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Measurement of A_{Γ}

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The measurement of the charm CP violation observable A_{Γ} using 1 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ recorded by the LHCb detector in 2011 is presented. This new result is the most accurate to date.

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1 Introduction

CP violation in charm meson decays is expected to be small in the Standard Model (SM) and any significant enhancement would be a signal of New Physics (NP). Thus far no CP violation has been unambiguously observed in the charm system.

The CP violation observable A_Γ is defined as the asymmetry of the effective lifetimes of D^0 and \bar{D}^0 decaying to the same CP eigenstate, K^+K^- or $\pi^+\pi^-$,

$$A_\Gamma = \frac{\hat{\Gamma}(D^0 \rightarrow K^+K^-) - \hat{\Gamma}(\bar{D}^0 \rightarrow K^+K^-)}{\hat{\Gamma}(D^0 \rightarrow K^+K^-) + \hat{\Gamma}(\bar{D}^0 \rightarrow K^+K^-)} \approx \frac{A_m + A_d}{2} y \cos \phi - x \sin \phi, \quad (1)$$

where A_m and A_d are the asymmetries due to CP violation in mixing and decay respectively, ϕ is the interference phase between mixing and decay and x and y are the charm mixing parameters.

In the Standard Model A_Γ is expected to be small[1]($\sim 10^{-4}$) and roughly independent of the final state. New Physics (NP) models may introduce larger CP violation and some final state dependence of the phase ϕ leading to a difference in A_Γ between the K^+K^- and $\pi^+\pi^-$ final states[2],

$$\Delta A_\Gamma = A_\Gamma(KK) - A_\Gamma(\pi\pi) = \Delta A_D y \cos \phi + (A_M + A_D) y \Delta \cos \phi - x \Delta \sin \phi. \quad (2)$$

The experimental status of the measurement of A_Γ , including the Heavy Flavour Averaging Group (HFAG)[3] average and excluding the results presented here, is shown in Fig. 1.

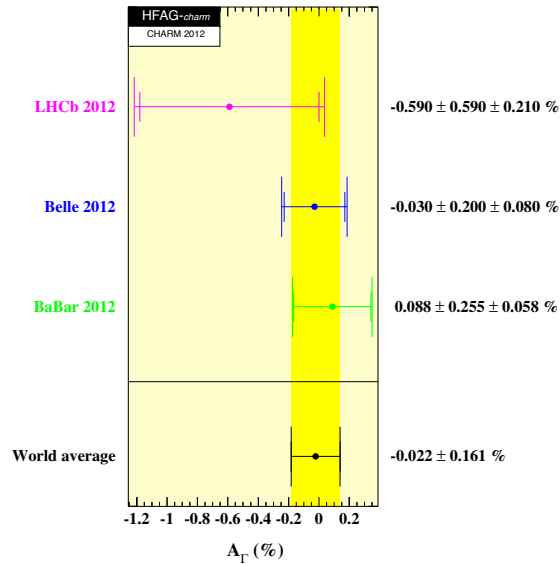


Figure 1: Experimental status of A_Γ .

Presented here are new results for the measurement of A_Γ using 1 fb^{-1} of pp collisions at a centre of mass energy of 7 TeV recorded by the LHCb detector in 2011[4].

2 Analysis Method

The mean lifetimes of the D^0 and \bar{D}^0 are extracted via a fit to their decay times. The data to be fitted is broken into eight subsets. The splits are motivated by the two detector magnet polarities with which data was taken and two separate data-taking periods to account for known differences in detector alignment and calibration. Finally the D^0 and \bar{D}^0 candidates have been fitted separately.

The initial flavour of the D^0 is determined by searching for the decay $D^{*+} \rightarrow D^0 \pi_s^+$ where the charge on the pion indicates the flavour. Due to the small Q value of this decay the pion is referred to as slow.

The procedure is carried out in two stages. In the first the D^0 mass and the difference between the D^{*+} and D^0 masses (Δm) are fitted simultaneously. This allows for the separation of the signal and background components and the determination of the background probability density functions in the subsequent fits. Example mass and Δm fit results for the K^+K^- final state can be seen in Fig. 2.

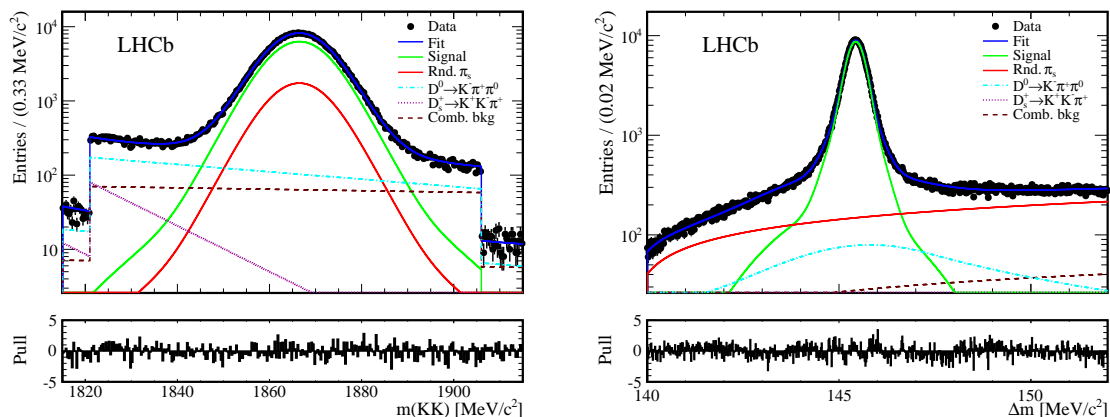


Figure 2: Fit of the D^0 mass (left) and Δm (right) for subset of data containing $\bar{D}^0 \rightarrow K^+K^-$ candidates with magnet polarity down for the earlier run period.

The second stage fits D^0 decay times and the natural logarithm of the D^0 impact parameter χ^2 ($\ln(\text{IP}\chi^2)$). Those D^0 candidates originating from B decays (secondary) have longer measured lifetimes than those originating at the primary vertex (prompt) as the B has not been reconstructed. It is therefore necessary to separate these in the fit to avoid biasing the lifetime measurement. This is done using the $\ln(\text{IP}\chi^2)$

variable. Due to the flight distance of the B the impact parameter of the D^0 is larger than those of prompt candidates as shown in Fig. 3. Example fits are in Fig. 4.

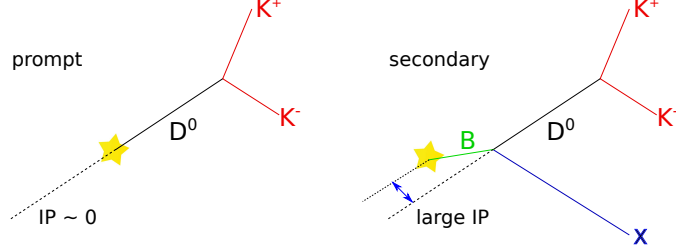


Figure 3: The separation of prompt (left) and secondary (right) decays by considering their impact parameters.

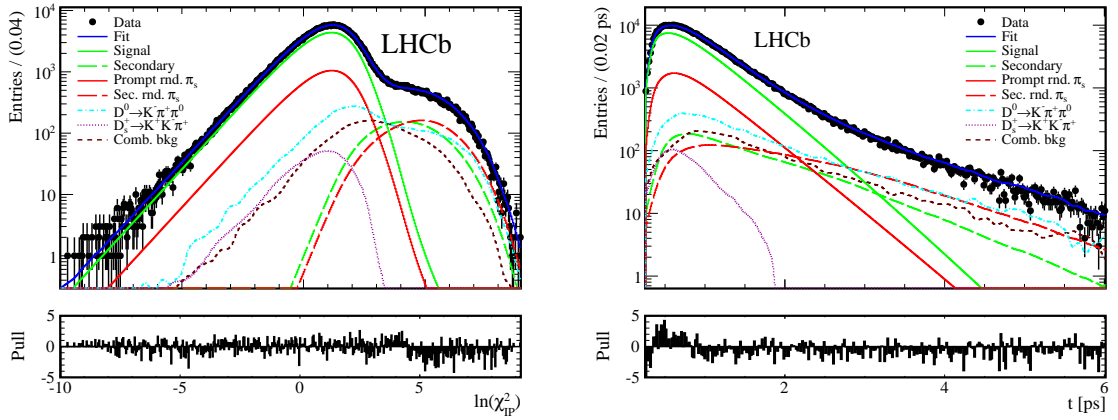


Figure 4: Fit of the $\ln(\text{IP}\chi^2)$ (left) and decay time (right) for data subset containing the $\bar{D}^0 \rightarrow K^+K^-$ candidates with magnet polarity down for the earlier run period.

Lifetime biases due to the acceptance of the trigger and selections are corrected for using the “swimming” method. The D^0 primary vertex is moved along the direction of its flight and the trigger rerun to find the point in D^0 lifetime at which the candidate changes from being rejected to accepted. One can thus construct an acceptance function in D^0 lifetime for each event as shown in Fig. 5. An average acceptance function for the whole data set can then be constructed and folded in to the fit. For a complete description see [5].

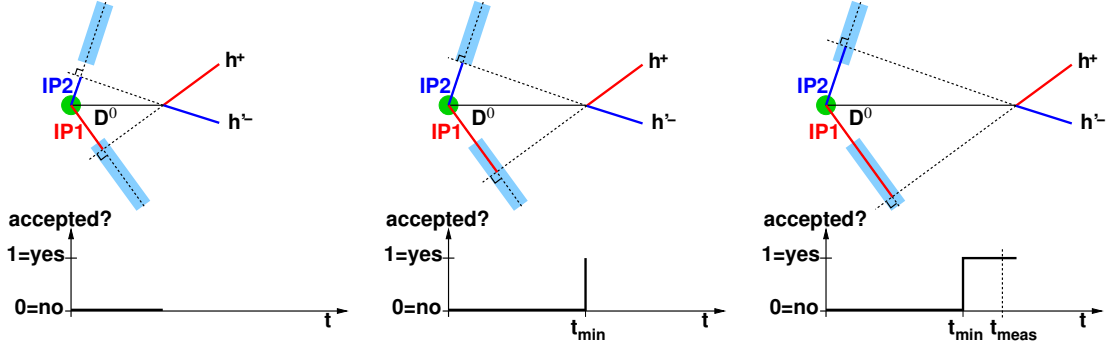


Figure 5: The swimming method. The D^0 primary vertex is ‘swum’ along the D^0 direction (from left to right). The trigger is rerun for each position and the lifetime of the candidate at which it becomes accepted by the trigger is found (middle).

Effect	$A_\Gamma (K^+K^-) \times 10^{-3}$	$A_\Gamma (\pi^+\pi^-) \times 10^{-3}$
Mis-reconstructed bkg.	± 0.02	± 0.00
Charm from B	± 0.07	± 0.07
Other backgrounds	± 0.02	± 0.04
Acceptance function	± 0.09	± 0.11
Total	± 0.12	± 0.14

Table 1: Summary of the systematic uncertainties on the measurement of A_Γ for the two final states.

3 Summary of systematic uncertainties

The systematic uncertainties of the method are evaluated through a mixture of studies on simplified simulated data and variations to the fit. Table 1 summarises the results of these studies. Additionally some extra considerations such as detector resolution and track reconstruction efficiency (amongst others) are looked at and found to have a negligible effect on the resultant A_Γ measurement. The data are also split into bins of various kinematic variables (for example D^0 momentum p , transverse momentum p_T and flight direction) and no systematic variation in the result is found.

The dominant systematic uncertainty comes from the acceptance function. This includes the uncertainty of the turning point positions determined by the swimming method and their subsequent utilisation in the fit procedure.

4 Results

The results of the A_Γ measurement for the K^+K^- and $\pi^+\pi^-$ final states are:

$$A_\Gamma(KK) = (0.35 \pm 0.62_{stat} \pm 0.12_{syst}) \times 10^{-3} \quad (3)$$

$$A_\Gamma(\pi\pi) = (0.33 \pm 1.06_{stat} \pm 0.14_{syst}) \times 10^{-3} \quad (4)$$

The two numbers show no CP violation within the experimental uncertainty and are consistent with each other. They show a considerable improvement in accuracy over previous results. At the same time a complimentary measurement of A_Γ was made on the same data using an alternative method by which the time evolution of the ratio of D^0 and \bar{D}^0 yields was examined. The two methods yielded consistent results. Analysis of the 2 fb^{-1} 2012 data set is to follow which will increase the precision further.

5 Acknowledgements

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