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Observation of the suppressed $\Lambda_b^0 \to DpK^-$ decay with $D \to K^+\pi^-$ and measurement of its CP asymmetry

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Abstract

A study of Λ_b^0 baryon decays to the DpK^- final state is presented based on a proton-proton collision data sample corresponding to an integrated luminosity of $9\,\text{fb}^{-1}$ collected with the LHCb detector. Two Λ_b^0 decays are considered, $\Lambda_b^0 \to DpK^-$ with $D \to K^-\pi^+$ and $D \to K^+\pi^-$, where D represents a superposition of D^0 and $\overline{D}^0$ states. The latter process is expected to be suppressed relative to the former, and is observed for the first time. The ratio of branching fractions of the two decays is measured, and the CP asymmetry of the suppressed mode, which is sensitive to the CKM angle γ, is also reported.

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1 Introduction

Few studies of beauty-baryon decays to final states involving a single open-charm meson exist, but they are nonetheless promising for measurements of *CP* violation [1–3]. A measurement of a set of branching fraction ratios of Λ_b^0 and Ξ_b decays to final states including a D meson yielded the first observation of the singly-Cabibbo-suppressed $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ decay [4], where D represents a D^0 or $\overline{D}{}^0$ meson.[1] This was followed by a study of the resonant structure of $\Lambda_b^0 \to D^0 p\pi^-$ decays [5]. This paper reports the results of a study of $\Lambda_b^0 \to DpK^-$ decays with the objectives of observing for the first time the $\Lambda_b^0 \to DpK^-$ decay with $D \to K^+\pi^-$, denoted as $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ and measuring its *CP* asymmetry. This decay is expected to be suppressed relative to the $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ decay. An estimate of the ratio of branching fractions between the favoured and suppressed modes is obtained by considering the relevant Cabibbo-Kobayashi-Maskawa (CKM) matrix elements [6]

$$R \approx \left|\frac{V_{cb}V_{us}^*}{V_{ub}V_{cs}^*}\right|^2 = 6.0. \tag{1}$$

The $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ ($\Lambda_b^0 \to [K^+\pi^-]_D pK^-$) decay with same (opposite) sign kaons are referred to as the favoured (suppressed) decay throughout this paper. The suppressed decay is of particular interest since its decay amplitude receives contributions from $b \to c$ and $b \to u$ amplitudes of similar magnitude, given the CKM suppression between the two D decays. The interference between these two amplitudes, which depends upon the CKM angle γ, is expected to be large [7, 8], but the different strong phases associated with the various configurations of polarisation states for the Λ_b^0, proton, and intermediate resonances complicate determination of γ.

The analysis is based on proton-proton (pp) collision data collected with the LHCb detector at $\sqrt{s} = 7$, 8, and 13 TeV, corresponding to a total integrated luminosity of $9\,\text{fb}^{-1}$. The suppressed $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ decay is observed for the first time. In addition the ratio of branching fractions of the favoured and suppressed decays, R, and the *CP* asymmetry in the suppressed mode, A, which is expected to be sensitive to the CKM angle γ, are measured where

$$R = \frac{\mathcal{B}(\Lambda_b^0 \to [K^-\pi^+]_D pK^-)}{\mathcal{B}(\Lambda_b^0 \to [K^+\pi^-]_D pK^-)},$$

including both flavours, and

$$A = \frac{\mathcal{B}(\Lambda_b^0 \to [K^+\pi^-]_D pK^-) - \mathcal{B}(\overline{\Lambda}_b^0 \to [K^-\pi^+]_D \overline{p}K^+)}{\mathcal{B}(\Lambda_b^0 \to [K^+\pi^-]_D pK^-) + \mathcal{B}(\overline{\Lambda}_b^0 \to [K^-\pi^+]_D \overline{p}K^+)}. \tag{2}$$

Sensitivity to *CP*-violation requires interference between amplitudes involving intermediate D^0 and $\overline{D}{}^0$ mesons. This interference is anticipated to be amplified in regions of the phase space involving $\Lambda_b^0 \to DX$ contributions, where X labels excited Λ states. Therefore, the ratio of branching fractions and the *CP* asymmetry in the suppressed mode are measured separately in the full phase space and in a restricted phase-space region which involves $\Lambda_b^0 \to DX$ decays, where an enhanced sensitivity to γ is expected.

[1] Charge conjugation is implied throughout this document except in reference to *CP* asymmetries or comparisons of Λ_b^0 and $\overline{\Lambda}_b^0$ samples.

2 Detector and simulation

The LHCb detector [9,10] is a single-arm forward spectrometer covering the pseudorapidity range $2 < \eta < 5$, designed for the study of particles containing b or c quarks. The detector includes a high-precision tracking system consisting of a silicon-strip vertex detector surrounding the pp interaction region [11], a large-area silicon-strip detector located upstream of a dipole magnet with a bending power of about 4 Tm, and three stations of silicon-strip detectors and straw drift tubes [12, 13] placed downstream of the magnet. The tracking system provides a measurement of the momentum, p, of charged particles with a relative uncertainty that varies from 0.5% at low momentum to 1.0% at 200 GeV/c. The minimum distance of a track to a primary pp collision vertex (PV), the impact parameter (IP), is measured with a resolution of $(15 + 29/p_{\rm T})\,\mu$m, where $p_{\rm T}$ is the component of the momentum transverse to the beam, in GeV/c. Different types of charged hadrons are distinguished using information from two ring-imaging Cherenkov detectors [14]. Hadrons are identified by a calorimeter system consisting of scintillating-pad and preshower detectors, an electromagnetic and a hadronic calorimeter. The online event selection is performed by a trigger [15], which consists of a hardware stage, based on information from the calorimeter, followed by a software stage, which applies a full event reconstruction.

Simulation is required to model the effects of the detector acceptance and the imposed selection requirements. In the simulation, pp collisions are generated using Pythia [16] with a specific LHCb configuration [17]. Decays of unstable particles are described by EvtGen [18], in which final-state radiation is generated using Photos [19]. The interaction of the generated particles with the detector, and its response, are implemented using the Geant4 toolkit [20] as described in Ref. [21].

The particle identification (PID) response in the simulated samples is corrected using control samples of $\Lambda_c^+ \to pK^-\pi^+$ decays in LHCb data, taking into account its correlation with the kinematic properties of each track and with the event multiplicity. To parametrise the PID response, an unbinned method is employed, where the probability density functions (PDFs) are modelled using kernel density estimation [22].

3 Reconstruction and selection of candidates

Neutral D meson candidates are reconstructed by combining kaon and pion candidates having opposite charge. To form Λ_b^0 candidates, the neutral D meson candidates are combined with proton and kaon candidates having opposite charge. Each Λ_b^0 candidate is associated to the PV for which the value of $\chi^2_{\rm IP}$ is minimised, where $\chi^2_{\rm IP}$ is the difference between the vertex χ^2 of a given PV with and without the Λ_b^0 candidate included in the PV fit. The tracks forming the Λ_b^0 candidate are required to have good fit quality and to be well separated from any PV in the event. The invariant masses of the Λ_b^0 candidate, $M(DpK^-)$, and of the D candidate, $M(K\pi)$, are required to be in the intervals from 5200 to 7000 MeV/c^2 and 1850 to 1880 MeV/c^2, respectively. Candidates with $M(K\pi)$ in a wider mass range from 1765 to 1965 MeV/c^2 are retained to quantify the background contribution from charmless b-hadron decays. A kinematic fit is performed in which $M(K\pi)$ is constrained to the known D^0 mass [6] and the Λ_b^0 candidate's trajectory is required to point back to the associated PV [23]. To improve the resolution of the squared

invariant masses $M^2(Dp)$, $M^2(DK^-)$ and $M^2(pK^-)$, the fit is repeated when calculating these variables, with the additional constraint that the invariant mass of the DpK^- combination is equal to the known Λ_b^0 mass [6]. Inclusion of the mass constraint improves the resolution on the two-body masses by 50% or more, depending upon position in the three-body phase space.

Background from $\Lambda_b^0 \to \Lambda_c^+ h^-$ decays, with $\Lambda_c^+ \to p h^- h^+$ where h is a charged kaon or pion, are vetoed by requiring that the invariant mass of any ph^-h^+ combination differs from the known Λ_c^+ mass [6] by more than $20\,\mathrm{MeV}/c^2$. To suppress the contribution of events from charmless $\Lambda_b^0 \to p h^- h^+ h^-$ decays, the decay-time significance of the D meson candidates with respect to the Λ_b^0 vertex is required to be larger than 2.5. The decay-time significance of the D candidate is defined as the measured decay time divided by its uncertainty.

To suppress combinatorial background, a Boosted Decision Tree (BDT) algorithm using adaptive boosting [24] is employed as implemented in the TMVA toolkit [25]. To train the BDT classifier, one for the full and another for the restricted phase space, a sample of simulated $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ decays is used as a proxy for signal and candidates in the Λ_b^0 mass sidebands with mass in the intervals from 5300 to 5400 MeV/c^2 and from 5900 to 6000 MeV/c^2 are used to represent combinatorial background. The variables that enter the BDT selection are the quality of the kinematic fit, the quality of the Λ_b^0 and D vertices and their decay-time significances, PID variables, and the p_T of the final-state particles. The optimisation criterion used to determine the choice of BDT working point is the maximum expected statistical significance of the suppressed signal, $N_\mathrm{sig}/\sqrt{N_\mathrm{sig}+N_\mathrm{bkg}}$, where N_sig and N_bkg are the expected numbers of signal and background candidates in the mass interval from 5600 to 5640 MeV/c^2. The expected number of suppressed signal decays is determined by dividing the observed yield in the favoured decay by the Cabibbo suppression factor defined in Eq. 1 using values for the CKM matrix elements taken from [26]. In 0.1% of events multiple Λ_b^0 candidates are reconstructed. All the candidates are retained.

4 Determination of signal yields

The mass distributions for the DpK^- candidates in the favoured and suppressed data samples in the full phase space are shown in Fig. 1. The number of signal candidates is obtained by an extended unbinned maximum-likelihood fit to the $M(DpK^-)$ mass distributions using the RooFit package [27]. The favoured and suppressed samples are fitted simultaneously. The PDF used for the favoured sample is made of two components to model $\Lambda_b^0 \to DpK^-$ and $\Xi_b^0 \to DpK^-$ signals, a background from misidentified $\Lambda_b^0 \to Dp\pi^-$ decays, and a partially reconstructed background from $\Lambda_b^0 \to D^* pK^-$ decays where $D^{*0} \to D^0\gamma$ or $D^{*0} \to D^0\pi^0$ and the γ or π^0 particle is not reconstructed. Additional components are required to describe the background due to partially reconstructed $\Lambda_b^0 \to D^* p\pi^-$ decays, with $D^{*0} \to D^0\gamma$ or $D^{*0} \to D^0\pi^0$ and having the pion from the Λ_b^0 decay misidentified as a kaon, partially reconstructed $\Xi_b^0 \to D^* pK^-$ decays, which peak in the signal region, and from combinatorial background. The PDF used to fit the suppressed sample is the same, except that it does not include contributions from the $\Xi_b^0 \to D^{(*)} pK^-$ and $\Lambda_b^0 \to D^{(*)} p\pi^-$ decays, which are expected to be negligible.

The parametrised shape of each component is taken from a fit to simulated decays

after all selections are applied. The signal and partially reconstructed background are each modelled by the sum of two Crystal Ball (CB) functions [28], where the parameters governing the shape of the tails are fixed to their values in fits to simulated samples. The background from misidentified $\Lambda_b^0 \to Dp\pi^-$ decays is parametrised by the sum of a Gaussian and a CB function. In the restricted phase-space region, $M^2(pK^-) < 5\,\mathrm{GeV}^2/c^4$, the same functional forms are used, except that the partially reconstructed background is parametrised by the sum of a bifurcated Gaussian and a CB function. The combinatorial background is described by an exponential function. The slope of the combinatorial background is allowed to vary independently in the favoured and suppressed samples. The widths of each peaking component are multiplied by a common free parameter in order to account for the difference between the invariant-mass resolution observed in data and simulation. The mass of the Λ_b^0 baryon is a free parameter, while the mass difference between Ξ_b^0 and Λ_b^0 baryons is fixed to its known value [6]. The yields of each component are allowed to vary independently in the favoured and suppressed samples.

The projection of the fit to the invariant-mass distribution $M(DpK^-)$ in the favoured and suppressed data samples in the full phase space is shown in Fig. 1. The Λ_b^0 yields are given in Table 1. Figure 2 shows the invariant-mass distribution $M(DpK^-)$ in the favoured and suppressed data samples in the restricted phase-space region $M^2(pK^-) < 5\,\mathrm{GeV}^2/c^4$ with the fit projections overlaid. The signal yields obtained from this fit are given in Table 1. The invariant-mass distributions $M(DpK^-)$ and $M(D\overline{p}K^+)$, overlaid with the fit projections, used to calculate the *CP* asymmetry of the suppressed decay in the full phase space and in the restricted phase-space region are shown in Figs. 3 and 4, respectively.

Table 1: Signal Λ_b^0 yields obtained from fits to the invariant-mass distributions, $M(DpK^-)$, for the favoured and suppressed decay samples in the two phase-space regions.

Phase-space region	$\Lambda_b^0 \to [K^-\pi^+]_D pK^-$	$\Lambda_b^0 \to [K^+\pi^-]_D pK^-$
Full	1437 ± 92	241 ± 22
Restricted	664 ± 36	84 ± 14

The resonant structure of the favoured and suppressed decays can be illuminated by considering projections of the Λ_b^0 phase space. Figure 5 shows the $M^2(pK^-)$ versus $M^2(Dp)$ distributions of favoured and suppressed candidates in the signal region $5600 < M(DpK^-) < 5640\,\mathrm{MeV}/c^2$. The signal purity in this region is 76% and 72% for the favoured and suppressed modes, respectively. Despite the smaller combinatorial background, the signal purity for the favoured decay is comparable to that for the suppressed decay due to the presence of the background from $\Xi_b^0 \to D^*pK^-$ and $\Lambda_b^0 \to Dp\pi^-$ decays in the signal region. Figures 6 and 7 show invariant-mass projections onto $M(pK^-)$, $M(Dp)$ and $M(DK^-)$ for selected candidates. The dominant resonant amplitudes in the favoured mode could generate structures in the $M(Dp)$ and $M(pK^-)$ distributions, corresponding to states having *udc* and *uds* quark content, respectively. The $M(Dp)$ distribution shows an increased density of events in the low-$M(Dp)$ region with a contribution from $\Lambda_c(2860)^+ \to D^0p$ decays. The distribution of $M(pK^-)$ contains a contribution from the $\Lambda(1520)$ baryon at low-$M(pK^-)$ and an enhancement at $2.5 \lesssim M(pK^-) \lesssim 3.5\,\mathrm{GeV}/c^2$, which is the reflection of the $\Lambda_c(2860)^+$ resonance seen in the $M(Dp)$ distribution. Different resonant structure is anticipated in the suppressed sample given the contributions from, and interference between, the $\Lambda_b^0 \to D^0pK^-$ and $\Lambda_b^0 \to \overline{D}^0pK^-$ amplitudes. The $M(DK^-)$

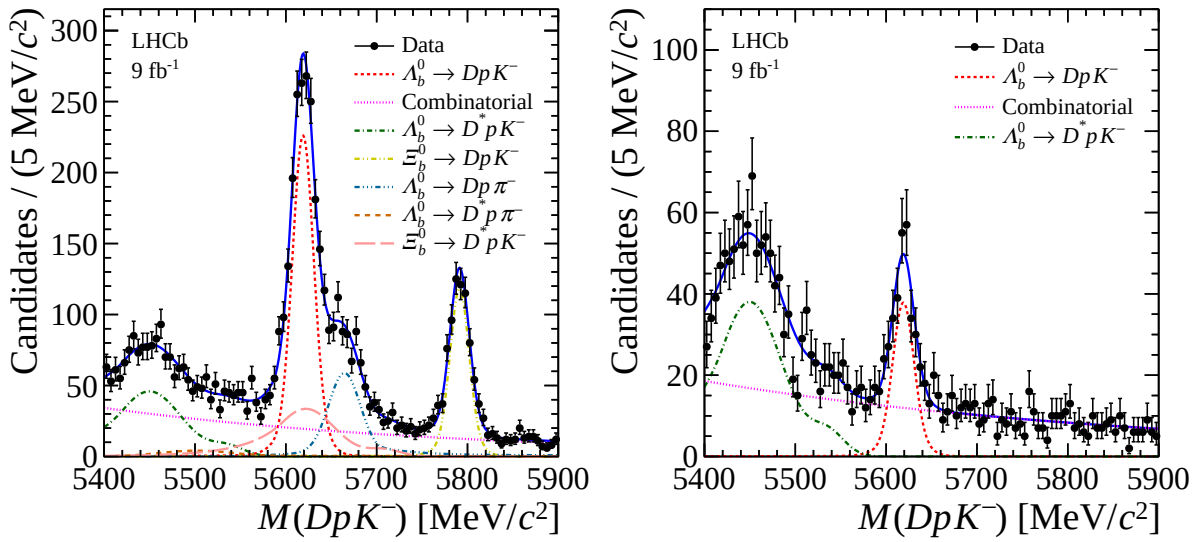

Figure 1: Distributions of the invariant mass for selected (left) $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ and (right) $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ candidates in the full phase space (black points) corresponding to the favoured and suppressed decays, respectively. The total fit model, as described in the text, is indicated by the solid blue line, and individual components are indicated.

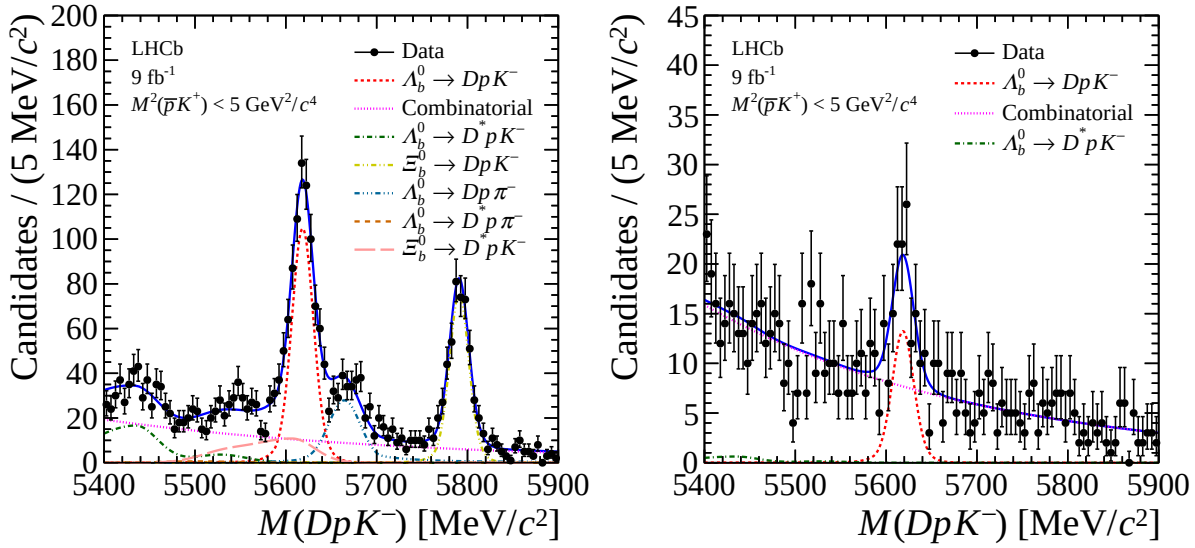

Figure 2: Distributions of the invariant mass for (left) $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ and (right) $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ candidates, corresponding to the favoured and suppressed decays, respectively, in the restricted phase-space region $M^2(pK^-) < 5\,\mathrm{GeV}^2/c^4$. The fit, as described in the text, is overlaid.

distribution in the suppressed sample shows an increased density of events in the low-mass region with a contribution from resonances decaying to DK^- such as the $D_{s1}^*(2700)^\pm$.

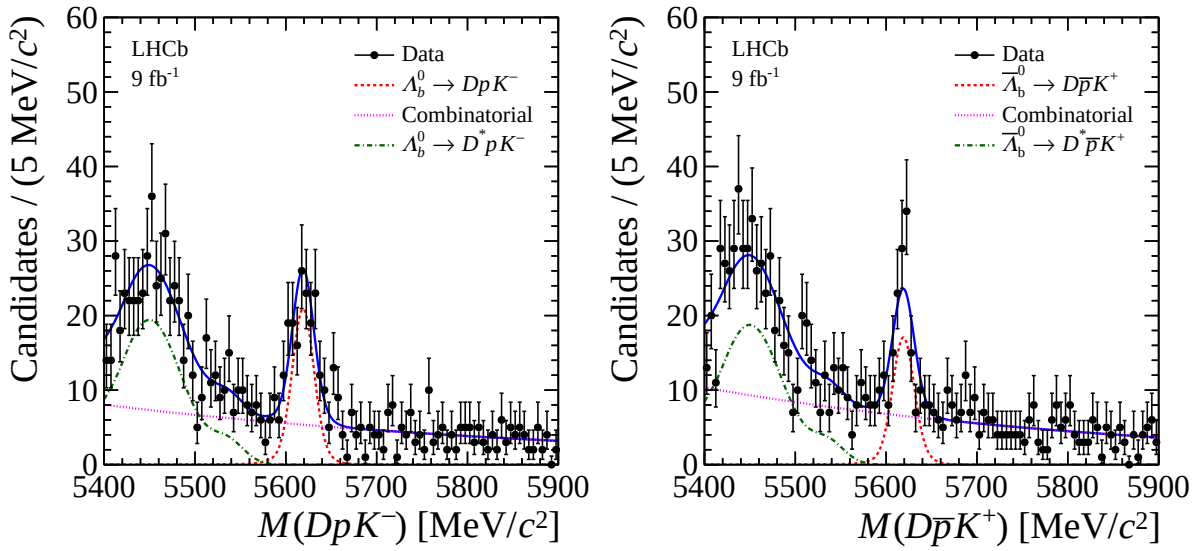

Figure 3: Distributions of the invariant mass for (left) $\Lambda_b^0 \to [K^+\pi^-]_D p K^-$ and (right) $\overline{\Lambda}_b^0 \to [K^-\pi^+]_D \overline{p} K^+$ candidates in the full phase space (black points), corresponding to separation of the suppressed decay sample by Λ_b^0 flavour. The fit, as described in the text, is indicated by the solid blue line, and individual components are indicated.

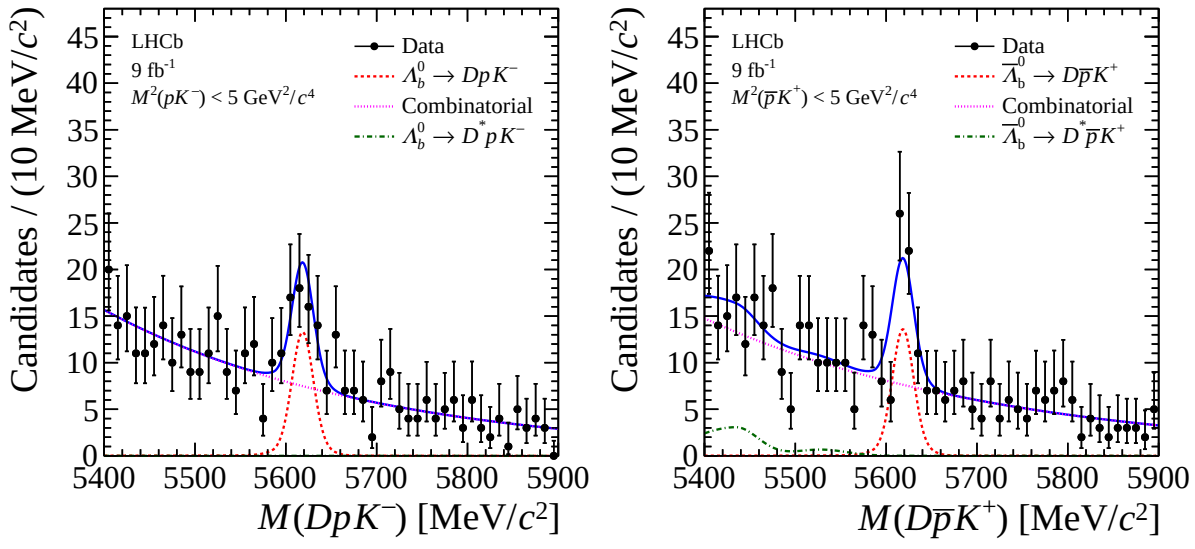

Figure 4: Distributions of the invariant mass for (left) $\Lambda_b^0 \to [K^+\pi^-]_D p K^-$ and (right) $\overline{\Lambda}_b^0 \to [K^-\pi^+]_D \overline{p} K^+$ candidates in the restricted phase-space region (black points), where the separation is made according to the Λ_b^0 flavour. The fit, as described in the text, is indicated by the solid blue line, and individual components are indicated.

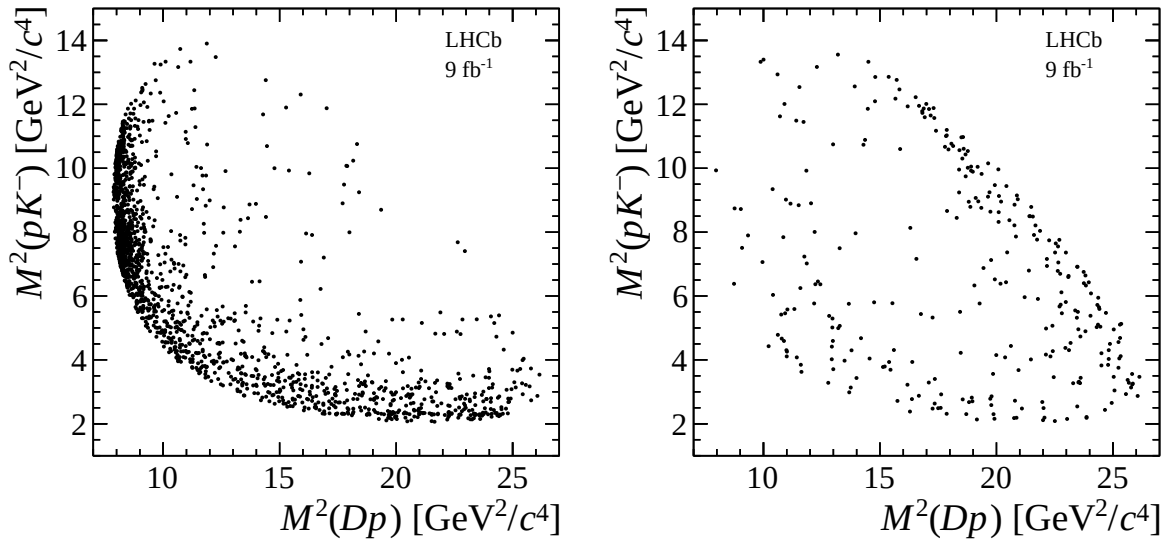

Figure 5: Phase space of the (left) $\Lambda_b^0 \to [K^-\pi^+]_D p K^-$ and (right) $\Lambda_b^0 \to [K^+\pi^-]_D p K^-$ candidates having a mass between 5600 and 5640 MeV/c^2. No background subtraction is applied.

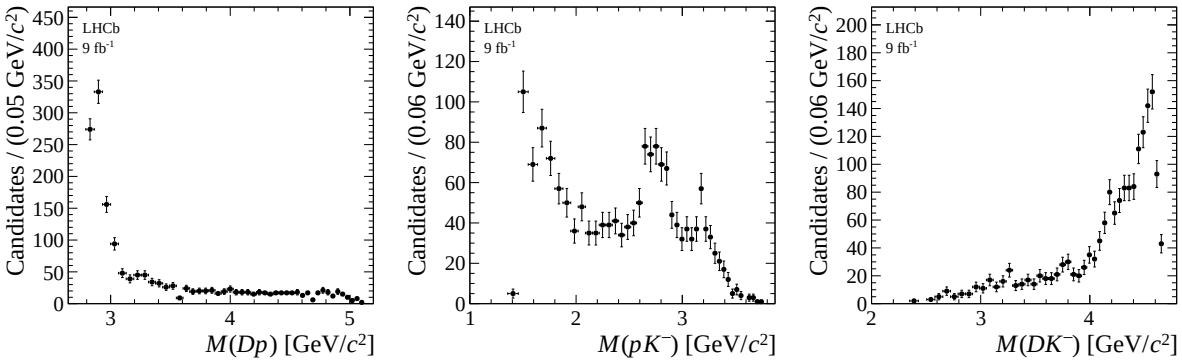

Figure 6: Invariant-mass projections of the Λ_b^0 phase space in (left) $M(Dp)$, (middle) $M(pK^-)$, and (right) $M(DK^-)$ for the $\Lambda_b^0 \to [K^-\pi^+]_D p K^-$ candidates.

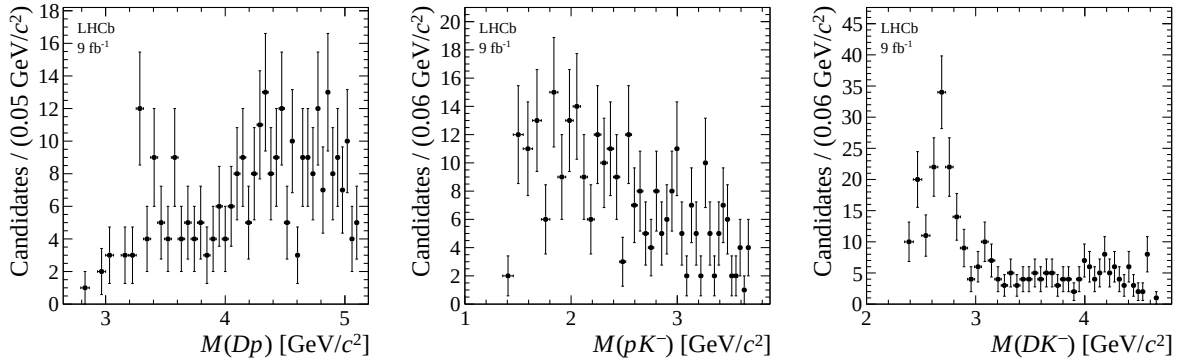

Figure 7: Invariant-mass projections of the Λ_b^0 phase space in (left) $M(Dp)$, (middle) $M(pK^-)$, and (right) $M(DK^-)$ for the $\Lambda_b^0 \to [K^+\pi^-]_D p K^-$ candidates.

5 Calculation of branching fraction ratio and *CP* asymmetry

The ratio of branching fractions of the favoured and suppressed decays and the *CP* asymmetry of the suppressed decay are calculated from the ratio of yields of the corresponding decays after applying efficiency correction factors as

$$R = \frac{\sum_i w^i_{\rm FAV}/\epsilon^i}{\sum_i w^i_{\rm SUP}/\epsilon^i}, \tag{3}$$

$$A = \frac{\sum_i w^i_{{\rm SUP},\Lambda_b^0}/\epsilon^i - \sum_i w^i_{{\rm SUP},\overline{\Lambda}_b^0}/\epsilon^i}{\sum_i w^i_{{\rm SUP},\Lambda_b^0}/\epsilon^i + \sum_i w^i_{{\rm SUP},\overline{\Lambda}_b^0}/\epsilon^i} \tag{4}$$

where the sum is over the selected candidates. Here $w^i_{\rm FAV}$ and $w^i_{\rm SUP}$ are the weights obtained using the *sPlot* technique [29] for background subtraction of the favoured or suppressed samples, respectively, with $M(DpK^-)$ as the discriminating variable. The subscripts Λ_b^0 and $\overline{\Lambda}_b^0$ label the samples split by flavour and ϵ^i are the relative efficiencies. The efficiency corrections are determined as a function of the Λ_b^0 phase-space variables $M^2(Dp)$ and $M^2(pK^-)$ using the simulated $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ sample and parameterised by a kernel density estimation technique [22]. Across the phase space, the relative efficiencies vary from 0.7 to 1.2, as shown in Figure 8.

The measured values of R and A in the full phase space with their statistical and

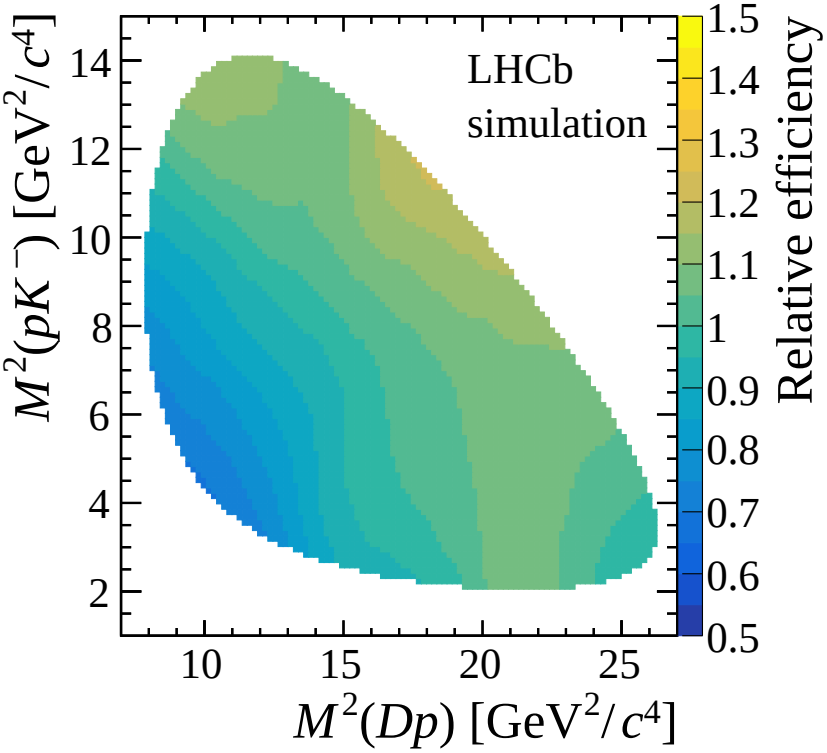

Figure 8: Relative efficiency correction as a function of position within the Λ_b^0 phase space, obtained from simulated samples.

systematic uncertainties are

$$R = 7.1 \pm 0.8\,(\text{stat.})^{+0.4}_{-0.3}\,(\text{syst.}),$$
$$A = 0.12 \pm 0.09\,(\text{stat.})^{+0.02}_{-0.03}\,(\text{syst.}),$$

and in the restricted phase-space region $M^2(pK^-) < 5\,\text{GeV}^2/c^4$,

$$R = 8.6 \pm 1.5\,(\text{stat.})^{+0.4}_{-0.3}\,(\text{syst.}),$$
$$A = 0.01 \pm 0.16\,(\text{stat.})^{+0.03}_{-0.02}\,(\text{syst.}).$$

The data samples in the full and restricted phase-space region partially overlap and the statistical uncertainties on the ratios and asymmetries measured in these two regions are correlated. A positive correlation between the statistical uncertainties of $\rho = 0.33$ is estimated, given the number of events in the two samples and their overlap.

6 Systematic uncertainties

The systematic uncertainties on the ratio of branching fractions of the favoured and suppressed decays and the *CP* asymmetry of the suppressed decay are listed in Table 2. For each variation, the determination of R and A is performed, and the difference with respect to the nominal result is taken as systematic uncertainty. Where multiple variations are considered, the largest negative and positive deviations are taken. For the measurement of R and A, many systematic effects cancel in the ratios. The total systematic uncertainties are obtained by summing all the contributions in quadrature.

To assess systematic uncertainties due to the description of signal and background contributions in the invariant mass fit model, alternative parameterisations for the Λ_b^0 mass peak, partially reconstructed background components and combinatorial background are used. The corresponding systematic uncertainties amount to (1–5)%. The efficiency corrections are impacted by the limited size of the signal simulation sample. This is assessed by varying the parameters of the kernel density estimation. The corresponding systematic uncertainties are (1–3)%.

The PID response in data is obtained from calibration samples [30, 31]. The associated systematic uncertainty includes the kernel width variation and the uncertainty due to finite sample size of the calibration samples. The resulting uncertainty is 2% for R, and less than 1% for A.

The hardware-level trigger decision is not perfectly simulated. The impact of this mismodelling is estimated by varying the efficiency map according to a correction obtained from data control samples. The resulting systematic uncertainty is at the level of 0.5%.

The background from charmless decays is estimated by interpolating from the D mass sidebands into the D mass region after all selection requirements are imposed and found to be 0.5% and 1% in the favoured and suppressed samples, respectively. These values are taken as uncertainties and propagated to the measurement of R, resulting in an uncertainty of 1% on R, while the corresponding uncertainty on A is assumed to cancel.

Doubly misidentified background, where the kaon and pion in the favoured mode are swapped, leads to a background that peaks at the Λ_b^0 mass in the suppressed sample. This contribution is estimated from simulation to be 0.5% in the suppressed sample, and this value is assigned as an uncertainty in R. Furthermore, the impact of $\Lambda_b^0 \to DpK^-$ decays

Table 2: Absolute uncertainties on the ratio of branching fractions, R, and CP asymmetry, A, related to the sources of systematic uncertainty studied. The statistical and total systematic uncertainties are also shown.

	R	A
Systematic uncertainties		
fit model	$^{+0.37}_{-0.15}$	$^{+0.000}_{-0.011}$
efficiency corrections	$^{+0.21}_{-0.24}$	$^{+0.010}_{-0.008}$
PID efficiency	$^{+0.08}_{-0.16}$	$^{+0.001}_{-0.002}$
hardware trigger efficiency	± 0.03	± 0.001
charmless background	± 0.08	
double misid. background	± 0.005	
single misid. background	± 0.001	
Λ_b^0 production asymmetry		± 0.015
p detection asymmetry		± 0.015
π detection asymmetry		± 0.005
Total systematic uncertainty	$^{+0.43}_{-0.33}$	$^{+0.024}_{-0.026}$
Statistical uncertainty	± 0.79	± 0.088

with subsequent $D \to K^-K^+$ or $D \to \pi^-\pi^+$ decays, when one of the D decay products is misidentified, is found to be 0.1%.

The asymmetry in Λ_b^0 and $\overline{\Lambda}_b^0$ production is expected to influence the measurement of A. The average values were measured to be $(1.92 \pm 0.35)\%$ and $(1.09 \pm 0.29)\%$ at 7 and 8 TeV centre-of-mass energies, respectively [32]. The production asymmetry is expected to decrease still further for a centre-of-mass energy of 13 TeV [33, 34]. A 1.5% systematic uncertainty is assigned. Furthermore, the detection asymmetry of the Λ_b^0 decay products is also expected to influence the measurement of A. The asymmetry in detecting protons versus antiprotons has been studied in detail [32] and does not exceed 1.5% for various values of proton momentum. The asymmetry of π^+ and π^- detection was studied in Ref. [35] and found to be less than 0.5%. These values are assigned as systematic uncertainties. Any influence of K^+ and K^- detection asymmetry is expected to cancel for the K^+ meson from the D meson and the K^- meson from the Λ_b^0 baryon.

Pseudoexperiments were used to verify that the fit used to determine the Λ_b^0 signal yields was unbiased, and no uncertainty from this source is included.

7 Conclusion

A study of Λ_b^0 baryon decays to the $[K^\pm\pi^\mp]_D pK^-$ final state, where D indicates a superposition of D^0 and $\overline{D}^0$, is reported, using a data sample corresponding to an integrated luminos-

ity of $9\,\text{fb}^{-1}$ collected with the LHCb detector. The suppressed $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ decay is observed for the first time. The ratio of branching fractions for the $\Lambda_b^0 \to [K^-\pi^+]_D pK^-$ and $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ decays, and the *CP* asymmetry, are measured in the full phase space to be

$$R = 7.1 \pm 0.8\,(\text{stat.})^{+0.4}_{-0.3}\,(\text{syst.}),$$
$$A = 0.12 \pm 0.09\,(\text{stat.})^{+0.02}_{-0.03}\,(\text{syst.}).$$

In the phase-space region $M^2(pK^-) < 5\,\text{GeV}^2/c^4$ the ratio and *CP* asymmetry are measured to be

$$R = 8.6 \pm 1.5\,(\text{stat.})^{+0.4}_{-0.3}\,(\text{syst.}),$$
$$A = 0.01 \pm 0.16\,(\text{stat.})^{+0.03}_{-0.02}\,(\text{syst.}).$$

Within the uncertainties, the ratio of the favoured and suppressed branching fractions is consistent with the estimate based on the relevant CKM matrix elements. The measured asymmetry values are consistent with zero, both in the full phase space and in the region where enhanced sensitivity to the CKM angle γ is expected. While the present signal yields are too low to be used to extract γ, larger samples are expected to be collected by LHCb in the coming years, and the study of this mode will contribute to the overall determination of γ.

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