DEEP UNDERGROUND NEUTRINO EXPERIMENT

# TMS Calibration Requirements

*A non-exhaustive overview of initial ideas for TMS calibration needs, informed by the past.*

*Mario*


## DUNE TMS

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*Gavin*

# Calibration Needs

- This talk is meant to reignite conversation about out calibration needs
- We want to leverage the experience and skills of everyone involved
  - Let's leave no stone unturned
- So what do we need to calibrate? Some of these will be posed as questions herein

- Detector response
- Energy scale / Absolute energy.
  - What is the expected calibration target?
- Spatial (x – y, UV?) resolution
- Temporal resolution
  - For MINERvA, the timing resolution was set to be better than ~ 5 ns [1]

- Magnetic Field Map
- Alignment
- Curvature resolution
  - How to define?
- Particle identification
  - dE/dx
- Sources of attenuation in optical fibers

[1] MINERvA Collaboration, L. Aliaga et al., "Design, Calibration, and Performance of the MINERvA Detector," Nucl. Instrum. Meth. A 743 (2014) 130–159

# Summary of Needs

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We'd need to define/set a strategy, focusing on priorities.

| | |
|---|---|
| Energy scale | 6-8% energy resolution depending on KE |
| Momentum resolution | < 20% for [0.5, 5.0] GeV/c |
| Spatial resolution | X-Y resolution of few-cm is all that is needed (< 50 cm)<br>U-V + Y planes to improve Y resolution |
| Temporal resolution | Few-ns to separate muons in different RF buckets |
| PMT response | Low photosensor noise, light yield sufficient for MIP (define) |
| Magnetic field | 1T leads to ~8cm total sagitta<br>○ We need to distinguish +8cm from -8cm to determine charge |

- Info from "TMS Module Design Mini-Review Friday" J Abel, A. Furmanski, M. Sanchez, A. Sutton, 2024

# Learning from the past

MINOS / MINERvA / T2K (ECal) experience can inform us

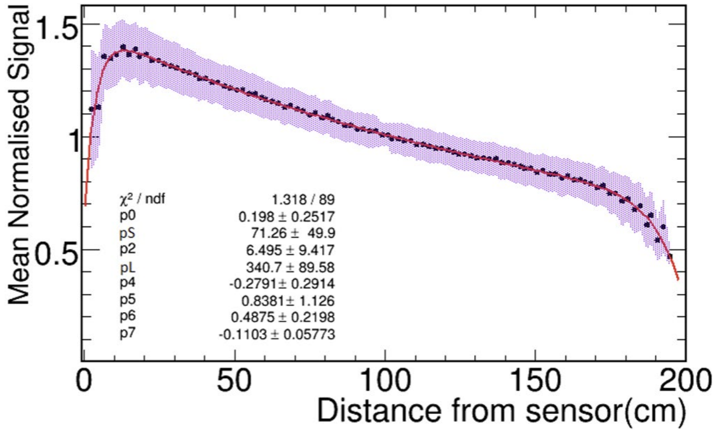
- Attenuation curves from individual scintillator readout Cosmic ray hodoscope for QA/QC
  - Full layer scan using radioactive source
  - Need to consider database needs
- Light Injection LEDs in-situ
  - T. Arihara et al., *Development of the in-situ Calibration System using LEDs and Light Guide Plates for the SuperFGD*, J.Phys.Conf.Ser. 2374 (2022) 1, 012118
  - MINERVA, NIM A 743 (2014)
- Small scale or "prototype" TMS time in testbeam
- In-situ cosmic ray data – nail down CR flux
- Utilise rock muons as a calibration source (study possible now)
- Through-going muons provide a standard candle to set the overall energy scale, timing calibration, and a measurement of the cross-talk (study possible now)
- Understand utility of Michel electrons (study possible now)

# Calibration during fabrication

- QA/QC during fabrication provides initial calibration
  - Scintillator Bars
    - Optical QA: cosmic ray hodoscope, light injection
  - Modules
    - For T2K a custom-built 2D scanner to scan each layer module in-situ
      - Attenuation curves, initial calibration
        - double/quadruple exponential, plus end effects
      - QA: any broken fibers during construction
- Test-beam
  - Build one layer for initial testbeam efforts
  - Alternatively, put entire TMS in testbeam: integration tests
    - Cosmic rays
    - Single particle in terms of muon energy unit
      - Hadronic and EM shower profiles
      - Test reconstruction/PID
    - Validation of the simulation

$^{137}$Cs scan of modules


T2K DS-ECal, CERN Cosmic rays




*GD Thesis:* https://www.t2k.org/docs/thesis/009

# CalDet

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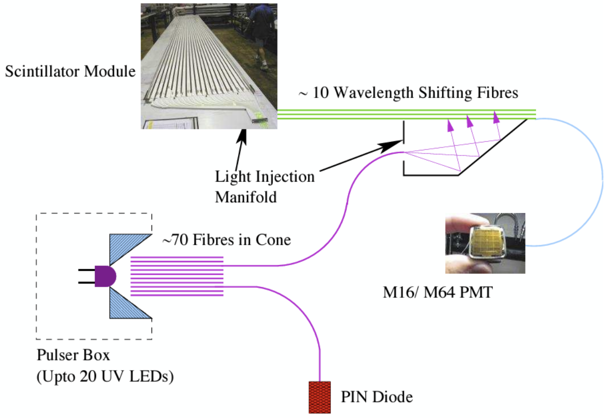
MINOS CalDet system used Cosmics and Test-beam to correct:

- Intra-detector variations
  - gain non-uniformity
  - gain drift over time
  - PMT and electronics non-linearity
  - non-uniformity in strip-light output
  - attenuation in optical cabling
  - temperature dependent response variations
    - Light output dependence of scintillator f(T)
- Inter-detector variations
  - Stopping muons as standard candle
  - Muon energy unit

Light injection system



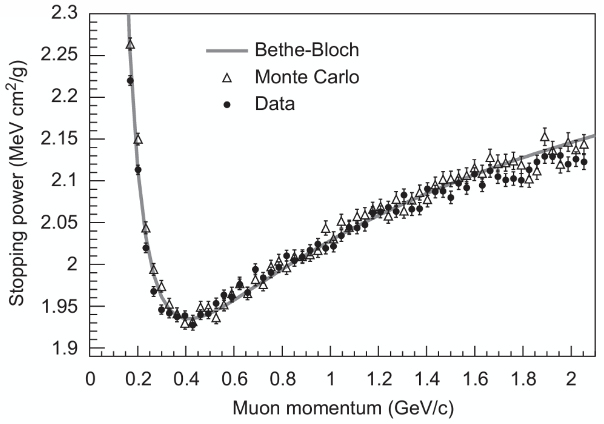




**Fig. 39.** Stopping power for muons. The gray line shows the Bethe–Bloch calculation of the stopping power for muons in polystyrene scintillator. The solid circles and open triangles show the response of stopping muons in the far detector data and GEANT3 Monte Carlo simulations, respectively. Both data and Monte Carlo points have been normalized to the Bethe–Bloch calculation to give the expected stopping power at the minimum ionizing point.

Credit: Ryan Nichol

The MINOS calibration detector (MINOS), *Nucl. Instrum. Meth. A* 556 (2006) 119-133

# Summary

- This is a brief reignition of trying to define our calibration requirements
- We need to understand what constants we'd want to eventually calculate and store
  - Feeds into database needs
- Slow controls also needs to be part of the conversation
  - See temperature dependence for example
- Priority measurements we consider at present:
  - Energy scale, Energy/Momentum/Spatial resolution, Magnetic Field map
  - Alignment, temperature (slow controls?)
- We're sparking interest and ideas and hope to iterate with the group over the coming weeks

# More References


- • "The Magnetized steel and scintillator calorimeters of the MINOS experiment", Nucl. Instrum. Meth. A596 (2008) 190-228
- "The MINOS calibration detector", Nucl. Instrum. Meth. A556 (2006) 119-133
- "On the linearity of the MINOS light-injection calibration system", Nucl. Instrum. Meth. A521 (2004) 361-366
- "The MINOS light injection calibration system", Nucl. Instrum. Meth. A492 (2002) 325-343
- Ryan Nichol, Ph.D Thesis: "Calibration of the MINOS detectors", FERMILAB-THESIS-2003-41