Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 May 2022 doi:10.20944/preprints202006.0304.v4

On the quark scaling theorem and the polarisable dipole of the quark in a scalar field

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Summary
In this article the possible impact is discussed of two unrecognized theoretical elements on the present state of particle physics theory. These elements are the awareness that (a) the quark is a Dirac particle with a polarisable dipole moment in a scalar field and that (b) Dirac's wave equation for fermions, if derived from Einstein's geodesic equation, reveals a scaling theorem for quarks. It is shown that the recognition of these elements proves by theory quite some relationships that are up to now only empirically assessed, such as for instance, the mass relationships between the elementary quarks, the mass spectrum of hadrons and the mass relationships between the topquark, the W/Z bosons and the Higgs boson.

Keywords: polarisable Dirac dipole; quark scaling; hadron mass spectrum; Z boson; Higgs boson; topquark

1. Introduction

This article is aimed to discuss the possible impact that the awareness of a polarisable dipole moment of quarks in a scalar potential field of quarks, conceived as Dirac particles in a particular format, may have on the interpretation of particle physics theory. The discussion will be focussed on the bonds between quarks in mesons and baryons. As is well-known, canonical particle physics theory is captured in a rather abstract mathematical formalism. This formalism has been developed under adoption of some axiomatic attributes that have been unknown prior to the development of the Standard model. Among these are, for instance, weak isospin and hypercharge. They show up as quantum numbers attributed to the elementary fermions [1], such as listed in Table I.

Table I

Fermions	u	d	e^-	ν_e
s-spin quantum	1/2	1/2	1/2	1/2
m_0-mass	?	?	m_e	≈ 0
I_Z-weak isospin charge	1/2	-1/2	-1/2	1/2
Y-hypercharge	1/3	1/3	-1	-1
$Q = I_Z + Y/2$	2/3	-1/3	-1	0

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It is my aim to show how these attributes are related to those of a quark that has a polarisable dipole moment in a scalar potential field. Such a dipole moment is a unique property of a particular non-electron format of Dirac's particle, while it is absent in electron-type ones. As will be shown, this dipole moment could be the key for assigning reliable figures to the rest masses of elementary quarks and their hadron composites. It will be shown that a re-interpretation of these attributes allows a physical interpretation of isospin and removes the reason to accept the asymmetrical electric charge assignment to quarks. It will be shown as well that the number of elementary fermions would be reduced significantly.

Like all elementary fermions, quarks follow Fermi-Dirac statistics, obey the Pauli exclusion principle, have half integer spin and have distinct antiparticles. They can be modelled with the Dirac equation. The canonic formulation of Dirac's particle equation reads as [2,3],

$$(i\hbar\gamma^{\mu}\partial_{\mu}\psi - \beta m_0 c\psi) = 0\,,$$

in which β is a 4 x 4 unity matrix and in which the 4 x 4 gamma matrices have the properties,

$$\gamma_{\mu}\gamma_{\nu} + \gamma_{\nu}\gamma_{\mu} = 0 \text{ if } \mu \neq \nu; \text{ and } \gamma_0^2 = 1; \gamma_i^2 = -1;\ \beta^2 = 1\,. \qquad (1)$$

As usual, c is the vacuum light velocity, $\hbar$ is the reduced Planck constant and m_0 is the rest mass of the particle. While this equation captures a basic attribute as mass and attributes as spin state and particle/antiparticle state, it does not include quite some other properties of elementary fermions. It does not even include electric charge as an attribute, while Dirac's theory is originally conceived for electrons. It includes mass m_0 and spin S, but the hypercharge and weak isospin are missing. These are rather artificial attributes, conceived in the mathematical standard model, in which empirical phenomena are captured by axiomatic abstraction.

While the spin quantum s can be physically understood in relationship with the quantization of the observable value of the angular momentum in integer values of the magnitude of the elementary angular momentum **ℏ**, weak isospin has no known physical interpretation. Apart from its relationship with the electric charge as shown by the Gell-Mann-Nishijma formula [4,5] at the bottom line of Table I, it plays a role in the classification of hadrons, in interactions between nuclear particles and in the interaction with the omni-present energetic background field, known as the Higgs field. Weak isospin shows the same behaviour as spin $S \in \{-s, -(s-1), ..., (s-1), s\}$ in the sense of being subject to the same algebra rules as spin, thereby in a "(iso)spin 1/2 doublet" establishing an isospin triplet state $|1,\pm 1\rangle$ and $|1,0\rangle$ next to a singlet state $|0,0\rangle$.

Particle physics theory has been developed over many decades of years. As is well-known, a major milestone in this development was set in 1961 by Gell-Mann and Ne'eman, dubbed as the Eightfold Way [6]. One may wonder how this scheme would have been set up if isospin would have been understood physically. Within the scope of this article, it is my aim to show that a physical interpretation allows a less heuristic alternative for the Eightfold Way.

To show that such a novel view might be a useful complement to present theory, some problems will be addressed that are difficult to solve with present-state theory. Examples of such problems are mass related, because present theory shows a weakness in that respect. In particular, it will be shown how the mass spectrum of hadrons can be calculated to a rather high precision, how the masses of the weak interaction bosons and the Higgs boson can be calculated and why the topquark mass is out of scale in comparison with those of the other quark flavours.

After the introduction in paragraph 2 of an unconventional non-electron format of a Dirac particle, the quark and the archetype mesons and hadrons will be profiled in the next two paragraphs in terms of this particle, followed by a structural description of the meson model. In paragraph 6 a description will be given of the quark-scaling theorem as a basic quark property next to its polarisable dipole moment under a scalar potential. Paragraph 7 contains an assessment by theory of the Higgs boson mass, followed in paragraph 8 by an assessment of the Z boson by theory.

In paragraph 9, the structural view as developed in this article will be compared and related with the mathematical view of the Standard Model. Paragraph 10 deals with the electroweak unification, followed (in paragraph 11) by a comparison between the G(lashow)-W(einberg)-S(alam) model and the developed structural model. For convenience, the reader may skip these paragraphs 9,10,11, because they have no other purpose than showing that the structural model is not in conflict with the heuristic axioms adopted in the GSW theory.

The subsequent paragraphs deal with the strong interaction in mesons (paragraph 12) and in baryons (paragraph 13), including its relationship with Quantum Chromo Dynamics (QCD) and the role of gluons (paragraph 14). In paragraph 15 it will be shown why the topquark is out of scale and how and why it relates to particles with comparable mass values, such as the Higgs boson and the weak interaction bosons. Paragraph 16 contains a discussion and the conclusion. In these texts, quite some results are invoked from previously documented works in publications and preprints. The highlight on the quark-type Dirac particle and the quark-scaling theorem as two unrecognized theoretical principles will place those previous results in a better context.

2. Dirac particles with a polarisable dipole moment in a scalar potential field

The canonical set of gamma matrices in Dirac's equation is given by,

$$\gamma_0 = \begin{bmatrix} I & 0 \\ 0 & -I \end{bmatrix}; \gamma_1 = \begin{bmatrix} 0 & \sigma_1 \\ -\sigma_1 & 0 \end{bmatrix}; \gamma_2 = \begin{bmatrix} 0 & \sigma_2 \\ -\sigma_2 & 0 \end{bmatrix}; \gamma_3 = \begin{bmatrix} 0 & \sigma_3 \\ -\sigma_3 & 0 \end{bmatrix}; \beta = \begin{bmatrix} I & 0 \\ 0 & I \end{bmatrix}. \quad (2)$$

The calculation of the excess energy of an electron in motion subject to a vector potential $\boldsymbol{A}(A_0, A_x, A_y, A_z)$, gives [2,7],

$$\Delta E = \frac{e}{2m_0}\begin{bmatrix} \overline{\sigma} & 0 \\ 0 & \overline{\sigma} \end{bmatrix} \boldsymbol{\hbar}.\mathbf{B} + \mathrm{i}\frac{e}{2m_0}\begin{bmatrix} 0 & \overline{\sigma} \\ \overline{\sigma} & 0 \end{bmatrix} \boldsymbol{\hbar/c}.\mathbf{E}, \tag{3}$$

in which $\overline{\sigma}$ is the Pauli coefficient state variable, defined as

$$\overline{\sigma} = \overline{\sigma}(\sigma_1, \sigma_2, \sigma_3) \tag{4}$$

and in which $\mathbf{B}$ and $\mathbf{E}$ are generic field vectors (i.e. not necessarily of electromagnetic nature if e is a generic coupling factor) derived from the vector potential. The matrices are state variables with a real eigenvalue $|\overline{\sigma}| = 1$, such that the angular momentum (associated with $\mathbf{B}$) can be conceived as a spin vector with eigenvalue $|\boldsymbol{\hbar}|$. Next to the angular momentum, a second momentum $\boldsymbol{\hbar/c}$ (associated with $\mathbf{E}$) can be identified with eigenvalue $|\boldsymbol{\hbar/c}|$. In terms of these two dipole moments, eq. (3) can be written as,

$$\Delta E = \frac{e}{2m_0}\,|\boldsymbol{\hbar}|.\mathbf{B} + \mathrm{i}\frac{e}{2m_0}\,|\boldsymbol{\hbar/c}|.\mathbf{E} \tag{5}$$

The electron has a real first dipole moment ($e\hbar/2m_0$), known as the magnetic dipole moment, and an imaginary second dipole moment ($\mathrm{i}e\hbar/2m_0c$). The latter is one of the two anomalies of Dirac's theory, pointed out by himself. He noticed a negative energy solution next to a positive energy solution. And he noticed a real magnetic moment next to an imaginary electrical dipole moment. About the first item he remarked that that the problem would disappear if the electron would change its polarity, but that "this is a phenomenon not yet observed". About the second item he remarked that he doubted about the physical meaning of an imaginary electrical dipole moment. Curiously, like proven in [7] and in its update [8], a different set of γ matrices may turn the imaginary electrical dipole moment into a real one.

To show this modality, let us start from the canonic format of Dirac's equation as captured by,

$$(\mathrm{i}\hbar\gamma^{\mu}\partial_{\mu}\psi - m_0 c\psi) = 0 \rightarrow (\hbar\gamma^{\mu}\frac{\partial_{\mu}\psi}{\mathrm{i}} - \frac{1}{\mathrm{i}^2}m_0 c\psi) = 0\,, \tag{6}$$

It can be rewritten after division by $m_0 c$, in terms of wave function operators as,

$$[\gamma_0\hat{p}'_0 + (\overline{\gamma}\cdot\hat{\mathbf{p}}') + I_4]\psi = 0\,, \tag{7}$$

in which $\hat{\mathbf{p}}' = \hat{\mathbf{p}}'(\hat{p}_1, \hat{p}_2, \hat{p}_3)$ with

$$\hat{p}_i' = \frac{1}{m_0 c}\frac{\hbar}{\mathrm{i}}\frac{\partial}{\partial x_i} \text{ and } \hat{p}_0' = \frac{1}{m_0 c}\frac{\hbar}{\mathrm{i}}\frac{\partial}{\partial c\tau}, \tag{8}$$

and in which I_4 is the 4 x 4 identity matrix.

Note that the variables are signed by ' to emphasize their normalization on $m_0 c$. Note also that the temporal parameter is written as proper time τ to emphasize the (special) relativistic nature of Dirac's equation in free space. Rewriting (7) in the Weyl format gives,

$$\begin{bmatrix} I & 0 \\ 0 & -I \end{bmatrix}\begin{bmatrix} \hat{p}_0'\psi \\ \hat{p}_0'\chi \end{bmatrix} + \begin{bmatrix} 0 & \overline{\sigma} \\ -\overline{\sigma} & 0 \end{bmatrix}\begin{bmatrix} \hat{\mathbf{p}}'\psi \\ \hat{\mathbf{p}}'\chi \end{bmatrix} + \begin{bmatrix} I & 0 \\ 0 & I \end{bmatrix}\begin{bmatrix} \psi \\ \chi \end{bmatrix} = 0, \tag{9}$$

in which $\overline{\sigma} = \overline{\sigma}(\sigma_1, \sigma_2, \sigma_3)$ is the Pauli state variable with the three Pauli matrices.

As known, Dirac's equation is based upon a heuristic elaboration of the Einsteinean energy expression under the use of particular properties of the γ matrices. These properties can be summarized as,

$$\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu = 0 \text{ if } \mu \neq \nu; \text{ and } \gamma_0^2 = 1; \gamma_i^2 = -1; \beta^2 = 1, \tag{10a}$$

in which β is the last matrix term in (9). Recognizing that the last term in the left hand part of (9) represents a matrix β and that (6) is valid for a plus sign in front of m_0 as well, one should add in fact,

$$\gamma_\mu \beta \mp \beta \gamma_\mu = 0; \; \beta = \pm 1, \tag{10b}$$

which is trivial as long as β is the identity matrix. The very same properties are met if (9) is modified into,

$$\begin{bmatrix} I & 0 \\ 0 & -I \end{bmatrix}\begin{bmatrix} \hat{p}_0'\psi \\ \hat{p}_0'\chi \end{bmatrix} + \begin{bmatrix} 0 & \overline{\sigma} \\ -\overline{\sigma} & 0 \end{bmatrix}\begin{bmatrix} \hat{\mathbf{p}}'\psi \\ \hat{\mathbf{p}}'\chi \end{bmatrix} + \mathrm{i}\begin{bmatrix} 0 & I \\ I & 0 \end{bmatrix}\begin{bmatrix} \psi \\ \chi \end{bmatrix} = 0. \tag{11}$$

Note that the β is modified from the 4 x 4 identity matrix into the imaginary value of the "fifth" gamma matrix γ_5. The two representations (9) and (11) are equivalent. Both represent the common electron-type Dirac particle with a real magnetic dipole moment and an imaginary electric dipole moment. If β would have been modified into the real value of γ_5, we would have obtained the tachyon format, which reads as,

$$\begin{bmatrix} I & 0 \\ 0 & -I \end{bmatrix}\begin{bmatrix} \hat{p}_0'\psi \\ \hat{p}_0'\chi \end{bmatrix} + \begin{bmatrix} 0 & \overline{\sigma} \\ -\overline{\sigma} & 0 \end{bmatrix}\begin{bmatrix} \hat{\mathbf{p}}'\psi \\ \hat{\mathbf{p}}'\chi \end{bmatrix} + \begin{bmatrix} 0 & I \\ I & 0 \end{bmatrix}\begin{bmatrix} \psi \\ \chi \end{bmatrix} = 0. \tag{12}$$

 doi:10.20944/preprints202006.0304.v4

This tachyon format is studied in the context of the hypothetical existence of superluminal particles [9]. It does meet the constraint (10a), but it violates constraint (10b). Instead it meets,

$$\gamma_\mu\beta+\beta\gamma_\mu=0;\;\; \beta^2=-1. \tag{13}$$

Note the subtle difference between (10b) and (12). The dipole moments of the tachyon are similar to those of the electron-type: the equivalent magnetic one is real and the equivalent electric one is imaginary.

Both dipole moments are real for a *third* modification of Dirac's particle [7,8]. This modification reads as,

$$\mathrm{i}\begin{bmatrix} I & 0 \\ 0 & -I \end{bmatrix}\begin{bmatrix} \hat{p}'_0\psi \\ \hat{p}'_0\chi \end{bmatrix}+\begin{bmatrix} 0 & \overline{\sigma} \\ -\overline{\sigma} & 0 \end{bmatrix}\begin{bmatrix} \hat{\mathbf{p}}'\psi \\ \hat{\mathbf{p}}'\chi \end{bmatrix}+\begin{bmatrix} 0 & I \\ I & 0 \end{bmatrix}\begin{bmatrix} \psi \\ \chi \end{bmatrix}=0. \tag{14}$$

As compared with the electron-type (11), the γ_0 matrix is made imaginary. It meets the constraints,

$$\gamma_\mu\gamma_\nu+\gamma_\nu\gamma_\mu=0 \text{ if } \mu\neq\nu;\;\; \gamma_\mu\beta+\beta\gamma_\mu=0;\; \gamma_0^2=-1; \gamma_i^2=-1;\; \beta^2=-1. \tag{15}$$

To understand the violations of the constraints (10) and the modifications into (13) and (15), it is instructive to solve the various formats (11), (12) and (14) of Dirac's equation. In full expansion mode, (14) reads as

$$\mathrm{i}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}\begin{bmatrix} \hat{p}'_0\psi_0 \\ \hat{p}'_0\psi_1 \\ \hat{p}'_0\psi_2 \\ \hat{p}'_0\psi_3 \end{bmatrix}+\begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} \hat{p}'_1\psi_0 \\ \hat{p}'_1\psi_1 \\ \hat{p}'_1\psi_2 \\ \hat{p}'_1\psi_3 \end{bmatrix}+\begin{bmatrix} 0 & 0 & 0 & -\mathrm{i} \\ 0 & 0 & \mathrm{i} & 0 \\ 0 & \mathrm{i} & 0 & 0 \\ -\mathrm{i} & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} \hat{p}'_2\psi_0 \\ \hat{p}'_2\psi_1 \\ \hat{p}'_2\psi_2 \\ \hat{p}'_2\psi_3 \end{bmatrix}+\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}\begin{bmatrix} \hat{p}'_3\psi_0 \\ \hat{p}'_3\psi_1 \\ \hat{p}'_3\psi_2 \\ \hat{p}'_3\psi_3 \end{bmatrix}+\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}\begin{bmatrix} \psi_0 \\ \psi_1 \\ \psi_2 \\ \psi_3 \end{bmatrix}=0$$

and written differently,

$$\begin{bmatrix} \mathrm{i}\hat{p}'_0 & 0 & \hat{p}'_3+1 & (\hat{p}'_1-\mathrm{i}\hat{p}'_2) \\ 0 & \mathrm{i}\hat{p}'_0 & (\hat{p}'_1+\mathrm{i}\hat{p}'_2) & -\hat{p}'+1_3 \\ -\hat{p}'_3+1 & (\hat{p}'_1-\mathrm{i}\hat{p}'_2) & -\mathrm{i}\hat{p}'_0 & 0 \\ -(\hat{p}'_1+\mathrm{i}\hat{p}'_2) & \hat{p}'+1_3 & 0 & -\mathrm{i}\hat{p}'_0 \end{bmatrix}\begin{bmatrix} \psi_0 \\ \psi_1 \\ \psi_2 \\ \psi_3 \end{bmatrix}=0. \tag{16}$$

Let $\psi=u_\mu\exp\{\mathrm{i}(\mathbf{k}\cdot\mathbf{r}-\omega\tau)\};\;\; \mathbf{k}=\mathbf{p}/\hbar;\; \omega=W/\hbar.$ (17)

Applying (17) on (16) gives after some elaboration,

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$$\begin{bmatrix} -\mathrm{i}W & 0 & cp_3 + m_0c^2 & c(p_1 - \mathrm{i}p_2) \\ 0 & -\mathrm{i}W & c(p_1 + \mathrm{i}p_2) & -cp_3 + m_0c^2 \\ -cp_3 + m_0c^2 & -c(p_1 - \mathrm{i}p_2) & \mathrm{i}W & 0 \\ -c(p_1 + \mathrm{i}p_2) & cp_3 + m_0c^2 & 0 & \mathrm{i}W \end{bmatrix} \begin{bmatrix} u_0 \\ u_1 \\ u_2 \\ u_3 \end{bmatrix} = 0. \tag{18}$$

This homogeneous set of equations has the solution (17) indeed under the constraint of the determinant value

$$W^2 = (m_0c^2)^2 - c^2|\mathbf{p}|^2. \tag{19}$$

The canonical equations (9) or (11) show the same solution (17), but different from (19), under the constraint,

$$W^2 = E_W^2 = c^2|\mathbf{p}|^2 + (m_0c^2)^2 . \tag{20}$$

The tachyon equation (12) shows solution (17) for

$$W^2 = c^2|\mathbf{p}|^2 - (m_0c^2)^2. \tag{21}$$

For a meaningful wave function, ω and $\mathbf{k}$, hence W and $\mathbf{p}$, must be real. Hence, let us consider the condition (19) more closely. It can be rewritten as,

$$\frac{W^2}{(m_0c^2)^2} = 1 + \frac{(v/c)^2}{(v/c)^2 - 1} = 0 \rightarrow \frac{W^2}{(m_0c^2)^2} = \frac{1 - 2(v/c)^2}{1 - (v/c)^2}. \tag{22}$$

The condition for the momentum $\mathbf{p}$evolves as,

$$\frac{c^2|\mathbf{p}|^2}{(m_0c^2)^2} = 1 - \frac{W^2}{(m_0c^2)^2} = 1 - \frac{1 - 2(v/c)^2}{1 - (v/c)^2} \rightarrow \frac{|\mathbf{p}|}{m_0c} = \pm\sqrt{\frac{(v/c)^2}{1 - (v/c)^2}}. \tag{23}$$

Hence,

$$W = \pm m_0c^2\sqrt{\frac{1 - 2(v/c)^2}{1 - (v/c)^2}}\ ; \quad |\mathbf{p}| = \pm\frac{m_0v}{\sqrt{1 - (v/c)^2}}. \tag{24,25}$$

The similar elaboration for the tachyon format results into,

$$W = \pm\frac{m_0c^2}{\sqrt{(v/c)^2 - 1}}; \quad \frac{|\mathbf{p}|}{m_0c} = \pm\frac{m_0v}{\sqrt{(v/c)^2 - 1}}. \tag{26,27}$$

The tachyon format shows real values for W and $\mathbf{p}$ under superluminal conditions. It is a reason for speculations on the potential existence of superluminal particles. It is not meaningful under subluminal conditions, because the real values turn into imaginary ones.

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The properties of the "third" format, though, as shown by (24,25) are real under subluminal conditions. The real value of its second dipole moment makes it of interest.

Note: It may seem that Dirac's equation (6) under the constraints (15) is not Lorentz covariant, because of the violation of the invariance of the space-time interval if W is equated with the Einsteinean energy E. This invariance is a basic theorem in Einstein's Relativity theory. Let us take into consideration, though, that this theorem applies to gravitational objects, in which energy is conceived as the sum of massive energy embodied in the rest mass and the kinetic energy of an object. Prior to Dirac's relativistic electron theory, the concept of negative energy has been considered as a violation of physical principles. After all, it was realized that the concept of negative energy did not violate the Einsteinean space-time invariance. Dirac himself proved the Lorentz covariance of his electron theory. But…if a particle with negative energy is physically viable, why would a particle that eats its kinetic energy from its rest mass not physically viable? It requires to identify such a particle as being different from a gravitational object and to redefine the space-time interval variance. As shown in Appendix A, such a non-gravitational object in confinement with another one is compliant with the Lorentz covariance.

The interpretation of its W as energy, shown by (21) implies that this energy decreases if it goes from rest into motion. This is contra-intuitive, because In true empty space one would expect the opposite, such as expressed by the Einsteinean energy expression (20) that holds for the canonical case. There is, however, no compelling reason why, in spite of its dimensional appearance, W should be identical with the Einsteinean energy. The only thing that matters is its real value under subluminal condition, such as shown by (23). We are used to the Einsteinean energy relationship that says that a particle gains energy when it moves from rest into motion. This happens, however, only if additional energy is fed into the particle. In a conservative system, like an orbiting electron, this additional energy is given as initial state. The quark described by (14), though, shows the opposite: it seems to lose energy if it moves from rest into motion. It inherits its motional energy from its rest mass. This is, possibly, in its fundament, not essentially different from adding some initial energy to the rest mass like in the case of an orbiting electron. Like proven in [7,8], such a particular Dirac particle has a polarisable dipole moment in a scalar field. Hence, under the hypothesis that the quark is a Dirac particle of the "third" type , it possesses a polarisable dipole moment $\mathbf{p}_{\mathrm{h/c}}$ in a generic scalar nuclear field ∇A_0 given by,

$$\mathbf{p}_{\mathrm{h/c}} = \frac{g}{2m_0}\overline{\sigma}\ \boldsymbol{\hbar/c}, \tag{28a}$$

in which g is a generic unknown nuclear coupling factor. An essential point to be made here is that the spin state of the polarisable dipole moment is an intrinsic property independent from its spatial orientation given by the dipole moment vector $\boldsymbol{\hbar/c}$. The latter is subject to a potential field, while the spin state is an attribute without vectorial properties. The insensitivity of $\overline{\sigma}$ to either a magnetic field or a the scalar part of the vector potential, implies that, similarly as in the case of particle/antiparticle state, quarks in the two states of $\overline{\sigma}$ can be regarded as two different quarks, which by convention can be indicated as an "up isospin" u quark and a "down isospin" d quark. More specifically, isospin can now be identified in terms of the eigen values ±1, of the matrix $\overline{\sigma}$. For a single particle as ±1/2, being similar to the projection of a common spin vector on the vertical axis in the complex plane.

It will be clear now that isospin is closely connected with the spin of the elementary angular momentum. The latter will be denoted as particle spin. Whereas isospin is connected with the momentum vector ***ħ/c***, particle spin is related with the angular momentum vector ***ħ*** in the nuclear equivalent of the electron's anomalous magnetic dipole moment,

$$\mathbf{p}_{\mathrm{h}} = \frac{g}{2m_0}\overline{\sigma}\,\boldsymbol{\hbar}\,. \tag{28b}$$

In quite some textbooks $\bar{\sigma}$ is represented as a vector and *ħ* as a scalar quantity. Within the scope of this article, however, it is essential to emphasize that $\overline{\sigma}$ is a state variable and that ***ħ*** and ***ħ/c*** are vectors. It is essential to emphasize once more as well that ***ħ*** is an angular momentum and that ***ħ/c*** is a position vector. They have a different spatial dimensionality. This makes a difference in the spin interpretation of $\overline{\sigma}$ ***ħ*** as compared to $\overline{\sigma}$ ***ħ/c***. It makes the quantum numbers ± 1/2 associated with isospin and associated with particle spin independent from each other because of the handiness of the angular motion.

For proper distinction, the up-state particle spin of an u quark (or a d quark) and the down-state of an u quark (or a d quark) will be indicated as, respectively, u and $\underline{u}$ (or d and $\underline{d}$ for d quarks). The particle state and the antiparticle state of an u quark will be indicated as, respectively u and $\overline{u}$. Analogously d and $\overline{d}$ for d quarks.

Summarizing: accepting the existence of "third-type" Dirac particles allows considering the quark as a particle with two real dipole moments in two mutually independent quantum states, in spite of their common origin from the same state variable. Whereas in the Standard Model isospin is a heuristic axiomatic concept, it has in fact a similar physical origin as common particle spin.

3. Profiling a quark

Let us proceed by profiling a quark as a field. One of the issues to cope with in the context of this article are the different semantics of the field concept in classical physics, in quantum mechanical physics and in particle physics. In classical physics, the field is the static solution of an energetic wave equation. The field has an energetic interpretation. In quantum mechanics, the field is a solution of Schrödinger's equation, which in fact is the non-relativistic limit of Dirac's equation. This field has an probabilistic interpretation, because its integrated squared value is considered as the probability that a particle is at some moment in some spatial position. In particle physics theory, the two fields are unified in a single concept: the quantum field. This is done on the basis of (second) quantization. This allows the description of processes that are subject to an interchange between matter and energy, such as occur in decay processes and scattering processes, including, for instance, recoil. This

Quantum Field Theory (QFT) is one of the pillars of the Standard Model of particle physics. Because interchange between matter and energy is beyond the scope, the field view within the scope of this article is either classical, formalized as Φ, or quantum mechanical, formalized as a multi-component spinor $\Psi(\psi_\mu)$, eventually reduced to a single component ψ.

Modeling the quark's field as a classical scalar Φ, it can be characterized by a Lagrangian density with the format

$$L = -\frac{1}{2}\partial_\mu \Phi \partial^\mu \Phi + U(\Phi) + \rho\Phi\,, \tag{29}$$

in which $U(\Phi)$ is the potential energy of an energetic background field and in which $\rho\Phi$ is the source term. If the background field would have the format,

$$U(\Phi) = U_{DB} = \lambda_{DB}^2 \frac{\Phi^2}{2}\,, \tag{30}$$

the stationary format of the wave equation, obtained after application of the Euler-Lagrange equation from the Lagrangian, is the inhomogeneous Helmholtz equation [10], which for a pointlike source ρ shows the solution

$$\Phi_{DB} = \Phi_0 \frac{\exp(-\lambda_{DB} r)}{\lambda_{DB} r}\,. \tag{31}$$

Such a field (31) is of a type as described by Debije [11] for a charged particle in an ionic plasma The wave equation associated with this Lagrangian (29,30) has the same format as the Klein-Gordon equation, which originally has been conceived as a relativistic extension of the Schrödinger one. In present quantum field theory, this equation is considered as the field equation for a massive spin-zero particle. Conceived, however, as a wave equation of a classical field, it originates from Proca's Lagrangian for a massive photon. One might object that Proca's Lagrangian is not Lorentz covariant. This is true indeed for empty space, in which $U(\Phi)$ is considered as a mass term. In fact, however, it represents an energetic background field of (nuclear) space charge that gives dispersion to the bosons emitted by a pointlike source. Viewed in terms of Debije's theory of the shielded Coulomb field, it is the influence of the nuclear equivalent of a polarized ionic plasma composed by elementary dipoles that shields the boson field from the one in empty space. A more theoretical view is invoking the Stueckelberg action for its justification [12].

Similarly as an electron, the quark has an energetic monopole, represented by the source term $\rho\Phi$ in the Lagrangian (29). For an electron, the monopole is an electric point charge. For the quark it is the nuclear equivalent of the electric point charge. Next to the monopole, the electron and the quark have two dipole moments [2,7,8]. These dipole moments are the results from the elementary angular momentum ***ħ*** and the elementary mass dipole moment ***ħ/c***. In the case of an electron, these dipole moments give rise to, respectively, a real magnetic dipole and an *imaginary* electric dipole. In the case of a quark, these dipole

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moments give rise to, respectively, a real equivalent of the magnetic dipole and a *real* nuclear equivalent of the electric dipole. While, due to its imaginary value, the electric dipole moment of the electron cannot be polarized in a scalar potential field, the nuclear equivalent can, because of its real value.

Similarly as the monopole of the electron, the monopole of the quark, spreads a scalar potential field. This field is able to polarize the electric dipole equivalent of another quark. Such a dipole spreads an en energetic potential with x^{-2} dependency along the orientation axis of the dipole. As a consequence, an equilibrium of forces can arise between a repelling force from the r^{-1} monopole field dependency and the attractive force with x^{-2} dipole field dependency from suitably aligned dipoles of two quarks. Because nuclear forces have a short range, these potential fields must experience a shielding effect akin to the shielding of the field of an electric point charge in an ionized plasma. This shielding is known as the Debije effect. It occurs under influence of an omni-present fluidal field of energy. In particle physics such a background field is known as the Higgs field. Hence, in qualitative terms, the potential field of a quark along the axis of the polarisable dipole, can be expressed as,

$$\Phi(\lambda x) = \Phi_0 \exp(-\lambda x)\{\frac{1}{(\lambda x)^2} - w\frac{1}{\lambda x}\}, \tag{32}$$

in which λ (with dimension m^{-1}) is a measure for the range of the nuclear potential, in which Φ_0 (in units of energy, i.e. joule) is a measure for the quark's "charge", and in which w is a dimensionless weigh factor that relates the strength of the monopole field to the dipole field. The far field, decaying as $\exp(-\lambda x)/\lambda x$ is due to the monopole. As will be shown later, it can be seen as the major component of the weak interaction between the quarks. The near field, decaying as $\exp(-\lambda x)/(\lambda x)^2$ can be seen as the major component of the strong interaction between the quarks. This component is due the polarisable dipole.

While the spatial Debije format (31) of the field has been straightforwardly calculated from the functional expression of the background field (30), the spatial field expression of the quark's field in this text has been derived indirectly. One may ask if it would be possible to arrive at the format (32) analytically from a functional field expression as well. Obviously, the simple unbiased symmetric background field expression (30), in which $U(\Phi) = 0$ for $\Phi = 0$, has to be modified for the purpose. The most simple approach is modifying (30) into

$$U(\Phi) = -\frac{\mu_H^2}{2}\Phi^2 + \frac{\lambda_H^2}{4}\Phi^4. \tag{33}$$

For positive values of λ_H^2 and μ_H^2, it is a broken field that is zero for

$$\Phi_0 = (\mu_H / \lambda_H)\sqrt{2},$$

known as the vacuum expectation value.

(Note: this field format, originally conceived by Nambu [13] from quite a different perspective, has been dubbed later as the Higgs field because of its particular property to give mass to spin-1 particles, shown by Higgs [14] and Englert and Brout [15].)

Unfortunately the high non-linearity of this field prevents deriving an analytical solution $\Phi(r)$ from (33) and (29). However, a numerical procedure allows deriving a two-parameter expression for $\Phi(r)$ that closely approximates a true analytical solution. In that approach a generic Ansatz format is adopted for $\Phi(r)$ from which an expression is retrieved of $U(\Phi)$. Subsequently, a fit of is searched on (33). Doing so, first of all, the Euler-Lagrange equation is applied on the static Lagrangian density (29). Hence, from

$$\frac{\partial \mathrm{L}}{\partial \Phi} - \partial_i \left(\frac{\partial \mathrm{L}}{\partial(\partial_i \Phi)}\right) = 0\,, \tag{34}$$

we have from (29),

$$\partial_i \Phi \partial^i \Phi = \frac{d}{d\Phi} U(\Phi) + \rho\,. \tag{35}$$

The Ansatz format of the field $\Phi(r)$ is chosen as,

$$\Phi(r) = \Phi_0' \frac{\exp(-\lambda r)}{\lambda r}\left\{\frac{\exp(-\lambda r)}{\lambda r} - 1\right\}. \tag{36}$$

The rationale behind the choice (36) is the assumption that the inter-quark potential will behave similarly as the inter-nucleon potential [16,17]. It is also nicknamed as the "liquid drop model" .

Substitution of (36) into (34) and subsequent calculation of $U(\Phi)$ gives a fit with (33) for μ_H^2 and λ_H^2, such that

$$\frac{1}{2}\mu_H^2 = 1.06\lambda^2 \text{ and } \frac{1}{4}\lambda_H^2 = 32.3\frac{\lambda^2}{\Phi_0'^2}\,. \tag{37a}$$

A numerical calculation and a proof for this fit has been documented in [18].

Without loss of generality Φ_0' can be rescaled to the vacuum expectation value Φ_0 (33) by modifying (37a) into

$$\frac{1}{2}\mu_H^2 = 1.06\lambda^2 \text{ and } \frac{1}{4}\lambda_H^2 = \frac{(1.06\lambda)^2}{\Phi_0^2}\,. \tag{37b}$$

The two-parameter field is indistinguishable from the three-parameter field,

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$$\Phi(r) = \Phi_0 \exp(-\lambda r)\{\frac{1}{(\lambda r)^2} - w\frac{1}{\lambda r}\} \text{ for } w = 1/0.555 \,. \tag{38}$$

The quark's field would show the characteristics as shown in the right-hand part of Figure 1. It is nicknamed as the "Mexican hat model", owing to its shape if rotated around the vertical axis.

It would imply that a quark would be repelled by any other quark under influence of the far field, but attracted by the near field, thereby giving rise to mesons as stable two-quark junctions and baryons as three-quark junctions. Unfortunately, this radial symmetric format is not viable, because it violates the renormalization constraint. However, comparing (38) with (32) reveals a striking correspondence. Nevertheless, there is a major difference as well. While the derivation of (38) has been based upon a presupposed energetic monopole model for the quark, (32) is the result of a dipole moment next to a monopole.

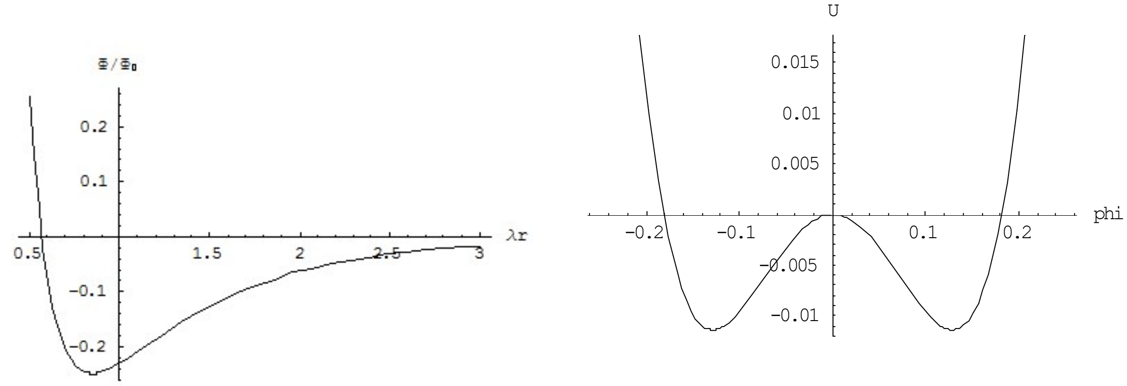

Fig. 1. (Left) The quark's scalar field Φ / Φ_0 as a function of the normalized radius λx ; (Right) The background field $U_H(\Phi) = -U(\Phi)$ retrieved from the spatial expression.

Hence, by restricting the validity of (38) to the dipole axis x, the renormalization problem is removed by rewriting (38) as a sum of a far field and a near field, such that,

$$\Phi(x) = \Phi_F(x) + \Phi_N(x) \text{ with } \Phi_F(x) = -w\Phi_0 \frac{\exp(-\lambda x)}{\lambda x} \text{ and } \Phi_N(x) = \Phi_0 \frac{\exp(-\lambda x)}{(\lambda x)^2} \tag{39}$$

The conclusion therefore is that the Higgs field has to be interpreted as the shielded radial symmetric field of an energetic monopole in conjunction with a one-dimensional dipole field. The quark, conceived as a subluminal tachyon-type Dirac particle, in this article futher denoted as a *pseudo-tachyon*, is compatible with this model. The near field is due to the dipole and gives an interpretation for the near field that glues the quarks together in hadronic structures. The break in the field that spoils the symmetry of the Debije field, thereby modifying it into the Higgs field, can be ascribed to the quark's polarisable dipole moment.

4. Profiling mesons and baryons

Let us suppose that we wish to build the archetype meson (quark plus antiquark) and the

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archetype baryons, i.e. the proton and the neutron (three quarks) by a single archetype quark. Would that be possible, and if not, what kind of theoretical instruments (read axioms) would be needed to do so? Figure 2 shows a schematic configuration between two elementary quarks. As noted before, the far field, decaying as $\exp(-\lambda x)/\lambda x$, due to the monopole, can be seen as the weak interaction between the quarks. The near field, decaying as $\exp(-\lambda x)/(\lambda x)^2$ is due the polarisable dipole. Unlike quark bonds, such lepton bonds don't exist, because of the lack of such dipole. In the figure it is supposed that the far field is repelling while the near field is attracting. In fact, the mechanism remains the same under an attracting far field and a repelling near field. In spite of the structural constraint on the polarization orientation of the second dipole moments in the meson bond, statistical freedom is left for assigning a state of isospin to these dipole moments. Taking into account the relationship between isospin and electric charge, it suggests that a same state of isospin can be interpreted as the magnetic dipole moment of an elementary amount of electric charge. This interpretation explains the appearance of the archetype quark into two different modes u and d. It also suggests that the quark's monopole characteristics can be described in Maxwellian terms. Such a description is left beyond the scope of this article. It can be found in a preprint [19]. From these considerations we may compose a classification scheme for the archetype mesons as shown in Table I. Under antiparallel particle spin condition, stable structures require compositions shown in the second column of Table I.

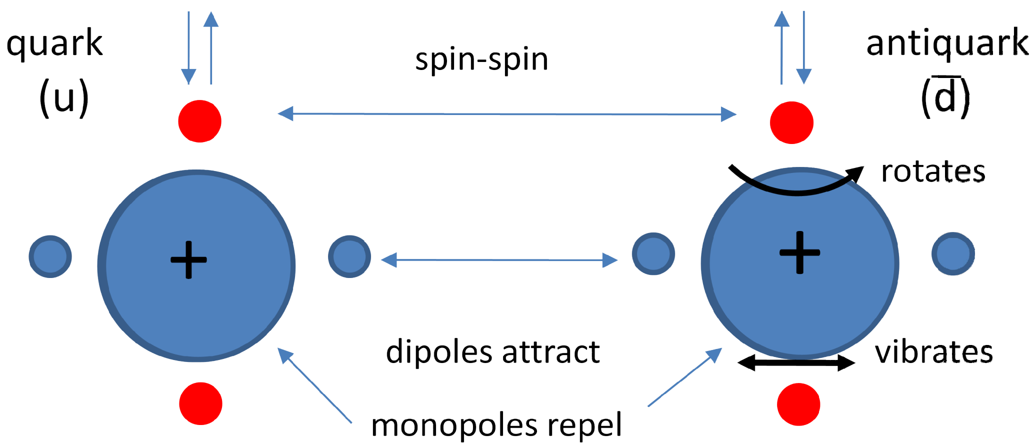

Fig. 2. A quark has two real dipole moments, hence two dipoles. One of these (horizontally visualized) is polarisable in a scalar potential field. The other one (vertically visualized) is not. The dipole moments are subject to spin statistics. However, the polarity of the horizontal one is restrained by the bond: the horizontal dipoles are only oriented in the same direction: either inward to the centre or outward from the centre.

The upper bar in $\overline{u}$ denotes that the u quark is in antiparticle state. The up-state particle spin of an u quark is denoted as u, its down-state is denoted by lower bar in $\underline{u}$. Mutatis mutandis for d quarks. The possible parallel particle spin configurations are shown in the fifth column. Whereas the up-spin is supposed as being in isospin state 1/2, the down spin state is in isospin state -1/2. The antiquarks, of course, have opposite signs. Note the additional neutral configuration ω of vector mesons and its difference with ρ^0. Note also that the picture shown in figure 2 and the associated coding scheme maintains its validity in

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the case that the monopoles are repelling and the isospin dipoles are attracting. Note that $\underline{u}u$ and (consequently) $u\overline{u}$ does not show up because of the Pauli constraint on isospin.

Table I: archetype mesons

meson	pseudoscalar coding	symb	isospin sum (Q)	vector mode coding	symb	isospin sum (Q)
qq	$\underline{u}\overline{d}$	π^+	1	$\underline{u}\overline{d}$	ρ^+	1
	$\underline{d}\overline{u}$	π^-	-1	$\underline{d}\overline{u}$	ρ^-	-1
	$(\underline{u}\overline{d}+\underline{d}\overline{u})/2$	π^0	0	$(\underline{u}\overline{d}+\underline{d}\overline{u})/2$	ρ^0	0
				$(\underline{u}\overline{d}+\underline{d}\overline{u})/2$	ω	0

What about the archetype baryon? Figure 3 shows its basic configuration. It illustrates that the monopole fields of the quarks are balancing the fields of the polarisable dipole moments. Like explained before, the orientation of these dipoles is unrelated from their isospin status. This independence is illustrated in figure 4.

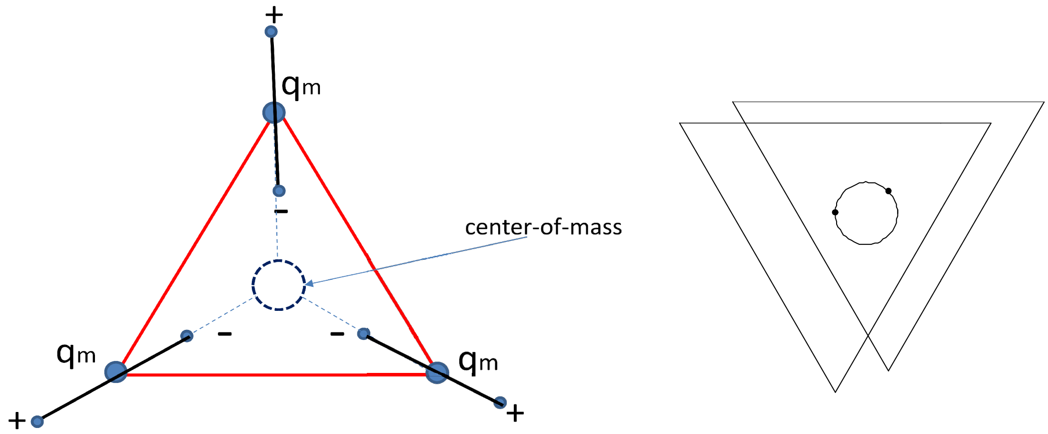

Fig.3: Left: the basic baryon structure as a harmonic oscillator. The polarisable dipole moments balance the fields of the monopoles. The vibra-rotations of the monopoles have an equivalent in the behavior of the center-of-mass. Right: illustration of the frame spin of the baryon.

In this picture, the isospin states are symbolized as either inward (u) or outward oriented (d), which either show up as particle spin 1/2 (two spins parallel, one anti parallel) or as particle spin 3/2 (three spins parallel). The possible configurations are shown in Table II. In ground state all three quarks have to be in a different condition, be it in particle spin or in isospin. As shown in the upper part, the ground state configuration with particle spin 1/2 shows only two different possible modes. The 3/2 spin state allows four possible modes. However, like demonstrated in figure 4, two of these modes are fully symmetrical. And this symmetry is a problem, because a wave function for fermions should show asymmetry to avoid conflicts with the Fermi-Dirac statistics. This would be a problem for ground state wave functions, because of the availability of a single level of energy. Hence, three quarks building the ground state should all be different. The same principle says that under

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availability of excited levels of energy, the constraint is relaxed, because the quarks in the same state of attributes can distributes themselves over various available level of energy. This is what happens with electrons in atomic shells. Considering that a spin flip from spin 1/2 to spin 3/2 is an excitation, the creation of the from the nucleon state into the Δ^0 / Δ^+ states with higher mass, like illustrated in the upper part of figure 4 can readily be understood. Like to shown later in this text, an isospin flip has a similar effect, albeit that the corresponding shift in energy is much less than in the case of a spin flip. This means that the origin of the Δ^- / Δ^{++}, shown in the lower part of figure 4 can be easily understood. Like pointed out by Comay [20] in more mathematical terms, there is no need whatsoever to invoke the QCD color charge as an additional axiom.

Inspection of the tables I and II shows that whereas in the case of mesons their electric charge is straightforwardly related with the isospin state, the isospin state of the baryons is extended with a bias term to obtain the same result. The origin of the bias is not clear. Accepting it as a phenomenological fact has given rise to the assignment of different electric charges to u quarks and d quarks in a split of the elementary charge e in respectively, 2/3e and 1/3e. Because quarks are subject to confinement and can therefore not observed in isolation, there is no hard proof for this asymmetry. Equally well, one may consider the electric charge as a holistic attribute of the whole hadron without a need for such a split. Doing so, the bias can be understood by recognizing that the quantum e of electric charge is related with the elementary quantum step $\hbar$. Projected this phenomenon on the two possible states of the nucleon inevitably means a difference in electric charge of just one electric charge quantum, thereby making a charged nucleon (proton) and an uncharged nucleon (neutron). The charge itself might be a distributed cloud over the structure instead of being a pointlike attribute of the quark.

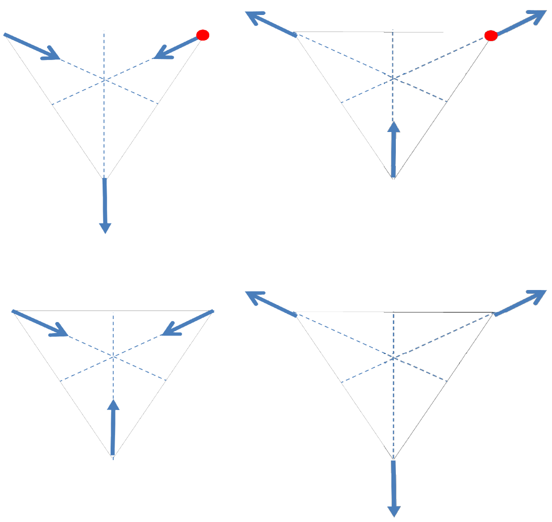

Fig.4: The basic baryon configurations. The arrows represent a symbolic representation of the isospins. The upper part holds for particle spin 1/2 (with dot) and for particle spin 3/2 (without dot). The particle spin 3/2 condition has two additional modes, shown in the lower part. The isospins oriented toward or outward the center-of-mass are regarded as, respectively, up spins (u) or down spins (d).

The simple adoption of a single archetype quark in two different modes, is, by far, not adequate for the explanation on observations from mesons and baryons. A first extension to the considerations just given has led to the inevitable conclusion that next to the u quark and the d quark at least a third quark had to exist. There seemed being no escape than defining a new elementary particle that became known as the s(trange) quark. In this article it will be shown, though, that its existence can be explained as a further consequence from the quark conceived as a polarisable Dirac particle. Before doing so, let us first extend the meson and baryon tables by including the s quark. It can be done systematically similar as in the case of the basic quarks by distinguishing between the particle spin antiparallel configuration (spin +/- 1/2 for baryons) and the spin parallel configuration (spin +/- 3/2 for baryons). The s quark appears being a particle with negative electric charge. The c(harmed) quark, identified later in 1974, appeared being just positively charged. Because the electric charge of the hadron is a holistic attribute, one may still explain the charge of the hadrons as a consequence from asymmetrical charge splits or as symmetrical contributions on top of a bias.

From the rest masses of the hadrons, shown in the tables III and IV, it is obvious that the parallel particle spin configurations show significant higher values than the antiparallel configurations. The particle spin flip between parallel and antiparallel is known as strong decay. The spin +/- 1/2 table of the eight light (u,d,s) baryons is known as an octet, and the spin +/- 3/2 table of the ten light (u,d,s) baryons is known as a decuplet. Note the mass difference between the Λ^0 baryon and the Σ^0 baryon. It makes a difference whether quarks with equal mass are in parallel or whether quarks with unequal mass are in parallel. In the +/- 3/2 configuration the difference has disappeared and the two configurations coincide. Hence, it is obvious that de particle spin orientations have a major impact on the rest masses of the hadrons. More about this in quantitative terms will be discussed later in this article.

Table II: archetype baryons

baryon	scalar spin inward/outward	spin (nuclear	isospin sum	bias	charge	symb
(qqq)	$(ud)\underline{u}$	$\pm 1/2$	+1/2	+1/2	1	p
	$(du)\underline{d}$	$\pm 1/2$	-1/2	+1/2	0	n

baryon	scalar spin inward/outward	spin (nuclear)	isospin sum	bias	charge	symb
(qqq)	$(ud)u$	$\pm 3/2$	+1/2	+1/2	1	Δ^+
	$(du)d$	$\pm 3/2$	-1/2	+1/2	0	Δ^0
	$(uu)u$	$\pm 3/2$	+3/2	+1/2	2	Δ^{++}
	$(dd)d$	$\pm 3/2$	-3/2	+1/2	-1	Δ^-

(two isospins in the same particle spin are allowed against a third particle)

As noted before, whereas in the Standard Model the emergence of quarks heavier than the archetype u/d has been accepted by defining new elementary particles, it will be demonstrated now that such particles are a theoretical consequence of the Dirac quark as a polarisable particle. If so, the heavier quarks will no longer be elementary.

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From inspection of the basic meson and the basic baryon in figure 2, respectively figure 3, it will be clear that those stable structures show, respectively, a two-quark (an)harmonic oscillator and a three-quark (an)harmonic oscillator. Both structures can be analyzed by a one-body equivalent. Obviously, the meson is easier to handle than the baryon, albeit that the meson has to be analyzed in its center-of-mass frame and subsequent relativistic correction. In that respect the baryon is different. However, a three-body problem is notoriously difficult. One might oppose that these (an)harmonic oscillator structures are oversimplifications of the actual problem, because they suggest that the behavior of a quark can be captured in a non-relativistic Schrödinger-type wave function, while actually a relativistic Dirac-type wave function is required. But let us see where this road takes us.

Table III

	Mesons (light sector)							
meson	pseudo scalar	symb	vector		isospin sum	Q	mass calculated	mass (MeV/c^2
$(q\bar{q})$	$(\underline{u}\bar{d})$	π^+	$(\underline{u}\bar{d})$	ρ^+	1	1	140/780	139/775
	$(\underline{d}\bar{u})$	π^-	$(\underline{d}\bar{u})$	ρ^-	-1	-1		
	$(\underline{u}\bar{d}+\underline{d}\bar{u})/2$	π^0	$(u\bar{d}+d\bar{u})/2$	ρ^0	0	0		
			$(u\bar{u}+d\bar{d})/2$	ω	0	0	n.a./780	n.a/782
	$(\underline{u}\bar{s})$	K^+	$(\underline{u}\bar{s})$	K^{*+}	1	1	484/896	489/892
	$(\underline{s}\bar{u})$	K^-	$(\underline{s}\bar{u})$	K^{*-}	-1	-1		
	$(\underline{d}\bar{s})$	$\bar{K}^0$	$(\underline{d}\bar{s})$	$\bar{K}^{*0}$	0	0		
	$(\underline{s}\bar{d})$	$\bar{K}^0$	$(\underline{s}\bar{d})$	$\bar{K}^{*0}$	-1	0		
	$(\underline{s}\bar{s})$	x	$(\underline{s}\bar{s})$	φ	0	0	1032	n.a/1020

Table IV

	Baryons (light sector)								
baryon	spin $\pm$1/2	symb	spin $\pm$3/2	symb	isospin sum	frame spin	Q	mass calculated	mass actual (MeV/c2)
qqq	$(ud)\underline{u}$	p	$(ud)u$	Δ^+	1/2	1/2	1	939/1246	939/1232
	$(du)\underline{d}$	n	$(du)d$	Δ^0	-1/2	1/2	0		
			$(uu)u$	Δ^{++}	3/2	1/2	2		
			$(dd)d$	Δ^-	-3/2	1/2	1		
	$(ud)\underline{s}$	Λ^0			-1/2	1/2	0	1113/	1116/
	$(us)\underline{u}$	Σ^+	$(us)u$	Σ^{*+}	1/2	1/2	1	1179/1386	1190/1385
	$(ds)\underline{d}$	Σ^-	$(ds)d$	Σ^{*-}	-3/2	1/2	-1		
	$(us)\underline{d}$	Σ^0	$(us)d$	Σ^{*0}	-1/2	1/2	0		
	$(s\underline{s})u$	Ξ^0	$(ss)u$	Ξ^{*0}	-1/2	1/2	0	1324/1532	1320/1530
	$(s\underline{s})d$	Ξ^-	$(ss)d$	Ξ^{*-}	-3/2	1/2	-1		
	$(s\underline{s})s$	x	$(ss)s$	Ω^{-1}	-3/2	1/2	-1	n.a./1683	n.a. /1672

5. The meson

Conceiving the pion as a structure in which a quark couples to the field of the antiquark by the generic quantum mechanical coupling factor g (it will turn out later that its value can be exchanged with Φ_0 under invariance of the product $g\Phi_0$), the pion can be modeled as the one-body equivalent of a two-body oscillator, described by the equation for its wave function ψ ,

$$-\frac{\hbar^2}{2m_m}\frac{\mathrm{d}^2\psi}{\mathrm{d}x^2}+\{U(d+x)+U(d-x)\}\psi=E\psi\,;\;\; U(x)=g\Phi(x)\,, \tag{40}$$

in which $\Phi(x)$ is the quark's scalar field as derived before and eventually expressed by (32), $2d$ the quark spacing, m_m the reduced mass that embodies the two massive contributions from the constituting quarks, $V(x)=U(d+x)+U(d-x)$ its potential energy, and E the generic energy constant, which is subject to quantization.

It will be clear from (40) that the potential energy $V(x)$ can be expanded as,

$$V(x)=U(d+x)+U(d-x)=g\Phi_0(k_0+k_2\lambda^2x^2+....)\,, \tag{41}$$

in which k_0 and k_2 are dimensionless coefficients that depend on the spacing $2d$ between the quarks.

Note that the effective mass m_m of the two quarks is not necessarily the same as the constituent mass that results from an a-posteriori assignment from the non-observable rest mass of the pion calculated from the observable decay products. The constituent mass is mainly a result of the ground state energy of the oscillator, which is taken up from the field. Furthermore, it has to be kept in mind that this model holds in the center of mass frame, so that a lab frame interpretation will need a relativistic correction. To facilitate the analysis, (40) is normalized as,

$$-\alpha_0\frac{\mathrm{d}^2\psi}{\mathrm{d}x'^2}+V'(x')\psi=E'\psi\,, \tag{42}$$

in which $\alpha_0=\dfrac{\lambda^2\hbar^2}{2m_m g\Phi_0}$, $x'=x\lambda$, $d'=d\lambda$, $E'=\dfrac{E}{g\Phi_0}$, $U'(x')=\dfrac{U(\lambda x)}{g\Phi_0}$ and

$$V'(x')=U'(d'+x')+U'(d'-x')=k_0+k_2x'^2+.......$$

Invoking previous work [21, eq. (24)], and to be confirmed later in this text once more, we get for α_0,

$$\alpha_0 = \frac{1}{4k_2}. \quad (43)$$

Normalized quantities in this text will be indicated by a "prime" ('). The coefficients $k_0(d')$ and $k_2(d')$ can be straightforwardly calculated from (42) and (36) as,

$$k_0 = 2(\frac{\exp(-2d')}{d'^2} - \frac{\exp(-d')}{d'})$$
$$k_2 = \frac{\exp(-2d')}{d'^4}(6 + 4d'^2 + 8d') - \frac{\exp(-d')}{d'^2}(2 + d' + \frac{2}{d'}). \quad (44)$$

The two quarks in the meson settle in a state of minimum energy, at a spacing $2\lambda d = 2d'_{\min}$, such that [21,22],

$$d'_{\min} = \lambda d = 0.853;\ k_0 = -1/2 \text{ and } k_2 = 2.36. \quad (45)$$

Note: the field format (36) has been preferred above the indistinguishable field format (32) because (36) is a two-parameter format, while (32) is a three-parameter one. It has to emphasized that the wave equation can be numerically solved without simplifying it to the harmonic format with the two constants k_0 and k_2 only.

Table V: meson excitations

Bottom level	E'_{bind} = - 1/2	mass ratio	mass in MeV/c^2
Ground state	$E'_0 - E'_{bind}$ = 0.84	1	137 (pion = 135-140)
First excitation	$E'_1 - E'_{bind}$ = 3.00	3.57	489 (kaon = 494-498)
Second excitation	$E'_2 - E'_{bind}$ = 6.06	7.21	988 (η'= 958)
Third excitation	$E'_3 - E'_{bind}$ = 9.94	11.83	???

The archetype, the pion, is the two-quark oscillator in its ground state. The first excitation state transforms a pion into a kaon. The mass ratio between the two is the same as the mass ratio of the normalized energy constants $E' - k_0$. This is not trivial and it reflects the basic theorem of the theory. This theorem states that the energy wells of the two quarks are not massive. Instead, the mass attribute of two-quark junctions (mesons) and three-quark junctions (baryons) is made up by the vibration energy as expressed by the energy state of the quantum mechanical oscillator that they build. The distribution of this mass over constituent quarks is a consequence of this mechanism. Unfortunately, an analytical calculation of the $E' - k_0$ ratio of kaons over pions, is only possible for the quadratic approximation of the series expansion of the potential energy $V'(z')$. A more accurate calculation requires a numerical approach. A procedure to do so has been documented in

[21, Appendix C]. It shows that some simple lines of code in Wolfram's *Mathematica* [23] may do the job. The numerically calculated ratio of the energy constants appears to be 3.57 instead of 3 as it would have been in the harmonic case. The result explains the excitation of the 137 MeV/c^2 pion mass to the 490 MeV/c^2 mass of the pseudoscalar kaon. This result gives a substantial support for the viability of the theory as will be further developed in this article. This result also gives rise to the question if other mesons can be regarded as a result from enhanced excitation. Table V gives a survey of the calculated ratios for higher excitation ratios. It gives the pseudoscalar η' meson as a candidate from second level excitation. The table gives no candidate for third level excitation. As shown in [24], the corresponding level of energy would imply a meson state with a positive value for the binding energy (as is reflected in the value of k_0), which prevents a sustainable quasi-stable configuration.

6. The quark-scaling theorem and its impact on the meson's mass spectrum

The wave equation of the simple pion model as shown in (42) is Schrödinger's one, which, in fact, is the non-relativistic approximation of Dirac's covariant wave equation. As is well known, Dirac adopted the Einsteinean energy formula as a starting point. He might have chosen Einstein's geodesic equation instead. There is no reason why the momenta in the geodesic equation would not allow the same momentum-wave function transformation as in the energy equation. But why doing so? The reason is the consideration that the geodesic equation may give additional results on top of those from the energy equation. It contains an additional symmetry. Apart from energy conservation, it complies momentum conservation. As to be discussed in this paragraph, exploitation of this symmetry will reveal an interesting theorem. To avoid an excessive length of this article it is a summary of previous documented work [24].

It starts from the meson's quantum mechanical wave equation (42), once more in its denormalized format,

$$-\frac{\hbar^2}{2m_m}\frac{\mathrm{d}^2\psi}{\mathrm{d}x^2} + g\Phi_0\{k_0 + k_2\lambda^2 x^2 + ...\}\psi = E\psi\,. \tag{46}$$

This represents an anharmonic quantum mechanical oscillator characterized by quantum steps $\hbar\omega$ related with the effective mass m_m, such that

$$\frac{1}{2}m_m\omega^2 = g\Phi_0 k_2\lambda^2 \rightarrow \frac{m'_m(\hbar\omega)^2}{(\hbar c)^2} = 2g\Phi_0 k_2\lambda^2\,. \tag{47}$$

Conventionally, m_m represents is the central mass of the oscillator. In the non-relativistic center-of-mass model described in chapter 5, it does not represent the individual masses of the two bodies, but, like stated before, it is an equivalent mass that captures the energy of the field. As usual, ω is related with the vibration energy $E_n = (n+1/2)\hbar\omega$. Considering that the pion decays into a fermion via the weak interaction boson, it makes sense to equate the boson $\hbar\omega$ with the weak interaction boson. Hence,

$$\hbar\omega_W = \hbar\omega . \tag{48}$$

It also implies that the actual bond between the quark and the antiquark in a meson is sustained by the weak interaction boson. Hence, the spacing $2d\lambda = 2d'_{\min}$ is expected about equal to a half wave length of the weak interaction boson $\hbar\omega_W$. Hence,

$$\lambda = \frac{2(\hbar\omega_W)d'_{\min}}{\alpha\pi(\hbar c)}, \tag{49}$$

in which α is a dimensionless correction factor of order 1. From (47)-(49), we have

$$\Phi_0 = \frac{m'_m}{8gk_2}\frac{(\alpha\pi)^2}{d'^2_{\min}} . \tag{50}$$

At this point, I would like to invoke a particular relationship from previously documented work [22]. In this work it has been shown that the 2D quantum mechanical wave equation as shown in (34) can equally well be derived from Dirac's equation as commonly derived from the Einsteinean energy relationship, as well as derived from Einstein's geodesic equation. The equivalence of the two approaches applied to the anharmonic quantum mechanical oscillator has revealed the relationship (see eq.(49) of [22]),

$$\hbar\omega_W = g\Phi_0 . \tag{51}$$

Hence, from (49) and (51),

$$\frac{g\Phi_0}{\lambda} = \frac{\alpha\pi(\hbar c)}{2d'_{\min}}, \tag{52}$$

in which k_0 =1/2 and $d'_{\min}$ = 0.853 as shown in (45). This ratio holds for all quarks. It means that the strength Φ_0 as well as the range λ^{-1} of the potential field may be different for different quark flavors under invariance of the of the Φ_0/λ ratio. In the basic meson configuration, i.e. the pion, Φ_0 is fixed by the weak interaction boson cf. (52). Like shown later, λ is fixed by the Higgs boson cf. (58). Scaled mesons, such as kaons have different values for Φ_0 and λ under invariance of (52).

From (50) and (52), we have,

$$m'_m = \frac{8k_2 d'^2_{\min}}{(\alpha\pi)^2}(\frac{g\Phi_0}{\lambda})\lambda = \frac{8k_2 d'^2_{\min}}{(\alpha\pi)^2}(\frac{g\Phi_0}{\lambda})\lambda = \frac{8k_2 d'^2_{\min}}{(\alpha\pi)^2}(\frac{g\Phi_0}{\lambda})(\frac{2\hbar\omega_W}{\alpha\pi(\hbar c)}d'_{\min} . \tag{53}$$

Hence, after invoking (52),

$$m'_m = \frac{8k_2 d'^2_{\min}}{(\alpha\pi)^2}\left(\frac{g\Phi_0}{\lambda}\right)\left(\frac{2\hbar\omega_W}{\alpha\pi(\hbar c)} d'_{\min}\right) = \frac{8k_2 d'^2_{\min}}{(\alpha\pi)^2}\hbar\omega_W . \qquad (54)$$

From (54) ,(49) and (52) the dimensionless constant α_0 in the normalized wave equation (42) can be readily calculated as (43) indeed. Note that α_0 is different from α shown in (54). This unknown dimensionless constant α of order 1, introduced in (49), has been assessed as $\alpha \approx$ 0.69 in a study on the relationship between the gravitational constant and quantum physics [22]. In the next paragraph, its value will be discussed in a different context, which nevertheless will give the same result. It is tempting to suppose that m'_m is the center-of-mass equivalent of the pion's rest mass. More basically even, we should expect that $\hbar\omega_W$ is the relativistic value of the pion's rest mass energy m'_π (= 140 MeV). This expectation is based upon the view that the pion's rest mass is assessed from its decay products that result from the decay boson $\hbar\omega_W$. This view is a basic element of the theory exposed in this article. It is something not recognized in the Standard Model. Its impact will become clear later in this text. If this is true indeed, one would expect that the term in the right hand part in front of $\hbar\omega_W$ just equals 1. However, inserting $d'_{\min}$ = 0.853, k_2 = 2.36 and $\alpha =$ 0.69 gives a value 2.92. How to explain this discrepancy? The discrepancy is due to the influence of the particle spin interaction. As will be shown in paragraph 8, this influence will result in significant downward and upward corrections for, respectively, the pseudoscalar meson and the vector-type meson. In spite of these substantial corrections, the mass expression (54) is highly relevant for the calculation mass *ratios* of mesons in relation to the pion's rest mass.

This can be understood from addressing the issue about the origin of other mesons next to the archetype. It all starts by recognizing that the pion is subject to excitation because of its nature as an anharmonic oscillator structure. Like discussed in the previous paragraph, this excitation brings the pion in a state with a 3. 57 times higher energy. This particular state of energy not only corresponds with the energy of the pion in excitation, but corresponds as well with the ground state energy of a meson composed by a quark and an antiquark with different values for Φ_0 and λ under invariance of the ratio Φ_0/λ, like expressed by (52). While in this ground state the spacing between the quark and the antiquark still assumes the normalized value $2d'_{\min}$, the actual numerical value for the spacing is reduced because of the new value for λ. This process is illustrated by figure 5. It can be readily understood from the role of the curving parameter k_2 in (54). Because of its dependence on spacing, like shown in (44), the mass ratio of the new meson in ground state and the pion in ground state is determined by the ratio $k_2(d_0)/k_2(d_{\min})$, in which d_0 and $d_{\min}$ are denormalized values. Without loss of generality, this ratio can be normalized on the value of λ *in pion state* as $k_2(d'_0)/k_2(d'_{\min})$. Figure 5 shows that the energy of the pion at its first excitation level corresponds with the ground state of a new meson under shrink of the quark spacing parameter from $d'_{\min}$ = 0.853 to d'_0 = 0. 699. The new meson is the kaon. Rather than being composed by two newly created quarks, only one of the two quarks is newly created. It is the s quark. The other one still remains the u/d archetype. The asymmetrical structure still behaves as a symmetrical equivalent.

This process marks the birth of the s quark as a result of the deterministic excitation process from the pion state. Because of this determinism, the s quark, as well as the other quark flavors should not be considered as elementary ones. The lower curve in the figure is $k_0'(d')$. It represents the binding energy, which should remain negative to allow a stable bond. Hence, the light sector (u,d,s) stops after second excitation from the ground state. Let us conclude so far that figure 5 illustrates the significance of the quark scaling theorem (52) on the origin of the mass spectrum of the mesons. Showing a more complete picture of this spectrum, though, requires the inclusion of the influence of the particle spin-spin interaction, to be discussed in paragraph 9. Another issue to be discussed later is the influence of electromagnetic interactions, which have been ignored so far. As to be shown in paragraph 10, its influence on mass is of second order.

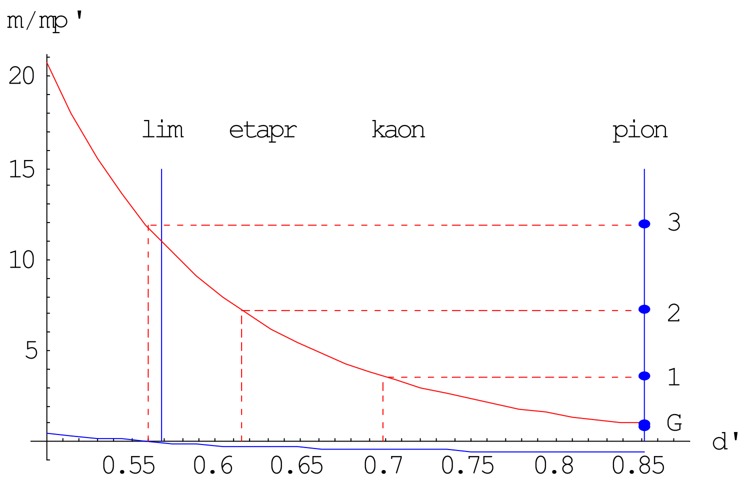

Fig. 5. The light sector limit. The graph shows the increase of the massive energy of a quark/antiquark pair relative to the pion state as a function of the quark spacing. Two excitation levels beyond the pion's ground state are converted into the ground state of, respectively, the kaon and the η', thereby producing the $(u,s)-$ quark family. Third level excitation is prevented by the loss of binding energy (lower curve).

7. The Higgs boson

In the preceding chapters it has been demonstrated that the meson's mass spectrum can be explained from the quark's far field as defined in (39), supplemented by a near field from a dipole moment. The far field is a scalar field obtained from the steady state solution of a Proca-type wave equation with the format

$$\frac{1}{c^2}\frac{\partial^2 r\Phi}{\partial t^2}-\frac{\partial^2}{\partial r^2}r\Phi+\lambda^2 r\Phi=\rho_H(r,t)\,, \tag{55}$$

in which $\rho_H(r,t)$ is a Dirac-type pointlike source that can be expressed as,

$$\rho_H(r,t)=4\pi\frac{\Phi_0}{\lambda}\delta^3(r)H(t)\,, \tag{56}$$

in which $H(t)$ is Heaviside's step function. Its solution is given by [23],

$$r\Phi(r,t) \leftrightarrow \frac{\Phi_0}{\lambda}\frac{1}{s}\exp[-(\lambda r\sqrt{s^2/(\lambda c)^2+1})]. \quad (57)$$

If, under violence of particle collisions, the equilibrium between the quarks is broken, the far field bosons will show up in decay channels of boson pairs, which will manifest themselves into a decay path of fermions. Momenta and energies of these fermions can be measured and can be traced back to numerical values for the energy of a nuclear boson pair. So, ultimately, the far field will show up as two quantum fields. The massive energy of the far field part, if interpreted as a single Higgs boson, would therefore be assigned as,

$$m'_H \approx 2\lambda(\hbar c). \quad (58)$$

Subsequent application of (49) on this gives,

$$m'_H = \frac{4d'_{\min} m'_W}{\alpha\pi} \rightarrow \alpha = \frac{4d'_{\min}}{\pi}\frac{m'_W}{m'_H}, \quad (59)$$

which, under consideration of m'_W = 80.4 GeV and m'_H = 127 GeV for the Higgs boson just gives $\alpha \approx$ 0.69 quoted before. Or stated otherwise, accepting the value $\alpha \approx$ 0.69 as a result obtained from theory**,** the Higgs boson mass has a theoretical root. Note that (58) is in agreement with the Standard Model value m'_H of the Higgs boson in natural units documented in [1], defined as,

$$m'_H = \mu_H\sqrt{2}. \quad (60)$$

Under consideration of (37), and inserting the natural units, the correspondence with (58) is readily found. However, whereas the Standard Model considers the Higgs boson as a single boson with an empirical elementary value, the Higgs boson is a signature of a two boson channel. Later in this article, the two bosons will be identified as gluons. See paragraph 14.

8. The Z boson and its impact on the meson's mass spectrum

Like demonstrated in paragraph 6, the simple anharmonic oscillator model described by (40-42) enables the mass spectrum calculation of the pseudoscalar mesons as excitations from the pion state. The mass spectrum calculation of the vector mesons requires the inclusion of the impact of the particle spin shown in the upper part of figure 2. A spin flip marks the difference between the pseudoscalar pion and the vector type sisters rho. The massive energy difference ΔE between the two types is a consequence of a spin-spin interaction process. It is of a similar nature as the analysis of the interaction process between the spin of electron and the spin of the proton nucleus in a hydrogen atom. This requires a detailed quantum mechanical computation including recoiling. More on this can be found in [24]. Recognizing, though, that this is essentially a bosonic process, allows, in retrospect, a surprising simple approach. The step to be taken is conceiving the massive energy difference ΔE as a result of a bosonic interaction, mediated by Z bosons in virtual state. Because of the asymmetry in the spin-spin interaction ($-3\hbar^2/4$ and $+\hbar^2/4$), we have,

$$m'_\pi = 2m'_u - 3m''_Z \text{ and } m'_\rho = 2m'_u + m''_Z, \tag{61}$$

in which m'_π, m'_ρ, m'_u and m''_Z are the energies of, respectively, the rest masses of pion and the rho meson, the constituent massive energy of the u/d quark and the energy of the Z boson *in virtual state* in the rest frame of mesons. The statement that the energy of the rest mass of the pion is equal to the non-relativistic equivalent of the energy of the W boson enables to calculate the energy m''_Z of the Z boson in virtual state as,

$$m''_Z = m'_Z(\frac{m'_\pi}{m'_W}). \tag{62}$$

Under use of (61) and (62), the constituent rest mass energy m'_u of the u/d quark is calculated as

$$m'_u = \frac{1}{2}m'_\pi(1+3\frac{m'_Z}{m'_W}). \tag{63}$$

From (63) the energy of the constituent mass of the u/d quark is, under consideration of the energetic values of the weak interaction bosons m'_W = 80.4 GeV and m'_Z = 91.2 GeV, under adoption of the rest mass of the pion $m_\pi \approx$ 140 MeV/c^2, calculated as 308 MeV. Under use of this value, the energy of the rho meson is calculated from (61) and (62) as m'_ρ = 775 MeV. This is a perfect fit with experimental evidence!

We may go a step further by invoking the mass relationships due to the particle spin interactions as derived in Griffith's textbook in conjunction with the theoretically established ratio 3.57 of the kaon mass over the pion mass, listed in TableIV . The constituent mass value for the s quark is calculated from,

$$m'_\kappa = m'_u + m'_S - 3\frac{m'^2_u}{m'_u m'_s}m''_Z = 3.57m'_\pi \rightarrow m'_s = \text{489 MeV}. \tag{64}$$

The calculated values of the charmed quark (c) and the bottom quark (b) can be found in [24]. As noted before, the top quark (t) is out of scale. As to be discussed in paragraph 15, this is due to its different origin.

Unifying the boson process associated with the particle spin-spin interaction as mediated by the Z bosons with the boson process associated with the quark-scaling mechanism mediated by the W bosons allows an interpretation of the meson's mass spectrum in the light sector as shown in figure 6. The $(\pi, K, \eta*)$ curve is the result the quark-scaling mechanism as shown before in figure 5. The mass dots on the vertical axes represent, respectively, the constituent mass sums $2m'_u$, $m'_u + m'_s$ and $2m'_s$. The horizontal dotted line at a level zero on the vertical axis E splits the energy level in a part with negative energy and a part with positive energy. The negative energy is the binding energy between the quarks. The ground state energy of the pion (π) is just slightly positive. The mass ratio between the quarks is shown along the vertical axis "mass'. The reference value is the lower horizontal axis. It is tempting to suppose that the η^* meson is the pseudoscalar version of the vector-type φ. In fact, it is not, because the Pauli constraint on isospin prohibits a pseudoscalar $s\bar{s}$ meson. As discussed before, the η^* meson shows up as a consequence of the meson's anharmonic excitation process. In the empirically conceived classification of "The Eightfold Way", there is no obvious place for it. It means that in the Standard Model of particle physics the existence of the η^* meson has no simple explanation [25].

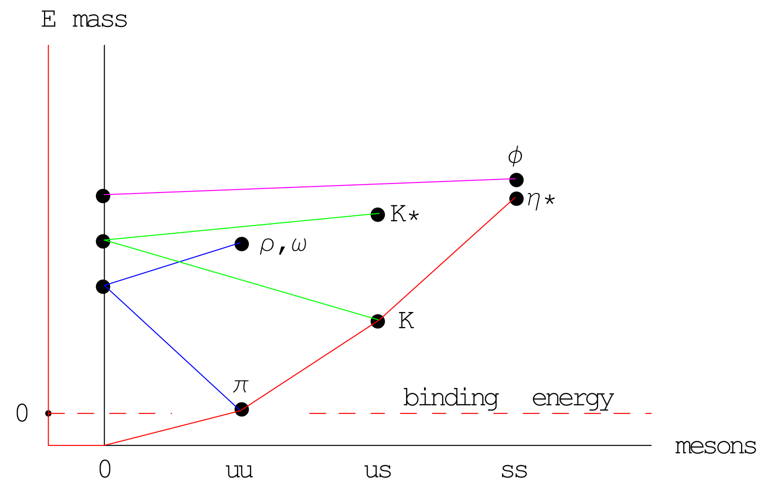

Figure 6. Illustration of the excitation mechanism of mesons and the scaling mechanism of quarks in the light sector.

We have seen before that third level excitation from the pion state is prevented by the loss of binding energy. This has been the reason that excitation is continued by a different process, i.e., by bootstrapping as $s\bar{s} \to c\bar{c} \to b\bar{b}$. Meson scaling, however, is only possible as long as the energy won by excitation is larger than the loss in binding energy. Figure 7 shows that this may come to an end. If the spacing between stressed quarks in the basic mode becomes too small, energy won by excitation cannot longer compensate the loss in binding energy. This will happen for $d' < d'_0$, where d'_0 is defined by

$$E'_{bind}(d'_0) - E'_1(d'_0) = 0 .$$

Calculation from (42) – (44), illustrated in figure 7, shows that this happens to be for $d'_0 \leq$ 0.39.

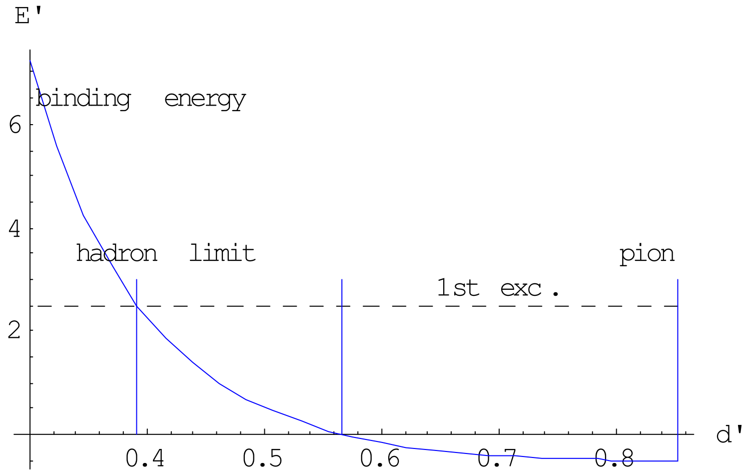

Figure 7. The hadronization limit. Bootstrapping stops as soon as the energy gained by excitation (represented by the dotted line) is not sufficient to compensate the loss in binding energy (represented by the curve showing the binding energy as a function of the quark spacing).

A more extensive analysis of this phenomenon has been documented in previous work [24].

All this means that the constituent masses of the quarks can be theoretically derived, next to the energy values of the weak interaction bosons from a single reference for which we have adopted the rest mass of the archetype meson. In principle even better than this, because the relationship between energies of the W and Z can be derived by theory as well, like shown in [24]. It implies anyhow that there is no reason to consider the quark flavors as elementary. Note the difference with the calculation in Griffiths' textbook, which is purely empirically based and denoted as "shaky", but nevertheless rather accurate. It has to be taken into account, though, that the constituent massive energies of the quark flavors are somewhat artificial, because they represent the harmonic oscillator energy distributed over the quarks. For that reason the constituent quark energies in baryons are different from those in mesons. In the present state of theory the masses of hadrons are calculated by lattice QCD [26]. Different from using the rest mass of the pion as input reference, the bare masses of the quarks are used as reference. The value of these bare masses, however, are "tuned from the masses of mesons" [26]. It is fair to conclude that the quark model based upon the polarisable dipole moment of Dirac's third particle and its application in the excitation model of hadrons shows undeniable intriguing relationships between the mass values of the quark flavors and the weak interaction bosons. It enables to calculate the mass spectrum of hadrons with great precision [24,27].

9. Relationship with the Standard Model

The given description of the bond between the u quark and the d quark has revealed the existence of two different binding forces that each can be modeled in terms of force interacting particles. The interacting force due to the polarisable dipole moment of a quark in a scalar potential field has been identified as the W boson and the interaction force due to the particle spin interaction has been identified as the Z boson. Let us now take a more abstract point of view, in which no knowledge is available about the actual physical mechanism of the nuclear force. This brings us to the basic question in particle physics, which, in words, is the simple one: how to describe the field of a quark in an ambient field of nuclear forces? The recipe is trying to find a covariant equivalent for the quark's field in an ambient field from the quark's field in free space. Because in the context of the Standard Model the quark has not been recognized as polarisable in a scalar field , physical knowledge of the nuclear forces could not been taken into account. While for electromagnetic interactions the gauge needed for covariance could be understood from a physical mechanism, the gauge for nuclear interactions had to be conceived from an abstract point of view. Its description might reveal the relationship between the structural view developed in this article with the gauge based view adopted in the Standard Model. This is the issue to be discussed in this paragraph. It touches the crux of the article, in which the view is taken that the SU(2) and SU(3) gauges, if interpreted properly, have a physical structural basis of a similar kind as the physical structural basis of the U(1) gauge.

The interaction model between two quarks shown in the preceding paragraph is based upon *spatial* field descriptions. Such spatial descriptions are uncommon in the canonic field descriptions of the Standard model, in which fields are exclusively described in *functional* field parameters. It is instructive viewing the field of a nuclear particle as the mapping of its momenta p_μ on the amplitudes Ψ_μ of the four components of the solution of Dirac's equation, i.e., as

$$\{p_0, p_1, p_2, p_3\} \to \{\Psi_0, \Psi_1 \Psi_2, \Psi_3\}.$$

This mapping is visualized in figure 8 for 1+2 dimensionality.

The left hand part is a geometric interpretation of the determinant condition (19),

$$W^2 = (m_0 c^2)^2 - c^2 |\mathbf{p}|^2 , \tag{65}$$

in which $\mathbf{p}$ is the three-vector momentum ($\mathrm{d}s/\mathrm{d}t$, not be confused with the fourvector momentum $\boldsymbol{p}$). It can be normalized as,

$$p_0'^2 + p_1'^2 + p_2'^2 + p_3'^2 = 1; \; p_i' = \frac{p_i}{m_0 c}; \; p_0' = \frac{W}{m_0 c^2} . \tag{66}$$

This allows representing the momentum space of a moving particle in free space as a sphere with unit radius.

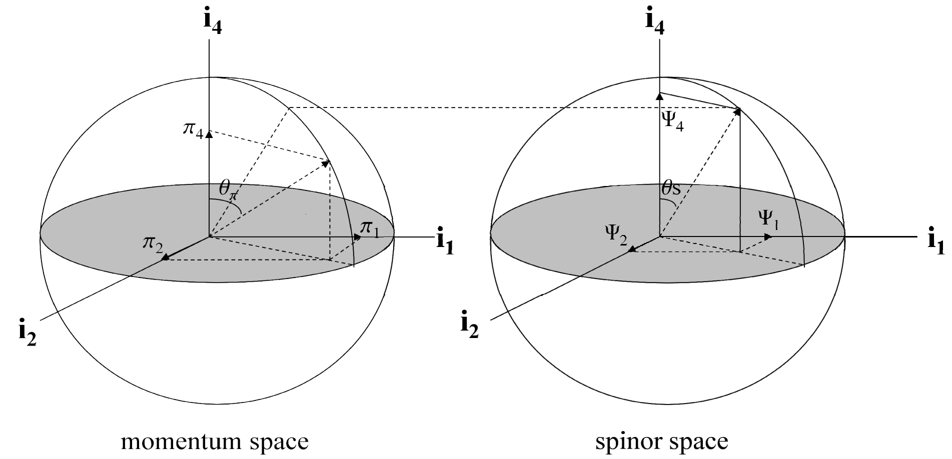

Fig. 8. A visual interpretation of the mapping of the particle's momenta into amplitudes of Dirac's wave function solution. Be aware that this mapping is not 1 to 1.

The right-hand part is a geometric interpretation of the absolute values of the amplitudes Ψ_μ of the four components of the solution of Dirac's equation. The amplitudes themselves are complex quantities. As a consequence of the semantics of the particle's wave function, these amplitudes can be represented as orthogonal vectors in a unit sphere. Note that this mapping is not one-to-one. In momentum space, the angle ϑ_π between the temporal momentum p_0 and the vector sum of the spatial momenta p_i is a global invariant. As long as the particle's energy is not changed by a field of force, the angle remains the same. In spinor space, there is a characteristic angle ϑ_s between the component Ψ_0 associated with the temporal momentum and the vector sum of the components Ψ_i associated with the spatial momenta. Although the mapping is not one-to one, the angle ϑ_s is globally invariant. Under influence of forces on the momenta, the angle ϑ_π will change, while the radius of the momentum space will remain the same owing to the normalization. The angle in the spinor space will change as well and the radius of the spinor space will remain the same because of the wave function semantics. These angles play a role in the modification of Dirac's free space equation into a covariant one. By definition, the covariant equation, valid for particles moving in a field of forces, has the same format as the free space equation after redefining the normal differential operators into covariant ones, i.e. $\partial_\mu \to D_\mu$. The prescription how to do it, is the modification of a global invariant quantity into a local invariant one. By modifying the global invariance of the Lorentz transform into a local invariant one, Einstein has been able to derive the transformation rule for the covariant derivatives that modified his equations of Special Relativity in free space into covariant equivalents for his equations of General Relativity. Paul Dirac's prescription for making his equation (1) covariant in a conservative field of forces $\boldsymbol{A}(A_0, \mathbf{A})$,

$$p'_\mu \to p'_\mu + gA'_\mu \quad \text{and} \quad p'_\mu \to \hat{p}_\mu \psi + gA'_\mu \psi \, ; \; \hat{p}'_\mu = \frac{1}{m_0 c}\frac{\hbar}{\mathrm{i}}\frac{\partial}{\partial x_\mu}, \tag{67}$$

can be interpreted as the modification of the global invariance of ϑ_π and ϑ_s into local invariant ones, because (67) represents, as we shall see below, just infinitesimal rotations in, respectively, momentum space and spinor space. Effectively, these rotations takes place in 2D space, as long as a single particle is involved.

It is instructive to consider the particle's antiparticle in this picture. Let us compare the amplitudes of the spinor components of the particle with the ones of the antiparticle. Like shown, for instance on page 220 of Griffith's textbook [1] from the solution of Dirac's equation in free space. It is instructive to split these components into two parts, namely into a sum Ψ_{is} of amplitudes related with the spatial momenta and the amplitude component Ψ_{it} related with the temporal momentum. This allows to represent the particle-antiparticle bond as a 2 x 2 matrix Ψ_{pa},

$$\Psi_{pa} = \begin{bmatrix} \Psi_{1t} & \Psi_{1s} \\ \Psi_{2t} & \Psi_{2s} \end{bmatrix}. \tag{68}$$

This matrix has the following properties,

$$\Psi_{1t}\Psi_{1t}^* + \Psi_{1s}\Psi_{1s}^* = 1;\ \Psi_{2t}\Psi_{2t}^* + \Psi_{2s}\Psi_{2s}^* = 1;\ \Psi_{2s} = \Psi_{1t}^* \text{ and } \Psi_{2t} = \Psi_{1s}^*. \tag{69}$$

Because of this relationship, the matrix (68) is unitary, i.e.

$$\Psi_{pa}\Psi_{pa}^T = 1, \tag{70}$$

in which Ψ_{pa}^T is the transpose conjugate of Ψ_{pa}. Note that the elements of Ψ_{pa} are complex numbers.

These properties allow to consider mesons as an SU(2) Lie group. This conclusion allows the development of an interesting mathematical view on the bond between the quark and the antiquark in mesons. As an equivalent alternative to the structural bond discussed before. Note that the elements of Ψ_{pa} are complex numbers.

A complex *n x n* matrix has $2n^2$ real parameters. The unitary condition on the rows removes n^2 of these and an additional one is removed by the constraint of unit determinant. That leaves 3 degrees of freedom for the SU(2) operator. The matrix (68) can then be generically represented as,

$$\begin{bmatrix} e^{i\beta}\cos\alpha & e^{i\gamma}\sin\alpha \\ -e^{-i\gamma}\sin\alpha & e^{-i\beta}\cos\alpha \end{bmatrix}. \tag{71}$$

Obviously, this matrix is unitary, thereby meeting the constraints as imposed by (69). Lie-group theory states that any matrix multiplication with the generic SU(2) format as defined

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in (71) leaves the object in the group. Hence, the transformation that maintains the desired property of Lagrangian equivalence for $\Psi_{pa} = \Psi$ is given by

$$\Psi \rightarrow \Psi \exp(\mathrm{i}\overline{\sigma}\overline{\vartheta}) \text{ with } \overline{\vartheta} = \overline{\vartheta}(\vartheta_1, \vartheta_2, \vartheta_3) \text{ and } \overline{\sigma} = \overline{\sigma}(\sigma_1, \sigma_2, \sigma_3), \tag{72}$$

as long as the matrices $\overline{\sigma} = \overline{\sigma}(\sigma_1, \sigma_2, \sigma_3)$ match with (70). The most simple ones are the three Pauli matrices,

$$\sigma_1 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix};\ \sigma_2 = \begin{bmatrix} 0 & -\mathrm{i} \\ \mathrm{i} & 0 \end{bmatrix};\ \sigma_3 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}. \tag{73}$$

From (72) should follow $D_\mu \Psi \rightarrow D_\mu \Psi \exp(\mathrm{i}\overline{\sigma}\overline{\vartheta})$. This is true if

$$D_\mu \Psi = \partial_\mu \Psi - \mathrm{i}\Psi \partial_\mu (\overline{\sigma}\overline{\vartheta}). \tag{74}$$

By identifying

$$\overline{\sigma}\overline{\vartheta} = \sigma_k \vartheta^k = g_W \sigma_k W^k, \tag{75}$$

in which g_W is a generic dimensionless coupling factor,

we get,

$$D_\mu \Psi = (\partial_\mu - \mathrm{i} g_W \sigma_k W_\mu^k)\Psi; \quad k = 1,2,3. \tag{76}$$

Note: the subscript in g_W has been added for distinction from the coupling factor g introduced in (28) in a somewhat different context.

Because $\sigma_k W_k$ are operations in the field domain with a complex number type, W_k cannot be identified as mappings of real valued momenta. Hence, it makes sense to redefine,

$$W_1^+ = W_1 + \mathrm{i}W_2;\ W_1^- = W_1 - \mathrm{i}W_2;\ W^0 = W_3. \tag{77}$$

From (76) and (77),

$$D_\mu \Psi = \{\partial_\mu - \mathrm{i} g_W (\tau_1 W_\mu^+ + \tau_2 W_\mu^- + \tau_0 W_\mu^0)\}\Psi, \tag{78}$$

in which τ_k now are real valued matrices,

$$\tau_1 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix};\ \tau_2 = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix};\ \tau_0 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}. \tag{79}$$

Note that as yet the $+$ sign and the $-$ sign have no electrical meaning here. Note that this covariant derivative derived from SU(2) perspective contains the Pauli elements of Dirac's equation as represented by (1). It includes the influence of the angular momentum. However, particular properties of the field of forces that necessitates a covariant derivative are not yet taken into account. The relevancy within the context of this article is that the recognition of the full-dimensionality of Dirac's equation (which includes the spin phenomenon) in a bond of SU(2) particles reveals the existence of three interaction forces or, equivalently, the existence of interaction bosons in three modalities. It will be clear that apart from this conclusion, more is needed for proving the viability of a stable bond of SU(2) constituents. So, the next question to be addressed is: "what are the characteristics of the energetic background field that guarantees such a stable bond?". The answer is a simple one: its Lagrangian density should remain locally invariant under substitution of a covariant derivative as specified by (76). One may expect that this condition will require certain properties of the interaction bosons ($W_\mu^+, W_\mu^-, W_\mu^0$). This gives the recipe for defining a covariant derivative, formally dubbed as gauge, in Dirac-type wave equations of particle bonds. The gauge for particle bonds with a wave function (= field) that is subject to the unitary constraint, has been originally generically formulated by Yang and Mills [28].

Whereas the recipe for finding the answer to the problem is clear, finding the solution itself of is not a piece of cake. The GWS (Glashow, Weinberg, Salam) electroweak theory [29,30,31] has given the answer. Not surprisingly, the nuclear background energy field has the format of the Higgs field, such as introduced by (33). Under the influence of such a field, the bosons shown in (77), which are mass less in free space, gain mass. The proof for this can be found in many textbooks and tutorials. Whereas the mass of the bosons W_μ^+ and W_μ^- is the same, the mass of the third boson is different, because in the GWS theory it evolves from a mix of contributions from the nuclear field and the electromagnetic field. It makes the neutral Z boson. Omitting the influence of the electromagnetic field in the GWS theory would make the mass of the Z boson the same as those of W_μ^+ and W_μ^-, which is in conflict with experimental evidence. Inspection of (76) however, makes clear that there is no reason why the coupling factor g_W should be necessarily equal for all three bosons. Accepting this theoretical option would identify the W_μ^0 as a Z boson without being mixed up with electromagnetic energy, while still having a mass different from the W bosons. (Note that in the structural view the Z boson has shown up as the energy carrier of the interaction force between the nuclear spins, while the W bosons have shown up as the carriers of the sustaining energy of the bond between the quark and the antiquark.).

Let us continue by adopting a difference between W_μ^+ and W_μ^- on the one hand and W_μ^0 on the other hand, while leaving the origin of this difference for an issue to be discussed later. A convenient starting point is the pion spinor representation as shown by (68). This spinor can be conceived as an SU(2) doublet Φ of two complex fields, symbolically represented as,

$$\Phi = \begin{bmatrix} \Phi^+ \\ \Phi^0 \end{bmatrix}; \quad \Phi^+ = \frac{\varphi_1 + \mathrm{i}\varphi_2}{\sqrt{2}}; \; \Phi^0 = \frac{\varphi_3 + \mathrm{i}\varphi_4}{\sqrt{2}}. \tag{80}$$

This field doublet is exposed to an energetic ambient field, thereby composing an energy density with the Lagrangian,

$$\mathcal{L} = (\partial_\mu \Phi)^\dagger (\partial^\mu \Phi) + V(\Phi),$$

in which $V(\Phi)$ is the potential of the energetic ambient field. In the SU(2) GWS theory this ambient field has been defined *by axiom* as a broken field, known as the Higgs field, defined by

$$V(\Phi) = \frac{\mu_H^2}{2}\Phi^\dagger\Phi - \frac{\lambda_H^2}{4}(\Phi^\dagger\Phi)^2, \tag{81}$$

in which,

$$\Phi^\dagger\Phi = \begin{bmatrix}\Phi^{+\bullet} & \Phi^{0\bullet}\end{bmatrix}\begin{bmatrix}\Phi^+ \\ \Phi^0\end{bmatrix} = \Phi^{+\bullet}\Phi^+ + \Phi^{0\bullet}\Phi^0 = \frac{\varphi_1^2 + \varphi_2^2 + \varphi_3^2 + \varphi_4^2}{2}. \tag{82}$$

Deriving a wave function from this Lagrangian requires a proper format for a covariant derivative. The suitable one is the one as defined before in (78),

$$D_\mu \varphi_\nu = \{\partial_\mu - ig_W(\tau_1 W_\mu^+ + \tau_2 W_\mu^-) + ig_Z \tau_0 W_\mu^0\}\varphi_\mu. \tag{83}$$

Note: in most texts on GWS the (unknown) coupling factors g_W and g_Z are written as $g/2$ and $g'/2$. As noted by Klauber [32], this is just by convention, because the factor $1/2$ is sometimes omitted as well.

Note: whereas at this point a physical motivation for the conception of the SU(2) doublet of two complex fields is given from the pion spinor, such a motivation is lacking in most, if not all, texts on the GWS theory.

The potential $V(\Phi)$ is minimum at Φ_0, found from (82) by differentiation and equating to zero as,

$$\Phi^T\Phi = \frac{\mu_H^2}{\lambda_H^2} = \frac{\Phi_0^2}{2} \to \Phi_0 = \frac{\mu_H}{\lambda_H}\sqrt{2}, \tag{84}$$

corresponding to the vacuum expectation value indentified in (33). By substituting the covariant derivative (83) into the field Lagrangian (81), one may try to obtain field expressions in terms of φ, but, like shown in the GWS theory, it is more effective trying to obtain field expressions in terms of variations around the vacuum expectation value (84). How to do so, can be found in many texts [1,32]. Replacing the normal derivatives in the field Lagrangian (81) by the covariant ones as defined in (83) and subsequent elaboration of the fields as variations around the field minimum of the Higgs field (known as the vacuum

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expectation value), produces new fields in which the bosons $W_\mu^\pm$ and $W_\mu^0 = Z_\mu$ have gained mass, such that

$$m'_W = g_W \Phi_0 \,; \quad m'_Z = g_Z \Phi_0 \,. \tag{85}$$

Next to these boson masses, an additional boson is produced, known as the Higgs boson, which is considered as being the carrier of the background field, to the amount of,

$$m'_H = \mu_H \sqrt{2}. \tag{86}$$

Note that λ_H is dimensionless, while μ_H has the dimension of energy. For m'_W and m'_H, it are the same expressions as previously shown in (52), respectively in (58). While in the context of the GWS theory the assessment of the mass ratio $m_Z / m_W (= g_W / g_Z)$ requires an numerical value for m_Z from empirical evidence, this value for m_Z can be found in the structural model by theory from (61). Something similar holds for the Higgs boson. Rather than from straight empirical evidence, it can be found in the structural model from the relationship between m'_W and m'_H as shown by Eqs. (58-59). Note that these results do not reveal numerical values for the coupling constants g_W and g_Z, nor for the vacuum expectation value Φ_0. The numerical values are related to m'_W as the reference. So far, we have only included the effect of the Z boson as the third weak interaction gauge boson in the covariant derivative while potentially still leaving electromagnetism as a second order add-on effect. So far, it has been shown that the structural view developed in the previous paragraphs is not in contradict with the more abstract gauge view as developed in this paragraph. More on the correspondences and differences will be discussed in paragraph 11.

In the full GWS theory, electromagnetism is made an integral part of it. It is done by unifying electromagnetism with the weak interaction on a theoretical fundament. This will be the subject of the next paragraph.

10. Electroweak unification

Making electromagnetism as an integral part of the SU(2) GWS theory has been achieved by Weinberg by adapting the covariant derivative (83) into

$$D_\mu \varphi_\nu = \{\partial_\mu - ig_W(\tau_1 W_\mu^+ + \tau_2 W_\mu^- + \tau_0 W_\mu^0) - ig_e B_\mu\}\varphi_\mu \,. \tag{87}$$

As compared to the "naked" format shown in (83), the adapted format (87) contains an additional boson field to account for the electromagnetism that shows up in the SU(2) doublet field. Without an additional mechanism there is no reason why this additional boson field would not gain mass as a result of the same mechanism as the W bosons do. The only way to prevent this, is conceiving a preventing mechanism, be it an artificial one or a physically viable one. The hypothesis that such a mechanism exists became a corner stone in the GWS theory. From the straightforward covariant derivative (87), Weinberg constructed a modified one by hypothesizing a mechanism that mixes the (mass less) boson fields W_μ^0 and B_μ into two other (mass less) bosons fields A_μ and Z_μ such that,

$$\begin{bmatrix} A_\mu \\ Z_\mu \end{bmatrix} = \begin{bmatrix} \cos\vartheta_W & \sin\vartheta_W \\ -\sin\vartheta_W & \cos\vartheta_W \end{bmatrix} \begin{bmatrix} B_\mu \\ W_\mu^0 \end{bmatrix}, \tag{88}$$

which is equivalent with

$$\begin{aligned} A_\mu &= B_\mu \cos\vartheta_W + W_\mu^0 \sin\vartheta_W \\ Z_\mu &= -B_\mu \sin\vartheta_W + W_\mu^0 \cos\vartheta_W \ . \end{aligned} \tag{89}$$

Multiplying the upper equation with $\sin\vartheta_W$, the lower one with $\cos\vartheta_W$ and addition gives W_μ. Multiplying the upper one $\cos\vartheta_W$ etc., gives B_μ. Hence,

$$W_\mu^0 = Z_\mu \cos\vartheta_W + A_\mu \sin\vartheta_W \quad \text{and} \quad B_\mu = -Z_\mu \sin\vartheta_W + A_\mu \cos\vartheta_W . \tag{90}$$

The two are substituted in the covariant derivative (87), which is, as before, subsequently evaluated around the Higgs field minimum. It then appears that, if the Weinberg angle ϑ_W has a suitable value, the mass less boson field Z_μ gains mass, while the mass less boson field A_μ remains mass less. In this condition the mass ratio m'_W / m'_Z happens to be,

$$\frac{m'_W}{m'_Z} = \cos\vartheta_W \ . \tag{91}$$

The discovery of neutral bosons m'_Z (≈91.2 GeV) with a different mass value from charged bosons m'_W (≈80.4 GeV) is considered as the viability proof of the GWS theory. This in spite of the inability to assess a numerical value for ϑ_W by theory. It confirms Weinberg's hypothesis that an SU(2) field, like the pion's one, contains a particular physical mechanism that creates electromagnetism. Strictly spoken, the discovery shows that the third expected weak interaction boson is different in its charge transferring capabilities and has a somewhat different energy from the symmetrical weak interaction pair. As discussed before, the third weak interaction boson should show up anyhow. Mixing it up with electromagnetism is an artificial construct. The bare fact that the GWS theory has predicted a third interaction boson and the experimental evidence of a third one does not necessarily prove the correctness of the GWS theory, because without electroweak unification the gauge approach predicts a third weak interaction boson anyway. We have seen before in this text that another mechanism, like the origin of electric charge from isospin predicts a third gauge boson as well.

Let us proceed by addressing the issue whether the GWS theory proves the charge split over u and d quarks. This can be done by inspecting the influence of the created A_μ field. on the covariant derivative (87). Hence, let us evaluate (87) under consideration of (90), thereby omitting non-A_μ containing terms for simplicity reason. Doing so, we have from (87) and (90),

$$D_\mu \varphi = \{\partial_\mu \text{ - ig}_W \tau_0 W_\mu^0 - \text{ig}_e B_\mu) + \text{.........}\}\varphi =$$
$$\{\partial_\mu \text{ - ig}_W \tau_0 (Z_\mu \cos\vartheta_W + A_\mu \sin\vartheta_W) - \text{ig}_e(-Z_\mu \sin\vartheta_W + A_\mu \cos\vartheta_W) + \text{.......}\}\varphi \rightarrow \quad (92)$$
$$D_\mu \varphi = \{\partial_\mu - \text{i}(g_w \tau_0 + g_e \frac{\cos\vartheta_W}{\sin\vartheta_w}) A_\mu \sin\theta_W + \text{.....}\}\varphi.$$

This can be written as,

$$D_\mu \varphi = (\partial_\mu - \text{i}q_{\text{u,d}} A_\mu + \text{....})\varphi, \quad (93)$$

in which

$$q_{u,d} = (\pm I_z + \frac{Y}{2})(2g_w \sin\vartheta_W) \quad \text{with} \quad I_z = \frac{\tau_0}{2}; Y = \frac{g_e}{g_W}\frac{\cos\vartheta_w}{2\sin\vartheta_W}. \quad (94)$$

Because of the eigen value $\tau = 1$, we have conveniently,

$$g_W = \frac{e}{2\sin\vartheta_W}; \quad Y = 1 = \frac{g_e}{g_W}\frac{\cos\vartheta_w}{2\sin\vartheta_W} \rightarrow \frac{g_W}{g_e} = \frac{2\sin\vartheta_W}{\cos\vartheta_W}, \quad (95)$$

This relationship is graphically illustrated in figure 9. The expression (94a) for the charge of the $SU(2)$ bond has been shown in Table I as an expression for the charge of the composing quarks with dedicated values for I_z and Y. It has to be noted, though, that the GWS theory produces a holistic result for the quark-antiquark bond (= a doublet). That means that the assignment $Y = 1/3$ to u and d quarks is arbitrary, because its influence disappears in the junction of a quark and an antiquark. Considering that the bias Y is a holistic property of the composite particle, there is no particular need to assign asymmetrical charges to the composing quarks. This view is reflected Table VII. It means that the GWS theory does not exclude a symmetrical charge distribution over u and d quarks.

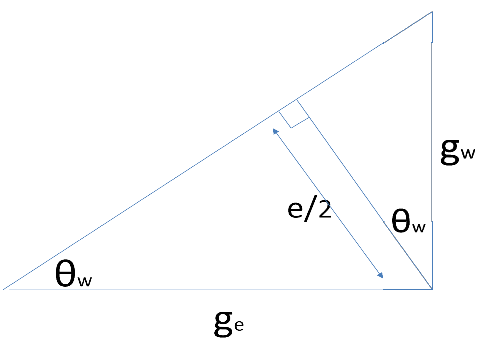

Fig.9. Graphical picture of the Weinberg angle.

Table VII

Fermions	u	$\bar{d}$
S- spin	1/2	1/2
m_0-mass	?	?
I_Z -weak isospin charge	1/2	1/2
Y-hypercharge	Y	$-Y$
Q	$(\pm I_z + Y)e$	$(\pm I_z - Y)e$
$Q_{u\bar{d}} = Q_u + Q_{\bar{d}} = \pm 2I_z$	$\pm e,0$	

Let us now address the issue whether the GWS theory may predict or show properties that the structural model cannot do. An intriguing question is the one about the elementary nature of the W and Z bosons. Within the context of the GWS theory they are elementary. It means that their energies have to be assessed empirically from experiments. Let us give this issue a closer inspection. The substitution of the covariant derivative (93) into (81) and subsequent evaluation reveals relationships between the parameters μ_H and λ_H of the Higgs field and the energies of the the $W^{+/-}$ bosons and the Z boson. By convention the weak interaction boson m'_W is related by coupling factor g with the vacuum expectation value Φ_0, such that

$$m'_W = g\Phi_0. \tag{96}$$

This is just the same as the relationship (51) derived in the structural model. Note that the adoption of m'_W as an elementary quantity gives freedom to different choices of g and Φ_0 under the constraint of a fixed value for the product. In the structural model, the coupling factor g has been related by convention with the electromagnetic fine structure constant as $g = 1/\sqrt{137}$, thereby deriving the magnitude of vacuum expectation value. In the GWS theory the vacuum expectation value has been related by convention with Fermi's constant G_F such that $\Phi_0^2 = (G_F\sqrt{2})^{-1}$ = (246 GeV)^2. This makes a coupling factor g = 80.4/246 = 0.326.

The substitution of the covariant derivative (93) into (81) and subsequent evaluation to reveal the relationships between the boson energies and the parameters μ_H and λ_H can be found in textbooks [32,33]. It gives the final result,

$$m'_H = \mu_H\sqrt{2}\,;\;\; m'_W = g\Phi_0\,;\;\; m'_Z = m'_W/\cos\vartheta_W\,,$$

$$\text{with } \Phi_0 = \frac{\mu_H}{\lambda_H}\sqrt{2}\,. \tag{97}$$

It leaves the energy values of the Higgs boson and the weak interaction bosons as elementary values without a means to relate them numerically. This is different from the

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structural model, in which these numerical relationships could be assessed by choosing a single one as a reference.

It has to be emphasized now that, whereas in the GWS theory the origin of the Z boson is related with electromagnetism, it shows up in the structural model as a consequence of particle spin interaction. In the structural model, the origin of electric charge is related with the physical nature of isospin. Rather than incorporating the effect of electric charge in a covariant derivative, its influence is accounted for in the interaction force between the quarks, under a slight modification of the far field. How to do so can be found in previous work [27], including its numerical impact. It has to be noted, though, that this electric interaction causes slight shifts on the energetic state of the quarks. This is the reason why, like stated before, the origin of the charged Δ baryons don't need a justification from an additional attribute like color charge.

11. Comparison of Weinberg's model with the structural model

Weinberg's model consists of a Lagrangian density composed by a doublet of two complex fields and a particularly shaped potential field (the Higgs field). From this density, a wave function for the two fields can be derived as the solution of a wave equation described in terms of covariant derivatives These covariant derivatives are composed as normal derivatives extended by gauge fields associated with a coupling factor. The substitution of these covariant derivatives in the Lagrangian density and subsequent evaluation reveals the properties of the gauge fields in terms of bosonic masses as dependencies of the Higgs field potential.

This model evokes a number of questions that are not discussed in textbooks. The first question is: What is the rationale behind the composition of Weinberg's Lagrangian density? More specifically: Why adopting a doublet of two complex fields, i.e., why two, why complex and why are the two fields intimately connected as an SU(2) group? The second question is: Why is this doublet subject to a potential field and why has this field the format of the Higgs field? The success of this model by experimental evidence, exposed by a pair of massive charged weak interaction bosons and one neutral one, is usually considered as proof enough, without a need for further explanation.

The structural model as introduced in this article, though, may give an answer to those otiose (?) questions. Obviously, the two complex fields in the Weinberg Lagrangian are (fermionic) fields of particles. Because these fields compose a doublet, the two particles are intimately connected. Such an intimately connected pair of particles is shown in the structural model of figure 2. The Weinberg model states that the two particles are subject to the same energy field. Where does this field comes from? The obvious answer is that the field experienced by one of the two particles is the energy field of the other particle. A remaining problem is how to explain the shape of the energy field. In the structural model, this energy field has three components that explains its particular format. It is a classical monopole field associated with a dipole field, both shielded by a polarisable ambient background field. This explanation requires to distinguish the fermionic fields of the two particles from their potential fields. The description of the particle's fermionic field as a complex field is a model for its actual nature as a Dirac spinor. The two components of the complex field can be viewed as the two components of the Dirac spinor split up in a temporal related part and a spatial related part (discussed in paragraph 9). This model gives an adequate explanation for the origin of two massive weak interaction as the bond between the two particles. It is incomplete still, because a the particle spin interaction has still to be accounted for. After having done so, the origin of a third weak interaction boson has shown up, qualitatively as well as quantitatively.

As long as the origin of electric charge is ignored, there is no difference between the Weinberg model and the structural model, albeit that the models are conceived from a different point of view. Because of mathematical reasons, the Weinberg model needs a third boson, next to a paired one. Like shown in paragraph 9, it can, in principle, be introduced without taking electromagnetism into account, just by assigning a coupling factor to the third gauge field different in magnitude from the one assigned to the paired gauges. This means that the only essential difference between the Weinberg model and the structural model is the incorporation of electromagnetism in the covariant derivative. This is done in the Weinberg model by an artificial mechanism on the simple argument that somehow an explanation has to be found for the origin of electric charge in elementary nuclear particles. As noted before, experimental evidence of the existence of the Z boson cannot be considered as a proof for the correctness of this mechanism, because the third boson should show up anyway. In the structural model the charge of the W bosons is taken for granted as a consequence of the quark's second dipole moment. In a recent preprint, a more fundamental explanation for the origin of electric charge in the structural model is given [34].

The hypothetical axiomatic mechanism to explain the origin of the Z boson is equivalent with the spin-spin interaction mechanism as developed in this article from a structural point of view. However, the GWS theory is unable to relate the masses of numerical values of this Z boson and the Higgs boson with the mass value of the W bosons, while the structural theory can. On the other hand, whereas in the structural theory the electric charge of the mesons is just accepted as a physical attribute related to isospin and unified with the weak force in a physical model that enables to calculate its influence on the mass of the quark-antiquark junction, the electroweak theory explains the origin of the electrical charge in a model that unifies the weak interaction with electromagnetism by a mathematical theory.

12. Strong interaction

One of the problems left is the unification of the GWS theory with strong interaction. This problem has given rise to the development of the QCD (Quantum Color Dynamics) theory, in which an additional boson is introduced, dubbed as gluon, as the carrier of an additional force next to the electromagnetic force and the weak interaction. This is done by extending the SU(2) model for the quark junction between the u quark and the $\bar{d}$ quark toward the SU(3) model for three-quark junctions (baryons).

Before discussing this model, it might be useful to emphasize the difference between the concept of strong interaction with the ill defined semantically related concepts strong decay and strong force. The decay of the vector-type rho-meson into the pseudo-scalar type pion may serve as an example. As a rule of thumb, it is usually said that strong decay comes first before weak interaction decay takes place. For that reason, the rho-pion decay is considered as a strong decay mechanism. However, the structural view as developed in this article has revealed that this decay is nothing else but the particle spin flip in the spin-spin interaction process. We have seen that the nuclear spin-spin interaction is mediated by the Z boson in virtual state. This does not necessarily imply that this boson actually shows up in this strong decay process. Another example is the interaction force that binds protons and neutrons together in an atomic nucleus. Historically, this force is denoted as the strong force. Its origin can be traced back to the outer potential field of a baryon in distinction from the inter-quark potential built up by the gluons.

The true strong interaction issue has to do with the problem how to explain the composition of the 3/2 spin (Δ) excitations from the 1/2 spin nucleons. Because this composition violates the spin constraints of Pauli's law, the origin of these Δ 's was not clear. Because of the lack of knowledge on the physical forces that glue three quarks together, the problem has been solved in the same way as the lack of knowledge of the physical force that glues two quarks has been solved. The successful approach for modeling a two-quark junction as a member of an SU(2) group and defining three hypothetical gauge bosons responsible for their physical bond, has been copied by modeling a three-quark junction as a member of an SU(3) group and defining eight ($= n^2 - 1$) hypothetical gauge bosons responsible for their physical bond. The issue how to explain the origin of these bosons has been solved by assigning a new attribute to the quarks, named color charge. Similarly as an electric charge in a particle bond is a source of photons (= electromagnetic bosons), the color charge in a quark bond is seen as a source of gluons (= strong interaction bosons). The need for eight gluons can be met by combinations from three "colors". This approach for explaining the origin of the Δ baryons marks the birth of the QCD (Quantum Chromo Dynamics) theory.

This (QCD) theoretical instrument for explaining the behavior of quarks in decay and scattering experiments has been proven quite powerful and successful. Next to the SU(2) electroweak theory, the SU(3) QCD theory became a corner stone of the Standard Model of particle physics theory. Let us continue by trying to give it a structural basis, similarly as done in this article for the SU(2) electroweak theory. It starts from the observation that the motivation for assigning "color charge" as a new attribute for a quark is rather weak, if not incorrect. If the energy state between the four $(\Delta^{-1}, \Delta^0, \Delta^+, \Delta^{++})$ baryons is somewhat different for whatever reason, there is no violation of the Pauli spin constraint. As discussed in paragraph 4, Comay [20] has put the color charge fundament of QCD into doubt. Having shown in this article the relationship of charge with the dipole interpretation of isospin, the criticism is even more justified.

13. Baryons

Whereas a meson can be conceived as the one-body equivalent of a two-body harmonic oscillator, a baryon can be conceived as the one-body equivalent of a three-body harmonic oscillator. The one-body equivalent of the three-body quantum mechanical oscillator can be analyzed in terms of pseudo-spherical Smith Whitten coordinates [35]. The Smith-Whitten system of coordinates is six-dimensional. Next to a (hyper)radius ρ, the square of which is the sum of the squared spaces between the three bodies, there are five angles $\varphi, \vartheta, \alpha, \beta, \gamma$, in which φ and ϑ model the changes of shape of the triangular structure and in which α, β and γ are the Euler angles. The latter ones define the orientation of the body plane in 3D-space. The planar forces between three identical interacting bodies not only are the cause of dynamic deformations of the equilateral structure, but also are the cause of a Coriolis effect that result in vibra-rotations around the principal axes of inertia of the three-body structure [36]. The application of this approach for baryons has been documented by the author in [37], showing that the wave equation of the quasi-equilateral baryon structure can be formulated as

$$-\alpha_0\{\frac{d^2\psi}{d\rho'^2}+\frac{5}{\rho'}\frac{d\psi}{d\rho'}+\frac{R(m,v,k)}{\rho'^2}\psi\}+V'(\rho')=E'\psi,$$

in which $\alpha_0=\frac{\hbar^2\lambda^2}{6mg\Phi_0}$; $E'=\frac{E}{3g\Phi_0}$; $V'=\frac{V}{3g\Phi_0}$; $\rho'=\rho\lambda$, and

$$V(\rho')=3g\Phi_0(k_0+k_2\rho'^2+.......) \tag{98}$$

$$R(m,v,k)=4m+|v-k|(4m+|v-k|+4)$$

This wave equation is the three-body equivalent of the pion's two-body wave equation shown in (46). In the ground state we have $m=0$. Hence,

$$R=R(0,v,k)=l(l+4);\ l=|v-k|. \tag{99}$$

The radial variable ρ is the already mentioned hyper radius. The potential field is just the threefold of the potential field in the wave equation of the pion. There are three quantum numbers involved. Two of those are left in the ground state, effectively bundled to a single one. . From the mathematical representation (98) it will be clear that three quantum numbers are representative for the quantum states of the three quarks. These quantum states express rather complicated vibra-rotations that are subject to the interacting bosons between the quarks. The quantum number k allows a visual interpretation, while v is difficult to visualize. The impact of k is shown in the right hand part of figure 3. It illustrates the motion of the center of mass under influence of k. Note that this rotation is quite different from a rotation of the triangular frame around the center of mass. It is the center of mass itself that rotates, while the frame does not. Actually, the small motions of the individual quarks are responsible for this motion. As shown in [37], this relatively simple wave function expression allows a pretty accurate calculation of the mass spectrum of baryons. The octet states in the baryon classification are the counter part of the meson pseudoscalar states, the decuplet states are the counter part of the vector mesons. A single integer step in the quantum number l, brings the p,n/Δ level to the Σ/Σ^*-level, etc. The results of the mass calculations are shown in the most right-hand columns of the tables IV and V. As before, these tables are constructed by conceiving the u quark and the d quark as the archetype quark in a different state of isospin. The up-state particle spin of an u quark (or a d quark) and the down-state of an u quark (or or a d quark) are indicated as, respectively u and $\underline{u}$ (or d and $\underline{d}$ for d quarks). More on this mass spectrum, with inclusion of charmed and bottom quarks, can be found in [37].

Because of the unawareness of the physical mechanism associated with the dipole properties of the archetype quark, the interaction between quarks in the baryons in the gauge theory of the Standard model has been conceived, similarly as in the case of mesons, from an abstract point of view. The bare fact that three basic quarks assemble a stable configuration is taken as a starting point. While the mesons in this article are considered as members of an SU(2) group, it makes sense considering the baryons as members of an SU(3) group. This is reflected in the wave function representation shown in (100). Because the archetype quarks are supposed to be identical, they hold each other in equilibrium by spatial momenta (p_x, p_y) with relative values of, respectively, $(\sqrt{3}/2,1/2),(-\sqrt{3}/2,1/2)$ and $(0,1)$. See figure 3. These values are reflected in the spatial components of the wave function

$$\Psi_{pa} = \begin{bmatrix} \Psi_{1t} & \Psi_{1x} & \Psi_{1y} \\ \Psi_{2t} & \Psi_{2x} & \Psi_{2y} \\ \Psi_{3t} & \Psi_{3x} & \Psi_{3y} \end{bmatrix} \rightarrow \begin{bmatrix} -ib & a\sqrt{3}/2 & a/2 \\ -ib & -a\sqrt{3}/2 & -a/2 \\ -ib & 0 & -a \end{bmatrix}. \qquad (100)$$

It is not difficult to prove that, under proper scaling of the amplitudes, this matrix is unitary (i.e. $\Psi\Psi^{+} = 1$, in which Ψ^{+} is the transpose conjugate of Ψ), and that its determinant is equal to 1 for any value of the ratio a/b. In a conservative field of forces, like it is the case of interaction between the quarks as a consequence of their nuclear potential fields, the ratio a/b is subject to change. This implies that the nine-component spinor Ψ_{amp} may rotate over eight spatial angles $\overline{\vartheta}(\vartheta_i)$ in a nine-dimensional spinor space. Under the same formalism as with SU(2), we have in SU(3),

$$\Psi \rightarrow \Psi \exp(i\overline{\lambda}\,\overline{\vartheta}) \text{ with } \overline{\vartheta} = \overline{\vartheta}(\vartheta_1, \vartheta_2 ... \vartheta_8) \text{ and } \overline{\lambda} = \overline{\lambda}(\lambda_1, \lambda_2,..\lambda_8), \qquad (101)$$

in which $\overline{\lambda} = \overline{\lambda}(\lambda_1, \lambda_2,..\lambda_8)$ are the eight 3 x 3 Gell-Mann matrices [1]. From an abstract point view the eight angles can be captured in three quantum numbers. In QCD the three quantum numbers are visualized as colors. This allows visualizing the eight possible states of the SU(3) baryon as a color state. In the most simple condition, one of the quarks has a pure blue charge, the second one has a pure green charge and the third one has a pure red charge. Any three quark combination with mixed colors ending up in overall "white" may represent a physical state as well. It will be clear that this view on the wave function of the baryonic confined three-quark quantum function Ψ is an extrapolation of the view on the wave function of the mesonic confined two-quark junction. Any color composition of the baryon marks a different state. In this picture, the Gell-Mann matrices can be seen as state variables playing the same role as the Pauli matrices in SU(2). The preservation of state is supposed to be mediated by SU(3) bosons, dubbed as gluons. The gluons protect the confinement state of the quarks in the baryon.

At this point it is instructive to remark that whereas the structural model for the confined two-quark junction is richer than the gauge-based SU(2) model, the opposite seems being the case for the confined three-quark junction. The structural baryon model as discussed so far does not show additional bosons next to the ones associated with the two real dipole moments of the quarks conceived as Dirac particles in "third mode". Considering, however, that the wave function shown in (98) is a single dimensional Schrödinger approximation of the generic nine-dimensional wave function (100), the fine nuances of the confined three-quark quantum function Ψ shown by (100) are possibly left out. Nevertheless, the structural model of the baryon has proven its strength in the calculation of the baryonic mass spectrum without a need to hypothesize an additional force carrying boson next to the ones related with the two real dipole moments of the quark.

This raises the question on the interpretation that has to be given to the gluons as they manifest themselves in nuclear experiments. in which they show up as the nuclear equivalents of photons. In an attempt trying to find the answer to this, let us consider a comparison between the quark as described in this article and an electron, as a stepping stone to the comparison between a gluon and a photon. This is the subject of the next paragraph.

14. The gluon

Similarly as the photon, the gluon will become physically manifest, either directly as a free mass less particle, or indirectly as a bound ("virtual") one in the spin-spin interactions of the type discussed in paragraph 8. Whereas the (three) SU(2) bosons and the (eight) SU(3) bosons are indirect manifestations, which, like analyzed in this article, can be described by the behavior of the quark in terms of a monopole and two dipole moments, the direct manifestation shows up quite differently. Probably the most obvious one is the well-known "three-jet event". This event shows up in a experiment in which a high energetic electron bundle scatters on a high energetic positron bundle. This now classical experiment dates from the TASSO experiment, in 1979 conducted with the PETRA accelerator at the DESY laboratory. This experiment is considered as the proof for the existence of gluons. If the energy of the electrons and positrons is high enough, new particles are created under the conservation laws of energy and momentum. One might expect, for instance, the production of two hadron bundles (jets) under 180^{o} (back-to-back). However, under suitable conditions three hadron jets are produced under 120^{o}, like shown in figure 10 (left). Because quarks, composing the hadrons, are confined in pairs, the appearance of the third jet can only be explained if it originates by "bremsstrahlung" of a boson capable of producing quark pairs. The existence of the third bundle is considered as the experimental confirmation of gluons [38,39].

But does it proof the existence of gluons in the sense of QCD? The three-jet event reveals an interesting parallel between the gamma photon-electron relationship on the one hand and the gluon-quark relationship on the other hand. This parallel becomes clear if these relationships are described in the same terms. An adequate description is the time-dependent wave equation of the quark's far field as shown by (55). If $\lambda \rightarrow 0$, this is just the Maxwellian wave equation for the scalar part of the electromagnetic vector potential. It is interesting to consider the building of the quark's potential field from a sudden energy eruption from its source. This requires solving the Proca wave equation (55), documented in [40]. Figure 11 shows how the building of this field evolves in time. The field evolves as the sum of a stationary component and a transient pulse. The opposite is true as well. A sudden disappearance of the gluon (for instance by annihilation) leaves the transient as a propagating boson. The comparison with the very same process as occurs in the case of a sudden appearance or disappearance of an electron makes clear that the transient pulse represents the equivalent of a gamma photon. However, unlike the gamma photon, the quark's transient pulse is subject to dispersion. The dispersion is due to the λ^2 term in the Proca wave equation (55). As shown by (57), the term is a consequence of the energetic ambient field, known as the Higgs field. The transient pulse, better known as gluon, propagates at light speed but dies quickly. Because the gluon jet experiments do not allow identifying the skew of individual quark pairs nor the identification of single gluons, the three jet experiments don't proof the existence of gluons in the sense of QCD All what can be observed are bundles of hadronized fermions. Interpretation is done with a theory in mind. The gluon interpretation as shown in figure 11 fits equally well to the observed phenomenon.

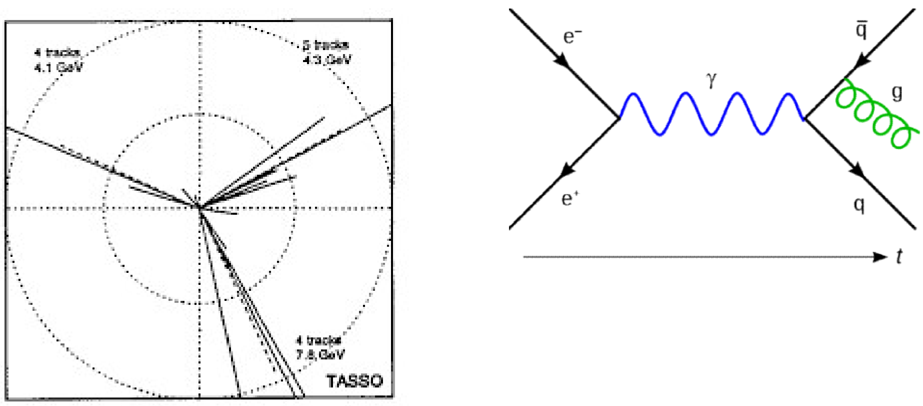

Fig.10. The three jet event. Under suitable conditions, the scattering of a high energetic electron bundle on a high energetic positron bundle, produces three hadron bundles separated under 120°. Two of the bundles are the result of a direct creation. The third one is the result from gluons that show up as bremsstrahlung. These gluons are converted into hadrons, similarly as gamma photons may create electron-positron pairs. Left: from EPJ H **36,** 245 (2011), Right: from Physics Stacks Exchange May 7, (2017).

The boson characteristics of the gluon are different from those of the weak interaction W/Z bosons. Whereas the latter ones can be characterized as particles with a defined energy, expressed into a rest mass quantity or a defined quantum mechanical frequency (like mesons), the gluon energy is built up, similarly as the photon one, by the amplitudes of an ensemble of frequencies. The energy may have any value. Hence, the gluon can be considered as a mass less particle in spite of its dispersion on an energetic background field.

A proof of equivalence with the QCD view, if possible, would need a challenging extensive elaboration beyond the scope of this article. On the other hand, there seems being no particular reason why the structural view on gluons as summarized in this paragraph as part of the structural view on particle physics developed in this article would be in conflict with

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the axiomatically conceived QCD view. Both views support an SU(3) gauging, three quantum numbers for the baryon composition and the existence of gluons.

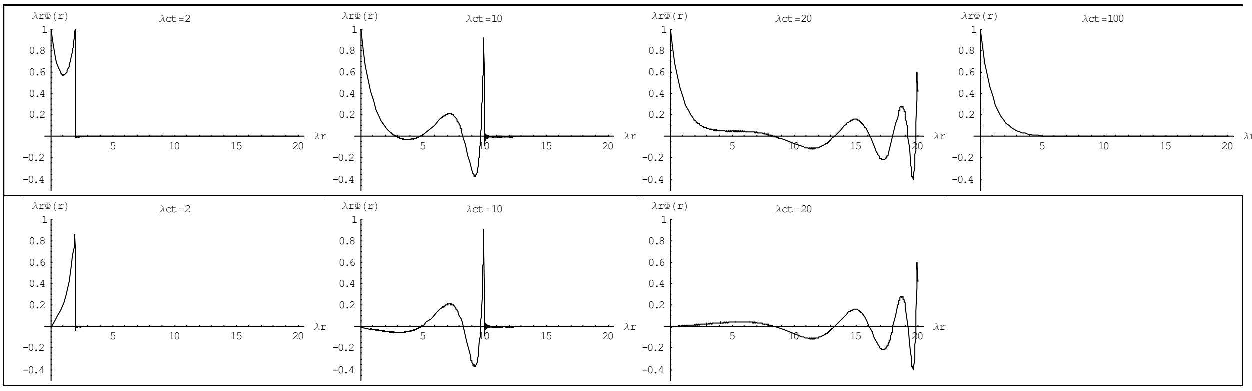

Fig.11. The building of the quark's potential field as a result of a sudden energy eruption from its source. The field is the sum of the steady solution shown at the right and the transient pulse shown in the lower part of the figure. This pulse is the actual gluon. It propagates at light speed and it eventually disappears as a result of dispersion. If λ is zero, the transient is a never disappearing gamma photon and the stationary situation is shown by an unfinished rectangular shape of the upper most right graph. Note that the field is represented by $r\Phi(r)$.

15. The topquark

Further elaboration might reveal additional relationships. Whereas a gluon behaves as the nuclear equivalent of the photon, the behavior of the W/Z bosons is more meson-like, like suggested by Comay [41]. Let us suppose that the meson-like behavior of the W/Z bosons is more than just an appearance and that they are mesons indeed in a hierarchical system, such as illustrated in figure 12. Like discussed in paragraph 8, the loss of binding energy in the excited anharmonic oscillator structure that binds the quarks together inhibits heavier quarks beyond $u/d, s, c$ and b. Nevertheless, there happens to be a topquark. Curiously however, the assigned rest mass of the topquark is out of scale. But if the topquark would be the constituent of the W/Z boson, its existence can be well understood. This is possible by invoking the relationship (61) as shown in paragraph 8 for the pion. It says,

$$m'_\pi = 2m'_u - 3m''_Z, \tag{102}$$

expressing that the pion's massive energy is built up by those from two archetype u/d quarks, under a correction from Z bosons in virtual state. This result has been obtained by transforming the result found in the pion's center-of-mass frame to the lab frame, under the recognition that the weak interaction massive energy m'_W is the relativistic equivalent of m'_π. Transforming back to the relativistic level, we have

$$m'_W = 2m''_u - 3m'_Z, \tag{103}$$

in which m''_u is the relativistic value of the rest mass energy of the u/d quark. Under consideration of $m'_W \approx$ 80.4 GeV for the W boson and $m'_Z \approx$ 91.2 GeV for the Z boson, the result is m''_u = 177 GeV. And this is just near to the energy of the topquark, found in 1995 [42], after an intensive search for the missing quark in the third generation predicted in 1973 [43,44]. In the interpretation of this article, though, this particle is not the sixth member in the quark hierarchy, but, intead, the relativistic (at the pion's speed) appearance of the u/d quark. If so, it should have an isospin sister. Hence, the production of neutral $t_u\bar{t}_u$ and $t_d\bar{t}_d$ pairs from colliding beams of high-energy protons and antiprotons may result in the creation of charged pseudo-scalar topquark mesons. This view enables to conceive (charged) W bosons as topquark mesons without violating the interpretation of the jets produced in topquark generating experiments. This means that the topquark should not be considered as the isospin sister of the bottom quark like taken for granted in the Standard Model. Like shown by figure 7, the existence of such one as a regular sixth member in the sequence $u/d, s, c$ and b is prevented by the loss of binding energy between the quark and antiquark.

The view just explained is not without problems, though. The first one is the lack of precision of (103) for predicting the mass of the topquark. Whereas the non-relativistic equivalent (61,102) is rather precise in explaining the mass difference between the pion and its vector-type counterpart, the relativistic equivalent is somewhat less precise. Curiously, the difference of 4 GeV with the (172 +/- 0.3) GeV PDG value is just the same as the mass of a bottom quark. In the author's view, discussed in Appendix B, the discrepancy is due to the interpretation of the topquark mass by retrieval from the associated decay paths. The second problem is the question how to explain the Z boson in these terms. The mass difference between the W boson and the Z boson is too large for ascribing it simply to the electromagnetic interaction from charge. Nevertheless, explaining the W boson as the relativistic manifestation of the pseudo-scalar u/d boson (pion) imposes accepting the existence of a neutral W^0 boson next to the $W^{+/-}$ ones. As shown in paragraph 9, such a boson shows up indeed, as a gauge boson in the GWS SU(2) theory, as well as in its structural alternative. It has been shown as well that the coupling factors to the bosons are different. In the covariant derivative (85) these couplings show up, respectively as $g_W W^{+/-}$ and $g_Z W^0$. As shown in paragraph 10, the difference between the coupling factors marks a difference between the massive energies between, respectively, the Z boson (the neutral W^0 boson) and the $W^{+/-}$ bosons, such that

$$\frac{m'_W}{m'_Z} = \frac{g_W}{g_Z} = \cos\vartheta_W, \tag{104}$$

in which $\vartheta_W < \pi/2$ is the Weinberg angle. Within the Standard Model, this angle is considered as an elementary empirical factor, thereby defining the Z boson as an elementary particle. In the structural view, the Z boson shows up as the carrier of the bosonic interaction between the pion and its vector-type counter part (the rho meson). As shown in paragraph 8, the acceptance of the Z boson as elementary yields a very precise relationship between the masses of the pion and its vecior-type counter part (the rho meson). In fact, it is the other way around. As discussed in previous work [21], this interaction is due to the particle spin interaction, which numerically appears being the strength of the Z boson, thereby giving the Weinberg angle $\vartheta_w = \arctan(m_Z/m_W)$ a theoretically established value.

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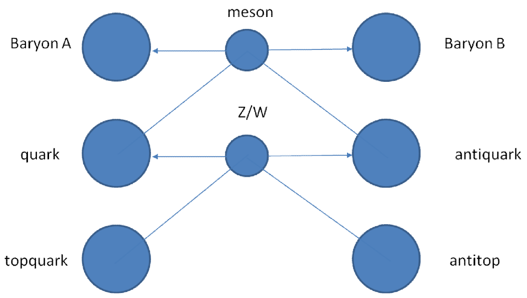

Fig 12. Meson hierarchy. The quantum of the bosonic field between two baryons is a meson in virtual state. The meson in real state is a quark-antiquark assembly bound by W/Z bosons in virtual state. The W/Z in real state behaves as mesonic topquark-antitop bond.

It is fair to conclude that (a) the topquark cannot be the isospin sister of the bottom quark and that (b) the W/Z bosons are pseudo-scalar topquark mesons. Appendix B gives the proof.

16. Discussion and conclusion

The theory described in this article is a structural view on particle physics with a physical interpretation on some of the axiomatic principles adopted in the mathematical formalism of the Standard Model. The model description of the mesons and the baryons is based upon a non-relativistic approximation of Dirac's multi-dimensional fermionic wave equation to a single-dimensional Schrödinger one in the center of mass frame of hadrons, extended by separate additions of some second order effects not covered in the approximation and interpreted in the lab frame after relativistic correction. Although in this respect it lacks the rigidity of the conventional Standard Model description and although the scope of the presented theory is limited in the sense that scattering and decay processes are left beyond scope (apart from the topquark analysis in Appendix B), the highlight on two additional principles that are not yet covered in the Standard Model, reveals useful complements to the present status of theory. The two basic principles highlighted in this article that can be added to the Standard Model are,

a. The quark is an unrecognized Dirac particle that has, next to the well-known real dipole moment associated with the elementary angular momentum ***h***, a second real dipole moment associated with an elementary linear dipole ***h/c***, which, unlike as in the case of electrons, is polarisable in a scalar potential field.
b. Deriving Dirac's fermionic wave equation from Einstein's geodesic equation rather than from Einstein's energy expression reveals a complementary property to the quark conceived as a Dirac particle described in the first highlight. This property is the invariance of the frame-independent ratio Φ_0/λ, in which Φ_0, expressed in units of energy, is a measure of the quark's potential and in which λ, expressed in m^{-1}, is a measure for the range of the quark's potential. In the article, this property is dubbed as the quark-scaling theorem.

In the article it has been shown how these two unrecognized theoretical consequences from Dirac's electron theory may influence the view on the Standard Model of particle physics without substantially affecting its basics of SU(2) and SU(3) gauging, electroweak unification and the mass generation mechanism from the Higgs field. Most of the presented results have been documented by me in literature in more detail before, some in journals, others in prepublications that met opposition because of a seeming conflict with common views that are considered as proven in the wealth of studies and experiments in the high standard of present theory. The highlight on the two additional principles that are not yet covered in the Standard Model, may help showing that principles quite some problems can be tackled that so far have remained unsolved, like shown in the following non-exhaustive list,

1. The quark-antiquark model shown in figure 2 has allowed to express the Gravitational Constant G into quantum mechanical quantities with a successful numerical proof [17,20].
2. Different from a theoretical axiomatic concept, isospin is a physical attribute associated with the quark's polarisable dipole moment (this article).
3. The number of elementary quarks can be reduced to a single basic archetype [22]
4. The big gap between the rest masses of the ($u/d, s, c, b$) quarks on the one hand hand and the topquark on the other hand is a consequence of the loss of binding energy between the quarks (this article).
5. The massive energies of the Higgs boson, the W/Z bosons and the topquark can be numerically related by theory. This implies that only a single one of these is true elementary , the massive energy of which has to be empirically assessed (this article).
6. The gluon-quark relationship is the equivalent of the photon-electron relationship (this article)
7. The mathematical axiomatic SU(2) and SU(3) gauges of particle physics theory can be replaced by physically based gauges similar to the electromagnetic U(1) gauge (this article).

Moreover, it has been demonstrated that the mass spectrum of hadrons can be calculated in a rather easy way, which can probably compete in accuracy with the results from cumbersome lattice QCD computations. It may seem as if the theory as described in this article is different from the Standard Model, or even be in conflict. Differences in interpretation of concepts cannot be denied, because of its aim and the obtained goal to provide a physical basis for quite some underlying axioms that are accepted in present theory. There is no reason why such a basis would not allow application of the same powerful analytical techniques as used in the Standard Model. The structural view might be helpful for better understanding and a key for further progress, like demonstrated in the just given list.

Acknowledgements

The author is indebted to prof. D. Zeppenfeld, who pointed to the erroneous format reported in [7, eq. (27)], which has led to the improved format shown in (14). He gratefully acknowledges Prof. H. Nicolic for exchanging views on the Lorentz covariance issue of the quark concept described in this article. He is also grateful to Dr. E. Comay and Dr. D. Derbes

for their responsiveness and positive opposition on the various unconventional issues described in this article.

Appendix A : Lorentz covariance of a non-gravitational object

Whereas a gravitational object is subject to the Einsteinean energy expression,

$$W_G^2 = (m_0 c^2)^2 + c^2 |\mathbf{p}|^2 , \tag{A-1}$$

the quark, as a non-gravitational object, is subject to

$$W_Q^2 = (m_0 c^2)^2 - c^2 |\mathbf{p}|^2 . \tag{A-2}$$

Defining $W_G^2 = (m_0 \dfrac{\mathrm{d}ct}{\mathrm{d}\tau})^2$, (A-3)

the Einsteinean energy expression (A-1) is conveniently expressed as,

$$(m_0 \frac{\mathrm{d}ct}{\mathrm{d}\tau})^2 = (m_0 c^2)^2 + (m_0 \frac{\mathrm{dx}}{\mathrm{d}\tau})^2 + (m_0 \frac{\mathrm{dy}}{\mathrm{d}\tau})^2 + (m_0 \frac{\mathrm{dz}}{\mathrm{d}\tau})^2 . \tag{A-4}$$

which is equivalent with,

$$(\mathrm{d}ct)^2 - \{(\mathrm{d}x)^2 + (\mathrm{dy})^2 + (\mathrm{dz})^2\} = (c\mathrm{d}\tau)^2 . \tag{A-5}$$

Note: τ is proper time.

Transforming this property to a different space-time frame $(\xi, \eta, \zeta, \tau')$, related by the Lorentz transform

$$x = \frac{1}{w}(\xi + v\tau') ; \; t = \frac{1}{w}(\tau' + \frac{v\xi}{c^2}) ; \; w^2 = 1 - \frac{v^2}{c^2} ; \; y = \eta ; \; z = \zeta , \quad \text{(A-6)},$$

we get, after substitution of (B-6) into (B-5),

$$-\frac{1}{w^2}(1 - \frac{v^2}{c^2})(\mathrm{d}\xi^2 - c^2 \mathrm{d}\tau'^2) - \mathrm{d}\eta^2 - \mathrm{d}\zeta^2 = (c\mathrm{d}\tau)^2 . \tag{A-7}$$

Note that τ' is different from proper time τ.

This result (A-7) has the same format as (A-4). It proves the Lorentz covariance of the Einsteinean energy expression.

In a similar view on the non-gravitational object (A-2),

$$(m_0 \frac{\mathrm{d}ct}{\mathrm{d}\tau})^2 = (m_0 c^2)^2 - \{(m_0 \frac{\mathrm{dx}}{\mathrm{d}\tau})^2 + (m_0 \frac{\mathrm{dy}}{\mathrm{d}\tau})^2 + (m_0 \frac{\mathrm{dz}}{\mathrm{d}\tau})^2\}. \tag{A-8}$$

which is equivalent with,

$$(\mathrm{d}ct)^2 + \{(\mathrm{dx})^2 + (\mathrm{dy})^2 + (\mathrm{dz})^2\} = (c\mathrm{d}\tau)^2. \tag{A-9}$$

Transforming under the Lorentz transform gives

$$\begin{aligned} &\frac{1}{w^2}\mathrm{d}(c\tau + \frac{v\xi}{c})^2 + \frac{1}{w^2}\mathrm{d}(\xi + v\tau')^2 + \mathrm{d}\eta^2 + \mathrm{d}\zeta^2 = \\ &\frac{1}{w^2}(1+\frac{v^2}{c^2})(\mathrm{d}\xi^2 + c^2\mathrm{d}\tau'^2) + \mathrm{d}\eta^2 + \mathrm{d}\zeta^2 + \frac{4}{w^2}v\mathrm{d}\xi\mathrm{d}\tau' = (c\mathrm{d}\tau)^2 \end{aligned} \tag{A-10}$$

It is clear that the last term of the left hand part of (A-10) violates the Lorentz covariance. This seems being a show stopper for the existence of a non gravitational particle with the property shown in (A-2), as required for the existence of quarks with two real dipole moments. It is known however that quarks in isolation don't exist, such as formalized in the confinement axiom. Taking this into consideration, it might be that the Lorentz violating term in (A-10) disappears for two and three quarks in conjunction. The structural meson (an)harmonic oscillator model, shown in figure 2, demonstrates that the two quarks vibrate in opposite direction under a stationary position of their center-of-mass. Hence, showing opposite signs for $\mathrm{d}\xi$. Consequently, the Lorentz violation of one of the quarks is cancelled by the opposite Lorentz violation of the other quark. This makes mesons composed by quarks with two real dipole moments Lorentz covariant in spite of the Lorentz covariance violation of quarks in isolation.

Appendix B: the weak interaction boson as a topquark meson

As discussed in the main text, the topquark mass as empirically assessed in the context of the Standard Model has a somewhat different value from the value as derived by the theory developed in this article. The origin of this difference can be made more comprehensible from inspection on two different Feynman diagrams, shown in figure B1. The diagram at the left side shows the generation and the decay of the topquark as conceived in the Standard Model. In that concept the topquark is considered as the sixth flavor in the quark generation. It decays conventionally into a b quark and via a weak interaction boson into high-energetic quarks as sources of hadronic jets. In this diagram the weak interaction boson shown is not more than a symbolic representation of some energetic process that converts quarks from flavors into other flavors. It is instructive to note that in the context of the Standard Model the very same weak interaction boson symbol is used for energetic interaction processes with various different semantics, like, for instance, (a) isospin conversion, (b) flavor conversion and (c) meson decay. Examples are shown in figure B2.

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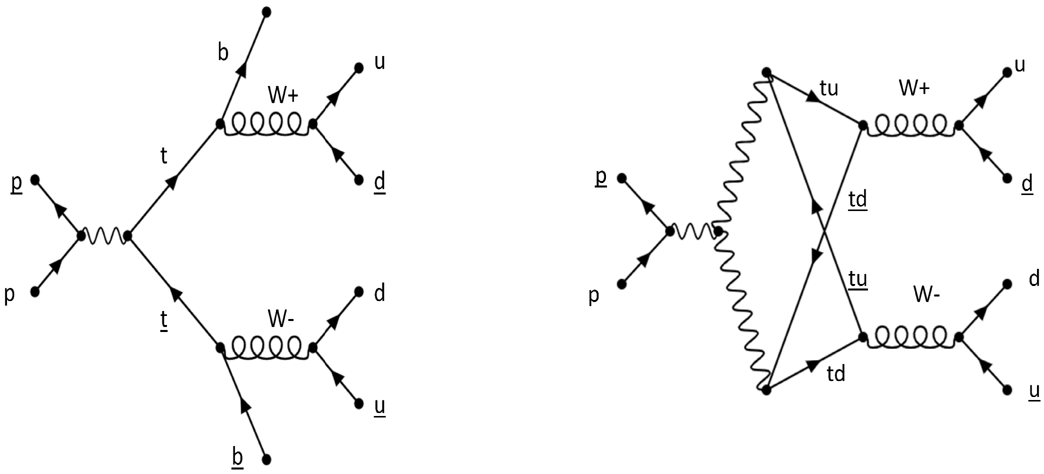

Fig. B1: **T**opquark generation from colliding proton anti-proton beams and subsequent decay. Left: conform the Standard Model. Right: conform the structural model.

At the left side of figure B1, the weak interaction boson shown is not a meson, because it is not composed by a quark and an antiquark. At the right side the alternative representation is shown, in which the weak interaction boson is conceived as a meson. Similarly as in the conventional representation, the output from the weak interaction boson are high-energetic quarks as sources of hadronic jets. The dual u/d output may assume an energetic equivalent leptonic output. This means that the jets may either be full hadronic, mixed hadronic/leptonic or full leptonic with branch ratio probability of, respecrively, 46%, 44% and 10%. [45]. It is probably not bold to suggest that the generation of topquarks and its decay into high energetic quarks can be viewed as the manifestation of a confinement break process.

As derived in the main text, the topquark massive energy is determined by theory as,

$$m'_W = 2m''_u - 3m'_Z \, , \qquad \text{(B1)}$$

in which m''_u is the relativistic value of the rest mass energy of the u/d quark. Under consideration of $m'_W \approx$ 80.4 GeV for the W boson and $m'_Z \approx$ 91.2 GeV for the Z boson, the result is $m''_u =$ 177 GeV. Figure B1 shows a semantic difference between the topquark t as conceived in the Standard Model and the topquarks t_u and t_d as conceived in the structural model as developed in this article. The experimental mass assessment from the final decay products, imposes the following relationship

$$m_{tu} = m_{td} = m_t + m_b \, , \qquad \text{(B2)}$$

in which $m_{tu}, m_{td\,t}$ are the masses of the theoretically assessed 177 GeV/c^2, m_b the constituent mass of the b quark (4.18 +/-0.4 GeV/c^2) and m_t the empirically 172.8 +/- 0.4GeV/c^2 Standard Model topquark. This gives a perfect fit! This result is yet another proof for the viability of the theory as developed in this article.

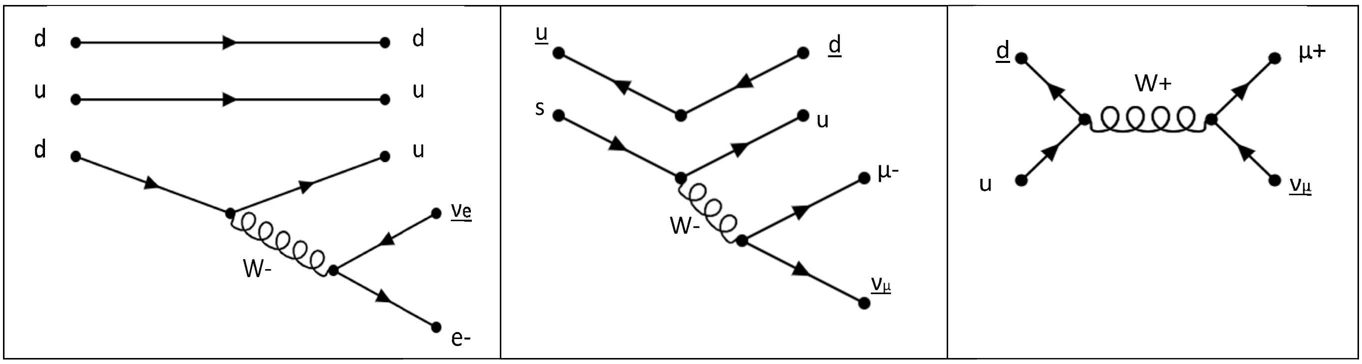

Fig. B2: Different semantics of the weak interaction boson in the Standard Model. Left: neutron to proton decay (isospin flip). Middle: kaon to pion decay (flavor flip). Right: pion decay (meson decay).

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