Status of NuMI and MINOS

DOE Program Review

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NuMI Project Manager
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Outline

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

NuMI (Neutrinos at the Main Injector)
MINOS (Main Injector Neutrino Oscillation Search)
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.
Appearance of Electrons

90% CL Exclusion

- MINOS sensitivities based on varying numbers of protons on target

\[ \Delta m^2 = 0.0025 \text{ eV}^2 \]
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
MI-65 Underground Target 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 3rd 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 ν’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 $\Delta m^2=0.003 \text{ eV}^2$, $\sin^2 2\theta = 1.0$

<table>
<thead>
<tr>
<th>Neutrino</th>
<th>Antineutrino</th>
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<tbody>
<tr>
<td>Reco’d contained vertex with muon</td>
<td>440</td>
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<tr>
<td>Reco’d upward going muon</td>
<td>280</td>
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</table>
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.
# Doe Milestones FY2002-2005

<table>
<thead>
<tr>
<th>Milestone Description</th>
<th>PEP Milestone</th>
<th>DOE Milestones</th>
<th>January</th>
<th>Forecast</th>
<th>Float</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Cosmic Rays Observed in Far Detector</td>
<td>L-2-10</td>
<td>3/22/2002</td>
<td>8/31/2001</td>
<td>203</td>
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<td>Technology Choice Made for Muon Monitors</td>
<td>L-2-16</td>
<td>5/30/2002</td>
<td>12/10/2001</td>
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<tr>
<td>Service Building &amp; Outfitting Bid Package Out</td>
<td>L-1-10</td>
<td>7/30/2002</td>
<td>2/25/2002</td>
<td>155</td>
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<td>75% Scintillator Produced</td>
<td>L-2-19</td>
<td>8/30/2002</td>
<td>5/24/2002</td>
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<td>Near Detector Hall Excavation Complete</td>
<td>L-2-7</td>
<td>12/30/2002</td>
<td>8/30/2002</td>
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<td>Target Hall Excavation Complete</td>
<td>L-1-5</td>
<td>12/30/2002</td>
<td>10/4/2002</td>
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<td>Lambertson &amp; C-Magnets Assembled &amp; Tested</td>
<td>L-2-12</td>
<td>2/1/2003</td>
<td>10/31/2002</td>
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<td>First Far Detector Super Mod Complete &amp; Tested</td>
<td>L-1-7</td>
<td>3/15/2003</td>
<td>7/24/2002</td>
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<tr>
<td>Inner &amp; Outer Conductors for First Production Horn Assembled</td>
<td>L-1-6</td>
<td>4/14/2003</td>
<td>2/5/2003</td>
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<td>Target Service Building Shell Complete</td>
<td>L-2-18</td>
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<td>6/17/2003</td>
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<td>Near Plane Pre-assembly Complete</td>
<td>L-2-20</td>
<td>10/10/2003</td>
<td>12/17/2002</td>
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<td>Far Detector Complete &amp; Tested</td>
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<td>4/25/2004</td>
<td>7/9/2003</td>
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<td>Start Commissioning with Both Near and Far DAQ</td>
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<td>8/30/2004</td>
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<td>Near Detector Complete &amp; Tested</td>
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<td>3/31/2005</td>
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<td>First Horn Installed</td>
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<td>4/7/2005</td>
<td>6/21/2004</td>
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<td>Start Commissioning</td>
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<td>9/1/2005</td>
<td>2/15/2004</td>
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Start commissioning with protons in December 2004
NuMI Project Status

<table>
<thead>
<tr>
<th>Reporting Date</th>
<th>Status</th>
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<tbody>
<tr>
<td>March 2003</td>
<td>82% with $28M to go</td>
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<tr>
<td>September 2003</td>
<td>92% with $13M to go</td>
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<tr>
<td><strong>March 2004 (PROJECTION)</strong></td>
<td><strong>97% with ~$5M to go</strong></td>
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</table>

Authorized Cost
Earned Value
Next Year:

Progress

- 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

Challenges

- 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.
Supplemental slide
• 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 heirarchy
  • Search for CP violation