Neutron Generator Calibration System for DUNE

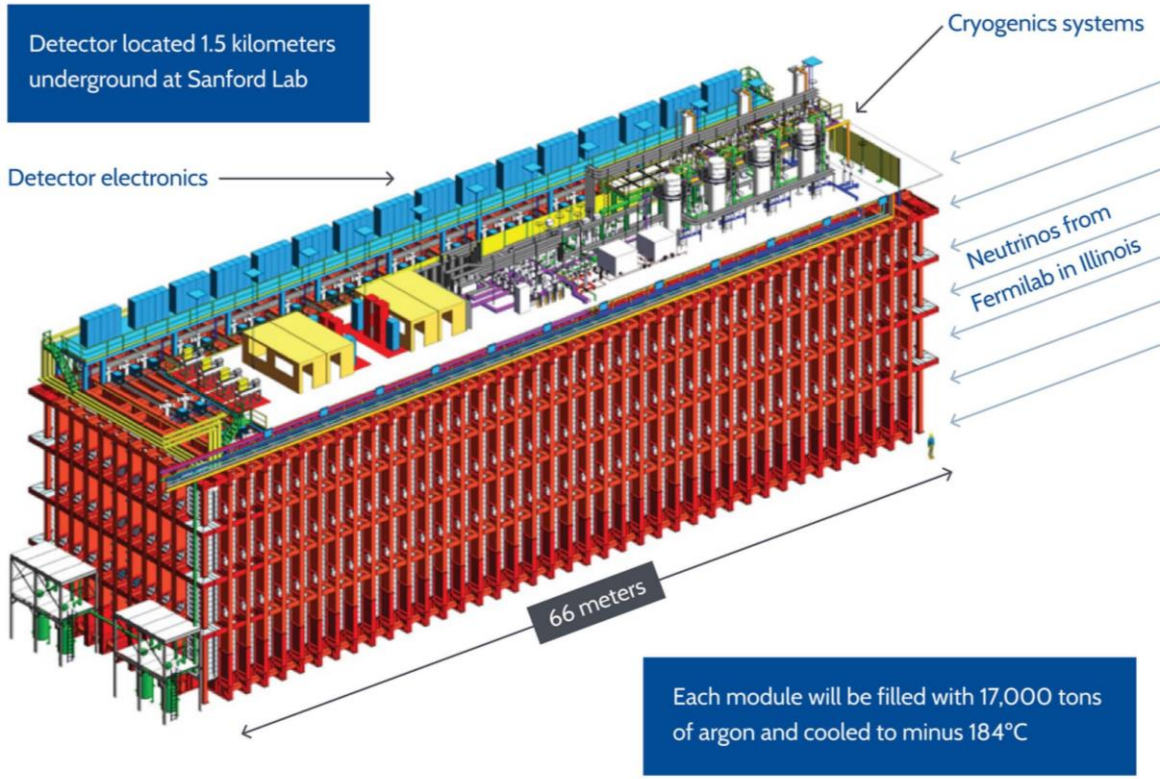
Yashwanth Bezawada
University of California, Davis
For the DUNE Collaboration

XIX International Workshop on Neutrino Telescopes
25 February 2021

UC DAVIS
UNIVERSITY OF CALIFORNIA

DUNE

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

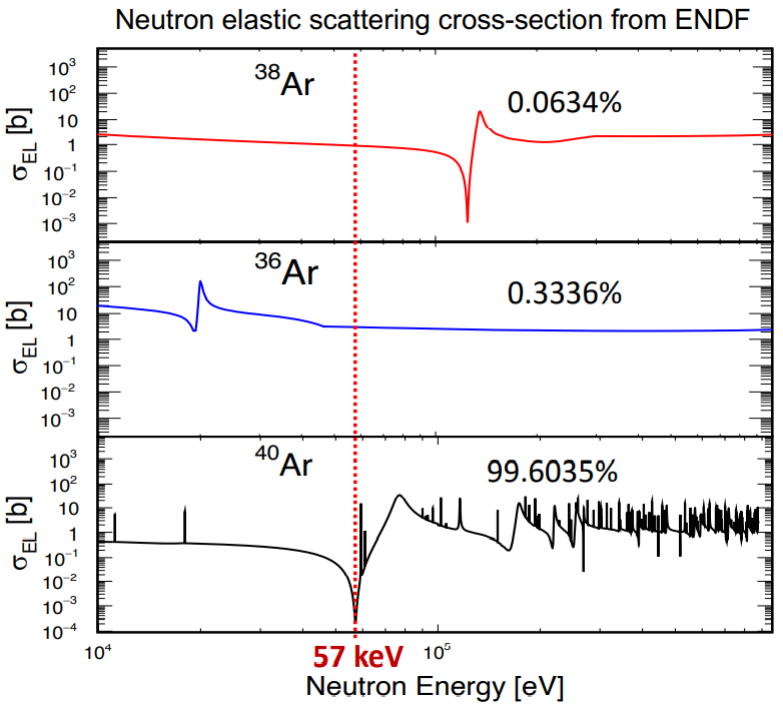
Neutrons for Calibration

- 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

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



Pulsed Neutron Source (PNS)

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

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

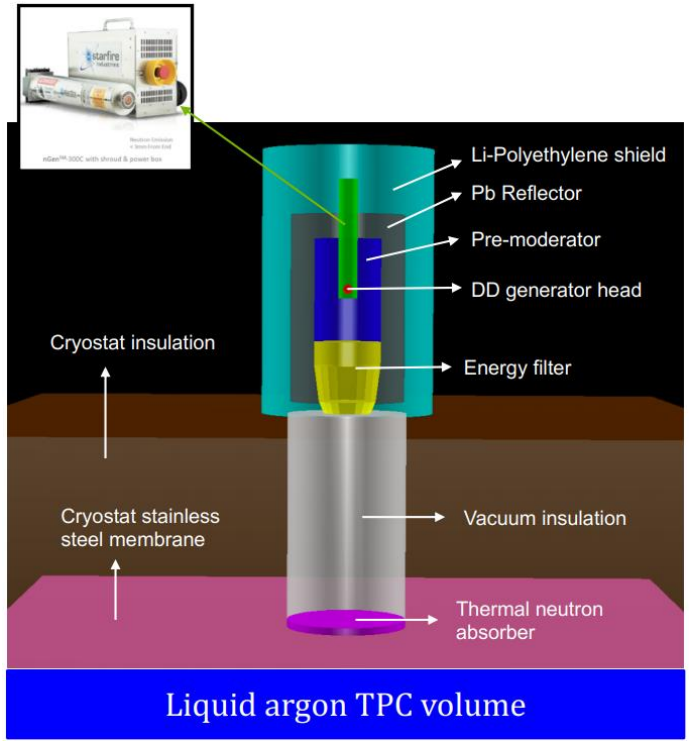
- After moderation, can reduce energy down to below 100 keV

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



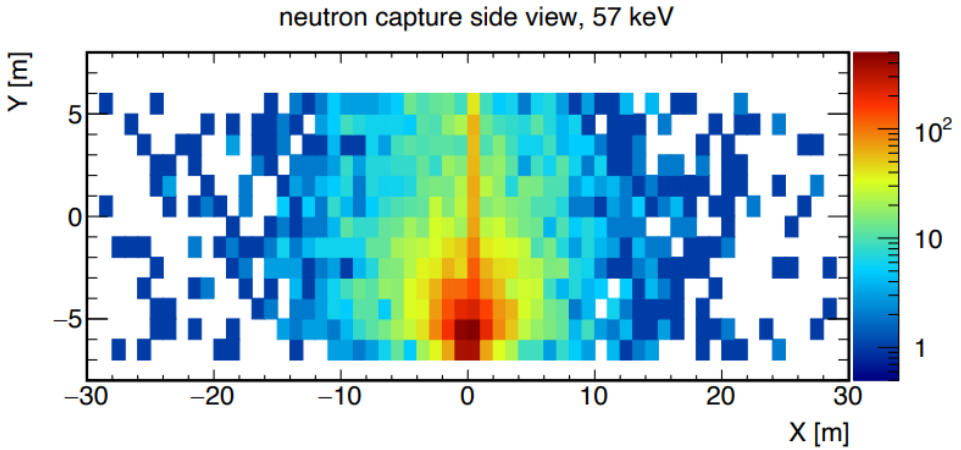
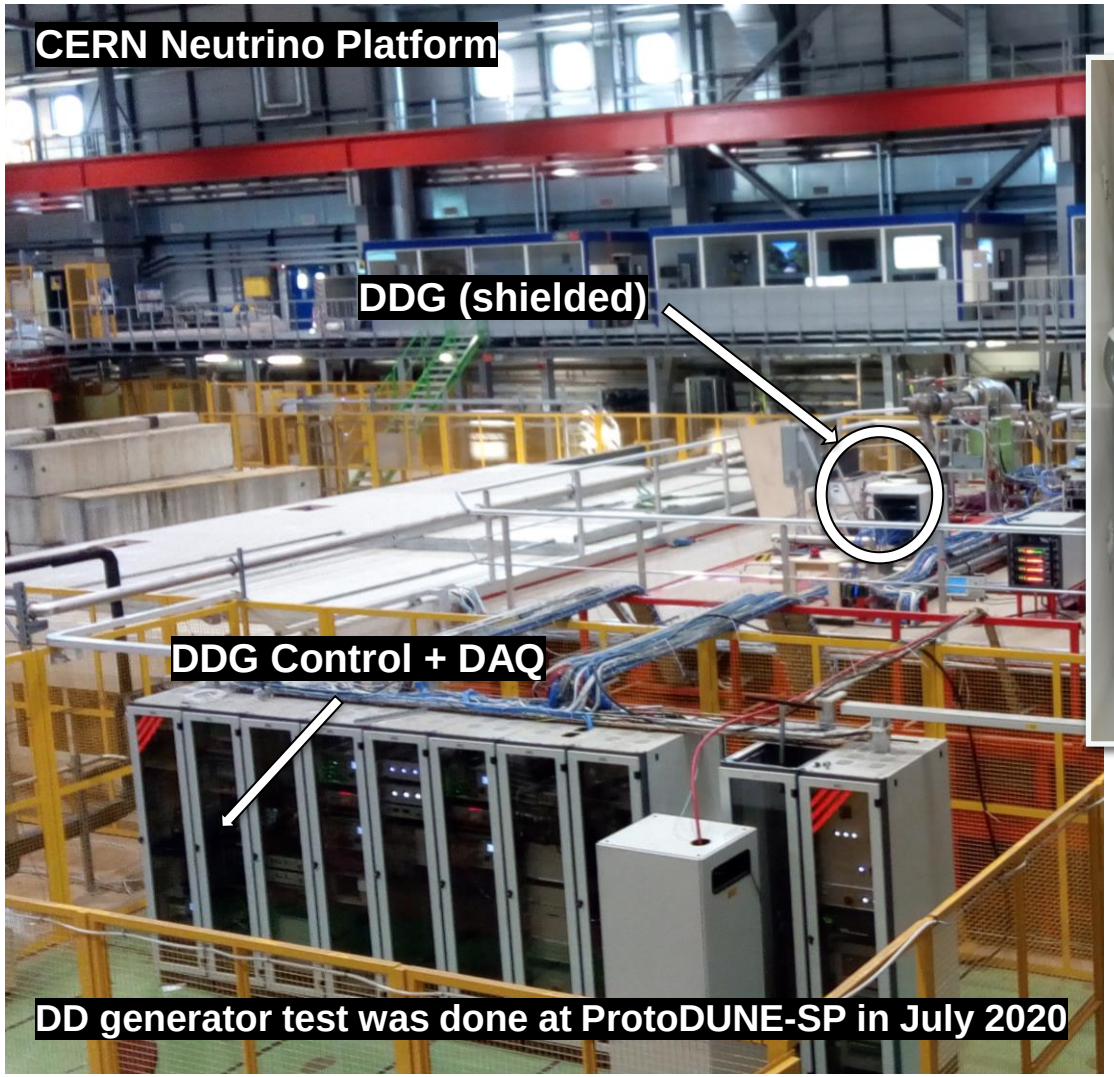
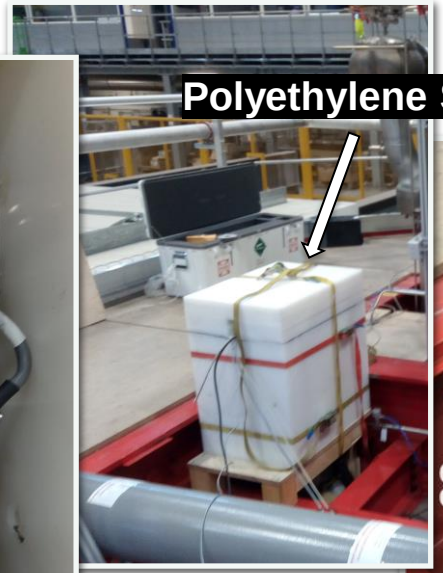


Fig. Simulated spread of 57 keV neutrons in the protoDUNE module (work done by J. Wang)

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)

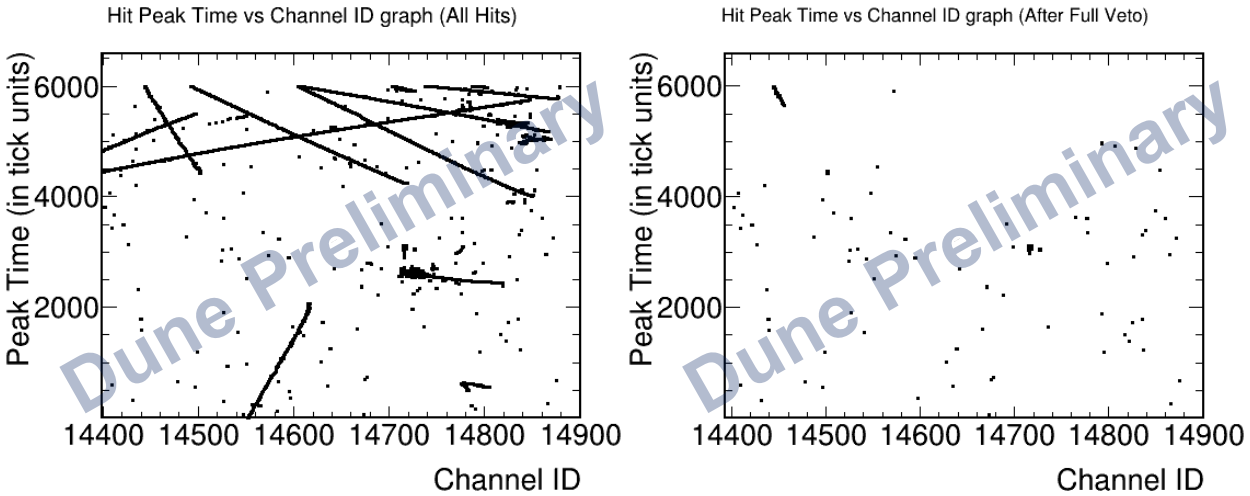


Fig. Peak Time vs Channel ID plot for one event; Before and after cosmic removal respectively

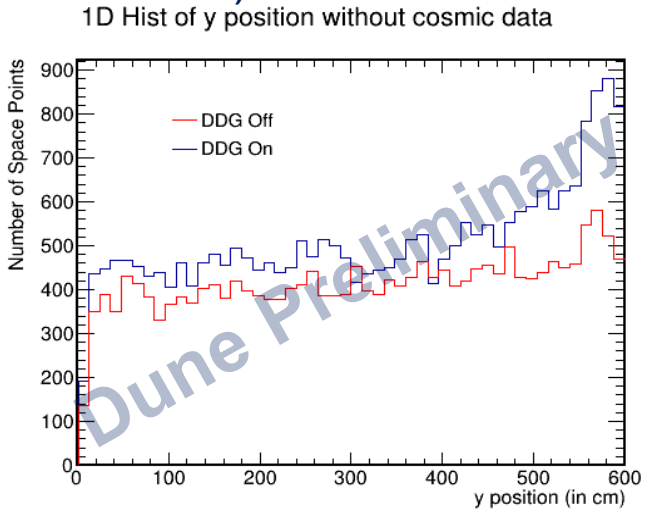


Fig. y distribution (vertical direction with y=600 cm at the top); Can see the excess activity in the "DDG on" run

Ongoing Tasks

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

Backup Slides