On the Higgs Boson's Range

A n t o n i o   P u c c i n i

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Abstract

The discovery of the Higgs boson (*HB*) has revealed a highly massive particle, the value of which lies between 125 and 126.5 GeV/c^2. Bearing in mind the basic concepts of Quantum Field Theory, and in full compliance with the Heisemberg Uncertainy Principle, we were able to calculate the maximum limit of the *HB*'s range: in perfect agreement with its high mass, it presents a value really very small, of slightly less than 10^{-15}[cm], namely $9.8828 \cdot 10^{-16}$[cm].

Introduction

The technical basis of the Standard Model (SM) of elementary particles is made up of a basic principle, known as Local *Gauge Invariance* or local G*auge Symmetry*.

That is, as Emmy Noether [1] had already intuited and demonstrated, the behavior of Nature is invariant under certain transformations on its fundamental constituents, such as the fields of fundamental particles. Thus the introduction of a simple mass parameter, necessary to describe the mass of a particle, is in contradiction with the existence of this fundamental symmetry: it is said, that is, that the mass breaks the gauge symmetry, thus risking to make insubstantial the entire theory of the SM, and thus preventing to comprise, at a fundamental level, the origin of the interactions between the particles. According to SM the problem can be solved by assuming that all particles have a null intrinsic mass and postulating the existence of a *complex scalar field* permeating the space. The re-introduction of the mass parameter causes the gauge symmetry to be no more explicit, but that is spontaneously broken: *Spontaneous Symmetry Breaking* [2],[3],[4].

It is in this case a *symmetry hidden from the mass*. So it was conjectures more or less at the same time, and independently by Englert and Brout, [5] by Higgs [6], Guralnik, Hagen and Kibble [7] that particles would tend to interact , to mate with this *complex scalar field*, now known as Higgs field (HF), acquiring an energy at rest which is not null, which for almost all respects is analogous to a value of mass at rest, then describable as a parameter mass. As it is well known, the mechanism just described is the so-called *Higgs Mechanism* (HM). The HM requires the intervention of a permeating particle the HF, i.e. the Higgs Boson (*HB*). This particle is so named because, in referring his work to the Journal, Higgs talked in a statement the possibility of the existence of another spin zero heavy boson, which he described as "the prediction of incomplete multiplets of scalar and vector bosons"[6].

It is interesting to note that the coupling between the various particles (to be exact "only those bearers of weak charge" [8]) and HF (steeped in weak charge) complies with the *gauge symmetry* and explains the presence of non-null rest masses.

Discussion

The research of the *HB* was delayed for a long time. Frequent were his probable measurements in particle accelerators, but it reached a value of reliability (or confidence level) of 2 sigma (σ) and then to 3 σ: still a too low value to be able to proclaim a discovery [8], since a signal at 3 σ it corresponds to a confidence level of 99.7%, that is, to a probability of 0.3% that the signal is actually due to the case [9]. Subsequently, when the CERN of Geneve began operating with an energy of collisions of 7 and 8 TeV, it was possible to reach the much longed 5 σ. In fact, as known, to be able to announce the discovery of a new particle, it is required a signal with a confidence level $\geq$ 5 σ [8], as a signal to 5 σ corresponds to a confidence level of 99.9999% [9].

So, at the Congress of the CERN on 4 July 2012 it was announced a series of reliable surveys for *HB* [10]. The first to speak was Incandela, head of the study group working with the detector Compact Muon SolenoidCMS): He announced that, working with an energy of collision of 7 and 8 TeV, they carried out repeated surveys, with a confidence level to 5 σ, of a particle of mass apparently equal to 125.5 GeV/c^2. Then it was the time of Gianotti, head of the study group working with the ATLAS detector (A Thoroidal LHC Apparatus). She announced that, working with the same energy used by CMS, they had found numerous surveys, with 5 σ of reliability, of a particle of mass approximately between 125 and 126.5 GeV/c^2. Both study groups communicated that the decay products of the particle detected could match those of *HB*. So: we have the *HB*, and we know its mass, which we could consider between the values measured with the CMS and ATLAS, which is roughly equal to 125.5 GeV /c^2.

At which point we would like to know his range: this is the purpose of our work. One wonders: where does the *HB* take all this *mass-energy*? From his field, that is the field in which it is immersed: the HF. According to the Quantum Field Theory (QFT) the higher the value of the mass of the particle, i.e. the more the energy (Δ_E) taken from the field, the sooner (Δ_t) the energy must be returned to the field itself. This is an inviolable rule of Quantum Mechanics, dictated by the Heisemberg Uncertainty Principle (HUP)[11][12]:

$$\Delta_E \cdot \Delta_t \geq h \qquad (1),$$

where h is Planck's constant, equal to $6.626 \cdot 10^{-27}$[erg · sec]. Applying the HUP to *HB*, we have that the Δ_E of Eq. (1) corresponds to the energy value of *HB*, i.e. 125,5 GeV/c^2. What we do not know, in this case, is the value of Δ_t, i.e. of duration (t) of the *HB*'life, before it returns to the field all the energy

(E) taken, so to speak, *borrowed* . The duration of this energy loan, in favor of *HB*, is provided by Eq. (1), from which we have:

$$t = h/E \qquad (2).$$

Eq. (2) shows that time and energy are inversely proportional. That's why the higher the energy value borrowed, as saying subtracted from the field, the sooner this energy must be returned. To this point we take into account the principle of equivalence mass-energy (MEEP):

$$E = m c^2 \qquad (3).$$

Therefore, by replacing the value of E in Eq.(2) with that of Eq. (3), we obtain:

$$t = h/ m c^2 \qquad (4).$$

Eq. (4), as Fermi reminds us "it is the time in which the boson issued may remain in free space. If then it is assumed that its speed is the maximum speed at which a particle can move, that is the speed of light (c), it is seen that the maximum distance (d) it can reach, before being recalled to weld the debt, is given, as order of magnitude, by the product of time (t) for the maximum rate at which the particle can move" [13], namely:

$$d = t\, c \qquad (5).$$

So we put in Eq. (5) the value of t expressed by Eq. (4):

$$d = (h/ m c^2)\cdot c \qquad (6),$$

namely:

$$d = h/ m c \qquad (7).$$

Thus, the maximum distance the *HB* can take is the one expressed by Eq. (7), i.e. the upper limit of its range. It comes more useful to express in grams [g] the mass *HB*, using the cgs system. Since 1 MeV/c^2 = $1.782\cdot10^{-27}$ [g] [14], it follows that 1 GeV/c^2= $1.782\cdot10^{-24}$ [g], so the mass of *HB* will be:

$$m_{HB} = 125.5 \cdot (1.782 \cdot 10^{-24} \text{ [g]}) \qquad (8),$$

that is:

$$m_{HB} = 2.23641\cdot10^{-22} \text{ [g]} \qquad (9).$$

So we replace this value to m of Eq. (7):

$$d = 6.626 \cdot10^{-27} \text{ [erg} \cdot \text{s] / (2.23641} \cdot 10^{-22} \text{ [g]) (2.99792} \cdot 10^{10}\text{[cm/s])} \qquad (10).$$

Since 1 erg = g·cm/s^2 · cm, we can write:

$$d = 6.626 \cdot10^{-27} \text{ [g} \cdot\text{cm}^2\text{/s] / } 6.7045782 \cdot 10^{-12}\text{[g} \cdot\text{cm/s]} \qquad (11),$$

$$d_{HB} = 9.8828 \cdot 10^{-16}\text{[cm]} \qquad (12).$$

Conclusions

So, the value expressed by Eq. (12) represents the maximum limit of the *HB* range, i.e. the maximum distance (*d*) the *HB* can take before it returns the energy to the field in which it is immersed, namely the HF. Our calculations reveal a range of *HB* really very small, slightly smaller than 10^{-15}[cm], but this value is justified by the considerable mass that the *HB* acquires. This is certainly a very small value, which shows a very marked space limitation of this boson, but these are the rules imposed by Quantum Mechanics, through one of its most profound concepts: the HUP. Therefore the range of *HB* will never exceed the distance expressed by Eq. (12), otherwise the HUP would be violated and as Hawking precised "HUP is a fundamental, inescapable property of the world" [15]. Besides as Feynman says: “No one has ever found (or even thought of) a way around the Uncertainty Principle. So we must assume that it describes a basic characteristic of nature” [16].

References

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