International Journal of Modern Physics A

MEASUREMENT OF THE $D\bar{D}$ CROSS SECTIONS AND D HADRONIC BRANCHING FRACTIONS

Guang-Pei Chen

Physics Department, Carnegie Mellon University, 5000 Forbes Avenue Pittsburgh, PA 15213, U.S.A

Received (Day Month Year)
Revised (Day Month Year)

Using 57.2 pb^{-1} of data collected with the CLEO-c detector at the $\psi(3770)$ resonance, we measure absolute branching fractions for three D^0 and two D^+ Cabibbo-allowed hadronic decay modes, and the cross section for $e^+e^- \to D\bar{D}$ at $\sqrt{s} = 3.77$ GeV.

Keywords: cross section; hadronic; branching fraction.

1. Introduction

The "double tag" technique [1] for e^+e^- collisions at $\sqrt{s} = 3.77$ GeV is powerful to solve the problem to accurately determine the number of D mesons produced at higher energies in absolute D branching fraction measurements. At $\sqrt{s} = 3.77$ GeV, no additional hadrons accompany the $D\bar{D}$ pairs are produced. Reconstruction of one D meson (called single tag or ST) serves to tag the event as $D\bar{D}$. For a mode i, the number of observed ST events N_i depends on the corresponding branching fraction $\mathcal{B}_i$, the detection efficiency ϵ_i, and the number of $D\bar{D}$ events $N_{D\bar{D}}$: $N_i = 2\epsilon_i\mathcal{B}_i N_{D\bar{D}}$. Reconstruction of the other D (called double tag or DT) means full reconstruction of the $D\bar{D}$. The number of observed DT events with mode i and j is $N_{ij} = (2-\delta_{ij})\epsilon_{ij}\mathcal{B}_i\mathcal{B}_j N_{D\bar{D}}$, where ϵ_{ij} is the double tag efficiency. DT can then be used to determine the D branching fractions independent of the luminosity:

$$\mathcal{B}_j = \frac{2\epsilon_i}{(2-\delta_{ij})\epsilon_{ij}} \cdot \frac{N_{ij}}{N_i}. \tag{1}$$

On the other hand, the number of $D\bar{D}$ pairs produced is given by:

$$N_{D\bar{D}} = \frac{(2-\delta_{ij})\epsilon_{ij}}{4\epsilon_i\epsilon_j} \cdot \frac{N_i N_j}{N_{ij}}. \tag{2}$$

Note that $\epsilon_{ij} \approx \epsilon_i\epsilon_j$. Hence, a branching fraction $\mathcal{B}_j$ obtained using this procedure is nearly independent of the efficiencies of tagging modes, and the number of $D\bar{D}$ events is not sensitive to the efficiencies at all.

In this analysis, our measurements are limited to three D^0 modes ($K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^+\pi^-$) and two D^+ modes ($K^-\pi^+\pi^+$, $K^0_S\pi^+$).

2. Data Sample and Event Selection

Our measurements are based on an integrated luminosity of 57.2 ± 1.7 pb^{-1} of $\psi(3770)$ data collected with the CLEO-c detector at the Cornell Electron Storage Ring (CESR). The detector is a modification of CLEO III detector [2], and CESR was operating in a configuration that six of twelve wiggler magnets had been installed to enhance synchrotron radiation damping at energies in the charm threshold region.

We reconstructed all events the following way. Charged track candidates must pass the basic quality requirements, they are identified as pions or kaons with a combined dE/dx and RICH particle identification technique. Neutral pion candidates have to pass a mass cut, and a subsequent kinematic fit is applied. K_S^0 candidates are built with pairs of tracks that pass a mass cut after a vertex constrained fit. To select D candidates, we apply cut on the absolute value of the energy difference, $\Delta E \equiv E(D) - E_{\rm beam}$, where $E(D)$ is the energy of the D candidate. For the ST analysis, we chose the candidate with the smallest $|\Delta E|$, if there was more than one D candidate in a particular mode. To obtain $D\bar{D}$ events for DT yields, we select only one candidate per event per combination D and $\bar{D}$ decay modes. This best candidate is defined as the one which has average mass closest to the nominal D mass. Monte Carlo (MC) study demonstrates that this procedure does not generate false peaks at the D mass in the $M(D)$ *vs.* $M(\bar{D})$ distributions. To improve the D mass resolution, the beam constrained mass $\sqrt{E^2_{\rm beam} - \vec{p}^2}$ is always used instead of the invariant mass, where $\vec{p}$ is the momentum of the D candidate.

The Monte Carlo $e^+e^- \to \psi(3770) \to D\bar{D}$ events were generated with (1) the EvtGen program [3] which includes simulation of initial state radiation (ISR); (2) GEANT [4] for the detector response; and (3) the program PHOTOS [5] to simulate final state radiation (FSR).

3. Results

We used binned likelihood fits to extract ST yields. The signals are modeled with an inverted Crystal Ball [6] function (a core Gaussian is used instead for MC without ISR), along with a wider bifurcated Gaussian to account for signal tail. Combinatorial backgrounds are modeled with an ARGUS background function [7]. Unbinned 2-D maximum likelihood fits were used to extract the double tag yields. The components are similar to those in ST fit but much more complicated.

We developed a χ^2 fitting procedure which fits simultaneously all charged and neutral D branching fractions and the numbers of charged and neutral $D\bar{D}$ pairs. The fitter deals with the correlation between ST and DT samples, correlation for measurements of $\mathcal{B}_j$ using different tagging modes i, as well as correlations from systematic effects. All experimental measurements, such as event yields, efficiencies, and background branching fractions, are treated in a consistent manner. The χ^2 fitter was tested with generic Monte Carlo events. The testing results were in excellent agreement with the inputs used by EvtGen in generating the events.

The results of the data fit are shown in Table 1. All five branching fractions are consistent with – but also higher than –the current PDG averages [8]. The PDG values don't include FSR. If no FSR is included in our simulations to calculate signal efficiencies, then all the branching fractions would be 0.5% to 2% lower.

Using the fitted number of $D\bar{D}$ events along with the luminosity, we obtain the $e^+e^- \to D\bar{D}$ cross sections at $\sqrt{s} = 3.77$ GeV, the values are also listed in Table 1. These results are in good agreement with the cross sections measured by the MARK III collaboration [1] and in excellent agreement with recent BES results [9].

Table 1. Preliminary fitted branching fractions, $D\bar{D}$ pair yields, and $D\bar{D}$ cross sections. Uncertainties are statistical and systematic, respectively.

Parameter	Fitted Value	Cross Section (nb)
$N_{D^0\bar{D}^0}$	$(1.98 \pm 0.04 \pm 0.03) \times 10^5$	$3.47 \pm 0.07 \pm 0.15$
$\mathcal{B}(D^0 \to K^-\pi^+)$	$0.0392 \pm 0.0008 \pm 0.0023$	
$\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$	$0.143 \pm 0.003 \pm 0.010$	
$\mathcal{B}(D^0 \to K^-\pi^+\pi^+\pi^-)$	$0.081 \pm 0.002 \pm 0.009$	
$N_{D^+D^-}$	$(1.48 \pm 0.06 \pm 0.04) \times 10^5$	$2.59 \pm 0.11 \pm 0.11$
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$	$0.098 \pm 0.004 \pm 0.008$	
$\mathcal{B}(D^+ \to K^0_S\pi^+)$	$0.0161 \pm 0.0008 \pm 0.0015$	

There are many contributions to the systematic errors. Among all these contributions, the one from tracking efficiencies–conservatively 3% per track–dominates in these preliminary results. We expect to significantly reduce our systematic uncertainties in the future.

4. Conclusions

Based on the CESR pilot run data sample, we measured three D^0 and two D^+ branching fractions, as well as the $D\bar{D}$ cross sections at $\sqrt{s} = 3.77$ GeV. Since these data were taken, six additional wiggler magnets have been installed in CESR. We expect to provide more results soon.

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