DD Generator run in the DUNE VD ColdBox

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Contents:

Neutron capture for energy scale calibration of DUNE VD Photon Detection System Data [more details in DUNE collaboration meeting talk (here)

→Neutron capture on Ar-40 produces a 6.1 MeV gamma cascade: This is a well-defined energy deposition which can be used as a standard candle for calibration.

→Neutrons can travel long distances (~30 m attenuation length) before being captured thus providing a good coverage in the entire DUNE detector.

→Gamma cascade is confined within a relatively small region (~ 1 m).

This makes neutron capture events suitable for calibrating large detectors like DUNE. Using neutron capture gamma cascade energy deposition, we want to remove non-uniformity in light yield (photo-electrons per MeV of energy deposit) and perform energy calibration.

In the DUNE VD coldbox we want to demonstrate the calibration capability of DDG for Photon Detection System energy calibration

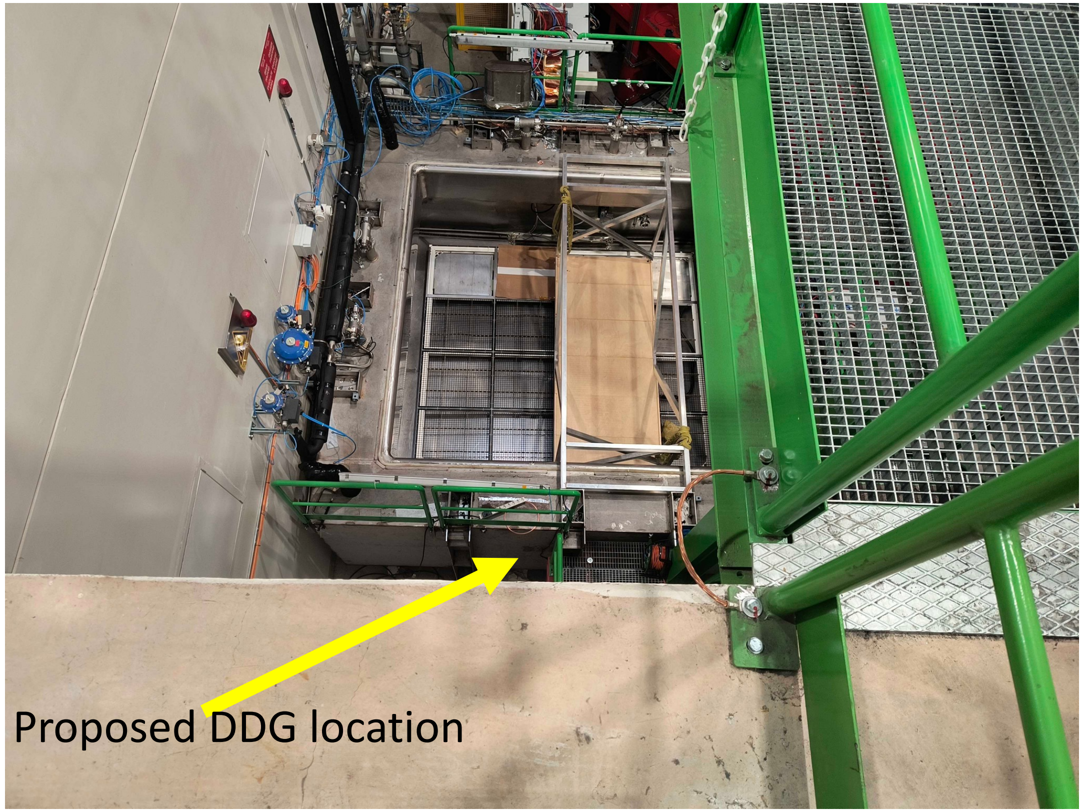
Neutron generator to be used (and location):

The neutrons will be generated from a commercial Thermo Fisher MP-320 Deuterium-Deuterium Generator (DDG), which produces monoenergetic 2.45 MeV neutrons with a flux of up to 10^6 neutrons/second. When not operating, the generator does not produce neutrons.

DDG is planned to be placed on the side of the DUNE VD coldbox, with the DDG opening centered at the center of the drift volume (as shown in figure aside).

A capture rate of 4000-5000 neutrons per second is estimated in the active volume through geant4 simulation for this location.

Top view of DUNE VD coldbox



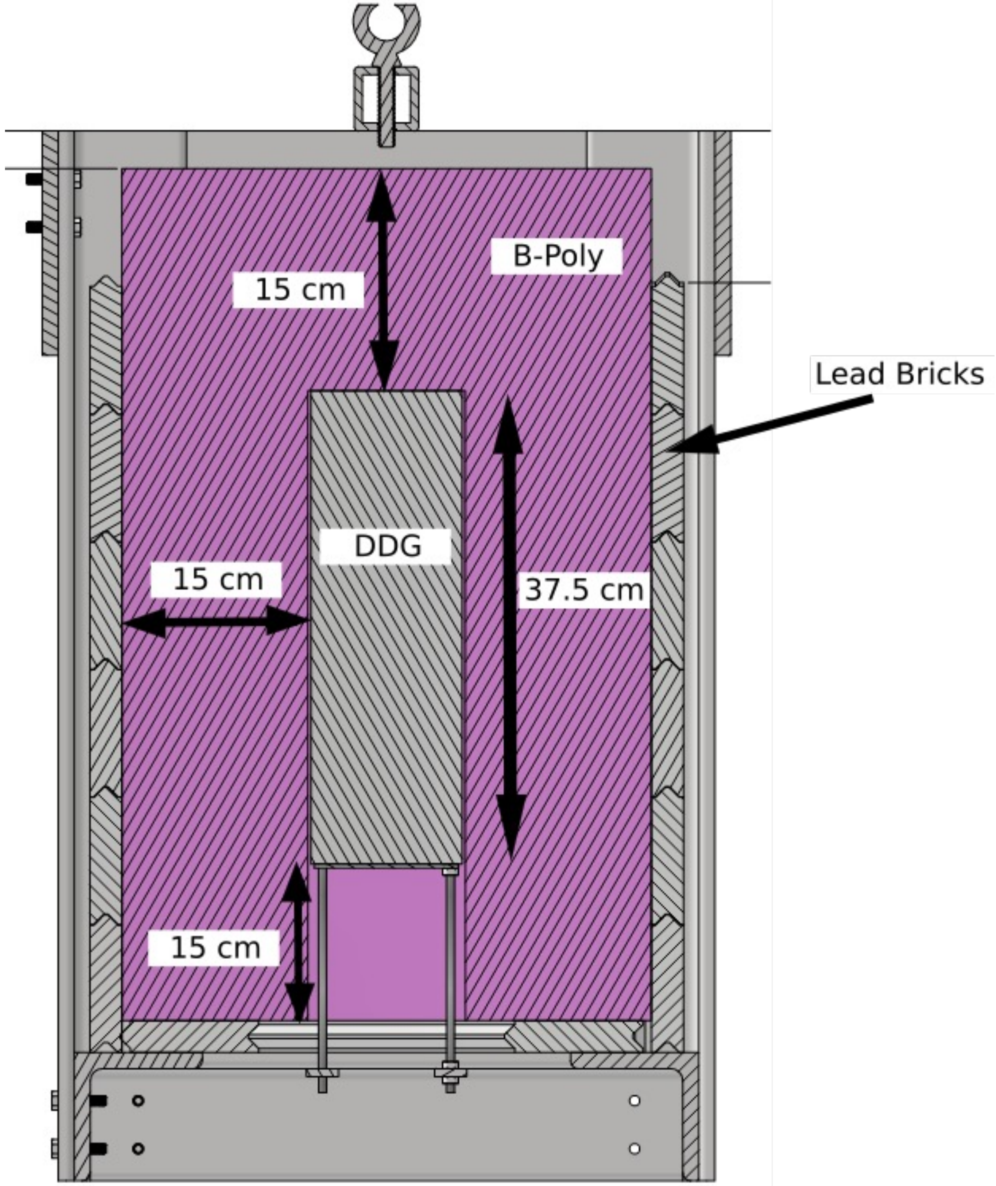


Fig: Drawing of the DDG with shielding

Shielding Details for DDG:

→15cm of Borated polyethylene on all sides of the neutron source (except the window) - 5% boron by weight

→1" of lead (the chevron shaped interlocking pieces near the outside edge in the drawing)

→12cm square 'window' for collimating outgoing neutrons

→The supporting structure is primarily made from angle-aluminum, eye-bolt at the top is for moving the structure

Some pictures of the shielding (not fully assembled in the picture):


Installation and operation:

- Final testing and preparation for shipment of DDG is ongoing at South Dakota School of Mines.
- Proposed run for DDG is at the final week of VD ColdBox run (for which filling is foreseen to begin on January 8, 2024). And the VD ColdBox run will last around 3 weeks.
- A combined CRP and PDS data will be taken during the DDG run, with trigger being provided by DDG with following specification:

Trigger details (Type: BNC Description: This is a 5V TTL signal capable of driving into 50 Ohms. This signal is reserved for use by the customer for triggering equipment synchronized with the neutron pulse).

Further, trigger primitive studies are ongoing.

Coldbox Standalone G4 Simulation

Walker Johnson

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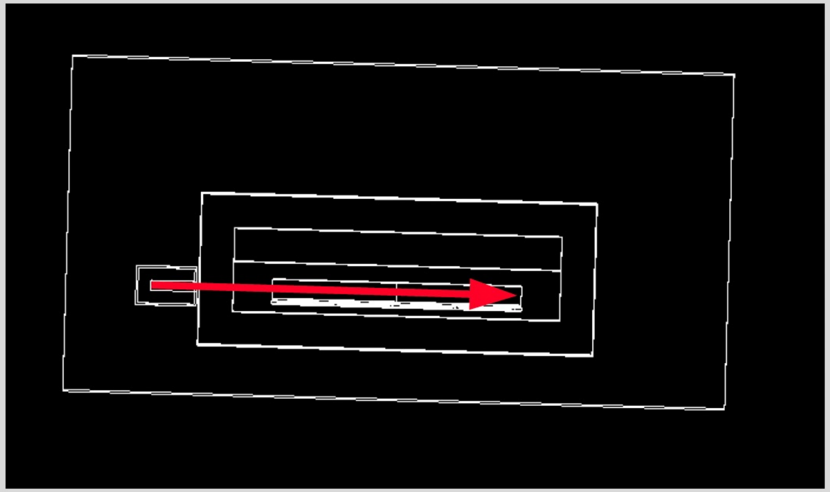
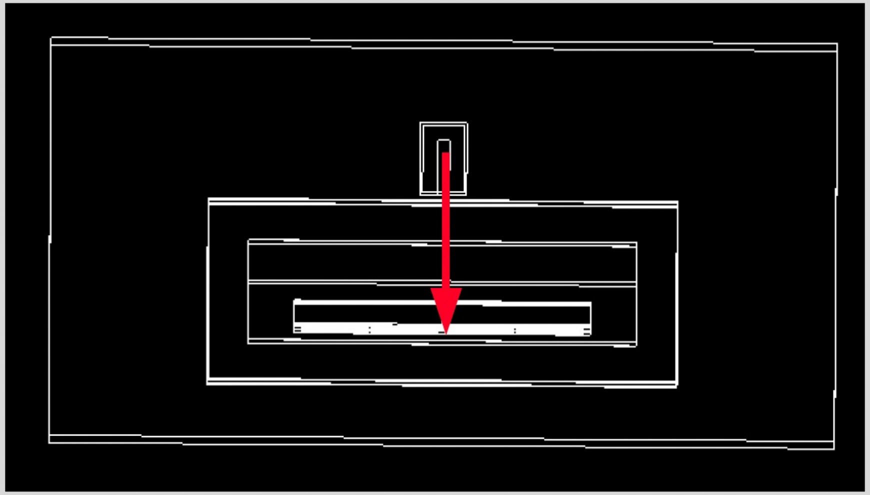
An engineering, science and technology university

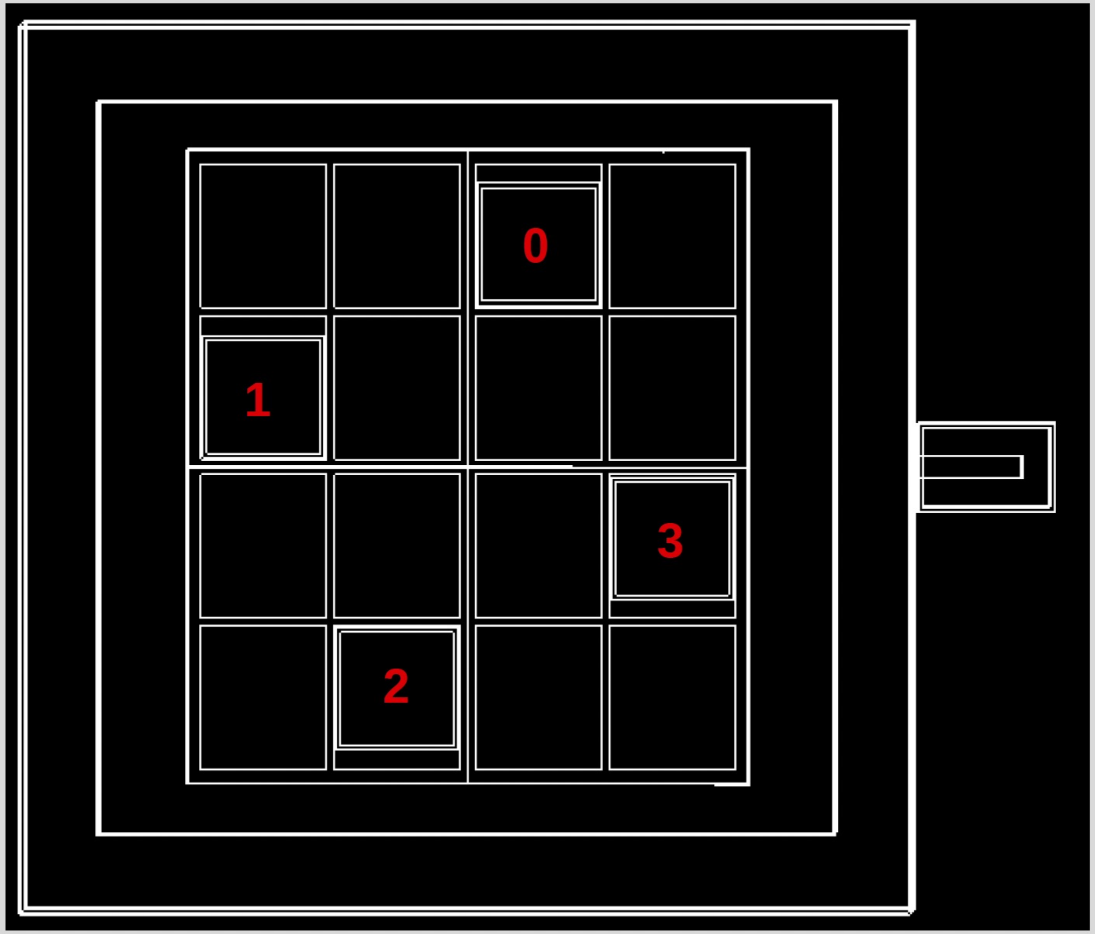
Locations

- The two location options are: on top of the Coldbox detector, and on the side of the detector
  - We may be better served pointing the PNS directly over one of the photodetectors to maximize captures that will give us a trigger



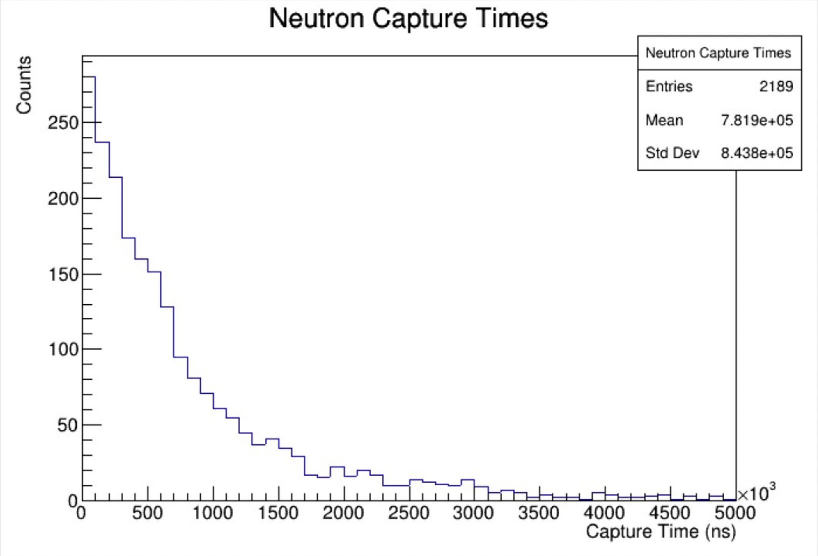


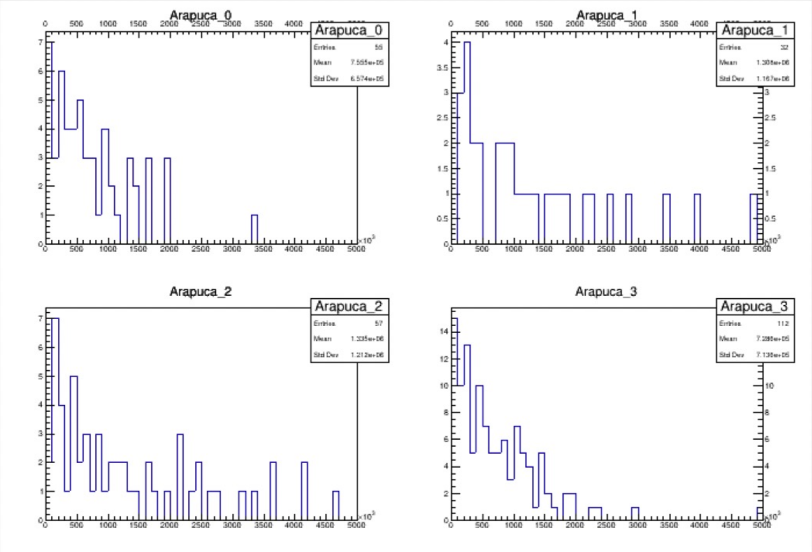
Photodetector locations



Side Position

- Centered in x-z
- 5x10^5 neutrons simulated (isotropic from DDG)
- ~0.44% capture rate, .7819 ms mean capture time

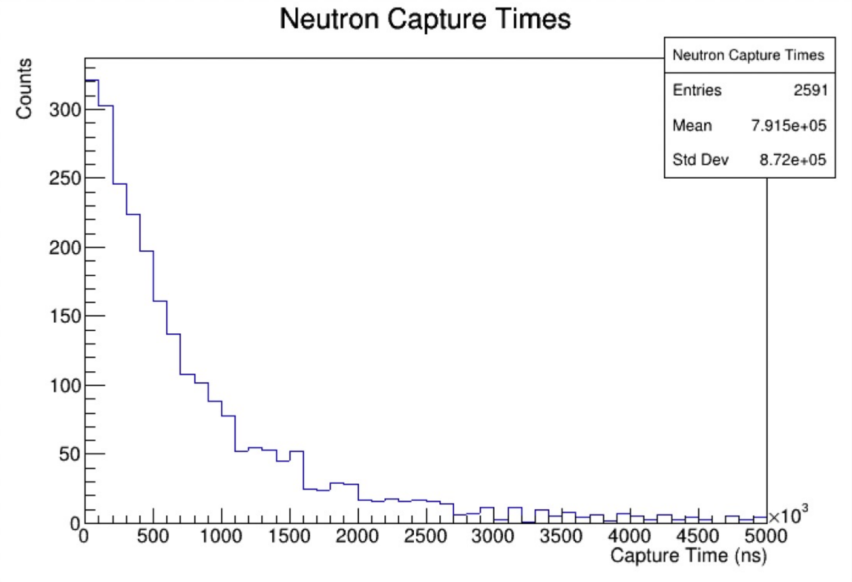


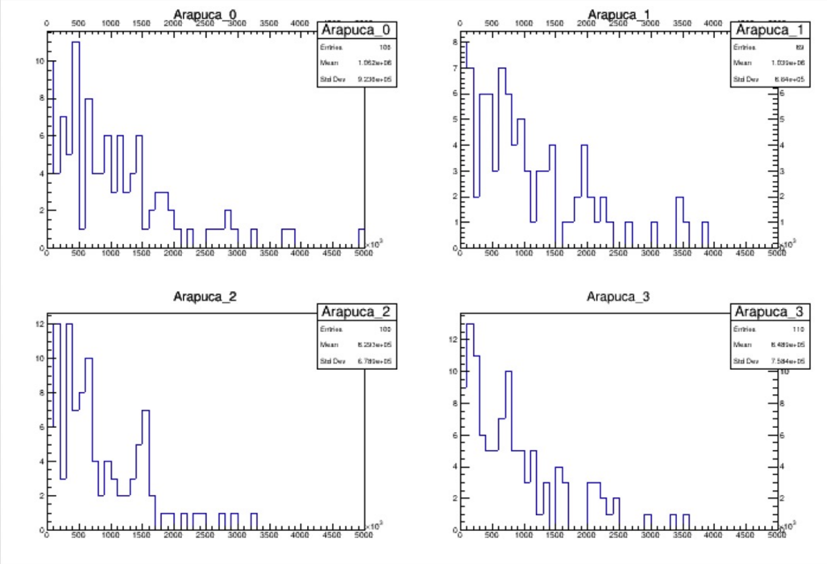


Captures in active volume directly above the phtotodetectors

Top Position

- Centered in y-z
- 5x10^5 neutrons simulated (isotropic from DDG)
- ~0.52% capture rate, .7915 ms mean capture time





Conclusions

- Roughly the same capture rate in both positions
  - Top has slightly higher rate of captures
- For 1s total PNS-On time we can expect ~4000-5000 captures in the active volume
  - For a 400us pulse width, this equates to about 2 captures every pulse
  - With current positions tested ~1/10 of these captures occur directly above a photodetector
  - The chance for a capture to result in a 4.7MeV gamma that undergoes pair production = ~1/5
  - Roughly **1 event for every 25 pulses** (without accounting for the acquisition window)

Data-taking and analysis plans (more details in Wei's talk next):

- Take data to cover the entire active volume with neutron capture events. It will depend on the binning we want to use and minimum entry on each bin.

- Record and identify the signals from neutron capture using photon detectors.

- Divide the active volume into small voxels and estimate the light yield map (number of photo-electrons per MeV) as a function of position. Using the TPC and PDS combined information to reconstruct the position of capture.

- The goal of the run is to demonstrate the capability of using DD generator for the energy scale calibration of the photon detection system data.