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Fast Neutron Backgrounds for Anti-Neutrino Based Nuclear Reactor Monitoring as a Function of Overburden

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Introduction

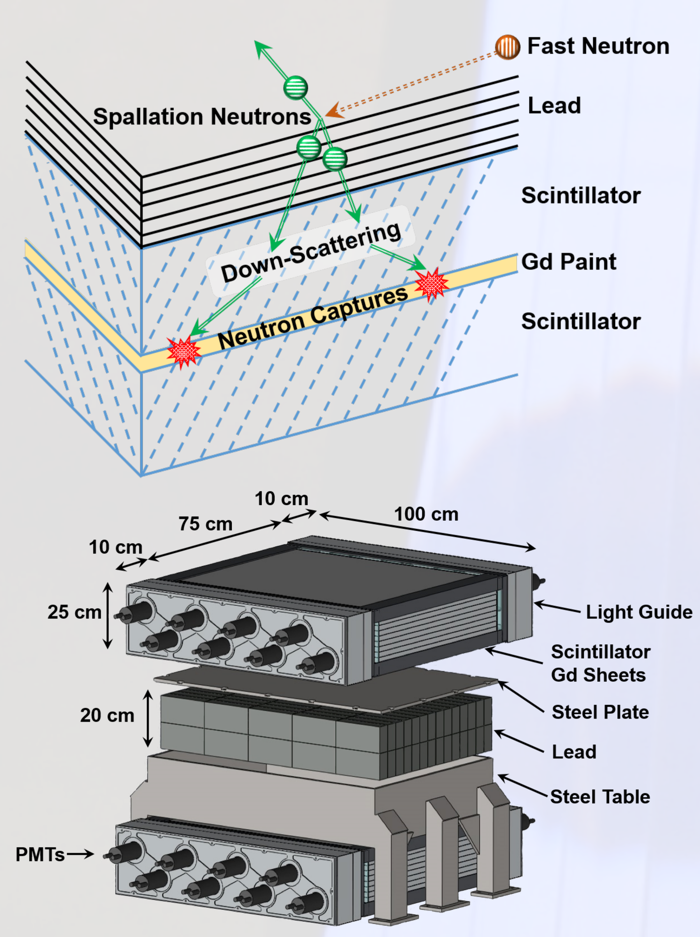
The Multiplicity And Recoil Spectrometer (MARS) is a transportable high-energy neutron detection system for measuring neutron spectra and flux ranging from tens to hundreds of MeV. The portability of the spectrometer reduces the detector-related systematic bias between different neutron spectra and flux measurements, which allows for the comparison of measurements above or below ground.

MARS has completed measurements at dephts of 380, 600, and 1450 meter water equivalent (m.w.e.) at the Kimballton Underground Research Facility (KURF). A verification measurement has been performed above ground using the known neutron spectra. Preliminary above ground results are presented here.

A Novel High-Energy Neutron Detector Concept

To measure high-energy neutron spectra we have constructed a multiplicity detector. A multiplicity event sequence is as follows:

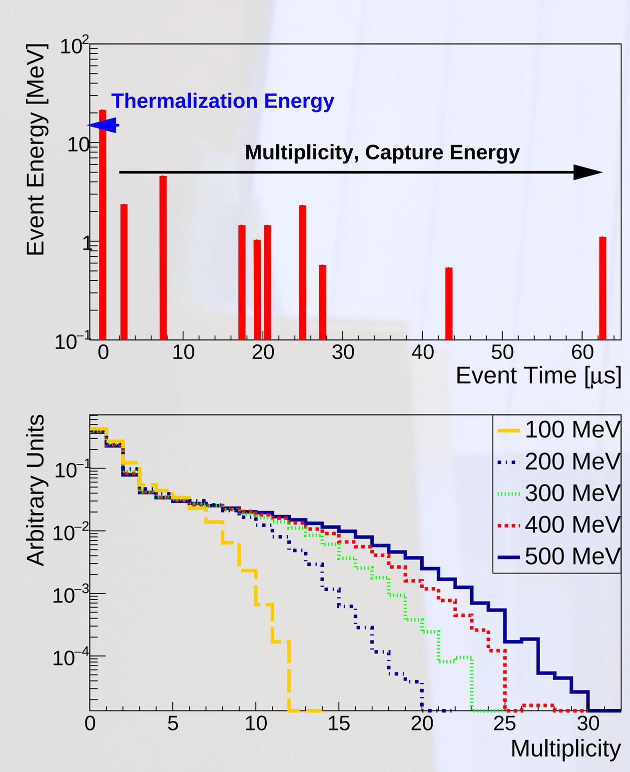
1. A fast neutron spallates on the lead creating secondary neutrons
2. Secondary neutrons down-scatter and capture on Gd nuclei
3. Gd de-excitation results in gamma rays totaling ∼8 MeV



Expected Detector Response

The high-energy neutron response can be characterized by:

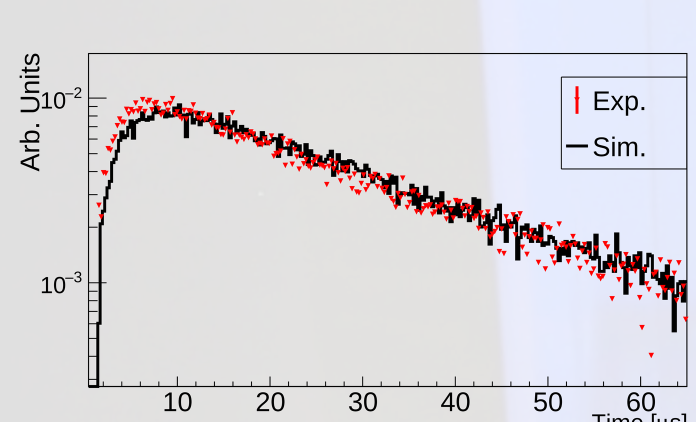
1. Number of neutron captures (Multiplicity)
2. Total energy of neutron captures (Capture Energy)
3. Down-scatter energy (Thermalization Energy)
4. These 3 components are proportional to the incident neutron energy



Detector Calibration and Model Validation

MARS is modeled using Geant4.9.6.p02 [1, 2] and MENATE_R [3, 4]. To validate the Monte Carlo model the following measurements were performed:

1. Energy and position dependent response calibrations using gamma ray sources
2. Capture time and total efficiency measurements using a Cf-252 source



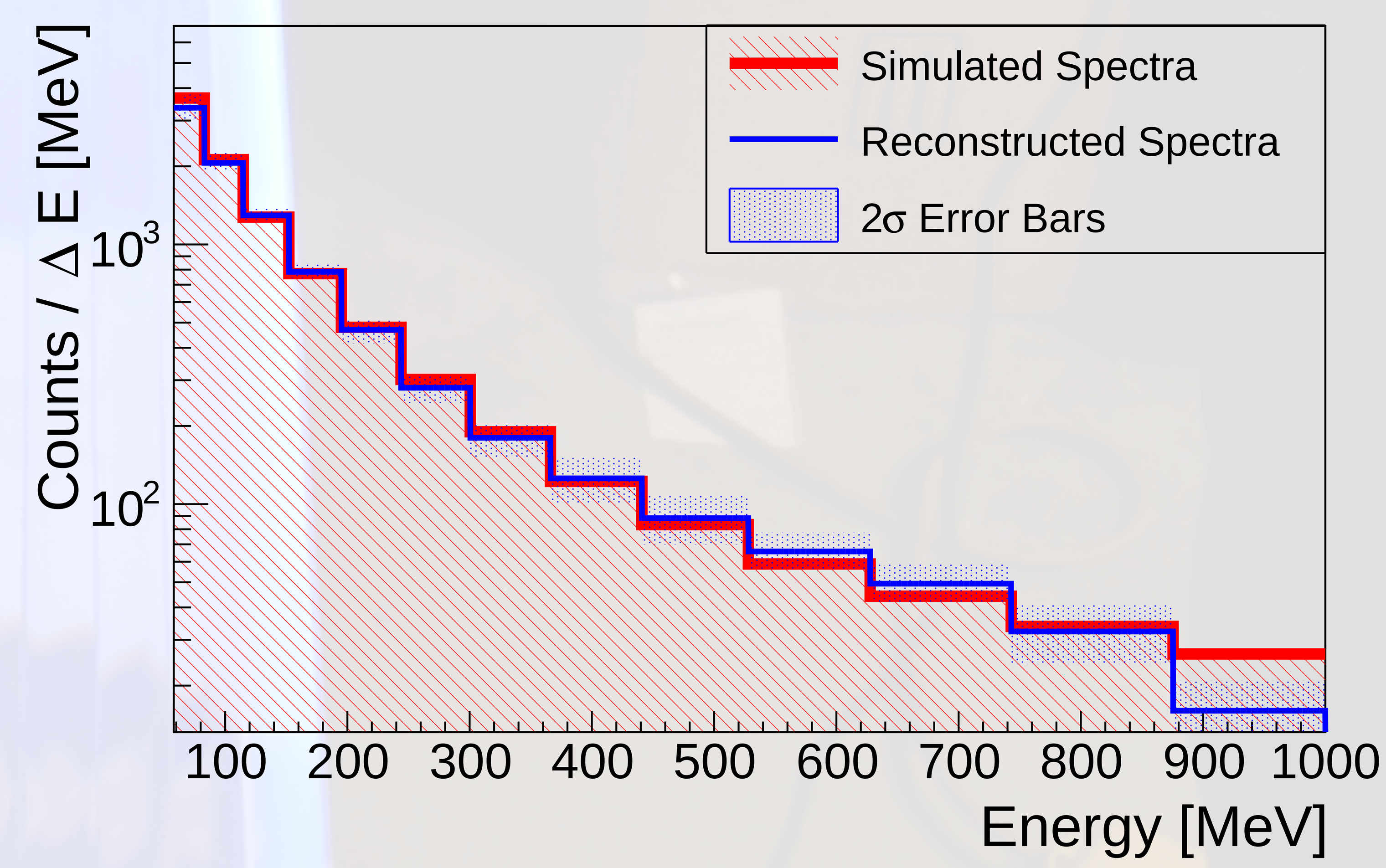
Ratio	Exp. ϵ (%)	Sim. ϵ (%)
M(3)/M(4)	13.0 ± 0.4	12.8 ± 0.2
M(3)/M(5)	12.8 ± 0.6	12.7 ± 0.4
M(4)/M(5)	12.6 ± 1.4	12.6 ± 0.8
Average	12.8 ± 0.5	12.7 ± 0.3

Unfolding Methodology and Simulation Results

To reconstruct the incident neutron energy spectrum we use a Markov Chain Monte Carlo (MCMC) algorithm with regularization and bias reduction [5]. We solve the matrix equation

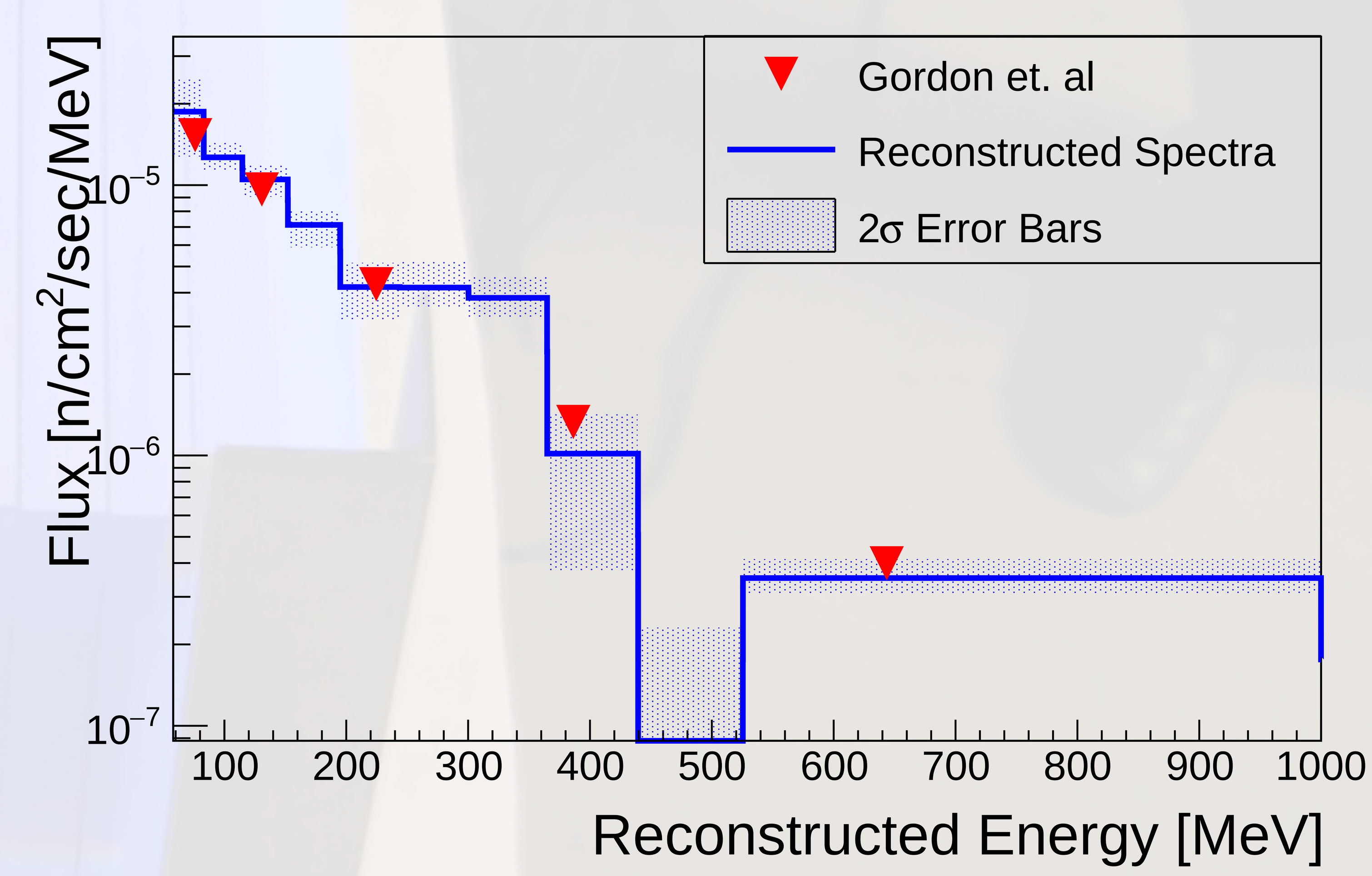
$$\vec{g}_{meas} = \mathbf{A}\vec{f} + \vec{b}, \quad (1)$$

where $\vec{g}_{meas}$ is the 3 vector recorded space, **A** is the kernel matrix created from simulation, $\vec{f}$ is the energy dependent neutron flux, and $\vec{b}$ is the background. The following graph displays the algorithms ability to reconstruct a known simulated input spectra and generate appropriate error bars.



Preliminary Above Ground Results

Preliminary results above ground at KURF are presented below and are compared to Gordon et. al [6]. Reasonable agreement is observed below 400 MeV.



Conclusions & Future Work

We have designed, constructed, and calibrated a novel spallation based high-energy neutron spectrometer. A reconstruction algorithm has been developed and successfully used to unfold simulated data. We have measured the above ground neutron spectrum and results agrees with previous measurements.

We are currently working on including systematic errors into the reconstruction analysis. In the future we will reconstruct the below ground spectra for the 3 depths at KURF. These three spectra will be used to develop a depth dependent neutron energy spectrum model.

References

[1] S. Agostinelli et. al. *NIM A*, 506(3):250 – 303, 2003.
[2] J. et. al Allison. *Nuclear Science, IEEE Transactions on*, 53(1):270–278, Feb 2006.
[3] B. Roeder. *EURISOL Design Study*, 3(0):31 – 44, 2008.
[4] Z. Kohley et. al. *NIM A*, 682(0):59 – 65, 2012. ISSN 0168-9002.
[5] M. Kuusela and V. M. Panaretos. *ArXiv e-prints*, May 2015.
[6] M.S. Gordon et. al. *Nuclear Science, IEEE Transactions on*, 51(6):3427–3434, 2004.

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