Status of the MIPP Experiment

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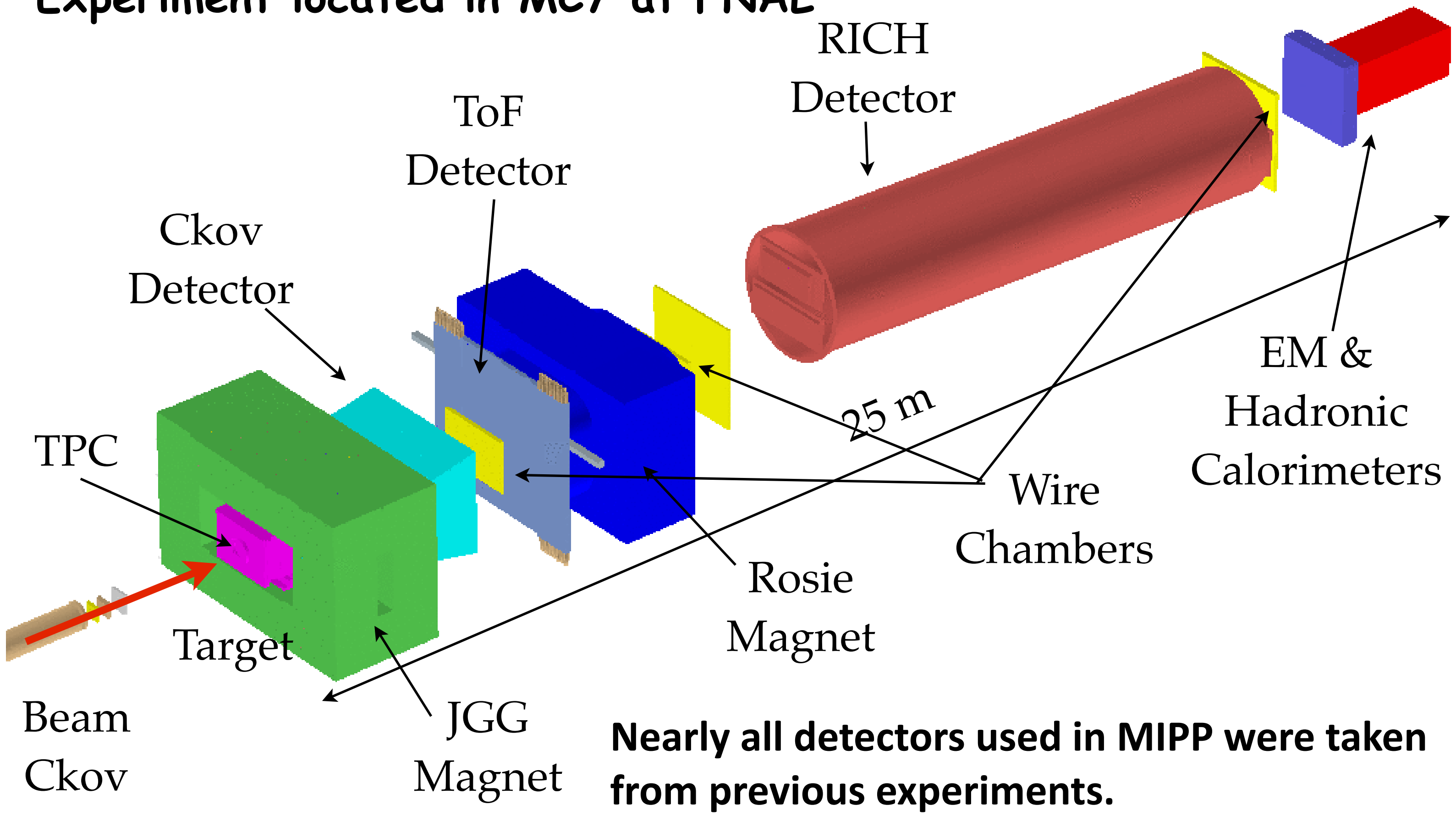
Main Injector Particle Production (MIPP) Experiment

Experiment located in MC7 at FNAL

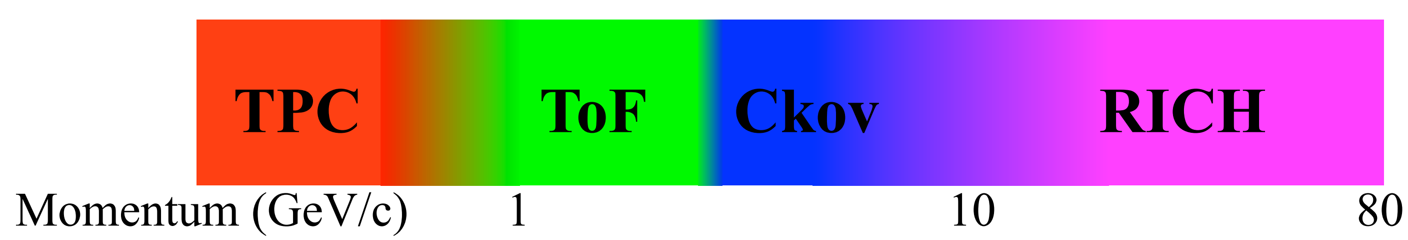


Nearly all detectors used in MIPP were taken from previous experiments.

- Goal: collect comprehensive hadron production cross-section data set with particle id using various beams and targets (thick and thin).

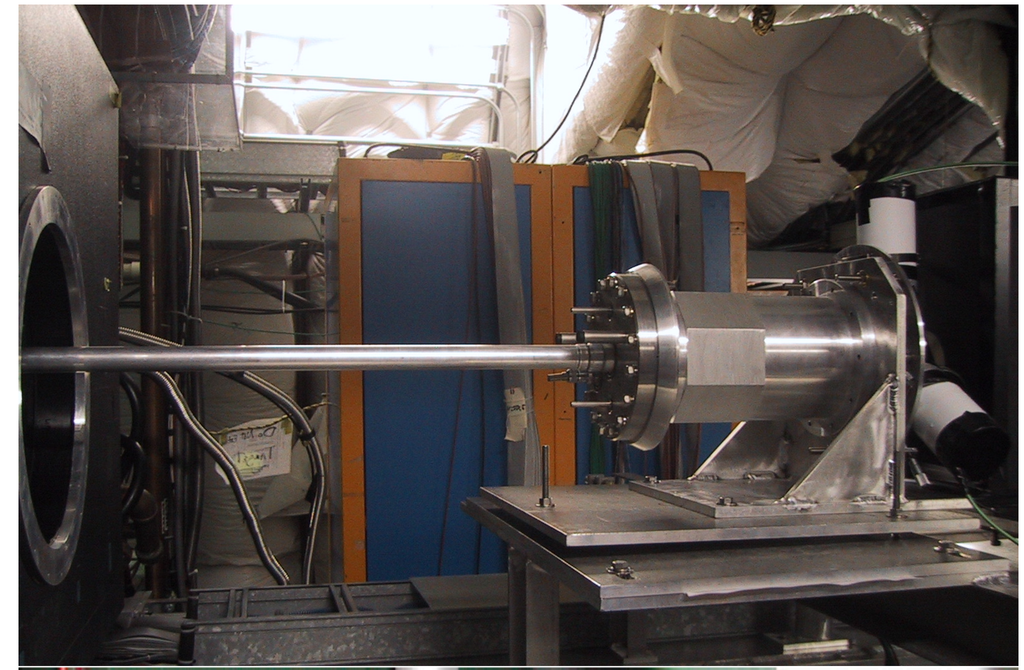
- Full acceptance spectrometer
- Two analysis magnets deflect in opposite directions
- TPC + 4 Drift Chambers + 2 PWCs

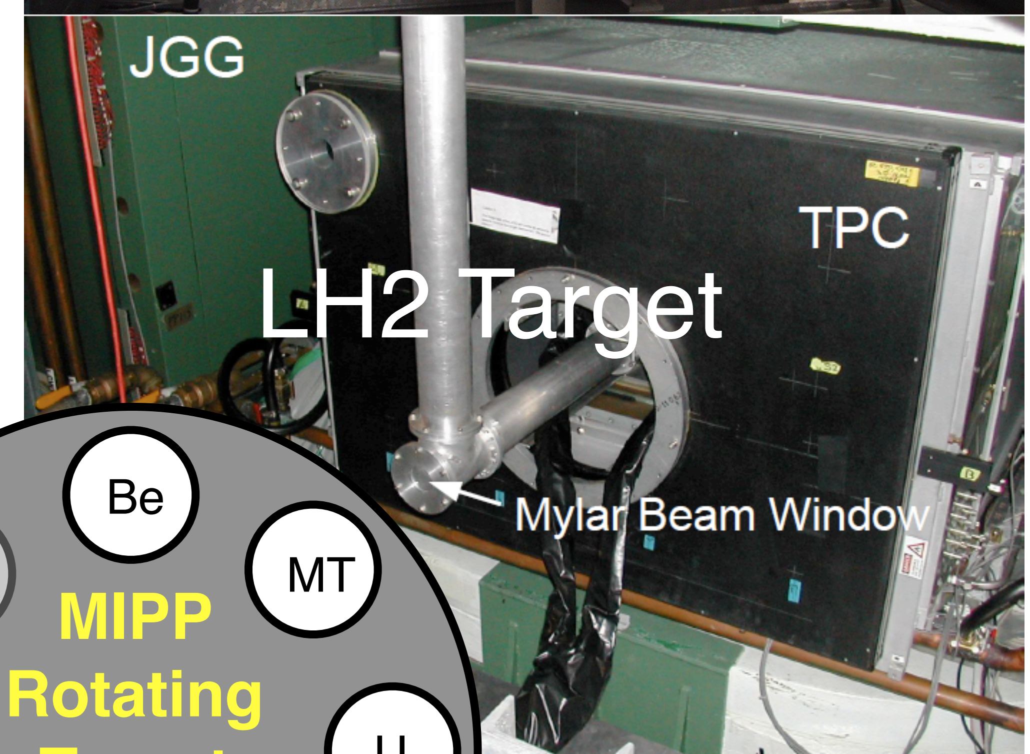
- Designed for excellent particle ID (PID) separation (2-3σ)

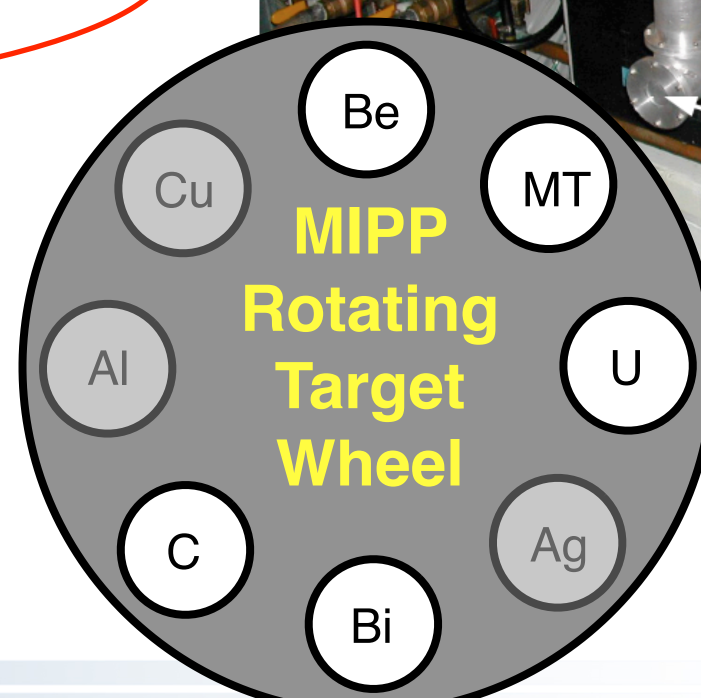


The 2005-06 Data Run

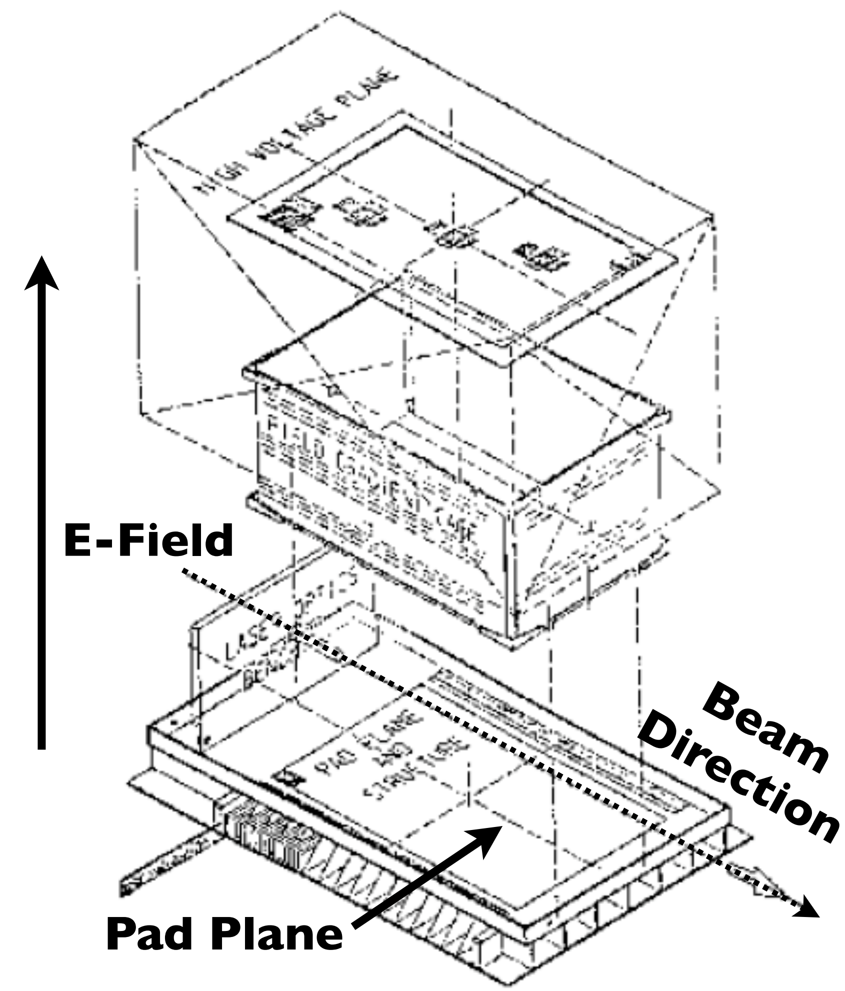
- MIPP began its physics run in December 2004 and ran until February 2006.
- DAQ rate was ~25 Hz, with MIPP receiving ~5% of MI beam.
- Data collected:
- ~1.6 x 10^6 events of Main Injector 120 GeV/c protons on a spare NuMI target.
- ~3.2 x 10^6 π's, K's and p's at 120, 60, 35 and 20 GeV/c on 1-2% λ_L C and Be targets.
    - ~7 x 10^6 π's, K's and p's at 85, 60, 20 and 5 GeV/c on 1% λ_L LH2 target.
    - ~4 x 10^6 π's, K's and p's at 35, 60 and 120 GeV/c on Bi and U targets.





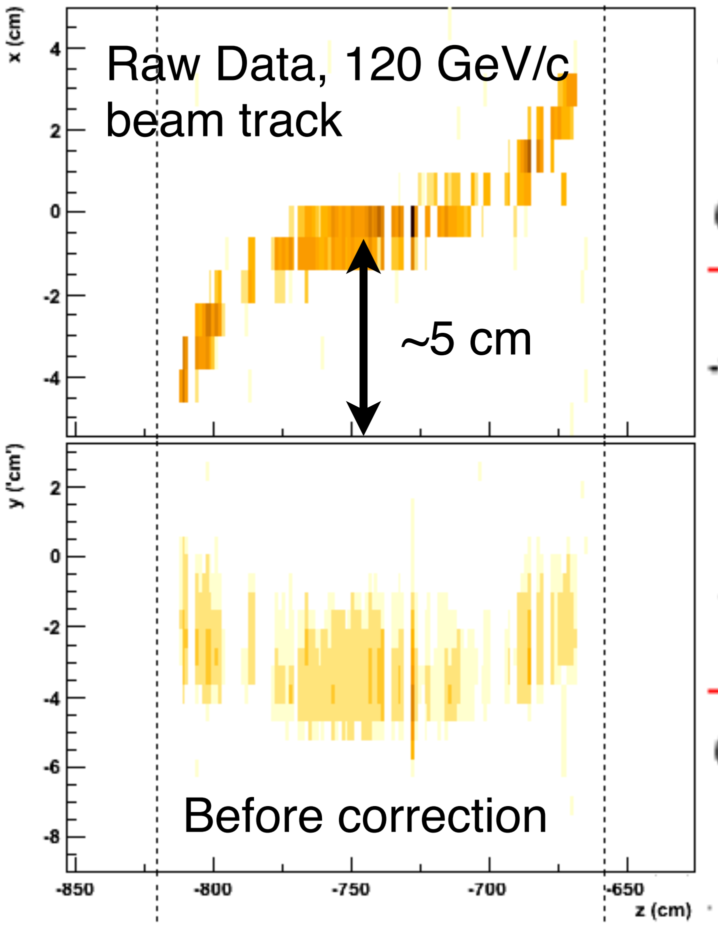


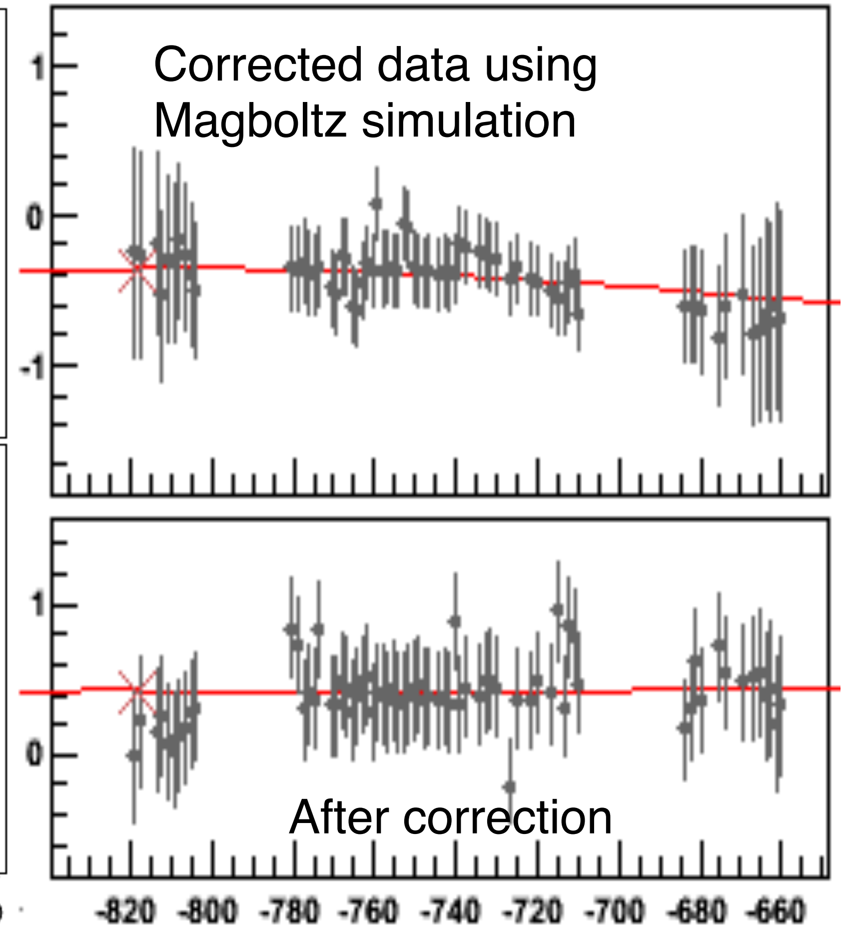
Time Projection Chamber (TPC)

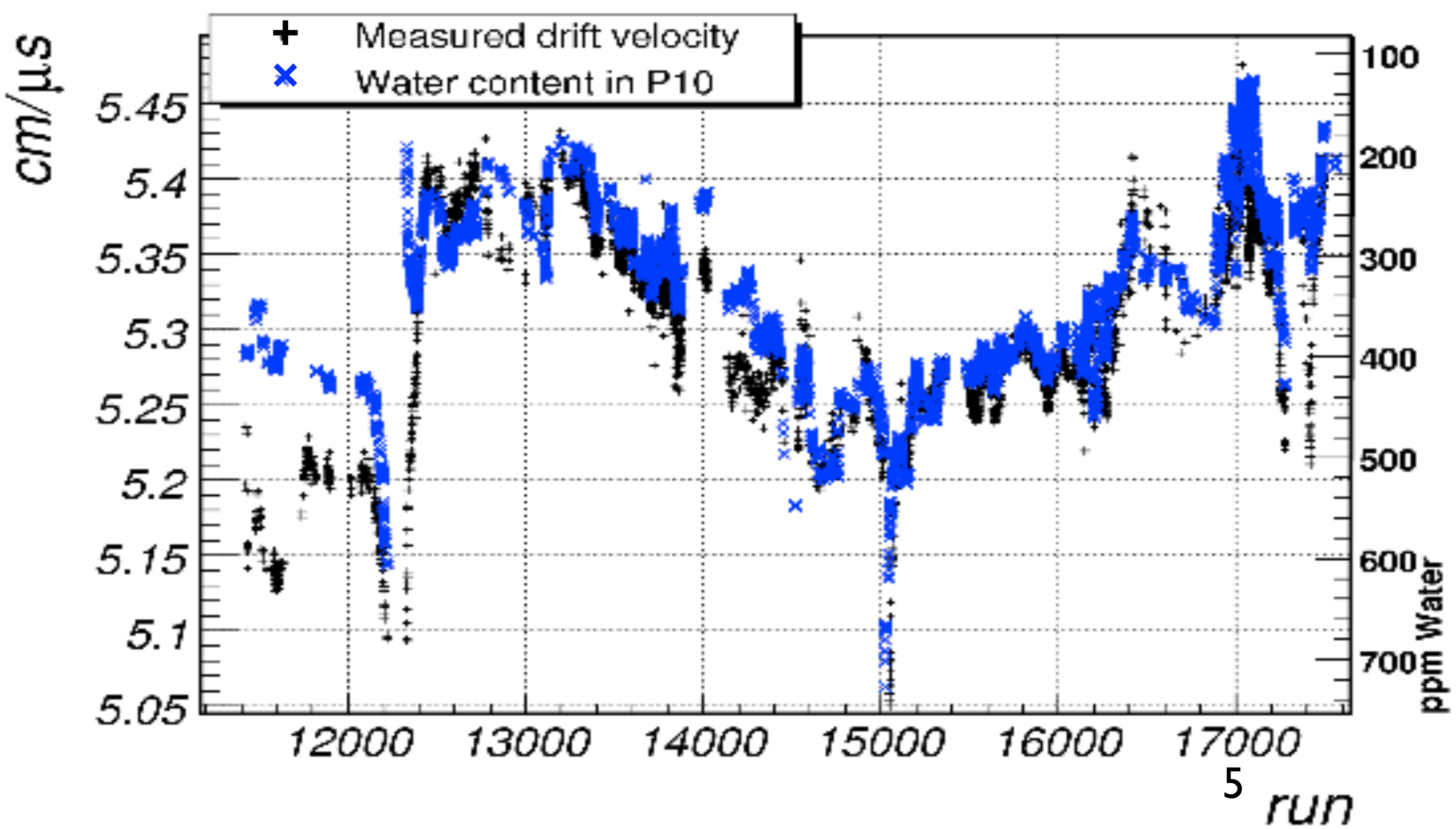


- Centerpiece of MIPP, originally built for the EOS experiment and used in several other prior experiments.
- Measures track trajectory in 3D: (x,z) position → pad locations, y position → drift time.
- Active volume of ~1 m^3 and a resolution of ~0.5 cm^3.
- PID via <dE/dx> below ~1 GeV/c.

TPC Calibrations

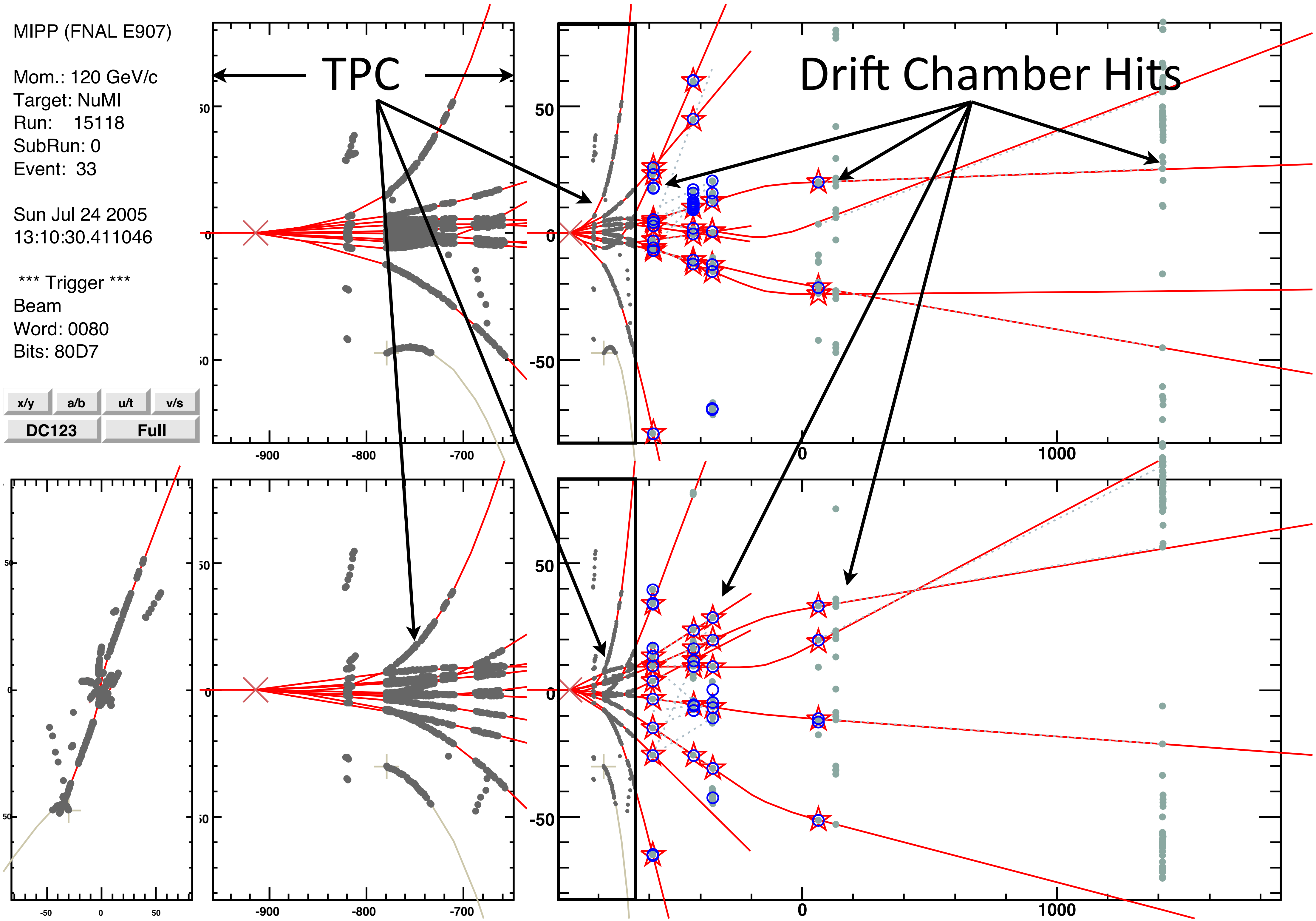






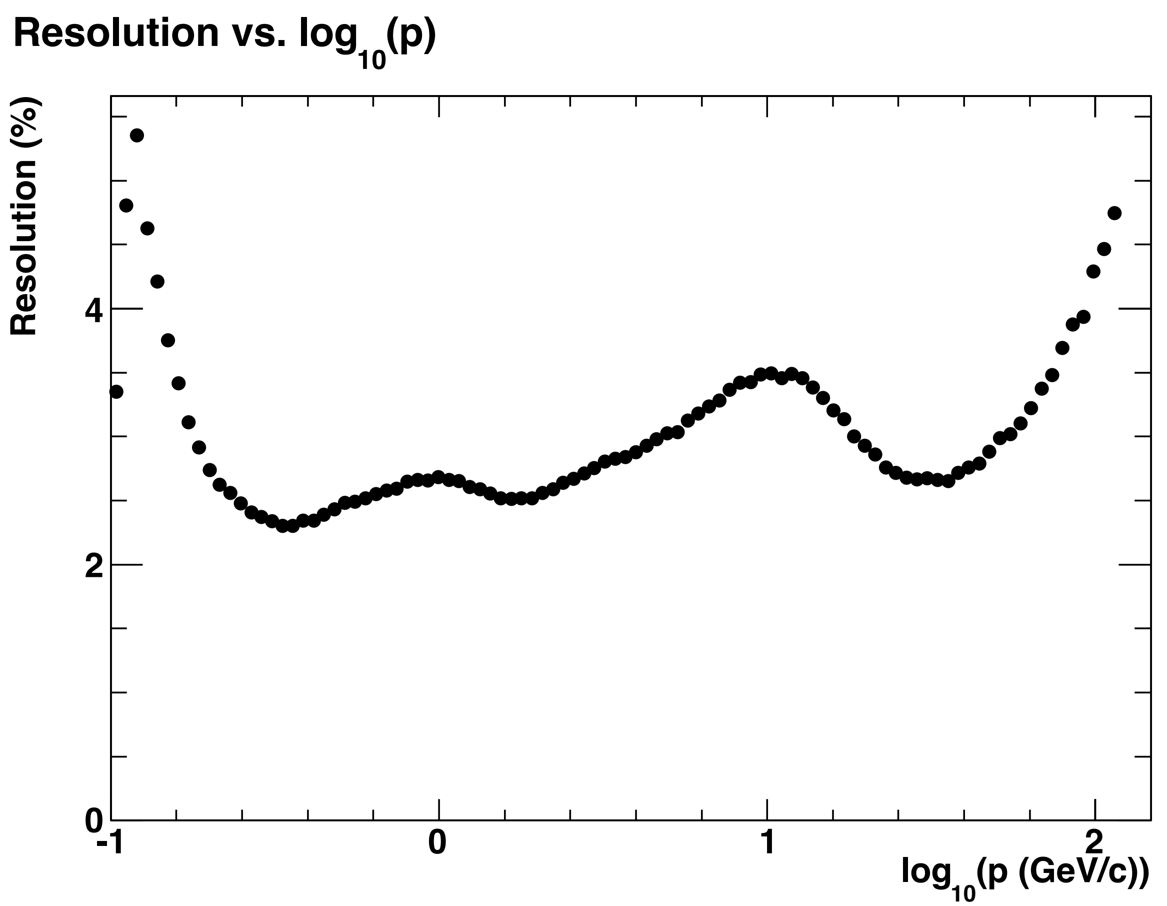
- Inhomogeneous magnetic field causes drift electrons to deviate from straight-line path to pad plane on bottom on TPC. Deviations of up to ~5 cm are observed!
- Using a map of the magnetic field and the Magboltz simulation, we correct these ExB drift effects to the level of ~90% (~2 mm worst case).
- Electron drift velocity is found to be run/time dependent: sensitive to the water contamination in the P10 gas!
- Time-dependent corrections to the drift velocity are made and $\delta v_D / v_D$ ~ 1%.

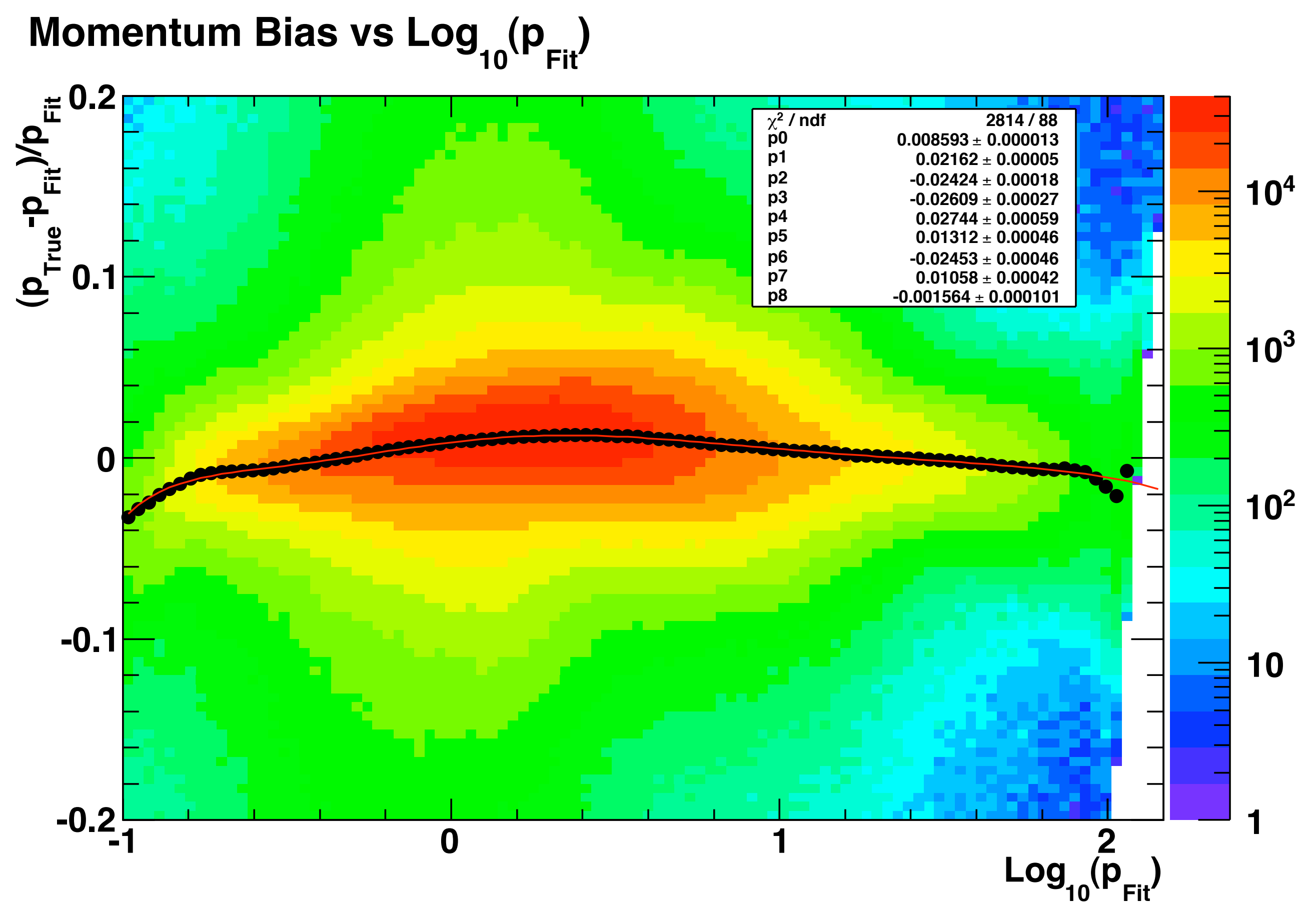
Global Track Reconstruction



TPC track segments are matched to downstream drift chamber hits, momentum is determined from bend in both magnets.

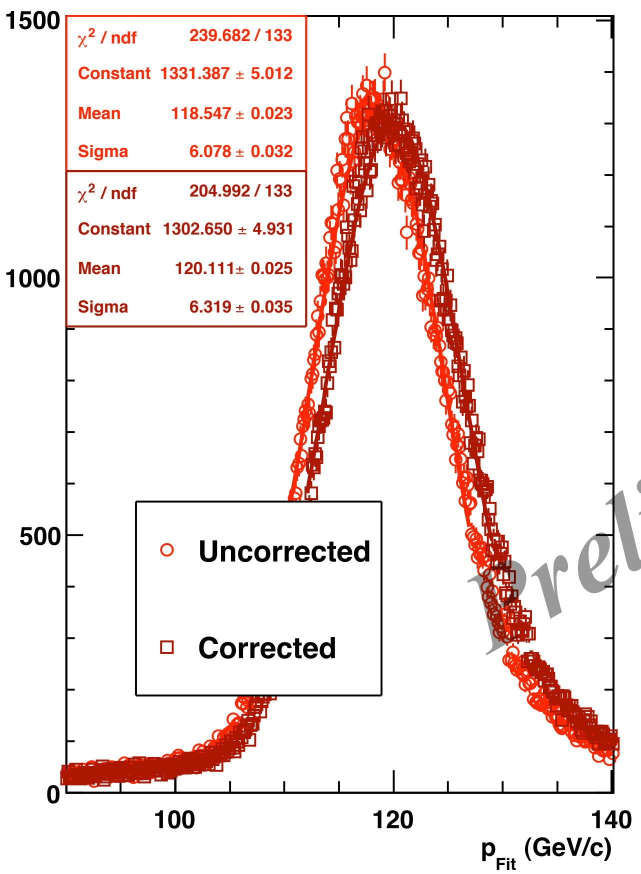
Momentum Resolution and Bias

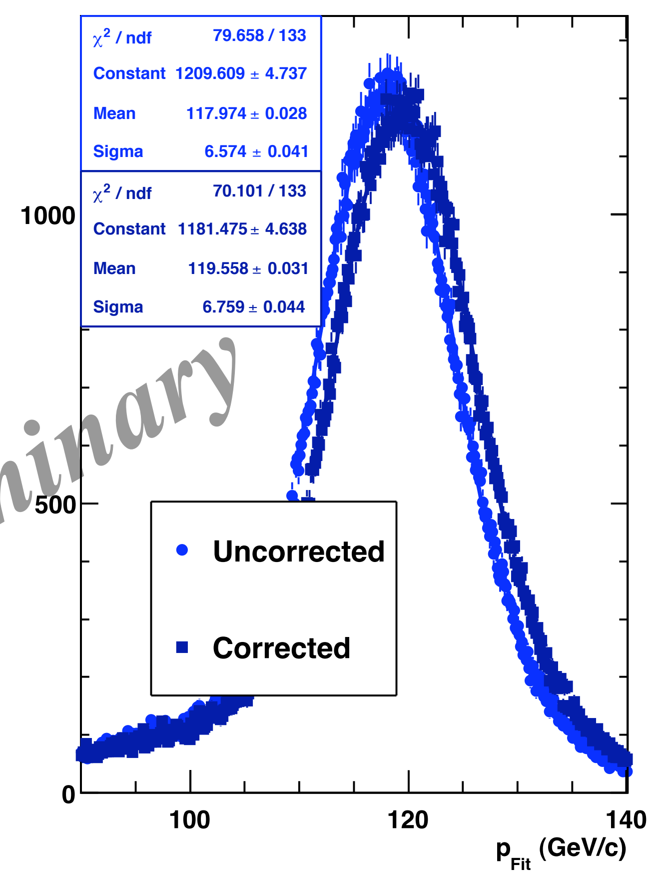


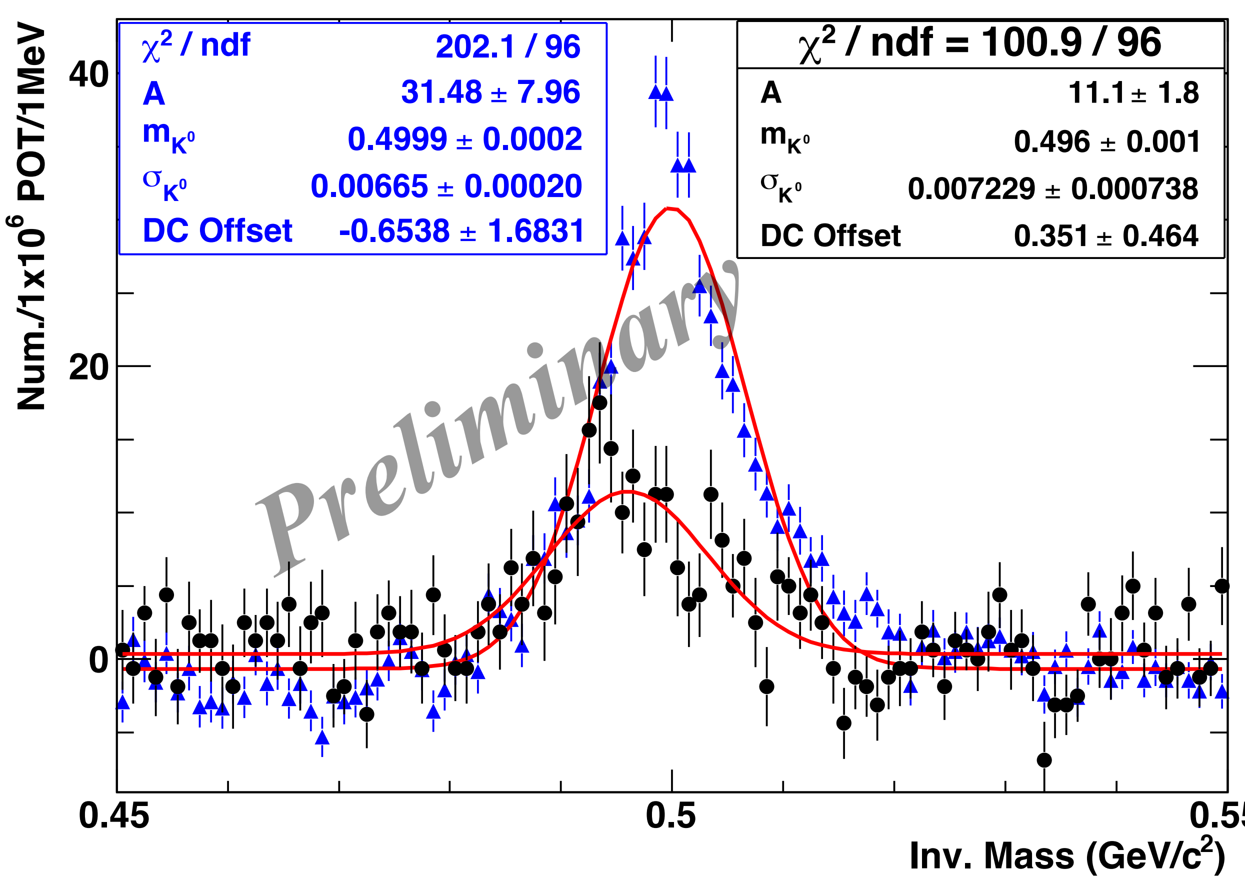


- Black points determined by fitting central peaks of slices of dp/p to Gaussian.
- Momentum resolution is < ~5%
- Bias < ~2%. Correction is applied and has a very small uncertainty.
- Transverse momentum resolution is < 0.02 GeV

Absolute Momentum Scale

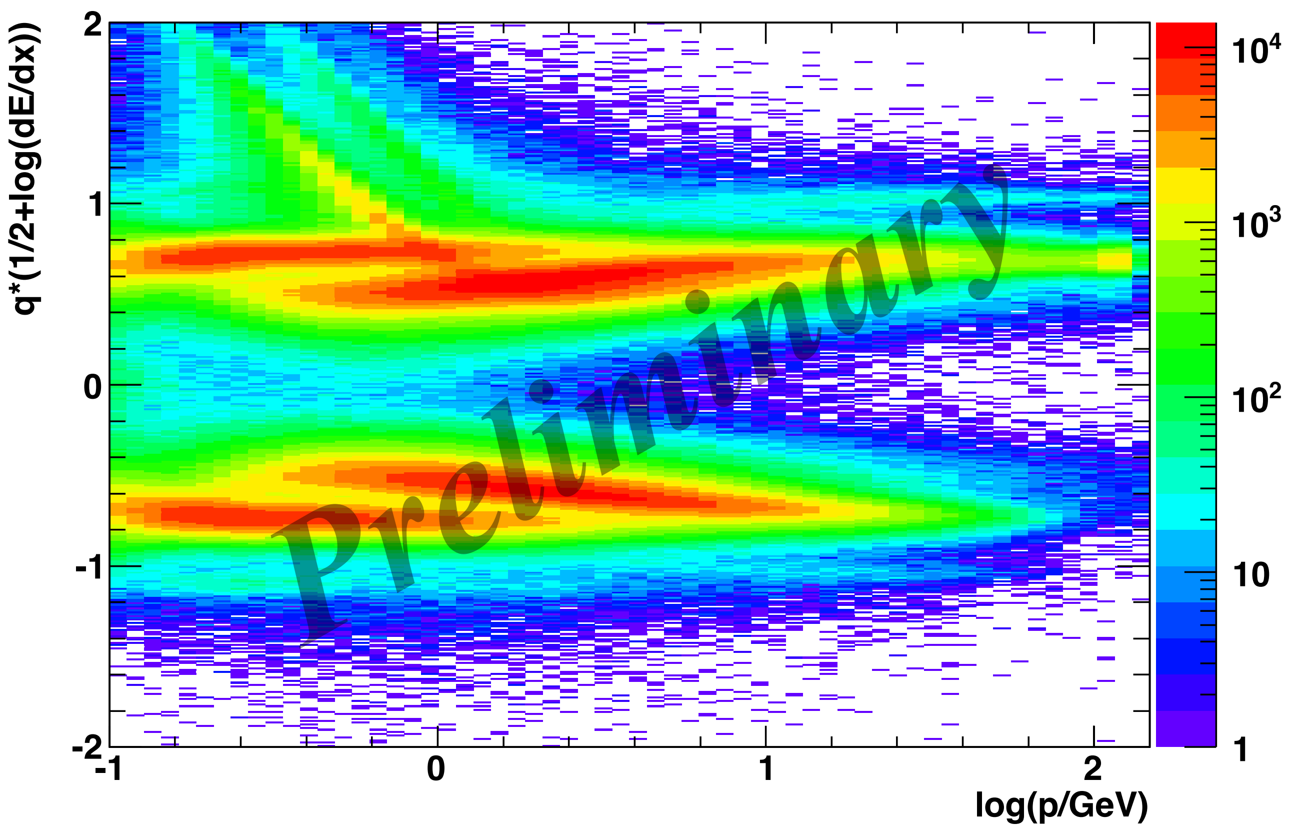


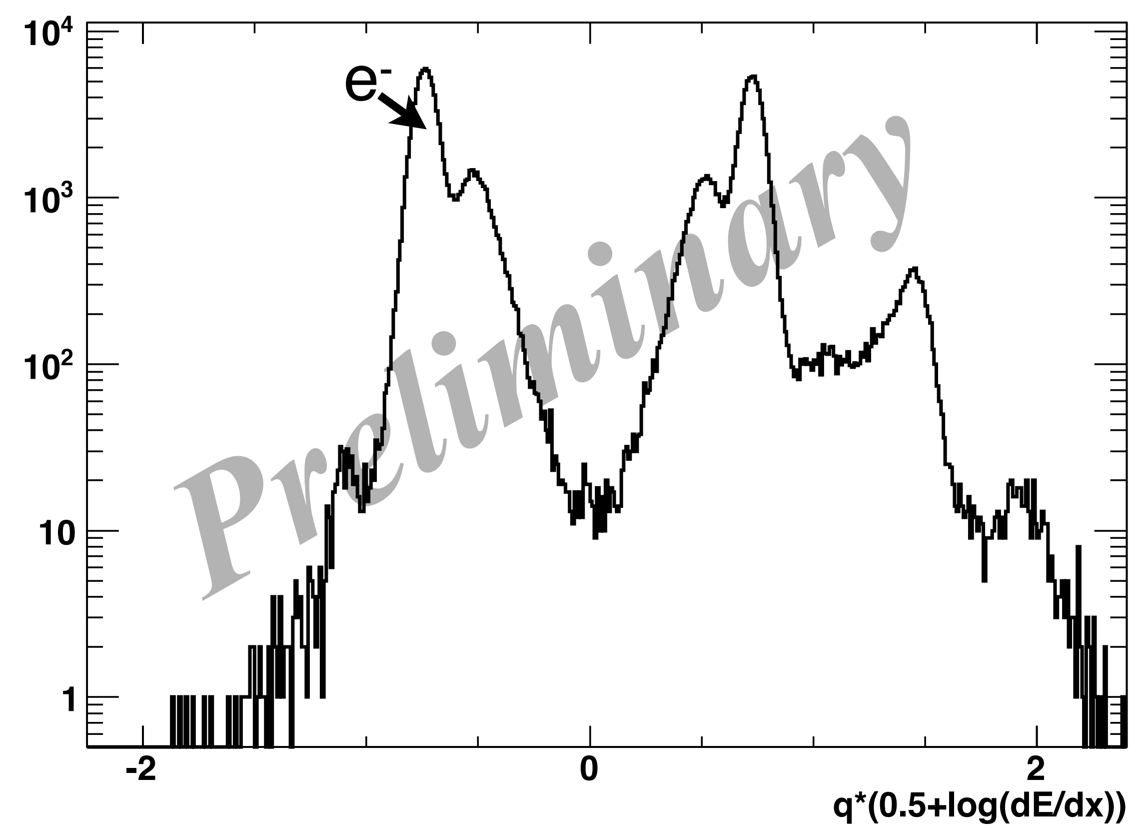




- After momentum bias correction, single proton beam data and MC agree.
- Reconstructed K^0 invariant mass using tracks with $p < 2$ GeV/c indicates systematic offset of ~-1%.

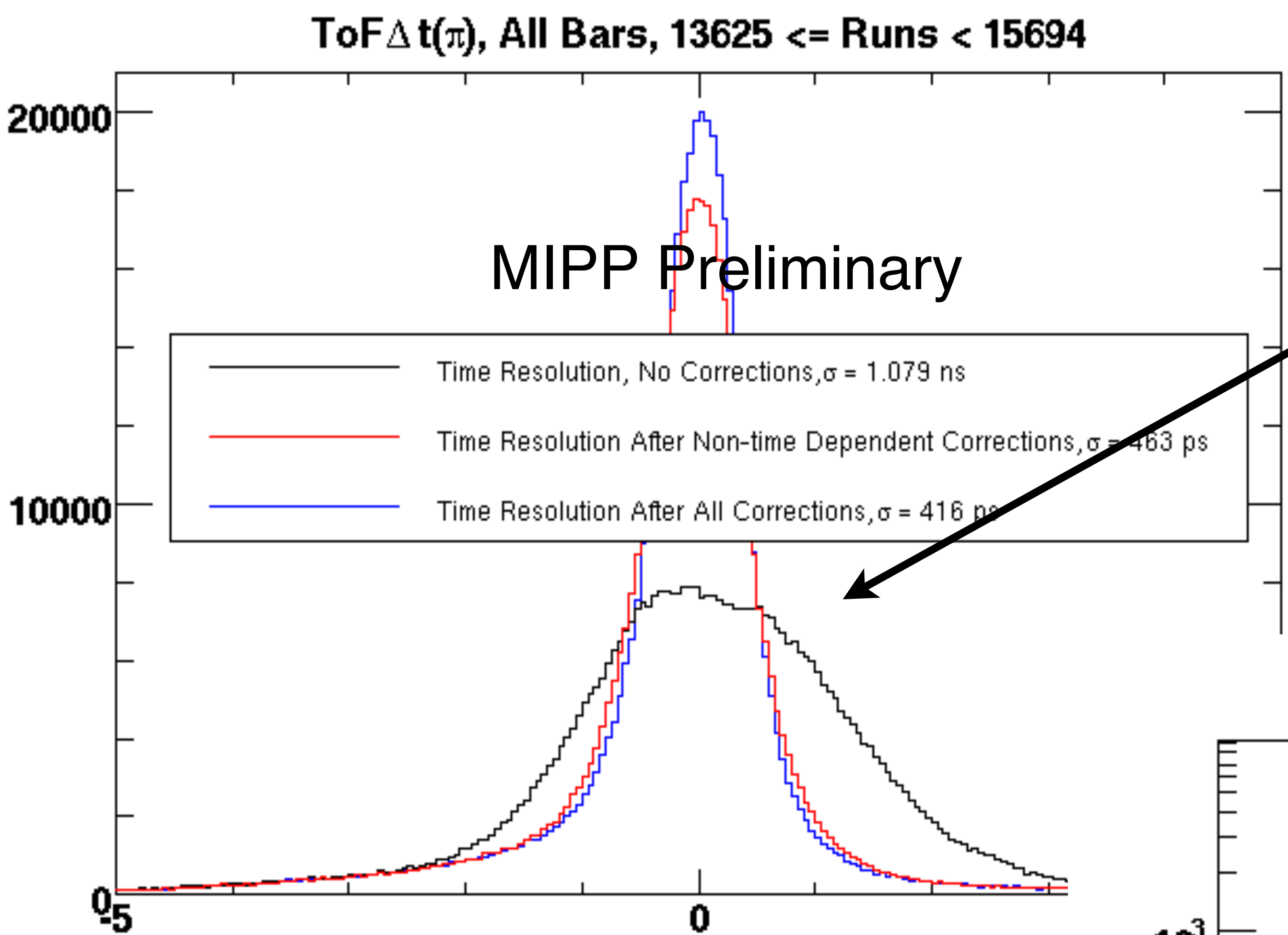
TPC PID Performance



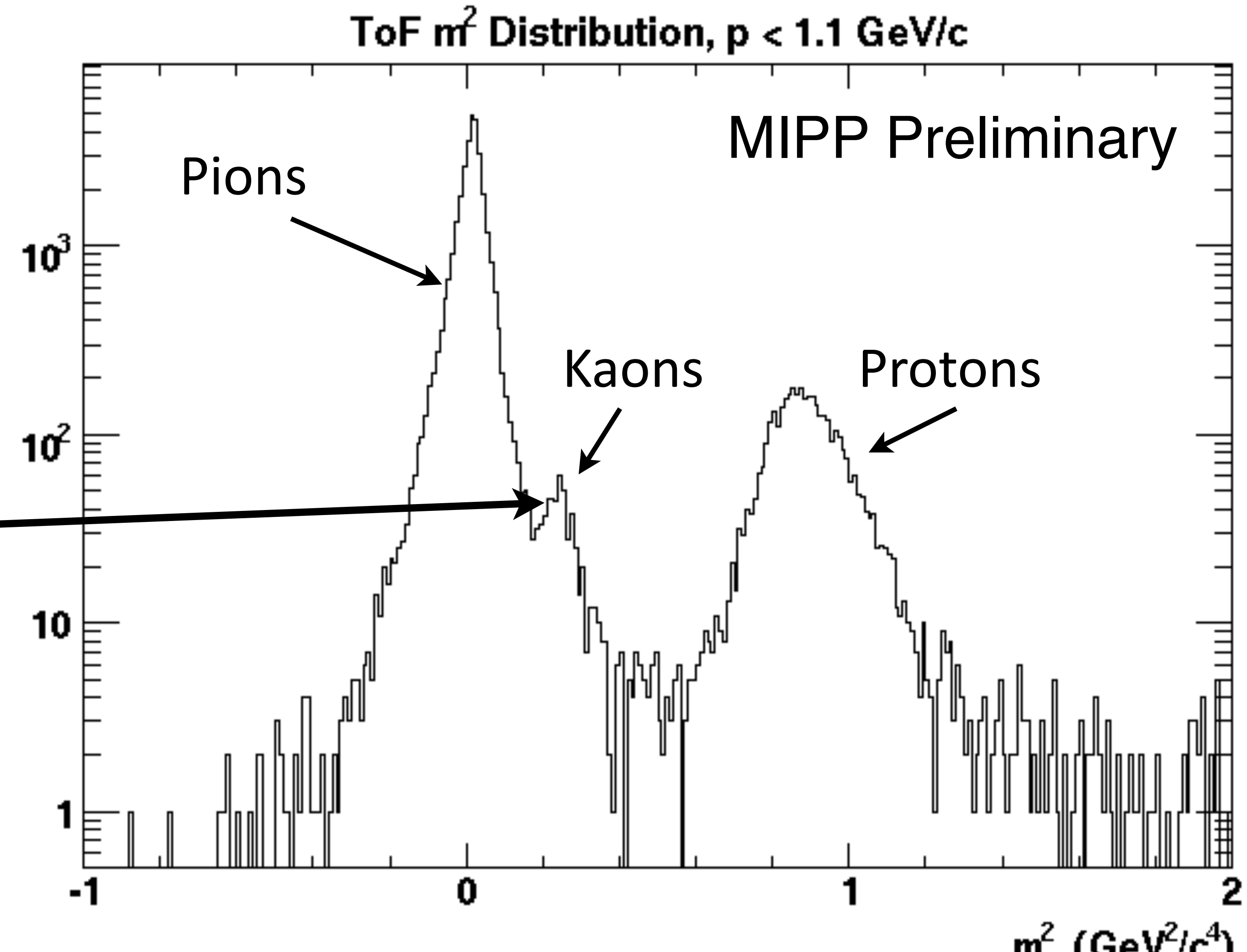


- TPC data are calibrated such that <dE/dx>(π) is 1 for p = 0.4 GeV/c and give expected Bethe-Bloch functional form.
- <dE/dx> resolution ~10%.
- Clean π, p separation between 0.2 and 1.2 GeV/c.

ToF PID Performance

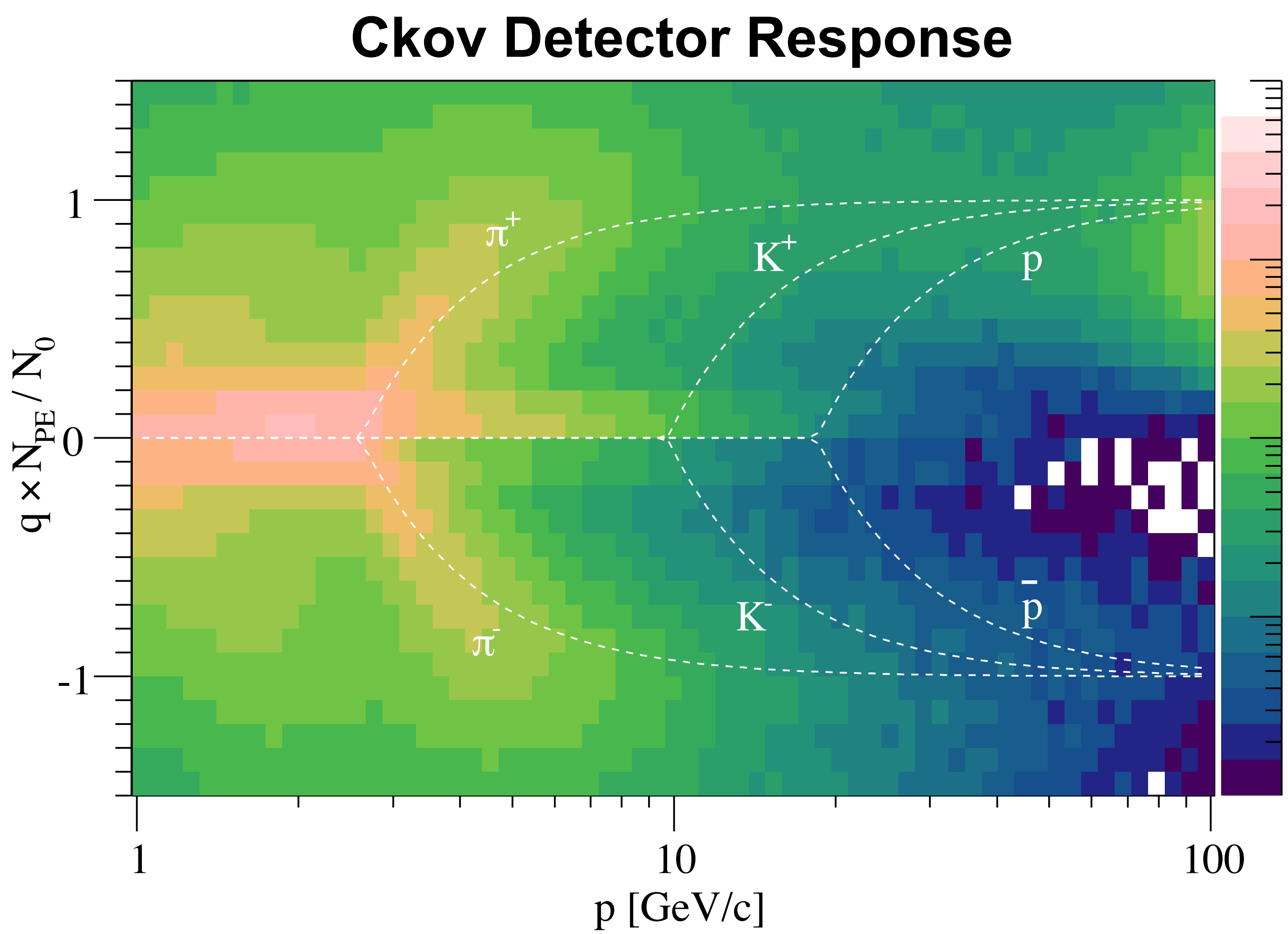


Data-driven calibration improved timing resolution by about a factor of 2.5

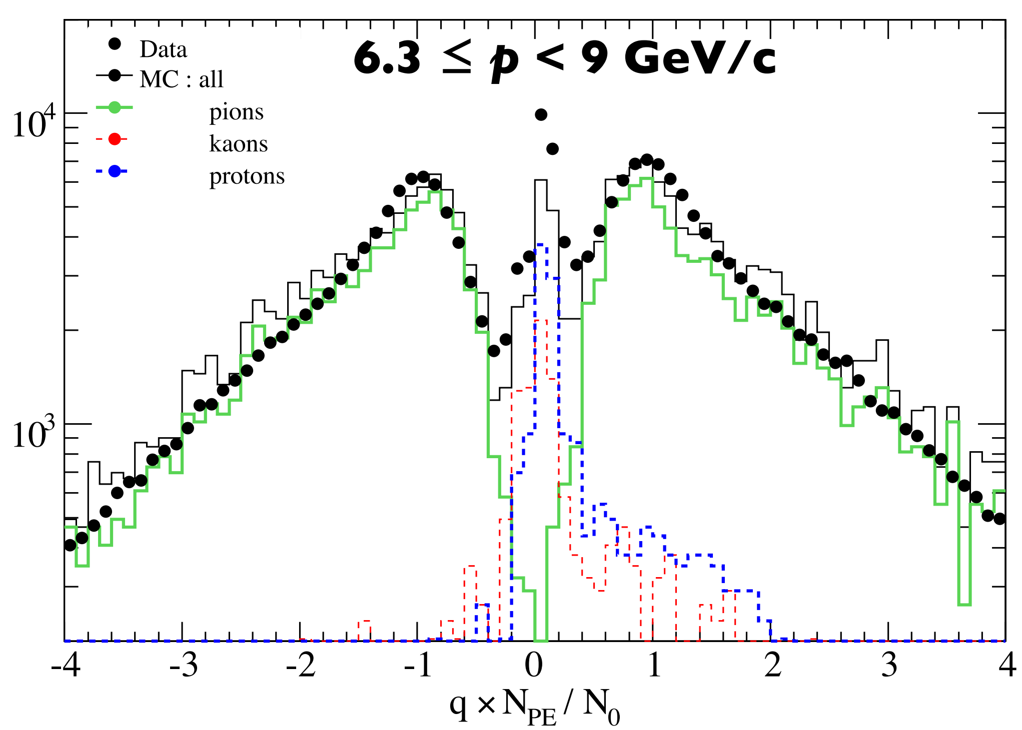


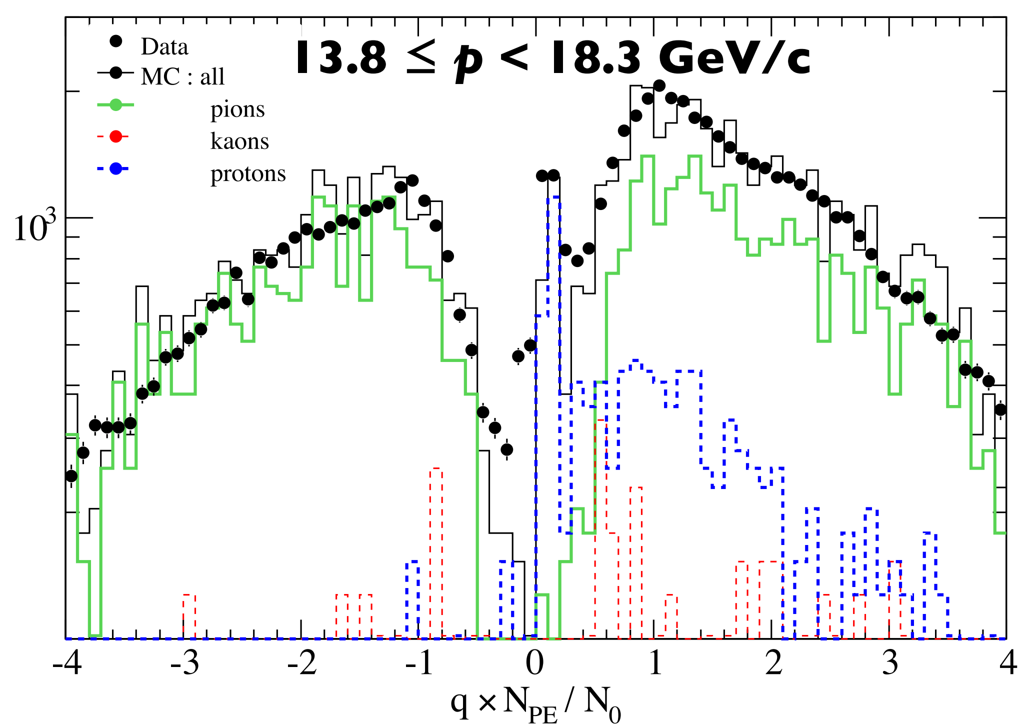
Kaon peak clearly visible in ToF m^2 distribution!

Ckov PID Performance



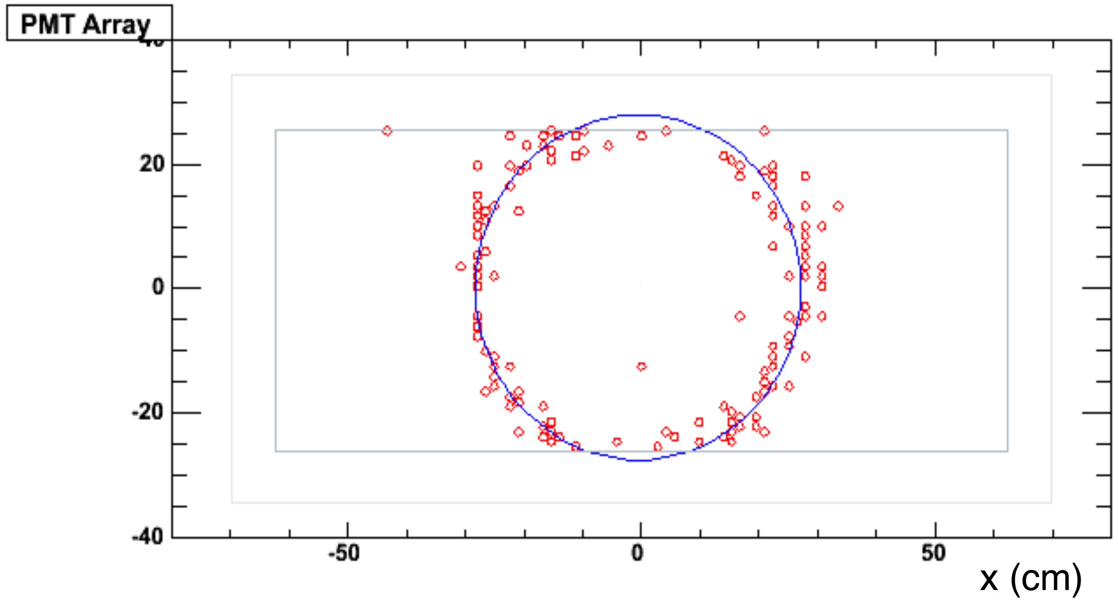
- Since all mirrors have a different response, each measurement of Npe is normalized to that of a β=1 particle.
- Pion "turn-on" clearly visible; proton "turn-on" also visible in slices of momentum.
- Shape of normalized response dist. in MC agrees very well with data.
- Data-driven calibration of 96 mirrors found detector response gives <10 pe/β=1 track.

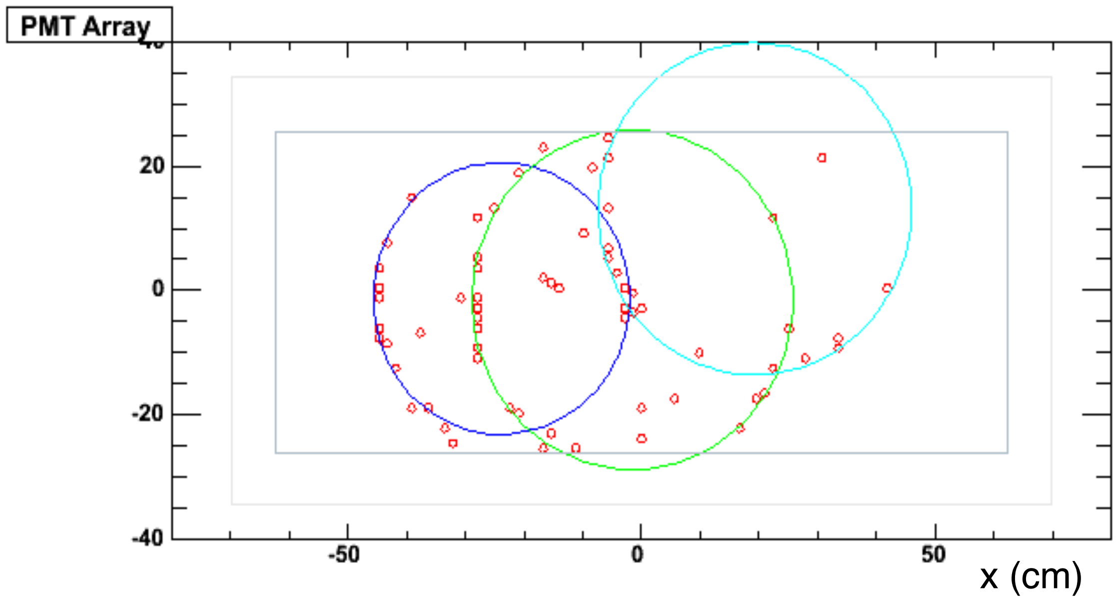


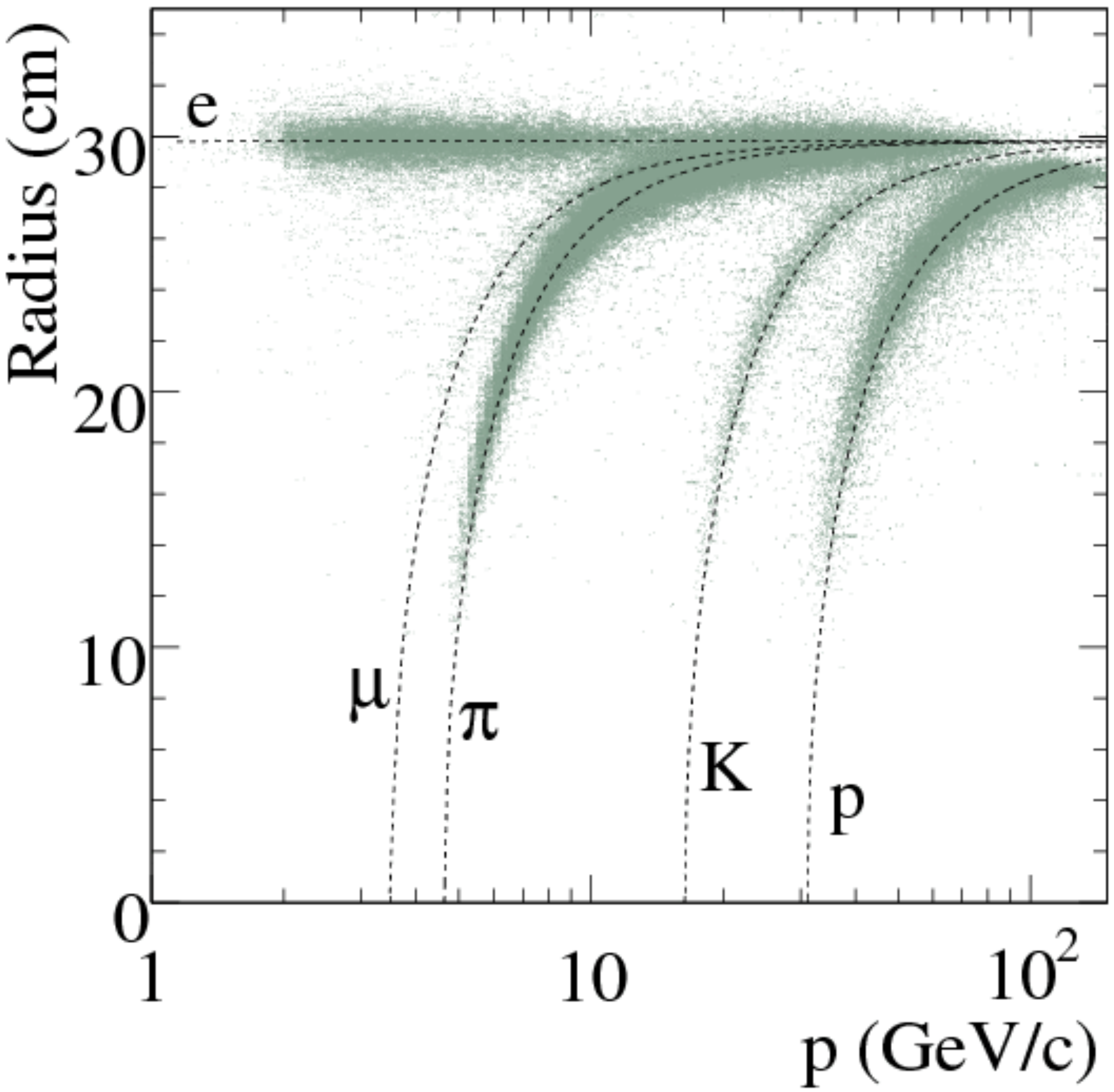


- Must only consider "isolated" tracks passing through mirrors; reject ~50% of Ckov PID data.

RICH PID Performance





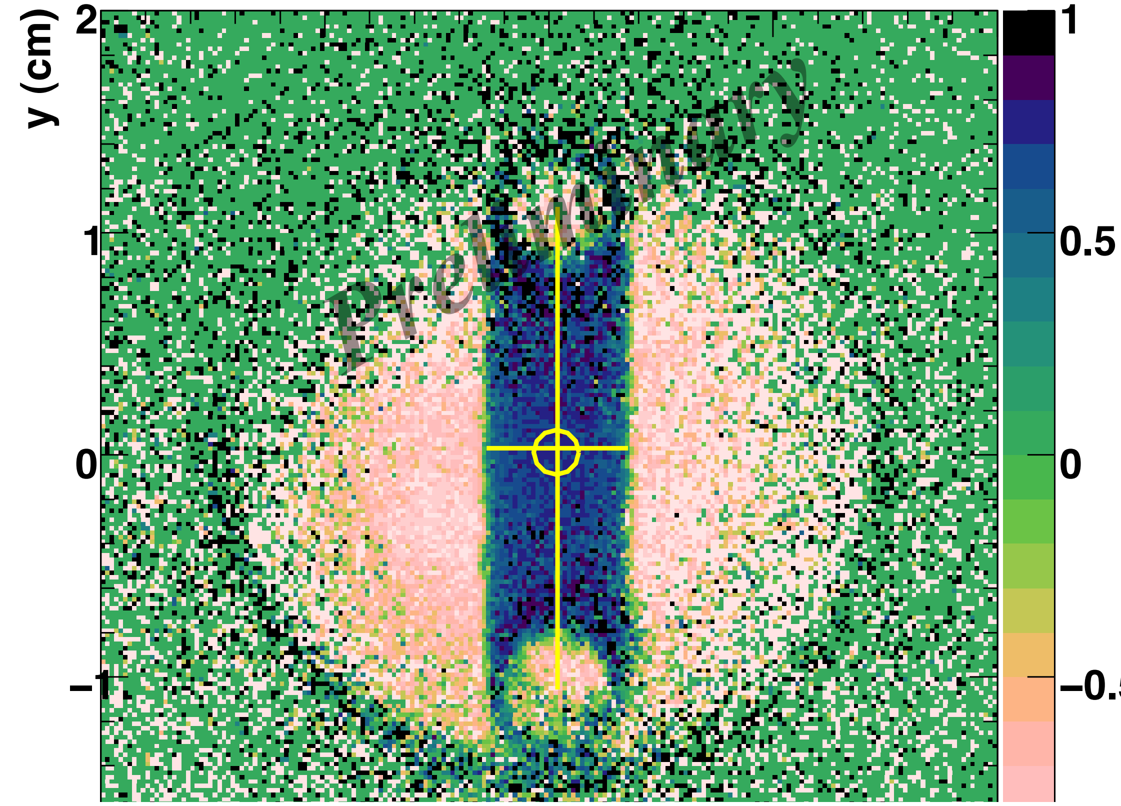


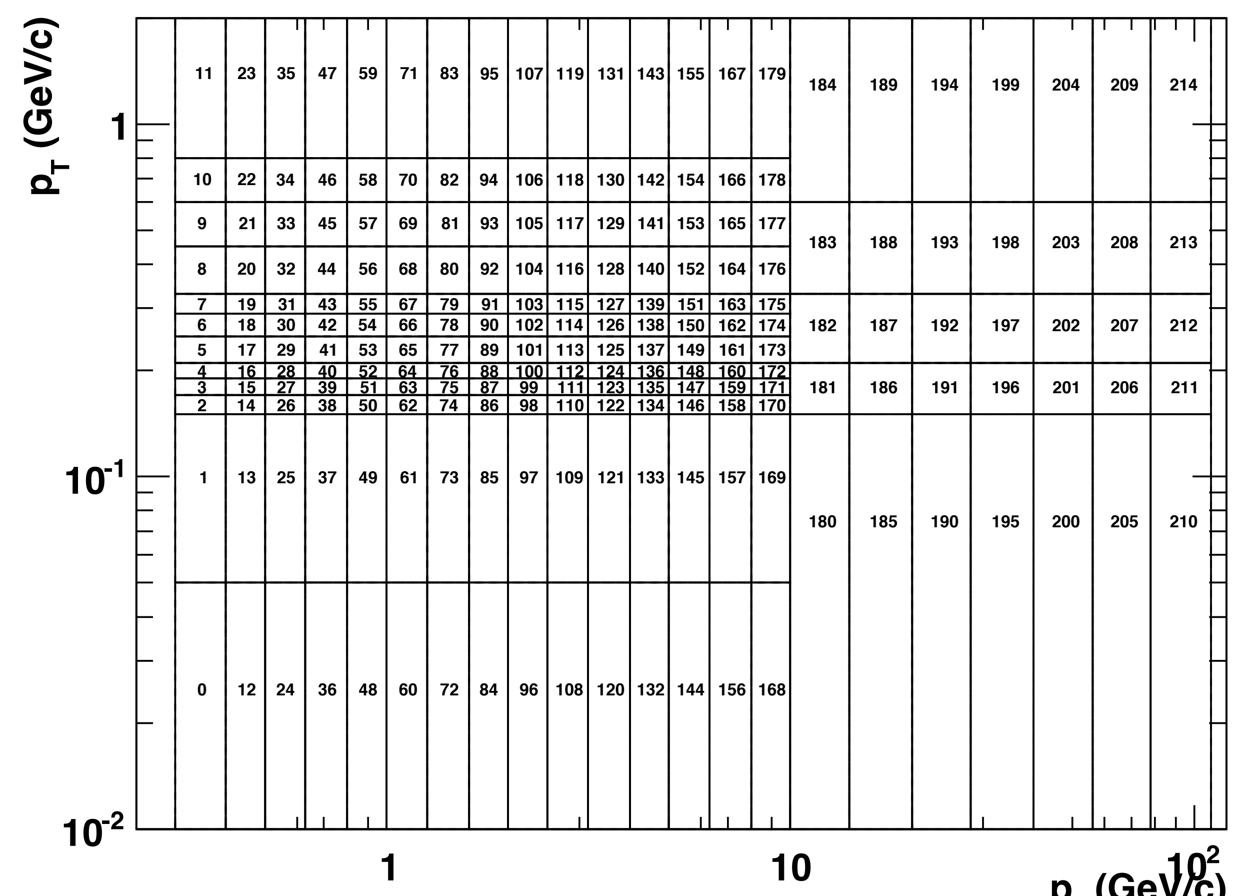
- Ckov light ring formed on array of ~2300 1/2" PMTs.
- Ring radius ~ Ckov angle ~ velocity.
- 3σ π/K separation up to 80 GeV/c, 3σ p/K separation up to 120 GeV/c

Status of the NuMI Target Analysis

NuMI Target Analysis

- MINOS adjusts their predicted ND neutrino energy spectra to agree with the measured spectra using (p_z,p_T)-dependent weights; these weights are an empirical fit, similar to the BPMT parameterization.
- The goal of this analysis is to provide similar weights to adjust the hadron production prediction off of the NuMI target with a direct measurement of the particle yields.
- The MIPP results will be particle yields, binned in (p_z,p_T).

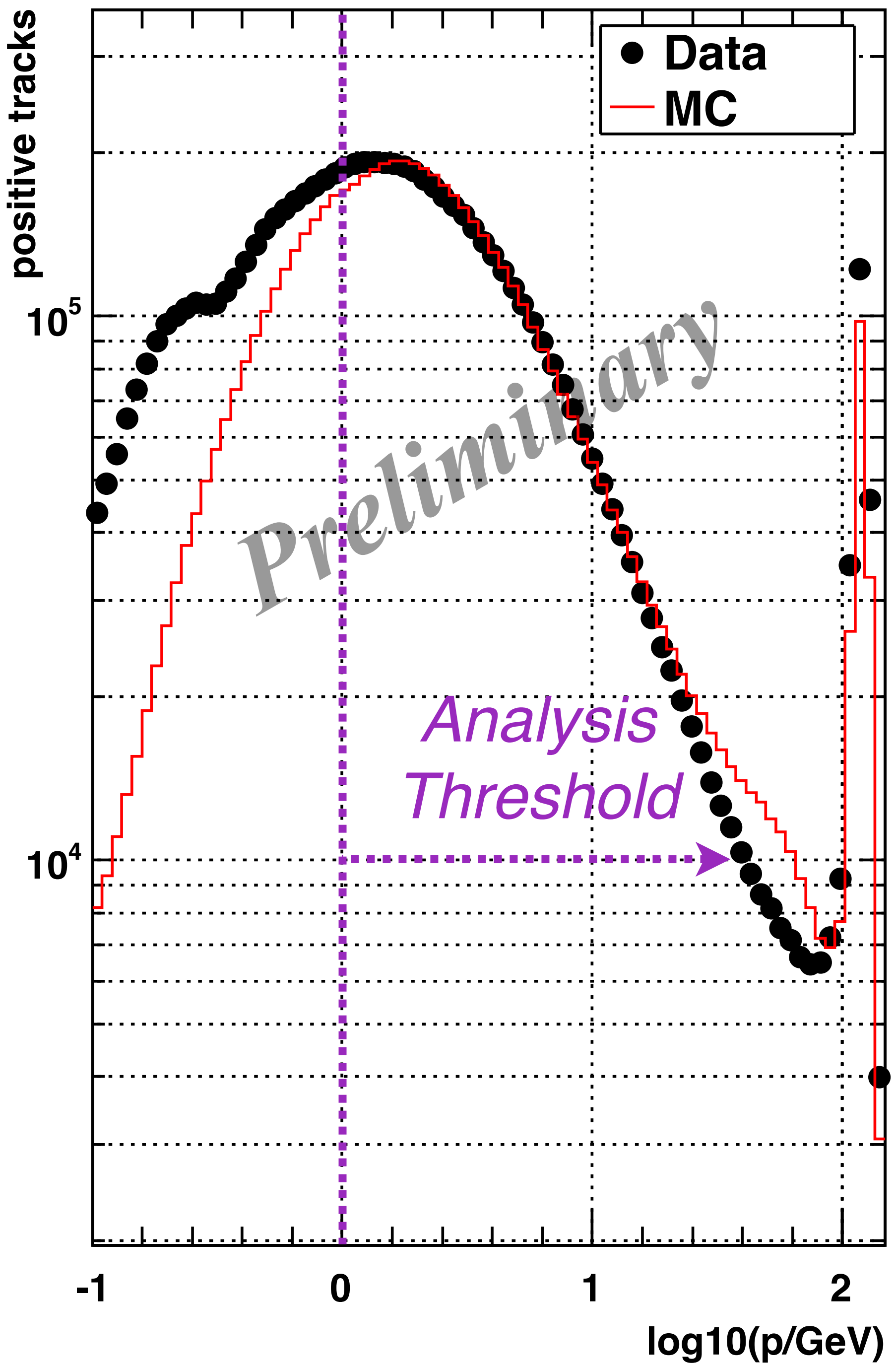


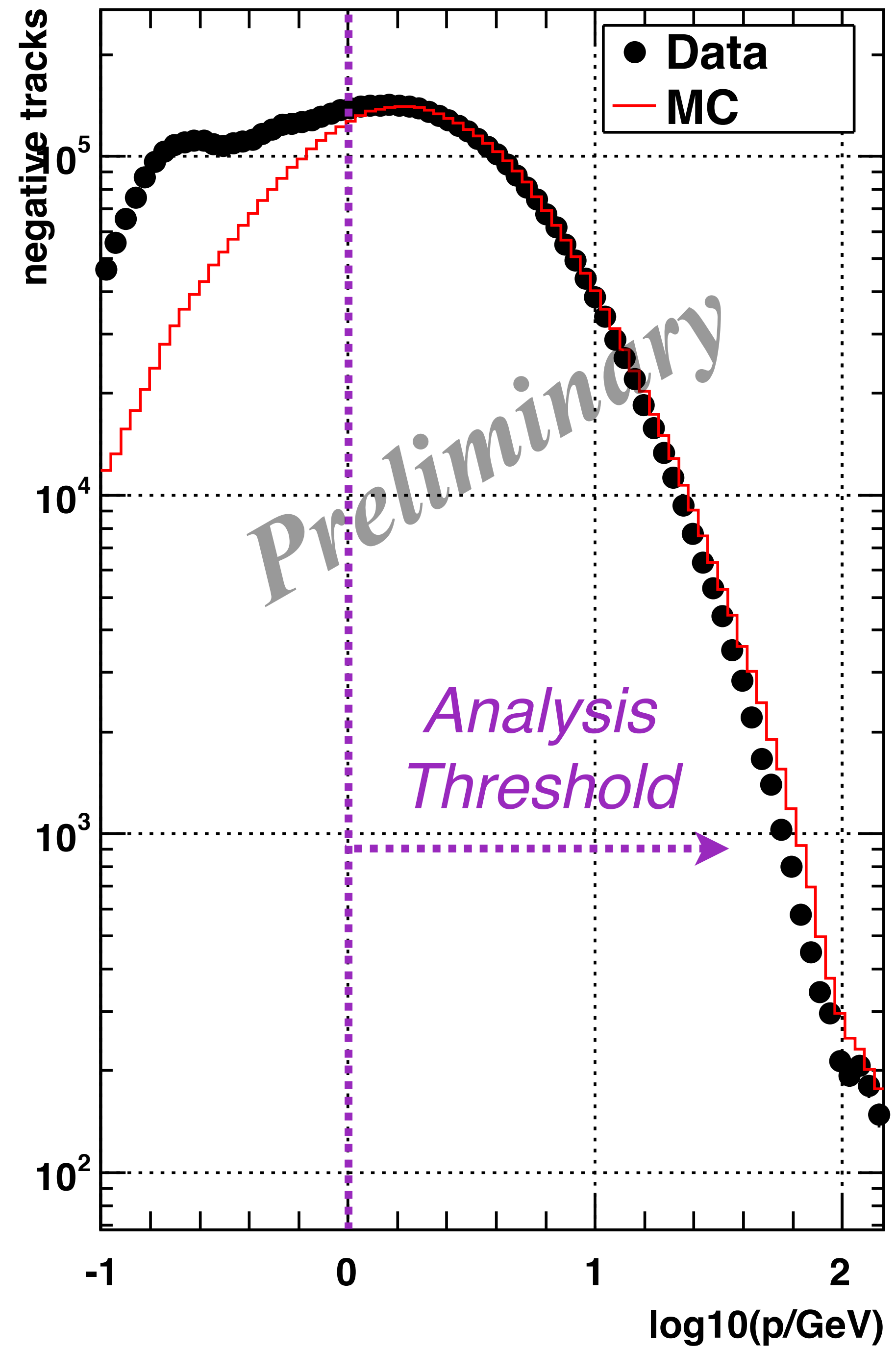


Where We Are With the Analysis

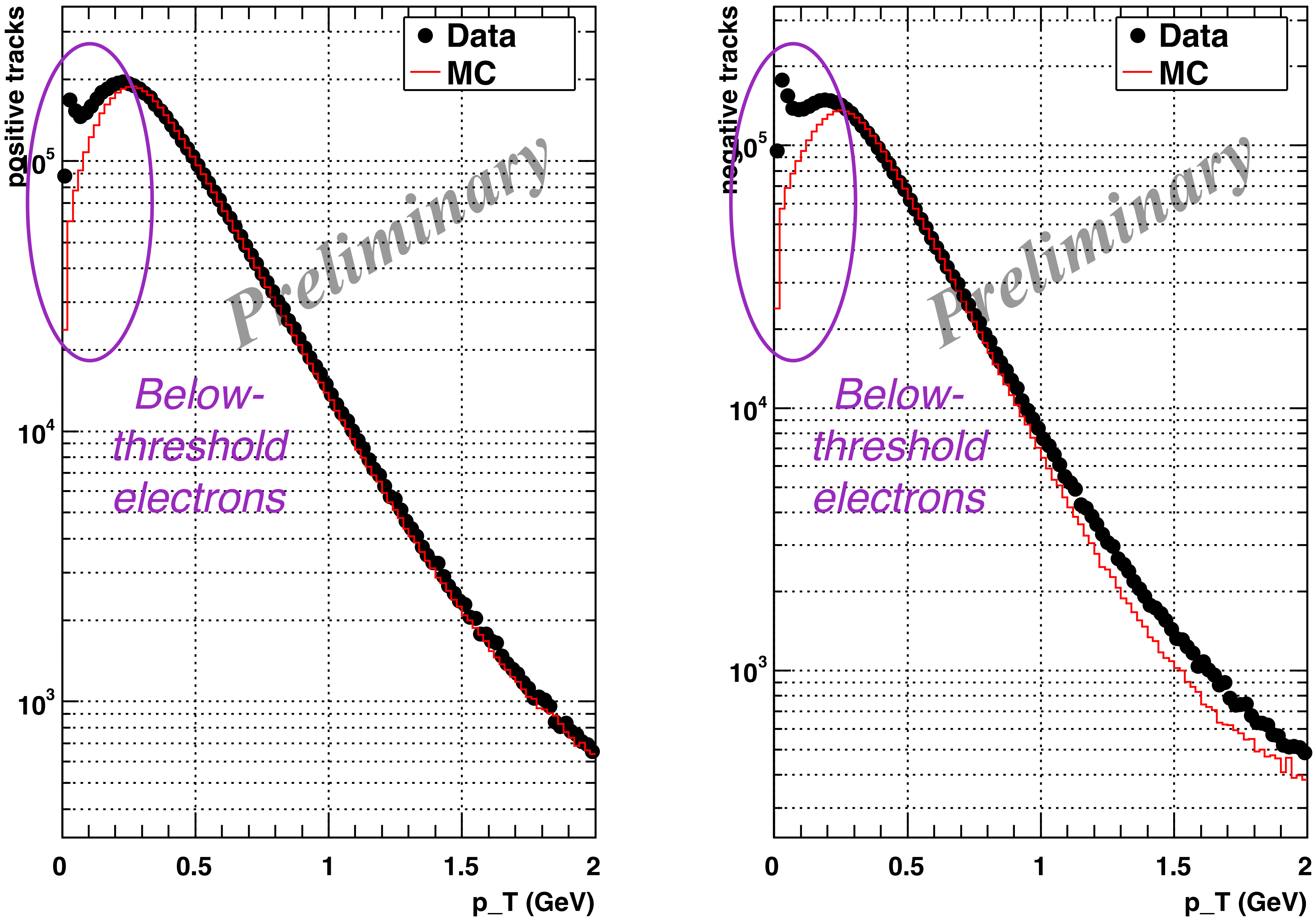
- I had been making good progress with the analysis before I made the choice to focus on NOvA in early 2010:
  - Event selection criteria finalized (begin with 2.11×10^6 POT, end with 1.45×10^6 POT)
  - Momentum bias and scale corrections finalized. Estimates on uncertainties on these are quite small compared to our proposed (p_z,p_T) bin sizes.
  - (p_z,p_T) bins determined based on $\sigma(N(\pi+)) < 3\%$. There are 133 bins. In most cases (at low momenta), $\sigma(N(\pi+)) < 1\%$. Probably don't need that many bins, so to expedite the analysis, one could easily decrease the number of bins by factor of 2-5 and still have a big impact on flux constraints.
  - Large MC data set generated **(but needs further tuning)**
  - Analysis (fitting) strategy outlined and mock data tests had begun on the approach. **This needs to be revisited**, in particular there may be better/quicker ways of doing this using modern/standard tools (eg, Root TMVA).
- Some further progress has been made on the NuMI target analysis by other MIPP colleagues since I "disappeared", eg, data-driven calibration of TCP <dE/dx> all the way to 120 GeV/c (there is information beyond ~1.5 GeV/c).

Comparison of Data and MC p_z Spectra



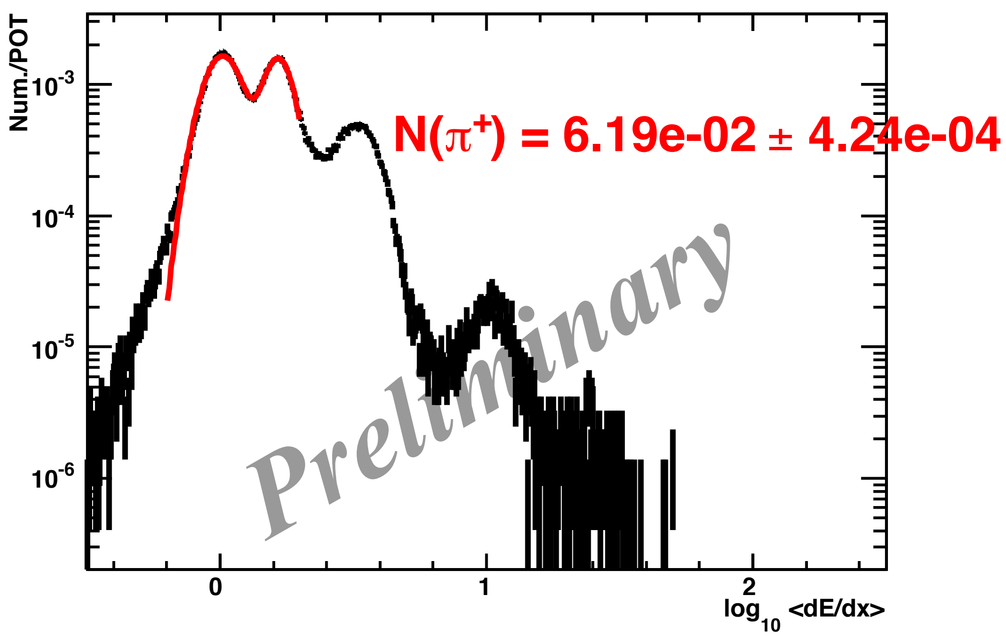


Comparison of Data and MC p_T Spectra

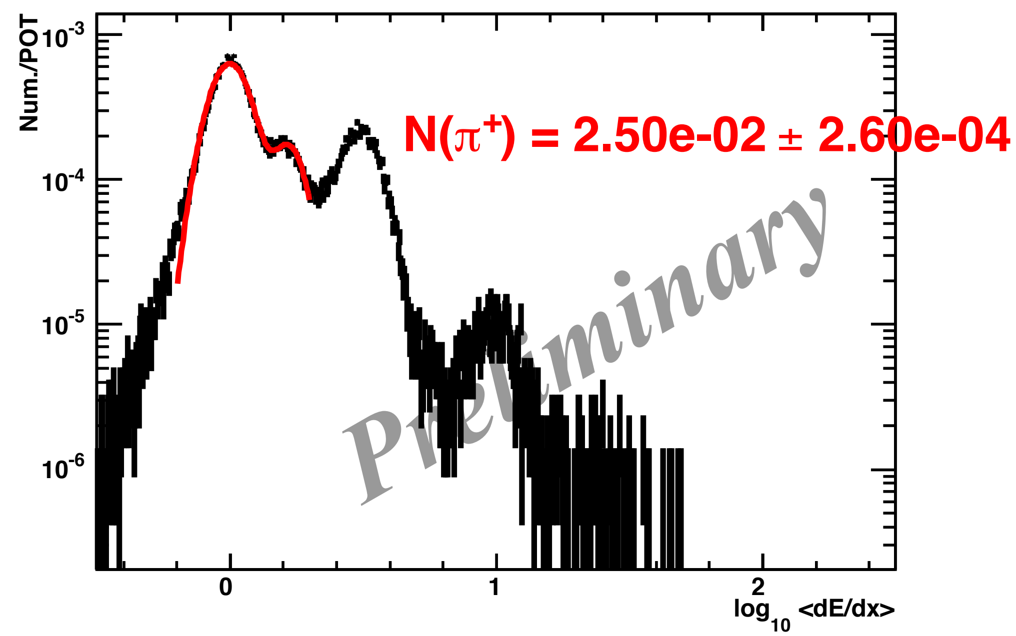


Preliminary Pion Yield Measurement (TPC-only)

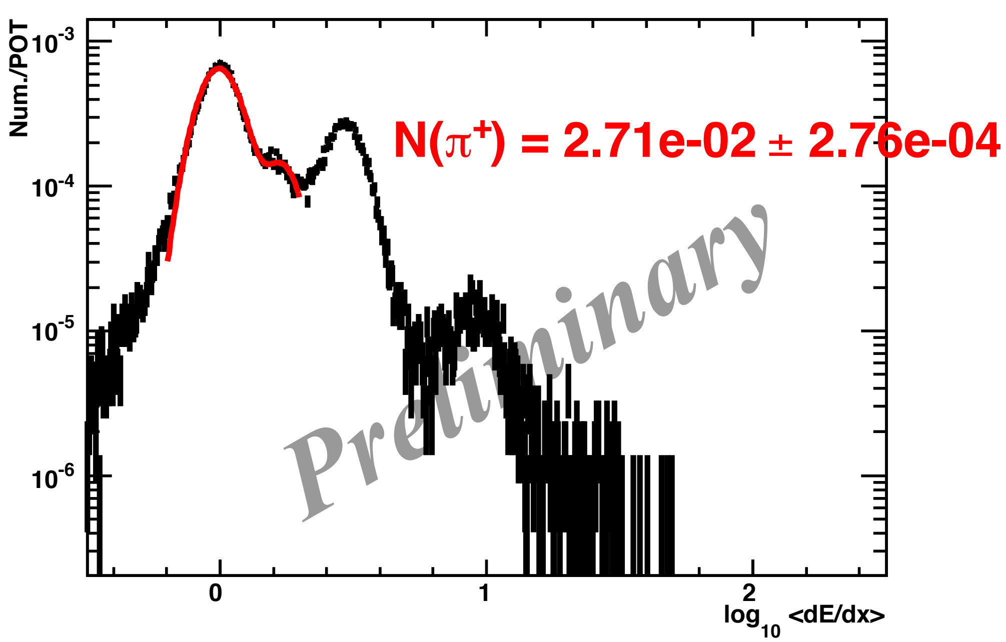
Data TPC <dE/dx> Distribution, q > 0, Bin 15



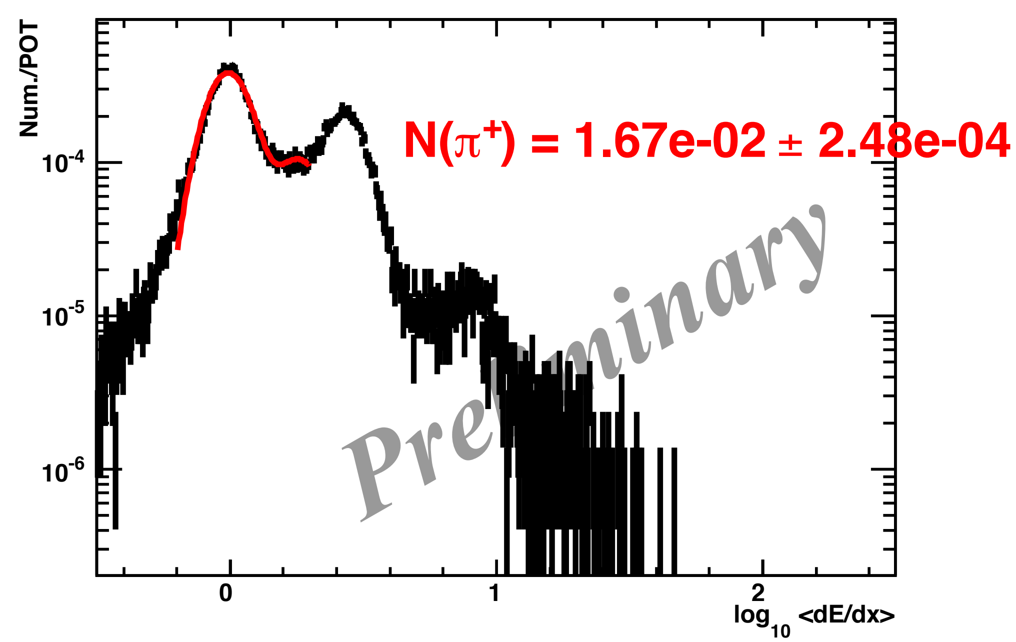
Data TPC <dE/dx> Distribution, q > 0, Bin 16



Data TPC <dE/dx> Distribution, q > 0, Bin 17

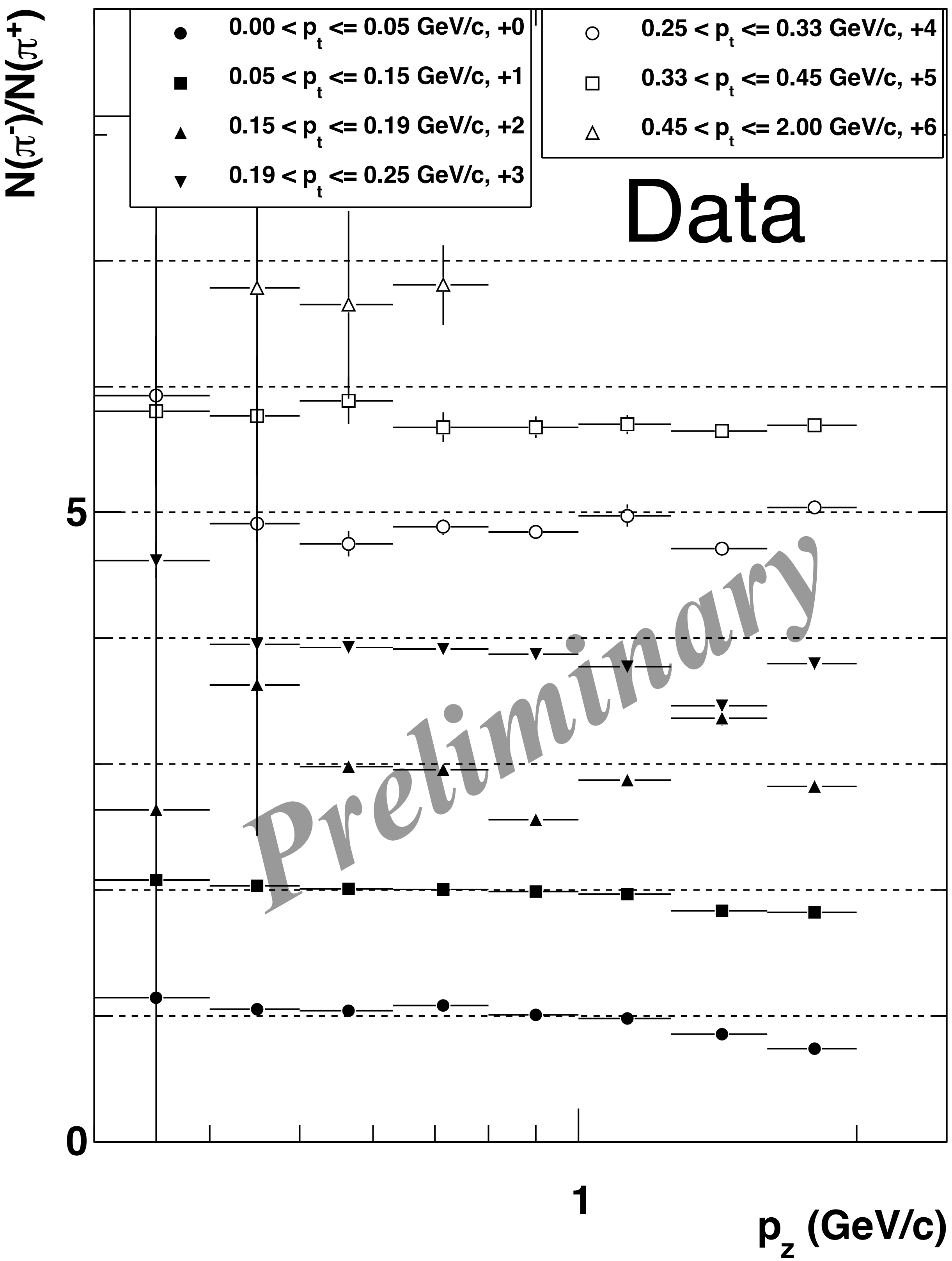


Data TPC <dE/dx> Distribution, q > 0, Bin 18

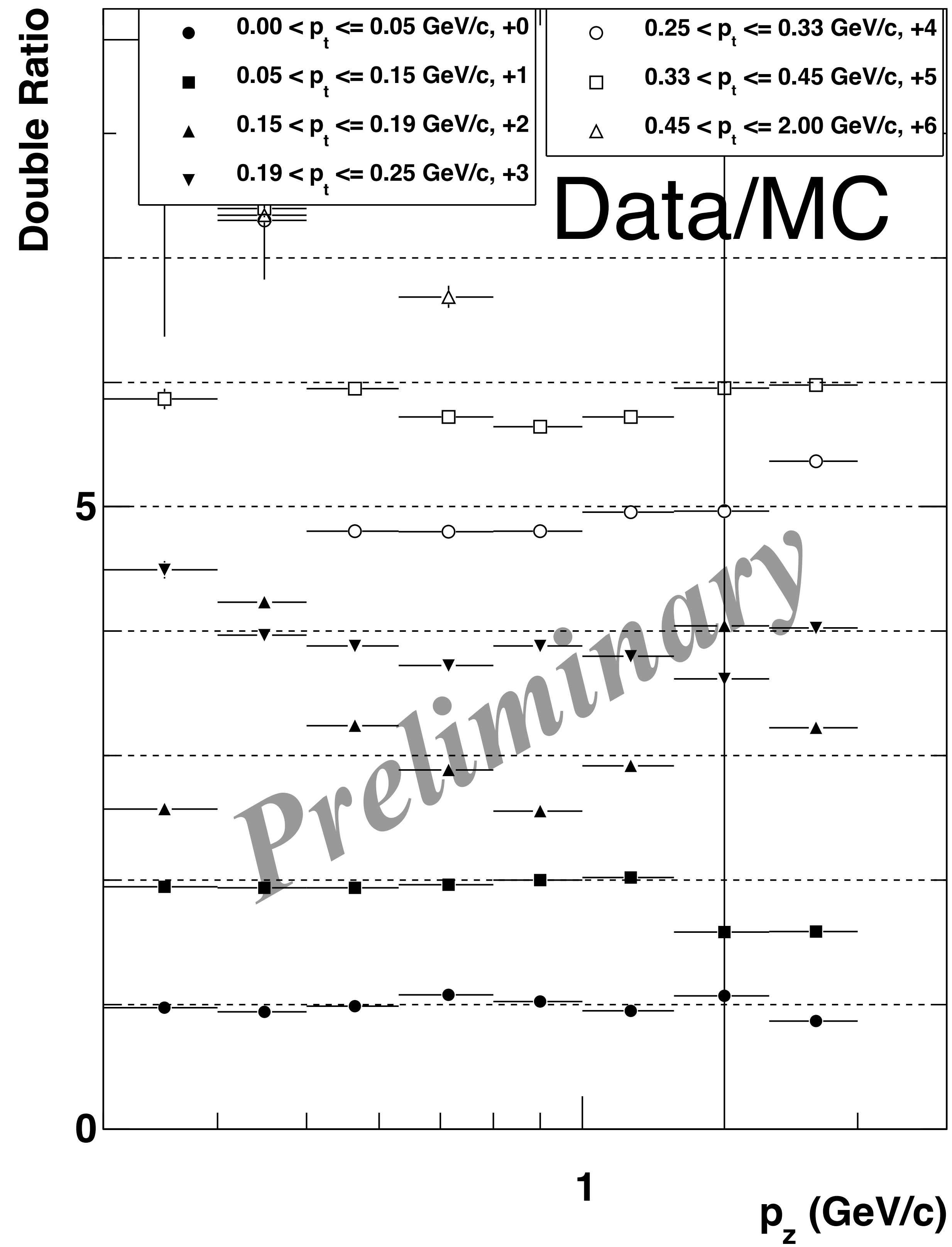


Preliminary Pion Yield Measurement (TPC-only)

$N(\pi^-)/N(\pi^+)$ vs. p_z



$Data(\pi^-/\pi^+)/MC(\pi^-/\pi^+)$ vs. p_z



Conclusions and Thoughts on Possible Paths Forward

- MIPP collected several millions of events of π, K and p beams at various momenta incident on various targets, 1.6 x 10^6 120 GeV protons on an actual NuMI target.
- All MIPP sub-detector systems have been calibrated and the MC tuned to the data. MC/Data PID agreement looks reasonable, but some further fine-tuning is needed.
- PID response in MC can be tuned "by hand" using the above files to be "good enough". ToF and RICH need some fine-tuning, TPC and Ckov should be ok now.
- Using Root tools (TMVA, TSVD) could make analysis more straightforward (**not** saying it'll be "easy"!)
- Low-energy $K^{\pm}$ and K-short production measurement is relevant for NOvA NDOS analysis, obviously other experiments would benefit from anything MIPP produces (yields or ratios, p < 3 GeV/c, p > 20 GeV/c, etc.)
- Help from experiments that would benefit from these data would be appreciated, and it should not be difficult to get postdoc up and running. Eg, flat Root ntuple format of data and MC exists.