MINERVA

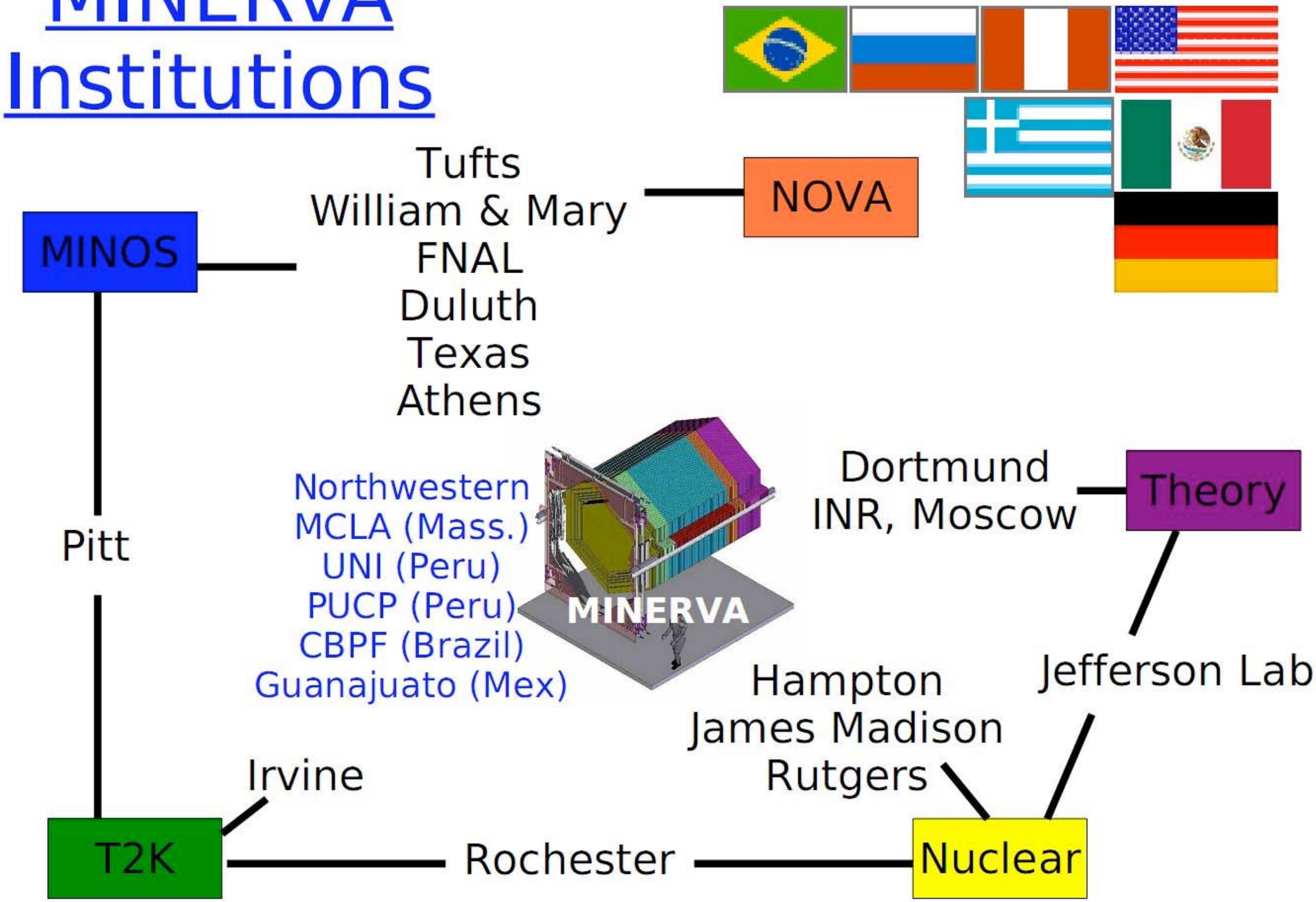
Neutrino Interactions at Fermilab

Lauren Wielgus
NEPPSR 8/14/09

What is MINERvA?

- Main Injector Experiment for ν-A
- Will take advantage of the high-ν flux of NuMI beam(1-20GeV)
- Finely segmented and fully active scintillator tracking chamber surrounded by ECAL and HCAL
  - Fully reconstructed exclusive final states
- Nuclear targets to study neutrino-nucleon interactions
  - He,C,Fe,Pb
- Upstream of MINOS(muon spectrometer)

MINERvA Institutions



Tufts
William & Mary
FNAL
Duluth
Texas
Athens

NOVA

MINOS

Northwestern
MCLA (Mass.)
UNI (Peru)
PUCP (Peru)
CBPF (Brazil)
Guanajuato (Mex)

Dortmund
INR, Moscow

Theory

Pitt

Jefferson Lab

Hampton
James Madison
Rutgers

Irvine

T2K

Rochester

Nuclear

MINERvA Physics Topics

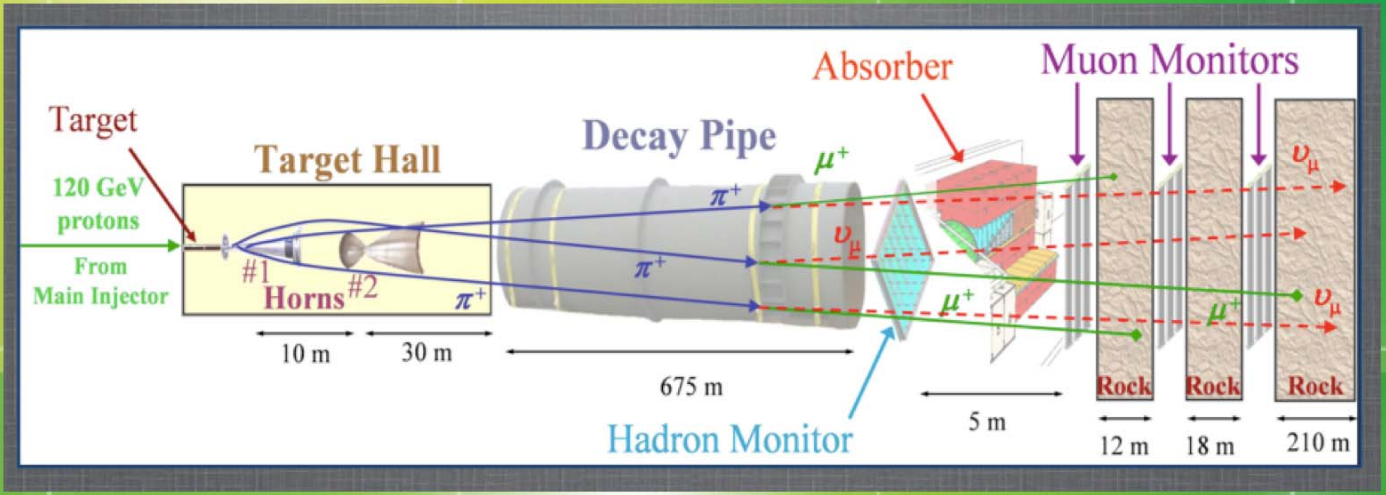
- Will have millions of events on carbon for:
- Quasi-elastic: $(\nu_\mu + n \rightarrow \mu^- + p)$
  - $(\text{anti-}\nu_\mu + p \rightarrow \mu^+ + n)$
- Resonance Production: $(\nu_\mu + N \rightarrow \mu + N^* \rightarrow \mu + N' + \pi)$
  $(\nu_\mu + N \rightarrow \nu_\mu + N^* \rightarrow \nu_\mu + N' + \pi)$
- Coherent Pion Production: $(\nu_\mu + A \rightarrow \nu_\mu + A + \pi^o)$
  $(\nu_\mu + A \rightarrow \mu^- + A + \pi^+)$
- Deep Inelastic Scattering (DIS),
- Structure Funcs., and high-x PDFs
- Strange and Charm Particle Production
- Nuclear Effects

The need for MINERvA

- Entering era of precision neutrino measurements
- Requires precise knowledge of cross sections, final states, and nuclear effects
  - Current cross sections poorly known
    - 20-100% total error
  - Current unresolved discrepancies
    - CCQE, Coherent pion production, nu-Fe nuclear effects
  - 2-det expts depend upon neutrino interaction models to extrapolate backgrounds from near to far detector

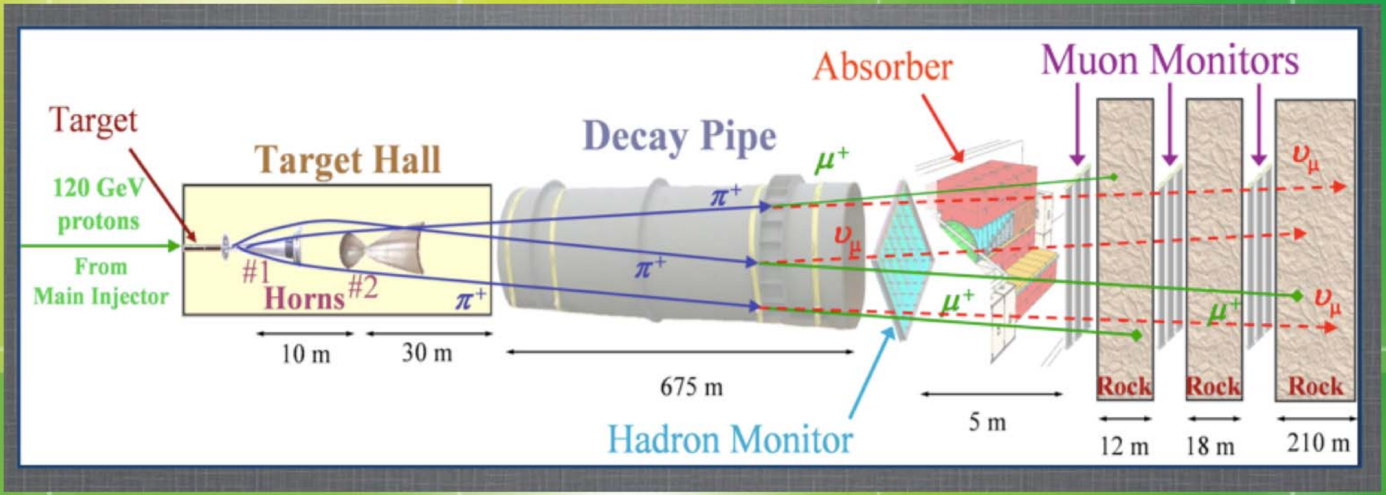
- *No other experiment exists to perform precision measurements in MINERvAs energy range!*

The Neutrino Beam



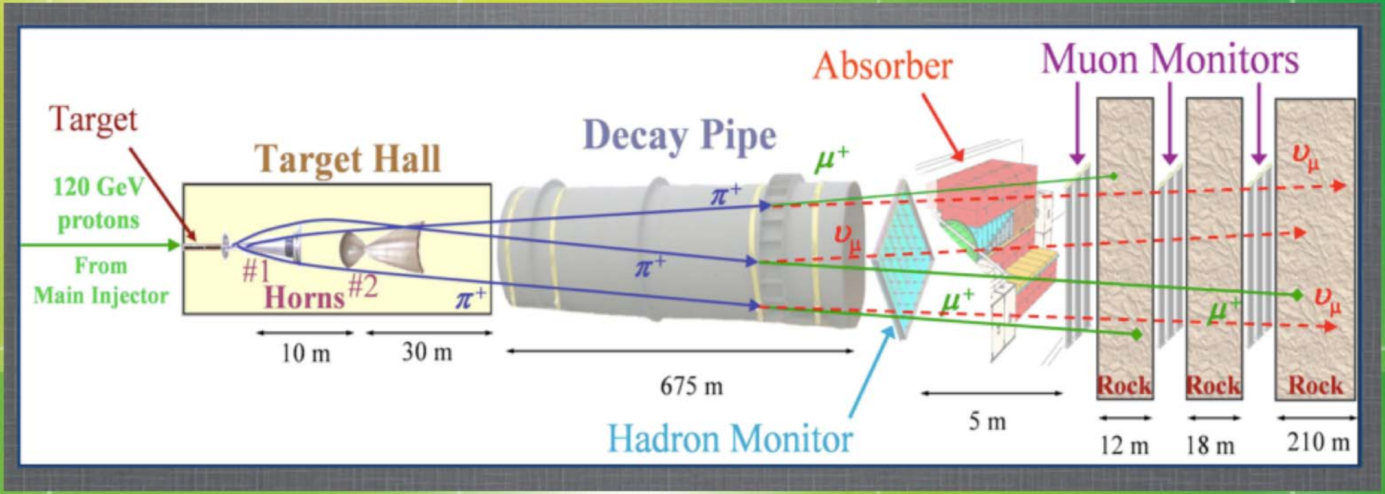
- Accelerator-based experiment
- High-energy protons + target = mesons
  - $\pi^\pm$, $K^\pm$, some K^0
- Mesons decay to produce neutrino beam
  - Decay At Rest = low energy ν (max ~54 MeV)
  - Decay In Flight = high energy νs

The Neutrino Beam



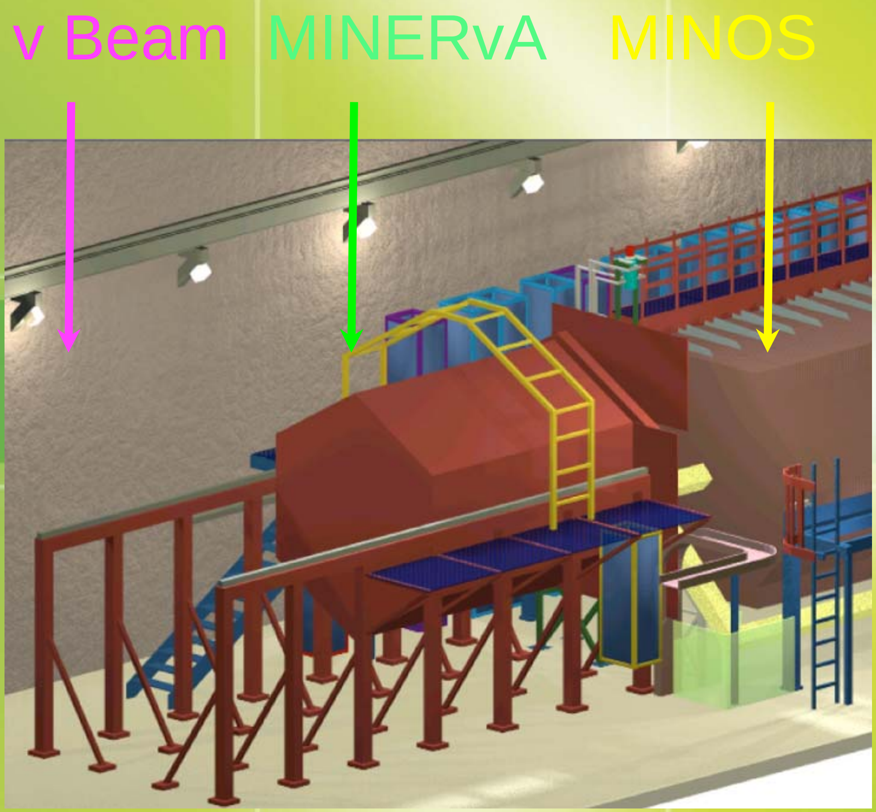
- 120 GeV protons
- Graphite target
- Magnetic focusing horns
  - Polarity of horns = neutrino or antineutrino beam
  - Movable horn/target = tunable neutrino beam energy

The Neutrino Beam



- 675 m long decay pipe
- Hadron absorber stops any undecayed mesons, non-interacting protons from the beam
- 240m of absorber (rock!) stops μs from meson decay

MINERvA Detector

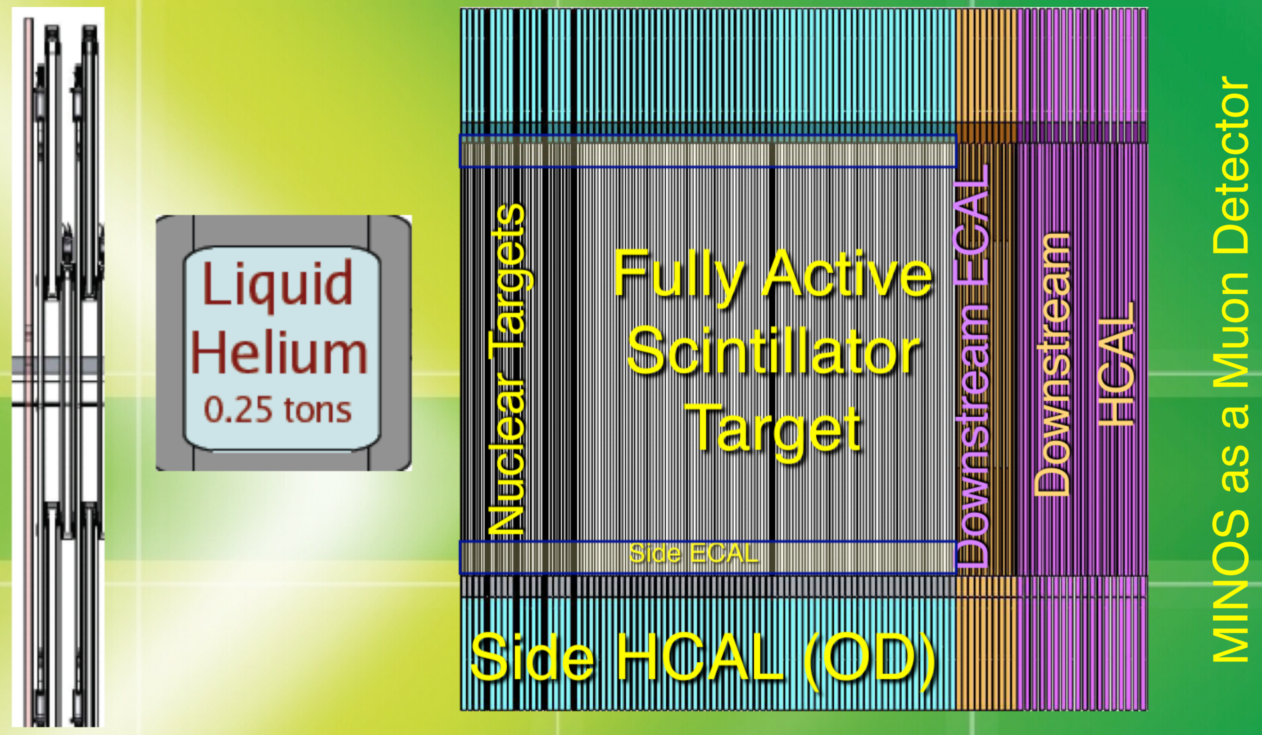


- Must reconstruct exclusive final states
- high granularity for charged particle tracking and ID, low momentum thresholds for particle detection such as $\nu_\mu\, n \rightarrow \mu^- p$ (quasi-elastic, QE)

- Also must contain
- EM showers (π^0, $e^\pm$)
- high momentum hadrons ($\pi^\pm$, p, etc.)
- $\mu^\pm$ from QE, contained well enough to measure momentum
- nuclear targets to study nuclear effects

MINERvA Detector

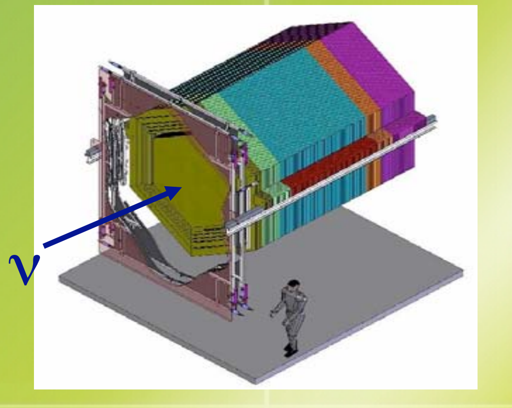
Neutrino Beam



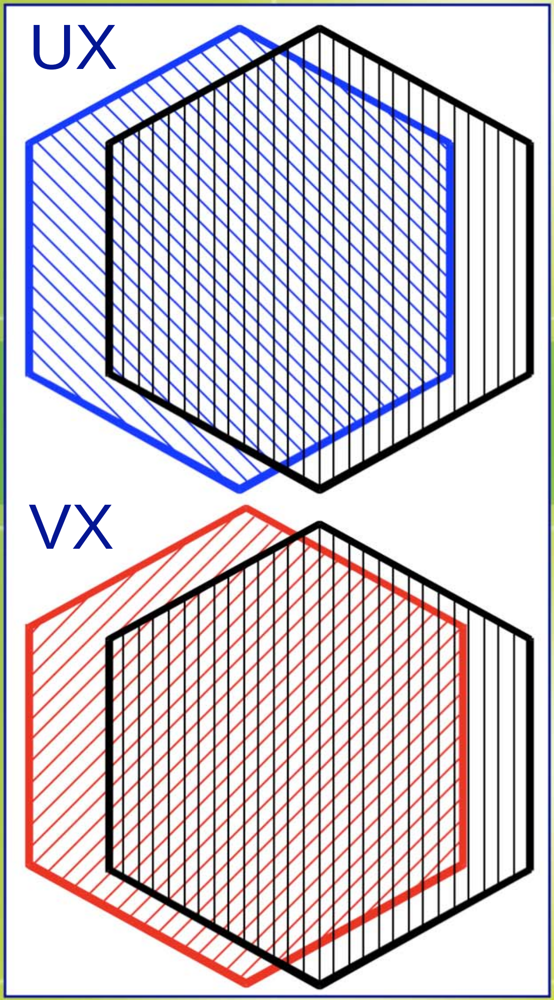
Veto Wall

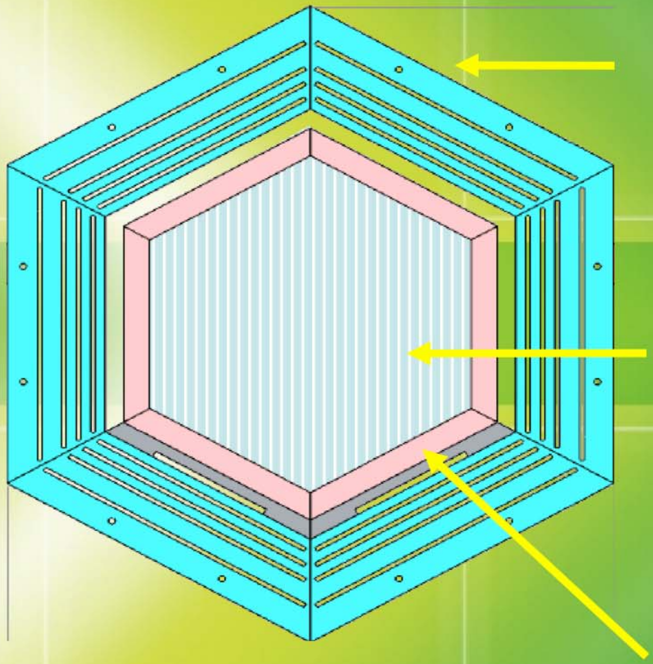
Not to scale!

SIDE: 0.6 tons ECAL, 116 tons HCAL
END: 15 tons ECAL, 30 tons HCAL
ACTIVE: 8.3 tons



Scintillator Planes

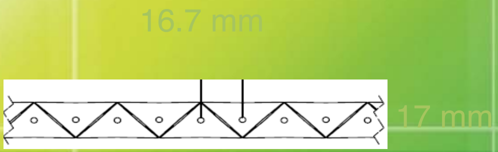




Outer Detector
Fe+scintillator towers for hadron calorimetery

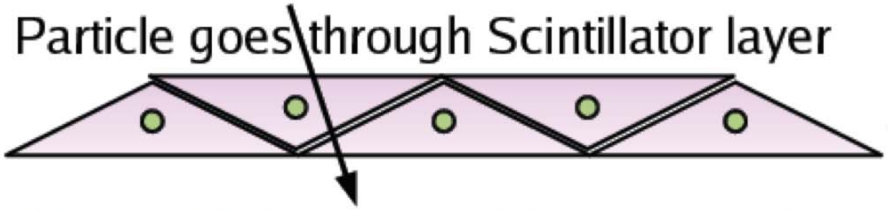
Inner Detector
UXVX planes for 3D tracking

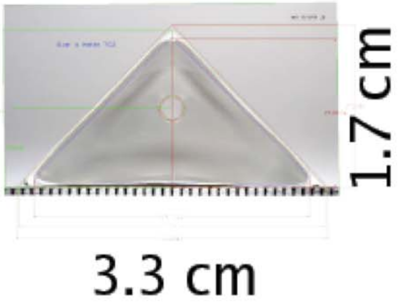
Side ECAL
Pb+scintillator bars for EM calorimetery



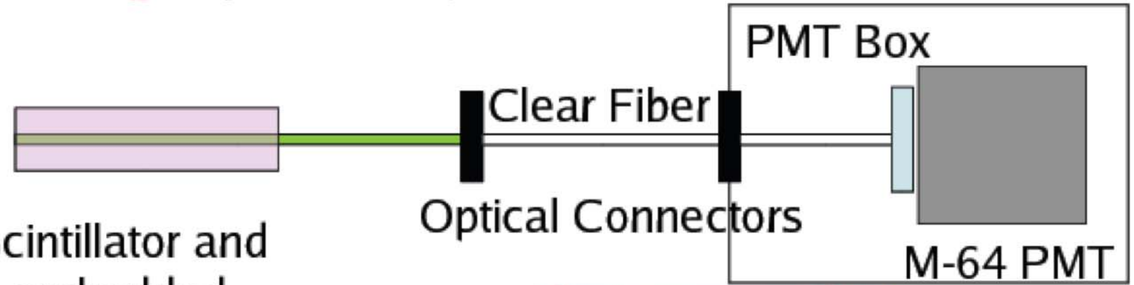
Tracking System

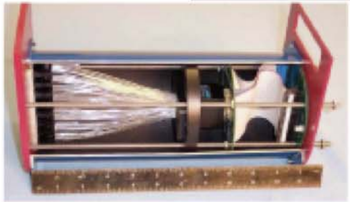
Optical System





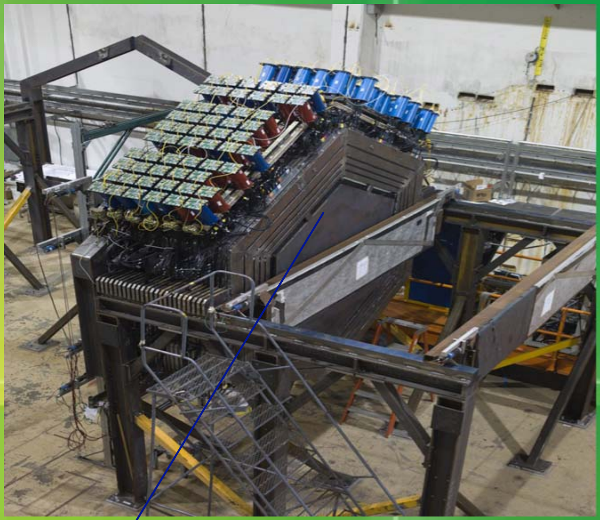
Achieved 2.5 mm position resolution using charge sharing and light yield 6.5 pe/MeV

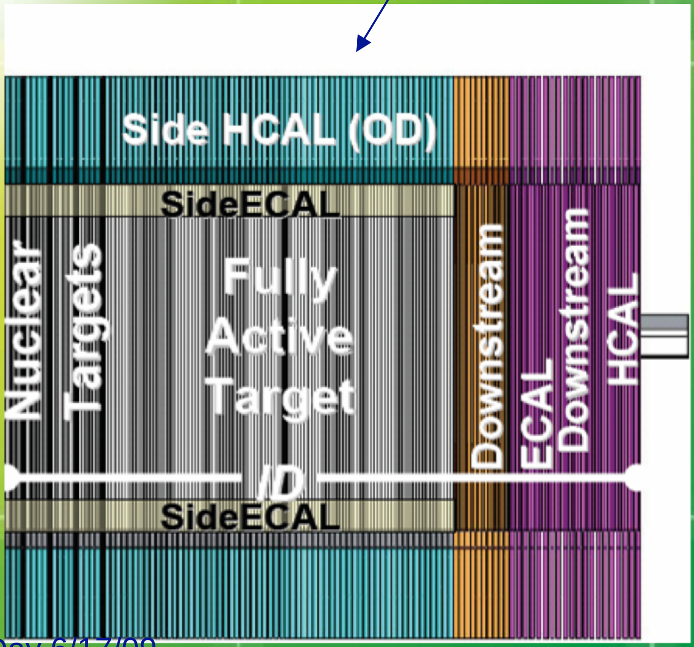




Tracking Prototype(TP)

- Fully functional
- Built and commissioned June ’08-March ’09
- Moved to NuMI March 16-April 17
- 20% of full detector
  - 10 tracker modules
  - 10 ECAL modules
  - 4 HCAL modules
  - Upstream steel target scint. veto





Schedule and plans

- Mid-July: TP modules will be disassembled and moved to a storage rack in NuMI
- Mid-July to mid-August: Install final 16 HCAL and replace TP
- Late August downstream portion of detector in place. Have around 35 additional tracker modules on-site
- Beam returns in early September in anti-neutrino mode

Reconstruction

- While beam is off, collaboration is working on the software for track reconstruction.
- We have both data from the TP and we can simulate MC data
- Want to be able to identify νe events
  - Should be a small fraction of the beam
  - Need to know the background of νe's in the beam at the near detector

So, how good are we at identifying these events?

Questions to be Answered

- At what energy does our ability to classify events break down?
- Which types of interactions are hardest to identify?
- Which particles are hardest to identify?
- What are the potential pitfalls for those doing hand-scanning and writing reconstruction software?

My Project

1- Scan ~1500 simulated events after completing training scans; classify their interaction type (charged current $\nu\mu$, charged current νe or neutral current) and prong number

2- Compare my answers to the true information

3 -Create truth tables and efficiency plots

Software Tools

- I am using data simulated by Hugh Gallagher using GENIE and the SystemTests Package in GAUDI.
- I adapted a macro written by Wojciech Musial, a fellow Tufts undergrad, to view and scan Monte Carlo data.
- I then compare the scanned data to the true data from GENIE.
- I use another ROOT macro to combine the results of my scans and print out truth tables, efficiency plots, and relevant graphs.

Monte Carlo Simulation

- Simulate data using the GENIE (Generates Events for Neutrino Interaction Experiments)
- Used the tracking prototype for the geometry
- Scaled the νe flux by 100 so it would be roughly equal to the $\nu\mu$ flux
    - This is not realistic for the beam
    - However, we wanted to have more information about our ability to ID rare νe events
- Passed simulated events through mockup of the tracking prototype to get raw data files
- Once we have the raw files, I scan them, selecting the type of interaction and number of prongs

Types of Interactions

- Charged Current

  -Neutrino transforms into its partner lepton

  -Charged boson is exchanged

  -Target particle changes character

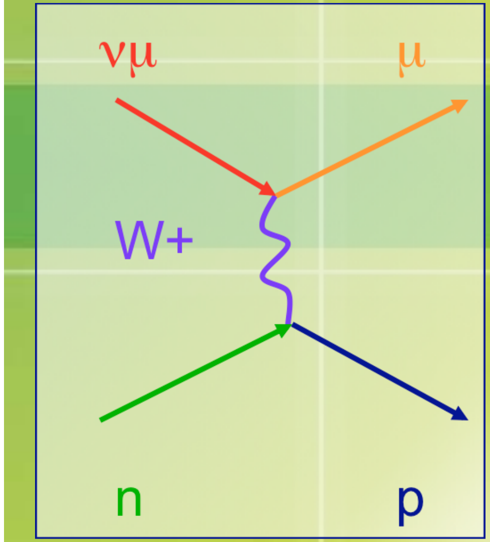
- Neutral Current

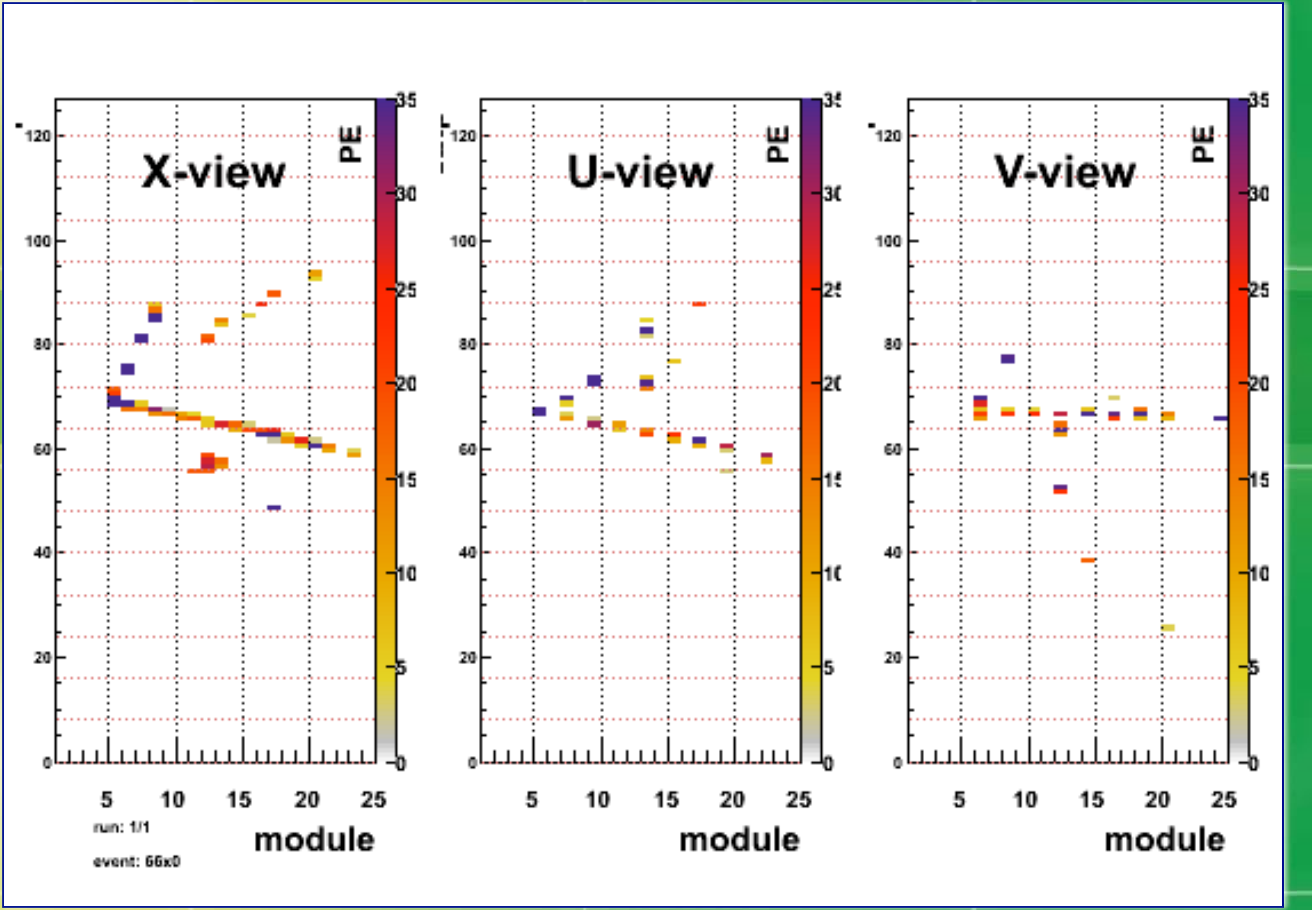
  -Neutrino leaves detector after transferring energy and momentum to target particle

  -No flavor information is left behind

  -Neutral boson is exchanged

Charged Current νμ





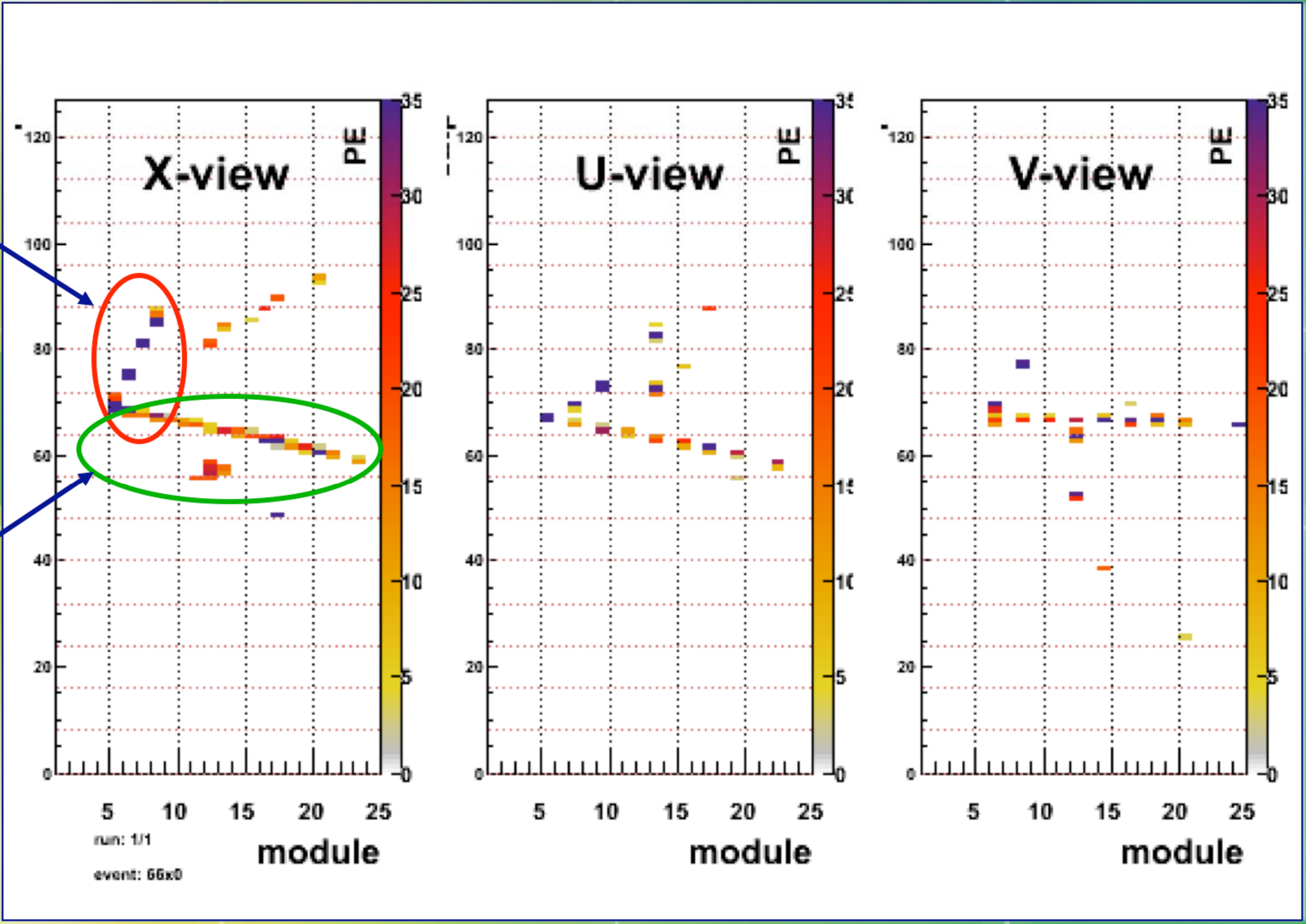
Charged Current νμ

Proton track

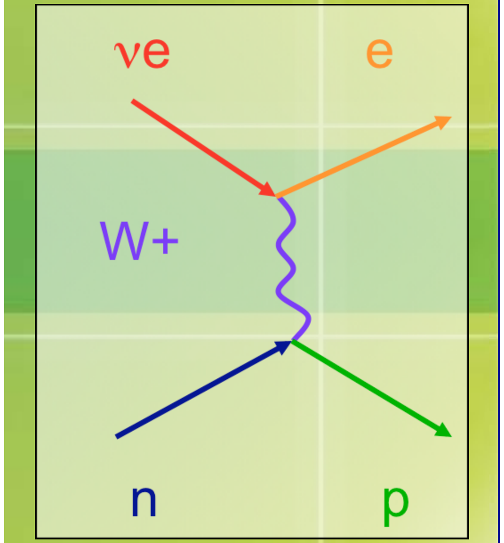
Px: 0.741 GeV/c
Py: 0.033 GeV/c
Pz: 0.655 GeV/c
E: 1.364 GeV

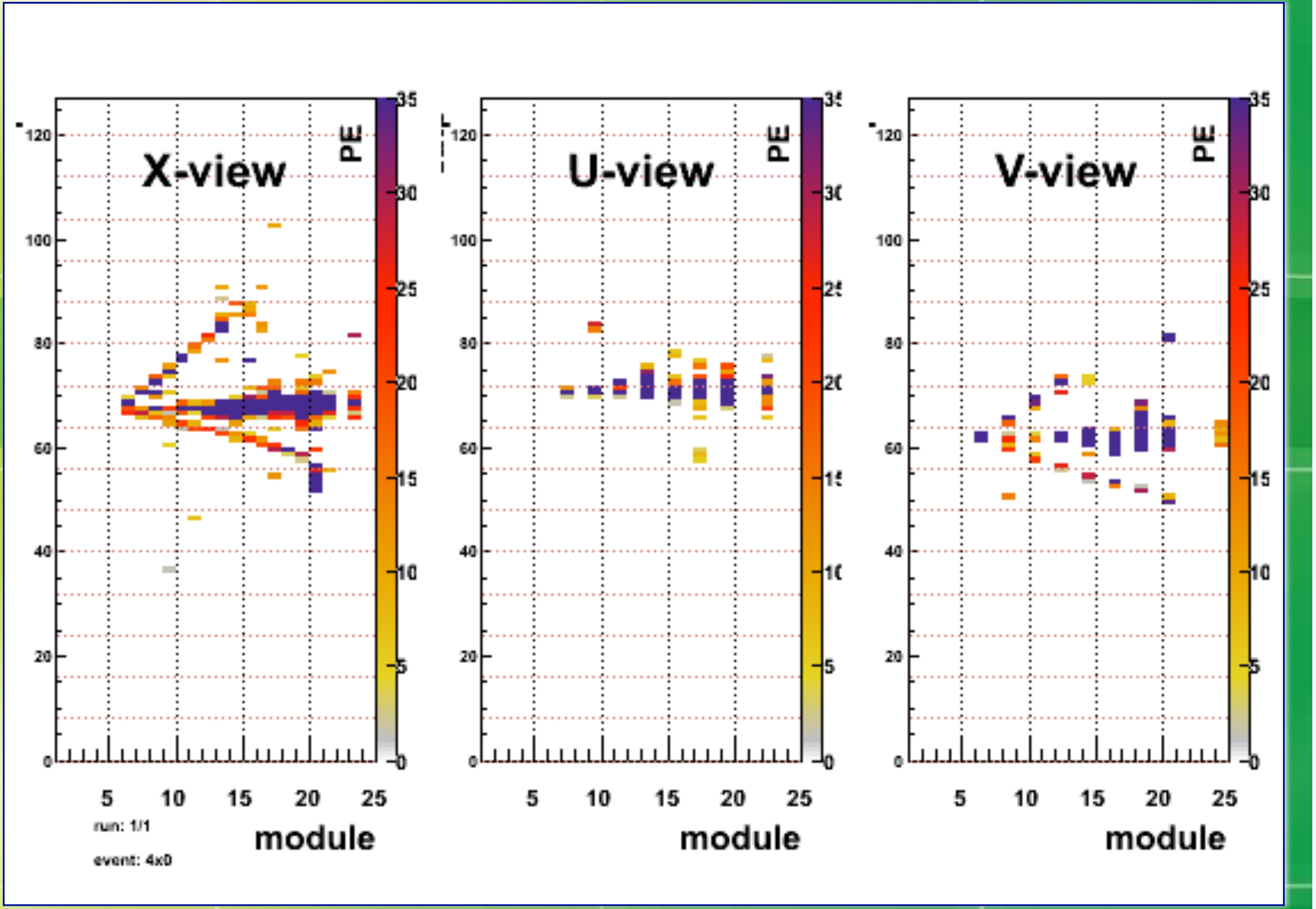
Muon track

Px: -0.650 GeV/c
Py: 0.290 GeV/c
Pz: 3.318 GeV/c
E: 3.395 GeV

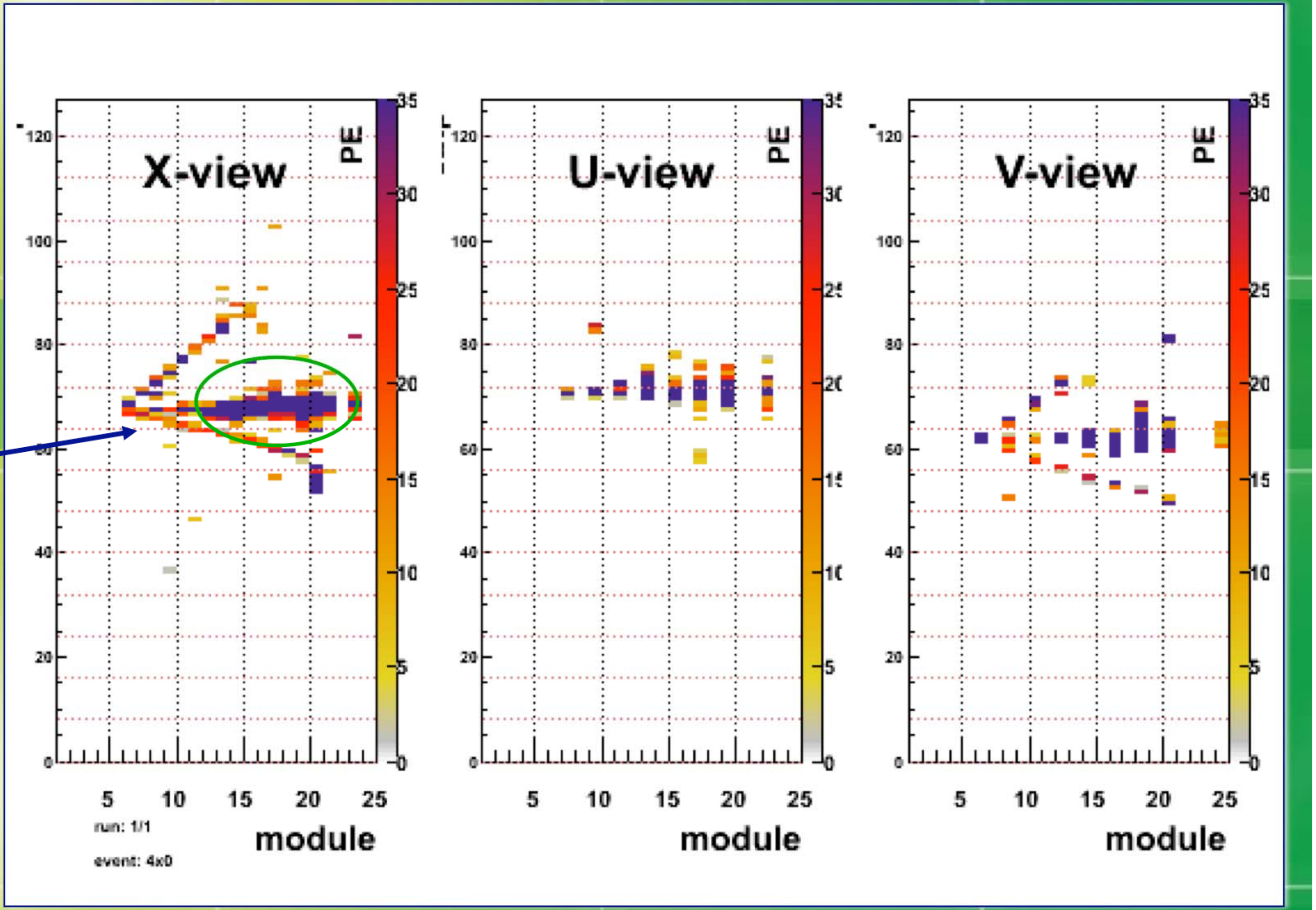


Charged Current νe





Charged Current νe



Electron shower

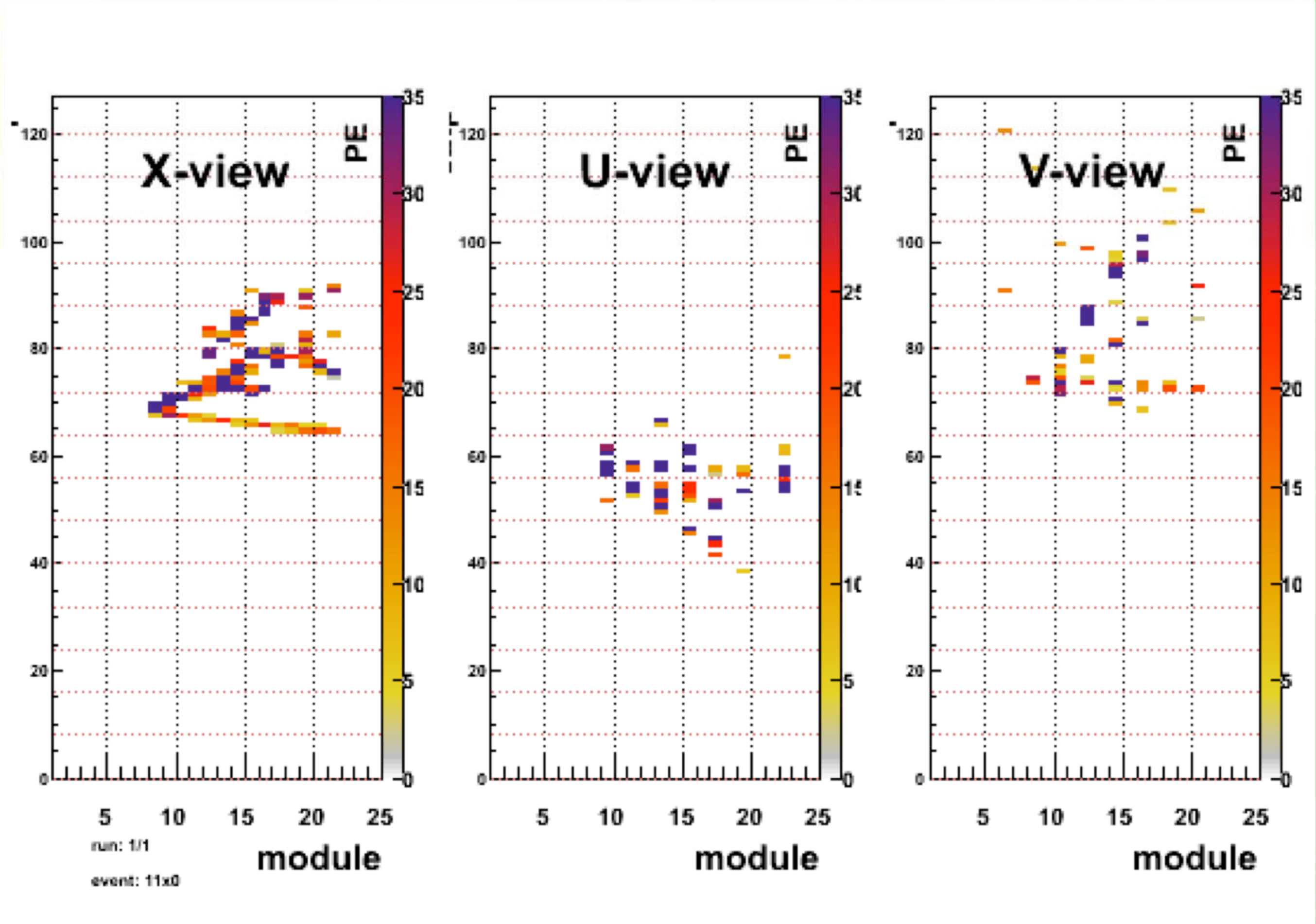
Px: 0.273 GeV/c
Py: -0.044 GeV/c
Pz: 9.171 GeV/c
E: 9.175 GeV

Neutral Current

νe

E (incoming): 20.772

E(outgoing): 17.039



Expected Results

- Want to make truth tables and plots to find trends in the data
- Interesting plots to make will include:
    - Efficiency vs. energy
    - Efficiency vs. channel

		CALLED		
		CC $\nu\mu$	CC νe	NC
TRUE CLASS	CC $\nu\mu$	62	4	2
	CC νe	24	89	6
	NC	22	6	35

Truth table from a training scan

Future Work

- MINERνA collaboration is currently working to get a general scan together of the TP data (~20K events)
- Can compare results of my scan of the MC data with the results of the general scan

Thanks

- Research supported by the Tufts Summer Scholars Program and the Department of Energy
- And thanks to NEPPSR