NEW RESULTS ON CHARM HADROPRODUCTION

The WA82 Collaboration

M. Adamovich[6], Y. Alexandrov[6], F. Antinori[3], D.P. Barberis[2], W. Beusch[2], A. Buys[5], M. Dameri[3], M. Davenport[2], J.P. Dufey[2], A. Forino[1], B.R. French[2], S. Gerasimov[6], R. Gessaroli[1], F. Grard[5], R. Hurst[3], A. Jacholkowski[2], A. Kirk[2], S. Kharlamov[6], J.C. Lassalle[2], P. Legros[5], L. Malinina[6], P. Mazzanti[1], C. Meroni[4], F. Muller[2†], B. Osculati[3], A. Quareni[1], N. Redaelli[4], L. Rossi[3], G. Tomasini[3], F. Viaggi[1] and M. Zavertyaev[6]

Presented by: A. Kirk, CERN

1 Dipartimento di Fisica and INFN, Bologna, Italy.
2 CERN, European Organization for Nuclear Research, Geneva, Switzerland.
3 Dipartimento di Fisica and INFN, Genova, Italy.
4 Dipartimento di Fisica and INFN, Milano, Italy.
5 Université de l'Etat, Mons, Belgium.
6 Lebedev Physical Institute, Moscow, USSR.
† Deceased.

Abstract

Experiment WA82 has measured charm production by 340 GeV pions and 370 GeV protons on a target made of silicon and tungsten. Clean, high statistics charmed meson and baryon mass peaks have been obtained. These signals have been used to measure the charm differential cross section and its dependence on nucleon number. The semileptonic decay of charm to $K\pi e\nu_e$ has been studied. The ratio of branching ratios $B(D^+ \to \overline{K}^{*0} e^+ \nu_e)/B(D^+ \to K^- \pi^+ \pi^+) = 0.7 \pm 0.2$ and the $\overline{K}^{*0}$ mesons have a ratio of longitudinal to transverse polarisation of 0.6 ± 0.4.

The aim of experiment WA82 is to study the production and decay properties of charmed particles produced in hadronic interactions. These properties contribute to the understanding of perturbative and non-perturbative QCD and through a study of semileptonic decays give information on the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements.

A major problem in the study of charmed particles is to select the events including charm from the 1000 times more abundant background. This has been achieved, in part, by triggering on events having a high impact parameter track using silicon microstrip detectors. This trigger [1] increases the charm content of the recorded data by a factor of $\sim$ 15. The accuracy with which the tracks are measured using the microstrips enables the separation of the charmed vertices from the main vertex in a good fraction of the events in which charm is produced The data come from experiment WA82 that was performed using the CERN Omega Spectrometer. Details of the layout of the apparatus, the trigger conditions and the data processing have been given in a previous publication [2].

The charm events presented in this paper have been selected from data samples consisting of 1.8×10^7 and 1×10^7 triggers from π^- and p beams respectively. Events are selected with the following characteristics: (1) a primary vertex reconstructed in the target; (2) a secondary vertex separated from the primary vertex by $> 6\sigma$ and located outside the thin target (1-2 mm); (3) total momentum vector of the secondary vertex tracks pointing back to the primary vertex within $60\mu m$.

Fig. 1(a) shows the effective mass spectra for the events compatible with being $D^+ \to K^-\pi^+\pi^+$, $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$ and charge conjugate states. A clear D signal is seen with 991 events above background. In this figure RICH information is not used. Use of the RICH information decreases the background by a factor of 3. The ratio of the number of D^-/D^+ is found to be 1.4 ± 0.2 and 1.4 ± 0.4 for π^- and p beams respectively. Fig. 1(b) shows the $K^+K^-\pi^\pm$ effective mass spectrum requiring that the K^+K^- mass is consistent with being a ϕ. Clear $D^\pm$ and $D_S^\pm$ signals are observed. Fig. 1(c) shows the $pK\pi$ effective mass spectrum where the p and K have been identified using the RICH a clear Λ_C signal is observed.

Figs. 2 (a) and (b) show the acceptance corrected x_F distributions for the incident

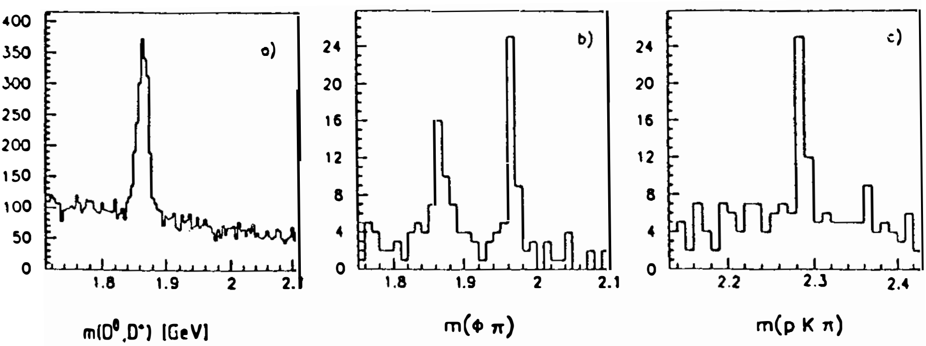

Figure 1: Invariant masses of secondary vertex tracks for the assumptions (a)$K\pi\pi$,$K\pi$ and $K\pi\pi\pi$, (b)$\phi\pi$ and (c) $pk\pi$.

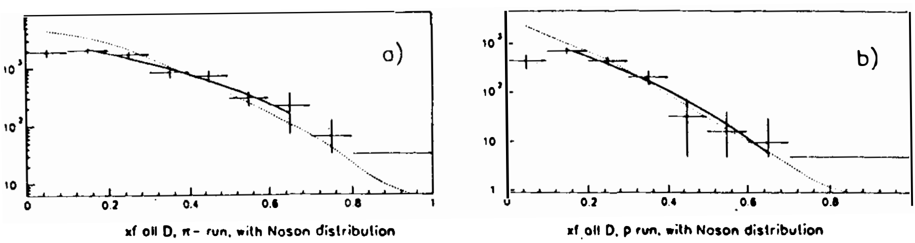

Figure 2: Acceptance corrected x_F distributions for D mesons from (a) π^- and (b) p incident data with fit described in the text (solid) and QCD prediction (dotted).

π^- and p beams respectively. The data has been fitted to the form

$$\frac{d\sigma}{dx_F} \propto (1 - x_F)^n$$

for $0.1 \leq x_F \leq 0.7$. For the π^- incident beam we find $n = 2.9 \pm 0.3$ and for the proton beam we find $n = 5.5 \pm 0.8$. The distributions give information on the structure functions of the incident particles. If charm production is dominated by gluon-gluon fusion the x_F distribution for the π^- data should be harder than that of the p data as observed. Also shown in figs. 2 (a) and (b) are the prediction from next to leading order QCD calculations [3] in both cases there is moderate agreement with the data but the experimental distributions are harder.

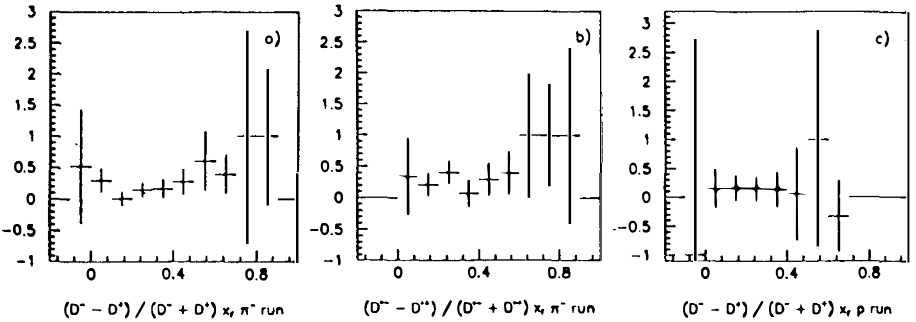

Figure 3: x_F distributions for (a) $(D^- - D^+)/(D^- + D^+)$ (b) $(D^{*-} - D^{*+})/(D^{*-} + D^{*+})$ for the π^- beam and (c) $(D^- - D^+)/(D^- + D^+)$ for the p beam.

Since a π^- beam is composed of $(d\bar{u})$ quarks it could be possible that $D^-(d\bar{c})$ mesons would be produced more forward than $D^+(c\bar{d})$ mesons. In fact a leading particle effect, as this is called, has been claimed by NA27 [4] but has yet to be confirmed. Figs. 3 (a) and (b) show for the π^- beam data the x_F distributions for $(D^- - D^+)/(D^- + D^+)$ and $(D^{*-} - D^{*+})/(D^{*-} + D^{*+})$ respectively. Although there is some slight indication of a rise the effect is not as strong as that indicated by the NA27 data. Fig. 3(c) shows the x_F distribution for $(D^- - D^+)/(D^- + D^+)$ for the p beam, no rise is observed in this data.

The dependence on the atomic number (A) of the target is usually parameterised as

$$\sigma(A) = \sigma_0 A^\alpha$$

where theoretically $\alpha = 2/3$ for a purely geometrical cross section and $\alpha = 1$ for a pure point like process. Therefore by determining α for charm the applicability of QCD in the case of charm can be established. In order to measure α WA82 has used a target split vertically into two equal sections of tungsten and silicon. This allows a simultaneous measurement of σ_W/σ_{Si} both for ordinary interactions and for charm production. A control measurement has been made using the K_S^0 signal and for $< x_F >= 0.06$ we find

$$\alpha_{K_S^0} = 0.74 \pm 0.01$$

which is in good agreement with previous measurements [5]. For D mesons for

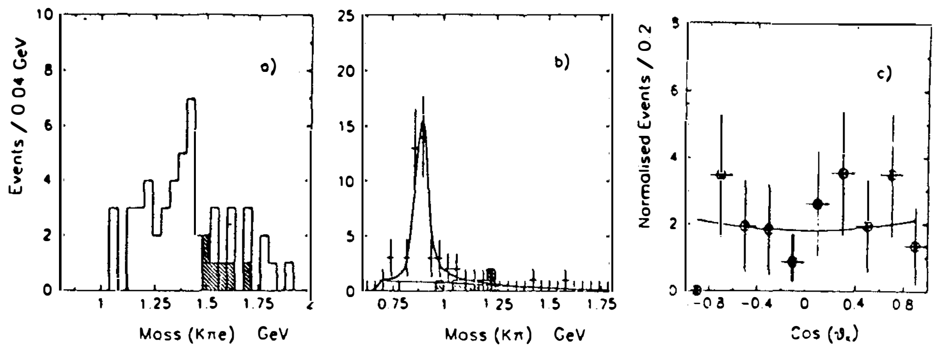

Figure 4: (a) the $K\pi e$ effective mass spectrum, (b) the corresponding $K\pi$ spectrum and (c) the $\cos\theta_K$ distribution with fit described in the text.

$< x_F >= 0.24$ we find

$$\alpha_D = 0.88^{+0.04}_{-0.05}$$

which is in good agreement from the latest value from E772 for J/ψ production of $\alpha_{J/\psi} = 0.92 \pm 0.008$ [6].

A preliminary analysis of the semileptonic decay $D^+ \to \overline{K}^- \pi^+ e^+ \nu_e$ plus c.c. has been performed. The candidate events are selected with the following characteristics: (1) a primary vertex reconstructed in the target; (2) a 3 prong secondary vertex separated from the primary vertex by $> 6\sigma$ and outside the target with one of the like signed particles identified as an electron by the electromagnetic calorimeter; (3) one of the other two particles was required to be identified as a K by the RICH; (4) require that the maximum missing p_T relative to the D line of flight be less than the maximum p_T of the ν_e. If the K and e have opposite (same) charge then they are considered to be a signal (background) event. Fig. 4 (a) shows the resulting $K\pi e$ effective mass spectrum for the 50 signal events and the 6 background events shown shaded. The $K\pi$ effective mass spectrum for the signal and background events is shown in fig. 4(b) where it can be seen that the decay is dominated by the K^* resonance. A fit to fig. 4 (b) using a relativistic P-wave Breit-Wigner plus an S-wave background yields a resonance fraction of 0.7 ± 0.2 which is consistent with the K^* domination found by E691

[7] and Mark III [8]. We find

$$\frac{B(D^+ \to \overline{K}^{*0} e^+ \nu_e)}{B(D^+ \to K^- \pi^+ \pi^+)} = 0.7 \pm 0.2$$

The acceptance corrected normalised $\cos\theta_K$ distribution, where θ_K is the helicity angle of the kaon in the K^* centre of mass is shown in fig. 4(c). It has been fitted to the form

$$\frac{dN}{d(cos\theta_K)} \propto (1 + (2\frac{\Gamma_L}{\Gamma_T} - 1)\cos^2\theta_K)$$

and gives $\frac{\Gamma_L}{\Gamma_T} = 0.6 \pm 0.4$. This measurement is in agreement with the value obtained by Mark III [8] of $(0.5^{+1.0}_{-0.1}\,^{+0.1}_{-0.2})$ and is consistent with theoretical predictions which range from 0.9 to 1.2 but is smaller than the value of $(1.8^{+0.6}_{-0.4} \pm 0.3)$ found by E691 [7].

In summary good charm signals have been extracted from the WA82 data. The x_F distributions for π^- and p are harder than next to leading order QCD calculations. At present there is no clear positive evidence for a leading particle effect. For $< x_F >= 0.24$, a measurement of the A dependence of the open charm cross section gives $\alpha = 0.88^{+0.04}_{-0.05}$. The semileptonic decay of charm to $K\pi e\nu_e$ has been studied. The ratio of branching ratios $B(D^+ \to \overline{K}^{*0} e^+\nu_e)/B(D^+ \to K^-\pi^+\pi^+) = 0.7 \pm 0.2$ and the $\overline{K}^{*0}$ mesons have a ratio of longitudinal to transverse polarisation of 0.6 ± 0.4.

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