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**A-DEPENDENCE OF THE CHARM PRODUCTION CROSS-SECTION
IN 320 GeV/c π^- INTERACTIONS**

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ABSTRACT

Using a 320 GeV/c π^- beam incident on three different target materials Al, Fe, and U, the A-dependence of charm production is studied by measuring the yield of prompt single muons. Parametrizing the charm cross-section as $\sigma_{cc}(\pi^- A) = \sigma_0 A^\alpha$ the measured α values are $\alpha(\mu^+) = 0.76 \pm 0.08$ and $\alpha(\mu^-) = 0.83 \pm 0.06$.

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In this letter we report on a study comparing charm production on three different target materials (Al, Fe, and U) using an incident π^- beam with a momentum of 320 GeV/c. The production of charm is deduced from the yield of prompt single muons originating from the semileptonic decays of the charmed particles.

The set-up has been described in detail elsewhere [1]. Here we simply recall its main features. The essential parts of the experimental layout are formed by the muon spectrometer and the target calorimeter. The spectrometer consists of a bipolar superconducting magnet completed with a system of drift chambers and multiwire proportional chambers as indicated in fig. 1. The hadronic calorimeter, which is constructed as a sandwich of dense absorbers and scintillator sheets, is divided into two parts: an upstream expandable part and a downstream fixed part.

The dense absorbers used in the fixed part, which was never modified during data-taking, were made of iron. The expandable part has a mechanical structure that allows an easy replacement of the absorber plates as well as an easy change in the target density. Table 1 shows a summary of the various configurations in which the calorimeter has been used.

Measurements were performed with U, Fe, and Al targets at three different densities, the expansion factor being 1 (compact form), 1.5, and 2 (fully expanded form), respectively. The position of the interaction vertex was obtained from the start of the shower development. In the analysis only the events for which the shower starts in the target section have been taken into account. The total number of effective interactions collected with the Al, Fe, and U targets are shown in table 2.

The trigger required at least one muon detected in the spectrometer. Background resulting from coincidences between a hadron interaction and a beam- or halo-muon were effectively removed by imposing an upper limit on the muon momentum of 100 GeV/c and a maximum calorimeter energy of 360 GeV/c. Beam muons crossing the apparatus were eliminated, requiring a lower limit on the calorimeter energy of 80 GeV. In the following analysis all muon momenta are required to be in the interval 20–100 GeV/c, ensuring a good spectrometer reconstruction.

An important contribution to the measured single-muon rate is due to the non-prompt muons from π and K decays. Elimination of this non-prompt rate was performed using the density extrapolation method. Figures 2a, b and c show the variation of the single-muon rate and dimuon rate as a function of the target density for U, Fe, and Al, respectively. The independence of the dimuon rate on the target density is as expected for a prompt process. The difference in slope between μ^+ and μ^- for the same target is due to the fact that for incident π^- there is a more abundant production of π^- than π^+ in the forward direction. The intercept at $1/\rho = 0$, i.e. infinite density, represents the prompt muon rate. However, there is still a non-prompt contribution from showers not fully contained in the expandable section of the calorimeter. This contribution has been estimated experimentally for the U and Fe targets by positioning in compact form the expandable section of the calorimeter at different distances from the fixed calorimeter part. Muon rates obtained at various positions showed that the possible non-prompt contribution is of the order of 2%. As the Al section represents only $2.5 \lambda_{\text{int}}$, a considerable fraction of the apparent prompt rate obtained from the Al expansion includes the non-prompt rate from the downstream U part. This contribution was measured by expanding the U section, keeping the Al section in compact form (fig. 2d).

The production of a $\mu^+ \mu^-$ pair in which one muon is not detected leads to a prompt background contribution in the single-muon channel. To estimate this contribution, muon pairs were generated according to a parametrization given by Anderson [2]. The Monte Carlo data were then processed as real data, resulting in a dimuon momentum spectrum in agreement with the experimentally measured one. From this analysis the ratio of the acceptances for a $\mu^+ \mu^-$ pair with one and two detected muons was estimated to be 0.85. This number combined with the measured dimuon rate allows the removal of this background, estimated to be less than 20% of the single-muon rate. Table 3 shows the rates

for the different targets after all corrections. It shows that the rate for the μ^- substantially exceeds the rate for the μ^+ . This effect has previously been observed [3] and explained as a result of a combined effect of the leading particle and the difference in semileptonic branching ratios of charged and neutral D's. Figure 3 shows the rates as a function of the atomic number, the solid lines representing a fit to a power law in A. The fitted slopes combined with the A-dependence of the absorption cross-section for pions [4] leads to the following values of α

$$\alpha(\mu^+) = 0.76 \pm 0.08$$

$$\alpha(\mu^-) = 0.83 \pm 0.06 .$$

A possible variation of the α -value with the muon momentum was investigated by repeating the above analysis using three different momentum cuts (table 4); the corresponding acceptance variation as a function of x_F^{charm} is shown in fig. 4. Within the statistical accuracy no significant dependence of α on x_F is observed.

In conclusion, the present data, obtained with a π^- beam show that the charm-production cross-section variation with atomic number is very similar to the pion-nucleus absorption cross-section. Comparable values for α have been obtained in previous experiments using proton [5] and neutron [6] beams. In the present experiment proton data were also taken; the analysis is in progress and will allow a more direct comparison between proton and pion data.

REFERENCES

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Table 1
Summary of calorimeter configurations

Al target	Fe target	U target	
50 mm Al ($\times 20$)	25 mm Fe ($\times 52$)	10 mm U ($\times 20$)	expandable
15 mm U ($\times 32$)		15 mm U ($\times 32$)	expandable
25 mm Fe ($\times 48$)	25 mm Fe ($\times 48$)	25 mm Fe ($\times 48$)	fixed

Table 2
Effective number of interactions

Target	Interactions
Al	31×10^6
Fe	33×10^6
U	70×10^6

Table 3
Muon rates from charm decays/ 10^6 pions

Target	μ^+	μ^-
Al	55.0 ± 14.0	93.0 ± 16.0
Fe	73.0 ± 9.0	104.0 ± 11.0
U	68.0 ± 5.0	115.0 ± 6.0

Table 4
 α dependence on muon momentum cut

p_μ (GeV/c)	$\alpha_{\mu+}$	$\alpha_{\mu-}$
> 20	0.76 ± 0.08	0.83 ± 0.06
> 30	0.75 ± 0.14	0.86 ± 0.07
> 40	0.65 ± 0.16	0.88 ± 0.09

Figure captions

- Fig. 1** Experimental set-up of the WA78 experiment with the calorimeter in compact form.
- Fig. 2** The $1/q$ extrapolation for (a) the uranium, (b) the iron, and (c, d) the Al target data. (c) and (d) correspond respectively to the aluminium target expansion (compact uranium) and the uranium section expansion (compact aluminium). The quoted errors are only statistical.
- Fig. 3** Calculated μ^+ and μ^- rates from charm events as a function of atomic number. The fitted slopes are $\alpha'(\mu^+) = 0.01 \pm 0.08$ and $\alpha'(\mu^-) = 0.08 \pm 0.06$.
- Fig. 4** Geometrical acceptance as a function of x_F^{charm} for different muon momentum cuts.

Fig. 1

Fig. 2

Fig. 2

Fig. 3

Fig. 4