The Long Term Performance of the MINOS Calibration Procedure

Sarah Phan-Budd (Argonne National Lab), Jeff de Jong (Oxford University), Luke Corwin (Indiana University), Mark Mathis (College of William and Mary), Richa Sharma (Fermilab), Nathaniel Tagg (Otterbein University)

For the MINOS Collaboration

The MINOS Experiment

MINOS consists of three parts; A beam of muon neutrinos from Fermilab and two detectors made of magnetized layers of steel and scintillator.

Far Detector	Near Detector
735 km from target	1 km from target
5.4 kilotons	1 kiloton
700m underground	100m underground

Detector Technology

Tracking sampling calorimeters
- Steel absorber 2.54cm thick (1.4 X_0)
- Scintillator strips 4.1 cm wide
- 1 GeV muons penetrate 28 layers

Magnetized
- We can measure muon energy from range and curvature, and we can distinguish μ^+ from μ^-

Functionally equivalent
- The detectors have the same segmentation, materials, and mean B field (1.3 T)

The MINOS Calibration Scheme

Raw Pulse Height → **Linearity Correction** → **Drift Correction** → **Strip to Strip Correction** → **Transverse Position (Attenuation)** → **Energy Scale** → **Fully Corrected Signal**

We use cosmic ray muon tracks as a standard candle to measure the response of the scintillator

Linearizes the response of each channel with pulse-height

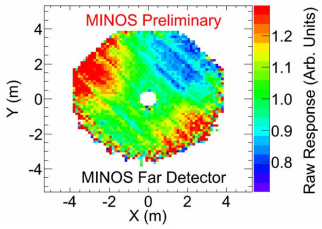
Accounts for PMT, electronics and scintillator response changing with temperature and age

Removes differences in response, both strip to strip and channel to channel

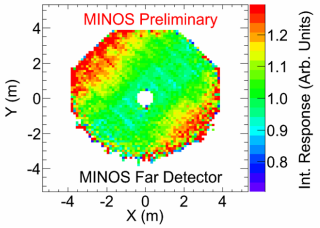
Describes the attenuation of light on the event position along each strip

An overall scale factor coverts corrected pulse height into the same absolute energy unit for all detectors

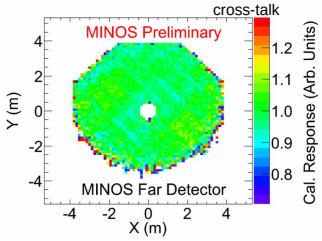
Also, a timing calibration is performed on FD data and the PMT response is adjusted for thresholds and cross-talk



Raw response of the Far Detector

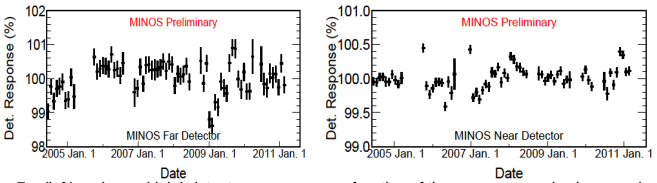


Partially calibrated response of the Far Detector after all calibrations have been applied except attenuation



Calibrated response of the Far Detector

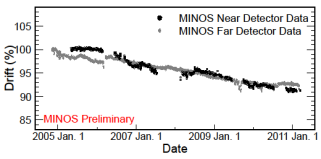
Calibration Stability



Far (left) and near (right) detector response as a function of time, as measured using cosmic stopping muons. Each point corresponds to one month's worth of data and is normalized to the overall response for the whole period. The response is stable within 1.5% for the far detector and within 0.5% for the near detector.

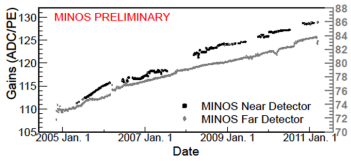
Long Term Detector Behavior

Drift



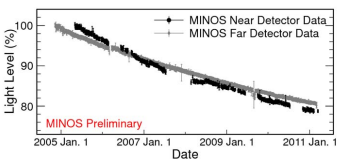
The drift correction accounts for change in PMT, electronic and scintillator response. Since 2005, the detector response has decreased by roughly 8%.

Gains

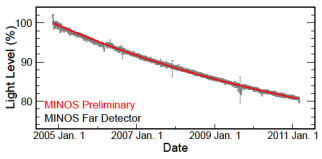


The detector gains have increased by 3.0 ADC's/PE (1.4 ADC's/PE) per year in the near (far) detector. The left axis indicates the far detector gains and the right axis indicates the near detector gains. The gains are well fit by an exponential function in both detectors.

Light Level



Light Level is calculated as the drift response divided by the gain response. The light level has decreased by 3.5% (3%) per year in the near (far) detector.



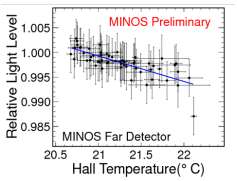
The light level is well fit by an exponential function in both detectors. The far detector fit is shown above. The time constant for this fit is 5.4 ± 0.05 years.

Temperature Dependence

We used periods with large, relatively smooth changes in temperature in short periods of time to quantify the detector behavior as a function of temperature. We average over several of these periods. We see a decrease in light and the increase in gains as a function of temperature.

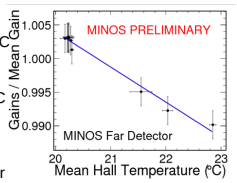
Light Level

The light level decreases by 0.2±0.06%/°C in the near detector and 0.37±0.07%/°C in the far detector. A sample fit for the far detector is shown.



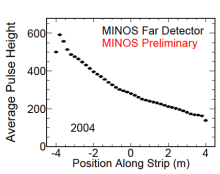
Gains

The gains decrease by 0.25 ±0.03%/°C in the near detector and 0.60±0.05%/°C in the far detector. A sample fit for the far detector is shown.

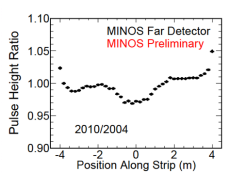


Light Level Studies

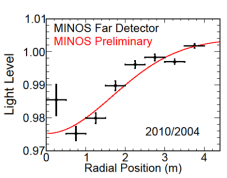
We studied the change in the pulse height to quantify the change in light level as the detector aged. We used only the longest, 8m strips, located towards the center of the detector. We see variations caused by non-uniform aging and changes in the wavelength shifting fiber. Our studies indicate that, after 6 years, we are getting 1.8% more light from the end of the strips than we are from a point closer to the readout.



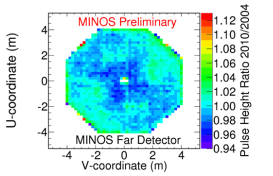
Average light output as a function of longitudinal strip position along the strips in 2004.



Ratio of average light output in the year 2010 to that in 2004. We see that the light in the center of the detector decreases.



Ratio of light output in 2010 to 2004 as a function of radial distance from the center of the detector. The light level at the center changes by 2.6% w.r.t the average.



Ratio of average light output in 2010 and 2004. Mechanical stresses appear to be aging the center of the detector faster than the edges.