Can the particle mass spectrum be explained within the Standard Model?

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A modified version of PQCD considered in previous works is further investigated here in the case of retaining only the quark condensate. In this situation the Green functions generating functional is expressed in a simple form in which Dirac's delta functions are now absent from the free propagators. The new expansion implements the dimensional transmutation effect through a single interaction vertex in addition to the standard ones in mass less QCD. The results of a two loop evaluation of the vacuum energy indicate that the quark condensate is dynamically generated. However, the energy as a function of the condensate parameter is unbounded from below and thus, further corrections should be evaluated to define if the system approaches to a stable ground state. The effective potential is parameterized as a function of the quark mass m_q, defined by the pole of the first corrections to the quark propagator, the assumed finite zero momentum limit of the coupling constant g and the dimensional regularization parameter μ. The condensate dependent first corrections to the gluon and quark self-energies and propagators are also calculated. Assuming the existence of a minimum of the vacuum energy at the experimental value of the top quark mass $m_q = 173$ GeV, we evaluate the two particle propagator in a $t\bar{t}$ channel in zero order in the coupling and a ladder approximation in the condensate vertex. Then, assuming the notion from the former *top* quark models, in which the Higgs field corresponds to the quark condensate, the result indicates that the Higgs particle should be considered as a $t\bar{t}$ meson which could appear at energies near to two times the *top* quark mass.

Overview

1. **Resume on the indications about mass generation obtained in previous works.**

2. **Derivation of a simple functional integral expression for the Green's functions generating functional, implementing the dimensional transmutation effect**

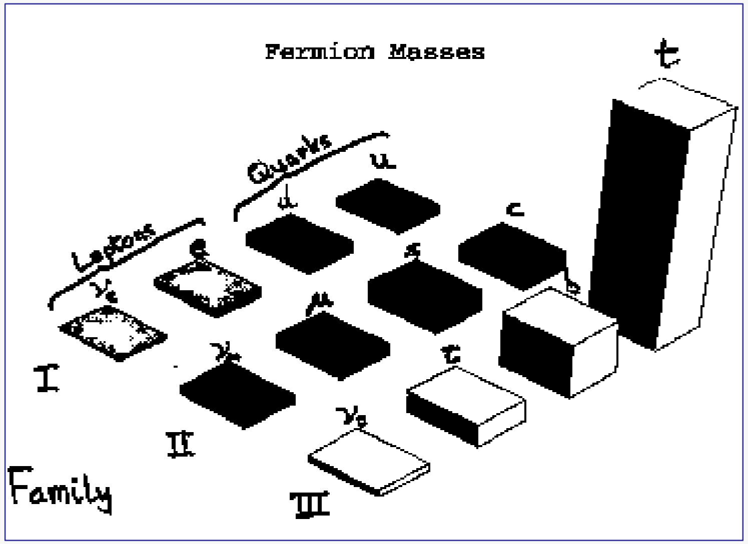
3. **Evaluation of a second order in the couping contributions to the vacuum energy: dynamical generation of a quark condensate**

4. **Evaluation of the two particle Green function in the quark antiquark channel in the ladder approximation in the condensate dependent vertex. The Higgs particle as a** *top anti-top* **meson.**

5. **Two comments**

6. **Summary and possible extensions of the work**

1. Resume on the indications about mass generation obtained previous works.

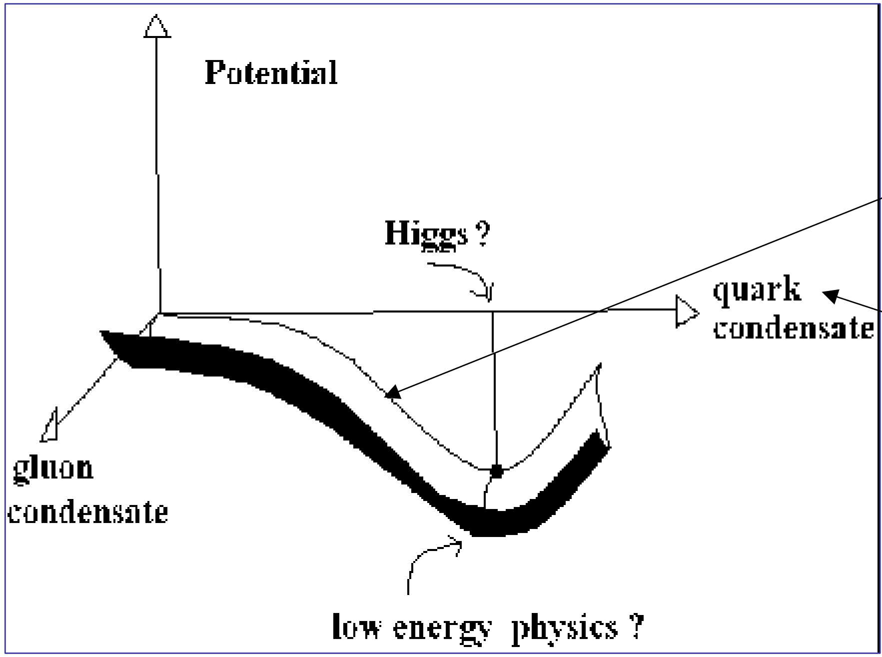


Determining the causes of the wide range of values spanned by the **quark masses**, and more generally, the structure of the **lepton and quark mass spectrum** (illustrated in the figure on the left, but not at a correct scale) is one of the central problems of **High Energy Physics**.

For very high energy collisions the usual perturbative expansion for **QCD (PQCD)** produces good experimental predictions, thanks to the asymptotic freedom effect. However, the limitations of this standard Feynman diagram expansion in describing the low energy properties, by example in the Nuclear effects, are recognized.

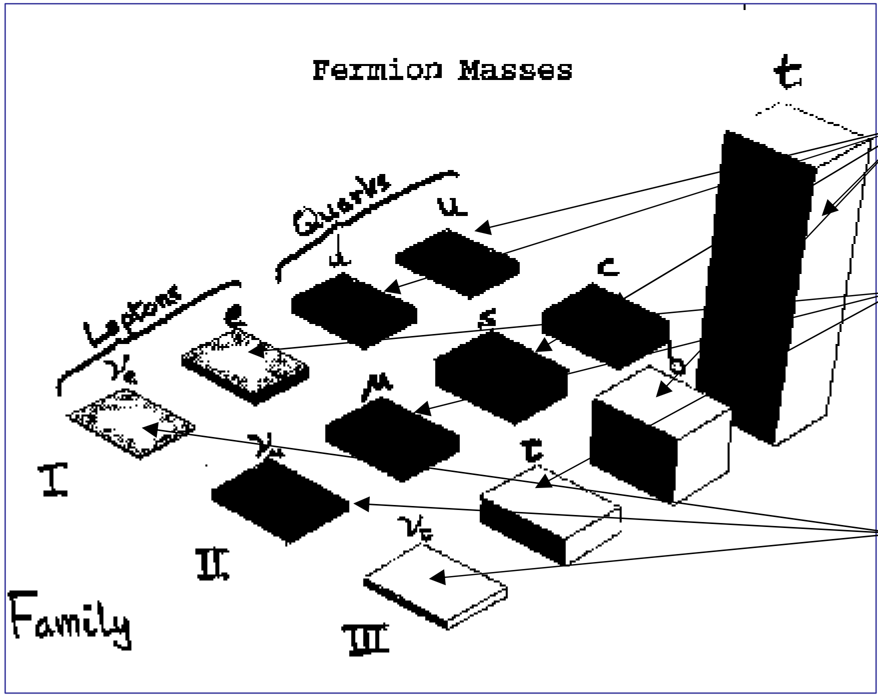
In former works (**Mod. Phys. Lett. A10, 2413 (1995), Phys. Rev. D 62 074018 (2000), Eur. Phys. J. C23, 289 (2002), JHEP (04), 044 (2003), Eur. Phys. J. C47, 95 (2006), Eur. Phys. J. C47, 355 (2006), Eur. Phys. J. C 55, 85 (2008)**), the formulation and implications of a modified version of the **PQCD**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

A general motivation was generated 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**) could allow for modified rules being able to furnish useful non-perturbative results. The expectation is that the scheme could show similar merits as the so called "Bogoliubov shift" procedure in scalar field theories, which gives physical ideas about non-perturbative effects in Bose condensation. However, historically, the first motivation was the aim in developing a sort of improved "Savvidi Chromomagnetic field model" not showing the known symmetry difficulties, which affected that helpful early scheme. It was one of the first models indicating the existence of confinement in QCD.



Assumed the analysis will turn to be correct, the following picture could arise:

- A sort of the *top* condensate model as an effective action for massless QCD.
- The role of the Higgs field could be played by the *top* quark condensate.
- The SM could be "closed" by generating all the masses within its proper context as follows:



The six quarks could get their masses thanks to the proposed 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.

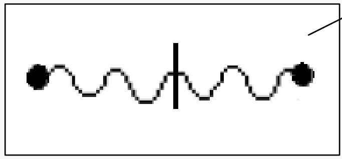
Finally, the only weak interacting character of the three neutrinos with all the particles could determine their even smaller mass values.

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)**, **Eur. Phys. J. C 55, 85 (2008))**,

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

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)),**

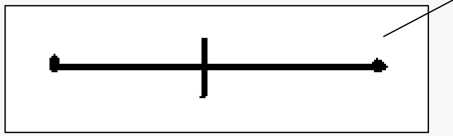
$$G^{ab}_{\mu\nu}(p) = \left(\frac{1}{p^2 + i\epsilon} - i\delta(p)C\right)\delta^{ab}g_{\mu\nu}$$



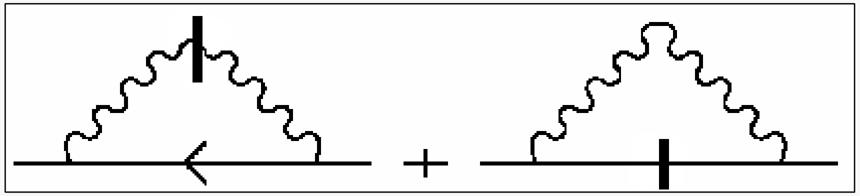
The results for gluons motivated the idea of also considering the quarks as massless and search for the possibility of dynamically generate their masses, thanks to the condensation of quark pairs. For this purpose the **BCS** like initial state was generalized to include the quark pair condensates in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

$$|\phi^*\rangle = \lim_{p\to 0}\exp\left(\sum_{f_1 f_2}\bar{C}^{f_1f_2}_q(p)\bar{q}^+_{f_1}(p)q^+_{f_2}(p)\,|\phi\rangle\right)$$

$$G^{i_1i_2;f_1f_2}_q(p) = \left(-\frac{\gamma^\mu p_\mu \delta^{f_1f_2}}{p^2 + i\epsilon} + i\delta(p)C^{f_1f_2}\right)\delta^{i_1i_2}$$



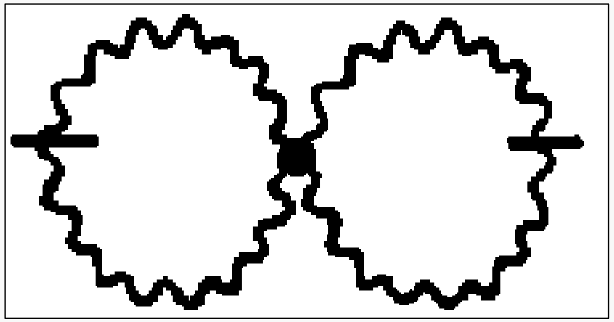
In this case a covariant **free-quark propagator** can be obtained in the form.



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

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

Homogeneous Dyson equation for quarks with the above self-energies



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

The gluonic Lagrangian mean value in the simplest approximation

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

Estimated gluon condensate

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

A relation for the parameter ***C***

$Quark\ q$	$m_{qLow}^{Exp}(MeV)$	$m_{qUp}^{Exp}(MeV)$	$m_q^{Theo}(MeV)$
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 can be fixed in a diagonal form in order to produce the observable Lagrangian quark masses as the solutions of the Dyson equation.

2) After that, the solution of the same Dyson equation adopting the value of ***C*** furnished the "constituent" values of 1/3 of the nucleon mass for the light quarks obtained before in Ref. **Eur. Phys. J C23, 289 (2002).**

2. Derivation of a simple functional integral expression for the Green functions generating functional, implementing the dimensional transmutation effect

The complete generating functional introduced in Ref. **Eur. Phys. J. C 55, 85–93 (2008)** as restricted to a vanishing gluon condensate can be expressed in the form

$$Z[j,\xi,\xi^*,\eta,\overline{\eta}] = \exp[i\int dx \int \mathcal{L}_1(\frac{\delta}{i\delta j^{a,\mu}},\frac{\delta}{i\delta\xi^*}\frac{\delta}{-i\delta\xi}\frac{\delta}{i\delta\overline{\eta}}\frac{\delta}{-i\delta\eta})]\times Z^{(0)}[j,\xi,\xi^*,\eta,\overline{\eta}]$$

$$Z^{(0)}[j,\xi,\xi^*,\eta,\overline{\eta}] = Z^G[j]Z^{FP}[\xi,\xi^*]Z^F[\eta,\overline{\eta}]$$

Free generating functional

$$\mathcal{L}_1(A_\mu,\chi,\chi,\psi,\overline{\psi}) = -\frac{g}{2}f^{abc}(\partial_\mu A_\nu-\partial_\nu A_\mu)A^{b\mu}A^{c\nu} - g^2 f^{abe}f^{cdec}A^a_\mu A^b_\nu A^{c\mu}A^{d\nu} - \\ - gf^{abc}\partial^\mu(\chi^{a*})\chi^b A^c_\mu + g\overline{\psi}T^a\gamma^\mu\psi A^a_\mu$$

Interaction part of the Lagrangean

$$Z^G[j] = \exp[\frac{i}{2}\int dx\ dy\ j^{a\mu}(x)D^{ab}_{\mu\nu}(x-y)\ j^{b\nu}(x)]$$

$$Z^{FP}[\xi,\xi^*] = \exp[i\int dx\ dy\ \xi^{a*}(x)D(x-y)\ \xi^a(x)]$$

$$Z^F[\eta,\overline{\eta}] = \exp[i\int dx\ dy\ \overline{\eta}(x)S^C(x-y)\eta(y)]$$

Gluon, ghost and quark free generating functionals: only th quark one includes a condensate term

$$S^C(x-y) = \int \frac{dk}{(2\pi)^D}\left(\frac{1}{-p_\mu\gamma^\mu} - i\ C\ \delta^D(p)\right)\exp(-i\ p.x)$$

Quark propagator

The condensate part

$$Z^F[\eta,\overline{\eta}] = \exp[i\int dxdy\ \overline{\eta}(x)S(x-y)\eta(y)] \times \exp[\int dx\ \overline{\eta}(x)\frac{C}{(2\pi)^D}\int dy\ \eta(y)]$$

$$\exp[\int dx\ \overline{\eta}(x)\frac{C}{(2\pi)^D}\int dy\ \eta(y)] = \int \mathcal{D}\overline{\chi}\mathcal{D}\chi\exp[-\overline{\chi}\chi + \\ + i(\int dx\ \overline{\eta}(x)\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\chi + \overline{\chi}\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\int dy\ \eta(y))]$$

The quadratic form in the sources can be represented as linear ones by introrucing auxiliary fermion fields with color and spinor indices

$$\mathcal{F}[\frac{\delta}{i\delta\overline{\eta}},\frac{\delta}{-i\delta\eta}]\exp[i(\int dx\ \overline{\eta}(x)\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\chi + \overline{\chi}\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\int dy\ \eta(y))]$$
$$= \exp[i(\int dx\ \overline{\eta}(x)\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\chi + \overline{\chi}\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\int dy\ \eta(y))]\times$$
$$\mathcal{F}[\frac{\delta}{i\delta\overline{\eta}} + \frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}\chi, \frac{\delta}{-i\delta\eta} + \overline{\chi}\frac{1}{i}(\frac{C}{(2\pi)^D})^{\frac{1}{2}}]$$

Tje modified form of the free generating functional after expressing the cuadratic forms in the sources as linear ones.

gluon fields

quark fields

ghost fields

auxiliary fields

quark condensate generated terms

sources terms

$$Z^{(0)}[j,\eta,\overline{\eta},\xi,\overline{\xi}|C_q] = \frac{1}{\mathcal{N}}\int\int\int d\overline{\chi}d\chi\mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\exp[i\ S^{(0)}[A,\overline{\Psi},\Psi,\overline{c},c,\overline{\chi},\chi]]$$

$$= \frac{1}{\mathcal{N}}\int\int d\overline{\chi}d\chi\exp[-\overline{\chi}_u^i\chi_u^i]\int\mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\times$$

$$\times\exp[-i\int\frac{dk}{(2\pi)^D}[\frac{1}{2}A_\mu^a(-k)(k^2g^{\mu\nu}-(1-\frac{1}{\alpha})k_\mu k_\nu)A_\nu^a(k)+$$

$$i\int\frac{dk}{(2\pi)^D}\overline{c}^a(-k)k^2c^a(k)+$$

$$+i\int\frac{dk}{(2\pi)^D}\overline{\Psi}^i(-k)\ \gamma_\mu k^\mu\ \Psi^i(k)\ +$$

$$+i\int\frac{dk}{(2\pi)^D i}\overline{\Psi}^{i,u}(-k)\ g(\frac{C_q}{(2\pi)^D})^{\frac{1}{2}}\gamma_\mu^{u\ v}T_a^{ij}\ \chi^{j,v}\ \ A^{\mu,a}(k)+$$

$$+i\int\frac{dk}{(2\pi)^D i}A^{\mu,a}(-k)\overline{\chi}^{i,u}\ g(\frac{C_q}{(2\pi)^D})^{\frac{1}{2}}\ \gamma_\mu^{u\ v}T_a^{ij}\ \Psi^{j,v}(k)+$$

$$+i\int\frac{dk}{(2\pi)^D}(j_\mu(-k)A^\mu(k)+\overline{\eta}(-k)\Psi(k)+\overline{\Psi}(k)\eta(-k)+$$

$$\overline{\xi}(-k)c(k)+\overline{c}(-k)\xi(k))].$$

The Lagrange equations associated to the auxiliary parameters

$$\frac{\delta S^{(0)}[A,\overline{\Psi},\Psi,\overline{c},c,\overline{\chi},\chi]}{\delta\overline{\chi}^{i}_{u}} = -\chi^{i}_{u} + i\int \frac{dk}{(2\pi)^{D} i} A^{\mu,a}(-k) g(\frac{C_q}{(2\pi)^{D}})^{\frac{1}{2}}\ \gamma^{u\ v}_{\mu} T^{ij}_{a}\ \Psi^{j,v}(k) = 0,$$

$$\frac{\delta S^{(0)}[A,\overline{\Psi},\Psi,\overline{c},c,\overline{\chi},\chi]}{\delta\chi^{i}_{u}} = \overline{\chi}^{i}_{u} - i\int \frac{dk}{(2\pi)^{D} i} \overline{\Psi}^{j,v}(-k)\ g(\frac{C_q}{(2\pi)^{D}})^{\frac{1}{2}} \gamma^{vu}_{\mu}\ T^{ji}_{a}\ \ A^{\mu,a}(k) = 0.$$

The generating functional now gets an additional four legs vertex

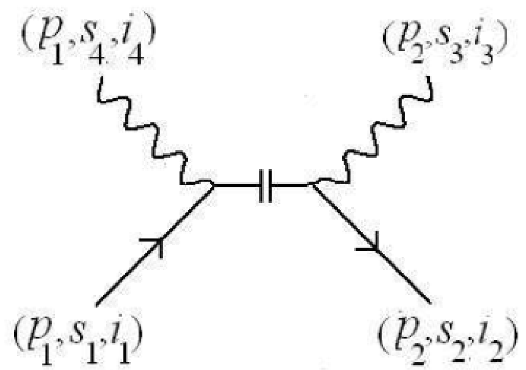
$$Z^{(0)} = \frac{1}{\mathcal{N}} \int \mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c] \exp[iS^{(0)}[A,\overline{\Psi},\Psi,\overline{c},c] + i\ S^{(C_q)}[A,\overline{\Psi},\Psi]],$$

$$S^{(0)}[A,\overline{\Psi},\Psi,\overline{c},c] =\ S^{(0)}[A,\overline{\Psi},\Psi,\overline{c},c,\overline{\chi},\chi]\Big|_{\overline{\chi},\chi=0},$$

The formula of the new action term:

$$\begin{aligned}
S^{C_q}[A,\overline{\Psi},\Psi] &= \frac{g^2 C_q}{i(2\pi)^D} \int \frac{dk}{(2\pi)^D} \overline{\Psi}^{i,u}(-k) \gamma^{uv}_{\mu} T^{ij}_{a} A^{\mu,a}(k) \times \\
&\quad \int \frac{dk'}{(2\pi)^D} A^{\mu',a'}(-k') \gamma^{vu'}_{\mu'} T^{ji'}_{a} \Psi^{i'u'}(k') \\
&= \frac{g^2 C_q}{i(2\pi)^D} \int\int dx dx' \overline{\Psi}^{i,u}(x) \gamma^{uv}_{\mu} T^{ij}_{a} A^{\mu,a}(x) A^{\mu',a'}(x') \gamma^{vu'}_{\mu'} T^{ji'}_{a'} \Psi^{i'u'}(x') \\
&= \frac{g^2 C_q}{i(2\pi)^D} \int\int dx dx' \overline{\Psi}(x) \not{A}(x) \not{A}(x') \Psi'(x').
\end{aligned}$$

The diagram associated to the new vertex: the momentum should now be separately conserved between the gluon and fermion lines arriving at each of the two points associated to the condensate dependent vertex.



After acting with the exponential operator associated to the vertices, the formula for the full generating functional Z follows

$$Z[j,\eta,\overline{\eta},\xi,\overline{\xi}|C_q] = \frac{1}{\mathcal{N}}\int \mathcal{D}[A,\overline{\Psi},\Psi,\overline{c},c]\exp[i\ S[A,\overline{\Psi},\Psi,\overline{c},c] + i\ S^{C_q}[A,\overline{\Psi},\Psi]],$$

$$S = \int dx(\mathcal{L}_0+\mathcal{L}_1),$$

$$\mathcal{L}_0 = \mathcal{L}^g + \mathcal{L}^{gh} + \mathcal{L}^q,$$

$$\mathcal{L}^g = -\frac{1}{4}(\partial_\mu A^a_\nu - \partial_\nu A^a_\mu)(\partial^\mu A^{a,\nu} - \partial^\nu A^{a,\mu}) - \frac{1}{2\alpha}(\partial_\mu A^{\mu,a})(\partial^\nu A^a_\nu),$$

$$\mathcal{L}^{gh} = (\partial^\mu\chi^{*a})\partial_\mu\chi^a,$$

$$\mathcal{L}^q = \overline{\Psi}(i\gamma^\mu\partial_\mu)\Psi,$$

$$\mathcal{L}_1 = -\frac{g}{2}f^{abc}(\partial_\mu A^a_\nu - \partial_\nu A^a_\mu)A^{b,\mu}A^{c,\nu} - g^2 f^{abe}f^{cde}A^a_\mu A^b_\nu A^{c,\mu}A^{d,\nu} - - gf^{abc}(\partial^\mu\chi^{*a})\chi^b A^c_\mu + g\overline{\Psi}T^a\gamma^\mu\Psi A^a_\mu.$$

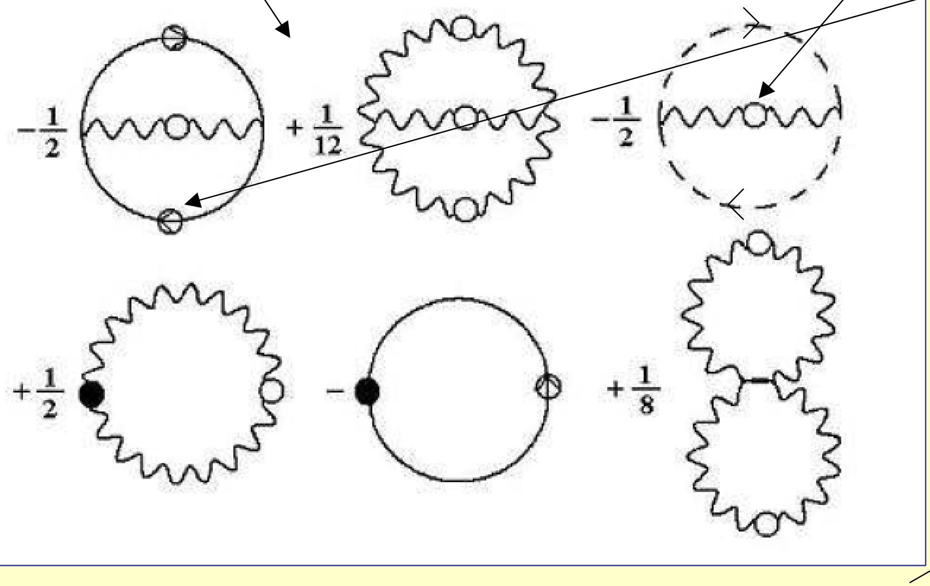
The total action now is the usual one S for mass less QCD , plus a single new term which incorporates the effects of the quark condensates

An interesting possibility seems to extend the discussion to general forms of the matrix formed by the quark condensate parameters as follows:

$$S^C[A,\overline{\Psi},\Psi] = \sum_{f_1,f_2}^{\sigma_1,\sigma_2} \frac{C^{\sigma_1\sigma_2}_{f_1f_2}}{i(2\pi)^D} \int\int dx dx' \overline{\Psi}_{f_1,\sigma_1}(x) \not{A}(x) \not{A}(x') \Psi_{f_2,\sigma_2}(x'),$$

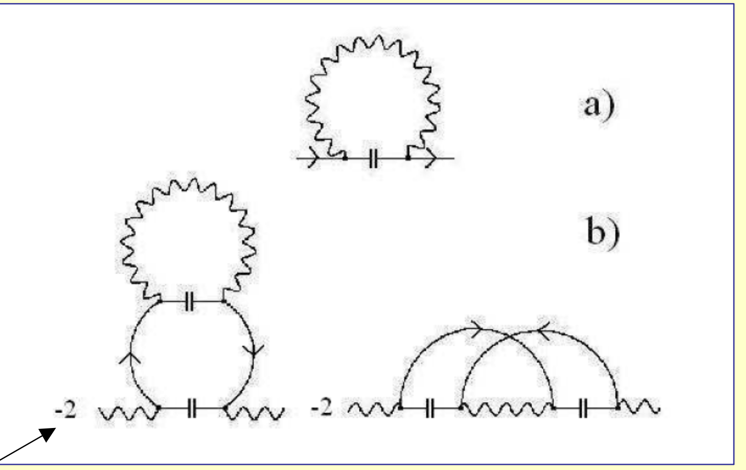
3. Evaluation of a second order in the coupling contributions to the vacuum energy: dynamical generation of the quark condensate

The two loop correction to the vacuum energy considered



wavy lines with open circles: ***dressed* gluon propagators**

lines with arrows enclosed by open circles: ***dressed* quark propagators**



The self energy insertions defining the ***dressed* propagators** in the ladder approximation.

$$\Sigma_{i,j}^{u,v}(p) = -S\frac{\delta^{ij}\delta^{uv}}{p^2},$$

$$S = -\frac{g^2 C_q}{(2\pi)^D}\frac{D(N^2-2)}{2N},$$

$$\Pi_{\mu\nu}^{ab}(p) = -\frac{\delta^{ab}}{(p^2)^2}(a\ (g_{\mu\nu} - \frac{p_\mu p_\nu}{p^2}) + (a+b)\frac{p_\mu p_\nu}{p^2}),$$

$$a = S^2\frac{8N(DN^2+4-2D)}{D^2(N^2-1)^2}, \quad b = S^2\frac{16N(D-2)}{D^2(N^2-1)^2},$$

The expressions for the quark and gluon self-energy insertions defining the *dressed* propagators. The relevant parameter is ***S***, that have mass dimension equal to 3 as ***Cq***

$$G_{i_1 i_2}^{u_1 u_2}(p) = \delta^{i_1 i_2}(\frac{1}{-p_\mu\gamma^\mu + \frac{S}{p^2}})^{u_1 u_2}$$

$$= -\frac{\delta^{i_1 i_2}}{p^2 - \frac{S^2}{(p^2)^2}}(p_\mu\gamma^\mu + \frac{S}{p^2})^{u_1 u_2},$$

$$S = -m_q^3,$$

Quark *dressed* propagator . Note that there is a single pole for the squared momentum in the positive real axis.This define what we will call the quark mass ***mq***

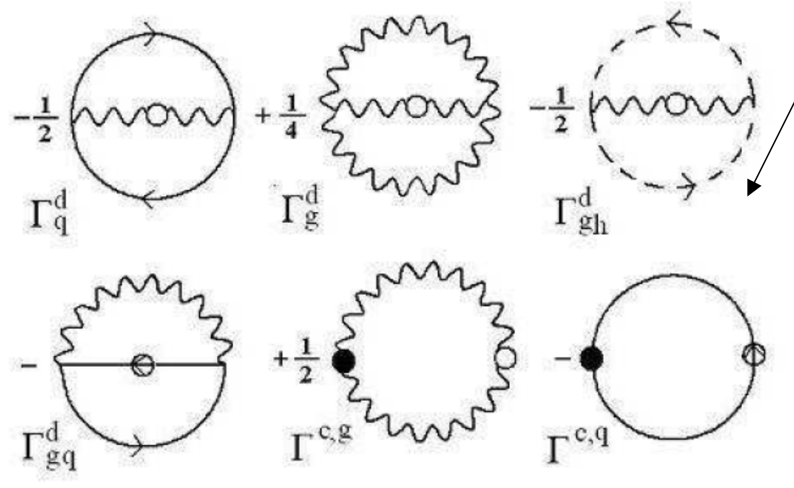
$$D_{\mu\nu}^{ab}(p) = D_{\mu\nu}^{(0)ab}(p) + D_{\mu\nu}^{(1)ab}(p) + D_{\mu\nu}^{(2)ab}(p),$$

$$D_{\mu\nu}^{(0)ab}(p) = \frac{\delta^{ab}g_{\mu\nu}}{p^2},$$

$$D_{\mu\nu}^{(1)ab}(p) = -\frac{a\delta^{ab}g_{\mu\nu}}{p^2((p^2)^3+a)},$$

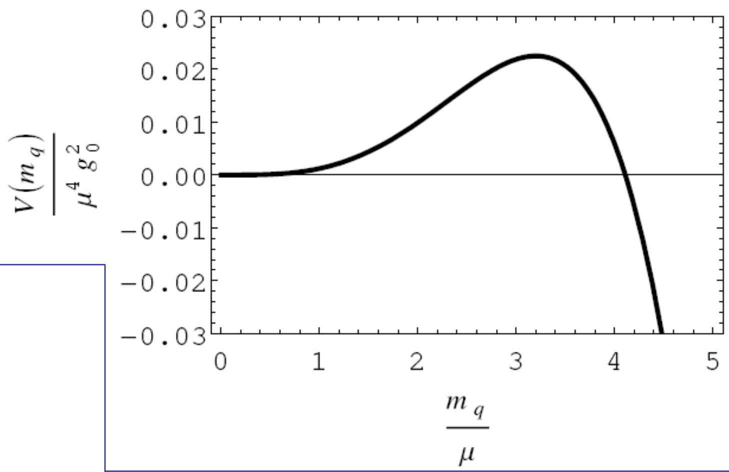
$$D_{\mu\nu}^{(2)ab}(p) = -\frac{b\delta^{ab}p^2 p_\mu p_\nu}{((p^2)^3+a)((p^2)^3+(a+b))},$$

Gluon *dressed* propagator . Note that all the singularities are *tachyonic* due to the sign of ***a*** and a ***b***. The apparent pole at squared momentum equal to zero is fictitious since it cancels in this approximation in which the gluon condensation is disregarded.



Due to the large dimension of ***S*,** each time that a diagram is convergent, the results is simply proportional to ***mq*** to the fourth power. Then, the terms determining the behavior at large ***mq*** are the logarithmic ones appearing after the elimination of the divergences by the counterterms. That is, since such logarithmic terms will dominate the result at large as well as for small condensate values, we will consider their evaluation.

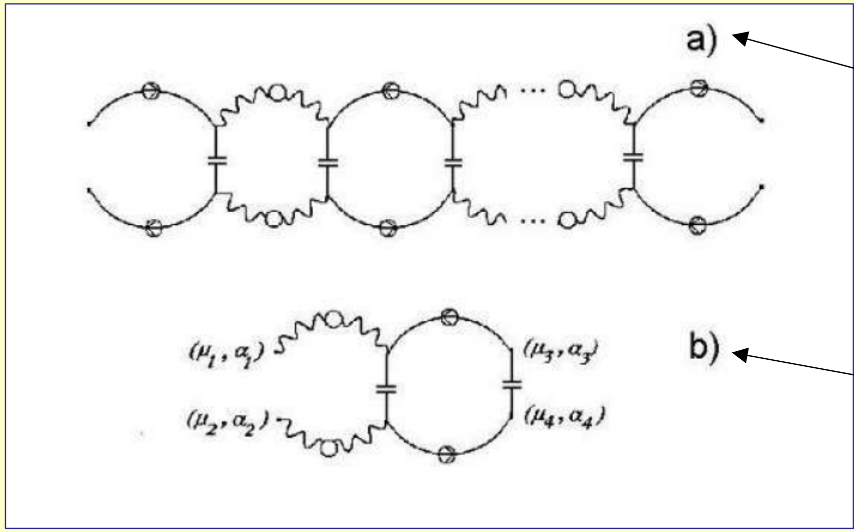
The total logarithmic dependence of the vacuum energy on the quark condensate parameter. The result indicates the dynamical generation of large condensate values.



$$
\begin{aligned}
V(m_q) &= V_a(m_q) + V_b(m_q) + V_c(m_q) \\
&\cong g_0^2\ m_q^4(-C_1\ \log(\frac{m_q}{\mu}) + C_2),
\end{aligned}
$$

$$C_1 = 8.5788 \times 10^{-4}, \quad C_2 = 1.21224 \times 10^{-3}.$$

4. Evaluation of the two particle Green function in the quark anti-quark channel and the ladder approximation in the condensate dependent vertex. The Higgs particle as a *top-anti top* meson



A general term in the geometric series defining the ladder approximation for the two particle Green function in the *top-anti top* channel

The diagram which repetitive insertions determines the general contribution shown in figure a) and its analytic expression

$$T^{a_1,a_2;a_3,a_4}_{\mu_1,\mu_2;\mu_3,\mu_4}(p_1,p_2) = \frac{2(p_1^2p_2^2)^2}{((p_1^2)^3+a)((p_2^2)^3+a)}\left(-\frac{g^2C_q}{(2\pi)^D}\right)^2 Tr_c(T^{a_1}T^{a_2}T^{a_4}T^{a_3})\times$$
$$Tr_s(\gamma_{\mu_1}\gamma_{\mu_2}G(-p_2)\gamma^{\mu_4}\gamma^{\mu_3}G(p_1)).$$

$$Tr_c(T^{a_1}T^{a_1}T^{a_4}T^{a_3}) = \frac{C_F}{2}\delta^{a_3a_4},$$

$$Tr_s(\gamma_{\mu_1}\gamma^{\mu_1}G(-p_2)\gamma^{\mu_4}\gamma^{\mu_3}G(p_1)) = \frac{4D(-p_1.p_2+\frac{S^2}{p_1^2p_2^2})}{(p_1^2-\frac{S^2}{(p_1^2)^2})(p_2^2-\frac{S^2}{(p_2^2)^2})}g^{\mu_3\mu_4},$$

These relations allow to evaluate the traces in the above formula.when the color and spinor contraction of the indices at the input are assumed.

$$g^{\mu_1\mu_2}T^{a_1,a_1;a_3,a_4}_{\mu_1,\mu_2;\mu_3,\mu_4}(p_1,p_2) = -\frac{4DC_F(p_1^2p_2^2)^2}{((p_1^2)^3+a)((p_2^2)^3+a)}(\frac{g^2C_q}{(2\pi)^D})^2\times \frac{(-p_1.p_2+\frac{S^2}{p_1^2p_2^2})}{(p_1^2-\frac{S^2}{(p_1^2)^2})(p_2^2-\frac{S^2}{(p_2^2)^2})}\delta^{a_3a_4}g^{\mu_3\mu_4}, = T(p_1,p_2)\delta^{a_3a_4}g^{\mu_3\mu_4}.$$

This formula indicates that the color and spinor indices contraction at the input and output determines that at all internal connections are also contracted.

$$g^{\mu_1\mu_2}G^{a_1,a_1;a_3,a_3}_{\mu_1,\mu_2;\mu_3,\mu_4}(p_1,p_2)g^{\mu_3\mu_4} = \frac{1}{1-T(p_1,p_2)}F(p_1,p_2)$$

The geometric series can be calculated to determine the contracted Green function being evaluated to this form

Then, the Green function shows singularities when T satifies

$$0 = 1-T(p_1,p_2) = 1+(\frac{g^2C_q}{(2\pi)^D})^2\frac{4DC_F(p_1^2p_2^2)^2}{((p_1^2)^3+a)((p_2^2)^3+a)}\times \frac{(-p_1.p_2+\frac{S^2}{p_1^2p_2^2})}{(p_1^2-\frac{S^2}{(p_1^2)^2})(p_2^2-\frac{S^2}{(p_2^2)^2})}.$$

We can define now center of mass and relative momentum variables as

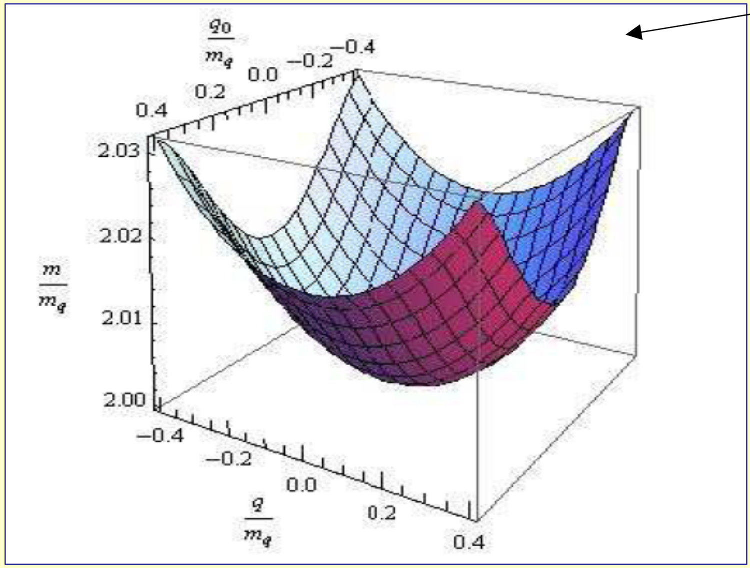
$$p = p_1+p_2$$
$$q = p_1-p_2,$$

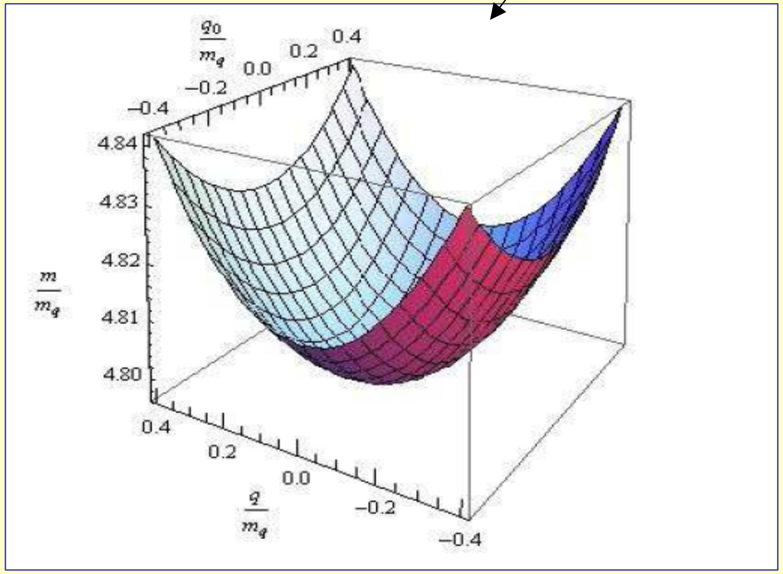
The dispersion relation for the considered excitations takes the form

$$1 = -\frac{S^2}{C_F}\frac{((p+q^2)^2-4(p.q)^2)^4}{4^4(\frac{(p^2+2p.q+q^2)^3}{2^6}+\frac{4}{3}S^2)(\frac{(p^2-2p.q+q^2)^3}{2^6}+\frac{4}{3}S^2)}\times$$
$$\frac{(-\frac{1}{4}(p^2-q^2)+\frac{16S^2}{(p^2+q^2)^2-4(p.q)^2})}{(\frac{(p^2+2p.q+q^2)^3}{2^6}-S^2)\frac{(p^2-2p.q+q^2)^3}{2^6}-S^2}.$$

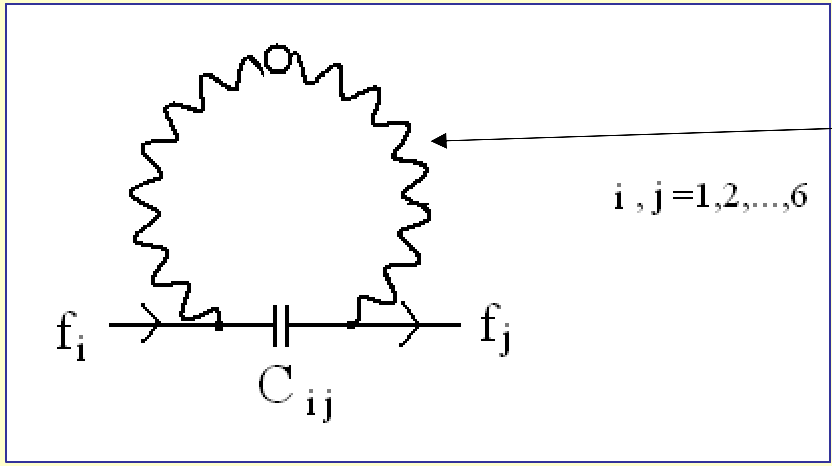
$$p = (m,0,0,0),$$
$$q = (q_0,\mathbf{q},0,0).$$

Defining three new parameters by chosing the reference system to express *p* and *q* as:
the dispersion relations show the two continuous spectrum of solutions illustrated below:



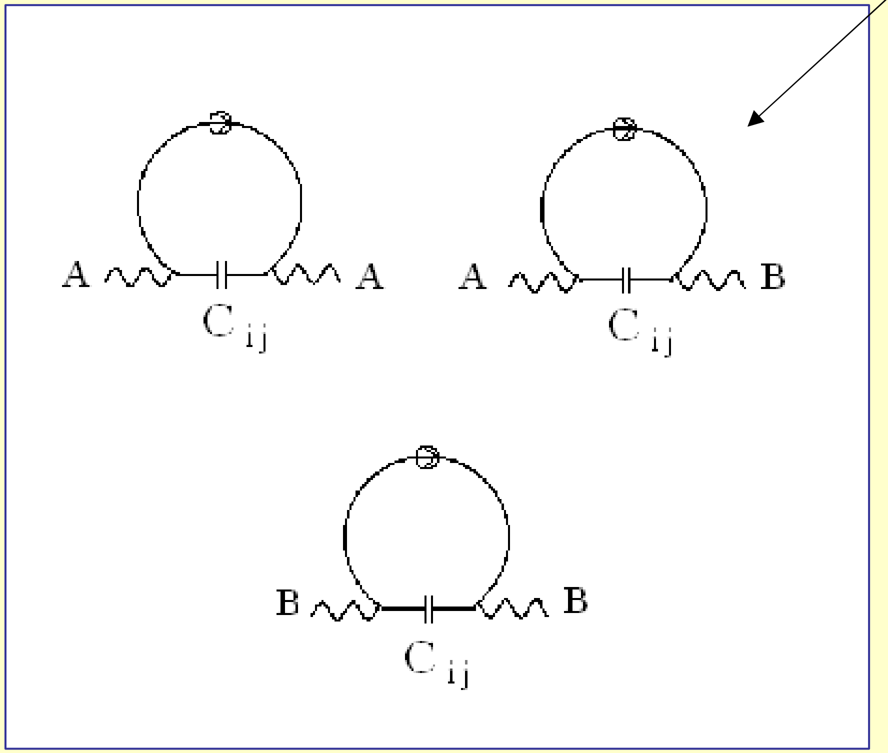


Comment 1: Possibility of generating the quark mass and CKM matrices



The large mass of the gluon modified propagator should make the interaction between the input and output fermions short ranged and then the vertex should be equivalent to a Yukawa one.

Possibility of generating the W and Z masses



It might be also possible that the large mass of the quark modified propagator can make the forces between weak interaction gauge bosons also short ranged and leading to a similar picture than the Higgs spontaneous symmetry breaking effect.

The above possibilities are in some measure supported by the fact that in the context of the standard *top* condensate models, it has been argued that the *top anti*-top condensate technically implements the role of the Higgs field.

$$
\begin{aligned}
V(m_q) &= -|a|\ m_q^4 + |b| m_q^4 \log(\frac{m_q}{\mu}) \\
&= |b|\ m_q^4 (-\frac{|a|}{|b|} + \log(\frac{m_q}{\mu})) \\
&= |b|\ m_q^4 (-\log(\exp(\frac{|a|}{|b|})) + \log(\frac{m_q}{\mu})) \\
&= |b|\ m_q^4 \log(\frac{m_q}{\exp(\frac{|a|}{|b|})\mu})
\end{aligned}
$$

Comment 2: Possibility of the compatibility between a large condensate and mass and a small Lambda QCD

$$
m_q^3 (4 \log(\frac{m_q}{\exp(\frac{|a|}{|b|})\mu}) + 1) = 0
$$

$$
\exp(\frac{|a|}{|b|})\mu = e^{-\frac{1}{4}} m_q
$$

$$
\begin{aligned}
\exp(\frac{|a|}{|b|}) &= e^{\frac{1}{4}} \frac{m_q}{\mu} \\
\frac{|a|}{|b|} &= \log(e^{\frac{1}{4}} \frac{m_q}{\mu}) \\
&\approx \log(e^{\frac{1}{4}} \frac{173}{0.1}) \\
&= 7.70
\end{aligned}
$$

Summary

1) A simple form of the Feynman diagram expansion associated to the modified PQCD including a fermion condensate is derived. The new expression for the generating functional implements the dimensional transmutation effect though a single new vertex which adds to the usual QCD Lagrangian.
2) A second order in the coupling contribution to the vacuum energy was evaluated as a function of the *top* quark condensate parameter. The result, like in a formerly done one loop evaluation, becames unbounded from below as a function of the quark mass *mq* (defined by the pole of the propagator in the first approximations). Therefore, a dynamical generation of top quark condensate is indicated. Further corrections need yet to be evaluated in order to determine whether a minimal energy state appears. The potential is parameterized by *mq*, the zero moment limit of coupling constant *g* and the dimensional regularization parameter μ.
3) The expansion is employed to evaluate the two particle Green function associated to the color and spin singlet channel in the ladder approximation, in terms of the condensate parameter dependent vertex. Assumed that the quark mass can be fixed to the observed value of the *top* quark mass, the result of the evaluation shows a continuous spectrum of excitations laying above a threshold of two times the *top* quark mass. Thus, it is suggested that the Higgs particle could correspond to *top anti-top* meson with proper mass laying below that value.
4) The discussion suggests a path for constructing a modification of the SM in which top quark condensate could play the role of the Higgs field.