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Study of $B^{\pm} \to D_{CP} K^{\pm}$ and $B^{\pm} \to D^{*}_{CP} K^{\pm}$

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We report a study of the modes $B^{\pm} \to DK^{\pm}$ and $B^{\pm} \to D^{*}K^{\pm}$ where $D^{(*)}$ decays to CP eigenstates. The data sample used contains 274 million $B\bar{B}$ events collected at the $\Upsilon(4S)$ resonance with the Belle detector at KEKB. Measurements are made of $\mathcal{A}_1$ and $\mathcal{A}_2$, the magnitudes of the CP asymmetries for $D_{CP}K$ and for $D^{*}_{CP}K$.

Keywords: CP violation; CP eigenstates; GLW method

1. Introduction

Measurements of the decay rates of $B^{\pm} \to D^{(*)}K^{\pm}$ provide a theoretically clean method for extracting ϕ_3 [1], an angle in the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix [2]. When the neutral D meson produced in $B^{-} \to D^{(*)}K^{-}$ decays is reconstructed in a final state into which both $D^{(*)0}$ and $\bar{D}^{(*)0}$ can decay, the $b \to c$ transition $B^{-} \to D^{(*)0}K^{-}$ and the $b \to u$ transition $B^{-} \to \bar{D}^{(*)0}K^{-}$ interfere, resulting in observables which depend on their relative weak phase ϕ_3. The partial rate asymmetries for CP-even (D_1) or CP-odd (D_2) eigenstates are

$$\mathcal{A}_{1,2} \equiv \frac{\Gamma(B^{-} \to D_{1,2}K^{-}) - \Gamma(B^{+} \to D_{1,2}K^{+})}{\Gamma(B^{-} \to D_{1,2}K^{-}) + \Gamma(B^{+} \to D_{1,2}K^{+})} = \frac{2R_{DK}\sin\delta'_{DK}\sin\phi_3}{1 + R_{DK}^2 + 2R_{DK}\cos\delta'_{DK}\cos\phi_3}$$

where

$$\delta'_{DK} = \begin{cases} \delta_{DK} & \text{for } D_1 \\ \delta_{DK} + \pi & \text{for } D_2. \end{cases}$$

The ratio R_{DK} is defined as $R_{DK} = |A(B^{-} \to \bar{D}^0K^{-})/A(B^{-} \to D^0K^{-})|$, ϕ_3 is the weak phase difference and δ_{DK} is the strong phase difference. The value of R_{DK}, which is predicted to lie in the range $0.1 - 0.2$ [1], and has recently been measured by the Belle Collaboration to be $R_{DK} = 0.21 \pm 0.08 \pm 0.03 \pm 0.04$ [3], determines the maximum size of the CP asymmetry. Note that the CP asymmetries $\mathcal{A}_1$ and $\mathcal{A}_2$ have opposite signs.

In order to extract ϕ_3, external input on the values of R_{DK} and δ_{DK} is required. The ratios of the decay rates for $B^{\pm} \to DK^{\pm}$ with the D meson reconstructed in a CP eigenstate to that with the D meson reconstructed in a flavour specific final state provide the necessary additional observables. Experimentally, it is convenient to normalize these decay rates to those for the corresponding $B^{\pm} \to D\pi^{\pm}$ decays, and measure double ratios of branching fractions, defined by

$$\mathcal{R}_{1,2} \equiv \frac{R^{D_{1,2}}}{R^{D^0}} = 1 + R_{DK}^2 + 2R_{DK}\cos\delta'_{DK}\cos\phi_3$$

where the ratios $R^{D_{1,2}}$ and R^{D^0} are defined as

$$R^{D_{1,2}} = \frac{\Gamma(B^- \to D_{1,2}K^-) + \Gamma(B^+ \to D_{1,2}K^+)}{\Gamma(B^- \to D_{1,2}\pi^-) + \Gamma(B^+ \to D_{1,2}\pi^+)}$$
$$R^{D^0} = \frac{\Gamma(B^- \to D^0K^-) + \Gamma(B^+ \to \bar{D}^0K^+)}{\Gamma(B^- \to D^0\pi^-) + \Gamma(B^+ \to \bar{D}^0\pi^+)}$$

The asymmetries and double ratios can be calculated for $B^- \to D^*K^-$ in a similar manner; note that both R_{D^*K} and δ_{D^*K} can take values that are different from their counterparts in the DK system. This paper reports more precise measurements of these decay modes than previous studies [4 5 6], using 250 fb^{-1} collected with the Belle detector [7 8] and the first observation of the decays $B^- \to D_1^{*0}K^-$ and $B^- \to D_2^{*0}K^-$.

2. Technique

We reconstruct $B^- \to D^0K^-$ and $B^- \to D^0\pi^-$ decays [9] using the flavour specific decay mode $D^0 \to K^-\pi^+$. CP-even modes are reconstructed using the decays $D_1 \to K^+K^-$ and $D_1 \to \pi^+\pi^-$ and CP-odd modes using the decays $D_2 \to K_S^0\pi^0$, $D_2 \to K_S^0\omega$, $D_2 \to K_S^0\phi$ and $D_2 \to K_S^0\eta$. The same modes are used for $B^- \to D^*K^-$ and $B^- \to D^*\pi^-$ using the decay chain $D^* \to D\pi^0$.

Signal events are separated from continuum using the standard Belle method [10]. Backgrounds coming from B decays are studied using large Monte Carlo (MC) samples and also using the D mass sidebands [11].

3. Results

The results of the fits to the $D_1^{(*)}K$ and $D_2^{(*)}K$ modes are shown in Fig. 1. Table 1 summarizes the yields of the fits to the ΔE distributions and the corresponding asymmetries for $B^{\pm} \to D^{(*)}K^{\pm}$. The central values are opposite in sign, in agreement with expectation.

The yields for D_1^*K and D_2^*K are 56 ± 11 and 33 ± 10 candidates respectively, which correspond to significances of 5.6 and 4.5.

In summary, we have studied the decays $B^{\pm} \to D_{CP}K^{\pm}$ and $B^{\pm} \to D_{CP}^*K^{\pm}$. The partial rate asymmetries $\mathcal{A}_{1,2}$ and double ratios $\mathcal{R}_{1,2}$ are measured in both cases. The study of $D_{CP}K$ is made with 3 times the statistics of previous studies. First observations of the modes D_1^*K and D_2^*K are reported.

Table 1. Yields, asymmetries and double ratios obtained for $D^{(*)}K$ modes.

	$\sum B$	B^{+}	B^{-}	$\mathcal{A}$	$\mathcal{R}$
$D_1 K$	114 ± 21	49 ± 15	63 ± 14	0.07 ± 0.14 ± 0.06	0.98 ± 0.18 ± 0.10
$D_2 K$	167 ± 21	94 ± 17	75 ± 16	-0.11 ± 0.14 ± 0.05	1.29 ± 0.16 ± 0.08
$D_1^{*} K$	56 ± 11	33 ± 8	19 ± 8	-0.27 ± 0.25 ± 0.04	1.43 ± 0.28 ± 0.06
$D_2^{*} K$	33 ± 10	13 ± 6	22 ± 7	0.26 ± 0.26 ± 0.03	0.94 ± 0.28 ± 0.06

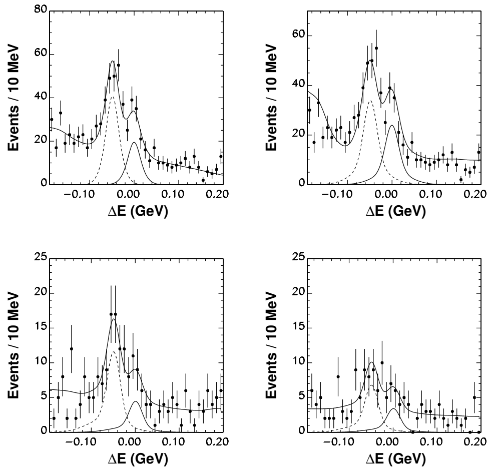

Fig. 1. ΔE distributions for (top left) $B^{\pm} \to D_1 K^{\pm}$, (top right) $B^{\pm} \to D_2 K^{\pm}$, (bottom left) $B^{\pm} \to D_1^{*} K^{\pm}$, (bottom right) $B^{\pm} \to D_2^{*} K^{\pm}$. The signal are modelled by a double gaussian for each peak(centered at zero for $B^{\pm} \to D^{(*)}\pi^{\pm}$ and shifted by ~ 50MeV for $B^{\pm} \to D^{(*)}K^{\pm}$).

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