Reformulated Quantum Chromodynamics

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Abstract: Within the Quantum Chromodynamics (QCD) we cannot answer following three fundamental questions: What is the origin of masses of the quarks? What is the origin of the mass of muon? Why for decades we cannot calculate precise masses and spin of proton and neutron which are the fundamental components of Nature? It suggests that QCD must be reformulated. We already answered the above questions within the Scale-Symmetric Theory (SST). Here we present the next arguments that QCD must be extended and modified. We showed that the Titius-Bode law for the strong interactions follows from the coupling constants for electromagnetic and nuclear weak interactions of the core of baryons. We also showed that the sums of the squared charges of the components of baryons calculated within SST are consistent with experimental data for wide energy range. Within the atom-like structure of baryons do not appear singularities and infinities so renormalization is unnecessary - it causes that the reformulated QCD is mathematically very simple. We present also the theoretical curve for the kaon-to-pion ratio and we calculated the cross sections for production of the W bosons. We described as well the similar/dual structures in the reformulated QCD, General Relativity and in the theory of neutrinos (their shapes result from the Kasner metric) and we described the liquid-like plasma.

1. Introduction

Emphasize that all not calculated here but used theoretical results and used arguments without sufficient explanations follow from paper [1] (Particle Physics), [2] (Cosmology), and [3] (Chaos Theory). In these three papers we described the foundations of the Scale-Symmetric Theory (SST).

Within the Quantum Chromodynamics (QCD), for decades we cannot answer following three fundamental questions: What is the origin of masses of the quarks? What is the origin of the mass of muon? Why within the 3-valence-quarks model of baryons we are not able to calculate precise masses and spin of proton and neutron which are the very numerous components of Nature? It suggests that QCD must be reformulated. We already answered the above questions within SST. Here we present the next arguments that QCD must be extended and modified. We showed that the Titius-Bode law for the strong interactions follows from the coupling constants for electromagnetic and nuclear weak interactions of the core of baryons. We also showed that the sums of the squared charges of the components of baryons calculated within SST (the ratio $R(s) = f(s^{1/2})$) are consistent with experimental data for wide spectrum of energy. Within the atom-like structure of baryons do not appear singularities and infinities so renormalization is unnecessary – it causes that the reformulated QCD is mathematically very simple and there do not appear free parameters. Contrary to the Standard Model in which appear tens of free parameters, the total number of parameters applied in SST is 7. We present also the theoretical curve for the kaon-to-pion ratio and we calculated the cross sections for production of the W bosons. We described as well the similar/dual structures in the reformulated QCD, General Relativity and in the theory of neutrinos (shapes of the structures follow from the Kasner metric for flat anisotropy model of spacetime – SST shows that the ground state of the Einstein spacetime behaves as empty volume) and we described the liquid-like plasma.

General Relativity leads to the superluminal Higgs field [1]. The succeeding phase transitions of this field lead to different scales. One of such scale leads to the atom-like structure of baryons and to structure of charged leptons and mesons [1]. All particles in this scale are built of confined and/or entangled neutrino-antineutrino pairs the Einstein spacetime consists of and of neutrinos [1].

Properties of particles in this scale follow from the structure of baryons. There is the core of baryons composed of the central condensate (C) (which is responsible for the nuclear weak interactions) and the torus (T) (which is responsible for the nuclear strong and electromagnetic interactions), and outside the core there are the Titius-Bode orbits (O) because of the nuclear strong interactions [1]. The condensate is the modified black hole in respect of the weak interactions whereas the core (as a whole) is the modified black hole in respect of the strong interactions [1]. The two first orbits ($d = 0$ and $d = 1$) lie under the Schwarzschild surface for the strong interactions [1]. Such condensate-torus-orbits model of baryons we will call the CTO-Model. Within the CTO-Model, we calculated a thousand theoretical results (using 7 parameters only) which are consistent or very close to experimental data and observational facts [1], [2], [3]. We, for example, calculated precise masses and spin of nucleons [1]. For the nuclear strong interactions of baryons are responsible the pions composed of gluons (the gluons are the rotational energies of the neutrino-antineutrino pairs) – there are 8 Types of gluons (number of Types of gluons follow from their three different internal helicities/colours [1]). SST is the complete theory so we can calculate within this theory the masses of quarks [1].

Table 1 *Masses of quarks*

Physical quantity	**Theoretical value**
Mass of up quark	2.23 MeV
Mass of down quark	4.89 MeV
Mass of strange quark	87.85 MeV or (96 ± 8) MeV
Mass of charm quark	1267 MeV
Mass of bottom quark	4190 MeV
Mass of top quark	171.9 GeV

Emphasize that the CTO-Model described within SST shows that in hadrons there are not free quarks and that some their properties are different than assumed in the QCD. There are produced only the virtual or real quark-antiquark pairs.

We must add some comment to Table 1. SST shows that the pairs of the strange quarks are produced in the $d = 2$ state and mass of a pair is equal to mass of relativistic neutral pion in this state that is 175.71 MeV. But there are exchanged neutral pions in $d = 1$ and $d = 2$

states. The relativistic mass of the neutral pion in the $d = 1$ state is 208.64 MeV. It leads to conclusion that the mean mass of strange quark we can write as follows: 96 ± 8 MeV.

To calculate masses of the three heaviest quarks, we derived formula (3) [1].

Quark-antiquark pair is a pair of loops that can be created from a condensate. A loop has 10 degrees of freedom [1]. A hypervolume of the phase space and its total mass (the mass is in proportion to the hypervolume), i.e. mass of a quark, must be in proportion to radius of a gluon loop to the power of 10.

On the equator of the torus, there arise the gluon condensates which masses are the same as the calculated within the atom-like structure of baryons. Range of a condensate is r_{range}. Then, there is created a loop with radius $r_{loop} = r_{range} + A$. Mass of such a loop we can calculate from following formula

$$M_{Loop}\,[\text{GeV}] = a\,(r_{Loop}\,[\text{fm}])^{10} = a\,(r_{range}\,[\text{fm}] + A\,[\text{fm}])^{10}, \tag{1}$$

where a is a factor whereas $A = 0.6974425$ fm is the equatorial radius of the torus in the core [1]. For $M = 0.72744$ GeV (it is mass of the core [1]) we should obtain $r_{loop} = A$ so then $a = 26.7124\ \text{GeV/fm}^{10}$.

Knowing that range of mass equal to $m_{S(+,-),d=4} = 187.573$ MeV is $4B = 2.00736$ fm [1], we can calculate range for a gluon condensate from formula

$$r_{range}\,[\text{fm}] = m_{S(+,-),d=4}\,[\text{MeV}]\ 4B\,[\text{fm}] / m_{condensate}\,[\text{MeV}] = b / m_{condensate}\,[\text{MeV}], \tag{2}$$

where $m_{condensate}$ is the mass of a gluon condensate whereas $b = 376.527$ fm·MeV.

We can rewrite formula (1) as follows

$$M_{Loop}\,[\text{GeV}] = a\,(b / m_{condensate}\,[\text{MeV}] + A\,[\text{fm}])^{10}. \tag{3}$$

We used this formula to calculate masses of the three heaviest quarks [1].

2. The origin of the Titius-Bode law for the nuclear strong interactions from the coupling constants

Constants of interactions are directly proportional to the inertial mass densities of fields carrying the interactions. The following formula defines the coupling constants of all interactions

$$\alpha_i = G_i M_i m_i / (c\,\hbar), \tag{4}$$

where M_i defines the sum of the masses of the sources of interaction being in touch via field plus the mass of the component of the field, whereas m_i defines the mass of the carrier of interactions.

Existence of the core of baryons and its internal structure follows from the succeeding phase transitions of the initial inflation field i.e. the superluminal Higgs field [1]. For the charged core of baryons we can rewrite formula (4) as follows (notice that for the core is $M_i = 727.44$ MeV and $G_i M_i = const.$ because at fixed energy, density of field produced by the core is invariant [1])

$$\alpha_i / m_i = G_i M_i / (c\,\hbar) = const. \tag{5}$$

If a carrier interacts with the core due to more than one type of interactions then formula (5) looks as follows

$$\Sigma_i \alpha_i / m_i = const. \qquad (6)$$

The neutral pions are produced inside the core of baryons and there is obligatory the four-particle/object symmetry so the virtual quadrupoles of bound neutral pions are very numerous inside the core and their mass is $m_{i,1}$ = 539.864 MeV [1]. They carry the nuclear weak interactions between the equator of the core of baryons and the condensate Y in its centre i.e. the range of this interaction is A. Assume that on the equator appear quadrupoles with a mass $m_{i,2}$ composed of charged virtual bosons. Then, such charged bosons interact both weakly with Y and electromagnetically with the torus/charge inside the core of baryons. We know that ranges of particles are inversely proportional to masses so applying formula (6) we can calculate mass and range B of the second quadrupole

$$(\alpha_{w(proton)} + \alpha_{em}) / \alpha_{w(proton)} = m_{i,2} / m_{i,1} = A / B, \qquad (7)$$

where $\alpha_{w(proton)} = 0.0187229$ is the coupling constant for the nuclear weak interactions of baryons, whereas α_{em} is the fine-structure constant [1]. From formula (6) we obtain $m_{i,2}$ = 750.29 MeV and its range is B = 0.5018395 fm so A / B = 1.38977.

The second quadrupole can decay symmetrically on the equator to two parts or four parts – it leads to the Titius-Bode law for the nuclear strong interactions

$$R = A + d\,B, \qquad (8)$$

where d = 0, 1, 2, 4. Such is the origin of the Titius-Bode law. Moreover, the Chaos Theory applied to proton shows that baryons can produce virtual dark-matter loops overlapping with the Titius-Bode orbits [3]. They appear as well outside the nuclear strong fields i.e. in the Einstein spacetime composed of the neutrino-antineutrino pairs [3]. Such dark-matter structures can interact with baryonic matter so there can appear planetary systems with distribution of planets similar to solar system, of course, if some other phenomena do not destroy the Titius-Bode configuration.

SST shows that the gluons, which are responsible for the nuclear strong interactions, on the equator of the core of baryons have the spin speed equal to the speed of light in "vacuum", c, so the core as a whole is the modified black hole in respect of the nuclear strong interactions. On the surface of the condensates Y, the spin speeds of the neutrino-antineutrino pairs are as well equal to c so the condensates are the modified black holes in respect of the nuclear weak interactions.

Why single quarks could not be produced even during the inflation? Due to the inflation, there appeared the Einstein spacetime composed of the neutrino-antineutrino pairs and there is obligatory the matter-antimatter symmetry [2]. In the Einstein spacetime, sometimes are produced big vortices having internal helicity [2]. Internal helicity is the property that distinguishes particles from antiparticles [1], [2]. The vortex, which evolution had led to creation of our expanding Universe, had left-handed internal helicity [2]. It caused that there sometimes the positron-electron pairs had transformed into proton-electron pairs. Such phenomena had led to the matter-antimatter asymmetry in the Universe [2]. For the transformations of positron-electron pairs into the proton-electron pairs there is only one solution for mass and electric charge of proton (it follows from the phase transitions of the Higgs field) and only one solution for mass and the same electric charge for electron (it results from the mass density of the Einstein spacetime). It means that creations of free particles carrying electric charges not equal to this of proton or electron is impossible. But for very short time there can be produced quark-antiquark pairs with arbitrary electric charges of components but resultant electric charge of such pair must be equal to zero. Such pairs appear as loop-antiloop pairs with antiparallel spins and the same left-handed internal helicity of the two components when produced in baryons or with the same right-handed internal helicity when produced in antibaryons. The loops are composed of entangled gluons i.e. of the rotating neutrino-antineutrino pairs – in baryons, there dominate the left-handed gluons whereas in antibaryons the right-handed. Abundance of loops/quarks overlapping with the Titius-Bode (T-B) orbits (A, $A + B$, $A + 2B$, and $A + 4B$), the circular axis ($2A / 3$) and the inner equator of the torus ($A / 3$), [1], is highest. The mass of the charged core of baryons ($H^+ = 727.44$ MeV [1]) and radius of its equator (A) are associated with the unitary electric charge ($+1Q$). Charges of other quarks are directly proportional to their mass or to radius of loop.

We proved that a condensate with a mass of loop overlapping with the last T-B orbit (about 2821 MeV) leads to the mass of bottom quark and it is the reason that the QCD gives best results when we use this mass, for example, to describe the asymptotic freedom.

3. The essential part of the curve $R(s) = f(s^{1/2})$ for electron-positron collisions

Describe following curve [4]:

$$R(s) = \sigma(e^+e^- \rightarrow hadrons, s) / \sigma(e^+e^- \rightarrow \mu^+\mu^-, s) = \Sigma_i Q_i^2, \quad (9)$$

where summation concerns the squared electric charges of the core of proton ($+1Q$) and squared electric charges of all quarks in different quark-antiquark pairs produced in collisions.

For low energies, there are following electric charges: $\pm 1Q/3$, $\pm 2Q/3$ and $+1Q$ so we obtain $R(s) = 2.111$.

All quantities describing the ground state of the Einstein spacetime composed of the free luminal neutrino-antineutrino pairs are invariant, [1], so it behaves as non-gravitating field (as empty volume) so we can apply to it the Kasner metric that is an exact solution to Einstein's equations of General Relativity (0, 0, 1) [5]. It means that we can apply this solution as well to the carriers of gluons. In Paragraph 9 we show that this solution we can interpret as two different pairs of quarks (0 and 0 because the total charge of a pair is equal to zero) and the charge of the core of baryons (1). When energy of collisions increases then pairs of lighter quarks disappear whereas of heavier ones appear in such a way that there still are two different pairs of quarks plus the charge of the core.

For production of the core-anticore pairs too (i.e. there are following charges: $\pm 2Q/3$, $+1Q$ and $\pm 1Q$) is $R(s) = 3.889$.

For higher energies there are produced gluon loops overlapping with the $d = 1$ T-B orbit so the charges of quarks are $\pm 1.72Q$ and we obtain $R(s) = 8.957$.

In formula (1) is the 10 powers of radius of a loop. On the other hand, in formula (9) there is squared charge so squared radius of loop. It leads to conclusion that in a formula describing dependence of energy of $R(s)$ should be 5 powers of $R(s)$.

In the electron-positron collisions, the gluon loops arise as the quadrupoles. Lightest meson that consists of four gluon loops is the kaon K. The electron-positron-pair$\rightarrow$four-gluon-loops(quadrupole) transition looks as an analog to the decay of neutral kaon (there are two opposite electric charges) to charged kaon (there is quadrupole of gluon loops) [1]. In each neutral-kaon→positive-kaon decay, is emitted energy approximately 4.026 MeV (calculated masses of kaons are as follows: $m_{Kaon(+,-)}$ = 493.733693 MeV, $m_{Kaon(o)}$ = 497.759913 MeV, [1], so the theoretical value for the distance of masses is $m_{Kaon(o)} - m_{Kaon(+,-)} \approx 4.026$ MeV).

Calculate the energy thresholds for *sqrt(s)* [GeV] from following formula

$$sqrt(s)\ [GeV] = (m_{kaon(o)} - m_{kaon(+,-)})\ [MeV]\ R(s)^5 / 1000. \quad (10)$$

For *R(s)* = 2.111 we obtain *sqrt(s)* ≈ 0.17 GeV. Baryons arise as the baryon-antibaryon pairs. This means that to create two the lightest quark-antiquark pairs, the minimum energy for the essential part should be $sqrt(s)_{minimum}$ = 0.97 GeV ≈ 1 GeV (it is 4 $H^+/3$).

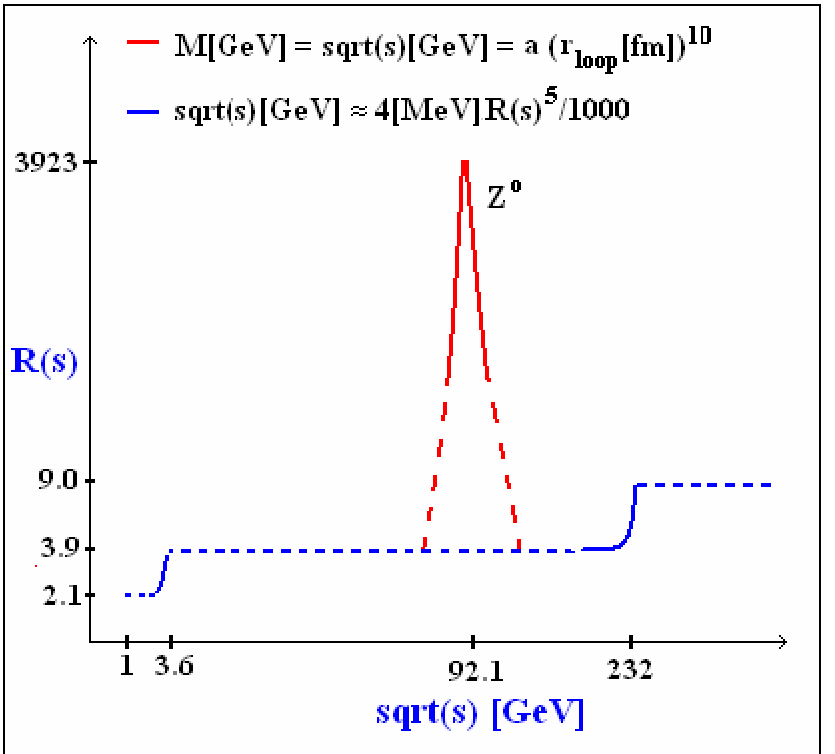
For *R(s)* = 3.889 we obtain *sqrt(s)* = 3.58 GeV.

For *R(s)* = 8.957 we obtain *sqrt(s)* = 232 GeV.

Notice that there is a broadening of obtained energy thresholds.

4. The additional part of the curve $R(s) = f(s^{1/2})$

The additional part of the curve $R(s) = f(s^{1/2})$ we can calculate from formula (3).



R(s) = f(sqrt(s)) for electron-positron collisions

We can see that gluon condensates carrying greater mass (due to higher energy of collisions) produce lighter particles. This is the reason why at very high energies the number of produced pions and kaons is greater than expected [6]. This means also that for higher and higher energies of collisions, there are weaker and weaker signals that there is in existence the atom-like structure of baryons. Just for higher and higher energies, more and more baryons have destroyed the T-B orbits for the strong interactions.

Due to the interactions of the core of baryons with bosons, we observe the mass broadening for the Z^o boson. Calculate mass of particle produced by gluon condensate carrying mass equal to the sum of mass of the charged core of baryons (727.44 MeV) and charged pion (139.57 MeV) – the total mass is 867 MeV. Calculated mass of the particle is 92.1 GeV and it is the Z^o boson. The higher than expected width of Z^o boson for the lower $R(s)$ results from creation of condensates with masses equal to the mass of the core of baryons and with masses equal to the masses of nucleons.

Calculate the maximum value of the ratio $R(s)$. Outside the modified black hole in respect of the strong interactions, i.e. outside the $d = 1$ state, there are the transitions of the relativistic pions between the states $d = 4$ and $d = 2$. Due to such transitions, there appear virtual or real bosons with mean mass/energy equal to E = 19.367 MeV [1] (see Paragraph "Hyperons"). Radius of a loop corresponding to E is $R = H^+ A / E$. But it appears on the Titius-Bode orbit with a radius of $A + 2B$ so the maximum radius of the loops is $R_{Max} = A + 2B + R = 39.262A = N_1 A$. The next smaller radius is for $2E$ so we obtain $R^* = A + 2B + R_{Max} / 2 = 20.482A = N_2 A$. The Kasner metric leads to two binary systems of loop and 1. Since charge $1Q \rightarrow 1$ corresponds to A so the maximum value of the ratio $R(s)$ is

$$R(s)_{Max} = 2 N_1^2 + 2 N_2^2 + 1^2 = 3923. \quad (11)$$

5. Why renormalization does not appear in the reformulated QCD

The SST shows that in baryons there appear the lower and upper boundaries for nuclear strong field. The radius of lower boundary is $2A/3$ whereas of the upper boundary is 2.9582094 fm. On the other hand, energy of the virtual field cannot be higher than $2M$, where M is the real bare mass of a particle [1]. It causes that there do not appear infinite energies/masses. Moreover, high increase in energy of collision does not lead to higher energies of produced particles but to production of groups of particles with lower energies/masses characteristic for the baryons, especially there appear more and more pions and kaons which production is associated with the core of baryons. The dynamic pressure in the Einstein spacetime is very high (about 10^{45} Pa [1]) – it causes that instead a turbulence there are created next and next particles.

6. Expanding the real and dark-matter loops

Due to the faster-than-light particles (i.e. the non-gravitating tachyons the Higgs field consists of, and entanglons the neutrinos consist of that are responsible for the superluminal quantum entanglement [1]) the quantum physics is non-local. It causes that there can appear real and virtual small and very huge loops composed of entangled neutrino-antineutrino pairs. When the pairs do not rotate then they are the dark-matter structures. When the spin speeds of the pairs is c then such structures can be stable. But some disturbances can force expansion of such loops – then spin speed decreases whereas radius and radial speed increase.

For a growing spinning loop is

$$x = v_{radial} t + \lambda \varphi / (2 \pi), \quad (12)$$

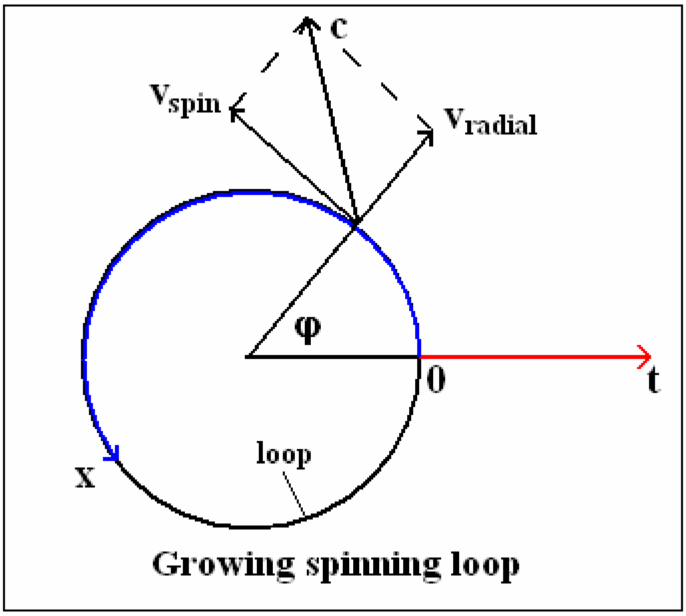
where

$$v^2_{radial} + v^2_{spin} = c^2. \quad (13)$$

Growing loop accelerates its expansion. We can see that the axis x overlaps with the loop whereas the axes of time t are radial and begin with the loop.

For $v_{radial}\, t >> \lambda$ is $v_{radial} = c$ (since $m\, v_{spin}\, r = \hbar$ then for increasing v_{radial}, so also r, the spin speed decreases) then

$$x = c\, t + \lambda\, \varphi\, /\, (2\, \pi). \quad (14)$$



Since $k' = p\, /\, \hbar$, $\lambda = h\, /\, p$, $2\, \pi\, \nu = \omega$, and $E = h\, \nu = \hbar\, \omega$, we obtain

$$k'\, x - \omega\, t = \varphi. \quad (15)$$

Moving rotating-spin loop (the transverse wave) we can describe using following function

$$\psi(x,t) = a\, e^{i\, \varphi} = a\, (cos\varphi + i\, sin\varphi), \quad (16)$$

where $\varphi = k'\, x - \omega\, t$ and $i = sqrt(-1)$.

The large loops produced on the circular axis inside the torus in the core of baryons are responsible for the strong interactions of mesons (coupling constant is 1) whereas the binary systems of such loops, i.e. the pions, are responsible for the strong interactions of baryons (due to the law of conservation of spin, the running coupling decreases from 14.4 for low energies to 0.1176 ± 0.0005 for mass of the Z boson) [1].

7. Theoretical curve for the kaon-to-pion ratio

The atom-like structure of baryons leads to two curves for ratio $K/\pi = f(s^{1/2})$ and they are consistent with experimental data. In the figure are collected theoretical results. Experimental data that concern the kaon-to-pion ratio are collected on following website [7].

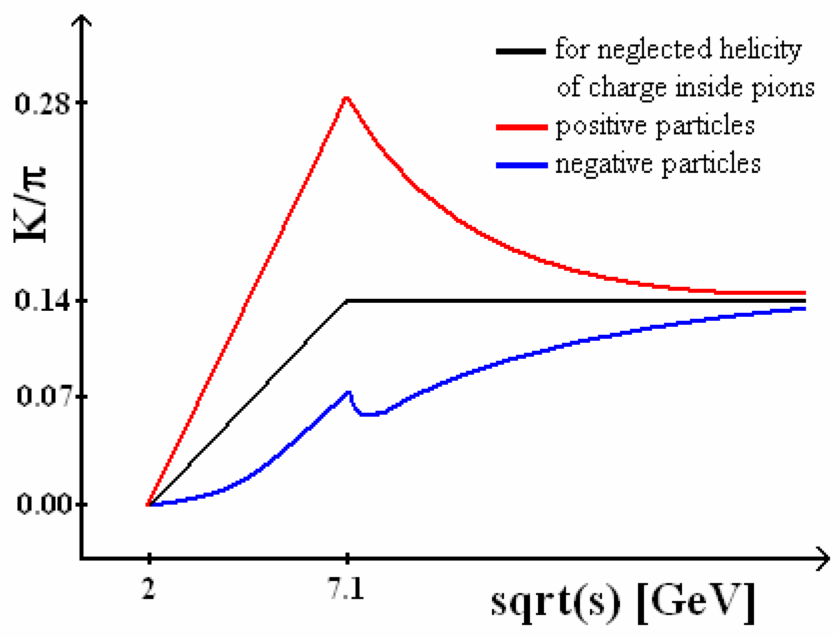
Number of produced particles is inversely proportional to their mass. For the K/π ratio is

$$K / \pi = m_i / m_{kaon(+-)} , \tag{17}$$

where m_i is the mass of loops composed of gluons or structures composed of gluon loops whereas $m_{kaon(+-)}$ is the mass of the charged kaon. With increasing energy of collision there appears more and more of the more energetic gluons, loops and structures. Pions are the binary systems of gluon loops and mass of each loop for resting pion is 67.54 MeV and consists of two neutrinos. Each such neutrino carries energy equal to 33.77 MeV. Mass of charged pion is 139.57 MeV. The mass of pion leads to the coupling constant for the strong interactions of the non-relativistic nucleons $\alpha_s^{NN} = 14.4$. For a very short period of the K and π production in the nucleon-nucleon collisions, the produced nucleon-antinucleon pairs are in the rest. The strong masses of the charged pion and kaon we can calculate multiplying their masses by the coupling constant. For the charged pion, we obtain about $sqrt(s) = 2$ GeV and it is the starting point of the curve for the K/π ratio. For the charged kaon we obtain $sqrt(s) = 7.1$ GeV. A kaon is the binary system of binary systems of loops so it is a quadrupole of loops. Masses of the gluon loops the resting kaons consist of are greater than in the resting pions [1]. Due to the pairing of gluon loops (pions) and the four-object symmetry, there can appear particles built of following number of gluon loops x

$$x = 2^d , \tag{18}$$

where $d = 0, 1, 2, 4, 8\ldots$



The 'horn' for the K/π ratio

We can see that for energies lower than 7.1 GeV the pions and kaons arise from the single loops ($x = 1$ for $d = 0$). When the energy of collisions increases then there arise more and more the more energetic gluons from which the kaon loops arise. For energies higher than 7.1

GeV, pions are produced from single loops (m_i = 67.54 MeV) whereas kaons are produced at once as the quadrupoles of gluon loops ($x = 4$ for $d = 2$). This leads to K/π = 67.54 / 493.7 ≈ 0.14 and it is the asymptote for positive and negative particles (the black basic curve in the figure). To obtain the real curve we must take into account also the helicity of electric charge inside pions. The division of the basic (black) curve follows from the different helicities of electric charges of pions (left helicity for positive pions and right for negative ones) in relation to the helicity of the colliding nucleons (left helicity). We can neglect the helicities of charges of the kaons because they are the binary systems. In such systems appears additional spin speed that causes that the resultant helicity is equal to zero. The helicity of charge of the negative pions are opposite to the colliding nucleons so for the threshold energy for kaons, i.e. 7.1 GeV, they are produced from the neutrinos that carry energy equal to m_i = 33.77 MeV. This means that for energy $sqrt(s)$ = 7.1 GeV, for the negative particles should be K/π = 33.77 / 493.7 ≈ 0.07. We can see that the curve $K/\pi = f(s^{1/2})$ is lowered in relation to the basic (black) curve and has small maximum for the threshold energy. The helicity of charge of the positive pions is the same as of the colliding nucleons so they arise at once as the positive pions. This means that for the threshold energy, for the positive particles should be K/π = 139.57 / 493.7 ≈ 0.28. We can see that the curve $K/\pi = f(s^{1/2})$ is elevated and there appears the big "horn".

8. The cross section for production of the W boson

Here we will show how from the atom-like structure of baryons follows the cross section for production of the W boson as a function of collision energy.

We know that cross section is inversely in proportion to squared mass of created particle. For resting proton, the cross section for the weak interactions is the equatorial cross section of the condensate in the centre of the core of baryons. Then, for the W boson, for collision energy equal to the mass of the W boson (this theory leads to 80.10 GeV or 80.38 GeV for 4 bare electron-positron pairs that mass is increased $X_w = \alpha_{w(proton)} / \alpha_{w(electron-muon} = 19{,}685.3$ times because of the change of type of weak interactions from the electron-muon interactions for the weak interactions of proton – such object interacts with an electron) is

$$\sigma_W(m_W = 80.38\ \text{GeV}) = \pi\, r_{p(proton)}^{\ 2} / (m_W / m_{proton})^2 = 0.3248\ \text{nb}, \qquad (19)$$

where $r_{p(proton)} = 0.8711 \cdot 10^{-17}$ m is the radius of the condensate [1], whereas m_W is the mass of the W boson.

When energy of collision increases then increases the radius of the condensate so the cross section also. Cross section is in proportion to the equatorial cross section of the condensate whereas the volume of the condensate is in proportion to collision energy E. This means that there appears following factor f

$$f = (E / m_W)^{2/3}. \qquad (20)$$

We can see that the formula for the mean cross section for production of the W^+ and W^- bosons as a function of collision energy looks as follows

$$\sigma_{W,mean}(E\ [TeV]) = \pi\, r_{p(proton)}^{\ 2}\, (E / (m_W / 1000))^{2/3} / (m_W / m_{proton})^2 = 1.744 \cdot E^{2/3}\ nb. \qquad (21)$$

This is the mean value for the W^+ and W^- bosons.

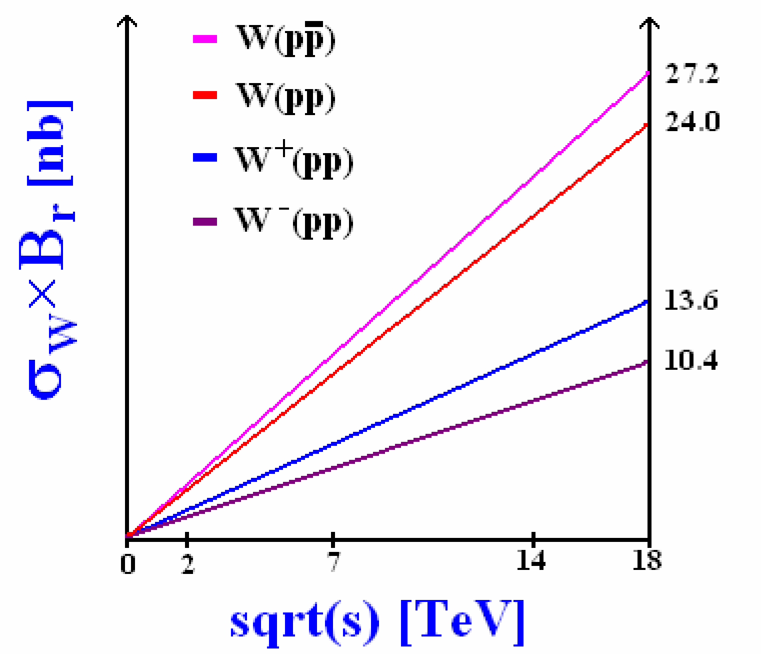
Inside the core of baryons appear the quark-antiquark pairs which carry following electric charges: ±1/3 and ±2/3. The electric charge of the core of proton is +1. The charge helicities of the W^+ boson and proton are the same so the W^+ boson is associated with the greatest positive electric charge i.e. the +1. The charge helicities of the W^- boson and proton are opposite so the W^- boson is associated with the absolute value of the –2/3. We know that involved energy is in proportion to the absolute value of the electric charge. This leads to following formula

$$(\sigma_{W+} + \sigma_{W-}) / 2 = \sigma_{W,mean} , \qquad (22)$$

where $\sigma_{W-} = (2/3)^{2/3}\sigma_{W+}$. This condition and formula (22) leads to conclusion that in the formula for the cross section for the W^+ boson appears the factor $g_1(+) = \sigma_{W+} / \sigma_{W,mean} = 1.13434$ whereas for the W^- boson the factor $g_2(-) = 0.865662$. For the total cross section for the proton-proton collisions appears the factor $g_3(\pm) = g_1(+) + g_2(-) = 2$ whereas for the proton-antiproton collisions the factor $g_4(\pm) = 2g_1(\pm) = 2.26868$. Now, the formula for the cross section looks as follows

$$\sigma_W[nb] = g_i\, \sigma_{W,mean}(E\ [TeV]) = 1.744 \cdot g_i\, E^{2/3}, \qquad (23)$$

where i = 1, 2, 3 or 4. The formula (23) is not a final formula.



The cross section for production of the W boson as a function of collision energy

For mesons carrying mass close to the proton (for example, $\omega(782)$) or for nuclei composed of such mesons (for example, $Y(9460\ MeV)$), the cross section should be close to the equatorial cross section of the condensate of the proton in the rest i.e. about $2.4 \cdot 10^{-3}$ mb.

When energy of proton increases then emitted energy also increases and for energy in approximation 18 TeV is 100 % [1]. Then, the radius of the condensate of proton is equal to $A/3$ and it is the radius of the gluon loop from which the quark with lowest electric charge is produced. Masses of the quarks are in proportion to their radii so energy emitted by relativistic proton is in proportion to radius of the condensate of proton. This means that ability to production of the W bosons increases with energy of collision and is equal to one for 18 TeV. To obtain correct value for the cross section, we must multiply the formula (23) by following function

$$B_r = r_{Condensate} / (A / 3) = (E\ [TeV] / E_o\ [TeV])^{1/3}\ , \quad (24)$$

where $E_o = 18$ TeV.

The final formula for the cross section looks as follows

$$\sigma_W[nb] \times B_r = g_i\, \sigma_{W,mean}(E\ [TeV])\, B_r = 0.6655 \cdot g_i\, E\ , \quad (25)$$

This is the linear function. We can see that the cross section for 7 TeV is 3.5 times greater than for 2 TeV. For 7 TeV, for the W^+ boson we obtain 5.3 nb whereas for W^- boson 4.0 nb and it is consistent with experimental data.

9. The similar/dual structures in the reformulated QCD, General Relativity, and in the theory of neutrinos

The Friedman isotropic model leads to a singularity due to the initial simplification that there is the symmetry. In reality, the inflation and the evolution of our Universe are the two very different phenomena. After the inflation, there appeared the left-handed rotary vortex in the Einstein spacetime so we should consider the flat anisotropic model. In the nature the spatial distances do not disappear for distances approaching zero. This means that there are not in existence singularities of the oscillatory mode as well. But there is an oscillatory mode in the approach to singularity.

The nuclear strong fields behave similar to strong gravitational fields produced by modified black holes which consist of the modified neutron black holes [2]. For both types of fields is in force the Titius-Bode law ($R = A + dB$) and for both types of fields the ratio A/B has practically the same value about 1.39. This means that there should be in existence some self-similar structures in the General Theory of Relativity and the reformulated Quantum Chromodynamics.

Parameters describing the ground state of the Einstein spacetime are invariant so it behaves as empty volume but there can appear the vortices having internal helicity. It looks as the flat anisotropic model in the General Relativity. Within the GR, the flat anisotropic model was described by Edward Kasner in 1921 [5]. There are two semi-symmetrical solutions for the Kasner metric (2/3, 2/3, –1/3) and (0, 0, 1). Notice that within the modified QCD, we showed that the second solution represents resultant electric charges of two quark-antiquark pairs plus the charge of the torus in the core of baryons. On the other hand, the first solution we can interpret as a torus that radius of the circular axis increases (2/3, 2/3), i.e. increases equatorial radius of the torus, whereas size in the third orthogonal direction decreases (–1/3). It means that size of the torus increases but the torus collapses to a loop or vice versa i.e. a loop transforms into torus – the last looks as creation of charge of a quark from a quark loop. Within SST we showed that in three scales there appear such structures i.e. loops and tori i.e. in the neutrino scale, QCD scale, and cosmological scale [1], [2].

We can say that we partially unified particle physics and cosmology (or the modified Standard Model with General Relativity) via some interpretation of the Kasner metric described within GR (there appear the different tori/charges and loops.

10. Liquid-like plasma

Electron-positron pairs that decay into photons arise close to the tori/electric-charges of colliding protons. At low energy, the ratio X_1 of the energy of particles that have a transverse-momentum to the energy of emitters (i.e. of protons having atom-like structure) is

$$X_1 = 2m_{electron} / m_{proton}. \quad (26)$$

When energy of collision increases then there appears along a transverse direction the core-anticore pairs in such a way that the spins of the cores are parallel to the transverse direction. Half of such a segment has a length equal to r_T

$$r_T = E\,D / (2\,H^+), \quad (27)$$

where the E is the amount of energy of the colliding pp pair expressed in TeV, the $H^+ = 727.44 \cdot 10^{-6}$ TeV is the mass of the charged core of a baryon and $D = 2A/3$ is the across of a charged torus of a baryon placed inside the core ($A = 0.697442$ fm). The segments behave in a similar way to liquid-like plasma. The energy released during the nuclear strong interactions transits towards the ends of the segments.

Within the CMS (the Compact Muon Solenoid) many pp collisions take place therefore liquid-like plasma appears (i.e. the segments). The segments fill a prolate cylinder. Inside such a cylinder are core-anticore pairs whereas the protons that have an atom-like structure are only on a lateral surface of the cylinder with such a surface having a thickness equal to D. Since inside the cylinder the $d = 1, 2, 4$, states are destroyed, inside the liquid-like plasma only arise pions, kaons and the contracted electrons having energy of approximately 4.6 MeV as particle-antiparticle pairs. The components of pions arise inside the tori whereas the kaons and contracted electrons are produced in the $d = 0$ state i.e. on the equators of the tori [1]. Pairs of the cores of baryons appear because of the symmetries characteristic for the nuclear strong interactions. All particles produced inside the liquid-like plasma have transverse-momentum – they are the non-single-diffractive fraction (the NSD fraction). The protons that have an atom-like structure produce hadrons that have momentum tangential to the surface of a cylinder also – this is the single-diffractive fraction (the SD fraction). This means that the ratio X_2 of energy of the NSD hadrons that have transverse-momentum to the total energy emitted by the lateral surface of liquid-like plasma (i.e. by the protons having an atom-like structure) is (the SD fraction is emitted by the surface whereas the NSD fraction goes through the surface)

$$X_2 = X_1\,\pi\,r_T^2\,H_{CMS} / (2\,\pi\,r_T\,H_{CMS}\,D) = X_1\,r_T / (2\,D), \quad (28)$$

where H_{CMS} is the longitudinal length of the liquid-like plasma.

Following simple conversions we obtain

$$X_2 = X_3 E_N, \qquad (29)$$

where $X_3 = 0.37434$ and E_N is the number equal to the amount of energy per one *pp* collision expressed in TeV.

The liquid-like plasma behaves in a similar way to a black body because the interiors of nucleons behave like a black body. This means that the energy emitted is directly in proportion to absolute temperature of a body to the power of four. The temperature of liquid-like plasma is directly in proportion to the pseudorapidity density found in a central region ($pseudorapidity\ density = dN_{charged\text{-}hadrons} / d\eta$; $\eta<0.5$; pseudorapidity is defined as $\eta = -\ln [\tan(\Theta / 2)]$, where Θ is the polar angle) for the NSD interactions so also to the NSD fraction, whereas the emitted transverse-energy is directly in proportion to the X_2. This means that the NSD fraction is

$$NSD\text{-}fraction = (0.37434 \cdot E_N)^{1/4} \cdot 100\%. \qquad (30)$$

For energy of 0.9 TeV, we obtain the NSD fraction equal to 76.18% whereas for 2.36 TeV we obtain 96.95%. We can see that there is an increase of 27.3% from 0.9 TeV to 2.36 TeV. This theoretical result is consistent with experimental data [8]. There is a threshold for $E_N = 2.672$ TeV. For energy higher than 2.672 TeV, the NSD energy becomes higher than the energy of protons that have an atom-like structure on the lateral surface of liquid-like plasma. This means that the external layers of liquid-like plasma can separate from it explosively – it means that above this threshold energy there should dominate production of the pions and kaons.

The Compton wavelength of the bare electron is equal to the external radius of the polarized torus so similar to it, the characteristic wavelength for colliding nucleons, leading to liquid-like plasma, is equal to the $A = 0.697442$ fm. It follows from the fact that in liquid-like plasma the T-B orbits for strong interactions are destroyed. Using the theory in Wien's law, we obtain that the lowest temperature of liquid-like plasma, corresponding to the characteristic wavelength A, equals $4.155 \cdot 10^{12}$ K. Using the Uncertainty Principle, energy of a loop having a circumference equal to $2\pi \cdot 2A/3$ is 67.5444 MeV (it is for unitary spin of such a loop but length of wave is not unitary), therefore, for a length equal to A, the energy is approximately 283 MeV. Following such energy, a $\pi^+\pi^-$ pair can be produced. We also know that for energy equal to the threshold 2.672 TeV per colliding pair of nucleons, the released energy is equal to the mass of a nucleon i.e. approximately 939 MeV. This means that the 283 MeV leads to following number E_0 equal to the energy per colliding pair of nucleons expressed in TeV: $E_0 = 2.672 \cdot 283 / 939 = 0.805$. Such energy is needed in order to create liquid-like plasma having the lowest temperature i.e. the $4.155 \cdot 10^{12}$ K. Because the temperature is directly relative to the NSD-fraction, we obtain following formula for temperature T for liquid-like plasma

$$T = X_4 (0.37434 \cdot E_N)^{1/4}, \qquad (31)$$

where $X_4 = 5.6 \cdot 10^{12}$ K. For example, for energy equal to 9.1 TeV per colliding pair of nucleons, we obtain the temperature of liquid-like plasma about $7.6 \cdot 10^{12}$ K.

At the lowest temperature of liquid-like plasma, with each core of baryon, energy equal to approximately 727 + 283 = 1010 MeV is present and such a core occupies volume equal to approximately $V = 8A^3/3$. This leads to the lowest mass density of liquid-like plasma which is $2 \cdot 10^{18}$ kg/m^3. With an increasing energy of collisions, the volume of the core of baryons is constant whereas released energy E_R increases because of the strong interactions $E_R = 283 \cdot E_N / E_0$ [MeV]. Density of the liquid-like plasma is $\rho = (H^+ + E_R)/V$. This formula can be expressed as follows:

$$\rho = X_5 (2.07 + E_N), \tag{32}$$

where $X_5 = 0.692 \cdot 10^{18}$ kg/m^3.

11. Summary

Within the Quantum Chromodynamics (QCD), for decades we cannot answer following three fundamental questions: What is the origin of masses of the quarks? What is the origin of the mass of muon? Why within the 3-valence-quarks model of baryons we are not able to calculate precise masses and spin of proton and neutron which are the very numerous components of Nature? It suggests that QCD must be reformulated. We already answered the above questions within the Scale-Symmetric Theory (SST). Here we present the next arguments that QCD must be extended and modified.

We showed that mathematical descriptions of difficult problems can be very simple and we showed that they lead to theoretical results consistent with experimental data. The significant simplification results from the fact that the Kasner solution for flat anisotropic model leads to internal structure of bare particles (density of fields are very low in comparison with the Einstein spacetime, whereas the ground state of the Einstein spacetime behaves as empty volume so we can apply the Kasner metric). Moreover, such structure shows that finite size of the strong fields does not result from asymptotic freedom but follows from the structure of bare baryons i.e. follows from the structure of the core of baryons – in such theory do not appear the infinities and singularities (renormalization is unnecessary).

References

[1] Sylwester Kornowski (25 November 2015). ”Foundations of the Scale Symmetric Physics (Main Article No 1: Particle Physics)” http://vixra.org/abs/1511.0188

[2] Sylwester Kornowski (23 November 2015). ”Foundations of the Scale Symmetric Physics (Main Article No 2: Cosmology)” http://vixra.org/abs/1511.0223

[3] Sylwester Kornowski (30 November 2015). ”Foundations of the Scale Symmetric Physics (Main Article No 3: Chaos Theory)” http://vixra.org/abs/1511.0284

[4] http://pdg.lbl.gov/current/xsect; K. Nakamura *et al.* (Particle Data Group), J. Phys. G **37**, 075021 (2010)

[5] Kasner Edward; *“Geometrical Theorems on Einstein’s Cosmological Equations.”*; American Journal of Mathematics **43** (4): 217 – 221 (1921)

[6] The CMS Collaboration; *Transverse-momentum and pseudorapidity distribution of charged hadrons in pp collisions at sqrt(s) = 0.9 and 2.36 TeV*; arXiv: 1002.0621v2 [hep-ex] 8 Feb 2010

[7] http://en.wikipedia.org/wiki/File:Strange_production_7.gif

[8] The CMS Collaboration; Transverse-momentum and pseudorapidity distribution of charged hadrons in pp collisions at sqrt(s) = 0.9 and 2.36 TeV; arXiv: 1002.0621v2 [hep-ex] 8 Feb 2010.