[LatinoAmerican Workshop on High Energy Physics: Particles and Strings]

Havana, 15-21 July 2012

The Latinoamerican Workshop on High Energy Physics: Particles and Strings aims to bring together scientist of Europe and Latin-american countries with the purpose of develop and strengthen scientific links and collaborations between the various physics communities. The program of the conference will include a set of review lectures on the following topics:

- **Physics of the Standard Model and Beyond.**
- **Theories of fundamental interactions: QCD, Nuclear physics, Astrophysics, Dark matter.**
- **LHC: Experiments and first signatures.**
- **String phenomenology**
- **D-branes, holography, black hole physics.**

The program will also includes informal talks given by young scientist from Latin-American countries and short talks by other participants in the meeting. Open discussions on scientific areas of common interests will be included.

webpage:

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A proposal of a local modified QCD

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Overview

1. Resume on the indications about mass generation in a modified version of PQCD (MQCD).

2. The non local expression for the Feynman expansion .

3. “Moving” the gluon and quark condensate effects to vertices in the modified action.

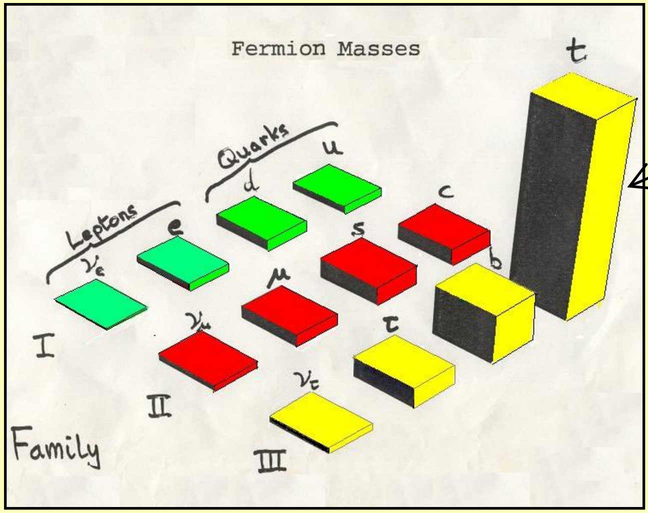
4. The proposal of a local alternative form of the QCD Lagrangian.

5. The pure “quark” condensate case: A local and renormalizable theory of massive quarks as a possible effective theory of massless QCD.

6. One loop polarization tensor and the two loop effective potential as functions of the condensate parameters.

7. The possibility of describing the quark mass generation.

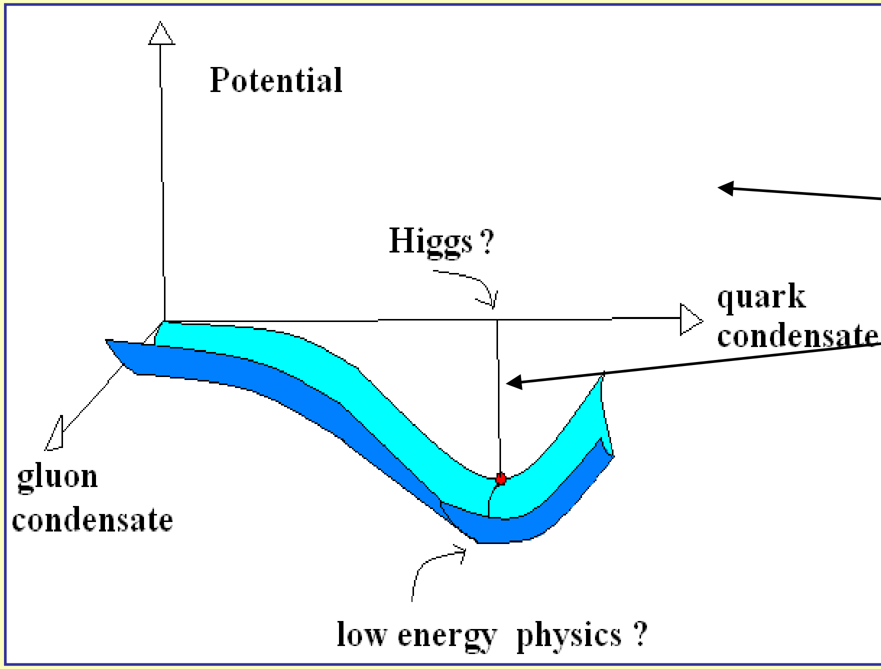
1. Resume on the indications about mass generation in a modified version of PQCD



Determining the origin of the wide range of values spanned by the **quark masses**, and more generally, the structure of the **lepton and quark mass spectrum** (illustrated in the figure on the left, but not at a correct scale) is one of the central problems of **High Energy Physics**.

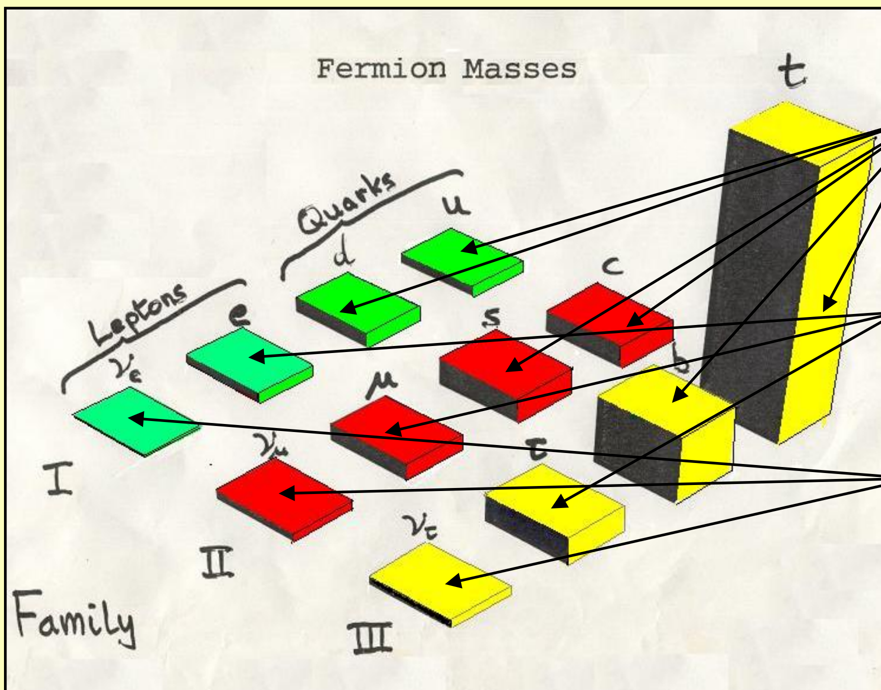
In former works (**Mod. Phys. Lett. A10, 2413 (1995), Phys. Rev. D 62 074018 (2000), Eur. Phys. J. C23, 289 (2002), JHEP (04), 044 (2003), Eur. Phys. J. C47, 95 (2006), Eur. Phys. J. C47, 355 (2006), Eur. Phys. J. C 55, 85 (2008), Eur. Phys. J. C 64: 133 (2009), Eur. Phys. J. C 71, 1620, (2011)**), the formulation and implications of a modified version of the **PQCD** have been explored.

The general motivation was created by the suspicion about that the strong degeneration of the non-interacting QCD vacuum (the state which is employed for the construction of the standard Feynman rules of **PQCD**) in combination with the strong forces carried by the QCD fields, could produce a large **dimensional transmutation effect,** implying the generation of large quark and gluon condensates, and correspondingly **large quak masses and confinement**. Historically, the first motivation was the aim in to develop a sort of improved "Savvidi Chromomagnetic field model" not showing the known symmetry difficulties, which affect that scheme. Which was one the first models indicating the existence of confinement in QCD.



The following picture could arise:

- A sort of the Top condensate model might be the effective action for massless QCD.
- A Top quark condensate arising at the same SM model level could play the role of the Higgs.
- The SM could be closed by generating all the masses within its proper framework as follows:



The six quarks could get their masses thanks to the mentioned flavour symmetry breaking.

The electron, muon and tau leptons, would receive their intermediate mass values due to radiative corrections mediated by their electromagnetic interactions with quarks.

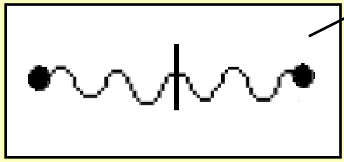
Finally, only the weak interacting character of the three neutrinos with all the particles could determine their even smaller mass values.

$$|\phi\rangle = \exp \sum_a \left[C_1(p) A^{a+}_{p,1} A^{a+}_{p,1} + C_2(p) A^{a+}_{p,2} A^{a+}_{p,2} + C_3(p) \right.$$
$$\left. \times \left(B^{a+}_p A^{L,a+}_p + i\bar{c}^{a+}_p c^{a+}_p\right)\right]|0\rangle,$$

The **BCS like initial state** for the derivation of the modified Feynman rules for the case of gluon condensation in the absence of quark pair condensation. **(Phys. Rev. D 62 074018 (2000)**

$$G^{ab}_{\mu\nu}(p) = \left(\frac{1}{p^2 + i\epsilon} - i\delta(p)C\right)\delta^{ab} g^{\mu\nu}$$

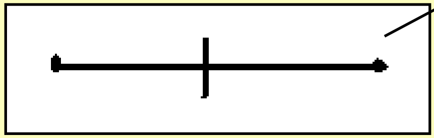
The originally proposed modified gluon propagator reflecting the condensation of zero momentum gluons, was reproduced after chosing appropriate values for the parameters in the initial **BCS** like state. (**Mod. Phys. Lett. A10, 2413 (1995))**



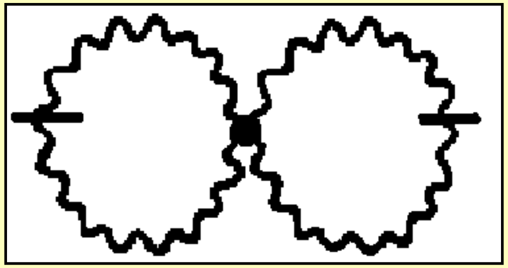
$$|\phi^*\rangle = \lim_{p\to 0} \exp\left(\sum_{f_1 f_2} \tilde{C}_q^{f_1 f_2}(p)\, \bar{q}^{+}_{f_1}(p)\, q^{+}_{f_2}(p)\, |\phi\rangle\right)$$

The results for gluons motivated the idea of also considering the quarks as massless and search for the possibility of generate their masses dynamically, thanks to the condensation of quark pairs. For this purpose the **BCS like initial state** was generalized to include the quark pair condensates in massless QCD. (**JHEP (04), 044 (2003), Eur. Phys. J. C 47, 95–112 (2006))**

$$G_q^{i_1 i_2; f_1 f_2}(p) = \left(-\frac{\gamma^\mu p_\mu \delta^{f_1 f_2}}{p^2 + i\epsilon} + i\delta(p) C^{f_1 f_2}\right)\delta^{i_1 i_2}$$



In this case a covariant **free-quark propagator** was obtained.



The scheme determines a gluonic Lagrangian mean value in the simplest approximation in terms of *C* and *g.*

$$\langle G^2 \rangle = \frac{288 g^2 C^2}{(2\pi)^8},$$

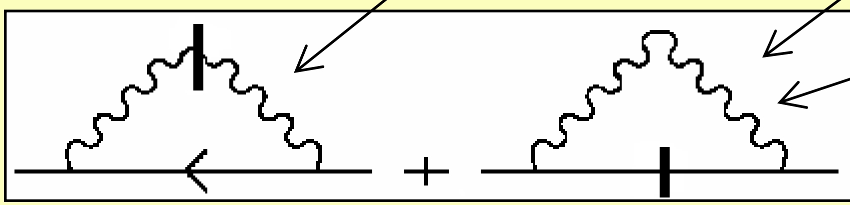
$$\langle g^2 G^2 \rangle \cong 0.5 \left(\mathrm{GeV}/c^2\right)^4$$

Then, with an estimate for the mean value of the gluon Lagrangian, the parameter ***g²C*** was evaluated.

$$g^2 C = 64.9394 \left(\mathrm{GeV}/c^2\right)^2$$

$$\frac{1}{p^2}\left(-p^2 p_\mu \gamma^\mu \left(1 - \frac{M^2}{p^2}\right)\delta^{f_1 f_2} - \frac{4 g^2 C_F}{(2\pi)^4} C^{f_1 f_2}\right)\Psi_i^{f_2}(p) = 0\,,$$

Dyson equation for quarks in the simplest condensate dependent approximation.



The quark self-energy in the lowest order in the power expansion in the condensate parameters.

$Quark\ q$	$m^{Exp}_{qLow}(MeV)$	$m^{Exp}_{qUp}(MeV)$	$m^{Theo}_{q}(MeV)$
u	1.5	5	333
d	3	9	333
s	60	170	339–326
c	1100	1400	1255
b	4100	4400	4233
t	168600	17900	173500

1) Disregarding the gluon condensate, the quark condensate matrix was fixed in a diagonal form by reproducing the observable Lagrangian quark masses as the solutions of the Dyson equation.
2) After that, the solution of the Dyson equation including the value of ***g²C*** through the constant *M* **,** furnished the "constituent" values of 1/3 of the nucleon mass for the light quarks obtained in Ref. **Eur. Phys. J C23, 289 (2002).**

2. The non local expression for the previous Feynman expansion for the modified QCD

The general Feynman expansion of the modified perturbative expansion is expressed by the generating functional of form

$$Z[j,\eta,\overline{\eta},\xi,\overline{\xi}] = \frac{I[j,\eta,\overline{\eta},\xi,\overline{\xi}]}{I[0,0,0,0]},$$

$$I[j,\eta,\overline{\eta},\xi,\overline{\xi}] = \exp(V^{int}[\frac{\delta}{\delta j},\frac{\delta}{\delta\overline{\eta}},\frac{\delta}{-\delta\eta},\frac{\delta}{\delta\overline{\xi}}\frac{\delta}{-\delta\xi}])\times$$

$$\exp(\int\frac{dk}{(2\pi)^D}j(-k)\frac{1}{2}D(k)j(k))\times$$

$$\exp(\sum_f\int\frac{dk}{(2\pi)^D}\overline{\eta}_f(-k)G_f(k)\eta_f(k))\times$$

$$\exp(\int\frac{dk}{(2\pi)^D}\overline{\xi}(-k)G_{gh}(k)\xi(k)),$$

$$f = 1,2,...6.$$

where *D, G_f* and *G_{gh}* are the previously mentioned modified gluon, quark and ghost propagators.

The Lagrangian defining the vertex part V^{int} of the Wick expansion is the usual QCD one.

$$S_g = \int dx(-\frac{1}{4}F^a_{\mu\nu}F^a_{\mu\nu} - \frac{1}{2\alpha}\partial_\mu A^a_\mu\partial_\nu A^a_\nu + \overline{c}^a\overleftarrow{\partial}_\mu D^{ab}_\mu c^b - \sum_f\overline{\Psi}^i_f\; i\gamma_\mu D^{ij}_\mu\Psi^j_f),$$

$$V^{int} = S_g - S_0,$$

with the standard conventions.

$$F^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu - gf^{abc}A^b_\mu A^c_\nu,$$

$$D^{ij}_\mu = \partial_\mu\delta^{ij} + ig\;A^a_\mu T^{ij}_a,\qquad D^{ab}_\mu = \partial_\mu\delta^{ab} + gf^{abc}\;A^c_\mu,$$

$$\{\gamma_\mu,\gamma_\nu\} = -2\delta_{\mu\nu},\qquad [T_aT_b] = if^{abc}T_c.$$

The gluon, quark and ghost propagators take the forms (***Eur. Phys. J. C* 47**, 95–112 (2006)):

$$D^{ab}_{\mu\nu}(k) = \delta^{ab}\left(\frac{1}{k^2}(\delta_{\mu\nu} - (1-\alpha)\frac{k_\mu k_\nu}{k^2})\theta_N(k) + C_g\delta^D(k)\delta_{\mu\nu}\right),$$

$$G^{ij}_f(k) = \delta^{ij}\left(\frac{\theta_N(k)}{m+\gamma_\mu k_\mu} + C_f\delta^D(k)I\right),$$

$$G^{ab}_{gh}(k) = \delta^{ab}\frac{\theta_N(k)}{k^2}.$$

These are basically the same Feynman propagators of PQCD, after adding the Dirac delta functions at zero momentum that represent the gluon and quark condensates and including a Heaviside function (introduced by Nakanishi to solve difficulties in the quantization of the free gauge theory). They make the Feynman contribution to the propagator vanish in a small neighborhood of the zero value of the momentum. The introduction of this function allowed to get rid of various singular contributions to the Feynman expansion that could have been appeared, due to the distributional character of the Dirac delta function modifications of the propagators (***Eur. Phys. J. C* 47**, 95–112 (2006)).

3. “Moving” the gluon and quark condensate effects to vertices in the modified action

Noting that the gluon and quark terms modifying the propagators are quadratic forms in the zero momentum component of the spacial Fourier transforms of the sources:

- The exponential of those terms in ***Z*** were expressed as gaussian integrals over auxiliary vector and fermion parameters $\alpha, \chi, \overline{\chi}$ which makes the depence of the Feynman integrands linear in the gluon and fermion sources.
- Then, after evaluating the simple commutator of an exponential factor with an argument being linear in the sources with the exponential of the vertex part ***V**^int^* as expressed in terms of the functional derivatives over the fields, ***Z*** was expressed as

$$Z[j,\eta,\overline{\eta},\xi,\overline{\xi}] = \frac{1}{\mathcal{N}}\int\int d\alpha d\overline{\chi} d\chi \exp[-\sum_f \overline{\chi}^i_{f,\,r}\chi^i_{f,\,r} - \frac{\alpha^a_\mu\alpha^a_\mu}{2}]$$

$$\exp\,[\overline{S}^*_g[\frac{\delta}{\delta j},\frac{\delta}{\delta\overline{\eta}},\frac{\delta}{-\delta\eta},\frac{\delta}{\delta\overline{\eta}},\frac{\delta}{-\delta\eta},\alpha,\chi,\overline{\chi}]]\times$$

$$\int \mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\exp\,[\int dx\ (j(x)A(x)+\sum_f(\overline{\eta}_f(x)\Psi_f(x)+\overline{\Psi}_f(x)\eta_f(x)))]$$

$$= \frac{1}{\mathcal{N}}\int\int d\alpha d\overline{\chi} d\chi \exp\,[-\sum_f \overline{\chi}^i_{f,\,r}\chi^i_{f,\,r} - \frac{\alpha^a_\mu\alpha^a_\mu}{2}]\times$$

$$\int \mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\exp\,[\int dx\ (\overline{S}^*_g[A,\Psi,\overline{\Psi},c,\overline{c},\alpha,\chi,\overline{\chi}]+$$

$$j(x)A(x)+\sum_f(\overline{\eta}_f(x)\Psi_f(x)+\overline{\Psi}_f(x)\eta_f(x)))].$$

The action appearing has the form

$$
\begin{aligned}
\overline{S}_g^* &= \overline{S}_g^*[A,\Psi,\overline{\Psi},c,\overline{c},\alpha,\chi,\overline{\chi}] \\
&= \int dx[-\frac{1}{4}F_{\mu\nu}^a(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha)F_{\mu\nu}^a(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha) \\
&\quad -\frac{1}{2\alpha}\partial_\mu A_\mu^a\partial_\nu A_\nu^a-\overline{c}^a\partial_\mu D_\mu^{ab}(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha)c^b \\
&\quad -\sum_f(\overline{\Psi}_f^i\ i\gamma_\mu D_\mu^{ij}(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha)\Psi_f^j+\overline{\Psi}_f^i\ i\gamma_\mu D_\mu^{ij}(A)\chi_f^j(\frac{C_f}{(2\pi)^D})^{\frac{1}{2}}+(\frac{C_f}{(2\pi)^D})^{\frac{1}{2}}\overline{\chi}_f^i\ i\gamma_\mu D_\mu^{ij}(A)\Psi_f^j \\
&\quad +(\frac{C_f}{(2\pi)^D})(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\overline{\chi}_f^i\ i\gamma_\mu\ ig\alpha_\mu^a T_a^{ij}\chi_f^j)].
\end{aligned}
$$

It is needed to uderline that the parameters resulted as constants independent of the space time coordinates. This was a consequence of the simple perturbative modifications of the free QCD vacuum employed to connect the interaction for the construction of the Wick expansion. Therefore, all the space time derivatives of these parameters in the above formula, in fact vanish, which makes that the expression can not be associated to a quantized gauge theory. This represents a limitation of the previous version of the modified QCD considered up to now. However, the above written form of the action suggests a direct solution of this issue to be examined in what follows.

4. The proposal of a local alternative form of the QCD Lagrangian

$$Z[j,\eta,\overline{\eta},\xi,\overline{\xi}]=\frac{1}{\mathcal{N}}\int\int\mathcal{D}[\alpha,\overline{\chi},\chi]\exp[-\sum_f\overline{\chi}^i_{f,\,r}(x)\chi^i_{f,\,r}(x)-\frac{\alpha^a_\mu(x)\alpha^a_\mu(x)}{2}]\times$$
$$\int\mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\exp\Big[\int dx\,\big(S^*_g[A,\Psi,\overline{\Psi},c,\overline{c},\alpha,\chi,\overline{\chi}]+$$
$$j(x)A(x)+\sum_f(\overline{\eta}_f(x)\Psi_f(x)+\overline{\Psi}_f(x)\eta_f(x))\big)\Big],$$

The solution suggested starts by ¨promoting the $\alpha,\chi,\overline{\chi}$ parameters to be full space-time dependent functions.

$$\begin{aligned}
S^*_g&=S^*_g[A,\Psi,\overline{\Psi},c,\overline{c},\alpha,\chi,\overline{\chi}]\\
&=\int dx[-\frac{1}{4}F^a_{\mu\nu}(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha)F^a_{\mu\nu}(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha)\\
&-\frac{1}{2\alpha}\partial_\mu A^a_\mu\partial_\nu A^a_\nu-\overline{c}^a\partial_\mu D^{ab}_\mu(A)c^b)\\
&-\sum_f\overline{\Psi}^i_f\; i\gamma_\mu D^{ij}_\mu(A+(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\alpha)\;\Psi^j_f\\
&-\sum_f\overline{\Psi}^i_f\; i\gamma_\mu D^{ij}_\mu(A)\chi^j_f\;(\frac{C_f}{(2\pi)^D})^{\frac{1}{2}}-\sum_f(\frac{C_f}{(2\pi)^D})^{\frac{1}{2}}\overline{\chi}^i_f\; i\gamma_\mu D^{ij}_\mu(A)\Psi^j_f\\
&-\sum_f(\frac{C_f}{(2\pi)^D})(\frac{2C_g}{(2\pi)^D})^{\frac{1}{2}}\overline{\chi}^i_f\; i\gamma_\mu\; ig\alpha^a_\mu T^{ij}_a\chi^j_f].
\end{aligned}$$

The new action becomes the same one as in the previous modified QCD which now turns to be associated to a gauge theory if the new fields transform $\alpha,\chi,\overline{\chi}$ homogeneous way under gauge changes.

5. The pure "quark" condensate case: A local and renormalizable theory of massive quarks as a possible effective theory of massless QCD

In the limit of vanishing gluon condensates, the Z functional reduces to

$$Z[j,\eta,\overline{\eta},\xi,\overline{\xi}] = \frac{1}{\mathcal{N}}\int\int \mathcal{D}[\alpha,\overline{\chi},\chi]\exp[-\sum_f \overline{\chi}^i_{f,\,r}(x)\chi^i_{f,\,r}(x) - \frac{\alpha^a_\mu(x)\alpha^a_\mu(x)}{2}]\times$$
$$\int \mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\exp[\int dx\,(S^*_g[A,\Psi,\overline{\Psi},c,\overline{c},\chi,\overline{\chi}]+$$
$$j(x)A(x)+\sum_f(\overline{\eta}_f(x)\Psi_f(x)+\overline{\Psi}_f(x)\eta_f(x)))],$$

where the action now adopts the simpler form

$$S^*_g = S^*_g[A,\Psi,\overline{\Psi},c,\overline{c},\chi,\overline{\chi}]$$
$$= \int dx\,[-\frac{1}{4}F^a_{\mu\nu}F^a_{\mu\nu} - \frac{1}{2\alpha}\partial_\mu A^a_\mu\partial_\nu A^a_\nu - \overline{c}^a\partial_\mu D^{ab}_\mu c^b)$$
$$-\sum_f(\overline{\Psi}^i_f\, i\gamma_\mu D^{ij}_\mu\Psi^j_f + \overline{\Psi}^i_f\, i\gamma_\mu D^{ij}_\mu\chi^j_f\,(\frac{C_f}{(2\pi)^D})^{\frac{1}{2}} + (\frac{C_f}{(2\pi)^D})^{\frac{1}{2}}\overline{\chi}^i_f\, i\gamma_\mu D^{ij}_\mu\Psi^j_f)],$$

which is basically the massless QCD action plus two linear terms in the new fermion fields $\chi,\overline{\chi}$

The gaussian integral over the auxiliary functions $\chi, \overline{\chi}$ can be evaluated by solving the equations

$$\frac{\delta S_g^*[A,\overline{\Psi},\Psi,\overline{c},c,\overline{\chi},\chi]}{\delta\overline{\chi}_f^i} = -\chi_f^i - (\frac{C_q}{(2\pi)^D})^{\frac{1}{2}} i\gamma_\mu D_\mu^{ij}\Psi_f^j = 0,$$

$$\frac{\delta S_g^*[A,\overline{\Psi},\Psi,\overline{c},c,\overline{\chi},\chi]}{\delta\chi_f^i} = \overline{\chi}_f^i + \overline{\Psi^j}_f\ i\gamma_\mu \overleftarrow{D}_\mu^{ji}(\frac{C_q}{(2\pi)^D})^{\frac{1}{2}} = 0,$$

$$D_\mu^{ji} = \delta^{ji}\partial + igA_\mu^a T_a^{ji}, \quad \overleftarrow{D}_\mu^{ji} = -\delta^{ji}\overleftarrow{\partial} + igA_\mu^a T_a^{ji},$$

Then Z reduces to the form

$$Z = \frac{1}{\mathcal{N}}\int \mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c,]\exp[S[A,\overline{\Psi},\Psi,\overline{c},c]],$$

$$S[A,\overline{\Psi},\Psi,\overline{c},c] = S_{mqcd}[A,\overline{\Psi},\Psi,\overline{c},c] + S^q[A,\overline{\Psi},\Psi]$$

$$S_{mqcd}[A,\overline{\Psi},\Psi,\overline{c},c] = \int dx(-\frac{1}{4}F_{\mu\nu}^a F_{\mu\nu}^a - \frac{1}{2\alpha}\partial_\mu A_\mu^a \partial_\nu A_\nu^a - \sum_f \overline{\Psi}_f^i\ i\gamma_\mu D_\mu^{ij}\Psi_f^j - \overline{c}^a\partial_\mu D_\mu^{ab}c^b),$$

In which the associated action coincides with the massless QCD one with the added local terms

$$S^q[A,\overline{\Psi},\Psi] = -\sum_{f\ f'}\frac{C_{f\ f'}}{(2\pi)^D}\int dx\overline{\Psi}_f^j\ i\gamma_\mu \overleftarrow{D}_\mu^{ji}\ i\gamma_\nu D_\nu^{ik}\Psi_{f'}^k.$$

which are gauge invariant and also does not disturb power counting renomalizability because they also make the quark propagator to decrease with the square of the momentum at large values.

The quark propagator of the new expansion takes the form

$$S_f(p) = \frac{1}{-\gamma_\nu p^\nu - \frac{C_f}{(2\pi)^D}p^2} \equiv \frac{(-\gamma_\nu p^\nu - \frac{C_f}{(2\pi)^D}p^2)^{rr'}\delta^{ii'}}{p^2(1-(\frac{C_f}{(2\pi)^D})^2p^2)}$$

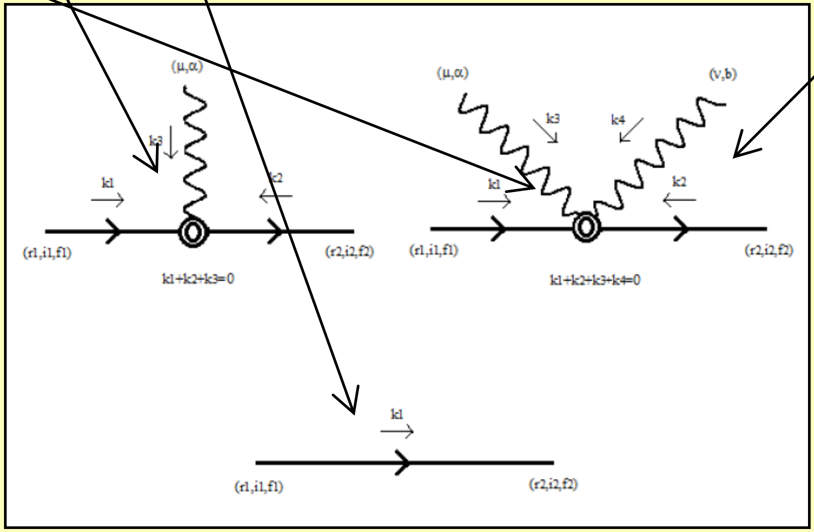
$$= \frac{m_f}{(m_f^2-p^2)} - \frac{m_f^2}{(m_f^2-p^2)}\frac{\gamma_\nu p^\nu}{p^2} = S_f^{(s)}(p) + S_f^{(f)}(p).$$

which clearly shows its decreasing with the square of the momentum, and decomposes in the sum of a scalar like and a Dirac like components.and determines masses for the quarks.

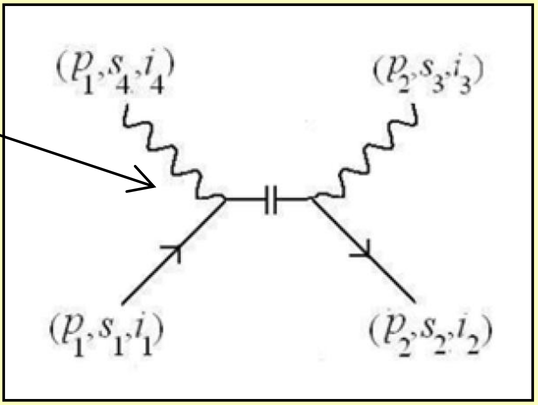
The new action terms also create two new vertices in the modified Feynman expansion

$$V^{(3)(\mu,a)}_{(r_1,i_1,f_1)((r_2,i_2,f_2)}(k_1,k_2,k_3) = g\frac{C_{f_1f_2}}{(2\pi)^D}T_a^{i_1i_2}(-(k_{1\alpha}\gamma^\alpha)^{r_1s}(\gamma^\mu)^{sr_2} + (\gamma^\mu)^{r_1s}(k_{2\alpha}\gamma^\alpha)^{sr_2}),$$

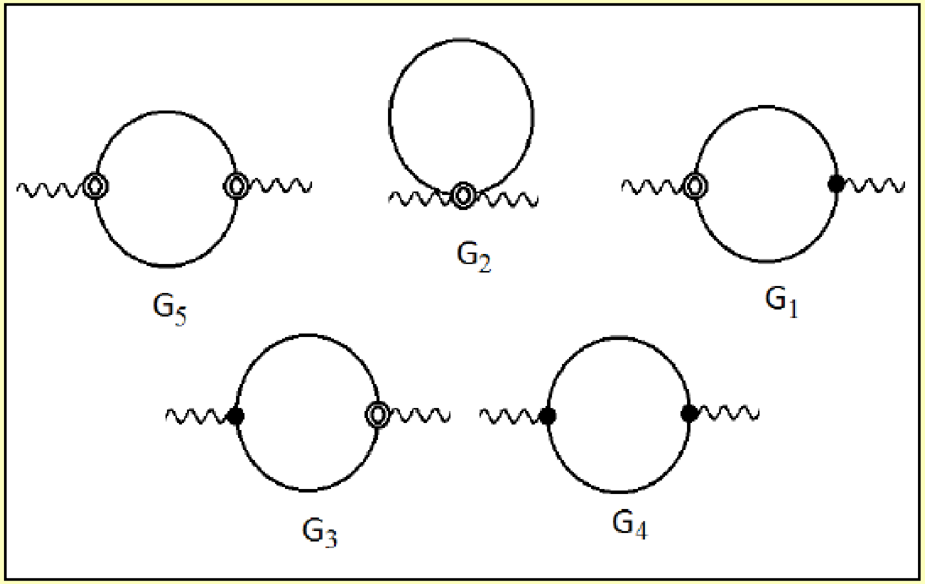
$$V^{(4)\ (\mu,a)(\nu,b)}_{(r_1,i_1,f_1)((r_2,i_2,f_2)}(k_1,k_2,k_3,k_4) = g^2\frac{C_{f_1f_2}}{(2\pi)^D}T_a^{i_1i}T_b^{ii_2}(\gamma^\mu)^{r_1s}(\gamma^\nu)^{sr_2}.$$



The four legs vertex is the local counterpart of the non local one appearing in the previous modified expansion



The contributions to the polarization operator determined by the new vertices



The gluon and ghost one loop contrbutions are the same as in massless QCD

The result became transversal, thus satisfied the Ward identity associated to the gauge invariance

$$\Pi^{ab}_{\mu\nu}(q) = \Pi^{ab}_{T}(q)(g_{\mu\nu} - \frac{q_\mu q_\nu}{q^2}),$$

$$\Pi^{ab}_{T}(q) = \Pi^{ab}_{5T}(q) + \Pi^{ab}_{2T}(q) + \Pi^{ab}_{1T}(q) + \Pi^{ab}_{3T}(q) + \Pi^{ab}_{4T}(q)$$

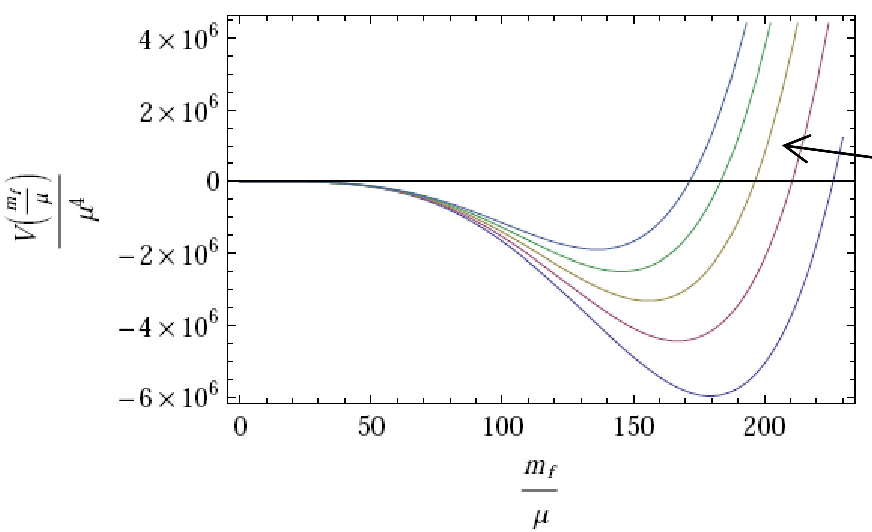
$$= -\frac{g^2\delta^{ab}}{D(D-1)}(D(D-26)+8)L_m(m_f) + \frac{g^2\delta^{ab}(2-D)}{(D-1)}q^2 L_{12}(q) +$$

$$+ \frac{g^2\delta^{ab}}{2(D-1)}(-2D(D+17)m_f^2 - 9D(2+D)q^2)L_{34}(q, m_f).$$

The effective potential up to the two loops approximation, is determined by the integral over the momentum of the evaluated polarization operator after contracted with the free gluon propagator

$$V(m_f) = 0.0656145\ m_f^4\ + 273.18\ m_f^4\ \frac{g_0^2}{4\pi} - (0.0379954 + 322.47\ \frac{g_0^2}{4\pi})\ m_f^4\ Log(\frac{m_f}{\mu}) + 132.527\ m_f^4\ \frac{g_0^2}{4\pi}\ Log^2(\frac{m_f}{\mu}).$$

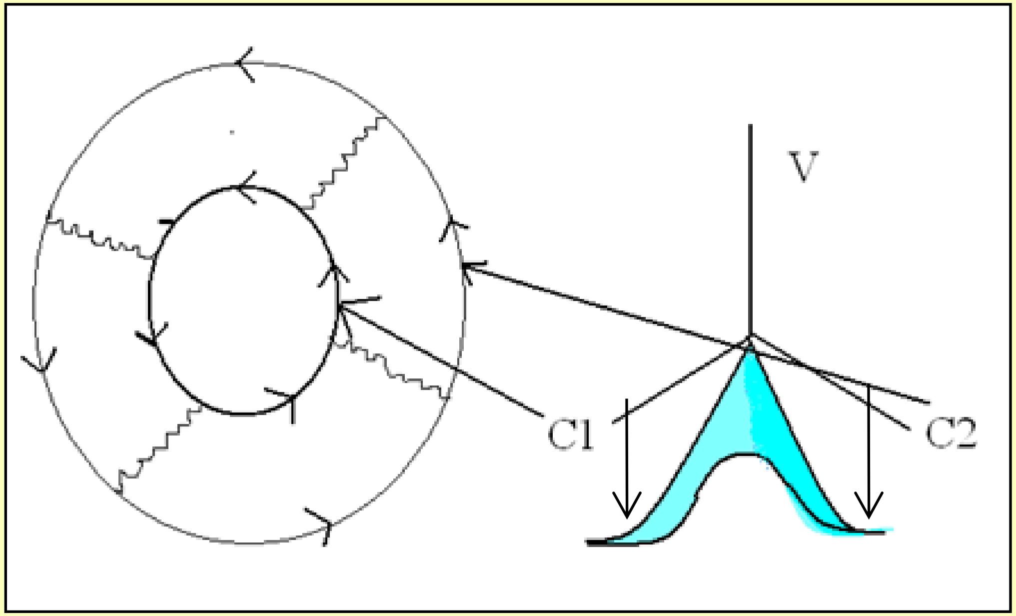
The calculated expression for the finite part of the effective potential as a function of the fermion mass (condensate parameter), the dimensional regularization parameter and the coupling.



The figure illustrates the effective potential as a function of the ratio between the fermion mass m_f and the dimensional regularization parameter μ. At μ = 1 GeV, various small values of the coupling constant around g_0 = 0.0271828 were chosen to evidence that the minimum of the potential can be fixed at a m_f being close to the top quark mass of 173 GeV. For higher values of the coupling the minimum tends to disappear in this one loop approximation.

The results show that, assumed that the coupling is small, the treatment produces a flavour symmetry breaking. This conclusion could be of interest for studying the possibility of a dynamical generation of a weak interaction sector as in the SM model.

7. A possibility of describing the quark mass generation and confinement



○ It can be noted that the two loop result for the effective potential in the case of strong coupling might be insufficient to decide about the possibility or not of a dynamical breaking of the flavour symmetry.

○ By example, in the two loop case, in a given diagram only one kind of quark propagator can appear. Thus, the results for the potential as a function of their flavour condensate parameters are identical for all the quark flavours. Therefore, the minimum of the potential is simply the sum of six identical contributions, which does not show any symmetry breaking.

○ However, in three and higher loop contributions, as the one illustarted in the above figure, two or more types of quark porpagators can participàte. Those terms are increasingly relevant at higher coupling values.

○Therefore, these terms of the potential could be able to generate minima of the potential as functions of the six quark condensates, around a non vanishing value of a particular quark condensate , for nearly null or smaller values of the other condensates. Hence, the appearance of this effect could furnish an explanation for the quark mass spectrum. If further analogous steps occur, the hierarchical behavior of fermions masses could also appear.

Summary

1) We have proposed an improved version of the modifed version of QCD discussed in previous works. The model shows local gauge invariance and include the same kind of gluon and fermion condensate parameters.
2) The analysis done for constructing the proposal suggests its equivalence with massless QCD. In the pure quark condensate case this equivalence is indicated after considering that the new vertices might be classifed as allowed counterterms within a renormalization procedure in massless QCD.
3) A promising direction of study is determined by the appearance of Gaussian means over color fields . This outcome suggests the possibility of allowing a derivation of the linear confining effects predicted by the stochastic vacuum models of QCD .
4) For the case of only retaining the quark condensate parameters, the fermion auxiliary functions were integrated leading to a QCD theory described by an alternative Lagrangian. It is given by the massless QCD one, to which new gauge invariant terms, one for each quark flavour, are added.
5) The new terms determine masses for all the six quarks which are given by the reciprocal of the new flavour condensate couplings linked with each quark type. The strength of the condensate couplings decreases with the masses of the associated quarks.
6) The gluon self-energy is evaluated up to the second order in the gauge coupling including all orders of the flavour condensate ones. The result, satisfies the transversality condition as required by the gauge invariance.
7) The transversal part of the self energy is employed to evaluate the two loop contribution to the effective action at zero mean fields, as a function of the flavour condensate couplings. The transversality and gauge parameter independence of the gluon self-energy, also determines the gauge parameter independence of the result for the potential.

8) The effective potential is evaluated in the two loop approximation, the potential in this approximation is able to predict the dynamic generation of quark masses, but only for sufficiently small values of the QCD coupling.

9) However, it can be noted that in the two loop order, the considered effective potential diagrams can not yet incorporate contributions associated to two different kinds of flavours. Thus, in this first approximation, the minimal energy will simply correspond to all the quark condensates for the different flavours minimizing their independent contributions to the effective potential.

10) Therefore , for the different flavour condensates to interfere one with other, at least three loops corrections to the effective potential are required. Thus, in order to explain the quark mass hierarchy as a dynamical flavour symmetry breaking, such "interference" like effects in the vacuum energy corrections should exist. In them, the contributions of diagrams showing two or more kinds of fermion lines might tend to rise the energy of the configurations with equal values of the quark condensates, making them more energetic that one in which a single quark condensate parameter gets a large value, and the others take hierarchical lower ones.

11) At the moment we have the impression that the considered framework seems very appropriate to realize the *Democratic Symmetry Breaking* properties of the mass hierarchy remarked by H. Fritzsch.

12) The prediction of the general discussion including gluon condensates for the low energy processes, as well as the renormalization properties and the evaluation of three loop contributions in the case of only having the fermion condensate, are expected to be considered elsewhere.

LatinoAmerican Workshop on High Energy Physics: Particles and Strings

Havana, 15-21 July 2012

The Latinoamerican Workshop on High Energy Physics: Particles and Strings aims to bring together scientist of Europe and Latin-american countries with the purpose of develop and strengthen scientific links and collaborations between the various physics communities. The program of the conference will include a set of review lectures on the following topics:

- **Physics of the Standard Model and Beyond.**
- **Theories of fundamental interactions: QCD, Nuclear physics, Astrophysics, Dark matter.**
- **LHC: Experiments and first signatures.**
- **String phenomenology**
- **D-branes, holography, black hole physics.**

The program will also includes informal talks given by young scientist from Latin-American countries and short talks by other participants in the meeting. Open discussions on scientific areas of common interests will be included.

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