Higher twist corrections to doubly-charmed baryonic B decays

2025.10.25-27，北京， HFCPV-2025

汇报人：邹芝田

合作者：周锐，李营

烟台大学
YANTAI UNIVERSITY

Outline

01 Motivation

Why baryonic B decays ?

- In 2022, when consider contributions of high-twist LCDAs, they are consistent with Lattice QCD.

	Lattice/exp	PQCD(2009)	PQCD(2022)
$f_1^{\Lambda_b \to p}(0)$	0.22 ± 0.08	0.002 ± 0.001	0.27 ± 0.12

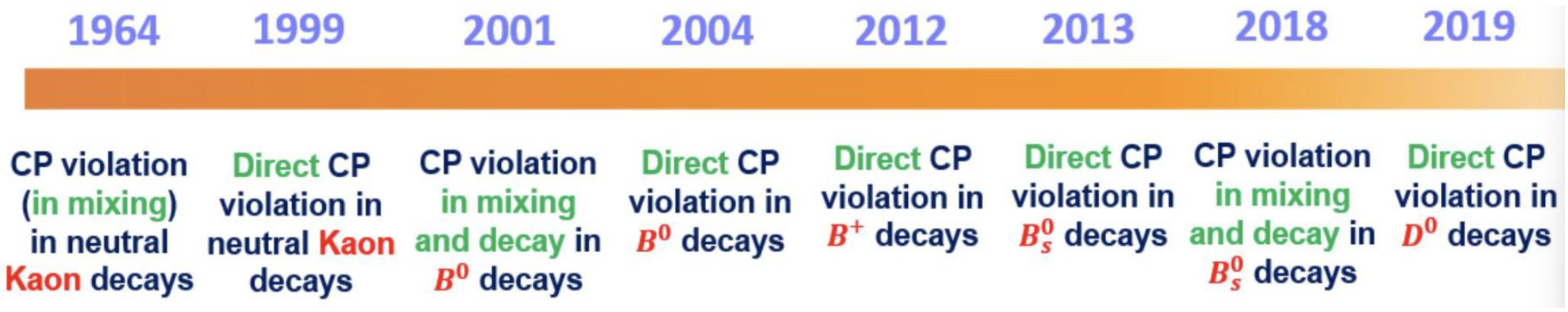
	twist-3	twist-4	twist-5	twist-6	total
exponential					
twist-2	0.0007	-0.00007	-0.0005	-0.000003	0.0001
twist-3^{+-}	-0.0001	0.002	0.0004	-0.000004	0.002
twist-3^{-+}	-0.0002	0.0060	0.000004	0.00007	0.006
twist-4	0.01	0.00009	0.25	0.0000007	0.26
total	0.01	0.008	0.25	0.00007	$0.27 \pm 0.09 \pm 0.07$

More tests in $\Lambda_b \to \Lambda_c \pi, \Lambda_c K$ …… ?

$\Xi_b \to \Xi_c l^- \bar{\nu}_l$ $\Lambda_b \to \Lambda_c l^- \bar{\nu}_l$ …… ?

baryonic B decays ?

- CPV is an intriguing topic of heavy flavor physics.



$\Lambda_b^0 \to pK^-\pi^+\pi^-$ $\mathcal{A}_{CP} = (2.45 \pm 0.46 \pm 0.10)\%$ LHCb:Nature 643 (2025) 8074, 1223-1228

- Maybe, the baryonic B decay is another excellent platform for searching for large CP violation
  - Not only direct CPV but also mixing induced CPV.
  - The final baryons (at least two) with half-integer spin : more plentiful CPV observations.
  - First evidence (3.5σ)for CPV in $B \to p\bar{p}K(\boldsymbol{\pi})$ decays. LHCb: PRL 113, 141801 (2014)

New phenomena in baryonic B decays:

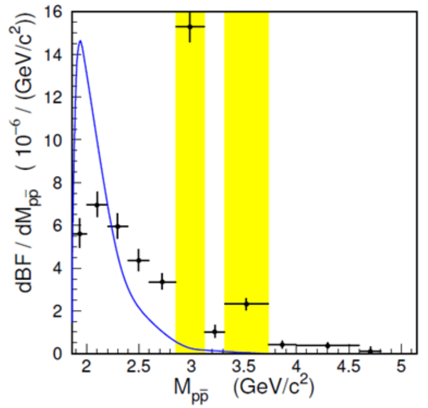
Threshold enhancement

Belle observed threshold enhancement effect at $m(p\bar{p}) = m(p) + m(\bar{p})$

in three-body $p\bar{p}K_{+}$ final state

Recent work describe the baryon-antibaryon enhancements via:

Gluonic and fragmentation mechanisms
Pole models
Intermediate X(1835) baryonium bound state



(a) $B^+ \to p\bar{p}K^+$ (Wei, 2008b)

Multiplicity effects and hierarchy of branching ratios

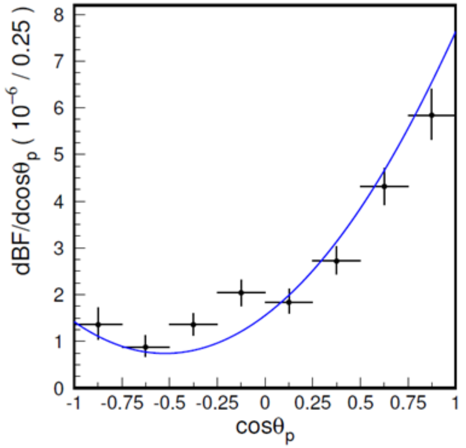
$$\mathcal{B}(\overline{B}^0 \to \Lambda_c^+\overline{p}\pi^+\pi^-) \gg \mathcal{B}(\overline{B}^0 \to \Lambda_c^+\overline{p}\pi^0) \gg \mathcal{B}(\overline{B}^0 \to \Lambda_c^+\overline{p}),$$

$$\mathcal{B}(B^- \to \overline{\Lambda}_c^- \Xi_c^0)(\sim 10^{-3}) \gg \mathcal{B}(\bar{B}^0 \to \bar{p}\Lambda_c^+)(\sim 10^{-5}) \gg \mathcal{B}(\bar{B}^0 \to \bar{p}p)(\sim 10^{-8}),$$

Angular correlation puzzle

$$\mathcal{A}_{\rm FB}(B^- \longrightarrow p\bar{p}\pi^-, p\bar{p}K^-) = (-40.9 \pm 3.4, 49.5 \pm 1.4)\%$$

indicate that one of the dibaryons favors to move collinearly with the meson.



(a) $B^+ \to p\bar{p}K^+$ (Wei, 2008b)

For more about the status of baryonic B decays refer to the review articles by Cheng or Hsiao

Jun feng Sun et al.

Reinvestigating $B \rightarrow PP$ and PV decays by including contributions from ϕ_{B2} with the perturbative QCD approach

Phys.Rev.D 103 (2021) 5, 056006

Chin.Phys.C 46 (2022) 8, 083103

$\bar{B}^0 \to \pi^+\pi^-$	PDG	5.12 ± 0.19
	$\phi_{B1} + \phi_{B2}$	$5.52^{+0.34+0.37+0.47}_{-0.32-0.36-0.43}$
	ϕ_{B1}	$3.81^{+0.25+0.31+0.23}_{-0.23-0.30-0.20}$
$B^- \to \pi^-\bar{K}^0$	PDG	23.7 ± 0.8
	$\phi_{B1} + \phi_{B2}$	$24.12^{+1.73+3.69+2.50}_{-1.60-3.32-2.36}$
	ϕ_{B1}	$17.89^{+1.36+2.97+1.30}_{-1.26-2.65-1.24}$
$\mathcal{A}_{CP}(\bar{B}^0 \to \pi^+K^-)$	PDG	-8.3 ± 0.4
	$\phi_{B1} + \phi_{B2}$	$-7.33^{+0.29+0.41+1.98}_{-0.30-0.44-2.04}$
	ϕ_{B1}	$-8.14^{+0.33+0.49+2.38}_{-0.34-0.54-2.54}$

In this work we firstly investigate the $B/B_s \rightarrow \Xi_c(\Lambda_c)\overline{\Lambda}_c$ decays with in PQCD approach involving the high twist LCDAs of baryons and the subleading contributions from B wave functions.

02

baryonic B decays in PQCD approach

Theoretical progresses since 1990:

- QCD sum rule, Chernyak and Zhitnitsky (1990);
- Pole model, Jarfi et al. (1990) , Cheng and Yang (2002);
- Diquark model, Ball and Dosch (1991), Chang and Hou(2002);
- $3P_0$ model, Cheng et al. , (2006,2009);
- PQCD, He, Li ,Li, and Wang(2006);
- Topological Diagrammatic Approach, Chua (2014,2015,2022);
- Bag model+SU3, Geng, Liu, and Jin (2022);
- $3P0$ model and chiral selection rule , Geng, Liu, and Jin (2023);
- SU(3) flavor symmetry, Hsiao(2023);
- Final state interactions, Geng, Liu, Jin, and Yu (2024,2025).

The PQCD approach has achieved great success in the two-body B meson decays;

Significant progress has also been made in the weak decays of the heavy baryons;

Hsiang-Nan Li, (1993), Sudakov suppression and the proton form factors;
H.H.Shih, S.C.Lee, Hsiang-Nan Li, (1998), The $\Lambda b \to pl\nu$ decay in PQCD;
H.H.Shih, S.C.Lee, Hsiang-Nan Li, (1999), Applicability of PQCD to $\Lambda b \to \Lambda c$ decays
C.H.Chou, H.H.Shih, S.C.Lee, Hsiang-Nan Li, (2002), $\Lambda b \to \Lambda J/\psi$ decay in PQCD;
P.Guo, H.W.K, Yu-Ming Wang, et.al. (2007), Diquarks and semi-leptonic decay of Λb in the hybrid scheme;
X. G. He, T. Li, X. Q. Li, and Y. M. Wang,(2006), PQCD calculation for $\Lambda b \to \Lambda \gamma$ in the standard model
Cai-Dian Lv, Yu-Ming Wang, Hao Zou, (2009), $\Lambda b \to p\pi, pK$ decays in PQCD.

$\Lambda_b \to p, p\mathbf{h}$, JJH, YL, HNL, YLS, ZJX, FSY, 2022-2025;
$\Lambda_b \to \Lambda$, LY,JJH, QC, FSY, 2025;
$\Lambda_b \longrightarrow \Lambda_c\pi(K), \Lambda(J/\psi, \phi, \eta, \eta'), \Sigma(\phi, J/\psi)$,
$\Xi_b \longrightarrow \Xi_c$, $\Lambda_b \longrightarrow \Lambda_c$, ZR,ZZT,YL,2022-2025.

- ✓ Establishing CPV in b-Baryon Decay. [Han,Yu,Li,LI,Wang,Xiao,Yu,2024, PRL134, 221801 (2025)]
- ✓ Internal W-emission diagrams provide abundant sources of strong phase required for direct CPV.
- ✓ Many asymmetries in the angular distribution can be evaluated reliably in PQCD.

However, baryonic B decays are more challenging for PQCD approach;

1) More complex dynamics

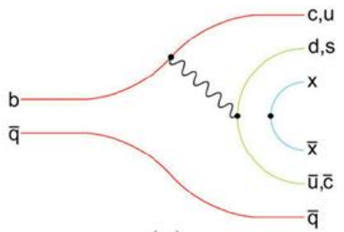
Baryons are made of three quarks, one more quark requires one more gluon.

2) Baryon LCDAs are not well determined

A primary source of theoretical uncertainties

3) Factorization is also different from before

internal W-emission is not necessarily color suppressed

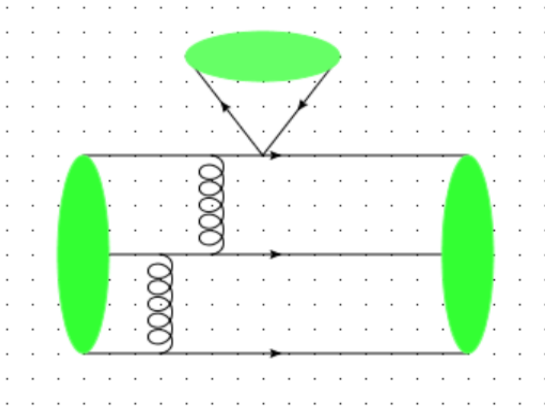


(a)

PQCD CALCULATIONS

- The decay amplitudes are decomposed into the convolution of hard scattering kernels with the hadronic LCDAs

$$M \propto \psi_{\mathrm{B}} \otimes H \otimes \psi_{\overline{B_c}} \otimes \psi_{B_c}$$



- The hard amplitude involves eight external on shell quarks, four of which correspond to the four-fermion operators and four of which are the spectator quarks in the final states.

- The hard kernels start at α_s^2 in the PQCD approach.

- Hadronic LCDAs are the necessary inputs in PQCD calculations.

Distribution amplitudes of B meson

$$\int_0^1 \phi_B^{\pm}(y)dy = \frac{f_B}{2\sqrt{2N_c}}$$

$$\Phi_B = -\frac{i}{\sqrt{2N_c}}(\not{q} + M)\gamma_5 \left(\phi_B^- + \frac{\not{n}_+}{\sqrt{2}}(\phi_B^- - \phi_B^+)\right)$$

$\phi_B = \phi_B^-$ leading, $\overline{\phi_B} = \phi_B^- - \phi_B^+$ subleading

Distribution amplitudes of charmed baryon

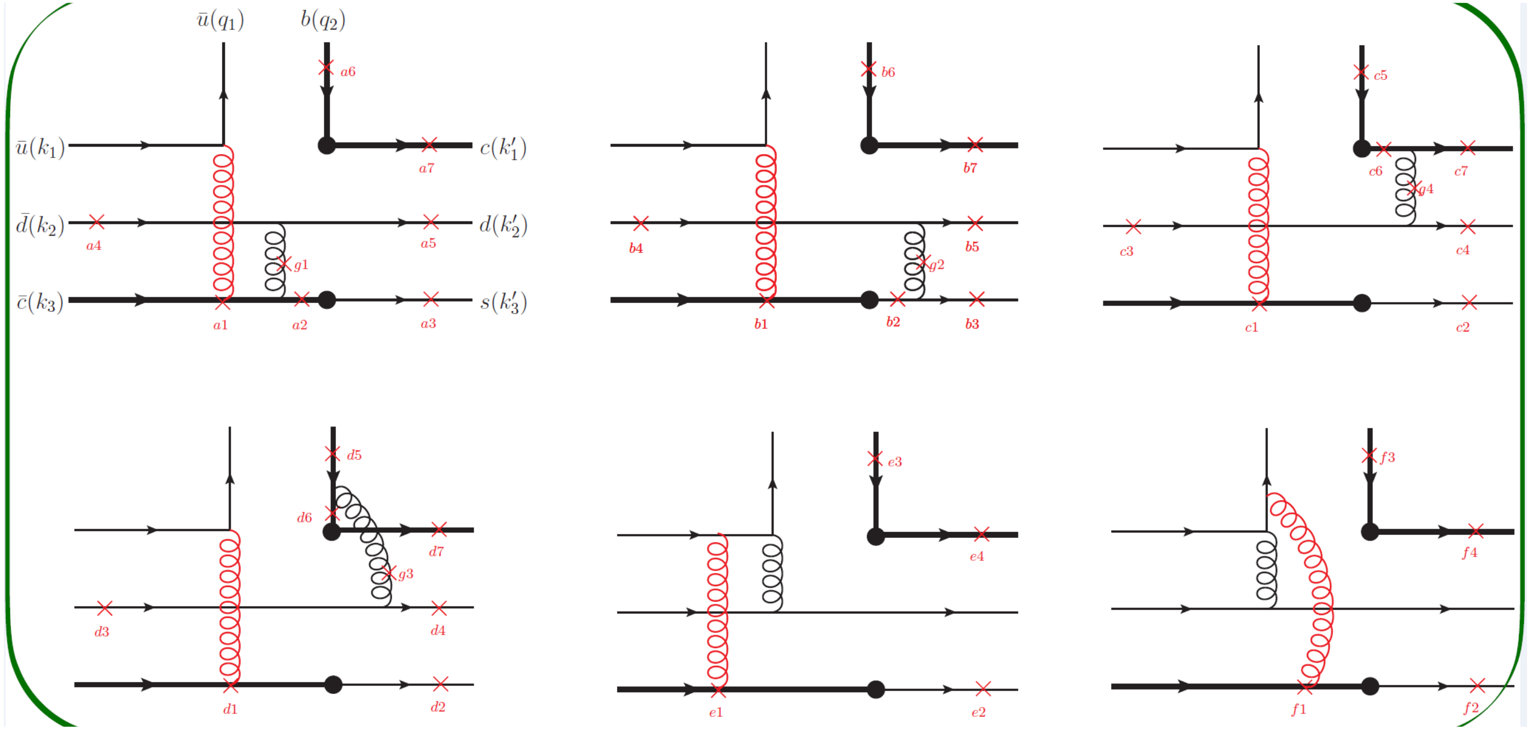
$$\begin{aligned}
\epsilon^{ijk}\langle \mathcal{B}_c|\bar{q}^i_{1\alpha}(t_1)\bar{q}^j_{2\beta}(t_2)\bar{c}^k_{\gamma}(0)|0\rangle &= -\gamma^0_{\alpha\alpha'}\gamma^0_{\beta\beta'}\gamma^0_{\gamma\gamma'}\epsilon^{ijk}\langle 0|q^i_{1\alpha'}(t_1)q^j_{2\beta'}(t_2)c^k_{\gamma'}(0)|\mathcal{B}_c\rangle^\dagger \\
&= \frac{f^{(1)}}{8}\bar{u}_\gamma[(C\gamma_5\not{\bar{n}})_{\beta\alpha}\phi_2(t_1,t_2) + (C\gamma_5\not{n})_{\beta\alpha}\phi_4(t_1,t_2)] \\
&+ \frac{f^{(2)}}{4}\bar{u}_\gamma[(C\gamma_5)_{\beta\alpha}\phi^s_3(t_1,t_2) + \frac{i}{2}(C\gamma_5\sigma_{\bar{n}n})_{\beta\alpha}\phi^a_3(t_1,t_2)].
\end{aligned}$$

$$\begin{aligned}
\epsilon^{ijk}\langle \bar{\mathcal{B}}_c|q^i_{1\alpha}(t_1)q^j_{2\beta}(t_2)c^k_{\gamma}(0)|0\rangle &= -C_{\alpha'\alpha}C_{\beta\beta'}C_{\gamma\gamma'}\epsilon^{ijk}\langle \mathcal{B}_c|\bar{q}^i_{1\alpha'}(t_1)\bar{q}^j_{2\beta'}(t_2)\bar{c}^k_{\gamma'}(0)|0\rangle \\
&= -\frac{f^{(1)}}{8}v_\gamma[(\not{\bar{n}}\gamma_5 C)_{\beta\alpha}\phi_2(t_1,t_2) + (\not{n}\gamma_5 C)_{\beta\alpha}\phi_4(t_1,t_2)] \\
&+ \frac{f^{(2)}}{4}v_\gamma[(\gamma_5 C)_{\beta\alpha}\phi^s_3(t_1,t_2) + \frac{i}{2}(\sigma_{\bar{n}n}\gamma_5 C)_{\beta\alpha}\phi^a_3(t_1,t_2)].
\end{aligned}$$

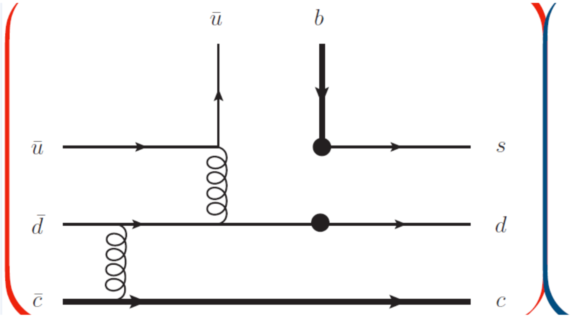
$$
\begin{aligned}
\phi_2(x_2,x_3) &= x_2x_3m^4\sum_{n=0}^{2}\frac{a_n^{(2)}}{{\varepsilon_n^{(2)}}^4}C_n^{3/2}\left(\frac{x_2-x_3}{x_2+x_3}\right)e^{-\frac{(x_2+x_3)m}{\varepsilon_n^{(2)}}},\\
\phi_3^s(x_2,x_3) &= (x_2+x_3)m^3\sum_{n=0}^{2}\frac{a_n^{(3)}}{{\varepsilon_n^{(3)}}^3}C_n^{1/2}\left(\frac{x_2-x_3}{x_2+x_3}\right)e^{-\frac{(x_2+x_3)m}{\varepsilon_n^{(3)}}}\\
\phi_3^a(x_2,x_3) &= (x_2+x_3)m^3\sum_{n=0}^{3}\frac{b_n^{(3)}}{{\eta_n^{(3)}}^3}C_n^{1/2}\left(\frac{x_2-x_3}{x_2+x_3}\right)e^{-\frac{(x_2+x_3)m}{\eta_n^{(3)}}},\\
\phi_4(x_2,x_3) &= m^2\sum_{n=0}^{2}\frac{a_n^{(4)}}{{\varepsilon_n^{(4)}}^2}C_n^{1/2}\left(\frac{x_2-x_3}{x_2+x_3}\right)e^{-\frac{(x_2+x_3)m}{\varepsilon_n^{(4)}}},
\end{aligned}
$$

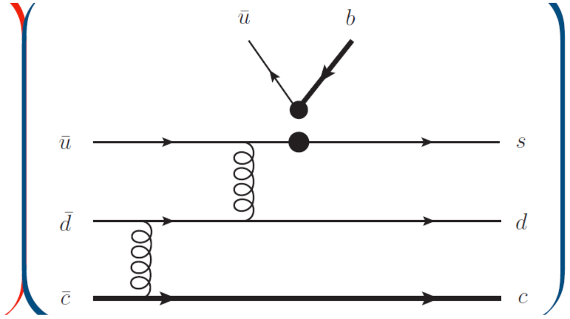
Diagrams (C) for the decay $B^- \longrightarrow \Xi_c^0 \Lambda_c^-$

The internal W-emission diagrams for $b \to c$ transition



The penguin-loop diagrams for $b \to s$ transition

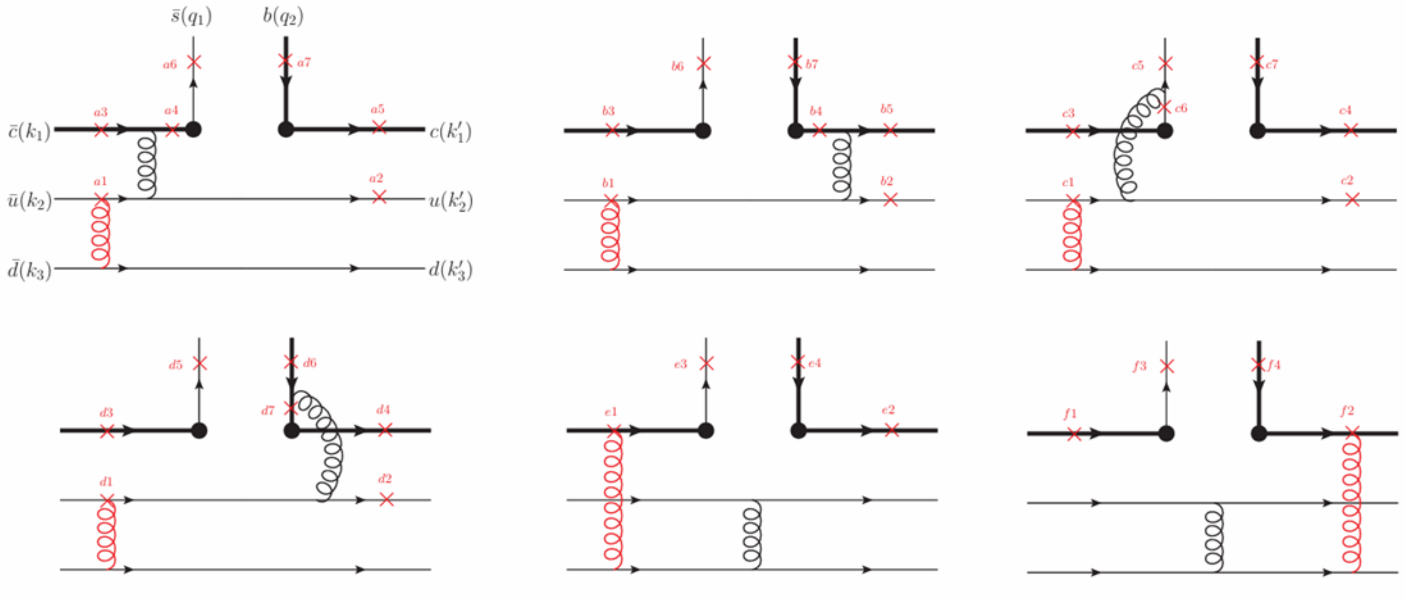




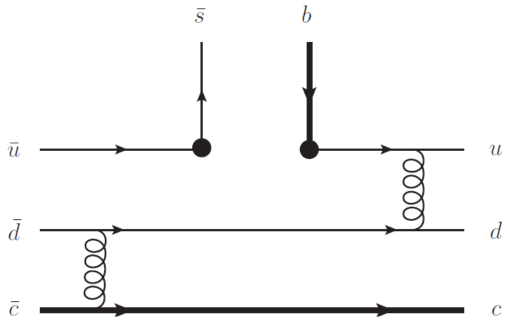
The weak-annihilation diagrams for $b \to u$ transition

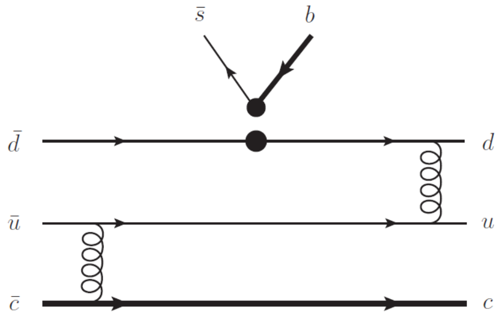
diagrams (E) for the decay $B_s \longrightarrow \Lambda_c^+ \Lambda_c^-$

The internal W–exchange diagrams for $b \rightarrow c$ transition



The internal W-exchange diagrams for $b \rightarrow u$ transition





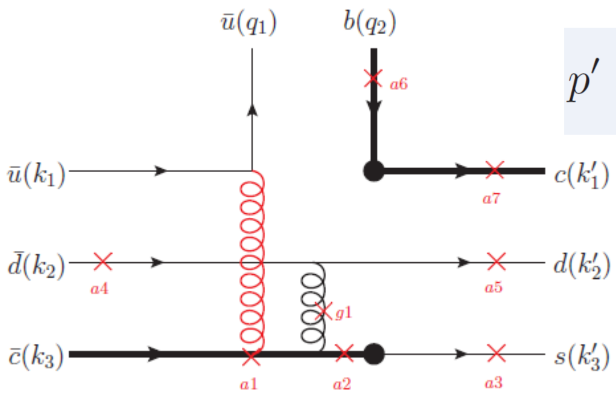
The penguin-annihilation diagrams for $b \rightarrow s$ transition

Kinematics:

- In the rest frame of $\boldsymbol{B}$ in the light-cone coordinates

$$q = \frac{M}{\sqrt{2}}(1, 1, \mathbf{0}_T)$$

The b and c quarks are considered to be massive, while the masses of all light quarks are neglected.



$$p' = \frac{M}{\sqrt{2}}(1 - f^+, 1 - f^-, \mathbf{0}_T)$$

$$f^{\pm} = \frac{1}{2}\left(1 - r^2 + \bar{r}^2 \pm \sqrt{(1 - r^2 + \bar{r}^2)^2 - 4\bar{r}^2}\right)$$

$$p = \frac{M}{\sqrt{2}}(f^+, f^-, \mathbf{0}_T)$$

$$q_1 = \left(0, \frac{M}{\sqrt{2}}y, \mathbf{q}_T\right), \quad q_2 = q - q_1,$$

$$k_1 = \left(\frac{M}{\sqrt{2}}f^+ x_1, 0, \mathbf{k}_{1T}\right), \quad k_2 = \left(\frac{M}{\sqrt{2}}f^+ x_2, 0, \mathbf{k}_{2T}\right), \quad k_3 = p - k_1 - k_2,$$

$$k_1' = p' - k_1' - k_2', \quad k_2' = \left(0, \frac{M}{\sqrt{2}}(1 - f^-)x_2', \mathbf{k}_{2T}'\right), \quad k_3' = \left(0, \frac{M}{\sqrt{2}}(1 - f^-)x_3', \mathbf{k}_{3T}'\right),$$

The conservation laws $\quad x_1 + x_2 + x_3 = 1, \quad \mathbf{k}_{1T} + \mathbf{k}_{2T} + \mathbf{k}_{3T} = 0,$

The decay amplitude can be described

$$M = \langle B_c \overline{B}_c | \mathscr{H}_{eff} | B \rangle = \bar{u}[H_S + H_P \gamma_5] v,$$

S-wave and P -wave invariant amplitudes

$$H_{S/P} = \frac{16 f_{B_c} f_{\overline{B}_c} \pi^2 G_F}{27\sqrt{3}} \sum_{R_{ij}} \int \mathscr{D}x \mathscr{D}b \alpha_s^2(t_{R_{ij}}) e^{-S_B - S_{B_c} - S_{\bar{B}_c}} \Omega_{R_{ij}}(b, b', b_q) \sum_{\sigma=LL,SP} a_{R_{ij}}^{\sigma} H_{R_{ij}}^{\sigma,S/P}(x, x', y),$$

$$\mathscr{D}x = dx_1 dx_2 dx_3 \delta(1 - x_1 - x_2 - x_3) dx_1' dx_2' dx_3' \delta(1 - x_1' - x_2' - x_3') dy,$$

$$\mathscr{D}b = d^2\mathbf{b}_q d^2\mathbf{b}_2 d^2\mathbf{b}_3 d^2\mathbf{b}_2' d^2\mathbf{b}_3' .$$

03

Numerical results and discussions

a): Invariant amplitudes

$\mathcal{M} = \langle \mathcal{B}_c \bar{\mathcal{B}}_c | \mathcal{H}_{eff} | B \rangle = \bar{u}[H_S + H_P \gamma_5] v$

Mode	Type	Amplitude	ϕ_B	$\bar{\phi}_B$	$\phi_B + \bar{\phi}_B$
		H_S	$1.2\times10^{-7}+i8.3\times10^{-9}$	$2.0\times10^{-8}+i3.2\times10^{-8}$	$1.4\times10^{-7}+i4.0\times10^{-8}$
$B^- \to \Xi_c^0 \bar{\Lambda}_c^-$	C	H_P	$-7.8\times10^{-9}+i4.9\times10^{-8}$	$-1.0\times10^{-8}+i1.5\times10^{-8}$	$-1.8\times10^{-8}+i6.4\times10^{-8}$
		$\lvert\mathcal{M}\rvert$(GeV)	3.7×10^{-7}	1.3×10^{-7}	4.8×10^{-7}
		H_S	$4.8\times10^{-9}-i1.1\times10^{-8}$	$5.0\times10^{-9}+i8.6\times10^{-9}$	$9.8\times10^{-9}-i2.4\times10^{-9}$
$\bar{B}_s^0 \to \Lambda_c^+ \bar{\Lambda}_c^-$	E	H_P	$-9.6\times10^{-10}+i1.9\times10^{-8}$	$5.8\times10^{-9}-i3.0\times10^{-9}$	$4.8\times10^{-9}+i1.6\times10^{-8}$
		$\lvert\mathcal{M}\rvert$(GeV)	1.1×10^{-7}	4.5×10^{-8}	9.5×10^{-8}
		H_S	$7.8\times10^{-9}+i6.1\times10^{-9}$	$1.0\times10^{-10}+i1.7\times10^{-9}$	$7.9\times10^{-9}+i7.8\times10^{-9}$
$\bar{B}^0 \to \Lambda_c^+ \bar{\Lambda}_c^-$	$C+E$	H_P	$-2.5\times10^{-9}+i1.5\times10^{-9}$	$-2.8\times10^{-9}+i2.3\times10^{-9}$	$-5.3\times10^{-9}+i3.8\times10^{-9}$
		$\lvert\mathcal{M}\rvert$(GeV)	3.0×10^{-8}	2.0×10^{-8}	4.5×10^{-8}

- The subleading contributions can reach as much as (30–70)% of leading ones.
- The interference patterns for C and E amplitudes differ, with the former being constructive and the latter destructive.
- The subleading correction of B meson LCDA can obviously enhance or reduce the total amplitudes

b)： Magnitude of amplitude |M|(GeV) from various twist combinations of the baryon and antibaryon LCDAs.

	Twist-2	Twist-3	Twist-4
$B^- \to \Xi_c^0 \bar{\Lambda}_c^-$			
Twist-2	3.5×10^{-8}	1.7×10^{-7}	9.6×10^{-8}
Twist-3	1.4×10^{-7}	1.9×10^{-7}	1.4×10^{-7}
Twist-4	1.1×10^{-7}	2.0×10^{-7}	1.6×10^{-7}
$\bar{B}_s^0 \to \Lambda_c^+ \bar{\Lambda}_c^-$			
Twist-2	3.2×10^{-9}	0	1.5×10^{-7}
Twist-3	0	1.5×10^{-7}	0
Twist-4	5.8×10^{-8}	0	1.5×10^{-8}
$\bar{B}^0 \to \Lambda_c^+ \bar{\Lambda}_c^-$			
Twist-2	5.0×10^{-9}	2.6×10^{-8}	4.1×10^{-8}
Twist-3	2.1×10^{-8}	5.0×10^{-8}	1.5×10^{-8}
Twist-4	2.4×10^{-8}	3.0×10^{-8}	2.4×10^{-8}

- Higher-twist baryon LCDAs give dominant contributions to the decay amplitudes due to the endpoint enhancement behaviors caused by the higher-twist baryon LCDAs. [Eur. Phys. J. C 82 (2022) 686]
- The contributions of the twist-4-twist-4 combination are also remarkably larger than that of twist-2-twist-2 but less than the dominant twist-3-twist-3 .

c): Branching ratios

$$\mathcal{B} = \frac{P_c\tau_B}{8\pi M^2}|\mathcal{M}|^2 = \frac{P_c\tau_B}{8\pi M^2}(|H_S|^2Q_+ + |H_P|^2Q_-), \qquad Q_\pm = M^2 - (m \pm \bar{m})^2$$

Mode	Transition	PQCD-I	PQCD-II	SU(3) [28]	Data [17, 21–23]
$B^- \to \Xi_c^0\bar{\Lambda}_c^-$	$b \to sc\bar{c}$	$(5.7^{+2.3+1.9+1.1+0.7}_{-1.6-2.5-0.9-0.6}) \times 10^{-4}$	$(9.5^{+3.0+2.6+1.7+1.2}_{-2.3-3.5-1.4-1.1}) \times 10^{-4}$	$7.8^{+2.3}_{-2.0} \times 10^{-4}$	$(9.5 \pm 2.3) \times 10^{-4}$
$\bar{B}^0 \to \Xi_c^+\bar{\Lambda}_c^-$	$b \to sc\bar{c}$	$(5.3^{+2.1+1.7+1.0+0.6}_{-1.4-2.2-0.8-0.6}) \times 10^{-4}$	$(8.8^{+2.7+2.6+1.5+1.1}_{-2.1-3.1-1.2-1.0}) \times 10^{-4}$	$7.2^{+2.1}_{-1.9} \times 10^{-4}$	$(12 \pm 8) \times 10^{-4}$
$\bar{B}_s^0 \to \Lambda_c^+\bar{\Lambda}_c^-$	$b \to sc\bar{c}$	$(5.0^{+0.7+0.3+1.4+1.4}_{-0.6-0.5-0.9-1.0}) \times 10^{-5}$	$(4.0^{+0.7+0.2+0.9+1.0}_{-0.3-0.1-0.7-0.8}) \times 10^{-5}$	$8.1^{+1.7}_{-1.5} \times 10^{-5}$	$< 9.9 \times 10^{-5}$
$\bar{B}^0 \to \Lambda_c^+\bar{\Lambda}_c^-$	$b \to dc\bar{c}$	$(4.0^{+2.5+1.7+0.7+0.6}_{-1.4-1.3-0.6-0.4}) \times 10^{-6}$	$(8.8^{+4.4+3.5+1.1+1.0}_{-2.8-3.6-0.9-0.6}) \times 10^{-6}$	$2.1^{+1.0}_{-0.8} \times 10^{-5}$	$< 1.6 \times 10^{-5}$

- Theoretical uncertainties: B meson LCDAs, charmed baryon LCDAs, the scale dependence, and the Sudakov resummation.
- The branching ratios suffer large theoretical uncertainties from the nonperturbative LCDAs.
- The PQCD predictions for the first two modes agree with the SU(3) and PDG data, while those of the last two modes reach half of the measured upper limits.

$$\alpha = \frac{|H_+|^2 - |H_-|^2}{|H_+|^2 + |H_-|^2}, \quad \beta = \frac{2Re(H_+H_-^*)}{|H_+|^2 + |H_-|^2}, \quad \gamma = \frac{2Im(H_+H_-^*)}{|H_+|^2 + |H_-|^2} \qquad H_\pm = \frac{1}{\sqrt{2}}(\sqrt{Q_+}H_S \mp \sqrt{Q_-}H_P)$$

Mode	α	β	γ
$B^- \to \Xi_c^0\bar{\Lambda}_c$	$-0.01^{+0.10+0.12+0.05+0.01}_{-0.10-0.29-0.14-0.01}$	$-0.99^{+0.01+0.09+0.00+0.00}_{-0.00-0.01-0.00-0.00}$	$-0.07^{+0.07+0.38+0.04+0.07}_{-0.06-0.13-0.05-0.08}$
$\bar{B}_s^0 \to \Lambda_c^+\bar{\Lambda}_c$	$-0.03^{+0.05+0.03+0.05+0.01}_{-0.04-0.04-0.03-0.00}$	$-0.57^{+0.02+0.02+0.00+0.05}_{-0.03-0.02-0.02-0.05}$	$-0.82^{+0.03+0.02+0.01+0.04}_{-0.01-0.01-0.00-0.03}$
$\bar{B}^0 \to \Lambda_c^+\bar{\Lambda}_c$	$0.17^{+0.08+0.08+0.03+0.02}_{-0.08-0.05-0.18-0.01}$	$-0.97^{+0.04+0.06+0.02+0.02}_{-0.03-0.00-0.02-0.01}$	$-0.15^{+0.17+0.54+0.14+0.09}_{-0.14-0.16-0.11-0.11}$

d): SU(3) breaking through $BR(B \longrightarrow \Lambda_c^+\Lambda_c^-)$ and $BR(B^- \longrightarrow \Xi_c^0\Lambda_c^-)$

- In SU(3) limit and without the **E** amplitude, one has,

$$\mathrm{BR}(B \longrightarrow \Lambda_c^+\Lambda_c^-) \approx (V_{cd}/V_{cs})^2\, \tau_{B^0}/\tau_B\text{-}BR(B^- \longrightarrow \Xi_c^0\Lambda_c^-) = (4.7 \pm 1.1) \times 10^{-5},$$

Far larger than the upper limit of 1.6×10^{-5}

- By considering the **E** and assuming $Arg\left(\frac{E}{C}\right) = \pi$, the SU(3) approach gives

$$\mathrm{BR}(B \longrightarrow \Lambda_c^+\Lambda_c^-) = 2.1^{+1.0}_{-0.8} \times 10^{-5}$$

still exceeds the current experimental limit

- In our calculations, the SU(3) breaking effect is taken into account in the $B \longrightarrow \Lambda_c^+\Lambda_c^-$ decay .

Amplitude	C	E	$\lvert\frac{E}{C}\rvert$	Arg(E/C)
H_S	$1.0 \times 10^{-8} + i7.5 \times 10^{-9}$	$-2.3 \times 10^{-9} + i3.0 \times 10^{-10}$	0.18	2.37
H_P	$-4.1 \times 10^{-9} + i7.4 \times 10^{-9}$	$-1.1 \times 10^{-9} - i3.7 \times 10^{-9}$	0.44	2.34

$\mathrm{BR}(B \longrightarrow \Lambda_c^+\Lambda_c^-) = 4.5 \times 10^{-5}$ without SU(3) breaking and without E

$\mathrm{BR}(B \longrightarrow \Lambda_c^+\Lambda_c^-) = 1.4 \times 10^{-5}$ with SU(3) breaking (m_{B_c}, f_{B_c}, LCDAs)

$\mathrm{BR}(B \longrightarrow \Lambda_c^+\Lambda_c^-) = 8.8 \times 10^{-6}$ with SU(3) breaking and E

- The significant SU(3) breaking effect can also explain why our value is lower than the SU(3) one by a factor 2.

04 Summary

Baryonic two-body B mesons decays provides an excellent ground for studying the QCD of baryonic B decays.

We investigate the two-body doubly-charmed baryonic B decays in PQCD approach including higher twist contributions to the light-cone distribution amplitudes (LCDAs).

The charmed baryon LCDAs are included up to the twist four and the effect of the subleading component of the B meson LCDAs is studied for details.

With the inclusion of these higher-power contributions, the PQCD results on rates can explain the current experimental data well.

SU(3) symmetry breaking is important in the concerned processes and play an essential role in understanding the data.

THANKS

Backup Slides

Baryon		ϵ_0	ϵ_1	ϵ_2	a_1	a_2
Λ_c	ϕ_2	$0.201^{+0.143}_{-0.059}$	0	$0.551^{+\infty}_{-0.356}$	0	$0.391^{+0.279}_{-0.279}$
	ϕ_3^s	$0.232^{+0.047}_{-0.056}$	0	$0.055^{+0.010}_{-0.020}$	0	$-0.161^{+0.108}_{-0.207}$
	ϕ_4	$0.352^{+0.067}_{-0.083}$	0	$0.262^{+0.116}_{-0.132}$	0	$-0.541^{+0.173}_{-0.090}$
Ξ_c	ϕ_2	$0.228^{+0.068}_{-0.061}$	$0.429^{+0.654}_{-0.281}$	$0.449^{+\infty}_{-0.473}$	$0.057^{+0.055}_{-0.034}$	$0.449^{+0.236}_{-0.380}$
	ϕ_3^s	$0.258^{+0.031}_{-0.038}$	$0.750^{+0.308}_{-0.093}$	$0.520^{+0.229}_{-0.060}$	$0.339^{+0.261}_{-0.160}$	$5.244^{+0.696}_{-1.132}$
	ϕ_4	$0.378^{+0.065}_{-0.080}$	$2.291^{+\infty}_{-0.842}$	$0.286^{+0.130}_{-0.150}$	$0.039^{+0.030}_{-0.018}$	$-0.090^{+0.037}_{-0.021}$
		η_1	η_2	η_3	b_2	b_3
Λ_c	ϕ_3^a	$0.324^{+0.054}_{-0.026}$	0	$0.633^{+0.0??}_{-0.0??}$	0	$-0.240^{+0.240}_{-0.147}$
Ξ_c	ϕ_3^a	$0.218^{+0.043}_{-0.047}$	$0.877^{+0.820}_{-0.152}$	$0.049^{+0.005}_{-0.012}$	$0.037^{+0.032}_{-0.019}$	$-0.027^{+0.016}_{-0.027}$