Pramana – J. Phys. (2017) 88: 13
DOI 10.1007/s12043-016-1306-7

Analysis of the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay

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MS received 28 July 2015; revised 16 November 2015; accepted 18 April 2016; published online 6 December 2016

Abstract. We analysed the process of $B_c^+ \to D_s^+ \overline{K}^{0^*}$ using QCD factorization (QCDF) and final-state interaction (FSI) effects. First, the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay is calculated using QCDF method. The value found by using the QCDF method is less than the experimental value. Then we considered FSI effect as a sizable correction where the intermediate state $D^{+^*}\pi^0$ mesons via the exchange of $K^0(K^{0^*})$ are produced. To consider the amplitudes of this intermediate state, the QCDF approach was used. The experimental branching ratio of $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay is less than 0.4×10^{-6} and our results are $(0.21 \pm 0.04) \times 10^{-7}$ and $(0.37 \pm 0.05) \times 10^{-6}$ from QCDF and FSI, respectively.

Keywords. QCD factorization; final-state interaction; intermediate state; branching ratio.

PACS Nos 13.25.HW; 12.39.Hg; 12.39.St

1. Introduction

The study of the two-body non-leptonic weak decay of $B_c^+ \to D_s^+ \overline{K}^{0^*}$ may be useful in the search for new physics beyond the Standard Model. Several useful methods such as the perturbative QCD approach [1], QCDF by Beneke and Neubert [2] and FSI effects by Lu *et al* [3] are there to calculate the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay. In perturbative QCD, Xiao *et al* have considered complete twist-3 contributions, and in the QCDF, state-of-the art analysis was performed according to QCDF by four-parameter scenarios. The branching ratios obtained from these scenarios, considering large arbitrary numbers (the same work has been conducted in scenario 4 in ref. [2]), are smaller than experimental ones. In FSI, the $D^{+^*}\pi^0$ mesons have been considered as intermediate states. We mainly used the same framework in the QCDF approach and selected the leading-order Wilson coefficients at the scale m_b [2,4] and estimated the amplitude of the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay while assuming the annihilation contributions. In this case, we obtained $(0.21 \pm 0.04) \times 10^{-7}$ as the branching ratio. Motivated by the above-mentioned study, we contributed FSI corrections in the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay mode. As, in B decays, resonant FSI is expected to be suppressed due to the absence of resonances at energies close to the mass of the B meson, we considered only t-channels and estimated it via the one-particle exchange processes at the hadronic loop level (HLL) as explained in §4. The FSI can give sizable corrections. Rescattering amplitude can be derived by calculating the absorptive part of triangle diagrams. In this decay, intermediate state is $D^{+^*}\pi^0$. Then we calculated the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay using the HLL method. Using the FSI method we obtain the branching ratio of $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay, $(0.37 \pm 0.05) \times 10^{-6}$, and the experimental result of this decay is less than 0.4×10^{-6} [5]. We present the calculation of QCDF for the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay in §2. In §3, we calculate the amplitudes of the intermediate state. Then we present the calculation of HLL for $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay in §4. In §5, we give the numerical results, and in §6, we have conclusions.

2. QCD factorization in the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay

In this section, we calculate the amplitude of the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay by the QCDF method. The $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay has tree, penguin and annihilation diagrams that are shown in figure 1. According to these

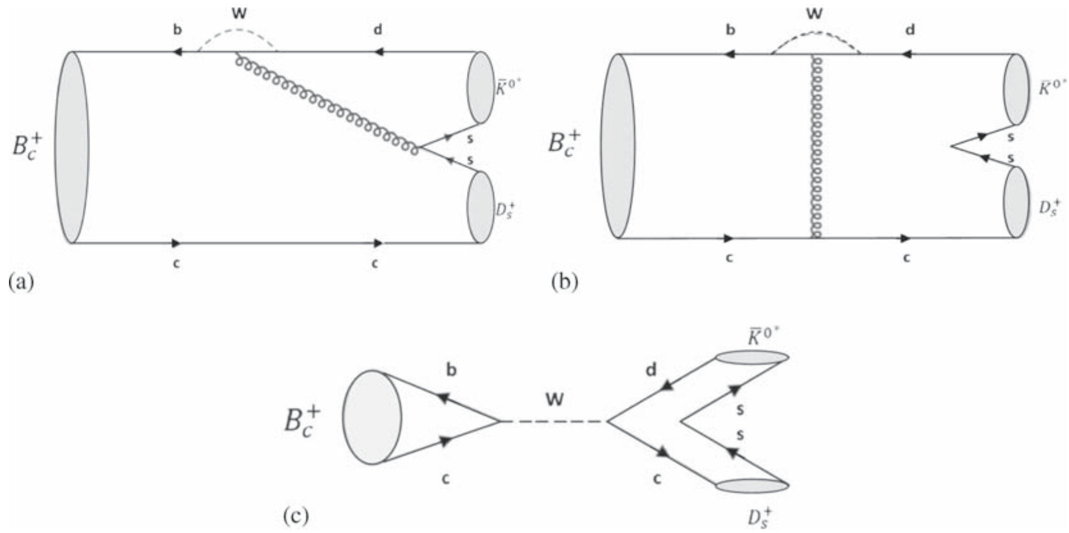

Figure 1. Feynman diagrams for $B_c^+ \to D_s^+ \overline{K}^{0*}$ decay.

Feynman diagrams, we wrote the amplitude of this decay by the QCDF method as follows:

$$\begin{aligned} A_{\mathrm{QCD}} &= -i\sqrt{2} G_F f_{D_s} m_{K^*} (\varepsilon_{K^*}.p_B) A_0^{BK^*} \\ &\quad \times \left[\left(a_4 - \frac{1}{2} a_{10} \right) + r_\chi^{K^*} \left(a_6 - \frac{1}{2} a_8 \right) \right] \lambda_p \\ &\quad - \frac{i G_F}{\sqrt{2}} f_{B_c} f_{D_s} f_{K^*} [b_2 (V_{cb} V_{cd}^*) \\ &\quad + (b_3 - b_{3\mathrm{eW}}) \lambda_p], \end{aligned} \tag{1}$$

where λ_p are the products of elements of the quark mixing matrix. Using the unitarity relation $\lambda_p + \lambda_c + \lambda_t = 0$, we get

$$\lambda_p = \sum_{p=u,c} V_{pb} V_{pd}^*. \tag{2}$$

We also define a_i coefficients obtained from a combination of Wilson coefficients appeared in decay amplitude as [6,7]

$$\begin{aligned} a_i &= c_i + \frac{1}{N_c} c_{i+1} \quad (i = \text{odd}), \\ a_i &= c_i + \frac{1}{N_c} c_{i-1} \quad (i = \text{even}). \end{aligned} \tag{3}$$

b_2, b_3 and $b_{3\mathrm{eW}}$ correspond to the current–current annihilation, penguin annihilation and electroweak penguin annihilation. These non-singlet annihilation coefficients are given as [8,9]

$$\begin{aligned} b_2 &= \frac{C_F}{N_c^2} c_2 A_2^i, \\ b_3 &= \frac{c_F}{N_c^2} [c_3 A_1^i + c_5 (A_3^i + A_3^f) + N_c c_6 A_3^f], \\ b_{3\mathrm{eW}} &= \frac{c_F}{N_c^2} [c_9 A_1^i + c_7 (A_3^i + A_3^f) + N_c c_8 A_3^f], \end{aligned} \tag{4}$$

where c_i are the Wilson coefficients, N_c is the colour number and

$$\begin{aligned} A_1^i &\approx -A_2^i = 6\pi\alpha_s \left[3 \left(X_A - 4 + \frac{\pi^2}{3} \right) \right. \\ &\qquad \left. + r_\chi^{D_s} r_\chi^{K^*} (X_A^2 - 2X_A) \right], \\ A_3^i &= 0, \\ A_3^f &= 2\pi\alpha_s (r_\chi^{D_s} + r_\chi^{K^*})(2X_A^2 - X_A), \end{aligned} \tag{5}$$

$$C_F = \frac{N_c^2 - 1}{2N_c}. \tag{6}$$

There are large theoretical uncertainties related to the modelling of power corrections corresponding to weak annihilation effects. We parametrize these effects in terms of the divergent integrals X_A (weak annihilation) [9]

$$X_A = (1 + \rho e^{i\phi}) \ln \frac{m_B}{\Lambda_h}, \quad \rho \le 1, \quad \Lambda_h = 0.5\ \text{GeV}, \tag{7}$$

and for the pseudoscalar mesons of D_s and K^*, the ratios $r_\chi^{D_s}$ and $r_\chi^{K^*}$ are defined as

$$\begin{aligned} r_\chi^{D_s} &= \frac{2m_{D_s}^2}{(m_b - m_c)(m_s + m_c)}, \\ r_\chi^{K^*} &= \frac{2m_{K^*}}{m_b} \frac{f_{K^*}^\perp}{f_{K^*}}. \end{aligned} \tag{8}$$

3. Weak amplitudes of intermediate state

To consider the FSI effects in the $B_c^+ \to D_s^+ \overline{K}^{0*}$ decay, we must extract the accessible intermediate states and

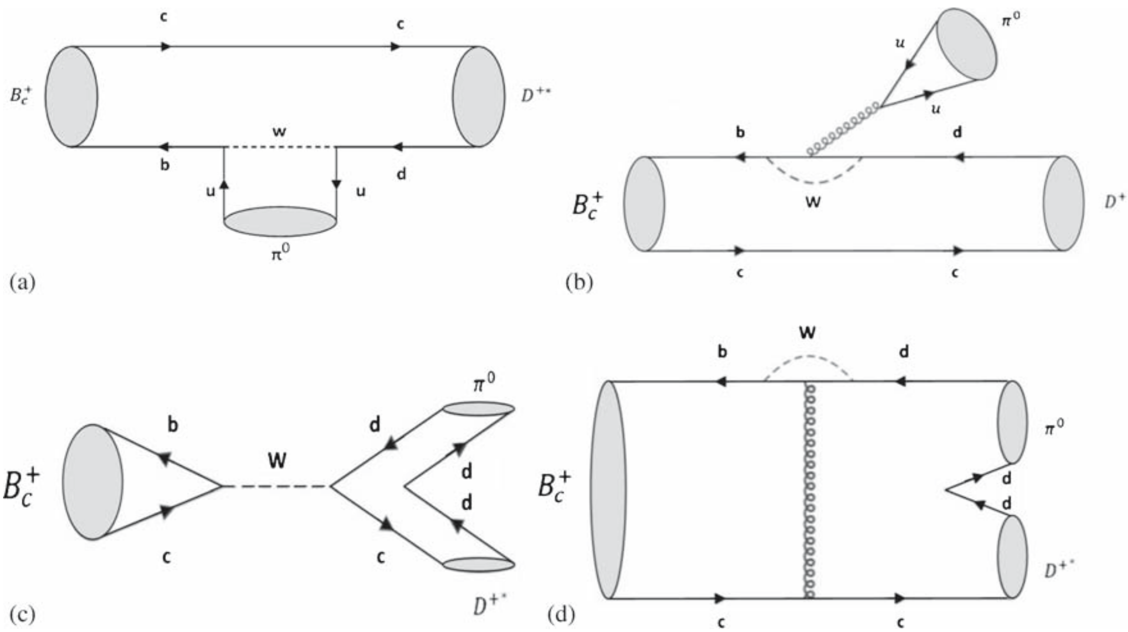

Figure 2. Feynman diagrams for $B_c^+ \to D^{+^*}\pi^0$ decay.

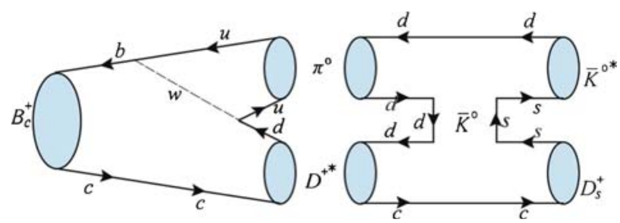

Figure 3. Quark level diagram for $B_c^+ \to D^{+^*}\pi^0 \to D_s^+ \overline{K}^{0^*}$ decay.

calculate their weak amplitude. According to figure 2, the $D^{+^*}\pi^0$ mesons can be a product for intermediate state via exchange $\overline{K}^0$ meson. Now that the intermediate state is obtained, we can calculate the amplitude of this intermediate state which is produced in $B_c \to M_1 M_2$ decay modes, where M_1 and M_2 are the intermediate state mesons. According to Feynman diagrams related to the $B_c^+ \to D^{+^*}\pi^0$ decay that are shown in figure 2, we calculated the amplitude of this decay by the QCDF method as follows (figure 3):

$$\begin{aligned} A_{\mathrm{QCD}} = &-i\sqrt{2} G_F f_\pi m_{D^*} (\varepsilon_{D^*} \cdot p_B) A_0^{BD^*} [a_2 (V_{ub} V_{ud}^*) \\ &+ (a_3 + a_4)\, \lambda_p] \\ &- \frac{iG_F}{\sqrt{2}} f_{B_c} f_\pi f_{D^*} [b_2 (V_{cb} V_{cd}^*) \\ &+ (b_3 - b_{3\mathrm{eW}}) \lambda_p]. \end{aligned} \tag{9}$$

4. The one-particle exchange method for FSI

It is extremely difficult to calculate the FSI effects, but at the hadronic level formulated as re-scattering processes with s-channel resonances and one-particle exchange in the t-channel can calculate the FSI effects. The s-channel resonant FSI effects in the $B_c^+ \to D_s^+ \overline{K}^{0^*}$ decay is expected to be vanished because of the absence of resonances. Therefore, one can model the FSI effects as re-scattering processes of two-body intermediate state with one-particle exchange in the t-channel and compute the absorptive part via the optical theorem [10]. So, according to the hadronic loop level (HLL) diagrams, shown in figure 4, the absorptive part of the amplitude is calculated using the following formula:

$$\begin{aligned} &\mathrm{Abs}\; M(B_c^+(p_B) \to M(p_1) M(p_2) \to M(p_3) M(p_4)) \\ &= \frac{1}{2} \int \frac{\mathrm{d}^3\mathbf{p_1}}{2E_1 (2\pi)^3} \frac{\mathrm{d}^3\mathbf{p_2}}{2E_2 (2\pi)^3} (2\pi)^4 \delta^4 (p_{B_c} - p_1 - p_2) \\ &\quad \times M(B_c \to D^{+^*}\pi^0) G(D^{+^*}\pi^0 \to D_s^+ \overline{K}^{0^*}), \end{aligned} \tag{10}$$

where $M(B_c \to D^{+^*}\pi^0)$ is the amplitude of the $B_c \to D^{+^*}\pi^0$ decay calculated using the QCDF method and $G(D^{+^*}\pi^0 \to D_s^+ \overline{K}^{0^*})$ denotes the hadronic vertices factor related to the hadronic diagrams shown in figure 4. The hadronic diagrams in figure 4 include vertices up and down and G is the multiplication value between vertices up and vertices down that is defined as

$$\begin{aligned} &\langle K(p_3) K^*(\varepsilon_2, p_2) | i\pounds | \pi(p_1) \rangle = -i g_{\pi K K^*} \epsilon_2 \cdot (p_1 + p_3), \\ &\langle K^*(\epsilon_3, p_3) K^*(\epsilon_2, p_2) | i\pounds | \pi(p_1) \rangle \\ &\quad = -i\sqrt{2} g_{\pi K^* K^*} \varepsilon_{\mu\nu\alpha\beta} \varepsilon_2^\mu \varepsilon_3^{*^\nu} p_1^\alpha p_2^\beta. \end{aligned} \tag{11}$$

The dispersive part of the rescattering amplitude can be obtained from the absorptive part via the dispersion relation [10,11]:

$$\text{Dis}\, M(m_{B_c}^2) = \frac{1}{\pi}\int_s^\infty \frac{\text{Abs}\, M(s')}{s' - m_{B_c}^2}\text{d}s', \tag{12}$$

where s' is the square of the momentum carried by the exchanged particle and s is the threshold of intermediate states, and in this case $s \sim m_{B_c}^2$. Unlike the absorptive part, the dispersive contribution suffers from large uncertainties arising from the complicated integration.

So, for figure 4a, the absorptive part of the amplitude of the $B_c^+ \to D^{+^*}\pi^0 \to D_s^+ \overline{K}^{0^*}$ process where K^0 meson is exchanged particle at t-channel, is given by

$$\begin{aligned}
\text{Abs 4 ``(a)''} =& \frac{-iG_F}{2\sqrt{2}}\int_{-1}^1 \frac{\text{d}^3\mathbf{p_1}}{2E_1(2\pi)^3}\frac{\text{d}^3\mathbf{p_2}}{2E_2(2\pi)^3}(2\pi)^4\delta^4 \\
&\times (p_{B_c} - p_1 - p_2) \\
&\times (-ig_{D^*KD_s})\varepsilon_3 \cdot (p_1 + q)(-ig_{\pi KK^*}) \\
&\times \varepsilon_2 \cdot (-q)\{2m_{D^*}(\varepsilon_2 \cdot p_1) f_\pi A_0^{BD^*} \\
&\times [a_2(V_{ub}V_{ud}^*) + (a_3 + a_4)\lambda_p] \\
&- f_{B_c} f_{D^*} f_\pi [b_2(V_{cb}V_{cd}^*) \\
&+ (b_3 - b_{3\text{eW}})\lambda_p]\}\frac{F^2(q^2, m_K^2)}{T_1} \\
=& \frac{-iG_F}{8\sqrt{2}\pi m_B} g_{D^*KD_s} g_{\pi KK^*} \\
&\times \int_{-1}^1 |P_1|\text{d}(\cos\theta)\{2H_1 m_{D^*} f_\pi A_0^{BD^*} \\
&\times [a_2(V_{ub}V_{ud}^*) + (a_3 + a_4)\lambda_p] \\
&- f_{B_c} f_{D^*} f_\pi [b_2(V_{cb}V_{cd}^*) \\
&+ (b_3 - b_{3\text{eW}})\lambda_p]H_2\}\frac{F^2(q^2, m_K^2)}{T_1}.
\end{aligned} \tag{13}$$

Here

$$\begin{aligned}
H_1 &= (\varepsilon_2 \cdot p_1)(\varepsilon_2 \cdot p_4)(\varepsilon_3 \cdot p_1) \\
&= \left(-p_1 \cdot p_4 + \frac{(p_1 \cdot p_2)(p_2 \cdot p_4)}{m_\pi^2}\right) \\
&\quad \times \left(\frac{E_1|p_3| - E_3|p_1|\cos\theta}{m_{B_c}|p_3|}\right), \\
H_2 &= (\varepsilon_3 \cdot p_1)(\varepsilon_2 \cdot p_4) = \left(\frac{E_1|p_3| - E_3|p_1|\cos\theta}{m_{B_c}|p_3|}\right) \\
&\quad \times \left(\frac{E_4|p_2| - E_2|p_4|\cos\theta}{m_{B_c}|p_2|}\right), \\
T_1 &= (p_1 - p_3)^2 - m_K^2 \\
&= p_1^2 + p_3^2 - 2p_1^0 p_3^0 + 2\mathbf{p_1} \cdot \mathbf{p_3} - m_K^2, \\
q^2 &= m_1^2 + m_3^2 - 2E_1E_3 + 2|\mathbf{p_1}||\mathbf{p_3}|\cos\theta \\
&= m_{D^*}^2 + m_{D_s}^2 - 2p_1^0 p_3^0 + 2|\mathbf{p_1}||\mathbf{p_3}|\cos\theta,
\end{aligned} \tag{14}$$

θ is the angle between $\mathbf{p_1}$ and $\mathbf{p_3}$, q is the momentum of the exchange K meson and $F(q^2, m_K^2)$ is the form factor defined to take care of the off-shell of the exchange particles, which is introduced as [3]

$$F(q^2, m_K^2) = \left(\frac{\Lambda^2 - m_K^2}{\Lambda^2 - q^2}\right)^n. \tag{15}$$

The calculations of hadronic diagrams for FSIs involve many theoretical uncertainties. As the particle exchanged in the t-channel is off-shell and as final-state particles are hard mesons, form factors or cut-offs must be introduced to the strong vertices to render the calculation meaningful in perturbation theory. The form factor (i.e. $n = 1$) is normalized to unity at $q^2 = m_K^2$. The monopole behaviour of the form factor (i.e. $n = 1$) is preferred as it is consistent with the QCD sum rule expectation [12]. m_K and q are the physical parameters of the exchange particle and Λ is phenomenological parameter.

It is obvious that for $q^2 \to 0$, $F(q^2, m_K^2)$ becomes a number. If $\Lambda \gg m_K$ then $F(q^2, m_K^2)$ turns to be unity,

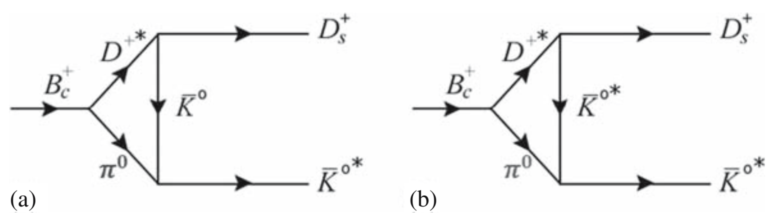

Figure 4. t-channel contributions to final-state interaction in the $B_c^+ \to D^{+^*}\pi^0 \to D_s^+ \overline{K}^{0^*}$ decay due to one-particle exchange.

whereas, as $q^2 \to \infty$ the form factor approaches zero and the distance becomes small and the hadron interaction is no longer valid. As Λ should not be far from m_K and q, we choose

$$\Lambda = m_K + \eta \Lambda_{\mathrm{QCD}}, \tag{16}$$

where η is the phenomenological parameter and its value in the form factor is expected to be of the order of unity and can be determined from the measured rates. Also the parameter η depends not only on the exchanged particle, but also on the external particles involved in strong interaction. The range of η parameter is from 0.5 to 3 and we used 0.6 to 1.6 in this paper.

$$\begin{aligned}
\text{Abs } 4\text{ “(b)”} = {} & \frac{-iG_F}{2\sqrt{2}} \int_{-1}^{1} \frac{\mathrm{d}^3\mathbf{p_1}}{2E_1(2\pi)^3} \frac{\mathrm{d}^3\mathbf{p_2}}{2E_2(2\pi)^3} \\
& \times (2\pi)^4 \delta^4(p_{B_c} - p_1 - p_2) \\
& \times (-i\sqrt{2} g_{D^*K^*D_s}) \varepsilon_{\mu\nu\alpha\beta} \varepsilon_3^{\mu} \varepsilon_{K^*}^{\nu} p_1^{\alpha} p_3^{\beta} \\
& \times (-i\sqrt{2} g_{\pi K^* K^*}) \varepsilon_{\rho\sigma\lambda\eta} \varepsilon_2^{\rho} \varepsilon_{K^*}^{\sigma} p_2^{\lambda} p_4^{\eta} \\
& \times \{2m_{D^*}(\varepsilon_2 \cdot p_1) f_\pi A_0^{BD^*} \\
& \times [a_2(V_{ub}V_{ud}^*) + (a_3 + a_4)\lambda_p] \\
& - f_{B_c} f_{D^*} f_\pi [b_2(V_{cb}V_{cd}^*) \\
& + (b_3 - b_{3\mathrm{eW}})\lambda_p]\} \frac{F^2(q^2, m_{K^*}^2)}{T_2} \\
= {} & \frac{iG_F}{8\sqrt{2}\pi m_B} g_{D^*K^*D_s} g_{\pi K^* K^*} \\
& \times \int_{-1}^{1} |P_1| \mathrm{d}(\cos\theta) \\
& \times \{2H_3 m_{D^*}(\varepsilon_2 \cdot p_1) f_\pi A_0^{BD^*} \\
& \times [a_2(V_{ub}V_{ud}^*) + (a_3 + a_4)\lambda_p]\lambda_p \\
& - f_{B_c} f_{D^*} f_\pi [b_2(V_{cb}V_{cd}^*) \\
& + (b_3 - b_{3\mathrm{eW}})\lambda_p] H_4\} \frac{F^2(q^2, m_{K^*}^2)}{T_2}.
\end{aligned} \tag{17}$$

Here

$$\begin{aligned}
H_3 &= m_3^2(p_1 \cdot p_2) - (p_1 \cdot p_3)(p_2 \cdot p_3) \\
&\quad + \left(\frac{E_2|p_3| - E_3|p_2|\cos\theta}{m_{B_c}|p_3|} \right) \\
&\quad \times [(p_{B_c} \cdot p_1)(p_3 \cdot p_4) - (p_{B_c} \cdot p_3)(p_1 \cdot p_4)], \\
H_4 &= \varepsilon_{\mu\nu\alpha\beta} \varepsilon_{\rho\sigma\lambda\eta} \varepsilon_3^{\mu} \varepsilon_{K^*}^{\nu} p_1^{\alpha} p_3^{\beta} \varepsilon_2^{\rho} \varepsilon_{K^*}^{\sigma} p_2^{\lambda} p_4^{\eta}, \\
T_2 &= (p_1 - p_3)^2 - m_{K^*}^2 = p_1^2 + p_3^2 - 2p_1^0 p_3^0 \\
&\quad + 2\mathbf{p_1} \cdot \mathbf{p_3} - m_{K^*}^2, \\
q^2 &= m_1^2 + m_3^2 - 2E_1E_3 + 2|\mathbf{p_1}||\mathbf{p_3}|\cos\theta \\
&= m_{D^*}^2 + m_{D_s}^2 - 2p_1^0 p_3^0 + 2|\mathbf{p_1}||\mathbf{p_3}|\cos\theta.
\end{aligned} \tag{18}$$

The dispersion relation is

$$\text{Dis } 4(m_{B_c}^2) = \frac{1}{\pi} \int_s^{\infty} \frac{\text{Abs } 4a(s') + \text{Abs } 4b(s')}{s' - m_{B_c}^2} \mathrm{d}s' \tag{19}$$

and the decay amplitude of the $B_c^+ \to D_s^+ \overline{K}^{0*}$ decay via the HLL diagrams is

$$\begin{aligned}
\mathrm{A}(B_c^+ \to D_s^+ \overline{K}^{0*}) = {} & \text{Abs } 4\text{ “(a)”} + \text{Abs } 4\text{ “(b)”} \\
& + \text{Dis } 4(m_{B_c}^2).
\end{aligned} \tag{20}$$

5. Numerical results

Numerical values of effective coefficients a_i for $\bar{b} \to \bar{d}$ transition at $N_c = 3$ are given by [13]

$$\begin{aligned}
& a_1 = 1.05, && a_2 = 0.053, \\
& a_3 = 0.0048, && a_4 = -0.046 - 0.012i, \\
& a_5 = -0.0045, && a_6 = -0.059 - 0.012i, \\
& a_7 = 0.00003 - 0.00018i, && a_8 = 0.0004 - 0.00006i, \\
& a_9 = -0.009 - 0.00018i, && a_{10} = -0.0014 - 0.00006i.
\end{aligned} \tag{21}$$

The CKM matrix is a 3×3 unitary matrix as [14]

$$V = \begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix}. \tag{22}$$

We obtain [5]

$$\begin{aligned}
& V_{ud} = 0.9745, \quad V_{us} = 0.2257, \quad V_{ub} = 0.0035, \\
& V_{cd} = 0.230, \quad V_{cs} = 0.9745, \quad V_{cb} = 0.0415.
\end{aligned} \tag{23}$$

For end-point parametrizing in QCD factorization approach, according to the polarization of the final mesons, we get [15]

$$\begin{aligned}
& \rho = 0.5, \quad \Lambda_{\mathrm{QCD}} = 0.225\ \mathrm{GeV}, \quad \Phi_A = -55^{\circ}(PP), \\
& \Phi_A = -70^{\circ}(VP), \quad \Phi_A = -20^{\circ}(PV).
\end{aligned} \tag{24}$$

The mass of the mesons and decay constants are given in units of MeV (the uncertainties on the prediction are in mass, decay constants and form factors) [3,10,16,17]:

$$\begin{aligned}
& m_{B_c} = 5279 \pm 0.3, \quad m_D = 187 \pm 0.2, \\
& m_{D^*} = 2010.2 \pm 0.17, \\
& m_K = 493.6 \pm 0.016, \quad m_{K^*} = 891 \pm 0.26, \\
& m_\pi = 139.5, \\
& m_{D_s} = 197 \pm 0.34, \quad f_{B_c} = 480, \quad f_\pi = 130.7 \pm 0.46, \\
& f_{D^*} = 230 \pm 20, \quad f_{D_s} = 294 \pm 27, \quad f_{K^*} = 217 \pm 5, \\
& A_0^{B_c D^*}(m_{D^*}^2) = 2.5, \quad A_0^{B_c K^*}(m_{K^*}^2) = 0.3.
\end{aligned} \tag{25}$$

Table 1. The branching ratio of $B_c^+ \to D_s^+ \overline{K}^{0*}$ decay, with $\eta = 0.6$–1.4 (in units of 10^{-6}).

η	0.6	0.8	1	1.2	1.4	1.6	E.
BR	0.01 ± 0.01	0.06 ± 0.02	0.15 ± 0.03	0.37 ± 0.05	0.75 ± 0.07	1.11 ± 0.10	< 0.4

The other input parameters used are given by [3,10]

$$g_{D^*KD_s} = 18.37, \quad g_{\pi KK^*} = 4.6,$$
$$g_{D^*K^*D_s} = 2.79, \tag{26}$$

We calculated the branching ratio using the QCDF method as $(0.21 \pm 0.04) \times 10^{-7}$ which is small compared to the experimental result. Within FSI, the branching ratio is shown in table 1 and if $\eta = 1.2$ is selected, the branching ratio is $(0.37 \pm 0.05) \times 10^{-6}$ which is close to the experimental result.

6. Conclusions

We analysed the $B_c^+ \to D_s^+ \overline{K}^{0*}$ decay in the QCD factorization approach and then we added the final-state interaction effects. For evaluating the FSI effects, we have considered only the absorptive part of the HLL because both hadrons produced via the weak interaction are on their mass shells. The experimental result of this decay is less than 0.4×10^{-6}. According to QCDF and FSI, our results are: $\mathrm{BR}(B_c^+ \to D_s^+ \overline{K}^{0*}) = (0.21 \pm 0.04) \times 10^{-7}$ and $(0.37 \pm 0.05) \times 10^{-6}$, respectively. The main phenomenological parameter in the FSI effects is η which is determined from the measured ratios. Its value in form factor is expected to be of the order of unity. In this work we have considered $\eta = 0.6-1.4$ and the best result is obtained when $\eta = 1.2$. We observed that the branching ratio, from 0.6 to 1.6, is close to the experimental value. But by increasing η from 1.2 to 1.6, we showed that the branching ratio exceeds the experimental value.

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