

Design and Simulation of a 9 MeV γ -Ray Calibration Source for the DUNE Neutrino Experiment at Sanford Lab

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The Deep Underground Neutrino Experiment (DUNE) is located at the Sanford Underground Research Facility (SURF) in the former Homestake Mine in Lead, SD. The DUNE detector will be comprised of four individual 10 kton liquid argon modules. The first module is scheduled to be operational in July 2026.

For DUNE it is important to understand the detector response to low low-energy neutrino events from both supernova and solar sources. The deployment of a calibration source which can mimic these low energy events is necessary to ensure that the signal response of the DUNE detector is well understood. The deployed nickel (n, γ) calibration source will be designed to emit clean 9 MeV gamma-rays induced by neutron captures on nickel to meet this task.

There are specific requirements to the deployment of a calibration source; the source must be able to endure cryogenic temperatures (87 K), it must not float, it must fit easily through the sealable flanges which have a relatively small diameter of 20 cm, and the moderator thus limited in size must still be efficient enough to thermalize neutrons so that the desired $^{58}\text{Ni}(n, \gamma)^{59}\text{Ni}$ reaction can occur and produce the desired 9 MeV γ -rays at a sufficient rate and purity for calibration purposes of DUNE.

Results from computer simulations utilizing the GEANT4 simulation framework are presented. Feasibility of a new compact nickel (n, γ) calibration source has been demonstrated by optimizing the configuration, location pattern and number of natural nickel rods placed inside a moderator made of high density plastic (Delrin) and by surrounding the entire assembly with a neutron absorbing boron loaded shell. Such a viable nickel (n, γ) calibration source can then simply utilize a commercially available AmLi (Americium Lithium) as internal neutron emitter. Further simulations of the calibration deployment in the DUNE detector are shown that demonstrate the clean detection signature of the optimized 9 MeV γ -ray calibration source.

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