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RESULTS ON SEMILEPTONIC D^0 AND D_s DECAYS AND EVIDENCE FOR NON-$D\bar{D}$ DECAYS OF THE ψ (3770)*

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I. INTRODUCTION

The spectator picture of charm decays and the assumption of isospin symmetry allows us to conclude that the partial widths (Γ_i) for the semileptonic decays of any species of charmed particle are identical:

$$\Gamma_{D^0}(c \to s\ell\nu) = \Gamma_{D^+}(c \to s\ell\nu) = \Gamma_{D_s}(c \to s\ell\nu)$$

Since the lifetimes of charmed particles (τ_i) are well-known (see Table I), this can be approximately tested by measurements of their individual semileptonic branching ratios B^i_{SL}:

$$\Gamma_{D_i}(c \to s\ell\nu)) \approx B^i_{SL}/\tau_{D_i} = \mathrm{B}(D_i \to \ell + X)/\tau_{D_i}$$

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We see in Table I[1] that $\Gamma_{sl}(D^+)$ and $\Gamma_{sl}(D^0)$ are remarkably close, and that the $B_{sl}(D_s)$ is expected to be about (7.8±1.0)% when averaging D^0 and D^+ partial widths.

Table I. B_{sl} and τ_D for D^0, D^+ and D_s from MKIII and E-691

Decay	Lifetime (10^{-13})	BR($c \to s\ell\nu$)	Γ_{sl} (sec^{-1})
D^0	4.22 ± 0.13	7.5 ± 1.2 %	$1.78 \pm 0.29 \times 10^{11}$
D^+	10.9 ± 0.39	$17.0 \pm 2.0\%$	$1.56 \pm 0.19 \times 10^{11}$
D_s	4.70 ± 0.45	$\Rightarrow 7.8 \pm 1.0\%$	$< 1.67 > \times 10^{11}$

We note that the assumption implicit here is the smallness of Cabibbo suppressed D decays, for each species. Currently, the only measurement of $\mid Vcd \mid \approx 0.24 \pm 0.03$ comes from CDHS,[2] and is an indirect one.

II. OBSERVATION OF CABIBBO SUPPRESSED SEMILEPTONIC D^0 DECAYS

These decays are searched for using 3329 $D^0\bar{D}^0$ events at the $\psi(3770)$ where one D^0 decays hadronically to $K^-\pi^+, K^-\pi^+\pi^+\pi^-, \bar{K}^0\pi^+\pi^-$, $K^-\pi^+\pi^0$ and the other decays semileptonically to $K^+e^-\nu_e$ or $K^+\mu^-\nu_\mu$. Figure 1 shows the mass from the tags in the 9.5 pb^{-1} sample.

In the recoil, hadrons are identified by TOF and DEDX information while electrons are identified by TOF (for $p < 300$ MeV) and by energy deposit in the shower counter (for $p > 300$ MeV). Muons are identified by TOF and the requirement of a small shower counter energy deposit.

The principle kinematic separation between $K\ell\nu$ and $\pi\ell\nu$ events comes from the U = $(E_{miss} - P_{miss})$ variable. Finally, backgrounds from hadronic decays such as $K^-\pi^+\pi^0$ where the π^0 is lost and the π or K is misidentified as a lepton are rejected by allowing no *isolated* photons in the events and an adequate P_T^{miss} (> 200 MeV) to force photons from π^0's out of the beam pipe and into the calorimeters. Table II summarizes our results, while Fig. 2 shows the signal events and the expectation from Monte Carlo for the U distributions.

Table II. Preliminary Mark III $B_{SL}(D^0)$

Decay Mode	Signal Events	Bkd. Events	Effic.	Branching Ratio (%)
$Ke\nu_e$	51	7.5	0.32	$4.1 \pm 0.7 \pm 0.4$
$K\mu\nu_\mu$	50	17.6	0.22	$4.4 \pm 1.0 \pm 0.9$
$\pi e\nu_e$	6	1.1	0.37	$0.40^{+0.30}_{-0.13} \pm 0.08$

Averaging the muon and electron modes (after a small phase space correction), we obtain $\mathrm{Br}(D^0 \to K^-e^+\nu_e) = 4.20 \pm 0.55 \pm 0.41$. The six $\pi^-e^+\nu_e$ events with 1.1 expected background events represent a 3.4σ signal and hence the first observation $D^0 \to \pi^+e^-\nu_e$. Integrating the matrix elements (assuming simple poles at the D^* and D_s^* masses for each vector form factor f_+) we find:

$$\left|\frac{V_{cd}}{V_{cs}}\right|^2 = \left(\frac{f_+^K(q^2=0)}{f_+^\pi(q^2=0)}\right)^2 \quad (0.051^{+0.039}_{-0.018} \pm 0.010)$$

The ratio of the form factors at $q^2 = 0$ is a model dependent quantity. The individual form factors for $D \to K$ or $D \to \pi$ each are expected to deviate strongly from unity, owing to SU(4) breaking. The ratio should be less sensitive, and only deviate at the SU(3) breaking level. Recent calculations place f_+^K/f_+^π near $0.76/0.69 \sim 1.1$.[3]

III. SEARCH FOR D_s SEMILEPTONIC DECAYS

This analysis is similar to the proceeding except that the data used is $6.3\mathrm{pb}^{-1}$ at $\sqrt{s} = 4.14$ GeV and $D_s\bar{D}_s^*$ is the principle production channel. D_s are tagged in three channels; $D_s \to \phi\pi^+, \bar{K}^{*o}K^+$ and $\bar{K}^0K^+$. There are 73±10 tags (see Fig. 3). When tracks in the recoil of the tags are examined we find 9(82) electrons (pions) of the expected charge ("right" sign) and 3(36) electron (pions) of the "wrong" charge. The electrons are shown cross hatched in Fig. 3 at their corresponding tag mass. Using the observed numbers of $\pi^\pm$, we correct the electrons (of both signs) for particle misidentification. The number of true right sign electrons is reduced to 6.6 and wrong sign to 1.9. After efficiency correction these become 9.4 and 2.7 electrons, respectively. Using the number of tags, and ignoring the possible D background under the tags we obtain (using Poisson statistics) a branching ratio of $9^{+9}_{-7} \pm 1.4\%$, which while consistent with expectations (see Table I) represents a signal of only 1.2σ from zero. We therefore quote a limit of $\leq$24% at 90% CL for the D_s semileptonic branching ratio.

IV. PRELIMINARY EVIDENCE FOR NON-D$\bar{\text{D}}$ DECAYS OF THE ψ(3770)

The discrepancy in recent years between $\sigma_{D\bar{D}}$ and $\sigma_{\psi(3770)}$ has been reduced, but still remains non-negligible.[4] One possible explanation is the existence of non-$D\bar{D}$ decays of the $\psi(3770)$. Previously, only lower limits of 71% (96.2%) of $D\bar{D}$ ($B\bar{B}$) decays at the $\psi(3770)$ (Υ(4S)) had been set. While the partial widths for hadronic decays $\Gamma(\psi'' \to \pi^+\pi^-\psi)$ are expected to be $\leq$ 100 KeV ($\sim$ 0.4%) and the electromagnetic decays $\Gamma(\psi'' \to \gamma\chi_c^J)$ less than 400 KeV ($\sim$ 1.6%) each, none of these charmonium transitions have yet been observed.

We have searched for the reaction $e^+e^- \to \pi^+\pi^-\psi, \psi \to e^+e^-$ or $\mu^+\mu^-$. These reactions are 4C fit, applying particle identification from the TOF, muon and shower systems. The main background, $e^+e^- \to \gamma\psi', \psi' \to \pi^+\pi^-\psi$ is removed by cutting on the $\pi^+\pi^-$ energy, which is significantly lower for the background reaction (see Fig. 4 inset). After cutting $E_{\pi\pi} > 608$ MeV, and requiring no additional photons in the event, a signal of 9 events ($4e^+e^-, 5\mu^+\mu^-$) is observed (Fig. 4). From the 16K underlying ψ' radiative events, 0.3 events are expected to contaminate the signal after cuts. We obtain $\sigma_{\psi''} \times$ Br $(\psi'' \to \pi^+\pi^-\psi) = (1.1 \pm 0.5 \pm 0.2) \times 10^{-2}$ nb.

The electric dipole transitions are searched for via $e^+e^- \to \gamma\chi_J$, $\chi_J \to \gamma\psi$ or $\pi^+\pi^+\pi^-\pi^-$ or $\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$. The radiative χ decay is observed in events which have two photons and two muons, and satisfy a 5C kinematic fit (E, $\bar{P}$ and M_ψ). The mass of $\psi\gamma_{high}$ is plotted in Fig. 5. Again, the ψ' radiative tail is the primary physics background contributing 0.25 events. From eight signal events and 2.4 total background events we find $\sigma_{\psi''} \times Br(\psi'' \to \gamma\chi_1) = (0.083 \pm 0.042 \pm 0.015)$nb.

We also report here preliminary results of a search for the $\pi^+\pi^+\pi^-\pi^-$ and $\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$ hadronic decays of the χ_J. Here, to increase efficiency, a kinematic 1C fit with the transition photon allowed to be missing is performed. The ψ' radiative backgrounds are again rejected by the fit, and the requirement of no more than one photon in the events. Backgrounds from $e^+e^- \to \pi^0 + 4$ or 6π are rejected by using 4C and 5C fits as well. Figure 6a and 6b shows the resulting 4π and 6π mass distributions. These yield $\sigma_{\psi''} \times Br(\psi'' \to \gamma\chi_0) = (0.092 \pm 0.034 \pm 0.027)$ nb and $(0.13 \pm 0.07 \pm 0.05)$ nb, and $\sigma_{\psi''} \times Br(\psi'' \to \gamma\chi_1) = (0.077 \pm 0.063 \pm 0.027)$ nb and $(0.10 \pm 0.05 \pm 0.05)$nb for $\gamma 4\pi$ and $\gamma 6\pi$ final states, respectively. The combined upper limit on $\gamma\chi_2$ is 0.1 nb at 90% C.L. These values should be considered preliminary in nature, as the backgrounds and kinematic fits remain under further study.

If we use[5] $\sigma_{D\bar{D}} = 5$ nb, and assume that these are small corrections to the total $\psi(3770)$ cross section, then we see the χ_0, χ_1, and χ_2 transitions represent about $2.0 \pm 0.8\%$, $1.7 \pm 0.7\%$ and $\leq 2.0\%$ at 90% C.L. of the $\psi(3770)$ decays. The hadronic transition to $(\pi\pi)^0\psi$ is $\sim 0.33 \pm 0.16\%$. We see then, that these decays being consistent with theoretical expectations, cannot in themselves account for differences between earlier total cross section measurements and $\sigma_{D\bar{D}}$.

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3. See for example, M. Bauer et al., Z.Phys. **C29**, 637, 1985, B. Grinstein et al., Caltech Report No. CALT–68–1311, 1985, C. Dominguez and N. Paver, Phys. Lett. **207**, 499 1988. These are potential model calculations using relativistic wave functions, non-relativistic wave functions, and QCD sum rules, respectively. Lattice calculations are also being performed, (A. Soni, private communication).
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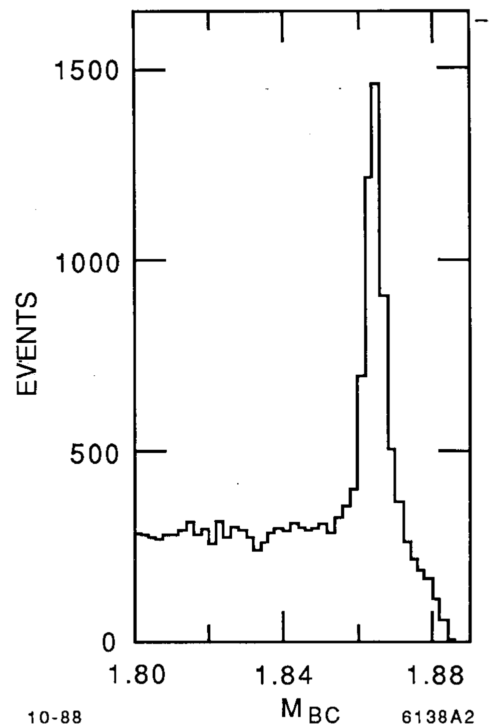

Fig. 1 Beam-constraint mass of D^0 tags.

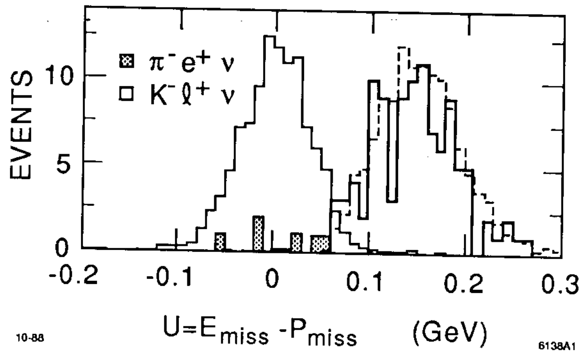

Fig. 2 U-distribution for $\pi^- e^\mp \nu_e$ events (shaded), $K^- \ell^+ \nu_\ell$ events (histogram) where the K^- is intentionally interpreted as a π^-. Overlayed curves are Monte Carlo for these two classes of events.

Fig. 3 Fitted mass distribution of tags (bold curve, left scale), wrong-sign electrons (shaded, right scale) and right-sign electrons (light curve) plotted at the tag's mass.

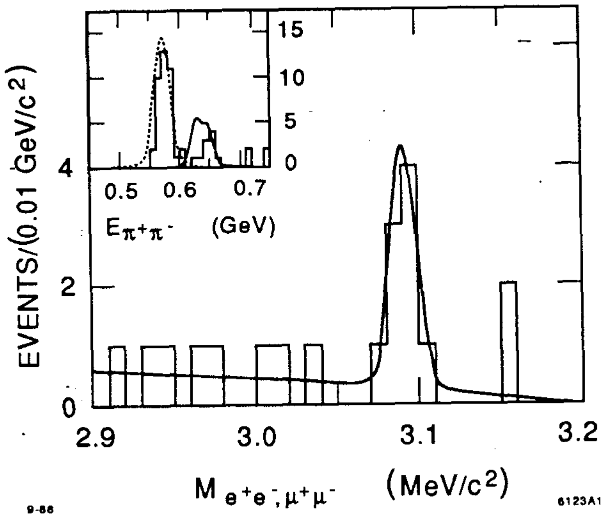

Fig. 4 Dilepton mass from 4C fits to $\psi(3770) \rightarrow \pi^+\pi^-\ell^+\ell^-$. Inset shows the expected separation of events in $E_{\pi^+\pi^-}$ (dotted) from the radiative ψ' background process (solid), and the data.

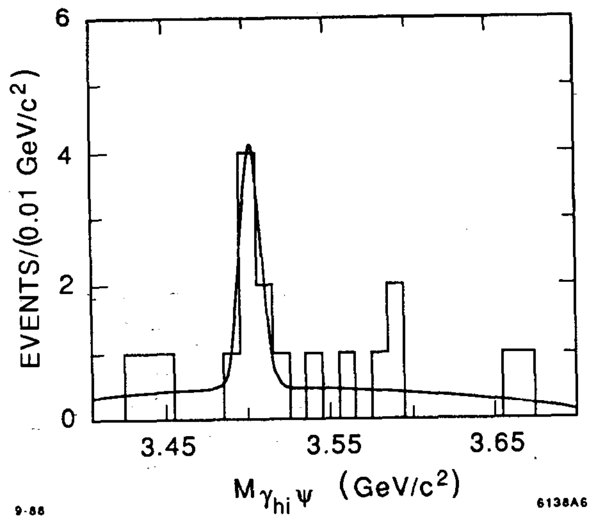

Fig. 5 Fitted mass of $\psi\gamma_{high}$ in the process $\psi(3770) \rightarrow \gamma\chi_J \rightarrow \psi\gamma_{high}$.

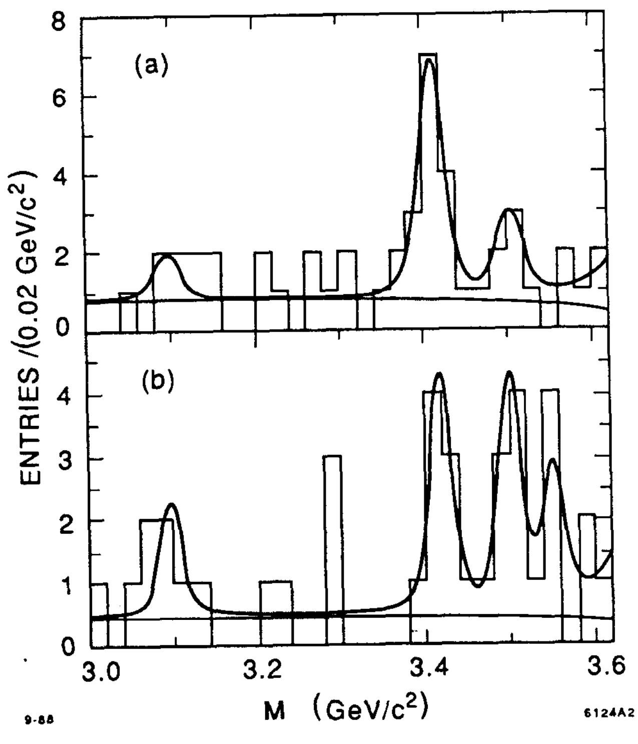

Fig. 6 Fitted mass of 4π (a) and 6π (b) in the processes $\psi(3770) \rightarrow \gamma\chi_J \rightarrow 4\pi$ or 6π. This result is preliminary in nature.