Hadronic Cross Sections for Neutrino Production in MIPP

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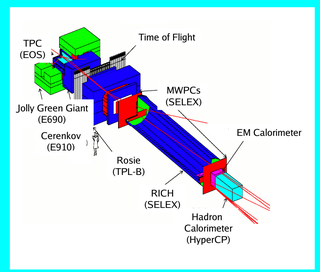
The MIPP Spectrometer



- 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

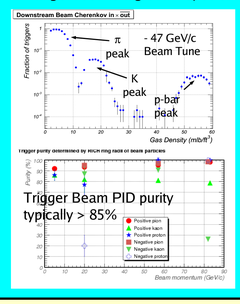
The EOS TPC being prepared in a clean-room before it was installed in the MIPP hall.

Most components of the MIPP spectrometer are taken from previous experiments!

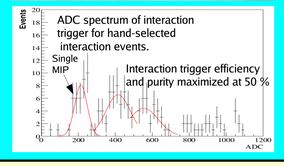
The SELEX RICH detector vessel being installed in the MIPP hall, before the hall was enclosed.

MIPP Event Trigger

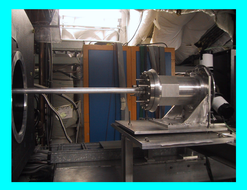
- Primary 120 GeV/c proton beam from Fermilab Main Injector; secondary target and beamline upstream provides lower momentum p's, π's and K's.
- Must tag incoming particle id!
- Two Ckov detectors upstream of target used to tag beam species.



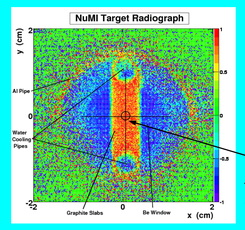
- DAQ rate is low (~30 Hz), so we enhance our sample of interaction events using a track multiplicity trigger.
- An interaction trigger was constructed using a thin piece of scintillator and spare MINOS parts (optical fibers and connectors).

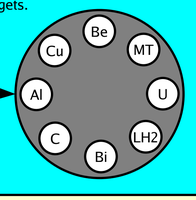


The MINOS and Other Targets in MIPP



- Six week run with a spare MINOS target installed in the MIPP hall.
- Collected ~1.6 x 10^6 events of Main Injector 120 GeV/c protons on the MINOS target.
- Target wheel installed ~2 cm upstream of TPC allows switching between various thin targets.
  - 3.2 x 10^6 p's, π's and K's at 120, 60, 35 and 20 GeV/c on thin C and Be targets.
  - Other physics interests: several million events of p's, π's and K's at momenta ranging from 5-120 GeV/c on thin (<2% λ) LH_2, Bi, and U targets.



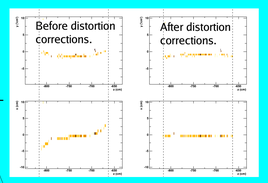


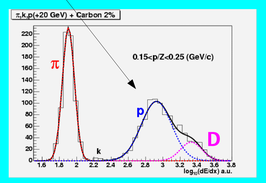
Beam is aligned to within 0.5 mm of the target center (Δx = 0.002 cm, Δy = 0.051 cm)

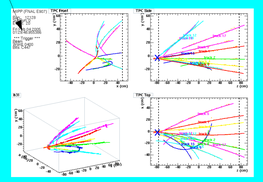
Detector Performance

Time Projection Chamber (TPC)

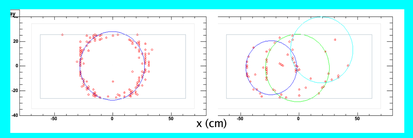
- The TPC data are "distorted" due to the non-uniform magnetic field. These distortions are corrected as shown on the right.
- Track finding efficiency now ~100%. Vertex-constrained fits are a work-in-progress.
- Preliminary results of <dE/dx> (uncalibrated and with poor momentum resolution) are very promising.



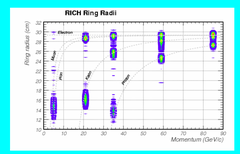




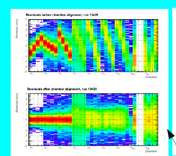
Ring Imaging Cherenkov (RICH) Detector

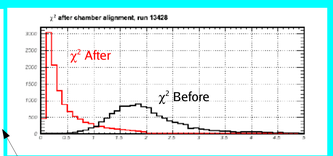


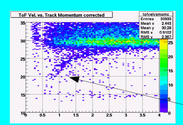
- The RICH detector was extremely stable during the data run.
- RICH rings are found and fit to a circle of radius R
  - $R \sim \sqrt{2(1-1/n\beta)}$
- Matching rings to track trajectories, we are able to separate π's and K's above ~17 GeV/c!

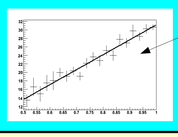


Drift Chambers, ToF and DCkov Detectors



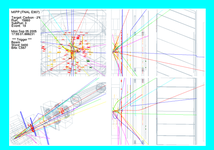




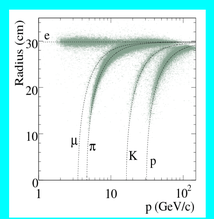


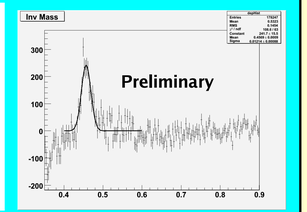
- Drift chambers are aligned on a run-by-run basis; dramatic improvement in the χ^2 distribution of track fits after alignment.
- ToF still requires calibration, but already we see protons.
- DCkov response found to be linear, next step requires improved global tracking.

Putting It All Together...

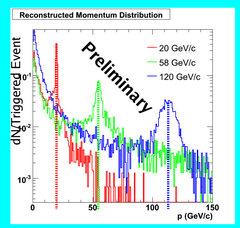


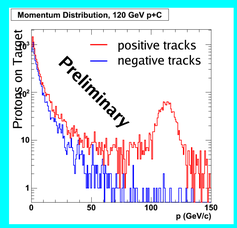
- Global fits use data from all detectors to obtain track momenta.
- Tracks are matched to RICH ring centers, hit ToF bars, and DCkov mirrors.
- Simple vertexing used to reconstruct the K0 invariant mass.

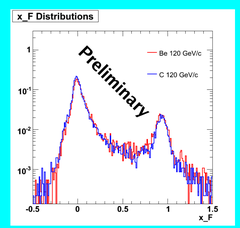


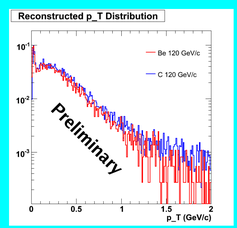


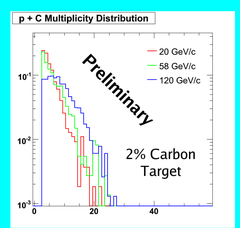
Preliminary Results

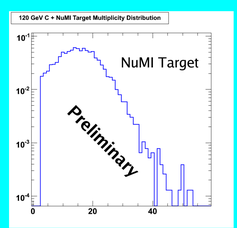


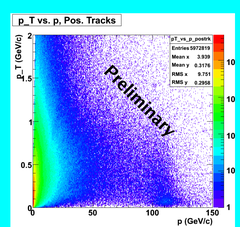


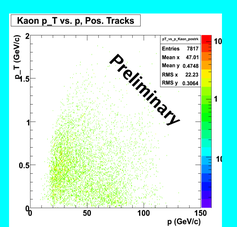


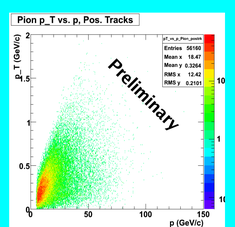










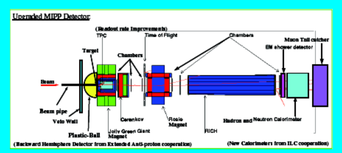


- Current momentum resolution is ~3% at 20 GeV/c and ~7% at 120 GeV/c.
- ~100% efficient at charge determination up to 120 GeV/c.
- MIPP measures x_F between -0.25 and 1.
- Thin C-target data will be essential in building cascade models of more complicated graphite-based targets (eg, the MINOS target).
- Thin Be-target data may also be used to enhance our thin C-target data sample.
- Multiplicity distributions of hadronic interactions with both thin and MINOS targets.
- Inclusive p_T vs p spectra for the MINOS target for all momenta.
- Using the RICH to select π^+'s and K's, p_T vs p spectra for these particles off the MINOS target.
  - Measurements of π/π^+, π/K^- and π^+/K^+ ratios for p > 20 GeV/c will help MINOS constrain the predicted high-energy tail of the nm energy-spectrum.
- Hope to have preliminary p_T vs. p spectra of full momentum range by Dec. 2006.

Analysis Goals

- Kalman-filter based reconstruction is currently being incorporated to improve momentum resolution.
- π/K and π/π^+ ratios off of NuMI target.
- p_T vs p spectra for the NuMI, thin C and thin Be targets.
- Novel precise measurement (~50 ppm) of the charged Kaon mass.
- HBT (pion interferometry).
- A-dependence of inclusive and exclusive cross-sections.
- Testing the Scaling Law of inclusive cross-sections.
- Provide data for studies of non-perturbative QCD.

MIPP Upgrade



- Current experiment is limited by DAQ rate, dominated by the TPC readout rate (~30 Hz).
- An upgrade of the TPC electronics, using the ALICE ALTRO chip, can increase this readout rate by up to 50x.
- Further upgrades include repair of analysis magnet coils, wire-chamber electronics upgrade, improved interaction trigger, recoil proton detector, addition of large veto wall, and an improved beamline.
- Estimated total cost:$500K.
- Expanded run plan would support US and world-wide neutrino program by including more data on the MINOS/NOvA and C and Be targets, as well as cross-section measurements for O_2 and N_2.
- Beam would span the full range of momenta from a few GeV/c up to 120 GeV/c.
- MIPP welcomes new institutions to join the upgrade effort!