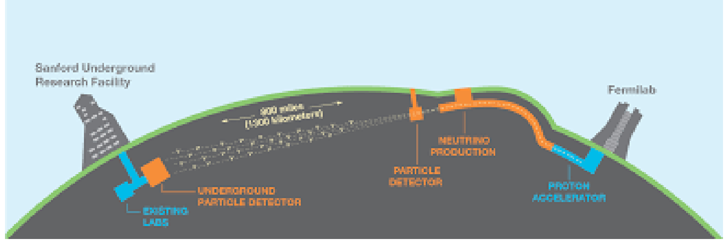
DUNE DD Neutron Shielding

Keegan Harrison, Jingbo Wang, Walker Johnson
South Dakota School of Mines and Technology
Physics Department

The DUNE Experiment



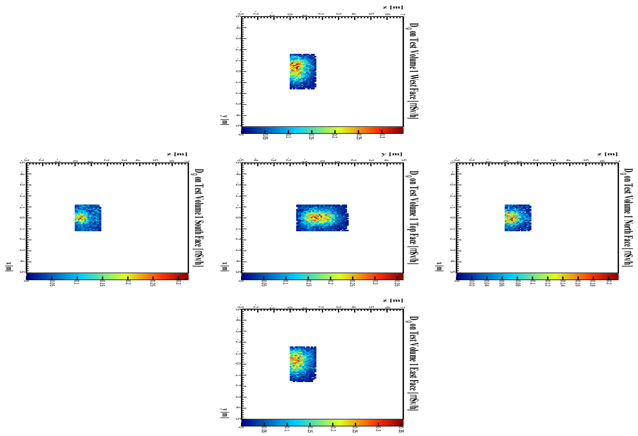
The Deep Underground Neutrino Experiment (DUNE) is the future leading-edge, international experiment for neutrino science and discoveries of physics beyond the Standard Model. The experiment consists of a high intensity neutrino beam, a near detector at Fermilab in Illinois, and a 40-kton fiducial mass far detector deep-underground in the Sanford Underground Research Facility (SURF) in South Dakota. For the experiment, trillions of neutrons will be fired from Fermilab to SURF. At SURF the neutrinos will hit a liquid argon detector.
Achieving physics sensitivity in DUNE requires a precision detector calibration that constrains the uncertainties from relevant detector response parameters. A novel way to do this is to inject neutrons into the liquid argon detector using a Deuterium-Deuterium (DD) neutron generator. The DD generator gives off high amounts of radiation and therefore must be shielded. Through our simulations we have found that we can safely build a shielding structure that has borated Polyethylene for neutron radiation and lead lining around it for gamma radiation.

DD neutron generator

Interior Shielding

The design that was put forth consisted of Borated Polyethylene around the generator and a lead brick lining around the Polyethylene. Using Excel we were able to build an optimization equation to see, with the materials we had, how thick we could make the interior shielding and cover the whole generator.
We found that the thickest we could go with the polyethylene was 27 cm. Having this information, we were able to use GEANT4 simulations to simulate the radiation coming from the neutron generator at 2.5 MeV with a 27 cm thick polyethylene shield and lead lining.

Results of Simulation Neutron Radiation

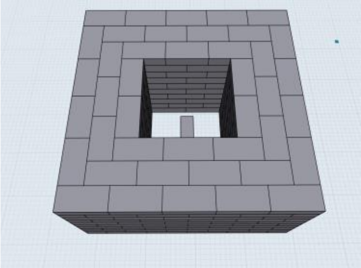


This simulation showed that with the material we had we could not build a shield that met the standard radiation limits needed for a lab environment. Therefor we needed another method to shield the gamma and neutron radiation.

Exterior shielding

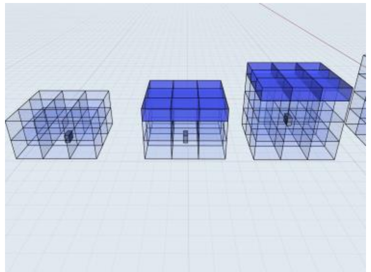
We determent that an external shield would be appropriate to block the excess radiation. Using a 3D modeling soft ware named sharp3D and Excel we were able to design multiple types and builds of an exterior shield. Using these programs we could determine the overall weight, height, and cost of different materials with different thicknesses of shielding.

Concrete Shield



We first looked at the feasibility of using concrete as a shield. This shielding option would need to be a meter thick. This option was cheaper costing about $1,500
But would weigh about 18 tones

Water Tank Shields



The second option we investigated was water tanks. This option, we found, would be more expensive costing about $6,300.on the upside it would only weigh 6.7 tones

With the information we gathered we were able to determent that a 15 cm think polyethylene shield with an exterior water shield added will keep the radiation to acceptable standards in a lab environment

References:
Johnson, Walker. *Shielding Construction*. South Dakota School of Mines and Technology, Department of Physics, 25 June 2021.
Fantidis, Jacob G. "The Comparison between Simple and Advanced Shielding Materials for the Shield of Portable Neutron Sources." *International Journal of Radiation Research*, International Journal of Radiation Research, 10 Oct. 2015, ijrr.com/article-1-1583-en.html.

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