Module-1 Physics Calibration Run with PNS (Pulsed Neutron Source)

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FD2-PDS Longevity qualification and Stability test Workshop

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Outline

- Photon Detector System(PDS) as an energy calorimeter
- Pulsed Neutron Source (PNS) for PDS calibration
- Prior developments in PNS calibration:
- More details in:
  - Jingbo Wang's DUNE collaboration meeting talk
  - Walker Johnson's Dune Collaboration meeting talk
  - Nicholas Carrara's DUNE collaboration meeting talk

- Deploying PNS in ColdBox Module 1 run
- Summary

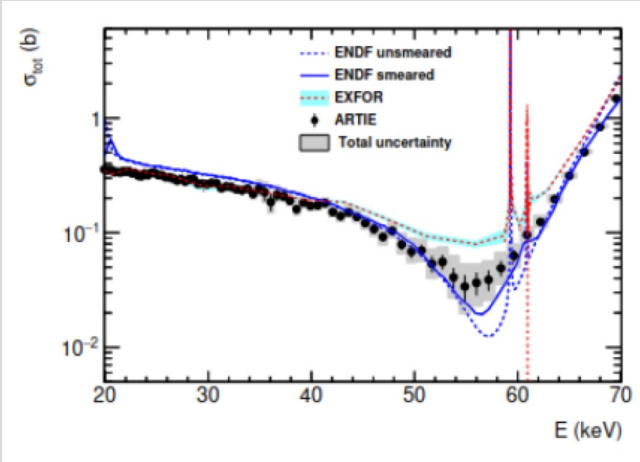
PDS as a calorimetric tool:

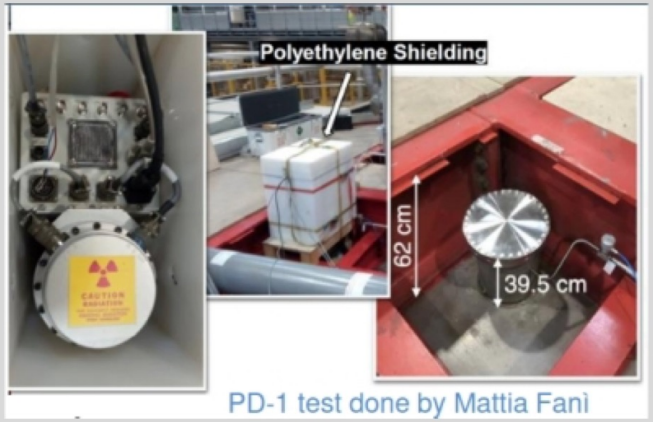
- Liquid Argon detectors have predominantly used PDS for event time (t0) reconstruction
- SoF and PoF technology → better PDS coverage → improved uniformity in Light collection
- We are now able to use PDS for energy reconstruction
- In addition to realistic simulation, we need a standard candle for energy scale determination
- Next few slides will describe why Pulsed Neutron source could be the most practical calibration source for PDS system like DUNE-FD2

Slide from Walker Johnson

Neutrons for LArTPC Callibration

- Neutron capture on Ar-40 produces a 6.1 MeV gamma cascade
  - This well defined energy deposition can be used as a standard candle for calibration
- Neutrons can travel far distances in liquid Argon
  - A dip in the elastic scattering cross-section at 57 keV → ~30m attenuation length
  - Neutrons above this energy are likely to fall into the dip
- The total neutron capture cross section was measured in the ARTIE experiment to confirm this dip
- We can inject neutrons into the LArTPC using the PNS



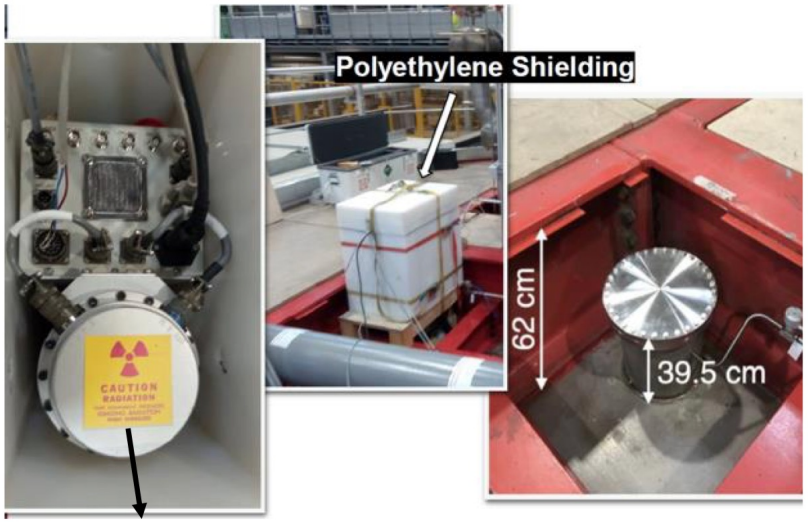


Slide from Jingbo Wang

ProtoDUNE-I DD Generator Test

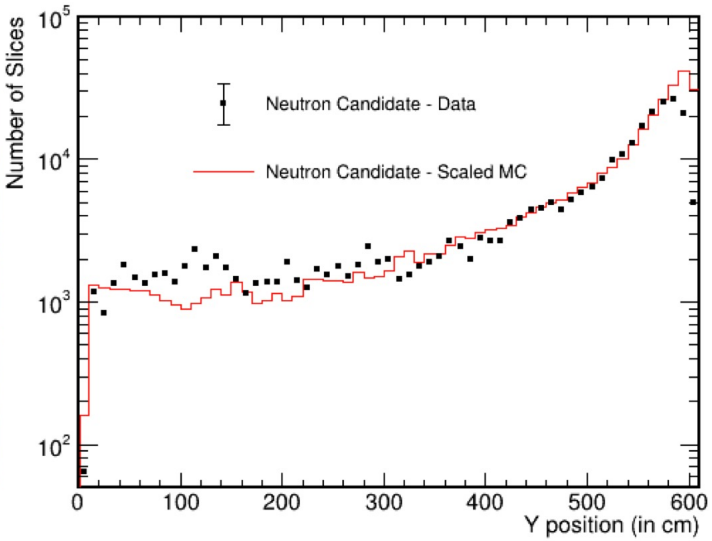
- The DD generator was tested at the PD single phase detector during PD-I.
- Neutron capture yields were good without a heavy and complex moderator System can be simple and portable
- Data and simulation have a reasonable agreement in term of capture positions.
- Was not able to isolate complete neutron captures from cosmic ray backgrounds

ProtoDUNE-I test done by Mattia Fanì



ThermoFisher MP320 loan from LANL

Data analyzed by Y. Bezawada and J. Huang

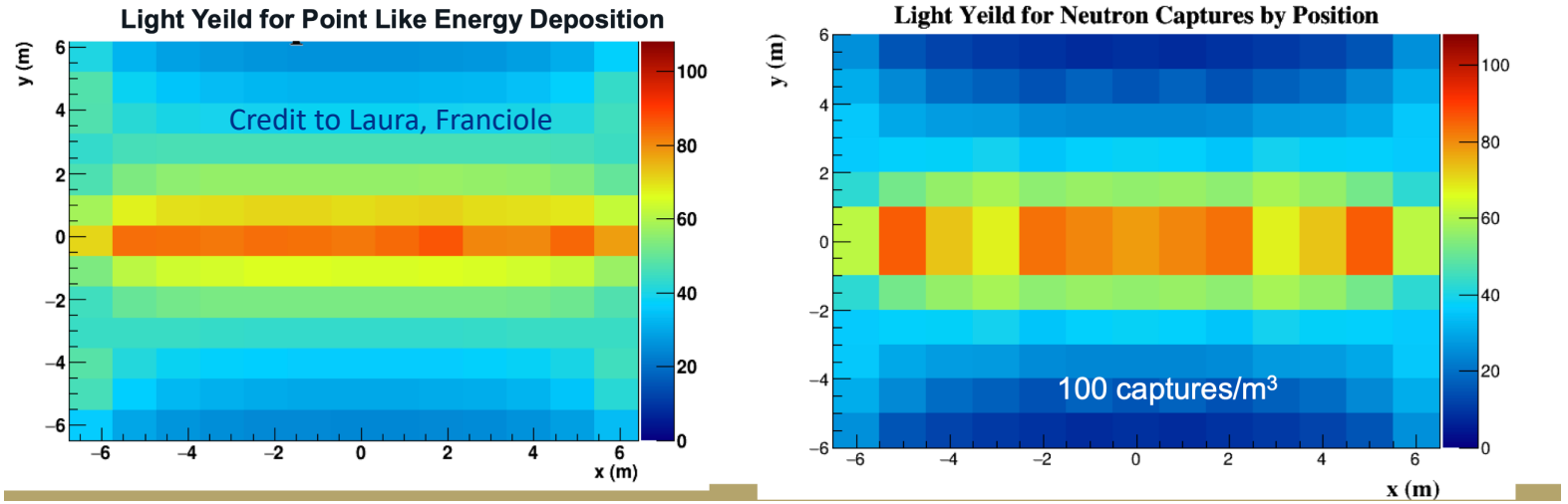


Fermilab

Study of VD-PDS Calibration

- Neutron captures can be used to calibrate the photodetector response.
- First Geant4 stand-alone simulation has been performed and LY map has been made with the neutron captures (right plot)
- The overall features of LY map from neutron capture is similar to the LY map from a point source (left plot).
- More realistic simulation by introducing uncertainty to position reconstruction is underway.

Credit to W. Johnson



[Note: It's not the latest stand-alone simulation, just showing to compare the LY from point source and neutron capture]

Next Steps:

- Laura Paulucci already has prepared LArSoft geometry file for ColdBox (for first coldbox run)
- Photon simulation (in LArSoft) was also carried out to study Light Yield
- However, there have been a many changes to the PDS configuration since the first run
- Plan is to modify the geometry file to reflect the configuration planned for module 1 run
- Simulate neutron captures to obtain a light yield map
- Use the neutron generator to take experimental data
- Compare data-simulation (Can be a first validation of simulation parameters and a major achievement)

PNS run in ColdBox:

- We have the neutron generator used for ProtoDUNE-I still at CERN
- If we have CRP and TPC combined data, we can get a much better position resolution
- Need more discussion on the detailed run plan (triggering, collection window etc)
- As the cold box is on surface isolating neutron capture events from cosmic ray contamination will be challenging. However, it will be interesting to see if we can exploit PDS's excellent timing resolution capability to isolate neutron capture events with high purity.

Summary:

- This is a proposal for having PNS calibration during ColdBox module 1 run
- A physics calibration run is very important to understand the detector performance and will be a big step forward to validate our detector capability
- I think it will be ideal from analysis point of view if we can have CRP and PDS information. However, only PDS data will also give a lot of information.

- We have a slack channel to discuss the PNS-PDS calibration, which is a good platform to bring up discussion**(vdpdscalibration)**

THANK YOU

BACK UP SLIDES

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.
- DUNE project and SD Mines purchased n-Gen310 and received it during this csollaboration meeting week

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/cm²*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