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PRODUCTION AND DECAY PROPERTIES OF D AND D^* MESONS IN π^-Be INTERACTIONS

ACCMOR Collaboration

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ABSTRACT

$D^{*\pm}$, $D^\pm$, D^0, and $\bar{D}^0$ production has been observed in π^-Be interactions at 120, 175, and 200 GeV. The dependence of the D cross-section on transverse and longitudinal momentum is presented. The ratio of D^* to D and charged to neutral D production is determined. Leading particle effects in D production are investigated. Relative branching ratios for several D decay modes are evaluated. A limit on D^0-$\bar{D}^0$ mixing is given.

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1. INTRODUCTION

In an accompanying letter [1] we have discussed the observation of D^* and D meson production in π^-Be interactions at 120, 175, and 200 GeV. In this contribution we present results on properties of charmed meson production -- including differential cross-sections of longitudinal and transverse momentum, ratio of D^* to D production, and possible evidence for leading particle effects. We also give results on relative branching ratios for several decay channels and on a limit on D^0-$\bar{D}^0$ mixing.

For this study we use only the 175 and 200 GeV data. The 120 GeV data do not allow a meaningful analysis of the production characteristics by themselves because of their small statistics; they are, however, checked for consistency with the high-energy data.

2. PRODUCTION CHARACTERISTICS

The production characteristics of D mesons in π^-Be interactions at 175 and 200 GeV/c have been investigated. Significant signals are only seen in the data sample with best invariant mass resolution (all particles passing through both spectrometer magnets, see ref. [1] and for $x_F > 0.2$. We use those signals to determine the p_T^2 and x_F dependence.

2.1 Transverse momentum dependence of the cross-section

For the determination of the differential cross-section $d\sigma/dp_T^2$ of inclusive D production, the inclusive $\overset{(-)}{D}{}^0 \to K\pi$ signal has been used. The mass spectra, grouped in Δp_T^2 bins of 0.8 GeV^2, have been fitted by a polynomial background and a Gaussian for the D signal. The result, corrected for acceptance, is shown in fig. 1. Parametrizing the experimental distributions by $d\sigma/dp_T^2 \propto \exp(-bp_T^2)$ yields $b = 1.1 \pm 0.5$ GeV^{-2}.

2.2 Longitudinal momentum dependence of the cross-section

The differential cross-section $d\sigma/dx_F$ has been determined for the two production processes: (i) $D^* \to D^0(K\pi) + \pi$ for $x_F > 0.2$, and (ii) inclusive D^0, $\bar{D}^0$, and $D^\pm$ production for $x_F > 0.2$. We can add the $D^0 \to K\pi$ and $D^\pm \to K\pi\pi$ channels, since their acceptance is very similar. The differential cross-section $d\sigma/dx_F$

has been parametrized by $d\sigma/dx_F \propto (1 - x_F)^n$ and fitted to the acceptance-corrected and background-subtracted data. The fits yield for the two processes:
(i) $n = 3.2 \pm 1.5$, the rather large error being due to low statistics, and
(ii) $n = 0.8 \pm 0.4$ (fig. 2).

Assuming the x_F distribution in the interval $0 < x_F < 0.2$ to be the same as the one measured above $x_F = 0.2$, we can explain that we see no charm signal at low x_F. Most of the events in the x_F region below $x_F = 0.2$ are of the type where π's pass only through the first magnet. This data sample has lower acceptance, a three times higher combinatorial background, and about two times worse mass resolution. Hence the signal-to-background ratio is too small to allow observation of a charm signal.

We have also investigated possible leading particle effects in the differential cross-section $d\sigma/dx_F$. Some quark-parton models, for example that of Gunion [2], predict a higher cross-section and a flatter x_F distribution for outgoing particles containing a common valence quark with the beam particle. For incoming π^- one might therefore expect more D^{*-} than D^{*+} and more directly produced D^- and D^0 than D^+ and $\bar{D}^0$ at high x_F. We do not observe a difference for D^* production [$(15 \pm 5)D^{*+}$ compared to $(13 \pm 5)D^{*-}$], but we do find an excess of inclusive D^- and D^0 over D^+ and $\bar{D}^0$ at higher x_F. The integrated x_F distributions for D^- and D^0, and D^+ and $\bar{D}^0$, for $x_F > 0.3$ are shown in fig. 3. The shapes of the two x_F distributions are similar: for the ratio of events we find $N(D^- + D^0)/N(D^+ + \bar{D}^0) = 2.0 \pm 1.0$.

2.3 Ratio of D^* to D production

The ratio α of D^* to D production can be determined from the measured number of $D^* \to D^0(K\pi) + \pi$ events and inclusive $D^0 \to K\pi$ events, and the known branching ratio $D^{*\pm} \to \overset{(-)}{D}{}^0\pi^\pm$ [3] of 44%. Since we do not measure D^{*0} production we have to assume that charged and neutral D^*'s are produced at the same rate. We then determine $\alpha = 0.9^{+3.1}_{-0.6}$.

The ratio of $\overset{(-)}{D}{}^0$ to $D^\pm$ is found to be 1.4 ± 0.8, using the measured $D^0 \to K\pi$ and $D^\pm \to K\pi\pi$ branching ratios [4] and relative acceptances. This ratio is in agreement with $\alpha = 0.9$.

3. DECAY PROPERTIES

3.1 Branching ratios of the $\overset{(-)}{D}{}^0$ and $D^{\pm}$

We have observed, in various decay channels, ∿ 60 D^*'s and ∿ 320 D's with a signal-to-background ratio of 1/1 and 1/4, respectively. This allows us to determine ratios of relative decay widths.

From the signals in the decay chain $D^* \to D^0\pi$, with the D^0 decaying into $K\pi$ and $K\pi\pi\pi$, we obtain

$$\frac{\Gamma(\overset{(-)}{D}{}^0 \to K^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\pm})}{\Gamma(\overset{(-)}{D}{}^0 \to K^{\mp}\pi^{\pm})} = (2.0 \pm 1.0)$$

compared with the value of 1.9 ± 0.6 from e^+e^- experiments [4].

Both the $D^{*\pm} \to \overset{(-)}{D}{}^0(K\pi\pi\pi) + \pi^{\pm}$ channel and the inclusive $K\pi\pi\pi$ spectra show significant $\overset{(-)}{D}{}^0$ signals when $K^{\pm}\pi^{\mp}$ and $\pi^{\pm}\pi^{\mp}$ combinations in the K^{*0}_{890} $(0.84 < m_{K\pi} < 0.94$ GeV) and the ρ region $(0.61 < m_{\pi\pi} < 0.93$ GeV) are selected. In the case of the $D^{*\pm}$ channel (fig. 4) we determine the fractions of $\overset{(-)}{D}{}^0 \to K^{*0}\rho^0$, $\overset{(-)}{D}{}^0 \to K\pi\rho^0$, and $\overset{(-)}{D}{}^0 \to K^*\pi\pi$ decays of all $D \to K\pi\pi\pi$ decays:

$$\frac{BR(D^0 \to K^{*0}\rho^0)}{BR(D^0 \to K\pi\pi\pi)} = 0.5 \pm 0.2\ , \quad \frac{BR(D^0 \to K\pi\rho^0)}{BR(D^0 \to K\pi\pi\pi)} = 0.2 \pm 0.2\ , \quad \frac{BR(D^0 \to K^*\pi\pi)}{BR(D^0 \to K\pi\pi\pi)} < 0.18 \text{ (90\% C.L.)}.$$

No signal is observed in the $D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\pm}$ decay channel. We obtain

$$\frac{\Gamma(D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\pm})}{\Gamma(D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm})} < 0.16 \text{ with 90\% C.L.}$$

compared with the limit of 0.65 with 90% C.L. obtained by the Mark II experiment [5].

No signal is observed in the $D^{\pm} \to \overset{(-)}{K}{}^{*0}\pi^{\pm}$ channel. We obtain

$$\frac{\Gamma(D^{\pm} \to \overset{(-)}{K}{}^{*0}\pi^{\pm})}{\Gamma(D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm})} < 0.22 \text{ with 90\% C.L.}$$

compared with the limit of 0.39 with 90% C.L. from the MARK II experiment [5].

3.2 D^0-$\bar{D}^0$ mixing

As with the K^0-$\bar{K}^0$ system, transition between D^0 and $\bar{D}^0$ can occur via common Cabibbo suppressed decay modes. Within the standard models of the 3 × 3 mixing matrix, the effect is expected to be very small $(10^{-4}$-$10^{-7})$ [6]. The present best upper limit of 4.4% on D^0-$\bar{D}^0$ mixing comes from a hadronic beam dump experiment comparing the rate of μ pairs with equal and opposite charges [7].

This experiment can detect D^0-$\bar{D}^0$ mixing either via the decay chains $D^{*+} \to \bar{D}^0(\to K^+\pi^-)\pi^+$ and $D^{*-} \to D^0(\to K^-\pi^+)\pi^-$ or by observing $D^0 \to K^-\pi^+$ or $\bar{D}^0 \to K^+\pi^-$ decays in which the kaon has the opposite charge to the trigger electron. No significant signal has been found, thus resulting in an upper limit for the transition probability D^0-$\bar{D}^0$:

$$T(D^0 \to \bar{D}^0) < 7\% \text{ at } 90\% \text{ C.L.} \; .$$

4. DISCUSSION OF THE RESULTS

Production of D^* and D mesons has been observed in a counter experiment in π^-Be interactions at 120, 175, and 200 GeV. The following conclusions can be drawn.

i) The differential cross-section $d\sigma/dp_T^2$ for $\overset{(-)}{D}{}^0$ production can be parametrized by $e^{-bp_T^2}$ with $b = 1.1 \pm 0.5$ GeV^{-2}. The differential cross-section $d\sigma/dx_F$ for D production for $x_F > 0.2$ can be described by $(1 - x_F)^{0.8\pm0.4}$, which rules out gluon-gluon fusion or quark-antiquark annihilation [8] as the dominant process in this kinematic range. Models including the charm excitation process [9] are able to explain qualitatively the shape of $d\sigma/dx$.

ii) The data do not support the prediction that charm mesons containing a valence quark of the beam particle (e.g. $\pi^- \to D^{*-}$ or D^- or D^0) are produced with a flatter x_F distribution than charm particles which do not contain a common valence quark with the beam particle [2], but they seem to be produced more abundantly.

iii) The following production ratios have been determined:

$$D^*/D = 0.9 \begin{array}{l} + 3.1 \\ - 0.6 \end{array}$$

$$\overset{(-)}{D}{}^0/D^{\pm} = 1.4 \pm 0.8 \; .$$

iv) The following relative decay widths of D's have been measured:

$$\Gamma(D^0 \to K\pi\pi\pi)/\Gamma(D^0 \to K\pi) = 2.0 \pm 1.0$$

$$\Gamma(D^0 \to K^*\rho^0)/\Gamma(D^0 \to K\pi\pi\pi) = 0.5 \pm 0.2$$

$$\Gamma(D^0 \to K\pi\rho^0)/\Gamma(D^0 \to K\pi\pi\pi) = 0.2 \pm 0.2$$

$$\Gamma(D^0 \to K^{*0}\pi\pi)/\Gamma(D^0 \to K\pi\pi\pi) < 0.18 \text{ with } 90\% \text{ C.L.}$$

$$\Gamma(D^\pm \to K^\mp\pi^\pm\pi^\mp\pi^\pm\pi^\pm)/\Gamma(D^\pm \to K^\mp\pi^\pm\pi^\pm) < 0.16 \text{ with } 90\% \text{ C.L.}$$

$$\Gamma(D^\pm \to \overset{(-)}{K}{}^{*0}\pi^\pm)/\Gamma(D^\pm \to K^\mp\pi^\pm\pi^\pm) < 0.22 \text{ with } 90\% \text{ C.L.}$$

v) An upper limit for the transition probability D^0-$\bar{D}^0$ is given:

$$T(D^0 \to \bar{D}^0) < 7\% \text{ at } 90\% \text{ C.L.}\ .$$

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Figure captions

Fig. 1 : $d\sigma/dp_T^2$ for inclusive $\overset{(-)}{D}{}^0$ production at 175/200 GeV. The line is a fit of an $e^{-bp_T^2}$ distribution, yielding b = 1.1 ± 0.5.

Fig. 2 : $d\sigma/dx_F$ for inclusive $\overset{(-)}{D}{}^0 + D^{\pm}$ production at 175/200 GeV. The abscissa is logarithmic in $(1 - x_F)$. The straight line is a fit of a $(1 - x_F)^n$ distribution with n = 0.8 ± 0.4.

Fig. 3 : Integrated x_F distribution for inclusive D production. The black dots are the data for $D^- + D^0$ production; the solid line is a fit of $(1 - x_F)^{n+1}$ with n = 1. The open triangles are the data for $D^+ + \bar{D}^0$ production; the dotted line is a fit to $(1 - x_F)^{n+1}$ with n = 1.

Fig. 4 : Projections of bands in a scatter plot of mass $m(K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp})$ versus mass difference $\Delta m = m(K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\mp}) - m(K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp})$ with $x_F(K\pi\pi\pi\pi) > 0.5$. The bands selected are $143 \leq \Delta m \leq 148$ MeV and $1.84 \leq m_{K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp}} \leq 1.88$ GeV. The fits parametrize the data with a Gaussian plus a polynomial. In (c) and (d) the $K^{\pm}\pi^{\mp}\pi^{\pm}\pi^{\mp}$ combination is considered only if it fulfils the $K^{*0}\rho^0$ criteria defined as $0.84 \leq m_{K^{\pm}\pi^{\mp}} \leq 0.94$ GeV and $0.61 \leq m_{\pi^{\pm}\pi^{\mp}} \leq 0.93$ GeV.

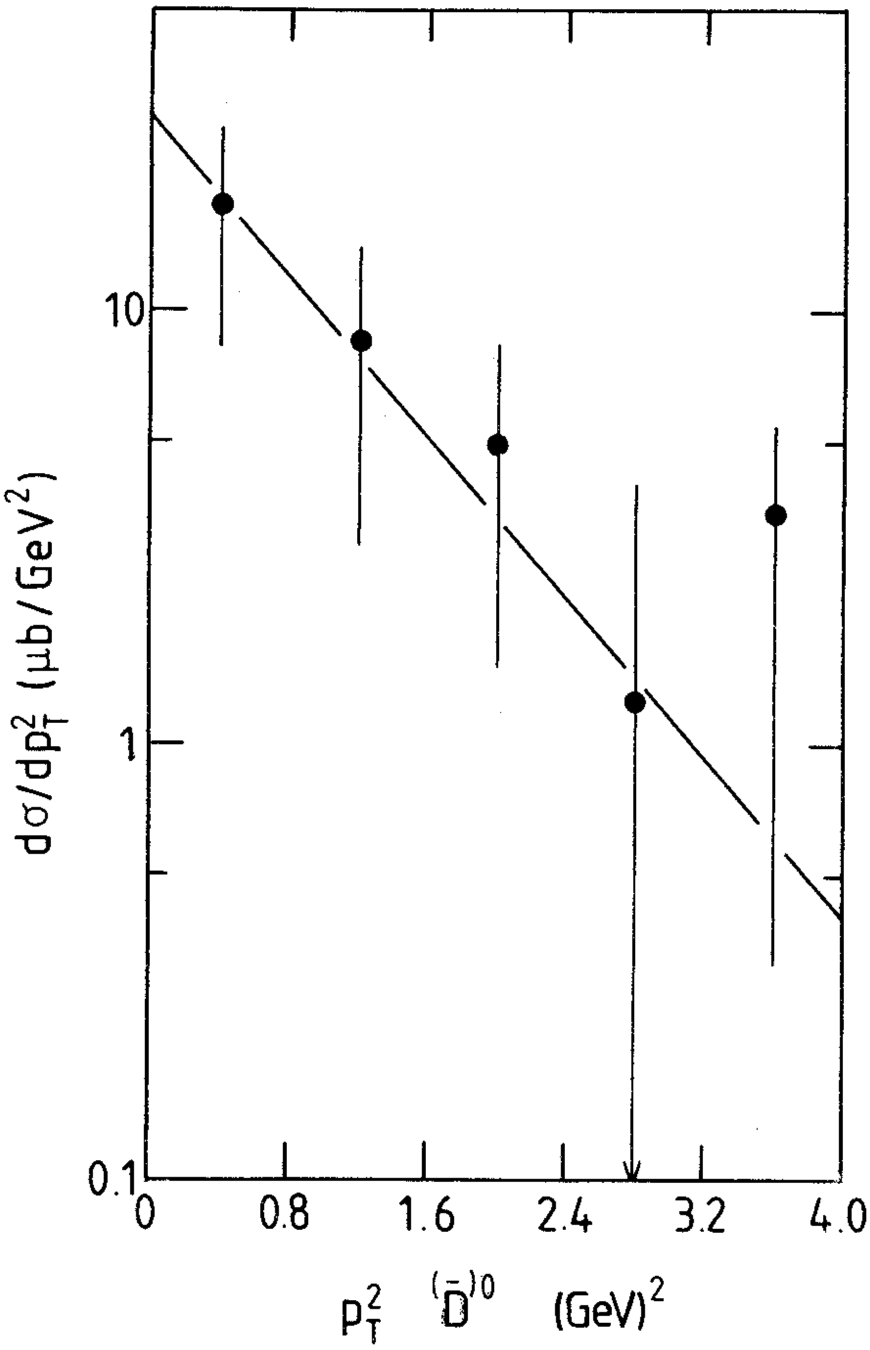

Fig. 1

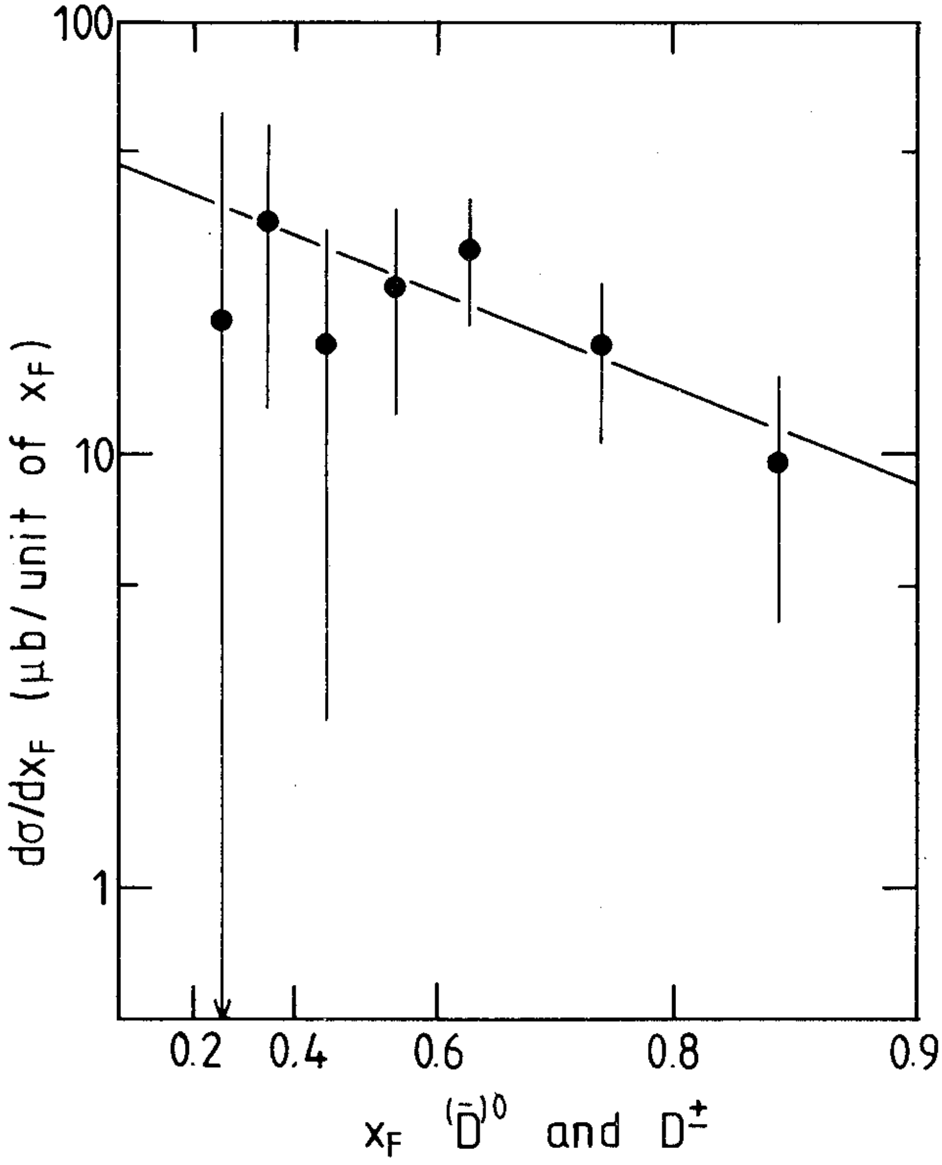

Fig. 2

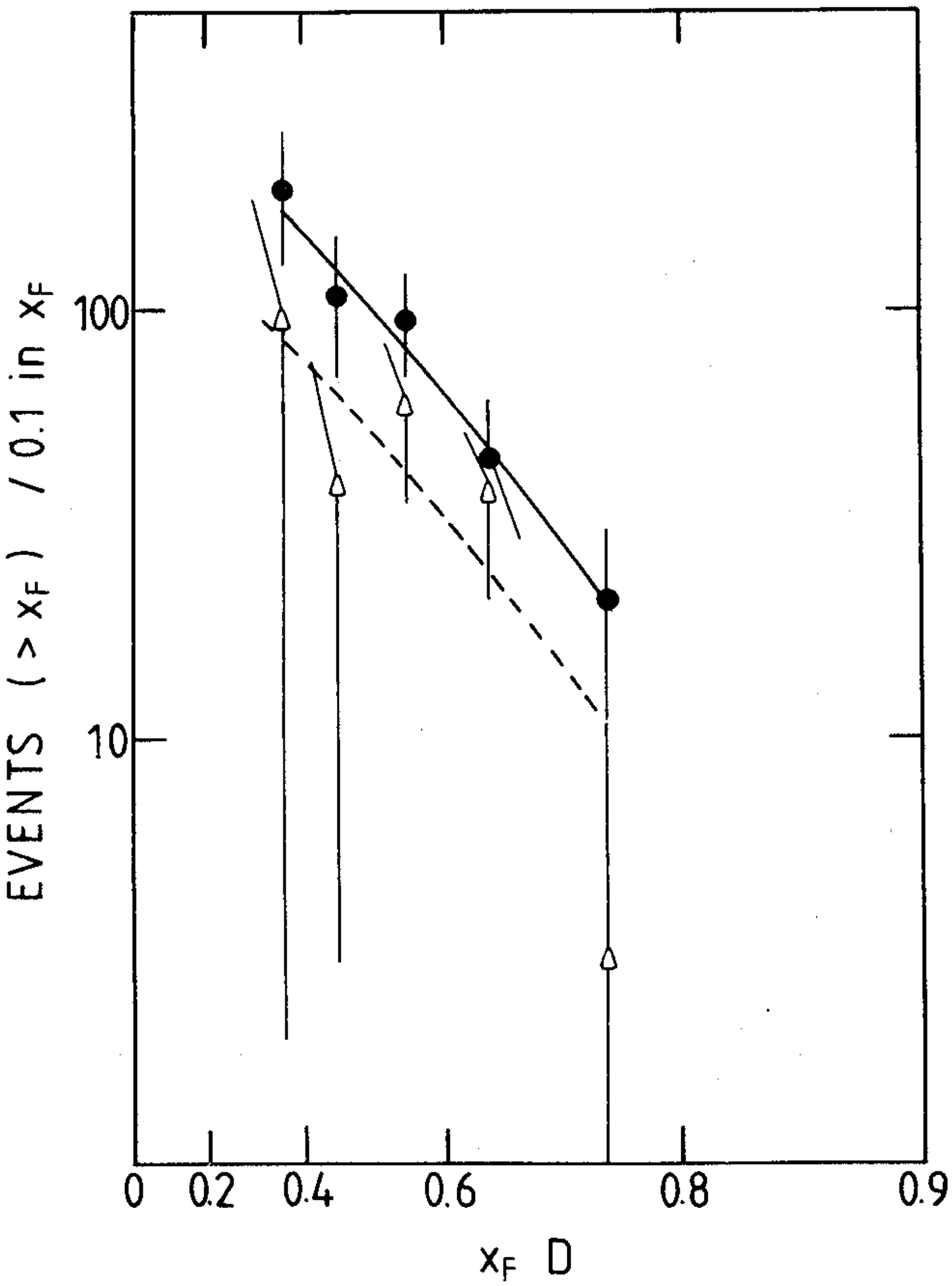

Fig. 3

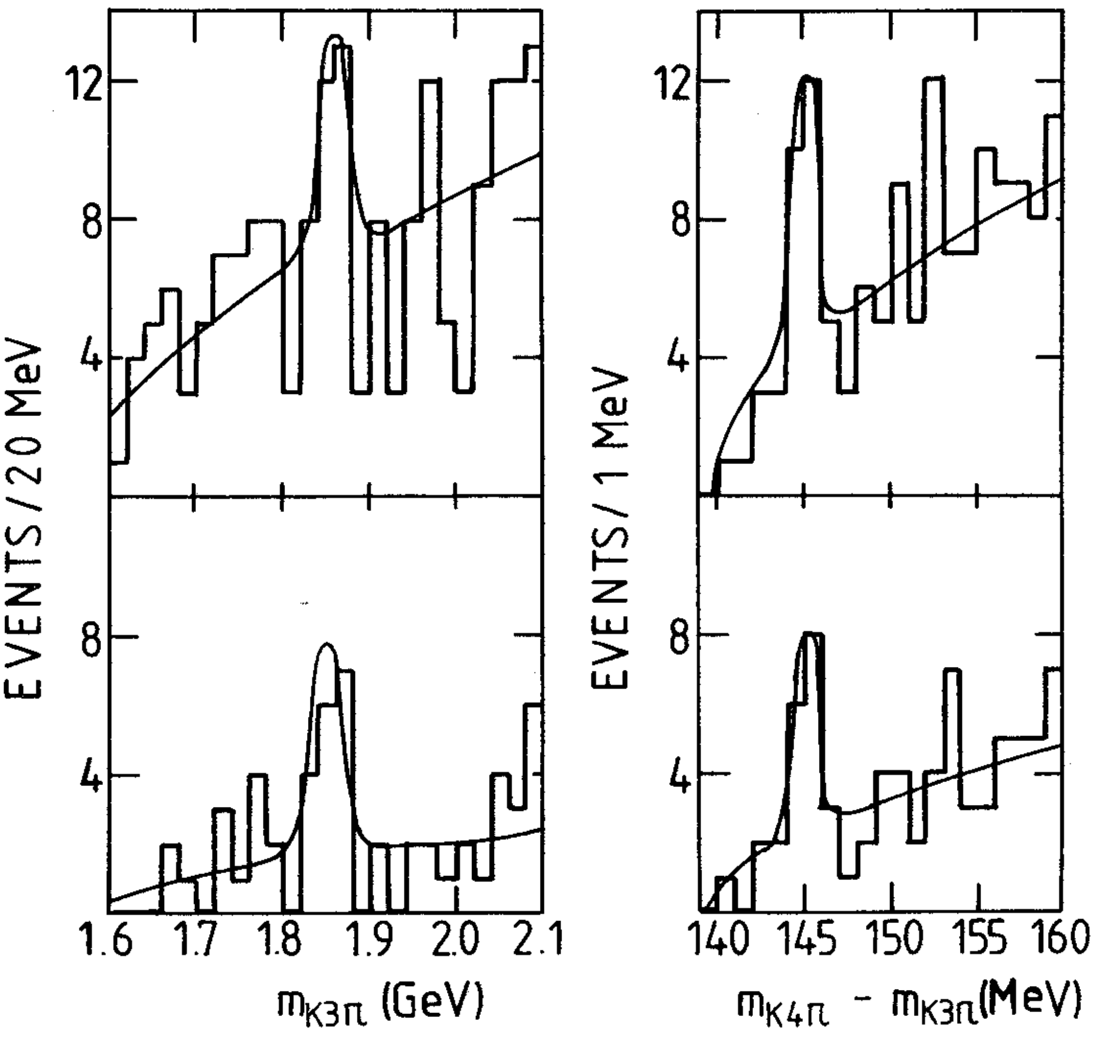
EVENTS / 20 MeV
12
8
4
8
4
1.6
1.7
1.8
1.9
2.0
2.1
$m_{K3\pi}$ (GeV)
EVENTS / 1 MeV
140
145
150
155
160
$m_{K4\pi}$ - $m_{K3\pi}$(MeV)

Fig. 4