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with the Multiparticle Spectrometer at BNL

presented by

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ABSTRACT

Two recent experiments at the BNL Multiparticle Spectrometer searched for charm production in the π^-p interactions at 16 and 17 GeV/c. One experiment looked for D^{*-} production with a fast K^+ trigger, while the other experiment triggered on single-electron events. The K^+-trigger experiment finds that the D^{*-} cross-section at 16 GeV/c is less than 130 nb at 95% confidence level.

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The detection of charm production in hadronic processes has proved to be difficult, mainly because the cross-sections are ∿ 10^{-4} or less of the total cross-section and the detectable branching ratios are small$^{1)}$. In order to achieve high sensitivity and good background rejection necessary for observation of charm at BNL, two separate approaches have been adopted with the BNL Multiparticle Spectrometer. The method of one experiment utilized the small Q value ($m_{D*} - m_D - m_\pi =$ $= 5.7 \pm 0.4$ MeV) in the decay chain $D^{*-} \rightarrow \bar{D}^0\pi^-$ and $\bar{D}^0 \rightarrow K^+\pi^-$ to reject the non-charm background$^{2,3)}$. The strategy employed by the other experiment was to trigger on a single electron from the decay $D^- \rightarrow e^- + X^0$ to suppress the hadronic background$^{4)}$. A brief description of the experiments and the results are presented here.

The first experiment described here, the K^+-trigger experiment, utilized the D^* decay chain for the charm search$^{5,6)}$. The layout of the experiment$^{7)}$ is given in Fig. 1. The central element of the trigger requirement was the identification of a fast forward K^+ with momentum in the range 6.5 to 11.0 GeV/c with two Čerenkov counters and three-dimensional coincidence-matrix logic systems$^{8)}$. In addition, there was also a minimum multiplicity requirement of three or more tracks around the liquid hydrogen target.

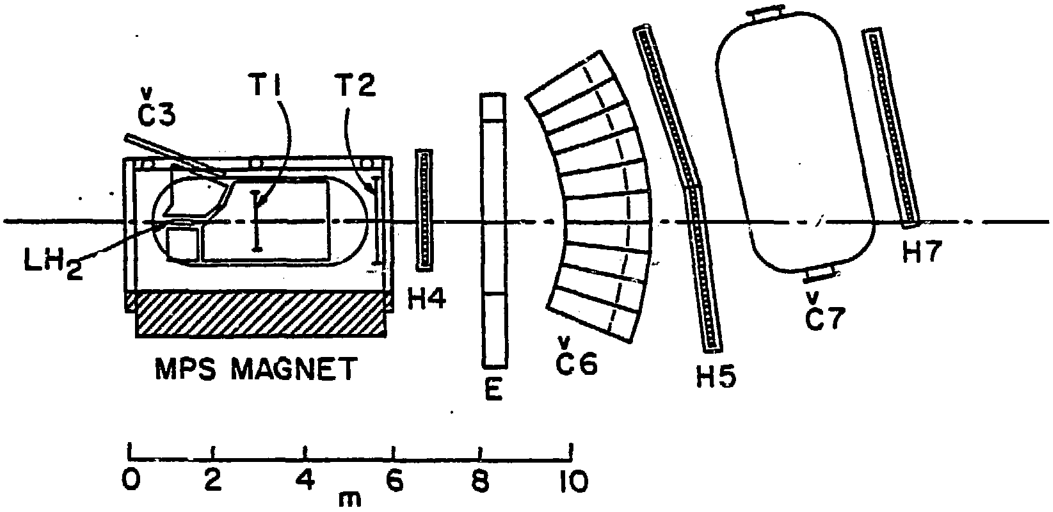

Fig. 1 Layout of the K^+-trigger experiment at the BNL Multiparticle Spectrometer. T_1 and T_2 are planar proportional wire chambers (PWCs); H_5 and H_7 are scintillation counter hodoscopes; C_6 and C_7 are atmospheric and high-pressure Čerenkov counters. Also shown are the outlines of three groups of spark-chamber modules around the liquid-hydrogen target (LH_2), and in addition other detector elements not used in the K^+ trigger.

This experiment searched for charm production in the inclusive reaction

$$\pi^- p \rightarrow D^{*-} + X \tag{1}$$

and also the exclusive reaction

$$\pi^- p \rightarrow D^{*-} + \Lambda_c^+ \tag{2}$$

with the D^* decay

$$D^{*-} \rightarrow \overline{D}^0 + \pi^- , \; \overline{D}^0 \rightarrow K^+ + \pi^- \tag{3}$$

at the π^- beam momentum of 16 GeV/c.

A total of 2.5×10^6 K^+ triggers were recorded and analysed, corresponding to a raw sensitivity of 68 events/nb. Figure 2a shows $K^+\pi^-$ mass spectra for those

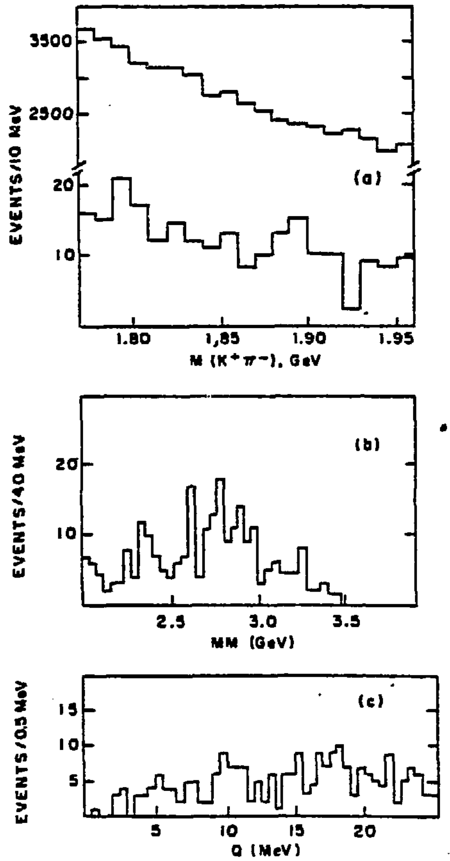

Fig. 2 a) $K^+\pi^-$ effective mass spectrum. Top histogram shows all events between 1.77 and 1.96 GeV. Bottom histogram shows remaining events after requiring at least one additional negative track, MM > 2.0 GeV and Q < 25 MeV. b) Missing mass spectrum off $K^+\pi^-\pi^-$ (MM) for $K^+\pi^-$ mass between 1.77 and 1.96 GeV and Q < 25 MeV. c) Q spectrum for events with $K^+\pi^-$ mass between 1.77 and 1.96 GeV and MM > 2.0 GeV.

events having one or more negative tracks in addition to the triggered K^+, and also for those with the additional requirements of $Q < 25$ MeV and the missing mass (MM) recoiling off $K^+\pi^-\pi^-$ greater than 2 GeV/c. The enormous reduction (by a factor of ~ 100) in the data sample results mainly from the cut in Q. Figures 2b and 2c show the MM and Q spectra for the reduced data sample with the $M(K^+\pi^-)$ in the range 1.77 to 1.96 GeV. The calculated $K^+\pi^-$ mass resolution is typically better than 10 MeV, the MM resolution better than 45 MeV, and the Q resolution better than 1 MeV.

To estimate the acceptance, Monte Carlo events were generated with the D^{*-} produced peripherally with an $e^{2.7t}$ distribution. The acceptance is actually fairly insensitive to the slope of the t distribution*). These Monte Carlo events were processed through the same chain of data-reduction programs as that used for the real data. The overall acceptance is 6.4% at the Λ_c^+ mass (2.26 GeV) and varies slowly as a function of MM between 2.2 GeV and 3.0 GeV; above 3.0 GeV it decreases rapidly. There are additional losses due to inefficiencies of the trigger elements, beam losses, etc., which reduce the acceptance by an additional 30%. The visible sensitivity for observing $D^{*-} \to D^0\pi^-$ ($D^0 \to K^+\pi^-$) is 3.0 events/nb for MM < 3.0 GeV.

Figure 3 shows a scatter plot of Q vs MM for events with $K\pi$ effective mass between 1.82 and 1.90 GeV. For MM < 3.0 GeV there are 10 events in the range

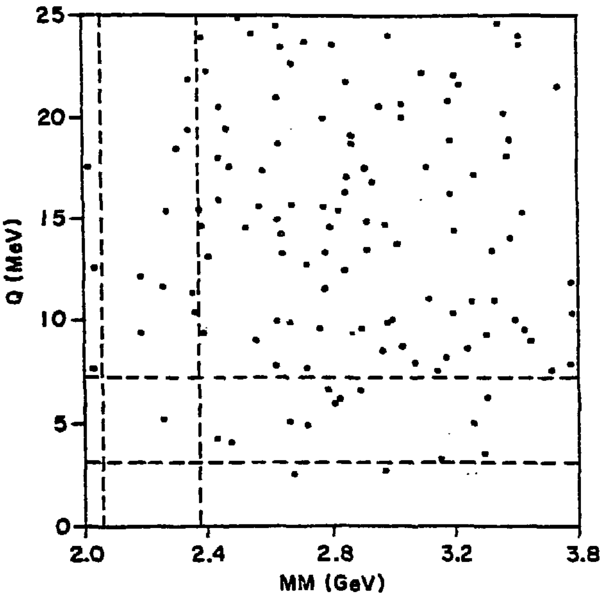

Fig. 3 Scatter plot of MM vs Q. The dotted lines indicate the ranges 2.14 < MM < 2.38 GeV and 3.7 < Q < 7.7 MeV.

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*) The slope used for the t distribution corresponds to that expected from D^0 exchange (assuming the Regge trajectory to have a slope of 0.4 GeV^{-2}).

$3.7 < Q < 7.7$ MeV. From studying events outside this Q range and also those outside the selected Kπ mass range, the background is estimated to be 11 events. Thus one obtains a cross-section times branching ratio ($\sigma\cdot B$) upper limit for D^{*-} production of 2.4 nb at 95% confidence level. Using the branching ratios[1,9] 0.64 ± 0.11 for $D^{*-} \rightarrow D^0\pi^-$ and 0.03 ± 0.006 for $D^0 \rightarrow K^+\pi^-$ one obtains a cross-section upper limit of 130 ± 30 nb, where the error reflects the uncertainties in the branching ratios. In the MM range from 2.14 to 2.38 GeV and the Q range from 3.7 to 7.7 MeV, there is only 1 event and the estimated background is 1 event. This gives a $\sigma\cdot B$ upper limit of 1.3 nb for the exclusive reaction $\pi^-p \rightarrow D^{*-}\Lambda_c^+$ and a corresponding cross-section upper limit of 70 ± 18 nb*).

The second Multiparticle Spectrometer experiment to be reported here, the electron-trigger experiment, was carried out again at the BNL Multiparticle Spectrometer with a π^- beam at 17 GeV/c on a hydrogen target. It was sensitive to the following specific reactions:

$$\pi^-p \rightarrow \Lambda_c D^-$$

$$(D^- \rightarrow e^- + X,\ \Lambda_c \rightarrow \Lambda\pi^+ \tag{4}$$

$$\Lambda_c \rightarrow pK_S \tag{5}$$

$$\Lambda_c \rightarrow \Lambda\pi^+\pi^+\pi^-) \tag{6}$$

$$\pi^-p \rightarrow D^0D^-p$$

$$(D^- \rightarrow e^- + X,\ D^0 \rightarrow K_S\pi^+\pi^-) \tag{7}$$

$$\pi^-p \rightarrow D^+D^-n$$

$$(D^- \rightarrow e^- + X,\ D^+ \rightarrow K_S\pi^+) \tag{8}$$

The strategy employed was to trigger on a single electron of momentum greater than 2.5 GeV/c and veto the γ and e^+ which arise from the most likely source of such electrons, i.e. $\pi^0 \rightarrow e^+e^-\gamma$ (either internal or external conversions). The electron trigger allowed a large suppression of the hadron background to these reactions. However, since there would always be a missing neutrino, the analysis required a signal in a two-dimensional plot of the MM of the D^- versus the effective mass of the other charmed particle. In the case of reaction (8) one can only search for the D^-n mass. The effective mass in each required identification of K_S or Λ.

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*) The upper limits are based on Poisson statistics. If the expected number of events to be observed is $\bar{n} = 4.8$, then the probability for observing 1 or 0 event is 5%. This gives then an upper limit signal of 3.8 events. Similarly if $\bar{n} = 17.0$, then there is a 5% probability of observing 10 or less events giving an upper limit signal of 7.0 events.

The charged particles in these reactions were measured in the planar chambers downstream of the target, as well as the cylindrical chambers surrounding the target. The electron trigger was accomplished by using two lithium-foil transition radiators each followed by a xenon-filled proportional chamber[10)] and a lead/acrylic-scintillator sandwich shower detector[11)]. The experimental layout is given in Fig. 4. On line, a triple coincidence was required between these devices, corresponding to the trajectory of a negative track. Off line, the hadron rejection exceeded 3000:1.

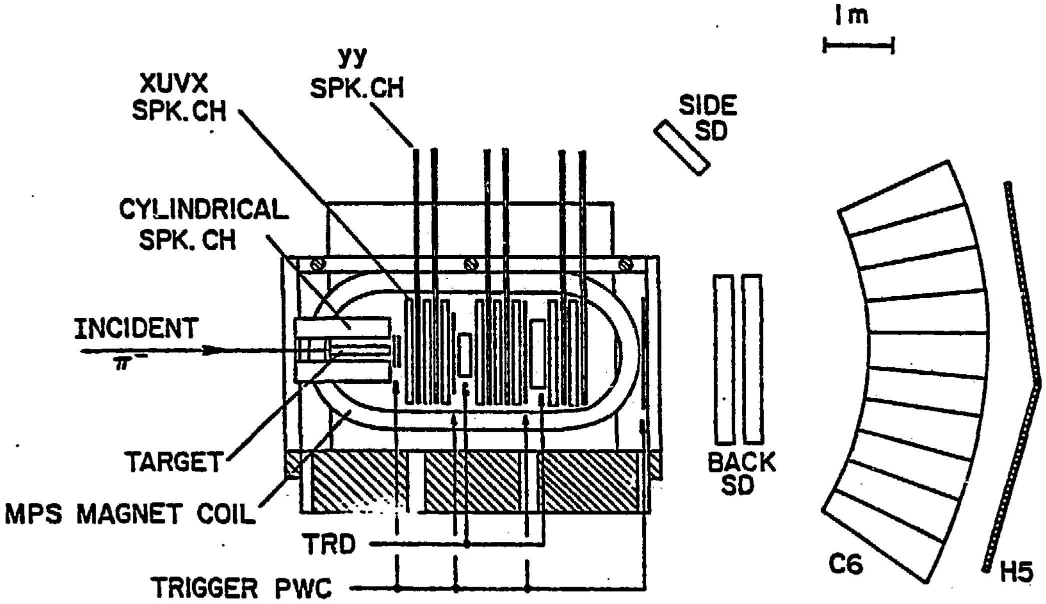

Fig. 4 Layout of the electron-trigger experiment. The electron detection is achieved via two transition-radiation detectors (TRDs), a set of lead-scintillator shower detectors (SDs), and trigger PWCs. In addition, cylindrical and planar spark-chamber modules have been used for measurement of the electron and hadron tracks within the Multiparticle Spectrometer.

A total good beam flux of 6.60×10^{10} pions was incident on a 90 cm hydrogen target leading to $\sim 1.3 \times 10^6$ events triggered. The analysis consisted of rejecting almost all these events since they did not meet the requirements of the reactions (4) to (8). An electron candidate was required to originate from a production vertex inside the target. To reduce the e^+e^- pair background further, the trigger electron was paired with all positive tracks to form an e^+e^- hypothesis. If the invariant mass was less than 100 MeV, the event was rejected. The remaining events were searched for neutral decay candidates which were separated from the production vertex. A final sample of 5700 events remained which had a single unpaired e^- of good quality, at least one K_S or Λ downstream of the production vertex, a good production vertex with at least three tracks and no visible γ's with an energy exceeding 1 GeV. Detailed Monte Carlo calculations simulated the experiment and, when subjected to the same cuts as the data, yielded the efficiency for finding each reaction.

Scatter plots of the effective mass versus the missing mass of the D^- were made. Within a conservatively sized rectangle based on the mass resolution, no events remained for the associated charm production reactions (4) to (6) and one event each remained for reactions (7) and (8).

Using efficiencies and acceptances from this experiment and the measured branching ratios$^{12)}$, upper limits for the total cross-sections for reactions (4) to (8) were determined at 95% confidence level as follows:

$$\begin{array}{llll}
\sigma(4)B^2 < & 6.3\ \mathrm{nb}\ , & \sigma(4) < & 2.4\ \mu\mathrm{b}\ , \\
\sigma(5)B^2 < & 7.3\ \mathrm{nb}\ , & \sigma(5) < & 3.3\ \mu\mathrm{b}\ , \\
\sigma(6)B^{\overset{2}{\cancel{3}}} < & 69\ \mathrm{nb}\ , & \sigma(6) < & 11\ \mu\mathrm{b}\ , \\
\sigma(7)B^2 < & 13\ \mathrm{nb}\ , & \sigma(7) < & 1.5\ \mu\mathrm{b}\ , \\
\sigma(8)B^2 < & 4.7\ \mathrm{nb}\ , & \sigma(8) < & 1.6\ \mu\mathrm{b}\ .
\end{array}$$

The failure to observe any event for reactions (4) to (6) yields a combined upper limit for the reaction $\pi^- p \to \Lambda_c D^-$ of 1.6 μb.

In conclusion, two separate searches for charm production at BNL energies have been carried out at the BNL Multiparticle Spectrometer. From these experiments one can conclude that the charm cross-section is at least 20 times smaller than those at Fermilab or CERN energies. In particular, the cross-section upper limit for 16 GeV/c $\pi^- p$ collisions is less than 130 nb; this represents an improvement of a factor of 20 on a previous similar experiment$^{5)}$.

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REFERENCES

1) J.J. Aubert et al., Phys. Rev. Lett 35, 416 (1975). Limits given in this paper should be increased to $\gtrsim 10^{-32}$ cm^2 if peripheral production is assumed.
R. Cester et al., Phys. Rev. Lett. 37, 1178 (1976).

2) G.J. Feldman et al., Phys. Rev. Lett. 38, 1313 (1977).

3) J. Kirkby, Proc. 9th Int. Symposium on Lepton and Photon Interactions at High Energies, Batavia, 1979 (Fermilab, Batavia, Ill., 1980), p. 107.
J. Blietschau et al., Phys. Lett. 86B, 108 (1979).
P. Avery et al., Phys. Rev. Lett. 44, 1309 (1980).
J.E. Wiss, Proc. 6th Int. Conf. on Experimental Meson Spectroscopy, Brookhaven National Laboratory, Upton, 1980 (Amer. Inst. Phys., NY, 1981), AIP Conference Proceedings No. 67, p. 257.

4) E.S. Crandall, Search for charm production in 17 GeV/c π^-p reactions, Ph.D Dissertation, State University of New York at Stony Brook (1981);
E.S. Crandall et al., to be submitted to Phys. Rev. D.

5) R. Cester et al., Phys. Rev. Lett. 40, 138 (1978).

6) V.L. Fitch et al., Phys. Rev. Lett. 46, 761 (1981).

7) S.U. Chung et al., Phys. Rev. Lett. 45, 1611 (1980).

8) E.D. Platner et al., IEEE Trans. Nucl. Sci. 24, 1225 (1977).

9) R.H. Schindler et al., SLAC-PUB-2507, LBL-10905 (1981), submitted to Phys. Rev.

10) R. Bosshard et al., Nucl. Instrum. Methods 130, 365 (1975).

11) G. Abshire et al., Nucl. Instrum. Methods 164, 67 (1979).

12) G. Trilling, Phys. Reports 75, 57 (1981).