



Main Injector Particle Production Experiment

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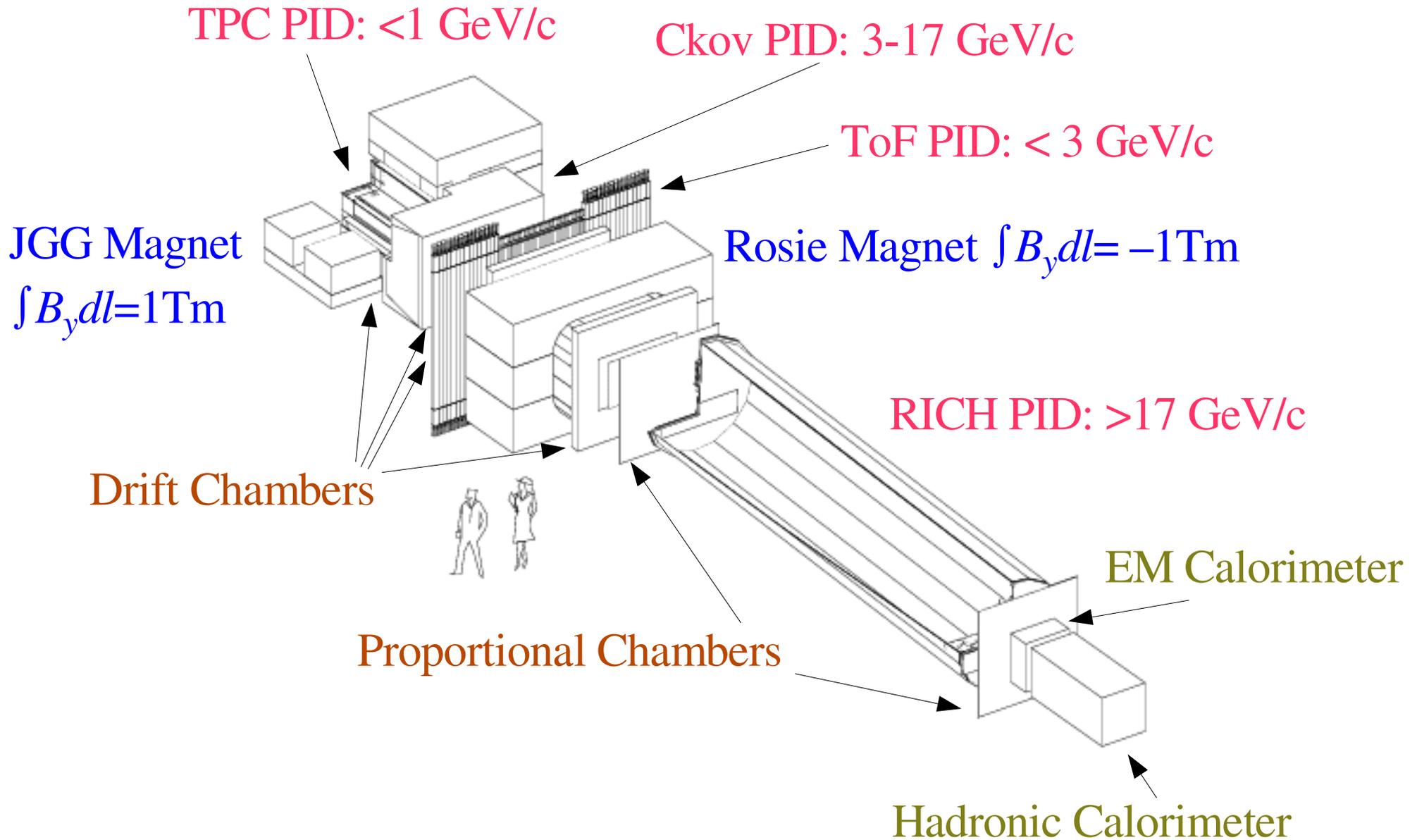


Overview

- MIPP (FNAL-E907) is a large acceptance spectrometer to measure hadronic particle production
 - TPC and wire chambers to measure track parameters
 - TPC dE/dx , ToF, differential Cherenkov and ring imaging Cherenkov give $\pi/K/p$ separation up to 100 GeV/c
- Primary 120 GeV/c beam from the Main Injector
- Secondary beam of tagged π^\pm , K^\pm , p^\pm from 5 to 85 GeV/c
- Collected 20M triggers on cryogenic H_2 , Be, C, Bi, U, and NuMI target



Spectrometer Geometry

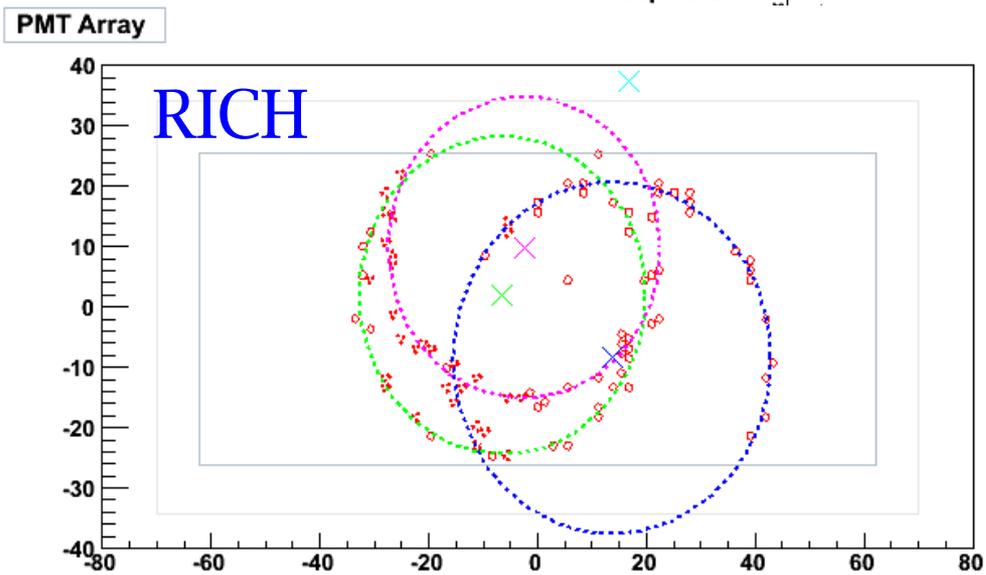
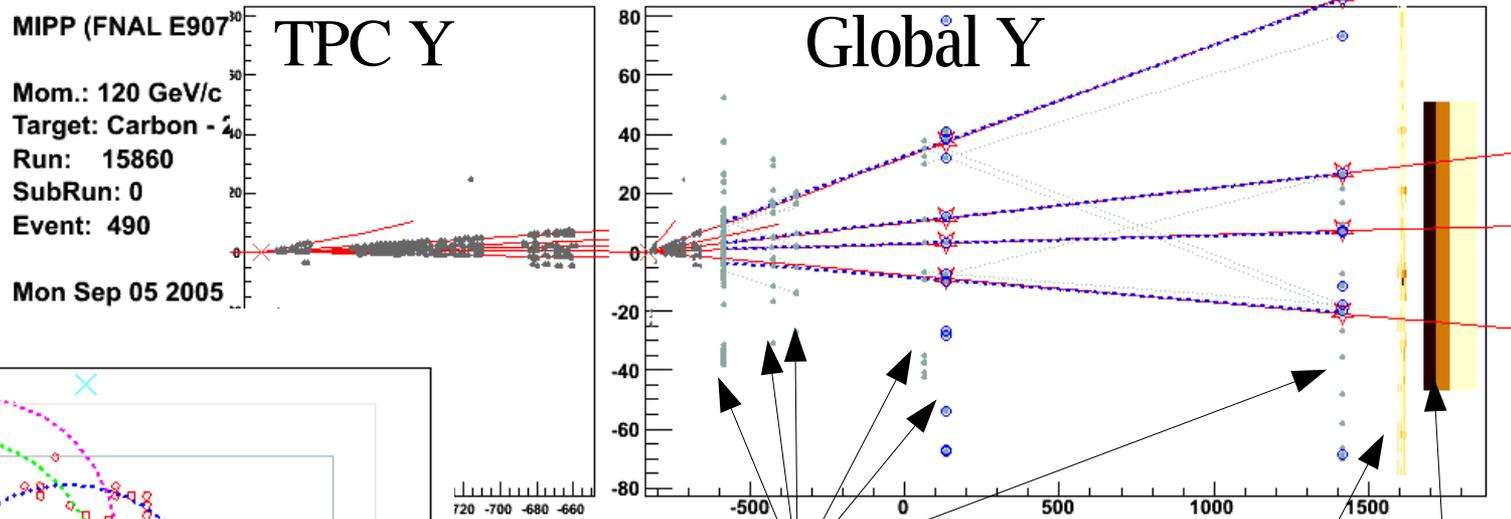
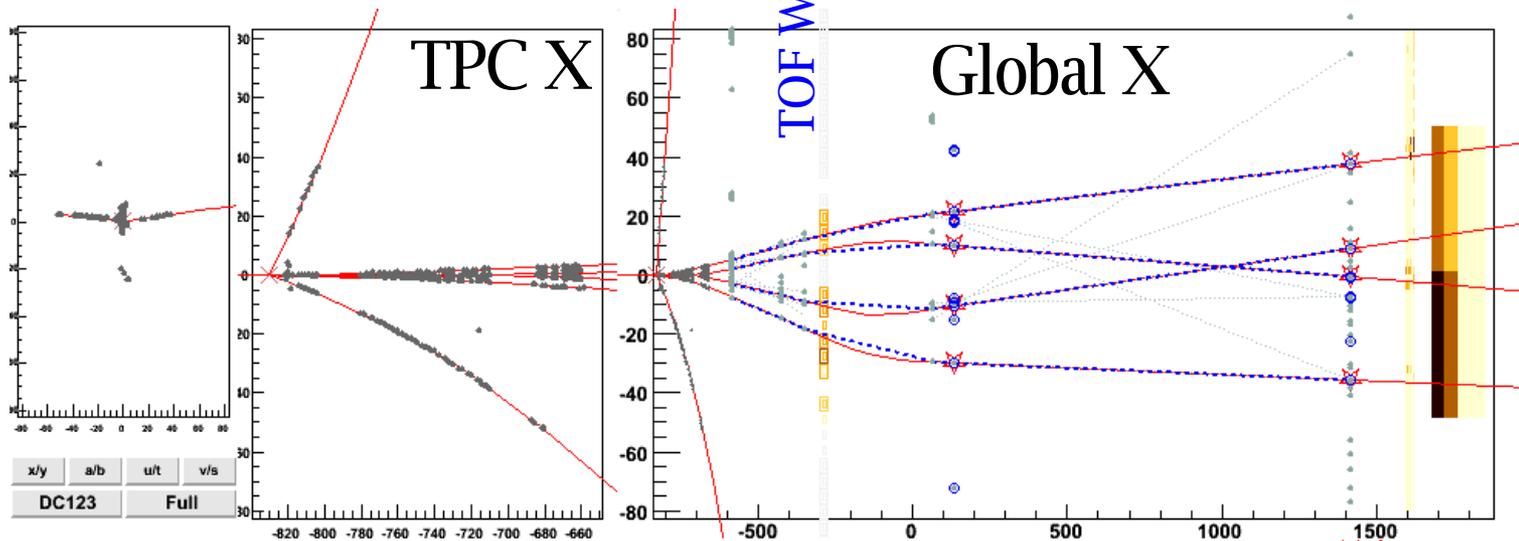




MIPP Physics

- Hadronic production cross section measurements
 - Improve hadron shower models in Fluka, Geant4, MARS
- Non-perturbative QCD
 - Particle fragmentation scaling laws can be probed in 36 reactions
- Service measurements
 - Proton radiography, stockpile stewardship
 - Particle flux from NuMI target
 - Reduce uncertainty of MINOS neutrino flux prediction

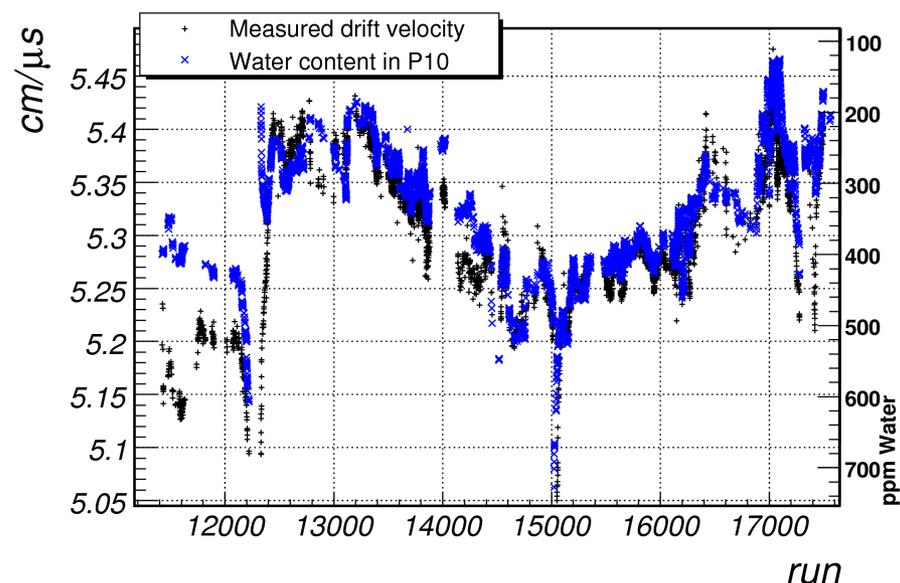
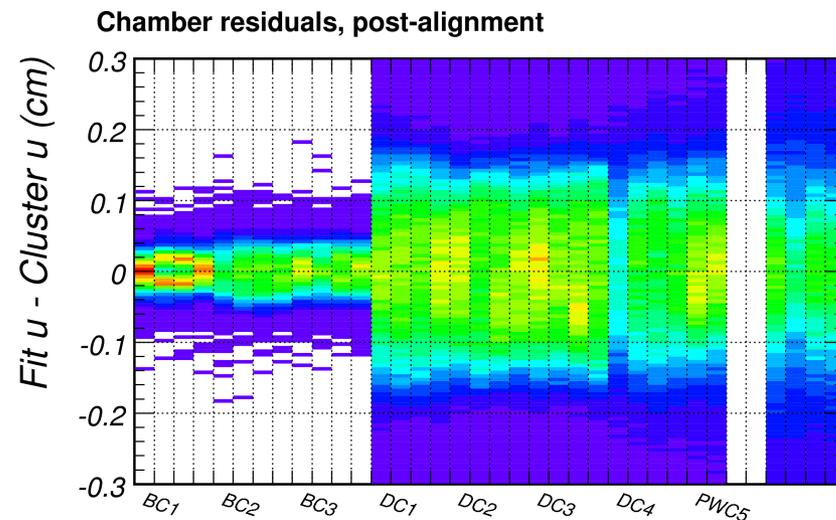
Reconstructed Proton-Carbon at 120 GeV/c Event





Spectrometer Calibration

- Chamber alignment done for every run
 - Helped to find bugs in geometry description and refine magnetic field maps
- TPC electron drift velocity measured for every run
 - Strong correlation with water vapor contamination

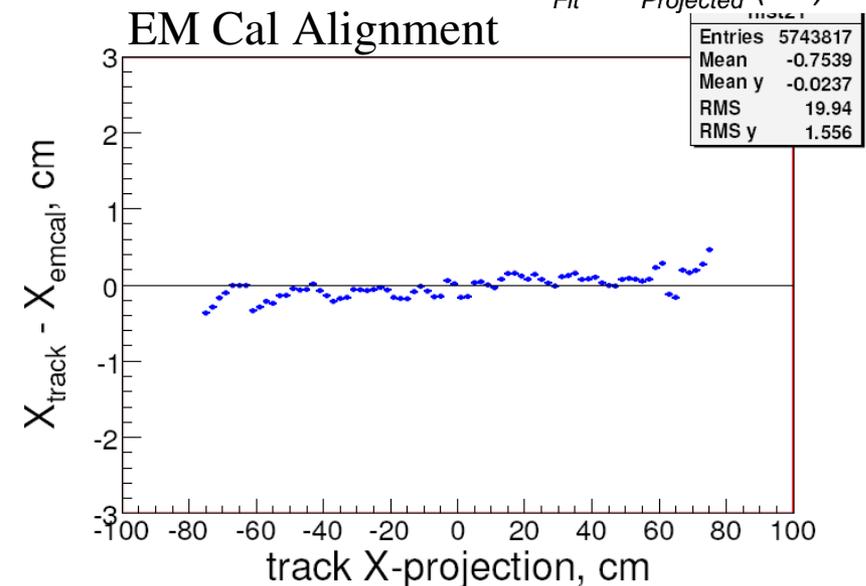
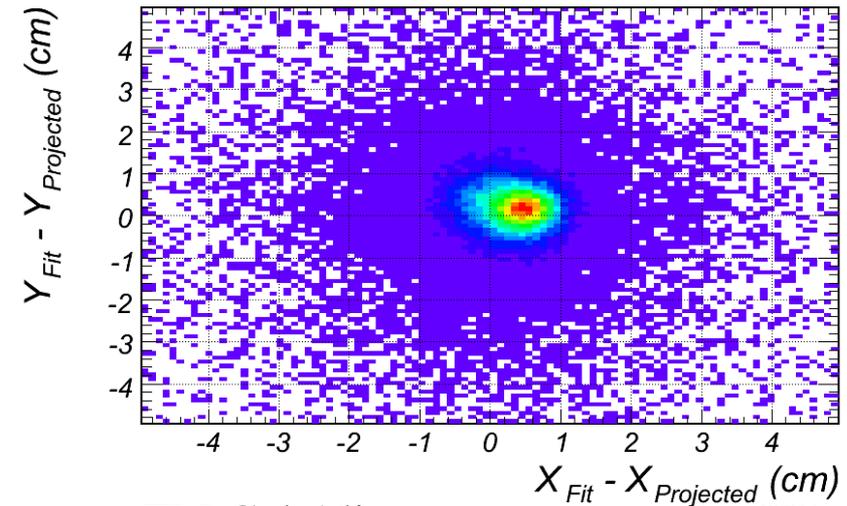




Calibration (cont.)

- Global tracking is used to
 - Align the RICH
 - Align EM calorimeter
 - Compute drift attenuation in the TPC
 - Compute ToF cable delays
 - Calibrate Ckov light output
 - Calibrate RICH index of refraction
- Calibration to be completed within 2 weeks

RICH Ring Center Shift, before alignment





Event Reconstruction Summary

- Track reconstruction
 - Form hits in TPC, find tracks and fit to helices
 - Match TPC tracks to chamber hits, fit using track template method
- Vertex reconstruction
 - Find vertices using Deterministic Annealing Filter (DAF)
 - Make vertex constrained fits using track templates
- Particle identification
 - Compute TPC dE/dX , track ToF, Cherenkov likelihood
 - Match tracks to RICH rings and compute likelihoods
 - Match tracks to calorimeter showers

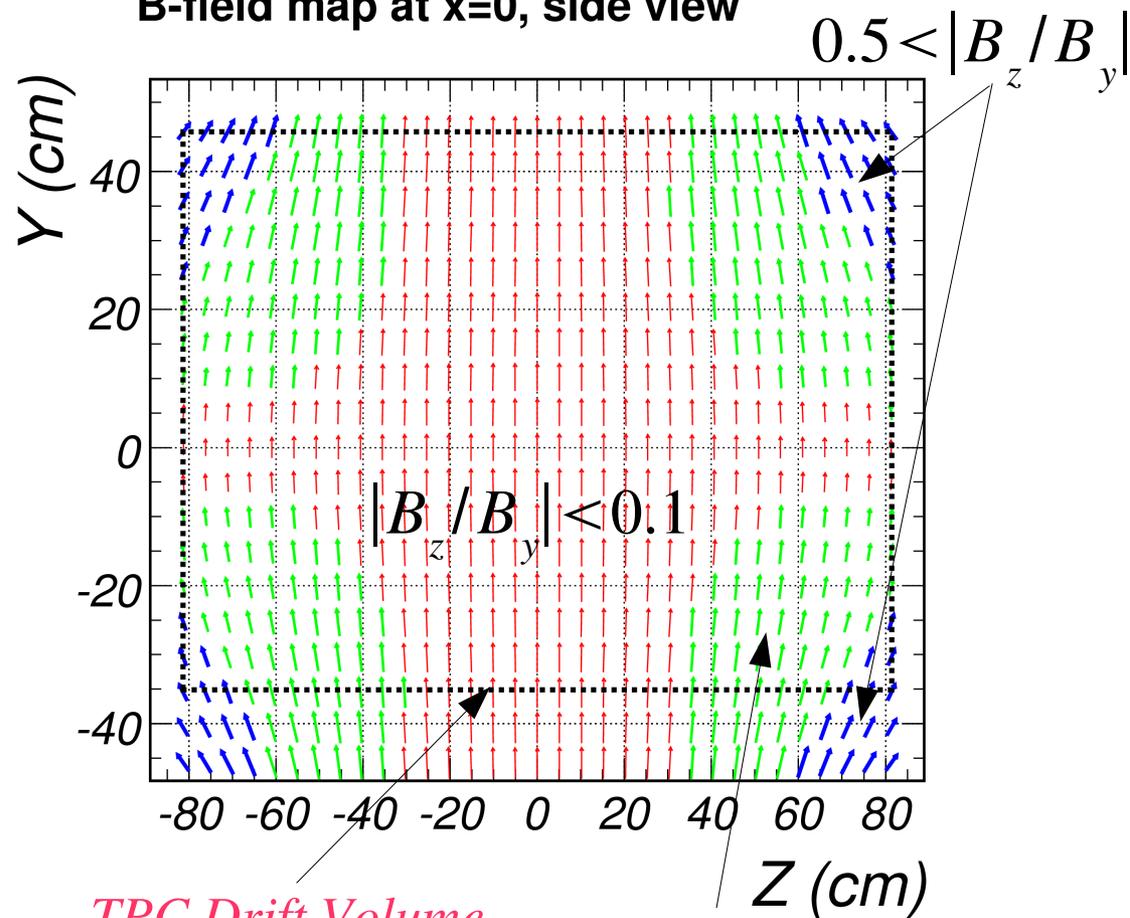


TPC Hit Reconstruction

- JGG field is non-uniform
 - Enormous effect on electron drift in Ar/CH₄
- Previous experiments applied corrections based on steady state solution to linear model

$$m \frac{d\vec{v}}{dt} = e \vec{E} + e \vec{v} \times \vec{B} - \frac{1}{\tau} \vec{v}$$

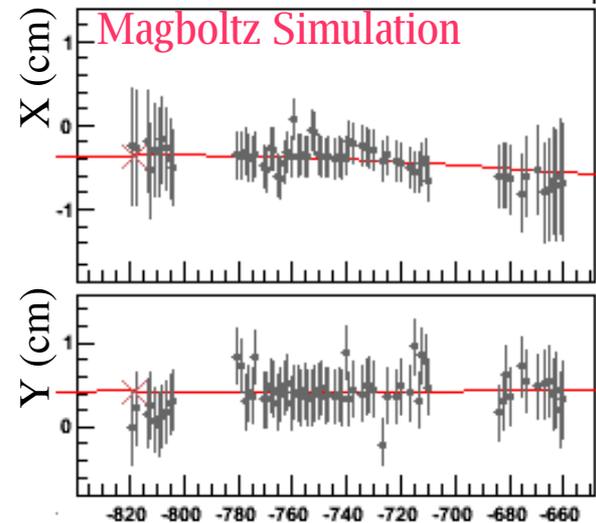
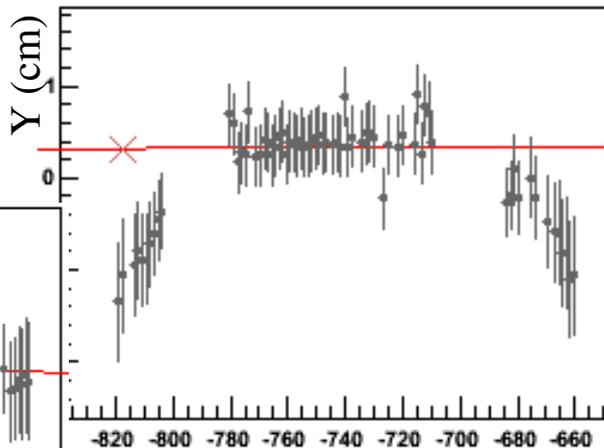
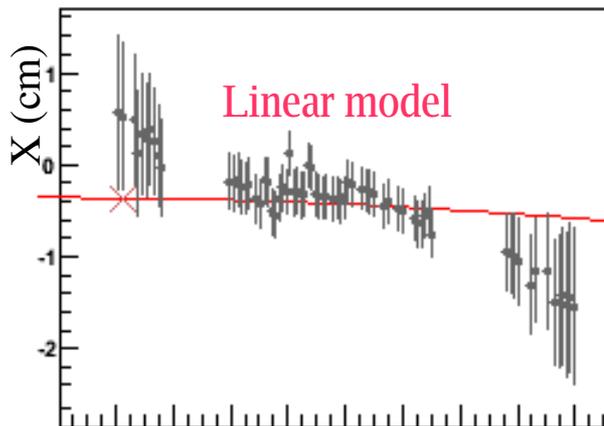
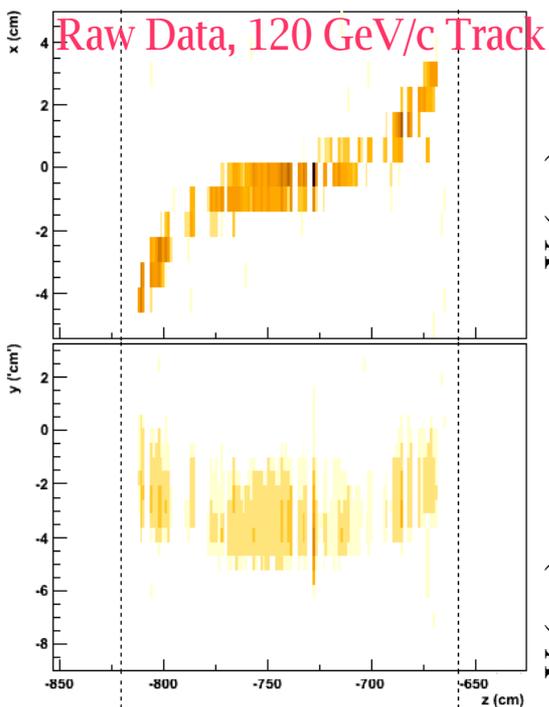
B-field map at x=0, side view



$$0.1 < |B_z / B_y| < 0.5$$



TPC Hit (cont.)

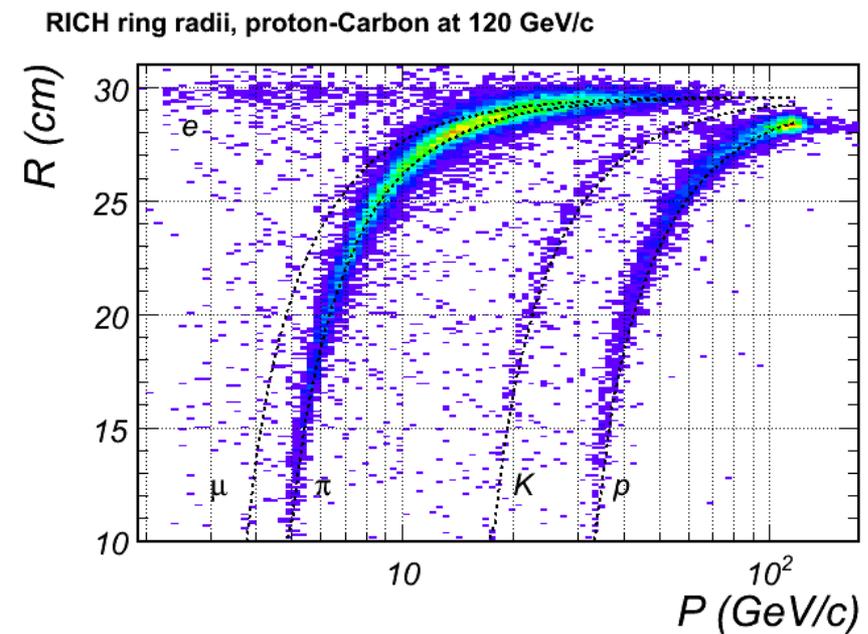
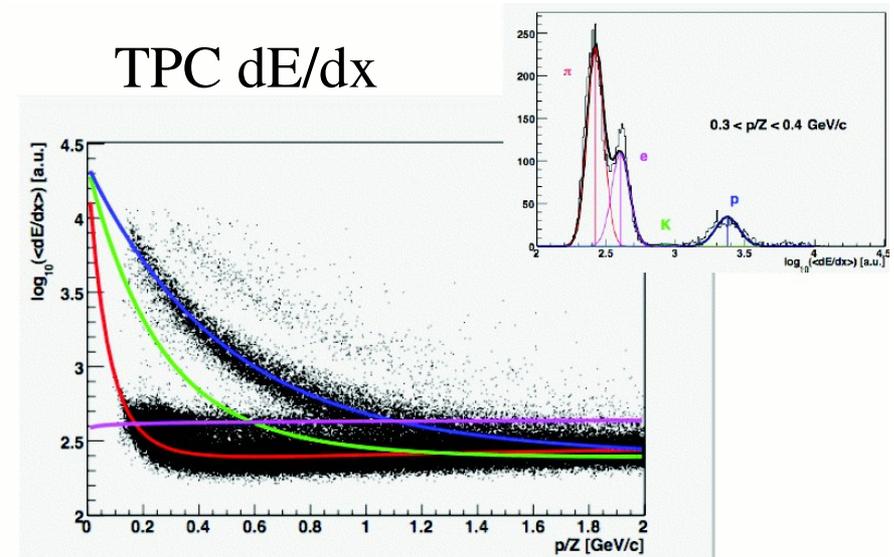


- Linear model fails to describe electron drift
- We use Magboltz simulation to map out drift velocity components as a function of v_0 , B-field strength, and angle between E and B-fields
- Good agreement with TPC data



Particle ID status

- TPC dE/dx calibration is in progress,
 - Results to-date are promising
- TOF cable delays to be determined soon
- Cherenkov light calibration is largely done
- RICH calibration and likelihood calculation are nearly complete





MIPP Analyses In Progress

- These projects are under way, expect results in 2-3 months
 - Target fragmentation multiplicities
 - HBT effect
 - Soft pion production cross sections
 - π/K production ratio on carbon at 120 GeV/c
 - π/K production ratio on NuMI target
 - K^+ mass (dedicated 17M beam $\pi/K/p$ triggers)
- Many more projects available: new collaborators are welcome!



Upgrade Proposal

- Current data rate limitation is ~ 30 Hz due to TPC electronics
- Upgrade electronics to get 3 kHz data rate
 - TPC with ALICE ALTRO chips – prototype boards in the works
 - New electronics for drift chambers and proportional chambers
- New silicon pixel interaction trigger
- Add recoil detector
- New JGG coils (better field uniformity) – to be delivered in May
- Improve beamline design to get 1-85 GeV/c secondary momenta
- Strong support from FNAL



Upgrade Physics

- More statistics for existing data sets
- Other neutrino experiment targets
 - NOvA, T2K, ...
- Production cross sections on liquid N₂
 - Atmospheric neutrino and cosmic ray experiments
- Variety of nuclear targets to get uniform coverage in A
- Test beam for calorimeters
 - Minerva, ILC, ...
- Target and beam requests by new collaborators!



Summary

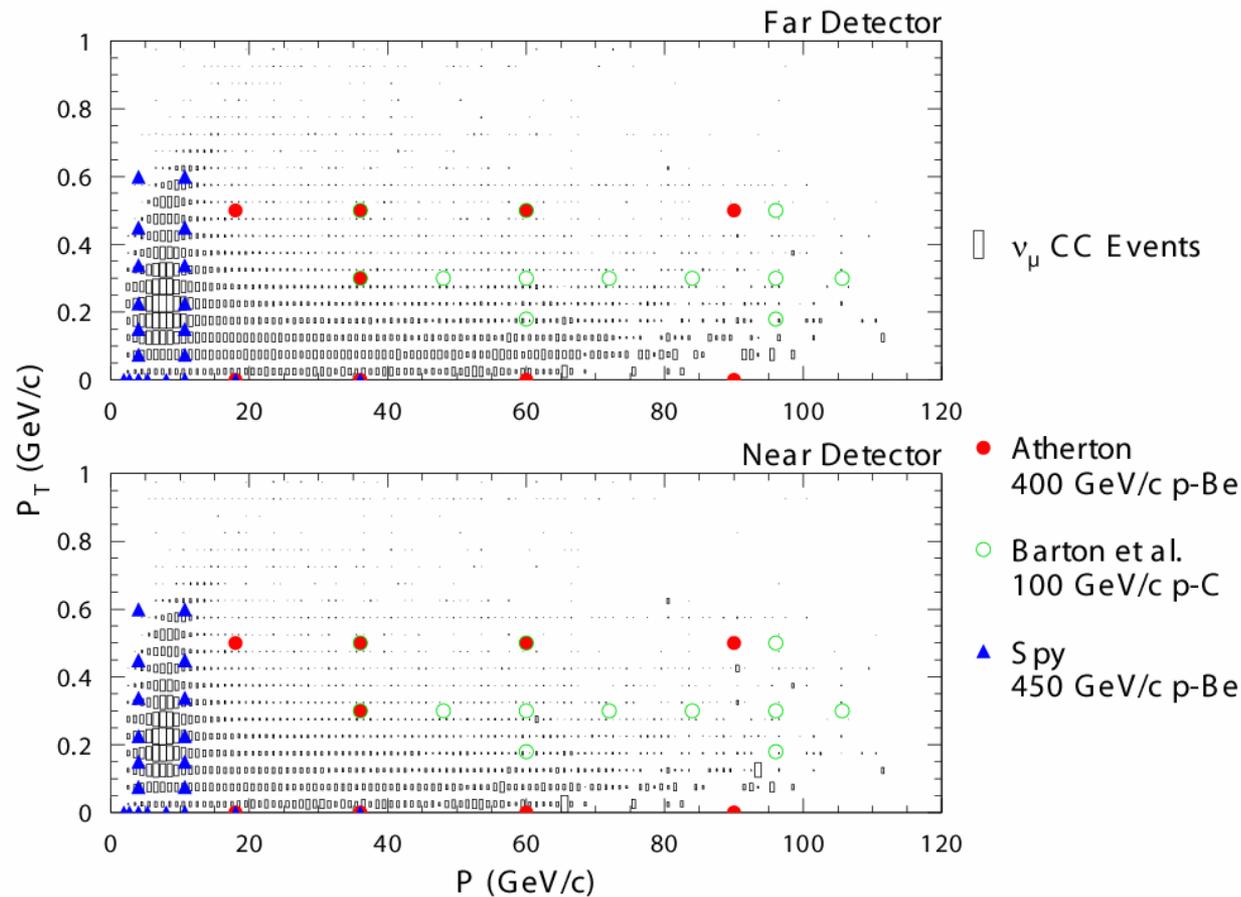
- MIPP gathered 20M triggers of hadronic interactions
 - Unique data set that covers a range of physics topics
- Collaboration made a lot of progress in understanding our data and the spectrometer
 - Data summaries to be produced shortly
 - Expect first results from analyses in the summer
- Upgraded experiment can improve statistics and cover a broader range of physics topics



Backup Slides



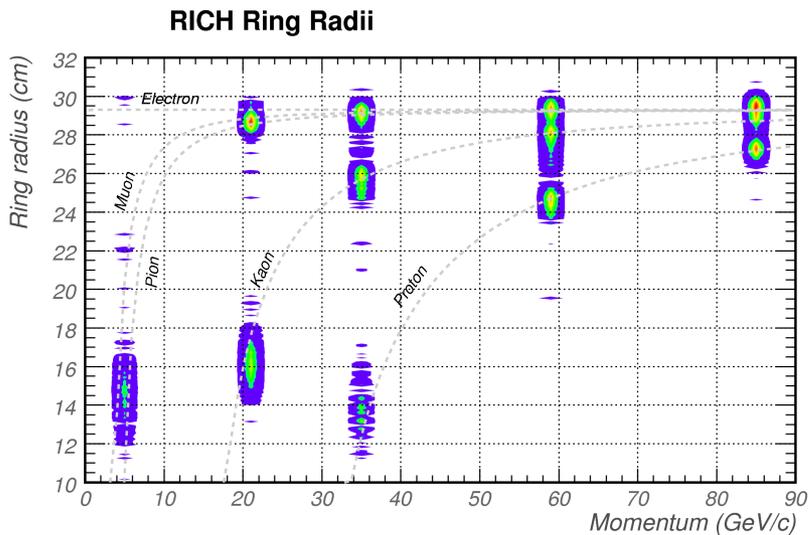
Motivation for NuMI/MINOS



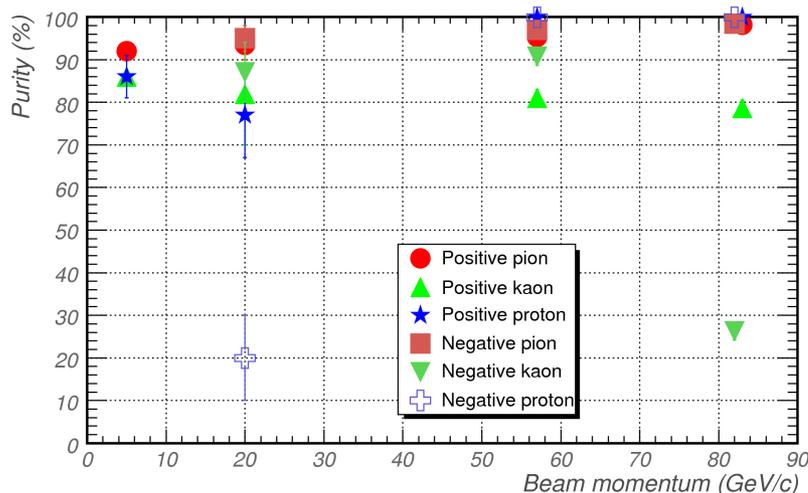
- Single-arm spectrometer data provides spotty coverage of pion production
- NA49 published pC at 158 GeV/c
 - hep-ex/0606028



Secondary Beam Particle ID



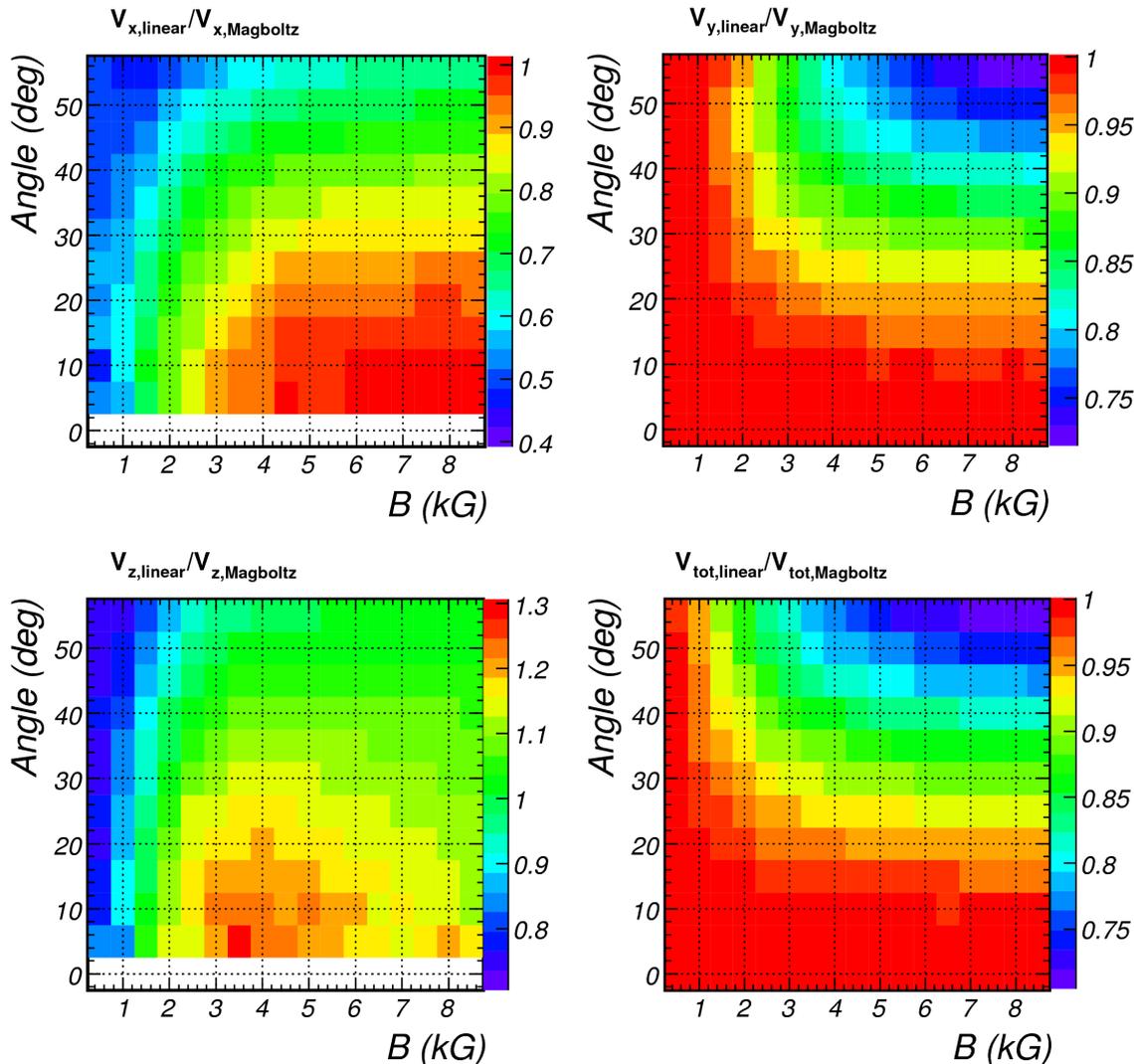
Trigger purity determined by RICH ring radii of beam particles



- 2 beam Cherenkov threshold counters separate $\pi/K/p$ from 20 to 90 GeV/c
 - N_2 for momenta above 30 GeV/c
 - C_4F_8O for proton at 20 GeV/c
- Trigger purity measured with the RICH is typically above 80% for minority particle



Linear Drift Model vs Magboltz



- Magnetic field inside the TPC varies from 3.5 to 8 kG
- The angle between E and B fields goes up to 50 degrees
- Difference in drift velocity components reaches 30%
 - With 5 cm correction that's 1.5 cm!