Three anomalies of hadron physics from TGD perspective

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Abstract

Three anomalies related to hadron physics will be discussed. The first anomaly relates to proton spin puzzle. The latest discovery is that there are more $\overline{d}$ type sea quarks than $\overline{u}$ type sea quarks in proton - this is difficult to understand in QCD picture. The contribution of $\overline{d}$ quarks to the spin of proton is however smaller than $\overline{u}$ type sea quarks. TGD suggests that the notion of sea quark should be replaced with quarks associated with the ends of color flux tubes connecting valence quarks to a triangle like structure. This allows to understand the anomaly and also why old Gell-Mann model works so well. Also the mass of proton can be deduced with high precision from p-adic mass calculation as will be found.

Also the old Aleph anomaly has made a comeback. TGD explanation is in terms of scaled-up variants of b quark forming pion and ρ meson like bound states. One ends up with the identification of production mechanism for both 55 GeV pion-like state and pion and ρ meson like bound states with mass 28 and 30 GeV.

The third anomaly is evidence for a new bump with 400 GeV at LHC assumed to be created by gluon-gluon fusion via top quark pair to parity odd state tentatively identified as pseudoscalar Higgs predicted by SUSY scenarios. The mass happens to exactly 512 times that of pseudovector meson ω and one can consider the identification as ρ meson of M_{89} hadron physics predicted by TGD encouraged also by the large 5 per cent decay width compared to decay with of order 10^{-5} for ordinary Higgs.

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1 Introduction

Anomalies are the theoretician's best friends, and if one is a proponent of a new theory, one becomes very keen for anomalies and sooner or later realizes that a huge amount of understanding of physics coded in a concise form by what we call standard model is actually full of anomalies. If you believe in main stream theory, which you have got into your spine with hard work, you must work hardly against the very humane desire to get rid of the anomalies by simply hiding them under the rug. Our belief systems are vulnerable parts of our egos.

QCD as a theory of strong interactions is part of standard model. It has problems. Perturbation theory fails at low energies so that one cannot calculate hadron properties. Skeptic can even ask whether the theory even exists at low energies and even whether the view about QCD color is really completely correct. Perturbative QCD itself is a strange mixture of kinetic equations and quantum theory and cannot be the final theory. For instance, the notion of sea partons can be challenged. One can even challenge quantum field theory (QFT) approach itself: the assumption that fundamental entities are point-like might be the reason for the divergence difficulties as the successes of superstring models as mathematical theory have demonstrated.

There are a lot of phenomenological models for the properties of say baryons - one of them is the old Gell-Mann quark model, which predicts baryon masses and magnetic moments surprisingly well. The required constituent quark masses are however large: about $m_p/3$ for u and d quark whereas the masses of u and d type current quarks deduced from perturbative QCD are much smaller and in few MeV range. The contribution of quarks to proton mass is only about 1 per cent and the remaining contribution often assigned to gluons is not really understood. String models are second class of rather successful models and suggest that hadrons are in some sense geometric objects.

There is also the spin puzzle of proton and as will be explained new findings make the picture even more complex. The experiments demonstrate that the amounts of $\overline{u}$ and $\overline{d}$ sea quarks are different, which is very strange if sea quarks and antiquarks come from the decays of gluons. Although there are more $\overline{d}$ sea quarks than $\overline{d}$ sea quarks, their contribution to proton spin is smaller!

TGD started as a solution to what I call energy problem of General Relativity and as a generalization of hadronic string models. TGD relies on the generalization of point-like objects with 3-surfaces and is therefore generalization of string models. TGD allows to geometrize the notion of classical field and unifies color and electroweak interactions in terms of CP_2 geometry and predicts both classical counterparts of standard model gauge fields and gives quantal description of field quanta in terms of space-time geometry.

Color symmetries are not however strictly speaking gauge symmetries but more like Kac-Moody type symmetries. In particular, color is not spin-like quantum number but colored states for fundamental fermions have partial waves of $H = M^4 \times CP_2$ spinor fields as building bricks. Quarks and leptons correspond to different conserved H-chiralities and lepton and baryon numbers are separately conserved so that proton is stable against the decays allowed by GUTs.

The vision about many-sheeted space-time leads to the notion of color magnetic flux tubes connecting valence quarks to triangle like structures. The flux tubes connecting valence quarks and having quark and anti-quark as counterparts of sea quarks at their ends could be analogous to pion and ρ meson. The classical color magnetic energy of flux tubes would give the dominant contribution to the mass of nucleon (classical physics is an exact part of quantum TGD and classical charges in Cartan sub-algebra of symmetries are equal to eigenvalues of quantal charges). Also nuclei would be nuclear strings with nucleons connected by flux tubes.

TGD predicts hierarchy of Planck constants $h_{eff} = n \times h_0$ and interprets it in terms of dark matter hierarchy [K6]. Also nuclear physics is proposed to have dark variants and cold fusion, which is one of the possible anomalies of strong interaction physics, could involve dark nuclei [L2]. Dark nuclear strings could be important also in biology. Ironically, although fundamental objects are 3-D in TGD, strings and string like objects are present in all length scales in TGD Universe whereas in superstring models they are present only in Planck length scale.

p-Adic mass calculations based on p-adic variant of ordinary thermodynamics provide a surprisingly successful model for elementary fermion masses [K1, K2, K5, K3, K4]. In the case of gauge bosons the thermodynamical contributions are probably dominated by stringy contributions associated to the flux tube structures assigned to the gauge bosons. p-Adic length scale hypothesis allows however to understand their mass scales and predicts W/Z mass ratio correctly. For hadrons one must construct models but the p-adic arithmetics makes the models highly predictable as will be found by estimate of proton mass.

p-Adic thermodynamics suggests that particles can appear in several p-adic length scales coming as octaves of fundamental scale. What is nice that the masses for the scale variant of say hadron physics can be predicted: for instance, for M_{89} hadron physics which should appear at LHC length scales the masses are obtained by scaling using factor 512. There are handful of bumps identifiable as scaled-up mesons with predicted masses [K3] and the recent evidence for scaled variant of ω meson adds new bump to to the list.

The anomalies of neutrino physics could be understood in terms of octaves of neutrinos. The so called X-boson claimed to give rise to fifth force could be interpreted as scaled down variant of pion and the model [L1] leads to ask whether also weak bosons could have scaled down variants in nuclear scale labelled by Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$. Aleph anomaly discovered already 1991-1992 and to be discussed below has experienced re-incarnation and suggests the existence of scaled variants of b-quark.

2 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* $\sqrt{s} = 510\,GeV$ [C6] (see `http://tinyurl.com/y34e9y99`).

1. 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.

2. The amount of $\overline{d}$ type sea quark is larger than that of $\overline{u}$ type sea quark. But the amount of proton spin assignable to $\overline{d}$ quark is smaller!

2.1 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 ealier 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.

1. uud with standard wave function describes valence quarks which are almost point like entities assignable to partonic 2-surfaces.

2. There are 3 color bonds in the triangle like structure formed by valence quarks. Assign to these

   - $\overline{d} - d$ spin singlet analogous to pion with spin 0,
   - $\overline{d} - u$ spin singlet,
   - $\overline{u} - d$ vector analogous to ρ meson with spin 1.

   Identify the quarks and antiquarks of color bonds with the TGD counterpart of the sea.

3. 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.

4. Also the observations can be understood qualitatively.

   - The amount $\overline{d}$ in the sea is two times larger than the amount of $\overline{u}$.

- The average contribution of $\overline{d}$ to spin is vanishing in spin singlet bonds and spin 1 bond does not even contain $\overline{d}$. Hence the average contribution to sea quark spin vanishes.
- The contribution of $\overline{u}$ in $\overline{u}-d$ spin 1 bond is non-vanishing and experimentally known to be larger than that $\overline{d}$ sea quark.

2.2 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.

1. 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.
2. 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.
3. 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

$$x_p = \sum_n x_n p^n \rightarrow x_R = \sum x_n p^{-n}$$

   mapping p-adic numbers in continuous manner to reals.
4. 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.

2.3 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 meases are estimated as a check of the model.

2.3.1 Estimating nucleon and pion masses

A detailed estimate for nucleon mass using p-adic mass calculations [K1, K2, K5, K3, K4] shows the power of p-adic arithmetics even in the case that one cannot perform a complete calculation.

1. 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.

2. 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.

3. 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 tis 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.

4. What about pion mass? The naive 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.

2.3.2 Masses of other hadrons

I have considered in [K5] 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.

1. 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.
   - $(n_K = 5, k) = (5, 107)$ 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 as whether strange quark is very light also in mesons.

2. 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.

3. 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 $m_p^2 \sim 1$ GeV^2 so that a good guess form 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.

2.3.3 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 $m_W = 80.4$ GeV and $m_Z = 91.2$ GeV. The mass ratio m_W/m_Z allows group theoretical interpretation. The standard model mass formulas in terms of vacuum expectation $v = 246.22$ GeV of Higgs read as $m_Z = \sqrt{g^2 + (g')^2}v/2$ and $m_W = gv/2 = cos(\theta_w)m_Z$, $cos(\theta_W) = g/\sqrt{g^2 + (g')^2}$.

1. A natural guess is that Higgs expectation $v = 246.22$ 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 $v = 2^{19} \times m_e \simeq 262.1$ GeV: the error is 6 per cent. For $n_e = 4$ one would obtain $v = 2^{19} \times \sqrt{4/5}m_e \simeq 234.5$ GeV: the error is now 5 per cent.

For $n = 1$ the mass scale would correspond to the lower bound $m_{min} = 117.1$ 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?

2. 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 $m_Z = 92.7$ 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 two 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 $k(\pi) = k(p) - 4 = 111$.

3. 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.

3 Aleph anomaly just refuses to disappear

I learned about evidence for a bump around 28 GeV (see `http://tinyurl.com/y5macuek`). 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*" [C3]. 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.

3.1 Two dejavus

3.1.1 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*" [C1] (see `http://tinyurl.com/y5683ab6`). 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 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?

3.1.2 Second dejavu

Concerning quarks, I remember an old anomaly reported by Aleph at 56 GeV. This anomaly is mentioned in a preprint published 1996 [C5] (see `http://tinyurl.com/y6kb984n`) and there is reference to old paper: ALEPH Collaboration, D. Buskulic et al., CERN preprint PPE/96052.. 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 $\overline{b}$ 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.

3.2 What the resonance are and how could they be produced?

The troubling question is why the two masses around 28 GeV ad 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-magnetc 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.

1. If one has 56 GeV pseudo-scalar resonance consisting mostly of $b\overline{b}$ - 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.

2. $\pi(56)$ 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.

1. 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.

2. 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 $r_1 = \Delta m/m \simeq .5$.

   $r_1 = \Delta m/m$ is due to the interaction of color magnetic moments and proportional to the parameter $r_2 = \alpha_s^2 m^2(\pi)/m^2(d)$. 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 $r_1/r_2 \simeq .57$.

3. 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 [L3, L4]? This invariance is not global but implies discrete coupling constant evolution.

4 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*" [C4] (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 annilate 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 inital 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 Mersennen prime M_{107}). Since there exists a handful of bumps [K3] 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*" [C2] (see `http://tinyurl.com/y26vvmot`) one gets some idea about the symmetries amplitudes involved also in the recent case.

1. 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.

2. For pseudovector ω the transformation of the propagator part of the amplitude (there sonance) under P is the sameas for pseudoscalar Higgs (change of sign) so that ω is consistent with A in this respect.

3. The coupling of (pseudo-)vector particle to $t\bar{t}$ pair is of form LL+RR. For pseudoscalar it is of from 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 (peudoscalar) 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 [K2].

4. 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.

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