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A The main injector particle production (MIPP) experiment at Fermilab uses particle beams of charged pions, kaons, proton and antiproton with beam momenta of 5-90 GeV/c to measure particle production cross-sections of various nuclei including liquid hydrogen, MINOS target and thin targets of beryllium, carbon, bismuth and uranium. The physics motivation to perform such cross-section measurements is described here. Recent results on the analysis of NuMI target and forward neutron cross-sections are presented here. Preliminary cross-section measurements for 58 GeV/c proton on liquid hydrogen target are also presented. A new method is described to correct for low multiplicity inefficiencies in the trigger using KNO scaling.

Main injector particle production; neutrinos; neutrons; NuMI; KNO

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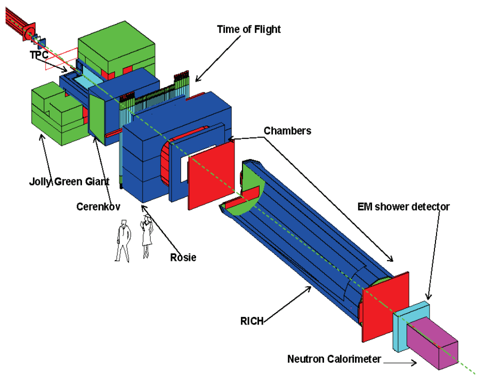
The main injector particle production (MIPP) experiment at Fermilab is a hadron production experiment which uses 120 GeV/c primary protons from the main injector to produce secondary beams of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ from 5 to 90 GeV/c [1]. It was designed to measure the total charged particle production of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ using beams of charged pions, kaons, proton and antiproton on nuclear targets.
The MIPP is a full-acceptance spectrometer. It provides excellent particle ID (PID) separation. The lay-out of the experiment is shown in figure 1.



F 1 Lay-out of the MIPP experiment.

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Previous experiments used single-arm spectrometers and did not provide complete coverage of space in longitudinal and transverse momentum. As a result, hadronic production models like GEANT4, MARS, and FLUKA have limited amount of data to be compared with and in some cases give significantly different results. The MIPP is an open-geometry spectrometer giving complete angular coverage in (p_Z, p_T) space.
Neutrino flux problems in MINOS, MiniBooNE, K2K, T2K, NOνA and MINERνA can be reduced to one problem: the current status of insufficient knowledge of strong interactions. Better understanding of hadronic production can minimize the systematic error in neutrino flux predictions.

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Forward neutron inclusive cross-sections. The MIPP has measured cross-sections for forward neutron production from a variety of targets using 58, 84 and 120 GeV/c proton beam momenta [2]. The cross-sections show reasonable agreement with FLUKA and DPMJET Monte Carlos. Figure 2 shows the comparison of measured cross-sections with predictions from the Monte Carlo (a) and the cross-sections as a function of target atomic weight A (b).
Preliminary results from MINOS target data analysis. The MIPP has obtained data on particle production using 120 GeV/c protons from the main injector impinging on the MINOS target. It has determined the rates for inclusive production of $e^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ particles as a function of longitudinal and transverse momentum of the final-state particle [3]. This analysis uses the Bayes' theorem algorithms to identify the particle. In Figure 3, the left plot shows the comparison of GlobalPid spectra with the MCTRUTH in the Monte Carlo sample and the right plot shows the comparison of positive and negative spectra for the four particle types in the data. GlobalPid agrees well with the MCTRUTH.

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The MIPP has developed a KNO-based fitting algorithm to obtain the trigger efficiencies. The MIPP uses scintillator-based interaction trigger which requires at least three charged tracks for the scintillator to be fired which causes inefficiencies at low multiplicities. The method uses a K matrix $K(n_o|n_t)$ which denotes the probability of obtaining observed multiplicity n_o, given a true multiplicity n_t. The K matrix is multiplied by true probabilities from KNO function [4] to get predicted distribution which includes elastics at the two-prong. The observed distribution is fitted to the predicted distribution to extract the trigger efficiencies. Figure 4a shows the comparison of the observed and predicted distribution at the minimum and figure 4b shows the cross sections as a function of multiplicity for 58 GeV/c proton incident on liquid hydrogen target using the KNO-based trigger efficiencies for correction.

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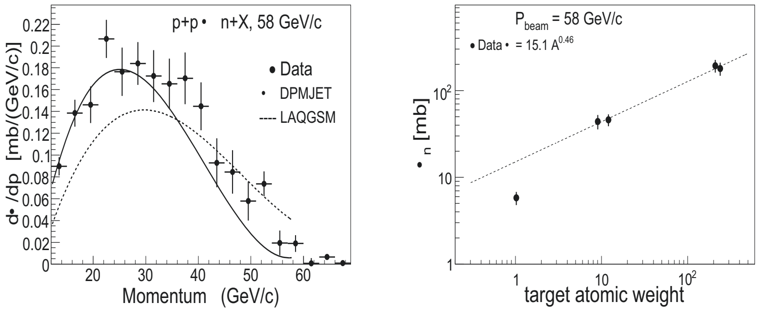
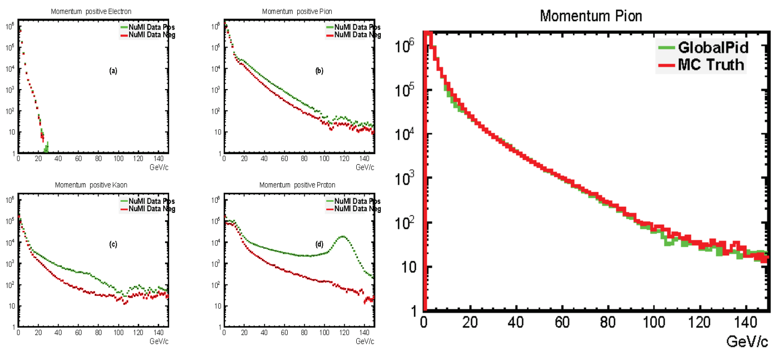


(a) (b)

F 2 (a) Measured cross-sections from MIPP experiment compared with predictions from Monte Carlo. (b) Neutron production cross-sections as a function of target atomic weight A.



F 3 Left- Comparison of the GlobalPid spectra with the MCTRUTH in the Monte Carlo sample for both charges of pions. Right- Comparison of the positive and negative spectra (a) for electrons, (b) for pions, (c) for kaons, and (d) for protons.

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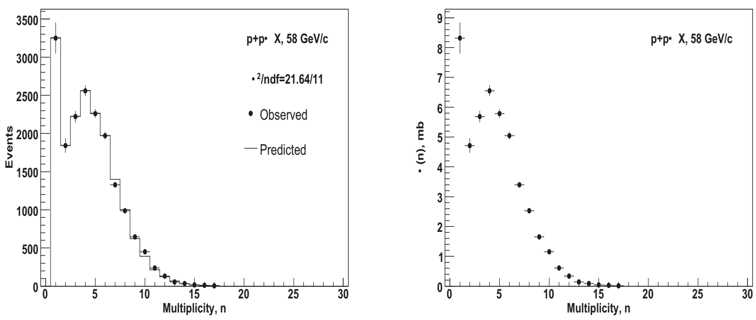

(a) (b)

F (a) Comparison of the observed and predicted distribution at the minimum. (b) Cross sections as a function of multiplicity for 58 GeV/c proton incident on liquid hydrogen target using KNO-based efficiencies for correction.