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Measurements of $A_{CP}(B^0 \to K^+\pi^-)$ and $A_{CP}(B_s \to \pi^+K^-)$ at LHCb

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Summary. — The LHCb experiment is designed to perform flavour physics measurements at the Large Hadron Collider. Using data collected during the 2010 run, we reconstruct a sample of $H_b \to h^+h'^-$ decays, where H_b can be either a B^0 meson, a B_s^0 meson or a Λ_b baryon, while h and h' stand for π, K or p. We provide preliminary values of the direct $\mathcal{CP}$ asymmetries of the neutral B^0 and B_s^0 mesons $A_{CP}(B^0 \to K^+\pi^-) = -0.074 \pm 0.033(\text{stat.}) \pm 0.008(\text{syst.})$ and $A_{CP}(B_s^0 \to \pi^+K^-) = 0.15 \pm 0.19(\text{stat.}) \pm 0.02(\text{syst.})$.

PACS 11.30.Er – Charge conjugation, parity, time reversal, and other discrete symmetries.
PACS 12.15.Hh – Determination of Cabibbo-Kobayashi & Maskawa (CKM) matrix elements.
PACS 13.25.Hw – Decays of bottom mesons.
PACS 14.40.Nd – Bottom mesons ($|B| > 0$).

1. – Introduction

The family of $H_b \to h^+h'^-$ comprises a large set of decays, namely: $B^0 \to \pi^+\pi^-$, $B^0 \to K^+\pi^-$, $B_s^0 \to K^+K^-$, $B_s^0 \to \pi^+K^-$, $\Lambda_b \to pK^-$, $\Lambda_b \to p\pi^-$, $B^0 \to K^+K^-$, $B_s^0 \to \pi^+\pi^-$ plus their $\mathcal{CP}$-conjugate states. Such decays are sensitive probes of the Cabibbo-Kobayashi-Maskawa [1, 2] matrix and have the potential to reveal the presence of New Physics (NP) [3, 4]. NP may alter in a subtle but sizeable way the Standard Model (SM) prediction of the $\mathcal{CP}$ asymmetries in these decays. Exploiting the $37\,\text{pb}^{-1}$ of integrated luminosity collected by LHCb during 2010, at a centre of mass energy of 7 TeV, we measure the direct $\mathcal{CP}$ asymmetries in the $B^0 \to K^+\pi^-$ and $B_s^0 \to \pi^+K^-$ decays.

2. – Events selection

Candidates used in this analysis are obtained fitting into a common vertex, displaced from the proton-proton interaction region, two tracks characterized by high transverse momentum and large impact parameter with respect to the reconstructed primary vertex.

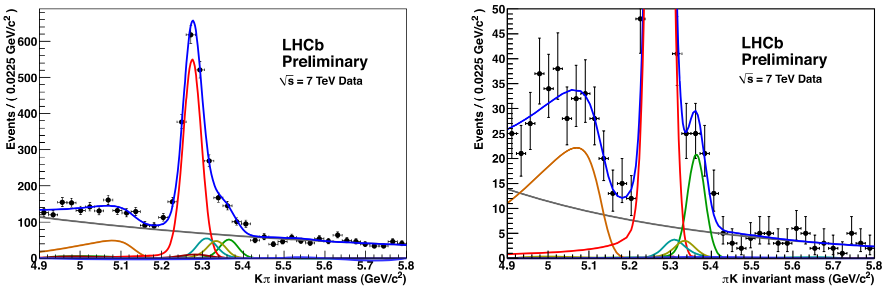

Fig. 1. – (Colour on-line) $K^+\pi^-$ (plus charge conjugate) invariant mass spectrum for events surviving the event selection optimised for the best sensitivity on $A_{CP}(B^0 \to K^+\pi^-)$ (left) and $A_{CP}(B_s^0 \to \pi^+K^-)$ (right). The result of the unbinned maximum likelihood fit is superimposed. The main components contributing to the fit model explained in the text are also visible: $B^0 \to K\pi$ (red), wrong sign $B^0 \to K\pi$ combination (dark red), $B^0 \to \pi^+\pi^-$ (light blue), $B_s^0 \to K^+K^-$ (dark yellow), $B_s^0 \to \pi K$ (green), combinatorial background (grey), 3-body partially reconstructed decays (orange).

Then the different final states hypothesis ($K^+\pi^-$, $K^-\pi^+$, $\pi^+\pi^-$, K^+K^-, $p\pi^-$, $\bar{p}\pi^+$, pK^- and $\bar{p}K^+$) are separated using the capabilities of the two Ring Imaging Cherenkov (RICH) detectors of LHCb. The Particle Identification (PID) observables have been calibrated using sample of large statistics and high purity of $D^{*+} \to D^0(K^-\pi^+)\pi^+$ and $\Lambda \to p\pi^-$, obtained without using any PID information. In order to achieve the best sensitivity on $A_{CP}(B^0 \to K^+\pi^-)$ and $A_{CP}(B_s^0 \to \pi^+K^-)$ we optimise two different selections, one for each measurement, characterized by the same set of cuts but with different values.

3. – Fits to the $H_b \to h^+h'^-$ mass spectra

We perform unbinned maximum likelihood fits to the mass spectra of events passing the optimised offline selections for the measurements of $A_{CP}(B^0 \to K^+\pi^-)$ or $A_{CP}(B_s^0 \to K^-\pi^+)$. The fits are performed simultaneously on all the eight categories defined by means of the PID selection criteria. The signals are parameterized with a single Gaussian function convolved with a component accounting for final state QED radiation [5]. The combinatorial background is modeled with an exponential function. The invariant mass shapes of cross-feed backgrounds are parameterized by means of full simulated events, while the normalization of each mis-identified channel is determined from the calibrated PID efficiencies. For the $K^\pm\pi^\mp$ and $\pi^+\pi^-$ categories it is necessary to model also a component due to partially reconstructed 3-body B-hadron decays.

The results of the fits superimposed to the $K^\pm\pi^\mp$ mass spectra (seperately for the samples obtained using the two optimised selections) are shown in fig. 1. The asymmetries obtained from the fits are, respectively, $A_{CP}^{RAW}(B^0 \to K^+\pi^-) = -0.086 \pm 0.033(\text{stat.})$ and $A_{CP}^{RAW}(B_s^0 \to K^-\pi^+) = 0.15 \pm 0.19(\text{stat.})$. The systematic errors due to the fit model and PID calibration are estimated to be respectively 0.002 and 0.004 for $A_{CP}(B^0 \to K^+\pi^-)$ and 0.021 and 0.001 for $A_{CP}(B_s^0 \to K^+\pi^-)$.

4. – Correction to the A_{CP}^{RAW}

The physical $\mathcal{CP}$ asymmetries we want to measure are related to the raw asymmetries obtained from the invariant mass fit by $A_{CP} = A_{CP}^{RAW} - A_D(K\pi) - \kappa A_P$.

$A_D(K\pi)$ is the detector induced asymmetry in reconstructing $K^+\pi^-$ and $K^-\pi^+$ final states; A_P is the production asymmetry of B mesons defined in terms of the B and $\bar{B}$ production rates $A_P = (R_{\bar{B}} - R_B)/(R_{\bar{B}} + R_B)$; κ is a factor that takes into account the $B - \bar{B}$ oscillation and depends also on the proper-time acceptance introduced by the events selection. The detector induced asymmetry $A_D(K\pi)$ is determined using high statistics samples of tagged $D^{*+} \to D^0(K^-\pi^+)\pi^+$, $D^{*+} \to D^0(K^+K^-)\pi^+$ and $D^{*+} \to D^0(\pi^+\pi^-)\pi^+$, and untagged $D^0 \to K^-\pi^+$ decays (plus their charge conjugates). Following the method shown in [6] we obtain: $A_D(K\pi) = -0.004 \pm 0.004$.

The production asymmetry A_P is determined measuring the integrated raw asymmetry of $B^\pm \to J/\psi(\mu^+\mu^-)K^\pm$ decays, correcting it by the world average of the direct $\mathcal{CP}$ asymmetry $A_{CP}(B^+ \to J/\psi K^+)$ [7], and taking into account the reconstruction asymmetry between K^+ and K^-. We measure $A_P(B^0) = -0.024 \pm 0.013 \pm 0.010$. The second error has been introduced to take into account possible differences between $A_P(B^+)$ and $A_P(B^0)$ [8]. The κ factors are evaluated by means of full simulated events, obtaining, respectively, for B^0 and B_s^0, $\kappa_d = 0.33$ and $\kappa_s = 0.015$. The value of κ_s makes negligible the correction due production asymmetry in the case of $B_s^0 \to K^-\pi^+$ decay.

The corrected central values of the direct $\mathcal{CP}$ asymmetries are $A_{CP}(B^0 \to K^+\pi^-) = -0.074$ and $A_{CP}(B_s^0 \to K^+\pi^-) = 0.15$. The errors of $A_D(K\pi)$ and κA_P are considered as systematic uncertainties contributing to $A_{CP}(B^0 \to K^+\pi^-)$ and $A_{CP}(B_s^0 \to K^+\pi^-)$.

5. – Final result

Using data collected by the LHCb detector during the 2010 run we provide preliminary values of the direct $\mathcal{CP}$ asymmetries:

$$A_{CP}(B^0 \to K^+\pi^-) = -0.074 \pm 0.033(\text{stat.}) \pm 0.008(\text{syst.}), \tag{1}$$

$$A_{CP}(B_s^0 \to \pi^+K^-) = 0.15 \pm 0.19(\text{stat.}) \pm 0.02(\text{syst.}). \tag{2}$$

The current HFAG average [9] $A_{CP}(B^0 \to K^+\pi^-) = -0.098^{+0.012}_{-0.011}$ and the CDF measurement [10] $A_{CP}(B_s^0 \to K^-\pi^+) = 0.39 \pm 0.15(\text{stat.}) \pm 0.08(\text{syst.})$ are in agreement with our values.

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