The MINOS Calibration System

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Detector Calibration on the Main Injector Neutrino Oscillation Search

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Agenda

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1.0 Introduction to MINOS

2.0 Update on MINOS and beam

3.0 Calibrations performed

4.0 Summary

1.0 The MINOS Experiment

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- A long baseline (700 km) neutrino oscillation experiment.
- Muon neutrinos from the Fermilab Main Injector's NuMI beam, plus atmospheric neutrinos.
- Two "identical" tracking calorimeter detectors: Near (at Fermilab) and Far (at Soudan, MN).
- Neutrino spectrum is compared between NearDet and FarDet.
- First precision measurement of neutrino mixing parameters.
- Official start of beam experiment earlier this month.

1.1 The Baseline

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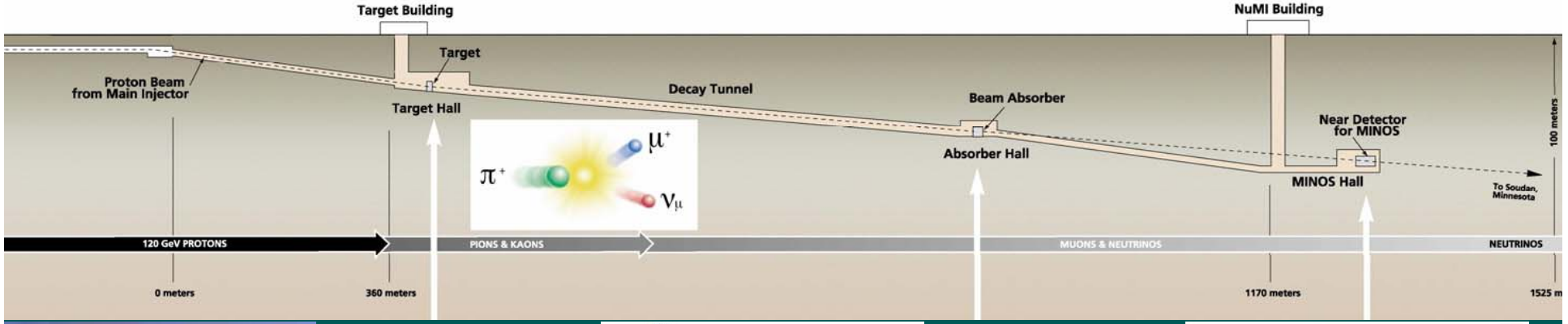
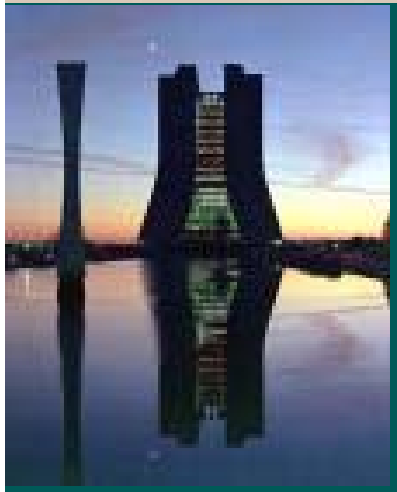
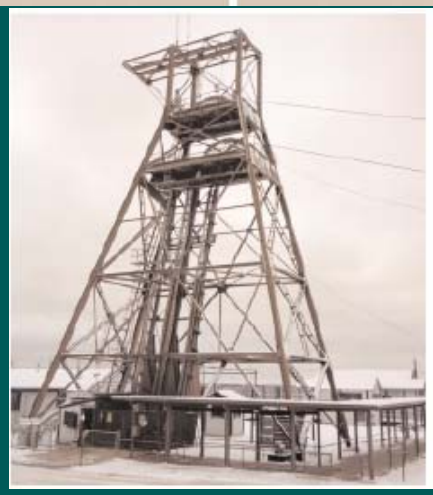
- The NuMI baseline and beam from Fermilab to Soudan





ν_μ

$\nu_?$



1.2 The MINOS Experiment

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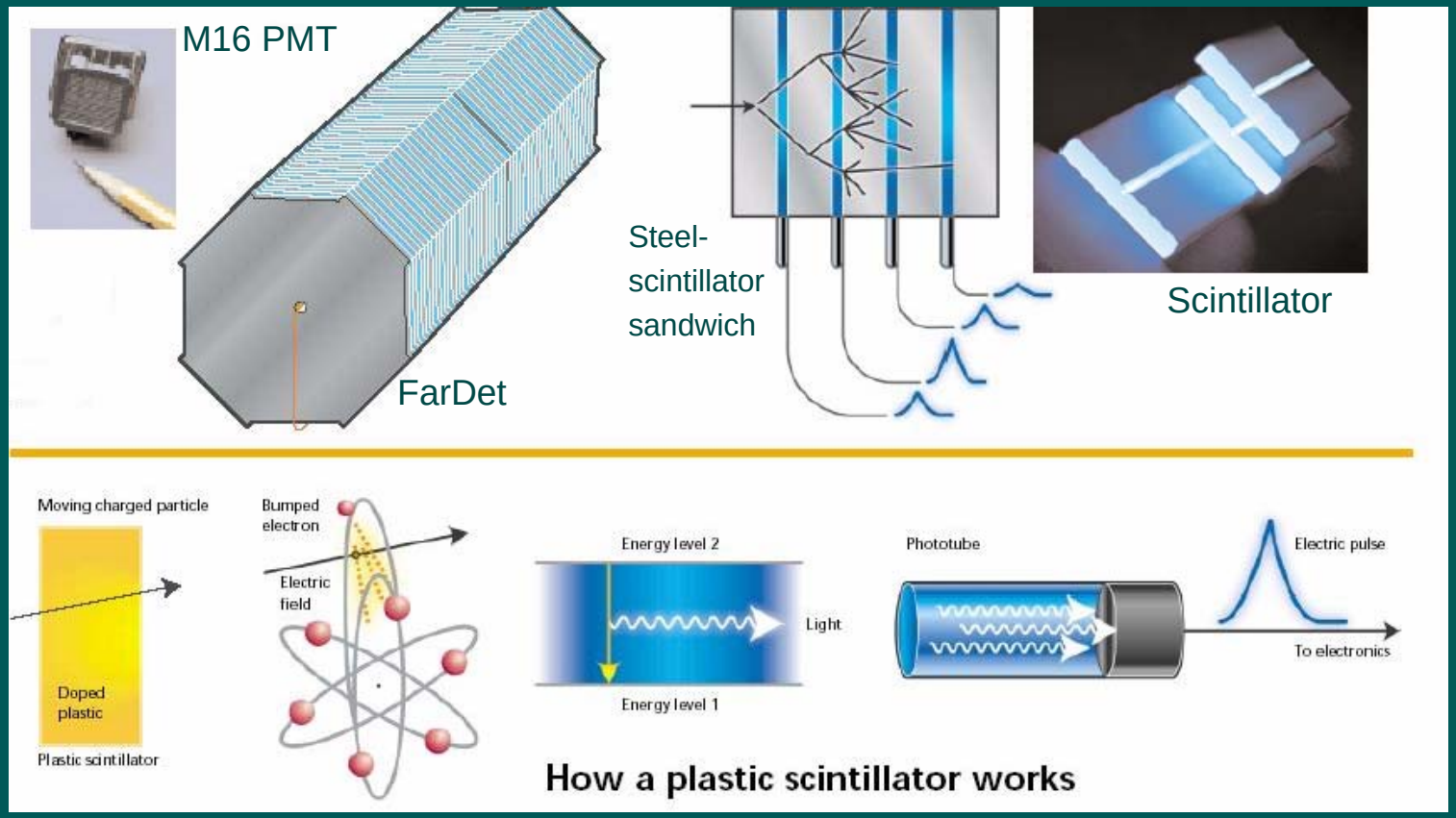
- Steel-scintillator sandwich design of the detectors



1.3 The Two Detectors

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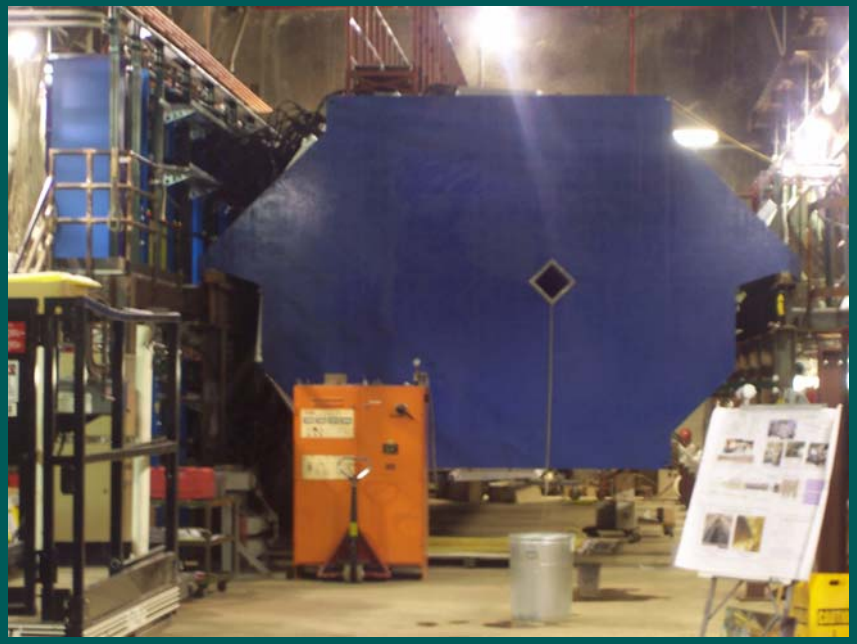
The Far Detector in Soudan is 485 planes of 192x192 strips. It is 8m across and 30m long. The magnet coil is through the centre.

The Near Detector is 281 planes long, but the geometry is complicated. It is up to 96 strips wide, but not all the planes are fully instrumented. The coil hole is off-centre.



2.0 Status and Latest News from the MINOS Experiment

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- The MINOS Near Detector was completed last summer
- We had our first beam from the NuMI beam-line in January
- Official start of experiment on 7th March
- Lots of press releases: very exciting time to be on MINOS

2.1 First MINOS Beam Neutrino Events

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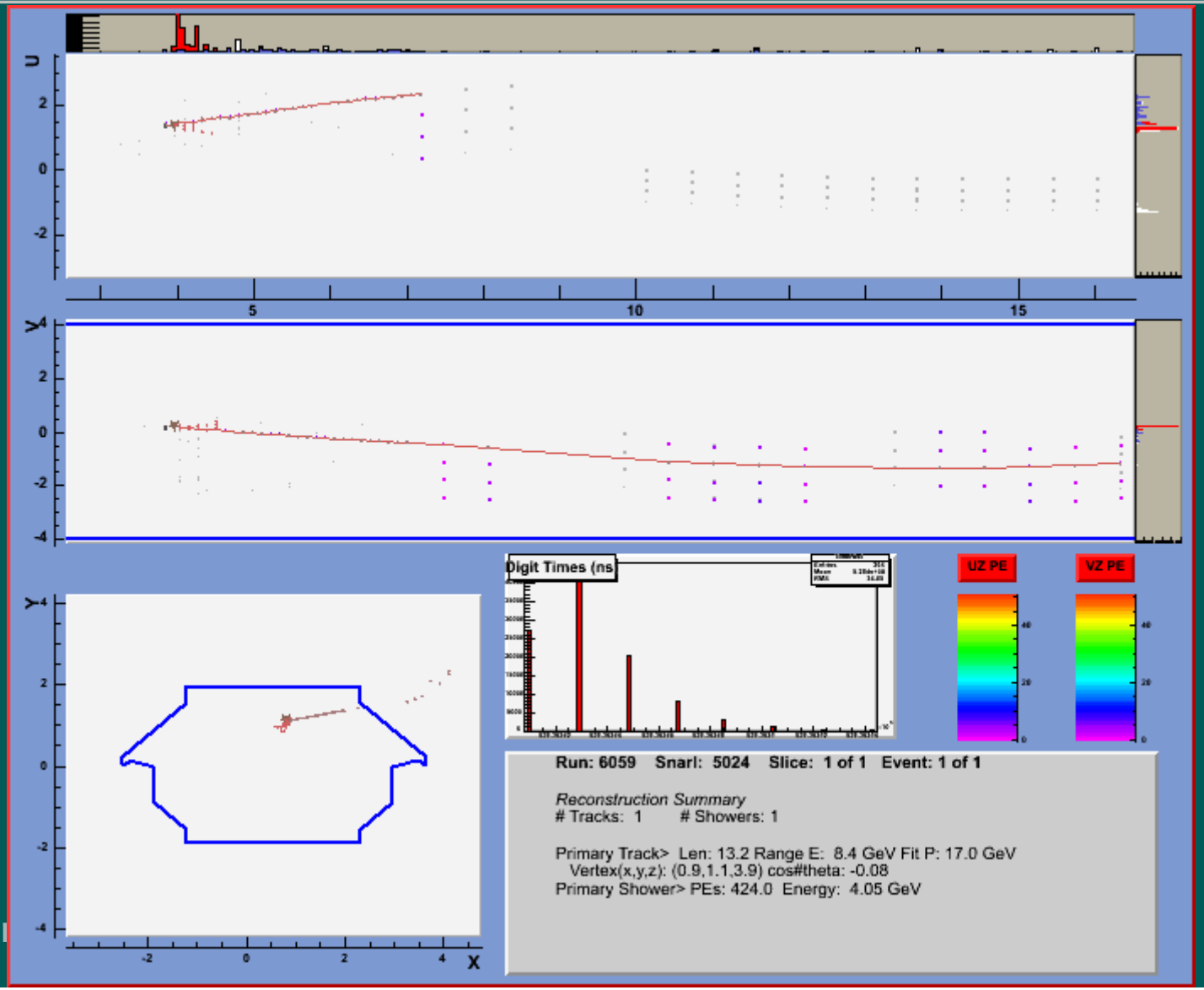
- First ever beam neutrino event at NearDet, 14:19 21/1/05



2.2 First MINOS Beam Neutrino Events

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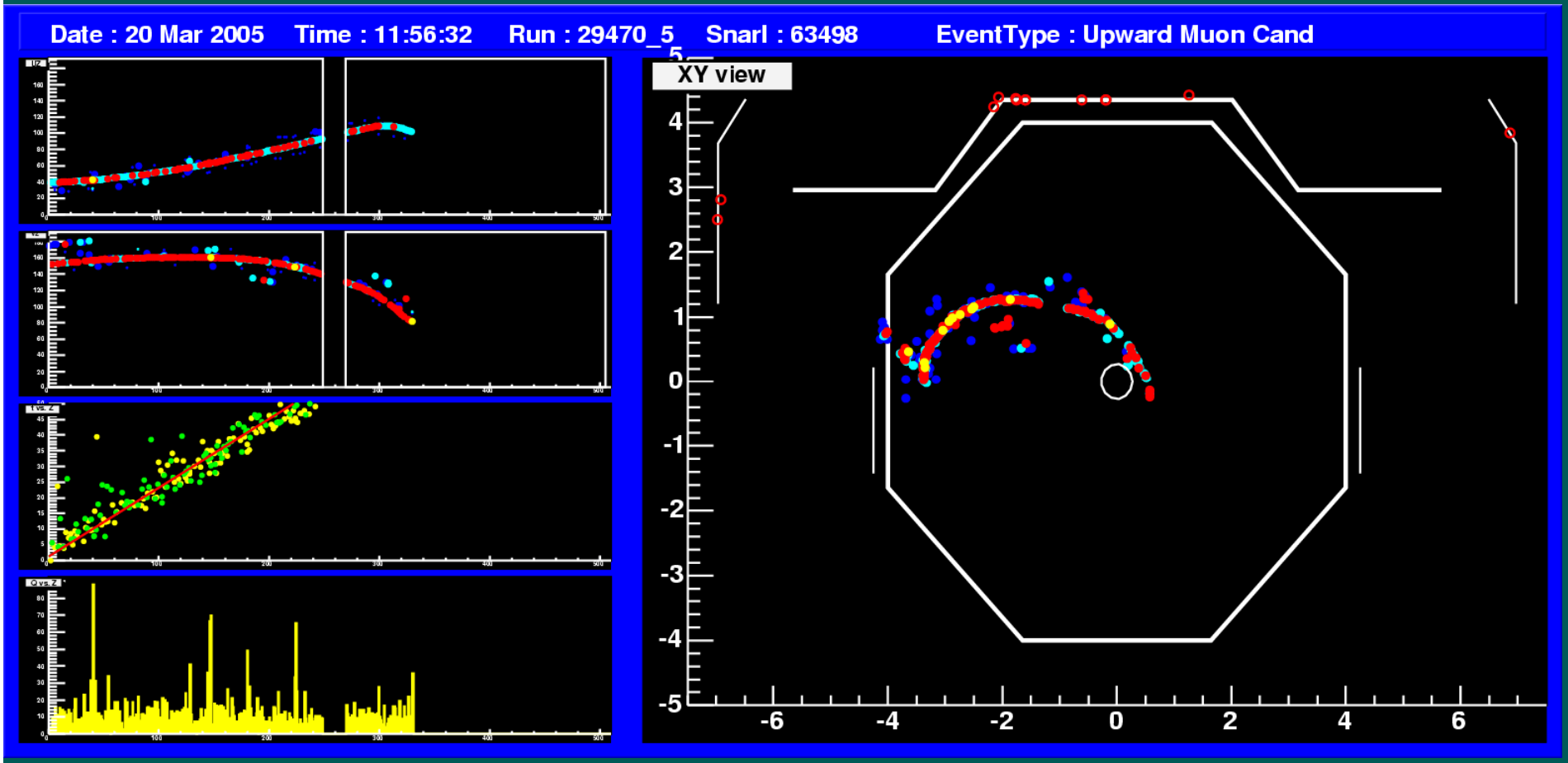
- First beam neutrino event at FarDet: beam induced rock muon on Sunday



3.0 Getting Precision Results: The MINOS Calibration System

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- The MINOS detectors are designed to be calibrated to 2% absolute uncertainty and 5% u/c between detectors
- This is vital if MINOS is to fulfil its role as a precision measurement of the neutrino oscillation parameters
- There are several different types of calibration applied to the data at different stages

3.1 Hardware Level Calibrations

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- The first stage in the calibration chain is the electronics linearisation and pedestal subtraction.
- Pedestal subtraction is done using the background noise on the PMT readout with the high voltage off.
- The ADC readout electronics is linearised by injecting known amounts of charge into the system.
- Both of these calibrations are done on the hardware level, with no DAq readout.

3.2 Light Injection

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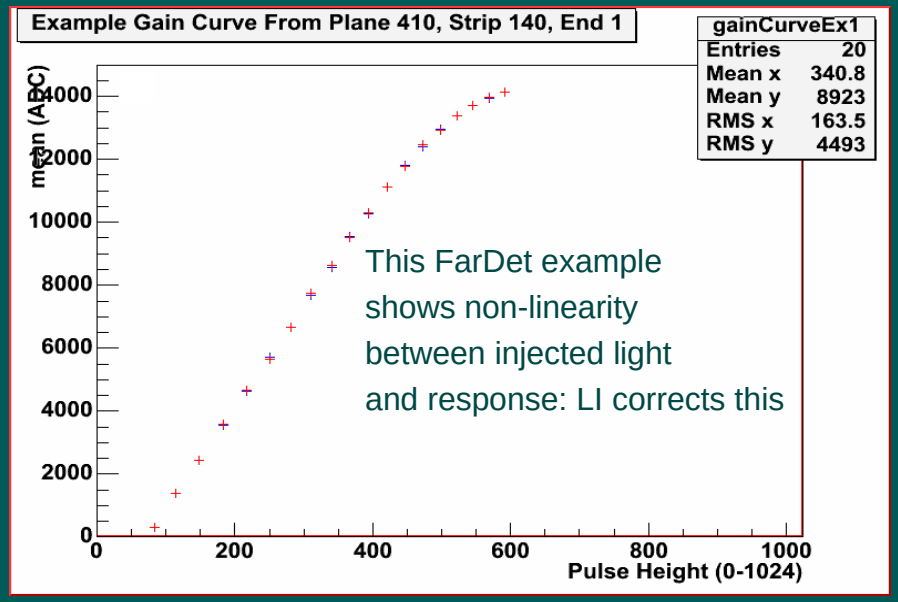
- LEDs are used to inject measurable amounts of light into the detector

- A full run is done monthly to measure PMT “gain curves”



- PMT drift is measured every 3 hours by this system
- This interpolates between gain curves
- This mainly corrects for temperature related changes
- A good handle for debugging and monitoring detector performance

3.3 Detector Normalisation: "Strip-to-strip" calibration

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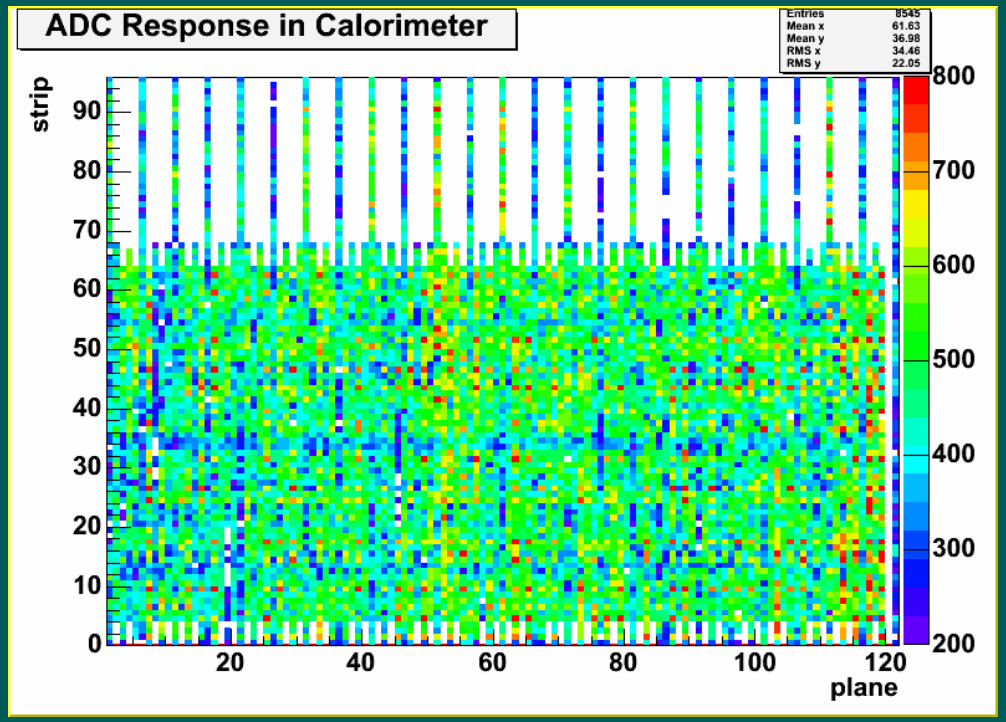
- Cosmic ray muons are used to normalise strip responses across each detector
- Also a very powerful way of making sure everything is working right



- This early strip v. plane map for part of NearDet shows some readout holes (now fixed)

3.3 Detector Normalisation: "Strip-to-strip" calibration

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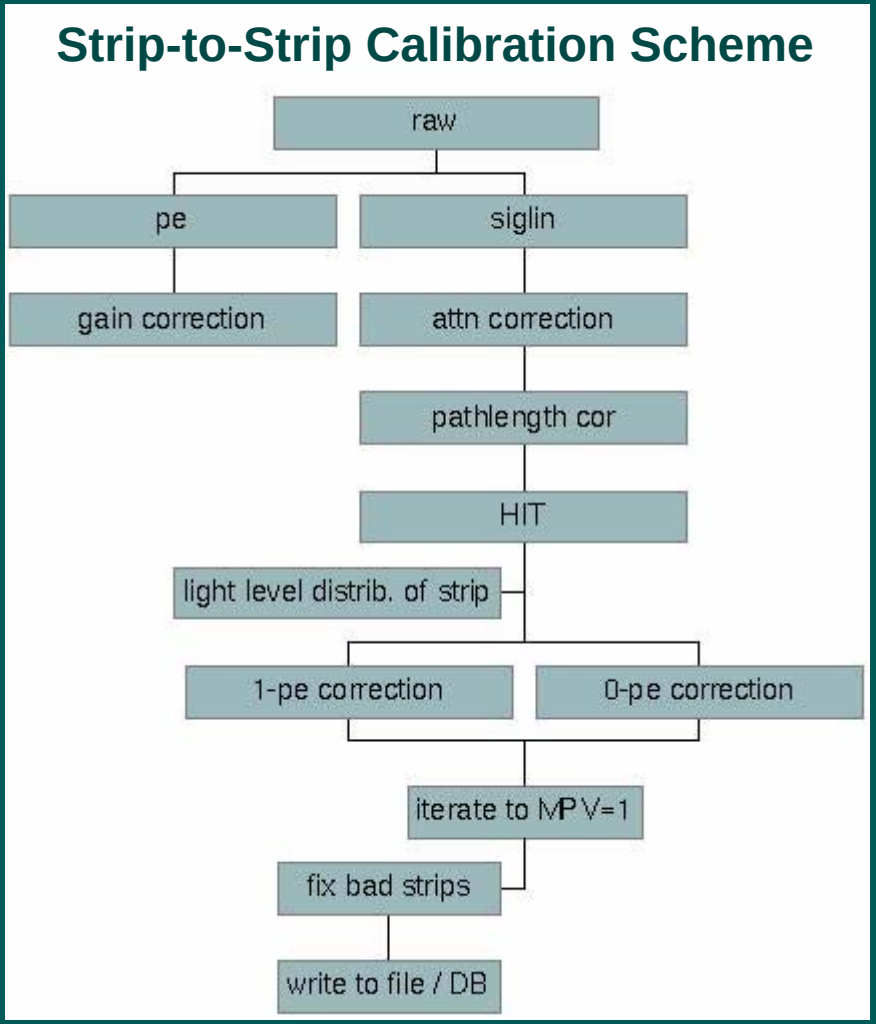
- In order to do this calibration properly, several corrections have to be applied:
- The attenuation correction is also a stage in the calibration applied at track/shower finding time



3.4 Detector Normalisation: Relative calibration

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- At the calibration detector, the $^{dE}/_{dx}$ curve for muons of known range can be measured
- This can be compared with the curve for stopping cosmic muons at the other detectors
- The different $^{dE}/_{dx}$ in muon energy units for each detector is then used to normalise each detector's energy scale
- This curve is the same within each the detector: can be used to check validity of calibrations

3.5 Absolute Calibration

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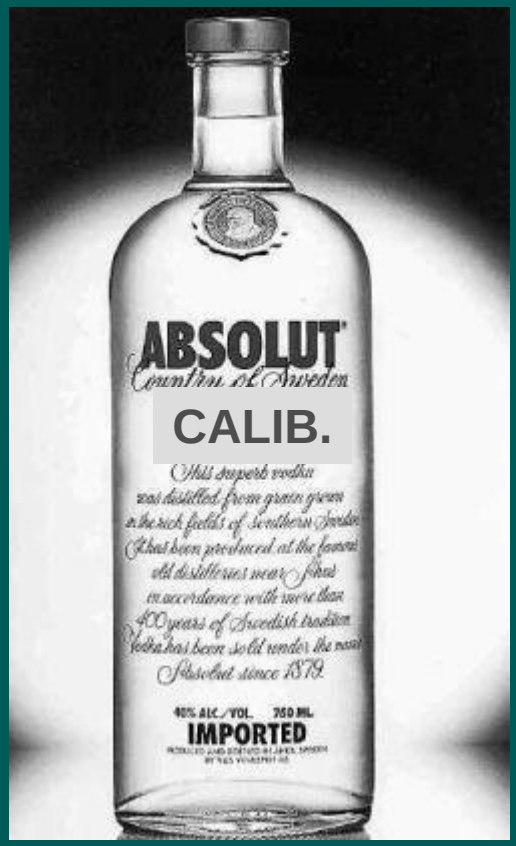
- Energy scale (muon energy units to GeV) is final stage
- Done by comparing different particle responses to muon response at various energies
- Different particles have different $^{dE}/_{dx}$
- Work done at calibration detector on hadrons, $e^{+/-}$s, etc.



4.0 Summary

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- MINOS is a 730 km long precision neutrino oscillation experiment from Fermilab to Soudan
- All the MINOS detectors have been commissioned and are now receiving ν_μ beam and seeing neutrinos
- The several stages of calibration are vital for MINOS to reach specified precision

…especially light injection and strip-to-strip calibration