# Scintillation Light Simulation Updates

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# Overview

- Our last general update was at the September CM
- We had interesting developments to report, mainly
  - VD TDR completed and approved by LBNC
  - New FD production
  - Physics analysis with the PDS moving forward
  - Progress on ProtoDUNE (HD, VD – also coldbox, SP)
- Since then, further developments were performed
  - More progress on ProtoDUNE
  - LE light trigger studies in FD
  - Light propagation models
  - FD3 studies

# FD1-HD new MC production

- The last MC production for FD1 was MCC11 (2018): TDR-era
- Some areas of the current DUNE FD workflow still rely on ancient services/tunings/configurations from the MCC11 era → **This has been updated**
- We do not currently have an apples-to-apples comparison of HD and VD performance (comparing MCC11 HD to modern era VD)
- LBNF production
  - Nearly finished. Will have ready-to-use light info in FD-HD
  - Will run future smaller FD-VD larger geo production for calorimetry studies
- MARLEY interactions in both VD and HD
  - Ticket to be submitted (hopefully) this month

# ProtoDUNE-HD

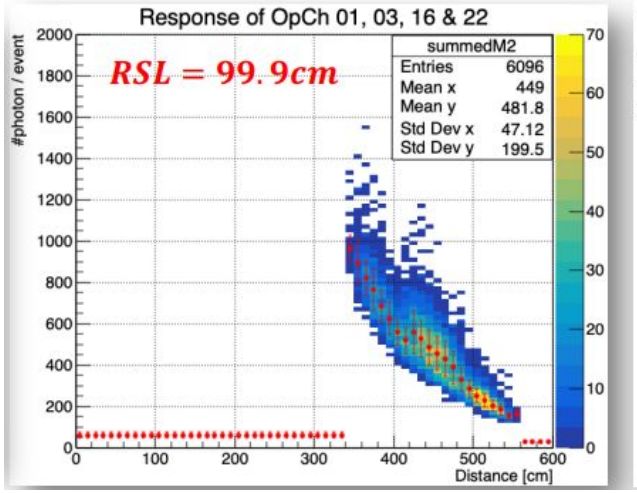
- The machinery for the performance studies is being developed:
  - Example scripts to analyze raw data and to dump the raw data to root files have been prepared.
  - Raw-to-LArSoft converter is ready.
  - IV-curves codes.
  - Identifying key studies and people interested in performing them → spreadsheet

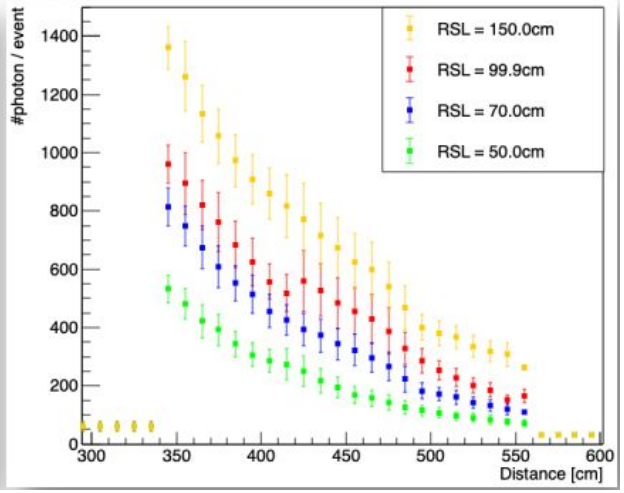
| Task item |
|---|
| Single PE characterization |
| Gain vs voltage, SNR, calibration |
| Cross-talk & afterpulses |
| Stability overtime |
| |
| Dark count rate |
| Time resolution |
| |
| Arapuca detection efficiency |
| |
| Comparison of components' performance |
| PDS LY calibration |
| Michel electrons |
| Q+L calorimetry |
| L Calorimetry with the beam |
| Cosmic muon analysis (rate and calorimetric studies) |

- Current simulation is based on photon libraries, since the semi-analytical model is not ready yet for the last updated geometry.
- Last MC production sample includes the PDS data.

# ProtoDUNE-VD

- The simulation using the computable graph of Ar light is ready, and Xe will arrive soon (Shuaixiang, who is also preparing for Rayleigh scattering measurements [1]).
- Ar+Xe is available using photon libraries.
- The workflow to include the PMT response is not ready yet (Xuyang Ning, from BNL is working on this).
- Next MC production sample (on going) will include PDS data including Ar and Xe light using photon libraries, and Ar light only using the computable graph.



# VD ColdBox light simulation updates

- Simulation is focussed on studying neutron capture in argon (from pulsed neutron source). However, the framework can be extended to simulate other activities (such as cosmic muons) as well.
- Currently 4 cathode X-ARAPUCAs simulated. Work is ongoing to simulate 2 membrane X-ARAPUCAs.
- Full photon simulation in LArSoft carried out to study photon production and detection during neutron capture events.
- Simulation is in developmental phase, and more simulation studies are planned to be done as we collect the data from PNS run in the ongoing coldbox.

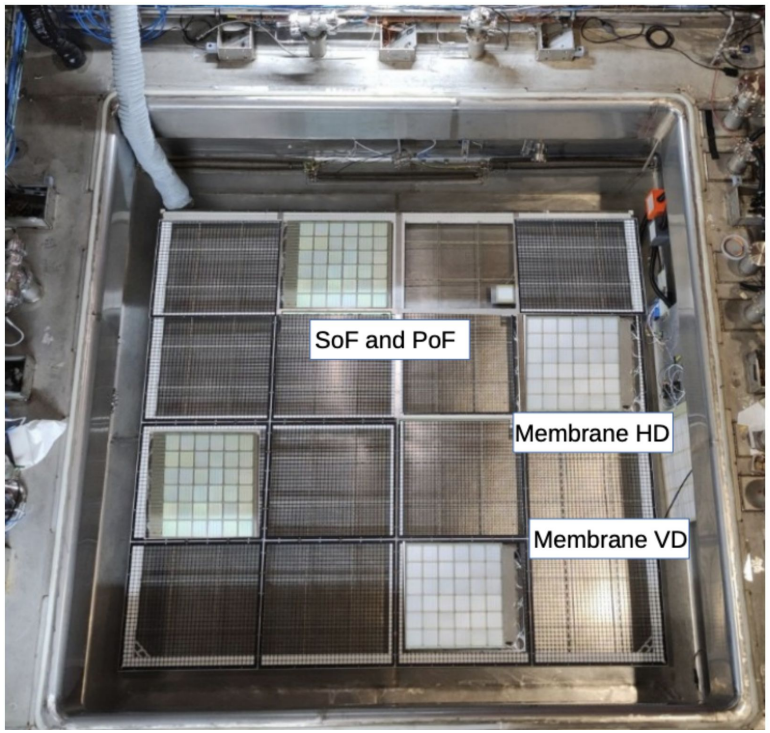



Fig: DUNE VD coldbox (top view)

Slide from Ajib Paudel

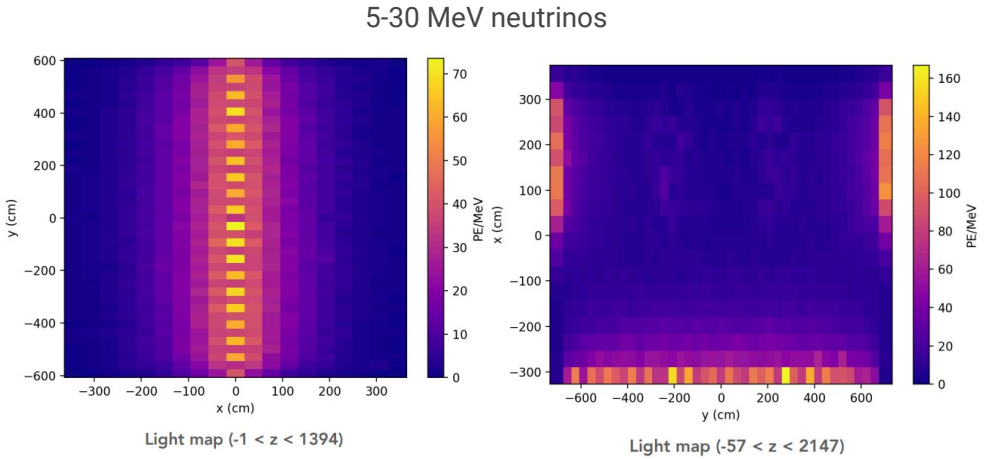
# LE events light studies

- Pablo Barham has been working on trigger with the PDS in VD [1] and new background model validation [2]

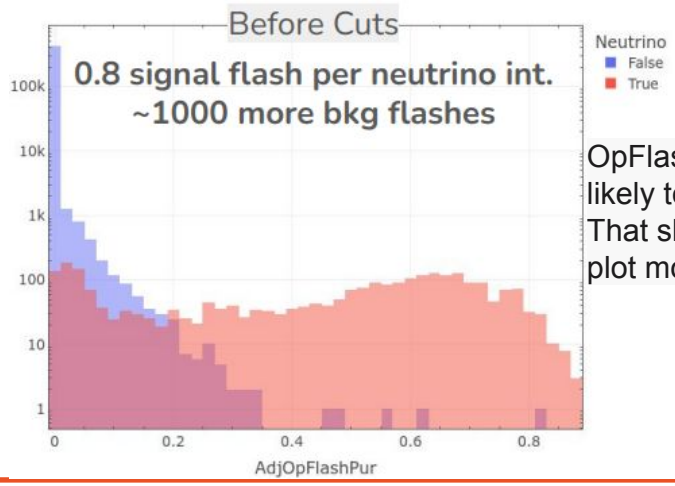
| | 10 kpc | 15 kpc | 20 kpc | 95% thresh |
|---|---|---|---|---|
| Livermore | 1 | 0.997 | 0.791 | 18.61 kpc |
| Garching | 0.969 | 0.212 | 0.014 | 10.63 kpc |
| GKVM | 1 | 1 | 1 | 36.34 kpc |

Trigger efficiencies (computational graph 12 kt)

| Ar39 | Total (Hz/ARAPUCA) | Total (Hz/cm2) |
|---|---|---|
| HD | 600 | 1.193 |
| VD | 4000 | 1.093 |




- Sergio Manthey is working on solar neutrinos in HD [1]
- Results indicate a more challenging scenario with the updated background model



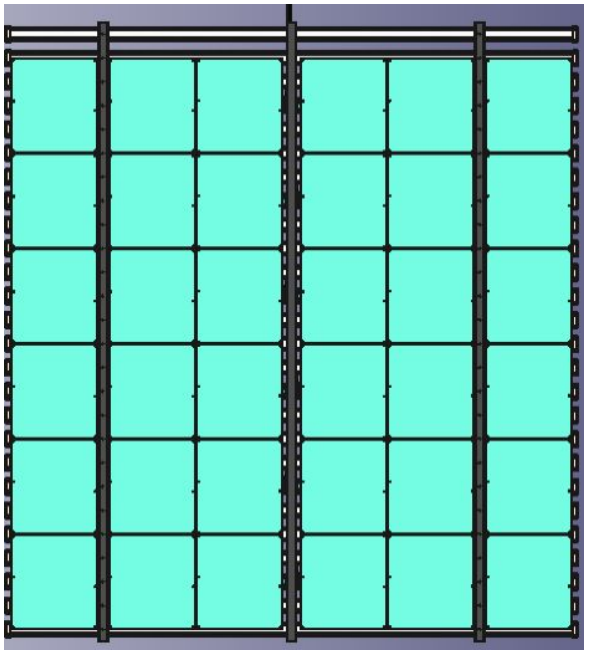

OpFlash algorithm likely to improve. That should make plot more bi-modal

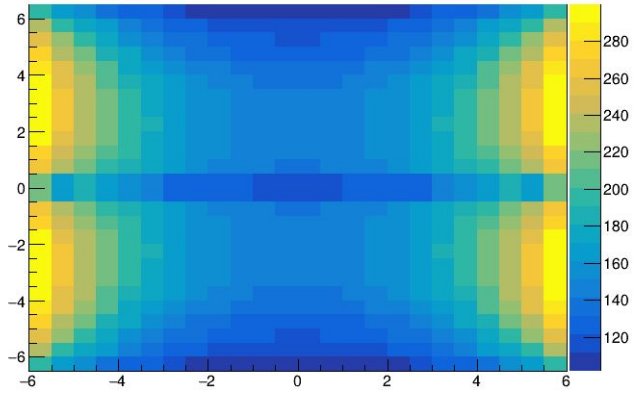
# Light propagation models

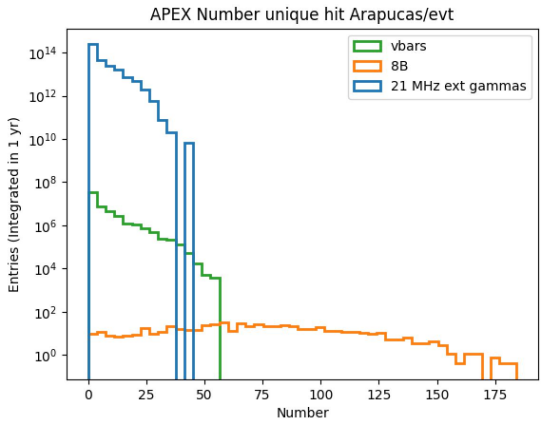
- Marc Patterno [1] [2]
  - Optimizing the PDFastPAR module
    - Increase speed by changing specific calculation functions and decrease memory by changing data products
    - Goal: parallelization of the processing
- Marcio Adames [1]
  - Proposal of a new 100% analytical model for light propagation in Lar
    - Still at early stage

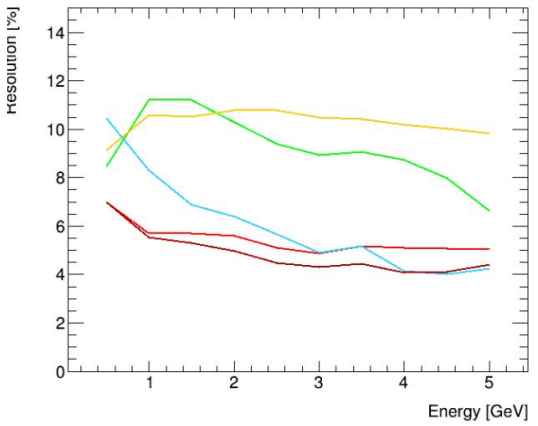
# FD3 - APEX

- Franciole Marinho: Standalone Geant4 simulation → LY map and first performance estimators [1]
  - Eric Church: Backgrounds and impact on LE physics [1]
  - Chao Zhang, Xuyang Ning: Neutrino E reconstruction (charge+light) [1]







# Moving forward

- Our next big challenge is moving to the 10kton detector
  - Single muons, G4 stage

| TimeTracker printout (sec) | Min | Avg | Max | Median | RMS | nEvts |
|---|---|---|---|---|---|---|
| Full event | 103.496 | 115.616 | 136.319 | 114.455 | 9.1209 | 10 |
| source:RootInput(read) | 0.000425749 | 0.000550976 | 0.00066299 | 0.000561156 | 7.50674e-05 | 10 |
| simulate:rns:RandomNumberSaver | 7.9944e-05 | 0.00013105 | 0.000248878 | 0.000115492 | 4.76166e-05 | 10 |
| simulate:largeant:larg4Main | 0.149618 | 0.161804 | 0.190967 | 0.15406 | 0.0142845 | 10 |
| simulate:IonAndScint:IonAndScint | 0.0184137 | 0.0214621 | 0.0294655 | 0.0203172 | 0.00315511 | 10 |
| simulate:elecDrift:SimDriftElectrons | 0.0954569 | 0.105173 | 0.128246 | 0.101722 | 0.00998182 | 10 |
| **simulate:PDFastSim:PDFastSimPAR** | **102.807** | **114.835** | **135.442** | **113.674** | **9.05806** | **10** |
| [art]:TriggerResults:TriggerResultInserter | 1.7786e-05 | 3.48886e-05 | 6.6846e-05 | 3.1768e-05 | 1.70212e-05 | 10 |
| end_path:out1:RootOutput | 3.859e-06 | 2.36379e-05 | 5.4575e-05 | 1.8838e-05 | 1.47984e-05 | 10 |
| end_path:out1:RootOutput(write) | 0.424044 | 0.49047 | 0.59212 | 0.478889 | 0.0499981 | 10 |

- **The PDFastSim is quite slow compared to the rest**

# Summary

- We keep progressing with the light simulation and reconstruction
  - Advances with FDs and ProtoDUNEs
- We have still a lot to do
  - Optimizing our reconstruction methods to handle xenon and specially backgrounds for LE events
  - Keep pushing physics analysis to include light not only for t0
  - Analyzing ProtoDUNE-HD data will be top priority in the near future
  - Prepare for ProtoDUNE-VD is also key
    - Does the PDS Consortium have any particular request for beam?

# How to get involved

- There has been a lot of progress but there is still a lot to do!
- If you want to develop any PDS simulation related task, please

1. Get in touch with the conveners (e-mail, Slack)
2. Attend the PDS simulation related working group meetings

- FD Sim/Reco meetings:
  Indico page, mailing list: dune-reco@fnal.gov

Mondays at 9:30am FNAL time, biweekly

- PDS ProtoDUNE meetings:
  Indico page, mailing list: dune-proto-sp-dra@fnal.gov

- LE meetings:
  Indico page, mailing list: dune-physics-snb@fnal.gov

Wednesdays at 10am FNAL time, biweekly

# BACKUP

# FD1-HD new MC production

- A non-exhaustive list of improvements relevant to the PDS are:
  - New background model: Decay-0
  - New optical fast simulation mode: now using the semi-analytical model instead of a photon library for the active volume
    - Significantly lower memory use, good resolution and bias
    - not possible to get the light generated behind PDs → need to implement hybrid model?
  - Updated Rayleigh scattering value (from 60cm to 99cm @ 128nm)
  - New scintillation light generator model: LArQL
    - # of scintillation photons correlated to the # of ionization electrons (depends on the Edeposited instead of a fixed LY)
    - Increased LY where the Efield is lower

# FD1-HD new MC production

- A non-exhaustive list of improvements relevant to the PDS are:
  - May be moving to testbench PE and deconvolution algorithm for OpHits
  - Geometry for HD used in the simulation
    - HD TDR still had the WLS bars. Now with X-Arapucas
    - Smaller geometry: 1x2x6
    - Need to expand the argon volume if we want to consider the impact of external backgrounds
    - Notice we are not simulating the APAs which are closer to the cryostat wall