MIPP

The Main Injector Particle Production experiment

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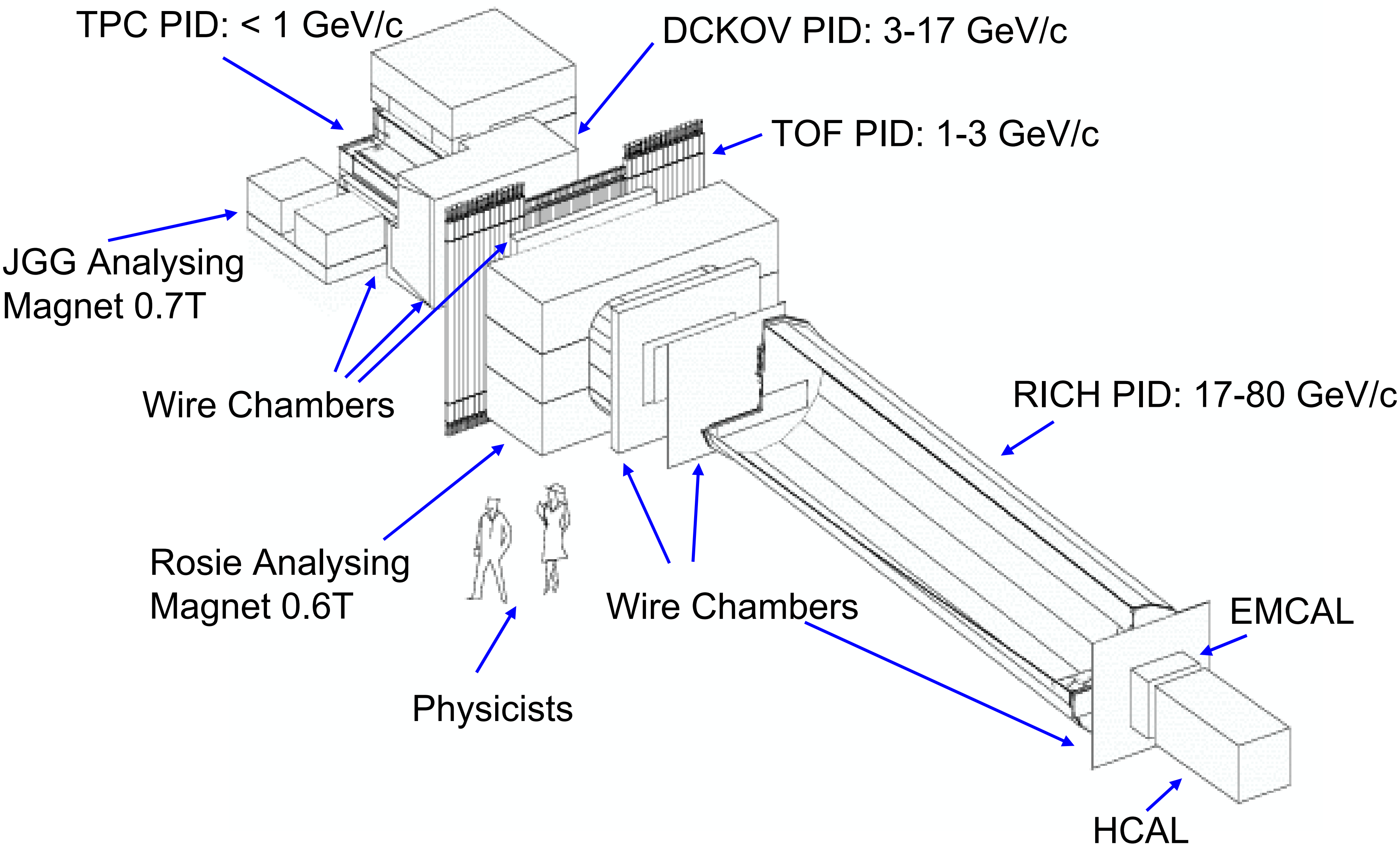
MIPP overview

- Measure particle production off various nuclei
- Incoming secondary beams of $\pi^{\pm}$, $K^{\pm}$ and $p^{\pm}$ from 5 to 80 GeV/c or primary p beam from the Main Injector (120 GeV/c)
- Large acceptance spectrometer featuring a Time Projection Chamber
- Measure momentum of all charged particles produced
- Identify particles with dE/dx, ToF, differential and ring imaging Cerenkovs.

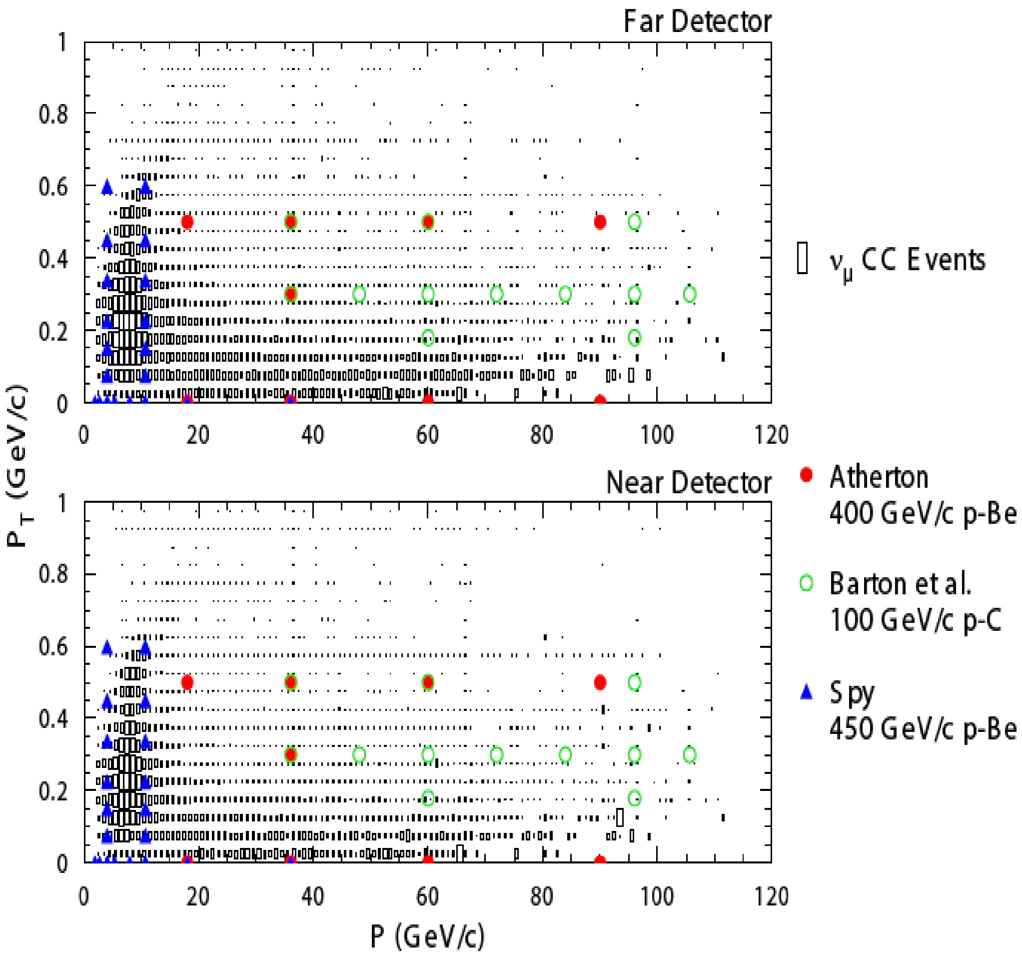
The MIPP Spectrometer



MIPP Physics

- Particle Physics
  - Non-perturbative QCD hadron dynamics, Particle fragmentation scaling laws (MIPP can test general scaling law in 36 reactions)
  - Spectroscopy – Search for missing baryon resonances, glueballs
- Nuclear physics
  - Y-scaling (Measure cross sections of hadrons on nucleons *in the nuclear medium.*)
  - Propagation of strangeness through nuclei
- Service measurements
  - Hadron shower models in Geant4, MARS,...
  - Proton radiography, stockpile stewardship, national security applications
  - Neutrino production (NuMI, T2K, MiniBooNE, atmospheric)
  - ν-factory

Application to neutrino experiments



Distribution of hadrons decaying to produce neutrinos at the MINOS far (top) and near detectors

- Hadron production is largest uncertainty in neutrino flux prediction
- Existing hadron production data sparse
- Measure production from NuMI target
- Use event by event measurement as input to NuMI beam simulator (replace Fluka target)
- Also use to tune beam simulations and fits
- Thin C, Al and Be targets also measured – help simulate interactions downstream of the target
- Combine thin and thick target data to benchmark cascade calculations in thick targets

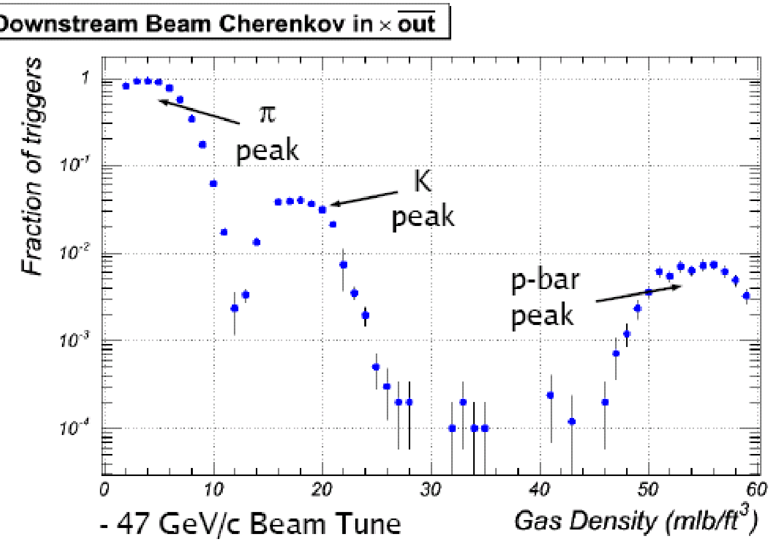
Data collected

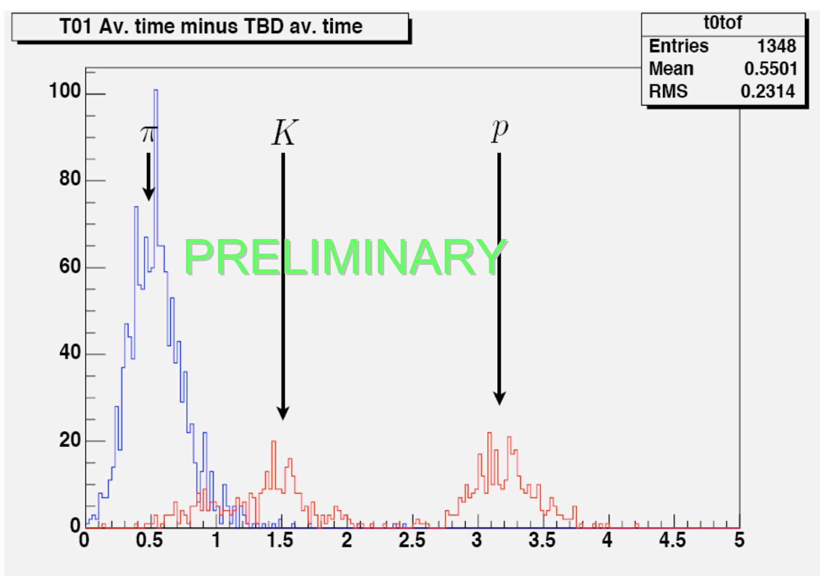
- Ran throughout 2005 and first two months of 2006
- 5 thin targets Be, C, Al, Bi, U
- 7 million Liquid Hydrogen triggers
- 1.78 million triggers on the NuMI target
- 14 million triggers with no TPC (faster data rate) for Kaon mass measurement from RICH ring diameter
- First reconstruction pass completed – DST produced for analyses

Data Summary 27 February 2006			Acquired Data by Target and Beam Energy Number of events, x 10^6									
Target			E GeV/c									Total
Z	Element	Trigger Mix	5	20	35	40	55	60	65	85	120	
0	Empty[1]	Normal		*0.10*	*0.14*			*0.52*			*0.25*	***1.01***
	K Mass[2]	No Int.				*5.48*	*0.50*	*7.39*	*0.96*			***14.33***
	Empty LH[1]	Normal		*0.30*				*0.61*		*0.31*		**7.08**
1	LH	Normal	0.21	**1.94**				**1.98**		**1.73**		
4	Be	*p* only									1.08	**1.75**
		Normal			0.10			0.56				
6	C	Mixed						**0.21**				**1.33**
	C 2%	Mixed		**0.39**				**0.26**			**0.47**	
	NuMI	*p* only									**1.78**	**1.78**
13	Al	Normal			*0.10*							***0.10***
83	Bi	*p* only									1.05	**2.83**
		Normal			0.52			1.26				
92	U	Normal						1.18				**1.18**
Total			**0.21**	**2.73**	**0.86**	**5.48**	**0.50**	**13.97**	**0.96**	**2.04**	**4.63**	**31.38**

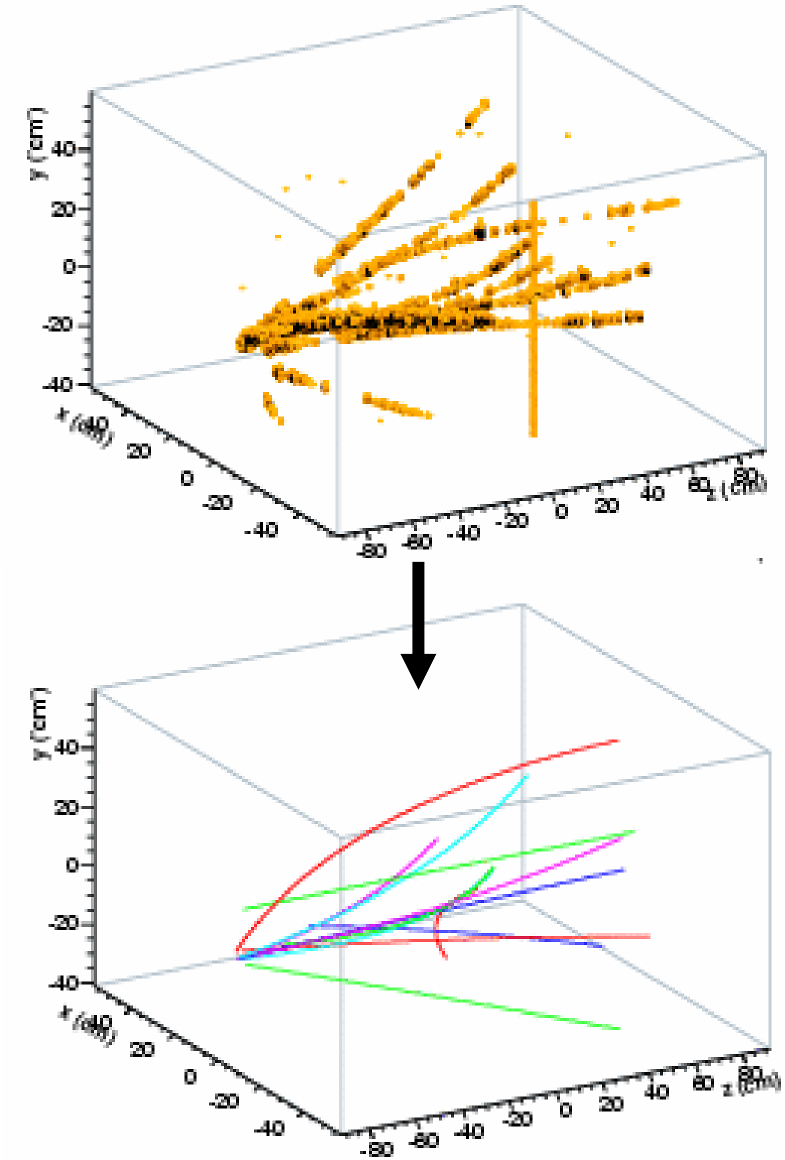
Beam particle ID and trigger

- Tag incoming particle, use two upstream Cerenkov detectors
- >85% purity (tested with RICH)
- Can use beam TOF for 5 GeV/c (and lower)
- Added small scintillator trigger upstream of thin targets
- Combined with multiplicity in first drift chamber
- Purpose built scintillator trigger for NuMI target





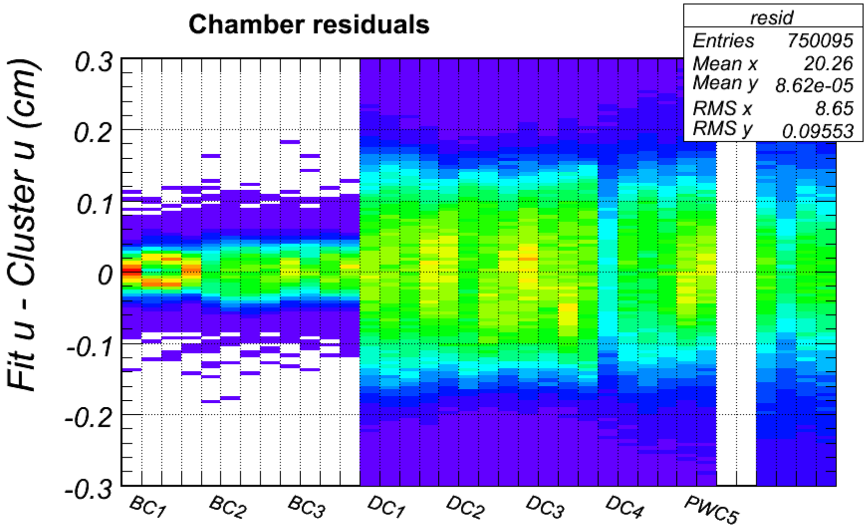
TPC Reconstruction

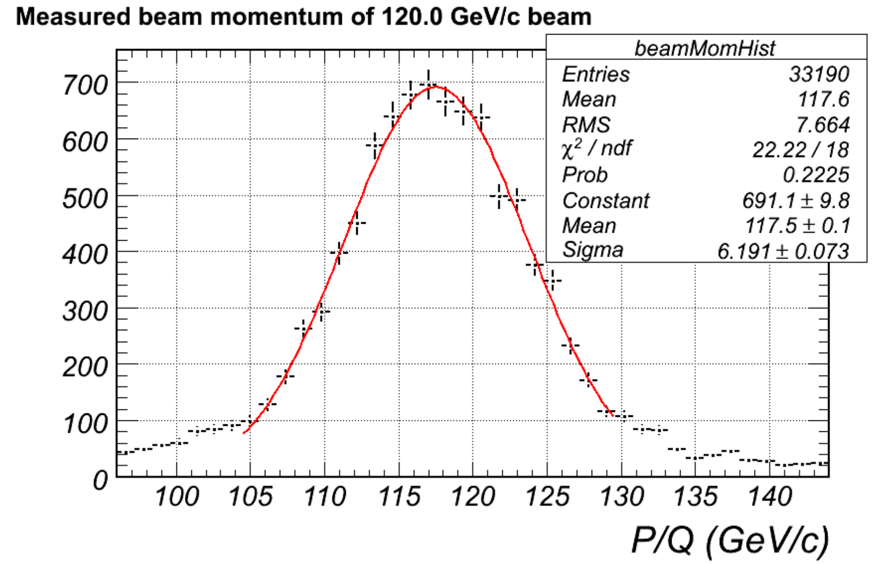


- From raw TPC data form clusters of hits in Z slices, then form tracks and the vertex
- TPC distortion effects:
  - Inhomogeneous magnetic field causes drift electrons to deviate from path to readout
  - Corrections applied using a measured magnetic field map
  - Distortion effects now < 3mm

Chamber Alignment

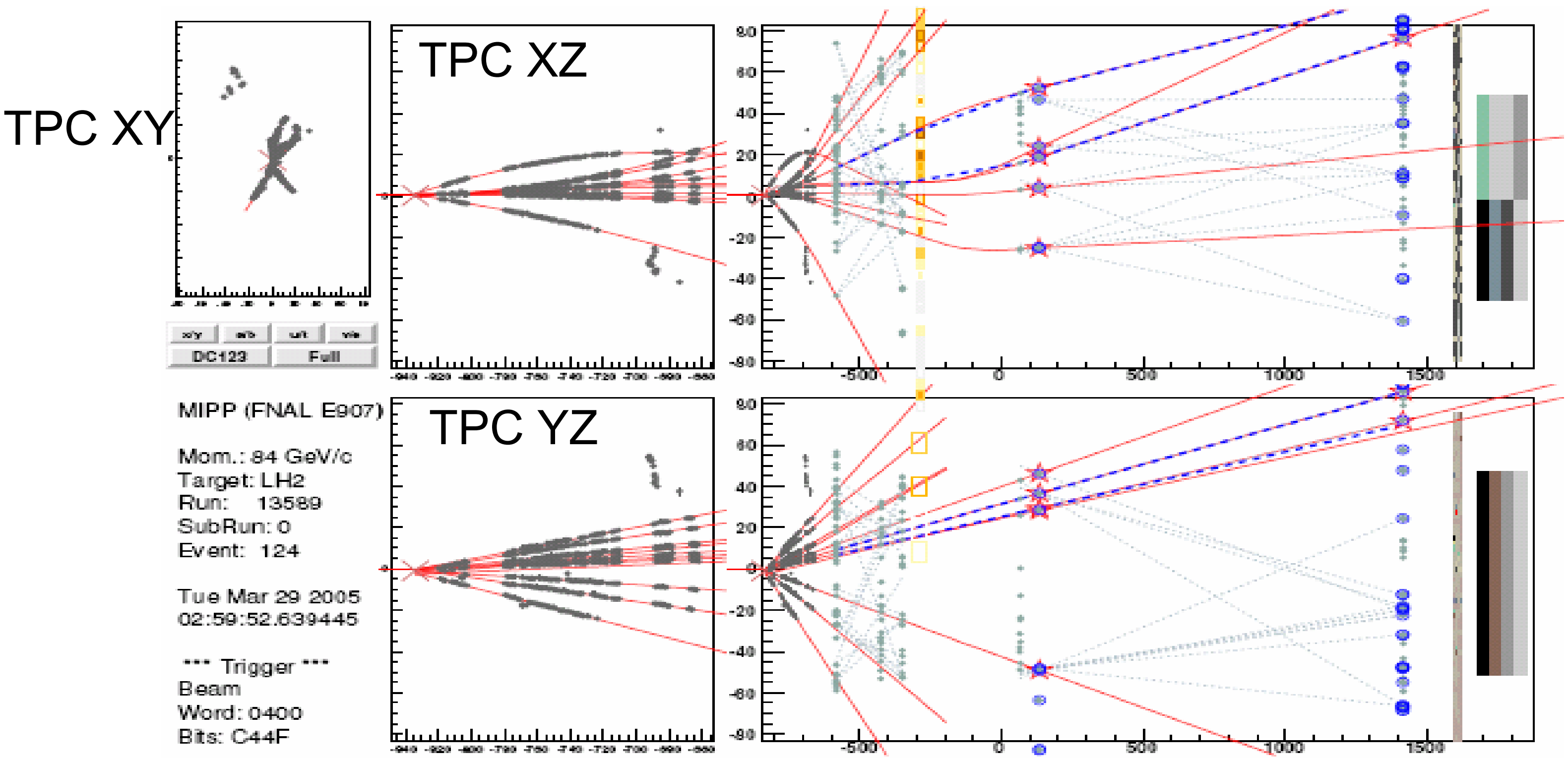
- First determine Drift Chamber time offsets
- Compute residual of track fits for each wire when it is NOT used in the fit, move plane (of wires) within 30% of this residual and iterate
- Then align chambers together using beam tracks that hit all 3 beam and 6 post target chambers, or secondary tracks that hit all 6 post target chambers
- Original alignment found problems in the survey and its implementation in our geometry and in the field maps – Corrected
- Average RMS of wire plane alignment is now ~60μm





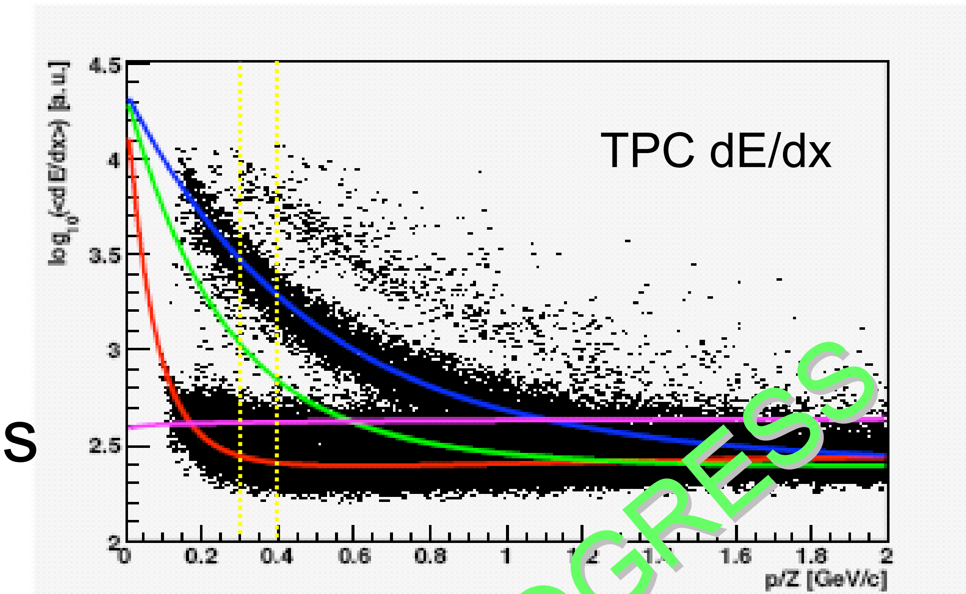
Tracking

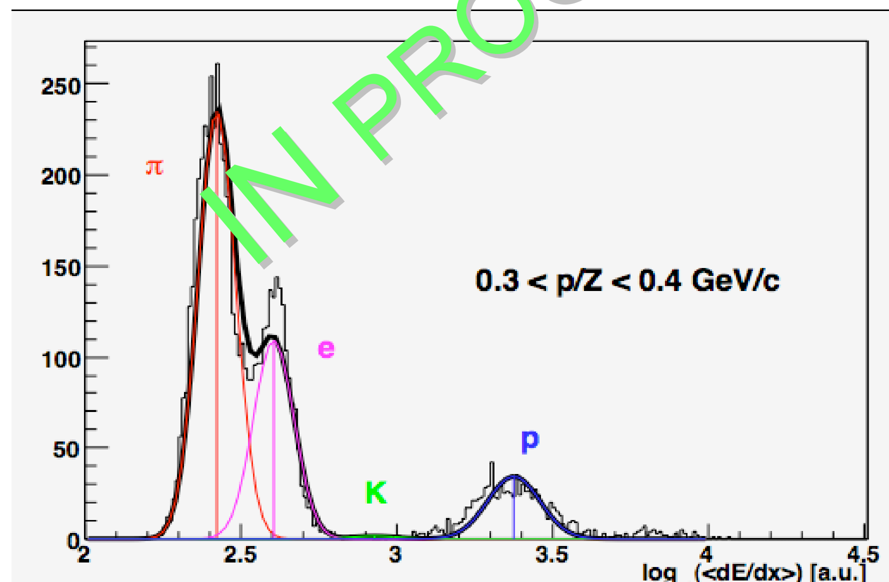
- Basic procedure is to fit TPC tracks then match track candidates from chambers to these TPC tracks
- Improvements: Track merging (eliminate duplicates), included high angle tracks (needed for vertexing)
- Kalman filter based tracking also being developed for TPC and then global tracking



Particle ID - TPC

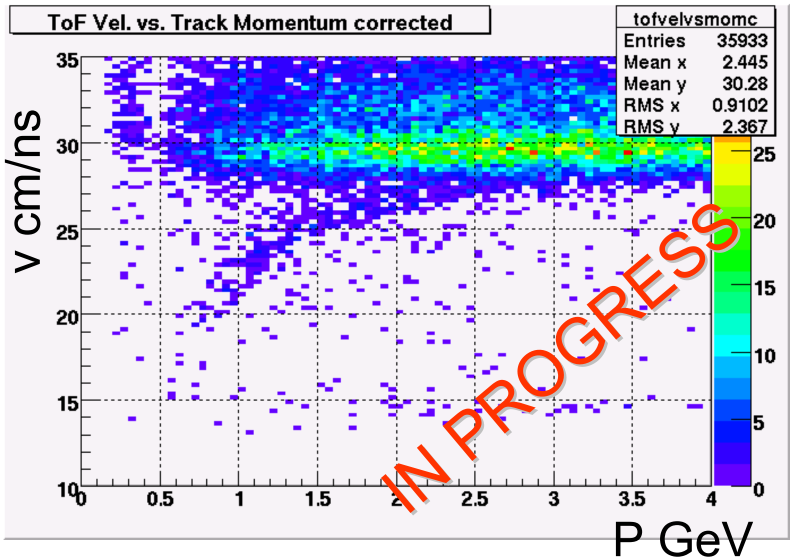
- TPC dE/dx already shows reasonable Pi/K/P separation
- Calibrate anode voltage and drift times
- Normalise dE/dx to minimum ionization level
- Continue improving dE/dx resolution
- Then extract Particle ID probabilities



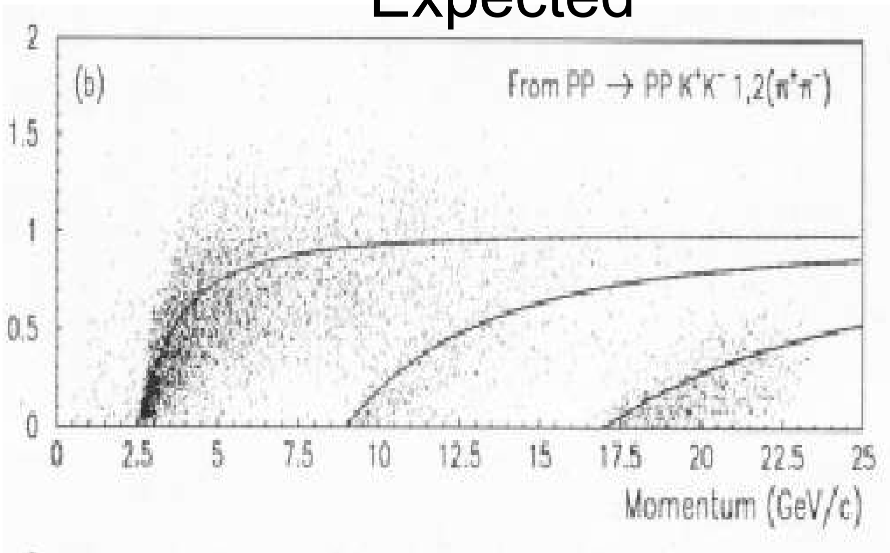


Particle ID – TOF and CKOV

- Calibrating delays of individual bars in TOF wall
- With rough timing and previous tracking can see proton band
- Calibration of CKOV light levels in progress



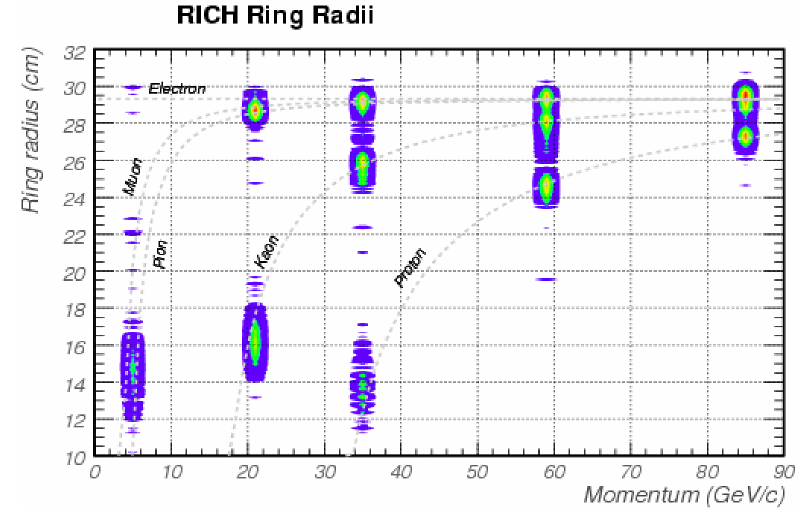
Expected



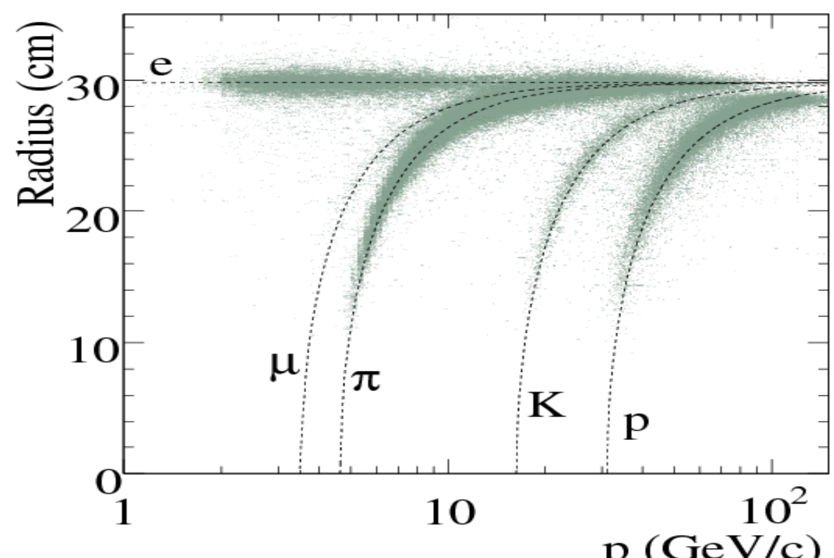
Particle ID - RICH

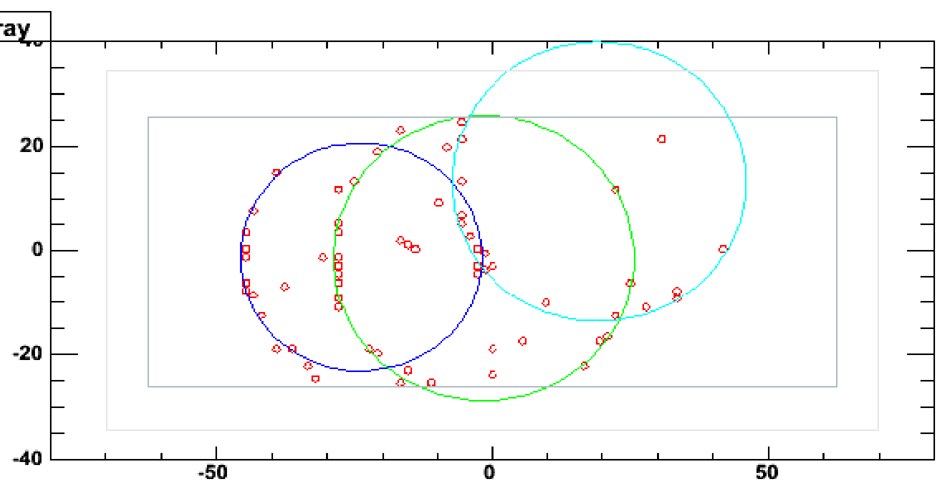
- ID by radius of cerenkov ring
- Ring finding and fitting algorithms complete

Beam Tracks



Secondary Tracks



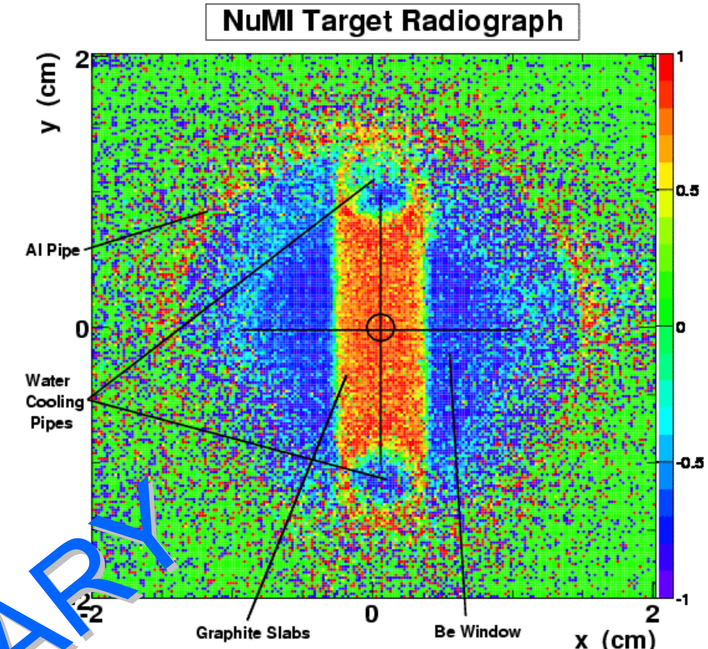


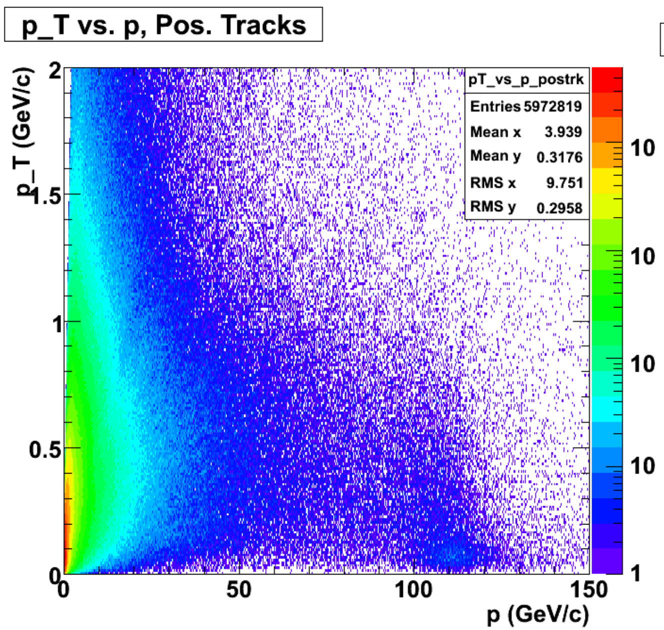
Reconstruction Summary

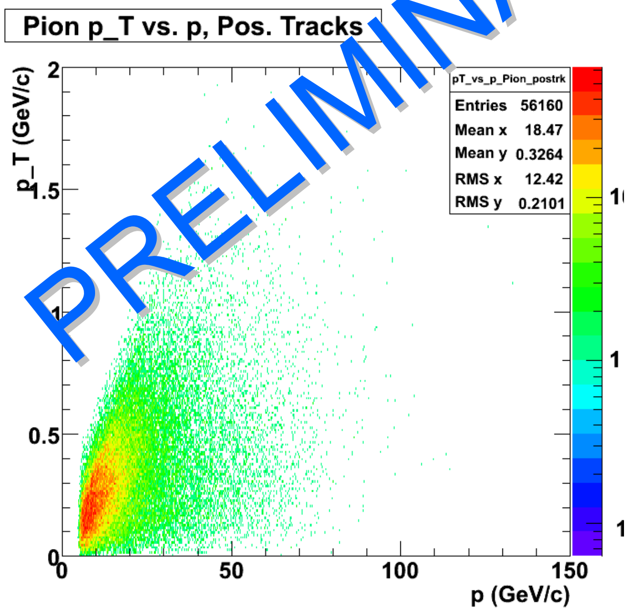
- New deterministic annealing vertexing method improves vertex resolution
- Developing tracking with Kalman-filter based technique (RecPack) in parallel to current tracking efforts
- New DST production in a month to include these major improvements
- TPC, TOF and Differential Cerenkov PID continuing
- Full detector Monte Carlo almost complete
  - Recreates different target and running conditions

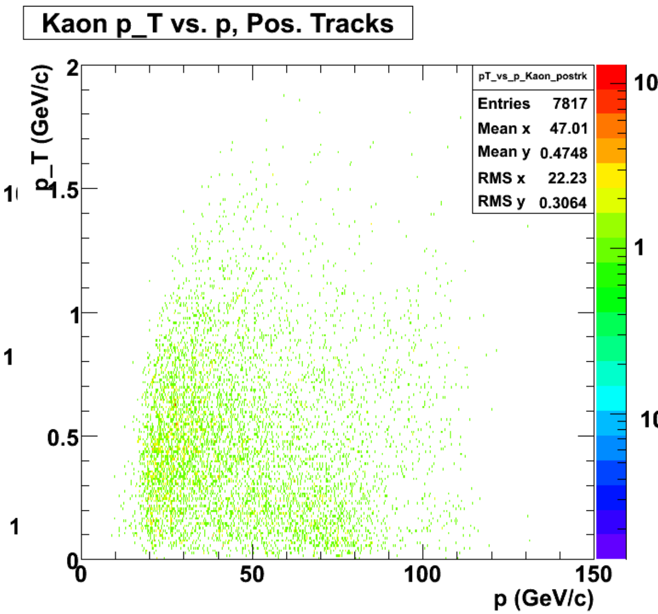
NuMI target data

- Beam aligned Δx=0.002 cm Δy=0.051 cm
- Total positive tracks, Pions and Kaons identified by the RICH





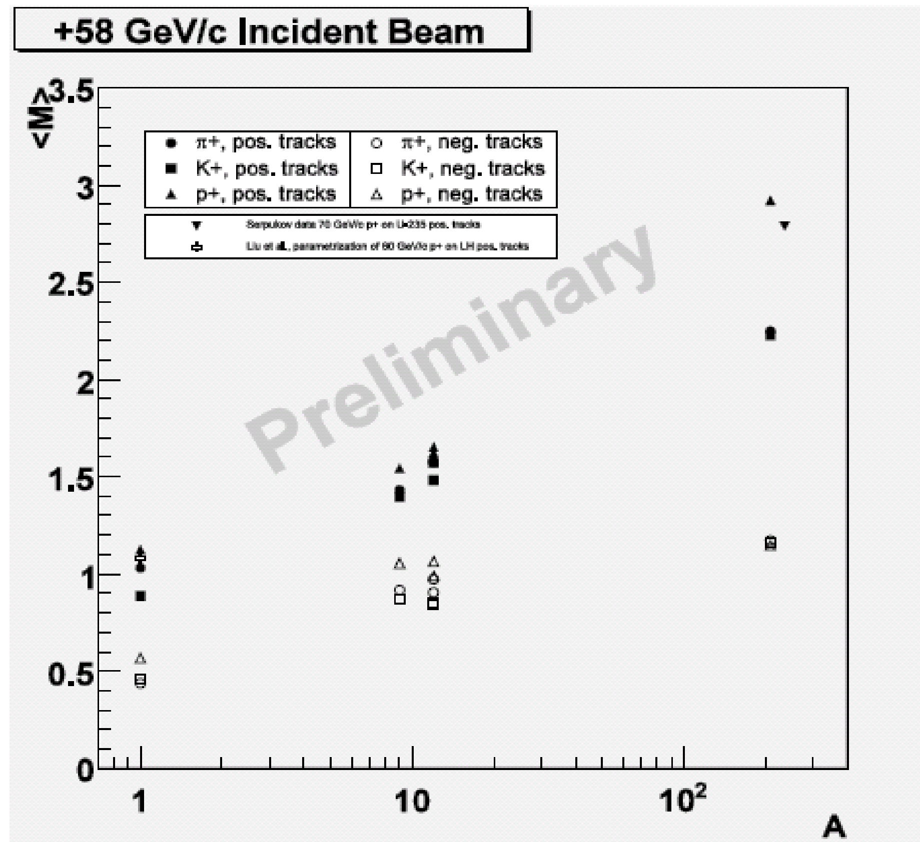




PRELIMINARY

Physics analyses in progess

- Target fragmentation multiplicities
- Hanbury Brown and Twist quantum interference effect
- Charged kaon mass
- Soft pion production cross sections
- Proton and anti-proton production cross sections



MIPP Upgrade - Hardware

Hundred fold increase in data taking rate – record 5 million events per day from limited beam (spill every 2 minutes)

- TPC readout electronics limit data taking (30Hz)– use ALICE ALTRO chips
- JGG coil replacement
- New silicon pixel trigger (B-TeV design) with veto
- New chamber electronics
- New TOF/CKOV readout eletronics (TripT chip)
- New Recoil detector
- DAQ upgrade
- Beamline optics and shielding – run with 1 to 85 GeV/c beam

MIPP Upgrade - Physics

- More MINOS target statistics, NOvA target and others (MiniBooNE, T2K)
- Pi and K production cross sections on liquid nitrogen for atmospheric neutrino or cosmic ray experiments
- Larger list of targets:

  H_2, D_2, Li, Be, B, C, N_2, O_2, Mg, Al, Si, P, S, Ar, K, Ca, Fe, Ni, Cu, Zn, Nb, Ag, Sn, W, Pt, Au, **Hg**, Pb, Bi, U
- Target area to be reengineered – can accommodate any unusual target system – but need details soon
- ILC - Tagged neutral beams and higher statistics for hadron shower simulations
- ILC calorimeters need to achieve $30\%/\sqrt{E}$ – current shower simulators are in a poor state (see HSSW06)
- Limiting factor is manpower, new collaborators welcome!

Summary

- MIPP collected 17 million events that will address a broad range of physics
- Reconstruction is being finalised, preliminary analysis results expected throughout the summer
- Upgrade work is ongoing. Most of the new electronics is designed. Encouragement from Fermilab management for the upgrade but our proposal needs more support to be approved
- The upgrade will allow MIPP to drastically improve its statistics of complete particle coverage events
- Current plan is to start commissioning run in Q1 2008
- New collaborators most welcome – opportunities to have specific NFMC targetry data taken
- Excellent training for students and postdocs