B_c meson decays involving pseudoscalar and *p*-wave mesons in the final state using non-relativistic model

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Abstract

We study Cabibbo-Kobayashi-Maskawa (CKM) favored and suppressed weak decays of B_c mesons in the Isgur-Scora-Grinstein-Wise (ISGW) quark model. We present a detailed analysis of the B_c meson decaying to pseudoscalar meson and p-wave mesons in the final state. We also give the form factors involving $B_c \to p$-wave transitions in the ISGW II framework and consequently, predict the branching ratios.

UNIQUELY OBSERVED BOTTOM CHARM (*Bc*) MESON

Studies of the B_c meson decays are important for several reasons. The B_c meson discovered at Fermilab is the only quark-antiquark bound system $(\bar{b}c)$ composed of heavy quarks (b, c) with different flavors, and are thus flavor asymmetric.

The decay processes of the B_c meson can be broadly divided into three classes:

i) involving the decay of b quark with c being spectator,

ii) involving the decay of c quark with b being spectator and

iii) the two component annihilate, b and $\bar{c}$, weakly.

Processes i) and ii), as mentioned above, can contribute to semileptonic and nonleptonic weak decays, while the process iii) can only contribute to leptonic decays.

B_c MESON EMITTING DECAYS OF PSEUDOSCALAR AND AXIAL-VECTOR MESONS

WEAK HAMILTONIAN

Bottom changing ($\Delta b = 1$) decays,

a. The CKM favored $b \to c$ transition,

$$H_W = \frac{G_F}{\sqrt{2}} \{ V_{cb} V_{ud}^* [c_1 (\bar{c}b)(\bar{d}u) + c_2 (\bar{d}b)(\bar{c}u)] + V_{cb} V_{cs}^* [c_1 (\bar{c}b)(\bar{s}c) + c_2 (\bar{s}b)(\bar{c}c)] + V_{cb} V_{us}^* [c_1 (\bar{c}b)(\bar{s}u) + c_2 (\bar{s}b)(\bar{c}u)] + V_{cb} V_{cd}^* [c_1 (\bar{c}b)(\bar{d}c) + c_2 (\bar{d}b)(\bar{c}c)] \},$$

b. The CKM suppressed $b \to u$ transition,

$$H_W = \frac{G_F}{\sqrt{2}} \{ V_{ub} V_{cs}^* [c_1 (\bar{u}b)(\bar{s}c) + c_2 (\bar{s}b)(\bar{u}c)] + V_{ub} V_{ud}^* [c_1 (\bar{u}b)(\bar{d}u) + c_2 (\bar{d}b)(\bar{u}u)] + V_{ub} V_{us}^* [c_1 (\bar{u}b)(\bar{s}u) + c_2 (\bar{s}b)(\bar{u}u)] + V_{ub} V_{cd}^* [c_1 (\bar{u}b)(\bar{d}c) + c_2 (\bar{d}b)(\bar{u}c)] \},$$

Bottom conserving and charm changing ($\Delta b = 0$) decays

a. CKM favored ($\Delta C = -1$, $\Delta S = -1$) decays,

$$H_W = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs}^* [c_1 (\bar{u}d)(\bar{s}c) + c_2 (\bar{s}d)(\bar{u}c)];$$

b. CKM suppressed ($\Delta C = 1$, $\Delta S = 0$) decays,

$$H_W = \frac{G_F}{\sqrt{2}} \{V_{cd} V_{ud}^* [c_1 (\bar{c}d)(\bar{d}u) + c_2 (\bar{c}u)(\bar{d}d)]$$

$$+ V_{cs} V_{ud}^* [c_1 (\bar{c}s)(\bar{d}u) + c_2 (\bar{c}u)(\bar{d}s)]\},$$

c. CKM doubly suppressed ($\Delta C = -\Delta S = -1$) decays,

$$H_W = \frac{G_F}{\sqrt{2}} V_{us} V_{cd}^* [c_1 (\bar{u}s)(\bar{d}c) + c_2 (\bar{d}s)(\bar{u}c)].$$

where

$$c_1(\mu) = 1.26 \; , \; c_2(\mu) = -0.51 \text{ at } \mu \approx m_c^2 ,$$

$$c_1(\mu) = 1.12 \; , \; c_2(\mu) = -0.26 \text{ at } \mu \approx m_b^2 .$$

DECAY AMPLITUDE RELATIONS

Decay amplitudes of CKM-favored mode of $B \to PA$ decays for bottom conserving and charm changing modes.

Decays	Amplitude
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = -1$	
$B_c^+ \to \pi^+ B_{s1}^0$	$a_1 f_\pi (\sin\theta_5\, F^{B_c\to B_{s1A}}(m_\pi^2) + \cos\theta_5\, F^{B_c\to B_{s1B}}(m_\pi^2))$
$B_c^+ \to \pi^+ \underline{B}_{s1}^0$	$a_1 f_\pi (\cos\theta_5\, F^{B_c\to B_{s1A}}(m_\pi^2) - \sin\theta_5\, F^{B_c\to B_{s1B}}(m_\pi^2))$
$B_c^+ \to \bar{K}^0 B_1^+$	$a_2 f_K (\sin\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) + \cos\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to \bar{K}^0 \underline{B}_1^+$	$a_2 f_K (\cos\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) - \sin\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = 1$	
$B_c^+ \to K^+ B_1^0$	$-a_1 f_K (\sin\theta_4\, F^{B_c\to B_{1A}}(m_K^2) + \cos\theta_4\, F^{B_c\to B_{1B}}(m_K^2))$
$B_c^+ \to K^+ \underline{B}_1^0$	$-a_1 f_K (\cos\theta_4\, F^{B_c\to B_{1A}}(m_K^2) - \sin\theta_4\, F^{B_c\to B_{1B}}(m_K^2))$
$B_c^+ \to K^0 B_1^+$	$-a_2 f_K (\sin\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) + \cos\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to K^0 \underline{B}_1^+$	$-a_2 f_K (\cos\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) - \sin\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = 0$	
$B_c^+ \to K^+ B_{s1}^0$	$a_1 f_K (\sin\theta_5\, F^{B_c\to B_{s1A}}(m_K^2) + \cos\theta_5\, F^{B_c\to B_{s1B}}(m_K^2))$
$B_c^+ \to K^+ \underline{B}_{s1}^0$	$a_1 f_K (\cos\theta_5\, F^{B_c\to B_{s1A}}(m_K^2) - \sin\theta_5\, F^{B_c\to B_{s1B}}(m_K^2))$
$B_c^+ \to \pi^+ B_1^0$	$-a_1 f_\pi (\sin\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) + \cos\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to \pi^+ \underline{B}_1^0$	$-a_1 f_\pi (\cos\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) + \sin\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to \pi^0 B_1^+$	$\frac{1}{\sqrt{2}} a_2 f_\pi (\sin\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) + \cos\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to \pi^0 \underline{B}_1^+$	$\frac{1}{\sqrt{2}} a_2 f_\pi (\cos\theta_4\, F^{B_c\to B_{1A}}(m_\pi^2) - \sin\theta_4\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to \eta B_1^+$	$-\frac{1}{\sqrt{2}} a_2 f_\eta (\sin\theta_4 \sin\theta_5\, F^{B_c\to B_{1A}}(m_\pi^2) + \cos\theta_4 \cos\theta_5\, F^{B_c\to B_{1B}}(m_\pi^2))$
$B_c^+ \to \eta \underline{B}_1^+$	$-\frac{1}{\sqrt{2}} a_2 f_\eta (\cos\theta_4 \sin\theta_5\, F^{B_c\to B_{1A}}(m_\pi^2) - \sin\theta_4 \cos\theta_5\, F^{B_c\to B_{1B}}(m_\pi^2))$

CALCULATION OF THE FORM FACTORS IN ISGW II MODEL

$B_c \to A / A'$ TRANSITION FORM FACTORS

The form factors have the following simplified expressions in the ISGW II model for $B_c \to A / A'$ transitions caused by $b \to c$ quark transition:

$$l = -\tilde{m}_{B_c} \beta_{B_c} [\frac{1}{\mu_-} + \frac{m_c \tilde{m}_A (\tilde{\omega} - 1)}{\beta_{B_c}^2} (\frac{5 + \tilde{\omega}}{6 m_q} - \frac{m_c \beta_{B_c}^2}{2 \mu_- \beta_{B_c A}^2})] F_5^{(l)},$$

$$c_+ + c_- = -\frac{\tilde{m}_A}{2 \tilde{m}_{B_c} \beta_{B_c}} \left(1 - \frac{m_c^2 \beta_{B_c}^2}{2 \tilde{m}_A \mu_- \beta_{B_c A}^2}\right) F^{(c_+ + c_-)},$$

$$c_+ - c_- = -\frac{\tilde{m}_A}{2 \tilde{m}_{B_c} \beta_{B_c}} \left(\frac{\tilde{\omega} + 2}{3} - \frac{m_c^2 \beta_{B_c}^2}{2 \tilde{m}_A \mu_- \beta_{B_c A}^2}\right) F^{(c_+ - c_-)},$$

$$r = \frac{\tilde{m}_{B_c} \beta_{B_c}}{\sqrt{2}} [\frac{1}{\mu_+} + \frac{\tilde{m}_A}{3 \beta_{B_c}^2} (\tilde{\omega} - 1)^2] F_5^{(r)},$$

$$s_+ + s_- = \frac{m_c}{\sqrt{2} \tilde{m}_{B_c} \beta_{B_c}} \left(\frac{m_c \beta_{B_c}^2}{2 \mu_+ \beta_{B_c A}^2}\right) F^{(s_+ + s_-)},$$

$$s_+ - s_- = \frac{1}{\sqrt{2} \beta_{B_c}} \left(\frac{4 - \tilde{\omega}}{3} - \frac{m_c^2 \beta_{B_c}^2}{2 \tilde{m}_A \mu_+ \beta_{B_c A}^2}\right) F^{(s_+ - s_-)},$$

where

$$F_5^{(l)} = F_5^{(r)} = F_5 (\frac{\bar{m}_B}{\tilde{m}_B})^{1/2} (\frac{\bar{m}_A}{\tilde{m}_A})^{1/2},$$

$$F_5^{(c_+ + c_-)} = F_5^{(s_+ + s_-)} = F_5 (\frac{\bar{m}_B}{\tilde{m}_B})^{-3/2} (\frac{\bar{m}_A}{\tilde{m}_A})^{1/2},$$

$$F_5^{(c_+ - c_-)} = F_5^{(s_+ - s_-)} = F_5 (\frac{\bar{m}_B}{\tilde{m}_B})^{-1/2} (\frac{\bar{m}_A}{\tilde{m}_A})^{-1/2}.$$

$$\beta_{BX}^2 = \frac{1}{2} \quad \beta_B^2 + \beta_X^2$$

The value of β parameter for s-wave and p-wave are

Quark content	$u\bar{d}$	$u\bar{s}$	$s\bar{s}$	$c\bar{u}$	$c\bar{s}$	$u\bar{b}$	$s\bar{b}$	$c\bar{c}$	$b\bar{c}$
β_s **(GeV)**	0.41	0.44	0.53	0.45	0.56	0.43	0.54	0.88	0.92
β_p **(GeV)**	0.28	0.30	0.33	0.33	0.38	0.35	0.41	0.52	0.60

and

$$\mu_{\pm} = \left(\frac{1}{m_q} \pm \frac{1}{m_b} \right)^{-1}$$

Form factors of $B_c \to A$ transition at $q^2 = t_m$ in the ISGW II quark model

Modes	Transition	l	c_+	c_-
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	$B_c \to B_{s1}$	-15.816	1.710	0.177
	$B_c \to B_1$	-2.838	0.453	0.065
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	$B \to D_1$	-2.129	-0.030	-0.001
	$B_c \to D_{s1}$	-1.982	-0.043	-0.001
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	$B_c \to \chi_{c1}(c\bar{c})$	-0.491	-0.148	-0.006

Form factors of $B_c \to A'$ transition at $q^2 = t_m$ in the ISGW II quark model

Modes	Transition	r	s_+	s_-
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	$B_c \to \underline{B}_{s1}$	-10.424	-0.701	-0.279
	$B_c \to \underline{B}_1$	-3.947	-0.201	0.0003
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	$B \to \underline{D}_1$	1.451	0.038	-0.023
	$B_c \to \underline{D}_{s1}$	1.424	0.062	-0.032
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	$B_c \to h_{c1}(c\bar{c})$	2.129	0.212	-0.062

$B_c \to P$ TRANSITION FORM FACTORS

For $B_c \to P$ transition form factors also, we have following expressions:

$$f_+ + f_- = \left[1 - \frac{\tilde{m}_P}{m_c}\left(1 - \frac{m_c^2 \beta_{B_c}^2}{2\tilde{m}_P \mu_+ \beta_{B_c P}^2}\right)\right] F_3^{(f_+ + f_-)} R^{(f_+ + f_-)},$$

$$f_+ - f_- = \frac{\tilde{m}_{B_c}}{m_c}\left(1 - \frac{m_c^2 \beta_{B_c}^2}{2\tilde{m}_P \mu_+ \beta_{B_c P}^2}\right) F_3^{(f_+ - f_-)} R^{(f_+ - f_-)},$$

Form factors of $B_c \to P$ transition at $q^2 = t_m$ in the ISGW II quark model

Modes	Transition	f_+	f_-
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	$B_c \to B_s$	0.926	-0.374
	$B_c \to B$	1.103	-0.652
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	$B_c \to D$	2.110	-1.975
	$B_c^- \to D_s$	1.543	-1.356
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	$B_c \to \eta_c(c\bar{c})$	1.193	-0.716

NUMERICAL RESULTS AND DISCSSIONS

Branching ratios of CKM-favored mode of $B_c \to PA$ decays for bottom conserving and charm changing modes

Decays	**Branching ratio**
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	
$B_c^+ \to \pi^+ B_{s1}^0$	2.92×10^{-2}
$B_c^+ \to \pi^+ \underline{B}_{s1}^0$	0.47×10^{-2}
$B_c^+ \to \overline{K}^0 B_1^+$	0.54×10^{-2}
$B_c^+ \to \overline{K}^0 \underline{B}_1^+$	0.10×10^{-2}
$\Delta b = 0, \Delta C = -1, \Delta S = 1$	
$B_c^+ \to K^+ B_1^0$	9.10×10^{-5}
$B_c^+ \to K^+ \underline{B}_1^0$	1.58×10^{-5}
$B_c^+ \to K^0 B_1^+$	1.47×10^{-5}
$B_c^+ \to K^0 \underline{B}_1^+$	2.55×10^{-6}

$\Delta b = 0, \Delta C = -1, \Delta S = 0$	
$B_c^+ \to K^+ B_{s1}^0$	7.49×10^{-4}
$B_c^+ \to K^+ \underline{B}_{s1}^0$	1.11×10^{-4}
$B_c^+ \to \pi^+ B_1^0$	0.22×10^{-2}
$B_c^+ \to \pi^+ \underline{B}_1^0$	4.05×10^{-4}
$B_c^+ \to \pi^0 B_1^+$	181×10^{-4}
$B_c^+ \to \pi^0 \underline{B}_1^+$	3.33×10^{-5}
$B_c^+ \to \eta B_1^+$	2.12×10^{-4}
$B_c^+ \to \eta \underline{B}_1^+$	3.64×10^{-5}

Branching ratios of CKM-favored modes of $B_c \to PA$ decays for bottom changing modes

Decays	Branching ratios
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	
$B_c^- \to D^- D_1^0$	3.13×10^{-5}
$B_c^- \to D^- \underline{D}_1^0$	9.77×10^{-6}
$B_c^- \to \eta_c a_1^-$	0.31×10^{-2}
$B_c^- \to \eta_c b_1^-$	2.59×10^{-8}
$B_c^- \to \pi^- \chi_{c1}$	0.07×10^{-2}
$B_c^- \to \pi^- h_{c1}$	0.06×10^{-2}
$B_c^- \to D^0 D_1^-$	6.10×10^{-5}
$B_c^- \to D^0 \underline{D}_1^-$	6.53×10^{-6}

$\Delta b = 1, \Delta C = 0, \Delta S = -1$	
$B_c^- \to \overline{D}^0 K_1^-$	4.93×10^{-7}
$B_c^- \to \overline{D}^0 \underline{K}_1^-$	1.52×10^{-7}
$B_c^- \to D_s^- a_1^0$	1.13×10^{-8}
$B_c^- \to D_s^- f_1$	1.34×10^{-8}
$B_c^- \to \pi^0 D_{s1}^-$	7.85×10^{-9}
$B_c^- \to \pi^0 \underline{D}_{s1}^-$	7.17×10^{-10}
$B_c^- \to \eta D_{s1}^-$	4.89×10^{-9}
$B_c^- \to \eta D_{s1}^-$	4.33×10^{-10}
$B_c^- \to K^- \overline{D}_1^0$	2.49×10^{-7}
$B_c^- \to K^- \underline{D}_1^0$	3.63×10^{-8}
$B_c^- \to \eta' D_{s1}^-$	2.96×10^{-9}
$B_c^- \to \eta' \underline{D}_{s1}^-$	2.45×10^{-10}

$B_c^- \to D_s^- h_{c1}$	0.15×10^{-2}
$B_c^- \to D_s^- \chi_{c1}$	0.10×10^{-2}
$B_c^- \to \eta_c D_{s1}^-$	3.25×10^{-3}
$B_c^- \to \eta_c \underline{D}_{s1}^-$	1.27×10^{-4}

$\Delta b = 0, \Delta C = 1, \Delta S = -1$	
$B_c^- \to K^- \chi_{c1}$	5.06×10^{-5}
$B_c^- \to K^- h_{c1}$	4.40×10^{-5}
$B_c^- \to D^0 D_{s1}^-$	5.96×10^{-6}
$B_c^- \to D^0 \underline{D}_{s1}^-$	3.31×10^{-7}
$B_c^- \to D_s^- D_1^0$	8.62×10^{-7}
$B_c^- \to D_s^- \underline{D}_1^0$	2.69×10^{-7}
$B_c^- \to \eta_c K_1^-$	1.35×10^{-4}
$B_c^- \to \eta_c \underline{K}_1^-$	4.04×10^{-5}

$\Delta b = 0, \Delta C = 0, \Delta S = 0$	
$B_c^- \to \pi^0 D_1^-$	1.04×10^{-7}
$B_c^- \to \pi^0 \underline{D}_1^-$	1.38×10^{-8}
$B_c^- \to \pi^- \overline{D}_1^0$	3.80×10^{-6}
$B_c^- \to \pi^- \underline{\overline{D}}_1^0$	5.02×10^{-6}
$B_c^- \to \eta D_1^-$	6.51×10^{-8}
$B_c^- \to \eta \underline{D}_1^-$	8.42×10^{-9}
$B_c^- \to \eta' D_1^-$	3.98×10^{-8}
$B_c^- \to \eta' \underline{D}_1^-$	4.87×10^{-9}

$B_c^- \to D^- a_1^0$	2.59×10^{-6}
$B_c^- \to D^- f_1$	3.08×10^{-6}
$B_c^- \to D^- \chi_{c1}$	2.45×10^{-5}
$B_c^- \to D^- h_{c1}$	4.83×10^{-5}
$B_c^- \to \overline{D}^0 a_1^-$	8.64×10^{-5}
$B_c^- \to \overline{D}^0 b_1^-$	7.30×10^{-11}
$B_c^- \to \eta_c D_1^-$	5.88×10^{-5}
$B_c^- \to \eta_c \underline{D}_1^-$	6.79×10^{-5}

$\Delta b=0, \Delta C=-1, \Delta S=0$	
$B_c^- \to D^- \bar{D}_1^0$	4.01×10^{-7}
$B_c^- \to D^- \underline{\bar{D}}_1^0$	2.91×10^{-8}
$B_c^- \to \bar{D}^0 D_1^-$	6.24×10^{-8}
$B_c^- \to \bar{D}^0 \underline{D}_1^-$	3.33×10^{-8}
$\Delta b=0, \Delta C=-1, \Delta S=-1$	
$B_c^- \to \bar{D}^0 D_{s1}^-$	5.72×10^{-7}
$B_c^- \to \bar{D}^0 \underline{D}_{s1}^-$	6.72×10^{-7}
$B_c^- \to D_s^- \bar{D}_1^0$	1.51×10^{-5}
$B_c^- \to D_s^- \underline{\bar{D}}_1^0$	1.18×10^{-6}

DOMINANT DECAYS

i) For charm changing and bottom conserving are:

$B(B_c^+ \to \pi^+ B_{s1}^0) = 2.92\times10^{-2}$, $B(B_c^+ \to \bar{K}^0 B_1^+) = 0.54\times10^{-2}$, $B(B_c^+ \to \pi^+ \underline{B}_{s1}^0) = 0.47\times10^{-2}$, $B(B_c^+ \to \pi^+ B_1^0) = 0.24\times10^{-2}$ and $B\ (B_c^+ \to \bar{K}^0 \underline{B}_1^+) = 0.10\times10^{-2}$.

ii) For bottom changing transitions the dominating decays are:

$B(B_c^- \to \eta_c a_1^-) = 0.31\times10^{-2}$, $B(B_c^- \to D_s^- h_{c1}) = 0.15\times10^{-2}$ and $B(B_c^- \to D_s^- \chi_{c1}) = 0.10\times10^{-2}$.

The rest of the decay modes remain highly suppressed partly due to the small values of the CKM matrix elements and the small values of the form factors.

Bc MESON EMITTING DECAYS OF PSEUDOSCALAR AND TENSOR MESONS

CALCULATION OF THE FORM FACTORS

The required form factors h, k, b_+ and b_- are calculated from the following expressions of ISGW II model:

$$h = \frac{m_d}{2\sqrt{2\tilde{m}_{B_c}\beta_{B_c}}}\left(\frac{1}{m_q} - \frac{m_d\beta_{B_c}^2}{2\mu_-\tilde{m}_T\beta_{B_cT}^2}\right)F_5^{(h)},$$

$$k = \frac{m_d}{\sqrt{2\beta_{B_c}}}(1+\varpi)\ F_5^{(k)},$$

$$b_+ + b_- = \frac{m_d^2}{4\sqrt{2}m_q m_b \tilde{m}_{B_c}\beta_{B_c}}\frac{\beta_T^2}{\beta_{B_cT}^2}\left(1 - \frac{m_d}{2\tilde{m}_{B_c}}\frac{\beta_T^2}{\beta_{B_cT}^2}\right)F_5^{(b_+ + b_-)},$$

$$b_+ - b_- = -\frac{m_d}{\sqrt{2}m_b\tilde{m}_T\beta_{B_c}}\left(1 - \frac{m_d m_b}{2\mu_+\tilde{m}_{B_c}}\frac{\beta_T^2}{\beta_{B_cT}^2} + \frac{m_d}{4m_q}\frac{\beta_T^2}{\beta_{B_cT}^2}\left(1 - \frac{m_d}{2\tilde{m}_{B_c}}\frac{\beta_T^2}{\beta_{B_cT}^2}\right)\right)F_5^{(b_+ - b_-)},$$

Form factors of $B_c \to T$ transition at $q^2 = t_m$ in the ISGW II quark model

Modes	Transition	h	k	b_+	b_-
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	$B_c \to D_2$	0.017	0.556	-0.008	0.011
	$B_c \to D_{s2}$	0.019	0.739	-0.011	0.014
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	$B_c \to B_2$	0.100	2.722	-0.034	0.148
	$B_c \to B_{s2}$	0.119	3.632	-0.049	0.165
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	$B_c \to \chi_{c2}$	0.023	1.411	-0.017	0.019

DECAY AMPLITUDE RELATIONS

Decay amplitudes of $B_c \to PT$ decays for Charm changing decay mode:

Decays	Amplitude
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	
$B_c^+ \to \pi^+ B_{s2}^0$	$a_1 f_\pi F^{B_c \to B_{s2}}(m_\pi^2) V_{cs} V_{ud}^*$
$B_c^+ \to \overline{K}^0 B_2^+$	$a_2 f_K F^{B_c \to B_2}(m_K^2) V_{cs} V_{ud}^*$
$\Delta b = 0, \Delta C = -1, \Delta S = 1$	
$B_c^+ \to K^+ B_2^0$	$a_1 f_K F^{B_c \to B_2}(m_K^2) V_{cd} V_{us}^*$
$B_c^+ \to K^0 B_2^+$	$a_2 f_K F^{B_c \to B_2}(m_K^2) V_{cd} V_{us}^*$
$\Delta b = 0, \Delta C = -1, \Delta S = 0$	
$B_c^+ \to K^+ B_{s2}^0$	$a_1 f_K F^{B_c \to B_{s2}}(m_K^2) V_{cs} V_{us}^*$
$B_c^+ \to \pi^+ B_2^0$	$a_1 f_\pi F^{B_c \to B_2}(m_\pi^2) V_{cd} V_{ud}^*$
$B_c^+ \to \pi^0 B_2^+$	$\frac{1}{\sqrt{2}} a_2 f_\pi F^{B_c \to B_2}(m_\pi^2) V_{cd} V_{ud}^*$
$B_c^+ \to \eta B_2^+$	$-\frac{1}{\sqrt{2}} a_2 f_\eta \cos\phi_P F^{B_c \to B_2}(m_\eta^2) V_{cs} V_{us}^*$

NUMERICAL RESULTS

Branching ratios of $B_c \rightarrow PT$ decays for Charm changing decay modes

Decays	Branching ratios
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	
$B_c^+ \rightarrow \pi^+ B_{s2}^0$	3.0×10^{-4}
$B_c^+ \rightarrow \overline{K}^0 B_2^+$	1.0×10^{-5}
$\Delta b = 0, \Delta C = -1, \Delta S = 1$	
$B_c^+ \rightarrow K^+ B_2^0$	1.8×10^{-7}
$B_c^+ \rightarrow K^0 B_2^+$	2.7×10^{-8}
$\Delta b = 0, \Delta C = -1, \Delta S = 0$	
$B_c^+ \rightarrow K^+ B_{s2}^0$	3.7×10^{-7}
$B_c^+ \rightarrow \pi^+ B_2^0$	1.6×10^{-5}
$B_c^+ \rightarrow \pi^0 B_2^+$	1.4×10^{-6}
$B_c^+ \rightarrow \eta B_2^+$	2.0×10^{-7}

Branching ratios of $B_c \to PT$ decays for Bottom changing decay modes

Decays	Branching ratios
$\Delta b = 1,\ \Delta C = 1,\ \Delta S = 0$	
$B_c^- \to \pi^- \chi_{c2}$	2.0×10^{-4}
$B_c^- \to D^0 D_2^-$	4.0×10^{-6}
$\Delta b = 1,\ \Delta C = 0,\ \Delta S = -1$	
$B_c^- \to \pi^0 D_{s2}^-$	6.8×10^{-10}
$B_c^- \to \eta D_{s2}^-$	3.6×10^{-10}
$B_c^- \to K^- \overline{D}_2^0$	1.6×10^{-8}
$B_c^- \to \eta' D_{s2}^-$	3.1×10^{-10}
$B_c^- \to D_s^- \chi_{c2}$	3.2×10^{-4}
$B_c^- \to \eta_c D_{s2}^-$	1.4×10^{-5}
$\Delta b = 1,\ \Delta C = 1,\ \Delta S = -1$	
$B_c^- \to K^- \chi_{c2}$	1.5×10^{-5}
$B_c^- \to D^0 D_{s2}^-$	4.4×10^{-7}
$\Delta b = 1,\ \Delta C = 0,\ \Delta S = 0$	
$B_c^- \to \pi^0 D_2^-$	5.7×10^{-9}
$B_c^- \to \pi^- \overline{D}_2^0$	2.1×10^{-7}
$B_c^- \to \eta D_2^-$	3.0×10^{-9}
$B_c^- \to \eta' D_2^-$	2.6×10^{-9}
$B_c^- \to D^- \chi_{c2}$	1.2×10^{-5}
$B_c^- \to \eta_c D_2^-$	4.5×10^{-7}

$\Delta b = 1,\ \Delta C = -1,\ \Delta S = 0$	
$B_c^- \to D^- \overline{D}_2^0$	3.0×10^{-8}
$B_c^- \to \overline{D}^0 D_2^-$	1.6×10^{-9}
$\Delta b = 1,\ \Delta C = -1,\ \Delta S = -1$	
$B_c^- \to \overline{D}^0 D_{s2}^-$	6.7×10^{-8}
$B_c^- \to D_s^- \overline{D}_2^0$	9.9×10^{-7}

DOMINANT DECAYS

i) Dominant decays for bottom changing decay modes are:

$$B(B_c^- \to D_s^- \chi_{c2}) = 3.2 \times 10^{-4} \quad \text{and}$$

$$B(B_c^- \to \pi^- \chi_{c2}) = 2.0 \times 10^{-4},$$

ii) Branching ratio of dominant decay for charm changing decay mode is:

$$B(B_c^+ \to \pi^+ B_{s2}^0) = 3.0 \times 10^{-4},$$

which seems to be at the reach of future experiments.

Bc MESON EMITTING DECAYS OF PSEUDOSCALAR AND SCALAR MESONS

CALCULATION OF THE FORM FACTORS

The required form factors for $B_c \rightarrow S$, u_+ and u_-, are calculated from the following expressions taken from ISGW II model:

$$u_+ + u_- = -\sqrt{\frac{2}{3}}\frac{m_d}{\beta_{s_c}} F_5^{(u_+ + u_-)},$$

$$u_+ - u_- = \sqrt{\frac{2}{3}}\frac{m_d \tilde{m}_{s_c}}{\tilde{m}_s \beta_{s_c}} F_5^{(u_+ - u_-)},$$

Form factors for $B_c \to S$ (Heavy Scalar Meson) transition at $q^2 = t_m$ in the ISGW II quark model

Modes	Transition	u_+	u_-
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	$B_c \to B_0$	0.104	-1.602
	$B_c \to B_{s0}$	0.120	-2.120
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	$B_c \to D_0$	0.246	-0.536
	$B_c \to D_{s0}$	0.316	-0.695
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	$B_c \to \chi_{c0}$	0.314	-1.054

Form factors for $B_c \to P$ transition at $q^2 = t_m$ in the ISGW II quark model

Modes	Transition	f_+	f_-
$\Delta b = 0, \Delta C = -1, \Delta S = -1$	$B_c \to B_s$	0.969	-0.486
	$B_c \to B$	1.262	-0.733
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	$B_c \to D$	2.484	-2.326
	$B_c^- \to D_s$	1.649	-1.477
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	$B_c \to \eta_c(c\bar{c})$	1.201	-0.935

DECAY AMPLITUDE RELATIONS

Decay amplitudes of $B_c \to PS$ decays for Bottom conserving and Charm changing modes

Decays	Amplitude
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = -1$	
$B_c^+ \to \pi^+ B_{s0}^0$	$a_1 f_\pi F^{B_c \to B_{s0}}(m_{B_c}^2 - m_{B_{s0}}^2) V_{cs} V_{ud}^*$
$B_c^+ \to \overline{K}^0 B_0^+$	$a_2 f_K F^{B_c \to B_0}(m_B^2 - m_{B_0}^2) V_{cs} V_{ud}^*$
$B_c^+ \to B^+ \overline{K}_0^0$	$a_2 f_{K_0} F^{B_c \to B}(m_{B_c}^2 - m_B^2) V_{cs} V_{ud}^*$
$B_c^+ \to B_s^0 a_0^+$	$a_1 f_{a_0} F^{B_c \to B_s}(m_{B_c}^2 - m_{B_s}^2) V_{cs} V_{ud}^*$
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = 0$	
$B_c^+ \to K^+ B_{s0}^0$	$a_1 f_K F^{B_c \to B_{s0}}(m_{B_c}^2 - m_{B_{s0}}^2) V_{cd} V_{ud}^*$
$B_c^+ \to \pi^+ B_0^0$	$-a_1 f_\pi F^{B_c \to B_0}(m_{B_c}^2 - m_{B_0}^2) V_{cd} V_{ud}^*$
$B_c^+ \to \pi^0 B_0^+$	$a_2 f_\pi F^{B_c \to B_0}(m_{B_c}^2 - m_{B_0}^2) V_{cd} V_{ud}^*$
$B_c^+ \to \eta B_0^+$	$\frac{1}{\sqrt{2}} a_2 f_\eta F^{B_c \to B_0}(m_{B_c}^2 - m_{B_0}^2) V_{cd} V_{ud}^*$
$B_c^+ \to B^0 a_0^+$	$-a_1 f_{a_0} F^{B_c \to B}(m_{B_c}^2 - m_B^2) V_{cd} V_{ud}^*$
$B_c^+ \to B_s^0 K_0^+$	$a_1 f_{K_0} F^{B_c \to B_s}(m_{B_c}^2 - m_{B_s}^2) V_{cs} V_{us}^*$
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = 1$	
$B_c^+ \to K^+ B_0^0$	$-a_1 f_K F^{B_c \to B_0}(m_{B_c}^2 - m_{B_0}^2) V_{cd} V_{us}^*$
$B_c^+ \to K^0 B_0^+$	$-a_2 f_K F^{B_c \to B_0}(m_{B_c}^2 - m_{B_0}^2) V_{cd} V_{us}^*$
$B_c^+ \to B^+ K_0^0$	$-a_2 f_{K_0} F^{B_c \to B}(m_{B_c}^2 - m_B^2) V_{cd} V_{us}^*$
$B_c^+ \to B^0 K_0^+$	$-a_1 f_{K_0} F^{B_c \to B}(m_{B_c}^2 - m_B^2) V_{cd} V_{us}^*$

NUMERICAL RESULTS

Branching ratios for $B_c \to PS$ decays for Bottom conserving and Charm changing modes

Decays	Branching ratios
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = -1$	
$B_c^+ \to \pi^+ B_{s0}^0$	1.30×10^{-2}
$B_c^+ \to \bar{K}^0 B_0^+$	7.87×10^{-4}
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = 0$	
$B_c^+ \to K^+ B_{s0}^0$	9.65×10^{-5}
$B_c^+ \to \pi^+ B_0^0$	7.66×10^{-4}
$B_c^+ \to \pi^0 B_0^+$	6.31×10^{-5}
$B_c^+ \to \eta B_0^+$	2.15×10^{-5}
$\Delta b = 0,\ \Delta C = -1,\ \Delta S = 1$	
$B_c^+ \to K^+ B_0^0$	1.36×10^{-5}
$B_c^+ \to K^0 B_0^+$	2.14×10^{-6}

Branching ratios of $B_c \to PS$ decays for Bottom changing modes

Decays	Branching ratios
$\Delta b = 1, \Delta C = 1, \Delta S = 0$	
$B_c^- \to D^- D_0^0$	5.14×10^{-5}
$B_c^- \to \eta_c a_0^-$	1.22×10^{-7}
$B_c^- \to \pi^- \chi_{c0}$	7.99×10^{-2}
$B_c^- \to D^0 D_0^-$	1.52×10^{-3}
$\Delta b = 1, \Delta C = 0, \Delta S = -1$	
$B_c^- \to \overline{D}^0 K_0^-$	6.06×10^{-8}
$B_c^- \to \pi^0 D_{s0}^-$	2.73×10^{-7}
$B_c^- \to \eta D_{s0}^-$	1.69×10^{-7}
$B_c^- \to K^- \overline{D}_0^0$	5.89×10^{-6}
$B_c^- \to \eta' D_{s0}^-$	1.01×10^{-7}
$B_c^- \to D_s^- \chi_{c0}$	15.10×10^{-2}
$B_c^- \to \eta_c D_{s0}^-$	1.20×10^{-2}

$\Delta b = 1, \Delta C = 1, \Delta S = -1$	
$B_c^- \to D_s^- D_0^0$	1.25×10^{-6}
$B_c^- \to \eta_c K_0^-$	9.19×10^{-6}
$B_c^- \to K^- \chi_{c0}$	5.99×10^{-5}
$B_c^- \to D^0 D_{s0}^-$	1.87×10^{-4}
$\Delta b = 1, \Delta C = 0, \Delta S = 0$	
$B_c^- \to \overline{D}^0 a_0^-$	8.10×10^{-10}
$B_c^- \to \pi^0 D_0^-$	2.08×10^{-6}
$B_c^- \to \pi^- \overline{D}_0^0$	7.55×10^{-5}
$B_c^- \to \eta D_0^-$	1.29×10^{-6}
$B_c^- \to \eta' D_0^-$	7.79×10^{-7}
$B_c^- \to D^- \chi_{c0}$	5.19×10^{-5}
$B_c^- \to \eta_c D_0^-$	4.19×10^{-4}

$\Delta b = 1$, ΔC = -1, ΔS = 0	
$B_c^- \to D^- \overline{D}_0^0$	1.24×10^{-5}
$B_c^- \to \overline{D}^0 D_0^-$	1.93×10^{-6}
$\Delta b = 1$, ΔC = -1, ΔS = -1	
$B_c^- \to \overline{D}^0 D_{s0}^-$	5.66×10^{-5}
$B_c^- \to D_s^- \overline{D}_0^0$	3.96×10^{-4}

* $f_{\chi_{c0}} = 0$.

DOMINANT DECAYS

i) For charm changing and bottom conserving is:

$$B(B_c^+ \to \pi^+ B_{s0}^0) = 1.30\times10^{-2}.$$

ii) For bottom changing transitions the dominating decays are:

$$B(B_c^- \to D_s^- \chi_{c0}) = 15.10\times10^{-2},$$
$$B(B_c^- \to \pi^- \chi_{c0}) = 7.99\times10^{-2} \text{ and}$$

$$B(B_c^- \to \eta_c D_{s0}^-) = 1.20\times10^{-2}.$$

The rest of the decay modes remain highly suppressed partly due to the small values of the CKM matrix elements and the small values of the form factors.

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