The main Injector Particle Production Experiment (MIPP) at Fermilab – Status and plans

Rajendran Raja
Fermilab

- Review Status of MIPP - E907 - Took data till 2006 -- 18 million events - Analysis status
- Physics case for MIPP - Non perturbative QCD, scaling laws, missing baryon resonances
- Review the status of hadronic shower simulation models
  » Status of particle production data
- Difficulties in using shower simulation models in experiments such as MINOS, MiniBoone, Atmospheric neutrino production, muon collider neutrino factory, particle production, Project X kaon production, mu2e exp experiment, fluxes all have a common source - our lack of knowledge of the strong interaction / non-perturbative QCD

- Relevance to Cosmic Ray Air showers and Atmospheric neutrinos
- Review status of MIPP Upgrade Proposal FNAL-P960
  » to obtain much higher statistics/quality data - Deferred till we publish
- Ways to use new data directly in simulators - Hadronic Interaction libraries
- Conclusions
MIPP I-E907-collaboration list

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**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 85 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, multi-cell Cherenkov and RICH technologies.
- Physics Case for E907 and P960
We have a theory of the strong interaction—in theory

- Why study non-perturbative QCD? Answer:- We do not know how to calculate a single cross section in non-perturbative QCD! This is >99% of the total QCD cross section. Perturbative QCD has made impressive progress. But it relies on structure functions for its calculations, which are non-perturbative and derived from data.

- Feynman scaling, KNO scaling, rapidity plateaus are all violated. We cannot predict elastic cross sections, diffractive cross sections, let alone inclusive or semi-inclusive processes. Regge “theory” is in fact a phenomenology whose predictions are flexible and can be easily altered by adding more trajectories.

- Most existing data are old, low statistics with poor particle id.

- QCD theorist states- We have a theory of the strong interaction and it is quantum chromodynamics. Experimentalist asks- what does QCD predict?

- David Gross’ 25 Important questions—“Will we ever solve QCD?”

- We have declared this physics as “uninteresting” for ~ 30 years and hence our problems with systematics in every experiment where the strong interaction is either the signal or the background.
**General scaling law of particle fragmentation**

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

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

- 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 \(c\). PRD18(1978)204.

- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed \(s\).

- MIPP will in principle test this in 36 reactions. MIPP upgrade can extend these scaling relation tests to two particle inclusive reactions which requires more statistics.
Scaling Law

\[ \sigma(abc \to X) = F(M^2, s, t)D_X(M^2) \]
\[ \sigma(abc \to X_s) = F(M^2, s, t)D_{X_s}(M^2) \]

\[ \frac{\sigma(abc \to X_{sub})}{\sigma(abc \to X)} = \frac{F(M^2, s, t)D_{X_{sub}}(M^2)}{F(M^2, s, t)D_X(M^2)} = \alpha_{sub}(M^2) \]

Continuing on to physical \( t \) values, one gets

\[ \frac{f(ab \to \bar{c} + X_{sub})}{f(ab \to \bar{c} + X)} = \alpha_{sub}(M^2) \]

Essentially, it states that semi-inclusive cross sections are not all independent but are connected by these relations.
Scaling Law - EHS results
Other physics interests

High Multiplicity excess due to Bose- Einstein effects in pion emission?

GSI Darmstadt/ KVI are interested in measuring anti-proton cross sections for helping them design the PANDA detector better.

Nuclear physics- γ scaling, propagation of strangeness through nuclei. Measure spallation products.

Measure particle production off targets such as mercury, tantalum for neutrino factory/muon collider

Measure production off nitrogen- Cosmic ray/atmospheric neutrinos
**Hadronic Shower Simulation 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 current state of hadronic shower simulators.
**Missing baryon Resonances**

- Partial wave analyses of $\pi N$ scattering have yielded some of the most reliable information of masses, total widths and $\pi N$ branching fractions. In order to determine couplings to other channels, it is necessary to study in elastics such as

  \[ \pi^- p \to \eta n; \pi^- p \to \pi^+ \pi^- n; \pi^- p \to K^0 \Lambda \]

  \[ \gamma p \to \pi^0 p; \gamma p \to K^+ \Lambda; \gamma p \to \pi^+ \pi^- p \]

- All of the known baryon resonances can be described by quark-diquark states. Quark models predict a much richer spectrum. Where are the missing resonances? F. Wilczek, A. Selem

- “..this could form the quantitative foundation for an effective theory of hadrons based on flux tubes” – F. Wilczek
MIPP Secondary Beam

MIPP
Main Injector Particle Production Experiment (FNAL-E907)

Vertically cut plane
Installation in progress - Collision Hall
TPC
RICH rings pattern recognized
Beam Cherenkovs

Upstrm Beam Cherenkov in × out

Dwnstrm Beam Cherenkov in × out

Upper Beam Cherenkov in × out

Lower Beam Cherenkov in × out

+40 GeV/c

-40 GeV/c

January 2009 Rajendran Raja, Nu Horizons2, Allahabad, India
Comparing Beam Cherenkov to RICH for +40 GeV beam triggers—No additional cuts!

Distribution of RICH Ring Radii in Beam

Distribution of RICH Ring Radii with Proton Trigger

Distribution of RICH Ring Radii with Kaon Trigger

Distribution of RICH Ring Radii with Pion Trigger
TPC Reconstructed tracks
$dE/dx$ in the TPC

**$\pi, k, p (+20 \text{ GeV}) + \text{Carbon 2\%}$**

**$0.15 < p/Z < 0.25 \text{ (GeV/c)}$**

**$0.3 < p/Z < 0.4 \text{ GeV/c}$**
NUMI target pix
Preliminary Comparison of NUMI target to FLUKA predictions

NuMI Target Analysis

RICH Rings from NUMI target
Particle ID (cont.)

- RICH ring radius gives very good particle ID within acceptance
  \[ \text{e/\mu/\pi to 12 GeV/c} \]
  \[ \text{\approx \pi/K/p to 100 GeV/c} \]

- Detector is calibrated and well understood
# Data Taken In current run

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<th>Data Summary</th>
<th>Acquired Data by Target and Beam Energy</th>
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<tr>
<td>Total</td>
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<td></td>
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<td><strong>0.21</strong></td>
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Reconstructed Proton-Carbon at 120 GeV/c Event
MIPP Cherenkov

C4F10 gas

Thresholds

π = 2.5 GeV/c

K = 8.9 GeV/c

P = 17.5 GeV/c
Ckov analysis

- Every mirror calibrated with data assuming pions and Poisson statistics. Light yield lower than expected.
Time of Flight Wall

Designed and built by MIPP
5cmx 5cm square scintillator bars in Rosie aperture, 10cmx10cm outside.
~200ps resolution.

MIPP- Time of flight system

Temperature systematics
Crosstalk when neighboring bars hit
Tof analysis
Calorimeters

EM calorimeter followed by hadron calorimeter
Calorimeter Analysis
Acceptances and resolutions

• Full MC Geant3 based. Use known tracks and match them to found tracks.

• MC event display
Acceptances
Feynman $x$ acceptance
**MIPP Momentum resolution**

HARP MIPP Resolution Comparison

![Graph showing the comparison of HARP and MIPP resolution vs. track momentum in GeV/c.](image-url)
**Hadron Shower Simulator problem**

- Timely completion of MIPP upgrade program can help systematics in, CMS/ATLAS, CALICE and all neutrino experiments.
- Describe how showering is done in calorimeter simulations
- Why are correlations important?
- 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 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.—plastic ball detector
- Current simulators use a lot of „Tuned theory“. Propose using real library of events and interpolation.
Hadronic Shower Simulation Workshop
HSSW06

- Venue—Fermilab
  September 6-8, 2006
- Experts from GEANT4, FLUKA, MARS, MCNPX, and PHITS attended as well users from Neutrino, ILC, Atlas, CMS communities. Goal was to reduce systematics between various models and arrive at a suite of programs that can be relied on.
- Major conclusion—too many models—new particle production data on thin targets needed to improve models.
Describe a widely used model—

There exists no workable theory of the strong interaction in the non-perturbative regime. No cross section (elastic, diffractive, central) can be calculated from first principles. People resort to models with tunable parameters and arbitrary assumptions. To illustrate—let us review briefly DPMJET (Dual Parton Jet) concepts similar to QGSJET. Used in Fluka as well as by itself similar to QGSJET in Geant4.

Reggeon exchange. Can either be thought of as a sum of t channel exchanges or as a sum of s channel resonances—Hence Dual.

Pomeron exchange Does not depend on flavor of scattering particles.
Dual Parton Model - Concepts - Optical theorem

Reggeon Exchange - Single string of hadrons

Pomeron Exchange - Two strings of hadrons
Conceptual problem- Matching soft and hard processes.

This is done by tuning the transition region carefully! And arbitrarily
DPMJET-Multiplicities-Slides from R. Engel

DPMJET in p-p mode:
simulation of particle production from energy threshold on

proton - proton, $E_{\text{lab}} = 200\text{GeV}$

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<tr>
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<th>Exp.</th>
<th>DPMJET-III</th>
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<td>charged neg.</td>
<td>$7.69 \pm 0.06$</td>
<td>$7.64$</td>
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<tr>
<td>p</td>
<td>$2.85 \pm 0.03$</td>
<td>$2.82$</td>
</tr>
<tr>
<td>n</td>
<td>$1.34 \pm 0.15$</td>
<td>$1.26$</td>
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<tr>
<td>$\pi^+$</td>
<td>$0.61 \pm 0.30$</td>
<td>$0.66$</td>
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<tr>
<td>$\pi^-$</td>
<td>$3.22 \pm 0.12$</td>
<td>$3.20$</td>
</tr>
<tr>
<td>$\pi^-$</td>
<td>$2.62 \pm 0.06$</td>
<td>$2.55$</td>
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<tr>
<td>$K^+$</td>
<td>$0.28 \pm 0.06$</td>
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<tr>
<td>$K^-$</td>
<td>$0.18 \pm 0.05$</td>
<td>$0.20$</td>
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<tr>
<td>$\Lambda$</td>
<td>$0.096 \pm 0.01$</td>
<td>$0.10$</td>
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<tr>
<td>$\bar{\Lambda}$</td>
<td>$0.0136 \pm 0.004$</td>
<td>$0.0105$</td>
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**DPMJET - Collider distributions (R. Engel)**

Charged particle multiplicity distribution at 200 GeV cms.

Charged particle pseudorapidity distributions
**HSSW06 programs and models used by them**

<table>
<thead>
<tr>
<th>Program</th>
<th>Event Generator Models</th>
<th>Nuclear Break up models</th>
</tr>
</thead>
</table>
| Fluka05 | Isobar model (below few GeV)  
          own version of DPM + hadronization | PEANUT (Includes GINC)  
          Generalized InterNuclear Cascade |
| Geant4  | QGS + Fritiof String model $> 20 GeV$  
          Bertini Cascade Model $< 10 GeV$  
          Binary Cascade model  
          Low Energy Parametrized Models &  
          High Energy Parametrized Models (GHEISHA origin) | Geant4 Pre-compound model  
          Bertini evaporation model  
          Chiral Invariant Phase Space model (CHIPS)  
          $< 20 MeV$ Nuclear break-up libraries |
| MARS15  | Inclusive event generator  
          CEM03, LAQGSM03 Quark-Gluon String model | Generalized intra-nuclear cascade  
          evaporation and fission models |
| PHITS   | Jet AA Microscopic Transport Model (JAM) $> 20 MeV$  
          Jaeri Quantum Molecular Dynamics model JQMD | Neutrons done as in MCNP  
          JQMD |
| MCNPX   | Fluka79 or LAQGSM | Intra Nuclear Cascade models  
          Bertini, ISABEL, CEM, INCL4... |
Models Fit to data where they have been tuned

- Tuning done in single inclusive variable - eg Feynman x or multiplicity.
- Errors in models multiply when applied to the calorimeter problem. Repeated showering causes systematics to be enlarged.
- In order to get longitudinal and transverse shapes correctly, one needs to not only single particle inclusive cross sections but also multiparticle correlations.
- To do this we need new data.
- To illustrate—Neutrino targets (many interaction lengths) and transverse size of target restricted.
Miniboone-Sanford-Wang (SW) parametrization of E910 and HARP compared to other models

The differences are dramatic in the between models! But the E910 and HARP cross sections determine the correct model, which is very close to MARS. — Does this mean MARS is now the correct simulator to use?

D. Schmitz

Momentum

Theta
MINOS problem– (from S. Kopp)

LE10/185kA

(other beams fit simultaneously)

Events/bin

Data/MC

Reconstructed Energy (GeV)
Benchmark example from HSSW06- (N. Mokhov, S. Striganov, D. Wright et al)

- Energy deposit profile as a function longitudinal depth in a tungsten rod of 1 cm radius—Challenges to get longitudinal and transverse distributions correctly simultaneously.
Models plotted as a function of ratio to data.

- Plotted on right are the ratios of model/data for various final state particles for 67 GeV/c protons on a thick aluminum target at Protvino. Discrepancies of order 5-6 are evident between model and data. Models disagree amongst themselves.
Model Input data unreliable—some over 30 yrs old
a recent example 60% normalization error between 2 experiments.
Thin target data model comparisons

Graph showing the comparison of different models for thin target data at different energies.
Thin target data model comparisons

![Graph showing comparisons of thin target data models with histograms and probability distributions.]
Meurer et al - Cosmic ray showers Discontinuity - Gheisha at low energies and QGSJET at higher energies - Simulation of air showers
Shower Simulation Problem

• In order to solve the shower simulation problem it is important to acquire data at a variety of beam momenta, beam species and targets.

• Measuring liquid nitrogen thin target at one incident beam momentum and beam species will not do the job.

• Using MIPP events obtained at ~100 GeV/c, it is possible to simulate incident beam momenta well in excess of 500 GeV/c using KNO scaling and random access libraries.
U/D asymmetries in INO-Indumathy, Murthy-hep-ph0407336
U/D asymmetries in INO-Indumathy, Murthy-hep-ph0407336

- MIPP upgrade will measure pion production in nitrogen from 1 - 120 GeV incident beams ($\pi^\pm, K^\pm, p^\pm$).
- Will solve flux problem.
- Up and down fluxes are not same for neutrinos. Up going events further away. So solid angle subtended by detector is different from down going ones. Same as MINOS near detector/far detector systematics. Flux measurement crucial.
- In addition, MIPP will help pin down the $\pi^+/\pi^-$ spectra as a function of rapidity and transverse momentum and incident beam energy. This is of crucial importance to the neutrino/anti-neutrino asymmetries.
- Models notoriously unreliable.
- $U/\bar{U}$ ratios can be directly employed to determine the sign of $\delta m^2$.
- Will make INO physics case more compelling.

FIG. 8. The same as Fig. 7 for $|\delta_{23}| = 2 \times 10^{-3}$ eV$^2$. 
January 10, 2008

Dr. R. Raja
Fermilab

Re: Interest in data provided by the upgraded MIPP experiment at Fermilab

Dear Raja:

We would like to express our keen interest in utilizing the data provided by the upgraded MIPP experiment at Fermilab in improving the predictive power of hadronic shower simulation codes. The upgraded MIPP experiment will provide high quality data with final state particle identification on 30 nuclei using six beam species with momentum ranging from 1 to 90 GeV/c. The present codes use models that are tuned on single-particle inclusive data taken over many years and not always mutually consistent with each other. The MIPP upgrade data will eliminate a significant portion of the systematic uncertainties involved in hadronic shower simulations. Improved codes will benefit diverse fields within the HEP community, such as the fixed target neutrino and kaon programs, the atmospheric neutrino program, cosmic rays, calorimetry simulations in hadron collider experiments, as well as outside HEP such as studies to design radiation safe spacecraft environments. Improved codes will also help planning and calorimeter design studies for the International Linear Collider and a Muon Collider.

Sincerely,

John Apostolakis (CERN), Dennis Wright (SLAC), on behalf of the GEANT4 team

Nikolai Mokhov (Fermilab) on behalf of the MARS team

Koji Niita (RIST/JAEA) on behalf of the PHITS team

Laurie Waters (LANL) on behalf of the MCNPX team
### MIPP Upgrade P-960-collaboration list

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<thead>
<tr>
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<td>University of Virginia</td>
<td>P. Desiati, F. Halzen, T. Montaruli, P. Sokolsky, W. Springer</td>
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<tr>
<td>University of Utah</td>
<td>University of Utah</td>
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10 new institutions have joined. More in negotiations. Previous collaboration built MIPP up from ground level. Less to do this time round. More data.
The Proposal in a nutshell

- MIPP one can take data at ~30Hz. The limitation is the TPC electronics which are 1990’s vintage. We plan to speed this rate up to 3000Hz using ALTRO/PASA chips developed for the ALICE collaboration.

- Beam delivery rate- We assume the delivery of a single 4 second spill every two minutes from the Main Injector. We assume a 42% downtime of the Main Injector for beam manipulation etc. This is conservative. Using these figures, we can acquire 5 million events per day.

- Jolly Green Giant Coil Replacement- Towards the end of our run, the bottom two coils of the JGG burned out. We have decided to replace both the top and bottom coils with newly designed aluminum coils that have better field characteristics for the TPC drift. The coil order has been placed ($200K).

- Beamline upgrade- The MIPP secondary beamline ran satisfactorily from 55GeV/c-85GeV/c. We plan to run it from ~1 GeV/c to 85 GeV/c. The low momentum running will be performed using low current power supplies that regulate better. Hall probes in magnets will eliminate hysteresis effects.

- TPC Readout Upgrade- We have ordered 1100 ALTRO/PASA chips from CERN ($80K). The order had to go in with a bigger STAR collaboration order to reduce overhead. We expect delivery in the new year of tested chipsets.
The Proposal in a nutshell

• MIPP- Recoil detector- GSI- Darmstadt / KVI Groningen have joined us. They will bring the plastic ball detector (a hemisphere of it) which will serve to identify recoil (wide angle) neutrons, protons and gammas from our targets.

• Triggering system- We propose to replace the MIPP interaction trigger (scintillator/wire chamber) with 3 planes of silicon pixels based on the B-TeV design. Will enable us to trigger more efficiently on low multiplicity events.

• Drift Chamber/ PWC electronics- These electronics (E690/RMH) worked well for the first run. They are old (1990’s). RMH will not do 3kHz. We will replace both systems with a new design that utilizes some of the infrastructure we developed for the RICH readout.

• ToF/CKOV readout- Plan to build new readout based on TripT chip (Used by Minerva) and a high resolution TDC chip. Will use the VME readout cards in common with RICH, TPC.

• RICH detector and the Beam Cerenkovs will work as is.

• Calorimeter Readout- Switch to FERA ADC’s (PREP).

• DAQ software upgrade- Front end DAQ software needs to be developed. The MIPP DAQ control software+ Data base can be kept as is.

• Plan is to store one spill’s worth of data on each detector and read out the whole lot at end of spill.
Nuclei of interest- 1st pass list

- The A-List
  - \( H_2, D_2, Li, Be, B, C, N_2, O_2, Mg, Al, Si, P, S, Ar, K, Ca, Fe, Ni, Cu, Zn, Nb, Ag, Sn, W, Pt, Au, Hg, Pb, Bi, U \)

- The B-List
  - Na, Ti, V, Cr, Mn, Mo, I, Cd, Cs, Ba

- On each nucleus, we can acquire 5 million events/day with one 4sec beam spill every 2 mins and a 42% downtime.

- We plan to run several different momenta and both charges.

- The libraries of events thus produced will be fed into shower generator programs which currently have 30 year old single arm spectrometer data with high systematics.
The recoil detector

Detect recoil protons, neutrons, pizeros and charged pions, kaons
Can we reduce our dependence on models?

• Answer- Yes- With the MIPP Upgrade experiment, one can acquire 5 million events per day on various nuclei with six beam species ($\pi^\pm,K^\pm,p^\pm$) with beam momenta ranging from 1 GeV/c-90 GeV/c. Full acceptance over phase space, including info on nuclear fragmentation

• This permits one to consider random access event libraries that can be used to generate the interactions in the shower.
Random Access Data Libraries

- Typical storage needed

<table>
<thead>
<tr>
<th>Nuclei</th>
<th>beam species</th>
<th>momentum bins</th>
<th>events/bin</th>
<th>tracks/event</th>
<th>words/track</th>
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<td>6</td>
<td>10</td>
<td>100000</td>
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</table>

- Mean multiplicities and total and elastic cross section curves are parametrised as a function of \( s \).
**TPC Electronics Upgrade**

15,360 pads in TPC. 16\(\mu\)s to drift from top to bottom. IN principle, there are 3,800,000 individual data points possible. Each data point is a time bucket and a dE/dx ADC value. A MIPP event sparsely populates this space and is \(~ 110\)kBytes in size. The old readout is 1990’s vintage and the readout system is heavily multiplexed and limited to 60Hz maximum. For our events, we were able to achieve \(~30\)Hz.

Redesign with ALICE ALTRO/PASA chips with inbuilt zero suppression can produce a readout working at 3kHz. A factor of 100 in speed.

*10 times more data using 10 times less beam time!*
**TPC electronics upgrade**

- Old MIPP TPC “Stick” – 120 of these.
- New MIPP TPC “stick” layout using ALTRO/PASA chips. Chips in hand
MIPP Trigger Upgrade

- Beam sizes are large in MIPP due to the “low divergence” condition needed for beam CKOV’s.
- Previous trigger of SCINT counter + 1st drift chamber wire signals performed satisfactorily for MIPP –I physics but needs improvement at low multiplicities—Landau tails.
- We propose to use silicon pixel counters (B-TEV, Phenix).
- Use a “Bull’s Eye” system to detect absence of beam particle in final state to signal interactions. Also use the multiplicity in the final state as an additional piece of information.
**Drift Chamber/ PWC readout Upgrade**

- Large PWC's use old CERN RMH electronics- Needs replacement.
- E690 electronics will work at these speed, if CAMAC DMA is implemented. The electronics are also aging and also put out a lot of heat.
- MIPP proposes a unified scheme for reading out both sets of chambers using a system that modifies the MIPP RICH readout cards by changing the latch to a TDC.
- Preamp cards being replaced Preamp/Discriminator front end cards.
- The RICH cards will store an entire spill's worth of events, which are readout in between spills.
- WBS task 4.2 M&S $121.2K, Labor $28.7K. Newest of the design efforts. Probably need to add 50% contingency.
**ToF, CkOV, Calorimeter readouts**

- **ToF/CkOV readout**
  - Front end boards—TripT chip used by Minerva(ADC) and a high end TDC chip (TDC-GPX from ACAM, also used by LHC-b 30 ps timing resolution). Will buffer an entire spill. Delay cables will be eliminated.
  - Backend will use RICH VME readout card for ToF/CkoV.
  - WBS Task 4.3 M&S $16K Labor $18K

- **Calorimeter Readout**
  - Propose 4 crates of FERA ADC's (K-TeV + PREP)
  - Read out by 2 Hytec1365 CAMAC readout controllers.
  - WBS Task 4.4 M&S $15K

**Beam Line Upgrade**

Add low current power supplies and hall probes to facilitate low momentum running

WBS task 8 M&S $56K
MIPP DAQ System upgrade

- Most of the DAQ upper layer software (Run control, Book keeping, plots) can be kept as is.
- New Power PC 5500’s replace 6 existing ones.
- Linux kernel to migrate to it (10 person weeks)
- Camac Hytec 1365V5 Module software (2 weeks)
- Update Event builder (6 weeks)
- FERA ADC readout (5 weeks)
- Modify event monitor (2 weeks)
- New fPix readout PC, DAQ PC with 1TB disk storage. All PC’s will have GBit and 100MBit fast ethernet ports.
- 100 kbytes/event. 1.2 Gbyte of data per spill.
- 200Mbits/sec transfer from MC7 to Ptkmp.
- 6 Mbytes/second transfer rate into ENSTORE is needed to transfer 5 million events/day. CDF/D0 do 30-60 Mbytes/sec routinely.

WBS Task 6 M&S $47K, Labor $39K
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<th>Fermi M&amp;S Cost</th>
<th>Fermi Labor Cost</th>
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# Run Plan

## Phase 1 Run Plan

<table>
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<tr>
<th>Target</th>
<th>Number of Events (Millions)</th>
<th>Running Time (Days)</th>
<th>Physics Need Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>NuMI Low Energy target</td>
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<td>MINOS MINERVA</td>
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<td>NuMI Medium Energy Target</td>
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<td>MINERVA NOVA</td>
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<td>Liquid Hydrogen</td>
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<td>4</td>
<td>QCD PANDA DUBNA</td>
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<td>Liquid Nitrogen</td>
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<td>12 Nuclei</td>
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## Phase 2 Run Plan

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## Phase 3 - Tagged Neutral beams for ILC 5 million events/day LH2 target

Missing baryon resonance search may request additional running depending on what is found.

January 2009 Rajendran Raja, Nu Horizons2, Allahabad, India
Conclusions

• The MIPP Upgrade Collaboration has proposed a cost effective way to upgrade the experiment to speed up the DAQ by a factor of 100.
• We propose to add a recoil detector+chamber that will enhance the physics reach of the experiment.
• We propose to measure the NUMI LE/ ME targets.
• As well as 30 nuclei to benefit hadron shower simulators and the cosmic ray community.
• Tagged neutral beams possible for PFA studies(?)
• We propose to increase the momentum range of the beams (down to 1 GeV/c) that will benefit the hadron shower simulators and permit the search for missing baryon resonances.
• Collaborators Welcome
Plastic Ball Mount
MIPP LH$_2$ target