UCHEP-13-04
December 22, 2013

CP Asymmetry Measurements in D Decays from Belle

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We present measurements of CP asymmetries in D decays performed by the Belle experiment running at the KEKB asymmetric-energy e^+e^- collider.

PRESENTED AT

The 6^{th} International Workshop on Charm Physics
(CHARM 2013)
Manchester, UK, 31 August – 4 September, 2013

1 Introduction

The phenomenon of CP violation (CPV) is well-established in the K^0-$\overline{K}^0$ and B^0-$\overline{B}^0$ systems [1, 2]. The rate observed confirms the Cabibbo-Kobayashi-Maskawa (CKM) theory of quark flavor mixing [3]. The CKM theory predicts only tiny CPV in the D^0-$\overline{D}^0$ system [4], and to-date such CPV has not been observed. Both time-independent and time-dependent measurements of partial widths can exhibit CP asymmetries. The former results mainly from interference between two decay amplitudes with different weak phases; this is called "direct" CPV. The latter results from either unequal rates of flavor mixing (called "indirect" CPV) or interference between a mixed and an unmixed decay amplitude. In all cases new physics can increase the rate of CPV significantly above that predicted by the CKM theory [4]. Here we present results from searches for CPV in D decays from the Belle experiment. For a review of mixing and CPV formalism, see Ref. [5].

2 Time-dependent $D^0(t)\to K^+K^-/\pi^+\pi^-$

The Belle experiment has measured the mixing parameter y_{CP} and the CP-violating parameter A_Γ using 977 fb^{-1} of data [6]. Both observables depend on mixing parameters x and y and CPV parameters $|q/p|$ and ϕ. To lowest order the relations are

$$y_{CP} = \frac{(|q/p|+|p/q|)}{2} y\cos\phi - \frac{(|q/p|-|p/q|)}{2} x\sin\phi \quad (1)$$

$$A_\Gamma = \frac{(|q/p|-|p/q|)}{2} y\cos\phi - \frac{(|q/p|+|p/q|)}{2} x\sin\phi \quad (2)$$

The parameters are determined by measuring lifetimes of D^0 and $\overline{D}^0$ mesons to flavor-specific and CP-specific final states, e.g.,

$$y_{CP} = \frac{\tau(K^-\pi^+)}{\tau(K^+K^-)} - 1 \quad (3)$$

$$A_\Gamma = \frac{\tau(\overline{D}^0\to K^+K^-) - \tau(D^0\to K^+K^-)}{\tau(\overline{D}^0\to K^+K^-) + \tau(D^0\to K^+K^-)}\,. \quad (4)$$

The latter measurement requires tagging the flavor of the decaying D meson, and this is done by reconstructing $D^{*+}\to D^0\pi^+$ and $D^{*-}\to\overline{D}^0\pi^-$ decays, i.e., the charge of the accompanying $\pi^\pm$ (which has low momentum and is often called the "slow pion") identifies the D flavor. Both K^+K^- and $\pi^+\pi^-$ final states are used by Belle, and the fitted lifetime distributions are shown in Fig. 1. The precision of the measurement depends upon good understanding of the decay time resolution of the detector. For Belle, the resolution function depends upon θ^*, the polar angle with respect to the e^+

beam of the D^0 in the e^+e^- center-of-mass (CM) frame. Thus the ratios in Eqs. (3) and (4) are measured in bins of $\cos\theta^*$. The resolution function also depends on the detector configuration: for the first 153 fb^{-1} of data a 3-layer silicon vertex detector (SVD) was used, while for the remaining data a 4-layer SVD was used. These running periods ("SVD1" and "SVD2") are treated separately. The results for SVD2 data are plotted in Fig. 2. Fitting both SVD1 and SVD2 values to constants gives

$$y_{CP} = (+1.11 \pm 0.22 \pm 0.11)\% \tag{5}$$
$$A_\Gamma = (-0.03 \pm 0.20 \pm 0.08)\% . \tag{6}$$

As a test of the resolution function, the absolute lifetime for $D^0 \to K^-\pi^+$ [7] decays is also measured. The result is 408.5 ± 0.5 fs, which is consistent with the world average [8].

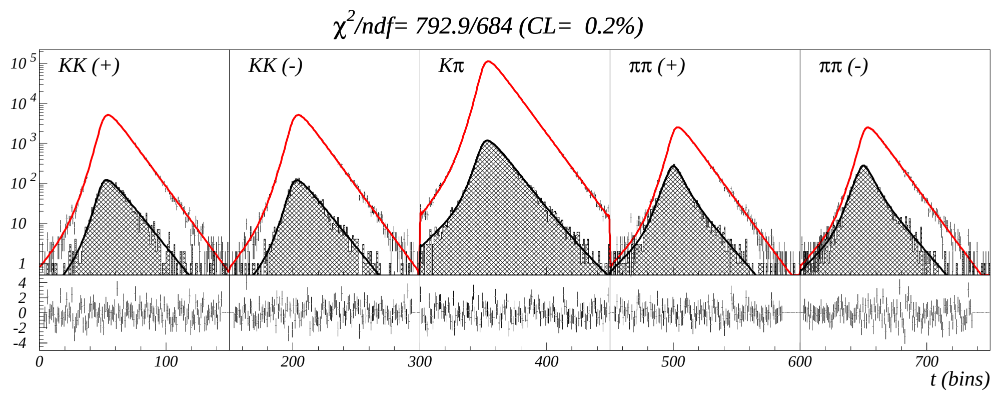

Figure 1: Decay time distributions for $D^0 \to K^+K^-/\pi^+\pi^-$, $\overline{D}^0 \to K^+K^-/\pi^+\pi^-$, and $D^0 \to K^-\pi^+$. Fitting these distributions yields y_{CP} and A_Γ via Eqs. (3) and (4). The shaded histograms show background contributions; the lower plots show the fit residuals.

3 Time-integrated $D^0 \to K^+K^-/\pi^+\pi^-$

The $D \to K^+K^-/\pi^+\pi^-$ samples used previously can be integrated over all decay times to measure the CP asymmetry A^f_{CP}, defined as

$$A^f_{CP} \equiv \frac{\Gamma(D^0 \to f) - \Gamma(\overline{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\overline{D}^0 \to f)} . \tag{7}$$

This parameter is a difference in partial widths rather than a difference in lifetimes and thus depends strongly on the specific final state. In addition to the underlying CP asymmetry, there is a "forward-backward" asymmetry (A_{FB}) in $D^0/\overline{D}^0$ production

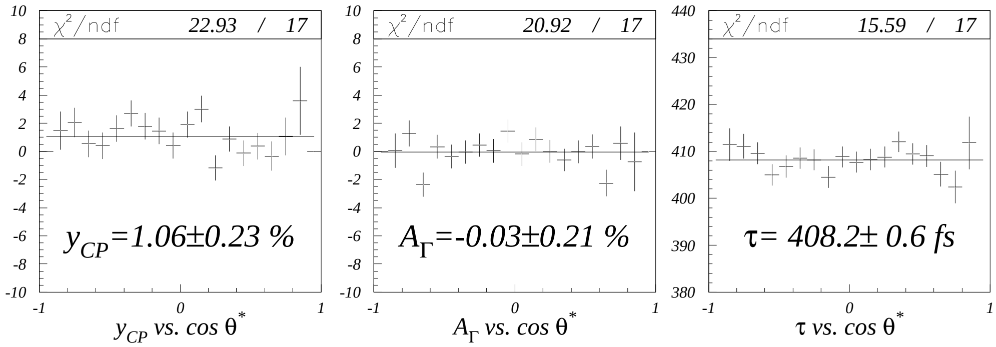

Figure 2: Fitted values of y_{CP}, A_Γ, and τ_{D^0} for SVD2 data in 18 bins of $\cos\theta^*$ (see text). Fitting these points to constants yields the overall values listed.

due to γ-Z^0 electroweak interference and higher order QED effects in $e^+e^-\to c\overline{c}$; and there is an asymmetry A^π_ε in the reconstruction of $\pi^\pm_s$ from $D^{*\pm}\to D\pi^\pm_s$ decays used to tag the D flavor. The reconstructed asymmetry one measures is the sum of all three: $A^f_{\rm recon} = A^f_{CP} + A_{FB} + A^\pi_\varepsilon$. Belle has measured $A^f_{\rm recon}$ for $D^0\to K^+K^-/\pi^+\pi^-$ decays using 977 fb^{-1} of data [9] to determine A^{KK}_{CP} and $A^{\pi\pi}_{CP}$.

To correct for A^π_ε, Belle measures $A^f_{\rm recon}$ for flavor-tagged and untagged $D^0\to K^-\pi^+$ decays. These decays have an additional asymmetry due to differences in the reconstruction efficiency of $K^-\pi^+$ versus $K^+\pi^-$; this difference is denoted $A^{K\pi}_\varepsilon$. Thus

$$A^{K\pi}_{\rm tagged} = A^{K\pi}_{CP} + A_{FB} + A^{K\pi}_\varepsilon + A^\pi_\varepsilon \tag{8}$$
$$A^{K\pi}_{\rm untagged} = A^{K\pi}_{CP} + A_{FB} + A^{K\pi}_\varepsilon\,, \tag{9}$$

and taking the difference $A^{K\pi}_{\rm tagged} - A^{K\pi}_{\rm untagged}$ yields A^π_ε. In practice this is done by re-weighting events: $A^{K\pi}_{\rm tagged}$ is calculated by weighting D^0 decays by a factor $1 - A^{K\pi}_{\rm untagged}(p_{D^0},\cos\theta_{D^0})$ and weighting $\overline{D}{}^0$ decays by a factor $1+A^{K\pi}_{\rm untagged}(p_{\overline{D}{}^0},\cos\theta_{\overline{D}{}^0})$, where p_D and θ_D are the momentum and polar angle with respect to the e^+ beam of the D. The resulting $A^{K\pi}_{\rm tagged}$ equals A^π_ε. The signal asymmetry $A^f_{\rm recon}$ is then calculated by weighting D^0 decays by a factor $1 - A^\pi_\varepsilon(p_\pi,\cos\theta_\pi)$ and $\overline{D}{}^0$ decays by a factor $1 + A^\pi_\varepsilon(p_\pi,\cos\theta_\pi)$. The asymmetry A^π_ε is calculated in bins of p_π and θ_π to reduce systematic errors. The result equals $A^f_{CP}+A_{FB}$. Since A_{FB} is an odd function of $\cos\theta^*$, where θ^* is the polar angle of the D in the CM frame, and A^f_{CP} is nominally an even function of θ^*, the individual asymmetries are extracted via

$$A^f_{CP} = \frac{A^{f,{\rm corr}}_{\rm recon}(\cos\theta^*) \;+\; A^{f,{\rm corr}}_{\rm recon}(-\cos\theta^*)}{2} \tag{10}$$

$$A_{FB} = \frac{A^{f,{\rm corr}}_{\rm recon}(\cos\theta^*) \;-\; A^{f,{\rm corr}}_{\rm recon}(-\cos\theta^*)}{2}\,. \tag{11}$$

The results of Eq. (10) for K^+K^- and $\pi^+\pi^-$ final states are plotted in Fig. 3 for each bin of $\cos\theta^*$. Fitting these values to constants yields

$$A_{CP}^{KK} = (-0.32 \pm 0.21 \pm 0.09)\% \quad (12)$$
$$A_{CP}^{\pi\pi} = (+0.55 \pm 0.36 \pm 0.09)\%\,, \quad (13)$$

and $\Delta A_{CP} \equiv A_{CP}^{KK} - A_{CP}^{\pi\pi} = (-0.87 \pm 0.41 \pm 0.06)\%$.

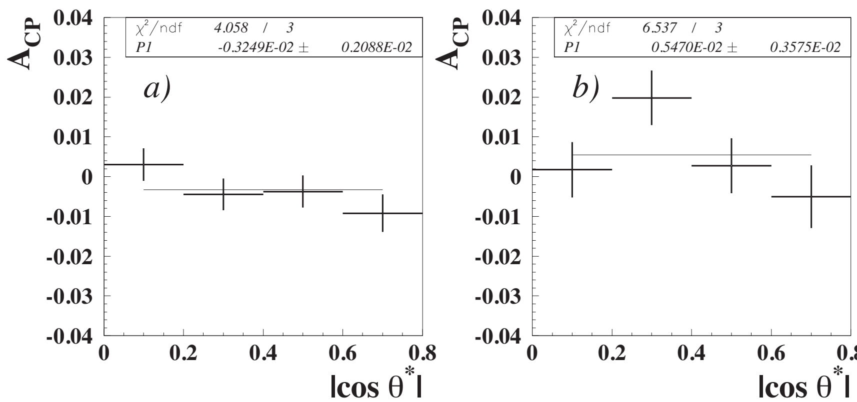

Figure 3: Asymmetries A_{CP}^{KK} (left) and $A_{CP}^{\pi\pi}$ (right) calculated in bins of $\cos\theta^*$ (see text). Fitting these values to constants yields the results listed in Eqs. (12) and (13).

4 Direct CPV in Neutral D^0 Decays

The above measurements of A_Γ, A_{CP}^{KK}, and $A_{CP}^{\pi\pi}$ are sensitive to underlying parameters [4]

$$a_{CP}^{\text{indir}} = \frac{(|q/p| + |p/q|)}{2} x \sin\phi - \frac{(|q/p| - |p/q|)}{2} y \cos\phi \quad (14)$$
$$a_{CP}^{\text{dir}} = 2\left|\frac{\overline{\mathcal{A}}}{\mathcal{A}}\right| \sin\phi\, \sin(\overline{\delta} - \delta)\,, \quad (15)$$

where $\mathcal{A} \equiv \mathcal{A}(D^0 \to h^+h^-)$, $\overline{\mathcal{A}} \equiv \mathcal{A}(\overline{D}^0 \to h^+h^-)$, and $\delta(\overline{\delta})$ is the strong phase for amplitude $\mathcal{A}(\overline{\mathcal{A}})$. Parameters a_{CP}^{indir} and a_{CP}^{dir} parameterize the amounts of indirect and direct CP violation in D decays, respectively. Since D decays are well-dominated by tree amplitudes, the phase $\phi \equiv \text{Arg}[(q/p)(\overline{\mathcal{A}}/\mathcal{A})] \approx \text{Arg}(q/p)$ is "universal," i.e., common to all D^0 decay modes. From Eq. (14) this implies that a_{CP}^{indir} is also universal. On the other hand, a_{CP}^{dir} depends on the final state.

The relations between the observables and parameters are, to subleading order [10],

$$A_\Gamma \approx -a_{CP}^{\text{indir}} - a_{CP}^{\text{dir}}\, y \cos\phi \quad (16)$$

$$A_{CP}^{hh} \approx a_{CP}^{\rm dir} - A_\Gamma \frac{\langle t \rangle}{\tau}\,, \tag{17}$$

where $\langle t \rangle$ is the mean decay time for $D^0 \to h^+h^-$ and τ is the D^0 lifetime. The second term in Eq. (16) is the subleading contribution – compare to Eq. (2). It is $O(10^{-4})$ or smaller and usually neglected; i.e., $A_\Gamma \approx -a_{CP}^{\rm indir}$ and is considered universal. Inserting Eq. (16) into Eq. (17) gives

$$A_{CP}^{hh} = a_{CP}^{\rm dir} + a_{CP}^{\rm indir}\frac{\langle t \rangle}{\tau} + a_{CP}^{\rm dir} y\cos\phi \frac{\langle t \rangle}{\tau}\,. \tag{18}$$

Experimentally, many systematic errors cancel when measuring the difference $\Delta A_{CP} \equiv A_{CP}^{KK} - A_{CP}^{\pi\pi}$. Using Eq. (18) to calculate this difference, one obtains

$$\Delta A_{CP} = \Delta a_{CP}^{\rm dir} + a_{CP}^{\rm indir}\frac{\Delta\langle t \rangle}{\tau} + \left(a_{CP}^{KK\ {\rm dir}}\frac{\langle t \rangle_{KK}}{\tau} - a_{CP}^{\pi\pi\ {\rm dir}}\frac{\langle t \rangle_{\pi\pi}}{\tau}\right) y\cos\phi \tag{19}$$

$$= \Delta a_{CP}^{\rm dir}\left(1 + y\cos\phi \frac{\overline{\langle t \rangle}}{\tau}\right) + \left(a_{CP}^{\rm indir} + \overline{a_{CP}^{\rm dir}}\, y\cos\phi\right)\frac{\Delta\langle t \rangle}{\tau} \tag{20}$$

$$\approx \Delta a_{CP}^{\rm dir}\left(1 + y\cos\phi \frac{\overline{\langle t \rangle}}{\tau}\right) + a_{CP}^{\rm indir}\frac{\Delta\langle t \rangle}{\tau}\,, \tag{21}$$

where $\Delta a_{CP}^{\rm dir} \equiv a_{CP}^{KK\ {\rm dir}} - a_{CP}^{\pi\pi\ {\rm dir}}$, $\overline{a_{CP}^{\rm dir}} \equiv \left(a_{CP}^{KK\ {\rm dir}} + a_{CP}^{\pi\pi\ {\rm dir}}\right)/2$, $\Delta\langle t \rangle \equiv \langle t \rangle_{KK} - \langle t \rangle_{\pi\pi}$, and $\overline{\langle t \rangle} \equiv \left(\langle t \rangle_{KK} + \langle t \rangle_{\pi\pi}\right)/2$. Using Eq. (21) and $A_\Gamma = -a_{CP}^{\rm indir}$, one can fit the measured values of A_Γ and ΔA_{CP} for parameters $a_{CP}^{\rm dir}$ and $a_{CP}^{\rm indir}$. A deviation from zero of either of these parameters would indicate CPV in D decays. Such an observation would hint at new physics. To perform this fit requires knowledge of $\overline{\langle t \rangle}$, $\Delta\langle t \rangle$, and $y\cos\phi$.

The Heavy Flavor Averaging Group (HFAG) [11] performs this fit for all available data: Belle, BaBar, CDF, and LHCb measurements. They use values of $\overline{\langle t \rangle}$ and $\Delta\langle t \rangle$ specific to each experiment, and $y\cos\phi$ is calculated using world average values [12]. The resulting fit is shown in Fig. 4, which plots all relevant measurements in the two-dimensional $\Delta a_{CP}^{\rm dir}$-$a_{CP}^{\rm indir}$ plane. The most likely values and $\pm 1\sigma$ errors are [13]

$$a_{CP}^{\rm indir} = (+0.015 \pm 0.052)\% \tag{22}$$

$$\Delta a_{CP}^{\rm dir} = (-0.333 \pm 0.120)\%\,. \tag{23}$$

Whereas $a_{CP}^{\rm indir}$ is consistent with zero, $\Delta a_{CP}^{\rm dir}$ indicates direct CPV. The p-value of the no-CPV point $(a_{CP}^{\rm indir}, \Delta a_{CP}^{\rm dir}) = (0, 0)$ is 0.02.

5 Direct CPV in $D^+ \to K_S^0\, K^+$

The decay $D^+ \to K_S^0\, K^+$ is self-tagging, there is no $D^{*\pm} \to D\pi^\pm$ decay, and thus there is no correction for A_ε^π. However, the final state $K^\pm$ introduces a correction ($A_\varepsilon^{K^+}$)

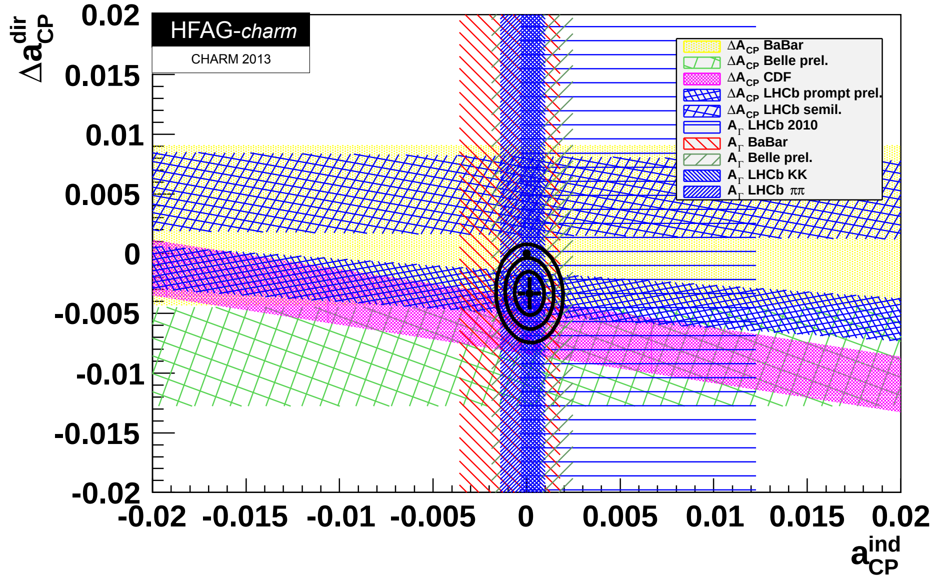

Figure 4: Two-dimensional $\Delta a_{CP}^{\rm dir}$-$a_{CP}^{\rm indir}$ plane with constraints from individual experiments overlaid, from Ref. [13]. The cross denotes the fitted central value, and the ellipses denote 1σ, 2σ, and 3σ confidence regions.

due to possible differences in K^+ and K^- reconstruction efficiencies. In addition, as the neutral K^0 or $\overline{K}{}^0$ is reconstructed via $K^0_S \to \pi^+\pi^-$ decay, there is an asymmetry ($A_{CP}^{\overline{K}{}^0}$) due to the small difference in rates between $K^0 \to K^0_S$ and $\overline{K}{}^0 \to K^0_S$, or equivalently between $K^0 \to \pi^+\pi^-$ and $\overline{K}{}^0 \to \pi^+\pi^-$ [14]. Thus:

$$A_{\rm recon}^{K_S K^+} \;=\; A_{CP}^{\overline{K}{}^0 K^+} + A_{CP}^{\overline{K}{}^0} + A_{FB} + A_\varepsilon^{K^+}\,.$$

Belle has measured $A_{\rm recon}^{K_S K^+}$ using 977 fb^{-1} of data [15] to determine $A_{CP}^{\overline{K}{}^0 K^+}$.

To determine $A_\varepsilon^{K^+}$, Belle measures the asymmetries for untagged samples of $D^0 \to K^-\pi^+$ and $D_s^+ \to \phi\pi^+$ decays. These asymmetries have the following components:

$$A_{\rm recon}^{K^-\pi^+} \;=\; A_{FB} + A_\varepsilon^{\pi^+} - A_\varepsilon^{K^+} \qquad (24)$$

$$A_{\rm recon}^{\phi\pi^+} \;=\; A_{FB} + A_\varepsilon^{\pi^+}\,. \qquad (25)$$

To isolate $A_\varepsilon^{K^+}$, the weighting procedure performed for time-integrated $D^0 \to K^+K^-$ decays (see Section 3) is repeated here: $D^0 \to K^-\pi^+$ decays are weighted by a factor $(1 - A_{\rm recon}^{\phi\pi^+})$, and $\overline{D}{}^0 \to K^+\pi^-$ decays are weighted by a factor $(1 + A_{\rm recon}^{\phi\pi^+})$. With this weighting the asymmetry $A_{\rm recon}^{K^-\pi^+}$ is calculated; the result equals $-A_\varepsilon^{K^+}$. This procedure is then repeated for the signal sample: $D^+ \to K^0_S K^+$ decays are weighted by a factor $(1 - A_\varepsilon^{K^+})$, and $D^- \to K^0_S K^-$ decays are weighted by a factor $(1 + A_\varepsilon^{K^+})$. The resulting $A_{\rm recon}^{K_S K^+}$ equals $A_{CP}^{\overline{K}{}^0 K^+} + A_{CP}^{\overline{K}{}^0} + A_{FB}$. Since the sum $A_{CP}^{\overline{K}{}^0 K^+} + A_{CP}^{\overline{K}{}^0}$ is an even function of $\cos\theta^*$ (θ^* is the polar angle with respect to the e^+ beam of the D^+ in the e^+e^- CM frame), and A_{FB} is an odd function, the two types of asymmetries are separated by taking sums and differences as done in Eqs. (10) and (11). The results are plotted in Fig. 5 in bins of $\cos\theta^*$; fitting these values to a constant yields

$$A_{CP}^{\overline{K}^0 K^+} + A_{CP}^{\overline{K}^0} \;=\; (-0.25 \pm 0.28 \pm 0.14)\%\,. \tag{26}$$

To extract $A_{CP}^{\overline{K}^0 K^+}$ from $A_{CP}^{\overline{K}^0 K^+} + A_{CP}^{\overline{K}^0}$, one corrects for $A_{CP}^{\overline{K}^0}$ using the calculation of Ref. [14]. The result is

$$A_{CP}^{\overline{K}^0 K^+} \;=\; (+0.08 \pm 0.28 \pm 0.14)\%\,, \tag{27}$$

which is consistent with zero.

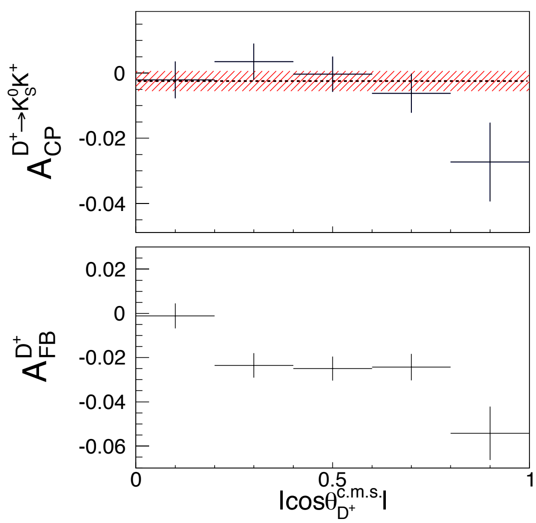

Figure 5: $A_{CP}^{K_S K^+} = A_{CP}^{\overline{K}^0 K^+} + A_{CP}^{\overline{K}^0}$ (top) and A_{FB} (bottom) measured from $D^\pm \to K_S^0 K^\pm$ decays [15].

6 Direct CPV in $D^+ \to K_S^0\,\pi^+$

The decay $D^+ \to K_S^0\,\pi^+$ is similar to $D^+ \to K_S^0\,K^+$ in that it is also self-tagging and thus has no correction for $D^{*\pm} \to D\pi^\pm$. However, the final state π^+ introduces a correction $A_\varepsilon^{\pi^+}$ due to possible differences between π^+ and π^- reconstruction efficiencies. The asymmetry $A_{CP}^{\overline{K}^0}$ is also present and must be corrected for as done for $D^+ \to K_S^0\,K^+$ decays. Thus:

$$A_{\rm recon}^{K_S\pi^+} \;=\; A_{CP}^{\overline{K}^0\pi^+} + A_{CP}^{\overline{K}^0} + A_{FB} + A_\varepsilon^{\pi^+}\,. \tag{28}$$

Belle has measured $A_{\rm recon}^{K_S\pi^+}$ using 977 fb^{-1} of data [16] to determine $A_{CP}^{\overline{K}^0\pi^+}$.

To determine $A_\varepsilon^{\pi^+}$, Belle measures the asymmetries for untagged samples of three-body $D^+ \to K^-\pi^+\pi^+$ and $D^0 \to K^-\pi^+\pi^0$ decays. These asymmetries have the following components:

$$A_{\rm recon}^{K^-\pi^+\pi^+} = A_{FB} + A_\varepsilon^{K^-\pi^+} + A_\varepsilon^{\pi^+} \qquad (29)$$

$$A_{\rm recon}^{K^-\pi^+\pi^0} = A_{FB} + A_\varepsilon^{K^-\pi^+} . \qquad (30)$$

To isolate $A_\varepsilon^{\pi^+}$, the weighting procedure done for time-integrated $D^0 \to K^+K^-$ decays (Section 3) and $D^+ \to K_S^0 K^+$ decays (Section 5) is repeated again: $D^+ \to K^-\pi^+\pi^+$ decays are weighted by a factor $(1 - A_{\rm recon}^{K^-\pi^+\pi^0})$, and $D^- \to K^+\pi^-\pi^-$ decays are weighted by a factor $(1 + A_{\rm recon}^{K^-\pi^+\pi^0})$. The resulting asymmetry $A_{\rm recon}^{K^-\pi^+\pi^+}$ equals $A_\varepsilon^{\pi^+}$. The weighting procedure is then repeated for the signal sample: $D^+ \to K_S^0\pi^+$ decays are weighted by a factor $(1 - A_\varepsilon^{\pi^+})$, and $D^- \to K_S^0\pi^-$ decays are weighted by a factor $(1 + A_\varepsilon^{\pi^+})$. The resulting $A_{\rm recon}^{K_S\pi^+}$ equals $A_{CP}^{\overline{K}^0\pi^+} + A_{CP}^{\overline{K}^0} + A_{FB}$. Taking sums and differences in bins of $\cos\theta^*$ as done in Eqs. (10) and (11) isolates $A_{CP}^{\overline{K}^0\pi^+} + A_{CP}^{\overline{K}^0}$. The results are plotted in Fig. 6; fitting these values to a constant yields

$$A_{CP}^{\overline{K}^0\pi^+} + A_{CP}^{\overline{K}^0} = (-0.363 \pm 0.094 \pm 0.067)\% . \qquad (31)$$

To extract $A_{CP}^{\overline{K}^0\pi^+}$, one applies a correction for $A_{CP}^{\overline{K}^0}$ [14]. The result is

$$A_{CP}^{\overline{K}^0\pi^+} = (-0.024 \pm 0.094 \pm 0.067)\% . \qquad (32)$$

The statistics of this measurement are high enough to observe the asymmetry due to $A_{CP}^{\overline{K}^0}$ with a significance of 3.2σ. However, after correcting for $A_{CP}^{\overline{K}^0}$ the result for $A_{CP}^{\overline{K}^0\pi^+}$ is consistent with zero.

7 Other Searches for Direct *CPV*

In addition to the searches described above, there have been numerous other searches for direct CPV in D decays at Belle. A complete listing of these searches and their results is given in Table 1. In all cases there is no evidence for direct CPV.

ACKNOWLEDGEMENTS

We are thankful to the organizers of CHARM 2013 for a fruitful and enjoyable workshop.

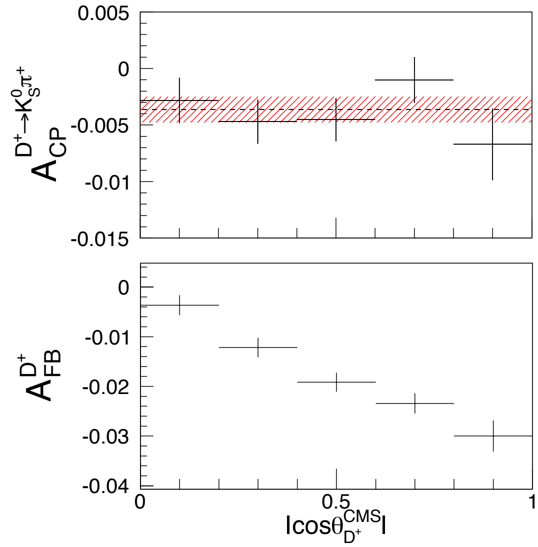

Figure 6: $A_{CP}^{K_S\pi^+} = A_{CP}^{\overline{K}^0\pi^+} + A_{CP}^{\overline{K}^0}$ (top) and A_{FB} (bottom) measured from $D^{\pm} \to K_S^0\pi^{\pm}$ decays [16].

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Decay mode	Data	A_{CP} (%)	Reference
$D^0 \to \pi^+\pi^-$	977 fb^{-1}	$(+0.55 \pm 0.36 \pm 0.09)\%$	[9]
$D^0 \to K^+K^-$	977 fb^{-1}	$(-0.32 \pm 0.21 \pm 0.09)\%$	[9]
$D^0 \to K^0_S\,\pi^0$	791 fb^{-1}	$(-0.28 \pm 0.19 \pm 0.10)\%$	[17]
$D^0 \to K^0_S\,\eta$	791 fb^{-1}	$(0.54 \pm 0.51 \pm 0.16)\%$	[17]
$D^0 \to K^0_S\,\eta'$	791 fb^{-1}	$(0.98 \pm 0.67 \pm 0.14)\%$	[17]
$D^0 \to K^+\pi^-\pi^0$	281 fb^{-1}	$(-0.6 \pm 5.3)\%$	[18]
$D^0 \to K^+\pi^-\pi^+\pi^-$	281 fb^{-1}	$(-1.8 \pm 4.4)\%$	[18]
$D^+ \to K^0_S\,K^+$	977 fb^{-1}	$(0.08 \pm 0.28 \pm 0.14)\%$	[15]
$D^+ \to K^0_S\,\pi^+$	977 fb^{-1}	$(-0.024 \pm 0.094 \pm 0.067)\%$	[16]
$D^+ \to \phi\,\pi^+$	955 fb^{-1}	$(0.51 \pm 0.28 \pm 0.05)\%$	[19]
$D^+ \to \pi^+\eta$	791 fb^{-1}	$(1.74 \pm 1.13 \pm 0.19)\%$	[20]
$D^+ \to \pi^+\eta'$	791 fb^{-1}	$(-0.12 \pm 1.12 \pm 0.17)\%$	[20]
$D^+_s \to K^0_S\,\pi^+$	673 fb^{-1}	$(5.45 \pm 2.50 \pm 0.33)\%$	[21]
$D^+_s \to K^0_S\,K^+$	673 fb^{-1}	$(0.12 \pm 0.36 \pm 0.22)\%$	[21]

Table 1: Searches for direct CPV in D^0, D^+, and D^+_s decays at Belle.

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