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}Be* of an unstable isotope of ^{8}Be (4 protons and 4 neutrons) to ground state ^{8}Be. The anomaly manifests itself as a bump in the distribution of e^+e^- pairs in the transitions ^{8}Be*→ ^{8}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 6.8σ 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}Be* of an unstable isotope of ^{8}Be (4 protons and 4 neutrons) to ground state ^{8}Be [L4, C3] (see http://arxiv.org/abs/1604.07411). For the theoretical interpretation of the finding in terms of fifth force see [C3] (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}Be*→ ^{8}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 6.8σ - 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 protophoby. 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 phobies. 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 [K4] 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 [C3].

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_π 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 where 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 ρ 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

$$g_{X\gamma\gamma} F^{\mu\nu} \tilde{F}_{\mu\nu} \ , \tag{1.1}$$

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

$$g_{\pi\gamma\gamma} = \frac{\alpha}{\pi f_\pi} \ . \tag{1.2}$$

$f_\pi = 93$ 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_π on α and α_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 α_s. α 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 [K1]: 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 the 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 α_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 $q\overline{q} \rightarrow \gamma\gamma$ 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 α_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 α_k and should increase/reduce the rate by reducing/increasing f_π^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

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

   In this expression the only h_{eff}-dependence is contained by f_π. Using units $\hbar = 1, c = 1$ one would have apparent α^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 [C3] all values of $1/g_{\pi\gamma\gamma}$ outside the range [.1 GeV,10^{18} GeV] have been excluded. This translates to the allowed range [.2 MeV, 2.3×10^{15} GeV] implying $f_\pi \geq .2$ MeV. The p-adically scaled down value of $f_{\pi(113)} = f_\pi/8 = f_\pi/8 = 11$ MeV is inside the allowed range.

3. f_π depends on non-perturbative aspects of QCD and therefore on α_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_π scales like m_π. In absence of h_{eff} dependence the scaling from the pion decay width would give $\Gamma(\pi(113)) = \Gamma(\pi)/8 = .95$ eV. Scaling down of f_π by a factor 55 is allowed by the experimental limits and there is no limit on scaling up. Contrary to the expectations inspired by [C3] $\Gamma(\pi, \gamma\gamma)$ 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 [C3] for the decay width of $\Gamma(X, e^+e^-)$ (Eq. (6) of the article) of *spin* 1 X boson is of the form

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

The estimate of the authors for the range of allowed values of ϵ is $[2\times10^{-4}, 1.4\times10^{-3}]$. The rate would vary in the range $[2.3\times10^{-3}, 0.1]$ eV. A weaker lower bound for ϵ is 1.3×10^{-5} giving lower bound for decay width as 1.5×10^{-4} eV. The optimistic guess is that these bounds apply to pseudoscalar X.

The observed e^+e^- branching fraction for the ordinary pion is about $B(\pi, e^+e^-) = 7.5\times10^{-8}$ (see `http://arxiv.org/pdf/0704.3498.pdf`) giving the estimate $\Gamma(\pi, e^+e^-) \simeq 5.6\times10^{-7}$ 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

$$\begin{aligned} R(\pi, e^+e^-) &\equiv \frac{B(\pi, e^+e^-)}{B(\pi, \gamma\gamma)} = 2(\frac{\alpha}{\pi}\frac{m_e}{m_\pi})^2\beta_e(q^2)|A(m_\pi^2)|^2 \quad , \\ \beta_e(q^2) &= \sqrt{1 - \frac{4m_e^2}{q^2}} \quad . \end{aligned} \tag{1.5}$$

   $\beta_e(m_\pi^2)$ 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.

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

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

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

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 unkown 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 dilogarith function. In good approximation one has

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

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

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

s^1 is essentially ρ 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 transer $q^2=0$ and ρ 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 $\Gamma(\pi(113),e^+e^-)\simeq 60\times\times .35\times\Gamma(\pi,e^+e^-)\simeq .17\times 10^{-5}$ eV. The experimental lower bound is 1.5×10^{-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 lepto-quark like states, the only solution seems to be that $F^2_{\pi\gamma*\gamma*}$ is scaled up by factor of order 30. This requires a reduction of f_π^2 by factor 1/88. As found, the limit on $\Gamma(X, \gamma\gamma)$ allows downwards scaling of f_π^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 $F^2_{\pi\gamma*\gamma*}$ 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 $F^2_{\pi\gamma*\gamma*}$ could also come from the reduction of axial coupling strength f_π 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 α^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 α_s^4 proportionality of f_π^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 [K1]. 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!)

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

   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 [K5] 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 $m_{\pi(113)}^{-3}$ proportionallity 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 [C3]. The estimate is however above the general experimental lower bound 1.5×10^{-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

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

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 [K1] 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 [K6] 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 [K4] 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 neuron from the point of view of chemistry or some protons replaced with neutron plus positively charged flux tube. Nuclear excitation with energy determined buy 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 ρ 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 ρ and π 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}Be* $\rightarrow$ ^{8}Be $+X$.

1. ^{8}Be* could correspond to a state for which pionic color(ed) bond is excited to ρ type color(ed) bond. The decay of ^{8}Be* $\rightarrow$ ^{8}Be $+X$ would mean a snipping of a color singlet π 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 π 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}Be* as the mass difference of ρ and π type colored bonds (cb): $E_{ex}(^8Be*) = m(\rho, cb) - m(\pi, cb) = m(\pi, 113) = 17$ 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 makes sense in this framework. Hence protophoby 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 [C3] 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 Ytterbium anomaly

Sabine Hossenfelder talked about a very interesting nuclear physics anomaly known as Ytterbium anomaly (see this). There is a Phys. Rev. Lett. article about this anomaly titled "Probing New Bosons and Nuclear Structures with Ytterbium Isotope Shifts" [C2]. What makes this anomaly so interesting is that it is reported to have a significance level of 23 sigmas! 5 sigmas is usually regarded as the significance, which makes it possible to speak of a discovery. It turns out that X boson could solve the Yb anomaly.

1. Ytterbium (see this) is a heavy nuclear with charge $Z = 70$ and mass number of $A = 173$ so that neutron number would be $N = 103$ for the most general isotope (it seems that the definition of isotope number varies depending on whether its defined in terms of mass or the actual number of nucleons). The mass numbers of Yb vary in the range 168-176. Ytterbium is a rare earth metal with electron configuration [Xe] $4f^{14}$ $6s^2$.

2. The electronic state seems to be very sensitive to the number of neurons in Yb and this is why Yb is so interesting from the point of view of atomic physics. The anomaly is related to the isotope shift for the electron energies. So called Frequency Comb method amplifies the mismatch with the standard theory. Mismatch indeed exists and could be understood in terms of a new particle with a mass of few MeVs.

3. There is an earlier anomaly known as Atomki anomaly [L4, C3] explained by what is called X boson in mass range 16-17 meV and the Yb anomaly could be explained in terms of X boson (see `http://arxiv.org/abs/1604.07411`this).

I have discussed the X boson in the TGD framework and proposed that it could be a pion-like state [L4].

1. The proposed model provides new insights on the relation between weak and strong interactions. One can pose several questions. Could X could be a scaled variant of pion? Or could weak interaction physics have a scaled down copy in nuclear scale?

2. The latter option would mean that some weak boson could become dark and its Compton length would be scaled up by factor h_{eff}/h to nuclear p-adic length scale. I have proposed a scaled up copy of hadron physics characterized by Mersenne prime M_{89} with a mass scale, which is 512 higher than for ordinary hadrons with M_{107}. In the high energy nuclear collisions in which quark-gluon plasma is believed to be created at quantum criticality, M_{89} hadrons would be generated. They would be dark and have $h_{eff}/h = 512$ so that the scaled up hadronic Compton length would be the same as for ordinary hadrons [K2, K3]. M_{89} hadron physics would explain a large number of particle physics anomalies and there is considerable evidence for it. The most radical implications of M_{89} hadron physics would be for solar physics [L5].

Could also weak interaction physics have dark variants at some kind of quantum criticality and could the Yb anomaly and Atomki anomaly be understood as manifestations of this new physics.

1. Weak bosons are characterized by $p \simeq 2^k$, $k = 91$, from the mass scale of weak bosons. A little confession: for a long time I believed that the p-adic mass scale of weak bosons corresponds to $k = 89$ rather than $k = 91$. For the Higgs boson the mass scale would correspond to M_{89}. TGD also predicts a pseudoscalar variant π_W of the Higgs boson. Could the dark variant of the pseudoscalar Higgs boson π_W with Compton length assignable to the X boson be involved?

2. The scaled up weak boson should have a p-adic length scale which equals nuclear length scale or is longer. Dark π_W could become effectively massless below its Compton length. The mass of X boson about 16-17 MeV corresponds to a Compton length of 6×10^{-14} m and is by factor 3 longer than the nuclear p-adic length scale $L(k = 113) \simeq 2 \times 10^{-14}$ m. For $k_{\pi_W} = 91$ would give $h_{eff}/h = 2^{(113-91)/2} = 2^{11}$ to give the nuclear Compton scale. $k = 115$ would give the length scale 4×10^{-14} m not far from 6×10^{-14} m and require $h_{eff}/h = 2^{(115-91)/2} = 2^{12}$. If π_W corresponds to $k = 89$ then $h_{eff}/h = 2^{(115-89)/2} = 2^{13}$.

   If the π_W Compton scale is scaled from M_{91} by factor $2^{(113-89)/2} = 2^{12}$ to a Compton length corresponding for ordinary Planck constant to the mass of about $m_{\pi_W}/2^{12}$. This would give $m_{\pi_W} \simeq 64$ GeV, essentially one half of the mass of the ordinary Higgs about 125.35 GeV and corresponds to the p-adic length scale $k = 91$ just like other weak bosons.

3. Could dark π_W give rise to a dark weak force between electron and nucleus inducing the anomalous isotope shift to electron energies? The increase of the Compton length would

suggest the scaling up of the electron nucleus weak interaction geometric cross section by the ratio $(m_X/m_W)^4 \sim 10^{20}$? The weak cross section for dark π_W have the same order of magnitude than nuclear strong interaction cross sections since, apart from numerical factors depending on the incoming four-momenta, the weak cross section for electron-nucleon scattering goes like $G_F \sim 1/\text{TeV}^2$. This would scale up to $2^{113-91=22}/TeV^2 = 4/MeV^2$ (see this). The alternative manner to understand the enhancement could be by assuming that weak bosons are massless below the nuclear scale.

4. Quantum criticality would be essential for the generation of dark phases and long range quantum fluctuations about which the emergence of scaled up dark weak bosons would be an example. Yb is indeed a critical system in the sense that the isotope shift effects are large: this is one reason for why it is so interesting. Why would the quantum criticality of some Yb isotopes induce the generation of dark weak bosons?

It should be noticed that for $k = 512$ assigned with dark M_{89} hadrons, the scaled down Compton length of dark π_W would be by a factor 8 shorter and correspond to mass 128 MeV not far from the pion mass. What could this mean? Could ordinary pion correspond to a dark dark variant of π_W? This looks strange since usually strong and weak interactions are regarded as completely separate although the CVC and PCAC suggest that they are closely related. In TGD, the notion of induced gauge field implies extremely tight connections between strong and weak interactions.

1.6 Calcium anomaly as evidence for a new boson with mass in the range 10 eV to 10 MeV

I learned about findings giving support for the view about a new interaction implying that the energies of electrons depend on the neutron number of the atom in a way, which is not explainable in the standard model [?] (see this). A new interaction mediated by a scalar boson with mass in the range 10 eV-10 MeV is proposed as an explanation for the findings. There are many other anomalies, which a boson with a mass $\sim$ 17 MeV could explain.

The following gives the abstract of the article published in Phys Rev Letters.

Nonlinearities in King plots (KP) of isotope shifts (IS) can reveal the existence of beyond-standard-model (BSM) interactions that couple electrons and neutrons. However, it is crucial to distinguish higher-order standard model (SM) effects from BSM physics. We measure the IS of the transitions $^3P_0 \rightarrow ^3 P_1$ *in* Ca^{14+} *and* $^2S_{1/2} \rightarrow ^2 D_{5/2}$ *in* Ca^+ *with sub-Hz precision as well as the nuclear mass ratios with relative uncertainties below* 4×10^{-11} *for the five stable, even isotopes of calcium* ($^{40,42,44,46,48}Ca$).

Combined, these measurements yield a calcium KP nonlinearity with a significance of $\sim 10^3\sigma$. *Precision calculations show that the nonlinearity cannot be fully accounted for by the expected largest higher-order SM effect, the second-order mass shift, and identify the little-studied nuclear polarization as the only remaining SM contribution that may be large enough to explain it. Despite the observed nonlinearity, we improve existing KP-based constraints on a hypothetical Yukawa interaction for most of the new boson masses between* $10\ eV/c^2$ *and* $10^7\ eV/c^2$.

My understanding of what has been done is as follows.

1. Nonlinear isotope shift (IS) in KP for Ca isotopes A=42,44,46,48 relative to the isotope A=40 observed. Note that or $^3P_0 \rightarrow ^3 P_1$ in Ca^{14+} 14-fold electronic ionization so that the electronic configuration is $[He]2s^2 2p^2$.

2. What is measured are the differences $\delta\nu^A_{570}$ and $\delta\nu^A_{729}$ of the frequencies (equivalently energies) of the initial and final electronic configuration for these two transitions as function of $A \in \{10, 42, 44, 46, 48\}$. From these shifts the differences $\delta\nu^{A,40}_{570} = \delta\nu^A_{570} - \delta\nu^{40}_{570}$ and $\delta\nu^{A,40}_{729} = \delta\nu^A_{729} - \delta\nu^{40}_{729}$ of these shifts for $\delta\nu^{A,40}_{570} = \delta\nu^A_{570} - \delta\nu^{40}_{570}$ with $A \in \{42, 44, 46, 48\}$ are deduced.

3. If the effects of the neutron number on the electron energies equals to that predicted by standard model, $\delta\nu^{A,40}_{729}$ should be a linear function of $\delta\nu^{A,40}_{570}$. In the graphical representation the linearity allows to replaced the shifts with $\delta\nu^{A,40}_{570} \rightarrow \delta\nu^{A,40}_{570} - 452[GHzamu] == X$ and $\delta\nu^{A,40}_{729} \rightarrow \delta\nu^{A,40}_{729} - 2327[GHzamu] == Y$ are performed. This gives the King plot representing Y as a function of X.

4. Fig 1. of [?] gives the shifts for Ca isotopes for $A \in \{42, 44, 46, 48\}$ and from the 4 boxes magnifying the graph for the isotope shifts for these values of A show a small non-linearity: the red ellipses are not located at the blue vertical lines. For $A = 42, 44, 48$ the red ellipse is shifted to the right but for $A = 46$ it is shifted to the left.

A Yukava scalar with mass in range 10 eV to 10^7 eV proposed as an explanation. I am not able to conclude whether the scalar property is essential or whether also pseudoscalar is possible. The coupling to the boson affects the binding energies of electrons so that they have additional dependence on the neutron number. If the King plot were linear, the difference would be proportional to the neutron number implying proportional to $A-40$. The slope of the curve would be 45 degrees. Note that from the table I of [?], the differences are in the range .1 meV to 1 meV about $\Delta E/E \sim 10^{-4}$. One neutron pair corresponds to an energy difference of order .1 meV.

One can consider two options in the TGD framework.

1. The upper bound for the boson mass is about 10 MeV and this suggests 17 MeV pseudoscalar which could explain several earlier nuclear physics anomalies [L4, C2] and for which I have proposed a TGD inspired model [L4]. In particular, X boson explains Yb anomaly for which also non-linearity of the King plot was observed. This anomaly to the deformations of nuclei caused by adding neutrons.

2. In the TGD framework one can consider also a second option, which is M^4 Kähler force as a new interaction. It should be very weak and might be too weak to cause the effect. It is, however, good to check whether this interaction is weak enough.

   M^4 Kähler potential contributes to measured electroweak $U(1)$ coupling if total Kähler potential replaces CP_2 Kähler potential in classical U(1) gauge potential. Could M^4 Kähler potential give a contribution of the required size to the neutron-electron interaction? I have discussed this interaction in [L6]. A simple model shows that the effects are extremely small. This implies that the new interaction does not imply any obvious anomalies. At the level of the embedding space Dirac equation, the effects are dramatic. The basic implication is that colored states of fermions have mass of order CP_2 mass and only color singlets can be light. One implication is that the $g-2$ anomaly is real since the calculation using hadronic data as input rather than lattice QCD gives the anomaly [L6].

1.7 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 [K3]. 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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