
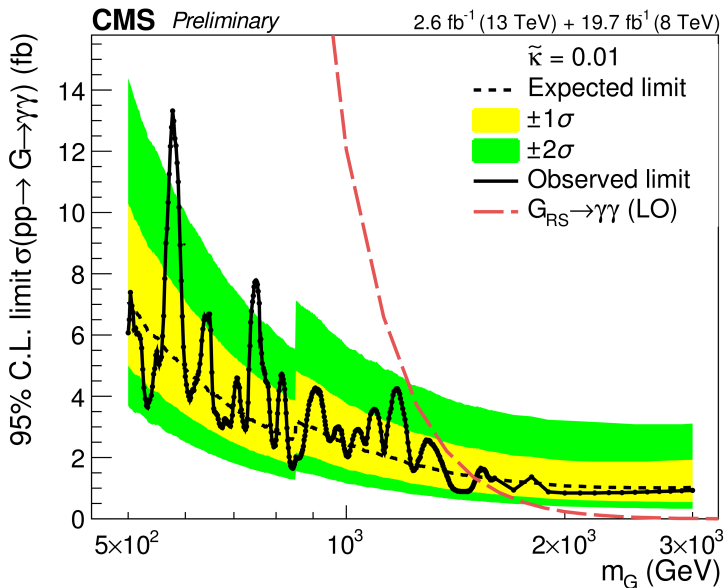
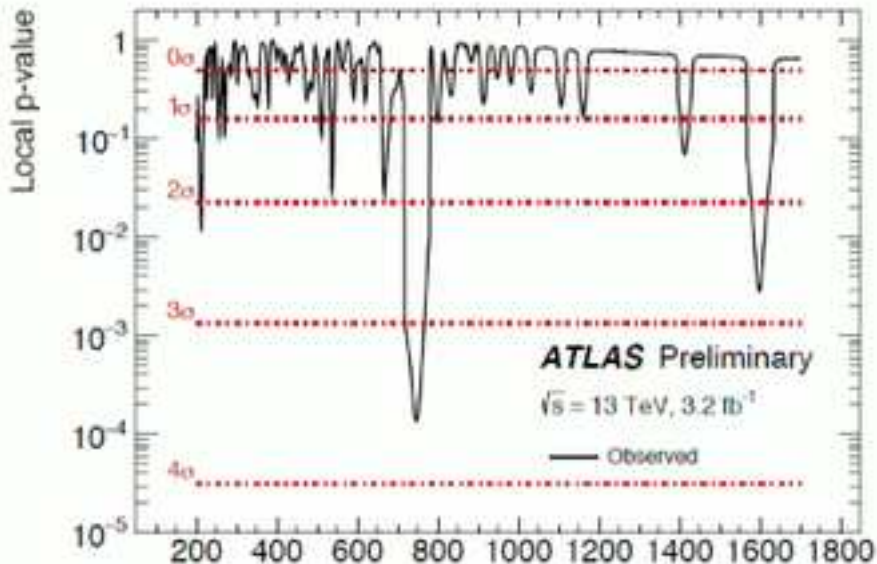


Interpretation of a newly found excess of diphoton decays in LHC as a bound state of 6 top + 6 anti top quarks.

Last December (2015) the “Large Hadron Collider” at CERN(= Cooperation Europeene de Research Nucleaire) found some presumably not statistically significant enough to survive peak/excess in the spectrum of masses of two photons in proton + proton collisions with energy together $\sqrt{s} = 13 \text{ TeV}$ (TeV means terra electron volts, i.e. energy achieved by a charge quantum by passing a potential difference of 10^9 volts) at the mass-value $\sim 750 \text{ GeV} = 0.75 \text{ TeV}$ for the potentially existing “new” particle. 



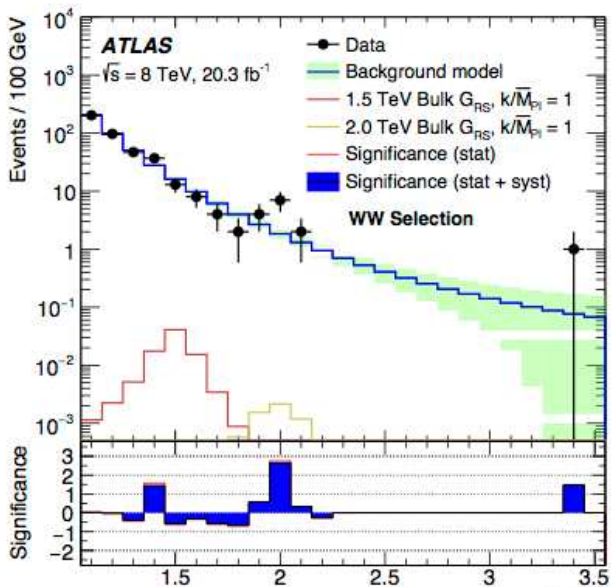


“Diphoton”

Since the perhaps existing new particle with mass $750 \text{ GeV} = 0.75 \text{ TeV}$ is seen to become a pair of lightquanta / photons we call it “diphoton”, or $F(750)$. An unstable particle we typically call resonance.

We call it “new” because it seems - and my colleagues believe - that there is no place to understand inside the at so phantastically well functioning quantum field theory “The Standard Model” for the observed 750 GeV resonance. It namely then in principle signals that the true theory / the true model must be another one than this Standard Model.

Only I and my collaborators see this resonance as being inside the Standard model!



Standard Model

The Standard Model is a quantum field theory.

When using it one almost always uses *perturbation* approximation, which means that one assumes that a series of parameters in the model (such as the Standard Model) called coupling constants are so small that we can expand in them.

But especially what concerns the part of the Standard Model involved with the gluons and the quarks has some effective coupling constant to be used in the energy range of a few GeVs which is *not* small. This gives rise to the regime of *strong interactions* and of hadrons which *cannot* be treated alone by perturbation theory. So one supplements by speculative approximations, confinement ...

Actually the main message of my interpretation of the “new” resonance(s) (there is actually also one with mass 1.8 TeV) is as a non-perturbative effect - a bound state - inside the Standard Model!

Our (= Froggatt's, Laperashvili's, and mine (etc.s?)) Main Point:

In spite of the hopes of my colleagues, that the new resonances represent *new fundamental particles* and thus shows the way to the model behind the Standard Model we claim that we can speculate these resonances to **exist inside the pure Standard Model**, so that **no new physics is needed!**

Well, Not Quite though:

We developed our bound state ideas long before the recent experimental potential finding of “our bound state”(s) under the extra assumption of a **new law of nature**, which we (Bennett (and Brene), me and Froggatt) proposed and call “Multiple Point Principle”.



Main Point Calculating from MPP mass of (Higgs and) F(750)

Main point of present talk:

Assuming several (actually 3) vacuum states or phases having all very small energy density(=cosmological constants), i.e. our principle MPP, we obtain information on/predict the masses of both the Higgs boson and the F(750).

Actually assuming the experimental mass of the Higgs we can claim our prediction for the mass of the F(750) (we call it often S) to be two independent ones coinciding crudely and being close to 750 GeV !

Optimistically the typically accuracy of our postdictions are about 20 %.

Our New Law of Nature, “Multipel Point Principle”

Myself and my collaborators - mainly Donald Bennett og Colin D. Froggatt (and at very early stage N. Brene involved)- propose a new law of nature (Multipel Point Principle):

There are several vacua(=states of empty space) with very very small energy densities (=cosmological constants= dark energies). It is a situation analogous to a combination of e.g. ice and water. A situation, which enforces just the temperature 0^0 Celsius. That such a combination in spite of the temperature being special is rather common is supported by the fact that we have a special word for such a mixture “slush”.

“Multipel Point Principle” (Our Own Law of Nature) Predicted Something

Our own speculative law of nature in fact *predicted*:

- **The number of families** In a very speculative and presumably too complicated model - with multipel point principle built into it (even though we did not talk about that at that time) we (Niels Brene, Don Bennett, ...and me) fitted the finestructure constants, parameters/coupling constants analoguos to the electric elementary charge squared (divided by 4π), and used the number of families as a parameter (=e.g. antallet af electron-analogous charged particles: electron, μ og τ). We fitted 3 and *later* it were found that there were indeed 3 families. Hurra!

Predictions continued:

- **The mass of the Higgs boson** Under use of pure Standard Model (the best for the time being for accelerator physics) and of Multipel Point Principle Colin Froggatt and I *predicted* the Higgs-boson mass to be $135\text{GeV}/c^2 \pm 10\text{GeV}/c^2$. At that time the Higgs-boson were only theory. It was first found in 2012, ~ 20 years later, and even after I had been painted together with the Danish member of cabinet Mogens Lykketoft and the predicted Higgs mass behind his head.

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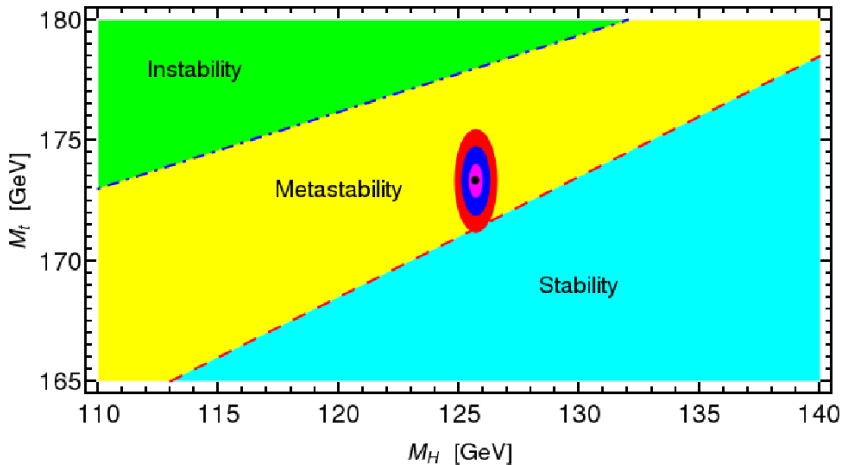


H.B. Nielsen, Copenhagen

Interpretation of a newly found excess of diphoton decays in LHC as a bound state of 6 top + 6 anti top quarks.

Plan for “Interpretation of a newly found excess of diphoton decays in LHC as a bound state of 6 top + 6 anti top quarks.”

- **Introduction** Little resume of main points.
- **New** The new particles
- **MPP** Our new law of nature with degenerate vacua.
- **Masses** Calculation/fitting Resonance Masses using MPP.
- **Decays** How should our 6 top + 6 anti top bound state decay?
- **1.8** The actually first of the two peaks observed; interpret as two of the 0.75 TeV ones ?
- **Conclusion** Conclusion.



In the notation of \vec{r} being the position of a constituent quark relative to the center of mass of the bound state S

$$\langle \vec{r}^2 \rangle = 3r_0^2, \quad (1)$$

$$r_0 = \frac{b}{m_t}, \quad (2)$$

we obtain a theoretical estimate

$$b = \sqrt{\frac{\langle \vec{r}^2 \rangle}{3}} m_t \approx 2.34, \quad (3)$$

and by a slightly different calculation /estimate The parameter b is just the radius of the bound state S in units of top-quark Compton wave length $1/m_t$

How little is Vacuum Unstable, due to High Higgs Field One

If the “high Higgs-field vacuum” following our Multiple Point Principle should be very accurately degenerate in energy-density with the present vacuum, then the renormalization-group running self-coupling of the Higgs $\lambda(\mu)$ taken as a function of the (scale given by) the Higgs field $\mu = \phi$ must go very accurately to 0 for the value of the Higgs field ϕ “high field” for the “high Higgs field vacuum”. However, it is not quite so small as to give degeneracy corresponding to the energy density in the vacuum, we live in, and the by best calculation in (naive) Standard Model gives for the running self-coupling at the “high Higgs field vacuum” (close to Planck scale)

$$\lambda(\phi \text{ “high field”}) = -0.01 \pm 0.002. \quad (4)$$

It is the value of this running $\lambda(\mu)$ but for $\mu \sim$ weak scale, say 100 GeV, that determines the Higgs mass - which is now measured to 125 GeV - in terms of the Higgs field expectation value which is measured as related to the weak interaction strength, or the masses of Z and W. So if we impose that we want MPP we get the Higgs mass changed a bit to $129.4 \text{ GeV} \pm 1.8 \text{ GeV}$ (slightly, by 3 standard deviations) disagreeing with the 125 GeV (the uncertainty now $\sim 0.2 \text{ GeV}$).

Correction of Higgs-mass from MPP from the bound state S

A strongly bound state, such as our bound state S of 6 top + 6 anti top, gives an extra contributions in perturbation theory and e.g. gives a correction to the Higgs mass, which experiment should observe, by there being an extra effective term $\lambda_S = \delta\lambda$ given by various perturbation diagrams in the expression for the Higgs selfcoupling at the weak scale - i.e. correct $\lambda(m_Z) \rightarrow \lambda(m_Z) + \lambda_S$. The dominant diagram/correction is

$$\lambda_S \approx \frac{1}{\pi^2} \left(\frac{6g_t}{b} \frac{m_t}{m_S} \right)^4$$

where we have the estimated or measured values

$$g_t = 0.935; m_t = 173\text{GeV}; b \approx 2.34\text{or}2.43$$

$$\delta\lambda = \text{[Diagram]} + \dots$$

The diagram shows a central square loop with thick black lines. The four vertices of the loop are connected to external lines. The top-left vertex is connected to a line labeled 'H' (top) and 'S' (left). The top-right vertex is connected to a line labeled 'S' (top) and 'H' (right). The bottom-right vertex is connected to a line labeled 'S' (left) and 'H' (bottom). The bottom-left vertex is connected to a line labeled 'H' (left) and 'S' (bottom). To the right of the diagram is an ellipsis '...'.

The Needed Mass for the Bound State S

Using the after all rather small deviation from perfect MPP

$$\lambda_{\text{high field}} = -0.01 \pm 0.002$$

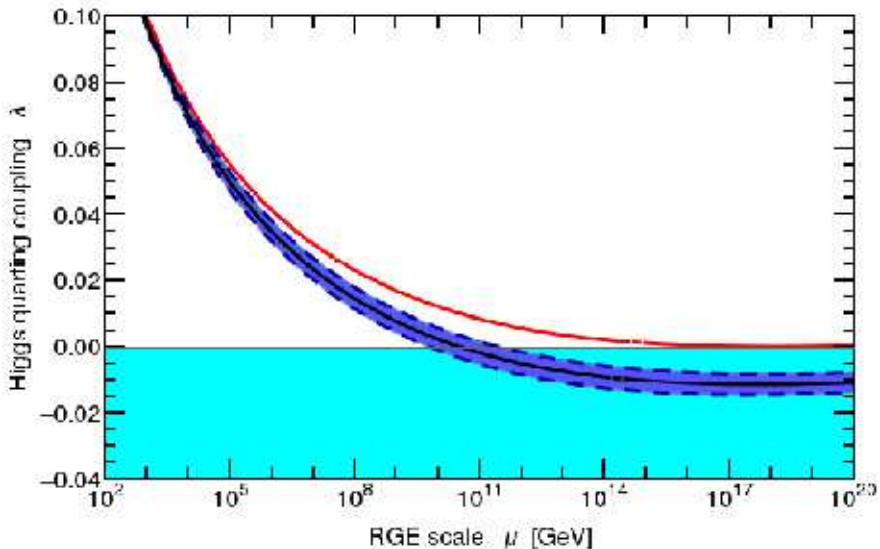
and requiring it to be cancelled by the correction from the bound state we get the requirement

$$\lambda_S = \frac{1}{\pi^2} \left(\frac{6g_t}{b} * \frac{m_t}{m_S} \right)^4 * (\sim 2) \approx 0.01 \pm 0.002, \quad (5)$$

where $g_t = .935$, $m_t = 173\text{GeV}$, $b \approx 2.43$ and the factor “(~ 2)” were taken in to approximatesome neglected diagrams.

The solution w.r.t. the mass of the bound state m_S gives

$$\begin{aligned} m_S &\approx \frac{6g_t m_t}{b} \left(\frac{\sim 2}{\pi^2 * 0.01 \pm 0.002} \right) 1.3^{1/4} \\ &\approx 2.31 * 173\text{GeV} * 2.1 = 4.9 * 173\text{GeV} = 850\text{GeV} \pm 20\% \end{aligned}$$



Yet a MPP-determination of the Bound State S Mass

Also crudely estimate, what mass m_S the bound state should have to make third vacuum, “condensate of S’s vacuum”, have very accurately zero energy density. For this use diamond-like model for structure with the S’s as the carbon atoms and the binding of the neighboring S-bound states to each other as if having the quarks and antiquarks of the neighbors in the atomic orbit $n=2$ of the neighboring “atom” with binding $1/4$ of that of the $n=1$ orbit. We assume - as seems crudely true - that an exchange of W’s and Z’s compensate for the effect of “screening” : half the quarks and anti quarks are further out from center than a considered quark, so that the strength of attraction gets down by a factor 2. Having really four Higgses at short distance brings it up again.

$$\text{Binding per S in “diamond” vac.} \approx \frac{4}{2} * \frac{1}{4} (12m_t - m_S) = \frac{1}{2} (12m_t - m_S) \quad (6)$$

Having

$$\text{Binding per S in "diamond" vac. of the S's} \approx \quad (7)$$

$$\approx \frac{4}{2} * \frac{1}{4} \text{Binding of constituents in S} = \quad (8)$$

$$= \frac{1}{2}(12m_t - m_S) \quad (9)$$

we get

$$m_S \approx \frac{12m_t}{3} = 4m_t = 4 * 173\text{GeV} = 692\text{GeV}(\pm 40\%\text{say}) \quad (10)$$

also close to the 750 GeV. (we assumed the screening just cancelled)

Three Degenerate Vacua give Three Parameters Specified

Each time one by our Multiple Point Principle assume a vacuum to have zero (or exceedingly small) energy density one fix one relation between the parameters of the theory(of the Standard Model), but instead of using it that way you can fix some quantities you in principle but not in reality can calculate such as e.g. the bound state mass(using then the experimental values for the parameters). In this way we got even two calculations for the bound state mass - using in addition crude estimation -

$$m_S(\text{from "high field vacuum"}) \approx 850\text{GeV} \pm 30\% \quad (11)$$

$$m_S(\text{"condensate vac."}) \approx 692\text{GeV} \pm 40\% \quad (12)$$

The agreement of the two is encouraging, even if the diphoton resonance found in LHC with mass 750 GeV should wash out.



Decays of S to Other Channels May Not have been seen, But it is Close

Crude estimates by Colin Froggatt and me suggests that the decay rates to other channels than the diphoton one, say to top + anti top or to two jets(gluons), WW , or ZZ etc. , are typically appreciably larger than to the only observed channel $\gamma + \gamma$ the back ground in these alternative channels and the so far performed analysis make that the observation of the there even to expected bigger number of events should not yet have been seen. But it is very close, and if one does not rather soon see other decay channels of the same particle S , then our hypotesis about what it is gets falcified.

Final state f	Bound	$\frac{\Gamma(S \rightarrow f)}{\Gamma(S \rightarrow \gamma\gamma)}$	Comment
$\gamma\gamma$	$< 0.8(r/5)$	1	
gluon + gluon	$< 1300(r/5)$	117	
Higgs + Higgs	$< 20(r/5)$	15	Higgs-particles
ZZ	$< 6(r/5)$	15	longitudinal
WW	$< 20(r/5)$	30	longitudinal
$Z\gamma$	$< 2(r/5)$	1.0	
ZZ	$< 6(r/5)$	0.3	transverse
WW	$< 20(r/5)$	1.1	transverse
top + anti top	$< 300(r/5)$	378	
$\Gamma_{total}(S)/\Gamma(S \rightarrow \gamma\gamma):$		558	

Table: Benchmark model with $\epsilon^2 = 0.15$. Predictions are given for the decay branching ratios of S relative to the diphoton decay width and compared to the experimental upper bounds from ref. [?]. In our model $r \simeq 10$.

The Mass = 1.8 TeV Fluctuation/Particle

Actually before the 750 GeV peak were found LHC had found an also very doubtful peak corresponding to a resonance decaying into weak gauge bosons WW with a mass 1.2 TeV. This is not very far from double the mass of the as bound state of 6 top + 6 anti top suggested S ($2 * 750 \text{ GeV} = 1.5 \text{ TeV} \approx 1.8$), and so it is very suggestive that this 1.8 TeV could be a resonance in scattering of two S 's against each other.

Such a pair of S 's should fit one of our calculations - namely the one for the "condensate vacuum" with the diamond-like structure model be bound with a binding energy $m_S/2$ because

- There are effectively $2 = 4/2$ S - S (neighboring) bindings per S in the "diamond modelled" structure.
- This two bindings must together cancel the mass-energy of the S in the "condensate vacuum".

Simple Story on 1.8 TeV Resonance Mass

If the binding between the two S's I suggest the 1.8 TeV resonance to consist of were the same as in the “condensate vacuum” arranged to get the energy density of it be 0, then the mass of the 1.8 TeV would have to be

$2m_S - m_S/2 = 3M_S/2 = 3 * 0.75/2 TeV = 1.125 TeV$. But now we expect the effective mass of the Higgs to be smaller inside the “condensate vacuum” than in more free space such as is the situation in the two S system that is hoped to be the 1.8 TeV observation.

If indeed the effective Higgs mass would be essentially zero in the “condensate vacuum” but nevertheless big enough to essentially remove the interaction by simple Higgs exchange in the S-S system, then we would roughly get the sign of the mass correction shifted and we would get for “1.8 TeV” the mass

$2m_S + m_S/2 = 5m_S/2 = 5 * 0.75 TeV/2 = 1.875 TeV$.

Effect on SS-state Mass of Removing Higgs-attraction between Two S-particles

in the massless Higgs approximation one has virial theorem argument telling that the potential energy in an eigensate is just -2 times the kinetic. If one removes the potential energy by letting the exchanged Higgs get a big mass so that the binding between the two S's due to simple Higgs exchange vanish the original bound state with binding energy $m_S/2$ get shifted up in mass by twice this amount, and thus ends up having an amount of mass $m_S/2$ over the sum of the two S-masses (of the constituents). So if indeed the effective Higgs mass in resonance consisting of two S's is effectivel small for the purpose of binding the quarks together to S but huge for the purpose of binding the S's to each other, then the mass of the resonance formed from two S's becomes

$$m_{\text{"1.8 TeV"}} = 2m_S + m_S/2 = \frac{5}{2} * m_S = 2.5 * 0.75 \text{ TeV} = 1.88 \text{ TeV}$$

Conclusion Resume

- In spite of some doubtful resonances observed with masses $m_S = 0.75 \text{ TeV}$ ("seen" in two intersections) and $m_{"1.8\text{TeV}"} = 1.8\text{TeV}$, we claim that pure Standard Model is sufficient !
- Because these resonances may be explained as *bound states* of respectively 6 top + 6 anti top and of two of the first type, i.e. as 2 S's interacting with each other.
- We long had speculations on the S before it were potentially found in a scenario having as an ingredient also:
- The Multiple Point Principle, a by us proposed new law of nature saying that there are several (we say in Standard Model 3) all having very very small energy densities/cosmological constants.

Conclusion (Continued)

- We made mass estimates mainly based on this Multiple Point Principle and found by very crude calculational technique

$$m_S \approx 4m_t \text{ and } m_{\text{"1.8TeV"}} \approx \frac{5}{2}m_S$$

- We even got the mass for the diphoton resonance in two different ways, namely using two different vacua, "high field vacuum" and "condensate vacuum", to be required to have same energy density (i.e. very small) as the vacuum we live in.
- It has also been one of the most remarkably results of the running of the accelerator LHC so far that it has found only limits supporting non-existence of anything new relative to the Standard Model ("Rosner Bjorken Nightmare")

Conclusion (Yet continued)

- In spite of its success the Standard Model has of the order of 8 problems suggesting that something more is needed.
- I also mentioned that at first it looks quite accidental why Nature should chosen just the gauge group, the structure group $S(U(2) \times U(3))$ as the group relevant for the Standard Model that works so almost surprisingly well ? I have some idea of that it in a sense which is made precise in a may be special way has the smallest possible faithful representations relative to the “adjoint” representation. A sort of averaged and generalized Dynkin index is what selects the group deserving to be the right one for physics.