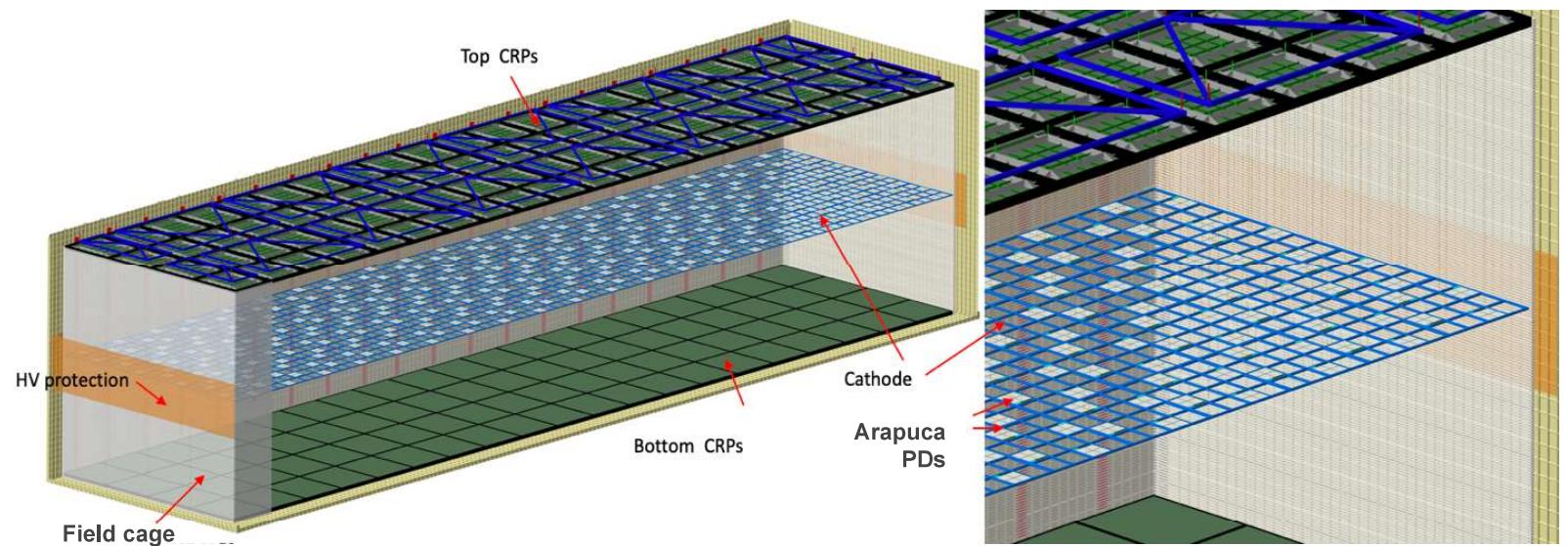
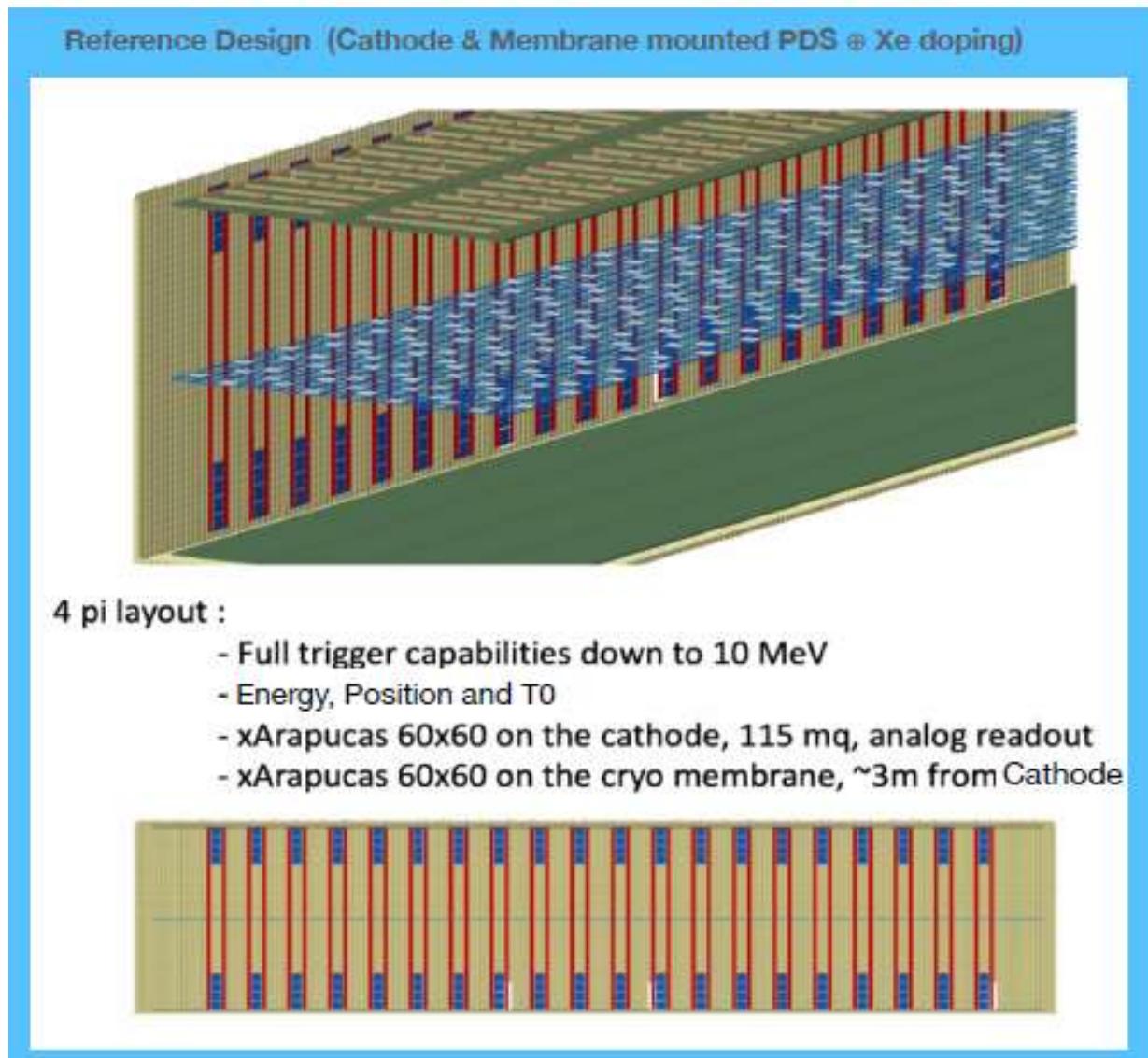


FD2 (VD) PDS: Features and Potentialities for DUNE Low Energy Physics

Laura Paulucci, Franciole Marinho, Flavio Cavanna, Dante Totani
DUNE FD-2 Photon Detector Workshop
July 26 2021



Vertical drift single phase PDS



Reference Design

**PD Active Optical Coverage onto
3 sides**

(w/ modified FC - 70% T)

+

**PD Passive Optical Coverage
(reflector) on the Anode side**

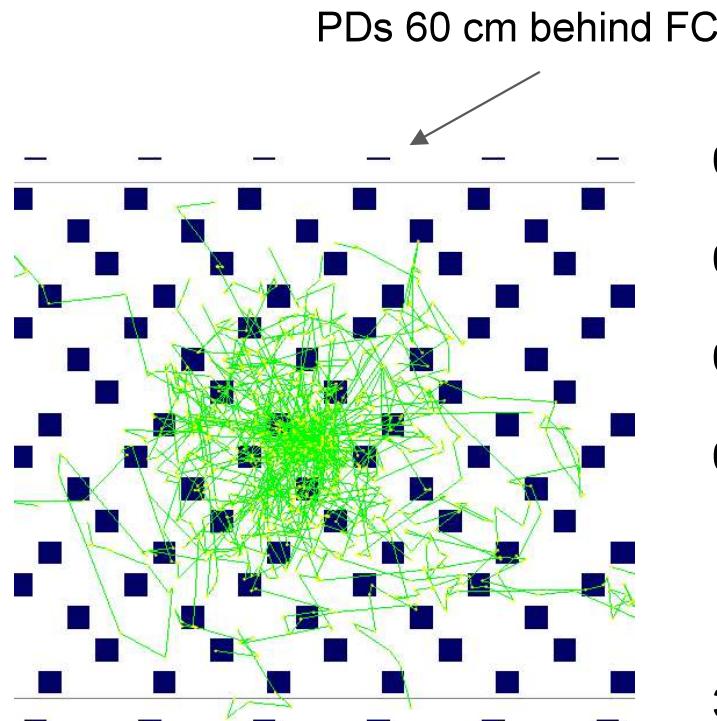
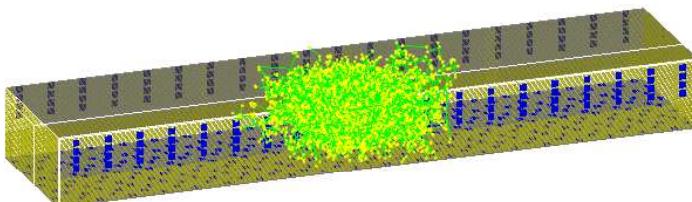
+

Xe doping

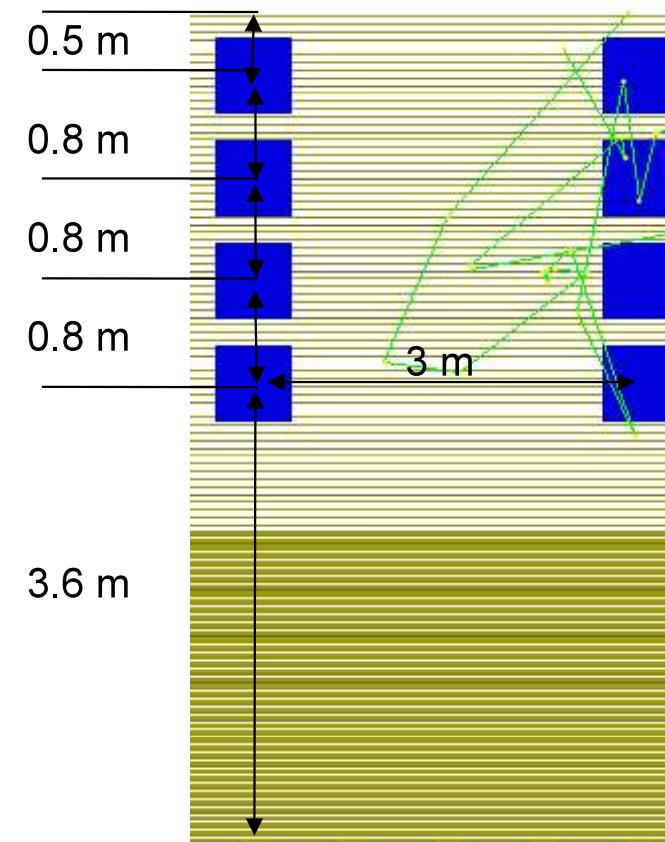
- *good uniformity of response*
- *low detection&trigger threshold*
- *energy resolution and position resolution capability*

Reference Design Simulation

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



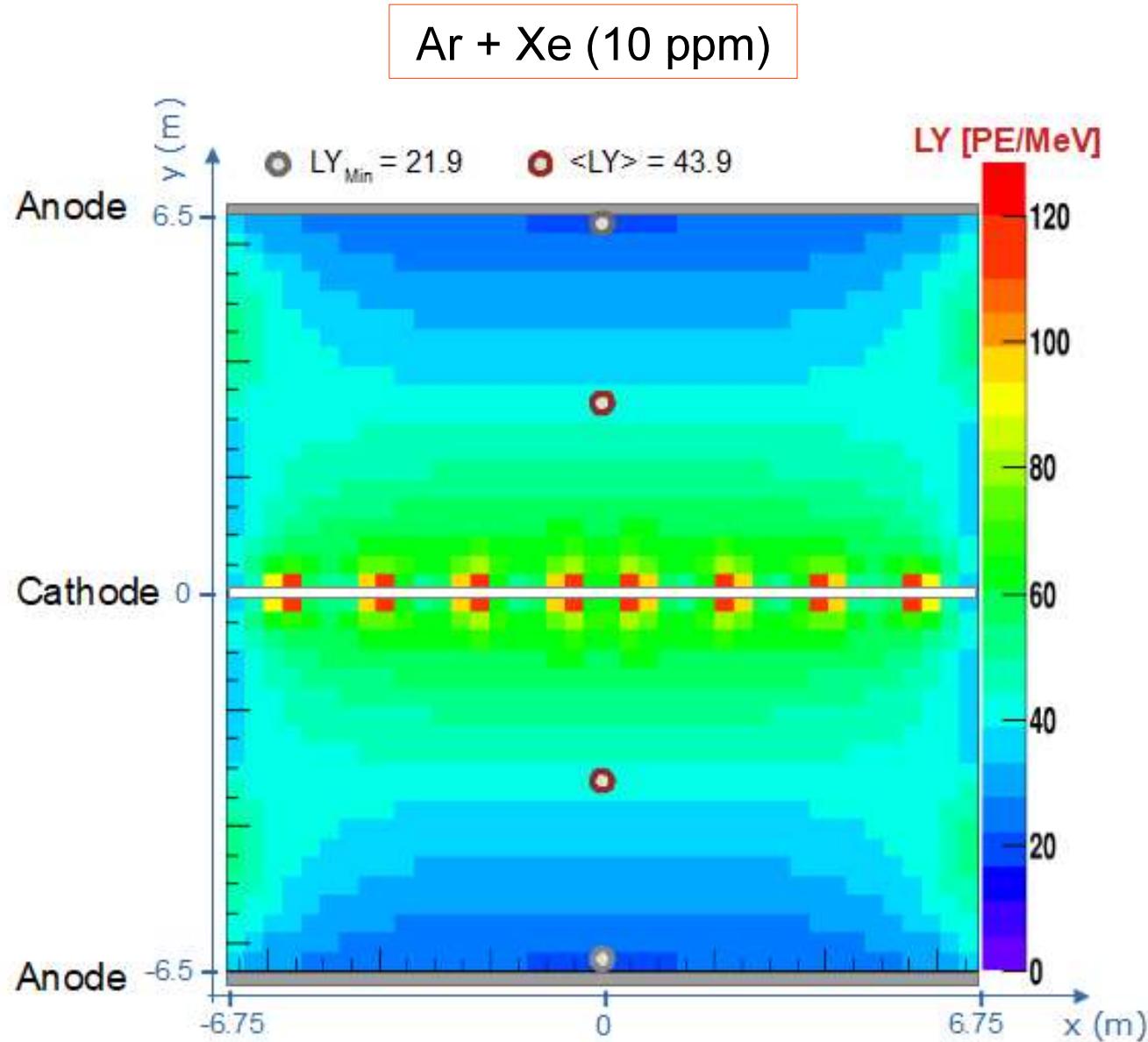
Top volume: 20 columns per side, each with 4 tiles



PDS Reference Design: Light Yield Map

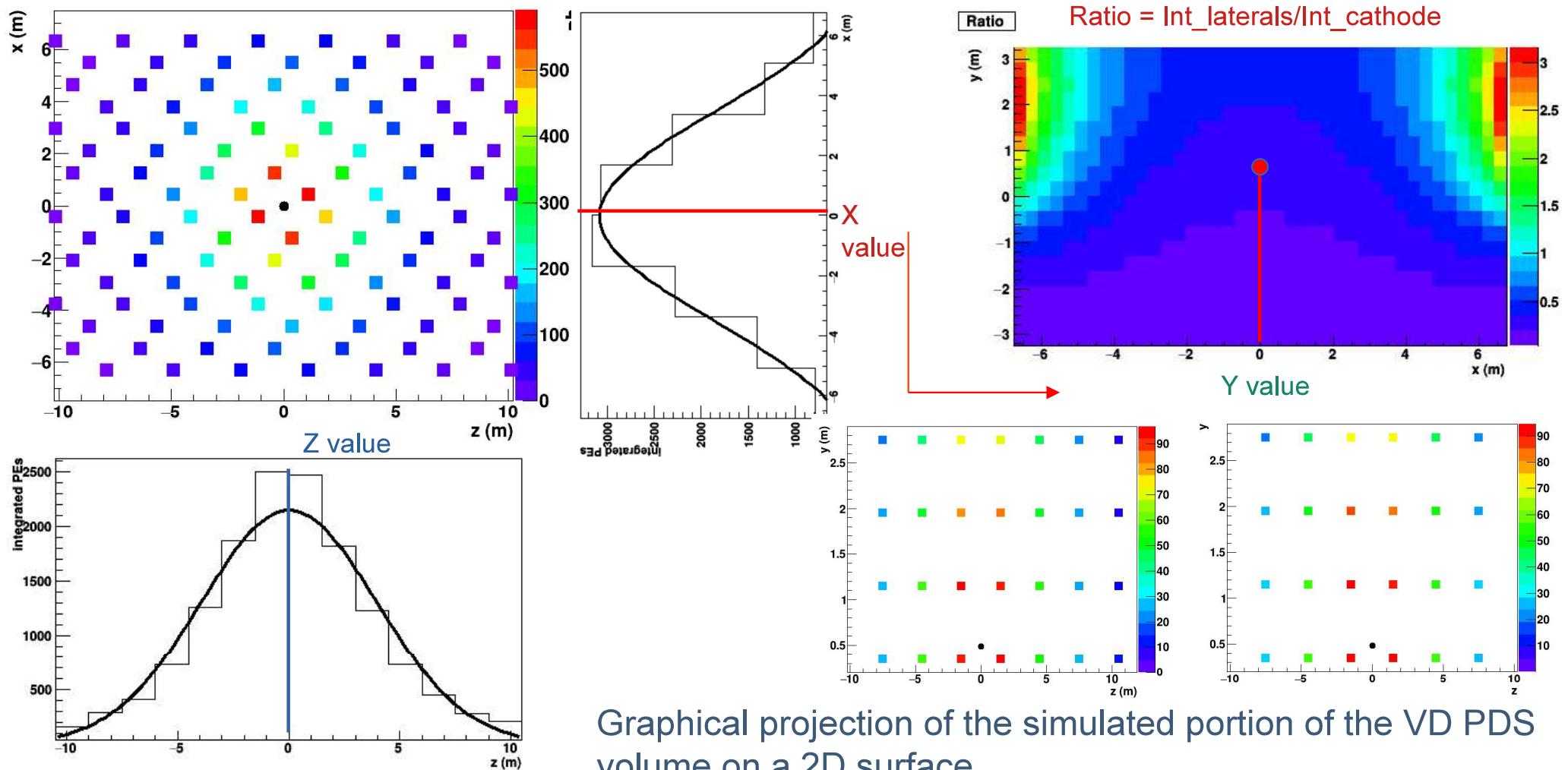
- 25000 photons per MeV of energy deposited
 - 75% for Xe
 - 25% for Ar
- 3% detection efficiency

$LY_{min} = 21.9 \text{ PE/MeV}$
 $\langle LY \rangle = 43.9 \text{ PE/MeV}$



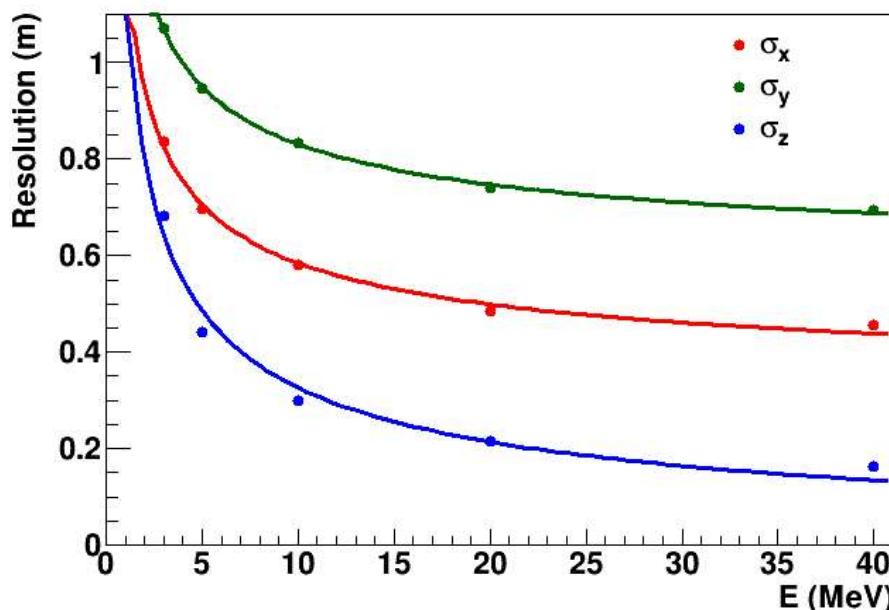
Position Resolution in the Reference Design

- Position taking from analyzing the PE seen by each line/row of PDs on the cathode plane. Coordinates x and z from barycenter; y is taken from an analysis of the ratio of total light on the laterals over the cathode.

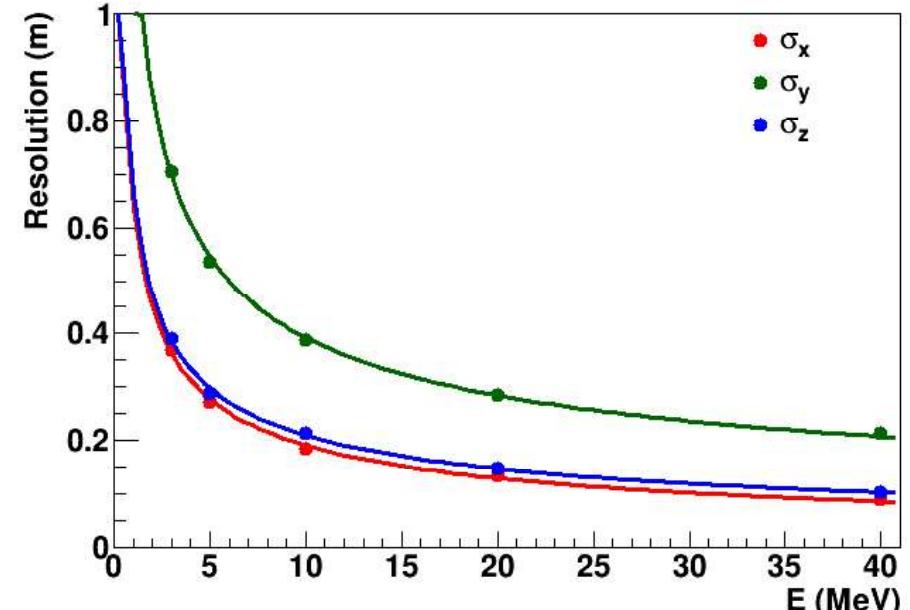


Position Resolution in the Reference Design

- Resolution proportional to $1/\sqrt{E}$
- Good position resolution
 - Border effects
 - Expect improvements with timing



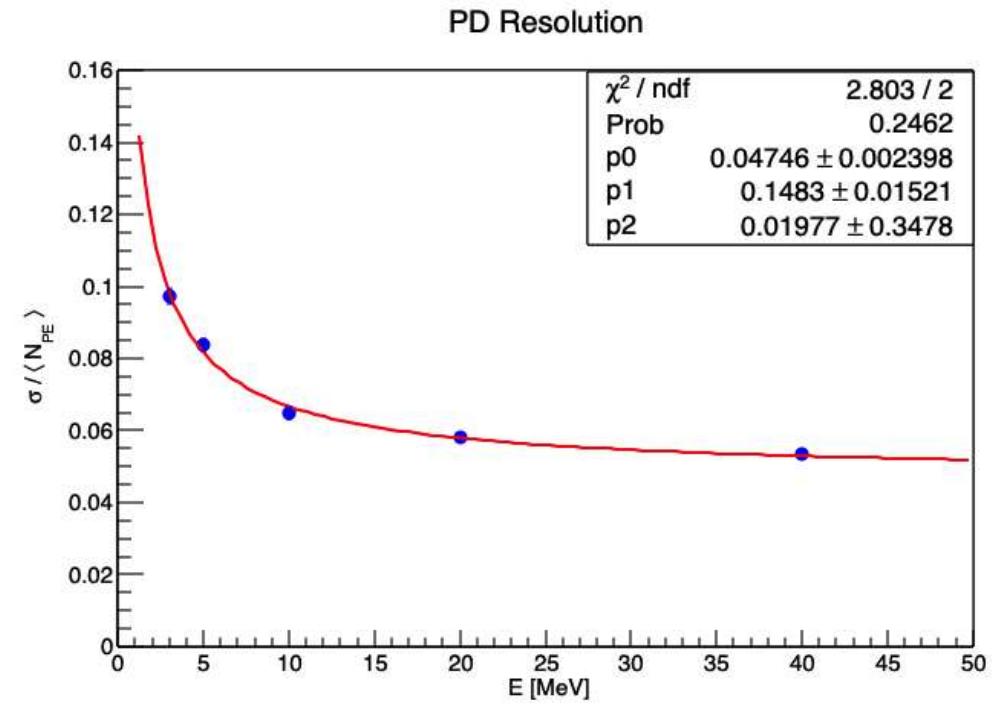
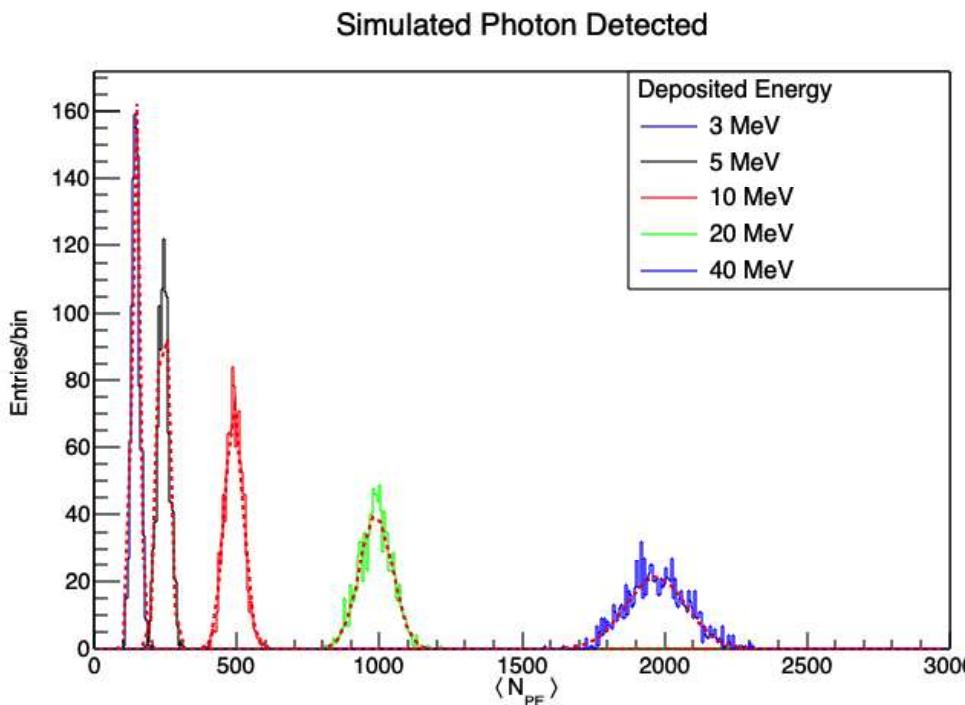
2800 events per energy anywhere in the volume
(central region)



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

Energy Resolution in the Reference Design

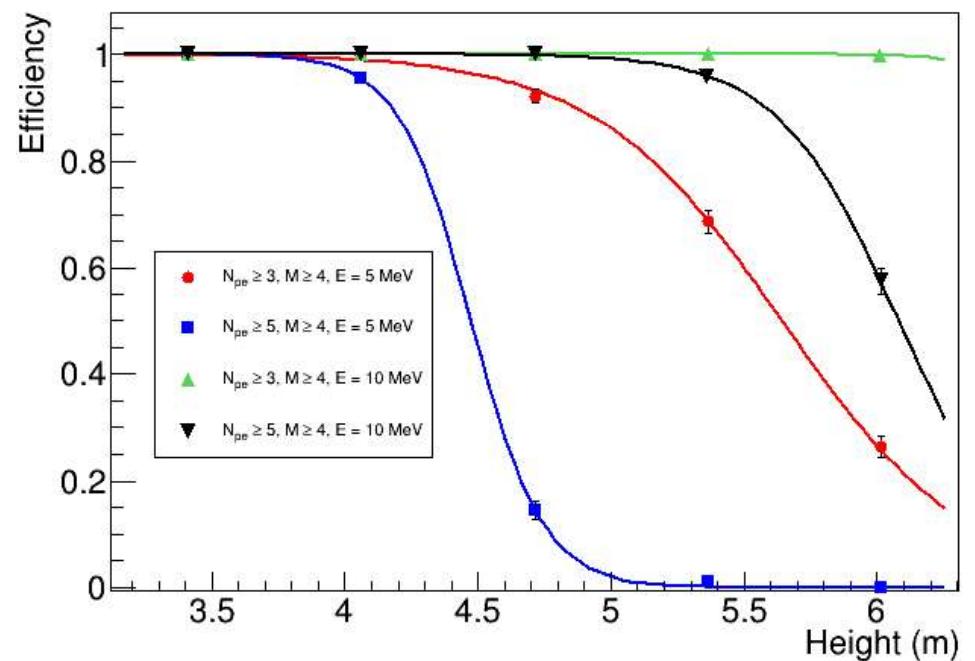
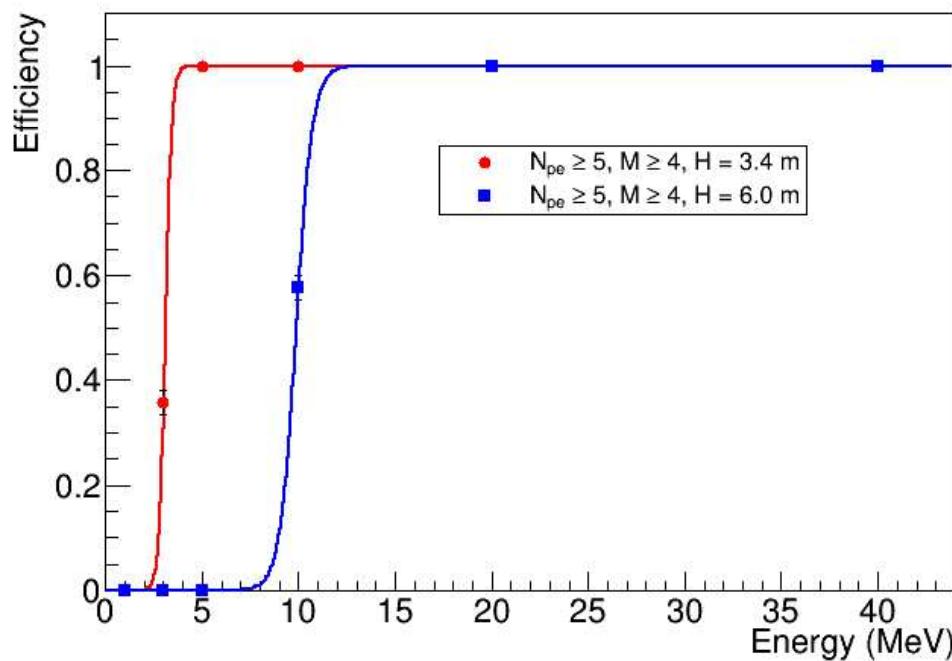
- Point-like source at the center of top volume
 - Uncertainty on energy calibration (p_0)
 - Statistical fluctuation (p_1) on the number of detected PEs
 - Noise term (p_2)



Trigger Efficiency

- Point-like source at the center of top volume

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

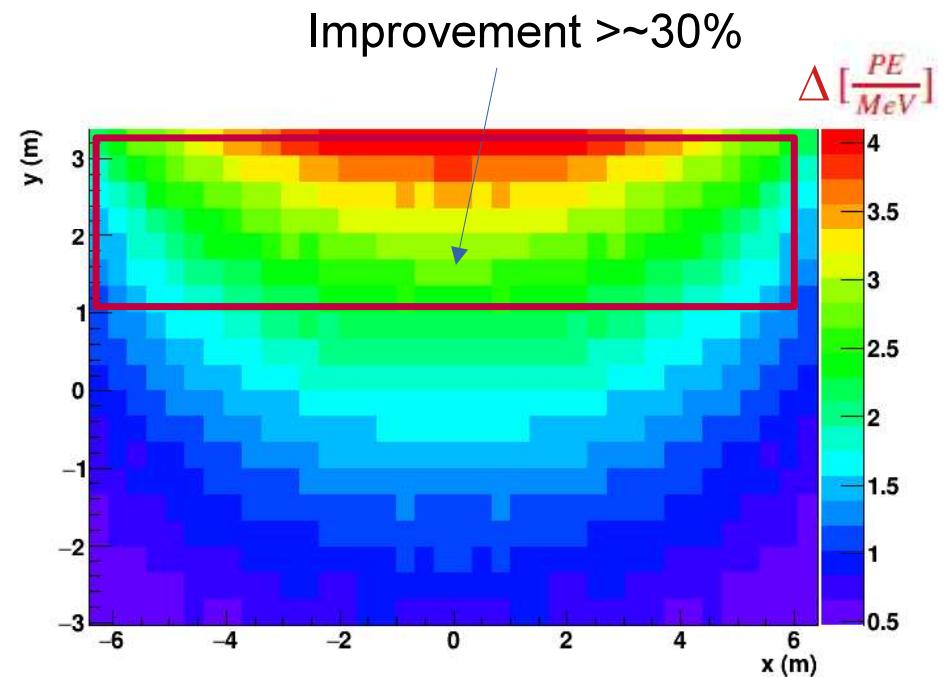
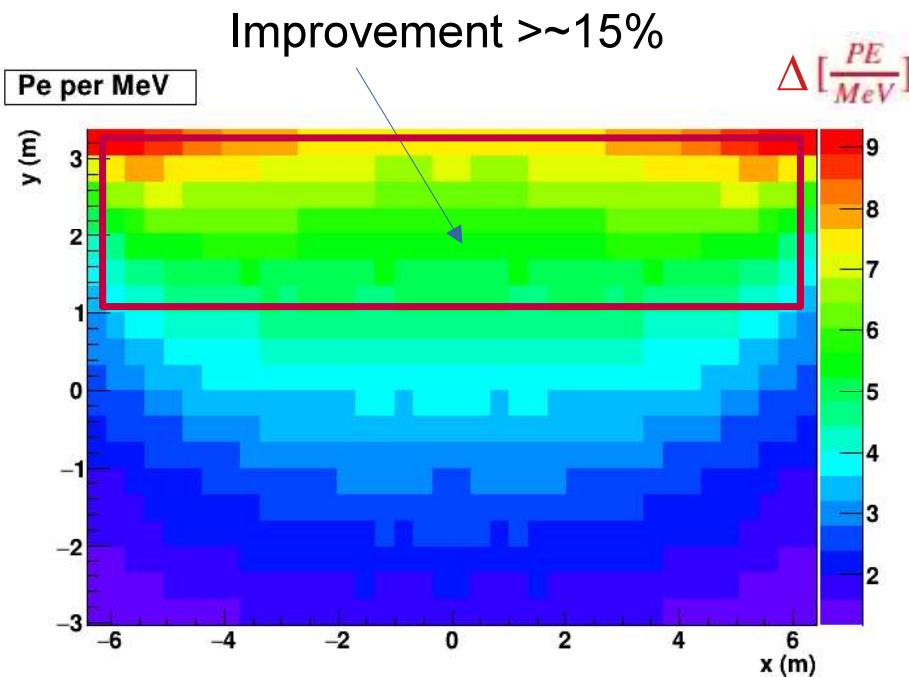


Using Monte Carlo Tools for Designing the PDS

- What are the PDS requirements?
 - How can performance be improved?
 - Number and position of PDs
 - Improvements on individual components physical properties
 - Better reconstruction algorithms
 - ...
 - What is the impact on physics?
 - Supernova LY requirements depend on backgrounds, which might be different with different geometries and doping schemes
- ✓ First: find configurations which meet minimum requirements
 - ✓ Then map out physics benefit of various options
 - ✓ Verify physics conclusions with full simulation and reconstruction

Anode Reflection

- Impact of improving the anode reflectivity from 25% to 50%:
Impact on LY uniformity



Former 4π
design:

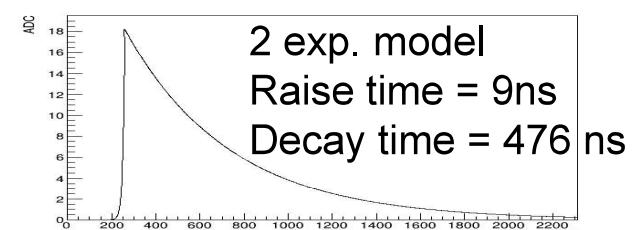
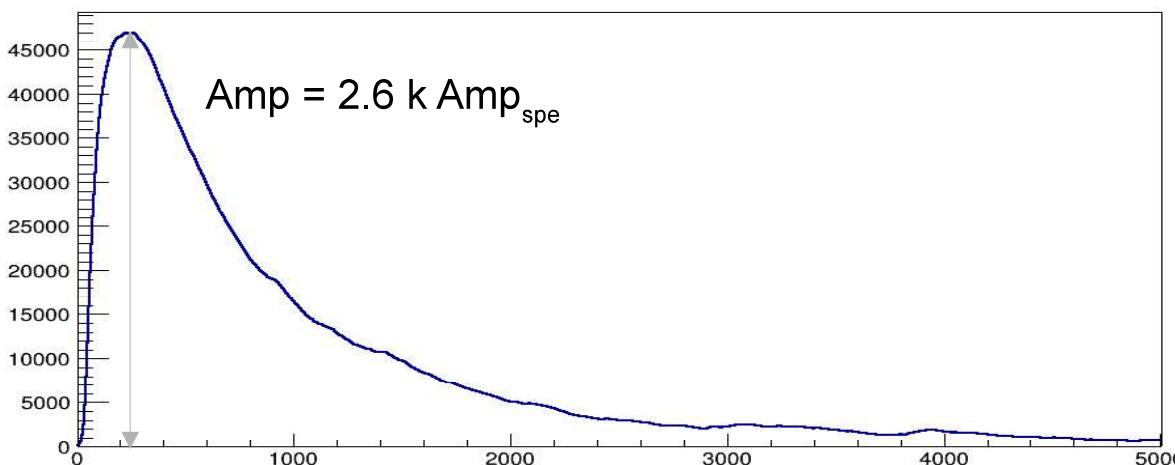
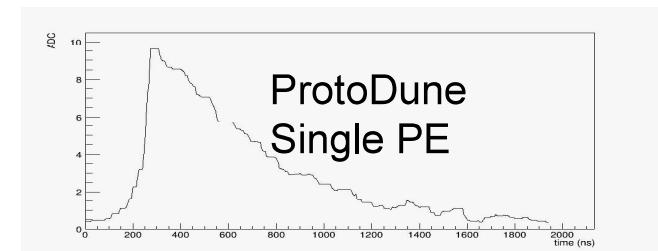
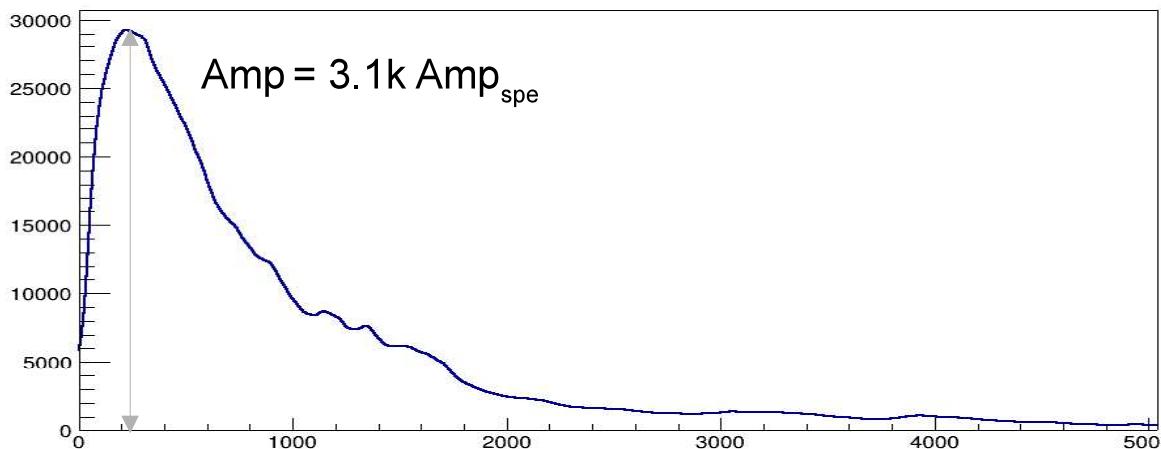
Average LY
up by ~6.6%

Cathode
only:

Average LY
up by ~6%

Preliminary Dynamic Range Studies

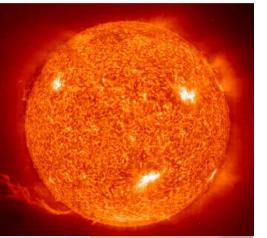
- 6 GeV e- shower @ 0.5m from cathode
- Pure LAr, $\lambda_{\text{absorption}} = 50\text{m}$



Summary

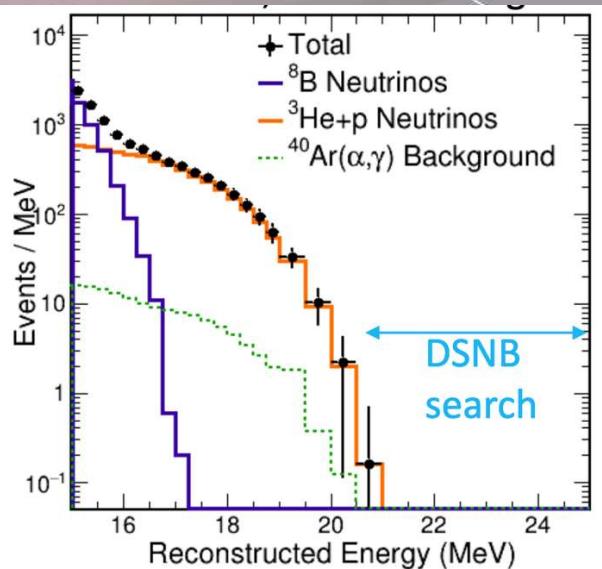
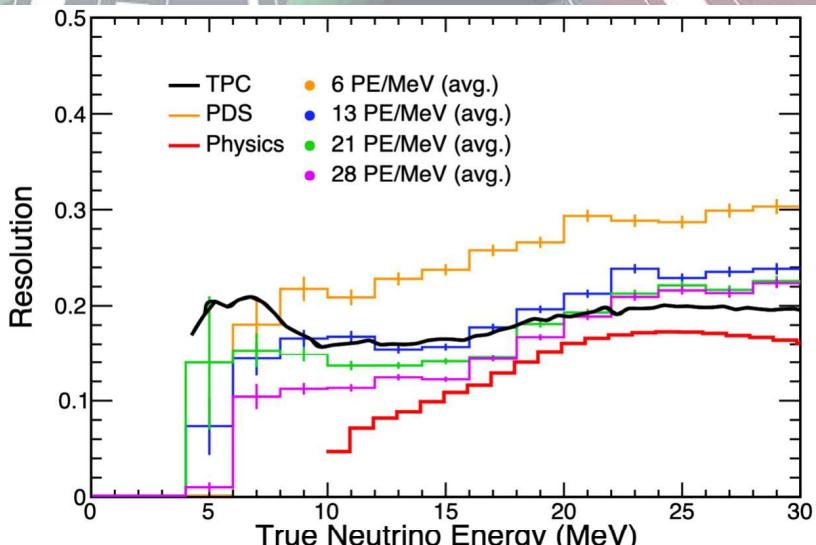
- Preliminary evaluation of Physics capabilities of the VD PDS:
 - Light Yield, energy and position resolutions, trigger efficiency
- Simulation as tools for developing the PDS design
 - Digitizer requirements (dynamic range, sampling freq., bandwidth)
 - Improve PDS performance

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



K. Scholberg, D. Pershey