The Higgs Mechanism and Tower of Higgs Bosons

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Abstract: Here, applying the Scale-Symmetric Theory (SST), we described the real Higgs mechanism that transformed partially the superluminal non-gravitating Higgs field (the inflation field) into the luminal gravitating Einstein spacetime composed of the neutrino-antineutrino pairs. The lightest Higgs boson is the quadrupole of the four stable neutrinos (the tau-neutrino is unstable) so its gravitational mass is very low but the superluminal non-gravitating energy frozen inside such ground-state Higgs boson is about 119 powers of ten higher than the observed energy/mass - the geometric mean is close to the Planck energy. There can appear the composite Higgs bosons composed of the confined lightest Higgs bosons - their masses are quantized and such quantization follows from properties of the nuclear plasma described within SST. There appear the composite Higgs bosons with masses of 125 GeV, 742 GeV and about 17.1 TeV. There is as well the virtual composite Higgs boson with a mass of 424.12 MeV. But probably there can appear other quantized masses as well as the components of the tower of the masses of the composite Higgs bosons.

1. Introduction, Higgs mechanism and the lightest Higgs boson

The Higgs mechanism was proposed by Philip Anderson [1].

The relativistic model was developed in 1964 by François Englert and Robert Brout [2], Peter Higgs [3], and Gerald Guralnik, Carl Hagen, and Tom Kibble [4].

We know that no adequate mathematical model of the Higgs mechanism has been suggested within the quantum gauge theory so many scientists assume that there is some analogy to Cooper pairs in condensed matter physics. There are many arbitrary mathematical descriptions of the Higgs-like mechanism, for example, the Abelian Higgs mechanism, Nonabelian Higgs mechanism or affine Higgs mechanism. There can be a classical model as well.

Here, we refer to the Higgs boson with a mass of 125 GeV the composite Higgs boson because this mass is not the ground state in the tower of masses of the Higgs bosons. The mass of the ground-state Higgs boson is very small but is associated indirectly with the Planck critical energy [5A]. Moreover, the masses of the composite Higgs bosons do not follow directly from the Higgs mechanism (in reality, they are built of the ground-state Higgs bosons) – there are needed some additional conditions to quantize the masses of the composite Higgs bosons. These additional conditions are described in this paper.

The classical approach to the Higgs mechanism that leads to a complete description of the Higgs mechanism realized by Nature (such mechanism cannot be arbitrary), we described within the Scale-Symmetric Theory [5A], [6], [7]. Within the other mathematical models we cannot fully understand the Higgs mechanism because within them we cannot calculate many physical quantities associated with the physical structures that appear in the complete Higgs mechanism.

The Scale-Symmetric Theory (SST) shows that the succeeding phase transitions of the superluminal non-gravitating Higgs field (of the inflation field) lead to the different scales of sizes [5A]. Due to the saturation of interactions via the Higgs field and due to the law of conservation of the half-integral spin that is obligatory for all scales, there consequently appear the superluminal binary systems of closed strings (entanglons) responsible for the quantum entanglement, stable neutrinos and luminal neutrino-antineutrino pairs which are the components of the luminal Einstein spacetime (it is the Planck scale), cores of baryons, and the cosmic structures (protoworlds) that evolution leads to the dark matter, dark energy and expanding universes [5A], [5B]. The non-gravitating tachyons have infinitesimal spin so all listed structures have internal helicity (helicities) which distinguish particles from their antiparticles [5A]. The inflation field started as the liquid-like field composed of non-gravitating pieces of space [5A]. During the inflation, the liquid-like inflation field (the non-gravitating superluminal Higgs field) transformed partially into the luminal Einstein spacetime [5A]. In our Cosmos, the two-component spacetime is surrounded by timeless wall – it causes that the fundamental constants are invariant [5A], [5B].

Due to the symmetrical decays of bosons on the equator of the core of baryons, there appears the atom-like structure of baryons described by the Titius-Bode orbits for the nuclear strong interactions [5A].

The two first phase transitions describe the Higgs mechanism. Mathematically this mechanism is already described within SST [5A]. During the inflation, the initial liquid-like inflation field transformed partially into the entanglons and next, the entanglons were grouped inside the neutrinos. The tachyons that were and are the components of the inflation-field/Higgs-field and the entanglons are the non-gravitating objects but due to the dynamic viscosity between the free tachyons and the bound tachyons the entanglons consist of, each neutrino produces divergent jets that produce gradient in the inflation-field/Higgs-field – it is the gravitational field that causes that we can say about gravitational mass of neutrinos.

Nature tries to eliminate turbulences in the two-component spacetime (Higgs field plus Einstein spacetime). Such scenario can be realized because of the superluminal quantum entanglement and/or confinement (the confinement results from the Mexican-hat mechanism [5A]) of the neutrino-antineutrino pairs and/or neutrinos all Principle-of-Equivalence particles consist of. There do not appear turbulences when resultant charge, resultant spin and resultant internal helicity of created a group of particles are equal to zero. It causes that there appears the four-particle symmetry (the quadrupole symmetry) [5A]. Each such quadrupole is a scalar. SST shows that there are only four stable neutrinos i.e. the electron-neutrino, muon-neutrino and their antiparticles [5A]. The tau-neutrino is unstable and consists of three different stable neutrinos [5A]. It leads to conclusion that the lightest/ground-state Higgs boson consists of four different stable neutrinos and its gravitational mass is about $1.33 \cdot 10^{-66}$ kg [5A]. But SST shows that the non-gravitating energy frozen inside the lightest Higgs boson is tremendous i.e. is about $0.6 \cdot 10^{119}$ times higher than its gravitational mass – it is the energy predicted within the Quantum Physics.

The discovered Higgs boson with a mass of 125 GeV consists of tremendous number of the confined lightest Higgs bosons. Here we described the mechanisms that quantize the masses of the composite Higgs bosons. Within the mainstream theories there is not a mathematical method to quantize the masses of the condensates. It is possible only within the Scale-Symmetric Theory because this theory leads to the internal structures of the bare fermions and bosons. We can see that within the Scale-Symmetric Theory we as well can define the lower limit for observed mass of such scalar condensates.

2. The tower of the composite Higgs bosons

There is only one renormalizable model where a complex scalar field Φ acquires a nonzero value. It is the Mexican-hat mechanism. In such mechanism the field energy has a minimum away from zero. The relevant Lagrange density can be split up into kinetic and potential terms. The potential term $V(\Phi)$ can describe the Mexican-hat potential. An arbitrary example of such potential was used by Jeffrey Goldstone [8]

$$V(\Phi) = -10 \mid \Phi \mid^2 + \mid \Phi \mid^4. \tag{1}$$

This Mexican-hat potential has minima given by

$$\Phi = sqrt(5)\, e^{i\,\theta}\,, \tag{2}$$

for angles θ between 0 and 2π. For $\Phi = 0$ the system is unstable.

On the other hand, the confinement of the neutrino-antineutrino pairs that follows from the Mexican-hat mechanism, which can be realized by Nature, is described mathematically and physically within SST [5A].

Now we describe the processes that lead to the tower of the quantized masses of the composite Higgs bosons. They are characteristic for the nuclear plasma [5D]. SST shows that due to the tremendous value of the coupling constant for the two shortest-distance quantum entanglement of the neutrino-antineutrino pairs (about $3 \cdot 10^{92}$ [5A]), the cores of baryons are practically indestructible. It causes that nuclear plasma consists of the cores of baryons with destroyed the Titius-Bode orbits for the nuclear strong interactions. It leads to conclusion that processes characteristic for the cores of baryons should define the quantized masses of the composite Higgs bosons that are the scalars composed of the quadrupoles of stable neutrinos.

The core of resting baryons consists of the central condensate with a mass of Y = 424.1245 MeV (it is the Type composite-Higgs-boson scalar but there are only the virtual versions of such Higgs boson) and of the torus/charge with a mass of X = 318.2955 MeV [5A]. The mass Y is very close to mass of a muon quadrupole so production of such quadrupoles is possible. The uncharged core of baryons consists of the electric charges of the core and electron – the electromagnetic binding energy is E_{em} = 3.0969530 MeV [5A]. To the equator of the torus there is tangent the $d = 0$ orbit and a rest mass of a particle on this orbit increases F = 9.00362 times [5A]. The mass distance between the charged and uncharged states of the core of baryons is ΔH = 2.66332 MeV [5A].

We as well need the bare mass of electron $m_{bare(electron)}$ = 0.510407011 MeV [5A], the mass of stable neutrino $m_{neutrino}$ = $3.3349306 \cdot 10^{-67}$ kg [5A] and the non-gravitating energy frozen inside stable neutrino $E_{neutrino(frozen)}$ = $1.96076 \cdot 10^{52}$ kg [5B], and we should know that mass of the Einstein spacetime corresponding to electromagnetic energy equal to E is f = 40,362.942 times higher [5A].

The gravitational mass of the ground-state Higgs boson H_0 is

$$H_0 = 4\, m_{neutrino} = 1.33 \cdot 10^{-66} \text{ kg}. \quad (3)$$

The geometric mean of the gravitational mass of the ground-state Higgs boson and the non-gravitating energy frozen inside it is

$$H_{0(mean)} = sqrt(H_0\, 4E_{neutrino(frozen)}) = 3.23 \cdot 10^{-7} \text{ kg} = 1.81 \cdot 10^{20} \text{ GeV}. \quad (4)$$

This energy is close to the Planck energy (for one stable neutrino we obtain about $4.54 \cdot 10^{19}$ GeV whereas the Planck energy is $1.22 \cdot 10^{19}$ GeV).

The gravitational mass of the Higgs boson with a mass of 125 GeV we can calculate from following formula

$$H_1 = E_{em}\, f = 125.002 \text{ GeV}. \quad (5)$$

It is consistent with experimental data [9].

The gravitational mass of the Higgs boson with a mass of 742 GeV we can calculate from following formula

$$H_2 = 4\, m_{bare(electron)}\, F\, f = 741.953 \text{ GeV}. \quad (6)$$

It is close to experimental data [10] (about 750 GeV).

The gravitational mass of the Higgs boson with a mass of 17.1 TeV we can calculate from following formula

$$H_3 = 4\, m_{bare(muon)}\, f \approx Y f = 17.119 \text{ TeV}. \quad (7)$$

It is the expected mass to verify SST.

Notice that in the formulae for the masses of the real composite Higgs bosons (formulae (5), (6) and (7)) there always appears the factor f = 40,362.942 so production of such Higgs bosons results directly from interactions of some quanta of energy with the Einstein spacetime.

The obtained results are collected in Table 1.

Table 1. *The tower of masses of Higgs bosons*

Higgs boson	Mass (SST)
H_0 (ground state)	~$1.3 \cdot 10^{-66}$ kg **Geometric mean of mass and frozen energy:** ~$1.8 \cdot 10^{20}$ GeV
H_1	~125 GeV
H_2	~742 GeV
H_3	~17.1 TeV
H_4 (virtual only)	~424 MeV

3. Summary

Here, applying the Scale-Symmetric Theory (SST), we described the real Higgs mechanism that transformed partially the superluminal non-gravitating Higgs field (the inflation field) into the luminal gravitating Einstein spacetime composed of the neutrino-antineutrino pairs.

The lightest Higgs boson is the quadrupole of the four stable neutrinos (the tau-neutrino is unstable) so its gravitational mass is very low but the superluminal non-gravitating energy frozen inside such ground-state Higgs boson is about 119 powers of ten higher than the observed energy/mass – the geometric mean is close to the Planck energy.. The calculated geometric mean of the gravitational mass of the lightest Higgs boson and the non-gravitating energy frozen inside it ($\sim 1.8 \cdot 10^{20}$ GeV) is close to the Planck critical energy.

There can appear the composite Higgs bosons composed of the confined lightest Higgs bosons – their masses are quantized and such quantization follows from properties of the nuclear plasma described within SST. According to SST, such liquid-like plasma consists of the cores of baryons. Due to the tremendous value of the coupling constant for the two shortest-distance quantum entanglement of the neutrino-antineutrino pairs, the cores of baryons are practically indestructible.

There appear the composite Higgs bosons with masses of 125 GeV, 742 GeV and about 17.1 TeV. Notice that in the formulae for the masses of the real composite Higgs bosons there always appears the factor $f = 40{,}362.942$ so production of such Higgs bosons results directly from interactions of some quanta of energy with the Einstein spacetime.

There is as well the virtual composite Higgs boson with a mass of 424.12 MeV.

But probably there can appear other quantized masses as well as the components of the tower of the masses of the composite Higgs bosons.

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