very massive or somehow special.

- (f) If $J(M^4)$ is present, the masses of the left-handed mode and corresponding right-handed mode differ by the $S = J^{kl}(M^4)\Sigma_{kl}$ whose eigenvalues define the vacuum conformal weight $\pm h_{vac}$. Assume that S is non-vanishing for the right-handed mode. The number of right-handed modes with tachyonic mass squared would be the number of CP_2 modes with mass squared smaller than h_{vac} . Covariantly constant neutrino would certainly define this kind of state.

If the mass is identified as the longitudinal M^2 mass, it might be possible to select the values of the conformal weights n_1 and n_2 for the modes in such a way that the masses are identical for the left- and right-handed modes and they can superpose. This should happen for charged modes. If this is not possible for neutrinos, the mixing of chiralities could not occur. This does not work.

The masses of modes related by multiplication with Dirac operator have always identical mass squared values as follows from the commutativity of D and D^2 . However, the covariantly constant right-handed neutrino does not have a left-handed companion. Both mixed states as modes of D and unmixed states satisfy $D^2\Psi = 0$. Why would neutrinos always have a definite handedness? Does the absence of standard model interactions for ν_R imply that the state preparation and reduction involving weak interactions creates only purely left-handed neutrinos?

In the TGD Universe, even covariantly constant right-handed neutrino mode couples to M^4 Kähler form. Could this make it possible to project from mostly left-handed neutrino the non-covariantly constant right-handed part? Could their large mass make their creation impossible?

5.3 Problems related to neutrinos

In what follows, the problem of missing right-handed neutrinos and the problem created by apparently contradictory findings of Mini-Boone and Micro-Boone about neutrino mixing

are discussed. Also the topological model for neutrino and D-quark CKM mixing is briefly considered.

5.3.1 Why only left-handed neutrinos are observed?

A basic theoretical motivation for the sterile neutrinos is the difficulty posed by the fact that the neutrinos behave like massive particles. This is not consistent with their left-handedness, which is an experimental fact.

As a matter of fact, the sterile neutrinos would be analogous to the covariantly constant right-handed neutrinos in TGD if only $J(cP_2)$ would be present.

Remark: As already stated, in the sequel it is assumed that leptons as bound states of 3 anti-quarks can be described using spinors of H with chirality opposite to that for quarks. They have colored modes and the action of super-symplectic algebra is assumed to neutralize the color and also give rise to a massless state getting its small mass by p-adic thermodynamics.

How could one understand the fact that only left-handed neutrinos are observed although neutrinos are massive? One can consider two approaches leading to the same conclusion.

Is it possible to have time evolution respecting M^4 chirality and neutrinos with fixed chirality possible despite their mass?

- (a) All spinor modes in CP_2 are of the form Φ_L or $D(CP_2)\Phi_L$ and therefore generated from left-handed spinors Φ_L .

If one assumes $D(H)\Psi = 0$, the spinor modes of H are of the form $D(M^4)\Psi_R \otimes \Phi_L + \Psi_R \otimes D(CP_2)\Phi_L$. The modes of form $D(M^4)\Psi_L \otimes \Phi_R + \Psi_L \otimes D(CP_2)\Phi_R$ are therefore of the form $D(M^4)\Psi_L \otimes D\Phi_L + \Psi_L \otimes D^2(CP_2)\Phi_L$. The mixing of chiralities is unavoidable.

- (b) However, if one assumes only the condition $D^2(H)\Psi = 0$, one can obtain both left- and right-handed modes without mixing of M^4 chiralities and M^4 Kähler structure could make the lowest mass second right-handed neutrino (covariantly constant in CP_2) tachyonic. The time evolution generated by the exponent of L_0 would respect M^4 chirality.

This does not prevent superpositions of right- and left-handed fermions if their masses are the same. If only charged leptons can satisfy this condition, one can understand why right-handed neutrinos are not observed.

An alternative approach would rely on quantum measurement theory but leads to the same conclusion.

- (a) Suppose that neutrinos can appear as superpositions of both right- and left-handed components. To detect a right-handed neutrino, one must have a measurement interaction, which entangles both length and right-handed components of the neutrino with the states of the measuring system. Measurement would project out the right-handed neutrino. If only the $J(CP_2)$ form is present, the right-handed neutrino has only gravitational interactions, and this kind of measurement interaction does not seem to be realizable.
- (b) Putting it more explicitly, the reduction probability should be determined by a matrix element of a neutral (charged) weak current between a massive neutrino (charged lepton) spinor with a massless right-handed neutrino spinor. This matrix element should have the form $\bar{\Psi}_R O \Psi_L$, where O transforms like a Dirac operator. If it is proportional to $D(H)$, the matrix element vanishes by the properties of the massless right-handed neutrino.
- (c) There is however a loophole: the transformation of left- to right-handed neutrinos analogous to the transformation to sterile neutrino in the neutrino beam experiments could demonstrate the existence of ν_R just like it was thought to demonstrate the existence of the inert neutrino in Mini-Boone experiment. Time evolution should thus respect M^4 chirality.

If $J(M^4)$ is present, one might understand why right- and left-handed neutrinos have different masses.

- (a) Also the right-handed neutrino interacts with Kähler gaug potential $A(M^4)$ and one can consider an entanglement distinguishing between right- and left-handed components and the measurement would project out the right-handed component. How could this proposal fail?

Could it be that right- and left-handed neutrinos cannot have modes with the same mass so that these superpositions are not possible as mass eigen states? Why charged modes could have the same mass squared but not the neutral ones?

- (b) The modes with right-handed CP_2 chirality are constructed from the left-handed ones by applying the CP_2 Dirac operator to them and they have the same CP_2 contribution to mass squared. However, for the right-handed modes the $J^{kl}(M^4)\Sigma_{kl}$ term splits the masses. Could it be that for right- and left-handed charged leptons the same value of mass is possible.

The presence of $J(M^4)$ breaks the Poincare symmetry to that for M^2 which corresponds to a Lagrangian manifold. This suggests that the physical mass is actually M^2 mass and the QCD picture is consistent with this. Also the p-adic mass calculations strongly support this view. The E^2 degrees of freedom would be analogous to Kac-Moody vibrational degrees of freedom of string. This would allow right- and left-handed modes to have different values of "cyclotron" quantum numbers n_1 and n_2 analogous to conformal weights. This could allow identical masses for left- and right-handed modes. For a Lagrangian manifold M^2 , one would have $n_1 = n_2 = 0$, which could correspond to ground states of super-symplectic representation.

- (c) Why identical masses would be impossible for right- and left-handed neutrinos? Something distinguishing between right- and left-handed neutrinos should explain this. Could the reason be that Z^0 couples to left-handed neutrinos only? Could the fact that charged leptons and neutrinos correspond to different representations of color group explain why only charged states can have right and left chiralities with the same mass?

Perhaps it is of interest to notice that the presence of $J^{kl}(M^4)\Sigma_{kl}$ for right-handed modes makes possible the existence of a mode for which mass can vanish for a suitable selection of B .

5.3.2 Mini-Boone and Micro-Boone anomalies and TGD

After these preliminaries we are ready to tackle the anomalies associated with the neutrino mixing experiments. The incoming beam consists of muonic neutrinos mixing with electron neutrinos. The neutrinos are detected as they transform to electrons by an exchange of W boson with nuclei of the target and the photon shower generated by the electron serves as the experimental signature.

The basic findings are as follows.

- (a) Mini-Boone collaboration reported 2018 [C57] an anomalously large number of electrons generated in the charged weak interaction assumed to occur between neutrino and a nucleus in the detector. "Anomalous" meant that the fit of the analog of the CKM matrix of neutrinos could not explain the finding. Various explanations including also inert neutrinos were proposed. Muonic inert neutrino would transform to inert neutrino and then to electron neutrino increasing the electro neutrino excess in the beam.
- (b) The recently published findings of Micro-Boone experiment [C56] studied several channels denoted by $1eNpM\pi$ where $N = 0, 1$ is the number of protons and $M = 0, 1$ is the number of pions. Also the channel $1eX$, where "X" denotes all possible final states was studied.

It turned out that the rate for the production of electrons is below or consistent with the predictions for channels $1e1p$, $1eNp0\pi$ and $1eX$. Only one channel was an exception and corresponds to $1e0p0\pi$.

If one takes the finding seriously, it seems that a neutrino might be able to transform to an electron by exchanging the W boson with a nucleus or hadron, which does not belong to the target.

In TGD, the only imaginable candidate for this interaction could be charged current interaction with a dark nucleus or with a nucleon with $h_{eff} > h$. This could explain the absence of ordinary hadrons in the final state for 1e events.

- (a) Dark particles are identified as $h_{eff} > h$ phases of the ordinary matter because they are relatively dark with respect to phases with a different value of h_{eff} . Dark protons and ions play a key role in the TGD inspired quantum biology [L63] and even in the chemistry of valence bonds [L23]. Dark nuclei play a key role in the model for "cold fusion" [L9, L49] and also in the description of nuclear reactions with nuclear tunnelling interpreted as a formation of dark intermediate state [L43].
- (b) I have proposed that dark protons are also involved with the lifetime anomaly of the neutron [L34] [L34]. The explanation relies on the transformation of some protons produced in the decay of neutrons to dark protons so that the measured life time would appear to be longer than real lifetime. In this case, roughly 1 percent of protons from the decay of n had to transform to dark protons.
- (c) If dark protons have a high enough value of h_{eff} and weak bosons interacting with them have also the same value of h_{eff} , their Compton length is scaled up and dark W bosons behave effectively like massless particles below this length scale. The minimum scale seems to be nuclear or atomic scale. This would dramatically enhance the dark rate for $\nu p \rightarrow e + n$ so that it would have the same order of magnitude as the rates for electromagnetic interactions. Even a small fraction of dark nucleons or nuclei could explain the effect.

5.3.3 CKM mixing as topological mixing and unitary time evolution as a scaling

The scaling generator L_0 describes basically the unitary time evolution between SSFRs [L45] [K52] involving also the deterministic time evolutions of space-time surfaces as analogs of Bohr orbits appearing in the superposition defining the zero energy state. How can one understand the neutrino mixing and more generally quark and lepton mixing in this picture?

- (a) In the TGD framework, quarks are associated with partonic 2-surfaces as boundaries of wormhole contacts, which connect two Minkowskian space-time sheets and have an Euclidean signature of induced metric and light-like projection to M^4 [K11, K22].
- (b) For some space-time surfaces in their superposition defining a zero energy state, the topology of the partonic 2-surfaces can change in these time evolutions. The mixing of boundary topologies would explain the mixing of quarks and leptons. The CKM matrix would describe the difference of the mixings for U and D type quarks and for charged and neutral leptons. The topology of a partonic 2-surface is characterized by the genus g as the number of handles attached to a sphere to obtain the topology.

The 3 lowest genera with $g \leq 2$ have the special property that they always allow Z_2 as a conformal symmetry [K11, K22]. The proposal is that handles behave like particles and thanks to Z_2 symmetry $g = 2$ the handles form a bound state. For $g > 2$ one expects a quasi-continuous spectrum of mass eigenvalues. These states could correspond to so-called unparticles introduced by Howard Georgi (<https://cutt.ly/sRZKSFm>).

- (c) The time evolution operator defined by L_0 induces mixing of the partonic topologies and in a reasonable idealization one can say that L_0 has matrix elements between different genera. The dependence of the time evolution operator on mass squared differences is natural in this framework. In standard description it follows from the approximation of relativistic energies as $p_0 \simeq p + m^2/2p$. Also the model of hadronic CKM relies on mass squared as a basic notion and involves therefore L_0 rather than Hamiltonian.

5.4 Could inert neutrinos be dark neutrinos in the TGD sense?

I learned about a new-to-me anomaly related to nuclear physics and possible neutrino physics (<https://cutt.ly/mKb9265>). The so-called Gallium anomaly [C90] is actually well-known but had escaped my attention. Baksan Experiment on Sterile Transitions (BEST) studies the nuclear reaction $\nu_e + {}^{71}\text{Ga} \rightarrow e^+ + {}^{71}\text{Ga}$ in which an electronic neutrino is produced in the beta decay of ${}^{51}\text{Cr}$. The reaction rate has been found to be about 20-24 per cent lower than predicted. The articles [C80, C80] by Barinov et al published in Phys Rev Letters and Phys Rev C of the experiment, can be found from arXiv (<https://arxiv.org/abs/2109.11482>, <https://arxiv.org/abs/2201.07364>).

Gallium anomaly is reported to be consistent with the sterile neutrino explanation stating that part of the electron neutrinos from the beta decay of ${}^{51}\text{Cr}$ transform to their sterile counterparts so that the reaction rate is reduced. A thorough discussion of the standard nuclear physics predictions for the reaction rate of the reaction can be found in the article "The gallium anomaly revisited" by Kostensalo et al [C90] (<https://cutt.ly/5Kb95nz>).

The already discussed MicroBoone experiment [C56] however seems to exclude inert/sterile neutrinos.

- (a) What was reported is the following. Liquid Argon scintillator was used as a target. Several channels denoted by $1eNpM\pi$ where $N = 0, 1$ is the number of protons and $M = 0, 1$ is the number of pions, were studied. Also the channel $1eX$, where "X" denotes all possible final states was studied. It turned out that the rate for the production of electrons is *below or consistent* with the predictions for channels $1e1p$, $1eNp0\pi$ and $1eX$. Only one channel was an exception and corresponds to $1e0p0\pi$. This anomalous scattering without hadrons in the final state was interpreted in terms of the scattering of ν_e on dark weakly interacting matter. Also the neutrino must be dark and the values of h_{eff} must be identical for this dark matter and dark neutrino if they interact.
- (b) The strange scattering in the 0-proton channel would take place from weakly interacting matter, which is dark in the sense that it has non-standard value of effective Planck constant $h_{eff} = nh_0$: this proposal has a number theoretic origin in the TGD framework. Darkness implies that the particles with the same value of h_{eff} appear in the vertices of scattering diagrams. Dark and ordinary particles can however transform to each other in 2-vertex and this corresponds to mixing. The identification of what this weakly interaction dark matter might be, was not considered.

The anomaly associated with the neutron life-time is another anomaly, which the dark proton hypothesis explains [L34]. The two methods used to determine the lifetime of neutrons give different results. The first method measures the number of protons emerging to the beam in neutron decays. Second method measures the number of neutrons. The TGD explanation of the anomaly is that a fraction of neutrons decay to a dark proton, which remains unobserved in the first method. Second method detects the reduction of the intensity of the neutron beam and is insensitive to what happens to the proton so that the measurements give slightly different results.

These findings inspire the question whether the inert neutrinos are dark neutrinos in the TGD sense and therefore have $h_{eff} > h$? The mixing of the incoming neutrinos with their dark variants would take place in the ${}^{71}\text{Ga}$ experiment. Dark neutrinos would not interact with ${}^{71}\text{Ga}$ target since neutrons inside the ${}^{71}\text{Ga}$ nuclei are expected to be ordinary so that the $\nu_e + n \rightarrow p + e^-$ scattering rate would be lower as observed.

The identification of sterile neutrinos as dark neutrinos can be consistent with the MicroBoone anomaly if one can identify the weakly interacting dark matter.

- (a) Dark neutrons should not be present in the liquid Argon. Could the weakly interacting dark matter be meson-like states consisting of dark d or \bar{u} quarks? Since the scattering from them cannot contribute to the nuclear weak interaction, these flux tubes must be outside Argon nuclei. By the large value of h_{eff} , they would connect Argon nuclei.

- (b) The TGD inspired model of nuclei describes them as nuclear strings consisting of nucleons connected by meson-like strings with quark and antiquark at its ends. The model of "cold fusion" [L9, L21, L49] inspired the proposal that dark nuclei consisting of dark protons connected by dark meson-like strings are formed in a water environment and give rise to what might be called dark nuclei.

The nuclear binding energy of the dark nuclei is scaled down by the ratio of the length scale defined by the distance between dark protons to nuclear length scale. The decay of dark nuclei to ordinary nuclei liberates more nuclear energy than ordinary nuclear reactions. Also strings of nuclei connected by dark meson-like flux tubes can be imagined. One can also consider flux tube bonded clusters of nuclei.

- (c) The TGD based model for living matter involves in an essential way the formation of dark proton sequences at flux tubes when water is irradiated in presence of gel, by say infrared light.

Could these dark flux tube bonds between nuclei relate to hydrogen bonds and hydrogen bonded clusters of water molecules? Could the " $Y \cdots H$ " of the hydrogen bond $Y \cdots H - X$ actually correspond to a dark meson-like flux tube bond between nuclei of Y and H? Could the attractive nuclear interaction between Y and X generated in this way increase the density of the liquid phase and explain the strange finding that the density of water above freezing point is higher than the density of the solid state?

Interestingly, according to the Wikipedia article (<https://cutt.ly/5KWribE>), Ga has some strange thermodynamic properties. The density of Ga above freezing point is higher than that of solid state. This property is shared also by water, silicon, germanium, bismuth, and plutonium. Ga has a strong tendency to supercool down to temperatures below 90 K.

- (d) This suggests that liquid phases could in some situations form structures connected by dark meson-like flux tubes. If $h_{eff} > h$ phases are generated as long range quantum fluctuations at quantum criticality and if quantum criticality is behind the thermodynamic criticality, this could happen near or above criticality for solid-liquid phase transition and even solid-gas phase transition.

If this kind of flux tubes connecting Argon nuclei (Argon does not have anomalous thermodynamics) are present in a liquid Argon detector, they explain the observed anomalous contribution to neutrino-Argon scattering.

Also in Gallium this could be the case as suggested by the higher density above freezing point. Could one detect the anomalous scattering of neutrinos from the proposed flux tube bonds connecting Ga atoms and study the anomalous scattering as a function of the temperature?

6 Scaled Variants of Hadron Physics and Electroweak Physics

6.1 Leptohadron Physics

TGD suggest strongly ("predicts" is perhaps too strong expression) the existence of color excited leptons. The mass calculations based on p-adic thermodynamics and p-adic conformal invariance lead to a rather detailed picture about color excited leptons.

- (a) The simplest color excited neutrinos and charged leptons belong to the color octets ν_8 and L_{10} and $L_{\bar{10}}$ decouplet representations respectively and lepto-hadrons are formed as the color singlet bound states of these and possible other representations. Electroweak symmetry suggests strongly that the minimal representation content is octet and decouplets for both neutrinos and charged leptons.
- (b) The basic mass scale for lepto-hadron physics is completely fixed by p-adic length scale hypothesis. The first guess is that color excited leptons have the levels $k = 127, 113, 107, \dots$ ($p \simeq 2^k$, k prime or power of prime) associated with charged leptons

as primary condensation levels. p-Adic length scale hypothesis allows however also the level $k = 11^2 = 121$ in case of electronic lepto-hadrons. Thus both $k = 127$ and $k = 121$ must be considered as a candidate for the level associated with the observed lepto-hadrons. If also lepto-hadrons correspond non-perturbatively to exotic Super Virasoro representations, lepto-pion mass relates to pion mass by the scaling factor $L(107)/L(k) = k^{(107-k)/2}$. For $k = 121$ one has $m_{\pi_L} \simeq 1.057$ MeV which compares favorably with the mass $m_{\pi_L} \simeq 1.062$ MeV of the lowest observed state: thus $k = 121$ is the best candidate contrary to the earlier beliefs. The mass spectrum of lepto-hadrons is expected to have same general characteristics as hadronic mass spectrum and a satisfactory description should be based on string tension concept. Regge slope is predicted to be of order $\alpha' \simeq 1.02/MeV^2$ for $k = 121$. The masses of ground state lepto-hadrons are calculable once primary condensation levels for colored leptons and the CKM matrix describing the mixing of color excited lepton families is known.

The strongest counter arguments against color excited leptons are the following ones.

- (a) The decay widths of Z^0 and W boson allow only $N = 3$ light particles with neutrino quantum numbers. The introduction of new light elementary particles seems to make the decay widths of Z^0 and W intolerably large.
- (b) Lepto-hadrons should have been seen in e^+e^- scattering at energies above few MeV . In particular, lepto-hadronic counterparts of hadron jets should have been observed.

A possible resolution of these problems is provided by the loss of asymptotic freedom in lepto-hadron physics. Lepto-hadron physics would effectively exist in a rather limited energy range about one MeV.

The development of the ideas about dark matter hierarchy [?, K42, K15, K13] led however to a much more elegant solution of the problem.

- (a) TGD predicts an infinite hierarchy of various kinds of dark matters which in particular means a hierarchy of color and electro-weak physics with weak mass scales labelled by appropriate p-adic primes different from M_{89} : the simplest option is that also ordinary photons and gluons are labelled by M_{89} .
- (b) There are number theoretical selection rules telling which particles can interact with each other. The assignment of a collection of primes to elementary particle as characterizer of p-adic primes characterizing the particles coupling directly to it, is inspired by the notion of infinite primes [K43], and discussed in [?]. Only particles characterized by integers having common prime factors can interact by the exchange of elementary bosons: the p-adic length scale of boson corresponds to a common primes.
- (c) Also the physics characterized by different values of h_{eff} are dark with respect to each other as far quantum coherent gauge interactions are considered. Laser beams might well correspond to photons characterized by p-adic prime different from M_{89} and de-coherence for the beam would mean decay to ordinary photons. De-coherence interaction involves scaling down of the Compton length characterizing the size of the space-time of particle implying that particles do not anymore overlap so that macroscopic quantum coherence is lost.
- (d) Those dark physics which are dark relative to each other can interact only via graviton exchange. If lepto-hadrons correspond to a physics for which weak bosons correspond to a p-adic prime different from M_{89} , intermediate gauge bosons cannot have direct decays to colored excitations of leptons irrespective of whether the QCD in question is asymptotically free or not. Neither are there direct interactions between the QED:s and QCD:s in question if M_{89} characterizes also ordinary photons and gluons. These ideas are discussed and applied in detail in [?, K42, K15].

Skeptic reader might stop the reading after these counter arguments unless there were definite experimental evidence supporting the lepto-hadron hypothesis.

- (a) The production of anomalous e^+e^- pairs in heavy ion collisions (energies just above the Coulomb barrier) suggests the existence of pseudo-scalar particles decaying to e^+e^- pairs. A natural identification is as lepto-pions that is bound states of color octet excitations of e^+ and e^- .
- (b) The second puzzle, Karmen anomaly, is quite recent [C79]. It has been found that in charge pion decay the distribution for the number of neutrinos accompanying muon in decay $\pi \rightarrow \mu + \nu_\mu$ as a function of time seems to have a small shoulder at $t_0 \sim ms$. A possible explanation is the decay of charged pion to muon plus some new weakly interacting particle with mass of order $30 MeV$ [C16]: the production and decay of this particle would proceed via mixing with muon neutrino. TGD suggests the identification of this state as color singlet lepto-baryon of, say type $L_B = f_{abc}L_8^a L_8^b \bar{L}_8^c$, having electro-weak quantum numbers of neutrino.
- (c) The third puzzle is the anomalously high decay rate of orto-positronium. [C93]. e^+e^- annihilation to virtual photon followed by the decay to real photon plus virtual lepto-pion followed by the decay of the virtual lepto-pion to real photon pair, $\pi_L \gamma \gamma$ coupling being determined by axial anomaly, provides a possible explanation of the puzzle.
- (d) There exists also evidence for anomalously large production of low energy e^+e^- pairs [C75, C88, C83, C114] in hadronic collisions, which might be basically due to the production of lepto-hadrons via the decay of virtual photons to colored leptons.

In this chapter a revised form of lepto-hadron hypothesis is described.

- (a) Sigma model realization of PCAC hypothesis allows to determine the decay widths of lepto-pion and lepto-sigma to photon pairs and e^+e^- pairs. Ortopositronium anomaly determines the value of $f(\pi_L)$ and therefore the value of lepto-pion-lepto-nucleon coupling and the decay rate of lepto-pion to two photons. Various decay widths are in accordance with the experimental data and corrections to electro-weak decay rates of neutron and muon are small.
- (b) One can consider several alternative interpretations for the resonances.

Option 1: For the minimal color representation content, three lepto-pions are predicted corresponding to 8, 10, $\bar{10}$ representations of the color group. If the lightest lepto-nucleons e_{ex} have masses only slightly larger than electron mass, the anomalous e^+e^- could be actually $e_{ex}^+ + e_{ex}^-$ pairs produced in the decays of lepto-pions. One could identify 1.062, 1.63 and 1.77 MeV states as the three lepto-pions corresponding to 8, 10, $\bar{10}$ representations and also understand why the latter two resonances have nearly degenerate masses. Since d and s quarks have same primary condensation level and same weak quantum numbers as colored e and μ , one might argue that also colored e and μ correspond to $k = 121$. From the mass ratio of the colored e and μ , as predicted by TGD, the mass of the muonic lepto-pion should be about 1.8 MeV in the absence of topological mixing. This suggests that 1.83 MeV state corresponds to the lightest $g = 1$ lepto-pion.

Option 2: If one believes sigma model (in ordinary hadron physics the existence of sigma meson is not established and its width is certainly very large if it exists), then lepto-pions are accompanied by sigma scalars. If lepto-sigmas decay dominantly to e^+e^- pairs (this might be forced by kinematics) then one could adopt the previous sceneario and could identify 1.062 state as lepto-pion and 1.63, 1.77 and 1.83 MeV states as lepto-sigmas rather than lepto-pions. The fact that muonic lepto-pion should have mass about 1.8 MeV in the absence of topological mixing, suggests that the masses of lepto-sigma and lepto-pion should be rather close to each other.

Option 3: One could also interpret the resonances as string model “satellite states” having interpretation as radial excitations of the ground state lepto-pion and lepto-sigma. This identification is not however so plausible as the genuinely TGD based identification and will not be discussed in the sequel.
- (c) PCAC hypothesis and sigma model leads to a general model for lepto-hadron production in the electromagnetic fields of the colliding nuclei and production rates for lepto-pion

and other lepto-hadrons are closely related to the Fourier transform of the instanton density $\vec{E} \cdot \vec{B}$ of the electromagnetic field created by nuclei. The first source of anomalous e^+e^- pairs is the production of $\sigma_L\pi_L$ pairs from vacuum followed by $\sigma_L \rightarrow e^+e^-$ decay. If $e_{ex}^+e_{ex}^-$ pairs rather than genuine e^+e^- pairs are in question, the production is production of lepto-pions from vacuum followed by lepto-pion decay to lepto-nucleon pair.

Option 1: For the production of lepto-nucleon pairs the cross section is only slightly below the experimental upper bound for the production of the anomalous e^+e^- pairs and the decay rate of lepto-pion to lepto-nucleon pair is of correct order of magnitude.

Option 2: The rough order of magnitude estimate for the production cross section of anomalous e^+e^- pairs via $\sigma_l\pi_l$ pair creation followed by $\sigma_L \rightarrow e^+e^-$ decay, is by a factor of order $1/\sum N_c^2$ (N_c is the total number of states for a given colour representation and sum over the representations contributing to the orthopositronium anomaly appears) smaller than the reported cross section in case of 1.8 MeV resonance. The discrepancy could be due to the neglect of the large radiative corrections (the coupling $g(\pi_L\pi_L\sigma_L) = g(\sigma_L\sigma_L\sigma_L)$ is very large) and also due to the uncertainties in the value of the measured cross section.

Given the unclear status of sigma in hadron physics, one has a temptation to conclude that anomalous e^+e^- pairs actually correspond to lepto-nucleon pairs.

- (d) The vision about dark matter suggests that direct couplings between leptons and lepto-hadrons are absent in which case no new effects in the direct interactions of ordinary leptons are predicted. If colored leptons couple directly to ordinary leptons, several new physics effects such as resonances in photon-photon scattering at cm energy equal to lepto-pion masses and the production of $e_{ex}\bar{e}_{ex}$ (e_{ex} is lepto-baryon with quantum numbers of electron) and $e_{ex}\bar{e}$ pairs in heavy ion collisions, are possible. Lepto-pion exchange would give dominating contribution to $\nu-e$ and $\bar{\nu}-e$ scattering at low energies. Lepto-hadron jets should be observed in e^+e^- annihilation at energies above few MeV:s unless the loss of asymptotic freedom restricts lepto-hadronic physics to a very narrow energy range and perhaps to entirely non-perturbative regime of lepto-hadronic QCD.

During 18 years after the first published version of the model also evidence for colored μ has emerged. Towards the end of 2008 CDF anomaly gave a strong support for the colored excitation of τ . The lifetime of the light long lived state identified as a charged τ -pion comes out correctly and the identification of the reported 3 new particles as p-adically scaled up variants of neutral τ -pion predicts their masses correctly. The observed muon jets can be understood in terms of the special reaction kinematics for the decays of neutral τ -pion to 3 τ -pions with mass scale smaller by a factor 1/2 and therefore almost at rest. A spectrum of new particles is predicted. The discussion of CDF anomaly led to a modification and generalization of the original model for lepto-pion production and the predicted production cross section is consistent with the experimental estimate.

6.2 First Evidence For M_{89} Hadron Physics?

The first evidence -or should we say indication- for the existence of M_{89} hadron physics has emerged from CDF which for two and half years ago provided evidence also for the colored excitations of tau lepton and for lepto-hadron physics.

6.2.1 Has CDF discovered a new boson with mass around 145 GeV?

The story began when the eprint of CDF collaboration (see <http://tinyurl.com/5uhrwyz>) [C3] reported evidence for a new resonance like state, presumably a boson decaying to a dijet (jj) with mass around 145 GeV. The dijet is produced in association with W boson. The interpretation as Higgs is definitely excluded.

Bloggers reacted intensively to the possibility of a new particle. Tommaso Dorigo (see <http://tinyurl.com/ycxxy3rc>) gave a nice detailed analysis about the intricacies of the analysis

of the data leading to the identification of the bump. Also Lubos Motl (see <http://tinyurl.com/ybk2axxc>) and Resonaances (see <http://tinyurl.com/6399hqs>) commented the new particle. Probably the existence of the bump had been known for months in physics circles. The flow of eprints to arXiv explaining the new particle begun immediately.

One should not forget that 3 sigma observation was in question and that 5 sigma is required for discovery. It is quite possible that the particle is just a statistical fluke due to an erratic estimation of the background as Tommaso Dorigo emphasizes. Despite this anyone who has a theory able to predict something is extremely keen to see whether the possibly existing new particle has a natural explanation. This also provides the opportunity for dilettantes like me to develop the theoretical framework in more detail. We also know from general consistency conditions that New Physics must emerge in TeV scale: what we do not know what this New Physics is. Therefore all indications for it must be taken seriously.

CDF bump did not disappear and the most recent analysis assigns 4.1 sigma significance to it. The mass of the bump was reported to be at 147 ± 5 GeV. Also some evidence that the entire W_{jj} system results in a decay of a resonance (see <http://tinyurl.com/5tw6mjd>) with mass slightly below 300 GeV has emerged. D0 was however not able to confirm the existence of the bump and the latest reincarnation of the bump is as 2.8 sigma evidence for Higgs candidate in the range 140-150 GeV range and one can ask whether this is actually evidence for the familiar 145 GeV boson which cannot be Higgs. The story involves many twists and turns and teaches how cautiously theoretician should take also the claims of experimentalists. In the following I pretend that the 145 GeV bump is real but this should not confuse the reader to believe that this is really the case.

6.2.2 Why an exotic weak boson a la TGD cannot be in question?

For the inhabitant of the TGD Universe the most obvious identification of the new particle would be as an exotic weak boson. The TGD based explanation of family replication phenomenon predicts that gauge bosons come in singlets and octets of a dynamical $SU(3)$ symmetry associated with three fermion generations (fermion families correspond to topologies of partonic wormhole throats characterized by the number of handles attached to sphere). Exotic Z or W boson could be in question.

If the symmetry breaking between octet and singlet is due to different value of p-adic prime alone then the mass would come as a power of half-octave of the mass of Z or W . For W boson one would obtain 160 GeV only marginally consistent with 145 GeV. Z would give 180 GeV mass which is certainly too high. The Weinberg angle could be however different for the singlet and octet so that the naïve p-adic scaling need not hold true exactly.

Note that the strange forward backward asymmetry (see <http://tinyurl.com/yc5zrheq>) in the production of top quark pairs [C31, C94] might be understood in terms of exotic gluon octet whose existence means neutral flavor changing currents as discussed in this chapter.

The *extremely* important data bit is that the decays to two jets favor quark pairs over lepton pairs. A model assuming exotic Z -called Z' - produced together with W and decaying preferentially to quark pairs has been proposed (see <http://tinyurl.com/y8pjpled>) as an explanation [C5]. Neither ordinary nor the exotic weak gauge bosons of TGD Universe have this kind of preference to decay to quark pairs so that my first guess was wrong.

6.2.3 Is a scaled up copy of hadron physics in question?

The natural explanation for the preference of quark pairs over lepton pairs would be that strong interactions are somehow involved. This suggests a state analogous to a charged pion decaying to W boson two gluons annihilating to the quark pair (box diagram). This kind of proposal is indeed made in "Technicolor at the Tevatron" (see <http://tinyurl.com/yclfr29y>) [C9]: the problem is also now why the decays to quarks are favored. Technicolor has as its rough analog second fundamental prediction of TGD that p-adically scaled up variants of hadron physics should exist and one of them is waiting to be discovered in TeV

region. This prediction emerged already for about 15 years ago as I carried out p-adic mass calculations and discovered that Mersenne primes define fundamental mass scales.

Also colored excitations of leptons and therefore lepto-hadron physics are predicted [K47]. What is amusing that CDF discovered towards the end of 2008 what became known as CDF anomaly giving support for tau-pions. The evidence for electro-pions and mu-pions had emerged already earlier (for references see [K47]). All these facts have been buried underground because they simply do not fit to the standard model wisdom. TGD based view about dark matter is indeed needed to circumvent the fact that the lifetimes of weak bosons do not allow new light particles. There is also along series of blog postings in my blog summarizing development of the TGD based model for CDF anomaly.

As should have become already clear, TGD indeed predicts p-adically scaled up copy of hadron physics in TeV region and the lightest hadron of this physics is a pion like state produced abundantly in the hadronic reactions. Ordinary hadron physics corresponds to Mersenne prime $M_{107} = 2^{107} - 1$ whereas the scaled up copy would correspond to M_{89} . The mass scale would be 512 times the mass scale 1 GeV of ordinary hadron physics so that the mass of M_{89} proton should be about 512 GeV. The mass of the M_{89} pion would be by a naïve scaling 71.7 GeV and about two times smaller than the observed mass in the range 120-160 GeV and with the most probable value around 145 GeV as Lubos Motl reports in his blog. $2 \times 71.7 \text{ GeV} = 143.4 \text{ GeV}$ would be the guess of the believer in the p-adic scaling hypothesis and the assumption that pion mass is solely due to quarks. It is important to notice that this scaling works precisely only if CKM mixing matrix is same for the scaled up quarks and if charged pion consisting of u-d quark pair is in question. The well-known current algebra hypothesis that pion is massless in the first approximation would mean that pion mass is solely due to the quark masses whereas proton mass is dominated by other contributions if one assumes that also valence quarks are current quarks with rather small masses. The alternative which also works is that valence quarks are constituent quarks with much higher mass scale.

According to p-adic mass calculations the mass of pion is just the sum of mass squared for the quarks composing. If one assumes that u and d quarks of M_{89} hadron physics correspond to $k = 93$ (top corresponds to $k = 94$, the mass of these quarks is predicted to be 102 GeV whereas the pion mass is predicted to be 144.3 GeV (the argument will be discussed in detail later). My guess based on deep ignorance about the experimental side is that this signature should be easily testable: one should try to detect mono-chromatic gamma pairs with gamma ray energy around 72.2 GeV.

6.2.4 The simplest identification of the 145 GeV resonance

The picture about CDF resonance has become (see the postings “Theorists vs. the CDF bump” (see <http://tinyurl.com/ybkdxox>) and More details about the CDF bump (see <http://tinyurl.com/5tw6mjd>) by Jester [C11]. One of the results is that leptophobic Z' can explain only 60 per cent of the production rate. There is also evidence that W_{jj} corresponds to a resonance with mass slightly below 300 GeV as naturally predicted by technicolor models (see <http://tinyurl.com/yclfr29y>) [C71].

The simplest TGD based model indeed relies on the assumption that the entire W_{jj} corresponds to a resonance with mass slightly below 300 GeV for which there is some evidence as noticed. If one assume that only *neutral pions* are produced in strong non-orthogonal electric and magnetic fields of colliding proton and antiproton, the mother particle must be actually second octave of 147 GeV pion and have mass somewhat below 600 GeV producing in its possibly allowed strong decays pions which are almost at rest for kinematic reasons. Therefore the production mechanism could be exactly the same as proposed for two and one half year old CDF anomaly and for the explanation of DAMA events and DAMA-Xenon100 discrepancy,

- (a) This suggests that the mass of the mother resonance is in a good accuracy two times the mass of 145 GeV bump for which best estimate is $147 \pm 5 \text{ GeV}$. This brings in

mind the explanation for the two and half year old CDF anomaly in which tau-pions with masses coming as octaves of basic tau-pion played a key role (masses were in good approximation $2^k \times m(\pi_\tau)$, $m(\pi_\tau) \simeq 2m_\tau$, $k = 1, 2$). The same mechanism would explain the discrepancy between the DAMA and Xenon100 experiments.

- (b) If this mechanism is at work now, the mass of the lowest M_{89} pion should be around 73 GeV as the naïvest scaling estimate gives. One can however consider first the option for which lightest M_{89} has mass around 147 GeV so that the 300 GeV resonance could correspond to its first p-adic octave. This pion would decay to W and neutral M_{89} pion with mass around 147 GeV in turn decaying to two jets. At quark level the simplest diagram would involve the emission of W and exchange of gluon of M_{89} hadron physics. Also the decay to Z and charged pion is possible but in this case the decay of the final state could not take place via annihilation to gluon so that jet pair need not be produced.
- (c) One could also imagine the mother particle to be ρ meson of M_{89} hadron physics with mass in a good approximation equal to pion mass. At the level of mathematics this option is very similar to the technicolor model of CDF bump based also on the decay of ρ meson discussed in [C71] (see <http://tinyurl.com/yclfr29y>). In this model the decays of π to heavy quarks have been assumed to dominate. In TGD framework the situation is different. If π consists of scaled up u and d quarks, the decays mediated by boson exchanges would produce light quarks. In the annihilation to quark pair by a box diagram involving two gluons and two quarks at edges the information about the quark content of pion is lost. The decays involving emission of Z boson the resulting pion would be charged and its decays by annihilation to gluon would be forbidden so that Wjj final states would dominate over Zjj final states as observed.
- (d) The strong decay of scaled up pion to charged and neutral pion are forbidden by parity conservation. The decay can however proceed by via the exchange of intermediate gauge boson as a virtual particle. The first quark would emit virtual W/Z boson and second quark the gluon of the hadron physics. Gluon would decay to a quark pair and second quark would absorb the virtual W boson so that a two-pion final state would be produced. The process would involve same vertices as the decay of ρ meson to W boson and pion. The proposed model of the two and one half year old CDF anomaly and the explanation of DAMA and Xenon100 experiments assumes cascade like decay of pion at given level of hierarchy to two pions at lower level of hierarchy and the mechanism of decay should be this.

Consider next the masses of the M_{89} mesons. naïve scaling of the mass of ordinary pion gives mass about 71 GeV for M_{89} pion. One can however argue that color magnetic spin-spin splitting need not obey scaling formula and that it becomes small because it is proportional to eB/m where B denotes typical value of color magnetic field and m quark mass scale which is now large. The mass of pion at the limit of vanishing color magnetic splitting given by m_0 could however obey the naïve scaling.

- (a) For (ρ, π) system the QCD estimate for the color magnetic spin-spin splitting would be

$$(m(\rho), m(\pi)) = (m_0 + 3\Delta/4, m_0 - \Delta/4) .$$

p-Adic mass calculations are for mass squared rather than mass and the calculations for the mass splittings of mesons [K30] force to replace this formula with

$$(m^2(\rho), m^2(\pi)) = (m_0^2 + 3\Delta^2/4, m_0^2 - \Delta^2/4) . \quad (6.1)$$

The masses of ρ and ω are very near to each other: $(m(\rho), m(\omega)) = (.770, .782)$ GeV and obey the same mass formula in good approximation. The same is expected to hold true also for M_{89} .

- (b) One obtains for the parameters Δ and m_0 the formulas

$$\Delta = [m^n(\rho) - m^n(\pi)]^{1/n} , \quad m_0 = [(m^2(\rho) + 3m(\pi)^2)/4]^{1/n} . \quad (6.2)$$

Here $n = 1$ corresponds to ordinary QCD and $n = 2$ to p-adic mass calculations.

- (c) Assuming that m_0 experiences an exact scaling by a factor 512, one can deduce the value of the parameter Δ from the mass 147 GeV of M_{89} pion and therefore predict the mass of ρ_{89} . The results are following

$$m_0 = 152.3 \text{ GeV} , \quad \Delta = 21.3 \text{ GeV} , \quad m(\rho_{89}) = 168.28 \text{ GeV} \quad (6.3)$$

for QCD model for spin-spin splitting and

$$m_0 = 206.7 \text{ GeV} , \quad \Delta = 290.5 \text{ GeV} , \quad m(\rho_{89}) = 325.6 \text{ GeV} . \quad (6.4)$$

for TGD model for spin-spin splitting.

- (d) Rather remarkably, there are indications from D0 (see <http://tinyurl.com/28jj6yw>) [C10] for charged and from CDF (see <http://tinyurl.com/28jj6yw>) [C10, C12] for neutral resonances with masses around 325 GeV such that the neutral one is split by 2 GeV: the splitting could correspond to $\rho - \omega$ mass splitting. Hence one obtains support for both M_{89} hadron physics and p-adic formulas for color magnetic spin-spin splitting. Note that the result excludes also the interpretation of the nearly 300 GeV resonance as ρ_{89} in TGD framework.
- (e) This scenario allows to make estimates also for the masses other resonances and naïve scaling argument is expected to improve as the mass increases. For (K_{89}, K_{89}^*) system this would predict mass $m(K_{89}) > 256 \text{ GeV}$ and $m(K_{89}^*) < 456.7 \text{ GeV}$.

The nasty question is why the octaves of pion are not realized as a resonances in ordinary hadron physics. If they were there, their decays to ordinary pion pairs by this mechanism would very slow.

- (a) Could it be that also ordinary pion has these octaves but are not produced by ordinary strong interactions in nucleon collisions since the nucleons do not contain the p-adically scaled up quarks fusing to form the higher octave of the pion. Also the fusion rate for two pions to higher octave of pion would be rather small by parity breaking requiring weak interactions.
- (b) The production mechanism for the octaves of ordinary pions, for M_{89} pions in the collisions of ordinary nucleons, and for lepto-hadrons would be universal, namely the collision of charged particles with cm kinetic energy above the octave of pion. The presence of strong non-orthogonal electric and magnetic fields varying considerably in the time scale defined by the Compton time of the pion is necessary since the interaction Lagrangian density is essentially the product of the abelian instanton density and pion field. In fact, in [C71] it is mentioned that 300 GeV particle candidate is indeed created at rest in Tevatron lab -in other words in the cm system of colliding proton and antiproton beams.
- (c) The question is whether the production of the octaves of scaled up pions could have been missed in proton-proton and proton antiproton collisions due to the very peculiar kinematics: pions would be created almost at rest in cm system [K47]. Whether or not this is the case should be easy to test. For a theorists this kind of scenario does not look impossible but at the era of LHC it would require a diplomatic genius and authority of Witten to persuade experimentalists to check whether low energy collisions of protons produce octaves of pions!

There is also the question about the general production mechanisms for M_{89} hadrons.

- (a) Besides the production of scalar mesons in strong non-orthogonal magnetic and electric fields also the production via annihilation of quark pairs to photon and weak bosons in turn decaying to the quarks of M_{89} hadron physics serves as a possible production mechanism. These production mechanisms do not give much hopes about the production of nucleons of M_{89} physics.
- (b) If ordinary gluons couple to M_{89} quarks, also the production via fusion to gluons is possible. If the transition from M_{107} hadron physics corresponds to a phase transition transforming M_{107} hadronic space-time sheets/gluons to M_{89} space-time sheets/gluons, M_{107} gluons do not couple directly to M_{89} gluons. In this case however color spin glass phase for M_{107} gluons could decay to M_{89} gluons in turn producing also M_{89} nucleons. Recall that naïve scalings for M_{89} nucleon the mass 481 GeV. The actual mass is expected to be higher but below the scaled up Δ resonance mass predicted to be below 631 GeV.

6.2.5 How could one understand CDF-D0 discrepancy concerning 145 GeV resonance?

The situation concerning 145 GeV bump has become rather paradoxical. CDF claims that 145 GeV resonance is there at 4.3 sigma level. The new results from D0 however fail to support CDF bump (see <http://tinyurl.com/5vrgwxf>) [C48] (see Lubos Motl (see <http://tinyurl.com/67g15z1>), Jester (see <http://tinyurl.com/3wgspwm>), and Tommaso Dorigo (see <http://tinyurl.com/3kbkn6b>).

This shows only that either CDF or D0 is wrong, not that CDF is wrong as some of us suddenly want to believe. My own tentative interpretation -not a belief- relies on bigger picture provided by TGD and is that both 145 GeV, 300 GeV, and 325 GeV resonances are there and have interpretations in terms of π and its p-adic octave, ρ , and ω of M_{89} hadron physics. I could of course be wrong. LHC will be the ultimate jury.

In any case, neither CDF and D0 are cheating and one should explain the discrepancy rationally. Resonances (see <http://tinyurl.com/3wgspwm>) mentions different estimates for QCD background as a possible explanation. What one could say about this in TGD framework allowing some brain storming?

- (a) There is long history of this kind of forgotten discoveries having same interpretation in TGD framework. Always pionlike states-possibly coherent state of them- would have been produced in strong non-orthogonal magnetic and electric fields of the colliding charges and most pion-like states predicted to be almost at rest in cm frame.

Electro-pions were observed already at seventies in the collisions of heavy nuclei at energies near Coulomb wall, resonances having interpretation as mu-pions about three years ago, tau-pions detected by CDF for two and half years ago with refutation coming from D0, now DAMA and Cogent observed dark matter candidate having explanation in terms of tau-pion in TGD framework but Xenon100 found nothing (in this case one can understand the discrepancy in TGD framework). The octaves of M_{89} pions would represent the last episode of this strange history. In the previous posting universality of the production mechanism forced to made the proposal that also the collisions of ordinary nuclei could generate octaves of ordinary pions. They have not been observed and as I proposed this might due to the peculiarity of the production mechanism.

What could be a common denominator for this strange sequence of almost discoveries? Light colored excitations of leptons can be of course be argued to be non-existent because intermediate boson decay widths do not allow them but it is difficult to believe that this would have been the sole reason for not taking lepto-pions seriously.

- (b) Could the generation of a pionic coherent state as a critical phenomenon very sensitive to the detailed values of the dynamical parameters, say the precise cm energies of the colliding beams? For lepto-pions a phase transition generating dark colored variants of leptons (dark in the sense having non-standard value of Planck constant) would indeed take place so that criticality might make sense. Could also M_{89} quarks be dark or colored

excitations of ordinary quarks which are dark? Could the $M_{107} \rightarrow M_{89}$ phase transition take place only near criticality? This alone does not seem to be enough however.

- (c) The peculiarity of the production mechanism is that the pion like states are produced mostly at rest in cm frame of the colliding charges. Suppose that the cm frame for the colliding charged particles is not quite the lab frame in D0. Since most dark pions are produced nearly at rest in the cm frame, they could in this kind of situation leave the detector before decaying to ordinary particles: they would behave just like dark matter is expected to behave and would not be detected. The only signature would be missing energy. This would also predict that dark octaves of ordinary pions would not be detected in experiments using target which is at rest in lab frame.
- (d) This mechanism is actually quite general. Dark matter particles decaying to ordinary matter and having long lifetime remain undetected if they move with high enough velocity with respect to laboratory. Long lifetime would be partially due to the large value of \hbar and relativistic with respect to laboratory velocities also time dilation would increase the lifetime. Dark matter particles could be detected only as a missing energy not identifiable in terms of neutrinos. A special attention should be directed to state candidates which are nearly at rest in laboratory.

An example from ordinary hadron physics is the production of pions and their octaves in the strong electric and magnetic field of nuclei colliding with a target at rest in lab. The lifetime of neutral pion is about 10^{-8} seconds and scaled up for large \hbar and by time dilation when the colliding nucleons have relativistic energies. Therefore the dark pion might leave the measurement volume before decay to two gammas when the target is at rest in laboratory. It is not even clear whether the gammas need to have standard value of Planck constant.

For the second octave of M_{89} pion the lifetime would be scaled down by the ratio of masses giving a factor 2^{11} and lifetime of order $.5 \times 10^{-11}$ seconds. Large \hbar would scale up the lifetime. For non-relativistic relativistic velocities the distance travelled before the decay to gamma pair would $L = (\hbar/\hbar_0) \times (v/c) \times 1.1$ mm.

If also the gamma pair is dark, the detection would require even larger volume. TGD suggests strongly that also photons have a small mass which they obtain by eating the remaining component of Higgs a la TGD (transforming like 1+3 under vectorial weak SU(2)). If photon mass defines the upper bound for the rate for the transformation to ordinary photons, dark photons would remain undetected.

6.2.6 Higgs or a pion of M_{89} hadron physics?

D0 refuted the 145 GeV bump and after this it was more or less forgotten in blogs, which demonstrates how regrettably short the memory span of blog physicists is. CDF reported it in Europhysics 2011 and it seems that the groups are considering seriously possible explanations for the discrepancy. To my opinion the clarification of his issue is of extreme importance.

The situation changed at the third day of conference (Saturday) when ATLAS reported about average 2.5 sigma evidence for what might be Higgs in the mass range 140-150 GeV. The candidate revealed itself via decays to WW in turn decaying to lepton pairs. Also D0 and CDF told suddenly that they have observed similar evidence although the press release had informed that Higgs had been located to the mass range 120-137 GeV. There is of course no reason to exclude the possibility that the decays of 145 GeV resonance are in question and in this case the interpretation as standard model Higgs would be definitely excluded. If the pion of M_{89} physics is in question it would decay to WW pair instead of quark pair producing two jets. Since weak decay is in question one can expect that the decay rate is small.

If this line of reasoning is correct, standard model Higgs is absent. TGD indeed predicts that the components of TGD Higgs become longitudinal components of gauge bosons since also photon and graviton gain a small mass. This however leaves the two Higgses predicted by MSSM under consideration. The stringent lower bounds for the masses of squarks and gluinos of standard SUSY were tightened in the conference (see <http://tinyurl.com/yd2kubzp>) and

are now about 1 TeV and this means that the basic argument justifying MSSM (stability of Higgs mass against radiative corrections) is lost.

The absence of Higgs forces a thorough re-consideration of the fundamental ideas about particle massivation. p-Adic thermodynamics combined with zero energy ontology and the identification of massive particles as bound states of massless fermions is the vision provided by TGD.

6.2.7 Short digression to TGD SUSY

Although the question about TGD variant of SUSY is slightly off-topic, its importance justifies a short discussion. Although SUSY is not needed to stabilize Higgs mass, the anomaly of muonic g-2 suggests TGD SUSY and the question is whether TGD SUSY could explain it.

- (a) Leptons are characterized by Mersennes or Gaussian Mersennes: $(M_{127}, M_{G,113}, M_{107})$ for (e, μ, τ) . If also sleptons correspond to Mersennes or Gaussian Mersennes, then (selectron, smuon, stau) should correspond to $(M_{89}, M_{G,79}, M_{61})$ if one assumes that selectron corresponds to M_{89} . Selectron mass would be 250 GeV and smuon mass 13.9 TeV. g-2 anomaly for muon [K25] suggests that the mass of selectron should not be much above 1 TeV and M_{89} fits the bill. Valence quarks correspond to the Gaussian Mersenne $k \leq 113$, which suggests that squarks have $k \geq 79$ so that squark masses should be above 13 TeV. If sneutrinos correspond to Gaussian Mersenne $k = 167$ then sneutrinos could have mass below electron mass scale. Selectron would remain the only experiment signature of TGD SUSY at this moment.
- (b) One decay channel for selectron would be to electron+ sZ or neutrino+ sW. sZ/sW would eventually decay to possibly virtual Z+ neutrino/W+neutrino: that is weak gauge boson plus missing energy. Neutralino and chargino need not decay in the detection volume. The lower bound for neutralino mass is 46 GeV from intermediate gauge boson decay widths. Hence this option is not excluded by experimental facts.
- (c) If the sfermions decay rapidly enough to fermion plus neutrino, the signature of TGD SUSY would be excess of events of type lepton+ missing energy or jet+ missing energy. For instance, lepton+missing jet could be mis-identified as decay products of possibly exotic counterpart of weak gauge boson. The decays of 250 GeV selectron would give rise to decays which might be erratically interpreted as decays of W' to electron plus missing energy. The study of CDF at $\sqrt{s} = 1.96$ TeV in p-pbar collisions excludes heavy W' with mass below 1.12 TeV [C33]. The decay rate to electron plus neutrino must therefore be slow.

There are indications for a tiny excess of muon + missing energy events in the decays of what has been tentatively identified as a heavy W boson W^{prime} (see Figure 1 of [C23] at <http://tinyurl.com/ycm2h6ee>). The excess is regarded as insignificant by experimenters. W^{prime} candidate is assumed to have mass 1.0 TeV or 1.4 TeV. If smuon is in question, one must give up the Mersenne hypothesis.

6.2.8 The mass of u and d quarks of M_{89} physics

While updating the chapter about the p-adic model for hadronic masses [K30] I found besides some silly numerical errors also a gem that I had forgotten. For pion the contributions to mass squared from color-magnetic spin-spin interaction and color Coulombic interaction and super-symplectic gluons cancel and the mass is in excellent approximation given by the $m^2(\pi) = 2m^2(u)$ with $m(u) = m(d) = 0.1$ GeV in good approximation. That only quarks contribute is the TGD counterpart for the almost Goldstone boson character of pion meaning that its mass is only due to the massivation of quarks. The value of the p-adic prime is $p \simeq 2^k$, with $k(u) = k(d) = 113$ and the mass of charged pion is predicted with error of .2 per cent.

If the reduction of pion mass to mere quark mass holds true for all scaled variants of ordinary hadron physics, one can deduce the value of u and d quark masses from the mass of the pion

of M_{89} hadron physics and vice versa. The mass estimate is 145 GeV if one identifies the bump claimed by CDF (see <http://tinyurl.com/yc98cau6>) [C32] as M_{89} pion. Recall that D0 did not detect the CDF bump (see <http://tinyurl.com/5vrgwxf>) [C48] (I have discussed possible reasons for the discrepancy in terms of the hypothesis that dark quarks are in question). From this one can deduce that the p-adic prime $p \simeq 2^k$ for the u and d quarks of M_{89} physics is $k = 93$ using $m(u, 93) = 2^{(113-93)/2}m(u, 113)$, $m(u, 113) \simeq .1$ GeV. For top quark one has $k = 94$ so that a very natural transition takes place to a new hadron physics. The predicted mass of $\pi(89)$ is 144.8 GeV and consistent with the value claimed by CDF. What makes the prediction non-trivial is that possible quark masses comes as as half-octaves meaning exponential sensitivity with respect to the p-adic length scale.

The common mass of $u(89)$ and $d(89)$ quarks is 102 GeV in a good approximation and quark jets with mass peaked around 100 GeV should serve as a signature for them. The direct decays of the $\pi(89)$ to M_{89} quarks are of course non-allowed kinematically.

6.2.9 A connection with the top pair backward-forward asymmetry in the production of top quark pairs?

One cannot exclude the possibility that the predicted exotic octet of gluons proposed as an explanation of the anomalous backward-forward asymmetry in top pair production correspond to the gluons of the scaled up variant of hadron physics. M_{107} hadron physics would correspond to ordinary gluons only and M_{89} only to the exotic octet of gluons only so that a strict scaled up copy would not be in question. Could it be that given Mersenne prime tolerates only single hadron physics or lepto-hadron physics?

In any case, this would give a connection with the TGD based explanation of the backward-forward asymmetry in the production of top pairs (see <http://tinyurl.com/yc5zrheq>) also discussed in this chapter. In the collision incoming quark of proton and antiquark of antiproton would topologically condense at M_{89} hadronic space-time sheet and scatter by the exchange of exotic octet of gluons: the exchange between quark and antiquark would not destroy the information about directions of incoming and outgoing beams as s-channel annihilation would do and one would obtain the large asymmetry. The TGD based generalized Feynman diagram would involve an exchange of a gluon represented by a wormhole contact. The first wormhole throat would have genus two as also top quark and second throat genus zero. One can imagine that the top quark comes from future and then travels along space-like direction together with antiquark wormhole throat of genus zero and then turns back to the future. Incoming quark and antiquark perform similar turn around [K25].

This asymmetry observed found a further confirmation (see <http://tinyurl.com/4ywbkbf>) in Europhysics 2011 conference [C44]. The obvious question is whether this asymmetry could be reduced to that in collisions of quarks and antiquarks. Tommaso Dorigo (see <http://tinyurl.com/3mkaoy9>) tells that CMS (see <http://tinyurl.com/ydx5n8o>) has found that this is not the case, which suggests that the phenomenon might be assignable to valence quarks only.

6.3 Other Indications For M_{89} Hadron Physics

Also other indications for M_{89} hadron physics have emerged during this year and although the fate of these signals is probably the usual one, they deserve to be discussed briefly.

6.3.1 Bumps also at CDF and D0?

It seems that experimentalists have gone totally crazy. Maybe new physics is indeed emerging from LHC and they want to publish every data bit in the hope of getting paid visit to Stockholm. CDF and ATLAS have told about bumps and now Lubos Motl (see <http://tinyurl.com/ya2taxjh>) [C10] tells about a new 3 sigma bump reported by D0 collaboration at mass 325 GeV producing muon in its decay producing W boson plus jets [C47]. The proposed identification of bump is in terms of decay of t' quark producing W boson.

Lubos Motl mentions also second mysterious bump at 324.8 GeV or 325.0 GeV reported by *CDF* collaboration [C34] and discussed by Tommaso Dorigo (see <http://tinyurl.com/28jj6yw>) [C12] towards the end of the last year. The decays of these particles produce 4 muons through the decays of two Z bosons to two muons. What is peculiar is that two mass values differing by 2 GeV are reported. The proposed explanation is in terms of Higgs decaying to two Z bosons. TGD based view about new physics suggests strongly that the three or four particles forming a multiplet is in question.

One can consider several explanations in TGD framework without forgetting that these bumps very probably disappear. Consider first the D0 anomaly alone.

- (a) TGD predicts also higher generations but there is a nice argument based on conformal invariance and saying that higher particle families are heavy. What “heavy” means is not clear. It could mean heavier than intermediate gauge boson mass scale. This explanation does not look convincing to me.
- (b) Another interpretation would be in terms of scaled up variant of top quark. The mass of top is around 170 GeV and p-adic length scale hypothesis would predict that the mass should equal to a multiple of half octave of top quark mass. Single octave would give mass of 340 GeV. The deviation from predicted mass would be 5 per cent.
- (c) The third interpretation is in terms of ρ and ω mesons of M_{89} . By assuming that the masses of M_{89} π and ρ in absence of color magnetic spin-spin splitting scale naïvely in the transition from M_{107} to M_{89} physics and by determining the parameter characterizing color magnetic spin-spin splitting from the condition that M_{89} pion has 157 GeV mass, one predicts that M_{89} ρ and ω have same mass 325.6 GeV in good approximation. The 2 GeV mass difference would have interpretation as $\rho - \omega$ mass difference. In TGD framework this explanation is unique.

6.3.2 Indications for M_{89} charmonium from ATLAS

Lubos Motl commented (see <http://tinyurl.com/y85mmsfj>) last ATLAS release (see <http://tinyurl.com/yammtrqf>) about dijet production. There is something which one might interpret as the presence of resonances above 3.3 TeV [see Fig. 2] of the article [C25]. Of course, just a slight indication is in question, so that it is perhaps too early to pay attention to the ATLAS release. I am however advocating a new hadron physics and it is perhaps forgivable that I am alert for even tiniest signals of new physics.

In a very optimistic mood I could believe that a new hadron physics is being discovered (145 GeV boson could be identified as charged pion and 325 GeV bumps could allow interpretation as kaons). With this almost killer dose of optimism the natural question is whether this extremely slight indication about new physics might have interpretation as a scaled up J/Ψ and various other charmonium states above it giving rise to what is not single very wide bump to a family of several resonances in the range 3-4 TeV by scaling the 3-4 GeV range for charmonium resonances. For instance, J/Ψ decay width is very small, about 1 MeV, which is about $.3 \times 10^{-4}$ of the mass of J/Ψ . In the recent case direct scaling would give decay of about 300 MeV for the counterpart of J/Ψ if the decay is also now slow for kinematic reasons. For other charmonium resonances the widths are measurement in per cents meaning in the recent case width of order of magnitude 30 GeV: this estimate looks more reasonable as the first estimate.

One can also now perform naïve scalings. J/Ψ has mass of about 3 GeV. If the scaling of ordinary pion mass from 14 GeV indeed gives something like 145 GeV then one can be very naïve and apply the same scaling factor of about 1030 to get the scaled up J/Ψ ; with mass of order 3.1 TeV. The better way to understand the situation is to assume that color-magnetic spin spin splitting is small also for M_{89} charmonium states and apply naïve scaling to the mass of J/Ψ ; to get a lower bound for the mass of its M_{89} counterpart. This would give mass of 1.55 TeV which is by a factor 1/2 too small. p-Adic mass calculations lead to the conclusion that c quark is characterized by $p \simeq 2^k$, $k = 104$. naïve scaling would give $k = 104 - 18 = 86$ and 1.55 TeV mass for J/Ψ . Nothing however excludes $k = 84$ and the lower bound 3.1 TGD

for the mass of J/Ψ . Since color magnetic spin-spin splitting is smaller for M_{89} pion, same is expected to be true also for charmonium states so that the mass might well be around 3.3 TeV.

6.3.3 Blackholes at LHC: or just bottonium of M_{89} hadron physics?

The latest Tommaso Dorigo's posting has a rather provocative title: "The Plot Of The Week - A Black Hole Candidate" (see <http://tinyurl.com/3w3raor>). Some theories inspired by string theories predict micro black holes at LHC. Micro blackholes have been proposed as explanation for certain exotic cosmic ray events such as Centauros (see <http://tinyurl.com/y84n152o>), which however seem to have standard physics explanation.

Without being a specialist one could expect that evaporating black hole would be in many respects analogous to quark gluon plasma phase decaying to elementary particles producing jets. Or any particle like system, which has forgot all information about colliding particles which created it- say the information about the scattering plane of partons leading to the jets as a final state and reflecting itself as the coplanarity of the jets. If the information about the initial state is lost, one would expect more or less spherical jet distribution. The variable used as in the study is sum of transverse energies for jets emerging from same point and having at least 50 GeV transverse energy. QCD predicts that this kind of events should be rather scarce and if they are present, one can seriously consider the possibility of new physics.

The LHC document containing the sensational proposal is titled "Search for Black Holes in pp collisions at $\sqrt{s} = 7$ TeV" (see <http://tinyurl.com/ycfa9ctx>) [C20] and has the following abstract:

An update on a search for microscopic black hole production in pp collisions at a center-of-mass energy of 7 TeV by the CMS experiment at the LHC is presented using a 2011 data sample corresponding to an integrated luminosity of 190 pb1. This corresponds to a six-fold increase in statistics compared to the original search based on 2010 data. Events with large total transverse energy have been analyzed for the presence of multiple energetic jets, leptons, and photons, typical of a signal from an evaporating black hole. A good agreement with the expected standard model backgrounds, dominated by QCD multijet production, has been observed for various multiplicities of the final state. Stringent model-independent limits on new physics production in high-multiplicity energetic final states have been set, along with model-specific limits on semi-classical black hole masses in the 4-5 TeV range for a variety of model parameters. This update extends substantially the sensitivity of the 2010 analysis.

The abstract would suggest that nothing special has been found but in sharp contrast with this the article mentions black hole candidate decaying to 10 jets with total transverse energy S_T . The event is illustrated in the figure 3 of the article. The large number of jets emanating from single point would suggest a single object decaying producing the jets.

Personally I cannot take black holes as an explanation of the event seriously. What can I offer instead? p-Adic mass calculations rely on p-adic thermodynamics and this inspires obvious questions. What p-adic cooling and heating processes could mean? Can one speak about p-adic hot spots? What p-adic overheating and over-cooling could mean? Could the octaves of pions and possibly other mesons explaining several anomalous findings including CDF bump correspond to unstable over-heated hadrons for which the p-adic prime near power of two is smaller than normally and p-adic mass scale is correspondingly scaled up by a power of two?

The best manner to learn is by excluding various alternative explanations for the 10 jet event.

- (a) M_{89} variants of QCD jets are excluded both because their production requires higher energies and because their number would be small. The first QCD three-jets (see <http://tinyurl.com/y9qyatmm>) were observed around 1979 [C112]. $q - \bar{q} - g$ three-jet was in question and it was detected in e^+e^- collision with cm energy about 7 GeV. The naïve scaling by factor 512 would suggest that something like 5.6 TeV cm energy is needed to observed M_{89} parton jets. The recent energy is 7 TeV so that there are

hopes of observing M_{89} three-jets in decays of heavy M_{89} . For instance, the decays of charmonium and bottomium of M_{89} physics to three gluons or two-gluons and photon would create three-jets.

- (b) Ordinary quark gluon plasma is excluded since in a sufficiently large volume of quark gluon plasma so called jet quenching (see <http://tinyurl.com/yc7mo6jt>) [C4] occurs so that jets have small transverse energies. This would be due to the dissipation of energy in the dense quark gluon plasma. Also ordinary QCD jets are predicted to be rare at these transverse energies: this is of course the very idea of how black hole evaporation might be observed. Creation of quark gluon plasma of M_{89} hadron physics cannot be in question since ordinary quark gluon plasma was created in p-anti-p collision with cm energy of few TeV so that something like 512 TeV of cm energy might be needed!
- (c) Could the decay correspond to a decay of a blob of M_{89} hadronic phase to M_{107} hadrons? How this process could take place? I proposed for about 15 years ago [K25] that the transition from M_{89} hadron physics to M_{107} hadron physics might take place as a p-adic cooling via a cascade like process via highly unstable intermediate hadron physics. The p-adic temperature is quantized and given by $T_p = n/\log(p) \simeq n/k\log(2)$ for $p \simeq 2^k$ and p-adic cooling process would proceed in a step-wise manner as $k \rightarrow k+2 \rightarrow k+4 + \dots$. Also $k \rightarrow k+1 \rightarrow k+2 + \dots$ with mass scale reduced in powers of $\sqrt{2}$ can be considered. If only octaves are allowed, the p-adic prime characterizing the hadronic space-time sheets and quark mass scale could decrease in nine steps from M_{89} mass scale proportional to $2^{-89/2}$ octave by octave down to the hadronic mass scale proportional $2^{-107/2}$ as $k = 89 \rightarrow 91 \rightarrow 93 \dots \rightarrow 107$. At each step the mass in the propagator of the particle would be changed. In particular on mass shell particles would become off mass shell particles which could decay.

At quark level the cooling process would naturally stop when the value of k corresponds to that characterizing the quark. For instance b quark one has $k(b) = 103$ so that 7 steps would be involved. This would mean the decay of M_{89} hadrons to highly unstable intermediate states corresponding to $k = 91, 93, \dots, 107$. At every step states almost at rest could be produced and the final decay would produce large number of jets and the outcome would resemble the spectrum blackhole evaporation. Note that for u, d, s quarks one has $k = 113$ characterizing also nuclei and muon which would mean that valence quark space-time sheets of lightest hadrons would be cooler than hadronic space-time sheet, which could be heated by sea partons. Note also that quantum superposition of phases with several p-adic temperatures can be considered in zero energy ontology.

This is of course just a proposal and might not be the real mechanism. If M_{89} hadrons are dark in TGD sense as the TGD based explanation of CDF-D0 discrepancy suggests, also the transformation changing the value of Planck constant is involved.

- (d) This picture does not make sense in the TGD inspired model explaining DAMA observations and DAMA-Xenon100 anomaly, CDF bump discussed in this chapter and two and half year old CDF anomaly [K47]. The model involves creation of second octave of M_{89} pions decaying in stepwise manner. A natural interpretation of p-adic octaves of pions is in terms of a creation of over-heated unstable hadronic space-time sheet having $k = 85$ instead of $k = 89$ and p-adically cooling down to relatively thermally stable M_{89} sheet and containing light mesons and electroweak bosons. If so then the production of CDF bump would correspond to a creation of hadronic space-time sheet with p-adic temperature corresponding to $k = 85$ cooling by the decay to $k = 87$ pions in turn decaying to $k = 89$. After this the decay to M_{107} hadrons and other particles would take place.

Consider now whether the 10 jet event could be understood as a creation of a p-adic hot spot perhaps assignable to some heavy meson of M_{89} physics. The table below is from [K22, K22] and gives the p-adic primes assigned with constituent quarks identified as valence quarks. For current quarks the p-adic primes can be much large so that in the case of u and d quark the masses can be in 10 MeV range (which together with detailed model for light hadrons supports the view that quarks can appear at several p-adic temperatures).

- (a) According to p-adic mass calculations [K22] ordinary charmed quark corresponds to $k = 104 = 107 - 3$ and that of bottom quark to $k = 103 = 107 - 4$, which is prime and correspond to the second octave of M_{107} mass scale assignable to the highest state of pion cascade. By naïve scaling M_{89} charmonium states (Ψ would correspond to $k = 89 - 3 = 86$ with mass of about 1.55 TeV by direct scaling. $k = 89 - 4 = 85$ would give mass about 3.1 GeV and there is slight evidence for a resonance around 3.3 TeV perhaps identifiable as charmonium. Υ (bottomonium) consisting of $b\bar{b}$ pair correspond to $k = 89 - 4 = 85$ just like the second octave of M_{89} pion. The mass of M_{89} Υ meson would be about 4.8 TeV for $k = 85$. $k = 83$ one obtains 9.6 TeV, which exceeds the total cm energy 7 TeV.
- (b) Intriguingly, $k = 85$ for the bottom quark and for first octave of charmonium would correspond to the second octave of M_{89} pion. Could it be that the hadronic space-time sheet of Υ is heated to the p-adic temperature of the bottom quark and then cools down in a stepwise manner? If so, the decay of Υ could proceed by the decay to higher octaves of light M_{89} mesons in a process involving two steps and could produce a large number jets.
- (c) For the decay of ordinary Υ meson 81.7 per cent of the decays take place via ggg state. In the recent case they would create three M_{89} parton jets producing relativistic M_{89} hadrons. 2.2 per cent of decays take place via γgg state producing virtual photon plus M_{89} hadrons. The total energies of the three jets would be about 1.6 TeV each and much higher than the energies of QCD jets so that this kind of jets would serve as a clearcut signature of M_{89} hadron physics and its bottom quark. Note that there already exists slight evidence for charmonium state. Recall that the total transverse energy of the 10 jet event was about 1 TeV.

Also direct decays to M_{89} hadrons take place. $\eta' + \text{anything}$ (see <http://tinyurl.com/y8upgujn>) - presumably favored by the large contribution of $b\bar{b}$ state in η' - corresponds to 2.9 per cent branching ratio for ordinary hadrons. If second octaves of η' and other hadrons appear in the hadron state, the decay product could be nearly at rest and large number of M_{89} would result in the p-adic cooling process (the naïve scaling of η' mass gives 5 TeV and second octave would correspond to 2 TeV.

- (d) If two octave p-adic over-heating is dynamically favored, one must also consider the first octave of scaled variant of J/Ψ state with mass around 3.1 GeV scaled up to 3.1 TeV for the first octave. The dominating hadronic final state in the decay of J/Ψ is $\rho^\pm \pi^\mp$ with branching ratio of 1.7 per cent. The branching fractions of $\omega \pi^+ \pi^+ \pi^- \pi^-$, $\omega \pi^+ \pi^- \pi^0$, and $\omega \pi^+ \pi^+ \rho^-$ are 8.5×10^{-3} , 4.0×10^{-3} , and 8.6×10^{-3} respectively. The second octaves for the masses of ρ and π would be 1.3 TeV and 6 TeV giving net mass of 1.9 TeV so that these mesons would be relativistic if charmonium state with mass around 3.3 TeV is in question. If the two mesons decay by cooling, one would obtain two jets decaying two jets. Since the original mesons are relativistic one would probably obtain two wide jets decomposing to sub-jets. This would not give the desired fireball like outcome.

The decays $\omega \pi^+ \pi^+ \pi^- \pi^-$ (see Particle Data Tables (see <http://tinyurl.com/y8upgujn>)) would produce five mesons, which are second octaves of M_{89} mesons. The rest masses of M_{89} mesons would in this case give total rest mass of 3.5 TeV. In this kind of decay -if kinematically possible- the hadrons would be nearly at rest. They would decay further to lower octaves almost at rest. These states in turn would decay to ordinary quark pairs and electroweak bosons producing a large number of jets and black hole like signatures might be obtained. If the process proceeds more slowly from M_{89} level, the visible jets would correspond to M_{89} hadrons decaying to ordinary hadrons. Their transverse energies would be very high.

q	d	u	s	c	b	t
n_q	4	5	6	6	59	58
s_q	12	10	14	11	67	63
$k(q)$	113	113	113	104	103	94
$m(q)/GeV$.105	.092	.105	2.191	7.647	167.8

Constituent quark masses predicted

for diagonal mesons assuming $(n_d, n_s, n_b) = (5, 5, 59)$ and $(n_u, n_c, n_t) = (5, 6, 58)$, maximal CP_2 mass scale ($Y_e = 0$), and vanishing of second order contributions.

To sum up, the most natural interpretation for the 10-jet event in TGD framework would be as p-adic hot spots produced in collision.

6.3.4 Has CMS detected λ baryon of M_{89} hadron physics?

In his recent posting Lubos Motl tells about a near 3-sigma excess of 390 GeV 3-jet RPV-gluino-like signal reported by CMS collaboration in article “Search for Three-Jet Resonances in p-p collisions at $\sqrt{s} = 7$ TeV” (see <http://tinyurl.com/42sm8oh>) [C24]. This represents one of the long waited results from LHC and there are good reason to consider it at least half-seriously.

Gluinos are produced in pairs and in the model based on standard super-symmetry decay to three quarks. The observed 3-jets in question would correspond to a decay to uds quark triplet. The decay would be R-parity breaking. The production rate would however too high for standard SUSY so that something else is involved if the 3 sigma excess is real.

1. Signatures for standard gluinos correspond to signatures for M_{89} baryons in TGD framework

In TGD Universe gluinos would decay to ordinary gluons and right-handed neutrino mixing with the left handed one so that gluino in TGD sense is excluded as an explanation of the 3-jets. In TGD framework the gluino candidate would be naturally replaced with $k = 89$ variant of strange baryon λ decaying to uds quark triplet. Also the 3-jets resulting from the decays of proton and neutron and Δ resonances are predicted. The mass of ordinary λ is $m(\lambda, 107) = 1.115$ GeV. The naïve scaling by a factor 512 would give mass $m(\lambda, 107) = 571$ GeV, which is considerably higher than 390 GeV. naïve scaling would predict the scaled up copies of the ordinary light hadrons so that the model is testable.

It is quite possible that the bump is a statistical fluctuation. One can however reconsider the situation to see whether a less naïve scaling could allow the interpretation of 3-jets as decay products of M_{89} λ -baryon.

2. Massivation of hadrons in TGD framework

Let us first look the model for the masses of nucleons in p-adic thermodynamics [K30].

- (a) The basic model for baryon masses assumes that mass squared -rather than energy as in QCD and mass in naïve quark model- is additive at space-time sheet corresponding to given p-adic prime whereas masses are additive if they correspond to different p-adic primes. Mass contains besides quark contributions also “gluonic contribution” which dominates in the case of baryons. The additivity of mass squared follows naturally from string mass formula and distinguishes dramatically between TGD and QCD. The value of the p-adic prime $p \simeq 2^k$ characterizing quark depends on hadron: this explains the mass differences between baryons and mesons. In QCD approach the contribution of quark masses to nucleon masses is found to be less than 2 per cent from experimental constraints. In TGD framework this applies only to sea quarks for which masses are much lighter whereas the light valence quarks have masses of order 100 MeV.

For a mass formula for quark contributions additive with respect to quark mass squared quark masses in proton would be around 100 MeV. The masses of $u, d,$ and s quarks are in good approximation 100 MeV if p-adic prime is $k = 113$, which characterizes the

nuclear space-time sheet and also the space-time sheet of muon. The contribution to proton mass is therefore about $\sqrt{3} \times 100$ MeV.

Remark: The masses of u and d sea quarks must be of order 10 MeV to achieve consistency with QCD. In this case p-adic primes characterizing the quarks are considerably larger. Quarks with mass scale of order MeV are important in nuclear string model which is TGD based view about nuclear physics [L2].

- (b) If color magnetic spin-spin splitting is neglected, p-adic mass calculations lead to the following additive formula for mass squared.

$$M(\text{baryon}) = M(\text{quarks}) + M(\text{gluonic}) , \quad M^2(\text{gluonic}) = nm^2(107) . \quad (6.5)$$

The value of integer n can almost predicted from a model for the TGD counterpart of the gluonic contribution [K30] to be $n = 18$. $m^2(107)$ corresponds to p-adic mass squared associated with the Mersenne prime $M_{107} = 2^{107} - 1$ characterizing hadronic space-time sheet responsible for the gluonic contribution to the mass squared. One has $m(107) = 233.55$ MeV from electron mass $m_e \simeq \sqrt{5} \times m(127) \simeq 0.5$ MeV and from $m(107) = 2^{(127-107)/2} \times m(127)$.

- (c) For proton one has

$$M(\text{quarks}) = \left(\sum_{\text{quarks}} m^2(\text{quark}) \right)^{1/2} \simeq 3^{1/2} \times 100 \text{ MeV}$$

for $k(u) = k(d) = 113$ [K30].

3. Super-symplectic gluons as TGD counterpart for non-perturbative aspects of QCD

A key difference as compared to QCD is that the TGD counterpart for the gluonic contribution would contain also that due to “super-symplectic gluons” besides the possible contribution assignable to ordinary gluons.

- (a) Super-symplectic gluons do not correspond to pairs of quark and antiquark at the opposite throats of wormhole contact as ordinary gluons do but to single wormhole throat carrying purely bosonic excitation corresponding to color Hamiltonian for CP_2 . They therefore correspond directly to wave functions in WCW (“world of classical worlds”) and could therefore be seen as a genuinely non-perturbative objects allowing no description in terms of a quantum field theory in fixed background space-time.
- (b) The description of the massivation of super-symplectic gluons using p-adic thermodynamics allows to estimate the integer n characterizing the gluonic contribution. Also super-symplectic gluons are characterized by genus g of the partonic 2-surface and in the absence of topological mixing $g = 0$ super-symplectic gluons are massless and do not contribute to the ground state mass squared in p-adic thermodynamics. It turns out that a more elegant model is obtained if the super-symplectic gluons suffer a topological mixing assumed to be same as for U type quarks. Their contributions to the mass squared would be $(5, 6, 58) \times m^2(107)$ with these assumptions.
- (c) The quark contribution $(M(\text{nucleon}) - M(\text{gluonic}))/M(\text{nucleon})$ is roughly 82 per cent of proton mass. In QCD approach experimental constraints imply that the sum of quark masses is less than 2 per cent about proton mass. Therefore one has consistency with QCD approach if one assumes that the light quarks correspond to sea quarks.

4. What happens in $M_{107} \rightarrow M_{89}$ transition?

What happens in the transition $M_{107} \rightarrow M_{89}$ depends on how the quark and gluon contributions depend on the Mersenne prime.

- (a) One can also scale the “gluonic” contribution to baryon mass which should be same for proton and λ . Assuming that the color magnetic spin-spin splitting and color Coulombic conformal weight expressed in terms of conformal weight are same as for the ordinary baryons, the gluonic contribution to the mass of $p(89)$ corresponds to conformal weight $n = 11$ reduced from its maximal value $n = 3 \times 5 = 15$ corresponding to three topologically mixed super-symplectic gluons with conformal weight 5 [K30]. The reduction is due to the negative colour Coulombic conformal weight. This is equal to $M_g = \sqrt{11} \times 512 \times m(107)$, $m(107) = 233.6$ MeV, giving $M_g = 396.7$ GeV which happens to be very near to the mass about 390 GeV of CMS bump. The facts that quarks appear already in light hadrons in several p-adic length scales and quark and gluonic contributions to mass are additive, raises the question whether the state in question corresponds to p-adically hot ($1/T_p \propto \log(p) \simeq k \log(2)$) gluonic/hadronic space-time sheet with $k = 89$ containing ordinary quarks giving a small contribution to the mass squared. Kind of overheating of hadronic space-time sheet would be in question.
- (b) The option for which quarks have masses of thermally stable M_{89} hadrons with quark masses deduced from the questionable 145 GeV CDF bump identified as the pion of M_{89} physics does not work.

- i. If both contributions scale up by factor 512, one obtains $m(p, 89) = 482$ GeV and $m(\lambda) = 571$ GeV. The values are too large.
- ii. A more detailed estimate gives the same result. One can deduce the scaling of the quark contribution to the baryon mass by generalizing the condition that the mass of pion is in a good approximation just $m(\pi) = \sqrt{2}m(u, 107)$ (Goldstone property). One obtains that u and d quarks of M_{89} hadron physics correspond to $k = 93$ whereas top quark corresponds to $k = 94$: the transition between hadron physics would be therefore natural. One obtains $m(u, 89) = m(d, 89) = 102$ GeV in good approximation: note that this predicts quark jets with mass around 100 GeV as a signature of M_{89} hadron physics.

The contribution of quarks to proton mass would be $M_q = \sqrt{3} \times 2^{(113-93)/2} m(u, 107) \simeq 173$ GeV. By adding the quark contribution to gluonic contribution $M_g = 396.7$ GeV, one obtains $m(p, 89) = 469.7$ GeV which is rather near to the naïvely scaled mass 482 GeV and too large. For $\lambda(89)$ the mass is even larger: if $\lambda(89) - p(89)$ mass difference obeys the naïve scaling one has $m(\lambda, 89) - m(p, 89) = 512 \times m(\lambda, 107) - m(p, 107)$. One obtains $m(\lambda, 89) = m(p, 89) + m(s, 89) - m(u, 89) = 469.7 + 89.6$ GeV = 559.3 GeV rather near to the naïve scaling estimate 571 GeV. This option fails.

Maybe I would be happier if the 390 GeV bump would turn out to be a fluctuation (as it probably does) and were replaced with a bump around 570 GeV plus other bumps corresponding to nucleons and Δ resonances and heavier strange baryons. The essential point is however that the mass scale of the gluino candidate is consistent with the interpretation as λ baryon of M_{89} hadron physics. Quite generally, the signatures of R-parity breaking standard SUSY have interpretation as signatures for M_{89} hadron physics in TGD framework.

6.3.5 3-jet and 9-jet events as a further evidence for M_{89} hadron physics?

The following arguments represent a fresh approach to 390 GeV bump which I developed without noticing that I had discussed already earlier the above un-successful explanation.

Lubos Motl (see <http://tinyurl.com/zbu3br7>) told about slight 3-jet and 9-jet excesses seen by CMS collaboration in LHC data (see <http://tinyurl.com/ya6fsd78>). There is an article about 3-jet excess titled “Search for Three-Jet Resonances in pp Collisions at $s^{1/2} = 7$ TeV” by CMS collaboration [C37]. The figure in Lubos Motl’s blog (see <http://tinyurl.com/z3wcke8>) shows what has been found. In 3-jet case the effects exceeds 3-sigma level between 350 GeV and 410 GeV and the center is around 380-390 GeV.

Experimenters see 3-jets as 1.9 sigma evidence for SUSY. It is probably needless to tell that 1.9 sigma evidences come and go and should not be taken seriously. Gluino pair would be

produced and each gluino with mass around 385 GeV would decay to three quarks producing three jets. In tri-jet case altogether 3+3=6 jets would be produced in the decays of gluinos. The problem is that there is no missing energy predicted by MSSM scenario without R-parity breaking. Therefore the straightforward proposal of CMS collaboration is that R-parity is broken by a coupling of gluino to 3 quark state so that gluino would effectively have quark number three and gluino can decay to 3 light quarks- say uds .

The basic objection against this idea is that the distribution of 3-jet masses is very wide extending from 75 GeV (slightly below 100 GeV for selected events) to about 700 GeV as one learns from figure 1 (see <http://tinyurl.com/42sm8oh>) [C24] of the CMS preprint [C37]. Resonance interpretation does not look convincing to me and to my humble opinion this is a noble but desperate attempt to save the standard view about SUSY. After proposing the explanation which follows I realized to my surprise that I had already earlier tried to explain the 390 GeV bump in terms of M_{89} baryon but found that this explanation fails [L6] since the mass is too low to allow this interpretation.

There is also an article about nona-jets titled “Has SUSY Gone Undetected in 9-jet Events? A Ten-Fold Enhancement in the LHC Signal Efficiency” (see <http://tinyurl.com/44bpth9>) [C92] but I will not discuss this except by noticing that nona-jet events would serve as a unique signature of M_{89} baryon decays in TGD framework if the proposed model for tri-jets is correct.

Before continuing I want to make clear my motivations for spending time with thinking about this kind of events which are probably statistical fluctuations. If I were an opportunist I would concentrate all my efforts to make a maximum noise about the successes of TGD. I am however an explorer rather than career builder and physics is to me a passion- something much more inspiring than personal fame. My urge is to learn what TGD SUSY is and what it predicts and this kind of activity is the best manner to do it.

1. *Could one interpret the 3-jet events in terms of TGD SUSY without R-parity breaking?*

I already mentioned the very wide range of 3-jet distribution as a basic objection against gluino pair interpretation. But just for curiosity one can also consider a possible interpretation in the framework provided by TGD SUSY.

As I have explained in the article [L5], one could understand the apparent absence of squarks and gluinos in TGD framework in terms of shadronization which would be faster process than the selectro-weak decays of squarks so that the standard signatures of SUSY (jet plus missing energy) would not be produced. The mass scales and even masses of quark and squark could be identical part from a splitting caused by mixing. The decay widths of weak bosons do not however allow light exotic fermions coupling to them and this in the case of ordinary hadron physics this requires that squarks are dark having therefore non-standard value of Planck constant coming as an integer multiple of the ordinary Planck constant [K16]. For M_{89} hadron physics this constraint is not necessary.

One can indeed imagine an explanation for 3-jets in terms of decays of gluino pair in TGD framework without R-parity breaking.

- (a) Both gluinos would decay as $\tilde{g} \rightarrow \tilde{q} + \bar{q}$ (or charge conjugate of this) and squark in turn decays as $\tilde{q} \rightarrow q + \tilde{g}$. This would give quark pair and two virtual gluinos. Virtual gluinos would transform to a quark pair by an exchange of virtual squark: $\tilde{g} \rightarrow q + \bar{q}$. This would give 3 quark jets and 3 anti-quark jets.
- (b) Why this option possible also in MSSM is not considered by CMS collaboration? Do the bounds on squark masses make the rate quite too low? The very strong lower bounds on squark masses in MSSM type SUSY were indeed known towards the end of August when the article was published. In TGD framework these bounds are not present since squarks could appear with masses of ordinary quarks if they are dark in TGD sense. Gluinos would be however dark and the amplitude for the phase transition transforming gluon to its dark variant decaying to a gluino pair could make the rate too low.
- (c) If one takes the estimate for the M_{89} gluino mass seriously and scales to a very naïve mass estimate for M_{107} gluino by a factor 1/512, one obtains $m(\tilde{g}_{107}) = 752$ MeV.

As already noticed, I do not take this explanation too seriously: the tri-jet distribution is quite too wide.

2. *Could tri-jets be interpreted in terms of decays of M_{89} quarks to three ordinary quarks?*

3+3 jets are observed and they correspond to 3 quarks and antiquarks. If one takes 3-jet excess seriously it seems that one has to assume a fermion decaying to 3 quarks or two quarks and antiquark. All these quarks could be light (u, d, s type quarks).

Could M_{89} quarks decaying to three M_{107} (ordinary) quarks ($q_{89} \rightarrow q_{107}q_{107}\bar{q}_{107}$) be in question? If this were the case the 9-jets might allow interpretation as decays of M_{89} proton or neutron with mass which from naïve scaling would be $512 \times .94 \text{ GeV} \simeq 481 \text{ GeV}$ resulting when each quark the nucleon decays to three ordinary quarks. Nona-jets would serve as a unique signature for the production of M_{89} baryons!

M_{89} quarks must decay somehow to ordinary quarks.

- (a) The simplest guess is that the transformation $q_{89} \rightarrow q_{107}q_{107}\bar{q}_{107}$ begins with the decay $q_{89} \rightarrow q_{107} + g_{89}$. Here g_{89} can be virtual.
- (b) This would be followed by $g_{89} \rightarrow q_{107}\bar{q}_{107}$. The final state would consist of two quarks and one antiquark giving rise to tri-jet. The decay of M_{89} gluon could produce all quark families democratically apart from phase space factors larger for light quarks. This would produce 3+3 jets with a slight dominance of light quark 3-jets.

There are two options to consider. The first option corresponds to a production of a pair of on mass shell M_{89} quarks with mass around 385 GeV (resonance option) and second option to a production of a pair of virtual M_{89} quarks suggested by the wide distribution of tri-jets.

- (a) Could the resonance interpretation make sense? Can the average 3-jet mass about 385 GeV correspond to the mass of M_{89} quark? The formulas $m(\pi_{89}) = 2^{1/2}m(u_{89})$ (mass squared is additive) together with $m(\pi_{89}) = 144 \text{ GeV}$ would give $m(u_{89}) \simeq 101.8 \text{ GeV}$. Unfortunately the mass proposed for the gluino is almost 4 times higher. The naïve scaling by factor 512 for $m(c_{107}) = 1.29 \text{ GeV}$ would give 660.5 GeV, which is quite too high. It seems very difficult to find any reasonable interpretation in terms of decays of on mass shell M_{89} quarks with mass around 385 GeV.
- (b) One can however consider completely different interpretation. From figure 1 (see <http://tinyurl.com/42sm8oh>) of [C37] of the CMS preprint one learns that the distribution of 3-jet masses is very wide beginning around 75 GeV (certainly consistent with 72 GeV, which is one half of the predicted mass 144 GeV of M_{89} pion) for all triplets and slightly below 100 GeV for selected triplets.

Could one interpret the situation without selection by assuming that a pair of M_{89} quarks forming a virtual M_{89} pion is produced just as the naïve expectation that the old-fashioned proton-pion picture could make sense at “low” energies (using of course M_{89} QCD Λ as a natural mass scale) also for M_{89} physics. The total mass of M_{89} quark pair would be above 144 GeV and its decay to virtual M_{89} quark pair would give quark pair with quark masses above 72 GeV. Could the selected events with total 3-jet mass above 100 GeV correspond to the production of a virtual M_{89} quark pair?

To sum up, if one takes the indications for 3-jets seriously, the interpretation in terms of M_{89} hadron physics is the most plausible TGD option. I am unable to say anything about the 9-jet article but 9-jets would serve as a unique and very dramatic signature of M_{89} baryons: the naïve prediction for the mass of M_{89} nucleon is 481 GeV.

6.3.6 3 sigma evidence for kaons of M_{89} hadron physics?

The news about Moriond conference (for details see for the posting of Phil Gibbs at <http://tinyurl.com/yb1165g7>) did not bring anything really new concerning the situation with Higgs. The two-photon discrepancy is still there although the production rate is now about

1.6 times higher than predicted. The error bars are however getting narrower so that there are excellent reasons to hope/fear that unexpected kind of new physics is trying to tell about itself. Also the masses deduced from gamma pair and Z pair decay widths are slightly different.

The TGD-based explanation (see <http://tinyurl.com/ycfjrtxh>) would be in terms of M_{89} hadron physics, a fractal copy of ordinary hadron physics with 512 times higher overall mass scale. If the pion of this new physics has mass not too far from 125 GeV its decays to gamma and Z pairs would affect the observed decay rates of Higgs to gamma and Z pairs if one assumes just standard model. Fermi anomaly suggests mass of about 135 GeV for the pion of M_{89} hadron physics. The observations of RHIC and those from proton-heavy nucleus collisions - correlated pairs of charged particles moving in same or opposite directions- could be understood in terms of decays of M_{89} mesons behaving like hadronic strings in low energies in the relevant energy scale.

Lubos Motl (see <http://tinyurl.com/y8xvmocm>) tells in his recent posting about 3 sigma excess (see <http://tinyurl.com/y89mur5z>) for new charged and neutral particles with mass around 420 GeV [C28]. They would be produced as pairs of charged and neutral particle. M_{89} physics based explanation would be in terms of kaons of M_{89} hadron physics. The naïve scaling by the ratio $r = m(\pi_{107}^+)/m(K_{107}^+)$ of masses of ordinary pion and kaon predicts that the M_{89} pion should have mass $m(\pi_{89}^+) = r \times 420$ GeV. This would give $m(\pi_{89}^+) = 119$ GeV not too far from 125 GeV to affect the apparent decay rates of Higgs to gamma and Z pairs since its width as strongly interacting particle decaying to ordinary quarks and gluons is expected to be large. This mass however deviates from the 135 GeV mass suggested by Fermi data by 18 per cent.

6.3.7 Evidence for a new pseudo-vector particle?

Lubos Motl told (see <http://tinyurl.com/y5ysybt6>) that CMS has reported evidence for a bump at 400 GeV decaying to top quark pairs. Local evidence is 3.5 sigma. Look elsewhere effect reduces it to 1.5 sigma. What was searched was new neutral scalar or pseudoscalar Higgs particle predicted by minimal SUSY extensions of the standard model. The largest deviation from standard model background was observed for pseudoscalar Higgs.

Lubos wants to interpret this as evidence for CP odd Higgs called "A" (C even, P odd). The article with title "*Search for heavy Higgs bosons decaying to a top quark pair in proton-proton collisions at $s^{1/2} = 13$ TeV*" [C63] (see <http://tinyurl.com/y27x5qnz>) tells that the search is sensitive to the spin of the resonance. I do not however know how well the spin and CP of the decaying resonance candidate are known.

It is assumed that the resonance candidate is produced as two gluons annihilate dominantly to top quark pair which couples to the Higgs candidate resonantly and decays dominantly to top quark pair. There are two effects involved. Resonance like contribution and interference with the contribution of the ordinary Higgs for pseudoscalar Higgs. The parity of the pseudoscalar Higgs shows itself in the angular distribution. CP=-1 character in principle shows itself too since it introduces to the amplitude sign -1. The CP transformation of final state consisting of superpositions of RR or LL fermion pairs is induced by $(RR, LL) \rightarrow -(LL, -RR)$ (R and L refer to helicities). If initial state consist of two gluons one expects that CP acts trivially.

TGD almost-predicts a scaled variant of hadron physics at LHC. Mersenne prime M_{89} characterizes this hadron physics whereas ordinary hadron physics corresponds to Mersennens prime M_{107}). Since there exists a handful of bumps [K25] with masses differing by factor 512 from the masses of ordinary mesons, I have the habit of scaling down the masses of the bumps (usually identified as candidates for SUSY Higgs) reported from LHC. This habit means also killing all desperate attempts of Lubos to interpret them in terms of SUSY Higgses. And indeed. Now the scaling of 400 GeV gives 781 MeV, which is very precisely the mass 782 GeV of ω meson having $C = P = -1$ and spin 1.

Could spin=0 state of this meson behaving like pseudoscalar and explain the finding? By looking the article "*Production of CP-even and CP-odd Higgs bosons at Muon colliders*" [C15]

(see <http://tinyurl.com/y26vvmot>) one gets some idea about the symmetries amplitudes involved also in the recent case.

- (a) If the resonance is scalar or pseudoscalar, the initial state helicities must be opposite. In spin 1 case there is also a contribution proportional to a matrix element of spin 1 rotation matrix corresponding to a rotation transforming to each other the axis defined by the initial and final state cm momenta of gluons and top quarks.
- (b) For pseudovector ω the transformation of the propagator part of the amplitude (there sonance) under P is the same as for pseudoscalar Higgs (change of sign) so that ω is consistent with A in this respect.
- (c) The coupling of (pseudo-)vector particle to $t\bar{t}$ pair is of form LL+RR. For pseudoscalar it is of form LR. The massivation of fermions mixing L and R allows the coupling to the longitudinal zero helicity component of spin 1 particle mimic the coupling to pseudoscalar. For massive fermions the gradient coupling of (pseudo)scalar to fermions is indeed equivalent with the ordinary (pseudoscalar) scalar coupling.

Remark: Note that the longitudinal components of weak bosons are proportional to the gradient of weakly charged part of Higgs).

Remark: Higgs mechanism can be argued to be a pseudo solution to the massivation problem, which only reproduces fermion masses but does not predict them (Higgs couplings must be chosen proportional to fermion masses). If fermions get masses by some other genuine massivation mechanism, Higgs couplings proportional to mass follow automatically from gradient coupling. Fermion masses in turn follow in TGD from p-adic thermodynamics [K22].

- (d) For Higgs the decay width is about 10^{-5} of the mass and one expects that the decay width should be also now of the same order of magnitude. The actual decay width of the bump is 5 per cent of the mass, and it is not clear to me how kinematics could cause so large a difference. To me this strongly suggests that strong rather than electroweak interactions are involved as TGD indeed predicts.

6.4 LHC Might Have Produced New Matter: Are M_{89} Hadrons In Question?

“Large Hadron Collider May Have Produced New Matter” (see <http://tinyurl.com/zkxws89>) is the title of popular article explaining briefly the surprising findings of LHC made for the first time September 2010. A fascinating possibility is that these events could be seen as a direct signature of brand new hadron physics. I distinguish this new hadron physics using the attribute M_{89} to distinguish it from ordinary hadron physics assigned to Mersenne prime $M_{107} = 2^{107} - 1$.

6.4.1 Some background

Quark gluon plasma is expected to be generated in high energy heavy ion collisions if QCD is *the* theory of strong interactions. This would mean that quarks and gluons are de-confined and form a gas of free partons. Something different was however observed already at RHIC: the surprise was the presence of highly correlated pairs of charged particles. The members of pairs tended to move in parallel: either in same or opposite directions.

This forced to give up the description in terms of quark gluon plasma and to introduce what was called color glass condensate. The proposal was that so called color glass condensate, which is liquid with strong correlations between the velocities of nearby particles rather than gas like state in which these correlations are absent, is created: one can imagine that a kind of thin wall of gluons is generated as the highly Lorentz contracted nuclei collide. The liquid like character would explain why pairs tend to move in parallel manner. Why they can move also in antiparallel manner is not obvious to me although I have considered the TGD based view about color glass condensate inspired by the fact that the field equations for preferred

extremals are hydrodynamical and it might be possible to model this phase of collision using scaled version of critical cosmology which is unique apart from scaling of the parameter characterizing the duration of this critical period. Later LHC found a similar behavior in heavy ion collisions. The theoretical understanding of the phenomenon is however far from complete.

The real surprise was the observation of similar events in proton proton collisions at LHC: for the first time already at 2010. Lubos Motl (see <http://tinyurl.com/yc2r5u29>) wrote a nice posting about this observation. Now the findings have been published: preprint can be found in arXiv (see <http://tinyurl.com/yacr7hfv>) [C40]. Below is the abstract of the preprint.

Results on two-particle angular correlations for charged particles emitted in pPb collisions at a nucleon-nucleon center-of-mass energy of 5.02 TeV are presented. The analysis uses two million collisions collected with the CMS detector at the LHC. The correlations are studied over a broad range of pseudorapidity η , and full azimuth ϕ , as a function of charged particle multiplicity and particle transverse momentum, p_T . In high-multiplicity events, a long-range ($2 < |\Delta\eta| < 4$), near-side $\Delta\phi$ approximately 0) structure emerges in the two-particle $\Delta\eta$ - $\Delta\phi$ correlation functions. This is the first observation of such correlations in proton-nucleus collisions, resembling the ridge-like correlations seen in high-multiplicity pp collisions at $s^{1/2} = 7$ TeV and in A on A collisions over a broad range of center-of-mass energies. The correlation strength exhibits a pronounced maximum in the range of $p_T = 1$ -1.5 GeV and an approximately linear increase with charged particle multiplicity for high-multiplicity events. These observations are qualitatively similar to those in pp collisions when selecting the same observed particle multiplicity, while the overall strength of the correlations is significantly larger in pPb collisions.

6.4.2 Could M_{89} hadrons give rise to the events?

Second highly attractive explanation discussed by Lubos Motl (see <http://tinyurl.com/yc2r5u29>) is in terms of production of string like objects. In this case the momenta of the decay products tend to be parallel to the strings since the constituents giving rise to ultimate decay products are confined inside 1-dimensional string like object. In this case it is easy to understand the presence of both parallel and antiparallel pairs. If the string is very heavy, a large number of particles would move in collinear manner in opposite directions. Color quark condensate would explain this in terms of hydrodynamical flow.

In TGD framework these string like objects would correspond to color magnetic flux tubes. These flux tubes carrying quark and antiquark at their ends should however make them manifest only in low energy hadron physics serving as a model for hadrons, not at ultrahigh collision energies for protons. Could this mean that these flux tubes correspond to hadrons of M_{89} hadron physics? M_{89} hadron physics would be low energy hadron physics since the scaled counterpart of QCD Λ around 200 MeV is about 100 GeV and the scaled counterpart of proton mass is around 5 TeV (scaling is by factor is 512 as ratio of square roots of $M_{89} = 2^{89} - 1$, and M_{107}). What would happen in the collision would be the formation of p-adically hot spot at p-adic temperature $T = 1$ for M_{89} .

For instance, the resulting M_{89} pion would have mass around 67.5 GeV if a naïve scaling of ordinary pion mass holds true. p-Adic length scale hypothesis allows power of $2^{1/2}$ as a multiplicative factor and one would obtain something like 135 GeV for factor 2: Fermi telescope has provided evidence for this kind particle although it might be that systematic error is involved (see the nice posting of Resonance at <http://tinyurl.com/hpeq4q3>). The signal has been also observed by Fermi telescope for the Earth limb data where there should be none if dark matter in galactic center is the source of the events. I have proposed that M_{89} hadrons - in particular M_{89} pions - are also produced in the collisions of ultrahigh energy cosmic rays with the nuclei of the atmosphere: maybe this could explain also the Earth limb data. Recall that my first erratic interpretation for 125 GeV Higgs like state was as M_{89} pion and only later emerged the interpretation of Fermi events in terms of M_{89} pion.

One can consider a more concrete model for the situation.

- (a) The first picture is that M_{89} color magnetic flux tubes are created between the colliding protons and have length and thickness which is 512 shorter than that of ordinary hadronic color flux tubes and therefore also 512 times higher energy. The energy of colliding protons would be partially transformed to that of M_{89} mesons. This process should occur above critical collision energy $E_{cr}(p) = 512m_p \sim .5$ TeV and perhaps already above $E_{cr}(p) = m(pi_{89}) = 67.5$ GeV. One can worry about the small geometric size of M_{89} mesons: is it really possible to transfer of energy of protons consisting of quarks to a scale shorter by factor 1/512 or does this process occur at quark level and doesn't one encounter the same problem here? This problem leads to second picture.
- (b) M_{89} mesons could be dark so that their size is same as the size of protons: this could make possible a collective transfer of collision energy in the scale of entire proton to that of dark M_{89} mesons transforming later to much smaller ordinary M_{89} mesons. If this is the size the value $h_{eff}/h = 512$ is favourable.
- (c) The proposal [?] is that dark phases of matter are generated at quantum criticality: does quantum criticality mean now that dark M_{89} mesons are created only near the threshold for the process but not at higher collision energies? If so, the production of M_{89} mesons would be observed only near energies E_{cr} assignable to proton-proton cm and quark-quark cm. For constituent quarks identifiable as current quark plus its magnetic body, the masses would be roughly $m_p/3$ and one would have $E_{cr}(q) = 3E_{cr}(q)$ (note that the masses of u and d current quarks are the scale of 5-20 MeV so that color magnetic energy dominates baryon mass).
- (d) This brings in mind leptohadron model [K47] explaining the reported production of mesonlike states in heavy ion collisions. These states had mass slightly larger than twice the mass of electron and they decayed to electron-positron pair. The production was observed only in the vicinity of Coulomb wall of order MeV, the mass of electro-pion. The explanation is in terms of color excited electrons forming pion like bound state. If color excited leptons are light, the decay widths of weak bosons are predicted to be too large. If the produced states are dark, one circumvents this problem. Quantum criticality corresponds to Coulomb wall and explains why the production occurs around it.

In the recent case quantum criticality could mean the threshold for production of M_{89} mesons. The bad news is that quantum criticality could mean that M_{89} mesons are not produced at higher LHC energies so that the observed bumps assignable to M_{89} would suffer the usual fate of the bump. Since quantum criticality does not belong to the conceptual repertoire of particle physicist, one cannot expect that the notion of M_{89} hadron would be accepted easily by the community.

What about the explanation in terms of M_{89} color spin glass? It does not make sense. First of all, both color spin glass and quark gluon plasma would be higher energy phenomena in QCD like theory. Now low energy M_{89} hadron physics would be in question. Secondly, for the color spin glass of ordinary hadron physics the temperature would be about 1 GeV, the mass of proton in good approximation. For M_{89} color spin glass the temperature would be by a factor 512 higher, that is .5 TeV: this cannot make sense since the model based on temperature 1 GeV works satisfactorily.

6.4.3 How this picture relates to earlier ideas?

I have made three earlier proposals relating to the unexpected correlations just discussed. The earlier picture is consistent with the recent one.

- (a) I have already earlier proposed a realization of the color glass condensate in terms of color magnetic flux tubes confining partons to move along string like objects. This indeed explains why charged particle pairs tend to move in parallel or antiparallel manner. Amusingly, I did not realize that ordinary hadronic strings (low energy phenomenon) cannot be in question, and therefore failed to make the obvious conclusion that M_{89} hadrons could be in question. Direct signals of M_{89} hadron physics have been in front

of our eyes since the findings of RHIC around 2005 but our prejudices - in particular, the stubborn belief that QCD is a final theory of strong interactions - have prevented us to see them! Instead of this we try desperately to see superstrings and standard SUSY!

- (b) One basic question is how the hadrons and quarks of M_{89} hadron physics decay to ordinary hadrons. I proposed the basic idea for about fifteen years ago - soon after the discovery of p-adic physics. The idea was that the hadrons of M_{89} physics are p-adic hot spots created in the collisions of hadrons. Also quarks get heated so that corresponding p-adic prime increases and the mass of the quark increases by some power of $\sqrt{2}$ meaning a reduction in size by the same power. The cooling of these hot spots is a sequence of phase transitions increasing the p-adic prime of the appropriate (hadronic or partonic) space-time sheet so that the eventual outcome consists of ordinary hadrons. p-Adic length scale hypothesis suggests that only primes near powers of 2 (or their subset) appear in the sequence of phase transitions. For instance, M_{89} hadronic space-time sheet would end up to an ordinary hadronic space-time sheets consisting of at most 18 steps from $M_{107}/M_{89} \simeq 2^{18}$. If only powers of 2 are allowed as scalings (the analog of period doubling) there are 9 steps at most.

Each step scales the size of the space-time sheet in question so that the process is highly analogous to cosmic expansion leading from very short and thin M_{89} flux tube to M_{107} flux tube with scaled up dimensions. Since a critical phenomenon is in question and TGD Universe is fractal, a rough macroscopic description would be in terms of scaled variant of critical cosmology, which is unique apart from its finite duration and describes accelerated cosmic expansion. The almost uniqueness of the critical cosmology (see <http://tinyurl.com/y7ebrm24>) follows from the imbeddability to $M^4 \times CP_2$. Cosmic expansion would take place only during these periods. Both the cosmic expansion expansion associated with the cooling of hadronic and partonic space-time sheets would take via jerks followed by stationary periods with no expansion. The size of the scale of the hadronic or partonic space-time sheet would increase by a power of $\sqrt{2}$ during a single jerk.

By the fractality of the TGD Universe this model of cosmic expansion based on p-adic phase transitions should apply in all scales. In particular, it should apply to stars and planetary systems. The fact that various astrophysical objects do not seem to participate in cosmic expansion supports the view that the expansion takes place in jerks identifiable as phase transitions increasing the p-adic prime of particular space-time sheet so that in the average sense a continuous smooth expansion is obtained. For instance, I have proposed a variant of expanding Earth model (see <http://tinyurl.com/mha72yk>) [K32] explaining the strange observation that the continents would nicely cover the entire surface of Earth if the radius of Earth were one half of its recent radius. The assumed relatively rapid phase transition doubling the radius of Earth explains several strange findings in the thermal, geological, and biological history of Earth.

This approach also explains also how the magnetic energy of primordial cosmic strings identifiable as dark energy has gradually transformed to dark or ordinary matter [L4] (see <http://tinyurl.com/ybez17tj>). In this model the vacuum energy density of inflation field is replaced with that of Kähler magnetic field assignable to the flux tubes originating from primordial cosmic strings with a 2-D M^4 projection. The model explains also the magnetic fields filling the Universe in all scales: in standard Big Bang cosmology their origin remains a mystery.

- (c) What about the energetics of the process? If the jerk induces an overall scaling, the Kähler magnetic energy of the magnetic flux tubes decreases since - by the conservation of magnetic flux giving $B \propto 1/S$ - the energy is proportional to L/S scaling like $1/\sqrt{p}$ (L and S denote the length and the transversal area of the flux tube). Therefore magnetic energy is liberated in the process and by p-adic length scale hypothesis the total rest energy liberated is $\Delta E = E_i(1 - 2^{(k_i - k_f)/2})$, where i and f refer to initial and final values of the p-adic prime $p \simeq 2^k$. Similar consideration applies to partons. The natural assumption is that the Kähler magnetic (equivalently color magnetic) energy is liberated as partons. These partons would eventually transform to ordinary partons and materialize to ordinary hadrons. The scaling of the flux tube would preserve its

size would force the observed correlations.

To conclude, the brave conjecture would be that a production of M_{89} hadrons could explain the observations. There would be no quark gluon plasma nor color spin glass (a highly questionable notion in high energy QCD). Instead of this new hadron physics would emerge by the confinement of quarks (or their scaled up variants) in shorter length scale as collision energies become high enough, and already RHIC would have observed M_{89} hadron physics!

6.5 New Results From Phenix Concerning Quark Gluon Plasma

New results have been published on properties of what is conventionally called quark gluon plasma (QGP). As a matter fact, this phase does not resemble plasma at all. The decay patterns bring in mind decays of string like objects parallel to the collision axes rather than isotropic blackbody radiation. The initial state looks like a perfect fluid rather than plasma and thus more like a particle like object.

The results of QGP - or color glass condensate (CGC) as it is also called - come from three sources and are very similar. The basic characteristic of the collisions is the cm energy \sqrt{s} of nucleon pair. The data sources are Au-Au collisions at RHIC, Brookhaven with $\sqrt{s} = 130$ GeV, p-p collisions and p-nucleus collisions at LHC with $\sqrt{s} = 200$ GeV [C69] and d-Au collisions at RHIC with $\sqrt{s} = 200$ GeV studied by PHENIX collaboration [C61].

According to the popular article telling about the findings of PHENIX collaboration (<http://tinyurl.com/y88f3h4w>) the collisions are believed to involve a creation of what is called hot spot. In Au-Au collisions this hot spot has size of order Au nucleus. In d-Au collisions it is reported to be much, much smaller. What does this mean? The size of deuteron nucleus or of nucleon? Or something even much smaller? Hardly so if one believes in QCD picture. If this is however the case, the only reasonable candidate for its size would be the longitudinal size scale of colliding nucleon-nucleon system of order $L = \hbar/\sqrt{s}$ if an object with this size is created in the collision. I did my best to find some estimate for the very small size of the hot spot from articles some related to the study but failed [C60, C61, C69]: paranoid would see this as a conspiracy to keep this as a state secret.

6.5.1 How to understand the findings?

I have already earlier considered the basic characteristics of the collisions. What is called QGP does not behave at all like plasma phase for which one would expect particle distributions mimicking blackbody radiation of quarks and gluons. Strong correlations are found between charged particles created in the collision and the best manner to describe them is in terms of a creation of longitudinal string-like objects parallel to the collision axes.

In TGD framework this observation leads to the proposal that the string like objects could be assigned with M_{89} hadron physics introduced much earlier to explain strange cosmic ray events like Centauro. The p-adic mass scale assignable to M_{89} hadron physics is obtained from that of electron (given by p-adic thermodynamics in good approximation by $m_{127} = m_e/\sqrt{5}$) as $m_{89} = 2^{(127-89)/2} \times m_e/\sqrt{5}$. This gives $m_{89} = 111.8$ GeV. This is conveniently below the cm mass of nucleon pair in all the experiments.

In standard approach based on QCD the description is completely different. The basic parameters are now thermodynamical. One assumes that thermalized plasma phase is created and is parametrized by the energy density assignable to gluon fields for which QCD gives the estimate $\epsilon \geq 1$ GeV/fm³ and by temperature which is about $T = 170$ GeV and more or less corresponds to QCD Λ . One can think of the collision regions as highly flattened pancake (Lorentz contraction) containing very density gluon phase called color glass condensate, which would be something different from QGP and definitely would not conform with the expectations from perturbative QCD since QGP would be precisely a manifestation of perturbative QGP [C69].

Also a proposal has been made that this phase could be described by AdS/CFT correspondence non-perturbatively - again in conflict with the basic idea that perturbative QCD should

work. It has however turned out that this approach does not work even qualitatively as Sabine Hossenfelder lucidly explains this in her blog article *Whatever happened to AdS/CFT and the Quark Gluon Plasma?* (<http://tinyurl.com/y8b5dhxy>).

Strangely enough, this failure of QGP and AdS/CFT picture has not created any fuss although one might think that the findings challenging the basic pillars of standard model should be seen as sensational and make happy all those who have publicly told that nothing would be more well-come than the failure of standard model. Maybe particle theorists have enough to do with worrying about the failure of standard SUSY and super string inspired particle phenomenology that they do not want to waste their time to the dirty problems of low energy phenomenology.

A further finding mentioned in the popular article is stronger charm-anticharm suppression in head-on collisions than in peripheral collisions [C78]. What is clear that if M_{89} hadrons are created, they consist of lightest quarks present in the lightest hadrons of M_{89} hadron physics - that is u and d (and possibly also s) of M_{89} hadrons, which are scaled variants of ordinary u and d quarks and decay to u and d (and possibly s) quarks of M_{107} hadron physics. If the probability of creating a hot M_{89} spot is higher in central than peripheral collisions the charm suppression is stronger. Could a hot M_{89} spot associated with a nucleon-nucleon pair heat some region around it to M_{89} hadronic phase so that charm suppression would take place inside larger volume than in periphery?

There is also the question whether the underlying mechanism relies on specks of hot QGP or some inherent property of nuclei themselves. At the first sight, the latter option could not be farther from the TGD inspired vision. However, in nuclear string model [L2] inspired by TGD nuclei consists of nucleons connected by color bonds having quark and antiquark at their ends. These bonds are characterized by rather large p-adic prime characterizing current quark mass scale of order 5-20 GeV for u and d quarks (the first rough estimate for the p-adic scales involved is $p \simeq 2^k$, $k = 121$ for 5 MeV and $k = 119$ for 20 MeV). These color bonds Lorentz contract in the longitudinal direction so that nearly longitudinal color bonds would shorten to M_{89} scale whereas transversal color bonds would get only thinner. Could they be able to transform to color bonds characterized by M_{89} and in this manner give rise to M_{89} mesons decaying to ordinary hadrons?

6.5.2 Flowers to the grave of particle phenomenology

The recent situation in theoretical particle physics and science in general does not raise optimism. Super string gurus are receiving gigantic prizes from a theory that was a failure. SUSY has failed in several fronts and cannot be anymore regarded as a way to stabilize the mass of Higgs. Although the existence of Higgs is established, the status of Higgs mechanism is challenged by its un-naturalness: the assumption that massivation is due to some other mechanism and Higgs has gradient coupling provides a natural explanation for Higgs couplings. This coupling is dimensional and could be criticized for this reason. Also Higgs couplings contain dimensional parameter (tachyonic Higgs mass squared).

The high priests (<http://tinyurl.com/y8vj5x2>) are however talking about “challenges” instead of failures. Even evidence for the failure of even basic QCD is accumulating as explained above. Peter Higgs, a Nobel winner of this year, commented the situation ironically (<http://tinyurl.com/lq3n335>) by saying that he would have not got a job in the recent day particle physics community since he is too slow.

The situation is not much better in the other fields of science. Randy Scheckman, also this year’s Nobel prize winner in physiology and medicine (<http://tinyurl.com/q87h6h3>) has declared boycott of top science journals Nature, Cell and Science. Scheckman said that the pressure to publish in “luxury” journals encourages researchers to cut corners and pursue trendy fields of science instead of doing more important work. The problem is exacerbated, he said, by editors who were not active scientists but professionals who favoured studies that were likely to make a splash.

Theoretical and experimental particle physics is a marvellous creation of humankind. Perhaps

we should bring flowers to the grave of the particle physics phenomenology and have a five minutes respectful silence. It had to leave us far too early.

6.6 Anomalous Like Sign Dimuons At LHC?

We are not protected against particle physics rumors even during Christmas. This time the rumor was launched from the comment section of Peter Woit's blog (<http://tinyurl.com/ybhx4hu8>) and soon propagated to the blogs of Lubos Motl (<http://tinyurl.com/y8aewpm8>) and Phil Gibbs (<http://tinyurl.com/y93gotrb>).

The rumor says that ATLAS has observed 5 sigma excess of like sign di-muon events. This would suggest a resonance with charge $Q = \pm 2$ and muon number two. In the 3-triplet SUSY model there is a Higgs with charge 2 but the lower limit for its mass is already now around 300-400 GeV. Rumors are usually just rumors and at this time the most plausible interpretation is as a nasty joke intended to spoil the Christmas of phenomenologists. Lubos Motl however represents a graph from a publication of ATLAS (<http://tinyurl.com/ydz7zj39>) [C27] based on 2011 data giving a slight support for the rumor. The experiences during last years give strong reasons to believe that statistical fluctuation is in question. Despite this the temptation to find some explanation is irresistible. Also CMS has reported same Christmas rumor but 4 years later (see <http://tinyurl.com/y8rkhmru>).

6.6.1 TGD view about color allows charge 2 leptomesons

TGD color differs from that of other unified theories in the sense that colored states correspond to color partial waves in CP_2 . Most of these states are extremely massive but I have proposed that light color octet leptons are possible [K47], and there is indeed some evidence for pion like states with mass very near to $m = 2m_L$ for all charged lepton generations decaying to lepton-antilepton pairs and gamma pairs also p-adically scaled up variant having masses coming as octaves of the lowest state have been reported for the tau-pion.

Since leptons move in triality zero color partial waves, color does not distinguish between lepton and anti-lepton so that also leptons with the same charge can in principle form a pion-like color singlet with charge $Q = \pm 2$. This is of course not possible for quarks. In the recent case the p-adic prime should be such that the mass for the color octet muon is $105/2$ GeV which is about $2^9 m(\mu)$, where $m(\mu) = 105.6$ MeV is the mass of muon. Therefore the color octet muons would correspond to $p \simeq 2^k$, $k = k(\mu) - 2 \times 9 = 113 - 18 = 95$, which not prime but is allowed by the p-adic length scale hypothesis.

But why just $k = 95$? Is it an accident that the scaling factor is same as between the mass scales of the ordinary hadron physics characterized by M_{107} and M_{89} hadron physics? If one applies the same argument to tau leptons characterized by M_{107} , one finds that like sign tau pairs should result from pairs of M_{89} τ leptons having mass $m = 512 \times 1.776 \text{ GeV} = 909$ GeV. The mass of resonance would be twice this. For electron one has $m = 512 \times .51 \text{ MeV} = 261.6$ MeV with resonance mass equal to 523.2 MeV. Skeptic would argue that this kind of states should have been observed for long time ago if they really exist.

6.6.2 Production of parallel gluon pairs from the decay of strings of M_{89} hadron physics as source of the leptomesons?

The production mechanism would be via two-gluon intermediate states. Both gluons would decay to unbound colored lepton-antilepton pair such that the two colored leptons and two antileptons would fuse to form two like sign lepton pairs. This process favors gluons moving in parallel. The required presence of also other like sign lepton pair in the state might allow to kill the hypothesis easily.

The presence of parallel gluons could relate to the TGD inspired explanation [K25] for the correlated charged particle pairs observed in proton proton collisions (QCD predicts quark gluon plasma and the absence of correlations) in terms of M_{89} hadron physics. The decay

of M_{89} string like objects is expected to produce not only correlated charged pairs but also correlated gluon pairs with members moving in parallel or antiparallel manner. Parallel gluons could produce like sign di-muons and di-electrons and even pairs of like sign μ and e . In the case of ordinary hadron physics this mechanism would not be at work so that one could understand why resonances with electron number two and mass 523 MeV have not been observed earlier.

Even leptons belonging to different generations could in principle form this kind of states and Phil Gibbs has represented a graph which he interprets as providing indications for a state with mass around 105 GeV decaying to like sign μe pairs. In this case one would however expect that mass is roughly $105/2$ GeV since electron is considerably lighter than muon in given p-adic length scale.

The decay of bound states of two colored leptons with same (or opposite) charge would require a trilinear coupling gLL_8 analogous to magnetic moment coupling. Color octet leptons L_8 would transform to ordinary leptons by gluon emission.

To sum up, if the rumor is true, then M_{89} hadron physics would have begun to demonstrate its explanatory power. The new hadron physics would explain the correlated charged particle pairs not possible to understand in high energy QCD. The additional gamma pair background resulting from the decays of M_{89} pions could explain the two-gamma anomaly of Higgs decays, and also the failure to get same mass for the Higgs from ZZ and gamma-gamma decays. One should not forget that M_{89} pion explains the Fermi bump around 135 GeV. And it would also explain the anomalous like sign lepton pairs if one accepts TGD view about color.

6.7 Could $M_{G,79}$ hadron physics be seen at LHC?

Gaussian Mersennes $M_{G,n} = (1 + i)^n - 1$ (<http://tinyurl.com/pptxe9c>) are much more abundant than ordinary Mersennes and corresponding p-adic time scales seem to define fundamental length scales of cosmology, astrophysics, biology, nuclear physics, and elementary physics [K23]. There are as many as 10 Gaussian Mersennes besides 9 Mersennes above LHC energy scale suggesting a lot of new physics in sharp contrast with the GUT dogma that nothing interesting happens above weak boson scale- perhaps copies of hadron physics or weak interaction physics. In the following I consider only those Gaussian Mersennes possibly interesting from the point of view of very high energy particle physics.

$n \in \{2, 3, 5, 7, 11, 19, 29, 47, 73\}$ correspond to energies not accessible at LHC. $n = 79$ might define new copy of hadron physics above TeV range -something which I have not considered seriously before. The scaled variants of pion and proton masses (M_{107} hadron physics) are about 2.2 TeV and 16 TeV. Is it visible at LHC is a question mark to me.

Few weeks later after writing this I saw the posting of Lubos Motl suggesting that $M_{G,79}$ pion might have been already seen! Lubos Motl tells about a bump around 2(!)TeV energy observed already earlier at ATLAS and now also at CMS (<http://tinyurl.com/ybfnpezd>: see the article "Something goes bump" (<http://tinyurl.com/ok9ycxv> in Symmetry Magazine. The local significance of the bump is about 3.5 sigma and global significance about 2.5 sigma. Bump decays to weak bosons.

Many interpretations are possible. An interpretation as a new Higgs like particle has been suggested. Second interpretation - favored by Lubos - is as right-handed W boson predicted by left-right- symmetric variants of the standard model. If this is correct interpretation, one can forget about TGD since the main victory of TGD is that the very strange looking symmetries of stanardad model have an elegant explanation in terms of CP_2 geometry, which is also twistorially completely unique and geometrizes both electroweak and color quantum numbers.

Note that the masses masses of $M_{G,79}$ weak physics would be obtained by scaling the masses of ordinary M_{89} weak bosons by factor $2^{(89-79)/2} = 512$. This would give the masses about 2.6 TeV and 2.9 TeV.

There is however an objection. If one applies p-adic scaling $2^{(107-89)/2} = 2^9$ of pion mass in the case of speculated M_{89} hadron physics, M_{89} pion should have mass about 69 GeV

(this brings in mind the old and forgotten anomaly known as Aleph anomaly at 55 GeV). I proposed that the mass is actually an octave higher and thus around 140 GeV: p-adic length scale hypothesis allows to consider octaves. Could it really be that a pion like state with this mass could have slipped through the sieve of particle physicists? Note that the proton of M_{89} hadron physics would have mass about .5 TeV.

I have proposed [K25] that M_{89} hadron physics has made itself visible already in heavy ion collisions at RHIC and in proton- heavy ion collisions at LHC as strong deviation from QCD plasma behavior meaning that charged particles tended to be accompanied by particles of opposite charged in opposite direction as if they would be an outcome of a decay of string like objects, perhaps M_{89} pions. There has been attempts - not very successful - to explain non-QCD type behavior in terms of AdS/CFT. Scaled up variant of QCD would explain them elegantly. The findings from LHC during this year will probably clarify this issue.

Lubos (<http://tinyurl.com/y9eqvhuo>) is five days later more enthusiastic about superstring inspired explanation of the bump than the explanation relying on left-right symmetric variant of the standard model. The title of the posting of Lubos is “*The 2 TeV LHC excess could prove string theory*”. The superstringy model [C77] involves as many as six superstring phenomenologists as chefs (<http://tinyurl.com/y8bys2w5>) and the soup contains intersecting branes, anomalies, and large extra dimensions corresponding to scale of 20 TeV as ingredients.

The article gives further valuable information about the bump also for those who are not terribly interested on intersecting branes and addition of new anomalous factors to the standard model gauge group. The following arguments show that the information is qualitatively consistent with the TGD based model.

- (a) Bump is consistent with both ZZ, WZ, and according to Lubos also $Z\gamma$ final states and is in the range 1.8-2.1 TeV. Therefore bump could involve both charged and neutral states. If the bump corresponds to neutral elementary particle such as new spin 1 boson Z' as proposed by superstring sextet, the challenge is to explain ZZ and $Z\gamma$ bumps. WZ pairs cannot result from primary decays.
- (b) There is dijet excess, which is roughly by a factor of 20 larger than weak boson excesses. This would suggest that some state decays to quarks or their excitations and the large value of QCD coupling strength gives rise to a the larger excess. This also explains also why no lepton excess is observed.

For the superstring inspired model the large branching fraction to hadronic dijets suggesting the presence of strong interactions is a challenge: Lubos does not comment this problem. Also the absence of leptonic pairs is problematic and model builders deduce that Z' suffers syndrome known as lepto-phobia.

- (c) Neutral and charged $M_{G,79}$ pions can decay to virtual $M_{G,79}$ or M_{89} quark pair annihilating further to a pair of weak bosons (also $\gamma\gamma$ pair is predicted) or by exchange of gluon to $M_{G,79}$, M_{89} (or M_{107}) quark pair producing eventually the dijet. This would explain the observations qualitatively. If the order of magnitude for the relative mass splitting between neutral and charged $M_{G,79}$ pion is same as for ordinary pion one, the relative splitting if of order $\Delta M/M \simeq 1/14$ - less that 10 per cent meaning $\Delta M < .2$ TeV. The range for the position of the bump is about .3 TeV.
- (d) The predictions of TGD model are in principle calculable. The only free parameter is the $M_{G,79}$ color coupling strength so that the model is easy to test.

6.8 Has Icecube Detected Neutrinos Coming From Decays Of P-Adically Scaled Up Copies Of Weak Bosons?

There is a very interesting posting Storm in IceCube by Jester (see <http://tinyurl.com/yd8yyzb3>). IceCube is a neutrino detector located at South Pole. Most of the neutrinos detected are atmospheric neutrinos originating from Sun but what one is interested in are neutrinos from astrophysical sources.

- (a) Last year (see <http://tinyurl.com/y887ktwf>) the collaboration reported [C51] the detection for neutrino cascade events, with with energy around 1 PeV=10⁶ GeV. The atmospheric background decreases rapidly with energy and at these energies the detection of a pair of events at these energies corresponds to about 3 sigma. The recent (see <http://tinyurl.com/y9nqlutd>) report [C65] tells about a broad excess of events (28 events) above 30 TeV: only about 10 are expected from atmospheric neutrinos alone. The flavor composition is consistent with 1: 1: 1 ratio of the 3 neutrino species as expected for distant sources for which the oscillations during the travel should cause complete mixing. The distribution of the observed events is consistent with isotropy.
- (b) There is a dip ranging from .4 PeV to about 1 PeV and the spectrum has probably a sharp cutoff somewhat above 1 TeV. This suggests a monochromatic neutrino line resulting from the decays of some particle decaying to neutrino and some other particle - possibly also neutrino [C84] (see <http://tinyurl.com/yc9ohozf>). Astrophysical phenomena with standard model physics are expected to produce smooth power-law spectrum - typically $1/E^2$ - rather than peak. The proposal is that the events around 1 PeV could come from the decay of dark matter particles with energy scale of 2 TeV. The observation of two events gives a bound for the life-time of dark matter particle in question: about 10²¹ years much longer than the age of the Universe. The bound of course depends on what density is assumed for the dark matter.
- (c) There is also a continuum excess in the range [.1, .4] PeV. This could result from many-particle decay channels containing more than 2 particles.

6.8.1 TGD based interpretation

What says TGD?

- (a) TGD almost-predicts a fractal hierarchy of hadron physics and weak physics labelled by Mersenne primes $M_n = 2^n - 1$. Also Gaussian primes $M_{G,n} = (1 + i)^n - 1$ are possible. M_{107} would correspond to the ordinary hadron physics. M_{89} would correspond to weak bosons and a scaled up copy of hadron physics, for which there are several indications: in particular, the breaking of perturbative QCD at rather high energies assignable at LHC to proton heavy nucleus collisions. The explanation in terms of AdS/CFT correspondence has not been successful and is not even well-motivated since it assumes strong coupling regime.
- (b) The next Mersenne prime is M_{61} and the first guess is that the observed TeV neutrinos result from the decay of W and Z bosons of scaled up copy of weak bosons having mass near 1 TeV. The naivest estimate for the masses of these weak bosons is obtained by the naïve scaling the masses of ordinary weak bosons by factor $2^{(89-61)/2} = 2^{14}$. For $m_W = 80$ GeV and $m_Z = 90$ GeV one obtains $m_{W(61)} = 1.31$ PeV and $m_{Z(61)} = 1.47$ PeV. The energy of the mono-chromatic neutrino would be about about .65 PeV and .74 PeV in the two cases. This is in the almost empty range between .4 PeV and 1 PeV and too small roughly by a factor of $\sqrt{2}$.
 An improved estimate for upper bound of Z^0 mass is based on the p-adic mass scale $m(M_{89})$ related to the p-adic mass scale M_{127} of electron by scaling factor $2^{(127-89)/2} = 2^{19}$ giving $m(M_{89}) \simeq 120$ GeV for $m_e = \sqrt{5+X}m(M_{127}) = .51$ MeV and $X = 0$ ($X \leq 1$ holds true for the second order contribution to electron mass [K22]). The scaling by the factor $2^{(89-61)/2} = 2^{14}$ gives $m(61) = 1.96$ TeV consistent with the needed 2 TeV. The exact value of weak boson mass depends on the value of Weinberg angle $\sin^2(\theta_W)$ and the value of the second order contribution to the mass: $m(61)$ gives upper bound for the mass of $Z(61)$. The model predicts two peaks with distance depending on the value of Weinberg angle of M_{61} weak physics.
- (c) What about the interpretation of the continuum part of anomaly? The proposed interpretation for many-particle decays looks rather reasonable. The simplest possibility is the decay to a pair of light quarks of M_{61} hadron physics, followed by a decay of quark or antiquark via emission of W boson decaying to lepton-neutrino pair.

TGD predicts 3 generations of gauge bosons. In TGD the 3 generations of fermions correspond to the 3 lowest genera for 2-surfaces (handle number 0,1,2). One can formally interpret fermion generations as a triplet of broken dynamical symmetry $U(3)$. Gauge bosons correspond to pairs of fermions and antifermions. One obtains octet and singlet with respect $U(3)$. The 3 $U(3)$ “neutral” bosons are expected to be the lightest ones. There are 3 states of this kind analogous to neutral pion, η and η' of Gell-Mann model.

A possible interpretation for M_{61} weak bosons is as weak bosons of third generation. The second generation would correspond to M_{79} and the first generation to M_{89} and ordinary weak bosons. There is evidence for a bump at the mass of Higgs boson of M_{79} physics whose mass is obtained by scaling with the factor $2^{10/2} = 32$ from the ordinary Higgs mass 125 GeV. One obtains 4 TeV, which is the mass of the bump. M_{61} Higgs would have mass $2^9 = 512$ times higher mass - that is 2048 TeV= 2.048 PeV.

6.8.2 Further evidence for the third generation of weak bosons

Matt Strassler had a blog posting (see <http://tinyurl.com/y926u8q2>) about interesting finding from old IceCube data revealed at thursday (July 12, 2018) by IceCube team. The conclusion supports the view that so called blazars, thin jets of high energy particles suggested to emerge as matter falls into giant black hole, might be sources of high energy neutrinos. In TGD framework one could also think that blazars originate from cosmic strings containing dark matter and energy. Blazars themselves could be associated with cosmic strings thickened to magnetic flux tubes. The channeling to flux tubes would make possible observation of the particles emerging from the source whatever it might be.

Only the highest energy cosmic neutrinos can enter the IceCube detector located deep under the ice. IceCube has already earlier discovered a new class of cosmic neutrinos with extremely high energy: Matt Strassler has written a posting also about this two years ago (see <http://tinyurl.com/ybu464q2>): the energies of these neutrinos were around PeV.

Last year one of these blazars flared brightly producing high energy neutrinos and photons: neutrinos and photons came from the same position in the sky and occurred during the same period. IceCube detector detected a collision of one (!) ultrahigh energy neutrino with proton generating muon. The debris produced in the collision contained also photons, which were detected. IceCube team decided to check whether old data could contain earlier neutrino events assignable to the same blazar and found a dramatic burst of neutrinos in 2014-2015 data during period of 150 days associated with the same flare; the number of neutrinos was 20 instead of the expected 6-7. Therefore it seems that the ultrahigh energy neutrinos can be associated with blazars.

By looking the article [C52] (see <http://tinyurl.com/y8jtc1ag>) one learns that neutrino energies are of order few PeV (Peta electron Volt), which makes 1 million GeV (proton has mass .1 GeV). What kind of mechanism could create these monsters in TGD Universe? TGD suggests scaled variants of both electroweak physics and QCD and the obvious candidate would be decays of weak bosons of a scaled variant of ew physics. I have already earlier considered a possible explanation interms of weak bosons of scaled up variant of weak physics characterizes by Mersenne prime $M_{61} = 2^{61} - 1$ (see <http://tinyurl.com/y7axat8j>).

- (a) TGD “almost-predicts” the existence of three families of ew bosons and gluons. Their coupling matrices to fermions must be orthogonal. This breaks the universality of both ew and color interactions. Only the ordinary ew bosons can couple in the same manner to 3 fermion generations. There are indeed indications for the breaking of the universality in both quark and leptons sector coming from several sources such as B meson decays, muon anomalous anomalous (this is not a typo!) magnetic moment, and the finding that the value of proton radius is different depending on whether ordinary atoms or muonic atoms are used to deduce it (see this chapter).
- (b) The scaled variant of W boson could decay to electron and monster neutrino having same energies in excellent approximation. Z^0 boson could decay to neutrino-antineutrino pair. The essentially mono-chromatic energy spectrum for the neutrinos would serve

as a unique signature of the decaying weak boson. One might hope of observing two kinds of monster neutrinos with mass difference of the order of the scaled up W-Z mass difference. Relative mass difference would same as for ordinary W and Z - about 10 per cent - and thus of order .1 PeV.

One can look the situation quantitatively using p-adic length scale hypothesis and assumption that Mersenne primes and Gaussian Mersennes define preferred p-adic length scales assignable to copies of hadron physics and electroweak physics.

- (a) Ordinary ew gauge bosons correspond in TGD framework to Mersenne prime $M_k = 2^k - 1$, $k = 89$. The mass scale is 90 GeV, roughly 90 proton masses.
- (b) Next generation corresponds to Gaussian Mersenne Gaussian Mersenne prime $M_{G,79} = (1 + i)^{79} - 1$. There is indeed has evidence for a second generation weak boson corresponding to $M_{G,79}$ (see this chapter). The predicted mass scale is obtained by scaling the weak boson mass scale of about 100 GeV with the factor $2^{(89-79)/2} = 32$ and is correct.
- (c) The next generation would correspond to Mersenne prime M_{61} . The mass scale 90 GeV of ordinary weak physics is now scaled up by a factor $2^{(89-61)/2} = 2^{14} \simeq 64,000$. This gives a mass scale 1.5 PeV, which is the observed mass scale for the neutrino monsters detected by Ice-Cube. Also the earlier monster neutrinos have the same mass scale. This suggests that the PeV neutrinos are indeed produced in decays of $W(61)$ or $Z(61)$.

6.9 Some Comments About $\tau - \mu$ Anomaly Of Higgs Decays And Anomalies Of B Meson Decays

Lubos Motl (<http://tinyurl.com/ycmj6ro9>) mentions a 2.5 sigma anomaly (<http://tinyurl.com/y8gsgyyh>) [L12] observed in the decay of Higgs to $\tau - \mu$ pair or its charge conjugate not allowed by standard model. Lubos Motl mentions a model <http://tinyurl.com/ycy3w43x> explaining the anomaly and also other anomalies related to semileptonic decays of neutral B meson in terms of double Higgs sector and gauged $L_\mu - L_\tau$ symmetry. In a more recent posting <http://tinyurl.com/y8x69u4u> Lubos Motl mentions another paper (<http://tinyurl.com/yb8fjag8>) explaining the anomaly in terms of a frighteningly complex E_6 gauge model inspired by heterotic strings.

TGD suggests however an amazingly simple explanation of the $\tau - \mu$ anomaly in terms of neutrino mixing. As a matter fact, after writing the first hasty summary of the childish simple idea discussed below but still managing to make mistakes, I became skeptic. Perhaps I have misunderstood what is meant by anomaly. Perhaps the production of $\tau - \mu$ pairs is not the anomaly after all. Perhaps the anomaly is the deviation from the prediction based on the model below. It however seems that my hasty interpretation was correct.

6.9.1 The relationship between topological mixing and CKM mixing

It is good to explain first the TGD based model for CKM mixing in terms of topological mixing for partonic topologies. Cabibbo-Kobayashi-Maskawa (CKM) matrix (see <http://tinyurl.com/zxay2f5>) is 3×3 unitary matrix describing the mixing of D type quarks in the couplings of W bosons to a pair of U and D type quarks. For 3 quarks it can involve phase factors implying CP breaking. The origin of the CKM matrix is a mystery in standard model.

In TGD framework CKM mixing is induced by the mixing of the topologies of 2-D partonic surfaces characterized by genus $g = 0, 1, 2$ (the number handles added to sphere to obtain topology of partonic 2-surface) assignable to quarks and also leptons [K11, K30]. The first three genera are special since they allow a global conformal symmetry always whereas higher genera allow it only for special values of conformal moduli. This suggests that handles behave like free particles in many particle state that for higher genera and for three lowest genera the analog of bound state is in question.

The mixing is in general different for different charge states of quark or lepton so that for quarks the unitary mixing matrices for U and type quarks - call them simply U and D - are different. Same applies in leptonic sector. CKM mixing matrix is determined by the topological mixing being of form $CKM = UD^\dagger$ for quarks and of similar form for charged leptons and neutrinos.

The usual time-dependent neutrino mixing would correspond to the topological mixing. The time constancy assumed for CKM matrix for quarks must be consistent with the time dependence of U and D . Therefore one should have $U = U_1X(t)$ and $D = D_1X(t)$, where U_1 and D_1 are time independent unitary matrices.

In the adelic approach to TGD [K50] [L16] fusing real and various p-adic physics (correlates for cognition) would have elements in some algebraic extension of rationals inducing extensions of various p-adic number fields. The number theoretical universality of U_1 and D_1 matrices is very powerful constraint. U_1 and D_1 would be expressible in terms of roots of unity and e (e^p is ordinary p-adic number so that p-adic extension is finite-dimensional) and would not allow exponential representation. These matrices would be constant for given algebraic extension of rationals.

It must be emphasized that the model for quark mixing developed for about 2 decades ago treats quarks as constituent quarks with rather larger masses determining hadron mass (constituent quark is identified as current valence quark plus its color magnetic body carrying most of the mass). The number theoretic assumptions about the mixing matrices are not consistent with the recent view: instead of roots of unity trigonometric functions reducing to rational numbers (Pythagorean triangles) were taken as the number theoretic ideal.

$X(t)$ would be a matrix with real number/p-adic valued coefficients and in p-adic context it would be an imaginary exponential $exp(itH)$ of a Hermitian generator H with the p-adic norm $t < 1$ to guarantee the existence of the p-adic exponential. CKM would be time independent for $X_U = X_D$. TGD view about what happens in state function reduction [K24, K4, K27] implies that the time parameter t in time evolution operator is discretized and this would allow also $X(t_n)$ to belong to the algebraic extension.

For quarks $X_U = X_D = Id$ is consistent with what is known experimentally: of course, the time dependent topological mixing of U or D type quarks would be seen in the behavior of proton. One also expects that the time dependent mixing is very small for charged leptons whereas the non-triviality of $X_\nu(t)$ is suggested by neutrino mixing. Therefore the assumption $X_L = X_\nu$ is not consistent with the experimental facts and $X_L(t) = Id$ seems to be true a good approximation so that only $X_\nu(t)$ would be non-trivial? Could the vanishing em charge of neutrinos and/or the vanishing weak couplings of right-handed neutrinos have something to do with this? If the $\mu - e$ anomaly in the decays of Higgs persists, it could be seen as a direct evidence for CKM mixing in leptonic sector.

CP breaking is also possible. As a matter fact, one day after mentioning the CP breaking in leptonic sector I learned about indications for leptonic CP breaking (see <http://tinyurl.com/zr8xm26>) emerging from T2K experiment performed in Japan: the rate for the muon-to-electron neutrino conversions is found to be higher than that for antineutrinos. Also the NOvA experiment in USA reports similar results. The statistical significance of the findings is rather low and the findings might suffer the usual fate. The topological breaking of CP symmetry would in turn induce the CP breaking the CKM matrix in both leptonic and quark sectors. Amusingly, it has never occurred to me whether topological mixing could provide the first principle explanation for CP breaking!

6.9.2 Model for the $h \rightarrow \mu - \tau_c$ anomaly in terms of neutrino mixing

To my humble opinion both models mentioned by Lubos Motl are highly artificial and bring in a lot of new parameters since new particles are introduced. Also a direct Yukawa coupling of Higgs to $\tau - \mu$ pair is assumed. This would however break the universality since lepton numbers for charged lepton generations would not be conserved. This does not look attractive and one can ask whether the allowance of transformation of neutrinos to each other by mixing

known to occur could be enough to explain the findings assuming that there are no primary flavor changing currents and without introducing any new particles or new parameters. In the hadronic sector the mixing for quarks D type quarks indeed explains this kind of decays producing charged quark pair of say type cu_c . In TGD framework, where CKM mixing reduces to topological mixing of topologies of partonic 2-surfaces, this option is especially attractive.

- (a) In standard model neutrinos are massless and have no direct coupling to Higgs. Neutrinos are however known to have non-vanishing masses and neutrino mixing analogous to CKM mixing is also known to occur. Neutrino mixing is enough to induce the anomalous decays and the rate is predicted completely in terms of neutrino mixing parameters and known standard physics parameters so that for a professional it should be easy to made the little computer calculations to kill the model.
- (b) In absence of flavor changing currents only $WL_i\nu_j$ vertices can produce the anomaly. The $h \rightarrow \mu - \tau_c$ or its charge conjugate would proceed by several diagrams but the lowest order diagram comes from the decay of Higgs to W pair. If Higgs vacuum expectation value is non-vanishing as in standard model then Higgs could decay to a virtual W^+W^- pair decaying to $\tau\mu$ pair by neutrino exchange. Decay to Z^0 pair does not produce the desired final state in accordance with the absence of flavor changing neutral currents in standard model. Triangle diagram would describe the decay. Any lepton pair is possible as final state. Neutrino mixing would occur in either W emission vertex. The rates for the decays to different lepton pairs differ due to different mass values of leptons which are however rather small using Higgs mass as as scale. Therefore decays to all lepton pairs are expected.
- (c) In higher order Higgs could decay lepton pair to lepton pair decaying by neutrino exchange to W pair in turn decaying by neutrino exchange to lepton pair. As a special case one obtains diagrams Higgs decays $\tau - \mu$ pair with final state preferentially ν_τ exchange to W^+W^- pair decaying by ν_τ exchange to $\mu - \tau$ pair. The CKM mixing parameter for neutrino mixing would in either the upper vertices of the box. Note that Z^0 pair as intermediate state does not contribute since neutral flavor changing currents are absent.

The proposed mechanism should be at work in *any* generalization of standard model claiming to explain neutrino masses and their mixing without flavor changing neutral currents. If the observed anomaly is different from this prediction, one can start to search for new physics explanations but before this brane constructions in multiverse are not perhaps the best possible strategy.

6.9.3 What about the anomalies related to B meson decays?

The model (<http://tinyurl.com/ycy3w43x>) that Lubos Motl refers to tries to explain also the anomalies related to semileptonic decays of neutral B meson. Neutrino mixing is certainly not a natural candidate if one wants to explain the 2.5 sigma anomalies reported for the decays of B meson to K meson plus muon pair. Lubos Motl (<http://tinyurl.com/hx9dv2b>) has a nice posting about surprisingly many anomalies related to the leptonic and pion and kaon decays of neutral B meson. Tommaso Dorigo (<http://goo.gl/k0Imz4>) tells about 4-sigma evidence for new physics in rare B meson decays. There is also an anomaly related to the decay of neutral B meson to muon pair reported by Jester (<http://tinyurl.com/grzld8c>).

TGD predicts M_{89} hadron physics as a p-adically scaled up variant of ordinary M_{107} hadron physics with hadron mass scale scaled up by factor 512 which corresponds to LHC energies. Could it be that the box diagrams containing W pair and two quark exchanges involve also quarks of M_{89} hadron physics? A quantitative modelling would require precise formulation for the phase transition changing the p-adic prime characterizing quarks and gluons.

One can however ask whether one might understand these anomalies qualitatively in a simple manner in TGD framework. Since both leptons and quarks are involved, the anomaly must

related to W-quark couplings. If M_{89} physics is there, there must be radiatively generated couplings representing the decay of W to a pair of ordinary M_{107} quark and M_{89} quark. A quark of M_{89} hadron physics appearing as a quark exchange between W^+ and W^- in box diagram would affect the rates of B meson to kaon and pion. This would affect also the semileptonic decays since the the photon or Z^0 decaying to a lepton pair could be emitted from M_{89} quark.

6.9.4 But doesn't Higgs vacuum expectation vanish in TGD?

While polishing this posting I discovered an objection against TGD approach that I have not noticed earlier. This objection allows to clarify TGD based view about elementary particles [K29] and particle massivation in particular [K22, K18, K25, K26] so that I will discuss it here.

- (a) In standard model the decay of Higgs decays to gauge bosons is described quite well by the lowest order diagrams and the decay amplitude is proportional to Higgs vacuum expectation. In TGD p-adic mass calculations [K22] describe fermion massivation and Higgs vacuum expectation vanishes at the fundamental level but must make sense at the QFT limit of TGD involving the replacement of many-sheeted space-time with single slightly curved region of Minkowski space defining GRT space-time. Various gauge fields are sums of induced gauge fields at the sheets.
- (b) Note that the decays of Higgs to W pairs with a rate predicted in good approximation by the lowest order diagrams involving Higgs vacuum expectation have been observed. Hence Higgs vacuum expectation must appear as a calculable parameter in the TGD approach based on generalized Feynman diagrams. In this approach the vertices of Feynman diagrams are replaced with 3-D vertices describing splitting of 3-D surface, in particular that of partonic 2-surfaces associated with it and carrying elementary particle quantum numbers by strong form of holography. The condition that em charge is well-defined requires that the modes of the induced spinor fields are localized at string world sheets at which induced W fields vanish. Also induced Z^0 fields should vanish above weak scale at string world sheets. Thus the description of the decays reduces at microscopic level to string model with strings moving in space-time. String world sheets would have boundaries at parton orbits and interpreted as world lines of fundamental point-like fermions.
- (c) Elementary particles are constructed as pairs of wormhole contacts with throats carrying effective Kähler magnetic charge. Monopole flux runs along first space-time sheet, flows to another space-time sheet along contact and returns back along second space-time sheet and through the first wormhole contact so that closed magnetic flux tube is obtained. Both sheets carry string world sheets and their ends at the light-like orbits of wormhole throats are carriers of fermion number.
- (d) This description gives non-vanishing amplitudes for the decays of Higgs to gauge boson pairs and fermion pairs. Also the couplings of gauge bosons to fermions can be calculated from this description so that both the gauge coupling strengths and Weinberg angle are predicted. The non-vanishing value of the coupling of Higgs to gauge boson defines the Higgs vacuum expectation which can be used in gauge theory limit. The breaking of weak gauge symmetry reflects the fact that weak gauge group acts as holonomies of CP_2 and is not a genuine symmetry of the action. Since weak gauge bosons correspond classical to gauge potentials, the natural conjecture is that the couplings are consistent with gauge symmetry.
- (e) Massivation of particles follows from the fact that physical particles are composites of massless fundamental fermions whose light-like momenta are in general non-parallel. It seems however possible to regard particles as massless in 8-D sense. At classical level this is realized rather elegantly: Minkowskian and Euclidian regions give both a contribution to four-momentum and the contribution from the lines of generalized Feynman diagrams is imaginary due to the Euclidian signature of the induced metric.

This gives rise to complex momenta and twistor approach suggests that these momenta are light-like allow real mass squared to be non-vanishing. Also the massivation of light particles could be described in this manner.

This description would conform with $M^8 - H$ duality [K50] at momentum space level: at embedding space level one would have color representations and at space-time level representations of $SO(4)$ associated with mass squared=constant sphere in Euclidian three space: this would correspond to the $SU(2)_L \times SU(2)_R$ dynamical symmetry group of low energy hadronic physics.

7 QCD And TGD

During last week I have been listening some very inspiring Harward lectures relating to QCD, jets, gauge-gravity correspondence, and quark gluon plasma. Matthew Schwartz (see <http://tinyurl.com/y98o9hg4>) gave a talk titled *The Emergence of Jets at the Large Hadron Collider* [C108]. Dam Thanh Son (see <http://tinyurl.com/y9o87jz2>) gave a talk titled *Viscosity, Quark Gluon Plasma, and String Theory* [C68]. Factorization theorems of jet QCD discussed in very clear manner by Ian Stewart (see <http://tinyurl.com/y9wj55vz>) [C103] in this talk titled *Mastering Jets: New Windows into Strong Interaction and Beyond*.

These lecture inspired several blog postings and also the idea about systematical comparison of QCD and TGD. This kind of comparisons are always very useful - at least to myself - since they make it easier to see why the cherished beliefs- now the belief that QCD is *the* theory of strong interactions - might be wrong.

There are several crucial differences between QCD and TGD.

- (a) The notion of color is different in these two theories. One prediction is the possibility oflepto-hadron physics [K47] involving colored excitations of leptons.
- (b) In QCD AdS/CFT duality is hoped to allow the description of strong interactions in long scales where perturbative QCD fails. The TGD version of gauge-gravity duality is realized at space-time level and is much stronger: string-parton duality is manifest at the level of generalized Feynman diagrams.
- (c) TGD form of gauge-gravity duality suggests a stronger duality: p-adic-real duality. This duality allows to sum the perturbation theories in strong coupling regime by summing the p-adic perturbation series and mapping it to real one by canonical correspondence between p-adics and reals. This duality suggests that factorization “theorems” have a rigorous basis due to the fact that quantum superposition of amplitudes would be possible inside regions characterized by given p-adic prime. p-Adic length scale hypothesis suggests that p-adically scaled up variants of quarks are important for the understanding of the masses of low lying hadrons. Also scaled up versions of hadron physics are important and both Tevatron and LHC have found several indications for M_{89} hadron physics [K25].
- (d) Magnetic flux tubes are the key entities in TGD Universe. In hadron physics color magnetic flux tubes carrying Kähler magnetic monopole fluxes would be responsible for the non-perturbative aspects of QCD. Reconnection process for the flux tubes (or for the corresponding strings) would be responsible for the formation of jets and their hadronization. Jets could be seen as structures connected by magnetic flux tubes to form a connected structure and therefore as hadron like objects. Ideal QCD plasma would be single hadron like objects. In QCD framework quark-gluon plasma would be more naturally gas of partons.
- (e) Super-symmetry in TGD framework differs from the standard SUSY and the difficult-to-understand X and Y bosons believed to consist of charmed quark pair force to consider the possibility that they are actually smesons rather than mesons [K25]. This leads to a vision in which squarks have the same p-adic length scale as quarks but that the strong mixing between smesons and mesons makes second mass squared eigenstate tachyonic and thus unphysical. This together with the fact that shadronization is a fast process

as compared to electroweak decays of squarks weak bosons and missing energy would explain the failure to observe SUSY at LHC.

- (f) p-Adic length scale hypothesis leads to the prediction that hadron physics should possess scaled variants. A good guess is that these scaled variants correspond to ordinary Mersenne primes $M_n = 2^n - 1$ or Gaussian (complex) Mersenne primes. $M_{89} = 2^{89} - 1$ hadron physics would be one such scaled variant of hadron physics. The mass scale of hadrons would be roughly 512 higher than for ordinary hadrons, which correspond to M_{107} . In zero energy ontology Higgs is not necessarily needed to give mass for gauge bosons and if Higgs like states are there, all of them are eaten by states which become massive. Therefore Higgs would be only trouble makers in TGD Universe.

The neutral mesons of M_{89} hadron physics would however give rise to Higgs like signals since their decay amplitudes are very similar to those of Higgs even at quantitative level if one accepts the generalization of partially conserved axial current hypothesis [K25] [L7].

The recent reports by ATLAS and CMS about Higgs search support the existence of Higgs like signal around about 125 GeV. In TGD framework the interpretation would be as pion like state. There is however also evidence for Higgs like signals at higher masses and standard Higgs is not able to explain this signals. Furthermore, Higgs with about 125 GeV mass is just at the border of vacuum stability, and new particles would be needed to stabilize the vacuum. The solution provided by TGD is that entire scaled up variant of hadron physics replaces Higgs. Within a year it should become clear whether the observed signal is Higgs or pionlike state of M_{89} hadron physics or something else.

7.1 Basic Differences Between QCD And TGD

The basic difference between QCD and TGD follow from different views about color, zero energy ontology, and from the notion of generalized Feynman diagram.

7.1.1 How the TGD based notion of color differs from QCD color

TGD view about color [K22] is different from that of QCD. In QCD color is spin like quantum number. In TGD Universe it is like angular momentum and one can speak about color partial waves in CP_2 . Quarks and leptons must have non-trivial coupling to CP_2 Kähler gauge potential in order to obtain a respectable spinor structure. This coupling is odd multiplet of Kähler gauge potential and for $n = 1$ for quarks and $n = 3$ for leptons one obtains a geometrization of electro-weak quantum numbers in terms of induced spinor structure and geometrization of classical and color gauge potentials. This has several far reaching implications.

- (a) Lepton and baryon numbers are separately conserved. This is not possible in GUTs. Despite the intense search no decays of proton predicted by GUTs have been observed: a strong support for TGD approach.
- (b) Infinite number of color partial waves can assigned to leptons and quarks and they obey the triality rule: $t = 0$ for leptons and $t = +1/ - 1$ for quarks/antiquarks. The color partial waves however depend on charge and CP_2 handedness and therefore on M^4 chirality. The correlation is not correct. Also the masses are gigantic of order CP_2 mass as eigenvalues of CP_2 Laplace operator. Only right handed covariantly constant lepton would have correct color quantum numbers.

The problem can be cured if one accepts super-conformal invariance. Conformal generators carrying color contribute to the color quantum numbers of the particle state. p-Adic mass calculations show that if ground states have simple negative conformal weight making it tachyon, it is possible to have massless states with correct correlation between electroweak quantum numbers and color [K22].

- (c) Both leptons and quarks have color excited states. In leptonic sector color octet leptons are possible and there is evidence already from seventies that states having interpretation as lepto-pion are created in heavy ion collisions [K47]. During last years evidence

for muo-pions and tau-pions has emerged and quite recently CDF provided additional evidence for tau-pions.

Light colored excitations of leptons and quarks are in conflict what is known about the decay width of intermediate gauge bosons and the way out is to assume that these states are dark matter in the sense that they have effective value of Planck constant coming integer multiple of the ordinary Planck constant [K16]. Only particles with the same value of Planck constant can appear in the same vertex of generalized Feynman diagram so that these particles are dark in the weakest possible sense of the world. The Planck constant can however change when particle tunnels between different sectors of the generalized embedding spaces consisting of coverings of the embedding space $M^4 \times CP_2$.

The attribute “effective” applies in the simplest interpretation for the dark matter hierarchy based on many-valuedness of the normal derivatives of the embedding space coordinates as functions of the canonical momentum densities of Kähler action. Many-valuedness is implied by the gigantic vacuum degeneracy of Kähler action: any 4-surface with CP_2 projection which is Lagrangian manifold of CP_2 is vacuum extremal and preferred extremals are deformations of these. The branches co-incide at 3-D space-like ends of the space-time surface at boundaries of CD and at 3-D light-like orbits of wormhole throats at which the signature of the induced metric changes. The value of the effective Planck constant corresponds to the number of sheets of this covering of embedding space and there are arguments suggesting that this integer is product of two integers assignable to the multiplicities of the branches of space-like 3-surfaces and light-like orbits. At partonic 2-surfaces the degeneracy is maximal since all $n = n_1 \times n_2$ sheets co-incide. This structure brings very strongly in mind the stack of branes infinitesimally near to each other appearing in AdS/CFT duality. TGD analogs of 3-branes of the stacks would be distinct in the interior of the space-time surface.

- (d) TGD predicts the presence of long ranged classical color gauge potentials identified as projections of CP_2 Killing forms to the space-time surface. Classical color gauge fields are proportional to induced Kähler form and Hamiltonians of color isometries: $G_A = H_A J$. All components of the classical gluon field have the same direction. Also long ranged classical electroweak gauge fields are predicted and one of the implications is an explanation for the large parity breaking in living matter (chiral selection of molecules). Long ranged classical color fields mean a very profound distinction between QCD color and TGD color and in TGD inspired hadron physics color magnetic flux tubes carrying classical color gauge fields are responsible for the strong interactions in long length scales. These color magnetic fields carrying Kähler magnetic monopole fluxes are absolutely essential in TGD based view about quark distribution functions and hadronic fragmentation functions of quarks and represent the long range hadron physics about which QCD cannot say much using analytic formulas: numerical lattice calculations provide the only manner to tackle the problem.
- (e) Twistorial approach to $\mathcal{N} = 4$ super-symmetric gauge theory could be seen as a diametrical opposite of jet QCD. It has been very successful but it is perturbative approach and I find it difficult to see how it could produce something having the explanatory power of color magnetic flux tubes.

7.1.2 Generalized Feynman diagrams and string-parton duality as gauge-gravity duality

Generalized Feynman diagrams reduce to generalized braid diagrams [K17]. Braid strands have unique identification as so called Legendrean braids identifiable as boundaries of string world sheets which are minimal surfaces for which area form is proportional to Kähler flux. One can speak about sub-manifold braids.

There are no $n > 2$ -vertices at the fundamental braid strand level. Together with the fact that in zero energy ontology (ZEO) all virtual states consist of on mass shell massless states assignable to braid strands, this means that UV and IR infinities are absent. All physical

states are massive bound states of massless on mass shell states. Even photon, gluon, and graviton have small masses. No Higgs is needed since for the generalized Feynman diagrams the condition eliminating unphysical polarizations eliminates only the polarization parallel to the projection of the total momentum of the particle to the preferred plane M^2 defining the counterpart of the plane in which one usually projects Feynman diagrams.

The crossings for the lines of non-planar Feynman diagrams represent generalization of the crossings of the braid diagrams and integrable M^2 QFT is suggested to describe the braiding algebraically. This would mean that non-planar diagrams are obtained from planar ones by braiding operations and generalized Feynman diagrams might be constructed like knot invariants by gradually trivializing the braid diagram. This would allow to reduce the construction of also non-planar Feynman amplitudes to twistorial rules.

One can interpret gluons emission by quark as an emission of meson like state by hadron. This duality is exact and does not require $N_c \rightarrow \infty$ limit allowing to neglect non-planar diagrams as AdS/CFT correspondence requires. The interpretation is in terms of duality: one might call this duality parton-hadron duality, gauge-gravity duality, or particle-string duality.

7.1.3 Q^2 dependent quark distribution functions and fragmentation functions in zero energy ontology

Factorization of the strong interaction physics (see <http://tinyurl.com/yac3tvhh>) in short and long time scales is one of the basic assumptions of jet QCD and originally motivated by parton model which preceded QCD [C111, C66]. The physical motivation for the factorization in higher energy collision is easy to deduce at the level of parton model. By Lorentz contraction of colliding hadrons look very thin and by time dilation the collision time is very long in cm system. Therefore the second projectile moves in very short time through the hadron and sees the hadron in frozen configuration so that the state of the hadron can be thought of as being fixed during collision and partons interact independently. This looks very clear intuitively but it is not at all clear whether QCD predicts this picture.

1. Probabilistic description of quarks in ZEO

Probabilistic description requires further assumptions. Scattering matrix element is in good approximation sum over matrix elements describing scattering of partons of hadron from -say- the partons of another hadron or from electron. Scattering amplitudes in the sum reduce to contractions of current matrix elements with gluon or gauge boson propagator. Scattering probability is the square of this quantity and contains besides diagonal terms for currents also cross terms. Probabilistic description demands that the sum of cross terms can be neglected. Why the phases of the terms in this sum should vary randomly? Does QCD really imply this kind of factorization?

Could the probabilistic interpretation require and even have a deeper justification?

- (a) p-Adic real correspondence to be discussed in more detail below suggest how to proceed. Quarks with different p-adic mass scales can correspond to different p-adic number fields with real amplitudes or probabilities obtained from their p-adic counterparts by canonical identification. Interference makes sense only for amplitudes in the same number field. Does this imply that cross terms involving different p-adic primes cannot appear in the scattering amplitudes?
- (b) Should one assume only a density matrix description for the many quark states formed from particles with different values of p-adic prime p ? If so the probabilistic description would be un-avoidable. This does not look an attractive idea as such. Zero energy ontology however replaces density matrix with M -matrix defined as the hermitian square root of the density matrix multiplied by a universal unitary S -matrix. The modulus squared of M -matrix element gives scattering probability.

One can imagine that M -matrix at least approximately decomposes to a tensor product of M -matrices in different length scales: these matrices could correspond to

different number fields before the map to real numbers and probabilities could be formed as “numbers” in the tensor product of p-adic number fields before the mapping to real numbers by canonical identification.

In finite measurement resolution one sums over probabilities in short length scales so that the square of M-matrix in short scale gives density matrix. Could this lead to a probabilistic description at quark level? Distribution functions and fragmentation functions could indeed correspond to these probabilities since they emerge in QCD picture from matrix elements between initial and final states of quark in scattering process. Now these states correspond to the positive and negative energy parts of zero energy state.

2. Q^2 dependence of distribution and fragmentation functions in ZEO

The probabilistic description of the jet QCD differs from that of parton model in that the parton distributions and fragmentation functions depend on the value of Q^2 , where Q is defined as the possibly virtual momentum of the initial state of the parton level system. Q could correspond to the momentum of virtual photon annihilation to quark pair in the annihilation of e^+e^- pair to hadrons, to the virtual photon decaying to $\mu^+\mu^-$ pairs and emitted by quark after quark-quark scattering in Drell-Yan process, or to the momentum of gluon or quark giving rise to a jet, ... What is highly non-trivial is that distribution and fragmentation functions are universal in the sense that they do not depend on the scattering process. Furthermore, the dependence on Q^2 can be determined from renormalization group equations (see <http://tinyurl.com/yac3tvhh>) [C111, C66].

What does Q^2 's dependence mean in TGD framework?

- (a) In partonic model this dependence looks strange. If one thinks the scattering at quantum level, this dependence is very natural since it corresponds to the dependence of the matrix elements of current operators on the momentum difference between quark spinors in the matrix element. In QCD framework Q^2 dependence is not mysterious. It is the emergence of probabilistic description which is questionable in QFT framework.
- (b) One could perhaps say that Q^2 represents resolution and that hadron looks different in different resolutions. One could also say that there is no hadron “an sich”: what hadron looks like depends on the process used to study it.
- (c) In zero energy ontology the very notion of state changes. Zero energy state corresponds to physical event or quantum superposition of them with M -matrix defining the time like entanglement coefficient and equal to a hermitian square root of density matrix and S -matrix. In this framework different values of Q correspond to different momentum differences for spinor pairs appearing in the matrix element of the currents and Q^2 dependence of the probabilistic description is very natural. The universality of distribution and fragmentation functions follows in zero energy ontology if one assumes the factorization of the dynamics in different length scales. This should follow from the universality of the S -matrix in given number field (in given p-adic length scale).

7.2 P-Adic Physics And Strong Interactions

p-Adic physics provides new insights to hadron physics not provided by QCD.

7.2.1 p-Adic real correspondence as a new symmetry

The exactness of the gauge-gravity duality suggests the presence of an additional symmetry. Perhaps the non-converging perturbative expansion at long scales could make sense after all in some sense. The proposed p-adic-real duality [K31] suggests how.

- (a) The perturbative expansion is interpreted in terms of p-adic numbers and the effective coupling constant g^2MN_c is interpreted as p-adic number which for some preferred

primes is proportional to the p-adic prime p and therefore p-adically small. Hence the expansion converges rapidly p-adically. The p-adic amplitudes would be obtained by interpreting momenta as p-adic valued momenta. If the momenta are rationals not divisible by any non-trivial power of p the canonical identification maps the momenta to themselves. If momenta are small rationals this certainly makes sense but does so also more generally.

- (b) The converging p-adic valued perturbation series is mapped to real numbers using the generalization of the canonical identification appearing quantum arithmetics [K31]. The basic rule is simple: replace powers of p with their inverses everywhere. The coefficients of powers of p are however allowed to be rationals for which neither numerator or denominator is divisible by p . This modification affects the predictions of p-adic mass calculations only in a negligible manner.
- (c) p-Adic-real duality has an interpretation in terms of cognition having p-adic physics as a correlate [K45]: it maps the physical system in long length scale to short length scales or vice versa and the image of the system assigning to physical object thought about it or vice versa provides a faithful representation. Same interpretation could explain also the successful p-adic mass calculations. It must be emphasized that real partonic 2-surfaces would obey effective p-adic topology and this would be due to the large number of common points shared by real and p-adic partonic 2-surfaces. Common points would be rational points in the simplest picture: in quantum arithmetics they would be replaced by quantum rationals.

p-Adic-real correspondence [K31] generalizes the canonical identification used to map the p-adic valued mass squared predicted by p-adic thermodynamics as the analog of thermal energy to a real number. An important implication is that *p-adic mass squared value is additive* [K30].

- (a) For instance, for mesons consisting of pairs of quark and its antiquark the values of p-adic mass squared for quark and antiquark are additive and this sum is mapped to a real number: this kind of additivity was observed already at early days of hadron physics but there was no sensible interpretation for it. In TGD framework additivity of the scaling generator of Virasoro algebra is in question completely analogous to the additivity of energy.
- (b) For mesons consisting of quarks labelled by different value of p-adic prime p , one cannot sum mass squared values since they belong to different number fields. One must map both of them first to real numbers and after this sum real mass values (rather than mass squared values).

This picture generalizes. Only p-adic valued amplitudes belonging to same p-adic number field and therefore corresponding to the same p-adic length scales can be summed. There is no interference between amplitudes corresponding to different p-adic scales.

- (a) This could allow to understand at deeper level the somewhat mysterious and ad hoc assumption of jet QCD that the strong interactions in long scales and short scales factorize at the level of probabilities. Typically the reaction rate is expressible using products of probabilities. The probability for pulling out quarks from colliding protons (non-perturbative QCD), the probability describing parton level particle reaction (perturbative QCD), and the probability that the scattering quarks fragment to the final state hadrons (non-perturbative QCD). Ordinary QCD would suggest the analog of this formula but with probability amplitudes replacing probabilities and in order to obtain a probabilistic description one must assume that various interference terms sum up to zero (de-coherence). p-Adic-real duality would predict the relative decoherence of different scales as an exact result. p-adic length scale hypothesis would also allow to define the notion of scale precisely. From the stance provided by TGD it seems quite possible that the standard belief that jet QCD follows from QCD is simply wrong. The repeated emphasis of this belief is of course part of the liturgy: it would be suicidal for a specialist of jet QCD to publicly conjecture that jet QCD is more than QCD.

- (b) The number theoretical de-coherence would be very general and could explain the somewhat mysterious de-coherence phenomenon (see <http://tinyurl.com/y3c5vg>). De-coherence could have as a number theoretical correlate the decomposition of space-time surfaces to regions characterized by different values of p-adic primes. In given region the amplitudes would be constructed as p-adic valued amplitudes and then mapped to real amplitudes by canonical identification. A space-time region characterized by given p would be the number theoretical counterpart of the coherence region. The regions with different value of p would behave classically with respect to each other and region with given p could understand what happens in regions with different values of p using classical probability. This would also resolve paradoxes like whether the Moon is there when no-one is looking. It could also mean that the anti-commutative statistics for fermions holds true only for fermionic oscillator operators associated with a space-time region with given value of p-adic prime p . Somewhat ironically, p-adic physics would bring quantum reality much nearer to the classical reality.

7.2.2 Logarithmic corrections to cross sections and jets

Even in the perturbative regime exclusive cross sections for parton-parton scattering contain large logarithmic corrections (see <http://tinyurl.com/yd66oguo>) of form $\log(Q^2/\mu^2)$ [C111], where Q is cm energy and μ is mass scale which could be assigned to quark or - perhaps more naturally - to jet. These corrections spoil the convergence of the perturbative expansion at $Q^2 \rightarrow \infty$ limit. One can also say that the cross sections are singular at the limit of vanishing quark mass: this is the basic problem of the twistor approach.

For “infra-red safe” cross sections the logarithmic singularities can be eliminated by summing over all initial and final states not distinguishable from each other in the energy and angle resolutions available. It is indeed impossible to distinguish between quark and quark and almost collinear soft gluon and one must therefore sum over all final states containing soft gluons. A simple example about IR safe cross section is the cross section for e^+e^- annihilation to hadrons in finite measurement resolution, from which logarithms $\log(Q/\mu)$ disappear.

In hadronic reactions jets are studied instead of hadrons. IR safety is one criterion for what it is to be a jet. Jet can be imagined to result as a cascade. Parton annihilates to a pair of partons, resulting partons annihilate into softer partons, and so on... The outcome is a cascade of increasingly softer partons. The experimental definition of jet is constrained by a finite measurement resolution for energy and angle, and jet is parameterized by the cm energy Q , by the energy resolution ϵ , and by the jet opening angle δ : apart from a fraction ϵ all cm energy Q of the jet is contained within a cone with opening angle δ . According to the estimate [C111] the mass scale of the jet resulting at the k : th step of the cascade is roughly $\delta^k Q$.

What could be the counterpart for this description of jets in TGD framework?

- (a) Jet should be a structure with a vanishing total Kähler magnetic charge bound by flux tubes to a connected hadron like structure. By hadron-parton duality gluon emission from quark has interpretation as a meson emission from hadron: jets could be also interpreted as collections of hadrons at different space-time sheets. Reconnection process could play a key role in the decay of jet to hadrons. p-Adic length scale hypothesis suggests the interpretation of jets as hadron like objects which are off mass shell in the sense that the p-adic prime $p \simeq 2^k$ characterizing the jet space-time sheets is smaller than M_{107} characterizing the final state hadrons. One could say that jets represent p-adically hot hadron-like objects which cool and decay to hadrons. If so, the transition from M_{107} hadron physics to M_{89} hadron physics could be rather smooth. The only new thing would be the abnormally long lifetime of M_{89} hadrons formed as intermediate states in the process.
- (b) p-Adic length scale hypothesis suggests that the p-adic length scale assignable to the parton (hadron like object) at the $k + 1$: th step is by power of $\sqrt{2}$ longer than that associated with k : th step: $p \rightarrow p_{next} \simeq 2 \times p$ is the simplest possibility. The naïve

formula $Q(k+1) \sim \delta \times Q(k)$ would probably require a generalization to $Q(k+1) \sim 2^{-r/2} \times Q(k)$, r integer with $\delta = 2^{-nr/2} \times 2\pi$, n an integer. $r = 1$ would be the simplest option. The cascade at the level of jet space-time sheets would stop when the p-adic length scale corresponds to M_{107} , which corresponds to 5 GeV mass scale. At the level of quarks one can imagine a similar cascade stopping at p-adic length scales corresponding to the mass scale about 5 MeV for u and d quarks.

- (c) Zero energy ontology brings in natural IR cutoffs since also gluons have small mass. Final and initial state quarks could emit only a finite number of gluons as brehmstrahlung and soft gluons could not produce IR divergences.
- (d) The notion of finite measurement resolution in QCD involves the cone opening angle δ and energy resolution characterized by ϵ . In TGD framework the notion of finite measurement resolution is fundamental and among other things implies the description in terms of braids. Could TGD simplify the QCD description for finite measurement resolution? Discretization in the space of momentum directions is what comes in mind first and is strongly suggested also by the number theoretical vision. One would not perform integral over the cone but sum over all events producing quark and a finite number of collinear gluons with an upper bound form them deducible from cm energy and gluon mass. For massive gluons the number of amplitudes to be summed should be finite and the jet cascade would have only finite number of steps.

Could number theoretical constraints allow additional insights? Are the logarithmic singularities present in the p-adic approach at all? Are they consistent with the number theoretical constraints?

- (a) The p-adic amplitudes might well involve only rational functions and thus be free of logarithmic singularities resulting from the loop integrals which are dramatically simplified in zero energy ontology by on mass shell conditions for massless partonic 2-surfaces at internal lines.
- (b) For the sheer curiosity one can consider the brehmstrahlung from a quark characterized by p-adic prime p . Do the logarithms $\log((Q^2/\mu^2))$, where μ^2 is naturally p-adic mass scale, make sense p-adically? This is the case of one has $Q^2/\mu^2 = (1 + O(p))$. The logarithm would be of form $O(p)$ and p-adically very small. Also its real counterpart obtained by canonical identification would be very small for $O(p) = np$, $n \ll p$. For $Q^2/\mu^2 = m(1 + O(p))$, m integer, one must introduce an extension of p-adic numbers guaranteeing that $\log(m)$ exists for $1 < m < p$. Only single logarithm $\log(a)$ and its powers are needed since for primitive roots a of unity one has $m = a^n \pmod{p}$ for some n . Since the powers of $\log(a)$ are algebraically independent, the extension is infinite-dimensional and therefore can be questioned.
- (c) For the original form of the canonical identification one would have $O(p) = np$. In the real sense the value of Q^2 would be gigantic for $p = M_{107}$ (say). p-Adically Q^2 would be extremely near to μ^2 . The modified form of canonical identification replaces binary expansion $x = \sum x_n p^n$, $0 \leq x_n < p$, of the p-adic integer with the quantum rational $q = \sum q_n p^n$, where q_n are quantum rationals [K31], which are algebraic numbers involving only the quantum phase $e^{i2\pi/p}$ and are not divisible by any power of p [K31]. This would allow physically sensible values for $Q^2/\mu^2 = 1 + qp + ..$ in the real sense for arbitrarily large values of p-adic prime. In the canonical identification they would be mapped to $Q^2/\mu^2 = 1 + q/p + ..$ appearing in the scattering amplitude. For q/p near unity logarithmic corrections could be sizeable. If qp is of order unity as one might expect, the corrections are of order q/p and completely negligible. Even at the limit $Q^2 \rightarrow \infty$ understood in the real sense the logarithmic corrections would be always negligible if Q^2 is p-adic quantum rational. Similar extremely rapid convergence characterizes p-adic thermodynamics [K22] and makes the calculations practically exact. Smallness of logarithmic corrections quite generally could thus distinguish between QCD and TGD.
- (d) In p-adic thermodynamics the p-adic mass squared defined as a thermal average of conformal weight is a ratio of two quantities infinite as real numbers. Even when finite

cutoff of conformal weight is introduced one obtains a ratio of two gigantic real numbers. The limit taking cutoff for conformal weight to infinity does not exist in real sense. Does same true for scattering amplitudes? Quantum arithmetics would guarantee that canonical identification respects discretized symmetries natural for a finite measurement resolution.

7.2.3 p-Adic length scale hypothesis and hadrons

Also p-adic length scale hypothesis distinguishes between QCD and TGD. The basic predictions are scaled variants of quarks and the TGD variant of Gell-Mann Okubo mass formula indeed assumes that in light hadrons quarks can appear in several p-adic mass scales. One can also imagine the possibility that quarks can have short lived excitations with non-standard p-adic mass scale. The model for tau-pion needed to explain the 3-year old CDF anomaly for which additional support emerged recently, assumes that color octet version of tau lepton appears as three different mass scales coming as octaves of the basic mass scale [K47]. Similar model has been applied to explain also some other anomalies.

M_{89} hadron physics corresponds to a p-adic mass scale in TeV range [K25]: the proton of M_{89} hadron physics would have mass near 500 GeV if naïve scaling holds true. The findings from Tevatron and LHC have provided support for the existence of M_{89} mesons and the bumps usually seen as evidence for Higgs would correspond to the mesons of M_{89} hadron physics. It is a matter of time to settle whether M_{89} hadron physics is there or not.

7.3 Magnetic Flux Tubes and Strong Interactions

Color magnetic flux tubes carrying Kähler magnetic monopole flux define the key element of quantum TGD and allow precise formulation for the non-perturbative aspects of strong interaction physics.

7.3.1 Magnetic flux tube in TGD

The following examples should make clear that magnetic flux tubes are the central theme of entire TGD present in all scales.

- (a) Color magnetic flux tubes are the key element of hadron physics according to TGD and will be discussed in more detail below.
- (b) In TGD Universe atomic nucleus is modelled as nuclear string with nucleons connected by color magnetic flux tubes which have length of order Compton length of u and d quark [K42, L2]. One of the basic predictions is that the color flux tubes can be also charged. This predicts a spectrum of exotic nuclei. The energy scale of these states could be small and measured using keV as a natural unit. These exotic states with non-standard value of Planck constant giving to the flux tubes the size of the atom and the scaling up electroweak scale to atomic scale could explain cold fusion for which empirical support is accumulating [L2, K15].
- (c) Magnetic flux tubes are also an essential element in the model of high T_c superconductivity [K9]. The transition to superconductivity in macroscopic scale would be a percolation type process in which shorter flux tubes would combine at critical point to form long flux tubes so that the supra currents could flow over macroscopic distances. The basic prediction is that there are two critical temperatures. Below the first one the superconductivity is possible for “short” flux tubes and at lower critical temperature the “short” flux tubes fuse to form long flux tubes. Two critical temperatures have been indeed observed.
- (d) Magnetic flux tubes carrying dark matter are the corner stone of TGD inspired quantum biology, where the notion of magnetic body is in a central role. For instance, the vision about DNA as topological quantum computer [K2] is based on the braiding of flux tubes connecting DNA nucleotides and the lipids of nuclear or cellular membrane.

- (e) In the very early TGD inspired cosmology [K41] string like objects with 2-D M^4 projection are the basic objects. Cosmic evolution means gradual thickening of their M^4 projection and flux conservation means that the flux weakens. If the lengths of the flux tubes increase correspondingly, magnetic energy is conserved. Local phase transitions increasing Planck constant locally can occur and led to a thickening of the flux tube and liberation of magnetic energy as radiation which later gives rise to radiation and matter. This mechanism replaces the decay of the energy of inflation field to radiation as a [L4] [K40]. The magnetic tension is responsible for the negative pressures explaining accelerated expansion and magnetic energy has identification as the dark energy.

7.3.2 Reconnection of color magnetic flux tubes and non-perturbative aspects of strong interactions

The reconnection of color magnetic flux tubes is the key mechanism of hadronization and a slow process as compared to quark gluon emission.

- (a) Reconnection vertices have interpretation in terms of stringy vertices $AB + CD \rightarrow AD + BC$ for which interiors of strings serving as representatives of flux tubes touch. The first guess is that reconnection is responsible for the low energy dynamics of hadronic collisions.
- (b) Reconnection process takes place for both the hadronic color magnetic flux tubes and those of quarks and gluons. For ordinary hadron physics hadrons are characterized by Mersenne prime M_{107} . For M_{89} hadron physics reconnection process takes place in much shorter scales for hadronic flux tubes.
- (c) Each quarks is characterized by a p-adic length scale: this scale characterizes the length scale of the magnetic bodies of the quark. Therefore reconnection at the level of the magnetic bodies of quarks take places in several time and length scales. For top quark the size scale of magnetic body is very small as is also the reconnection time scale. In the case of u and d quarks with mass in MeV range the size scale of the magnetic body would be of the order of electron Compton length. This scale assigned with quark is longer than the size scale of hadrons characterized by M_{89} . Classically this does not make sense but in quantum theory Uncertainty Principle predicts it from the smallness of the light quark masses as compared to the hadron mass. The large size of the color magnetic body of quark could explain the strange finding about the charge radius of proton [K25].
- (d) Reconnection process in the beginning of proton-proton collision would give rise to the formation of jets identified as big hadron like entities connected to single structure by color magnetic flux tubes. The decay of jets to hadrons would be also reconnection process but in opposite time direction and would generate the hadrons in the final state (negative energy part of the zero energy state). The short scale process would be the process in which partons scatter from each other and produce partons. These processes would have a dual description in terms of hadronic reactions.
- (e) Factorization theorems are the corner stone of jet QCD. They are not theorems in the mathematical sense of the word and one can quite well ask whether they really follow from QCD or whether they represent correct physical intuitions transcending the too rigid framework provided by QCD as a gauge theory. Reconnection process would obviously represent the slow non-perturbative aspects of QCD and occur both for the flux tubes associated with quarks and those assignable to hadrons. Several scales would be present in case of quarks corresponding to p-adic length scales assigned to quarks which even in light hadrons would depend on hadron [K30]. The hadronic p-adic length scale would correspond to Mersenne prime M_{107} . One of the basic predictions of TGD is the existence of M_{89} hadron physics and there are several indications that LHC has already observed mesons of this hadron physics. p-Adic-real duality would provide a further mathematical justification for the factorization theorems as a consequence of the fact that interference between amplitudes belong to different p-adic number fields is not possible.

Reconnection process is not present in QCD although it reduces to string re-connection in the approximation that partonic 2-surfaces are replaced by braids. An interesting signature of 4-D stringyness is the knotting of the color flux tubes possible only because the strings reside in 4-D space-time. This braiding and knotting could give rise to effects not predicted by QCD or at least its description using AdS/CFT strings. The knotting and linking of color flux tubes could give rise to exotic topological effects in nuclear physics if nuclei are nuclear strings.

7.3.3 Quark gluon plasma

A detailed qualitative view about quark-gluon plasma in TGD Universe can be found from [K17].

- (a) The formation of quark gluon plasma would involve a reconnection process for the magnetic bodies of colliding protons or nuclei in short time scale due to the Lorentz contraction of nuclei in the direction of the collision axis. Quark-gluon plasma would correspond to a situation in which the magnetic fluxes are distributed in such a way that the system cannot be decomposed to hadrons anymore but acts like a single coherent unit. Therefore quark-gluon plasma in TGD sense does not correspond to the thermal quark-gluon plasma in the naïve QCD sense in which there are no long range correlations. Ideal quark gluon plasma is like single very large hadron rather than a gas of partons bound to single unit by the conservation of magnetic fluxes connecting the quarks and antiquarks.
- (b) Long range correlations and quantum coherence suggest that the viscosity to entropy ratio is low as indeed observed [K25]. The earlier arguments suggest that the preferred extremals of Kähler action have interpretation as perfect fluid flows [K51]. This means at given space-time sheet allows global time coordinate assignable to flow lines of the flow and defined by conserved isometry current defining Beltrami flow. As a matter fact, all conserved currents are predicted to define Beltrami flows. Classically perfect fluid flow implies that viscosity, which is basically due to a mixing causing the loss of Beltrami property, vanishes. Viscosity would be only due to the finite size of space-time sheets and the radiative corrections describable in terms of fractal hierarchy CDs within CDs. In quantum field theory radiative corrections indeed give rise to the absorptive parts of the scattering amplitudes. In the case of quark gluon plasma viscosity is very large although the viscosity to entropy ratio is near to its minimum $\eta/s = \hbar/4\pi$ predicted by AdS/CFT correspondence.
- (c) There are good motivations for challenging the belief that QCD predicts strongly interacting quark gluon plasma having very large viscosity begin more like glass than a gas of partons. The reason for the skepticism is that classical color magnetic fields carrying magnetic monopole charges are absent. Also the notion of many-sheeted space-time (see **Fig.** <http://tgdtheory.fi/appfigures/manysheeted.jpg> or **Fig. 9** in the appendix of this book) is essential element of the description. The recent evidence for the failure of AdS/CFT correspondence in the description of jet fragmentation in plasma support the pessimistic views.

7.4 Does Color Deconfinement Really Occur?

Bee (<http://tinyurl.com/yapfwrnk>) had a nice blog posting related to the origin of hadron masses and the phase transition from color confinement to quark-gluon plasma involving also restoration of chiral symmetry in the sigma model description.

The origin of hadron masses is poorly understood in QCD for the simple reason that perturbative QCD does not exist at low energies. The belief is that the couplings of pions to nucleons generate the mass and sigma model provides a Higgs model type description for this. The phase transition from color confinement to quark-gluon plasma is expected to involve the restoration of chiral symmetry for quarks. In the ideal situation the outcome should be a

black body spectrum with no correlations between radiated particles. In the sigma model description nucleons and pions becomes massless in good approximation. Quark gluon plasma suggests that they disappear completely from the spectrum.

The situation is however not this. Some kind of transition occurs and produces a phase, which has much lower viscosity than expected for quark-gluon plasma. Transition occurs also in much smoother manner than expected. And there are strong correlations between opposite charged particles - charge separation occurs. The simplest characterization for these events would be in terms of decaying strings emitting particles of opposite charge from their ends. Conventional models do not predict anything like this.

TGD approach strongly suggests the existence scaled up variants of ordinary hadron physics: actually two of them assignable to Mersenne prime M_{89} and Gaussian Mersenne $M_{G,79}$ respectively should make them visible at LHC and there are indications about the predicted anomalies. This picture allows to consider the possibility that instead of de-confinement a quantum phase transition from the ordinary M_{107} hadron physics to a dark variant of M_{89} hadron physics would occur.

By quantum criticality M_{89} hadron physics would be characterized by the value of effective Planck constant $h_{eff} = n \times h$. $n \simeq 2^9 - 2^{10}$ guarantees that the sizes the scaled up sizes of M_{89} hadrons are of the size scale of nucleons or even nuclei. Quantum coherence in this scale explains the unexpected properties of what was expected to be quark-gluon plasma and explains charge asymmetries in terms of decay of string like color magnetic flux tubes associated with M_{89} pions.

7.4.1 Some background

The masses of current quarks are very small - something like 5-20 MeV for u and d . These masses explain only a minor fraction of the mass of proton. The old fashioned quark model assumed that quark masses are much bigger: the mass scale was roughly one third of nucleon mass. These quarks were called constituent quarks and - if they are real - one can wonder how they relate to current quarks.

Sigma model provide a phenomenological description for the massivation of hadrons in confined phase. The model is highly analogous to Higgs model. The fields are meson fields and baryon fields. Now neutral pion and sigma meson develop vacuum expectation values and this implies breaking of chiral symmetry so that nucleon become massive. The existence of sigma meson is still questionable.

In a transition to quark-gluon plasma one expects that mesons and protons disappear totally. Sigma model however suggests that pion and proton do not disappear but become massless. Hence the two descriptions might be inconsistent.

The authors of the article assumes that pion continues to exist as a massless particle in the transition to quark gluon plasma. The presence of massless pions would yield a small effect at the low energies at which massless pions have stronger interaction with magnetic field as massive ones. The existence of magnetic wave coherent in rather large length scale is an additional assumption of the model: it corresponds to the assumption about large h_{eff} in TGD framework, where color magnetic fields associated with M_{89} meson flux tubes replace the magnetic wave.

In TGD framework sigma model description is at best a phenomenological description as also Higgs mechanism. p-Adic thermodynamics replaces Higgs mechanism and the massivation of hadrons involves color magnetic flux tubes connecting valence quarks to color singles. Flux tubes have quark and antiquark at their ends and are mesonlike in this sense. Color magnetic energy contributes most of the mass of hadron. Constituent quark would correspond to valence quark identified as current quark plus the associated flux tube and its mass would be in good approximation the mass of color magnetic flux tube.

There is also an analogy with sigma model provided by twistorialization in TGD sense. One can assign to hadron (actually any particle) a light-like 8-momentum vector in tangent space $M^8 = M^4 \times E^4$ of $M^4 \times CP_2$ defining 8-momentum space. Massless implies that ordinary

mass squared corresponds to constant E^4 mass which translates to a localization to a 3-sphere in E^4 . This localization is analogous to symmetry breaking generating a constant value of π^0 field proportional to its mass in sigma model.

7.4.2 An attempt to understand charge asymmetries in terms of charged magnetic wave and charge separation

One of the models trying to explain the charge asymmetries is in terms of what is called charged magnetic wave effect and charge separation effect related to it. The experiment [C74] (<http://tinyurl.com/y75qndol>) discussed by Bee attempts to test this model.

- (a) So called chiral magnetic wave effect and charge separation effects are proposed as an explanation for the linear dependence of the asymmetry of so called elliptic flow on charge asymmetry. Conventional models explain neither the charge separation nor this dependence. Chiral magnetic wave would be a coherent magnetic field generated by the colliding nuclei in a relatively long scale, even the length scale of nuclei.
- (b) Charged pions interact with this magnetic field. The interaction energy is roughly $h \times eB/E$, where E is the energy of pion. In the phase with broken chiral symmetry the pion mass is non-vanishing and at low energy one has $E = m$ in good approximation. In chirally symmetric phase pion is massless and magnetic interaction energy becomes large a low energies. This could serve as a signature distinguishing between chirally symmetric and asymmetric phases.
- (c) The experimenters try to detect this difference and report slight evidence for it. This is change of the charge asymmetry of so called elliptic flow for positively and negatively charged pions interpreted in terms of charge separation fluctuation caused by the presence of strong magnetic field assumed to lead to separation of chiral charges (left/right handedness). The average velocities of the pions are different and average velocity depends azimuthal angle in the collision plane: second harmonic is in question (say $\sin(2\phi)$).

7.4.3 Phase transition to dark M_{89} hadron physics instead of deconfinement?

In TGD framework the explanation of the un-expected behavior of should-be quark-gluon plasma is in terms of M_{89} hadron physics.

- (a) A phase transition indeed occurs but means a phase transition transforming the quarks of the ordinary M_{107} hadron physics to those of M_{89} hadron physics. They are not free quarks but confined to form M_{89} mesons. M_{89} pion would have mass about 135 GeV [K25]. A naïve scaling gives half of this mass but it seems unfeasible that pion like state with this mass could have escaped the attention - unless of course the unexpected behavior of quark gluon plasma demonstrates its existence! Should be easy for a professional to check. Thus a phase transition would yield a scaled up hadron physics with mass scale by a factor 512 higher than for the ordinary hadron physics.
- (b) Stringy description applies to the decay of flux tubes assignable to the M_{89} mesons to ordinary hadrons. This explains charge separation effect and the deviation from the thermal spectrum. The color magnetic flux flux tube corresponds to chiral magnetic wave in the model tested in the experiment. Effects caused by the presence of strong color magnetic fields in nuclear length scale could be present also now but a more feasible interpretation for the observed anomalous effects is in terms of the decays of M_{89} pions. Note that in TGD framework color gauge field associated with single space-time sheet is proportional to induced Kähler form, which contribute also the classical electromagnetic field as induced gauge field. At QFT limit effective gauge fields are independent in good approximation.
- (c) In the experiments discussed in the article the cm energy for nucleon-nucleon system associated with the colliding nuclei varied between 27-200 GeV so that the creation of

even on mass shell M_{89} pion in single collision of this kind is possible at highest energies. If several nucleons participate simultaneously even many-pion states are possible at the upper end of the interval.

- (d) These hadrons must have large $h_{eff} = n \times h$ since collision time is roughly 5 femtoseconds, by a factor about 500 (not far from 512!) longer than the time scale associated with their masses if M_{89} pion has the proposed mass of 135 MeV for ordinary Planck constant and scaling factor 2×512 instead of 512 in principle allowed by p-adic length scale hypothesis. There are some indications for a meson with this mass. The hierarchy of Planck constants allows at quantum criticality to zoom up the size of much more massive M_{89} hadrons to nuclear size! The phase transition to dark M_{89} hadron physics could take place in the scale of nucleus producing several M_{89} pions decaying to ordinary hadrons.
- (e) The large value of h_{eff} would mean quantum coherence in the scale of nucleus explaining why the value of the viscosity was much smaller than expected for quark gluon plasma. The expected phase transition was also much smoother than expected. Since nuclei are many-nucleon systems and the Compton wavelength of M_{89} pion would be of order nucleus size, one expects that the phase transition can take place in a wide collision energy range. At lower energies several nucleon pairs could provide energy to generate M_{89} pion. At higher energies even single nucleon pair could provide the energy. The number of M_{89} pions should therefore increase with nucleon-nucleon collision energy, and induce the increase of charge asymmetry and strength of the charge asymmetry of the elliptic flow.
- (f) Hydrodynamical behavior is essential in order to have low viscosity classically. Even more, the hydrodynamics had better to be that of an ideal liquid. In TGD framework the field equations have hydrodynamic character as conservation laws for currents associated with various isometries of embedding space. The isometry currents define flow lines. Without further conditions the flow lines do not however integrate to a coherent flow: one has something analogous to gas phase rather than liquid so that the mixing induced by the flow cannot be described by a smooth map.

To achieve this given isometry flow must make sense globally - that is to define coordinate lines of a globally defined coordinate ("time" along flow lines). In this case one can assign to the flow a continuous phase factor as an order parameter varying along the flow lines. Super-conductivity is an example of this. The so called Frobenius conditions guarantee this at least the preferred extremals could have this complete integrability property making TGD an integrable theory see the appendix of the article [L10] or section of [K35] (<http://tinyurl.com/y89rsq9c>). In the recent case, the dark flux tubes with size scale of nucleus would carry ideal hydrodynamical flow with very low viscosity.

7.4.4 Large parity breaking effects at RHIC?

Ulla Matfolk reminded me about an old Sciencedaily article (see <http://tinyurl.com/yzo6ptx>) [C2] telling about discovery of large parity breaking effects at RHIC studying collisions of relativistic heavy ions at energies at which QCD suggests the formation of quark gluon plasma. Something exotic is observed but it seems to be something different from quark gluon plasma in that long range correlations not characteristic for plasma phase are present and the particle production does not look like black body radiation. Similar findings are made also at LHC and also for proton-proton collisions. This suggests new physics and M_{89} hadron physics is the TGD inspired candidate for it. In any case, I took the article as a hype as I read it for four years ago.

Now I read the article again and started to wonder on what grounds authors claim large parity violation. What they claim to observed are magnetic fields in which u and d quarks with charges $2/3$ and $-1/3$ move in opposite directions along the magnetic field lines (flux tubes in TGD). They assign these motions to the presence of strong parity breaking, much stronger than predicted by the standard model.

1. Instanton density as origin of parity breaking

What says TGD? In TGD magnetic fields would form flux tubes, even flux tubes carrying monopole flux are possible. The findings suggests that magnetic field was accompanied by electric field and that both were parallel to the flux tubes and each other in average sense. Helical magnetic and electric fields parallel in average sense could be associated with flux tubes in TGD.

The helical classical field patterns would break the parity of ground state. Instanton density for Kähler field, essentially $E \cdot B$, measuring the non-orthogonality of E and B would serve as a measure for the strength of parity breaking occurring at the level of ground state and thus totally different from weak parity breaking. u and d quarks with opposite signs of em charges would move in opposite directions in the electric force.

2. The origin of instanton density in TGD Universe

What is the origin of these non-orthogonal magnetic and electric fields? Here I must dig down to a twenty years old archeological layer of TGD. Already at seventies an anomalous creation of anomalous e^+e^- pairs having axion-like properties in heavy ion collisions near Coulomb wall was observed (for references and TGD based explanation see [K47]). Effect was forgotten since it was not consistent with standard model. TGD explanation is in terms of pairs resulting from the decay of lepto-pion formed as bound states of color excited electron and positron and created in strong non-orthogonal electric and magnetic fields of colliding nuclei.

Objection: Color excited leptons do not conform with standard model view about color. In TGD this is not a problem since colored states correspond to partial waves in CP_2 and both leptons and quarks can move in higher color partial waves but usually with much higher mass.

Non-vanishing instanton density would mean that the orthogonal E and B created by colliding protons appear at the *same* space-time sheet so that a coherent instanton density $E \cdot B$ is created and gives rise to the generation of pairs. Large value of $E \cdot B$ means large parity breaking at the level of ground state. One expects that in most collisions the fields of colliding nuclei stay at different space-time sheets and therefore do not interfere directly (only their effects on charged particles sum up) but that with some property the fields can enter to the same space-time sheet and generate the physics not allowed by standard model.

Objection: Standard model predicts extremely weak parity breaking effects: this is due to the massivation of weak bosons, for massless weak bosons the parity breaking would be large. Indeed, if the non-orthogonal E and B are at different space-time sheets, no instantons are generated.

Objection: The existence of new particle in MeV scale would change dramatically the decay widths of weak bosons. The TGD solution is that colored leptons are dark in TGD sense ($h_{eff} = n \times h$, $n > 1$). Large h_{eff} would make weak bosons effectively massless below scaled up Compton length of weak bosons proportional to h_{eff} and large parity breaking could be understood also the “conventional” manner.

3. Strong parity breaking as signature of dark variant of M_{89} hadron physics

This picture would apply also now and also leads to an increased understanding of M_{89} hadron physics [K25] about which I have been talking for years and which is TGD prediction for LHC. Very strong non-orthogonal E and B fields would be most naturally associated with colliding protons rather than nuclei. The energy scale is of course much much higher than in the heavy ion experiment. Instanton-like space-time sheets, where the E and B of the colliding nuclei could be formed as magneto-electric flux tubes (a priori this of course need not occur since fields remain at different space-time sheets).

The formation of axionlike states is expected to be possible as pairs color excited quarks. M_{89} hadron physics is a scaled up copy of the ordinary M_{107} hadron physics with mass scale which is by a factor 512 higher. The natural possibility is pions of M_{89} hadron physics

but with large $h_{eff}/h \simeq 512$ so that the size of M_{89} pions could increase to a size scales of ordinary hadrons! This would explain why heavy ion collisions involve energies in TeV range appropriate for M_{89} hadrons and thus Compton scales of order weak scale whereas size scales are associated with QCD plasma of M_{107} hadron physics and is by a factor $1/512$ smaller. Brings in mind a line from an biblical story: *The hands are Esau's hands but the voice is Jacob's voice* ! Quite generally, the failure estimates based on Uncertainty Principle could serve as a signature for non-standard values of h_{eff} : two great energy scale for effect as compared to its length scale.

To sum up, the strange findings about heavy ion and proton proton collisions at LHC for which I suggested M_{89} physics as an explanation would indeed make sense and one also ends up to a concrete mechanism for the emergence of dark variants of weak physics. The magnetic flux tubes playing key role in TGD inspired quantum biology [K44] would carry also electric fields not-orthogonal to magnetic fields and the two fields would be twisted. As a matter of fact, the observed strong parity breaking would be very analogous to that observed in biology if one accepts TGD based explanation of chiral selection in living matter.

4. Could this relate to non-observed SUSY somehow?

Dark matter and spartners have something in common: it is very difficult to observe them! I cannot resist typing a fleeting crazy idea, which I have managed to fend several times but is popping up again and again from the murky depths of subconscious to tease me. TGD predicts also SUSY albeit different from the standard one: for instance, separate conservation of lepton and baryon numbers is predicted and fermions are not Majorana fermions. Whether covariantly constant right-handed neutrino mode which carries no quantum numbers except spin could be seen as a Majorana lepton is an open question.

One can however assume that covariantly constant right-handed neutrino, call it ν_R , and its antiparticle $\nu_{R,c}$ span $\mathcal{N} = 2$ SUSY representation. Particles would appear as SUSY 4-plets: particle, particle+ ν_R , particle + $\nu_{R,c}$, particle+ $\nu_R+\nu_{R,c}$. Covariantly constant right-handed neutrinos and antineutrino would generate the least broken sub-SUSY. Sparticles should obey the same mass formula as particles but with possibly different p-adic mass scale.

But how the mass scales of particles and its spartners can be so different if right handed does not have any weak interactions? Could it be that sparticles have same p-adic mass scale as particles but are dark having $h_{eff} = n \times h$ so that the observation of sparticle would mean observation of dark matter! Particle cannot of course transform to its spartner directly: already angular momentum conservation prevents this. For $\mathcal{N} = 2$ SUSY one can however consider the transformation of particle to the state particle + $\nu_R+\nu_{R,c}$ representing a dark variant of particle and having same quantum numbers. It would have non-standard value $h_{eff} = n \times h$ of Planck constant. The resulting dark particles could interact and generate also states in dark SUSY 4-plet. Dark photons could be spartners of photons and decay to biophotons. SUSY would be essential for living matter!

Critical reader asks whether leptopions could be actually pairs of (possibly color excited) $\mathcal{N} = 2$ SUSY partners of selectron and spositron. The masses of (color) excitations making up electropion must be indeed identical with electron and positron masses. Should one give up the assumption that color octet excitations of leptons are in question? But if color force is not present, what would bind the spartners together for form electropion? Coulomb attraction so that dark susy analog of positronium would be in question? But why not positronium? If spartner of electron is color excited, one can argue that its mass need not be the same as that of electron and could be of order CP_2 ! The answer comes out only by calculating. But what happens to leptohadron model if color excitation is not in question? Nothing dramatic, the mathematical structure of leptohadron model is not affected since the calculations involve only the assumption that electropion couples to electromagnetic "instanton" term fixed by anomaly considerations.

If this makes sense, the answers to four questions: *What is behind chiral selection in biology?* ; *What dark matter is?* ; *What spartners are and why they are not seemingly observed?* ; *What is behind various forgotten axion/pion-like states?* would have a lot in common!

7.5 Exotic Pion Like States: “Infra-Red” Regge Trajectories Or Shnoll Effect?

TGD based view about non-perturbative aspects of hadron physics (<http://tinyurl.com/y8semjtv>) relies on the notion of color magnetic flux tubes. These flux tubes are string like objects and it would not be surprising if the outcome would be satellite states of hadrons with string tension below the pion mass scale. One would have kind of infrared Regge trajectories satisfying in a reasonable approximation a mass formula analogous to string mass formula. What is amazing that this phenomenon could allow new interpretation for the claims for a signal interpreted as Higgs at several masses (115 GeV by ATLAS, at 125 GeV by ATLAS and CMS, and at 145 GeV by CDF). They would not be actually statistical fluctuations but observations of states at IR Regge trajectory of pion of M_{89} hadron physics!

7.5.1 IR Regge trajectories

Consider first the mass formula for the hadrons at IR Regge trajectories.

- (a) There are two options depending on whether the mass squared or mass for hadron and for the flux tubes are assumed to be additive. p-Adic physics would suggest that if the p-adic primes characterizing the flux tubes associated with hadron and hadron proper are different then mass is additive. If the p-adic prime is same, the mass squared is additive.
- (b) The simplest guess is that the IR stringy spectrum is universal in the sense that m_0 does not depend on hadron at all. This is the case if the flux tubes in question correspond to hadronic space-time sheets characterized by p-adic prime M_{107} in the case of ordinary hadron physics. This would give for the IR contribution to mass the expression

$$m^2 = \sqrt{m_0^2 + nm_1^2} .$$

- (c) The net mass of hadron results from the contribution of the “core” hadron and the stringy contribution. If mass squared is additive, one obtains $m(H_n) = \sqrt{m^2(H_0) + m_0^2 + nm_1^2}$, where H_0 denotes hadron ground state and H_n its excitation assignable to magnetic flux tube. For heavy hadrons this would give the approximate spectrum

$$m(H_n) \simeq m(H_0) + \frac{m_0^2 + nm_1^2}{2m(H_0)} .$$

The mass unit for the excitations decreases with the mass of the hadron.

- (d) If mass is additive as one indeed expects since the p-adic primes characterizing heavy quarks are smaller than hadronic p-adic prime, one obtains

$$m(H_n) = m(H_0) + \sqrt{m_0^2 + nm_1^2} .$$

For $m_0^2 \gg m_1^2$ one has

$$m(H_n) = m(H_0) + m_0 + n \frac{m_1^2}{2m_0} .$$

If the flux tubes correspond to p-adic prime. This would give linear spectrum which is same for all hadrons.

There is evidence for this kind of states. The experimental claim (see <http://tinyurl.com/ybq323yy>) of Tatischeff and Tomasi-Gustafsson is that pion is accompanied by pion like states organized on Regge trajectory and having mass 60, 80, 100, 140, 181, 198, 215, 227.5, and 235 MeV. means that besides pion also other pion like states should be there. Similar satellites have been observed for nucleons with ground state mass 934 MeV: the masses of the satellites are 1004, 1044, 1094 MeV. Also the signal cross sections for Higgs to gamma pairs

at LHC [C26, C39] suggest the existence of several pion and spion like states, and this was the reason why I decided to again the search for data about this kind of states (I remembered vaguely that Tommaso Dorigo had talked about them but I failed to find the posting). What is their interpretation? One can imagine two explanations which could be also equivalent.

- (a) The states could be “infrared” Regge trajectories assignable to magnetic flux tubes of order Compton length of u and d quark (very long and with small string tension) could be the explanation. Hadron mass spectrum would have microstructure. This is something very natural in many-sheeted space-time with the predicted p-adic fractal hierarchy of physics. This conforms with the proposal that all baryons have the satellite states and that they correspond to stringy excitations of magnetic flux tubes assignable to quarks. Similar fine structure for nuclei is predicted for nuclei in nuclear string model [L2]. In fact, the first excited state for ${}^4\text{He}$ has energy equal to 20 MeV not far from the average energy difference 17.5 MeV for the excited states of pion with energies 198, 215, and 227.5 MeV so that this state might correspond to an excitation of a color magnetic flux tube connecting two nucleons.

This idea should be made more precise. Color magnetic flux tubes would correspond to ordinary Regge trajectories. The magnetic flux tubes in electro-magnetic sense would correspond to IR Regge trajectories.

- (b) The p-adic model for Shnoll effect [K3] relies on universal modification of the notion of probability distribution based on the replacement of ordinary arithmetics with quantum arithmetics. Both the rational valued parameters characterizing the distribution and the integer or rational valued arguments of the distribution are replaced with quantum rationals. Quantum arithmetics is characterized by quantum phase $q = \exp(i2\pi/p)$ defined by the p-adic prime p . The primes in the decomposition of integer are replaced with quantum primes except p which remains as such. In canonical identification powers of p are mapped to their inverses. Quite generally, distributions with single peak are replaced with many peaked ones with sub-peak structure having number theoretic origin. A good example is Poisson distribution for which one has $P(n) = \lambda^n/n!$. The quantum Poisson distribution is obtained by replacing λ and $n!$ with their quantum counterparts. Quantum Poisson distribution could apply in the case of resonance bump for which the number of count in a given mass squared interval is integer valued variable.

There are objections against Shnoll effect based explanation.

- i. If the p-adic prime assignable to quark or hadron characterizes quantum arithmetics it is not distinguishable from ordinary arithmetics since the integers involved are certainly much smaller than say $M_{107} = 2^{107} - 1$. In the case of nuclear physics Shnoll effect involves small primes so that this argument is not water tight. For instance, if $p = 107$ defines the quantum arithmetics, the effects would be visible in good enough resolution and one might even expect variations in the bump structure in the time scale of year.
- ii. The effect is present also for nucleons but the idea about a state with large width splitting into narrower bumps does not fit nicely with the stability of proton.

For Higgs like signals IR-Regge trajectories/Shnoll effect would be visible as a splitting of wide bumps for spion and pion of M_{89} physics to sub-bumps. This oscillatory bumpy structure is certainly there but is regarded as a statistical artefact. It would be really fascinating to see this quantum deformation of the basic arithmetics at work even in elementary particle physics.

A further piece of evidence for scaled variants of pion comes from two articles by Eef van Beveren and George Rupp. The first article [C17] is titled *First indications of the existence of a 38 MeV light scalar boson* (see <http://tinyurl.com/yat1b97o>). Second article [C18] has title *Material evidence of a 38 MeV boson* (see <http://tinyurl.com/yczo7juy>).

The basic observations are following. The rate for the annihilation $e^+ + e^- \rightarrow u\bar{u}$ assignable to the reaction $e^+ + e^- \rightarrow \pi^+\pi^-$ has a small periodic oscillation with a period of 78 ± 2 MeV and amplitude of about 5 per cent. The rate for the annihilation $e^+ + e^- \rightarrow b\bar{b}$, assignable

to the reaction $e^+ + e^- \rightarrow \Upsilon \pi^+ \pi^-$ has similar oscillatory behavior with a period of 73 ± 3 MeV and amplitude about 12.5 per cent. The rate for the annihilation $p\bar{p} \rightarrow c\bar{c}$ assignable to the reaction $e^+ + e^- \rightarrow J/\Psi \pi^+ \pi^-$ has similar oscillatory behavior with period of 79 ± 5 MeV and amplitude .75 per cent.

In these examples universal Regge slope is consistent with the experimental findings and supports additive mass formula and the assignment of IR Regge trajectories to hadronic flux tubes with fixed p-adic length scale. There is also consistency with the experiments of Tatitscheff and Tomasi-Gustafsson.

What does one obtain if one scales up the IR Regge trajectories to the M_{89} which replaces Higgs in TGD framework?

- (a) In the case of M_{89} pion the mass differences 20 MeV and 40 MeV appearing in the IR Regge trajectories of pion would scale up to 10 GeV and 20 GeV respectively. This would suggest the spectrum of pion like states with masses 115, 125, 145, 165 GeV. What makes this interesting that ATLAS reported during last year evidence for a signal at 115 GeV taken as evidence for Higgs and CDF reported before this signal taken as evidence for Higgs around 145 GeV! 125 GeV is the mass of the most recent Higgs candidate. Could it be that all these reported signals have been genuine signals - not for Higgs- but for M_{89} pion and corresponding spion consisting of squark pair and its IR satellites?
- (b) In the case of M_{89} hadron physics the naïve scaling of the parameters m_0 and m_1 by factor 512 would scale 38 MeV to 19.5 GeV.

7.5.2 New particle having no interpretation in standard model discovered?

A new piece of evidence for IR Regge trajectories years after writing the above text - thanks for Wilhelmus de Wilde for a link. The popular article in Schitechdaily (<http://tinyurl.com/wb98u6u>) tells about completely unexpected finding by a team led by professors Tacemichi Okui and Kohsaku Tobioka. The decay of longlived kaon K_L suggests the existence of new longlived particle with quantum numbers of axion - or equivalently pion. The finding is published in Physical Review Letters [C89] (<http://tinyurl.com/v2rwh3e>). Standard model cannot explain this kind of particle.

A rough estimate for mass is not far from pion mass. There exists earlier evidence that pion has mass spectrum. Could an excitation of pion be involved?

This is actually not new. The experimental claim [C118] (see <http://tinyurl.com/ybq323yy>) of Tatischeff and Tomasi-Gustafsson is that pion is accompanied by pion like states organized on Regge trajectory and having mass 60, 80, 100, 140, 181, 198, 215, 227.5, and 235 MeV means that besides pion also other pion like states should be there. Similar satellites have been observed for nucleons with ground state mass 934 MeV: the masses of the satellites are 1004, 1044, 1094 MeV. Also the signal cross sections for Higgs to gamma pairs at LHC suggest the existence of several pion and spion like states, and this was the reason why I decided to again the search for data about this kind of states. Their possible interpretation in TGD framework is discussed in [K25] (<http://tinyurl.com/rk7b3dd>).

One explanation could be that the states correspond to “infrared Regge trajectories” of pion related to the structure of its magnetic body. Genuine Regge trajectories would have slope of about GeV and now the slope less than 10 per cent of this, which conforms with the ratio of fine structure constant to coupling strength. IR trajectories would be associated with the electromagnetic body and ordinary Regge trajectories with the color magnetic body. One can also consider p-adically scaled down variant of color interactions.

It is interesting to look the situation quantitatively.

- (a) It is clear that the masses in question do not fit to a single Regge trajectory. One can however restrict the consideration to Regge trajectory $M^2 = M_0^2 + nT(\pi)$, where $T(\pi)$ denotes string tension. Since the masses obey approximately linear formula one can assume linear approximation $\Delta M^2 = 2M\Delta M$ at pion mass $M_1 = m(\pi) = .140$ GeV

and consider the mass squared difference for pion and its predecessor with $M_0 = .100$ GeV so that one has $\Delta M = .040$ GeV.

One obtains $\Delta M^2 = M_1^2 - M_0^2 = T(\pi)$. This would give for the string tension $T(\pi) = 0.96 \times 10^{-2} T_H \simeq .96 \times 10^{-2} \text{ GeV}^2$, where $T_H \simeq 1 \text{ GeV}^2$ is hadronic string tension assignable to color interactions.

- (b) What about the value of M_0^2 ? In string models it tends to be negative but one can assume that the values of mass squared for physical states are negative. Also in TGD the value is negative in p-adic mass calculations. One must require that several values for pion mass below $m(\pi)$ are possible. The formula $m(\pi)^2 = M_0^2 + nT(\pi)$ gives formula $M_0^2 = (m(\pi)^2 - nT(\pi))$. For $n(\pi) = 2$, which looks rather reasonable guess, one has $M_0^2 = .04 \text{ GeV}^2$, which corresponds to $M_0 = 20 \text{ MeV}$.

There is actually a lot of confusion about the value of hadronic string tension.

- (a) In early models hadronic string tension was taken to be 1 GeV. Much smaller values for the string tension smaller by a factor or order $x \times 10^{-2} \text{ GeV}^2$, x in the range 2-11.1 for mesons and in the range 2.2-4.55 for baryons are however suggested by the study of hadronic spectrum (<http://tinyurl.com/s5jwawx>). Intriguingly, the lower bounds is twice the above estimate $T(\pi) \simeq .01 \text{ GeV}^2$ obtained above. Does this mean that the p-adic prime involved is about 2 times smaller or is this factor due to a numerical factor 1/2 related to the difference between N-S and Ramond type representations of Super-Virasoro algebra.
- (b) The reason for the confusion about string tension could be simple: besides the string tension 1 GeV assignable to color flux tubes there are string tensions assignable to possible scaled down color flux tubes and possible electromagnetic and even weak flux tubes. Several p-adic length scales could be associated coming in powers of 2 by p-adic length scales hypothesis are involved.

7.5.3 Indications for an axion-like state in mass range 1.7 eV from XENON

There was a popular article about bump claimed by XENON group (<https://tinyurl.com/yaqoo2y9>) and suggesting the existence of an axion-like state with mass in the range 1-7 keV. Also Jester (<https://tinyurl.com/y94hcmdj>) discusses the evidence for the claimed bump.

Originally XENON searched evidence for WIMPs - weak interacting very massive particles. They would have made themselves visible via scattering from ZENON nuclei. Nothing was found. Second candidate for dark matter particles are very light axions, which could be produced copiously in Sun. They would not have any detectable effect on heavy XENON atom but they could scatter from electrons and ionize XENON atom. The figure in the posting of Jester summarizes the energy spectrum of the observed ionization events. There is approximately constant background below 30 keV down to 1 keV below which it drops abruptly suggesting a threshold. There are also indications for a peak around 1-2 keV. There is 3.5 sigma excess of events in the range 1-7 keV.

The mass of the dark particle candidate is in the range 1-7 keV. TGD allows to imagine several options but for all of them one would have analog of pion as dark matter candidate.

- (a) TGD Universe is fractal and this predicts p-adically scaled variants of hadron physics and electroweak physics. Mass squared scales would come as powers of 2. Mersenne primes and Gaussian Mersennes define especially promising candidates.
 - i. M_{89} hadron physics [K25] would be scaled up variant of ordinary hadron physics (M_{107}) and would make itself visible at LHC. The masses of M_{89} hadrons would be scaled up by factor 512 from those of ordinary hadrons. There is evidence for bumps with predicted masses and the original proposal as Higgs did not work and they were forgotten. The mesons of this physics would be dark with $h_{eff}/h_0 = n \simeq 512$ so that the Compton lengths would be those of ordinary mesons and they would appear at quantum criticality for what was expected to be de-confinement phase transition.

- ii. There are indications for the particles of these physics having mass scaled by a power of 2 from that for say ordinary meson. Could the particle be a scaled down pion of some kind. There are actually several candidates for scaled variants of pion. There is evidence for so called X boson with mass around 16-17 MeV proposed to be spin 1 boson of a fifth force [L18, C85] (see <http://arxiv.org/abs/1604.07411>). In TGD framework the identification as pion-like state is more natural and provides new insights on the relation between weak and strong interactions [L18]. There is also quite recent evidence for pionlike exotic particle with mass not far from that of pion showing itself in the decays of long-lived kaon [C89]: there is actually evidence for scaled variants of pion also from earlier experiments [C17, C118]. These pieces of evidence are discussed from TGD point of view in [L50] (<https://tinyurl.com/y9c1yf5y>).
- iii. In biologically important length scales there are as many as 4 Gaussian Mersenne $M_{G,n} = (1 + i)^n - 1$ with $n = 151, 157, 163, 167$ defining p-adic length scales in the range 10 nm (cell membrane thickness) and $2.5 \mu\text{m}$ (cell nucleus size) and might involve scaled variants of hadron and electroweak physics..

p-Adic length scale hypothesis also allows the possibility of p-adically scaled variants of leptons and quarks with mass scaled down or up by a power of 2 and there are some indications for this kind of states. For instance, the claimed axionlike state could be a scaled down pion as bound state of scaled down quarks.

- (b) Heavy ion collisions near Coulomb wall gave already around seventies indications for a pion-like state of mass 1 MeV decaying to electron positron pair. TGD inspired interpretation [K47] was in terms of electropion identified as bound state of color octet electrons. TGD view about color indeed allows colored excitation of leptons since color is not spin-like but angular momentum like quantum number assignable to CP_2 color partial waves. Later evidence for muon and tau analogs of this state has emerged. The decay widths of weak bosons do not allow color octet pions in MeV scale and this forced the interpretation that they are dark in some sense and appear only at quantum criticality - now at collision energies around Coulomb wall.

Leptopion could also be color bound state of quark and antiquark. As noticed, there is evidence for several bound states of this kind.

- (c) The TGD based model for “cold fusion” [K10] [L21, L49] led to a new view about nuclear physics [L43] in which dark nuclei appear also as intermediate states of ordinary nuclear reactions. Dark nuclei as nuclear string with distance of about electron Compton length would be crucial for “cold fusion”.

What is remarkable is they would have scaled down dark nuclear binding energies in few keV range. This because the binding energy scale of ordinary nuclear physics about 7 MeV would be scaled down by the ratio $2^{-10} \simeq 10^{-3}$ of the p-adic length scales of proton and electron labelled by $k = 107$ and $k = 127$ to a value about 7 keV, which represents the upper end of the range 1-7 keV. There is also evidence that X ray emission with energies of this order of magnitude from Sun affects nuclear decay rates at Earth. The pion-like particles could be indeed dark in TGD sense (ordinary particle but with $h_{eff} = n \times h_0 > h$). Could the axion candidate be scaled down variant of electro-pion with mass 1 MeV with $k = 127$: if the mass of electro-pion scales down like the nuclear binding energy, the scaling $k = 107 \rightarrow 127$ would take the mass of electro-pion to 1 keV. Also scaled down pion formed by quarks could be in question.

7.5.4 New view about nuclear physics provided by IR Regge trajectories

This picture led to an unexpected development in the nuclear string model that I constructed more than 2 decades ago [L2] (<http://tinyurl.com/rc4umgv>). The key assumption - very natural in TGD, where monopole flux tubes prevail in all scales - is that nucleons form nuclear strings. Nuclear radius satisfies $R \propto A^{1/3}$, A mass number, so that nuclei have constant density in good approximation (<http://tinyurl.com/rtc9jdh>) so that the flux

tube would fill the entire volume. I have proposed that also blackholes and other final states of stars are flux tube spaghettis of this kind [L41].

The basic objection against the model is that the harmonic oscillator model for nuclear works surprisingly well. The justification for this model is that one can reasonably well describe nucleus as motion of nucleons in an effective nuclear potential, which in linearization becomes harmonic. Nucleons themselves have no mutual interactions in this approximation.

Could nuclear string model allow to understand harmonic oscillator model of nuclei as an approximation?

- (a) It is best to start from the problems of the harmonic oscillator model. The first problem is that the description of nuclear binding energies is poorly understood. For instance, nuclear binding energies have scale measured in MeVs. The scale is much smaller than energy scale of hadronic strong interactions for which pion mass is a natural scale. Rather remarkably, the ratio of the scales is roughly the ratio of fine structure constant to color coupling strength. Could one imagine that electromagnetic interactions somehow determine the energy scale of nuclear binding energies and excitations?
- (b) As noticed, also nucleons are reported to have IR Regge trajectories. The first guess is that the trajectories have same string tension as in the case of pion. TGD suggests a model of nuclei as three nucleons connected by color flux tubes characterized by hadronic string tension $T_H \simeq 1 \text{ GeV}^2$. Besides color flux tubes hadrons are expected to have also electromagnetic and perhaps also weak flux tubes with a smaller value of string tension. Em flux tubes should give a contribution to the energy, which is of the order of Coulomb energy of nucleon about $\alpha/L^c(p) \simeq 7.5 \text{ MeV}$. Intriguingly, this is of same order of magnitude as nuclear binding energy: could IR Regge trajectories correspond to em interaction so that the spectrum of nuclear binding energies and excitation energies would be determined by electromagnetic interactions?
- (c) If the value of p-adic prime $p \simeq 2^k$ corresponds to $k = 113$ assumed to characterize nuclei in nuclear string model, hadronic string tension would be scaled down by factor $2^{107-113} = 1/64$ to $T_H/64$, which corresponds to a mass of 125 MeV, which is somewhat larger than the value about 96 MeV obtained from the above estimate. For $\Delta M^2 \simeq 2M\Delta M = nT(\pi)$ this gives $\Delta M \simeq 7.8 \text{ MeV}$ for $\Delta n = 1$, which corresponds to the maximal nuclear binding energy per nucleon to be denoted by e_B . This string tension is naturally assignable to em flux tubes assignable nuclei as 3 -quark states. Color flux tubes would be responsible for the hadronic string tension T_H .

Remark: Flux tubes carry all classical gauge fields, which are induced from the spinor connection of CP_2 but it seems that one can assign to given flux tube quanta of particular interaction.

- (d) In the case of baryons one would have 3 color flux tubes and 3 em flux tubes. For large mass excitations one would have in linear approximation for M^2 harmonic oscillator spectrum! Could linearization of mass squared formula replace linearization of effective potential function leading to harmonic oscillator model? The dimension $D = 3$ for the nuclear harmonic oscillators would correspond to the fact that nucleons consist of 3 quarks. The free nucleon approximation would have simple justification: in good approximation one can treat the nucleons of nuclear strings as independent particles!
- (e) Could the nuclear e_B correspond to a reduction of the value of n for the IR Regge trajectory of free nucleon? The mass squared formula for IR trajectory would be $M^2 = M_0^2(N) + nT(\pi)$. This mechanism requires that the one has $M_0 \leq m(N)$ so that one has $n > 0$ for nucleons. For $\Delta n = -1$ one has $\Delta M = T(\pi)/2m(N) \simeq 7.8 \text{ MeV}$.

Could one understand the qualitative features of the nuclear binding energy spectrum on basis of this picture?

- (a) e_B is below 3 MeV for nuclei lighter than ${}^4\text{He}$ and has tendency to increase up to Fe. For the most abundant stable isotope of Fe with $(Z,A)=(26,56)$ it is 8.78 MeV. For heavier nuclei neutron number N increases and e_B starts to decrease.

- (b) For D one must have $\Delta n = 0$ and p-n pairing would be somehow responsible for the binding. For T the total binding energy is 8.478 MeV and could involve $\Delta n = -1$ for one nucleon. ${}^3\text{He}$ has total binding energy 7.715 MeV and also now one nucleon could have $\Delta n = -1$. ${}^4\text{He}$ has $e_B = 7.07$ eV. This suggests that p-n pairing causes reduction $\Delta n = -1$ for all nucleons in ${}^4\text{He}$ units proposed to be building bricks of nuclei.

For nuclei with odd Z and nuclei there are would be also deuteron sub-unit present and also $|A - Z|$ unpaired neutrons. This would reduce the binding energy. The prediction is that for nuclei with $N=Z$ with even Z the binding energy exceeds that for ${}^4\text{He}$. For heavier nuclei this can happen also for odd Z and also for N different from Z .

- (c) The pairing of to D subunits should be rise to binding energy 2.223 MeV per deuteron unit. Why the value is so small? Could deuteron unit correspond to a smaller string tension: perhaps corresponding to $k = 9$ instead of $k = 6$ as the ratio of ${}^4\text{He}/D$ binding energies per nucleon would suggest. The ratio of the maximal binding energy 8.7892 MeV per nucleon to deuteron binding energy is rather precisely 8, which supports the interpretation.
- (d) What causes the increase of e_B up to Fe ? Attractive potential energy does not look like an elegant interpretation in TGD framework. Some repulsive interaction should reduce the binding energy per nucleon for lighter nuclei than Fe from the value 8.8 MeV. The increase from ${}^4\text{He}$ to Fe is about 1 MeV. Why does this repulsive contribution decrease up to Fe ? Does it start to increase after that or is the presence of surplus neutrons the reason for the reduction? Or are both mechanisms involved?

The IR Regge trajectories considered are not the only ones as already the findings of Tatischeff and Tomasi-Gustafsson suggest and there might be trajectories with smaller string tension. The value of $k = 9$ with string tension $T(\pi)/8$ assignable to D , which corresponds to a e_B of about 1 MeV and this is roughly the total variation of the e_B from ${}^4\text{He}$ to Fe . Could both $k = 6$ and $k = 9$ flux tubes be present for given nucleon. Could the reduction of n for $k = 9$ flux tubes take place also for ${}^4\text{He}$ units as nuclei become heavier. What happens in nuclei heavier than Fe ? Could the increase of neutron surplus reduce e_B ?

Nuclear string has tension and reduces total binding energy e_B a contribution proportional to the length L of the string. Constant density for nuclei gives $R = r_0 A^{1/3}$, $r_0 = 1.2$ fm for the nuclear radius and $L \propto A \propto R^3$ for L . From this the contribution of string energy per nucleon is proportion to $L/A = \text{constant}$. The 20 per cent variation of r_0 is due the variation of e_B and cannot explain the variation of e_B .

To sum up, nuclear string model would reduce nuclear physics that for the magnetic body of the nucleon - obviously an enormous simplification.

7.6 A new twist in proton spin crisis

A new twist has appeared in proton spin crisis (see <http://tinyurl.com/yyzaa5ra>). The popular article tells about a rapid communication to Phys Rev d with title "Measurement of the longitudinal spin asymmetries for weak boson production in proton-proton collisions at $\sqrt{s} = 510 \text{ GeV}$ " [C73] (see <http://tinyurl.com/y34e9y99>).

- (a) u and d sea antiquarks contribute differently to proton spin which looks *very strange* if sea quarks originate from the decays of gluons as perturbative QCD predicts.
- (b) The amount of \bar{d} type sea quark is larger than that of \bar{u} type sea quark. But the amount of proton spin assignable to \bar{d} quark is smaller!

7.6.1 TGD based model for the anomaly

In TGD framework these findings give very valuable hints concerning the detailed structure of proton and also the proper interpretation of what are called sea quarks.

First of all, the notion of sea parton is rather fuzzy statistical notion tailored to the needs of perturbative QCD. Could it be that there could be a much more structured description analogous to that of atom or nucleus? In TGD framework nuclear string model describes nuclei as collection of nucleons connected by flux tubes having quark and antiquark at ends.

What does one obtain if one applies this picture to the earlier model in which valence quark space-time sheets are assumed to be connected by color flux tubes having quark and antiquark at their end forming meson like states. Consider the following picture.

- (a) uud with standard wave function describes valence quarks which are almost point like entities assignable to partonic 2-surfaces.
- (b) There are 3 color bonds in the triangle like structure formed by valence quarks. Assign to these
 - $\bar{d} - d$ spin singlet analogous to pion with spin 0,
 - $\bar{d} - u$ spin singlet,
 - $\bar{u} - d$ vector analogous to ρ meson with spin 1.

Identify the quarks and antiquarks of color bonds with the TGD counterpart of the sea.

- (c) Bonds taken together would carry total spin 1. As one forms spin 1/2 state with valence quarks with spin 1/2 valence quarks carry vanishing spin in the resulting state: this solves the core part of proton spin puzzle. Given valence quark has vanishing average spin due to the entanglement with bonds.
- (d) Also the observations can be understood qualitatively.
 - The amount \bar{d} in the sea is two times larger than the amount of \bar{u} .
 - The average contribution of \bar{d} to spin is vanishing in spin singlet bonds and spin 1 bond does not even contain \bar{d} . Hence the average contribution to sea quark spin vanishes.
 - The contribution of \bar{u} in $\bar{u} - d$ spin 1 bond is non-vanishing and experimentally known to be larger than that \bar{d} sea quark.

7.6.2 Why Gell-Mann quark model was so successful?

This model could also allow to understand how the old-fashioned Gell-Mann quark model with constituent quarks having masses of order $m_p/3$ about 310 MeV much larger than the current quark masses of u and d quark masses of order 10 MeV.

- (a) I have proposed that the current quark + color flux tube would correspond to constituent quark with the mass of color flux tube giving the dominating contribution in the case of u and quarks. If the sea quarks at the ends of the flux tubes are light as perturbative QCD suggests, the color magnetic energy of the flux tube would give the dominating contribution.
- (b) One can indeed understand why the Gell-Mann quark model predicts the masses of baryons so well using p-adic mass calculations. What is special in p-adic calculations it is mass squared, which is additive as essentially the eigenvalue of scaling generator of super-conformal algebra denoted by L_0 .

$$m^2 = \sum m_n^2 .$$

This due to the fact that energy is replaced by mass squared. Mass squared contributions with different p-adic primes cannot be added and must be mapped to their real counterparts first. On the real side is masses rather than mass squared, which are additive.

- (c) Baryon mass receives contributions from valence quarks and from flux tubes. Flux tubes have same p-adic prime characterizing hadron but quarks have different p-adic prime so that the total flux tube contribution $m^2(tube, p)$ mapped by canonical identification to

$m_R(tubes) = \sqrt{m_R^2(tubes)}$ and analogous valence quark contributions to mass add up. $m_B = m_R(tube) + \sum_q m_R(valence, q)$. The map $m_p^2 \rightarrow m_R^2$ is by canonical identification defined as

$$x_p = \sum_n x_n p^n \rightarrow x_R = \sum_n x_n p^{-n}$$

mapping p-adic numbers in continuous manner to reals.

- (d) Valence quark contribution is very small for baryons containing only u and d quarks but for baryons containing strange quarks it is roughly 100 MeV per strange quark. If the dominating constant contribution from flux tubes adds with the contribution of valence quarks one obtains Gell-Mann formula.

7.7 p-Adic mass calculations in flux tube model

The model for the findings about spin crisis led to a modification of the picture behind p-adic mass calculations. In the following hadron masses and also weak boson masses are estimated as a check of the model.

7.7.1 Estimating nucleon and pion masses

A detailed estimate for nucleon mass using p-adic mass calculations [?] shows the power of p-adic arithmetics even in the case that one cannot perform a complete calculation.

- (a) Flux tube contribution can be assumed to be independent of flux tube in the first approximation. Its scale is determined by the Mersenne prime $M_k = 2^k - 1$, $k = 107$, characterizing hadronic space-time sheets (flux tubes). Electron corresponds to Mersenne prime M_{127} and the mass scales are therefore related by factor $2^{(127-107)/2} = 2^{10}$: scaling of electron mass $m_{e,127} = .5$ MeV gives mass $m_{e,107} \simeq .5$ GeV, the mass electron had if it would correspond to hadronic p-adic length scale.

p-Adic mass calculations give for the electron mass the expression

$$m_e \simeq \frac{1}{\sqrt{n_e + X}} \times 2^{-127/2} \times m(CP_2) .$$

$n_e = 5$ corresponds to the lowest order contribution. $X < 1$ corresponds to the higher order contributions.

- (b) By additivity of mass squared for flux tubes one has $m^2(tubes) = 3m^2(tube, p)$ and $m_R(tubes) = \sqrt{3}m(tube, R)$: one has factor $\sqrt{3}$ rather than 3. Irrespective whether $m_R(tubes)$ can be calculated from p-adic thermodynamics or not, it has general form $m^2(tube, p) = np$ in the lowest order - higher orders are very small contribute to m_R^2 at most $1/p$. k is a small integer so that even one cannot calculate the its precise value one has only few integers from which to choose. The real mass from flux tubes is given by

$$m_R = \sqrt{3n_p/M_{107}} \times m_{CP_2} = \sqrt{3n_p/5} \times m(e, 107) .$$

For $n_p = 6$ (for electron one has $n_e = 5$) one has $m_R(tubes) = 949$ MeV to be compared with proton mass $m_p = 938$ MeV. The prediction is too large by 1 per cent.

- (c) Besides being by 1 per cent too large the mass would leave no room for valence quark contributions, which are about 1 per cent too (see <http://tinyurl.com/7496a6e>). There error would be naturally due to the fact that the formula for electron mass is approximate since higher order contributions have been neglected. Taking this into account means replacing $\sqrt{n_e} = \sqrt{5}$ with $\sqrt{5 + X}$, $X < 1$, in the formula for m_R . This implies the replacement $m_{e,107} \rightarrow \sqrt{5/(5 + X)}m_{e,107}$. The correct mass consistent with valence quark contribution is obtained for $X = .2$. The model would therefore fix also the precise value of $m(CP_2)$ and CP_2 radius.

- (d) What about pion mass? The naïve guess as mass of single flux tube assumed to be same as for proton gives mass equal to $m_p/\sqrt{3} \simeq 542$ MeV. Partially conserved axial current hypothesis assumes that pion is approximately massless. This could mean in TGD framework that its p-adic length scale is longer than that associated with M_{107} . For $p \simeq 2^{109}$ it would be 2 times longer, and one would have $m_p/2\sqrt{3} \simeq 271$ MeV, which is twice the mass $m(\pi_0) = 135$ MeV of π_0 ! Should one assume $p \simeq 2^{111}$? Note that the p-adic length scale assignable to deuteron correspond naturally to $k = 109$ and that assignable to nuclei corresponds to $k = 113$ so that the length scales would come as octaves.

7.7.2 Masses of other hadrons

I have considered in [?] the description of these effects in terms of a physical model for various contributions to mass squared. In the case of interactions describable in terms of contributions to energy - such as Coulomb interaction and spin-spin splitting for em and color interactions - one can ask whether this description is possible at all for p-adic mass squared and how to achieve that if it is possible.

One could be modest and start by looking whether an effective description using single p-adic prime is possible. For given n_X the maximal higher order contribution corresponds to the limit $k + X \rightarrow k + 1$. This in principle allows to fit any value of mass but if the fit is possible for small value of X , one can say that one might have more than a fit.

- (a) The lightest mesons π, K, η, η' have masses $(m(\pi), m(K), m(\eta), m(\eta')) = (135, 498, 548, 958)$ MeV. One obtains rather nice lowest order fits in terms of parameters (n_X, k) .
- $(n_\pi, k) = (6, 111)$ as already found.
 - $(n_K, k) = (5, 107)$ gives $m_K = 495$ MeV. The error is .8 per cent.
 - $(n_\eta, k) = (6, 107)$ gives $m_\eta = 543$ MeV. The error is .9 per cent.
 - $(n_{\eta'}, k) = (5, 105)$ gives $m_{\eta'} = 886$ MeV. Error is 7 per cent. k is taken to be larger than $k = 107$ in the fit. For $k = 107$ one would have $n_{\eta'} = 23$ giving 950 MeV with error .8 per cent.

The mass differences between mesons are usually ascribed to the large mass of strange quark but if the fit is taken at face value one must ask whether strange quark is very light also in mesons.

- (b) What about description of various additional effects such as electromagnetic splittings? Can one describe them effectively in terms of higher order p-adic contributions, which are approximately additive?

The color-magnetic spin-spin splitting in $\pi - \rho, \eta - \omega$ and $K - K^*$ systems is large and certainly not describable in this manner: can one describe it as first order effect. For $\pi - \rho$ system even the p-adic prime of π reduced by two actives. In the case of baryons color magnetic spin-spin splitting is relatively small.

The above estimates for the lightest mesons give very nice results in the lowest p-adic order: this suggests that for the lightest hadrons in multiplets differing by spin value the higher order contributions are very small. Color magnetic spin-spin splitting must be first order effect for light mesons. Taking (n_X, k) as the parameters to be fitted one obtains

- $(n_\rho, k) = (12, 107)$ predicting $m(\rho) = 768$ MeV to be compared with $m(\rho) = 770$ MeV. Error is .2 per cent. The large value offlux tube contribution conforms with the idea that color-magnetic interaction energy is in question.
- $(n_\omega, k) = (12, 107)$ giving $m_\omega = 768$ MeV to be compared with $m_\omega = 782$ MeV. The error is 1.8 per cent.
- $(n_{K^*}, k) = (16, 107)$ giving $m_{K^*} = 886$ MeV to be compared with $m_{K^*} = 895$ MeV. The error is 1.0 per cent.

- (c) The only natural description of Regge trajectories is using same value of k for all states so that the first order contribution gives the dominant contribution. The value of Regge slope is roughly $m_p^2 \sim 1 \text{ GeV}^2$ so that a good guess for the value of n along trajectory is as a multiple of $3 \times 6 = 18$.

To my opinion, these observations give good hopes that this model replacing quark sea with color bonds solve the proton spin crisis.

7.7.3 What about the masses of Higgs and weak bosons?

p-Adic mass calculations give excellent predictions for the fermion masses but the situation for weak boson masses is less clear although it seems that the elementary fermion contribution to p-adic mass squared should be sum of mass squared for fermion and antifermion forming the building bricks of gauge bosons. For W the mass should be smaller as it indeed is since neutrino contribution to mass squared is expected to be smaller. Besides this there can be also flux tube contribution and a priori it is not clear which contribution dominates. Assume in the following that fermion contributions dominate over the flux tube contribution in the mass squared: this is the case if second order contributions are p-adically $O(p^2)$.

Just for fun one can ask how strong conclusions p-adic arithmetics allows to draw about W and Z masses $m_W = 80.4 \text{ GeV}$ and $m_Z = 91.2 \text{ GeV}$. The mass ratio m_W/m_Z allows group theoretical interpretation. The standard model mass formulas in terms of vacuum expectation $v = 246.22 \text{ GeV}$ of Higgs read as $m_Z = \sqrt{g^2 + (g')^2}v/2$ and $m_W = gv/2 = \cos(\theta_w)m_Z$, $\cos(\theta_w) = g/\sqrt{g^2 + (g')^2}$.

- (a) A natural guess is that Higgs expectation $v = 246.22 \text{ GeV}$ corresponds to a fundamental mass scale. The simplest guess for v would be as electron mass $\sqrt{n_e}m_{127}$, $n_e = 5$, in the p-adic scale M_{89} assigned to weak bosons: this would give $v = 2^{19} \times m_e \simeq 262.1 \text{ GeV}$: the error is 6 per cent. For $n_e = 4$ one would obtain $v = 2^{19} \times \sqrt{4/5}m_e \simeq 234.5 \text{ GeV}$: the error is now 5 per cent.

For $n = 1$ the mass scale would correspond to the lower bound $m_{min} = 117.1 \text{ GeV}$ considerably higher than Z mass. Higgs mass is consistent with this bound. $n_h = 1$ is the only possible identification and the second order contribution to mass squared in $m_h^2 \propto n_h + X_h$ must explain the discrepancy. This gives $X_h = (m_h/m_{min})^2 - 1 \simeq .141$, Higgs mass can be understood but gauge boson masses are a real problem. Could the integer characterizing the p-adic prime of W and Z be smaller than $k = 89$ just as $k(\pi) = 111 = k(p) - 4$ is smaller than kp ?

- (b) Could one understand $\cos(\theta_w) = m_W/m_Z \simeq .8923$ as a ratio $\sqrt{n_W/n_Z}$ obtained using p-adic mass formulas for m_W and m_Z characterizing the masses in the lowest order by integer n ? For $n_W = 4$ and $n_Z = 5$ one would obtain using first order mass formulas $\cos(\theta_w) = \sqrt{n_W/n_Z} = .8944..$: the error is .1 per cent. For $k_Z = 89$ one would however have $m_Z = v = m_{e,89}$, which is quite too high. $k = 86$ using $m_e \propto \sqrt{5}$ would give $m_Z = 92.7 \text{ GeV}$: the mass is 1.6 per cent high. For $m_e \propto \sqrt{5 + X_e}$, $X_e \simeq .2$ deduced from proton mass, the mass is scaled down by $\sqrt{5/(5 + X_e)}$ giving 90.0 GeV which is smaller than 91.2 GeV : the mass is too large by 2 per cent. Higher order corrections via $X_Z = .05$ give a correct mass.

$k = 86$ is however not consistent with the octave rule so that one must $k_Z = k_W = 85$ with $(n_W, n_Z) = (8, 10)$. This strongly suggests that p-adic mass squared is sum of two identical contributions labelled by $n_W = 4$ and $n_Z = 5$: this is what one indeed expects from p-adic thermodynamics and the representation of gauge bosons as fermion-antifermion bound states. Recall that also for hadrons proton and baryonic space-time sheet correspond to M_{107} and pion to $k(\pi) = k(p) - 4 = 111$.

- (c) There can be also corrections characterized by different p-adic prime: electromagnetic binding energy between fermion and anti-fermion forming Z boson could be such a correction and would reduce Z^0 mass and therefore increase Weinberg angle since W boson does not receive this correction. Higher order corrections to m_W and m_Z however

replace the expression of Weinberg angle with $\cos(\theta_W) = \sqrt{n_W + X_W / (n_Z + X_Z)}$ and allow to obtain correct Weinberg angle. Note that canonical identification allows this if the second order correction is of form rp^2/s , s small integer.

8 Still about quark gluon plasma and M_{89} physics

I heard an excellent finnish radio program about the experimentation done by ALICE collaboration at LHC. ALICE (see <http://tinyurl.com/ybbhw2vj>) studies quark gluon plasma (QGP, see <http://tinyurl.com/yb916ege>) believed to be created in p-p, p-A, and A-A high energy collisions. Here p denotes proton and A heavy nucleus such as Au or Pb chosen so that it has spherical shape - this just to simplify the data analysis.

In the first approximation the nuclei are expected to go through each other but for high enough collision energy QGP is predicted to be created. The kinetic energy of the incoming beams would materialize to quarks and gluons giving rise to QGP. The high density of this phase would be one of its key signatures.

The existence of this high density phase was first shown at RHIC and at LHC its existence has been shown for p-p, p-A, and A-A collisions at ALICE. The plasma appears around $T \sim .17$ GeV (pion mass is about .14 GeV). The plasma region is cylindrical (see <http://tinyurl.com/ybbnx8sa>). In the case of Au nuclei the longitudinal radius is in the range of 7-8 fm. Transversal radii orthogonal to beam direction and orthogonal or parallel to the scattering plane are same and about 6-7 fm. All radii decrease as the transverse momentum of the jet from which it is deduced increases. The energy density of plasma is about GeV/fm³. The total energy of plasma would be about 288 GeV.

8.1 What QCP should look like?

If QGP is what QCD predicts it to be it should have certain signatures.

- (a) QCD predicts that QGP is non-Abelian analog of ordinary electromagnetic plasma: non-Abelianity implies color confinement at large distances and asymptotic freedom at small distances. These are due to the growth of color coupling strength α_s as function of the length scale.
- (b) Color confinement means that QGP has vanishing total color charges. Asymptotic freedom implies that the interaction becomes weak at short distances. As in ordinary plasma, color charges are screened within a sphere, whose radius is known as Debye radius.
- (c) Quark jets do not propagate in the plasma it which has explanation in terms of long ranged color interactions not present in hadronic phase. QGP phase is predicted to appear in high enough temperature $T \sim .17$ GeV. This temperature is higher than the rest mass of strange quarks about 100 MeV and this makes possible the production of strange hadrons.

These predictions have been verified. The QGP at criticality is however something between hadronic phase and quark gluon gas and implies new effects.

- (a) In QCD one expects critical phase associated with the transition from hadronic gas with very short ranged interactions to QGP having gas like behavior. The intermediate phase would be analogous to that encountered in phenomena like freezing and boiling and involve criticality meaning long range correlations and fluctuations. The transition is analogous to the formation of the ordinary electromagnetic plasma consisting of charged particles from a gas of neutral particles by ionization at some critical temperature.
- (b) I heavy ion collisions one expects that the formation takes place in the volume containing the nucleons of colliding nuclei so that about 400 nucleons are involved. The

intermediate phase would have quite large size, and one expects that the quarks originally inside nucleons are de-localized to this volume, which is quite large and should define the size scale of QGP in the transition region. Somewhat surprisingly, also p-A collisions have show unexpected phenomena characterizing A-A collisions.

- (c) Could criticality and long range fluctuations appear in the scale of the entire collision region? In TGD framework one can even ask whether quantum criticality rather than only thermodynamical criticality could be considered in the scale of the collision region. This would bring in totally new quantum effects.

8.2 Unexpected findings

Several unexpected phenomena have been found.

- (a) An extremely low shear viscosity (see <http://tinyurl.com/y7kekzmzm>) to entropy ratio $\eta/s \sim \hbar x/4\pi$, $x \in (1, 3)$ have been observed. This ratio is essentially the ratio of entropy to the particle number density. Shear viscosity describes how effectively the velocity gradient orthogonal to flow velocity dissipates momentum. Water has low η/s , honey has high η/s .

Hadronic gas consisting in good approximation of mesons π, ρ, K, K^* predicts η/s ratio by a factor 2 or 3 higher than the observed ratio. One expects that at higher temperatures gas behavior emerges and has higher η/s ratio proportional to \hbar/α_s^2 as a signature. $\alpha_s \sim .1$ implies that η/s is quite large. Low value of η/s should thus relate to the criticality of the transition somehow.

$\eta/s = \hbar/4\pi$ is a prediction of many theories such as $\mathcal{N} = 4$ SUSY but also lower values are known to be possible theoretically. Low η/s ratio means that viscosity has a small effect and one has almost ideal liquid. Liquid property means that one can speak about flow of quarks and hydrodynamics (see <http://tinyurl.com/y9nwyawg>) should allow a good description of the situation.

Ideal liquid like behavior suggested by the low value of η/s conforms with the long range correlations expected at criticality. In gas phase the particles would move randomly and one could not speak about flow. What is essential is that one can assign to a system a distributed order parameter - now the flow velocity - in the scale of the plasma region. At quantum criticality this distributed parameter would be analogous to wave function characterizing quantum state and defined in the entire plasma volume.

- (b) Double ridge structure detected in p-Pb collisions (see <http://tinyurl.com/y81cqbjq>) and also in other collisions came as a total surprise and has no explanation in pure QCD picture. To explain what is involved, one must introduce (η, ϕ) plane, where η denotes the hyperbolic angle of 2-D Minkowski plane M^2 determined by time axis and the momentum direction of the detected particle and tells the velocity of the particle, and ϕ is the azimuthal angle in the scattering plane.

One assumes that the first particle moves in direction specified by the value of ϕ and determines the distribution of particles moving in direction $\phi + \Delta\phi$. One finds that there is high probability finding a particle in the same direction having thus $\Delta\phi = 0$ and also that the particle can have widely different value of η so that one obtains a ridge like structure in (η, ϕ) -plane with a length $\Delta\eta \sim \pm 5$ units. This is the nearside ridge. One observes also completely symmetric ridge with $\Delta\phi \sim \pi$ and particles moving to opposite direction - the awayside ridge. I have already earlier proposed that correlations reflect creation of pairs of particles in a decay of M_{89} pion modellable as a string like like object - color magnetic flux tube with length of order of the Compton length of ordinary pion.

- (c) In QCD picture charmoniums are expected to be produced with a slow rate since the high temperature higher than the binding energy scale should melt them. It seems that this prediction is not true in heavy ion collisions. A possible QCD based explanation would be regeneration of charmoniums or a large number of charmoniums in the initial state.

I have already earlier proposed explanation in terms of a creation of dark pions (and possibly also heavier mesons) of M_{89} hadron physics with Planck constant $h_{eff} = 512 \times h$. M_{89} pions would be flux tube like structures having mass 512 times that of ordinary pion but having the same Compton length as ordinary pion and being of the same size as heavy nuclei. The unexpected features of QGP, in particular long range correlations, would reflect quantum criticality. Double ridge structure would reflect the decay of dark mesons to ordinary hadrons. In the sequel this proposal is discussed in more detail.

8.3 Could criticality of QGP correspond to quantum criticality and dark variant of M_{89} hadron physics?

Consider first the key ideas relevant for the TGD based model.

- (a) p-Adic length scaled hypothesis is the first building brick of the model. TGD strongly suggests the existence of fractally scaled variants of hadron physics at p-adic length scales which correspond to Mersenne primes $M_n = 2^n - 1$ or Gaussian Mersennes $M_{G,n} = (1+i)^n - 1$. M_{89} hadron physics is especially interesting from the point of view of LHC. Bumps with masses which are obtained by scaling masses of ordinary mesons by factor 512 have been reported and could be see indications for the production of also heavier M_{89} mesons.
- (b) Second key notion is quantum criticality characterized by $h_{eff}/h_0 = n$ [?]. on basis of quantum criticality, which is basic aspect of TGD based physics at the level of single space-time sheet. Many-sheeted space-time is replaced at QFT limit by a region of Minkowski space since the sheets are lumped together. Therefore quantum criticality is in general lost at this limit.
Quantum criticality at QFT limit requires that single sheet dominates the dynamics. More generally, single sheet can correspond to n-sheeted covering of M^4 with sheets related by Galois symmetry and characterized by $h_{eff}/h_0 = n$ telling the order of the extension of rationals involved and the order of the Galois groups in case of Galois extension. By Galois symmetry one has single sheet but h is replaced with $h_{eff} = nh_0$.
- (c) Twistor lift of TGD is the third key element. $\mathcal{N} = 4$ SUSY predicting $\eta/s = 1/4\pi$ is characterized by Yangian symmetry, which more or less dictates the twistorial scattering amplitudes [K46, L30]. Twistor Grassmann approach generalizes in TGD framework as also the twistorial construction of scattering amplitudes, which suggests that it might be possible to understand the low value of η/s .
- (d) The notion of magnetic body (MB) carrying dark matter is central in the applications of quantum TGD. For instance, in cosmology the Kähler magnetic energy of flux tubes carrying monopole flux would decay to ordinary matter during cosmic expansion and this process would be analogous to the decay of the vacuum expectation value of inflaton field.

In the case of hadrons MB would correspond to a color magnetic body carrying most of the energy of hadron with quarks contributing only a tiny fraction to the rest energy. Also the parton sea could give only a small fraction to the rest energy of hadron. As a matter of fact, all elementary particles correspond in TGD to closed flux tubes carrying monopole flux and also dark M_{89} meson would be such flux tube like structure.

Could the entities overlapping in the collisions above critical temperature be color magnetic body associated with the colliding systems possibly formed during the collision? Could the color magnetic bodies of nucleons fuse together to form a larger color magnetic body having size of order pion Compton length consisting of M_{89} mesons? Could the decay of the color magnetic energy of M_{89} mesons materialized from the collision energy of the nuclei to ordinary quarks and leptons produce QGP?

8.3.1 Could dark M_{89} hadron physics explain the strange findings about QGP candidate?

Could the phase transition correspond to a transition to M_{89} quantum critical phase decaying to ordinary QGP predicted by QCD?

- (a) The mass of M_{89} pion is estimated to be $m_{\pi_{89}} = 512 \times m_{\pi} \sim 70$ GeV so that the mass 288 GeV of the plasma region of volume about 288 fm^3 created in Au-Au collisions would correspond to about 4 M_{89} pions. This allows to consider the possibility that a few meson state of M_{89} hadrons is formed at quantum criticality and decays to the ordinary quark gluon plasma.

The strange properties of the observed state could be induced from the properties of this quantum critical quantum state. The unexpectedly low value of η/s indeed suggests the existence of an order parameter in the scale of colliding nuclei and the wave function for the quantum critical M_{89} few-meson state would correspond to this parameter.

- (b) M_{89} dark particles must however have so large value of $n = h_{eff}/h$ that their scaled up Compton length $\lambda_{89,n} = n \times \lambda_{89} = n \times \lambda_{107/512}$ of M_{89} pion is of the order of the transversal size of the colliding particles. One can argue that for p-p collisions the scaled up Compton length could of the order of the Compton length of the ordinary pion about 8 fm: this would give $n = 2^{(107-89)/2} = 512$. The radius of Gold nucleus about 7 fm. Heaviest nuclei have radius about 7.5 fm so that this seems to make sense. The simplest assumption is that $\lambda_{89,512}$ characterizes also p-A collisions and perhaps even p-p collisions. This could explain the observation of effects expected to be present only for A-A collisions also in p-p and p-A collisions. One must however remember that also other values of n can be considered and the long range quantum fluctuations realized at quantum criticality could corresponds to a spectrum for n .

One could also consider A-A collisions and argue that heavy nuclei are characterized by the nuclear p-adic length scale $L(113) = 2^{(127-113)/2}L(127) = 128L(127)$. If one identifies $L(127)$ as electron Compton length $L_e \sim 2.4 \times 10^{-12}$ m this gives, $L(113) = 19$ fm. If Compton length corresponds to diameter geometrically then this would give scale 9.5 fm marginally consistent with the above estimate.

One could visualize dark M_{89} pion as 512 ordinary pions on top of each other (in CP_2 degrees of freedom) and forming 512-sheeted structure as covering of M^4 defined by the space-time surface.

- (c) The observed ridges would reflect the decays of M_{89} pion identified as a string like object (color magnetic flux tube) with length of order ordinary pion Compton length but with mass of about 70 GeV to ordinary quarks and gluons. There are also indications for the bumps assignable to other M_{89} mesons [K25].
- (d) There is a general order of magnitude estimate for η/s (see <http://tinyurl.com/y9nwyawg>) as

$$\eta/s = \tau_R T = \hbar \tau_R / \tau_q ,$$

where τ_R is particle relaxation time and $\tau_q = \hbar/T$ is thermodynamical quantum time scale: it should be difficult to transfer energy with rate higher than $1/\tau_q$.

The estimate for η/s is proportional to \hbar . If τ_R is assignable to dark M_{89} phase, it should be proportional to \hbar_{eff} and $\hbar_{eff} = 512\hbar$ would make η/s very large. Therefore the quantum critical state cannot correspond to the observed plasma state. Rather, the observed state (as ordinary matter) would correspond to ordinary matter produced in the phase transition reducing the value of \hbar_{eff} and giving rise to ordinary quarks and gluons transforming to hadrons.

The interpretation of τ_R could be as a time scale for the decay of the dark quantum critical M_{89} few meson state to ordinary quarks and gluons.

- (e) The production of charmoniums in p-A and A-A collisions is in conflict with the QCD expectations. A possible explanation is suggested by TGD based explanation of family replication phenomenon in terms of generation-genus correspondence [K11, K25].

Fermion generations would correspond to the topologies of orientable partonic 2-surfaces with genera $g = 0, 1, 2$ distinguished from the higher genera because they allow always global Z_2 as conformal symmetry. Different fermion genera form effectively a triplet representation of a dynamical gauge group $U(3)_g$.

Ordinary gauge bosons as fermion-antifermion pairs would correspond to a singlet of $U(3)_g$. Besides this there would be also an octet consisting of two $SU(3)_g$ neutral gauge bosons and 3+3 $SU(3)_g$ charged gauge bosons assumed to be heavy. The $U(3)_g$ charge matrices of $SU(3)_g$ boson generations are orthogonal to that assignable to the ordinary gauge bosons (unit matrix implying the universality of standard model interactions). This predicts breaking of universality for which there are some indications as also for the predicted 2 $SU(3)_g$ neutral generations of electroweak gauge boson [K25].

M_{89} gluons need not be exact fractally scaled up copies of ordinary gluons but could correspond to second generation gluons and therefore break the universality of the ordinary color interactions - there are indications also for this [K25]. This could lead to a higher rate for the production of higher quark generations in the decay of M_{89} pions if it involves M_{89} gluons as intermediate states and could perhaps explain higher rate for charmonium production. The quarks forming M_{89} mesons should be ordinary quarks and only the color magnetic energy (the counterpart of gluonic ground state energy in QCD) would distinguish them from the ordinary mesons.

The proposed option is perhaps the simplest one found hitherto. One can consider also different options.

- (a) Could the quantum coherence in the scale of colliding nuclei correspond to the formation of dark M_{107} hadronic phase with $n = 2^{(113-107)/2} = 8$ corresponding to the ratio of nuclear and hadronic scales? Amusingly, this would scale up nuclear volume by a factor 512. Could one imagine in many-sheeted space-time that also $M_{107,8}$ dark level is present besides $M_{89,512}$?
- (b) I have earlier [K25] considered the possibility that peripheral collisions as quantum critical events could give rise to the generation of M_{89} mesons with mass above 70 GeV. However, in peripheral collisions ordinary short range strong interactions are absent, and one can argue that the energy transfers involved are so small that the formation of plasma phase with total energy of about 288 GeV from the kinetic energy of the colliding particles is highly implausible.

The formation of dark quantum critical phase in the length scale defined by the volume of the colliding nuclei would be required and this looks infeasible unless new physics is involved. The miracle would require that the color magnetic bodies of the colliding nuclei overlap considerably also in the peripheral collisions. This would predict the detection of QGP also in peripheral collisions. This prediction very probably kills this idea using the existing data.

9 About parity violation in hadron physics

Strong interactions involve small CP violation revealing itself as small differences in the properties of neutral kaon and its anti-kaon. An interesting question is whether CP violation and also P violation could be seen also in hadronic reactions.

In QCD framework the de-confinement phase transition from a phase in which quarks are confined inside hadrons to quark-gluon plasma consisting of free quarks and gluons is believed to occur. This transition would be also accompanied by a phase transition in which chiral symmetry is restored. The breaking of chiral symmetry is due to the mass of quarks: one cannot assign definite chirality to massive quarks. When the massive quarks become massless or at least effectively massless, the chiral symmetry should be restored. What really happens in this transition is however not well-understood.

There are several effects associated with the de-confinement phase transition.

- (a) The so called chiral magnetic effect (CME) in which Poles receive opposite charges (Equator is defined by scattering plane) is proposed to be associated with the transition and would involve also P violation.
- (b) One also expects chiral separation effect (CSE) meaning separation of quarks and anti-quarks having opposite chiralities along the magnetic axis. There are some experimental indications for CME and CSE.
- (c) Chiral magnetic wave (CMW) appearing in quark-gluon plasma is a combination of CME and CSE. In CWM Poles get a positive charge increment and Equator a negative charge increment. Chiral magnetic wave (CMW) is a combination of CME and CSE associated with the chirally symmetric phase. CMW involves transformation of electric dipole to quadrupole. I must admit that I do not really understand the mechanism giving rise to CMW.

To get an intuitive view about CME consider what happens in HN-HN collision, which is not head-on.

- (a) One can speak of scattering plane and the system possesses angular momentum transformed to a rotational angular momentum of quarks as the colliding nuclei fuse together. There is large positive charge density involved. Therefore rotating quarks create a magnetic field parallel to the rotation axis. The positive charge density creates radial electric field parallel to the magnetic field due to the quarks swirling in the reaction plane. Quarks and antiquarks flow to opposite directions in the electric field and charge separation takes place.
- (b) The prediction would be that oppositely charged pions tend to flow to opposite directions orthogonal to the scattering plane. CME would occur near criticality for the formation of quark-gluon plasma and would be quantum critical phenomenon involving macroscopic quantum coherence. The experimental signature is a surplus of positive pions over negative pions in either hemisphere defined by scattering plane and surplus of negative pions over positive pions in the opposite hemisphere. CME means also P breaking.
- (c) CME should appear in heavy nucleus (HN-HN-) collisions and there are indications that something like this indeed takes place. CME should not occur in proton-nucleus collisions since the proton now goes through the nucleus and most collisions are central and there is no angular momentum so that no magnetic field is generated.

Therefore the recent discovery of evidence for the charge separation also in proton-Pb collisions challenges CME (see <http://tinyurl.com/1t5reno> and <http://tinyurl.com/kkx4x2y>) and motivates the attempt to understand whether CME and related effects have analogs in TGD.

9.1 Timeline for CME

It is appropriate to begin with a brief time-line about CME.

- (a) 2005: Dmitry Kharzeev proposed that de-confinement transition involves chiral magnetic effect (CME). For a brief Wikipedia summary of CME see <http://tinyurl.com/1t93ve4>. The article *Parity violation in hot QCD: why it can happen, and how to look for it* [C106] (see <http://tinyurl.com/1wk17cu>) considers a theoretical model based on QCD.
- (b) 2009: STAR collaboration found the first evidence for CME [C98].
- (c) 2015: STAR collaboration working at RHIC found evidence for the emerged evidence for CMW in heavy nucleus collisions. The popular article *Scientists see ripples of a particle-separating wave in primordial plasma* (see <http://tinyurl.com/mus4xz9>) might help to get an idea about what was found. The technical article *Observation of charge asymmetry dependence of pion elliptic flow and the possible chiral magnetic wave in heavy-ion collisions* [C106] can be found at <http://tinyurl.com/1wk17cu>.

- (d) 2016: Evidence for CME is reported also in condensed matter physics (see *Chiral magnetic effect generates quantum current* at <http://tinyurl.com/mmet3h4>). Quarks are however replaced with quasiparticles which can be positively and negatively charged. What was found that when material called zirconium pentatellurite is placed in parallel electric and magnetic fields, it responds with an imbalance in the number of right and left handed quasiparticles - a chiral imbalance pushing opposite charged particles in opposite directions and creating an electric current. The current would not dissipate because it is topological. This suggests a new kind of super-conductivity, which does not involve spontaneous symmetry breaking.
- (e) 2017: Evidence for CME was discovered in proton-nucleus collisions. This was not expected. Rice physicists Wei Li and Zhoudunming (Kong) Tu proposed a new approach for studying CME and found that it is present also for proton-nucleon collision. This does not conform with the theoretical expectations. See the popular article *Proton-nuclei smashups yield clues about 'quark gluon plasma'* at <http://tinyurl.com/lt5reno>.

The article *Observation of Charge-Dependent Azimuthal Correlations in p-Pb Collisions and Its Implication for the Search for the Chiral Magnetic Effect* [C96] by V. Khachatryan *et al* gives a representation for specialists (see <http://tinyurl.com/kkx4x2y>). I glue the abstract of the article here.

Charge-dependent azimuthal particle correlations with respect to the second-order event plane in p-Pb and Pb-Pb collisions at a nucleon-nucleon center-of-mass energy of 5.02 TeV have been studied with the CMS experiment at the LHC. The measurement is performed with a three-particle correlation technique, using two particles with the same or opposite charge within the pseudo-rapidity range $|\eta| < 2.4$, and a third particle measured in the hadron forward calorimeters ($4.4 < |\eta| < 5$). The observed differences between the same and opposite sign correlations, as functions of multiplicity and η gap between the two charged particles, are of similar magnitude in p-Pb and Pb-Pb collisions at the same multiplicities. These results pose a challenge for the interpretation of charge-dependent azimuthal correlations in heavy ion collisions in terms of the chiral magnetic effect.

CME is not directly observed for p-Pb collisions but the three-particle correlations as functions of particle multiplicity and η gap for two charged particles are deduced. The differences between the same and opposite sign correlations interpreted as signatures of CME are found to be of similar magnitude in p-Pb and Pb-Pb collisions. Note that pseudorapidity $\eta = -\log((|p| + p_L)/(|p| - p_L))$ (see <http://tinyurl.com/lg3goeh>) characterizes the angle θ between beam direction and particle momentum. η changes sign when longitudinal momentum p_L changes sign.

9.2 About CME and related effects in QCD framework

In the sequel I review briefly my non-specialist understanding about strong CP breaking and CME and related effects.

9.2.1 Strong CP problem

QCD in principle allows strong CP violation. The origin of CP violation is the possibility of multi-instanton solutions in QCD. Instantons are either self-dual or anti-self-dual exact solutions of Yang-Mills equations. Instantons break the conservation of axial currents expected to hold true in massless theories. The divergence of the axial current is proportional to the instanton density, which reduces to a total divergence, whose space-time integral is however non-vanishing and integer valued and gives the change of total axial charge.

Atiyah-Singer index theorem (see <http://tinyurl.com/k6daqco>) implies that the change of axial charge is identifiable as the difference for the numbers of fermions with right-handed and left handed chirality. The fermions are assumed to be massless, and the argument is somewhat questionable when fermions are massive.

The vacuum can be written as a superposition of ground states with varying number of instantons. By simple argument one can conclude that the ground state with instanton number n has weight $\exp(in\theta)$, where θ is an angle parameter about which QCD does not tell anything. One can describe the situation in a simple manner by adding to the QCD YM action, whose exponential defines the theory, an instanton term, which is θ times the integer valued instanton charge. In principle one must perform perturbation theory in instanton background for each value of n and sum up the results. The instanton term modifies the scattering amplitudes, and the evaluation of these non-perturbative effects is difficult mathematically since in instanton background one loses momentum conservation for the basic vertices and one must perform path integral over different instanton configurations.

Also the modification of Dirac action is possible. In this case one has second angle - θ' - replacing mass m with $\exp(i\gamma_5\theta') \times m$ in massive Dirac action. In massless case the modification is trivial. The factor $\exp(i\gamma_5\theta')$ can be however absorbed to the definition of gamma matrices. The modification of YM action is non-trivial even in massless case. If at least one quark is massless, θ is claimed to become unobservable for a reason that I failed to understand. Unfortunately, there are no massless quarks.

The big problem of QCD is that strong CP violation have not been observed (see <http://tinyurl.com/phju91lj>): one has $\theta < 3 \times 10^{-13}$ from the electric dipole moment of neutron. Peccei-Quinn axion (see <http://tinyurl.com/q9p56ke> and <http://tinyurl.com/k2x1h6d>) has been proposed as a solution of the problem. θ is made a dynamical field - axion - coupling to the instanton density linearly. Several axion candidates have been proposed and excluded. Axion could be also very weakly interacting particle and thus dark matter: the mass scale should be between 50-1500 μeV from various constraints.

Remark: Pseudoscalar-instanton coupling appears also in other anomaly considerations. For instance, coupling of neutral pion to electromagnetic counterpart of instanton term appears in the model predicting the pion life-time from partial conservation of axial current hypothesis (PCAC).

9.2.2 Kharzeev's model for CME

For ordinary QCD vacuum the parameter θ characterizing strong CP breaking is essentially zero. The proposal of Kharzeev [C106] (see <http://tinyurl.com/lwk17cu>) is that in deconfinement phase transition a metastable regions θ domains - with position dependent θ are formed and they induce separation of quark chiralities - chiral separation effect (CSE) - and charge separation by CME. The interpretation of $\theta(x)$ is left open. Could it correspond to some variant of Peccei-Quinn axion field?

For given value of instanton number n a chiral asymmetry is generated and instanton number tells the change of the chiral flips for fermions. Massless quark and antiquark have opposite chiralities and the transition can also generate asymmetry as asymmetric production of quarks and antiquarks. The model predicts fluctuations since the sign and value of n can vary so that the effect is not easily restable.

A net chirality generated by instanton defining the metastable state in question. The net chirality could be realized either by the spin flips for quarks and antiquarks in magnetic field and by opposite directions of motion for quarks and antiquarks. Kharzeev assumes that a mass field $m \times \exp(i\theta(x))$ scattering quarks is present. I failed to understand why one does not have $m \times \exp(i\gamma_5\theta)$ as in the original representation of the axial anomaly.

The definition of chirality for massive quarks is problematic since spinors are not eigenstates of γ_5 . The idea is to assume that spin direction in some fixed frame defining spin quantization axis defines chirality: this is intuitively plausible if the quarks/antiquarks move parallel/antiparallel to this axis. In non-head-on collision the magnetic field generated by the incoming heavy nuclei defines the preferred spin quantization axis. For p-HN head on collision this is not the case.

9.3 CP breaking in TGD Universe

Chiral magnetic effect (CME) is very interesting effect from TGD point of view since it involves breaking of CP and P possibly relating to the breaking of CP in hadron physics.

9.3.1 Kähler form of M^4

Twistor lift of TGD [K17, K7, L30] forces to assume the analog of self-dual covariantly constant Kähler form $J(M^4)$ for Minkowski space M^4 contributing to the Kähler form (or rather for causal diamond of M^4). $J(CD)$ corresponds to the presence of parallel constant $U(1)$ electric and magnetic fields coupling to fermion number. This is the just prerequisite for charge separation in CME!

- (a) Does the M^4 Kähler form contribute to the $U(1)$ of em field or does it represent a classical field of its own? $J(CD)$ couples to fermion number. In particular, it has also a coupling to right-handed neutrinos! Since neutrinos are em neutral this allows only the interpretation as an additional $U(1)$ field coupling to fermion number. Right-handed neutrinos are known to be extremely weakly interacting, which demands that the preferred extremals are such that the electric component of $J(CD)$ is small. Alternatively, the corresponding gauge coupling is very small: a reasonable guess inspired by the size of CP breaking of K mesons is that the coupling is some power of l_p^2/R^2 [L30].
- (b) In TGD the induced $J(CD)$ field created by the density of nuclear baryonic number replaces the electromagnetic field created by a constant charge density in HN-HN collisions. For the canonical embedding of M^4 the induced $J(CD)$ would be self-dual and charge separation would be forced by $J(CD)$ in the direction defined by the $M^4 = M^2 \times E^2$ decomposition defined by $J(CD)$. There is strong temptation to think that matter-antimatter asymmetry is basically due to CME along $U(1)$ magnetic flux tubes connecting the regions containing matter and antimatter.
- (c) $J(CD)$ couples to fermion number defined as $F = B + L$. Since leptons and baryons have opposite fermion numbers, $U(1)$ flux tubes as counterparts of field lines can connect baryons and leptons. Note that atoms have vanishing $U(1)$ charge F .
- (d) What is important that space-time surfaces themselves satisfy the analogs of field equations for point like particles in $U(1)$ field. They are obtained by replacing point like particles 3-D objects. This is one of the key predictions of twistor lift of TGD predicting that 4-D action contains a volume term besides Kähler action. The volume term alone would give the analog of geodesic motion and Kähler action adds coupling to $U(1)$ force. Asymptotic state are minimal surfaces analogous to geodesics having vanishing $U(1)$ force. $U(1)$ force appears only in transient situations like particle scattering events. The first interpretation of volume term would be in terms of cosmological constant. It however seems that the more plausible interpretation of the entire action is in terms of cosmological constant.
- (e) Atomic nuclei have baryon number equal the sum $B = Z + N$ of proton and neutron numbers and neutral atoms have $B = N$. Only hydrogen atom would be also $U(1)$ neutral. The dramatic prediction of $U(1)$ force would be that neutrinos need not be so weakly interacting particles as has been thought. If the quanta of $U(1)$ force are not massive, a new long range force is in question. $U(1)$ quanta could of course become massive via $U(1)$ super-conductivity causing Meissner effect.

Suppose that $U(1)$ force is long ranged. Could $B = N$ be neutralized by neutrinos? Could the cosmic background of neutrinos neutralize the $U(1)$ charge of matter? Could this occur even at the level of single atom or does one have plasma like state?

I have earlier considered Z^0 atoms but these are excluded in the recent model of elementary particle in which weak isospin is screened by neutrinos in the scale of Compton length of particle. Interestingly, for Z^0 force neutrino Bohr radius would be of order $a_0 = \hbar/\alpha_Z m_\nu$ and for $m_\nu = .1$ eV it would be of 12 μm , which corresponds to cell length scale.

What about $U(1)$ force? Suppose α_1 is of order of $\alpha_1 = l_P/R = 2^{-12}$ (l_P is Planck length and R is CP_2 radius as the arguments related to cosmological constant [K7] and to the size scale of CP breaking [L30] suggest). The Bohr radius of the neutrino atom would be for $m_\nu = .1$ eV about $a_0 = .8$ nm. Ground state binding energy would be about $E_0 = \alpha_1^2 m_\nu/2$ giving $E_0 = .34 \times 10^{-8}$ eV: this is below the thermal energy of cosmic neutrinos estimate to be about 1.95×10^{-4} eV (see <http://tinyurl.com/1du95o9>). Thus matter would be $U(1)$ plasma. $U(1)$ superconductor would be second option. If right-handed neutrinos generate $\mathcal{N} = 2$ SUSY then $U(1)$ charge would break this symmetry.

One could neutralize $U(1)$ charge in atomic scale using also electrons giving exotic ions. For $\alpha_1 = 2^{-12}$ Bohr radius would be something like cell membrane size scale $a_0 = 43$ nm. Note that the diameter would roughly $L(157) \simeq 8$ nm, $MG, 157 = (1+i)^{157} - 1$ is one of the miraculous Gaussian Mersennes associated with $k = 151, 157, 163, 167$ in the range of biologically most important length scales between 10 nm and $2.5 \mu\text{m}$. The resulting state would be negatively charged and one can ask whether the negative charges of DNA and cell could relate to the formation of $U(1)$ neutral states. Binding energy for would be around $E_0 = .03$ eV, which rather near to membrane potential. These exotic ions could be thermally stable for $Z \geq 2$ due to the presence of N^2 factor.

One can represent an objection against the assumption that only covariantly constant $J(CD)$ are allowed: one can imagine also spherically and cylindrically symmetric and Lorentz invariant $J(CD)$ s. Consider the $U(1)$ Coulomb field of point charge.

- (a) Should one assign the $U(1)$ electric flux with radial flux tubes? One would assign to each flux tube M^4 Kähler form $J(CD)$ for which the directions of electric and magnetic fields are in the direction of the flux tube. Every flux tube would be accompanied by its own CD and $J(CD)$! A lot of CDs, which also overlap! Isn't this too complex? Also the simple minimal surface solutions serving as models for stellar objects are lost if only covariantly constant $J(CD)$ s are allowed and can appear as approximations only.

One should have a good explanation for why so much CDs are allowed. The proposed explanation is that CD represents the perceptive field of a conscious entity and the preferred directions of CD fix the rest system and spin quantization axis associated with it [L31]. CDs would represent the analog for the covering by open sets defining topological space or manifold. In TGD the notion of adelic/monadic manifold requires an analogous covering with CDs associated with the discrete set of points of space-time surface with the property that the coordinates belong to an extension of rationals [L26].

- (b) Or should one accept also non-covariantly constant self-dual $J(CD)$ s with radial electric and magnetic fields necessarily having electric charge and magnetic monopole at the time-like line connecting the tips of CD? Self-dual $J(CD)$ with $J_{\theta\phi} \propto \sin(\theta)$ and $J^{0r} = \epsilon^{0r\theta\phi} J_{\theta\phi}$ (note that $\epsilon^{0r\theta\phi}$ is permutation symbol divided by $1/\sqrt{g_4}$ having em charge and magnetic monopole charge at the line connecting the tips of CD would satisfy the conditions. Genuine monopole singularity is not an attractive idea. Lorentz invariant solution in Robertson-Walker coordinates (a, r, θ, ϕ) is completely analogous. Cylindrically symmetric variant would have fermion charge density along 2-D surface within CD M^2 and is unphysical.

Clearly, the first option suggesting deep connection between the notions of topological space and manifold, number theory, and consciousness is the more plausible one.

9.3.2 Strong CP problem disappears in TGD

Does strong CP problem appear in TGD framework? Can one have analogs of instanton solutions in TGD?

- (a) M^4 chirality is replaced in TGD with H -chirality with different chiralities corresponding to leptons and quarks. 8-D chiral invariance is exact in TGD and all particles are massless in 8-D sense: this makes possible for the twistorialization of TGD to overcome

the problems of ordinary twistor approach cause by particle masses [K7, L30]. 8-D chiral invariance does not have axial anomaly.

- (b) One can talk about M^4 -chirality but axial current conservation is broken already at the level of the action since particles are not massless in M^4 sense and induced gamma matrices, which are mixtures of M^4 and CP_2 gamma matrices lead to the breaking of chiral invariance: particle with definite H -chirality does not possess well-defined M^4 chirality - this serves as a space-time signature form M^4 -massivation.
- (c) One can argue that since instantons are topological objects they can be present at the QFT limit of TGD only if they are present at the level of many-sheeted space-time. Instantons would have analogs the maps $M^4 \rightarrow CP_2$ with non-vanishing winding number (CP_2 itself is gravitational instanton). One can regard these surfaces also as multi-valued maps $CP_2 \rightarrow M^4$.

Self-duality poses strong conditions on the induced metric and self duality seems implausible. Instantons should be also vacuum extremals with 4-D M^4 and CP_2 projections. This is not possible. Note however that CP_2 type extremals with light-like geodesic as M^4 projection and 4-D CP_2 projection are however possible [K8, K5]. There is no strong CP problem in TGD.

One can of course argue that $J(CD)$ is a potential problem for TGD since it can imply large CP violation for both quarks and leptons. Why the breaking is so small experimentally? I have already earlier considered this problem and made a quantitative estimate based on the observation that the CP breaking should be characterized by a power of G/R^2 . If CP breaking is small, one can however wonder why the associated P breaking is visible in HN-HN and even p-HN collisions [L30]?

Could a large value of h_{eff} implying “macroscopic” quantum coherence amplify the CP violation by a factor N^2 , where N is essentially the total baryon number of colliding nuclei? For canonically imbedded M^4 the induced $J(CD)$ is non-vanishing but the action and energy momentum tensor vanish by self-duality. If M^4 projection of space-time surface is lower than 4-D, also then the $J(CP)$ action vanishes.

9.3.3 Quantitative picture about CP breaking in TGD

One must specify the value of α_1 and the scaling factor transforming $J(CD)$ having dimension length squared as tensor square root of metric to dimensionless $U(1)$ gauge field $F = J(CD)/S$. This leads to a series of questions.

How to fix the scaling parameter S ?

- (a) The scaling parameter relating $J(CD)$ and F is fixed by flux quantization implying that the flux of $J(CD)$ is the area of sphere S^2 for the twistor space $M^4 \times S^2$. The gauge field is obtained as $F = J/S$, where $S = 4\pi R^2(S^2)$ is the area of S^2 .
- (b) Note that in Minkowski coordinates the length dimension is by convention shifted from the metric to linear Minkowski coordinates so that the magnetic field B_1 has dimension of inverse length squared and corresponds to $J(CD)/SL^2$, where L is naturally be taken to the size scale of CD defining the unit length in Minkowski coordinates. The $U(1)$ magnetic flux would be the signed area using L^2 as a unit.

How $R(S^2)$ relates to Planck length l_P ? l_P is either the radius $l_P = R$ of the twistor sphere S^2 of the twistor space $T = M^4 \times S^2$ or the circumference $l_P = 2\pi R(S^2)$ of the geodesic of S^2 . Circumference is a more natural identification since it can be measured in Riemann geometry whereas the operational definition of radius requires embedding to Euclidian 3-space.

How can one fix the value of $U(1)$ coupling strength α_1 ? As a guideline one can use CP breaking in K and B meson systems and the parameter characterizing matter-antimatter symmetry.

- (a) The recent experimental estimate for so called Jarlskog parameter characterizing the CP breaking in kaon system is $J \simeq 3.0 \times 10^{-5}$. For B mesons CP breaking is about 50 times larger than for kaons and it is clear that Jarlskog invariant does not distinguish between different meson so that it is better to talk about orders of magnitude only.
- (b) Matter-antimatter asymmetry is characterized by the number $r = n_B/(n_\gamma \sim 10^{-10})$ telling the ratio of the baryon density after annihilation to the original density. There is about one baryon 10 billion photons of CMB left in the recent Universe.

Consider now various options for the identification of α_1 .

- (a) Since the action is obtained by dimensional reduction from the 6-D Kähler action, one could argue $\alpha_1 = \alpha_K$. This proposal leads to unphysical predictions in atomic physics since neutron-electron $U(1)$ interaction scales up binding energies dramatically.
- (b) One can also consider the guess $\alpha_1 = R^2(S^2)/R^2(CP_2)$, the ratio of the areas of twistor spheres of $T(M^4)$ and $T(CP_2)$. There are two options corresponding to $l_P = R(S^2)$ and $l_P = 2\pi R(S^2)$.
 - i. For $l_P = R$ one would have $\alpha_1 = 2^{-24} \simeq 6 \times 10^{-8}$ [L30]. For $l_P = R$ α_1 is more than one order of magnitude smaller than the parameter $r \simeq 10^{-10}$ above. The CP breaking parameter for K and B system could be proportional to $g_1 = \sqrt{4\pi\alpha_1} \simeq 2 \times 10^{-4}$ and by order of magnitude larger than the Jarlskog parameter $J \simeq 3.0 \times 10^{-5}$ for K system.
 - ii. For $l_P = 2\pi R(S^2)$ one would have $\alpha_1 = R^2(S^2)/R^2(CP_2) = (1/4\pi^2) \times l_P^2 \simeq 3.8 \times 10^{-11}$, which is of the same order of magnitude as the parameter $r \simeq 10^{-10}$ characterizing matter-antimatter asymmetry. For $g_1 = \sqrt{4\pi \times \alpha_1}$ one would obtain $g_1 \simeq 6.9 \times 10^{-5}$ to be compared with $J \simeq 3.0 \times 10^{-5}$ for K system. This is the more plausible option - also in the sense that it involves only length scales quantities determined by the Riemann geometry of the twistor space.
- (c) There is an intriguing numerical co-incidence involved. $h_{eff} = \hbar_{gr} = GMm/v_0$ in solar system corresponds to $v_0 \simeq 2^{-11}$ and appears as coupling constant parameter in the perturbative theory obtained in this manner [K40]. What is intriguing that one has $\alpha_1 = v_0^2/4\pi^2$ in this case. Where does the troublesome factor $(1/2\pi)^2$ come from? Could the p-adic coupling constant evolutions for v_0 and α_1 correspond to each other and could they actually be one and the same thing? Can one treat gravitational force perturbatively either in terms of gravitational field or $J(CD)$? Is there somekind of duality involved?

9.4 Is the analog of CME possible in TGD?

CME and related QCD effects involve violation of CP and P . The Kähler form of $J(M^4)$ is Abelian self-dual covariantly constant self-dual $U(1)$ field coupling to fermion number with B and E parallel and breaking both CP , P , and T . This field satisfy just the conditions pose on em field assigned to CME.

One can consider the situation at the level of space-time surface itself or at the level of string world sheets if one believes in strong form of holography (SH) predicting that the information about dynamics is coded by string world sheets and that action reduces to 2-D bosonic and fermionic action associated with them.

9.4.1 Description at space-time level

Consider first the model at space-time level.

- (a) In TGD framework SH implies and induced field concept imply that the set of field patterns representable as induced fields at single space-time sheet is extremely limited. Various gauge fields of standard model correspond to sums of the induced gauge fields associated with space-time sheets with which particle is in contact (touches them). QFT

limit is obtained by replacing the sheets with single curved region of M^4 and identifying gauge potentials with the sum of the induced gauge potentials: similar recipe applies to the deviation of induced metric from Minkowski metric.

There is also topological field quantization. For instance, the classical em fields of colliding protons are at different space-time sheets. Furthermore, the fields are topologically quantized. For instance, electric flux from point charge flows along radial flux tubes if only covariantly constant $J(CD)$ s are allowed.

- (b) At space-time surface itself $J(M^4)$ associated with flux tube gives rise both E and B and they are parallel to each other in the approximation that space-time surface is just a piece of M^4 . The Abelian instanton density is non-vanishing. Quarks and antiquarks moving in this field rotate along the magnetic field and move in opposite directions and charge separation occurs.

In HN-HN angular momentum conservation forces quarks swirl around circles in the scattering plane in the collision region. This creates closed magnetic flux tubes analogous to those associated with dipole field. There is net baryon number involved and if it serves as a source for $J(M^4)$. $U(1)$ field with roughly parallel E and B is generated and CME becomes possible. Quarks and antiquarks are driven to the opposite poles. This means that there is surplus of U and D type quarks at North Pole and their antiquarks at South Pole. North/South Pole have positive/negative em charge if the numbers of U and D type quarks are roughly the same. Baryon number separation would give also separation of em charge.

- (c) What about p-HN collisions? Now the angular momentum conservation does not force generation of $U(1)$ magnetic field. If $U(1)$ field has fermion number as source, the $U(1)$ electric field is present since one has large baryonic number in the collision region. By self-duality $U(1)$ electric field is necessarily accompanied by magnetic field if the flux tube in question is near to canonically imbedded M^4 .
- (d) Can one have say anything interesting about possible TGD counterpart of CMW? CMW would be a charge wave adding positive charge to poles and negative charge to Equator. Negative charge at Equator would mean excess of \bar{U} and \bar{D} at equator and excess of U and \bar{D} at Poles. There would be asymmetry in em charge but not baryon number. Therefore this phenomenon would be related to em field. The minimum condition is that the total E_{em} and B_{em} as sum of em fields of colliding nuclei are not orthogonal. The instanton density for em field measures the non-orthogonality. This kind of situation is encountered in collisions, which tend to be peripheral.

A couple of remarks are in order.

- (a) I have proposed that electromagnetic instanton density serves as source of what I call lepto-pions, which are analogs of hadrons possible in TGD if the color octet excitations of leptons are light [K47]. Lepto-pions would have mass of ~ 1 MeV and would explain the anomaly observed in heavy ion collisions already at seventies. TGD strongly suggested the existence of several p-adically scaled up copies of hadron physics. One of them would be M_{89} hadron physics.

The same mechanism could apply to the production of pseudo-scalar mesons of M_{89} hadron physics in peripheral HN-HN collisions and p-HN collisions [K25] [L25]. There are indeed two handfuls of bumps identifiable as M_{89} mesons with masses by factor 512 higher than those for ordinary mesons. Unfortunately, these bumps have been forgotten since it was not possible to identify them as Higgses of SUSY: one can find only what one wants to find!

The possible TGD counterparts of CSE, CME, and CMW and the emergence of dark variants of M_{89} hadrons would be quantum critical phenomena [?] assignable to a phase transition (whatever it might be in TGD framework, where quark gluon plasma need not exist at all!). The quarks at the flux tubes would be dark with $h_{eff} = n \times h$. The value of n would be determined by the condition that the p-adic length scale associated with M_{89} hadrons is same order of magnitude as that associated with the ordinary M_{107} hadrons. Therefore

$n = 2^9 = 512$ is a good guess. Note that “macroscopic” quantum coherence and analog of super-conductivity suggested to accompany also CME would be possible.

9.4.2 Description at the level of string world sheets

SH suggests a complementary of 4-D description with 2-D description based on string world sheets and quarks moving along their boundaries. At string world sheets quarks see the induced $U(1)$ field. One cannot speak about self-dual $U(1)$ field anymore. Maxwellian intuition suggests that also point like quarks see the $U(1)$ force. This is indeed the case. The world lines defined by string boundaries at the boundaries of string world sheet located at light-like 3-surfaces correspond to the orbits of fermions. They solve the equations of motion for a particle in $U(1)$ force field. The light-likeness of the world line (otherwise the world line is space-like) suggests that the total force due to $J(M^4) + J(CP_2)$ vanishes.

Since the induced field is 2-dimensional both $U(1)$ electric and magnetic fields might be seen only in very special situations at string world sheets. If the M^4 projection of the string world sheet represented as surface in $M^2 \times E^2$ is such that one can represent it as graph $M^2 \rightarrow E^2$ both B and E in M^4 contribute to the net field to which quarks couple.

9.5 How the QFT-GRT limit of TGD differs from QFT and GRT?

Yesterday evening I got an interesting idea related to both the definition and conservation of gauge charges in non-Abelian theories. First the idea popped in QCD context but immediately generalized to electro-weak and gravitational sectors. It might not be entirely correct: I have not yet checked the calculations.

9.5.1 QCD sector

I have been working with possible TGD counterparts of so called chiral magnetic effect (CME) and chiral separation effect (CSE) proposed in QCD to describe observations at LHC and RHIC suggesting relatively large P and CP violations in hadronic physics associated with the deconfinement phase transition.

The QCD based model for CME and CSE is not convincing as such. The model assumes that the theta parameter of QCD is non-vanishing and position dependent. It is however known that theta parameter is extremal small and seems to be zero: this is so called strong CP problem of QCD caused by the possibility of instantons. The axion hypothesis could make $\theta(x)$ a dynamical field and θ parameter would be eliminated from the theory. Axion has not however been found: various candidates have been gradually eliminated from consideration!

What is the situation in TGD? In TGD instantons are impossible at the fundamental space-time level. This is due to the induced space-time concept. What this means for the QFT limit of TGD?

- (a) Obviously one must add to the action density a constraint term equal to Lagrange multiplier θ times the instanton density. If θ is constant the variation with respect to it gives just the vanishing of instanton number.
- (b) A stronger condition is local and states that *instanton density* vanishes. This differs from the axion option in that there is no kinetic term for θ so that it does not propagate and does not appear in propagators.

Consider the latter option in more detail.

- (a) The variation with respect to $\theta(x)$ gives the condition that instanton density rather than only instanton number vanishes for the allowed field configurations. This guarantees that axial current having instanton term as divergence is conserved if fermions are massless. There is no breaking of chiral symmetry at the massless limit and no chiral anomaly which is mathematically problematic.

(b) The field equations are however changed. The field equations reduce to the statement that the covariant divergence of YM current - sum of bosonic and fermionic contributions - equals to the covariant divergence of color current associated with the constraint term. The classical gauge potentials are affected by this source term and they in turn affect fermionic dynamics via Dirac equation. Therefore also the perturbation theory is affected.

(c) The following is however still uncertain: This term *seems* to have vanishing *ordinary* total divergence by Bianchi identities - one has topological color current proportional to the contraction of the gradient of θ and gauge field with 4-D permutation symbol! I have however not checked yet the details.

If this is really true then the sum of fermionic and bosonic gauge currents not conserved in the usual sense equals to a topological color current conserved in the usual sense! This would give conserved total color charges as topological charges - in spirit with "Topological" in TGD! This would also solve a problem of non-abelian gauge theories usually put under the rug: the gauge total gauge current is not conserved and a rigorous definition of gauge charges is lost.

(d) What the equations of motion of ordinary QCD would mean in this framework? First of all the color magnetic and electric fields can be said to be orthogonal with respect to the natural inner product. One can have also solutions for which θ is constant. This case gives just the ordinary QCD but without instantons and strong CP breaking. The total color current vanishes and one would have *local* color confinement classically! This is true irrespective of whether the ordinary divergence of color currents vanishes.

(e) This also allows to understand CME and CSE believed to occur in the deconfinement phase transition. Now regions with non-constant $\theta(x)$ but vanishing instanton density are generated. The sum of the conserved color charges for these regions - droplets of quark-gluon plasma - however vanish by the conservation of color charges. One would indeed have non-vanishing local color charge densities and deconfinement in accordance with the physical intuition and experimental evidence. This could occur in proton-nucleon and nucleon-nucleon collisions at both RHIC and LHC and give rise to CME and CSE effects. This picture is however essentially TGD based. QCD in standard form does not give it and in QCD there are no motivations to demand that instanton density vanishes.

9.5.2 Electroweak sector

The analog of $\theta(x)$ is present also at the QFT limit of TGD in electroweak sector since instantons must be absent also now. One would have conserved total electroweak currents - also Abelian U(1) current reducing to topological currents, which vanish for $\theta(x) = \text{constant}$ but are non-vanishing otherwise. In TGD the conservation of em charge and possibly also Z^0 charge is understood if strong form of holography (SH) is accepted: it implies that only electromagnetic and possibly also Z^0 current are conserved and are assignable to the string world sheets carrying fermions. At QFT limit one would obtain reduction of electroweak currents to topological currents if the above argument is correct. The proper understanding of W currents at fundamental level is however still lacking.

It is now however not necessary to demand the vanishing of instanton term for the U(1) factor and chiral anomaly for pion suggest that one cannot demand this. CP_2 actually represents a Kähler instanton. Also the TGD inspired model for so called leptohadrons is based on the non-vanishing electromagnetic instanton density. In TGD also M^4 Kähler form $J(\text{CD})$ is present and same would apply to it. If one applies the condition empty Minkowski space ceases to be an extremal.

9.5.3 Gravitational sector

Could this generalize also the GRT limit of TGD? In GRT momentum conservation is lost - this one of the basic problems of GRT put under the rug. At fundamental level Poincare

charges are conserved in TGD by the hypothesis that the space-time is 4-surface in $M^4 \times CP_2$. Space-time symmetries are lifted to those of M^4 .

What happens at the GRT limit of TGD? The proposal has been that *covariant* conservation of energy momentum tensor is a remnant of Poincare symmetry. But could one obtain also now ordinary conservation of 4- momentum currents by adding to the standard Einstein-YM action a Lagrange multiplier term guaranteing that the gravitational analog of instanton term vanishes?

- (a) First objection: This makes sense only if vier-bein is defined in the M^4 coordinates applying only at GRT limit for which space-time surface is representable as a graph of a map from M^4 to CP_2 .
- (b) Second objection: If metric tensor is regarded as a primary dynamical variable, one obtains a current which is symmetry 2-tensor like T and G . This cannot give rise to a conserved charges.
- (c) Third objection: Taking vielbein vectors e_μ^A as fundamental variable could give rise to a conserved vector with vanishing covariant divergence. Could this give rise to conserved currents labelled by A and having interpretation as momentum components? This does not work. Since e_μ^A is only covariantly constant one does not obtain genuine conservation law except at the limit of empty Minkowski space since in this case vielbein vectors can be taken to be constant.

Despite this the addition of the constraint term changes the interpretation of GRT profoundly.

- (a) Curvature tensor is indeed essentially a gauge field in tangent space rotation group when contracted suitably by two vielbein vectors e_μ^A and the instanton term is formally completely analogous to that in gauge theory.
- (b) The situation is now more complex than in gauge theories due to the fact that second derivatives of the metric and - as it seems - also of vielbein vectors are involved. They however appear linearly and do not give third order derivatives in Einstein's equations. Since the physics should not depend on whether one uses metric or vielbein as dynamical variables, the conjecture is that the variation states that the contraction of $T - kG$ with vielbein vector equals to the topological current coming from instanton term and proportional to the gradient of θ

$$(T - kG)^{\mu\nu} e_\nu^A = j^{A\mu} .$$

The conserved current $j^{A\mu}$ would be contraction of the instanton term with respect to e_μ^A with the gradient of θ covariantized. The variation of the action with respect to the gradient of e_μ^A would give it. The resulting current has only vanishing *covariant* divergence to which vielbein contributes.

The multiplier term guaranteing the vanishing of the gravitational instanton density would have however highly non-trivial and physically desirable consequences.

- (a) The covariantly conserved energy momentum current would be sum of parts corresponding to matter and gravitational field unlike in GRT where the field equations say that the energy momentum tensors of gravitational field and matter field are identical. This conforms with TGD view at the level of many-sheeted space-time.
- (b) In GRT one has the problem that in absence of matter (pure gravitational radiation) one obtains $G=0$ and thus vacuum solution. This follows also from conformal invariance for solutions representing gravitational radiation. Thanks to LIGO we however now know that gravitational radiation carries energy! Situation for TGD limit would be different: at QFT limit one can have classical gravitational radiation with non-vanishing energy momentum density thanks the vanishing of instanton term.

10 Phase transition from M_{107} hadron physics to M_{89} hadron physics as counterpart for de-confinement phase transition?

Quark gluon plasma assigned to de-confinement phase transition predicted by QCD has turned out to be a problematic notion. The original expectation was that quark gluon plasma (QGP) would be created in heavy ion collisions. A candidate for QGP was discovered already at RHIC but did not have quite the expected properties such as black body spectrum [C60, C61, C69, C78] but behaved like an ideal liquid with long range correlations between charged particle pairs created in the collision. Then LHC discovered that this phase is created even in proton-heavy nucleus collisions [C96] (see <http://tinyurl.com/1t5reno> and <http://tinyurl.com/kkx4x2y>). Now this phase have been discovered even in proton-proton collisions [C21]. This does not conform with the expectations. The details for the enhanced production of strange mesons deviate form QCD predictions.

A second anomaly has been discovered by LHCb collaboration [C97] (see <http://tinyurl.com/mjucnwl>).

- (a) The production of J/Ψ mesons in proton-proton collisions in the Large Hadron Collider (LHC) at CERN does not agree with the predictions made by a widely used computer simulation, Pythia. The result comes from CERN's LHCb experiment studying the jets of hadrons created as protons collide at 13 TeV cm energy.
- (b) These jets contain large numbers of J/Ψ mesons consisting of charmed quark and a charmed anti-quark. The LHCb measured the ratio of the momentum carried by the J/Ψ mesons to the momentum carried by the entire jet. They were also able to discriminate between J/Ψ mesons created promptly (direct/prompt production) in the collision and J/Ψ mesons that were created after the collision by the decay of charmed hadrons produced by jets (jet production).
- (c) Analysis of the data demonstrates that PYTHIA - a Monte Carlo simulation used to model high-energy particle collisions - does not predict correctly the momentum fraction carried by prompt J/Ψ mesons. The conclusion is that the apparent shortcomings of PYTHIA could have a significant effect on how particle physics is done because the simulation is used both in the design of collider detectors and also to determine which measurements are most likely to reveal information about physics beyond the Standard Model of particle physics. Heretic could go further and ask whether the problem is really with Pythia: could it be with QCD?

These discoveries are unexpected and both a challenge and opportunity to TGD.

- (a) In TGD framework QGP is replaced with quantum critical state appearing in the transition from ordinary hadron physics characterized by Mersenne prime M_{107} to dark variant of M_{89} hadron physics characterized by $h_{eff}/h = n = 512$. At quantum criticality partons are hybrids of M_{89} and M_{107} partons with Compton length of ordinary partons and mass $m(89) \leq 512m(107)$ since also $1/n$ -fractional quarks and gluons are possible.
- (b) TGD predicts besides ordinary bosons two additional boson generations, whose family charge matrices in the space of fermion families are hermitian, diagonal and orthogonal to each other to the unit charge matrix for ordinary bosons, and most naturally same for all bosons. The charge matrices for higher generations necessarily break the universality of fermion couplings. The model for strangeness enhancement and the violation of lepton universality in B-meson decays predicts that the bosonic family charge matrix for second generation favours decays to third generation quarks and dis-favors decays to quarks of first and second generation.
- (c) The observed strangeness enhancement can be understood as a violation of quark universality if the gluons of M_{89} hadron physics correspond to second generation of gluons whose couplings necessarily break quark universality. This also predicts that the rate

for prompt production of J/Ψ is lower and jet production rate from b -hadron decays is higher than predicted by QCD.

10.1 Some background about TGD

In hope of making the representation more comprehensible, I list some of the basic ideas and notions of TGD involved.

10.1.1 Some Basic concepts and ideas

Here is a concise list about the basic notions and ideas of TGD related to particle physics.

- (a) There are several new geometric notions involved. Many-sheeted space-time (surface in $M^4 \times CP_2$) and topological field quantization implying the notions of field body and magnetic body and of magnetic flux tubes carrying monopole flux. The twistor lift of TGD replaces $M^4 \times CP_2$ to the Cartesian product of twistor spaces of M^4 and CP_2 . The spaces are completely unique in the sense that they have Kähler structure [K17, K7, L30]. The analog of Kähler structure for M^4 predicts CP, P, and T violation in all scales having far reaching implications in many fields of physics, in particular in hadron physics [L19] and cosmology and galaxy models [L20].
- (b) Zero energy ontology (ZEO) is also crucial in the formulation of scattering amplitudes and in the interpretation of TGD, in particular of TGD inspired theory of consciousness. In ZEO causal diamond (CD) defines the perceptive field of conscious entity. Zero energy states coding scattering amplitudes are constructed using the data associated with preferred extremals of the action principle defined by twistor lift inside CD. CDs for a fractal hierarchy. ZEO leads to a generalization of quantum measurement theory giving rise to a theory of consciousness.
- (c) Strong holography (SH) following from strong form of general coordinate invariance (GCI) is a central notion [K51, K35].

SH allows effective localization of fermions at string world sheets carrying vanishing induced W boson fields in the sense that effective action can be formulate in terms of induces spinor fields at string world sheets having sources at their boundaries. String world sheets would code for the data needed to construct scattering amplitudes and their boundaries at the orbits of partonic 2-surfaces correspond to world-lines of fundamental fermions serving as building bricks of all elementary particles.

The dual 4-D description would be in terms of induced spinor fields in the interior of space-time surface having sources at light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. SH applies also in bosonic degrees of freedom meaning that the 4-D action determining space-time surface reduces to 2-D effective action for string world sheets. The 4-D space-time surface are obtained by SH from these surfaces in analogy with analytic continuation process.

- (d) Number theoretic vision [K50] leads to the notion of adelic physics [L26] based on the fusion of real and various p-adic number fields to adeles. Adeles form a hierarchy labelled by extensions of rationals inducing extensions of p-adic number fields. The interpretation is as an evolutionary hierarchy with levels characterized by the complexity of extension.

Various p-adic physics are interpreted as physics of cognition. p-Adic length scale hypothesis states that elementary particles are labelled by certain p-adic primes $p \simeq 2^k$. The most important p-adic length scales correspond to Mersenne primes and Gaussian Mersennes. Preferred p-adic primes $p \simeq 2^k$ could correspond to so called ramified primes for the extensions, which are winners in the fight for number theoretical survival.

The hierarchy of Planck constants $h_{eff}/h = n$ defining a hierarchy of phases of ordinary matter identifiable as dark matter hierarchy. Both hypothesis reduce in adelic physics to the number theory associated with extensions of rationals inducing extensions of p-adic number fields. For instance, $h_{eff}/h = n$ corresponds to the dimension of the Galois

group of the extension giving the number of sheets of space-time surface as covering. A natural hypothesis is that second quantization in this discrete space of sheets is possible for fermions so that has fractional quarks, gluons, leptons and hadrons. One has extensions of extensions so that one should write $h_{eff,f}/h_{eff,i} = n_{if}$ to be precise.

10.1.2 TGD view about elementary particles

The TGD view of elementary particle relies crucially on many-sheeted space-time.

- (a) Elementary particles are 2-sheeted structures forming closed flux tubes carrying monopole flux assignable to the induced Kähler form of CP_2 . Flux tube has shape of very long flattened square and has wormhole contacts at its turning points: wormhole contacts are regions with Euclidian induced metric. For fundamental fermions a neutrino pair at the throat of wormhole contact is assumed to neutralize weak spin. This neutralization would take place for all fermions and would be analogous to electroweak confinement.
- (b) To consider gauge bosons and TGD counterpart of Higgs, one can label the wormhole contacts as W_i , $i = 1, 2$ and the corresponding throats $T_{i,\pm}$. One could have at opposite throats $q \in T_{i,+}$ and $\bar{q} \in T_{i,-}$, $i = 1$ or $i = 2$. Neutrino-antineutrino pairs neutralizing weak isospin would reside at opposite throats. Also more general configurations with $q \in T_{1,\pm}$ and $\bar{q} \in T_{2,\pm}$ are possible: they allow the decay of boson to fermion antifermion pair by re-connection of the flux tube splitting it. The quantum state should be superposition of these various states.
- (c) For mesons one can consider two different models.
 - i. Quark and antiquark are at different wormhole contacts of the same closed flux tube.
 - ii. Meson consists of closed flux tubes associated with quark and antiquark feeding part of the color magnetic fluxes to hadronic space-time sheet, where they sum up to zero.

The model for strangeness enhancement suggest that latter option is the more natural: the mesons would consist of quark antiquark represented as fermionic strings and also the magnetic flux tube at the hadronic space-time sheet would have stringy character.

The topological explanation of family replication phenomenon is essential piece of the picture [K11, K30] .

- (a) The boundaries of string world sheets are lines at the light-like orbits of partonic 2-surfaces. Partonic 2-surfaces at the boundaries of CD carrying fermions have topology characterized by genus g . Quantum states are superpositions of 3 lowest topologies for partonic 2-surfaces having genus $g = 0, 1, 2$ (sphere, torus, sphere with two handles) and topological mixing matrices U and D describe the mixing. These genera are exceptional that they are always hyper-elliptic allowing Z_2 global conformal symmetry. For higher genera this symmetry is possible only for special values of conformal moduli. The proposal is that the handles form at them free particles or bound states of at most 2 handles. Therefore higher genera would be many-particle states. The different mixings for U and D type quarks imply that CKM matrix appearing in W boson vertices is non-trivial.
- (b) Family replication phenomenon is predicted also for bosons. One has dynamical family-SU(3) with quarks and lepton generations defining triplets of this group. Bosons belong to singlet and octet representation of this group. Ordinary bosons correspond to singlet and have universal couplings. Only the two neutral members of octet representation (analogous to neutral pion and η in Gell-Mann's SU(3)) are light and have charged matrices orthogonal to that for singlet and therefore their couplings violate universality.
- (c) The TGD based model is based on the predicted higher generations of electroweak bosons, whose charge matrices necessarily break fermion universality since they are orthogonal with each other and orthogonal to the singlet charge matrix which is unit matrix and thus universal.

10.1.3 Quarks, gluons, and hadrons

The TGD view about color quantum numbers differs from the QCD view. One must consider both embedding space level and space-time level.

- (a) At the level of embedding space spinor harmonics define the ground states of super-symplectic representations. Color corresponds to CP_2 color partial waves and is not spin-like quantum number except approximately in length scales much longer than CP_2 size scale. This view about color makes possible separate conservation of baryon and lepton numbers that one must give up in GUTs. Note that no evidence for the decay of protons predicted by GUTs have been found.
- (b) Quantum classical correspondence (QCC) requires a correlate for color also at the level of space-time surfaces. Induced spinors do not have color as spin like quantum number and one cannot talk about color partial waves at space-time level.

Color magnetic flux emanating from quark, which is identified as 2-sheeted structure, flows to a larger hadronic space-time sheet through wormhole contact and could define the correlate for color hyper charge. The flux of color magnetic hyper-charge is defined by Kähler form multiplied by hyper-charge Hamiltonian which is determined up to additive constant. This constant term should give the color flux as proportional to Kähler magnetic flux.

The sum of Kähler magnetic fluxes (homology charges) must vanish for orientable surfaces and thus for hadronic space-time sheet must vanish unless one allows non-orientable 3-surfaces in which case it would vanish only modulo 2. Orientability is required by the well-definedness of induced gauge fields.

Vanishing occurs if the values of Kähler magnetic charge are 2 and -1, -1 and would correspond to the values $2/3, -1/3, -1/3$ of color hyper charge for color triplet of quarks. For higher color partial waves color confinement condition requires large values of Kähler magnetic flux and this might prevent higher color partial waves for leptons and quarks or make them very massive. This is actually very important point since there is no evidence for higher color partial waves.

- (c) QCC suggests also space-time correlates for isospin and spin. Two-sheeted covering space structure for elementary particles could correspond to this. One would have 2-sheeted covering space completely analogously to how $SU(2)$ serves as 2-sheeted covering of $SO(3)$. The rotations would lead from the point of wormhole throat to the point at opposite throat. This would apply to both color, spin, and electroweak spin, in which case parallel translation would define the transformation. Galois group permutes the space-time sheets and an attractive idea is that Galois group could represent discrete subgroups of the these symmetry groups.

A more precise view about gluons and hadrons is needed.

- (a) The general structure of bosons was already considered. The presence of configuration with $q \in T_{1,\pm}$ and $\bar{q} \in T_{2,\pm}$ makes possible decays of gluon to $q\bar{q}$ pairs by splitting of the closed gluon flux tube by reconnection to closed flux tubes representing quark and antiquark. In this process a neutrino pair neutralizing weak isospin is created at the emerging wormhole contacts. Similar superposition for weak bosons makes possible their decays to lepton and quark pairs.
- (b) Hadronic space-time sheet is the third space-time sheet involved and is present always and could corresponds to color magnetic body. Quarks and gluons feed color magnetic fluxes to hadronic spacetime sheet defining field body/magnetic body of hadron. The color magnetic flux entering along flux enter here and sum up to zero.
- (c) QCC would be analogous to electric-magnetic duality. At quark space-time sheets color and other quantum numbers would be quantum numbers. At the larger hadronic space-time sheet color hypercharge would correspond to Kähler magnetic charge for effective monopole like entity.

- (d) Hadronization would occur at hadronic space-time sheet as a formation combinations of quark flux tubes with vanishing total Kähler magnetic charge. Gluon flux tubes decay to pairs of quark and antiquark flux tubes and quarks as closed flux tubes. They feed color magnetic fluxes to hadronic space-time sheets and form in hadronization bound states of color magnetic monopoles with vanishing total color magnetic charge. The magnetic confinement process would occur at the level of hadronic space-time sheet since only magnetic singlets can escape the reactor volume.

If this picture is correct, color confinement would reduce to second homology of CP_2 and hadronization would have a concrete topological description whereas in QCD it involves introduction of statistical jet hadronization functions characterization hadronization.

10.2 TGD based model for the enhanced strangeness production

With above prerequisites one can consider explicit model for the enhanced strangeness production.

10.2.1 What has been found?

The discovery of QGP candidate in proton proton collisions is discussed in popular article at <http://tinyurl.com/mcmekne> and in the article [C21] at <http://tinyurl.com/kse8p3t>. I glue below the abstract of the research article.

At sufficiently high temperature and energy density, nuclear matter undergoes a transition to a phase in which quarks and gluons are not confined: the quark-gluon plasma (QGP). Such an exotic state of strongly interacting quantum chromodynamics matter is produced in the laboratory in heavy nuclei high-energy collisions, where an enhanced production of strange hadrons is observed. Strangeness enhancement, originally proposed as a signature of QGP formation in nuclear collisions⁷, is more pronounced for multi-strange baryons. Several effects typical of heavy-ion phenomenology have been observed in high-multiplicity proton-proton (pp) collisions, but the enhanced production of multi-strange particles has not been reported so far.

Here we present the first observation of strangeness enhancement in high-multiplicity proton-proton collisions. We find that the integrated yields of strange and multi-strange particles, relative to pions, increases significantly with the event charged-particle multiplicity. The measurements are in remarkable agreement with the p-Pb collision results, indicating that the phenomenon is related to the final system created in the collision. In high-multiplicity events strangeness production reaches values similar to those observed in Pb-Pb collisions, where a QGP is formed.

Some comments are in order.

- (a) The enhanced production of hadrons containing strange quarks is taken as a signature for the production of the QGP candidate: why this enhancement should occur is not however obvious. In the case of nucleus-nucleus collisions this interpretation was justified as a first guess but not so in the case for proton-nucleus collisions and even less in the case of p-p collisions. Something exotic is produced and it is better to just ask what this something might be. One must be even ready to challenge the status of QCD.
- (b) The enhancement depends on the final state and only weakly on the initial state suggesting that some phase new phase is indeed created and responsible for the enhancement. Already in the case of nucleus-nucleus collisions the unexpected correlations associated with charged particle pairs in the final state led to ask whether string like objects decaying to quark pair, which eventually decaying eventually to ordinary hadrons, might be created. Also the presence of some kind of macroscopic quantum phase is suggested by long range correlations and also by chiral magnetic effect (CME) and chiral separation effect (CSE) for which a TGD inspired model is discussed in [L19] [K25].
- (c) The ratios of differential cross sections for pairs of strange particles K , λ , Ω to the cross section for production of pions are very similar to those in proton-nucleus collisions

suggesting that also in this case proton-nucleus collision is the basic mechanism for creating the new unidentified phase (see <http://tinyurl.com/kse8p3t>).

- (d) The integrated yields of strange particles increase with charged particle multiplicity. This is an hint about the production mechanism: the first step could be the decay of gluon like states to quark-antiquark pairs. Ordinary quarks need not be in question. The enhancement of strangeness production increases with the number of strange quarks in the hadron produced. According to the article, the existing models are not able to reproduce this behavior. Hence there might be the place for a new physics.

10.2.2 Enhanced strangeness production as a violation of quark universality

The TGD based explanation [K25] [L22] is in terms of topological explanation of family replication phenomenon using genus-generation correspondence [K11].

- (a) A natural starting point is another anomalous finding by LHC: the decays of B and K mesons seem to violate lepton universality. The observations are summarized at <http://tinyurl.com/m7gahup> and the analysis of data is explained at <http://tinyurl.com/m1335qf>. This suggests the existence of heavy variants of W resp. Z bosons, which prefer to decay to $\tau\nu$ resp. $\tau^+\tau^-$ pairs. Also the anomaly for the anomalous magnetic moment of muon suggests a violation of lepton universality as do also the different values of proton charge radii deduced from hydrogen and muonium atom [L22].

- (b) Ordinary electroweak bosons would correspond to Mersenne prime M_{89} . The Gaussian Mersenne $M_{G,79}$ would characterize the second generation of weak bosons and one prediction is enhanced production of τ pairs due to the larger coupling of second generation weak bosons to τ pairs. If the charge matrices of second generation gluons in the space defined by triplet of fermion generations are same for triplets electroweak bosons and gluons, the decays of second generation gluons should produce more $g = 2$ quark pairs (t or b pairs) than $g < 2$ pairs. The decay of $g = 2$ quarks to c and s quarks followed by the decay of c quarks to s and u plus the long lifetime of s would lead to strangeness enhancement.

The weak boson families would correspond to subsequent (possibly Gaussian) Mersennes $M_{89}, M_{G,79}, M_{61}$.

- (c) The model for enhanced strangeness production is implied by e TGD based model for the violation of lepton universality. Also gluons and even gravitons should possess higher generations and this suggests that strangeness enhancement is a signal about violation of flavor universality due to second generation gluons.

Two additional gluon families are predicted and the 3 gluon generations would naturally correspond to subsequent Mersennes $M_{107}, M_{89}, M_{G,79}$. Their couplings to quarks would violate universality. The simplest hypothesis is that the charge matrices for family-SU(3) are same for gluons and ew bosons and maybe even gravitons of which only the singlet graviton is expected to be massless.

- (d) What charge matrices could look like? Ordinary gauge bosons correspond by universality to charge matrix $(1, 1, 1)$. All charge matrices are orthogonal to each other and those for second and third generation bosons are hermitian, diagonal matrices with vanishing trace. The simplest proposal for second generation charge matrix is as matrix proportional to hyper charge matrix $Y = (-1/3, -1/3, 2/3)$. Third generation charge matrix is proportional to $I_3 = (1/2, -1/2, 0)$. The coupling by hypercharge matrix would be two times stronger than by isospin matrix and favor decays of gluons to third generation quarks. This guess might hold true in absence of topological mixing of the partonic topologies with genus $g = 0, 1, 2$.

Topological mixing for fermions would cause mixing of fermion families depending on the charge state of fermion: U resp. D type quarks are mixed by unitary matrix U resp. D . For first generation neutral weak bosons and gluons the charge matrices are not affected. For higher generations one has $Q_i \rightarrow UQU^\dagger$ and $Q_i \rightarrow DQ_iD^\dagger$. For charge weak bosons one has $Q_i \rightarrow UQ_iD^\dagger$ giving for the lowest generation CKM matrix

$CKM = UD^\dagger$ and its along for higher generations. CKM matrix would therefore show itself in the couplings. If one accepts the identification of charge matrices as Y and I_3 the model predicts the couplings apart from the normalization of these matrices.

A similar 3-levelled hierarchy of hadron physics is highly suggestive.

- (a) A more precise formulation of M_{89} hadron physics emerges [K25]. The original hypothesis was that M_{89} hadron physics is just a copy of the usual M_{107} hadron physics with masses scale by a factor 512 in the first approximation.
- (b) In the refined vision M_{89} gluons would be actually second generation gluons, whose couplings violate universality by preferring to decay to $g = 2$ quark pairs (t, and b pairs) just as second generation of weak bosons prefer to decay to $g = 2$ lepton pairs. The explanation for the appearance of bumps with masses of ordinary mesons scaled by factor 512 provides the basic support for the presence of M_{89} hadron physics [L25] [K25].

10.2.3 Is QGP replaced with criticality for the phase transition from M_{107} hadron physics to M_{89} hadron physics?

The view about quantum criticality assigned to quark-gluon plasma also sharpens. Quantum criticality would be associated with the phase transition from M_{107} (standard gluons) to M_{89} hadron physics associated with the second generation gluons.

- (a) I have proposed that the dark variants of M_{89} mesons appear at quantum criticality for a phase transition usually interpreted as formation of QGP. The long range correlations associated with quantum criticality would correspond to $h_{eff}/h = n$ phases with Compton lengths scaled up by factor n . By quantum classical correspondence (QCC) also the scales of space-time sheets would be scaled up in this manner.

This quantum criticality might be also associated with the collision producing the bumps with the masses of M_{89} mesons for which there is evidence [L25] [K25] but forgotten as it turned out that the interpretation in terms of SUSY is not possible. One possibility is peripheral collisions since for these the electromagnetic instanton density would be large and give rise to a generation of M_{89} pseudo scalars coupling to it. For $h_{eff}/h = 512$ dark M_{89} hadrons and ordinary hadrons would have the same size scale.

- (b) For gluons these $n = 512$ -sheeted structures would be analogous to Bose-Einstein condensates of ordinary hadrons and gluons. At the level of quarks Fermi sphere is a better analogy. If all sheets are occupied the mass would $n = 512$ the mass of the ordinary hadron. The simplest option is $1/512$ -fractionization for spins and other quantum numbers.

An attractive idea is that also partly filled Fermi spheres are possible and that the fractional quarks thrown out from full Fermi spheres correspond to sea quarks. If one has this kind of 512-sheeted dark M_{89} gluon preferring to decay to t and b quark pairs, one indeed obtains strangeness enhancement. TGD Universe is quantum critical and the idea that quantum criticality would be realized in this manner is attractive.

A comment about a long standing problem related to the fractionization of quantum numbers is in order although it is not absolutely relevant for the recent situation. One can consider two interpretations for what $h_{eff}/h = n$ means depending on whether the quantum numbers are fractionized or not. The first option works for the above model and second option leads to strange results.

- (a) Charge fractionization means that the unit of charge (say spin) is scaled down by $1/n$, $h_{eff}/h = n$. The dark matter fermion with all n sheets of covering containing $1/n$ -fractional fermion is analogous to a full Fermi sphere and has non-fractional quantum numbers. Also fractional filling is possible. Total quantum numbers must be however fractional and one has anyonic states consisting of several fractional particles [K34]. The transition to ordinary phase at single particle level is possible only for a particle with

full Fermi sphere. Otherwise anyons with complementary Fermi spheres must fuse to give ordinary particles.

For years ago I proposed that pairs formed by dark fractional particle and its complement assignable to a pair of biomolecules could have meant the emergence of symbolic dynamics at molecular level and of what might be called molecular sex [?, ?]. This could correspond to the assignment of fractional proton triplets to DNA codon and its complementary fractional triplet to conjugate codon. DNA double strand would represent the visible part of molecular marriage of dark DNA sequences.

- (b) Half-odd integer value of the total angular momentum for the many-anyon system guarantees that the action of 2π rotation in Minkowski space is consistent with the ordinary statistics. One can also consider rotations at the level of space-time surface. For n -fold covering only the M^4 rotation of $n \times 2\pi$ acting on point of space-time surface has the usual effect and one can say that the particle has fractional spin at space-time level.
- (c) There is however an objection to fractionization. The original idea behind hierarchy of Planck constants was that the energy $E = hf$ associated with frequency f is scaled up to $E = h_{eff}f$. For cyclotron frequencies $f_c \propto qB/m$. Suppose transition to dark phase occurs and all sheets are filled. The fractionizations of q and m compensate each other. If B has the original values at all n sheets, the cyclotron energies increase by factor n as required. One has n copies of the original space-time sheet carrying the original magnetic field so that a kind of space-time correlate for Bose-Einstein condensation is in question.

Deconfinement phase transition does not make sense in TGD framework. Only the scale in which magnetic monopoles are free, can increase.

- (a) M_{107} gluons of first generation would become dark M_{89} dark gluons of second generation in number theoretic phase transition increasing the dimension of Galois group identified as $h_{eff}/h = n$ with the sheets of n -sheeted objects permuted by Galois group. Kind of Bose-Einstein condensation of ordinary gluons to n -sheeted structures would be in question. Ordinary M_{89} hadron would result in the decay reducing the value of h_{eff}/h by factor 2^{-9} . Alternatively bunches of $m \leq n$ M_{107} hadrons could result in the decay.
- (b) At quantum criticality one would have hybrids of M_{107} and M_{89} hadrons. M_{89} dark particles the spatial scale would correspond to M_{107} but mass scale to M_{89} . Voice would be Jacob's voice but the hands would be Esau's hands. Large size scale for them would correspond to quantum fluctuations and long range correlations associated with $M_{107} \rightarrow M_{89}$ phase transition. Instead of liberation of ordinary quarks one would have almost-liberation of M_{89} quarks having size scale of ordinary hadrons equal 512 times their ordinary Compton length.

10.2.4 Model for strangeness enhancement

Consider now the mechanism for strangeness enhancement.

- (a) If gluons consist dominantly of $g = 2$ quark pairs (t and b), they prefer to decay to $g = 2$ quark pairs. These in turn prefer to decay via W boson emission to $g = 1$ pairs (c and s). c quarks in turn decay to s and u quark. The lifetimes of strange mesons are so long that they are not detected in the reactor volume. The outcome is strangeness enhancement. Note however that CKM mixing is involved, which allows to produce also d quarks in the decays of c quarks.
- (b) Why the enhancement of strange baryons would increase with the number of strange quarks in hadron? Could M_{89} gluon define the volume in which process occurs? The density of ordinary gluons would very small in this volume, and the probability that hadronization produces hadrons containing u and d quarks would be due to the decay products of second generation gluons and therefore small.

Hadronization would correspond to the formation of color bound/magnetically bound states of quarks coming from the decays of second generation gluons to quark pairs with

t and b pairs preferred. These quarks forming effectively magnetic monopoles at throats of wormhole contacts would then form mesons and baryons as color bound states and the probability for the hadron to contain first generation quarks would be the lower the higher the number of them is. This would explain why the production rate for hadrons decreases with the number of non-strange light quarks.

- (c) Could the region containing very few light ordinary quarks correspond to dark M_{89} gluon occupying the volume with a size scale of ordinary hadron? This could be the case if the decay of dark M_{89} gluon to quark pairs occurs first and is followed by the decay of this M_{89} 512 \times 2-sheeted structure to dark M_{89} quark pairs in turn decay decay to 512 ordinary quarks and antiquarks. If the partonic 2-surface tends to have $g = 2$ then all the decay products would tend to have also $g > 0$ and consist of strange quarks.

10.3 Anomalous J/Ψ production and TGD

A new anomaly [C97] (see <http://tinyurl.com/l3xnxtj>) has been discovered by LHCb collaboration. For popular summary see <http://tinyurl.com/mjucnwl>. The production of J/Ψ mesons in proton-proton collisions in the Large Hadron Collider (LHC) at CERN does not agree with the predictions made by a widely used computer simulation, Pythia. The result comes from CERN's LHCb experiment studying the jets of hadrons created as protons collide at 13 TeV cm energy.

These jets contain large numbers of J/Ψ mesons consisting of charmed quark and a charmed anti-quark. The LHCb measured the ratio of the momentum carried by the J/Ψ mesons to the momentum carried by the entire jet. They were also able to discriminate between J/Ψ mesons created promptly (direct/prompt production) in the collision and J/Ψ mesons that were created after the collision by the decay of charmed hadrons produced by jets (jet production).

Analysis of the data demonstrates that PYTHIA - a Monte Carlo simulation used to model high-energy particle collisions - does not predict correctly the momentum fraction carried by prompt J/Ψ mesons. The conclusion is that the apparent shortcomings of PYTHIA could have a significant effect on how particle physics is done because the simulation is used both in the design of collider detectors and also to determine which measurements are most likely to reveal information about physics beyond the Standard Model of particle physics. Heretic could go further and ask whether the problem is really with Pythia: could it be with QCD?

The TGD explanation for the finding is same as that for strangeness enhancement in p-p collisions [L27] in the same energy range at which the de-confinement phase transition is predicted to occur in QCD. In TGD one would have quantum criticality for a phase transition from the ordinary M_{107} hadron physics to M_{89} hadron physics with hadronic mass scale by a factor 512 higher than for ordinary hadrons. The gluons and quarks at quantum criticality would be dark in the sense of having $h_{eff}/h = n = 512$. Also $1/n$ -fractional quarks and gluons are possible.

TGD predicts besides ordinary bosons two additional boson generations, whose family charge matrices in the space of fermion families are hermitian, diagonal and orthogonal to each other to the unit charge matrix for ordinary bosons, and most naturally same for all bosons. The charge matrices for higher generations necessarily break the universality of fermion couplings. The model for strangeness enhancement and the violation of lepton universality in B-meson decays predicts that the bosonic family charge matrix for second generation favours decays to third generation quarks and dis-favors decays to quarks of first and second generation. This predicts that the rate for prompt production of J/Ψ is lower and jet production rate from b-hadron decays is higher than predicted by QCD.

10.3.1 The prediction for prompt production of J/Ψ does not conform with the Pythia simulation

The abstract of the article [C97] published in Phys Rev Letters (see <http://tinyurl.com/l3xnxtj>) gives a more technical summary about the discovery.

The production of J/Ψ mesons in jets is studied in the forward region of proton-proton collisions using data collected with the LHCb detector at a center-of-mass energy of 13 TeV. The fraction of the jet transverse momentum carried by the J/Ψ meson, $z(J/\Psi) \equiv p_T(J/\Psi)/p_T(jet)$, is measured using jets with $p_T(jet) \geq 20$ GeV in the pseudorapidity range $2.5 \leq \eta(jet) \leq 4.0$. The observed $z(J/\Psi)$ distribution for J/Ψ mesons produced in b-hadron decays is consistent with expectations.

However, the results for prompt $p_T(J/\Psi)$ production do not agree with predictions based on fixed-order non-relativistic QCD. This is the first measurement of the p_T fraction carried by prompt J/Ψ mesons in jets at any experiment.

Some explanation about the basic notions are needed before continuing.

- (a) Pythia is a simulator producing QCD predictions in p-p, p-N, and N-N collisions. The collisions are extremely complex so that this kind of simulation involves uncertainties. QCD model involves distribution functions for partons inside hadron and fragmentation functions for jets telling the probabilities for production of various hadrons from the jet initiated by quark or gluon. Furthermore, at energy range believed to correspond to the transition from confined phase of quarks and gluons to quark-gluon plasma the modelling becomes especially difficult. Situation is made even more difficult by the fact that the quark-gluon plasma (QGP) does not look like plasma but more like ideal fluid with long range correlations. The problem might with QCD itself.
- (b) There are two mechanisms for J/Ψ production.
 - i. In direct/prompt production J/Ψ is produced in gluon annihilation. Two gluons from the colliding nucleons annihilate to quark pair either via intermediate gluon or by quark exchange. For this mechanism the production is fast, there is large transverse polarization of J/Ψ reflecting the polarization of gluon pair fusing to $c\bar{c}$ pair, and J/Ψ events are isolated in the momentum space. For $z(J/\Psi) = p_T(J/\Psi)/p_T(jet) > .6$ normalized distribution $d\sigma/dz(J/\Psi)/\sigma$ is considerably smaller than predicted by QCD (see Fig. 4 of <http://tinyurl.com/13xnxtj>).
 - ii. In jet production of J/Ψ mesons come from the decays of b-hadrons (hadrons containing b-quarks) resulting in the fragmentation of b-jets to hadrons. The mechanism is slow since c quark results from the weak decay of b quark. Pythia simulation gives a good fit in this case (see Fig. 4 of <http://tinyurl.com/13xnxtj>)
- (c) LHCb team measures the ratio of the transversal momentum of the part of jet consisting of J/Ψ mesons to the transverse momentum of the jet. This is consistent with the jet model. The team manages also to separate the jet production from prompt production and concludes that prompt production is smaller than predicted by Pythia.

The heretic questions are following. Could the direct production be smaller than predicted by QCD? Could b-quarks giving rise to jets containing more b-hadrons than QCD predicts?

10.3.2 TGD inspired model

Before going to the model it is good to explain some background.

- (a) Rather recently I proposed a TGD inspired model explaining the enhanced strangeness production observed in p-p collisions [L27] [K25]. TGD predicts 3 generations for all bosons and the family charge matrices act in the triplet representation defined by 3 fermion families for what could be called family-SU(3) acting as a spectrum generating group.

The additional two boson generations necessarily violate the universality of standard model interactions since they must be orthogonal with each other and with the charge matrix of ordinary bosons. The strongest assumption is that the charge matrices are identical for all bosons (including Higgs, photon, and even graviton).

I have talked for years about scaled-up copy of hadrons assignable to the Mersenne prime $M_{89} = 2^{89} - 1$ (ordinary hadron physics would correspond to M_{127}). The mass

scale for the hadrons of M_{89} hadron physics would be 512 times that for ordinary hadron physics and in the first approximation the masses of the scaled up hadron physics would be 512 those of the ordinary hadron physics. There are indications for roughly 10 bumps identifiable as M_{89} hadrons and having the predicted masses.

If second generation gluons prefer to decay to a quark pair of third generation (t or b pair), strangeness enhancement can be understood qualitatively since the third generation quarks would decay to c and s quarks by weak boson emission and c quarks in turn would decay to s quarks, which are rather long-lived.

- (b) The violation of the universality would take place also for weak interactions. Second generation of weak bosons in turn explain the anomalous CP violation and the violation of the lepton universality observed in the decays b -mesons. Also now it is essential that the second generation of weak bosons prefers to decay to a pair of third generation leptons, that is τ pair. Also the anomaly of muon's anomalous magnetic moment and different values of charge proton radius deduced from hydrogen atom and muonium atom could be understood in terms of the violation of lepton universality induced by the same mechanism [L22].

For these reasons and also because both c quark and s quark correspond to the second quark generation, it is interesting to see whether the too low yield of prompt c quarks and perhaps too high yield of c quarks from jets could be understood in terms of second generation of gluons preferring to decay to b quark pair and having reduced coupling to first and second fermions.

Let us look what the assumptions of this model could be.

- (a) Second generation gluons are somehow created in the collision, and they fuse to quark pair. t quark pairs (if kinematically possible) and b quark pairs are preferred due to their charge matrix in family-space for fermions. The decay to first and second generation quark pairs would be disfavored by the properties of the charge matrix. This could be enough to explain why direct production is reduced and jet production enhanced. Situation would be very similar to strangeness enhancement which should be due to the jet production.
- (b) De-confinement phase transition is believed to produce QGP. The behavior of the QGP candidate produced at RHIC and LHC is however not that of QGP. The presence of this phase even in p-p collisions looks rather strange. The TGD based model for enhanced production of strange hadrons assumes that the quantum criticality for deconfinement corresponds to that for the transition to QCD for second generation gluons. Quantum criticality for a phase transition from M_{107} hadron physics to M_{89} hadron physics would be in question.

Quantum criticality corresponds to a creation of phase with non-standard value $h_{eff}/n = n$ of Planck constant, and $n = 512$ would imply that the Compton length of second generation gluons with given energy 512 longer than for ordinary gluons: this would be a counterpart for long range quantum fluctuations at quantum criticality. The counterpart for the mass scale Λ_{QCD} would be by a factor 512 higher than its value in ordinary QCD and correspond to a mass scale about 75 GeV slightly higher than the mass of M_{89} pion.

- (c) If quantum criticality is accepted and family-charge matrices are universal, the fusion mechanism would produce from dark M_{89} gluons a pair of dark M_{89} quarks with preferring to decay to b or t quark pair and disfavoring decays to lower generation quark pairs. These quarks would transform to ordinary quarks and after that the situation would be as in ordinary QCD.

How the second generation gluons could be generated at quantum criticality?

- (a) Could ordinary gluons make a direct single particle transition to dark second generation gluons with ordinary quantum numbers or could they decay to dark fractional gluons of second generation? For both options the gluon distributions of incoming nucleons

appear in the convolution giving the cross section for gluon fusion as function of collision energy. If this assumption is not made, the distribution functions would be replaced by their analogs for the intermediate state created in the collision and having weak dependence on colliding particles. This might be tested experimentally.

- (b) Depending on whether one approaches critical energy range from below or above, $M_{107} - M_{89}$ quantum criticality means that either the ordinary M_{107} or M_{89} hadron physics becomes unstable. Long range quantum fluctuations correspond to the scaling of the correlation length by $h_{eff}/h = n = 512$. The quantum critical phase would be hybrid of these two hadron physics. This hybrid nature would resolve the paradox due to the fact that two distinct phases become single phase at criticality.

There should exist some critical parameters such as collision energy, whose variation induces the transition and the bosonic counterparts of elementary particle vacuum functionals [K11] in the moduli space of partonic 2-surfaces should change in the transition. What would happen at the level of partonic 2-surfaces? Certainly their size for ordinary M_{89} hadrons would be by a factor $1/512$ smaller.

10.4 Could ordinary nuclei contain dark $M_{G,113}$ variants of ordinary nucleons?

It is usually assumed that nuclear nucleons do not differ from free nucleons. The above proposal however raises questions about their true identity. What one can say about quarks and gluons inside atomic nuclei for which Gaussian Mersenne $M_{G,113}$ characterizes nuclear space-time sheet as an analog of hadronic space-time sheet?

Could ordinary M_{107} gluon and quarks be replaced with their dark variants with $h_{eff}/h = n = 2^6 = 64$ inside nuclei. I have consider TGD view about nuclear physics in [K42, L2, K15] and developed what I call nuclear string model. I have also considered the possibility that $M_{G,113}$ hadron physics could be involved with atomic nuclei [L17, L18] but have not proposed that they could be dark and correspond to the p-adic length scale $M_{G,113}$ of nuclei requiring $h_{eff}/h = n = 2^6$.

One can imagine several options.

- (a) Option I: Nuclear string model [L2] assumes that ordinary nuclei consist of nucleons bound together by $M_{G,113}$ meson-like flux tubes to form strings. The mass of $M_{G,113}$ pion would be about $m(\pi)/64 \simeq 2.8$ MeV, which corresponds to the scale of binding energy per nucleon for nuclear strong interactions. Nucleus could consist of strings formed by nucleons connected by meson-like flux tubes. There is an obvious analogy with the pearl-in-necklace model of galaxies. The galaxies would be ordinary matter suggesting that also the nuclear nucleons are ordinary nucleons.
- (b) Option II: Meson-like flux tubes are dark 64-sheeted structures with $m \leq 64$ -sheeted fractional quarks-antiquark pairs at ends. For $m = 64$ the flux tube has mass of ordinary pion, which does not make sense. Fractionization would be necessary. The total quantum numbers should be non-fractional. For baryon number this gives no constraint since it vanishes for mesons. Neither does spin give constraints if the bonds are pion-like spin singlets.
- (c) Option III: Also nuclear nucleons are dark having Compton lengths of order nuclear size inside nuclei and give rise to a kind of superfluid. Could one have distinct superfluids for protons and neutrons? $M_{G,113}$ nuclei would have masses $m = m_N/64 \simeq 14.9$ MeV and dark variants of ordinary M_{107} nucleons would contain at most 64 for of them - at most one at each sheet of the Galois covering and have fractionized spin and other quantum numbers. The analog with partially filled Fermi sphere is suggestive.

An interesting question is whether the decay of nuclei could produce a bunch of 64 M_{113} nuclei with ordinary value of h_{eff} . This kind of events would be rather spectacular. The rate for them should be however very small.

What about free nucleons and colliding nucleons?

- (a) In collisions of hadron with proton target the nucleons of target would be dark $M_{G,113}$ nucleons. What about proton-proton and proton-antiproton collisions. Would the protons in this case be ordinary? Or could a phase transition to dark $M_{G,113}$ phase take place so that the quarks making nucleon become fractional and one would have more than 3 genuinely fractional quarks such that the total baryon number is one. Could the resulting quarks carrying small fraction of baryon number and spin be assigned with parton sea? Could this allow to explain the proton spin puzzle.
- (b) What happens lepton proton collisions allow to see proton as consisting of ordinary valence quarks only? This does not look plausible. Could one think that in accordance with quantum criticality of TGD, nucleons are quantum critical systems and that even electromagnetic interaction with leptons generates the dark $M_{G,113}$ phase?

What about quark masses? One can imagine two options.

- (a) If dark current quark with mass of say 5 MeV consists of 64 $M_{G,113}$ fractional quarks, the fractional variant with minimal mass has mass .08 MeV. This option conforms with the view that most of the mass of hadron is due the energy of the color magnetic body of the hadron. Note that one would have spectrum of quark masses between .08 MeV and 5 MeV.
- (b) If current quark with mass of 5 MeV actually corresponds to dark $M_{G,113}$ fractional quark with minimal mass, ordinary quark would have 64 times larger mass of 320 MeV, quite near to one third of proton mass identified as mass of constituent quark in the quark model proposed by Gell-Mann at sixties.

This identification might make sense if the dark nucleus like state is generated also in proton-proton and proton-antiproton collisions as intermediate state. One could also imagine free proton is dark $M_{G,113}$ proton. Is the mass of 5 MeV too high to allow realistic masses for the meson like bonds correcting the nucleons? The scaled down pion mass is a reasonable estimate and would give a mass of 2.8 MeV, which looks realistic.

One can wonder about the TGD description for the mechanism giving rise to the nuclear binding energy. Could it be understood at deeper level in terms of splitting of nucleon to fractional nucleons and re-organization of color magnetic fluxes?

Are there any experimental findings justifying these speculative questions?

- (a) EMC (see <http://tinyurl.com/mvj5vwj>) observed around 1980 that the nucleons inside deuterium and iron behave differently as polarized targets and could have different quark sub-structures. The presence of color flux tube bonds between ordinary nucleons alone could explain this effect but also the possible 64-sheetedness of flux tubes and even the possible darkness of nuclear nucleons themselves could relate to the effect.
- (b) EMC also discovered the spin crisis of proton: quark model explains only a fraction of proton's spin (see <http://tinyurl.com/n6ghs6v>). In the experiment, a polarized muon beam collided with polarized proton target, whose protons are nuclear protons and could thus be dark variants of ordinary protons.

The first guess would be that the presence of ρ meson like flux tube bonds carrying spin could solve the spin crisis: there would be no need for dark nucleons.

Dark nucleons and fractionization of quark quantum numbers suggests second explanation. If also the colliding nucleons are dark and genuinely fractional, the fractionization baryon number and dark quark spin as $n/64 \leq 1$ -multiple of $\hbar/2$ could transfer part of dark quark spin to the parton sea. Fermi sphere provides a good analogy. Ideal nuclear nucleon has all 64 levels filled with fractional $M_{G,113}$ quarks. Interacting and even free nucleons could have lost some fraction of baryon number and spin from full Fermi sphere. These additional fractional nucleons could be part of parton sea besides gluons and the quark pairs from their decays.

The phase transition to dark phase should occur also for proton-proton collisions suggesting the existence of a kind of intermediate nucleus.

One can wonder about the TGD description for the mechanism giving rise to the nuclear binding energy.

- (a) One expects that the fundamental description involves Yangian extension of super-symplectic symmetry assigning to the system multi-local algebra generators giving hopes about first principle description of bound states [?] Since fractionization of quantum numbers is associated also with the Yangians and various quantum groups, one might expect that there is a close relationship between adelic physics and fractionization due to $h_{eff}/h = n$ hierarchy associated with the extensions of rationals.

Super-conformal invariance allows to express mass squared operator in terms of Casimir operator in vibrational degrees of freedom of Super-Virasoro algebra represented in terms of local Kac-Moody algebra generators. One might expect something analogous but for the Yangian algebra of super-symplectic algebra multilocal with respect to partonic 2-surfaces. Multilocal generators in the mass squared operator could serve as the analog of interaction Hamiltonian. I am however unable to say anything more detailed about this idea. One can however be less ambitious and make questions.

- (b) Somehow the nucleons lose some of their mass. Could one imagine a description of this loss without phenomenological notions like potential energy or interaction Hamiltonian? Adelic physics suggests that the formation of bound states represents an evolutionary step identifiable as emergence of number theoretical complexity. That is extension of rationals with a larger Galois group with order identifiable as $h_{eff}/h = n$. n represents the number of sheets of covering and the natural hypothesis is that second quantization in this discrete space of sheets is possible for fermions so that one indeed has fractional quarks, gluons, and nucleons.

Could the binding energy be understood in terms of splitting of nucleon to fractional nucleons and re-organization of color magnetic fluxes? Quantum classical correspondence suggests the possibility of classical description in terms of color-magnetic energy and one can check whether this could make any sense.

- (c) Suppose that color magnetic energy explains the energy of nucleus apart from a small 1 per cent contribution of quarks. Idealize this energy by associating it with single color-magnetic flux tube carrying constant Kähler magnetic field. Suppose that the nucleon splits into $(64 - m)/64$ -fractional nucleon and $m/64$ -fractional nucleon such that the total color flux is conserved and that color flux is fractionize unlike Kähler flux. This requires that the additive constants in the color hypercharge Hamiltonian become scaled by $(64 - m)/64$ and $m/64$. Suppose also that the thickness of flux tubes is scaled up by $S/S_0 = 64$. Kähler magnetic field scales as $(S_0/S)^2$: the reason is that there are 64 sheets in the covering. Kähler magnetic energy scales as $(S_0/S) = 1/64$.

- (d) What happens to the color magnetic energy in the splitting? Suppose that color magnetic energy is integral I of B_Y^2 and same order of magnitude as integral of B_K^2 . The division to two flux tubes gives E as sum of integrals $E_1 = [(64 - m)/64]^2 X$ and $E_2 = [m/64]^2 \times X$, $X = (S_0/S) \times I$, giving $E = E_1 + E_2 = (1 - m/32) \times X$. The change of the color magnetic energy is $\Delta E = -mX/2^{11}$ for $S_0/S = 1/64$. If the energy of constituent quarks makes about 1 per cent of hadron mass, one has $I \simeq 930$ MeV for proton and $\Delta E/I = -m/2^{11}$. One would have $\Delta E \simeq -m \times .47$ MeV. For $m = 1$ this is considerably smaller than the typical binding energy per nucleon. 5 MeV binding energy per nucleon would require $m \sim 10$. m could characterize the binding energy of nucleon. Note that color bonds between nucleons give a positive contribution to the energy per nucleon in nuclear string model. Scaled down pion mass is only 2.6 MeV. This contribution must be smaller in size that the contribution from fractionization.

11 Cosmic Rays And Mersenne Primes

Sabine Hossenfelder has written two excellent blog postings about cosmic rays. The first one is about the GKZ (see <http://tinyurl.com/ybdf1mg1>) cutoff for cosmic ray energies and second one about possible indications for new physics above 100 TeV (see <http://tinyurl.com/ybdf1mg1>).

com/ydewc2ug). This inspired me to read what I have said about cosmic rays and Mersenne primes- this was around 1996 - immediately after performing for the first time p-adic mass calculations. It was unpleasant to find that some pieces of the text contained a stupid mistake related to the notion of cosmic ray energy. I had forgotten to take into account the fact that the cosmic ray energies are in the rest system of Earth- what a shame! The recent version should be free of worst kind of blunders. Before continuing it should be noticed I am now living year 2012 and this section was written for the first time for around 1996 - and as it became clear - contained some blunders due to the confusion with what one means with cosmic ray energy. The recent version should be free of worst kind of blunders.

TGD suggests the existence of a scaled up copy of hadron physics associated with each Mersenne prime $M_n = 2^n - 1$, n prime: M_{107} corresponds to ordinary hadron physics. Also leptohadrons are predicted. Also Gaussian Mersennes $(1+i)^k - 1$, could correspond to hadron physics. Four of them ($k = 151, 157, 163, 167$) are in the biologically interesting length scale range between cell membrane thickness and the size of cell nucleus. Also leptonic counterparts of hadron physics assignable to certain Mersennes are predicted and there is evidence for them (see <http://tinyurl.com/ybfkptns>) [K47].

The scaled up variants of hadron physics corresponding to $k < 107$ are of special interest. $k = 89$ defines the interesting Mersenne prime at LHC, and the near future will probably tell whether the 125 GeV signal corresponds to Higgs or a pion of M_{89} physics. Also cosmic ray spectrum could provide support for M_{89} hadrons and quite recent cosmic ray observations [C115] are claimed to provide support for new physics around 100 TeV (see <http://tinyurl.com/y8s8swa5>). M_{89} proton would correspond to .5 TeV mass considerably below 100 TeV but this mass scale could correspond to a mass scale of a scaled up copy of a heavy quark of M_{107} hadron physics: a naïve scaling of top quark mass by factor 512 would give mass about 87 TeV. Also the lighter hadrons of M_{89} hadron physics should contribute to cosmic ray spectrum and there are indeed indications for this.

The mechanisms giving rise to ultra high energy cosmic rays are poorly understood. The standard explanation would be acceleration in huge magnetic fields. TGD suggests a new mechanism based on the decay cascade of cosmic strings. The basis idea is that cosmic string decays $cosmic\ string \rightarrow M_2\ hadrons \rightarrow M_3\ hadrons \dots \rightarrow M_{61} \rightarrow M_{89} \rightarrow M_{107}\ hadrons$ could be a new source of cosmic rays. Also variants of this scenario with decay cascade beginning from larger Mersenne prime can be considered. One expects that the decay cascade leads rapidly to extremely energetic ordinary hadrons, which can collide with ordinary hadrons in atmosphere and create hadrons of scaled variants of ordinary hadron physics. These cosmic ray events could serve as a signature for the existence of these scale up variants of hadron physics.

- (a) Centauro events and the peculiar events associated with $E > 10^5$ GeV radiation from Cygnus X-3. E refers to energy in Earth's rest frame and for a collision with proton the cm energy would be $E_{cm} = \sqrt{2EM} > 10$ TeV in good approximation whereas M_{89} variant of proton would have mass of .5 TeV. These events be understood as being due to the collisions of energetic M_{89} hadrons with ordinary hadrons (nucleons) in the atmosphere.
- (b) The decay $\pi_n \rightarrow \gamma\gamma$ produces a peak in the spectrum of the cosmic gamma rays at energy $\frac{m(\pi_n)}{2}$. These produce peaks in cosmic gamma ray spectrum at energies which depend on the energy of π_n in the rest system of Earth. If the pion is at rest in the cm system of incoming proton and atmospheric proton one can estimate the energy of the peak if the total energy of the shower can be estimated reliably.
- (c) The slope in the hadronic cosmic ray spectrum changes at $E = 3 \cdot 10^6$ GeV. This corresponds to the energy $E_{cm} = 2.5$ TeV in the cm system of cosmic ray hadron and atmospheric proton. This is not very far from M_{89} proton mass .5 TeV. The creation of M_{89} hadrons in atmospheric collisions could explain the change of the slope.
- (d) The ultra-higher energy cosmic ray radiation having energies of order 10^9 GeV in Earth's rest system apparently consisting of protons and nuclei not lighter than Fe might be actually dominated by gamma rays: at these energies γ and p induced showers have

same muon content. $E = 10^9$ GeV corresponds to $E_{cm} = \sqrt{2Em_p} = 4 \times 10^4$ GeV. M_{89} nucleon would correspond to mass scale 512 GeV.

- (e) So called GKZ cutoff should take place for cosmic gamma ray spectrum due to the collisions with the cosmic microwave background. This should occur around $E = 6 \times 10^{10}$ GeV, which corresponds to $E_{cm} = 3.5 \times 10^5$ GeV. Cosmic ray events above this cutoff (see <http://tinyurl.com/y75jho96>) are however claimed. There should be some mechanism allowing for ultra high energy cosmic rays to propagate over much longer distances as allowed by the limits. Cosmic rays should be able to propagate without collisions. Many-sheeted space-time suggests ways for how gamma rays could avoid collisions with microwave background. For instance, gamma rays could be dark in TGD sense and therefore have large value of Planck constant. One can even imagine exotic variants of hadrons, which differ from ordinary hadrons in that they do not have quarks and therefore no interactions with the microwave background.
- (f) The highest energies of cosmic rays are around $E = 10^{11}$ GeV, which corresponds to $E_{cm} = 4 \times 10^5$ GeV. M_{61} nucleon and pion correspond to the mass scale of 6×10^6 GeV and 8.4×10^5 GeV. These events might correspond to the creation of M_{61} hadrons in atmosphere.

The identification of the hadronic space-time sheet as super-symplectic mini black-hole [K30] suggests the science fictive possibility that part of ultra-high energy cosmic rays could be also protons which have lost their valence quarks. These particles would have essentially same mass as proton and would behave like mini black-holes consisting of dark matter. They could even give a large contribution to the dark matter. Since electro-weak interactions are absent, the scattering from microwave background is absent, and they could propagate over much longer distances than ordinary particles. An interesting question is whether the ultrahigh energy cosmic rays having energies larger than the GZK cut-off of 5×10^{10} GeV in the rest system of Earth are super-symplectic mini black-holes associated with M_{107} hadron physics or some other copy of hadron physics.

11.1 Mersenne Primes And Mass Scales

p-Adic mass calculations lead to quite detailed predictions for elementary particle masses. In particular, there are reasons to believe that the most important fundamental elementary particle mass scales correspond to Mersenne primes $M_n = 2^n - 1$, $n = 2, 3, 7, 13, 17, 19, \dots$

$$m_n^2 = \frac{m_0^2}{M_n} ,$$

$$m_0 \simeq 1.41 \cdot \frac{10^{-4}}{\sqrt{G}} , \quad (11.1)$$

where \sqrt{G} is Planck length. The lower bound for n can be of course larger than $n = 2$. The known elementary particle mass scales were identified as mass scales associated identified with Mersenne primes $M_{127} \simeq 10^{38}$ (leptons), M_{107} (hadrons) and M_{89} (intermediate gauge bosons). Of course, also other p-adic length scales are possible and it is quite possible that not all Mersenne primes are realized. On the other hand, also Gaussian Mersennes could be important (muon and atomic nuclei corresponds to Gaussian Mersenne $(1+i)^k - 1$ with $k = 113$).

Theory predicts also some higher mass scales corresponding to the Mersenne primes M_n for $n = 89, 61, 31, 19, 17, 13, 7, 3$ and suggests the existence of a scaled up copy of hadron physics with each of these mass scales. In particular, masses should be related by simple scalings to the masses of the ordinary hadrons.

An attractive first working hypothesis hypothesis is that the color interactions of the particles of level M_n can be described using the ordinary QCD scaled up to the level M_n so that masses and the confinement mass scale Λ is scaled up by the factor $\sqrt{M_n/M_{107}}$.

$$\Lambda_n = \sqrt{\frac{M_n}{M_{107}}} \Lambda . \quad (11.2)$$

In particular, the naïve scaling prediction for the masses of the exotic pions associated with M_n is given by

$$m(\pi_n) = \sqrt{\frac{M_n}{M_{107}}} m_\pi . \quad (11.3)$$

Here $m_\pi \simeq 135 \text{ MeV}$ is the mass of the ordinary pion. This estimate is of course extremely naïve and the recent LHC data suggests that the 125 GeV Higgs candidate could be M_{89} pion. The mass would be two times higher than the naïve estimate gives. p-Adic scalings by small powers of $\sqrt{2}$ must be considered in these estimates.

The interactions between the different level hadrons are mediated by the emission of electro-weak gauge bosons and by gluons with cm energies larger than the energy defined by the confinement scale of level with smaller p . The decay of the exotic hadrons at level M_{n_k} to exotic hadrons at level $M_{n_{k+1}}$ must take place by a transition sequence leading from the effective M_{n_k} -adic space-time topology to effective $M_{n_{k+1}}$ -adic topology. All intermediate p-adic topologies might be involved.

11.2 Cosmic Strings And Cosmic Rays

Cosmic strings are fundamental objects in quantum TGD and dominated during early cosmology.

11.2.1 Cosmic strings

Cosmic strings (not quite the same thing in TGD as in GUTs) are basic objects in TGD inspired cosmology [K12, K41].

- (a) In TGD inspired galaxy model galaxies are regarded as mass concentrations around cosmic strings and the energy of the string corresponds to the dark energy whereas the particles condensed at cosmic strings and magnetic flux tubes resulting from them during cosmic expansion correspond to dark matter [K12, K41]. The galactic nuclei, often regarded as candidates for black holes, are the most probable seats for decaying highly entangled cosmic strings.
- (b) Galaxies are known to organize to form larger linear structures. This can be understood if the highly entangled galactic strings organize around long strings like pearls in necklace. Long strings could correspond to galactic jets and their gravitational field could explain the constant velocity spectrum of distant stars in the galactic halo.
- (c) In [K12, K41, K40] it is suggested that decaying cosmic strings might provide a common explanation for the energy production of quasars, galactic jets and gamma ray bursters and that the visible matter in galaxies could be regarded as decay products of cosmic strings. The magnetic and Z^0 magnetic flux tubes resulting during the cosmic expansion from cosmic strings allow to assign at least part of gamma ray bursts to neutron stars. Hot spots (with temperature even as high as $T \sim \frac{10^{-3,5}}{\sqrt{G}}$) in the cosmic string emitting ultra high energy cosmic rays might be created under the violent conditions prevailing in the galactic nucleus.

The decay of the cosmic strings provides a possible mechanism for the production of the exotic hadrons and in particular, exotic pions. In [C82] the idea that cosmic strings might produce gamma rays by decaying first into “X” particles with mass of order 10^{15} GeV and

then to gamma rays, was proposed. As authors notice this model has some potential difficulties resulting from the direct production of gamma rays in the source region and the presence of intensive electromagnetic fields near the source. These difficulties are overcome if cosmic strings decay first into exotic hadrons of type M_{n_0} , $n_0 \geq 3$ of energy of order $2^{-n_0+2}10^{25}$ GeV, which in turn decay to exotic hadrons corresponding to M_k , $k > n_0$ via ordinary color interaction, and so on so that a sequence of M_k : s starting some value of n_0 in $n = 2, 3, 7, 13, 17, 19, 31, 61, 89, 107$ is obtained. The value of n remains open at this stage and depends on the temperature of the hot spot and much smaller temperatures than the $T \sim m_0$ are possible: favored temperatures are the temperatures $T_n \sim m_n$ at which M_n hadrons become unstable against thermal decay.

11.2.2 Decays of cosmic strings as producer of high energy cosmic gamma rays

In [C109] the gamma ray signatures from ordinary cosmic strings were considered and a dynamical QCD based model for the decay of cosmic string was developed. In this model the final state particles were assumed to be ordinary hadrons and final state interactions were neglected. In the recent case the string decays first to M_{n_0} hadrons and the time scale of for color interaction between M_{n_0} hadrons is extremely short (given by the length scale defined by the inverse of π_{n_0} mass) as compared to the time time scale in case of ordinary hadrons. Therefore the interactions between the final state particles must be taken into account and there are good reasons to expect that thermal equilibrium sets on and much simpler thermodynamic description of the process becomes possible.

A possible description for the decaying part of the highly tangled cosmic string is as a “fireball” containing various M_{n_0} ($n \geq 3$) partons in thermal equilibrium at Hagedorn temperature T_{n_0} of order $T_{n_0} \sim m_{n_0} = 2^{-2+n_0} \frac{10^{-4}}{k\sqrt{G}}$, $k \simeq 1.288$. The experimental discoveries made in RHIC suggest [C107] that high energy nuclear collisions create instead of quark gluon plasma a liquid like phase involving gluonic BE condensate christened as color glass condensate. Also black hole like behavior is suggested by the experiments.

RHIC findings inspire a TGD based model for this phase as a macroscopic quantum phase condensed on a highly tangled color magnetic string at Hagedorn temperature. The model relies also on the notion of dynamical but quantized \hbar [K13] and its recent form to the realization that super-symplectic many-particle states at hadronic space-time sheets give dominating contribution to the baryonic mass and explain hadronic masses with an excellent accuracy.

This phase has no direct gauge interactions with ordinary matter and is identified in TGD framework as a particular instance of dark matter. Quite generally, quantum coherent dark matter would reside at magnetic flux tubes idealizable as string like objects with string tension determined by the p-adic length scale and thus outside the “ordinary” space-time. This suggests that color glass condensate forms when hadronic space-time sheets fuse to single long string like object containing large number of super-symplectic bosons.

Color glass condensate has black-hole like properties by its electro-weak darkness and there are excellent reasons to believe that also ordinary black holes could by their large density correspond to states in which super-symplectic matter would form single connected string like structure (if Planck constant is larger for super-symplectic hadrons, this fusion is even more probable).

This inspires the following mechanism for the decay of exotic boson.

- (a) The tangled cosmic string begins to cool down and when the temperature becomes smaller than $m(\pi_{n_0})$ mass it has decayed to M_{n_1} matter which in turn continues to decay to M_{n_2} matter. The decay to M_{n_1} matter could occur via a sequence $n_0 \rightarrow n_0 - 1 \rightarrow \dots n_1$ of phase transitions corresponding to the intermediate p-adic length scales $p \simeq 2^k$, $n_1 \geq k > n_0$. Of course, all intermediate p-adic length scales are in principle possible so that the process would be practically continuous and analogous to p-adic length scale evolution with $p \simeq 2^k$ representing more stable intermediate states.

- (b) The first possibility is that virtual hadrons decay to virtual hadrons in the transition $k \rightarrow k-1$. The alternative option is that the density of final state hadrons is so high that they fuse to form a single highly entangled hadronic string at Hagedorn temperature T_{k-1} so that the process would resemble an evaporation of a hadronic black hole staying in quark plasma phase without freezing to hadrons in the intermediate states. This entangled string would contain partons as “color glass condensate”.
- (c) The process continues until all particles have decayed to ordinary hadrons. Part of the M_n low energy thermal pions decay to gamma ray pairs and produce a characteristic peak in cosmic gamma ray spectrum at energies $E_n = \frac{m(\pi_n)}{2}$ (possibly red-shifted by the expansion of the Universe). The decay of the cosmic string generates also ultra high energy hadronic cosmic rays, say protons. Since the creation of ordinary hadron with ultra high energy is certainly a rare process there are good hopes of avoiding the problems related to the direct production of protons by cosmic strings (these protons produce two high flux of low energy gamma rays, when interacting with cosmic microwave background [C82]).

11.2.3 Topologically condensed cosmic strings as analogs super-symplectic black-holes?

Super-symplectic matter has very stringy character. For instance, it obeys stringy mass formula due the additivity and quantization of mass squared as multiples of p-adic mass scale squared [K30]. The ensuing additivity of mass squared defines a universal formula for binding energy having no independence on interaction mechanism. Highly entangled strings carrying super-symplectic dark matter are indeed excellent candidates for TGD variants of black-holes. The space-time sheet containing the highly entangled cosmic string is separated from environment by a wormhole contact with a radius of black-hole horizon. Schwarzschild radius has also interpretation as Compton length with Planck constant equal to gravitational Planck constant $\hbar/\hbar_0 = 2GM^2$. In this framework the proposed decay of cosmic strings would represent nothing but the TGD counterpart of Hawking radiation. Presumably the value of p-adic prime in primordial stage was as small as possible, even $p = 2$ can be considered.

11.2.4 Exotic cosmic ray events and exotic hadrons

One signature of the exotic hadrons is related to the interaction of the ultra high energy gamma rays with the atmosphere. What can happen is that gamma rays in the presence of an atmospheric nucleus decay to virtual exotic quark pair associated with M_{n_k} , which in turn produces a cascade of exotic hadrons associated with M_{n_k} through the ordinary scaled up color interaction. These hadrons in turn decay $M_{n_{k+1}}$ type hadrons via mechanisms to be discussed later. At the last step ordinary hadrons are produced. The collision creates in the atmospheric nucleus the analog of quark gluon plasma which forms a second kind of fireball decaying to ordinary hadrons. RHIC experiments have already discovered these fireballs and identified them as color glass condensates [C107]. It must be emphasized that it is far from clear whether QCD really predicts this phase.

These showers differ from ordinary gamma ray showers in several respects.

- (a) Exotic hadrons can have small momenta and the decay products can have isotropic angular distribution so that the shower created by gamma rays looks like that created by a massive particle.
- (b) The muon content is expected to be similar to that of a typical hadronic shower generated by proton and larger than the muon content of ordinary gamma ray shower [C104].
- (c) Due to the kinematics of the reactions of type $\gamma + p \rightarrow H_{M_n} + \dots + p$ the only possibility at the available gamma ray energies is that M_{89} hadrons are produced at gamma ray energies above 10 TeV. The masses of these hadrons are predicted to be above 70 GeV and this suggests that these hadrons might be identified incorrectly as heavy nuclei (heavier than ^{56}Fe). These signatures will be discussed in more detail in the sequel in

relation to Centauro type events, Cygnus X-3 events and other exotic cosmic ray events. For a good review for these events and models form them see the review article [C70].

Some cosmic ray events [C99, C59] have total laboratory energy as high as 3000 TeV which suggests that the shower contains hadron like particles, which are more penetrating than ordinary hadrons.

- (a) One might argue that exotic hadrons corresponding M_k , $k > 107$ with interact only electro-weakly (color is confined in the length scale associated with M_n) with the atmosphere one might argue that they are more penetrating than the ordinary hadrons.
- (b) The observed highly penetrating fireballs could also correspond super-symplectic dark matter part of incoming, possibly exotic, hadron fused with that for a hadron of atmosphere. Both hadrons would have lost their valence quarks in the collision just as in the case of Pomeron events. Large fraction of the collision energy would be transformed to super-symplectic quanta in the process and give rise to a large color spin glass condensate. These condensates would have no direct electro-weak interactions with ordinary matter which would explain their long penetration lengths in the atmosphere. Sooner or later the color glass condensate would decay to hadrons by the analog of blackhole evaporation. This process is different from QCD type hadronization process occurring in hadronic collisions and this might allow to understand the anomalously low production of neutral pions.

Exotic mesons can also decay to lepton pairs and neutral exotic pions produce gamma pairs. These gamma pairs in principle provide a signature for the presence of exotic pions in the cosmic ray shower. If M_{89} proton is sufficiently long-lived enough they might be detectable. The properties of Centauro type events however suggest that M_{89} protons are short lived.

Jester (see <http://tinyurl.com/y78f1pbw>) told in his blog "Resonaances" about an evidence for anomalies in the decays of B meson to K meson and lepton pair. There exist several anomalies.

- (a) The 3.7 sigma deviation from standard model predictions in the differential distribution of the $B \rightarrow K^* \mu^+ \mu^-$ decay products (see <http://tinyurl.com/ycwc5t9k>) [C53].
- (b) The 2.6 sigma violation of lepton flavor universality in $B^+ \rightarrow K^+ l^+ l^-$ decays (see <http://tinyurl.com/n7nbgrk>) [C41].

The reported violation of lepton universality (, which need not be real) is especially interesting. The branching ratio $B(B^+ \rightarrow K^+ e^+ e^-)/B(B^+ \rightarrow K^+ \mu^+ \mu^-) \simeq .75$ holds true. Standard model expectation is very near to unity.

Scalar lepto-quark (see <http://tinyurl.com/y8vafz6v>) [C42] has been proposed as an explanation of the anomaly. The lowest order diagram for lepton pair production in standard model is penguin diagram (see <http://tinyurl.com/ycqrafo5>) obtained from the self energy diagram for b quark involving tW^- intermediate in which W emits γ/Z decaying to lepton pair. Lepton universality is obvious. The penguin diagram involves 4 vertices and 4 propagators and the product of CKM matrix elements $V_{tb} V_{st}^*$.

In TGD framework, and very probably also in the model studied in the article, the diagram involving lepto-quark is obtained from the tW^- self-energy loop by allowing W^- to decay to virtual antineutrino $\bar{\nu}_\mu \equiv \bar{\nu}(g=1)$ and on mass shell charged lepton $L^-(g_1)$. Virtual antineutrino in turn decays to on-shell s quark and lepto-quark of type $\sum_g D(g) \bar{\nu}(g)$, which combines with t quark to form $l^+(g_2)$. The amplitude is proportional to the product $V_{tb} V_{tD(g_2)}^*$ implying breaking of lepton universality. The amplitude for production of $e^+ l^-$ pair is considerably smaller than that for $\mu^+ l^-$ and $\tau^+ l^-$. If neutrino CKM mixing is taken into account, there is also a proportionality to the matrix element $V_{l(g_1)\nu_{g=1}}^L$. In absence of leptonic CKM mixing only $\mu^- l^+(g)$ pairs are produced and the possibility to have $g \neq 1$ is also a characteristic of lepton non-universality which is however induced by the hadronic CKM mixing: lepto-quark couplings are universal. The penguin diagram is expected to be proportional to

the resonance factors $m_t^2/(m_t^2 - m_W^2)$ and $m_X^2/(m_X^2 - m_t^2)$ so that the dependence on the mass of X is not expected to be strong.

The diagram would induce the reported effective four-fermion coupling $\bar{b}_L \gamma^\mu s_L \mu_L^\dagger \gamma_\mu \mu_L^-$ representing neutral current breaking universality. Authors propose a heavy scalar boson exchanges with quantum numbers of lepto-quark and mass of order 10 TeV to explain why no anomalous weak interactions between leptons and quarks by lepto-quark exchange have not been observed. Scalar nature would suggest Higgs type coupling proportional to mass of the lepton and this could explain why the effect of exchange is smaller in the case of electron pair. The effective left-handed couplings would however suggest vector lepto-quarks with couplings analogous to W boson coupling. Note that the effect should reduce the rate: the measured rate for $B_s \rightarrow \mu^- \mu^+$ is $.79 \pm .20$: reduction would be due to destructive interference of amplitudes.

11.3 General Ideas

Some general ideas about TGD [K25] are needed in the model and are listed in order to avoid the impression that the model is just ad hoc construct.

- (a) In TGD all elementary particle can be regarded as pairs of wormhole contacts through which monopole magnetic flux flows: two wormhole contacts are necessary to get closed magnetic field lines. Monopole flux in turn guarantees the stability of the wormhole contact. In the case of weak bosons second wormhole contact carries fermion and antifermion at opposite throats giving rise to the net charges of the boson. The neutrino pair at the second wormhole contact neutralize the weak charges and guarantees short range of weak interactions.
- (b) The TGD inspired explanation of family replication phenomenon [K11] is in terms of the genus of the partonic 2-surfaces (wormhole throat) at the end of causal diamond. There is topological mixing of partonic topologies which depend on weak quantum numbers of the wormhole throat leading to CKM mixing. Lepton and quark families obvious correspond to each other: $L(g) \leftrightarrow q(g)$ and this is important in the model to be considered.

The genera of the opposite wormhole throats are assumed to be identical for bosonic wormhole contacts. This can be assumed also for fermionic wormhole contacts for which only second throat carries fermion number. The universality of standard model couplings inspires the hypothesis that bosons are superpositions of the three lowest genera forming singlets with respect effective symmetry group $SU(3)_g$ associated with the 3 lowest genera. Gauge bosons involve also superpositions of various fermion pairs with coefficients determined by the charge matrix.

- (c) p-Adic length scale hierarchy is one of the key predictions of TGD [K22]. p-Adic length scale hypothesis (to be used in the sequel) stating that p-adic primes are near powers of 2: $p \simeq 2^k$, k integer, relies on the success of p-adic mass calculations. p-Adic length scale hypothesis poses strong constraints on particle mass scales and one can readily estimate the mass of possible p-adically scaled up variants of masses of known elementary particles.

One of the basic predictions is the possibility of p-adically scaled up variants of ordinary hadron physics and also of weak interaction physics. One such prediction is M_{89} hadron physics, which is scaled up variant of the ordinary M_{107} hadron physics with mass scale which is by a factor 512 higher and corresponds to the energy scale relevant at LHC. Hence LHC might eventually demonstrate the feasibility of TGD.

Quite generally, one can argue that one should speak about M_{89} physics [K25] in which exotic variants of weak bosons and scaled up variants of hadrons appear. There would be no deep distinction between weak bosons and M_{89} hadrons and elementary particles in general: all of them would correspond to string like objects involving both magnetic flux tubes carrying monopole flux between two wormhole throats and string world sheets connecting the light-like orbits of wormhole throats at which the signature of the induced metric changes.

- (d) TGD predicts dark matter hierarchy based on phases with non-standard value $h_{eff} = n \times h$ of Planck constant [K16]. The basic applications are to living matter but I have considered also particle physics applications.
- i. Dark matter in TGD sense provides a possible explanation for the experimental absence of super partners of ordinary particles: sparticles would be dark and would be characterized by the same p-adic mass scales as sparticles [K39].
 - ii. TGD predicts also colored leptons and there is evidence for meson like bound states of colored leptons [K47]. Light colored leptons are however excluded by the decay widths of weak bosons but also now darkness could save the situation.
 - iii. I have also proposed that RHIC anomaly observed in heavy ion collisions and its variant for proton heavy ion collisions at LHC suggesting string like structures can be interpreted in terms of low energy M_{89} hadron physics but with large value of h_{eff} meaning that the M_{89} p-adic length scale increases to M_{107} p-adic length scale (ordinary hadronic length scale) [K25].

One can consider also the adventurous possibility that vector lepto-quarks are dark in TGD sense.

- (e) TGD view about gauge bosons allows to consider also lepto-quark type states. These bosons would have quark and lepton at opposite wormhole throats. One can consider bosons which are $SU(3)_g$ singlets defined by superpositions of $L(g)q(g)$ or $L(g)\bar{q}(g)$. These states can be either M^4 vectors or scalars (all bosons are vectors in 8-D sense in TGD by 8-D chiral symmetry guaranteeing separate conservation of B and L). Left handed couplings to quarks and leptons analogous to those of W bosons are suggested by the model for the anomalies. Vector lepto-quarks can be consistent with what is known about weak interactions only if they are dark in TGD sense. Scalar lepto-quarks could have ordinary value of Planck constant.

11.4 A TGD Based Model For The B Anomaly In Terms Of Lepto-Quarks

It is natural to approach also the anomaly under discussion by assuming the basic framework just described. The anomaly in the decay amplitude of $B \rightarrow K\mu^-\mu^+$ could be due to an additional contribution based on a simple modification for the standard model amplitude.

- (a) In TGD framework, and very probably also in the model studied in the article, the starting point is the penguin diagram (see <http://tinyurl.com/ycqrafo5>) [C119] for lepton pair production in $B \rightarrow K\mu^-\mu^+$ decay involving only the decay $b \rightarrow s l^+ l^-$ by virtual tW state emitting virtual γ/Z decaying to lepton pair and combining with t to form s .
- i. The diagram for lepton pair production involving virtual lepto-quark is obtained from the tW^- self-energy loop for b . One can go around the W^- branch of the loop to see what must happen. The loop starts with $b \rightarrow tW^-$ followed by $W^- \rightarrow l^-(g_1)\bar{\nu}(g_1)$ producing on mass shell charged lepton $l^-(g_1)$. This is followed by $\bar{\nu}(g_1) \rightarrow sX(\bar{D}\bar{\nu})$ producing on mass shell s . The genus of the virtual neutrino must be $g = 1$ unless leptonic CKM mixing is allowed in the W decay vertex. After this one has $X = \sum \bar{D}(g)\bar{\nu}(g) \rightarrow \bar{D}(g_2)\bar{\nu}(g_2)$. Any value of g_2 is possible. Finally, one has $t\bar{D} \rightarrow W^+$ and $W^+\bar{\nu}(g_2) \rightarrow l^+(g_2)$. There are two loops involved and four lines contain a heavy particle (two W bosons, t , and X). The diagram contains 6 electroweak vertices whereas the standard model diagram has 4 vertices.
 - ii. All possible lepton pairs can be produced. The amplitude is proportional to the product $V_{tb}V_{tD(g_2)}^*$ implying breaking of lepton universality. The amplitude for production of $e^+\mu^-$ pair is considerably smaller than that for $\mu^+\mu^-$ and $\tau^+\mu^-$ as the experimental findings suggest. If neutrino CKM mixing is taken into account, there is also a proportionality to the matrix element $V_{l(g_1)\nu_{g=1}}^L$. In absence of leptonic CKM mixing (mixing explains the recently reported production of μ^+e^- pairs in the decays of Higgs) only $\mu^-l^+(g)$ pairs are produced. The

possibility to have $g_2 \neq 1$ is also a characteristic of lepton non-universality, which is however induced by the hadronic CKM mixing: lepto-quark couplings are universal. Note that flavour universality of the gauge couplings means in the case of lepto-quarks that Lq pairs superpose to single $SU(3)_g$ singlet as for ordinary gauge bosons. If $L(g)q(g)$ would appear as separate particles, only $\mu^+\mu^-$ pairs would be produced in absence of leptonic CKM mixing.

- (b) A rough estimate for the ratio r of lepto-quark amplitude $A(b \rightarrow sl^-(g_1)l^+(g_2))$ to the amplitude $A(b \rightarrow sl^-(g)l^+(g))$ involving virtual photon decaying to l^+l^- pair is

$$z = \frac{X_1}{X_2} \times \frac{F_1(x_X, x_t)}{F_2(x_t)}$$

$$X_1 = V_{tD(g_2)} V_{l_1\nu(g=1)}^L [\sum_g V_{l^-(g_2)\nu(g)}^L V_{D(g)t}^*] g_X^2 g_W^2, \quad X_2 = V_{dt}^* e^2,$$

$$x_X = \frac{m^2(X)}{m^2(W)}, \quad x_t = \frac{m^2(t)}{m^2(W)}.$$

The functions F_i correspond come from the loop integral and depend on mass ratios appearing as the argument. The factors X_i collect various coupling parameters together. The functions F_i correspond come from the loop integral and depend on mass ratios appearing as the argument.

- (c) The objection is that the model predicts a contribution to the scattering of leptons and quarks of the same family ($L(g) - q(g)$ scattering) by the exchange of lepto-quark, which is of the same order of magnitude as for ordinary weak interactions. This should have been observed in high precision experiments testing standard model if the mass of the lepto-quark is of the same magnitude as weak boson mass. 10 TeV mass scale for lepto-quarks should guarantee that this is not the case and is probably the basic motivation for the estimate of [C42]. This requires that the ratio of the loop integrals appearing in z is of the order of unity. For a processional it should be easy to check this. Since the loop integral in the case of scalar lepto-quark studied in [C42] has the desired property and should not depend on the spin of the particles in the loops, one has good reasons to expect that the same holds true also for vector lepto-quarks.

Without a precise numerical calculation one cannot be sure that the loop integral ratio is not too large. In this case one could reduce the gauge coupling to lepto-quarks (expected to be rather near to weak coupling constant strength) but this looks like ad hoc trick. A more adventurous manner to overcome the problem would be to assume that lepto-quarks represent dark matter in TGD sense having effective Planck constant $h_{eff} = n \times h$. Therefore they would not be visible in the experiments, which do not produce dark matter in elementary particle length scales.

- (d) The proposal of the article is that lepto-quark is scalar so that its coupling strength to leptons and quarks would increase with mass scale. If I have understood correctly, the motivation for this assumption is that only in this manner the effect on the rate for e^+e^- production is smaller than in the case of $\mu^+\mu^-$ pair. As found, the presence of CKM matrix elements in lepto-quark emission vertices at which quark charge changes, guarantees that both anomalous contributions to the amplitude are for electron pair considerably smaller than for muon pair.
- (e) Can one say something interesting about the mass of the lepto-quark using p-adic length scale hypothesis?

Consider first a mass estimate for *dark vector lepto-quark* expected to have weak boson mass scale. Even the estimate $m(X) \sim m(W)$ is much higher than the very naïve estimate as a sum of μ^- and s masses would suggest. Quite generally, if weak bosons, lepto-quarks, and M_{89} hadrons are all basic entities of same M_{89} physics, the mass scale is expected to be that of M_{89} hadron physics and of the order of weak mass scale. A very naïve scaling estimate for the mass would be by factor 512 and give an estimate around 50 GeV. If μ^- mass is scaled by the same factor 512, one obtains mass of order 100 GeV consistent with the estimate for the magnitude of the anomaly.

Second p-adic mass scale estimate assumes vector or scalar lepto-quark with mass scale not far from 10 TeV. Ordinary μ^- corresponds to Gaussian Mersenne $M_{G,k}$, $k = 113$. If p-adically scaled up variant of lepton physics is involved, the electron of the p-adically scaled up lepton physics could correspond to M_{89} . If muons correspond to Gaussian primes then the scaled up muon would correspond to the smallest Gaussian Mersenne prime below M_{89} , which is $M_{G,79}$. The mass of the scaled up muon would be obtained from muon mass by scaling by a factor $2^{(113-79)/2} = 2^{17} = 1.28 \times 10^5$ giving mass of order 10 TeV, which happens to be consistent with the conservative estimate of the article (see <http://tinyurl.com/y8vafz6v>) [C42].

- (f) An interesting possibility is that light leptoquarks (using CP_2 mass scale as unit) actually consist of quark and lepton, which is right-handed neutrino apart from possible mixing with left-handed antineutrino, whose addition to the one-particle state generates broken $\mathcal{N} = \infty$ supersymmetry in TGD. The above model could be consistent with this interpretation since the scalar leptoquark is assumed to consist of right-handed neutrino and quark ($D\nu_R$). This would resolve the long-standing issue about the p-adic mass scale of sparticles in TGD. I have made also other proposals - in particular the idea that sparticles could have same p-adic mass scales as particles but appear only as dark in TGD sense- that is having non-standard value of Planck constant.

Leptoquarks have received considerable attention in blogs. Both Jester (see <http://tinyurl.com/yd6jksu3>) and Lubos (see <http://tinyurl.com/ybosxc93>) have written about the topic. Jester lists 3 B-meson potential anomalies, which leptoquarks could resolve:

- A few sigma deviation in differential distribution of $B \rightarrow K^* \mu^+ \mu^-$ decays.
- 2.6 sigma violation of lepton flavor universality in $B \rightarrow D \mu^+ \mu^-$ vs. $K \rightarrow D e^+ e^-$ decays.
- 3.5 sigma violation of lepton flavor universality, but this time in $B \rightarrow D \tau \nu$ vs. $B \rightarrow D \mu \nu$ decays.

There is also a 3 sigma discrepancy of the experimentally measured muon magnetic moment, one of the victories of QED. And old explanation has been in terms of radiative corrections brought in by SUSY. In TGD framework one can consider an explanation in terms of $\mathcal{N} = 2$ SUSY generated by right-handed neutrino. It has been claimed (see <http://tinyurl.com/yd7ghca>) that leptoquark with quantum numbers of $D\nu_R$, where D denotes D type quark actually s quark, which in TGD framework corresponds to genus $g = 1$ for the corresponding partonic 2-surface, could explain all these anomalies.

11.5 A TGD Based Model For The B Anomaly In Terms Of Higher Weak Boson Generations

An alternative model would explain the breaking of lepton universality in terms of bosonic analogs of higher fermion generations. The charge matrix of ordinary gauge boson is unit matrix in the 3-D state space assignable with the three generations representing various fermion families. Gauge bosons correspond to charge 3×3 matrices, which must be orthogonal with respect to the inner product defined by trace. Hence fermion universality is broken for the 2 higher gauge boson generations. The first guess is that the mass scale of the second boson generation corresponds to Gaussian Mersenne $M_{G,79}$ [K25] [L13].

The model for the breaking of universality in lepton pair production is in terms of $M_{G,79}$ bosons. In standard model the production of charged lepton pairs would be due to the decay of virtual W bosons appearing in self-energy loop of penguin diagram. W emits Z^0 or γ decaying to a charged lepton pair. If a virtual higher generation W_{79} boson appears in self energy loop, it can transform to W by emitting Z_{79}^0 or γ_{79} decaying to lepton pair and inducing a breaking of lepton universality. Direct decays of W_{79} to $l\nu_L$ pairs imply a breaking of lepton universality in lepton-neutrino pair production.

The breaking of the universality is characterized by charge matrices of weak bosons for the dynamical $SU(3)$ assignable with family replication. The first generation corresponds

to unit matrix whereas higher generation charge matrices can be expressed as orthogonal combinations of isospin and hypercharge matrices I_3 and Y . I_3 distinguishes between tau and lower generations (third experiment) but not between the lowest two generations. There is however evidence for this (the first two experiments above). Therefore a mixing of the I_3 and Y should occur.

The coupling to second generation Z boson could thus explain the breaking of universality in the decays of B boson. In TGD Z' would correspond to second generation Z boson. p-Adic length scale hypothesis plus assumption that new Z boson corresponds to Gaussian Mersenne $M_{G,79} = (1+i)^{79} - 1$ predicts that its mass is by factor 32 higher than mass of ordinary Z boson making 2.9 TeV for 91 GeV mass for Z. There are indications for a bump at this mass value. Leptoquark made of right handed neutrino and quark is less plausible explanation but predicted by TGD as squark.

Recently additional more direct evidence for the existence of this kind of weak boson has emerged (see <http://tinyurl.com/gqrg9zt>). If I understood correctly, the average angle between the decay products of B meson is not quite what it is predicted to be. This is interpreted as an indication that Z' type boson appears as an intermediate state in the decay.

Does the breaking of universality occurs also for color interactions? If so, the predicted M_{89} and $M_{G,79}$ hadron physics would break universality in the sense that the couplings of their gluons to quark generations would not be universal. This also forces to consider to the possibility that there are new quark families associated with these hadron physics but only new gluons with couplings breaking lepton universality. This looks somewhat boring at first.

On the other hand, there exist evidence for bumps at masses of M_{89} hadron physics predicted by scaling to be 512 time heavier than the mesons of the ordinary M_{107} hadron physics. According to the prevailing wisdom coming from QCD, the meson and hadron masses are however known to be mostly due to gluonic energy and current quarks give only a minor contribution. In TGD one would say that color magnetic body gives most of the meson mass. Thus the hypothesis would make sense. One can also talk about constituent quark masses if one includes the mass of corresponding portion of color magnetic body to quark mass. These masses are much higher than current quark masses and it would make sense to speak about constituent quarks for M_{89} hadron physics. Constituent quarks of the new hadron physics would be different from those of the standard hadron physics.

With a lot of good luck both mechanisms are involved and leptoquarks are squarks in TGD sense. If also M_{89} and M_{79} hadron make themselves visible at LHC (there are several pieces of evidence for this), a breakthrough of TGD would be unavoidable. Or is it too optimistic to hope that the power of truth could overcome academic stupidity, which is after all the strongest force of Nature?

12 New Indications For The New Physics Predicted By TGD

TGD predicts a lot of physics in LHC scales. Two scaled up copies of hadron physics, higher families of gauge bosons and Higgs particles, and fundamental sfermions identifiable as bound states of fermions and right handed neutrino or antineutrino or their pair giving rise to leptoquarks states in quark sector, are suggestive. The predictive power of TGD approach comes from the p-adic length scale hypothesis allowing to predict the masses of new states from known ones by simple scaling argument. One knows precisely what to search for unlike in the case of a typical model containing large number of unknown parameters. The key prediction are two spectroscopies of new hadrons rather than a couple of some exotic particles and sooner or later their existence should become manifest. In this article I summarize the recent indications for the existence of these states. In particular, the identification of the recently reported bump at 750 GeV as $\eta(755 \text{ GeV})$ meson of M_{89} hadron physics, of the reported 2 TeV bump as pion of $M_{G,79}$ physics, and of the reported 4 TeV bump as Higgs

of M_{79} electroweak physics assignable to the second generation of weak gauge bosons. The existence of M_{89} neutral pion with mass around 67.5 GeV is now a rather firm prediction.

12.1 Some Almost Predictions Of TGD

TGD predicts a lot of new physics at LHC energy scale.

- (a) TGD suggests the existence of two scaled up copies of the ordinary hadron physics labelled by Mersenne prime $M_{107} = 2^{107} - 1$ [K25]. The first copy would correspond to M_{89} with mass spectrum of ordinary hadrons scale by factor $2^9 = 512$ and second one to Gaussian Mersenne $M_{G,179} = (1 + i)^{79} - 1$ with mass spectrum of ordinary hadrons scaled by 2^{14} . The signature of this new physics is the existence of entire hadronic spectroscopy of new states rather than just a couple of exotic elementary particles. If this new physics is there it is eventually bound to become visible as more information is gathered. What is especially interesting that in heavy ion collisions at RHIC and in proton heavy ion collisions at LHC dark variants of M_{89} hadrons with Compton length scaled up by $h_{eff}/n = n$ to hadronic or even nuclear dimensions could have been produced. This might be the case in all collisions of ordinary hadrons.
- (b) TGD also suggests [K25, K11] the existence of copies of various gauge bosons analogous to higher fermion generations assigned to the genus $g = 0, 1, 2$ of boundary topology of partonic 2-surface: genus is actually the of partonic 2-surface whose light-like orbit is the surface at which the induced metric changes its signature from Minkowskian to Euclidian. Copies of gauge bosons (electroweak bosons and gluons) and Higgs correspond to octet representations for the dynamical "generation color" group SU(3) assignable to 3 fermion generations. The 3 gauge bosons with vanishing "color" are expected to be the lightest ones: for them the opposite throats of wormhole contact have same genus. The orthogonality of charge matrices for bosons implies that the couplings of these gauge bosons (gluons and electroweak bosons) to fermions break universality meaning that they depend on fermion generations. There are indications for the breaking of the universality. TGD differs from minimal supersymmetric extension of standard model in that all these Higgses are almost eaten by weak gauge bosons so that only the neutral Higgses remain.

One can ask whether the three lightest copies of weak and color physics for various boson families could correspond M_{89} , $M_{G,79}$ and M_{61} .

- (c) TGD SUSY is not $\mathcal{N} = 1$ [K39]. Instead superpartners of particle is added by adding right handed neutrino or antineutrino or pair of them to the state. In quark sector one obtains leptoquark like states and the recent indications for the breaking of lepton universality has been also explained in terms of leptoquarks which indeed have quantum numbers of bound states of quark and right-handed neutrino also used to explain the indications for the breaking of lepton universality.

12.2 Indications For The New Physics

During last years several indications for the new physics suggested by TGD have emerged. Recently the first LHC Run 2 results were announced and there was a live webcast (see <http://tinyurl.com/p7kwtjy>).

- (a) The great news was the evidence for a two photon bump at 750 GeV about which there had been rumors. Lubos told earlier about indications for diphoton bump around 700 GeV. If the scaling factor is the naïve 512 so that M_{89} pion would have mass about 70 GeV, there are several meson candidates. The inspection of the experimental meson spectrum (see <http://tinyurl.com/z6ayt2h>) shows that there is quite many resonances with desired quantum numbers. The scaled up variants of neutral scalar mesons $\eta(1405)$ and $\eta(1475)$ consisting of quark pair would have masses 719.4 GeV and 755.2 GeV and could explain both 700 GeV and 750 bump. There are also neutral exotic

mesons which cannot be quark pairs but pairs of quark pairs (see <http://tinyurl.com/g13nby8>) $f_0(400)$, $f_0(980)$, $f_2(1270)$, $f_0(1370)$, $f_0(1500)$, $f_2(1430)$, $f_2(1565)$, $f_2(1640)$, $f_7(1710)$ (the subscript tells the total spin and the number inside brackets gives mass in MeVs) would have naïvely scaled up masses 204.8, 501.8, 650.2, 701.4, 768.0, 732.2, 801.3, 840.0, 875.5 GeV. Thus f_0 meson consisting of two quark pairs would be also a marginal candidate. The charged exotic meson $a_0(1450)$ scales up to 742.4 GeV state.

- (b) There is a further mystery involved. Matt Strassler (see <http://tinyurl.com/hvz2qd8>) emphasizes the mysterious finding fact that the possible particle behind the bump does not seem to decay to jets: only 2-photon state is observed. Situation might of course change when data are analyzed. Jester (<http://tinyurl.com/j7t3ab4>) in fact reports that 1 sigma evidence for $Z\gamma$ decays has been observed around 730 GeV. The best fit to the bump has rather large width, which means that there must be many other decay channels than digamma channels. If they are strong as for TGD model, one can argue that they should have been observed.

As if the particle would not have any direct decay modes to quarks, gluons and other elementary particles. If the particle consists of quarks of M_{89} hadron physics it could decay to mesons of M_{89} hadron physics but we cannot directly observe them. Is this enough to explain the absence of ordinary hadron jets: are M_{89} jets somehow smoothed out as they decay to ordinary hadrons? Or is something more required? Could they decay to M_{89} hadrons leaking out from the reactor volume before a transition to ordinary hadrons?

Or could a more mundane explanation work? Could 750 GeV states be dark M_{89} eta mesons decaying only via digamma annihilation to ordinary particles be in question? For ordinary pion the decays to gamma pairs dominate over the decays to electron pairs. Decays of ordinary pions to lepton or quark pairs must occur either by coupling to axial weak current or via electromagnetic instanton term coupling pseudo-scalar state to two photon state. The axial current channel is extremely slow due to the large mass of ordinary weak bosons but I have proposed that variants of weak bosons with p-adically scaled down masses are involved with the decays recently called X bosons [L18] and perhaps also with the decays of ordinary pion to lepton pairs). Pseudoscalar can also decay to virtual gamma pair decaying to fermion pair and for this the rate is much lower than for the decay to gamma pair. This would be the case also for M_{89} mesons if the decays to lepton or quark pair occurs via these channels. This might be enough to explain why the decay products are mostly gamma pairs.

- (c) In the previous section arguments suggesting the production of dark M_{89} hadrons with $h_{eff}/h = 512$ at quantum criticality were developed. The TGD inspired idea that M_{89} hadrons are produced at RHIC in heavy ion collisions and in proton heavy ion collisions at LHC as dark variants with large value of $h_{eff} = n \times h$ with scaled up Compton length of order hadron size or even nuclear size conforms with finding that the decay of string like objects identifiable as M_{89} hadrons in TGD framework explains the unexpected properties of what was expected to be simple quark gluon plasma analogous to blackbody radiation.

Quantum criticality [?] suggests that the production of dark M_{89} mesons (responsible for quantal long range correlations) is significant only near the threshold for their production (the energy transfer would take place in scale of proton to dark M_{89} meson with size of proton). Note that in TGD inspired biology dark EEG photons would have energies in bio-photon energy range (visible and UV) and would be exactly analogous to dark M_{89} hadrons. The criticality could correspond to the phase transition from confined to de-confined phase (at criticality confinement with much larger mass but with scaled up Compton wavelength!).

The bad news is that the rate for the production of M_{89} mesons with standard value of Planck constant at higher LHC energies could be undetectably small. If this is the case, there is no other way than tolerate the ridicule, and patiently wait that quantum criticality finds its place in the conceptual repertoire of particles physicists. There have been “reliable” rumors that 750 GeV bump is disappearing and Lubos Motl (see <http://tinyurl.com/h9gx2ep>) announced 5 August in the commentary ICHEP 2016

conference held in Chicago that the bump has indeed disappeared. If the bump is real but disappears at higher energies, it would provide support for quantum criticality.

This explanation might indeed apply to lighter M_{89} meson candidates detected in the earlier runs at lower energies but not to 750 GeV bump as I thought first. 750 GeV bump was announced in December 2015 on basis of the first analysis of data gathered since May 15 2015 (see <http://tinyurl.com/hfvhjtj>). Hence the diphoton bump that I identified as M_{89} eta meson is lost if one takes the outcome of the analysis as the final word.

One should not give up so easily. If the production mechanism is same as for electro-pion [K47] (see <http://tinyurl.com/zvk3umn>), the production amplitude is by anomaly considerations proportional to the Fourier transform of the classical "instanton density" $I = E \cdot B$. In head-on collisions one tends to have $I = 0$ because E (nearly radial in cylindrical coordinates) and B (field lines rotating around z-axis) for given proton are orthogonal and differ only apart from sign factors when the protons are in same position. For peripheral collisions in which also strange looking production of string like configurations parallel to beams was observed in both heavy ion and proton-proton collisions, $E_1 \cdot B_2$ can be vanishing as one can understand by figuring out what the electric and magnetic fields look like in the cm coordinates. There is clearly a kind of quantum criticality involved also in this sense. Could these events be lost by posing various reasonable looking constraints on the production mechanism? But why the first analysis would have shown the presence of these events? Have some criteria changed?

To find M_{89} pseudoscalars one should study peripheral collisions in which protons do not collide quite head-on and in which M_{89} pseudoscalars could be generated by em instanton mechanism (see <http://tinyurl.com/hxges8w>). In peripheral situation it is easy to measure the energy emitted as particles since strong interactions are effectively absent - only the $E \cdot B$ interaction plus standard em interaction if TGD view is right. Unfortunately peripheral collisions are undesired since the beams are deflected from head-on course! These events are however detected but data end up to trash bin usually as also deflected protons!! Luckily, the team led by my finnish colleague Risto Orava (we started as enthusiastic physics students at the same year and were coffee table friends) is studying just those p-p collisions, which are peripheral (see <http://tinyurl.com/yc8xvve> and <http://tinyurl.com/hxges8w>) to find if Cernettes could be found in trashbin! It would be wonderful if they would find Cernettes and maybe also other M_{89} pseudo-scalars from the trashbin!

- (d) Lubos mentions in his posting <http://tinyurl.com/p7muf9p> several excesses, which could be assigned with the above mentioned states. The bump at 750 GeV could correspond to scaled up copy of $\eta(1475)$ or - less probably - $f_0(1500)$. Also the bump structure around 700 GeV for which there are indications (see <http://tinyurl.com/jjuuzj>) could be explained as a scaled up copy of $\eta(1405)$ or $f_0(1370)$ with mass around 685 GeV. Lubos mentions also a 662 GeV bump (see <http://tinyurl.com/jl7sksof>). If it turns out that there are several resonances in 700 TeV region (and also elsewhere) then the only reasonable explanation relies on hadron like states since one cannot expect a large number of Higgs like elementary particles. One can of course ask why the exotic states should be seen first.
- (e) Remarkably, for the somewhat ad hoc scaling factor $2 \times 512 \sim 10^3$ one does not have any candidates so that the M_{89} neutral pion should have the naïvely predicted mass around 67.5 GeV. Old Aleph anomaly [?]ad mass 55 GeV. This anomaly did not survive. I found from my old writings [K39] that Delphi and L3 have also observed 4-jet anomaly with dijet invariant mass about 68 GeV: M_{89} pion? There is indeed an article about search of charged Higgs bosons in L3 (see <http://arxiv.org/pdf/hep-ex/0105057.pdf>) telling about an excess in $c\bar{s}\tau^-\bar{\nu}_\tau$ production identified in terms of H^+H^- annihilation suggesting charged Higgs mass 68 GeV. TGD based interpretation would in terms of the annihilation of charged M_{89} pions.

The gammas in 130-140 GeV range detected by Fermi telescope [E1] (see <http://tinyurl.com/htosagn>) were the motivation for assuming that M_{89} pion has mass twice the naïvely scaled up mass. The digammas could have been produced in the annihilation

of a state with mass 260 GeV. The particle would be the counterpart of the ordinary η meson $\eta(548)$ with scaled up mass 274 GeV thus decaying to two gammas with energies 137 GeV. An alternative identification of the galactic gamma rays in terms of gamma ray pairs resulting in the annihilation of two dark matter particles nearly at rest. It has been found that this interpretation cannot be correct (see <http://tinyurl.com/zve4fap>).

Also scaled up eta prime should be there. Also an excess in the production of two-jets above 500 GeV dijet mass has been reported (see <http://tinyurl.com/o6hmry4>) and could relate to the decays of $\eta'(958)$ with scaled up mass of 479 GeV! Also digamma bump should be detected.

- (f) What about M_{89} kaon? It would have scaled up mass 250 GeV and could also decay to digamma. There are indications for a Higgs like state with mass of 250 GeV from ATLAS (see <http://tinyurl.com/z5vzz141>! It would decay to 125 GeV photons - the energy happens to be equal to Higgs mass. There are thus indications for both pion, kaon, all three scaled up η mesons and kaon and η' with predicted masses! The low lying M_{89} meson spectroscopy could have been already seen!
- (g) Lubos mentions (see <http://tinyurl.com/hzxsnmy>) also indications for 285 GeV bump decaying to gamma pair. The mass of the eta meson of ordinary hadron physics is .547 GeV and the scaling of eta mass by factor 512 gives 280.5 GeV : the error is less than 2 per cent.
- (h) Lubos tells (see <http://tinyurl.com/jpunanb>) about 3 sigma bump at 1.650 TeV assigned to Kaluza-Klein graviton in the search for Higgs pairs hh decaying to $b\bar{b} + b\bar{b}$. Kaluza-Klein gravitons are rather exotic creatures and in absence of any other support for superstring model they are not the first candidate coming into my mind. I do not know how strong the evidence for spin 2 is but I dare to consider the possibility of spin 1 and ask whether M_{89} hadron physics could allow an identification for this bump.
- i. Very naïvely the scaled up J/Psi of the ordinary M_{107} hadron physics having spin $J = 1$ and mass equal to 3.1 GeV would have 512 times higher mass 1.585 TeV: error is about 4 per cent. The effective action would be based on gradient coupling similar in form to Zhh coupling. The decays of scaled up Ψ/J could take place via $hh \rightarrow b\bar{b}b + b\bar{b}$ also now.
 - ii. This scaling might be too naïve: the quarks of M_{89} hadron physics might be same as those of ordinary hadron physics so that only the color magnetic energy would be scaled up by factor 512. c quark mass is equal 1.29 GeV so that the magnetic energy of ordinary J/Psi would be equal to .52 GeV. If so, M_{89} version of J/Psi would have mass of only 269 GeV. Lubos tells also about evidence for a 2 sigma bump at 280 GeV identified as CP odd Higgs - this identification of course reflects the dream of Lubos about standard SUSY at LHC energies. However, the scaling of η meson mass 547.8 MeV by 512 gives 280.4 GeV so that the interpretation as η meson proposed already earlier is convincing. The naïve scaling might be the correct thing to do also for mesons containing heavier quarks.
- (i) In his latest posting Lubos (see <http://tinyurl.com/z8np21c>) tells about an excess (I am grateful for Lubos for keeping book about the bumps: this helps enormously), which could have interpretation as the lightest M_{89} vector meson - ρ_{89} or ω_{89} . Mass is the predicted correctly with 5 per cent accuracy by the familiar p-adic scaling argument: multiply the mass of ordinary meson with 512.

This 375 GeV excess might indeed represent the lightest vector meson of M_{89} hadron physics. ρ and ω of standard hadron physics have mass 775 MeV and the scaled up mass is about 397 GeV, which is about 5 per cent heavier than the mass of $Z\gamma$ excess. The decay $\rho \rightarrow Z + \gamma$ describable at quark level via quark exchange diagram involving emission of Z and γ . The effective action would be proportional to $Tr(\rho * \gamma * Z)$, where the product and trace are for antisymmetric field tensors. This kind effective action should describe also the decay to gamma pair. By angular momentum conservation the photons of gamma pairs should be in relative $L = 1$ state. Since Z is relativistic, $L = 1$ is expected to be favored also for $Z + \gamma$ final state. Professional could immediately tell whether this is correct view. Similar argument applies to the decay of ω which is isospin

singlet. For charged ρ also decays to $W\gamma$ and WZ are possible. Note that the next lightest vector meson would be K^* with mass 892 MeV. K_{89}^* should have mass 457 GeV.

- (j) Lubos (see <http://tinyurl.com/hweqnnu>) tells also that ATLAS sees charged boson excess manifesting via decay to tb in the range 200-600 TeV. Here Lubos takes the artistic freedom to talk about charged Higgs boson excess since Lubos still believes in standard SUSY predicting copies several Higgs doublets. TGD does not allow them. In TGD framework the excess could be due to the presence of charged M_{89} mesons: pion, kaon, ρ , ω .
- (k) A smoking gun evidence would be detection of production of pairs of M_{89} nucleons with masses predicted by naïve scaling to be around 470 GeV. This would give rise to dijets above 940 GeV cm energy with jets having total quantum numbers of ordinary nucleons. Each M_{89} nucleon consisting of 3 quarks of M_{89} hadron physics could also transform to ordinary quarks producing 3 ordinary hadron jets.

What about exotic mesons not allowed by the standard quark model?

- (a) Lubos Motl told in his blog about very interesting new bumps reported by CMS in ZZ channel (see <http://tinyurl.com/h19au3p>). There is 3-4 sigma evidence in favor of a 650 GeV boson (see <http://tinyurl.com/hd2pcug>). Lubos suggests an interpretation as bulk graviton of Randall-Sundrum model. Lubos mentions also evidence for a boson of gamma-gamma resonance with mass 975 GeV.

M_{89} hadron physics explains the masses for a variety of bumps observed hitherto. The first guess therefore that mesons of M_{89} hadron physics are in question. By performing the now boringly familiar scaling down of masses by factor $1/512$ for the masses one obtains the masses of corresponding mesons of ordinary hadron physics: one obtains 1270 MeV and 1904 MeV corresponding to 650 GeV and 975 GeV. Do ordinary mesons with these masses exist?

- (b) To see that this is the case, one can go to the table of exotic mesons (see <http://tinyurl.com/g13nby8>). There indeed is exotic graviton like meson $f_2^{++}(1270)$ with correct mass. There is also exotic meson $f_2^{++}(1910)$: the mass differs from the predicted 1904 MeV by .15 per cent. Graviton like states understandable as tetraquark states not allowed by the original quark model would be in question. The interested reader can scale up the masses of other exotic mesons identifiable as candidates for tetraquarks to produce predictions for new bumps to be detected at LHC.

Both states have spin 2 as also Randall-Sundrum bulk gravitons. What distinguishes the explanations that TGD predicts the masses of these states with an excellent accuracy and predicts a lot of more: just take the table of mesons and multiply by 512 and you can tell your grand children that you predicted entire spectroscopy correctly!

- (c) In TGD framework these states are indeed possible. All elementary particles and also meson like states correspond to pairs of wormhole contacts. There is closed monopole flux tube with the shape of highly flattened square with long sides of the order of Compton length in question and short sides of the order of CP_2 size. The wormhole throats of both wormhole contact carry quark and antiquark and one can see the structure either as a pair of gauge boson like states associated with the contacts or as a pair of mesonlike states at the two space-time sheets involved.

Is there any evidence for $M_{G,79}$ hadron physics? Tommaso Dorigo (see <http://tinyurl.com/ngdhwhf>) told about indications for a neutral di-boson bump at 2 TeV (see <http://tinyurl.com/hbevkmx>). The mass of M_{79} pion is predicted to be 2.16 TeV by a direct scaling of the mass 135 MeV of the ordinary neutral pion!

What about higher generations of gauge bosons?

- (a) There has been also a rumour about a bump at 4 TeV. By scaling Higgs mass 125 GeV by 32 one obtains 4 TeV! Maybe the Higgs is there but in different sense than in standard SUSY! Could one have copy of weak physics with scale up gauge boson masses and Higgs

masses waiting for us! Higgs would be second generation Higgs associated with second generation of weak bosons analogous to that for fermions predicted by TGD? Actually one would have octet associated with dynamical "generation color" symmetry $SU(3)$ but neutral members of the octet are expected to be the lightest states. This Higgs would have also only neutral member after massivation and differ from SUSY Higgs also in this respect. The scaled up weak boson masses would be by scaling with factor 32 from 80.4 GeV for W and 91 GeV for Z would be 2.6 TeV and 2.9 TeV respectively. Lubos (see <http://tinyurl.com/zjbdn7a>) mentions also 2.9 GeV dilepton event: decay of second generation Z^0 !

- (b) There is already evidence for second generation gauge bosons from the evidence for the breaking of lepton universality [K25]. The couplings of second generation weak bosons depend on fermion generation because their charge matrices must be orthogonal to those of the ordinary weak bosons. The outcome is breaking of universality in both lepton and quark sector. An alternative explanation would be in terms leptoquarks (see <http://tinyurl.com/oat538m>), which in TGD framework are super partners of quarks identifiable as pairs of right-handed neutrinos and quarks.
- (c) New evidence for the existence of this kind of weak boson has emerged (see <http://tinyurl.com/gqrg9zt1>). If I understood correctly, the average angle between the decay products of B meson is not quite what it is predicted to be. This is interpreted as an indication that Z' type boson appears as an intermediate state in the decay.
- (d) Lubos Motl told in his blog (see <http://tinyurl.com/jpunanb>) about direct evidence for Z' boson now: earlier the evidence was only indirect: breaking of universality and anomaly in angle distribution in B meson decays. Z' bump has mass around 3 TeV. TGD predicts 2.94 TeV mass for second generation Z breaking universality (mass would differ by scaling factor 32 from that of ordinary Z). The decay width would be by direct scaling .08 TeV and is larger than deviation .06 TeV from 3 TeV. Lubos reported half year ago (see <http://tinyurl.com/zqsdpvw> about excess at 2.9 GeV which is also consistent with TGD prediction.

We are living exciting times! Evidence for three new branches of physics predicted by TGD is accumulating! As such each bump is not convincing but when large number of bumps has just the predicted masses, situation changes. If TGD is right, experimenters and theorists are forced to change their paradigm completely. Instead of trying to desperately to identify elementary particle predicted by already excluded theories like SUSY they must realize that there is entire zoo of hadron resonances whose existence and masses are predicted by scaled up hadron physics. Finding a needle in haystack is difficult. In the recent situation one does not even know what one is searching for! Accepting TGD framework one would know precisely what to search for. The enormous institutional inertia of recent day particle physics community will not make the paradigm shift easy. The difficult problem is how to communicate bi-directionally with the elite of particle physics theorists, which refuses to take seriously anyone coming outside the circles.

12.3 Muon surplus in high energy cosmic ray showers as an indication for new hadron physics

The latest twistor in the story comes from cosmic ray physics. According to the article "Viewpoint: Cosmic-Ray Showers Reveal Muon Mystery" in APS Physics (see <http://tinyurl.com/q86hnte>) Pierre Auger Observatory reports that there is at least 30 per cent muon surplus in cosmic rays at ultrahigh energy around 10^{19} eV [C62] (see <http://tinyurl.com/ol8ardk>). These events are at the knee of cosmic ray energy distribution: at higher energies the flux of cosmic rays should be reduced due to the loss of energy with cosmic microwave background. There are actually indications that this does not take place but this is not the point now. The article [C116] at <http://tinyurl.com/nw5hnqt> tells about how these showers are detected and also provides a simple model for the showers.

This energy is estimated in the rest system of Earth and corresponds to the energy of 130 TeV in cm mass system for a collision with nucleon. This is roughly 10 times the cm energy

of 14 TeV at LHC. The shower produced by the cosmic ray is a cascade in which high energy cosmic rays gradually loses its energy via hadron production. The muons are relatively low energy muons resulting in hadronic decays, mostly pion decays, since most of the energy ends up to charged pions producing muons and electrons and neutral pions decaying rapidly to gamma pairs. The electron-positron pairs produced in the electromagnetic showers from neutral pions mask the electrons produced in neutral pion decay to electrons so that the possible surplus can be detected only for muons.

Since cosmic rays are mostly protons and nuclei the primary collisions should involve a primary collision of cosmic ray particle with a nucleon of atmosphere. The anomalously large muon yield suggests an anomalous yield of proton-antiproton pairs produced in the first few collisions. Protons and antiprotons would then collide with nuclei of atmosphere and lose their energy and give rise to anomalously large number of pions and eventually muons.

Unless the models for the production (constrained by LHC data) underestimate muon yield, new physics is required to explain the source of proton-antiproton pairs is needed.

In TGD framework one can consider two scaled up variants of hadron physics as candidates for the new physics.

- (a) The first candidate corresponds to M_{89} hadron physics for which hadron masses would be obtained by a scaling with factor 512 from the masses of ordinary hadrons characterized by Mersenne prime $M_{1+07} = 2^{107} - 1$. There are several bumps identifiable as pseudo-scalar mesons with predicted masses also some bumps identifiable as some scaled up vector mesons [L25] (see <http://tinyurl.com/o92aq4g>). Also the unexpected properties of what was expected to be quark gluon plasma suggest M_{89} hadron physics. In particular, the evidence for string like states suggests M_{89} mesons. If the situation is quantum critical, M_{89} have scaled up Compton length. The natural guess is that it corresponds to the size of ordinary hadrons.

The proton of M_{89} hadron physics would have mass of 512 GeV so that the production of M_{89} hadrons could take place at energies, which for ordinary hadrons would correspond to 260 GeV meaning that perturbative M_{89} QCD could be used. The quarks of this hadron physics would hadronize either directly to ordinary M_{107} or to M_{89} hadrons. In both cases a phase transition like process would lead from M_{89} - or M_{107} -hadrons and produce a surplus of protons and antiprotons, whose collisions with the nuclei of atmosphere would produce a surplus of pions.

- (b) One can also consider M_{79} hadron physics, where $M_{G,79}$ corresponds to Gaussian Mersenne $(1+i)^{79} - 1$. The mass scale would be 32 times higher than that for M_{89} hadron physics and correspond to 8 GeV for ordinary hadron collisions. Also now perturbative QCD would apply.

One can argue that M_{89} and/or $M_{G,79}$ hadron physics comes in play for collisions with small enough impact parameter and gives an additive contribution to the total rate of protons and antiproton production. The additional contribution would be of the same order of magnitude as that from M_{107} hadron physics.

Could quantum criticality play some role now?

- (a) What is the situation is quantum critical with $h_{eff}/h > 1$? The first naïve guess is that at the level of tree diagrams corresponding to classical theory the production rate has no dependence on Planck constant so that nothing happens. A less naïve guess is that something similar to that possibly taking place at LHC happens. Quantum critical collisions in which protons just pass by each other could yield dark pseudo-scalar mesons.
- (b) If quantum criticality corresponds to peripheral collisions, the rate for pseudo-scalar production would be large unlike for central collisions. The instanton action determined to a high degree by anomaly considerations would be determined the rate of production for pseudo-scalar mesons. Vector boson dominance would allow to estimate the rate for the production of vector bosons. Peripherality could make the observation of these

collisions difficult: especially so if the peripheral collisions are rejected because they are not expected to involve strong interactions and be therefore uninteresting. This might explain the disappearance of 750 GeV bump.

- (c) Suppose that quantum criticality for peripheral collisions at LHC and RHIC enters into game above the mass scale of M_{89} pion with mass about $65 \times m_p \simeq 65$ GeV and leads to creation of M_{89} mesons. By a simple scaling argument the same would happen in the case of $M_{G,79}$ hadron physics above $65 \times m_p(89) = 3.3 \times 10^4$ TeV to be compared with the collision energy of ultrahigh energy cosmic rays about 13×10^4 TeV.

12.4 Newest indications for dark M_{89} hadrons

I received a link to a quite interesting popular article (see <http://tinyurl.com/khm6qbp>) telling about surplus of antiprotons from cosmic rays interpreted in terms of dark matter particles decays to protons and antiprotons. The article mentions two articles summarizing essentially similar experimental findings.

The first article *Novel Dark Matter Constraints from Antiprotons in Light of AMS-02* is published in Phys Rev Letters (see <http://tinyurl.com/kn44zce>). The abstract of the article is here.

We evaluate dark matter (DM) limits from cosmic-ray antiproton observations using the recent precise AMS-02 measurements. We properly take into account cosmic-ray propagation uncertainties, fitting DM and propagation parameters at the same time and marginalizing over the latter. We find a significant indication of a DM signal for DM masses near 80 GeV, with a hadronic annihilation cross section close to the thermal value, $\langle\sigma v\rangle \sim 2 \times 10^{-26} \text{ cm}^3/\text{s}$. Intriguingly, this signal is compatible with the DM interpretation of the Galactic center gamma-ray excess. Confirmation of the signal will require a more accurate study of the systematic uncertainties, i.e., the antiproton production cross section, and the modeling of the effect of solar modulation. Interpreting the AMS-02 data in terms of upper limits on hadronic DM annihilation, we obtain strong constraints excluding a thermal annihilation cross section for DM masses below about 50 GeV and in the range between approximately 150 and 500 GeV, even for conservative propagation scenarios. Except for the range around ~ 80 GeV, our limits are a factor of ~ 4 stronger than the limits from gamma-ray observations of dwarf galaxies.

The second article *Possible Dark Matter Annihilation Signal in the AMS-02 Antiproton Data* is also published in Phys Rev Letters (see <http://tinyurl.com/m3uhnam>). The abstract is here.

Using the latest AMS-02 cosmic-ray antiproton flux data, we search for a potential dark matter annihilation signal. The background parameters about the propagation, source injection, and solar modulation are not assumed a priori but based on the results inferred from the recent B/C ratio and proton data measurements instead. The possible dark matter signal is incorporated into the model self-consistently under a Bayesian framework. Compared with the astrophysical background-only hypothesis, we find that a dark matter signal is favored. The rest mass of the dark matter particles is $\sim 20 - 80$ GeV, and the velocity-averaged hadronic annihilation cross section is about $(0.2 - 5) \times 10^{-26} \text{ cm}^3/\text{s}$, in agreement with that needed to account for the Galactic center GeV excess and/or the weak GeV emission from dwarf spheroidal galaxies Reticulum 2 and Tucana III. Tight constraints on the dark matter annihilation models are also set in a wide mass region.

The proposal is that decay of dark matter particles possibly arriving from the Galactic center produce proton-antiproton pairs. The mass of the decaying particles would be between 40-80 GeV. I have been talking for years about M_{89} hadron physics - a scaled up copy of ordinary hadron physics with mass scale 512 times higher than that of ordinary hadron physics. The pion of this physics would have mass about 69 GeV (by scaling from the mass of ordinary pion by factor 512). There are indications for two handfuls of bumps with masses of mesons of ordinary hadron physics scaled up by 512 [L25] (see <http://tinyurl.com/o92aq4g>).

These scaled up pions could be produced abundantly in collisions of cosmic rays in atmosphere (situation would be analogous to that at LHC). It would not be surprising if they would produce also proton and antiproton pairs in their decays? This view about the origin of the dark pions is different from the usual view about dark matter. Dark pions would be created by the cosmic rays arriving from galactic center and colliding with nuclear matter in the Earth's atmosphere rather than arriving from the galactic center.

Can one say that they represent dark matter and in what sense? The TGD based proposal explaining various bumps observed at LHC and having masses 512 times those of ordinary mesons assumes that they are produced at quantum criticality [?] and are dark in TGD sense meaning that the value of effective Planck constant for them is $h_{eff} = n \times h$, $n = 512$. Scaled up Compton length would realize long range quantum correlations at criticality. Dark mesons at criticality would be hybrids of ordinary and scaled up mesons: Compton length would same as for ordinary mesons but mass would 512 times higher: Esau's hands and Jacob's voice. This would give a precise meaning to what it means for two phases to be same at quantum criticality: half of both.

The new element of the model for M_{89} hadron physics [L27] is that the gluons would be second generation gluons with charge matrices in the space of fermion families orthogonal to the similar charge matrix for ordinary gluons. This implies violation of quark universality. The violation of universality for second generation electroweak bosons could explain breaking of lepton universality. Family charge matrices could depend on em charge of the boson as do also the topological mixing matrices for fermion families (genus corresponds to the handle number for partonic 2-surface [K11]). The first guess is that family charge matrices are universal.

12.5 Is the new physics really so elementary as believed?

I think that many colleagues have been thinking about the situation in particle physics. Is it really true that the "nightmare scenario" is realized: no deviations from the standard model. The basic disappointment of course comes from the fate 750 GeV Cernette, which does not exist anymore officially. I am personally puzzled. Various bumps about which Lubos have kept count fit nicely to the spectrum of mesons of M_{89} hadron physics (almost)-predicted by TGD [L25]. They have precisely the predicted masses differing by a factor 512 from those of M_{107} hadron physics, the good old hadron physics. Is it really possible that Universe has made a conspiracy to create so many statistical fluctuations just to the correct places? Could it be that something is wrong in the basic philosophy of experimental particle physics, which leads to the loss of information?

First of all, it is clear that new physics is badly needed to solve various theoretical problems such as fine tuning problem for Higgs mass to say nothing about the problem of understanding particle mass scales. New physics is necessary but it is not found. What goes wrong? Could it be that we are trying to discover wrong type of new physics?

Particle physics is thought to be about elementary objects. There would be no complications like those appearing in condensed matter physics: criticality or even quantum criticality, exotic quasiparticles, ... This simplifies the situation enormously but still one is dealing with a gigantic complexity. The calculation of scattering rates is technically extremely demanding but basically application of well-defined algorithms; Monte Carlo modelling of the actual scattering experiments such as high energy proton-proton collisions is also needed. One must also extract the signal from a gigantic background. These are extremely difficult challenges and LHC is a marvellous achievement of collaboration and coherence: like string quartet but with 10,000 players.

What one does is however not to just look what is there. There is no label in the particle telling "I am the exotic particle X that you are searching for". What one can do is to check whether the small effects - signatures - caused by a given particle candidate can be distinguished from the background noise. Finding a needle in haystack is child's play when compared with what one must achieve. If some totally new physics not fitting into the basic paradigms behind search algorithms is there, it is probably lost.

Returning to the puzzle under consideration: the alarming fact is that the colliding protons at LHC form a many-particle system! Could it happen that the situation is even more complex than believed and that phenomena like emergence and criticality encountered in condensed matter physics could be present and make life even more difficult?

As a matter of fact, already the phase transition from confined phase to perturbative QCD involving thermodynamical criticality would be example of this complexity. The surprise from RHIC and later LHC was that something indeed happened but was different than expected. The transition did not seem to take place to perturbative QCD predicting thermal "forgetfulness" and isotropic particle distributions from QCD plasma as black body radiation. For *peripheral* collisions - colliding particles just touching - indications for string like objects emerged. The notion of color glass was introduced and even AdS/CFT was tried (strings in 10-D space-time!) but without considerable success. As if a new kind of hadron physics with long range correlation in proton scale but with energy scale of hundreds of proton masses would have been present. This is mysterious since Compton lengths for this kind of objects should be of order weak boson Compton length.

In TGD Universe this new phase would be M_{89} hadron physics with large value $h_{eff} = n \times h$, with $n = 512$ to scale up M_{89} hadron Compton length to proton size scale to give long range correlations and fluctuation in proton scale characterizing quantum criticality. Instanton density $I \propto E \cdot B$ for colliding protons would appear as a state variable analogous to say pressure in condensed matter and would be large just for the *peripheral* collisions. The production amplitude for pseudoscalar mesons of new hadron physics would by anomaly arguments be obtained as Fourier transform of I . The value of I would be essentially zero for head-on collisions and large only for peripheral collisions - particles just touching - in regions where E and B tend to be parallel. This would mean criticality. There could be similar criticality with respect to energy. If experimenter poses kinematical cutoffs - say pays attention only to collisions not too peripheral - the signal would be lost.

This would not be new. Already at seventies anomalous production of electron-positron pairs perhaps resulting from pseudoscalar state created near collision energy allowing to overcome Coulomb wall were reported: criticality again. The TGD model was in terms of leptopions (electro-pions) [K47] and later evidence for their muonic and tau counterparts have been reported. The model had of course a bad problem: the mass of leptopion is essentially twice that of lepton and one expects that colored lepton is also light. Weak boson decay widths do not allow this. If the leptopions are dark in TGD sense, the problem disappears. These exotic bumps were later forgotten: a good reason for this is that they are not allowed by the basic paradigms of particle physics and if they appear only at criticality they are bound to experience the fate of being labelled as statistical fluctuations.

This has served as an introduction to a heretic question: Could it be that LHC did not detect 750 GeV bosons because the kinematical cuts of the analysis eliminate the peripheral collisions for which protons just touch each other? Could these candidates for pseudo-scalars of M_{89} hadron physics be created by the instanton anomaly mechanism and only in periphery? And more generally, should particle physicists consider the possibility that they are not anymore studying collisions of simple elementary systems?

One can make this more concrete (I am repeating what I already wrote once because I see this as really important). To find M_{89} pseudoscalars one should study peripheral collisions in which protons do not collide quite head-on and in which M_{89} pseudoscalars could be generated by em instanton mechanism. In peripheral situation it is easy to measure the energy emitted as particles since strong interactions are effectively absent - only the $E \cdot B$ interaction plus standard em interaction if TGD view is right (note that for neutral vector mesons the generalization of vector meson dominance based on effective action coupling neutral vector boson linearly to em gauge potential is highly suggestive). Unfortunately peripheral collisions are undesired since beams are deflected from head-on course! These events are however detected but the data end up to trashbin usually as also the deflected protons! Luckily, Risto Orava's team (see <http://tinyurl.com/yc8xvne> and <http://tinyurl.com/hxges8w>) is studying just those p-p collisions, which are peripheral! It would be wonderful if they would find Cernettes and maybe also other M_{89} pseudo-scalars from the trashbin! Same is true in

gravitational sector: reductionism demands that string model leads to GRT and the various anomalies challenging GRT are simply forgotten.

Large statistical fluctuation certainly occurred. The interpretation for the large statistical fluctuation giving rise to Cernette boom could be as the occurrence of un-usually large portion of peripheral events allowing the production of M_{89} mesons, in particular Cernettes.

To sum up, the deep irony is that particle physicists are trying desperately to find new physics although it has been found long ago but put under the rug since it did not conform with QCD and standard model. The reductionistic dogma dictates that the acceptable new physics must be consistent with the standard model: no wonder that everything indeed continues to be miraculously consistent with standard model and no new physics is found! Same is true in gravitational sector: reductionism demands that string model leads to GRT and the various anomalies challenging GRT are simply forgotten.

12.6 96 GeV bump (2019) as electroweak pseudoscalar predicted by TGD?

Lubos had a second posting mentioning new bump at about 96 GeV discovered at LHC (see <http://tinyurl.com/yyqwlh44>) slightly above the masses of weak bosons and tells that physicists seem to take it very seriously. Lubos of course wants to interpret it as a Higgs predicted by standard SUSY already excluded at the energies considered.

What about TGD interpretation?

- (a) TGD predicts besides weak gauge bosons, Higgs, and pseudoscalar: about the prediction of pseudoscalar I became aware only now. This follows taking tensor products for spin-isospin representations formed by quarks but for some reason I had not noticed this. The mass scale of pseudoscalar Higgs is most naturally the same as that of scalar Higgs or of weak bosons and p-adic mass calculations allow to estimate its mass. Higgs mass 125 GeV is very nearly the minimal mass for $k = 89$. The minimal mass for $k = 90$ defining also the p-adic mass scale of weak bosons would be 88 GeV so that the interpretation as pseudo-scalar with $k = 90$ might make sense [L46] (see <http://tinyurl.com/y4pdb2xz>).
- (b) This lower bound is somewhat smaller than 96 GeV but the estimate neglects effects related to isospin: doublet and complex doublet are actually predicted (or triplet and singlet when $SU(2)_w$ action is by automorphism on the 2×2 matrix defined by the doublets rather than as left or right action on the doublets appearing as its rows/columns). Mass splitting looks natural and the neutral state might be the heavier one as in case of W,Z splitting.

The situation is extremely interesting, since after decades of efforts I finally managed to formulate and understand SUSY in TGD framework.

- (a) First of all, SUSY is there but it is very different from standard N=1 SUSY predicting Majorana fermions. The reason is that due to fermion number conservation theta parameters appearing in super-field must be replaced with fermionic - actually quark-like - oscillator operators. The simplest model predicts that theta parameters and their conjugates appearing in the super-fied correspond to quark oscillator operators in a number theoretic discretization of space-time surface. They thus anticommute non-trivially. Anticommutators are finite for cognitive representations for which space-time surface is replaced with a discrete set of points with preferred embedding space coordinates in an extension of rationals.
- (b) Super-spinor field is odd polynomial of creation operators and its conjugate is odd function of annihilation operators whereas the embedding space coordinates appearing in bosonic action (Kahler action plus volume term) and modified super-Dirac action are replaced by embedding space super-coordinates, which are polynomials in which

super-monomials have vanishing total quark number and appear as sums of monomial and its conjugate to guarantee the hermiticity of the super-coordinate.

These assumptions guarantee that super-Dirac field describes local states with odd fermion number and propagators have the behavior required by statistics.

- (c) In continuum variant of the theory the bosonic Wick contractions would give rise to infinities: this vanishing conforms with the vanishing of loops required quite generally by the number theoretical vision and implying discrete coupling constant evolution. This simplifies the analogs of Feynman diagrams appearing at the level of discrete "cognitive representations" to mere tree diagrams. In twistor approach the vanishing of loops means enormous simplification and implies behavior analogous to that in dual resonance models which initiated superstring models.

The vanishing of Wick contractions from super-space-time parts of the modified Dirac action and super-counterpart of classical action gives rise to conserved Noether currents having interpretation in terms of symmetries: the most natural interpretation is in terms of gigantic super-symplectic symmetries predicted by TGD. TGD predicts also their Yangian analogs multi-local symmetries.

- (d) Super-symmetric vertices are just vacuum expectations of the action. In this picture leptons would be spartners of quarks as local 3-quarks composites. This little discovery I could have made four decades ago. The allowance of only quarks as fundamental fermions follows from $SO(1,7)$ triality in number theoretic vision: here $M^8 - H$ ($H = M^4 \times CP_2$) duality and the part of number theoretic vision involving classical number fields is needed. We would have been staring at super-symmetries for more than century! My heart bleeds for the unlucky colleagues still trying to find standard SUSY at LHC. I can only pray that these lost lambs of experimental and theoretical physics could find their way back to their shepherd.

- (e) The quark numbers or protons and leptons would be opposite and matter antimatter asymmetry would mean preference of antiquarks to arrange into local triplets - leptons-whereas quarks would arrange to non-local triplets- baryons. Both (quark) matter and antimatter would have been in front of eyes all the time we have been producing literature about mechanisms possibly explaining the absence of antimatter.

CP breaking is necessary for this picture and twistor lift of TGD indeed predicts CP breaking term which would be due to the Kaehler structure of Minkowski space required by twistor lift of TGD - also non-commutative quantum field theories predict it.

- (f) What about SUSY breaking. It has been clear for a long time that the mass formulas could be same for the members of super-multiplet but that p-adic length scale could differ. I realized few weeks ago that the breaking of SUSY is universal and has very little to do with the details of dynamics. In the general case zero energy states are superpositions (mixtures) of states with different mass squared eigenvalues and $M^8 - M^4 \times CP_2$ duality allows to find an embedding of M^4 to M^8 making mass squared vanishing for states without this mixing. For mixtures p-adic thermodynamics predicts the masses. That Minkowski space is a relative notion means obviously new view about the notion of mass.

It is fair to say, that as far as particle physics is considered, TGD is done. The simplicity and elegance of the picture is so stunning that it is difficult to imagine alternatives. Already earlier, I realized that the breaking of SUSY is universal and has very little to do with the details of dynamics. Zero energy states are superpositions (mixtures) of states with different mass squared eigenvalues and $M^8 - H$ duality allows to find an embedding of M^4 to M^8 making mass squared vanishing for states without this mixing. For mixtures p-adic thermodynamics predicts the masses.

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