Is it really Higgs?

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Abstract

The discovery of a new spinless particle at LHC has dominated the discussions in physics blogs during July 2012. Quite many bloggers identify without hesitation the new particle as the long sought for Higgs although some aspects of data do not encourage the interpretation as standard model Higgs or possibly its SUSY variant. Maybe the reason is that it is rather imagine any other interpretation. In this article the TGD based interpretation as a pion-like states of scaled up variant of hadron physics is discussed explaining also why standard model Higgs - by definition provider of fermion masses - is not needed. Essentially one assumption, the separate conservation of quark and lepton numbers realized in terms of 8-D chiral invariance, excludes Higgs like states in this sense as also standard $\mathcal{N}=1$ SUSY.

One can however consider Higgs like particles giving masses to weak gauge bosons: motivation comes from the correctly predicted group theoretical W/Z mass ratio. The pion of M_{89} hadron physics is the TGD proposal for a state behaving like Higgs and its decays via instanton coupling mimic the decays of Higgs to gauge boson pairs. For this option also charged Higgs like states are prediction.

The instanton coupling can however generate vacuum expectation value of pion and this indeed happens in the model for leptopion. This would lead to the counterpart of Higgs mechanism with weak bosons "eating" three components of Higgs. This is certainly a problem. The solution is that at microscopic level instanton density can be non-vanishing only in Euclidian regions representing lines of generalized Feynman diagrams. It is Euclidian pion - a flux tube connecting opposite throats of a wormhole contact which develops vacuum expectation whereas ordinary pion is Minkowskian and corresponds to flux tube connecting throats of separate wormhole contacts and cannot develop vacuum expectation.

This identification could explain the failure to find the decays to τ pairs and also the excess of two-gamma decays. The decays gauge boson pairs would be caused by the coupling of pion-like state to instanton density for electro-weak gauge fields. Also a connection with the dark matter researches reporting signal at 130 GeV and possibly also at 110 GeV suggests itself: maybe also these signals also correspond to pion-like states.

1 Background

The discovery of the new spinless particle at LHC [C11, C12] is believed to be a turning point in physics, and for a full reason. Before discussing TGD based view about the discovery it is appropriate to discuss briefly the historical background to demonstrate that the answer to the question "Higgs or not Higgs?" indeed determines the path followed in future particle physics.

1.1 GUT paradigm

The leading thread in the story of particle physics is GUT paradigm, which emerged for four decades ago. It however has its problems besides the fact that not a single thread of evidence has accumulated to support it.

1. The basic idea of GUTs is to put all fermions and bosons to multiplets of some big gauge group extending the standard model gauge group. This idea is applied also in the generalization of gauge theories to supersymmetric gauge theories and in superstring models. Scalar fields developing vacuum expectations define a key element of this approach and give hopes of obtaining a realistic mass spectrum. This rather simple minded approach would make unification an easy job. There are however difficulties.

2. One of the basic implications is that baryon and lepton numbers are not conserved separately. Proton decays would make this non-conservation manifest. These decays have not been however observed, and one of the challenges of the GUT based models is fine-tuning of couplings so that proton is long-lived enough. This raises the question whether one could somehow understand the separate conservation of B and L from basic principles.

3. Putting all fermions in the same multiplet would suggest that the mass ratios for fermions should be simple algebraic numbers not too far from unity. Fermion families have however widely differing mass scales and the ratio of top quark mass scale to neutrino mass scale is gigantic. This suggests that fermion generations and even different charge states of fermions of single generation are characterized by inherent mass scales and do not belong to a multiplet of a big gauge group. Standard model gauge group would be the fundamental gauge group and the challenge would be to deduce it from some fundamental principles. In TGD framework number theoretical vision indeed leads to an explanation for standard model gauge group [K15].

It is also an empirical fact that fermion generations are identical copies of each other apart from widely different masses. This suggests some non-group theoretic explanation for family replication phenomenon. In TGD framework 2-D wormhole throats characterized topological by their genus in orientable category are the fundamental particle like objects. This provides a possible explanation for the family replication phenomenon. One must of course explain why genera higher than $g = 2$ are heavy or absent from the spectrum, and one can indeed develop an argument for this based on the fact that $g \leq 2$ 2-surfaces allow always Z_2 as conformal symmetries unlike $g > 2$ 2-surfaces [K3].

4. Particle massivation is in GUT framework is described by coupling the fermions and gauge bosons to a scalar field. The vacuum expectation values of the scalar fields define the mass scales. In the case of standard model one has only single scalar/Higgs field and by choosing the couplings to Higgs field to be proportional to fermion mass one can reproduce particle masses. Only a reproduction is in question and theory is certainly not microscopic. Vacuum expectation value (VEV) paradigm is central also for the inflationary cosmology - in fact for the entire theoretical particle physics developed during last decades. The no-existence of Higgs would force to return to the roots to the situation four decades ago. Therefore the new spinless particle could be a turning point in the history of physics, and it is easy to understand why the attitudes against or on behalf of Higgs interpretation are so passionate and why facts tend to be forgotten.

1.2 How to achieve separate conservation of B and L?

A possible manner to understand the separate conservation of both B and L would be via the identification of spinors as different chiralities of higher-dimensional spinors.

1. This would however require the identification of color quantum numbers as angular momentum like quantum numbers assignable to partial waves in internal space. This is indeed the identification performed in TGD framework and $H = M^4 \times CP_2$ is the unique choice of imbedding space coding for the standard model quantum numbers. In TGD approach quarks and leptons correspond to different imbedding space chiralities, and this excludes Higgs as a genuine imbedding space scalar since it would couple to quark-lepton pairs. To get the couplings correctly Higgs should correspond to imbedding space vector having components only the direction of CP_2 but it is rather difficult to imagine how gauge bosons could "eat" components of Higgs in this case. As a matter fact, Higgs components should be characterized by same charge matrices as weak bosons and would be a TGD counterpart for a mixture of scalar and pseudoscalar.

2. Chiral invariance is indeed essential for the renormalizability of 4-D gauge theories.The absence of 8-D scalars would allow also a generalization of chiral invariance from 4-D to 8-D context implying separate conservation of B and L. This is the case even in string model framework if separate conservation of B and L is assumed. It is worth of mentioning that the separate conservation of B and L is not consistent with the standard $\mathcal{N} = 1$ SUSY realized in terms of Majorana spinors. This is not a catastrophe since LHC has already excluded quite a considerable portion of parameter space for $\mathcal{N} = 1$ SUSY. $\mathcal{N} = 2$ SUSY however is and is generated in TGD framework by right-handed neutrino and its antiparticle.

   There are however quite intricate delicacies involved discussed in detail in [K20]. For instance, the modes of covariantly constant right-handed neutrino spinor of CP_2 generates 4-D generalization of super-conformal symmetry as modes delocalized into entire space-time surfaces whereas other modes are localized to 2-D surfaces and generate badly broken SUSY with very large value of $\mathcal{N}$. An open question is whether the ν_R covariantly constant also in M^4 degrees of freedom could generate $\mathcal{N} = 1$ SUSY analogous to the standard SUSY. In any case, TGD seems to be inconsistent with both scalar VEV paradigm and standard $\mathcal{N} = 1$ SUSY.

3. p-Adic physics and p-adic length scale hypothesis allow to understand the widely different mass scales of fermions and various gauge bosons since p-adic prime and the primary p-adic length scale defined by it become the characterizers of elementary particle. Also the secondary p-adic length and time scales are important: for electron secondary p-adic time scale is .1 seconds and quite intriguingly the fundamental time scale of biology. p-Adic thermodynamics provides the microscopic theory of particle massivation leading to highly successful predictions not only for

particle mass scale ratios but also for the particle masses. p-Adic primes near powers of two - in particular Mersenne primes - pop up naturally and define positive integer characterizing given particle. Number theory becomes the tool of understanding the mystery number 10^{38} defined by the ratio of Planck mass and proton mass (this number is essentially the ratio of CP_2 mass to electron mass) [K9].

If Higgs is needed in TGD framework at all, it might provide gauge bosons with longitudinal polarizations. Even this function seems to be un-necessary. Here so called zero energy ontology (ZEO) comes in rescue.

1.3 Particle massivation from p-adic thermodynamics

p-Adic thermodynamics defines a core element of p-adic mass calculations [K3, K9, K12]. p-Adic thermodynamics is thermodynamics for the conformal scaling generator L_0 in the tensor product representation of super-conformal algebra and the masses are fixed one the p-adic prime characterizing the particle is fixed. p-Adic length scale hypothesis $p \simeq 2^k$, k integer, implies an exponential sensitivity of the particle mass scale on k so that a fitting of particle masses is not possible.

1. The first thing that one can get worried about relates to the extension of conformal symmetries. If the conformal symmetries for light-like surfaces and $\delta M^4_\pm \times CP_2$ generalize to $D = 4$, how can one take seriously the results of p-adic mass calculations based on 2-D conformal invariance? There is actually no reason to worry. The reduction of the conformal invariance to 2-D one for the solutions of modified Dirac equation takes care of this problem [K20] This however requires that the fermionic contributions assignable to string world sheets and/or partonic 2-surfaces - Super- Kac-Moody contributions - dictate the elementary particle masses. For hadrons also super-symplectic contributions would be present and would give the dominating contribution to baryon masses.

   The modes of right handed neutrino are delocalized to a 4-D region of space-time surface and characterized by two integers. The absence of all standard model interactions suggests that no thermalization takes place for them. These modes are de-localized either to a region of Euclidian signature identifiable as 4-D line of generalized Feynman graph or to a region of Minkowskian signature. Since modified gamma matrices vanish identically for CP_2 type vacuum extremals one can ask whether the 4-D neutrino modes are associated only with Minkowskian regions. In this case the counterpart of $\mathcal{N} = 1$ SUSY would assign spartner to a many-particle state rather than to elementary particle. This could explain for why LHC has not seen the analog of standard SUSY.

2. ZEO suggests that the wormhole throats carrying many-fermion states with parallel momenta are massless: this applies even to virtual wormhole throats [K17]. As a consequence, the twistor approach would work and the on mass shell kinematical constraints to the vertices would allow the cancellation of UV divergences. The 2-D Kac-Moody generators assignable to the boundaries of string world sheets would generate Yangian algebra [K18]. IR divergences would cancel because incoming and outgoing particles would be massive on mass shell particles as states involving several wormhole throats. The p-adic thermal expectation value is for the longitudinal M^2 momentum squared rather than for the four-momentum squared (the definition of CD selects $M^1 \subset M^2 \subset M^4$ as also does number theoretic vision). Also propagator would be determined by M^2 momentum. Lorentz invariance would be achieved by averaging over the moduli for CD including also Lorentz boosts of CD.

3. In the original approach states with arbitrary large values of L_0^{tot} were allowed as physical states. Usually one would require that the generator L_0^{tot} of conformal scaling annihilates the states. In the calculations however mass squared was assumed to be proportional L_0^{tot} apart from vacuum contribution. This is a questionable assumption. ZEO suggests that total mass squared vanishes and that one can decompose mass squared to a sum of longitudinal and transversal parts. If one can do the same decomposition for the longitudinal and transverse parts also for the Super Virasoro algebra, one can calculate longitudinal mass squared as a p-adic thermal expectation of L_0^{tr} in the transversal Super-Virasoro algebra and only states with $L_0^{tot} = 0$ would contribute

and one would have conformal invariance in the standard sense. The decomposition is indeed possible since longitudinal parts correspond to pure gauge degrees of freedom.

Thermodynamics - or rather, its square root - would become part of quantum theory in ZEO. M-matrix is indeed product of hermitian square root of density matrix multiplied by unitary S-matrix and defines the entanglement coefficients between positive and negative energy parts of zero energy state. Different M-matrices orthogonal to each other with respect to trace become rows of the unitary U-matrix.

4. The crucial constraint is that the number of super-conformal tensor factors is $N = 5$: this suggests that thermodynamics applied in Super-Kac-Moody degrees of freedom assignable to string world sheets is enough if one is interested in the masses of fermions and gauge bosons. Super-symplectic degrees of freedom can also contribute and determine the dominant contribution to baryon masses. Should also this contribution obey p-adic thermodynamics in the case when it is present? Or does the very fact that this contribution need not be present mean that it is not thermal? The symplectic contribution should correspond to hadronic p-adic length scale rather the much longer (!) p-adic length scale assignable to say u quark (this paradoxical looking result can be understood in terms of uncertainty principle and the assignment of quarks to the color magnetic body of hadron). Hadronic p-adic mass squared and partonic p-adic mass squared cannot be summed since primes are different. If one accepts the basic rules [K12], longitudinal energy and momentum are additive as indeed assumed in perturbative QCD.

5. Calculations work if the vacuum expectation value of the mass squared must be assumed to be tachyonic. There are two options depending on whether one whether p-adic thermodynamics gives total mass squared or longitudinal mass squared.

   (a) One could argue that the total mass squared has naturally tachyonic ground state expectation since for massless extremals (MEs, topological light rays [K1]) longitudinal momentum is light-like and transversal momentum squared is necessary present and non-vanishing by the localization to topological light ray of finite thickness of order p-adic length scale. Transversal degrees of freedom would be modeled with a particle in a box.

   (b) If longitudinal mass squared is what is calculated, the condition would require that transversal momentum squared is negative so that instead of plane wave like behavior exponential damping would be required. This would conform with the localization in transversal degrees of freedom.

This is the general picture. One crucially important implication is that gauge conditions in Lorentz gauge must be modified. Only longitudinal M^2 momentum appears in the propagators (recall that total mass squared vanishes and cannot appear in the propagator if virtual particles are massless). Therefore only M^2 momentum appears in gauge conditions: $p_L \cdot \epsilon = 0$ holds true and implies that also longitudinal polarization is allowed. Massivation is also unavoidable. The first guess for gauge boson state is as a wormhole contact containing fermion and anti-fermion at 3-D light-like wormhole throats. One must have spin 1 but since fermion and anti-fermion are massless they must have non-parallel 3-momenta in order to have parallel spins. For instance, they could have parallel and massive longitudinal momenta but non-parallel transverse momenta. The longitudinal mass squared would be in general non-vanishing and hence mass squared as the average over moduli of CD involving also integration over Lorentz boosts of CD. Higgs is not needed in TGD framework and its possible TGD counterpart seems also incapable of fulfilling its functions.

1.4 Could a TGD counterpart of scalar boson have useful functions in TGD Universe?

The social pressures tending to force the interpretation of the new resonance as Higgs are rather strong and most bloggers seem to take this interpretation as granted. In this kind of situation theoretician with visions deviating from the mainstream thinking of course feels excitement and stress. I am not an exception to this rule. What if the production rate and branching ratios are those predicted by standard model? Is my vision wrong in this case? How it could be wrong? Can I modify it without losing something essential?

Recall that standard model Higgs has two functions. Higgs VEV gives masses for fermions and weak gauge bosons and Higgs gives longitudinal components for massive gauge bosons. Could one have Higgs like states performing only one or none of these functions?

1. In TGD framework fermion massivation by Higgs vacuum expectation is replaced by p-adic thermodynamics giving the dominant contribution to the longitudinal mass squared p_L^2 (all particle states are massless at fundamental level). One cannot however exclude scalar vacuum expectations giving a small corrections to fermion masses. p-Adic thermodynamics as a microscopic mechanism of fermion massivation is so beautiful and predictive that it beats massivation based on Higgs expectation, which in TGD framework can be seen as a phenomenological parametrization at best.

2. In the case of weak gauge bosons p-adic temperature $T = 1/n$ would be probably smaller ($T \leq 1/2$ instead of $T = 1$ for fermions) and the analog of Higgs expectation could give a significant or even dominating contribution to weak gauge boson masses. There are however conceptual problems. What is the TGD counterpart of Higgs VEV? Does it characterize coherent state? Does this expectation have classical space-time correlate as gauge bosons have?

What about the second function of Higgs as a provider of longitudinal polarizations for massive gauge bosons?

1. TGD allows to imagine the existence of analogs of Higgs like states [K10] (see the previous posting). They generalize the notions of scalar and pseudo-scalar in Minkowski space to vector and pseudo-vector in 8-D imbedding space with components only in CP_2 directions defining the analogs of polarizations. These states appear always as singlet and charged triplet and are very much analogous to 1+3 formed by electroweak gauge bosons.

2. In standard model the three components of standard model Higgs also provide the longitudinal components of weak bosons W and Z. ZEO allows to understand the massivation of spin 1 bosons as something unavoidable without the need for Higgs like particle and I do not have any elegant proposal how the possible scalar 1+3 could transform to longitudinal components of weak bosons and single neutral Higgs. Thus there is a tendency to conclude that if Higgs like states exist in TGD Universe they appear as full multiplets 1+3 containing also charged states as physical particles.

I could of course be wrong! Maybe Higgs could after all manage to serve as a provider of longitudinal polarizations. Could one imagine the classical counterparts of gauge bosons eating Higgs components in classical TGD? To get some perspective, consider modified Dirac equation for induced spinors at preferred extremals of Kähler action.

1. For the TGD counterparts of induced Dirac equation both gamma matrices and gauge potentials appearing in the modified Dirac equation are induced from those of imbedding space by simply projecting them to the space-time surface. This implies that induced gamma matrices contain also CP_2 part. This gives rise to new kind of couplings proportional to the contraction of gauge potential with CP_2 part of induced gamma matrices.

   Induced gamma matrices are actually replaced by modified gamma matrices defined by Kähler action to obtain supersymmetry and internal consistency of the theory but the conclusion remains the same. Modified gamma matrices are proportional to Maxwell energy momentum tensor expressible in terms of Einstein equations using Einstein tensor and metric for the proposed ansatz for preferred extremals. Could these couplings involving energy momentum tensor and thus mass mimic Higgs couplings? I do not regard this interpretation as plausible.

2. Quantum classical correspondence requires the existence of classical counterparts of quanta, also Higgs. My inability to imagine any convincing candidate has been one of the reasons for my skepticism concerning Higgs like states. While writing this I however decided to try once again. I failed but learned that em charge as isospin like quantum number for fermions should be conserved in TGD classically - something very non-trivial that I have taken as granted and shown to be true only for the octonionic representation of imbedding space gamma matrices [K6].

Therefore it seems that the possibility to realize the longitudinal polarizations of weak gauge bosons using Higgs like states are rather meager.

1.5 Could the conservation of em charge allow to identify unitary gauge and from this classical Higgs field?

An important aspect of the standard model Higgs mechanism is that it respects em charge leaving photons massless. In standard model the conservation of em charge defined as isospin like quantum number is non-trivial since the presence of classical gauge fields induces transitions between different charge states of fermions. In second quantization this problem is circumvented by replacing classical gauge fields with quantized ones. The so called unitary gauge defined by a gauge transformation depending on Higgs fields allows to express the action in terms of physical (in general massive) fields and makes charge conservation explicit. How the conservation of em charge is obtained in TGD?

1. Doesn't one have the same problem but as a much worse variant since classical long range electro-weak gauge fields are unavoidable in TGD and there is no path integral but preferred extremals? Could it make sense to speak about unitary gauge also in TGD framework? Could one turn around this idea to derive classical Higgs from the possibly existing gauge transformation to unitary gauge? The answer is negative. There is actually no need for the unitary gauge.

   As a matter fact, the conservation for em charge in spinorial sense leads to the earlier conjecture that the solutions of the modified Dirac equations are localized at 2-D surfaces whose ends define braid strands at space-like 3-surfaces at the ends of causal diamonds and at the light-like 3-surfaces connecting them and defining lines for generalized Feynman diagrams. This picture was earlier derived from the notion of finite measurement resolution implying discretization at the level of partonic 2-surfaces and also from number theoretical vision suggesting that basic objects correspond to 2-D commutative and co-commutative identifiable as sub-manifolds of 4-D associative and co-associated surfaces.

2. The point is that the Kähler form of CP_2 is covariantly constant and one can identify covariantly constant em charge as a matrix of form $Q = aI + bJ_{kl}\Sigma^{kl}$: the coefficients a and B are different for quarks and leptons (different chiralities of H-spinors). This matrix is covariantly constant also with respect to the induced spinor structure and commutes with Dirac operator (be it the TGD counterpart of the ordinary massless Dirac operator or modified Dirac operator). Therefore one should be able to choose the modes of induced spinor field to have a well-defined em charge at each point of space-time surface. The covariantly constant Kähler form of CP_2 is an important element in making possible the conservation of em charge and derives from the supersymmetry generated by covariantly constant right-handed neutrino. This is however not enough as it became clear.

3. Rather unexpectedly, the challenge of understanding the charge conservation in the spinorial sense led to a breakthrough in understanding of the modes of the modified Dirac equation. The condition for conservation leads to three separate analogs of Dirac equations and the two additional ones are satisfied if em charged projections of the generalized energy momentum currents defining components of modified gamma matrices vanish. If these components define Beltrami fields expressible as products $j = \Psi\nabla\Phi$ the conditions can be satisfied for $\Psi = 0$. Since Ψ is complex or hyper-complex, the conditions are satisfied for 2-dimensional surfaces of space-time surfaces identifiable as string world sheets and partonic 2-surfaces. This picture was earlier derived from various arguments. Em charge conservation does not there give rise to a counterpart of unitary gauge but leads to a bridge between modified Dirac equation and general view about quantum TGD based on generalization of super-conformal invariance.

Higgsteria had therefore at least one very positive impact in TGD framework! Note that only slightly earlier emerged the construction recipe for preferred extremals of Kähler action based on a generalization of minimal surface equations of string models to 4-D context and generalizing the 2-D conformal invariance to its four-dimensional analog. This had also a surprising and very pleasant outcome: Einstein's equations with cosmological term follow as consistency conditions for the reduction of field equations to purely algebraic conditions solved by assuming that Euclidian space-time region has hermitian structure and Minkowskian region its counterpart that I have christened Hamilton-Jacobi structure. This simplified considerably the vision about the representations of super-conformal symmetries [K20].

2 M_{89} hadron physics instead of Higgs?

In TGD framework the most plausible interpretation for 125 GeV state would be as pion-like state of scaled up copy of hadron physics. Two-photon decay and also the decays to other weak bosons and perhaps even gluons would be due to axial anomaly and involve only gauge boson loops.

2.1 Scaled copies of hadron physics as a basic prediction of TGD

One of the most surprising "almost-predictions" of TGD is the possibility of scaled variants of hadron physics.

1. Ordinary hadron physics is characterized by Mersenne prime $M_n = 2^n - 1$, $n = 107$. There are also other physically interesting Mersenne primes. M_{127} corresponds to electron and has been tentatively assigned to electro-hadron physics for which color octet states of electron replace color triplet of quarks. Muon corresponds to Gaussian Mersenne $M_{G,n} = (1+i)^n - 1$, $n = 113$, and τ to the hadronic Mersenne prime M_n, $n = 107$.

2. There is evidence for leptohadron physics associated with these charged leptons too [K16].

3. The masses of current quarks are from QCD estimates in 10 MeV scale and there exists some evidence for Regge trajectories in 20 MeV string tension. The interpretation would be in terms of magnetic flux tubes associated with the "magnetic body" of the hadron and the question. It however seems that M_{127} variant of hadron physics with characteristic mass scale of order .5 MeV cannot be in question.

4. In biologically relevant length scale range ranging from cell membrane thickness (10 nm) to the size scale of cell nucleus about 5 μm there are as many as four Gaussian Mersennes $M_{G,n}$ corresponding to $n = 151, 157, 163, 167$. Dark matter identified as phases with non-standard value of effective Planck constant coming as integer multiple of ordinary Planck constant is essential for what it is to be living in TGD Universe. The dark matter residing at magnetic flux quanta could correspond to quarks and gluons free in the size scale involved.

M_{89} corresponds to a candidate for a hadron physics with mass scale of hadron physics scaled up by a factor 512: this corresponds to TeV range. For instance, proton mass of order .94 GeV would be scaled up to about 500 GeV. General arguments suggests that some new physics must emerge at TeV energy scale. Could it be that M_{89} hadron physics is this new physics? If so then the identification of 125 GeV resonance as a pion-like state of the new hadron physics would be natural. It should be easy to kill this hypothesis at LHC since entire spectroscopy of hadron like states is predicted and the experience from QCD allows to predict the dynamics of these states. p-Adic mass calculations in turn allow to estimate the mass spectrum using simple scaling arguments.

2.2 Is it really Higgs?

After the first wave of Higgsteria the attitudes to the discovery at LHC have become more realistic and i "Higgs discovery" is indeed transforming to "discovery". I of course feel empathy for those who have spent their professional career by doing calculations with Higgs: it is not pleasant to find that something totally different might be in question. In the latest New Scientist [C13] the problems are acknowledged and summarized.

For most decay channels the rates differ from standard model predictions considerably [C3]. In particular, gamma gamma decay rate is about three times too high and tau lepton pairs are not produced at all. This is very alarming since Higgs should couple to leptons with coupling proportional to its mass. It is becoming clear that it is not standard model Higgs. People have begun to talk about "Higgs like" state since nothing else they do not have because technicolor scenario is experimentally excluded.

The most natural - albeit not the only possible - TGD identification is as a pion-like state. This would mean that it is pseudo-scalar: also SUSY predicts pseudo-scalar as one of the several Higgses.

The basic predictions of TGD scenario deserve to be summarized.

1. Also two charged and one neutral companion of the effective pseudo-scalar should exist. This is because pseudo-scalar must be replaced by imbedding space axial vector having only CP_2 components (4) forming electroweak triplet and singled just as ew gauge bosons do. The identification as CP_2 tangent space vector looks promising at first but it is difficult to imagine how charged components of Higgs could be eaten by weak bosons.

2. ATLAS and CMS see their Higgs candidates at slightly different masses: mass difference is about 1 GeV. Could this mean that the predicted two neutral states contribute and have been already observed? Could this also explain the too large decay rate to two gammas.

   One can however counter-argue that ordinary pion has no neutral companion of same mass. In hadronic sigma model it has scalar companion with which it forms 1+3 multiplet of SO(4), the tangent space group of CP_2 reducing to $SU(2)_L \times U(1)$ identifiable as $U(2) \subset SU(3$ in the concrete representation of pion states. Could one think that this is the case also now and sigma develops vacuum expectation analogous to that of Higgs determining most of the couplings just as in sigma model for ordinary hadrons? The problem is that the neutral component should be scalar.

   Could one get rid of the additional sigma state? CP_2 allows two geodesic spheres and the homologically trivial one allows $SO(3)$ as isometries instead of $U(2)$. In this case one would have naturally $SO(3)$ triplet instead of 3+1 and no sigma boson. For the four kaon like states one would have 3+1 naturally. This could distinguish between pion-like and kaon-like multiplets also in the ordinary hadron physics [K10]. What is genuinely new that strong isospin groups $U(2)$ and $SO(3)$ would reduce to subgroups of color group in spinor representation.

3. If there is pion-like state there, it is pseudo-scalar: this might become clear during this year. SUSY people would identify it as one of the SUSY Higgses.

4. Pion-like states consist of "scaled up" quarks of M_{89} hadron physics and they prefer to decay to hadrons. Lepton pairs are produced only in higher order via box diagrams with weak boson pair as vertical edges and quark line and lepton line as horizontal edges. This explains why tau pairs are not observed. The fastest decays could take place to two gluons of M_{89} hadron physics transforming to ordinary gluons in turn decaying to quarks and producing jets.

5. The simplest option is that effective action for decays to weak gauge bosons is instanton action assignable to axial current anomaly. WW production rate is consistent with standard Higgs and this fixes the coefficient of the instanton term if one assumes that electroweak symmetry is not broken so that γ, Z, and W would have different coefficients.

6. Associated production of $b\bar{b} + W$ has been observed as predicted. In TGD $b\bar{b}$ would correspond to decay to two gluons annihilating to quark pair. Light quark pairs would be produced much more than in Higgs decays where Higgs-quark coupling is proportional to quark mass.

7. What is intriguing that the plots for the ratio of observed cross section divided by standard model prediction as a function of Higgs mass show periodically occurring peaks as a function of Higgs mass with period of order 20 GeV. This might be of course a mere artifact related to the size of data bin and probably is and also to the character of the plot. There is however intriguing similarity with the reported existence of satellites of ordinary pion with period of order 20-40 MeV. By scaling 40 MeV by a factor 512 one obtains 20 GeV. Could the 145 GeV state reported earlier by CDF collaboration [C1] correspond to this kind of state?

What experimenters have to say about these predictions after year is interesting. The discovery of charged partners, too low rate for the decays to lepton pairs, and too fast decays to light quark pairs would destroy the Higgs interpretation.

2.3 How pionlike state can give rise to Higgs like behavior with gamma pair anomaly?

The reported decay rates of the new particle to electro-weak gauge bosons give important guidelines in the attempts to guess the production mechanism and the effective action responsible for the decays.

The surplus of gamma pairs is an important hint and suggests an additional decay channel to gamma pairs. The recent data from ATLAS (see figure 10 [C4]) support the Higgs like behavior for the decays to Z and W pairs. The decay rates to tau pairs and to b pairs in associated production together with W are lower than predict.

Statistical fluctuations could be in question but the spokesperson Fabiola Gianotti says that "It could well be that it's not the standard model Higgs boson" and later continues "When the uncertainties become even smaller, when we have even more data and more studies, we'll be able to understand better the properties of this particle, if it's a Higgs boson or a more exotic object". So we still do not know if it is Higgs, Higgs like particle, or something else.

2.3.1 Is Higgs like state a pseudoscalar?

The characteristic Higgs like behavior is implied by the vacuum expectation value in the gauged kinetic term for the pion field whereas for gamma pairs this term gives only decays via W loop. This suggests that the pion field generates vacuum expectation as indeed happens in the general model for the production of lepto-pions [K16]. The additional decay channel would by PCAC hypothesis correspond to the coupling of the pion to electromagnetic instanton density giving also rise to the vacuum expectation. Hence one would obtain Higgs like behavior with anomalous gamma pair production.

1. The models for the electro-pion and tau-pion production via the formation of a coherent state of pions is a natural first guess for the production mechanism. The strong non-orthogonal electric and magnetic fields of colliding quarks give rise to non-vanishing instanton density $E \cdot B$ and by PCAC hypothesis pion field develops a vacuum expectation value proportional to $E \cdot B$. Note that nonvanishing of $E \cdot B$ means that the dimension d CP_2 projection of preferred extremal is higher than $d = 2$ and this holds always true for the proposed ansatz for the preferred extremals of Kähler action [K20].

2. To get perspective, consider first the decays of Higgs to electroweak gauge boson pairs. The gauged kinetic term in the action of Higgs is responsible for the primary decays to W and Z bosons and contains terms quadratic in Higgs and gauge bosons. As Higgs develops a vacuum expectation, this term gives in the lowest order a term, which is linear in both Higgs field and Higgs vacuum expectation, and quadratic in gauge fields W and Z.

   The gauged kinetic term gives rise to decays to virtual W and Z pairs decaying in turn to lepton and quark pairs. The ratio of rates to Z pairs and rate to W pairs reported by ATLAS [C4] is consistent with Higgs interpretation and poses a strong constraint on modeling. Decays to gamma pairs take place via W loop and the rate contains additional α^2 factor tending to reduce the decay rate. The loop integral gives an additional numerical factor expressible in terms of the mass ratios but the naive expecation is that the decay rate to gamma pairs is slower than to W and Z pairs.

3. In the case of pion-like states the kinetic term for pion gives exactly similar structure with vacuum expectation of $E \cdot B$ replacing that of Higgs. Hence the basic predictions for the decay rates to weak boson pairs are essentially identical as for Higgs apart from the anomalously high rate to gamma pairs. In particular, the rate ratios $R(\pi \rightarrow ZZ)/R(\pi \rightarrow WW)$ and $R(\pi \rightarrow \gamma\gamma)/R(\pi \rightarrow WW)$ are predicted to be the same as for Higgs option.

   PCAC however predicts an additional decay channel to gamma pairs due to the coupling pion to the quantum part of $E \cdot B$. This terms gives additional contribution to the decay rate proportional to α^2 rather than α^3. By a suitable choice of the parameter f_π it might well be possible to explain the observed anomalously high rate of gamma pairs.

The pseudoscalar nature of pionlike state, the existence of charged pionlike states, the weak dependence on fermion mass of the decay rates to fermion pairs are the relatively easily testable killer predictions.

To see that the model indeed survives also quantitative tests one can consider the decay rate of pion like state to gamma pairs using PCAC. Axial current anomaly tells that the divergence $\partial_\mu A^\mu$ of the axial current equals to $f_\pi m_\pi^2 \pi_0$, where π_0 is the neutral pion field. Axial current divergence contains a part proportional to the instanton density for electromagnetic field and this defines the effective action allowing to calculate the production amplitude and rate for gamma pairs.

1. From Iztykson-Zuber [B1] the decay width of pion to two-gamma would be given as

$$\Gamma(\pi) = \frac{\alpha^2 m_\pi^2}{64\pi^2 f_\pi^2} \ .$$

f_π is expected to be of order m_{pi}. Let us write $f_\pi = X m_\pi$.

2. The decay rates of Higgs can be found here [B2]. For the decay of Higgs to two photons the rate is

$$\Gamma(h) = \alpha^2 g_W^2 2^{-10} \pi^{-3} m_h^3 m_W^{-2} \ .$$

The prediction is exactly the same in the case of M_{89} pion. One only replaces scalar with pseudoscalar and Higgs vacuum expectation with that for pseudoscalar and given by PCAC anomaly expressible in terms of instanton density for classical induced em field F_{em} associated with the space-time sheet assignable to colliding quarks and defining the hadronic space-time sheet for M_{89} hadron physics (note that this space-time sheet could be also assicated with colliding protons).

$$\pi_0(vac) = -\frac{1}{32\pi^2 m_\pi^2 f_\pi} \times I \ , \ I = \epsilon_{\alpha\beta\gamma\delta} F_{em}^{\alpha\beta} F_{em}^{\gamma\delta} = 2E \cdot B \ .$$

Here F_{em} is defined by identifying gauge potential as eA_{mu}, which corresponds to the classical gauge potentials in TGD. It is essential that the induced electric and magnetic fields are non-orthogonal: this is true if CP_2 projection of space-time sheet has dimension larger than $d = 2$: this is actually always the case for preferred extremals so that the generation of the analog of Higgs expectation is basic phenomenon in TGD Universe but does not give rise to massivation. Instanton density I appears as a parameter which is in the first approximation constant.

3. The ratio of these rates is for $m(\pi) = m(h)$

$$r \equiv \frac{\Gamma(h)}{\Gamma(\pi)} = X^2 [\alpha \times sin^2(\theta_W)]^{-1} \ .$$

Some comments about the result are in order.

   (a) For $X = 93/135$ holding true for the ordinary neutral pion π_0 and $m(h) = m(\pi) = 125$ GeV this gives $r = 1.63$ and $f(\pi) = 1.07 m_W$. Therefore the contribution from the axial anomaly is .61 times the contribution of the gauge kinetic term to the decay rate assuming that the contributions of the amplitudes do not interfere. Interference effects can change the situation. Therefore PCAC anomaly alone is not enough and the prediction for the ratio $r \equiv \frac{\Gamma(h)+\Gamma(\pi)}{\Gamma(h)}$ is 1.61 times higher than predicted by Higgs. Constructive interference can give rise to 3.17 times larger rate and destructive interference to rate which is only .05 of the rate predicted by Higgs alone.

   The relative phase of the amplitudes from anomaly and kinetic term is expected to vary and the first guess is that the interference term gives a vanishing contribution average contribution. Local constructive interference in phase space would allow to understand the local values of r above 1.61. The ratio of the observed Higgs to gamma pair signal cross section to the predicted one is certainly consistent with this picture! Note that the anomalous contribution is present also for W and Z since instanton term is non-Abelian and only its vacuum expectation value is Abelian. This means that also the rates to W and Z pairs are enhanced as indeed observed by ATLAS.

   (b) The value of I characterizing the hadronic space-time sheet appears in the kinetic term responsible for the decays and also in the model for the production rate. The expression for the decay rate to gamma pairs involves a relation between Higgs vacuum expectation and Higgs mass provided by standard model. This relationship need not be same for the pion like state.

One cannot predict absolute production rates without a detailed model for the electric and magnetic fields of colliding quarks or protons predicting the instanton density I. This kind of model has been proposed in [K16].

(c) Does the production M_{89} pions provide the only window to M_{89} hadron physics? I have also considered a window which involves transformation of ordinary gluons to those of M_{89} physics and also direct transformation of ordinary hadronic space-time sheet to that of M_{89} physics. If pions are the only window to the new hadron physics, the production of other M_{89} hadrons should take place via the reactions of the pions of M_{89} pion condensate producing other M_{89} hadrons.

2.3.2 Objection and its resolution

The above picture is attractive but a closer look leads to an objection. If one accepts that gauge theory is a reasonable M^4 QFT limit of TGD then- also other aspects of Higgs mechanism related to weak bosons are unavoidable: the pseudo-scalar nature of pion does not matter. In particular, gauge bosons become massive by eating 3 components of the pseudo-scalar. Therefore the pion like state in question cannot be M_{89} pion but something else - one could call it "Higgsy" pion or "Higgs like state". The construction of pseudo-scalar like states as axial vectors of imbedding space (pseudo-scalars of M^4) indeed demonstrated that one obtains two kinds of pions - and more generally - meson like states. Pion-like states associated with the long Minkowskian flux tubes connecting wormhole throats assigned with different wormhole contacts and pion-like states associated with short Euclidian flux tubes connecting opposite throats of a given wormhole contact. These two kinds of pion like states would naturally correspond to pions and "Higgsy" pions. There are indications for two pion like states at energies 126 GeV and around 140 GeV and the natural identification would be as Euclidian and Minkowskian M_{89} pions respectively.

2.4 Could TGD allow pseudo-scalar Higgs as Euclidian pion?

The preceding observations and earlier work suggest that pion field in TGD framework is analogous to Higgs field. This raises questions. Assuming that QFT in M^4 is a reasonable approximation, does a modification of standard model Higgs mechanism allow to approximate TGD description? What aspects of Higgs mechanism remain intact when Higgs is replaced with pseudo-scalar? Those assignable to electro-weak bosons? The key idea allowing to answer these questions is that "Higgsy" pion and ordinary M_{89} pion are not one and the same thing: the first one corresponds to Euclidian flux tube and the latter one to Minkowskian flux tube. Hegel would say that one begins with thesis about Higgs, represents anti-thesis replacing Higgs with pion, and ends up with a synthesis in which Higgs is transformed to pseudo-scalar Higgs, "Higgsy" pion, or Higgs like state if you wish! Higgs certainly loses its key role in the massivation of fermions.

2.4.1 Can one assume that M^4 QFT limit exists?

The above approach assumes implicitly - as all comparisons of TGD with experiment - that M^4 QFT limit of TGD exists. The analysis of the assumptions involved with this limit helps also to understand what happens in generation of "Higgsy" pions.

1. QFT limit involves the assumption that quantum fields and also classical fields superpose in linear approximation. This is certainly not true at given space-time sheet since the number of field like is only four by General Coordinate Invariance. The resolution of the problem is simple: only the effects of fields carried by space-time sheets superpose and this takes place in multiple topological condensation of the particle on several space-time sheets simultaneously. Therefore M^4 QFT limit can make sense only for many-sheeted space-time.

2. The light-like 3-surfaces representing lines of Feynman graphs effectively reduce to braid strands and are just at the light-like boundary between Minkowskian and Euclidian regions so that the fermions at braid strands can experience the presence of the instanton density also in the more fundamental description. The constancy of the instanton density can hold true in a good approximation at braid strands. Certainly the M^4 QFT limit treats Euclidian regions as 1-dimensional lines so that instanton density is replaced with its average.

3. In particular, the instanton density can be non-vanishing for M^4 limit since E and B at different space-time sheets can superpose at QFT limit although only their effects superpose in the microscopic theory. At given space-time sheet I can be non-vanishing only in Euclidian regions representing lines of generalized Feynman graphs.

4. The mechanism leading to the creation of pion like states is assumed to be the presence of strong non-orthogonal electric and magnetic fields accompanying colliding charged particles [K16]: this of course in M^4 QFT approximation. Microscopically this corresponds to the presence of separate space-time sheets for the colliding particles. The generation of "Higgsy" pion condensate or pion like states must involve formation of wormhole contacts representing the "Higgsy" pions. These wormhole contacts must connect the space-time sheets containing strong electric and magnetic fields.

2.4.2 Higgs like pseudo-scalar as Euclidian pion?

The recent view about the construction of preferred extremals predicts that in Minkowskian space-time regions the CP_2 projection is at most 3-D. In Euclidian regions M^4 projection satisfies similar condition. As a consequence, the instanton density vanishes in Minkowskian regions and pion can generate vacuum expectation only in Euclidian regions. Long Minkowskian flux tubes connecting wormhole contacts would correspond to pion like states and short Euclidian flux tubes connecting opposite wormhole throats to "Higgsy" pions.

1. If pseudo-scalar pion like state develops a vacuum expectation value the QFT limit, it provides weak gauge bosons with longitudinal components just as in the case of ordinary Higgs mechanism. Pseudo-scalar boson vacuum expectation contributes to the masses of weak bosons and predicts correctly the ratio of W and Z masses. If p-adic thermodynamics gives a contribution to weak boson masses it must be small as observed already earlier. Higgs like pion cannot give dominant contributions to fermion masses but small radiative correction to fermion masses are possible.

   Photon would be massless in 4-D sense unlike weak bosons. If ZEO picture is correct, photon would have small longitudinal mass and should have a third polarization. One must of course remain critical concerning the proposal that longitudinal M^2 momentum replaces momentum in gauge conditions. Certainly only longitudinal momentum can appear in propagators.

2. If 3 components of Euclidian pion are eaten by weak gauge bosons, only single neutral pion-like state remain. This is not a problem if ordinary pion corresponds to Minkowskian flux tube. Accordingly, the 126 GeV boson would correspond to the remaining component Higgs like Euclidian pion and the boson with mass around 140 GeV for which CDF has provided some evidence to the Minkowskian M_{89} pion [C5] and which might have also shown itself in dark matter searches [C15, C9].

3. By the previous construction one can consider two candidates for pion like pseudo-scalars as states whose form apart from parallel translation factor is $\overline{\Psi}_1 j^{Ak}\gamma_k\Psi_2$. Here j^A is generator of color isometry either in $U(2)$ sub-algebra or its complement. The state in $U(2)$ algebra transforms as 3+1 under $U(2)$ and the state in its complement like $2+\overline{2}$ under $U(2)$.

   These states are analogous of CP_2 polarizations, whose number can be at most four. One must select either of these polarization basis. $2+\overline{2}$ is an unique candidate for the Higgs like pion and can be be naturally assigned with the Euclidian regions having Hermitian structure. 3+1 in turn can be assigned naturally to Minkowskian regions having Hamilton-Jacobi structure.

   Ordinary pion has however only three components. If one takes seriously the construction of preferred extremals the solution of the problem is simple: CP_2 projection is at most 3-dimensional so that only 3 polarizations in CP_2 direction are possible and only the triplet remains. This corresponds exactly to what happens in sigma model combining describing pion field as field having values at 3-sphere.

4. Minkowskian and Euclidian signatures correspond naturally to the decompositions 3+1 and $2+\overline{2}$, which could be assigned to quaternionic and co-quaternionic subspaces of $SU(3)$ Lie algebra or imbedding space with tangent vectors realized in terms of the octonionic representation of gamma matrices.

One can proceed further by making objections.

1. What about kaon, which has a natural $2+\overline{2}$ composition but can be also understood as $3+1$ state? Is kaon is Euclidian pion which has not suffered Higgs mechanism? Kaons consists of $u\overline{s}$ $d\overline{s}$ and their antiparticles. Could this non-diagonal character of kaon states explain why all four states are possible? Or could kaon corresponds to Minkowskian triplet plus singlet remaining from the Euclidian variant of kaon? If so, then neutral kaons having very nearly the same mass - so called short lived and long lived kaons - would correspond to Minkowskian and Euclidian variants of kaon. Why the masses if these states should be so near each other? Could this relate closely to CP breaking for non-diagonal mesons involving mixing of Euclidian and Minkowskian neutral kaons? Why CP symmetry requires mass degeneracy?

2. Are also M_{107} electroweak gauge bosons? Could they correspond to dark variant of electroweak bosons with non-standard value of Planck constant? This would predict the existence of additional - possibly dark - pion-like state lighter than ordinary pion. The Euclidian neutral pion would have mass about $(125/140)\times 135 \sim 125$ MeV from scaling argument. Interestingly, there is evidence for satellites of pion: they include also a states which are lighter than pion [C2]. The reported masses of these states would be $M = 62, 80, 100, 181, 198, 215, 227.5$, and 235 MeV. 125 MeV state is not included. The interpretation of these states is as IR Regge trajectories in TGD framework.

2.4.3 How the vacuum expectation of the pseudo-scalar pion is generated?

Euclidian regions have 4-D CP_2 projection so that the instanton density is non-vanishing and Euclidian pion generates vacuum expectation. In the following an attempt to understand details of this process is made using the unique Higgs potential consistent with conformal invariance.

1. One should realize the linear coupling of Higgs like pion to instanton density. The problem is that $Tr(F\wedge F\pi)$ since π does not make sense as such since π is defined in terms of gamma matrices of CP_2 and F in terms of sigma matrices. One can however map gamma matrices to sigma matrices in a natural manner by using the quaternionic structure of CP_2. γ_0 corresponding to e_0 is mapped to unit matrix and γ_i to the corresponding sigma matrix: $\gamma_i \rightarrow \epsilon_{ijk}\sigma^{jk}$. This map is natural for the quaternionic representation of gamma matrices. What is crucial is the dimension $D=4$ of CP_2 and the fact that it has $U(2)$ holonomy.

2. Vacuum expectation value derives from the linear coupling of pion to instanton density. If instanton density is purely electromagnetic, one obtains correct pseudo-scalar Higgs vacuum expectation commuting with photon.

3. If the action density contains only the mass term $m^2\pi/2$ plus instanton term $\frac{1}{32\pi^2 f_\pi}\pi I$, where I is the instanton density, one obtains the standard PCAC relation between the vacuum expectation of the pion field and instanton density.

$$\pi_0 = \frac{1}{32\pi^2 f_{pi} m_\pi^2} I \quad .$$

   This relation appears also in the model for leptopion production [K16]. In the standard model the mass term must be tachyonic. This leads to so called hierarchy problem hierarchy problem [**?**] The source of the problem are the couplings of Higgs to fermions proportional to the mass of fermion. The radiative corrections to Higgs mass squared are positive and proportional to fermion mass so that top quark gives the dominating contribution. This implies that the sign of the mass squared can become positive and the state with vanishing vacuum expectation value of Higgs field becomes the ground state. In the recent situation this is not a problem since fermions couple to the pion like state only radiatively.

4. The mass of Euclidian pion is determined by p-adic thermodynamics. For highest possible p-adic temperature $T_p = 1$ characterizing also fermions the minimum mass is obtained by scaling the p-adic mass scale m_{127} assignable to electron having upper bound $m_{127} \leq m_e/\sqrt{5}$ with the factor $\sqrt{M_{127}/M_{89}} \simeq 2^{(127-89)/2}$. This gives $m_{min} \leq 119.8$ GeV, which is about 4 per cent smaller

than the actual mass estimate 125 GeV. This suggests that p-adic mass squared of Euclidian pion is given by $m_\pi^2 = p + O(p^2)$ mapping to $m_{\pi,R}^2 = 1/p + O(p^{-2})$ by canonical identification $\sum x_n p^n \rightarrow \sum x_n p^{-n}$. The correction could be due to radiative corrections or second order contributions from p-adic thermodynamics. The vacuum expectation value of Higgs is $v = 246$ GeV, which is slightly larger than $v = 2m_{min}$ and from this one can deduce the value of instanton density I as $I = 32\pi^2 f_\pi m_\pi^2 v$.

5. When one adds to the fields appearing in the classical instanton term the quantum counter parts of electroweak gauge fields, one obtains an action giving rise to the anomaly term inducing the anomalous decays to gamma pairs and also other weak boson pairs. The relative phase between the instanton term and kinetic term of pion like state is highly relevant to the decay rate. If the relative phase corresponds to imaginary unit then the rate is just the sum of the anomalous and non-anomalous rates since interference is absent.

2.4.4 What is the window to M_{89} hadron physics?

Concerning the experimental testing of the theory one should have a clear answer to the question concerning the window to M_{89} hadron physics. One can imagine several alternative windows.

1. Two gluon states transforming to M_{89} gluons could be one possibility proposed earlier. The model contains a dimensional parameter characterizing the amplitude for the transformation of M_{107} gluon to M_{89} gluon . Dimensional parameters are not however well-come.

2. Instanton density as the portal to new hadron physics would be second option but works only in the Euclidian signature. One can however argue that M_{89} Euclidian pions represent just electroweak physics and cannot act as a portal.

3. Electroweak gauge bosons correspond to closed flux tubes decomposing to long and short parts. Two short flux tubes associated with the two wormhole contacts connecting the opposite throats define the "Higgsy" pions. Two long flux tubes connect two wormhole contacts at distance of order weak length scale and define M_{89} pions and mesons in the more general case. In the case of weak bosons the second end of long flux tube contains neutrino pair neutralizing the weak isospin so that the range of weak interactions is given the length of the long flux tube. For M_{89} the weak isospins at the ends need not sum up to zero and also other states that neutrino pair are allowed, in particular single fermion states. This allows an interpretation as electroweak "de-confinement" transition producing M_{89} mesons and possibly also baryons. This kind of transition would be rather natural and would not requite any specific mechanisms.

2.5 Connection with dark matter searches?

An additional fascinating thread to the story comes from the attempts to detect dark matter. The prediction of TGD approach is that dark matter resides at magnetic flux tubes as phases with large value of Planck constant and that dark energy corresponds to the magnetic energy of the flux tubes and is characterized by a gigantic value of (effective) Planck constant [K5]. This leads to a rather detailed vision about cosmic evolution with magnetic energy replacing the vacuum energy assigned with inflaton fields. The decay of the magnetic flux tubes rather than vacuum expectation of inflaton field would create ordinary matter and dark matter [K14].

The results of the dark matter searches are inconclusive. Some groups claim the detection of what they identify as dark matter [C7, C10], some groups see nothing [C8, C6]. The analysis is sensitive to the assumptions made and if the assumption that dark matter corresponds to WIMPs - say neutralino of standard SUSY- the analysis might fail. Second source of failure relates to the distribution of dark matter. For instance, the standard assumption about spherical halos around galaxies might be wrong and TGD indeed suggests that this particular form of dark matter is concentrate string like magnetic flux tubes containing galaxies around it like pearls in a necklace. It has been indeed reported that the nearby space around Earth does not contain dark matter [E2]. On the other hand, evidence for string like magnetic flux tubes containing dark matter and connecting galactic clusters has been reported [E1]. Even if dark matter candidates are detected, they could be fake since the particles in question could be created in atmosphere in the collisions of highly energetic cosmic rays creating hadrons of M_{89} hadron physics: certain mysterious cosmic ray events with ultra high energies could be indeed due to M_{89} hadron physics [K11].

Independent positive reports come from groups studying the data from Fermi satellite in the hope of identifying particles of galactic dark matter. 3 sigma evidence has been represented for the claim that there is signal for dark particle with mass around 130 GeV [C15]. Gamma pairs would be produced in the annihilation of particles with this mass. Another group [C9] reports a signal at the same energy but argues that due to kinematical effects this signal actually corresponds to a particle with a mass of about 145 GeV: similar signal was earlier reported earlier by CDF at Fermilab [C1]. Also some indications for a signal at 110 GeV is proposed by the latter group: direct extrapolation to take into account the kinematical effects would suggest a particle at 125 GeV. It has been also claimed that the signal is too strong to be interpreted as neutralino, the main candidate for a WIMP defining dark matter in the standard sense [C14]. This is a further blow against standard SUSY. If the Higgs candidate is actually a pionlike state of scaled up variant of hadron physics, one can ask whether M_{89} hadron physics could be active in the extreme conditions of the galactic center and lead to a copious production of pionlike state of M_{89} physics annihilating and decaying to gamma pairs.

3 About the microscopic description of gauge boson massivation

The conjectured QFT limit allows to estimate the quantitative predictions of the theory. This is not however enough. One should identify the microscopic counterparts for various aspects of gauge boson massivation relying on Euclidian pion - something radically new in the space-time ontology. There is also the question about the consistency of the gauge theory limit with the ZEO inspired view about massivation and suggesting gauge conditions differing dramatically from the conventional ones. The basic challenge are obvious: one should translate notions like Higgs vacuum expectation, massivation of gauge bosons, and finite range of weak interactions to the language of wormhole throats, Kähler magnetic flux tubes, and string world sheets.

3.1 Elementary particles in ZEO

Let us first summarize what kind of picture ZEO suggests about elementary particles.

1. Kähler magnetically charged wormhole throats are the basic building bricks of elementary particles. The lines of generalized Feynman diagrams are identified as the Euclidian regions of space-time surface. The weak form of electric magnetic duality forces magnetic monopoles and gives classical quantization of the Kähler electric charge. Wormhole throat is a carrier of many-fermion state with parallel momenta and the fermionic oscillator algebra gives rise to a badly broken large $\mathcal{N}$ SUSY [K7].

2. The first guess would be that elementary fermions correspond to wormhole throats with unit fermion number and bosons to wormhole contacts carrying fermion and antifermion at opposite throats. The magnetic charges of wormhole throats do not however allow this option. The reason is that the field lines of Kähler magnetic monopole field must close. Both in the case of fermions and bosons one must have a pair of wormhole contacts connected by flux tubes. The most general option is that net quantum numbers are distributed amongst the four wormhole throats. A simpler option is that quantum numbers are carried by the second wormhole: fermion quantum numbers would be carried by its second throat and bosonic quantum numbers by fermion and antifermion at the opposite throats. All elementary particles would therefore be accompanied by parallel flux tubes and string world sheets.

3. A cautious proposal in its original form was that the throats of the other wormhole contact could carry weak isospin represented in terms of neutrinos and neutralizing the weak isospin of the fermion at second end. This would imply weak neutrality and weak confinement above length scales longer than the length of the flux tube. This condition might be un-necessarily strong.

   The realization of the weak neutrality using pair of left handed neutrino and right handed antineutrino or a conjugate of this state is possible if one allows right-handed neutrino to have also unphysical helicity. The weak screening of a fermion at wormhole throat is possible if ν_R is a constant spinor since in this case Dirac equation trivializes and allows both helicities as solutions. The new element from the solution of the modified Dirac equation is that ν_R would be interior mode delocalized either to the other wormhole contact or to the Minkowskian flux tube. The state at the other end of the flux tube is spartner of left-handed neutrino.

It must be emphasized that weak confinement is just a proposal and looks somewhat complex: Nature is perhaps not so complex at the basic level. To understand this better, one can think about how M_{89} mesons having quark and antiquark at the ends of long flux tube returning back along second space-time sheet could decay to ordinary quark and antiquark.

3.2 ZEO and gauge conditions

ZEO suggests a new approach to gauge conditions. The proposal is of course something which must be taken with extreme cautiousness.

1. In ZEO all wormhole throats - also those associated with virtual particles - are massless. Fermionic propagators identified as 4-D massless propagators would divergence identically. The first guess is that only the longitudinal momentum p_L defined as M^2 projection of four-momentum appears in propagators. The construction of the functional integral however implies that the propagator defined by the modified Dirac operator appears naturally in the fermion part of perturbation theory. For the light-like braid strands the perturbation theory for fermion n-point function is conjectured to reduce from stringy perturbation theory to 1-D theory involving only the fermion propagators assigned with the braid strands. The propagator defined by the modified Dirac operator need not of course reduce to M^2 propagator even in this case but this is possible in principle. The momentum in the propagator brings in mind the region momentum of the twistor approach.

2. In the light of 2-D fermionic propagation it would not be terribly surprising if p_L would appear in the gauge conditions for the physical states so that one would have $p_L \cdot \epsilon = 0$. M^2 would be the counterpart of string world sheet at imbedding space level and its presence is strongly suggested both by number theoretical vision and by ZEO. For M^2 option also the third polarization is possible for states massless in 4-D sense - a clear signal about longitudinal massivation (at least this) of gauge bosons. The simplest interpretation of the p-adic mass calculations for fermions would be that p-adic thermodynamics gives longitudinal momentum squared as a thermal expectation value in a state satisfying Virasoro conditions and having massless state as the ground state. One must be however very cautious in introducing completely new elements to the theory.

3. The introduction of M^2 does not Lorentz invariance since one has integral over all CDs characterized by the choice of $M^2 \subset M^4$ defining the energy quantization axis (rest system) and spin quantization axis. One should demonstrate that this integration yields sensible scattering amplitudes.

To sum up, for states consisting of several wormhole throats longitudinal massivation allows state to be massless in 4-D sense but does not require this. At least weak bosons could be massive also in 4-D sense, maybe also photon.

3.3 Gauge bosons and pseudoscalars must be massive in 4-D sense

What Higgs mechanism for gauge bosons really means? Is it a QFT counterpart for the M^2 massivation or for a massivation in 4-D sense? The wormhole contacts could have non-parallel massless momenta without giving up the idea about on mass shell massless propagation essential for the twistor approach so that the answer to the question is not obvious. For fermions p-adic thermodynamics suggests strongly longitudinal massivation and masslessness in 4-D sense. Internal consistency would favos M^2 massivation also in the case of bosons.

The construction of massless states for bosons assuming that second wormhole contact carries the momentum however yields a surprise: spin 1 bosons are necessarily massive in 4-D sense whereas spin 0 bosons can be massless. The Higgs mechanism based on instanton anomaly however implies the massivation of also pseudoscalar bosons. Scalar boson states are the only ones that can remain massless. 4-D form of gauge conditions is therefore possible and obviously the safest option also in ZEO.

Consider now the argument in detail.

1. If one assumes that both fermions are not only massless but also have only physical polarization (in other words satisfy massless Dirac equation with the same sign of energy) one finds that fermion-antifermion state with parallel four-momenta must have vanishing net spin since fermion and antifermion with same M^4 chirality have opposite helicities. Thus it would seem that spin 0 states can be massless but that all spin 1 particles, including photon and gluon, are inherently massive in 4-D sense since the momenta of fermions cannot be exactly parallel. What is important is that this holds true irrespective of gauge conditions.

2. Indeed, if fermions are massless on mass shell states satisfying therefore also massless Dirac equation in M^4, wormhole throats must carry slightly non-parallel light-like momenta in order to have helicity one states. Massivation of spin one states is unavoidable. Situation changes if one requires masslessness but gives up massless Dirac equation for second fermion so that it can have opposite energy or 3-momentum implying non-physical polarization. The value of either fermion or antifermion energy can dominate and corresponding momentum defines the direction of helicity for the non-vanishing helicity. This being the case one could use also M^4 momentum in gauge conditions since one would would obtain three polarizations in any case.

3. If only M^2 momentum appears in the gauge conditions, also the longitudinal polarization is possible for states which remain massless in 4-D sense (note however that this requires unphysical polarization state). This is possible because M^2 momentum is in general massive: wormhole throats can carry parallel massless 4-momenta with massive M^2 momentum.

4. Spinless states exactly massless states with on mass shell fermions with physical helicities are possible since the spins of the parallel on mass shell massless fermion and antifermion sum up to zero. The analog of Higgs mechanism would however make this state massive making the momenta slightly un-parallel. If also the wormhole throat at the second end of flux tube carries momentum, the massivation mechanism is more complex.

It must be noticed that the massivation of gauge bosons is obtained without any reference to Higgs like particle. In gauge theory context the choice of gauge transfers part of Higgsy degrees of freedom to gauge bosons.

3.4 The role of string world sheets and magnetic flux tubes in massivation

What is the role of string world sheets and flux tubes in the massivation? At the fundamental level one studies correlation functions for particles and finite correlation length means massivation.

1. String world sheets define as essential element in 4-D description. All particles are basically bi-local objects: pairs of string at parallel space-time sheets extremely near to each other and connected by wormhole contacts at ends. String world sheets are expected to represent correlations between wormhole throats.

2. Correlation length for the propagator of the gauge boson characterizes its mass. Correlation length can be estimated by calculating the correlation function. For bosons this reduces to the calculation of fermionic correlations functions assignable to string world sheets connecting the upper and lower boundaries of CD and having four external fermions at the ends of CD. The perturbation theory reduces to functional integral over space-time sheets and deformation of the space-time sheet inducing the deformation of the induced spinor field expressible as convolution of the propagator associated with the modified Dirac operator with vertex factor defined by the deformation multiplying the spinor field. The external vertices are braid ends at partonic 2-surfaces and internal vertices are in the interior of string world sheet. Recall that the conjecture is that the restriction to the wormhole throat orbits implies the reduction to diagrams involving only propagators connecting braid ends. The challenge is to understand how the coherent state assigned to the Euclidian pion field induces the finite correlation length in the case of gauge bosons other than photon.

3. The non-vanishing commutator of the gauge boson charge matrix with the vacuum expectation assigned to the Euclidian pion must play a key role. The study of the modified Dirac operator suggests that the braid strands contain the Abelianized variant of non-integrable phase factor defined as $exp(i\int Adx)$. If A is identified as string world sheet Hodge dual of Kac-Moody charge the opposite edges of string world sheet with geometry of square given contributions which compensate each other by conservation of Kac-Moody charge if A commutes with the operators building the coherent Higgs state. For photon this would be true. For weak gauge bosons this would not be the case and this gives hopes about obtaining destructive interference leading to a finite correlation length.

One can also consider try to build more concrete manners to understand the finite correlation length.

1. Quantum classical correspondence suggests that string with length of order $L \sim \hbar/E$, $E = \sqrt{p^2+m^2}$ serves as a correlate for particle defined by a pair of wormhole contacts. For massive particle wave length satisfies $L \leq \hbar/m$. Here (p,m) must be replaced with (p_L, m_L) if one takes the notion of longitudinal mass seriously. For photon standard option gives $L = \lambda$ or $L = \lambda_L$ and photon can be a bi-local object connecting arbitrarily distant objects. For the second option small longitudinal mass of photon gives an upper bound for the range of the interaction. Also gluon would have longitudinal mass: this makes sense in QCD where the decomposition $M^4 = M^2 \times E^2$ is basic element of the theory.

2. The magnetic flux tube associated with the particle carries magnetic energy. Magnetic energy grows as the length of flux tube increases. If the flux is quantized magnetic field behaves like $1/S$, where S is the area of the cross section of the flux tube, the total magnetic energy behaves like L/S. The dependence of S on L determines how the magnetic energy depends on L. If the magnetic energy increases as function of L the probability of long flux tubes is small and the particle cannot have large size and therefore mediates short range interactions. For $S \propto L^\alpha \sim \lambda^\alpha$, $\alpha > 1$, the magnetic energy behaves like $\lambda^{-\alpha+1}$ and the thickness of the flux tube scales like $\sqrt{\lambda^\alpha}$. In case of photon one might expect this option to be true. Note that for photon string world sheet one can argue that the natural choice of string is as light-like string so that its length vanishes.

What kind of string world sheets are possible? One can imagine two options.

1. All strings could connect only the wormhole contacts defining a particle as a bi-local object so that particle would be literally the geometric correlate for the interaction between two objects. The notion of free particle would be figment of imagination. This would lead to a rather stringy picture about gauge interactions. The gauge interaction between systems S_1 and S_2 would mean the emission of gauge bosons as flux tubes with charge carrying end at S_1 and neutral end. Absorption of the gauge boson would mean that the neutral end of boson and neutral end of charge particle fuse together line the lines of Feynman diagram at 3-vertex.

2. Second option allows also string world sheets connecting wormhole contacts of different particles so that there is no flux tube accompanying the string world sheet. In this case particles would be independent entities interacting via string world sheets. In this case one could consider the possibility that photon corresponds to string world sheet (or actually parallel pair of them) not accompanied by a magnetic flux tube and that this makes the photon massless at least in excellent approximation

The first option represents the ontological minimum.

3.5 The counterpart of Higgs vacuum expectation in microscopic language

The challenge is to translate the QFT description of gauge boson massivation to microscopic description. One can say that gauge bosons "eat" the components of Higgs. In unitary gauge one gauge rotates Higgs field to electromagnetically neutral direction defined by the vacuum expectation value of Higgs. The rotation matrix codes for the degrees of freedom assignable to non-neutral part of Higgs and they are transferred to the longitudinal components of Higgs in gauge transformation. This gives rise to the third polarization direction for gauge boson.

1. In path integral formulation the description of the situation is straightforward: unfortunately the mathematical status of path integral formalism is not established. This formulation does not have any obvious connection with its microscopic counterpart in TGD framework.

2. In QFT language the generation of vacuum expectation value could correspond to a formation of coherent state defined as eigenstate for the negative frequency part of Higgs field and obtained by acting with the exponential of positive frequency part of Higgs field to vacuum. Formally can regard the state as a continuous tensor product of states associated with point of 3-space with coherent state with same coherence parameter at each point. Also this notion is mathematically questionable. The parameter in the exponential would be a parameter with dimensions of mass and define the vacuum expectation value of Higgs like field. Note that the Higgs expectation can be constant although the coherent state contains many particle states associated with all possible frequencies and momenta.

One might hope that the latter description has a microscopic counterpart. Higgs like state is a wormhole contact with fermion and antifermion at the throats. This state is different from its Hermitian conjugate since the permutation of the wormhole throats takes place in Hermitian conjugation. One might hope that this pair of operators defines a pair of bosonic operators analogous to a pair formed by bosonic annihilation and creation operator, and that the exponential of the creation operator like part acting on vacuum would define the counterpart of coherent state now. More general coherent state $|coh\rangle$ could be defined by a series in monomials $P^{N\dagger}_{m_1,...,m_n} = a^{\dagger,m_1}...a^{\dagger,m_N}$ of fermionic creation operators with some coefficients $C_{m_1,....,m_N}$. One can also assume some canonical ordering of the oscillator operators.

The counterpart A of the bosonic annihilation operator would be defined by the Higgs like state as a sum $\sum_{mn} A_{mn} P^2_{mn}$ of monomials $P^2_{mn} = a_m a_n$ of two fermionic annihilation operators with some coefficients.

The action of a pair $a_m a_n$ of annihilation operators in A on $P^N_{m_1,...,m_N}$ produces zero if either of the operators is not contained in $P^{N\dagger}$ and otherwise cancels the $a^\dagger_m$ and $a^\dagger_n$ from it. There is also a sign factor from anticommutators. In the lowest order term one would have $\sum_{mn} A_{mn} C_{mn} P^{2\dagger}_{mn} = h$. General conditions would read

$$\begin{array}{l} \sum_{n_1 n_2} A_{n_1 n_2} C_{m_1,.....m_N} P^{N\dagger}_{m_1,...,\hat{m_r},...\hat{m_s},..m_N} \delta_{n_1,m_r} \delta_{n_2,m_s} (-1)^{r+s+\epsilon(r,s)} \\ = h \times C_{m_1,..,...,...,m_N} P^{N-2\dagger}_{m_1,...m_N} \quad . \\ \epsilon(r,s) = 0 \ \text{ for } \ r < s \ \ , \ \ \epsilon(r,s) = 1 \ \text{ for } \ r > s \ \ . \end{array} \qquad (3.1)$$

Apart from n_1 and n_2 all indices appearing $P^{N\dagger}$ appear in $P^{N-2\dagger}$ in the same order. The equations have a solution only if the number of the oscillator operators is infinite since if N_{max} is finite, the action produces a polynomial of degree $N_{max} - 2$. One can of course consider the weakening of the coherence conditions so that it need not hold for the highest monomials. Finite measurement resolution indeed suggest that the number of oscillator operators is finite and proportional to the number braid strands.

The parameter h defining the vacuum expectation value should be propotional to the electromagnetic part of instanton density at the end of braid strand. Each component of the Euclidian pion is pseudoscalar so that h must be pseudoscalar and proportionality to instanton density is the only possible option. The value of the parameter characterizing the instanton density should be characterized by p-adic length scale. Since one needs the Higgs expectation only at the ends of braid strands, the coherent state is well defined since everything is discrete.

3.6 Cautious conclusions

The discussion of TGD counterpart of Higgs mechanism gives support for the following general picture.

1. p-Adic thermodynamics contributes to the masses of all particles including photon and gluons: in these cases the contributions are however small. For fermions they dominate. For weak bosons the contribution from Euclidian Higgs is dominating as the correct group theoretical prediction for the W/Z mass ratio demonstrates. The mere spin 1 character for gauge bosons implies that they are massive in 4-D sense. The mass term for Euclidian pion in the analog of Higgs potential is not tachyonic, and the absence of linear couplings to fermions proportional to their masses

saves from radiative instability which standard $\mathcal{N} = 1$ SUSY was hoped to solve. Therefore the usual space-time SUSY associted with imbedding space in TGD framework is not needed, and there are strong arguments suggesting that it is not present [K19]. For space-time regarded as 4-surfaces one obtains 2-D super-conformal invariance for fermions localized at 2-surfaces and for right-handed neutrino it extends to 4-D superconformal symmetry generalizing ordinary SUSY to infinite-D symmetry.

2. The basic predictions to LHC are following. Euclidian pion will be found to decay to fermion pairs in a manner inconsistent with Higgs interpretation and its pseudoscalar nature will be established. M_{89} hadron physics will be discovered. Fermi satellite has produced evidence for a particle with mass around 140 GeV and this particle could correspond to the pion of M_{89} physics. This particle should be observed also at LHC and CDF reported already earlier evidence for it. There has been also indications for other mesons of M_{89} physics from LHC discussed in [K10].

3. The new view about Higgs allows to see several conjectures related to ZEO in new light.

   (a) The basic conjecture related to the perturbation theory is that wormhole throats are massless on mass shell states in imbedding space sense: this would hold true also for virtual particles and brings in mind what happens in twistor program. The recent progress [K20] in the construction of n-point functions leads to explicit general formulas for them expressing them in terms of a functional integral over four-surfaces. The deformation of the space-time surface fixes the deformation of basis for induced spinor fields and one obtains a perturbation theory in which correlation functions for imbedding space coordinates and fermionic propagator defined by the inverse of the modified Dirac operator appear as building bricks and the electroweak gauge coupling of the modified Dirac operator define the basic vertex. This operator is indeed 2-D for all other fermions than right-handed neutrino.

   (b) The functional integral gives some expressions for amplitudes which resemble twistor amplitudes in the sense that the vertices define polygons and external fermions are massless although gauge bosons as their bound states are massive. This suggests perturbation at imbedding space level such that fermionic propagator is defined by longitudinal part of M^4 momentum. Integration over possible choices $M^2 \subset M^4$ for CD would give Lorentz invariance and transform propagator terms to something else. As a matter of fact, Yangian invariance suggests general expressions very similar to those obtained in $\mathcal{N} = 4$ SUSY for amplitudes in Grassmannian approach.

   (c) Another conjecture is that gauge conditions for gauge bosons hold true for longitudinal (M^2-) momentum and automatically allow 3 polarization states. This allows to consider the possibility that all gauge bosons are massless in 4-D sense. By above argument this conjecture must be wrong. Could one do without M^2 altogether? A strong argument favoring longitudinal massivation is from p-adic thermodynamics for fermions. If p-adic thermodynamics determines longitudinal mass squared as a thermal expectation value such that 4-D momentum always light-like (this is important for twistor approach) one can assume that Super Virasoro conditions hold true for the fermion states. There are also number theoretic arguments and supporting the role of preferred M^2. Also the condition that the choice of quantization axes has WCW correlates favors M^2 as also the construction of the generalized Feynman graphs analogous to non-planar diagrams as generalization of knot diagrams [K8].

   The ZEO conjectures involving M^2 remain open. If the conjecture that Yangian invariance realized in terms of Grassmannians makes sense it could allow to deduce the outcome of the functional integral over four-surfaces and one could hope that TGD can be transformed to a calculable theory.

4 Appendix: The particle spectrum predicted by TGD

The detailed model of elementary particles has evolved slowly during more than 15 years and is still in progress. What SUSY means in TGD framework is second difficult question. In this problem text books provide no help since the SUSY differs in several respects from the standard SUSY. It must be admitted that there are open questions and several competing candidates for interpretations at the level of details and following just summarizes various competing approaches.

4.1 The general TGD based view about elementary particles

A rough overall view about the particle spectrum predicted by TGD has remained rather stable since 1995 when I performed first p-adic mass calculations but several important ideas have emerged allowing to make the vision more detailed.

1. The discovery of bosonic emergence [K13] had far reaching implications for both the formulation and interpretation of TGD. Bosonic emergence means that the basic building bricks of bosons are identifiable as wormhole contacts with throats carrying fermion and anti-fermion quantum numbers.

2. A big step was the realization wormhole throats carry Kähler magnetic charge [K6]. This forces to assume that observed elementary particles are string like objects carrying opposite magnetic charges at the wormhole ends of magnetic flux tubes. The obvious idea is that weak massivation corresponds to the screening of weak charges by neutrino pairs at the second end of the flux tube.

   At least for weak gauge bosons this would fix the length of the flux tube to be given by weak length scale. For fermions and gluons the length of flux tube could also correspond to Compton length: the second end would be invisible since it would contain only neutrino pair. In the case of quarks an attractive idea is that flux tubes carry color magnetic fluxes and connect valence quarks and have hadronic size scale.

   There are thus several stringy length scales present. The most fundamental corresponds to wormhole contacts and to CP_2 length scale appearing in p-adic mass calculations and is analogous to the Planck scale characterizing string models. String like objects indeed appear at all levels in TGD Universe: one can say that strings emerge. The assumption that strings are fundamental objects would be a fatal error.

3. p-Adic massivation does not involve Higgs mechanism [K9]. The idea that Higgs provides longitudinal polarizations for gauge bosons is attractive, and its TGD based variant was that *all* Higgs components become longitudinal polarizations so that also photon has a small mass. The recent formulation of gauge conditions as $p_{M^2} \cdot \epsilon = 0$, where p_{M^2} is a projection of the momentum to to a preferred plane $M^2 \subset M^4$ assignable to a given CD and defining rest system and spin quantization axis, allows three polarizations automatically. Also the construction of gauge bosons as wormhole contacts with fermion and anti-fermion at the ends of throat massless on mass-shell states implies that all gauge bosons must be massive. Therefore Higgs does not seem to serve its original purposes in TGD.

4. This does not however mean that Higgs like states - or more generally spin 0 particles, could not exist. Here one encounters the problem of formulating what the notions like "scalar" and "pseudo-scalar" defined in M^4 field theory mean when M^4 is replaced with $M^4 \times CP_2$. The reason is that genuine scalars and pseudo-scalars in $M^4 \times CP_2$ would correspond to lepto-quark states and chiral invariance implying separate conservation of quark and lepton numbers denies their existence.

   These problems are highly non-trivial, and depending on what one is willing to assume, one can have spin 0 particles which however need not have anything to do with Higgs.

   (a) For a subset of these spin 0 particles the interpretation as 4 polarizations of gauge bosons in CP_2 direction is highly suggestive: the polarizations can be regarded as doublets $2 \oplus +\overline{2}$ defining representations of $u(2) \subset su(3)$ in its complement and therefore being rather "Higgsy". Another subset consists of triplet and singlet representations for $u(2) \subset u(3)$ allowing interpretation as the analog of strong isospin symmetry in CP_2 scale for the analogs of hadrons defined by wormhole contacts.

   (b) $3 \oplus 1$ representation of $u(2) \subset su(3)$ acting on $u(2)$ is highly analogous to (π, η) system and $2 \oplus \overline{2}$ representation assignable naturally to the complement of $u(2)$ is analogous to kaon system. Exactly the same representations are obtained from the model of hadrons as string like objects and the two representations explain the difference between (π, η) like and $(K, \overline{K}$ systems in terms of SU(3) Lie-algebra. Also the vector bosons associated with pseudo-scalar mesons identified as string like objects have counterparts at the level of wormhole contacts. A surprisingly precise analogy between hadronic spectrum and the spectrum of elementary particle states emerges and could help to understand the details of elementary particle spectrum in TGD Universe.

In both cases charge matrices are expressible in terms of Killing vector fields of color isometries and gamma matrices or sigma matrices acting however on electroweak spin degrees of freedom so that a close connection between color and strong isospin is suggestive. This connection is empirically suggested also by the conserved vector current hypothesis and and partially conserved vector current hypothesis allowing to express strong interaction observables in terms of weak currents. In TGD framework color and electro-weak quantum numbers are therefore not totally unrelated as they are in standard model and it would be interesting to see whether this could allow to distinguish between TGD and standard model.

The detailed model for elementary particles involves still many un-certainties and in the following some suggestions allowing more detailed view are considered.

4.2 Construction of single fermion states

The general prediction of TGD is that particles correspond to partonic 2-surfaces, which can carry arbitrary high fermion number. The question is why only wormhole throats seem to carry fermion number 1 or 0 and why higher fermion numbers can be only assigned to the possibly existing super-partners.

1. p-Adic calculations assume that fermions correspond at imbedding space level to color partial waves assignable to the CP_2 cm degrees of freedom of partonic 2-surface. The challenge is to give a precise mathematical content to the statement that partonic 2-surface moves in color partial wave. Color partial wave for the generic partonic 2-surface in general varies along the surface. One must either identify a special point of the surface as cm or assume that color partial wave is constant at the partonic 2-surface.

2. The first option looks artificial. Constancy condition is however very attractive since it would correlate the geometry of partonic 2-surface with the geometry of color partial wave and therefore code color quantum numbers to the geometry of space-time surface. This quantum classical correlation cannot hold true generally but could be true for the maxima of Kähler function.

3. Similar condition can be posed in M^4 degrees of freedom and would state that the plane wave representing momentum eigenstate is constant at the partonic 2-surface.

For momentum eigenstates one obtains only one condition stating

$$p_{M^4} \cdot m = constant = C$$

at the partonic 2-surface located at the light-like boundary of CD. Here p_{M^4} denotes the M^2 projection of the four-momentum. CD projection is at most 2-dimensional and at the surface of ellipsoid of form

$$x^2 + y^2 + k^2(z - z_0)^2 = R^2 \quad ,$$

where the parameters are expressible in terms of the momentum components p_0, p_3 parameter C. In this case, the assumption that fermions have collinear M^2 momentum projection allows to add several fermions to the state provided the conditions in CP_2 degrees of freedom allow this. In particular, covariantly constant right-handed neutrino must be collinear with the other fermions possibly present in the state.

For color partial waves the condition says that color partial wave is complex constant at partonic 2-surface $\Psi = C$.

1. The condition implies that the CP_2 projection of the color partial wave is 2-dimensional so that one obtains a family of 2-surfaces Y^2 labelled by complex parameter C. Color transformations act in this space of 2-surfaces. In general Y^2 is not holomorphic since only the lowest representations (1,0) and (0,1) of $SU(3)$ correspond to holomorphic color partial waves. What is highly satisfying is that the condition allows CP_2 projection with maximal possible dimension.

2. If one requires covariant constancy of fermionic spinors, only vanishing induced spinor curvature is possible and CP_2 projection is 1-dimensional, which does not conform with the assumption that elementary particles correspond to Kähler magnetic monopoles.

3. There is an objection against this picture. The topology of CP_2 projection must be consistent with the genus of the partonic 2-surface [K3]. The conditions that plane waves and color partial waves are constant at the partonic 2-surface means that one can regard partonic 2-surfaces as sub-manifolds in 4-dimensional sub-manifold of $A \times B \subset \delta CD \times CP_2$. The topologies of $AandB$ pose no conditions on the genus of partonic 2-surface locally. Therefore the objection does not bite.

One can consider also partonic 2-surfaces containing several fermions. In the case of covariantly constant right-handed neutrino this gives no additional conditions in CP_2 degrees of freedom if the right handed neutrino has M^2 momentum projection collinear with the already existing fermion. Therefore $\Psi = C$ constraint is consistent with SUSY in TGD sense. For other fermions N-fermion state gives $2N$ conditions in CP_2 degrees of freedom. Already for $N = 2$ the solutions consist of discrete points of CP_2. Physical intuition suggests that the states with higher fermion number are not realized as maxima of Kähler function and are effectively absent unlike the observed states and their spartners.

4.3 About the construction of mesons and elementary bosons in TGD Universe

It looks somewhat strange to talk about the construction of mesons and elementary bosons in the same sentence. The construction recipes are however structurally identical so that it is perhaps sensible to proceed from mesons to elementary bosons. Therefore I will first consider the construction of meson like states relevant for the TGD based model of hadrons, in particular for the model of the pion of M_{89} hadron physics possibly explaining the 125 GeV state for which LHC finds evidence. The more standard interpretation is as elementary spin 0 boson, which need not however have anything to do with Higgs. Amusingly, the two alternatives obey very similar mathematics.

4.3.1 Construction of meson like states in TGD framework

The challenge is how translate attributes like scalar and pseudo-scalar making sense at M^4 level to statements making sense at the level of $M^4 \times CP_2$.

In QCD the view about construction of pseudo-scalar mesons is roughly that one has string like object having quark and antiquark at its ends, call them A and B. The parallel translation of the antiquark spinor from A to B is needed in order to construct gauge invariant object of type $\overline{\Psi} O \Psi$, where O characterizes the meson. The parallel translation implies stringy non-locality. In lattice QCD this string correspond to the edge of lattice cell. For a general meson O is "charge matrix" obtained as a combination of gamma matrices (γ_5 matrix for pseudo-scalar), polarization vectors, and isospin matrices.

This procedure must be generalized to TGD context. In fact a similar procedure applies also in the construction of gauge bosons possible Higgs like states since also in this case one must have general coordinate invariance and gauge invariance. Consider as an example pseudo-scalars.

1. Pseudo-scalars in M^4 are replaced with axial vectors in $M^4 \times CP_2$ with components in CP_2 direction. One can say that these pseudo-scalars have CP_2 polarization representing the charge of the pseudo-scalar meson. One replaces γ_5 with $\gamma_5 \times O_a$ where $O_a = O_a^k \gamma_k$ is the analog of $\epsilon^k \gamma_k$ for gauge boson. Now however the gamma matrices are CP_2 gamma matrices and O_a^k is some vector field in CP_2. The index a labels the isospin components of the meson.

2. What can one assume about O_a at the partonic 2-surfaces? In the case of pseudo-scalars pion and η (or vector mesons ρ and ω with nearly the same masses) one should have four such fields forming isospin triplet and singlet with large mass splitting. In the case of kaon would should have also 4 such fields but with almost degenerate masses. Why such a large difference between kaon and (π, η) system? A plausible explanation is in terms of mixing of neutral pseudo-scalar mesons with vanishing weak isospin mesons raising the mass of η but one might dream of alternative explanations too.

   (a) Obviously O_a:s should form strong isospin triplets and singlets in case of (π, η) system. In the case of kaon system they should form strong isospin doublets. The group in question should be identifiable as strong isospin group. One can formally identify the subgroup $U(2) \subset SU(3)$ as a counterpart of strong isospin group. The group $SO(3) \subset SU(3)$ defines second candidate of this kind. These subgroups correspond to two different geodesic spheres of S^2. The first gives rise to vacuum extremals of Kähler action and second one to non-vacuum extremals carrying magnetic charge at the partonic 2-surface. Cosmic strings as vacuum extremals and cosmic strings as magnetically charged objects are basic examples of what one obtains. The fact that partonic 2-surfaces carry Kähler magnetic charge strongly suggests that $U(2)$ option is the only sensible one but one must avoid too strong conclusions.

   (b) Could one identify O_a as Killing vector fields for $u(2) \subset su(3)$ or for its complement and in this manner obtain two kinds of meson states directly from the basic Lie algebra structure of color algebra? For $u(2)$ one would obtain 3+1 vector fields forming a representation of $u(2)$ decomposing to a direct sum of representations 3 and 1 of $U(2)$ having interpretation in terms of π and η the symmetry breaking is expected to be small between these representations. For the complement of $u(2)$ one would obtain doublet and its conjugate corresponding to kaon like states. Mesons states are constructed from the four states $U_i\overline{D}_j$, $\overline{U}_iD_j$, $U_i\overline{U}_j$, $D_i\overline{D}_j$. For $i = j$ one would have $u(2)$ and for $i \neq j$ its complement.

   (c) One would obtain a connection between color group and strong isospin group at the level of meson states and one could say that mesons states are not color invariants in the strict sense of the world since color would act on electroweak spin degrees of freedom non-trivially. This could relate naturally to the possibility to characterize hadrons at the low energy limit of theory in terms of electroweak quantum numbers. Strong force at low energies could be described as color force but acting only on the electroweak spin degrees of freedom. This is certainly something new not predicted by the standard model.

3. Covariant constancy of O_a at the entire partonic 2-surface is perhaps too strong a constraint. One can however assume this condition only at the the braid ends.

   (a) The holonomy algebra of the partonic 2-surface is Abelian and reduces to a direct sum of left and right handed parts. For both left- and right-handed parts it reduces to a direct sum of two algebras. Covariant constancy requires that the induced spinor curvature defining classical electroweak gauge field commutes with O_a. The physical interpretation is that electrowak symmetries commute with strong symmetries defined by O_a. There would be at least two conditions depending only on the CP_2 projection of the partonic 2-surface.

   (b) The conditions have the form

   $$F^{AB}j^a_B = 0 \ ,$$

   where a is color index for the sub-algebra in question and A, B are electroweak indices. The conditions are quadratic in the gradients of CP_2 coordinates. One can interpret F^{AB} as components of gauge field in CP_2 with Abelian holonomy and j^a as electroweak current. The condition would say that the electroweak Lorentz force acting on j^a vanishes at the partonic 2-surface projected to CP_2. This interpretation looks natural classically. The conditions are trivially satisfied at points, where one has $j^a_B = 0$, that is at the fixed points of the one-parameter subgroups of isometries in question. O_a would however vanish identically in this case.

(c) The condition $F^{AB}j^a_B = 0$ at all points of the partonic 2-surface looks un-necessary strong and might fail to have solution. The reason is that quantum classical correspondence strongly suggests that the color partial waves of fermions and planewaves associated with 4-momentum are constant along the partonic surface. The additional condition $F^{AB}j^a_B = 0$ allows only a discrete set of solutions.

A weaker form of these conditions would hold true for the braid ends only and could be used to identify them. This conforms with the notion of finite measurement resolution and looks rather natural from the point of view of quantum classical correspondence. Both forms of the conditions allows SUSY in the sense that one can add to the fermionic state at partonic 2-surface a covariantly constant right-handed neutrino spinor with opposite fermionic helicity.

(d) These conditions would be satisfied only for the operators O_a characterizing the meson state and this would give rise to symmetry breaking relating to the mass splittings. Physical intuition suggests that the constraint on the partonic 2-surface should select or at least pose constraints on the maximum of Kähler function. This would give the desired quantum classical correlation between the quantum numbers of meson and space-time surface.

4. The parallel translation between the ends connecting the partonic 2-surfaces at which quark and antiquark reside at braid ends is along braid strand defining the state of string like object at the boundary of CD. These stringy world sheets are fundamental structures in quantum TGD and a possible interpretation is as singularity of the effective covering of the imbedding space associated with the hierarchy of Planck constans and due to the vacuum degeneracy of Kähler action implying that canonical momentum densities correspond to several values for the gradients of imbedding space coordinates. The parallel translation is therefore unique once the partonic 2-surface is fixed. This is of outmost importance for the well-definedness of quantum states. Obviously this state of affairs gives an additional "must" for braids.

The construction recipe generalizes trivially to scalars. There is however a delicate issue associated with the construction of spin 1 partners of the pseudo-scalar mesons. One must assign to a spin 1 meson polarization vector using $\epsilon^k\gamma_k$ as an additional factor in the "charge matrix" slashed between fermion and antifermion. If the charge matrix is taken to be $Q_a = \epsilon^k\gamma_k j^a_k\Gamma^k$, it has matrix elements only between quark and lepton spinors. The solution of the problem is simple. The triplet of charge matrices defined as $Q_a = \epsilon^k\gamma_k D_k j^a_l\Sigma^{kl}$ transforms in the same manner as the original triplet under $U(2)$ rotations and can be used in the construction of spin 1 vector mesons.

4.3.2 Generalization to the construction of gauge bosons and spin 0 bosons

The above developed argument generalizes with trivial modifications to the construction of the gauge bosons and possible Higgs like states as well as their super-partners.

1. Now one must form bi-linears from fermion and anti-fermion at the opposite throats of the wormhole contact rather than at the ends of magnetic flux tube. This requires braid strands along the wormhole contact and parallel translation of the spinors along them. Hadronic strings are replaced with the TGD counterparts of fundamental strings.

2. For electro-weak gauge bosons O corresponds to the product $\epsilon_k\gamma^k Q_i$, where Q_i is the charge matrix associated with gauge bosons contracted between both leptonic and quark like states. For gluons the charge matrix is of form $Q_A = \epsilon_k\gamma^k H_A$, where H_A is the Hamiltonian of the corresponding color isometry.

3. One can also consider the possibility of charge matrices of form $Q_A = \epsilon^k\gamma_k D_k j^A_l\Sigma^{kl}$, where j^A is the Killing vector field of color isometry. These states would compose to representations of $u(2) \subset u(3)$ to form the analogs of (ρ,ω) and $(K^*,\overline{K}^*)$ system in CP_2 scale. This is definitely something new.

4. In the case of spin zero states polarization vector is replaced with polarization in CP_2 degrees of freedom represented by one of the operators O_a already discussed. One would obtain the analogs of (π,η) and $(K,\overline{K})$ systems at the level of wormhole contacts. Higgs mechanism for these does

not explain fermionic masses since p-adic thermodynamics gives the dominant contributions to them. It is also difficult to imagine how gauge bosons could eat these states and what the generation of vacuum expectation value could mean mathematically. Higgs mechanism is essentially 4-D concept and now the situation is 8-dimensional.

5. At least part of spin zero states corresponds to polarizations in CP_2 directions for the electroweak gauge bosons. This would mean that one replaces $\epsilon_k\gamma^k$ with $j_a^k\Gamma_k$, where j_a is Killing vector field of color isometry in the complement of $u(2) \subset su(3)$. This would give four additional polarization states. One would have 4+2=6 polarization just as one for a gauge field in 8-D Minkowski space. What about the polarization directions defined by $u(2)$ itself? For the Kähler part of electroweak gauge field this part would give just the (ρ,ω) like states already mentioned. Internal consistency might force to drop these states from consideration.

The nice aspect of p-adic mass calculations is that they are so general: only super-conformal invariance and p-adic thermodynamics and p-adic length scale hypothesis are assumed. The drawback is that this leaves a lot of room for the detailed modeling of elementary particles.

1. Lightest mesons are lowest states at Regge trajectories and also p-adic mass calculations assign Regge trajectories in CP_2 scale to both fermions and bosons.

2. It would be natural to assign the string tension with the wormhole contact in the case of bosons and identifiable in terms of the Kähler action assignable to the wormhole contact modelable as piece of CP_2 type vacuum extremal and having interpretation in terms of the action of Kähler magnetic fields.

3. Free fermion has only single wormhole throat. The action of the piece of CP_2 type vacuum extremal could give rise to the string tension also now. One would have something analogous to a string with only one end, and one can worry whether this is enough. The magnetic flux of the fermion however enters to the Minkowskian region and ends up eventually to a wormhole throat with opposite magnetic charge. This contribution to the string tension is however expected to be small being proportional to $1/S$, where S is the thickness of the magnetic flux tube connecting the throats. Only if the magnetic flux tube remains narrow, does one obtain the needed string tension from the Minkowskian contribution. This is the case if the flux tube is very short. It seem that the dominant contribution to the string tension must come from the wormhole throat.

4. The explanation of family replication phenomenon [K3] based on the genus of wormhole throat works for fermions if the the genus is same for the two throats associated with the fermion. In case of bosons the possibility of different genera leads to a prediction of dynamical SU(3) group assignable to genus degree of freedom and gauge bosons should appear also in octets besides singlets corresponding to ordinary elementary particles. For the option assuming identical genera also for bosons only the singlets are possible.

5. Regge trajectories in CP_2 scale indeed absolutely essential in p-adic thermodynamics in which massless states generate thermal mass in p-adic sense. This makes sense in zero energy ontology without breaking of Poincare invariance if CD corresponds to the rest system of the massive particle. An alternative way to achieve Lorentz invariance is to assume that observed mass squared equals to the thermal expectation value of thermal weight rather than being thermal expectation for mass squared.

It must be emphasized that spin 0 states and exotic spin 1 states togetherwith their super-partners might be excluded by some general arguments. Induced gauge fields have only two polarization states, and one might argue that that same reduction takes place at the quantum level for the number of polarization states which would mean the elimination of $F_L\overline{F}_R$ type states having interpretation as CP_2 type polarizations for gauge bosons. One could also argue that only gauge bosons with charge matrices corresponding to induced spinor connection and gluons are realized. The situation remains open in this respect.

4.4 What SUSY could mean in TGD framework?

What SUSY means in TGD framework is second long-standing problem. In TGD framework SUSY is inherited from super-conformal symmetry at the level of WCW [K2, K4]. The SUSY differs from $\mathcal{N} = 1$ SUSY of the MSSM and from the SUSY predicted by its generalization and by string models. One obtains the analog of the $\mathcal{N} = 4$ SUSY in bosonic sector but there are profound differences in the physical interpretation.

1. One could understand SUSY in very general sense as an algebra of fermionic oscillator operators acting on vacuum states at partonic 2-surfaces. Oscillator operators are assignable to braids ends and generate fermionic many particle states. SUSY in this sense is badly broken and the algebra corresponds to rather large $\mathcal{N}$. The restriction to covariantly constant right-handed neutrinos (in CP_2 degrees of freedom) gives rise to the counterpart of ordinary SUSY, which is more physically interesting at this moment.

2. Right handed neutrino and antineutrino are not Majorana fermions. This is necessary for separate conservation of lepton and baryon numbers. For fermions one obtains the analog $\mathcal{N} = 2$ SUSY.

3. Bosonic emergence [K13] means the construction of bosons as bound states of fermions and anti-fermions at opposite throats of wormhole contact. This reduces TGD SUSY to that for fermions. This difference is fundamental and means deviation from the SUSY of $\mathcal{N} = 4$ SUSY, where SUSY acts on gauge boson states. Bosonic representations are obtained as tensor products of representation assigned to the opposite throats of wormhole contacts. Further tensor products with representations associated with the wormhole ends of magnetic flux tubes are needed to construct physical particles. This represents a crucial difference with respect to standard approach, where one introduces at the fundamental level both fermions and bosons or gauge bosons as in $\mathcal{N} = 4$ SUSY. Fermionic $\mathcal{N} = 2$ representations are analogous to "short" $\mathcal{N} = 4$ representations for which one half of super-generators annihilates the states.

4. The introduction of both fermions and gauge bosons as fundamental particles leads in quantum gravity theories and string models to $d = 10$ condition for the target space, spontaneous compactification, and eventually to the landscape catastrophe.

   For a supersymmetric gauge theory (SYM) in d-dimensional Minkowski space the condition that the number of transversal polarization for gauge bosons given by $d - 2$ equals to the number of fermionic states made of Majorana fermions gives $d - 2 = 2^k$, since the the number of fermionic spinor components is always power of 2.

   This allows only $d = 3, 4, 6, 10, 16, ...$ Also the dimensions $d + 1$ are actually possible since the number of spinor components for d and $d + 1$ is same for d even. This is the standard argument leading to super-string models and M-theory. It it lost - or better to say, one gets rid of it - if the basic fields include only fermion fields and bosonic states are constructed as the tensor products of fermionic states. This is indeed the case in TGD, where spontaneous compactification plays no role and bosons are emergent.

5. Spontaneous compactification leads in string model picture from $\mathcal{N} = 1$ SUSY in say $d = 10$ to $\mathcal{N} > 1$ SUSY in $d = 4$ since the fermionic multiplet reduces to a direct sum of fermionic multiplets in $d = 4$. In TGD imbedding space is not dynamical but fixed by internal consistency requirements, and also by the condition that the theory is consistent with the standard model symmetries. The identification of space-time as 4-surface makes the induced spinor field dynamical and the notion of many-sheeted space-time allows to circumvent the objections related to the fact that only 4 field like degrees of freedom are present.

The missing energy predicted standard SUSY is absent at LHC. The easy explanation would be that the mass scale of SUSY is unexpectedly high, of order 1 TeV. This would however destroy the original motivations for SUSY.

In TGD framework the natural first guess was hat the missing energy corresponds to covariantly constant right-handed neutrinos carrying four-momentum. The objection is that covariantly constant right-handed neutrinos cannot appear in asymptotic states because one cannot assign a super-multiplet to right-handed neutrinos consistently. Covariantly constant right-handed neutrinos can however generate SUSY.

This alone would explain the missing missing momentum at LHC predicted by standard SUSY. The assumption that fermions correspond to color partial waves in H implies that color excitations of the right handed neutrino that would appear in asymptotic states are necessarily colored. It could happen that these excitations are color neutralized by super-conformal generators. If this is not the case, these neutrinos would be like quarks and color confimenent would explain why they cannot be observed as asymptotic states in macroscopic scales. So called leptohadrons could correspond to bound states of colored sleptons and have same p-adic mass scale as leptons have [K16]. Even in the case of quarks the situation could be the same.

Second possibility considered earlier is that SUSY itself is generated by color partial waves of right-handed neutrino, octet most naturally. This option is not however consistent with the above model for one-fermion states and their super-partners.

The breakthrough in the understanding of the preferred extremals of Kähler action and solutions of the modified Dirac equation led to a radical reconsideration of the existing picture. The most natural conclusion is that the TGD counterpart of standard SUSY is most naturally absent. The arguments in favor of this conclusion disussed in the last section are rather strong. The breakthrough in understanding of TGD counterpart for Higgs like particle - Euclidian M_{89} pion - led to a model for the generation of weak gauge bosons masses free of the problem of the standard Higgs mechanism caused by the fact that tachyonic mass term is not stable under radiative corrections (due to couplings of Higgs to fermions proportional to their masses). In TGD framework this kind of term is absent. Therefore also the basic motivation for standard SUSY as stabilizer of radiative corrections disappears. Standard space-time SUSY would be replaced with 4-D generalization of 2-D super-conformal invariance but restricted to the modes of right-handed neutrino. For other fermion states the modes would be restricted to 2-D string world sheets and partonic 2-surfaces and super-conformal symmetry would reduce to 2-D one. The 2-D super-conformal symmetry is mathematically analogous to badly broken SUSY with very large value of $\mathcal{N}$ and massive neutrino would represent the least broken aspect of this symmetry. The masses of sparticles are expected to be higher than particles for this SUSY.

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