Journal of Modern Physics, 2024, 15, 2347-2364
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

An Investigation of the Harmonic Quark with an Energy-Mass Quantum of 253.4 GeV and How It Relates to the Heavy Particles of the Standard Model

Hongguang Yang, Weidong Yang

Munich, Germany
Email: hgyang2013@gmail.com, wdyconf@gmail.com

How to cite this paper: Yang, H.G. and Yang, W.D. (2024) An Investigation of the Harmonic Quark with an Energy-Mass Quantum of 253.4 GeV and How It Relates to the Heavy Particles of the Standard Model. *Journal of Modern Physics*, **15**, 2347-2364.
https://doi.org/10.4236/jmp.2024.1513096

Received: October 27, 2024
Accepted: December 17, 2024
Published: December 20, 2024

Abstract

The understanding of the mechanism for the mass building of elementary particles of Standard Model (SM) has made significant progresses since the confirmation of the existence of the Higgs boson, in particular the realization that the mass of an elementary particle of SM is not "God-given" but is created by interactions with involved energy fields. Nevertheless, a sophisticated model to answer fundamental questions is still missing. Further research is needed to compensate for the existing deficit. The current paper is aimed to contribute to such research by using "harmonic quark series". Harmonic quark series were introduced between 2003 and 2005 by O. A. Teplov and represented a relatively new approach to understanding the physical masses of elementary particles. Although they are not generally recognized, some research works have revealed very interesting and exciting facts regarding the mass quanta. The original harmonic quark series consists of mathematical "quark" entities with an energy-mass quantum between 7.87 MeV and 69.2 GeV. They obey a strict mathematical rule derived from the general harmonic oscillation theory. Teplov showed some quantitative relations between the masses of his harmonic quarks and the SM particles, especially in the intermediate mass range, *i.e.* mesons and hadrons up to 1000 MeV. Early research work also includes the investigation of H. Yang/W. Yang in the development of their so-called YY model for elementary particles (Ying-Yang model with "Ying" and "Yang" as quark components for a new theoretical particle framework). Based on Teplov's scheme and its mathematical formula, they introduced further harmonic quarks down to 1 eV and showed some quantitative relationships between the masses of these harmonic quarks and the masses of electrons and up and down quarks. In this article, we will extend the harmonic quark series according to the Teplov scheme up to a new entity with a mass quantum of

253.4 GeV and show some interesting new mass relations to the heavy particles of the Standard Model (W boson, Z boson, top quark and Higgs boson). Based on these facts, some predictions will be made for experimental verification. We also hope that our investigation and result will motivate more researcher to dedicate their work to harmonic quark series in theory and in experiments.

Keywords

Harmonic Quark Series, Teplov Mass Formula, YY Model for Atomic Kernel, Standard Model Particles, Mesons, W-Boson, Z-Boson, Top Quark, Higgs Boson

1. Harmonic Quark Series, Their Masses and Some Related Early Research Works

Between 2003 and 2005, O. A. Teplov introduced the concept of the harmonic quark oscillator based on quark-antiquark pairs and developed the formalism for calculating their exact masses (Ref. [1]-[4]). According to this approach, the quark mass is understood as the physical rest mass of the single-particle state of an interacting quantum field. The flavor quantum number (reflecting the quark production) is essentially a reflection of the internal energy of the quark, its physical mass. The quark mass model with a multiplicative pattern in the mass transformation between quark flavors focuses on the quark-antiquark interaction and its outcome: either a meson (e.g., a vector boson) or a complete annihilation of the pair with the birth of photons or quarks of lower mass or other particles.

Consider the flavor changes in the weak fundamental interaction of quarks as expressed in the following terms (n is the quark generation number, ν is the neutrino):

$$Q_{(n)} + W_{+/-} \sim Q_{(n+1)} \tag{1}$$

$$Q_{(n)} + e_{+/-} \sim Q_{(n+1)} + \nu \tag{2}$$

Teplov derived the formula for calculating the mathematically defined masses of harmonic quarks based on a multiplicative pattern:

$$m_{(n+1)} = \frac{\pi}{4-\pi} \times m_{(n)}, \quad m_{(n)} = \left(\frac{\pi}{4-\pi}\right)^n \times m_{(0)} \tag{3}$$

The constant multiplication factor $\pi/(4 - \pi)$ is about 3.66. We call this the "Teplov formula" or "Teplov mass scheme". According to this, the mass of the harmonic quark of generation $n + 1$ can be determined exactly by the mass of its lower generation n, starting from a hypothetical initial mass of the quark of generation 0. Furthermore, for a given quark, it can be assumed that its two neighbors (neighboring generations) have an upward excitation (the quark with the larger mass) and a downward excitation (the quark with the smaller mass), with the electric charges of the two excitations being equal. According to Teplov, such harmonic oscillators form a series of quarks, starting with the lightest "d" quark (with a harmonic oscillator mass of 28.815 MeV, flavor index 1), which are considered in **Table 1** as successive up excitations.

Table 1. Masses of harmonic quarks after Teplov (last left and last right columns are extended by H. Yang/W. Yang).

Harmonic quarks	-	"d"	"u"	"s"	"c"	"b"	"t"	"b'"	-
Masses (**MeV**)	7.873	28.815	105.456	385.95	1412.5	5169.4	18,919	69,239	253,402
Flavor index	Q0	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8

Please note that the names of the harmonic quarks in **Table 1** (e.g., "d" or "u" etc.) were used by Teplov as "up", "down" quarks. However, they do not refer to the SM particle in any way. It is not known why he used these terms. We therefore put them in quotation marks. Instead of them, we have introduced the symbol Qi (with flavor index $i = 0, 1, 2, \dots$) to better reflect the mathematical character of harmonic quarks and will use it throughout this paper.

The two harmonic quarks on the left and right edges of **Table 1** (Q0 with mass 7.873 MeV and Q8 with mass 253.4 GeV) were not part of Teplov's original harmonic quark series (hence they are labeled "-").

Using these harmonic quark masses, O. A. Teplov created a mass generation model for some leptons and baryons, numerically very accurate. The research of Teplov reveals a profound fact of the quark generation model, which essentially states that a quark generation of $n + 1$ results from the quark generation n by binding an electron or a positron of its own flavor (its own generation), as expressed in Formula (2). In particular, the masses (harmonic quark masses) between these two generations can be calculated exactly according to a simple Formula (3).

In his four publications, Teplov investigated the role of harmonic quarks in building up the mass of subatomic particles and atomic nuclei of the SM. He focused mainly on harmonically oscillating pairs and the middle range of mesons and hydrons up to 1000 MeV, using Q1 - Q7 in **Table 1**. Although Teplov considered the harmonic quark of 28.815 MeV as the "lower limit" of his series, he also mentioned a possible "downward excited" harmonic quark with an oscillator mass of 7.873 MeV, calculated from $(28.815/\pi)(4 - \pi)$. However, he did not pursue this idea any further.

This is made up for a later work of H. Yang/W. Yang (Ref. [5]), they continued this harmonic quark series by successive down-excitations as calculated in the following **Table 2**.

Table 2. Masses of harmonic quarks after "down excitations" using Formular (3) successively.

Harmonic quarks by H. Yang/W. Yang	-	-	-	-	-	-	-	-	-
Harmonic quark masses (**eV**)	7873	2151	588	161	43.9	12.0	3.28	0.89	0.243
Flavor index	Q0	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8

With this extended approach of Table 2, H. Yang/W. Yang theoretically investigated the mass formation of SM particles with small masses (electron, up and down quarks). They also showed by means of examples that all harmonic quarks from Table 1 and Table 2 together can be used as "primary" or "discrete" building blocks of SM particles in terms of mass and electric charge. This also implies that the harmonic quark series can represent the quantum fields of different energy levels and different superposition states.

Especially, H. Yang/W. Yang have introduced so-called "Ying and Yang" as building blocks to account for quark color confinement: Each harmonic quark has a specific electric charge as well as a specific color or anti-color (Ref. [6]). This aspect is not dealt with in this paper.

H. Yang/W. Yang also have discovered a fundamental relationship between harmonic quarks and Reduced Max-Planck constant $\hbar$ (Ref. [7]): By defining an initial constant y_0 based on $\hbar$, all masses of harmonic quarks can be calculated by facultative multiplications of Teplov factor as:

$$y_0 = 2\hbar \times 10^6 \text{ eV} \tag{4.1}$$

$$m_i = \left(\frac{\pi}{4-\pi}\right)^i y_0 \tag{4.2}$$

By using (4.1) and (4.2) all harmonic quark masses in Table 1 can be related to the Reduced Max-Planck constant $\hbar$:

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{28} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{28} y_0 = 7.8736 \text{ MeV} \tag{5.1}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{29} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{29} y_0 = 28.8159 \text{ MeV} \tag{5.2}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{30} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{30} y_0 = 105.4603 \text{ MeV} \tag{5.3}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{31} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{31} y_0 = 385.9630 \text{ MeV} \tag{5.4}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{32} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{32} y_0 = 1412.5443 \text{ MeV} \tag{5.5}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{33} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{33} y_0 = 5169.6187 \text{ MeV} \tag{5.6}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{34} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{34} y_0 = 18919.7312 \text{ MeV} \tag{5.7}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{35} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{35} y_0 = 69242.2878 \text{ MeV} \tag{5.8}$$

$$2\hbar \times \left(\frac{\pi}{4-\pi}\right)^{36} \times 10^6 = \left(\frac{\pi}{4-\pi}\right)^{36} y_0 = 253412.3950 \text{ MeV} \tag{5.9}$$

This numerically substantiated fact can be used for the interpretation that all harmonic quarks are multiplicative upward excitations of the energy quantum $2\hbar$ derived from the reduced Max Planck constant by the factor π/(4 − π). Each harmonic quark must be a bound energy state with a corresponding mass quantum that obeys a strict construction rule. Unfortunately, we can no longer find out whether O. A. Teplov was aware of this fundamental relationship or whether he even derived his own harmonic quarks from this relationship without mentioning it in his publications (see Acknowledgement).

Incidentally, and this should only be mentioned in passing, the factor π/(4 − π) is geometrically the ratio between the length of a circle and the length deficit of this circle compared to its enclosing rectangle, see Figure 1.

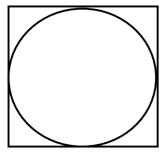

Figure 1. Geometrical meaning of the Teplov factor π/(4 − π).

At this point, it should also be mentioned that these "Teplov quarks" or synonymously "harmonic quarks" are purely mathematical and theoretical in nature, in contrast to the physical quarks of the Standard Model, which have already been well treated in both fundamental theories and experiments. Throughout this article, we should always be aware of this semantic difference when using terms for quarks.

2. Why Harmonic Quark Series Are Interesting for the Masses of SM Particles

To illustrate the close relationship between the (mathematically calculated) harmonic quark masses and the masses of particles from the SM, we give a few simple examples.

First, we define a new symbol <~> to describe the relationship between two sides of the formula. The symbol "~" says that the numerical quanta of mass/energy on both sides of the formula are "almost" equal by giving a delta difference (δ). The brackets "< >" symbolize the possible conversion from one side to the other while maintaining the mass/energy quanta. For example, the following formula:

$$100 <\sim> 33 \times 3 \ (\delta = 1 \text{ MeV or } \delta \sim 1\%)$$

means that a mass-energy quantum of 100 MeV is "comparable" or "convertible" to a mass-energy quantum of three times 33 MeV within a delta tolerance of 1 MeV.

Following examples show a close relationship between the masses of the harmonic quarks and the real particles of the SM, and ordered according to the masses involved from small to large:

Example 1: The strange quark of the SM with a mass of 93.5 Mev (Ref. [8]) can be represented as the sum of four harmonic quark masses (3 × 28.816 + 7.873 = 94.3, Three harmonic quarks of the same generation 3 × Q1 form a color-confined structure, Ref. [6]):

3 × Q1 + Q0 <~> strange quark, $\delta < 1$ MeV

Example 2: With its mass of 105.456 MeV, the harmonic quark Q2 is very close to the muon, 105.658 MeV (Ref. [9]):

Q2 <~> muon, $\delta \sim 0.2\%$

Example 3: The mass sum of the two neighboring harmonic quarks Q1 and Q2 (28.815 + 105.456 = 134.3, according to Teplov they form an oscillator pair) is close to the electrically neutral pion with a mass of 135.0 MeV (Ref. [10]):

Q1 + Q2 <~> pion(0), $\delta \sim 0.5\%$

Example 4: The mass sum of the two neighboring harmonic quarks Q2 and Q3 (105.456 + 385.95 = 491.4, according to Teplov also an oscillator pair) is close to a charged kaon with a mass of 493.7 MeV (Ref. [11]):

Q2 + Q3 <~> kaon(±), $\delta \sim 0.5\%$

Example 5: The double mass of the harmonic quark Q3 (2 × 385.95 = 771.9) is close to a charged $\rho(\pm)$ meson with a mass of 770 MeV (Ref. [12]):

2 × Q2 <~> $\rho(\pm)$ meson, $\delta \sim 0.2\%$

Example 6: (proton, SM, 938.272 *MeV*, Ref. [13]): The mass of a proton is the sum of a charged ρ-meson (770 MeV), a charged pion (139.6 MeV, Ref. [14]) and a harmonic quark Q1 (28.8 MeV), this also applies to a neutron (939.565 MeV, Ref. [15]):

proton (or neutron) <~> ρ-meson(±) + pion(±) + Q1, $\delta < 0.02\%$

also, by considering the harmonic quark composition 2 Q3 + Q2 + 2 Q1 = 935.1 MeV, a proton or a neutron may be mass calculated as:

proton <~> 2 × Q3 + Q2 + 2 × Q1 + δ, $\delta = 4.6$ MeV

neutron <~> 2 × Q3 + Q2 + 2 × Q1 + δ, $\delta = 3.3$ MeV

Example 7: (charm quark, SM, 1273 MeV, Ref. [16]): The sum of the masses of a charm quark and a charged pion (1273 + 139.6 = 1412.6) is very close to the harmonic quark Q4 with a mass of 1412.5 MeV

charm quark + pion(±) <~> Q4, $\delta < 0.01\%$

Example 8: (*bottom quark*, *ή-meson*, *SM*, Ref. [17] and [18]): The mass sum of a bottom quark and a ή meson (4183 + 958 = 5141) varies from the harmonic quark Q5 with a mass of 5169.4 MeV by a mass mount of Q1:

bottom quark + ή-meson + Q1 <~> Q5, $\delta < 0.01\%$

Example 9: Twice the mass of the neutral Y meson (Ref. [19]), namely 2 × 9460.3 = 18,920.6, is very close to the harmonic quark Q6 with a mass of 18,919 MeV:

2 × Y-meson <~> Q6, $\delta < 0.01\%$

Example 10: (top quark, W-boson, SM, Ref. [20] and Ref. [21]): The sum of the masses of a top quark and a W boson (±) (172,570 + 80,369 = 252,939) is very close to the harmonic quark Q8 with a mass of 253,402 MeV:

top quark + W-bson <~> Q8, δ = 463 MeV < 0.2%

More precisely:

top quark + W boson + Q2 + Q3 <~> Q8 + Q1

top quark + W boson + kaon(±) <~> Q8 + Q1

These few examples illustrate some internal relations between the real Standard Model particles and the purely mathematical series, the so-called harmonic quarks, in terms of masses. In the following sections, we will pursue this idea further using more examples and, in particular, we want to find out how this happens taking into account the QCD confinement and the charge balance of the harmonic quarks and Standard Model particles involved.

Since Teplov, in his four publications (Ref. [1]-[4]), has already treated many quantitative relations of masses and energies between the harmonic quarks and particles in the SM in the middle range of mass, *i.e.* between Q1 and Q7, and mesons, we will focus on heavier masses up to Q8 (253.4 GeV) in our current publication. In this mass range, the heavy particles of the SM (W boson, Z boson, Higgs boson and top quark) and their numerical correlations to the harmonic quarks are in the center of attention.

3. Higgs Boson and Harmonic Quark of Mass 253.4 GeV

First, we consider a composition of harmonic quarks that leads to a symmetric configuration with a total mass summation of 125.996 MeV (we call this configuration "Higgs field prototype" HFP). This mathematical correspondence between a symmetric structure and an entity definition is shown in **Figure 2**:

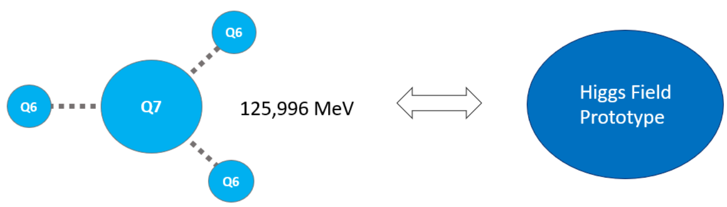

Figure 2. Defining HFP as a symmetric harmonic quark composition.

Compared to the mass of the Higgs particle of 125,200 MeV (Ref. [22]), there is an excess of 796 MeV, which contains twice the mass of the harmonic quark Q3 (385.9 MeV) with 772 MeV or the mass of a charged ρ-meson with 770 MeV. We can follow:

HFP <~> Higgs boson + 2 Q3, δ = 24 MeV ~ 0.02%

HFP <~> Higgs boson + ρ-meson, δ = 26 MeV ~ 0.02%

In other words, breaking the symmetric structure of the harmonic quark configuration with an energy level of 125,996 MeV (**Figure 2**, Higgs field prototype

HFP) leads to the emission of a Higgs boson with a rest energy of 125,200 MeV and an energy excess for the formation of two harmonic quarks Q3, which corresponds to a ρ meson. This can be seen as a "decay process of HFP", which is illustrated in Figure 3:

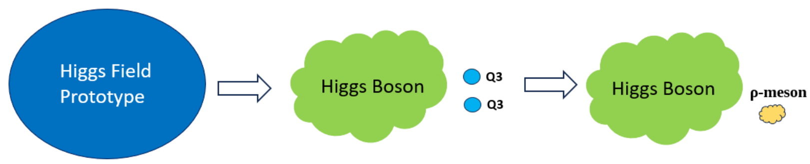

Figure 3. Decay of an HFP: Emission of a Higgs boson from a harmonic quark configuration.

This also means that a Higgs boson is created from a Higgs field prototype HFP by breaking the symmetry of a harmonic quark composition Q7-{Q6-Q6-Q6}.

The further considerations on color confinement and the electric charge of harmonic quarks (Ref. [6]) lead to an electrical charge of +2/3e (or −2/3e) and a single color charge (red, blue, green or anti-red, anti-blue, anti-green, depending on ±): The three surrounding Q6 contribute to a color-confined e-charge of +1e (or −1e), while the Q7 in the middle with −1/3e (or +1/3e) compensate +1e (or −1e) to +2/3e (or −2/3e) and itself determine the color charge of the entire configuration.

If we consider the harmonic quark Q8 = 253,402 MeV, its mass is twice that of the HFP (125,996 MeV) with an excess of 1410, which corresponds to the harmonic quark Q4 = 1412.5 MeV or, more precisely, a K*(1410) meson (Ref. [23]):

Q8 <~> 2 HFP + Q4 <~> 2 Higgs bosons + 2 ρ-mesons + Q4

Q8 <~> 2 HFP + Q4 <~> 2 Higgs bosons + 2 ρ-mesons + K*(1410)

This can also be seen as a "decay process" that transforms a highly symmetric mass-energy field (Q8) into less symmetric Higgs field prototypes and further into Higgs bosons and downward excited harmonic quarks or SM particles, as shown in Figure 4:

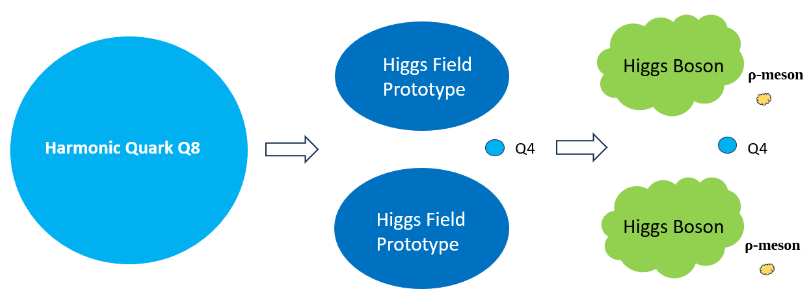

Figure 4. Harmonic quark Q8 "decays" to two Higgs bosons via two HFPs.

4. Z and W Boson and Harmonic Quark of Mass 253.4 GeV

Let us consider the Z boson with a mass of 91,188 (Ref. [24]) and the W boson with a mass of 80,369 (Ref. [21]). First, the mass sum of a W boson and half a Z boson is 125,963, which is very close to the Higgs field prototype HFP with 125,996 MeV, namely by only 33 MeV:

HFP <~> W boson + Z boson/2, $\delta < 0.03\%$

Thus, the following mass relation between the combined Z and W boson (Z + 2 W: 251,926) to the Higgs field prototype applies:

2 HFP <~> Z + 2 W, $\delta = 66$ MeV < 0.03%

This relationship is shown in Figure 5:

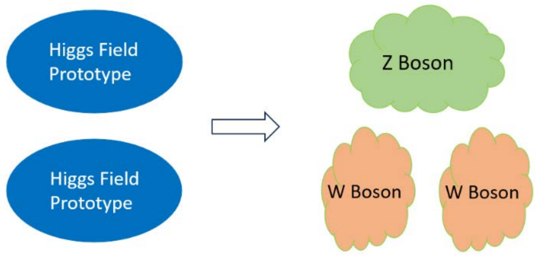

Figure 5. Emission of a heavy particle group from two Higgs field prototypes.

From the point of view of the big harmonic quark Q8 (253,402 MeV), we have:

Q8 <~> Z + 2 W + Q4, $\delta = 66$ MeV < 0.03%

This can also be seen as a decay of Q8 into a group of heavy bosons, as shown in Figure 6:

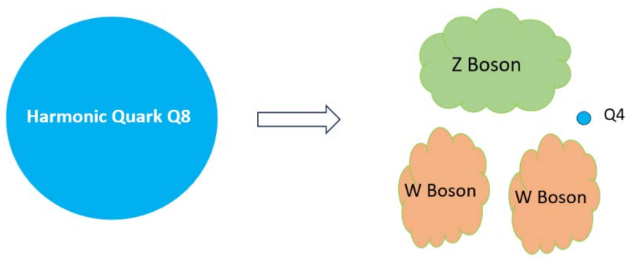

Figure 6. Harmonic quark Q8 "decays" to a heavy particle group.

Combined with Figure 4, the following mass equivalence (Figure 7) becomes obvious:

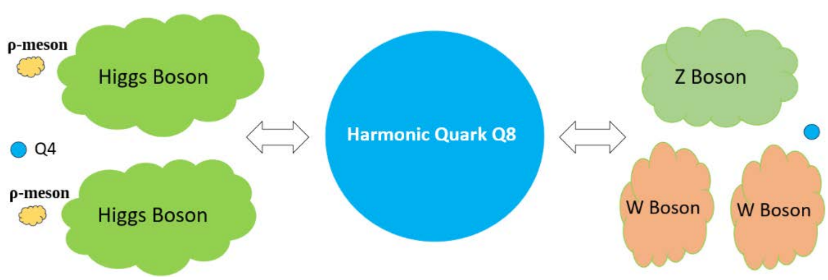

Figure 7. Equivalent transforms for Q8 from/to bosons: To a Higgs boson group on the left side and to a Z-2W group on the right side.

Or expressed as:

2 Higgs bosons <~> Q8 <~> Z boson + 2 W bosons, $\delta < 1\%$

5. Top Quark in the Context of Z, W Boson and Q8

In addition to the W and Z bosons, the top quark with its mass of 172,570 MeV (Ref. [20]) also plays a very interesting role in this league of heavy particles: The sum of the two masses of Z and W bosons (91,188 + 80,369) gives 171,557 MeV, which is close to the mass of the top quark:

top quark <~> Z boson + W boson, $\delta < 0.6\%$

The delta mass between 171,557 and 172,570 is about 1013 MeV, which is quite close to a kaon pair (K^0, _K^0) with a mass of 2 × 497 plus 19 MeV, so we can reformulate the transform above, and also see Figure 8.

top quark <~> Z boson + W boson + (K^0, _K^0), $\delta \sim 0.01\%$

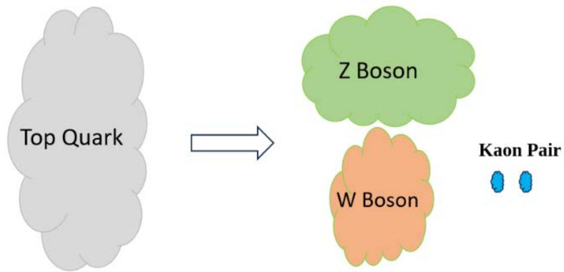

Figure 8. Equivalent transforms for top quark to a group of W-Z bosons.

Because 1013 MeV is also near to the mass of $\varphi(1020)$ (Ref. [25]), we also have:

top quark <~> Z boson + W boson + $\varphi(1020)$, $\delta \sim 0.004\%$

A W boson added to a top quark result in a mass of 252,939 MeV (172,570 + 80,369), which is close to the big harmonic quark Q8 (253,402 MeV), delta = 463:

Q8 <~> W boson + top quark, $\delta < 0.2\%$.

This is shown in Figure 9:

Figure 9. Equivalent transforms for Q8 from/to top quark and W boson.

Further consideration will lead to another interesting result. As already defined, the Higgs field prototype HFP is a symmetric field constellation with a mass of

125,996 MeV (**Figure 1**). In a next (down-)generation we define similar symmetric structure of harmonic quarks and call it "Little Higgs Field Prototype, L-HFP", see **Figure 10**.

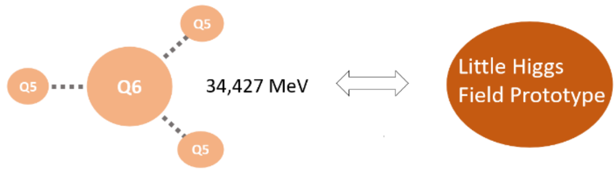

Figure 10. Defining Little Higgs field prototype (L-HFP) as symmetric quark composition.

The twice of Q7 plus one L-HFP (2 × 69,230 + 3,4423 = 172,883 MeV) contains the energy quantum for quiet a top quark and three harmonic quarks Q2 (105.456 MeV):

2 Q7 + L-HFP <~> Top quark + 3 Q2

This means that L-HFP with its composite mass also plays a role in the league of heavy bosons.

6. Field Interaction Patterns of Heavy Bosons in the Context of 253.4 GeV

In space, a chain of harmonic quarks Q8 can be considered as an interaction field path containing a translational symmetry with respect to Q8, … Q8 Q8 Q8 …, as shown in **Figure 11**:

Figure 11. Harmonic quarks Q8 as field constituents arranged along a spatial path.

If the excess mass Q4 in **Figure 4** are disregarded, the above field path can be transformed into an equivalent field path of Higgs field prototypes, **Figure 12**:

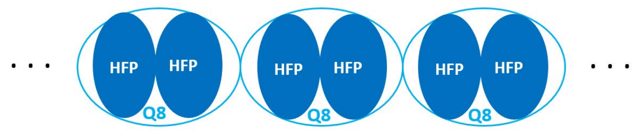

Figure 12. HFPs within Q8 as field constituents and along a spatial path.

The symbolic expression is:

… Q8{HFP HFP} Q8{HFP HFP} Q8{HFP HFP} …

In this case, there is a translation symmetry with respect to the HFP: Q8 fields can be rearranged by pairwise grouping of neighboring HFPs, as shown in **Figure**

13:

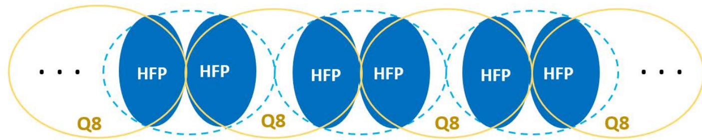

Figure 13. Rearrangement of Q8 by re-combining HFPs.

Taking Figure 5 into account and neglecting the excess mass Q4, the field arrangement of Q8 in Figure 13 can also be transformed into a field arrangement of groups of {W Z W} bosons, Figure 14:

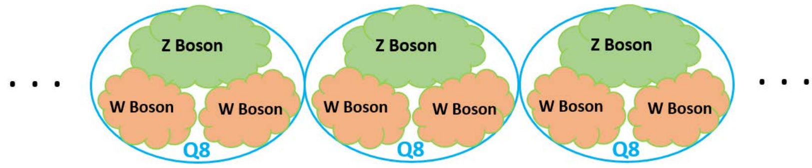

Figure 14. Groups of {W-Z-W} within Q8 and arranged along a spatial field path.

The symbolic expression becomes:

… Q8{W Z W} Q8{W Z W} Q8{W Z W} …

If we combine a Z boson with a W boson to form a top quark in each Q8 (see Figure 9, ignore also the small excess masses), we get an alternative field chain to Figure 14, as shown in Figure 15:

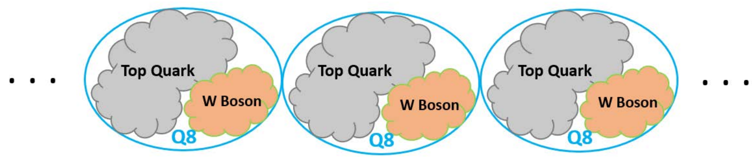

Figure 15. Groups of {TopQ -> W} within Q8 and arranged along a spatial field path.

Now we obtain a directed spatial field path, whereby the translation symmetry is partially lost (due to the direction of the field path):

… Q8{TopQ -> W} {TopQ -> W} Q8 {TopQ -> W} …

Obviously, the rearrangement of the neighboring top quark with the W boson also changes the direction of the field path, Figure 16:

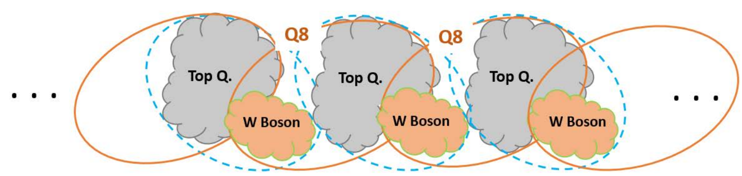

Figure 16. Rearrangement of Q8 by re-combining groups of {W <– TopQ] along a field path.

The field chain becomes now:

… {W <- TopQ} {W <- TopQ} {W <- TopQ} …

Based on the energies and masses involved, three heavy bosons (Higgs, Z and W boson, also with top quark) arrange themselves within the containing or between neighboring harmonic quarks Q8. Each constellation can represent a quantum state along a spatial field path of the underlying wave function.

7. Neutron and Proton in the Context of 253.4 GeV

The decay of Q8 with a mass of 253.4 GeV emits two HFPs for resulting Higgs bosons as well as a mass excess of about Q4 (1412.5 MeV, exactly 1410 MeV, Figure 4). This accounts for about 0.557% of the total field mass of 253.4 GeV. There is a possible and interesting interpretation for this mass if we also consider this excess in the context of the field interaction patterns described above, together with the heavy bosons involved.

Firstly, 1412.5 MeV corresponds to a mass of one and a half nucleons (e.g. a proton with 938.272 MeV or a neutron with 939.565 MeV). The possible combinations are listed below:

Q4 (1412.5) <~> Proton (938.272) + 1/2 Neutron (469.783) δ = 4.4 MeV < 0.4%

Q4 (1412.5) <~> Proton (938.272) + 1/2 Proton (469.136) δ = 5.1 MeV < 0.4%

Q4 (1412.5) <~> Neutron (939.565) + 1/2 Proton (469.136) δ = 3.8 MeV < 0.4%

Q4 (1412.5) <~> Neutron (939.565) + 1/2 Neutron (469.783) δ = 3.2 MeV < 0.4%

This numerical fact implies a quantum field context of its own, based on harmonic quarks, in which the hadron interacts with Higgs, Z and W bosons. Further research is required to uncover the underlying mechanism. The following considerations can be used for a rough description.

For the special harmonic quark Q4 (1412.5 MeV) we use the "nucleon field prototype, nfp" (lower case here because of the much smaller mass compared to HFP). We also refer to the nucleon as a nuc, so that two nfp(s) correspond to three nuc(s):

2 nfp <~> 3 nuc

The role of a half nucleon becomes clearer when two neighboring harmonic quarks Q8-Q8 are involved (namely within the field chain of Q8). The two neighboring half parts of a nucleon merge to form a complete nucleon. Since each harmonic quark Q8 can emit an excess mass nfp (Figure 7) by emitting a pair of HFP-HFP with larger mass or alternatively a group of W-Z-W, the Q8 chain in Figure 12 or Figure 14 can be expressed as follows:

… {HFP nfp HFP} {HFP nfp HFP} …

or

… {W (Z nfp) W} {W (Z nfp) W} …

while aggregated chain with Q8-Q8 pairs will get the forms:

… {{HFP nuc HFP nuc HFP nuc HFP}} …

or

… {{W Z nuc W nuc W Z nuc W}} …

These considerations lead to a simple explanation of why the baryon particles (e.g. neutron) are coupled with heavier bosons (e.g. W boson) in a decay process mediated by a weak interaction, as illustrated by the Feynman diagram in Figure 17 (Ref. [26]):

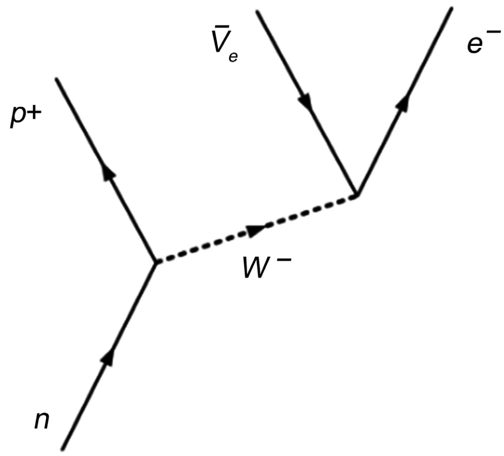

Figure 17. Feynman diagram for neutron decay.

This approach can also be used to interpret the real "spatial motion" of a nucleon through interaction with Higgs fields: The excited mass of 938/939 MeV from the energy field of Q8 (1412 MeV) "jumps" between associated HFPs (Higgs field prototypes with 126 GeV), passes over two half nucleon fields to a neighboring HFP and so on.

8. Some Predictions or Verifications That Can Be Tested Experimentally Using the LHC

If we follow the idea that the harmonic quark Q8 with a mass of 253.4 GeV represents an energy quantum field state that can be divided into two HFPs (Higgs field prototype Q7-{Q6-Q6-Q6}, Figure 2), each of which itself emits a Higgs boson and a ρ-meson, with an excess energy quantum state of 1.5 nucleons, we can claim that in the case of a head-on collision of two protons (frontal or inelastic scattering), when their total energy reaches 253.4 GeV, one of the following scenarios of the initial scattering pattern can occur:

- A pair of Higgs particles, a pair of $\rho(\pm)$ meson (770 MeV), one proton (or neutron) and three strange quarks;
- Three bosons (W – Z – W), one proton (or neutron) and a charged kaon (493.7 MeV);
- One W boson, one top quark and a pair of pions (135 MeV).

This means that an energy field of Q8 with a mass of 253.4 GeV is the prerequisite for the emission of heavy bosons in their various forms, accompanied by the formation of baryon particles such as protons or neutrons, mesons, or other leptons through subsequent decay processes.

9. Main Findings and Novelty, Possible Applications

The authors' research in the current paper on the particle masses of the SM uses an unusual methodological approach first developed and applied by O. A. Teplov. The novelty lies in combining mathematical quarks with their calculated masses to assemble the physical masses of the elementary particles of the SM. The most important results are:

- Extension of the existing mathematical quark series to a higher mass-energy quantum of 253.4 GeV, this is considered as the highest possible quark entity, namely the upper limit of the harmonic quark series, since there is no meaningful single physical particle that can exceed this energy-mass quantum.
- Demonstration of the relationship between this special quark entity (mass) and the physical particle masses of the heavy bosons and the top quark. These relationships extend the results obtained by O. A. Teplov in his early research work. They will also constrain the energy spectrum to produce heavy particles, especially the emission of a Higgs boson, its decay, the possible initial particles, and their grouping behavior. They also allowed the authors to make predictions that can potentially be tested by LHC experiments (Section 8).

Other possible practical applications may include: The concatenation of harmonic quarks as a spatial field path (Section 6) and the consideration of interactions with contained and neighboring heavy bosons may offer a new way to study quantum field interactions on a generalized level. Each harmonic quark behaves like a quantum field (eigen)state of the wave functions. Some interesting results (e.g. concerning the energy-mass and the spatial motion of a particle) can be obtained without getting lost in the tedious search for detailed solutions.

The theory still lacks a sophisticated quantum field solution for the "harmonic quark series", although the calculation patterns are derived from the harmonic oscillation theory and although very interesting correspondences of the mass quanta to the physical particles of the SM and even to the reduced Max Planck constant, the formulae (4.x) and (5.x), have been discovered.

10. Discussion of Physical and Mathematical Aspects

Two aspects represent an essential innovation of our approach: Namely, the consideration of the mass of an elementary particle of the SM as composed of harmonic quarks and the consideration that likewise a harmonic quark can be composed of elementary particles of the SM (Sections 2-5). Mass composition does not mean the composition of physical entities. If harmonic quarks are involved, they must be considered as "virtual" entities, as part of the new mathematical concept. Other physical aspects (electricity and colors of quarks) are also important for virtual composition, we have not treated them throughout because they are beyond the scope of this paper.

For example, a physical investigation would conclude that the emission of a pair of Higgs bosons (**Figure 4**) implies that they are the product of inverse pair annihilation. The participation of two W bosons as a possible emission of the Q8 decay (**Figure 6**) also leads to a pair of positively and negatively charged W bosons. These considerations must also be applied in detail for all subsequent decays and, of course, for further investigations in the future.

It should also be mentioned that, in contrast to usual approaches (e.g., Ref. [27], [28]), the emission of Higgs bosons is based on a virtual entity, namely a harmonic quark with a well-defined mathematical energy-mass quantum. This also leads to a certain grouped occurrence of particles as a boundary condition.

11. Summary and Outlook

We have used the harmonic quark with a mass of 253.4 GeV according to the Teplov generation scheme and have shown some quantitative, interesting relations to the masses of heavy bosons and mesons. In general, Teplov and the authors of this paper are of the opinion that the harmonic quark series are constituent quantum field states with significant symmetries. When these are broken, the particles of the Standard Model emerge. There is a strong indication that the heavy harmonic quark with an energy quantum of 253.4 GeV simultaneously produces heavy bosons, intermediate range mesons and a light harmonic quark with an energy quantum of 1412.5 MeV, which in turn produces the baryon mass of a proton or/and a neutron, and again a lighter harmonic quark with an energy quantum of 0.588 MeV, which in turn contains the mass of an electron. This could be an alternative way to study the interactions between SM particles and Higgs fields. A sophisticated mathematical formalism for this description has yet to be developed.

Harmonic quarks with masses smaller than 7.873 MeV (**Table 2**) extend the Teplov series to the range of downward excited small masses. They are essential for the study of the light particles of the SM, down quark (~4.7 MeV), up quark (~2.2 MeV) and electron (0.511 MeV). The authors believe that they are even important for the understanding of neutrinos and photons and are pursuing further research approaches.

In summary, there are wonderful correspondences between two chains ordered by mass: the harmonic quark series on one side and the standard model particles on the other. Therefore, it is important to find out the governing systematics behind these two "dancing chains" on the mass scale.

Acknowledgements

Some time ago, we learned about the death of O. A. Teplov. We would like to take this opportunity to express our deepest condolences on his departure from the world and on the loss of a pioneering thinker in physics.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Teplov, O.A. (2003) Harmonic Quarks and Their Precise Masses. arXiv: hep-ph/0306215 https://arxiv.org/abs/hep-ph/0306215

[2] Teplov, O.A. (2003) Harmonic quarks: Properties and Some Applications. arXiv: hep-ph/0308207 https://arxiv.org/abs/hep-ph/0308207

[3] Teplov, O.A. (2004) The Harmonic Quarks and Hadrons Up to 1000 MeV. arXiv: hep-ph/0408205 https://arxiv.org/abs/hep-ph/0408205

[4] Teplov, O.A. (2005) Precise Mass Spectrum of Mesons with Open Charm in the Harmonic Quarks and Oscillators. arXiv: hep-ph/0505267 https://arxiv.org/abs/hep-ph/0505267

[5] Yang, H. and Yang, W. (2022) Possible Modular Structure of Matter Based on the "YY Model" Approach—An Overview of the Construction Rules for Quarks and Atomic Nuclei with Configurative Examples for Neutron, Proton, Deuteron and Dineutron. *Journal of Modern Physics*, **13**, 225-255. https://doi.org/10.4236/jmp.2022.132016

[6] Yang, H. and Yang, W. (2020) Manifestation of Color Confinement in the YY Model for Atomic Nuclei. *Journal of Modern Physics*, **11**, 1999-2010. https://doi.org/10.4236/jmp.2020.1112127

[7] Yang, H. and Yang, W. (2022) The Fundamental Relationship between Harmonic Quark Masses and Reduced Max Planck Constant. *Journal of Modern Physics*, **13**, 858-863. https://doi.org/10.4236/jmp.2022.136049

[8] Navas, S., *et al.* (2024) Light Quarks (*u*, *d*, *s*). *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-light-quarks.pdf

[9] Navas, S., *et al.* (2024) μ MASS (Atomic Mass Units U). *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-muon.pdf

[10] Navas, S., *et al.* (2024) π^0 MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-pi-zero.pdf

[11] Navas, S., *et al.* (2024) Charged Kaon Mass. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-K-plus-minus.pdf

[12] Navas, S., *et al.* (2024) ρ(770) Mass. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-rho-770.pdf

[13] Navas, S., *et al.* (2024) p MASS (MeV). *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-p.pdf

[14] Navas, S., *et al.* (2024) $\pi^{\pm}$ MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-pi-plus-minus.pdf

[15] Navas, S., *et al.* (2024) n MASS (MeV). *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-n.pdf

[16] Navas, S., *et al.* (2024) *c*-QUARK MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-c-quark.pdf

[17] Navas, S., *et al.* (2024) b-QUARK MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-b-quark.pdf

[18] Navas, S., *et al.* (2024) η'(958) MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-eta-prime-958.pdf

[19] Beringer, J., *et al*. (2013) $b\bar{b}$ MESONS, Υ(1S). *Physical Review D*, **86**, 010001. https://pdg.lbl.gov/2013/tables/rpp2013-tab-mesons-b-bbar.pdf

[20] Navas, S., *et al*. (2024) t-QUARK MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-t-quark.pdf

[21] Navas, S., *et al*. (2024) W MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-w-boson.pdf

[22] Navas, S., *et al*. (2024) H MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-higgs-boson.pdf

[23] Navas, S., *et al*. (2024) K^* (1410) MASS. P *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-K-star-1410.pdf

[24] Navas, S., *et al*. (2024) Z MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-z-boson.pdf

[25] Navas, S., *et al*. (2024) φ(1020) MASS. *Physical Review D*, **110**, Article ID: 030001. https://pdg.lbl.gov/2024/listings/rpp2024-list-phi-1020.pdf

[26] Hayes, C.B. (2012) Neutron β-Decay. Department of Physics and Astronomy. http://aesop.phys.utk.edu/ph611/2012/projects/Hayes.pdf

[27] Wang, Y., *et al*. (2024) One-to-One Correspondence Reconstruction at the Electron-positron Higgs Factory. arXiv: 2411.06939 https://arxiv.org/pdf/2411.06939

[28] Ahmed, I., *et al*. (2024) Exploring Charged Higgs at the Future Circular Collider (FCC): A Review of Two-Higgs-Doublet Models. arXiv: 2411.04652 https://arxiv.org/pdf/2411.04652