FERMILAB-CONF-15-188-PPD

PARTICLE PRODUCTION MEASUREMENTS USING THE MIPP DETECTOR AT FERMILAB

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Abstract Inelastic cross sections have been measured for H, Be, C and Bi targets using proton beams at momenta of 58, 85 and 120 GeV/c using the MIPP experiment at Fermilab. The cross section dependence on the atomic weight (A) of the targets has been found to vary as A^{α}, where α is 0.75 ± 0.03 for a beam momentum of 58 GeV/c and 0.66 ± 0.03 for 120 GeV/c. The MIPP data have been compared with the Monte Carlo (DPMJET/FLUKA) predictions and previous measurements. Inelastic cross sections have also been measured as a function of multiplicity for H and C targets using proton beams at different momenta. The DPMJET/FLUKA multiplicity shapes disagree with those of data. Inclusive charged pion production cross sections have also been measured in bins of true momentum for C target using 58 and 120 GeV/c proton beams, and compared with the FLUKA Monte Carlo.

1 Introduction

The Main Injector Particle Production (MIPP) experiment is a fixed target hadron production experiment at Fermilab. It uses a primary beam of 120 GeV/c protons from the Main Injector and these protons impinge on a copper target to produce secondary beams of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ from 5 to 90 GeV/c [1]. The experiment is designed to measure the total charged particle production of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ off

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various nuclei including liquid hydrogen (LH_2), NuMI[1] target and thin targets of Be, C, Bi and U. Now, what is the motivation behind taking these data? Neutrino experiments depend on hadronic production models for neutrino flux prediction and these models give predictions that differ up to 20%, which introduces a large systematic error due to the neutrino flux. An improved understanding of hadronic rates can help to minimize this systematic error. The hadronic shower simulators such as GEANT4, MARS, FLUKA, etc. model hadronic interactions based on available data. MIPP is a high acceptance spectrometer and has high statistics data with 6 beam species. These data could be used to improve hadronic shower simulations.

2 Inelastic cross section measurements

Inelastic cross sections have been measured for 58 and 85 GeV/c proton interactions with LH_2 target, and 58 and 120 GeV/c proton interactions with Be, C and Bi targets. The interactions are selected using interacton trigger [2]. Inelastic cross sections as a function of lab momentum along with statistical and systematic errors for different targets are shown in figure 1. The Monte Carlo (DPMJET/FLUKA) predictions and previous measurements [3, 4] are also superimposed on the MIPP data. We expect a little rise in the inelastic cross section value as we go higher in the beam momentum but we have observed that the MIPP measurement at 120 GeV/c is lower than that at 58 GeV/c for all the three thin targets, and it is worst for Bi target. A similar feature was observed in the previous analyses [5]. With the present study, it was not possible to figure out the exact reason for this discrepancy. Inelastic cross sections as a function of target atomic weight using 58 and 120 GeV/c proton beams are shown in figure 2. Inelastic cross sections have also been measured as a function of multiplicity for p+p and p+C interactions at different beam momenta. The inelastic cross sections using MIPP data along with total combined (stat$\oplus$[2]syst) errors are compared with the Monte Carlo (MC) predictions and the existing data in figure 3. The MC multiplicity shapes disagree with those of data.

3 Inclusive charged pion production cross sections

TPC and RICH detectors have been used independently to do the particle identification (PID) in momentum ranges 0.3 – 1 GeV/c and 4.64 – 120 GeV/c, respectively. The maximum likelihood technique has been used to determine the spectrum of each particle type in data [2]. The observed (data) pion momentum spectrum is unfolded using the MC K-matrix $K(n_r|n_t)$, which denotes the probability of getting a reconstructed pion for a given true pion. Figure 4 shows the comparison of the data and

[1] NuMI stands for Neutrinos at the Main Injector and refers to the Fermilab Main Injector neutrino beam

[2] "$\oplus$" indicates addition in quadrature

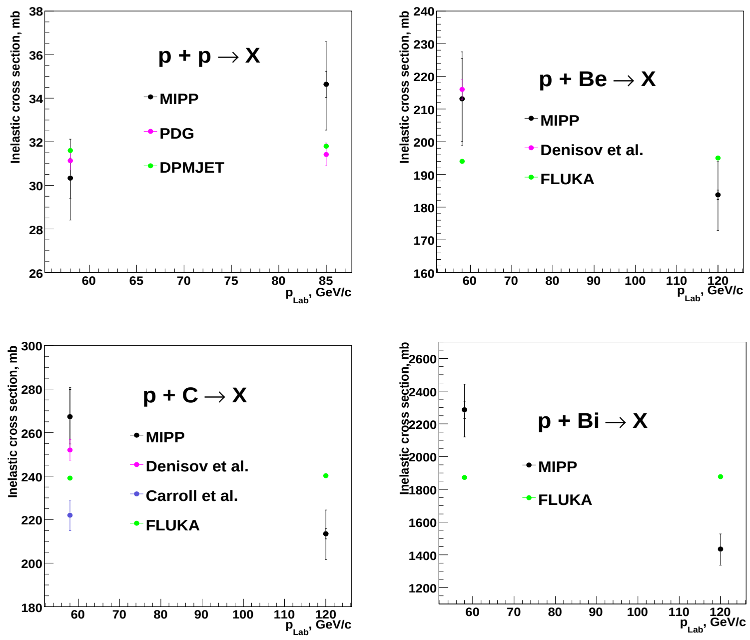
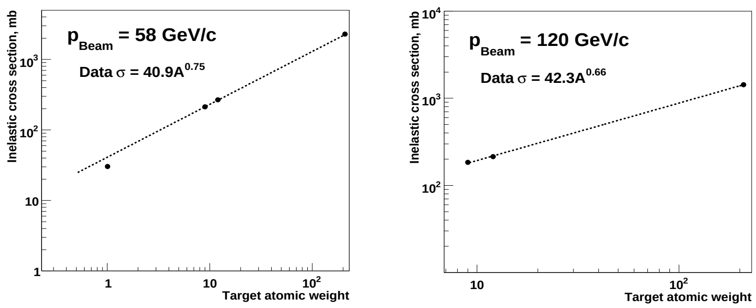


Fig. 1 Inelastic cross sections as a function of lab momentum for different targets.



(a) (b)

Fig. 2 Inelastic cross sections as a function of target atomic weight.

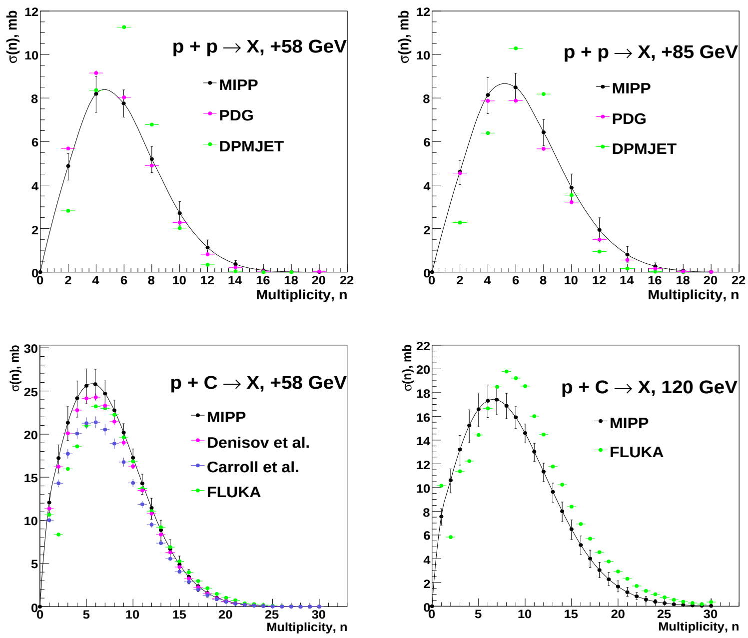


Fig. 3 Comparison of the data and MC inelastic cross sections as a function of multiplicity. The reference [3] and [4] data shown are the KNO scaling function normalized to the those experiments' absorption cross sections – see reference [2] for details.

MC (FLUKA) inclusive $\pi^{\pm}$ production cross sections in bins of true momentum along with the statistical and systematic errors using 58 and 120 GeV/c p+C interactions. The total inclusive pion production cross sections for the data and MC are listed in table 1. The cross sections at 120 GeV/c are lower than those at 58 GeV/c in the lower momentum range, but higher at the higher momenta which is expected due to the kinematics and available phase space. The discrepancies observed in the lower momentum range are not understood.

References

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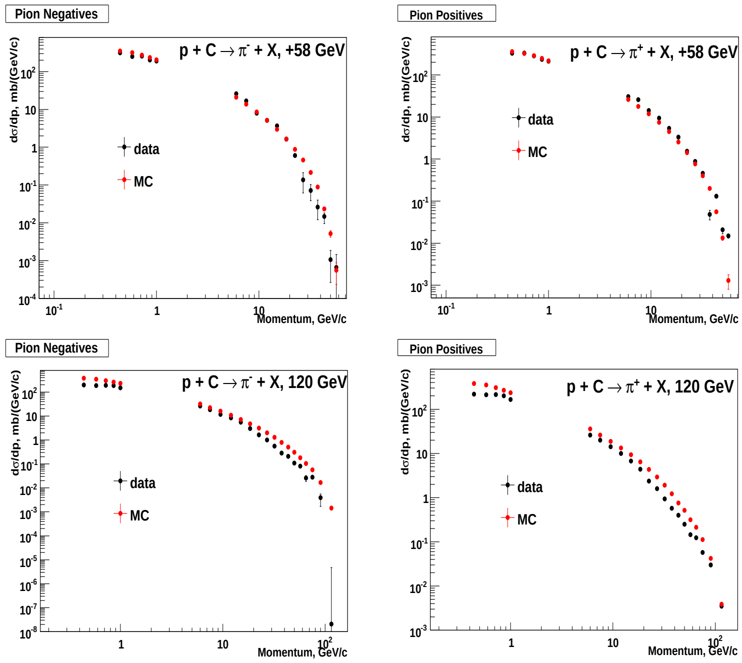

Fig. 4 Comparison of the data and MC inclusive $\pi^{\pm}$ production cross sections.

Momentum range (GeV/c)	Data (mb)	MC (mb)
	p + C → π^- + X, 58 GeV	
0.3 – 1	170.68 ± 4.14 (stat) $^{+9.34}_{-10.10}$ (syst)	193.83 ± 0.50 (stat)
4.64 – 60	109.83 ± 2.78 (stat) $^{+6.03}_{-6.51}$ (syst)	101.24 ± 0.36 (stat)
	p + C → π^+ + X, 58 GeV	
0.3 – 1	194.74 ± 4.72 (stat) $^{+10.63}_{-11.51}$ (syst)	201.19 ± 0.51 (stat)
4.64 – 60	173.99 ± 4.29 (stat) $^{+9.29}_{-10.23}$ (syst)	140.14 ± 0.43 (stat)
	p + C → π^- + X, 120 GeV	
0.3 – 1	127.72 ± 1.31 (stat) $^{+7.09}_{-7.68}$ (syst)	211.0 ± 0.46 (stat)
4.64 – 120	152.13 ± 1.73 (stat) $^{+8.03}_{-8.70}$ (syst)	212.62 ± 0.46 (stat)
	p + C → π^+ + X, 120 GeV	
0.3 – 1	141.92 ± 1.45 (stat) $^{+7.90}_{-8.57}$ (syst)	215.89 ± 0.47 (stat)
4.64 – 120	185.35 ± 1.99 (stat) $^{+10.12}_{-10.92}$ (syst)	269.67 ± 0.52 (stat)

Table 1 Total inclusive $\pi^{\pm}$ production cross sections for the data and MC.