

QUARKS and GLUONS CONFINEMENT: a POSSIBLE PHYSICAL EXPLANATION
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The rules established by Quantum Mechanics (QM) play a crucial role, through the Heisenberg Uncertainty Principle (HUP), in the *spatial Confinement of Quarks and Gluons*, which have remained eternally confined, since the dawn of time, in an extremely narrow space by the Strong Interaction. The enormous amount of energy the Q borrows in favor of the emitted G, prevents it from covering a long way. According to HUP the energy debt has to be paid immediately, and the G flow path, i.e. of its range, will be determined by the short existence that QM gives to the G.

Consequently, the very short range of G implies that, according to Yukawa Principle, but in disagreement with *gauge theories* and Quantum Fields Theory, its mass cannot be = 0, but very high. Our calculations, in fact, show that the range of G should correspond approximately to $8.44[\pm 1.44] \cdot 10^{-16}$ [cm]. This value, therefore, indicates the maximum distance that can separate a Q from the other two inside of a hadron.

Keywords: Strong Interaction (SI); Weak Interaction (WI); Quantum Mechanics(QM); Gluon(G); Brout-Englert-Higgs Mechanism (BEH-M); Electromagnetic(EM); Quark(Q).

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1. INTRODUCTION

1.1 QUARKS (Q_s) and NUCLEONS

As it is known, the Strong Nuclear Interaction(SI) acts inside both the atomic nucleus and the nucleons. In the first case it keeps together the nucleons inside the nucleus; in the second case it keeps together the quarks(Q_s) inside each nucleon.

Nucleons are made of protons and neutrons; each proton is made of 2 up Q_s (uQ) and 1 down Q (dQ), while each neutron is made of 2 dQ and 1 uQ.

Gell-Mann [1] and Zweig [2], in fact, independently, propose that hadrons are simply aggregates of more fundamental constituents, to which Gell-Mann gives the name of Q[1].

1.2 ISOSPIN SYMMETRY

In addition, it is interesting to consider the so-called *isospin symmetry*. The isospin symmetry, or isotopic spin symmetry, had been introduced by Heisenberg in relation to the surprising similarity of the masses of the proton and neutron (called "nucleons" just by Heisenberg [3]) and consisted in supposing that the nuclear forces were symmetrical for the proton and neutron substitution with arbitrary linear superimpositions of these two states. Obviously, this symmetry is not respected by the Electro-Magnetic Interaction (EMI), which distinguishes the proton (positive electric charge) from the neutron (zero electric charge). In the same manner what happens for particle spin (hence the name of symmetry), "symmetry implied that the nuclei occurred in *multiplets* of isotopic spin I , with $2I+1$ states and electrical charges one unit apart, according to the rule:

$$q = I_3 + \frac{1}{2} B, I_3 = -I, -I+1, \dots, +I, \quad (1),$$

where q is the electric charge in units of the proton charge, B is the Barionic Number and I_3 is the third component of the isotopic spin, analogous to the magnetic quantum number of the *angular momentum* [4]. The surprise was that even hadrons respected isospin symmetry and presented themselves in *multiplets*, each characterized by an I value of the isotopic spin and by electric charges given by a formula analogous to Eq.(1):

$$q = I_3 + \frac{1}{2} (B+S), I_3 = -I, -I+1, \dots, +I, \quad (2),$$

where S is a new quantum number introduced by Gell-Mann to characterize the *strange particles* ($S=0$ for nucleons and pions, $S=+1$ for K^+, K^0 , $S=-1$ for hyperon Λ , etc.).

Equation (2) is known as Gell-Man and Nishijima's *formula*.

As known, at the beginning of the fifties, attention was focused on Nuclear Interactions: i.e. the SI and the Weak Nuclear Interaction(WI). And so, "in the first pion beam experiments at the Chicago Cyclotron, Fermi had observed the first baryonic 'resonance' and obtained the surprising confirmation of the isospin symmetry, which characterizes the particles sensitive to SI.

Fermi's observations showed convincingly that symmetry was not something accidental, but referred to a fundamental property of SI, of general validity.

The success of isotopic spin symmetry suggested that the SI theory was its natural field of application and the spin 1 mesons discovered in 1961 were for some time identified with the SI gauge fields. However, some others, like J. Schwinger, indicate the WI and EMI as the natural field of application of the ideas of Yang and Mills"[4]. Thus, Gershtein and Zel'dovič in 1957 [5] and Feynman and Gell-Mann in 1958 [6] propose that WIs are of a vector nature, therefore due to the exchange of a spin 1 electrically charged particle, or intermediates vector bosons carrying WI: the W^+ and W^- particles. Thus, the isospin symmetry, so prominent in nuclear phenomena, represents

the basis for a WI and EMI gauge theory, unifying them in an *Electro-Weak Interaction* (EWI).

The scheme on which to adapt these ideas is based on matter *doublets* (hadron matter and lepton

matter), which all transform at the same time, under the *transformations* of a new group $SU(2)$, or *weak isospin*:

$$N = \begin{pmatrix} p \\ n \end{pmatrix}, \quad L_e = \begin{pmatrix} \nu_e \\ e \end{pmatrix}, \quad L_\mu = \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \quad (3),$$

$$N \rightarrow U N, \quad L_{e,\mu} \rightarrow U L_{e,\mu} \quad (4),$$

where: N =nucleon; p = proton; n = neutron; L_e =electronic lepton; $L_{e,\mu}$ = electronic or muonic lepton; e =electron; μ =muon; ν =neutrino; ν_e = electronic neutrino; ν_μ = muonic neutrino and U is a *complex matrix* 2×2 . As Maiani points out "The main obstacle on this line is represented by the mass of intermediate bosons which, far from being null as the Yang-Mills theory suspected, must be big enough so that these particles do not give visible effects in the weak decays of neutron, muon and other particles"[4]. Therefore, in 1961 Schwinger proposed to Glashow, as the theme of his thesis, to try to elaborate a theory that unifies the WI with the EMI, based on the Yang-Mills theory.

The classification below the weak isospin represented in Eq.3 is updated in the following schemes:

$$Q = \begin{pmatrix} u \\ d \end{pmatrix}, \quad (s) \quad (5),$$

$$L_e = \begin{pmatrix} \nu_e \\ e \end{pmatrix}, \quad L_\mu = \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \quad (6).$$

However the Neutron Decay, or *negative beta decay* (βd^-) of the *strange particles*, as

$$\Lambda \rightarrow p + e^- + \bar{\nu}_e \quad (7),$$

(where $\bar{\nu}_e$ is the electronic anti-neutrino) corresponds to the transition $uds \rightarrow uud$, or $sQ \rightarrow uQ$, which could not occur in this scheme because the *strange* Q (sQ) would have isospin 0 and would not be coupled to W^- , that is, the boson carrying the WI that governs the βd^- . To this purpose Cabibbo [7] observed that WI may not respect the scheme (5), but requires that the dQ , with defined isospin, is a superposition of the quarks d and s with a *mixing angle*, since then known as *Cabibbo angle* [4]. In this case, the weak isospin scheme is:

$$Q = \begin{pmatrix} u \\ \cos\theta d + \sin\theta s \end{pmatrix}, \quad (-s\theta d + \cos\theta s) \quad (8).$$

Comparing the decays of the baryons having *strangeness* with the neutron βd^- , the value we obtain is:

$$\sin \theta = 0.225 \quad (9).$$

As Maiani reminds us "The classification in Eq.(8) is not yet satisfactory to extend the Cabibbo theory to a unified Yang-Mills theory. If we do this, the neutral boson, Z^0 , would produce processes with change of *strangeness*, of the type:

$$K^0 \rightarrow \mu^+ \mu^- \quad (10),$$

which are observed to proceed with much lower probabilities than the processes mediated by the W , for example βd^- shown in eq.(7)"[4]. In 1970 Glashow, Iliopoulos and Maiani (GIM) hypothesized the existence of a fourth Q flavor, the Q *charm* (cQ), which would avoid the conflict just reported [8]. Thus, the Cabibbo scheme should be changed to a more symmetrical pattern:

$$\begin{aligned} Q^{(1)} &= \begin{pmatrix} u \\ \cos\theta d + \sin\theta s \end{pmatrix}, & L^{(1)} &= \begin{pmatrix} \nu_e \\ e \end{pmatrix} \\ Q^{(2)} &= \begin{pmatrix} c \\ -\sin\theta d + \cos\theta s \end{pmatrix}, & L^{(2)} &= \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \end{aligned} \quad (11).$$

The structure of (11) indicates that quarks (Q) and leptons (L) must be in two identical "generations", with perfect symmetry between quarks and leptons. Moreover, the 3 A.A.(GIM) show that the existence of the 4th Q *flavor*, or cQ , suppresses the processes with exchange of the Z^0 boson and change of *strangeness* (*GIM mechanism*), also deducing the probable mass of the cQ : $\sim 2\text{GeV}$ "[4]. Finally, the *mass-gap problem* of the Yang-Mills theory was solved with the Brout-Englert-Higgs Mechanism (BEH-M), linked to the *spontaneous breaking* of the gauge symmetry [9] [10]. The

theory formulated by Weinberg [11] and Salam [12] adopts the symmetry introduced by Glashow in 1961[13] and incorporates the BEH-M solving the problem of the mass of vector bosons, but is still limited to lepton doublets, leaving unsolved the problem of the *strange matter*. On a formal level, the problem is closed in 1972 by 't-Hooft and Veltman [14], which show that the Weinberg and Salam theory, with the mass of intermediate bosons associated with *spontaneous symmetry breaking (SSB)*, can be *renormalized* as the electro-dynamic.

However, "something is still missing for physics, since it does not allow us to introduce any violation of the symmetry between matter and antimatter, or violation $\mathcal{CP}$, in the WI, where by $\mathcal{C}$ we mean the *charge Conjugation* (which allows us to change every particle in its antiparticle) and with $\mathcal{P}$ the *Parity* (which reverses the orientation of the coordinated axes). In this way we must postpone the explanation of the violation observed in the decays of the K^0 mesons to a new interaction, to be introduced *ad hoc*"[4]. Then, extending the construction of Cabibbo, in 1973 Kobayashi and Maskawa [15] show that the existence of a further generation of Qs and leptons allows the introduction of complex coefficients in the weak current, besides confirming the violation of $\mathcal{CP}$. Thus, the scheme (11) should be extended to 3 particle *families*:

$$\begin{aligned} Q^{(1)} &= \begin{pmatrix} u \\ d_w \end{pmatrix}, & L^{(1)} &= \begin{pmatrix} \nu_e \\ e \end{pmatrix} \\ Q^{(2)} &= \begin{pmatrix} c \\ s_w \end{pmatrix}, & L^{(2)} &= \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \\ Q^{(3)} &= \begin{pmatrix} \tau \\ b_w \end{pmatrix}, & L^{(3)} &= \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix} \end{aligned} \quad (12),$$

where τ is the *top* Q (τQ), b is the *bottom* Q (bQ), i.e. the new quark family, and $D_w = (d_w, s_w, b_w)$ are the three linear combinations of the quarks fields $D = (d, s, b)$ obtained with a unitary matrix which generalizes the construction of Cabibbo:

$$D_w = U_{CKM} D \quad (13).$$

With three generations, the Cabibbo-Kobayashi-Maskawa matrix (U_{CKM}) can include complex coefficients that produce the violation of symmetry $\mathcal{CP}$.

1.3 QUANTUM FIELDS THEORY

In agreement with Quantum Fields Theory(QFT), Dirac field (Ψ), with a mass m and *not interacting*, is described by the (Dirac's) Lagrangian, $\mathcal{L}_D$:

$$\mathcal{L}_D = i \bar{\Psi} \gamma^\mu \partial_\mu \Psi - m \bar{\Psi} \Psi \quad (14),$$

where γ^μ is the Dirac matrix, which satisfies Clifford's algebra: $\{\gamma^\mu, \gamma^\nu\} = 2g^{\mu\nu}I$; i is the imaginary unit, $\bar{\Psi}$ is the anti-particle. The magnitude ($\mathcal{L}_D$) is, by construction, invariant under the action of the Poincaré group. Nevertheless, it presents a further symmetry, not associated with space-time transformations. Indeed, the $\mathcal{L}_D$ form remains unchanged if we rotate the phase of the field (Ψ) of a real angle (θ), that is if we perform the *gauge transformation*:

$$\Psi(x) \rightarrow e^{i\theta} \Psi(x) \quad (15).$$

Thus, the real quantity that appears is the so-called gauge coupling parameter; it depends on the particular field Ψ on which the transformation acts: it coincides, except for the sign, with its electric charge. Whereas, the value of the continuous parameter θ univocally identifies each particular *gauge transformation*, as shown in Eq.(15) [16].

1.4 GAUGE TRANSFORMATIONS and GAUGE THEORIES

As we are all aware, Maxwell's equations do not change, i.e. 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. Thus, working on the theory of continuous symmetry groups (the so-called Lie's *Groups*) and bearing in mind the Noether theorem [8], Weyl was convinced that the Conservation Laws are related to *local transformations of symmetry*, which gave the generic name of *Eichinvarianz* or gauge invariance (*eich*=gauge) under the change of measurement scale: or *gauge*, precisely; a term unfortunately rather obscure. *Eich* means *phase*, or even *scale* or *caliber*: a *measure of length*. Indeed, Weyl sought *invariance* by dilatations, i.e. with real $i\theta$, instead he found invariance in the case of real θ . Therefore, Weyl conjectured that a *gauge symmetry* might also be a *local* symmetry of General Relativity. Later, in 1918 Weyl formulated a *gauge theory* [18] to be applied to General Relativity. Maiani says: "In this framework, Weyl formulates its gauge theory of the Electro-Magnetic Interactions (EMI). Weyl postulates that the invariance for *local* coordinate transformations also extends to the calibration of physical lengths "[4]:

$$dx \rightarrow e^{\lambda(x)} dx \quad (16),$$

with λ (wave length) real function of the coordinates. Equation (16) shows that the scale factor, $\lambda(x)$, (as saying *gauge* factor) is determined by the coefficients of a differential form, $A_\mu(x)$:

$$\lambda(x) = \int^x A_\mu(y) dy^\mu \quad (17).$$

The integral must be performed on a *path* that, starting from the origin, arrives at point x . The path is arbitrary and the same result is or isn't obtained for all paths, depending on whether the condition of integrability occurs:

$$F_{\mu\nu}(x) = \frac{\partial A_\nu}{\partial x^\mu} - \frac{\partial A_\mu}{\partial x^\nu} = 0 \quad (18).$$

When this does not happen, there are new forces determined by $F_{\mu\nu}$ and the corresponding equation of motion takes the form:

$$\frac{\delta}{\delta x^\nu} \cdot F^{\mu\nu}(x) = e J^\mu(x) \quad (19).$$

Regarding Eq.(19) Maiani adds: "It is an equation of the type of Einstein's equation, a geometric entity equaled by a dynamic entity, which determines the forces exerted on the matter that carries the quality associated with the current J^μ . Weyl identifies, of course, J^μ with the electromagnetic current, the constant e with the elementary electric charge, and $F^{\mu\nu}$ with the Maxwell tensor, which sums up the electric and magnetic fields: $A_\mu(x)$ "[4].

Nevertheless, Einstein immediately replied that the laws of Physics are *not invariant* under *gauge transformations* and that the Weyl's *gauge theory* was in conflict with Relativity Theory[4].

However, after the development of Quantum Mechanics(QM), Fock and London modified *gauge* by replacing the scale factor with a complex quantity and turned the scale transformation into a change of phase, which is a $U(1)$ gauge symmetry. This explained the electromagnetic field effect on the wave function of a charged quantum mechanical particle. In fact, both Fock, 1926 [19], in relation to the Schrödinger equation for the electron, and London, 1927 [20], in formulating the superconductivity theory, observed that the minimal substitution of classical electro-magnetism:

$$\mathbf{H}_p \rightarrow \mathbf{H}_p - q\mathbf{A}^0 \quad (20),$$

$$\mathbf{p} \rightarrow \mathbf{p} - q\mathbf{A} \quad (21),$$

takes, in Schrödinger equation, to the substitution:

$$i\frac{\partial}{\partial t} \rightarrow i\frac{\partial}{\partial t} + e\varphi(\mathbf{x},t) \quad (22),$$

$$-i\frac{\partial}{\partial x} = -i\frac{\partial}{\partial x} + e\mathbf{A}(\mathbf{x},t) \quad (23),$$

which allows us to make the Schrödinger equation invariant for substitutions:

$$\Psi(x) \rightarrow e^{ie\lambda(x)} \Psi(x) \quad (24),$$

$$A_\mu(x) \rightarrow A_\mu(x) + \frac{\delta}{\delta x^\mu} \lambda(x) \quad (25),$$

on the wave function of the electron, $\Psi(x)$, and on the electromagnetic(EM) field, $A_\mu(x)$.

In 1929 Weyl accepted the crucial introduction of the imaginary unit (i) in the exponent and proposed, indeed, that the invariance for transformations (24) and (25) should be the principle from which to derive the laws of electrodynamics, principle which he gave the name of *gauge principle* or minimal principle. Weyl's 1929 work marks the beginning of modern *gauge theories* [4].

1.5 The MASS BREAKS the SYMMETRY

Thus, taking inspiration from Fock's works (1926) on the *electron's* Wave Function equation of Schrödinger, or the London's works (1927) on *superconductivity*, in 1929 Weyl published another work in which he attributed great importance to the *gauge theories* [21]. However, this article also fully preserves the same parameters and mathematical procedures previously contested by Einstein and Pauli, as the **assumption** that "**in an invariant gauge theory, all the particles should have zero mass like the photon**" [4].

In effect, the downside of the *gauge symmetry theories*, in our opinion, lies in the fact, really paradoxical from a *logical* point of view, that the introduction of a simple mass parameter, necessary to describe the *intrinsic mass of a particle*, is in contradiction with the existence of this symmetry: it is said, that is, that *the mass breaks the gauge symmetry*.

In agreement with the *Standard Model* of the elementary particles, the problem can be solved by **assuming** (as a *dogma*) **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(SSB)* [22][23][24]. It is in this case a *symmetry hidden from the mass*.

1.6 BROUT-ENGLERT-HIGGS MECHANISM

Then, it was conjectured more or less at the same time, and independently by Englert and Brout[9], by Higgs [10], Guralnik, Hagen and Kibble [25], 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 known, the mechanism just described is the so-called Brout-Englert-Higgs Mechanism(BEH-M). This BEH-M requires the intervention of a permeating particle the HF, i.e. the Higgs Boson (HB)[10][26].

To this purpose, it is interesting to note that the coupling between the various particles ("among bosons only those bearers of weak charge"[27]) and HF (steeped in weak charge) complies with the *gauge symmetry* and explains the presence of non-null rest masses.

2. DISCUSSION

2.1 GAUGE THEORIES in CONFLICT with RELATIVITY THEORY

As Penrose reminds, Noether theorem shows various limitations in the case of Gravitational Theory: when gravity is included, there must be the *gauge invariance* appropriate to gravity, i.e. the *invariance* with respect to the coordinates, using the mathematical formalism of *tensors* [28]. Indeed, in Weyl's theory *null cones* retain the fundamental role they play in Einstein theory (they define the boundary velocities for massive particles and give us the local *Lorentz group* that

must act in the vicinity of each point), so that a Lorentzian metric (eg, + - - -) g is still locally required in order to define these cones. There are, however, some additional structures to this structure of *null cone* (that is to say the *conformal* structure), and precisely a gauge connection - that Weyl introduced so that its *curvature* was Maxwell's tensor F (i.e. F_{ab}). This curvature measures the discrepancy of the clocks' rhythms [28].

In this context, Penrose wonders: "What is the geometric nature of the bundle on which this connection acts? It is appropriate to think that the *bundle* is the *vector bundle* of the possible values of the complex field (Ψ) in each point, where the freedom of phase (*gauge*) multiplication makes the bundle a $U(1)$ bundle on space-time $\mathcal{M}$ (Minkowski's curved space). In order for this to make sense, Ψ must be a complex field whose physical interpretation is, in a certain sense appropriate,

insensitive to substitution:
$$\Psi \mapsto e^{i\theta} \Psi \quad (26),$$

where $e^{i\theta}$ is a *complex unit number* expressing a *complete* or *global* phase (a rotation in the *complex plane*, rather than a *stretch*); i is the *imaginary unit* and θ is an arbitrary real position function, allowing us to change the way the phase varies!" [28].

The condition shown in Eq.(26) is called *electromagnetic gauge transformation*, and the fact that the physical interpretation does not depend on that substitution is known as *gauge invariance*.

In short, the Weyl idea of *gauge connection* should depend on the existence of a symmetry (which for electromagnetism should be the symmetry $\Psi \mapsto e^{i\theta} \Psi$) which, like a *dogma*, "is supposed to be exact, although it is not directly observable"[28]. But there is no absolute *scale* for time and space measurements in the Weyl scheme. "In line with Weyl 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. However, Weyl's idea contained a fatal mistake, which Einstein clearly saw from the beginning"[29]. Einstein explained, indeed, that the laws of physics are not invariant under *gauge transformations* and the elegant electromagnetic field theory had to be abandoned[4].

Einstein had shown that the mathematical formalism introduced by Weyl was excessively *incoherent* and *incongruous*, as well as blatantly clashing with the experimental evidence. At this regard, "Initially Weyl attributed the *gauge invariance* to the space itself. But, as Einstein soon pointed out, "this implied that the measure of the length of a ruler, or the hour marked by a clock, depended on their recent history. Thus, a clock, moved from one point to another of a room, would no longer mark the correct time"[30].

Briefly, the **Mathematics supported by Weyl belied and contradicted the basic principles of the Theory of Relativity!** It was really unacceptable for Einstein.

2.2 GAUGE THEORIES in CONFLICT with CAUSALITY PRINCIPLE

As concerns the *Quantum Fields Theory* (QFT), moreover, with reference to a Dirac (Ψ) field, of non-interacting mass m , as shown in equation (14), it is not clear whether the value of the continuous parameter θ uniquely identifies each particular gauge transformation represented by the aforementioned Eq.(14). In effect, if the angle θ had a physical meaning, the *globality* of the gauge transformations represented there, that is the fact that θ is constant in space-time, would entail a **violation of the Causality Principle**: it would in fact be necessary that the information of a phase change at one point spreads instantaneously throughout the space! [16]. Hence, it is necessary to

understand whether it is possible to promote the examined symmetry to *local gauge invariance*, that is, have the opportunity to choose point by point which phase to assign to the field. To do this, let's consider the generalization of Eq. (15) to the case where θ is a *smooth* function of the variable x :

$$\Psi(x) \rightarrow e^{ie\theta(x)} \Psi(x) \quad (27).$$

It is immediate to note that the second term of Eq. (14) is *locally* gauge invariant and does not need any modification. The first term of Eq.(14), on the other hand, requires particular attention, because under the *transformation* illustrated by equation (15), it is transformed in a non-trivial way:

$$i \bar{\Psi} \gamma^\mu \partial_\mu \Psi \rightarrow i \bar{\Psi} e^{-ie\theta} \gamma^\mu \partial_\mu [e^{ie\theta} \Psi] = i \bar{\Psi} \gamma^\mu \partial_\mu \Psi - e \bar{\Psi} \gamma^\mu \Psi \partial_\mu \theta \quad (28).$$

Note that the extra term that appears in equation (16), and that *breaks* the gauge invariance of the Dirac lagrangian (Eq.14), is generated by the presence of a derivation operator (∂)[16].

In this respect, we read: "The physical meaning of this *gauge invariance* formulated by Weyl lies in the possibility of assigning the phase to the fields in an arbitrary way, without changing the observable quantities. This way of thinking **contradicts Causality Principle**, since it requires to assign the phase of the fields simultaneously at all space-time points. It looks more physical to require the possibility of assigning the phase in an arbitrary way at each space-time point"[31].

In addition, as regards the *isospin symmetry*, the basic rule of isospin symmetry can be summarized in the substitution:

$$\begin{pmatrix} p \\ n \end{pmatrix} \rightarrow U \begin{pmatrix} p \\ n \end{pmatrix} \quad (29),$$

where p is the proton, n the neutron and U is any *complex matrix* 2×2 [4].

To this purpose, it is very important to bear in mind that "the substitution shown in Eq.(29) is similar to Eq.(27), but with 2 substantial differences: 1) The product of the matrices does not have the commutative property, which the product of the gauge factors in Eq. (27) have. 2) The transformations illustrated in Eq. (29) are *global transformations*, unlike Eq.(27), which shows *local* transformations, where the phase attributed to $\Psi(x)$ is different from one point to another, but without significant variations of the examined physical system. The *transformation* (27), then, is *invariant*, which implies exclusively massless particles! In *transformation* (29), instead, the p states refer to a definition of proton and neutron which must be shared, at a given instant of time, by all observers of the Universe and which is transformed by the U matrix in all points of the Universe, *simultaneously*"[4].

2.3 GAUGE THEORIES in conflict with BARYONIC NUMBER CONSERVATION LAW

Maiani states: "The conservation of the Electric Charge finds its theoretical basis in the gauge invariance of Maxwell equations" [32], while "the conservation of the Baryonic Number is not associated with any gauge invariance and has always appeared as an artificial rule, however it applies with great precision"[32]. Really, this leaves us perplexed because the gauge invariance does not coincide with one of the fundamental laws of Physics: the Law of Conservation of the Baryon Number. Yet this law is always preserved: "it applies with great precision"[32].

It is even possible to consider that maybe something "artificial" lies in the "rules", or dogmas, which are the basis of *gauge theories*, after all, according to Einstein and Pauli, that Mathematics is not up to standards. Concerning the *Standard Model*, indeed, Maiani underlines: "Unfortunately, the approximate calculation methods available (the *Perturbation Theory*) are not completely reliable"[33]. Thus, let's go into this last topic.

2.4 DIVERGENCES in PERTURBATION THEORY

As it is known, an approximation method is useful for finding the changes in the discrete energies and the associated wave functions of a system resulting from a small disturbance, or *perturbation*, provided the energies and the wave functions of the undisturbed system are known. Namely, in this method, usually referred to as the *Rayleigh-Schrödinger Perturbation Theory*, the changes in the energies and the wave functions are expressed as an infinite power series in the perturbation parameter. The approximation consists in neglecting terms in the *infinite series* after the first few terms. Approximating the series to the first n terms in the series, gives the *n th order approximation*[34]. After, in the 30s of the last century, scientists began to notice that in the equations of *perturbation development* of the Quantum Electro-Dynamics (QED) *divergences* emerged, which were considered un-eliminable. In fact, these equations resulted in zeroes and/or infinities! To be exact, the *Perturbation Theory* is a mathematical technique for finding an approximate solution to a problem that cannot be solved exactly, by starting from the exact solution of a related problem; used in modeling physical interactions between particles, etc. At that time, in effect, there was a widespread belief that the *infinities* coming from the equations inherent to the *Perturbation Calculus* in the QED were absolutely un-eliminable.

As it is well-known, QED describes all phenomena relating to electrically charged particles interacting through EM Interaction. And ‘interesting to note that *mathematically* the QED presents the structure of an *Abelian* gauge theory, with the symmetry group $U(1)$ where, *physically*, it means that charged particles interact with each other by the exchange of null-mass particles: the photons. The *gauge field*, indeed, which mediates the interaction between the charged spin - $1/2$ fields, is the Electro-Magnetic Field (EMF). The spinorial QED, or QED Lagrangian (L_{QED}), for a spin - $1/2$ field interacting with the EMF, is represented as follows:

$$L_{\text{QED}} = - \frac{1}{4} F^{\mu\nu} F_{\mu\nu} + \bar{\psi} (1/2 i \partial - M + e \mathcal{A}) \psi \quad (30),$$

where ψ and its antiparticle ($\bar{\psi}$) are the fields that represent charged particles (Dirac spinors: e.g. electron–positron field); i is the imaginary unity; M indicates the mass of the electron or positron; e is the coupling constant, equal to the electric charge of the 2-spinor field; $\mathcal{A}$ is the covariant four-potential of the EMF generated by the electron itself; $F_{\mu\nu}$ is the EMF *tensor*, which represents the evolution of the free field, that is in the absence of additional potentials.

Basically, Eq.(17) describes the interactions between a quantized material spinorial field (i.e. the electronic field) and a non-massive vector field that describes the EM radiation, i.e. the EMF managed by the photons, considered massless[35]. As such, Oppenheimer in 1930 (at the time in the *team* of Pauli) demonstrated that at the origin of the infinities there was the term expressing the interaction between the electronic current and the EMF produced by the electron [36].

Accurately, the *self-interaction* of the electron, considering at second order the processes in which the electron emits and resets a photon, causes an infinite shift (with quadratic *divergence*) of the hydrogen spectral lines. This occurs because in the equations a point value for the radius of the electron (a) is introduced, thus $a \rightarrow 0$ (which is as to give the value $a = 0$). Thus, the calculation results in an *infinite shift*: for $a \rightarrow 0$ diverges as $1/a^2$ [37], where a is the radius of the electron, considered size point, therefore equal to 0. Precisely, the EM energy of an electron (E_{em}), thought as a charge sphere, $E_{\text{em}} = e^2/4\pi a = \infty$ (e is the electron’s charge), is *divergent* in the limit $a \rightarrow 0$ [31].

Oppenheimer points out: “The paper develops a method for the systematic integration of the relativistic wave equations for the coupling of electrons and protons with each other and with the EMF. It is shown that, when the velocity of light is made *infinite*, these equations reduce to the Schrödinger equation in configuration space for the *many body* problem”[38].

Obviously, there is something wrong: the speed of light will never be able to reach infinity values! Waller reviews Oppenheimer's calculations, finding the same abnormal results, and writes: "Using the example of a free electron, we discuss whether, according to the methods of the Dirac radiation theory, it is possible to calculate the interaction of a free electron with its own field. Also in the non relativistic theory, fundamental difficulties seem to hinder them" [39].

As known, the literature of the time is full of results similar to those found by Oppenheimer.

At the 7th Solvay Congress (Paris, 1933), the *polarization of the vacuum* was explored, among other things. In this typical quantum phenomenon, in fact, the vacuum continuously generates pairs of particles, such as electron-positron. What happens is that positrons, surrounding the electron, create an asymmetry in the electron charge distribution. That is, as Barrow reminds us, a virtual cloud of positron reduces the charge of the electron [40] and the calculation of this effect highlights a *new infinity*, which is added to the infinity generated by the *electron self- interaction*. Dirac proposes to mutually subtract these 2 *infinities* [41]. Briefly, the method proposed by Dirac consists of a procedure of *subtraction of the infinities*, similar to the one used to subtract the *infinities* emerged from the calculations related to the *vacuum polarization*.

Then, after the Solvay Congress, Pauli instructs Weisskopf to recalculate the electron *self-energy* (cause of the 1st infinitive highlighted by Oppenheimer), taking into account the production of electron-positron pairs (generated by quantum vacuum fluctuations) and correlated to the *polarization of the vacuum*: another cause of *infinities*. Nevertheless, the result was depressing: an infinite was always obtained. In fact the divergence always existed, even if it was only logarithmic:

$$E = \frac{3e^2 mc^2}{hc} \log \left[\frac{h}{mca} + \sqrt{1 + \left(\frac{h}{mca}\right)^2} \right] \quad (31),$$

where E is the electron *self-energy*, m its mass and a its ray, considered as a point (thus 0). In the last equation the *null* value of a appears twice in the denominators: we shouldn't marvel at the *infinities*! It is clear that this occurs because in the equations a point value for the radius of the electron (a) is introduced, thus $a \rightarrow 0$ (which is as to give the value $a = 0$).

Consequently, the calculation results in an infinite shift: for $a \rightarrow 0$ diverges as $1/a^2$.

It is obvious that it is not possible, there is an error, which certainly does not lie in the values of m or c ; thus the error must be in the value given to a , that is to the radius of the electron, considered equal to a point, that is equal to zero. At the same time, as illustrated by equation (31), the energy of the electron tends to ∞ .

As we are all aware, however, the electron rest-energy is *only* equal to $0.511\text{MeV}/c^2$!

Further, being massive particles, in our opinion the electrons can in no way occupy a void or point volume of space (that is equal to 0) but necessarily its *wave volume*.

In this respect, Feynman comforts us: "Maybe the idea that two points may be infinitely close is incorrect, it is false the assumption that geometry will continue to be invariably unchanged [42]". Feynman goes on: "But if instead of including all the possible points of interaction until a 0 distance, the calculation is *cut off* when the distance between the points is very small, there exist defined values of the mass of the electron and of its charge, such that the calculated mass coincides with the value of the mass of the electron measured experimentally, and the calculated charge coincides with the experimental value of the electric charge of the electron"[42].

Furthermore, in Eq.(31), twice, the mass of the electron and the speed of light, both multiplied by zero (the electron point size), reset to zero, they cancel each other out! It is not possible, it is clear that there is an error, which certainly is not in the values of m or c ; thus the error must be in the value

attributed to a , that is to the radius of the electron, considered equal to a point, that is equal to zero. No! That's no good. So 1934 the rumor began to spread that something was definitely wrong in the QED, since on one hand the Dirac equation could not explain the experimental data, while, on the other, the Quantum Fields Theory (QFT) even produced *infinite* results.

Consequently, various alternative proposals to the QFT were elaborated in those years. Some authors think that the mistake lies in the mathematical formulation of the classical theory that we want to quantize, namely electrodynamics. Oppenheimer and Furry are convinced that the difficulties and *divergences* in the calculations concerning the self-energy of electrons "are based on the illegitimate application of the methods of Quantum Mechanics (QM) to the EMF" [43] and show that a QFT manages to incorporate antiparticles (and thus the creation of positron electron pairs), without resorting to the *Dirac sea* of infinite negative energy solutions.

At the same time Heisenberg arrives at the first complete formulation of the QED, containing the quantized field equations for the electron, for the EMF and for the interaction of the electron with its EMF, like electron-photon interaction. Similarly to Dirac, Heisenberg also adopts the technique of *subtraction of the infinitives*; however the infinities remain. Even the electrons, surrounded by the virtual *cloud* infused with positrons, which attenuate their electric charge, tends to lose the ability to react with other particles [40]. In this respect, Oppenheimer writes: "It is further shown that it is impossible on the present theory to eliminate the interaction of a charge with its own field, and that **the theory leads to false predictions** when it is applied to compute the energy levels and the frequency of the absorption and emission lines of an atom"[36].

Perhaps, unconsciously, Oppenheimer had been prophetic.

Afterwards, Dirac confirm the size-point character attributed to the electron radius: a concept widely shared by researchers. Dirac asserts: "One of the most attractive ideas in the Lorentz model of the electron, the idea that all mass is of electromagnetic (EM) origin, appears at the present time to be wrong, for two separate reasons. First, the discovery of the neutron has provided us with a form of mass which it is very hard to believe could be of EM nature. Secondly, we have the theory of the positron—a theory in agreement with experiment so far as is known—in which positive and negative values for the mass of an electron play symmetrical roles. This cannot be fitted in with the EM idea of mass, which insists on all mass being positive, even in abstract theory. The departure from the EM theory of the nature of mass removes the main reason we have for believing in the finite size of the electron. It seems now an unnecessary complication not to have the field equations holding all the way up to the electron's center, which would then appear as a point of singularity. In this way **we are led to consider a point model for the electron**. Further reasons for preferring the point-electron have been given by Frenkel (1925). We are now faced with the difficulty that, if we accept Maxwell's theory, **the field in the immediate neighbourhood of the electron has an infinite mass**. This difficulty has recently received much prominence in quantum mechanics (which uses a point model of the electron), where **it appears as a divergence in the solution of the equations that describe the interaction of an electron with an EMF** and prevents one from applying QM to high-energy radiative processes. However, some new physical idea is now required, an idea which should be intelligible both in the classical theory and in the quantum theory. A possible line of attack is to modify Maxwell's theory so as to make the energy of the field around the singularity that represents an electron finite" [44].

As we know, QED is a *Quantum Theory* of the Electromagnetic Field (EMF), i.e. a QFT. As it is known, the first formulation of a QFT describing the interaction between radiation and matter (i.e.

between photons and electrons) is Dirac's [45]. Likewise, Heisenberg and Pauli also formulated one of the first QFT, and even they could not solve the relative *field equations*, which tended to infinite values [46]. Therefore it was not possible to write a solution of the equations in the form of a single mathematically compact expression, applicable in all circumstances. They had to resort to an alternative solution method: the so-called *Perturbation Development* (or *Perturbation Theory*). Adopting this technique, the equation is rewritten as a potentially infinite sum of a series of terms: $x^0 + x^1 + x^2 + x^3 + \dots$ that is, the series begins with an expression of 'order zero', or x^0 , or *unperturbed*, corresponding to the total absence of interactions, so the equation is perfectly solvable. The other terms of the series, on the other hand, are *perturbative*: they represent corrections to the 1° order, as in the case of x^1 , or corrections to the 2° order (x^2), or to the 3° (x^3) and so on. The subsequent terms of the *Perturbation Development* make ever smaller corrections to the zero order result, progressively bringing the calculation closer to the exact solution. Thus, the accuracy of the final result depends on the number of perturbative terms included in the calculation. However, instead of ever smaller corrections, Heisenberg and Pauli found that some terms of the *Perturbation Development* 'exploded', tending to *infinite* values[31]. Applied to QED, these terms were identified with the so-called electron *self-energy*, due to the *self-interaction* of the electron with the *quanta* (ie photons) of the EMF generated by itself. This also occurs with the radius of the electron.

Briefly, the common interaction electron-photon generates *infinities*. Why? It's obvious! For the fact that **the photon is considered massless and the radius of the electron is considered null, i.e. equal to zero**. Consequently, the most elementary Algebra teaches that multiplying a value by zero we get 0, and dividing by zero we get ∞ .

We believe this represents a fundamental crossroads.

Thus, let's try to analyze these zero values more carefully.

2.5 On the MASSLESS PHOTON

Therefore, in this context, we deepen the nature of such a radiation. As we know, the electromagnetic radiation(EMR) carries a large number of *light quanta*, or photons (P_s), second after second[47]. The energetic values of each photon(P), without considering its oscillating frequency, corresponds to the *Planck's constant* (h), which is just an energetic value, corresponding to $6.626 \cdot 10^{-27} [\text{erg} \cdot \text{sec}]$. To this purpose, Barrow writes : "The non-null value of the Planck constant(h) is important for the stability of matter. In the impacts between the atoms and the EMR, the value of h is large enough to take a rather strong '*stroke*' to push the electrons to the immediately higher permissible level. As it is known, h identifies with Planck 'grain, with the quantum of light, that is with P. And yet, a massless P is capable of inferring such a *stroke*, besides giving "stability to matter!"[48]. Unless the P is not so massless.

The P, as known, goes with the speed of light: this value(c) is known too, it is $299792.458(\pm 0.4)$

Km/sec[49]. Let's now consider the equation related to the Principle of Equivalence Mass-Energy (MEEP)[50]:

$$E = mc^2 \quad (32),$$

that is:

$$m = \frac{E}{c^2} \quad (33).$$

That's how Einstein commented upon his MEEP: "The value of the considered mass refers to the value of an *inertial mass*"[51]. Let's apply Eq.(32) to the P, keeping in mind that one of the three parameters is well known, that is c , the speed of the P in the vacuum. The 2° parameter is the Energy of the P which, as described first by Planck[52][53] and later by Einstein[54], is expressed

by the formula:

$$E = h \cdot \nu \quad (34),$$

where ν is its oscillation frequency. Here things get more complicated since the equation (34) expresses the energetic value of a single light quantum (or P) in motion, that is at the highest speed, oscillating a number of times per second, depending on the EMR band to which the quantum of light is associated. On the contrary, the equations (32) and (33) represent the value of an *inertial mass*, just because it is involved the MEEP, it will express an *inertial energy*, as to say the *minimal energy*, or *Zeta Point Energy* (ZPE) [55][56] of the particle we are considering.

On the other hand, still for the MEEP, to an “energetic” particle, carrying energy, forces etc., should correspond a *mass equivalent* to the energy carried, divided c^2 [57]. Since there is no zero energy, for the ZPE, there should not be any particle carrying energy, with a zero mass [58]. To this purpose, Feynman says: “energy and mass differ just for a c^2 factor, which is merely a question of units, so we can say energy is the mass. Instead of having to write the c^2 , we put $E=m$ ” [59].

This is another authoritative confirmation of our concepts.

Hawking adds: “In line with Einstein’s equation ($E=mc^2$), the energy is proportional to the mass” [60] and, in agreement with Relativity itself, to every form of energy corresponds a mass.

Thus to a very small energy, as in the case of P, corresponds a very small mass, however $\neq 0$ [61].

In sum, it is crucial keeping in mind that the value of the *density of mass energy* carried out by h , by the Planck’s *grain*, although infinitesimal (and without considering its number of oscillations per second) will always be $\neq 0$! And this is incontrovertible.

Hence, in the case of a P at the *inertial state*, that is when it interacts with another particle, so it stops running, at least for that infinitesimal moment it will probably oscillate much less. We will never be able to know with *accuracy* how much an interacting P can oscillate, that is what could be the number of oscillations [c/s] in that moment. Let’s indicate this unknown value with 10^n [c/s], which is an *uncertainty factor*. The P stops running when hitting another particle, as it happens during a *measurement*, so it will not oscillate as when it was running, though it never stops running completely: it is the Heisenberg Uncertainty Principle (HUP) to deny it, since in this case we would know simultaneously the *position* and the *momentum* of the particle [62][63]. Hence, also in the inertial state the oscillating frequency (ν) of the P can never be 0, but always $\geq 1/s$, that is $\geq$ one oscillation per second (if not even $\frac{1}{2}$ oscillation per s., or a fraction of its). Therefore, if we want to consider the Energy of the P in its *inertial state*, indicated with E_o , we should have:

$$E_o = h \cdot \nu = h \cdot 10^n \text{ [c/s]} \quad (35),$$

$$E_o = 6.626 \cdot 10^{-27} \text{ [erg} \cdot \text{s]} \cdot 10^n \text{ [c/s]} \quad (36),$$

$$\text{i.e.:} \quad E_o = 6.626 \cdot 10^{-27+n} \text{ [erg]} \quad (37).$$

This should be the Energy value of a P at an inertial state. We may say its *minimal energy value*, or ZPE; as we can see this value is not easy to determine, rather, it is *undetermined*, as stated by the QM. As the *erg* value is expressed in $[\text{g} \cdot \text{cm}^2/\text{s}^2]$, that is in $[\text{g} \cdot \text{cm}^2/\text{s}^2]$, we have:

$$E_o = 6.626 \cdot 10^{-27+n} \text{ [g} \cdot \text{cm}^2/\text{s}^2] \quad (38).$$

In this way we can have information, with a certain approximation, about a 2nd parameter of Eq. (33), referred to the P. Thus, we can easily have the 3rd parameter, the *equivalent rest-mass* or *equivalent inertial mass* (m_o) of the P:

$$m_o = \frac{E_o}{c^2} = \frac{6.626 \cdot 10^{-27+n} [\text{g} \cdot \frac{\text{cm}^2}{\text{s}^2}]}{(2.9979 \cdot 10^{10})^2 [\text{cm/s}]^2} \quad (39).$$

Let us calculate this value following the cgs system:

$$m_0 = \frac{6.626 \cdot 10^{-27+n}}{(2.9979)^2} \cdot 10^{-20} \cdot \frac{[g \cdot \frac{cm^2}{s^2}]}{\frac{cm^2}{s^2}} \quad (40),$$

and we have:

$$m_0 = \frac{6.626}{(2.9979)^2} \cdot 10^{-27-20+n} \cdot \left[g \cdot \frac{cm^2}{s^2} \right] \cdot \frac{s^2}{cm^2} \quad (41),$$

$$m_0 = \frac{6.626}{(2.9979)^2} \cdot 10^{-47+n} [g] \quad (42),$$

$$m_0 = 7.372 \cdot 10^{-48+n} [g] \quad (43),$$

What we get is that the *inertial mass energy* of the P corresponds to 10^{-48+n} grams. Hence, if the value of n was 10^0 , that is one oscillation per second, m_0 would be $10^{-48}[g]$. Whereas if n was 10^3 oscillation per second, we would have $m_0 = 10^{-45}[g]$. Obviously, in all cases it is an extremely small value, but it is $\neq 0$, according to QM: *Zero Point Motion* [55]. Furthermore, one of characteristics of the P is to travel most of the time, so it also gets a *momentum*.

2.6 The MOMENTUM of PHOTON

To this purpose, Feynman says: “The energy of a light-particle is a constant times the frequency: $E=h\nu$. We now appreciate that light also carries a *momentum*($\mathbf{p}$) equal to the energy divided by c , so it is also true that these effective particles, these *photons*, carry a momentum”[59].

Fermi writes: “The photon(P) too, as other particles, is a corpuscle, a *light’s quantum* and has a its own *momentum*($\mathbf{p}$), through which transfers all its energy to the hit particle”[64].

In Newtonian Mechanics $\mathbf{p}$ is thus represented:

$$\mathbf{p} = m \cdot \mathbf{v} \quad (44),$$

where m is the mass and v the velocity of the involved particle[65].

In Quantum Mechanics(QM), in its turn, $\mathbf{p}$ is described by the *de Broglie formula*:

$$\mathbf{p} = \frac{h}{\lambda} \quad (45),$$

where λ is the wavelength of the considered P (or other *quantum object*).

As known, in fact, de Broglie suggested, without experimental data, to give particles the same property as waves. He gave each particle a its own wave length depending only on the *momentum* ($\mathbf{p}$) of the particle itself[66]. According to de Broglie, any *quantum object* (i.e. any particle) with a *momentum*($\mathbf{p}$) seems to be something periodic, oscillating as a wave, with an universal relation between the wave length of the particle, indicated by λ , and modulus $\mathbf{p}$ of its *momentum* [67].

Thus, in line with *de Broglie formula*, let us now to analyze the $\mathbf{p}$ value of photons with different wave length(λ). As Weinberg reminds us, the mean wave length of a photon (P) in the optical band corresponds to $\approx 5 \cdot 10^{-5}[cm]$ [68] and its $\mathbf{p}$ is:

$$\mathbf{p} = \frac{h}{\lambda} = \frac{6.626 \cdot 10^{-27} [erg \cdot s]}{5 \cdot 10^{-5} [cm]} \quad (46),$$

$$\mathbf{p} = \frac{6.626 \cdot 10^{-27} [g \cdot \frac{cm^2}{s}]}{5 \cdot 10^{-5} [cm]} \quad (47),$$

$$\mathbf{p} = 1.325 \cdot 10^{-22} [g \cdot \frac{cm}{s}] \quad (48).$$

As Eq.(48) shows, the momentum ($\mathbf{p}$) of a visible photon carries out a *dynamic-mass*, a *pushing momentum* bigger than the *rest mass* of 100 protons. No surprise! At this regard, Feynman writes: “The *momentum*, as a mechanical quantity, is difficult to hide. Nevertheless, momentum *can* be *hidden*, i.e., in the electromagnetic field(EMF). This case is another effect of relativity”[69].

It's like saying that *momentum* carries, albeit *hidden*, a dynamic-mass.

In short, the P cannot be considered massless. Its mass is simply, to say it with Feynman: "hidden". Penrose chases: "In a conference held in Japan in 1922, Einstein said: 'If a person falls freely he will not feel his own weight'. In fact, when you are in *free fall* (like when you launch from a plane, before you open the parachute) you have the impression that the earth Gravity Interaction(GI) is *suspended*: the Earth's gravitational field seems to have *disappeared*. Where's the GI? Actually the GI has not vanished, it is *hidden*"[70]. Well, in these circumstances, we seem to be able to see a significant behavioral analogy between EMF and gravitational field. That is, it is as if in both of them something disappeared, temporarily concealed, *hidden*, during the event: 1) the dynamic-mass, transported by the *momentum* of the P (in the EMF); 2) the GI (in the gravitational field).

Zeilinger chases: "What is the deep meaning of a relationship like $E=mc^2$? What is *hidden* behind these symbols? For many physicists the equation $E=mc^2$ is to say that energy and mass are the same thing, two faces of the same medal; there is therefore *equivalence between mass and energy*: **energy is just another form of mass**, and vice versa, **mass is another form of energy**"[71].

Briefly, as Feynman reminds us, "in the Einstein Relativity Theory, anything which has energy has mass, mass in the sense that it is attracted gravitationally. Even light, which has an energy, has a *mass*"[59]. He points out: "From now on we can say that the total energy of an object is mc^2 . Therefore we have a *new idea*: we do not have to know what things are made of inside; we cannot and need not identify, inside a particle, which of the energy is rest energy of the parts into which it is going to disintegrate. It is not convenient and often not possible to separate the total mc^2 energy of an object into rest energy of the inside pieces, kinetic energy of the pieces, and potential energy of the pieces; instead, we simply speak of the *total energy* of the particle. We 'shift the origin' of energy by adding a constant mc^2 to everything, and say that the total energy of a particle is the mass in motion times c^2 , and when the object is standing still, the energy is the mass at rest times c^2 "[59]. Feynman goes on: "When a light beam, which has energy in it, comes past the sun there is an attraction on it by the sun. Thus the light does not go straight, but is deflected"[59].

In this respect, it is interesting what Eddington said in 1919: "The simplest interpretation of the deflection of the light beam is the one that considers it as an effect of **the weight of light**" [72]. At the dinner of that meeting, Eddington read out some verses he had composed; we will quote the last quatrain: "We will compare the measures taken, One thing at least is certain, **light has weight**. One thing is certain and the rest debate. Light rays, when near the Sun, do not go straight"[72].

Thus, Lord Eddington clearly points out the *mechanical effect* exerted by light, fully in accordance with our conviction that light carries with it also a mass (the *dynamic-mass* of P)[73].

2.7 REMOVAL of MASSLESS PHOTON from PERTURBATIVE EQUATIONS

As it is known, in agreement with the Einstein's MEEP, as shown in the Eq.(32), to an "energetic" particle, carrying energy, forces etc., should correspond a *mass equivalent* to the energy carried, divided c^2 . Since there is no zero energy for the *zero point energy*(ZPE), as Chandrasekhar reminds us [56], there should not be any particle carrying energy, with a zero mass.

Therefore, it may be incongruous to say that a particle with energy does not have an *equivalent mass* [57], it does not "conceal", at least, a mass. It is Einstein's equation to show that this particle has a mass, otherwise the equation would be null, the result would be zero.

Thus, there should not be real particles, having any energy, with a zero mass. If there are, they should "subtend" a tiny mass, a *Zero Point Mass* [55][56]. Hence to a very small energy, as in the case of P, corresponds a very small mass, however $\neq 0$ [47].

Hence, we think that the base concept of the *gauge theories*: ‘the mass *breaks* the symmetry’ is not applicable to the Planck constant. No! Planck’s constant is a real value, ineradicable: represented by an *intrinsic* value, $6.626 \cdot 10^{-27} [\text{erg} \cdot \text{sec}]$, it expresses the value of the density of energy-(*equivalent mass*) of the *Planck Quantum*. Thus, reduce this value to zero, in order to correct the *divergences* and *infinities* emerging from the equations of the *Perturbation Calculus*, would totally cancel the very existence of *Planck Quantum* and, consequently, also the energy of light: we would have a world everywhere *dark* and totally devoid of power! No, it is not possible.

However, in our opinion especially a way could provide a solution: Correct the *infinities*, without Renormalization, but by removing the massless photons(P_s) from the equations of the *Perturbation Calculus*.

As reported in paragraph (2.4), from our simple calculations, taken from *Planck-Einstein’s formula* $E=h\nu$ (shown with the equation 34) and Einstein’ MEEP, emerges that the P is not completely massless since, even in its *minimum energy state*, or ZPE, or *inertial mass* (m_0), it shows a mass value which is not null, but corresponding to: $m_0 = 7.372 \cdot 10^{-48+n} [\text{g}]$, as shown in Eq. (43), where n indicates the oscillation number per second of the involved P. This is certainly a very small value, of no value in our macroscopic world and without the slightest meaning in our daily life.

However, although it is infinitesimal, it is still $\neq 0$, so it can assume, in our opinion, a its value, a its role, both in the sub-atomic world and in the mathematical formalism.

Furthermore, if we take into account the value of the energy charge of the P, we must calculate its *momentum* ($\mathbf{p}$), obtainable from the *de Broglie’s formula* ($\mathbf{p}=h/\lambda$), as shown in Eq.(45). Considering the mean wave length of a P of the optical band, we have: $\mathbf{p} = 1.325 \cdot 10^{-22} [\text{g} \cdot \text{cm/s}]$, as shown in Eq.(48). It is really surprising! A common luminous P carries a mass-energy value over 5 orders of magnitude greater than the rest-mass of an electron: other than massless P!

It is obvious therefore that we are going to replace this last value of the P with the massless P inserted in all equations of the *Perturbation Theory* and of the *Quantum Fields Theory*(QFT), including the Yang-Mills equation. What do we expect?

It is clear: the disappearance of *divergences* and *infinities*.

Likewise, even the calculation of the *electron self-energy* will not give null results any more. No! With a P value no more massless, the zeros disappear. They appeared whenever one tried to multiply the electron mass-energy with the *quanta* of his field, i.e. with P_s !

In brief, with this value of P other than zero, all *divergences* emerging from the equations of *Perturbation Calculus*, *Quantum Electro-Dynamics*(QED) and QFT disappear.

Concluding, in our opinion, the *removal of the infinites* emerging from the perturbative QED and the other QFT, can be obtained with 2 modes: 1) Replacing in the equations of such theories the value of 0 of a P massless, with the real energy value of P, as represented by equations (35) or (38). 2) Replacing in the equations of the QFT the point value attributed to the radius of the electron, therefore $\rightarrow 0$, with the real value of its radius.

2.8 REMOVAL of POINT-LIKE ELECTRON

About this last topic, Feynman comforts us: "Maybe the idea that two points may be infinitely close is incorrect, it is false the assumption that geometry will continue to be invariably unchanged"[42]. He goes on: "But if instead of including all the possible points of interaction until a 0 distance, the calculation is *cut off* when the distance between the points is very small, there exist defined values of the mass of the electron and of the its charge, such that the calculated mass coincides with the value

of the mass of the electron measured experimentally, and the calculated charge coincides with the experimental value of the electric charge of the electron "[42].

Obviously, being massive particles. the electrons can in no way occupy a void or a point volume of space, that is, equal to 0. Besides, considering the value of the minimum distance two particles can come close, no infinities should emerge from perturbation calculations of QED.

In addition, as you can read from literature, "as regards the *problem of infinities*, just think about the energy of the electric field of a charged sphere, which radius (r) tends to zero: $r \rightarrow 0$; i.e. the energy $\rightarrow \infty$, diverges, such as $1/r$. For the theory of Special Relativity, part of the mass of the sphere comes from the (divergent!) energy contained in the surrounding electromagnetic field(EMF). However, one might think that no electrical charge is actually point size and that the problem is simply due to a *mathematical abstraction* "[74].

Finally, let's try to calculate *mathematically* and *physically* the actual value of the electron ray. In this regard, we consider the value of the electron energy-mass density in its state of *minimal energy*, or *inertial mass* (m_0), which in the *cgs* metric system corresponds to $9.109383 \cdot 10^{-28}$ [g]. From Planck-Einstein formula $E = h\nu$ (shown in the equation 34), where ν is the frequency, thus $\nu = E/h$, we get the value of ν . In fact:

$$\nu = \frac{E}{h} = \frac{mc^2}{h} = \frac{9.109383 \cdot 10^{-28} [\text{g}] \cdot (2.99792 \cdot 10^{20} [\frac{\text{cm}}{\text{s}}])}{6.626 \cdot 10^{-27} [\text{erg} \cdot \text{s}]} = \frac{81.8697 \cdot 10^{-8} [\text{g} \cdot \frac{\text{cm}^2}{\text{s}^2}]}{6.626 \cdot 10^{-27} [\text{g} \cdot \frac{\text{cm}^2}{\text{s}^2}]} = 1.23558 \cdot 10^{20} \quad (49).$$

Thus, the electron frequency, in its *minimal energy state*, or ZPE, corresponds to $\approx 10^{20}$ oscillations per second, or Hertz, or cycles per second (c/s). Let us now consider the formula of the electromagnetic(EM) waves, i.e.: $\lambda \cdot \nu = c$, of which we now know 2 parameters, i.e. c and ν . Let's calculate the 3rd parameter, i.e. λ , which refers to wavelength of the electron in its *minimal energy state*:

$$\lambda = \frac{c}{\nu} = \frac{(2.9979 \cdot 10^{10} [\frac{\text{cm}}{\text{s}}])}{1.23558 \cdot 10^{20} [\frac{\text{cm}}{\text{s}}]} = 2.4263 \cdot 10^{-10} [\text{cm}] \quad (50).$$

This is the value that, in our opinion, should be inserted in the equations of the Perturbation Calculus and QFT (QED included) to represent the radius of the electron (a), replacing the null value which has been considered so far. It is obvious that no longer dividing by a zero value, *infinities* and *divergences* will disappear.

It is clear that, as in all material particles, the more the electron is accelerated, the more its wavelength will be restricted, but without never reaching zero or close to zero values!

It is obvious that if we replace this value with the null value of the electron ray inserted in the equations of the Perturbation Theory, of the QFT and the Yang-Mills theories, all *divergences*, that is all zeroes and infinities, would suddenly disappear. Subsequently, replacing in these equations also the null value of a P massless with its real mass-energy value, the limits imposed by the *spontaneous symmetry breaking(SSB)* vanish, so that there is no longer any need to deny the mass to the Nuclear Forces bosons, including the Yang-Mills **b quantum**, which corresponds to the boson of the Strong Nuclear Interaction(SI): the gluon(G). So, let's try to calculate the value of this mass.

2.9 On the YANG-MILLS **b Quantum**

As is well-known, Yang and Mills were convinced, just for "physical reasons"[75], that the gauge particle of the **b field** (as to say the intra-nuclear *strong field*) and represented by the **b quantum**, today

described as G , could not be massless. As concerns the value of this mass, we are not in disagreement with Yang and Mills, who consider it at least greater than the mass of pions, which as Yang himself says corresponds to "134.97 MeV for the π^0 , and to 139.58 MeV for $\pi^\pm$ " [76]. Then, with the introduction of the concepts of G and quarks (Q_s), the problem of Q_s symmetry in baryons arose, for spin and flavor.

This problem finds a natural solution if we assume that a Q of a given flavor has an additional quantum number (the so-called *color*) which takes three values. It is possible to satisfy the Pauli Exclusion Principle, if we assume that the baryons are, in the state completely anti-symmetric in the new quantum numbers, an invariant configuration for color transformations (*color singlet*) [4].

Maiani says: "In 1965, Han and Nambu gave an elegant formulation of this hypothesis, introducing a $SU(3)$ symmetry that operates on color indexes and hypothesizing that the *color symmetry* were gauge symmetry and gluons were Yang-Mills fields associated with the color itself" [4]. Indeed, Han and Nambu write: "It is shown that in a $U(3)$ scheme of triplets with integral charges, one is naturally led to three triplets located symmetrically under the constraint that the Nishijima-Gell-Mann relation remains intact" [77].

Hence, even if Yang and Mills have not quantified the mass of the ***b quantum***, they are still convinced that it has a mass at least higher than pions'. Otherwise, a ***b quantum*** with a mass similar to or lower than pions' would have already been highlighted easily [75].

This is another crucial point which, in our opinion, further contributes to denying those who want to continue to consider the G massless, i.e. the ***b quantum*** of Yang and Mills, and so all the other "particles having charge" [78] which, as Yang specifies, "could not be massless" [78].

2.10 YANG-MILLS MASS GAP PROBLEM

At this stage, one may wonder: what, then, is the mass of Yang-Mills ***b quantum***, now identifiable with G ? Well, the Yang-Mills ***b quantum***, following their reasoning, must have a mass-energy density certainly higher than pions'. In fact, being the vector of a Nuclear Interaction, thus acting exclusively within the very restricted nuclear space, the mass of the ***b quantum*** cannot be too lower than the values found for the Weak Nuclear Interaction (WI) bosons, corresponding to 80.4 and 91 GeV/c². But reflecting further, if it had similar values, the G , or Yang-Mills ***b quantum***, would have already been detected. The next step, of experimentally detected massive particles, corresponds to the values given, at CERN, to the Higgs Boson (HB): 125-126.5 GeV/c² [79].

In this case, as previously mentioned, there can be no absolute certainty, in the *Galilean scientific sense*, that the decay products, highlighted at the CMS and ATLAS detectors, cannot be attributable to a possible massive G , like a massive Yang -Mills ***b quantum***. On the other side, by accepting the coexistence of HB and, therefore, the Brout-Englert-Higgs *Mechanism* (BEH-*M*), in line with Randall [27] we could hypothesize the existence of another HB, capable in this case of giving mass to particles sensitive to Strong Interactions (SI).

Differently, Weinberg writes: "As early as 1960-61 with Nambu and Goldstone it was known that a *symmetry breaking* (SB) is possible in several theories: this implied the existence of new massless particles (the Nambu-Goldstone bosons) which instead, it was known, do not exist. It was the independent studies of Brout and Englert, Higgs, Guralnik, Hagen and Kibble, all of 1964, that showed that in some theories these Nambu-Goldstone bosons, without mass, disappear, giving instead mass to the force mediating particles (gauge bosons): this is what happens in the *electro-weak* (EW) theory proposed by Salam and myself in 1967-68.

What kind of matter or field breaks the EW symmetry? There were two possibilities: 1) The existence of fields, never observed, which pervade the vacuum and which (as the earth's magnetic field distinguishes the north from the other directions) distinguish Electromagnetic Interaction (EMI) from WI, giving mass to the mediating particles of WI and to other particles, but leaving photons (the mediators of EMI) massless. These fields are called *scalars* because, unlike the EM field (EMF), they do not identify any direction in ordinary space. *Scalar fields* of this type were introduced in the illustrative examples of *SB* used by Goldstone and then in 1964 by the various A.A. just mentioned. Salam and I used this *SB* to elaborate the EW theory, assuming that the *breaking* was due to *scalar fields* of the type described, pervasive of all space (a *SB* of this kind had already been hypothesized by Glashow, Salam and Ward, but not as exact property of the equations of the theory, for which they were not induced to introduce *scalar fields*). One of the consequences of the theories in which symmetries are broken by *scalar fields* (including the models considered by Goldstone or in the cited 1964 articles, as well as the EW Salam theory) is that, although some of these fields serve only for giving mass to the mediating force particles, other fields appeared in nature as physical particles observable in accelerators and particle colliders. Three of these *scalar fields* were used to give mass to the W^+ , W^- and Z^0 particles, i.e. the *heavy photons* that in our theory carry WI. A 4th *scalar field* remained outside, which showed as a physical particle, i.e. a *concentration* of energy and momentum of the field itself: the *Higgs particle*"[80].

However, there is an incomprehensible and unjustifiable asymmetry, in our opinion, between the two different known nuclear forces.

They have bosons with antipodal masses: on one side the WI, carrying very heavy gauge bosons, between 80 and 91 GeV, and on the other hand the SI, conveyed by bosons considered massless, although it also operates in the very restricted space of a nucleus or nucleon.

It is absolutely unjustified: a clear contradiction, physically and mathematically unacceptable, that a massless particle shows a range of action $\leq 10^{-13}$ [cm]! On the contrary, as all we know, a massless particle should have an infinite range of action, like the photon (P). It is in open and unacceptable contrast with Yukawa Principle[81], in accord with which the mass (m) of the boson carrying a *fundamental force* must absolutely be inversely proportional to the range (R) of the force it conveys:

$$R = \frac{h}{2\pi mc} \quad (51),$$

where h is the Planck's constant and c is the speed of light in the vacuum.

Furthermore, the same BEH-*M* would be incongruously asymmetric with respect to these two different nuclear forces. In fact, the BEH-*mechanism* gives a considerable mass to the WI bosons, leaving the G massless! Why? Due to the fact that the *Higgs field* (HF) would give mass *only* to WI-sensitive bosons. That's why G and P would remain massless.

Briefly, it is clearly unacceptable to consider massless a particle as energetic as the G, moreover operating in the very narrow range of $\leq 10^{-13}$ [cm], both from the *physical* and *mathematical* point of view, as well as from the *logic*. Among other things, there are numerous A.A. who say, scrupulously, that we cannot yet be sure that the particle detected at CERN is just the HB.

For example, Maiani states: "The possible discovery of HB (obligatory to underline *possible*)"[82].

As we all know, following the experiments carried out at the Petra of Hamburg in 1979 [83] it was deduced that the mass of G is zero, in agreement with the requirements of the *gauge theories*. Nevertheless, we believe that the zero mass attributed to G is patently incongruous and inconsistent: it is in disagreement with the simplest and most basic concepts of Arithmetic.

Indeed, the massless G would deny one of the basic principles of Special Relativity, the MEEP: $E=mc^2$. In line to MEEP, a massless G implies an energyless G! In effect, considering the gluon mass as zero, we would have: $E=0 \cdot c^2$, and thus $E=0$, as to say that the boson of a nuclear force, considered the most energetic boson, is *massless* and *energyless*, where the bosons of the another nuclear force, the WI, are highly massive! It is really against the reality of the facts: the MEEP of Einstein categorically forbids that the G can be massless: in that case, *ex abrupto*, its energy (which is enormous) would instantly vanish. Anyone who claims that G is massless affirms at the same time that the most famous equation in the world is not true, but is misleading, wrong.

On the contrary, Yang and Mills, and so many A.A., knew that the bosons of a Nuclear Force cannot for any reason be massless (in this case their range of action would extend to infinity).

For this reason, in fact, Glashow, since he couldn't find a mathematically congruent solution, in contrast to the *gauge theories* and the Quantum Fields Theory (QFT), forced the issue and introduced *ad hoc* massive WI bosons. In fact, according to the Glashow theory, the Yang-Mills Lagrangian is reduced, in the limit of null coupling constant ($g = 0$), to a Maxwell Lagrangian for each gauge field [84]:

$$\mathcal{L}^{(g=0)} = -\frac{1}{4} W_{\mu\nu}^i \cdot W_{\mu\nu}^i - \frac{1}{4} B_{\mu\nu} \cdot B_{\mu\nu} \quad (52).$$

At this point Glashow, to avoid the presence of zero mass bosons, adds a mass term (M) [13]:

$$\mathcal{L} = \frac{1}{2} [M^2 W_\mu \cdot W^\mu + M_0^2 B_\mu B^\mu + 2 M_{03} W_\mu^3 B^\mu] \quad (53).$$

In the case of charged fields ($i = 1, 2$), it is possible to define:

$$W_\mu = \frac{W_\mu^1 + i W_\mu^2}{\sqrt{2}}; \quad W_\mu^\dagger = \frac{W_\mu^1 - i W_\mu^2}{\sqrt{2}} \quad (54),$$

and we get:

$$\begin{aligned} \mathcal{L} = & W_{\mu\nu}^\dagger W^{\mu\nu} + M^2 W_\mu^\dagger \cdot W^\mu + \\ & - \frac{1}{4} [W_{\mu\nu}^3 (W^3)^{\mu\nu} + B_{\mu\nu} B^{\mu\nu}] + \\ & + \frac{1}{2} [M^2 W_\mu^3 (W^3)^\mu + M_0^2 B_\mu B^\mu + M_{03} W_\mu^3 B^\mu]. \end{aligned} \quad (55)$$

In reference to this context, Maiani describes equation(55): "The first line of (55) defines two 1 spin bosons, with electric charge ± 1 and mass M. As for the neutral fields, second and third line of (55), the physical fields (with defined mass) are identified by the self-vectors of the *mass matrix* ($\mathcal{M}$) which, in the bases (W^3 , B) are written as:

$$\mathcal{M} = \begin{pmatrix} \frac{M^2}{M_{03}^2} & \frac{M_{03}^2}{M_0^2} \end{pmatrix} \quad (56).$$

This matrix is not completely arbitrary because it must have a null auto-value, corresponding to the zero mass of the photon. We must therefore impose:

$$\det \mathcal{M} = 0; \Rightarrow (M_{03}^2)^2 = M^2 M_0^2 \quad (57).$$

We write the self-vectors of the matrix (M) illustrated in equation (56) as:

$$\begin{aligned} Z_\mu &= \cos\theta W_\mu^3 - \sin\theta B_\mu \\ A_\mu &= \sin\theta W_\mu^3 + \cos\theta B_\mu \end{aligned} \quad (58),$$

where A_μ is the electromagnetic field and Z_μ is a new electrically neutral vector field. The self not-zero value of $\mathcal{M}$ is simply given by its *trace*" [84]:

$$\begin{aligned} M_Z^2 &= M^2 + M_0^2 = \\ &= (\cos\theta, -\sin\theta) \mathcal{M} \begin{pmatrix} \cos\theta \\ -\sin\theta \end{pmatrix} = \\ &= \cos^2\theta M^2 - 2\cos\theta \sin\theta M M_0 + \sin^2\theta M_0^2 \end{aligned} \quad (59),$$

From which we get:

$$\frac{M_0^2}{M^2} = \tan^2 \theta \quad (60),$$

thus:

$$M_Z^2 = \frac{M^2}{\cos^2 \theta} \quad (61).$$

In sum, **Glashow knows that the bosons of a Nuclear Force cannot be massless**, otherwise their range of action would extend to infinity! Briefly Glashow, in order to try to unify EMI with WI (as suggested by Schwinger), has to solve a very complicated problem.

On the one hand, in fact, the QFT equations, related to the *gauge theories*, categorically impose that all the particles are massless. On the other hand, on the contrary, there emerges an absurd complication. In order not to collapse the whole theoretical construction of the *gauge invariance*, and with it the QFT, in obvious opposition with the Yukawa Principle [81], the bosons of a *Nuclear Force* are also considered to be massless, thus, like the photon(P), they should exercise their action for unlimited distances. Obviously Glashow cannot accept these absurd concepts, in full conflict with physical reality and experimental events, so he *manually introduces massive bosons*, as illustrated in equation(55). This equation, however, violates the *symmetry*, a fundamental presupposition for *gauge theories*, and furthermore it cannot be *renormalized*.

Weinberg activity was based on the same principles, however at the beginning he tried to assign a mass to the bosons of the other *nuclear force*: the Strong Interaction(SI). We read: "Weinberg had spent a couple of years studying the effects of the *Spontaneous Symmetry Breaking (SSB)* in SI described by a $SU(2) \otimes SU(1)$ gauge theory. As Nambu and Jona-Lasinio had discovered a few years earlier, the result of the *symmetry breaking* was that protons and neutrons acquire a mass. Weinberg was convinced that the Nambu-Goldstone bosons so created could be identified, to a certain approximation, with the pions"[30]. Indeed, Sutton states: "Steven Weinberg thought it promising to use the ideas of *symmetry breaking* in a Yang-Mills theory to describe SI. At the beginning, as he tried to assimilate the particles with and without mass, which appeared in his theory, with particles of strong interaction, his efforts seemed in vain"[85].

Baggott adds: "Weinberg had tried to apply the Higgs Mechanism to the SI, and now he realized that the mathematical structures he had tried to use for SI were precisely what was needed to solve the problems of WI and its heavy bosons" [30]. The mathematical difficulty encountered by both Glashow and Weinberg and Salam, in including hadrons in their unified theories, emerges when one tries to extend Cabibbo theory, see Eq.(8), to a unified Yang-Mills theory. At this regard, Maiani says: "If we did so, the neutral boson, Z^0 , would produce processes with strangeness change, of the type $K^0 \rightarrow \mu^+ \mu^-$ (equation 10), which are much less frequent than the processes mediated by boson W. Moreover, this was the reason that had prevented Glashow and, subsequently, Weinberg and Salam, from including hadrons in their unifying theories"[4].

Namely Weinberg, formerly Glashow's fellow student, "knew well that, if the masses of the $W^\pm$ and Z^0 particles were added by hand, as in Glashow Electro-Weak Theory $SU(2) \otimes SU(1)$, the result was a not renormalizable theory. Thus Weinberg wondered if breaking the symmetry with the Higgs Mechanism, besides giving mass to the particles and eliminating the unwanted Nambu-Goldstone bosons, a renormalizable theory could have resulted. The still remained the problem of neutral currents, that is the interactions due to the Z^0 particle, of which there was no experimental proof. Weinberg decided to avoid the problem by restricting his theory to leptons. Weinberg no longer trusted either hadrons (the particles subject to SI) nor the strange particles, which had become the main terrain of exploration on WI. Then, as Weinberg recounts: 'one day in the fall of 1967, I realized, while I was driving the car, that I had applied the right ideas to the wrong problem'. He realized that

the massless particle he needed was the photon, and that particles with mass were the particles of the weak field"[30].

However, Weinberg adds: "But there was always a 2nd possibility: 2) There could be no new all-pervasive *scalar field*, nor any Higgs particle. The symmetry could be broken by *strong forces*, called *Technicolor Forces*, acting on new type particles, never seen so far because too heavy"[80].

By concluding, Weinberg points out: "So these were the alternatives we had in front of us: *scalar fields* or *Technicolor*? The discovery of the new particle represents a point in favor of the *scalar fields* as the origin of the *symmetry breaking*, and against the *Technicolor Forces*. However, much remains to be done"[80].

How about, on the other hand, the decay products detected at CERN in 2012 were not those of the Higgs boson(HB), that is of "a hypothesized or *invented particle*"[30], but those of another particle? A particle of that weight, between 125 and 126.5 GeV [79], could very well be the gluon(G), if it were not massless. In addition, from the literature we learn that many products and channels of decay are in common between $W^\pm$ and Z^0 bosons, G and HB.

Thus, we could also imagine a slightly larger mass, conveyed by the ***b quantum***. In such an eventuality, we must wait for experiments to be performed at even higher energies.

The next step, among the particle surveys carried out, corresponds to that of the *top* Quark (tQ): $\approx 177 \text{ GeV}/c^2$. Even in this case, are we 100% sure that those decay products belong to the tQ?! Considering a massive ***b quantum***, it cannot be completely excluded that those decay products are not referable to G. Therefore, it is likely that a possible massive Yang-Mills ***b quantum*** can carry an *energy-mass density* between 125-126 and 177 GeV/c^2 (maybe even a little further).

What would be its radius of action, i.e. its *range*?

2.11 RADIUS of ACTION of GLUON (or YANG-MILLS ***b Quantum***)

1) Well, at this point we start from the alleged lower value, which should correspond to the *range* of decay products detected at the Large Hadron Collider(LHC)[79]. To this purpose, we made some calculations to evaluate the possible radius of action of the HB. In truth, it was very simple, as we knew the mass. Thus we applied the well-known Yukawa Principle, as shown in Eq.(51).

At this regard, one wonders: where does the HB take all this mass-energy? From his field, that is the field in which it is immersed: the Higgs field(HF). In line with QFT, the higher the value of the mass of the particle, i.e. the more the energy (ΔE) taken from the field, the sooner (Δt) the energy must be returned to the field itself [86]. As known, this is an inviolable rule of Quantum Mechanics (QM), dictated by the Heisenberg Uncertainty Principle (HUP) [62][63]:

$$\Delta E \cdot \Delta t \geq h \quad (62),$$

where h is Planck's constant, equal to $6.626 \cdot 10^{-27} [\text{erg} \cdot \text{sec}]$. Applying the HUP to HB, we have that the ΔE of Eq.(62) corresponds to the energy value of HB, i.e. $125.5 \text{ GeV}/c^2$.

What we do not know, in this case, is the value of Δt , 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. (62), from which we have:

$$t = \frac{h}{E} \quad (63).$$

Thus, Eq.(63) 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 Einstein's MEEP($E=mc^2$) represented in Eq.(32).

Hence, by replacing the value of E in Eq.(32) with that of Eq. (63), we obtain:

$$t = \frac{h}{m c^2} \quad (64).$$

Eq.(64), 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" [87], namely:

$$d = t c \quad (65).$$

So we put in Eq.(65) the value of t expressed by Eq.(64):

$$d = \frac{h}{m c^2} \cdot c \quad (66),$$

$$\text{i.e.:} \quad d = \frac{h}{m c} \quad (67).$$

And 'interesting to note that the *distance* (d) illustrated by the latter equation corresponds to the radius of action (R) obtainable from the Yukawa potential, as shown in Eq.(51).

Hence, one expressed by Eq.(67) is the maximum distance the HB can take, ie the upper limit of its range. It comes more useful to express in grams [g] the mass HB, using the *cgs* system.

Since $1 \text{ GeV}/c^2 = 1.782 \cdot 10^{-24} [\text{g}]$, it follows that the mass of HB (m_{HB}) will be:

$$m_{\text{HB}} = 125.5 \cdot (1.782 \cdot 10^{-24} [\text{g}]) \quad (68),$$

$$\text{that is:} \quad m_{\text{HB}} = 2.23641 \cdot 10^{-22} [\text{g}] \quad (69).$$

So we replace this value to m of Eq.(67):

$$d = \frac{6.626 \cdot 10^{-27} [\text{erg} \cdot \text{s}]}{(2.23641 \cdot 10^{-22} [\text{g}]) (2.99792 \cdot 10^{10} [\text{cm/s}])} \quad (70).$$

Since $1 \text{ erg} = \text{g} \cdot \text{cm}/\text{s}^2 \cdot \text{cm}$, we can write:

$$d = \frac{6.626 \cdot 10^{-27} [\text{g} \cdot \text{cm}^2/\text{s}]}{6.7045782 \cdot 10^{-12} [\text{g} \cdot \text{cm}/\text{s}]} \quad (71),$$

$$d_{\text{HB}} = 9.8828 \cdot 10^{-16} [\text{cm}] \quad (72).$$

Thus, it is interesting to consider that the value expressed by Eq.(72) represents the maximum limit of the HB range, 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 HB really very small, slightly smaller than $10^{-15} [\text{cm}]$, but this value is justified by the considerable mass that the HB acquires[26]. 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(QM) through one of its most profound concepts: the HUP. Therefore the range of HB will never exceed the distance expressed by Eq.(72), otherwise the HUP would be violated[86].

This very narrow range of HB (particle with a considerable mass) is perfectly congruent and in full accordance with the Yukawa Principle, along with which the range of a *fundamental force* must be inversely proportional to the mass of its bosons.

Furthermore, we have confirmation of these concepts from the bosons of the WI, whose mass is notoriously lower than that of HB. Even in this case, in fact, knowing the mass, it is very easy to calculate the *range* of such bosons. Our calculations show that the Z^0 boson (mass = $91.1876 \pm 0.0021 \text{ GeV}/c^2$) would have a radius of action equal to $1.36 \cdot 10^{-15} [\text{cm}]$, where the $W^\pm$ particles (mass = $80.385 \pm 0.015 \text{ GeV}/c^2$) extend their action up to a limit of $1.543 \cdot 10^{-15} [\text{cm}]$ [88]. As it is easy to see, in fact, even with nuanced mass differences, the range changes. Thus the most massive particle, the Z^0 , has a barely narrower range [89].

Nevertheless, the SI boson, i.e. the G, also operating exclusively at the intra-nuclear and intra-nucleonic levels, i.e. in the same spaces in which the WI operates, is considered massless! To this purpose, in fact, on all university Physics books we find that the G, operating in the very narrow space of a nucleon, is massless. Fermi and Yukawa would backfire in the tombs.

Likewise also the Yang-Mills **b quantum**, now identifiable with G, is considered massless, although Yang and Mills themselves, like so many authoritative Authors, were firmly convinced of the massiveness of this particle [4] [13] [75] [78] [80]. Then why did they accept this *compromise*?

Because the mathematical formalism of *gauge invariance* is used, i.e. a formalism in which the mass of particles tilts the equations: the mass *breaks the symmetry*. Hence, in order to deal with the problems, **the gauge theories require that all the particles are massless**.

Then, since 1964, with the invention of the BEH-Mechanism and the HF, various particles can acquire mass by reacting with this field, but not all: only those sensitive to WI. Therefore the G, **b quantum**, being sensitive to the SI, but not to the WI, remain massless!

In closing, we believe it is unacceptable to continue to support the notion that a particle such as the G, operating exclusively within a space ≤ 1 fermi, can be massless.

2) As reported, the next step, among the mass particle surveys greater than the HB, is the *top Quark* (tQ) ≈ 177.16 GeV/c². A very high value, which really left the researchers baffled, since they did not expect such high values attributable to a Q.

Even in this case, knowing the mass of the particle, it is very easy to obtain its action radius (d_{tQ}):

$$d_{tQ} = 7 \cdot 10^{-16} [\text{cm}] \quad (73).$$

This is the maximum distance that a particle with such a mass can travel, before having to return the energy loan to the field in which it is immersed. If a possible massive **b quantum** (or G) were to have values corresponding to those detected for the tQ , it would operate in spaces really very small, barely above the size of the quarks, considered around $\approx 10^{-16}$ [cm].

Moreover, comparing the distances (d) that can be traveled by particles of different mass, which are the particles with mass corresponding to that of the HB or of the tQ , we can note that *Yukava Principle* is perfectly respected. The heavier particle, in fact, shows a minor radius of action.

Briefly, we believe that the most likely and appropriate solution is to consider the range of the Yang-Mills **b quantum** (d_{bq}) corresponding to the intermediate value included among those calculated for the HB (equation 72) and tQ (eq.73), i.e.:

$$d_{bq} = 8.4414(\pm 1.4414) \cdot 10^{-16} [\text{cm}] \quad (74).$$

3) Yet, it is not reasonable to hypothesize that the **b quantum** can have a mass lower than that detected for the HB, otherwise it would have been detected at the LHC without much difficulty.

At most we can consider the possibility that the G, as to say the **b quantum** [77], may have a mass slightly higher than that detected for the tQ , but not too much further, otherwise its *range* would be narrowed beyond acceptable limits. Indeed, it is difficult to imagine that the *range* of **b quantum** can be $< 6.5 - 6 \cdot 10^{-16}$ [cm], that is, always close to the size of the Q.

Thus, if the mass of G corresponds to ≈ 190.786 GeV/c², its radius of action (d_{bq}) is:

$$d_{bq} = 6.5 \cdot 10^{-16} [\text{cm}] \quad (75).$$

It is less likely that this *range* is even shorter, however, if the **b quantum** had a mass of ≈ 206.7 GeV/c², its range of action would drop to:

$$d_{bq} = 6 \cdot 10^{-16} [\text{cm}] \quad (76).$$

Consider that this range corresponds to the space occupied by ≈ 6 Qs arranged in a row and contiguous, which is not possible, since between the Qs, as among other fermions, there is always a

space, *something* interposed between them, which separates them. We find it incongruous to go down to even lower *ranges*, since too narrow spaces would not be sufficient, in our opinion, so that the SI has the space and time to carry out its various tasks. This is because, in compliance with *QM and Yukawa Principle*, as the boson mass increases, its range and lifetime will decrease in parallel [81][87].

2.12 LIFETIME of a MASSIVE GLUON

Let us see if our theory and our calculations are still in accordance with Yang and Mills for the *lifetime* of the ***b quantum*** (as to say the G) in their "less than 10^{-20} sec" [75]. At this regard, we believe that the most likely range for a massive ***b quantum*** is between 125 and 177 GeV/c².

Even considering for the ***b quantum*** a higher mass, roughly equal to ≈ 191 GeV/c², in *cgs* metric system it corresponds to $\approx 3.4 \cdot 10^{-22}$ [g]. Hence, we insert this value into Eq.(64) and get the possible value of the lifetime(*t*) of the G:

$$t = \frac{h}{m c^2} = \frac{6.626 \cdot 10^{-27} [\text{erg} \cdot \text{s}]}{(3.4 \cdot 10^{-22} [\text{g}]) \cdot (2.99792 \cdot 10^{10} [\text{cm/s}])^2} \quad (77),$$

that is:

$$t = \frac{6.626 \cdot 10^{-27} [(g \cdot \text{cm}^2/\text{s}^2) \cdot \text{s}]}{(3.4 \cdot 10^{-22} [\text{g}]) \cdot (8.9874 \cdot 10^{20} [\frac{\text{cm}^2}{\text{s}^2}])} \quad (78),$$

$$t = \frac{6.626 \cdot 10^{-27} [g \cdot \text{cm}^2/\text{s}]}{30.557 \cdot 10^{-2} [g \cdot \frac{\text{cm}^2}{\text{s}^2}]} \quad (79),$$

from which we get:

$$t = 2.168 \cdot 10^{-26} \text{ sec} \quad (80).$$

This value inherent the lifetime of a G(i.e. the Yang-Mills ***b quantum***) corresponds exactly to the maximum term of the loan granted under the HUP, as it is shown by Eq.(63). Thus, from these calculations emerges a data of particular scientific importance: the life of the G corresponds to an infinitely short time, about 3 *orders of magnitude* lower than the common decay times governed by the SI, and 3 *orders of magnitude* lower than the time it takes light to cross an atomic nucleus. Hence, based on its extremely short existence, even the most powerful particle accelerators it is really extremely difficult to detect the trace of a G! However, although in accordance with the forecasts of Yang e Mills, it is a really too short time. About the SI's bosons, indeed, Fermi states: "Its speed is the maximum speed at which a particle can move, that is the speed of light"[87].

Conversely, a less massive G would have a slightly longer lifetime. Thus, it seems more reasonable to expect a massive ***b quantum*** between 125 and 177 GeV/c².

In this respect, if the possible mass of the G coincides roughly with the HB's, i.e. ≈ 125.5 GeV/c²; the corresponding in grams is $2.2364 \cdot 10^{-22}$ [g]. Hence, using the method just used, we have:

$$t = \frac{6.626 \cdot 10^{-27} [g \cdot \text{cm}^2 \cdot \text{s}]}{(2.2364 \cdot 10^{-22} [\text{g}]) \cdot (8.9874 \cdot 10^{20} [\frac{\text{cm}^2}{\text{s}^2}])} = 3.2966 \cdot 10^{-26} \text{ sec} \quad (81).$$

This last value expresses the lifetime of a particle as heavy as the HB. We then calculate the intermediate value between the values expressed in equations (80) and (81), obtaining:

$$t = 2.7323(\pm 0.5643) \cdot 10^{-26} \text{ sec} \quad (82).$$

Thus, these should be the life times of the ***b quantum*** provided with a mass likely between the weight of the HB and that of a particle barely heavier than the *tQ*. The HUP does not allow the lifetime of the ***b quantum*** to go beyond these limits, since the G must immediately return the energy loan. Hence, even the distances (*d_{bq}*) this particle travel, as represented in the equations (72-75), do not exceed the very limited space of 10^{-16} [cm]!

At this point we need to make a consideration: very probably it is precisely the very short lifetime of the G (probably among the shortest found for a particle) to determine the **Q_s Confinement**, the **G_s Confinement** and the **Colors Confinement**!

And why? Because the very short lifetime of ***b quantum*** is associated in parallel the reduction beyond measure of the space granted and practicable by the Q_s and G_s, since the HUP imposes that the energy debt must be repaid in the shortest possible time. Conversely, a massless ***b quantum*** (or G) exert its action for infinite spaces! This is imposed by the mathematical formalism adopted by the *gauge theories* and the Quantum Fields Theory(QFT): it is really paradoxical.

Thus, it should not cause denial and/or surprise the thesis of a massive G (supported, inter alia, by the presented calculations): a concept that, through the methods indicated above, is not in conflict with the Standard Model, just as no surprise aroused from the finding that the gauge bosons of the electroweak force were of considerable mass. We believe, that is, more than adequate and likely to expect a more *symmetrical and equal behavior* of the BEH-M towards the weak field and strong field. Moreover, it has often been considered the possibility of extending the BEH-M also to the *Yukawa potential* and therefore to the strong field, so as to be able to explain the mass of the fermions too, *without breaking the gauge symmetry*, but through a *spontaneous symmetry breaking (SSB)*. In this way the HF could also be responsible for the mass of the fermions and related bosons, through the extension of the BEH-M to the strong field and to the SI. That is, when the HF acquires a non-zero *Vacuum Expectation Value*, continuing to maintain the *gauge compatibility*, it induces the *SSB of chiral symmetry*, with consequent appearance in the Lagrangian of parameters describing, in field mode, the mass of the corresponding fermion and bosons carrying the SI, i.e. the mass of G. This should not be considered as an unrealistic hypothesis. Indeed, "Steven Weinberg considered promising to use the ideas of *symmetry breaking* in a Yang-Mills theory to describe SI.

At first, while trying to assimilate the particles with and without mass, which appeared in his theory with known strong interaction particles, his efforts seemed in vain. Then, as Weinberg recounts: I realized that I had applied the right ideas to the wrong problem. He realized that the massless particle he needed was the photon, and that the particles with mass were the particles of the weak field. Along with Weinberg, the Electromagnetic and Weak Interactions could be described in a unified way in terms of an exact gauge symmetry, but spontaneously violated" [85].

Yet we believe that the path initially undertaken by Weinberg, that is the application of an *SSB* to Yang and Mills Theory to describe the SI, was not at all "wrong", but equally valid. In other words, it would be much more natural, simple and symmetrical that the *SSB* was applicable to both WI bosons and SI bosons. In this case it would be enough for the HF to behave in a more symmetrical and equal manner, interacting with both the WI-sensitive particles and those sensitive to the SI: either through a single BEH-M, or through two different BEH *Mechanisms*.

Therefore, in this way the possible contrasts between the conjectures of the *gauge theories* and Einstein's MEEP would disappear, as well as the manifest contradictions between a massless G and the Yukawa Principle[81]. A G massless, in fact, would give SI an infinite range of action!

Likewise, as occurs with the *SSB* of the electroweak field, in the case of probable *SSB* of the strong field the Lagrangian (or the Hamiltonian), which define the considered physical system, are *invariant* with respect to a possible transformation group, as could be a rotation or a translation of the system itself. Consequently, the geometric figure represented by likely equilateral triangle (with the 3 *valence* Q_s at the top) or the plausible sphere-like aspect of each Q, are to be considered perfectly

symmetrical, since, if they are subjected to a spatial transformation, their shape will not change: they have a *geometric symmetry*, perfectly in agreement with the Standard Model.

2.13 QUARK and GLUON CONFINEMENT

At this regard, our calculations, concerning the possible range and lifetime of the Yang-Mills *b quantum*, may help us try to answer the question of the *confinement of Quarks*(Q_s).

Since the Q_s are kept together by G_s , **the distance between a Q and the other can never exceed the radius action of G!** It is categorically prohibited by the Quantum Mechanics(QM) through the HUP: the energy debt must be repaid in due time. We find very important emphasize that **the G's range should represent the keystone of the Q_s Confinement phenomenon.**

In order not to exceed the distance of that radius, and having to stay more or less equidistant between them, the 3 Q_s contained in a nucleon, should aim to draw very roughly a geometric figure in the shape of triangle, rotating on itself together with the nucleon, and tending to shrink - in a more or less uniform way - for that brief moment in which the Q_s are a little closer one to the other. Evidently, the 3 Q_s would occupy the vertices of that triangle, and the radius of the G would constitute the sides. Since the maximum value of that radius is the same among the various Q_s , we infer that the geometric figure drawn should approximately correspond to an equilateral triangle, obviously characterized by a perimeter continuously deformable. In this way, each Q can exchange the G likewise with the other 2 Q_s . As a result of the rotation of the hosting nucleon and its intrinsic angular momentum, similarly to the centrally arranged atomic nucleus, it seems more justified to imagine this triangle of Q_s rotating quite centrally within the hadron, thus leaving a huge space in the rest of the nucleon. It is as if this triangle constituted the *core* of the nucleon, with the difference, compared to the atom, that there are no orbiting particles as electrons: likely this space is filled by the so called *protonic sea* [27], i.e. a sea of G_s and *virtual* Q_s . An equilateral triangle very roughly, whose sides, as mentioned above, they should match the G's or *b quantum*'s range. It is obvious that we do not know this value (d_{bq}). We can try to deduce it from the experimental evidences, according to which this range could correspond to the one calculated for the HB, or the *tQ*, or an intermediate value which, in this case, would be: $d_{bq}=8.4414(\pm 1.4414) \cdot 10^{-16}[\text{cm}]$, as shown in Eq.(74).

Indeed, we consider it is very likely that the *b quantum*'s range is included between these values. At the same time, just to leave some wider margins, we can consider that the maximum G's range, acceptably congruous, should correspond to that of a massive *b quantum* equal to almost $207\text{GeV}/c^2$, as shown by Eq.(76). Therefore, we consider the intermediate value between that of Eq. (76) and that of Eq.(72) related to the HB range. This value corresponds to $7.9414(\pm 1.9) \cdot 10^{-16}[\text{cm}]$; it should represent the maximum limit range of intra-nucleonic SI.

Anyway, we think that the intermediate range expressed by Eq.(74) is more probable: in this case the *side* (S) of the triangle of Q_s has a height (H) of:

$$H^2 = S^2 - S^2/4 \quad (83),$$

where S is the side of the triangle. If we develop Eq.(83) we have:

$$4H^2 = 4S^2 - S^2 \quad (84),$$

$$\text{hence:} \quad H^2 = 3L^2/4 \quad (85),$$

$$\text{that is:} \quad H = \sqrt{3}S^2/2 = S\sqrt{3}/2 \quad (86),$$

$$\text{i.e.:} \quad H = [7.94(\pm 1.9) \cdot 10^{-16} \text{ cm}] \cdot \sqrt{3}/2 \quad (87),$$

$$H = [3.97(\pm 0.95) \cdot 10^{-16} \text{cm}] \cdot \sqrt{3} \quad (88),$$

finally: $H = 6.876(\pm 1.6454) \cdot 10^{-16} \text{cm} \quad (89).$

Imaging this triangle narrow centrally placed, we detract half of the value of its height (H) from the value of the nucleon' radius ($[10^{-13} \text{cm}]/2$) and we get the value of the radius (r) of the vacuum space contained inside the nucleonic sphere. It should correspond to:

$$r = 5 \cdot 10^{-14} \text{cm} - 3.438(\pm 0.8227) \cdot 10^{-16} \text{cm} \quad (90),$$

$$r = 500 - 3.438(\pm 0.8227) \cdot 10^{-16} \text{cm} \quad (91),$$

that is: $r = 496.562(\pm 0.8227) \cdot 10^{-16} \text{cm} \quad (92),$

or: $r = 4.9656(\pm 0.8227) \cdot 10^{-14} \text{cm} \quad (93).$

In brief, it really seems to us that it is the action radius of the G to *confine* the Q_s in a very narrow space, more or less decentralized within their nucleon arranging them probably in vertices of an equilateral triangle. A highly deformable triangle, both because of its rotational motion, and because of the varying intensity of the force exerted by the SI, in relation to the continuous variation of the distance between the Q_s , being provided with a relative autonomy of motorcycle (exclusively within that space). Very small space, and that always remains such, at least as far as its maximum limit is concerned, which can never exceed the G range, as illustrated in Eq.(75).

Moreover, if we compare Eq.(75) with Eq.(92), it immediately emerges that the space in which the Q_s are *confined*, corresponds to just about 1.6% of the space they occupy within the nucleon.

So there is an analogy with the atom, even if the nucleus occupies about $< 0.0000001\%$ of the atomic space, a space composed for $> 99.99\%$ by vacuum (excluding the orbiting electrons).

Furthermore, inside the nucleons the space in which Q_s do not operate, and which should correspond approximately to 98.4% of the nucleonic cavity, is not really empty but, as reported above, it is filled by "a sea of G_s and *virtual* Q_s " [27].

3. CONCLUSIONS

3.1 POSSIBLE PHYSICAL EXPLANATION of the *CONFINEMENT* of Q_s , G_s and Colors

Where the Quantum Mechanics(QM) plays a crucial physical role, through the Uncertainty Principle(HUP), it is the phenomenon represented by the *confinement of Q_s* . In our opinion, in fact, these particles have remained eternally confined, since the dawn of time, in an extremely narrow space. It is just because of the enormous amount of energy that the Q has borrowed, the emitted G will not be able to cover a long way: the energy debt has to be paid immediately, and the flow path of G, i.e. of its range, will be determined by the short existence that QM gives to the G.

But we shouldn't be surprised: it is not the only case of significant energy loans. The Weak Interaction(WI), in fact, runs on credit too. In that case too Q_s borrow the large-scale energy. The W boson, indeed, whose mass corresponds to $80.4 \text{GeV}/c^2$, is much heavier than the Q_s which emitted it: namely, it is ≈ 16000 times heavier than *down* Q and ≈ 40000 times heavier than *up* Q!

Clearly, in agreement with the rules of QM, to a *gauge boson* of such a mass will correspond a very short life and, consequently, an extremely small range, in keeping with Yukawa[81], Fermi[87], just to mention a few authors. In fact, our calculations show that the radius of action of the particle W corresponds to $1.542475 \cdot 10^{-15} \text{cm}$ [89].

Yet, while the WI performs other functions, the SI, or Color Force(CF), seems to be there just to keep *chained*, and *confined*, the Q_s and G_s (and their *colours*) inside the hadrons, giving shape

and substance to the matter. It has been so from immemorial time. Indeed, since the first protons and neutrons were formed, that is $\approx 1/100$ of second after the Big Bang, as Weinberg reminds us [68], G_s and those 3 Q_s (and their *colors*), have been *trapped, confined* inside, and never got out [37]. Trapped by whom, **confined** by what? By the very intense strength exerted by the CF on Q_s , but *in primis* by **the range and very short lifetime of G** which, inexorably, has never allowed Q_s to move away from each other by a distance greater than that radius!

Moreover, this coincides perfectly with the fact (and could also explain it) that a color charge carrier (as Q or G) can never appear alone, but always and only *combined*, so that, combining 3 Q_s of different colors, a neutral color hadron particle is obtained.

That is why, in normal conditions, it has never been possible to observe a Q or the trace of G isolated. No! **G_s and Q_s** (and their **Colors**) are closely and mutually bound and **confined** inside hadrons. In addition, it is interesting to consider that Q_s are not the only ones to be *confined* inside hadrons from the beginning of the Universe: this also applies to the G_s , of course, since they *are born* from Q_s . Thus, in this way you can explain both the **Quarks Confinement**, the **colors**

Confinement and the **Gluon Confinement**!

Moreover, we tried to *quantify* the possible value of the **Q_s Confinement**.

As illustrated by Eq.(74), this value (d_{bq}) may be $\approx 8.4414(\pm 1.4414) \cdot 10^{-16}$ [cm], that is the possible *range* of the intra-nucleonic SI, and therefore corresponding to the maximum distance that can ever separate, two Q_s : **Q_s spatial Confinement**.

To this purpose, indeed, we believe that the most likely and appropriate solution is to consider the range of the Yang-Mills **b quantum** (d_{bq}), or *gluon range*, among those calculated for the HB (equation 72) and tQ (Eq.73). Therefore, it should be kept in mind that the value of the energy-mass density of G_s it can never be constant, stable: never. It is easy to deduce, in fact, that the energy (and so its *equivalent mass*) carried by G_s can vary widely.

This should depend on the moment in which the G is detected, since at that moment, randomly, it may have already gathered, or not yet completely, the full amount of the loaned energy (through the Q_s or from the field where it is immersed).

Wilczek points out: "Protons and neutrons are very complicated dynamic balances of Q_s , anti- $Q_s(\bar{Q}_s)$ and G_s . The biggest part of their mass – and as a consequence also of the mass of the matter, including our brain and our body – comes from the pure energy of these objects in constant motion, basically mass less according to the equation $m=E/c^2$. At least at this level we are ethereal creatures"[90]. Consequently, most of the nucleonic mass is supplied to them by the G_s in them: **other than massless G!**

Analogous to Wilczek, Randall states: "In a nucleon the mass (therefore, according to Einstein, the energy $E = mc^2$) is given not only by the Q_s , but also by the bonds that hold them together" [27]. And these *bonds*, as known, are represented just by G_s . Randall goes on: "Protons have a composite structure. In fact, they contain the Q_s , held together by the G_s . The question is that the mass of a proton does not come entirely from the mass of the Q_s that constitute it. Its mass is mainly due to the energy involved in holding the proton together"[27] which, as we know, is held together namely by the SI, through the energy of G_s (continuously exchanged among Q_s). In this respect, Quigg adds: "The Higgs Field(HF) does not explain the origin of the whole mass. It has been a while since we actually understood the source of most of the proton mass (for example). Most of the mass - you and I included - comes from the SI"[91], as to say from its bosons: G_s !

It is important to emphasize, in our opinion, that there is a vast Literature considering that the real

mass of nucleons is supplied almost exclusively by G_s , or rather by the *energetic mass* carried by G . To this purpose, we can read: "The proton and the neutron are each composed of 3 *constituent* Q_s . The problem is that G_s are particles of zero mass and that the masses of the uQ and dQ are respectively about 400 and 200 times smaller than the mass of protons and neutrons. To understand the origin of the mass of protons and neutrons we go back to the well-known Einstein equation $E = mc^2$, which expresses the energy of a body of mass m when it is at rest (thus lacking in kinetic energy). This equation acquires a perhaps deeper meaning if rewritten in the form: $m=E/c^2$. Through this equation, the theory of Relativity explains how **the mass of a physical system is nothing but its quiet energy**. Mass is therefore a measure of the energy of the system. In the case of a nucleon at rest we find that its mass-energy originates only in a small part from the sum of the Q_s masses. The remaining part is provided instead by the energy of the *cloud* of Q_s and G_s : Q_s interact with each other exchanging G_s and these in turn can generate virtual pairs $Q_s \bar{Q}_s$ which, after a very short time, annihilate each other producing other G_s . The inside of a nucleon therefore appears as a dynamic tangle of strongly interacting particles, which appear and disappear continuously. The energy of this cloud constitutes most of the mass of the nucleons and, therefore, the mass of all the matter that surrounds us"[92], including all living beings: mass and matter where the Higgs Boson(HB) and the BEH- M have nothing to do with it, since the G does not interact with the HB.

In brief, though G_s are considered massless, they carry a great quantity of energy thus, in line with the *Mass Energy Equivalence Principle* (MEEP), they must have an *equivalent-mass*. The G seems to have a zero mass because it is "constantly in motion", as underlined by Wilczek, so it can show us only its *undulation aspect*, its *wave behavior*. At this regard, a well-known principle of Quantum Mechanics(QM), the Bohr Complementarity Principle, states that each *quantum object* can show both its corpuscular and wave-like behavior but, *conditio sine qua non*, only one at a time: never simultaneously![93]. Hence, until the G is in motion, it can show only its wave side. On the contrary, in the very short time the **b quantum** interacts, we may indirectly detect some aspects of its corpuscular behavior. Only the *corpuscular aspect* of a particle can give us the probable mass of a particle. Since the G is always in motion its mass is concealed under its *undulation aspect*, as to say under its *energetic aspect*.

In short, we believe that it is *physically* very complicated, if not impossible, to be able to detect a G , i.e. the Yang-Mills **b quantum**. And why? Because of the G very short lifetime which, from our calculations, is equal to $2.7323(\pm 0.5643) \cdot 10^{-26}$ sec, as shown in Eq.(82).

In this respect, as Maiani reminds us the SI, which as we know operate for distances $\leq 10^{-13}$ [cm], allow the formation of *Resonances (R)*: unstable states that disintegrate into final particles, due to the Interaction itself[94]. The typical times of decay (τ), by the SI, correspond to:

$$\tau \simeq \frac{R}{c} \simeq \frac{\sim 10^{-13} \text{ [cm]}}{3 \cdot 10^{10} \left[\frac{\text{cm}}{\text{s}} \right]} \simeq 10^{-23} \text{ sec} \quad (94).$$

To be exact, the typical decay times managed by SI are of the order it takes the light to cross the *resonance*, which has a linear dimension of order R [94], corresponding to the radius of the atomic nucleus (being a *nuclear force*).

Consequently, in our opinion, here a reflection is obligatory: comparing the equations (82) and (94), a difference of 3 orders of magnitude immediately stands out. Namely, the Yang-Mills **b quantum** lifetime is as many as 3 *orders of magnitude* shorter, compared to times that are already infinitely short themselves. As to say that the creation and disappearance of a G is resolved in less than one thousandth of the time taken by light to pass through a proton, a light nucleus! Or: the whole life-time

(so to speak) of the Yang-Mills ***b quantum*** resolves in less than a thousandth of the time necessary for an operation managed by the SI.

Well, they are really times beyond reach, like saying: *inaccessible*.

In conclusion, one wonders: are we able to examine and study physical phenomena that occur in such short times? We really don't think so! In other words, they are *virtual* phenomena.

This could also be said for ***b quantum***, i.e. G, a massive G - which can never be massless - is to be considered a *virtual particle*; obviously, this does not mean that G does not exist, but that it exists for such a short time that we cannot access it in time. For this reason, we believe that we will never be able to study ***b quantum*** directly, nor will we ever have enough time to detect it.

In short, we may say that **the *b quantum*, the G is Temporally Confined by its very short lifetime!** Consequently, a new parameter may be added: the ***Temporal Confinement of Gluon*** (and their ***Colors*** and ***anti-Colors***).

This Gluon Temporal Confinement should be added to the *Spatial Confinement* of Q_s (and their *Colors* and *Anti-Colors*) due, instead, to the extremely narrow range of action of a massive G, likely equal to $8.4414(\pm 1.4414) \cdot 10^{-16}$ [cm], as it is clear from Eq.(74).

REFERENCES

- 1) Gell-Mann M., "A Schematic Model of Baryons and Mesons" Phys. Lett., 8, 214-215 (1964).
- 2) Zweig G., "An Su(3) Model For Strong Interaction Symmetry And Its Breaking. 2", CERN -TH-412 (1964).
- 3) Heisenberg W., "Über den Bau der Atomkerne I", Zeitschrift für Physik, 77, 1-11 (1932).
- 4) Maiani L. "60 anni di Yang-Mills", Il Nuovo Saggiatore, 31, 5-6, 22-32 (2015).
- 5) Gershtein S.S., Zel'dovich J.B., "Meson corrections in the theory of beta decay", Sov. Phys. JETP, 2, 576 (1957).
- 6) Feynman R.P., Gell-Mann M., "Theory of the Fermi Interaction", Phys. Rev., 109, 193-197 (1958).
- 7) Cabibbo N., "Unitary Symmetry and Leptonic Decays", Phys. Rev. Lett., 10, 12, 531-533 (1963).
- 8) Glashow S.L., Iliopoulos J., Maiani L., "Weak Interactions with Lepton-Hadron Symmetry", Phys. Rev. D 2, 1285-1292 (1970).
- 9) Englert F. and Brout R., "Broken Symmetry and the Mass of Gauge Vector Mesons", Phys. Rev. Lett., 13, 321-323 (1964).
- 10) Higgs P.W., "Broken Symmetries and the Masses of Gauge Bosons", Phys. Rev. Lett., 13, 508-509 (1964).
- 11) Weinberg S., "A Model of Leptons", Phys. Rev. Lett., 19, 1264-1266 (1967).
- 12) Salam A., in "Elementary Particle Theory: Groups and Analyticity", in *Proceedings of the Nobel Symposium 1968*, Svartholm Ed., Almquist and Wiksell (Stockholm), Sweden, 367-377 (1968).
- 13) Glashow S.L., "Partial-Symmetries of Weak Interactions", Nuclear Physics, 22, 579-588 (1961).
- 14) 't Hooft G., Veltman M.J.G., "Regularization and Renormalization of Gauge Fields", Nuclear Physics B, 44, 189-213 (1972).
- 15) Kobayashi M., Maskawa T., "CP Violation in the Renormalizable Theory of Weak Interaction", Progr. Theor. Phys., 49, 652-657 (1973).
- 16) Martone G.I., "Separazione spin-carica nella teoria di Yang-Mills SU(2)", Tesi di Laurea in Fisica, relatore L. Martina, Salento's University, Italy (2010).
- 17) Noether E., "Invariante variationsprobleme", Math.-phys. Klasse, 235-257 (1918).
- 18) Weyl H., "Gravitation und Elektrizität", Sitzungsber Akademie der Wissenschaften,

Berlin,465,480 (1918).

- 19) Fock V., “Über die invariant Form der Wellenund der Bewegungsgleichungen für einen geladenen Massenpunkt”, Zeitschrift für Physik, Vol.39, Issue 2–3,226-232 (1926).
- 20) London, F., " Quantenmechanische Deutung die Theorie von Weyl". Zeitschrift für Physik, Vol.42, ,375-389 (1927).
- 21) Weyl H.,“Elektron und Gravitation”, Zeitschrift für Physik, 56, 330-352 (1929).
- 22) Nambu Y..and Jona-Lasinio G.,“Dynamical Model of Elementary Particles Based on an Analogy with Superconductivity.I”, Phys.Rev.,122,345-358 (1961).
- 23) Goldstone J., “Field theories with ‘Superconductor’ solutions”, Il Nuovo Cimento,19,1, 54-164 (1961).
- 24) Goldstone J., Salam A. and Weinberg S., “Broken Symmetries”, Phys.Rev.,127,965-970 (1962)
- 25) Guralnik G.S., Hagen C.R. and Kibble T.W.B., “Global Conservation Laws and Massless Particles”, Phys.Rev.Lett., 13, 585-587 (1964).
- 26) Puccini A., “On the Higgs Boson’s Range”, viXra.org, Quantum Physics:1705,0250 (2017).
- 27) Randall L., “Knocking on Heaven’s Door”,© Lisa Randall 2011-2012; il Saggiatore ed. (Milano) 293,92-98,442,123 (2012).
- 28) Penrose R., “The Road to Reality”,2004 ©Roger Penrose; RCS ed.,Milano,450-455,641-643, 654,743 (2005).
- 29) Quirantes A., “Lo Spazio-Tempo Quantistico”,©2015 RBA, Contenidos ed., Spagna; © RBA Italia, Milano,78-79 (2016).
- 30) Baggott J., “Higgs: The Invention and Discovery of the ‘God Particle’”, ©2012 Jim Baggott, Oxford University Press; Adelphi Ed., Milano, 47,45,55,9(Preface),77-80,92 (2013).
- 31) Casalbuoni R., “Teoria dei Campi”, INFN Firenze, Seminario Fisica-Filosofia, 4 e 11/5 (2001).
- 32) Maiani L., “Conservazione del numero barionico”, Fermi Lectures 25, INFN, Rome, 16th April (2015).
- 33) Maiani L., “Teoria Standard alle temperature del Big Bang”, Fermi Lectures 24, INFN, Rome, 20th March (2014).
- 34) Thankappan V.K., “Quantum Physics”, ©1993,1985; New Age International (P) Limited, Publishers, New Delhi, India, 267 (1993).
- 35) Puccini A., “The Missing Mass in the Universe May Be Represented by the Dynamic-mass of the Photons”, Session 3P1: Optics and Photonics, Progress in Electromagnetics Research Symposium Proceedings ,Cambridge (Ma), USA,816-818, July 5-8 (2010).
- 36) Oppenheimer J.R.,“On the Theory of Electrons and Protons”, Phys.Rev.(Letter to the Editor), vol.35, iss.5,562 (1930).
- 37) Peruzzi G., “Richard Feynman. Dall’elettromagnetismo classico alla QED”, Laboratori Nazionali di Frascati, Incontri di Fisica, 7 ottobre (2015).
- 38) Oppenheimer J.R., “Note on the Theory of the Interaction of Field and Matter”, Phys. Rev., Vol.35,iss.5,461-477 (1930).
- 39) Waller I., “Bemerkungen über die Rolle der Eigenenergie des Elektrons in der Quantentheorie der Strahlung“, Zeitschrift für Physik, Vol.62, Issue 9-10, 673-676 (1930).
- 40) Barrow J.D.,“The Book of Nothing”, ©John D. Barrow 2000,1st published by Jonathan Cape 2000; Mondadori Ed., Milano,220-221, 239-240 (2001).
- 41) Dirac P.A.M., “Structure et proprietes des noyaux atomiques”, Septiem Conseil de Physique Solvay, Paris, 22-29 October (1933).

- 42) Feynman, R.P., "QED. The Strange Theory of Light and Matter", ©1985 Richard P. Feynman; Adelphi ed., Milano, 158-160, 184-185, (1989).
- 43) Furry W.H., Oppenheimer J.R., "On the Theory of the Electron and Positive", Phys. Rev., 45, 4, 245-262 (1934).
- 44) Dirac P.A.M., "Classical theory of radiating electrons", Proc. Royal Society A, London, Vol.167, Issue 929, 148-169 (1938).
- 45) Dirac P.A.M., "The Quantum Theory of the Emission and Absorption of Radiation", Proc. Roy. Soc. A, London, Vol.114, 767, 243 (1927).
- 46) Heisenberg W., Pauli W. "Zur Quantendynamik der Wellenfelder", Zeitschrift für Physik, Volume 56, Issue 1-2, 1-61 (1929).
- 47) Puccini A., "Light Quantum Induces the Measurement Paradox", Journal of Advances in Physics, Vol.15, 6039-6055 (2018).
- 48) Barrow J.D., "The Constants of Nature. From Alfa to Omega", ©2002 John D. Barrow, Jonathan Cape 2002; Mondadori Ed., Milano, 293 (2003).
- 49) Achenbach J., National Geographic, Italian edition, Milano, 10, 8 (2001).
- 50) Einstein A., "Ist die Tragheit eines Körpers von seinem Energieinhalt abhängig?", Annalen der Physik, Vol.18, 639-641 (1905).
- 51) Galison P., " $E=mc^2$ ", in "It Must be Beautiful. Great equations of Moderne Science"; ©Graham Farmelo, 2002 Granta Publ., London, 2002; il Saggiatore ed., Milano, 119, 118 (2005).
- 52) Planck M., Verhandlungen der Deutschen Physikalischen Geseeshaff, Vol.2, 237 (1900).
- 53) Planck M., Annalen der Physik, Vol.4, 553 (1901).
- 54) Einstein A., Jahrbuch der Radioaktivitat und Elektronik, Vol.4, 443 (1907).
- 55) Puccini A., "About the Zero Point Energy, Zero Point Mass, Zero Point Temperature and Zero Point Motion in the Subatomic World and Photonics", *Proceedings of Progress In Electromagnetics Research Symposium*, Suzhou, China, 1169-1171, Sept. 12-16 (2011).
- 56) Chandrasekhar B.S., "Why Things Are the Way They Are", Cambridge University Press, 1998; Il Saggiatore ed., Milano, 84, 125, 304, (2004).
- 57) Puccini A., "The Equivalent Rest-mass of Photon" (Session 2P2: Electromagnetic Theory and Design on the Optical Dispersive Materials, Invisible Cloak and Photonic Crystals). *Proceedings of Progress in Electromagnetics Research Symposium*, Marrakesh, Morocco, 723-725, Mar. 20-23 (2011).
- 58) Puccini A., "About the Zero Mass of Photon", *Progress in Electromagnetics Research, (PIER)*, Vol.55, 117-146 (2005).
- 59) Feynman R.P., "*The Feynman Lectures on Physics*", Vol.1, ©1965, California Institute of Technology; Zanichelli ed., Bologna, Vol.1, 17-7; 15-14; 16-13; 15-15, 34-16 (2001).
- 60) Hawking, S., "A Brief History of Time", ©1988 by Stephen W. Hawking, Bantan Books ed.; Rizzoli ed., Milano, 128, (1990).
- 61) Puccini A., "Quantum Gravity is Induced by a Mechanical Effect Elicited by Momentum of Light's Quanta", *Asian Journal of Science and Technology*, Vol.10, 1, 9206-9220 (2019).
- 62) Heisenberg W., "Über den anscauliken Inhalt der Quantentheoritschen Kinematik und Mechanik", *Zeitschrift für Physik*, Vol.43, 172-198 (1927).
- 63) Puccini A., "Uncertainty Principle and Electromagnetic Waves", *Journal of Electromagnetic Waves and Applications, (JEMWA)*, Vol.19, Iss.7, 885-890 (2005).
- 64) Fermi E. "Argomenti pro e contro l'ipotesi dei quanti di luce", *Nuovo Cimento*, 3, 201-206 (1926).

- 65) Newton Is.(1687), “PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA”.
Imprimatur S.Pepys, Reg.Soc. Praeses. iulii 5.1686.Londini. Anno MDCLXXXVII
- 66) de Broglie L., “Ondes et quanta”, Comtes Rendus, Vol.177, 507-510 (1923).
- 67) Puccini A., “The Momentum of Photon May Explain the Measurement’s Paradox in the Subatomic World” (Session 1A2: Electromagnetic Theory and Design on the Optical Dispersive Materials, Invisible Cloak and Photonic Crystals). *Proceedings of Progress In Electromagnetics Research Symposium*, Suzhou, China,27-30,Sept.12-16 (2011).
- 68) Weinberg S., “The First Three Minutes. A Modern View of the Origin of the Universe”,© 1977 by S.Weinberg; Mondadori Ed.(Milano),75,125 (1977).
- 69) Feynman R.P., The Feynman Lectures on Physics, Vol.3: Quantum Mechanics,©1965, California Institute of Technology; Zanichelli Ed., Bologna,Vol.3,2-4 (2001).
- 70) Penrose R., “The Einstein Equation of General Relativity” in “It Must be Beautiful. Great Equations of Moderne Science”, ©Graham Farmelo,2002, Granta Publ., London,2002; il Saggiatore ed.,Milano,293,261 (2005).
- 71) Zeilinger A., “Einstein’s Schleier. Die neue Welt der Quantenphysik“, 2003,Verlag C.H., Munchen; G. Einaudi ed.,Torino,18,130-131 (2005).
- 72) Eddington A., “Joint Eclipse Meeting of the Royal Society and the Royal Astronomical Society”, in The Observatory (Review of Astronomy),vol.27, 545,389,Nov.(1919).
- 73) Puccini A., “Light Weighs”, Progress in Electromagnetics Research B,Vol.8,161-177 (2008).
- 74) Passera M., “L’Infinito sotto il tappeto”, asimmetrie.it *INFN* Padova, aprile (2016).
- 75) Yang C.N., Mills R.L., “Conservation of Isotopic Spin and Isotopic Gauge Invariance” *Phys.Rev.*,Vol.96, N°1,191-195 (1954).
- 76) Yang Chen Ning, “Elementary Particles”, Princeton University Press, New Jersey,1961; Boringhieri ed.(Torino), Table 5 (1969).
- 77) Han M.Y.,Nambu Y., “Three-Triplet Model with Double SU(3) Symmetry”, *Phys. Rev.*, Vol.139, Iss. 4B,1006-1010 (1965).
- 78) Yang Chen Ning, Selected Papers with Commentary, W.H. Freeman &,San Francisco (1983).
- 79) CERN Seminar, “Latest update in the search for the Higgs boson”, Geneve , 4th July,2012;
<http://cms.web.cern.ch/> and <http://atlas.ch/>
- 80) Weinberg S., Foreword in “Higgs: The Invention and Discovery of the God Particle”, by Baggott J., 2012; Adelphi Ed.(Milano),13-19 (2013).
- 81) Yukawa H., “On the Interaction of Elementary Particles”, *Proc. Phys. Math. Soc. Japan*, 17,48-57 (1935).
- 82) Maiani L., “Bosone di Higgs, ci siamo vicini”, *Il Sole24Ore*,RCS ED.,Milano,1 luglio (2012).
- 83) Barber D.P. et al., “Discovery of Three-Jet Events and a Test of Quantum Chromodynamics at PETRA”, *Phys.Rev.Lett.*,Vol.43,Iss.12,830-833 (1979).
- 84) Maiani L., “Interazioni Elettrodeboli”, *INFN Roma*, anno accademico 2009-2010.
- 85) Sutton C., “The Yang-Mills Equation”, in “It Must Be Beatiful. Great Equations of Modern Science“,Granta Publ., London,©G.Farmelo,2002;Il Saggiatore Ed.(Milano),330-333(2005).
- 86) Puccini A., “Higgs Boson Radius of Action”, *International Journal of Innovation Engineering and Science Research*, Vol.2, Iss.6, 43-46, November-December (2018).
- 87) Fermi E., “Atomi Nuclei Particelle”, a cura di V. Barone, Boringhieri Ed.(Torino), 140 (2009).
- 88) Puccini A., “On the Boson’s Range of the Weak Nuclear Force”, *viXra.org*, Nuclear and Atomic Physics: 1705.0351 (2017).

- 89) Puccini A., "On the Bosons' Range of the Weak Interaction", Journal of Advances in Physics, Vol.14, Issue 3, 5865-5868 (2018).
- 90) Wilczeck F., "Something Magic", in "It Must be Beautiful. Great Equations of Moderne Science", Granta Publications (London), 2002; Il Saggiatore ed., Milano, 221, 218-219 (2005).
- 91) Quigg, C., "Particelle elementari e forze", Le Scienze, Milano (Italian edition of Scientific American inc., New York), 2, 20-31 (1985).
- 92) Lubicz V., "Particelle a colori. L'energia che dà la massa alle cose", 19 aprile 2013, [asimmetrie.it\[as14\]massa INFN](http://asimmetrie.it[as14]massa INFN)
- 93) Bohr N., "The Quantum Postulate and the Recent Development of Atomic Theory", Nature, 121, 580–590 (1928).
- 94) Maiani L., "Gauge Theories", INFN Università di Roma 1, anno accademico 2005-2006.