CHARM MESON RESULTS FROM CLEO AND ARGUS

Ray Ammar
University of Kansas
Lawrence, KS 66045

Abstract

Recent results on P-wave charmed mesons are presented. Absolute branching fractions for the decay modes $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$ are also given.

P-WAVE CHARMED MESONS

The $c\bar{q}_i$ states ($\bar{q}_i = \bar{u}, \bar{d}, \bar{s}$), with relative orbital angular momentum L = 1 are a useful testing ground for Heavy Quark Effective Theory (HQET) [1]. For each $\bar{q}_i$ there are 4 spin-parity states with $J^P = 0^+,\ 1^+,\ 1^+$ and 2^+. In the limit $m_c \to \infty$, HQET predicts that these 4 states are organized into 2 doublets characterized by different $j = S_q + L$, the angular momentum of the light quark. The 2^+ and one of the 1^+ states have $j = 3/2$, while the other two states have $j = 1/2$. For the decays studied here, the $j = 3/2$ states are expected to proceed via a D-wave and be narrow while the $j = 1/2$ states are expected to decay via S-wave and be broad. Since m_c is not infinite, HQET predictions are not exact and, in particular, the two 1^+ states may mix.

We first present CLEO results for the $c\bar{u}$ system [2], where the 0^+, 1^+ and 2^+ states are named D_0^*, D_1 and D_2^* respectively. Figs. 1(a) and (b) show a $D_1^0 \to D^{*+}\pi^-$ signal with a high-mass shoulder from $D_2^{*0} \to D^{*+}\pi^-$. The D_2^{*0} is suppressed in Fig. 1(a) by the cut on cos α. The helicity angle α is the angle between the π^+ from $D^{*+} \to D^0\pi^+$ and the π^- from the decay of the D^{*+}'s parent, both measured in the D^{*+} rest frame.

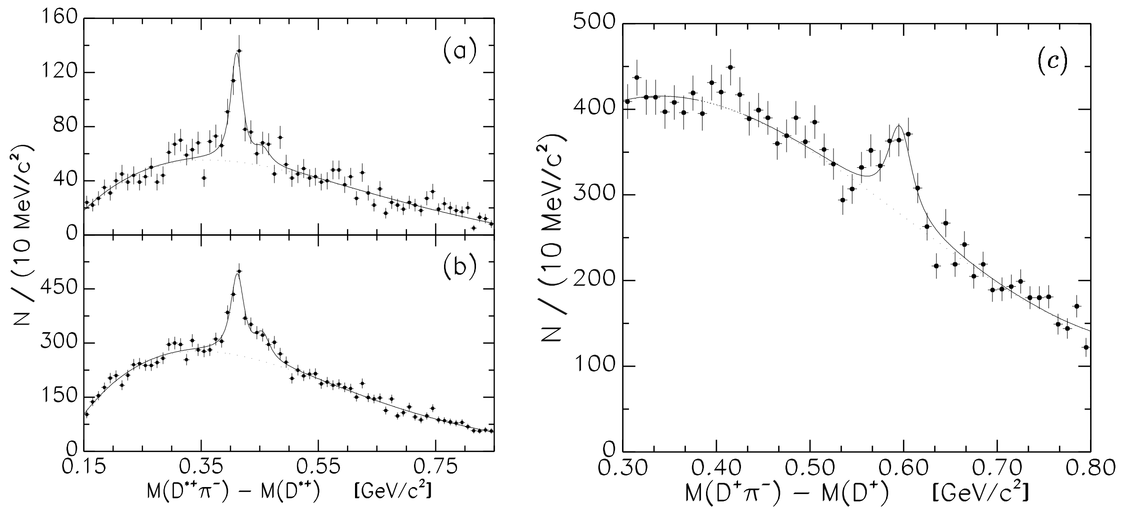

Figure 1: (a) $M(D^{*+}\pi^-) - M(D^{*+})$ for $|\cos\,\alpha| \geq 0.8$, (b) same as (a) but no cos α cut, and (c) $M(D^+\pi^-) - M(D^+)$. The fitted curves are discussed in the text.

Table 1: D_1^0, D_2^{*0}, D_{S1}^+, and D_{S2}^{*+} Masses and Widths in MeV/c^2.

	D_1^0	D_2^{*0}	D_{S1}^+	D_{S2}^{*+}
Mass	2421^{+1+2}_{-2-2}	$2465 \pm 3 \pm 3$	2535.1 ± 0.6	$2573.2^{+1.7}_{-1.6} \pm 0.8 \pm 0.5$
Width	20^{+6+3}_{-5-3}	28^{+8+6}_{-7-6}	< 2.3 (90% CL)	$16^{+5}_{-4} \pm 3$

Fig. 1(c) shows a signal representing $D_2^{*0} \to D^+\pi^-$. In this case there is no evidence for the D_1^0 whose decay into this final state is forbidden by the conservation of angular momentum and parity. The signal was fit to a Breit-Wigner shape convoluted with a Gaussian resolution function, plus a third-order polynomial for the background. Using the mass and width thus obtained for the D_2^{*0} one may similarly fit the signal in Figs. 1(a) and (b) to obtain the mass and width of the D_1^0. These results are summarized in Table 1, and are in agreement with the results found in other studies [3].

The $c\bar{d}$ system has also been studied by CLEO [4] and signals have been observed for the D_1^+ and D_2^{*+}. The isospin mass splittings, in MeV/c^2, are:

$$M(D_1^+) - M(D_1^0) = 4^{+2+3}_{-3-3} \qquad M(D_2^{*+}) - M(D_2^{*0}) = -2 \pm 4 \pm 4$$

consistent with earlier observations [5].

For the $c\bar{s}$ system the 1^+ and 2^+ states are labeled D_{S1} and D_{S2}^*. A CLEO study [6] finds signals for $D_{S1}^+ \to D^{*+}K^0$ and $D_{S1}^+ \to D^{*0}K^+$, observed earlier [7], as shown in Figs. 2(a) and (b), respectively. Fig. 2(c) shows a signal for a new state, discovered by CLEO [8], decaying into D^0K^+. This mode establishes that its J^P belongs to the series $0^+, 1^-, 2^+ ...$, and it is tentatively identified as the D_{S2}^{*+}. Each signal was fit to a Breit-Wigner (the D_{S1} width is consistent with 0), convoluted with a Gaussian resolution function; the background in Fig. 2(c) includes misidentified $D_2^{*+} \to D^0\pi^+$ (dashed curve). Masses and widths for the D_{S1} and D_{S2}^* are summarized in Table 1.

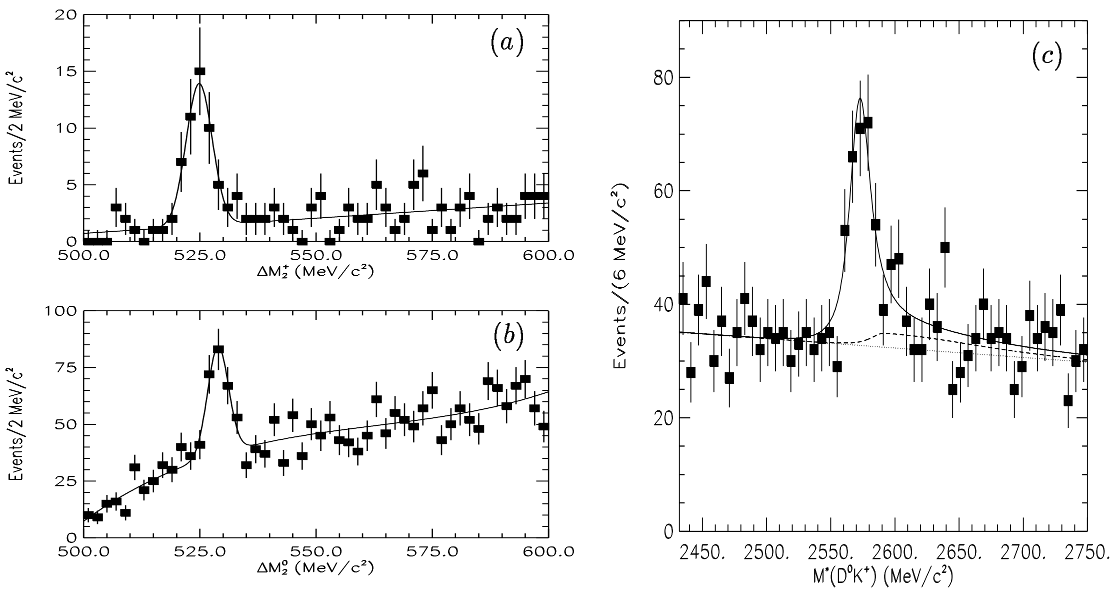

Figure 2: Distributions for (a) $M(D^{*+}K_S^0) - M(D^{*+})$, (b) $M(D^{*0}K^+) - M(D^{*0})$, and (c) $M^*(D^0K^+) = M(D^0K^+) - M(D^0) + M_{D^0}$ where M_{D^0} is the nominal D^0 mass.

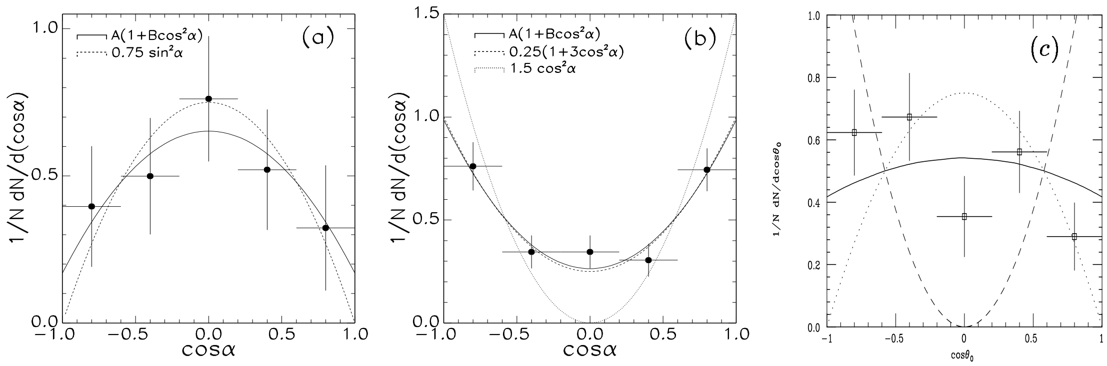

Figure 3: Helicity decay angle distribution of D^* from (a) $D_2^{*0} \rightarrow D^{*+}\pi^-$, (b) $D_1^0 \rightarrow D^{*+}\pi^-$ and (c) $D_{S1}^+ \rightarrow D^{*0}K^+$. In (c) the solid curve represents a fit to A(1+B$\cos^2\alpha$) while the dotted and dashed curves represent $\sin^2\alpha$ and $\cos^2\alpha$ distributions, respectively.

Fig. 3 presents helicity angle distributions for the decay of D^* produced in three separate processes. For D^* from the decay of a 2^+ state, a $\sin^2\alpha$ helicity angle distribution is predicted. This is consistent with the observed distribution in Fig. 3(a), supporting the D_2^{*0} interpretation. A fit to A(1+B$\cos^2\alpha$) yields $-0.74^{+0.49}_{-0.38}$ for B.

A 1^+ state decaying to $D^* + (\pi/K)$ via S-wave would yield an isotropic distribution while a D-wave decay would yield A(1+3$\cos^2\alpha$). The D_1^0 data in Fig. 3(b) gives a good fit (68% CL) to a (1+3$\cos^2\alpha$) distribution and, when fitted to A(1+B$\cos^2\alpha$), yields B $= 2.74^{+1.40}_{-0.93}$ which is consistent with the D-wave decay predicted by HQET. However the data is also consistent with the presence of both S- and D-wave amplitudes with a relative phase, and it is not possible to determine both the phase and the relative amounts of the two amplitudes from the above data [2]. In contrast, when the D_{S1} data in Fig. 3(c) is fitted to A(1+B$\cos^2\alpha$) one obtains B $= -0.23^{+0.40}_{-0.32}$ which is consistent with isotropy (solid curve). In this case the D-wave decay is strongly suppressed because $D_{S1} \rightarrow D^*K$ is near threshold.

Table 2: Absolute Branching Fractions for D^0 and D^+ Decays, in %.

	$D^0 \rightarrow K^-\pi^+$	$D^0 \rightarrow K^-\pi^+\pi^+\pi^-$	$D^0 \rightarrow \overline{K}^0\pi^+\pi^-$	$D^+ \rightarrow K^-\pi^+\pi^+$
ARGUS	$3.41 \pm .12 \pm .28$	$6.80 \pm .27 \pm .57$	$5.03 \pm .39 \pm .49$	
CLEO	$3.95 \pm .08 \pm .17$			$9.3 \pm .6 \pm .8$

ABSOLUTE BRANCHING FRACTIONS FOR D^0 AND D^+ DECAYS

ARGUS reports preliminary branching fractions for D^0 decay to $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, and $\overline{K^0}\pi^+\pi^-$ [9], complementing earlier measurements [10-12]. Tagged D^0's are used and their number is determined from a partial reconstruction of $D^{*+} \rightarrow D^0\pi^+$ using continuum D^{*+} which tend to travel along the jet axis and have high momenta. The energy release in the D^{*+} decay is small so the π^+ makes a small angle Θ with respect to the thrust axis of the event which closely approximates the unmeasured D^{*+} flight direction. Requiring $P_\pi > 200$ MeV/c excludes most D^{*+} from $B \rightarrow D^{*+}X$. An excess of events near $|\cos\,\Theta| = 1$ corresponds to the D^{*+} signal; there is a small background from $\Sigma_c \to \Lambda_c \pi$ which is corrected for. The shape of the signal function used to extract the number of events is obtained using the fully reconstructed decays whose branching fractions are being determined. The results are summarized in Table 2 along with a recent CLEO measurement for $D^0 \to K^-\pi^+$ [13] using the same technique.

CLEO has also recently measured the branching fraction $\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$ [14] using the ratio of the number of ($D^{*+} \to D^+\pi^0$, $D^+ \to K^-\pi^+\pi^+$) to the number of ($D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+$). The unknown number of D^{*+} events cancel in this ratio, and $\mathcal{B}(D^{*+} \to D^0\pi^+)$ / $\mathcal{B}(D^{*+} \to D^+\pi^0)$ is known (2.21 ± 0.07) from isospin and threshold phase space considerations [14]. Correcting for efficiencies one obtains $\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$ / $\mathcal{B}(D^0 \to K^-\pi^+) = 2.35 \pm .16 \pm .16$. Using CLEO's number for $\mathcal{B}(D^0 \to K^-\pi^+)$ one gets the $\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$ value given in Table 2 which agrees with the MARK III result [11] but is larger than the ACCMOR value [12].

REFERENCES

1. N. Isgur and M. B. Wise, Phys. Rev. Lett. **66**, 1130 (1991); S. Godfrey and R. Kokoski, Phys. Rev. **D 43**, 1679 (1991).

2. CLEO Collab., P. Avery *et al.*, Phys. Lett. **B 331**, 236 (1994).

3. ARGUS Collab., H. Albrecht *et al.*, Phys. Rev. Lett. **56**, 549 (1986); Phys. Lett. **B 221**, 422 (1989); Phys. Lett. **B 232**, 398 (1989); E691 Collab., J. C. Anjos *et al.*, Phys. Rev. Lett. **62**, 1717 (1989); CLEO Collab., P. Avery *et al.*, Phys. Rev. **D 41** 774 (1990); E687 Collab., P. L. Frabetti *et al.*, Phys. Rev. Lett. **72**, 324 (1994).

4. CLEO Collab., F. Butler *et al.*, "Observation of $D_1(2430)^+$ and $D_2^*(2470)^+$," submitted to the 1994 International Conference on High Energy Physics, Glasgow.

5. ARGUS Collab., H. Albrecht *et al.*, Phys. Lett. **B 231**, 208 (1989); see also E691 and E687 papers cited in Ref. [3].

6. CLEO Collab., J. P. Alexander *et al.*, Phys. Lett. **B 303**, 377 (1993).

7. ARGUS Collab., H. Albrecht *et al.*, Phys. Lett. **B 230**, 162 (1989); Phys. Lett. **B 297**, 425 (1992); see also CLEO paper cited in Ref. [3].

8. CLEO Collab., Y. Kubota *et al.*, Phys. Rev. Lett. **72**, 1972 (1994).

9. ARGUS Collab., H. Albrecht *et al.*, "Measurement of the Absolute Branching Fractions for D^0 Decays into $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $\overline{K^0}\pi^+\pi^-$." Preliminary draft of paper to be submitted to Phys. Lett. B.

10. ALEPH Collab., D. Decamp *et al.*, Phys. Lett. **B 266**, 218 (1991); HRS Collab., S. Abachi *et al.*, Phys. Lett. **B 205**, 411 (1988); LEBC-EHS Collab., M. Aguilar-Benitez *et al.*, Z. Phys. **C36**, 551 (1987).

11. MARK III: J. Adler *et al.*, Phys. Rev. Lett. **60**, 89 (1988).

12. ACCMOR: S. Barlag *et al.*, Z. Phys. **C55**, 383 (1992); Z. Phys. **C48**, 29 (1990).

13. CLEO Collab., D. S. Akerib *et al.*, Phys. Rev. Lett. **71**, 3070 (1993).

14. CLEO Collab., R. Balest *et al.*, Phys. Rev. Lett. **72**, 2328 (1994).