MIPP Experiment Upgrade

Rajendran Raja
Fermilab

- Beam
- MIPP experiment
  - Physics
  - Engineering measurements
- Particle ID
- Some results
- Upgrade plans


MIPP collaboration list

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8-Apr-2005 Rajendran Raja, PAC Presentation
Status of MIPP Now - Collision Hall
Brief Description of Experiment

• Approved November 2001
• Situated in Meson Center 7
• Uses 120GeV Main Injector Primary protons to produce secondary beams of $\pi^{\pm} K^{\pm} p^{\pm}$ from 5 GeV/c to 100 GeV/c to measure particle production cross sections of various nuclei including hydrogen.
• Using a TPC we measure momenta of ~all charged particles produced in the interaction and identify the charged particles in the final state using a combination of dE/dx, ToF, differential Cherenkov and RICH technologies.
• Open Geometry- Lower systematics. TPC gives high statistics. Existing data poor quality.
Particle acceptances and resolutions

- a) 10 Hits in TPC
- b) a hit in the Cerenkov
- c) a hit in Drift Chamber 10 (just before RICH)
- d) Passage through mid-Z plane of RICH.

- Regular Target and NUMI target
- Four cases of particles considered
- (Cumulative AND)
MIPP Particle ID

Particle ID Performance

π/K separation

K/p separation

Red: >3 sigma
Green: 2-3 sigma
Blue: 1-2 sigma
White: <1 sigma
Physics Interest

- Particle Physics-To acquire unbiased high statistics data with complete particle id coverage for hadron interactions.
  - Study non-perturbative QCD hadron dynamics, scaling laws of particle production
  - Investigate light meson spectroscopy, pentaquarks?, glueballs

- Nuclear Physics
  - Investigate strangeness production in nuclei- RHIC connection
  - Nuclear scaling
  - Propagation of flavor through nuclei

- Service Measurements
  - Atmospheric neutrinos - Cross sections of protons and pions on Nitrogen from 5 GeV- 120 GeV
  - Improve shower models in MARS, Geant4
  - Make measurements of production of pions for neutrino factory/muon collider targets
  - Proton Radiography- Stockpile Stewardship- National Security
  - MINOS target measurements - pion production measurements to control the near/far systematics

- HARP at CERN went from 2-15GeV incoming pion and proton beams. MIPP will go from 5-100 GeV/c for 6 beam species $\pi^\pm K^\pm p^\pm$ -- 420M triggers. 3KHZ TPC.
MIPP Secondary Beam

MIPP Physics Program

MIPP-I has 4 distinct clientele for its data, which are interconnected. They are

Liquid H2, D2 -non-perturbative QCD
p-A, p-rad (aka SURVEY)

NUMI thin and full target measurements

LN2- Atmospheric neutrinos

MIPP-Upgrade (100 times faster DAQ) will address
missing hadron resonances problem using low energy beams (1-5 GeV/c)
Obtain higher statistics NUMI target data
Solve the hadron shower simulation problem
Run Plan-Adopted after dir review Nov 2004

<table>
<thead>
<tr>
<th>Run Plan v7</th>
<th>Summary by Target and Beam Energy</th>
<th>Number of events, x 10^6</th>
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<tbody>
<tr>
<td>Target</td>
<td>Momentum (GeV/c)</td>
<td>Totals</td>
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<td>Z</td>
<td>Element</td>
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</tr>
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<td>1</td>
<td>H</td>
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<tr>
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<tr>
<td>Totals</td>
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<td>4.00</td>
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</table>

Run Plan v7 | Priority 1 Summary by Target and Beam Energy | Number of events, x 10^6 |
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<tr>
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<td>p only</td>
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<tr>
<td></td>
<td>Normal</td>
<td>0.50</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
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<td>0.40</td>
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<td>83</td>
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<td>p only</td>
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<td></td>
<td>Normal</td>
<td>0.50</td>
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<tr>
<td>92</td>
<td>U</td>
<td>Normal</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>0.40</td>
</tr>
</tbody>
</table>
General scaling law of particle fragmentation

- States that the ratio of a semi-inclusive cross section to an inclusive cross section

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

- where \(M^2, s, t\) are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles \(a\) and \(c\). PRD18(1978)204.
- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed \(s\).
- The proposed experiment will test the law as a function of \(s\) and \(t\) for various particle types \(a, b\) and \(c\) for beam energies between \(\sim 5 \text{ GeV/c}\) and \(120 \text{ GeV/c}\) to unprecedented statistical and systematic accuracy in 36 reactions.
Hadron Shower Simulator problem

- All neutrino flux problems (NUMI, MiniBoone, K2K, T2K, Nova, Minerva) and all Calorimeter design problems and all Jet energy scale systematics (not including jet definition ambiguities here) can be reduced to one problem - the sorry state of hadronic shower simulators. MIPP upgrade can solve this problem for once and for all.
- Timely completion of MIPP upgrade program can help CDF/D0 systematics, CMS/ATLAS, CALICE and all neutrino experiments.
- Myth-I Put designed calorimeter in test beam and use the data to tune the simulator - D0 experience. You need test beam to test the hardware.
- Myth-II Take test beam data at various incident angles and use it to interpolate - H-matrix experience
- In order to have better simulator, we need to measure event by event data with excellent particle ID using 6 beam species (pi, K, P and antiparticles) off various nuclei (LH2 critical) at momenta ranging from 1 GeV/c to ~100 GeV/c. MIPP upgrade is well positioned to obtain this data.
- MIPP can help with the nuclear slow neutron problem.
- Current simulators use a lot of “Tuned theory”. Propose using real library of events and interpolation.
Quality of existing data
Quality of existing data
Discrepancies between hadronic generators

Lack of experimental data and large uncertainties in the calculations, in particular for thick and high Z target materials

Differential distributions for pion production:

NO DATA!

⇒ Thin and thick targets, scan in Z
Discrepancies between hadronic generators

G. Battistoni
Historical overview (from M. Catenesi NUFACT04)

- Mostly based on measurement of particle yields along beam lines
- Experiments done making (smart) use of existing facilities
  - No experiments built on-purpose
- Low (~20 GeV/c) and high (~400 GeV/c) primary proton momenta, forward angular region (<150 mrad)
- Low statistics and/or limited number of data points
  - J. Allaby et al., CERN-70-12
    - p-nuclei (B4C, Be, Al, Cu, Pb) and p-p collisions at 19.2 GeV/c
    - Single arm spectrometer
    - p, K production in p-nuclei collisions (Be, B4C, Al, Cu, Pb targets) at 24 GeV/c
    - Single arm magnetic CERN-Rome spectrometer
PARTICLE PRODUCTION IN PROTON INTERACTIONS IN NUCLEI AT 24 GeV/c

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University of Torino, Italy

Received 15 March 1972

Abstract: Particle production by 24 GeV/c protons from Be, B, C, Al, Cu and Pb has been measured. Pion, kaon, proton and antiproton production spectra measured over a range of angles from 17 to 127 mrad and momenta from 4 to 18 GeV/c are given in a table.
• **Motivations and scope**

The aim of the present experiment was to measure pion and kaon production in proton-nucleus collisions at 24 GeV/c primary proton momentum. The measurements cover the secondary momentum range 4–18 GeV/c and the angular range 17–127 mrad. These data are essential for the estimation of the neutrino spectrum for the present CERN neutrino experiment.

• **Experiment’s uncertainties**

The statistical errors were nearly always negligible compared to the systematic errors. The overall scale error arising from the uncertainties in the spectrometer acceptance and in the absolute calibration of the primary proton beam intensity (by Al activation) is estimated to be 15% [4]. The systematic errors of individual data points are determined by the irreproducibility of a given spectrometer (setting (about 5%) and by the uncertainties in the corrections applied (2–5% depending on momentum). Ratios obtained from one and the same spectrometer setting (K/π ratios and ratios between different targets) are much more accurate (total error generally less than 4%), as most systematic errors drop out. Details of the data evaluation have been given in refs. [5, 6].
NA20 (Atherton et al.) @ CERN-SPS

- **Secondary energy scan:** 60, 120, 200, 300 GeV

- **H₂ beam line in the SPS north-area**

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**Overall quoted errors**

- Absolute rates: ~15%
- Ratios: ~5%

These figures are typical of this kind of detector setup

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**List of targets**

<table>
<thead>
<tr>
<th>Length (in beam direction) (mm)</th>
<th>Width (horizontal) (mm)</th>
<th>Height (vertical) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>150</td>
<td>2.0</td>
</tr>
<tr>
<td>300</td>
<td>160</td>
<td>2.0</td>
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<tr>
<td>500</td>
<td>160</td>
<td>1.5</td>
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<tr>
<td>100</td>
<td>160</td>
<td>2.0</td>
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<tr>
<td>40</td>
<td>160</td>
<td>2.0</td>
</tr>
</tbody>
</table>

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The total measurement error is dominated by the following three systematic errors:

- i) SEM calibration, see Section 3.2.1  $\approx 5\%$
- ii) errors in beam optics, see Section 3.1.4  $\approx 4\%$
- iii) collimator opening uncertainty  $\approx 1-4\%$.

All other corrections are of the order of or less than 1%.
SPS: NA56/SPY

- Most likely the most advanced study done with instrumented beam line experiments
- Dedicated to WANF (CHORUS/NOMAD) (and CNGS) experiments
- To address discrepancies beam spectrum, shape and composition as measured in CHORUS/NOMAD compared to MC predictions.
- 450GeV/c incident protons, 7→135 GeV/c secondaries (overlap with Atherton)
- Exploits TOF / Cherenkov / Calorimetry
SPY: 1996

0, ±15 mrad, ±30 mrad

spectrometer

Aug. 22, 2005 Rajendran Raja, Snowmass 05 23
SPY measurement principle

- TOF + Cherenkov, cross-check with calorimetry.

Aug 22, 2005

Rajendran Raja, Snowmass 05
The Harp detector: Large Acceptance, PID Capabilities, Redundancy

- TPC, momentum and PID (dE/dX) at large Pt
- Drift Chambers: Tracking and low Pt spectrometer
- Target-Trigger
- Drift Chambers: Tracking
- Threshold gas Cherenkov: π identification at large Pl
- TOF: π identification in the low Pl and low Pt region
- EM filter (beam muon ID and normalization)
- 0.7T solenoidal coil
- 1.5 T dipole spectrometer
- Threshold gas Cherenkov: π identification at large Pl
- TOF: π identification in the low Pl and low Pt region
- EM filter (beam muon ID and normalization)

Aug 22, 2005
Rajendran Raja, Snowmass 05
MIPP-TPC

- This Time Projection Chamber, built by the BEVALAC group at LBL for heavy ion studies currently sits in the E-910 particle production experiment at BNL, that has completed data taking. It took approximately $3 million to construct.

- Can handle high multiplicity events. Time to drift across TPC=16 $\mu$s.

- Electronic equivalent of bubble chamber, high acceptance, with dE/dx capabilities. Dead time 16$\mu$s. i.e unreacted beam swept out in 8$\mu$s. Can tolerate $10^5$ particles per second going through it.

- Can handle data taking rate ~60Hz with current electronics. Can increase this to ~1000 Hz with an upgrade.

- TPC dimensions of 96 x 75 x 150 cm.
MIPP Cherenkov
Preliminary results from Engineering run

Aug 22, 2005

Rajendran Raja, Snowmass 05
MIPP TPC DATA!
RICH rings pattern recognized
RICH radii for + 40 GeV beam triggers

![Distribution of RICH Ring Radii in Beam](chart.png)
Beam Cherenkovs

- Pressure curve Automated- Mini-Daq-APACS 30 minutes per pressure curve.+40GeV/c beam.
Beam Cherenkovs

- 40 GeV/c negative beam
Comparing Beam Cherenkov to RICH for +40 GeV beam triggers—No additional cuts!

### Distribution of RICH Ring Radii with Proton Trigger

<table>
<thead>
<tr>
<th>richProton</th>
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<tbody>
<tr>
<td>Entries: 987</td>
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<tr>
<td>Mean: 21.91</td>
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<tr>
<td>RMS: 0.5726</td>
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### Distribution of RICH Ring Radii with Pion Trigger

<table>
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<th>richPion</th>
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<tbody>
<tr>
<td>Entries: 1214</td>
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<tr>
<td>Mean: 29.11</td>
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<tr>
<td>RMS: 0.341</td>
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</tbody>
</table>

### Distribution of RICH Ring Radii with Kaon Trigger

<table>
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<th>richKa</th>
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<tbody>
<tr>
<td>Entries: 1125</td>
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<tr>
<td>Mean: 27.19</td>
</tr>
<tr>
<td>RMS: 1.124</td>
</tr>
</tbody>
</table>

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Aug 22, 2005

Rajendran Raja, Snowmass 05

35
NUMI target pix

Aug 22, 2005  Rajendran Raja, Snowmass 05

NUMI Target Radiograph

- Al Pipe
- Water Cooling Pipes
- Graphite Slabs
- Be Window
MIPP Upgrade program

• Speed up TPC DAQ by using ALICE ALTRO/PASA chips. We have been given the green light to acquire these chips from CERN ($80K).
• Speed up rest of DAQ.
ALICE PASA/ALTRO Chip

- PASA-Preamp/Pulse shaper One chip=16 pads.
- ALTRO-Digitizes, memory buffer. Controlled by ALTRO bus (40bits wide) with a Readout Control Unit.
- Thoroughly debugged and tested for ALICE. Needed by STAR, TOTEM, MIPP and being used by BONUS.

ALICE Front end card needs to be rearranged to look like a stick.
Upgrading the DAQ of the rest of MIPP to run at 3kHz.

- RICH and Hadron Calorimeter—Will work as is
- EM Cal- Use Lacroy FERA ADC’s from Prep.
- Proportional Chambers—Use Hyper CP electronics-5000 channels
- Multi Cell Cerenkov—Use FERA bus to readout the 96 channels faster.
- Time of Flight system~100 channels. Zero suppress, FERA bus.
- Drift chambers-7808 channels for drift chambers and 1920 for beam chambers.- CDF or KTEV electronics
- DAQ software—Improve interrupt handling. Write better VME drivers, Make use of DMA on the VME bus.

Jolly Green Giant Coil Fix

- One of the bottom coils has developed shorts. We are running with several turns shorted out. After the October shutdown, we propose to fix the coil.
**Labor and costs in repairing the JGG coil**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Action</th>
<th>Manpower</th>
<th>Manweeks</th>
<th>M&amp;S</th>
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<tbody>
<tr>
<td>GGG0Y</td>
<td>repair &amp; reconnect vacuum</td>
<td>2 techs, 2 weeks</td>
<td>4</td>
<td></td>
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<tr>
<td></td>
<td>de-install &amp; test</td>
<td>3 techs, 3 weeks</td>
<td>9</td>
<td></td>
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<tr>
<td></td>
<td>de-install cable &amp; function</td>
<td>3 techs, 1 week</td>
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<tr>
<td></td>
<td>de-install cable lid &amp; hardware</td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sheet pipe</td>
<td>move to site</td>
<td>4 techs, 1 week</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>re-install</td>
<td>4 techs, 2 weeks</td>
<td>8</td>
<td></td>
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<tr>
<td>LHC target</td>
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**Total Running time requested**

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<thead>
<tr>
<th>Physics Topic</th>
<th>Run Time (c)</th>
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<tbody>
<tr>
<td>MIPP - L</td>
<td>18.1 days</td>
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<tr>
<td>New neutrino experiment target (10 million events)</td>
<td>2.3 days</td>
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<tr>
<td>Additional Nucleus (5 million events)</td>
<td>1.15 days</td>
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<tr>
<td>Two particle inclusive scaling (100 million events)</td>
<td>23.1 days</td>
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<tr>
<td>Pentaquark search (K+ beam)</td>
<td>12 days</td>
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<tr>
<td>Cascades search (K- beam)</td>
<td>15 days</td>
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<tr>
<td>Missing baryon search using low momentum pions</td>
<td>82 days</td>
</tr>
</tbody>
</table>

• **Optional Upgrades**

- Cryogenic target - Extra cryo cooler $32,000
- TPC Rewind (M&S) $10,000
- RICH phototube upgrade (Hamamatsu tubes, bases) $204,000
Timeline

- Run Till next shutdown in current mode
- Acquire Alto/PASA chips
- Design New TPC Sticks
- Get approval for proposal. We have appealed the PAC decision
- Get new collaborators
- Run in 2006 (end of 206) in upgraded mode with current beam.
- Design lower momentum beam. Beam cernkovs may need redesign (too much multiple scattering)
- Lots of graduate student theses
- Possible to affect shower simulators on 2007 time frame.