

INELASTIC PROTON-PROTON SCATTERING AT VERY HIGH ENERGY^{*)}

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In a recent paper ¹⁾ we presented preliminary results on inelastic proton proton scattering at 500-1500 GeV from an experiment on the CERN Intersecting Storage Rings. The data was mostly on π^+ and proton production at $P_{\perp}^2 = .16 \text{ (GeV/c)}^2$ for inclusive reactions of the type

$$p + p \rightarrow \pi^+ + \text{anything},$$

$$p + p \rightarrow p + \text{anything}. \quad (1)$$

The results indicated that the inclusive cross section $E d^3\sigma/dP^3$ was independent of incident energy when plotted against the scaled momenta of the outgoing particles. However, our errors were 20 to 30 %.

We have now finished the experiment and have about a factor of 10 more data. This reduced the errors to 10 to 15% and extended the range of X and P_{\perp}^2 . We present here graphs of the complete data with a short discussion. We are preparing a long paper with a detailed discussion of the experimental problems of this particle production experiment on the ISR.

The spectrometer for detecting the outgoing particles was shown in fig. 1 of ref. 1). It contained 3 bending magnets for angular steering and momentum analysis, 5 scintillation counters to define the phase space bite $\Delta\Omega\Delta P$ and two threshold Čerenkov counters to tag the particles as pions, kaons or protons. The cross section was given by

$$\text{Events} = \text{Luminosity} \times \frac{d^2\sigma}{d\Omega dP} \times \Delta\Omega\Delta P \quad (2)$$

The Events were the number of 5-fold coincidences of the scintillation counters appropriately tagged by the Čerenkov coun-

ters. The luminosity was measured by the van der Meer technique ²⁾ of separating the two ISR beams vertically.

The main problems in this type of ISR experiment are accurately measuring the luminosity and determining the beam-gas and beam-wall backgrounds. Because of the outstanding vacuum and stability of the ISR these backgrounds were not too serious. By taking background runs with only one beam we found that the beam-gas background varied in a predictable way between 10 and 30% with errors normally less than $\pm 7\%$. We found no evidence for beam-wall background. The van der Meer method for measuring the luminosity appears good to about $\pm 6\%$. The other corrections were for decay and nuclear and coulomb scattering in the vacuum chamber and spectrometer. The uncertainty in these corrections was less than $\pm 7\%$ except for the points with $P_{LAB} \leq 2$ GeV/c. These errors were all added in quadrature to the statistical errors (normally 6 to 10%) to give net errors mostly in the 10 to 15% range.

We present our data as plots of $E \frac{d^3\sigma}{dP^3}$ vs X and P_{\perp}^2 . The quantity $E \frac{d^3\sigma}{dP^3}$ is the invariant cross section in the sense that dP^3/E is the invariant phase space. It is related to the experimentally observed cross section by

$$E \frac{d^3\sigma}{dP^3} = \frac{E}{P^2} \frac{d^2\sigma}{d\Omega dP} \quad (3)$$

The longitudinal momentum of the outgoing particle is related to X by $X = P_{\parallel}/P_{MAX}$ where P_{MAX} is the maximum value of P_{\parallel} which is essentially equal to the incident proton momentum. All cross sections and momenta are given in the center-of-mass which is almost identical to the lab at the ISR. Our data is plotted in fig. 1 against X and in fig. 2 against P_{\perp}^2 along with other data at accelerator energies ^{3,4,5,6} .

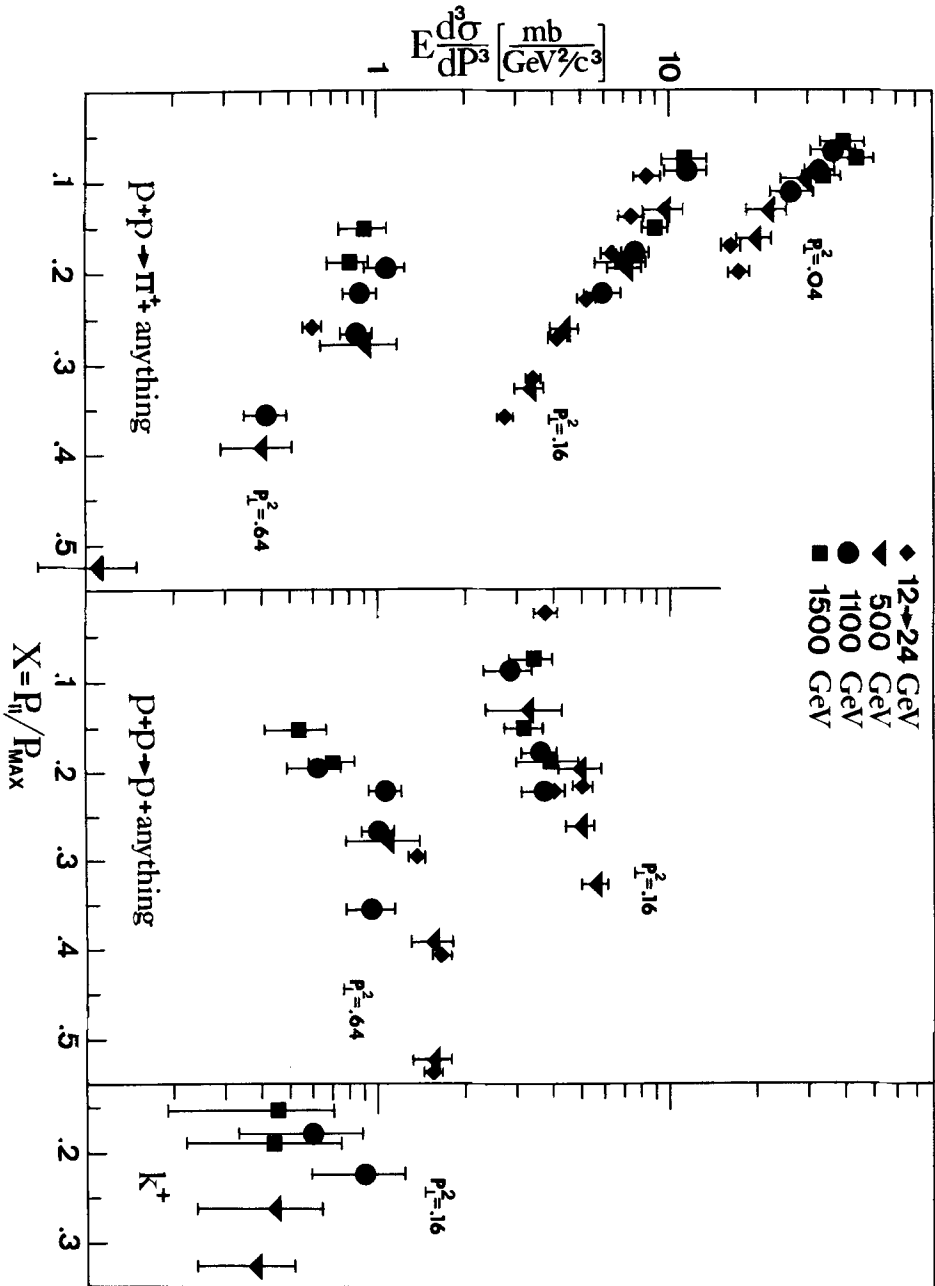


Fig. 1 : Plots of $E \frac{d^3\sigma}{dP^3}$ vs X with $P_{T,1}^2$ held fixed at the values indicated. The data of other groups ^{4,6)} have been interpolated to match our $P_{T,1}^2$ values.

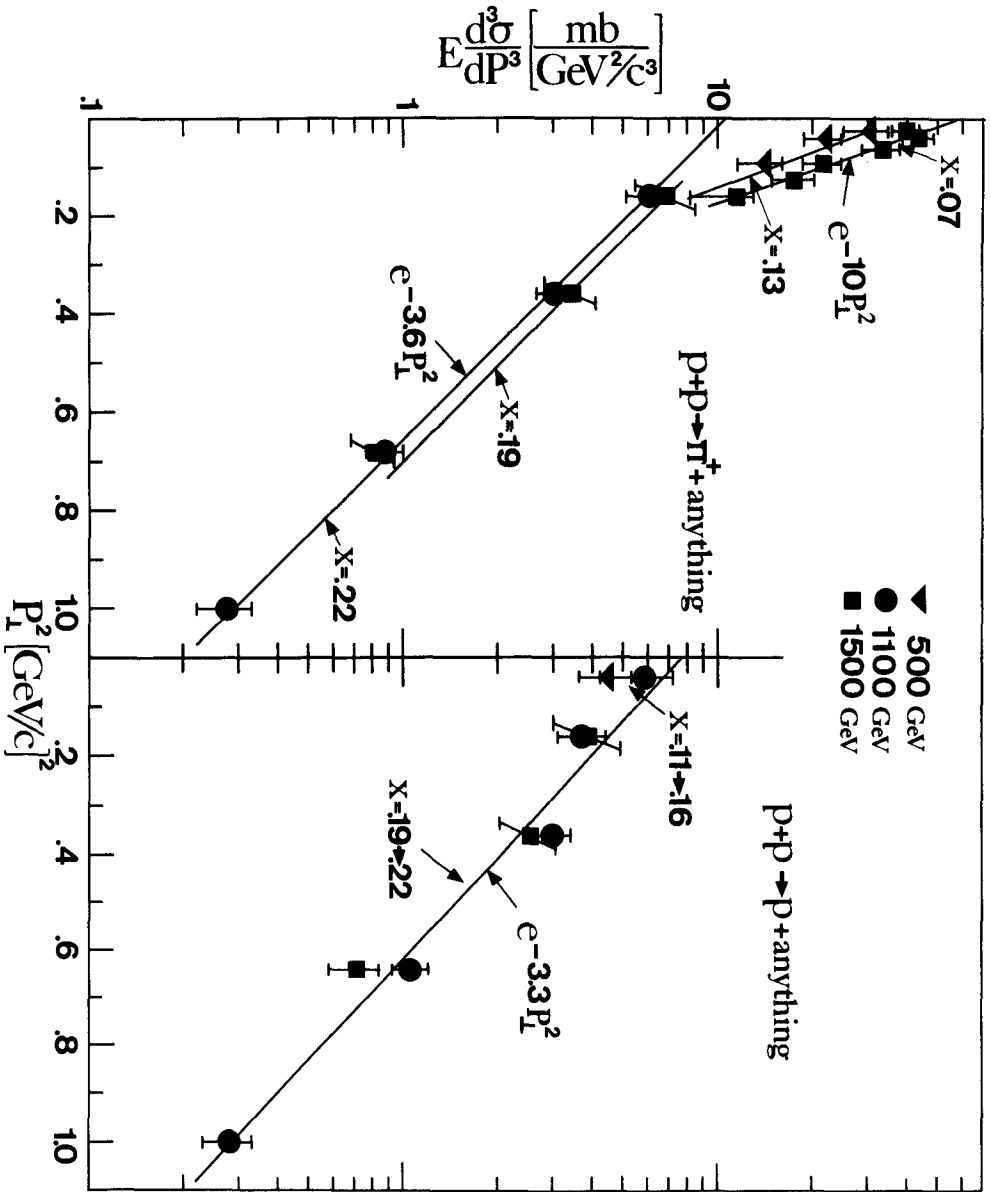


Fig. 2 : Plots of $E \frac{d^3\sigma}{dP^3}$ vs P_T^2 with X held fixed at the indicated values.

Looking at the X plot we see that in our now extended kinematic region both the π^+ and p cross sections are independent of energy from 12 GeV to 1500 GeV to a precision as high as 10%. Thus these cross sections obey a type of scaling suggested by Feynman ⁷⁾ and Yang ⁸⁾. We stress that only the cross section $E d^3\sigma/dP^3$, suggested by Feynman, obeys this scaling and other cross sections such as $d^3\sigma/dP^3$ do not. It instead deviates by more than a factor of 10 over the range 10 GeV to 1500 GeV.

Notice that the π^+ cross section shows no tendency to dip at small X . This is consistent with Yang's limiting fragmentation model, but we believe it favors a pionization model such as Feynman's, which specifically states that $E d^3\sigma/dP^3$ should be independent of energy and maximum at $X = 0$. The fact that X is the necessary variable favors a Lorentz-contracted geometrical model for the proton, such as that of Krisch ⁹⁾ and Huang ¹⁰⁾; because $X \approx P_{\parallel}/\gamma$ where γ is the Lorentz contraction factor.

The proton cross section does decrease somewhat at small X . This may be because it is difficult for the proton to lose all its energy and emerge at rest. The scaling also seems to work for K^+ production, but with larger errors. The fact that the K^+/π^+ ratio is about 8% makes it appear unlikely the K^+ production will ever approach π^+ production.

Next looking at the extended P_{\perp}^2 plot we see that for $P_{\perp}^2 > .1$ (GeV/c)² the pion and proton cross section both drop roughly as $e^{-3.5 P_{\perp}^2}$, much as they did at lower energy and as suggested by cosmic ray experiments. Notice however the sharp forward peak in the π^+ cross section, that is absent in the proton cross section. A similar peak in pion production has been seen at accelerator energies ^{4,6,11)}. Yen and Berger ¹²⁾ suggested that this peak was due to the decay of low mass nucleon iso-bars. The absence of the peak in the proton cross section supports this.

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