Higgs or M_{89} hadron physics?

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1 Introduction

The newest results about Higgs search using 4.9/fb of data were published yesterday and there are many articles in arXiv. The overall view is that there is evidence for something around 125 GeV. Whether this something is Higgs or some other particle decaying to Higgs remains to my opinion an open question. Lubos of course is strong in this faith on Higgs. Somewhat surprisingly Tommaso Dorigo seems the result as a firm evidence for Higgs. Matt Strassler is skeptic. The evidence comes basically from Higgs to $\gamma\gamma$ decays. There are some ZZ and WW events. CMS represented also data for more rare events. There are also indications about something at higher masses and the interpretation of them depends on the belief system of the blogger.

Bloggers were very active and Phil Gibbs certainly the most active one.

- Phil Gibbs [5] gave online comments and combinations of various data in his blog. In particular, Phil produced a combination of data from ATLAS, CMS, LEP, and Tevatron clearly supporting the existence of bump around 124 GeV. Also the other plots by Phil are very illustrative of the situation: for instance this.

- Tommaso Dorigo commented the results. Tommaso gives many illustrations and sees the results as firm evidence for standard model Higgs and is skeptic about SUSY Higgs.

- Lubos Motl has a nice -abeit over-optimistic from SUSY point of view- summary about the results and useful links to the articles by ATLAS and CMS.
- I liked very much about Matt Strassler's critical comments making clear what is known and what is not known. Also Resonaances had added comments on Higgs. And many other bloggers.

In TGD framework Higgs like states seem to be un-necessary. Zero energy ontology predicts that all states with spin 1 are massive and the third polarization state is allowed by the generalization of the gauge condition excluding the third polarization in the case of massless states [5]. If one assumes Higgs like states, the particles which become massive "eat" all of them. Also photon, gluon, and graviton become massive and the small mass allows to get rid of infrared divergences plaguing gauge theories.

The basic question is whether the data could be interpreted as signatures of Higgs or of M_{89} hadron physics. This question is discussed in detail in [2]. Here I represent just the main arguments.

1. The basic observation is that the generalization of PCAC hypothesis leads to very similar predictions for the direct couplings of pseudo-scalar mesons as Higgs has and the decay rates are of the same form. The generalization of the hadronic sigma model with vacuum expectation value of sigma field replacing that of Higgs field makes it easy to understand the close resemblance but does not seem to be absolutely necessary unless one wants additional predictions. What is remarkable that the vacuum expectation of sigma field equals apart from sign to W boson mass.
2. If one believes in the indications about structures at higher masses than 125 GeV, one must conclude that standard Higgs hypothesis fails. M_{89} hadron physics might be able to explain these structures but the coupling X defined by $f_\pi = X m_\pi$ would be smaller for these higher pion-like states. One of them would be around 139 GeV.
3. TGD suggests that the spartners of quarks correspond to the same mass scale as quarks. The pion-like states with masses 139 GeV and 125 GeV would correspond to pion and spion (pair of squarks) which could have suffered mixing by exchange of gluino. The original proposal that spartners are generated by covariantly constant right-handed neutrino and antineutrino has the problem that it might produce just the same missing energy signatures of SUSY as ordinary SUSY and thus be excluded experimentally.

   The simplest way out is the assumption that covariantly constant neutrino generates gauge supersymmetry and thus creates zero norm states. It would be color octet state of neutrino that would generate the dynamical supersymmetry and states with a non-vanishing norm. Color confinement would not allow the usual missing energy signature so that everything would be consistent with what we have learned from LHC. Lepto-hadrons [4] would consist of pairs of sleptons which would be color octets so that same picture would apply to both leptons and quarks.
4. This is however not quite enough. There is evidence for a bumpy structure of signal cross section. The easy explanation is in terms of statistical fluctuations and time will show whether this explanation works. The bumpy structure suggests the existence of additional states not explainable in terms of the doubling predicted by TGD SUSY. Rather remarkably, the already mentioned quite recent anomaly suggests that similar phenomenon is encountered also in ordinary hadron physics.

   According to a three-year old discovery [**?**], there is evidence for narrow pion-like and nucleon like states with a mass splitting which is of order few tens of MeV. p-Adic fractality predicts the same in the case of M_{89} hadron physics and the observed bumpy structure might have interpretation in terms of "infra-red" Regge trajectory with string tension assignable to the color magnetic flux tubes accompanying light quarks. This string tension is dramatically smaller than the hadronic string tension of order 1 GeV and measured using 10 MeV as a unit.

   Needless to say, the existence of the exotic hadrons would kill QCD as a theory of strong interactions and provide a strong support for the notion of color magnetic flux tube central for TGD vision about hadrons.

   An alternative explanation would be rely on Shnoll effect [1] implying the splitting of resonances to separate peaks. It is not clear whether the explanations exclude each other. The question

"Higgs or M_{89} hadron physics or something else?" will be probably answered within a year as the statistics from LHC improves.

2 The new data about Higgs candidate

2.1 Overall view

It is good to try to summarize what has been found.

1. According to ATLAS the bump is at 126 GeV. Altogether gamma-gamma and ZZ events give 3.6 sigma deviation reducing to 2.3-2.5 sigma by look-elsewhere effect.

2. According to CMS the bump resides at 124 GeV. CMS has 2.6 sigma deviation reducing to 1.9 sigma when look- elsewhere effect is taken into account.

3. The positions of bumps reported by ATLAS and CMS are not quite same so that there is still room for the possibility that the bumps are artifacts.

4. Both collaborations publish also the results about signal for Higgs to ZZ decays. Fig 7 in ATLAS eprint [?]eports three candidates Higss to ZZ events at 123.6 GeV, 124.3 GeV , and 124.8 GeV. CMS reports results about decays to $b\bar{b}$, $\tau\overline{\tau}$, WW, ZZ,$\gamma\gamma$, combines the data from various channels, and compares signal cross sections to those predicted by standard model Higgs. There is structure around 145 GeV in some channels. There is also data about higher energies bump like structures both below and above 300 GeV. Maybe the standard model Higgs is not enough. SUSY indeed predicts several Higgs like states and M_{89} hadron physics entire meson spectroscopy.

2.2 $\gamma\gamma$ channel

Both ATLAS [2] and CMS [4] have published an reprint in arXiv about Higgs to $\gamma\gamma$ signal.

The ratio of the $\gamma\gamma$ signal cross section to the cross section predicted by standard model is given together with 1 and 2 sigma bands describing the background signal without Higgs contributions.

1. Fig 8 in ATLAS paper gives the observed and expected 95 per cent confidence level limits as a function of hypothesized Higgs boson mass.

2. Fig 3 of CMS paper gives bump around 124 GeV.

I wish I would understand the strange oscillating behavior for the ratio of signal cross section to cross section for signals mimicking Higgs predicted in absence of Higgs. There are bumps around 126 GeV, 139 GeV and 146 GeV. Is this an artifact produced - say - by a discretization in the data processing. There is also a small bump around 113 GeV.

I am a statiastical dilettante so that I can make an innocent and possibly stupid question: Could these bumps be something real? For standard model Higgs this is certainly not the case but what about TGD inspired view [2] about new physics at LHC. Going to another extreme: could all bumps with 126 GeV bump included be only data processing artifacts? We do not know yet.

Also the probability p_0 that standard model without Higgs could explain the signal cross section is plotted.

1. Fig 7 of ATLAS paper [2] gives the observed and expected p_0 values as a function of the mass of hypothesized Higgs. Small p_0 tells that standard model without Higgs contribution requires upwards fluctuation whose probability is p_0 to explain the observed signal. There are strong downwards bumps at about 126 GeV and around 145 GeV. They are deeper than the prediction of standard model Higgs which might give rise to worries. There is also something very small at 139 GeV.

2. Fig 4 of CMS paper [4] gives similar plot. Now the bumps of p_0 are around 123.5 GeV, 137 GeV, and 147.5 GeV.

If taken at face value, also these figures suggest three-bump structure. This might well be a statistical artifact but one can make questions and one fool like me can make more or them than the wise guys are able to answer. Here are two of them.

1. Could M_{89} pion have higher excitations with a mass scale of 10-20 GeV? Could the pion-like state generating the signal besides ground state also excitations with excitation energy scale of order 20 GeV? Could these excitation assigned with the color magnetic flux tube structures associated associated with scaled up u and d quarks.

   A rough guess for the p-adic prime of scaled up u and d quark in M_{89} hadron is $k = 113-18 = 95$ ($k = 113$ corresponds to Gaussian Mersenne and nuclear p-adic length scale). This corresponds to the p-adic mass scale the estimate 16 GeV from electron's p-adic mass scale about .25 MeV. It however turns out that the actual mass must be by a factor two higher so that one would have 32 GeV mass scale.

   Could stringy excitations with string tension determined by 32 GeV scale be in question? If so then also ordinary pion should have similar fine structure in mass spectrum with energy scale of 31 MeV assignable with u and d quarks with $k = 113$. I have a vague memory that Tommaso Dorigo had reported something about low energy excitations of pion but I failed to find anything about this in web and concluded that I must have been hallucinating.

2. Shnoll effect is something which main stream colleagues certainly refuse to take seriously. In TGD framework one can develop a p-adic model for Shnoll effect, [1], which can be justified in terms of quantum arithmetics [6] giving a first principle justification for the canonical identification playing a key role in p-adic mass calculations. Typically a probabiity distribution with single bump decomposes to several ones and the phenomenon occurs also in nuclear physics.

   Could this deformation be at work even in particle physics? If so, it could cause the splitting of single very wide resonance bump around 125 GeV to several sharper bumps. Even the bump like structure at 113 GeV could correspond to this wide resonance bump. The original resonance bump could be rather wide: something like 30-40 GeV. Very naive guess would be that the width of leptopion obeys able to decay to ordinary quarks $\Gamma \sim \alpha_s(89)m(\pi_{89})$. Already for $\alpha_s = .1$ one could have a bump with width of about 15 GeV. For ordinary pion the impossibility of strong decays would not allow Shnoll effect. The splitting into sub-bumps by Shnoll effect would make this wide bump visible.

After a painful web search I managed to find an article [1] titled *Search for low-mass exotic mesonic structures: II. Attempts to understand the experimental results* reporting that there is experimental support for narrow excited states of pion at masses 62, 80, 100, 140, 181, 198, 215, 227.7, and 235 MeV (authors mention that the last might be uncertain). The states at 100, 140, and 198 MeV are half octaves of the lightest state. The article fits the states to Regge trajectories but it is not possible to use single slope for all states. The mass differences vary between 10 and 40 GeV so that the scale is what one would expect from the above string argument. Also Shnoll effect might explain the existence of the bumps and if the explanations are consistent the spectrum of the pion states is dictated by number theoretical arguments to a high degree.

2.3 Combination of signals from all channels

CMS has also a preprint about the combination of signals from all decay channels of Higgs.

1. CMS gives also a figure combination of all CMS searches ($\gamma\gamma$, bb,$\tau\tau$, WW, ZZ) [3].

2. Figure 1 of CMS article [3] shows a clear structure around 124 GeV. There is another structure around about 145 GeV. In standard model Higgs scenario the structure at 145 GeV would not be taken seriously since the cross section need to produce the bump would be much below the predicted one but if one accepts super-symmetric M_{89} hadron physics, the situation changes. There is also structure around 325 GeV and in the range 260-285 GeV. M_{89} hadron physics would assign these structures to vector mesons ρ and ω_{89} and corresponding smesons consisting of squark and anti-squark.

3. CMS gives a plot comparing the ratio of best fit for signal cross section to the predicted cross section for Higgs to $b\overline{b}$, $\tau\overline{\tau}$, $\gamma\gamma$, ZZ,WW. The fit is rather satisfactory for Higgs to $\gamma\gamma$ the signal cross section is about 1.7 times higher than predicted. One cannot deny that this can be seen as a strong support for standard model Higgs.

   The original idea behind M_{89} hadron physics was that it effectively replaces Higgs. If one takes the CMS result seriously this idea must be realized rather concretely: the predicted signal cross sections must be rather near to those predicted by standard model Higgs. The crucial tests are decay rates to fermion pairs and the possibly existing other resonances.

2.4 Higgsy character of 126 GeV bump is not proven!

Lubos has written a new post [**?**, **?**] where he makes the strange assumption that if there is a signal it must be Higgs. Lubos also uses as a "proof" of Higgsyness the fit of Phil for which the gamma-gamma signal cross section at maximum equals to the prediction. This holds true because the fit forces it to hold true! For some reason Lubos "forgets" this!

By inspecting the figure more closely one finds that the observed cross section has a long tail unlike the predicted cross section. This long tail could correspond to the large width of resonance splitting into sub-bumps if Shnoll effect is present. If Higgs option is correct, this tail should disappear as statistics improves. Also the other structures which are present, should disappear.

What is of course remarkable that CMS paper shows that $H \rightarrow \gamma\gamma$ cross section is of the same order of magnitude and only about 1.7 times higher than the predicted cross section. This gives a constraint onM_{89} hadron physics, which it of course might fail to satisfy unless the idea about replacement of Higgs withM_{89} hadron physics is true at a rather quantitative level.

One should also keep in mind that the value of Higgs mass is at the lower bound for the range with stable Higgs vacuum. This is not a good sign. An interesting question is whether the mass for pion-like state ofM_{89} hadron physics is in some sense also minimal and what this minimality could mean physically: some kind of criticality - maybe on instance of quantum criticality of TGD Universe- but not criticality against the decay of Higgs vacuum?

To sum up, one can agree with the official statement: the situation remains open. What is nice that there very probably is a signal and from TGD point view the nice thing is that this signal is still consistent with M_{89} hadron physics. To sum up, one can agree with the official statement: the situation remains open. What is nice that there very probably is a signal and from TGD point view the nice thing is that this signal could is still consistent with M_{89} hadron physics.

3 Higgs or M_{89} hadron physics?

The comments of Lubos and Andrew Oh-Willeke to the blog posting about LHC data release inspired some comments on my side. These hastily typed comments were imprecise and I decided to write an improved version collecting the main points to a more organized structure. I want also to write about these topics to clarify myself some important open issues in my own approach and I will do my best to debunk myself in the following. I will very probably make imprecise and even wrong statements. This is work in progress. Apologies.

3.1 The basic issues

1. The basic issue is whether the signal at LHC is a compelling evidence for Higgs or not. My claim is that it tells only that there is scalar or pseudo-scalar producing the signal and that under rather general assumptions this signal can be even quantitatively equivalent with the Higgs signal for the recently studied signatures.

2. Enthusiasts also forget that the signal cross section has features which do not favor its interpretation in terms of Higgs. Exclusion of Higgs does not mean the exclusion of signal! The clear structures around 135 and 145 GeV have not disappeared, there is a wide bump like structure in the entire region 110-150 GeV, and there is structure at both sides of 300 GeV. All these structures should disappear with increased statistics if Higgs interpretation is correct. We do not know whether this will happen and the natural question is whether one could interpret these structures by replacing Higgs paradigm with something else.

3. Higgs is also disfavored by profound theoretical reasons. It is just around the border of instability against the decay of vacuum. Could this criticality be a signal about the need to replace Higgs with something else? Presumably a microscopic description of particle massivation (provided by TGD already 15 years ago in terms of p-adic thermodynamics). Or are we happy with Higgs phenomenology which only reproduces instead of predicting?

3.2 Brief summary of the main results

The main results hitherto - preliminary of course - are following.

1. Various decay rates of pion like states of M_{89} hadron physics [2] can be estimated using the generalization of partially conserved axial vector hypothesis (PCAC) stating that the divergence of the axial vector current is proportional to pion field. The proportionality constant is $f_\pi m_\pi^2$. The divergence of axial current equals to the sum of instanton densities for electro-weak gauge fields and color gauge field plus the divergence of axial vector currents for u and d type quarks assuming that they are massive: this divergence is by Dirac equation proportional to the mass of the quark.

   The contribution of more massive quarks is absent, which is quite a remarkable difference as compared to the standard model Higgs for which the decay amplitudes to massive quark pairs are the most important ones by the proportionality of Higgs-fermion coupling to quark mass. This holds true in M^4 effective QFT picture: one can hope that it is a good approximation. It is is indeed known to work in orfdinary low energy hadron physics and p-adic fractality suggests that the same holds true for M_{89} hadron physics.

2. If the generalization of hadronic sigma model involving u and d type is accepted then f_π can be identified as the negative of the vacuum expectation value of sigma field: $f_\pi = -v$. The inspection of the decay rates of Higgs in standard model [2] and those predicted by PCAC (Iztykson-Zuber [1] is my source) shows that their structure is identical. This strongly suggests that by replacing Higgs vacuum expectation value by a suitable multiple of sigma field vacuum expectation it might be possible to reproduce all decay rates of standard model Higgs. This would apply also at the level of amplitudes.

   This kind of duality like relation would not be terribly surprising since the structure of these two models is very similar. This would allow to estimate the decay rates of pionlike state to various channels and have very similar results for the decay rates to weak gauge bosons and also to the states produced via the decay to virtual gauge boson pair decaying to quarks or leptons. The direct decays to other than u and d quark pairs do not appear in the lowest order.

3. Assuming $X = f_\pi/m_\pi = 91/140 = .65$ as for ordinary pion, the decay of pion-like state to gamma pair implied by PCAC is under very natural assumptions by a factor 1.54 times larger that the decay reate of Higgs. The observed signal cross section for gamma pair production by 125 GeV state is by the same factor about 1.5 higher than that predicted by the standard model! The value of $f_\pi = -v = -81.3$ GeV to be compared with W boson mass 80.4 GeV. $f_\pi = -m_W$ would give $m(\pi_{89}) = 123.6$ GeV which is second favored value for the mass of the resonance.

   This does not yet allow to shout *Heureka!* and claim that M_{89} pion hypothesis beats Higgs hypothesis. The production rates for Higgs and pion like state need not be the same. If however the production by fusion of electroweak bosons and gluons dominates and is described by PCAC (action would be just then one has excellent hopes that the production rates could indeed be identical for a propose choice of the parameter X! There is also associated production in which W or Z boson emitted by a scattered quark in either proton emits Higgs boson. Also this vertex would be governed by PCAC, when Higgs is replaced by M_{89}.

4. The experimental data suggests that Higgs signal is much smaller than the predicted signal above 127 GeV but has bump like structure and at bumps larger than the effective signal from the standard model background. Also the p-value telling the probability that standard model background is able to explain the signal cross section has sharp downwards peaks at two other masses about 127 GeV. TGD interpretation would be in terms of pion like states. This interpretation makes sense only if the proportionality coefficient X in $f_\pi = X m_\pi$ is considerably

large than its value for ordinary pion and lowest pion like state given by $X = 91/140 \sim 1.54$. This reduces the various couplings of pion like state by a factor $1/X^2$. This is of course possible but one should have a good explanation for why X increases with the mass of pseudo-scalar state.

One can clearly say that sigma model for low-lying M_{89} hadrons replaces Higgs mechanism as an approximate QFT description in TGD framework and a duality like relation between sigma model description of the meson decay amplitudes and those of standard model Higgs is highly suggestive.

In the following I will also criticize various aspects of the TGD vision about both ordinary and M_{89} hadron physics for the simple reason that this is the best manner to make progress if one is on the right track.

1. TGD SUSY is also in central role if one believes that higher pion like states are there and have explanation in terms of SUSY. 125 GeV pion like state would be apart from mixing effects spion consisting of squark pair. The assumption is that SUSY is essentially unbroken and that mixing of the quarks implies that mass squared matrix is non-diagonal having element between meson and smeson states.

   (a) The first possibility is that the second eigenstate is tachyonic due to very strong mixing proportional to α_s and must be excluded from the spectrum.

   (b) Second - aesthetically more attractive - option is that second eigenstate indeed is there and quite recently I indeed found evidence for narrow resonances with quantum numbers of pion [1] with mass differences between states typically in the range 10-40 MeV. Some of these might be SUSY states.

2. The experimental evidence suggests that pion has satellites but that their number is much larger than SUSY alone predicts. The bumpy structure of Higgs-like signal cross section suggests the same for M_{89} hadron physics. There are two alternative but not mutually exclusive explanations. The color magnetic flux tubes for light quarks have length of the order of Compton length and one could assign to them a string tension and IR Regge trajectories. Another explanation would be in terms of Shnoll effect implying that probability distributions with single peak decompose to distribution with several peaks. The TGD based explanation of Shnoll effect suggests that it is universal and could take place even at the level of particle physics.

3. A strong objection against TGD SUSY is that there is no missing energy signal which should result from the decays of squarks to quark and $\tilde{W}$ decaying in turn to lepton and sneutrino. This objection forces to consider a possible modification of the recent belief system. The covariantly constant right handed neutrino could act as super gauge symmetry annilating physical states. This reduction of SUSY is standard mechanism of SUSY breaking. The color octet CP_2 partial wave of right handed neutrino would generate superpartners. Color confinement would eliminate the decays producing right handed sneutrinos as missing energy. What would be nice is that leptohadrons could be interpreted in terms of color octet sleptons (dark in TGD sense) and TGD SUSY would be realized in a similar manner both for leptons and quarks and would have been discovered for decades ago. This is of course a speculation and p-adic mass calculations should be carried out to check whether this proposal really works.

4 Similarities and differences between Higgs and pion like state

The original - now 15 year old - vision was that M_{89} hadron physics or more precisely (pseudo-scalar) mesons of M_{89} hadron physics replace Higgs. Technicolor could be seen analogous proposal but extending the gauge group.

The first argument in favor of Higgs instead of a pion-like state is that the signal cross section is of the same order of magnitude as the predicted signal cross section. $\gamma\gamma$ cross section is only by a factor about 1.5 larger than the predicted one. This argument need not however bite.

4.1 PCAC implies similarity of Higgs and M_{89} pion

The key observation is that the generalization of PCAC from ordinary hadron physics to M_{89} hadron physics implies what might be seen as duality like relation at the level of decay amplitudes of Higgs and pionlike states of M_{89} hadron physics. If one is ready to take seriously the sigma model description of hadron physics this duality like relation becomes even more concrete since the vacuum expectation of Higgs field corresponds to the vacuum expectation of sigma field for M_{89} hadron physics. The vacuum expectation would now determine the mass of the M_{89} proton and would not say anything about the masses of fermions predicted by p-adic mass calculations.

1. Gauge symmetry alone implies that the couplings of charged pion like states regarded as particle fields (approximation) to weak gauge bosons are same as in the case of Higgs.
2. For the decays of Higgs to $\gamma\gamma$ the fermion and charged gauge boson loops involve direct couplings of Higgs to fermions and W boson. Also for WW and ZZ decays there is direct coupling for Higgs.
3. For neutral pseudo-scalars the generalization of PCAC [1] from ordinary low energy hadron physics suggests a universal mechanism allowing to describe all couplings of the pion like state boson and fermion pairs. These three particle couplings would replace corresponding couplings for Higgs. Note that in the case of Higgs the couplings gluons and photon are radiative and thus involve loops. Therefore the descriptions would be very similar structurally.
4. This description could apply also to the decays of other mesons than pion. This mechanism should have also a supersymmetric generalization. The basic assumption is that pion like state is proportional to the divergence of the axial current constructed from u and d type quarks and the instanton densities assignable to gauge boson: $\pi = \partial_\mu j_5^\mu / f_\pi m_\pi^2$. This hypothesis taken in the sense of effective action allows to describe both the decays of pion like states and their production amplitudes. The basic parameter characterizing the pion like state is the proportionality coefficient X in $f_\pi = X m_\pi$. The assumption that X is for 125 GeV same as for ordinary pion implies $X = 1.54$ and $f_\pi = -m_W$ for for $m(\pi) = 123.6$ GeV. The emergence of m_W as vacuum expectation value is highly encouraging since the number of parameters would be reduced by one.
5. PCAC implies that all couplings of pionlike state are proportional to $1/f_\pi m_\pi^2 = 1/X m_\pi^3$. The divergence of the axial current is essentially $\partial_\mu j_5^\mu = 2m\overline{\psi}\gamma_5\psi$ and has the same mass proportionality as the coupling of Higgs if one requires that Higgs mechanism produces Higgs masses. In TGD framework Higgs mechanism is replaced by massivation based on p-adic thermodynamics. Only u and d quarks (and squarks) contribute to the axial current in the case of pion like states. The generalization for higher M_{89} pseudoscalar mesons would allow only couplings to fermion pairs appearing in the the decomposition of the meson to quark pairs. This is an important distinction between TGD and ordinary Higgs mechanism. For instance, the decays of pion like states to lepton pairs are forbidden in the lowest order unlike in the case of Higgs. A good guess is that allow a description in terms of PCAC coupling and loops involving gauge boson exhange or decay to virtual gauge boson pair annihilating to fermion pair.

4.2 Could Higgs mechanism have M_{89} sigma model as counterpart?

Sigma model for nucleon, pion and sigma meson involves the analog of Higgs mechanism [1] so that it might be possible to develop rather close analogies. What is intriguing is the connection between strong and weak interactions expressed by conserved vector current hypothesis and partially conserved axial current hypothesis. The question is whether this connection could generalize to all electroweak axial currents and be useful in understanding of M_{89} hadron physics?

1. Could sigma model description make sense as an approximation in M_{89} hadron physics at low energies? If so this model would give generalization of the familiar relations used in low energy hadron physics. For instance, the mass of M_{89} nucleon would satisfy $m_N = gv$, where g is pion-nucleon coupling. The interpretation of sigma field and its vacuum expectation is interesting of course. The status of sigma in ordinary hadron physics has remained unclear and could be used as an objection against this kind of approach.

2. Could sigma model as M^4 QFT approximation bring in non-perturbative aspects such as the non-analytical dependence of the decay rate to gamma pair? Non-perturbative aspects for weak interactions would reduce to non-perturbative aspect of strong interactions understandable in terms of parton-string duality of generalized Feynman diagrams. The vacuum expectation v of sigma field equals to $v = -f_\pi$ and the decay width of pion to two-gamma and presumably also to other final states is proportional to $1/v^2$ just like the decay rates of Higgs boson are.

3. Could sigma model description of M_{89} hadron physics replace the description in terms of standard model Higgs mechanism which fails because Higgs mass has the critical value at which vacuum ceases to be stable? What it means that the vacuum expectation value for sigma field equals to W boson mass within experimental uncertainties?

4.3 Comparison of the decay width to gamma pairs for pion like state and Higgs

As an example one can consider the decay rate of pion like state to gamma pairs using PCAC. Axial current anomaly tells that the divergence of the axial current is $f_\pi m_\pi^2$ times 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 the decay width of pion to two-gamma would be given as

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

   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. For the decay of Higgs to two photons the rate is

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

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

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

   For $X = 91/140$ and $m(h) = m(\pi) = 123.6$ GeV this gives $r = 1.54$ and $f(\pi) = m_W$. The ratio of the observed Higgs to gamma pair signal cross section to the predicted one is very near to this value! If also the production amplitudes are same as in the case of Higgs as PCAC suggests and strong analogy with sigma model suggests, there are excellent hopes of obtaining correct signal cross section.

The decays to other gauge bosons can be treated in the similar manner. In the case of ZZ and WW only virtual states decaying to fermion pairs are possible but also in this case PCAC gives the vertex for the decay to virtual ZZ or WW pair and standard model vertices describe the decays of gauge bosons to lepton or quark pairs.

4.4 Comparison of the decay widths of Higgs and pion like states to fermions

The decays to fermion pairs would be mediated by two mechanisms.

1. Neutral M_{89} pion (spion) consists of superposition of p-adically scaled variant of $u\overline{u}$ and $d\overline{d}$ pair or a pair consisting of their spartners and by PCAC can be said to contain also a contribution expressible proportional to the sum of instanton densities of various gauge fields. In the lowest order the decays are expected to take mostly to $u\overline{u}$ and $d\overline{d}$ quark jet pairs and gamma pairs since the decay to WW and ZZ pairs is kinematically forbidden. Also the decays to gluon pairs are possible and produce hadronic jets. In Higgs scenario $b\overline{b}$ and $\tau\overline{\tau}$ are favored since direct decays to these are possible.

2. One can consider also higher order contributions to the decays. The pseudo-scalar couples democratically to all fermion pairs via the annihilation to virtual gauge boson (Z, W, γ, gluon) pair decaying to fermion pair. The couplings to gauge boson pairs are dictated by M_{89} generalization of PCAC and given by the instanton terms for gauge boson fields. This gives $1/v^2$ proportionality with $v = -f_\pi = Xm_\pi$. Similar factors appear also in Higgs decay rates as a consequence of Higgs mechanism and one expects the kinematical factors depending on mass to be essentially the same. The divergence of the fermionic contribution to the axial current is proportional to the mass of fermion so that the coupling to fermion pairs is proportional to fermion mass as in the case of Higgs boson.

3. The killer prediction is that for lepton pairs and also for quark pairs other than $u\overline{u}$ and $d\overline{d}$ the production is possible only in higher order. This should allow to distinguish between TGD and standard model. Reliable estimates for the decay rates of pion like states to all channels would be needed and should be compared with those for Higgs. At this moment most of the data is about $\gamma\gamma$ decay mode. About ZZ the are only some events and fermion pairs the data is meager.

Remark: It must be warned that in TGD framework one has $M^4 \times CP_2$ spinors and M^4 scalars/ pseudoscalars are necessarily CP_2 vectors/ axial vectors. This might mean some technical problems for M^4 QFT limit.

4.5 How to test the differences?

One can test this picture against Higgs hypothesis.

1. The presence of charged companions of Higgs like states is something new and a test for the scenario.

2. Signal cross sections have structure around 140 GeV and at both sides of 300 GeV. There are very clearly visible as peaks also in the probabiity p_0 that the signal cross section can be understood in terms of background only. The believer on Higgs can only hope that these structures disappear with bigger statistics. The interpretation in terms of M_{89} mesons would be natural in TGD framework. For the higher pion like states the parameter $X(\pi)$ must be smaller since the signal cross section is considerably belo that predicted by standard model.

5 Criticism of SUSY in TGD sense

Supersymmetry in TGD sense is essential for the proposed interpretation of Higgs like signals in terms of mixtures of pion and spion of M_{89} hadron physics. Giving up SUSY would mean giving up the idea that the structures at higher masses than 125 GeV are real. At this moment one cannot of course say anything definite about this.

The proposal inspired by the mysterious X and Y charmonium states is that SUSY is exact in the sense that p-adic mass scales of particle and spartner are same - even the masses could be same. 125 GeV bump would be mixture of pion and spion. The earlier bump at around 139 MeV would be neutral pion and bump around 144 GeV would correspond to charged pion. ρ, ω and the corresponding smeson states would be at both sides of 300 GeV (note that smeson means squark pair rather than super-partner of meson).

5.1 Super-symmetry and hadron physics

So called X and Y bosons are mysterious creatures having no obvious place in the quark model. They seem to consist of charmed quarks but they decay systematics suggest that something differentiates between these quarks and charmed quarks in the ordinary charmonium states. The TGD proposal [2] is that the super-partners of quarks have same the p-adic mass scale and even mass as quarks. There would be however a mixing between mesons and smesons and for light mesons this mixing would be very large making the second eigen state of mass squared matrix tachyonic and kicking it out of spectrum so that light mesons would be strong mixtures of mesons and smesons. For heavier quarks such as c the mixing would not be so large since color couplings strength would be reasonably small and one would obtain both mesons and smesons. The prediction is that also the mesons consisting of bbar pair would have smeson counterparts.

A further obvious objection is that intermediate gauge boson decay widths exclude light fermions. TGD based view about dark matter as ordinary particles with non-standard value of Planck constant and the fact that particles with different values of Planck constant cannot appear in the same vertex, allows to circumvent this objection. The superpartners would correspond to non-standard value of Planck constant.

Same picture about squarks would apply to M_{89} hadron physics and the failure to detect spartners at LHC would be the use of wrong signatures. Shadronization would be much faster process than the decay of squarks to quarks and electro-weak gauge bosons and missing energy so that these events would not be observed. Shadrons would in turn decay to hadrons by gluino exchanges.

This looks nice but there are objections.

1. The first objection relates to the tachyonicity. Mesons and smesons consisting of squark pair mix and for large α_s the mixing is large and can indeed make second eigenvalue of the mass squared matrix negative. If so, these states disappears from spectrum. At least to me this looks however somewhat unaesthetic.

   Luckily, the transformation of second pion-like state to tachyon and disappearance from spectrum is not the only possibility. After a painful search I found experimental work [1] claiming the existence of states analogous to ordinary pion with masses 60, 80, 100, 140,.... MeV. 100 GeV is first downwards half-octave of pion with mass about 140 MeV and also second half octave is there. Could it be that one of these states is spion predicted by TGD SUSY for ordinary hadrons? (But what about other states? They are not spartners: what are they?)

2. The second objection relates to the missing energy. SUSY signatures involving missing energy have not been observed at LHC. This excludes standard SUSY candidates and could do the same in the case of TGD. In TGD framework the missing energy would be eventually right handed neutrinos resulting from the decays of sfermions to fermion and sneutrino in turn decaying to neutrino and right handed neutrino. The above naive argument says that strong interactions are faster than weak decays of squarks to quark and spartner of weak boson whose decay would produce the usual signatures of SUSY so that shadronization would take place instead of production of the SUSY signatures. The problem with this argument is that the weak decays of squarks producing right handed neutrinos as missing energy are still there!

   This objection forces to consider the possibility that covariantly constant right handed neutrino which generates SUSY is replaced with a color octet. Color excitations of leptons of leptohadron hypothesis would be sleptons which are color octets so that SUSY for leptons would have been seen already at seventies in the case of electron. The whole picture would be nicely unified. Sleptons and squark states would contain color octet right handed neutrino the same wormhole throats as their em charge resides. In the case of squarks the tensor product $3 \otimes 8 = 3 + \overline{6} + 15$ would give several colored exotics. Triplet squark would be like ordinary quark with respect to color.

   Covariantly constant right-handed neutrino as such would represent pure gauge symmetry, a super-generator annihilating the physical states. Something very similar can occur in the reduction of ordinary SUSY algebra to sub-algebra familiar in string model context. By color confinement missing energy realized as a color octet right handed neutrino could not be produced and one could overcome the basic objections against SUSY by LHC.

This is view about TDG SUSY is just one possibility. The situation is not completely settled and one must keep mind open.

5.2 Exotic pion like states: "infra-red" Regge trajectories or Shnoll effect?

The experimental claim is that pion is accompanied by pion like states with mass 60, 80, 100, 140, 181, 198, 215, 227.5, and 235 MeV means that besides spion also other pion like states should be there. Similar satellites have been observed for nucleons with ground state mass 934 MeV: the masses of the satellites are 1004, 1044, 1094 MeV. Also the signal cross sections for Higgs to gamma pairs at LHC [2, 4] suggest the existence of several pion and spion like states, and this was the reason why I decided to to again the search for data about this kind of states (I remembered vaguely that Tommaso Dorigo had talked about them but I failed to find the posting). What is their interpretation? One can imagine two explanations which could be also equivalent.

1. The states could be "infrared" Regge trajectories assignable to magnetic flux tubes of order Compton length of u and d quark (very long and with small string tension) could be the explanation. Hadron mass spectrum would have microstructure. This is something very natural in many-sheeted space-time with the predicted p-adic fractal hierarchy of physics. This conforms with the proposal that all baryons have the satellite states and that they correspond to stringy excitations of magnetic flux tubes assignable to quarks. Similar fine structure for nuclei is predicted for nuclei in nuclear string model [3]. In fact, the first excited state for ^4He has energy equal to 20 MeV not far from the average energy difference 17.5 MeV for the excited states of pion with energies 198, 215, and 227.5 MeV so that this state might correspond to an excitation of a color magnetic flux tube connecting two nucleons.

2. The p-adic model for Shnoll effect [1] relies on universal modification of the notion of probability distribution based on the replacement of ordinary arithmetics with quantum arithmetics. Both the rational valued parameters characterizing the distribution and the integer or rational valued valued arguments of the distribution are replaced with quantum ratinals. Quantum arithmetics is characterized by quantum phase $q = exp(i2\pi/p)$ defined by the p-adic prime p. The primes in the decomposition of integer are replaced with quantum primes except p which remains as such. In canonical identification powers of p are mapped to their inverses. Quite generally, distributions with single peak are replaced with many peaked ones with sub-peak structure having number theoretic origin. A good example is Poisson distribution for which one has $P(n) = \lambda^n/n!$. The quantum Poisson distribution is obtained by replacing λ and $n!$ with their quantum counterparts. Quantum Poisson distribution could apply in the case of resonance bump for which the number of count in a given mass squared interval is integer valued variable.

   There are objections against Shnoll effect based explanation.

   (a) If the p-adic prime assignable to quark or hadron characterizes quantum arithmetics it is not distinguishable from ordinary arithmetics since the integers involved are certainly much smaller than say $M_{107} = 2^{107} - 1$. In the case of nuclear physics Shnoll effect involves small primes so that this argument is not water tight. For instance, if $p = 107$ defines the quantum arithmetics, the effects would be visible in good enough resolution and one might even expect variations in the bump structure in the time scale of year.

   (b) The effect is present also for nucleons but the idea about a state with large width splitting into narrower bumps does not fit nicely with the stability of proton.

   For Higgs like signals IR-Regge trajectories/Shnoll effect would be visible as a splitting of wide bumps for spion and pion of M_{89} physics to sub-bumps. This oscillatory bumpy structure is certainly there but is regarded as a statistical artifact. It would be really fascinating to see this quantum deformation of the basic arithmetics at work even in elementary particle physics.

The prediction of the additional pion-like states is one of the predictions of TGD about hadron physics at low energies and one of the first tasks is to look quantitatively possible realizations of Shnoll effect in the case of resonances.

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