SU(3) Flavor Symmetry for Weak Hadronic Decays of B_{bc} baryons

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Introduction

Baryons with a heavy b(c)-quark and two c-quarks

↓

Baryons with a heavy b-quark and c-quark

yet to discover

↓ **SU(3) symmetry**

$$B_{bc} = (bcu, bcd, bcs) = (\Xi_{bc}^{+}, \Xi_{bc}^{0}, \Omega_{bc}^{0})$$

↓

Identifying $\mathbf{B_{bc}}$ by dominant weak decays

Weak Decays

Weak Decays of B_{bc}

$$|V_{cb}/V_{cs}|^2 \sim 1.7 \times 10^{-3}$$

c-quark induced

dominant

Cabibbo allowed

$\lambda_{ds} = V_{ud}V_{cs}^*$

Cabibbo suppressed

$\lambda_{dd} = V_{ud}V_{cd}^*$

$\lambda_{ss} = V_{us}V_{cs}^*$

doubly Cabibbo suppressed

$\lambda_{sd} = V_{us}V_{cd}^*$

b-quark induced

$b \to c\bar{c}q$

$\lambda_{cq}^c = V_{cb}V_{cq}^*$

$b \to c\bar{u}q$

$\lambda_{uq}^c = V_{cb}V_{uq}^*$

Note: 1. Two decays to find some different favorable search strategies.

2. b-decay mode has a displaced vertex for subsequent decays traveling 10^3 longer distance before decaying than c-decay ones.

Effective Hamiltonian

c-quark decay

$$H^c_{eff} = \frac{G_F}{\sqrt{2}}\lambda_{q'q}[c_1\underline{(\bar{u}q')}(\bar{q}c) + c_2(\bar{u}_\beta q'_\alpha)(\bar{q}_\alpha c_\beta)]$$

b-quark decay

$$(\bar{q}_1 q_2) = \bar{q}_1\gamma_\mu(1-\gamma_5)q_2$$

$$H^b_{eff} = \frac{G_F}{\sqrt{2}}\lambda^c_{aq}[c_1(\bar{q}a)(\bar{c}b) + c_2(\bar{q}_\beta a_\alpha)(\bar{c}_\alpha b_\beta)]$$

a takes c and u

Nonzero entries

$$H^c_{eff}: H^{31}_2 = \lambda_{ds}, H^{21}_2 = \lambda_{dd}, H^{31}_3 = \lambda_{ss} = -\lambda_{dd}, H^{21}_3 = \lambda_{sd}$$

$$H^b_{eff}(a=u): \quad H^2_1 = \lambda^c_{ud}, H^3_1 = \lambda^c_{us}$$

approximation

$$H^b_{eff}(a=c): \quad H^2 = \lambda^c_{cd}, H^3 = \lambda^c_{cs}$$

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arXiv:2006.15291

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Two Body Decay Modes

Effective Hamiltonians can induce B$_{bc}$ to decay

Two body decays
- **multi body contains unknown resonance**
- **simple calculation and identified final states**

$$H_i^{jk} \qquad H_j^i \qquad H^i$$

$$B_{bc} \to \underline{B^{(\prime)}} + M_b \qquad B_{bc} \to B_{cc} + \underline{M} \qquad B_{bc} \to B_{cc} + M_{\bar{c}}$$

octet(decuplet) **octet**

$$B_{bc} \to \underline{B_b^{(\prime)}} + M \qquad B_{bc} \to B_c^{(\prime)} + \underline{M_c} \qquad B_{bc} \to B_c^{(\prime)} + M_{c\bar{c}}$$

anti-triplet(sextet) **anti-triplet**

Components of baryon and meson

octet baryon

$$B^i_j : (n, p, \Sigma^{\pm,0}, \Xi^{-,0}, \Lambda)$$

decuplet baryon

$$B'_{ijk} : (\Delta^{++,\pm,0}, \Sigma'^{\,\pm,0}, \Xi'^{\,-,0}, \Omega^-)$$

heavy cc baryon

$$B_{cc} : (\Xi^{++}_{cc}, \Xi^{+}_{cc}, \Omega^{+}_{cc})$$

octet pseudoscalar meson

$$M^i_j : (\pi^{\pm,0}, K^{\pm}, K^0, \bar{K}^0, \eta)$$

heavy b meson

$$M_b : (B^-, \bar{B}^0, \bar{B}^0_s)$$

heavy c meson

$$M_c : (D^0, D^+, D^+_s)$$

Components of baryon and meson

heavy b baryon

$$B_b = \begin{pmatrix} 0 & \Lambda_b^0 & \Xi_b^0 \\ -\Lambda_b^0 & 0 & \Xi_b^- \\ -\Xi_b^0 & -\Xi_b^- & 0 \end{pmatrix}$$

$$B_b' = \begin{pmatrix} \Sigma_b^+ & \Sigma_b^0/\sqrt{2} & \Xi_b'^{\,0}/\sqrt{2} \\ \Sigma_b^0/\sqrt{2} & \Sigma_b^- & \Xi_b'^{\,-}/\sqrt{2} \\ \Xi_b'^{\,0}/\sqrt{2} & \Xi_b'^{\,-}/\sqrt{2} & \Omega_b^- \end{pmatrix}$$

heavy c baryon

$$B_c = \begin{pmatrix} 0 & \Lambda_c^+ & \Xi_c^+ \\ -\Lambda_c^+ & 0 & \Xi_c^0 \\ -\Xi_c^+ & -\Xi_c^0 & 0 \end{pmatrix}$$

$$B_c' = \begin{pmatrix} \Sigma_c^{++} & \Sigma_c^+/\sqrt{2} & \Xi_c'^{\,+}/\sqrt{2} \\ \Sigma_c^+/\sqrt{2} & \Sigma_c^0 & \Xi_c'^{\,0}/\sqrt{2} \\ \Xi_c'^{\,+}/\sqrt{2} & \Xi_c'^{\,0}/\sqrt{2} & \Omega_c^0 \end{pmatrix}$$

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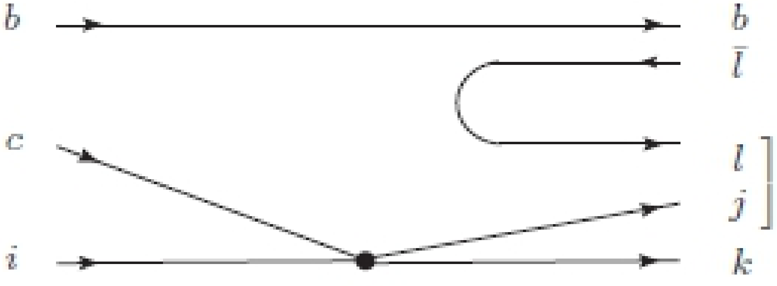
H^i_{jk} induced decays

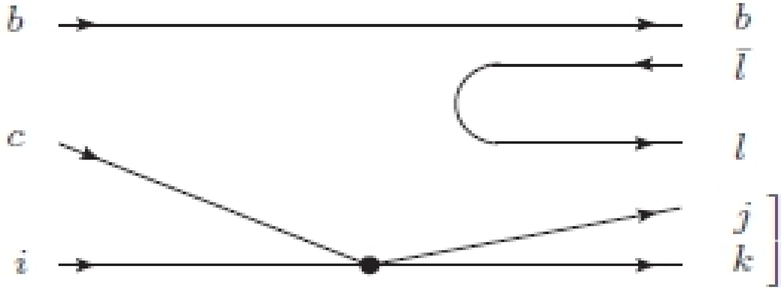
$$B_{bc} \to B + M_b$$

$$\mathcal{M} = d_1 \mathrm{B}^i_{bc} H^{jk}_i \mathrm{B}_{ljk} M^l_b + d_2 \mathrm{B}^i_{bc} H^{jk}_i \mathrm{B}_{jkl} M^l_b + \underline{d' \mathrm{B}^i_{bc} H^{jk}_i \mathrm{B}_{klj} M^l_b}$$

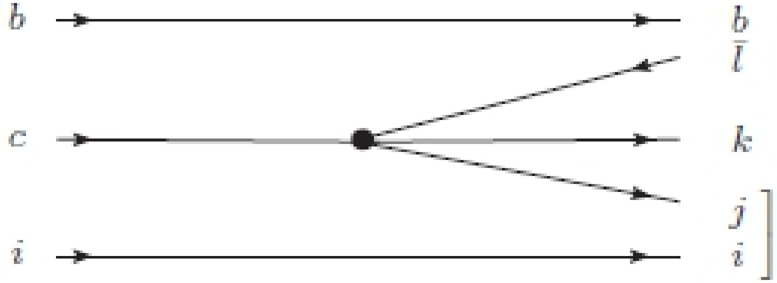
$$+ d_3 \mathrm{B}^i_{bc} H^{jk}_l \mathrm{B}_{ijk} M^l_b + d_4 \mathrm{B}^i_{bc} H^{jk}_l \mathrm{B}_{jki} M^l_b + \underline{d'' \mathrm{B}^i_{bc} H^{jk}_l \mathrm{B}_{kij} M^l_b}$$



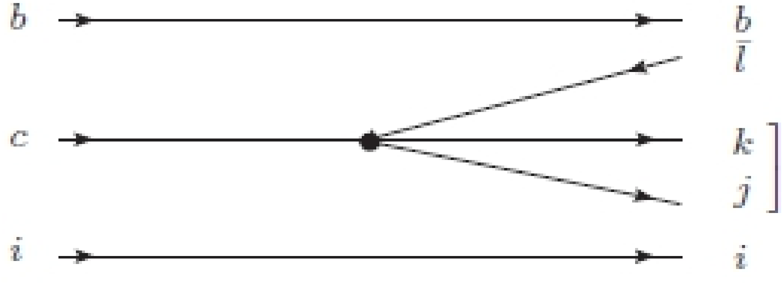
d_1



d_2



d_3

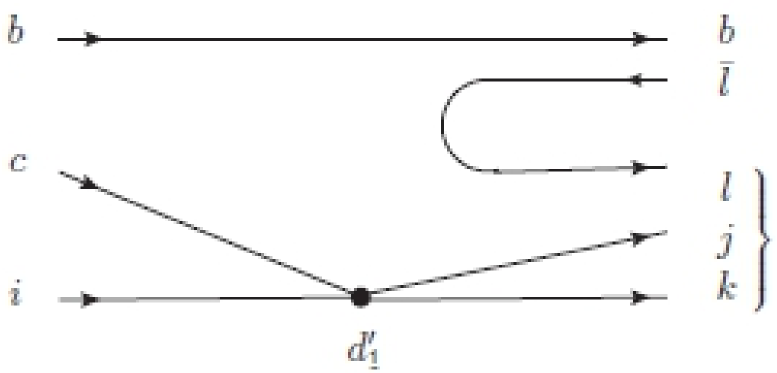


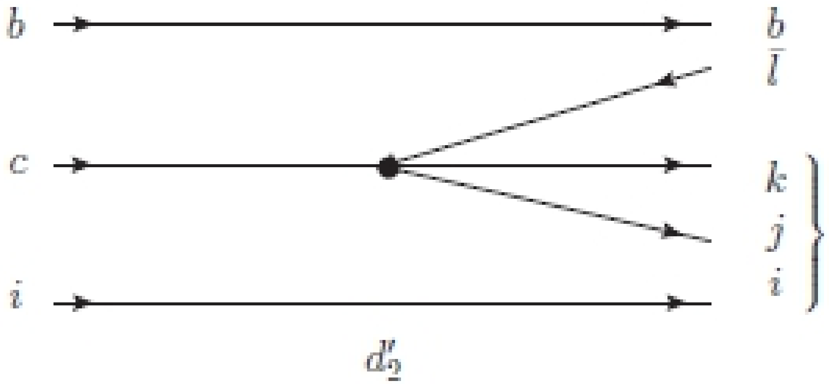
d_4

H^i_{jk} induced decays

$$B_{bc} \to B' + M_b$$

$$\mathcal{M} = d'_1 \mathrm{B}^i_{bc} H^{jk}_i \mathrm{B}'_{ljk} M^l_b + d'_2 \mathrm{B}^i_{bc} H^{jk}_l \mathrm{B}'_{ijk} M^l_b$$





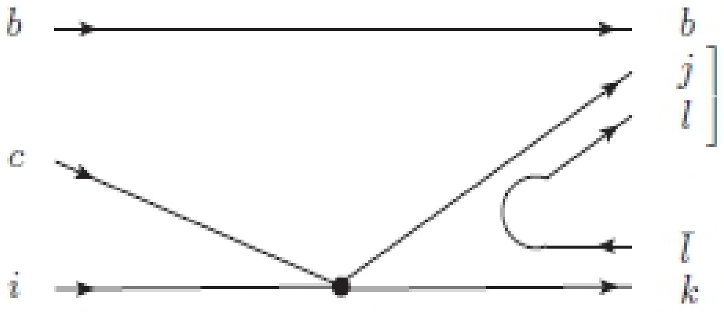
Contract up-down indices in hadron and Hamiltonian

↓

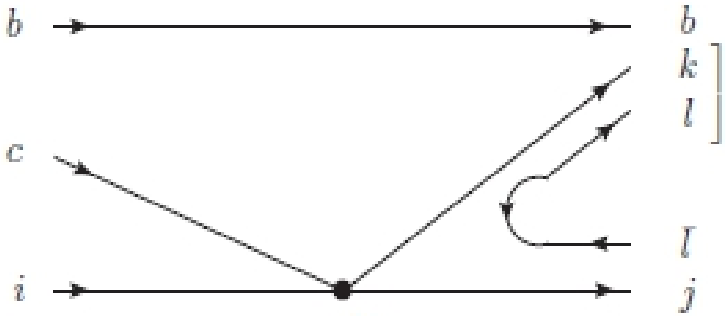
SU(3) singlet

H^i_{jk} induced decays

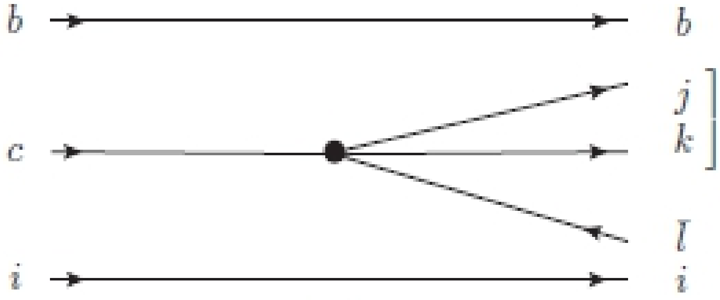
$$B_{bc} \to B_b^{(\prime)} + M$$



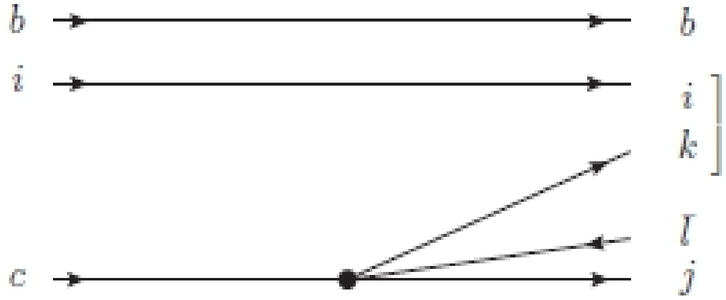
$e_1^{(\prime)}$



$e_2^{(\prime)}$



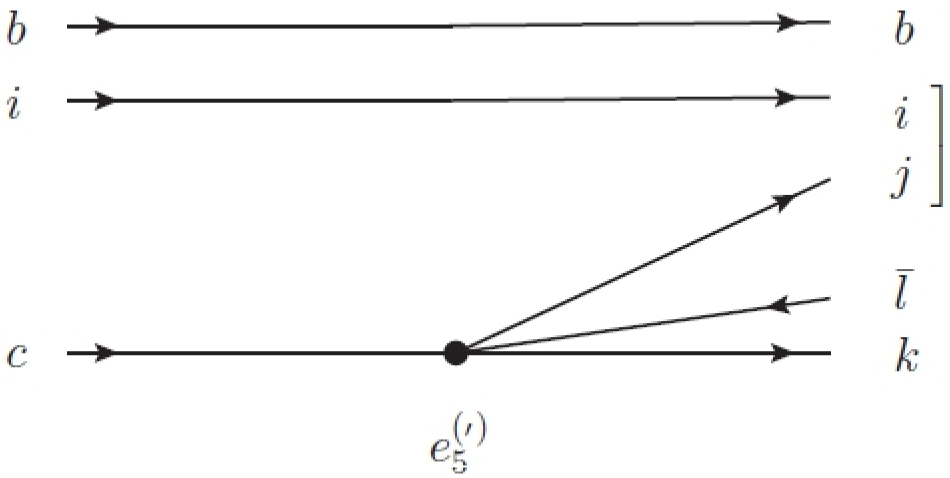
$e_3^{(\prime)}$



$e_4^{(\prime)}$

H^i_{jk} induced decays

$$B_{bc} \to B_b^{(\prime)} + M$$



$e_1 - e_5, e_2 + e_5$

$e_3 - e_5, e_4 + e_5$

$\downarrow$

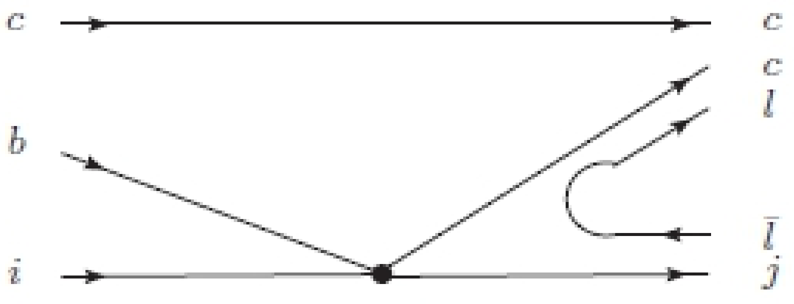
e_5 can be absorbed

$$\mathcal{M}(\mathbf{B}_b) = e_1 \mathbf{B}^i_{bc} H^{jk}_i \mathbf{B}_{b\,jl} M^l_k + e_2 \mathbf{B}^i_{bc} H^{jk}_i \mathbf{B}_{b\,kl} M^l_j + e_3 \mathbf{B}^i_{bc} H^{jk}_l \mathbf{B}_{b\,jk} M^l_i$$
$$+ e_4 \mathbf{B}^i_{bc} H^{jk}_l \mathbf{B}_{b\,ik} M^l_j + \underline{e_5 \mathbf{B}^i_{bc} H^{jk}_l \mathbf{B}_{b\,ij} M^l_k}$$

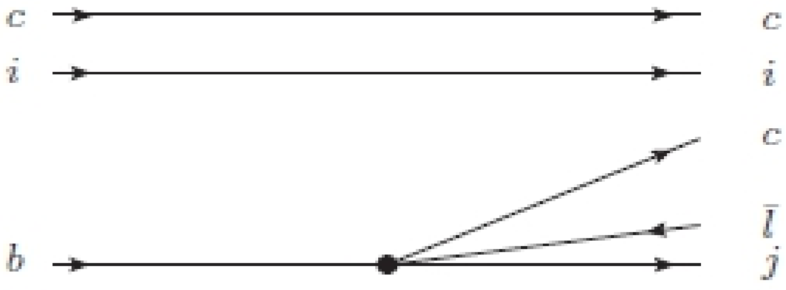
$$\mathcal{M}(\mathbf{B}'_b) = e'_1 \mathbf{B}^i_{bc} H^{jk}_i \mathbf{B}'_{b\,jl} M^l_k + e'_2 \mathbf{B}^i_{bc} H^{jk}_i \mathbf{B}'_{b\,kl} M^l_j + e'_3 \mathbf{B}^i_{bc} H^{jk}_l \mathbf{B}'_{b\,jk} M^l_i$$
$$+ e'_4 \mathbf{B}^i_{bc} H^{jk}_l \mathbf{B}'_{b\,ik} M^l_j + e'_5 \mathbf{B}^i_{bc} H^{jk}_l \mathbf{B}'_{b\,ij} M^l_k$$

$\mathrm{H}^{i}{}_{j}$ induced decays

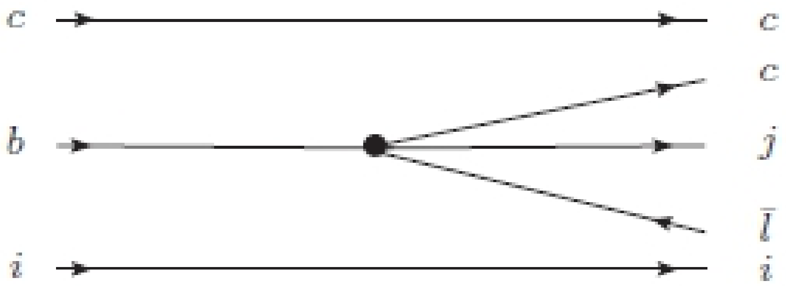
$$B_{bc} \to B_{cc} + M$$



a_1



a_2

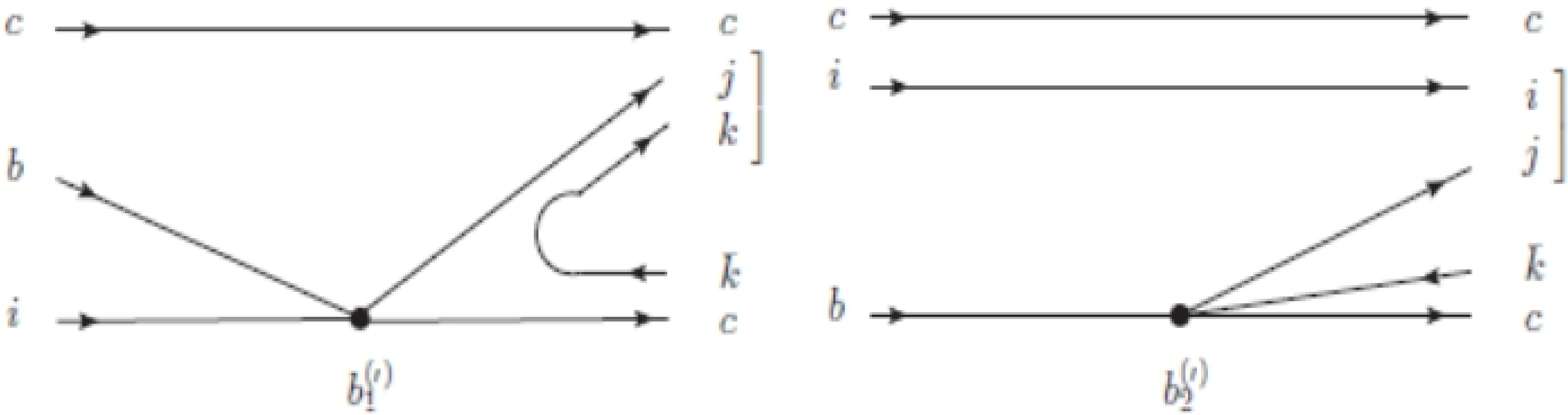


a_3

$$\mathcal{M} = a_1 \mathbf{B}^{i}_{bc} H^{j}_{i} \mathbf{B}_{cc\,l} M^{l}_{j} + a_2 \mathbf{B}^{i}_{bc} H^{j}_{l} \mathbf{B}_{cc\,i} M^{l}_{j} + a_3 \mathbf{B}^{i}_{bc} H^{j}_{l} \mathbf{B}_{cc\,j} M^{l}_{i}$$

H^i_j induced decays

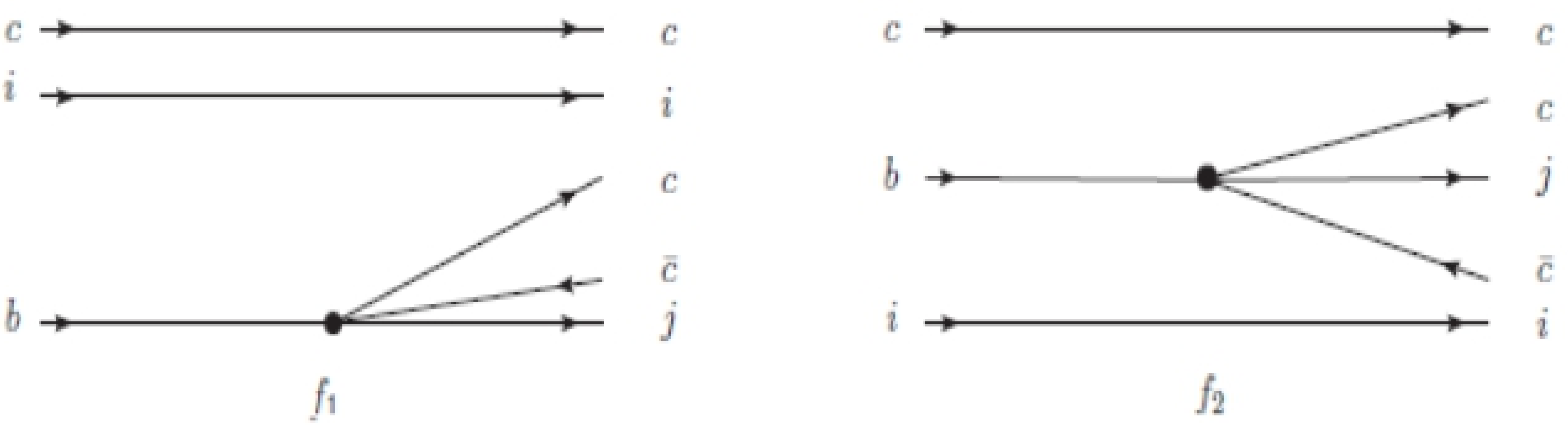
$$B_{bc} \to B_c^{(\prime)} + M_c$$



$$\mathcal{M} = b_1^{(\prime)} \mathbf{B}^i_{bc} H^j_i \mathbf{B}_{c\,jk} M^k_c + b_2^{(\prime)} \mathbf{B}^i_{bc} H^j_k \mathbf{B}_{c\,ji} M^k_c$$

Hⁱ induced decays

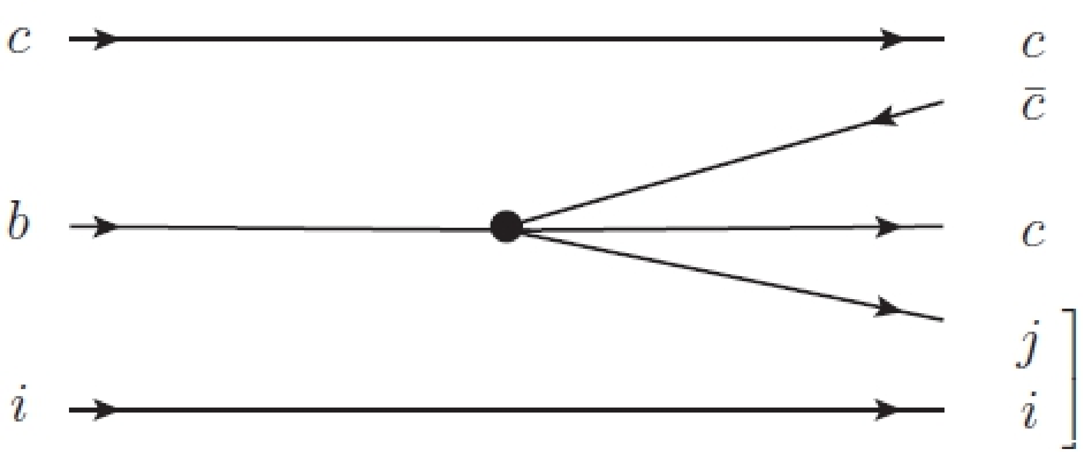
$$B_{bc} \to B_{cc} + M_{\bar{c}}$$



$$\mathcal{M} = f_1 \mathbf{B}^i_{bc} H^j \mathbf{B}_{cc\,i} M_{\bar{c}\,j} + f_2 \mathbf{B}^i_{bc} H^j \mathbf{B}_{cc\,j} M_{\bar{c}\,i}$$

H^{i} induced decays

$$B_{bc} \to B_c^{(\prime)} + M_{c\bar{c}}$$



$$\mathcal{M} = g_{c\bar{c}}^{(\prime)} \mathbf{B}^{i}_{bc} H^{j} \mathbf{B}^{(\prime)}_{c\,ij} M_{c\bar{c}}$$

$$\downarrow$$

Identifying dominant decay modes and relations for experiment

Contents

Experimental Analysis

Experimental discovery $\left\{ \begin{array}{l} \textbf{1. Large branching ratios} \\ \textbf{2. Easily analyzed final states} \end{array} \right.$

Take c induced decays as example

$B_{bc} \to B^{(\prime)} + M_b$ **advantage >** $B_{bc} \to B_b^{(\prime)} + M$

$\downarrow$

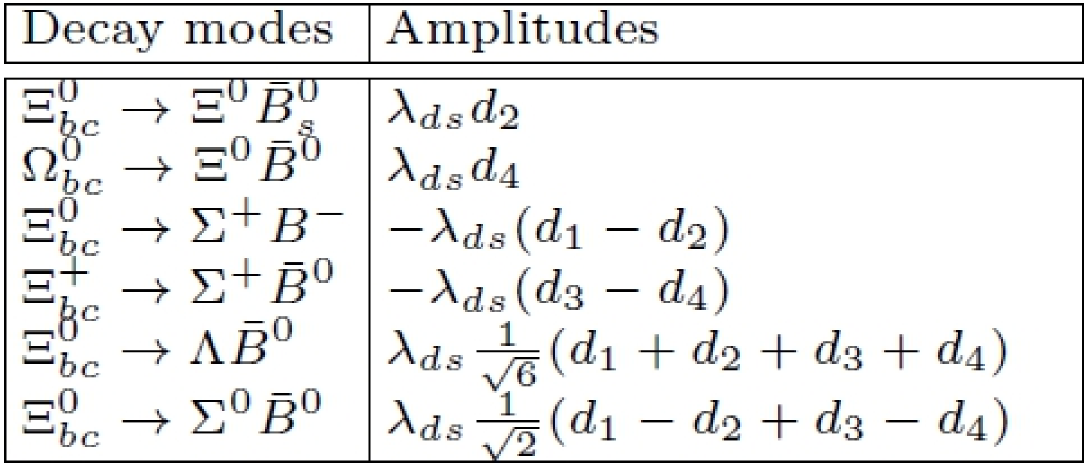
not well known

Optimizing the identification of B_b' to discover B_{bc}

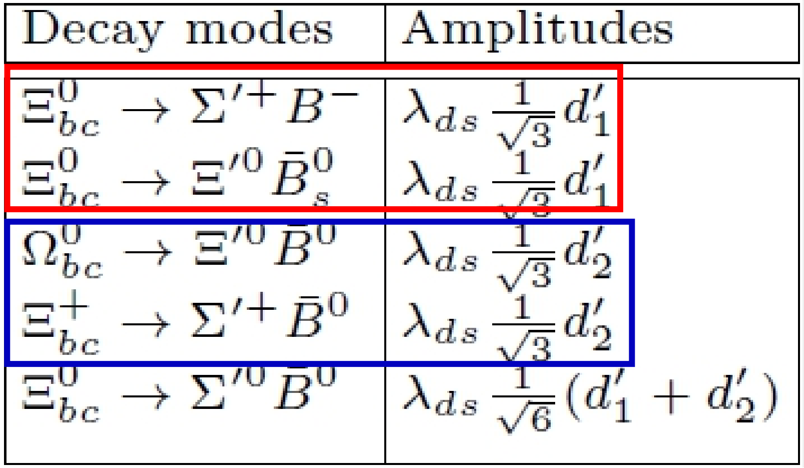
b induced decays in backup

Cabibbo allowed decays

$$B_{bc} \to B^{(\prime)} + M_b$$



Decay modes	Amplitudes
$\Xi_{bc}^0 \to \Xi^0 \bar{B}_s^0$	$\lambda_{ds} d_2$
$\Omega_{bc}^0 \to \Xi^0 \bar{B}^0$	$\lambda_{ds} d_4$
$\Xi_{bc}^0 \to \Sigma^+ B^-$	$-\lambda_{ds}(d_1 - d_2)$
$\Xi_{bc}^+ \to \Sigma^+ \bar{B}^0$	$-\lambda_{ds}(d_3 - d_4)$
$\Xi_{bc}^0 \to \Lambda \bar{B}^0$	$\lambda_{ds} \frac{1}{\sqrt{6}}(d_1 + d_2 + d_3 + d_4)$
$\Xi_{bc}^0 \to \Sigma^0 \bar{B}^0$	$\lambda_{ds} \frac{1}{\sqrt{2}}(d_1 - d_2 + d_3 - d_4)$



Decay modes	Amplitudes
$\Xi_{bc}^0 \to \Sigma'^+ B^-$	$\lambda_{ds} \frac{1}{\sqrt{3}} d'_1$
$\Xi_{bc}^0 \to \Xi'^0 \bar{B}_s^0$	$\lambda_{ds} \frac{1}{\sqrt{3}} d'_1$
$\Omega_{bc}^0 \to \Xi'^0 \bar{B}^0$	$\lambda_{ds} \frac{1}{\sqrt{3}} d'_2$
$\Xi_{bc}^+ \to \Sigma'^+ \bar{B}^0$	$\lambda_{ds} \frac{1}{\sqrt{3}} d'_2$
$\Xi_{bc}^0 \to \Sigma'^0 \bar{B}^0$	$\lambda_{ds} \frac{1}{\sqrt{6}}(d'_1 + d'_2)$

Triangle relation

$$\mathcal{M}(\Xi_{bc}^0 \to \Sigma'^+ B^-) = \mathcal{M}(\Xi_{bc}^0 \to \Xi'^0 \bar{B}_s^0) \qquad \mathcal{M}(\Omega_{bc}^0 \to \Xi'^0 \bar{B}^0) = \mathcal{M}(\Xi_{bc}^+ \to \Sigma'^+ \bar{B}^0)$$

$$\mathcal{M}(\Xi_{bc}^0 \to \Sigma'^+ B^-) + \mathcal{M}(\Xi_{bc}^+ \to \Sigma'^+ \bar{B}^0) = \sqrt{2}\mathcal{M}(\Xi_{bc}^0 \to \Sigma'^0 \bar{B}^0)$$

Cabibbo allowed decays

$$B_{bc} \to B_b^{(\prime)} + M$$

Decay modes	Amplitudes
$\Xi_{bc}^0 \to \Xi_b^- \pi^+$	$-\lambda_{ds} e_1$
$\Xi_{bc}^+ \to \Xi_b^0 \pi^+$	$-\lambda_{ds} e_3$
$\Xi_{bc}^0 \to \Xi_b^0 \pi^0$	$\lambda_{ds} \frac{-1}{\sqrt{2}}(e_1 - e_3)$
$\Omega_{bc}^0 \to \Xi_b^0 \bar{K}^0$	$-\lambda_{ds}(e_3 + e_4)$
$\Xi_{bc}^0 \to \Xi_b^0 \eta$	$\lambda_{ds} \frac{-1}{\sqrt{6}}(e_1 + 2e_2 + e_3)$
$\Xi_{bc}^0 \to \Lambda_b \bar{K}^0$	$\lambda_{ds}(e_2 - e_4)$

Decay modes	Amplitudes
$\Xi_{bc}^0 \to \Omega_b^- K^+$	$\lambda_{ds} e'_1$
$\Xi_{bc}^0 \to \Sigma_b^+ K^-$	$\lambda_{ds} e'_2$
$\Xi_{bc}^0 \to \Xi_b'^0 \eta$	$\lambda_{ds} \frac{1}{2\sqrt{3}}(e'_1 - 2e'_2 + e'_3)$
$\Xi_{bc}^+ \to \Sigma_b^+ \bar{K}^0$	$\lambda_{ds} e'_4$
$\Omega_{bc}^0 \to \Omega_b^- \pi^+$	$\lambda_{ds} e'_5$
$\Xi_{bc}^0 \to \Xi_b'^0 \pi^0$	$\lambda_{ds} \frac{1}{2}(e'_1 - e'_3)$
$\Xi_{bc}^+ \to \Xi_b'^0 \pi^+$	$\lambda_{ds} \frac{1}{\sqrt{2}}(e'_3 + e'_5)$
$\Xi_{bc}^0 \to \Xi_b'^- \pi^+$	$\lambda_{ds} \frac{1}{\sqrt{2}}(e'_1 + e'_5)$
$\Xi_{bc}^0 \to \Sigma_b^0 \bar{K}^0$	$\lambda_{ds} \frac{1}{\sqrt{2}}(e'_2 + e'_4)$
$\Omega_{bc}^0 \to \Xi_b'^0 \bar{K}^0$	$\lambda_{ds} \frac{1}{\sqrt{2}}(e'_3 + e'_4)$

$$M(\Xi_{bc}^+ \to \Xi_b^0 \pi^+) - M(\Xi_{bc}^0 \to \Xi_b^- \pi^+) = -\sqrt{2} M(\Xi_{bc}^0 \to \Xi_b^0 \pi^0)$$

$$M(\Xi_{bc}^+ \to \Sigma_b^+ \bar{K}^0) + M(\Xi_{bc}^0 \to \Sigma_b^+ K^-) = \sqrt{2} M(\Xi_{bc}^0 \to \Sigma_b^0 \bar{K}^0)$$

Cabibbo allowed decays

The above give all Cabibbo allowed decay modes

Cabibbo allowed decay modes $\left\{ \begin{array}{l} \textbf{dominant} \\ \textbf{most likely to-be-discoverd} \end{array} \right.$

$$\Gamma(\Xi_{Qc} \to \Xi_Q \pi^+) = \frac{G_F^2}{32\pi} (\lambda_{ds} a_1 f_\pi)^2 m^3_{\Xi_{Qc}} (1 - m^2_{\Xi_Q} / m^2_{\Xi_{Qc}})^3 \underline{(f_1^2 + g_1^2)}$$

$$\langle \Xi_Q | (\bar{s} c) | \Xi_{Qc} \rangle \simeq \bar{u}_{\Xi_Q} (f_1 \gamma_\mu - g_1 \gamma_\mu \gamma_5) u_{\Xi_{Qc}}$$

$$\downarrow$$

$$\frac{\Gamma(\Xi^+_{bc} \to \Xi^0_b + \pi^+)}{\Gamma(\Xi^{++}_{cc} \to \Xi^+_c + \pi^+)} \approx 1.4 \quad \longrightarrow \quad \mathcal{B}(\Xi^+_{bc} \to \Xi^0_b + \pi^+) \sim 10^{-2}$$

Phys.Rev.D101,034034(2020)

Analysis for discovery in LHC

$$\Xi_{bc}^0 \to \Lambda + \underline{\bar{B}^0}$$

b-meson

$$\mathcal{B}(\Xi_{bc}^0 \to \Lambda + \bar{B}^0) \sim 10^{-2}$$

$$\mathcal{B}(\Lambda \to p\pi^-) \simeq 64\%$$

$$\mathcal{B}(\bar{B}^0 \to D^+\pi^-) \simeq 2.5 \times 10^{-3}$$

$$\mathcal{B}(D^+ \to \pi^+\pi^0) \simeq 1.2 \times 10^{-3}$$

10^8 events

$$\Xi_{bc}^+ \to \underline{\Xi_b^0} + \pi^+$$

b-baryon

$$\mathcal{B}(\Xi_{bc}^+ \to \Xi_b^0 + \pi^+) \sim 10^{-2}$$

$$\mathcal{B}(\Xi_b^0 \to \Xi^0 J/\Psi) = 10^{-4} - 10^{-3}$$

$$\mathcal{B}(\Xi^0 \to \Lambda\pi^0, \Lambda \to p\pi^-) \simeq 64\%$$

$$\mathcal{B}(J/\Psi \to \mu^+\mu^- + e^+e^-) \simeq 12\%$$

$10^{6\text{-}7}$ events

PDG; Phys.Rev.D92,114013(2015)

Conclusions

1. B_{bc} can exist and yet await to be discovered.

2. We study two-body weak decays using SU(3) flavor symmetry to provide the promising modes for discovery.

3. We analyze b/c induced two decay modes and get several relations among BR to test SU(3) flavor symmetry.

4. We urge experimental colleagues to search for B_{bc} using two-body weak decays.

Thanks!

Backup

Masses for heavy baryons and mesons

bc baryon $m_{\Xi_{bc}} = 7.0 \text{ Gev}, \;\; m_{\Omega_{bc}} = 7.3 \text{ Gev}$

Int.J.Mod.Phys.A23,2817(2008)

cc baryon $m_{\Xi_{cc}^{++}} = m_{\Xi_{cc}^{+}} = 3.6212 \text{ Gev}$

b baryon $m_{\Lambda_b^0} = 5.6196 \text{ Gev}, \;\; m_{\Sigma_b^+} = 5.81056 \text{ Gev}, \;\; m_{\Sigma_b^-} = 5.81564 \text{ Gev},$

$m_{\Xi_b^0} = 5.7919 \text{ Gev}, \;\; m_{\Xi_b^-} = 5.7970 \text{ Gev}, \;\; m_{\Omega_b^-} = 6.0461 \text{ Gev},$

c baryon $m_{\Lambda_c^+} = 2.28246 \text{ Gev}, \;\; m_{\Sigma_c^{++}} = 2.45397 \text{ Gev}, \;\; m_{\Sigma_c^+} = 2.4529 \text{ Gev}, \;\; m_{\Sigma_c^0} = 2.45375 \text{ Gev},$

$m_{\Xi_c^+} = 2.46794 \text{ Gev}, \;\; m_{\Xi_c^0} = 2.47090 \text{ Gev}, \;\; m_{\Omega_c^0} = 2.6952 \text{ Gev},$

b meson $m_{B^\pm} = 5.27934 \text{ Gev}, \;\; m_{B^0} = 5.27965 \text{ Gev}, \;\; m_{B_s^0} = 5.36688 \text{ Gev},$

c meson $m_{D^\pm} = 1.86965 \text{ Gev}, \;\; m_{D^0} = 1.86483 \text{ Gev}, \;\; m_{D_s^\pm} = 1.96834 \text{ Gev},$

PDG

Example $\Xi_{Qc} \to \Xi_Q \pi^+$

Momentum of CM

$$P_c = \frac{1}{2m_{B_{bc}}}[m^4_{B_{bc}}(1-\frac{(m_B+m_m)^2}{m^2_{B_{bc}}})(1-\frac{(m_B-m_m)^2}{m^2_{B_{bc}}})]^{1/2} \sim \frac{1}{2}m_{B_{bc}}(1-m^2_B/m^2_{B_{bc}})$$

Factorize $A^2 \sim m^2_{B_{bc}}(1-\frac{m_B}{m_{B_{bc}}})^2 f_1^2$ $\quad B^2 \sim m^2_{B_{bc}}(1+\frac{m_B}{m_{B_{bc}}})^2 g_1^2$ $\quad \langle \pi^+|(\bar{u}d)|0\rangle = i f_\pi q^\mu$

$$\mathcal{M}(\Xi_{Qc} \to \Xi_Q \pi^+) = i\lambda_{ds} a_1 f_\pi q^\mu \langle \Xi_Q|(\bar{s}c)|\Xi_{Qc}\rangle \simeq i\lambda_{ds} a_1 f_\pi q^\mu \bar{u}_{\Xi_Q}(f_1\gamma_\mu - g_1\gamma_\mu\gamma_5)u_{\Xi_{Qc}}$$

Amplitude

$$|M|^2 = A^2(m_{B_{bc}}+m_B+m_m)(m_{B_{bc}}+m_B-m_m) + B^2(m_{B_{bc}}-m_B-m_m)(m_{B_{bc}}-m_B-m_m)$$

$$\sim m^2_{B_{bc}}(1+\frac{m_B}{m_{B_{bc}}})^2 A^2 + m^2_{B_{bc}}(1-\frac{m_B}{m_{B_{bc}}})^2 B^2 \sim m^4_{B_{bc}}(1-\frac{m^2_B}{m^2_{B_{bc}}})^2(f_1^2+g_1^2)$$

Decay width

$$\Gamma(\Xi_{Qc} \to \Xi_Q \pi^+) = \frac{G_F^2}{2}\frac{P_c}{8\pi m^2_{B_{bc}}}|M|^2 = \frac{G_F^2}{32\pi}(\lambda_{ds} a_1 f_\pi)^2 m^3_{\Xi_{Qc}}(1-m^2_{\Xi_Q}/m^2_{\Xi_{Qc}})^3(f_1^2+g_1^2)$$

b induced decay $|V_{cb}/V_{cs}| \simeq 0.04$

$B_{bc} \to B_{cc} + M$

Decay modes	Amplitudes
$\Xi_{bc}^{+} \to \Omega_{cc}^{+} K^{0}$	$\lambda_{ud}^{c} a_1$
$\Xi_{bc}^{+} \to \Xi_{cc}^{+} \bar{K}^{0}$	$\lambda_{us}^{c} a_1$
$\Omega_{bc}^{0} \to \Omega_{cc}^{+} \pi^{-}$	$\lambda_{ud}^{c} a_2$
$\Xi_{bc}^{0} \to \Xi_{cc}^{+} K^{-}$	$\lambda_{us}^{c} a_2$
$\Omega_{bc}^{0} \to \Xi_{cc}^{+} K^{-}$	$\lambda_{ud}^{c} a_3$
$\Xi_{bc}^{0} \to \Omega_{cc}^{+} \pi^{-}$	$\lambda_{us}^{c} a_3$
$\Xi_{bc}^{+} \to \Omega_{cc}^{+} \pi^{0}$	$\lambda_{us}^{c} \frac{1}{\sqrt{2}} a_3$
10 10^{-4} $\boxed{\Xi_{bc}^{+} \to \Xi_{cc}^{++} \pi^{-}}$	$\lambda_{ud}^{c} (a_1 + a_2)$
$\Xi_{bc}^{+} \to \Xi_{cc}^{++} K^{-}$	$\lambda_{us}^{c} (a_1 + a_2)$
$\Xi_{bc}^{0} \to \Xi_{cc}^{+} \pi^{-}$	$\lambda_{ud}^{c} (a_2 + a_3)$
$\Omega_{bc}^{0} \to \Omega_{cc}^{+} K^{-}$	$\lambda_{us}^{c} (a_2 + a_3)$
$\Xi_{bc}^{+} \to \Xi_{cc}^{+} \eta$	$\lambda_{ud}^{c} \frac{1}{\sqrt{6}} (a_1 + a_3)$
$\Xi_{bc}^{+} \to \Xi_{cc}^{+} \pi^{0}$	$\lambda_{ud}^{c} \frac{-1}{\sqrt{2}} (a_1 - a_3)$
$\Xi_{bc}^{+} \to \Omega_{cc}^{+} \eta$	$\lambda_{us}^{c} \frac{-1}{\sqrt{6}} (2a_1 - a_3)$

$\mathcal{B}(\Xi_{bc}^{+} \to \Sigma_c^{+} D^0) \sim 10^{-6}$

$B_{bc} \to B_c^{(\prime)} + M_c$

Decay modes	Amplitudes
$\Xi_{bc}^{+} \to \Xi_{c}^{0} D_s^{+}$	$\lambda_{ud}^{c} b_1$
$\Xi_{bc}^{+} \to \Xi_{c}^{0} D^{+}$	$-\lambda_{us}^{c} b_1$
$\Omega_{bc}^{0} \to \Xi_{c}^{0} D^{0}$	$\lambda_{ud}^{c} b_2$
$\Xi_{bc}^{0} \to \Xi_{c}^{0} D^{0}$	$-\lambda_{us}^{c} b_2$
$\Xi_{bc}^{+} \to \Lambda_{c}^{+} D^{0}$	$-\lambda_{ud}^{c} (b_1 + b_2)$
$\Xi_{bc}^{+} \to \Xi_{c}^{+} D^{0}$	$-\lambda_{us}^{c} (b_1 + b_2)$

$\Xi_{bc}^{+} \to \Sigma_{c}^{0} D^{+}$	$\lambda_{ud}^{c} b_1'$
$\Xi_{bc}^{+} \to \Omega_{c}^{0} D_s^{+}$	$\lambda_{us}^{c} b_1'$
$\Xi_{bc}^{+} \to \Xi_{c}^{\prime 0} D_s^{+}$	$\lambda_{ud}^{c} \frac{1}{\sqrt{2}} b_1'$
$\Xi_{bc}^{+} \to \Xi_{c}^{\prime 0} D^{+}$	$\lambda_{us}^{c} \frac{1}{\sqrt{2}} b_1'$
$\Xi_{bc}^{0} \to \Sigma_{c}^{0} D^{0}$	$\lambda_{ud}^{c} b_2'$
$\Omega_{bc}^{0} \to \Xi_{c}^{\prime 0} D^{0}$	$\lambda_{ud}^{c} \frac{1}{\sqrt{2}} b_2'$
$\Omega_{bc}^{0} \to \Omega_{c}^{0} D^{0}$	$\lambda_{us}^{c} b_2'$
$\Xi_{bc}^{0} \to \Xi_{c}^{\prime 0} D^{0}$	$\lambda_{us}^{c} \frac{1}{\sqrt{2}} b_2'$
$\boxed{\Xi_{bc}^{+} \to \Sigma_{c}^{+} D^{0}}$	$\lambda_{ud}^{c} \frac{1}{\sqrt{2}} (b_1' + b_2')$ 10^{-6}
$\Xi_{bc}^{+} \to \Xi_{c}^{\prime +} D^{0}$	$\lambda_{us}^{c} \frac{1}{\sqrt{2}} (b_1' + b_2')$

b induced decay

$$B_{bc} \to B_{cc} + M_{\bar{c}}$$

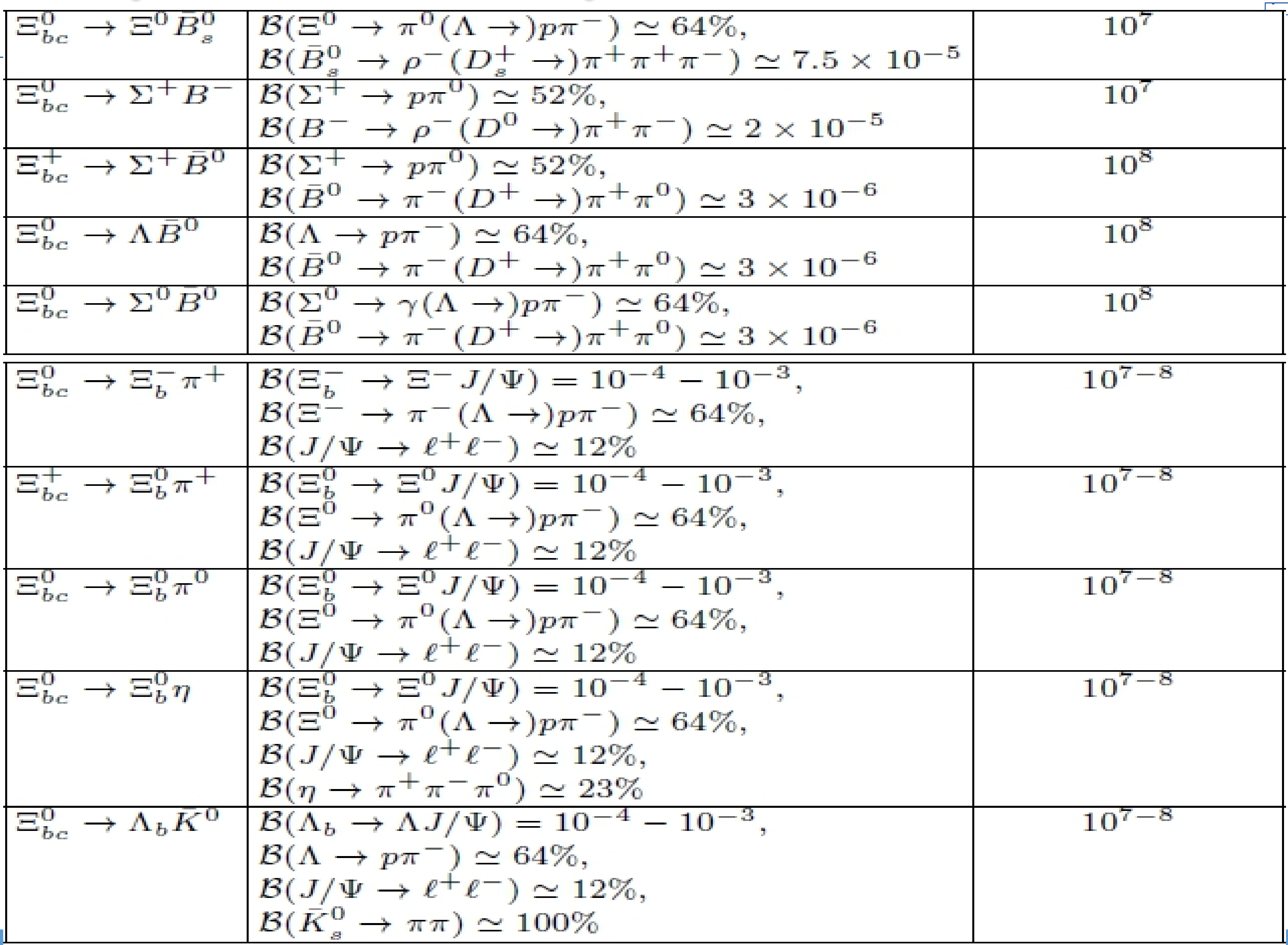
10^{-3}

Decay modes	Amplitudes
$\Xi_{bc}^{+} \to \Xi_{cc}^{++} D^{-}$	$\lambda^{c}_{cd} f_1$
$\Omega_{bc}^{0} \to \Omega_{cc}^{+} D^{-}$	$\lambda^{c}_{cd} f_1$
$\Xi_{bc}^{+} \to \Xi_{cc}^{++} D_s^{-}$	$\lambda^{c}_{cs} f_1$
$\Xi_{bc}^{0} \to \Xi_{cc}^{+} D_s^{-}$	$\lambda^{c}_{cs} f_1$
$\Xi_{bc}^{+} \to \Xi_{c}^{+} \bar{D}^{0}$	$\lambda^{c}_{cd} f_2$
$\Omega_{bc}^{0} \to \Xi_{cc}^{+} D_s^{-}$	$\lambda^{c}_{cd} f_2$
$\Xi_{bc}^{+} \to \Omega_{cc}^{+} \bar{D}^{0}$	$\lambda^{c}_{cs} f_2$
$\Xi_{bc}^{0} \to \Omega_{cc}^{+} D^{-}$	$\lambda^{c}_{cs} f_2$
$\Xi_{bc}^{0} \to \Xi_{cc}^{+} D^{-}$	$\lambda^{c}_{cd}(f_1 + f_2)$
$\Omega_{bc}^{0} \to \Omega_{cc}^{+} D_s^{-}$	$\lambda^{c}_{cs}(f_1 + f_2)$

$$B_{bc} \to B_{c}^{(\prime)} + M_{c\bar{c}}$$

Decay modes	Amplitudes
$\Xi_{bc}^{+} \to \Lambda_{c}^{+} M_{c\bar{c}}$	$\lambda^{c}_{cd} g_{c\bar{c}}$
$\Omega_{bc}^{0} \to \Xi_{c}^{0} M_{c\bar{c}}$	$-\lambda^{c}_{cd} g_{c\bar{c}}$
$\Xi_{bc}^{+} \to \Xi_{c}^{+} M_{c\bar{c}}$	$\lambda^{c}_{cs} g_{c\bar{c}}$ 10^{-5}
$\Xi_{bc}^{0} \to \Xi_{c}^{0} M_{c\bar{c}}$	$\lambda^{c}_{cs} g_{c\bar{c}}$
$\Xi_{bc}^{+} \to \Sigma_{c}^{+} M_{c\bar{c}}$	$\lambda^{c}_{cd} \frac{1}{\sqrt{2}} g^{\prime}_{c\bar{c}}$
$\Xi_{bc}^{0} \to \Sigma_{c}^{0} M_{c\bar{c}}$	$\lambda^{c}_{cd} g^{\prime}_{c\bar{c}}$
$\Omega_{bc}^{0} \to \Xi_{c}^{\prime 0} M_{c\bar{c}}$	$\lambda^{c}_{cd} \frac{1}{\sqrt{2}} g^{\prime}_{c\bar{c}}$
$\Xi_{bc}^{+} \to \Xi_{c}^{\prime +} M_{c\bar{c}}$	$\lambda^{c}_{cs} \frac{1}{\sqrt{2}} g^{\prime}_{c\bar{c}}$
$\Xi_{bc}^{0} \to \Xi_{c}^{\prime 0} M_{c\bar{c}}$	$\lambda^{c}_{cs} \frac{1}{\sqrt{2}} g^{\prime}_{c\bar{c}}$
$\Omega_{bc}^{0} \to \Omega_{c}^{0} M_{c\bar{c}}$	$\lambda^{c}_{cs} g^{\prime}_{c\bar{c}}$

Analysis for discovery in LHC



$\Xi_{bc}^0 \to \Xi^0 \bar{B}_s^0$	$\mathcal{B}(\Xi^0 \to \pi^0(\Lambda \to)p\pi^-) \simeq 64\%$, $\mathcal{B}(\bar{B}_s^0 \to \rho^-(D_s^+ \to)\pi^+\pi^+\pi^-) \simeq 7.5 \times 10^{-5}$	10^7
$\Xi_{bc}^0 \to \Sigma^+ B^-$	$\mathcal{B}(\Sigma^+ \to p\pi^0) \simeq 52\%$, $\mathcal{B}(B^- \to \rho^-(D^0 \to)\pi^+\pi^-) \simeq 2 \times 10^{-5}$	10^7
$\Xi_{bc}^+ \to \Sigma^+ \bar{B}^0$	$\mathcal{B}(\Sigma^+ \to p\pi^0) \simeq 52\%$, $\mathcal{B}(\bar{B}^0 \to \pi^-(D^+ \to)\pi^+\pi^0) \simeq 3 \times 10^{-6}$	10^8
$\Xi_{bc}^0 \to \Lambda \bar{B}^0$	$\mathcal{B}(\Lambda \to p\pi^-) \simeq 64\%$, $\mathcal{B}(\bar{B}^0 \to \pi^-(D^+ \to)\pi^+\pi^0) \simeq 3 \times 10^{-6}$	10^8
$\Xi_{bc}^0 \to \Sigma^0 \bar{B}^0$	$\mathcal{B}(\Sigma^0 \to \gamma(\Lambda \to)p\pi^-) \simeq 64\%$, $\mathcal{B}(\bar{B}^0 \to \pi^-(D^+ \to)\pi^+\pi^0) \simeq 3 \times 10^{-6}$	10^8
$\Xi_{bc}^0 \to \Xi_b^- \pi^+$	$\mathcal{B}(\Xi_b^- \to \Xi^- J/\Psi) = 10^{-4} - 10^{-3}$, $\mathcal{B}(\Xi^- \to \pi^-(\Lambda \to)p\pi^-) \simeq 64\%$, $\mathcal{B}(J/\Psi \to \ell^+\ell^-) \simeq 12\%$	10^{7-8}
$\Xi_{bc}^+ \to \Xi_b^0 \pi^+$	$\mathcal{B}(\Xi_b^0 \to \Xi^0 J/\Psi) = 10^{-4} - 10^{-3}$, $\mathcal{B}(\Xi^0 \to \pi^0(\Lambda \to)p\pi^-) \simeq 64\%$, $\mathcal{B}(J/\Psi \to \ell^+\ell^-) \simeq 12\%$	10^{7-8}
$\Xi_{bc}^0 \to \Xi_b^0 \pi^0$	$\mathcal{B}(\Xi_b^0 \to \Xi^0 J/\Psi) = 10^{-4} - 10^{-3}$, $\mathcal{B}(\Xi^0 \to \pi^0(\Lambda \to)p\pi^-) \simeq 64\%$, $\mathcal{B}(J/\Psi \to \ell^+\ell^-) \simeq 12\%$	10^{7-8}
$\Xi_{bc}^0 \to \Xi_b^0 \eta$	$\mathcal{B}(\Xi_b^0 \to \Xi^0 J/\Psi) = 10^{-4} - 10^{-3}$, $\mathcal{B}(\Xi^0 \to \pi^0(\Lambda \to)p\pi^-) \simeq 64\%$, $\mathcal{B}(J/\Psi \to \ell^+\ell^-) \simeq 12\%$, $\mathcal{B}(\eta \to \pi^+\pi^-\pi^0) \simeq 23\%$	10^{7-8}
$\Xi_{bc}^0 \to \Lambda_b K^0$	$\mathcal{B}(\Lambda_b \to \Lambda J/\Psi) = 10^{-4} - 10^{-3}$, $\mathcal{B}(\Lambda \to p\pi^-) \simeq 64\%$, $\mathcal{B}(J/\Psi \to \ell^+\ell^-) \simeq 12\%$, $\mathcal{B}(\bar{K}_s^0 \to \pi\pi) \simeq 100\%$	10^{7-8}