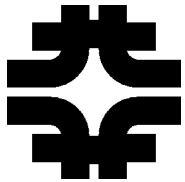


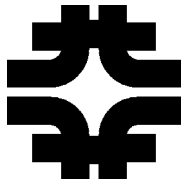
The MINOS Experiment

Gina Rameika

Fermilab

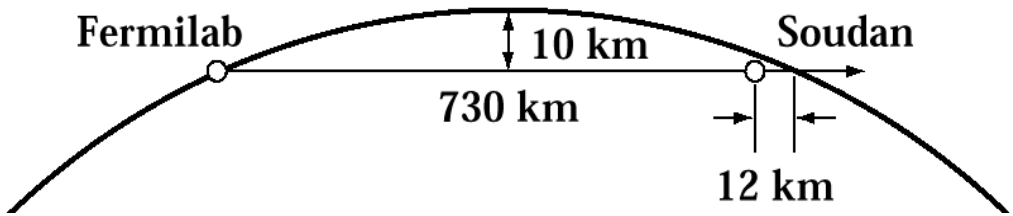
March 24, 2004

Outline



- Introduction
- MINOS Physics Goals
- MINOS Detectors
  - The NuMI Project
  - Detector Construction
  - The Calibration Detector
- Transition to Operations
  - Atmospheric neutrinos at Soudan
  - Commissioning Goals
- Conclusion

The MINOS Experiment



A 2-detector long-baseline neutrino oscillation experiment in a beam from Fermilab's Main Injector

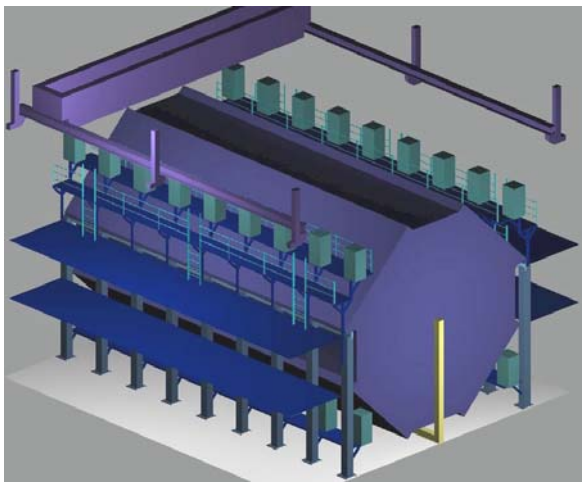
MINOS Proposal Submitted : April 1995
Stage 1 Approval : June 1995
R&D & Conceptual Design Funds: FY97-98
Equipment Funds : FY99-05

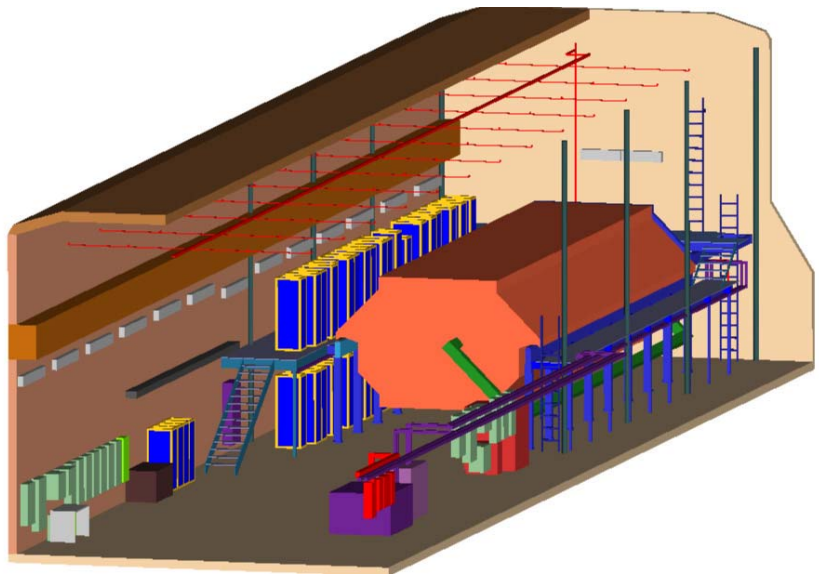
MINOS Physics Goals

- Demonstrate oscillatory behavior
  - Precise measurement of CC energy distribution between near & far detectors (2-4% sys. uncertainty in E_ν per GeV bin)
  - "Standard" or non-standard oscillations?
- Precise measurement of oscillation parameters
  - Δm^2_{23} at ~ 10%
  - How close to 1.0 is $\sin^2 2\theta_{23}$? (Can test to ~5% level)
- Improved determination of flavor participation
  - # of CC ν_μ events far/near (for ν_μ -> ν_x at about ~2%)
  - # of CC ν_e events far/near (for ν_μ -> ν_e down to about 2%)
  - # of NC events far/near (for ν_μ -> ν_s down to about 10%)
- Direct measurement of atmospheric ν vs anti-ν
  - CPT Violation

The MINOS Detectors

- Far Detector (Soudan Underground 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
  - **980 ton total mass**





The NuMI Project

- 1.0 The NuMI Facility
  - 1.1 Technical Components
  - 1.2 Civil Construction
  - 1.3 Project Management
- 2.0 The MINOS Detectors
  - 2.1 Steel and Coils
  - 2.2 Scintillator Systems
  - 2.3 Electronics, Trigger and DAQ
  - 2.4 Far Detector Installation
  - 2.5 Near Detector Installation
  - 2.6 Project Management
- 3.0 Other Project costs
  - 3.1 Detector R&D
  - 3.2 Consceptual Design
  - 3.3 Cavern Construction
  - 3.4 Project Support

- CD-1 Approval of Mission Need
  - 3/17/1997
- CD-3a Start Limited Construction
  - 2/15/1999
- CD-2 Approve Baselines
  - 2/17/1999
- CD-3b Continue Construction
  - 5/21/1999
- CD-4 Start Operations
  - **2/4/2005**

MINOS Detector Construction

WBS	Description	Baseline Cost	DOE		UK
			FNAL	Sub-Contract	
2.1	Magnet : Steel & Coils	7,621	7,522	99	
2.2	Scintillator Detector Fabrication	19,525	4,637	12,431	2,457
2.3	Electronics, DAQ & Database	9,069	3,476	2,778	2,815
2.4	Far Detector Installation	4,581	324	4,257	
2.5	Near Detector Installation *	5,074	4,992	82	
2.6	MINOS Project Management	1,658	1,560	98	
	Total	47,528	22,511	19,745	5,272
	* RBI SB&O		2,590		

MINOS Project is a very successful model of collaborative effort between the Laboratory and University sub-contractors.

As of February 29, 2004 MINOS Construction Project was 98% costed with $677K estimate to complete and $3796K contingency

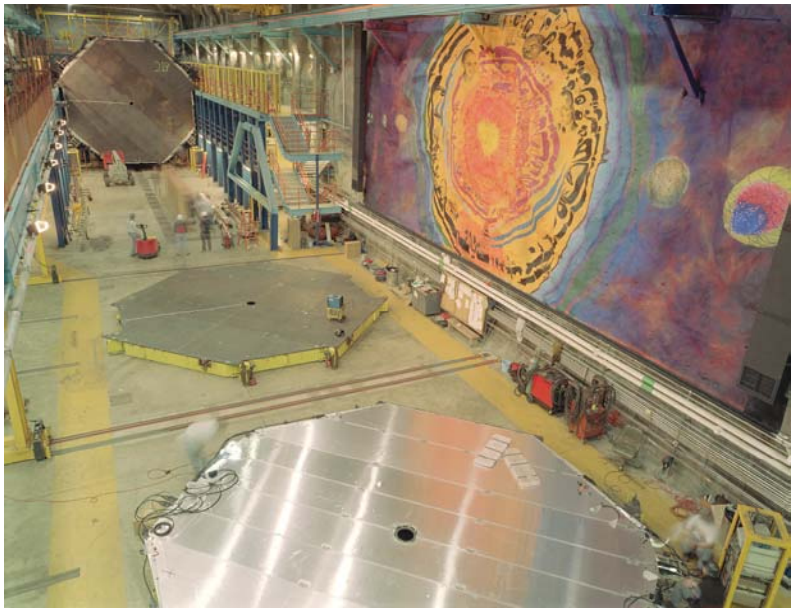
The MINOS Collaboration

190 physicists; 29 institutions

Argonne • Athens • Brookhaven • Caltech • Cambridge • Campinas • Fermilab
College de France • Harvard • IIT • Indiana • ITEP-Moscow • Lebedev • Livermore • Minnesota-Twin Cities
• Minnesota-Duluth • Oxford • Pittsburgh •
Protvino • Rutherford • Sao Paulo • South Carolina • Stanford • Sussex • Texas A&M
Texas-Austin • Tufts • UCL • Western Washington • Wisconsin

MINOS Far Detector Construction

Building a ship in a bottle



Installation begins July 2001

Construction completes July 2003

Two magnetized Super-modules operate routinely collecting Atmospheric Neutrino Physics Data

MINOS Near Detector Construction

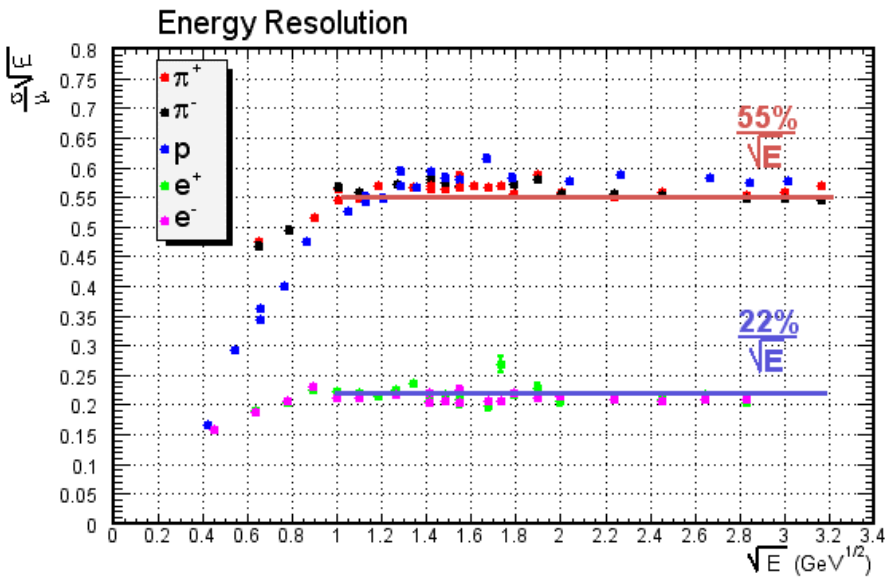
- All components ready for installation
  - –Planes & electronics (New Muon)
  - –Magnet Coil (D0)

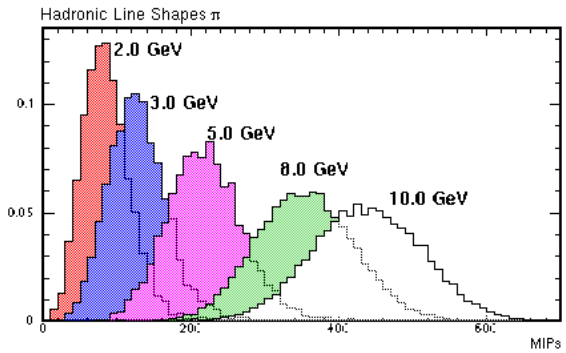
Installation : April 2004 - December 2004

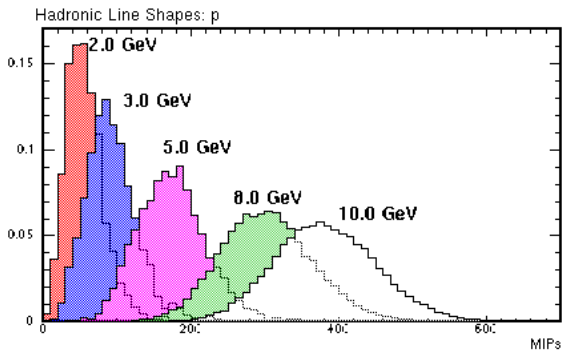
MINOS Calibration Detector

Three runs in CERN T7 and T11 beams

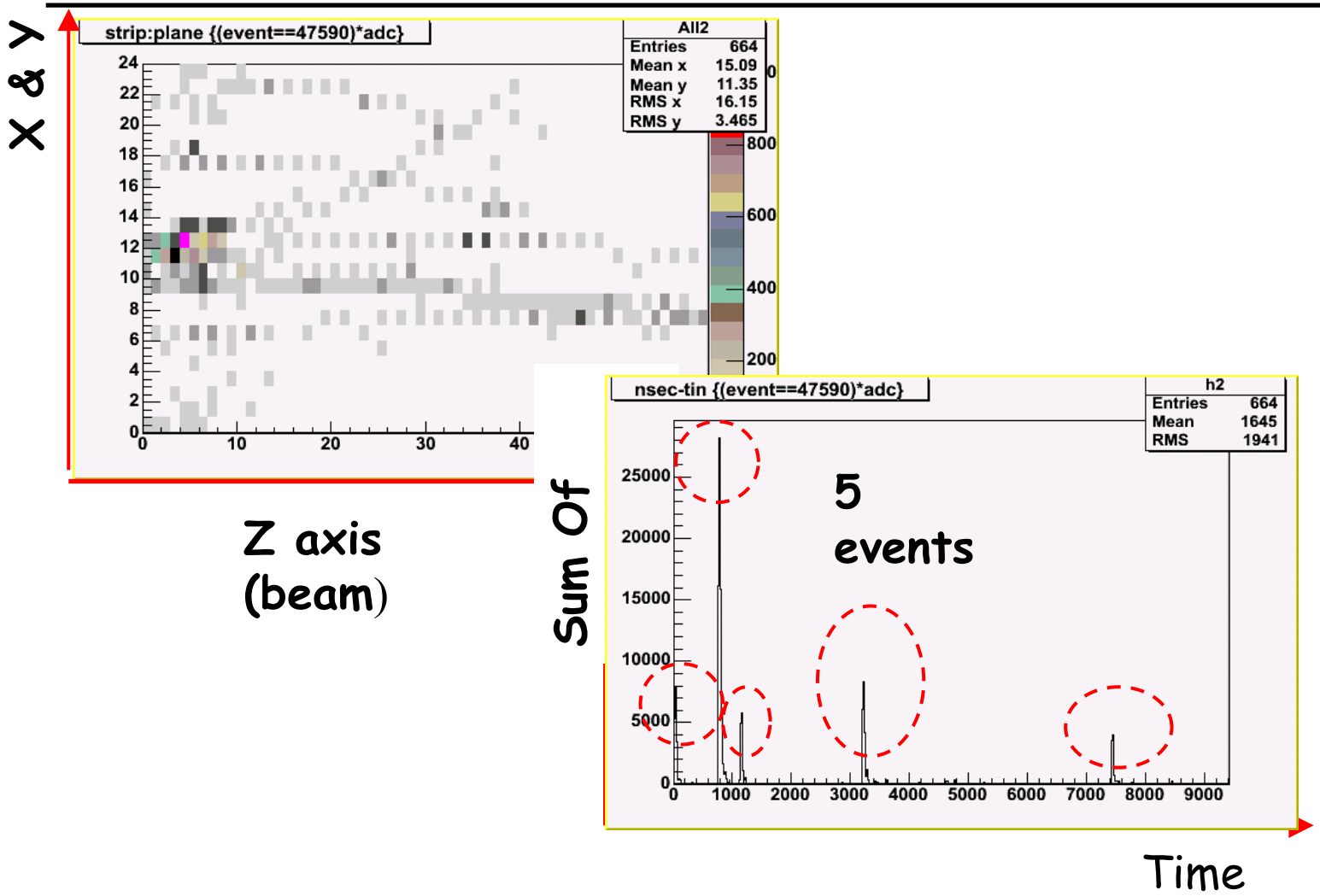
- –2001 June, July, Oct FD electronics shake down
- –2002 Summer : Far Detector calibration; Near Detector Shakedown
- –2003 Summer, October : Near Detector calibration; Near/Far Comparison



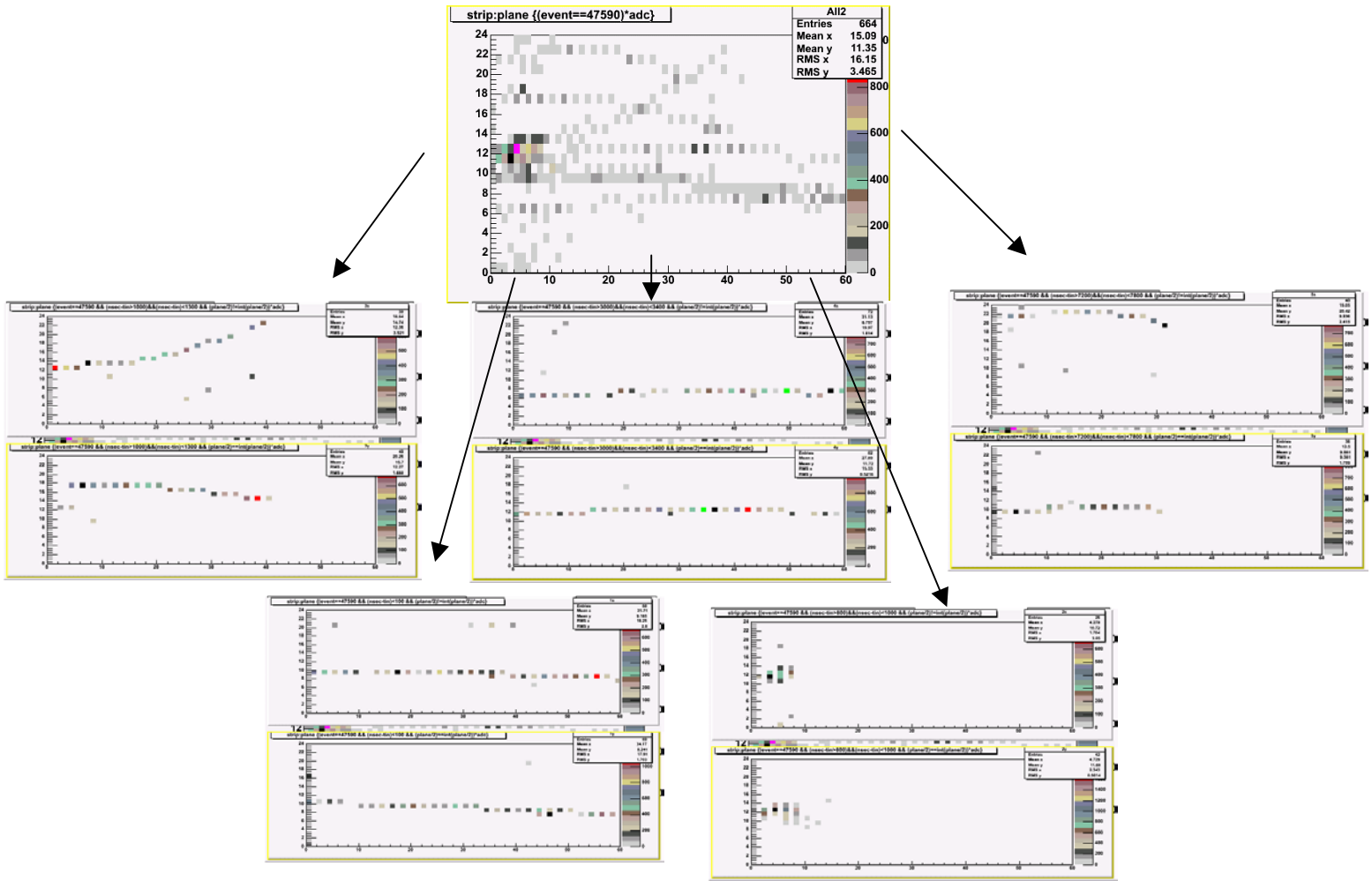




Caldet Events with ND Electronics



Near Detector Event Slicing



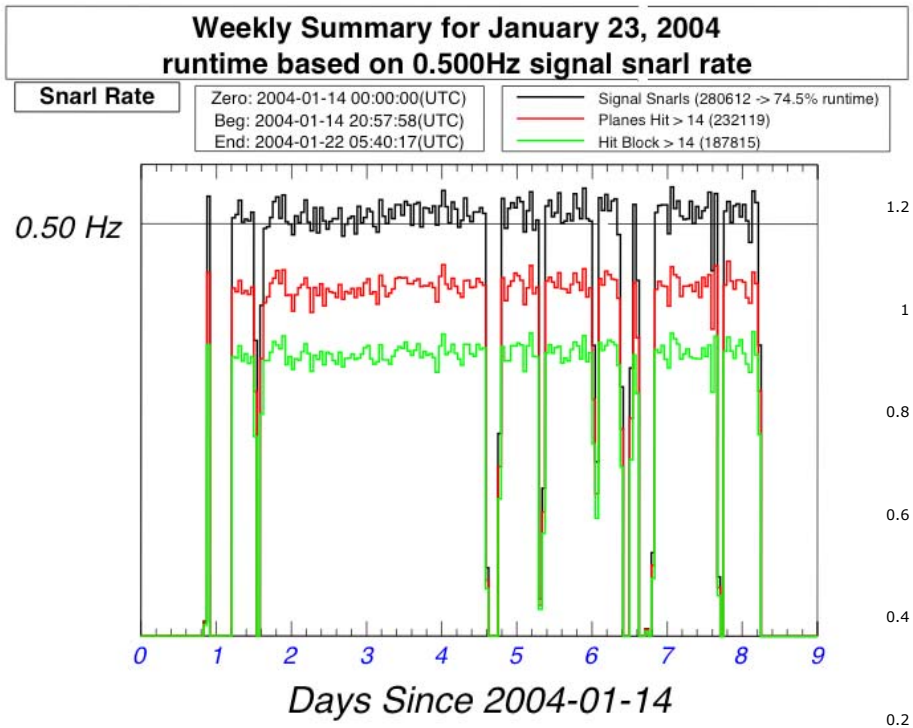
MINOS Project
Transition to Operations

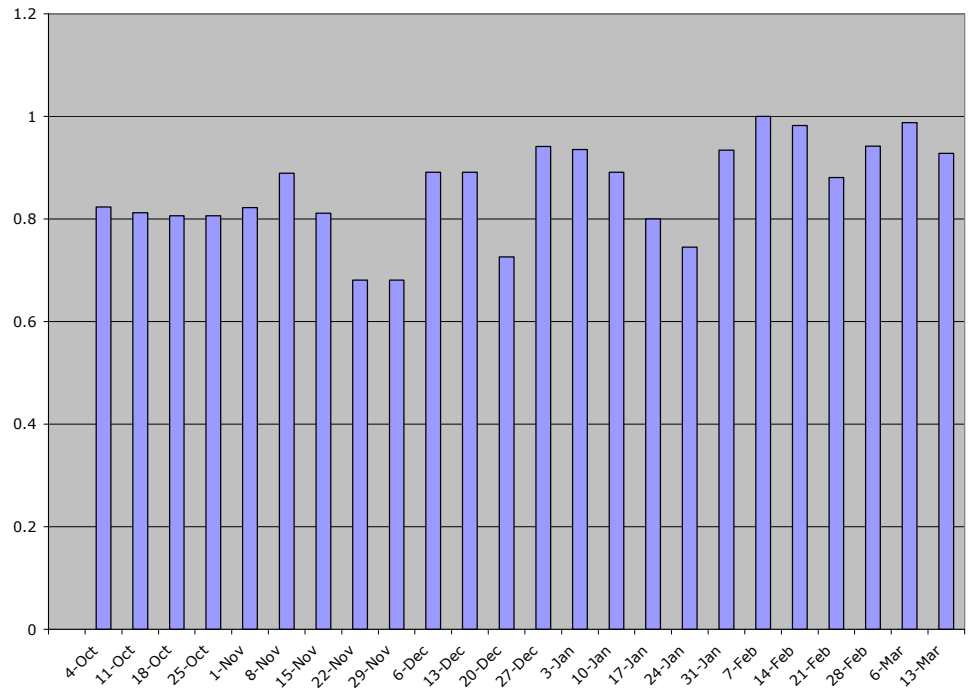
- Soudan Laboratory
  - Funding
    - Begin ramp up in FY01
    - All support from operating budget in FY04
  - Operations
    - Minecrew + visiting physicists underground Monday-Friday 7:30 am - 5:30 pm
    - Surface Building for evenings and weekends
    - Shift leaders house for evenings and weekends
    - 24/7 on-call for access (driven by CDMS need)
- Fermilab
  - Funding
    - Begin ramp up in FY04
    - All equipment funds expended by Q1 of FY05
  - Operations
    - Wilson Hall 12th floor control room (no control room at Exp Hall)
      - Monitors and controls Far Detector (evenings and weekends)
      - Commission and Operate Near Detector
- Remote Operation
  - DAQ, trigger, light injection control and development from Rutherford Lab and U of Sussex

Far Detector Operations 2003 - 2004

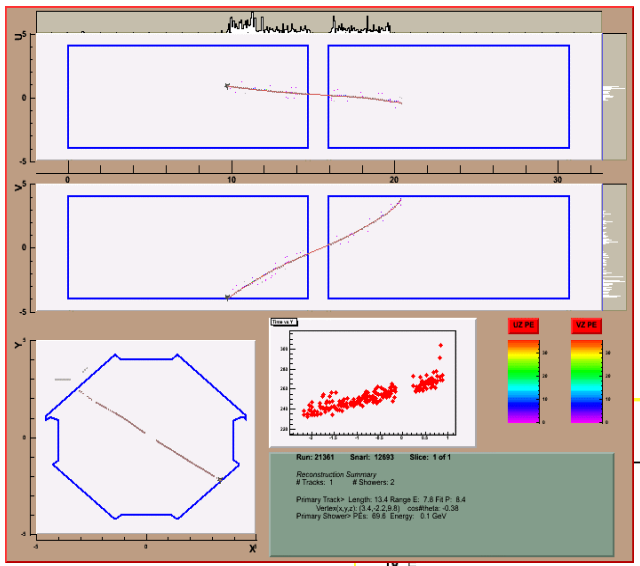
- Atmospheric Neutrino data
  - SM1 only : 131 days; Sept 02 - May 03
  - SM1 + SM2 : 92 live days; July 03 - Nov 03
  - SM1 + SM2 ; Dec 03 - Mar 03 weekly up time increasing from mid-80% to ~95%
- Through November
  - 14 candidates for SM1,
  - 32 candidates for SM1+SM2
  - For full detector, expect ~ 375 total
  - events over 5 years with SK oscillation parameters

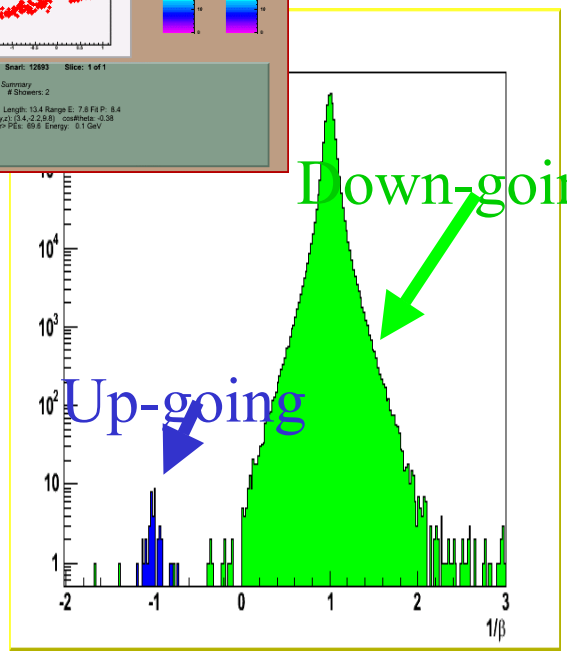
Far Detector Up-time





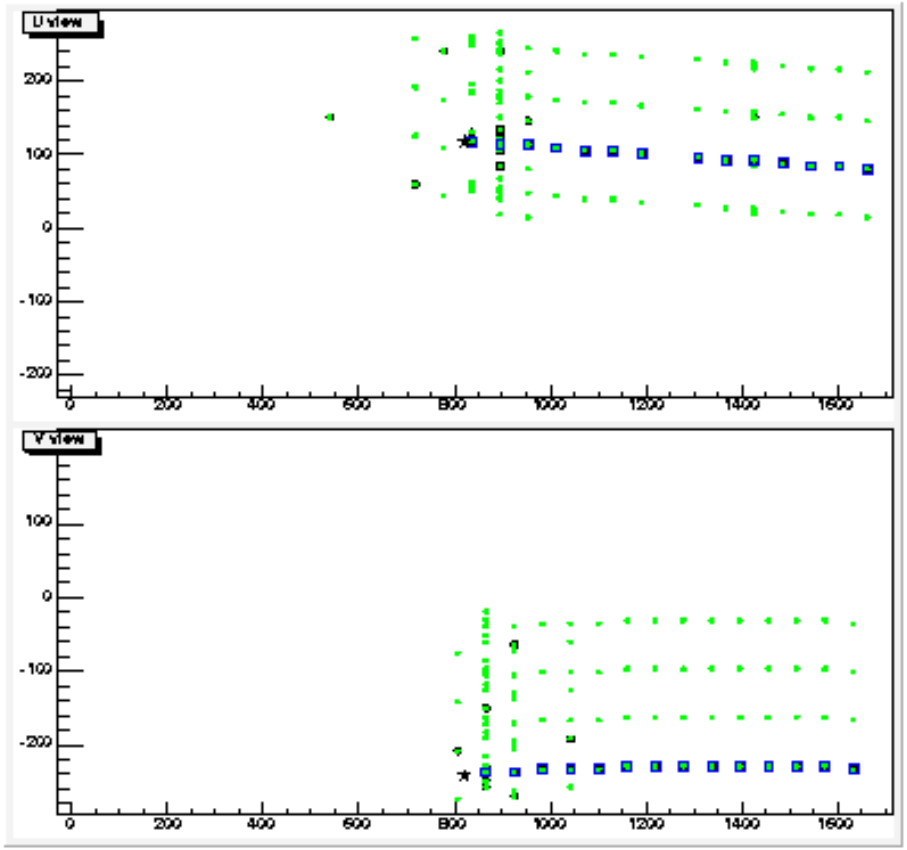
Upward going muons





- Good timing is essential to find up-going candidates
- Look at 1/β (=c/v) distribution to see how well timing system performs
- Determine 1/β by fitting straight line to time vs integrated path length for each hit
  - Timing is largest error, so put it in the numerator
- Expect peak of down-going events at 1/β = 1
- Tight distribution indicates good timing resolution – 2.6 ns for detector
- Peak at 1/β = -1 represents up-going events

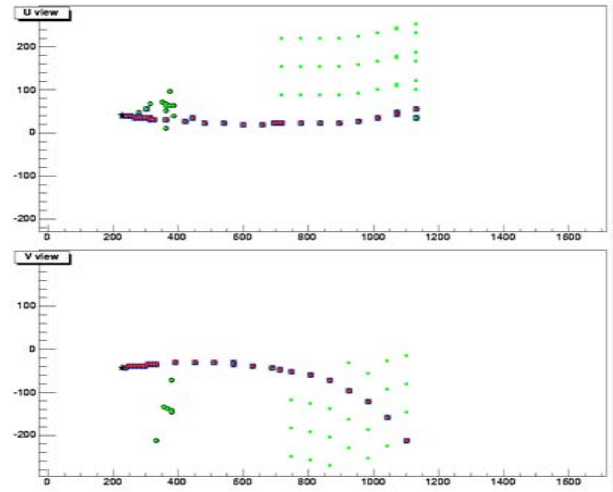
Near Detector Event Reconstruction



Near Detector is composed of three regions : Veto, Calorimeter, Spectrometer. Electronics in the spectrometer are multi-plexed giving a challenge for event reconstruction.

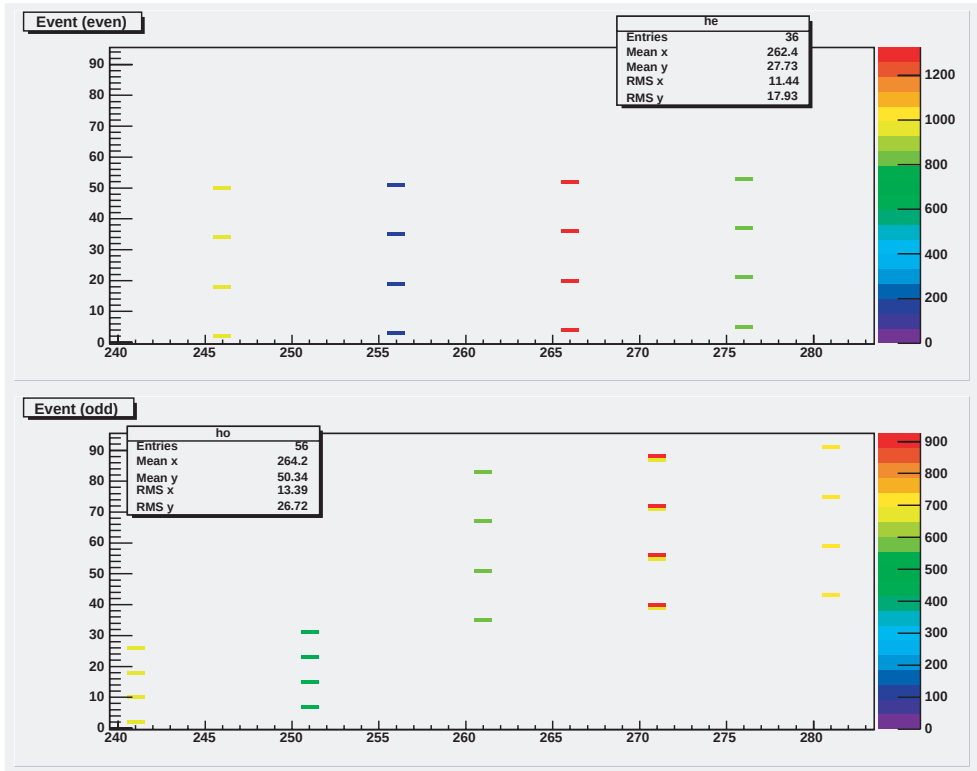
More than half of the neutrino events in the Near Detector will occur in the spectrometer region or very close to it where any weighting scheme is actually meaningless (in the spectrometer region we will, most of the time, have four identical 2D solutions with no way of identifying the true one).

First ND Readout

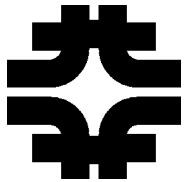


Monte Carlo

Data from 9-plane New Muon Commissioning

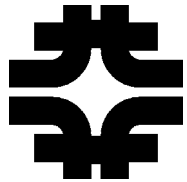


Commissioning Goals



Parameter	Measurement	Commissioning Goal	Status
Cosmic ray muons detected in MINOS Near Detector	Near Detector data readout through DAQ system	Majority of the 153 Near Detector planes sensitive to muons	
Near detector neutrino flux	Charged current event rate in 1.5 ton fiducial region	Observe neutrinos in the Near Detector produced by the NuMI beam	
Cosmic ray muons and atmospheric neutrinos detected in each of the MINOS Far detectr Super Modules	Far Detector data read out through DAQ system	Majority of the 484 planes of the Far Detector sensitive to muons and atmospheric neutrinos	DONE!

Conclusions



- Goals for FY04-FY06
  - Complete NuMI/MINOS construction and commissioning
  - Begin data taking with NuMI beam and get first physics results
  - Establish high efficiency, quality operations for both Near and Far Detectors centered at Fermilab
- Challenges
  - Complete construction safely
  - Regular physicist visits to Soudan to complete documentation and procedures
    - post-docs move on
    - Soudan is remote
  - CD4 is just the beginning...