Study of B baryonic decays at LHCb and D decays at BESIII

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Outline

Introduction

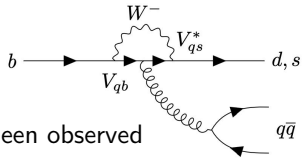
- Large mass of B meson makes possible the decays of $B \to \mathbf{B\bar{B}'(+Mesons)}$
- Searching for B charmless decays with baryons in the final states provide a nice platform of the SM and the CKM mechanism and search for new CP violation source(s)

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Charmed decay

Charmless decay

- FCNC: NP, new particle, new flavor structure

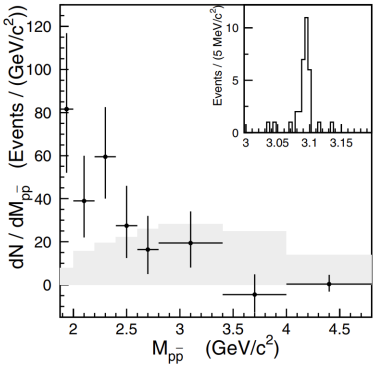


- A list of B meson purely Charmless Baryonic decays have been observed

$$\bar{B}^0 \to p\bar{p},\ \bar{B}^+ \to p\bar{p}h$$
$$\bar{B}^0 \to p\bar{p}p\bar{p},\ \bar{B}^0_{(s)} \to p\bar{p}hh$$

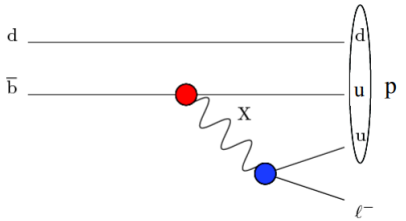
Introduction

- Threshold enhancement firstly observed at Belle in the decay of $B^+ \to p\bar{p}K^+$
- $B \to \mathbf{B\bar{B}'M}$ and $B \to \mathbf{B\bar{B}'MM'}$ decays also see the same effect
- Assume that the threshold effect also exists in charmless $B \to \mathbf{B_1\bar{B}_1{}'B_2\bar{B}_2{}'}$ decays
- The firstly observed four-body baryonic charmless decays: $\boldsymbol{B^0 \to p\bar{p}p\bar{p}}$



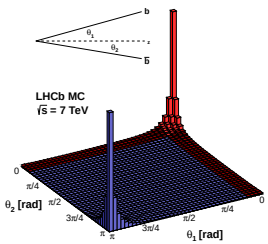
Introduction

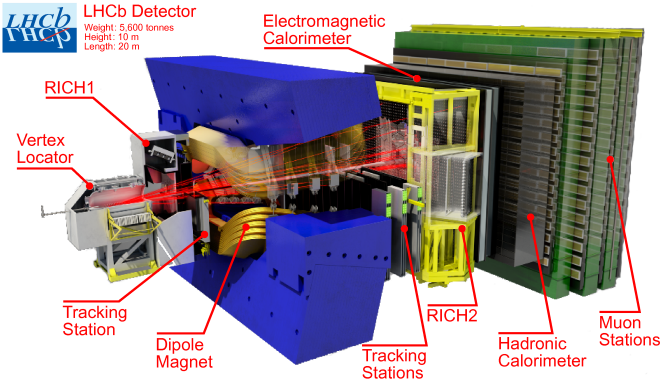
- Baryon (Lepton) number violation BNV (LNV) have been conserved for decades and only LNF observed at neutrino oscalling
- Sakharov conditions (1967) require both CP violation and Baryon Number violation (BNV): theories beyond SM
- BNV proton decay could be mediated by massive bosons (X&Y) which couple to quarks & leptons B-L as conserved quantity



LHCb detector

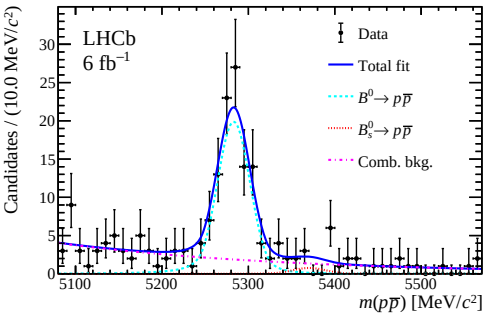
- LHCb originally designed for CP violation and rare decays measurements
- Run1+2: 9fb^{-1} of *pp* collisions (+ heavy ions, fixed target mode)
- Forward spectrometer ($2 < \eta < 5$) with excellent vertexing, tracking and particle identification [JINST 3 (2008) S08005]





Searching for $B_S^0 \to p\bar{p}$ [PRD108.012007]

- First observation of a charmless 2-body baryonic decay in Run1 $B^0 \to p\bar{p}$ [PRL119232001]



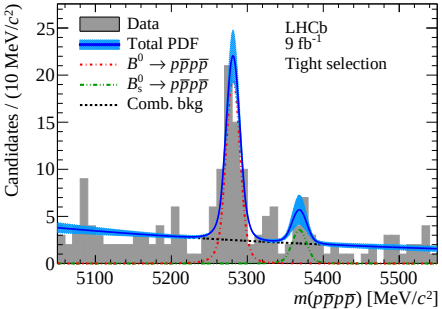
- With 6fb^{-1} data set collected by LHCb in **Run2**
- No evidence of the $B_S^0 \to p\bar{p}$ decay is found
- Determination of its branching fraction requires future data to be collected by LHCb

Update: $\mathcal{B}\left(B^0 \to p\bar{p}\right) = (1.27 \pm 0.15 \pm 0.05 \pm 0.04) \times 10^{-8}$

The world's best upper limit: $\mathcal{B}\left(B_s^0 \to p\bar{p}\right) < 4.4(5.1) \times 10^{-9}$ at $90\%(95\%)$ C. L.

Searching for $B^0_{(s)} \to p\bar{p}p\bar{p}$ [PRL**131**(2023)091901]

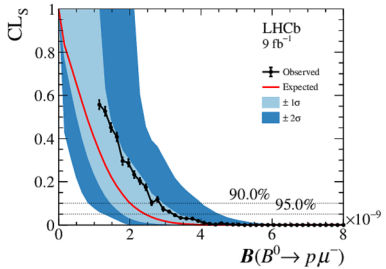
- The first purely four-body baryonic decay $\bar{B}^0 \to p\bar{p}p\bar{p}$ is observed using RunI+RunII LHCb data
- No clear evidence of threshold enhancement is found in $\bar{B}^0 \to p\bar{p}p\bar{p}$ given the statistics, unlike the observed in three-body baryonic B decays

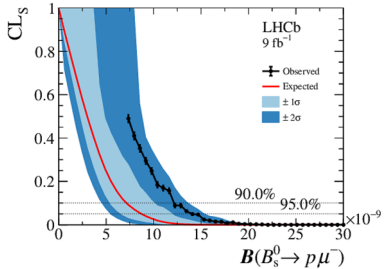


$$\mathcal{B}\left(B^0 \to p\bar{p}p\bar{p}\right) = (2.21 \pm 0.37 \pm 0.38 \pm 0.09) \times 10^{-8}$$
$$\mathcal{B}\left(\bar{B}^0_s \to p\bar{p}p\bar{p}\right) = (2.40 \pm 1.01 \pm 0.20 \pm 0.19) \times 10^{-8}$$

Searching for $B^0 \to p\mu^-$[PRD108(2023) 012021]

- First search on LNV&BNV B0(s) $\to p\mu^-$
- LEP method is used to determine the upper limit
- An unbinned maximum likelihood fit is simultaneously in each category





D decays at BESIII

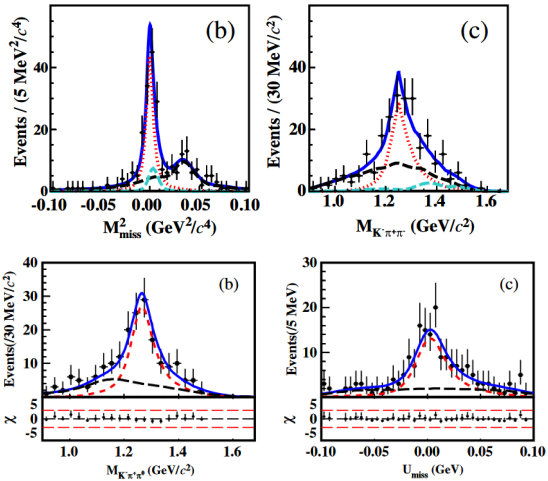
$D^+ \to K_1(1270)^- e^+ \nu_e$ and $D^0 \to \bar{K}_1(1270)^0 e^+ \nu_e$ [PRL123(2019)231801, PRL127(2021)131801]

- BESIII collects the world largest $\psi(3770)$ data providing opportunities to study D decays
- Benefit the understanding of the mixing angle of 1P1 and 3P1 states, K1(1270)-K1(1400) , which is much controversial in theory
- Test if isospin holds in decay $D^{0(+)} \to K_1(1270) e^+ \nu_e$
- Help to understand photon helicity in $B \to K_1 \gamma$ that provides a direct test of SM [PRL125,051802(2020)]

$D^+ \to K_1(1270)^- e^+ \nu_e$ and $D^0 \to \bar{K}_1(1270)^0 e^+ \nu_e$ [PRL123(2019)231801, PRL127(2021)131801]

- Data 2.93 fb^{-1} @$\sqrt{s} = 3.773$ GeV
- Double tag method to select candidates
- Maximum likelihood fit to $m(K\pi\pi)$ and M^2_{miss}

$$\mathcal{B}\left(D^+ \to K_1(1270) e^+ \nu\right) =$$
$$(2.21 \pm 0.37 \pm 0.38 \pm 0.09(ext.)) \times 10^{-4}$$
$$\mathcal{B}\left(D^0 \to K_1(1270) e^+ \nu\right) =$$
$$(1.17 \pm 0.13 \pm 0.12 \pm 0.13(ext.)) \times 10^{-4}$$
$$\frac{\Gamma\left(D^0 \to K_1^-(1270) e^+ \nu_e\right)}{\Gamma\left(D^+ \to \bar{K}_1^0(1270) e^+ \nu_e\right)} = 1.29 \pm 0.20 \pm 0.17 \pm 0.20($$



More works at BESIII

- Amplitude analysis of $D_s^+ \to K^-K^+\pi^+\pi^+\pi^-$ [JHEP07(2022)051]
  First study focusing on $D_s^+ \to AV$ decays, helps to improve the understanding of background processes of $D_s^+ \to \pi^+\pi^+\pi^-X$ in the measurement of $R(D^*)$
- Amplitude analysis of $D_s^+ \to \pi^+\pi^-\pi^+$ [PRD106(2022)112006]
  Improve understanding of scalar mesons f0(X) due to large coupling: $> 80\%$ S-wave contribution
- ...

Prospects

- Ongoing studies to $B \to \bar{\Lambda} p h h'$ and $B \to \bar{\Lambda}\Lambda h h'$

Decays	Observables	Feasibility	Probe for NP
$B \to \Lambda^0 p p \bar{p}$	BF, CPV, angular, exotic	⋆⋆⋆⋆⋆	⋆
$B \to \Lambda^0 p \pi^+ \pi^-$	CPV, angular asym., amplitudes	⋆⋆⋆⋆	⋆⋆⋆⋆⋆
$B \to \Lambda^0 p K \pi$ $B \to \bar{\Lambda}^0 p \pi^+ \pi^+$	BFs	⋆⋆⋆⋆⋆	⋆⋆⋆
$B \to \bar{\Lambda}^0 p \phi(K^+ K^-)$	CPV, angular asym.	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆
$B \to \bar{\Lambda}^0 p K K$	BFs, CPV, $c\bar{c}/\Lambda(1520)$contributions	⋆⋆⋆⋆	⋆
$B \to \bar{\Lambda}^0 p \mu^+ \mu^-$	BF	⋆⋆⋆	⋆⋆⋆⋆⋆

- Ongoing studies of D Decays:

* Searching for $D \to K_1(1270)(\to K\omega)e^+\nu_e$ with generic tagging method
* Measurement of the $D^*(2010)^+ - D^+$ Mass Difference
* ...