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RECENT RESULTS ON CHARM PHYSICS FROM CDF

PAUL E. KARCHIN

Department of Physics and Astronomy, Wayne State University
666 W. Hancock St., Detroit, MI 48201, U.S.A.

on behalf of the CDF Collaboration

Preliminary results are reported for measurements of the masses and widths of the $L = 1$ charm mesons $D_1^0(2420)$ and $D_2^0(2460)$, using data from Run II of the Fermilab Tevatron. Final results are presented for CP asymmetry and relative branching fraction for the decays $D^0 \to K^+K^-$ and $\pi^+\pi^-$.

1. Hadronic Trigger

In Run II of the Fermilab Tevatron, the CDF experiment employs an on-line trigger which reconstructs a secondary vertex from two charged particles. This trigger yields large statistics signals for charm particles.[1] For example, with a data set corresponding to an integrated luminosity $\int \mathcal{L}dt = 123$ pb^{-1} of $p\overline{p}$ collisions, for the decay $D^{*+} \to D^0\pi^+,\ D^0 \to K^-\pi^+$ (and charge conjugate), the signal is 180910 ± 480 events with a negligible background. Henceforth, reference to a charm decay reaction implicitly includes the charge conjugate reaction, unless otherwise noted.

2. Mass and Width of the Narrow Width $L = 1$ D^{**} Mesons

The D mesons, with quark content $c\overline{q}$ where $\overline{q}$ is a $\overline{u}$ or $\overline{d}$ quark, have radial and angular excited states. Precision measurements of the masses and widths of the excited states help refine heavy quark effective theory, a useful approximation for a heavy-light quark system.

The excited D states with quantum numbers $n = 1, L = 1$ and $J = 1, 2$ are commonly called the D^{**} states. CDF's large sample of reconstructed D^{*+} and D^+ decays allows study of the D^{**} states via the decays

$$D_{1,2}^0 \to D^{*+}\pi^-,\ D^{*+} \to D^0\pi^+,\ D^0 \to K^-\pi^+,\ \text{and} \tag{1}$$

$$D_2^0 \to D^+\pi^-,\ D^+ \to K^-\pi^+\pi^+. \tag{2}$$

Note that while both $D_{1,2}^0$ decay to D^{*+}, only D_2^0 decays to D^+.

The analysis reported here is based on $\int \mathcal{L}dt = 210$ pb^{-1}. The measured distributions of the difference in invariant mass between D^{**} and D candidates

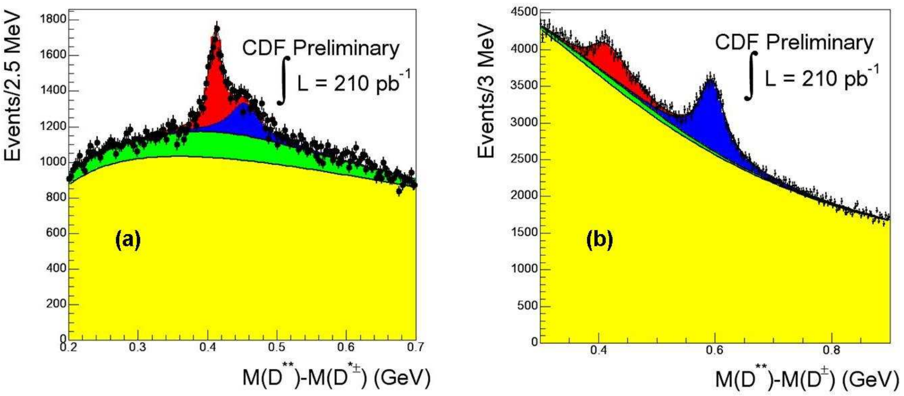

Fig. 1. Measured distributions (data points) of the difference in invariant mass between D^{**} and D candidates: $M(K^-\pi^+\pi^+\pi^-) - M(K^-\pi^+\pi^+)$. (a) Candidates for $D^0_{1,2} \to D^{*+}\pi^-$. (b) Candidates for $D^0_2 \to D^+\pi^-$. The shaded areas show fits to the signals and backgrounds, described in the text.

are shown in Figs. 1(a) and 1(b) for the decay chains of Eqs. (1) and (2). In both figures, the smooth background is primarily due to combinatorics, with a smaller contribution from the large-width states $D^0_0(J^P = 0^+)$ and $D^0_1(J^P = 1^+)$. The two peaks in Fig. 1(a) correspond to the $D^0_1(2420)$, $\sim$ 7000 signal, and $D^0_2(2460)$, $\sim$ 4000 signal. In Fig. 1(b), the higher mass peak is the signal for D^0_2, while the lower mass peak is due to partially reconstructed decays of the type $D^0_{1,2} \to D^{*+}\pi^-$, $D^{*+} \to D^+\pi^0$, $D^+ \to K^-\pi^+\pi^+$, where the π^0 is not detected. The D^0_2 mass and width are determined from a fit to the data of Fig. 1(b), where the D^0_2 signal is well separated from the partially reconstructed peak at lower mass.

The D^0_1 mass and width are determined from the data of Fig. 1(a), with the D^0_2 mass and width fixed. Fixing these parameters solves the problem that the D^0_1 and D^0_2 peaks overlap in Fig 1(a). The preliminary CDF results are presented in Table 1 and compared to the 2004 PDG values and more recent measurements from the BELLE[2] and FOCUS[3] experiments.

Table 1. CDF D^{**} mass and width results (*preliminary*) compared with those from other experiments.

	D^0_1 mass (MeV)	D^0_1 width (Mev)	D^0_2 mass (MeV)	D^0_2 width (Mev)
CDF 04	$2421.7 \pm 0.7 \pm 0.6$	$20.0 \pm 1.7 \pm 1.3$	$2463.3 \pm 0.6 \pm 0.8$	$49.2 \pm 2.1 \pm 1.2$
BELLE 03	$2421.4 \pm 1.5 \pm 0.9$	$23.7 \pm 2.7 \pm 4.0$	2461.6 ± 3.9	45.6 ± 8.0
FOCUS 04			$2464.5 \pm 1.1 \pm 1.9$	$38.7 \pm 5.3 \pm 2.9$
PDG 04	$2422 \quad \pm 1.8$	$18.9^{+4.6}_{-3.5}$	2458.9 ± 2.0	$23 \quad \pm 5$

It is evident from Table 1 that the CDF results significantly improve the precision on the D_1^0 and D_2^0 masses and widths. Furthermore, CDF confirms the recent measurements showing that the D_2^0 width is about twice as big as older measurements on which the PDG 04 value is based.

3. Study of the Decays $D^0 \to K^+K^-$ and $\pi^+\pi^-$

The results presented here on the singly Cabibbo-suppressed decays $D^0 \to K^+K^-$ and $\pi^+\pi^-$ have been submitted for publication.[4] The decays are reconstructed from the decay chain $D^{*+} \to D^0\pi^+$. Without particle identification, there are peaks in the K^+K^- and $\pi^+\pi^-$ mass distributions due to mis-identification of the Cabibbo-favored decay $D^0 \to K^-\pi^+$. However, these mis-identification peaks are well separated from the signals. Based on $\int \mathcal{L}dt = 123$ pb^{-1}, the signal statistics are 16220 ± 200 events for $D^0 \to K^+K^-$ and 7334 ± 97 events for $D^0 \to \pi^+\pi^-$.

The decays $D^0 \to K^+K^-$ and $\pi^+\pi^-$ may exhibit a CP asymmetry defined by

$$A_{CP} = \frac{\Gamma(D^0 \to f) - \Gamma(\overline{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\overline{D}^0 \to f)} \tag{3}$$

where f is the K^+K^- or $\pi^+\pi^-$ final state. A_{CP} is expected to be less than 10^{-3} in the Standard Model. A possible cause of the asymmetry could be the interference between tree and penguin amplitudes. The CDF results for asymmetries are compared with the best previous measurements (by CLEO[5]) in Table 2. The CDF results are the most sensitive to date, but no asymmetry is yet seen.

Table 2. CDF measurements of A_{CP} and comparison with the best previous results.

	CDF	CLEO 2002
$D^0 \to K^+K^-$	$2.0 \pm 1.2 \pm 0.6\%$	$0.0 \pm 2.2 \pm 0.8\%$
$D^0 \to \pi^+\pi^-$	$1.0 \pm 1.3 \pm 0.6\%$	$1.9 \pm 3.2 \pm 0.8\%$

Improved measurement of the ratio of decay rates, $R = \Gamma(D^0 \to K^+K^-)\ /\ \Gamma(D^0 \to \pi^+\pi^-)$, helps refine theoretical models for final state strong interactions and hence improves the predictive power for A_{CP}. The CDF result is $R = 2.76 \pm 0.04 \pm 0.03$, an improvement in precision over the best previous measurement from the FOCUS experiment[6] of $R = 2.81 \pm 0.10 \pm 0.06$.

References

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