Main Injector Particle Production Experiment at Fermilab

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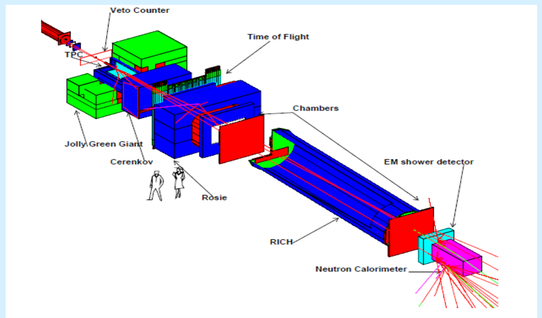
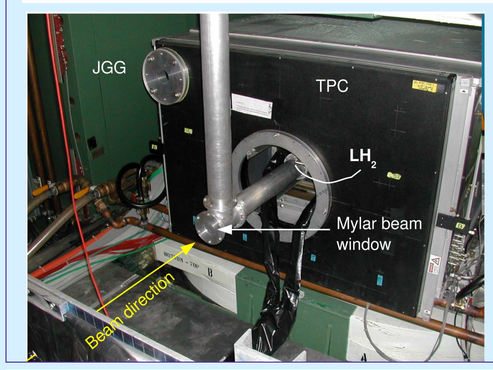
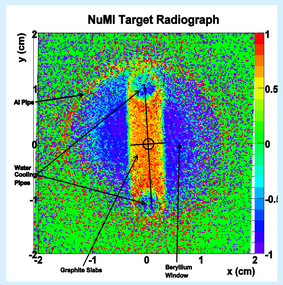
NuFact10

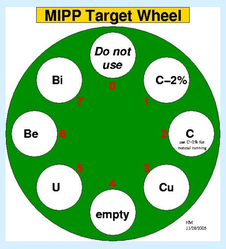
Introduction to the Experiment



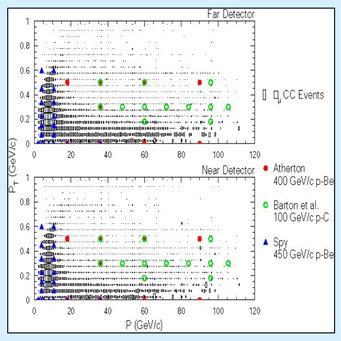


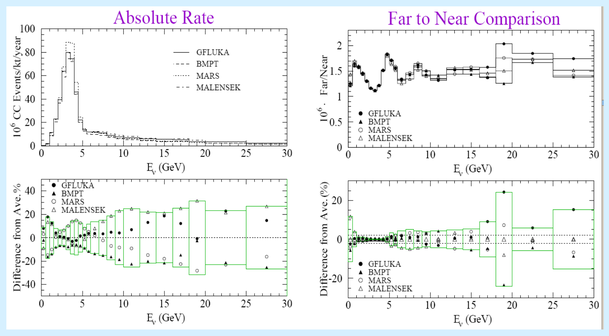
- MIPP is a hadron production experiment which uses 120 GeV/c Main Injector primary protons to produce secondary beams of π^+, π^-, K^+, K^-, p and $\bar{p}$ from 5 GeV/c to 90 GeV/c to measure particle production cross sections of various nuclei including hydrogen and NuMI target
- ***Full acceptance spectrometer***
- ***Excellent Particle ID (PID) separation***
  - TPC: up to 1 GeV/c
  - ToF: up to 2 GeV/c
  - Ckov: up to 17 GeV/c
  - RICH: up to 120 GeV/c





Motivation





- Previous experiments used single-arm spectrometers, giving only single (p,p_T) flux measurements
- Programs like Geant4, MARS, Fluka etc. model hadronic interactions based on available data
- **Most existing data are low statistics, with poor particle id, sometimes contradictory**
- Neutrino flux problems in NuMI, MiniBooNE, K2K, T2K, NOνA, MINERνA can be reduced to one problem: **the current insufficient state of hadronic shower simulators**

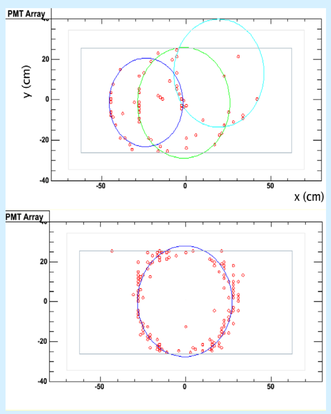
MIPP Detectors

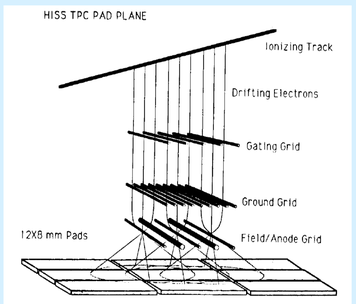
MIPP TPC:

- Particle tracks ionize P10 gas (10% Methane in Argon)
- Electrons drift in 10 kV electric field
- ***dE/dx depends on the particle type. From Bethe Bloch formula:***
  - ***$dE/dx \alpha z^2/m_e\beta^2$***
- 120 x 128 readout pads of 8 x 12 mm^2 area on bottom give position in x and z
- Drift time measurement gives y coordinate

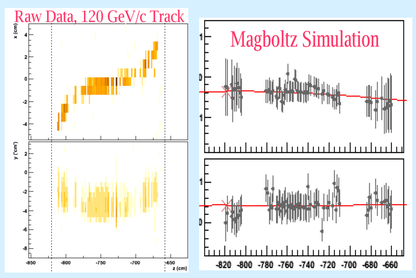
RICH:

- ***$Cos\theta_c = 1/n\beta$***
- **RICH rings are found and fitted to a circle of radius $R \sim \sqrt{2}(1-1/n\beta)$**



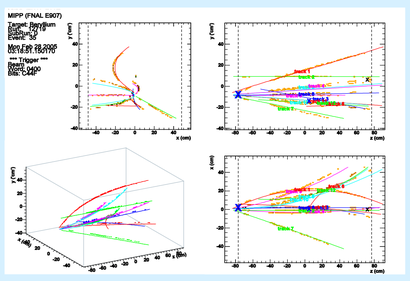


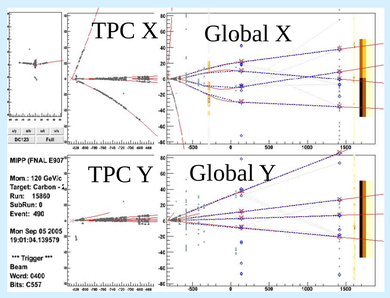
Track and Vertex Reconstruction



- JGG field is non-uniform. Huge ExB effect on electron drift in TPC
  - Distortions corrected using Magboltz simulation

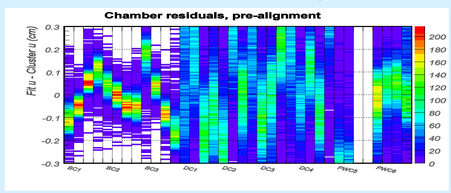
- MIPP TPC - Reconstructed tracks

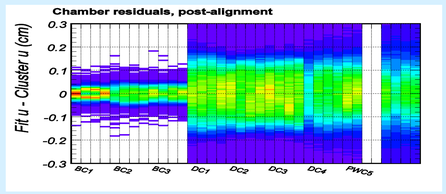


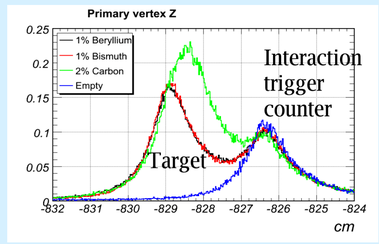


- Reconstructed p+C 120 GeV/c event

- Drift chambers are aligned on a run-by run basis

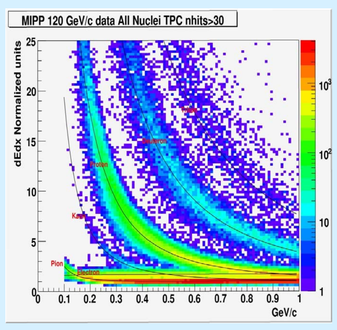






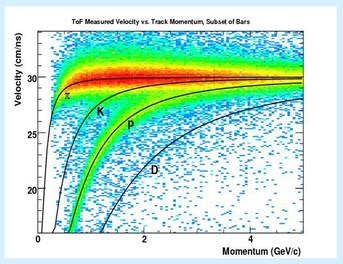
- Vertex resolution
  - Z resolution ~ 6 mm
  - X, Y resolution < 1 mm

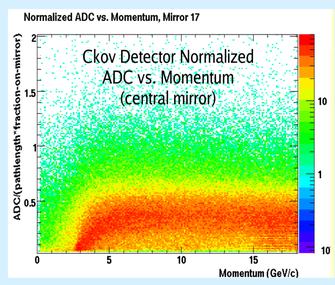
Particle Identification



- ❖ Separation of particles in momentum range 0.1 - 1 GeV/c
- ❖ <dE/dx> resolution ~12%

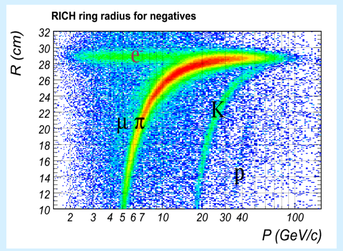
- ❖ Time-of-flight system calibrated and gives expected β vs. p distributions
- ❖ π/K/p separation in momentum range ~0.5 - 2 GeV/c





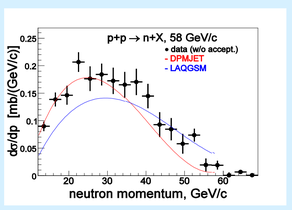
- ❖ Cherenkov detector gives:
  - π identification for $2.6 < p < 9$ GeV/c
  - p identification for $9 < p < 17$ GeV/c

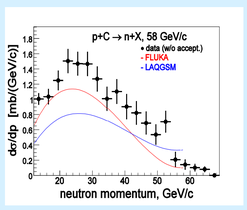
- ❖ RICH ring radii distributions give clean separation of π, K and p above ~20 GeV/c and e/μ/π up to 12 GeV/c



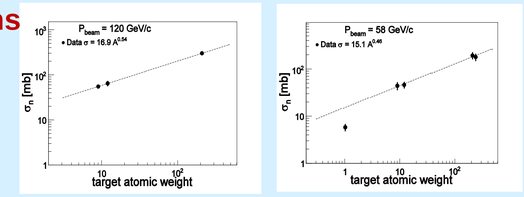
Recent Results

Forward neutron inclusive cross-sections



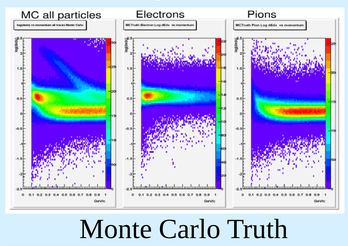


Measured cross-sections from this experiment compared with predictions from Monte Carlo

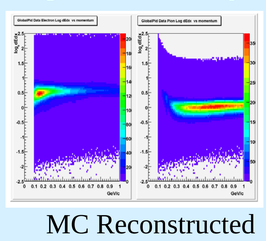


Neutron production cross sections from MIPP as a function of target atomic weight A

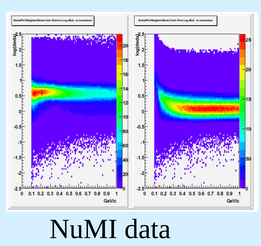
Preliminary results from NuMI target data Analysis



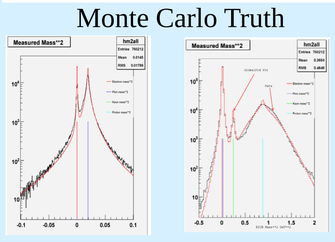
Monte Carlo Truth



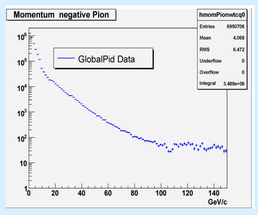
MC Reconstructed

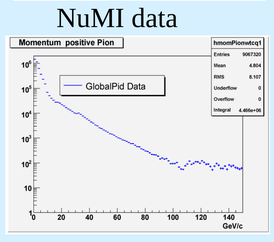


NuMI data



Comparison of Global Pid fits with data





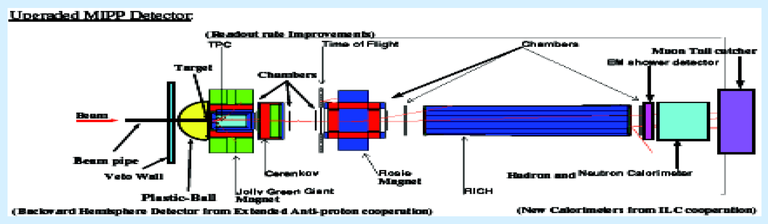
NuMI target analyzed by Global Pid

Future Analyses

- ❖ NuMI target analysis (See Preliminary Results, close to completion) *
- ❖ Production cross sections for 20, 58, 85 GeV/c π, K and p on LH_2 target and also thin targets C, Be, Bi and U *
- ❖ Neutral Kaon Production cross-sections
- ❖ Testing the "Scaling Law" of inclusive cross-sections
- ❖ Provide data for studies of non-perturbative QCD
- ❖ Investigate light meson spectroscopy, missing baryon resonances

* ***Analyses are in progress***

MIPP Upgrade



- ➢ Current experiment is limited by DAQ rate, dominated by the TPC readout rate (~30 Hz). An upgrade of the TPC electronics, using the ALICE ALTRO chip, can increase this readout rate by up to 100x.
  1100 chips have been delivered from CERN
- ➢ ***Jolly Green Giant Coil replaced and installed***
- ➢ Further upgrades include wire-chamber electronics upgrade, improved interaction trigger, recoil detector, addition of large veto wall, and an improved beamline
- ➢ Physics at Beam energies of 1 GeV/c up to 120 GeV/c
- ➢ Expanded run plan would support US and world-wide neutrino program by including more data on the MINOS/NOvA and C and Be targets, as well as cross-section measurements for ***Hg and N_2 targets*** which will be of importance to the **Muon Collider/Neutrino Factory and INO respectively**
- ➢ Significantly help Hadron Shower Simulation Programs

- ➢ ***MIPP welcomes new institutions to join the upgrade effort!***

Under India-Fermilab Neutrino Collaboration

NuFact10, 20-25 October, TIFR – Mumbai, India