The Reformulated Asymptotic Freedom

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Abstract: Within the Scale-Symmetric Theory we calculated the running coupling for the nuclear strong interactions applying three different methods. They lead to very close theoretical results. At very high energy there appears asymptote for 0.1139. When we add to the strong running coupling calculated within the Scale-Symmetric Theory the correction that follows from the weak interactions associated with the parton-shower production then we obtain theoretical results consistent with experimental data for the “strong” interactions. The Scale-Symmetric Theory shows that the origin of the strong running coupling results from the law of conservation of spin - this law forces that with increasing energy of collision of baryons, absolute mass of the virtual pions which are responsible for the strong interactions decreases. On the other hand, the asymptotic freedom described within the QCD is consistent with experimental data only because of free parameters.

1. Introduction

Many experimental results lead to conclusion that inside baryons is a core. The Scale-Symmetric Theory (SST) shows that due to the phase transitions of the superluminal Higgs field there appear the torus and ball/condensate in its centre both composed of the Einstein spacetime components i.e. of the neutrino-antineutrino pairs [1A]. The torus is the black hole in respect of the nuclear strong interactions whereas the ball/condensate is the black hole in respect of the weak interactions [1A].

Define energy of collision per nucleon as $E_N\,[\mathrm{GeV}] = n\, m_N = m_N / \beta$ i.e. $\beta = m_N / E_N$, where $m_N = 0.939$ GeV. Then, the two formulae derived within the Scale-Symmetric Theory [1A] for the upper and lower limits for the running coupling for the strong-weak interactions we can rewrite as follows:

$$\alpha_{sw} = \alpha_{sw,central\text{-}value} \pm \Delta\alpha_{sw}\,, \qquad (1)$$

$$\alpha_{sw} = \{\alpha_{w(proton)}\beta^2 + b\beta + c\} \pm (b - b_l)\beta, \qquad (2)$$

$\alpha_{w(proton)} = 0.0187229$,
$b = 0.36255$,

$c = 0.1139$,

$b - b_l = 0.04415$.

We can see that at very high energy there is asymptote $\alpha_{sw} = c = 0.1139$. The formula (2) follows from the internal structure of the core of baryons (the torus + ball/condensate), the law of conservation of spin and the uncertainty principle.

For $E_N \rightarrow \infty$ is $\alpha_{sw} = 0.1139$, for $E_N = 2.76$ GeV is 0.1140, for 91.19 GeV is 0.1176 ± 0.0005, for 20 GeV is 0.1309 ± 0.0021, for 10 GeV is 0.1481 ± 0.0041, for 5 GeV is 0.1827 ± 0.0083, for 2 GeV is 0.2882 ± 0.0207 and for 1 GeV is 0.4708 ± 0.0415.

Within the Standard Model the parton shower (PS) is not good understood so the phenomena associated with the PS can change the experimental data concerning the running coupling for the strong interactions.

In the Scale-Symmetric Theory, PS is produced due to the weak decays of condensates composed of the carriers of gluons and photons i.e. composed of the Einstein-spacetime components [1A]. According to SST, partons are the Einstein-spacetime components and each parton has three internal helicities so there are 8 different gluons that are the rotational energies of the neutrino-antineutrino pairs [1A]. The internal structure of partons is important in the strong fields whereas is not important in electromagnetic fields. It is because the strong fields have internal helicity whereas electromagnetic have not [1A]. We can see also that on the edge of the strong fields the gluons transform into photons [1A]. It causes that photon emission is so similar to gluon emission.

In the collisions of nucleons there are produced the Z bosons and their weak decays into parton shower weakens the weak interactions of the colliding nucleons. It is due to the holes produced in the Einstein spacetime in the places of decays of the Z bosons. Energy E of a condensate composed of interacting partons (it is due to the confinement [1A]) is directly proportional to volume i.e. $E \sim r^3$, where r is the radius of the condensate. On the other hand, the coupling constant for weak interactions is directly proportional to the radius of a condensate $\alpha_{W,proton,Z\text{-}production} \sim r$ [1A]. Since for $E = 0$ is $\alpha_{W,proton,Z\text{-}production} = \alpha_{W,proton} = 0.018723$ [1] whereas for $E = M_Z = 91.2$ GeV is $\alpha_{W,proton,Z\text{-}production} = 0$ so we obtain following formula

$$\alpha_{W,proton,Z\text{-}production} = \alpha_{W,proton}[1 - (E / M_Z)^{1/3}]. \quad (3)$$

Table 1

Q [GeV]	$\alpha_{SST}(E = Q)$
2,000	0.080
1,000	0.091
91.2	0.1176 ± 0.0005
50	0.1241 ± 0.0008
20	0.1316 ± 0.0021
10	0.1579 ± 0.0041
5	0.1943 ± 0.0083
1	0.4854 ± 0.0415

It leads to following formula that ties the experimental data for the "strong" running coupling $\alpha_{S,experiment}$ (in reality, it is the sum of coupling constants for strong and weak interactions) with the real strong running coupling α_{sw} described in this paper by formula (2)

$$\alpha_{SST} = \alpha_{S,experiment} = \alpha_{sw} + \alpha_{W,proton}[1 - (E / M_Z)^{1/3}]. \tag{4}$$

Calculate a few results that follow from formula (4) – they are collected in Table 1. We can see that they are consistent with experimental data [2]. The "strong" coupling $\alpha_{SST}(E = Q)$ is a function of the momentum transfer Q [GeV].

2. Calculations

On surface of the torus inside the core of baryons appear the gluon balls. Their energy M [GeV] we can calculate from formulae presented here [1A], [1D]. We can rewrite these formulae as follows

$$M\,[\mathrm{GeV}] = (C / E_N\,[\mathrm{GeV}] + D)^{10}, \tag{5}$$

$C = 0.52296$,
$D = 0.96868$.

Emphasize that formula (5) leads to the mass of bottom quark, [1A], that is used within the QCD asymptotic freedom.

Calculate following derivative $\partial M / \partial E_N$:

$$\partial M / \partial E_N = - 10\, C\, (C / E_N + D)^9 / E_N^2, \tag{6}$$

For $C / E_N << D$ i.e. for $E_N >> C / D = 0.54$, we obtain

$$\partial M / \partial E_N = - F / E_N^2, \tag{7}$$

$F = 3.927$.

The value F is for the strongly interacting torus which mass is $X = 318.3$ MeV [1A]. This torus produces gluons which energy m_g is the one fourth of the mass of the bound neutral pion (134.9661 MeV) [1A]. The change of the X onto m_g changes the value of the F: $F' = F\, m_g / X \approx 0.42$. So, we can rewrite formula (7) as follows

$$\partial M / \partial E_N = - F' / E_N^2, \tag{8}$$

$F' = 0.42$.

Integrate the equation (8). There appears the integration constant H which we can interpret as the ratio of the mass of the torus X to the mass of nucleon m_N : $H = X / m_N$. We obtain

$$M = F' / E_N + H, \tag{9}$$

$H = 0.339$.

We can define running coupling α_{sw} as follows $\alpha_{sw} = M^2$. It leads to following formula

$$\alpha_{sw} = (F' / E_N + H)^2, \tag{10}$$

For $E_N \rightarrow \infty$ is $\alpha_{sw} = 0.115$, for $E_N = 2.76$ GeV is 0.115, for 91.19 GeV is 0.118, for 20 GeV is 0.13, for 10 GeV is 0.15, for 5 GeV is 0.18, for 2 GeV is 0.30 and for 1 GeV is 0.58. We can see that only for 1 GeV the obtained result from formula (10) is not close to the central value obtained from formula (2).

The formula (10) can be derived in a different way. The gluon balls/condensates produced from the energy of collision look similarly to the ball/condensate in the centre of torus. Due to the confinement [1A], gluon balls/condensates have the same radius as the ball/condensate in centre of the torus. When energy of a gluon ball/condensate increases then increases the rotational energy of the carriers of the gluons the ball/condensate consists of. This energy does not increase mass density of the ball so it still is the black hole in respect of the weak interactions. For a rotating gluon ball/condensate is $E_b\, v\, r = const.$ i.e. $E_b \sim 1/v$, where v is the spin speed of the rotating components of the Einstein spacetime i.e. of the carriers of gluons. The relative mass R_{sw} responsible for asymptotic freedom, we can separate into two parts. The first part concerns the strong interactions of the torus that is the black hole in respect of the strong interactions. The R_strong should be $R\_strong = X / m_N$, where $X = 0.3183$ GeV is the rest mass of the torus. The second part concerns the weak interactions of the created gluon balls/condensates. They are the black holes in respect of the weak interactions. Due to the relation $E_b \sim 1 / v$, the intensity of weak interactions of the gluon balls/condensates decreases when energy increases. It leads to conclusion that the second part R_weak should be $R\_weak = Y / E_N$, where $Y = 0.4241$ GeV is the rest mass of the ball/condensate in centre of the torus.

The above description leads to following formula

$$R_{sw} = R\_weak + R\_strong = Y / E_N + X / m_N. \tag{11}$$

Similar as previously we can define the running coupling as R^2 so we obtain

$$\alpha_{sw} = (Y / E_N + X / m_N)^2. \tag{12}$$

This formula is correct for $E_N >> E_o = Y\, m_N / X = 1.25$ GeV. Due to the quadrupole symmetry for the weak interactions [1A], the lower limit for the E_N should be $4E_o = 5$ GeV and such value is characteristic for the QCD asymptotic freedom.

3. Summary

We described the "asymptotic freedom" applying three different methods. They lead to very close theoretical results. When we add to the strong running coupling calculated within the Scale-Symmetric Theory the correction that follows from the weak interactions associated with the parton-shower production then we obtain theoretical results consistent with experimental data.

The Scale-Symmetric Theory shows that the origin of the strong running coupling results from the law of conservation of spin – this law forces that with increasing energy of collision of baryons, absolute mass of the virtual pions which are responsible for the strong interactions decreases.

The asymptotic freedom described within the QCD is consistent with experimental data only because of free parameters.

References

[1] Sylwester Kornowski (2015). *Scale-Symmetric Theory*
[1A]: http://vixra.org/abs/1511.0188 (Particle Physics)
[1B]: http://vixra.org/abs/1511.0223 (Cosmology)
[1C]: http://vixra.org/abs/1511.0284 (Chaos Theory)
[1D]: http://vixra.org/abs/1512.0020 (Reformulated QCD)
[2] http://arxiv.org/pdf/1312.5694.pdf .