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What is the Main Injector Neutrino Oscillation Search?
Design & Detectors

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University of Sussex

Erice Neutrino Summer School,
Italy
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Agenda

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This Talk:

1.0 Experiment Overview

2.0 Physics Overview

3.0 Beam, Beam-line and Protons

4.0 Detectors

5.0 Calibration

Summary

Next:

Pedro Ochoa (CalTech) will discuss analysis and results

1.0 Experiment Overview

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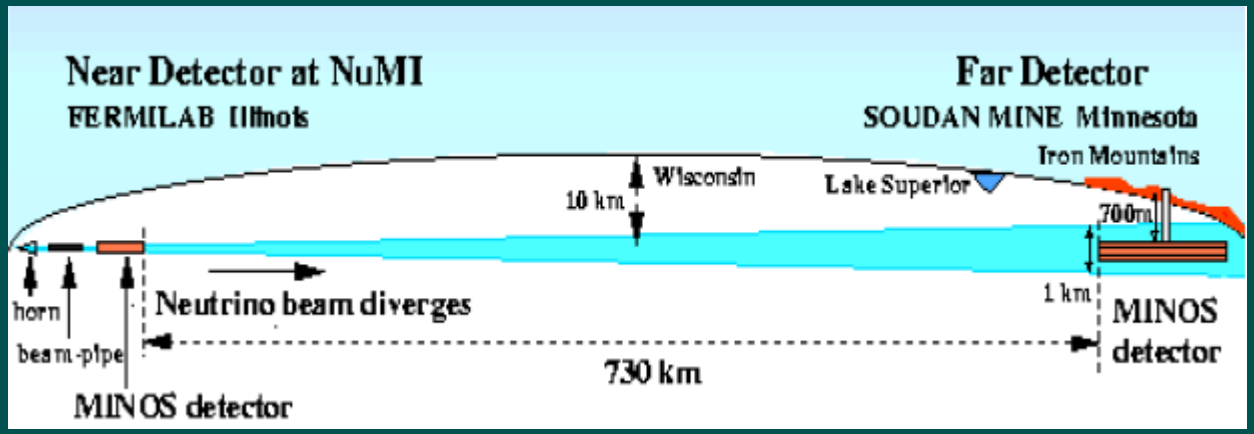
- An accelerator-based long baseline (735 *km*) neutrino oscillation experiment.
- Two “identical”, magnetised, tracking calorimeter detectors:
  - Near (at Fermilab)
  - Far (at Soudan, MN).



1.1 The Baseline

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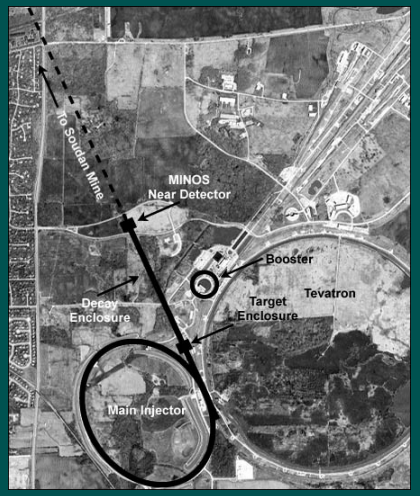
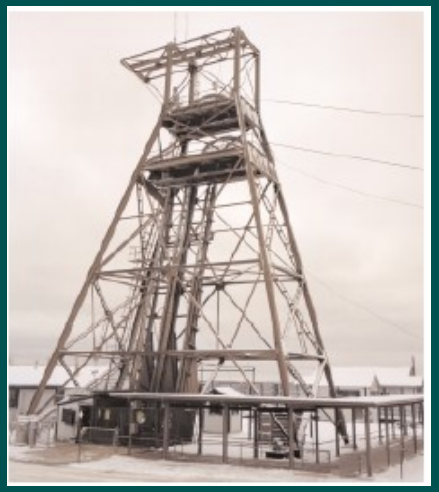
- Source is tuneable-energy ν_μ from the Fermilab's NuMI beam, plus atmospheric neutrinos at the Far Detector.
- Atmospheric neutrinos measured since 2003, beam-phase of the experiment started this March.



$\nu_\mu \longrightarrow$

$\nu_? \longrightarrow$



2.0 Physics Overview

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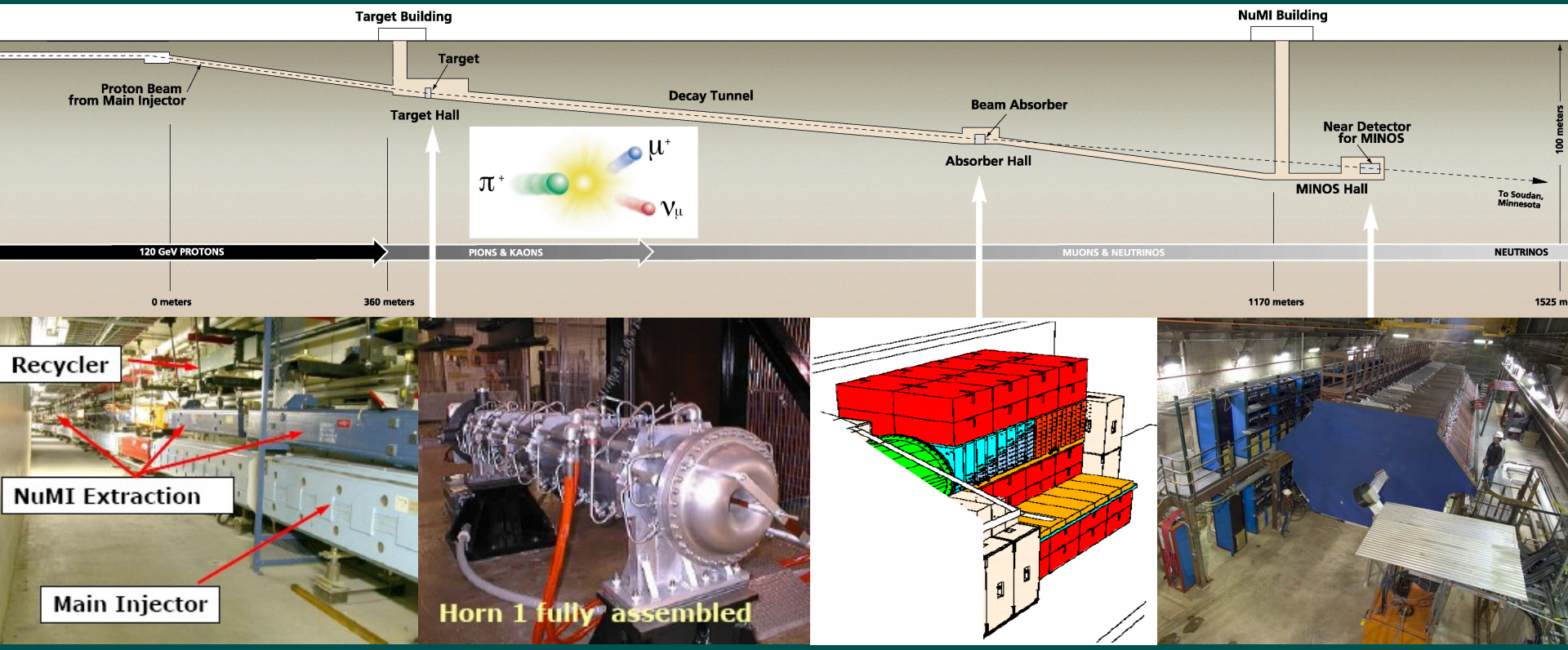
- Neutrino spectrum is compared between “NearDet” and “FarDet” to extract neutrino oscillation parameters in atmospheric and reactor sectors:
  - Precise (~10%) measurement of Δm^2_{23}
  - Verify maximal $\nu_\mu \rightarrow \nu_\tau$ mixing
    - rule-out alternatives such as decoherence
    - study energy dependence of the oscillation
  - Find signs of sub-dominant $\nu_\mu \rightarrow \nu_e$ oscillations
    - looking for ν_e appearance.
- Measurement of CP-violation by comparing ν with *anti-*ν oscillations
    - looking at atmospheric neutrinos and using the magnetic field.

3.0 The Beam-line



120 GeV protons from Fermilab's Main Injector are fired at a graphite target to produce π and K, which are focused by magnetic horns and then decay into ν_μ in the 675m decay tunnel; ~1 *km* from target to detector.

3.1 Protons

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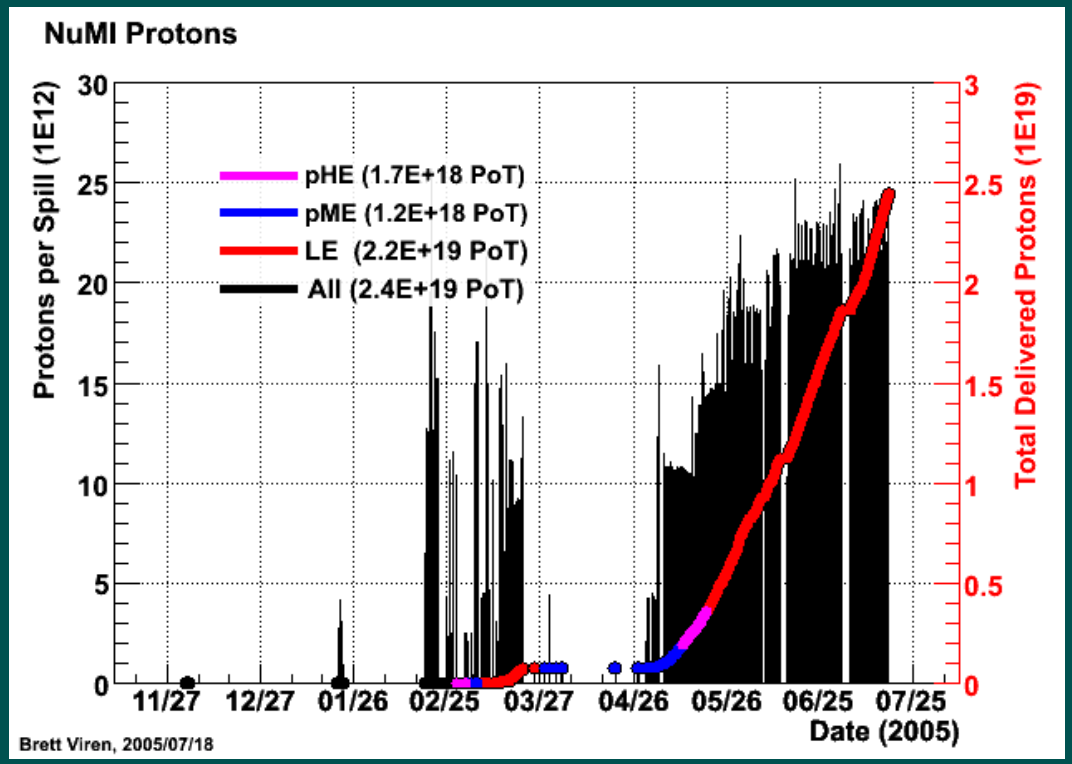
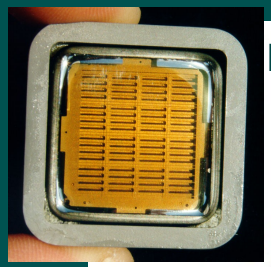
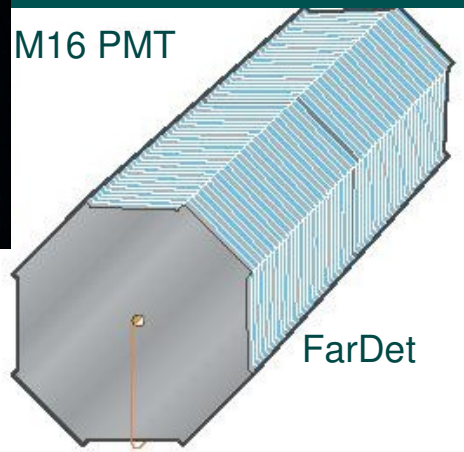
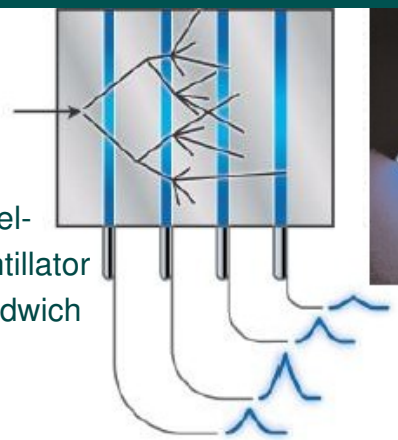
- First neutrinos to MINOS in January 2005
  - Saw first events in Jan at NearDet and March at FarDet
- 3 weeks of down-time in March/April due to target leak, otherwise the beam has been good
- Proton intensity at ~2.1 x 10^{13} */pulse* by July every ~3 *s* in low energy configuration
- Beam-line was tested to as high as 2.5 x 10^{13} */pulse* in Feb (no p-bar)
- Goal is ~2.5 x 10^{13} */pulse* every 2 *s* by the end of the year
  - ~11,000 ν interactions/day in the NearDet.

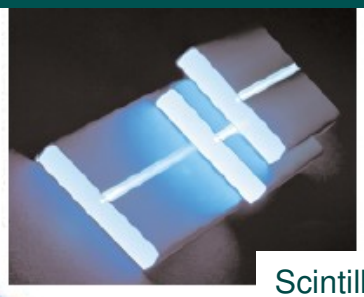


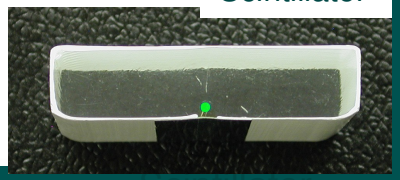
4.0 Detector Technology





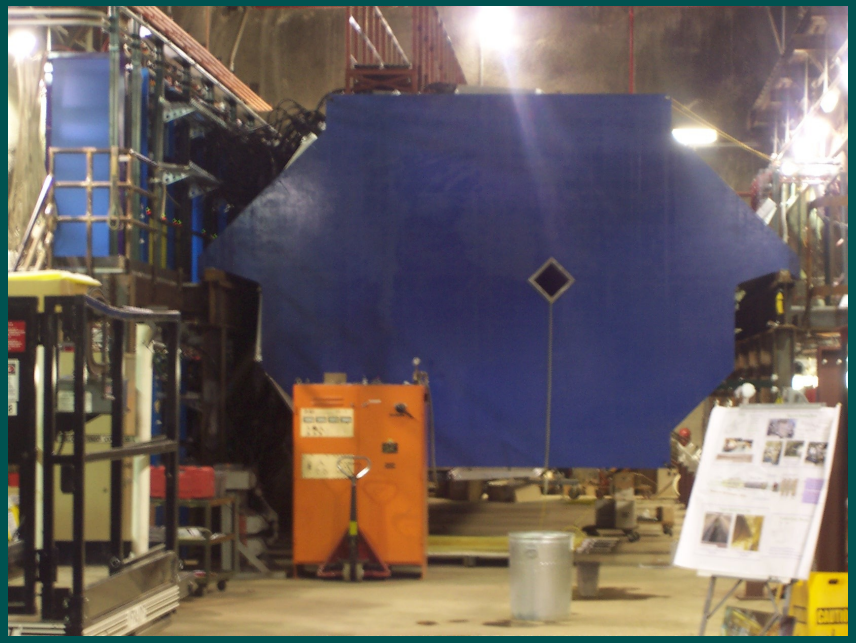


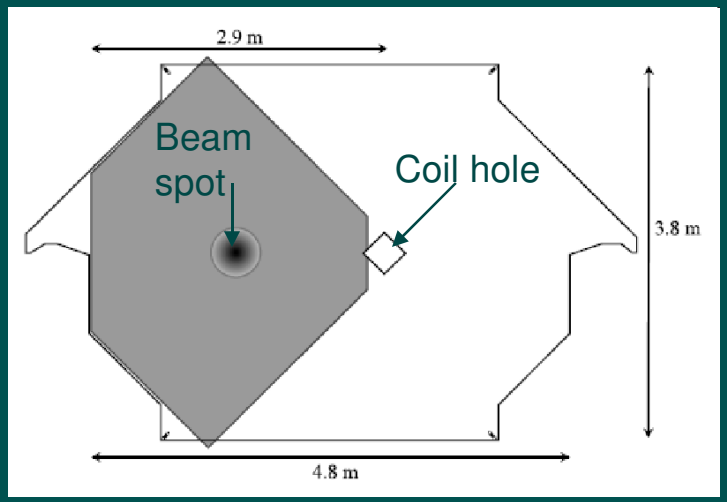


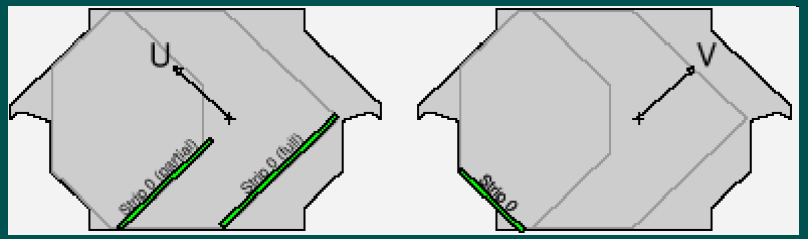


- The detector is built from planes of 1 ” thick steel and 1 *cm* thick scintillator.
- Thickness of each plane is 6 *cm*, including air gap.
- Alternating planes have strips oriented orthogonal to each other.
- Light is collected by wavelength-shifting optical fibres and read-out by PMTs.

4.1 The Near Detector 1







- NearDet is 282 planes long with strips oriented at 45° to vertical.
- The detector has a 1.5 *T* magnetic field, centred at the coil hole.
- The total mass is 1 *kton*.

4.2 The Near Detector 2

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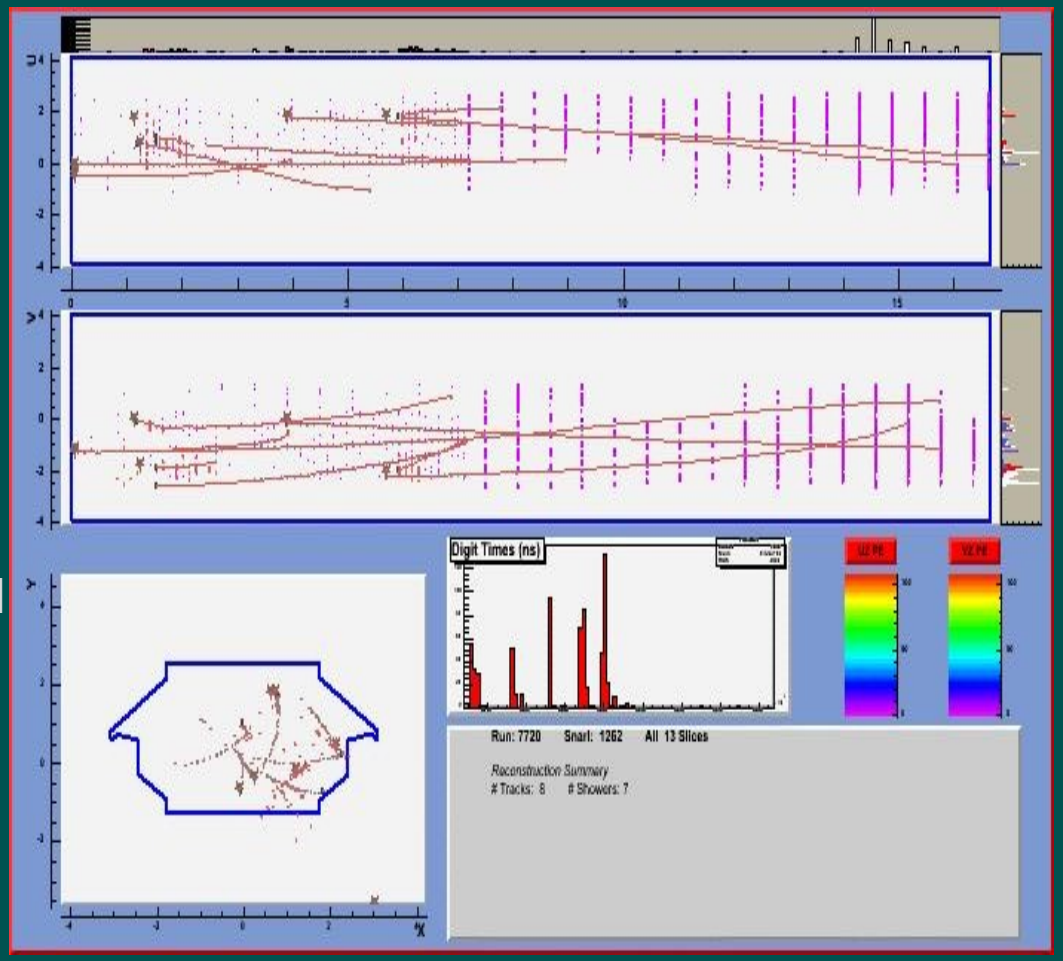
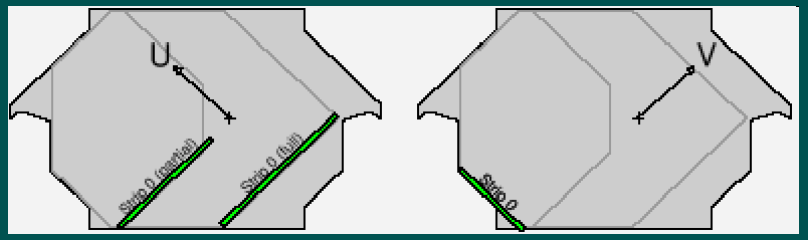
- Every 5th plane is fully instrumented (96 strips).
- The front 120 planes is the calorimeter, where the planes between full planes are partially instrumented.
- Partially instrumented planes have 64 strips.
- The back 160 planes are the spectrometer, where there is no readout between fully instrumented planes.

A High Energy Beam Spill (8 events)





4.3 The Far Detector 1

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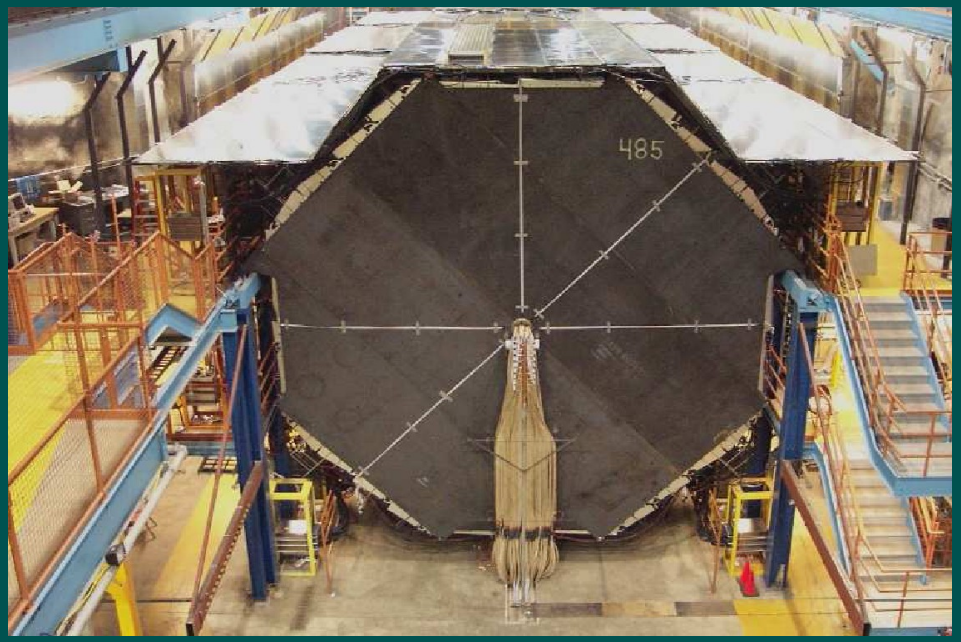

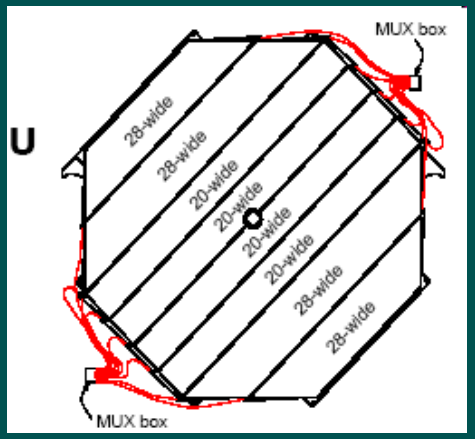

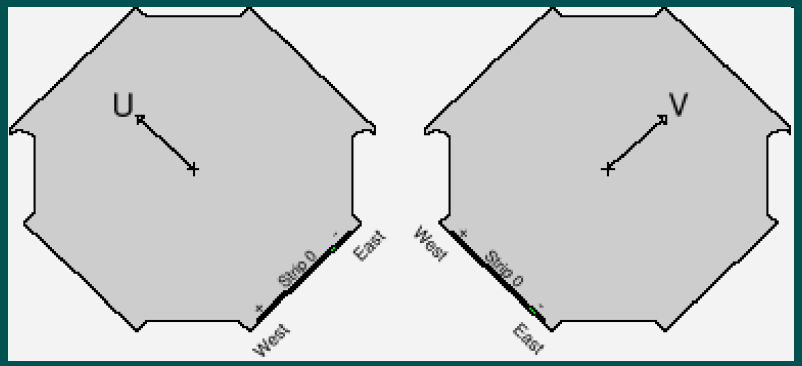

- The Far Detector in Soudan is 485 planes of 192x192 strips.
- It is 8m across and 30m long, with a mass of 5.4 *kton*.
- The magnetic coil producing the 1.5 *T* field runs through the centre of the detector.

4.4 The Far Detector 2

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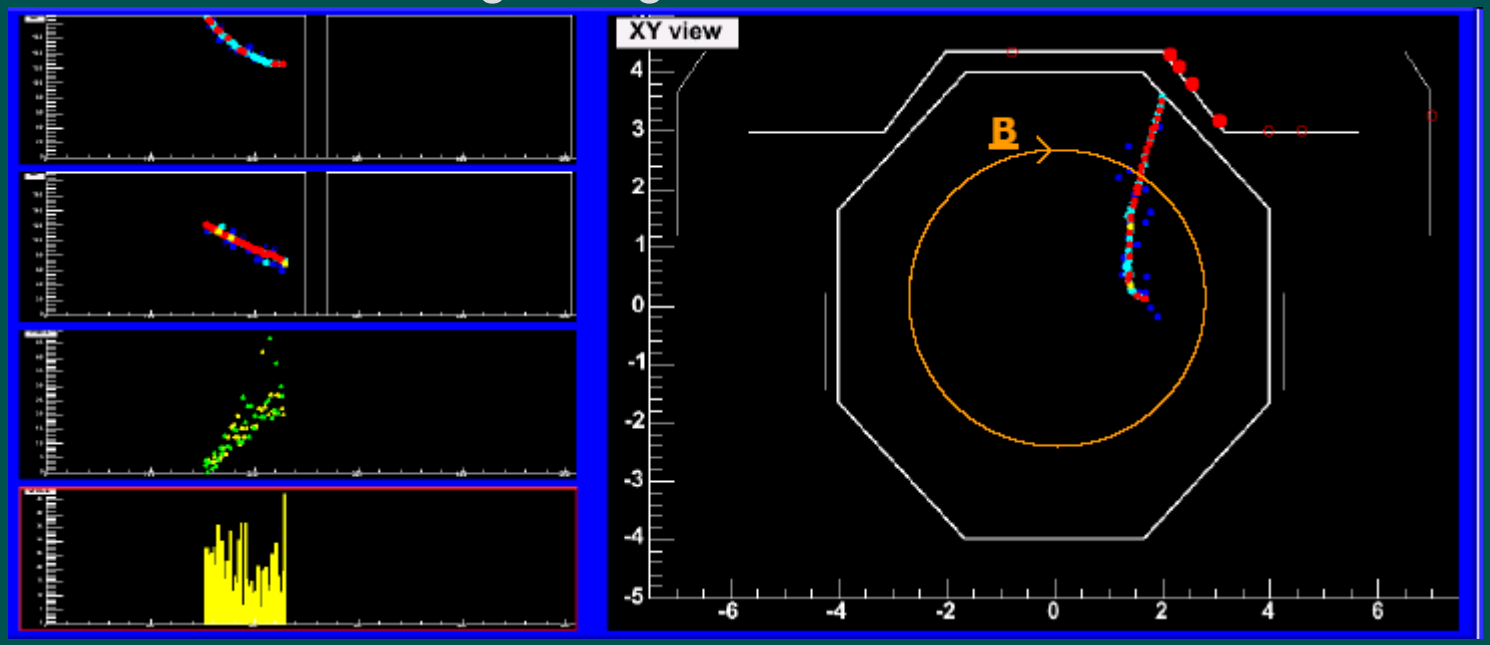
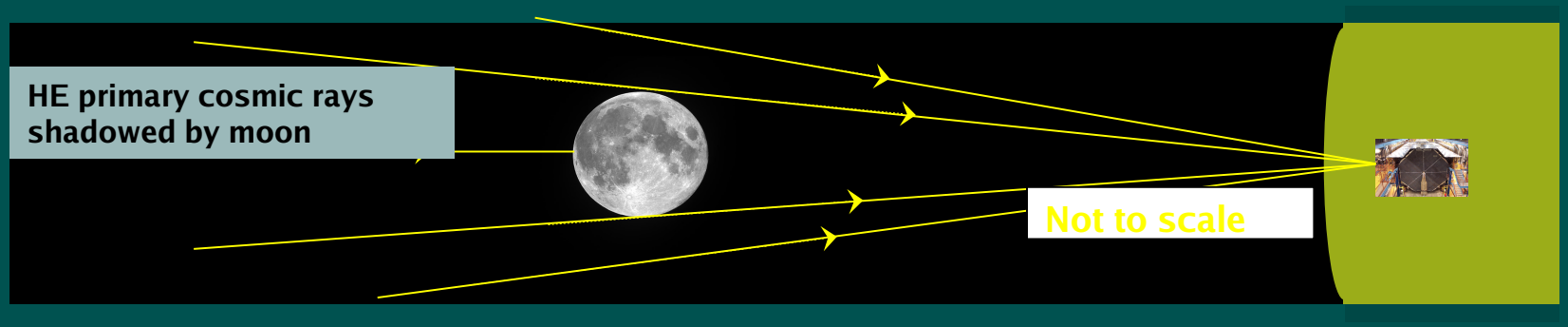
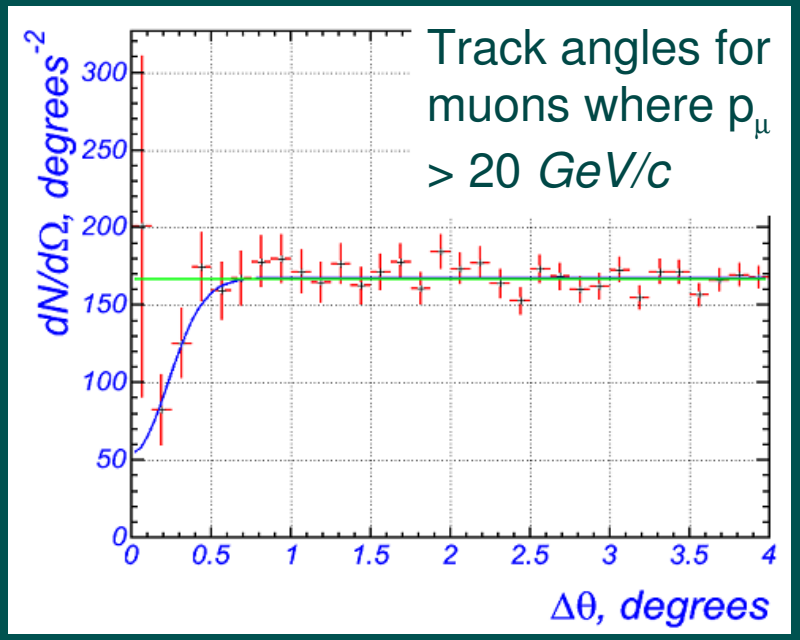
- Detector has already measured a “moon shadow” from 10M cosmic muon events
- A stopping muon event at the Far Detector (below)
  - stopping muons are distinguished from partially-contained neutrino events using timing.



4.5 Moon Shadow



- Detected ~10 M cosmic muons at the FarDet and observed the shadow of the moon
- Angular resolution <1°
- This can be improved by selecting only high-momentum muons (right)



5.0 Calibration Chain

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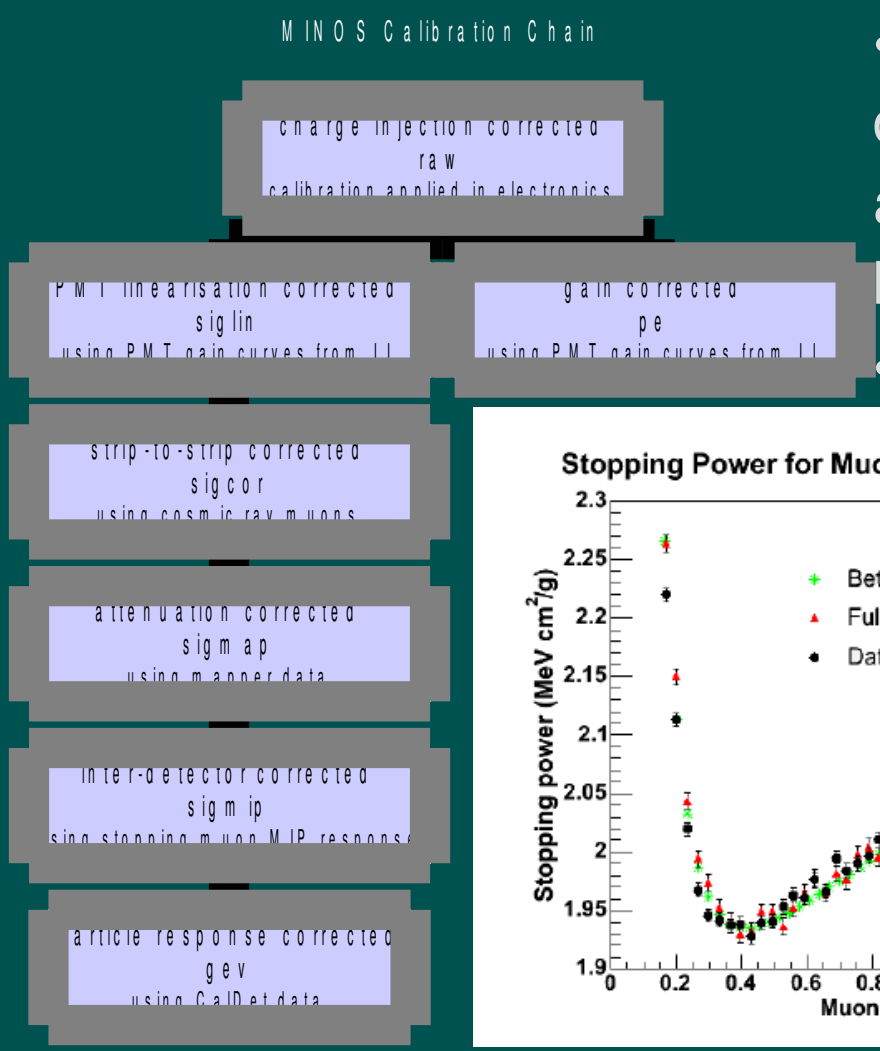
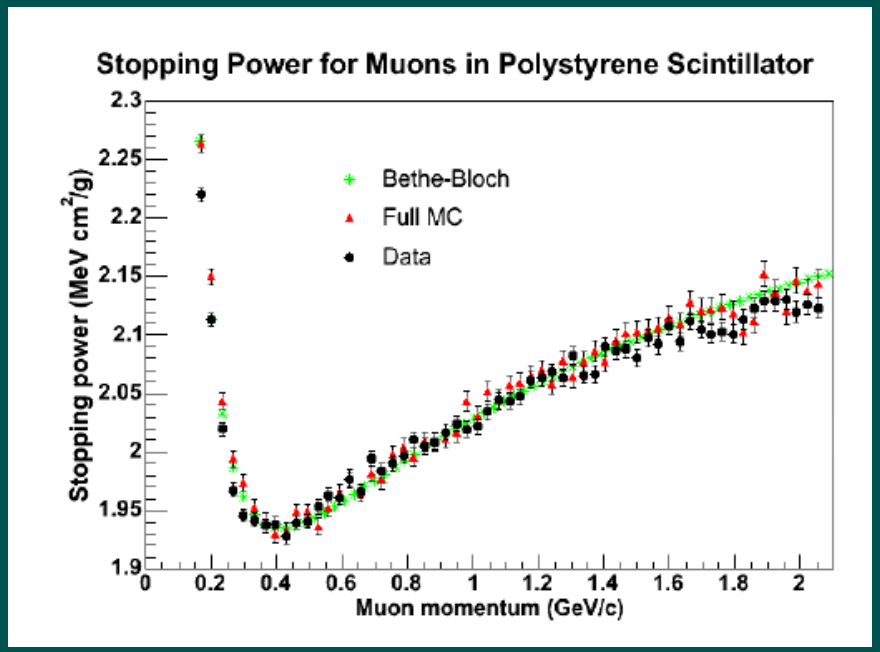


- The MINOS detectors are designed to be calibrated to 2% absolute uncertainty and 5% u/c between detectors
- MINOS uses light injection and cosmic muons as calibration sources



5.1 The Calibration Detector

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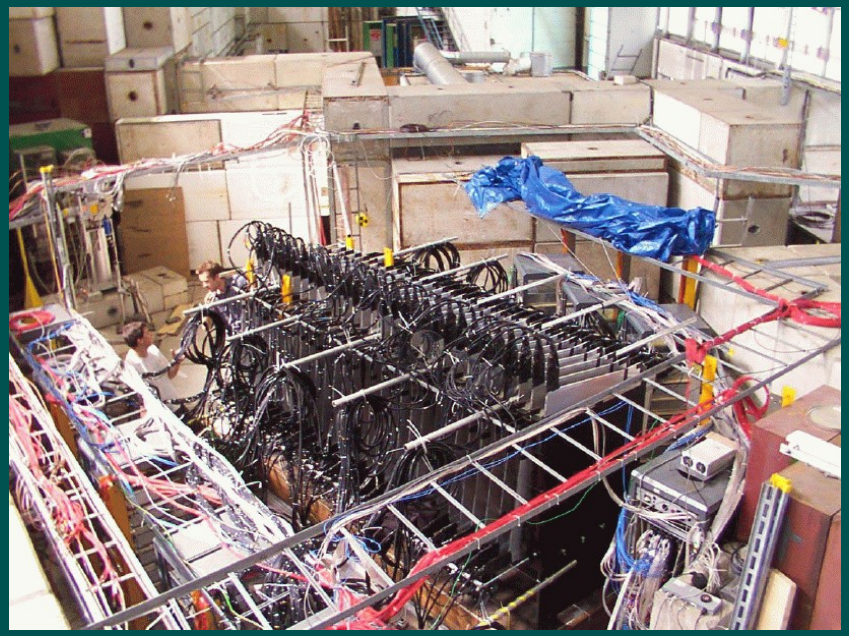
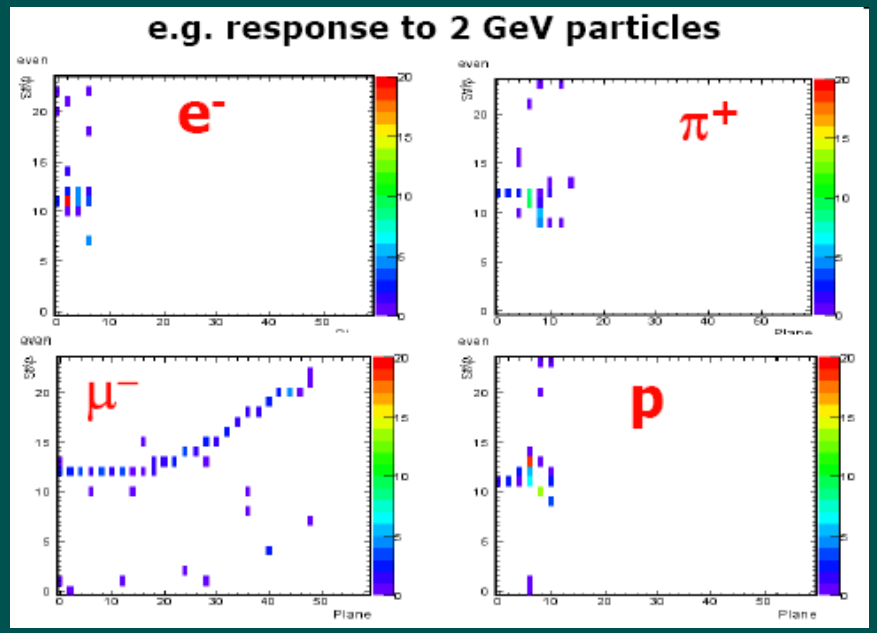
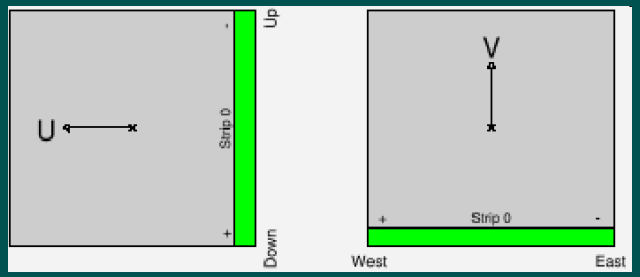




- The CalDet is 60 planes long with 24 vertical and horizontal strips in each plane.
- It was located at the PS test beams at CERN.
- The detector was designed to characterise the response to various particles at different energies.



Summary

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- MINOS is a 735 *km* long precision neutrino oscillation experiment from Fermilab to Soudan, MN
- The detectors are steel/scintillator sandwich tracking calorimeters
- MINOS is now a running experiment and has been receiving ν_μ beam from the NuMI beam-line for 6 months
- Several stages of calibration are necessary to ensure that…
- MINOS will, amongst other things, make a precision measurement of atmospheric sector neutrino oscillation parameters…Pedro Ochoa will elaborate…

Spare Water Leak in Target

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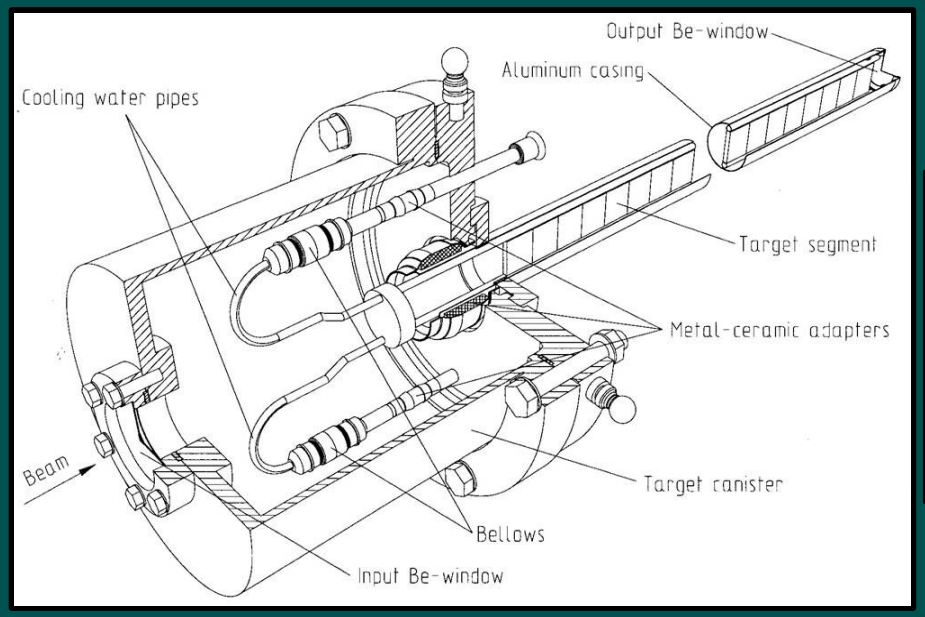
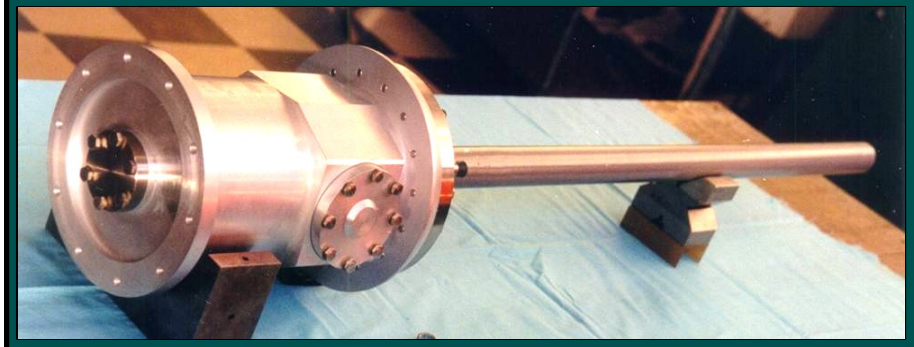
- Target developed a water leak in March and was fixed
- The cause of the leak wasn't found so it was back-pressurised with He…so far, so good…
- Now have a spare target with a spare carrier, so we can replace it if necessary





Spare The Far Detector 3

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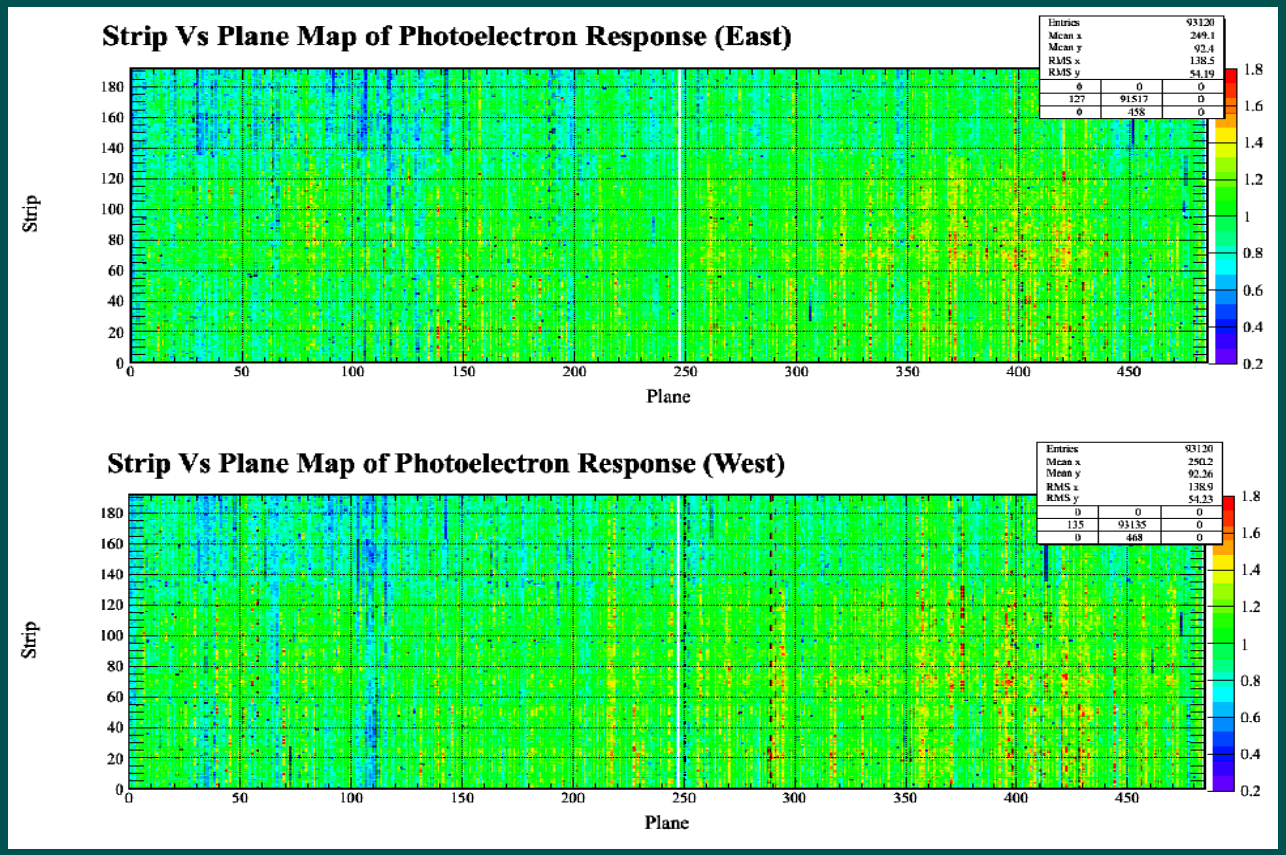
- A response map of FarDet using cosmic ray muons shows a healthy response



Relative scale

Spare The Near Detector

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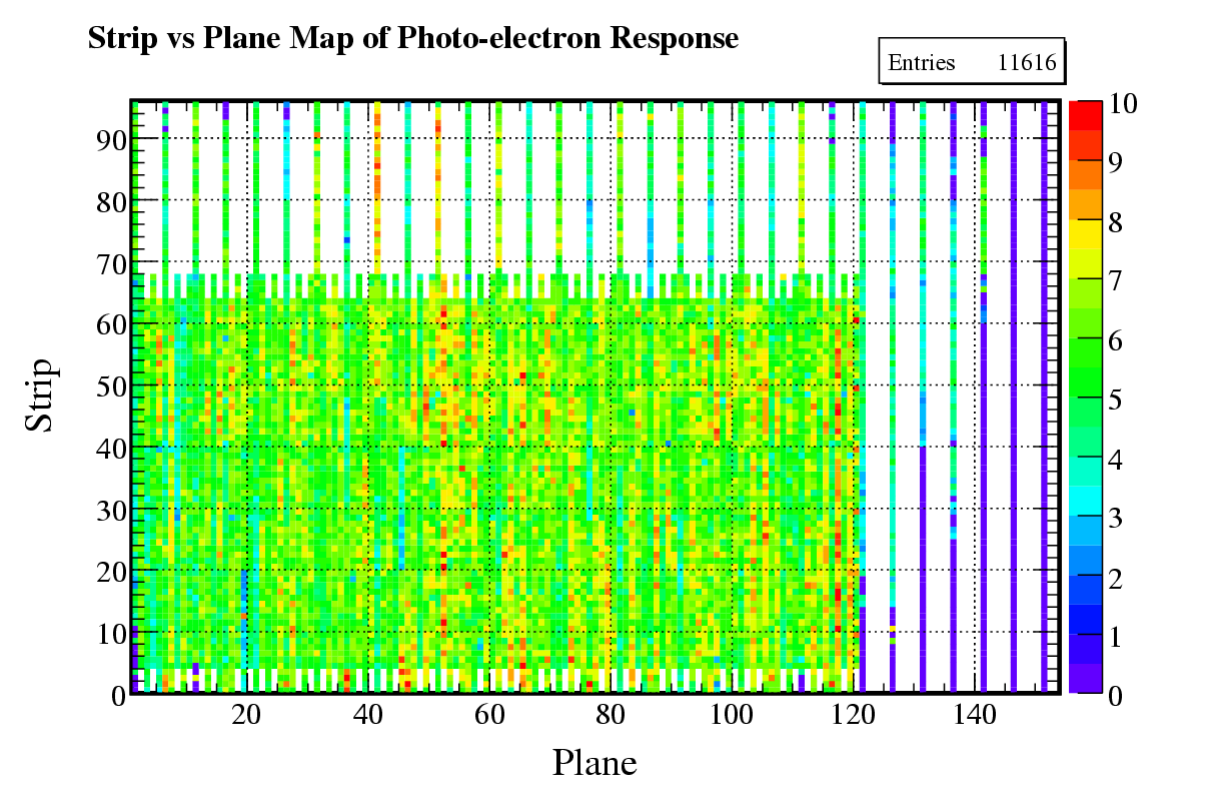
- A response map of the calorimeter section Near Detector using cosmic ray muons
- Low response in front end of spectrometer due to cross-talk