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$D^{*\pm}$ PRODUCTION IN JETS AT THE CERN SPS COLLIDER

UA1 Collaboration, CERN, Geneva, Switzerland

Aachen[1]-Annecy(LAPP)[2]-Birmingham[3]-CERN[4]-Harvard[5]-Helsinki[6]-Kiel[7]
Queen Mary College, London[8]-NIKHEF, Amsterdam[9]-Paris(Coll.de France)[10]-Riverside[11]
Roma[12]-Rutherford Appleton Lab.[13]-Saclay(CEN)[14]
Vienna[15]-Wisconsin[16] Collaboration

G. Arnison[13], O.C. Allkofer[7], A. Astbury[13,*], B. Aubert[2], C. Bacci[12], G. Bauer[16],
A. Bézaguet[4], R.K. Bock[4], T.J.V. Bowcock[8], M. Calvetti[4], P. Catz[2], P. Cennini[4],
S. Centro[+], F. Ceradini[12], S. Cittolin[4], D. Cline[16], C. Cochet[14], J. Colas[2],
M. Corden[3], D. Dallman[4,15], D. Dau[4,7], M. DeBeer[14], M. Della Negra[2,4],
M. Demoulin[4], D. Denegri[14], D. DiBitonto[4], A. DiCiaccio[12], L. Dobrzynski[10],
J. Dowell[3], K. Eggert[1], E. Eisenhandler[8], N. Ellis[4], P. Erhard[1], H. Faissner[1],
M. Fincke[7,*], P. Flynn[13], G. Fontaine[10], R. Frey[11], R. Frühwirth[15], J. Garvey[3],
S. Geer[5], C. Ghesquière[10], P. Ghez[2], W.R. Gibson[8], Y. Giraud-Héraud[10],
A. Givernaud[14], A. Gonidec[2], G. Grayer[13], T. Hansl-Kozanecka[1], W.J. Haynes[13],
L.O. Hertzberger[9], D. Hoffmann[1], H. Hoffmann[4], D.J. Holthuizen[9], R.J. Homer[3],
A. Honma[8], W. Jank[4], G. Jorat[4], P.I.P. Kalmus[8], V. Karimäki[6], R. Keeler[8,*]
I. Kenyon[3], A. Kernan[11], R. Kinnunen[6], W. Kozanecki[11], D. Kryn[4,10], P. Kyberd[8],
F. Lacava[12], J.-P. Laugier[14], J.-P. Lees[2], H. Lehmann[1], R. Leuchs[7], A. Lévêque[4],
D. Linglin[2], E. Locci[14], M. Loret[14], T. Markiewicz[16], G. Maurin[4], T. McMahon[3],
J.-P. Mendiburu[10], M.-N. Minard[2], M. Mohammadi[16], M. Moricca[12], K. Morgan[11], F. Muller[4],
A.K. Nandi[13], L. Naumann[4], A. Norton[4], A. Orkin-Lecourtois[10], L. Paoluzi[12], F. Pauss[4],
G. Piano Mortari[12], E. Pietarinen[6], M. Pimiä[6], D. Pitman[11], A. Placci[4], J.-P. Porte[4],
E. Radermacher[1], J. Ransdell[11], H. Reithler[1], J.-P. Revol[4], J. Rich[14], M. Rijssenbeek[4],
C. Roberts[13], J. Rohlf[5], P. Rossi[4], C. Rubbia[4], B. Sadoulet[4], G. Sajot[10],
G. Salvini[12], J. Sass[14], A. Savoy-Navarro[14], D. Schinzel[4], W. Scott[13], T.P. Shah[13],
I. Sheer[11], D. Smith[11], M. Spiro[14], J. Strauss[15], J. Streets[3], K. Sumorok[4], F. Szoncso[15],
C. Tao[10], G. Thompson[8], J. Timmer[4], E. Tscheslog[1], J. Tuominiemi[6],
B. Van Eijk[9], J.-P. Vialle[2], J. Vrana[10], V. Vuillemin[4], H. D. Wahl[15],
P. Watkins[3], J. Wilson[3], C.-E. Wulz[15], M. Yvert[2],

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*) Now at University of Victoria, Canada.

+) Visitor from the University of Padua, Italy.

ABSTRACT

We report evidence for the production of the charged D^* mesons in $p\bar{p}$ collisions at $\sqrt{s}$ = 540 GeV. The search was confined to the charged particle fragments of hadronic jets, which are expected to be predominantly gluon jets in this experiment. The fragmentation function and production rate for D^* in jets are given.

A striking feature of the data collected so far at the CERN proton-antiproton collider is the abundance of hadronic jets of large energy transverse to the beams (E_T) [1]. The understanding of the production of heavy quarks in these jets is of considerable interest. Several studies of c [2] and b [3] quark production in e^+e^- annihilation indicate that jets initiated by these heavy quarks fragment in such a way that the hadron carrying the heavy flavor takes a large fraction of the total jet momentum. However in $p\bar{p}$ interactions at $\sqrt{s}$ of 540 GeV, gluon rather than quark initiated jets are expected to dominate for jet E_T values below about 50 GeV [4]. In this paper [5] we present observations of D^{*+} production using the now standard procedure [2] of searching for the decay sequence $D^{*+} \to D^o\pi^+ \to K^-\pi^+\pi^+$ as well as the charge conjugate mode. (Both modes are implied by the mention of one throughout this paper.)

The UA1 detector is described elsewhere [6]. We mention briefly the detector elements of importance for this study. The Central Detector, a large drift chamber immersed in a 0.7T dipole magnetic field, was used for momentum and ionization measurement of charged particles. The mean value of $\Delta p/p^2$ is $(0.9 \times 10^{-2})/(\mathrm{GeV}/c)$ for the tracks used for the $D^{*\pm}$ search. Ionization accuracy is about 10% for a track of 1m length. Total jet energy is measured with accuracy $\Delta E/E \simeq 20\%$ by electromagnetic and hadronic calorimetry consisting of lead/scintillator stacks followed by the instrumented iron of the magnet yoke.

This work is based upon the data sample recorded in 1983 with integrated luminosity $113 nb^{-1}$. The following two simultaneously recorded triggers are relevant to this study:

i) An "electron trigger", namely at least 10 GeV of localized transverse energy deposited in the central electromagnetic calorimeters.

ii) A global "E_T trigger", requiring more than 60 GeV of total transverse energy in all calorimeters with $|\eta| < 1.5$.

The results presented here come from the 1.2×10^5 electron triggers having an electromagnetic cluster in excess of 15 GeV. These events were reconstructed in the search for the electronic decay modes of W and Z. However they also contain about 30% of all jets having E_T greater than 20 GeV. A subset (27%) of these triggers which also satisfied the trigger requirement (ii) was selected for this study.

Jets containing a minimum of three charged particles were identified by applying a clustering algorithm to the charged particle tracks in the events. The jets were required to satisfy the following conditions: $16 < p_T < 20$ GeV/c, $|\eta| < 1$, and $\phi > 45^o$ with respect to the horizontal plane. Jets closer to the horizontal plane were excluded because of relatively poorer momentum resolution in this region. The lower p_T limit is imposed due to reconstruction inefficiency of the π^+ from $D^{*+} \rightarrow D^o\pi^+$ at low momentum. Because of the steeply falling spectra in p_T few $D^{*+} \rightarrow K^-\pi^+\pi^+$ are lost by introducing the upper p_T limit, thus leaving a narrow range of p_T for the fragmentation function study.

$K^-\pi^+$ and $K^-\pi^+\pi^+$ mass combinations were formed from the charged tracks associated with the jets. No particle identification was used to distinguish between K and π, so both K and π assignments were considered for each track. The central detector ionization measurement was used to identify $e^\pm$ arising from photon conversions in the beam pipe, delta rays, etc.; these slow electrons can mimic the π^+ from $D^{*+} \to D^o\pi^+$ which has a mean momentum of about 0.4 GeV/c in the kinematic range under study. The average rejection factor of e/π for momentum below 1 GeV/c is estimated to be 8.

Figures 1a,b show the mass difference $\Delta M = M(K^-\pi_1^+\pi_2^+) - M(K^-\pi_1^+)$ for (a) all events , and (b) $1.83 < M(K^-\pi_1^+) < 1.92$ GeV/c^2. Figures 1c,d show the $K^-\pi_1^+$ invariant mass distribution for (c) all events, and (d) $146 < \Delta M < 148$ MeV/c^2. A fit of a Gaussian distribution to the peak in ΔM (fig. 1b) gives a mean of 147.0 MeV/c^2 and an rms deviation of 0.6 MeV/c^2. This width is compatible with estimated experimental resolution, whereas the mean is shifted by 1.6 MeV/c^2 from the standard value of 145.4 ± 0.2 MeV/c^2 [7]. This effect is associated with the fit of the slow π^+ track to the interaction vertex when it has undergone multiple scattering in the steel beam pipe. The fitted mean and width for the $K^-\pi^+$ peak (fig. 1d) are 1.870 GeV/c^2 and 23 MeV/c^2, compatible with the known D^o mass and the estimated mass resolution. The corresponding mass distributions for the wrong charge combinations $K^-\pi^+\pi^-$ and $K^-\pi^-\pi^+$ exhibited no evident signals.

The peaks in figs. 1b,d contain an estimated 20 $D^{*+} \to K^-\pi^+\pi^+$ events on a background of 8. We have investigated the distribution in $z = \vec{p}_{D^*} \cdot \vec{p}_{jet}/(p_{jet})^2$ for these events, where $\vec{p}_{D^*}$ is the D^* momentum measured in the central drift chamber and p_{jet} is the modulus of the total jet momentum determined from the energy deposited in the calorimeter modules. When the total momentum of the charged particle jet is within ±20° of the vertical, the efficiency of the calorimetry is reduced and a mismeasurement of p_{jet} could result. Such events were excluded from further consideration, leaving 9 events. After a visual scan two additional events were eliminated due to possible ambiguities in the association of the charged jet with the correct jet as recorded by the calorimetry. The z distribution for the remaining 7 events is shown in figure 2. The data points have been corrected for inefficiency in detecting the slow pion from $D^* \to D\pi$ decay. This inefficiency is less than 10% for $z > 0.1$, but increases rapidly for smaller z values. No attempt has been made here to extrapolate to below z of 0.1. The values of p_{jet} for these events range from 25 to 45 GeV/c. The sensitivity of $\langle z \rangle$ to various alternative definitions [8] for z is less than 10%.

We have observed 20 $D^{*+} \to K^-\pi^+\pi^+$ decays in 3.4×10^3 jets meeting the conditions discussed above. This number includes only jets with at least 3 tracks. The corresponding total number of jets was obtained as follows: A comparison of the (charged + neutral) energy of a jet from calorimetry and the (charged) energy from the tracking chamber for the same jet was made. This gave the probability that a jet have a charged p_T between 16 and 20 GeV/c as a function of the total (charged and neutral) transverse energy. All calorimeter jets meeting trigger and acceptance criteria equivalent to the charged jet sample were then weighted by this probability, yielding a total of 4.0×10^3 jets corresponding to the sample of 3.4×10^3 charged particle jets. The branching ratios used are $B(D^{*+} \to D^o\pi^+) = 0.44 \pm 0.10$ [9] and $B(D^o \to K^-\pi^+) = 0.030 \pm 0.006$ [10]. From the effects of quality cuts and the track reconstruction efficiency, the fraction of observed D^{*+} decays was estimated as 0.42 ± 0.18 for $z > 0.1$. The fraction of D^{*+} excluded by the mass cuts was found to be 0.16 ± 0.13. Then $N(D^{*\pm})/N(\text{jet}) = 1.1 \pm 0.2 \pm 0.6$ for $z > 0.1$. Although the systematic error is large, with roughly equal contributions from branching ratio and efficiency, this number of $D^{*\pm}$ per jet seems surprisingly high. And the number of D^{*o} could presumably be equal to $D^{*\pm}$. However we note that this measurement applies only to jets in events satisfying the combined electron and global E_T triggers, and may well be different for an unbiased jet selection.

Figure 2 implies a charm fragmentation which is much softer than that determined in e^+e^- annihilation, where the fragmentation distributions were found to have mean values near z of 0.6. This suggests that the charm production found here for $p\bar{p}$ collisions does not result from the fragmentation of jets initiated by a c-quark. In fact the number of observed $D^{*\pm}$ is about a factor of 10^2 higher than predicted for c-quark jets [4]. Since the jets studied here are expected to be predominantly initiated by gluons, a likely conclusion is then that the observed D^* production results from the fragmentation of gluon jets into charm quark pairs, although production via the decay of a copiously produced heavy object can not be ruled out at this point.

Little is known about the particle content of gluon jets, except perhaps that they contain a larger baryon fraction than quark jets [8]. Although the amount of charm produced in gluon jets would depend on the fragmentation mechanism, the large rate observed here is probably consistent with the flavor independence of the gluon coupling to quarks. Evidence supporting the flavor independence for the gluon coupling of charm relative to lighter quarks has indeed recently been obtained [11]. If the interpretation presented in this paper is correct, it is the first direct observation of heavy quark production from gluon jets.

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Figure Captions

Fig. 1a. ΔM distribution in the region of $M(D^{*+})-M(D^{o})$ with no $M_{K\pi}$ cut.

Fig. 1b. ΔM distribution for $1.83 < M_{K\pi} < 1.92$ GeV/c^2.

Fig. 1c. $M_{K\pi}$ distribution in the region of $M(D^{o})$ with no ΔM cut.

Fig. 1d. $M_{K\pi}$ distribution for $146 < \Delta M < 148$ MeV/c^2.

Fig. 2. $D^{*\pm}$ fragmentation distribution for $z > 0.1$. The data has been corrected for the track finding inefficiency of the π^+ from $D^{*+} \to D^{o}\pi^{+}$. The mean value of z for $z > 0.1$ is 0.2.

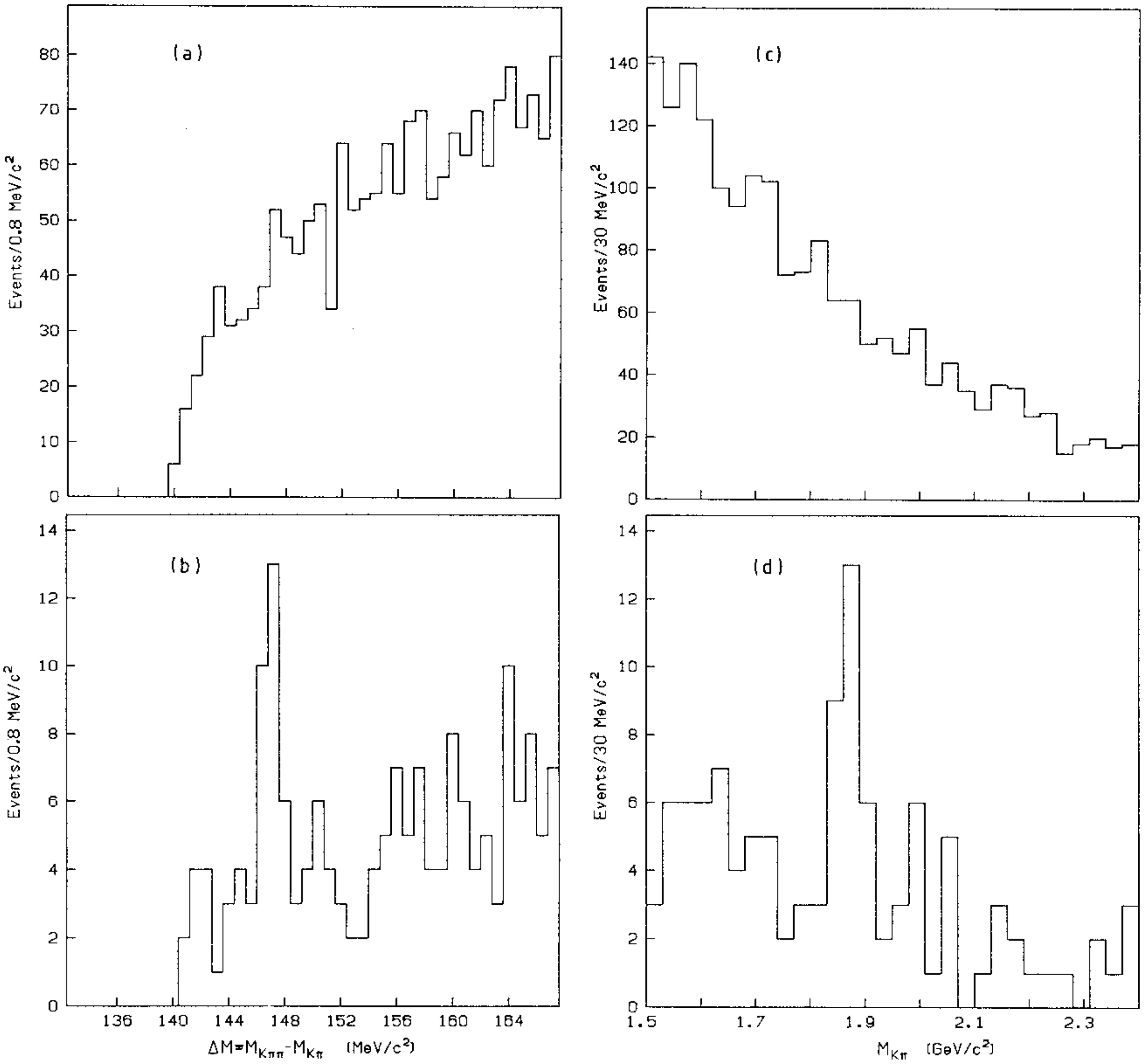
(a)
(b)
(c)
(d)
Events/0.8 MeV/c²
Events/30 MeV/c²
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
0
2
4
6
8
10
12
14
136
140
144
148
152
156
160
164
1.5
1.7
1.9
2.1
2.3
ΔM=M_{Kππ}-M_{Kπ} (MeV/c²)
M_{Kπ} (GeV/c²)

Fig. 1

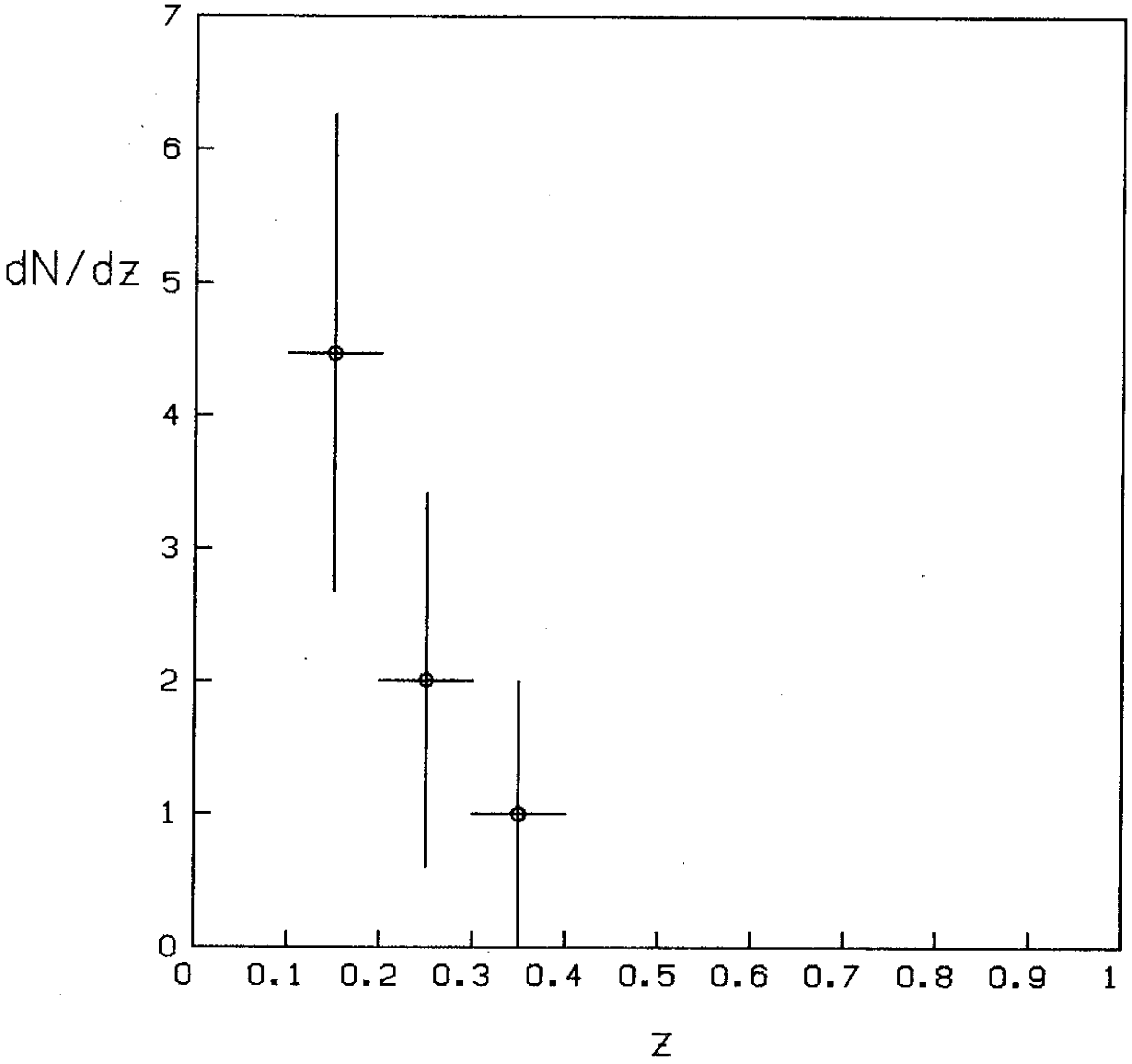

Fig. 2