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Measurement of ϕ_3 from Belle

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The latest studies of $B^{\pm} \to D^{(*)}K^{(*)\pm}$ from Belle are presented. The neutral $D^{(*)}$ meson is reconstructed in various decay modes which are accessible to both D^0 and $\bar{D}^0$, and observables which are sensitive to ϕ_3 are measured. These results use a large data sample collected near the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB asymmetric energy e^+e^- collider.

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1. Introduction

Precise measurements of the elements of the Cabibbo-Kobayashi-Maskawa matrix [1] constrain the Standard Model and may reveal new physics. However, the extraction of the Unitarity Triangle angle ϕ_3 [2] is a challenging measurement even with modern high luminosity B factories. The decays $B^\pm \to D^{(*)}K^{(*)\pm}$ provide the cleanest method to determine ϕ_3 [3]. The method employs the interference between $b \to c\bar{u}s$ and $b \to u\bar{c}s$ when the final state is accessible to both D^0 and $\bar{D}^0$ mesons. The theoretical uncertainty is completely negligible, and effects due to mixing and CP violation in the neutral D sector can be taken into account [4] (since these have not yet been discovered, at present they are neglected). In addition to ϕ_3, which is the weak phase difference between the contributing amplitudes, observables also depend on δ_B, the strong phase difference, and r_B, the ratio of the magnitude of the amplitudes. Results are available using various final states of the neutral $D^{(*)}$ meson.

2. $D^{(*)}$ Reconstructed as CP Eigenstates

The latest preliminary results from Belle use a data sample of 253 fb^{-1} corresponding to $275 \times 10^6 B\bar{B}$ pairs [5], and supercede the previous results [6]. Neutral D mesons are reconstructed in CP-even (K^+K^-, $\pi^+\pi^-$) and CP-odd ($K_S\pi^0$, $K_S\eta$, $K_S\phi$, $K_S\omega$) states; the final state $K^+\pi^-$ ($D_{\rm fav}$) is used as a control sample. [Subdecays $\pi^0 \to \gamma\gamma$, $\eta \to \gamma\gamma, \pi^+\pi^-\pi^0$, $\phi \to K^+K^-$, $\omega \to \pi^+\pi^-\pi^0$ are used.] D^* mesons are reconstructed via $D^* \to D\pi^0$. The $D^{(*)}$ candidates are combined with tracks identified as kaons using the Belle particle identification systems to make B candidates. [$B^\pm \to D^{(*)}\pi^\pm$ candidates are also selected as control samples.] Background from continuum ($e^+e^- \to q\bar{q}, q = u,d,s,c$) processes is suppressed using event shape variables, the B flight direction, and the topology of decay products in D decays to pseudoscalar-vector final states ($K_S\phi$, $K_S\omega$). Significant sources of peaking backgrounds from other B decays giving the same final state are vetoed using invariant mass requirements; residual peaking backgrounds are estimated from the D mass sidebands and subtracted from the results. Yields are extracted by fitting the $\Delta E = E_B - E_{\rm beam}$ distributions. Measurements are made of $\mathscr{R}_{1,2}$, the double ratios of the (charge averaged) rates of $B^\pm \to D^{(*)}_{1,2}K^\pm$ compared to those for the $D_{\rm fav}$ control sample, and normalised to the same ratio for $B^\pm \to D^{(*)}\pi^\pm$, and $A_{1,2}$, the CP asymmetries, defined in the usual way. The subscripts $1,2$ correspond to CP-even and CP-odd final states respectively. These observables depend on ϕ_3 as

$$\mathscr{R}_{1,2} = 1 + r_B^2 \pm 2r_B\cos(\delta_B)\cos(\phi_3), \qquad A_{1,2} = \pm 2r_B\sin(\delta_B)\sin(\phi_3)/\mathscr{R}_{1,2}. \tag{2.1}$$

[Note that r_B and δ_B are different, in general, for different B decays.] Results are given in Table 1. The decays $B^\pm \to D_1^*K^\pm$ and $B^\pm \to D_2^*K^\pm$ are observed for the first time with significances 5.6σ and 4.5σ respectively. No significant CP violation effects are seen.

3. $D^{(*)}$ Reconstructed in Suppressed States

If the neutral D meson is reconstructed in a non-CP eigenstate, then if r_D, the ratio of the magnitudes of the suppressed and favoured D decay amplitudes to that state, is comparable to r_B,

	$B^{\mp} \to DK^{\mp}$	$B^{\mp} \to D^{*}K^{\mp}$
A_1	$0.07 \pm 0.14(\text{stat}) \pm 0.06(\text{syst})$	$-0.27 \pm 0.25(\text{stat}) \pm 0.04(\text{syst})$
A_2	$-0.11 \pm 0.14(\text{stat}) \pm 0.05(\text{syst})$	$0.26 \pm 0.26(\text{stat}) \pm 0.03(\text{syst})$
$\mathscr{R}_1$	$0.98 \pm 0.18(\text{stat}) \pm 0.10(\text{syst})$	$1.43 \pm 0.28(\text{stat}) \pm 0.06(\text{syst})$
$\mathscr{R}_2$	$1.29 \pm 0.16(\text{stat}) \pm 0.08(\text{syst})$	$0.94 \pm 0.28(\text{stat}) \pm 0.06(\text{syst})$

Table 1: Results for the double ratios and CP asymmetries in $B^{\pm} \to D^{(*)}_{1,2}K^{\pm}$.

then CP violation effects may be near maximal. The latest results from Belle use a data sample of 357 fb^{-1} corresponding to 386×10^6 $B\overline{B}$ pairs [7], and supercede the previous results [8]. Both suppressed ($B^{\pm} \to [K^{\mp}\pi^{\pm}]_D K^{\pm}$) and favoured ($B^{\pm} \to [K^{\pm}\pi^{\mp}]_D K^{\pm}$) final states are reconstructed. [$B^{\pm} \to D\pi^{\pm}$ decays are used as a control sample.] As before, suppression of the background from continuum processes is achieved using the event topology, and major peaking background sources are vetoed. Yields are obtained by fitting the ΔE distributions. In the suppressed channel $2.4^{+4.9}_{-4.4}$ signal events are observed, as shown in Fig. 1. consistent with the expected residual peaking background of $2.4^{+2.3}_{-2.0}$ events. After subtracting this background, and normalising to the favoured mode (634^{+59}_{-99} signal events), the ratio $\mathscr{R}_{DK}$ is found to be

$$\mathscr{R}_{DK} = (0.0\,^{+8.4}_{-7.9}\,(\text{stat}) \pm 1.0\,(\text{syst})) \times 10^{-3} < 13.9 \times 10^{-3} \text{ @ 90\% C.L.} \quad (3.1)$$

In terms of ϕ_3, $\mathscr{R}_{DK} = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D) \cos(\phi_3)$, and therefore this upper limit on $\mathscr{R}_{DK}$ can be combined with the measured value of r_D [2] to obtain $r_B(B^{\pm} \to DK^{\pm}) < 0.18$ @ 90% C.L., as shown in Fig. 1. In the $D\pi^{\pm}$ channel, results consistent with expectation, and with the previous Belle result [8], are obtained.

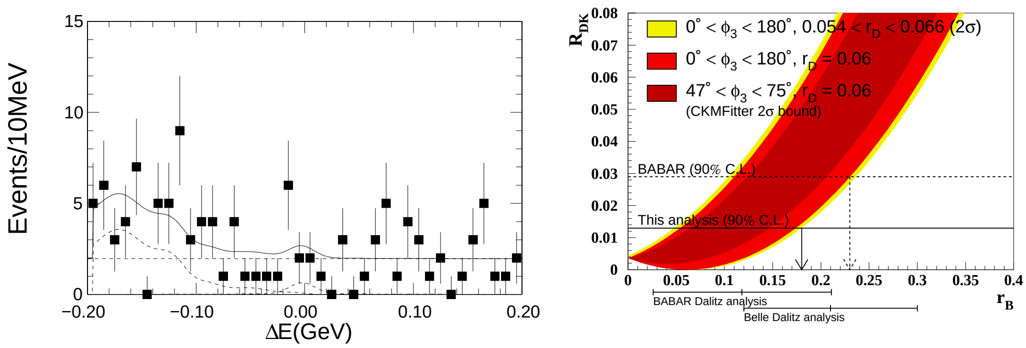

Figure 1: (Left) ΔE distribution for the suppressed decay mode $B^{\pm} \to [K^{\mp}\pi^{\pm}]_D K^{\pm}$; (Right) Constraint on r_B obtained from the limit on $\mathscr{R}_{DK}$.

4. $D^{(*)}$ Reconstructed in Multibody Decays

One of the major developments of the B factories over the past few years has been the use of the multibody decay $D \to K_S\pi^+\pi^-$ to measure ϕ_3 with the $B \to DK$ method. The rich interference pattern across the Dalitz plot results in regions which are highly sensitive to ϕ_3; in addition this mode is reasonably accessible experimentally, due to its large product branching fraction and clean signal. The latest preliminary results from Belle use a data sample of 253 fb^{-1} corresponding to $275 \times 10^6 B\overline{B}$ pairs. Results are available in the channels $B^\pm \to DK^\pm$, $B^\pm \to D^*K^\pm$ with $D^* \to D\pi^0$ and $B^\pm \to DK^{*\pm}$ with $K^{*\pm} \to K_S\pi^\pm$ [9], and supercede the previous results [10]. In all cases the multibody neutral D meson decay $D \to K_S\pi^+\pi^-$ is used. In the above decay modes, 276 (209 ± 16), 69 (58 ± 8) and 56 (36 ± 7) candidate events (signal yields) are obtained, respectively, where the yields are extracted by fitting the ΔE distributions. The D decay model is obtained by fitting the enormous sample of mesons produced in $e^+e^- \to c\overline{c}$ reactions, with charm content tagged via the decay $D^{*\pm} \to D\pi^\pm$. The Dalitz plot is described by a sum of 18 quasi-two-body amplitudes (with resonances described by Breit-Wigner shapes) and a nonresonant term. This model includes two broad scalars in the $\pi\pi$ channel to describe the S-wave; the parametrization of this term is the main source of model uncertainty. Results are extracted by unbinned maximum likelihood fits to the Dalitz plot distributions, followed by a statistical procedure to remove possible bias in the results due to the constraint that r_B is positive definite. The results are summarised in Table 2. [Recall that r_B and δ_B are different, in general, for different B decays.] The most restrictive measurement of ϕ_3 comes from combination of the $DK^\pm$ and $D^*K^\pm$ results, and is $\phi_3 = 68^\circ\,{}^{+14^\circ}_{-15^\circ}(\text{stat}) \pm 13^\circ(\text{syst}) \pm 11^\circ(\text{model})$.

	$B^\pm \to DK^\pm$	$B^\pm \to D^*K^\pm$	$B^\pm \to DK^{*\pm}$
ϕ_3	$64^\circ \pm 19^\circ(\text{stat}) \pm 13^\circ(\text{syst}) \pm 11^\circ(\text{model})$	$75^\circ \pm 57^\circ(\text{stat}) \pm 11^\circ(\text{syst}) \pm 11^\circ(\text{model})$	$112^\circ \pm 35^\circ(\text{stat}) \pm 9^\circ(\text{syst}) \pm 14^\circ(\text{model})$
r_B	$0.21 \pm 0.08(\text{stat}) \pm 0.03(\text{syst}) \pm 0.04(\text{model})$	$0.12\,{}^{+0.16}_{-0.11}(\text{stat}) \pm 0.02(\text{syst}) \pm 0.04(\text{model})$	$0.25 \pm 0.18(\text{stat}) \pm 0.09(\text{syst}) \pm 0.09(\text{model})$
δ_B	$157^\circ \pm 19^\circ(\text{stat}) \pm 11^\circ(\text{syst}) \pm 21^\circ(\text{model})$	$321^\circ \pm 57^\circ(\text{stat}) \pm 11^\circ(\text{syst}) \pm 21^\circ(\text{model})$	$353^\circ \pm 35^\circ(\text{stat}) \pm 8^\circ(\text{syst}) \pm 54^\circ(\text{model})$

Table 2: Results of the $B^\pm \to D^{(*)}K^{(*)\pm}$, with $D \to K_S\pi^+\pi^-$, analysis. The model error for the $B^\pm \to DK^{*\pm}$ results includes a component due to the effect of a possible $B^\pm \to D\,(K_S\pi^\pm)_{\text{non}-K^*}$ component.

References

[1] M. Kobayashi, T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).

[2] S. Eidelman *et al.* (Particle Data Group), Phys. Lett. B **592**, 1 (2004).

[3] M. Gronau, D. Wyler, Phys. Lett. B **165**, 172 (1991); M. Gronau, D. London, Phys. Lett. B **253**, 483 (1991); D. Atwood, I. Dunietz, and A. Soni, Phys. Rev. Lett. **78**, 3257 (1997); Phys. Rev. D **63**, 036005 (2001).

[4] See, for example, Y. Grossman, A. Soffer, J. Zupan, Phys. Rev. D **72**, 031501 (2005).

[5] K. Abe *et al.* (Belle collaboration), BELLE-CONF-0443.

[6] K. Abe *et al.*, Phys. Rev. Lett. **90**, 131803 (2003); S.K. Swain, T.E. Browder *et al.*, Phys. Rev. D **68**, 051101 (2003).

[7] K. Abe *et al.* (Belle collaboration), BELLE-CONF-0552 (hep-ex/0508048).

[8] M. Saigo *et al.* (Belle collaboration), Phys. Rev. Lett. **94**, 091601 (2005).

[9] K. Abe *et al.* (Belle collaboration), BELLE-CONF-0476 (hep-ex/0411049); BELLE-CONF-0502 (hep-ex/0504013).

[10] A. Poluektov *et al.* (Belle collaboration), Phys. Rev. D **70**, 072003 (2004).