Atmospheric Neutrinos At MINOS

MINOS

MINOS is a long baseline neutrino oscillation experiment. It comprises two detectors, the Near Detector based at Fermilab and the Far Detector, based at Soudan Underground Lab in northern Minnesota.

The ν_μ beam will be provided by the Main Injector at Fermilab.

Atmospheric Neutrinos?

The MINOS far detector is first deep underground neutrino detector to have a magnetic field. It is able to determine the charge of muons produced in charged current interactions and, therefore, able to distinguish ν_μ and $\bar{\nu}_\mu$.

The MINOS Far Detector was completed in July 2003.

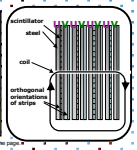
While the detector is designed to detect beam neutrinos originating from Fermilab, it also presents the possibility of atmospheric neutrinos physics.

MINOS is the first experiment able to measure the atmospheric oscillation parameters for neutrinos and anti-neutrinos independently.

The Far Detector

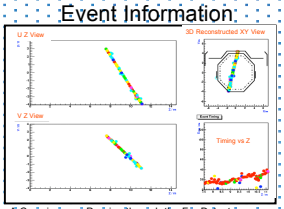
The Far Detector is a fine grained, iron/scintillator sampling calorimeter. Parallel planes made from 2.5cm of steel and 1 cm of scintillator. Each scintillator plane is made up of 192 parallel strips readout by PMTs on each end. Alternate planes have orthogonal strip orientations U and V.

The Far Detector has a 1.5T magnetic field for charge determination and momentum measurement. It is divided into two 2.7 KT "Super Modules" separated by a 60cm gap.



The MINOS Far Detector during construction, direction to Fermilab is into the page.

Event Information



A Cosmic muon Passing through the Far Detector.

- 2 views of an event, U/Z and V/Z.
- Timing, ~2.5 ns
- Charge deposition in the scintillator.

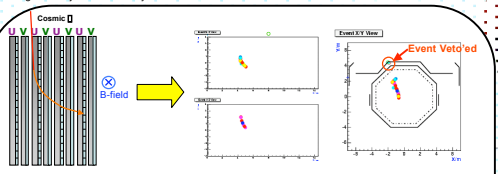
Contained Events

For an event to be classed as contained, the muon track must be within the fiduical volume of the detector. The fiducial volume of the Far Detector is defined to be 0.5 meter or 5 planes, from every edge. Each Super-module is treated as separate detector.

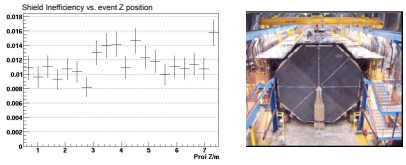
Background Rejection

The background is dominated by cosmic muons travelling down the steel planes and scattering into the active detector. Initial background studies have reduced the cosmic to signal rate to 1.5:1 while retaining 75-80% signal efficiency. To further reduce this background a veto shield was installed in July 2003.

The veto shield is constructed from the same scintillator modules used in the bulk of the detector. It provides a cheap and effective method of tagging cosmic muons. Preliminary studies estimate background rejection efficiency to be ~99%.



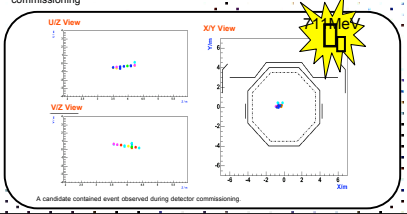
A cosmic muon entering the detector in the steel and scattering out. The result event looks contained but leaves hits in the veto shield.



Plot showing shield inefficiency for background events, left, and the completed vetoshield

Neutrinos!

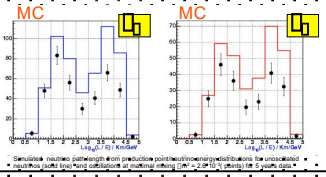
MINOS has already observed 5 contained atmospheric ν_μCC events during commissioning



A candidate contained event observed during detector commissioning

Summary

- MINOS has already observed contained atmospheric neutrino interactions and has been able to determine their charge. The background from cosmic muons is expected to be less than 5% of the signal.
- Over the next 5 years we expect 400 ν_μCC events.



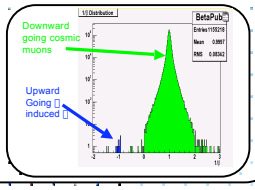
Simulated neutrino pathlength from production point, neutrino energy distributions for unoscillated neutrinos (solid line) and oscillations at maximal mixing ($\Delta m^2 = 2.0 \times 10^{-3}$ eV^2) for 5 years data

Upward Going Muons

The search for upward going muons produced by local neutrino interactions in the rock below the detector.

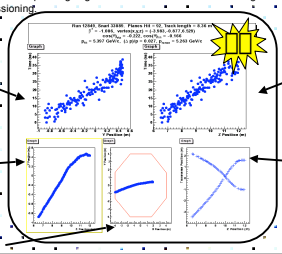
Event Selection

The direction of a muon track can be accurately determined from timing. The plot to the right shows $1/\beta$ (=velocity/c) for data. A negative value of $1/\beta$ indicates an upward going muon. To ensure accurate timing a 2m and 20 plane minimum track length cut is applied.

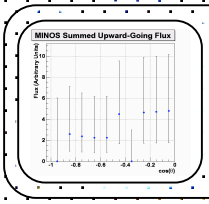


Events!

12 candidate upward going muon events were observed during far detector commissioning.



Summary



MINOS can do charge separated, upward going muon physics and has already recorded 12 events during detector commissioning.

Preliminary studies have shown that the background from horizontal cosmic muons is small.

Over the next 5 years we expect 150 μ^- and 300 μ^+ events.

MINOS will be able to measure neutrino oscillation parameters by examining muon fluxes close to the horizon.

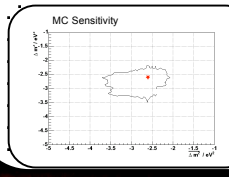
Brian Rebel (Indiana University)

Atmospheric Neutrinos: Windows to CPT violation?

The atmospheric, solar and LSND neutrino results cannot be accommodated in a conventional 3 mass system. CPT violation has the potential to explain all measured mass differences by introducing independent masses for neutrinos and antineutrinos without expanding the neutrino sector.

MINOS can determine the charge of a neutrino on an event by event basis. It will be the first experiment to DIRECTLY measure Δm^2 and $\bar{\Delta} m^2$.

Can MINOS Rule Out CPT Models?



The plot shows the simulated 95% confidence limits of a gone CPT violating model with $\Delta m^2 = \bar{\Delta} m^2 = 2.6 * 10^{-3}$ (marked with a star).

MINOS should be able to exclude CPT violating models with orders of magnitude difference in Δm^2 and $\bar{\Delta} m^2$.

This plot is preliminary and is expected to significantly improve with further development of the reconstruction software.

Presented By Caius Howcroft, August 2003 LP2003