Investigation of $g_{SV\gamma}$ and $g_{VP\gamma}$ Coupling Constants in Three Point QCD Sum Rules

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Overview

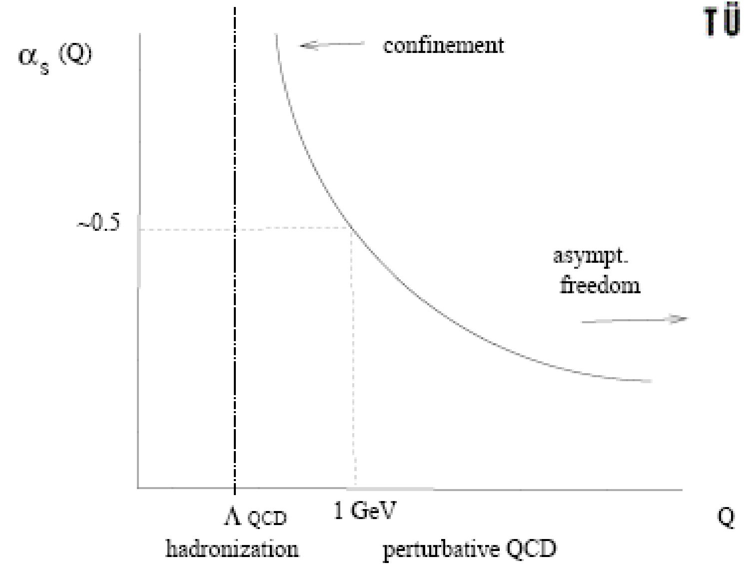
- QCD Sum Rules
- $S \to V\gamma$ Coupling Constant
- $V \to P\gamma$ Coupling Constant

$$L_{QCD} = -\frac{1}{4} G^a_{\mu\nu} G^a_{\mu\nu} + \sum_{q=u,d,\ldots} \overline{\psi}_q \left(i\not{D} - m_q \right) \psi_q$$

$$G^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + g\, f^{abc} A^b_\mu A^c_\nu$$

$$D_\alpha = \partial_\alpha + igA^a_\alpha T^a$$

$$\alpha_s(Q^2) \approx \frac{1}{4\pi\, \beta_0 \ln(Q^2/\Lambda^2_{QCD})}$$



At small distances:
- Asymptotic freedom
- Quasi-free quark propagation
- QCD perturbation theory

Non-perturbative methods:
- Phenomenological quark models
- Potential models
- Bag models
- Effective lagrangian methods
- QCD sum rules

At large distances (≥0.1 fm):
- Confinement
- Quarks build coherent bound states - hadrons
- QCD perturbation theory is inapplicable

QCD Sum Rules

(Shifman & Vainshtein & Zakharov (SVZ), 1979)

This method is a framework which connects hadronic parameters with QCD parameters.

The correlation function describes an evolution of a colorless quark-antiquark pair emitted and absorbed by external currents

$$\Pi(q^2) = i\int d^4x \; e^{iq\cdot x} \left\langle 0 \,|\, T\left\{ j_\Gamma(x) j_\Gamma(y) \right\} |0 \right\rangle \tag{1}$$

The T-ordered product of currents Wilson operator product expansion (OPE)

$$i\int d^4x \; e^{iq\cdot x} \left\langle 0 \,|\, T\left\{ j_\Gamma(x) j_\Gamma(0) \right\} |0 \right\rangle = C_I^\Gamma I + \sum_n C_n^\Gamma \left(q^2\right) O_n \tag{2}$$

I : Identity operator

C_I^Γ, C_n^Γ : Wilson coefficients

O_n : local gauge invariant operators

$$\Pi_{\mu\nu}\left(q^2\right)=C_I^\Gamma\left\langle 0\left|I\right|0\right\rangle+\sum_n C_n^\Gamma\left(q^2\right)\left\langle 0\left|O_n\right|0\right\rangle \qquad (3)$$

Short-distance coefficient

vacuum condensates

$$\left\langle q\bar{q}\right\rangle,\left\langle \alpha_s G^2\right\rangle,\ldots$$

The dispersion relation

$$\Pi_{\mu\nu}\left(q^2\right)=\frac{1}{\pi^2}\int\frac{\rho_{\mu\nu}\left(s\right)ds}{s+Q^2}+substr.terms \qquad Q^2=-q^2 \qquad (4)$$

The spectral density $\rho_{\mu\nu}\left(s\right)=\pi^2\sum_n\left\langle 0\left|J_\Gamma\left(x\right)\right|n\right\rangle\left\langle n\left|J_\Gamma\left(0\right)\right|0\right\rangle$

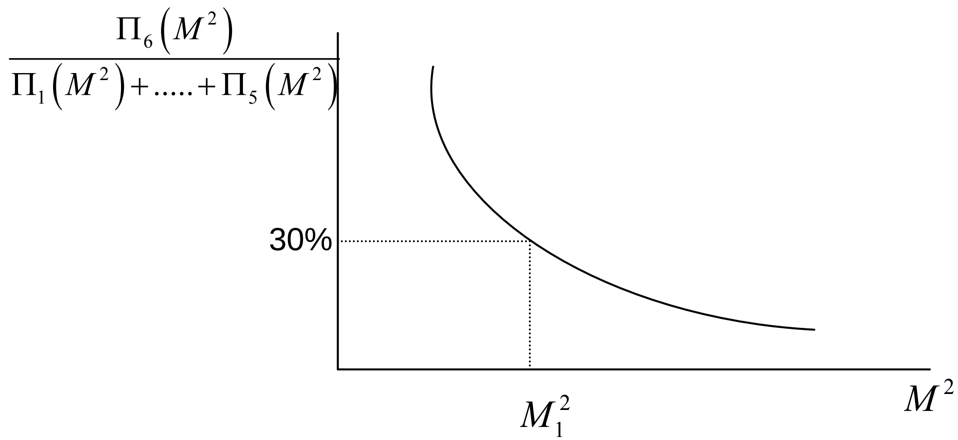
As a result, we have two different representations for the polarization operator. One of them is the Wilson expansion and the other one is the general dispersion relation. By means of equating these representations, we get the sum rules:

$$\frac{1}{\pi^2}\int\frac{\rho_{\mu\nu}\left(s\right)ds}{s+Q^2}+substr.terms=C_I^\Gamma\left\langle 0\left|I\right|0\right\rangle+\sum_n C_n^\Gamma\left(q^2\right)\left\langle 0\left|O_n\right|0\right\rangle \qquad (5)$$

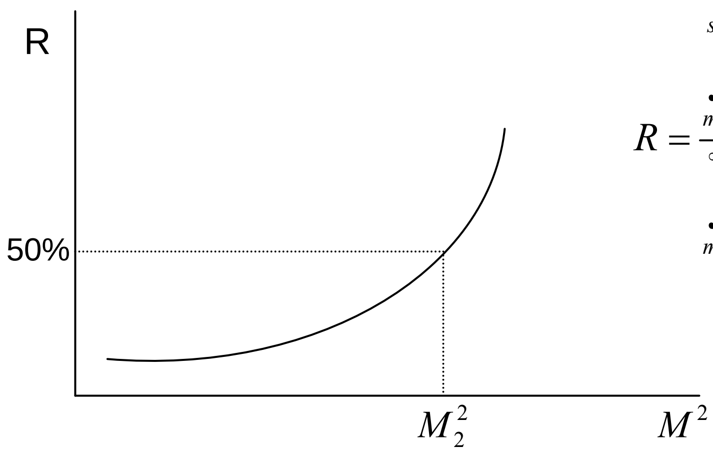
Finally, the sum rules:

$$\sum_n \langle 0|J_\Gamma(x)|n\rangle\langle n|J_\Gamma(0)|0\rangle e^{-m_n^2/M^2} = B\Pi_{\mu\nu}^{pert} + \sum_n B\, C_n^\Gamma(q^2)\langle 0|O_n|0\rangle$$

low limit on M^2.



upper limit on M^2



$$R = \frac{\int_{m_q^2}^{s_0} ds\, \rho^{OPE}(s)\, e^{-s/M^2}}{\int_{m_q^2}^{\infty} ds\, \rho^{OPE}(s)\, e^{-s/M^2}}$$

$$M_1^2 < M^2 < M_2^2$$

$S \to V\gamma$ Coupling Constant

The Correlation function

$$\Pi_{\mu\nu}(p, p') = d^4x \;\; d^4y\, e^{i\,p'\cdot y} e^{-i\,p\cdot x} \langle 0 | T \{ J_\mu^\gamma(0) J_\nu^S(x) J^V(y) \} | 0 \rangle$$

$S \to f_0$, a_0 ; $V \to \rho$, ω

The interpolating currents in terms of quark fields

$$J_{f_0} = \frac{1}{\sqrt{2}}\left(\bar{u}u + \bar{d}d\right)\sin\theta + \bar{s}s\cos\theta$$

θ ; scalar mixing angle

$$J_{a_0} = \frac{1}{2}\left(\bar{u}u - \bar{d}\,d\right)$$

$$J_\nu^\rho = \frac{1}{2}\left(\bar{u}\gamma_\nu u - \bar{d}\gamma_\nu d\right)$$

$$J_\nu^\omega = \frac{1}{2}\left(\bar{u}\gamma_\nu u + \bar{d}\gamma_\nu d\right)$$

$$m_d = m_u = 0$$

The electromagnetic current: $J_\mu^\gamma = e_u\left(\bar{u}\gamma_\mu u\right) + e_d\left(\bar{d}\gamma_\mu d\right)$

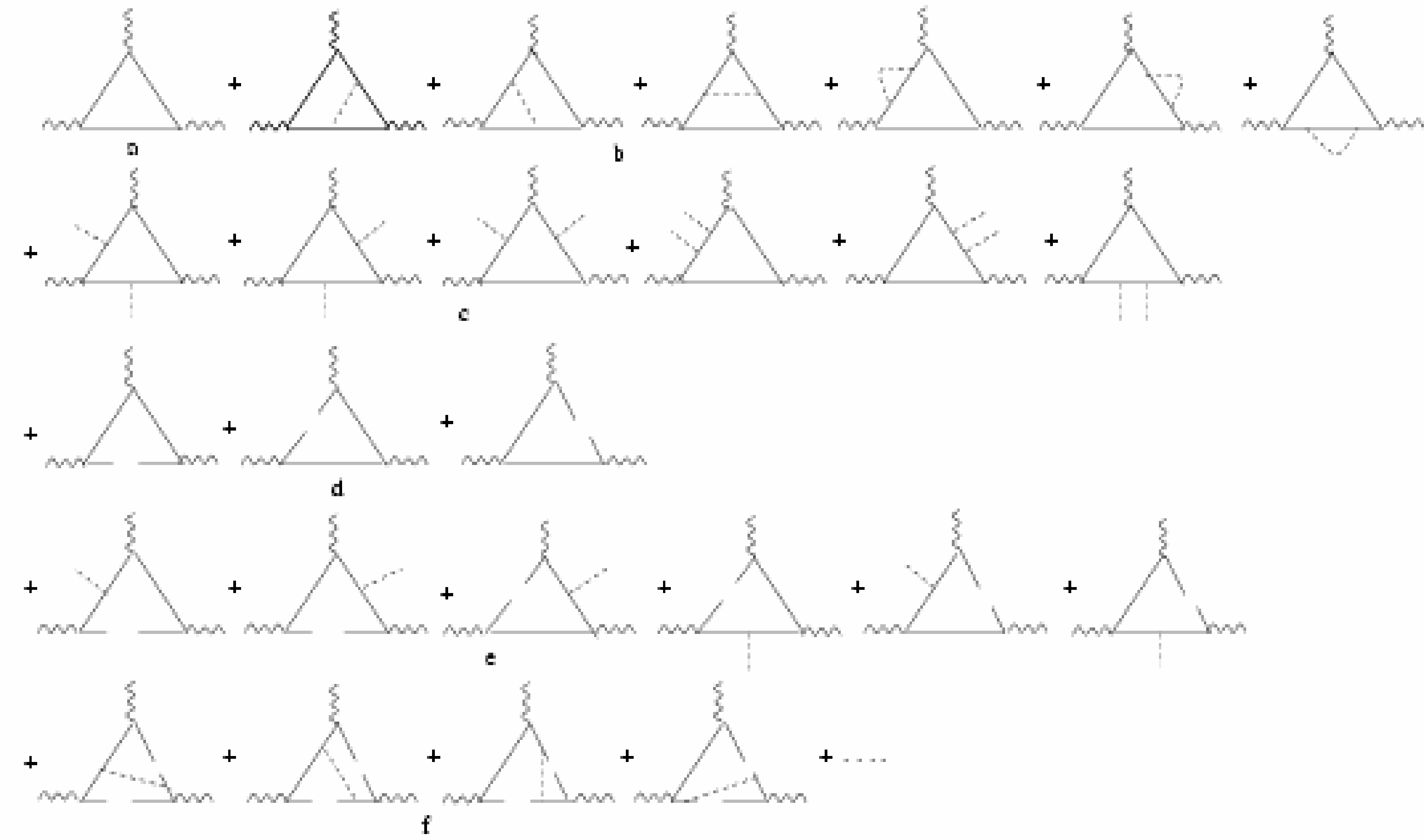


Figure 1. Possible diagrams for the three-point correlation function for d≤6 (a) lowest order bare-loop diagram, (b) bare loop with a virtual gluon, (c) gluon condansate diagrams, (d) quark condensate diagrams, (e) quark condansate diagrams with one external field, (f) diagrams obtained by simultanous cutting of two quark lines in the diagrams. Solid lines denote the quarks, dashed lines - gluons, wavy line external - currents.

Table 1: The propagators and vertex in QCD

Quark propagator	$D_F(p) = \frac{i}{\not{p} - m}$
Gluon propagator	$D^{ab}_{G\alpha\beta}(k) = -g_{\alpha\beta}\delta^{ab}\frac{i}{k^2}$
Quark-gluon vertex	$ig\gamma_\mu\left(\frac{\lambda^a}{2}\right)$

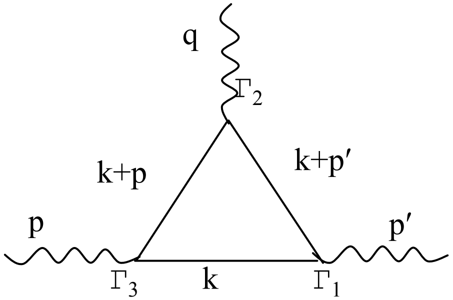


Figure 2: The bare loop diagram

The contribution of the bare loop diagram

$$F_2 = N_c \int \frac{d^4k}{(2\pi)^4} Tr\left[D(k)\Gamma_1 D(k+p')\Gamma_2 D(k+p)\Gamma_3\right] \quad (6)$$

In the fixed-point gauge, $x_\mu A^\mu = 0$ fermion and potential fields

$$\psi_\beta(x) = \psi_\beta(0) + x_\lambda\left[\nabla_\lambda \psi_\beta(x)\right]_{x=0} + \frac{1}{2} x_\lambda x_{\lambda'}\left[\nabla_\lambda \nabla_{\lambda'} \psi_\beta(x)\right]_{x=0} + \frac{1}{6} x_\lambda x_{\lambda'} x_{\lambda''}\left[\nabla_\lambda \nabla_{\lambda'} \nabla_{\lambda''} \psi_\beta(x)\right]_{x=0} + \ldots \tag{7}$$

$$A_\mu^a(k) = -\frac{i}{2} G_{\nu\mu}^a(0) \frac{\partial}{\partial k_\nu}(2\pi\ )^4 \delta^4(k) - \frac{1}{3}\left(D_\alpha G_{\nu\mu}^a(0)\right)\frac{\partial^2}{\partial k_\alpha \partial k_\nu}(2\pi\ )^4 \delta^4(k) + \ldots \tag{8}$$

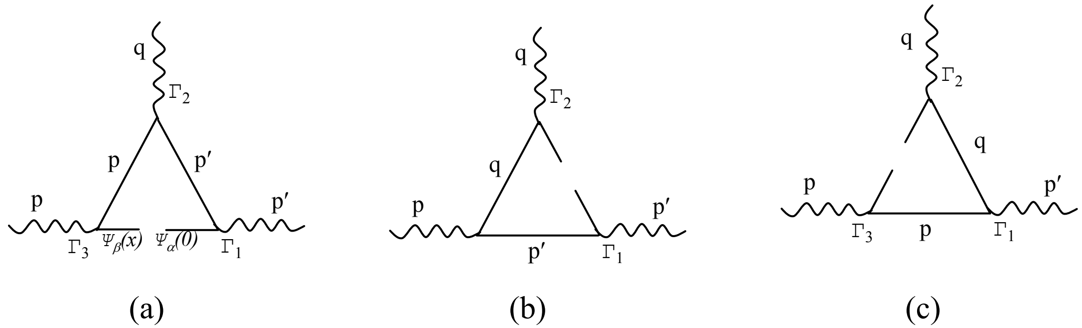


Figure 3: The quark condensate diagrams

For the first diagrams in Fig 3(a)

$$F_{3a} = N_c \left\langle 0 \,|\, \overline{\psi}^a_\alpha(0) \left[\Gamma_1 D_F(p') \Gamma_2 D_F(p) \Gamma_3 \right]_{\alpha\beta} \psi^a_\beta(x) \,|\, 0 \right\rangle \tag{9}$$

Using fermion field

$$\begin{aligned} F_{3a} &= N_c \left[\Gamma_1 D_F(p') \Gamma_2 D_F(p) \Gamma_3 \right]_{\alpha\beta} \left\langle 0 \,|\, \overline{\psi}^a_\alpha(0) \psi^a_\beta(x) \,|\, 0 \right\rangle \\ &= N_c \left[\Gamma_1 D_F(p') \Gamma_2 D_F(p) \Gamma_3 \right]_{\alpha\beta} \Big\{ \left\langle 0 \,|\, \overline{\psi}^a_\alpha(0) \psi^a_\beta(0) \,|\, 0 \right\rangle + x_\lambda \left\langle 0 \middle| \overline{\psi}^a_\alpha(0) \left[\nabla_\lambda \psi_\beta(x) \right]_{x=0} \middle| 0 \right\rangle \\ &+ \frac{1}{2} x_\lambda x_{\lambda'} \left\langle 0 \middle| \overline{\psi}^a_\alpha(0) \left[\nabla_\lambda \nabla_{\lambda'} \psi_\beta(x) \right]_{x=0} \middle| 0 \right\rangle + \frac{1}{6} x_\lambda x_{\lambda'} x_{\lambda''} \left\langle 0 \middle| \overline{\psi}^a_\alpha(0) \left[\nabla_\lambda \nabla_{\lambda'} \nabla_{\lambda''} \psi_\beta(x) \right]_{x=0} \middle| 0 \right\rangle + \ldots \Big\} \end{aligned} \tag{10}$$

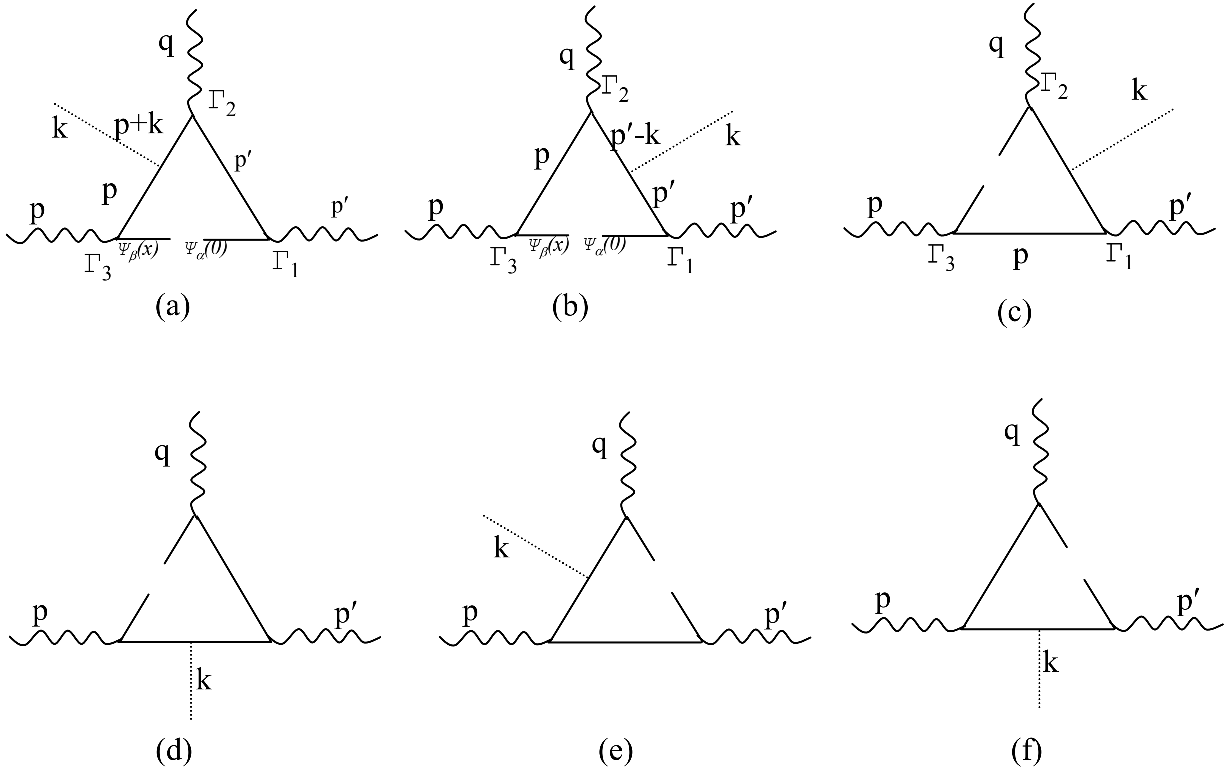


Figure 4. The quark condansate diagrams with one external field.

For the first diagrams in Fig 4(a)

$$F_{4a} = N_c \langle 0 | \overline{\psi}^a_\alpha(0) \left[\Gamma_1 D_F(p') \Gamma_2 D_F(p) (\Gamma_4)^{ij} D_F(p-k) \Gamma_3 \right]_{\alpha\beta} \psi^b_\beta(x) | 0 \rangle \tag{11}$$

And we obtain

$$
\begin{aligned}
F_{4a} &= N_c \langle 0 | \overline{\psi}^a_\alpha(0) \left[\Gamma_1 D_F(p')\Gamma_2 D_F(p)(\Gamma_4)^{ij} \left(ig\frac{\lambda^c}{2}\gamma_\rho A^c_\rho(k) \right) D_F(p-k)\Gamma_3 \right]_{\alpha\beta} \psi^b_\beta(x) | 0 \rangle \\
&= N_c \langle 0 | \overline{\psi}^a_\alpha(0) \left[\Gamma_1 D_F(p')\Gamma_2 D_F(p) \left(ig\frac{\lambda^c}{2} \right)^{ij} \gamma_\rho \right. \\
&\times \left. \left(-\frac{i}{2} G^a_{\lambda\rho}(0) \frac{\partial}{\partial k_\lambda}(2\pi)^4 \delta^4(k) - \frac{1}{3}\left(D_{\alpha'} G^a_{\lambda\rho}(0) \right) \frac{\partial^2}{\partial k_{\alpha'} \partial k_\lambda}(2\pi)^4 \delta^4(k) + \ldots \right) D_F(p-k)\Gamma_3 \right]_{\alpha\beta} \\
&\times \left(\psi^b_\beta(0) + x_\lambda \left[\nabla_\lambda \psi_\beta(x) \right]_{x=0} + \frac{1}{2} x_\lambda x_{\lambda'} \left[\nabla_\lambda \nabla_{\lambda'} \psi_\beta(x) \right]_{x=0} + \ldots \right) | 0 \rangle \\
&\equiv F_{4a}(5d) + F_{4a}(6d)_1 + F_{4a}(6d)_2 + \ldots
\end{aligned}
\qquad (12)
$$

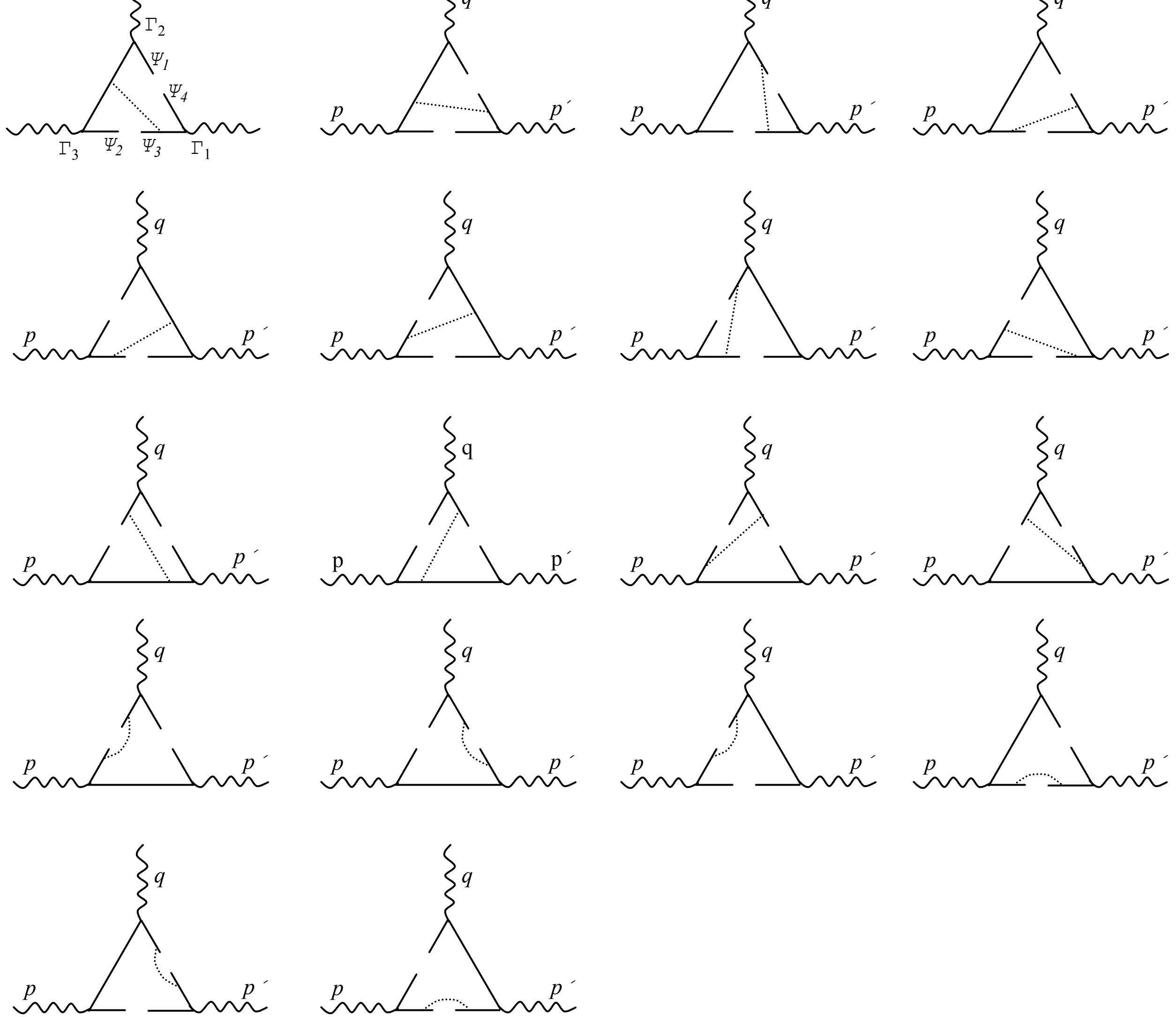


Figure 5. Diagrams obtained by simultanous cutting of two quark lines in the diagrams.

$$F_{5a} = N_c \frac{1}{144} g^2 \langle 0 | \overline{\psi}\psi | 0 \rangle^2 \mathrm{Tr}\left[\Gamma_2 D_F(p-p')\,\gamma_\rho D_F(p)\Gamma_3 \gamma_\rho D_F(-p')\Gamma_1\right] \mathrm{Tr}\left(\frac{\lambda^n}{2}\frac{\lambda^{n'}}{2}\right)\left(-\frac{i}{p'^2}\right) \tag{13}$$

$$= N_c \frac{4}{144} g^2 \langle \overline{\psi}\psi \rangle^2 \left(-\frac{i}{p'^2}\right) \mathrm{Tr}\left[\Gamma_2 D_F(p-p')\,\gamma_\rho D_F(p)\Gamma_3 \gamma_\rho D_F(-p')\Gamma_1\right]$$

Physical part of the sum rule

$$\Pi_{\mu\nu}(p,p') = \frac{\langle 0|J_\nu^V|V(p)\rangle\langle V(p)|J_\mu^\gamma|S(p')\rangle\langle S(p')|J_\alpha^S|0\rangle}{(p^2-m_V^2)(p'^2-m_S^2)} + ... \quad (14)$$

Overlap amplitudes;

$$\langle 0|J_\mu^V|V\rangle = \lambda_V \varepsilon_\mu^V \qquad \langle 0|J_S|S\rangle = \lambda_S$$

The matrix element of the electromagnetic current

$$\langle V(p)|J_\mu^\gamma(q)|S(p')\rangle = -i\frac{e}{m_V} g_{SV\gamma} K(q^2)(p\cdot q\,\varepsilon_\mu - \varepsilon\cdot q\,p_\mu) \quad (15)$$

The gauge-invariant structure $\quad p_\nu\, p'_\mu - p\cdot p' g_{\mu\nu}$

Correlation function

$$\Pi_{\mu\nu} = C_1 C_2 N_c \langle\overline{\psi}\psi\rangle\left[-\frac{1}{p'^2 p^2} + \frac{m_0^2}{4}\left(\frac{1}{p'^4 p^2} + \frac{1}{p'^2 p^4} - \frac{1}{6}\frac{1}{p'^4 p^2} - \frac{1}{2}\frac{1}{p'^2 p^4}\right)\right](p_\nu p'_\mu - p\cdot p' g_{\mu\nu}) \quad (16)$$

$f_0 \to \rho(\omega)\gamma$ coupling constants

$$g_{f_0\rho(\omega)\gamma} = (e_u \mp e_d)\frac{3m_{\rho(\omega)}}{2\sqrt{2}\lambda_{\rho(\omega)}\lambda_{f_0}} e^{m_{f_0}^2/M_1^2} e^{m_{\rho(\omega)}^2/M_2^2} < \bar{u}u > \left(-3 - \frac{3}{8}\frac{m_0^2}{M_1^2} - \frac{5}{8}\frac{m_0^2}{M_2^2}\right)\sin\theta \quad (17)$$

$(e_u - e_d) = 1$ for $g_{f_0\rho\gamma}$ $(e_u + e_d) = 1/3$ for $g_{f_0\omega\gamma}$

$a_0 \to \rho(\omega)\gamma$ coupling constants

$$g_{a_0\rho(\omega)\gamma} = (e_u \mp e_d)\frac{3m_{\rho(\omega)}}{4\lambda_{\rho(\omega)}\lambda_{a_0}} e^{m_{a_0}^2/M_1^2} e^{m_{\rho(\omega)}^2/M_2^2} < \bar{u}u > \left(-3 - \frac{3}{8}\frac{m_0^2}{M_1^2} - \frac{5}{8}\frac{m_0^2}{M_2^2}\right) \quad (18)$$

$(e_u + e_d) = 1/3$ for $g_{a_0\rho\gamma}$ $(e_u - e_d) = 1$ for $g_{a_0\omega\gamma}$

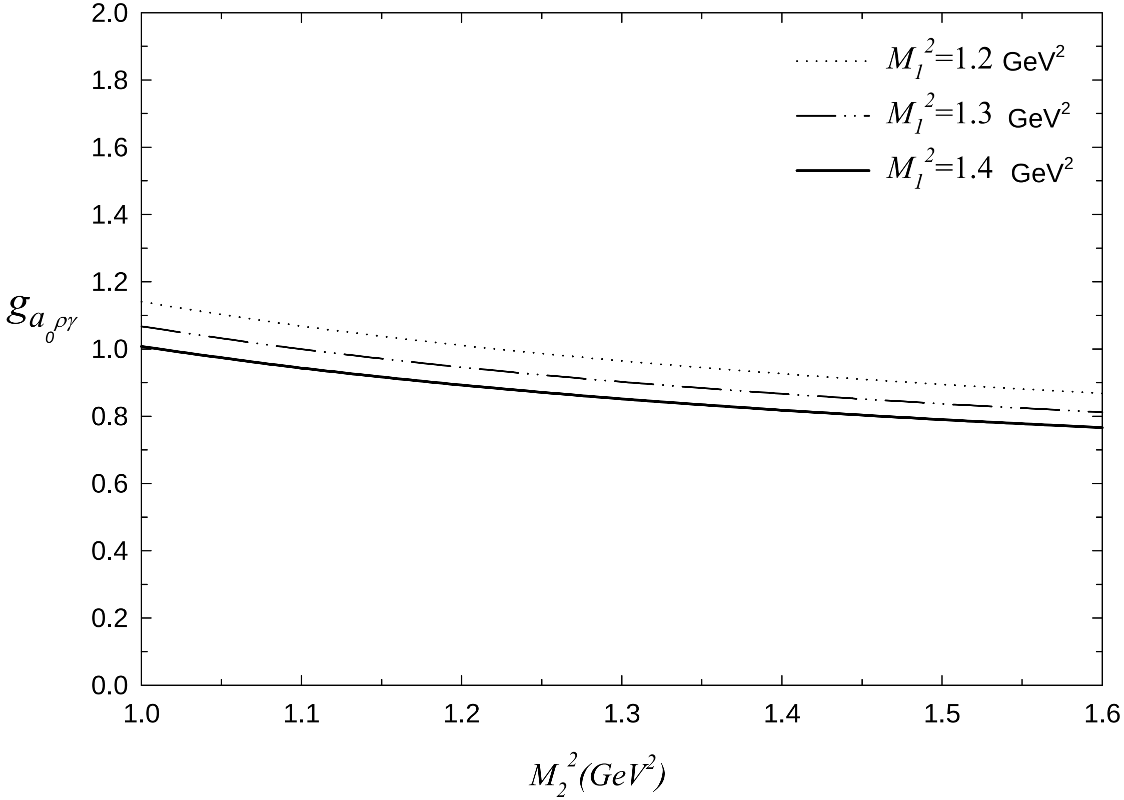


Figure 6. The coupling constant $g_{a_0\rho\gamma}$ as a function of the Borel parameter M_2^2

$$M_2^2 = 1.2 \quad GeV^2 \quad \Rightarrow \quad 0.63 < g_{a_0\rho\gamma} < 1.25$$

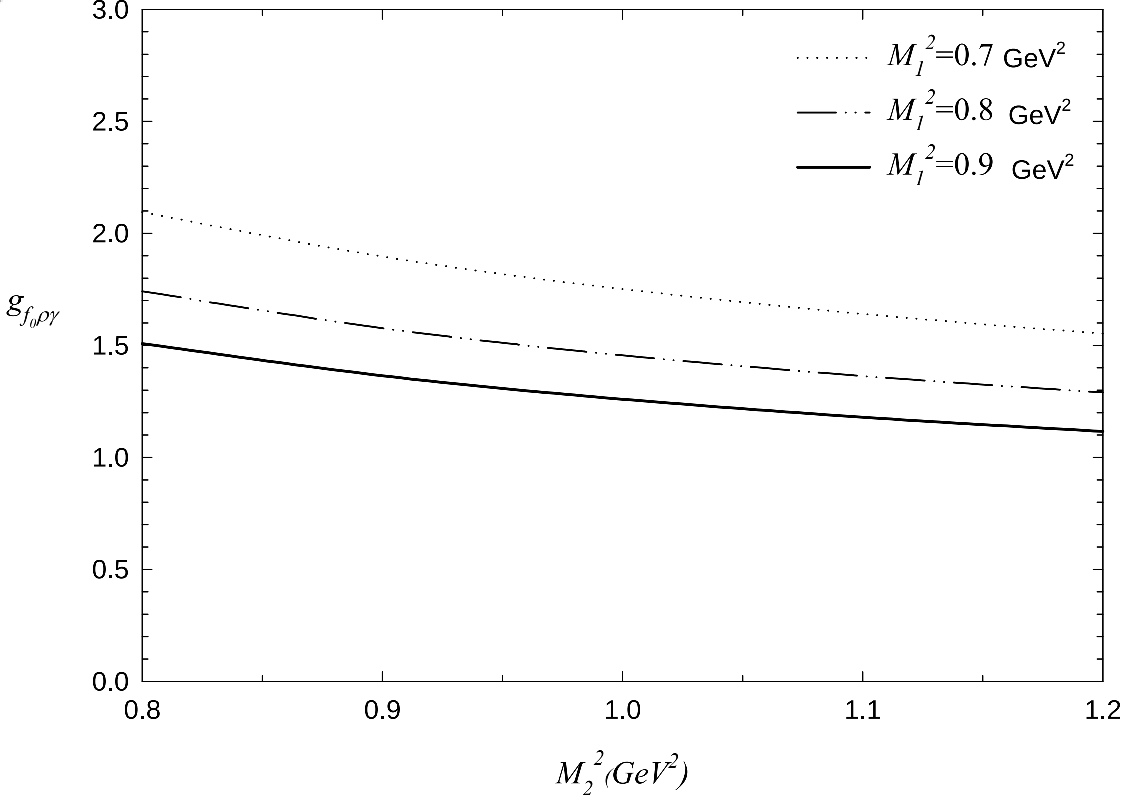


Figure 7. The coupling constant $g_{f_0\rho\gamma}$ as a function of the Borel parameter M_2^2 at θ=30°

$$M_2^2 = 1.0 \quad GeV^2 \;\Rightarrow\; 0.96 < g_{f_0\rho\gamma} < 2 \quad \text{at} \quad \theta = 30^\circ$$

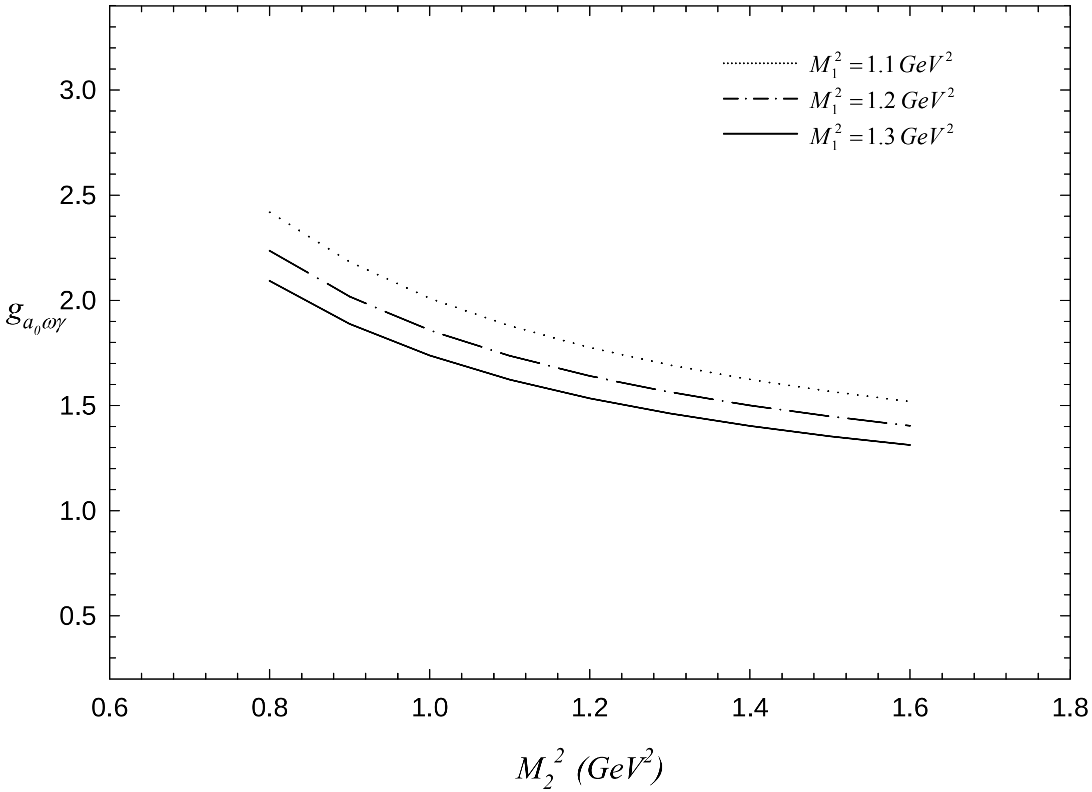


Figure 8. The coupling constant $g_{a_0\omega\gamma}$ as a function of the Borel parameter $M_2{}^2$

$$M_2{}^2 = 1.3 \ \ GeV^2 \quad \Rightarrow \quad g_{a_0\omega\gamma} = 1.46 \pm 0.37$$

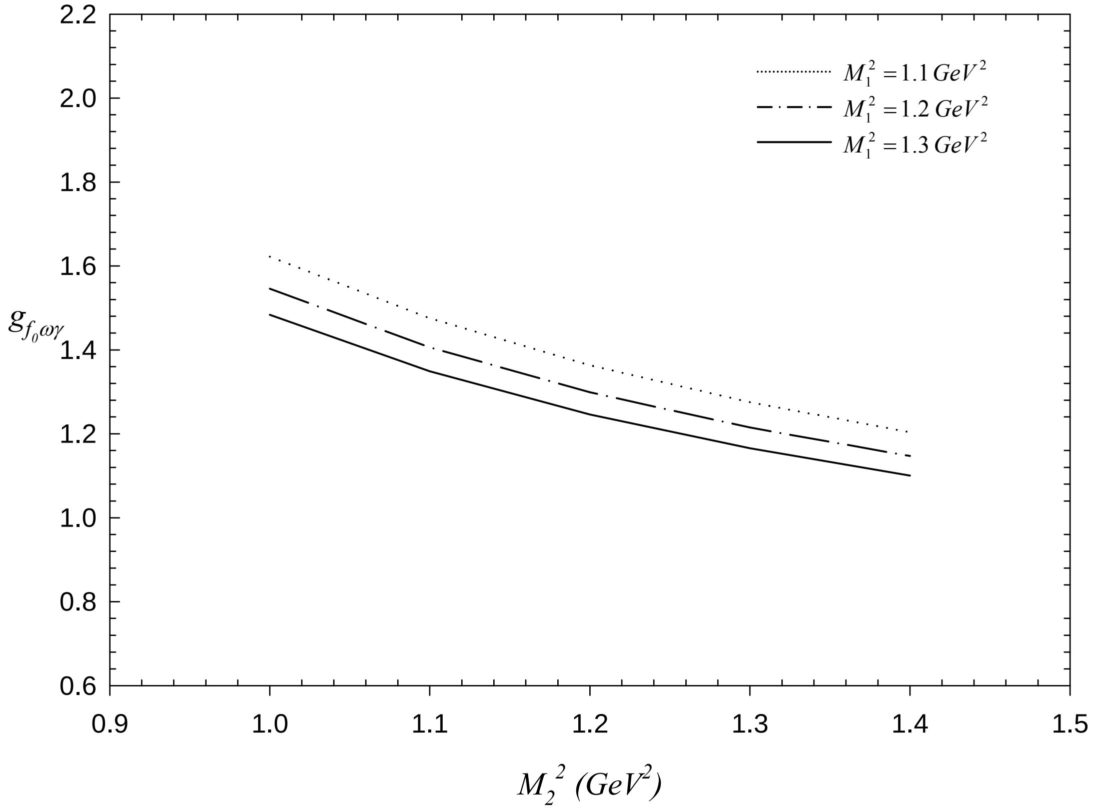


Figure 9. The coupling constant $g_{f_0\omega\gamma}$ as a function of the Borel parameter $M_2{}^2$ at θ=30°

$$M_1{}^2 = 1.2\ \ GeV^2 \qquad \Rightarrow \qquad g_{f_0\omega\gamma} = 1.21 \pm 0.15$$

$$M_2{}^2 = 1.4\ \ GeV^2$$

$V \to P\gamma$ Coupling Constant

The Correlation function

$$\Pi_{\mu\nu}(p,p') = d^4x\ d^4y\, e^{ip'\cdot y} e^{-ip\cdot x} \langle 0 | T\{J^{\gamma}_{\mu}(0) J^{V}_{\nu}(x) J^{P}(y)\} | 0 \rangle \quad (19)$$

$P \to K^0$, ; $V \to K^{0*}$

The interpolating currents in terms of quark fields

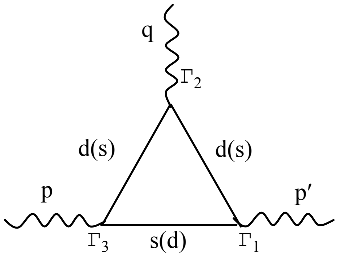
$$J_{K^0} = \bar{s}\, i\gamma_\alpha \gamma_5 d$$

$$J^{K^{0*}}_{\nu} = \bar{s}\gamma_\nu d$$

$$m_d = m_u = 0, \quad m_s \neq 0$$

$$J^{\gamma}_{\mu} = e_u \bar{u}\gamma_\mu u + e_d \bar{d}\gamma_\mu d$$

perturbative part



$$M = N_c \int \frac{d^4k}{(2\pi)^4} \langle 0 | Tr\left[D(k)\Gamma_1 D(p'+k)\Gamma_2 D(p+k)\Gamma_3\right] | 0 \rangle$$

$$= N_c \int \frac{d^4k}{(2\pi)^4} Tr\left\{ \frac{i}{\not{k} - m_s} \gamma_\alpha \gamma_5 \frac{i}{\not{p}' + \not{k} - m_d} \gamma_\mu \frac{i}{\not{p} + \not{k} - m_d} \gamma_\nu \right\}$$

$$\rho_a^{pert} = \frac{1}{4\left(Q^4 + (s-s')^2 + 2Q^2(s+s')\right)^{5/2}} \Big(m^4\left(-Q^4 + 2(s-s')^2 + Q^2(-5s-s')\right.$$
$$+ 2m^2\left(Q^6 + 2s(s-s')^2 + Q^2 s'(3s+s') + Q^4(3s+2s')\right)$$
$$+ s\left(Q^6 + 2s(s-s')^2 + Q^4(4s-s') + Q^2\left(5s^2 - 7ss' - 2s'^2\right)\right)\Big)\Big)$$

$$d \leftrightarrow s$$

$$\rho_b^{pert} = \frac{1}{4\left(Q^4 + (s-s')^2 + 2Q^2(s+s')\right)^{5/2}} \Big(m^4\left(-Q^4 + 2(s-s')^2\right.$$
$$+ Q^2(-5s-s') + m^2\left(-Q^6 - Q^4(s+s') + (s-s')^2 7(s+s') + Q^2\left(7s^2 + s'^2\right)\right)$$
$$+ s\left(Q^6 + 2s(s-s')^2 + Q^4(4s-s') + Q^2\left(5s^2 - 7ss' - 2s'^2\right)\right)\Big)\Big)$$

Physical part of the sum rule

$$\Pi_{\mu\nu}(p,p') = \frac{\langle 0|J_\nu^V|V(p)\rangle\langle V(p)|J_\mu^\gamma|P(p')\rangle\langle P(p')|J_\alpha^P|0\rangle}{(p^2-m_V^2)(p'^2-m_P^2)} + \ldots.. \qquad (20)$$

Overlap amplitudes;

$$\langle 0|J_\alpha^P|P\rangle = \lambda_P p'_\alpha \qquad\qquad \langle 0|J_\delta^V|V\rangle = \lambda_V \varepsilon_\delta^V$$

The matrix element of the electromagnetic current

$$\langle V(p)|J_\mu^\gamma(q)|P(p')\rangle = e\, g_{VP\gamma} K(q^2)\varepsilon_{\delta\sigma\mu\nu}\varepsilon^{V\delta}\varepsilon_\mu^\gamma p^\delta p'^\sigma \qquad (21)$$

$$\Pi_{\mu\nu}(p,p') = \frac{e\, g_{VP\gamma} K(q^2)\varepsilon_{\delta\sigma\mu\nu}\varepsilon^{V\delta}\varepsilon_\mu^\gamma \lambda_V \varepsilon_\delta^V \lambda_P p'_\alpha p^\delta p'^\sigma}{(p^2-m_V^2)(p'^2-m_P^2)} \qquad (22)$$

$$
\begin{aligned}
g_{K^{0*}K^{0}\gamma} = {}& \frac{3}{f_{K^{0*}} f_{K^{0}} m_{K^{0*}}} M^2 M'^2 e^{m_{K^{0*}}^2/M^2} e^{m_{K^{0}}^2/M'^2} \Bigg\{ \Bigg(\Bigg(\frac{1}{4\pi^2} \int_0^{s_0} ds \int_0^{s_0'} ds' \Bigg(e_d \Bigg(\frac{1}{4\left(Q^4 + (s-s')^2 + 2Q^2(s+s')\right)^{5/2}} \\
& \times \Big(m^4 \big(-Q^4 + 2(s-s')^2 + Q^2(-5s-s') + 2m^2 \big(Q^6 + 2s(s-s')^2 + Q^2 s'(3s+s') + Q^4(3s+2s') \big) \\
& + s\big(Q^6 + 2s(s-s')^2 + Q^4(4s-s') + Q^2(5s^2 - 7ss' - 2s'^2) \big)\big)\Big)\Bigg) + e_s \Bigg(\frac{1}{4\left(Q^4 + (s-s')^2 + 2Q^2(s+s')\right)^{5/2}} \\
& \times \Big(m^4 \big(-Q^4 + 2(s-s')^2 + Q^2(-5s-s') + m^2 \big(-Q^6 - Q^4(s+s') + (s-s')^2 7(s+s') + Q^2(7s^2 + s'^2) \big) \\
& + s\big(Q^6 + 2s(s-s')^2 + Q^4(4s-s') + Q^2(5s^2 - 7ss' - 2s'^2) \big)\big)\Big)\Bigg) e^{-s/M^2} e^{-s'/M'^2} \Bigg) \\
& + N_c g^2 (-i e_d) \frac{1}{9} \Bigg\{ -\frac{15i}{9} \langle \bar{d}d \rangle^2 \frac{1}{M^2 M'^6} - \frac{13i}{9} \langle \bar{d}d \rangle^2 \frac{1}{M'^4 M^4} - 4i \langle \bar{d}d \rangle \langle \bar{s}s \rangle \frac{1}{M^2 M'^6} \\
& + 4i \langle \bar{d}d \rangle \langle \bar{s}s \rangle \frac{1}{M^2 M'^4 q^2} + (-ie_s) \Bigg(-i N_c m_s \langle \bar{\psi}\psi \rangle \frac{1}{M^2 M'^4} e^{-m_s^2/M^2} e^{-m_s^2/M'^2} \\
& - \frac{15i}{81} N_c g^2 \langle \bar{\psi}\psi \rangle^2 \frac{1}{M^2 M'^6} e^{-m_s^2/M^2} e^{-m_s^2/M'^2} - \frac{13i}{81} N_c g^2 \langle \bar{\psi}\psi \rangle^2 \frac{1}{M^4 M'^4} e^{-m_s^2/M^2} e^{-m_s^2/M'^2} \\
& - \frac{8i}{9} N_c g^2 \langle \bar{\psi}\psi \rangle_1^2 \Bigg(\frac{1}{m_s^4 M^2 M'^2} e^{-m_s^2/M^2} - \frac{1}{m_s^4 M^2 M'^2} e^{-m_s^2/M^2} e^{-m_s^2/M'^2} \\
& - \frac{1}{m_s^2 M^2 M'^4} e^{-m_s^2/M^2} e^{-m_s^2/M'^2} \Bigg) - \frac{4i}{9} N_c g^2 \langle \bar{\psi}\psi \rangle_1^2 \frac{1}{m_s^2} \left(\frac{1}{M'^2} - \frac{1}{M'^2} e^{-m_s^2/M'^2} \right) \Bigg\}
\end{aligned}
$$

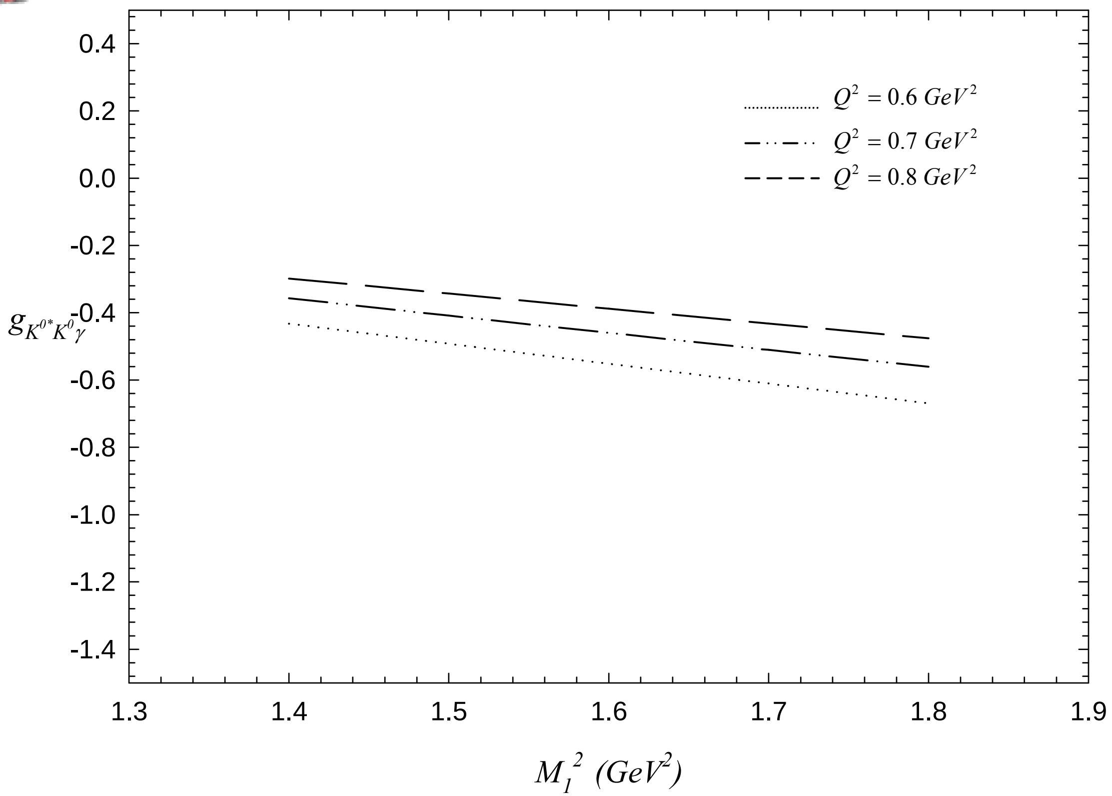


Figure 12. The coupling constant $g_{K^{0*}K^0\gamma}$ as a function of the Borel parameter M_1^2 at $M_2^2 = 1\ GeV^2$

$$s_0' = 2\ GeV^2$$

$$s_0 = 1\ GeV^2$$

$$0.28 \leq \left| g_{K^{0*}K^0\gamma} \right| \leq 0.68$$

Conclusion:

- The coupling Costants $S \to V\gamma$ and $V \to P\gamma$ were calculated in three point QCD sum rules

- Results:

$$0.63 < g_{a_0\rho\gamma} < 1.25$$

$$0.96 < g_{f_0\rho\gamma} < 2$$

$$g_{a_0\omega\gamma} = 1.46 \pm 0.37$$

$$g_{f_0\omega\gamma} = 1.21 \pm 0.15$$

$$0.28 \leq \left| g_{K^{0*}K^{0}\gamma} \right| \leq 0.68$$