Have lepto-quarks been observed in the decays of B mesons?

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Abstract

There is evidence for anomalies in the decays $B \to K\mu^+\mu^-$. If real, these anomalies would serve as the long waited signatures of new physics LHC mass scales. In this article I discuss the proposed lepto-quark interpretation in TGD framework, where the emergence of gauge bosons as bound states of fundamental fermions makes lepto-quarks natural: the really difficult challenge in TGD would be to explain why they are not there. Lepto-quarks can be both vectors or scalars. Vector lepto-quarks are especially attractive and in TGD framework the model automatically predicts that the modification of the production rate of $B \to Ke^+e^-$ involvinc CKM matrix elements is much smaller than for muon pairs. What is interesting that the members of the lepton pair can belong to different lepton families. The breaking of lepton universality motivation for the idea that the assumption that lepto-quark is scalar having couplings proportional to the mass geometric mean of the mass scales of the lepton and quark. The mere experimental absence of lepto-quarks in the scattering of quarks and leptons of same generation puts strong limits on its mass: the 10 TeV estimate of the article discussing lepto-quark model is probably motivated by this requirement. The rate for the anomalous production of lepton pairs involves a loop integral. One should check that this integral is of the same order of magnitude as the corresponding integral in the case of standard model with lepto-quarks replaced with W bosons: the expectation is that the dependence on X quark mass scale is weak.

1   Introduction

Jester told in his blog "Resonaances" about an evidence for anomalies in the decays of B meson to K meson and lepton pair. There exist several anomalies.

1. The 3.7 sigma [C3] deviation from standard model predictions in the differential distribution of the $B \to K^* \mu^+ \mu^-$ decay products.

2. The 2.6 sigma [C2] violation of lepton flavor universality in $B^+ \to K^+ l^+ l^-$ decays.

   The reported violation of lepton universality (, which need not be real) is especially interesting. The branching ratio $B(B^+ \to K^+ e^+ e^-)/B(B^+ \to K^+ \mu^+ \mu^-) \simeq .75$ holds true. Standard model expectation is very near to unity.

   Scalar lepto-quark [C1] has been proposed as an explanation of the anomaly. The lowest order diagram for lepton pair production in standard model is penguin diagram obtained from the self energy diagram for b quark involving tW^- intermediate in which W or t emits γ/Z decaying to lepton pair. Lepton universality is obvious. The penguin diagram involves 4 vertices and 4 propagators and the product of CKM matrix elements $V_{tb}V_{st}^*$. The diagram involving lepto-quark is obtained from this diagram by a modification.

   The diagram would induce an effective four-fermion coupling $\bar{b}_L \gamma^\mu s_L \mu_L^+ \gamma_\mu \mu_L^-$ representing neutral current breaking universality. Authors propose a heavy scalar boson exchanges with quantum numbers of lepto-quark and mass of order 10 TeV to explain why no anomalous weak interactions between leptons and quarks by lepto-quark exchange have not been observed. Scalar nature would suggest Higgs type coupling proportional to mass of the lepton and this could explain why the effect of exchange is smaller in the case of electron pair. The effective left-handed couplings would however suggest vector lepto-quarks with couplings analogous to W boson coupling. Note that the effect should reduce the rate: the measured rate for $B_s \to \mu^- \mu^+$ is $.79 \pm .20$: reduction would be due to destructive interference of amplitudes.

2   General ideas

Some general ideas about TGD [?] are needed in the model and are listed in order to avoid the impression that the model is just ad hoc construct.

1. In TGD all elementary particle can be regarded as pairs of wormhole contacts through which monopole magnetic flux flows: two wormhole contacts are necessary to get closed magnetic field lines. Monopole flux in turn guarantees the stability of the wormhole contact. In the case of weak bosons second wormhole contact carries fermion and antifermion at opposite throats giving rise to the net charges of the boson. The neutrino pair at the second wormhole contact neutralize the weak charges and guarantees short range of weak interactions.

2. The TGD inspired explanation of family replication phenomenon [K1] is in terms of the genus of the partonic 2-surfaces (wormhole throat) at the end

of causal diamond. There is topological mixing of partonic topologies which depend on weak quantum numbers of the wormhole throat leading to CKM mixing. Lepton and quark families obvious correspond to each other: $L(g) \leftrightarrow q(g)$ and this is important in the model to be considered.

The genera of the opposite wormhole throats are assumed to be identical for bosonic wormhole contacts. This can be assumed also for fermionic wormhole contacts for which only second throat carries fermion number. The universality of standard model couplings inspires the hypothesis that bosons are superpositions of the three lowest genera forming singlets with respect effective symmetry group $SU(3)_g$ associated with the 3 lowest genera. Gauge bosons involve also superpositions of various fermion pairs with coefficients determined by the charge matrix.

3. p-Adic length scale hierarchy is one of the key predictions of TGD [K3]. p-Adic length scale hypothesis (to be used in the sequel) stating that p-adic primes are near powers of of 2: $p \simeq 2^k$, k integer, relies on the success of p-adic mass calculations. p-Adic length scale hypothesis poses strong constraints on particle mass scales and one can readily estimate the mass of possible p-adically scaled up variants of masses of known elementary particles.

   One of the basic predictions is the possibility of p-adically scaled up variants of ordinary hadron physics and also of weak interaction physics. One such prediction is M_{89} hadron physics, which is scaled up variant of the ordinary M_{107} hadron physics with mass scale which is by a factor 512 higher and corresponds to the energy scale relevant at LHC. Hence LHC might eventually demonstrate the feasibility of TGD.

   Quite generally, one can argue that one should speak about M_{89} physics [?] in which exotic variants of weak bosons and scaled up variants of hadrons appear. There would be no deep distinction between weak bosons and M_{89} hadrons and elementary particles in general: all of them would correspond to string like objects involving both magnetic flux tubes carrying monopole flux between two wormhole throats and string world sheets connecting the lightlike orbits of wormhole throats at which the signature of the induced metric changes.

4. TGD predicts dark matter hierarchy based on phases with non-standard value $h_{eff} = n \times h$ of Planck constant [K2]. The basic applications are to living matter but I have considered also particle physics applications.

   (a) Dark matter in TGD sense provides a possible explanation for the experimental absence of super partners of ordinary particles: sparticles would be dark and would be characterized by the same p-adic mass scales as sparticles [K6].

   (b) TGD predicts also colored leptons and there is evidence for meson like bound states of colored leptons [K5]. Light colored leptons are however excluded by the decay widths of weak bosons but also now darkness could save the situation.

(c) I have also proposed that RHIC anomaly observed in heavy ion collisions and its variant for proton heavy ion collisions at LHC suggesting string like structures can be interpreted in terms of low energy M_{89} hadron physics but with large value of h_{eff} meaning that the M_{89} p-adic length scale increases to M_{107} p-adic length scale (ordinary hadronic length scale) [**?**].

One can consider also the adventurous possibility that vector lepto-quarks are dark in TGD sense.

5. TGD view about gauge bosons allows to consider also lepto-quark type states. These bosons would have quark and lepton at opposite wormhole throats. One can consider bosons which are $SU(3)_g$ singlets defined by superpositions of $L(g)q(g)$ or $L(g)\overline{q}(g)$. These states can be either M^4 vectors or scalars (all bosons are vectors in 8-D sense in TGD by 8-D chiral symmetry guaranteeing separate conservation of B and L). Left handed couplings to quarks and leptons analogous to those of W bosons are suggested by the model for the anomalies. Vector lepto-quarks can be consistent with what is known about weak interactions only if they are dark in TGD sense. Scalar lepto-quarks could have ordinary value of Planck constant.

3 A TGD based model for the B anomaly in terms of lepto-quarks

It is natural to approach also the anomaly under discussion by assuming the basic framework just described. The anomaly in the decay amplitude of $B \to K\mu^-\mu^+$ could be due to an additional contribution based on a simple modification for the standard model amplitude.

1. In TGD framework, and very probably also in the model studied in the article, the starting point is the penguin diagram [C4] for lepton pair production in $B \to K\mu^-\mu^+$ decay involving only the decay $b \to sl^+l^-$ by virtual tW state emitting virtual γ/Z decaying to lepton pair and combining with t to form s.

   (a) The diagram for lepton pair production involving virtual lepto-quark is obtained from the tW^- self-energy loop for b. One can go around the W^- branch of the loop to see what must happen. The loop starts with $b \to tW^-$ followed by $W^- \to l^-(g_1)\overline{\nu}(g_1)$ producing on mass shell lepton $l^-(g_1)$. This is followed by $\overline{\nu}(g_1) \to sX(\overline{D}\overline{\nu})$ producing on mass shell s. The genus of the virtual neutrino must ge $g = 1$ unless leptonic CKM mixing is allow in the W decay vertex.
   After this one has $X = \sum \overline{D}(g)\overline{\nu}(g) \to \overline{D}(g_2)\overline{\nu}(g_2)$. Any value of g_2 is possible. Finally, one has $t\overline{D} \to W^+$ and $W^+\overline{\nu}(g_2) \to l^+(g_2)$. There are two loops involved and four lines contain a heavy particle (two W bosons, t, and X). The diagram contains 6 electroweak vertices whereas the standard model diagram has 4 vertices.

(b) All possible lepton pairs can be produced. The amplitude is proportional to the product $V_{tb}V^*_{tD(g_2)}$ implying breaking of lepton universality. The amplitude for production of $e^+\mu^-$ pair is considerably smaller than that for $\mu^+\mu^-$ and $\tau^+\mu^-$ as the experimental findings suggest. If neutrino CKM mixing is taken into account, there is also a proportionality to the matrix element $V^L_{l(g_1)\nu_{g=1}}$.

In absence of leptonic CKM mixing (mixing explains the recently reported production of μ^+e^- pairs in the decays of Higgs) only $\mu^-l^+(g)$ pairs are produced. The possibility to have $g_2 \neq 1$ is also a characteristic of lepton non-universality, which is however induced by the hadronic CKM mixing: lepto-quark couplings are universal.

Note that flavour universality of the gauge couplings means in the case of lepto-quarks that Lq pairs superpose to single $SU(3)_g$ singlet as for ordinary gauge bosons. If $L(g)q(g)$ would appear as separate particles, only $\mu^+\mu^-$ pairs would be produced in absence of leptonic CKM mixing.

2. A rough estimate for the ratio r of lepto-quark amplitude $A(b \to sl^-(g_1)l^+(g_2))$ to the amplitude $A(b \to sl^-(g)l^+(g))$ involving virtual photon decaying to l^+l^- pair is

$$z = \tfrac{X_1}{X_2} \times \tfrac{F_1(x_X,x_t)}{F_2(x_t)}$$

$$X_1 = V_{tD(g_2)}V^L_{l_1\nu(g=1)}[\textstyle\sum_g V^L_{l^-(g_2)\nu(g)}V^*_{D(g)t}]g^2_X g^2_W \ , X_2 = V^*_{dt}e^2 \ ,$$

$$x_X = \tfrac{m^2(X)}{m^2(W)} \ , \ x_t = \tfrac{m^2(t)}{m^2(W)} \ .$$

The functions F_i correspond come from the loop integral and depend on mass ratios appearing as the argument. The factors X_i collect various coupling parameters together.

3. The objection is that the model predicts a contribution to the scattering of leptons and quarks of the same family ($L(g)-q(g)$ scattering) by the exchange of lepto-quark, which is of the same order of magnitude as for ordinary weak interactions. This should have been observed in high precision experiments testing standard model if the mass of the lepto-quark is of the same magnitude as weak boson mass. 10 TeV mass scale for lepto-quarks should guarantee that this is not the case and is probably the basic motivation for the estimate of [C1]. This requires that the ratio of the loop integrals appearing in z is of the order of unity. For a processional it should be easy to check this. Since the loop integral in the case of scalar lepto-quark studied in [C1] has the desired property and should not depend on the spin of the particles in the loops, one has good reasons to expect that the same holds true also for vector lepto-quarks.

Without a precise numerical calculation one cannot be sure that the loop integral ratio is not too large. In this case one could reduce the gauge coupling to lepto-quarks (expected to be rather near to weak coupling constant strength)

but this looks like ad hoc trick. A more adventurous manner to overcome the problem would be to assume that lepto-quarks represent dark matter in TGD sense having effective Planck constant $h_{eff} = n \times h$. Therefore they would not be visible in the experiments, which do not produce dark matter in elementary particle length scales.

4. The proposal of the article is that lepto-quark is scalar so that its coupling strength to leptons and quarks would increase with mass scale. If I have understood correctly, the motivation for this assumption is that only in this manner the effect on the rate for e^+e^- production is smaller than in the case of $\mu^+\mu^-$ pair. As found, the presence of CKM matrix elements in lepto-quark emission vertices at which quark charge changes, guarantees that both anomalous contributions to the amplitude are for electron pair considerably smaller than for muon pair.

5. Can one say something interesting about the mass of the lepto-quark using p-adic length scale hypothesis?

   Consider first a mass estimate for *dark vector lepto-quark* expected to have weak boson mass scale. Even the estimate $m(X) \sim m(W)$ is much higher than the very naive estimate as a sum of μ^- and s masses would suggest. Quite generally, if weak bosons, lepto-quarks, and M_{89} hadrons are all basic entities of same M_{89} physics, the mass scale is expected to be that of M_{89} hadron physics and of the order of weak mass scale. A very naive scaling estimate for the mass would be by factor 512 and give an estimate around 50 GeV. If μ^- mass is scaled by the same factor 512, one obtains mass of order 100 GeV consistent with the estimate for the magnitude of the anomaly.

   Second p-adic mass scale estimate assumes vector or scalar lepto-quark with mass scale not far from 10 TeV. Ordinary μ^- corresponds to Gaussian Mersenne $M_{G,k}$, $k = 113$. If p-adically scaled up variant of lepton physics is involved, the electron of the p-adically scaled up lepton physics could correspond to M_{89}. If muons correspond to Gaussian primes then the scaled up muon would correspond to the smallest Gaussian Mersenne prime below M_{89}, which is $M_{G,79}$. The mass of the scaled up muon would be obtained from muon mass by scaling by a factor $2^{(113-79)/2} = 2^{17} = 1.28 \times 10^5$ giving mass of order 10 TeV, which happens to be consistent with the conservative estimate of the article [C1].

6. An interesting possibility is that light leptoquarks (using CP_2 mass scale as unit) actually consist of quark and lepton, which is right-handed neutrino apart from possible mixing with left-handed antineutrino, whose addition to the one-particle state generates broken $\mathcal{N} = \in$ supersymmetry in TGD. The above model could be consistent with this interpretation since the scalar leptoquark is assumed to consist of right-handed neutrino and quark. This would resolve the long-standing issue about the p-adic mass scale of sparticles in TGD.

Leptoquarks have received considerable attention in blogs. Both Jester (see `http://resonaances.blogspot.fi/2015/11/leptoquarks-strike-back.html`) and Lubos (see `http://motls.blogspot.fi/2015/11/leptoquarks-may-arrive-lhc-to-prove-e6`

`html`) have written about the topic. Jester lists 3 B-meson potential anomalies, which leptoquarks could resolve:

- A few sigma deviation in differential distribution of $B \rightarrow K^* \mu^+ \mu^-$ decays.

- 2.6 sigma violation of lepton flavor universality in $B \rightarrow D\mu^+\mu^-$ vs. $K \rightarrow De^+e^-$ decays.

- 3.5 sigma violation of lepton flavor universality, but this time in $B \rightarrow D\tau\nu$ vs. $B \rightarrow D\mu\nu$ decays.

There is also a 3 sigma discrepancy of the experimentally measured muon magnetic moment, one of the victories of QED.

And old explanation has been in terms of radiative corrections brought in by SUSY. In TGD framework one can consider an explanation in terms of $\mathcal{N} = 2$ SUSY generated by right-handed neutrino. It has been claimed (see `http://arxiv.org/abs/1511.01900`) that leptoquark with quantum numbers of $D\nu_R$, where D denotes D type quark actually s quark, which in TGD framework corresponds to genus $g = 1$ for the corresponding partonic 2-surface, could explain all these anomalies.

An alternative model would explain the breaking of lepton universality in terms of bosonic analogs of higher fermion generations. The charge matrix of ordinary gauge boson is unit matrix in the 3-D state space assignable with the three generations representing various fermion families. Gauge bosons correspond to charge 3×3 matrices, which must be orthogonal with respect to the inner product defined by trace. Hence fermion universality is broken for the 2 higher gauge boson generations. The first guess is that the mass scale of the second boson generation corresponds to Gaussian Mersenne $M_{G,79}$ [K4] [**?**].

The model for the breaking of universality in lepton pair production is in terms of $M_{G,79}$ bosons. In standard model the production of charged lepton pairs would be due to the decay of virtual W bosons appearing in self-energy loop of penguin diagram. W emits Z^0 or γ decaying to a charged lepton pair. If a virtual higher generation W_{79} boson appears in self energy loop, it can transform to W by emitting Z^0_{79} or γ_{79} decaying to lepton pair and inducing a breaking of lepton universality. Direct decays of W_{79} to $l\bar{\nu}_L$ pairs imply a breaking of lepton universality in lepton-neutrino pair production.

The breaking of the universality is characterized by charge matrices of weak bosons for the dynamical SU(3) assignable with family replication. The first generation corresponds to unit matrix whereas higher generation charge matrices can be expressed as orthogonal combinations of isospin and hypercharge matrices I_3 and Y. I_3 distinguishes between tau and lower generations (third experiment) but not between the lowest two generations. There is however evidence for this (the first two experiments above). Therefore a mixing the I_3 and Y should occur.

Recently additional evidence for the existence of this kind of weak boson has emerged (see `http://tinyurl.com/gqrg9zt`). If I understood correctly, the average angle between the decay products of B meson is not quite what it is predicted to be. This is interpreted as an indication that Z$'$ type boson appears as an intermediate state in the decay.

Does the breaking of universality occurs also for color interactions? If so, the predicted M_{89} and $M_{G,79}$ hadron physics would break universality in the sense that the couplings of their gluons to quark generations would not be universal. This also forces to consider to the possibility that there are new quark families associated with these hadron physics but only new gluons with couplings breaking lepton universality. This looks somewhat boring at first.

On the other hand, there exist evidence for bumps at masses of M_{89} hadron physics predicted by scaling to be 512 time heavier than the mesons of the ordinary M_{107} hadron physics. According to the prevailing wisdom coming from QCD, the meson and hadron masses are however known to be mostly due to gluonic energy and current quarks give only a minor contribution. In TGD one would say that color magnetic body gives most of the meson mass. Thus the hypothesis would make sense. One can also talk about constituent quark masses if one includes the mass of corresponding portion of color magnetic body to quark mass. These masses are much higher than current quark masses and it would make sense to speak about constituent quarks for M_{89} hadron physics. Constituent quarks of the new hadron physics would be different from those of the standard hadron physics.

With a lot of good luck both mechanisms are involved and leptoquarks are squarks in TGD sense. If also M_{89} and M_{79} hadron make themselves visible at LCH (there are several pieces of evidence for this), a breakthrough of TGD would be unavoidable. Or is it too optimistic to hope that the power of truth could overcome academic stupidity, which is after all the strongest force of Nature?

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