The Study of Semileptonic B_c to D_{s1} Transitions in QCD Sum Rules

2012 J. Phys.: Conf. Ser. 348 012019

(http://iopscience.iop.org/1742-6596/348/1/012019)

3rd International Conference on Hadron Physics (TROIA'11) IOP Publishing
Journal of Physics: Conference Series **348** (2012) 012019 doi:10.1088/1742-6596/348/1/012019

The Study of Semileptonic B_c to D_{s1} Transitions in QCD Sum Rules

M Ghanaatian[1], R Khosravi[2] and A Bazrafshan[3]

[1]Physics Department, Payame Noor University, Jahrom, Iran
[2]Physics Department, Isfahan University of Technology, Isfahan, Iran
[3]Physics Department, Shiraz University, Shiraz, Iran

E-mail: m_ghanatian57@yahoo.com

Abstract. We consider the semileptonic *Bc* to D_{s1} transitions in the frame work of three-point QCD sum rules. Here, we investigate the D_{s1} meson as a conventional $c\bar{s}$ meson in the pure state. The obtained results for the form factors are used to evaluate the decay rates and branching ratios. Any future experimental measurement on these form factors as well as decay rates and branching fractions and their comparison with the obtained results in the present work can give considerable information about the structure of this meson.

1. Introduction

In this work, taking into account the gluon condensate corrections, we analyze the rare semileptonic $B_c \to D_{s1} l^+ l^-$, $l = \tau, \mu, e$ transition in three-point QCD sum rules (3PSR) approach. Note that, the $B_c \to (D^*, D_s^*, D_{s1}(2460))\nu\bar{\nu}$ transitions have been studied in Ref. [1], but assuming the D_{s1} only as $c\bar{s}$. The $B_c \to D_q l^+ l^- / \nu\bar{\nu}$ [2], $B_c \to D_q^* l^+ l^-$, (*q=d,s*) [3] transitions have also been analyzed in the same framework.

The rare semileptonic $B_c \to D_{s1} l^+ l^-$ decays occur at loop level by electroweak penguin and weak box diagrams in the standard model (SM) via the flavor changing neutral current (FCNC) transition of $b \to s l^+ l^-$. The FCNC decays of B_c meson are sensitive to new physics (NP) contributions to penguin operators. Therefore, the study of such FCNC transitions can improve the information about:

- The CP violation, T violation and polarization asymmetries in $b \to s$ penguin channels, that occur in weak interactions.
- New operators or operators that are subdominant in the SM.
- Establishing NP and flavor physics beyond the SM.

2. Transition form factors

To calculate the form factors within three-point QCD sum rules method, the following three-point correlation functions are used [1-4]:

$$\Pi_{\mu\nu}^{V-A}(p^2, p'^2 q^2) = i^2 \int d^4x\, d^4y e^{-ipx} e^{-ip'y} \left\langle 0 \middle| T[J_\nu^{D_{s1}}(y) J_\mu^{V-A}(0) J^{B_c^\dagger}(x)] \middle| 0 \right\rangle \tag{1}$$

$$\Pi_{\mu\nu}^{T-PT}(p^2, p'^2 q^2) = i^2 \int d^4x\, d^4y e^{-ipx} e^{-ip'y} \left\langle 0 \middle| T[J_\nu^{D_{s1}}(y) J_\mu^{T-PT}(0) J^{B_c^\dagger}(x)] \middle| 0 \right\rangle \tag{2}$$

where $J_\nu^{D_{s1}}(y) = \bar{c}\gamma_\nu\gamma_\mu s$ and $J^{B_c}(x) = \bar{c}\gamma_5 b$ are the interpolating currents of initial and final meson states, repectively. $J_\mu^{V-A} = \bar{s}\gamma_\mu(1-\gamma_5)b$ and $J_\mu^{T-PT} = \bar{s}\sigma_{\mu\nu}q^\nu(1+\gamma_5)b$ are the vector-axial vector and tensor-pseudo tensor parts of the transition currents. In QCD sum rules approach, we can obtain the correlation function of Eq. (1) and Eq. (2) in two sides. The phenomenological or physical part is calculated saturating the correlator by a tower of hadrons with the same quantum numbers as interpolating currents. The QCD or theoretical part, on the other side is obtained in terms of the quarks and gluons interacting in the QCD vacuum. We calculate the phenomenological part of the correlators in 3PSR. Therefore, we have,

$$\Pi_{\mu\nu}^{V-A}(p^2, p'^2 q^2) = -\frac{f_{B_c} m_{B_c}^2}{(m_b + m_c)} \frac{f_{D_{s1}} m_{D_{s1}}}{\left(p'^2 - m_{D_{s1}}^2\right)\left(p^2 - m_{B_c}^2\right)} \times [iA'^{B_c \to D_{s1}}_V(q^2) \varepsilon_{\mu\nu\alpha\beta} p^\alpha p'^\beta$$

$$+A'^{B_c\to D_{s1}}_0(q^2)g_{\mu\nu}+A'^{B_c\to D_{s1}}_1(q^2)P_\mu p_\nu+A'^{B_c\to D_{s1}}_2(q^2)q_\mu p_\nu] \quad (3)$$

$$\Pi^{V-A}_{\mu\nu}(p^2,p'^2q^2)=-\frac{f_{B_c}m^2_{B_c}}{(m_b+m_c)}\frac{f_{D_{s1}}m_{D_{s1}}}{(p'^2-m^2_{D_{s1}})(p^2-m^2_{B_c})}\times[iT'^{B_c\to D_{s1}}_V(q^2)\varepsilon_{\mu\nu\alpha\beta}p^\alpha p'^\beta$$

$$-iT'^{B_c\to D_{s1}}_0(q^2)g_{\mu\nu}-iT'^{B_c\to D_{s1}}_1(q^2)q_\mu p_\nu] \quad (4)$$

where $A'_V,\ A'_0,\ A'_1,\ A'_2,\ T'_V, T'_0$ and T'_1 are the transition form factors. On the QCD side, using the operator product expansion (OPE), we can obtain the correlation function in quark-gluon language. For this aim, by performing the double Borel transformations over the variables p^2 and p'^2 on the physical as well as perturbative parts of the correlation functions and equating the coefficients of the selected structures from both sides, the sum rules for the form factors $A'^{B_c\to D_{s1}}_i$ are obtained:

$$A'^{B_c\to D_{s1}}_i=-\frac{(m_b+m_c)}{f_{B_c}m^2_{B_c}f_{D_{s1}}m_{D_{s1}}}e^{\frac{m^2_{B_c}}{M_1^2}}e^{\frac{m^2_{D_{s1}}}{M_2^2}}\{-\frac{1}{4\pi^2}\int_{m_c^2}^{s'_0}ds'\int_{s_L}^{s_0}ds\rho_i^{V-A}(s,s',q^2)\,e^{\frac{-s}{M_1^2}}e^{\frac{-s'}{M_2^2}}$$

$$-iM_1^2M_2^2\,\langle\frac{\alpha_s}{\pi}G^2\rangle\frac{C_i^{V-A}}{6}\} \quad (5)$$

where $i=V,0,1,2$ and for the form factors $T'^{B_c\to D_{s1}}_j$, we get

$$T'^{B_c\to D_{s1}}_j=-\frac{(m_b+m_c)}{f_{B_c}m^2_{B_c}f_{D_{s1}}m_{D_{s1}}}e^{\frac{m^2_{B_c}}{M_1^2}}e^{\frac{m^2_{D_{s1}}}{M_2^2}}\{-\frac{1}{4\pi^2}\int_{m_c^2}^{s'_0}ds'\int_{s_L}^{s_0}ds\rho_j^{T-PT}(s,s',q^2)\,e^{\frac{-s}{M_1^2}}e^{\frac{-s'}{M_2^2}}$$

$$-iM_1^2M_2^2\,\langle\frac{\alpha_s}{\pi}G^2\rangle\frac{C_j^{T-PT}}{6}\} \quad (6)$$

where $j=V,0,1$. The s_0 and s'_0 are the continuum thresholds in B_c and D_{s1} channels, respectively and lower bound s_L in the integrals. We calculate the explicit expressions of the coefficients $C_{i(j)}^{V-A(T-PT)}$ correspond to gluon condensates.

3. Conclusion

we would like to consider the D_{s1} meson as the pure $|c\bar{s}\rangle$ state. We choose the values of the condensates, leptonic constants, CKM matrix element, quark and meson masses [5,6,7]. To calculate the branching ratios of the $B_c\to D_{s1}(2460[2536])l^+l^-$ decays, we use the total mean life time $\tau_{B_c}=(0.46\pm0.07)ps$ [7]. Our numerical analysis shows that the contribution of the non-perturbative part (the gluon condensate diagrams) is about 12% of the total and the main contribution comes from the perturbative part of the form factors. The values for the branching ratio of these decays are obtained as presented in Table 1, when only the short distance (SD) effects are considered.

Table 1. The branching ratios of the semileptonic $B_c\to D_{s1}(2460[2536])l^+l^-$ decays with SD effects.

MODS	BR	MODS	*BR*
$B_c\to D_{s1}(2460)e^+e^-$	$(5.40\pm1.70)\times10^{-6}$	$B_c\to D_{s1}(2536)e^+e^-$	$(2.91\pm0.93)\times10^{-6}$
$B_c\to D_{s1}(2460)\mu^+\mu^-$	$(2.27\pm0.95)\times10^{-6}$	$B_c\to D_{s1}(2536)\mu^+\mu^-$	$(1.96\pm0.63)\times10^{-6}$
$B_c\to D_{s1}(2460)\tau^+\tau^-$	$(1.42\pm0.45)\times10^{-8}$	$B_c\to D_{s1}(2460)\tau^+\tau^-$	$(0.68\pm0.21)\times10^{-8}$

References

[1] Azizi K, Khosravi R and Bashiry V 2008 *Eur. Phys. J.* C **56** 357
[2] Azizi K and Khosravi R 2008 *Phys. Rev.* D **78** 036005
[3] Azizi F, Falahati F, Bashiry V and Zebarjad S M 2008 *Phys. Rev.* D **77** 114024
[4] Ghahramany N, Khosravi R and Azizi K 2008 *Phys. Rev.* D **78** 116009
[5] Shifman M A, Vainshtein A I and Zakharov V I 1979 *Nucl. Phys.* B **147** 385
[6] Bashiry V and Azizi K 2007 *JHEP* **0707** 064
[7] Amsler C et al 2008 Particle Data Group *Phys. Lett.* B **667** 1