Calibration of the MINOS Detectors Using Stopping Muons

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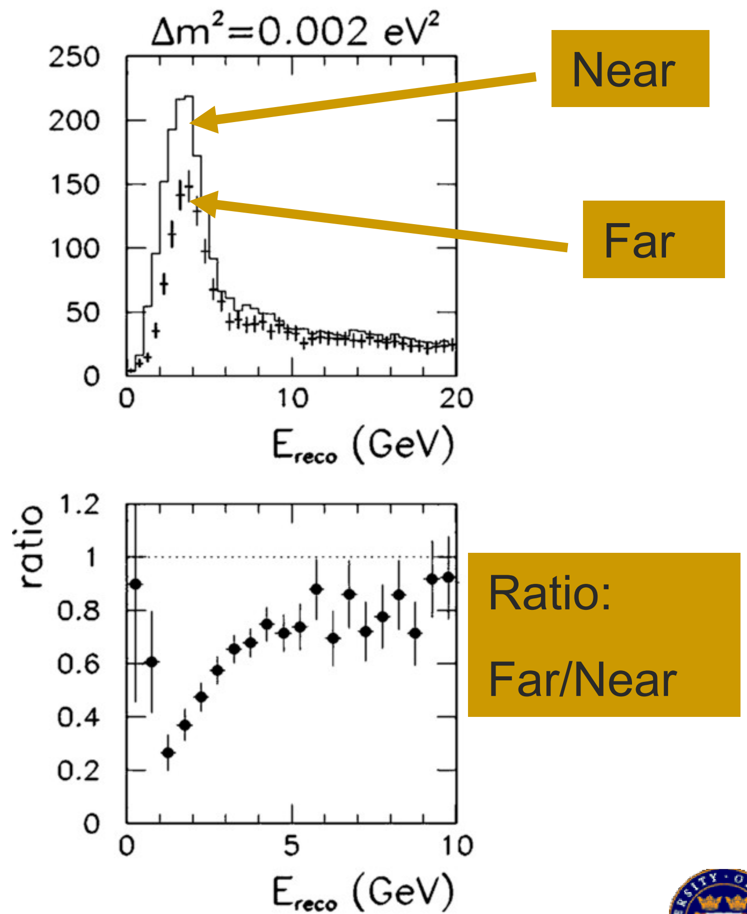
Talk Outline

- The MINOS Experiment
- Near, Far and Calibration Detectors
- Calibrating the Calorimeter
- Stopping Muons: Our Standard Candle

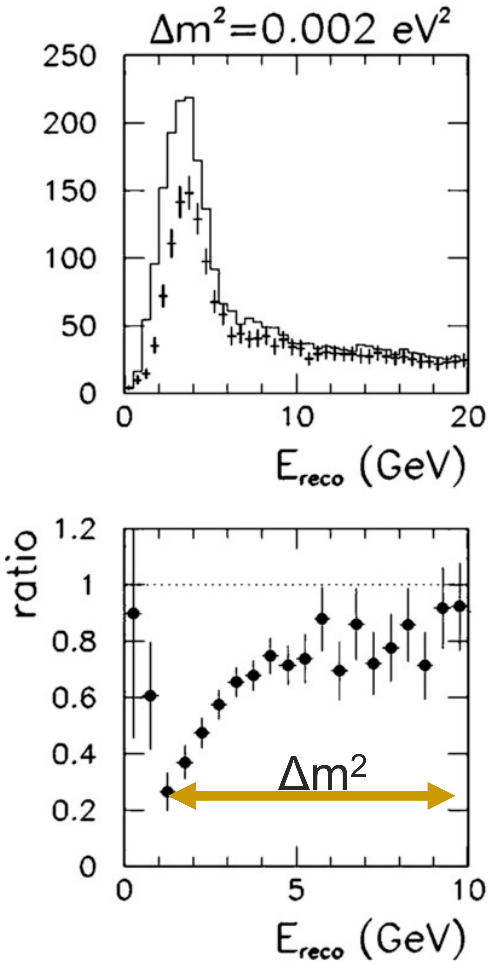
MINOS Neutrino Physics

- Long-baseline neutrino oscillation experiment.
- Compare Near and Far neutrino energy spectra.
- Looking for ν_μ disappearance as a function of energy – “the dip”.
- Very important that we can accurately reconstruct the neutrino energy.



Calibration Targets

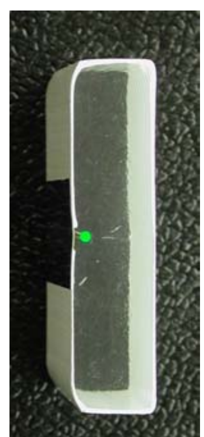
- Will hopefully have statistics for 10% measurement of Δm^2.
- Have a target of 5% for the absolute energy calibration.
- Require that the relative calibration between detectors is 2%.



MINOS Detectors (x3)

- Common features:
  - Alternating steel-scintillator, magnetised, tracking calorimeters
  - WLS fibre-optic cables to extract the scintillator light

Far Detector plane under construction

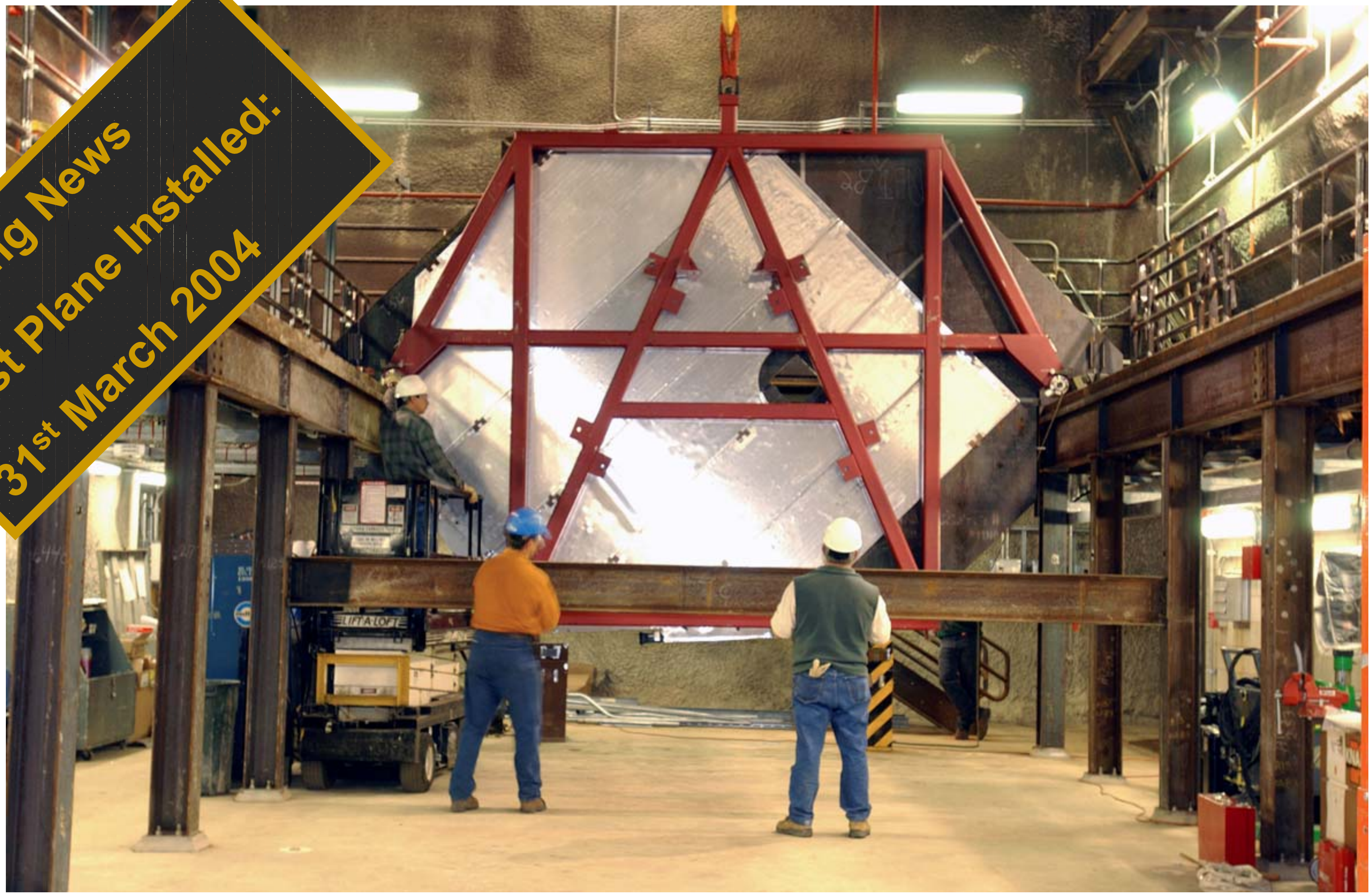


Near Detector

Breaking News

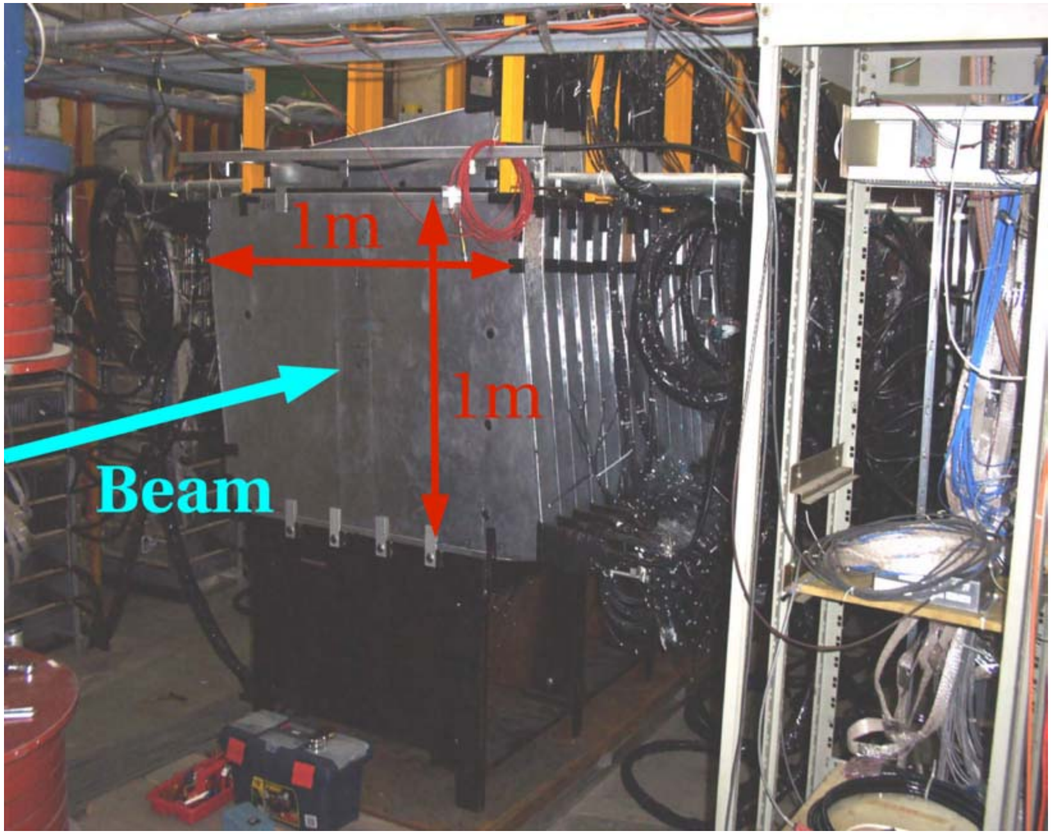
First Plane Installed:

31st March 2004



Calibration Detector at CERN (CalDet)

- Small version of Near and Far detectors
- Exposed to μ, p, e, π beams 0.5-10 GeV
- Hadronic & EM energy response
- Tune the MC



Neutrino Energy Reconstruction

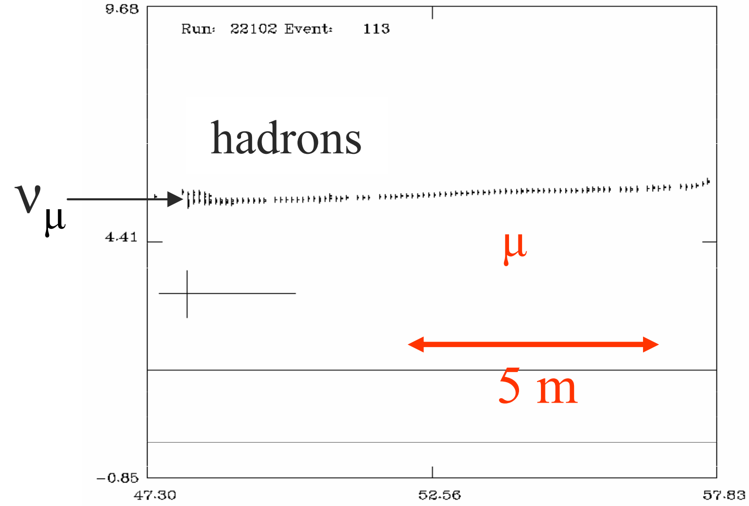
- Need to accurately determine original neutrino energy to see "the dip".

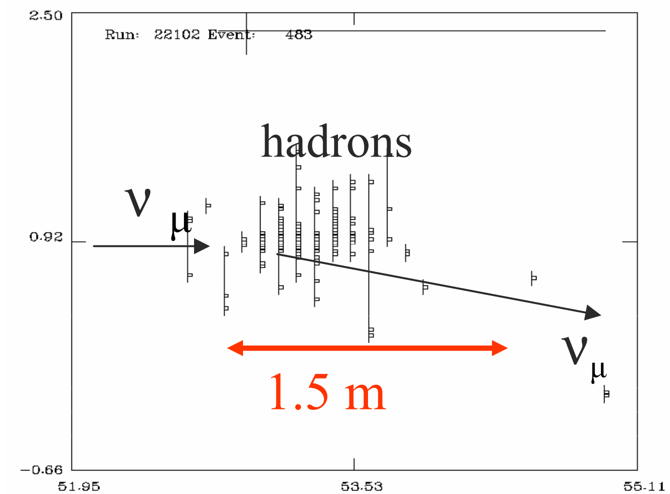
  $E_\nu = E_{Had} + E_\mu$ (Visible)

- E_μ= f(Range) &

  f(B-Curvature)

- E_{Had}= f(Energy Dep.)





Calibrating the Calorimeter

Problems:

Solutions:

- Scintillator output varies by up to 20% from strip to strip. → Normalise using cosmic muons.

- Light output depends on particle type and particle energy. → Measure response with Calibration Detector in MEU/GeV. (MEU=Muon Energy Unit)

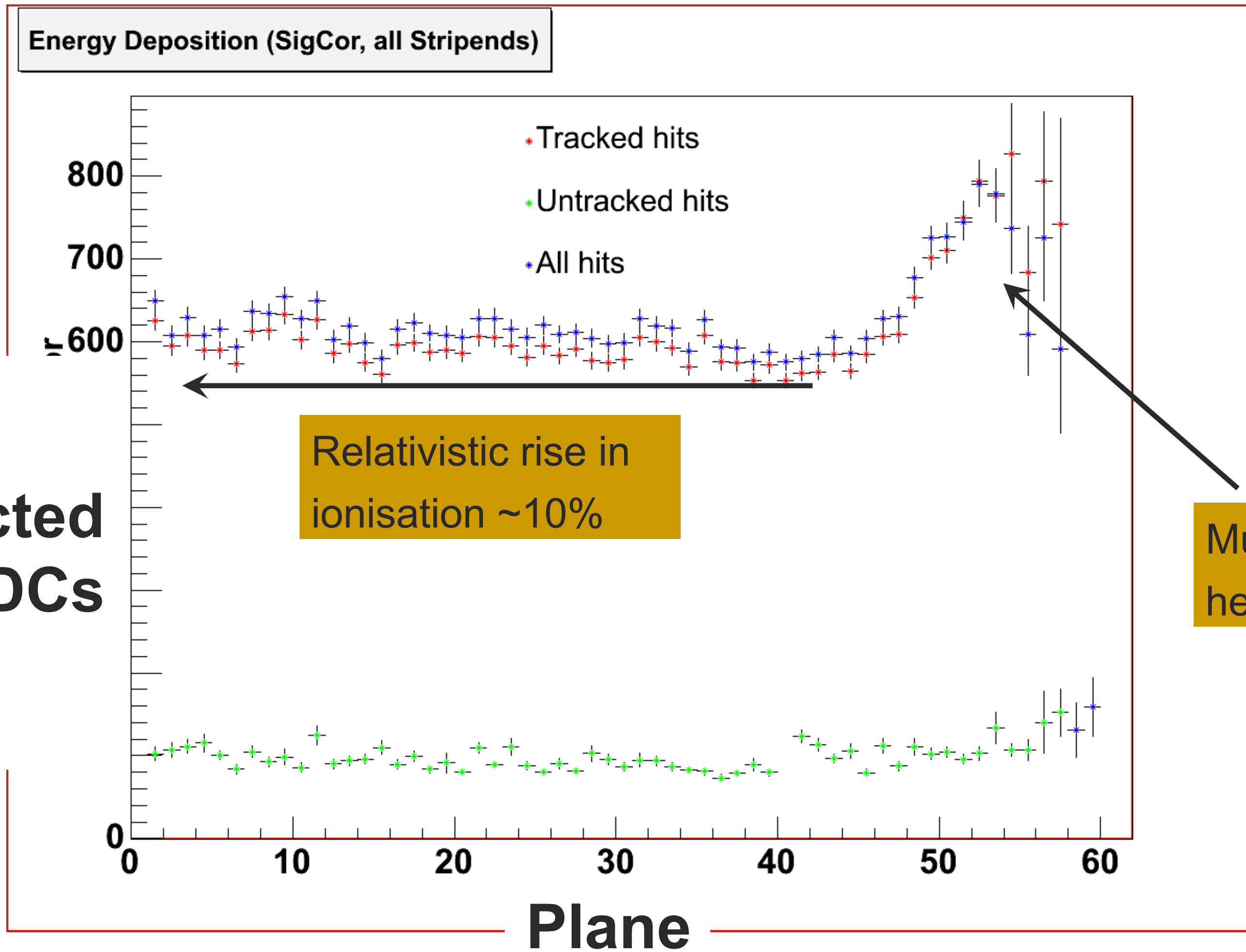
Why Stopping Muons?

- Need a calibration source of known energy - a "standard candle".
- Don't have a "PS" accelerator ½ mile underground to provide beams of particles
- The energy spectrum of cosmic muons (and hence energy deposition) is different for Near and Far detectors and not known accurately enough.
- Working backwards from the end of a stopping muon track you know its energy – Use to define a Muon Energy Unit (MEU).
- Stopping muons are the same at all 3 detectors!

Stopping Beam Muons in CalDet (at 1.8 GeV/c)

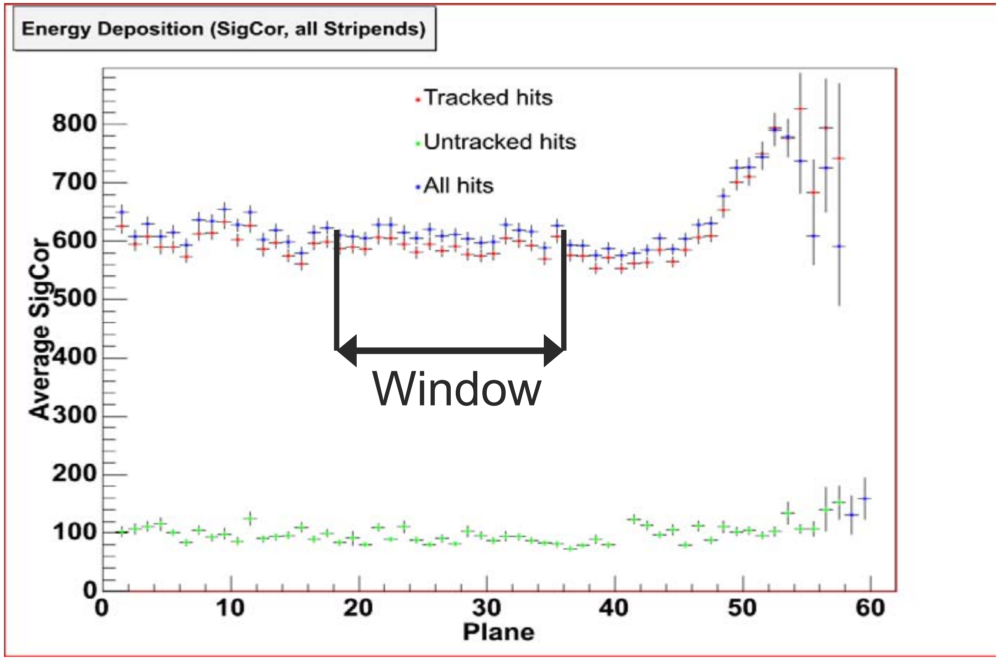
Beam Direction

Corrected ADCs



Track Window Method

- Want a method that is inherently robust and not sensitive to reconstruction problems.
- Sum up the energy deposition in a window.
- Define a Muon Energy Unit (MEU) to be the average energy deposited in the window by a perpendicular muon in one detector plane.



Conclusion

- The main physics measurement requires accurate reconstruction of the neutrino energy to 5%.
- Explained how MINOS has 3 detectors in very different environments. Need to set the absolute energy scale to be the same for each detector.
- No beam source of GeV particles for calibration underground so use stopping cosmic muons.
- Take a window on the stopping muon track to measure the detector response.
- Should enable us to meet our 2% relative calibration target and hence accurately measure Δm^2.

The End!