Pulsed Neutron Source Summary

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DEEP UNDERGROUND NEUTRINO EXPERIMENT

SOUTH DAKOTA MINES
An engineering, science and technology university

PNS WG Meeting
June 7, 2023

ThermoFisher VS Starfire

- Preferred condition (<100 µs pulse; <20 Hz rate) is not possible with the ThermoFisher **MP320** generator, but can be achieved with the Starfire **n-Gen310** generator.

Thermo Scientific MP 320 Neutron Generator

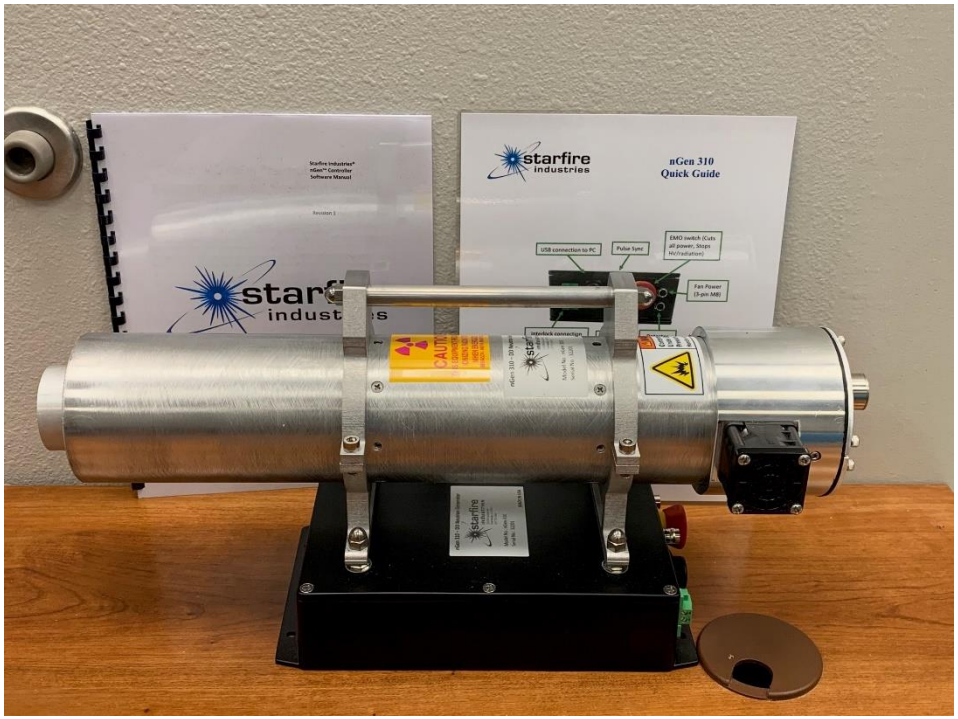
Technical Specifications	
Neutron Yield	1.0E+08 n/s for DT, 1.0E+6 n/s for DD
Neutron Energy	14 MeV
Typical Lifetime	1,200 hours @ $1x10^8$ n/s
Pulse Rate	250 Hz to 20 kHz, continuous
Duty Factor	5% to 100%
Minimum Pulse Width	5 µsec tested to be 400 µsec
Pulse Rise Time	Less than 1.5 µsec
Pulse Fall Time	Less than 1.5 µsec
Maximum Accelerator Voltage	95 kV
Beam Current	60 µamps
Power Supply	Integral
Neutron Module	12.07 cm x 57.15 cm (4.75 in x 22.5 in)
Control Module	Integral, digital
Safety Features	Keylock: on/off Emergency: on/off Normal-open and normal-closed interlocks Pressure switch
Total Weight	12 kg (26.46 lb)
Remote Control	RS-232/RS-485

Starfire n-Gen310 Neutron Generator

Neutron Output	
Time-averaged Yield	10^7 DD n/s max; $5x10^8$ DT n/s max
DD Neutron Energy	~2.5MeV (DT 14MeV option by special request)
Ion Source Type	Electrodeless RF
Pulse Options	Continuous, >50% duty factor optional
Max Neutron Flux	~$1x10^6$ n/cm^2•s
Pulse Rate	0-1 kHz standard
Pulse Width	2-1000µs
Pulse Rise/Fall Time	< 5µs
Nominal Duty Factor	5-10%
Power and Operation	
Operating Voltage	up to 140kV
Power Requirements	Up to 100W
System Information	
Neutron Source Dimensions	3" OD x 18" L (7.6 cm OD x 46 cm L)
Neutron Source Weight	10 lbs (4.5 kg)
Supporting Hardware Dimensions	4" W x 6" H x 9" L (10 cm W x 15 cm H x 22 cm L)
Supporting Hardware Weight	4.0 lbs (1.8 kg)
Integrated cooling w/ Cowling Dimensions	3.5" OD, 22.5" length with fan
Warranty	500 operating hours, or 12 months

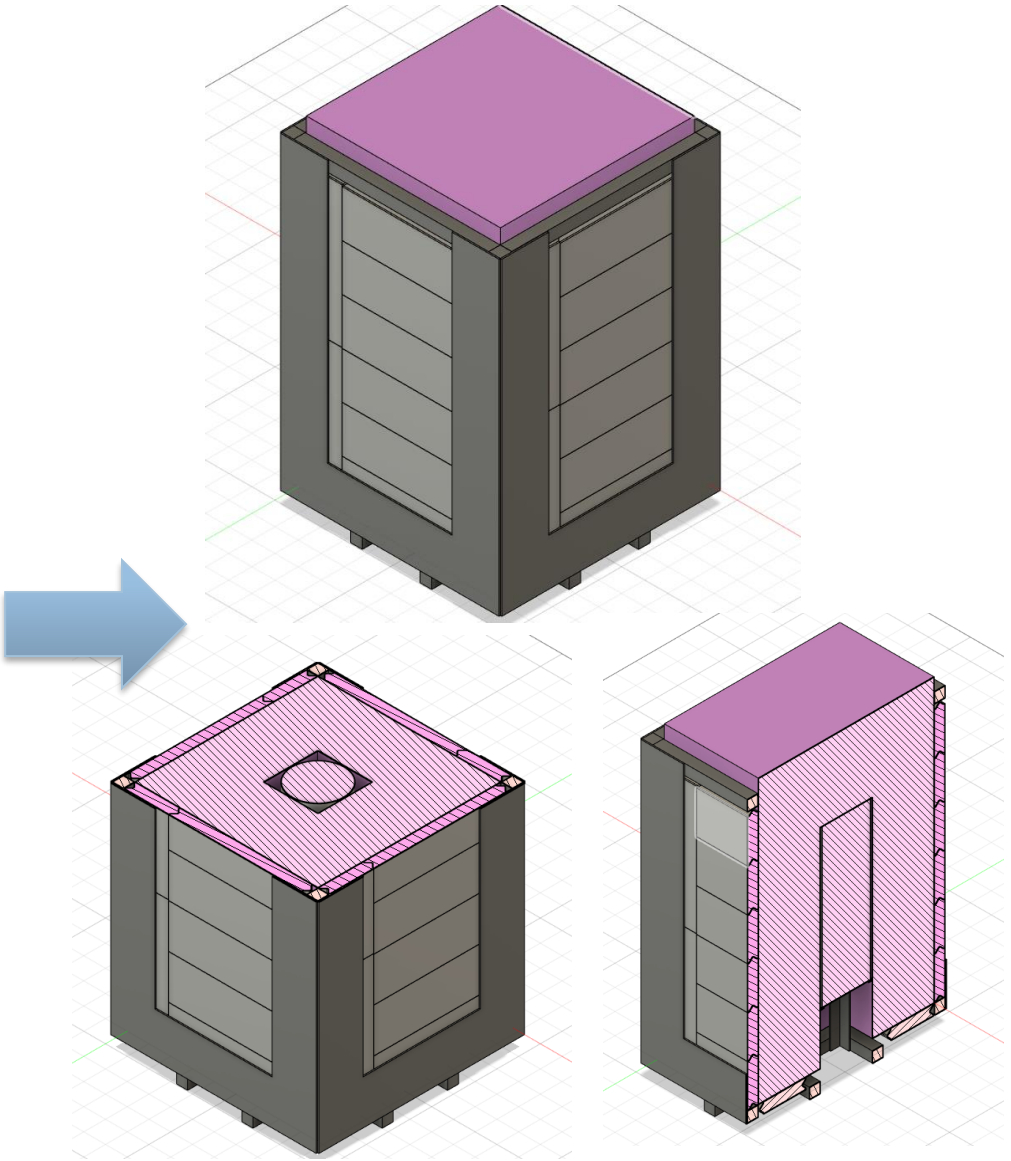
Thermofisher MP320
(loan from LANL)

Starfire nGen 310 (DUNE)



Immediate tasks during summer

- Assemble all the parts into a integrated PNS system, using ThermoFisher MP320
- Test Starfire nGen-310 in the lab and start the assembling



Calibration Opportunities

- DUNE far detector TPC calibration: both horizontal and vertical drift modules
  - ProtoDUNE-II test deployment planned
  - Need to work closely with *Physics:calibration* group to develop low-energy reconstruction technique
- DUNE far detector Photodetector light yield calibration
  - Plan to test at ColdBox first and then at ProtoDUNE-II VD module
  - Need to do some Geant4 and LArsoft simulations
- DUNE Near Detector ND-LAr calibration
  - Discussion recently initiated
  - Need to integrate detailed neutron physics into 2x2 Geant4 simulation
- SBND and NOvA both expressed interests in PNS calibration runs
- Either Thermofisher MP320 or Starfire nGen-310 will be shipped to CERN once assembled.

ND-LAr Calibration

Link to *ND Prototypes Analysis* (Saba Parsa, Brooke Russell)

Pulsed Neutron Source Deployment

Measure gamma cascade visible energy from from 6.1 MeV neutron binding energy (standard candle)

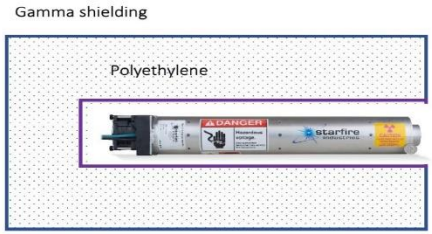
- Most common gamma cascade: 167 keV, 1.2 MeV, 4.7 MeV δs

Commercial D-D source deployed at ProtoDUNE-SP1 (pulsed, triggerable external source) *potential PNS available on loan from SDSMT*

Recent progress on simulation studies:

- Construct PNS geometry gdml
- Gamma cascade model
- Incorporation into 2x2 simulation

⇒ calibration purview, neutron capture cross section to be evaluated



*NEXUS DD generator cleared for operation in MINOS experimental hall

Generator shielding on-hand

Newly purchased source

- Thermo Fisher MP320 DD neutron generator
- Delivery expected May 2023
- Capable of 1 Hz pulse rate
- 10^6 n/s maximum yield
- First tests at SDSMT June-July
- Available as early as late summer

- **Off ν-beam source-based analyses**
  - Pulsed neutron source deployment
  - MBq gamma source(s) deployment

⇒ Detailed charge, light response characterization to MeV-scale point-like signals; viable irrespective of NuMI ν-beam status

VD Photodetector Calibration

How well can we map the energy scale parameters to neutron capture locations?

Study for detector LY calibration — Pulsed neutron source for PDS calibration:

W. Johnson
J. Wang
(SDSM)

A. Paudel
(FNAL)

- Neutron capture on Ar-40 produces 6.1 MeV gamma cascade
  Well defined energy deposition ideal for energy scale calibration
- Neutrons can travel large distances in LAr before being captured, which gives good coverage with fewer neutron generator

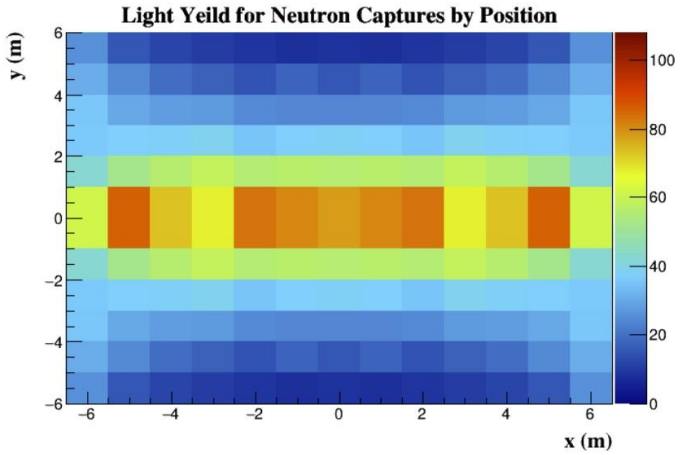


Fig: LY from neutron capture in LAr using Geant4 standalone simulation for DUNE VD (100 captures/m^3)

- Simulation of light from neutron capture events ongoing
- First Geant4 stand-alone simulation has been performed and LY map has been made (left plot)
- The overall features of LY map from neutron capture is similar to the LY map from a point source (there are slight differences near the edges which is being understood).
- More realistic simulation by introducing uncertainty in the knowledge of position of neutron capture is being worked on.

See Flavio's talk and Walker's talk in the 09/2022 CM

Today's Agenda

Pulsed Neutron Source Working Group Meeting

Wednesday Jun 7, 2023, 12:00 PM → 1:10 PM US/Central

12:00 PM → 12:10 PM **PNS summary and calibration opportunities in DUNE** 10m

Speakers: Jingbo Wang, Walker Johnson (South Dakota School of Mines & Technology)

12:10 PM → 12:25 PM **Overview of Low-energy reconstruction in LArTPC** 15m

Speakers: Bryce Littlejohn, Bryce Littlejohn (Illinois Institute of Technology)

12:25 PM → 12:35 PM **Neutron Capture Analysis Update** 10m

Speaker: Nicholas Carrara (UC Davis)

12:35 PM → 12:45 PM **Light response of neutron in liquid argon** 10m

Speakers: Adi Ashkenazi (Massachusetts Institute of Technology), Ajib Paudel (Fermi National Accelerator Laboratory), Vitaliy Popov (Tel Aviv University), Walker Johnson (South Dakota School of Mines & Technology)

12:45 PM → 1:05 PM **Discussion on physics opportunities** 20m