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Measurement of *CP* asymmetries in $\Lambda_b^0 \to pK^-$ and $\Lambda_b^0 \to p\pi^-$ decays at LHCb

F. Ferrari(*)

INFN, Sezione di Bologna and Dipartimento di Fisica e Astronomia, Università di Bologna Bologna, Italy

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Summary. — The LHCb experiment has been designed to perform precision measurements in the flavour physics sector at the Large Hadron Collider (LHC). The measurement of the *CP*-violating observable defined as $\Delta A_{CP} = A_{CP}(\Lambda_b^0 \to pK^-) - A_{CP}(\Lambda_b^0 \to p\pi^-)$, where $A_{CP}(\Lambda_b^0 \to pK^-)$ and $A_{CP}(\Lambda_b^0 \to p\pi^-)$ are the direct *CP* asymmetries in $\Lambda_b^0 \to pK^-$ and $\Lambda_b^0 \to p\pi^-$ decays, is presented for the first time using LHCb data. Using the full 2011 and 2012 data sets of *pp* collisions collected with the LHCb detector, corresponding to an integrated luminosity of about 3 fb^{-1}, the value $\Delta A_{CP} = (0.8 \pm 2.1 \pm 0.2)\%$ is obtained. The first uncertainty is statistical and the second corresponds to one of the dominant systematic effects. As the result is compatible with zero, no evidence of *CP* violation is found. This is the most precise measurement of *CP* violation in the decays of baryons containing the *b* quark to date. Once the analysis will be completed with an exhaustive study of systematic uncertainties, the results will be published by the LHCb Collaboration.

1. – Introduction

Since its discovery in 1964, a systematic study of *CP*-violating phenomena has been carried out by a number of experiments. *CP* violation is still nowadays a very promising field of research, with an exhaustive programme of precision measurements being pursued by LHCb, and another venue going to be opened by the Belle II experiment in Japan. In particular, charmless two-body decays of *beauty* baryons involve elements of the CKM matrix that could be sensitive to physics beyond the Standard Model, as these decays proceed also through loop-level quark transitions. For this reason, it is important to measure *CP* violation in such decays.

(*) E-mail: `Fabio.Ferrari@bo.infn.it`

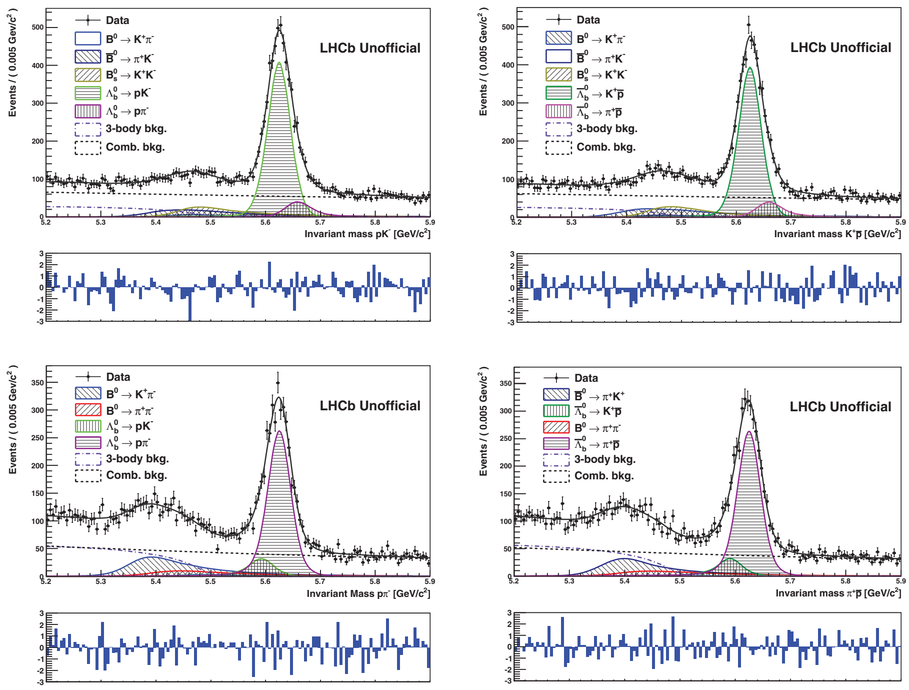

Fig. 1. – Invariant-mass spectra obtained using the event selection adopted for the best sensitivity on (top) $A_{CP}(\Lambda_b^0 \to pK^-)$ and (bottom) $A_{CP}(\Lambda_b^0 \to p\pi^-)$. Panels represent respectively (top left) pK^-, (top right) $K^+\bar{p}$, (bottom left) $p\pi^-$ and (bottom right) $\pi^+\bar{p}$ invariant mass spectra. The results of the maximum-likelihood fits are overlaid.

2. – Analysis

In order to measure ΔA_{CP}, firstly we need to determine the following quantities, called raw asymmetries:

$$A_{RAW}(pK^-) = \frac{N(\Lambda_b^0 \to pK^-) - \bar{N}(\bar{\Lambda}_b^0 \to \bar{p}K^+)}{N(\Lambda_b^0 \to pK^-) + \bar{N}(\bar{\Lambda}_b^0 \to \bar{p}K^+)}, \tag{1a}$$

$$A_{RAW}(p\pi^-) = \frac{N(\Lambda_b^0 \to p\pi^-) - \bar{N}(\bar{\Lambda}_b^0 \to \bar{p}\pi^+)}{N(\Lambda_b^0 \to p\pi^-) + \bar{N}(\bar{\Lambda}_b^0 \to \bar{p}\pi^+)}, \tag{1b}$$

where N and $\bar{N}$ are the number of occurrences of the corresponding decays, as determined from the fits to the invariant mass spectra.

We use the full 2011 and 2012 data set of pp collisions collected with the LHCb detector, corresponding to an integrated luminosity of about 3 fb^{-1}. The inclusion of charge-conjugate decay modes is implied throughout. The selection is divided in two steps: firstly, we apply a kinematic and geometric selection to all decay channels, using a multivariate analysis technique based on boosted decision trees (BDT). Then, to separate different final states, we require them to satisfy particle identification (PID) requirements. We optimize two different selections in order to obtain the best statistical sensitivity on the $A_{CP}(\Lambda_b^0 \to pK^-)$ and $A_{CP}(\Lambda_b^0 \to p\pi^-)$ quantities.

The signal p.d.f. is given by

$$g(m) = A' \cdot \varepsilon(m) \cdot \frac{1}{2}\left[\mathrm{sgn}(\mu - m)\right]\left[1 + \mathrm{sgn}(\mu - m)\right] |\mu - m|^{s\cdot \mathrm{sgn}(\mu - m)} \otimes G_2(m), \tag{2}$$

where A' is a normalisation factor, $\varepsilon(m)$ is an efficiency function depending on the reconstructed mass,“sgn” is the signum function, s is a parameter modeling the final state emission of photons, μ is the mass of the hadron and $G_2(m)$ stands for the sum of two Gaussian p.d.f.s. The combinatorial background is modeled using an exponential function. The partially reconstructed background is described by an ARGUS function [1]. The cross-feed background contribution, due to the mis-identification of final state particles, is taken into account using empirical shapes obtained from simulation.

We perform simultaneous binned maximum likelihood fits to all the invariant-mass spectra, *i.e.* $B^0 \to K^+\pi^-$, $B_s^0 \to \pi^+K^-$, $B_{(s)}^0 \to \pi^+\pi^-$, $B_{(s)}^0 \to K^+K^-$, $\Lambda_b^0 \to pK^-$, $\Lambda_b^0 \to p\pi^-$. This is done in order to determine the amount of cross-feed background under the pK^- and $p\pi^-$ signal peaks. In fig. 1 the invariant mass spectra of the $\Lambda_b^0 \to ph$ modes are shown, with the results of the binned maximum likelihood fits overlaid.

The difference of the CP asymmetries, ΔA_{CP}, can be expressed as

$$\Delta A_{CP} = \Delta A_{RAW} + A_D(K) - A_D(\pi) \tag{3}$$

where $\Delta A_{RAW} \equiv A_{RAW}(pK^-) - A_{RAW}(p\pi^-)$. The quantities $A_D(K)$ and $A_D(\pi)$ are the kaon and pion detection asymmetries, respectively, and have been measured by the LHCb Collaboration [2].

Using the raw asymmetries extracted from the invariant mass fits and the detection asymmetries measured by LHCb we obtain

$$\Delta A_{CP} = (0.8 \pm 2.1 \pm 0.2)\%, \tag{4}$$

where the first uncertainty is statistical and the second comes from the limited knowledge of detection asymmetries. No evidence for CP violation is observed.

REFERENCES

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