HADROPRODUCTION OF CHARM
AT FERMILAB E769(1)


(The Tagged-Particle Spectrometer Collaboration)

1Centro Brasileiro de Pesquisas Físicas, 2Fermi National Accelerator Laboratory, 3University of Mississippi, 4Northeastern University, 5University of Toronto, 6Tufts University, 7University of Wisconsin, 8Yale University

Presented by
Lee Lueking
Fermilab, Batavia, Ill. 60510, U.S.A.

Abstract

Experiment E769 at Fermilab obtained charm data during the 1987-88 Fixed Target running period with a 250 GeV tagged hadron beam incident on thin target foils of W,Cu,Al, and Be. From analysis of 25% of the recorded 400M trigger sample we have explored the Feynman x, p_T^2 and the atomic number dependence of charm quark production for D⁺ and D⁰ mesons.
1. INTRODUCTION

Experiment E769 has completed its first analysis pass on 25% of the data which was taken during the 1987-88 Fixed Target running period. This data was collected using a 250 GeV tagged hadron beam incident on a segmented foil target with four nuclear materials: Be, Al, Cu, and W. The total data set consists of 400 M triggers, with about 130 M negative beam events; 85% π, and 15% K and 240 M positive beam triggers; 40% π, 30% K, and 30% p. The principal focus of the experiment is to measure the characteristics of hadroproduction of charm, including total charm cross section, Feynman x, Pt, A dependence and beam particle type dependence.

The most important processes contributing to the hadroproduction of charm are gluon-gluon fusion and quark-antiquark annihilation. The contributions to the charm cross section \( \sigma_{c\bar{c}} \) of these processes were calculated to lowest order perturbative QCD by Ellis and Quigg, resulting in predictions for production characteristics \([1]\). Recent results have been obtained including the next to leading order terms, showing that 
\[
\frac{\sigma_{c\bar{c}}(a_1^2 + a_2^2)}{\sigma_{c\bar{c}}(a_1^2)} \approx 3 \quad [2]
\]
and measurement of the \( \sigma_{c\bar{c}} \) can be used to test values of the charm quark mass and structure functions employed in this calculation. For hard scattering there is no reason for a nuclear A dependence of the cross section other than \( \sigma_{c\bar{c}} \propto A^1 \), which is assumed in the theory. Any special effects caused by the final charm particle containing one of the valence quarks of the incident beam particle, the so-called "leading particle effect", are also not included in this model.

The current status of fixed target research in this area is marked by difficulty and success. Hadroproduction of charm is more difficult than photoproduction in that the charm cross section relative to the total cross section is about 5 times lower. Also, track multiplicities are higher, further increasing backgrounds. Despite these problems, the results for the \( \sigma_{c\bar{c}} \) are in good agreement with theory \([3]\). Early measurements of the \( \sigma_{c\bar{c}} \propto A^\alpha \) dependence indicate that \( \alpha < 1 \), and there is reason to believe \( \alpha \) may depend on the variables \( x_F \) and \( p_t \). Leading particle effects have been reported, but are not established.

2. APPARATUS

The E769 detector is the Tagged Photon Spectrometer described elsewhere \([4]\) with several improvements. The detector consists of 13 planes of Silicon Microstrip vertex Detectors (SMD), 35 planes of drift chambers, two threshold Cerenkov counters, and electromagnetic and hadronic calorimeters. The following enhancements were made to the E691 photoproduction apparatus for this data: 1) beam tracking for the incident hadron, 2) additional 25µm silicon immediately downstream of the target, 3) Y measurement 2mm PWC's before the first analysis magnet, 4) improved data acquisition capable of logging 400 events/second with a 40% dead time \([5]\). The silicon vertex detector provides 20µm x-y and 300µm z vertex resolution and the detector has an angular acceptance of \( \pm 100 \) mr. A trigger based on the transverse energy in the forward calorimeters is used to enhance the charm sample.

Consisting of 10 Be, 5 Al, 3 Cu and 4 W foils, the target represents 2% of a nuclear interaction length and was designed with the high Z materials located most upstream, to minimize multiple scattering effects. the Be, Al, and Cu foils were 250µm thick, and the W foils were 100µm in thickness. The foils are placed at 1.2 mm intervals in the beam.
The secondary hadron beam was tagged using two devices, a differential Cerenkov counter, and a transition radiation detector. The Differential Isochronous Self-focusing Cerenkov counter (DISC) was 50% efficient tagging kaons at a pion contamination level of less than 5% and it was employed in this capacity for most of the run. However, we recorded nearly 60M triggers with the DISC used to trigger on protons only. A 24 module TRD with polypropylene radiators was employed to tag pions with a 95% efficiency and a contamination level of < 3% from protons or kaons [6].

3. RESULTS

The portion of the data reported on here consists of about 100M negative beam triggers which are principally pions. From this sample of the data, we have extracted charm signals for the modes $D^+ \rightarrow K^-\pi^+\pi^+$ and $D^0 \rightarrow K^-\pi^+$ [7]. The charm signals are extracted by forming primary vertex candidates using the SMD track information. From this list of vertices for each event the primary vertex is defined to be the one with the largest number of attached tracks, and a secondary decay vertex candidate is chosen based on several criteria. First, the significance of the primary to secondary separation, $SDZ = \Delta z/(\sigma_{\Delta z}^{\text{fit}} + \sigma_{\Delta z}^{\text{MC}})^{1/2}$, must be greater than 12. Second, for each track in the secondary candidate, the transverse distance to the primary, $b_p$, and to the secondary, $b_s$, are determined. A parameter “RATIO” is then defined as the product of the ratios $\Pi_{n=1}^n b_s/b_p$, with $n$ being the number of tracks in the secondary decay mode. The value of RATIO must be less than 0.006 for the 3 body decays, and .06 for the two body decays. Third, the impact parameter of the momentum vector of the reconstructed D secondary decay with respect to the primary vertex must be less than 80µm for the 3 body decays and 100µm for the two body decays. Fourth, for the charged D's, the decay vertex location must be isolated by more than 60µ from additional tracks in the event. Finally, the sum of $p_T$ of the D candidate decay tracks relative to the D direction must be greater than .5 GeV/$c^2$. With these cuts imposed, for the $D^+ \rightarrow K\pi\pi$ and $D^0 \rightarrow K\pi$, modes respectively signal sizes of 684±42 and 496±39 events are observed (Fig. 1).

From the $K\pi\pi$ and $K\pi$ decay mode samples a preliminary analysis has been performed to extract the $x_F$ and $p_T^2$ distributions, and the $A$ dependence. Acceptance corrected $x_F$ distributions for the $D^+$ and $D^0$, are fit to $(1 - x_F)^n$. The value for $n$ from the two fits is $n = 3.6 \pm 0.4$ for the $D^+$ (Fig. 2a), and $n = 4.3 \pm 0.8$ for the $D^0$ (Fig. 2b). Shown in Fig. 3 are acceptance corrected $p_T^2$ distributions, with the fit representing $e^{-bx_F}$. For the $D^+$ and $D^0$ samples the value for $b$ are $b = 0.95 \pm 0.1$ and $b = 0.87 \pm 0.1$ respectively. The $A$ dependence is shown in Fig. 4a and b for the $D^+$ and $D^0$ signals and the fits represent $A^\alpha$ dependence. The values for $\alpha$ are $\alpha = 0.95 \pm 0.07$ for the $D^+$ and $\alpha = 1.00 \pm 0.1$ for the $D^0$. In all of the analyses the errors quoted are statistical only; the systematic errors are not yet determined. Also, there may be a systematic correction due to the effect of the $E_t$ trigger which has not been made pending further study.

Our plans for the future include completion of our reconstruction, analysis of more charm states and modes, measurement of the total and differential charm cross sections, and use of the beam tagging information. We have currently reconstructed nearly 90% of our raw data and hope to complete this processing by summer. Our analysis should proceed quickly and will include the $D^0 \rightarrow K\pi\pi\pi$ decay mode, additional charmed meson states such as the $D^*$, $D_s$, and charmed baryon states including $\Lambda_c$. We will search for...
Figure 1: Charm signals for the decay modes (a) $D^+ \rightarrow K^-\pi^+\pi^+$ ; 683 ± 42 signal events and (b) $D^0 \rightarrow K^-\pi^+$ ; 496 ± 39 signal events.

Figure 2: Acceptance corrected $x_F$ distribution for the (a) $D^+ \rightarrow K^-\pi^+\pi^+$ and (b) $D^0 \rightarrow K^-\pi^+$ modes with the fit representing $(1 - x_F)^n$, the value of $n$ is $n = 3.6 ± 0.4$ and $n = 4.3 ± 0.8$ respectively.
Figure 3: Acceptance corrected $p_T^2$ distributions, with the fit representing $e^{-bt^2}$ for (a) $D^+ \rightarrow K^-\pi^+\pi^+$ and (b) $D^0 \rightarrow K^-\pi^+$ modes; $b = 0.95 \pm 0.1$ and $b = 0.87 \pm 0.1$ respectively.

Figure 4: Nuclear $A$ dependence for the (a) $D^+$ and (b) $D^0$ signals; the fits represent $A^\alpha$. The values for $\alpha$ are $\alpha = 0.95 \pm 0.07$ for the $D^+$ and $\alpha = 1.0 \pm 0.1$ for the $D^0$. 
incident particle type related physics with the tagged hadrons in the positive beam.

4. SUMMARY

A preliminary analysis has been performed on approximately 25% of our 400 M trigger data sample. This sample has yielded signals for the decay modes for $D^+ \rightarrow K\pi\pi$ and $D^0 \rightarrow K\pi$ of 683 ± 42 and 496 ± 39 events respectively. For these modes distributions for $z_F$, $p_T$, and the nuclear A dependence have been extracted. Work is continuing to understand systematic errors and corrections, and to include more charmed states including charm-strange mesons and charmed baryons.

We gratefully acknowledge the assistance we received from the Fermilab staff and the support staffs at the various universities. This research was supported by the U.S. Department of Energy, the National Science and Engineering Research Council of Canada, and the Brazilian Conselho Nacional de Desenvolvimento Cientifico e Tecnológico.

REFERENCES

(*)Results presented here reflect the most recent analysis shown at the Spring Meeting of The American Physical Society, Washington D. C. April 16-19, 1990.

(a)Present address: SSC Laboratory, Dallas, Texas 75239.

(b)Present address: University of Oklahoma, Norman, Oklahoma 73019.

(c)Present address: University of Cincinnati, Cincinnati, Ohio 45221

[7] Throughout this paper, references to decays include both the particles and their charge conjugate states.