Higgs boson as a window into physics beyond the Standard Model

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In 1964 a mechanism of spontaneous symmetry breaking was proposed by Peter Higgs in the framework of the model of combining electromagnetic and weak interactions, providing for the emergence of the Higgs boson particle, connected with the masses of gauge particles, [1]. The discovery in 2012 of the Higgs boson with a mass of about 125 GeV at the LHC has been a triumph for the standard model, and the main channels for its formation and decay are still being studied at ATLAS, CMS detectors.

One of the key questions for studying the properties of the Higgs boson is the question of clarifying its mass at large energy scales. The question of the stability of an electroweak vacuum leads to a prediction of the Higgs boson mass of about 129 GeV, which differs from experimental data. The condition of absolute stability of electro-weak vacuum

$$M_H \geq 129.6 + 1.8 \times \left(\frac{m_t^{pole} - 173.2}{0.9} \right) - 0.5 \times \left(\frac{\alpha_s(M_Z) - 0.1184}{0.0007} \right) \pm 1.0 \tag{1}$$

depends on three components: the Higgs boson mass M_H, strong coupling constant α_s, the top quark pole mass, m_t^{pole}. If the Higgs mass is exactly $M_H = 125$ GeV, the stability of the electroweak vacuum up to the Planck scale is excluded, while the value $M_H = 126$ GeV allows for the stability of the vacuum [2].

The question of vacuum stability is connected with vacuum energy density of a specific kind used in the Higgs mechanism for spontaneous symmetry breaking. The inflationary scenario for the first picosecond after the Big Bang proposes that a fairly large vacuum energy density existed during the inflationary epoch. The presence of a dynamic Higgs field, which can change the potential $V(\varphi)$ from zero to maximum, allows for the possibility of changing the vacuum density, ρ, from 10^{80} kgm^{-3} to 10^{-26} kgm^{-3}. However, the presence of a false vacuum provides for the possibility of a multiverse with a complex potential. Our task is to predict such transitions into different universes within the framework of the multidimensional theory of type IIB superstring theory, [3]. In this case phase transitions are looking like black hole evolution connected with black hole evaporation. According to Susscind, [4], such process could be explained in the framework of the relations between space, time, matter and information. String theory does provide a microscopic framework for consistent microscopic theory of black hole entropy, which agrees with the BekensteinHawking entropy with the corresponding vacuum density. Topological invariants of type IIB superstring theory for every minimum of a multiverse with different vacuum are the Ramon-Ramon (RR) charges described by K-theory, [5]. Examples of calculating of the RR charges for special cases of extra dimensions are considered.

References

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