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## **A possible Explanation for the g-2 Experiment in Fermilab**

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## **Abstract**

The g-2 experiment at Fermi Lab shows that there is a difference for g for muons from two. This result becomes more and more secure and more reliable thanks to improved measurements. Now the question is what this result means for particle theory and/or how it can be explained. However, this result can also be explained by the assumption that the muon is not a point-shaped particle, but that the muon is a composite particle. A theory is presented here below that leads, among other things, to the muon being a composite particle. This would be consistent with the results of the g-2 experiment conducted at the Fermi Lab.

## **Introduction**

### **The color force and the strong interaction**

The color force is defined as a fundamental property of quarks, which is characterized by the associations between baryons [1]. The strong interaction extends beyond neutrons and protons, resulting in extraordinary properties that have not previously been noted between nucleons. The baryons facilitate the strong interaction and a residual force that does not taper off with distance. This process effectively results in the confinement of quarks. Conventionally, naturally occurring energy exists and expedites quark–antiquark pair production [2,3,4]. Due to the strong nature of the color force carried by the exchange of gluons, the quarks do not undergo separation.

Previous studies have reported that within the confines of a given space, quarks behave as free particles, as the color force exerts minimum pressure at short distances [5]. Stronger forces begin to be realized as further separation occurs. This concept is analogous to the widely held scientific understanding that ordinary mesons composed of conventional quarks are bound closely by the color force. This construct has immense scientific importance, especially in providing an in-depth understanding of atomic nuclei and defining the associations and interactions between neutrons, quarks, and protons [5,6,7]. The mediation of these relationships by gluons forms the foundation of quantum chromodynamics and is commonly used to discuss complex physical phenomena, including chiral symmetry breaking, asymptomatic freedom, and head collar confinement [8, 9].

Gluons act as gauge bosons or exchange particles that facilitate interaction between quarks via the strong force. Essentially, they enable the exchange of photons between charged particles via the electromagnetic force in addition to binding them together to form hadrons. Bosons are carrier particles with full-integer spin numbers, while fermions have odd half-integer spin numbers. Both types of particles act as force carriers, with the latter obeying the Pauli exclusion principle [8,9,10]. Conventionally, the color charge depends on the configuration of the particles. For instance, mixing together red, blue, and green results in white, with a net charge of zero. Additionally, the force may be negative, resulting in the emergence of cyan, magenta, and yellow. Fundamentally, the color charges exhibit a force that tends to remain constant despite separation but results in a corresponding increase in energy and subsequent spontaneous production of a quark–antiquark pair [11].

The concept of the color force is believed to have been introduced by Oscar Greenberg, who first theorized about the existence of quarks in 1964 [12]. Greenberg documented the phenomenon after an extensive analysis of the Pauli exclusion principle and its relation to the construct. He believed that this theory explained the coexistence of quarks within select hadrons despite exhibiting identical quantum states [13], a situation that would otherwise have constituted a theoretical impossibility due to its violation of the Pauli exclusion principle [14,15,16].

In 1964, Greenberg proposed that quarks were parafermions of order 3, and the corresponding implicit degree of freedom was soon perceived by Han and Nambu and called color [13].

Since that time, there have been extensive developments in quantum chromodynamics toward an improved understanding of quarks and the theory of the color force. Other individuals who have made immense contributions included Murray Gell-Mann, Heinrich Leutwyler, and Harald Fritsch. The concept has been revolutionary in enhancing the understanding of quantum electrodynamics due to the many similarities between the two fields. The strong force has been determined to have minimal behavioral autonomy over the basic subatomic particles constituting atomic nuclei.

The theories of the strong force and other associated aspects of quantum chromodynamics (QCD) were developed to provide an improved understanding of the roles of each aspect of the three-value color charge. Fundamental QCD concepts, including gluons, antiquarks, and quarks, remained relatively obscure prior to the discovery of the color force. Related analyses have been fundamental to the furthering of scholarly discourse as well as inspiring a plethora of other industrial applications, including specialist lighting such as in theatres and outdoors.

Starting from the well-known connection between the Rydberg constant and the electron mass, we start with the Rydberg energy:

$$E_{Rydberg} = \frac{1}{2} m_e c^2 \alpha^2 \quad (1)$$

in [eV], where alpha is the Sommerfeld fine structure constant.

Now, there are several methods and formulas for calculating the Sommerfeld fine structure constant, which is equal to approximately 1/137, by using the mathematical constant pi.

We use the following formula for the Sommerfeld fine structure constant alpha:

$$\alpha = \frac{2 \cdot \sqrt{\sqrt{1 - \frac{1}{3\pi}}}}{27\pi^2} \quad (2)$$

Next, we calculate the smallest quantum of mass and/or energy according to the Rydberg energy:

$$E_{Rydberg} = \frac{1}{2} m_e c^2 \alpha^2 \quad (1)$$

$$E_{Rydberg} = 13.60569 \text{ eV} \quad (3)$$

$$m_{Rydberg} = 13.60569 \text{ eV}/c^2 \quad (4)$$

This number is postulated here to be the smallest possible amount of mass and/or energy involved in crystallization of energy toward mass and in mass formation. It is the smallest amount of binding energy.

From both equations above, we obtain a formula for the electron mass as follows:

$$m_e = \frac{1}{2} 3^2 (3\pi)^4 \left( \frac{1}{\sqrt{\sqrt{\sqrt{\left(1 - \frac{1}{3\pi}\right)}}}} \right)^4 m_{Ryd} \quad (5)$$

We now consider this equation to be a special case of the following generalization of this formula to obtain the following generalized equation.

$$m_{particle} = 2^a 3^b (3\pi)^c \left( \frac{1}{\sqrt[8]{\sqrt{\left(1 - \frac{1}{3\pi}\right)}}}} \right)^d m_{Ryd}, \quad (6)$$

with a=-1, b=2, c=4, and d=4 for the electron e.

We now postulate that we can obtain all other particle masses through different combinations of (a,b,c,d)-tuples. However, it remains unclear how to interpret this last equation.

### **The Feynman-like ensemble of binding states within a single particle is related to the particle's partition function**

A single particle can be formulated as a series of different binding states. This series of different formulations of binding states forms an ensemble comparable to the statistical microcanonical ensembles used in statistical thermodynamics and/or statistical quantum mechanics.

In statistical quantum mechanics, if a system can be subdivided into N subsystems, then the total partition function is given by the product of the partition functions for the individual subsystems. Z and/or Omega is the **microcanonical partition function** (which depends on the multiplicity or number of possible configurations of the system/particle) [17]:

$$Z = \prod_{j=1}^N \zeta_j \quad \text{or} \quad \Omega = \prod_{j=1}^N \omega_j \quad (7a+7b)$$

Accordingly, the probability P is as follows [17]:

$$P = \frac{1}{\Omega} = \frac{1}{\prod_{j=1}^N \omega_j} \quad (8)$$

Starting from the Feynman-like ensemble for a complex particle, a single binding form is regarded as such a microcanonical subsystem here. There are four possible binding forms: two-quark binding (color and anticolor), three-quark binding (three colors), 3-vertex gluon interaction, and 4-vertex gluon interaction.

Within each of these binding-type subsystems, all the remaining subsubseries elements represent different subforms of the corresponding binding type. The elements of these subforms all have the same physical properties. Thus, their partition function, in turn, has a power-function form:

$$\zeta_j = \zeta_{jj}^n \quad \text{or} \quad \omega_j = \omega_{jj}^n \quad (9a+9b)$$

Here,  $n$  is the number of subsubseries present in the particle, meaning the number of two-quark interactions, three-quark interactions, 3-vertex gluon interactions, or 4-vertex gluon interactions.  $\zeta_{jj}$  is the energy of each of the basal binding states, i.e., the basal energy of the two-quark binding state, the three quark binding state, the 3-vertex state, or the 4-vertex state.

The basal energy  $\zeta_{jj}$  of each individual binding state can be visualized by an arrow in a Feynman-like diagram and corresponds to one single gluon. The basal energy of two-quark binding is represented by two arrows and two gluons, one of which is colorless and one of which is colored. The basal energy of three-quark binding is represented by three arrows and three gluons (r, g, and b). The basal energy of a 3-vertex gluon interaction can be visualized by three half-circles (the Dyson–Schwinger equations and the swordfish diagram) and is given by an arrow of length  $3\pi$ , and the basal energy of a 4-vertex gluon interaction is given by  $\frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}}$  and will be explained below.

Dyson-Schwinger equations, also named Schwinger-Dyson equations, are relations between various Green's functions of a quantum field theory found by Freeman Dyson and Julian S. Schwinger. Since they represent the equations of motion for Green's functions, they are also often called the Euler–Lagrange equations of quantum field theory. There are infinitely many functional differential equations, all of which are directly or indirectly coupled to one another. That is why one often speaks of the infinite tower of the Dyson-Schwinger equations.

The Dyson equations were originally derived by Dyson by summing an infinite number of Feynman diagrams and were extended by Schwinger in his quantum action principle to all Green's functions of any quantum field theory. Graphically, in the Feynman diagrams, sword fish diagrams result if the Dyson-Schwinger equations are applied to the 3 gluon vertices, which are virtual particles. Summing up these three half circles, the way-length within the 3 gluon vertex is  $3\pi$  in length. If we associate the length of virtual particles with energy, then the energy needed for the 3 gluon vertices is  $3\pi$  as the amount of a normal interaction.

In the following, considerations will be presented on partition functions in the context of particles at the elementary level. These particles consist either of quarks and gluons or only of gluons.

Both quarks and leptons are thought to consist of even smaller particles, the rishons. There are two fundamental rishons: the T-rishon and the V-rishon. All this is in-line with the H. Harari preon model described, e.g., in “A schematic model of quarks and leptons” Physics Letters 1997 [18].

An important initial hypothesis is that these particles cannot be broken down into even smaller particles.

Another important hypothesis is that fundamental particles (such as V and T) do not possess energy and/or mass. All energy and/or mass is the result of intraparticle interactions.

From these basic assumptions, it follows that even leptons (e.g., electrons) need to be composed of particles and that there needs to be some sort of interaction inside leptons.

The total partition function of a particle can be seen as an ensemble of subsystems and can be expressed as a product of the individual partition functions for these subsystems:

$$Z = \prod_{j=1}^N \zeta_j = \prod_{j=1}^N \zeta_{jj}^n = \zeta_2 \cdot \zeta_3 \cdot \zeta_{3\text{-vertex}} \cdot \zeta_{4\text{-vertex}} = \zeta_{2j}^a \cdot \zeta_{3j}^b \cdot \zeta_{3\text{-vertex},j}^c \cdot \zeta_{4\text{-vertex},j}^d \quad (10)$$

$$\Omega = \prod_{j=1}^N \omega_j = \prod_{j=1}^N \omega_{jj}^n = \omega_2 \cdot \omega_3 \cdot \omega_{3\text{-vertex}} \cdot \omega_{4\text{-vertex}} = \omega_{2j}^a \cdot \omega_{3j}^b \cdot \omega_{3\text{-vertex},j}^c \cdot \omega_{4\text{-vertex},j}^d \quad (11)$$

Consequently, at the elementary level, the total partition function must result from a product of individual partial partition functions.

### Considering quark color interactions

The task of these individual partial partition functions is to describe the individual interactions in an elementary particle and capture them mathematically. The following question therefore arises: What interactions exist at the elementary level? The answer is the color interactions among three quarks (i.e., **rgb** and **rgb**). In interactions of this form, three quarks and three standard gluons are always involved simultaneously. The number of standard gluons or interactions is thus three to the power of n. The partial partition function for this kind of interaction is consequently three to the power of b, where b is the number of three-gluon interactions that exist per particle.

$$\zeta_3 = \omega_3 = 3^b \quad \text{for } n=b \text{ three-color interactions per particle} \quad (12)$$

Another elementary interaction is the color–anticolor interaction between two quarks (e.g., in  $q\bar{q}$ ). Two quarks (a colored quark and an anticolored quark) and two standard gluons (a neutral and a colored gluon) are always involved in this interaction. The number of gluons or interactions is therefore two times the power of  $a$ . The corresponding partial partition function is similarly two times the power of  $a$ .

Here,  $a$  denotes the number of two-gluon interactions per particle. For quantum mechanical reasons, this bond is always mediated by two gluons that are exchanged between the quarks one after the other: first, a neutral gluon is exchanged, and then, a color gluon is exchanged.

$$\zeta_2 = \omega_2 = 2^a \quad \text{for } n=a \text{ color–anticolor interaction per particle} \quad (13)$$

### Considering the gluon vertices

According to the Dyson–Schwinger equation (DSE), the **3-vertex** interaction of a gluon can be described as the sum of three semicircles.

The 3-gluon vertex can be converted into a circular structure using a DSE on-loop correction. Doing so creates three circles with an entrance and with a 3-vertex, all facing each other at  $180^\circ$  [19]. This corresponds to a path length between entry and 3-vertex of 3 times  $1\pi$ . When using the Dyson–Schwinger equations, three such swordfish diagrams arise, each with a weighting of  $\frac{1}{2}$ , so that the loop correction leads to a total path length of  $3\pi$  for the 3-gluon vertex [19], [20].

$$\zeta_{3\text{-vertex},j} = \omega_{3\text{-vertex},j} = \frac{1}{2}(2\pi) + \frac{1}{2}(2\pi) + \frac{1}{2}(2\pi) = 3\pi \quad (14)$$

The distance that a gluon travels in this form of interaction is thus  $3\pi$  times as long as the ordinary gluon distance in one of the two interactions mentioned above. Consequently, the partial partition function for this form of interaction can be described as the term  $3\pi$  to the power of  $c$ . Here,  $c$  is again the number of interactions of this type per particle.

$$\zeta_{3\text{-vertex}} = \omega_{3\text{-vertex}} = (3\pi)^c \quad \text{for } n=c \text{ 3-vertex interactions per particle} \quad (15)$$

Now, the **4-vertex** interaction between two gluons is considered. The probability of this interaction occurring is proportional to the total probability (100%) minus the probability of the 3-vertex interaction occurring. This probability of the 3-vertex interaction occurring is the reciprocal of the partition function of the 3-vertex interaction. Therefore, the probability of the 4-vertex interaction occurring is proportional to  $1-1/(3\pi)$ . Since this interaction corresponds to a collision event involving two of the eight possible gluons, the 8th root of the term  $1-1/(3\pi)$  must be taken. The partial partition function of the 4-vertex interaction is then the reciprocal of this probability and thus



proportional to  $1/(8\text{th root}(1-1/(3\pi)))$  to the power of  $d$ . Again,  $d$  denotes the number of interactions of this type per particle.

$$\zeta_{4\text{-vertex}} = \omega_{4\text{-vertex}} = \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^d \quad \text{for } n=d \text{ 4-vertex interactions per particle} \quad (16)$$

### A closer look at quark color interactions a and b: Binding and nonbinding events

When looking at the partial partition functions  $\zeta_2$  and  $\zeta_3$ , we need to differentiate between events that have a binding nature, which should be considered negative, and events that have a nonbinding nature, which should be considered positive. This leads us to quotients for  $\zeta_2$  and  $\zeta_3$ , which are defined as follows:

$$\zeta_2 = \omega_2 = \frac{2^{a(\text{nonbinding})}}{2^{a(\text{binding})}} \quad \text{meaning that} \quad a > 0 \Rightarrow \text{nonbinding event} \Rightarrow \text{energy needed} \quad (17)$$

$$a < 0 \Rightarrow \text{binding event} \Rightarrow \text{energy released}$$

$$\zeta_3 = \omega_3 = \frac{3^{b(\text{nonbinding})}}{3^{b(\text{binding})}} \quad \text{meaning that} \quad b > 0 \Rightarrow \text{nonbinding event} \Rightarrow \text{energy needed} \quad (18)$$

$$b < 0 \Rightarrow \text{binding event} \Rightarrow \text{energy released}$$

### Calculation of all possible combinations of interaction possibilities for the nucleon (proton or neutron)

To calculate the number of interaction possibilities for the proton, a hypothesis must first be formulated:

In the following, the hypothesis is formulated that in the ground state, only two gluon–gluon interactions can follow one another. More than two interactions can follow one another only in higher or excited energy states of the nucleon. Such higher excitation states are realized in the sigma baryon, for example.

Based on this premise, the number of possible interaction combinations can be counted graphically, as illustrated in figure 1. The following numbers of possible combinations result for a nucleon in the ground state:

**The total partition function for the nucleon ((a,b,c,d)=(0, -2,9,4)) is as follows:**

$$Z_p = \Omega_p = 2^0 \cdot 3^{-2} \cdot (3\pi)^9 \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^4 = 6.8953127 \cdot 10^7 \quad (19)$$

or, in logarithmic form:

$$\ln Z_p = \ln \Omega_p = 0 \cdot \ln(2) - 2 \cdot \ln(3) + 9 \cdot \ln(3\pi) - \frac{4}{8} \ln \left( 1 - \frac{1}{3\pi} \right) \quad (20)$$

**The total partition function for the neutral pion ((a,b,c,d)=(-1,1,7,0)) is as follows:**

$$Z_{pion} = \Omega_{pion} = 2^{-1} \cdot 3^1 \cdot (3\pi)^7 \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^0 = 9.908071 \cdot 10^6 \quad (21)$$

or, in logarithmic form:

$$\ln Z_{pion} = \ln \Omega_{pion} = -\ln(2) + \ln(3) + 7 \cdot \ln(3\pi) - \frac{0}{8} \ln \left( 1 - \frac{1}{3\pi} \right) \quad (22)$$

**The total partition function for the neutral sigma baryon ((a,b,c,d)=(-3,2,8,16)) is as follows:**

$$Z_{Sigma} = \Omega_{Sigma} = 2^{-3} \cdot 3^2 \cdot (3\pi)^8 \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^{16} = 8.7648980 \cdot 10^7 \quad (23)$$

or, in logarithmic form,

$$\ln Z_{Sigma} = \ln \Omega_{Sigma} = -3 \ln(2) + 2 \ln(3) + 8 \cdot \ln(3\pi) - \frac{16}{8} \ln \left( 1 - \frac{1}{3\pi} \right) \quad (24)$$

**For the electron, the following total partition function  $Z_e$  is obtained:**

$$Z_e = \Omega_e = 2^{-1} \cdot 3^2 \cdot (3\pi)^4 \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^4 = 37553 \quad (25)$$

$$\ln Z_e = \ln \Omega_e = -1 \cdot \ln(2) + 2 \cdot \ln(3) + 4 \cdot \ln(3\pi) - \frac{4}{8} \ln \left( 1 - \frac{1}{3\pi} \right) \quad (26)$$

At first sight, the electron seems to have nothing to do with gluon interactions. However, according to the Rishons model (or preon model or Harari model), leptons are also composed of electrons from even smaller particles. According to Harari, these are the T- and V-particles. The rishons- composition of the electron is anti-T; anti-T; anti-T. Therefore, it is composed of three identical anti-T particles. In a later variant, Harari and Seiberg differentiated the electron to be composed of anti-T-R, anti-T-R, and anti-T-L [21]. They described how the electron is an  $e^- = (T_R T_R) T_L$  particle (table 8, page 156 in [21]).

The meaning of the electrons n-tuple (-1;2;4;4) could be interpreted as follows: the electron inside itself has 1 binding 2-particle interaction (the so called binding hypercolor H according to Harari et al, e.g., anti-T-R and anti-T-R), 2-nonbinding 3-particle interactions (anti-T-R; anti-T-R; anti-T-L and anti-T-L; anti-T-R; anti-T-R), four 3-vertices interactions and four 4-vertices interactions. In the case of the electron, these four 3-vertices and four 4-vertices interactions might be substantially different from the 3 and 4 gluon-vertices in the case of the more complex particles. Most likely, in the case of the electron, both interactions (3-vertex and 4-vertex) are combined to form four combined (3-vertex/4-vertex)- interactions. The easiest way to realize this structure is a linear formation. In this linear formation, we start with the first anti-T, followed by the first 3-vertex, next two 4-vertices, a second 3-vertex, the second anti-t, the third 3-vertex, two more 4-vertices, the fourth 3-vertex and the last anti-T-L. Counted together, we used the (-1;2;4;4) elements to form the structure.

### **Elements of the Higher Lepton Generations**

Elbaz et al. expanded the Harari Preon model toward higher generation of leptons [22], [23], [24]. To do so, they interpreted the higher lepton generations as excited states of the electron.

If we look at the exponent tuples for the muon (-3;2;7;3) and the tauon (1;2;7;7), we see a further analogy. Additionally, in the present theory, they are both excited states with an increased number of intraparticle interactions. We now have the interactions that make the excited states of the leptons and quarks, for which Elbaz and others were looking.

It can be realized that by comparing complex particles and leptons, even if different in nature, there seems to be some kind of repetition of the fundamental rules and laws between leptons and the more complex particles. Analogously the interactions and vertices seem to be some kind repeated.

### Weak and Strong Interaction

If we associate the n-tuple of compound particles (as baryons and mesons) with their strong interaction (color interaction) and the n-tuple of leptons and quarks with their weak interaction, we can easily see that there are many analogies between strong and weak interactions. Both types of interactions can be divided into 4 more basal interactions (which are the 2-particle, 3-particle, 3-vertex and 4-vertex interactions).

However, there are also some differences between the strong and weak interactions. First, we do not see negative a- and/or b-exponents within the weak interaction for quarks but only for leptons.

However, if we transfer this to the beta decay, which is in most cases the decay of a neutron, we obtain.

### Beta-Decay

$$d^{-0.3} \rightarrow u^{+0.67} + W^- \rightarrow u^{+0.67} + e^- + \bar{\nu} \quad (27)$$

Rishons:

$$\underline{VVT}^{-0.3} \rightarrow TTV^{+0.67} + (\underline{TT})\underline{TVV(V)} \rightarrow TTV^{+0.67} + \underline{TTT} + \underline{VVV}$$

Interactions:

$$(2;2;4;8) \rightarrow (1;2;4;8) + (0;0;10;5) \rightarrow (1;2;4;8) + (-1;2;4;4) + (-1;-2;0;0)$$

### Myon-Decay

$$\mu^- \rightarrow W^- + \nu_\mu \rightarrow e^- + \bar{\nu}_e + \nu_\mu \quad (28)$$

Rishon:

$$[\underline{\text{TTT}} + 3\underline{\text{VV}}] \rightarrow (\underline{\text{TT}})\underline{\text{TVV}}(\underline{\text{V}})^- + \underline{\text{VVV}} \rightarrow \underline{\text{TTT}}^- + \underline{\text{VVV}} + \underline{\text{VVV}}$$

Interactions:

$$(-3;2;7;3) \rightarrow (0;0;10;5) + (-1;-0;0;0) \rightarrow (-1;2;4;4) + (-1;-2;0;0) + (-1;-0;0;0)$$

### Pion-Decay

$$\pi^-(\underline{u},\underline{d}) \rightarrow W^- \rightarrow \mu^- + \nu_{\underline{\mu}} \quad (29)$$

Rishon:

$$\underline{\text{TTV}}^{-0.67} + \underline{\text{VVT}}^{-0.3} \rightarrow (\underline{\text{TT}})\underline{\text{TVV}}(\underline{\text{V}})^- \rightarrow \underline{\text{TTT}}^- + \underline{\text{VVV}}$$

Interactions:

$$(1;2;4;8) + (2;2;4;8) \rightarrow (0;0;10;5) \rightarrow (-3;2;7;3) + (-1;0;0;0)$$

### Strange-Quark-Decay

$$\underline{s}^{+0.33} \rightarrow W^+ + \underline{u}^{-0.67} \rightarrow \underline{u}^{-0.6} + \pi^+(\underline{u},\underline{d}) \quad (30)$$

from  $K^+(\underline{s},\underline{u})$   from  $\pi^0(\underline{u},\underline{u})$

Rishon:

$$[2\underline{\text{TT}} + \underline{\text{VV}} + \underline{\text{VVT}}^{+0.3}] \rightarrow (\underline{\text{TT}})\underline{\text{TVV}}(\underline{\text{V}})^+ + \underline{\text{TTV}}^{-0.67} \rightarrow \underline{\text{TTV}}^{+0.66} + \underline{\text{VVT}}^{+0.33} + \underline{\text{TTV}}^{-0.66}$$

Interactions:

$$(3;2;5;17) \rightarrow (0;0;10;5) + (1;2;4;8) \rightarrow (1;2;4;8) + (2;2;4;8) + (1;2;4;8)$$

Therefore, the Rishon-content of the strange quark and myon are written according to Elbaz [23,24].

According to the Elbaz notation of the elementary particles [24], which is slightly modified here, the intraparticle interactions are as follows:

Electron:  $a=-1$  [TTT(VV)]

Myon:  $a=-3$  [TTT(VV)<sub>3</sub>]

strange-Quark:  $a=3$  [VVT(TT)<sub>2</sub>(VV)]

$$a=4-1=3$$

[ V V ... T (-1,2,4,4)

[ V V ... T (-3.2.7.3)

[ V V ... V (3,2,5,17)

T

V V ... T

T T ... T

T ]

V V ... T ]

V ... T T ]

1 binding

3 binding

4 nonbinding, 1 binding

It can be recognized that a binding 2-particle interaction ( $a<0$ ) occurs between an antimatter T and a matter V and/or a matter T and an anti-matter V. It seems that **both need to change** T to V and matter to antimatter to form a binding interaction.

On the other hand, a matter V- to antimatter V interaction and/or a matter T- to antimatter T interaction, as in the strange quark, is nonbinding ( $a>0$ ). Additionally, T to V and/or anti-T to anti-V binding, as in the u-quark, d-quark, and s-quark, is nonbinding. Homomorphic bindings such as TT, TT and/or VV and/or VV bindings in the particles are not counted.

u-quark  $a=1$  [TTV]

u-quark  $a=1$  [TTV]

d-quark  $a=2$  [VTV]

[ T (1,2,4,8)

[ T (1,2,4,8)

[ V (2,2,4,8)

T

T

T

V ]

V ]

V ]

1 nonbinding

1 nonbinding

2 nonbinding

Tauon:  $a=1$  [TTT(VV)<sub>6</sub>]

W<sup>+</sup>-particle  $a=0$  [TTT(VVV)]

Z-particle:  $a=0$  [VVV(VVV)]

[ V V ... T (1,2,7,7)

[ V ... T (0,0,10,5)

[ V ... V (0,0,10,14)

V V ... T

V ... T

V ... V

V V ... T

V ... T ]

V ... V ]

(V V)<sub>3</sub> ...

1 nonbinding

zero binding

zero binding

$$v_t=[VVV(VV)_3]$$

$$W^- \text{-particle } a=0 \text{ [TTT(VVV)]}$$

$$v_e=[VVV]$$

When forming the W-particle, TTV is added to d, and the a- and b-interactions are somewhat lost. Only the c and d interactions are possible in the W-particle. Afterward, the W-particle forms two particles with a and b interactions again.

Modifications of the Elbaz notations were made to meet the particle decays.

**For the proportionality factor between the value of the partition function and the rest energy (equivalent to the rest mass) of the particle, the following values are obtained for the nucleon, the electron and the sigma baryon:**

for the proton:

$$f_p = E_{0,p} / Z_p = \frac{E_{0,p}}{\Omega_p} = 938.272 \cdot 10^6 \text{ eV} / 6.8953127 \cdot 10^7 = 13.6074137 \text{ eV} \quad (31)$$

for the electron:

$$f_e = E_{0,e} / Z_e = \frac{E_{0,e}}{\Omega_e} = 0.51099895 \text{ MeV} / 37553 = 13.6074068 \text{ eV} \quad (32)$$

for the sigma baryon:

$$f_{Sigma} = E_{0,\Sigma} / Z_{\Sigma} = \frac{E_{0,\Sigma}}{\Omega_{\Sigma}} = 1192.642 \cdot 10^6 \text{ eV} / 8.7648980 \cdot 10^7 = 13.60702657 \text{ eV} \quad (33)$$

### Rydberg proportionality factor

This factor is almost identical to the Rydberg energy ( $E_{\text{Ryd}}=13.605693122 \text{ eV}$ ). At first glance, this result seems astonishing. Since the 1s electron in the hydrogen atom is currently thought to be

almost electrostatically and/or QED- bound to the proton, we might expect that the Rydberg energy would be related to electrostatic and/or QED- binding. If we assume, however, that the Rydberg energy does not merely represent the binding energy of the electron to the proton but rather should be considered the smallest energy quantum for all binding, then the problem is solved. This smallest amount of binding represents binding in general and the binding energy in every particle.

Additionally, it becomes clear that the more interactions are present in a particle and the more binding-quanta are therefore needed and present in the particle, the more binding energy must consequently result and be present in the respective particle. This binding energy now seems to exist in a quantized form only, and the smallest quantum of this binding energy seems to be identical to the Rydberg energy. Hence, the Rydberg energy is not only the ionization energy of the hydrogen atom but also has a much more general meaning and importance.

If we consider the zero-tuple (0,0,0,0), then this zero-tuple has a value of 1 Rydberg. Therefore, for a binding mediated through zero gluons and with zero vertices involved, a binding energy of 1 Rydberg remains.

It could also be that, in a yet-to-be developed theory that is not within the well-established theories of QCD and/or QED, the binding of the 1s electron to the proton in hydrogen and helium is mediated through a new quantum represented by the zero-tuple (0,0,0,0) (called (0,0,0,0)- binding herein); this (0,0,0,0)- binding and the other particular binding energies seem to have a common origin, as they are similar in nature and energy level. They all represent an intraparticle quantum-mechanical binding state. In this newly developed theory, the binding of the 1s electron would not only be of electrostatic and/or QED nature but also of this novel general quantum-mechanical nature and would probably be mediated by a new quantum particle. This could be the case because of the close distance between the 1s electron and the proton and should then be related to the 1s electron only.

For quantum mechanical reasons, the 1s electron can approach extremely close to the proton in the density distribution.

The Rydberg energy seems to be the amount of energy of one microstate of the microcanonical ensemble that is formed by the binding states of an elementary particle. The partition function  $Z$  given here yields the number of microstates realized in one elementary particle, which can be visualized as an ensemble of Feynman-like structures describing the elementary particle in question.

However, the neutrinos should have negative exponents. This would allow smaller binding energies than Rydberg's energy. The experimental results suggest a neutrino mass smaller than  $<1 \text{ eV}/c^2$ .

We draw the following conclusions, which are valid for particles only:

$$m \sim E \sim Z \sim \Omega \sim N_{\text{microstates}} \quad \text{or} \quad m \sim E \sim \Omega \quad (34a+34b)$$



$$\frac{E}{Z} = E_{\text{Rydberg}} \quad \text{or} \quad \frac{E}{\Omega} = E_{\text{Rydberg}} \quad (35a+35b)$$

$$E = E_{\text{Rydberg}} \cdot Z \quad \text{or} \quad E = E_{\text{Rydberg}} \cdot \Omega \quad (36a+36b)$$

$$E = E_{\text{Rydberg}} \cdot e^{\ln Z} \quad \text{or} \quad E = E_{\text{Rydberg}} \cdot e^{\ln \Omega} \quad (37a+37b)$$

### Generalization of the partition function and generalization of the energy (mass) relation

A generalization of the partition function results in the following general formulation of the partition function of a particle.

The mass of an elementary particle can also be expressed in general using the following relationship.

$$E_{\text{particle}} = m_{\text{particle}} c^2 = 2^a \cdot 3^b \cdot (3\pi)^c \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^d \cdot E_{\text{Ryd}} \quad (38) \text{ similar to (6)}$$

Here, the exponents a, b, c, and d are related to the numbers of interactions present in the particle.

A generalization in this multiplicative form get possible, because the different interactions, which are in detail the color-anticolor interaction, the 3-color-interaction, the 3-gluon vertices, and the 4-gluon vertices, do not interact with each other. This might be confusing: While the gluons and quarks do interact in multiple and different ways, the interactions themselves do not super-interact.

This formulation yields the following hypotheses:

1.) The constant of proportionality between the partition function of a particle and the energy (mass) of that particle is always the Rydberg energy (energy per microstate).

$$Z = \Omega = 2^a \cdot 3^b \cdot (3\pi)^c \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^d \quad \text{and} \quad \ln Z = a \cdot \ln(2) + b \cdot \ln(3) + c \cdot \ln(3\pi) - \frac{d}{8} \ln \left( 1 - \frac{1}{3\pi} \right)$$

(39)

$$E = 2^a \cdot 3^b \cdot (3\pi)^c \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^d \cdot E_{Ryd} \quad (40)$$

2.) The individual exponents a, b, c, and d are always small whole numbers representing numbers of interactions. Z describes the number of possible combinations of such individual interactions. For all known particles, these exponents (a, b, c, d) can be determined through trial and error. Doing so leads us to the exponential series given in Table 1. These values result from comparing the masses for well-known particles resulting from the formula given above with the experimentally known values from the Particle Data Group. Another approach for determining the number of possible combinations consists of the graphic representation of all conceivable combination possibilities, analogous to what has been demonstrated here for the proton or nucleon and the pion.

3.) When we take a closer look at the values in Table 1, we see that there are some particles that have no quark–quark interactions at all. These particles seem to exist due to gluons only; examples include the W, Z and H particles. Because these particles are bosons and are known to transmit forces, this finding is consistent with current knowledge about particles.

4.) The fact that experimentally determined energy states of excited sigma-baryons can be described with a qq-model is in line with the description used here (quark-diquark model). The quark-diquark model was developed by Lichtenberg et al 1968 [25] and has successfully been used for the description of hadron spectroscopy (Nagata et al.[26]). The model for the sigma-baryon described herein is very similar to the quark-diquark model and can potentially be an explanation for why this model is working very well. The exponential series for the delta-resonances (uud, ddu) are (-3;2;8;18). Similar to the sigma baryon, the delta resonances also have an a of -3. Therefore, this could be an explanation for the quark di-quark model of Lichtenberg also fitting very well for the delta and nucleon resonances.

### Comparison with textbook knowledge

In textbooks [17], a proportional relation between energies and/or between the potency of energy and the partition function is described for a microcanonical ensemble. This relation is different than

that for a canonical or macrocanonical ensemble. For those two types of ensembles, a logarithmic relationship between the energy and the partition function has been described. Because we are instead dealing with a microcanonical ensemble and the microcanonical partition function, it could be expected that a linear relationship would exist between the appropriate partition function and the binding energy.

### Considerations on the accuracy of the calculations presented here

To compare the accuracy of the calculations presented here with that of the previously available formulas, we determine the electron mass or rest energy in two ways.

On the one hand, we calculate the electron rest energy using the new method presented here, and on the other hand, we use the well-known (and similar) relationship between the Rydberg constant and the electron mass ( $R_y=13.605693122$  eV).

$$E_{e,0} = \frac{1}{2} \cdot 3^2 \cdot (3\pi)^4 \cdot \left( \frac{1}{\sqrt[8]{1 - \frac{1}{3\pi}}} \right)^4 \cdot E_{Ryd} = 37554 \text{ Ry} \quad (41)$$

By comparing the results of both methods of determining the electron mass, we can see that with the new method, we determine the rest energy of the electron, measured in Rydbergs as the energy unit, to be 37554 Ry (nominal experimental value: 37557 Ry); this value is accurate to four decimal places ( $1 E_{Ryd}=13.605693122$  eV,  $m_{Ryd}=13.605693122\text{eV}/c^2$ ).

$$m_e = E_{Ryd} \frac{\varepsilon^2 h^2 8}{e^4} = 9.11282233567 \cdot 10^{-31} \text{ kg} \quad (42)$$

Using the analogous previously well-known common relationship, we determined the electron mass to be  $9.112822335674\text{E}-31$  kg (nominal experimental value  $9.109 \text{ E}-31$  kg), corresponding to an accuracy of only two decimal places. The relation between the Rydberg constant and the electron mass presented here is therefore far more precise than the previously known relationship, with an accuracy that is higher by two decimal places (a factor of approximately 100).

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## Figure Legends

### Figure 1

There are different kinds of interactions within a nucleon. These are the color–anticolor interactions, which are 2-particle interactions, the normal color interactions, which are three-particle interactions, the 3-gluon vertices, and the 4-gluon vertices. All these interactions can also be graphically displayed analogously to the chemical bonding in molecules. Here, this is done exemplarily for the nucleon.

- a.) Graphical representation of the number of color–anticolor interactions (a) for the nucleon
  - b.) Graphical representation of the number of three-color interactions (b) for the nucleon
  - c.) Graphical representation of the number of 3-gluon vertex interactions (c) for the nucleon
  - d.) Graphical representation of the number of 4-gluon vertex interactions (d) for the nucleon.
- Therefore, 3-gluon vertex interactions and 4-gluon vertex interactions are combined.

### Figure 2

There are different kinds of interactions within a neutral pion. These are the color-anticolor interactions, which are 2-particle interactions, the normal color interactions, which are normal three-particle interactions, the 3-gluon vertices, and the 4-gluon interactions. Again, all these interactions can be displayed graphically analogously to the chemical binding in molecules. Here, this is done for the neutral pion, which turned out to be a pion-pion dimer.

- a.) Graphical representation of the number of color–anticolor interactions (a) for the neutral pion. The neutral pion is considered a quantum-mechanical state of superposition. This superposition is considered to form a pion dimer, meaning that both pions involved enter into interactions.
- b.) Graphical representation of the number of three-color interactions (b) for the pion-dimer
- c.) Graphical representation of the number of 3-vertex gluon interactions (c) for the pi-dimer
- d.) Graphical representation of the number of 4-vertex gluon interactions (d) for the pion-dimer. Again, 3-gluon vertex interactions and 4-gluon vertex interactions are combined.

Since the pion is considered a superposition and/or dimer, the numbers a, b, c, and d need to be divided by two.

### Figure 3

Again, there are different kinds of interactions within a sigma baryon. These are the color–anticolor interactions, which are 2-particle interactions, the normal color interactions, which are normally three-particle interactions, the 3-gluon vertices, and the 4-gluon interactions. Again, all these interactions can be displayed graphically analogously to the chemical bindings in molecules. Here, this is done for the sigma baryon. The sigma baryon carries the strange quark, and the strange quark has the ability to take part in two particle interactions (=color–anticolor interactions).

a.) Graphical representation of the number of color–anticolor interactions (a) for the sigma baryon

The strange quark seems to have the ability to interact in anticolor interactions. Therefore, it seems to have the ability to carry anticolor.

b.) Graphical representation of the number of three-color interactions (b) for the sigma baryon

c.) Graphical representation of the number of 3-vertex gluon interactions (c) for the sigma baryon

d.) Graphical representation of the number of 4-vertex gluon interactions (d) for the sigma baryon.

Again, 3-gluon vertex interactions and 4-gluon vertex interactions are combined. Two 4-gluon interactions seem to occur subsequently in the sigma baryon.



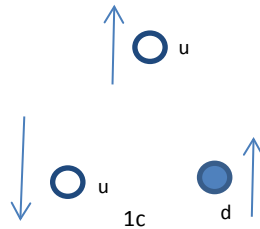
## Tables

### Table 1

This table gives the exponent series (a, b, c, d) for the most important particles.

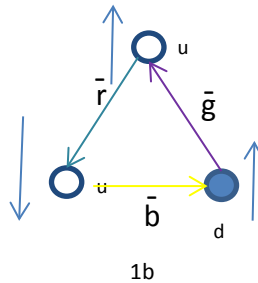
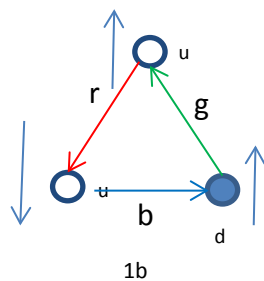
**Figure 1** Protons duu and Neutrons udd (a=0; b=-2; c=9; d=4)  
 Quantum State Sum Ensembles for the Parameters a and b  
 in the protons and/or neutrons we have the following interactions:

a.)



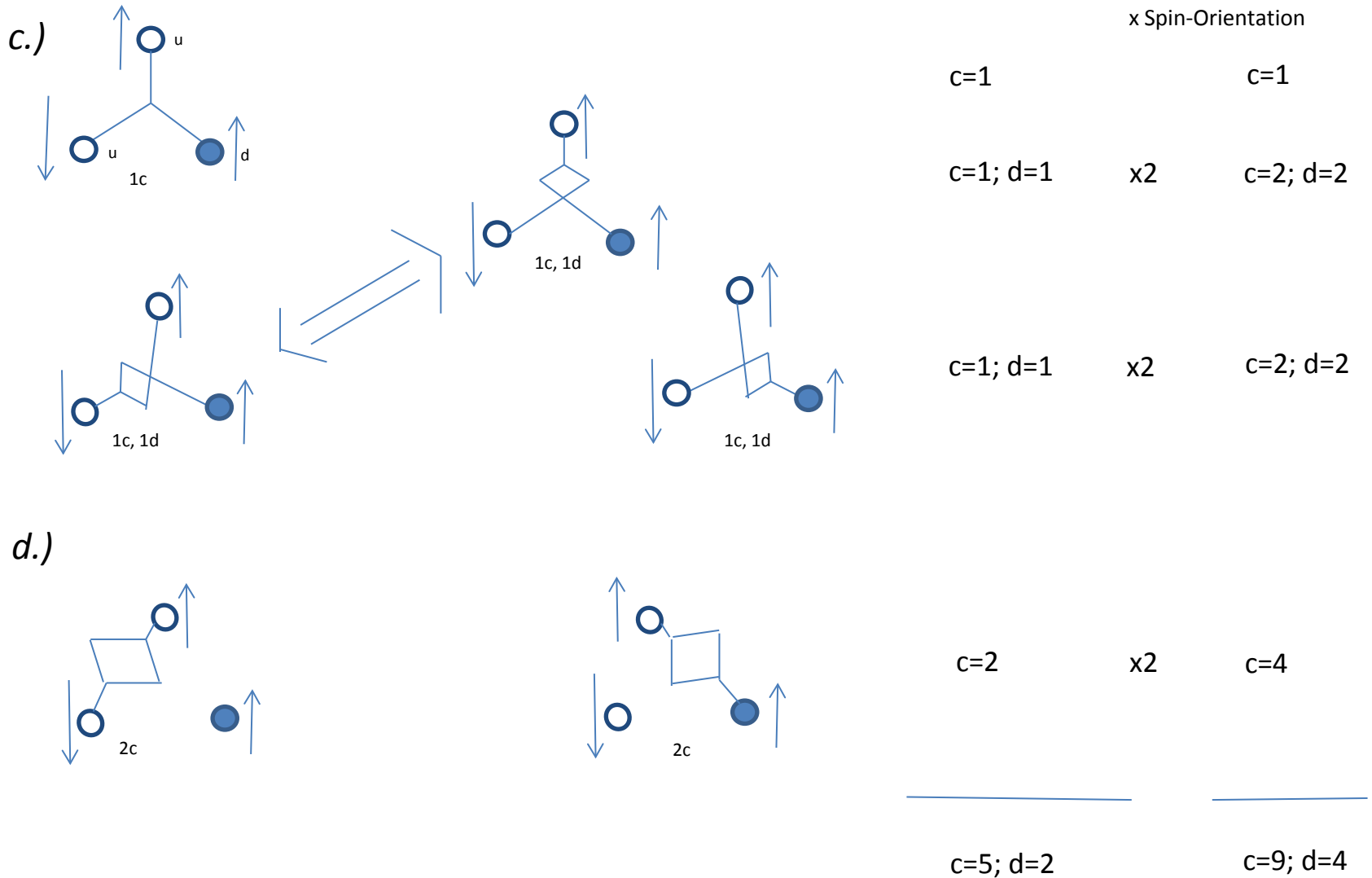
no color– anticolor interaction  
 $a=0$

b.)



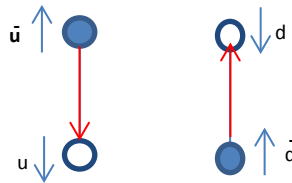
one three color interaction rgb  
 one three anticolor interaction  
 $b=-2$   
 both are binding

**Figure 1** Protons and Neutrons ( $a=0$ ;  $b=-2$ ;  $c=9$ ;  $d=4$ )  
 Quantum State Sum Ensembles for the Parameters  $c$  and  $d$   
 3-gluon vertices ( $c$ ) and 4-gluon vertices ( $d$ )



**Figure 2** neutral Pions  $u\bar{u}+d\bar{d}$  ( $a=-1$ ;  $b=1$ ;  $c=7$ ;  $d=0$ )  
 Quantum State Sum Ensembles for the Parameters  $a$  and  $b$   
 formulated as pion-dimers analog to the wave function

*a.)*

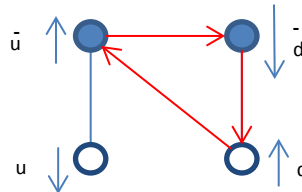


two color– anticolor interactions

$a=2$  for dimer

$a=-1$  per monomer - binding

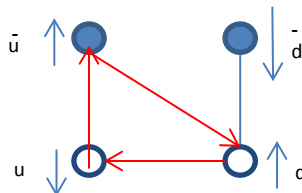
*b.)*



two three color interactions  $rgb$

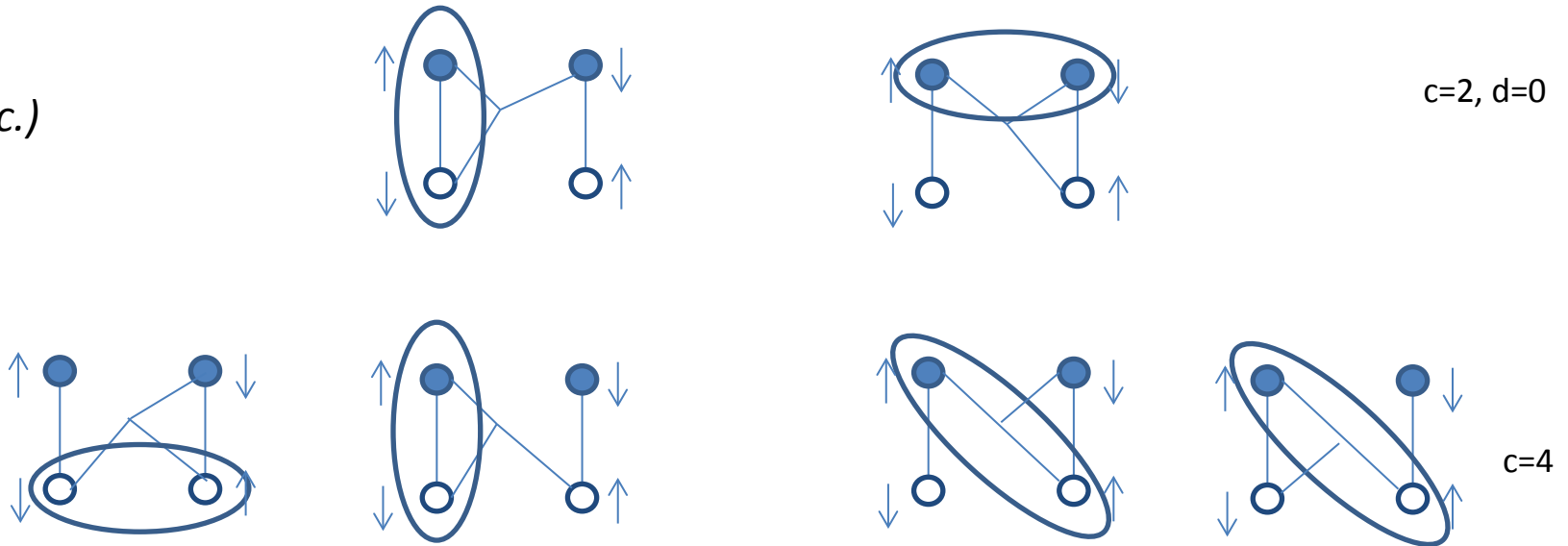
$b=2$  for dimer

$b=1$  per monomer -  
 nonbinding

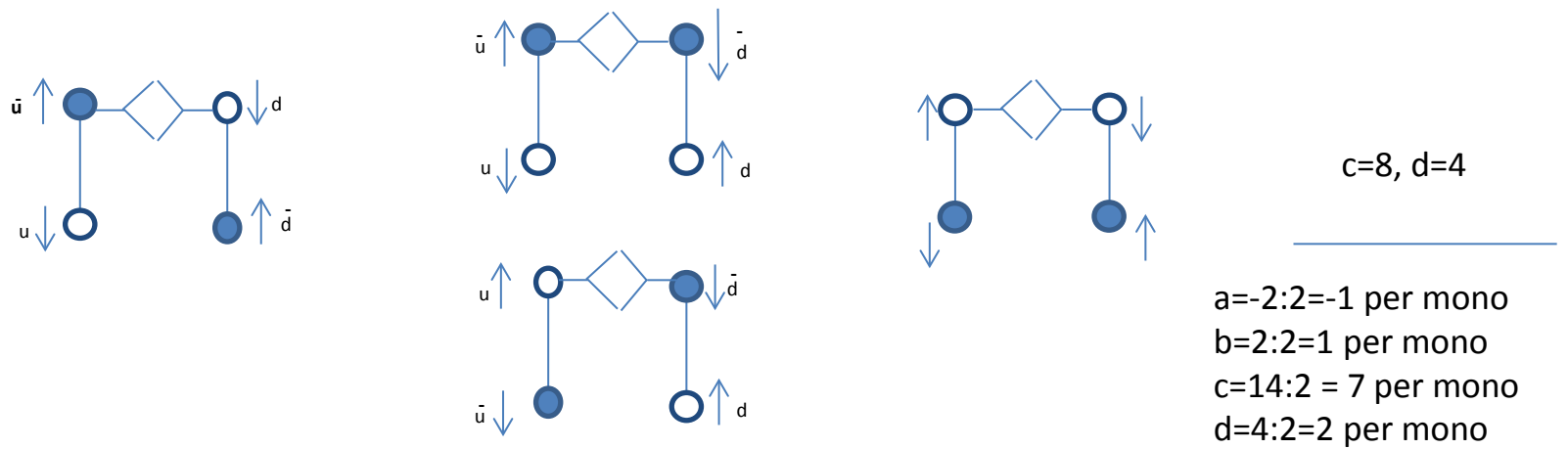


**Figure 2** neutral Pions ( $a=-1$ ;  $b=1$ ;  $c=7$ ;  $d=0$ ) State Sum, Parameters  $c$  and  $d$

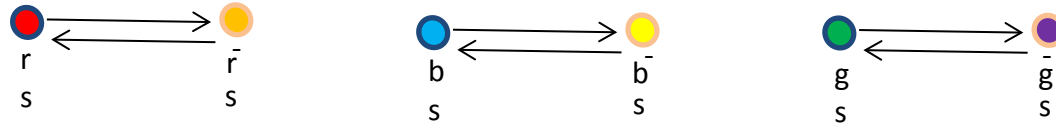
*c.)*



*d.)*

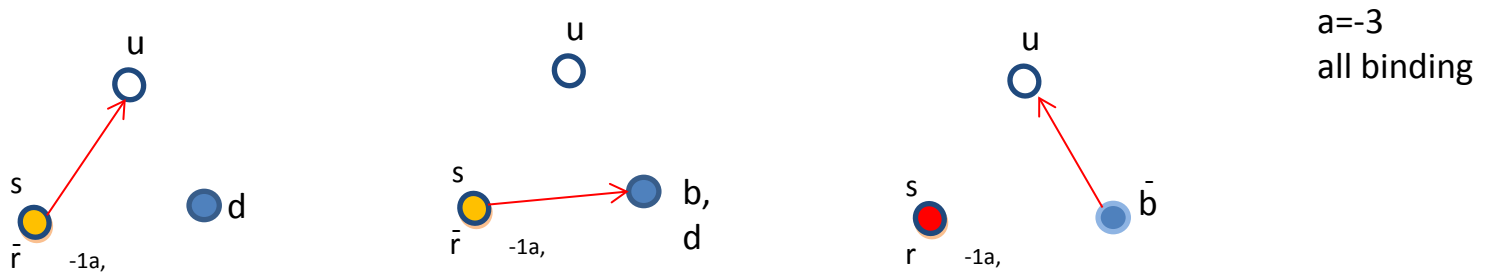


**Figure 3** neutral Sigma-baryon uds ( $a=-3$ ;  $b=2$ ;  $c=8$ ;  $d=16$ ) Parameters  $a$  and  $b$



*a.)*

three color-anticolor interactions

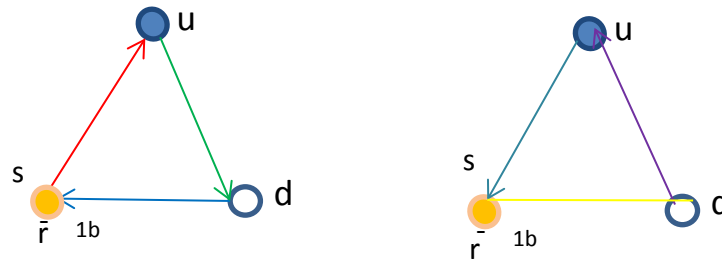


$a=-3$   
all binding

*b.)*

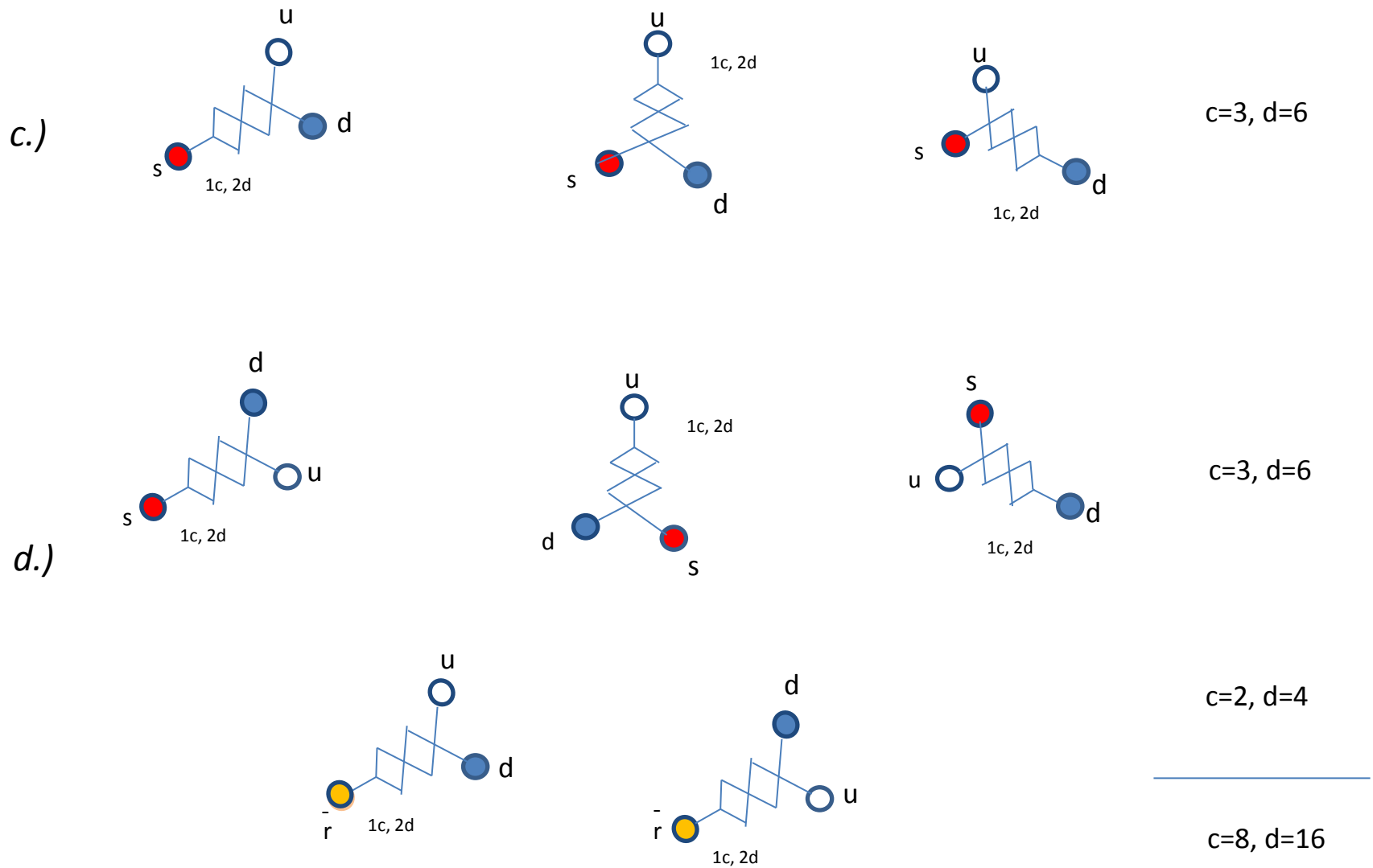
$s$ -quark participates in anticolor interaction

two three color interactions  $rgb$



$b=2$   
nonbinding

**Figure 3** neutral Sigma-baryon ( $a=-3$ ;  $b=2$ ;  $c=8$ ;  $d=16$ ) Parameters  $c$  and  $d$



**Table 1 Exponent- series of the mass- formula calculated for the different particles**

a	b	c	d	mass/[MeV]	particle	composition
<b>leptons</b>						
-1	-2	0	0	7E-7	neutrino	(VV)V
-1	2	4	4	0.5109	electron	(TT)T
-3	2	7	3	105.44	muon	TTT*
1	2	7	7	1784.49	tauon	TTT**
<b>quarks</b>						
1	2	4	8	2.16	up	u,(tt)v;tv;t;ttv
2	2	4	8	4.67	down	d, (VV)T;VTV;TVV
2	3	6	15	1270	charm	c ttv*
3	2	5	17	92	strange	s TVV*
1	2	9	13	172421	top	t ttv**
2	3	6	100	4184	bottom	b TVV**
<b>vector bosons</b>						
0	0	10	5	80700.0	W	(TT)T(VV)V
0	0	10	14	91554.0	Z	
0	0	10	36	124634.0	H	
<b>mesons</b>						
-1	1	7	0	134.8	pi 0	(uu-dd)/2
-1	0	8	11	494.128	K+	us
-1	-2	9	15	547.299	eta 0	uu+dd-2ss
0	0	8	9	960.9	eta dash	uu+dd+ss
1	0	8	7	1868.71	D+	cd
1	0	8	11	1976.5	Ds+	cs
-1	0	9	20	5283.0	B meson	ub
-1	0	9	22	5433.0	strange meson	sb
-1	0	9	33	6339.0	charm meson	cb
<b>vector mesons</b>						
3	0	7	5	771.0	rho 0	(uu-dd)/2
0	0	8	4	895872.0	K*0	ds
3	0	7	6	782.0	omega	(uu+dd)/2
0	0	8	13	1016	phi	ss
1	0	8	12	2004.0	D*0	cu
1	0	8	43	3095.6	J/psi	cc
<b>baryons</b>						
0	-2	9	4	938.15	proton	uud
-3	2	8	11	1111.0	lambda	uds
-3	2	8	16	1192.5	sigma 0	uds
-3	2	8	18	1226.4	delta	ddd
-3	2	8	23	1315.5	xi 0	uss
-1	-1	9	3	1387.6	sigma-*	dds
-3	2	8	29	1430.95	N(1440)	udd
-1	-1	9	10	1530.7	xi 0 reson	uss
1	0	8	1	1670.0	Omega -	sss



-3	2	8	63	2304.0	lambda-c	udc
-3	2	8	68	2472.0	c-sigma	ddc
			129	5815.0	cascade B	usb
-3	2	8	130	5897.0	bottom sigma	ddb
-3	2	8	72	2614.9	charmed xi prime	usc
-3	2	8	96	3661.0	double charmed xi	ucc