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Charm Physics at *BABAR*

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Abstract. Large production of the $c\bar{c}$ pairs and high integrated luminosity make the PEP-II B Factory an excellent place for studying the charm hadrons. In this paper, we present a few most recent results from *BABAR* collaboration in charm sector.

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INTRODUCTION

The *BABAR* detector [1] is a general purpose detector that collect data at PEP-II asymmetric e^+e^- collider, operating at the center-of-mass energy of $\Upsilon(4S)$ resonance or ~ 40 MeV below it. With copious production of $c\bar{c}$ pairs from the continuum and high integrated luminosity, *BABAR* is not only a B Factory, it is also an excellent laboratory to study the charm production and decays. In this paper, we present a few most recent charm analysis results from *BABAR*.

$D^0 - \bar{D}^0$ MIXING

Charm mixing is characterized by two dimensionless parameters, $x \equiv \Delta m/\Gamma$ and $y \equiv \Delta\Gamma/2\Gamma$, where Δm ($\Delta\Gamma$) is the mass (width) difference between the two neutral D mass eigenstates, and Γ is the average width. If either x or y is nonzero, then the $D^0 - \bar{D}^0$ mixing will occur. In the Standard Model (SM), $D^0 - \bar{D}^0$ mixing rate is heavily suppressed by the Glashow-Iliopoulos-Maiani (GIM) mechanism[2]. However, the SM mixing rate can be enhanced by the non-perturbative effects, and possible new physics beyond SM.

Based on a sample of 87 fb^{-1} data, *BABAR* performed a search of $D^0 - \bar{D}^0$ mixing [3] to measure the overall time-integrated mixing rate $R_{mix} = (x^2 + y^2)/2$ using the decay chain $D^{*+} \to D^0\pi^+$, $D^0 \to K^\pm e^\mp \nu$ [4]. The charge of the pion daughter of the charged D^* identifies the production flavor of the neutral D, while the charge of the electron identifies the decay flavor. These charges are the same for unmixed decays and different for mixed decay. Combining with the a neural network and charged kaon and electron particle identification, we obtained 49620 ± 265 unmixed events and 114 ± 61 mixed events. This gives us the final result

$$\begin{aligned} R_{mix} &= 0.0024 \pm 0.0012(\text{stat}) \pm 0.0004(\text{syst}) \\ R_{mix} &< 0.0042 \text{ at } 90\,\% \text{ CL.} \end{aligned} \tag{1}$$

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SEARCH FOR $D^0 \to \ell^+\ell^-$

In the SM, the flavor-changing neutral current (FCNC) decays $D^0 \to e^+e^-$ and $D^0 \to \mu^+\mu^-$ are highly suppressed by the GIM mechanism. The lepton-flavor violating (LFV) decay $D^0 \to e^\pm\mu^\mp$ is strictly forbidden in the SM. Some extensions to the Standard Model [5], such as the R-parity violating supersymmetry, can enhance the FCNC processes by many orders of magnitude, and also allow the LFV decays.

BaBar performed a search for the decays of $D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$, and $D^0 \to e^\pm\mu^\mp$ based on a sample of $122\,\mathrm{fb}^{-1}$ data [6]. To ensure as clean a sample as possible, the reconstructed $D^0 \to \ell^+\ell^-$ candidate is required to originate from a $D^{*+} \to D^0\pi^+$ decay. A minimum value of $2.4\,\mathrm{GeV}/c$ is imposed on the center-of-mass momentum of each D^0 candidate to further reduce the combinatorial background involving the decay products of B mesons. Tight particle selection criteria are also applied to the daughters of $D^0 \to \ell^+\ell^-$ decays.

We observed no significant signals in all three decay modes. As a result, the branching fraction upper limits (UL) have been calculated using the $D^0 \to \pi^+\pi^-$ decay as the normalization mode. We obtain

$$\begin{aligned} \mathrm{Br}(D^0 \to e^+e^-) &< 1.2\times10^{-6} \text{ at } 90\,\%\text{ CL.}, \\ \mathrm{Br}(D^0 \to \mu^+\mu^-) &< 1.3\times10^{-6} \text{ at } 90\,\%\text{ CL.}, \\ \mathrm{Br}(D^0 \to \mu^\pm e^\mp) &< 8.1\times10^{-7} \text{ at } 90\,\%\text{ CL..} \end{aligned} \tag{2}$$

These results represent significant improvements on the previous limits [7, 8], and further restrict possible new physics contribution to these decay processes.

SEARCH FOR $D_{SJ}(2632)^+$

The SELEX Collaboration at FNAL has recently reported the existence of a narrow state [9] at a mass of 2632 MeV/c^2 that decays to $D_s^+\eta$. Evidence for the same state in the corresponding D^0K^+ mass spectrum was also presented. BaBar has searched for this resonance in the final states $D_s^+\eta$, D^0K^+ and $D^{*+}K^0_S$ [10] produced in $e^+e^- \to c\bar{c}$ events, using $125\,\mathrm{fb}^{-1}$ data. As shown in Fig. 1, we don't see any signals in the $D_s^+\eta$ decay channel; similarly, no evidence of $D_{sJ}(2632)^+$ was found in the D^0K^+ and $D^{*+}K^0_S$ final states, although we have seen large and clean signals for the decay $D_{s2}(2573)^+ \to D^0K^+$ and $D_{s1}(2536)^+ \to D^{*+}K^0_S$.

Ξ_C^0 PRODUCTION AND DECAYS

Using a sample of $116\,\mathrm{fb}^{-1}$ data, *BABAR* performed a branching fraction ratio measurement of the Ξ_c^0 decayed to Ω^-K^+ and $\Xi^-\pi^+$ [11]. The result

$$\frac{\mathrm{Br}(\Xi_c^0 \to \Omega^-K^+)}{\mathrm{Br}(\Xi_c^0 \to \Xi^-\pi^+)} = 0.294 \pm 0.018\,(\mathrm{stat}) \pm 0.016\,(\mathrm{syst}) \tag{3}$$

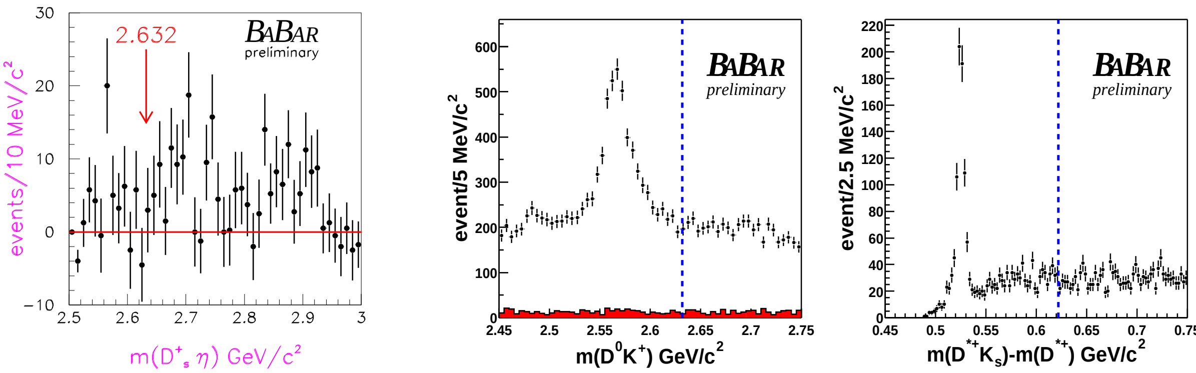

FIGURE 1. (Left:) The $D_s^+\eta$ invariant mass distribution after background subtraction. The arrow indicates the mass location of the expected $D_{sJ}(2632)^+$ state. (Middle:) The D^0K^+ invariant mass distribution. The red histogram is the invariant mass distribution of D^0K^- combination, and the blue line indicates the mass location of expected the $D_{sJ}(2632)^+$ state. (Right) The distribution of invariant mass difference between $D^{*+}K_S^0$ combination and D^{*+} candidate. The blue line indicates the mass location of the expected $D_{sJ}(2632)^+$ state.

is a significant improvement over the previous measurement by CLEO [12], and is consistent with a spectator quark model prediction [13].

Although copious production of Ξ_c^0 in B decays has been predicted, such process has been only observed by CLEO [14], with a significance of $\sim 3\sigma$ in the $\Xi_c^0 \to \Xi^-\pi^+$ decay mode and $\sim 4\sigma$ in the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ decay mode. We studied the Ξ_c^0 production by measuring the spectrum of the Ξ_c^0 momentum p^* in the e^+e^- center-of-mass frame. The Ξ_c^0 produced by the B decays tends to have a smaller momentum, its p^* distribution peaks below 1.5 GeV/c and has a kinematic limit of $p^* = 2.135$ GeV/c at *BABAR*. As for the Ξ_c^0 from continuum production, its momentum distribution peaks at a much higher p^* value. By examining the p^* distribution of the Ξ_c^0 from on-resonance and off-resonance sample, we found

$$\mathrm{Br}(B \to \Xi_c^0 X) \times \mathrm{Br}(\Xi_c^0 \to \Xi^-\pi^+) = 2.11 \pm 0.19\,(\mathrm{stat}) \pm 0.25\,(\mathrm{syst}) \times 10^{-4}, \qquad (4)$$

and

$$\sigma(e^+e^- \to \Xi_c^0 X) \times \mathrm{Br}(\Xi_c^0 \to \Sigma^-\pi^+) = 388 \pm 39\,(\mathrm{stat}) \pm 41\,(\mathrm{syst})\,\mathrm{fb}, \qquad (5)$$

where both Ξ_c^0 and $\bar{\Xi}_c^0$ are included in the cross-section.

MEASUREMENT OF Λ_C^+ MASS

The invariant masses of the charm hadron ground states are currently reported by the Particle Data Group (PDG) with a precision of about 0.5–0.6 MeV/c^2 [15]. The best individual measurements have a statistical and systematic precision of about 0.5 MeV/c^2 and use data samples of a few hundred events. The *BABAR* data sample contains a large amount of different charm hadron decays and, due to the excellent momentum and vertex resolution in *BABAR*, many of the decay modes can be reconstructed with an event-by-event mass uncertainty of a few MeV/c^2. We can therefore significantly improve the precision on the charm hadron mass measurements.

With a sample of $232\,\mathrm{fb}^{-1}$ data, *BABAR* performed a precision measurement of the Λ_c^+ mass. The measurement is based on the reconstruction of the decay modes $\Lambda_c^+ \to \Lambda \overline{K}^0 K^+$ and $\Lambda_c^+ \to \Sigma^0 \overline{K}^0 K^+$. Because almost all of the Λ_c^+ invariant mass in these decays results from the well-known rest mass values of the Λ_c^+ decay products, the systematic uncertainty in the reconstructed mass is significantly reduced compared to the precision obtained in other decay modes. Combining the results from those two modes, the final result of the Λ_c^+ mass is

$$m(\Lambda_c^+) = 2286.46 \pm 0.14\,\mathrm{MeV}/c^2. \tag{6}$$

This result is in agreement with the mass values measured in other much large sample of Λ_c^+ decays, including $\Lambda_c^+ \to pK^-\pi^+$ and $\Lambda_c^+ \to pK_S^0$ decays, although these are subject to large systematic uncertainty.

This Λ_c^+ mass measurement is the most precise measurement of an open charm hadron mass to date and is an improvement in precision by more than a factor of four over the current PDG value of $2284.9 \pm 0.6\,\mathrm{MeV}/c^2$. Our result is about 2.5σ higher than the PDG value, which is based on several high Q-value decay modes, mainly $\Lambda_c^+ \to pK^-\pi^+$ decays.

CONCLUSION

BABAR has a very rich and active charm physics program. In this paper we discussed only a few most recent results from *BABAR*. Given the excellent luminosity achieved by PEP-II, much more high precision charm physics results are expected in the near future.

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