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Charm Mixing at *BABAR*

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Abstract. We report on searches for D^0-$\bar{D}^0$ mixing using decay-time distributions of $D^0 \to K\pi$ and $D^0 \to K^{(*)}e\nu$ decays and a lifetime ratio analysis of $D^0 \to K^+K^-$, $\pi^+\pi^-$ decays using 91 fb^{-1} of e^+e^- data taken at the PEP-II asymmetric-energy storage ring at energies near 10.6 GeV. Searches for *CP*-violation in D^0 mixing and decay are also reported, as well as a measurement of R_D, the ratio of the doubly Cabibbo-suppressed decay rate to the Cabibbo-allowed decay rate.

Keywords: BaBar, PEP-II, charm, mixing, hadronic, semileptonic, lifetime ratio, CP violation
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Decays of charm mesons have long been known to be a potentially fruitful place to search for new physics. Observation of D^0-$\bar{D}^0$ mixing could signal new physics beyond the Standard Model; observation of *CP* violation involving D^0 mesons definitely would. Mixing may be characterized in terms of differences of the masses $\Delta M = m_1 - m_2$ and widths $\Gamma = \Gamma_1 - \Gamma_2$ of the mass eigenstates as $x = \Delta M/\Gamma$ and $y = \Delta\Gamma/2\Gamma$. Here we report on three analyses of D^0 decays using the *BABAR* detector [1].

HADRONIC $D^0 \to K\pi$ DECAY ANALYSIS

This analysis, performed on a 57 fb^{-1} dataset, uses the decay chain $D^{*+} \to \pi^+ D^0$, $D^0 \to K\pi$ (charge conjugate states implied). The π^+ from the D^{*+} tags the initial D^0 flavor; the kaon charge tags its flavor at decay. D^0 decays that do (do not) change flavor are denoted as “wrong-sign”, or WS (“right-sign”, or RS) decays. Doubly Cabibbo-suppressed (DCS) decays also produce WS events and must be separated from a potential mixing signal using the time distribution of WS events. An unbinned, maximum-likelihood fit is performed to both RS and WS components using cuts on the D^0 mass and $\Delta m \equiv m(D^{*+}) - m(D^0)$ mass difference to separate signal and backgrounds. Fits to signal and background time distributions are shown in Fig. 1. At 95% confidence level, no mixing or *CP* violation is observed (see Table 1). See Ref. [2] for additional results.

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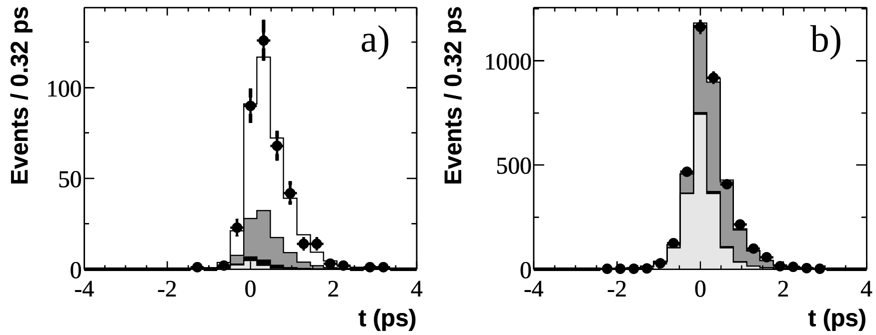

FIGURE 1. The decay-time distribution for $D^0 \to K\pi$ WS candidates in a) a signal region (73% signal purity) and b) a background region (50% combinatorial background). Data are shown as points with the contributions from the fit overlaid: signal (white), backgrounds (shaded).

TABLE 1. Results from the $D^0 \to K\pi$ hadronic analysis, for four cases: (1) full fit; (2) no mixing; (3) no *CP* violation; and (4) no *CP* violation or mixing. x' and y' are x and y rotated by an unknown strong phase between Cabibbo-allowed and DCS decays. A_D is the relative difference between D^0 and $\bar{D}^0$ DCS decay rates.

Fit case	Parameter	Central value ($x'^2=0$) ($/10^{-3}$)	95% CL interval ($/10^{-3}$)
CP violation allowed	R_D	3.1	$2.3 < R_D < 5.2$
	A_D	1.2	$-2.8 < A_D < 4.9$
	x'^2	0	$x'^2 < 2.2$
	y'	8.0	$-56 < y' < 39$
	R_{mix}		$R_{mix} < 1.6$
No *CP* violation	R_D	3.1	$2.4 < R_D < 4.9$
	x'^2	0	$x'^2 < 2.0$
	y'	8.0	$-27 < y' < 22$
	R_{mix}		$R_{mix} < 1.3$
No mixing	$R_D = (0.357 \pm 0.022\,(\text{stat.}) \pm 0.027\,(\text{syst.}))\%$		
	$A_D = 0.095 \pm 0.061\,(\text{stat.}) \pm 0.083\,(\text{syst.})$		
No *CP* violation or mixing	$R_D = (0.359 \pm 0.020\,(\text{stat.}) \pm 0.027\,(\text{syst.}))\%$		

SEMILEPTONIC $D^0 \to K^{(*)}e\nu$ DECAY ANALYSIS

This analysis uses an 87 fb^{-1} dataset and a method similar to that above, but uses the semileptonic D^0 decay mode $D^0 \to K^{(*)}e\nu$ which is not subject to background from DCS decays. The missing momentum of the ν is estimated using a neural net. A limit on the mixing rate $R_{mix} = (x^2+y^2)/2$ is found to be $R_{mix} < 0.0042$ at 90% CL [3].

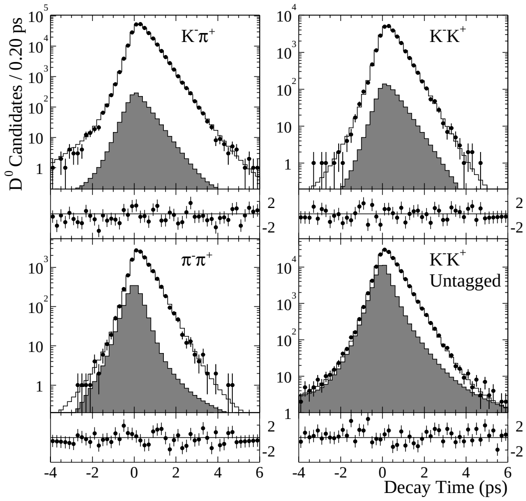

FIGURE 2. The decay-time distribution for the four D^0 samples (points) within a ± 15 MeV/c^2 mass signal window superimposed on a projection of the lifetime fit (histogram). The shaded histogram is the portion of the sample assigned by the fit to the background. The points presented below the histograms are the difference between data and fit divided by the statistical error with error bars of unit length.

LIFETIME RATIO ANALYSIS USING $D^0 \to K^+K^-, \pi^+\pi^-$

Mixing affects D^0 lifetimes for CP-even ($D^0 \to K^+K^-, \pi^+\pi^-$) or odd final states. Lifetime ratios between these and the CP-mixed state $D^0 \to K\pi$ can provide a measure of mixing. The pion in $D^{*+} \to \pi^+ D^0$ is used to tag the initial D^0 flavor; additionally, an untagged, high-statistics KK sample is also used. Fits to the decay-time distributions of these four modes from a 91 fb^{-1} dataset are shown in Fig. 2. Assuming CP conservation, this allows a measure of $y = \tau(K^-\pi^+)/\tau(CP\text{-even mode}) - 1 = (0.8 \pm 0.4^{+0.5}_{-0.4})\%$. See Ref. [4] for additional results.

SUMMARY

We have reported on searches for D^0-$\overline{D}^0$ mixing and CP violation using three different decay modes of the D^0. No mixing or CP violation has yet been observed; however, these analyses use only a fraction of the *BABAR* dataset that will be available in 2006.

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