Monte Carlo simulation of a dedicated neutron detector for the COHERENT experiment at the SNS, ORNL

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Introduction

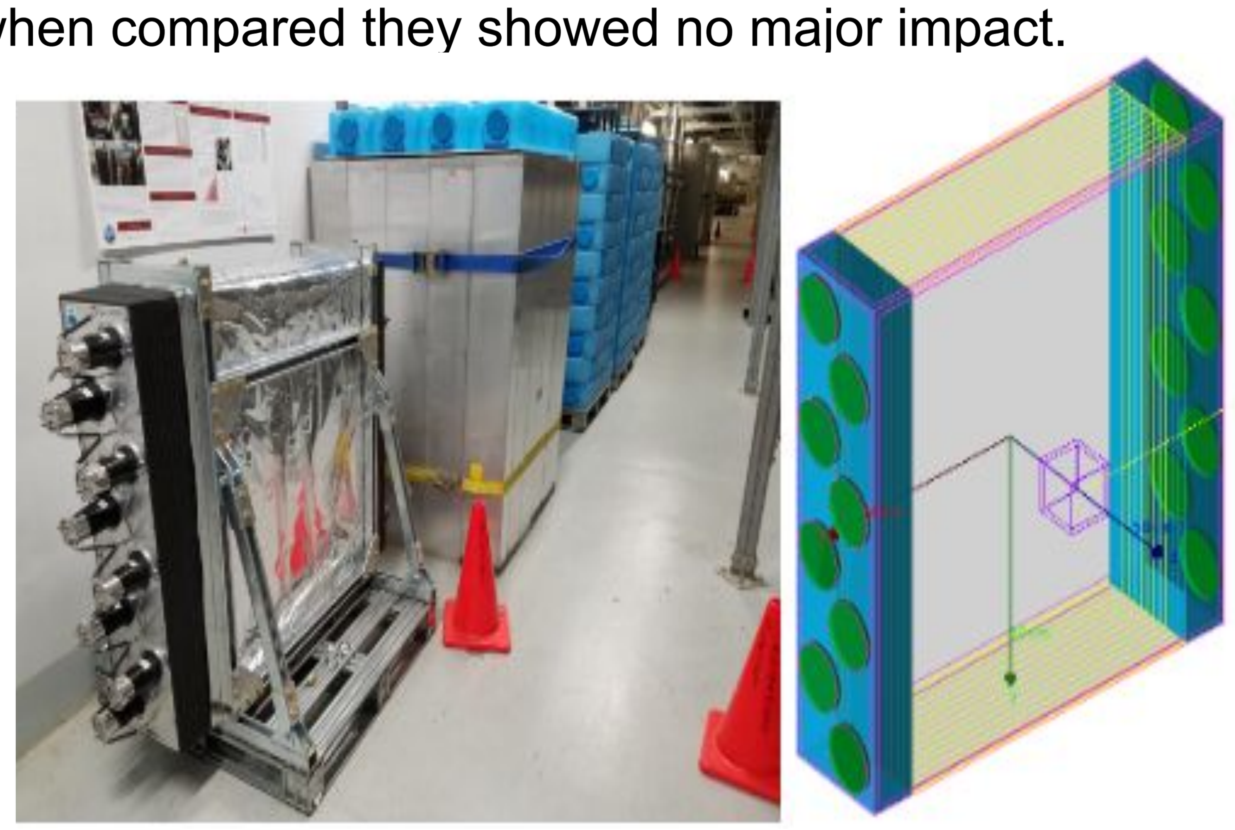
The COHERENT collaboration studies Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) with high-quality pion-decay-at-rest neutrinos from the Spallation Neutron Source (SNS) at Oak Ridge National Lab, Tennessee. Through CEvNS detection we can know more about the properties of neutrinos and nuclei.

Neutrons that survive thick shielding between the source and COHERENT detectors are a serious background for CEvNS detection. A dedicated neutron detector, MARS, is used to monitor this background.

The performance of this detector has been characterized using various radioactive sources, including a DT neutron generator. Two Geant4 Monte Carlo simulation packages were used to evaluate the efficiency of neutron detection of MARS, which can be used to estimate the neutron flux and the energy spectrum in Neutrino Alley, where neutrino detectors of COHERENT are located. The measured flux and spectrum can then be used to estimate the influence of the beam-related neutrons to the neutrino detection.

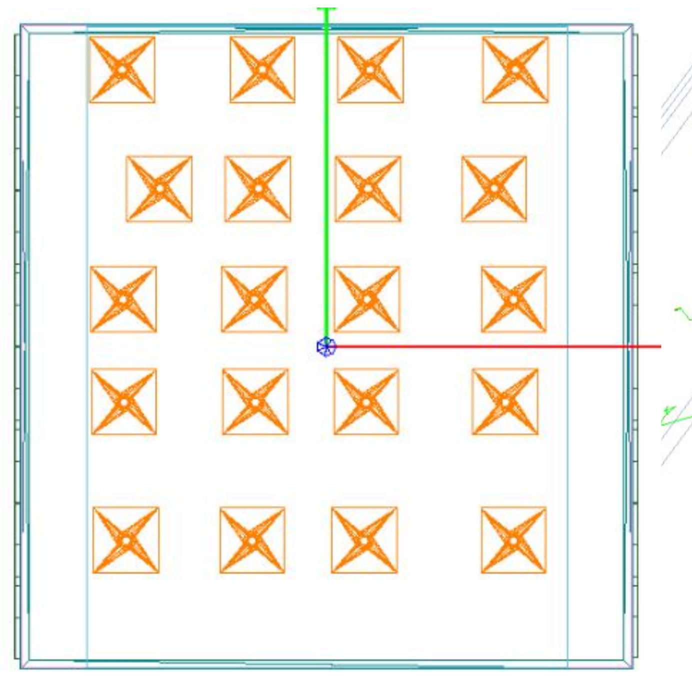
Experimental Setup

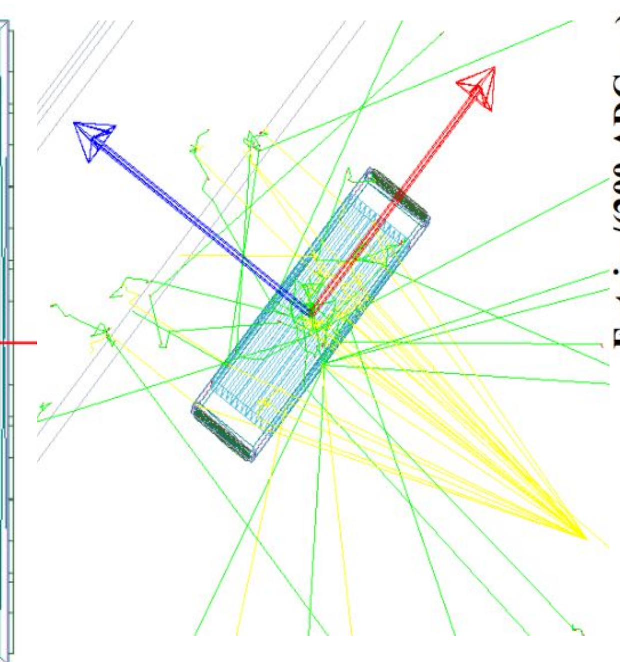
One of the Geant4 Monte Carlo simulation package allows definition of detector geometry in a text file, the visualization of it is shown below. Various macro files were used to simulate MARS's response to neutrons, Co-60 decay, and other background radiation. The back wall, floor and pallet of the detector were simulated, however when compared they showed no major impact.

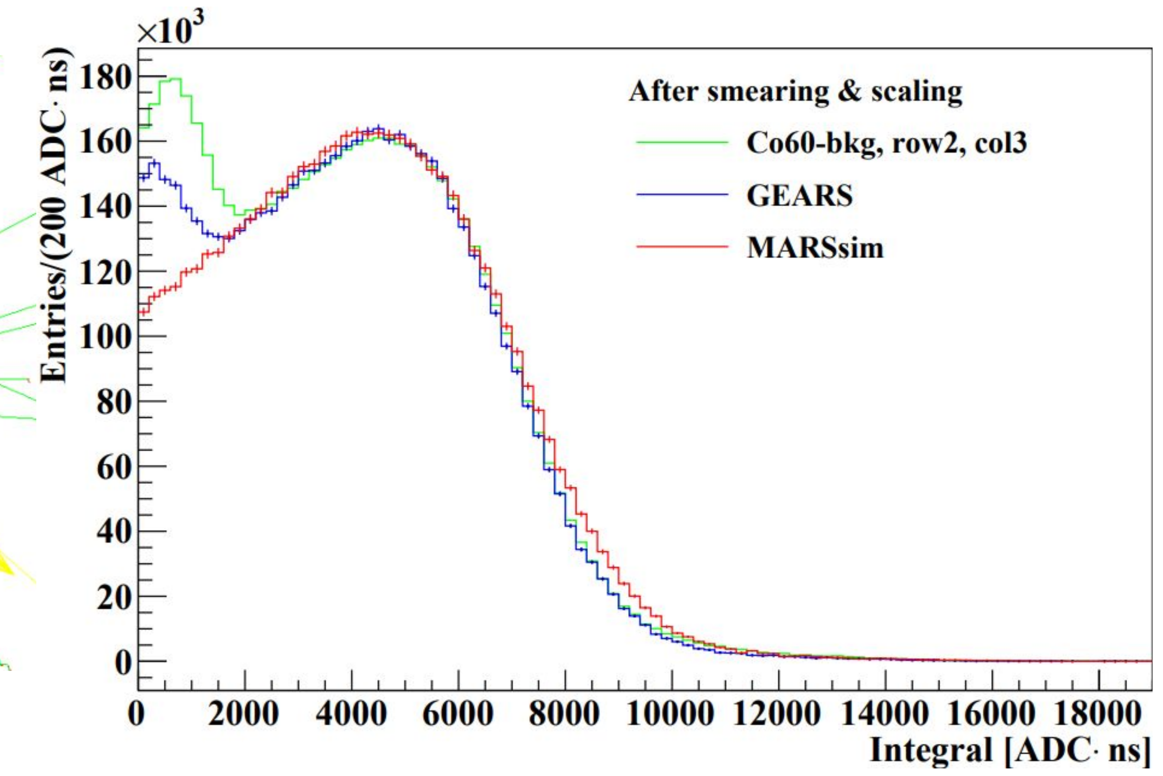


MARS (left) & its geometry implemented in simulation(right)

Gamma Ray Calibration







(Left) For Co 60 simulations a straight line or pencil beam was used, with collimators positioned as shown in front of the detector.

(Middle) Neutrons are simulated through the MARS detector in gears. They are set at an angle to simulate full coverage of the detector.

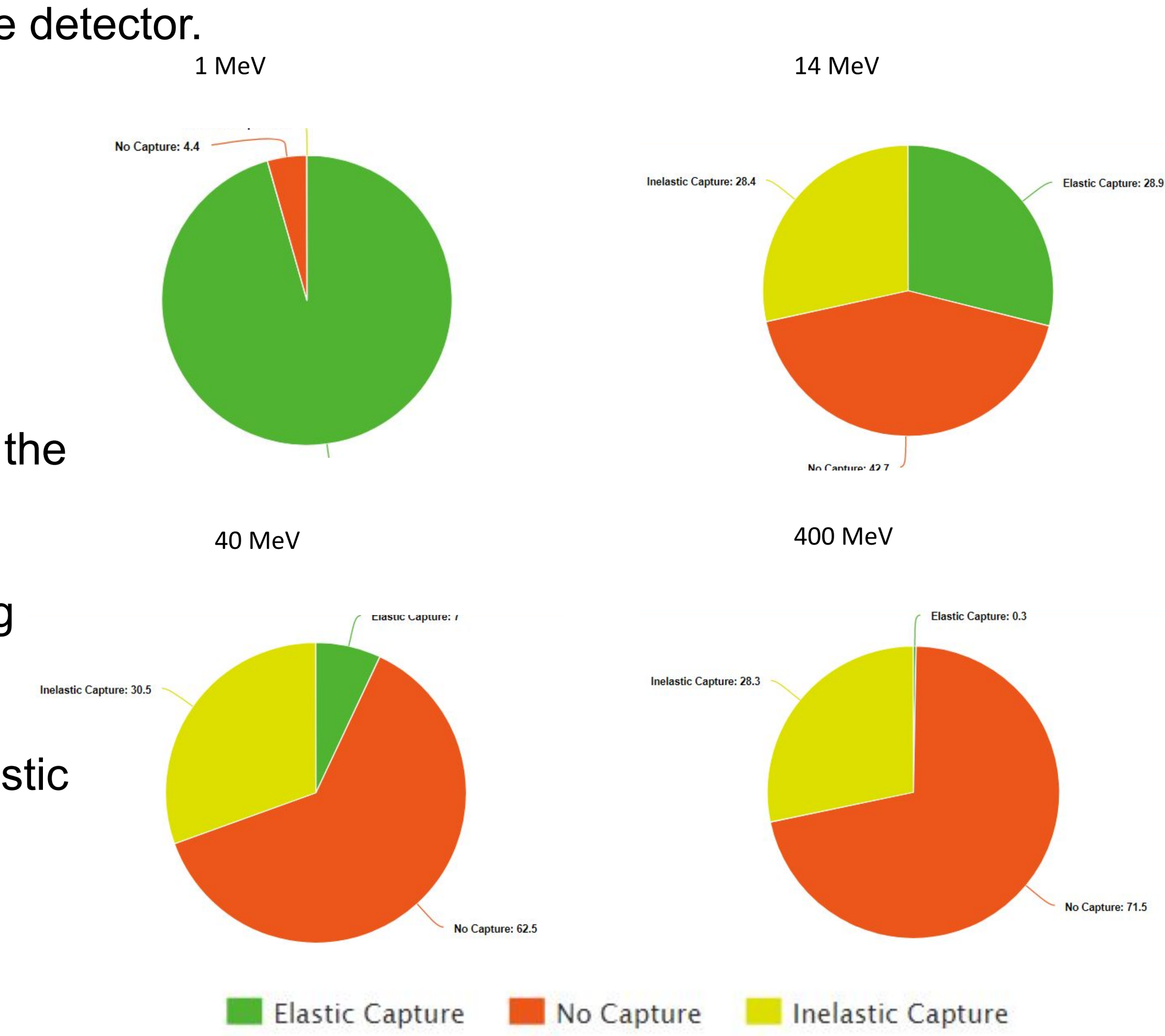
(Right) Co-60 decays were simulated and then compared to the data and a additional sim for of MARS calibration using Co 60.

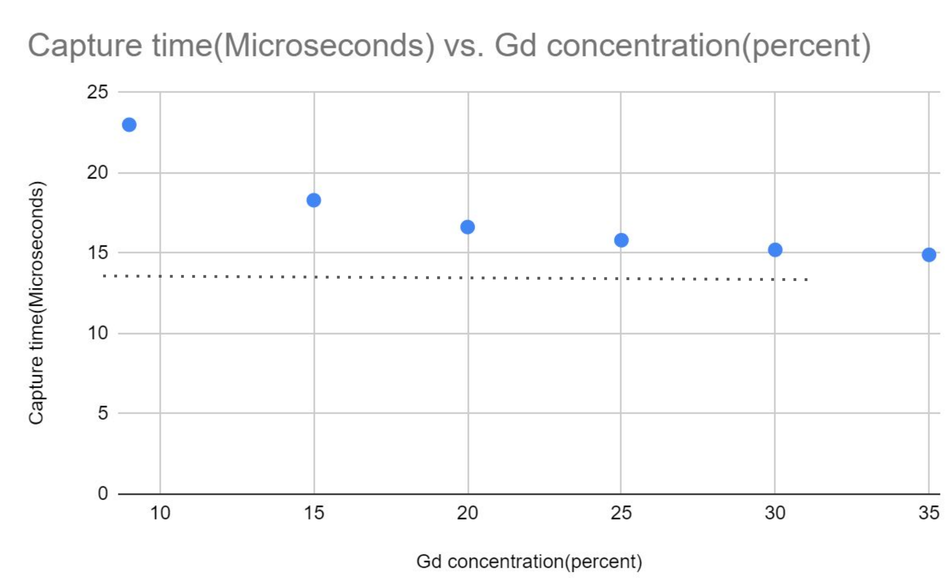
Neutron Calibration

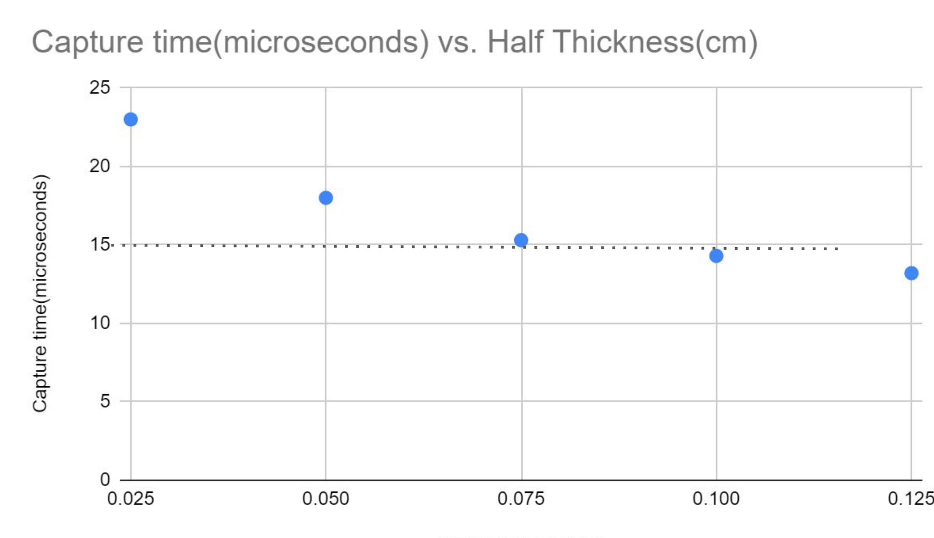
(Right) Simulating neutrons through the detector, the resulting data was categorized to

- capture with only elastic scattering
- capture with both elastic and inelastic scattering
- pure capture
- no capture

at different MeV. As the neutrons gain energy, elastic captures dominate the low MeVs, as we increase inelastic captures become more frequent with neutrons maintaining the energy to escape the detector, until elastic captures disappear entirely.

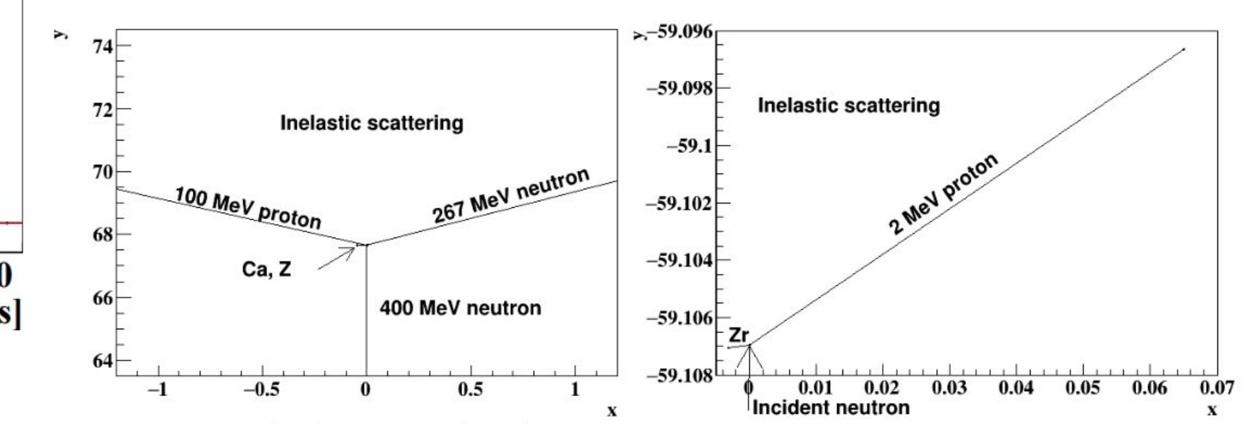






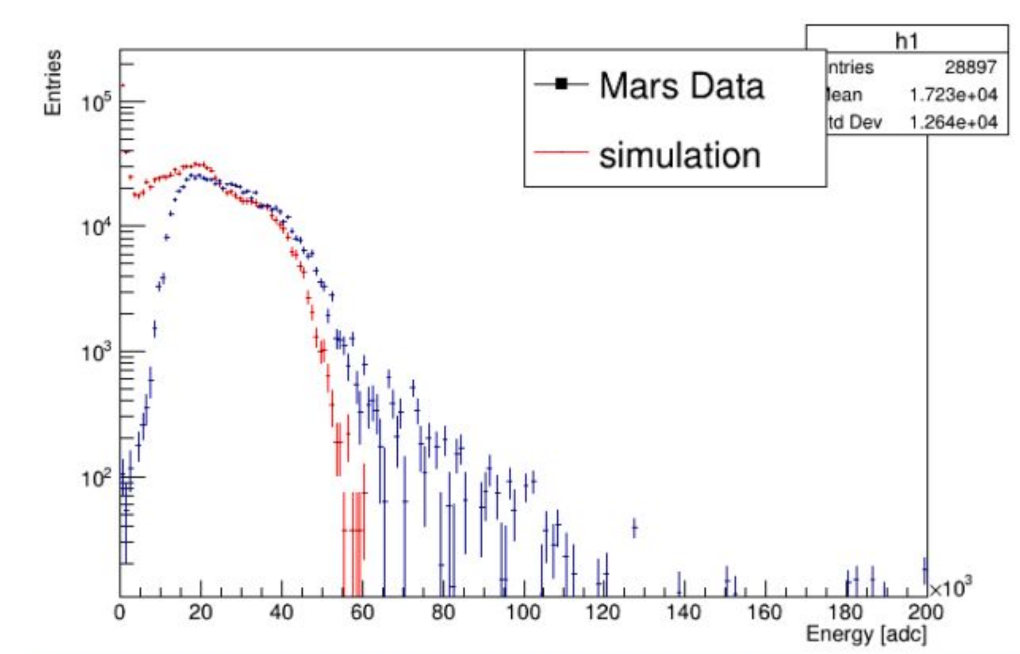
The capture time of neutrons was tested with changing the (Right)Gd concentration and (Left)half thickness of the paint, both starting points were the initial parameters, and comparing them to the data capture time of 15ns. Both Graphs result in an exponential curve related to the capture time.

Two typical inelastic events where low (left) or high (right) energy protons are created. Heavy ions are created together with the protons. Their tracks are very short. They deposit all their kinetic energies locally. Low energy protons have short tracks as well. Electron-hole pairs created by low energy protons and heavy ions may affect each other since they are created very close to each other.



Results

We take a look at the elastic captures and apply quenching and then smearing to our data set and compare it to data . We can see at low MeV the simulation does not match data, this fits as the MARS detector has energy threshold of 2.3 MeV. A new data set has also shown that the back and front of the detector to not match, whereas the simulation makes no distinction.



Conclusion

- The MARS detector can be recreated in Geant4 for simulation purposes.
- MARS can be calibrated using Co60 decays,
- The neutron calibration appears to be off slightly and falls in line with the fact the Gd or half thickness was too small, as well as the distinction between the back and front of the detector.
- Using the simulation we get a detector neutron efficiency of 8.2%