PHYSICAL REVIEW D VOLUME 41, NUMBER 3 1 FEBRUARY 1990

P-wave charmed mesons in e^+e^- annihilation

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(Received 24 August 1989)

Using the CLEO detector at the Cornell Electron Storage Ring, we have found evidence for $L=1$ charmed mesons in e^+e^- annihilations. We observe a D^{**0} state at mass $2461\pm3\pm1$ MeV/c^2 and width 20^{+9+9}_{-12-10} MeV/c^2 decaying to $D^+\pi^-$. We also see an enhancement in the $m(D^{*+}\pi^-)-m(D^{*+})$ mass-difference spectrum and by examining D^{*+} decay-angle dependence, we see structure consistent with two states decaying to $D^{*+}\pi^-$. We observe a lower-mass state, at mass $(2428\pm3\pm2)$ MeV/c^2 and width (23^{+8+10}_{-6-4}) MeV/c^2, assuming that the higher-mass component is from the decay $D^{**0}(2461)\rightarrow D^{*+}\pi^-$. We present arguments for the spin-parity assignments of these states. We also report observation of candidate $L=1$ $c\bar{s}$ state decaying to $D^{*+}K^0_S$.

I. INTRODUCTION

The study of heavy mesons with nonzero orbital angular momentum can provide an understanding of relativistic effects in hadrons and the nature of quark confinement.[1] In this paper we report evidence for D^{**} mesons which consist of one charmed quark and one light quark with orbital angular momentum $L=1$. For $L=1$, there should be four states with spin-parities (J^P) of 0^+, 1^+, 1^+, and 2^+ where, due to parity and angular momentum conservation, the 2^+ state can decay to both $D^*\pi$ and $D\pi$ while the 1^+ states can decay only to $D^*\pi$ and the 0^+ only to $D\pi$.

II. DATA SAMPLE AND EVENT SELECTION

The data for this analysis were collected with the CLEO detector at the Cornell Electron Storage Ring (CESR). The data sample consists of integrated luminosities of 212 pb^{-1} on the $\Upsilon(4S)$, 101 pb^{-1} of nearby continuum, and 117 pb^{-1} on the $\Upsilon(5S)$, giving a total of 430 pb^{-1}. The CLEO detector,[2] our hadronic-event selection criteria[3] and modifications to the main drift chamber[4] have been described in detail elsewhere. The momentum of charged particles is measured with three coaxial drift chambers inside a superconducting solenoid of radius 1.0 m, which produces a 1.0-T magnetic field. The main drift chamber, with 51 layers, has a rms resolution in track ionization (dE/dx) of 6.5%. The momentum resolution for the tracking system is $(\sigma_p/p)^2=(0.23\%p)^2+(0.7\%)^2$, where p is the momentum in GeV/c.

To search for D^{**} states, we first identify D^{*+} and D^+ candidates. (Reference to a specific state or decay will always imply the charge-conjugate state or decay as well.) D^{*+} candidates are observed in the sequential decays $D^{*+}\to D^0\pi^+$, $D^0\to K^-\pi^+$, or $D^0\to K^-\pi^+\pi^-\pi^+$, and D^+ candidates are observed through $D^+\to K^-\pi^+\pi^+$. After selecting hadronic events,[3] we require dE/dx consistency for the kaon and pion candidate tracks in these events. To select D^{*+} candidates, we form a χ^2:

$$\chi^2=\left[\frac{m_{D^0}-m_{D^0}^{\text{nominal}}}{\sigma_{m_{D^0}}}\right]^2+\left[\frac{\delta_{(D^0\pi^+\text{-}D^0)}-\delta_{\text{nominal}}}{\sigma_\delta}\right]^2,$$

where m_{D^0} is the invariant mass of the D^0 candidates and $m_{D^0}^{\text{nominal}}$ is the known D^0 mass; $\delta_{(D^0\pi^+\text{-}D^0)}$ is the measured $m(D^0\pi^+)-m(D^0)$ mass difference, and δ_{nominal} is the known $m(D^{*+})-m(D^0)$ mass difference. The rms resolutions σ_δ and $\sigma_{m_{D^0}}$ vary with momentum; the average values are $\sigma_\delta\approx 1$ MeV/c^2 and $\sigma_{m_{D^0}}\approx 12$ MeV/c^2. We require $\chi^2<4.6$. D^+ candidates must pass a 1.65σ cut on the D^+ mass where the rms mass resolution $\sigma=12$ MeV/c^2. Both the D^{*+} and D^+ cuts are 90% efficient. The $D^{*+}\to D^0\pi^+$, $D^0\to K^-\pi^+$ sample has 4238 ± 80 signal events over a background of about 1600 events, the $D^{*+}\to D^0\pi^+$, $D^0\to K^-\pi^+\pi^-\pi^+$ sample has 5464 ± 155 signal events over a background of about 16 000 and the $D^+\to K^-\pi^+\pi^+$ signal has $16\,925\pm1134$ events over a background of about $1.8\times10^{10^5}$ events. The invariant-mass spectra for the D^{*+} and D^+ candidates, for $x_p>0.6$, are shown in Fig. 1, where x_p is the scaled momentum defined by $x_p=p_D/p_{\max}$; $p_{\max}=(E_{\text{beam}}^2-m_D^2)^{1/2}$. For $x_p>0.6$ we find 1787 ± 45 $D^{*+}\to D^0\pi^+$, $D^0\to K^-\pi^+$ events over a background of about 270, 2550 ± 64 $D^{*+}\to D^0\pi^+$, $D^0\to K^-\pi^+\pi^-\pi^+$ events over a background of about 1650, and 5619 ± 157 D^+ events over a background of about 18 600.

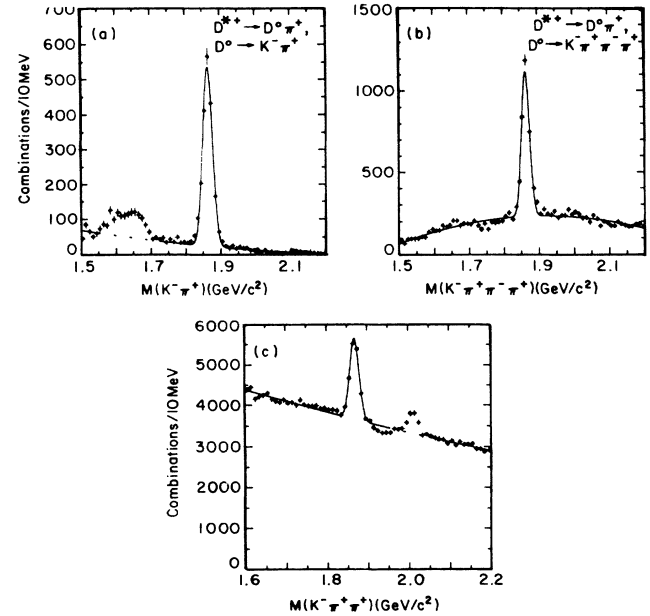

FIG. 1. Invariant-mass spectra: D^{*+} and D^+ candidates with $x>0.6$. (a) $m(K^-\pi^+)$ with cut on D^{*+}-D^0 mass difference, (b) $m(K^-\pi^+\pi^-\pi^+)$ with cut on D^{*+}-D^0 mass difference, and (c) $m(K^-\pi^+\pi^+)$.

Each D^{*+} or D^+ candidate is then combined with each of the remaining tracks in the event that have dE/dx consistent with that of pions to give the four-vectors of the candidate $D^{*+}\pi^-$ or the $D^+\pi^-$ systems. Since we expect the D^{**} momentum spectrum to be peaked toward large values of momentum and the combinatorial background to be peaked at low momentum, we further require $x_p>0.6$ where $x_p=p(D^+\pi^-)/p_{\max}$ or $x_p=p(D^{*+}\pi^-)/p_{\max}$ and $p_{\max}=(E_{\text{beam}}^2-m_{D^{**0}}^2)^{1/2}$. We also expect a large background due to combinations with the many slow pion tracks in an event, which appears as a peak near $\cos\theta_\pi^{**}=-1$, where θ_π^{**} is defined to be the angle between the π^- direction and the $(D^+\pi^-)$ or $(D^{*+}\pi^-)$ boost direction as measured in the $(D^+\pi^-)$ or $(D^{*+}\pi^-)$ rest frame. We require $\cos\theta_\pi^{**}>-0.9$ for $D^+\pi^-$ combinations and $\cos\theta_\pi^{**}>-0.8$ for $D^{*+}\pi^-$ combinations.

III. $D^{**0}\to D^+\pi^-$

The mass-difference spectrum $m(D^+\pi^-)-m(D^+)$ for $x_p>0.6$ and $\cos\theta_\pi^{**}>-0.9$ is shown in Fig. 2. We use a second-order Chebyshev polynomial to fit the background and a Breit-Wigner distribution to fit the signal.[5] We have excluded the region where we expect to see

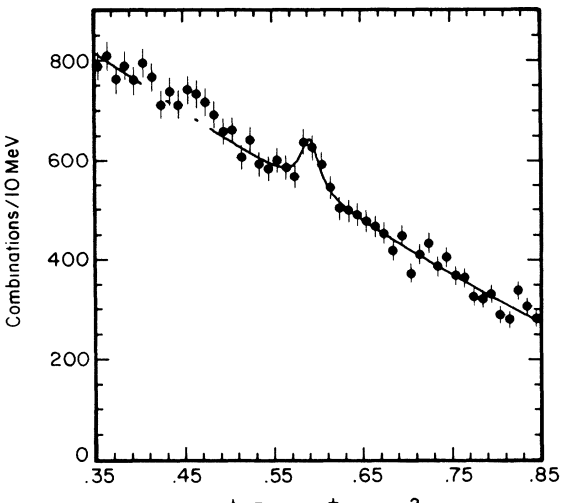

FIG. 2. The $m(D^+\pi^-)$-$m(D^+)$ mass-difference spectrum with fit for the $D^{**0}(2460)$ signal.

$D^{**0} \to D^{*+}\pi^-$, $D^{*+} \to D^+ +$neutral where the neutral is not detected. We find 440±97 signal events. We measure a D^{**0}-D^+ mass difference of $592\pm3\pm1$ MeV/c^2 which corresponds to a D^{**0} mass of $2461\pm3\pm1$ MeV/c^2. The second error is systematic which is estimated using CLEO measurements of the K_S^0 mass, where the K_S^0 decays to pions near 600 MeV/c. The intrinsic width, calculated from the measured width and a detector resolution of 15 MeV/c^2, is $20^{+9}_{-12}\pm9$) MeV/c^2.

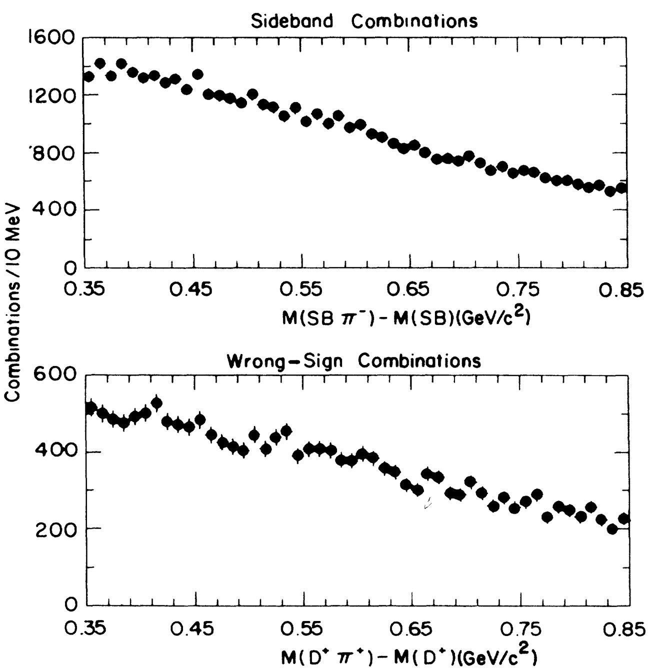

FIG. 3. The $m(D^+\pi^-)$-$m(D^+)$ mass-difference spectra (a) when the D^+ candidate is taken from sidebands above and below the D^+ signal and (b) when the D^+ candidate is combined with the wrong-sign pion.

The production rate $[D^{**0}(2461) \to D^+\pi^-]/D^+$ is $10\pm2^{+2}_{-1}$) %. We use the production rate in this paper to mean the production rate times the branching ratio into the stated decay mode; i.e., No. $[D^{**0}(2461) \to D^+\pi^-]$/No. $[D^+]$ for $x_p > 0.6$. The systematic errors in the width and production rate are estimated by including or excluding different background regions and by varying the order of polynomial used to fit the background.

In Fig. 3 we show the mass-difference spectra (a) when the D^+ candidate is taken from sidebands above and below the D^+ signal and (b) when the D^+ is combined with the wrong-spin pion. No signal is observed thus supporting the view that the effect is not merely kinematic in origin. Our measurements of this state are in agreement with previous measurements from two other experiments.[6,7] The masses, widths, and production rates of the three experiments are summarized in Table I.

IV. $D^{**0} \to D^{*+}\pi^-$

One method for discriminating between the D^{**0} states of different J^P that can decay to $D^{*+}\pi^-$ is to look for D^{*+} polarization. In general the D^{*+} polarization will depend on the spin-parity and the density matrix of the D^{**0}; however, if the D^{**0} has $J^P=2^+$, the orbital angular momentum between the decay products must be 2, and the D^{*+} helicity is ±1 regardless of the D^{**0} density matrix. We will then observe a $\sin^2\phi_{D^*}$ distribution for the D^{*+} decay where ϕ_{D^*} is the angle between the directions of the D^{**0} and the π^+ from $D^{*+} \to D^0\pi^+$ as measured in the D^{*+} rest frame. If the D^{**0} has $J^P=1^+$, the orbital angular momentum between the decay products can be 0 or 2 and the angular distribution for the D^{*+} decay will be proportional to $1+\alpha\cos^2\phi_{D^*}$ where α could vary between -1 and 3. Therefore, the 1^+D^{**0} and the 2^+D^{**0} states may have different signatures as functions of the D^{*+} decay angle.

In 1985, the ARGUS Collaboration[8] reported the first observation of an $L=1$ charmed-meson candidate, at mass 2420 MeV/c^2, decaying to $D^{*+}\pi^-$. Subsequently, the CLEO (Ref. 9) and E691 (Ref. 6) Collaborations confirmed the existence of this effect. We now see evidence that this enhancement is actually due to two states decaying to $D^{*+}\pi^-$ by examining the $\Delta = m(D^{*+}\pi^-) - m(D^{*+})$ mass-difference spectrum as a function of $\cos\phi_{D^*}$, where ϕ_{D^*} is the D^{*+} decay angle. In Fig. 4 we show the Δ spectrum for two angular regions (a) $0.5 < |\cos\phi_{D^*}| < 1$ and (b) $0 < |\cos\phi_{D^*}| < 0.5$ where we have required $x_p > 0.6$ and $\cos\theta_\pi^{**} > -0.8$. If we assume the enhancement is due to a single state and fit for the mass and width in these two angular bins, we find a mass of 2426±4 MeV/c^2 and width 34±10 MeV/c^2 for $0.5 < |\cos\phi_{D^*}| < 1$ and mass 2436±5 MeV/c^2, width 73^{+15}_{-13} MeV/c^2 for $0 < |\cos\phi_{D^*}| < 0.5$. Considering the difference in widths, it is unlikely that these are measurements of the same state. This difference can be explained, however, by two components in the enhancement which populate the $\cos\phi_{D^*}$ distribution differently.

If the $D^{**0}(2461)$ is a 2^+ state, we should see both the

TABLE I. The mass, width, and production rates for three experiments for $D^{**0}(2460)\to D^+\pi^-$.

Experiment	Mass (MeV/c^2)	Width (MeV/c^2)	Production rate D^{**0}/D^+
E691 (Ref. 5)	2459±3±2	20±10±5	7±2±2 %
ARGUS (Ref. 6)	2455±3±5	15^{+13+5}_{-10-10}	11±4±5 %
CLEO	2461±3±1	20^{+9+9}_{-12-10}	$10\pm2^{+2}_{-1}$ %

$D^{**0}\to D^+\pi^-$ decay mode and the $D^{**0}\to D^{*+}\pi^-$ decay mode, with a D^{**0}-D^{*+} mass difference of 451 MeV/c^2. Assuming this is the case, we fit the $m(D^{*+}\pi^-)-m(D^{*+})$ mass difference Δ distributions for two signals:[10] one with the mean and width fixed from the $D^{**0}(2461)$ found in the $D^+\pi^-$ analysis and the other with floating mean and width. Figure 5 shows the fits to the data in four regions of $\cos\phi_{D^*}$, each with two Breit-Wigner distributions and a fourth-order Chebyshev polynomial background.[10] Using a weighted average of these fits, we find that the floating Breit-Wigner component has a mean of $\Delta=418\pm3\pm2$ MeV/c^2, corresponding to a D^{**0} mass of $2428\pm3\pm2$ MeV/c^2, and intrinsic width 23^{+8+10}_{-6-4} MeV/c^2. The systematic errors are estimated by studying two effects. First, we change the fixed signal by $\pm1\sigma$ in both mean and width, and observe the changes to the floating signal. We then estimate the error due to our background assumptions by varying the order of polynomial used to fit the background and by examining different decay angle (θ_π^{**}) cuts which change the background shape.

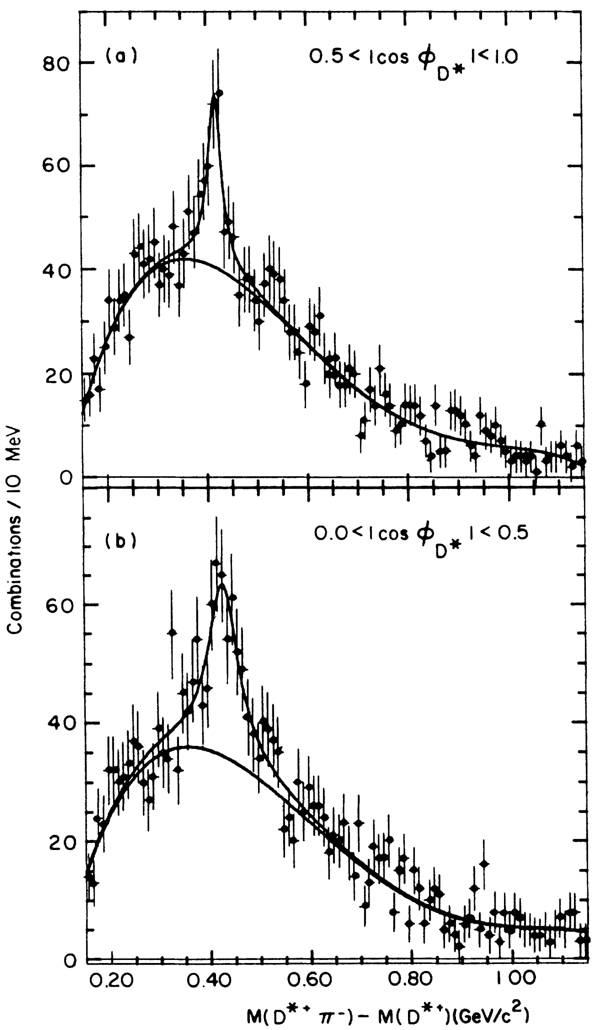

FIG. 4. The $m(D^{*+}\pi^-)-m(D^{*+})$ mass-difference spectra, (a) $0.5<|\cos\phi_{D^*}|<1.0$ and (b) $0.0<|\cos\phi_{D^*}|<0.5$. We use a Breit-Wigner distribution to fit the signal and fourth-order Chebyshev polynomial to fit the background.

In order to find the populations of the two states decaying to $D^{*+}\pi^-$ we fit the Δ distributions in the four regions of $\cos\phi_{D^*}$ with two signals of fixed mass and width. The mean and width for the lower-mass component are determined from the weighted average described above. In Fig. 6 we show the relative areas from these fits as a function of $\cos\phi_{D^*}$ for (a) the lower-mass component at $\Delta=418$ MeV/c^2 and (b) the higher-mass component at $\Delta=451$ MeV/c^2. Since we must have a $\sin^2\phi_{D^*}$ distribution for D^{*+} decay when the D^{*+} is from a 2^+ D^{**0}, we fit the two distributions to a $\sin^2\phi_{D^*}$ curve and to a flat line where we normalize both data and functions to unit area. For the lower-mass component (a) we find a 0.07% confidence level (C.L.) for the fit to $\sin^2\phi_{D^*}$ and a 37.5% C.L. for the fit to an isotropic distribution. For the higher-mass component (b) we find a 56.5% C.L. for the fit to $\sin^2\phi_{D^*}$ and a 8.6% C.L. for the fit to an isotropic distribution. Thus the higher-mass component $\Delta=451$

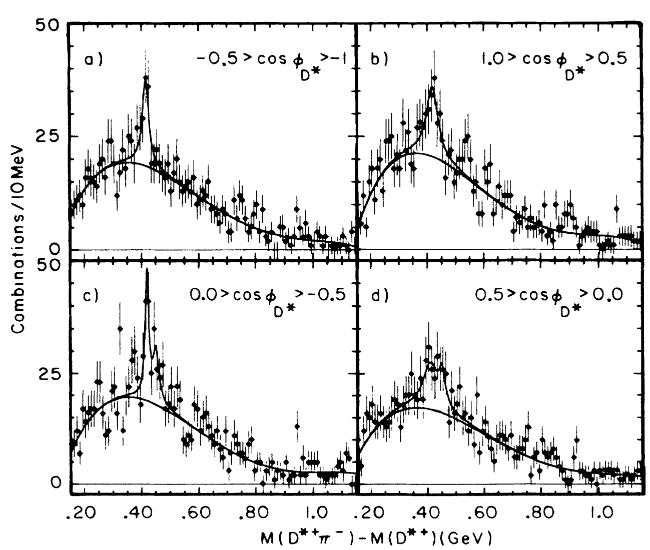

FIG. 5. Two-signal fits to the $m(D^{*+}\pi^-)$-$m(D^{*+})$ mass-difference spectra in different regions of $\cos\phi_{D^*}$.

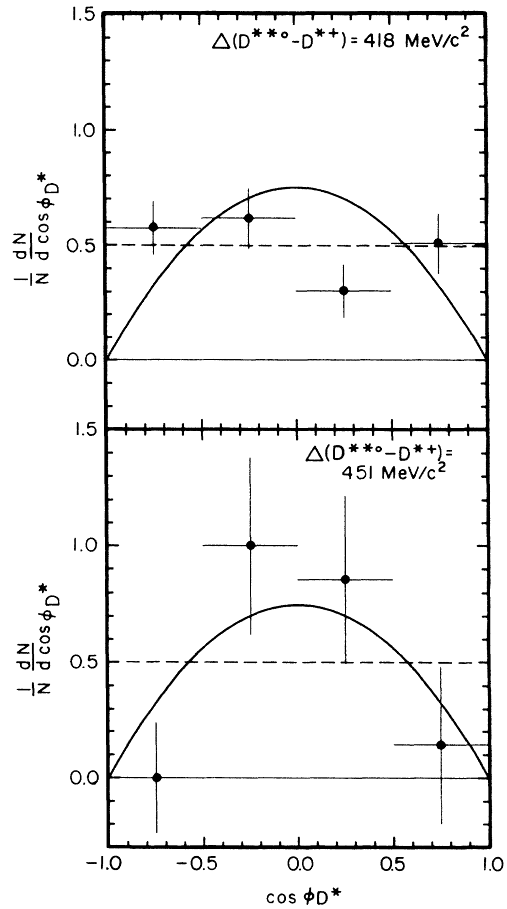

FIG. 6. Distributions in $\cos\phi_{D^*}$ when $m(D^{*+}\pi^-)$-$m(D^{*+})$ is fit for two signals, (a) lower-mass component, $\Delta m(D^{**0}-D^{*+})=418$ MeV/c^2 and (b) higher-mass component, $\Delta m(D^{**0}-D^{*+})=451$ MeV/c^2. The solid line indicates a $\sin^2\phi_{D^*}$ distribution and the dashed line indicates an isotropic distribution. (These plots are a compilation of the signal areas found in Fig. 5).

MeV/c^2 has a distribution consistent with $\sin^2\phi_{D^*}$ while the distribution for the lower-mass component $\Delta=418$ MeV/c^2 is consistent. We therefore favor the assignment of $J^P=1^+$ for the $D^{**0}(2428)$ (if it is inconsistent with the 2^+ state, it must be a 1^+ state in order to decay to $D^{*+}\pi^-$), and $J^P=2^+$ for the $D^{**0}(2461)$.

We measure a production rate $[D^{**0}(2428)\rightarrow D^{*+}\pi^-]/D^{*+}$ of $(8.9\pm1.1\pm0.5)\%$. For the higher-mass component, with Δ fixed at 451 MeV/c^2 and width fixed at 25 MeV/c^2 we find 78 ± 22 events in the bins with $0.0<|\cos\phi_{D^*}|<0.5$. After correcting for acceptance using a $\sin^2\phi_{D^*}$ shape, this corresponds to a production rate $[D^{**0}(2461)\rightarrow D^{*+}\pi^-]/D^{*+}$ of $(3.6\pm1.0^{+0.4}_{-0.8})\%$.

V. RATIOS OF PARTIAL DECAY WIDTHS

To further investigate the spin-parity assignments for these states, we have searched for $D^{**0}(2428)\rightarrow D^+\pi^-$, with mass difference $m(D^{**0})-m(D^+)=559$ MeV/c^2, which would only be possible if the $D^{**0}(2428)$ were a 2^+ state. By adding a second signal in the fit to the $m(D^+\pi^-)-m(D^+)$ spectrum with mass difference and width fixed from the D^{**0} state at 2428 MeV/c^2, we find -75 ± 95 events which gives a 90%-C.L. upper limit of 117 events. From theoretical predictions for the partial decay widths of the 2^+ state,[1] we expect, including kinematic factors, a ratio

$$\frac{\Gamma(2^+\rightarrow D\pi)}{\Gamma(2^+\rightarrow D^*\pi)}\sim1.5 \text{ to } 3.5 \ .$$

We measure

$$\frac{\Gamma(D^{**0}(2428)\rightarrow D\pi)}{\Gamma(D^{**0}(2428)\rightarrow D^*\pi)}<0.24 \ (90\% \text{ C.L.})$$

and

$$\frac{\Gamma(D^{**0}(2461)\rightarrow D\pi)}{\Gamma(D^{**0}(2461)\rightarrow D^*\pi)}=2.3\pm0.8 \ .$$

TABLE II. *P*-wave $c\bar{u}$ meson candidates, CLEO results.

State	Two-body decay products	Mass difference (MeV/c^2)	Width (MeV/c^2)	Number of events in signal	Comments
$D^{**0}(2461)$ $J^P=2^+$ favored	$D^+\pi^-$	$(D^{**}-D^+)$ $=592\pm3\pm1$ measured	20^{+9+9}_{-12-10} measured	440 ± 97	See Table I.
	$D^{*+}\pi^-$	$(D^{**}-D^{*+})$ $=451$ expected	20 expected	78 ± 22	Observed in bins with $0.0<\lvert\cos\phi_{D^*}\rvert<0.5$
$D^{**0}(2428)$ $J^P=1^+$ favored	$D^{*+}\pi^-$	$(D^{**}-D^{*+})$ $=418\pm3\pm2$ measured	23^{+8+10}_{-6-3} measured	279 ± 34	Measured with fixed signal at 451 MeV/c^2
	$D^+\pi^-$	$(D^{**}-D^+)$ $=559$ expected	23 expected	<117 90%-C.L. upper limit	This decay does not conserve J^P for a 1^+ D^{**} state.

Therefore, we find the $D^{**0}(2428)$ inconsistent and the $D^{**0}(2461)$ consistent with predictions for the partial decay widths of the 2^+ state. Table II contains a summary of our results for these two D^{**0} states.

VI. D_s^{**} CANDIDATE

We also search for an $L=1$ $c\bar{s}$ state decaying to $D^{*+}K^0$, $K^0 \rightarrow K_S^0$, $K_S^0 \rightarrow \pi^+\pi^-$. The D^{*+} candidates are selected as for the previous searches. The K_S^0 candidates are formed from oppositely charged tracks, assumed to be pions, where the intersection of the tracks is required to occur at a distance of 1–500 mm from the beam interaction point in the plane perpendicular to the beam. We then require $\chi_V^2 \leq 6.0$ on the secondary vertex quality factor:

$$\chi_V^2 = \left[\frac{\Delta_z}{\sigma_z}\right]^2 + \left[\frac{b_V}{\sigma_b}\right]^2 ,$$

where Δ_z is the z difference of the two-candidate-pion tracks at their $r-\phi$ intersection point and b_V is the impact parameter of the secondary vertex with respect to the average x-y position of the beam spot. The nominal rms errors are $\sigma_z = 10$ mm and $\sigma_b = 2$ mm. K_S^0 candidates are also required to have an invariant mass within 20 MeV/c^2 of the known K^0 mass.

Figure 7 shows the $m(D^{*+}K_S^0) - m(D^{*+})$ mass-difference spectrum for $x_p > 0.5$. We fit the background to a second-order Chebyshev polynomial and we use a Gaussian distribution for the signal. We find an effect in excess of four standard deviations at a mass difference of $525.5 \pm 0.7 \pm 0.4$ MeV/c^2, with a measured rms width $\sigma = 2.5 \pm 0.6 \pm 0.5$ MeV/c^2. This corresponds to a state at mass $2535.6 \pm 0.7 \pm 0.4$ MeV/c^2 (Ref. 11) which is consistent with predictions for the mass of an $L=1$ $c\bar{s}$ meson.[1] The width of this signal is comparable to our detector resolution for this combination of tracks, so we can only set an upper limit for the natural width. We obtain $\Gamma < 5.44$ MeV/c^2 (90% C.L.). After correcting for our K_S^0 efficiency we calculate the production rate $[D_s^{**}(2536) \rightarrow D^{*+}K^0]/D^{*+}$ to be $(2.6 \pm 0.7)\%$.

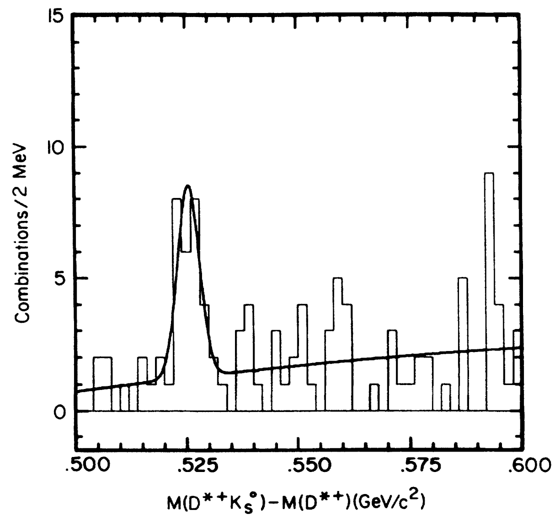

FIG. 7. The $m(D^{*+}K_S^0) - m(D^{*+})$ mass-difference spectrum.

VII. CONCLUSIONS

To summarize, we see evidence for three $L=1$ charmed mesons: two $c\bar{u}$ states and one $c\bar{s}$ state. Although we do not have conclusive measurements for the spin-parities of the $c\bar{u}$ states, our analysis favors the assignment of spin-parity $J^P = 1^+$ for the state at mass $2428 \pm 3 \pm 2$ MeV/c^2, and $J^P = 2^+$ for the state at mass $2461 \pm 3 \pm 1$ MeV/c^2.

[1] J. L. Rosner, Comments Nucl. Part. Phys. **16**, 109 (1986); S. Godfrey and N. Isgur, Phys. Rev. D **32**, 189 (1985); S. Godfrey and R. Kokoski, TRI Report No. 86-51, 1986 (unpublished).

[2] D. Andrews, *et al.*, Nucl. Instrum. Methods **211**, 47 (1983).

[3] CLEO Collaboration, S. Behrends *et al.*, Phys. Rev. D **31**, 2161 (1985).

[4] D. G. Cassel *et al.*, Nucl. Instrum. Methods A **252**, 325 (1986).

[5] A fit to the signal using a higher-spin relativistic Breit-Wigner distribution did not yield significantly different results.

[6] Tagged Photon Spectrometer Collaboration, J. C. Anjos *et al.*, in *Proceedings of the XXIV International Conference on High Energy Physics,* Munich, West Germany, 1988, edited by R. Kotthaus and J. Kuhn (Springer, Berlin, 1989).

[7] ARGUS Collaboration, H. Albrecht *et al.*, Phys. Lett. B **221**, 422 (1989).

[8] ARGUS Collaboration, H. Albrecht, *et al.*, Phys. Rev. Lett. **56**, 549 (1986).

[9] CLEO Collaboration, C. Bebek *et al.*, in *Lepton and Photon Interactions,* proceedings of the International Symposium, Hamburg, West Germany, 1987, edited by R. Rückl and W. Bartel [Nucl. Phys. B (Proc. Suppl.) **3** (1987)].

[10] ARGUS Collaboration, J. Parsons, in *Weak Interactions and Neutrinos,* proceedings of the Twelfth International Workshop, Ginosar, Israel, 1989, edited by P. Singer and B. Gad Eilam [Nucl. Phys. B (Proc. Suppl.) (in press)]. Preliminary results presented here showed evidence for two $L=1$ D^{**0} states decaying to $D^{*+}\pi^-$ which were distinguished by examining different $\cos\phi_{D^*}$ bins.

[11] H. Albrecht *et al.*, Phys. Lett. B **230**, 162 (1989).