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Measurements of $\mathcal{B}(B_s^0 \to D_s^{(*)\mp} K^\pm)/\mathcal{B}(B_s^0 \to D_s^{(*)-} \pi^+)$ at LHCb

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Summary. — The $B_s \to D_s^{(*)\mp} K^\pm$ and $B_s \to D_s^{(*)\mp} \pi^\pm$ decay amplitudes are of great interest, since, by means of a time-dependent analysis, they allow us to measure the weak phase γ. In this article, using an integrated luminosity of $3\,\text{fb}^{-1}$ recorded by the LHCb experiment until 2012, a measurement of the branching fraction of $B_s^0 \to D_s^\mp K^\pm$ with respect to $B_s^0 \to D_s^- \pi^+$ is presented, where $D_s^\mp \to K^\mp K^\pm \pi^\mp$. Moreover, the first observation of the $B_s^0 \to D_s^{*\mp} K^\pm$ and the measurements of its branching fraction are reported, where $D_s^{*\mp}$ are reconstructed through the decay chain $D_s^{*\mp} \to D_s^\mp(\to K^\mp K^\pm \pi^\mp)\gamma$. These decays are experimentally challenging for a detector operating at an hadronic collider due to the low photons transverse energy. Both measurements resulted to be compatible with QCD expectations.

1. – Introduction

The weak phase γ, one of the least well-determined CKM parameters, can be measured using time-dependent B meson decay rates, such as those of $B_s^0 \to D_s^\mp h^\pm$ and $B_s^0 \to D_s^{*\mp} h^\pm$, where h indicates a light meson [1]. The sensitivity to γ is a consequence of interference between the amplitudes of the $b \to u$ and $b \to c$ transitions occurring through mixing. The decays $B_s^0 \to D_s^{(*)\mp} h^\pm$ occur predominantly through colour-allowed tree diagrams. This paper describes the experimental measurements of the ratios of branching fractions $\mathcal{B}(B_s^0 \to D_s^{(*)\mp} K^\pm)/\mathcal{B}(B_s^0 \to D_s^{(*)-} \pi^+)$, using pp collision data corresponding to an integrated luminosity of $3\,\text{fb}^{-1}$ recorded by the LHCb detector until 2012. The LHCb detector is a single-arm forward spectrometer designed for the studies of particles containing b or c quark [2]. Based on $SU(3)$ flavour symmetry and measurements at the B factories, the theoretical expectations are predicted to be $\mathcal{R} = \mathcal{B}(B_s^0 \to D_s^\mp K^\pm)/\mathcal{B}(B_s^0 \to D_s^- \pi^+) = 0.086^{+0.009}_{-0.007}$ and $\mathcal{R}^* = \mathcal{B}(B_s^0 \to D_s^{*\mp} K^\pm)/\mathcal{B}(B_s^0 \to D_s^{*-} \pi^+) = 0.099^{+0.030}_{-0.036}$, where the uncertainty includes

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contributions from non-factorisable effects and from possible $SU(3)$-breaking effects [1]. The CDF and Belle Collaborations have pioneered the studies of $\mathcal{R}$ [3, 4]; instead, the presented $\mathcal{R}^*$ measurement is the first one as a consequence of the first observation of $B_s \to D_s^{(*)\mp} K^\pm$ decays at LHCb. The $B_s \to D_s^{(*)\mp} h^\pm$ decays are experimentally challenging for detectors operating at hadron colliders since they require the reconstruction of a soft photon in the $D_s^{(*)} \to D_s\gamma$ decays. The ratio of branching fractions $\mathcal{R}$ and $\mathcal{R}^*$ are evaluated according to

$$R^{(*)} \equiv \frac{\mathcal{B}(B_s^0 \to D_s^{(*)\mp} K^\pm)}{\mathcal{B}(B_s^0 \to D_s^{(*)-} \pi^+)} = \frac{n^{\rm obs}(B_s^0 \to D_s^{(*)\mp} K^\pm)}{n^{\rm obs}(B_s^0 \to D_s^{(*)-} \pi^+)} \frac{\epsilon(B_s^0 \to D_s^{(*)-} \pi^+)}{\epsilon(B_s^0 \to D_s^{(*)\mp} K^\pm)},$$

where $n^{\rm obs}$ and ϵ are the observed yields and the overall reconstruction efficiency, respectively.

2. – $B_s^0 \to D_s^\mp h^\pm$ invariant mass fits

Candidate B_s^0 are reconstructed by combining a $D_s^\pm$ with an additional pion or kaon, where $D_s^\mp \to K^\mp K^\pm \pi^\mp$. Each of the final hadrons is required to have a good track quality, high momentum and transverse momentum, and a large impact parameter with respect to any primary vertex. Signal events are selected within the mass windows $1940 < M(D_s^0) < 1990$ MeV/c^2 and $5000 < M(B_s^0) < 5800$ MeV/c^2. PID cuts are enforced to identify kaons and a multivariate algorithm is applied to reduce the combinatorial background. Finally, a further veto on $\Lambda_b \to \Lambda_c(\to pK\pi)\pi$ is imposed to reduce the background from decays where the proton is misidentified. An unbinned fit to the candidate invariant mass distribution is performed (fig. 1). The signal shape is parametrized by a double-sided Crystal Ball and the background contributions are fixed using MC templates. The functional form for the combinatorial background, corresponding to an exponential function, is obtained from a wrong sign sample [5].

3. – $B_s^0 \to D_s^{*\mp} h^\pm$ invariant mass fits

Candidate B_s^0 are reconstructed by combining a $D_s^{*\mp}$ with an additional pion or kaon of opposite charge. The $D_s^{*\mp}$ and a $D_s^\mp$ are reconstructed in the $D_s^\pm\gamma$ and $K^\mp K^\pm \pi^\mp$ decay modes, respectively. Each of the D_s daughters tracks is required to have good track quality, momentum $p > 1000$ MeV/c, transverse momentum $p_T > 100$ MeV/c, and any large impact parameter with respect to primary vertex. Photons are identified using energy deposits in the electromagnetic calorimeter that are not associated with any track in tracking system. Due to the small difference between the mass of D_s^* and a D_s, Δm, the average transverse energy of photons is of a few hundred MeV/c^2, and events are selected within the region $124 < \Delta m < 164$ MeV/c^2. PID requirements are applied to all final-state hadron. Moreover, the maximum distance in the η-ϕ plane between D_s and the photon is required to be less than 1. Finally a multivariate approch is used to reduce the combinatorial background. The signal yield are derived using unbinned maximum likelihood fits to the invariant mass distribution (fig. 1). The signal shape is parametrized by a double-sided Crystal Ball, instead to model the background contributions non-parametric PDF, obtained from simulated samples, are used [6].

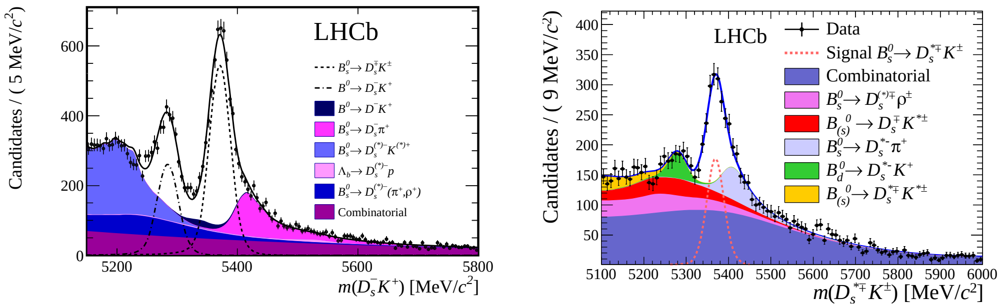

Fig. 1. – The $B_s^0 \to D_s^\mp K^\pm$ (left) and $B_s^0 \to D_s^{*\mp} K^\pm$ (right) invariant mass fit, 2011+2012 data [5, 6].

4. – Conclusions

The ratios of branching fractions $\mathcal{R}$ and $\mathcal{R}^*$ measured by LHCb are

$$\mathcal{R} \equiv \frac{\mathcal{B}(B_s^0 \to D_s^\mp K^\pm)}{\mathcal{B}(B_s^0 \to D_s^- \pi^+)} = 0.0752 \pm 0.0015(\text{stat.}) + 0.0019(\text{syst.}), \quad \text{see ref. [5]},$$

$$\mathcal{R}^* \equiv \frac{\mathcal{B}(B_s^0 \to D_s^{*\mp} K^\pm)}{\mathcal{B}(B_s^0 \to D_s^{*-} \pi^+)} = 0.068 \pm 0.005(\text{stat.})^{+0.003}_{-0.002}(\text{syst.}), \quad \text{see ref. [6]}.$$

These measurements of $\mathcal{R}$ and $\mathcal{R}^*$ are the most accurate in the world.

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