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# Status of the MINOS experiment

## *Next Generation of Nucleon Decay and Neutrino Detectors 8/04/2005*

Mary Bishai (MINOS collaboration)

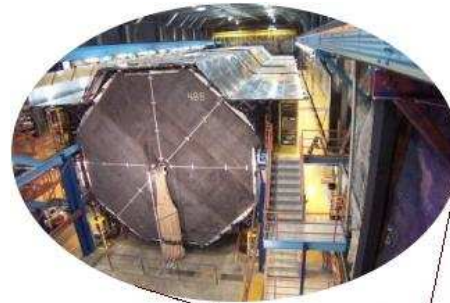
`mbishai@bnl.gov`



# Outline

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- Introduction to MINOS
- Physics sensitivities
- Status of MINOS:
  - MINOS Far Detector (FD)
  - Calibration Detector
  - NuMI beamline  
commisioning
  - MINOS Near Detector (ND)



**First beam neutrino events in FD & ND**

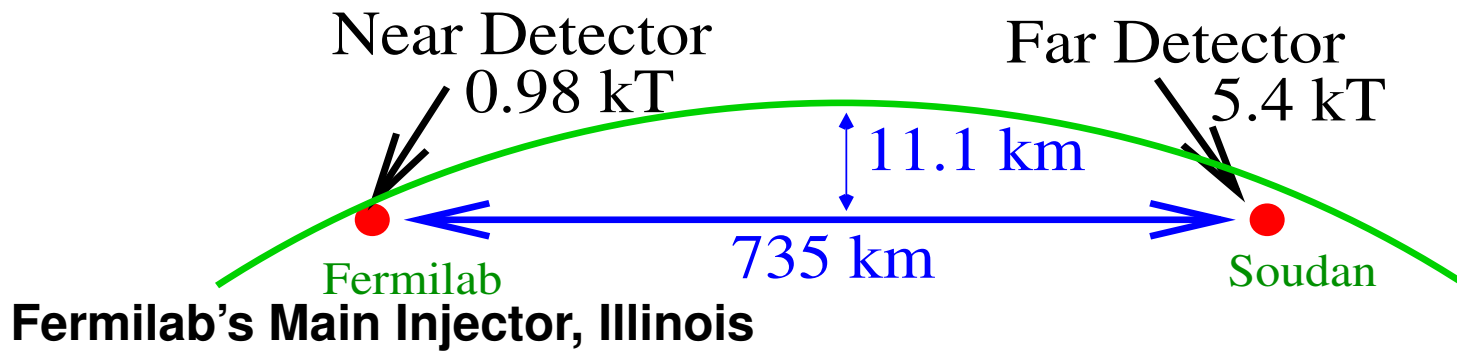


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## INTRODUCTION TO NuMI/MINOS



# NuMI/MINOS Concept



Soudan Underground Lab, Minnesota

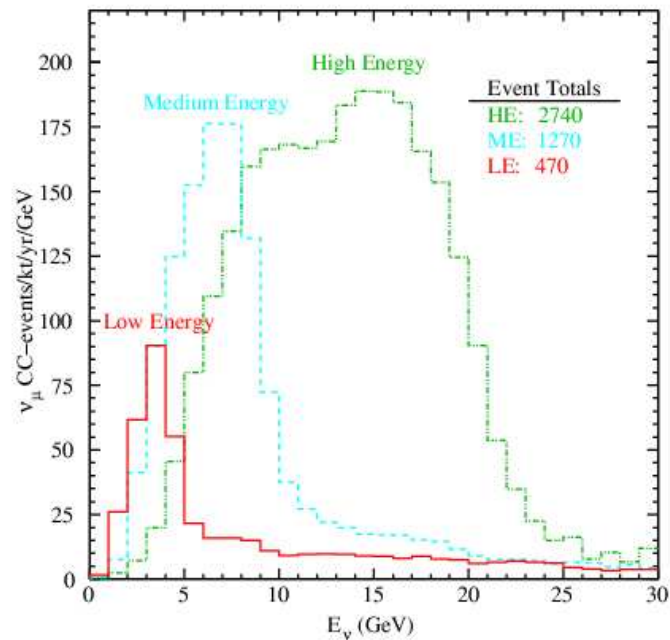
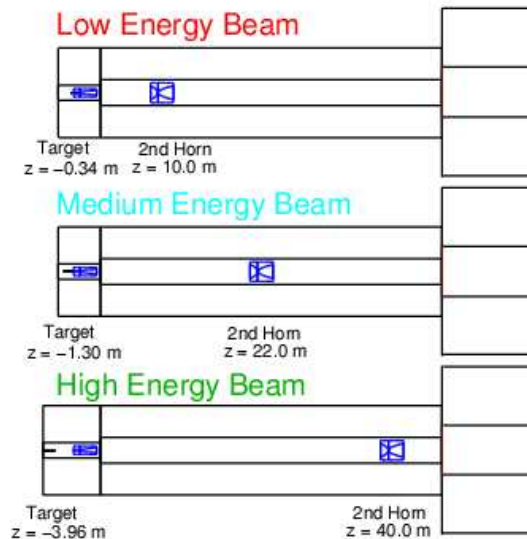
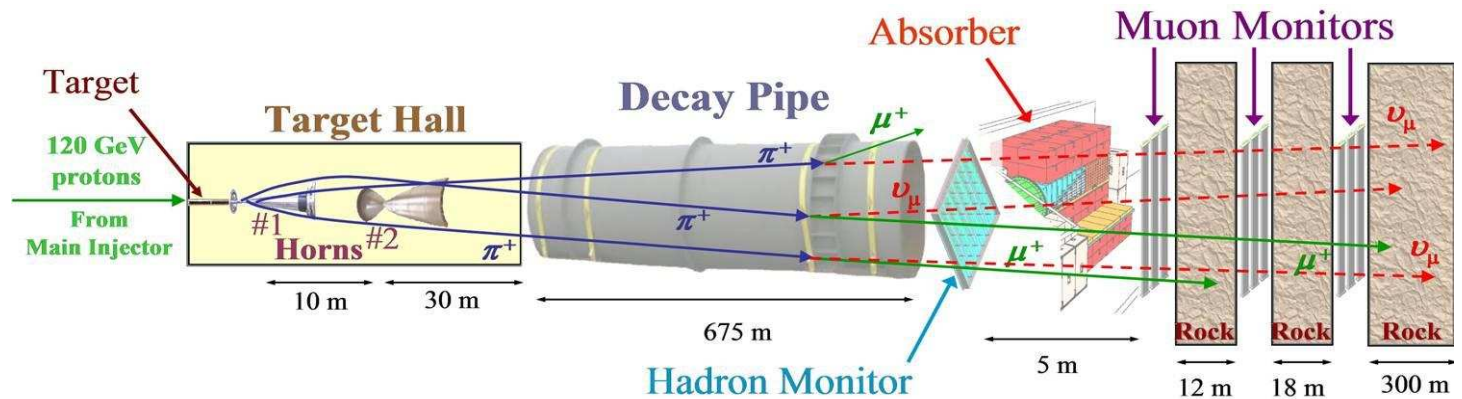


120 GeV protons,  $2.5 \times 10^{13}$  protons/  
 $8 \mu\text{sec}$  pulse, 1.9 sec rep rate.

⇒ 0.25 MW



# MINOS Beam Spectrum

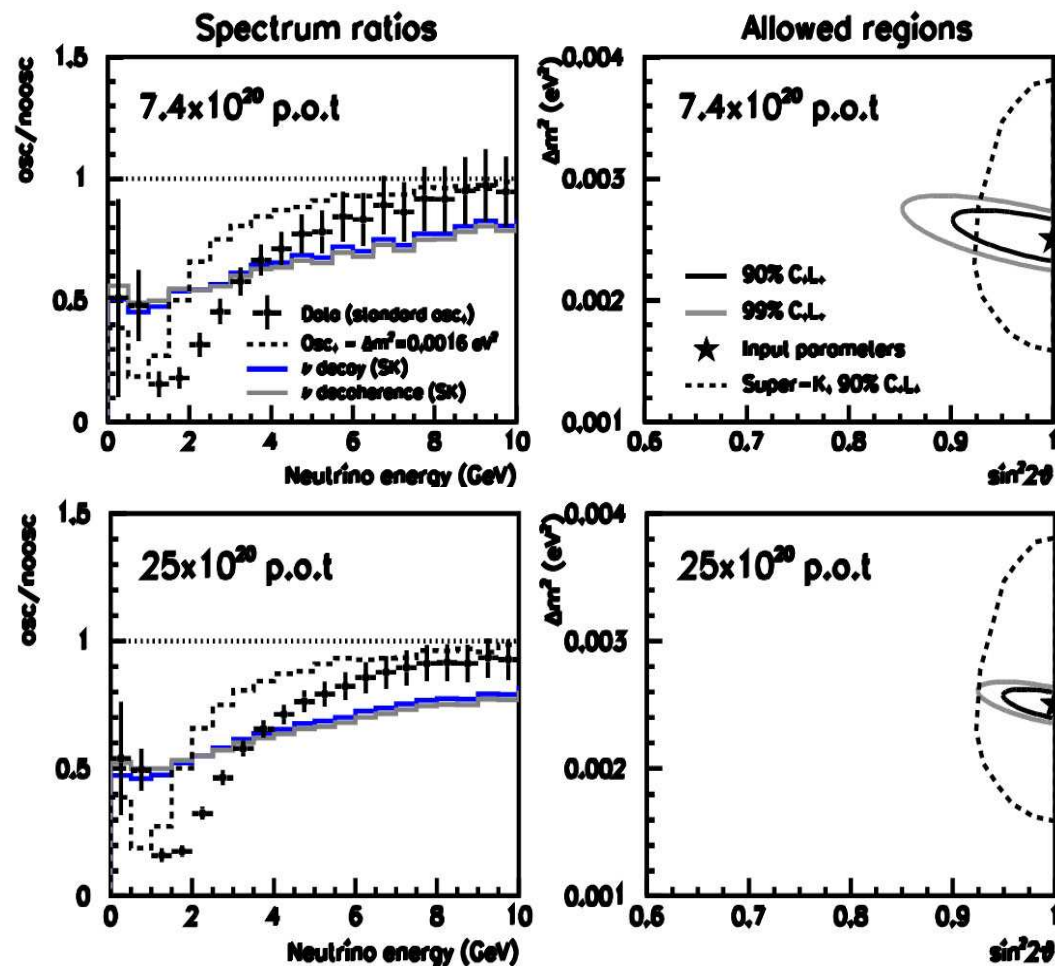


LE beam at  $2.5 \times 10^{20}$  POT/yr  $\Rightarrow$  expect 1600 events/yr in FD



# MINOS $\nu_\mu$ Disappearance

- Plot ratio of yield at far det. to expected from near det.
- Location and depth of dip yield  $\delta m^2$  and  $\sin^2 2\theta$
- Assume  $\delta m^2 = 0.0025 \text{ eV}^2$ ,  $\sin^2 2\theta = 1.0$



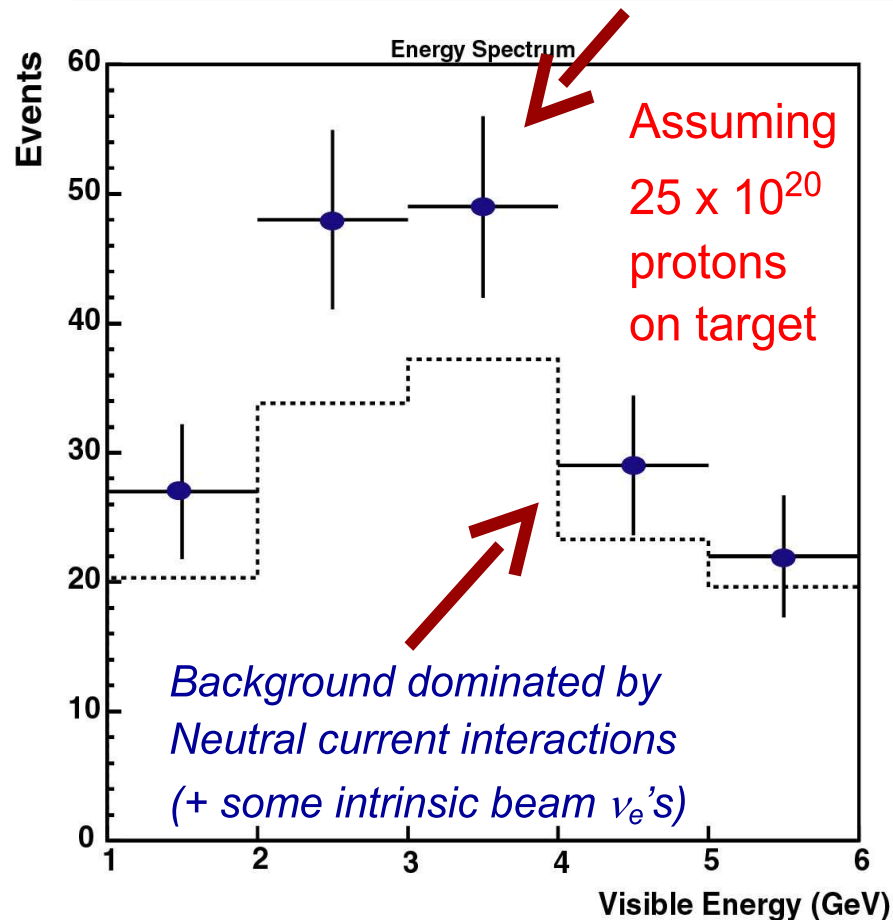
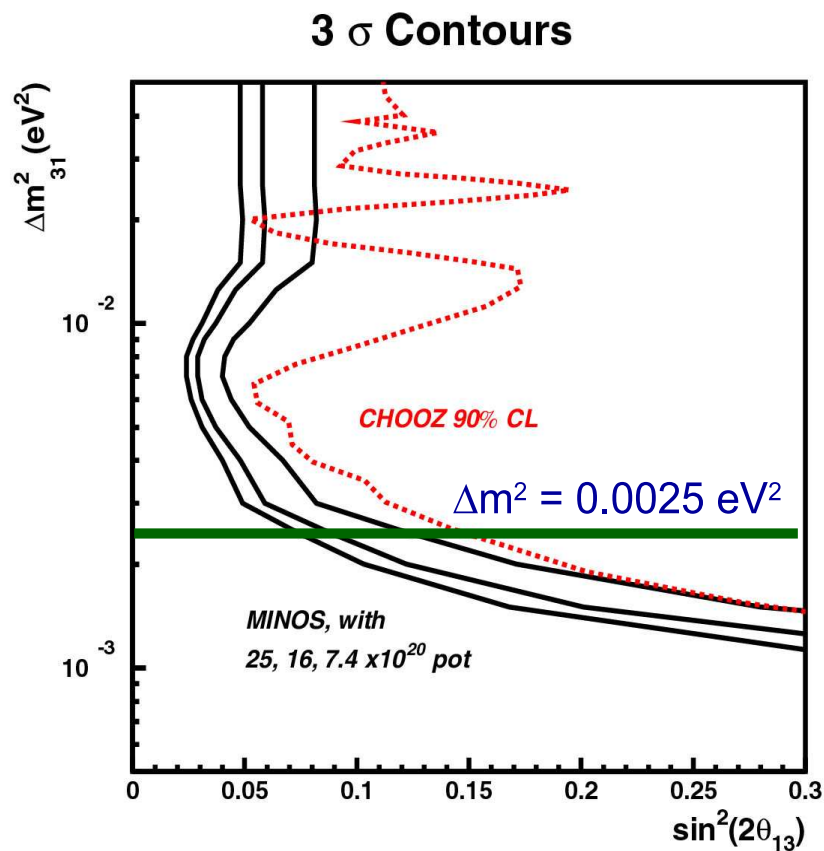
3 years at nominal intensity (top). Intensity upgrades (bottom)

Determine  $\delta m^2$  to 10 % Rule out exotic oscillation models



# MINOS $\nu_e$ Appearance Sensitivity

For  $\Delta m^2 = 0.0025 \text{ eV}^2$ ,  $\sin^2 2\theta_{13} = 0.067$



Detection of  $\nu_e$  at  $\Delta m^2_{atm}$ . Evidence for non-zero  $\theta_{13}$



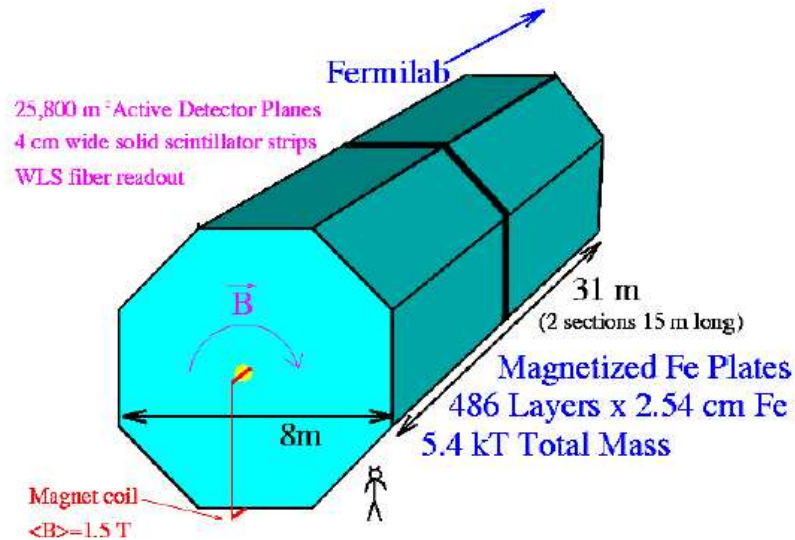
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# THE FAR DETECTOR

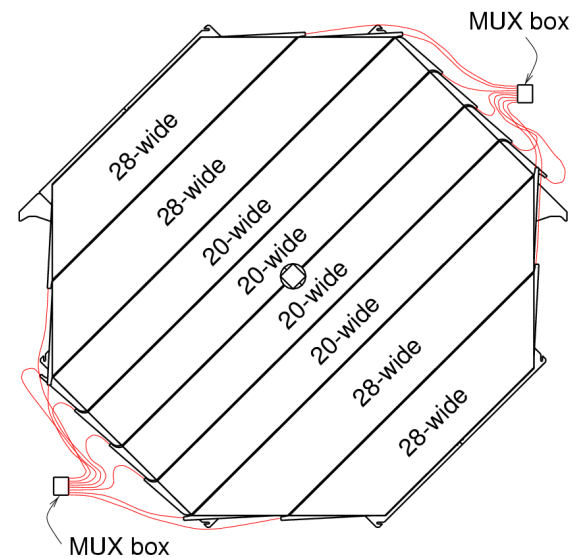




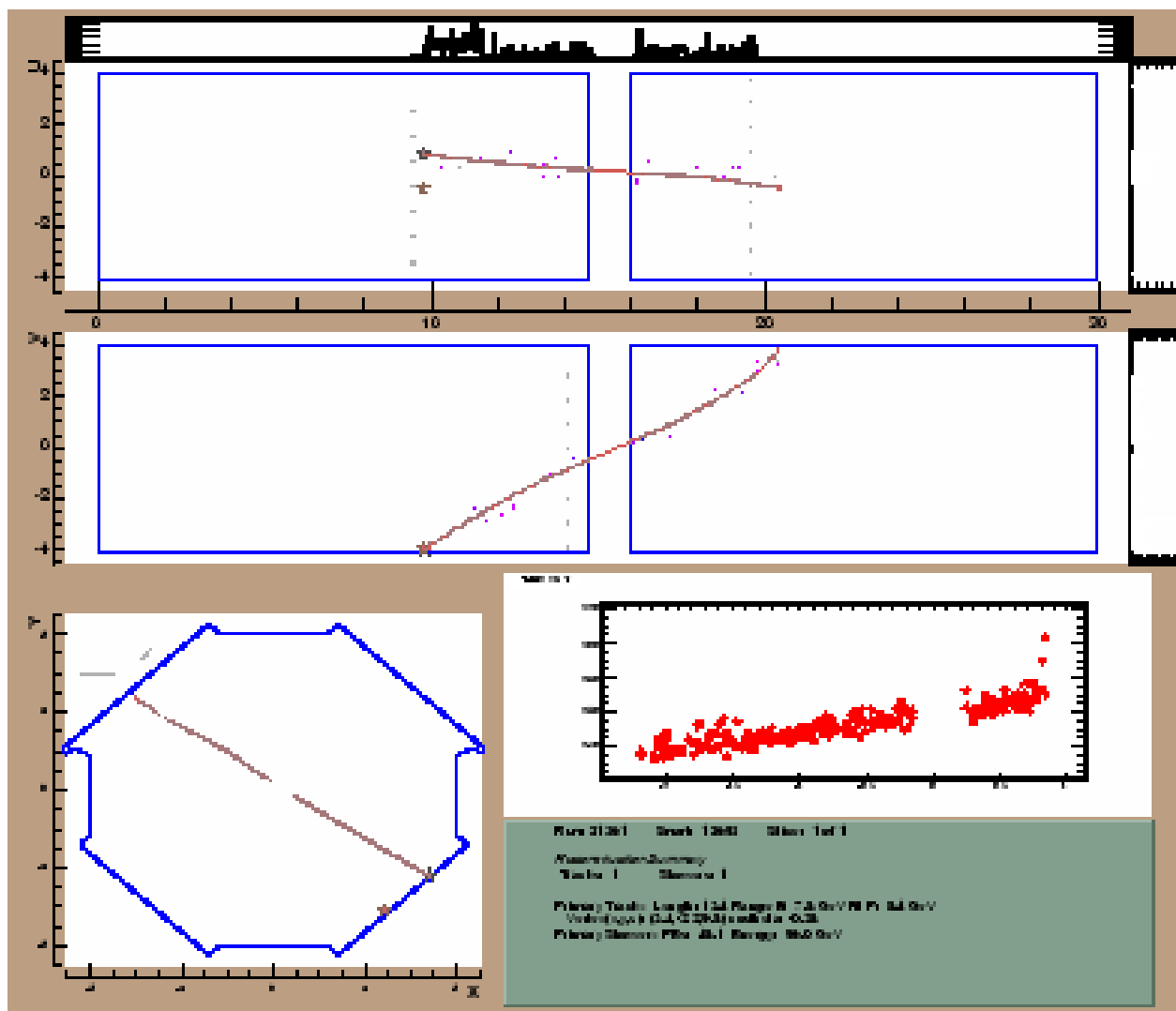
# The Far Detector



- **8m × 2.54 cm thick Fe plates**
- **4.1w × 1d × 800l cm**  
**scintillator strips with WLS fiber readout. 486 layers ⇒ 5.4kTon**
- **Toroidal  $B$ -field, 1.3 T at  $r = 2m$**
- **Cosmic  $\mu$  veto shield**



# Upward going muons in the FD



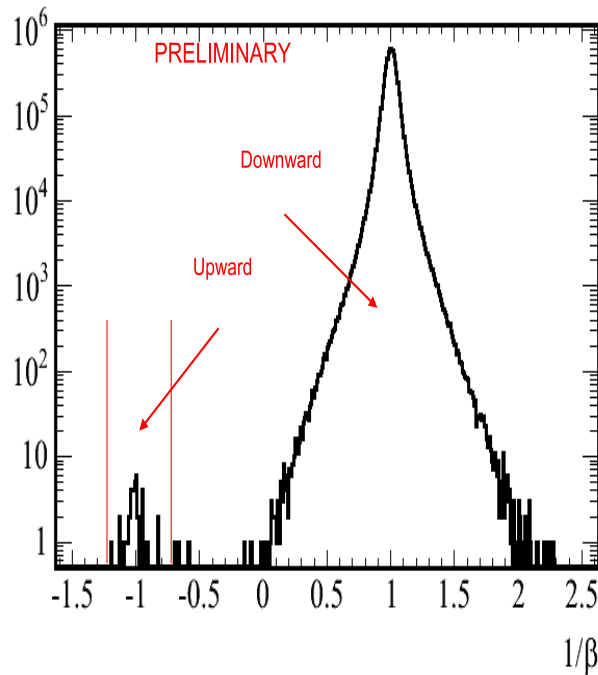
2.4 ns single hit timing resolution



# FD Cosmic Ray Physics

Based on  $\sim 1$ yr of data:

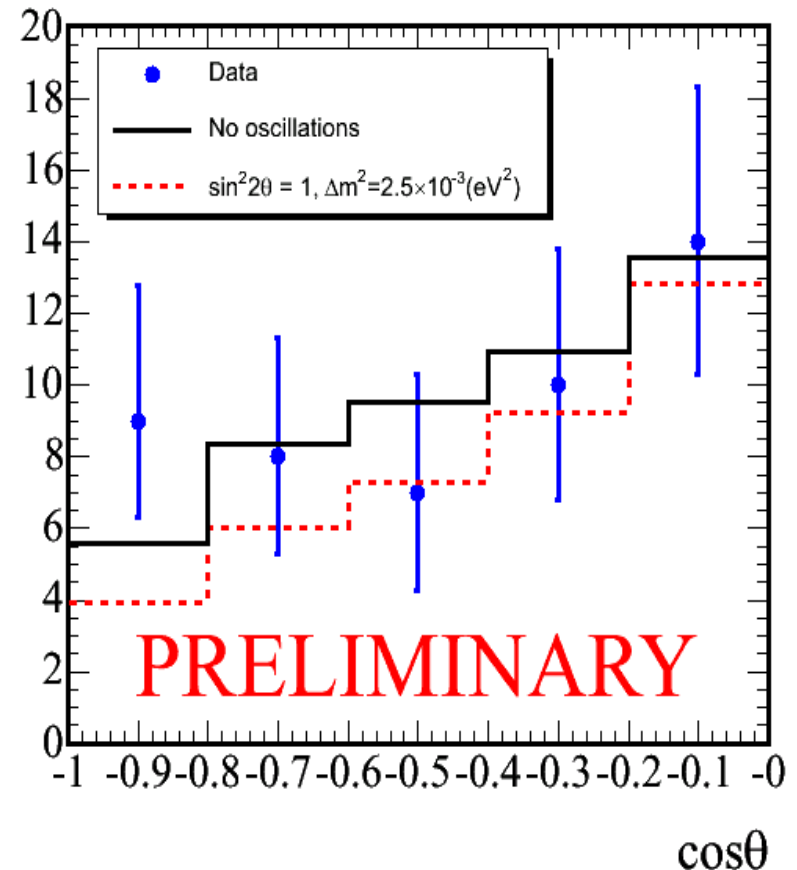
*Upward going muons -  $1/\beta$  plot*



$$1/\beta = c\delta t/\delta s$$

MC: Nuance w/Bartol '96 flux.

No-osc normalized to data.

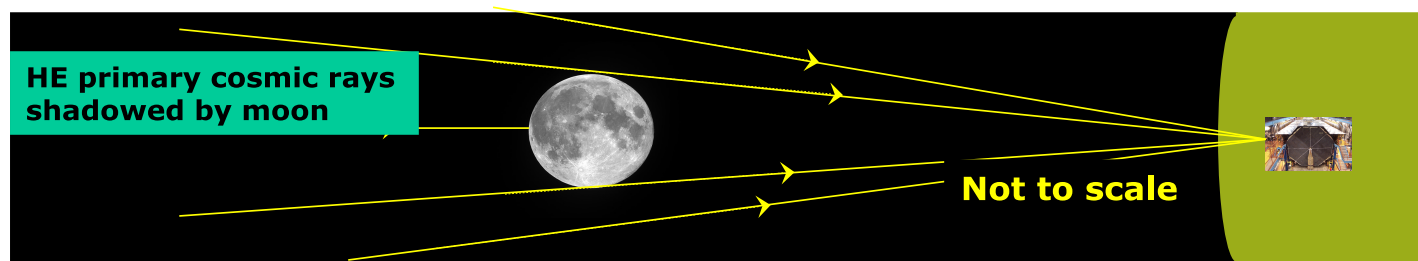


Zenith angle distribution.

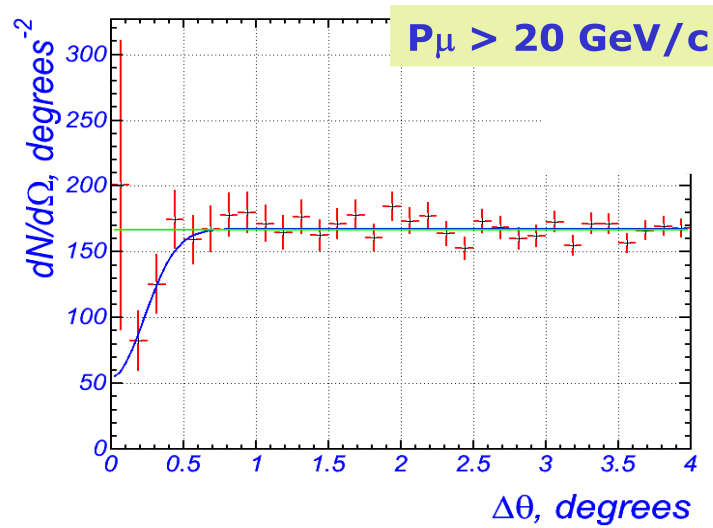
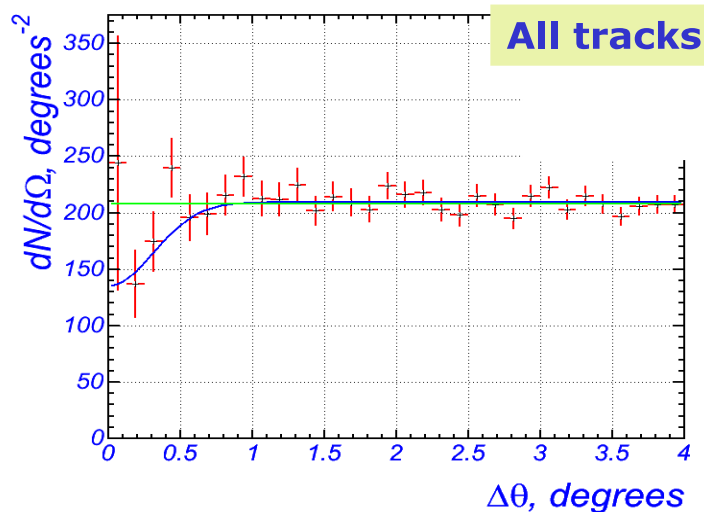


# Far Detector: Moon's Shadow

*Seeing the moon underground*



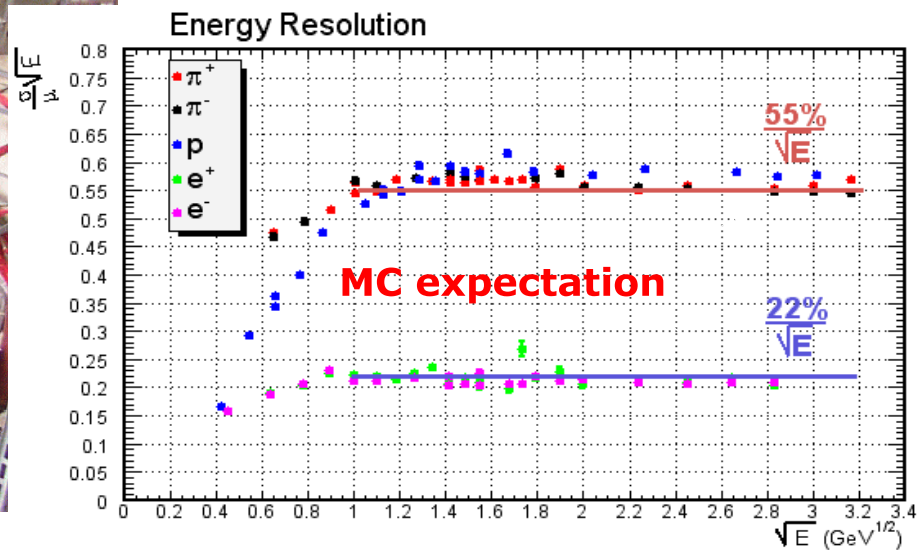
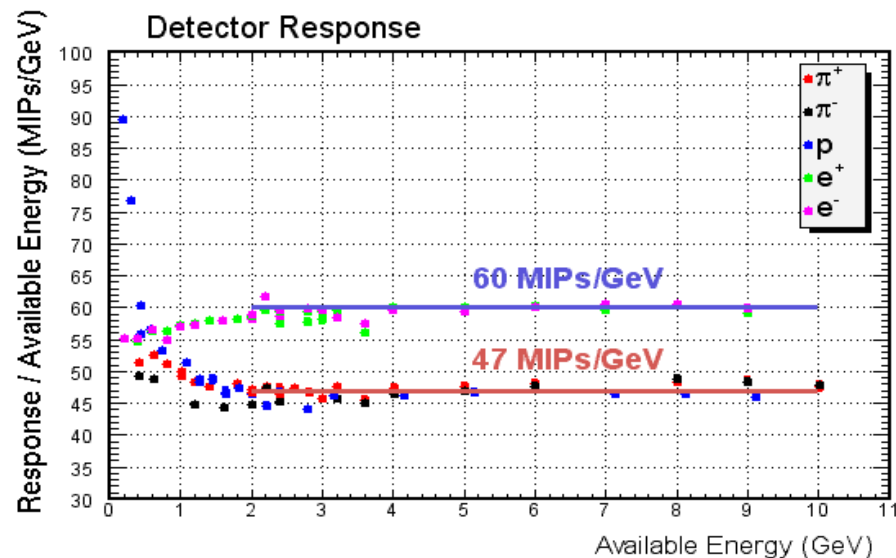
- ★ Have recorded 10 M cosmic muons  
observed shadow of moon
- ★ Angular res. improved by selecting high momenta muons



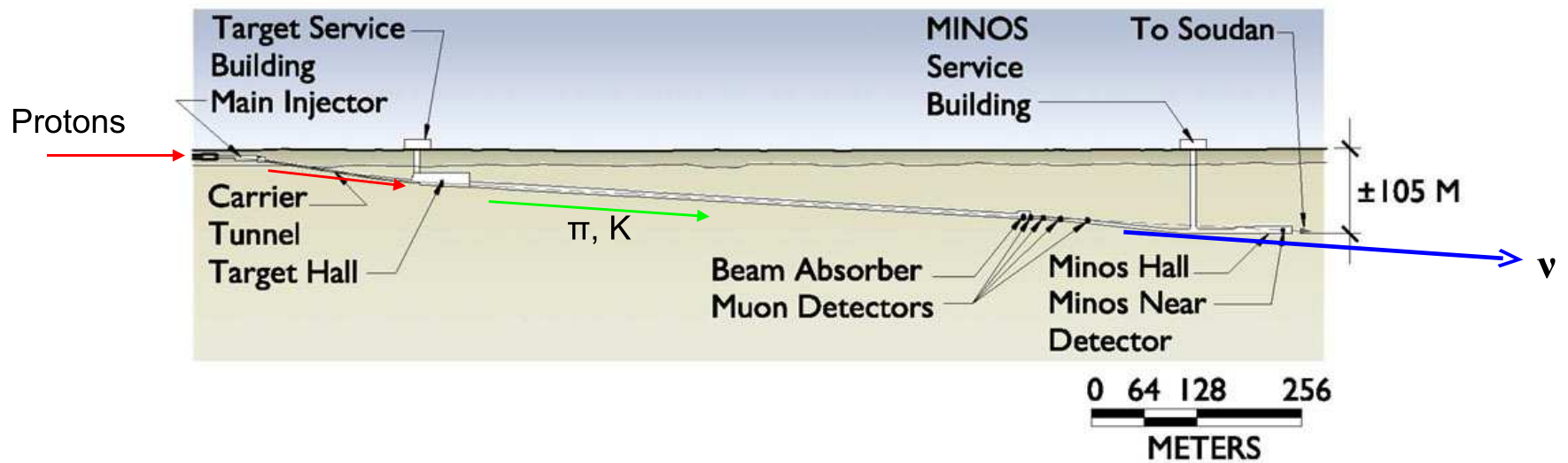
# The Calibration Detector

60-plane 'micro - MINOS'

-- has taken data at T7 & T11  
test beam lines at CERN  
during 2001, 2002, 2003



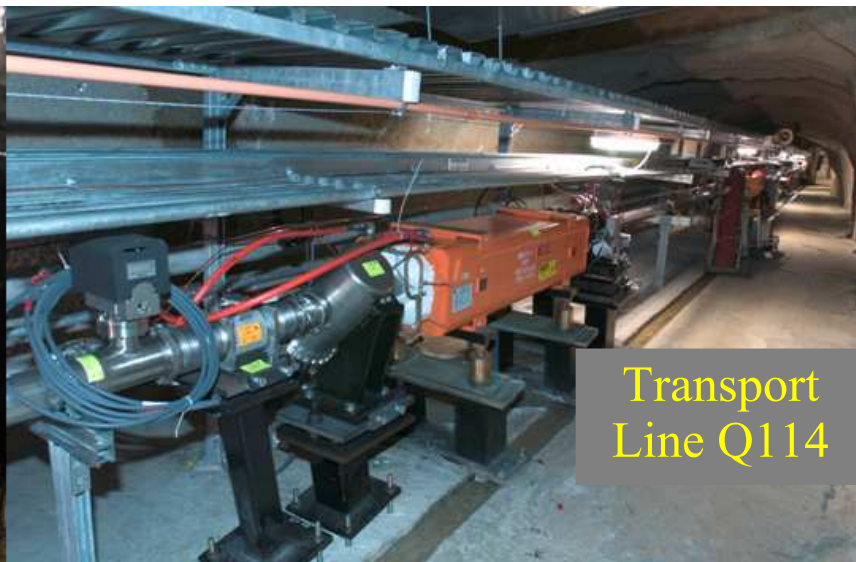
# COMMISSIONING THE NuMI BEAMLINE



# NuMI Primary Beamline



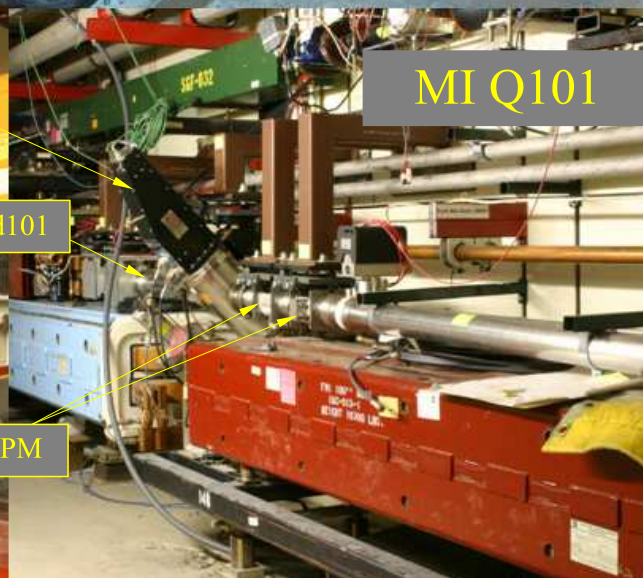
Transport  
Line Q115



Transport  
Line Q114



MI Q105



MI Q101

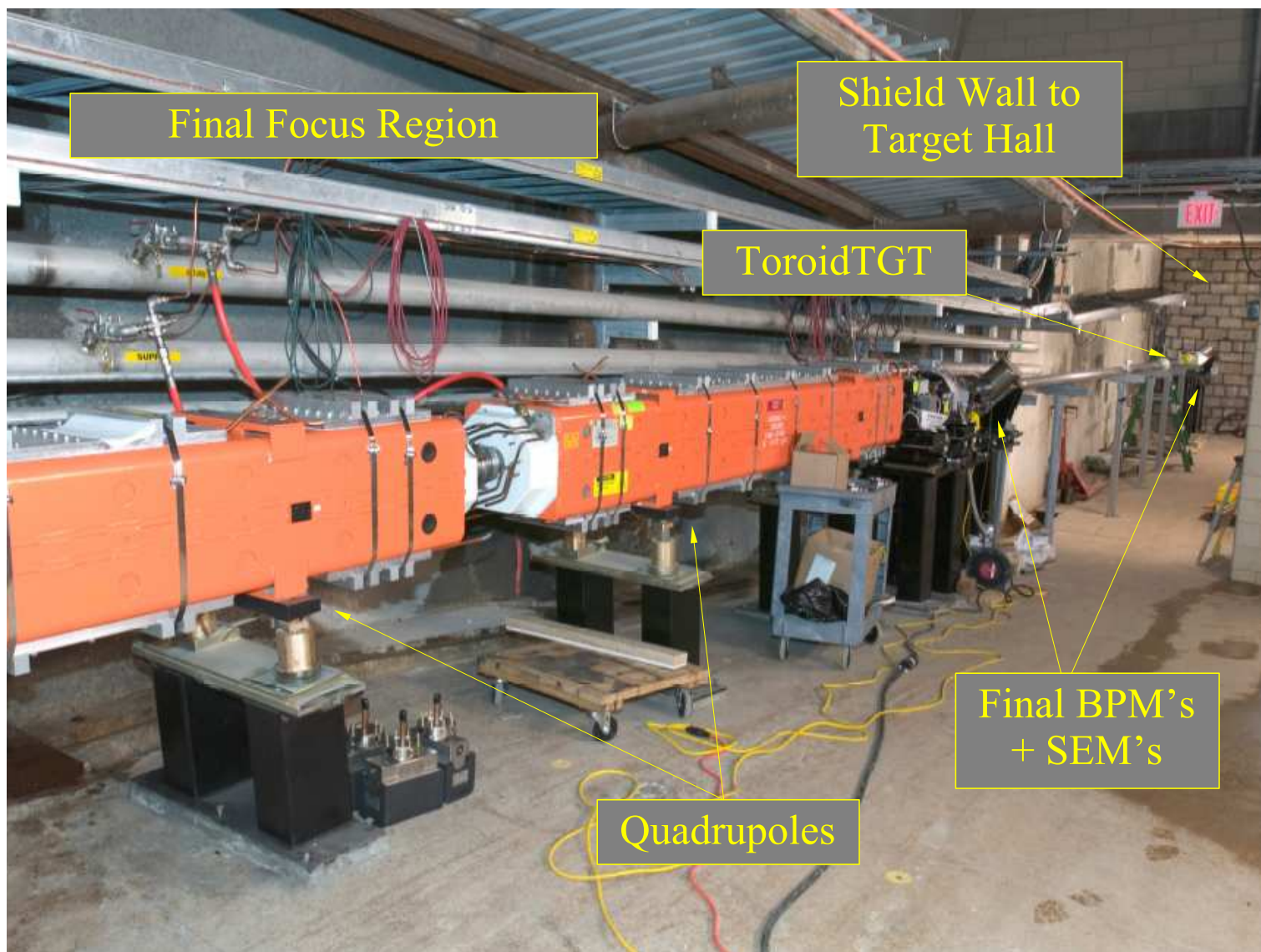
SEM

Toroid101

BPM



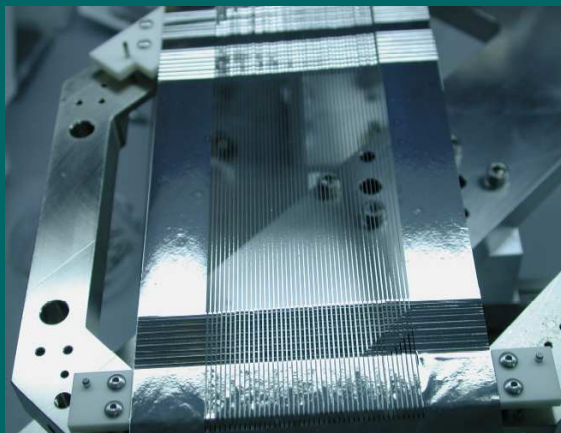
# NuMI Pretarget





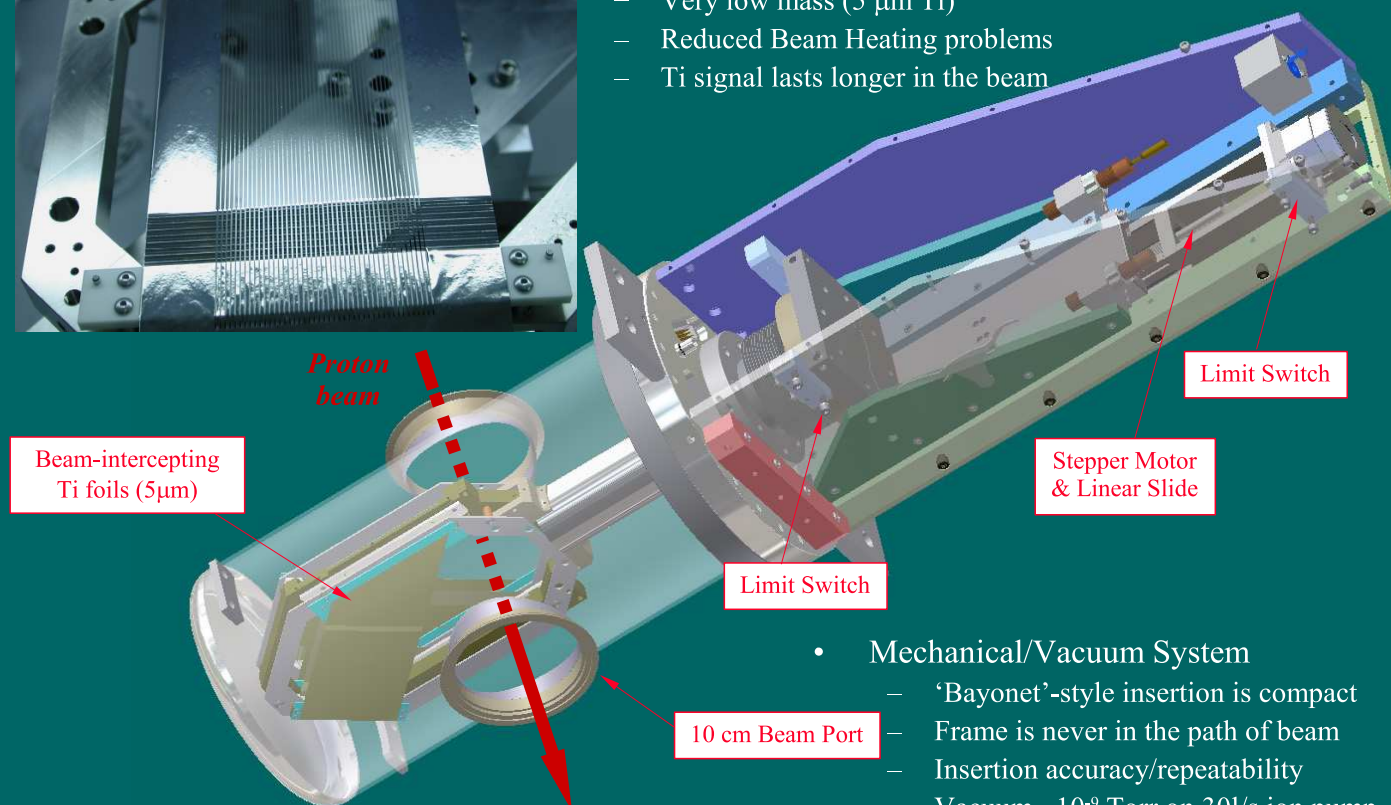
# Measuring the Beam Profile

## Segmented Foil SEM's



### Foil Secondary Emission Monitors

- Beam profile + halo measurement
- Very low mass (5  $\mu\text{m}$  Ti)
- Reduced Beam Heating problems
- Ti signal lasts longer in the beam



- Mechanical/Vacuum System
  - 'Bayonet'-style insertion is compact
  - Frame is never in the path of beam
  - Insertion accuracy/repeatability
  - Vacuum  $\sim 10^{-9}$  Torr on 30l/s ion pump

[www.hep.utexas.edu/~kopp/minos/sem/](http://www.hep.utexas.edu/~kopp/minos/sem/)



# Measuring the Beam Position

## Characteristics of NuMI Beam Position Monitors:

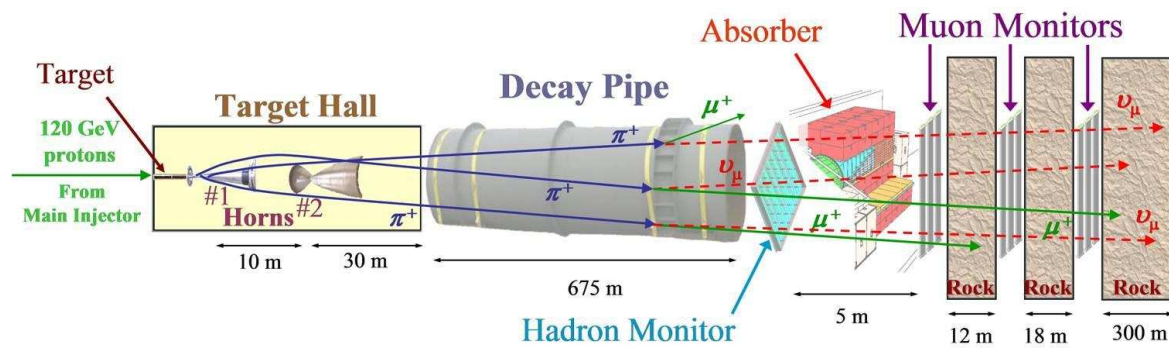
- Software algorithm to search 400  $\mu$ sec to find the beam.
- NuMI bunches come in 6 batches from booster. Position is measured batch by batch.
- Linear over 15-20 mm. 50  $\mu$ m resolution.



**BPMs used to auto-steer the beam to target center**

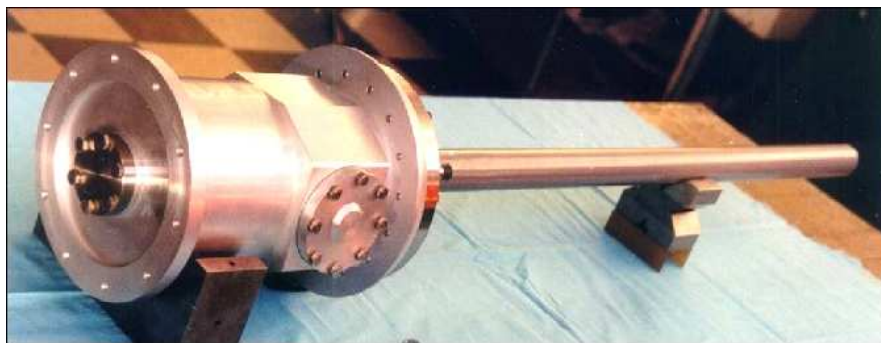


# Target Region Components



Horn 1

Target Enclosure



6.4 x 28 mm<sup>2</sup> graphite segments. 1m long = 1.9 interaction lengths.  $\mathcal{O}(10)$  KW beam power at 1 mm beam width.

Water cooled.

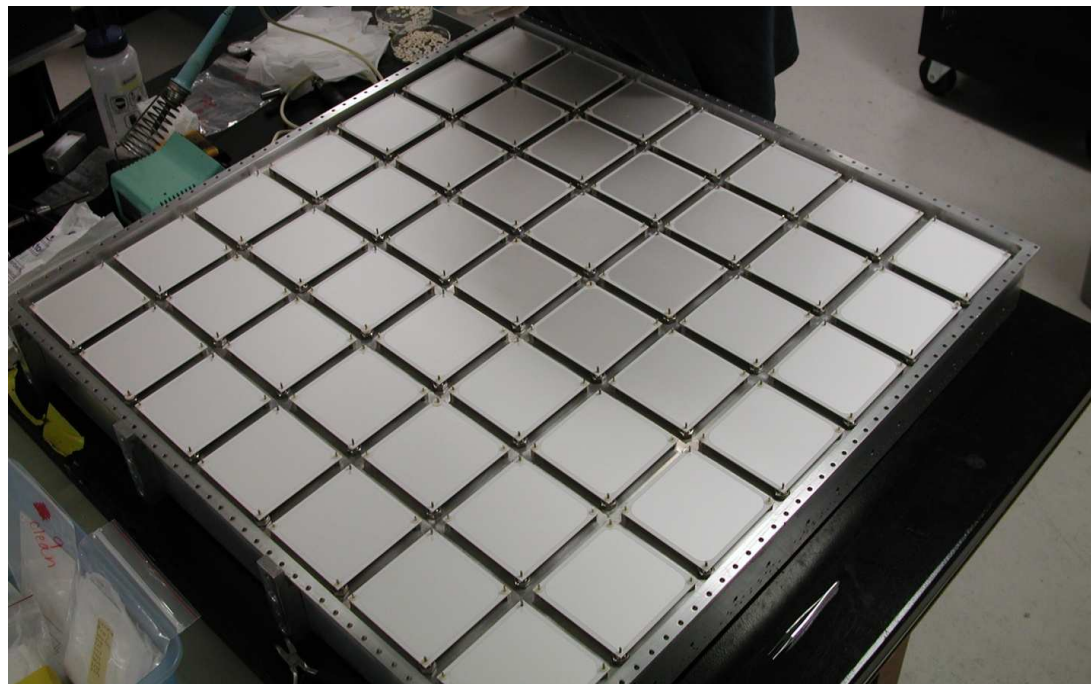
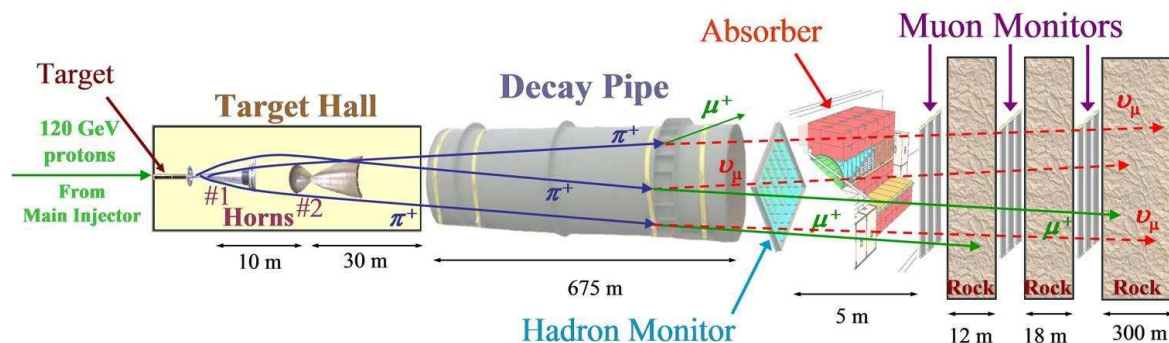


Parabolic magnetic lens.

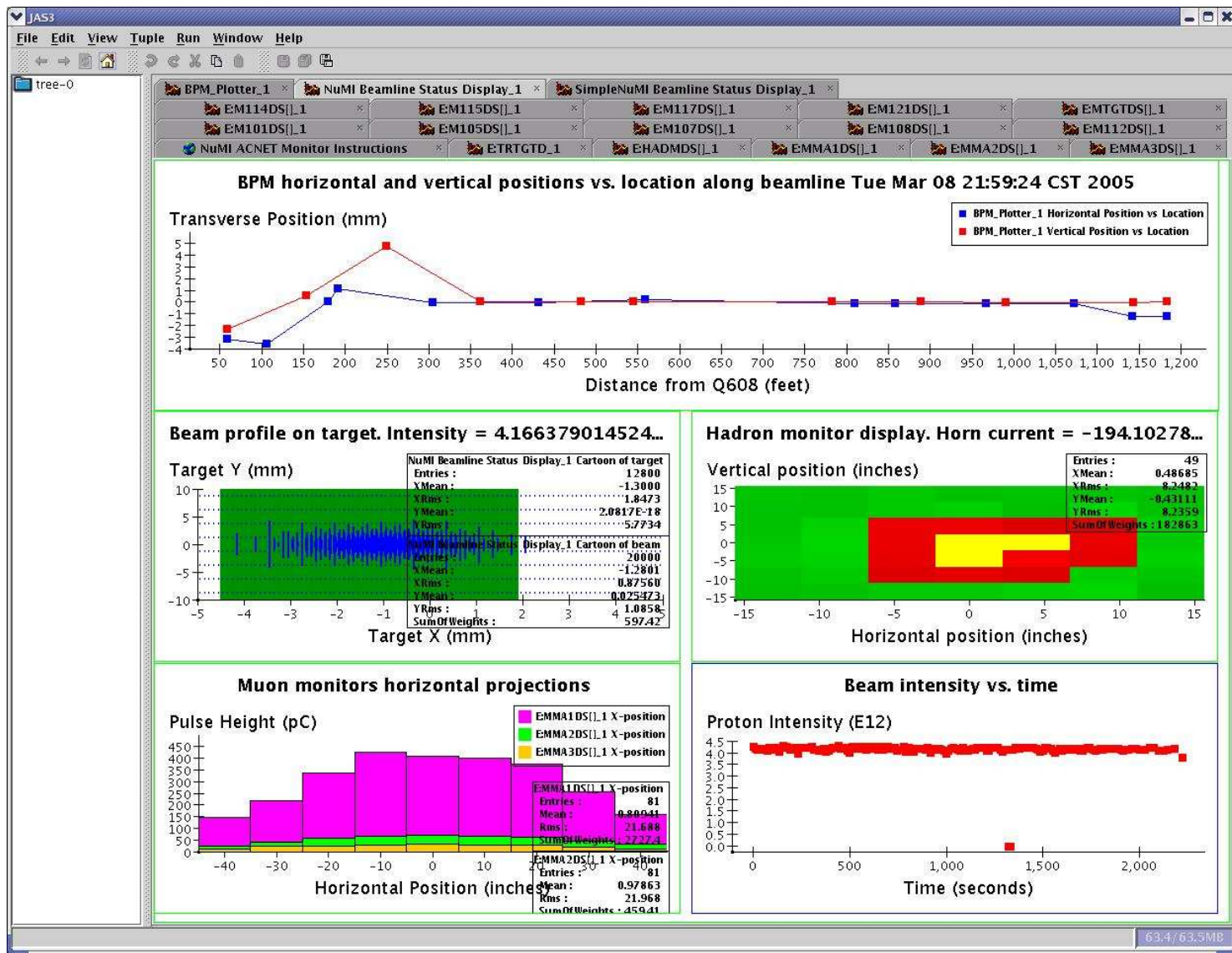


# Muon and Hadron monitors

Parallel-plate ionization chambers are used to monitor hadron and muon content of secondary beam.

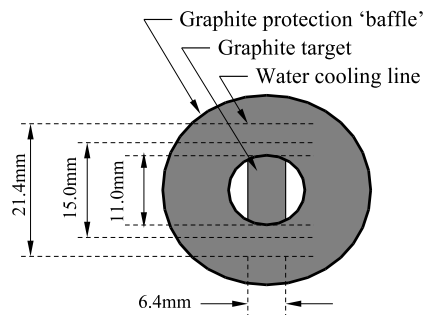


# Online Beam Status

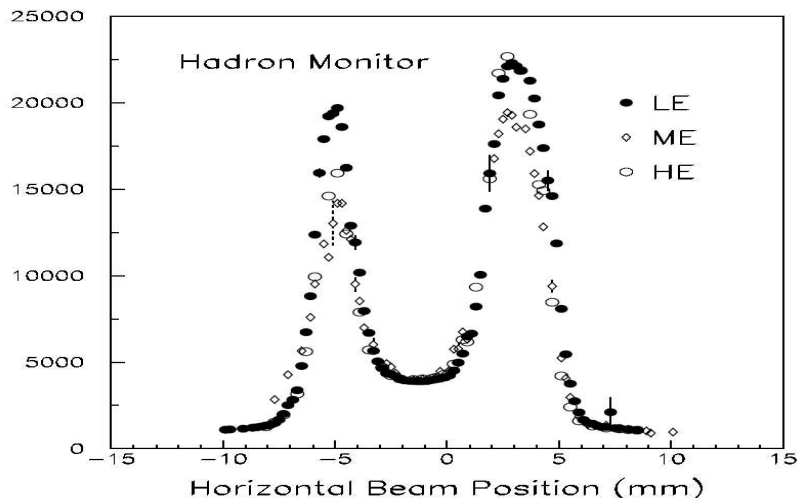


# Target position scan

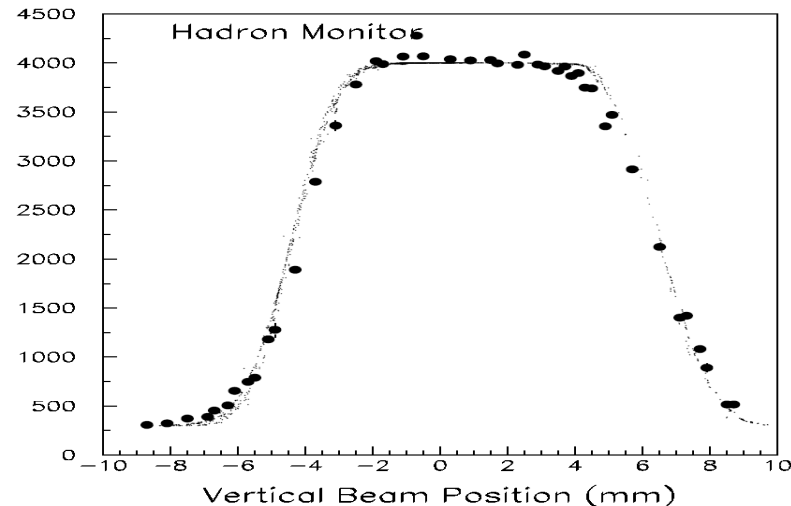
- Use low intensity beam and scan across target



- Maximum P.H. when beam passes between target and graphite protection baffle.



Horizontal scan (cm)

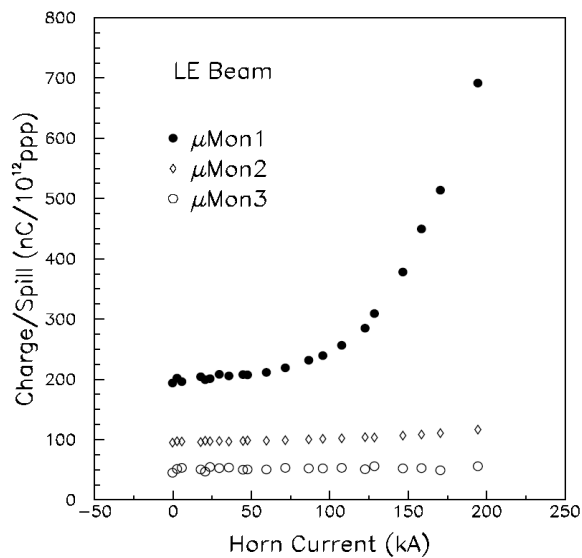


Vertical scan (mm)

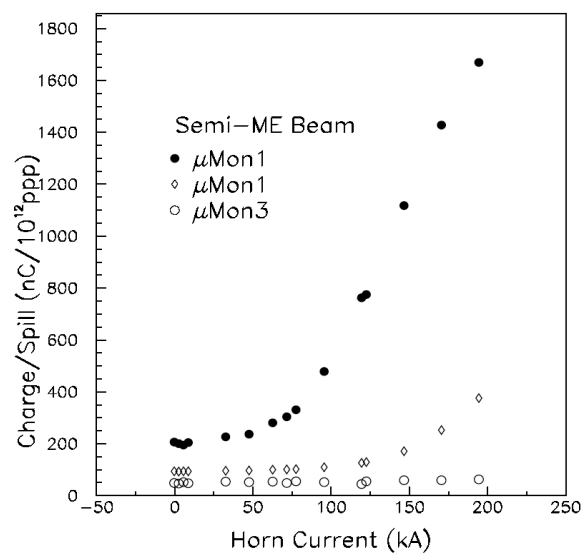


# Horn current scan

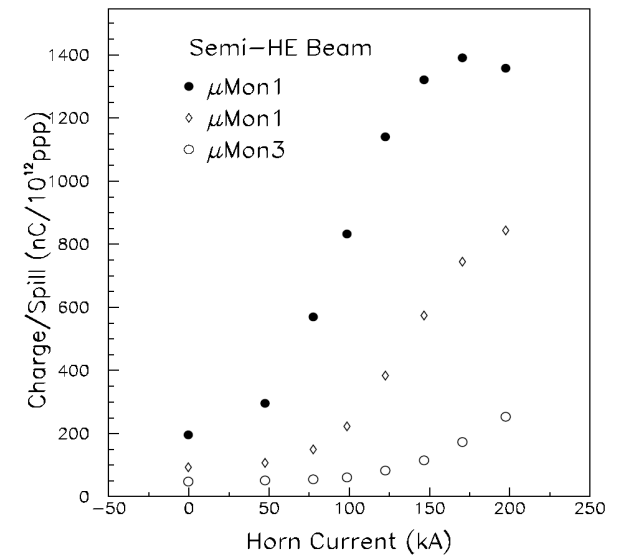
- As horn current changes we focus different  $\pi$  energies. **More current**  $\Rightarrow$  **more focusing**
- As target position changes we focus different energy  $\pi$ s. **Larger target/horn separation**  $\Rightarrow$  **higher  $\pi$  energy**



LE position



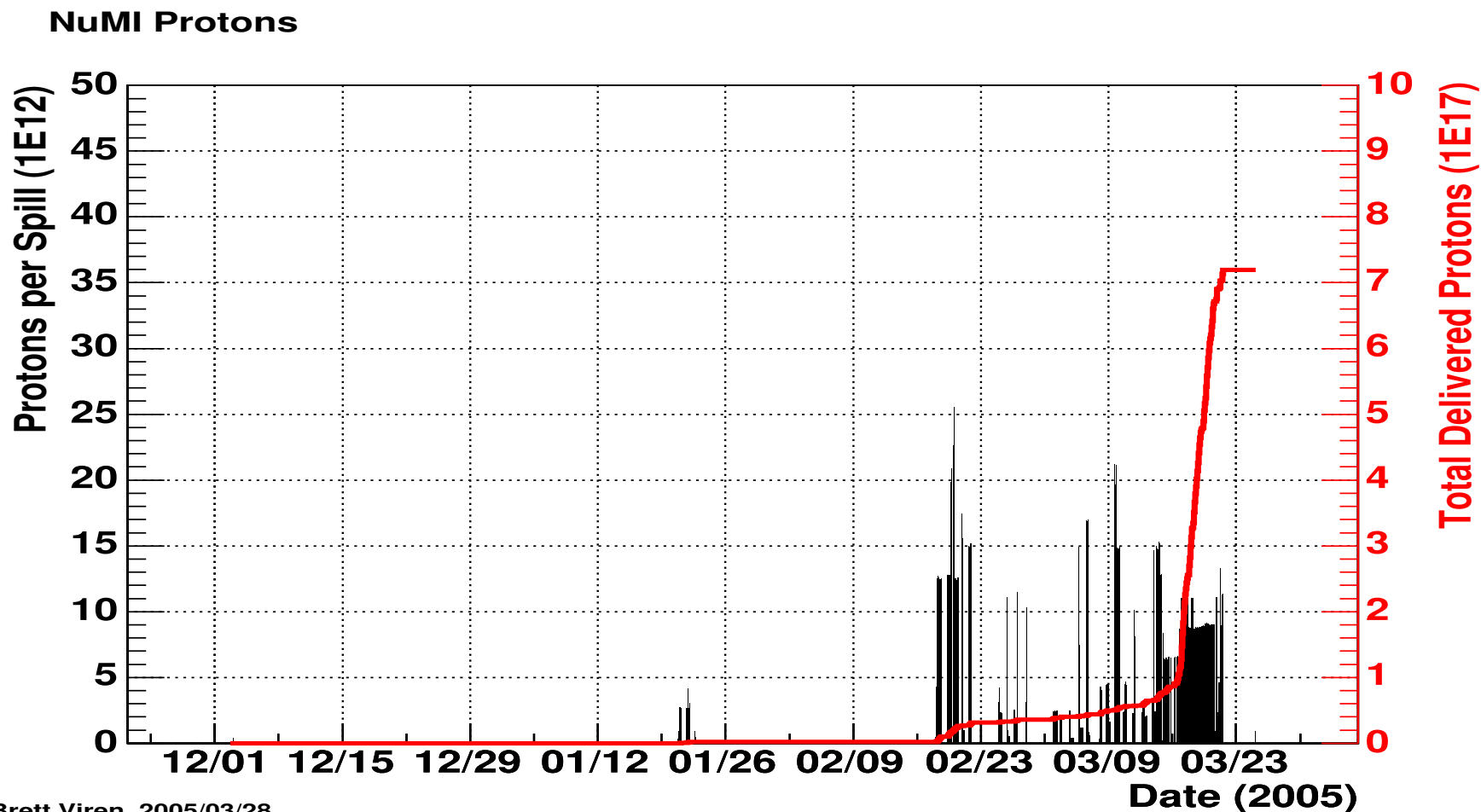
ME Position



HE Position



# NuMI Beamline Performance



Brett Viren, 2005/03/28

*Wed March 23: target vacuum compromised. Cooling water in target enclosure.*

*Incident under investigation.*



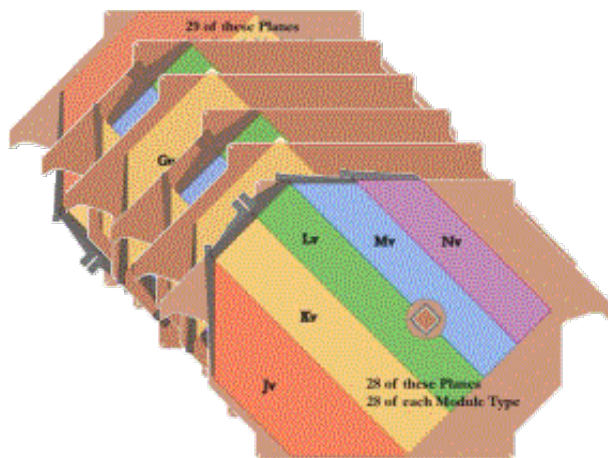


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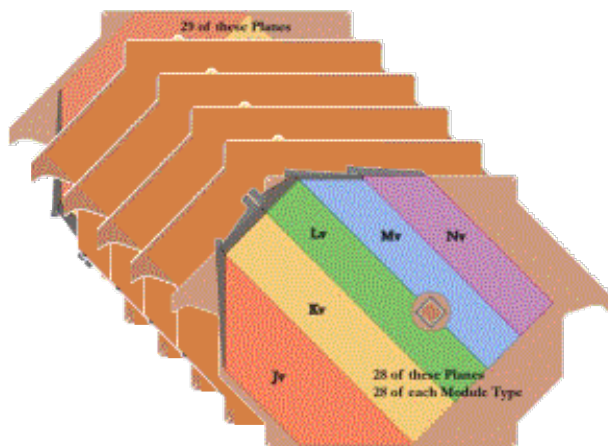
## THE NEAR DETECTOR



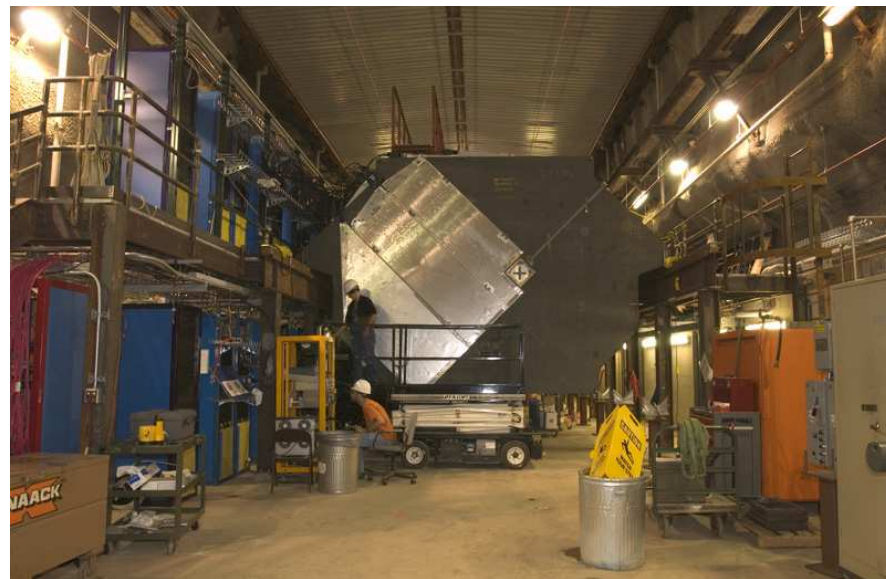
# The Near Detector



**Calorimeter region**



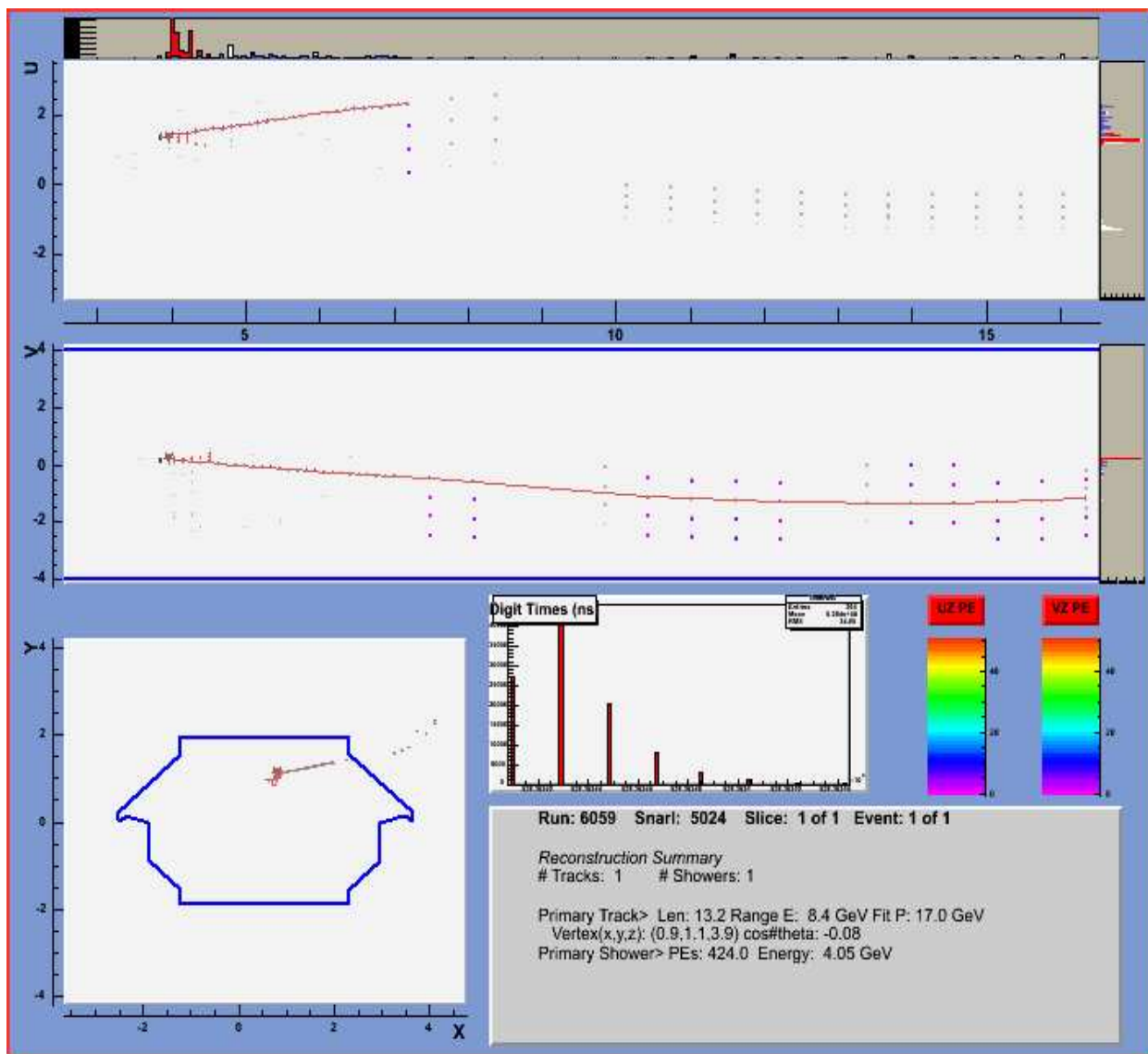
**Spectrometer region**



# ND 1st Beam Neutrino Jan 21, '05

Intensity was around  
 $2.5 \times 10^{12}$  pro-  
tons/spill.

Target in the ME posi-  
tion.



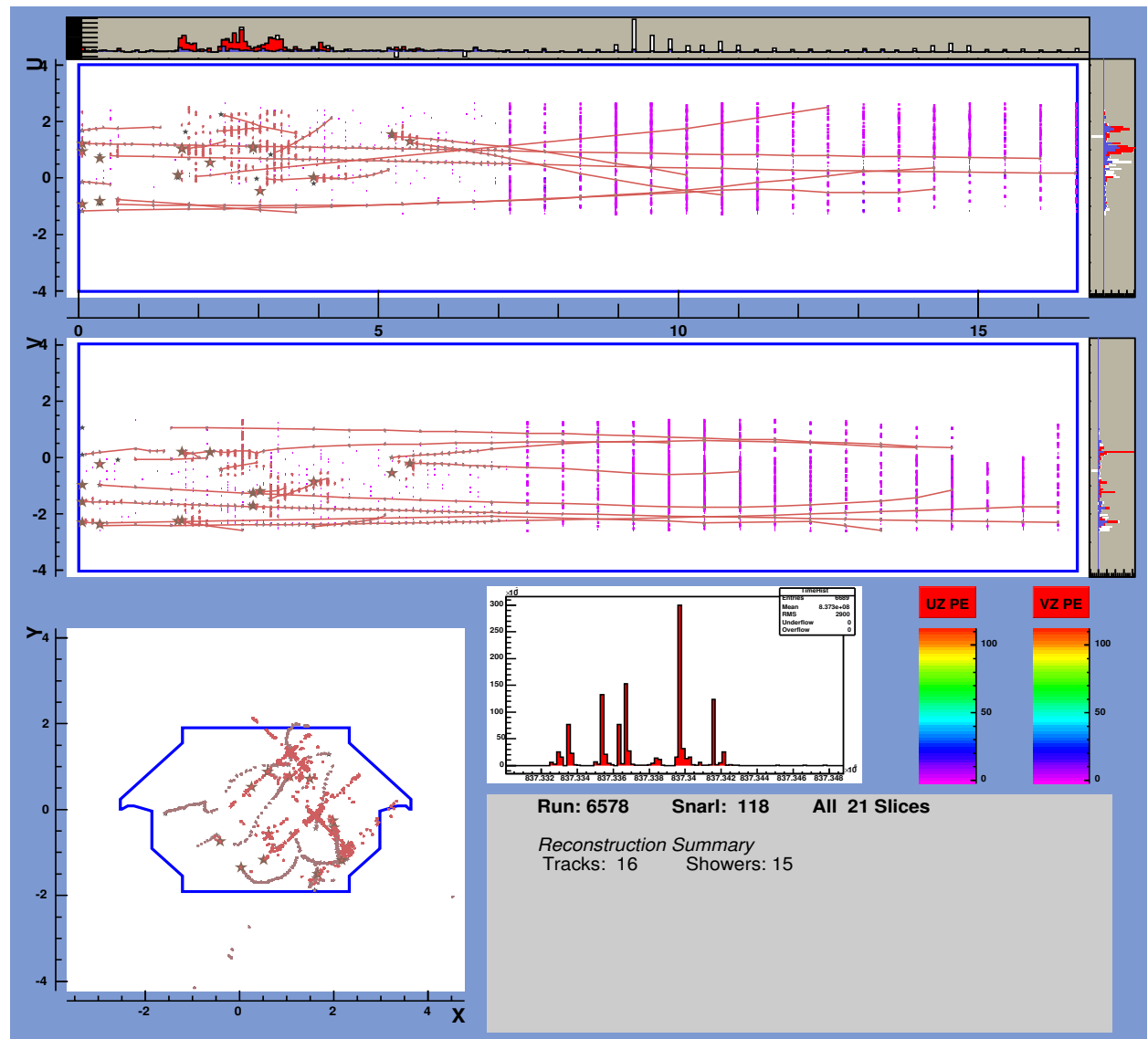
# ND Lots and Lots of $\nu$ s

At  $2.5 \times 10^{13}$  p/spill

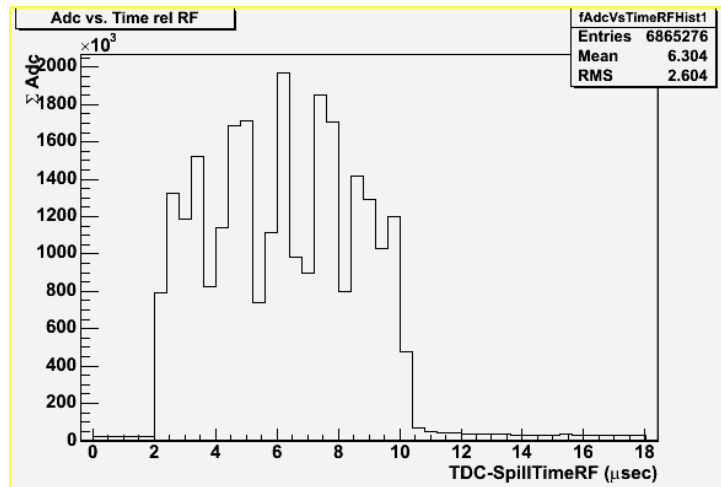
Target is in ME position.

ND scintillator readout has 19ns resolution (same as bunch length).

Timing information is used to separate events.



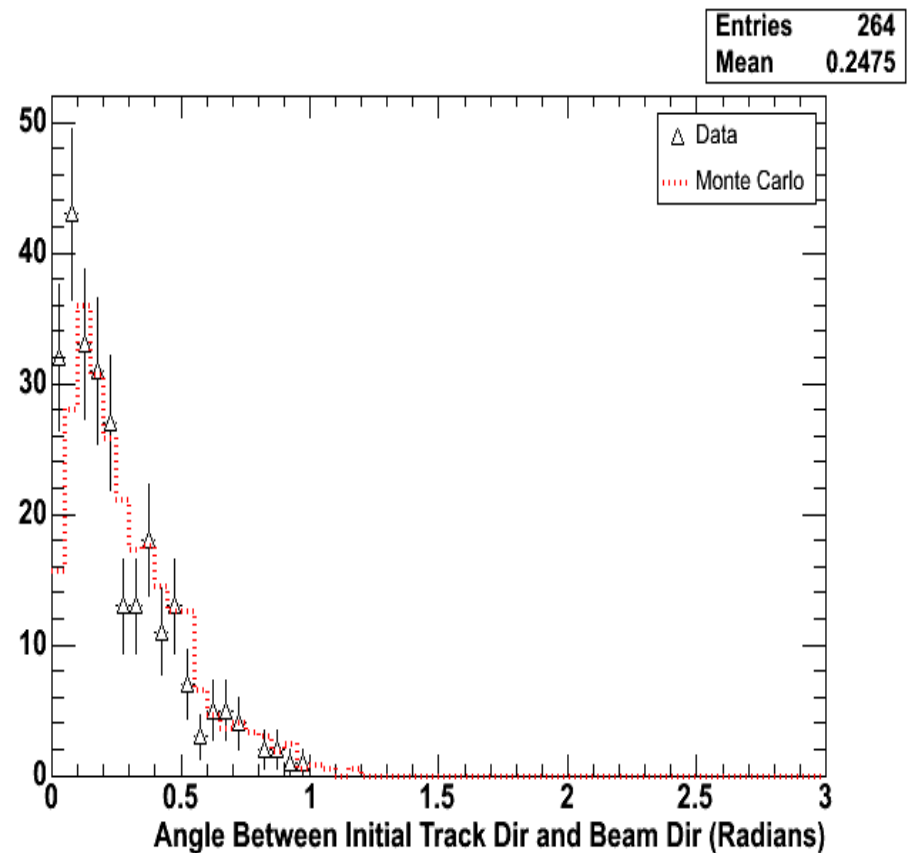
# ND Beam Neutrino Properties



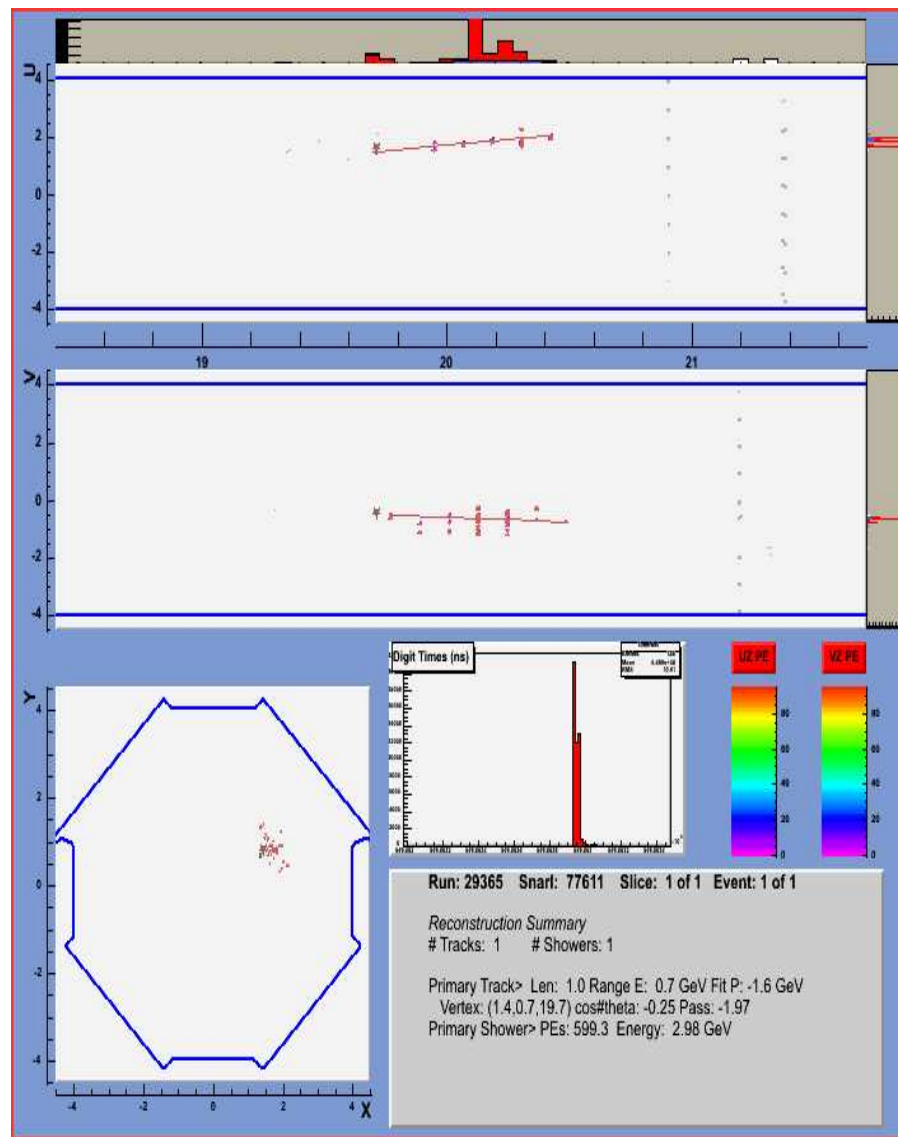
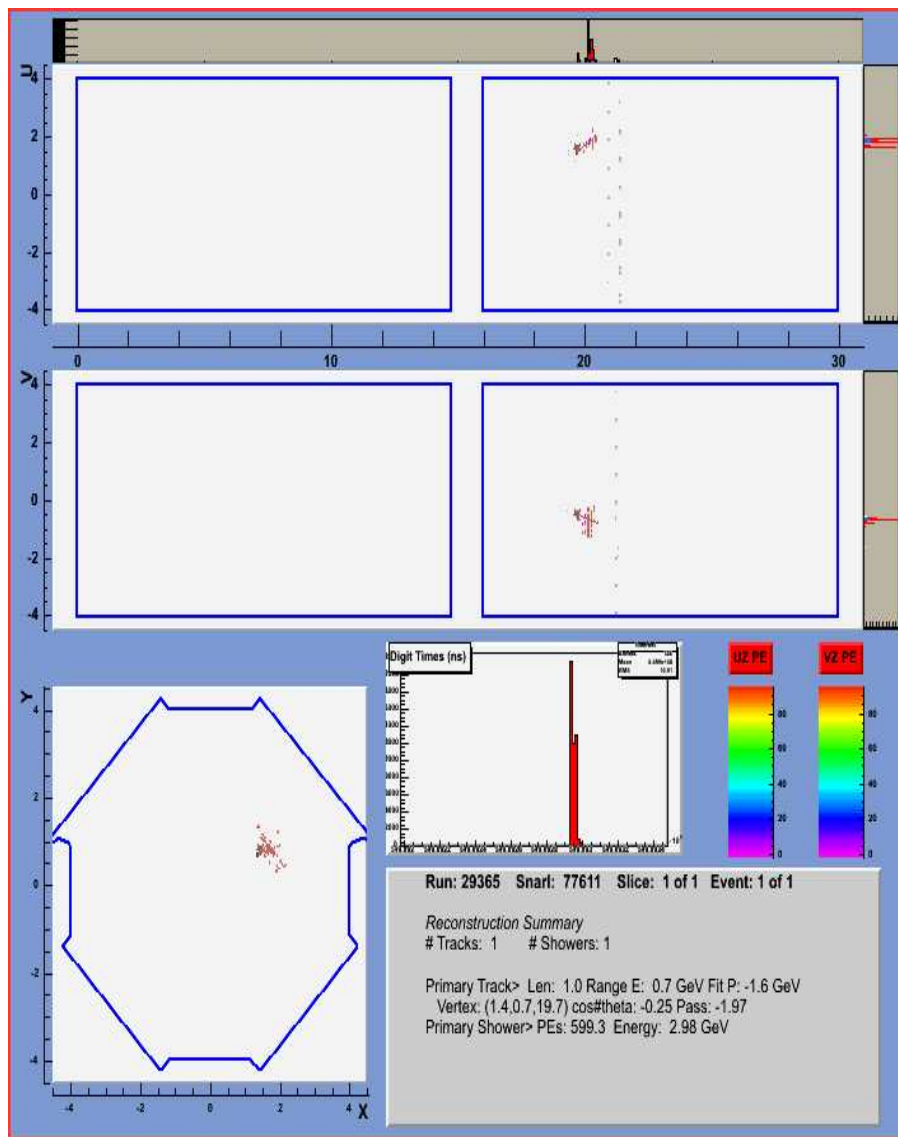
Time difference between ND hits and beam extraction.

NuMI 18.87ns bunches come in 5 batches.

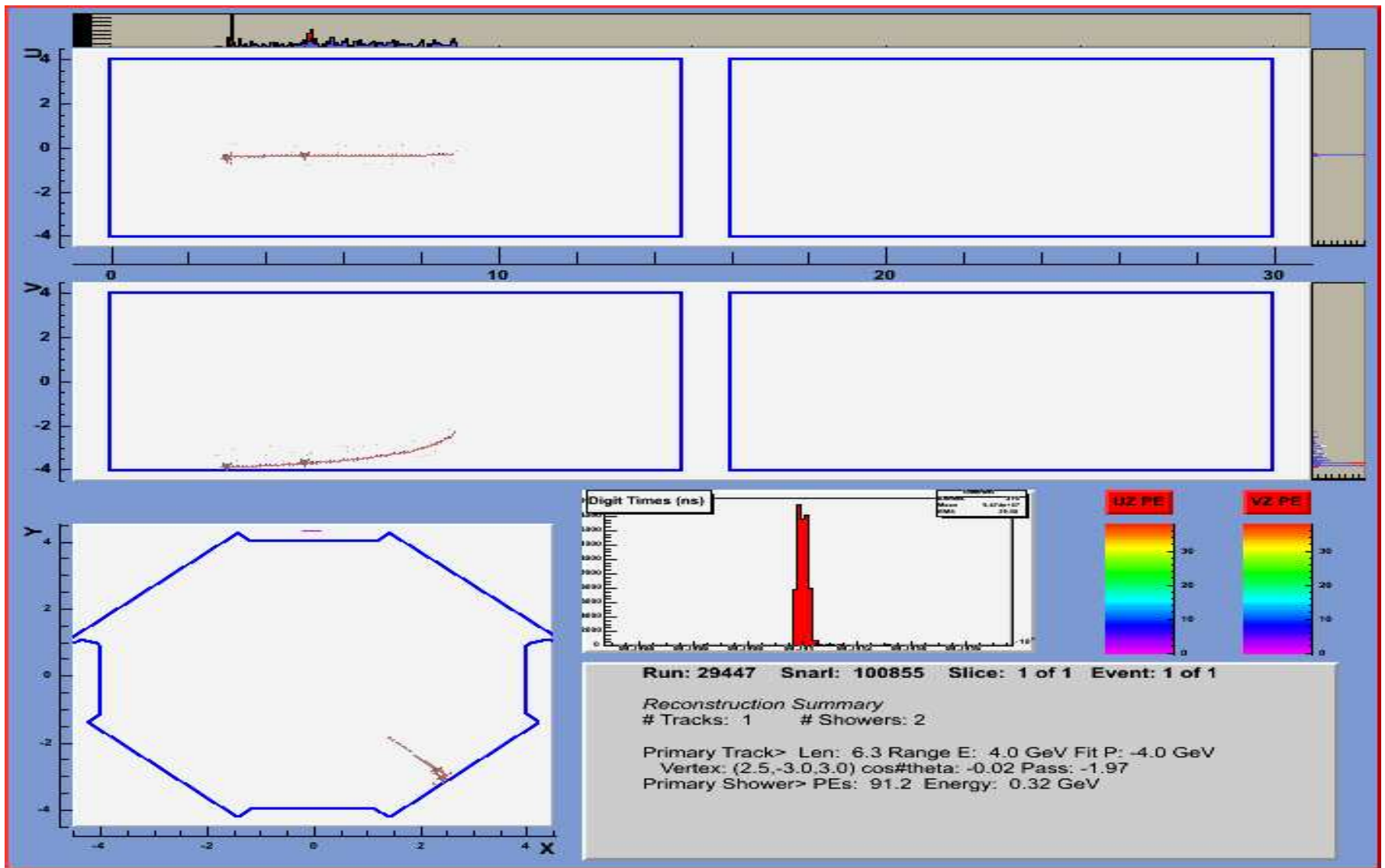
Angle between  $\mu$  track direction (both rock and contained) and beam direction:



# 1st FD Beam Neutrino, March 7 '05



# Far Detector Beam Neutrino #2



# Conclusions

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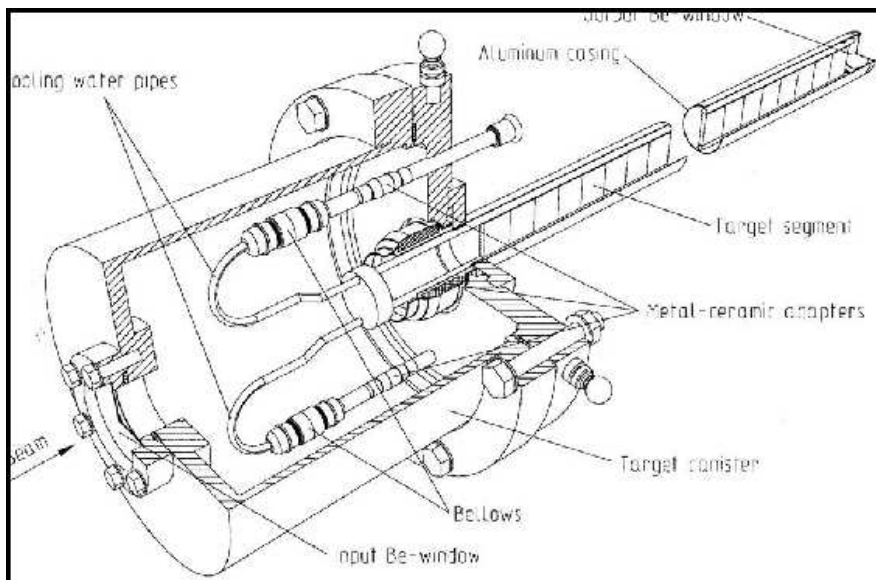
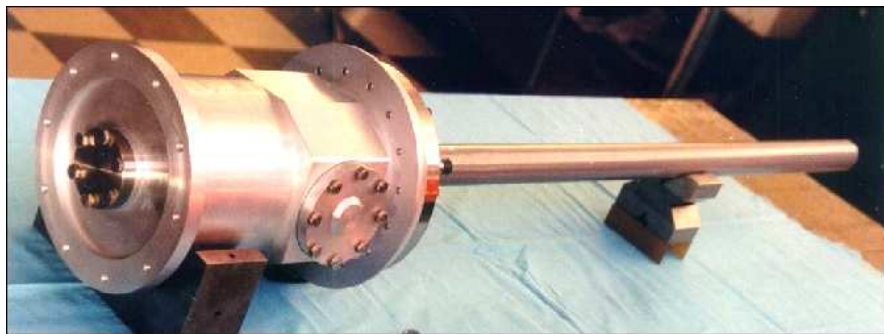
- **NuMI construction is now OFFICIALLY OVER**
- **The MINOS experiment had begun.**
- **Beamline commissioning is well underway. Initial design goal of  $2.5 \times 10^{13}$  protons/pulse and the 2 second rep. rate have been achieved separately.**
- **Main Injector and Booster improvements planned to increase intensity to  $4 \times 10^{13}$  protons/pulse with a 2 sec. rep. rate.**
- **Target water leak currently under investigation.**
- **Near and far detectors fully operational with  $> 90\%$  live time.**

**Beam neutrinos now observed in near and far detectors.**





# More info on MINOS target leak



**Target is being moved into workcell for further investigation.**

