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A-DEPENDENCE STUDY OF INCLUSIVE ϕ PRODUCTION

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ABSTRACT

The A-dependence of the inclusive ϕ meson cross-section is measured using two target materials, beryllium and tantalum, in the kinematic range $0 < x_F < 0.3$ and $p_T^2 < 1$ GeV^2. Parametrizing the cross-section with $\sigma(A) = \sigma(A{=}1)\, A^{\alpha}$, yields $\alpha = 0.90 \pm 0.02$ and $\alpha = 0.86 \pm 0.02$ for production of ϕ's with 120 GeV π^+ and p-beams respectively.

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1. INTRODUCTION

The comparison of cross-sections measured in different experiments often suffers from the fact that different target materials are used and that the A-dependence of the cross-section is poorly known. This is in particular the case for the relatively scarce data on inclusive resonance production.

The value of the exponent α in the expression $\sigma(A) = \sigma(A=1)\ A^{\alpha}$, which parametrizes the A-dependence of cross-sections, is a function of the cross-section of both the incident and the secondary produced particle with the target nucleus. The smaller the absorption cross-section of the secondary particle, the bigger the value of α. For π,ρ,K and K^* production for example, the measured A-dependence gives $\alpha \sim 0.75$–0.80, while for ψ production, where the ψ-meson has a much smaller absorption cross-section one has observed $\alpha \simeq 0.97$ [1]. For ϕ-meson production one would expect a value of α in between the two above-mentioned values, since $\sigma((\pi \text{ or } K)N) > \sigma(\phi N) > \sigma(\psi N)$.

The A-dependence of ϕ-production has been studied previously by this collaboration by comparison of the cross-section on hydrogen and Be-targets [ref. 2].

Results on the A-dependence for ϕ-mesons have also been obtained in μ-pair experiments [3,4]. However, the very small signal to background ratio makes it difficult to separate the A-dependence of the resonance cross-section from that of the continuum.

In this experiment we compare the production of ϕ-mesons using beryllium (A=9) and tantalum (A=181) as target materials. The ϕ-mesons, observed by their K^+K^- decay mode, are accepted in the kinematic range $0 < x_F < 0.3$ and $p_T^2 < 1\ GeV^2$.

2. EXPERIMENT AND DATA

The data were obtained with the NA11 spectrometer at the CERN SPS during 1982. Two differential Cerenkov counters (CEDAR) were positioned in the beamline to identify incident particles. The experimental setup is shown in Fig. 1. The main elements are:

- six silicon microstrip detectors (MSD) to measure the incident beam,
- six MSD's behind the target; the position of the primary vertex can be determined with a precision of 150 µm along the beamline and about 10 µm in the plane perpendicular to it,
- 48 planes of large area drift chambers (DC) and two spectrometer magnets to measure the momenta of the charged secondary particles,
- 3 multicellular Cerenkov countes C1, C2 and C3 and 2 scintillator planes MA and MB,
- 5 planes of multiwire proportional chambers P.

A detailed description of the spectrometer can be found in refs. 5-7.

The MSD's were installed to study the decay and production properties of charmed particles but are particularly useful for the reconstruction of the primary vertex if a short target is used.

The aim of the fast trigger is to select events with at least one positive kaon and one negative kaon. The spectrometer elements used for the fast trigger are the scintillator arrays MA and MB, as well as the Cerenkov hodoscopes C2,C3. The dimensions of the C2(C3) hodoscope elements match the MA(MB) elements; C3 is positioned along the beam line such that the elements of hodoscope C2 seen from the target project onto the C3 elements. The trigger selects inelastic interactions with at least two oppositely charged particles in the final state. These particles fulfil the requirement that they do not give light in C2 and give a hit in the corresponding MA element <u>or</u> that they give no light in C3, a hit in the corresponding MB element and light in the corresponding C2 element. Hit information from proportional chamber P32 is used to remove triggers caused by spurious hits in the MA elements. Table 1 gives a summary of the dimensions of the scintillator arrays and the π thresholds for C2 and C3.

In addition to kaon candidates, this trigger also selects pions with momenta below Cerenkov threshold coming from primary or secondary interactions. Since they contribute substantially to the total trigger rate, we introduced a second stage trigger to improve the sensitivity of the experiment. It uses five planes of multiwire proportional chambers (P31ab,P32ab,P33) and a microprocessor system (FAMP) which has access to the hit information from the MWPC's and the hodoscope elements (ref.8).

This system determines, with an average decision time of 450 μsec, whether two oppositely charged tracks have been produced in the interaction, with momenta within the Cerenkov limits for K-mesons, fulfilling the trigger requirements and originating from the primary vertex. In addition, it calculates the effective mass of the kaon pair. The trigger is accepted if this mass is less than 1.3 GeV. An increase in sensitivity of about factor 8 is obtained. In this data, taken as test data for a high statistics experiment on inclusive ϕ-production, the efficiency of the second stage trigger for finding high momentum particles (triggered by C3) was only 45% as compared to 95% for the low momentum particles (triggered by C2).

The 120 GeV positive beam contains 41% protons and 55% π mesons. Two different target materials have been used, beryllium and tantalum; we have used very thin targets in order to minimize effects from secondary interactions. Table 2 summarizes the properties of both targets, as well as the total number of collected triggers and the number of analysed events. To obtain a clean data sample, the interaction point is reconstructed with a precision of about 150 μm along the beam line using the microstrip detectors. A vertex cut selects for the Be-data sample about 95% of the accepted triggers, while this is about 75% for the Ta-data. The remaining triggers are due to interactions in the detectors surrounding the target.

3. RESULTS

Figure 2 shows the K^+K^- mass spectra for both data samples. The curve shows the result of a fit with a Breit-Wigner folded with the mass resolution, on a quadratic background. Table 3 summarizes the total number of observed ϕ's and the number of background events separated for the two data samples and subdivided according to beam particle. The number of ϕ's, as obtained in the fit, is restricted to the mass bin 1010-1030 MeV.

Fig 3a shows the acceptance as a function of x_F integrated over p_T^2, assuming $d\sigma/dp_T^2 \sim e^{-3p_T^2}$. As input for the Monte Carlo calculation for the x_F distribution we used the results of a fit to the experimental data in ref.[9]. The acceptance as a function of p_T^2 decreases linearly from about 10% at $p_T = 0$ to 0 at $p_T^2 > 0.8$ GeV^2.

The inclusive ϕ cross-section can be written as:

$$\sigma_\phi = \frac{N_\phi \quad W}{N_A \, \ell \, \rho \, N_B} \qquad (\mu b/\text{nucleon})$$

with ℓ, ρ the length and density of the target respectively.

- N_A number of Avogadro
- N_B the used beam flux
- N_ϕ the observed number of ϕ's
- W an average acceptance factor, including (for example) the geometry of the apparatus, various inefficiencies encountered at different trigger levels, as well as loss of K-mesons due to decay or overlap with π-mesons in Cerenkovs.

Under the assumption that the ϕ-mesons are produced with the same x_F and p_T distribution, the correction factor W is approximately the same for beryllium and tantalum data, and the cross-section ratios can be obtained with small systematic uncertainty. Fig. 3b shows the ratio of the number of ϕ events observed for Be and Ta as a function of x_F for incoming π mesons and protons. The ratios are constant within the statistical uncertainy of the data.

Small differences in W arise from:

i) different beam attenuation factors in the target,

ii) different losses of K-mesons from ϕ-decay due to secondary interactions in the target.

For the ratio W(Be)/W(Ta) we obtain the value 1.06±0.02.

Using the parametrization:

$$\sigma(A) = \sigma(A=1)\, A^\alpha$$

where A is the atomic mass of the target nucleus, we can determine the A-dependence from the ratio of the cross-sections.

Using the numbers given in Tables 2 and 3 we obtain for the ϕ's:

$\alpha = 0.90 \pm 0.02$ for incident π^+

$\alpha = 0.86 \pm 0.02$ for incident p.

and for the background:

$\alpha = 0.86 \pm 0.02$ for incident π^+

$\alpha = 0.82 \pm 0.02$ for incident p.

The estimated systematic error on α is about a factor 3 below the statistical error.

Fig. 4 shows the A-dependence as a function of x_F for the ϕ's. We do not observe a significant change in the α-parameter over the limited x_F-range 0 - 0.3.

In our previous experiment [2], with hydrogen and beryllium as target materials, we obtained the value α = 1.04±0.04, slightly higher than our present value. As already mentioned in ref.[2] the available data do suggest a steeper A-dependence of absorption and single particle inclusive cross-sections if target materials in the range 1≤A≤9 are used instead of target materials which have A≳9.

In dimuon experiments (refs. 3,4), where the ϕ-meson is produced with a lot of background events, the A-dependence is measured as a function of $M_{\mu\mu}$ in the same x_F and p_T range as our experiment. For $M_{\mu\mu}$ ~ 1 GeV, one obtains $\alpha \simeq 0.70 \pm 0.04$, significantly different from our result.

Several models relate the value of α with the absorption cross-section of the produced system [10,11]. We calculated the interaction probability of a particle with different nuclei, using the Saxon-Woods nuclear density distribution. The result is that our measurement α = 0.90±0.02 corresponds to $\sigma_{\phi N}$ = (8.8±2.2) mb. This value is in very good agreement with the value (8.3±0.5) mb obtained in a photo-production experiment [12], while one predicts 13.0±1.5 mb using the additive quark model [13].

4. CONCLUSION

We have measured the A-dependence of inclusive ϕ-meson production using beryllium and tantalum targets. The data allow a model dependent determination of the absorption cross-section of ϕ-mesons in nuclear matter.

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Figure captions

Fig. 1 : Top view of spectrometer.

Fig. 2 : K^+K^--mass distributions for Be and Ta target.

Fig. 3a : Acceptance inclusive ϕ production as function of x_F.

3b : Inclusive ϕ cross-section ratio for Be and Ta as function of x_F.

Fig. 4 : Distribution of α as function of x_F.

Table 1

Dimensions of hodoscopes

	# cells	dimension(mm)	π-threshold C
C2(MA)	2x11	$-1500 < x < 1500$	3.8 GeV
		$-550 < y < 550$	
C3(MB)	2x10	$-2750 < x < 2750$	6.5 GeV
		$-800 < y < 800$	

Table 2

Properties used targets and statistics data sample

	Be	Ta
A	9	181
$\rho(g/cm^3)$	1.845	16.6
ℓ(cm)	2.00±0.01	0.097±0.001
# triggers	118.4k	60.4k
$N_B(x10^9)$	0.68	0.78
# events used for analysis	96k	40k
beam attenuation factor	0.973	0.995
W(Be)/W(Ta)	(1.06±0.02%)	

Table 3

Statistics of ϕ sample

	Beam	Ta	Be	α
# ϕ	π^+	1150±66	2954±105	0.90±0.02
background	π^+	1417±84	4029±131	0.86±0.02
# ϕ	p	880±57	2506±100	0.86±0.02
background	p	1272±86	4097±163	0.82±0.02

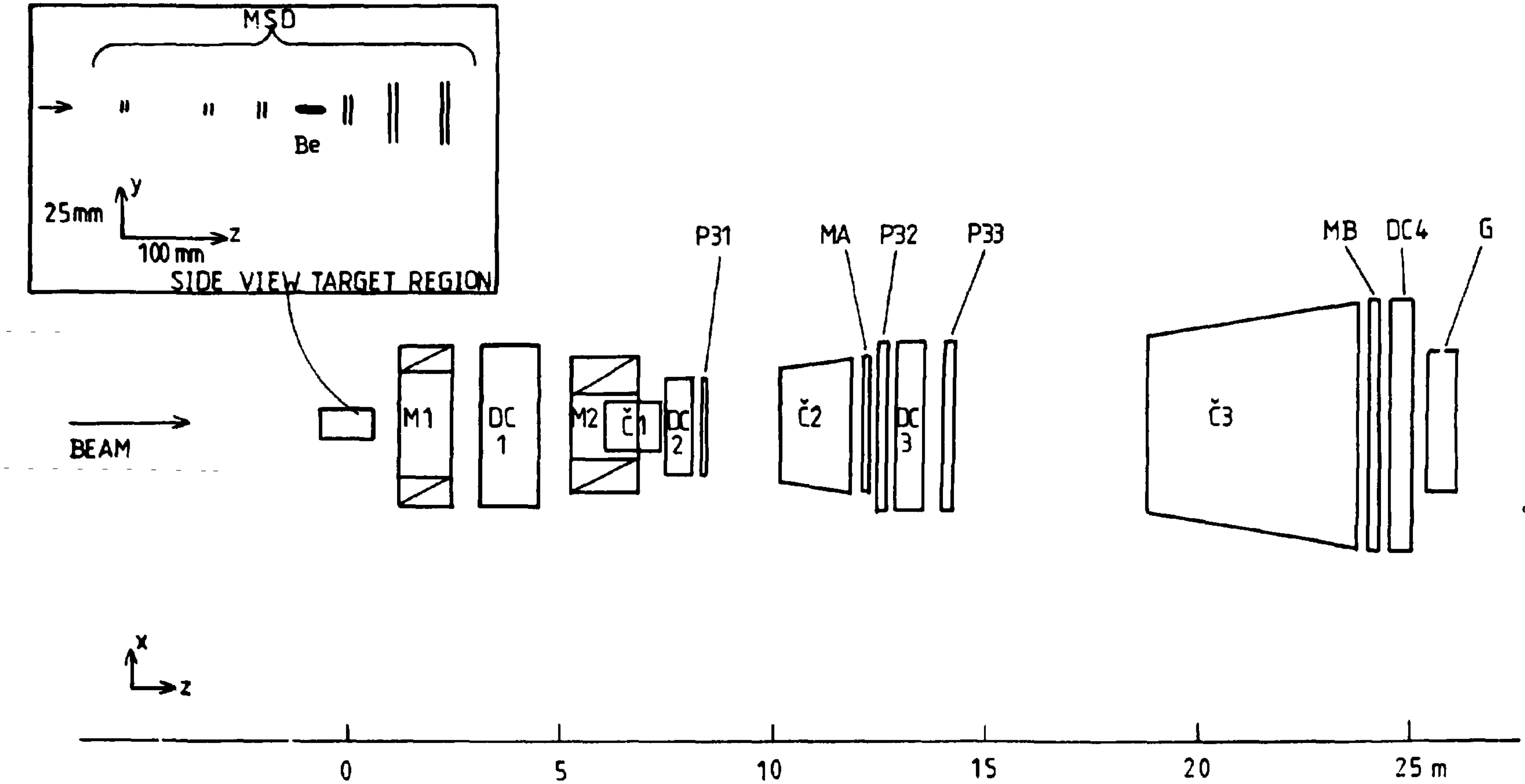

Fig. 1

Top view NA11 spectrometer, showing target (Be), silicon detector planes (MSD), magnets (M), drift chamber packs (DC), Čerenkovs (Č), proportional chamber planes (P), scintillator arrays (MA, MB) and the photon calorimeter (G)

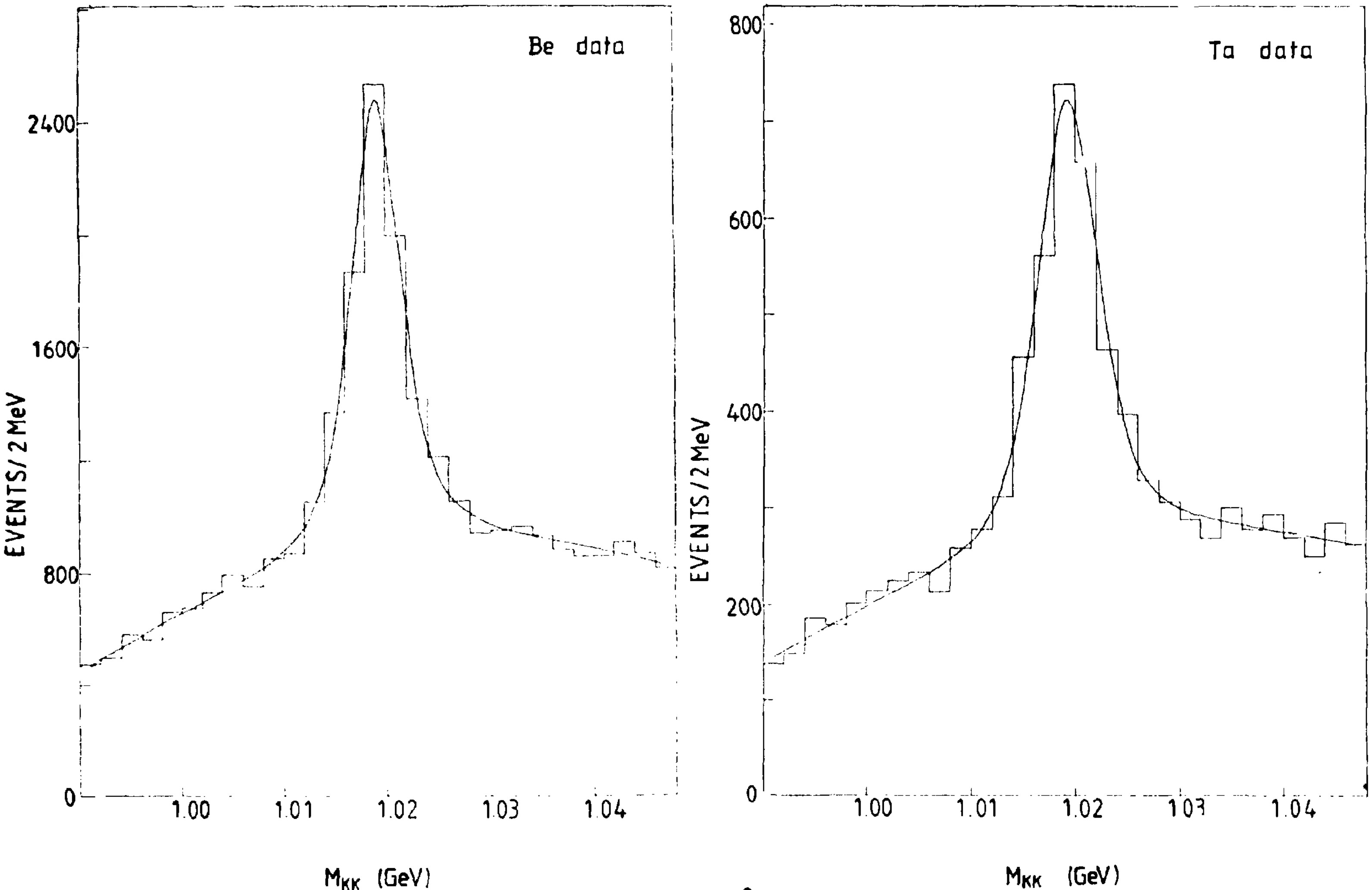
Be data
EVENTS/2 MeV
2400
1600
800
0
1.00
1.01
1.02
1.03
1.04
M_{KK} (GeV)
Ta data
800
600
400
200
0
M_{KK} (GeV)

Fig. 2

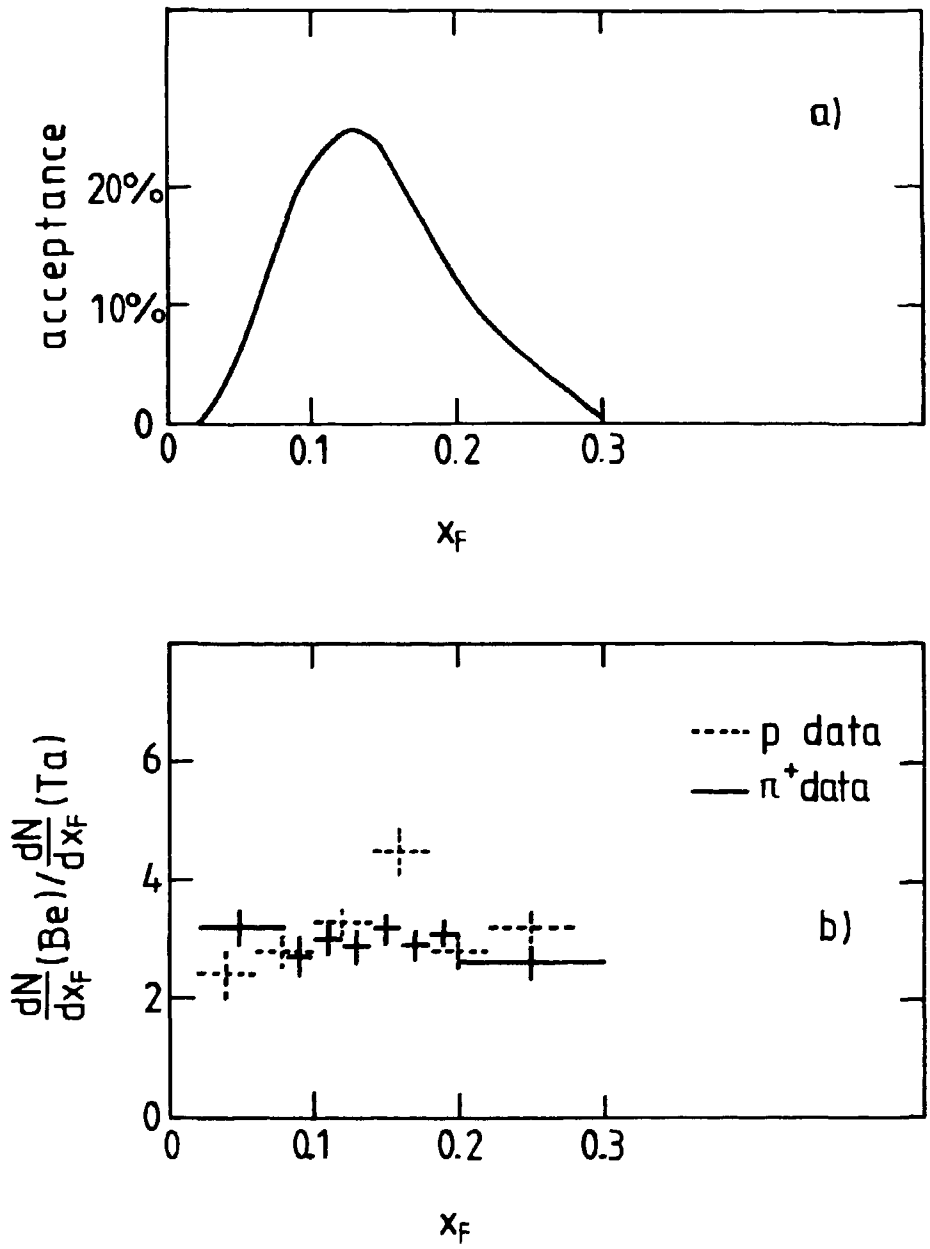
a)
acceptance
20%
10%
0
0
0.1
0.2
0.3
x_F
b)
p data
π^+data
$\frac{dN}{dx_F}(Be)/\frac{dN}{dx_F}(Ta)$
6
4
2
0
0
0.1
0.2
0.3
x_F

Fig. 3

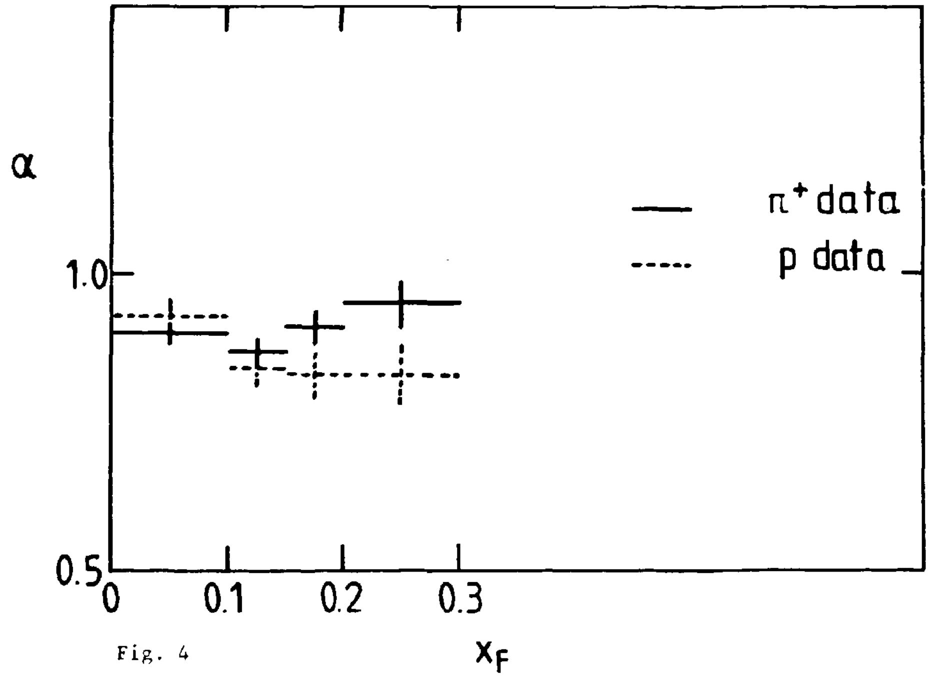

Fig. 4