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D^{*+} Production in e^+e^- Annihilation at 29 GeV.*

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ABSTRACT

We have observed the production of the charmed meson state D^{*+} in e^+e^- annihilation at 29 GeV. The fragmentation function for charmed quarks appears to be peaked about $z = 0.5$.

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The heavy quark fragmentation functions are of both theoretical and practical interest, but little is known of them. The production of charmed mesons in e^+e^- annihilation provides a clean way for studying the charmed fragmentation function[1]. Previous measurements of the differential cross-section $d\sigma/dz$ for inclusive D meson production, where z is the ratio of twice the D energy (E_D) to the center of mass energy ($E_{c.m.}$), were restricted to the kinematic range of $z > 0.54$ available at SPEAR energies[2,3]. Here we present the observation of the D^{*+} by its decay

$$D^{*+} \to D^0\pi^+, \quad D^0 \to K^-\pi^+$$

and a measurement of the inclusive energy spectrum for D^{*+} production in e^+e^- annihilation at an energy of 29 GeV. (To avoid cumbersome notation, reference to a state will always imply the sum of that state and its charge conjugate state.)

The data presented here were collected with the MARK II detector at the PEP storage ring at the Stanford Linear Accelerator Center, and correspond to an integrated luminosity of 15.4 pb^{-1}. The D^{*+} candidates were found in a sample of roughly 5000 hadronic events. The MARK II detector at the PEP is substantially the same as that at SPEAR[4]. Charged particle momenta were measured using a 16 layer drift-chamber in a 4.6 kG axial magnetic field. The charged particle rms momentum resolution was $(\delta p/p)^2 = (0.015)^2 + (0.006p)^2$ (p in GeV/c), when tracks were constrained to come from the interaction region. Outside the drift chamber, time-of-flight (TOF) scintillation counters provided an r.m.s. timing resolution of 360 ps. for hadron tracks, somewhat degraded from the value of 315 ps. at SPEAR because of decreased scintillator attenuation length. This resolution made possible a π-K separation of greater than 1 σ time difference for tracks with a momentum $p < 1.2$ GeV/c.

The TOF information was insufficient to assign unambiguous particle identities to most tracks. The tracks were designated pions, kaons, and protons if their measured TOF was within 580ps. of their calculated TOF; multiple identities were allowed. If the measured TOF was outside these limits, the particle was assumed to be a pion. If the TOF scintillation counter was crossed by more than one track, or for some other reason was unusable, the particle was tried both as a kaon and as a pion.

The invariant mass of all $K^-\pi^+$ combinations is shown in Fig. 1, split into two bands of $z = 2E_D/E_{c.m.}$. Although there is no statistically significant peak around the mass of the D^0 (1.863 GeV/c^2), mass combinations in the region $1.80 < M_{K\pi} < 1.93$ GeV/c^2 were taken as D^0 candidates. The two tracks were kinematically fit to the D^0 mass, and those with a poor χ^2 rejected. The D^0 candidates were then each combined with an additional pion candidate of opposite sign charge to the kaon candidate. The $D^0\pi^+ - D^0$ mass difference spectrum is shown in Fig. 2 for the two bands of $z = 2E_{D^*}/E_{c.m.}$. The restrictive kinematics of the D^{*+} decay give it a signal to background advantage over the D^0 decay of two orders of magnitude, and a clear D^{*+} peak may be seen for $z > 0.4$. For $0.2 < z < 0.4$, there is no obvious signal. At a center of mass energy of 29 GeV the kinematic range available for D^{*+} production is $0.14 < z < 1.0$. In this experiment the efficiency for detecting D^{*+}'s in the range $0.14 < z < 0.2$ is very low, and no information could be gained in this region. The observed width of the D^{*+} (σ = 1 MeV/c^2)

is consistent with that expected from experimental resolution alone. The $D^{*+} - D^0$ mass difference was determined by a maximum liklihood fit to be 145.5±0.5 MeV/c^2, where the error is dominated by the systematic error. This value is in good agreement with the previously reported values[5] averaging 145.5±0.3 MeV/c^2.

In order to get an inclusive energy spectrum the D^{*+} events were defined to be those with a mass difference of 144-147 MeV/c^2, and a background subtraction and efficiency correction performed for each bin of 0.2 in z. The background contribution to the D^{*+}'s was estimated by extrapolation of the data in the mass difference plot (Fig. 2) outside the D^{*+} mass peak, and by using two bands in the $K\pi$ mass plot outside the D^0 mass region. A total of 16 events were found with $z > 0.4$, where 1.0 would be expected from background processes. For $0.2 < z < 0.4$ the observed events are consistent with being all due to background processes. The efficiency for D^{*+} detection was estimated by means of a Monte-Carlo program that produced D^{*+}'s as the fragmentation product of charmed quarks in a standard QCD model which included initial state bremsstrahlung. The efficiency was found to be roughly constant at a value of 24% for $z > 0.2$. The D^{*+}'s detected correspond to an inclusive cross section for D^{*+} and D^{*-} production of 0.32±0.16 nb., where the error comprises the statistical error, the uncertainty in the efficiency calculation, and the errors in the measured branching fractions[3,4] (0.44±0.10 for $D^{*+} \rightarrow D^0\,\pi^+$ and 0.030±0.006 for $D^0 \rightarrow K^-\pi^+$). This cross-section is surprisingly large, but has a very large uncertainty. (The cross section for production of μ pairs is 0.10 nb. at this energy.) The corrected $s(d\sigma/dz)$ spectrum for D^{*+} production is shown in figure 3.

Any bin to bin systematic errors introduced by the background subtraction and efficiency correction are small compared with the statistical errors of the measurement.

The average z value of the produced D^{*+}'s in the range $0.2 < z < 1.0$ is found to be 0.58 ± 0.06. In the standard model, up to 20% of the D^{*+} mesons may be the decay products of B mesons, but the trend of the data in Fig. 3 should closely reflect the fragmentation function of charmed quarks into mesons. Previous measurements at lower $E_{c.m.}$ have shown a D meson production spectrum that is continually falling for z values above the kinematic limit. At SPEAR measurements were made for D^+ and D^0 mesons of $z > 0.60$,[2] and $z > 0.75$.[3] However, the data presented here for D^{*+} mesons over the wide kinematic range of $0.2 < z < 1.0$ favor a production spectrum which is peaked at an intermediate value of z. This shape is in qualitative agreement with that predicted from heavy particle kinematic considerations[6].

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$$\frac{d\sigma}{dz} = \frac{A}{z}\left(1 - \frac{1}{z} - \frac{\epsilon}{1-z}\right)^{-2}$$

where A is a the normalization, and ϵ a parameter related to the quark masses.

Figure Captions

1. The $K^-\pi^+ + K^+\pi^-$ mass spectrum for two bands of $z = 2E_D/E_{c.m.}$.
2. The $D^0\pi^+ - D^0$ mass difference for two bands of $z = 2E_{D^*}/E_{c.m.}$. A clear D^{*+} peak may be seen for $z > 0.4$.
3. The $s(d\sigma/dz)$ spectrum of produced D^{*+}'s. The errors shown are statistical only. There is an overall normalization uncertainty of ±42%, due to uncertainties in the efficiency calculation and branching fractions used.

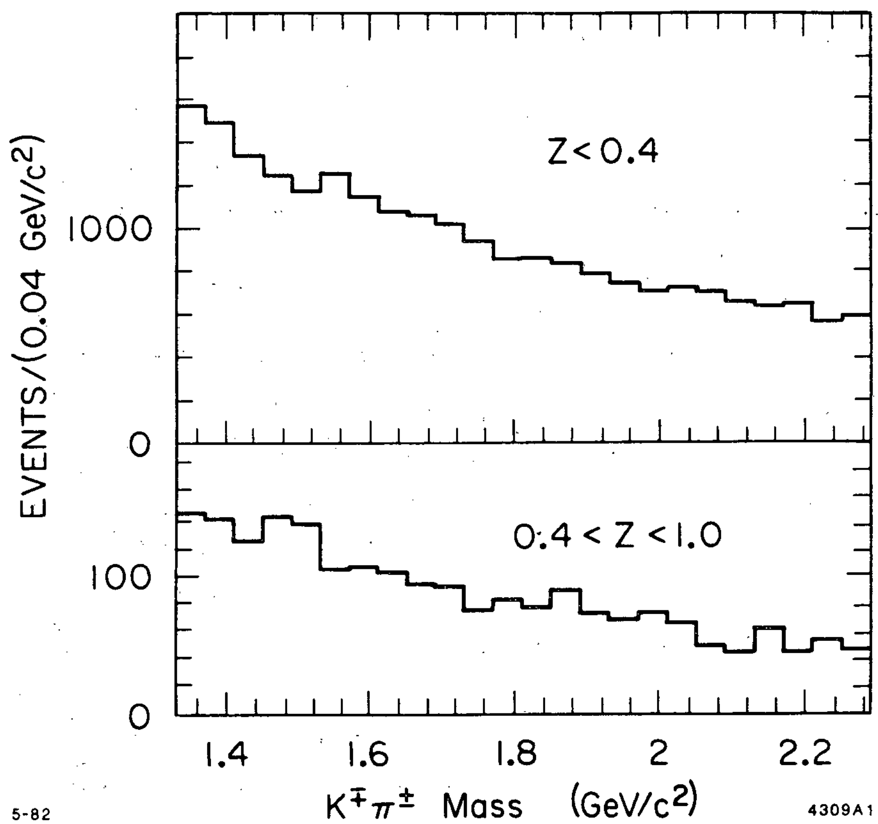

Fig. 1

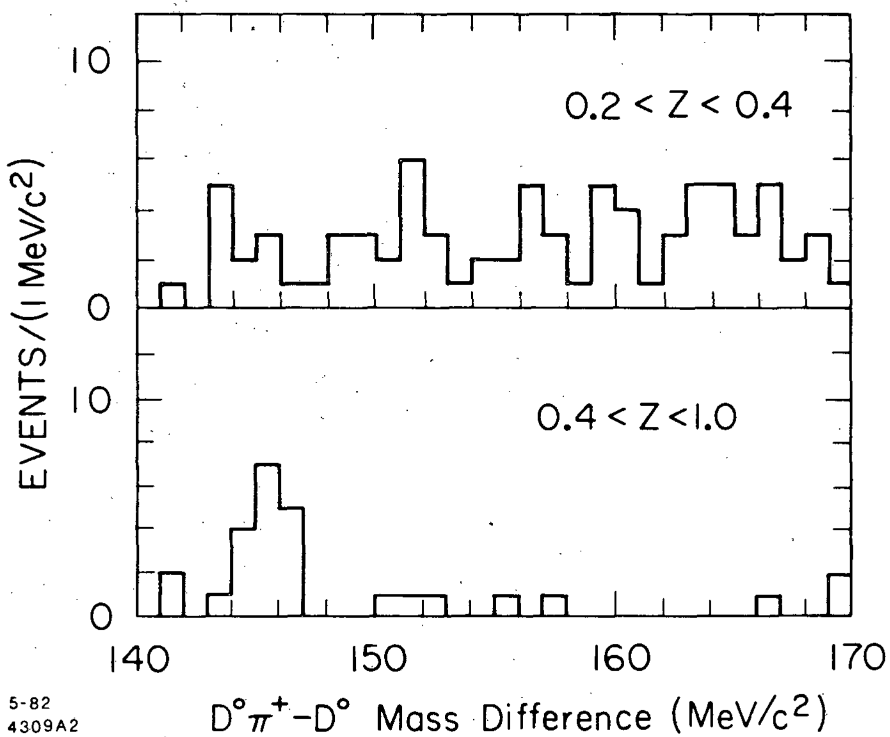
10
0.2 < Z < 0.4
0
10
0.4 < Z <1.0
0
EVENTS/(1 MeV/c2)
140
150
160
170
5-82
4309A2
D°π+-D° Mass Difference (MeV/c2)

Fig. 2

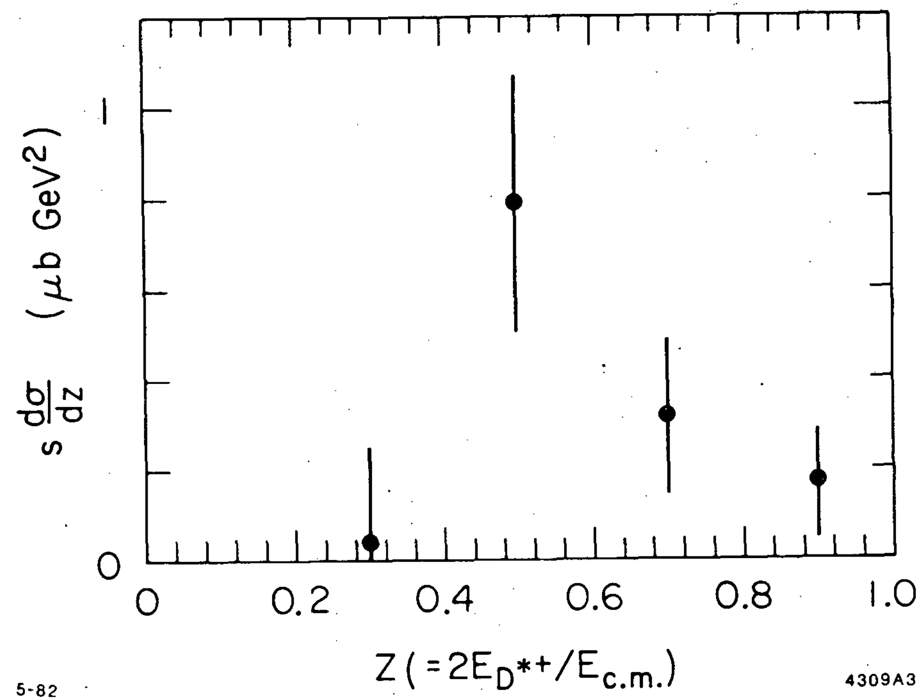
1
0
s dσ/dz (μb GeV2)
0
0.2
0.4
0.6
0.8
1.0
Z (=2ED*+/Ec.m.)
5-82
4309A3

Fig. 3

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