Muon Flux and Modulation at DEAP-3600

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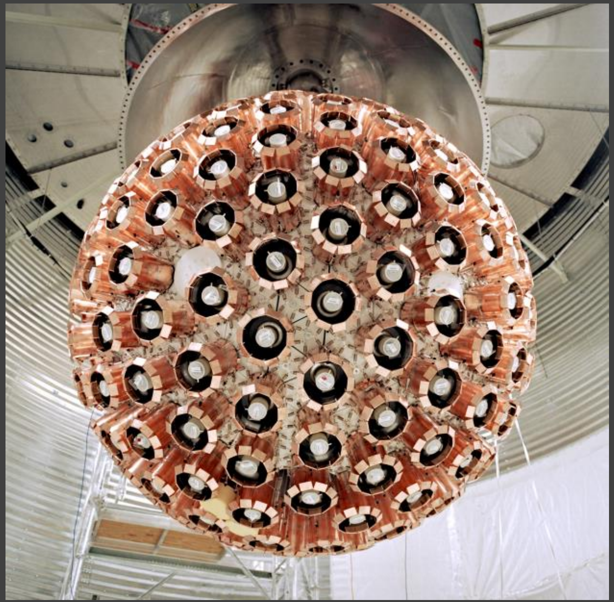
Background



- 2 km underground at SNOLAB (Sudbury, ON)
- Dark Matter Experiment using Argon Pulseshape Discrimination
- Attempting to observe WIMP scattering in liquid argon target
- Overburden shields sensitive detector from background radiation

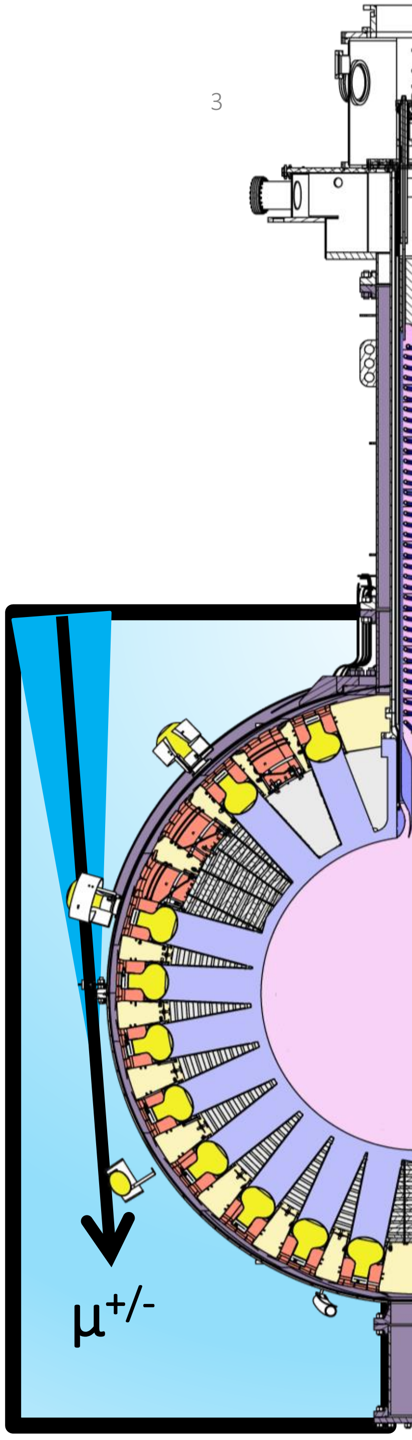
DEAP-3600

Inner Detector - steel shell

- 2-inch thick ultraclean acrylic vessel (inner radius 85 cm) filled with 3279 kg ultrapure liquid argon (pink)
- Cooled with LN_2 to ~ 85K
- Inner surface coated with TPB (shift LAr scintillation light from UV to visible)
- Light transmitted through acrylic light guides (purple) to 255 PMTs (yellow)
- Encased by 3.4 m diameter steel shell

Muon Veto - water tank and outside of steel shell

- Cylindrical steel tank (7.8 m height and diameter) filled with ultra-pure water
- Water tank provides shielding from natural radiation produced by rock
- Cherenkov radiation emitted by muons traveling through water faster than the speed of light through water
- 48 PMTs on outer surface of inner detector



Cosmic Rays & Muons

- Streams of high-energy particles (mostly protons and He-nuclei)
- Collision between cosmic rays and air molecules trigger hadronic showers
- Charged pions (& kaons) can either:
  - Decay into muons
  - Interact with air molecules, eventually produce lower energy muons
- Interactions occur in stratosphere, temperature changes slowly on time scale of seasons

Higher air temperature → Lower air density → Lower chance of pion/kaon interactions with air molecules → Greater proportion of high-energy muons produced

- Muons follow trajectory of original cosmic ray
- Lose energy as they propagate through bedrock
- Expect to see a greater rate of underground muon arrival in summer compared to winter

Analysis Steps

1

Get weekly temperature data

2

Calculate weekly average flux

3

Quantify correlation between temperature and flux

Methods

Eq. (1a)

$$T_{\text{eff}} \simeq \frac{\sum_{n=0}^{N} \Delta X_n T(X_n)(W_n^{\pi} + W_n^{K})}{\sum_{n=0}^{N} \Delta X_n (W_n^{\pi} + W_n^{K})}$$

Eq. (1b)

$$W^{\pi,K}(X) \simeq \frac{(1 - X/\Lambda'_{\pi,K})^2 e^{-X/\Lambda_{\pi,K}} A^1_{\pi,K}}{\gamma + (\gamma + 1) B^1_{\pi,K} K(X) (\langle E_{\text{th}} \cos\theta \rangle / \epsilon_{\pi,K})^2}$$

Adamson P., et al (2010)

Temperature

- European Centre for Medium-Range Weather Forcasts (ECMWF)
- Coordinates above Creighton Mine
- Reanalysis data from global atmosphere model & variety of measurements
- 3x3 gridded data (~ 90x90 km), 4 measurement per day at each of 37 available pressure levels
- Simplify atmosphere by approximating it as an isothermal body with an effective temperature (1a)
- Produce a timeseries of weekly average effective temperature over 3-year detector operation
  - Calculate weekly average temperature at each pressure level
  - Calculate weighted average over all pressure levels

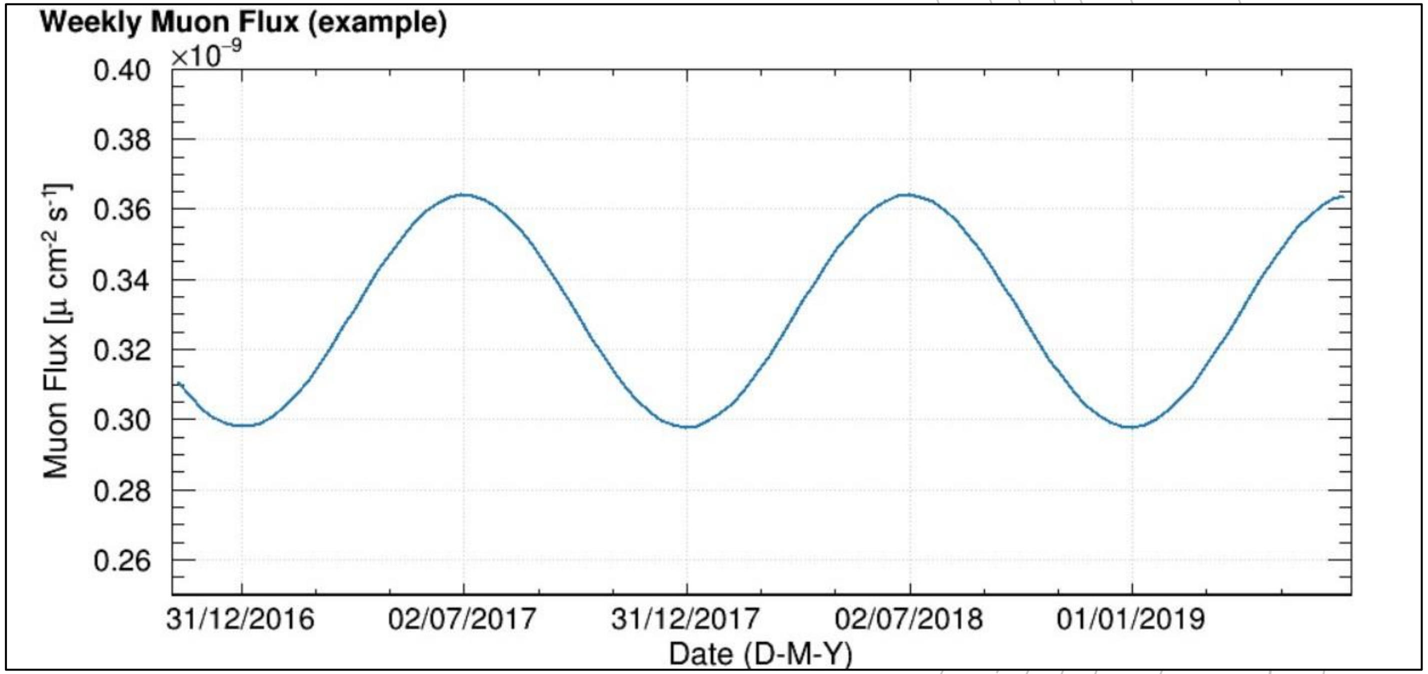
Methods

Eq. (2)

$$Flux = \frac{N_{obs}}{\epsilon \times livetime \times A}$$

Muon Flux

- "cut-and-count" approach
  - Count events passing tagging cuts
  - Correct by cut acceptance (ϵ, determined through Monte Carlo simulations)
  - Divide by detector livetime and water tank surface area (2)
- Livetime of each data-collection run must be corrected to account for weekly binning

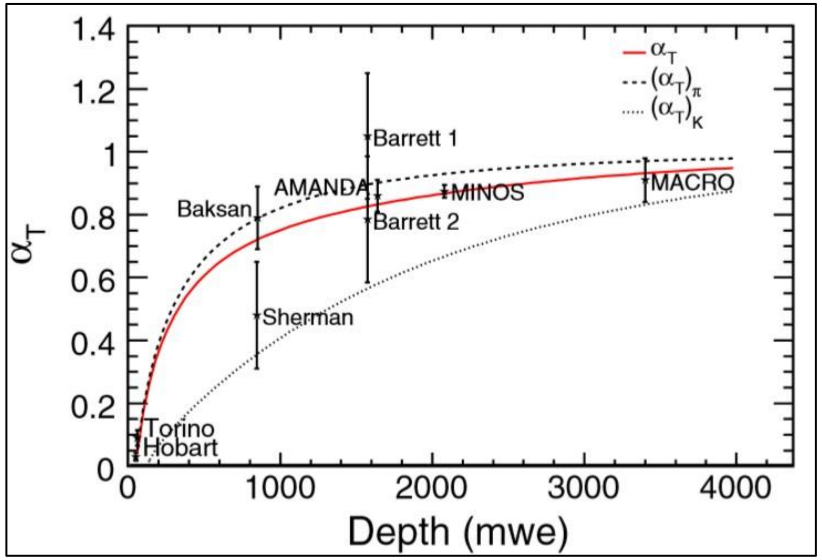


Expected Results

Goal: Measure α_T – a coefficient relating the changes in temperature and flux

$$\frac{\Delta R_\mu}{\langle R_\mu \rangle} = \alpha_T \frac{\Delta T_{\rm eff}}{\langle T_{\rm eff} \rangle}$$

Adamson P., et al (2010)



Adamson P., et al (2010)

- α_T predicted to be 1 near depth of DEAP-3600 (6000 mwe)
- Will be first measurement of this parameter below a depth of 3500 mwe
- Can be used to validate our current understanding of atmospheric physics
- Extend to measurement of atmospheric κ/π
- Useful for understanding cosmogenic backgrounds present in dark matter searches
- Study of muons has applications in fields such as space weather monitoring and muon tomography

Thank you!

References:

- Adamson, P., Andreopoulos, C., Arms, K. E., Armstrong, R., Auty, D. J., Ayres, D. S., . . . Zwaska, R. (2010). Observation of muon intensity variations by season with the MINOS far detector. *Physical Review D, 81*(1). doi:10.1103/physrevd.81.012001