Observation of CP Violation in $B^{\pm} \to DK^{\pm}$ Decays at LHCb

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The unitarity of the Cabibbo Kobayashi Maskawa (CKM) quark mixing matrix can be represented by a closed, 'unitarity triangle' (UT). Of the three CKM phases in the UT, the least well known is γ, currently measured to be $(66 \pm 12)^{\circ}$ in direct measurements [1]. The Large Hadron Collider beauty (LHCb) experiment is the only dedicated flavour physics experiment at the LHC and has as one of its primary objectives the precise measurement of this Standard Model (SM) parameter.

1 Measuring γ in $B^{\pm} \to [hh']_D K^{\pm}$ at LHCb

Sensitivity to γ arises as a result of interference between the amplitudes for $B^{\pm} \to D^0 K^{\pm}$ and $B^{\pm} \to \overline{D}^0 K^{\pm}$ decay processes where the intermediate neutral D meson decays to a common final state F, labelled by $[F]_D$. The complex phase between the two $B^{\pm}$ decay amplitudes is the sum or difference of the strong and weak phases, δ_B and γ respectively. Two classes of D meson final states were considered in the analysis [2], non-CP eigenstates ($D^0 \to K^+\pi^-$, an 'ADS' final state [3], described in this paper) and CP eigenstates ($D^0 \to K^+K^-, \pi^+\pi^-$ 'GLW' final states [4], discussed in the proceedings for my talk 'CP Violation in Hadronic B Decays at LHCb'). The observables are, for the ADS case, $R_{ADS} = \frac{\Gamma(B^- \to [\pi^- K^+]_D K^-) + \Gamma(B^+ \to [\pi^+ K^-]_D K^+)}{\Gamma(B^- \to [K^- \pi^+]_D K^-) + \Gamma(B^+ \to [K^+ \pi^-]_D K^+)}$ and $A_{ADS} = \frac{\Gamma(B^- \to [\pi^- K^+]_D K^-) - \Gamma(B^+ \to [\pi^+ K^-]_D K^+)}{\Gamma(B^- \to [K^- \pi^+]_D K^-) + \Gamma(B^+ \to [K^+ \pi^-]_D K^+)}$ which in turn depend on γ e.g. $A_{ADS} = 2 r_B r_D \sin(\gamma) \sin(\delta_D + \delta_B)$ where r_B, δ_B and r_D, δ_D are hadronic parameters of the $B^{\pm}$ and D decays.

The 2011 LHCb data set (1 fb^{-1}) was used and decay modes were selected for analysis: the 'ADS mode' $B^{\pm} \to [\pi^{\pm} K^{\mp}]_D K^{\pm}$ and the 'favoured' mode $B^{\pm} \to [K^{\pm}\pi^{\mp}]_D K^{\pm}$ where the interference, and therefore sensitivity to the CP violating phase γ, is negligible. A boosted decision tree was used, having been trained using simulated signal data and background candidates from the 2010 LHCb data sidebands. Due to the detector's good impact parameter ($20\mu m$ for tracks with high p_T) and momentum resolution ($(0.4 - 0.6)\%$ in the range of $5 - 100$GeV$/c$), the most effective variables were flight distances of the $B^{\pm}$ and D mesons, impact parameters, p_T cuts on the daughter tracks and vertex quality requirements. The Ring Imaging Cherenkov (RICH) detectors were used to distinguish pions and kaons in the final state.

2 Results and conclusion

The invariant mass spectra of the ADS mode $B^{\pm} \to (\pi^{\pm}K^{\mp})_D K^{\pm}$ are shown in Figure 1 along with the $B^{\pm} \to (\pi^{\pm}K^{\mp})_D \pi^{\pm}$ mode used to control elements of the signal fit. The visible charge asymmetry in the $B^{\pm} \to DK^{\pm}$ signals results in: $R_{ADS(K)} = 0.0152 \pm 0.0020 \pm 0.0004$ and $A_{ADS(K)} = -0.52 \pm 0.15 \pm 0.02$. The ADS mode is observed for the first time with $\sim 10\sigma$ statistical significance and displays evidence of an asymmetry at 4.0σ. Combined with the GLW results, CP violation is observed with 5.8σ significance.

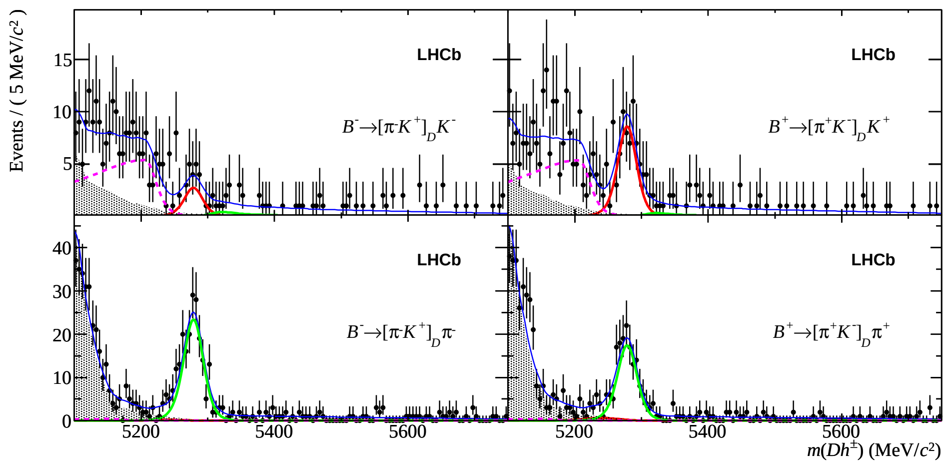

Figure 1: $B^{\pm}$ invariant mass spectrum from ADS modes with $B^{\pm} \to DK^{\pm}$ signal (solid red line) and $B^{\pm} \to D\pi^{\pm}$ control (solid green line) [2].

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References

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