UC DAVIS
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DUNE
DEEP UNDERGROUND
NEUTRINO EXPERIMENT

Neutron Generator Calibration System for DUNE

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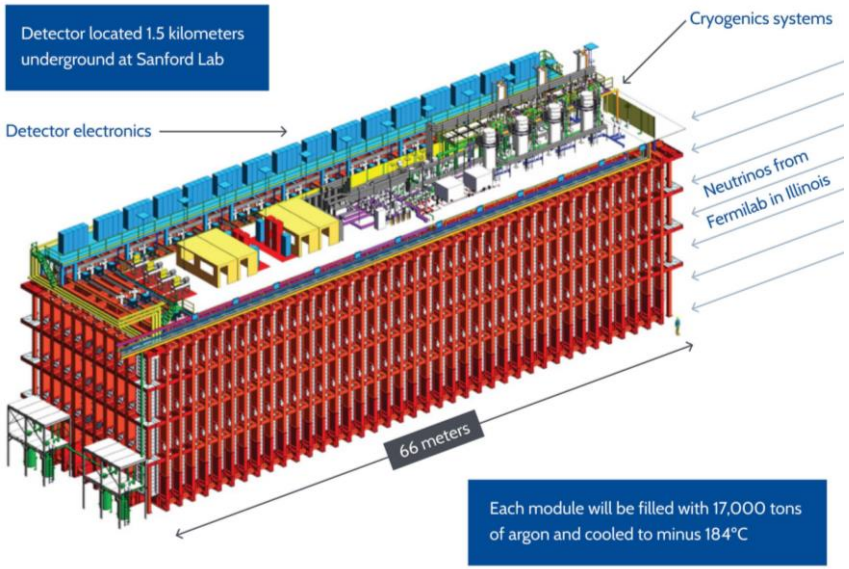
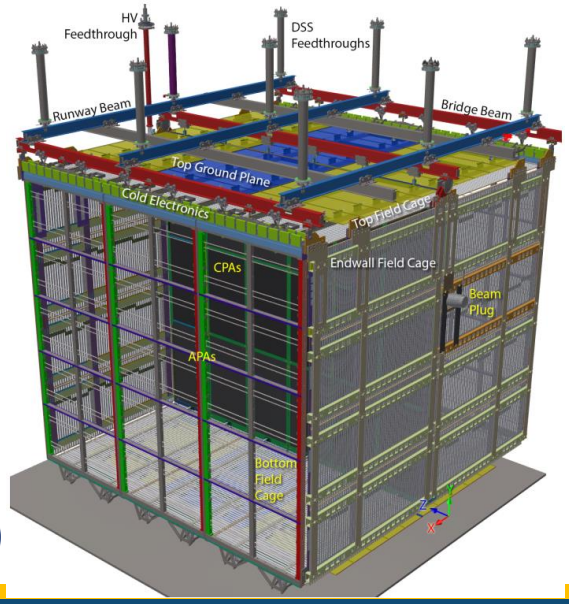
For the DUNE Collaboration

DUNE and ProtoDUNE



- The Deep Underground Neutrino Experiment (DUNE) will be a neutrino observatory hosted by the Fermilab
- Far Detector (FD):
  - Located at 1.5 km underground
  - Modular LArTPC
  - 4 x 17-kt modules (10 kt fiducial mass each)
- Physics goals: Long baseline neutrino oscillations, neutrino astrophysics, proton decay, 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



(arXiv:2007.06722)

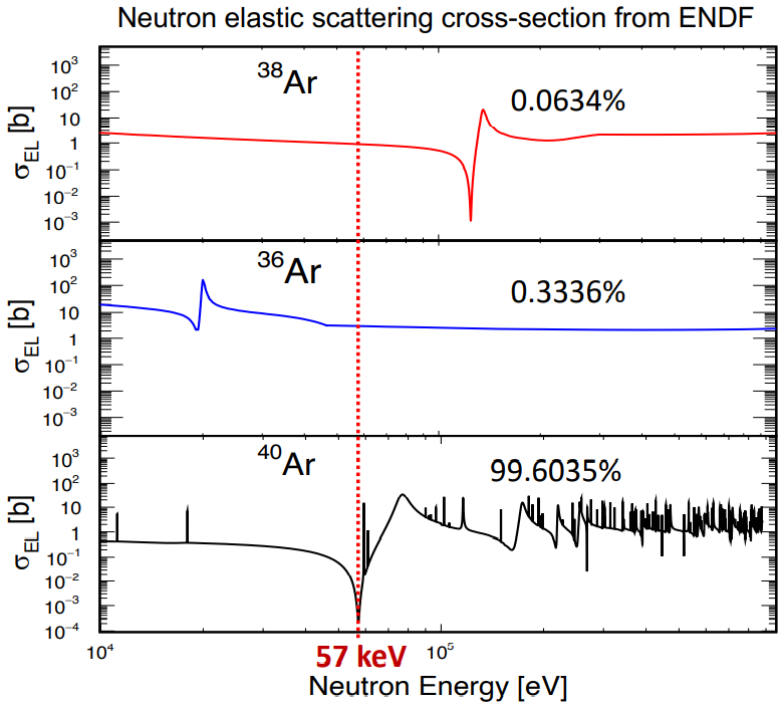
Neutrons for Calibration

- 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 (can travel ~30m in liquid Argon according to ENDF library)
- Neutron captures in liquid argon release distinct 6.1 MeV gamma rays

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



Pulsed Neutron Source

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

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

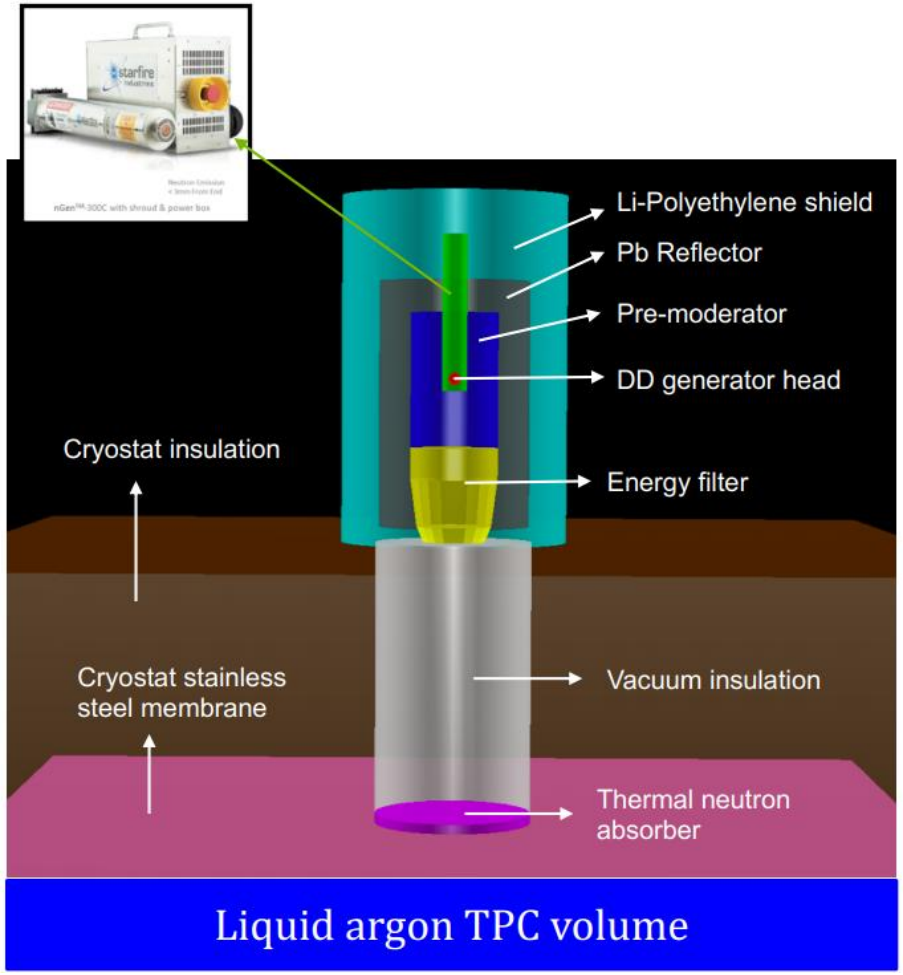
- After moderation, we can reduce the energy down to below 100 keV

Advantages

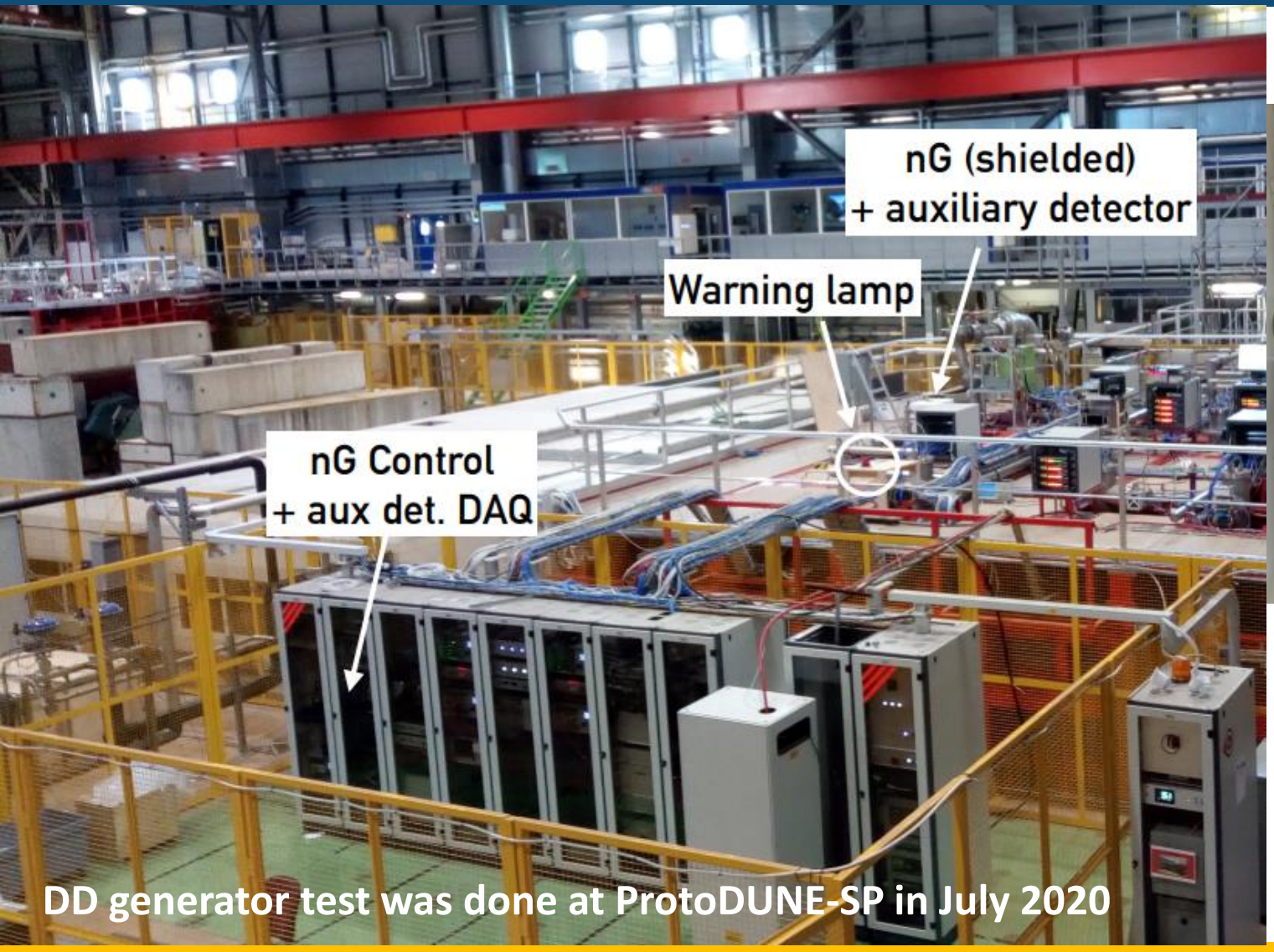
- External deployment of the source; no contamination of argon
- Pulsed trigger; helps reconstruct neutron capture location

How can PNS help us?

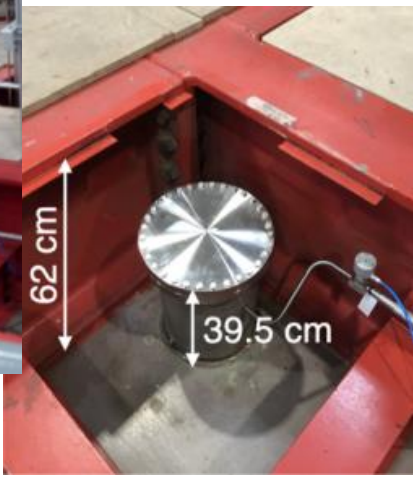
- Calibrate energy scale and resolution using 6.1 MeV gammas
- Helps in SNB trigger efficiency calibrations as the gamma cascades mimic SN events
- Measuring electron lifetime and drift velocity in active TPC



DDG Test at ProtoDUNE-SP



DD generator test was done at ProtoDUNE-SP in July 2020



(From left to right) protoDUNE-SP module and the DDG installation location; DDG; DDG inside the PE 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

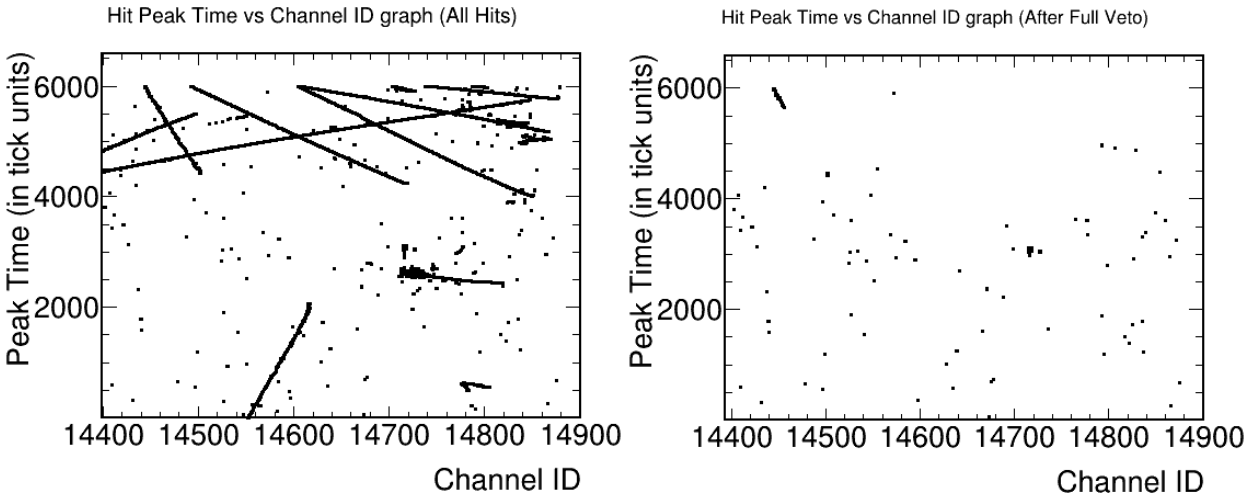


Fig. Peak Time vs Channel ID plot for one event; Before and after cosmic removal respectively

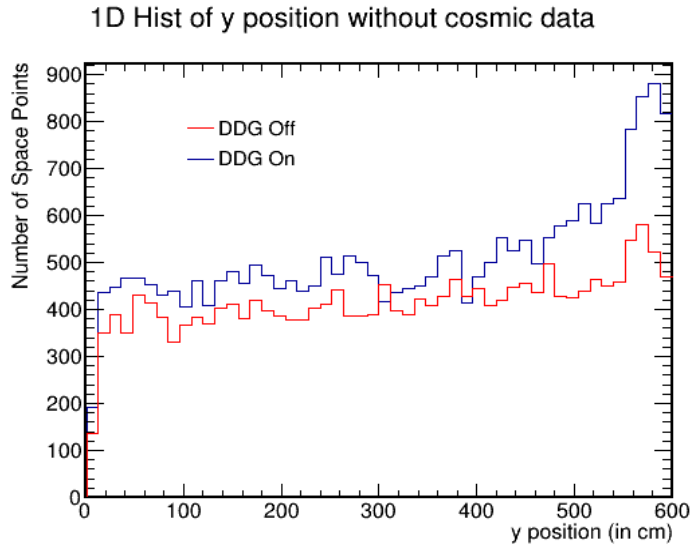


Fig. y distribution (vertical direction with y=600 cm at the top); Can see the excess activity in the DDG on run

Ongoing Tasks:

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

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