ANALYSES OF $D_s^{*}DK$ ($B_s^{*}BK$) VERTICES

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Outline

- Motivation
- Method
- QCD Sum Rules
- QCD Sum Rules for the Coupling Constants
- Numerical Analysis of the work

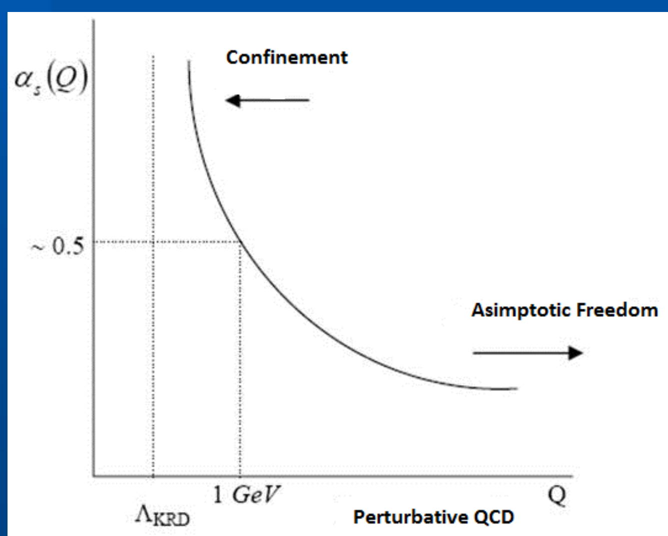
Motivation

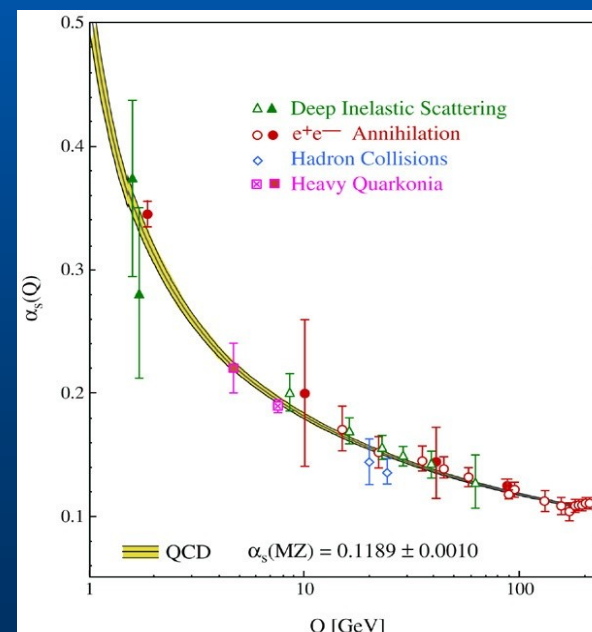
Why pseudoscalar mesons?

- The heavy-light (HL) pseudoscalar mesons are of great importance in evaluating charmonium cross sections.
- The absorption of charmonium by kaons in a nuclear medium can explain the J/ψ suppression in heavy-ion collision experiments.
- J/ψ suppression is believed to be the signal of Quark-gluon plasma in the early universe.
- Both B and the new charmonium states (X’ s, the Y’ s and the Z’ s)decay into an intermediate two body state with D’ s and/or D*’ s
- A precise determination of the coupling constants in the hadronic vertices is a vital task due to allow obtaining the cross sections.

Why we need nonperturbative methods?

- **Perturbative theory** → $\alpha_S = g^2/4 \ll 1$
- **Nonperturbative theory** → $\alpha_S = g^2/4 \gg 1$





Nonperturbative Methods

- QCD Sum Rules (QCDSR)
- Lattice QCD
- Nambu-Jona-Lasinio Model (NJL)
- Heavy-Quark Effective Theory
- Relativistic Quark Model or Light-front Quark Model
- Finite Energy Sum Rules (FESR)
- Chiral Perturbation Theory
- Linear Sigma Model

QCD Sum Rules

- Shifman, Vainshtein and Zakharov (1979)- Mesons
  Ioffe (1981)- Baryons

Correlation function

Physical (or *Phenomenological* side)
↓
Hadronic degrees of freedom

=

QCD (or *Theoretical* side)
↓
Quark degrees of freedom

- Mass, decay constant, coupling constant, form factor….

Calculation of D_s^*DK (B_s^*BK) coupling constant

1. Physical Side

Three point correlation function for D and K offshell states, respectively:

$$\Pi_\mu^{D(B)} = i^2 \int d^4x \, d^4y \, e^{ip'\cdot x} \, e^{iq\cdot y} \langle 0 | \mathcal{T} \left(\eta^K(x) \, \eta^{D(B)}(y) \, \eta_\mu^{D_s^*(B_s^*)\dagger}(0) \right) | 0 \rangle \qquad (1)$$

$$\Pi_\mu^{K} = i^2 \int d^4x \, d^4y \, e^{ip'\cdot x} \, e^{iq\cdot y} \langle 0 | \mathcal{T} \left(\eta^{D(B)}(x) \, \eta^K(y) \, \eta_\mu^{D_s^*(B_s^*)\dagger}(0) \right) | 0 \rangle \qquad (2)$$

Currents associate to meson fields:

$$\eta^K(x) = \overline{s}(x)\gamma_5 u(x)$$
$$\eta^{D(B)}(x) = \overline{u}(x)\gamma_5 c(b)(x) \qquad (3)$$
$$\eta_\mu^{D_s^*(B_s^*)}(x) = \overline{s}(x)\gamma_\mu c(b)(x)$$

Physical side for the correlation function:

$$\Pi_\mu^{D(B)}(p', p) = \frac{\langle 0|\eta^K|K(p')\rangle \langle 0|\eta^{D(B)}|D(B)(q)\rangle \langle K(p')D(B)(q)|D_s^*(B_s^*)(p,\epsilon)\rangle \langle D_s^*(B_s^*)(p,\epsilon)|\eta_\mu^{D_s^*(B_s^*)}|0\rangle}{(q^2 - m_{D(B)}^2)(p^2 - m_{D_s^*(B_s^*)}^2)(p'^2 - m_K^2)} + \ldots \qquad (4)$$

Meson decay constants definitions:

$$\langle 0|\eta_{\nu}^K|K(p')\rangle = i\frac{m_K^2 f_K}{m_u + m_s}$$
$$\langle 0|\eta^{D(B)}|D(B)(q)\rangle = i\frac{m_{D(B)}^2 \, f_{D(B)}}{m_{c(b)} + m_u}$$
$$\langle D_s^*(B_s^*)(p,\epsilon)|\eta_\mu^{D_s^*(B_s^*)}|0\rangle = m_{D_s^*(B_s^*)} f_{D_s^*(B_s^*)} \epsilon^*{}_\mu \qquad (5)$$
$$\langle K(p')D(B)(q)|D_s^*(B_s^*)(p,\epsilon')\rangle = g_{D_s^*DK(B_s^*BK)}(p' - q)\cdot\epsilon$$

Here p is D_s^*' momentum,

p' is D or K momentum,

q is the transfer momentum

Physical side of the correlation function for D(B) off-shell and K off-shell states

$$\Pi_\mu^{D(B)}(p',p) = -g^{D(B)}_{D_s^* DK(B_s^* BK)}(q^2)\frac{f_{D_s^*(B_s^*)} f_{D(B)} f_K m_K^2 m_D^2 m_{D_s^*(B_s^*)}}{(q^2-m^2_{D(B)})(p^2-m^2_{D_s^*(B_s^*)})(p'^2-m_K^2)(m_{c(b)}+m_u)(m_s+m_u)} \times \left[\left(1+\frac{m_K^2-q^2}{m^2_{D_s^*}}\right)p_\mu - 2p'_\mu\right] \quad (6)$$

$$\Pi_\mu^{K}(p,p') = -g^{K}_{D_s^* DK(B_s^* BK)}(q^2)\frac{f_{D_s^*(B_s^*)} f_{D(B)} f_K m_K^2 m_D^2 m_{D_s^*(B_s^*)}}{(q^2-m^2_{D(B)})(p^2-m^2_{D_s^*(B_s^*)})(p'^2-m_K^2)(m_{c(b)}+m_u)(m_s+m_u)} \times \left[\left(1+\frac{m^2_{D(B)}-q^2}{m^2_{D_s^*}}\right)p_\mu - 2p'_\mu\right] \quad (7)$$

Diagrams contributing to correlation function for D_s^*DK (B_s^*BK)

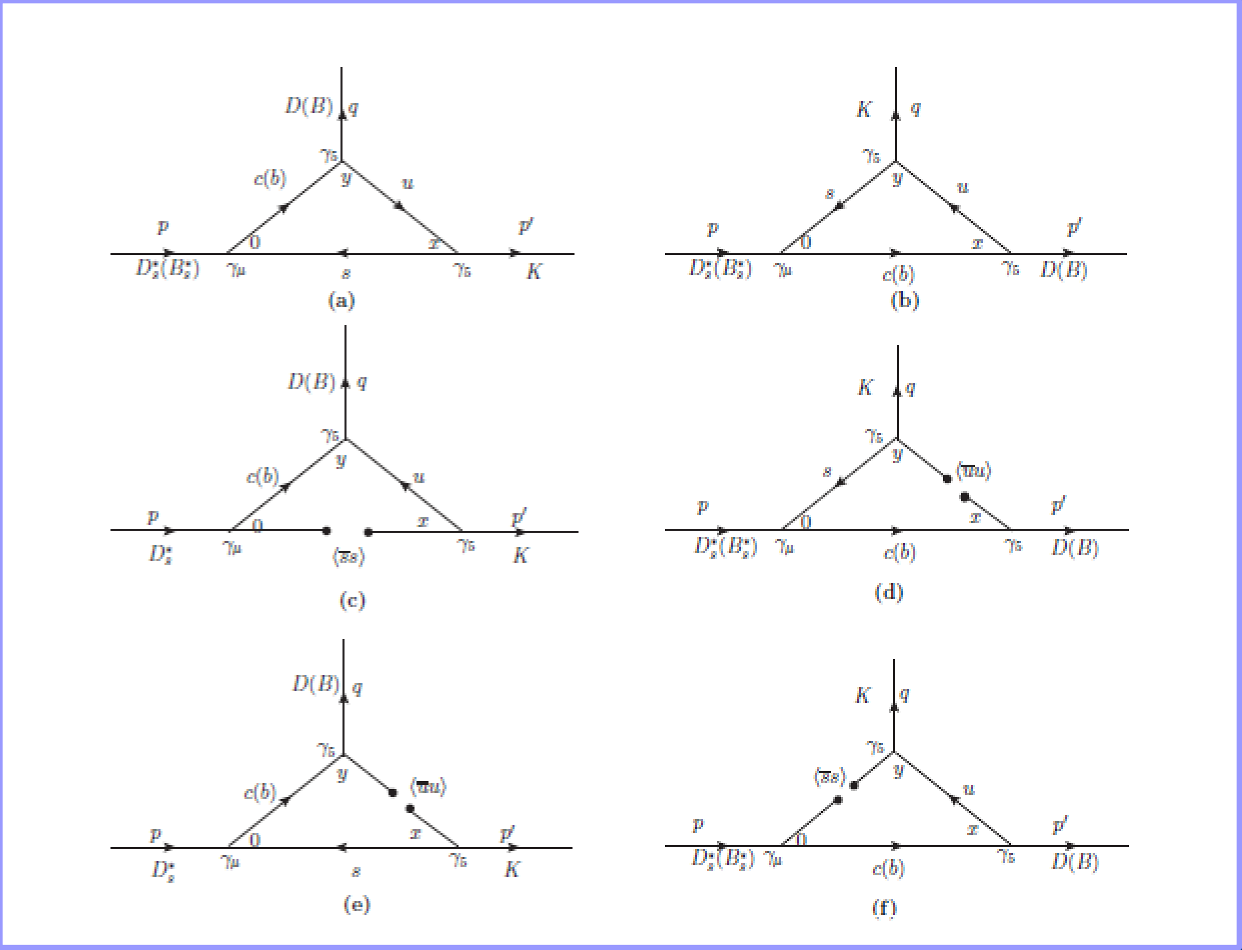


FIG. 1. (a) and (b): Bare loop diagram for the $D(B)$ and K off-shell, respectively; (c) and (e): Diagrams corresponding to quark condensate for the $D(B)$ off-shell; (d) and (f): Diagrams corresponding to quark condensate for the K off-shell.

2. QCD Side

Operator Product Expansion (OPE)

- 1960 –Wilson
- Separate short and long distance quark-gluon interactions

$$\Pi^{QCD} = \Pi_{pert.} + \Pi_{nonpert.}$$

$$i\int dx\, e^{iqx}\, T(j_\Gamma(x) j_\Gamma(0)) = C_I^\Gamma I + \sum_n C_n^\Gamma(q) O_n$$

Perturbative part — Nonperturbative part

I (unit operator)	$d=0$
$O_3 = \bar{\psi}\psi$	$d=3$
$O_4 = G^a_{\mu\nu} G^{a\mu\nu}$	$d=4$
$O_5 = \bar{\psi}\sigma_{\mu\nu} \frac{\lambda^a}{2} G^{a\mu\nu}\psi$	$d=5$
$O_6 = (\bar{\psi}\Gamma_r\psi)(\bar{\psi}\Gamma_s\psi)$	$d=6$
$O_6 = f_{abc} G^a_{\mu\nu} G^{b\nu}_\sigma G^{c\sigma\mu}$	$d=6$

$$\begin{aligned}\Pi^{QCD}(q^2) &= i\int d^4x\, e^{iq.x} \langle 0|T\{j_S(x) j_S(0)\}|0\rangle = \sum_n C_n(p,p',q) O_n \\ &= C_0 I + C_3 \langle 0|\bar{\psi}\psi|0\rangle + C_4 \langle 0|G^a_{\mu\nu} G^{a\mu\nu}|0\rangle \\ &+ C_5 \langle 0|\bar{\psi}\sigma_{\mu\nu} \frac{\lambda^a}{2} G^{a\mu\nu}\psi|0\rangle + C_6 \langle 0|(\bar{\psi}\Gamma_r\psi)(\bar{\psi}\Gamma_s\psi)|0\rangle + \ldots\end{aligned} \quad (8)$$

Perturbative part of QCD side

$$\Pi_{per} = -\frac{1}{4\pi^2}\int ds' \int ds \frac{\rho(s, s', q^2)}{(s-p^2)(s'-p'^2)} + subtraction \ \ terms \qquad (9)$$

Here, $\rho(s) = \frac{1}{4}\mathrm{Im}[\Pi^{QCD}(s)]$

s and s′ continuum thresholds

Using Cutkosky rule $1/(k^2 - m^2) \rightarrow -2\pi i \delta(k^2 - m^2) \qquad (10)$

$$\rho^D(s,s',q^2) = \rho_1^D(s,s',q^2)\, p_\mu + \rho_2^D(s,s',q^2)\, p'_\mu \qquad (11)$$

$$\begin{aligned}\rho_1^D(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[&(-m_s+m_u)(q^2-s)\Big(m_c(m_s^2-m_u^2)+m_u\Big(-m_s^2+m_u^2-q^2+s\Big)\Big)-s'\Big(-m_s^3m_u+m_u^4\\&+2m_c^3(-m_s+m_u)+m_s^2(m_u^2-2q^2)+m_c^2(2m_sm_u-2m_u^2+q^2-s)+q^2(-q^2+s)+m_sm_u(-m_u^2+q^2+s)\\&+m_c(m_s-m_u)(m_s^2+m_u^2+q^2+s)\Big)-s'^2(m_c^2-m_u^2-m_cm_s+m_cm_u+q^2)\Big]\end{aligned} \qquad (12)$$

$$\begin{aligned}\rho_2^D(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[&m_c^3(m_s-m_u)(q^2-s-u)+m_s^3m_u(q^2+s-u)+sm_sm_u\Big(-2m_u^2+q^2-s+s'\Big)\\&+m_c^2\Big(m_u(m_u-m_s)(q^2-s)-(s+q^2-m_sm_u+m_u^2)\Big)s'+s'^2+2s\Big(m_u^4+s'q^2-m_u^2(q^2-s+u)\Big)\\&-m_s^2\Big(m_u^2(q^2+s-s')+q^2(-q^2+s+u)\Big)+m_c\Big(-m_s^3(q^2+s-u)+m_s^2m_u(q^2+s-u)+m_us\\&\times(-2m_u^2+q^2-s+u)+m_s(-q^4+2m_u^2s+(s-s')s'+q^2(s+2s'))\Big)\Big]\end{aligned} \qquad (13)$$

$$\rho_1^K(s,s',q^2) = \rho_{11}^K(s,s',q^2)\, p_\mu + \rho_{12}^K(s,s',q^2)\, p'_\mu \qquad (14)$$

$$\begin{aligned}\rho_{11}^K(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[&(m_c-m_u)(q^2-s)\Big(m_c^2(m_c-m_u)+m_u(-m_sm_u+m_u^2-q^2+s)\Big)+\Big(m_c^3(m_s-m_u)\\&+2m_s^3m_u+m_u^4+m_c^2(-m_sm_u+m_u^2-2q^2)+m_s^2(-2m_u^2+q^2-s)+q^2(-q^2+s)-m_sm_u(m_u^2+q^2+s)\\&+m_c(-2m_s^3+2m_s^2m_u+m_u(-m_u^2+q^2+s)+m_s(m_u^2+q^2+s))\Big)s'+(-m_cm_s+m_s^2+m_sm_u-m_u^2+q^2)s'^2\Big]\end{aligned} \qquad (15)$$

$$\begin{aligned}\rho_{12}^K(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[&-m_s^3(m_c-m_u)(q^2-s-s')+m_cm_us(2m_u^2-q^2+s-s')-m_c^3m_u(q^2+s-s')\\&-2s(m_u^4+s'q^2-m_u^2(q^2-s+s'))+m_s^2\Big(m_cm_u(q^2-s-s')+(q^2+s-s')s'+m_u^2(-q^2+s+s')\Big)\\&+m_c^2(m_u^2(q^2+s-s')+q^2(-q^2+s+s'))+m_s\Big(m_us(2m_u^2-q^2+s-s')+m_c^3(q^2+s-s')\\&-m_c^2m_u(q^2+s-s')+m_c\Big(q^4-2sm_u^2-ss'+s'^2-q^2(s+2s')\Big)\Big)\Big]\end{aligned} \qquad (16)$$

$$\rho^B(s,s',q^2) = \rho_1^B(s,s',q^2)p_\mu + \rho_2^B(s,s',q^2)p'_\mu \qquad (17)$$

$$\rho_1^B(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[(-m_s+m_u)(q^2-s)\Big(m_b(m_s^2-m_u^2)+m_u\Big(-m_s^2+m_u^2-q^2+s\Big)\Big) - s'\Big(-m_s^3m_u+m_u^4 + 2m_b^3(-m_s+m_u)+m_s^2(m_u^2-2q^2)+m_b^2(2m_sm_u-2m_u^2+q^2-s)+q^2(-q^2+s)+m_sm_u(-m_u^2+q^2+s) + m_b(m_s-m_u)(m_s^2+m_u^2+q^2+s)\Big) - s'^2(m_b^2-m_u^2-m_bm_s+m_bm_u+q^2)\Big] \qquad (18)$$

$$\rho_2^B(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[m_b^3(m_s-m_u)(q^2-s-u)+m_s^3m_u(q^2+s-u)+sm_sm_u\Big(-2m_u^2+q^2-s+s'\Big) + m_b^2\Big(m_u(m_u-m_s)(q^2-s)-(s+q^2-m_sm_u+m_u^2)\Big)s'+s'^2+2s\Big(m_u^4+s'q^2-m_u^2(q^2-s+u)\Big) - m_s^2\Big(m_u^2(q^2+s-s')+q^2(-q^2+s+u)\Big)+m_b\Big(-m_s^3(q^2+s-u)+m_s^2m_u(q^2+s-u) + m_us(-2m_u^2+q^2-s+u)+m_s(-q^4+2m_u^2s+(s-s')s'+q^2(s+2s'))\Big)\Big] \qquad (19)$$

$$\rho_2^K(s,s',q^2) = \rho_{21}^K(s,s',q^2)p_\mu + \rho_{22}^K(s,s',q^2)p'_\mu \qquad (20)$$

$$\rho_{21}^K(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[(m_b-m_u)(q^2-s)\Big(m_b^2(m_b-m_u)+m_u(-m_sm_u+m_u^2-q^2+s)\Big)+\Big(m_b^3(m_s-m_u) + 2m_s^3m_u+m_u^4+m_b^2(-m_sm_u+m_u^2-2q^2)+m_s^2(-2m_u^2+q^2-s)+q^2(-q^2+s)-m_sm_u(m_u^2+q^2+s) + m_b(-2m_s^3+2m_s^2m_u+m_u(-m_u^2+q^2+s)+m_s(m_u^2+q^2+s))\Big)s'+(-m_bm_s+m_s^2+m_sm_u-m_u^2+q^2)s'^2\Big] \qquad (21)$$

$$\rho_{22}^K(s,s',q^2) = \frac{N_c}{\lambda^{3/2}(s,s',q^2)}\Big[-m_s^3(m_b-m_u)(q^2-s-s')+m_bm_us(2m_u^2-q^2+s-s')-m_c^3m_u(q^2+s-s') - 2s(m_u^4+s'q^2-m_u^2(q^2-s+s'))+m_s^2(m_bm_u(q^2-s-s')+(q^2+s-s')s'+m_u^2(-q^2+s+s')) + m_b^2(m_u^2(q^2+s-s')+q^2(-q^2+s+s'))+m_s\Big(m_us(2m_u^2-q^2+s-s')+m_b^3(q^2+s-s') - m_b^2m_u(q^2+s-s')+m_b\Big(q^4-2sm_u^2-ss'+s'^2-q^2(s+2s')\Big)\Big)\Big] \qquad (22)$$

Here, $N_c = 3,$ $\lambda(a,b,c) = a^2+b^2+c^2-2ac-2bc-2ab$

Nonperturbative part of QCD side

$$\Pi^{D}_{nonper} = -\frac{\langle \bar{q}q \rangle}{(p^2 - m_c^2)(p'^2 - m_u^2)} \left(m_u p_\mu - m_c p'_\mu \right) \qquad (23)$$

$$\Pi^{B}_{nonper} = -\frac{\langle \bar{q}q \rangle}{(p^2 - m_b^2)(p'^2 - m_u^2)} \left(m_u p_\mu - m_b p'_\mu \right) \qquad (24)$$

$$\hat{B} \frac{1}{(p^2 - m_1^2)^m} \frac{1}{(p'^2 - m_2^2)^n} \rightarrow (-1)^{m+n} \frac{1}{\Gamma(m)} \frac{1}{\Gamma(n)} e^{-m_1^2/M^2} e^{-m_2^2/M'^2} \frac{1}{(M^2)^{m-1}(M'^2)^{n-1}}$$

Here M **and** M′ are Borel parameters

$p^2 \longrightarrow M^2$, $p'^2 \rightarrow M'^2$

❖ D(B) off-shell state:

$$\Pi_{nonpert}^{D(B)} = -\langle \bar{s}s \rangle \left\{ \frac{m_u}{r r'} + \frac{m_0^2 m_u}{4 r^2 r'} + \frac{m_0^2 m_u}{2 r r'^2} \right\} \quad (25)$$

Here, $r = p^2 - m_{c(b)}^2$ $\quad r' = p'^2 - m_u^2$

❖ K off-shell state :

$\Pi_{nonpert1}^{K} = 0$ $\quad \Pi_{nonpert2}^{K} = 0$

Physical Side

Hadron DoF

$=$

Chosen structure is p_μ

Our Analytic Results

$$g^{D(B)}_{D^*_s DK(B^*_s BK)}(q^2) = \frac{(q^2 - m^2_{D(B)})(m_{c(b)} + m_u)(m_s + m_u)}{f_{D^*_s(B^*_s)} f_{D(B)} f_K m_{D^*_s(B^*_s)} m^2_K m^2_{D(B)} (1 + \frac{m^2_K - q^2}{m^2_{D^*_s(B^*_s)}})} e^{\frac{m^2_{D^*_s(B^*_s)}}{M^2}} e^{\frac{m^2_K}{M'^2}}$$

$$\times \left[-\frac{1}{4\pi^2} \int_{(m_{c(b)}+m_s)^2}^{s_0} ds \int_{(m_s+m_u)^2}^{s'_0} ds' \rho^{D(B)}(s, s', q^2) \theta[1 - (f^{D(B)}(s, s'))^2] e^{\frac{-s}{M^2}} e^{\frac{-s'}{M'^2}} + \hat{B}\Pi^{D(B)}_{nonper} \right] \quad (26)$$

$$g^{K}_{D^*_s DK(B^*_s BK)}(q^2) = \frac{(q^2 - m^2_K)(m_{c(b)} + m_u)(m_s + m_u)}{f_{D^*_s(B^*_s)} f_{D(B)} f_K m_{D^*_s(B^*_s)} m^2_K m^2_{D(B)} (1 + \frac{m^2_{D(B)} - q^2}{m^2_{D^*_s(B^*_s)}})} e^{\frac{m^2_{D^*_s(B^*_s)}}{M^2}} e^{\frac{m^2_{D(B)}}{M'^2}}$$

$$\times \left[-\frac{1}{4\pi^2} \int_{(m_{c(b)}+m_s)^2}^{s_0} ds \int_{(m_{c(b)}+m_u)^2}^{s'_0} ds' \rho^{K}(s, s', q^2)\ \theta[1 - (f^{K}(s, s'))^2] e^{\frac{-s}{M^2}} e^{\frac{-s'}{M'^2}} \right], \quad (27)$$

$$-1 \le f^D(s, s') = \frac{2\ s\ (m_s^2 - m_u^2 + s') + (m_c^2 - m_s^2 - s)(-q^2 + s + s')}{\lambda^{1/2}(m_c^2, m_s^2, s)\lambda^{1/2}(s, s', q^2)} \le 1$$

$$-1 \le f_1^{K^*}(s, s') = \frac{2\ s\ (-m_c^2 + m_u^2 - s') + (m_c^2 - m_s^2 + s)(-q^2 + s + s')}{\lambda^{1/2}(m_c^2, m_s^2, s)\lambda^{1/2}(s, s', q^2)} \le 1 \quad (28)$$

$$-1 \le f^B(s, s') = \frac{2\ s\ (m_s^2 - m_u^2 + s') + (m_b^2 - m_s^2 - s)(-q^2 + s + s')}{\lambda^{1/2}(m_b^2, m_s^2, s)\lambda^{1/2}(s, s', q^2)} \le 1$$

$$-1 \le f_2^{K^*}(s, s') = \frac{2\ s\ (-m_b^2 + m_u^2 - s') + (m_b^2 - m_s^2 + s)(-q^2 + s + s')}{\lambda^{1/2}(m_b^2, m_s^2, s)\lambda^{1/2}(s, s', q^2)} \le 1 \quad (29)$$

- **Fit functions used in our calculations:**

$$g^{(D)}_{D_s^* DK}(Q^2) = \frac{8.76}{Q^2 + 7.12}$$ Monopolar

$$g^{(K)}_{D_s^* DK}(Q^2) = 3.55\exp(-Q^2/7.25) - 0.88$$

$$g^{(B)}_{B_s^* DK}(Q^2) = 0.66\exp(-Q^2/23.34) + 0.23$$

$$g^{(K)}_{B_s^* DK}(Q^2) = 4.39\exp(-Q^2/4.02) - 1.03$$

Exponential

Here, $Q^2 = -q^2,\ Q^2 = -m^2_{meson}$

Conclusion

	$Q^2 = -m_D^2$	$Q^2 = -m_K^2$	Average
$g_{D_s^* DK}$ (Present work)	2.79 ± 0.24	2.99 ± 0.26	2.89 ± 0.25
$g_{D_s^* DK}$	2.72	2.87	2.84 ± 0.31

	$Q^2 = -m_B^2$	$Q^2 = -m_K^2$	Average
$g_{B_s^* BK}$	2.40 ± 0.22	3.62 ± 0.34	3.01 ± 0.28

Strong coupling constants of bottom and charmed mesons with scalar, pseudoscalar and axial vector kaons.
H. Sundu, J.Y. Sungu, S. Sahin, N. Yinelek , K. Azizi

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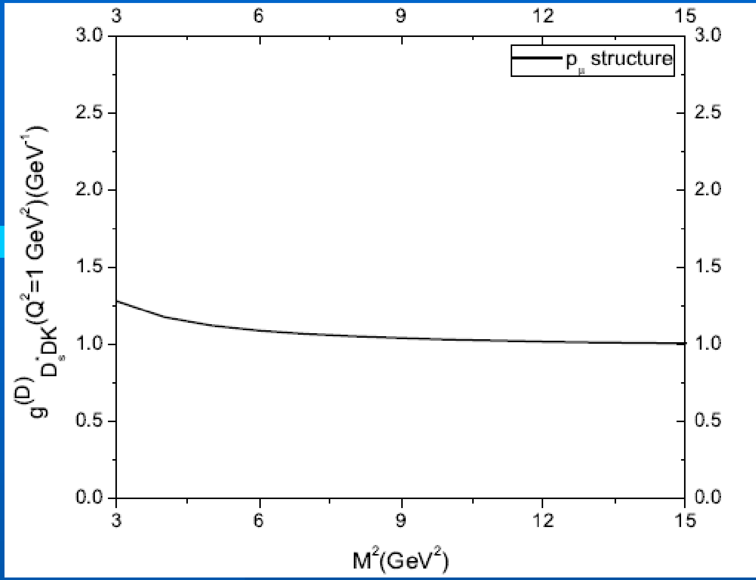
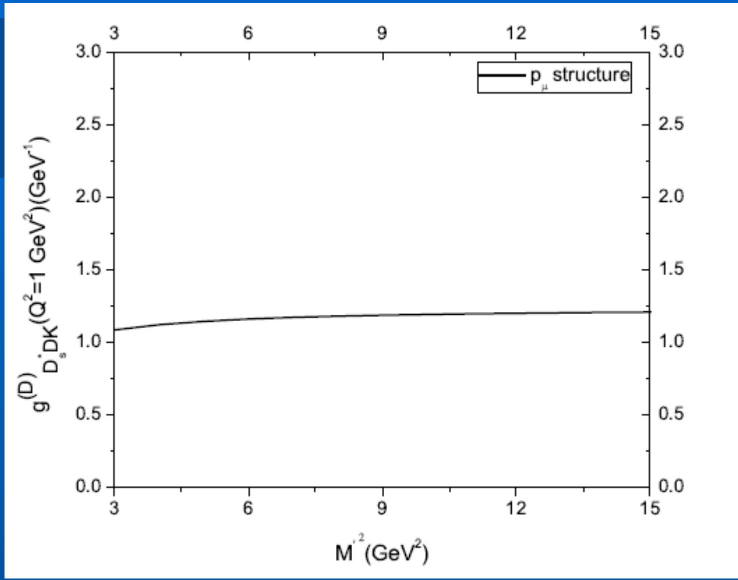
Input Parameters (μ=1GeV):

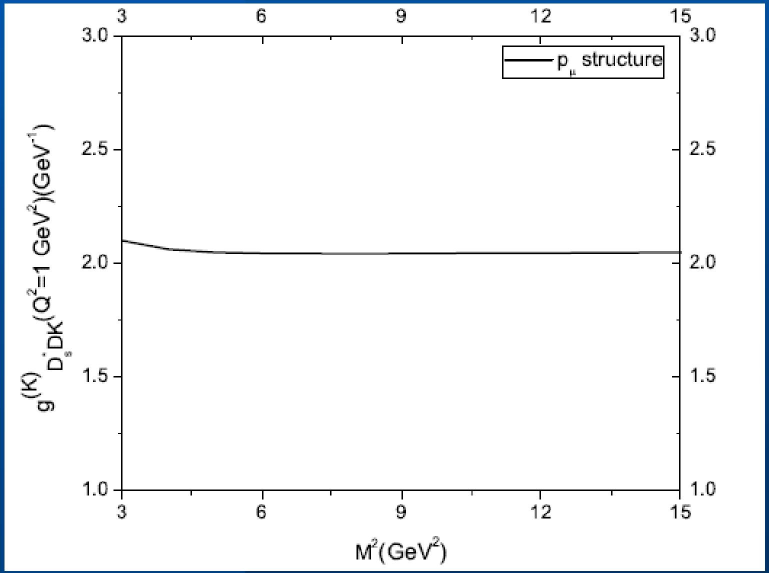
Parameters	Numerical Values
m_u	$0.005\ GeV$
m_d	$0.007\ GeV$
m_s	$0.14\ GeV$
m_c	$1.3\ GeV$
m_b	$4.7\ GeV$
$\alpha(M_Z)$	$0.119\ MeV$
$\langle \overline{\psi} g G^c_{\lambda\tau} \sigma_{\lambda\tau} \psi \rangle$	$m_0^2 \langle \overline{\psi}\psi \rangle$
m_0^2	$0.8\ GeV^2$
$\langle \frac{\alpha_s}{\pi} G^2 \rangle$	$0.012 \pm 0.004\ GeV^4$
$\langle \overline{u}u \rangle = \langle \overline{d}d \rangle$	$-(0.24)^3\ GeV^3$
$\langle \overline{s}s \rangle$	$0.8 \langle \overline{u}u \rangle$

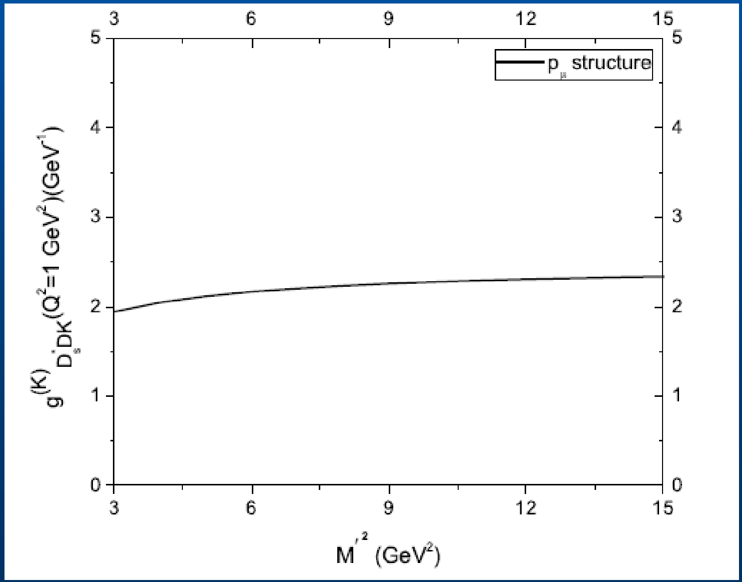
$$(m_{meson} + 0.3)^2 \leq s_0 \leq (m_{meson} + 0.7)^2$$

Coupling constant versus M^2 and M'^2 grafs for the D_s^*DK decay

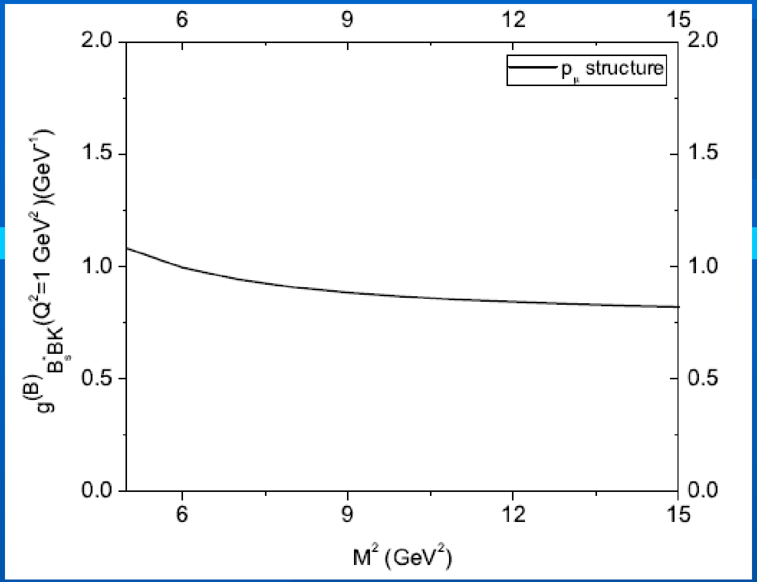


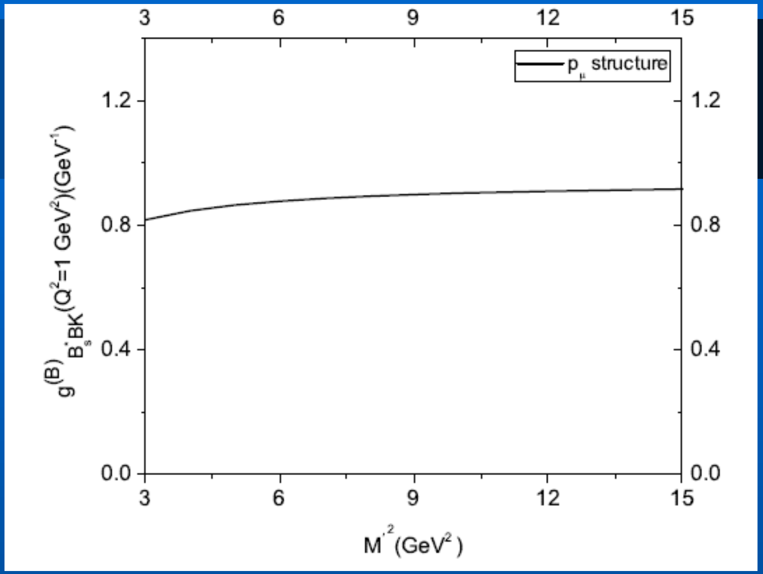


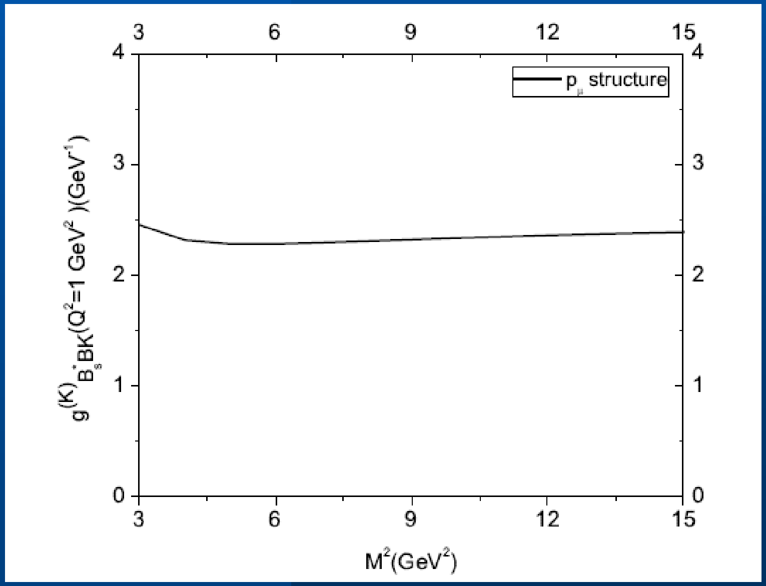


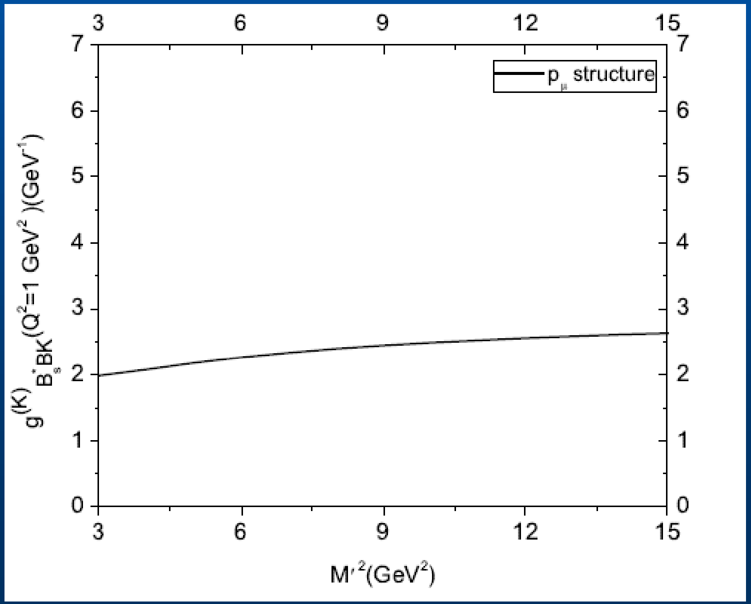


Coupling constant versus M^2 and M'^2 grafs for the B_s^*BK decay









Working Regions

D_s^*DK vertex:

D off-shell : $8GeV^2 \leq M^2 \leq 25GeV^2$ ve $5GeV^2 \leq M'^2 \leq 15GeV^2$
K off-shell : $6GeV^2 \leq M^2 \leq 15GeV^2$ ve $4GeV^2 \leq M'^2 \leq 12GeV^2$

B_s^*BK vertex:

B off-shell : $14GeV^2 \leq M^2 \leq 30GeV^2$ ve $5GeV^2 \leq M'^2 \leq 20GeV^2$
K off-shell : $6GeV^2 \leq M^2 \leq 20GeV^2$ ve $5GeV^2 \leq M'^2 \leq 15GeV^2$

THANKS FOR JOINING...

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