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ABSTRACT

We have measured inclusive ϕ production in proton-nucleus collisions at 400 GeV/c near Feynman $x = 0$. The invariant cross section and the ϕ to π^- ratio are presented for transverse momenta between 0.8 and 3.5 GeV/c. We also report on correlations with particles opposite the ϕ in the center-of-mass system as they relate to the Okubo - Zweig - Iizuka rule.

We have observed the ϕ in its K^+K^- decay mode in 400 GeV/c proton-nucleus collisions at the Fermi National Accelerator Laboratory. An accurate measurement of the production of a vector meson in high energy hadronic interactions is possible with the ϕ because its narrow width allows a clear separation from the background. This measurement is of interest for two reasons. First, measurement of the ϕ , a meson containing "hidden" strangeness, allows a test of the Okubo - Zweig - Iizuka (OZI) rule which in this case states that the production of the ϕ should be suppressed unless accompanied by strange particles. Second, the level of prompt muons contributed by the decay $\phi \rightarrow \mu^+\mu^-$ can be established. Previous measurements by others of ϕ production are described in references 1 and 2.

In our experiment the ϕ was detected when both decay kaons traversed the same arm of a two-arm spectrometer. This spectrometer has been described previously.³ Briefly, it consisted of two identical arms each positioned at 100 mrad with respect to a diffracted proton beam. Each arm included a momentum analyzing magnet, 16 drift chamber planes, trigger scintillation counters, three threshold Cherenkov counters, and, at the downstream end, muon identifiers. In most of the data collected subsequent to that reported in Ref. 3, the Cherenkov counter in each arm closest to the target was replaced by steel shielding with apertures for the beam and spectrometers. The function of the displaced counters was taken over by new Cherenkov counters positioned behind each analyzing magnet. Most of the data for this report were collected in the latter configuration.

Data were collected for measurement of inclusive ϕ production and for correlations with particles in the spectrometer arm opposite that in which the ϕ was observed.

For the inclusive measurement, the effective mass spectrum of neutral pairs within a single arm is displayed in Fig. 1 for those events whose Cherenkov signals were compatible with a K^+K^- pair. A clear ϕ signal is observed at a mass of $1019.7 \pm 0.2 \text{ MeV}/c^2$. The intrinsic width of the ϕ is determined to be $4.5 \pm 0.4 \text{ MeV}/c^2$. The mass and width were calculated by fitting the acceptance corrected mass spectrum from 1.002 to 1.042 MeV/c^2 with a relativistic Breit - Wigner shape,⁴ smeared by a Gaussian-shaped mass resolution with $\sigma = 0.83 \text{ MeV}/c^2$, plus a linear background. The mass resolution was determined from our measured K^0 width. A sample of 1300 ϕ 's was collected in our inclusive measurement.

The ϕ inclusive invariant cross section was obtained from the K^+K^- spectrum as follows. First, the events in the ϕ peak ($1013 < \text{mass}_{K^+K^-} < 1026 \text{ MeV}/c^2$) were binned in transverse momentum (p_{\perp}) and the background in each bin was subtracted. Corrections were made for geometric acceptance, kaon decay in flight, losses of kaons due to Cherenkov misidentification, tracking inefficiencies, finite target thickness, and the branching ratio of $\phi \rightarrow K^+K^-$. The geometric acceptance is shown in Fig. 2 as a function of transverse momentum. The correction for kaon decay in flight varied from a factor of ~ 2.2 at $p_{\perp} = 1.0 \text{ GeV}/c$ to ~ 1.3 at $p_{\perp} = 3.0 \text{ GeV}/c$. Spurious particles in Cherenkov counters caused a 10-20% loss of kaons. Tracking efficiency for the ϕ

was approximately 50%. (This efficiency is low due to losses when both tracks overlapped in a single drift chamber cell.) A correction for finite target thickness of 7% was applied for absorption of the beam and interaction of the outgoing kaons in the target.

The invariant cross section per nucleus for $p + \text{Be} \rightarrow \phi + X$ as a function of transverse momentum is displayed in Fig.

3. The mean Feynman x (x_F) and center-of-mass rapidity for these data were -0.08 and -0.55 respectively. Errors from all sources, except overall beam normalization, are included in the indicated errors. Beam normalization, determined by a calibrated monitor telescope, was estimated to be uncertain to $\pm 10\%$. Fitting the invariant cross section with the functional shape $\exp(-ap_\perp)$ yields $a = 3.18 \pm 0.11 \text{ (GeV/c)}^{-1}$. This may be compared to $a = 3.93 \pm 0.28 \text{ (GeV/c)}^{-1}$ obtained in a different experiment² at 150 GeV/c , $0.0 \lesssim p_\perp \lesssim 2.0 \text{ GeV/c}$, and $x_F > 0.15$.

The ϕ to π^- ratio has been determined as a function of transverse momentum utilizing inclusive hadron spectra obtained with the same apparatus and target (Fig. 4). As seen in Fig. 4 this ratio varies from approximately 1 to 7 percent as transverse momentum increases. As this experiment did not distinguish pions from kaons for $p_\perp \gtrsim 2.0 \text{ GeV/c}$, the kaon to pion ratios for Be computed from Ref. 6 were used to correct for the K^- component of our inclusive negative spectra above $p_\perp \gtrsim 2.0 \text{ GeV/c}$. The contribution to the prompt μ^- to π^- ratio near $x_F \sim 0$ from the decay $\phi \rightarrow \mu^+ \mu^-$, is also presented in Fig. 4. This contribution was calculated by Monte Carlo technique assuming a branching

ratio for $\phi \rightarrow \mu^+ \mu^-$ of 2.5×10^{-4} and no ϕ polarization. The level of prompt muons from the ϕ is two orders of magnitude below the prompt μ to π ratio of $\sim 10^{-4}$.⁷

We have recorded events in which a ϕ , pion, or kaon was detected in one arm in coincidence with another identified hadron with $0.7 \lesssim p_{\perp} \lesssim 2.0$ GeV/c in the other arm. With a sample of 490 ϕ -hadron coincidence events, we have searched for an enhancement of kaons that might result from ϕ mesons that are produced via an OZI allowed mechanism.

Two steps are required to test for a kaon enhancement in ϕ events. First, the probability of observing a charged kaon in coincidence with the ϕ is compared to the probability of observing a kaon in coincidence with a pion. The motivation for this comparison is that the ratio of kaon occurrence in ϕ events to kaon occurrence in pion events should be unity if the ϕ behaves like an ordinary non-strange particle such as the pion. If on the other hand, the ϕ is associated with additional strange particle production, as would be expected in an OZI allowed process, this ratio should be larger than one. As a measure of kaon occurrence in ϕ or pion events, we take the ratio of events in which a kaon is observed to events in which a pion is observed opposite the ϕ or pion. We express this quantity as $(K/\pi)_{\phi}$ or $(K/\pi)_{\pi}$. From our data, then, we measure $(K/\pi)_{\phi} / (K/\pi)_{\pi} = 1.21 \pm .24$. This ratio indicates no significant enhancement of kaons in events containing a ϕ .

The second step is to determine the expected size of the kaon enhancement in ϕ events under the assumption that the ϕ is always accompanied by two additional strange particles. We do this by measuring K^+K^- correlations. The motivation for this is similar to that given above in that the detection of a strange particle (e.g., K^+) in one arm should enhance the occurrence of a particle with opposite strangeness (e.g., K^-) in the other arm. We measure the ratio K^-/π^- opposite K^+ or π^+ , and conversely K^+/π^+ opposite K^- or π^- . The two ratios $(K^-/\pi^-)_{K^+}/(K^-/\pi^-)_{\pi^+}$ and $(K^+/\pi^+)_{K^-}/(K^+/\pi^+)_{\pi^-}$ are equal within their statistical errors. Their weighted average is $1.38 \pm .06$. Hence, the probability of detecting a kaon of opposite charge in the second arm is 38% larger when the particle in the first arm is a kaon instead of a pion. This sets the scale for interpreting the ϕ datum. If the ϕ were always accompanied by two additional strange particles, then one would predict $(K/\pi)_\phi/(K/\pi)_\pi = 1.76 \pm .12$ for our data as compared to the measured value of $1.21 \pm .24$.

Our measured ϕ/π^- ratio of ~ 0.01 at $p_\perp \sim 1$ GeV/c indicates a fairly strong suppression of inclusive ϕ production.⁸ Our results also suggest that ϕ mesons are produced primarily via a mechanism that does not generate additional strange particles. These observations are consistent with ϕ production by other than OZI allowed processes involving the strange quark constituents of the ϕ . For theoretical discussions of ϕ production with regard to the OZI rule, the reader is referred to Ref. 9.

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REFERENCES

- † Present address: LeCroy Research Systems/Far West, One First St., Los Altos, California 94022.
- ¹ V. Blobel et al., Phys. Lett. 59B, 88 (1975); R. A. Donald et al., Phys. Lett. 61B, 210 (1976); P. Woodworth et al., Phys. Lett. 65B, 89 (1976); D. Cohen et al., Phys. Rev. Lett. 38, 269 (1977); B. Ghidini et al., submitted to Phys. Lett., CERN/EP/Phys. 77-6, Feb. 1977.
- ² K. J. Anderson et al., Phys. Rev. Lett. 37, 799 (1976).
- ³ D. Bintinger et al., Phys. Rev. Lett. 37, 32 (1976); R. Thun et al., Nucl. Instrum. Methods 138, 437 (1976).
- ⁴ J. D. Jackson, Nuovo Cimento 34, 1644 (1964).
- ⁵ J. A. Appel et al., Phys. Rev. Lett. 35, 9 (1975).
- ⁶ D. Antreasyan et al., Phys. Rev. Lett. 38, 115 (1977); L. Kulberg et al., Phys. Rev. Lett. 38, 670 (1977).
- ⁷ J. P. Boymond et al., Phys. Rev. Lett. 33, 112 (1974); J. A. Appel et al., Phys. Rev. Lett. 33, 722 (1974); D. Bintinger et al., Phys. Rev. Lett. 35, 72 (1975); V. V. Abramov et al., in Proceedings of the Seventeenth International Conference on High Energy Physics, London, England, 1974, cited by J. R. Smith (Rutherford High Energy Laboratory, Didcot, Berkshire, England, 1974), p. V-53.
- ⁸ The measurements of Ref. 2 yield a ϕ/ρ^0 ratio of 0.077 while R. Singer et al. (Phys. Lett. 60B, 385 (1976)) find $\rho^0/\pi^- = 0.13 \pm .02$.
- ⁹ H. J. Lipkin, Phys. Lett. 60B, 371 (1976); S. C. Frautschi et al. Nucl. Phys. B121, 141 (1977).

FIGURE CAPTIONS

Figure 1: Uncorrected effective mass spectrum of K^+K^- candidates in a single spectrometer arm obtained in the inclusive measurement.

Figure 2: Geometric acceptance of $\phi \rightarrow K^+K^-$ versus transverse momentum per unit interval of rapidity.

Figure 3: Invariant cross section per nucleus versus transverse momentum for the reaction $p + Be \rightarrow \phi + X$ at $x_F \approx -0.08$.

Figure 4: Ratio of ϕ to π^- measured by this experiment at $x_F \approx -0.08$ and upper limits on ϕ/π^- (Ref. 5) at $x_F \approx 0.1$ (left scale). The μ^-/π^- ratio near $x_F = 0$ from the decay $\phi \rightarrow \mu^+\mu^-$ calculated from this experiment's measured ϕ/π^- ratio (right scale).

Figure 1.

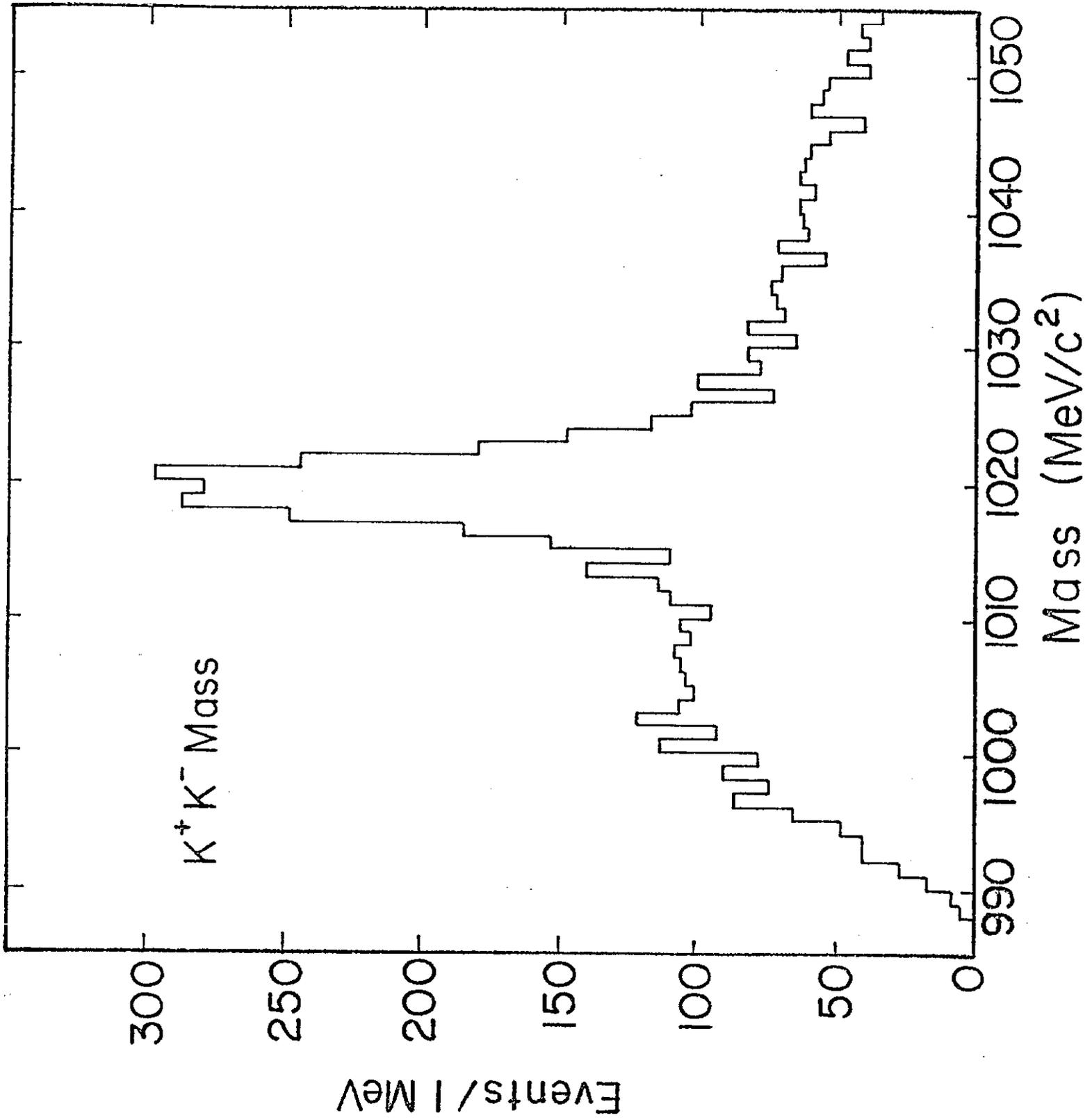


Figure 2.

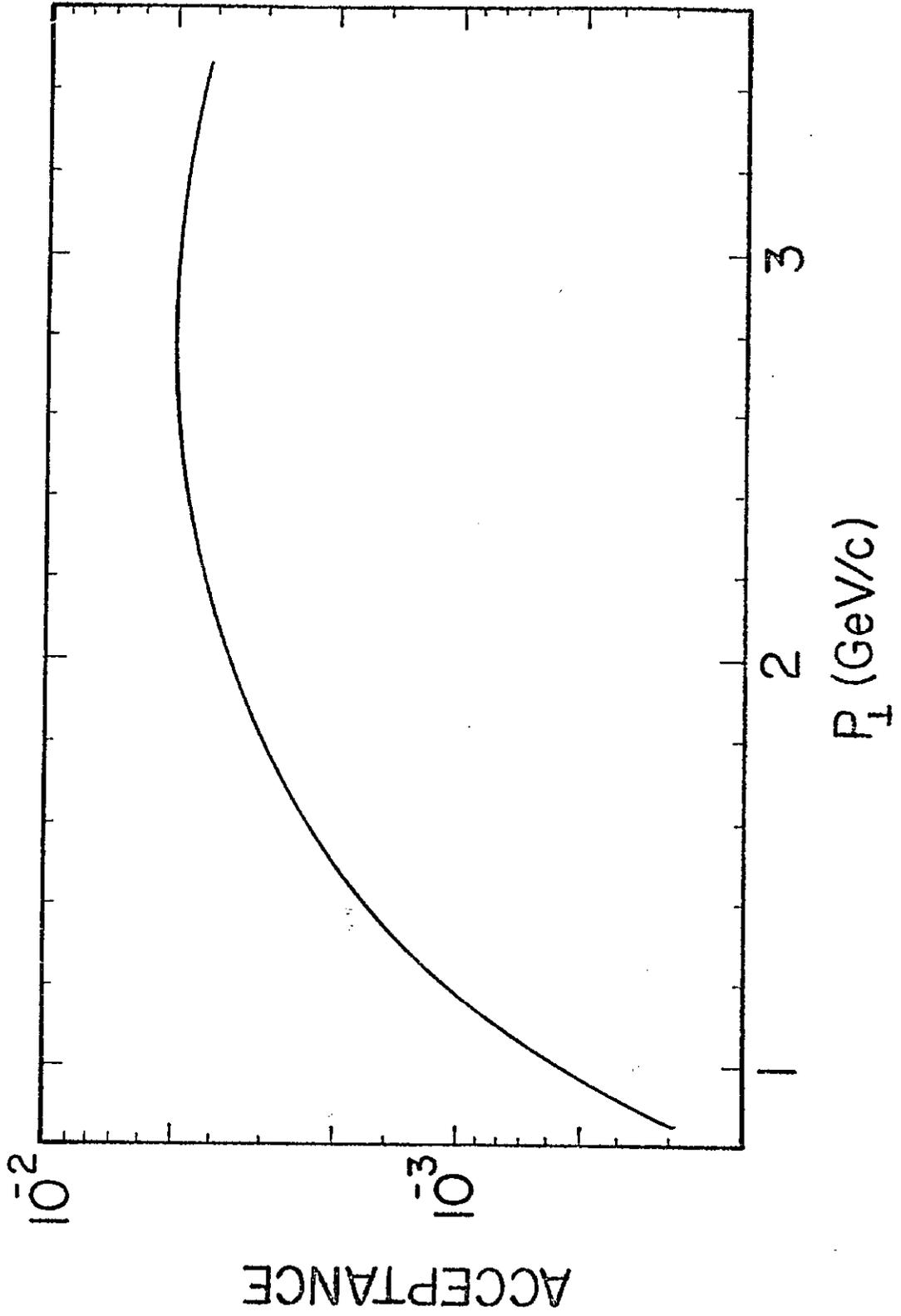


Figure 3.

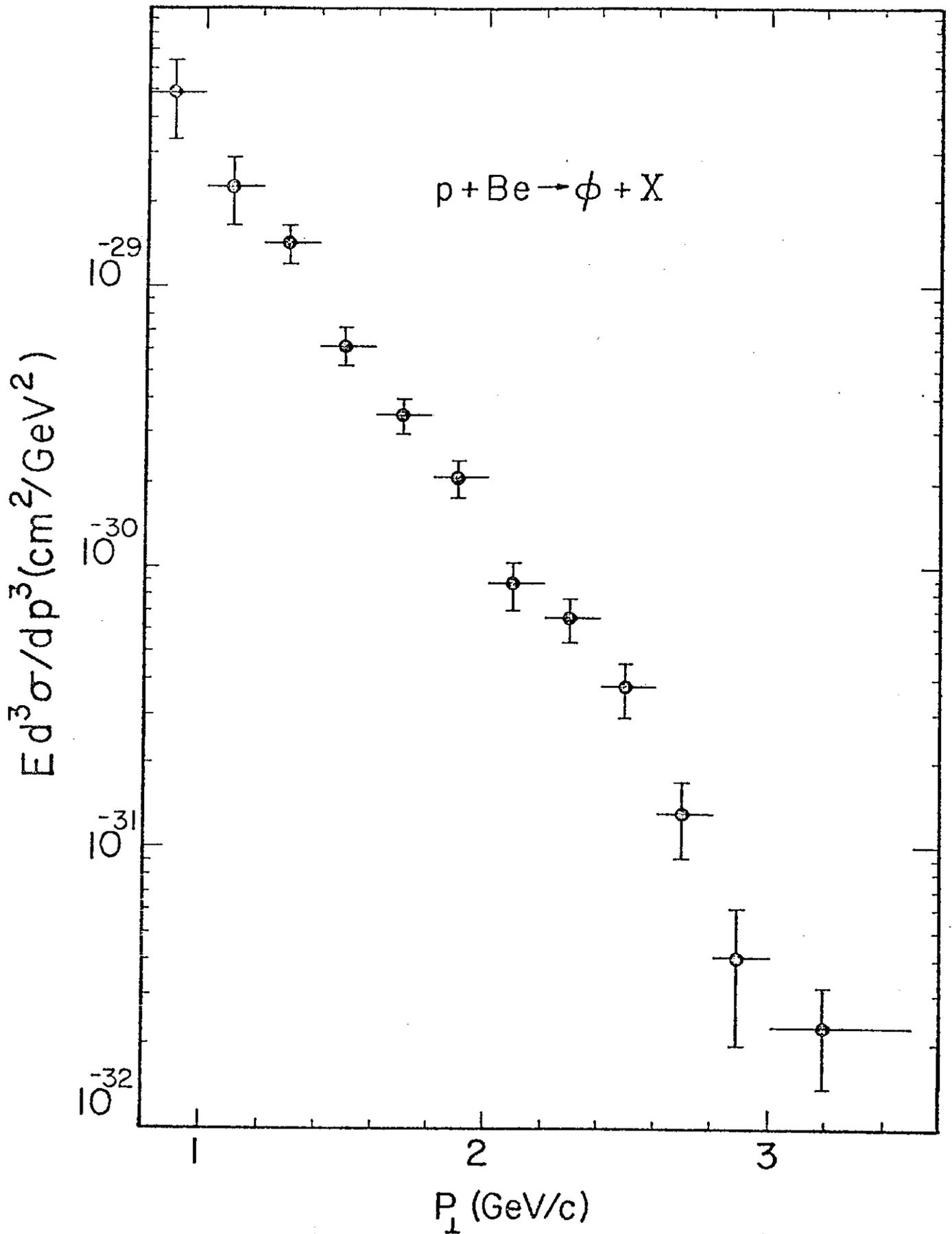


Figure 4.

