Mass of Higgs Boson and Branching Ratios

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Abstract: Within the Scale-Symmetric Theory we described mass spectrum of the composite Higgs boson with a mass of 125.00 GeV. Due to the quadrupole symmetry characteristic for the weak interactions and due to the interactions of the Higgs-boson pairs with the dominant gluon balls 3.30 GeV, there appear two masses 126.65 ± 0.73 GeV and 123.35 ± 0.73 GeV. Due to the confinement characteristic for the weak interactions, there arise the pairs of Higgs bosons. In their decays appear groups of photons composed of two photon pairs, i.e. composed of four photons, or quadrupoles of leptons. The decays of the Higgs boson pairs into 4 photons lead to the mean central mass of Higgs boson equal to 126.65 GeV whereas the decays into the quadrupoles of leptons lead to the mean central mass 123.35 GeV or 125.00 GeV. The reformulated Theory of Branching Ratios leads to conclusion that the relative signal strength of the decays into two photons to the decays into two Z bosons should be in approximation 1.87 times higher than predicted within the Standard Model. Since there is the pairing of the Higgs bosons then for the decays into two photons, the relative signal strength in relation to the Standard Model is 1.732 whereas for ZZ channel is 0.926.

1. Introduction and mass spectrum

The internal structure of the core of baryons and the confinement of the Einstein spacetime components (they are the neutrino-antineutrino pairs) produced by electromagnetic energy lead to the mass of the composite Higgs boson with a mass $m_o = 125.00$ GeV ([1]: Particle Physics). On the other hand, the reformulated Quantum Chromodynamics ([1]: Reformulated QCD) shows that there is an increase in number of gluon balls (the amplification) carrying mass equal to 3.304 GeV. Just such gluon balls produce identical gluon balls. Such gluon ball I will refer to as the amplifier. The unified formula is as follows

$$M\,[\mathrm{GeV}] = (C / E_N\,[\mathrm{GeV}] + D)^{10}, \qquad (1)$$

$C = 0.52296$,
$D = 0.96868$,

E_N is the energy of collision per nucleon,
M is the mass of produced gluon ball.

Due to the internal structure of the core of baryons (there is torus and ball/condensate in its centre composed of the Einstein spacetime components) there is valid the quadrupole symmetry ([1]: Particle Physics). This means that we should observe the decays into quadrupoles of leptons or into groups composed of two photon pairs but such decays should be characteristic for Higgs-boson pairs, not for single Higgs bosons. Since there dominate the amplifiers 3.304 GeV, so such mass can be absorbed by one of the two components and then the mean central mass of the components in a Higgs-boson pair is 126.65 GeV. But some amplifier can force emission of amplifier by one of the two components of a Higgs-boson pair. Then the mean central mass is 123.35 GeV. It looks as a Gluon Amplification by Stimulated Emission (the GASE). There is a broadening of mass of the amplifier 3.304 GeV which follows from its interaction with the core of baryons with a mass of 0.72744 GeV. This means that we can write the mass of the amplifier as follows: 3.304 ± 0.727 [GeV]. The two modified mean masses of the Higgs bosons should be as follows

$M_1 = 126.654 \pm 0.727$ GeV and $M_2 = 123.350 \pm 0.727$ GeV.

It is consistent with experimental data [2].

We can see that the real mass of the Higgs boson is 125.00 GeV because the observed mass distance 3.304 GeV is due to the interactions of the Higgs-boson pairs with the amplifiers.

Analyse thoroughly the equation (1). For $E_N \rightarrow \infty$, the mass of gluon ball is M = 727.44 MeV. It is the mass of the core of baryons ([1]: Particle Physics). Since mass of gluon ball M decreases when energy of collision per nucleon E_N increases (the energy E_N we will refer to as the gluon propagator) then we can assume that at low energy of gluon propagator, there arise the virtual gluon-ball pairs carrying the mass ±727.44 MeV = 0 as well. On the other hand, the equation (1) has physical sense also for negative energy of gluon propagator. This follows from the fact that negative energy of gluon propagator or negative mass of gluon ball means that there is created an energy/mass depression in the nuclear strong field. We can see that the mass of gluon ball(s) is equal to zero for negative energy of virtual gluon propagator equal to –539.9 MeV, i.e. for the rest mass of four confined virtual neutral pions $E_N = -4m_{pion(o)}$. Due to the quadrupole symmetry for the weak interactions ([1]: Particle Physics) that follows from the fact that resultant spin, charge and internal helicity of groups of particles created inside core of baryons must be equal to zero (then the state of the core is not destroyed), there can appear objects containing four confined neutral pions. At low energy there appear mostly the virtual pairs carrying energy ±539.9 MeV = 0. The negative propagator carrying energy –539.9 MeV creates the virtual gluon-ball pairs carrying mass ±727.44 MeV = 0. We can see that due to the equation (1), which follows from the internal structure of the core of baryons ([1]: Particle Physics), there is broken symmetry between the behaviour of the virtual negative and positive propagators. The negative propagator (energy = –539.9 MeV) leads to resultant mass of virtual gluon pair (±727.44 MeV) equal to zero whereas the positive one (energy = +539.9 MeV) to mass of single gluon-ball ~745 GeV. Such gluon ball cannot be created at low energy.

The above analysis is consistent with results presented here [3]. The conclusion is that the infrared data can be associated with a massive propagator up to momenta in approximation

500 MeV. There appears a constant gluon mass of 723(11) MeV. We obtain such result when we exclude the zero-momentum gluon propagator from the analysis. We can see that the formula (1) has no physical sense for zero-momentum gluon propagator as well.

At low energy, the all gluon balls have the same mass Y = 424.1 MeV ([1]: Particle Physics). They all are the black holes in respect of the weak interactions ([1]: Particle Physics). Due to the internal structure of the gluon balls (the hedgehog-like structure – see the next Paragraph), the gluon-balls are the scalars. In the nature the pairing is widespread. This follows from the fact that binary systems have additional angular momentum and in interactions this angular momentum can change if it is necessary. The massive gluon balls appear as the gluon-ball pairs i.e. probability of creation of Higgs-boson pairs or gluon-ball pairs is much higher than of single object. The gluon balls can transform into loops and then into tori ([1]: Particle Physics). The mean distance between the carriers of gluons in a gluon ball is a little shorter than in the Einstein spacetime ([1]: Particle Physics). This means that absorption of a gluon ball by some other gluon ball leads to decay into photons whereas an emission causes that the confinement is still valid so the gluon balls decay into leptons. Due to the quadrupole symmetry for the weak interactions ([1]: Particle Physics), in the decays of the pairs of Higgs bosons there appear four photons as the two pairs of photons ($\gamma\gamma$) or two quadrupoles of leptons ($llll$). From the formula (1) follows that there is higher number density of the gluon balls carrying energy 3.30 GeV (the G_o). This causes that the decays of the Higgs boson pairs into 4 photons $2(\gamma\gamma)$ lead to the mean central mass 126.65 GeV whereas the decays into the final states $2(llll)$ (the two pairs of four leptons) lead to the mean central mass 123.35 GeV or 125.00 GeV. Some summary for these two selected types of decays of the Higgs-boson-pair (the HH) is as follows:

$HH + G_o \rightarrow 2(\gamma\gamma)$: mean mass of H is 126.65 ± 0.73 GeV,
$HH - G_o \rightarrow 2(llll)$: mean mass of H is 123.35 ± 0.73 GeV,
$HH \pm G_o(= 0) \rightarrow 2(llll)$: mean mass of H is 125.00 GeV.

In the last case there is at first the amplifier-antiamplifier annihilation.

We can see that the observed differences in masses of the Higgs boson follow from its interactions. The real mass of the Higgs boson is 125.00 GeV. We can compare these theoretical results with experimental results observed with the ATLAS Detector at the LHC [2], [4] and the CMS Experiment at the LHC [5].

Due to the confinement ([1]: Particle Physics), the masses of gluon balls can accumulate. We can see that the sum of the masses of the characteristic mass of gluon propagator 539.9 MeV and the constant gluon mass 727.44 MeV, is in approximation 1267 MeV. It is the mass of the charm quark. When in the equation (1) we use the mass of the charm quark 1.267 GeV as the mass M of gluon ball then we obtain for the gluon propagator energy in approximation E_N = 9.460 GeV. This energy is the mass of the boson $Y(1S, 9460\ MeV)$. There, as well, appear masses of other known particles ([1]: Reformulated QCD). This follows from the atom-like structure of baryons.

The core of the baryons consists of the torus and ball in its centre ([1]: Particle Physics). The torus is the strong/electric charge. For distances shorter than about 3 fm, the torus behaves as the strong charge whereas for distances longer than about 3 fm the torus behaves as the electric charge ([1]: Particle Physics).

2. The reformulated Theory of Branching Ratios (the RTBR) for Higgs bosons and pairs of gluon balls

The branching ratios B_k depend on number k of succeeding decays in a decay channel. Define the branching ratios as follows

$$B_k = B_{\gamma\gamma} (2^k - 1), \tag{2}$$

where $k = 1, 2, 3, 4, 5, 6, 7$ and 8.

The value of $B_{\gamma\gamma} = B_1$ we can calculate from assumption that total branching ratio for all decay channels, which is the sum of the all B_k, is equal to 1. On the other hand, the smallest branching ratio is for the decays of the Higgs boson $m_o = 125$ GeV into two photons and is in approximation $B_{\gamma\gamma} \approx 0.002$. For $B_{\gamma\gamma} = 0.001992$, the total branching ratio is $B_t = \Sigma B_k = 1$. This means that there are 8 different decay channels and energies of initial gluon balls.

Define mass H_n of the components of the initial gluon-ball pairs as follows

$$H_n = 2 \cdot 2^{n/4} m_o / 2, \tag{3}$$

where $n = 0, 1, 2, 4, 8, 16, 32$ and 64 (they are the numbers in the Titius-Bode law [1]).

The branching ratios for the two selected decay channels are as follows:

$$B_{\gamma\gamma} = B (H_o \rightarrow \gamma\gamma) \approx 0.0020 \text{ and } B_3 = B_{ZW} = B(H_2 \rightarrow a(ZZ) + b(W^+W^-)) \approx 0.014.$$

The relative value is $B_{\gamma\gamma} / B_{ZW} \approx 0.0020/0.014 \approx 0.143$. The $B_{ZZ,SM}$ in the Standard Model is close to the B_{ZW} in the reformulated Theory of Branching Ratios but the assumption that these two branching ratios have the same value is incorrect. It is the reason that experimental results for the relative signal strength of the decays into two photons to the decays into two Z bosons are inconsistent with the value obtained within the Standard Model. The Standard Model leads to following value $\sigma_{SM} = B_{\gamma\gamma,SM} / B_{ZZ,SM} = 0.0023 / 0.016 \approx 0.144$ [6]. In reality, the B_{ZW} consists of two parts and abundance of the ZZ decay channel is $a = m(Z)/(m(W) + m(Z)) = 0.5315$. This leads to conclusion that the real branching ratio for the ZZ decay channel is $B_{ZZ} = aB_{ZW} = 0.007411$. We can see that the relative signal strength should be $\sigma_{RTBR} = B_{\gamma\gamma} / B_{ZZ} = 0.001992 / 0.007411 \approx 0.269$. This value is $\sigma_{RTBR} / \sigma_{SM} = 1.87$ times higher than the value predicted within the Standard Model. Since there is the pairing of the Higgs bosons then for the decays into two photons, the relative signal strength in relation to the Standard Model is $2B_{\gamma\gamma} / B_{\gamma\gamma,SM} = 2 \cdot 0.001992 / 0.0023 = 1.732$ whereas for ZZ channel is $2B_{ZZ} / B_{ZZ,SM} = 2 \cdot 0.007411 / 0.016 = 0.926$. We can compare these theoretical results with experimental data obtained in the CMS and ATLAS experiments [2], [4] and [5].

Why there are only 8 branching ratios and what is the origin of formula (3)?

Formula (1) leads to conclusion that the condensates appear outside the core of baryons. Maximum volume of a condensate can be the volume between the surface of the core of baryons (in an approximation its radius is $A = 0.6974425$ fm ([1]: Particle Physics)) and the boundary of the nuclear strong interactions (its radius is $R_{Strong} = 2.95821$ fm ([1]: Particle Physics)). On the other hand, the polarization of the components of the torus inside the core of baryons causes that there appear the hedgehog-like condensates in which there is the radial orientation of the spikes composed of the neutrino-antineutrino pairs. Due to the quantum entanglement, their number should be the same as in the central condensate with a mass of $Y = 0.42412$ GeV. But we must consider the virtual masses as well so we must take into account the density of the Einstein spacetime which is $F = 40{,}363$ times higher than the density of the central condensate. It leads to conclusion that maximum mass of created condensate can be the product of the mass Y, the factor F and of the ratio of length of spikes, L, and radius of the central condensate $r_p = 0.008710945$ fm. Upper limit for such condensate we can calculate from following formula

$$H_{max} = F\,Y\,(R_{Strong} - A) / r_p = 4443 \text{ TeV}. \qquad (4)$$

It is in an approximation a little greater mass than the half of the maximum mass of the gluon ball H_{64} that appears in the reformulated Theory of Branching Ratios. We can see that we proved that there are the 8 different branching ratios only. We can see that the H_nH_n pairs arise due to the interactions of four baryons.

Knowing the number of different branching ratios, we can from formula (2) calculate the $B_{\gamma\gamma}$ i.e. this quantity is not a parameter in the reformulated Theory of Branching Ratios.

It is easy to calculate that real mass of condensate that fills the volume between the Schwarzschild surface for the nuclear strong interactions ([1]: Particle Physics; the radius $r_1 = 2A$) and a sphere with a radius equal to the circumference of the large loop responsible for the nuclear strong interactions ([1]: Particle Physics; the radius $r_2 = 2\pi \cdot 2A/3$; it is the circumference of the smallest Wilson loop) is

$$H_1 / 2 = Y\,2\,A\,(2\,\pi / 3 - 1) / r_p = 74.3 \text{ GeV}. \qquad (5)$$

It is exactly the half of the mass of H_1 calculated from formula (3). The quadrupole symmetry characteristic for the weak interactions, leads to the mass of the pair H_1H_1. We can see that the origin of formula (3) results from the dynamics of the baryons.

The theoretical results concerning the RTBR are collected in Table 1.

Table 1 *Branching Ratios for gluon balls*

Branching ratios B_k for decay channels	**First decay**	**Mass H_n**
$B_{\gamma\gamma}$ = 0.001992 ≈ 0.002	$H_oH_o \rightarrow 2(\gamma\gamma) = 2 \cdot 1H_o$	$H_o = 2m_\gamma = 2 \cdot 62.5$ GeV
$B_2 \approx 0.006$	$H_1H_1 \rightarrow 2(llll)$	$H_1 = 2 \cdot 74.3$ GeV
$B_3 \approx B_{ZW} \approx 0.014$*	$H_2H_2 \rightarrow a2(ZZ) + b2(W^+W^-)$*	$H_2 = 2 \cdot 88.4$ GeV
$B_4 \approx 0.030$	$H_4H_4 \rightarrow 2 \cdot 2^1H_o$	$H_4 = 2 \cdot 125$ GeV
$B_5 \approx 0.062$	$H_8H_8 \rightarrow 2 \cdot 2^2H_o$	$H_8 = 2 \cdot 250$ GeV
$B_6 \approx 0.125$	$H_{16}H_{16} \rightarrow 2 \cdot 2^4H_o$	$H_{16} = 2 \cdot 1$ TeV
$B_7 \approx 0.253$	$H_{32}H_{32} \rightarrow 2 \cdot 2^8H_o$	$H_{32} = 2 \cdot 16$ TeV
$B_8 \approx 0.508$	$H_{64}H_{64} \rightarrow 2 \cdot 2^{16}H_o$	$H_{64} = 2 \cdot 4096$ TeV
***B_{ZZ} = 0.007411** $\Sigma B_k = 1.000$	*a = 0.5315 and b = 1 – a 1/a = 1.88	
Due to the pairing of the Higgs bosons, the relative signal strength is: **γγ**: $2B_{\gamma\gamma} / B_{\gamma\gamma,SM} = 2 \cdot 0.001992/0.0023 = 1.732$ **ZZ**: $2B_{ZZ} / B_{ZZ,SM} = 2 \cdot 0.007411/0.016 = 0.926$		

3. Summary

Within the Scale-Symmetric Theory we described mass spectrum of the composite Higgs boson with a mass of 125.00 GeV. Due to the quadrupole symmetry characteristic for the weak interactions and due to the interactions of the Higgs-boson pairs with the dominant gluon balls carrying mass 3.30 GeV, there appear two different masses $M_1 = 126.65 \pm 0.73$ GeV and $M_2 = 123.35 \pm 0.73$ GeV. The decays of the Higgs boson pairs into 4 photons lead to the mean central mass 126.65 GeV whereas the decays into quadrupoles of leptons lead to the mean central mass 123.35 GeV or 125.00 GeV.

At the low energy of interacting nucleons there appears constant gluon energy equal to 727.44 MeV and asymmetry in interactions of negative and positive virtual gluon propagators. Due to confinement of gluon balls and gluon propagators there can appear mass of the charm quark. Due to the atom-like structure of baryons there can appear the other masses of quarks as well ([1]: Particle Physics or reformulated QCD).

The Theory of Branching Ratios leads to conclusion that the relative signal strength of the decays into two photons to the decays into two Z bosons should be in approximation 0.269 i.e. about 1.87 times higher than predicted within the Standard Model: $B_{\gamma\gamma,SM} / B_{ZZ,SM} = 0.0023/0.016 = 0.144$. This follows from the fact that in reality there are the two parts in the decay channel $k = 3$ so there is less the decays into two Z bosons. There is $1/a = 1.88$ times less such decays. We can see that the factor $1/a = 1.88 \neq 1$, follows from the wrong initial conditions in the Standard Model for the ZZ decay channel, not for the $\gamma\gamma$ decay channel. But due to the neglected pairing and quadrupole symmetry in the Standard Model (which are characteristic for the Higgs bosons), the experimental branching ratio for the ZZ decay channel is close to the theoretical result obtained within the Standard Model. We can see that these two wrong assumptions almost cancel each other.

The theoretical result for the branching ratio for the decay of the Higgs boson into two photons is $B_{\gamma\gamma} = 0.001992$ whereas into two Z bosons is $B_{ZZ} = 0.007411$. Since there is the pairing of the Higgs bosons then for the decays into two photons, the relative signal strength in relation to the Standard Model is 1.732 whereas for ZZ channel is 0.926.

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