HIGGSBOSON RADIUS of ACTION

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ABSTRACT

As we are all aware,therecent discovery of the Higgs boson has revealed a highly massive particle, the value of which lies between 125and 126.5 GeV/c^2..

According to the basic concepts of Quantum Mechanics, and in full compliance with the Uncertainty Principle and Yukawa intuitions, we were able to calculate the maximum limit of the Higgs boson's field of action.

From the calculations show that the Higgs boson presents a range of action really very small, namely $9.8828 \cdot 10^{-16}$[cm], that is slightly smaller than 10^{-15}[cm].

This value is justified by the considerable mass that the Higgs bosonacquires, in perfect agreement with the Uncertainty Principle.

Keywords:Higgs boson(HB); Standard Model(*SM*)**;**Heisemberg Uncertainty Principle(HUP); Wave Function(WF); Higgs field(HF).

I. INTRODUCTION

As it is known, the Standard Model (*SM*) of elementary particles is made up of a basic principle, known as 'local *Gauge Invariance*' or 'local G*auge Symmetry*'.

1.1 The *GAUGE SYMMETRY*

According to Noether the behavior of nature is *invariant* under certain transformations on its fundamental constituents, such as the fields of fundamental particles[1][2].

The conservation of various physical quantities comes from this *invariance*. Applying this procedure to the *fields*, we have that in case of a *gauge-invariance*, we will have a charge conservation: e.g. in the case of the *gauge invariance* of the electromagnetic(EM) field.

As Chandrasekhar reminds us "the dualism wave-particle is an universal and fundamental property of the matter"[3]. In line with de Broglie[4], this dualism can be solved with the Quantum Mechanics living to the particles a *wave function* (WF) of their own, indicated with Ψ, which describes correctly both their wave and particle character.

In the case of the EM field, we will have a conservation of the electrical charge, respect to:

$$\Psi \rightarrow e^{i\theta}\Psi \qquad (1).$$

This *unobservable* transformation is the most famous *gaugetransformation* where Ψ represents the WF of an electrically charged particle (such as the electron),$e^{i\theta}$ is a *complexunitnumber* (with θ real), expressing a *complete* phase, and *i* is the *imaginary unit.*

Penrose points out: "If the WF describes a charged particle, then we can make *gauge transformations* of the form expressed by equation(1) where θ is an arbitrary real position function, allowing us to change the way the phase varies!"[5].

Maxwell's equations do not change, that is, they are *covariant*, so Weyl believed that it was possible to extend this *covariance* to the gravitational field too, as well as to General Relativity, thus trying to unify electromagnetism and gravity. In fact, in line with the Noether theorem, in 1918 Weyl formulated a *gauge theory* to be applied to General Relativity[6]. However,"Along with Weyl's theory, the way a clock measures time does not depend solely on its current position, but also on the previously positions. Likewise, the emission frequencies of a hydrogen atom will depend both on its current and past positions. It is like saying: the behavior of the atom will depend on its history, despite contradicting experimental evidence"[7].

II. DISCUSSION

In short, "Weyl's idea contained a fatal mistake, which Einstein clearly saw from the beginning"[7]. Pauli also pointed out with regret that error[8][9].

2.1 The MASS *BREAKS* the *SYMMETRY*

Thus the introduction of a simple mass parameter, necessary to describe the mass of a particle, is in contradiction with the existence of the*gauge symmetry*: it is said, that is, that the *mass breaks* the *gauge symmetry*, thus risking to make insubstantial the entire theory of the *SM.*.

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 is not more explicit, but that is spontaneously broken: *Spontaneous Symmetry Breaking*[10][11][12].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, [13] by Higgs [14], Guralnik, Hagen and Kibble[15] 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*.

The*Higgs Mechanism* requires the intervention of a permeating particle the HF, i.e.the Higgs Boson (HB).

It isinteresting to note that the coupling between the various particles (to be exact "only those bearers of weak charge"[16][17]) and HF (steeped in weak charge) complies with the *gauge symmetry* and explains the presence of non-null restmasses.

2.2 HIGGS BOSON HUNTING

As we all know the research of the HB was delayed for a long time.

Frequent were its 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 toproclaim a discovery [16], 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 [18].

Subsequently, when the CERN of Geneva began operating with an energy of collisions of 7 and 8 TeV, it was possible toreach the much longed 5 σ.

In short, as you will be aware, to be able to announce the discovery of a new particle, it is required a signal with a *confidence level* ≥ 5 σ [16], as a signal to 5 σ corresponds to a *confidence level* of 99.9999% [18].

2.3 HIGGS BOSON DISCOVERY

Finally, at the Congress of the CERN on 4 July 2012 it was announced a series of reliable surveys for HB [19].

As everyone knows, the first to speak was Joe Incandela, head of the study group working with the detector Compact Muon Solenoid(CMS). 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.

Next was the turn of Fabiola Gianotti, head of the study group working with the ATLAS (A Thoroidal LHC ApparatuS)detector. 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.

2.4 HIGGS BOSON RANGE

At which point we would like to know its range of action, its operating field: this is the purpose of our work.

One wonders: where does the HBtake all this *mass-energy*? From its field, that is the field in which it is immersed: the HF. According to the Quantum Field Theory 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)[20][21]:

$$\Delta_E \cdot \Delta_t \geq h \qquad (2),$$

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 equation (2) corresponds to the energy value of HB, i.e.125,5 GeV/c^2.

Obviously, 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 equation(2), from which we have: $t = \frac{h}{E}$ (3).

Observing the equation (3), we noticethat *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:

$$E = m\,c^2 \quad (4).$$

Hence, by replacing the value of *E* in equation (3) with that of equation (4), we obtain:

$$t = \frac{h}{mc^2} \quad (5).$$

Equation (5), as Fermi reminds us "it is the *time*(*t*) 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" [22], namely:

$$d = t\,c \quad (6).$$

So we put in equation (6) the value of *t* expressed by equation(5):

$$d = \frac{h}{mc^2} \cdot c \quad (7),$$

namely:

$$d = \frac{h}{m\,c} \quad (8).$$

And 'interesting to note that the *distance* (*d*) expressed by the latter equation corresponds exactly to the radius of action (R_o) obtainable from the *Yukawa* potential[23]:

$$R_o = \frac{h}{2\pi m\,c} \quad (9).$$

Thus one expressed by equation(8) is the maximum distance the HB can take, ie the upper limit of its *action field*. It comes more useful to express in grams [g] the mass HB, using the *cgs system*. Since 1 GeV/c^2= 1.782·10^{-24}[g],so the mass of HB will be:

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

that is:

$$m_{HB} = 2.23641 \cdot 10^{-22}\ [g] \quad (11).$$

So we replace this value to *m* of Eq. (8):

$$d = 6.626 \cdot 10^{-27}\ [erg \cdot s] \ / \ (2.23641 \cdot 10^{-22}\ [g])\ (2.99792 \cdot 10^{10} [cm/s]) \quad (12).$$

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

$$d = 6.626 \cdot 10^{-27}\ [g \cdot cm^2/s] \ / \ 6.7045782 \cdot 10^{-12} [g \cdot cm/s] \quad (13),$$

$$d_{HB} = 9.8828 \cdot 10^{-16} [cm] \quad (14).$$

III. CONCLUSIONS

In short, the value expressed by equation (14) represents the maximum limit of the*radius of action* of the HB, i.e. the maximum distance (*d*) passable by HB, before it returns the energy to the field in which it is immersed, namely the HF.

Our calculations reveal a *range of action* of HB really very small, slightly smaller than 10^{-15}[cm], but this value is justified by the considerable mass that the HB acquires, perfectly along with the known fact that the action rangeof a *force* is inversely proportional to the mass of the bosons the force conveys.

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.

In closing, the *range* of HB will never exceed the distance expressed by equation (14), otherwise the HUP would be violated and as Feynman specifies: "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" [24].

Hawking adds: "HUP is a fundamental, inescapable property of the world"[25].

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