Simulação do sistema de detecção de fótons do DUNE Vertical Drift

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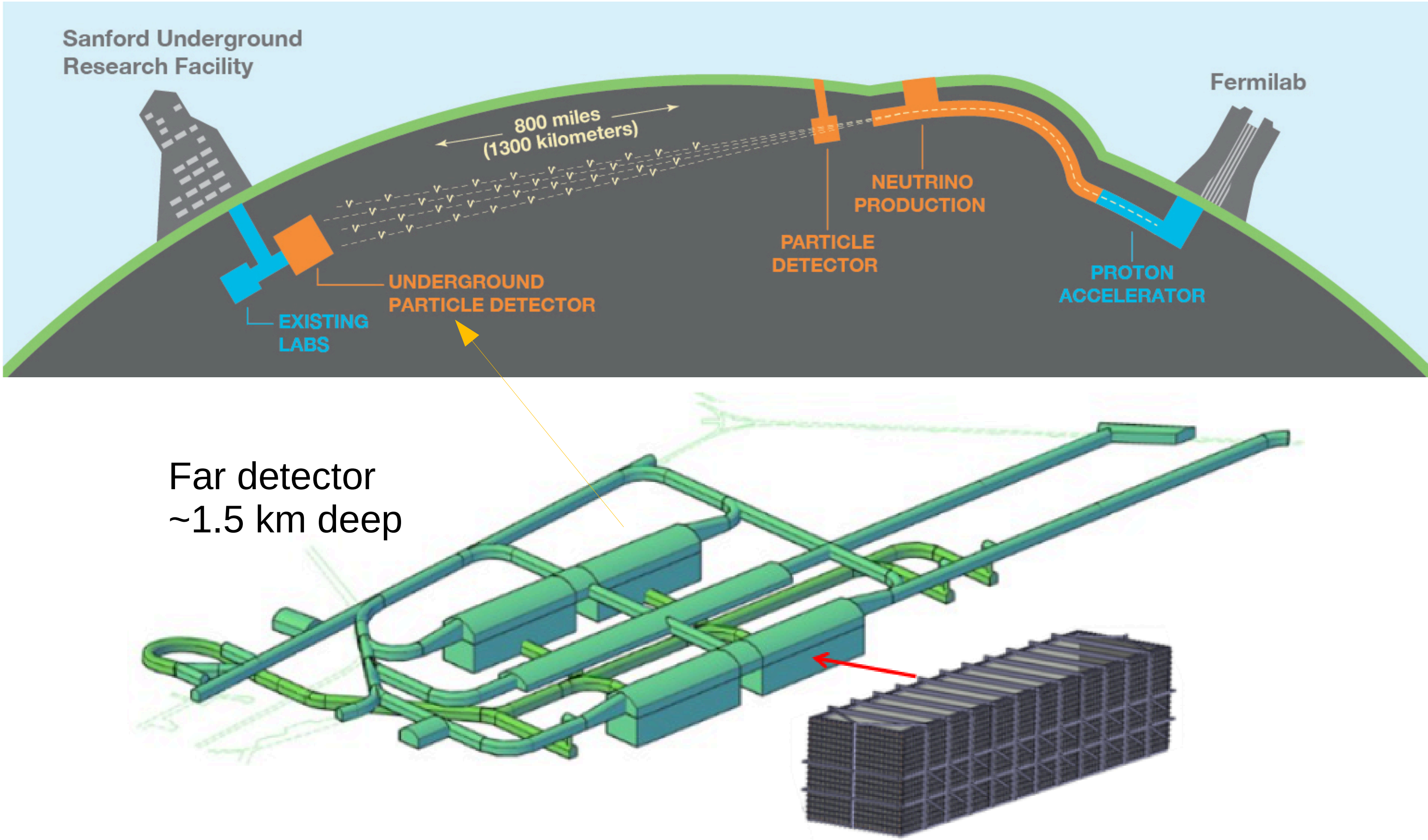
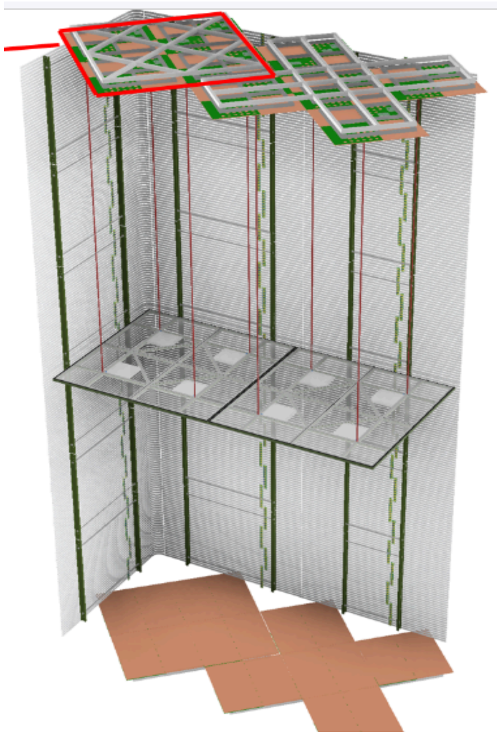
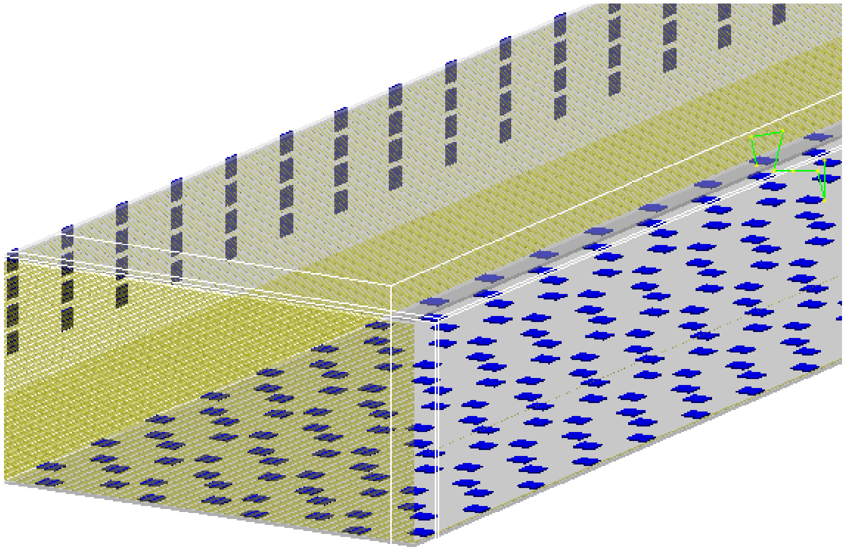
DUNE



4 Caverns for 4 cryostats for 4 10kt LArTPC FD-Modules

The Vertical Drift Module



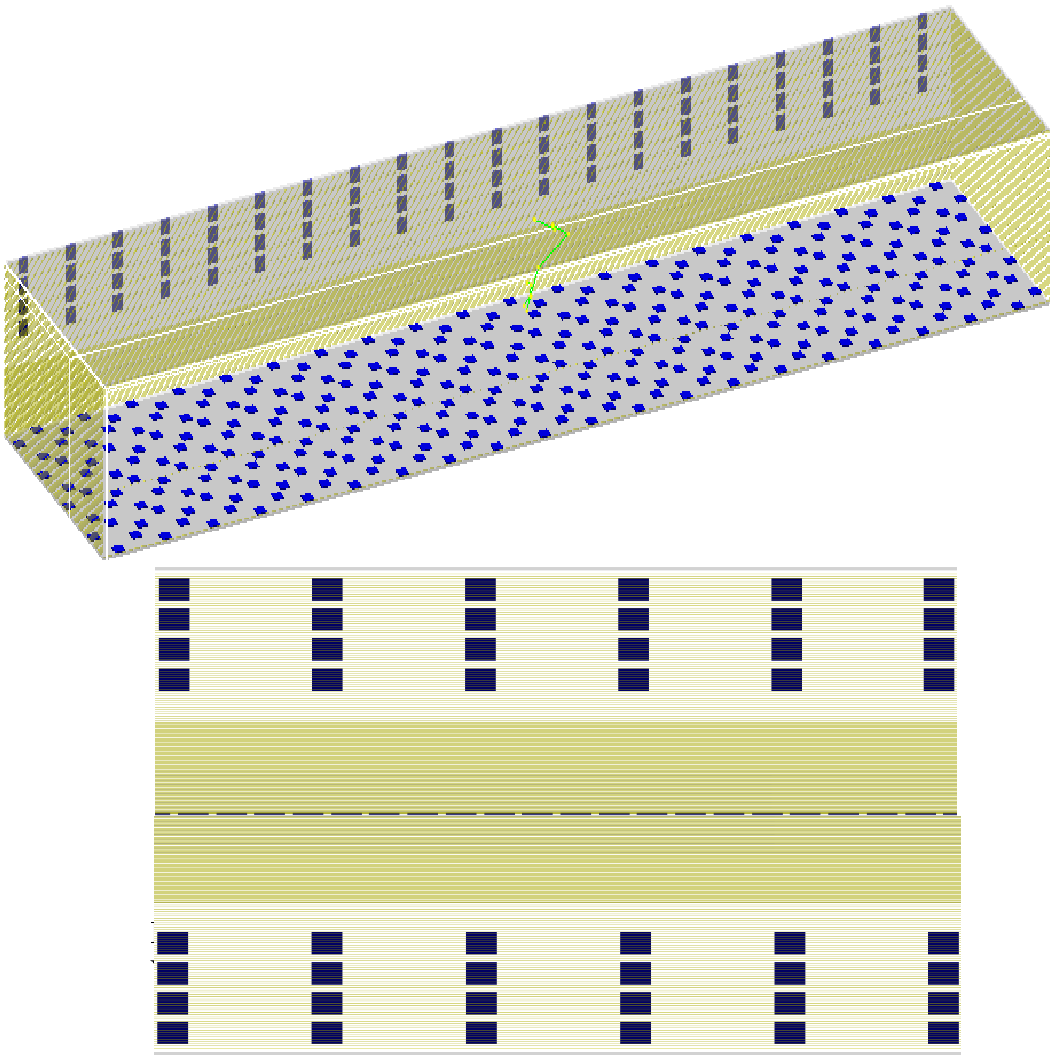


- 2 volumes (13.5 m x 6.5 m x 60 m) separated by a cathode plane
- 2 Anode planes (top & bottom)
- Photon detection system: large size X-Arapuca tiles
- 3 detection planes: cathode (double sided – HV), membranes (vertical)
- Active coverage: ~15% H-plane, ~7% V-planes
- Liquid Argon + Xenon doping

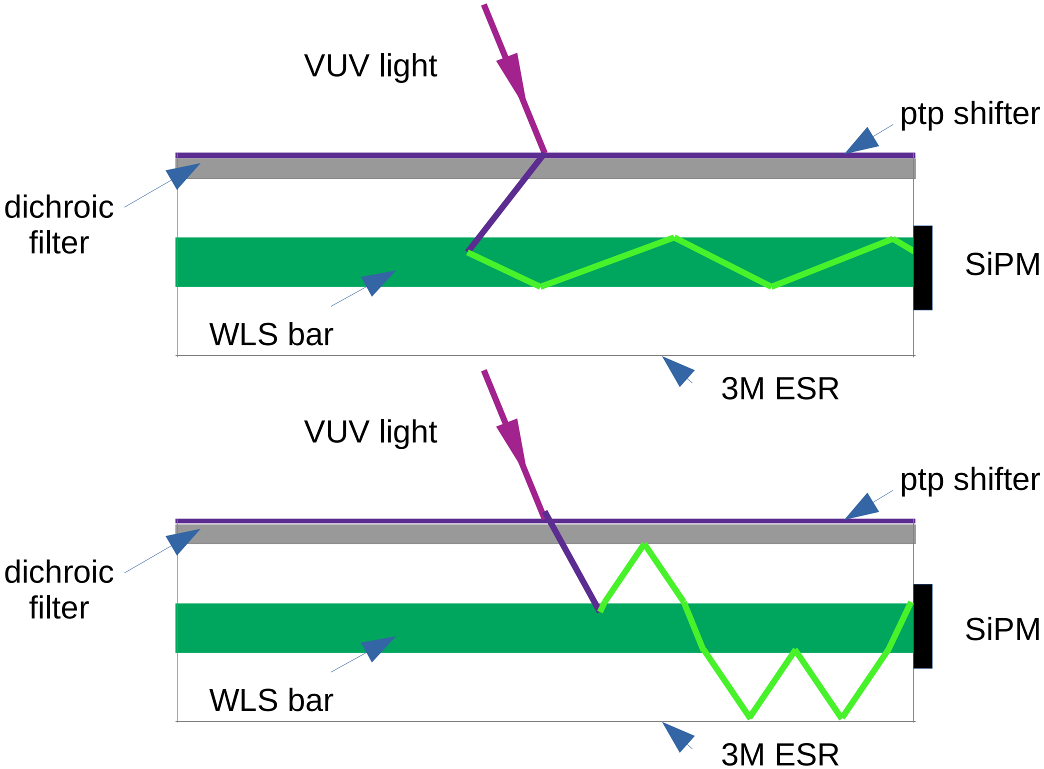
Vertical drift single phase PDS

Reference Design

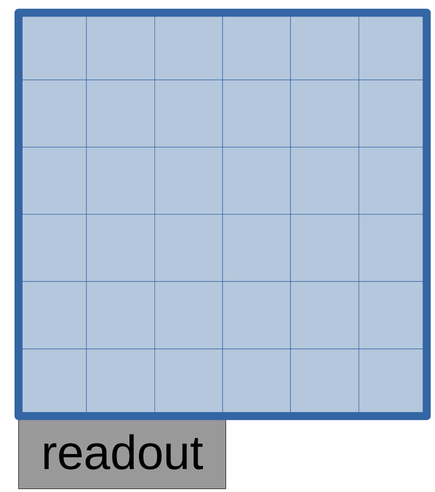
- Response: good uniformity
- Low detection & trigger threshold
- Energy and position resolution capability



PDS Sensitive Volumes: X-Arapucas



Tile design for VD PDS



- Expected efficiency: ~3.0%

C. Brizzolari *et al* 2021: arXiv:2104.07548
H. V. Souza *et al* 2021: arXiv:i2106.04505
L. Paulucci *et al* 2020 JINST 15 C01047

- Total active area ~3.6×10³ cm² (single or double sided)
- 160 SiPMs (40 per side)

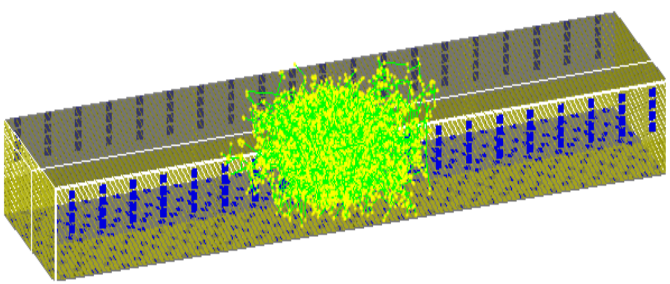
Reference Design Simulation

480 Photon Detectors

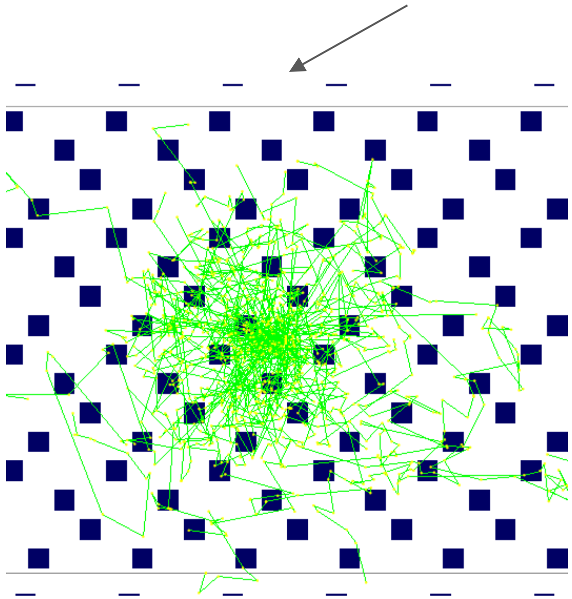
FC: R = 26%

Anode R = 20% (Xe)

λ_{Ar} = ~1 m, λ_{Xe} = ~8.5 m

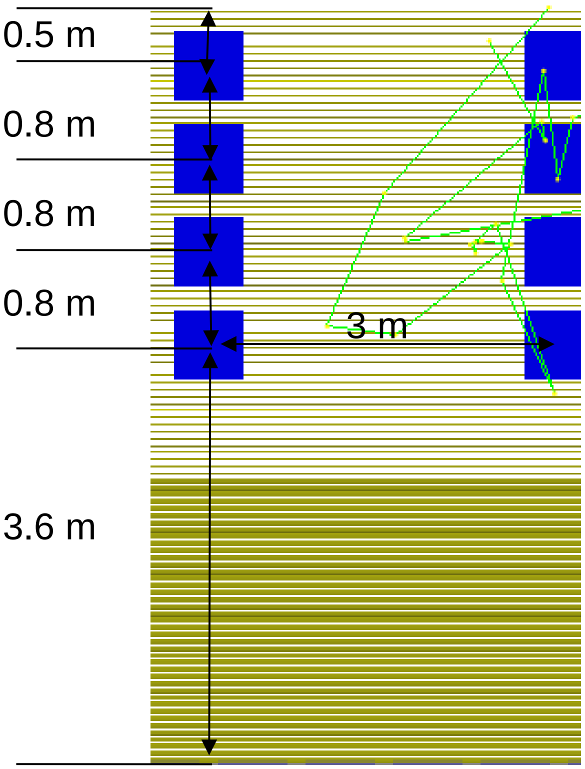


PDs 60 cm behind FC



Absorption length = 50 m
25000 photons/MeV

Top volume: 20 columns per side, each with 4 tiles

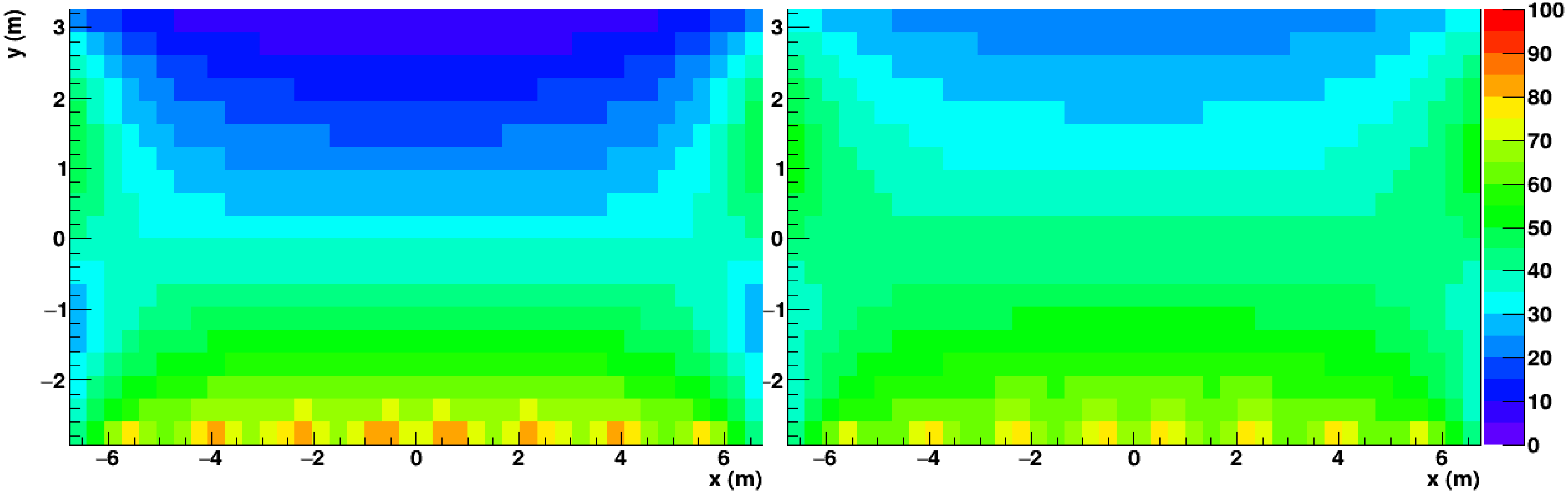


PDS Reference Design: Light Yield Map

- Effects of a longer Rayleigh scattering

<LY> = 38.09
LY_min: 6.09 (<LY_min> = 6.12)

<LY> = 43.9
LY_min = 21.87 (<LY_min> = 21.93)



Cathode: T = 80%

<LY> up ~ 15%
LYmin: ~2.6 x

PDS Reference Design: Light Yield Map

- 25000 photons per MeV of energy deposited

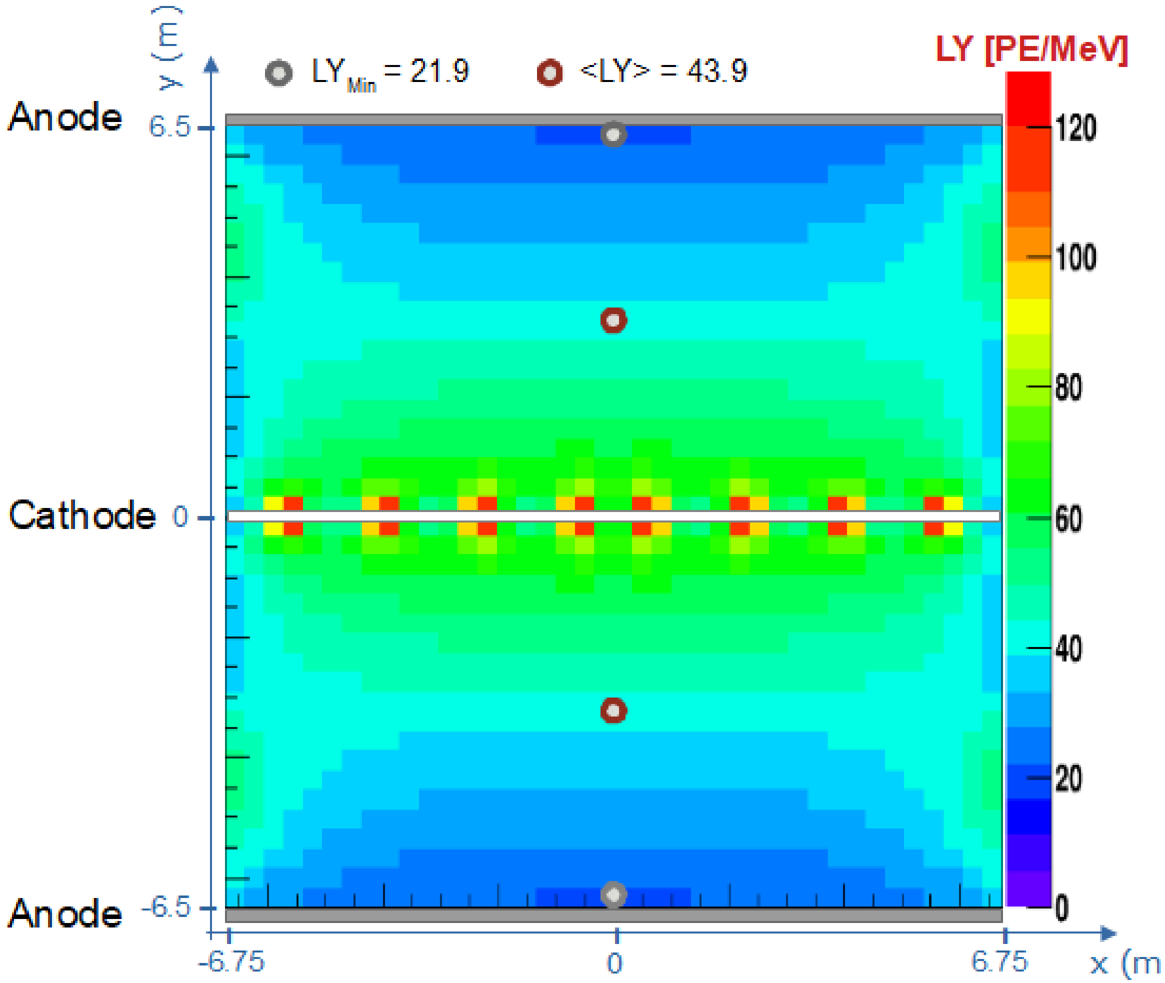
  75% Xe / 25% Ar

- 3% detection efficiency

LY_{min} = 21.9 PE/MeV

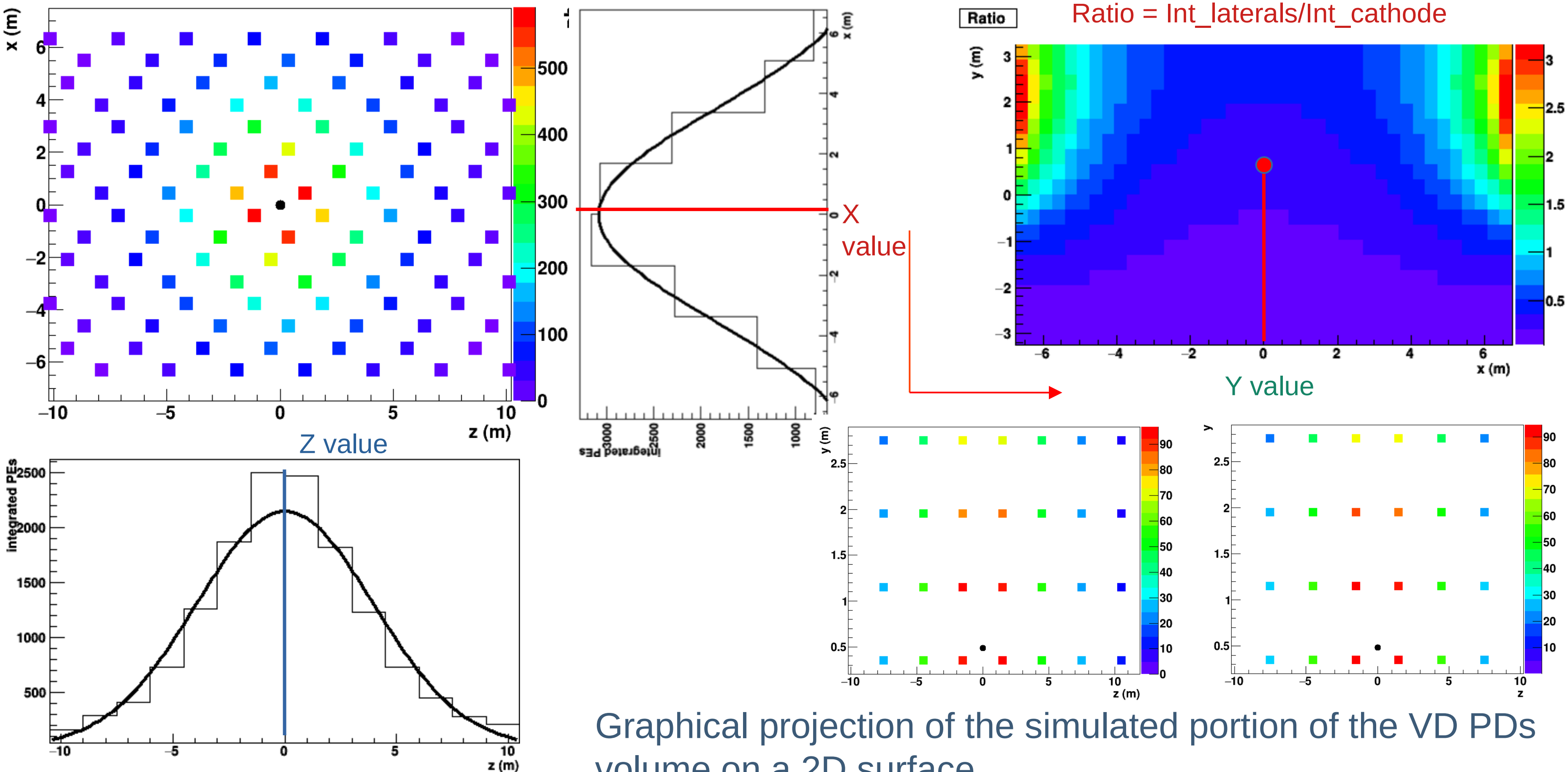
<LY> = 43.9 PE/MeV

Ar + Xe (10 ppm)



Position Resolution in the Reference Design

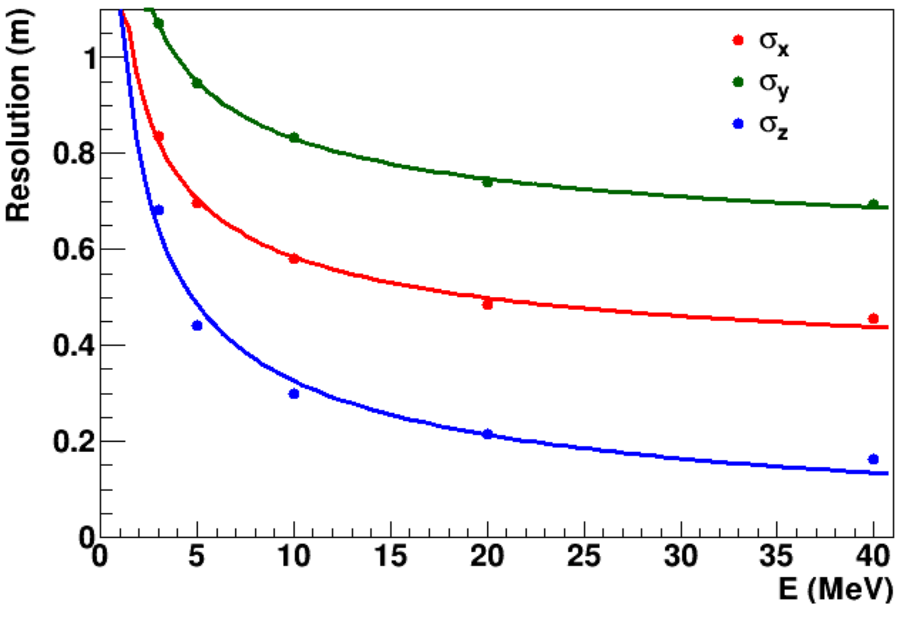
- Position from PE seen by each line/row of PDs planes: x, z from cathode, y from ratio of total light on laterals over cathode.



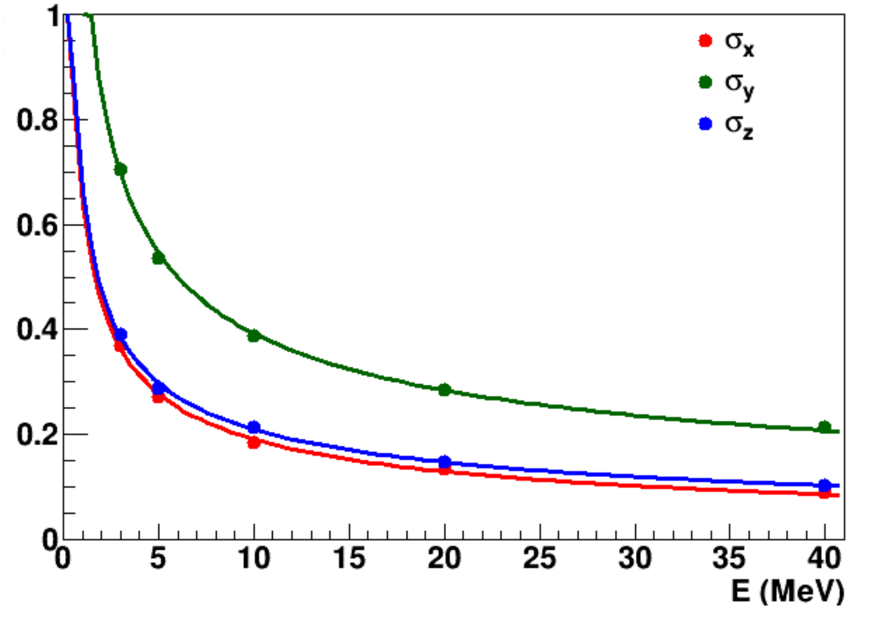
Graphical projection of the simulated portion of the VD PDs volume on a 2D surface

Position Resolution in the Reference Design

- Resolution: A/√E + B
- Good position resolution
  - Border effects
  - Expect improvements with timing



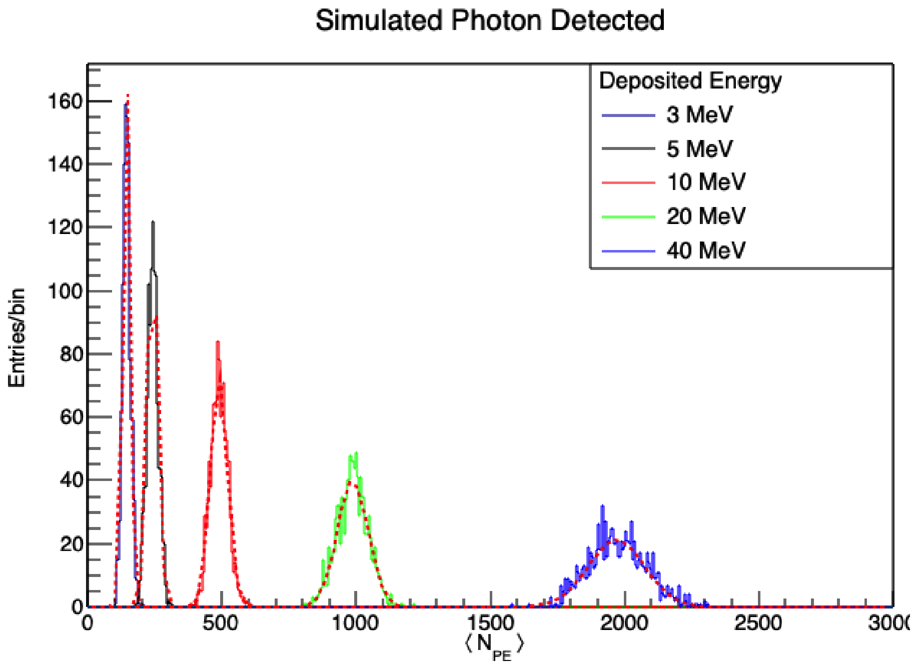
2800 events per energy anywhere in the volume (central region)

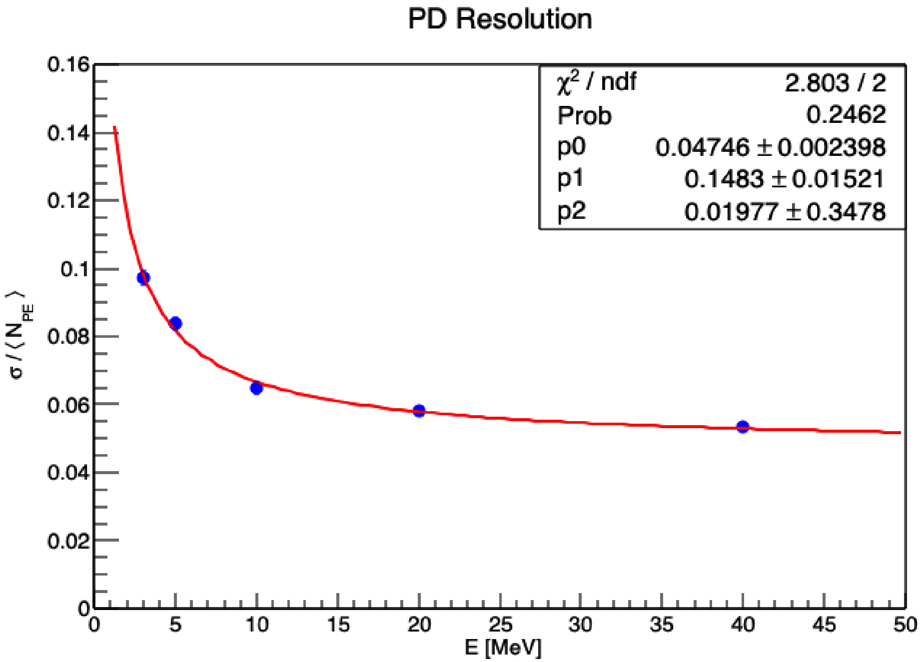


500 events for each energy at (0,0,0)

Energy Resolution in the Reference Design

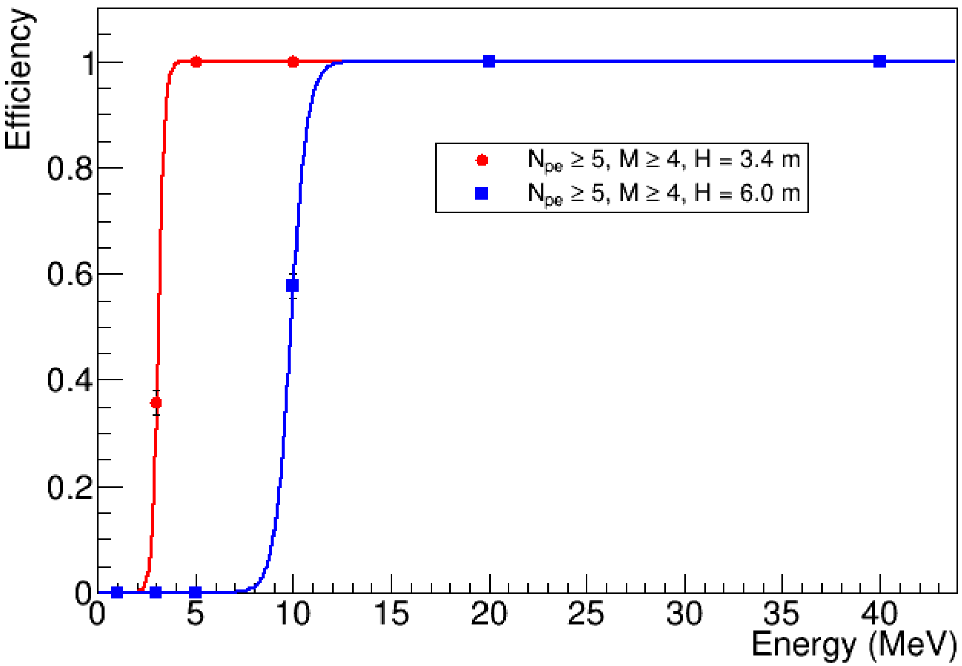
- Point-like source at the center of top volume
  - Uncertainty on energy calibration (p0)
  - Statistical fluctuation (p1) on the number of detected PEs
  - Noise term (p2)

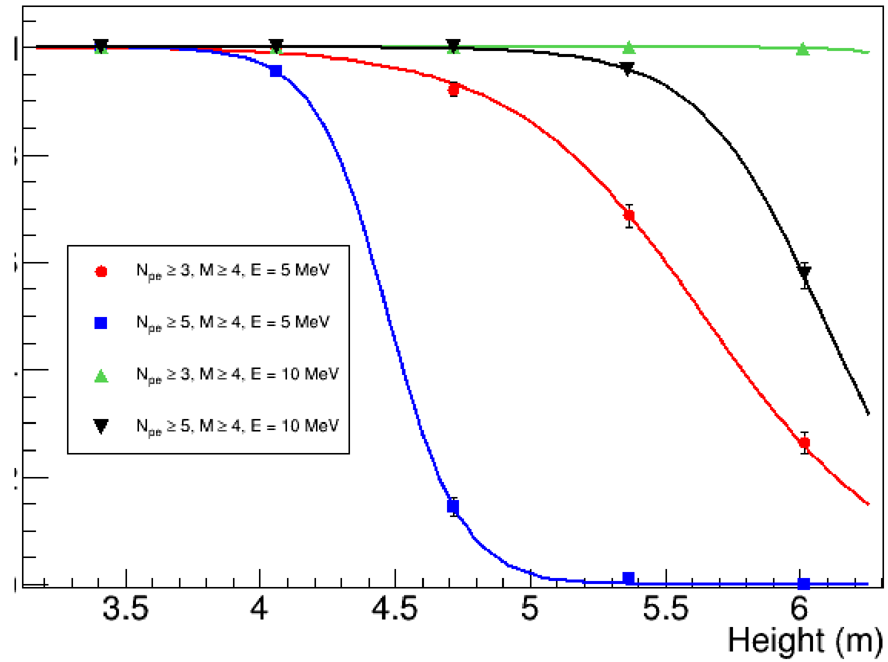




Trigger

- Point-like source 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

Summary:

- Current simulation efforts:
  - Tool for improving PDS performance
  - LArSoft Tools
    - determination of VD PDS requirements
    - physics studies
- Preliminary information on

  Position and energy resolution

  Trigger capabilities

Summary:

- Possible physics with VD PDS:
- T_0 at all non-beam events
  - Interaction to anode distance determination
    - Charge attenuation correction
    - Fiducial volume determination
- Calorimetry
  - Energy measurement down to low energy (MeV)
- Trigger
  - Alternative trigger primitive for Supernova bursts
  - Light+charge trigger strategy?

- Instituições/grupos envolvidos no projeto:
  UFSCar, UFABC, Fermilab, UCSB
- Estimativa de custos e possíveis fontes de recursos
  Custos de estadias para testes
  Participação no desenvolvimento e montagem do PDS
- Interações c/ outros grupos/experimentos
  UNICAMP/CTI – instrumentação, UNIFESP – computing
  ML, GPU: possibilidades de interação com outros grupos
- Cronograma
  2021/2: Otimização do PDS c/ Geant4, Inclusão do PDS e testes no LArSoft
  2022/1: Produção de MC c/ LArSoft e requerimentos de física
  2022/2 - 2023/1: Algoritmos de reconstrução & testes experimentais