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SELECTED CHARM PHYSICS RESULTS FROM *BABAR*[*]

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We perform a search for mixing and CP violation in D^0 decays from a 57 fb^{-1} dataset acquired by the Babar experiment near the Upsilon(4S). We measure the time-dependence of wrong-sign decays $D^0 \to K^+\pi^-$ and also the lifetime ratios $\tau(D^0 \to K^-\pi^+)/\tau(D^0 \to K^-K^+)$ and $\tau(D^0 \to K^-\pi^+)/\tau(D^0 \to \pi^-\pi^+)$. For the decays $D^0 \to K^0_S K^\pm\pi^-$ and $D^0 \to K^0_S K^+K^-$, we present preliminary measurements of their branching fractions relative to that of $D^0 \to K^0_S\pi^+\pi^-$, together with an analysis of their Dalitz plot distributions.

1. Introduction

Mixing is characterized by two dimensionless parameters $x \equiv \Delta m/\Gamma$ and $y \equiv \Delta\Gamma/(2\Gamma)$, where $\Delta m = m_1 - m_2$ and $\Delta\Gamma = \Gamma_1 - \Gamma_2$ are the mass and width differences of the two neutral meson mass eigenstates D_1 and D_2, and Γ is their average width. For $D^0\overline{D}^0$-mixing, the Standard Model (SM) predicts[1,2] values for x and y which are undetectable by current experiments. Hence, the observation of $D^0\overline{D}^0$ mixing would indicate new physics. Observation of CP violation (CPV) in $D^0\overline{D}^0$ mixing would be an unambiguous sign of new physics.[1,3]

Mixing and CPV may be observable in the *wrong-sign* (WS) decay $D^0 \to K^+\pi^-$ (charge conjugation is implied). The D^0 may decay to $K^+\pi^-$ directly through a doubly-Cabibbo suppressed (DCS) decay amplitude, or by mixing to a $\overline{D}^0$, followed by a Cabibbo-favored (CF) decay of the $\overline{D}^0$.

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To distinguish these two possibilities, we measure the proper time dependence of the WS decay rate together with that of the CF *right-sign* (RS) decay, $D^0 \to K^-\pi^+$. Preliminary *BABAR* results of this measurement are presented in Section 3. [a] In Section 4, we present preliminary *BABAR* measurements of the lifetime ratios $\tau(D^0 \to K^-\pi^+)/\tau(D^0 \to K^+K^-) - 1$ and $\tau(D^0 \to K^-\pi^+)/\tau(D^0 \to \pi^+\pi^-) - 1$. In the limit of CP conservation, these quantities are equal to y. For the decays $D^0 \to K^0_S K^\pm\pi^\mp$ and $D^0 \to K^0_S K^+K^-$, we present preliminary *BABAR* measurements of their branching fractions relative to that of $D^0 \to K^0_S\pi^+\pi^-$, together with an analysis of their Dalitz plot distributions in Section 5.

2. Event selection overview

The data for all three analyses were acquired with the *BABAR* detector.[4] The decay $D^{*+} \to \pi^+_s D^0$ is used to suppress backgrounds and to distinguish D^0 from $\overline{D}^0$. The D^0 decay products are identified using dE/dx from the tracking detector together with light output from a Cherenkov detector. To remove D^0 mesons from B decays and to reduce combinatorial backgrounds, each D^0 is required to have a center of mass momentum greater than 2.6, 2.4 and 2.2 GeV/c for the analyses presented in Sections 3, 4 and 5, respectively. Other criteria are imposed to select high quality tracks and to further reduce backgrounds.[5,6,7] Each event sample may be characterized by the invariant mass m_{D^0} of each candidate D^0, the difference δm between the invariant masses of the D^* and D^0 candidates, and for the mixing analyses, the proper time t and its error σ_t. Sidebands in m_{D^0} and δm are used to determine the level of background.

3. D^0 mixing: wrong sign decays

From a 57 fb^{-1} *BABAR* dataset, each neutral D candidate is assigned to one of four categories based on its origin as D^0 or $\overline{D}^0$ and its decay as RS or WS. In each of the D^0 and $\overline{D}^0$ datasets, the mixing parameters are determined by unbinned, extended maximum likelihood fits to the RS and WS samples simultaneously. The RS sample fixes the D^0 lifetime and signal resolution parameters. The mixing parameters themselves are determined from the WS sample; its t distribution is shown in Figure 1(a). In total, there are approximately 120,000 (430) RS (WS) signal events.

[a] We measure x'^2 and y', where $x' = x\cos\delta_{K\pi} + y\sin\delta_{K\pi}$, $y' = -x\sin\delta_{K\pi} + y\cos\delta_{K\pi}$, and $\delta_{K\pi}$ is an unknown strong phase between the CF and DCS amplitudes.

We present results for three different fit cases: first, a fit allowing for both CPV and mixing, where the WS D^0 and $\overline{D}^0$ samples are fitted separately; secondly, a fit allowing for mixing but no CPV, where the WS samples are fitted together, and finally, a fit where we assume no mixing, but allow for direct CPV. Here, we compute the CP asymmetry $A_{\rm D} \equiv (R_{\rm D}^{+} - R_{\rm D}^{-})/(R_{\rm D}^{+} + R_{\rm D}^{-})$, where $+$ $(-)$ refers to the D^0 $(\overline{D}^0)$ sample.

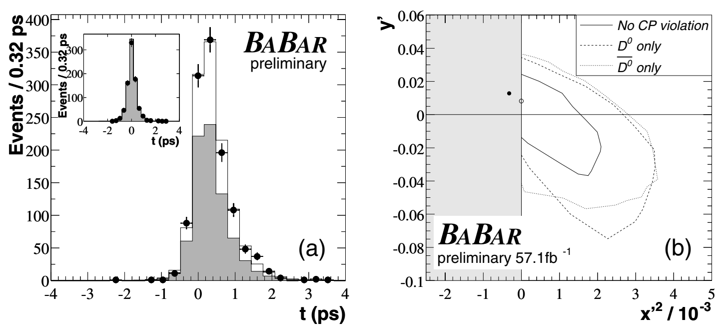

Figure 1. (a): Proper time distribution of WS events for data (points) in the signal region (main figure) and in a sideband (inset). The open (shaded) histograms are the fit results for signal (background). (b): 95% CL limit contours determined for the D^0 (dashed) and $\overline{D}^0$ (dotted) data sets separately, for the case allowing CPV and mixing. The solid contour is for the case assuming CP conservation. For this case, the solid point represents the best fit and the open point is the best fit with the constraint $x'^2 > 0$.

The 95% confidence level (CL) limits are shown in Figure 1(b). Toy Monte Carlo (MC) experiments generated from the probability density function (PDF) of the fit are used to evaluate the CL limits. Systematic uncertainties arising from uncertainties in the PDF parameterization, detector alignment and charge asymmetries, and the event selection criteria are included in the limit calculation. Projecting the contours onto the coordinate axes yields the limits for the mixing parameters for the different cases shown in Table 1.

4. D^0 mixing: lifetime ratios

In the limit of CP conservation where the mass eigenstates D_1 and D_2 are also CP even and odd eigenstates, respectively, the following lifetime ratios can be used to estimate y:

$$y_{KK} = \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to K^-K^+)} - 1, \;\; y_{\pi\pi} = \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to \pi^-\pi^+)} - 1. \qquad (1)$$

Table 1. Preliminary *BABAR* WS analysis results including systematic errors. A central value is reported for both the full fit allowing $x'^2 < 0$ and from a fit with x'^2 fixed at zero. The 95% CL limits are for the case where x'^2 is free.

		Fitted Central Value		
Fit case	Parameter	x'^2 free	x'^2 fixed at 0	95% CL
CPV and mixing	$R_D^+[\%]$	0.32	0.35	$0.18 < R_D^+ < 0.62$
	$R_D^-[\%]$	0.26	0.27	$0.12 < R_D^- < 0.56$
	x'^{+2}	-0.0008	0	$x'^{+2} < 0.0035$
	x'^{-2}	-0.0002	0	$x'^{+2} < 0.0036$
	y'^+	0.017	0.007	$-0.075 < y'^+ < 0.034$
	y'^-	0.012	0.009	$-0.057 < y'^- < 0.036$
No *CPV*	$R_D[\%]$	0.30	0.31	$0.22 < R_D < 0.46$
	x'^2	-0.0003	0	$x'^2 < 0.0021$
	y'	0.013	0.008	$-0.037 < y' < 0.024$
No mixing	$R_D[\%]$	0.357 ± 0.022 (stat) ± 0.027 (syst)		
	$A_D[\%]$	9.5 ± 6.1 (stat) ± 8.3 (syst)		

Table 2. The sizes and purities of the D^0 samples used in the lifetime ratio analysis.

Channel	Events	signal purity
$D^0 \to K^-\pi^+$	158,000	99.5%
$D^0 \to K^-K^+$	16,500	97.1%
$D^0 \to \pi^-\pi^+$	8,350	92.4%

Table 3. Summary of y measurements from *BABAR* and other experiments. The first error is statistical, the second systematic.

BABAR preliminary y measurement (%)		Experiment	y (%)
y_{KK}	$1.6 \pm 1.2^{+0.6}_{-0.7}$	BELLE[8]	$-0.5 \pm 1.0^{+0.7}_{-0.8}$
$y_{\pi\pi}$	$1.0 \pm 1.7^{+1.2}_{-1.4}$	CLEO[9]	$-1.2 \pm 2.5 \pm 1.4$
combined	$1.4 \pm 1.0^{+0.6}_{-0.7}$	E791[10]	$0.83 \pm 2.89 \pm 1.3$
		FOCUS[11]	$3.42 \pm 1.39 \pm 0.74$

Many systematic uncertainties present in the individual lifetime measurements cancel in the ratio of lifetimes. From a 57 fb^{-1} *BABAR* dataset we show the signal yields and purities in Table 2; the lifetime ratios from an unbinned maximum likelihood fit in Table 3 and the sources of systematic error in Table 4. The combined results from the WS decay and lifetime ratio analyses indicate no mixing and no CPV, consistent with SM predictions.

5. Three-Body D^0 decays

From a 22 fb^{-1} *BABAR* dataset, we measure[7] the branching fraction for each of the decays $D^0 \to K^0 K^- \pi^+$, $D^0 \to \overline{K}^0 K^+ \pi^-$ and $D^0 \to \overline{K}^0 K^+ K^-$

Table 4. Sources of systematic uncertainty on y.

Systematic	K^+K^- (%)	$\pi^+\pi^-$ (%)
Monte Carlo Statistics	$^{+0.4}_{-0.6}$	$^{+0.4}_{-0.9}$
Tracking	± 0.2	± 0.9
Particle Identification	± 0.2	± 0.4
Background	± 0.2	± 0.6
Alignment	$^{+0.2}_{-0.1}$	$^{+0.3}_{-0.1}$
Quadrature Sum	$^{+0.6}_{-0.7}$	$^{+1.2}_{-1.4}$

Table 5. Ratios of branching fractions relative to the decay $D^0 \to \overline{K}^0\pi^+\pi^-$.

Channel	BABAR preliminary	PDG world average[12]
$D^0 \to K^0K^-\pi^+$	$(8.32 \pm 0.29(\text{stat}) \pm 0.56(\text{syst}))\%$	$(11.7 \pm 1.7)\%$
$D^0 \to \overline{K}^0K^+\pi^-$	$(5.68 \pm 0.25(\text{stat}) \pm 0.41(\text{syst}))\%$	$(8.9 \pm 1.7)\%$
$D^0 \to \overline{K}^0K^+K^-$	$(16.30 \pm 0.37(\text{stat}) \pm 0.27(\text{syst}))\%$	$(17.2 \pm 1.4)\%$

relative to that for the decay $D^0 \to \overline{K}^0\pi^+\pi^-$ as shown Table 5. In these ratios, many systematic errors cancel.

We perform an amplitude analysis[7] of the Dalitz plot distributions in Figs. 2(a–c) to determine the relative fractions and phases of intermediate resonant and non-resonant amplitudes in D^0 decays. The PDF consists of a signal and a constant background term, each properly normalized. The signal term includes only those amplitudes containing known states and a non-resonant term with a fixed modulus and free phase.

The vertical band in Fig. 2(a) and the results of the amplitude analysis indicate that the D^0 decays to $K^0K^-\pi^+$ primarily through the $K_1^{*+}(892)K^-$ intermediate state. Only a small non-resonant contribution is required.

The Dalitz plot for the decay $D^0 \to \overline{K}^0K^+\pi^-$ is shown in Fig 2(b). The amplitude analysis indicates that this decay contains several interfering amplitudes: $K^{*-}(892)K^+$, $K_0^{*0}(1430)\overline{K}^0$ and $a_0^+(980)\pi^-$. A significant non-resonant term is required.

The Dalitz plot for the decay $D^0 \to \overline{K}^0K^+K^-$ is shown in Fig. 2(c). In the K^+K^- system, a strong $\phi(1020)$ signal is seen interfering with a threshold scalar. A clustering of events at low $\overline{K}^0K^+$ mass due to the $a_0^+(980)$ can also be seen. In the Dalitz analysis, the dominant amplitudes are $\overline{K}^0a_0^0(980)$, $\overline{K}^0\phi(1020)$ and $a_0^+(980)K^-$. A small $\overline{K}^0f_0(980)$ amplitude is also required. There is no significant non-resonant contribution.

The Dalitz plot for the decay $D^0 \to \overline{K}^0\pi^+\pi^-$ is shown in Fig. 2(d). Many intermediate resonances are evident, including the $\rho(770)$, $f_0(980)$ and $\overline{K^*}^+(890)$. An amplitude analysis of this decay is underway.

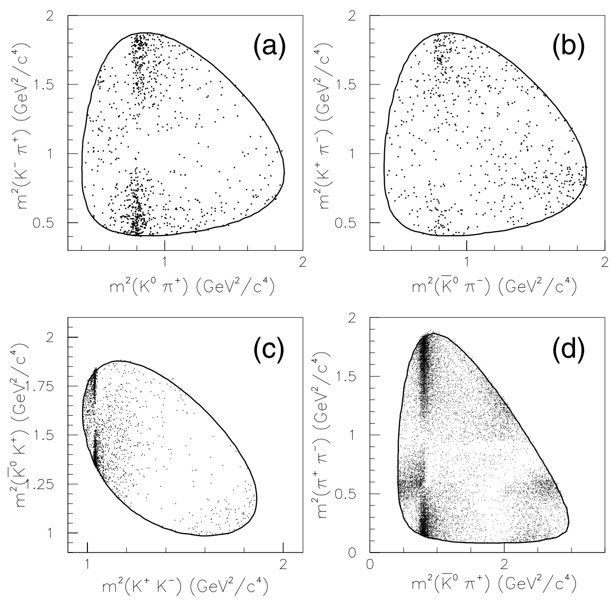

Figure 2. Dalitz plots of the decays (a) $D^0 \to K^0 K^- \pi^+$, (b) $D^0 \to \overline{K}^0 K^+ \pi^-$, (c) $D^0 \to \overline{K}^0 K^+ K^-$ and (d) $D^0 \to \overline{K}^0 \pi^+ \pi^-$. In (a), (b) and (c), the estimated D^0 signal purities are $(95.5 \pm 0.4)\%$, $(95.5 \pm 0.4)\%$ and $(97.5 \pm 0.2)\%$, respectively.

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