Baryonic decays of B-meson at LHCb

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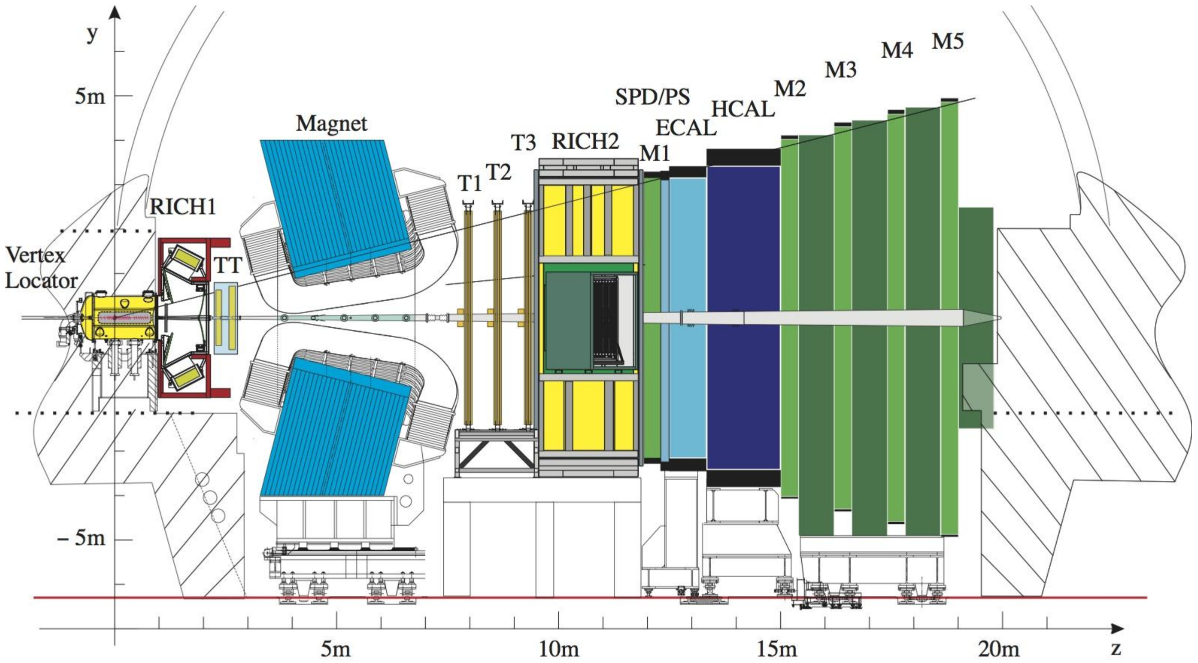
Outline

- Introduction
- Two body baryonic decays
  - □ $B^0_{(s)} \to \Lambda_c^+ \overline{\Lambda}_c^-$, $B^+ \to p\overline{\Lambda}$
- Muti-body baryonic decays
  - □ $B^0_{(s)} \to p\overline{p}p\overline{p}$, $B^+ \to \overline{\Lambda}p\overline{p}p$, $B^+ \to p\overline{\Lambda}\mu^+\mu^-$
- Summary and prospects

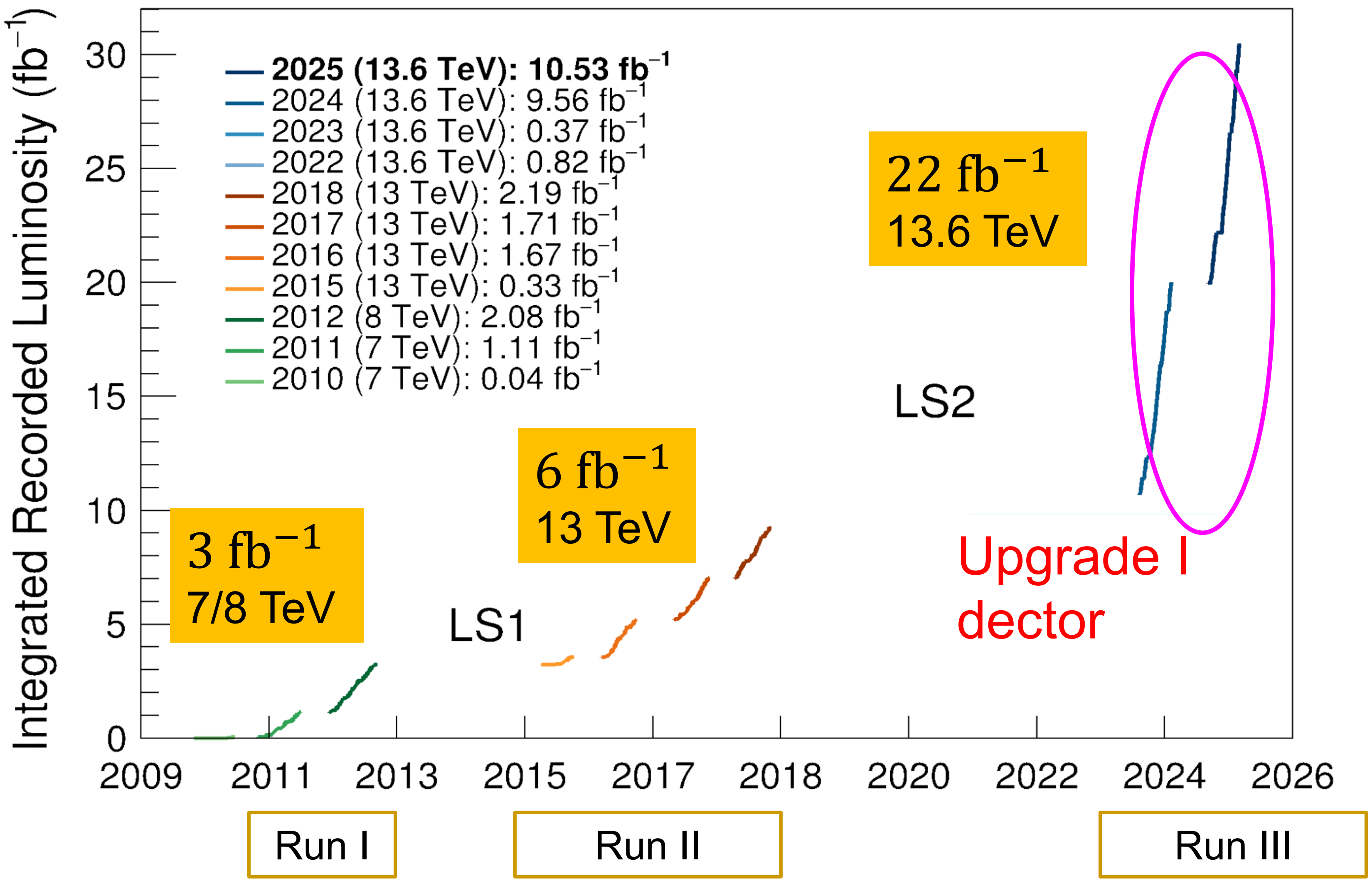
LHCb experiment

LHCb collaboration： 21 counties, 96 institutes, 1812 members



- Understand matter-antimatter imbalance (CP violation)
- Search for new physics (Rare decays)
- Explore and understand QCD (Hadron properties, exotic hadrons)

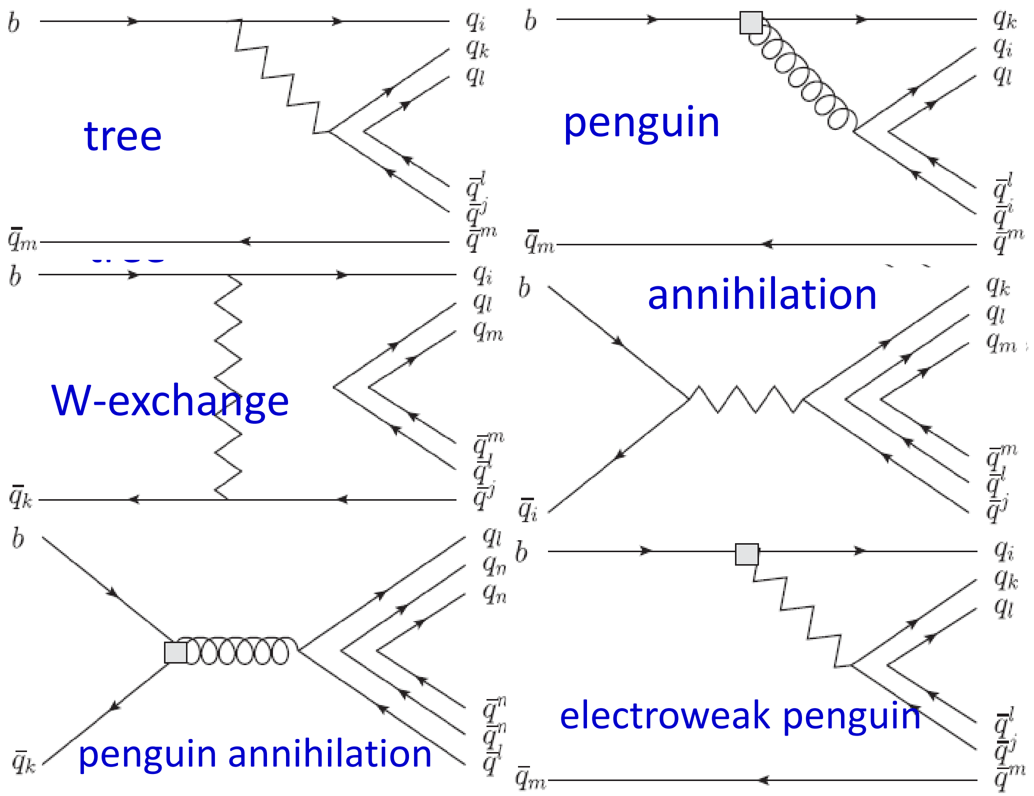
LHCb data



Integrated Recorded Luminosity (fb^{-1})
2025 (13.6 TeV): 10.53 fb^{-1}
2024 (13.6 TeV): 9.56 fb^{-1}
2023 (13.6 TeV): 0.37 fb^{-1}
2022 (13.6 TeV): 0.82 fb^{-1}
2018 (13 TeV): 2.19 fb^{-1}
2017 (13 TeV): 1.71 fb^{-1}
2016 (13 TeV): 1.67 fb^{-1}
2015 (13 TeV): 0.33 fb^{-1}
2012 (8 TeV): 2.08 fb^{-1}
2011 (7 TeV): 1.11 fb^{-1}
2010 (7 TeV): 0.04 fb^{-1}
3 fb^{-1} 7/8 TeV
LS1
6 fb^{-1} 13 TeV
LS2
22 fb^{-1} 13.6 TeV
Upgrade I dector
0 5 10 15 20 25 30
2009 2011 2013 2015 2017 2018 2020 2022 2024 2026
Run I
Run II
Run III

Two–body baryonic decays of B meson

- Provides information on the dynamics of B decays and tests QCD based models of the hadronization process



Phys. Rev. D 95, 096004 (2017)

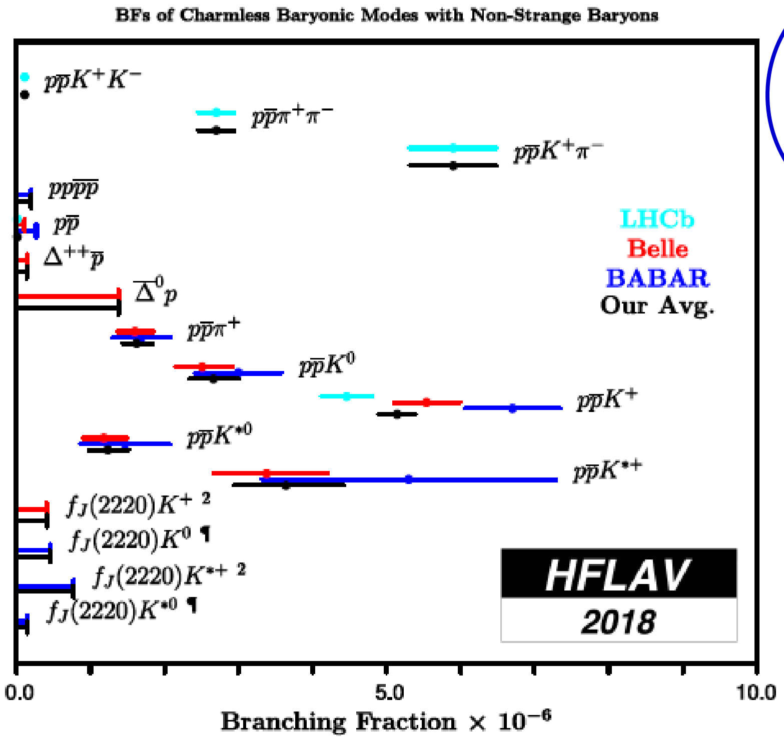
- Baryonic B decays are also interesting in the study of CP violation

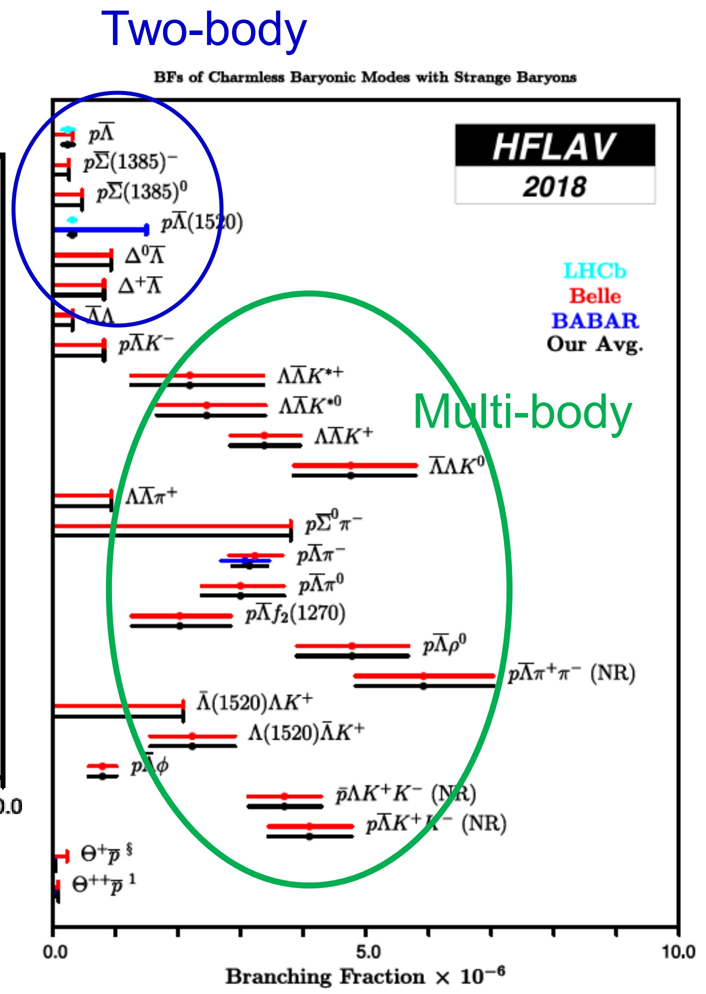
- Pure penguin modes are expected to be sensitive to new physics contributions

The feature of B baryonic decays

- Two-body baryonic decays suppressed with respect to multibody decays

- Decays of B mesons into multiple baryons still far from being fully understood



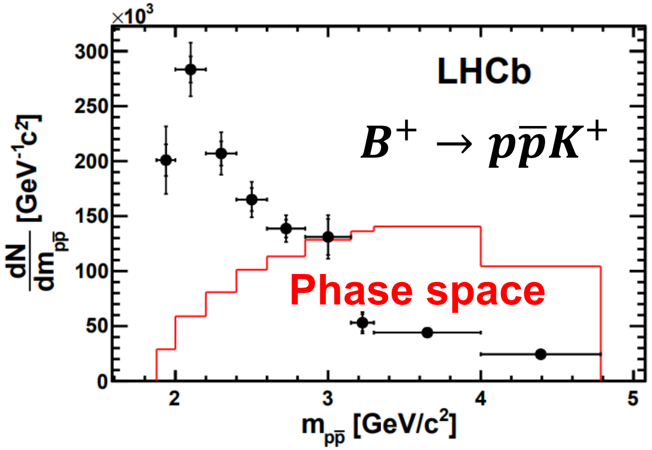


Charmless baryonic B^+ and B^0 modes branching fractions reported by HFLAV

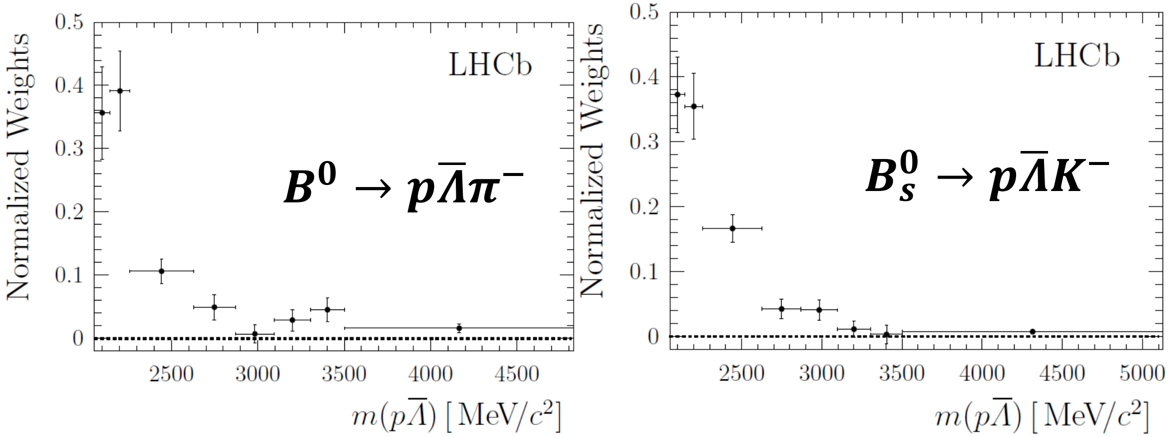
Threshold enhancement

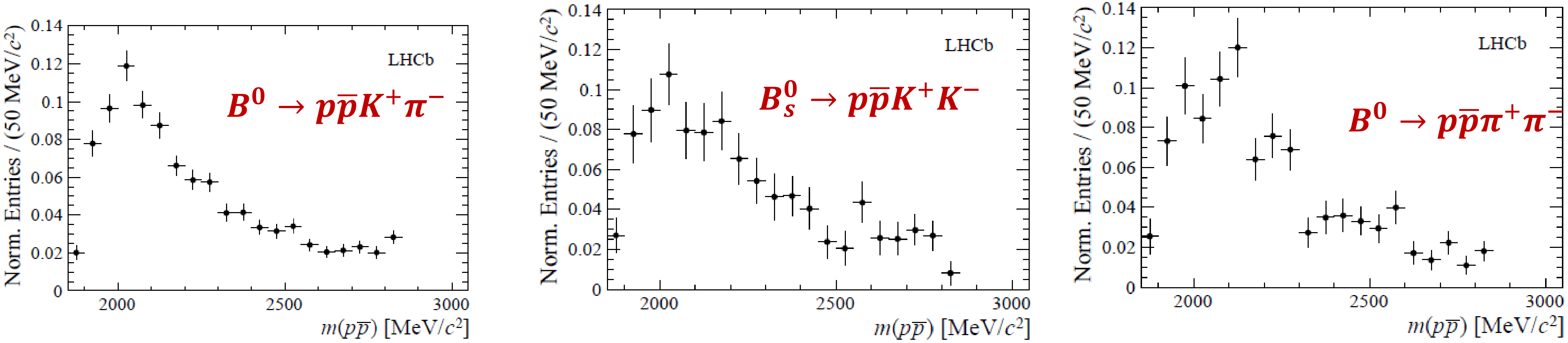
➢ Many channels have the special feature: baryon-antibaryon pair peaks near threshold

PRD 88, 052015 (2013)



Phys. Rev. Lett. 119 (2017) 041802



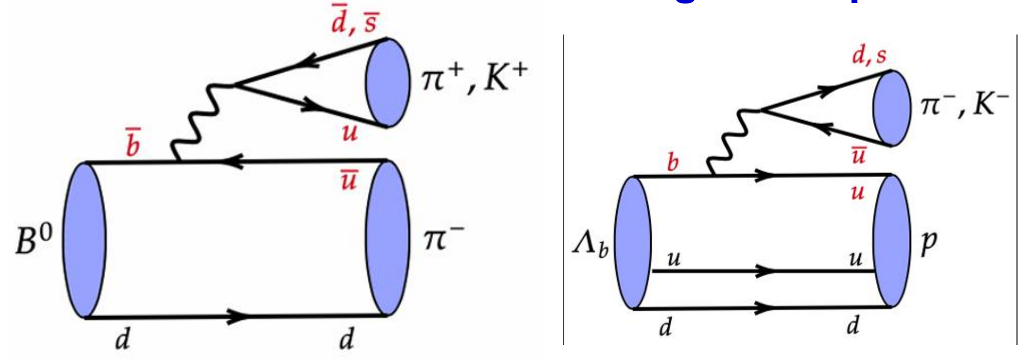


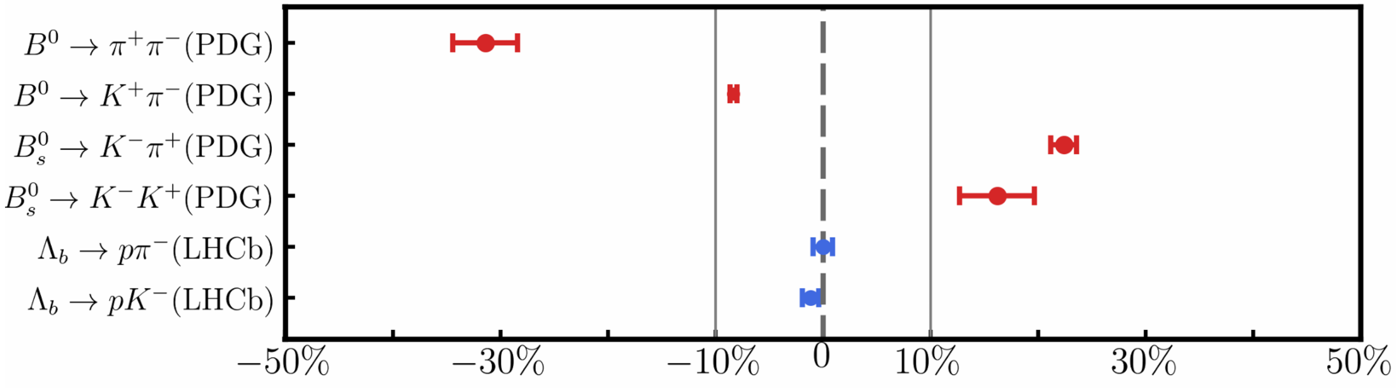
Phys. Rev. D 96 (2017) 051103

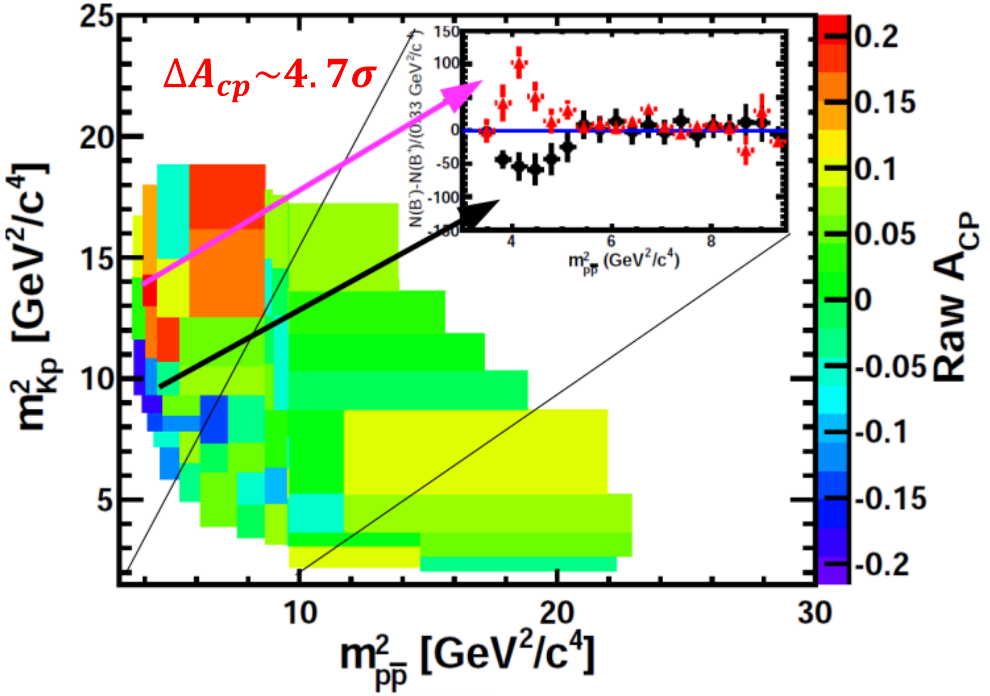
CP asymmetry

- CPV in some B-meson decays are **10%**， but b-baryon CPV only reach **1%**
- Provide a crucial bridge to understanding this puzzle
- CPV of multi-body decays: richer interference structures, more precise constraints on strong phases, more efficient utilization of statistics, and higher sensitivity to new physics

Fusheng Yu’s report





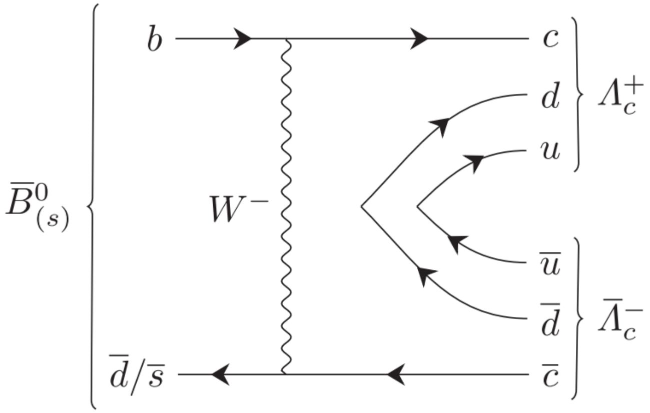


PRL 113, 141801 (2014)

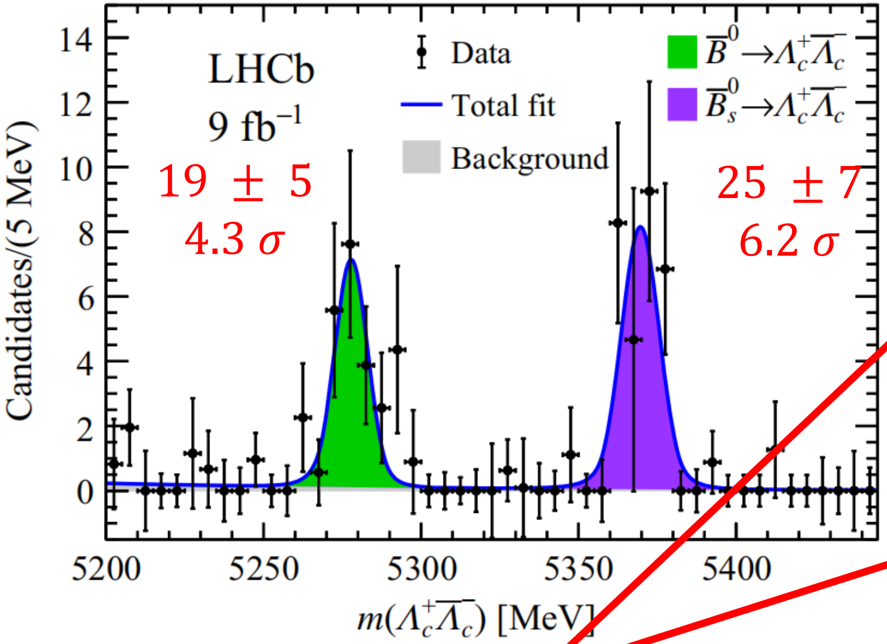
Two body baryonic decays

$$B^0_{(s)} \to \Lambda_c^+ \overline{\Lambda}_c^-,\ B^+ \to p\overline{\Lambda}$$

First Observation of the $B_s^0 \to \Lambda_c^+ \overline{\Lambda}_c^-$ decay



PRL 136, 061802 (2026)



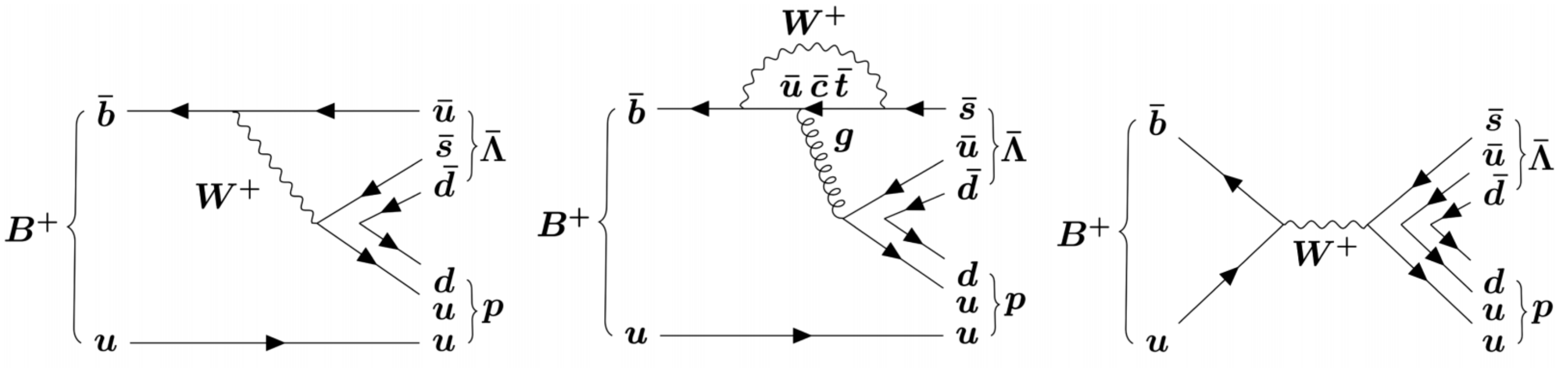
decay channel	this work	experimental data
$10^4 \mathcal{B}(\bar{B}^0 \to \Xi_c^+ \bar{\Lambda}_c^-)$	$7.2^{+2.1}_{-1.9}$	12 ± 8 [14]
$10^4 \mathcal{B}(B^- \to \Xi_c^0 \bar{\Lambda}_c^-)$	$7.8^{+2.3}_{-2.0}$	9.5 ± 2.3 [14]
$10^4 \mathcal{B}(\bar{B}_s^0 \to \Xi_c^0 \bar{\Xi}_c^0)$	$3.0^{+1.4}_{-1.1}$	
$10^4 \mathcal{B}(\bar{B}_s^0 \to \Xi_c^+ \bar{\Xi}_c^-)$	$3.0^{+1.4}_{-1.1}$	
$10^5 \mathcal{B}(\bar{B}_s^0 \to \Lambda_c^+ \bar{\Lambda}_c^-)$	$8.1^{+1.7}_{-1.5}$	< 9.9 [14, 15]
$10^4 \mathcal{B}(B_c^+ \to \Xi_c^+ \bar{\Xi}_c^0)$	$2.8^{+0.9}_{-0.7}$	
$10^5 \mathcal{B}(\bar{B}^0 \to \Xi_c^0 \bar{\Xi}_c^0)$	$1.5^{+0.7}_{-0.6}$	
$10^6 \mathcal{B}(\bar{B}^0 \to \Xi_c^+ \bar{\Xi}_c^-)$	3.0 ± 0.6	
$10^5 \mathcal{B}(\bar{B}^0 \to \Lambda_c^+ \bar{\Lambda}_c^-)$	$2.1^{+1.0}_{-0.8}$	< 1.6 [14, 15] ($2.2^{+2.6}_{-2.1}$ [16])
$10^5 \mathcal{B}(B^- \to \Xi_c^0 \bar{\Xi}_c^-)$	$3.4^{+1.0}_{-0.9}$	
$10^5 \mathcal{B}(\bar{B}_s^0 \to \Lambda_c^+ \bar{\Xi}_c^-)$	$3.9^{+1.2}_{-1.0}$	
$10^5 \mathcal{B}(B_c^+ \to \Lambda_c^+ \bar{\Xi}_c^0)$	$1.6^{+0.5}_{-0.4}$	

JHEP11(2023)117

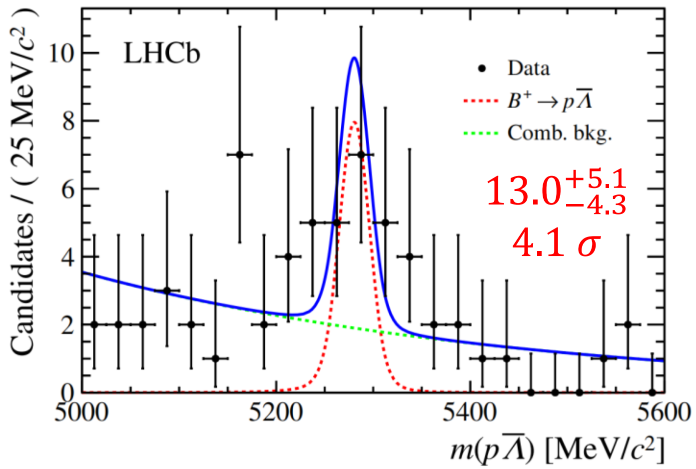
$$\mathcal{B}(\bar{B}^0 \to \Lambda_c^+ \bar{\Lambda}_c^-) = (1.01^{+0.27}_{-0.28} \pm 0.08 \pm 0.15) \times 10^{-5},$$
$$\mathcal{B}(\bar{B}_s^0 \to \Lambda_c^+ \bar{\Lambda}_c^-) = (5.0 \pm 1.3 \pm 0.5 \pm 0.8) \times 10^{-5},$$

- The first experimental verification of the W-exchange process
- Consistent with theoretical predictions
- Such effects may be important for improving predictions of CP -violating

Search for $B^- \to \Lambda\bar{p}$ decay



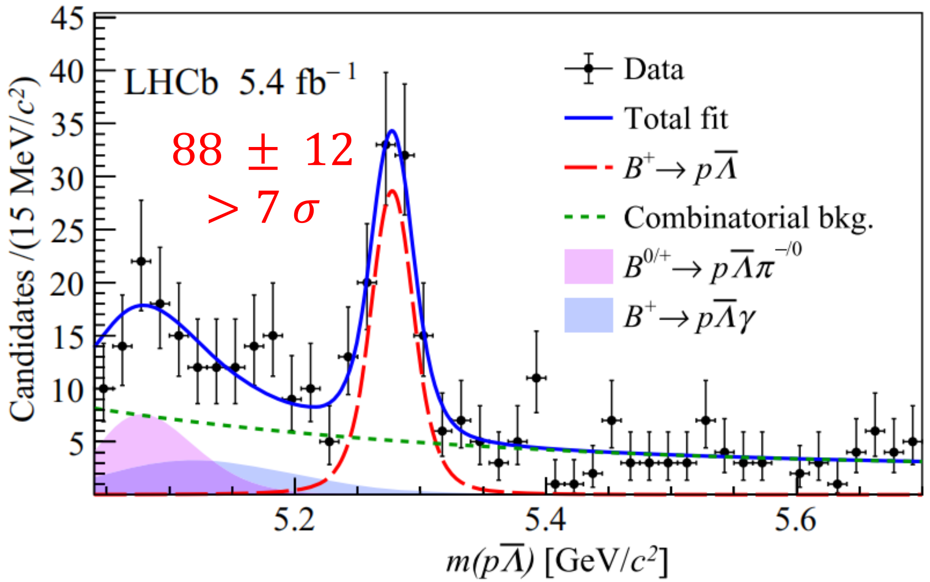
(a) (b) (c)

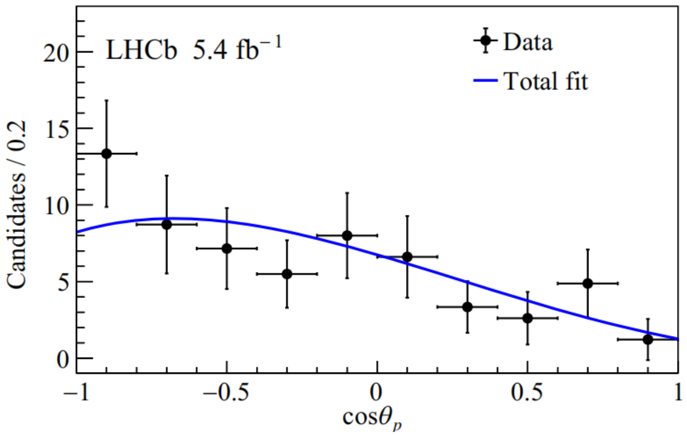


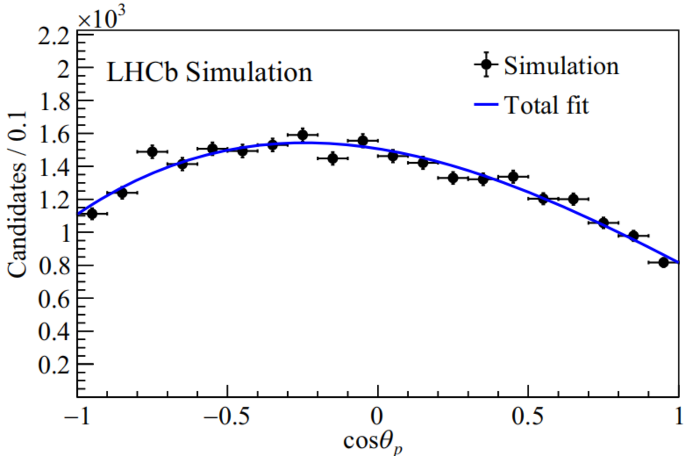
JHEP04(2017)162

- CP-violation of $B_s^0 \to K^+K^-$ and $B^0 \to K^+\pi^-$ $\sim 10\%$
- Why $A_{cp}(\Lambda_b^0 \to pK^-) = (-1.14 \pm 0.17)\%$
- Theoretical studies for $A_{cp}(B^- \to \Lambda\bar{p})$ could reach 10%, but S-wave and P-wave amplitudes cancellation could suppress CPV
- LHCb have searched this decay mode with Run I data

First observation of the $B^+ \to p\bar{\Lambda}$ decay







PRL 136, 051802 (2026)

$$\alpha_B = 0.87^{+0.26}_{-0.29} \pm 0.09,$$

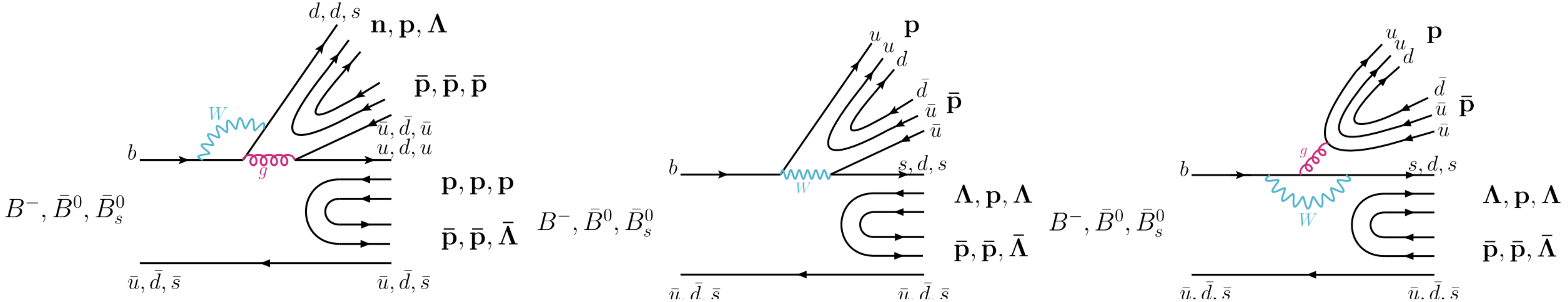
$$\mathcal{B}(B^+ \to p\bar{\Lambda}) = (1.24 \pm 0.17 \pm 0.05 \pm 0.03) \times 10^{-7}$$

- Consistent with available theoretical predictions
- $\alpha_B \neq 0$ indicates a strong interference between the competing S-wave and P-wave amplitudes
- $\mathcal{B}(B^+ \to p\bar{\Lambda}) \sim 10 \times \mathcal{B}(B^0 \to p\bar{p})$ →like mesonic two-body B-meson decays
- CPV of $B^+ \to p\bar{\Lambda}$ will become feasible

Muti-body baryonic decays

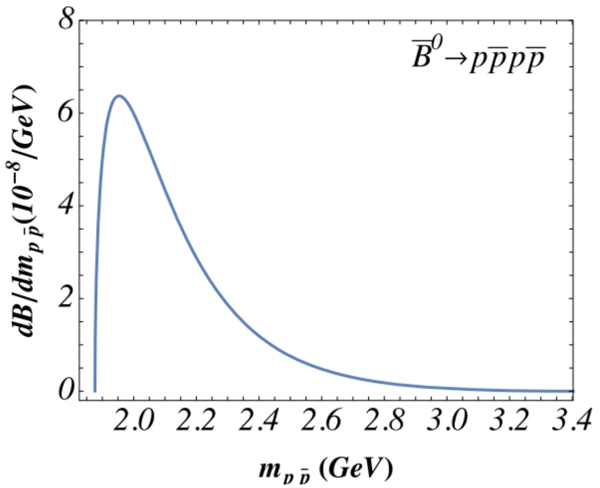
$B^0_{(s)} \to p\bar{p}p\bar{p}$, $B^+ \to \bar{\Lambda}p\bar{p}p$, $B^+ \to p\bar{\Lambda}\mu^+\mu^-$

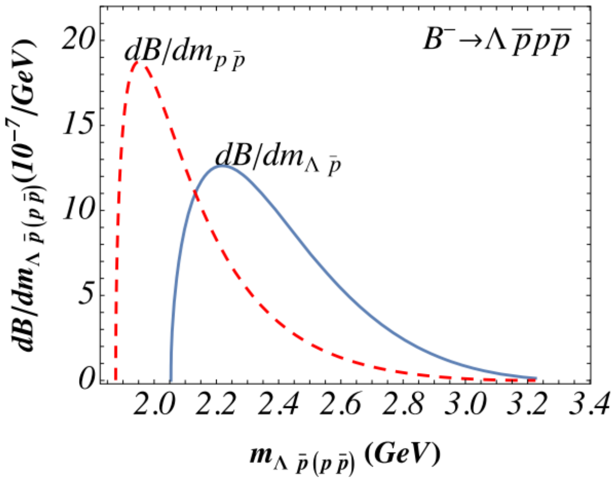
Four-body baryonic decays： $B^0_{(s)} \to p\bar{p}p\bar{p}$， $B^+ \to \bar{\Lambda}p\bar{p}p$



Physics Letters B 845 (2023) 138158

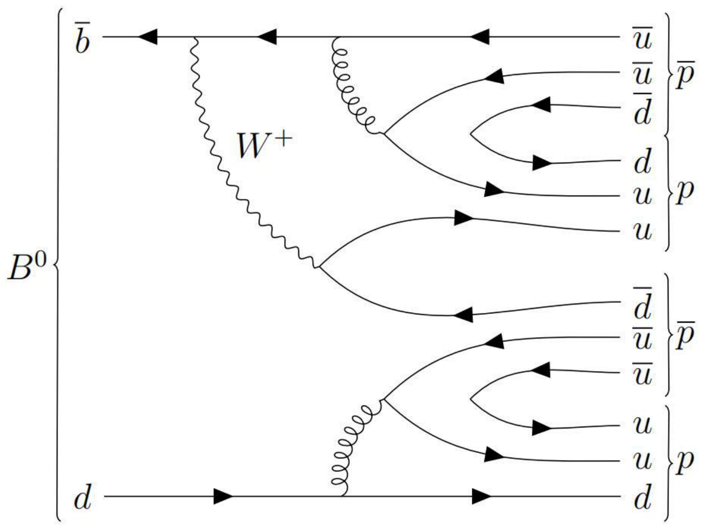
Decay mode	Our work	Data
$10^8\mathcal{B}(\bar{B}^0 \to p\bar{p}p\bar{p})$	$2.2 \pm 0.4 \pm 0.1 \pm 0.4$	2.2 ± 0.4 [10]
$10^7\mathcal{B}(B^- \to n\bar{p}p\bar{p})$	$1.7^{+0.4}_{-0.2} \pm 0.1^{+0.7}_{-0.4}$	--
$10^7\mathcal{B}(B^- \to \Lambda\bar{p}p\bar{p})$	$7.4^{+0.6}_{-0.2} \pm 0.03^{+3.6}_{-2.6}$	--
$10^7\mathcal{B}(\bar{B}^0_s \to \Lambda\bar{\Lambda}p\bar{p})$	$1.9^{+0.3}_{-0.1} \pm 0.01^{+1.1}_{-0.6}$	--

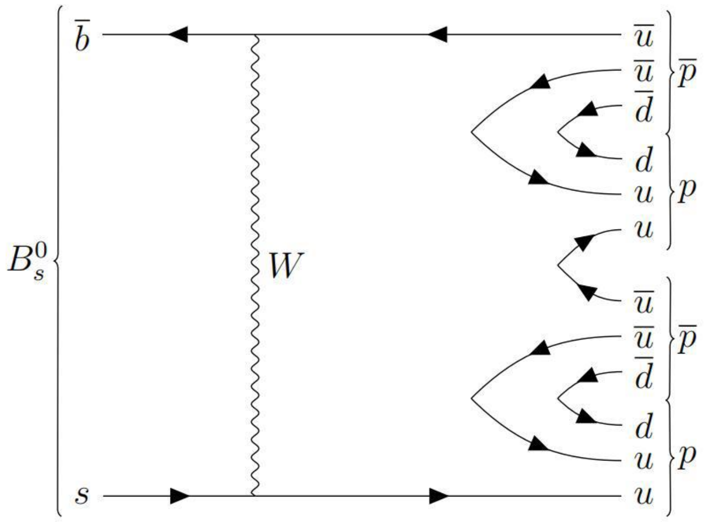




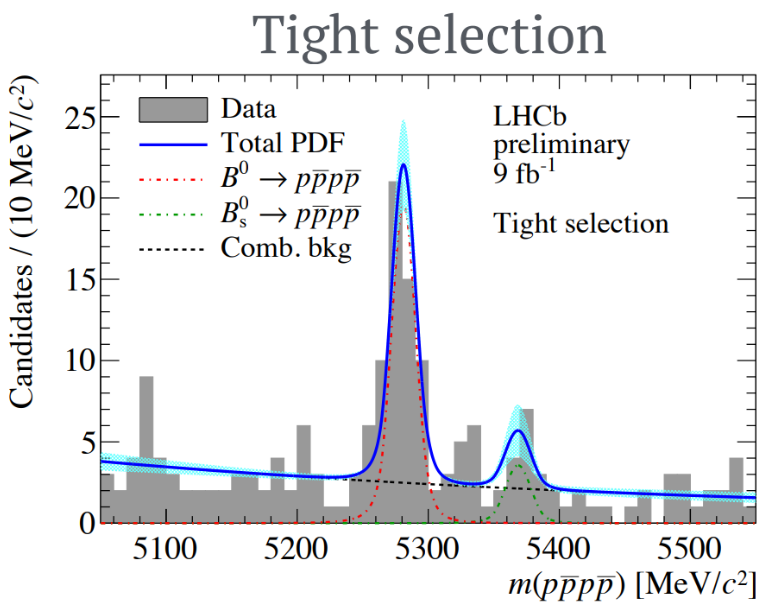
Search for $B^0_{(s)} \to p\bar{p}p\bar{p}$

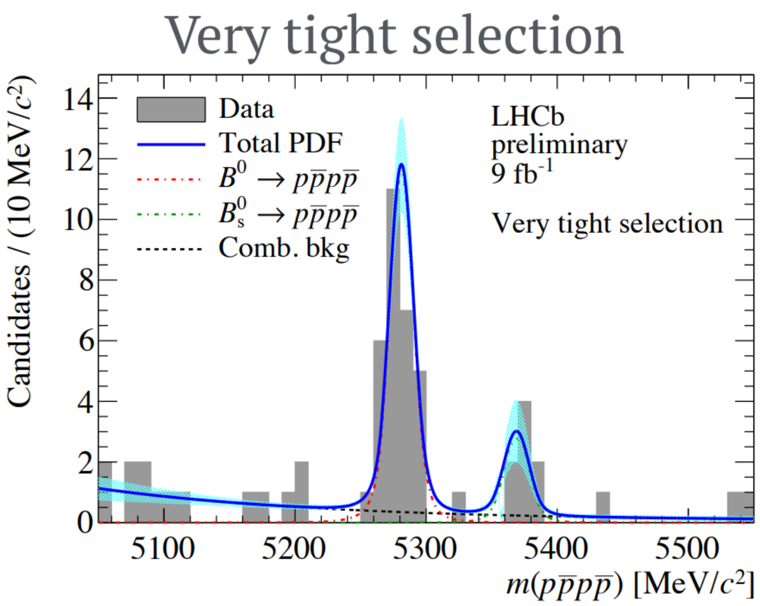
- B meson decay to 4 baryons was never observed
  - $B^0 \to pppp$ (2.9σ) **Phys. Rev. D 98, 071102 (2018)**
- $B_s \to pppp$ (**no study reported**) is expected to be further suppressed with respect to B^0
  - Hadronisation fraction $f_s/f_d \sim 25\%$, and $\left|\frac{V_{us}}{V_{ud}}\right|^2 \sim 5\%$





First observation of $B_s^0 \to p\bar{p}p\bar{p}$





PRL 131, 091901 (2023)

N($B^0 \to p\bar{p}p\bar{p}$) = 48 ± 8

Significance: > 9σ

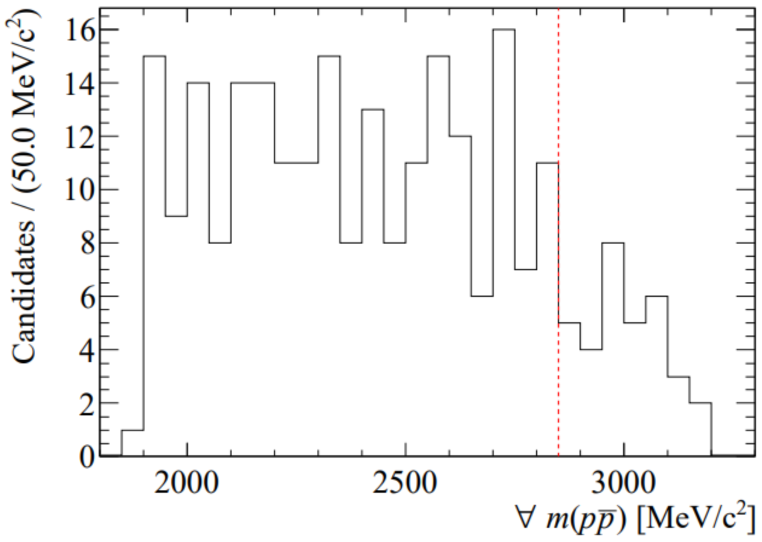
N($B_s^0 \to p\bar{p}p\bar{p}$) = 7 ± 3

Significance: 4σ

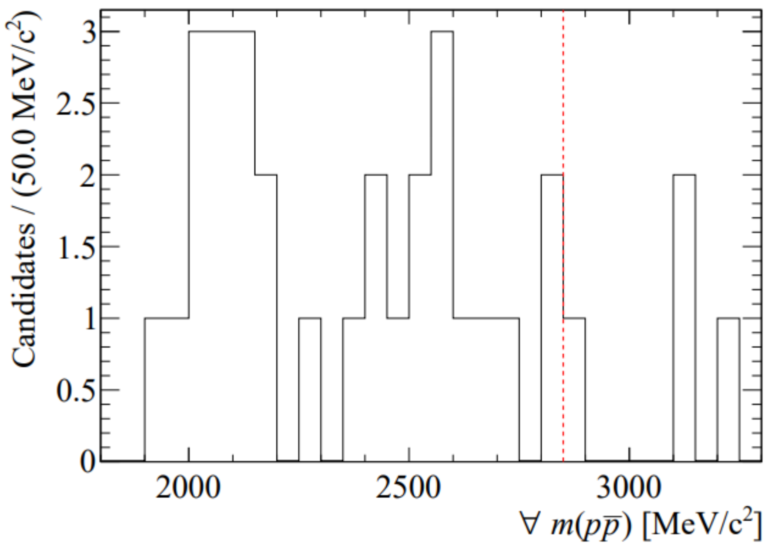
- $B^0 \to J/\psi(\to p\bar{p})K^{*0}(\to K^+\pi^-)$ and $B_s^0 \to J/\psi(\to p\bar{p})\phi(\to K^+K^-)$ as normalization channel
- $\mathcal{B}(B^0 \to p\bar{p}p\bar{p}) = (2.2 \pm 0.4 \pm 0.1 \pm 0.1) \times 10^{-8}$
- $\mathcal{B}(B_s^0 \to p\bar{p}p\bar{p}) = (2.3 \pm 1.0 \pm 0.2 \pm 0.1) \times 10^{-8}$
- $B_s^0 \to p\bar{p}p\bar{p}$ is not consistent with expected Cabibo suppression: $\left|\frac{V_{us}}{V_{ud}}\right|^2 \sim 5\%$
- Expect other theoretical explanations

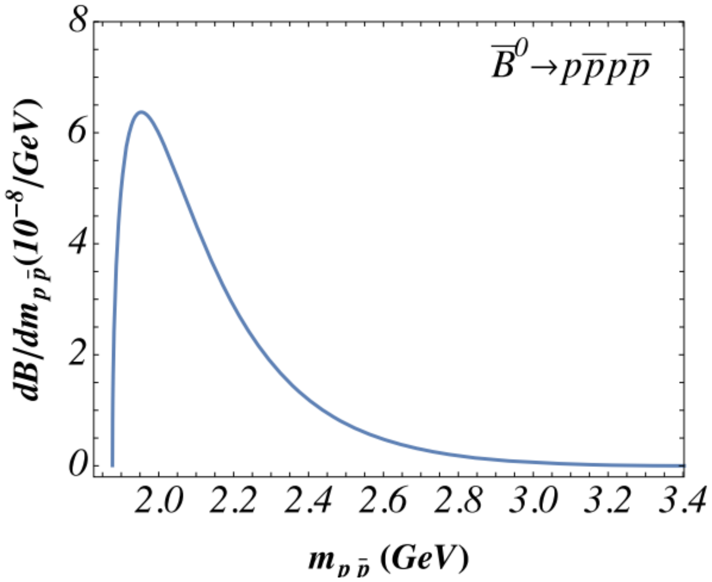
Mass distributions of $p\bar{p}$

Tight selection



Very Tight selection

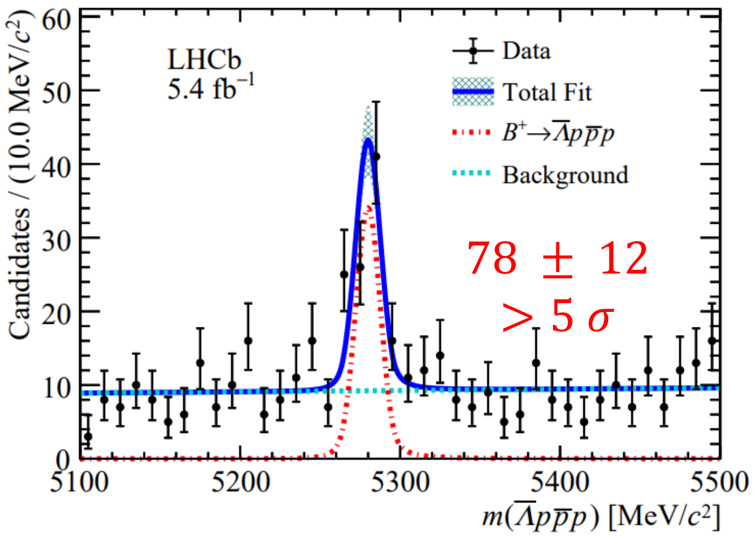




Data above the red-dashed line are excluded by the $c\bar{c}$ veto.

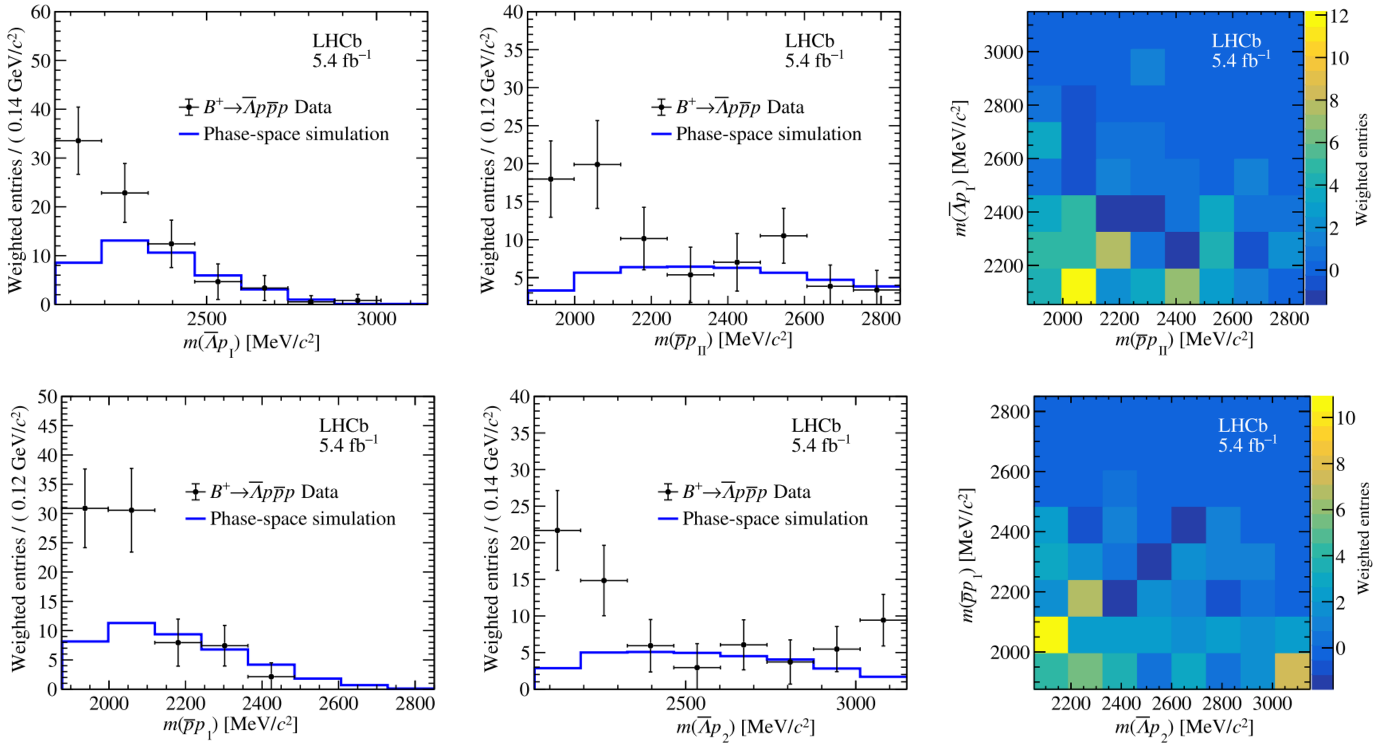
- To avoid $J/\psi \to p\bar{p}$, require $m(p\bar{p}) < 2.85\mathrm{GeV}/c^2$
- Branching fractions with $c\bar{c}$ veto (only stat. uncertainty)
  - $\mathcal{B}(B^0 \to p\bar{p}p\bar{p}) = (1.6 \pm 0.4) \times 10^{-8}$
  - $\mathcal{B}(B_s^0 \to p\bar{p}p\bar{p}) = (2.2 \pm 1.2) \times 10^{-8}$

First observation of $B^+ \to \bar{\Lambda} p \bar{p} p$



PRL 135, 261901 (2025)

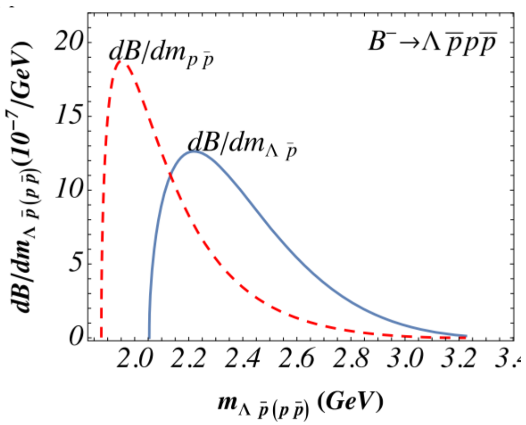
$\mathcal{A}_{CP} = (5.4 \pm 15.6 \pm 2.4)\%$.



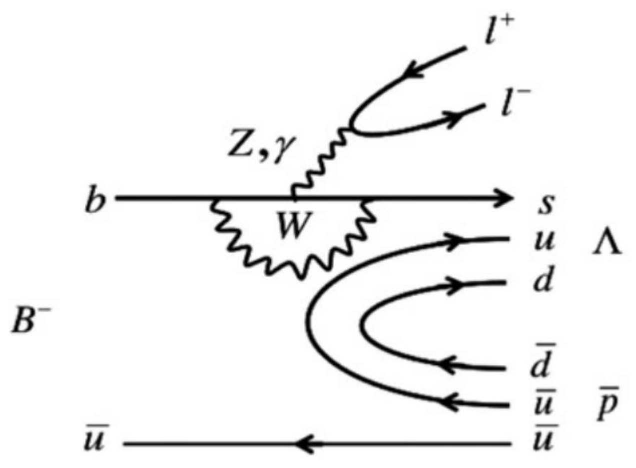
$m(\bar{\Lambda} p_1) < m(\bar{\Lambda} p_2)$

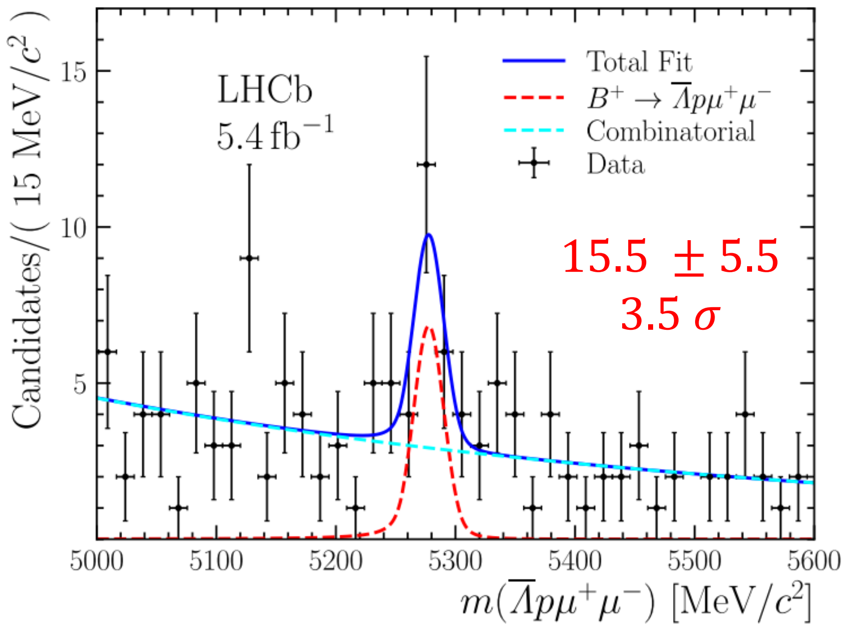
$m(\bar{p} p_1) < m(\bar{p} p_2)$

- LHCb result: $\mathcal{B}(B^+ \to \bar{\Lambda} p \bar{p} p) = (2.08 \pm 0.34 \pm 0.12 \pm 0.26) \times 10^{-7}$
- Theoretical result: $\mathcal{B}(B^+ \to \bar{\Lambda} p \bar{p} p) = (7.4^{+0.6}_{-0.2} \pm 0.03^{+3.6}_{-2.6}) \times 10^{-7}$
- A clear double-threshold enhancement in both baryon-antibaryon invariant-mass distributions

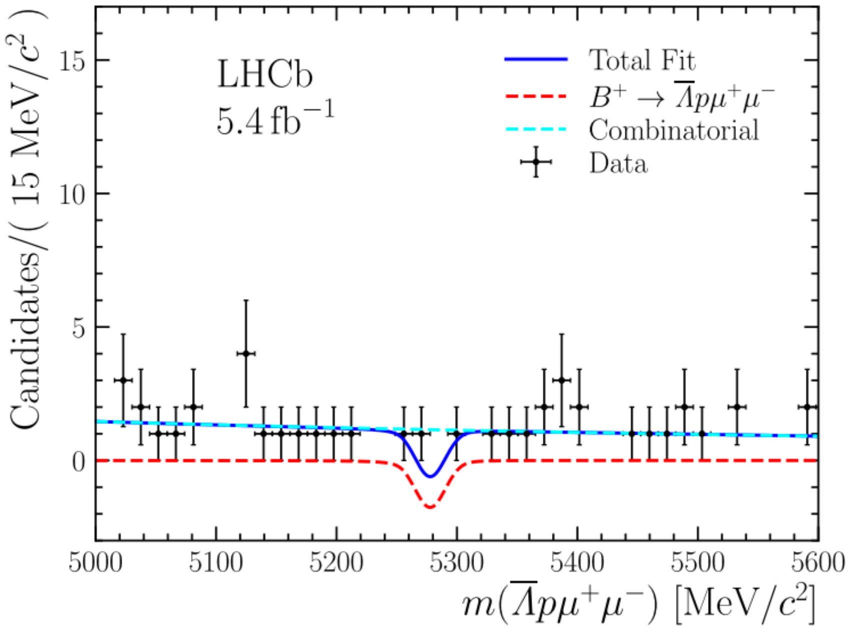


Evidence for the rare decay $B^+ \to p\bar{\Lambda}\mu^+\mu^-$





$m(\bar{\Lambda}p) < 2.8\,\mathrm{GeV}/c^2$



$m(\bar{\Lambda}p) > 2.8\,\mathrm{GeV}/c^2$

arXiv:2601.06878v1 accepted by PRL

- $B^+ \to J/\psi \Lambda p$ as normalization mode

$$\mathcal{B}(B^+ \to \bar{\Lambda}p\mu^+\mu^-)|_{m(\bar{\Lambda}p)<2.8\,\mathrm{GeV}/c^2} = (1.70 \pm 0.60_{\mathrm{stat}} \pm 0.19_{\mathrm{syst}} \pm 0.14_{\mathrm{ext}}) \times 10^{-8},$$

Summary and prospects

- **LHCb provides ideal environment for searching for baryonic decays of B mesons**
  - Observation: $B^+ \to p\bar{\Lambda}$, $B_s^0 \to \Lambda_c^+\bar{\Lambda}_c^-$, $B^0 \to p\bar{p}p\bar{p}$, $B^- \to \Lambda\bar{p}p\bar{p}$,
  - Evidence: $B^0 \to \Lambda_c^+\bar{\Lambda}_c^-$, $B_s^0 \to p\bar{p}p\bar{p}$, $B^+ \to p\bar{\Lambda}\mu^+\mu^-$
  - Double-threshold enhancement: $B^- \to \Lambda\bar{p}p\bar{p}$
- **Opportunities with Run III**
  - Wider scope for exploitation: $B^0 \to \Lambda_c^+\bar{\Lambda}_c^-$, $B_s^0 \to \Lambda_c^+\bar{\Xi}_c^-$, $B_{(s)}^0 \to \Xi_c\bar{\Xi}_c$, $B_{(s)}^0 \to \Lambda_c^+\bar{p}$, $B_{(s)}^0 \to \Xi_c^+\bar{p}$, $B_c^+ \to \Lambda_c^+ pK^-$, $B_s^0 \to p\bar{p}$, $B_{(s)}^0 \to \Lambda\bar{\Lambda}$, $B_{(s)}^0 \to \Xi^+\bar{\Xi}^-$, $B_{(s)}^0 \to \Omega\bar{\Omega}$ ...
  - Threshold enhancement: $B_{(s)}^0 \to p\bar{p}p\bar{p}$, $B_{(s)}^0 \to p\bar{p}hh$, $B_{(s)}^0 \to p\bar{\Lambda}h$, $B^+ \to p\bar{p}h$ ...
  - Rare decay and CPV: $B^+ \to p\bar{\Lambda}$, $B_{(s)}^0 \to \Lambda\bar{\Lambda}$, $B_{(s)}^0 \to \Xi^+\bar{\Xi}^-$, $B_{(s)}^0 \to \Omega\bar{\Omega}$ ...

谢 谢！