The DUNE Vertical Drift Photon Detection System

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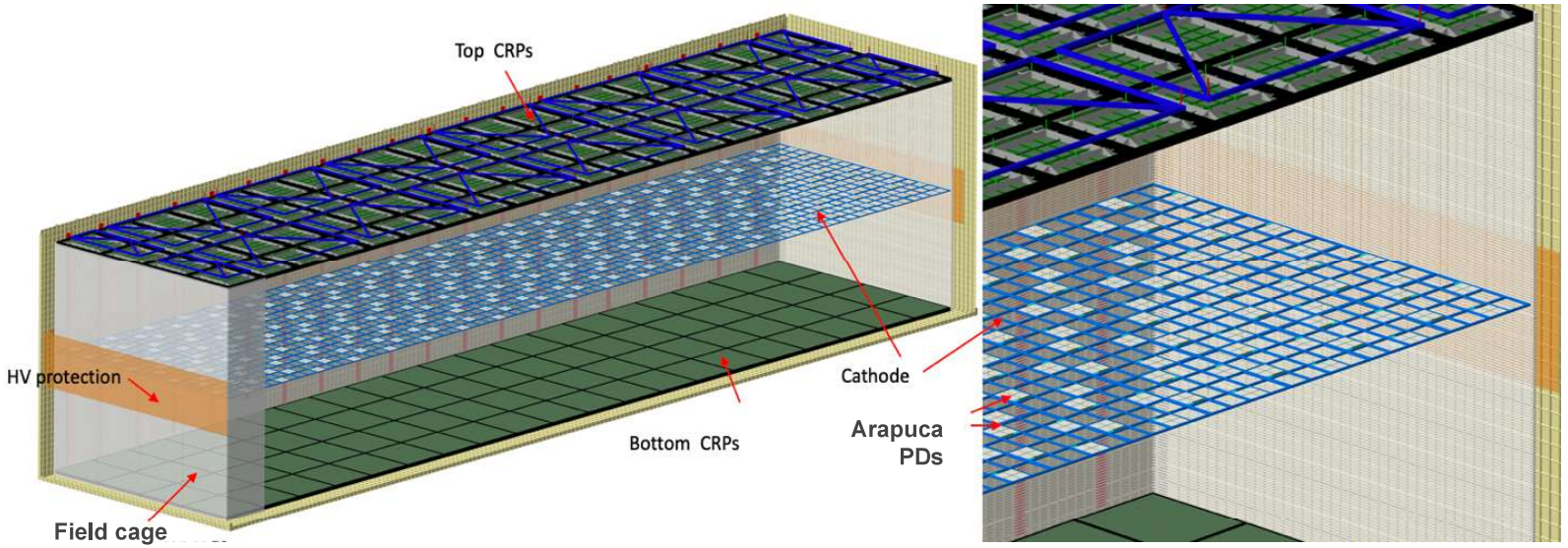
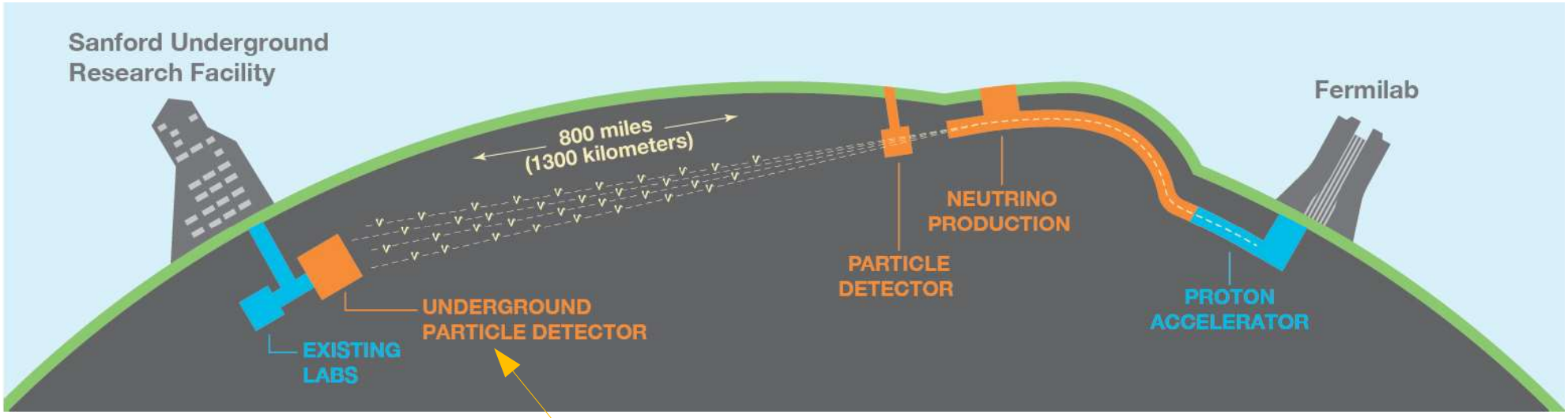
LIDINE 2021

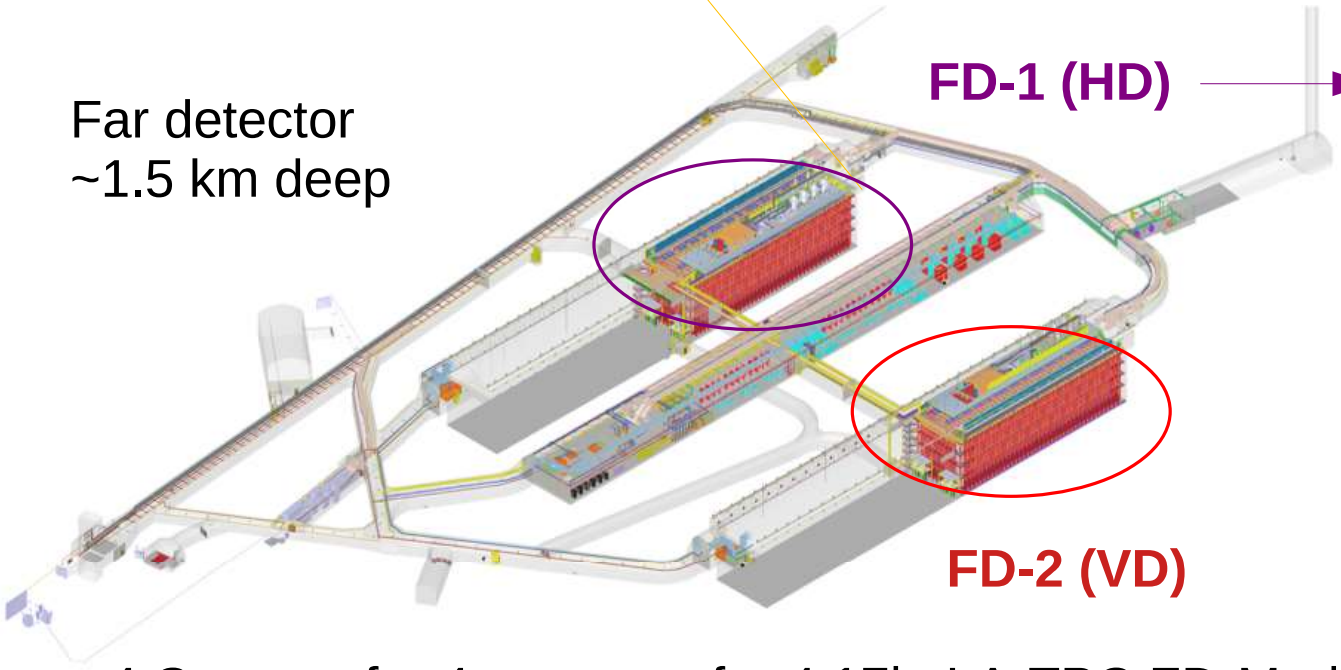
Sept 14 2021



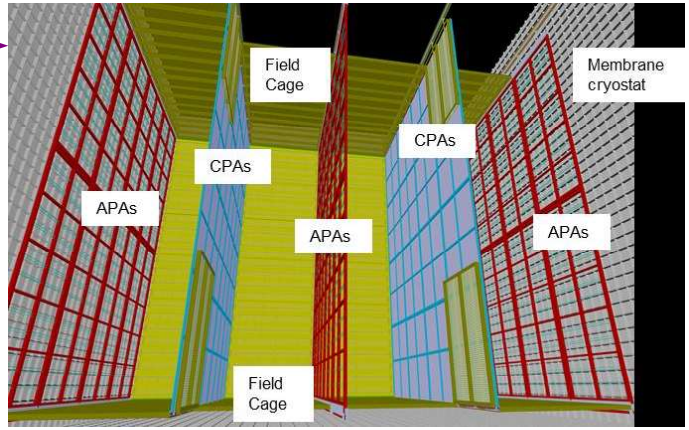
DUNE



Far detector
~1.5 km deep



FD-1 (HD)



FD-2 (VD)

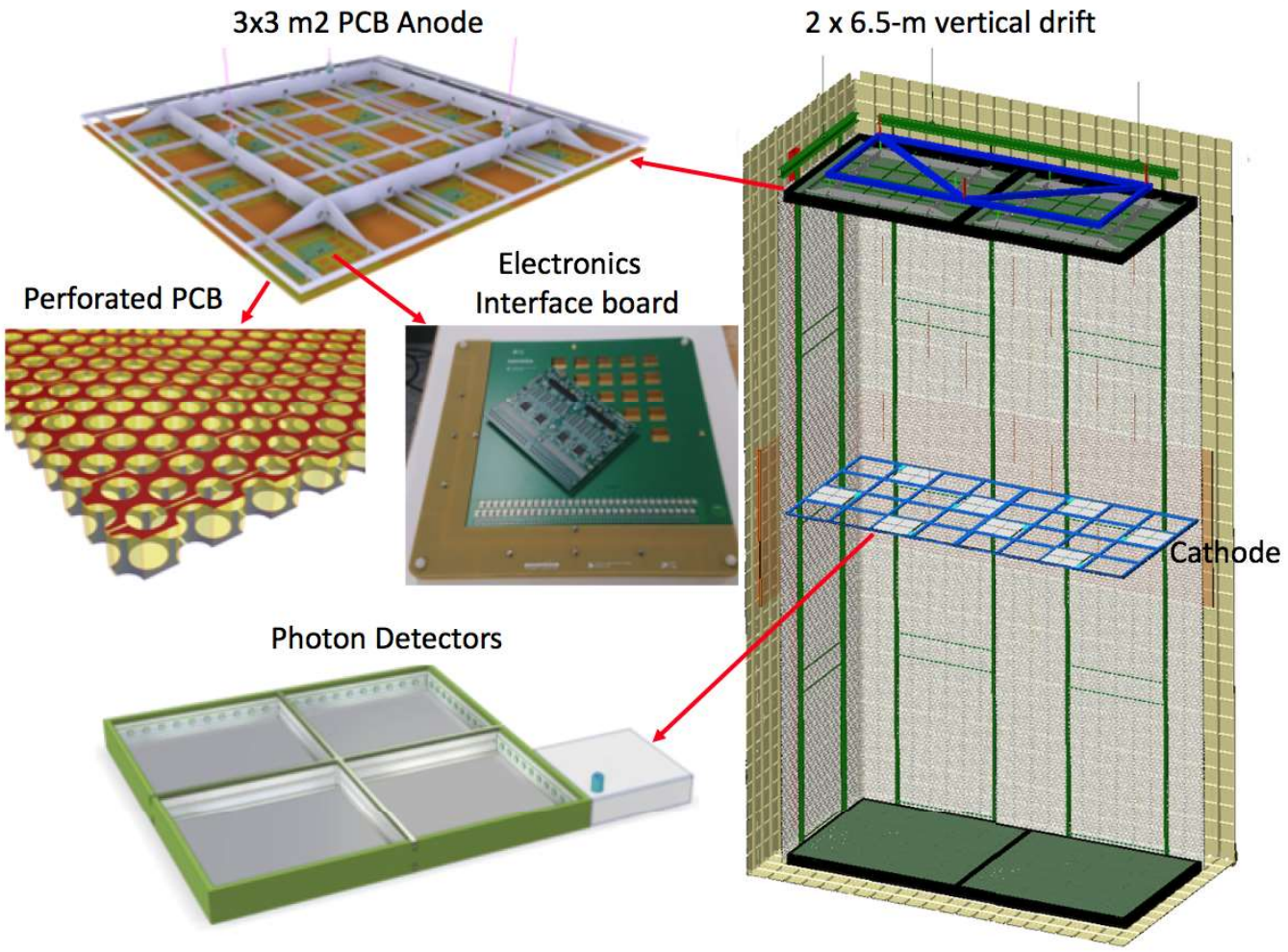
4 Caverns for 4 cryostats for 4 17kt LArTPC FD-Modules

The Vertical Drift Module

2 volumes (13.5 m x 6.5 m x 60 m) separated by a cathode plane

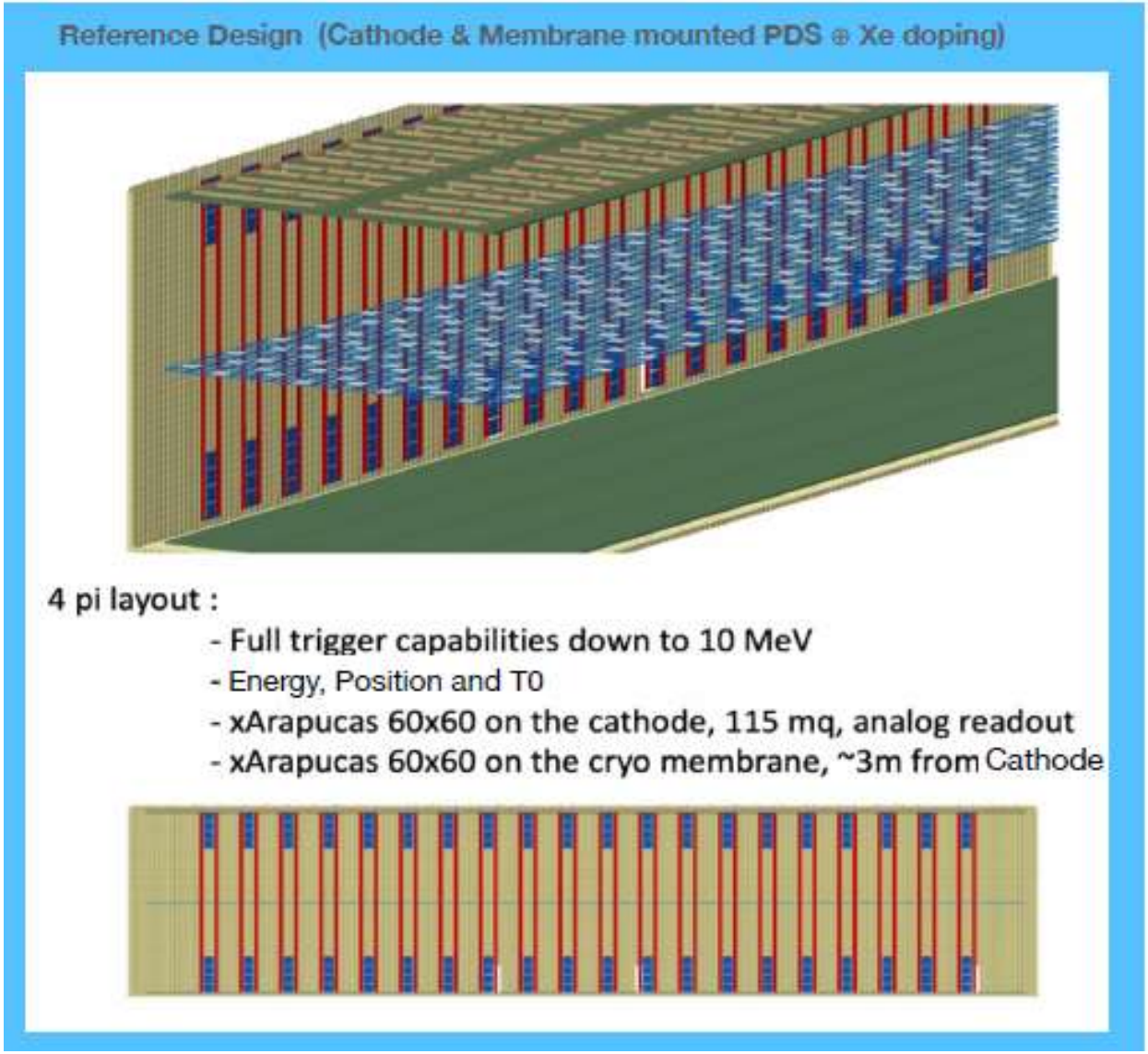
2 Anode planes (top & bottom)

Anode composed by stacked layers of a perforated PCB with electrode strips



Photon detector: large size X-Arapuca tile (0.6 x 0.6 m^2)

Vertical drift single phase PDS



Active coverage: 14.8% Cathode, 7.4% Laterals

Reference Design

PD Active Optical Coverage onto 3 sides

(w/ modified FC - 70% T)

+

PD Passive Optical Coverage (reflector) on the Anode side

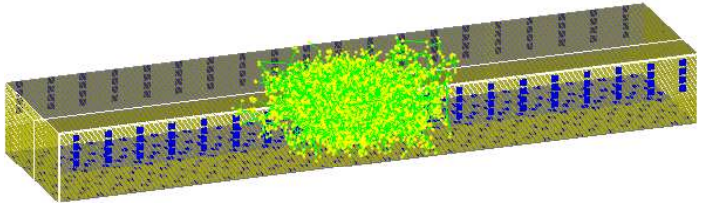
+

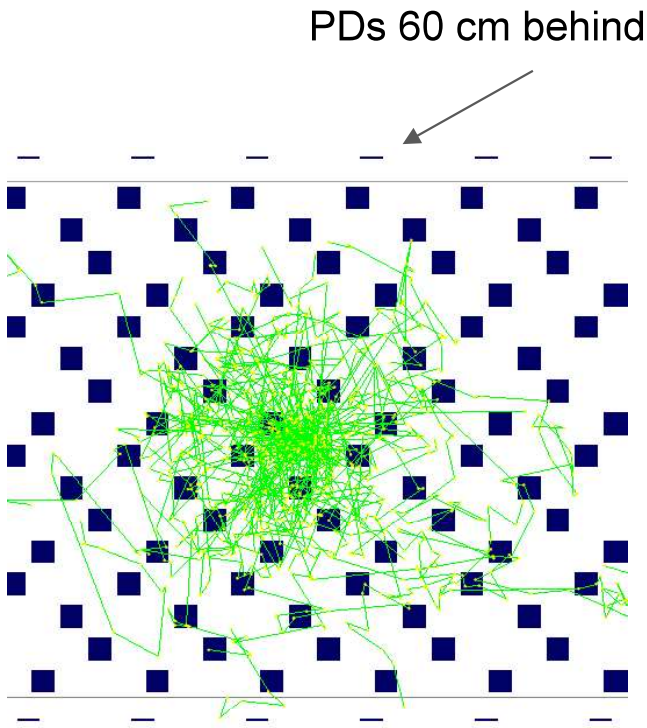
Xe doping

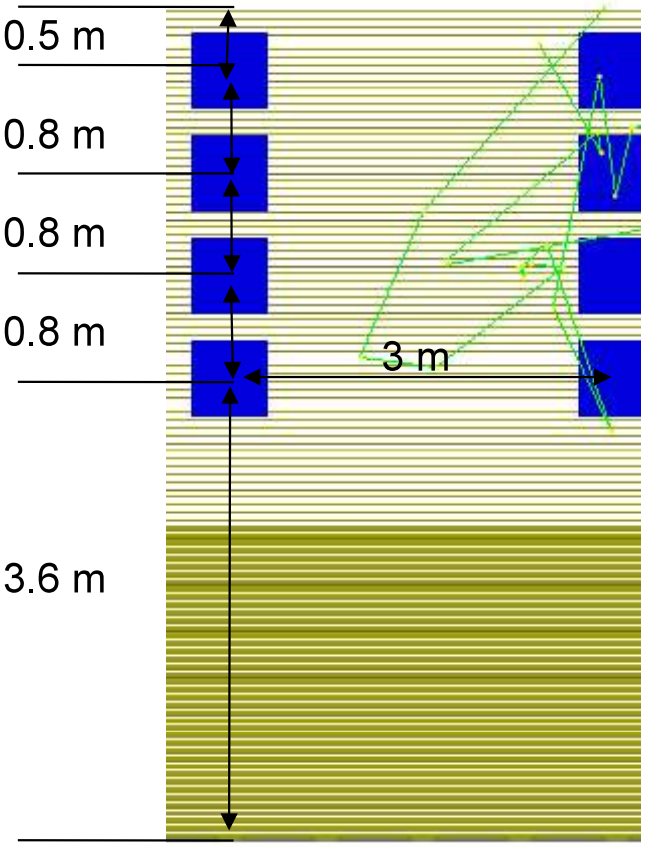
- *good uniformity of response*
- *low detection&trigger threshold*
- *energy resolution and position resolution capability*

Reference Design Simulation

- Geant4
- FC structure
- Semi-transparent Cathode: T = 80%
- Anode R=20% (Xe)
- Abs length = 50 m
- Rayleigh scattering*
  λ_{Ar} = 99.9 cm,
  λ_{Xe} = 8.5 m







320 over the laterals
(160 each volume)
320 on the cathode

*M. Babicz et al, JINST 15, P09009 (2020)

PDS Reference Design: Light Yield Map

- 25000 photons per MeV of energy deposited

  75% Xe / 25% Ar

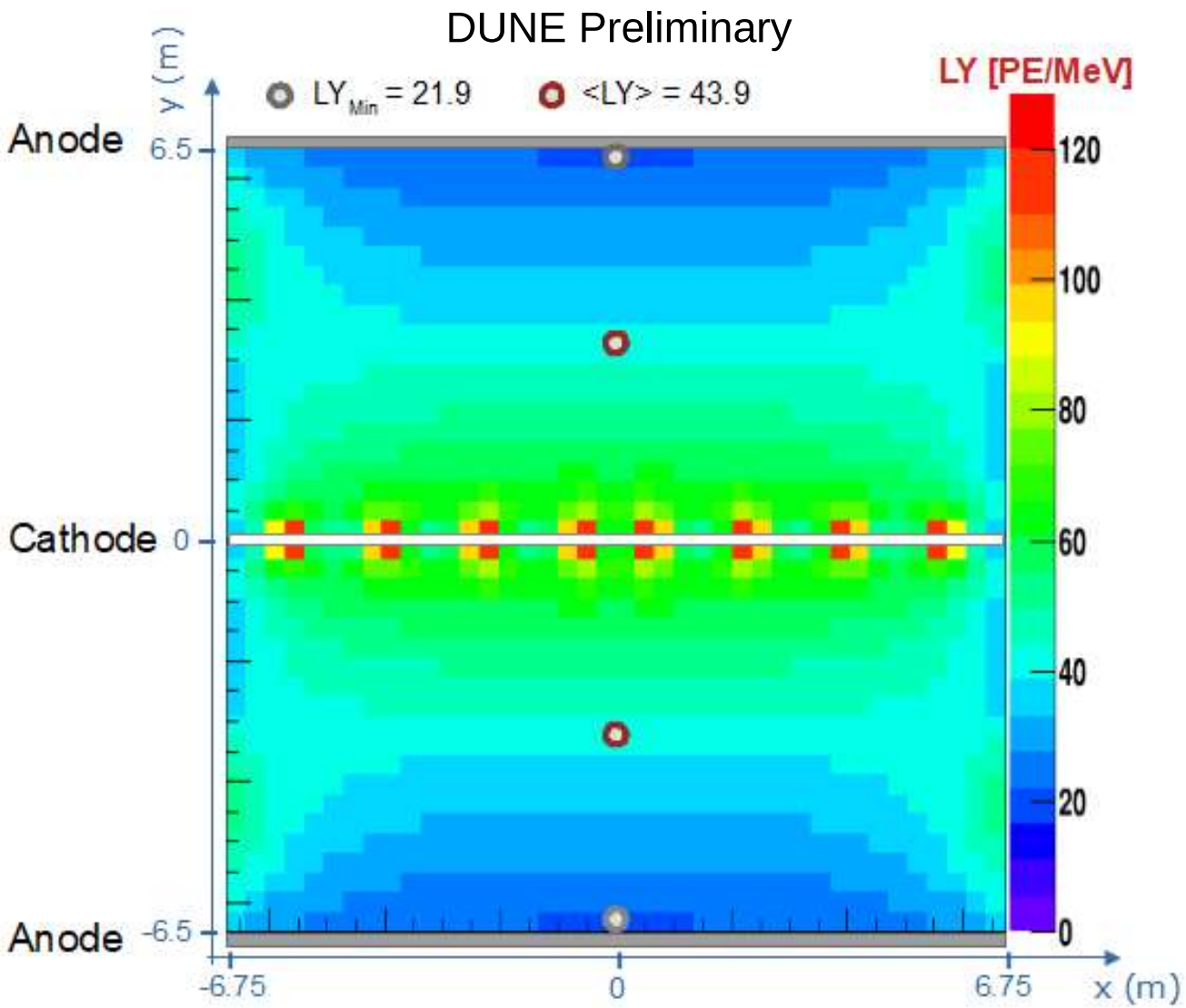
- 3% detection efficiency

LY_{min} = 21.9 PE/MeV

<LY> = 43.9 PE/MeV

Requirements:
Average - En res comparable to TPC for 5-7 MeV SN vs
Minimum - tagging of > 99% of nucleon decay

Ar + Xe (10 ppm by mass)

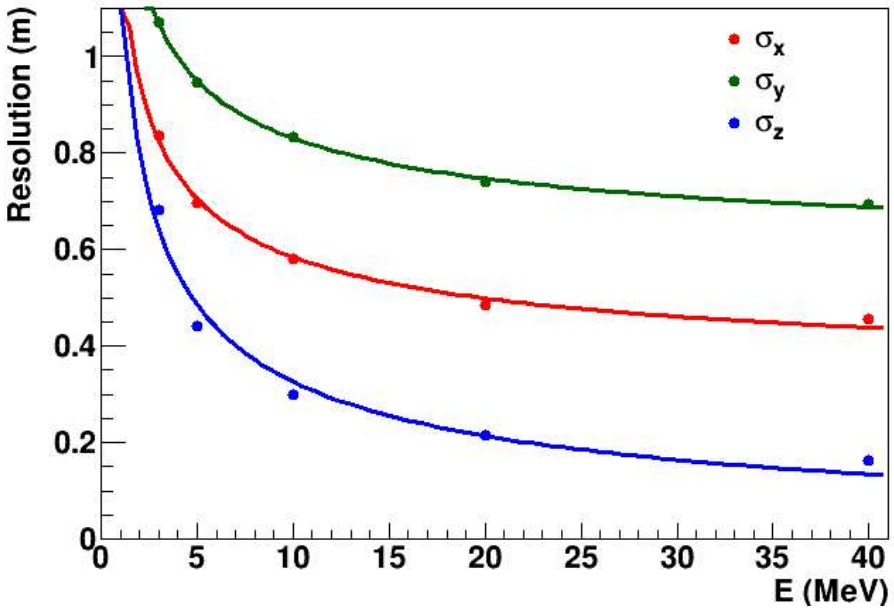


Position Resolution in the Reference Design

- From barycenter determination
- Resolution: $A/\sqrt{E} + B$
- Good position resolution
  - Border effects

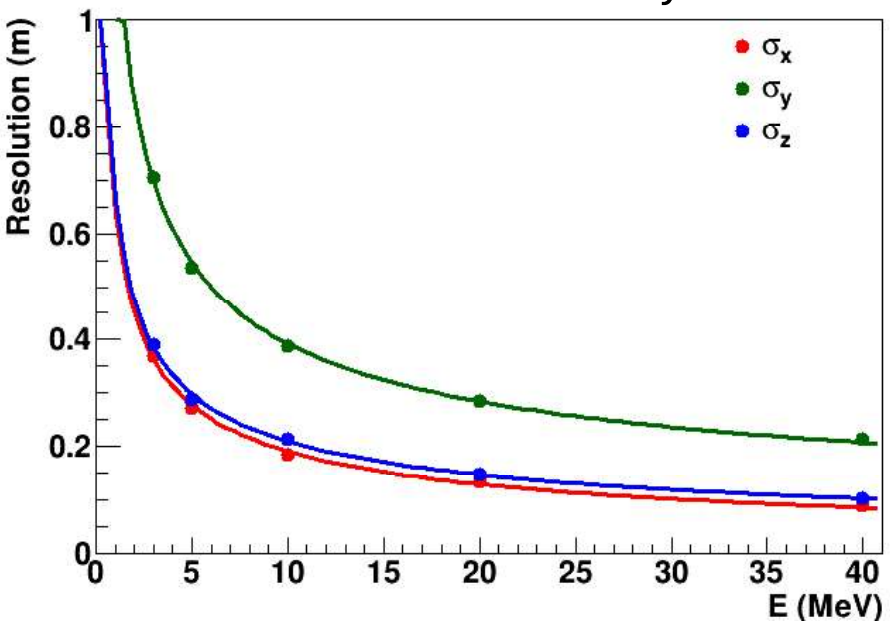
Requirement:
Spatial localization
(perpendicular to drift) < 2.5 m
Matching of PD and TPC signals

DUNE Preliminary



2800 events per energy deposit anywhere in the volume (central region)

DUNE Preliminary



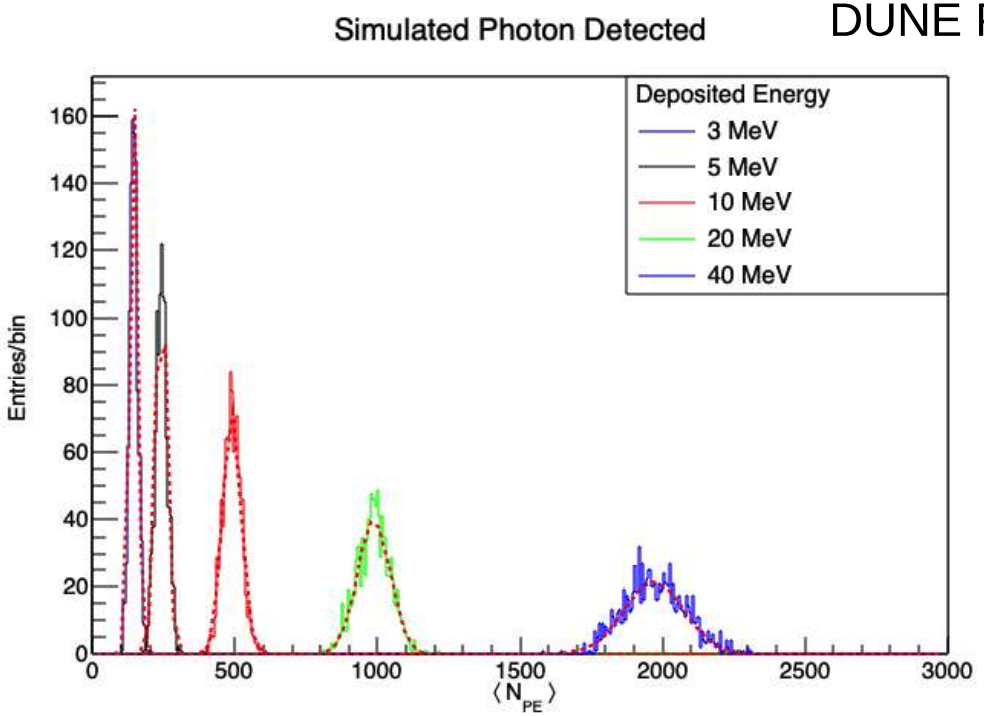
500 events for each energy deposit at (0,0,0)

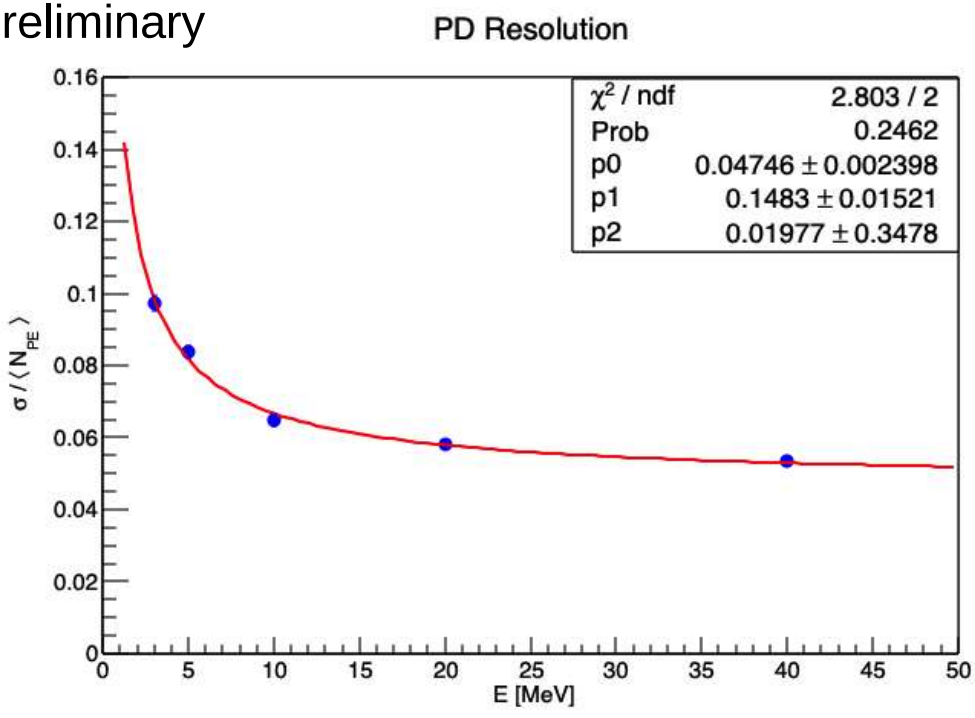
Energy Resolution in the Reference Design

Identification of SN spectrum features

- Point-like E deposits at center of top volume
  - Uncertainty on energy calibration (p0)
  - Statistical fluctuation (p1) on the number of detected PEs
  - Noise term (p2)

DUNE Preliminary



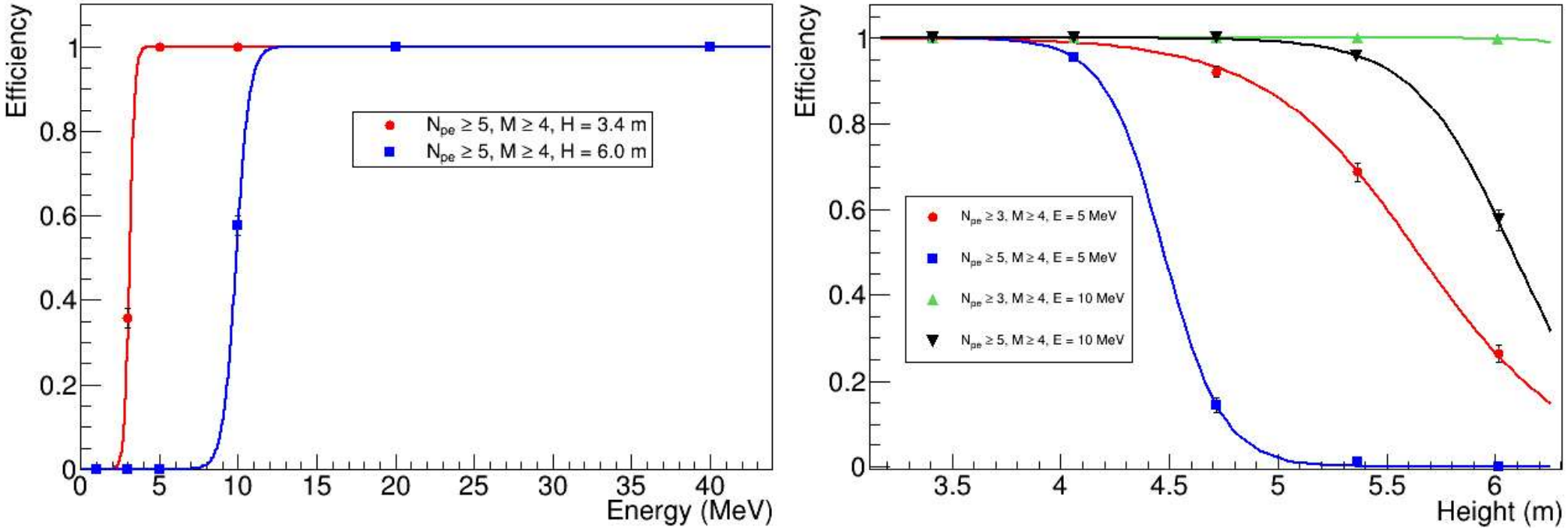


Trigger Efficiency

- Point-like E deposits at the center of top volume
  - Simple (N_{PE}, M) Majority condition on adjacent tiles

500 events with fixed (x=0, z=0) for a given energy deposit

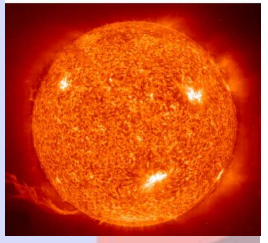
DUNE Preliminary



Summary

- Preliminary evaluation of Physics capabilities of the VD PDS
- LY map
  - Average and minimum above requirements
- Position resolution
- Calorimetry
  - Energy measurement down to low energy (MeV)
- Trigger
  - Efficiency

PD Impact on Low Energy Physics



- Event timing
- Energy resolution (photon calorimetry + drift correction)
- Position resolution (bckg rejection, reconstruction)
- Enhanced triggering, event selection, channel tagging
- Combination of TPC+PDS

improves SNB, solar neutrinos, DSNB