

## ***B*-meson Decays to Vector Mesons and Charmless Decays at LHCb**

---

**Yanxi Wu<sup>a,b,\*</sup>, on behalf of the LHCb collaboration**

<sup>a</sup>*School of Physics, Peking University,  
5 Yiheyuan Road, Beijing, China*

<sup>b</sup>*Cavendish Laboratory, University of Cambridge,  
JJ Thomson Avenue, Cambridge, United Kingdom*

*E-mail: [yanxi.wu@cern.ch](mailto:yanxi.wu@cern.ch)*

Recent studies of *B*-meson decays at the LHCb experiment have provided new insights into modes with vector–vector final states, including  $B^+ \rightarrow \rho(770)^0 K^*(892)^+$ ,  $B_s^0 \rightarrow J/\psi \bar{K}^*(892)^0$ , and  $B^0 \rightarrow \phi\phi$ , as well as modes with charmless final states like  $B_{(s)}^0 \rightarrow K^0 p \bar{p}$  and  $B^+ \rightarrow \bar{\Lambda} p \bar{p}$ . Precise measurements of their branching fractions, *CP* asymmetries, and polarisation observables serve as tests of the Standard Model, where deviations could signal the presence of new physics.

*The European Physical Society Conference on High Energy Physics (EPS-HEP2025)  
7-11 July 2025  
Marseille, France*

---

\*Speaker

## 1. Introduction

Decays of  $B$ -meson into two vector mesons ( $B \rightarrow VV$ ) form a class of processes of particular interest. The measurements of their branching fractions,  $CP$  asymmetries, and polarisation observables provide sensitive probes of the underlying dynamics. Enhancements or deviations in these quantities could indicate contributions from physics beyond the Standard Model (SM). Complementary studies of charmless  $B$ -meson decays, including searches for new decay modes and precise branching fraction measurements, offer further opportunities to confront theoretical predictions and refine our understanding of hadronic processes. Together, these measurements provide stringent tests of the SM and valuable inputs for exploring possible new physics effects. These proceedings present an overview of the most recent studies from the LHCb experiment on  $B$ -meson decays to vector mesons and charmless final states.

The LHCb detector is a single-arm forward spectrometer optimised for beauty and charm physics. Its excellent performance in vertex resolution, particle identification, and momentum resolution enables precise, world-leading measurements of  $B$ -meson decays. The results presented here are based on proton–proton collision data collected during Run 1 and Run 2 period, corresponding to integrated luminosities of 3 and 6 fb<sup>-1</sup>, respectively.

## 2. $B$ -meson decays to vector mesons

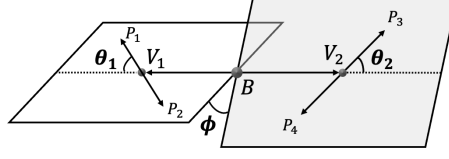
The  $B \rightarrow VV$  decays serve as a powerful probe for the dynamics of weak and strong interactions through their angular distributions. These decays are generally mediated by both tree-level and loop processes, carrying information about the SM flavor structure and the Cabibbo–Kobayashi–Maskawa (CKM) matrix [1]. The interference between these two types of processes can give rise to the combined charge conjugation and parity ( $CP$ ) violation.

Every  $B \rightarrow VV$  decay receives contributions from three helicity amplitudes, which, with an appropriate choice of basis, can be described by longitudinal ( $A_0$ ), perpendicular ( $A_\perp$ ), and parallel ( $A_\parallel$ ) components encoding different orbital angular momentum configurations between the two vector mesons [2]. In the naive factorisation ansatz [3], the SM predicts an almost total longitudinal polarisation,  $f_L \equiv |A_0|^2/(|A_0|^2 + |A_\perp|^2 + |A_\parallel|^2) \approx 1$ , which however has tension with the experimental measurements where  $f_L$  ranges from around 10% to almost 100% across different  $B \rightarrow VV$  decays. This “polarisation puzzle” motivates theoretical studies both in quantum chromodynamics (QCD) effects and new physics. To date, a coherent description of  $B \rightarrow VV$  decays remains challenging, which needs more detailed and precise measurements of them.

The decay topology of  $B \rightarrow VV$  decays is shown in Fig. 1, where each vector meson decays into two final-state particles, denoted  $P_i$  ( $i = 1, 2, 3, 4$ ). The differential decay rate of  $B \rightarrow (P_1 P_2)(P_3 P_4)$  is given by the squared modulus of the total amplitude

$$\frac{d\Gamma}{d\Omega} \propto \left| \sum_{i=1}^N A_i f_i(\Omega) \right|^2, \tag{1}$$

where  $\Omega$  denotes the set of kinematic variables, including the decay angles  $\theta_1$ ,  $\theta_2$  and  $\phi$  defined in Fig. 1, and may also include invariant masses when performing a full amplitude analysis. The functions  $f_i$  describe the dependence on the kinematic variables, with their specific forms



**Figure 1:** Decay angles for the  $B \rightarrow V_1(\rightarrow P_1 P_2) V_2(\rightarrow P_3 P_4)$  decay, where  $\theta_{1(2)}$  is the angle between the  $P_1(P_3)$  momentum in the  $V_{1(2)}$  rest frame and the  $V_{1(2)}$  momentum in the  $B$  rest frame.  $\phi$  is the angle between the two  $V$  decay planes.

determined by the models adopted in a given analysis. The coefficients  $A_i$  are the complex couplings for each amplitude. By studying the mass and angular distributions, the different amplitudes can be disentangled, enabling measurements of  $CP$  asymmetries and polarisation fractions.

### 2.1 Measurements of $CP$ violation and polarisation in $B^+ \rightarrow \rho(770)^0 K^*(892)^+$ decays

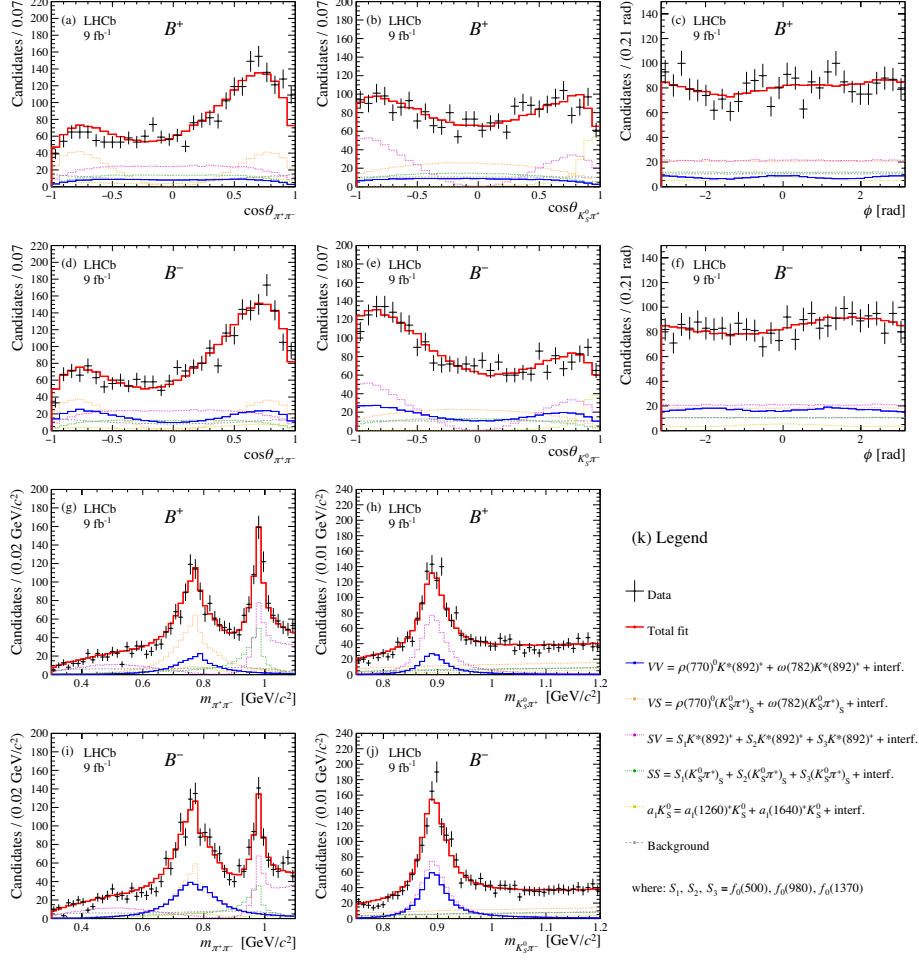
The  $B^+ \rightarrow \rho^0 K^{*+}$  decay, where  $\rho$  and  $K^*$  represent the  $\rho(770)$  and  $K^*(892)$  mesons, is a  $B \rightarrow VV$  decay with charmless final states, considering  $\rho^0 \rightarrow \pi^+ \pi^-$  and  $K^{*+} \rightarrow K_S^0 \pi^+$ . This decay was first observed by BaBar [4] collaboration. The measurement presented here is the first study by LHCb, with larger statistics expected from the full Run 1 and Run 2 datasets. The signal yields are obtained to be  $2208 \pm 53$  and  $2333 \pm 55$  for the  $B^+ \rightarrow (\pi^+ \pi^-)(K_S^0 \pi^+)$  and  $B^- \rightarrow (\pi^- \pi^+)(K_S^0 \pi^-)$  decays, respectively, where the quoted uncertainties are statistical [5].

A full amplitude analysis is performed for  $B^+ \rightarrow (\pi^+ \pi^-)(K_S^0 \pi^+)$  decays in the mass ranges  $0.3 < m_{\pi^+ \pi^-} < 1.1 \text{ GeV}/c^2$  and  $0.75 < m_{K_S^0 \pi^+} < 1.20 \text{ GeV}/c^2$ . In the  $\pi^+ \pi^-$  mass spectrum, in addition to the  $\rho(770)^0$  meson, several other resonances are identified, including the  $\omega(782)$ ,  $f_0(500)$ ,  $f_0(980)$  and  $f_0(1370)$  mesons. The  $K_S^0 \pi^+$  mass distribution is dominated by the  $K^*(892)^+$  resonance and a scalar contribution, denoted as the  $(K_S^0 \pi^+)_S$  component. A small fraction of  $B^+ \rightarrow a_1(1260)^+ K_S^0$  and  $B^+ \rightarrow a_1(1640)^+ K_S^0$  decays is observed in the sample, with  $a_1^+ \rightarrow \rho^0(\rightarrow \pi^+ \pi^-) \pi^+$ ,  $a_1^+ \rightarrow f_0(500)(\rightarrow \pi^+ \pi^-) \pi^+$ , and  $a_1^+ \rightarrow f_0(980)(\rightarrow \pi^+ \pi^-) \pi^+$ .

The amplitude fit projections onto five kinematic variables, including two invariant masses and three decay angles, are shown in Fig. 2. From the amplitude fit results, the  $CP$ -averaged longitudinal polarisation fraction is measured to be  $f_L = 0.720 \pm 0.028 \pm 0.009$ , and the direct  $CP$  asymmetry as  $\mathcal{A}_{CP} = 0.507 \pm 0.062 \pm 0.017$ , where the first uncertainties are statistical and the second systematic [5]. The significance of  $CP$  violation is measured to exceed nine standard deviations using a likelihood-ratio test [5]. This is the first observation of  $CP$  violation in the  $B^+ \rightarrow \rho^0 K^{*+}$  decay. The results are consistent with and more precise than those previously reported by the BaBar collaboration[4].

### 2.2 Measurements of $CP$ violation and polarisation in $B_s^0 \rightarrow J/\psi \bar{K}^*(892)^0$ decays

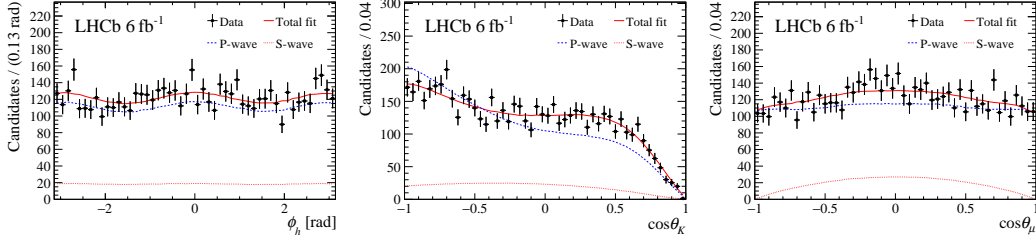
The  $B_s^0 \rightarrow J/\psi \phi$  decay serves as the benchmark channel for measuring the  $CP$ -violating phase  $\phi_s^{c\bar{c}s}$ . However, contributions from penguin diagrams can induce a phase shift, which makes the interpretation of experimental results complicated and theoretical calculations challenging. A data-driven approach has been proposed to constrain these penguin effects using  $CP$  asymmetries measured in  $b \rightarrow c\bar{c}d$  decays [6], such as  $B_s^0 \rightarrow J/\psi \bar{K}^{*0}$ , where the correspondence between  $b \rightarrow c\bar{c}s$  and  $b \rightarrow c\bar{c}d$  transitions is established under the assumption of  $SU(3)$  flavour symmetry.



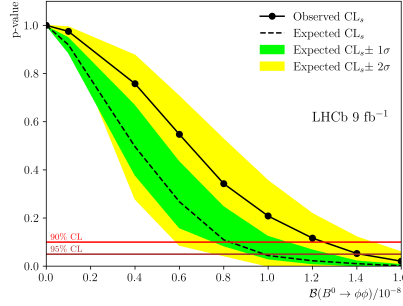
**Figure 2:** Projections of the multidimensional amplitude fit onto (a)  $\cos \theta_{\pi^+\pi^-}$ , (b)  $\cos \theta_{K_S^0\pi^+}$ , (c)  $\phi$ , (g)  $m_{\pi^+\pi^-}$ , and (h)  $m_{K_S^0\pi^+}$  for the  $B^+ \rightarrow (\pi^+\pi^-)(K_S^0\pi^+)$  decay. Plots (d)(e)(f)(i)(j) show the corresponding variables for the  $B^- \rightarrow (\pi^-\pi^+)(K_S^0\pi^-)$  decay [5].

This channel was previously studied by LHCb using Run 1 dataset [7], with the  $J/\psi$  reconstructed from  $\mu^+\mu^-$  and the  $\bar{K}^*$  from  $K^-\pi^+$ . The present work reports an updated angular analysis based on Run 2 dataset. The yield of  $B_s^0 \rightarrow J/\psi K^-\pi^+$  candidates is determined to be  $6098 \pm 84$  [8], where the uncertainty is statistical only.

The  $K^-\pi^+$  spectrum receives contributions from both the  $K^*$  resonance and the  $(K\pi)$  S-wave. An angular analysis is performed to measure the  $CP$  asymmetry and polarisation in  $B_s^0 \rightarrow J/\psi \bar{K}^{*0}$  decays. The angular fit projections onto the three decay angles are shown in Fig. 3. Combining the Run 2 results with those from Run 1 [7], the longitudinal and parallel polarisation fractions are measured to be  $f_L = 0.534 \pm 0.012 \pm 0.009$  and  $f_{\parallel} = 0.211 \pm 0.014 \pm 0.005$ , respectively [8], where the first and second uncertainties are statistical and systematic. The  $CP$  asymmetries are measured with a precision of 3 – 7% and are found to be consistent with zero. The branching fraction relative to  $B^0 \rightarrow J/\psi K^{*0}$  decay is determined to be  $\mathcal{B}(B_s^0 \rightarrow J/\psi \bar{K}^{*0})/\mathcal{B}(B^0 \rightarrow J/\psi K^{*0}) = (3.12 \pm 0.09 \pm 0.06 \pm 0.10)\%$  [8], where the last uncertainty comes from the ratio of hadronisation



**Figure 3:** Projections of the angular fit result onto the angles (left)  $\phi_h$ , (middle)  $\cos \theta_K$ , and (right)  $\cos \theta_\mu$  for the background-subtracted  $B_S^0 \rightarrow J/\psi \bar{K}^{*0}$  data sample [8].



**Figure 4:** Results of the  $CL_s$  method for setting an upper limit on the  $B^0 \rightarrow \phi\phi$  branching fraction [10].

fractions  $f_d/f_s$ . These combined results from LHCb provide the most precise determinations of these observables to date.

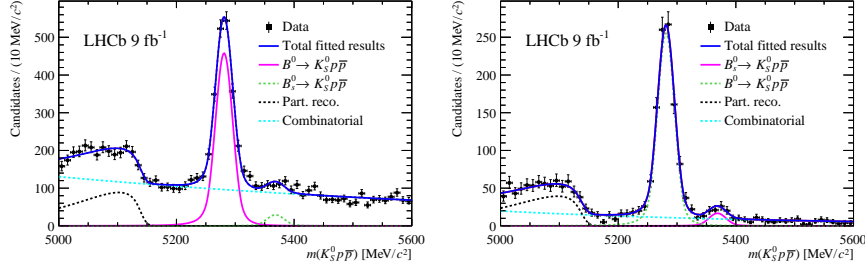
### 2.3 Search for the decay $B^0 \rightarrow \phi\phi$

The  $B^0 \rightarrow \phi\phi$  decay differs from the other  $B \rightarrow VV$  modes discussed above. It proceeds via a  $\bar{b}d \rightarrow s\bar{s}$  annihilation and is strongly suppressed, requiring at least one loop and being both Cabibbo and OZI suppressed. This decay has not yet been observed. Theoretical predictions for its branching fraction span a wide range,  $(0.5-5) \times 10^{-8}$ , with potential enhancements from long-range contributions such as  $\omega - \phi$  mixing, rescattering processes, or contributions from new physics. The previous most stringent limit, set by LHCb, was  $\mathcal{B}(B^0 \rightarrow \phi\phi) < 2.7 \times 10^{-8}$  at 90% confidence level (CL) [9], with  $\phi \rightarrow K^+K^-$ . This analysis uses the full Run 1 and Run 2 datasets, which not only double the statistics, but also provide a more detailed understanding of background, allowing for a significant reduction in background levels.

A maximum-likelihood fit to the invariant mass distribution  $m(K^+K^-K^+K^-)$  is performed to extract signal candidates. No significant signal is observed and the results are consistent with the background-only hypothesis at the level of  $1.9\sigma$  [10]. The  $CL_s$  calculation, shown in Fig. 4, yields an upper limit on the branching fraction of  $\mathcal{B}(B^0 \rightarrow \phi\phi) < 1.3(1.4) \times 10^{-8}$  at 90%(95%) CL [10]. This result improves the previous best limit [9] by nearly a factor of two.

## 3. Searches for new charmless B-meson decays

B-meson decays without charm or charmonium contribution in the final states, referred to as



**Figure 5:** Invariant-mass distributions of  $K_S^0 p \bar{p}$  candidates corresponding to the decays (left)  $B^0 \rightarrow K^0 p \bar{p}$  and (right)  $B_s^0 \rightarrow K^0 p \bar{p}$ , with fit results overlaid. [13]

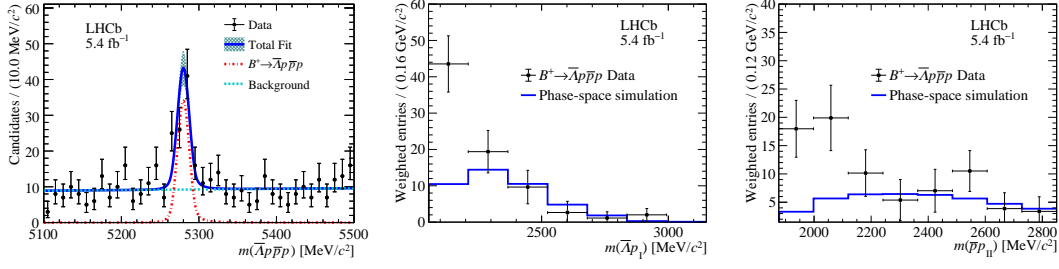
charmless  $B$ -meson decays, are suppressed in SM. They proceed either via the CKM-suppressed  $b \rightarrow u$  tree-level transition or through  $b \rightarrow s, d$  penguin processes. These two contributions have comparable magnitudes and a relative weak phase, and their interference can give rise to  $CP$  violation in the decay. Multi-body charmless  $B$ -meson decays also exhibit rich resonance structures that can be explored. Precise measurements of branching fractions and  $CP$  asymmetries in charmless decays provide important tests of QCD-based models and serve as sensitive probes of potential new physics, where additional particles could contribute to penguin loops or introduce new sources of  $CP$  violation.

### 3.1 Observation of the decay $B_s^0 \rightarrow K^0 p \bar{p}$ and measurement of the $B_{(s)}^0 \rightarrow K^0 p \bar{p}$ branching fractions

The  $B_{(s)}^0 \rightarrow K^0 p \bar{p}$  decays proceed via both the  $b \rightarrow u$  tree-level transition and the  $b \rightarrow q \bar{q} s$  ( $b \rightarrow q \bar{q} d$ ) penguin processes, where the spectator quark is  $d$  ( $s$ ) and  $q$  denotes  $u, d$ . The relative branching fractions of  $B^0 \rightarrow K^0 p \bar{p}$  and  $B_s^0 \rightarrow K^0 p \bar{p}$  decays provide precise tests of flavour symmetries, as their underlying quark-level diagrams are related by the interchange of  $d$  and  $s$  quarks. The observed threshold enhancement in the  $p \bar{p}$  mass spectrum indicates the involvement of non-trivial intermediate states that influence the decay dynamics. While the branching fraction of the  $B^0 \rightarrow K^0 p \bar{p}$  decay has been measured previously by Belle and BaBar [11, 12], the  $B_s^0 \rightarrow K^0 p \bar{p}$  decay has not been observed until now.

A search for the decay  $B_s^0 \rightarrow K^0 p \bar{p}$  and a measurement of the branching fraction of  $B_{(s)}^0 \rightarrow K^0 p \bar{p}$  decays are performed using the combined Run 1 and Run 2 datasets. In both decays,  $K^0$  candidates are reconstructed through the two-pion decay of its short-lived mass eigenstate,  $K_S^0 \rightarrow \pi^+ \pi^-$ . The overall event selection is similar for the two modes, but separate samples are obtained, optimised either for the branching fraction measurement of  $B_s^0 \rightarrow K^0 p \bar{p}$  or for the search for  $B^0 \rightarrow K^0 p \bar{p}$ . Signal yields are extracted using unbinned maximum-likelihood fits to the  $K_S^0 p \bar{p}$  invariant-mass distributions in the two optimised samples, as shown in Fig. 5. The  $B_s^0 \rightarrow K^0 p \bar{p}$  decay is observed for the first time, with a significance of 5.6 standard deviations, including both statistical and systematic uncertainties [13].

Using the  $B^0 \rightarrow K_S^0 \pi^+ \pi^-$  decay as the normalisation channel, the branching fractions are measured to be  $\mathcal{B}(B^0 \rightarrow K^0 p \bar{p}) = (2.82 \pm 0.08 \pm 0.12 \pm 0.10) \times 10^{-6}$  and  $\mathcal{B}(B_s^0 \rightarrow K^0 p \bar{p}) = (9.14 \pm 1.69 \pm 0.90 \pm 0.33 \pm 0.20) \times 10^{-7}$  [13]. Here, the first and second uncertainties are statistical and systematic, while the third and fourth arise from the uncertainties in the branching



**Figure 6:** (Left) Invariant-mass distribution of  $B^+ \rightarrow \bar{\Lambda} p \bar{p} p$  candidates with  $m(p\bar{p}) < 2850 \text{ MeV}/c^2$ . Distributions of background-subtracted (middle)  $m(\bar{\Lambda} p_{\text{I}})$  and (right)  $m(\bar{p} p_{\text{II}})$  for  $B^+ \rightarrow \bar{\Lambda} p \bar{p} p$  candidates in data compared with phase-space simulation [16].

fraction of the normalisation channel and in the ratio of hadronisation fractions  $f_s/f_d$ , respectively. The result for  $\mathcal{B}(B^0 \rightarrow K^0 p \bar{p})$  is consistent with and more precise than the world average of  $(2.66 \pm 0.32) \times 10^{-6}$  [14].

### 3.2 First observation of the charmless baryonic decay $B^+ \rightarrow \bar{\Lambda} p \bar{p} p$

The  $B^+ \rightarrow \bar{\Lambda} p \bar{p} p$  decay is a purely baryonic four-body mode that has not previously been observed. Its branching fraction is predicted to be  $(7.4^{+0.6}_{-0.2} \pm 0.03^{+3.6}_{-2.6}) \times 10^{-7}$  [15]. The mass spectrum of this decay is of particular interest, as it exhibits a double-threshold enhancement arising from the presence of two baryon–antibaryon pairs [15]. Its study also provides valuable input for understanding baryonium-like bound states, such as the  $X(1835)$  and  $X(2085)$ .

The search for the  $B^+ \rightarrow \bar{\Lambda} p \bar{p} p$  decay is performed using data collected between 2016 and 2018. Signal candidates are extracted with unbinned maximum-likelihood fits to the  $\bar{\Lambda} p \bar{p} p$  invariant-mass distributions, as shown in Fig. 6. The signal yield is measured to be  $78 \pm 12$ , corresponding to a significance exceeding five standard deviations. The branching fraction is measured to be  $\mathcal{B}(B^+ \rightarrow \bar{\Lambda} p \bar{p} p) = (2.08 \pm 0.34 \pm 0.12 \pm 0.26) \times 10^{-7}$  [16], where the first uncertainty is statistical, the second systematic, and the third arises from the external branching fraction of the normalisation channel  $B^+ \rightarrow J/\psi(\rightarrow \bar{\Lambda} p K^-) K^+$ . The  $CP$  asymmetry is measured to be  $\mathcal{A}_{CP} = (5.4 \pm 15.6 \pm 2.4)\%$ .

The background-subtracted invariant-mass spectra of the  $\bar{\Lambda} p_{\text{I}}$  and  $\bar{p} p_{\text{II}}$  pairs are shown in Fig. 6, where  $p_{\text{I}}$  denotes the proton combined with the  $\bar{\Lambda}$  baryon to yield the lower invariant mass  $m(\bar{\Lambda} p)$ , and  $p_{\text{II}}$  is the remaining proton paired with the antiproton to form the second baryon–antibaryon combination. A double threshold enhancement is observed, indicated by the peaks near the respective kinematic thresholds.

## 4. Conclusions

The most recent measurements of  $B \rightarrow VV$  and charmless  $B$ -meson decays performed by the LHCb collaboration have been reviewed. These include measurements of  $CP$  asymmetries and polarisation fractions in  $B^+ \rightarrow \rho^0 K^{*+}$  and  $B_s^0 \rightarrow J/\psi \bar{K}^{*0}$  decays, and a search for the  $B^0 \rightarrow \phi \phi$  decay that sets the most stringent upper limits on its branching fraction. The  $B_s^0 \rightarrow K^0 p \bar{p}$  and  $B^+ \rightarrow \bar{\Lambda} p \bar{p} p$  decays have been observed for the first time, with branching fractions measured for both channels. These results represent the most precise determinations to date and provide essential input for testing and refining theoretical models.

## References

- [1] C.-D. Lü, *Charmless hadronic B and B<sub>s</sub> decays in perturbative QCD approach*, *Int. J. Mod. Phys. A* **23** (2008) 3250, [arXiv:0807.3061](#).
- [2] M. Beneke, J. Rohrer, and D. Yang, *Branching fractions, polarisation and asymmetries of B → VV decays*, *Nucl. Phys. B* **774** (2007) 64, [arXiv:hep-ph/0612290](#).
- [3] J. G. Körner and G. R. Goldstein, *Quark and particle helicities in hadronic charmed particle decays*, *Phys. Lett. B* **89** (1979) 105.
- [4] BaBar collaboration, P. del Amo Sanchez *et al.*, *Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in B<sup>+</sup> → ρ<sup>0</sup>K<sup>\*+</sup> and B<sup>+</sup> → f<sub>0</sub>(980)K<sup>\*+</sup> decays*, *Phys. Rev. D* **83** (2011) 051101, [arXiv:1012.4044](#).
- [5] LHCb collaboration, R. Aaij *et al.*, *First observation of CP violation and measurement of polarization in B<sup>+</sup> → ρ(770)<sup>0</sup>K<sup>\*</sup>(892)<sup>+</sup> decays*, [arXiv:2508.13563](#), Submitted to *Phys. Rev. Lett.*
- [6] R. Fleischer, *Extracting CKM phases from angular distributions of B(d,s) decays into admixtures of CP eigenstates*, *Phys. Rev. D* **60** (1999) 073008, [arXiv:hep-ph/9903540](#).
- [7] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP violation parameters and polarisation fractions in B<sub>s</sub><sup>0</sup> → J/ψK<sup>\*0</sup> decays*, *JHEP* **11** (2015) 082, [arXiv:1509.00400](#).
- [8] LHCb collaboration, R. Aaij *et al.*, *Updated measurement of CP violation and polarisation in B<sub>s</sub><sup>0</sup> → J/ψK<sup>\*0</sup>(892)<sup>0</sup> decays*, *JHEP* **10** (2025) 173, [arXiv:2506.22090](#).
- [9] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP violation in the B<sub>s</sub><sup>0</sup> → φφ decay and search for the B<sup>0</sup> → φφ decay*, *JHEP* **12** (2019) 155, [arXiv:1907.10003](#).
- [10] LHCb collaboration, R. Aaij *et al.*, *Search for the decay B<sup>0</sup> → φφ*, [arXiv:2507.20945](#), Submitted to *JHEP*.
- [11] Belle collaboration, J. H. Chen *et al.*, *Observation of B<sup>0</sup> → p $\bar{p}$ K<sup>\*0</sup> with a large K<sup>\*0</sup> polarization*, *Phys. Rev. Lett.* **100** (2008) 251801, [arXiv:0802.0336](#).
- [12] BaBar collaboration, B. Aubert *et al.*, *Evidence for the B<sup>0</sup> → p $\bar{p}$ K<sup>\*0</sup> and B<sup>+</sup> → η<sub>c</sub>K<sup>\*+</sup> decays and study of the decay dynamics of B meson decays into p $\bar{p}$ h final states*, *Phys. Rev. D* **76** (2007) 092004, [arXiv:0707.1648](#).
- [13] LHCb collaboration, R. Aaij *et al.*, *Observation of the decay B<sub>s</sub><sup>0</sup> → K<sub>S</sub><sup>0</sup>p $\bar{p}$  and measurement of the B<sub>(s)</sub><sup>0</sup> → K<sub>S</sub><sup>0</sup>p $\bar{p}$  branching fractions*, *JHEP* **07** (2025) 121, [arXiv:2504.21269](#).
- [14] Particle Data Group, S. Navas *et al.*, *Review of particle physics*, *Phys. Rev. D* **110** (2024) 030001.
- [15] Y.-K. Hsiao, *Four-body baryonic B → B<sub>1</sub> $\bar{B}'_1$ B<sub>2</sub> $\bar{B}'_2$  decays*, *Phys. Lett. B* **845** (2023) 138158, [arXiv:2212.01954](#).
- [16] LHCb collaboration, R. Aaij *et al.*, *First observation of the charmless baryonic decay B<sup>+</sup> →  $\bar{\Lambda}$ p $\bar{p}$ p*, [arXiv:2508.16259](#), Submitted to *Phys. Rev. Lett.*