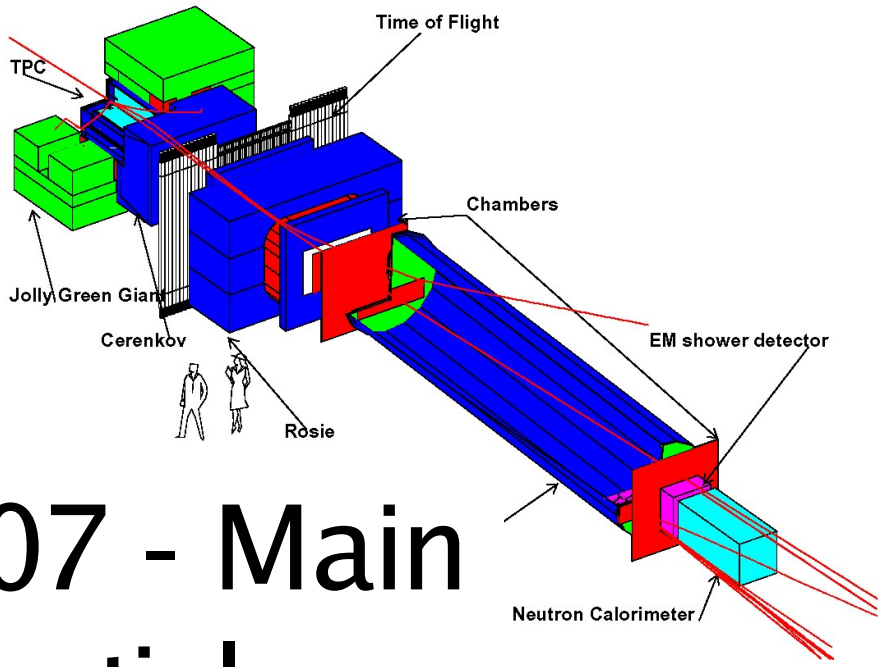
MIPP



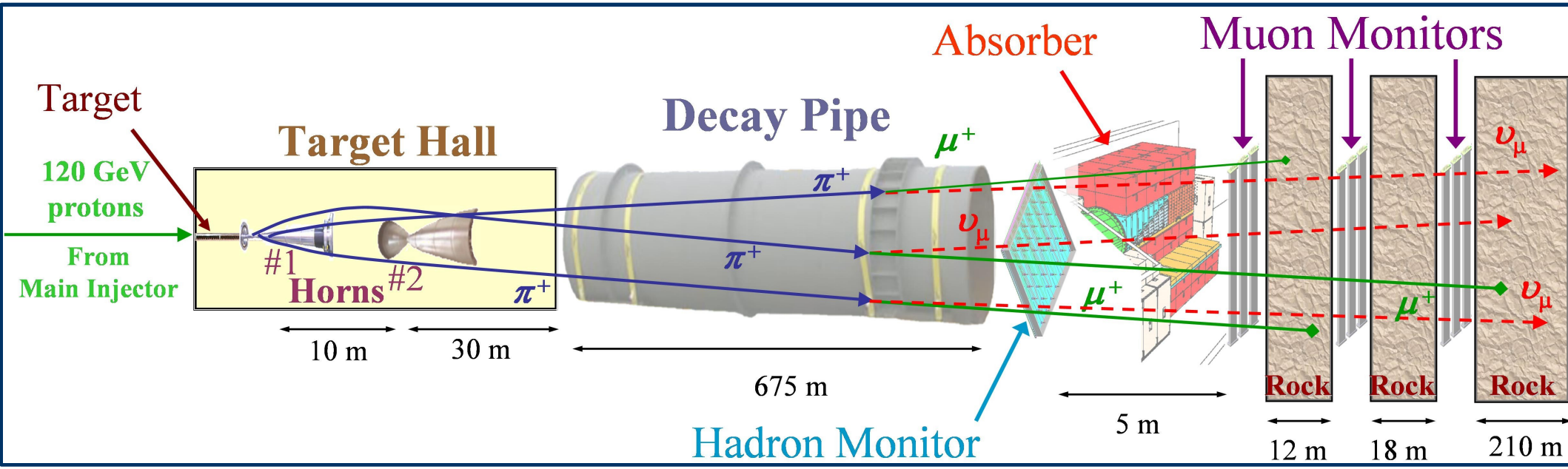
Status of E907 - Main Injector Particle Production Experiment

Jonathan M. Paley

Indiana University

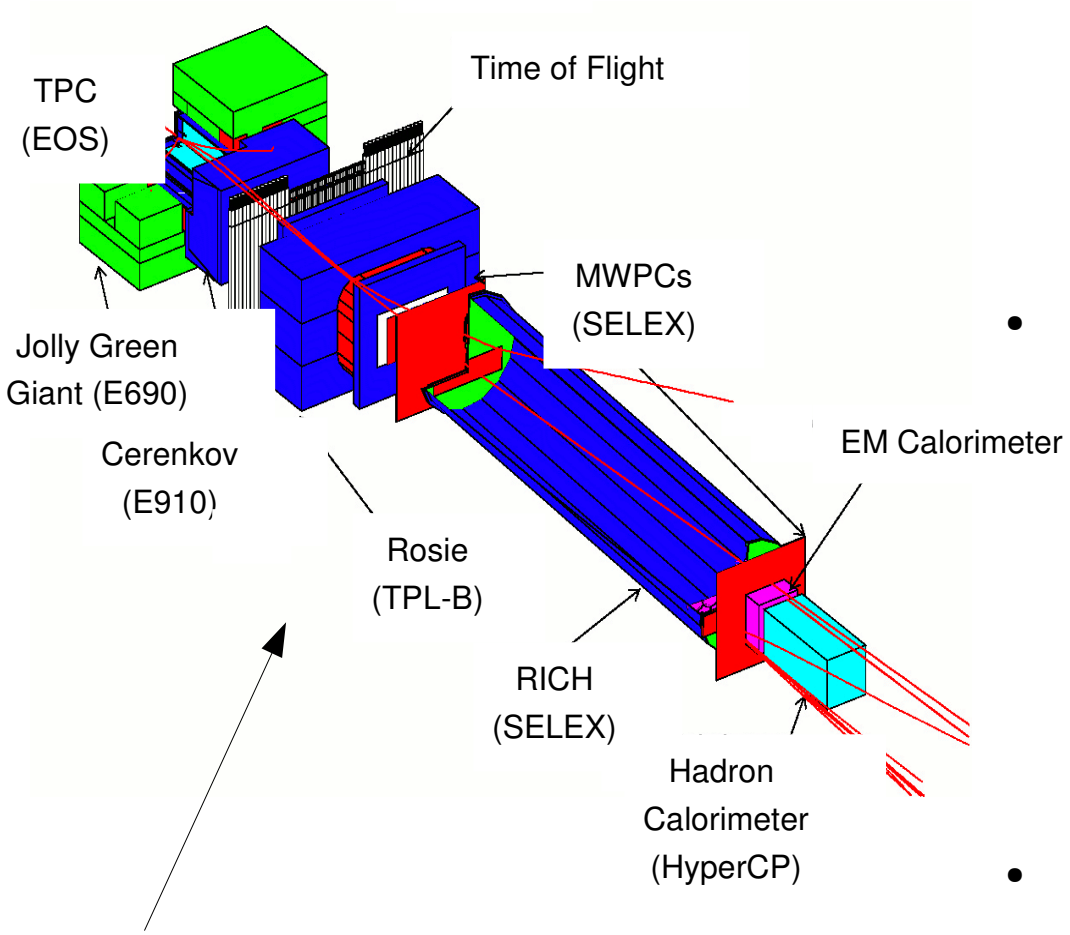
2006 NBI Workshop, CERN

Neutrino Production in MINOS



- Neutrinos in MINOS come from hadrons (p's, K's) produced when 120 GeV/c protons from the Main Injector strike a 90 cm long graphite target.
- Very large (~30%) uncertainty in neutrino flux due to lack of data on hadron production at this energy.

The MIPP Spectrometer

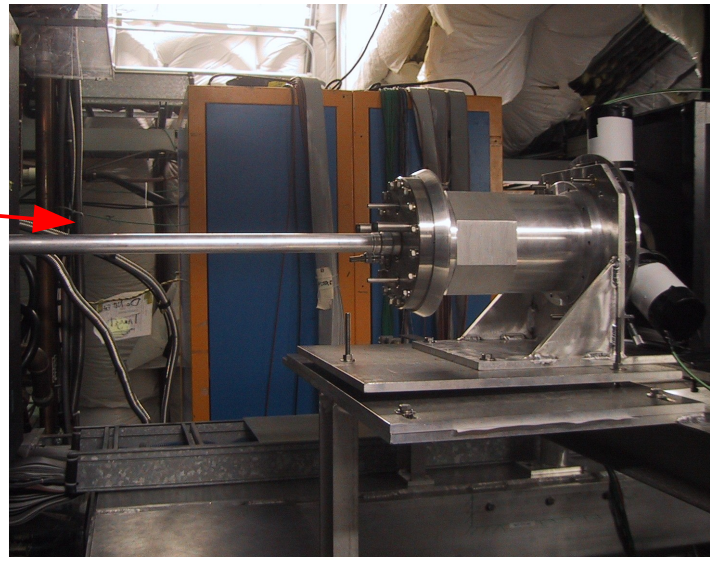


Nearly all detectors taken from previous experiments!

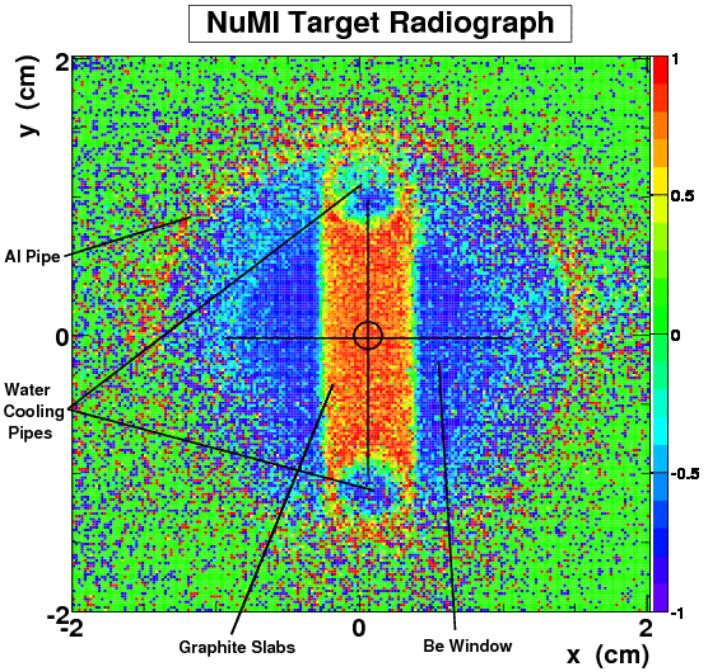
- Full acceptance spectrometer
  - Two analysis magnets deflect in opposite directions
  - TPC + 4 Drift Chambers + 2 PWCs
- Excellent Particle ID (PID) separation (2-3 σ)
  - TPC: < 1 GeV/c
  - ToF: 1-3 GeV/c
  - DCkov: 3-17 GeV/c
  - RICH: 17-80 GeV/c
- Goals of MIPP:
  - Collect comprehensive hadron production cross-section data set.
  - Measure hadron production off of NuMI target, providing ν flux to within ~5%

The 2005-06 MIPP Data Run at FNAL

- MIPP collected data from December 2004 until February 2006.
- MINOS spare target inserted into MIPP hall:
- Beam profile for MINOS target run: σ_x ~= σ_y ~= 1 mm
- Beam aligned on target: Δx = 0.02 mm, Δy = 0.51 mm (matches MINOS alignment extremely well)
- Data collected:

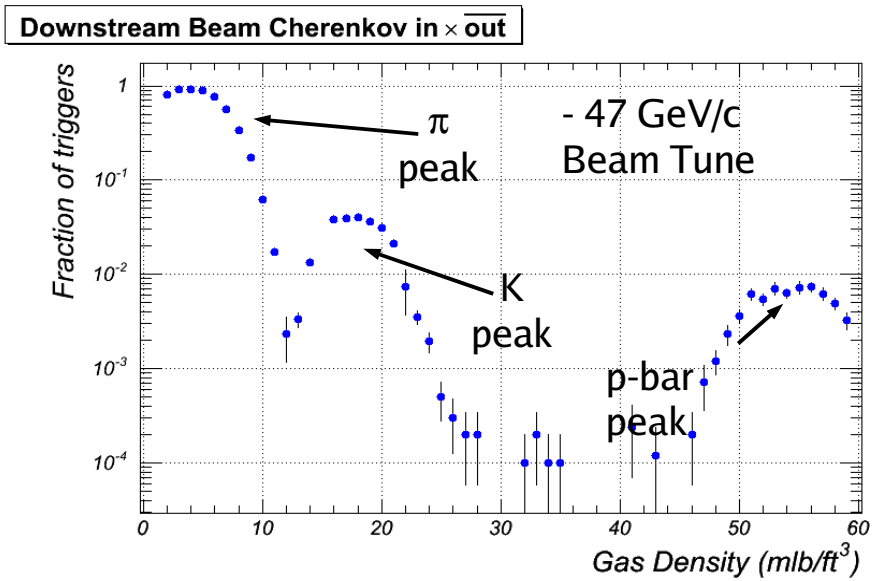


Target Z/Element	Momentum (GeV/c)									Total
	-85	-60	-35	-20	20	35	60	85	120	
1 / H	0.5	0.5		0.4	0.50		1.2	0.70		3.80
4 / Be		0.3	0.08			0.12	0.3		1.00	1.80
6 / C*					0.4		0.4		0.50	1.30
NuMI**									1.50	1.50
83 / Bi		0.6	0.30			0.3	0.5		1.00	2.70
Total	0.50	1.40	0.38	0.40	0.90	0.42	2.40	0.70	4.00	11.10

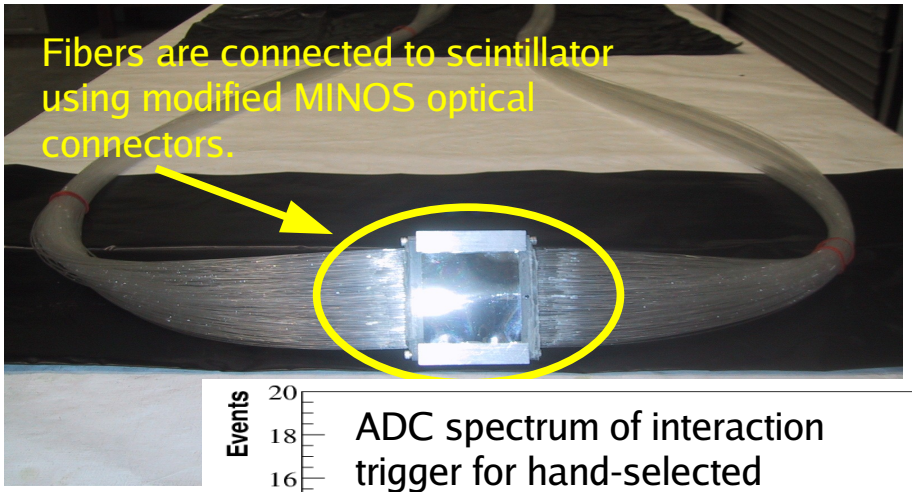


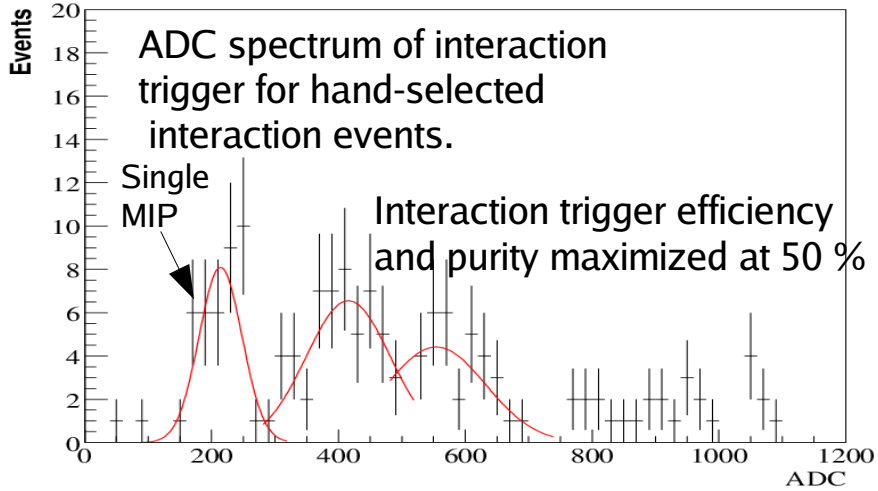
MIPP Trigger

- Primary 120 GeV/c proton beam from Main Injector; secondary target and beamline upstream provides lower momentum p's, π's and K's.
- Must tag incoming particle id!
- Two Ckov detectors upstream of target used to tag beam species.

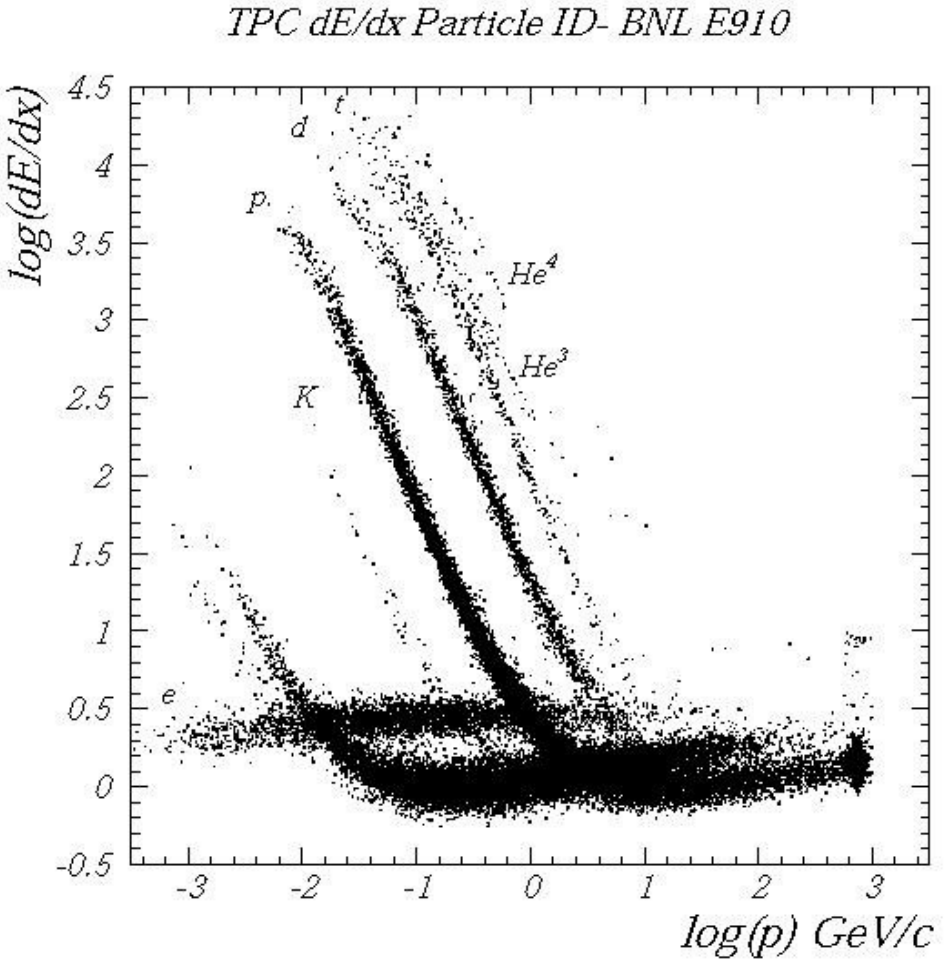


- DAQ rate is low (~30 Hz), so we enhance our sample of interaction events using a track multiplicity trigger.
- An interaction trigger was constructed using a thin piece of scintillator and spare MINOS parts (optical fibers and connectors).



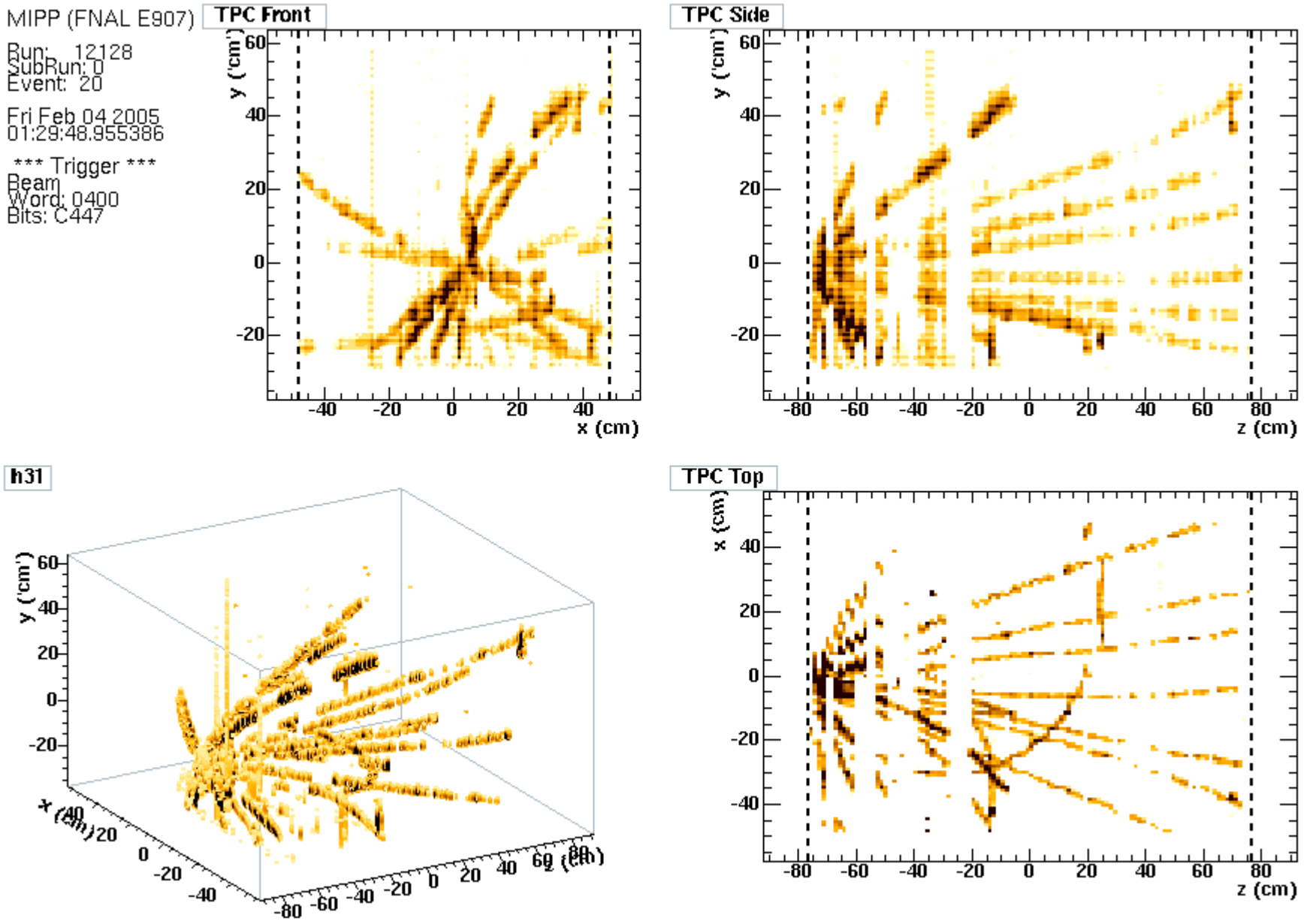


Time Projection Chamber (TPC)



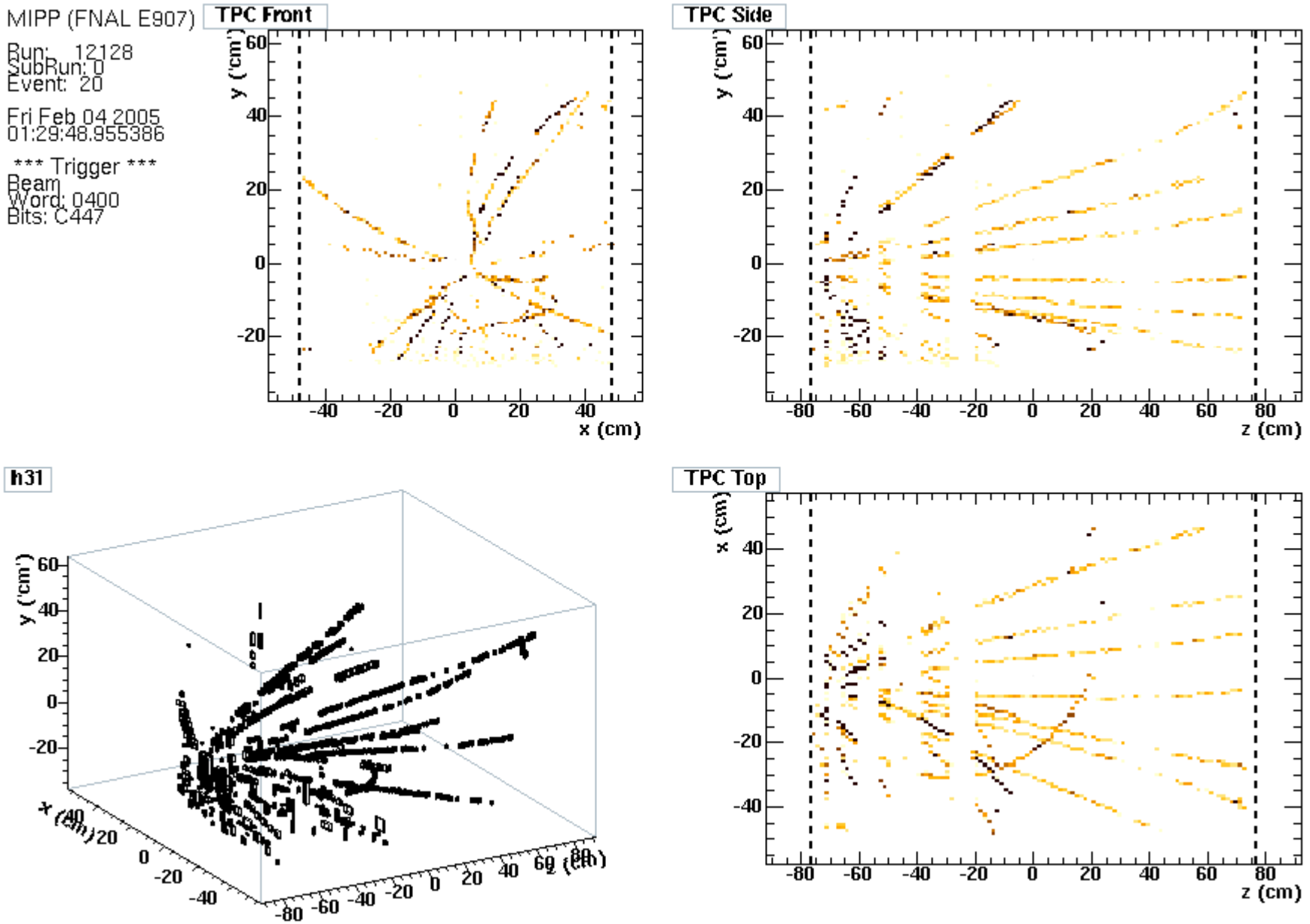
- Centerpiece of MIPP, originally built for the EOS experiment.
- (x,z) position --> pad locations, y position --> drift time.
- Active volume of ~ 1 m^3 and a resolution of ~0.5 cm^3.
- Designed to provide PID to ~3 sigma.

TPC Reconstruction



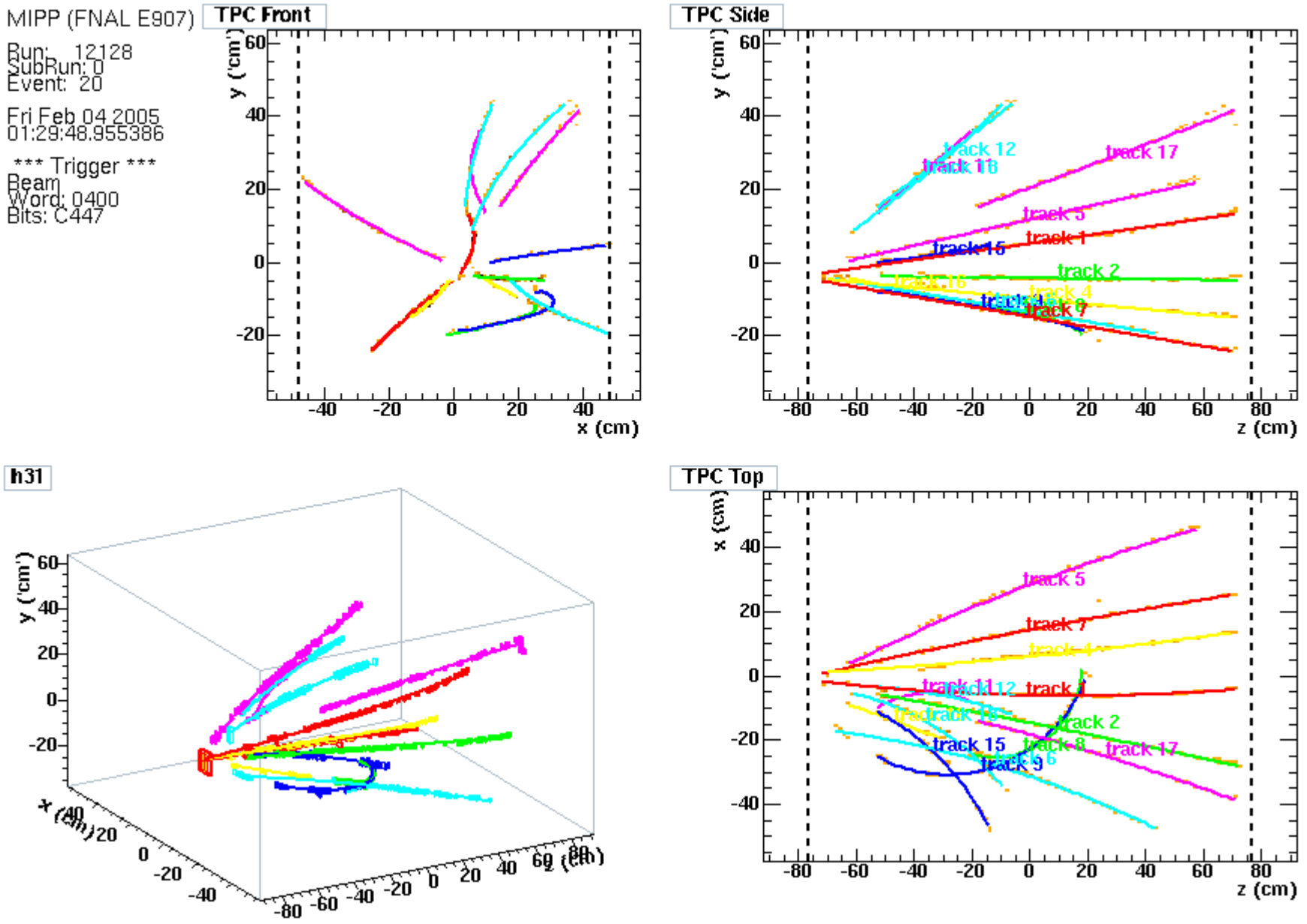
Start with raw TPC data...

TPC Reconstruction



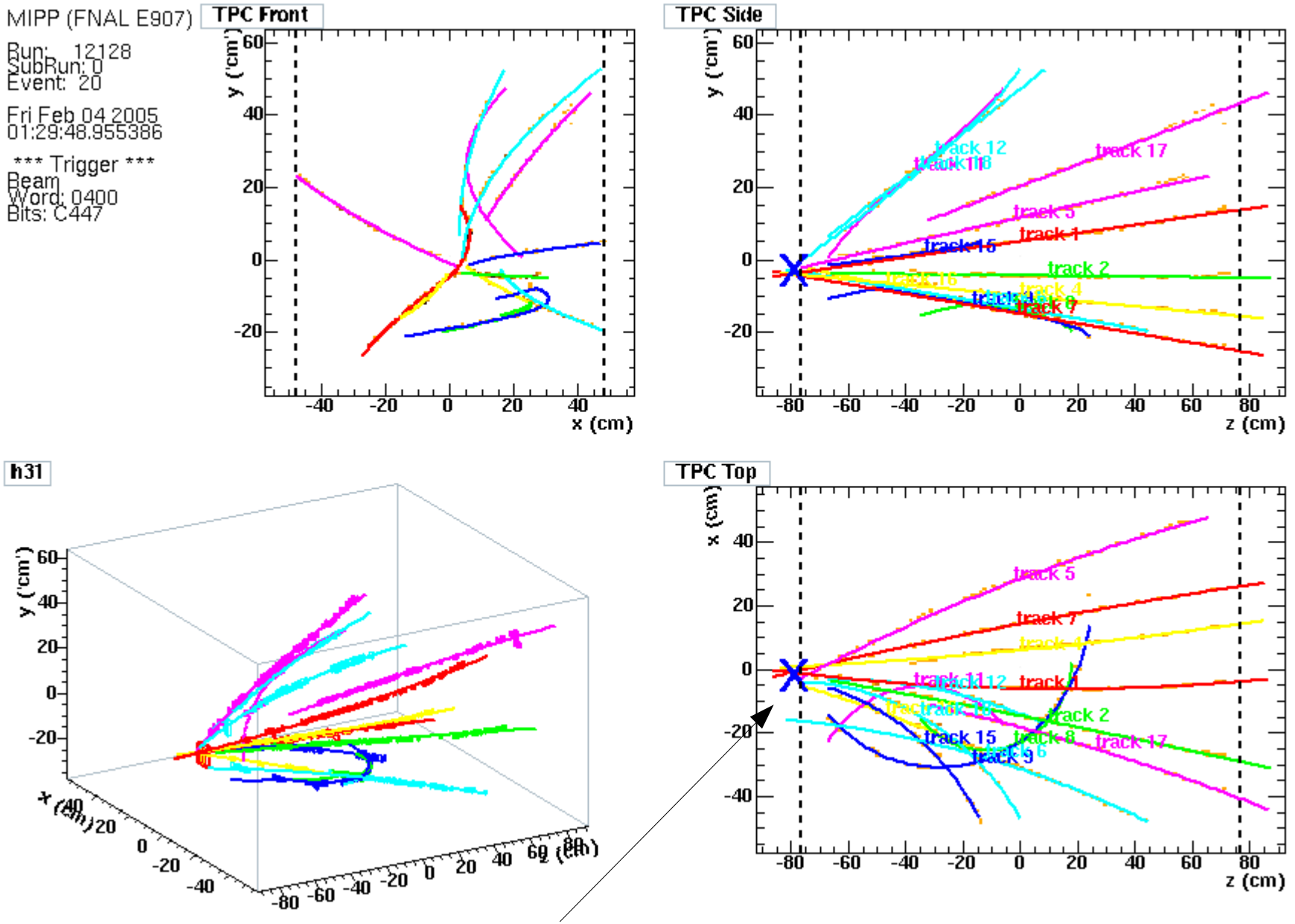
Form clusters of digits (hits) in slices of “z”….

TPC Reconstruction



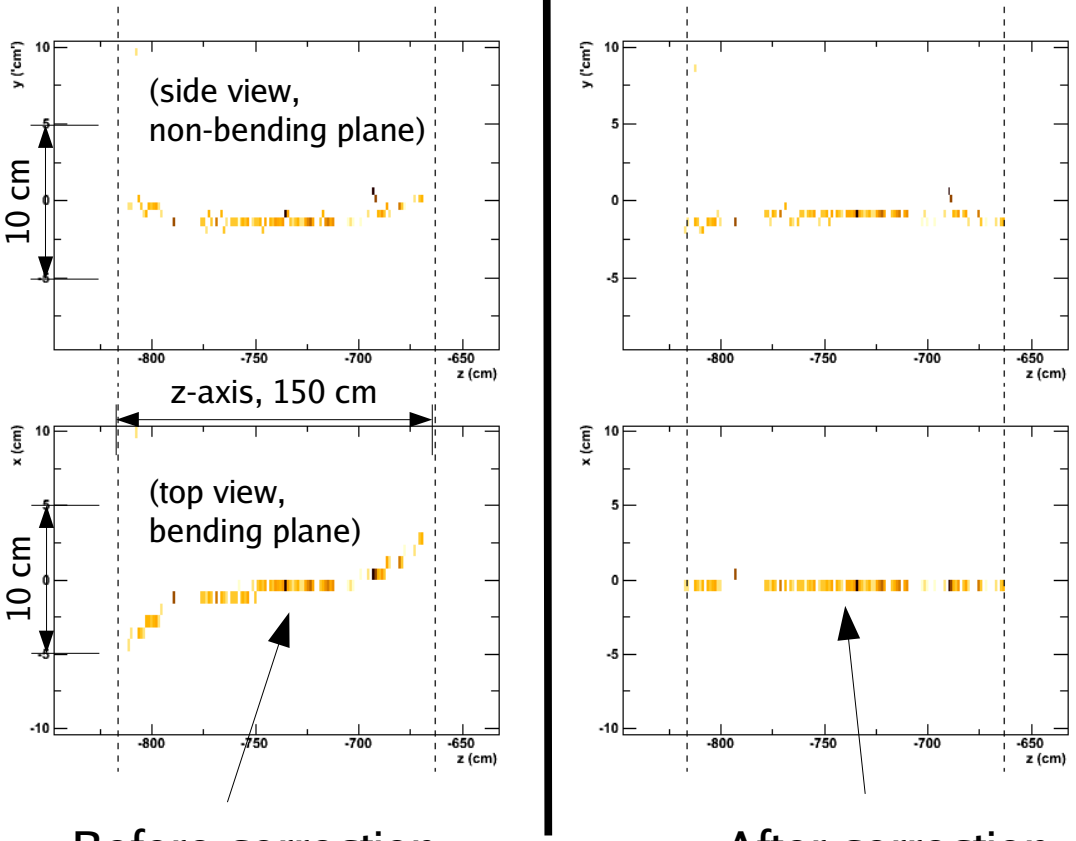
Form tracks from hits...

TPC Reconstruction



Form a vertex from tracks.

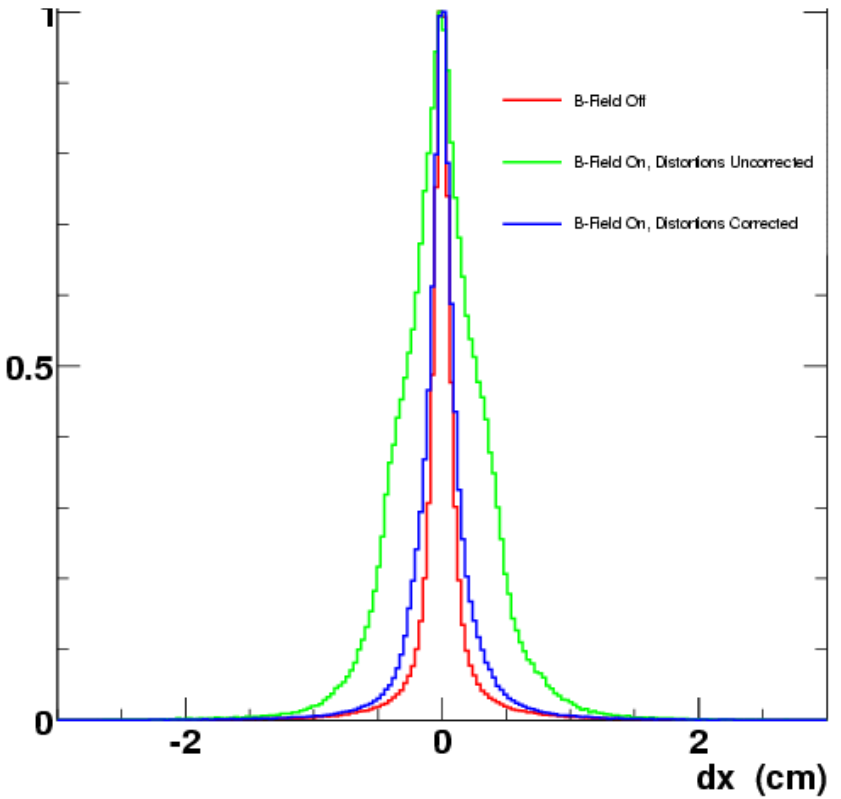
TPC Distortion Effects



Before correction

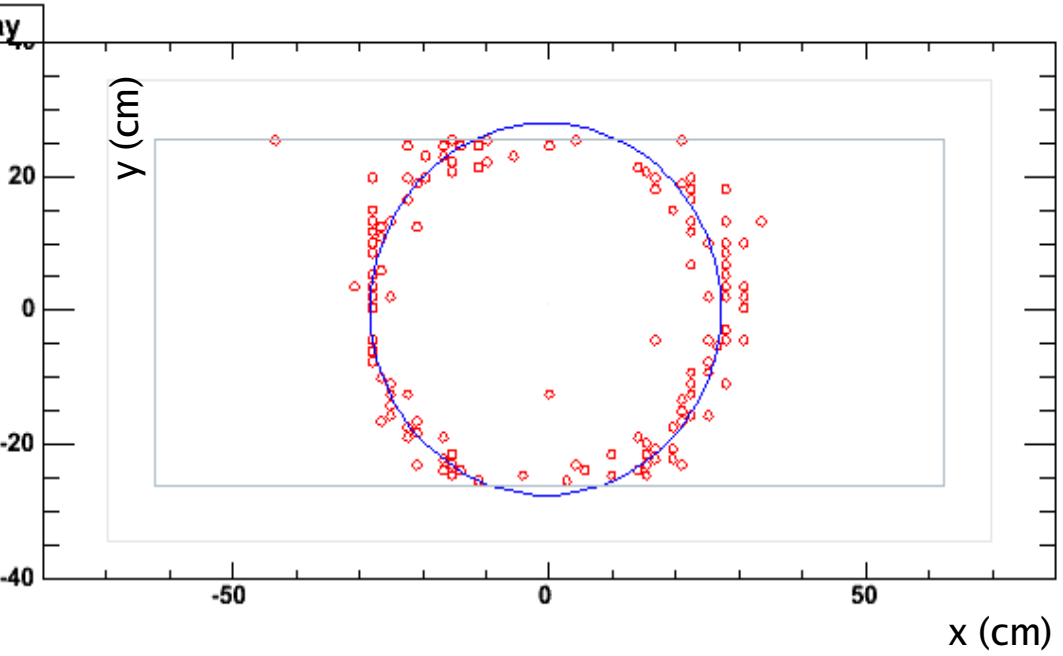
After correction

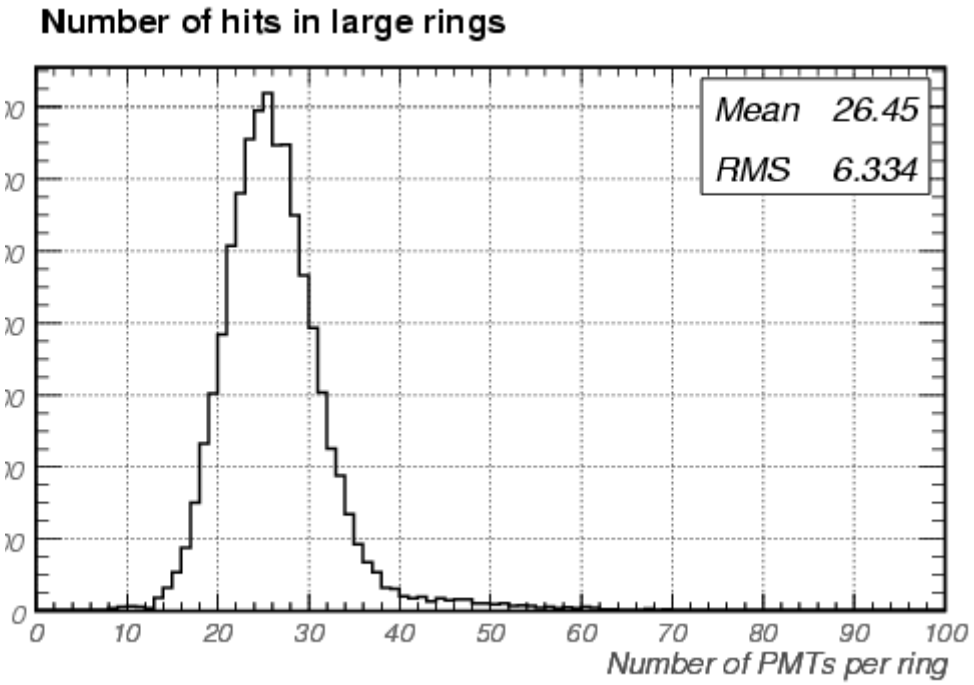
TPC Helix Fit x-Residuals

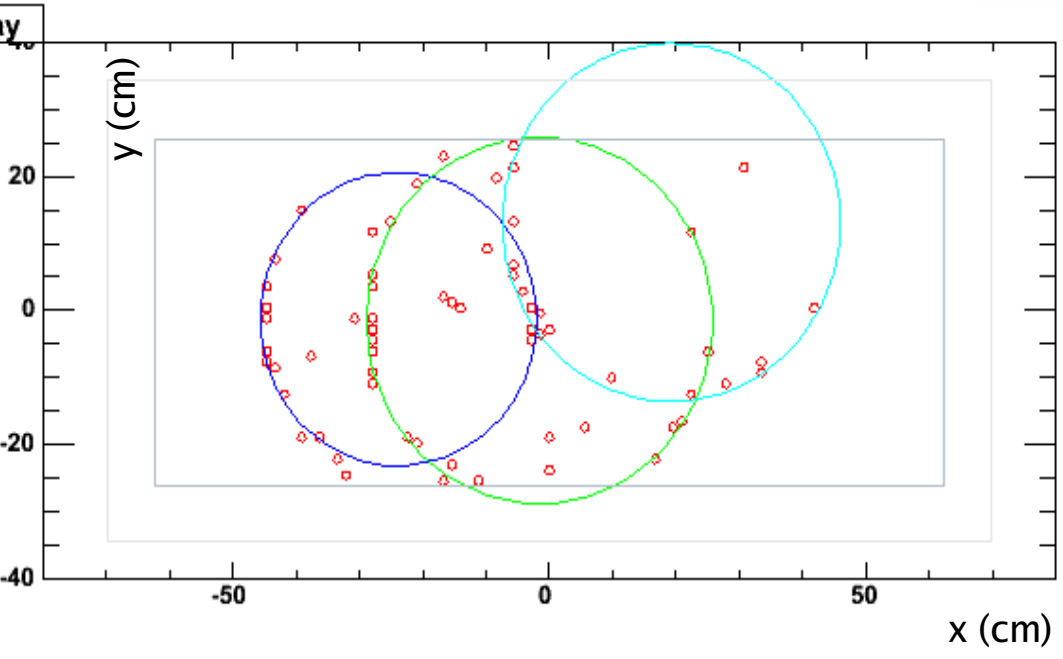


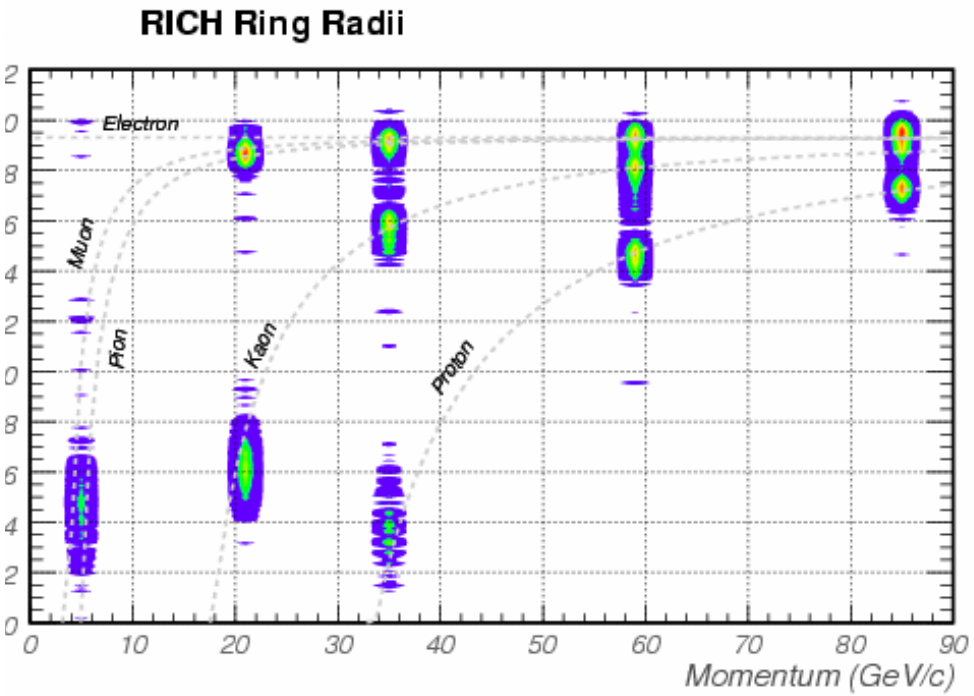
- Inhomogeneous magnetic field causes drift electrons to deviate from straight-line path to pad plane on bottom of TPC. Deviation is ~5 cm at edges.
- Corrections are applied using a measured map of the field; distortion effects are now < 3 mm.

RICH Ring Reconstruction

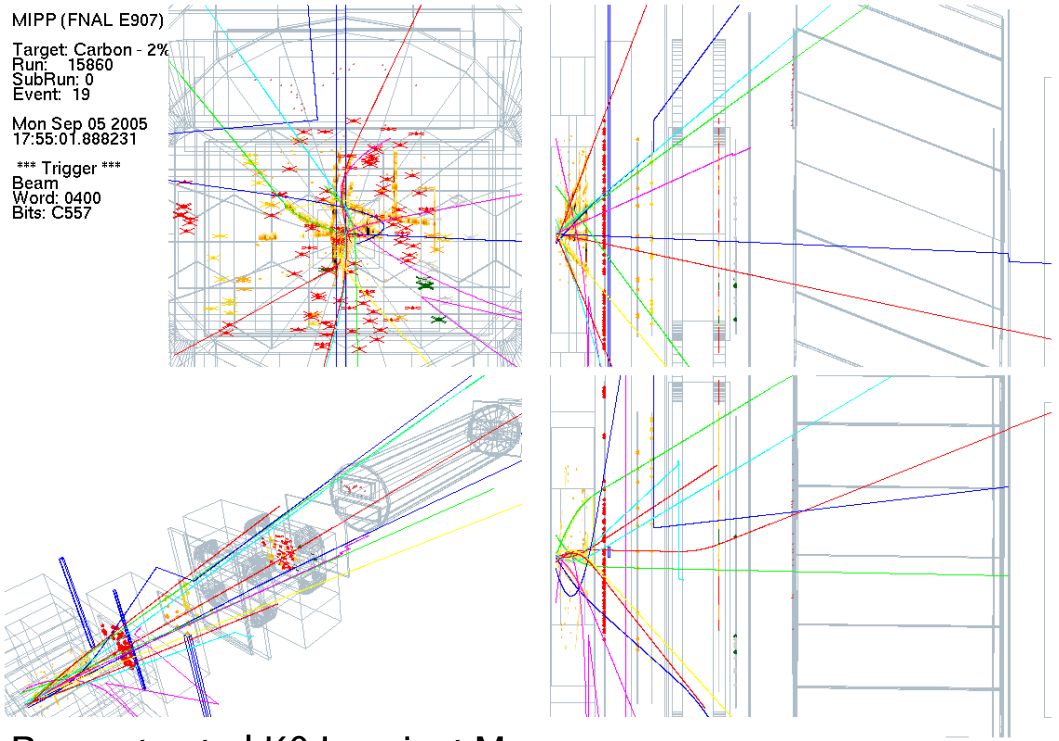


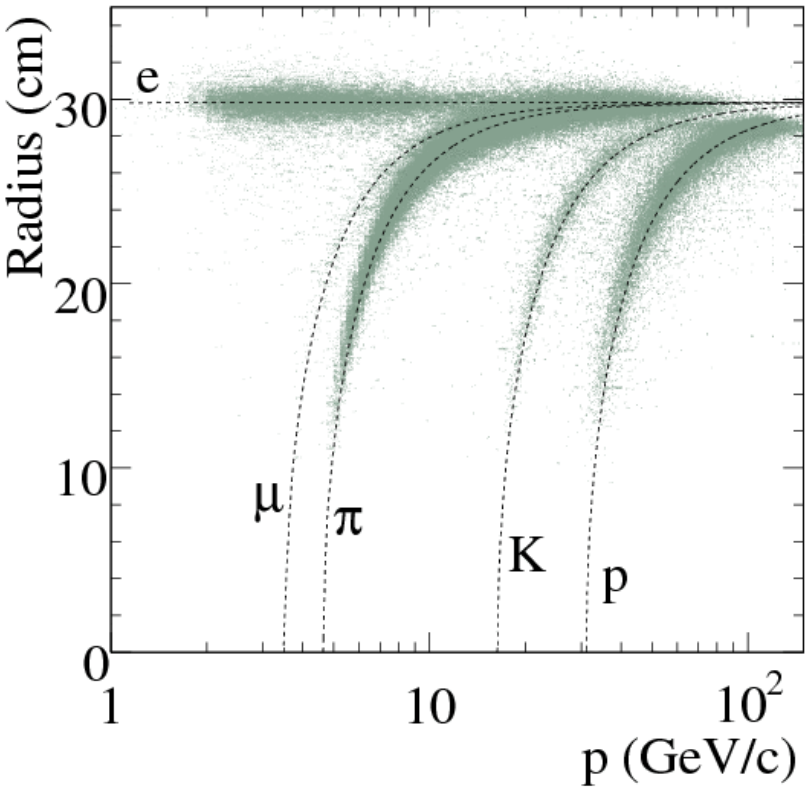




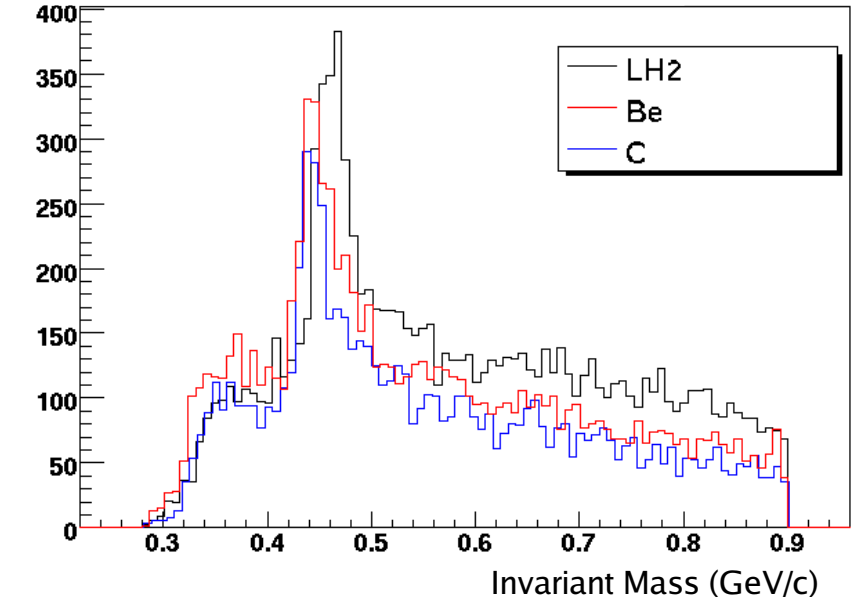


Global Track Reconstruction



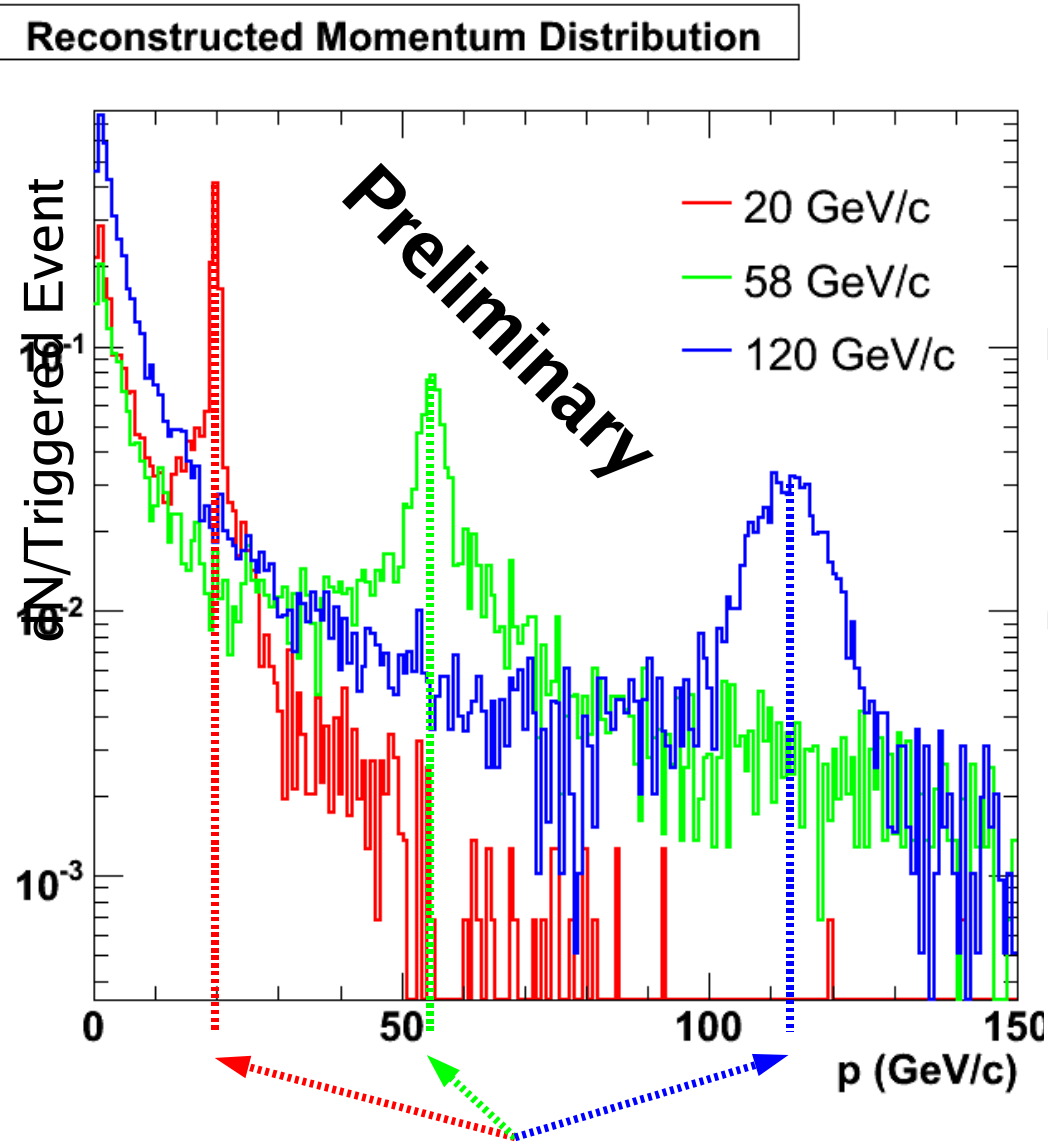


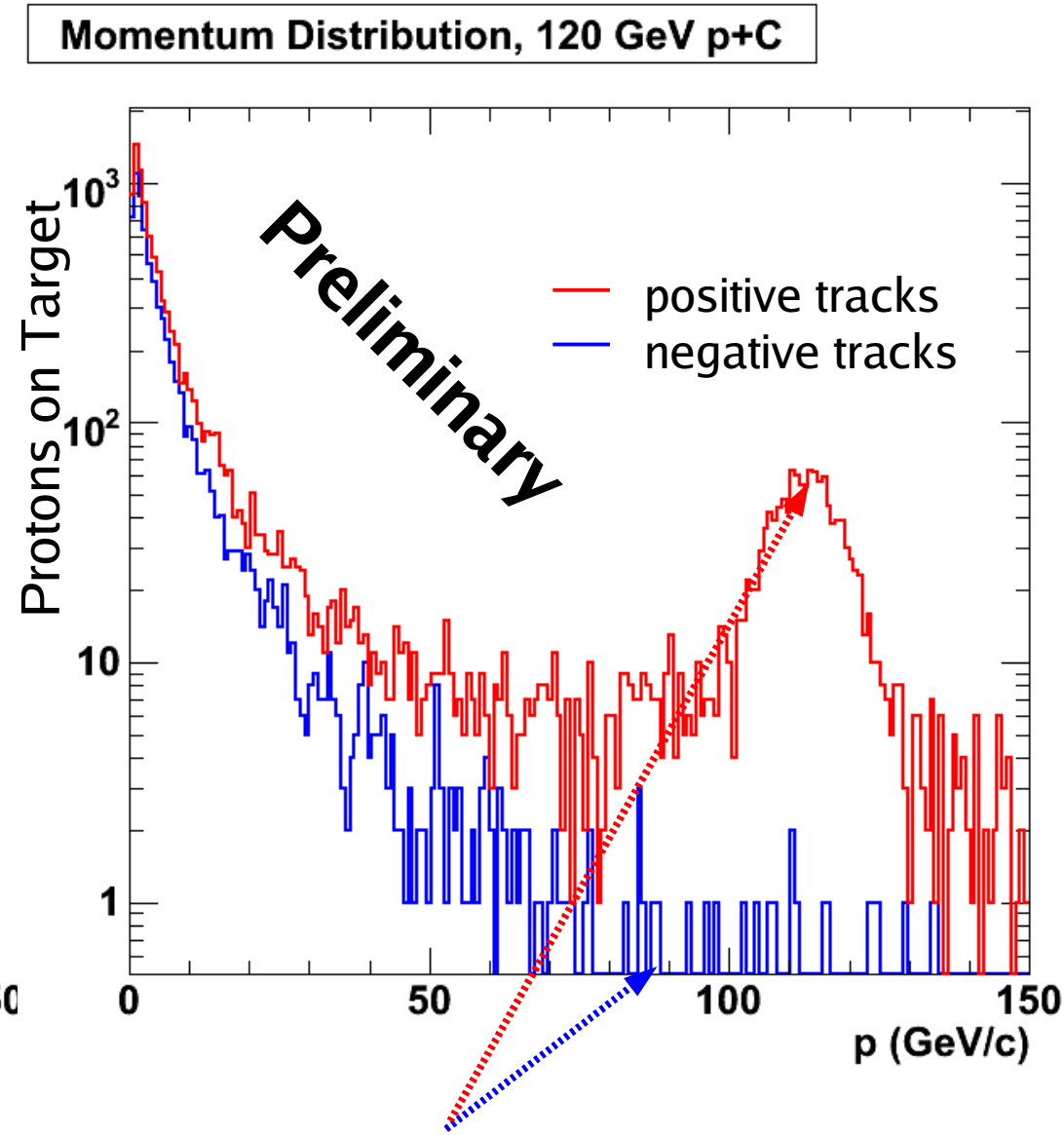
Reconstructed K0 Invariant Mass



- Global tracking connects TPC tracks with drift chamber hits.
- Tracks associated to reconstructed RICH rings shows us we have reasonable π, K and p separation from 17-80 GeV/c.
- Studies of the reconstructed K^0_s invariant mass will allow us to calibrate the magnetic fields.

Reconstructed Track Momenta

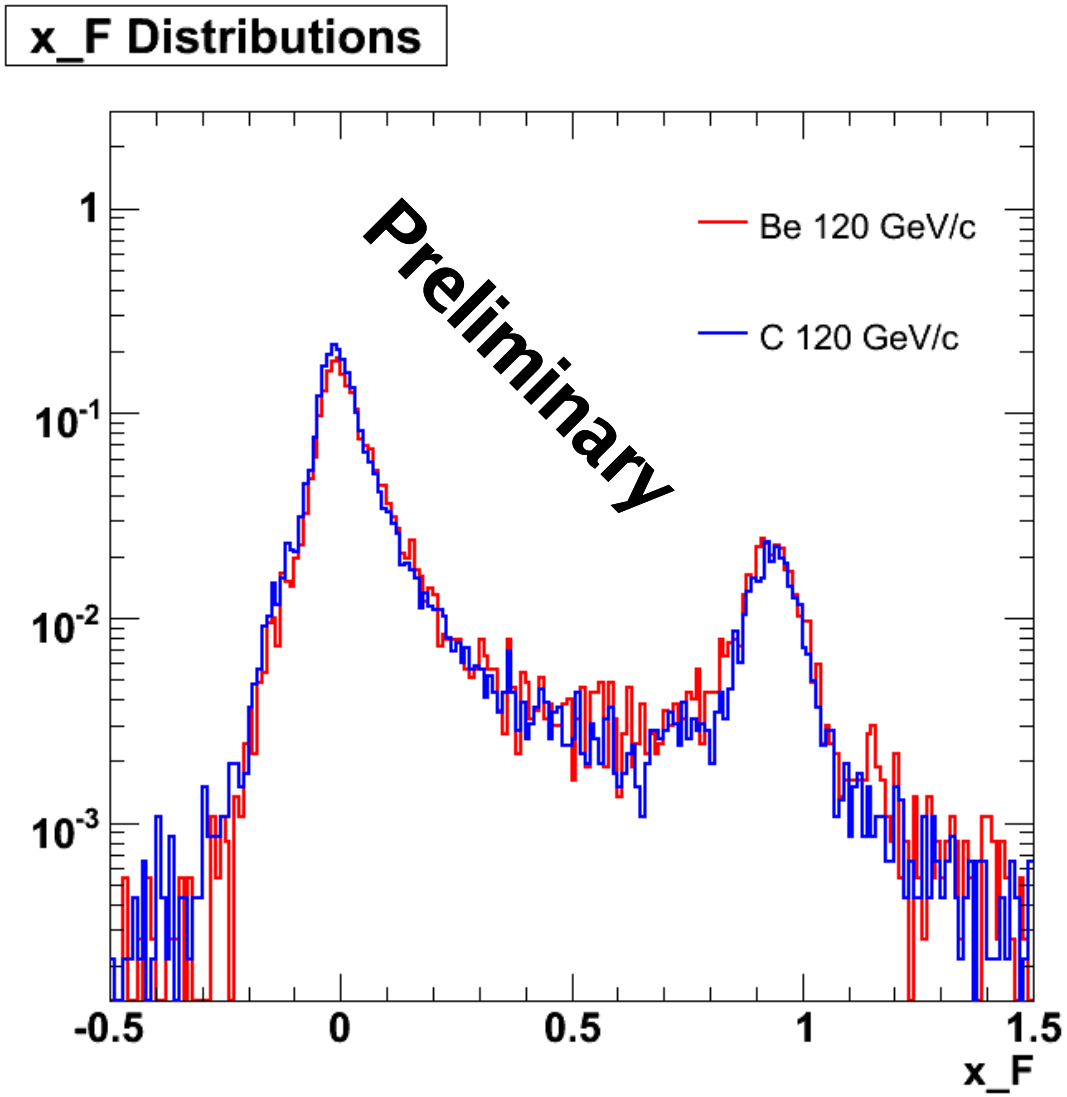


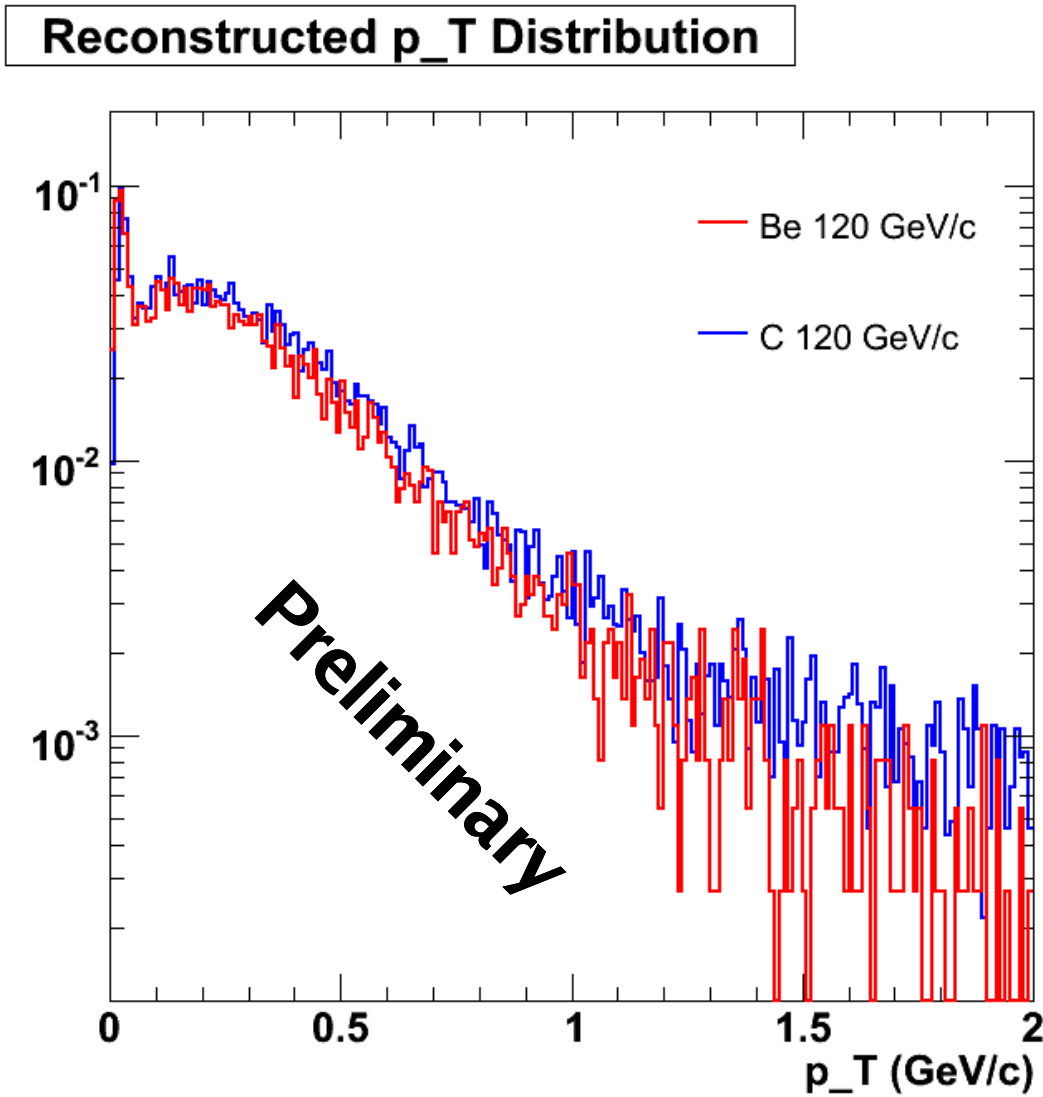


Momentum differences are likely a result of misalignment.

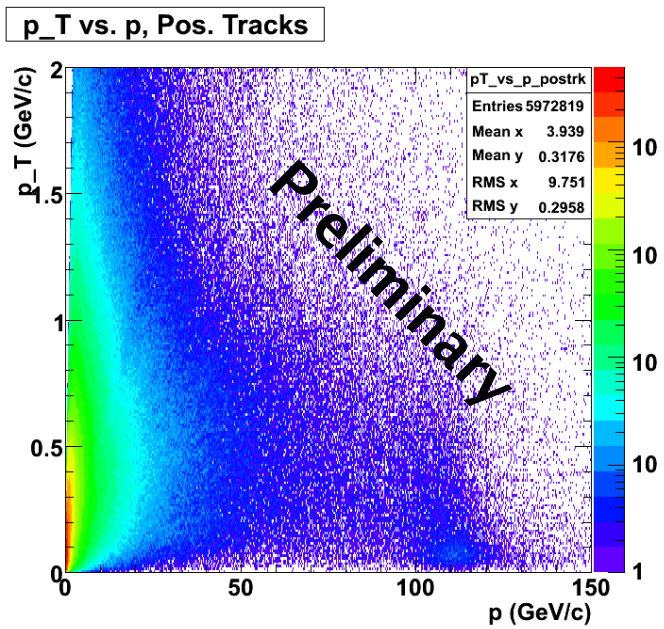
~100% efficient at charge determination up to 120 GeV/c.

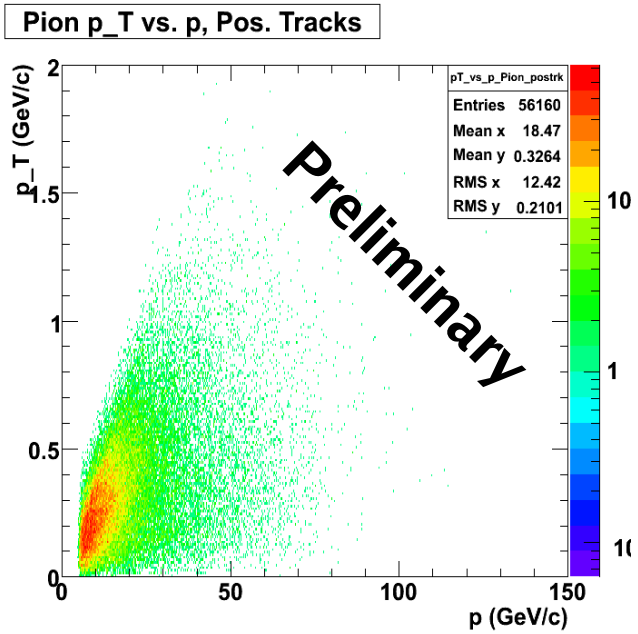
Carbon vs. Beryllium Targets

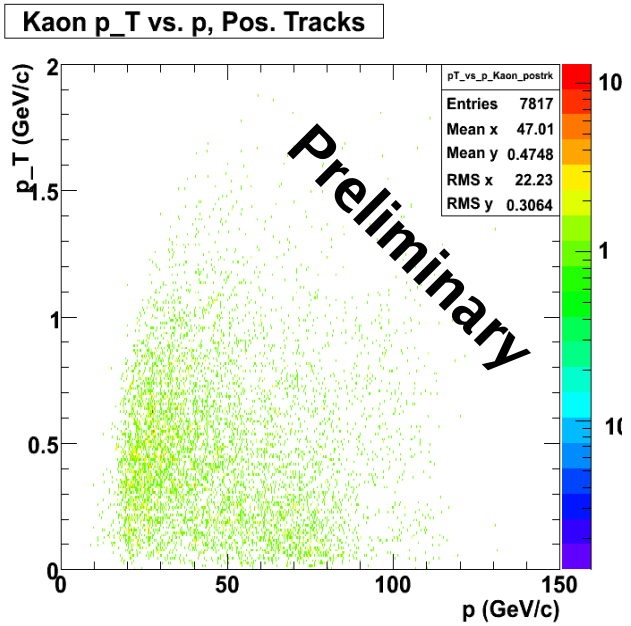




Preliminary NuMI Target Analysis







- Shape of uncorrected p_T and p distributions of charged tracks coming off of the NuMI target agree well with MC predictions.
- Good agreement between measured π+/K+ (integrated above 17 GeV/c) and predicted ratio. This ratio is already of great interest to MINOS, as it would help constrain the high-energy tail of their measured ν_μ spectrum.

Work-in-Progress

- Event reconstruction:
  - Global tracking code will soon be replaced by a Kalman-filter based track and vertex reconstruction.
  - TPC alignment will improve efficiency and accuracy of global track reconstruction.
  - ToF and DCkov calibration will soon provide PID for $p < 20$ GeV/c.
- Monte-Carlo data generation.
- Analysis:
  - MIPP will begin a pass through all the data with improved reconstruction in about 1 month.
  - π/K and π^+/π^- ratios above 17 GeV/c will likely be the first measurement provided to MINOS.
  - **GOAL: have preliminary results for the MINOS collaboration by the end of this year.**

MIPP Upgrade

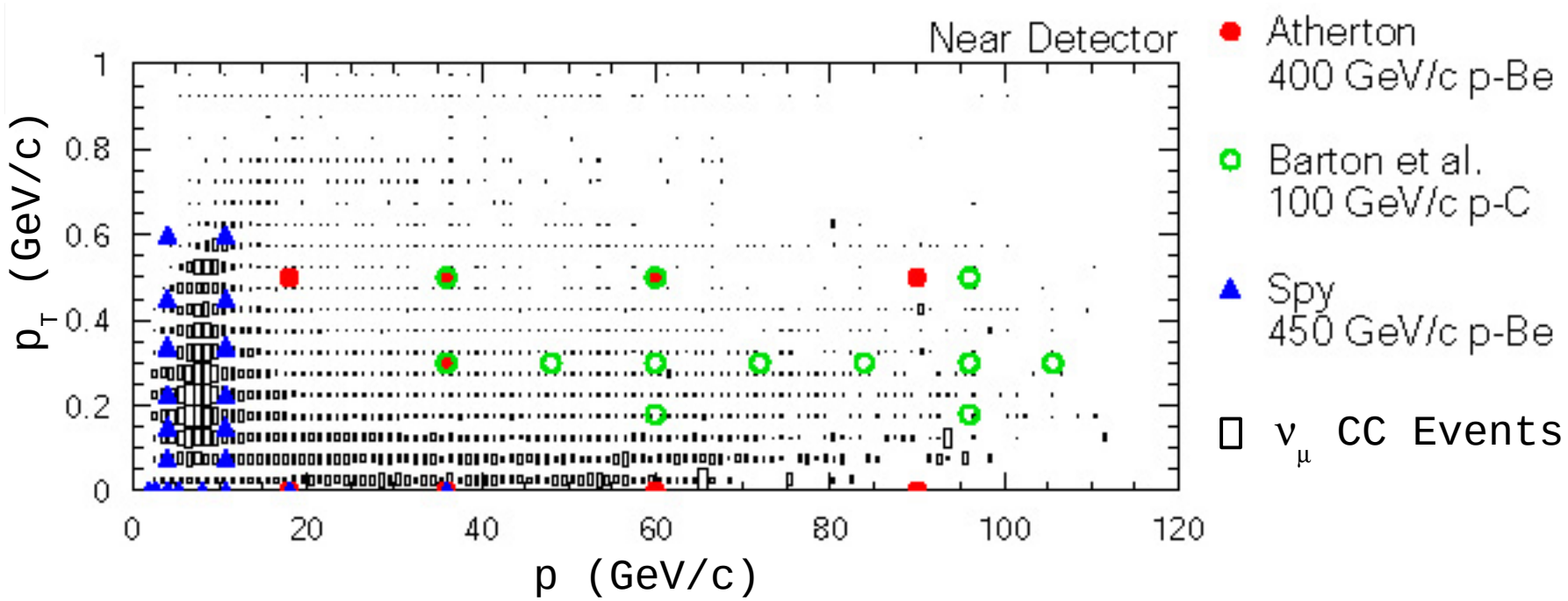
- Current experiment is severely limited by DAQ rate, dominated by the TPC readout time (~30 Hz). This resulted in MIPP only collecting ~1/6 of desired statistics for the MINOS target run.
- An upgrade of the TPC electronics, using the ALICE ALTRO chip, can increase this readout time by up to a factor of 50. Other improvements would result in:
  - more stable TPC performance
  - greatly reduced ExB effects in the TPC
  - an improved beamline for low (~1 GeV/c) momentum running
- An upgraded MIPP would allow for the measurement of hadron production for any target (eg, MINOS, NOνA, T2K, etc.) in a matter of just a few days!
- FNAL has approved the purchase of the ALTRO chips for the TPC upgrade. We are in the process of writing a proposal to be submitted to FNAL this October.
- **MIPP is looking for new institutions to join the upgrade effort, and would greatly benefit from involvement of the accelerator-based neutrino community!**

Conclusion

- Data taking for MIPP has finished:
  - ~1.5 x 10^6 events of 120 GeV/c protons on the NuMI target were collected.
  - Several millions of (π,K,p) + A --> X1 + X2 + ... events were collected over a wide range of momentum and A.
- Preliminary results using existing reconstruction and PID are very promising.
- The collaboration is now focused on improving the event reconstruction and data analysis.
- MIPP hopes to provide MINOS with preliminary results by the end of this year.
- Upgrade proposal is being worked on; potential for much improved measurement in the future.
- Stay tuned!

Backup Slides

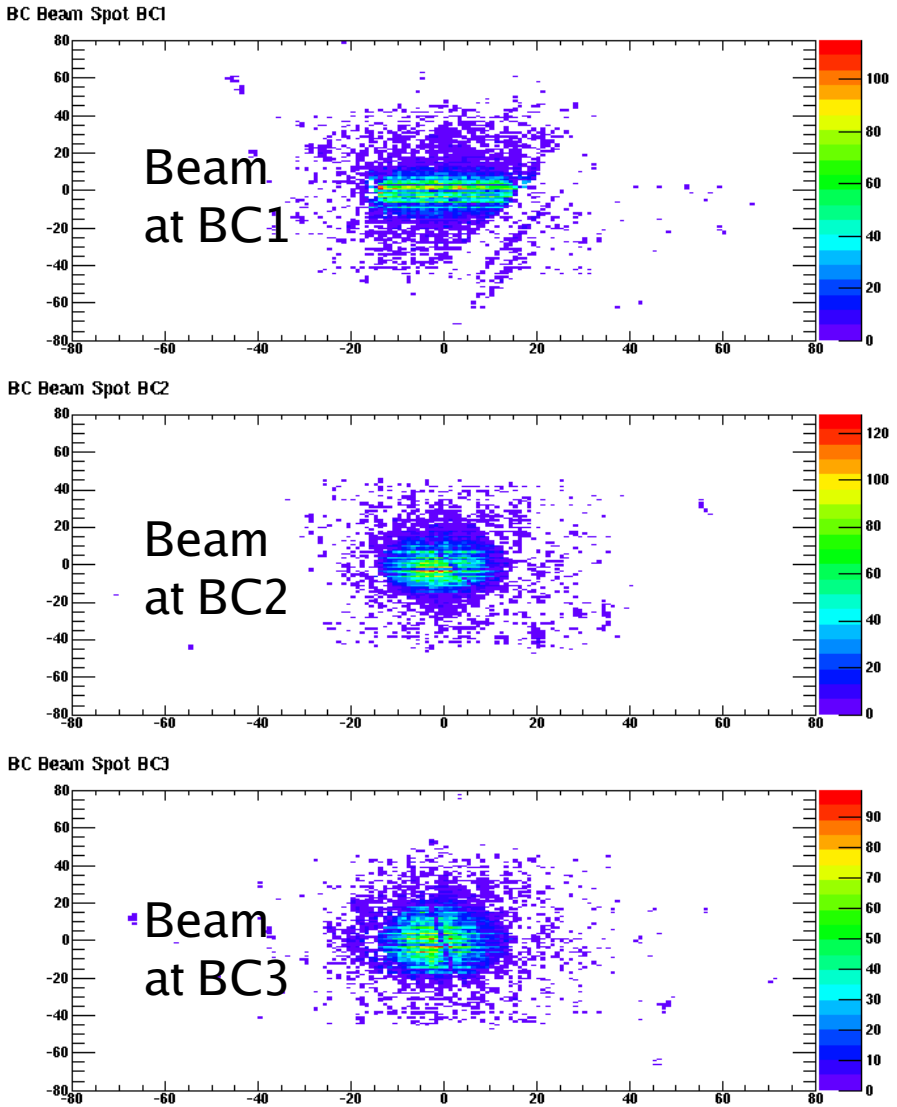
Existing Data

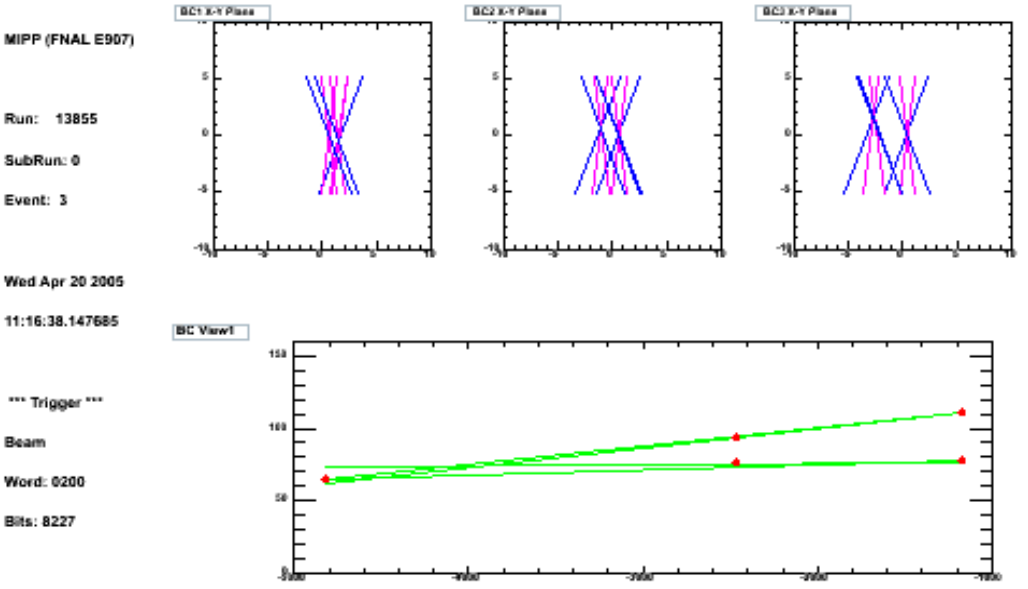


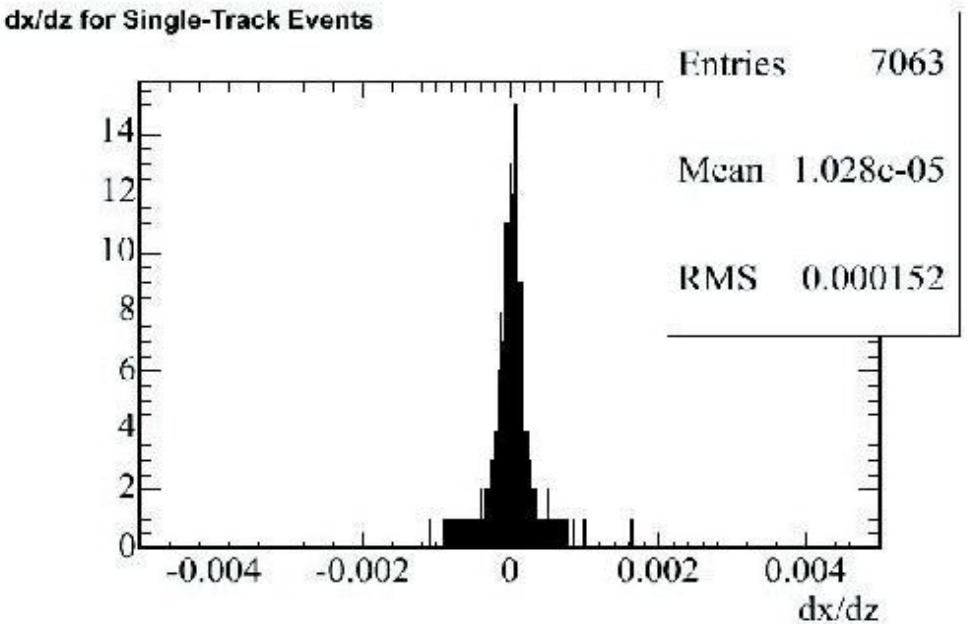
- Size of box is proportional to number of ν_μ CC events produced from a pion of that (p,p_T) value coming off of the MINOS target.
- Previous experiments used single-arm spectrometers, giving only single (p,p_T) flux measurements.

Beam Wire Chambers

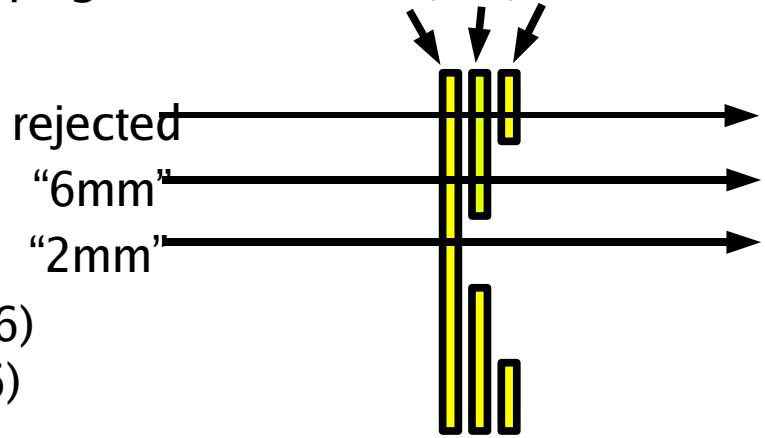
Three wire chambers sit upstream of target to measure trajectory of incoming particles.





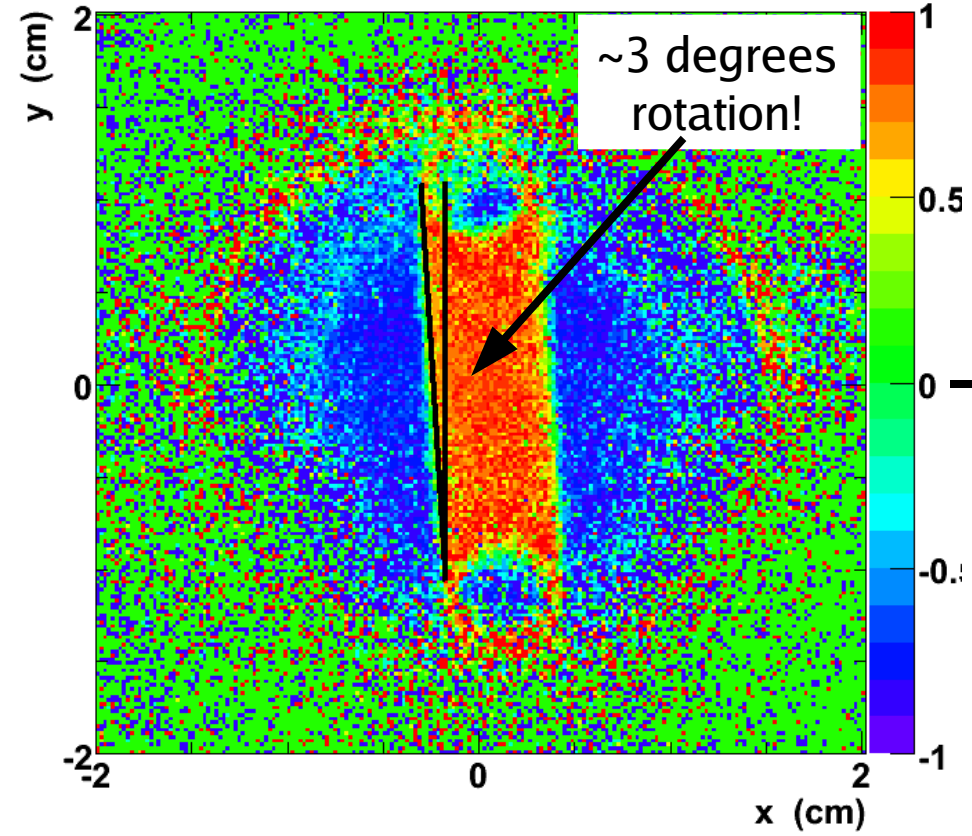


NuMI Trigger: three overlapping scintillators (vb, v2, v6)

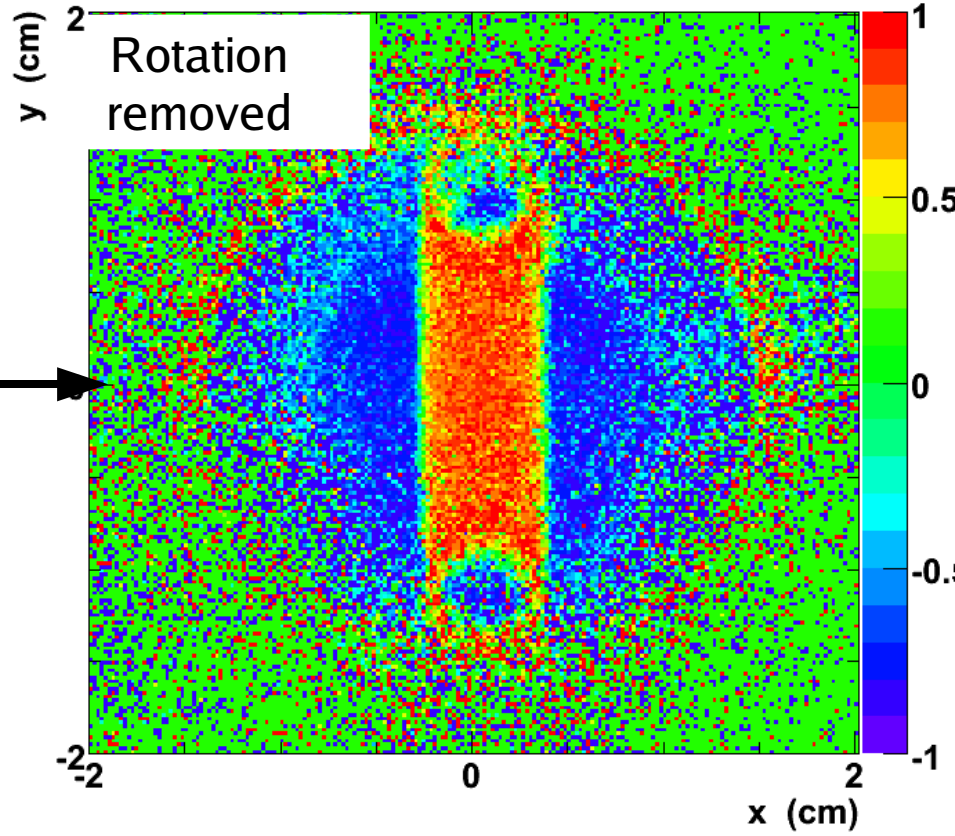


"2mm" trigger: (vb)*(!v2)*(!v6)
"6mm" trigger: (vb)*(v2)*(!v6)

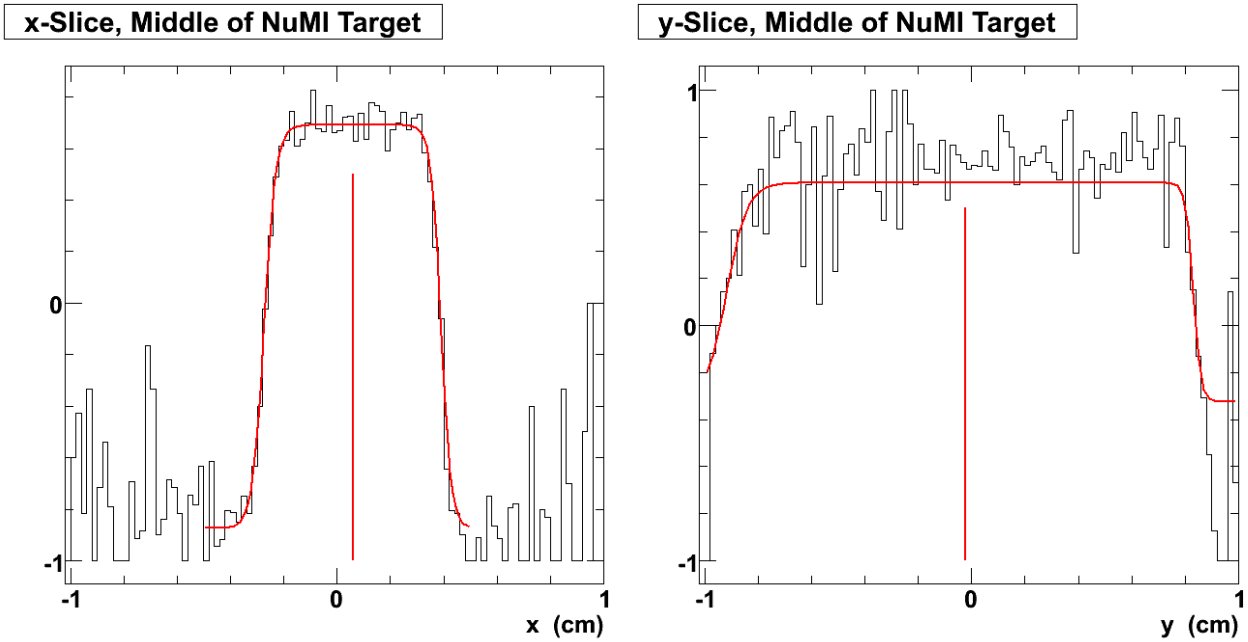
NuMI Target X-Ray

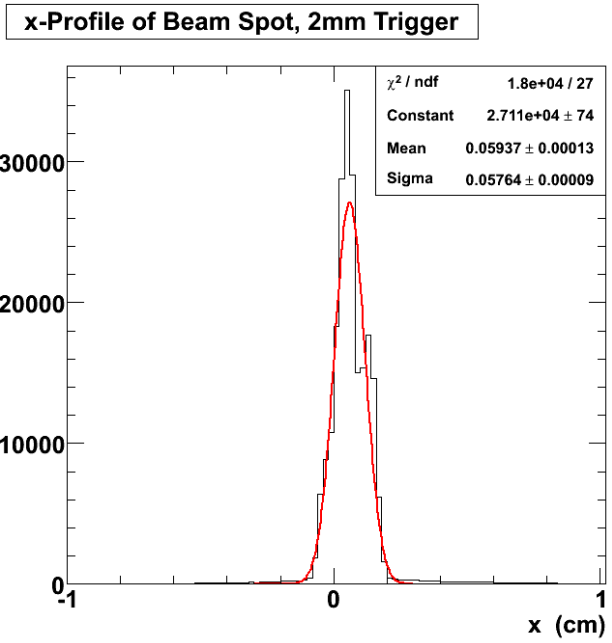


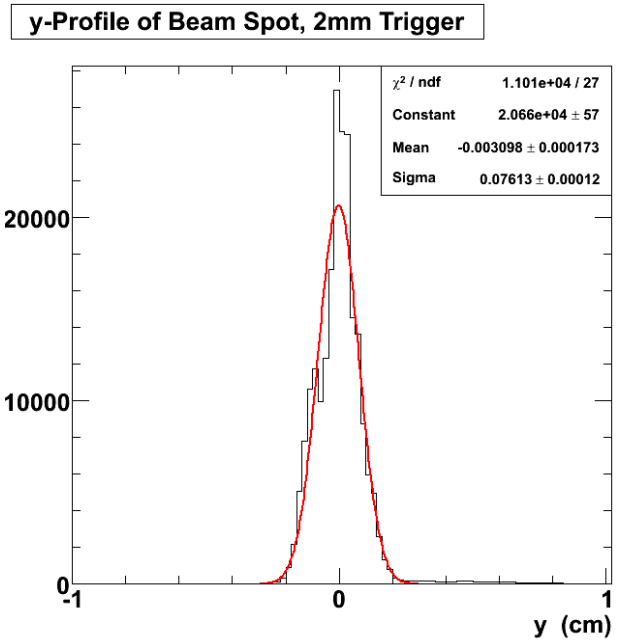
NuMI Target X-Ray (Rotated)



MIPP Beam Alignment on MINOS Target



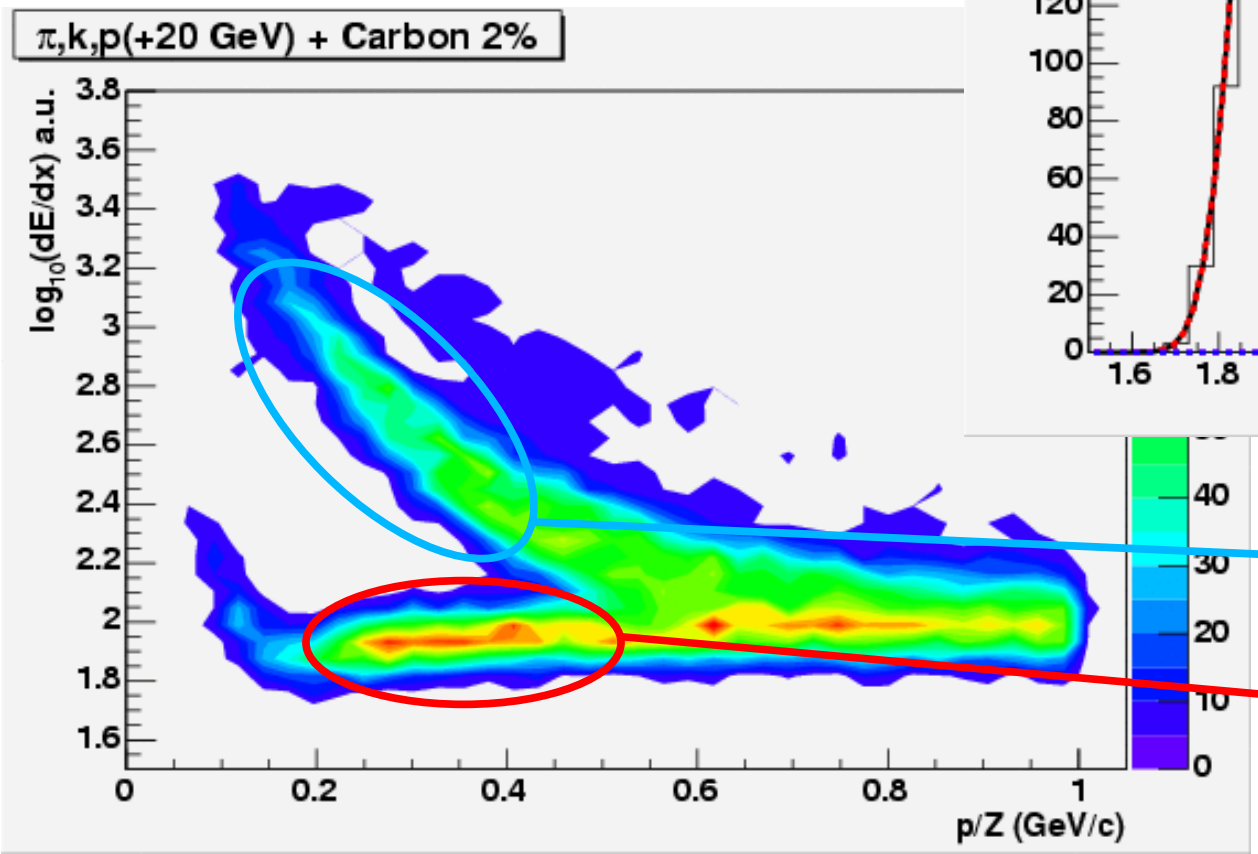


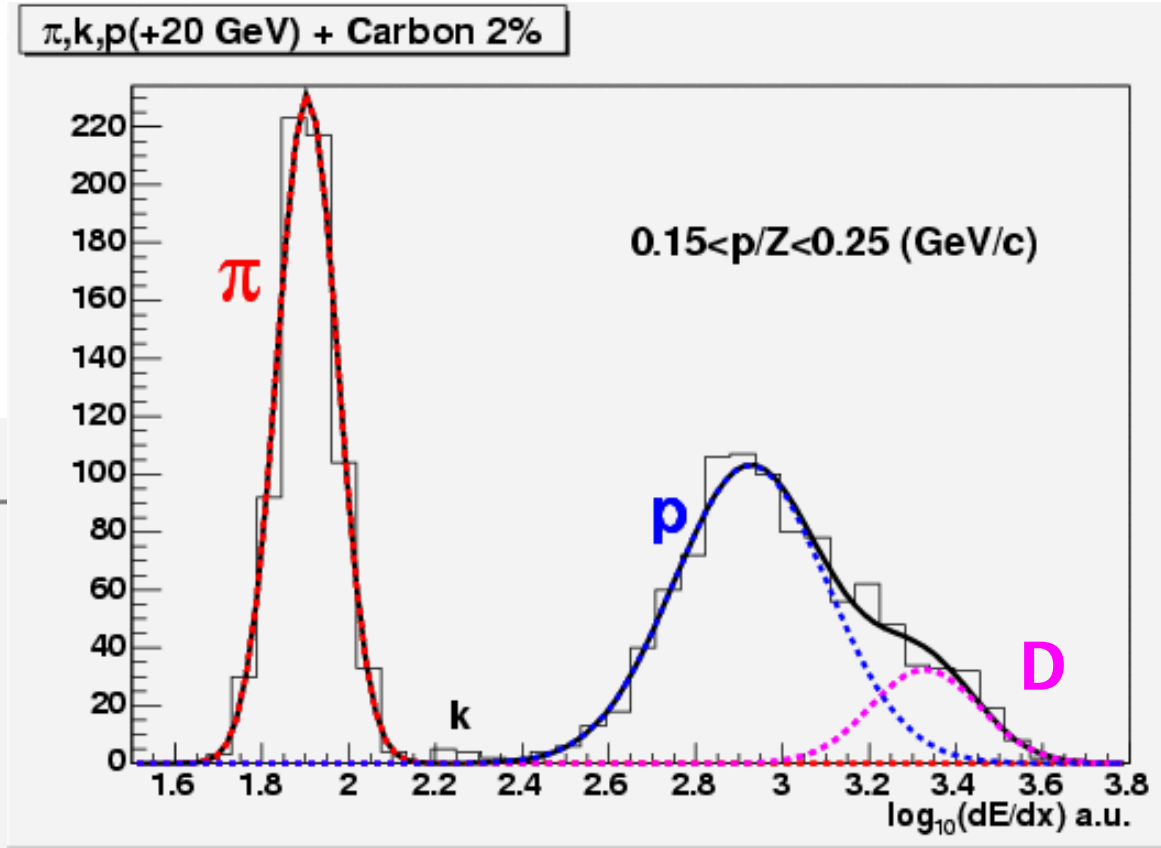


- All measurements are wrt to beam wire chambers (WCs).
- Therefore, first determine center of target in WC ref. frame. Center of target is defined by fitting for edges of graphite slabs.
- Beam center is determined from distribution of projected beam track position at (estimated) upstream end of MINOS target for “2mm” triggered events.

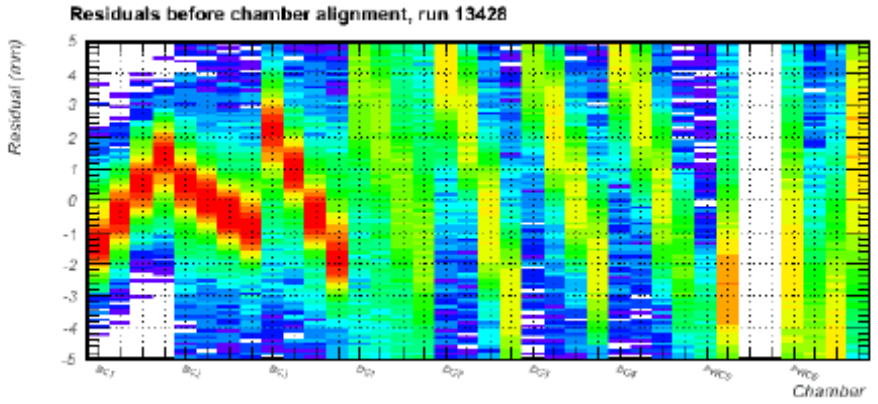
Status of TPC dE/dx

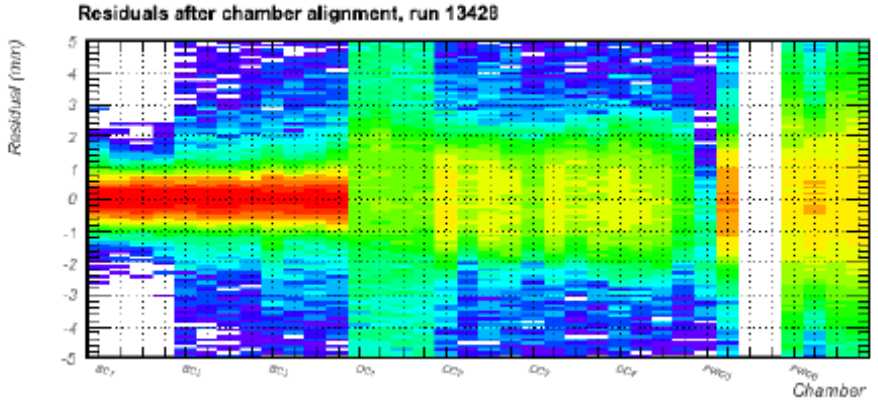
- Preliminary results (uncalibrated and with poor momentum resolution) very promising.
- Calibration is in progress...

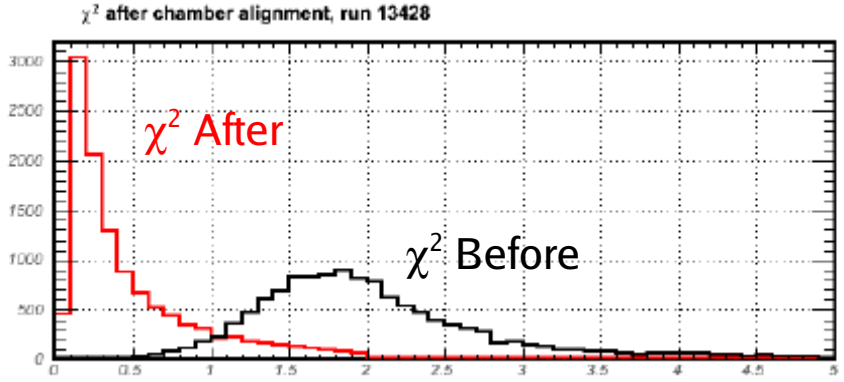




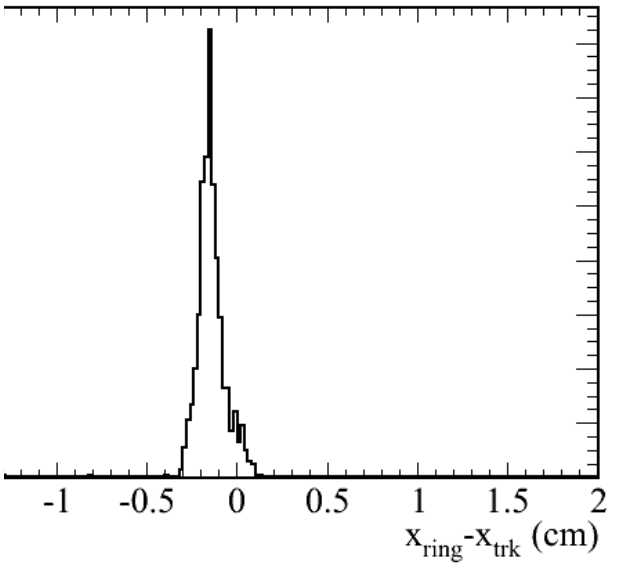
Detector Alignment

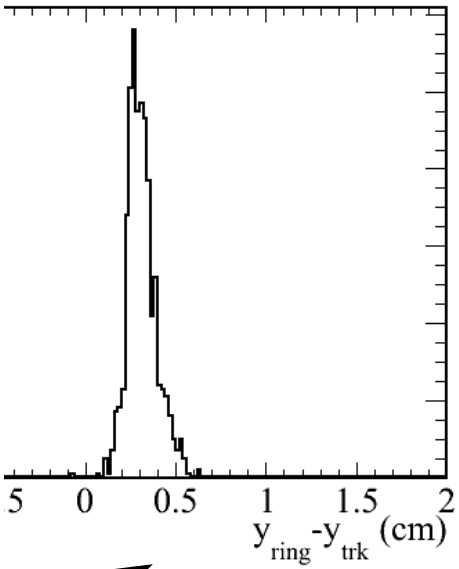






Track x(y) position at RICH – RICH ring center

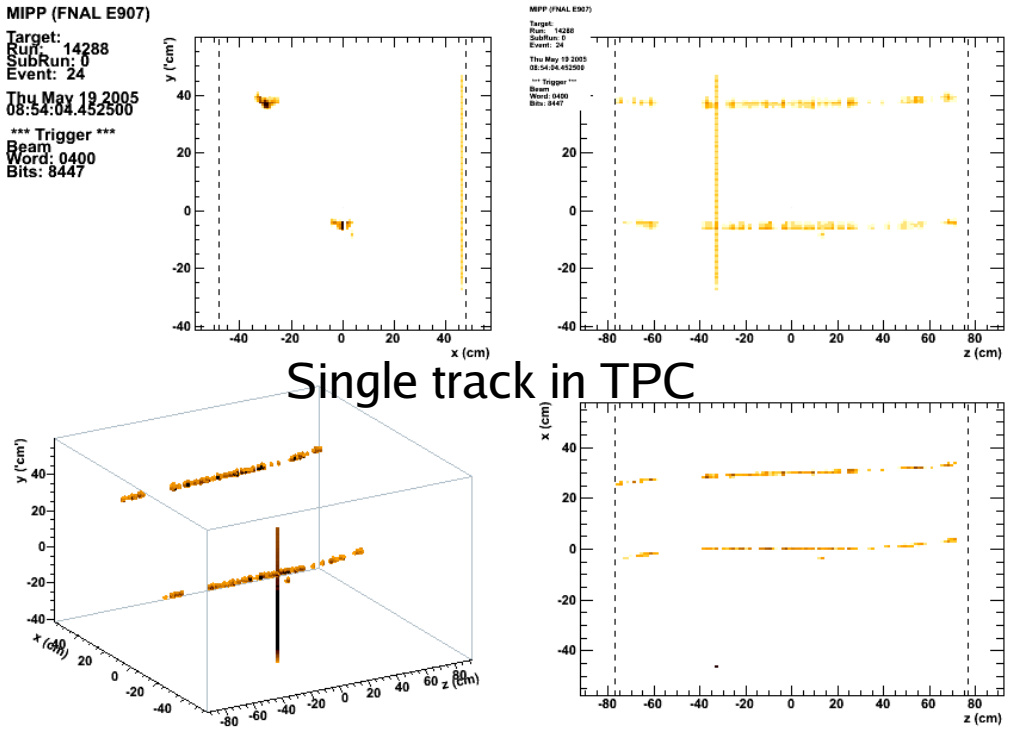




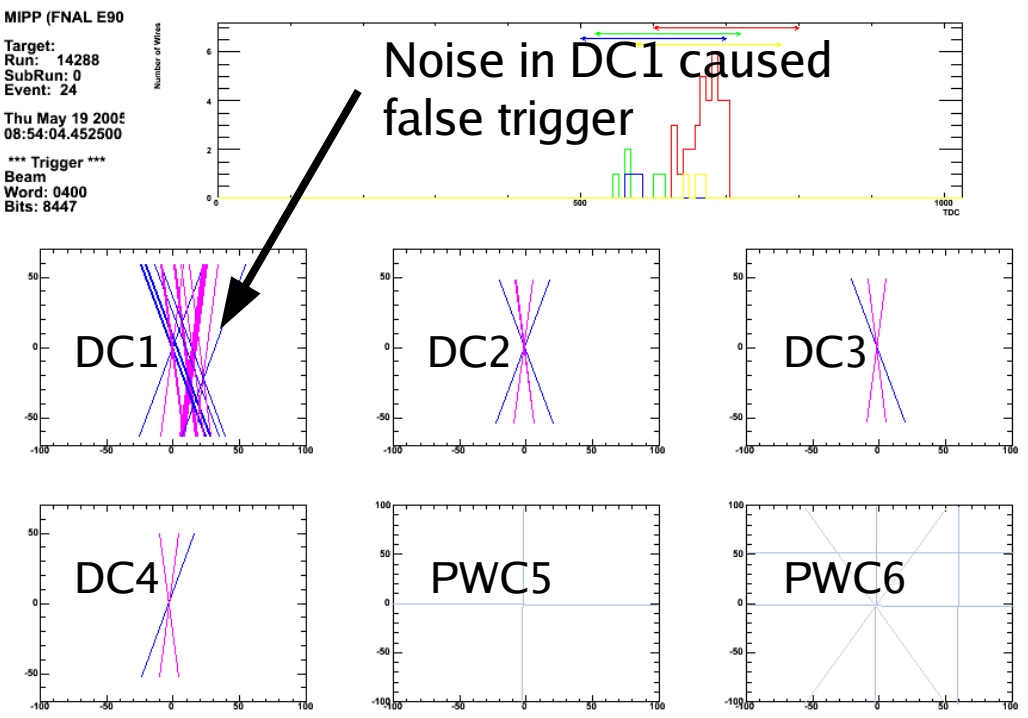
RICH alignment – mirrors aligned to within a few mm

Drift chamber alignment – analysis in-progress will align wire chambers to within 0.2 wire-spacing.

Interaction Trigger

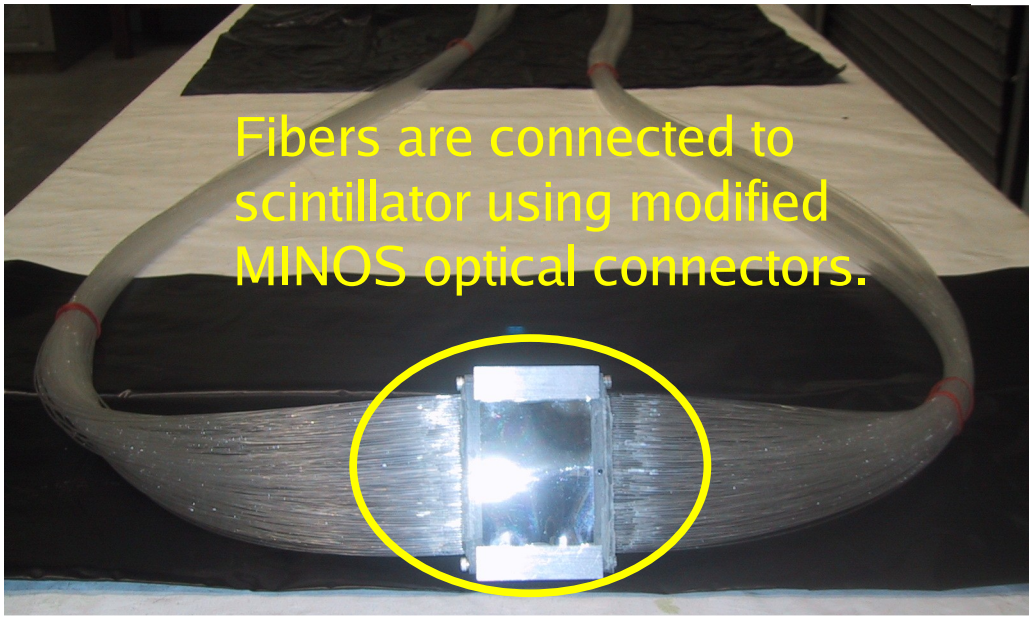


Single track in TPC

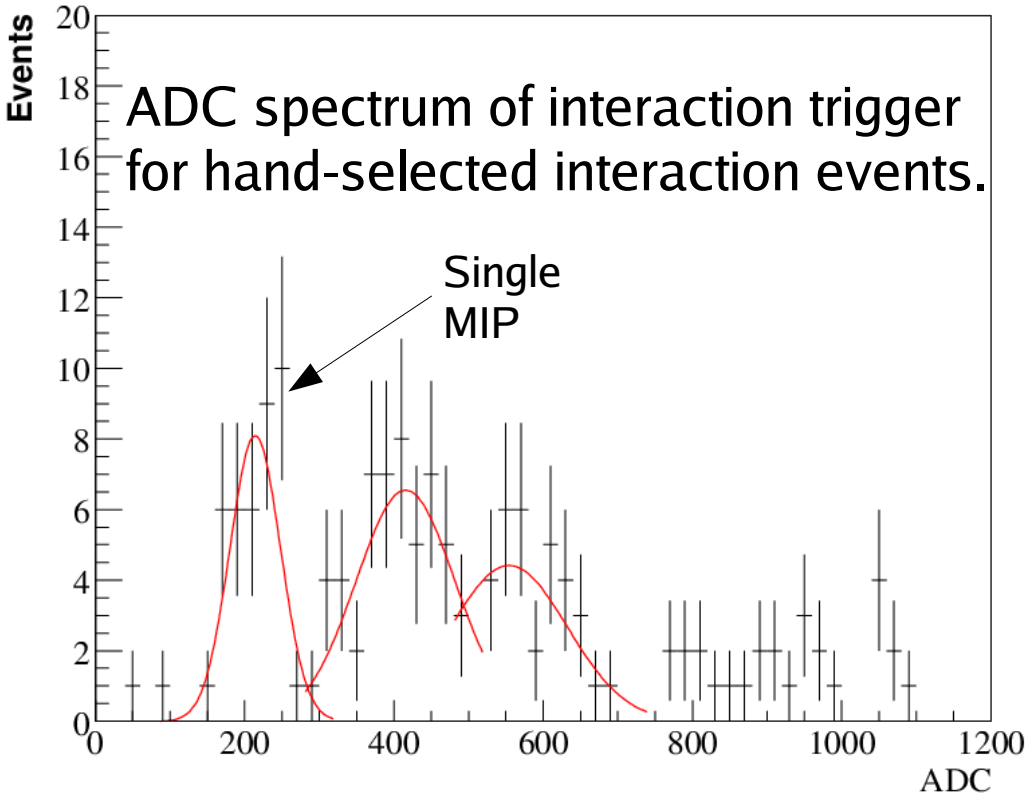


- Constrants: ~1% λ thick targets and slow DAQ rate (typically ~30 Hz)
- Original interaction trigger design was based on downstream drift chamber multiplicity. However the drift chambers were noisy and the trigger very susceptible to beam halo.

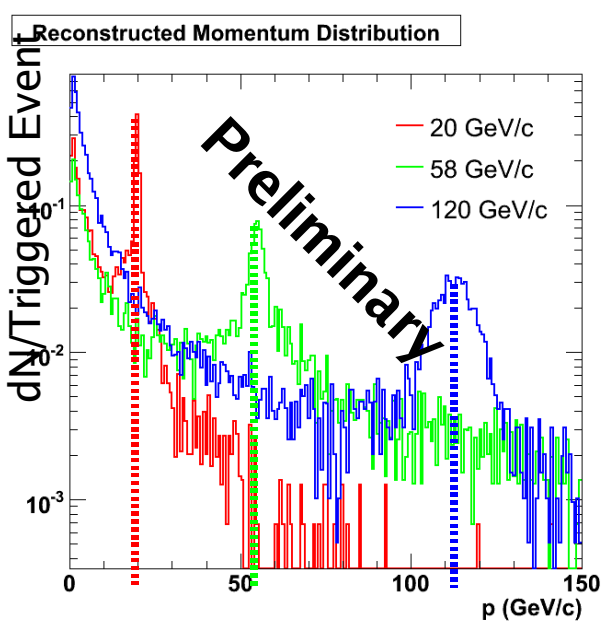
Interaction Trigger

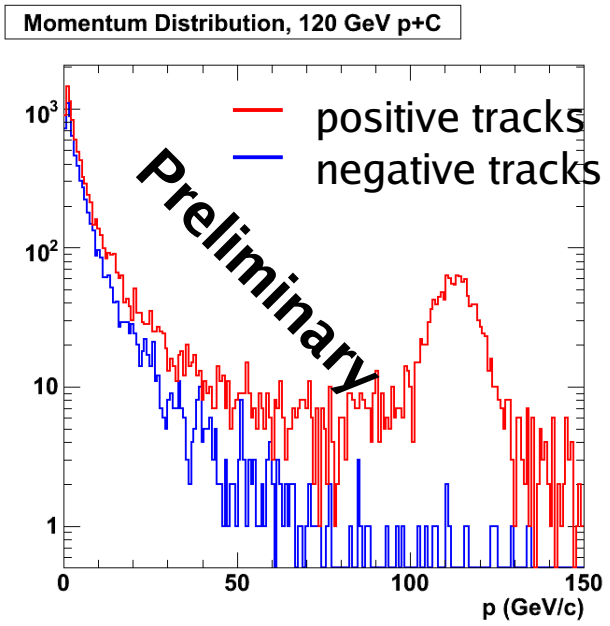


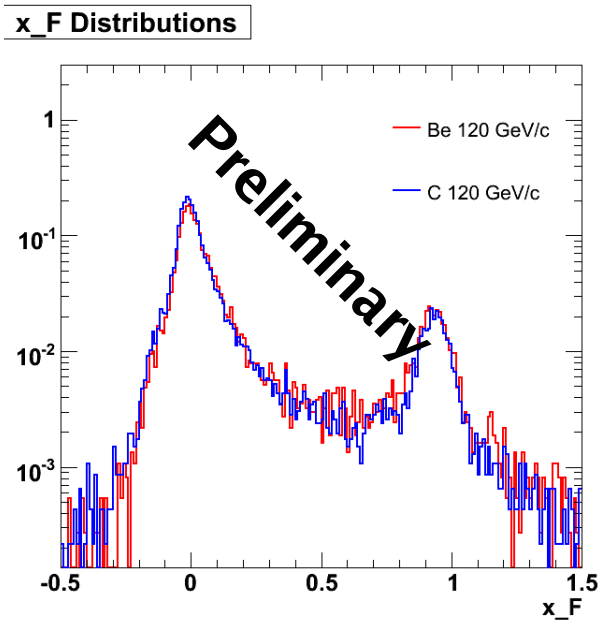
- A thin scintillator detector was placed ~1.5 cm downstream of the target, and a trigger formed on the discriminated signal from the scint.
- Threshold set to ~3 mips, giving a maximum ~50% in both efficiency and purity of trigger, based on hand-scan studies.



Preliminary Analyses







- Current track momentum reconstruction uncertainty is ~4% at 20 GeV/c, and ~10% at 120 GeV/c.
- Systematic offset of reconstructed beam momenta due to chamber and TPC misalignments.
- Tracking is ~100% at determining charge up to 120 GeV/c.
- x_F and p_T distributions of thin Be and C targets are very similar; Be data may be used to enhance our thin C target measurements.