Main Injector Particle Production Experiment

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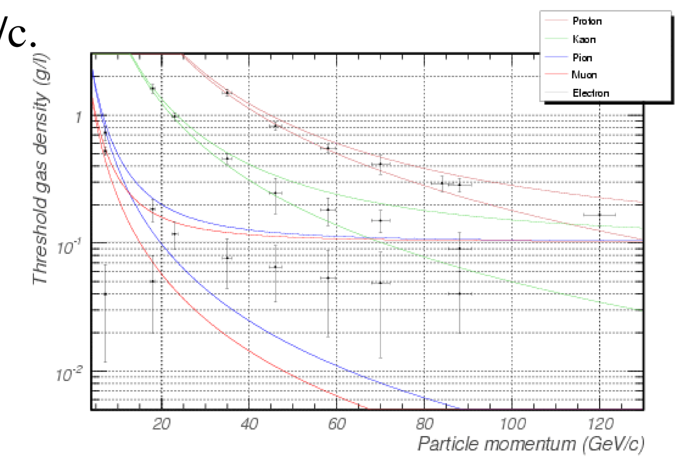
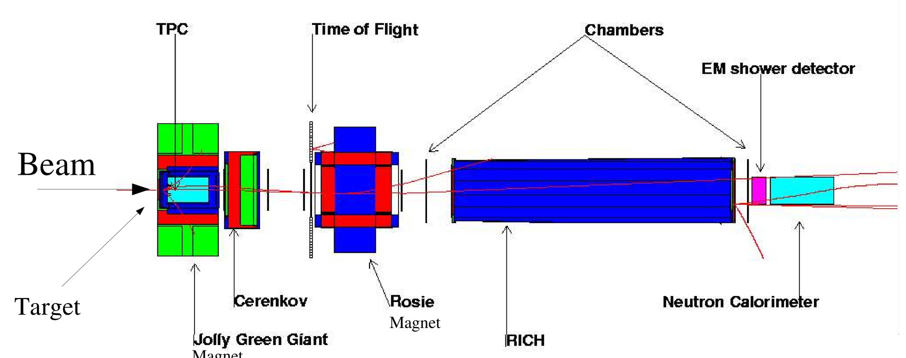
Beam:
Six beam species: π^+, K^+, p and antiparticles
98% tagging efficiency with Beamline-Ckov
Wide beam momentum range from 5 to 120 GeV/c.

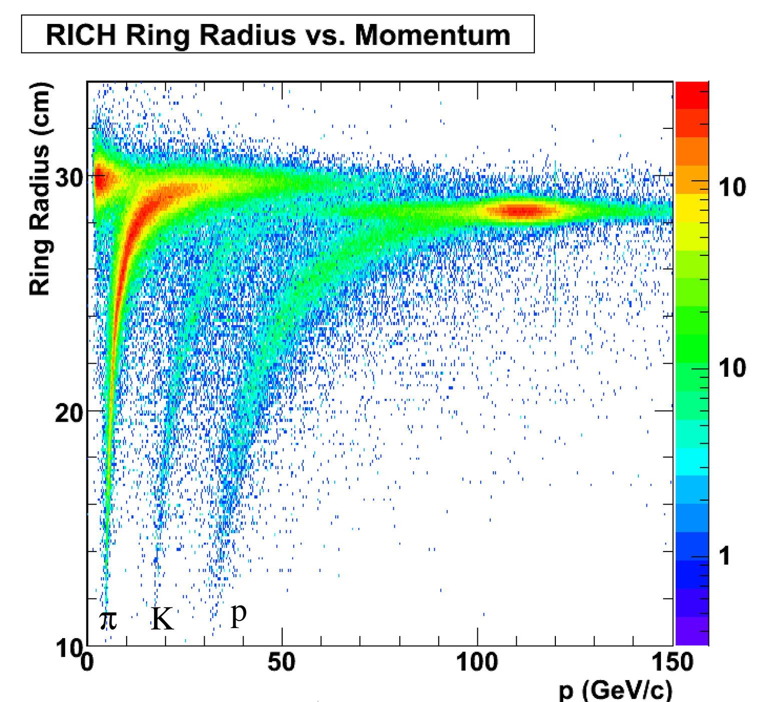


Detector Performance:

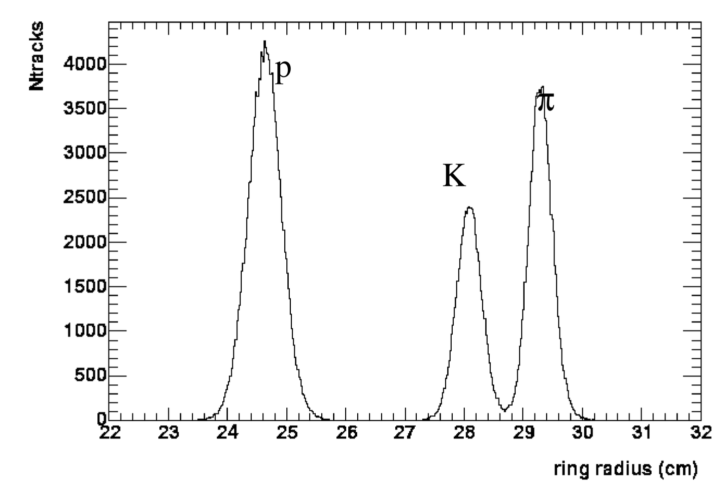
Detectors are preforming well in various stages of calibration, which we expect to finish in July. Plots shown use data from the 2005 run without selection. Momentum determination is not yet using the true B-field map, nor final tracking method, but the next pass through the data in June will.



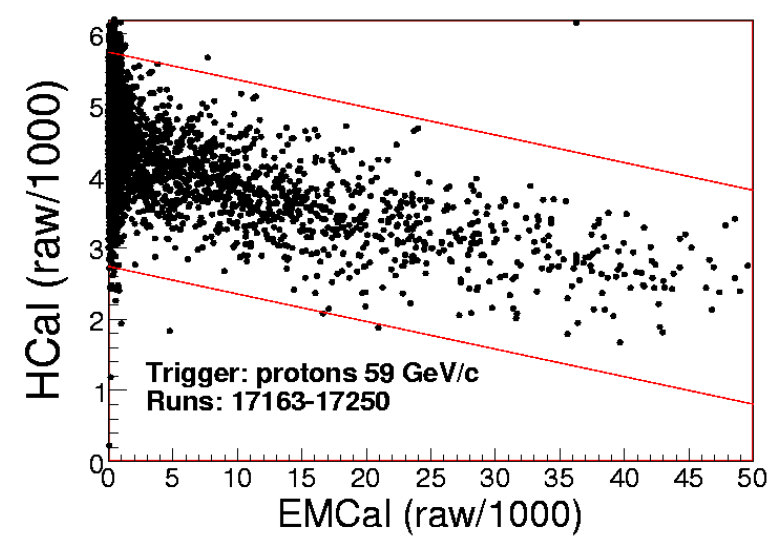
RICH:
Cerenkov Ring Radius Particle Identification



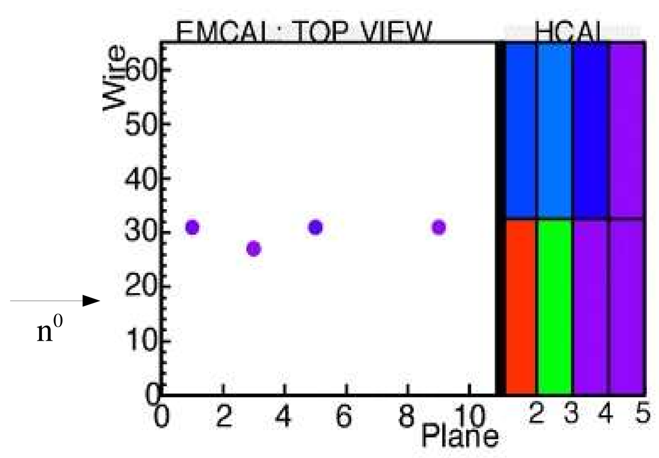
In a slice from 57 to 61 GeV/c

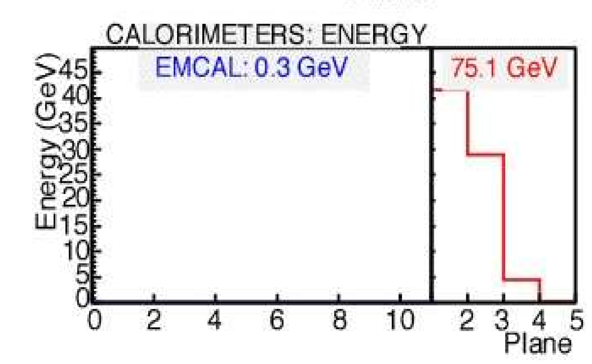


Calorimeters:
Electromagnetic and Hadronic Calorimeters provide a measure of the missing energy from the beam and tagging both neutrons and photons.

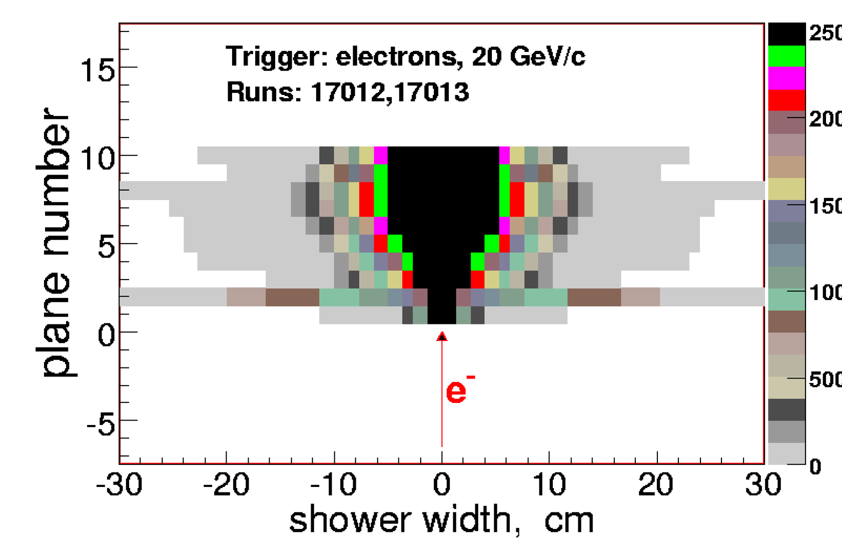


Both EM and Hadron Cal. preforming well, good momentum resolution and linear.



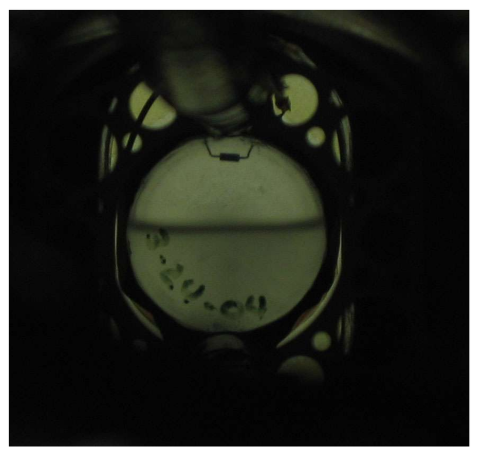


With a 84 GeV/c proton beam, the calorimeters see a 75.1 GeV neutron that deposits a small energy in the EM Cal., but leaves a large energy in the Hadron Calorimeter.



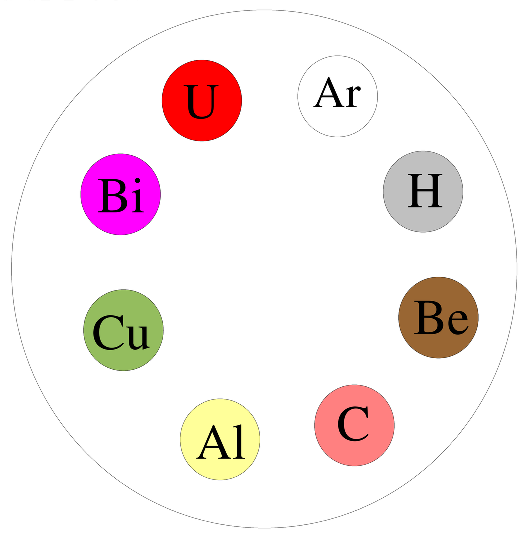
Top view of electron shower in EM Cal. shows expected position resolution for photons.

Targets and Events:



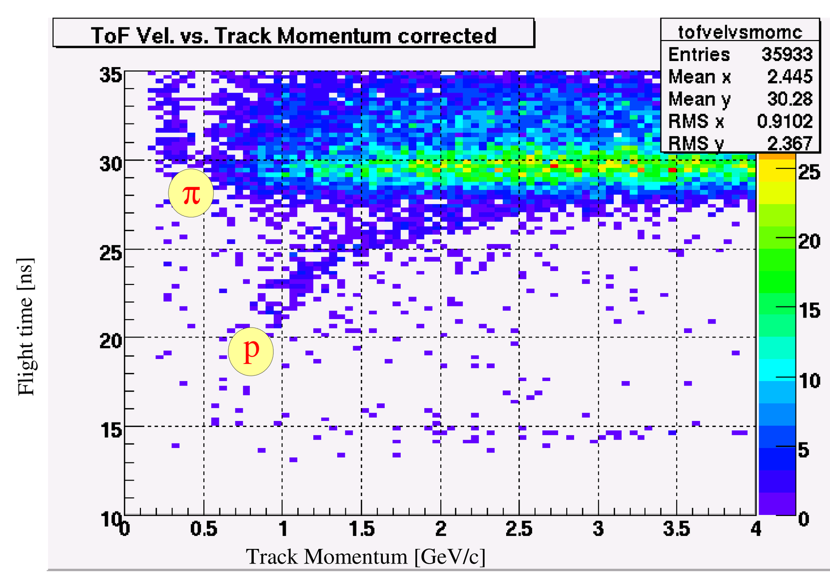
MIPP used a cryogenic Liquid Hydrogen target for 5 M events. Shown here while it is being filled.

MIPP collected 2 M events on the composite NuMI target and 10 M events on 6 thin Nuclear targets of 1% λ.

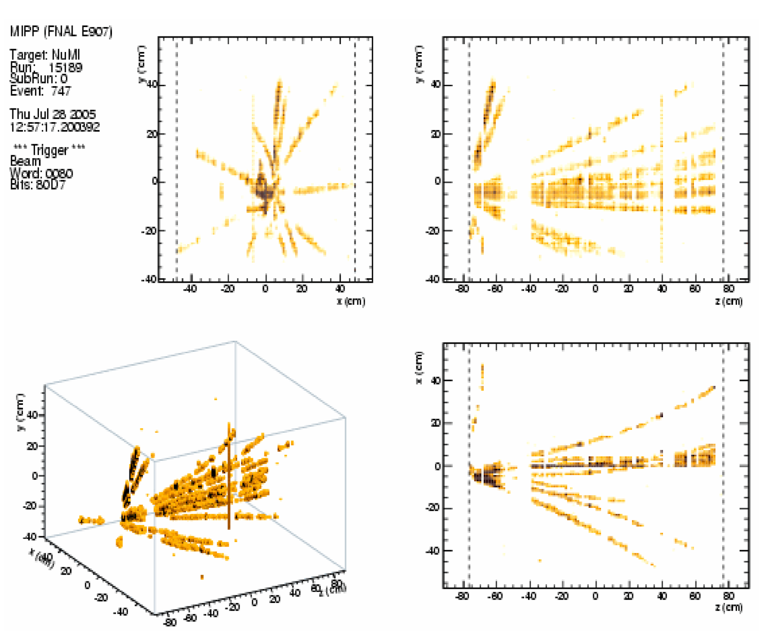


In addition we have a Argon gas target in the TPC and empty target runs for background subtraction.

TOF:
Time of flight wall for particle identification below 2.5 GeV/c.

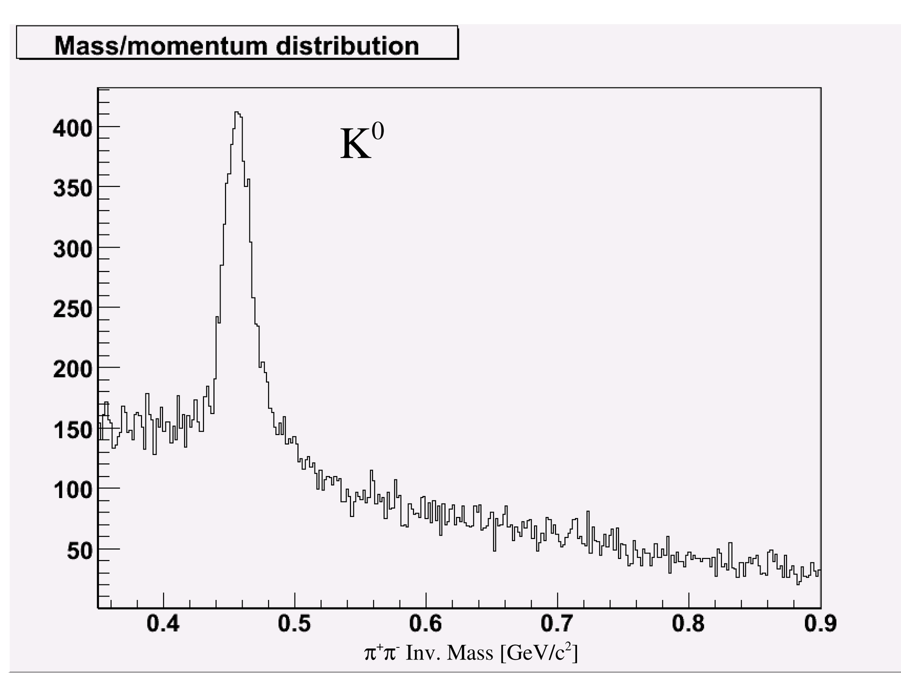


Time Projection Chamber:
Tracking for low momentum determination and Vertexing:

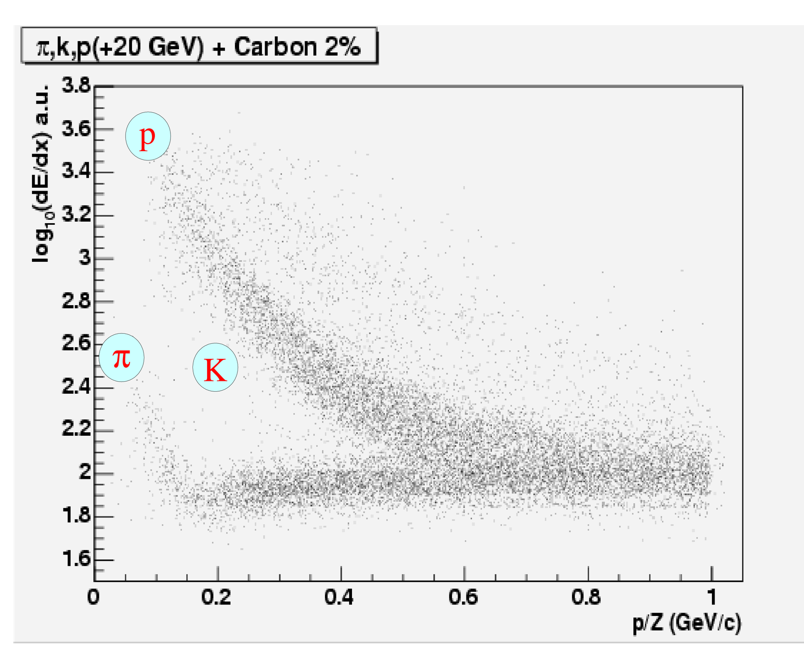


Event display in TPC projections

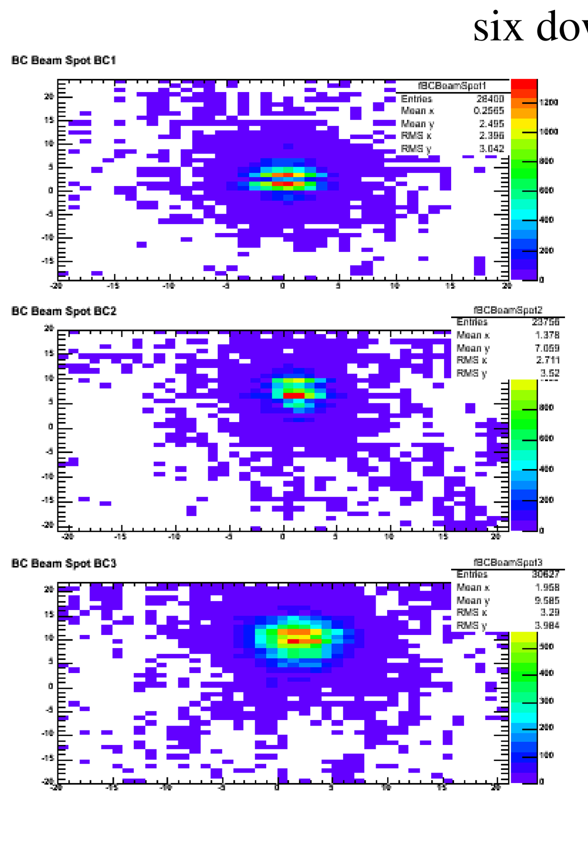
Invariant mass reconstruction:

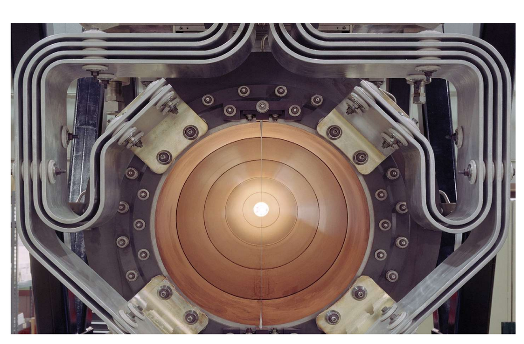


Particle Identification by dE/dx:



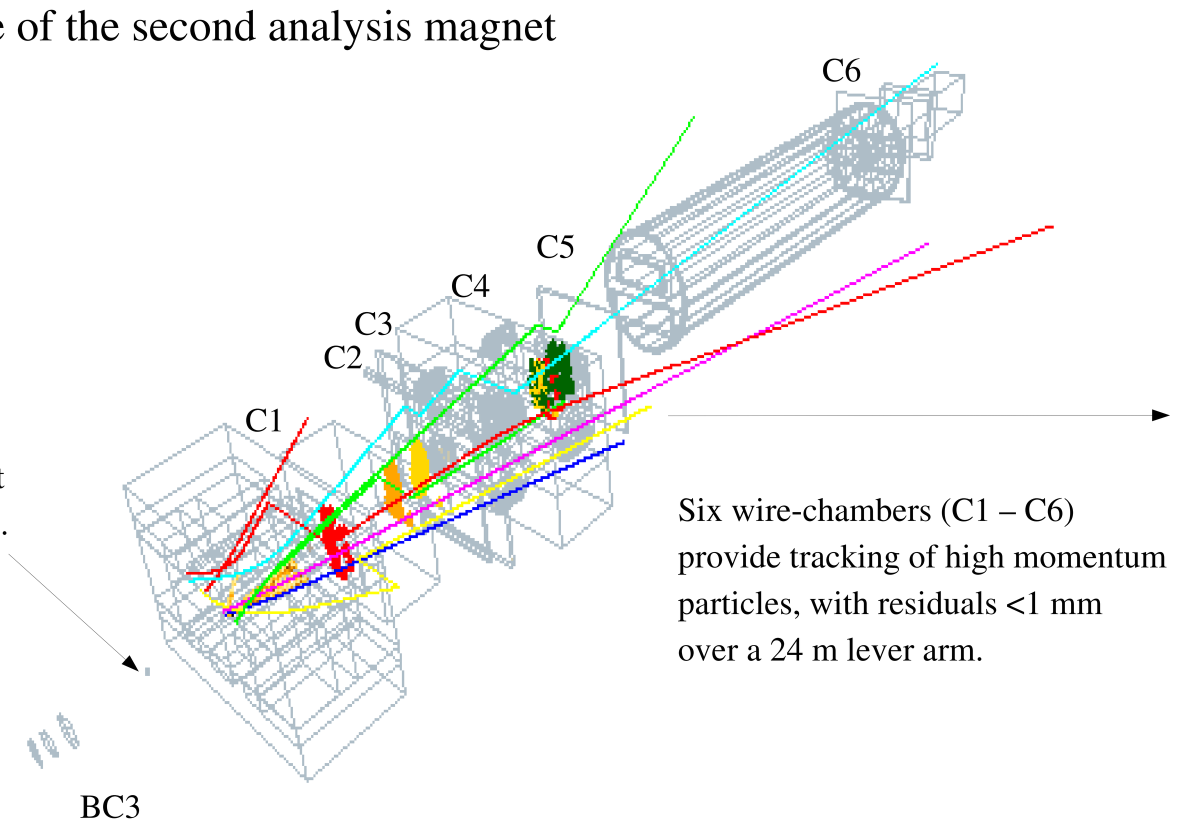
Tracking Chambers:
There are 9 wire chambers, 3 to track the projectile particle incident on the target and six downstream of the TPC, on both size of the second analysis magnet



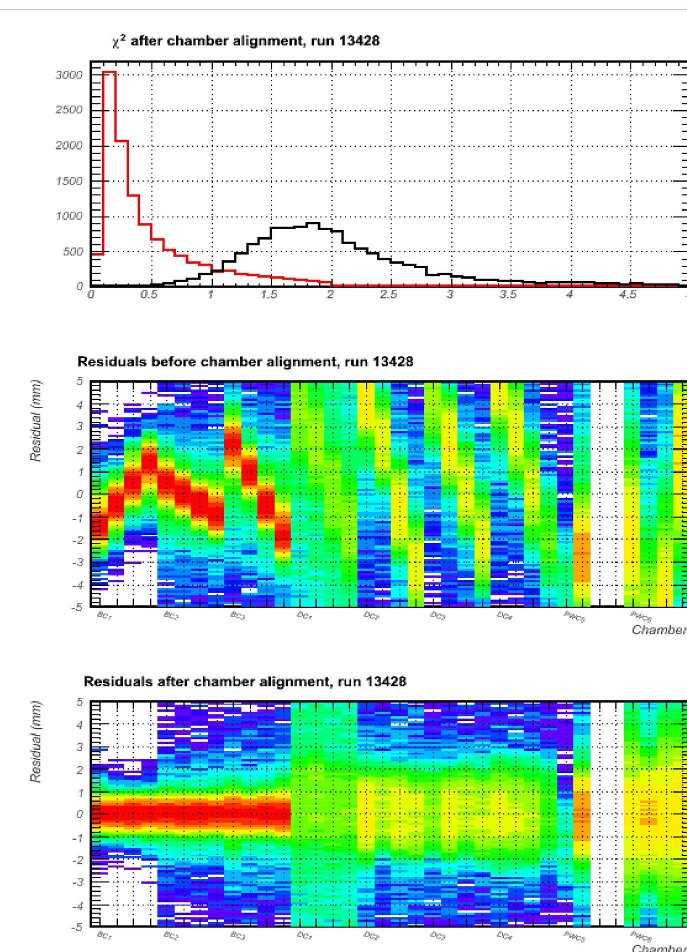


MIPP used the composite NuMI target from MINOS to collection 2 M events.

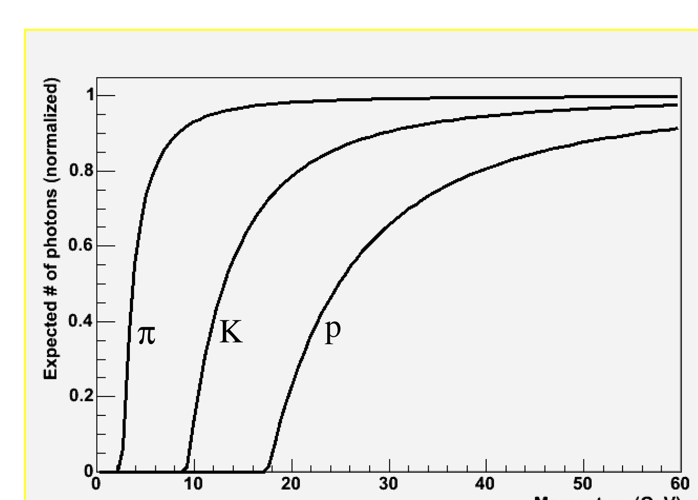
Three beam chambers provide tracking of projectile to the target. For reliable cross section measurements this is constantly monitored run by run.



Six wire-chambers (C1 – C6) provide tracking of high momentum particles, with residuals <1 mm over a 24 m lever arm.



Large Area Threshold Cerenkov:
Particle identification from 2.5 to 9 GeV/c uses the large Ckov with 96 cell and a C_4F_{10} gas.



This detector identifies charged particles coming directly form the interaction vertex.

Main Injector Particle Production Experiment

Preliminary Physics Results:

With detector calibration and final versions of tracking, momentum fitting and vertexing almost finished the MIPP experiment has started analysis to produce physics results.

Cross Section Measurement:

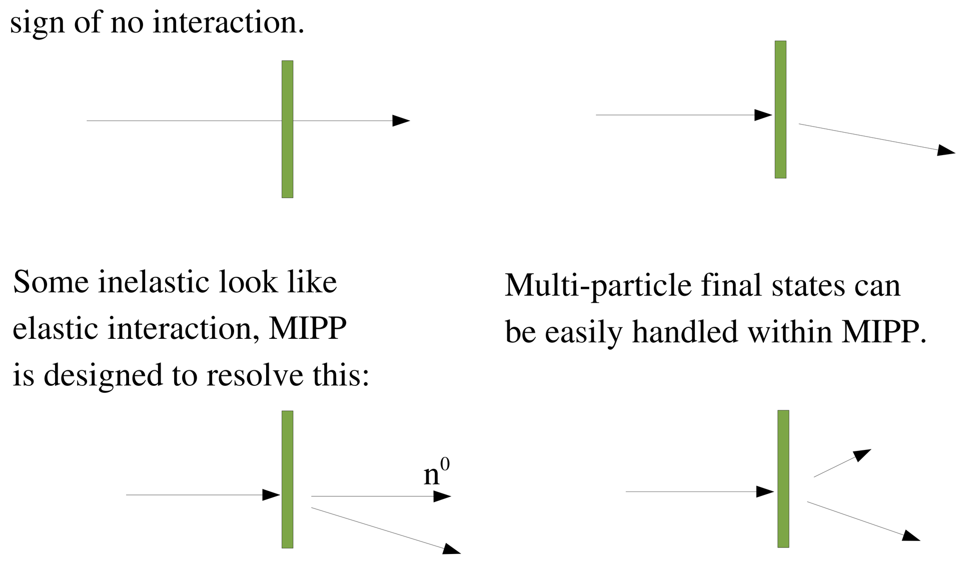
Selected interaction types:

1% λ, so a straight track is a sign of no interaction.

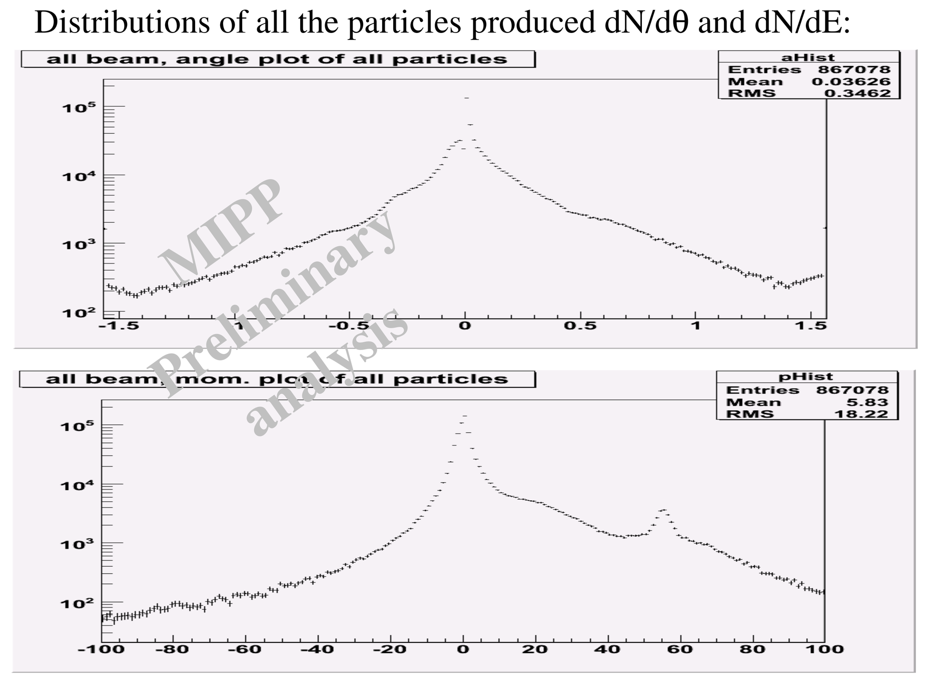
Elastic: noninteracting scattering:

Some inelastic look like elastic interaction, MIPP is designed to resolve this:

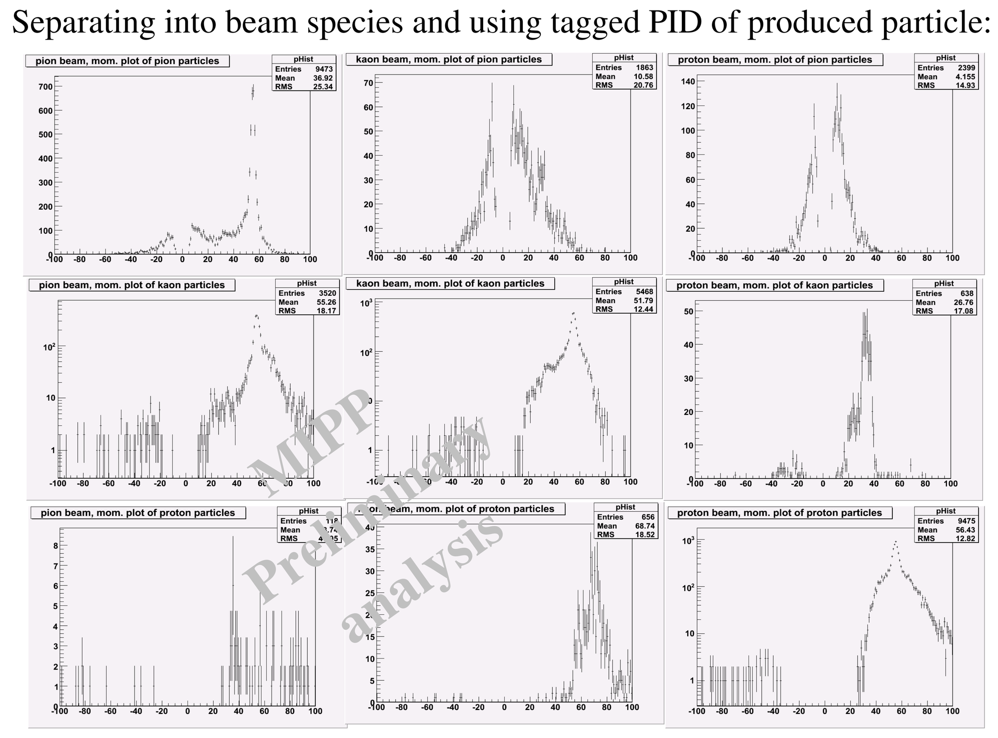
Multi-particle final states can be easily handled within MIPP.



60 GeV/c beam incident on Liquid Hydrogen target. Distributions of all the particles produced dN/dθ and dN/dE:

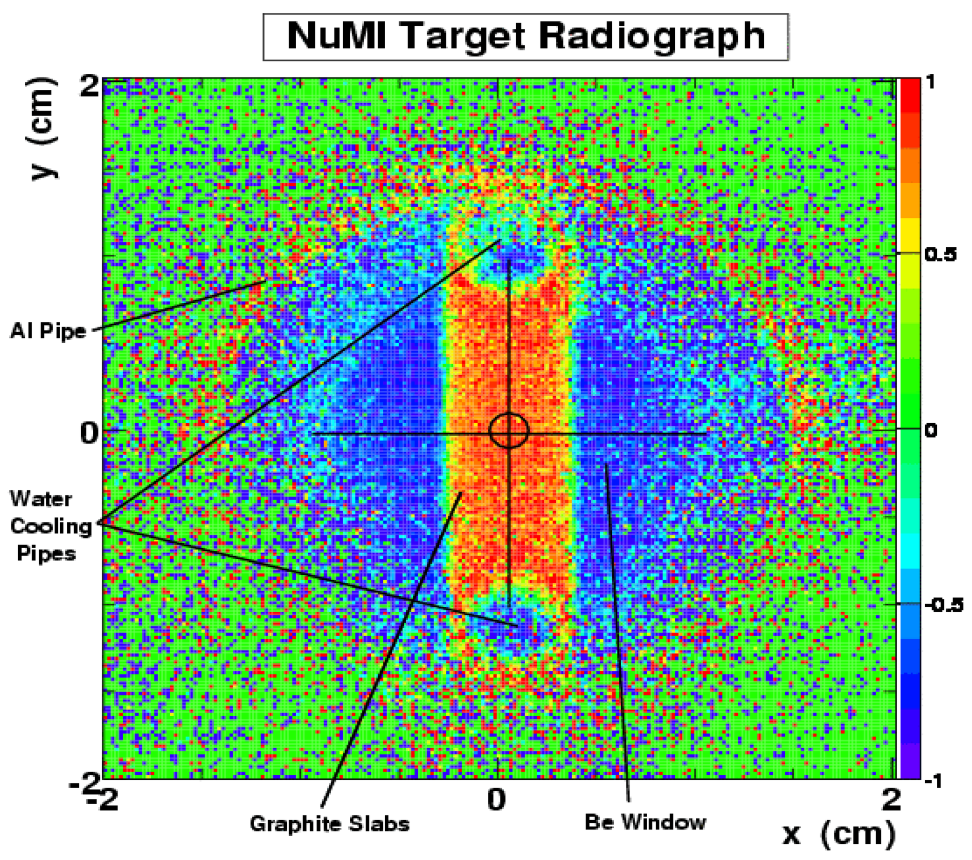


Separating into beam species and using tagged PID of produced particle:



NuMI Target Study for the MINOS Experiment:

Crucial pion and Kaon production studies that the MINOS experiment will eventually rely on are provided by the MIPP experiment data analysis using the composite NuMI target.



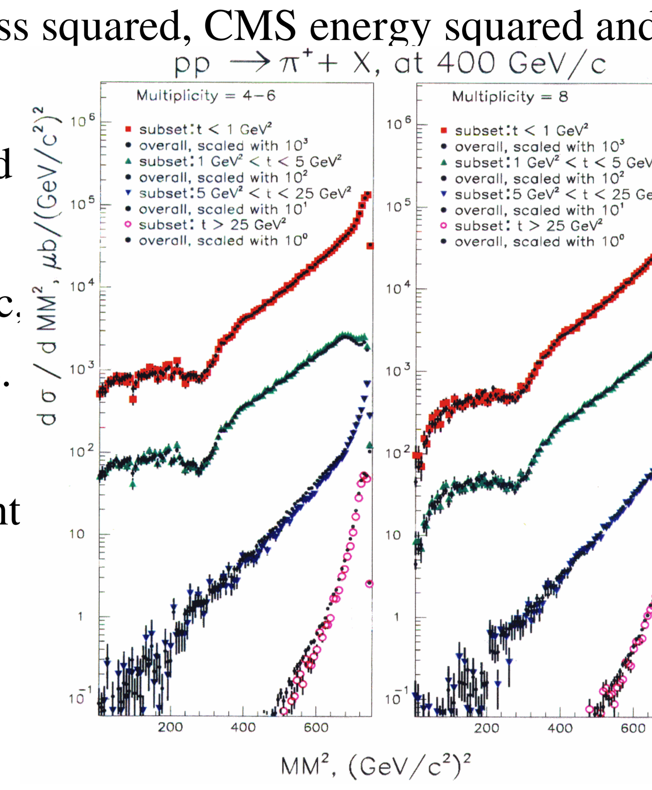
A 120 GeV/c beam of pure protons identical to that which hits the NuMI horn target was run in the MIPP experiment for two months and 2 million events. These events using the projectile particle tracking and secondary particle production show this analysis of the NuMI target structure.

Hadronic Fragmentation Scaling Law Tests:

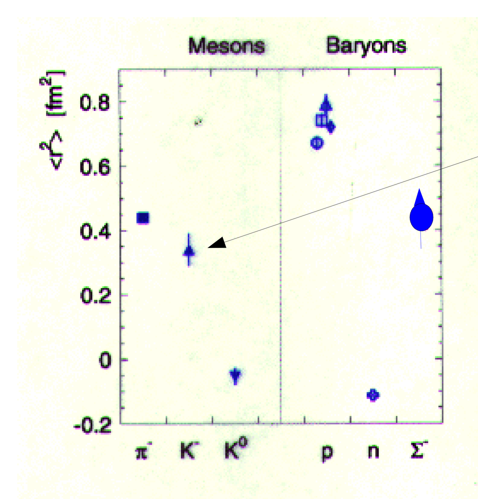
Ratio of a semi-inclusive to inclusive cross section

$$\frac{f(a+b\rightarrow c+X_{subset})}{f(a+b\rightarrow c+X)} \propto \frac{f_{subset}(M^2,s,t)}{f(M^2,s,t)} = \beta_{subset}(M^2)$$

where M^2, s and t are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles a and c. PRD v18, p204. Data from the EHS experiment shows this, but needs further confirmation.



Two Pion Interferometry:

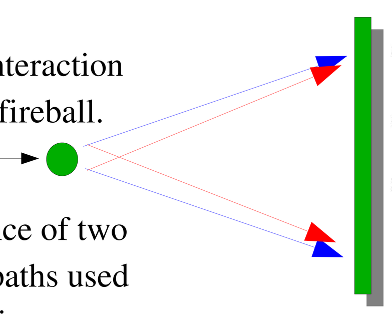


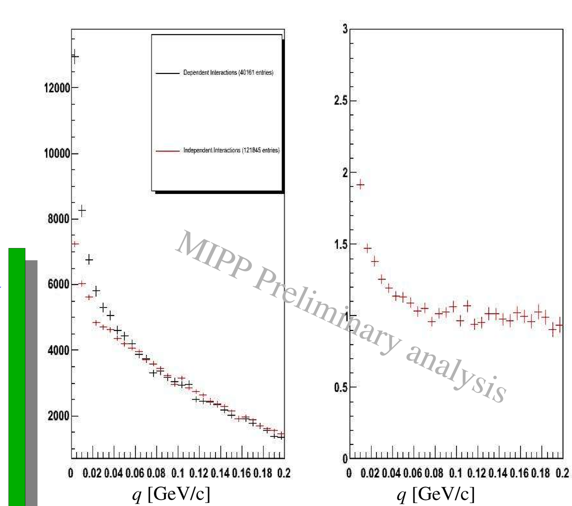
Identical bosons 2-π interference from interactions made with π, K and p projectiles on Liquid H2 target.

MIPP has 100x more data than the only other measurement with charged Kaon projectiles from the NA22 experiment.

Particle interaction produces fireball.

Interference of two possible paths used to determine interaction radius.





Particles detected away from fireball, $q = |p_{1\perp} - p_{2\perp}|$, for tracks in the same (black) and different (red) events.

More Physics Goals:

The MIPP experiment has an extensive list of further physics goals:

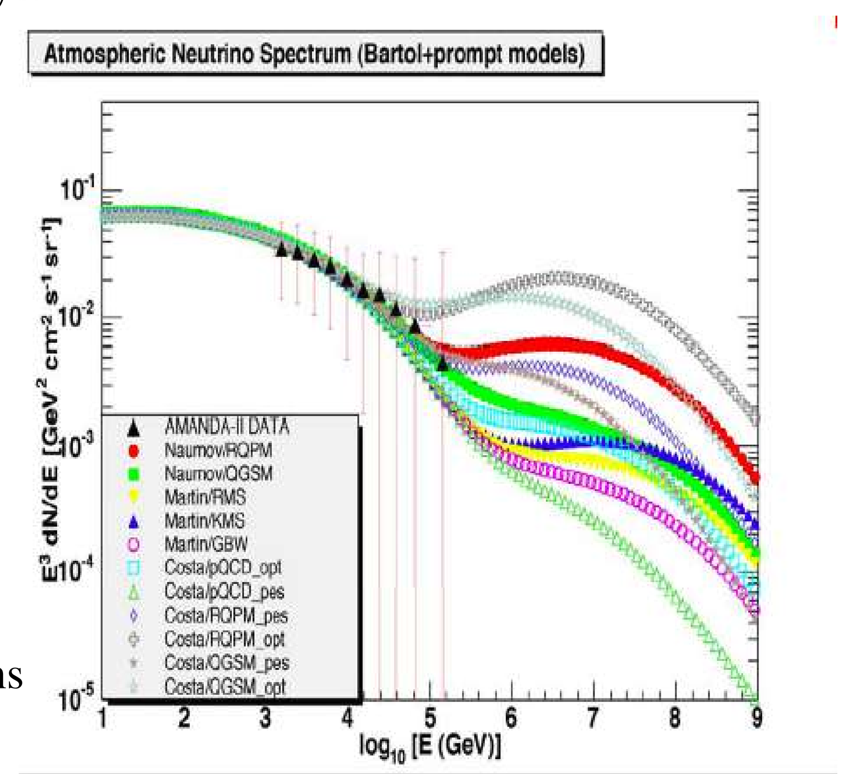
1) π^0 production
2) Hyperon Polarization studies
3) Nuclear target studies in a unique region of interest which is poorly known 10 to 100 GeV/c with six beam species.
4) Assisting USA Homeland Security with our Uranium target data which will help devise means to search for concealed Plutonium and Cesium radioactive sources.
5) Charged K mass by RICH ring radius measurement.

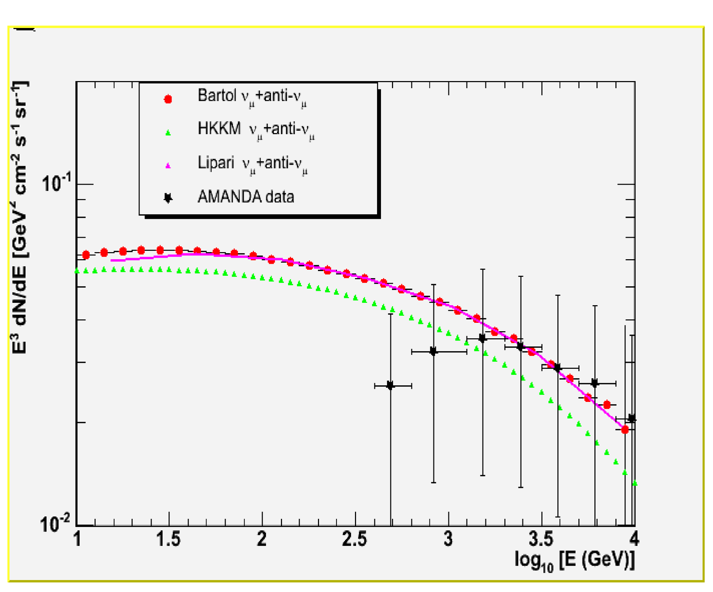
Expect to submit first data analysis results for publication by September 2006.

Neutrino Production Targets:

An extensive run with a Liquid Nitrogen target is needed for the atmospheric neutrino experiments such as: Fermilab's Pierre Auger Observatory, Ice-Cube and Hyper-K, to improve their neutrino flux from π and K decays.

The graph at right shows the current limitation to the small Amanda experiment above 4 GeV/c, this comes from the Cosmic Ray uncertainties of atmospheric production of Kaons and pions. Current models are uncertain above 5 GeV/c.





Members of the Univ. of Wisconsin Ice-Cube experiment and the Pierre Auger Experiment will joint the MIPP upgrade.

Further running with the NuMI target for 10 million events is needed for the final MINOS sample. Special Minerva and NOvA NuMI target runs along with the MiniBoone target are needed.

Future Run Expanded Physics Goals:

A new run of the MIPP experiment in 2007 has great physics potential to provide a leading role in both accelerator and atmospheric neutrino experiments, development of detectors for the ILC and keep Fermilab competitive in elementary particle physics with a small scale experiment.

Improvements:

1) Extend good beam performance down to 1 GeV/c, with triggered TOF Beam PID, lower multiple scattering and spray.
2) TPC and Wire Chamber readout electronics upgraded to 3 kHz.
3) Repair one of the analysis magnet coils.
4) Veto wall and backward hemisphere particle identification.
5) Silicon Detector interaction and secondary vertex trigger.

Costs, Schedule and Impact:

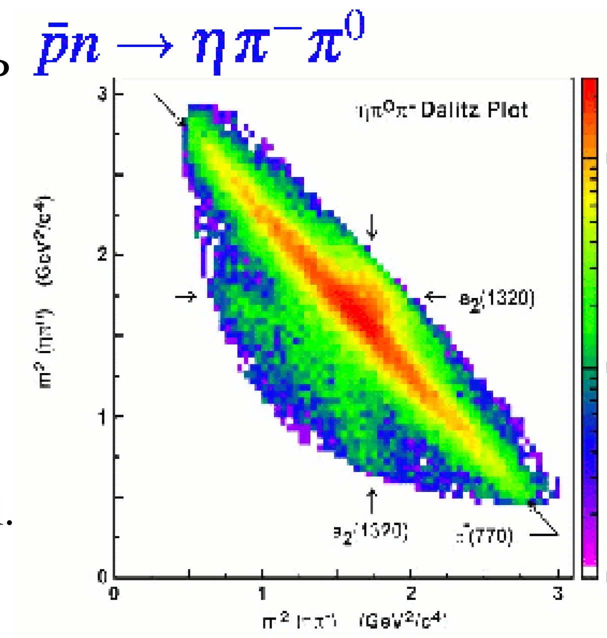
Total cost for the upgraded experiment is about half a million dollars.
After approval the experiment can be running within nine months.
As before the proton-economics impact would be minimal, < 5%.

Anti-protons:

An important goal of the upgraded MIPP experiment would be anti-protons for studying:

1) Charm production cross section
2) Fundamental Nuclear physics
3) Several experiments have seen exotic states unexplained by the current models but expected by the quark-model. MIPP's unique open geometry would be a first to permit resolving this question.

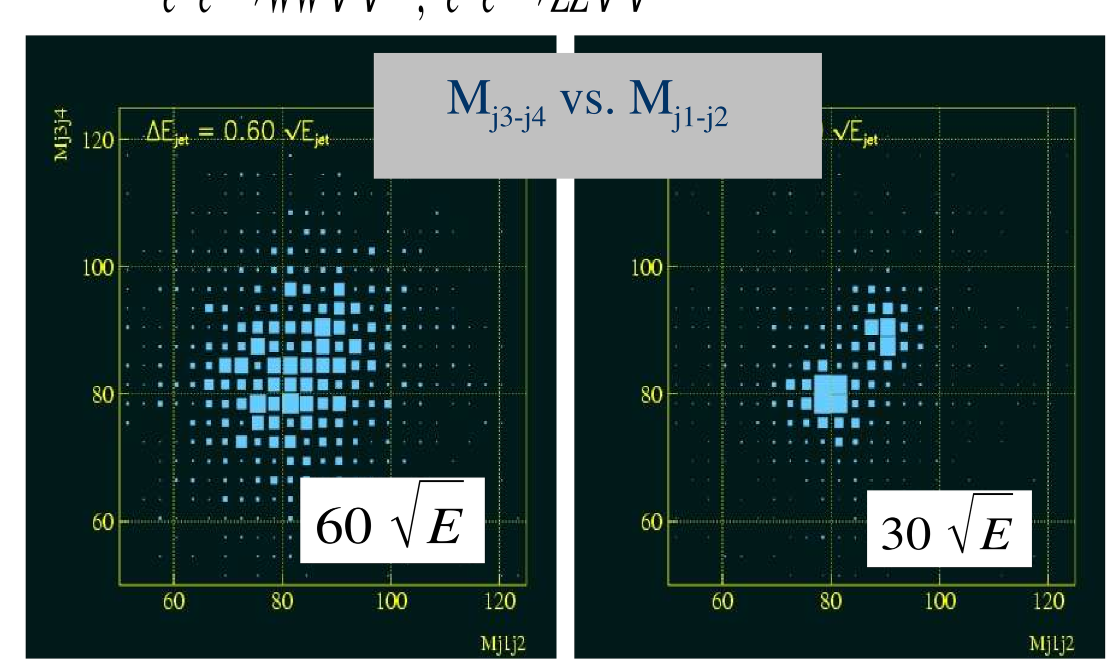
$\bar{p}n \rightarrow \eta\pi^-\pi^0$



International Linear Collider Calorimeter Research and Development:

The future MIPP experiment run will have a major component to help provide measurements vital to improving Hadron Calorimetry, this is the most important detector in the ILC. As can be seen the difference between a 60%/ √E and 30%/ √E resolution is crucial to separating the two jet background from W and Z:

$$e^+e^- \rightarrow WW\nu\bar{\nu}\ ,\ e^+e^- \rightarrow ZZ\nu\bar{\nu}$$



Current Hadron Calorimetry designers rely upon Monte-Carlo codes where the various detector materials are not well known. The MIPP experiment will study 30 nuclei from 1 to 100 GeV/c.

The response of the ILC test calorimeter to neutrons and its efficiency is essential to the Particle Flow algorithms. By putting the ILC hadron calorimeter in the MIPP beam line we will be able to provide a direct measure of neutron energy and efficiency response.