On the possible new 750 GeV heavy boson resonance at the LHC

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Abstract

We argue that the possible new heavy boson resonance of 750 GeV is an ideal candidate as a twin particle of the 125 GeV scalar boson, both emerging from the large mixing of the scalar toponium and scalar gluonium. Assuming that the mixing of the pseudoscalar toponium and pseudoscalar gluonium is small, just like the mixing of the light pseudoscalar quarkonium and pseudoscalar gluonium, the resulting new physical pseudoscalars are lighter than the scalar twins. We explain why it could be more difficult to observe these pseudoscalars. The absence of the Higgs scalar should not be considered an obstacle because the nonsingular theory with the UV cutoff fixed by the weak boson masses is superior to the Standard Model since it solves a few fundamental problems such as: (1) light neutrinos, (2) dark matter particles to be the heavy Majorana neutrinos and (3) broken lepton and baryon numbers.

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We are witnessing the great discovery potential of the Large Hadron Collider (LHC). The Run 1 experiments of the LHC at 7 and 8 TeV center of mass energy found new exotic hadrons interpreted as tetraquark [1] or pentaquark [2] states.

The special attention should be devoted to the discovery of the 125 GeV boson resonance [3]. It is established that it is indeed a scalar particle. Owing to the fact that the SM Higgs scalar cannot generate neutrino masses, one has to expand the scalar sector of the model if we adopt the approach that the Higgs mechanism is responsible for the generation of masses. On the other hand, the overall fit of the electroweak data of the LEP1, LEP2, SLC, etc. with the SM radiative corrections results in the mass of the Higgs $m_H = 89^{+22}_{-18} GeV$ [4]. The nonperturbative stability analysis of the SM Higgs sector requires much heavier Higgs mass $m_H > 180 GeV$ [5]. The measurements of the partial decay widths of the scalar 125 GeV resonance are too far from the scientific golden standard of precision to be considered compatible with the SM Higgs couplings.

Despite all these facts, the 125 GeV resonance is proclaimed to be the SM Higgs particle. Recently, the ATLAS and the CMS collaborations announced the possible discovery of the new 750 GeV heavy boson decaying into two photons [6].

Immediately after the discovery of the 125 GeV resonance, P. Cea suggested that this resonance could be the QCD bound state as a mixture of toponium and gluonium [7]. However, this interpretation implies the existence of two heavy bosons. Let us write the corresponding mass matrix:

$$M = \begin{pmatrix} m_{gg} + A & A \\ A & m_{t\bar{t}} + A \end{pmatrix}.$$

The eigenvalue problem is then reduced to the following algebraic system of the three nonlinear equations:

$$\begin{aligned} \sin\theta\cos\theta(m_{gg} - m_{t\bar{t}}) + (\cos^2\theta - \sin^2\theta)A &= 0, \\ \cos^2\theta\ m_{gg} + \sin^2\theta\ m_{t\bar{t}} + A(1 - 2\sin\theta\cos\theta) &= m_1, \\ \cos^2\theta\ m_{t\bar{t}} + \sin^2\theta\ m_{gg} + A(1 + 2\sin\theta\cos\theta) &= m_2, \end{aligned}$$

$$m_{gg} = gluonium\ mass,\ m_{t\bar{t}} = toponium\ mass,\ m_1 = lighter\ twin\ mass,$$

$$m_2 = heavier\ twin\ mass,\ \theta = mixing\ angle,\ A = annihilation\ matrix\ element,$$

$$|1>=\cos\theta\ |gg> - \sin\theta|t\bar{t}>,\ |2>=\sin\theta\ |gg> + \cos\theta|t\bar{t}> .$$

There are six variables in the system - therefore we can fix three variables and solve the system to find the remaining three.

If we assume that the $m_1 = 125GeV$ is a scalar boson and the masses of the scalar gluonium and toponium are roughly $m_{gg} = 1.5GeV,\ m_{t\bar{t}} = 345GeV$, one can conclude from the algebraic system that $A = 281.6GeV,\ \sin\theta = 0.4895,\ m_2 = 784.6GeV$. The dependence of the m_2 on the $m_{t\bar{t}}$ is depicted in Fig. 1. The annihilation matrix element and the mixing remain large for the range of $m_{t\bar{t}}$ in Fig. 1. Alternativley, we can fix $m_1 = 125GeV$, $m_2 = 750GeV$ and $m_{gg} = 1.5GeV$ to find out that $m_{t\bar{t}} = 365.3GeV,\ A = 254.1GeV$ and $\sin\theta = 0.457$.

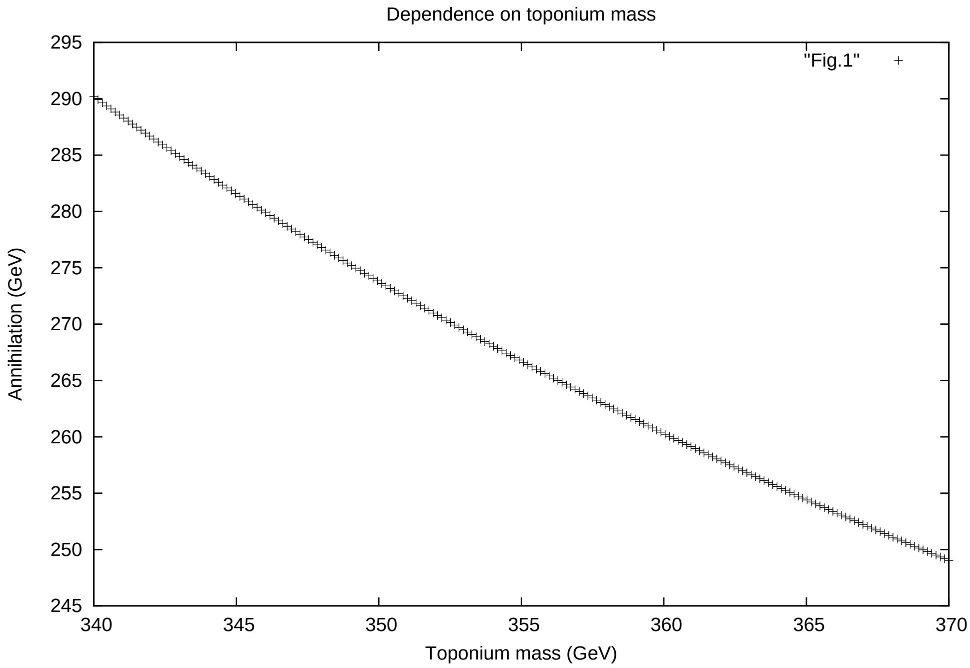

Fig. 1: Dependence of A(GeV) on $m_{t\bar{t}}$(GeV) for scalars with the following parameters m_{gg}=1.5 GeV, m_1=125 GeV.

The annihilation term A is large owing to the multigluon strong coupled exchange in the quantum loop. The saturation should be expected for strong interactions on the high top quark-gluon ladder.

It might be interesting to find the solutions to the algebraic system for the pseudoscalar mesons, assuming that the heavier twin is the possible new resonance $m_2 = 750 GeV$ and the masses of pseudoscalars are $m_{gg} = 2.6 GeV$, $m_{t\bar{t}} = 321 GeV$ [7]. The algebraic system provides the remaining three parameters: $A = 272.6 GeV$, $m_1 = 118.7 GeV$, $\sin\theta = 0.498$. However, the LHC did not discover any new boson resonance close to the 125 GeV boson. Therefore, the possible new resonance of 750 GeV should be a scalar, not a pseudoscalar.

We cannot ignore the possibility of formation of pseudoscalars. It is well known in hadron physics (lattice studies and QCD sum rules) that the mixture of the scalar light quarkonium and gluonium is large, but the mixture of the pseudoscalar light quarkonium and gluonium is small [8]. Let us solve the algebraic system for pseudoscalars with small annihilation matrix element of toponium and gluonium $A = 30.0 GeV$, $m_{gg} = 2.6 GeV$, $m_{t\bar{t}} = 321 GeV$. As one might expect, the resulting mixing angle is small $\sin\theta = 0.093$; the masses are $m_1 = 29.8 GeV$, $m_2 = 353.8 GeV$. The dependence of the mixing on the annihilation is shown in Fig. 2.

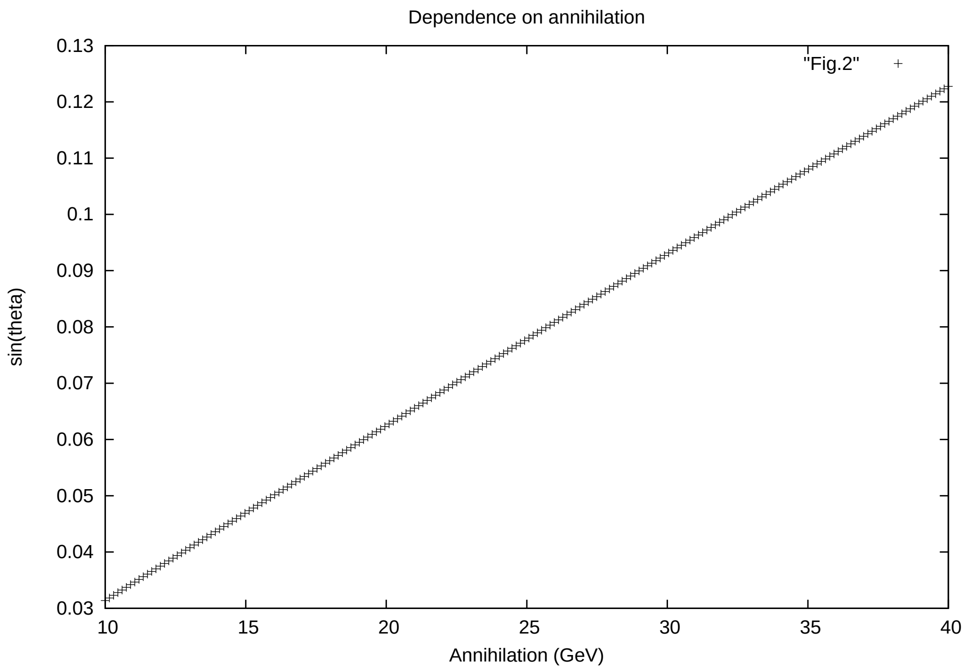

Fig. 2: Dependence of $\sin\theta$ on A(GeV) for pseudoscalars with the following parameters m_{gg}=2.6 GeV, $m_{t\bar{t}}$=321 GeV.

It is well known that the toponium states decay quickly via weak interactions and therefore cannot be observed by the LHC detectors. This is the reason why heavier pseudoscalar twin meson has yet to be observed, and it will prove to be difficult because it consists mainly of toponium. The lighter pseudoscalar twin meson is probably, at the moment, hidden in the huge LHC background at the energy level of $\mathcal{O}(10GeV)$.

To summarize, if the 125 GeV resonance is a scalar (rather than a pseudoscalar) boson, then the possible new resonance of roughly 750 GeV is its heavier scalar twin, both consisting of scalar toponium and gluonium. Lighter pseudoscalar twin QCD bound states might be more difficult to observe. There is a serious theoretical challenge ahead to evaluate the annihilation matrix elements in both scalar and pseudoscalar channels by solving Bethe-Salpeter equations or within the QCD on the lattice.

The possibility that we could be left without the Higgs scalar should not pose as a matter of concern. Namely, the Higgs mechanism built into the electroweak theory helped to establish the SM model, but does not solve the problem of masses of the elementary particles, i.e. Higgs potential and Yukawa couplings are free parameters. However, we know that the lepton and quark masses fulfil profound patterns: only three fermion families; characteristic mass gaps; quarks heavier than leptons within the same family, and very light neutrinos.

The resolution of these problems requires the introduction of a new paradigm. The theory of noncontractible space and its consequence on the relations between gauge, conformal and discrete symmetries are explained in ref. [9]. The masses of elementary particles are mass singularities of propagator Green functions which are solutions to the nonsingular Dyson-Schwinger equations. The theory contains three light and three heavy Majorana neutrinos [10]. The lepton and baryon numbers are broken [9, 11]. The impact of the theory on the phenomenology of the rare B-meson processes can be found in ref. [12], whereas the effect on the strong interactions - strong coupling, spin asymmetry in the single t-quark production or t-quark charge asymmetry, etc. in ref. [13].

The connection and the universality of the theory of noncontractible space with the Einstein-Cartan cosmology can be examined in ref. [14]. The heavy Majorana neutrinos are candidates for cold dark matter particles and the angular momentum of the Universe is the dark energy [15]. The right-handed rotation of the Universe is an inevitable consequence of the left-handed weak interactions [16].

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