Status of MINOS experiment

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Preview

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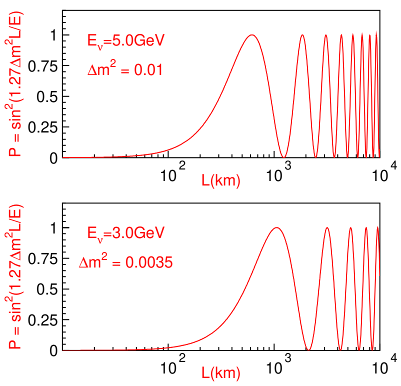
MINOS Physics Goals

- **A next generation long baseline neutrino accelerator experiment**

  - Explore the region of oscillation parameter space suggested by atmospheric neutrino experiments (SuperK, Soudan2, MACRO)

- **Match flux and efficiency to the region of the first oscillation maximum**

  - Check the oscillation interpretation through spectral measurements. Obtain improve measurements of oscillation parameters, Δm^2, $sin^2 2\theta$



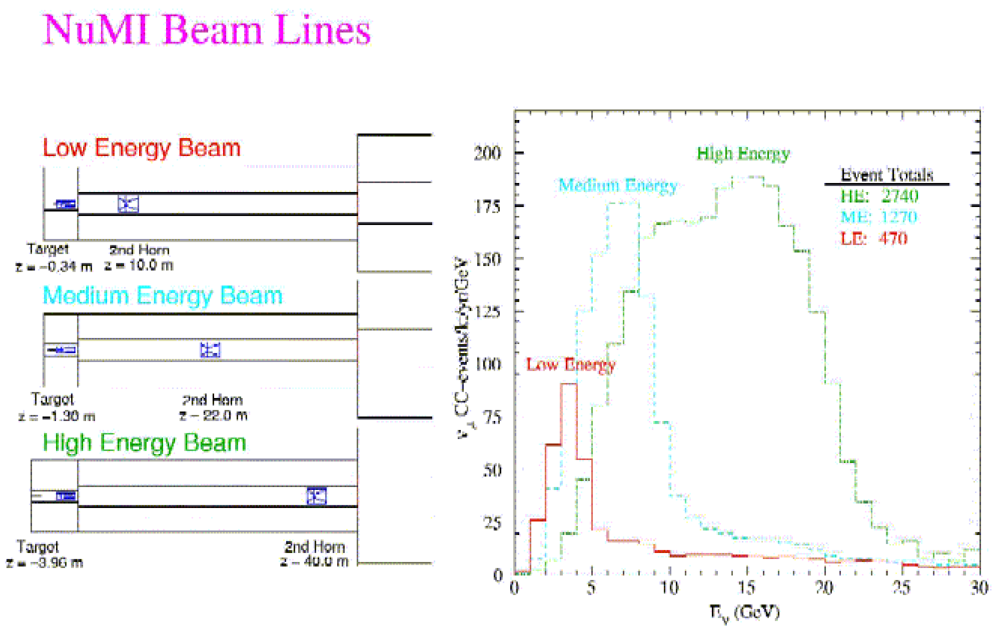
- **Determination of relative strengths of different oscillation modes**

MINOS detectors and NuMI Beam

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

- Near Detector: 980 tons, Far Detector:5400 tons

NuMI Horn Configurations and Beam Spectra



- Initial running in the Low Energy configuration. Expect $\sim$ 2500 CC events per year (no oscillations)

NuMI Status

- **Status of Excavation:**

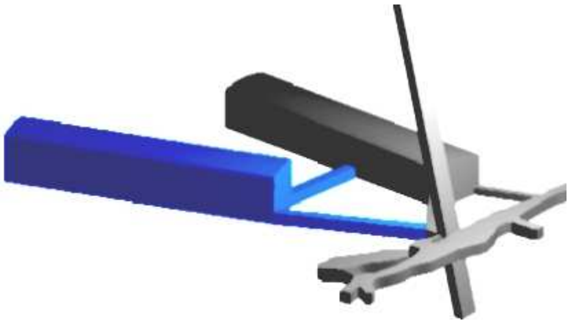
- Proton carrier tunnel completed
- Target hall and drifts completed
- Both shafts completed
- Drift to ND hall completed
- Decay volume 65% excavated

- **Prototype horn 1 in operation for 2.2×10^6 pulses**

- It meets mechanical and magnetic specifications

Soudan Underground Laboratory

MINOS Far Detector Cavern



- Excavation was completed in December 2000
- Facility outfitting was completed in July 2001
- Detector installation is under way

MINOS Detectors

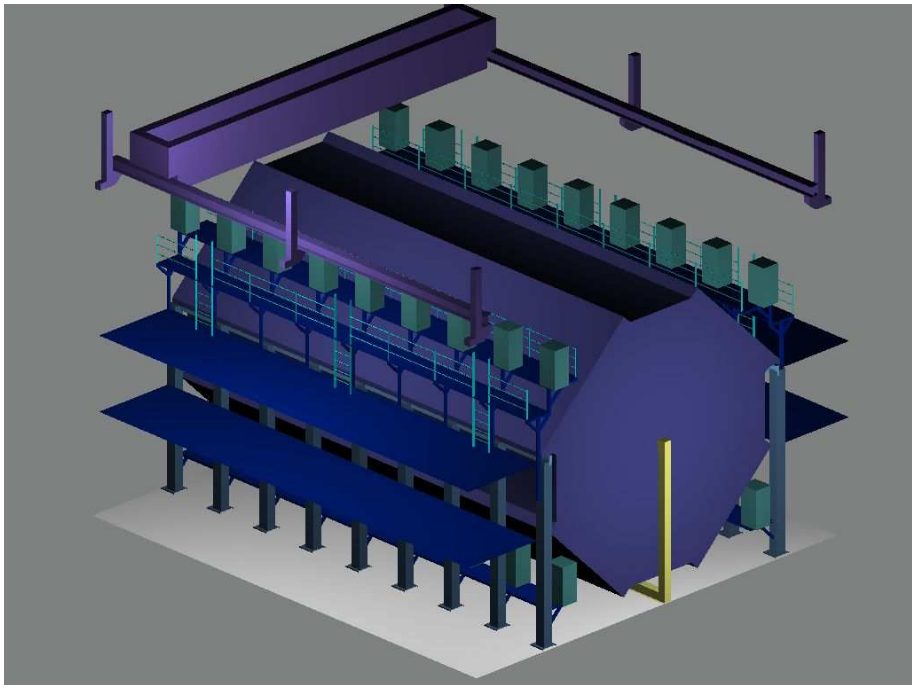
Basic Ingredients of MINOS Detectors

- **Fine grained Iron/scintillator sampling calorimeters**
- **2.54 cm thick Steel absorbers with toroidal B-field of $\approx$ 1.3T**
- **1cm thick, 4.1 cm wide scintillator strips**
- **1.2 mm diameter WLS and clear fiber**
- **Multi-Anode PMTs, M16(Far) and M64(Near)**
- **Front end Electronics and DAQ**

Both detectors have 2D views for Tracking

The detectors are designed to be as similar as possible but can not be identical!

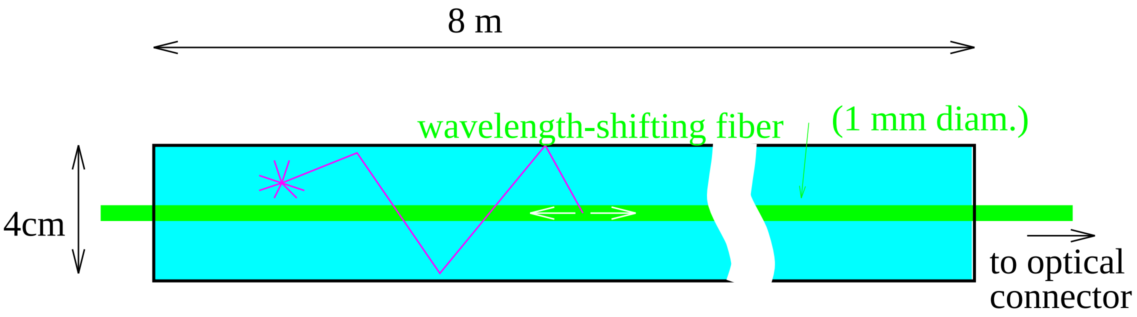
MINOS Far Detector



- 8m octagonal tracking calorimeter
- 486 layers of 2.54 cm Fe
- Two Supermodules (15m each)
- 1000 km of scintillator, 2000 km of WLS and clear fiber readout (25,800 m^2 of active detector planes)
- Toroidal $<$B$>\approx$ 1.3T. Total mass 5.4 kT
- hadron energy : $\frac{\Delta E}{E} \approx \frac{55\%}{\sqrt{E}}$
- muon momentum : $\frac{\Delta p}{p} \approx$ 12% (by curvature)

Scintillator Strip WLS Fiber Readout

- **Scintillator strips are commercially extruded polystyrene**
  - PPO and POPOP fluors
  - WLS fiber groove
  - Co-extruded TiO_2 reflective cap



1 cm x 4 cm extruded polystyrene scintillator

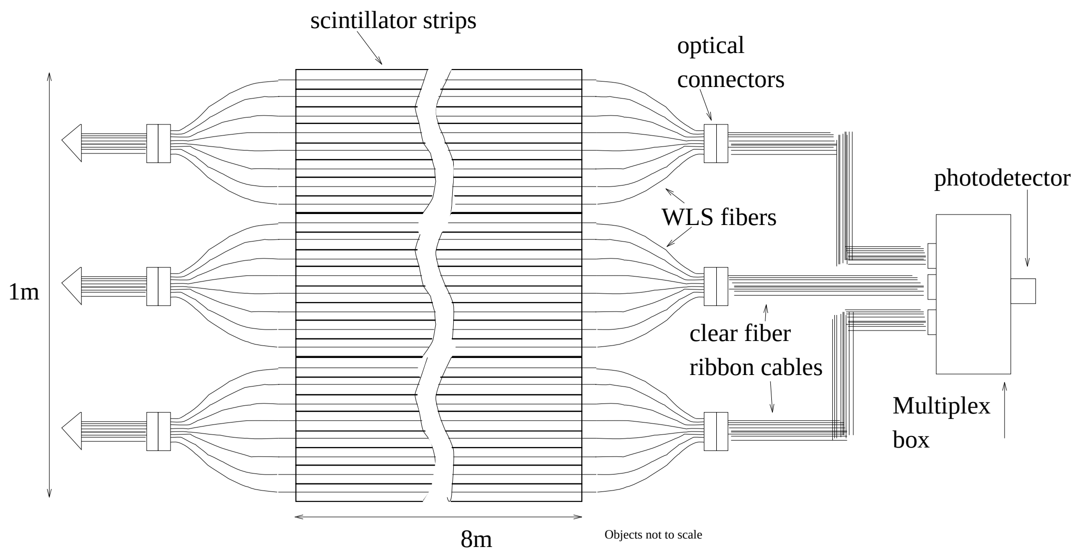
- **Light output: $\approx$ 5–10 p.e./mip.**

$\Downarrow$

Perfectly meets $\frac{\Delta E}{E}$ and muon observation efficiency requirements

Scintillator Readout Schematics

- Groups of 20 or 28 strips are assembled into “modules”
- 2-ended WLS fiber readout
- WLS to clear fiber cables at module connectors
- MUX boxes route 8 fibers to one PMT pixel (M16)
- Custom front-end electronics
- Commercial processors used for DAQ system
- No HW trigger (SW Trigger Farm)



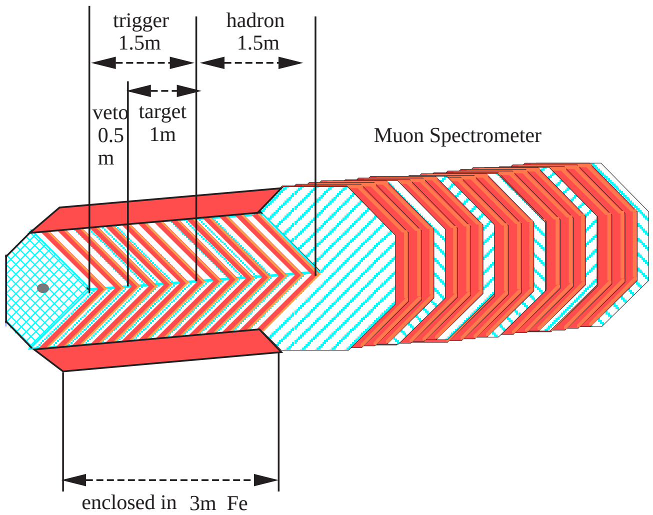
Far Detector Installation started in July

Far Detector Construction Status

- 54 completed planes as of Monday Nov 19 ($\approx$ 11% of the detector, $\sim$ 0.6 kT)
- Construction is on track with our schedule
- Currently installing at $\sim$1 plane/day

MINOS Near detector

- Measure E_ν^{near}, predict E_ν^{far}
- 282 squashed octagon plates. Same plate thickness scintillator thickness and width as far detector. $\approx$17m long Mass = 980 tons



- Trigger/Calorimeter Section: 120 planes
  - 4/5 partial area instrumented
  - 1/5 full area instrumented
- Muon spectrometer section: 162 planes
  - 4/5 uninstrumented
  - 1/5 full area instrumented
- Events used for data analysis have r$<$25cm, $E_\nu^{near} \approx E_\nu^{far}$

Near-Far Detector Differences

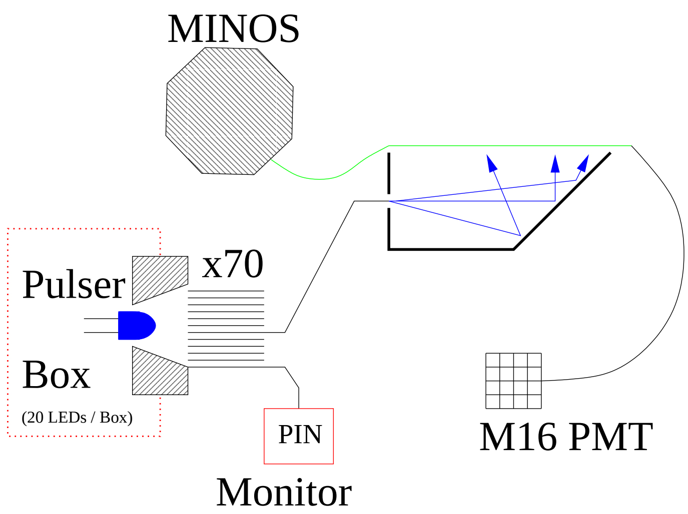
Difference	Near	Far	Comments
Rates (8μs spill)	$\approx$3MHz	$\approx$30Hz	Simulations: not a problem
Electronics	Dead time less 19ns dgts	Sample and Hold	Calibrate in test beam
Readout	Single ended w/reflector	Double ended	Similar light lev Calibrate in TB
Multiplexing	None	8-fold	Simulations: not a problem

Control of Systematics

- Near/Far extrapolation
- Efforts aiming at production expts at CERN & FNAL
- Beam pointing checked by:
- GPS & laser survey
- Checked with ND beam profile, downstream hadron monitors and muon monitors in the absorber pile and rock

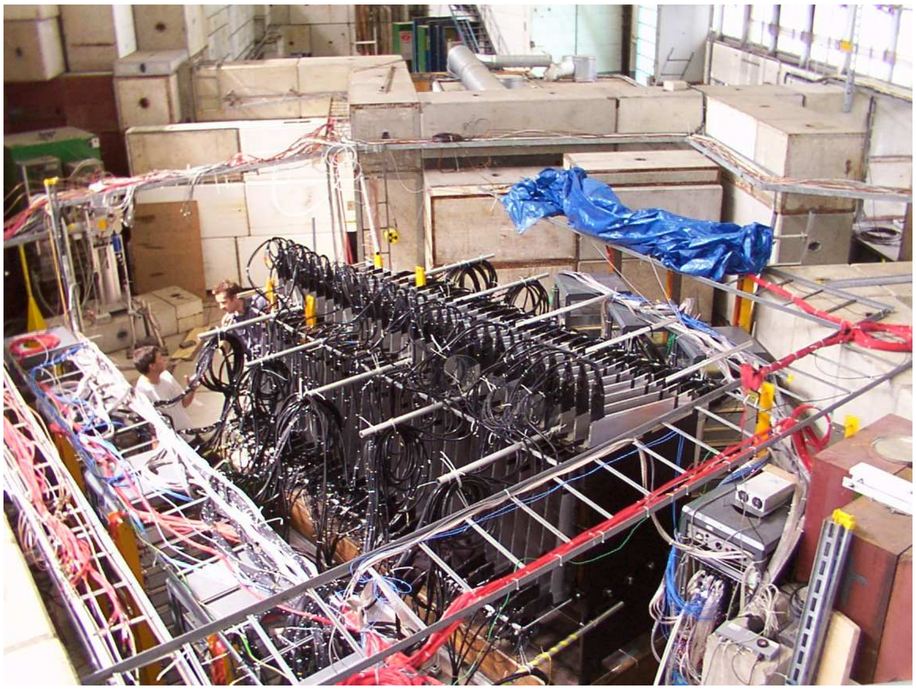
MINOS Calibration

- **To reach claimed accuracy of mixing parameters measurement the energy response has to be calibrated to 5% absolute, 2% Near-Far**
- **LI calibration system based on ultra bright blue LEDs will monitor and compensate for changes in gain and nonlinearity of the PMTs**



- **Cosmic muons are used to perform the strip-to-strip calibration and the relative calibration between ND and FD**
- **Calibration detector:**
  - Compare energy deposition by muons with that from hadron showers
  - Calibrate Near-Far differences in readout

MINOS Calibration Detector

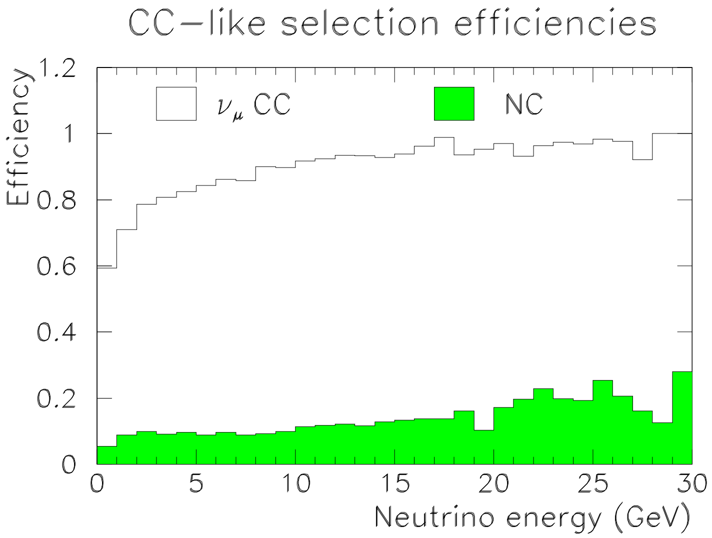


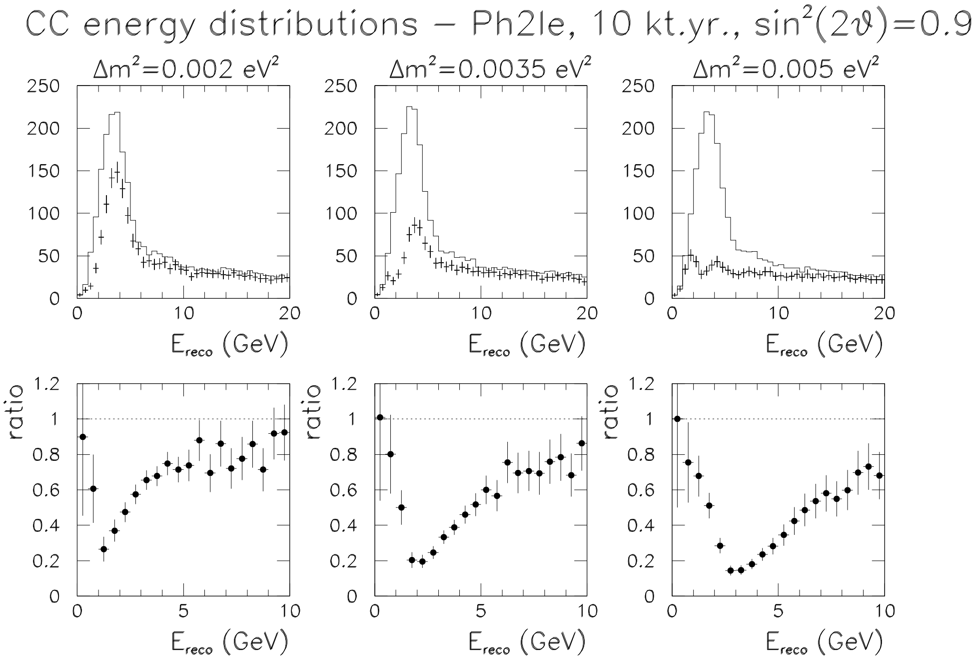
- 60 1m$\times$1m MINOS modules with Far/Near readout electronics
- Built, commissioned and exposed at T11 beam at CERN with Far Detector electronics (2 month exposure)
- Data analysis in progress

MINOS Physics Tools

- **ν_μCC spectrum**
  - Information from both rates and shape. The latter is independent of the near/far normalization
- **NC/CC ratio**
  - independent of the near/far normalization
- **ν_eCC appearance**
  - Use topological criteria: fraction of energy in first few radiation lengths, shower assymetry, etc.
- **Consistency between tests is vital for signal confirmation**
  - Example: Verify dominant $\nu_\mu \to \nu_\tau$ oscillations ν_μCC disappearance with no NC disappearance and no ν_eCC appearance $\Longrightarrow \nu_\mu \to \nu_\tau$

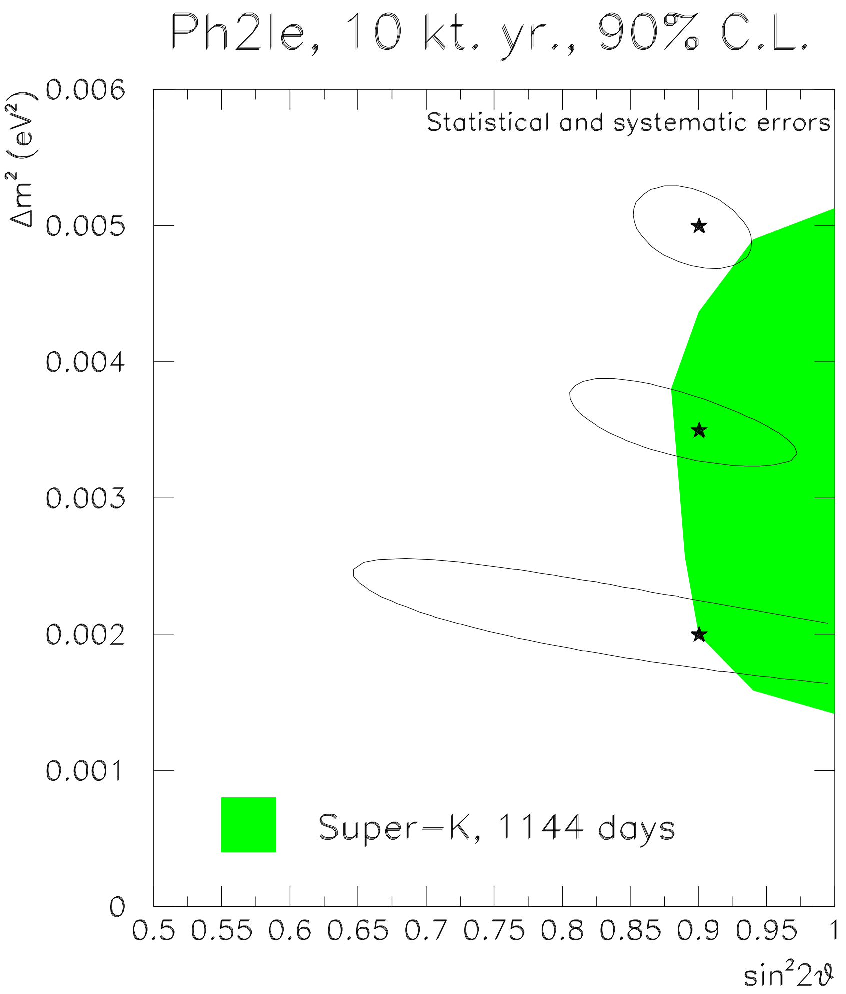
MINOS CC Spectra



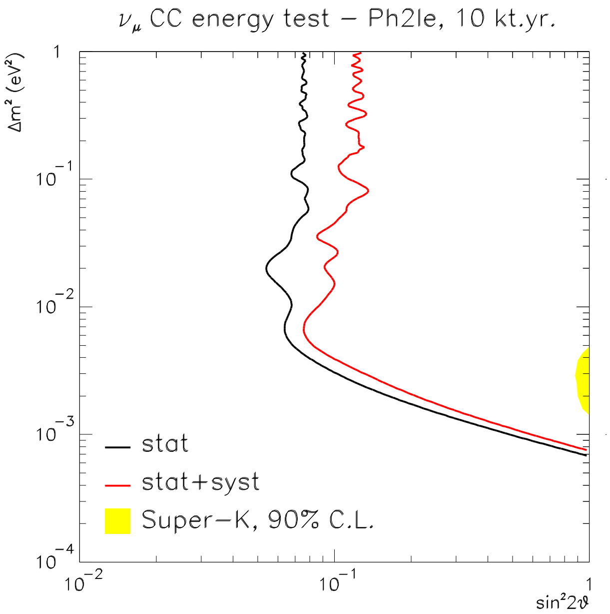


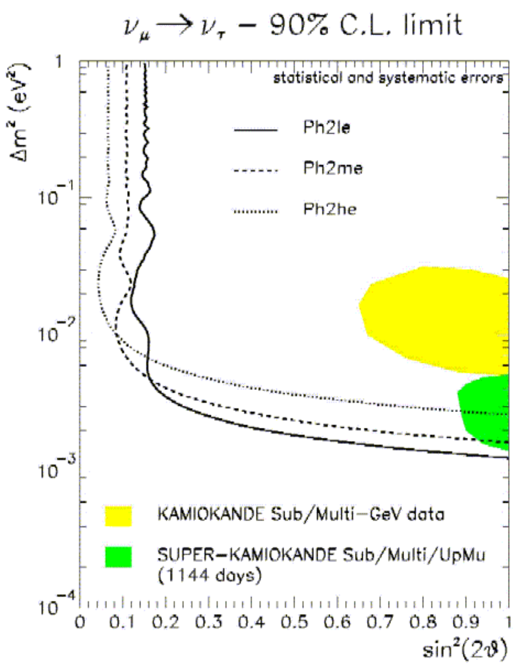
MINOS CC Energy Test Sensitivity

- With high statistics and good efficiencies MINOS will give substantially improved oscillation parameter measurements

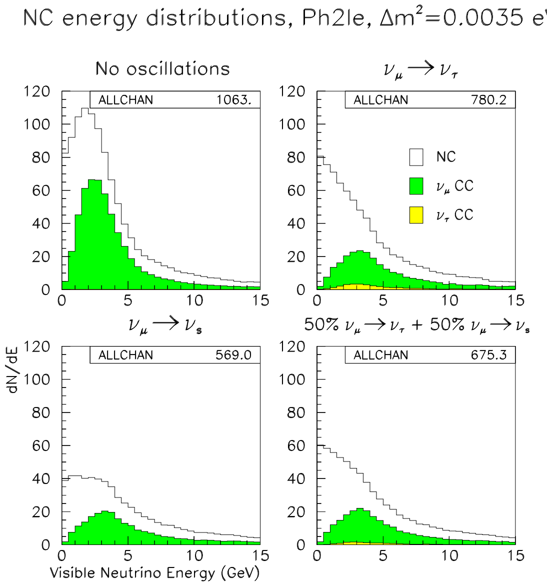


ν_μCC- and T- test limits

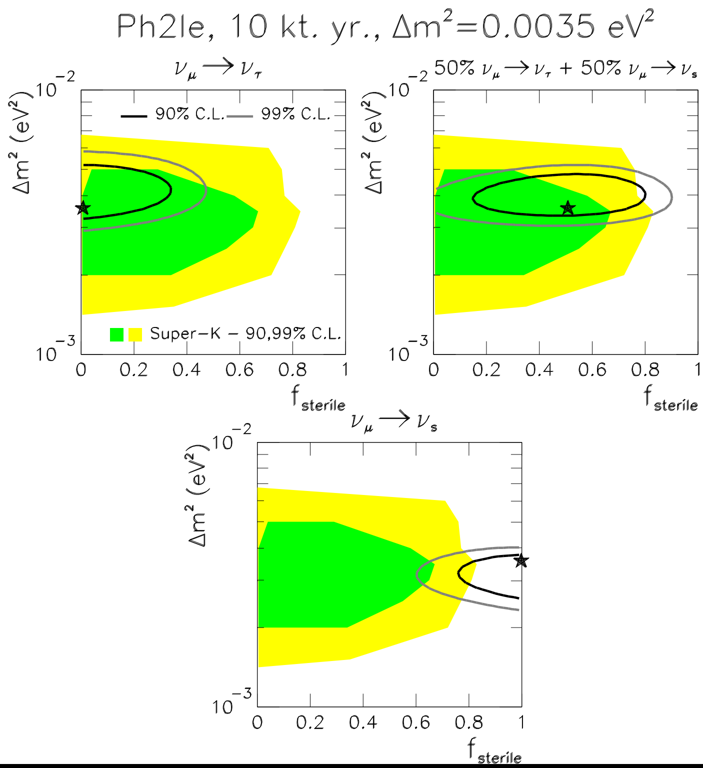




Improving Limits On Other Oscillation Modes

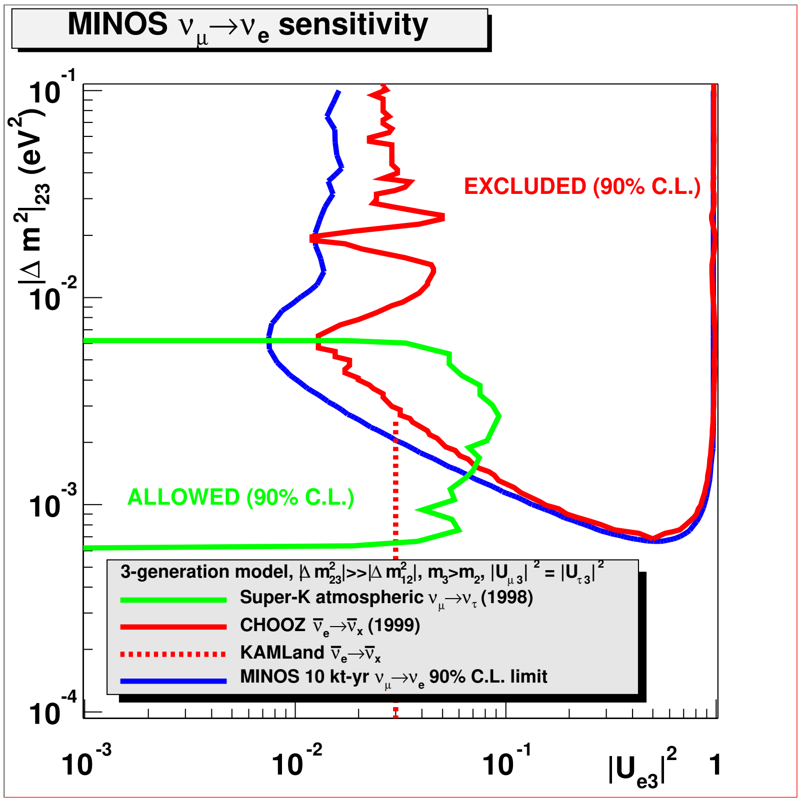


- Spectrum of NC-like events in MINOS gives information on $\nu_{\rm sterile}$
- Analysis of this and disappearance data will improve current limits



Improving Limits On Sub-dominate Mode

- ν_e appearance: Reliable EM shower ID: Analysis uses shower shapes and energies to eliminate backgrounds
- Modest improvement over the current limits (plot for 10kt-year exposure)



Schedule

- **Far Detector installation (2001–2003)**

  - Cosmic rays and atmospheric neutrinos with half the detector (and magnetic field) in summer 2002

  - 10 kt-years by 2005

  - Upward muons and momentum analyzed partially-contained events

- **Near Detector assembly and installation (2001–2003)**

- **Beam line commissioning (2004–2005)**

Summary

- **Last two years saw significant strengthening of evidence for oscillation hypothesis**
- **MINOS will study the oscillation signal with:**
  - High statistics accelerator data
  - Good flavour separation
  - Good control of systematics
- **Good progress is being made in all areas**
  - 11% of the FD installation complete ($\sim$0.6 kT)
  - First calibration data from Soudan and CERN (CalDet)
- **MINOS will offer exciting neutrino physics in the next few years!**