SELECTED RESULTS ON THE CKM ANGLE γ MEASUREMENT AT THE LHCb*

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The LHCb is a single arm forward spectrometer designed to study heavy-flavour physics at the LHC. Its very precise tracking and excellent particle identification play currently a major role in providing the world-best measurements of the Unitary Triangle parameters. In this paper, selected results of the Cabibbo–Kobayashi–Maskawa (CKM) angle γ measurements, with special attention for $B \to DK$ decays family, obtained at the LHCb, are presented.

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1. Introduction

The CKM angle $\gamma : \gamma = \arg(-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*)$ (the elements of CKM matrix specify the strength of weak transition between quarks, V_{ud}, V_{ub}, *etc.* are the CKM matrix elements) is the least precise measured one amongst the Unitarity Triangle angles. Discrepancies between precise measurements of the CKM angle γ in tree-level (direct, Fig. 1, left plot) and loop dominated processes (indirect, Fig. 1, right plot) might provide evidence of new physics beyond the Standard Model [1].

The CKM angle γ measurements are important in the determination of the violation of charge-parity (CP) symmetry. This violation is responsible for the matter–antimatter asymmetry. The CKM angle γ can be accessed in the tree-level processes (the theoretical uncertainties of these processes are very small), where interference between $b \to c$ and $b \to u$ quark transitions (*e.g.* $B \to DK$ decays) occurs.

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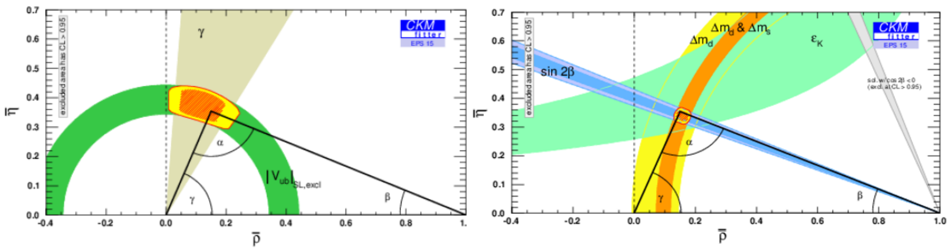

Fig. 1. Direct (left plot) and indirect (right plot) measurements of the Unitary Triangle angles (the constraints on different parameters of the CKM matrix are represented by different colours, parameters $\overline{\eta}$, $\overline{\rho}$ on the axis are the elements of the Wolfenstein parametrization of the CKM matrix) [2].

The LHCb potential to determine CKM angle γ results in vast measurement obtained via different methods. For a full summary, see [3]. In this short review, a few of them are presented, which base both on time-integrated and time-dependent analysis. The results of the analyses of decays: $B_0 \to DK^{*0}$, $B_0 \to DK^{\pm}\pi^{\mp}$, $B_s^0 \to D_s^{\pm}K^{\mp}$ and $B_s^0 \to D_s^{*\pm}K^{\mp}$ are presented. All results correspond to the 3 fb^{-1} of integrated luminosity and use full data sample collected during Run 1 (2010–2012, proton–proton collisions at energy of 7 TeV).

2. $B_0 \to DK^{*0}$ decay

The constraints on the CKM angle can be determined from $B_0 \to DK^{*0}$ ($D \to K_S^0\pi^+\pi^-$) measurements using the time-integrated method (Fig. 2) [4]. The model-dependent approach is used to describe the D meson decay am-

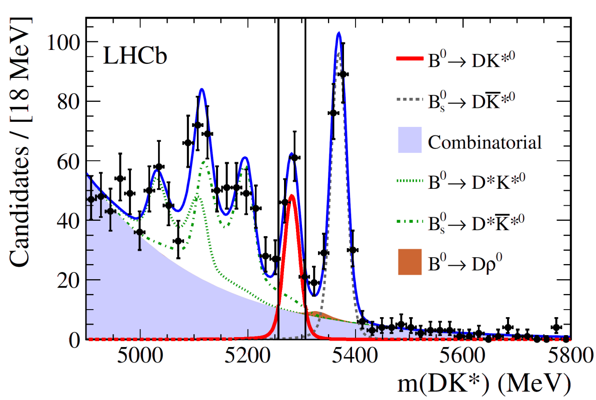

Fig. 2. (Colour on-line) DK^{*0} invariant mass distribution (black/blue line) [4]. The verticals lines represent the signal region of the $B_0 \to DK^{*0}$ decay (solid grey/red line) in which the CP-violation observables fit is performed.

plitude. The sensitivity to the CKM angle γ depends on the ratio of the suppressed and favoured[1] amplitudes (extracted from the CP-violation observables fit) and the number of selected candidates. The value of $\gamma = (80^{+21}_{-22})^\circ$ at 68% C.L. is consistent with results from direct measurement $\gamma = (72.2^{+6.8}_{-7.3})^\circ$ (also at 68% C.L.) [3].

3. $B_0 \to DK^\pm\pi^\mp$ decay

The amplitude analysis of the Dalitz plot [5] of $B^0 \to DK^\pm\pi^\mp$ decay ($D \to K^\pm\pi^\mp$, $D \to \pi^\pm\pi^\mp$, $D \to K^\pm K^\mp$) leads to constraints on the CKM angle γ. These constraints are obtained by comparing the distribution of mass of the $D \to h^+h^-$ events using $\bar{B}^0$ and B^0 meson decays [6]. Figure 3 (left plot) shows the B^0 candidates invariant mass distribution in the three-body decay. Only candidates within the signal region of $B^0 \to DK^\pm\pi^\mp$ decay are used in the Dalitz plot analysis (Fig. 3, right plot). No significant CP-violation effect has been observed, but results of the analysis with the $B^0 \to DK^{*0}$ mode can be used in a determination of constraints on the CKM angle γ.

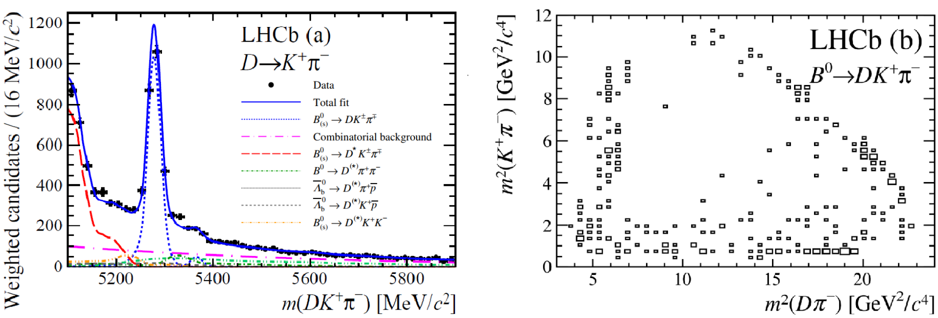

Fig. 3. $DK^\pm\pi^\mp$ invariant mass distribution with the signal of the $B_0 \to DK^\pm\pi^\mp$ decay (left plot) [6], Dalitz plot for candidates in signal region for B^0 (right plot) [6].

4. $B^0_s \to D^\pm_s K^\mp$ decay

The analysis of $B^0_s \to D^\pm_s K^\mp$ decay (Fig. 4, left plot) allows the CKM angle γ extraction from the time-dependent measurement [7]. CP violation in such decays occurs due to the interference of mixing and decay amplitudes. Several experimental aspects need to be taken into account. The finite detector decay-time resolution, as well as decay-time acceptance effects, need

[1] Where suppressed and favoured processes are related to different quark transitions and corresponding coupling constants from the CKM mixing matrix.

to be included due to fast B_s^0 meson oscillation. CP-violation parameters measurements lead to the value of the CKM angle γ : $\gamma = (115^{+28}_{-43})^\circ$ at 68% C.L.

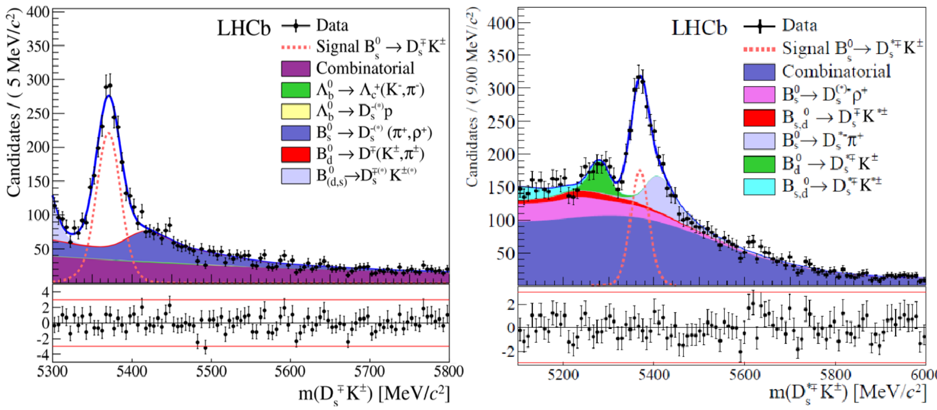

Fig. 4. $D_s^{\pm}K^{\mp}$ invariant mass distribution with the signal of the $B^0 \to D_s^{\pm}K^{\mp}$ decay (left plot) [7], $D_s^{*\pm}K^{\mp}$ invariant mass distribution with the signal of the $B_s^0 \to D_s^{*\pm}K^{\mp}$ decay (right plot) [8].

5. $B_s^0 \to D_s^{*\pm}K^{\mp}$ decay

The $B_s^0 \to D_s^{\pm}K^{\mp}$ and $B_s^0 \to D_s^{*\pm}K^{\mp}$ decay modes are topologically similar but the latter one has more complex final state due to $D_s^{*\pm} \to D_s^{\pm}\gamma$ decay [8]. The branching fraction: $\mathcal{B}(B_s^0 \to D_s^{*\pm}K^{\mp}) = 16.3 \pm 1.2\,(\text{stat.})^{+0.7}_{-0.5}\,(\text{syst.}) \pm 4.8(\text{norm.}) \times 10^{-5}$ has been measured with respect to the $B_s^0 \to D_s^{*\pm}\pi^{\mp}$ decay mode. The invariant mass distribution for the $B_s^0 \to D_s^{*\pm}K^{\mp}$ decay is shown in figure 4 (right plot). The obtained $B_s^0 \to D_s^{*\pm}K^{\mp}$ yield is promising in the context of the possible time-dependent measurement in the future.

6. Conclusion

The CKM angle γ is probed via theoretically clean tree-level $B \to DK$ processes (assuming negligible contribution from higher order loop diagrams) using many time-dependent and time-integrated methods. All currently on-going physics analyses focus on including Run 2 data (proton–proton collision at energy of 13 TeV). They, in principle, use the same techniques as described above but with increasing attention to decay processes with more complicated final states (see, for instance, the very recent result on the $B^{\pm} \to D^{*0}K^{\pm}$ [9]). The expected new large data samples will also make possible to explore new B_s^0 decays, like $B_s^0 \to D_s^{(*)+}K^{*\pm}$.

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