What it means if a Higgs-like particle decaying to $e\mu$ pairs exist?

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Abstract

There is 2.5 sigma evidence for the existence of a Higgs-like particle with mass 146 GeV decaying to a muon-electron pair. TGD based topological explanation of family replication phenomenon and the identification of also elementary bosons as pairs of fundamental fermions and antifermions predicts that fermions form effectively triplets under the combinatorial symmetry group $SU(3)_g$ whereas a given elementary boson (gluon, electroweak gauge boson, or Higgs) would form an octet and singlet under this group. The symmetry breaking $SU(3) \rightarrow SU(2) \times U(1) \rightarrow U(1) \times U(1)$ predicts that a given elementary boson extends to the analog of Gell-Mann octet and singlet. The reported anomaly could correspond to the analogs of π^+ and π^-.

In this article the implications of the $SU(3)_g$ symmetry for hadron physics are considered. In particular, the possibility of the existence of $SU(3)_g$ gluon octet is considered. Also the proposal that sea partons could correspond to dark quarks and possibly also dark $g > 0$-gluons is developed in detail. Dark sea could solve the EMC paradox and also solve the proton spin crisis.

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1 Introduction

It is a long time since I have written anything about particle physics. Now the LHC collaboration at CERN has represented evidence for a new anomaly [C1]. The evidence is 2.5 sigmas (standard deviation) so that the anomaly is much below the minimum of 5 sigma for a discovery and could quite well disappear.

What has been studied is the possible occurrence of lepton flavor violating decays of Higgs bosons in proton-proton collisions at cm energy of 13 TeV has been analyzed using data from 2016-2018 period. The integrated luminosity is 136 fb^{-1}.

A small anomaly has been observed. It could be due to the flavor violating decay $H \rightarrow e^{\pm}\mu^{\mp}$ of Higgs having mass 125 GeV. $e\mu$ pair could also come from the decay of a new boson, call it X, with mass assumed to be the range 110-160 GeV.

The dominant production modes for the Higgs boson are gluon fusion (ggH) and vector boson fusion (VBF). In both modes the interesting final state oppositely charged $e\mu$ pair. It would appear as a peak at mass $m(H)$ or $m(X)$ on top of a smoothly falling background due to the purely leptonic decays of $t\bar{t}$ and WW events, plus Drell-Yan events with a misidentified lepton. Monte Carlo fit indicates a 2.5 sigma bump 146 GeV.

In this article the implications of the $SU(3)_g$ symmetry for hadron physics are considered. In particular, the possibility of the existence of $SU(3)_g$ gluon octet is considered. The basic idea behind dark matter in the TGD sense is that the phase transition increasing h to $h_{eff} > h$ makes perturbation theory convergent so that Nature can be said to be theoretician friendly. At the low energy limit of hadron physics this kind of phase transition would be very natural. This motivates the proposal that sea partons could correspond to dark quarks and possibly also to dark $g > 0$-gluons. Dark sea could solve the EMC paradox and also solve the proton spin crisis.

2 About the TGD explanation of electron-muon anomaly and some other strange findings

2.1 Electron-muon anomaly and the topological explanation of family replication phenomenon

Could TGD explain this anomaly? The TGD [L1] based topological explanation of the family replication phenomenon indeed predicts new exotic bosons [K2, K1].

1. Fundamental fermions would in TGD framework correspond to partonic 2-surfaces, whose orbits define light-like 3-surfaces identifiable ad boundaries between Minkowskian and Euclidean space-time regions. The Euclidean regions correspond to deformations of what I call CP_2 type extremals. Orientable 2-surfaces are characterized by the genus g defined as the number of handles attached to a 2-sphere to obtain the topology in question.

2. TGD predicts that 3 lowest genera are special in the sense that they allow global Z_2 symmetry as a conformal symmetry unlike higher generations [K1]. This raises the 3 lowest genera in a special position. The handles behave like particles and the higher genera would not form bound states of handles and have a mass continuum characteristic for free many-particle states unlike the lowest ones corresponding to $g = 0, 1, 2$. This boils down to the assumption that only 2 handles can form a bound state.

3. The fundamental fermion would correspond to a partonic 2-surface carrying a point-like fermion and would serve as building bricks of both fermions as bosons as elementary particles. Elementary particles would correspond to closed monopole flux tube structures connecting two Euclidean wormhole contacts so that the monopole flux loop would run along the first Minkowskian space-time sheet and return along the other.

Group theoretically, the 3 fermion generations behave like an $SU(3)_g$ triplet, completely analogous to the (u,d,s) triplet introduced by Gell-Mann. This combinatorial symmetry could define an approximate dynamical symmetry involving $SU(3)_g \rightarrow U(2)_g$ symmetry breaking, analogous to that in the case of Gell-Mann's SU(3).

1. Each electroweak gauge boson and gluon would form an $SU(3)_g$ octet analogous to (π, K, η) and $SU(3)_g$ singlet analogous to η'.

2. Ordinary gauge bosons would $SU(3)_g$ singlets analogous to η'. Their couplings to fermion families would be identical and thus obey fermion universality. These states would be superpositions of pairs with $g \in \{0, 1, 2\}$.

3. Besides this, 2 additional SU(3)states with vanishing SU(3)g quantum number analogous to π_0 and η are predicted. Their couplings to fermions induce a violation of fermion universality coming from the coupling to both gluons and weak bosons.

   There are some indications for this violation from the earlier experiments [K2]and the p-adic mass scales of the higher boson families as analogs of π_0 and η correspond to p-adic length scales assignable to Mersennes or Gaussian Mersennes. The couplings of these states to fermionic loops imply deviations from the predictions of the standard model and might explain the reported anomalies.

   Here one would have a deviation from the expectations suggested by the analogy with the Gell-Mann's SU(3), which would suggest that the ordinary weak bosons are more massive than the exotic ones: this would not be the case.

4. Also non-diagonal bosons with non-vanishing $SU(3)_g$ quantum numbers, being analogous to $\pi^{\pm}$ and 2 kaon doublets, are predicted. I have earlier assumed [K2] that these states are much more massive than the $SU(3)_g$ neutral states.

   If one takes the recent finding at the face value, the situation would not be this. The analogy with the Gell-Mann's SU(3) suggests that one has a weakly broken $U(2)_g \subset SU(3)_g$ symmetry such that the two lowest generations correspond to u and d. Both gluons and electroweak gauge bosons, including Higgs, would have additional states decaying to oppositely charged $e\mu$ pairs and thus violate lepton universality. Also counterparts of kaons as pairs involving $g = 2$ partonic 2-surfaces are predicted.

5. The simplest interpretation for X would be in terms of a Higgs like state analogous to $\pi^{\pm}$. The $U(2)_g$ symmetry would be violated if the mass of X is 146 GeV; $\Delta m/\langle m \rangle = 2(m(X) - m(H))/(m(X) + m(H) \simeq 15$ %.

2.2 Could $SU(3)_g$ gluons relate to CKM mixing?

This picture raises questions related to the CKM mixing as mixing topologies of partonic 2-surfaces [K1].

1. It is assumed to be due to topology changing time evolution for partonic 2-surfaces: a kind of dispersion in the "world of classical worlds" [L1], or more precisely in the moduli space of conformal equivalence classes of 2-surfaces consisting of Teichmüller spaces for various genera, would be in question.

2. Could the exchanges of $SU(3)_g$ octet bosons between both fermions and bosons induce the mixing dynamically or at least contribute to the mixing. This mixing is not a single particle phenomenon. It conserves $SU(3)_g$ "isospin" and "hypercharge" and essentially this means conservation of total genus as sum of signed genera, which are opposite for fermions and antifermions. If $SU(3)_g$ octet has masses above M_{89} mass scale assignable to Higgs, this mixing is expected to be rather small and an effect comparable to weak interactions.

3. The mass scale of $SU(3)_g$ photon octet must be large, say M_{89} mass scale: otherwise one would lose approximate conservation of various lepton numbers and a bad failure of the Universality. Color confinement would allow a light $SU(3)_g$ gluon octet. What implications could the additional light gluons have?

2.3 Could $g = 1$-gluons relate to the intrinsic strangeness and charm of the proton?

Strange and charmed quarks s and c are produced in high energy collisions of protons. The effective presence of s and c in the initial states can be understood in terms of radiative corrections, which affect the scale dependent parton distribution functions (PDFs) of proton, which depend on the scale of momentum exchange Q^2. PDFs are determined by the renormalization group evolution equations, which are differential equations with respect to Q^2. $Q^2 \neq 0$ is associated with interacting proton and means that the light u and d quarks are excited to strange and charmed states. The initial values of PDFs at $Q^2 = 0$ correspond to non-interacting proton.

A long standing question has been whether proton has also intrinsic strangeness and charm, which should be distinguished from the radiatively generated energy scale dependent intrinsic charm and strangeness. The intrinsic strangeness and charm cannot be calculated perturbatively and would appear in the initial values of PDFs at the limit $Q^2 = 0$

Quite recently an article with the title "Evidence for intrinsic charm quarks in the proton" [C2] appeared in Nature (`https://rb.gy/8iq9e3`). Could the intrinsic charm be seen as an evidence for the presence of light g-gluons in the octet representation of $SU(3)_g$?

Could the presence of light g-gluons make possible intrinsic valence charm and strangeness so that the proton could be a superposition of states in which parton sea contains g-gluons and and valence quarks can be strange or charmed? These states would however be superpositions of states with same $SU(3)_g$ quantum numbers?

Is this energetically possible?

1. This is impossible in the simplest model of baryon involving only on-mass-shell constituent quarks, which in the TGD framework would correspond to current quark plus color magnetic flux tube.

2. However, current quarks contribute only a small fraction to the proton total mass. In the TGD framework, the remaining mass could be assigned to the color magnetic body (MB) of proton and sea partons. One could therefore consider a superposition of states for which color MBs could have varying masses. This would allow strange valence quark with a reduced mass of the color MB. This component in the proton wave function would involve sea g-gluon(s) at a color magnetic flux tubes assignable to the sea.

3. The mass of proton is smaller than that of charmed quark so that the charmed quark is off-mass shell. What does off-mass-shell property mean in the TGD framework?

   Galois confinement generalizes the color confinement to a universal mechanism for the formation of bound states. Galois confinement states that the observed particles consist of building blocks with momenta, whose components are algebraic integers, which can be complex. Momentum components can also have negative real parts so that they would be tachyonic. The interpretation as number theoretically quantized counterparts of off-mass-shell momenta is natural. Since mass squared correspond to conformal weight, Galois confinement involves also conformal confinement stating the total conformal weights are ordinary integers.

   In this picture, virtual quarks would correspond to on-mass-shell states in a number teoretical sense. Mass squared would be an algebraic number determined as a root of a polynomial P with integer coefficients smaller than the degree of P. Color confinement implies that it is strictly speaking not possible to talk about on-mass-shell quarks.

   For the physical states both mass squared and momentum components are ordinary integers in a scale determined by the p-adic length scale assigned to the particle: this scale is also determined by the polynomial P allowing however several ramified primes defining the p-adic primes. Mass squared obeys a stringy mass formula.

4. If the off-mass-shell $g = 1$-gluon is massive enough, its decay would reduce the mass of the sea and the total energy would be conserved. $\Lambda - n$ mass difference, pion mass, and Λ_{QCD}, which are all of order 100 MeV, give a rough idea about the mass scale of $g = 1$ gluons. This would support the $d \rightarrow s$ option which however increases the contribution of the valence quarks. Therefore the proposed idea does not look attractive.

3 Could sea partons be dark?

The model of hadrons involves, besides valence quarks, a somewhat mysterious parton sea. Could the sea consist of partons, which are dark in the TGD sense? This proposal was actually inspired by a model of Kondo effect having strong resemblances with a model of color confinement [L2].

The basic argument in favor of the proposal that at least some quarks are dark, is based on the idea that the phase transition increasing the value of $h_{eff} > h$ allows to have a converging perturbation expansion: one one half $\alpha_s = g^2/4\pi\hbar \rightarrow g^2/4\pi\hbar_{eff}$ which is so small that perturbation theory converges. Nature would be theoretician friendly and perform a phase transition guaranteeing preventing the failure of the perturbative approach.

A stronger assumption generalizes Nottale's proposal for gravitational Planck constant [?] and assumes $\hbar_{eff} = g_s^2/\beta_0$, $\beta_0 = v_0/c < 1$ giving $\alpha_s \rightarrow \beta_0/4\pi$. This would allow a perturbative approach to low energy hadron physics for which ordinary QCD fails.

3.1 Valence partons cannot be dark but sea partons can

The following argument suggests that valence quarks cannot be dark but sea partons can.

1. It is good to begin with a general objection against the idea that particles could be permanently dark.
   (a) The energies of quantum states increase as a function of h_{eff}/h_0 defining the dimension of extension of rationals. These tend to return back to ordinary states. This can be prevented by a feed of metabolic energy.
   (b) The way out of the situation is that the dark particles form bound states and the binding energy compensates for the feed of energy. This would take place in the Galois confinement. This would occur in the formation of Cooper pairs in the transition to superconductivity and in the formation of molecules as a generation of chemical bonds with $h_{eff} > h$. This would also take place in the formation of hadrons from partons.
2. It seems that valence quarks of free hadrons cannot be dark. If the valence quarks were dark, the measured spin asymmetries for the cross section would have only shown that the contribution of sea quarks to proton spin is nearly zero, which in fact could make sense. Unfortunately, the assumption that the measured quark distribution functions are determined by sea quarks seems to be inconsistent with the quark model. If only sea quarks contribute always to the lepton-hadron scattering, the deduced distribution functions would satisfy $q_i = \overline{q}_i$, which is certainly not true.

   Hence it seems that valence quarks must be ordinary but the TGD counterparts of sea partons could be dark and could have large h_{eff} increasing the size of the corresponding flux tubes. The color MBs of hadrons would be key players in the strong interactions between hadrons.
3. The EMC effect in which the deep inelastic scattering from an atomic nucleus suggests that the quark distribution functions for nucleons inside nuclei differ from those for free nucleons (`https://rb.gy/ex284o`). This looks paradoxical since deep inelastic scattering probes high momentum transfers and short distances. For $h_{eff} > h$ the situation however changes since quantum scales are scaled up by h_{eff}/h. If sea partons are dark, the corresponding color magnetic bodies of nucleons are large and could interact with other nucleons of the nucleus so that the dark valence quark distributions could change.
4. Dark quarks and antiquarks at the magnetic body might also provide a solution to the proton spin crisis.

3.2 Could dark valence partons be created in hadronic collisions?

By the above arguments, the valence quarks of free hadrons have $h_{eff} = h$ but sea quarks can be dark. Could dark valence quarks be created in hadronic scattering?

1. The values of h_{eff} of free particles tend to decrease spontaneously since energies increase with h_{eff}. The formation of bound states by Galois confinement prevents this. If not, the analog of metabolic feed increasing the value of h_{eff} is necessary. It would be also needed to create dark particles, which then form bound states.

2. Could the collision energy liberated in a high energy collision serve as "metabolic" energy generating $h_{eff} > h$ phases. This could take place in a transition interpreted in QCD as color deconfinement [K2, K3].

   The first option is that the phase transition makes valence quarks dark. This could however mean that they decouple from electroweak interactions with leptons. Second option is that the phase transition increases the value of $h_{eff} > h$ for the dark partons at color MB but leaves valence quarks ordinary.

3.3 What does one mean with parton sea?

In the TGD framework, one must reconsider the definition of valence quarks and of parton sea.

1. Valence quarks would correspond to the directly observable degrees of freedom whereas parton sea would correspond to degrees of freedom, which are not directly observablee in physics experiments. Usually large transversal momentum transfers are assumed to correspond to short length scales but the EMC effect is in conflict with this assumption. If the unobserved degrees of freedom correspond to $h_{eff} > h$ phase(s) forced by the requirement of perturbativity, the situation changes and these degrees of freedom can correspond to long length scales.

   The mathematical treatment of the situation requires integration over the unobserved degrees of freedom and would mean a use of a density matrix related to the pairs of systems defined by this division of the degrees of freedom. This would justify the statistical approach used in the perturbative QCD.

   Dark degrees of freedom associated with the color MB, possibly identifiable as parton sea at color MB, are not directly observable. The valence quarks would be described in terms of parton density distributions and quark fragmentation functions. In hadron-hadron scattering at the low energy limit, valence quarks and sea, possibly at color MB, would form a single quantum coherent unit, the hadron. In lepton-hadron scattering, the valence quarks would form the interacting unit. In hadron-hadron scattering also the dark MBs would interact.

2. Color MB could contain besides quark pairs also $g > 0$ gluons contributing to the parton sea. The naive guess is that $g = 1$ gluons are massive and correspond to the p-adic length scale $k = 113$ assignable to nuclei. Muon mass, Λ_{QCD}, and $\lambda - N$ mass difference correspond to this mass scale.

   The $g > 0$ many-gluon state must be color singlet, have vanishing spin, and have vanishing $U(2)_g$ or perhaps even $SU(3)_g$ quantum numbers, at least if $SU(3)_g$ is an almost exact symmetry in the gluonic sector. This kind of state can be built from two $SU(3)_g$ gluons as the singlet part of the representation $8_c \otimes 8_g$ with itself. The state is consistent with Bose-Einstein statistics.

   $g > 0$ gluons could be seen in hadron-hadron interactions. Perhaps as an anomalous production of strange and charmed particles and violation of fermion universality.

4 Could dark partons solve the proton spin crisis

The proton spin crisis (`https://rb.gy/imz7ls`) was discovered in the EMC experiment, which demonstrated that the quark spin in the spin direction of polarized protons was almost the same as in the opposite direction.

4.1 Basic facts about proton spin crisis

In the EMC experiment the contributions of u,d, and s quarks to the proton spin were deduced from the deep inelastic scattering of muons from polarized proton target (https://rb.gy/ktm2tw). What was measured, were spin asymmetries for cross sections and the conclusions about parton distribution functions (https://rb.gy/vcpths) were deduced from the experimental data from the muon scattering cross sections using Bjorken sum rule testing QCD and Ellis-Yaffe sum rule assuming vanishing strange quark contribution and testing the spin structure of the proton. Bjorken sum rule was found to be satisfied reasonably well. Ellis-Yaffe sum rules related to the spin structure of the proton were violated.

It was found that the contributions of u quarks were positive and those of s quarks (assuming that they are present) and d quarks negative and the sum almost vanished when the presence of s was assumed. The Gell-Mann quark model predicts that u-quarks contribute spin $2/3$ and d-duarks $-1/6$ units ($\hbar$) to the proton spin. For the fit allowing besides u, d contributions, also s contributions, the contributions were found to be 0.373, -0.254 and -0.113. The sum was 0.006 and nearly zero. For protons the contribution is roughly one half of Gell-Mann prediction. For d quark the magnitude of the contribution is considerably larger than the Gell-Mann prediction $-1/6 \simeq -.16$.

The Wikipedia article creates the impression that the proton spin crisis has been solved: the orbital angular momentum would significantly contribute to the spin of the proton. Also sea partons, in particular gluon helicity polarization would contribute to the proton spin. This might well be the case.

4.2 Dark sea partons and proton spin crisis

I have considered possible TGD inspired solutions of the proton spin crisis already earlier. One can however also consider a new version involving dark sea quarks.

1. The possibility that sea partons are dark in the TGD sense, forces us to ask what was really measured in the EMC experiment leading to the discovery of the proton spin crisis. If sea partons are dark, only the quark distribution functions corresponding to quarks with ordinary value of h_{eff} appearing in the coupling to muon would contribute? This should be the case in all experiments in which incoming particles are leptons.

   Assuming that also valence quarks can be part of time strange, the results of the EMC experiment assume that most of the proton spin could reside at the polarized dark sea. Note however that also orbital angular momentum can explain the finding and in the TGD framework color magnetic flux tubes could carry "stringy" angular momentum.

2. For this option one could identify the measured cross section in terms of scattering from quarks with $h_{eff} = h$. It has been proposed that valence quarks are large scale structures (low energy limit) and sea quarks are small scale structures (high energies) inside valence quarks.

   In the TGD framework, this suggests that valence quarks correspond to a larger p-adic prime than sea quarks. This does not imply that valence quarks have large h_{eff}. Large h_{eff} for the sea partons would increase their size so that, contrary to the expectations from the Uncertainty Principle, they could contribute to hadron-hadron scattering with large momentum transfer in long length scales.

The idea that the average spin of valence quarks in the baryons vanishes is attractive. What comes to mind is the following idea.

1. The valence quarks have an ordinary value of h_{eff} and the perturbation series does not converge. One should have a concrete realization for the transfer of color interactions at the level of valence quark to the level of the sea quarks with large h_{eff}. If only dark gluons exist, the color interactions take place at the level of the color MB and one the perturbation theoretic coupling would be $\alpha_s = \beta_0/4\pi$.

   The physical mechanism in question should map valence quarks to dark valence quarks at the MB.

Also color confinement could take place at the level of the color MB and induce it at the valence quark level. The ordinary electroweak interactions should take place between valence quarks but also a dark variant of ew interactions between dark quarks is possible and indeed assumed in TGD inspired quantum biology. Could the mechanism be as follows?

2. Consider a free hadron. The color MB contains dark sea quark and antiquark with opposite charges and spins such that dark antiquark combines with a valence quark to form an entangled color singlet meson-like spin singlet.

   The second dark quark with opposite color and electroweak quantum numbers would carry the spin of the valence quark. Quark quantum numbers would be transferred by entanglement to the color MB! Color confinement would take place at the level of MB and induce color confinement at the level of valence quarks.

3. Ordinary electroweak interactions would take place at the level of valence quarks. Electroweak interactions cannot measure color charges so that the color entanglement between valence quark and dark sea quark would be preserved.

   What happens when a quark changes to another quark with different charge in the ordinary electroweak mediated by W boson exchange? Entanglement would be now between different charge states, say between valence u and dark $\overline{d}$. In the ground states of hadron this cannot be the case. This suggests that the exchange of dark W boson transforms dark $\overline{d}u$ state to $\overline{u}u$ state. Dark W bosons could correspond to a lower mass scale than ordinary gauge bosons.

   What about spontaneous exchange of dark W boson transforming dark $\overline{u}u$ state to $\overline{d}u$ state? This would transform $u\overline{u}$ pair to $u\overline{d}$, which is not possible in equilibrium. The emission of ordinary W boson could transform d to $d\overline{d}$ and one would have beta decay induced by dark beta decay.

   The more general question is how the physics of ordinary matter can be seen as a shadow dynamics controlled by the dark matter at the magnetic body. The proposed pairing could provide the needed mechanism.

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