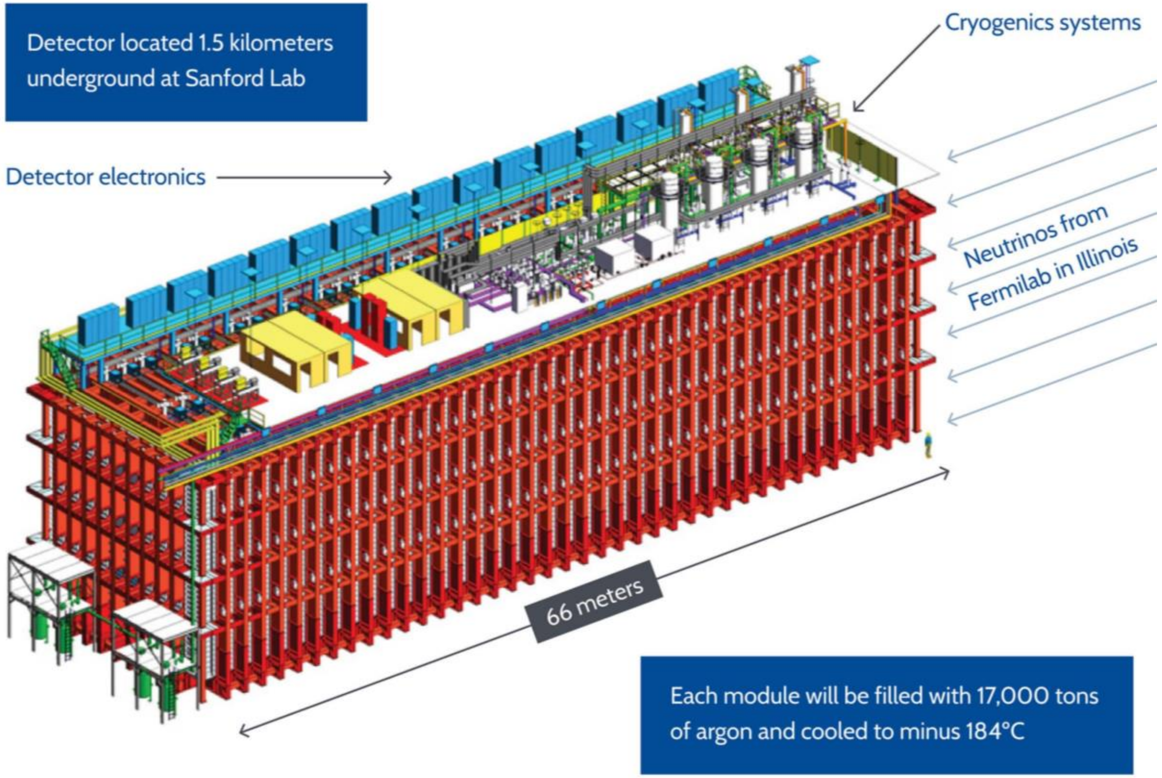
Neutron Generator Calibration System for DUNE

Yashwanth Bezawada
University of California, Davis
For the DUNE Collaboration

XIX International Workshop on Neutrino Telescopes
25 February 2021

DUNE and ProtoDUNE



- The Deep Underground Neutrino Experiment (DUNE) will be a neutrino observatory hosted by the Fermilab
- Far Detector (FD) at Sanford Underground Research Facility (SURF):
  - Located at 1.5 km underground
  - Modular Liquid Argon Time Projection Chamber (LArTPC)
  - 4 x 17-kt modules (10 kt fiducial mass each)
- Physics goals: Long baseline neutrino oscillations, supernova physics, etc.

- ProtoDUNE single-phase apparatus (ProtoDUNE-SP) is a test bed and full-scale prototype of a far detector module of DUNE
- Installed at CERN Neutrino Platform
- Contains 770 t of liquid Argon

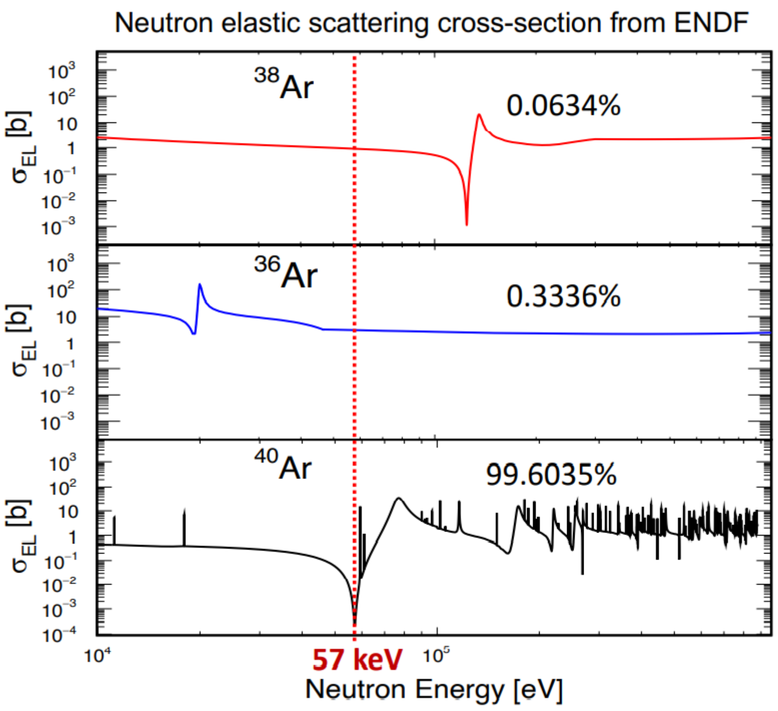
Neutrons for Calibration

- The stringent physics requirements for DUNE are unprecedented
  - Energy scale must be known to 2% or better for oscillation physics and 5% or better for supernova physics
- Understanding the overall detector response is crucial for DUNE to make a convincing measurement of CP violation or to understand the data from a supernova neutrino burst (SNB)
  - Need to measure detector response in both space and time

Neutrons can help us!!

- Average fractional energy loss per scatter only 4.8% for neutrons in liquid argon; can travel long distance
- Argon has a near transparency to neutrons of energy 57 keV due to anti-resonance section (see L. Pagani's talk on ARTIE)
- These neutrons can travel ~30m in Argon according to ENDF library
- Neutron captures in liquid argon release distinct 6.1 MeV gamma ray cascade

$$n + {}^{40}Ar \rightarrow {}^{41}Ar + 6.1\ MeV$$



UC DAVIS UNIVERSITY OF CALIFORNIA

Pulsed Neutron Source (PNS)

- Deuterium-Deuterium (DD) neutron generator produces 2.5 MeV neutrons; adjustable pulse width/rate

$$^{2}H + {}^{2}H \rightarrow {}^{3}H + n + Q(2.5\,MeV)$$

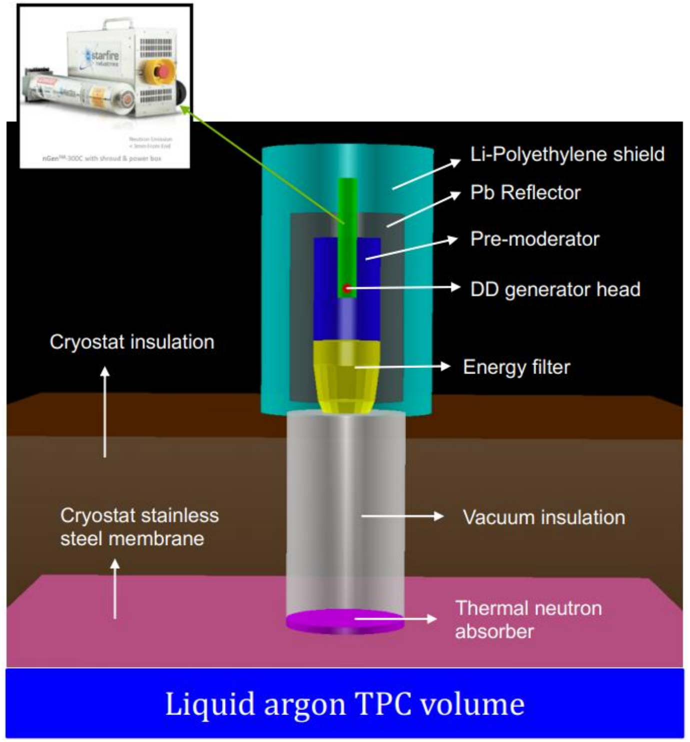
- After moderation, can reduce energy down to below 100 keV

Advantages

- **External deployment** of the source; no contamination of argon
- **Pulsed trigger**; helps reconstruct neutron capture location

How can PNS help us?

- Calibrate energy scale and resolution using 6.1 MeV gammas
- Helps in SNB trigger efficiency calibrations as the gamma-ray bursts cascade mimics SN events
- Calibrating electron lifetime and drift velocity in active TPC



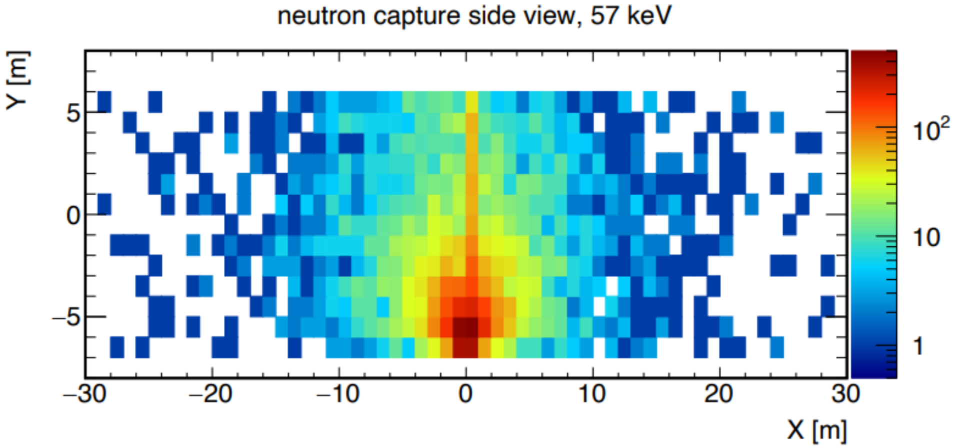
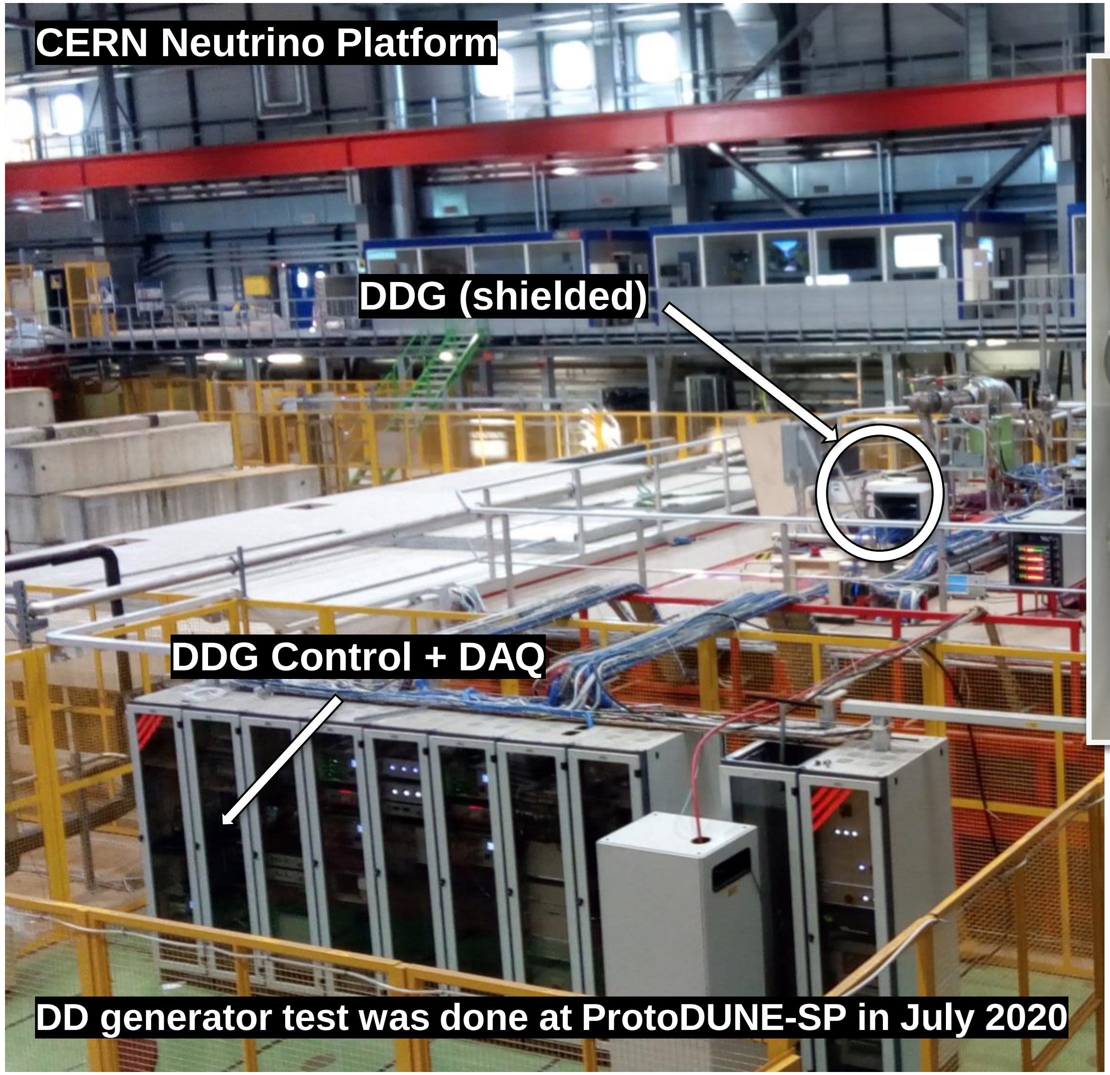
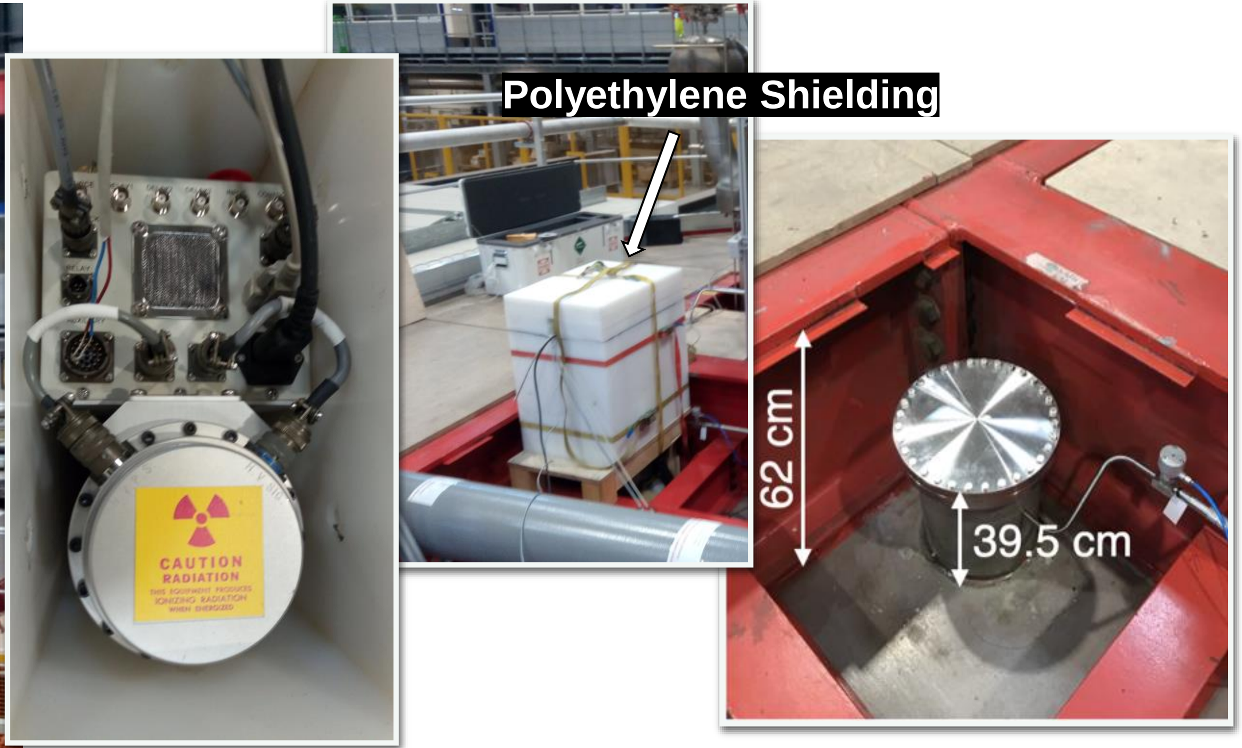


Fig. Simulated spread of 57 keV neutrons in the DUNE-size module (work done by J. Wang)

DDG Test at ProtoDUNE-SP





(From left to right) protoDUNE-SP module and the DDG installation location; DDG; DDG inside the shielding; roof feedthrough at which DDG is deployed

(Images from M. Fanì, DUNE Collab. Meeting, Sep 2020)

DDG Test at ProtoDUNE-SP

- Main goals: verify the neutron transport model and develop neutron capture analysis algorithms
- Data taking was done over 10 days with different trigger modes and neutron intensities
- Simulation and analysis tasks are ongoing (see J. Huang's talk on simulations)

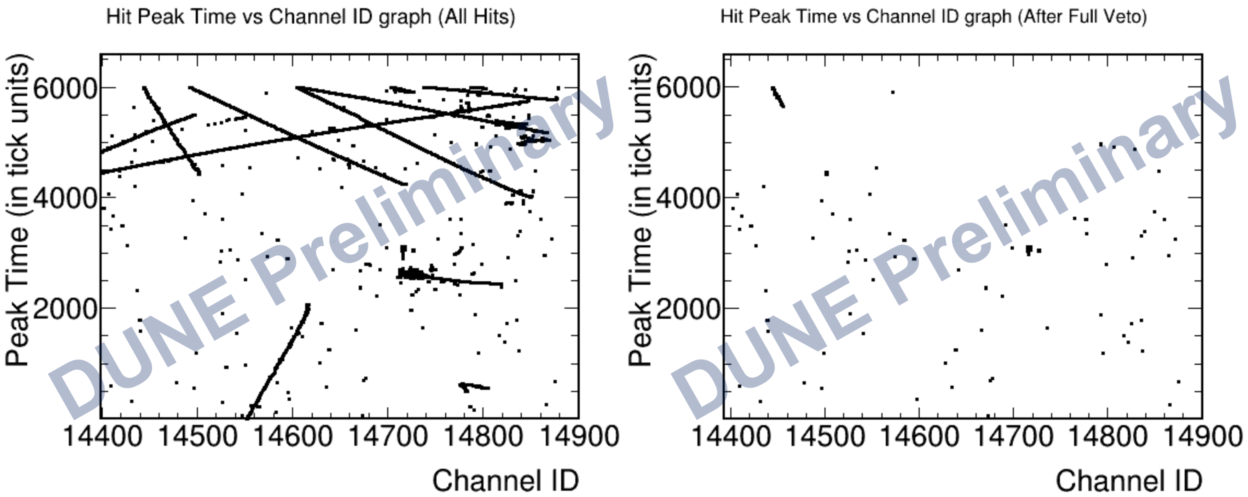


Fig. Peak Time vs Channel ID plot for one event; Before and after cosmic removal respectively

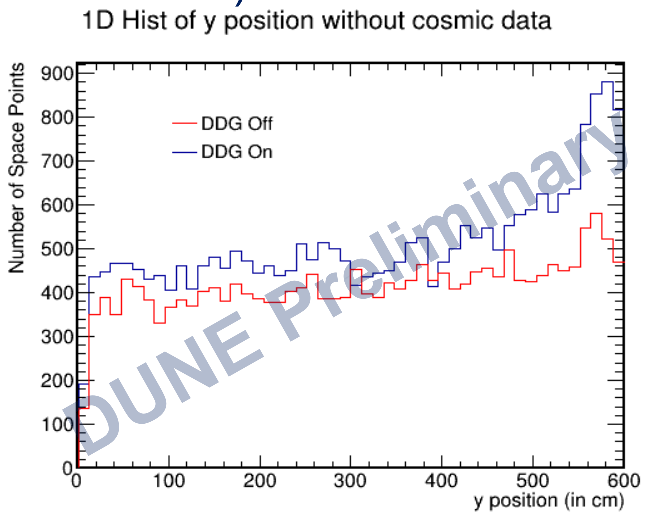


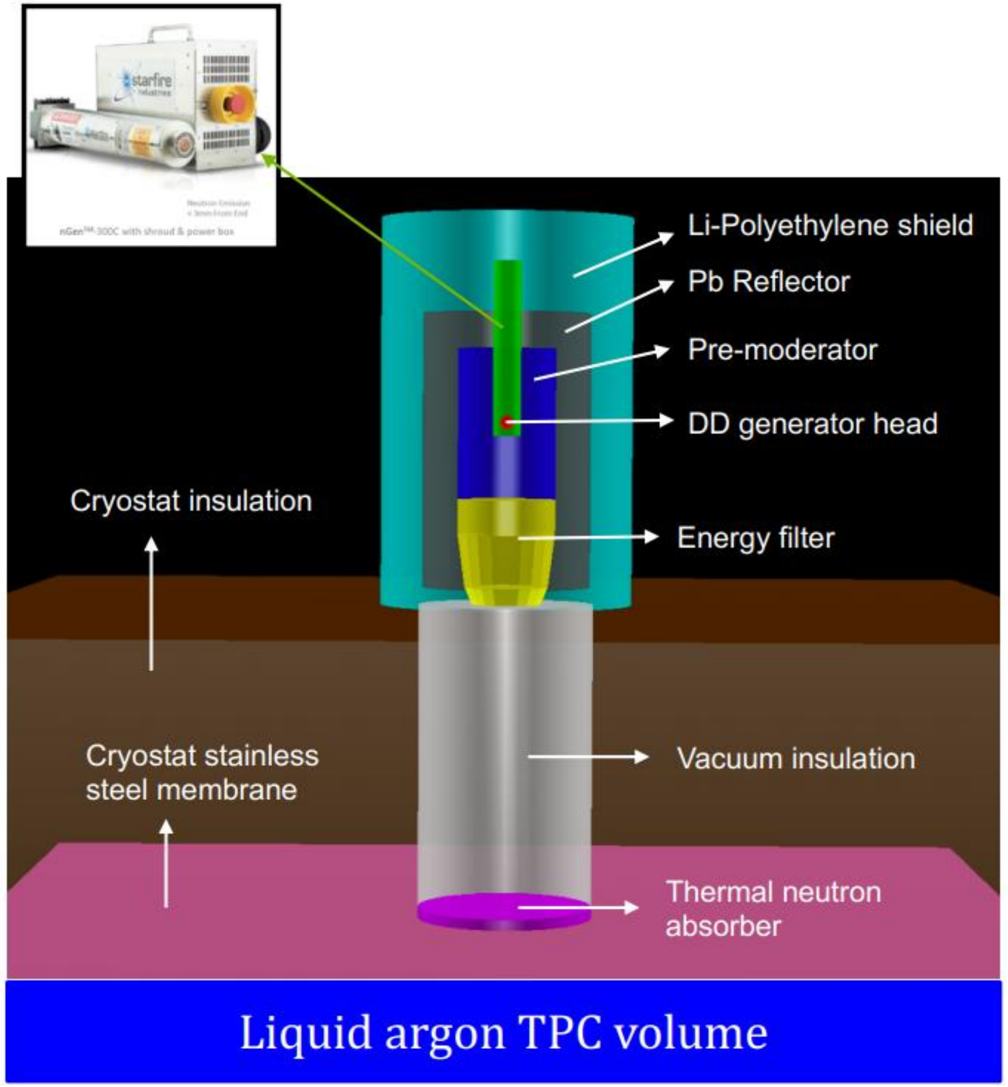
Fig. y distribution (vertical direction with y=600 cm at the top); Can see the excess activity in the "DDG On" run

Ongoing Tasks

- Energy Reconstruction of the data
- Comparing data with MC simulations

Backup Slides

Pulsed Neutron Source (PNS)



Conceptual Moderator:

- DD generator → 2.5 MeV neutrons
- Pre-moderator → efficiently reduce energy down to below 1 MeV
- Energy filter → reduce neutron energy down to sub-hundred keV level
- Pb reflector → Increase neutron yield
- Thermal absorber → suppress thermal neutrons
- Li-Polyethylene shield → radiation protection

UCDAVIS UNIVERSITY OF CALIFORNIA