Pulsed Neutron Source (PNS) for Photon Detector System (PDS) calibration

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DUNE Far Detector 3 Mini-workshop: Toward a Combined Photon Detection and Field Cage System

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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 more prepared 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 a practical calibration source for PDS system like DUNE-FD2 and same applies for FD3

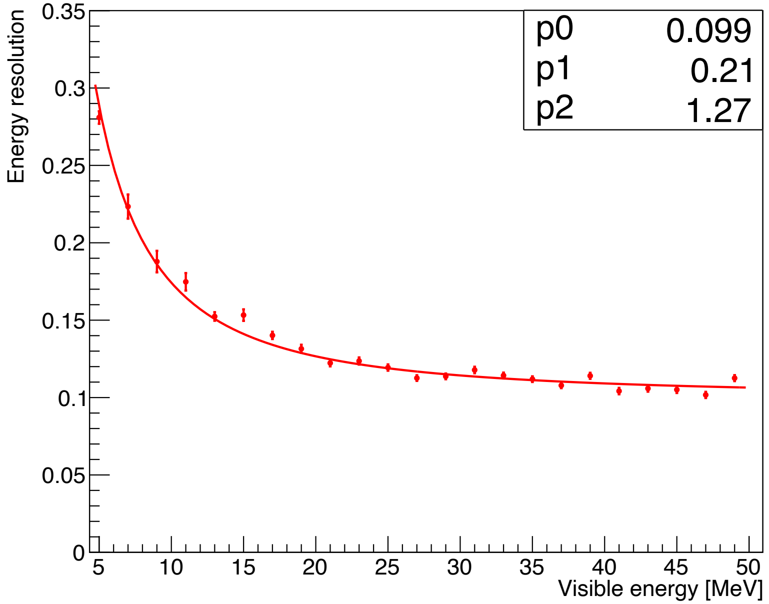
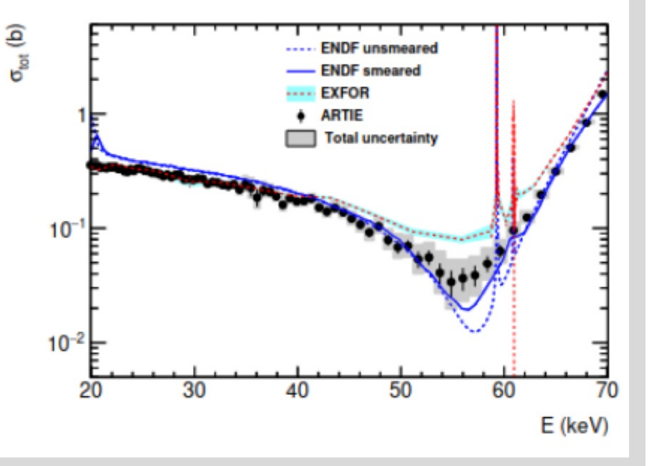
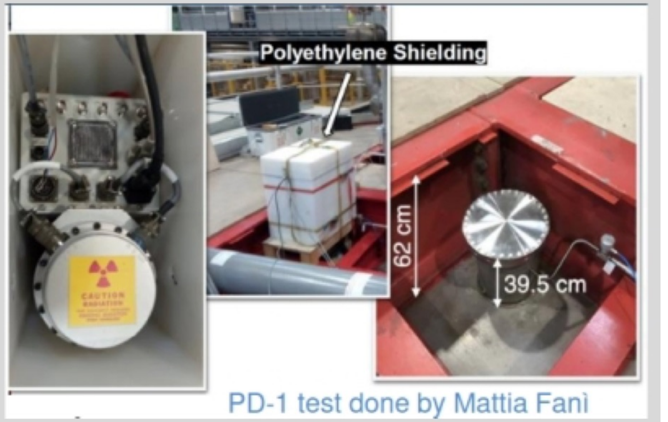


Fig: Energy resolution as a function of deposited energy for DUNE-FD2 simulation using PDS system

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





PD-1 test done by Mattia Fanì

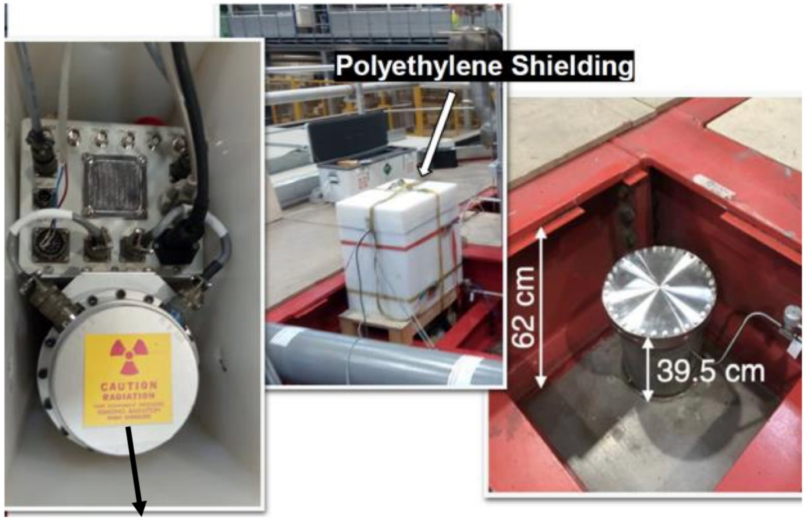
Fermilab

Slide from Jingbo Wang

ProtoDUNE-I DD Generator Test

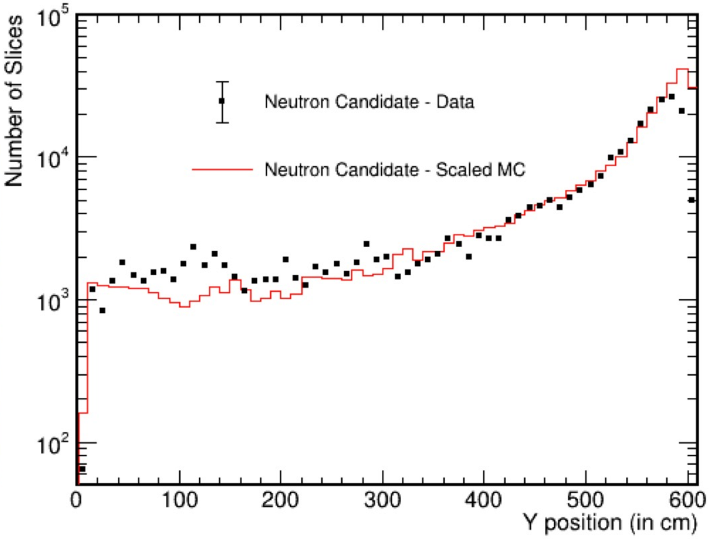
- The DD generator was tested at the PD single phase detector during PD-I.
- Neutron capture yields were good without a heavy and complex moderator System can be simple and portable
- Data and simulation have a reasonable agreement in term of capture positions.
- Was not able to isolate complete neutron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

ProtoDUNE-I test done by Mattia Fanì



ThermoFisher MP320 loan from LANL

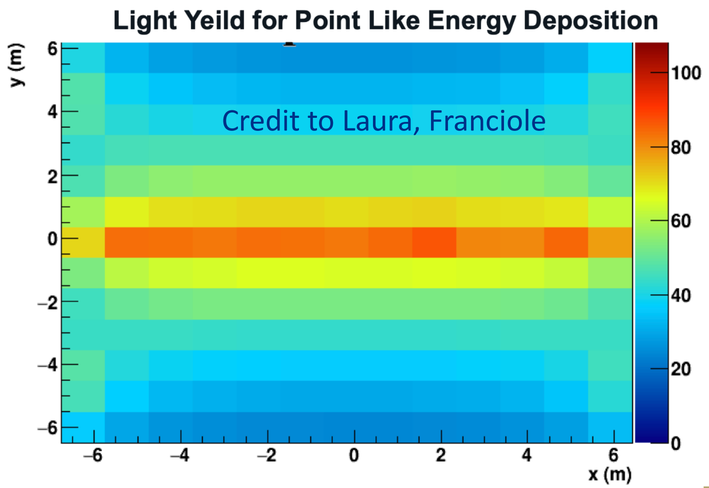
Data analyzed by Y. Bezawada and J. Huang

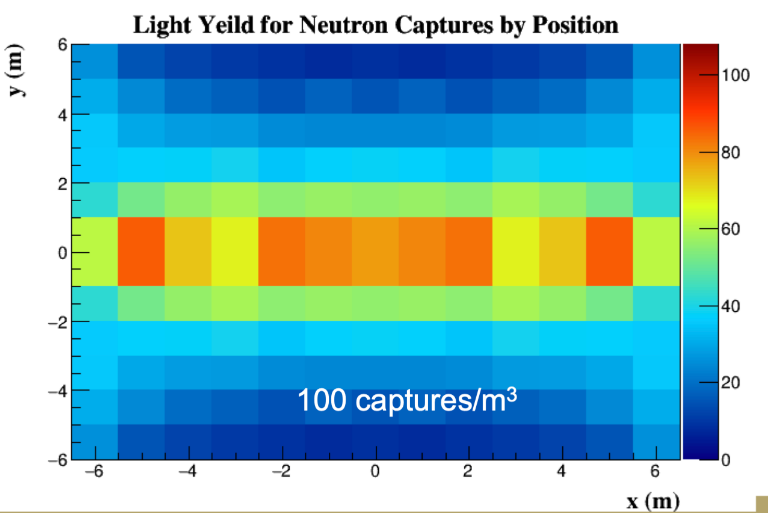


Study of VD-PDS Calibration

- 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 + Ongoing studies [PNS VD-ColdBox run]:

- Geometry file for VD ColdBox at CERN available (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
- Work is undergoing 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 (will validation simulation parameters and a major step forward)

PNS run in ColdBox:

- Neutron generator used for ProtoDUNE-SP (I) is at SDSMT and additionally a new neutron generotor have been procured recently
- Need more discussion on the detailed run plans
- 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:

- PNS can be a viable tool for calibrating photon detectors (simulation and proposed coldbox run will give more insight)
- A physics calibration run is very important to understand the detector performance and will be a big step forward to understand our detector capability
- Combining PDS and CRP data for the study will be ideal. 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/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