# First observation of charmless baryonic decay $\mathrm{B}^+ \to \bar{\Lambda}^0 \mathrm{p}\bar{\mathrm{p}}\mathrm{p}$

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## Physics Motivation

- Purely baryonic $B$ decays (e.g., $B^0_{(s)} \to p\bar{p}, p\bar{p}p\bar{p}$)* are suppressed compared to mesonic decays, which are sensitive to CPV, NP
- $\boldsymbol{B^+ \to \bar{\Lambda} p\bar{p}p}$ is dominated by $\boldsymbol{b \to s}$ transition, excellent candidate to study **baryon–antibaryon mass spectra**

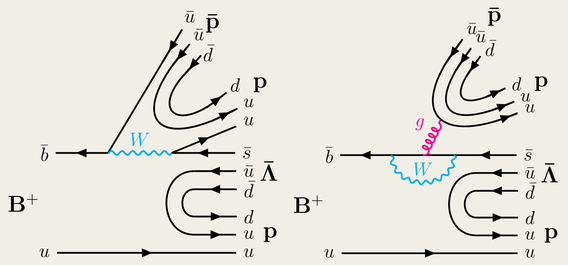
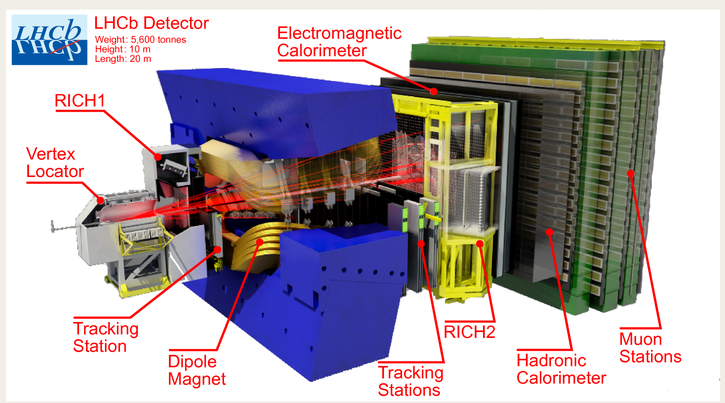


Figure 1. Possible (left) tree-level and (right) penguin-level diagrams for $B^+ \to \bar{\Lambda}p\bar{p}p$ decay.

*The inclusion of charge-conjugate processes is implied throughout, except in the discussion of asymmetries.

## Run2 LHCb detector and dataset

- **LHCb** is a single-arm forward spectrometer, specializing in the study of $b$- and $c$-hadrons, as well as for investigating matter and antimatter asymmetry
- **Dataset**: $pp$ collision data at $\sqrt{s} = 13$TeV during 2016–2018 ($5.4\mathrm{fb}^{-1}$)




[JINST**3**(2008)S08005]
[Int. J. Mod. Phys. A**30**(2015)1530022]

## Branching fraction and $\mathcal{A}_{CP}$ measurements

- Excluding the contributions from charmonium contributions in $\bar{\Lambda}p\bar{p}p$ final states and taking $B^+ \to J/\psi(\to \bar{\Lambda}pK^- + c.c.)K^+$ as the normalization channel
- **Simultaneous maximum-likelihood fit to signal and normalization channels is performed to extract the branching fraction (BF):**

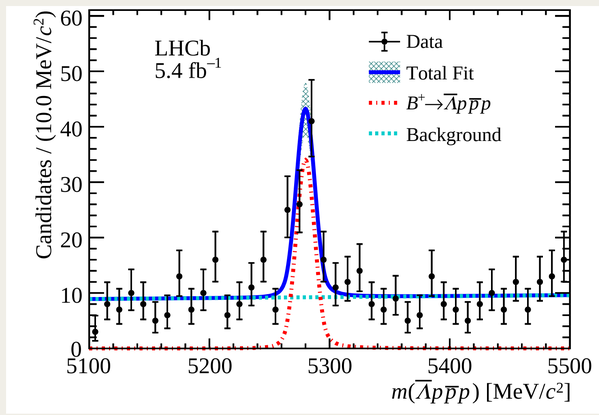
$$\boldsymbol{\mathcal{B}(B^+ \to \bar{\Lambda}p\bar{p}p) = (2.08 \pm 0.34_{\text{stat.}} \pm 0.12_{\text{sys.}} \pm 0.26_{\text{ext.}}) \times 10^{-7},}$$

where the third uncertainty arises from the BF of the normalization channel

- Maximum-likelihood fit to $m(\bar{\Lambda}p\bar{p}p)$ distribution yields a signal of:

$$N(B^+ \to \bar{\Lambda}p\bar{p}p) = 78 \pm 12,$$

corresponding to a signal significance greater than five standard deviations



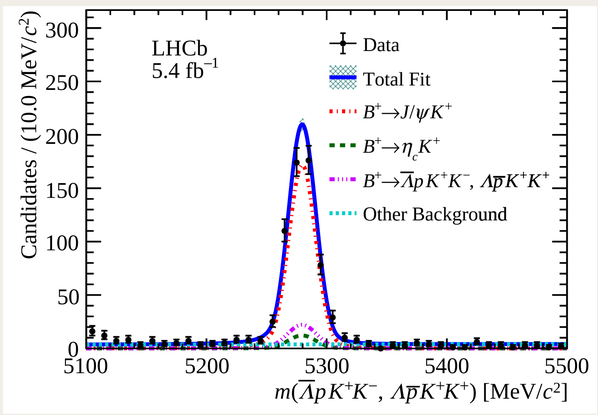




Figure 2. Invariant-mass distributions of (left) $\boldsymbol{B^+ \to \bar{\Lambda}p\bar{p}p}$ with $m(\bar{p}p) < 2850$ MeV/$c^2$ and (right) $B^+ \to J/\psi(\to \bar{\Lambda}pK^- + c.c.)K^+$ candidates.

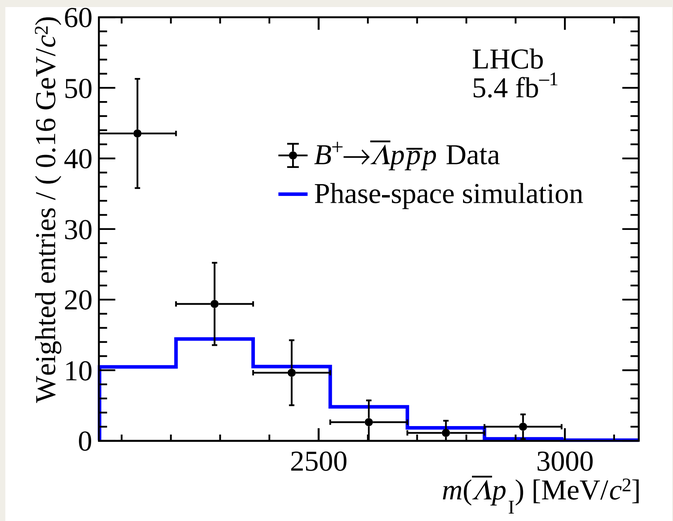
- Simultaneous maximum-likelihood fit to $B^+ \to \bar{\Lambda}p\bar{p}p$ and $B^- \to \Lambda\bar{p}p\bar{p}$ candidates to measure $\boldsymbol{\mathcal{A}_{CP} = \frac{\Gamma(B^+ \to f) - \Gamma(B^- \to \bar{f})}{\Gamma(B^+ \to f) + \Gamma(B^- \to \bar{f})}}$:

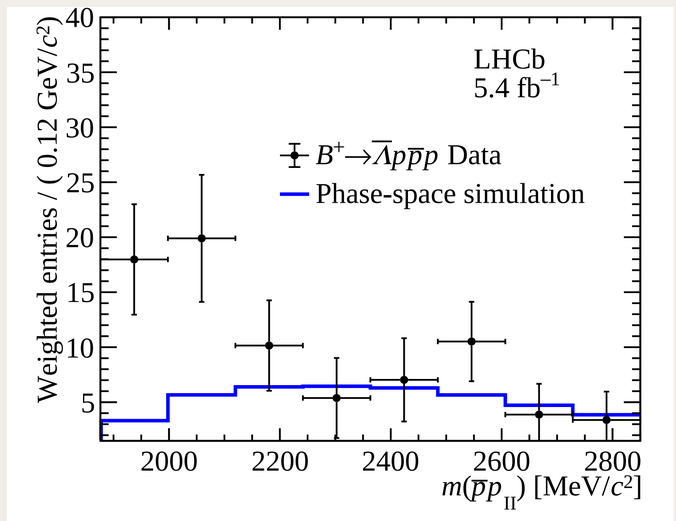
$$\boldsymbol{\mathcal{A}_{CP} = (5.4 \pm 15.6 \pm 2.4)\%}$$

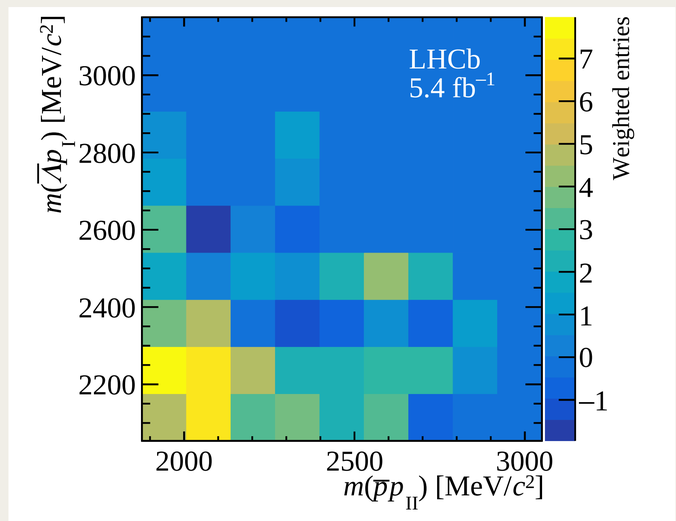
## Mass Spectra

The background-subtracted invariant-mass spectra of $\bar{\Lambda}p$ and $\bar{p}p$ obtained from the $sPlot$ technique , exhibit clear **threshold enhancement** near both the baryon–antibaryon mass thresholds. **The two protons are distinguished by the invariant mass with anti-baryons:**

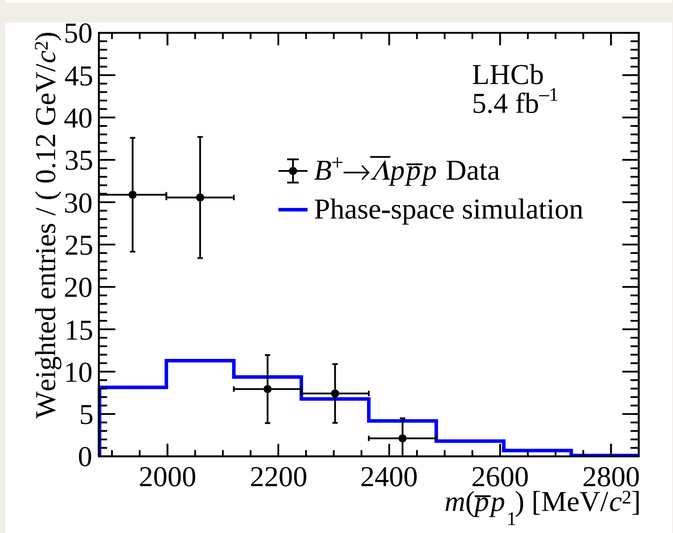
$m(\bar{\Lambda}p_{\mathrm{I}}) < m(\bar{\Lambda}p_{\mathrm{II}})$

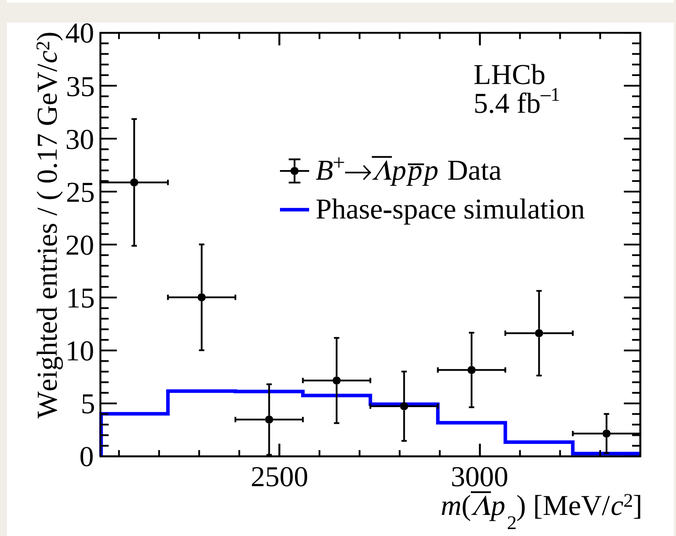


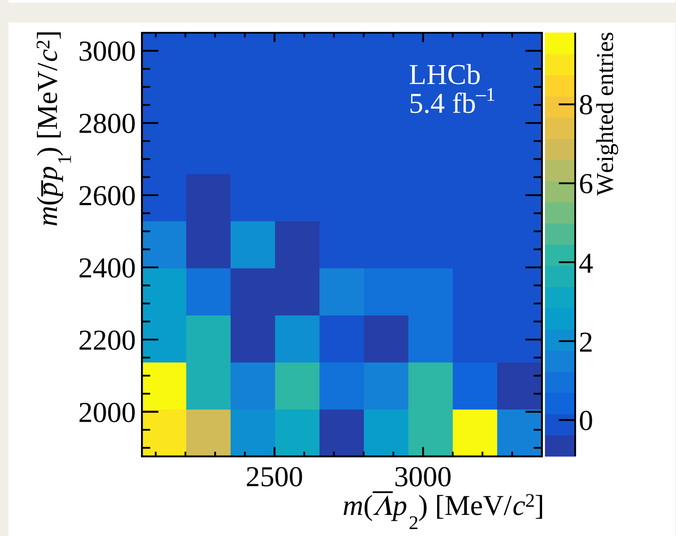




$m(\bar{p}p_1) < m(\bar{p}p_2)$




## Summary

- A purely baryonic four-body $B^+$ decay, $B^+ \to \bar{\Lambda}p\bar{p}p$ is observed with a signal significance greater than five standard deviations. The measured BF is lower than, but marginally consistent with a Standard Model prediction:

| | | |
|---|---|---|
| $\boldsymbol{\mathcal{B}(B^+ \to \bar{\Lambda}p\bar{p}p)}$ | $\boldsymbol{(2.08 \pm 0.34 \pm 0.12 \pm 0.26) \times 10^{-7}}$ | LHCb measurement |
| | $\boldsymbol{(7.4^{+0.6}_{-0.2} \pm 0.03^{+3.6}_{-2.6}) \times 10^{-7}}$ | Theory work: PL**B845**(2023)138158 |

- The background-subtracted invariant-mass spectra of $\bar{\Lambda}p$ and $\bar{p}p$ pairs exhibit a clear **double-threshold enhancement**
- Larger dataset from LHCb will allow for more precise measurement of the BFs, CP asymmetries, and **baryon-antibaryon structures**