



# Status of NuMI and MINOS

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## DOE Program Review

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NuMI Project Manager

March 23, 2004

### Outline

- Project overview
- Progress during the past year
- Schedule & Funding
- Plans for the coming year
- Summary and Outlook

**NuMI** (Neutrinos at the **M**ain **I**njector)

**MINOS** (**M**ain **I**njector **N**eutrino **O**scillation **S**earch)



MINOS

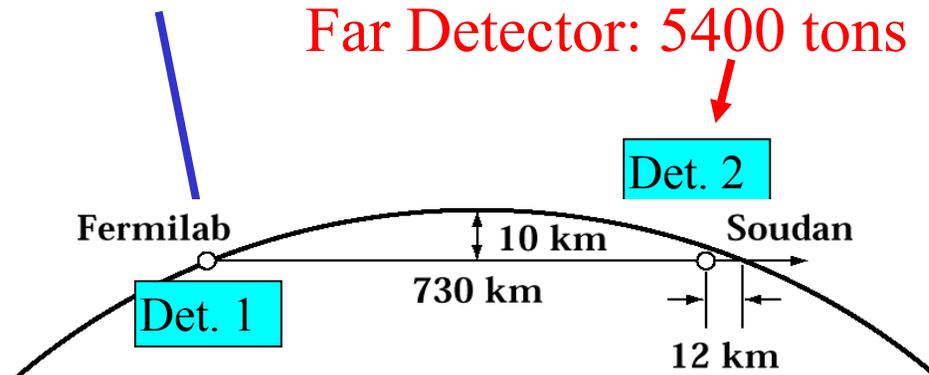
# NuMI Project

Construct Facilities and Equipment for a Two Detector Neutrino Oscillation Experiment with Variable Energy Neutrino Beam (Start 2005)

Obtain firm evidence for oscillations and measure oscillation parameters,  $\Delta m^2$ ,  $\sin^2 2\theta$ . Probe for  $\nu_\mu \rightarrow \nu_e$  appearance.

Near Detector: 980 tons

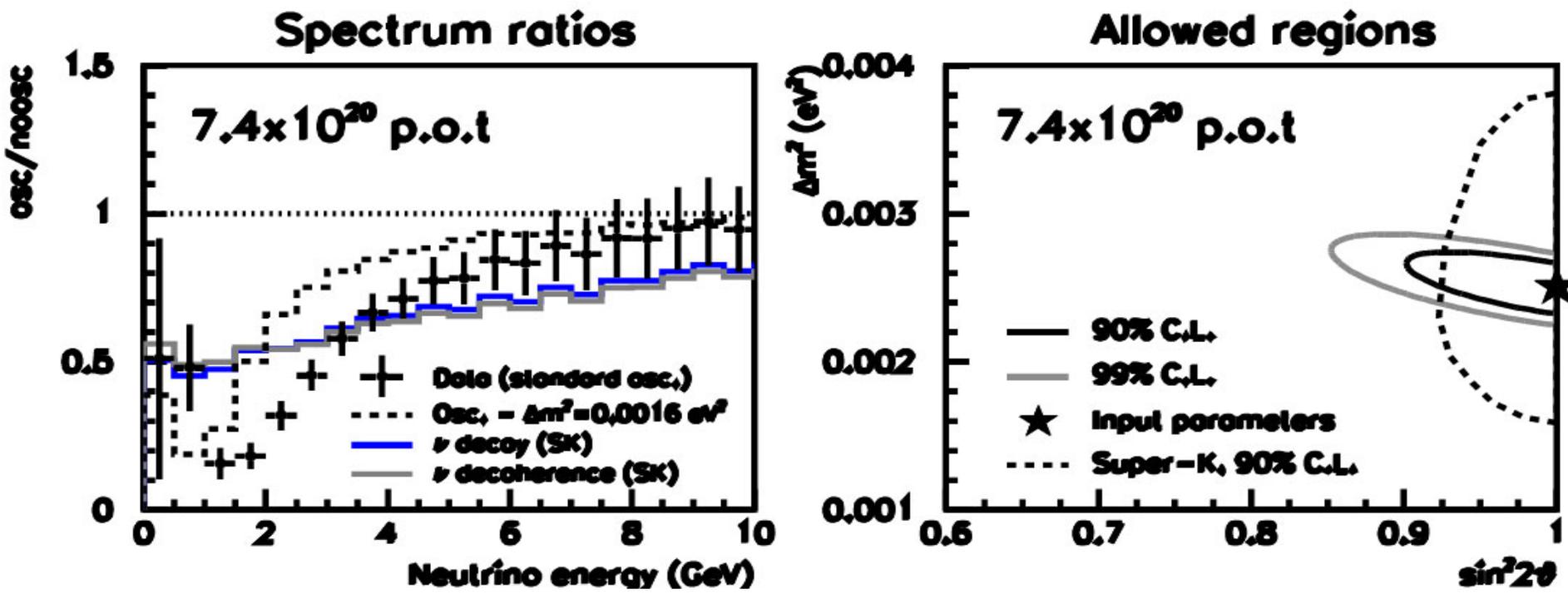
Far Detector: 5400 tons





# Project Scope

- **TEC** = WBS 1.0 NuMI Facility (\$109M)
  - « Construction of beam line facility at Fermilab
  - « project scope includes
    - \* underground excavation and outfitting of tunnels and halls
    - \* construction of two surface buildings
    - \* design, construction and installation of technical components in NuMI beamline
- **OPC** = WBS 2.0 MINOS Detector + WBS 3.0 Project Support (\$62M)
  - « Construction of two detectors and Soudan Far detector cavern
  - « project scope includes
    - \* WBS 2.0 : design , construction and installation of two detectors
    - \* WBS 3.0 : early phase of R&D tasks for NuMI and MINOS excavation and outfitting and pre-operating of MINOS Far detector cavern at Soudan Underground Laboratory



For  $\Delta m^2 = 0.0025 \text{ eV}^2$ ,  $\sin^2 2\theta = 1.0$

Oscillated/unoscillated ratio of number of  $\nu_\mu$  CC events in the far detector vs  $E_{\text{observed}}$

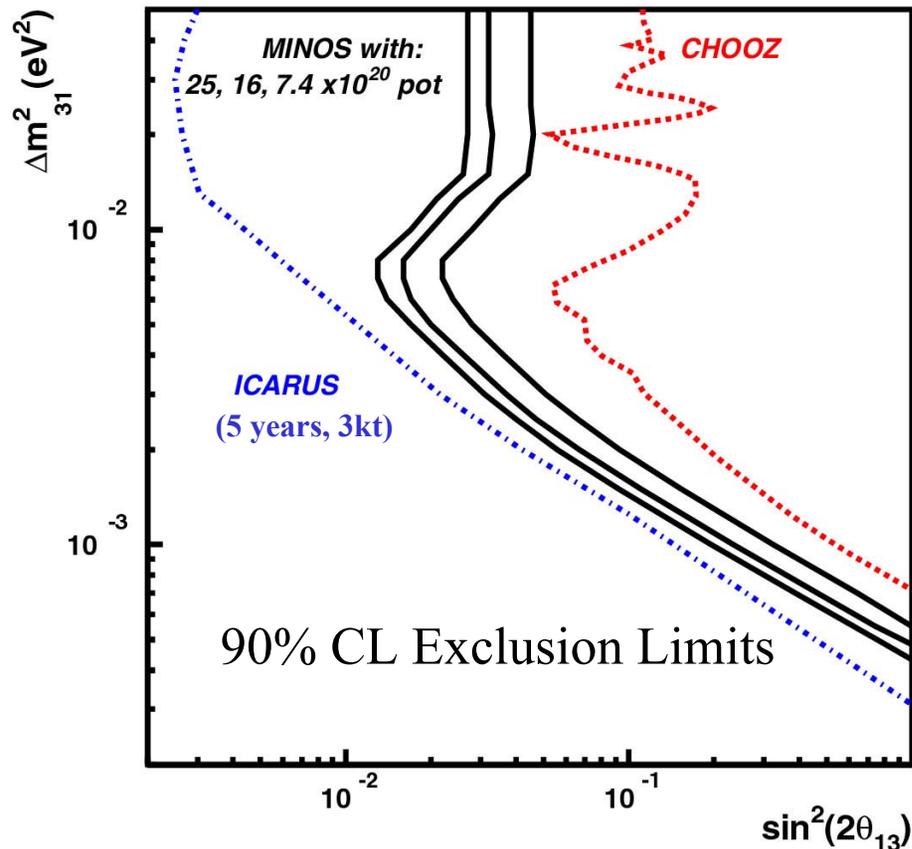
MINOS 90% and 99% CL allowed oscillation parameter space.



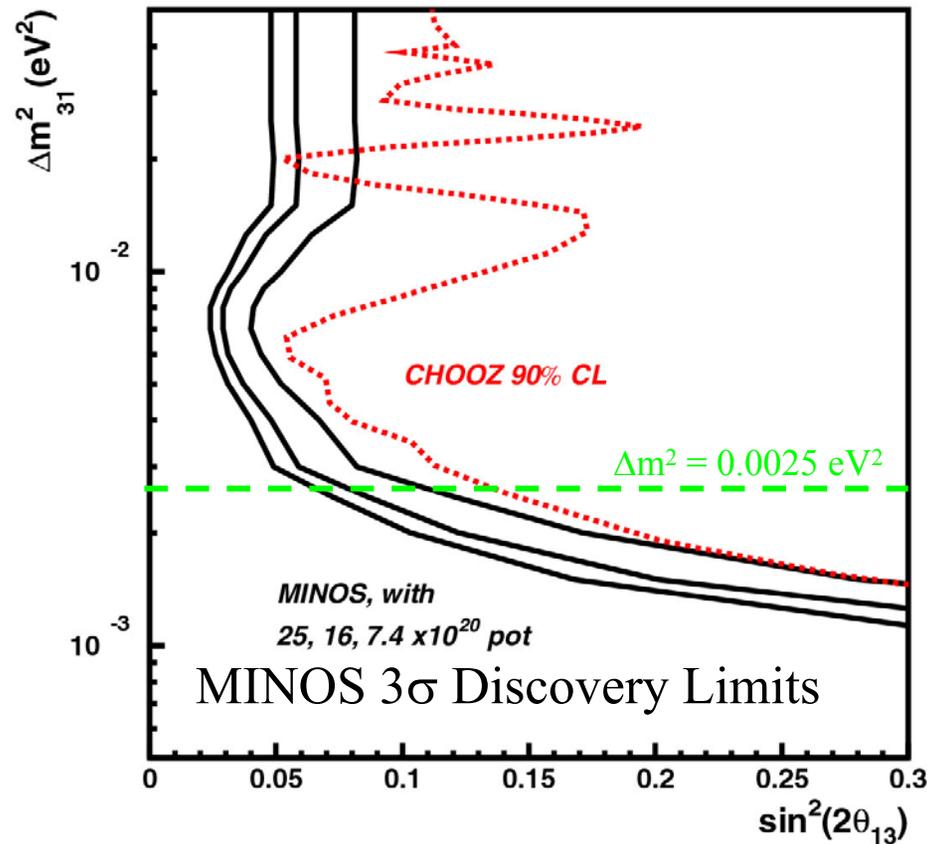
MINOS

# Appearance of Electrons

## 90% CL Exclusion



## $3\sigma$ Contours



- MINOS sensitivities based on varying numbers of protons on target

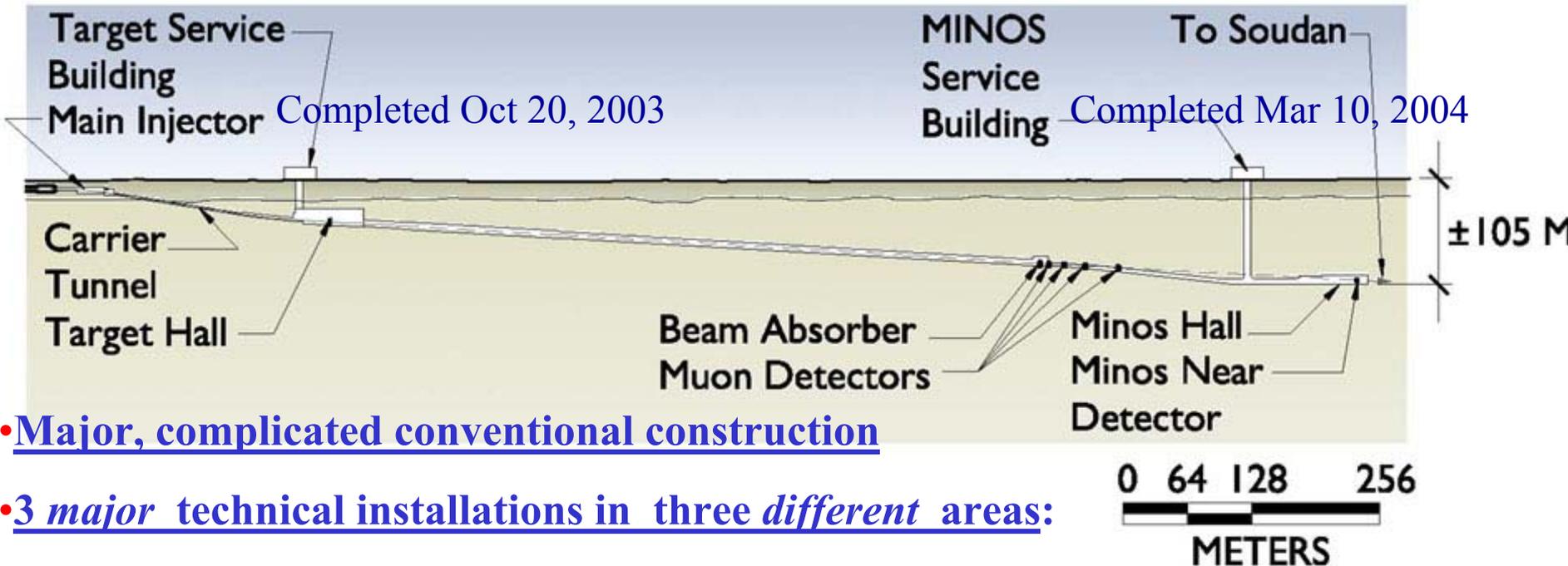


## Progress since March 2003

- Installation underway at Target and MINOS sites
- Installation in Main Injector enclosures underway—magnets, crane, instrumentation, and more.
- Finished Service Buildings and Outfitting
- ES&H program carried over into installation
- Far Detector complete and taking physics quality atmospheric neutrino data
- Primary Beam studies underway
- Preparing for “readiness reviews” including SAD
- Continued on cost and schedule plan



# NuMI Conventional Facilities at Fermilab



• Major, complicated conventional construction

• 3 major technical installations in three different areas:

- Several hundred feet of accelerator enclosure—half of which is between two operating machines
- Downstream end of carrier tunnel, Pre-Target and Target Areas--primary beam focus, 8KT neutrino beam target station
- MINOS area—beam monitoring, ~1 KT hadron absorber and ~ 1 KT neutrino detector



# NuMI Service Buildings



MI-65  
October 2003



MINOS  
March 2004



# MI-65 Underground Target Hall





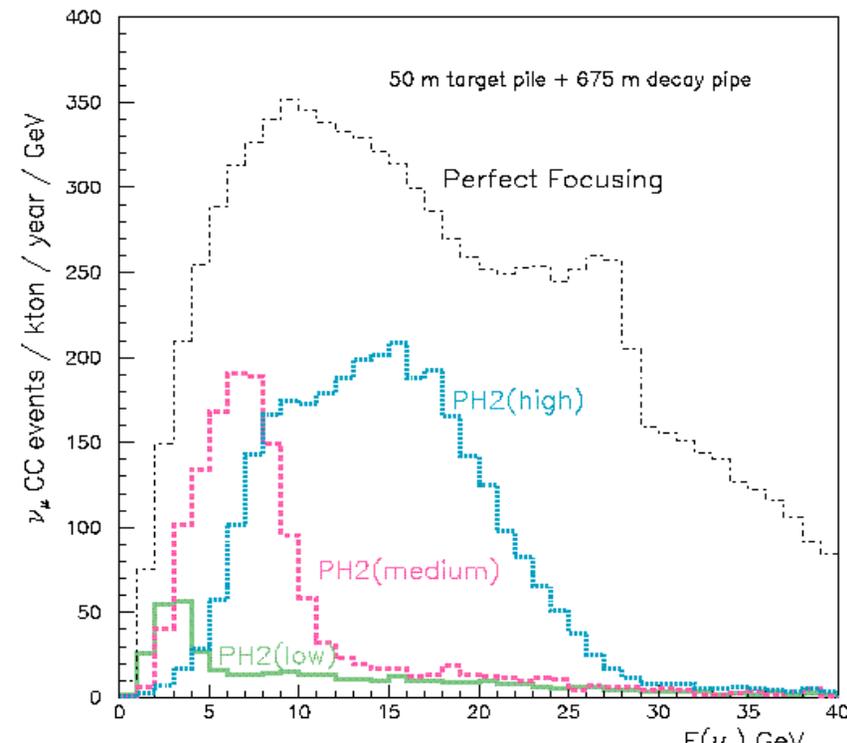
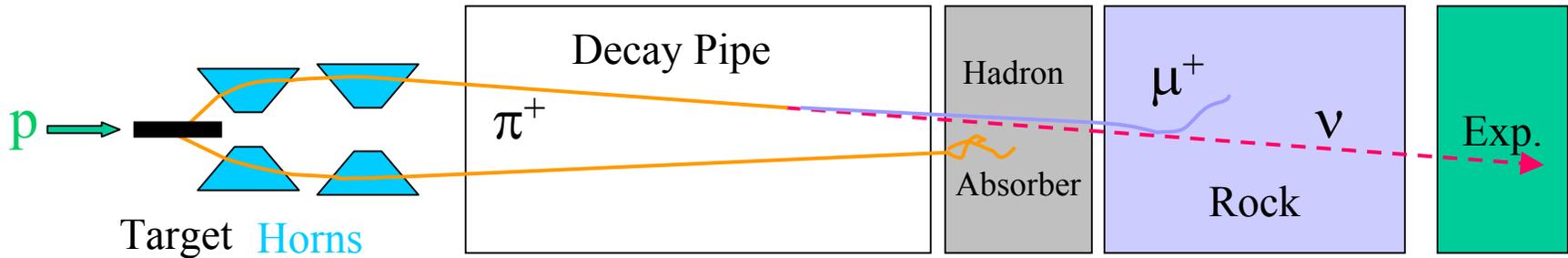
MINOS

# MINOS Underground Hall





# NuMI: Flexible Neutrino Beam



## Expected CC Events Rates in MINOS Far detector

«High 8,000 ev/2E20 p

«Medium 3,600 ev/2E20 p

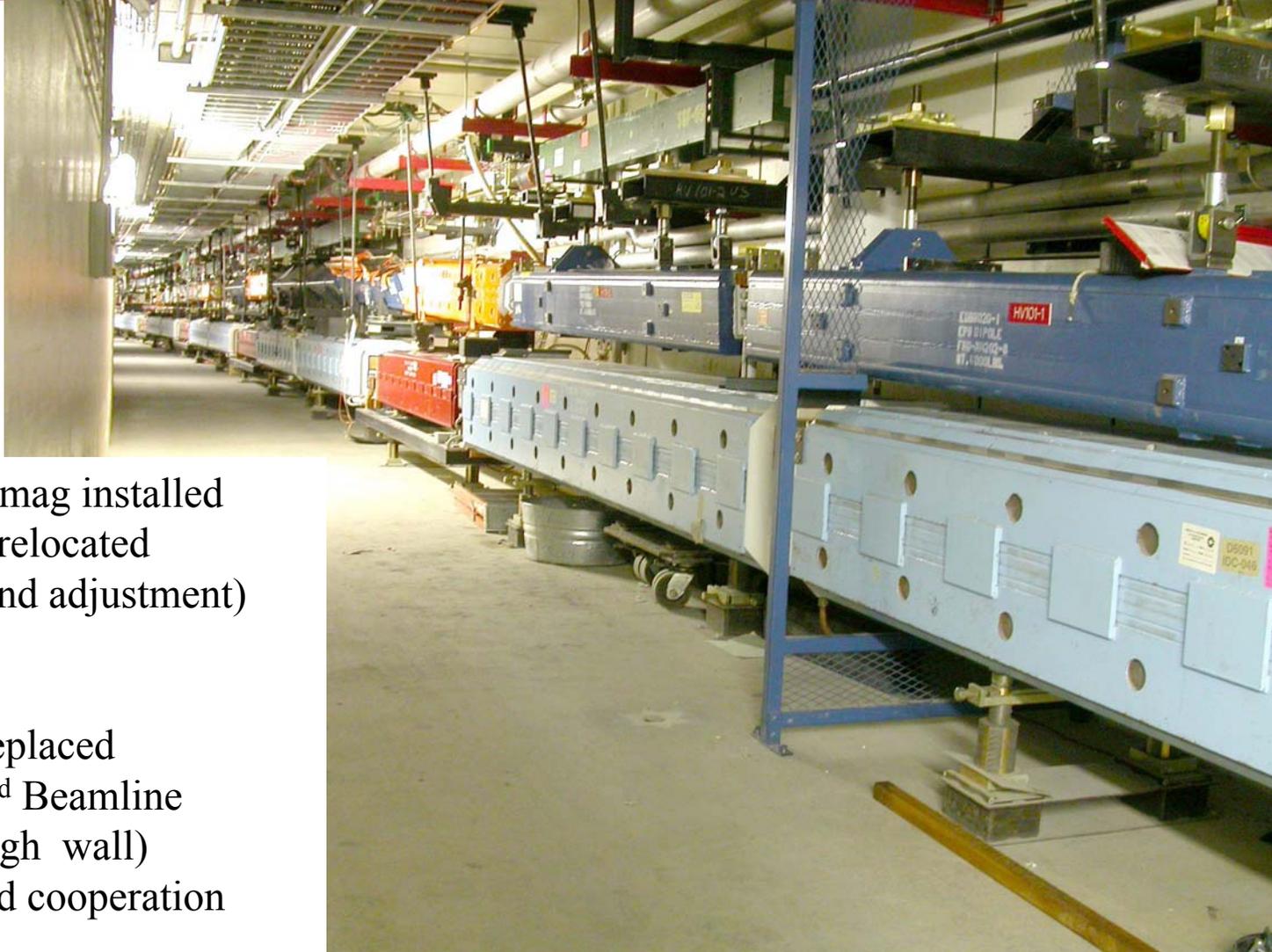
«Low 1,400 ev/2E20 p

(Off-Axis Beams come for free)



# NuMI Extraction Channel

## (In the Main Injector)



- Lambertsons and C-mag installed
  - MI Instrumentation relocated
  - 7 quads (one RR stand adjustment)
  - 5 dipoles
  - 9/13 rough aligned
  - Displaced utilities replaced
  - (Not fun to be the 3<sup>rd</sup> Beamline installed along 10' high wall)
- Outstanding work and cooperation with other groups!



# NuMI Pre-target

(Upstream end of new NuMI Facility)





## Recent Progress Production Horns



Horn 1 and Horn 2 both assembled, test pulsed,  
magnetic fields mapped.  
*Ready for installation.*



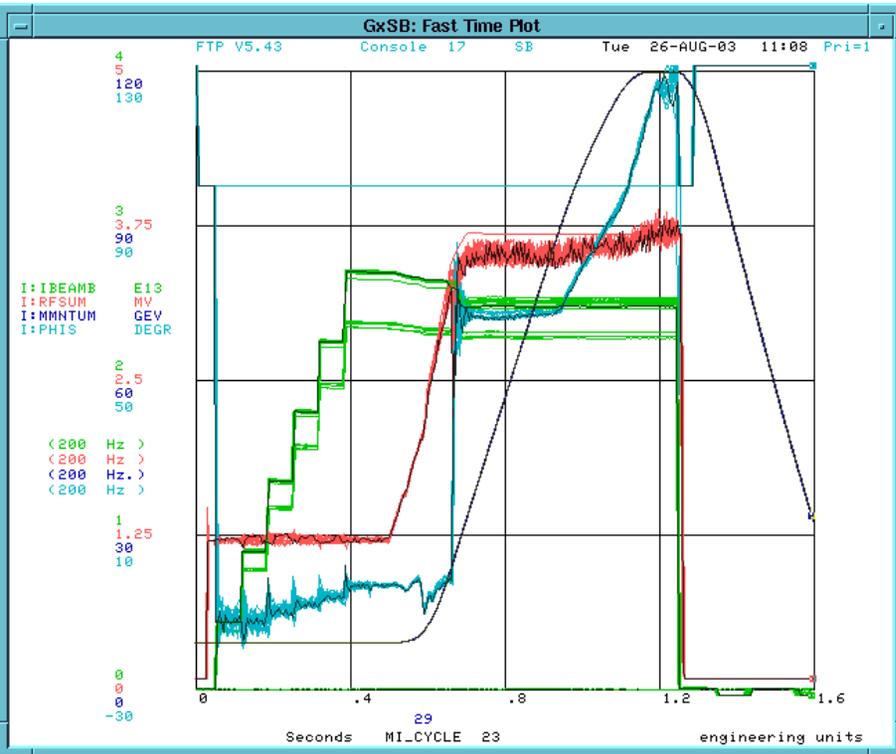


# CD4 Commissioning and the Transition to Operations

- Commissioning Plan for Project Completion (“CD4”)
  - « Demonstrate a functioning Far Detector (atmospheric neutrinos and muons)
  - « Demonstrate a functioning Beamline and Near Detector (with beam neutrinos)
- April 15 Commissioning Workshop
  - « CD4 preparations
  - « Main Injector
  - « Near Detector
  - « Commissioning for physics
- Planning for evolution to initial operational intensity
  - «  $2.5E13$  protons , 5/6 batches,  $5E12$  in Booster , 1.9s cycle
  - « Integrated into BD/HQ planning: tasks, people, studies
  - « Multi-batch studies, dampers, beam loading compensation, booster shielding, booster notch and timing



# Main Injector Commissioning

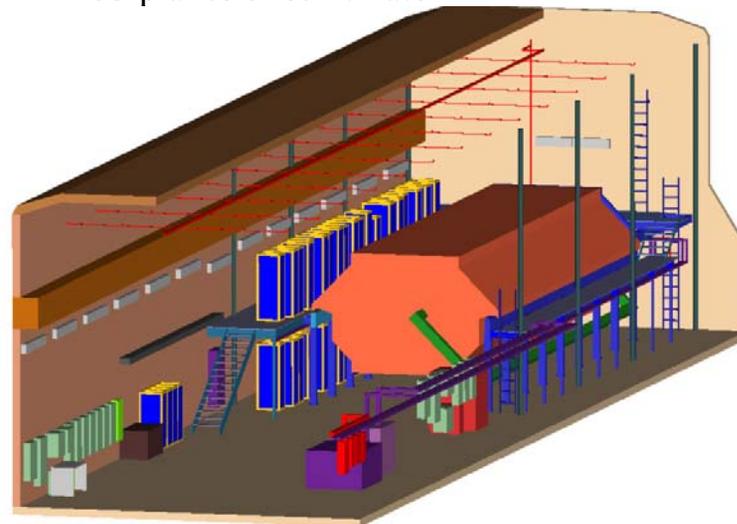
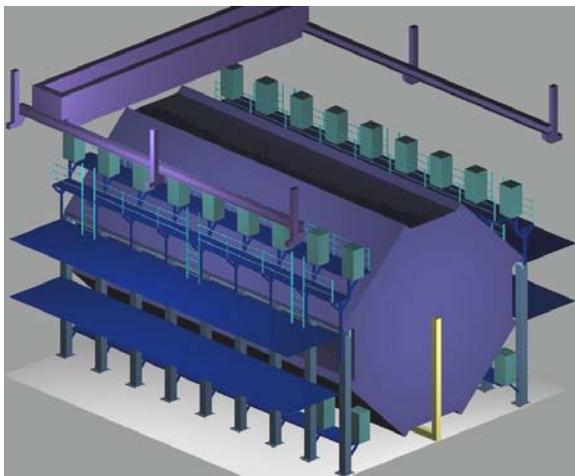


- **Team of accelerator physicists and MINOS collaborators in place and planned studies ongoing**
- **A beam intensity of  $2.3 \times 10^{13}$  protons/cycle is now operationally achievable in MI.  $3.3 \times 10^{13}$  at 8 Gev already**
- **Good performance of MI transverse damper should be operational in May.**
- **Good progress on Booster cogging**
- **By October 2004 we expect to meet intensity and beam quality goals**



# The MINOS Detectors

- Far Detector (Soudan Lab)
  - 8m Octagonal Tracking Calorimeter
  - 2 sections, 15m each
  - 486 planes of steel & scintillator
  - 95,000 scintillator strips
  - **5.4 kT total mass**
- Near Detector (MINOS Hall - FNAL)
  - « 3.8 x 4.8m “octagonal” steel & scintillator tracking calorimeter
  - « Same basic construction, sampling & response as the far detector
  - « 282 planes of steel
  - « 153 planes of scintillator



CALDET: Multi year calibration program at CERN concluded successfully in Fall

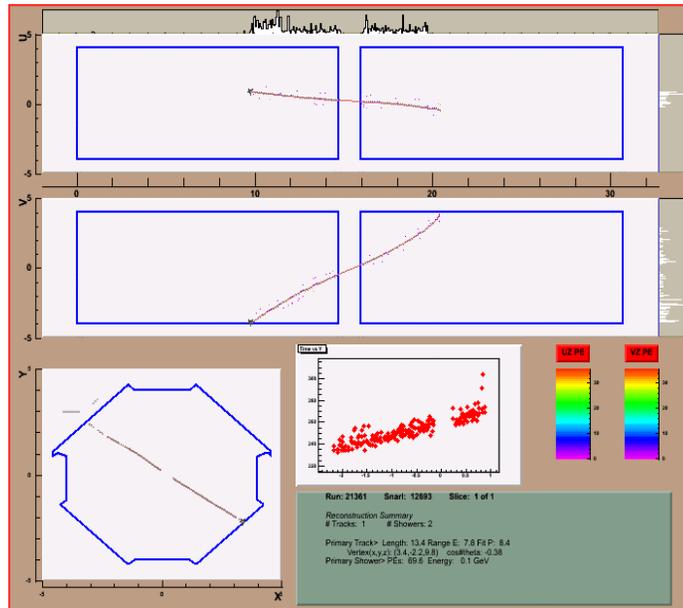


# MINOS Far Detector



- Two Magnetized Supermodules began routine operation August 2003
- All project components associated with Far Detector fully closed out
- Cosmic Ray Veto shield constructed from spare components installed to enhance atmospheric neutrino analysis

# Atmospheric $\nu$ 's in MINOS Far Detector



- Analyzed Exposure to date
  - ◀ SM1
    - \* 131 live days
    - \* Sept 02 - May 03
  - ◀ SM1+SM2
    - \* 92 live days
    - \* Jul 03 - Nov 03
- Analysis of Candidates continues
  - ◀ Upwardgoing muons
  - ◀ Contained Events

Expected Events in 24 kT years for  $\Delta m^2 = 0.003 \text{ eV}^2$ ,  $\sin^2 2\theta = 1.0$

Reco'd contained vertex with muon  
 Reco'd upward going muon

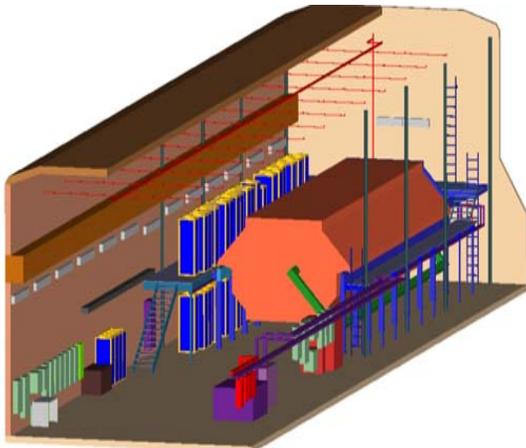
	Neutrino	Antineutrino
Reco'd contained vertex with muon	440	260
Reco'd upward going muon	280	120



# MINOS Near Detector



- All components ready for installation
  - « Planes & electronics (New Muon) (Install April-Oct)
  - « Magnet Coil (D0)
  - « 9-planes fully commissioned with cosmic ray muons





# Environment, Safety and Health

- 
- Safety across the project remains uppermost on all our minds. Deep underground facility unique at Fermilab.
  - Our safety plan emphasizes Fermilab's safe work policies. Throughout the project we are taking time to plan ahead, identify hazards, put controls in place, monitor, assess, and correct.
  - Take action when necessary. Investigate incidents and implement appropriate corrective actions including stand-downs and disciplinary actions.
  - Added ES&H staff to cover increase in activities for FY03. Maintaining dedicated ES&H staff for installation.
  - Documentation team formed: gather and finalize and post documents.
  - ES&H reviews continue. Joint BD/PPD Safety Committee provides oversight.
  - Continuing to monitor Environmental compliance.
  - Working on Shielding Assessment and SAD preparation for some time already. Goal is to be ready for approval in Summer 2004.



MINOS

# Doe Milestones FY2002-2005

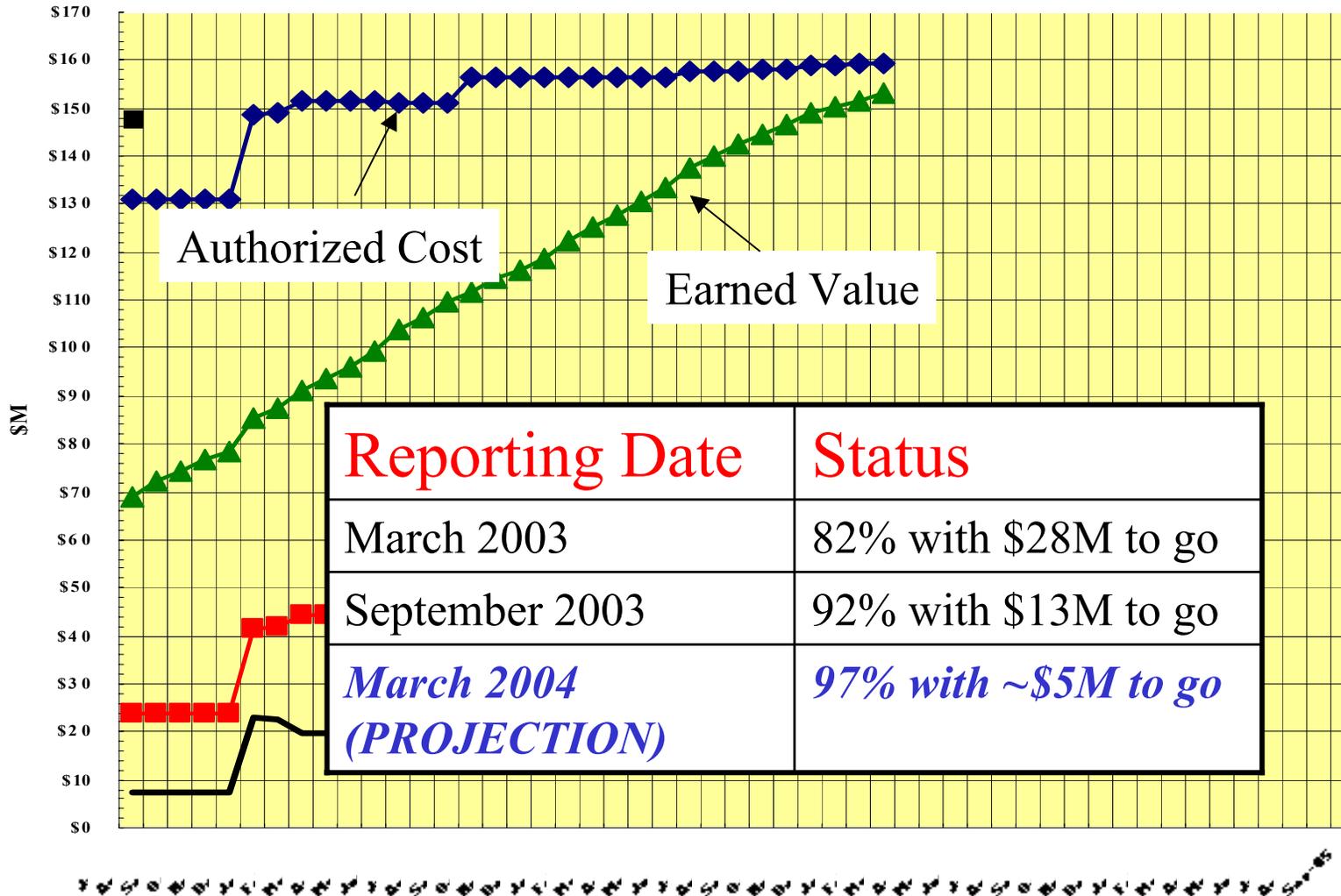
Milestone Description	PEP Milestone #	DOE Milestones	January Forecast	Float	Notes
Cosmic Rays Observed in Far Detector	L-2-10	3/22/2002	8/31/2001	203	Complete
Technology Choice Made for Muon Monitors	L-2-16	5/30/2002	12/10/2001	171	Complete
Service Building & Outfitting Bid Package Out	L-1-10	7/30/2002	2/25/2002	155	Complete
75% Scintillator Produced	L-2-19	8/30/2002	5/24/2002	98	Complete
Near Detector Hall Excavation Complete	L-2-7	12/30/2002	8/30/2002	122	Complete
Target Hall Excavation Complete	L-1-5	12/30/2002	10/4/2002	87	Complete
Lambertson & C-Magnets Assembled & Tested	L-2-12	2/1/2003	10/31/2002	93	Complete
First Far Detector Super Mod Complete & Tested	L-1-7	3/15/2003	7/24/2002	234	Complete
Inner & Outer Conductors for First Production Horn Assembled	L-1-6	4/14/2003	2/5/2003	68	Complete
Target Service Building Shell Complete	L-2-18	9/30/2003	6/17/2003	105	Complete
Near Plane Pre-assembly Complete	L-2-20	10/10/2003	12/17/2002	297	Complete
Far Detector Complete & Tested	L-1-8	4/25/2004	7/9/2003	291	Complete
Beneficial Occupancy of Service Buildings at Fermilab	L-2-11	5/31/2004	3/4/2004	88	<b>COMPLETED MAR 10</b>
Start Commissioning with Both Near and Far DAQ	L-2-21	8/30/2004	6/9/2004	82	
Complete Installation of Horn Power Supply	L-2-17	9/1/2004	3/16/2004	169	
MI Stub Installation Complete	L-2-15	3/11/2005	10/5/2004	157	
Near Detector Complete & Tested	L-2-14	3/31/2005	1/26/2005	64	
First Horn Installed	L-2-13	4/7/2005	6/21/2004	290	
Start Commissioning	L-1-9	9/1/2005	12/15/2004	260	
CD-4 Start Operations	L-0-3	9/30/2005	1/26/2005	247	End of Commissioning

**Start commissioning with protons in December 2004**



# NuMI Project Status

NuMI Total Project Cost





# Next Year:

## Progress

## Challenges

- 
- 
- Far Detector continuing to collect atmospheric neutrino data
  - Target hall installation finishing over the summer
  - Finish proton beam installation and commissioning
  - Near Detector installation completing in Fall
  - Project completion forecast for January 2005
  - Beam Neutrino events in Far Detector
  - Experiment taking data
- Installation, especially in the area inside the Main Injector enclosures will be at least as hard as we thought going into it, but it isn't any harder.
  - Must maintain good progress on installation and commissioning activities.
  - NuMI proton commissioning during Run II operations is difficult and needs to be carefully managed.
  - Must keep working safely--we want no accidents/injuries anywhere on the project.
  - Closeout completed project elements.



# Conclusion

- Last year was a very good year.
- We are only **months (!)** away from being ready to turn the beam and experiment on.
- We are looking forward to the final stage of the NuMI Project and the beginning of the MINOS experiment.

NuMI



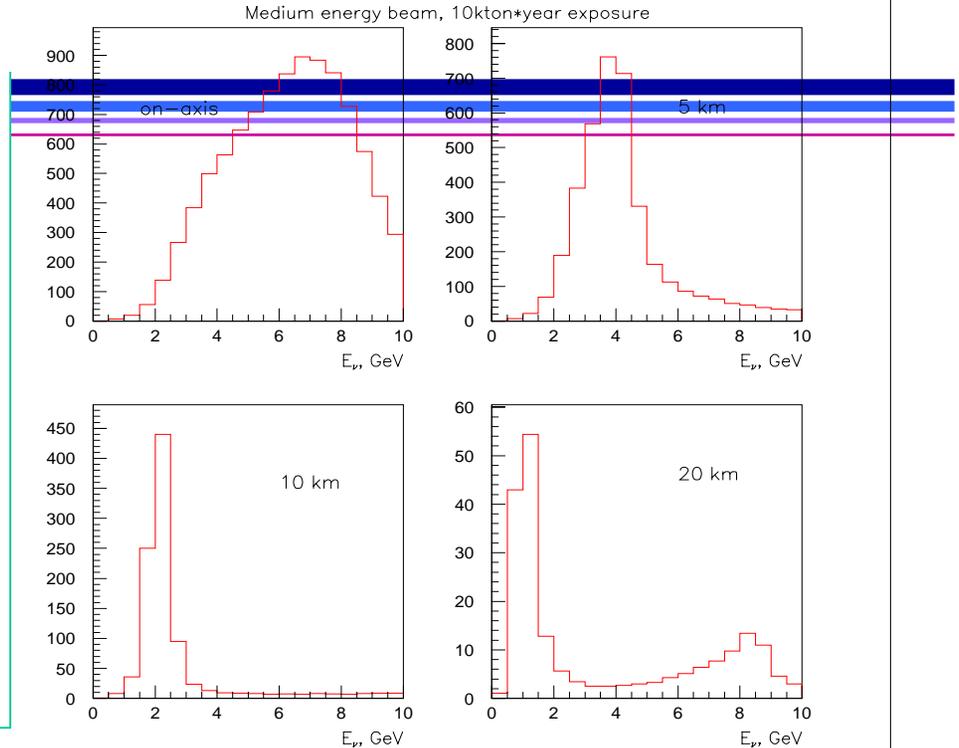
MINOS

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# Supplemental slide

# NuMI Off-Axis

G. Bock  
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- Build a new ~50 kt fine-grained, low Z detector in northern Minnesota or Canada
- Beam energy defined by the detector position (~20 mR off-axis gives an optimum beam).
- Narrow energy range (minimizes NC-induced background)
- Simultaneous operation (with MINOS and/or other detectors)
- Improve on MINOS oscillation measurements due to lower energy, narrow-band beam with much higher statistics due to more protons on target and much bigger detector.
  - Discover or better measure  $U_{e3}$  and other oscillation parameters
  - Matter effects can amplify oscillation probability and be used to determine mass hierarchy
  - Search for CP violation