

# $X$ boson as evidence for nuclear string model

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## Abstract

A new nuclear physics anomaly has been discovered in the decays of the excited state  ${}^8\text{Be}^*$  of an unstable isotope of  ${}^8\text{Be}$  (4 protons and 4 neutrons) to ground state  ${}^8\text{Be}$ . The anomaly manifests itself as a bump in the distribution of  $e^+e^-$  pairs in the transitions  ${}^8\text{Be}^* \rightarrow {}^8\text{Be}$  at certain angle between electrons. The proposed interpretation is in terms of a production of spin 1 boson - christened as  $X$  - identified as a carrier of fifth force with range about 12 fm, nuclear length scale. The attribute  $6.8\sigma$  tells that the probably that the finding is statistical fluctuation is about  $10^{-12}$ : already 5 sigma is regarded as a criterion for discovery. TGD inspired interpretation based on nuclear string model is different. The mass of the state is within .7 accuracy pion mass scaled down to nuclear p-adic scale  $k = 113$ . Scaled down pion in  $l = 1$  state is possible and allows to scale the decay rates to gamma pair and  $e^+e^-$  pair from those of pion.

Somewhat surprisingly, it turned out that the predicted decay width  $\Gamma(\pi(113), \gamma\gamma)$  is consistent with the experimental bounds. The problem is that  $\Gamma(\pi(113), e^+e^-)$  is at least by a factor of order 1/100 too low. If the decay occurs via annihilation  $Z^0$  boson annihilating to electron pair such that  $Z^0$  is a p-adically scaled down variant of ordinary  $Z^0$  with p-adic size scale identifiable as nuclear length scale, the decay width is in the middle of the experimentally allowed range. Also ordinary meson decays to lepton pairs could occur via the same mechanism so that p-adically scaled down weak interactions would manifest themselves in the leptonic decays of hadrons. One cannot exclude even dark variants of weak bosons from consideration. The mechanism for the decay as snipping of closed pionic flux loop from colored flux tube connecting nucleus is discussed.

## 1 Introduction

Anomalies seem to be popping up everywhere, also in nuclear physics and I have been busily explaining them in the framework provided by TGD. The latest nuclear physics anomaly that I have encountered (see <http://tinyurl.com/zlvngnv>) was discovered in Hungarian physics laboratory in the decays of the excited state  ${}^8\text{Be}^*$  of an unstable isotope of  ${}^8\text{Be}$  (4 protons and 4 neutrons) to ground state  ${}^8\text{Be}$  [C3, C2] (see <http://arxiv.org/abs/1604.07411>). For the theoretical interpretation of the finding in terms of fifth force see [C2] (see <http://arxiv.org/abs/1604.07411>) mediated by spin 1  $X$  boson.

The anomaly manifests itself as a bump in the distribution of  $e^+e^-$  pairs in the transitions  ${}^8\text{Be}^* \rightarrow {}^8\text{Be}$  at certain angle (140 degrees) between electrons. The interpretation is in terms of a production of spin 1 boson - christened as  $X$  - identified as a carrier of fifth force with range about 12 fm, nuclear length scale. The attribute  $6.8\sigma$  - if taken seriously - tells that the probably that the finding is statistical fluctuation is about  $10^{-12}$ : already 5 sigma is regarded as a criterion for discovery.

The assumption about vector boson character looks at first well-motivated: the experimental constraints for the rate to gamma pairs are believed to eliminate the interpretation as pseudo-scalar boson whereas spin 1 bosons do not have these decays. In the standard reductionistic spirit it is assumed that  $X$  couples to  $p$  and  $n$  and the coupling is sum for direct couplings to  $u$  and  $d$  quarks making proton and neutron. The comparison with the experimental constraints forces the coupling to proton to be very small: this is called protophobia. Perhaps it signifies something that many of

the exotic particles introduced to explain some bump during last years are assumed to suffer various kinds of phobias. The assumption that  $X$  couples directly to quarks and therefore to nucleons is of course well-motivated in standard nuclear physics framework relying on reductionism.

TGD inspired interpretation based on nuclear string model [K2] is different. The mass of the state is within .7 accuracy pion mass scaled down to nuclear p-adic scale characterized by p-adic prime  $p \simeq 2^k$ ,  $k = 113$ . Scaled down pion in  $l = 1$  state is possible and allows to p-adically scale the decay rates to gamma pair and  $e^+e^-$  pair from those of pion. The pleasant surprise was that the scaled  $\Gamma(\pi, \gamma\gamma)$  turned out to be consistent with the experimental bounds reported in [C2].

There is however a problem: the estimate for  $\Gamma(\pi, e^+e^-)$  obtained by p-adically scaling the model based on decay virtual gamma pair decaying to  $e^+e^-$  pair [C1] is by a factor 1/88 too low. One can consider the possibility that the dependence of  $f_\pi$  on p-adic length scale is not the naively expected one but this is not an attractive option. The increase of Planck constant seems to worsen the situation.

The dark variants of weak bosons appear in important role in both cold fusion and TGD inspired model for chiral selection. They are effectively massless below the scaled up Compton scale of weak bosons so that weak interactions become strong. Since pion couples to axial current, the decay to  $e^+e^-$  could proceed via annihilation to  $Z^0$  boson decay to  $e^+e^-$  pair. The estimate for  $\Gamma(\pi(113), e^+e^-)$  is in the middle of the allowed range. The same model explains also the decay width of the ordinary pion and a generalization of the model to all semileptonic decays of hadrons is highly suggestive and would explain the somewhat mysterious origin of CVC and PCAC [B1].

The model is also formulated in terms of nuclear string model. In particular, the mechanism for the decay as snipping of closed pionic flux loop from a colored flux tube connecting nucleus is discussed briefly. A possible manner to measure the value of  $h_{eff}$  emerges as a by-product. By measuring lifetime and decay width independently, one can deduce the value of  $h_{eff}/h$  predicted to be integer valued as  $h_{eff}/h = \tau\Gamma/\hbar$ . This essentially verifying of scaled up variant of Uncertainty Principle.

## 1.1 Two observations and a possible puzzle generated by them

What could TGD say about the situation? First two observations and the puzzle created by them.

1. The first observation is that 12 fm range corresponds rather precisely to p-adic length scale for prime  $p \simeq 2^k$ ,  $k = 113$  assigned to the space-time sheets of atomic nuclei in TGD framework. The estimate comes from  $L(k) = 2^{(k-151)/2}L(151)$ ,  $L(151) \simeq 10$  nm. To be precise, this scale is actually the p-adic Compton length of electron if it were characterized by  $k$  instead of  $k_0 = 127$  labelling the largest not super-astrophysical Mersenne prime.  $k = 113$  is very special: it labels Gaussian Mersenne prime  $(1+i)^k - 1$  and also muonic space-time sheet.
2. A related observation made few days later is that the p-adic scaling of the ordinary neutral pion mass 135 MeV from  $k = 107$  to  $k = 113$  by  $2^{-(113-107)/2} = 1/8$  gives 16.88 MeV! That p-adic length scale hypothesis would predict the mass of  $X$  with .7 per cent accuracy for nominal value  $m(X) = 17$  MeV is hardly an accident. Note that the measured value is  $16.7 \pm .35(stat) \pm .5(sys)$  MeV. This would strongly suggest that  $X$  boson is  $k = 113$  pion.
3. There is however a potential problem. The decays to photon pairs producing pion in  $l = 1$  partial wave have not been observed. Authors conclude that spin 1 particle is in question. If  $X$  is  $\rho$  meson like state with spin 1, why it should have same mass as pionic  $X$ ? This is not plausible.

It turns out that I was too easily gullible! The decay width  $\Gamma(\pi(113), \gamma\gamma)$  estimated by scaling from the decay width for ordinary pion is actually consistent with the experimental bound! The decay width  $\Gamma(\pi(113), \gamma\gamma)$  is however problematic and suggests that non-standard value of  $h_{eff}$  is involved.

## 1.2 The estimate for $\Gamma(\pi(113), \gamma\gamma)$ is consistent with the limits on $\Gamma(X, \gamma\gamma)$

The estimate for the decay rate  $\Gamma(\pi(113), \gamma\gamma)$  is easy to obtain by using effective action determined by PCAC hypothesis.

1. The effective action defined by the “instanton density” for Maxwell field is given by

$$g_{X\gamma\gamma} F^{\mu\nu} \tilde{F}_{\mu\nu} \ , \quad (1.1)$$

where  $\tilde{F}$  is the dual of  $F$ .  $g_{\pi\gamma\gamma}$  is given by

$$g_{\pi\gamma\gamma} = \frac{\alpha}{\pi f_\pi} \ . \quad (1.2)$$

$f_\pi = 93$  MeV characterizes the matrix elements of SU(2) axial currents between vacuum and 1 pion state and it scales like pion mass.

The direct dependence of  $g_{\pi\gamma\gamma}$  and implicit dependence of  $f_\pi$  on  $\alpha$  and  $\alpha_s$  determines the value of  $\Gamma(\pi, \gamma\gamma)$ . All vertices of tree diagrams containing coupling constant give rise to a coefficient  $g^2/m$  having identification as charge radius not affected in the scaling  $h \rightarrow h_{eff}$ .

1. One motivation for the introduction of hierarchy of Planck constants is that the scaled up  $h_{eff}$  allows perturbative approach since one has  $\alpha_k \rightarrow \alpha_k/n$ . This argument makes sense in QFT context. If one can approximate the amplitude as box diagram with fermionic exchange with photons at the upper vertices and gluon exchange associated with the lower vertices, the dependence on  $1/h_{eff}$  would come from  $\alpha_s$ .  $\alpha$  proportionality would boil down to the proportionality from the square of charge radius  $r_s = e^2/4\pi m_\pi$  or of its analog  $r_s = e^2/4\pi f_\pi$ .
2. An objection emerges from the vision that all scattering diagrams in TGD framework for given p-adic length scale and given value of  $h_{eff}$  can be transformed to tree diagrams at topological level [K5]: scattering diagrams would be analogous to computations and could be always reduced to those involving no loops. Coupling constant evolution would reduce to p-adic coupling constant evolution. Also the functional integral using exponent of Kähler as weighting would reduce to tree diagrams. This picture is strongly favoured by number theoretical vision. If this is the case, there are no topological loops in the minimal representation for diagrams and there is no dependence on coupling strengths  $\alpha_k = g_k^2/4\pi h_{eff}$  but only on classical charge radii  $r_s m$ ,  $r_s = g_k^2/4\pi m$  of particles appearing in the vertices of tree diagrams.

If loops are not present, the quark pair wave function of pion state should give rise to dependence on  $\alpha_k$  and thus on  $h_{eff}$ . Radiative corrections would be localizable to the positive and negative energy parts of zero energy states at the boundaries of causal diamond (CD). Pion decay could be seen as  $q\bar{q} \rightarrow \gamma\gamma$  scattering by quark exchange for quarks in bound state determined by color force. The dependence on  $1/h_{eff}$  would come from the dependence of quark-antiquark wave function on  $\alpha_s$  and would be analogous to  $|\Psi(0)|^2$  proportionality in the case of positronium. In  $\Gamma(\pi, \gamma\gamma)$   $h_{eff}$  dependence could be localized to the dependence of  $1/f_\pi^2$  on  $\alpha_k$  and should increase/reduce the rate by reducing/increasing  $f_\pi^2$ . It must be emphasized that also the dependent on p-adic scale could be of from  $f_\pi \propto 1/L(k)^n$ ,  $n \neq 1$  as expected, and for  $n > 1$  increase the scattering rate.

Consider now the detailed formula for the decay width  $\Gamma(\pi, \gamma\gamma)$  [B1].

1. The formula for the gamma decay width of ordinary pion can be written as

$$\Gamma(\pi, \gamma\gamma) = \frac{1}{2^6 \pi^3} \frac{m_\pi^2}{f_\pi^2} (r_\pi m_\pi)^2 m_\pi \ , \quad r_\pi = \frac{e^2}{4\pi m_\pi} \ . \quad (1.3)$$

In this expression the only  $h_{eff}$ -dependence is contained by  $f_\pi$ . Using units  $\hbar = 1, c = 1$  one would have apparent  $\alpha^2 (1/\hbar^2)$  dependence. One has  $\Gamma(\pi) = 7.63$  eV whereas the experimental value is  $\Gamma^{exp} = (7.37 \pm 1.5)$  eV. The radiative corrections are assumed to be possible only for the initial and final state wave functions in the case of bound states.

2. According to [C2] all values of  $1/g_{\pi\gamma\gamma}$  outside the range  $[.1 \text{ GeV}, 10^{18} \text{ GeV}]$  have been excluded. This translates to the allowed range  $[.2 \text{ MeV}, 2.3 \times 10^{15} \text{ GeV}]$  implying  $f_\pi \geq .2 \text{ MeV}$ . The p-adically scaled down value of  $f_{\pi(113)} = f_\pi/8 = f_\pi/8 = 11 \text{ MeV}$  is inside the allowed range.
3.  $f_\pi$  depends on non-perturbative aspects of QCD and therefore on  $\alpha_s$  and  $n$  in non-trivial manner. One might of course hope that the large value of  $h_{eff}$  makes the situation perturbative and that the dependence is simple. This could mean that  $f_\pi$  scales like  $m_\pi$ . In absence of  $h_{eff}$  dependence the scaling from the pion decay width would give  $\Gamma(\pi(113)) = \Gamma(\pi)/8 = .95 \text{ eV}$ . Scaling down of  $f_\pi$  by a factor 55 is allowed by the experimental limits and there is no limit on scaling up. Contrary to the expectations inspired by [C2]  $\Gamma(\pi, \gamma\gamma)$  does not exclude the identification of  $X$  as pion like state.

### 1.3 Model for $\Gamma(\pi(113), e^+e^-)$

The following considerations show that the generalization of the standard model for  $\Gamma(\pi, e^+e^-)$  predicts too small production rate for  $\Gamma(\pi(113), e^+e^-)$ . The modification based on the assumption that either p-adically scaled down weak bosons or their dark variants are possible and color magnetic flux tubes allows to understand  $\Gamma(\pi(113), e^+e^-)$  and leads to a radical proposal that dark or p-adically scaled up variants of weak physics are involved also with the semileptonic decays of hadrons so that the prevailing picture would be wrong.

#### 1.3.1 The standard model prediction for $\Gamma(\pi(113), e^+e^-)$ is not consistent with the experimental limits

The estimate of [C2] for the decay width of  $\Gamma(X, e^+e^-)$  (Eq. (6) of the article) of *spin* 1  $X$  boson is of the form

$$\Gamma(X, e^+e^-) = \epsilon_e^2 \frac{\alpha}{3} \left(1 + 2 \frac{m_e^2}{m_X^2}\right) \times m_X \quad . \quad (1.4)$$

The estimate of the authors for the range of allowed values of  $\epsilon$  is  $[2 \times 10^{-4}, 1.4 \times 10^{-3}]$ . The rate would vary in the range  $[2.3 \times 10^{-3}, 0.1] \text{ eV}$ . A weaker lower bound for  $\epsilon$  is  $1.3 \times 10^{-5}$  giving lower bound for decay width as  $1.5 \times 10^{-4} \text{ eV}$ . The optimistic guess is that these bounds apply to pseudoscalar  $X$ .

The observed  $e^+e^-$  branching fraction for the ordinary pion is about  $B(\pi, e^+e^-) = 7.5 \times 10^{-8}$  (see <http://arxiv.org/pdf/0704.3498.pdf>) giving the estimate  $\Gamma(\pi, e^+e^-) \simeq 5.6 \times 10^{-7} \text{ eV}$ . The challenge is to scale up this rate for  $\pi(113)$ . This requires a model for  $\Gamma(\pi, e^+e^-)$ .

In [C1]  $\Gamma(\pi, e^+e^-)$  (see <http://arxiv.org/pdf/0704.3498.pdf>) is estimated as a loop correction by assuming that the decay proceeds via annihilation to virtual gamma pair decaying to electron pair by electron exchange. The reason is that there is no spinless current coupling to quarks and leptons directly (leptoquarks as carriers of this current have been considered). The estimate involves uncertainties since the form factor  $F_{\pi\gamma^*\gamma^*}$  is not well-known off-mass-shell and must be modelled.

1. The general expression for the ratio of branching ratios to  $B(\pi, e^+e^-)$  and  $B(\pi, \gamma\gamma)$  reads as

$$R(\pi, e^+e^-) \equiv \frac{B(\pi, e^+e^-)}{B(\pi, \gamma\gamma)} = 2 \left(\frac{\alpha}{\pi} \frac{m_e}{m_\pi}\right)^2 \beta_e(q^2) |A(m_\pi^2)|^2 \quad ,$$

$$\beta_e(q^2) = \sqrt{1 - \frac{4m_e^2}{q^2}} \quad . \quad (1.5)$$

$\beta_e(m_\pi^2)$  is the relativistic velocity of electron. The strongest dependence of the branching ratio on pion mass is contained by the suppression factor  $x = (\alpha/\pi)^2 (m_e/m_\pi)^2$  coming from approximate helicity conservation (the helicities of electron and positron are parallel at massless limit where as the spin of pion vanishes). The dependence of  $A$  on mass ratios is logarithmic.

2. The general expression for  $A$  is as a loop integral with pion form factor defining the vertex.

$$\begin{aligned} A(q^2) &= \frac{2i}{q^2} \int \frac{d^4k}{\pi^2} \frac{q^2 k^2 - (q \cdot k)^2}{D(k^2)D((k-q)^2)D_e((k-p)^2)} F_{\pi\gamma^*\gamma^*}(-k^2 - (k-q)^2) , \\ D(k^2) &= k^2 + i\epsilon , D_e(k^2) = k^2 - m_e^2 + i\epsilon . \end{aligned} \quad (1.6)$$

To calculate the integral one must continue  $F_{\pi\gamma^*\gamma^*}$  for all values of its arguments and this requires modelling.

3. The approximate outcome of the calculations of [C1] is

$$\begin{aligned} Im(A(q^2)) &= \frac{\pi}{2\beta_e(q^2)} \log(y_e(q^2)) , \quad y_e = \frac{1 - \beta_e}{1 + \beta_e} , \\ Re(A(q^2)) &= A(q^2 = 0) + \frac{a^2}{\pi} \int_0^\infty ds \frac{Im(A)(s)}{s(s - q^2)} . \end{aligned} \quad (1.7)$$

The real part of the loop integral diverges logarithmically and  $A(m\pi^2)$  is obtained from a once subtracted dispersion relation.  $A(q^2 = 0)$  contains the unknown dynamics and is outcome of the regularization procedure. One obtains approximate expression for  $Re(A)$  as

$$Re(A(q^2)) = A(q^2 = 0) + \frac{1}{\beta(q^2)} \left[ \frac{1}{4} \log^2(y_e(q^2)) + \frac{\pi^2}{2} + Li_2(-y_e(q^2)) \right] \quad (1.8)$$

Here  $Li_2(z) = \int_0^z (dt/t) \log(1-t)$  is dilogarithm function. In good approximation one has

$$Re(A(m_{\rho i}^2)) = A(q^2 = 0) + \log^2\left(\frac{m_e}{m_\pi}\right) + \frac{\pi^2}{2} . \quad (1.9)$$

4. For  $A(q^2 = 0)$  containing the dynamics authors consider the parameterization

$$\begin{aligned} A(q^2 = 0) &= -\frac{3}{2} \log\left(\frac{s^1}{m_e^2}\right) = -23.2 \pm 1 . \\ s^1 &= (776 \pm 22 \text{ MeV})^2 . \end{aligned} \quad (1.10)$$

$s^1$  is essentially  $\rho$  meson mass squared. The value of the dispersion integral depends on the choice of cutoff fixing the value of the loop amplitude for zero momentum transfer  $q^2 = 0$  and  $\rho$  meson mass plays the role of the cutoff - this has also physical motivation coming from vector meson dominance.

5. The prediction is  $B(\pi, e^+e^-) = (6.23 \pm .09) \times 10^{-8}$  whereas the experimental value is  $B(\pi, e^+e^-) = (7.49 \pm 0.29 \pm 0.25) \times 10^{-8}$ . The result is rather satisfactory. Authors can reproduce the observed branching ratio by replacement  $m(\rho), m(\rho/2)$  but this leads to other problems.

What happens when ordinary pion is replaced with  $\pi(113)$ ?

1. The suppression factor  $x = (\alpha/\pi)^2 (m_e/m_\pi)^2$  is scaled up by 64 if  $h_{eff}$  is not changed.  $A$  depends logarithmically on mass ratios and is not affected much as one finds by checking what happens to the terms contributing the expression of  $|A|^2$ : one obtains scaling down by a factor .35. If the pion decay rate scales as p-adic mass scale, one has in reasonable approximation  $64 \times 7.5/8$ -fold scaling giving  $\Gamma(\pi(113), e^+e^-) \simeq 60 \times .35 \times \Gamma(\pi, e^+e^-) \simeq .17 \times 10^{-5} \text{ eV}$ . The experimental lower bound is  $1.5 \times 10^{-4}$ , which is 88 times higher than the estimate.

2. This is a real problem and unless one is ready to consider exotic particles such as leptoquark like states, the only solution seems to be that  $F_{\pi\gamma^*\gamma^*}^2$  is scaled up by factor of order 30. This requires a reduction of  $f_\pi^2$  by factor 1/88. As found, the limit on  $\Gamma(X, \gamma\gamma)$  allows downwards scaling of  $f_\pi^2$  by a factor about 1/55 so that it is marginally possible to satisfy the experimental bounds on both decay widths. Scaling by factor  $n^2 = 64$  might save the situation.
3. What the increase of  $F_{\pi\gamma^*\gamma^*}^2$  means is not quite clear. The analogy with positronium decay would suggest that the of  $|\Psi(0)|^2$  at the origin of quark-antiquark relative coordinate is enhanced by a factor order 30. The scaling up of the size of the color flux tube does not support this view.  
The increase of  $F_{\pi\gamma^*\gamma^*}^2$  could also come from the reduction of axial coupling strength  $f_\pi$  allowing interpretation in terms of the reduction of  $|\Psi(0)|^2$  at the origin of the relative coordinate: quarks tend to be father away since p-adic length scale is longer. This might bring additional power of 8.
4. It would seem that the scaling of Planck constant does not work for the model based virtual gamma pair. The presence of  $\alpha^2$  in loop correction would in fact imply scaling down of  $\Gamma(\pi, e^+e^-)$  by factor  $1/n^2$  so that the scaling up of  $1/f_\pi^2$  should compensate also this reduction: scaling by  $n^4$  coming from  $\alpha_s^4$  proportionality of  $f_\pi^2$  could do the job.

### 1.3.2 Could dark or p-adically scaled down weak bosons help?

In TGD framework one can criticize the model involving loop integral. If loops can be eliminated both topologically and at the level of Kähler action, they can be present only in QFT description, and one might argue that loopless description should be possible if the problem reduces to the level of single space-time sheet [K5]. If loops and radiative corrections appear at all, they do so only in the positive and negative parts of zero energy states but not in diagrams ad pion could contain also gamma pairs and electron pairs as contributions. This would end up with the virtual particle cloud picture. The most elegant description of course involves no loops at all and it seems that it is possible to achieve this by introducing dark or p-adically scaled down weak bosons.

If one does not accept loops then one must consider a loopless mechanism.

1. I have proposed dark weak bosons to be involved with both cold fusion and chiral selection in living matter [L2, L1, L3]. Since pion couples to axial current, it is natural ask whether dark weak boson  $Z^0$  coupling to axial current could be involved.

For ordinary weak boson the amplitude would be of course extremely small since it is proportional to  $1/m_Z^2$ . If weak bosons are dark at  $k = 113$  color magnetic flux tubes, the range of weak interactions is scaled up and weak boson becomes effectively massless within dark Compton scale. This would make weak interaction long ranged and make possible the decay of pion via  $Z^0$  annihilation of quark pair to dark  $Z^0$  annihilating to electron pair.  $Z^0$  propagator would be replaced with massless propagator at virtual mass squared given by the mass of dark pion and the rate would be scaled up by factor  $m_Z^4/m_{\pi(113)}^4 \simeq 0.7 \times 10^{15}$ .

2.  $\pi(113) - Z$  coupling  $f_{\pi(113)Z}$  is analogous to vector-boson-photon coupling  $f_{V\gamma}$  of vector boson dominance model.  $f_{\pi(113)Z}$  can be identified as the the coupling  $f_{\pi(113)Z} = f_\pi m_\pi$  of  $\pi(113)$  to axial current [B1]. The order of magnitude for  $\Gamma(\pi(113), e^+e^-)$  is given by the usual Feynman rules giving single particle decay rate, and one obtains (I hope that the numerical factors are correct!)

$$\Gamma(\pi, e^+e^-) = \frac{1}{8\pi} \frac{m_e^2}{m_\pi^2} \frac{f_\pi^2}{m_\pi^2} \left(1 - \frac{4m_e^2}{m_\pi^2}\right) \times m_\pi . \quad (1.11)$$

The estimate gives  $\Gamma(\pi, e^+e^-) = .93$  eV, which is reasonably near to the experimental upper bound .1 eV.

One must of course be very cautious here. It could also be that p-adically scaled up variant of weak physics with standard value of Planck constant is involved and the weak bosons involved have p-adically scaled down mass scale. I have also proposed [K3] that in living matter a kind of resonant coupling between dark physics ( $h_{eff} = n \times h$ ) and p-adically scaled up non-dark physics exists for  $L(k, h_{eff}) = nL(k) = L(k_1)$  requiring  $2^{(k-k_1)/2} = n$ . Scaled dark particles would transform to ordinary p-adically scaled particles and vice versa.

### 1.3.3 Could dark electro-weak physics manifest itself in ordinary hadron physics?

Could also ordinary pion decay be understood in terms of the same mechanism? Now the p-adic length scale of pion would be  $k = 107$ . One would have  $\Gamma(\pi(113), e^+e^-) = 2^9 \Gamma(\pi(107), e^+e^-)$ : the power of two comes from  $m_{\pi(113)}^{-3}$  proportionality of the rate. Using  $\Gamma(\pi(107), e^+e^-) = .55 \times 10^{-6}$  eV one obtains the prediction  $\Gamma(\pi(113), e^+e^-) = 2.8 \times 10^{-4}$  eV. This is an order of magnitude below the range  $[2.3 \times 10^{-3}, 0.1]$  eV of the allowed values deduced in [C2]. The estimate is however above the general experimental lower bound  $1.5 \times 10^{-4}$  eV.

Could the p-adic scaling down with ordinary value of Planck constant work better? The propagator factor would be  $1/(m_Z^2(k) - m_{\pi(113)}^2)^2$  and if the two masses are near to each other, could increase the rate by resonance factor

$$r = \frac{m_{\pi(113)}^4}{[m_Z^2(k) - m_{\pi(113)}^2]^2} = \left[ \frac{1}{\left(\frac{m_Z(k)}{m_{\pi(113)}}\right)^2 - 1} \right]^2. \quad (1.12)$$

From  $m_Z/m_Z(k) = 2^{(k-89)/2} \sim (91/17) \times 10^3$  one obtains the estimate  $k - 89 \in \{24, 25\}$  giving  $k \in \{113, 114\}$ .

1. For  $k = 113$  - nuclear scale (!) - the value of the resonance factor would be  $r = 1.6$  giving  $\Gamma(\pi(113), e^+e^-) = 4.5 \times 10^{-4}$  eV still by factor .16 smaller than the lower bound of authors. The improvement would not be large.
2. For  $k = 114$  the resonance factor would be 91.5 giving the estimate  $\Gamma(\pi(113), e^+e^-) = .04$  eV belonging to the middle of the range of allowed values. Assuming that there are no numerical errors involved, the best option is  $k = 114$  p-adically scaled up  $Z^0$  boson.

This amazing finding forces to ask whether the prevailing picture about leptonic pion decays of hadrons is really correct.

1. The basic motivation for large  $h_{eff} = n \times h$  hypothesis was that it makes perturbation theory possible. Strong interactions at low energies provide a key example of the situation in which this hypothesis could be useful.
2. The number theoretic vision that all scattering processes are describable using only tree diagrams in TGD framework [K5] suggests that the descriptions involving loops should have duals involving no loops and be based on couplings of mesons to dark weak bosons. A possible test is provided by the box diagrams associated with CP breaking for kaons and B mesons.
3. Could it be that dark weak interactions at length scale  $k = 107$  are responsible for hadronic decays to leptons? Could also vector meson dominance be formulated in terms of dark weak currents? This would explain why the symmetries group  $SU(2)_L \times SU(2)_R$  of low energy hadron physics is very much like weak gauge group and conserved vector current (CVC) hypothesis and partially conserved vector current (PCAC) hypothesis.
4. This picture would be also consistent with the  $M^8 - H$  duality [K4] explaining why  $SU(2)_L \times SU(2)_R$  for hadrons and  $SU(3)$  for partons provide dual descriptions. The identification of mesons as string like objects conforms with the description of hadronic reactions provided by hadronic string model and the couplings of various mesons to electroweak currents would allow to describe the hadronic weak decays. The scaled down variant of this description would apply to nuclear reactions. What is nice that this proposal is testable.

## 1.4 Model based on nuclear strings

One should construct a model for color bonds connecting nucleons to form nuclear strings.

1. In nuclear string model [K2] nuclei are identified as nuclear strings with nucleons connected by color flux tubes, which can be neutral or charged and can have net color so that color confinement would be in question in nuclear length scale. The possibility of charged color flux tubes predicts the existence of exotic nuclei with some neutrons replaced by proton plus negatively charged color flux tube looking like neutron from the point of view of chemistry or some protons replaced with neutron plus positively charged flux tube. Nuclear excitation with energy determined by the difference of initial and final color bond energies is in question.
2. The color magnetic flux tubes are analogous to mesons of hadron physics except that they can be colored and are naturally pseudo-scalars in the ground state. These pion like colored flux tube can be excited to a colored state analogous to  $\rho$  meson with spin 1 and net color. Color bonds would be rather long flux loops with size scale determined by the mass scale of color bond: 17 MeV gives estimate which as electron Compton length divided by 34 and would correspond to p-adic length scale  $k = 121 > 113$  so that length would be about  $2^{(121-113)/2} = 16$  times longer than nuclear length scale.
3. If the color bonds (cb) are indeed colored, the mass ratio  $m(\rho, cb)/m(\pi, cb)$  need not be equal to  $m(\rho, 107)/m(\pi, 107) = 5.74$ . If the  $\rho$  and  $\pi$  type closed string states are closed string like objects in the sense as elementary particles are so that there is a closed magnetic monopole flux tube along first sheet going through wormhole contact to another space-time sheet and returning back, the scaling  $m(\rho/\pi, 107)/m(\rho/\pi, 113) = 8$  should hold true.

With these ingredients one can construct a model for the decay  ${}^8\text{Be}^* \rightarrow {}^8\text{Be} + X$ .

1.  ${}^8\text{Be}^*$  could correspond to a state for which pionic color(ed) bond is excited to  $\rho$  type color(ed) bond. The decay of  ${}^8\text{Be}^* \rightarrow {}^8\text{Be} + X$  would mean a snipping of a color singlet  $\pi$  meson type *closed* flux tube from the color bond and leaving pion type color bond. The reaction would be analogous to an emission of closed string from open string.  $m(X) = 17$  MeV would be the mass of the color-singled closed string emitted equal to  $m(\pi, 113) = 17$  MeV. The emitted  $\pi$  would be in  $l = 1$  partial wave so that resonant decay to gamma pair would not occur but decay to  $e^+e^-$  pairs is possible just like for the ordinary pion.
2. Energy conservation suggests the identification of the excitation energy of  ${}^8\text{Be}^*$  as the mass difference of  $\rho$  and  $\pi$  type colored bonds (cb):  $E_{ex}({}^8\text{Be}^*) = m(\rho, cb) - m(\pi, cb) = m(\pi, 113) = 17$  MeV in the approximation that  $X$  is created at rest. If one has  $m(\rho, cb)/m(\pi, cb) = m(\rho)/m(\pi)$  - this is not necessary - this gives  $m(\rho, cb) \simeq 20.6$  MeV and  $m(\pi, cb) \simeq 3.5$  MeV.
3. This estimate is based on mass differences and says nothing about nuclear binding energy. If the color bonds carry positive energy, the binding energy should be localizable to the interaction of quarks at the ends of color bonds with nucleons. The model clearly assumes that the dynamics of color bonds separates from the dynamics of nuclei in the case of the anomaly.
4. The assumption about direct coupling of  $X$  to quarks and therefore to nucleons does not make sense in this framework. Hence photophobia does not hold true in TGD and this is due to the presence of long color bonds in nuclear strings. Also the spin 1 assignment of [C2] would be wrong. Also the vector boson character would be wrong assumption since pion property allows to obtain gamma decay rate consistent with the experimental limits.

## 1.5 Conclusion

To conclude, the proposed new nuclear physics is physics of the magnetic body of nucleus and involves hierarchy of Planck constants in an essential manner, and the proposed solution to the too low decay rate  $\Gamma(\pi(113), e^+e^-)$  could turn out to provide a direct experimental proof for the hierarchy of Planck constants. It also suggests a new approach to the leptonic decays of hadrons based on dark or p-adically scaled down variants of weak interactions. The proposal for the



explanation of the anomaly in charge radius of proton involves physics of the magnetic body of proton [K1]. TGD inspired quantum biology is to high degree quantum physics of magnetic body. Maybe the physics of magnetic body differentiates to its own branch of physics someday.

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