DOE/ER/40085--22

DE91 005978

# HADROPRODUCTION OF CHARM AT FERMILAB E769

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## ABSTRACT

### Abstract

Experiment E769 at Fermilab obtained charm hadroproduction data during the 1987-88 Fixed Target running period with a 250 GeV hadron beam incident on thin target foils of Be, Al, Cu,and W. From an 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 using samples of $D^+$ and $D^0$ mesons.

## 1. Introduction

Experiment E769 has completed its first analysis pass on 25% of the data which were taken during the Fermilab 1987-88 Fixed Target running period. These data were collected using a 250 GeV hadron beam, with $\pi$, K, and p identification, incident on a foil target assembly with four materials: Be, Al, Cu, and W, segmented in the beam direction. The total data set contains 400 M triggers, with about 130 M negative beam events: 85% $\pi$, and 15% K and 270 M positive beam events: 40% $\pi$, 30% K, and 30% p. The principal focus of the experiment is to measure the characteristics of charm hadroproduction, including the total charm cross section, and the dependence of the cross-section on the Feynman x, $p_t^2$, target atomic number and beam particle type.

At a beam energy of 250 GeV, the dominant processes producing charm in hadron-hadron collisions are expected to be gluon-gluon fusion and, to a lesser degree, quark-antiquark annihilation. Nason, Dawson, and Ellis calculated the contributions of these processes to $\mathcal{O}(\alpha_s^3)$ for the total[1] and differential[2] cross sections. Leading particle effects where the charm particle contains a valence quark from the beam particle are not accomodated in this model. The predicted cross section is in reasonable agreement with experimental data [3]. Measurement of the total charm cross section can be used to test the value of the charm quark mass and the structure functions used in the calculations. Note, however, that in reference 3 the experiments used a wide range of target materials, from hydrogen to tungsten, and that to convert the measurements into pN cross sections an A-dependence of $A^{1.0}$ was used. Early measurements of the $\sigma_{c\bar{c}} \propto A^{\alpha}$ dependence indicated 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 data were collected using the Tagged Photon Spectrometer which is described elsewhere [4]. Including upgrades made for this run, the spectrometer 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 apparatus for these data: 1) beam particle identification and tracking for the incident hadron, 2) two additional 25$\mu$m SMD planes immediately downstream of the target, 3) two y measurement proportional wire chambers with 2mm spacing 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 typical vertex resolutions of 20$\mu$m transverse to and 300$\mu$m along the beam direction. The detector has an angular acceptance of $\pm$100 mr. A trigger based on multiplicity and the total transverse energy in the forward calorimeters is used to enhance the charm sample.

The beam was tagged using two devices, a differential Cerenkov counter, and a transition radiation detector (TRD). The Differential Isochronous Self-focusing Cerenkov counter [6] (DISC) was 50 % efficient for tagging kaons at a pion contamination level of less than 5% and it was operated in this mode for most of the run. However, we recorded nearly 60M triggers for which the DISC was set to trigger on protons. A 24 module TRD with polypropylene radiators and xenon-filled proportional chambers was employed to tag pions with a 95% efficiency and a contamination level of < 3% from protons or kaons [7].

## 3. Analysis and Results

The subset of the data reported here contains about 110M negative beam triggers, principally pion induced. From this sample of the data, we have extracted charm signals for the modes $D^+ \to K^-\pi^+\pi^+$ and $D^0 \to K^-\pi^+$. (Throughout this paper, references to decays include both the particles and their charge conjugates.) The charm signals are extracted by forming primary vertex candidates using the SMD track information. From the list of vertices for each event, the primary vertex is taken to be the one with the largest number of attached tracks, and a secondary decay vertex candidate is chosen based on several criteria. Then, the significance of the primary to secondary vertex separation, $SDZ = \Delta z/(\sigma_{z_p}^2 + \sigma_{z_s}^2)^{1/2}$, must be greater than 12. Next, for each track in the secondary candidate vertex, 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 $\Pi_{i=1}^{n} b_s/b_p$, 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. In addition, the impact parameter of the momentum vector of the reconstructed D with respect to the primary vertex must be less than 80$\mu$m for the 3 body decays and 100$\mu$m for the two body decays. Also, for the charged D's, the decay vertex location must be isolated by more than 60$\mu$m from additional tracks in the event. Finally, the sum of $p_t^2$ of the D candidate decay tracks relative to the D direction must be greater than .5 GeV$^2$/c$^2$. The values for these cuts were chosen based on studies using Monte Carlo generated events for signals, and background events from the data. With these cuts imposed, signal sizes of 727$\pm$44 and 538$\pm$36 events are observed for the $D^+ \to K\pi\pi$ and $D^0 \to K\pi$ modes respectively (Fig. 1).

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 values for n from the two fits are $n = 3.8 \pm 0.4$ for the $D^+$ (Fig. 2a), and $n = 4.1 \pm 0.6$ for the $D^0$ (Fig. 2b). Shown in Fig. 3 are acceptance corrected $p_t^2$ distributions, with the fit representing $e^{-bp_t^2}$. For the $D^+$ and $D^0$ samples, the values for b are $0.98 \pm 0.07$ and $0.95 \pm 0.09$ 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 $0.97 \pm 0.07$ for the $D^+$ and $0.92 \pm 0.08$ for the $D^0$. All errors quoted are statistical only; systematic errors are being studied. The signals are acceptance corrected by a detailed Monte Carlo detector simulation using Pythia generation and Lund fragmentation. However, no correction for the $E_t$ trigger has been made yet.

## 4. Summary

A preliminary analysis of the A-dependence, Feynman x and ${p_t}^2$ distributions of $D^+$ and $D^0$ production has been performed on 110 M out of a total of 400 M events. Projecting these signals to the full data sample, and including other decay modes, yields $\approx$ 6K fully reconstructed charm decays. This should allow a very accurate A-dependence measurement, as well as high-statistics studies of leading particle effects. Efforts are ongoing to study systematic corrections and errors. Studies are also underway to obtain improved signal to background using Cerenkov identification. Other charm states and modes will soon be available, including: $D^0 \to K^-\pi^+\pi^-\pi^+$, $D_s^+ \to K^-K^+\pi^+$ and $\Lambda_c^+ \to pK^-\pi^+$. We also plan to measure the total cross section and the beam flavor dependence of charm production.

We gratefully acknowledge the assistance from support staffs at Fermilab and other collaborating institutions. This research was supported by the U.S. Department of Energy, thc National Science Foundation, the National Science and Engineering Research Council of Canada, and the Brazilian Conselho Nacional de Desenvolvimento Científico e Tecnológico.

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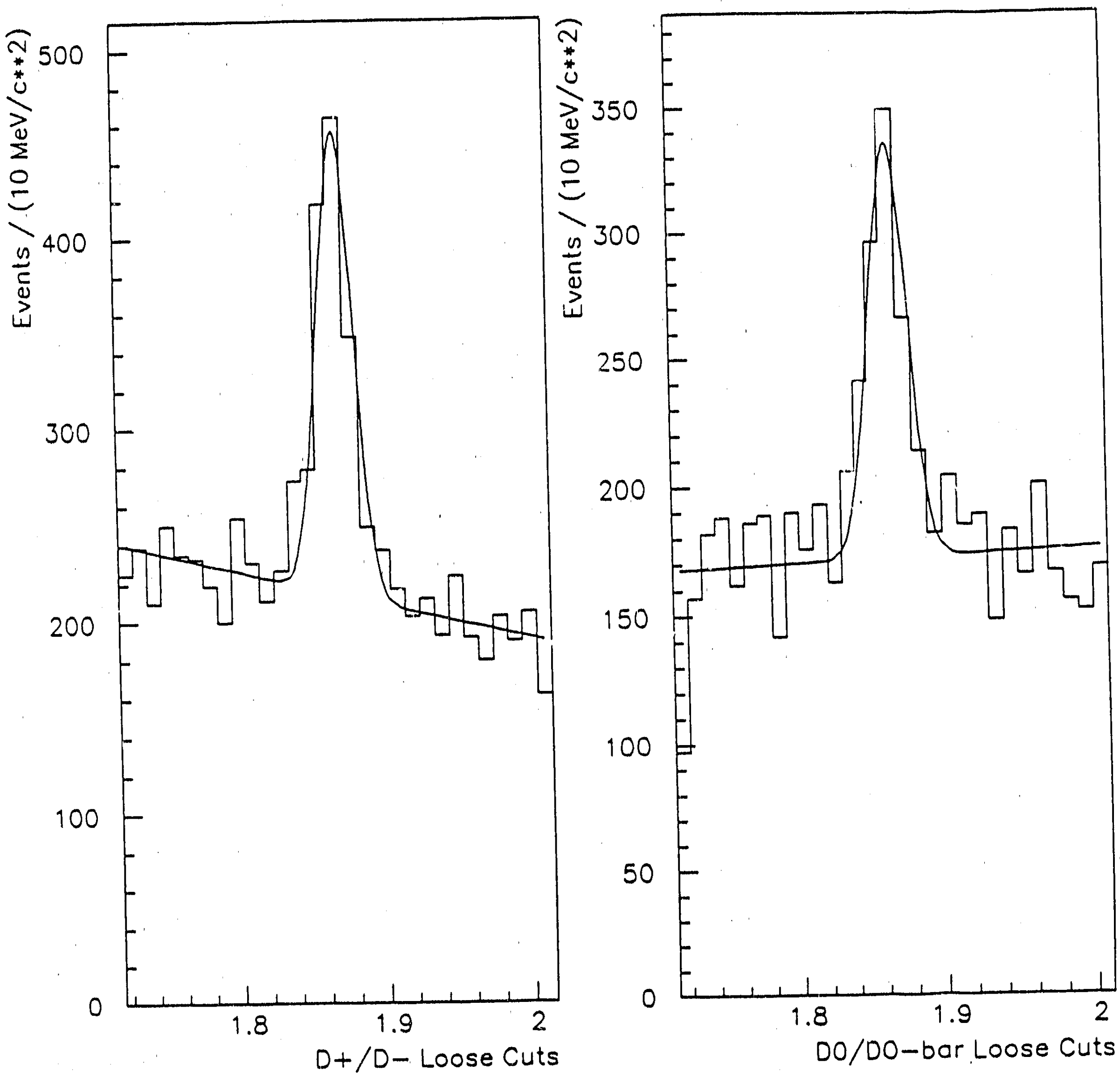


Figure 1: Charm signals for the decay modes (a) $D^+ \to K^-\pi^+\pi^+$ ; $727 \pm 44$ signal events and (b) $D^0 \to K^-\pi^+$ ; $538 \pm 36$ signal events.

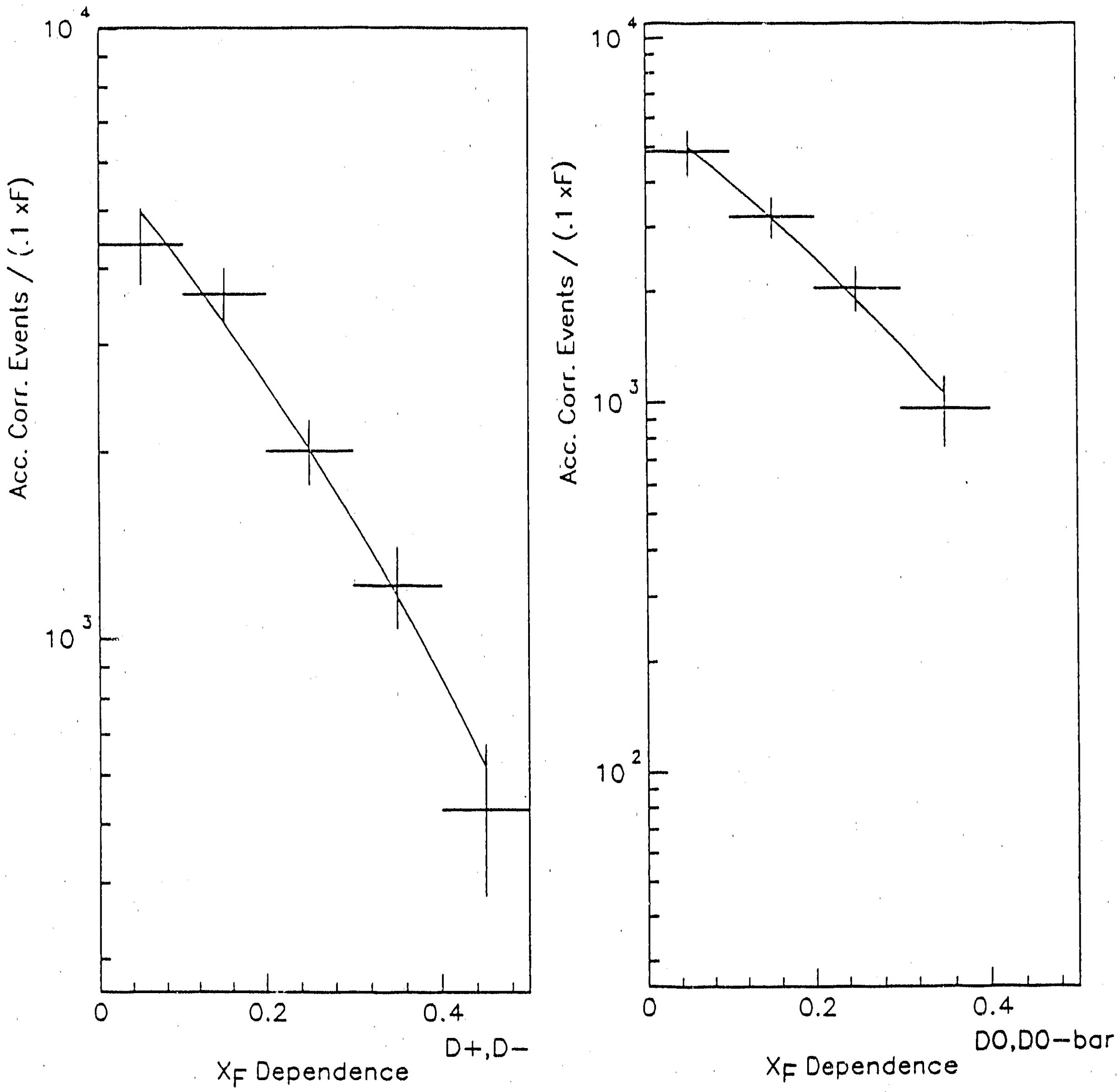


Figure 2: Acceptance corrected $x_F$ distribution for the (a) $D^+ \to K^-\pi^+\pi^+$ and (b) $D^0 \to K^-\pi^+$ modes with the fit representing $(1-x_F)^n$, the value of n is $n = 3.8 \pm 0.4$ and $n = 4.1 \pm 0.6$ respectively.

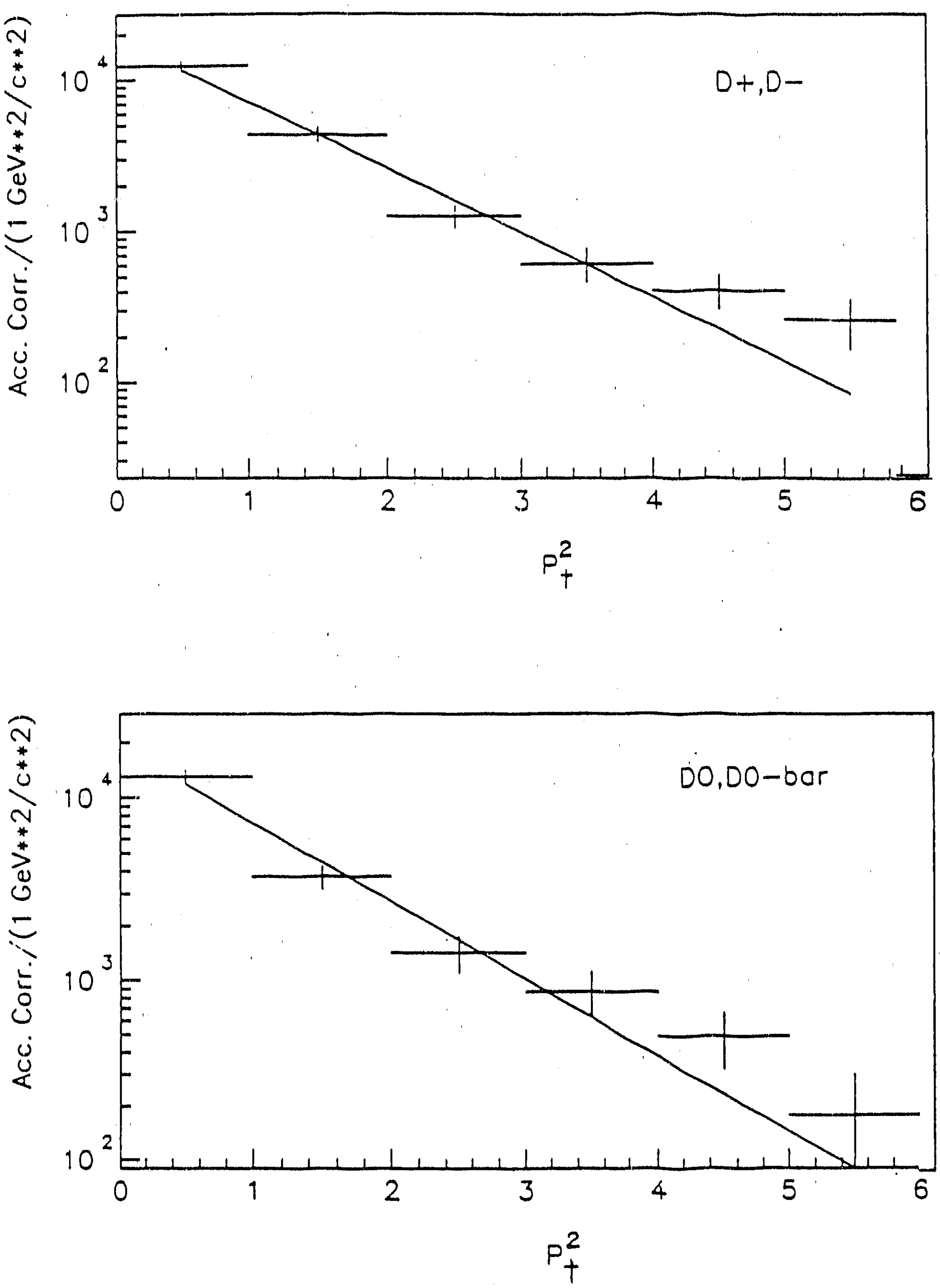


Figure 3: Acceptance corrected $p_t^2$ distributions, with the fit representing $e^{-bp_t^2}$ for (a) $D^+ \rightarrow K^-\pi^+\pi^+$ and (b) $D^0 \rightarrow K^-\pi^+$ ; $b = 0.98 \pm 0.07$ and $b = 0.95 \pm 0.09$ respectively.

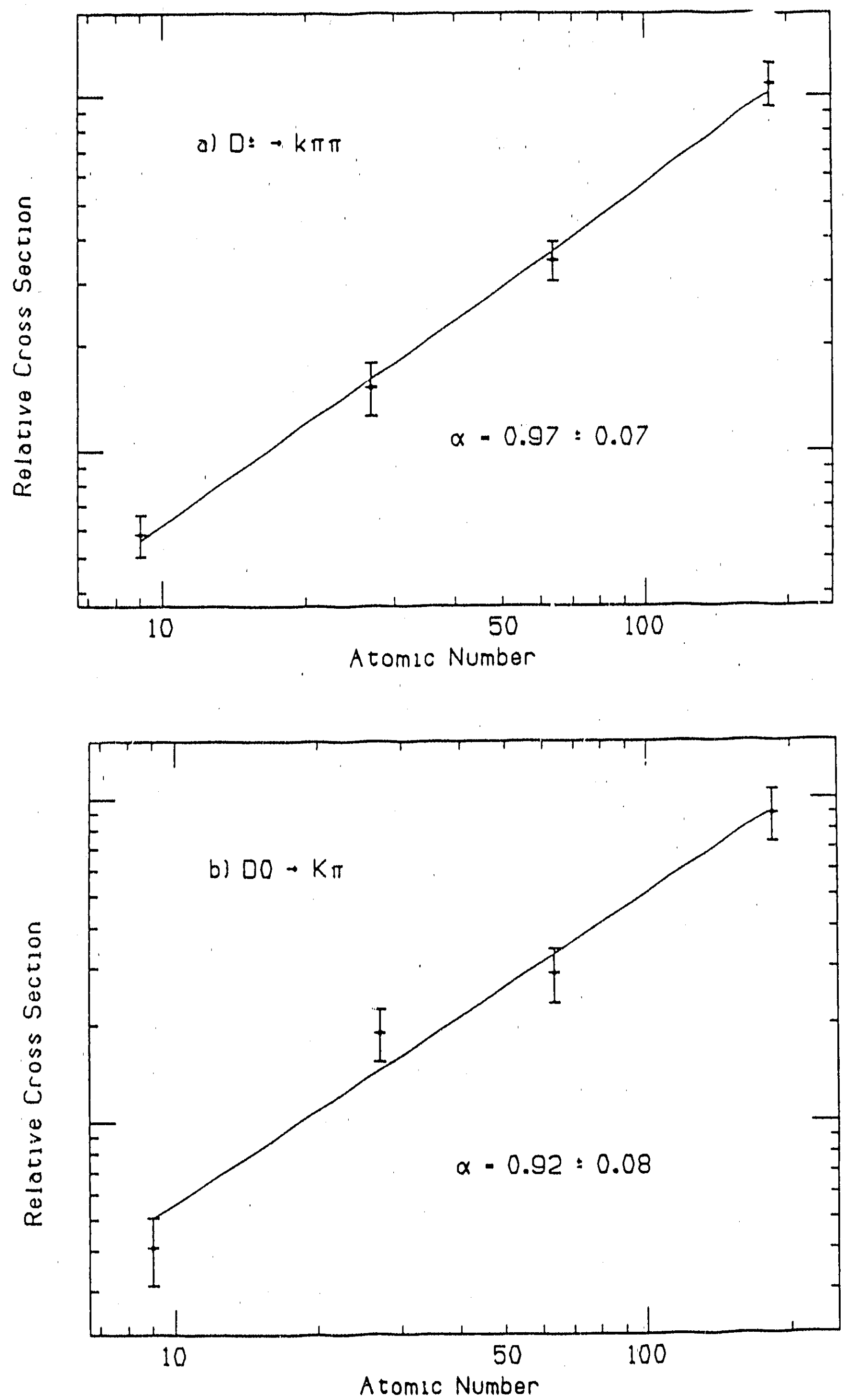


Figure 4: Nuclear A dependence for the (a) $D^+$ and (b) $D^0$ signals; the fits represent $A^\alpha$. The values for $\alpha$ are $\alpha = 0.97 \pm 0.07$ for the $D^+$ and $\alpha = 0.92 \pm 0.08$ for the $D^0$.

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