Particle Production Measurements using the MIPP Detector at Fermilab

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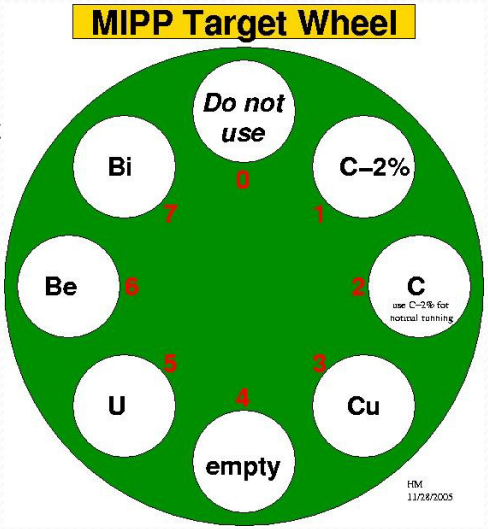
Outline of the talk

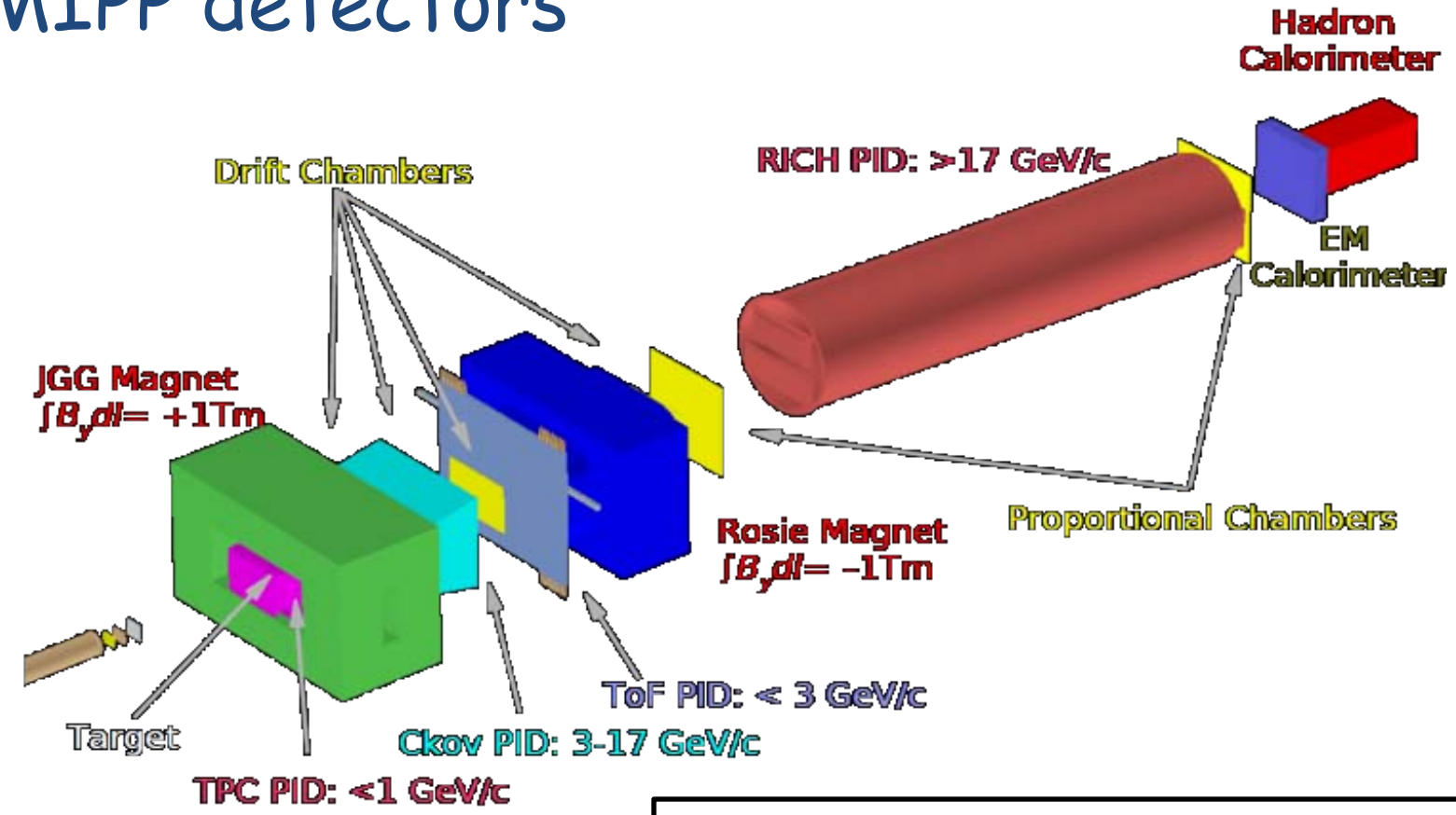
- **Introduction**
- **Detector description**
- **Track and vertex reconstruction**
- **Preliminary results**
- **Summary**

Introduction

- MIPP stands for Main Injector Particle Production
- A fixed target hadron production experiment. Located in Meson Center beam line at Fermilab
- Operated from January 2005 to February 2006 and collected ~18 million events
- Primary Beam – 120 GeV/c protons from Main Injector
- Secondary Beams – $\pi^{\pm}$, $K^{\pm}$, p and $\overline{p}$ from 5 to 90 GeV/c
- Targets – Liquid Hydrogen (1.5 % λ_I, 14 cm long and 3.8 cm diameter), Be, C (2 % λ_I, 2 inch diameter and 1 cm thick), NuMI, Bi and U (A=1 to A=238)



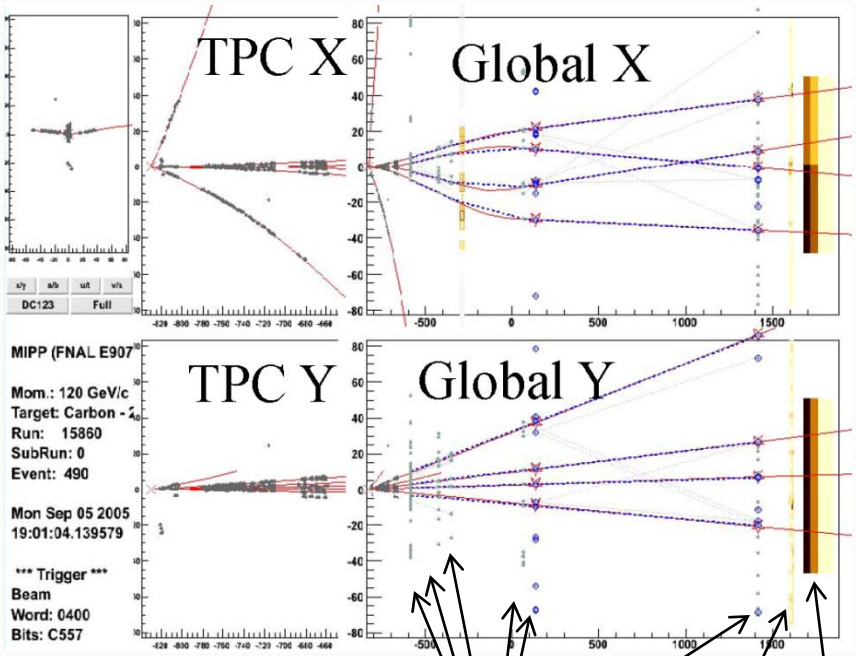
MIPP detectors



- TPC, 4 drift chambers and 2 proportional wire chambers for tracking
- 2 magnets for charge and momentum measurement
- 2 Beam Cherenkov for beam particle ID. TPC, Time of Flight, Cherenkov and RICH for outgoing particle ID, and Calorimeter for neutrons

Track and vertex reconstruction

Reconstructed 120 GeV/c proton on Carbon event



- TPC tracks combined with wire chambers hits to form global tracks
- Vertex constrained fit is done to form the vertices

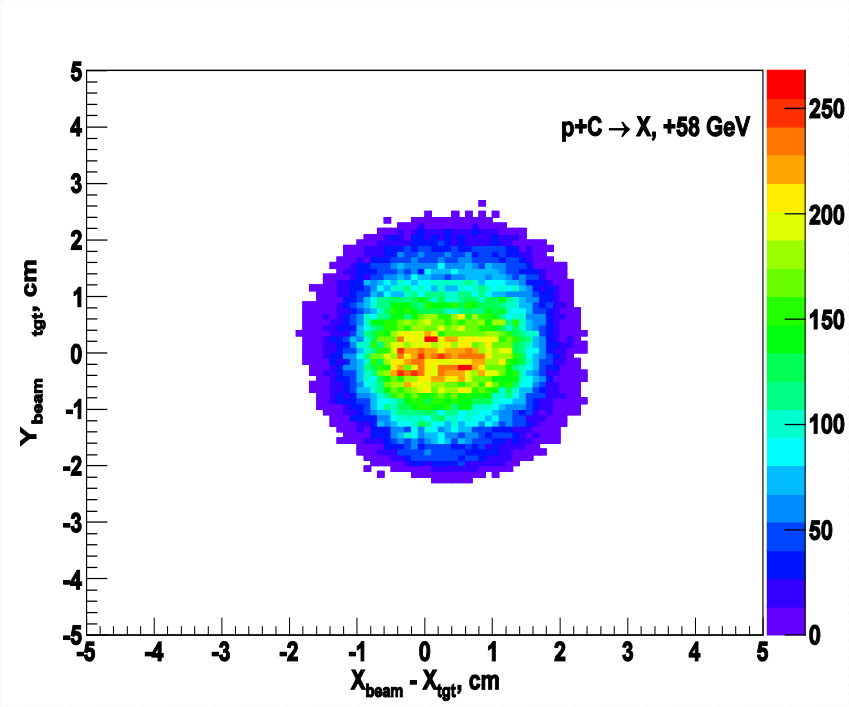
Event selection for preliminary inelastic cross section measurements

Data sets used: 58 and 85 GeV/c proton on LH_2 target, 58 and 120 GeV/c proton on Carbon target

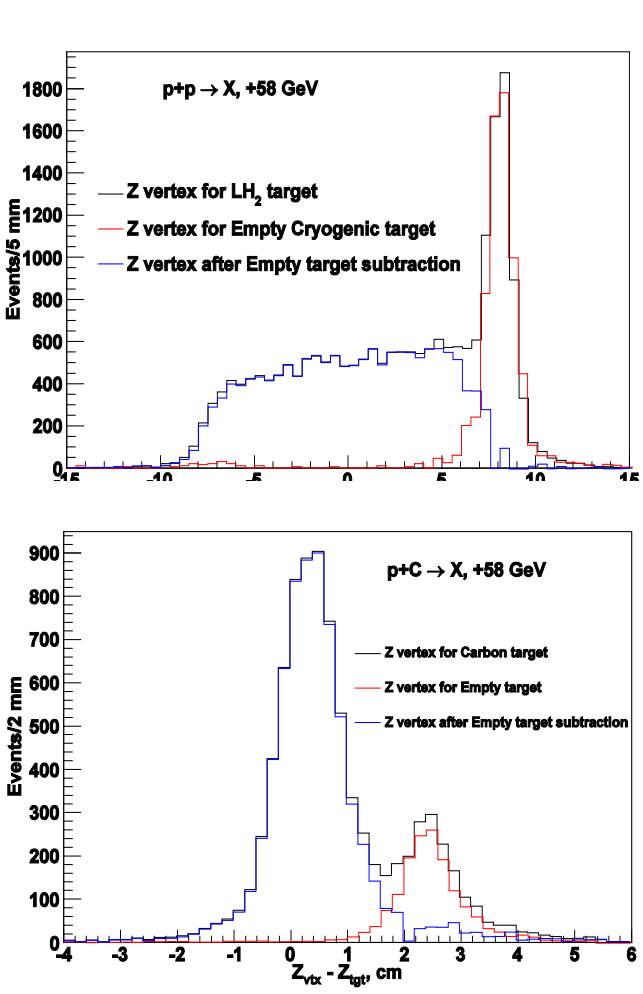
- Select interactions using interaction trigger
- Scintillator-based interaction trigger requires at least 3 charged particles for the scintillator to fire
- Incident beam should be within the target dimensions
- Empty target subtraction to reject the interactions with the scintillator
- **Cross section =** $\dfrac{N_{int}}{N_{beam} \times n_t \times \varepsilon}$

$$n_t = \frac{N_A \times \text{density} \times \text{thickness}}{\text{Atomic weight}}$$

Beam spot position



Z vertex wrt target



Inelastic cross section for 58 & 85 GeV/c proton interactions on Liquid Hydrogen target

Energy (GeV/c)	PDG (mb)	DPMJET (mb)	MIPP (MC ε_{trig} applied) (mb)	MIPP (Data ε_{trig} applied) (mb)
58	31.13	31.6	$31.68 \pm 0.949(stat)\ ^{+3.570}_{-4.103}$ (syst)	$34.66 \pm 1.038(stat)\ ^{+4.036}_{-4.604}$ (syst)
85	31.42	31.8	$36.95 \pm 0.627(stat)\ ^{+4.172}_{-4.794}$ (syst)	$39.71 \pm 0.674(stat)\ ^{+4.581}_{-5.236}$ (syst)

Inelastic cross section for 58 & 120 GeV/c proton interactions on Carbon target

Energy (GeV/c)	FLUKA (mb)	MIPP (MC ε_{trig} applied) (mb)	Other measurements (mb)
58	239.14	$263.13 \pm 8.240(stat)\ ^{+25.63}_{-30.65}$ (syst)	252 ± 4(stat) (Nucl. Phys. B61,(1973), 62) 222 ± 7(stat+syst) (Phys. Lett. B80,(1979), 319)
120	240.15	$191.95 \pm 2.180(stat)\ ^{+18.92}_{-22.55}$ (syst)	Acceptance corrections still need to be applied for Carbon target. Work in progress

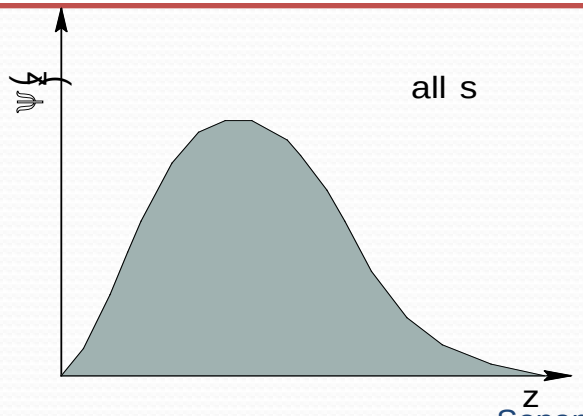
KNO-based technique to get trigger efficiency

KNO Scaling relation:

$$P_n(s) = \frac{\Psi(n/\langle n(s)\rangle)}{\langle n(s)\rangle}, \frac{n}{\langle n(s)\rangle} = Z$$

where $P_n(s)$ is probability of producing n charged particles at a particular energy 's', $\langle n(s)\rangle$ is average multiplicity and $\Psi(n/\langle n(s)\rangle)$ is the KNO function

$$\Psi(Z) = (3.97Z + 33.7Z^3 - 6.64Z^5 + 0.332Z^7)\, e^{-3.04Z}$$

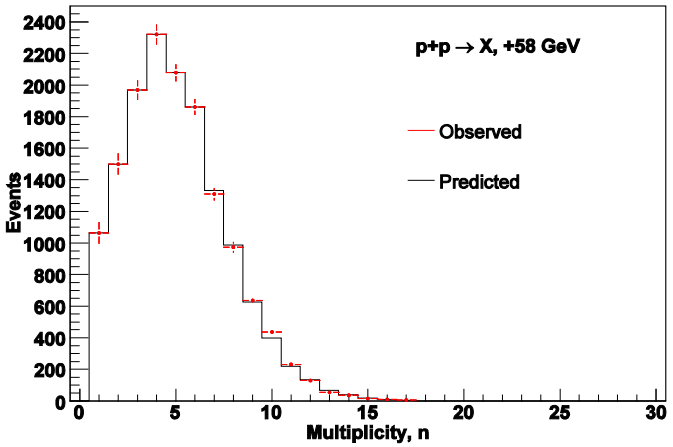


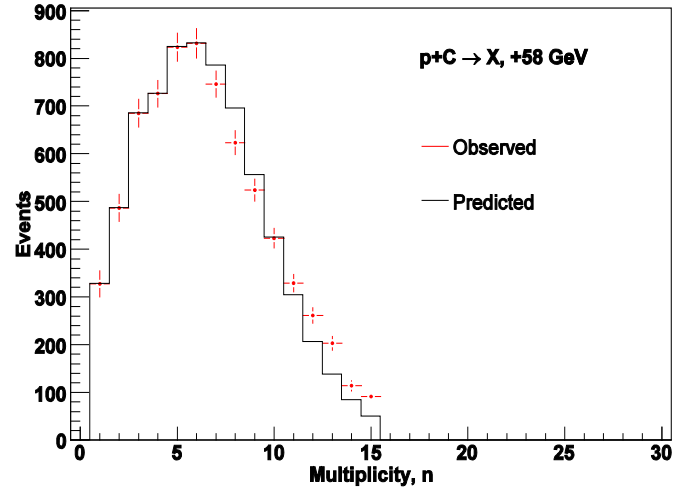
- The method uses a K matrix $K(n_o|n_t)$ – probability of obtaining observed multiplicity n_o, given a true multiplicity n_t (trigger is not required)
- This matrix is multiplied by true probabilities from KNO function to get the predicted distribution
- The observed distribution is fitted to the predicted distribution to extract the trigger efficiencies
- The fit function is:

  $$\chi^2 = (\text{Observed} - \text{Predicted})^2/\sigma^2$$

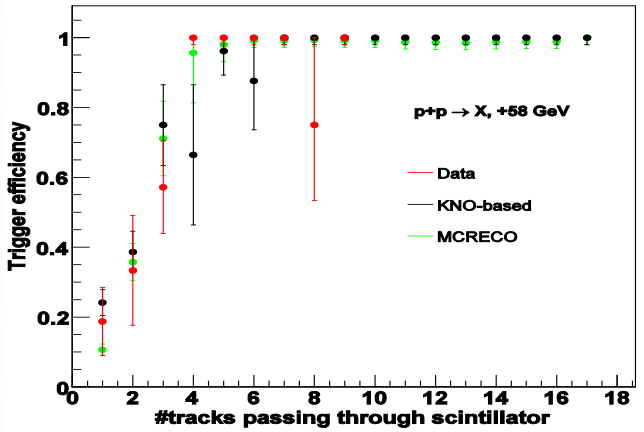
- Trigger efficiencies are the parameters going to be fitted

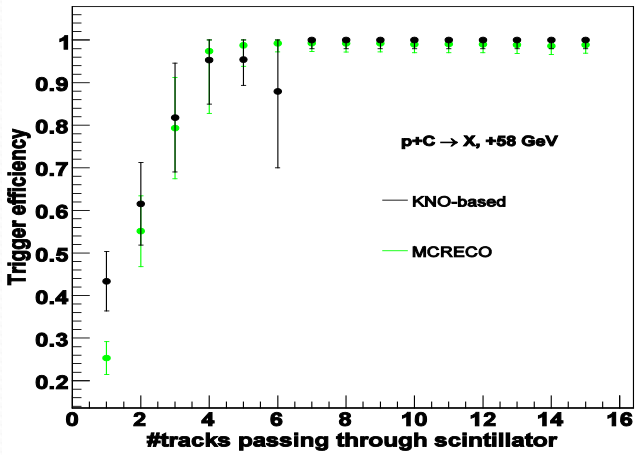
KNO fit results



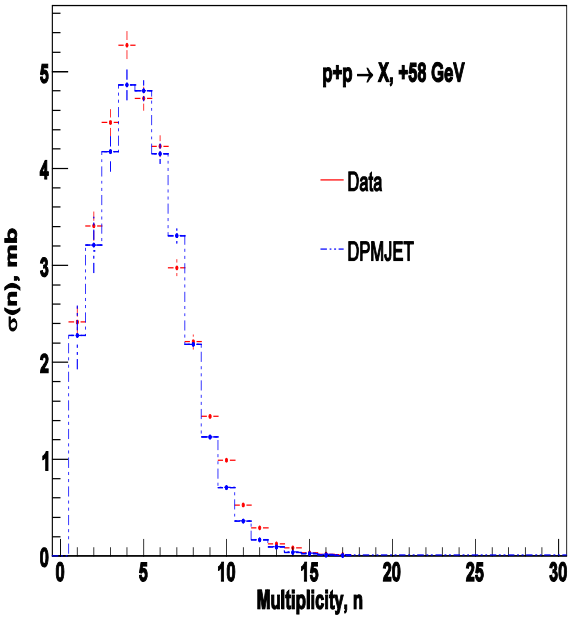


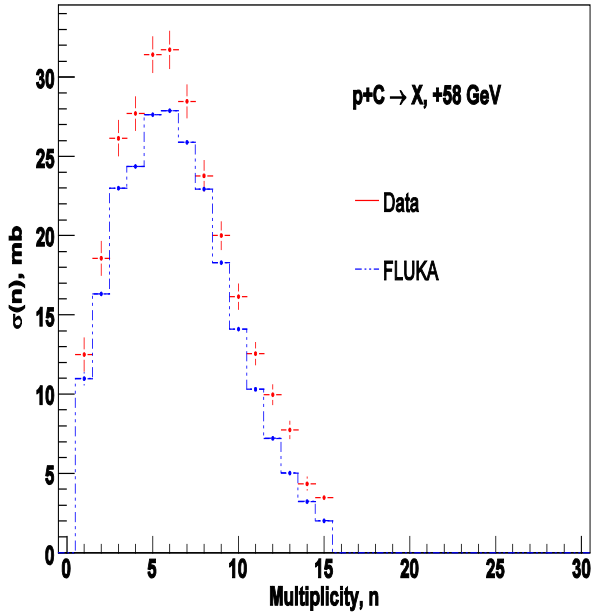
Comparison of trigger efficiencies

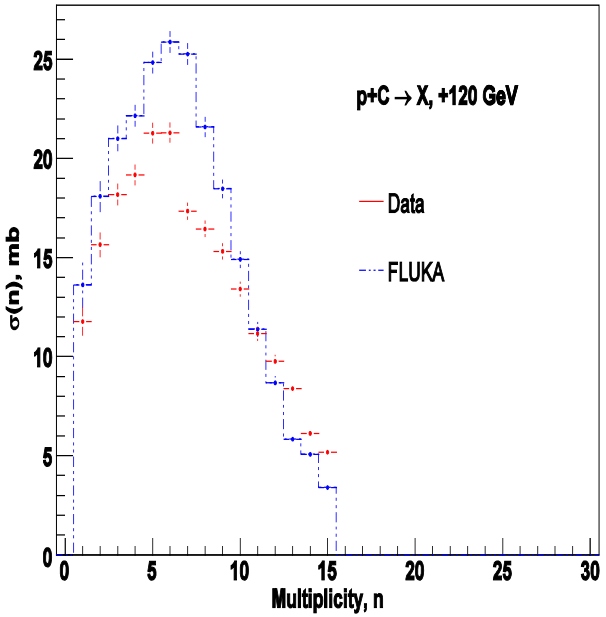




Comparison of MIPP data and MC cross sections using KNO-based trigger corrections



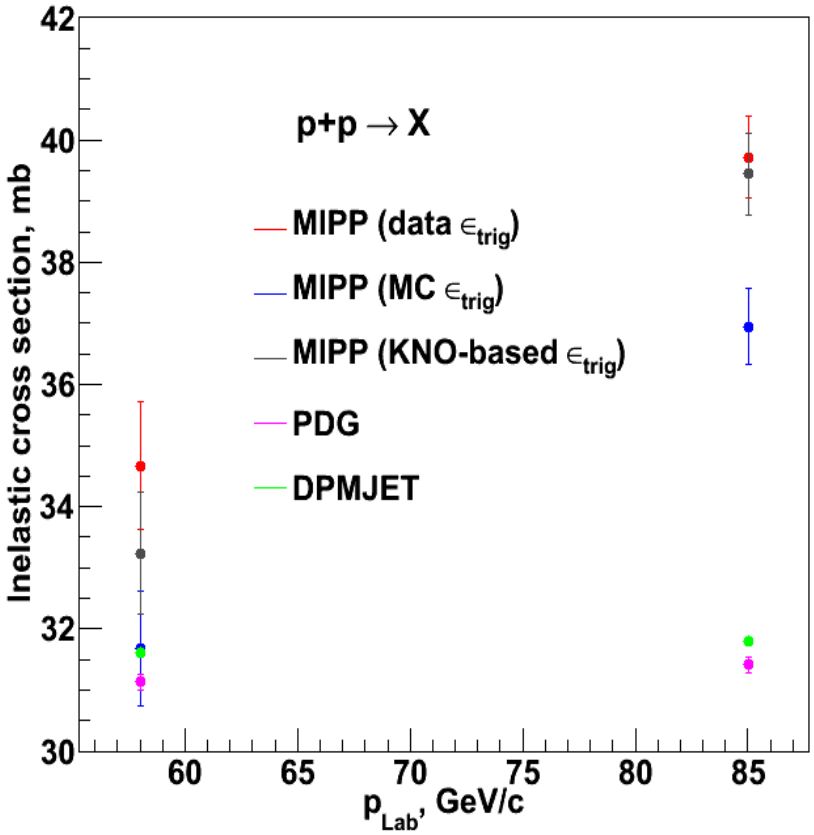


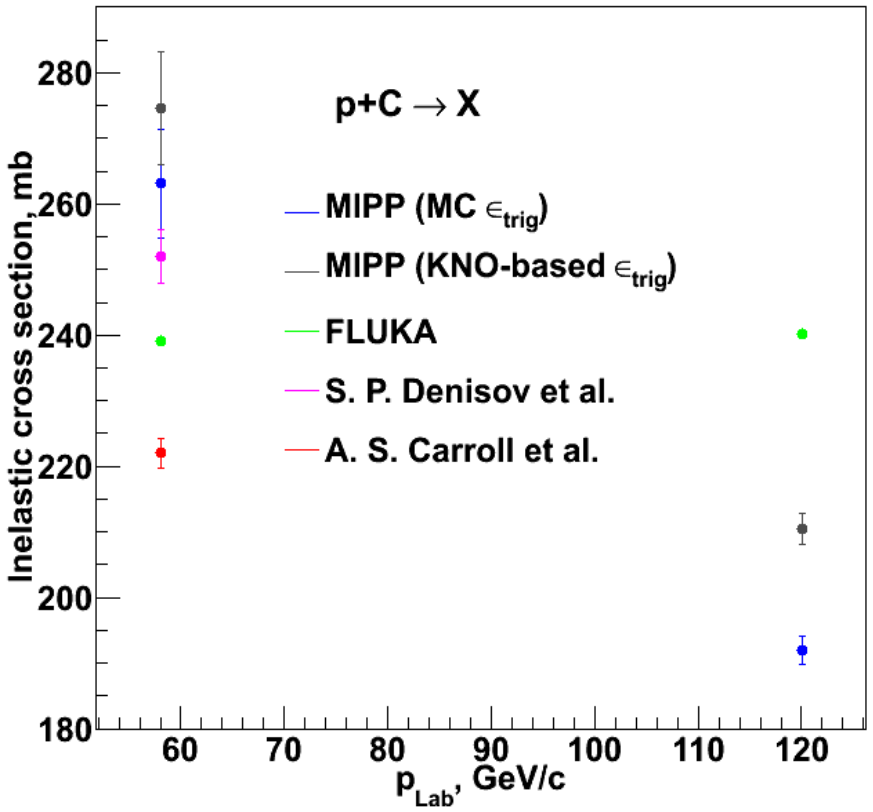


Inelastic cross section for p+p at 58 GeV/c = 33.24 ± 0.997(stat) ± 4.986(syst) mb
Inelastic cross section for p+C at 58 GeV/c = 274.51 ± 8.592(stat) ± 41.18(syst) mb
Inelastic cross section for p+C at 120 GeV/c = 210.47 ± 2.399(stat) ± 31.57(syst) mb

Discrepancies are found between the data and MC cross sections. Similar discrepancy was found between published data and DPMJET cross sections for pp interaction

Comparison of MIPP data cross sections with MC and other available cross sections



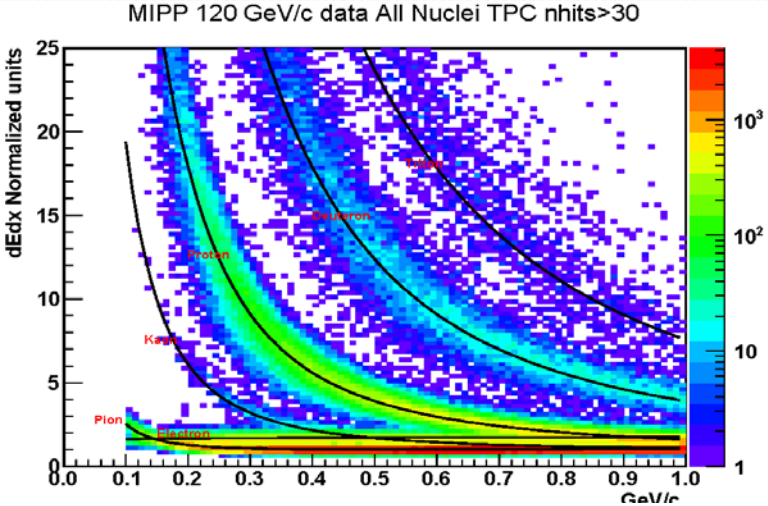


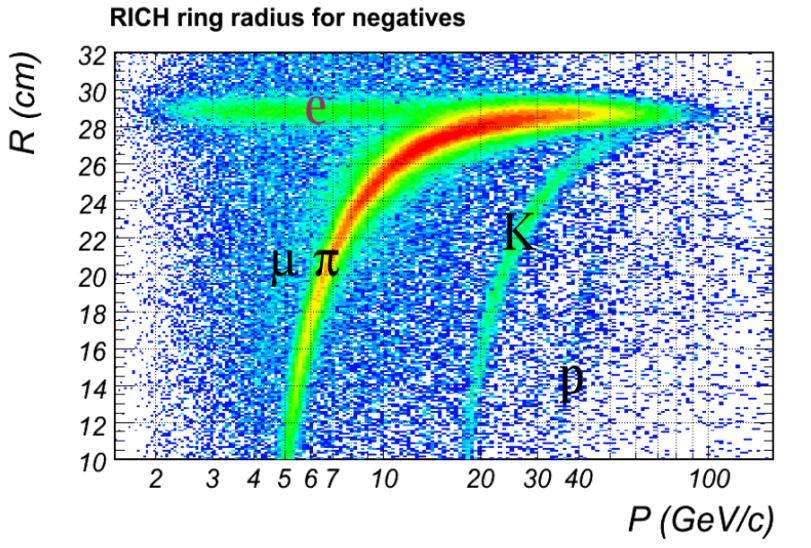
Summary

- ✓ Preliminary measurement of inelastic cross section for proton interaction at different beam energies with Liquid Hydrogen and Carbon target has been done
- ✓ Used KNO-based technique to get the trigger efficiency
- ✓ Compared MIPP data cross sections with MC and other available measurements
- ✓ Detailed study of systematic errors in progress
- ✓ Our next step will be the charged particle identification. $\pi^{\pm}$ and $K^{\pm}$ production cross sections as a function of p_T and x_F will be calculated
- ✓ Other analysis in progress: NuMI target analysis, K_S^0, Λ^0, $\bar{\Lambda}^0$ production, and cross section measurements from other targets

THANK YOU

Backup





TPC:

- dE/dx depends on the particle type
- From Bethe Bloch formula:

  $-dE/dx \alpha z^2/m_e\beta^2$
- Particle separation: 0.1 – 1 GeV/c

RICH:

- $\cos\theta_c = 1/n\beta$
- RICH rings are found and fitted to a circle of radius

  $R \sim \sqrt{2(1-1/n\beta)}$
- π/K/p separation above ~ 20 GeV/c
- e/μ/π separation up to 12 GeV/c