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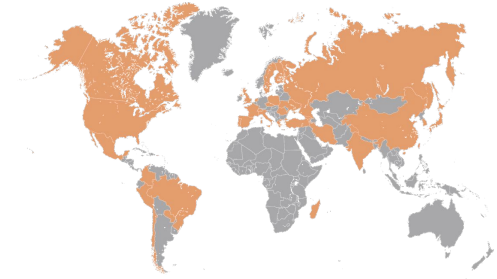
# Validation of DUNE Photon Detection System with ProtoDUNE data

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**Gabriel Botogoske**

# Deep Underground Neutrino Experiment (DUNE)



Next generation international neutrino oscillation experiment

LBNF neutrino beam

Near Detector

Two TPCs + magnetized beam monitor located at Fermilab, with the goal to characterize the neutrino beam

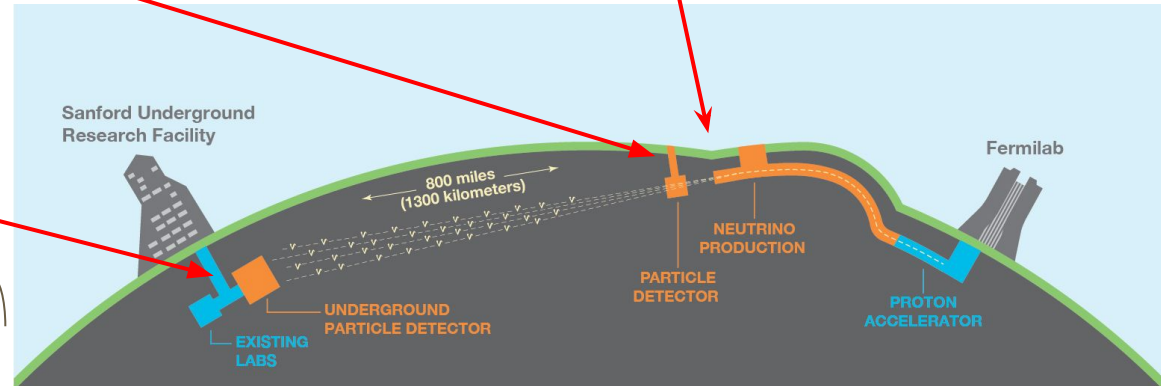
- ND-LAr
- TMS (Phase I)
- SAND

Far Detector

Phase I - FD1 and FD2  
Phase II - FD3 and FD4

Fermilab accelerators produce a 1 MW proton beam. The beam hits a target of graphite producing as a final result muonic neutrinos with an energy ranging from 0.5 to 5 GeV.

Power: 1.2 MW up to 2.1 MW



# DUNE Far Detectors

- 4 LArTPCs of 17 kton and 1.5 km underground
- Phase I :

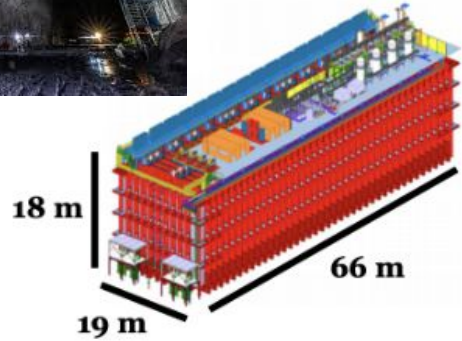
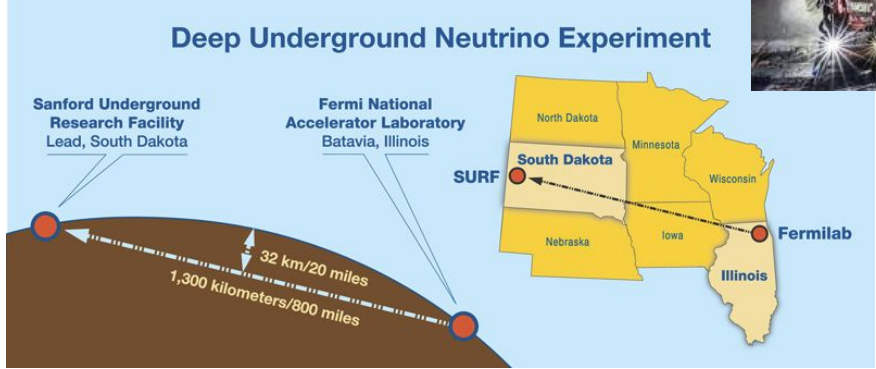
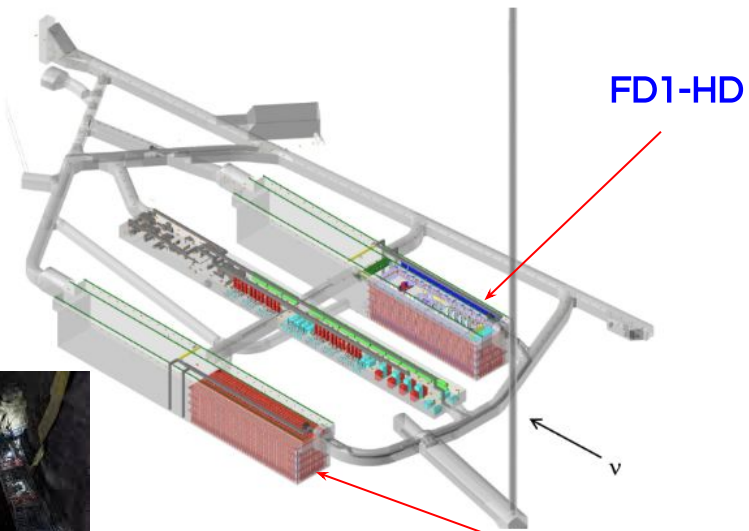
FD1 - Horizontal Drift LArTPC

FD2 - Vertical Drift LArTPC

- Phase II :

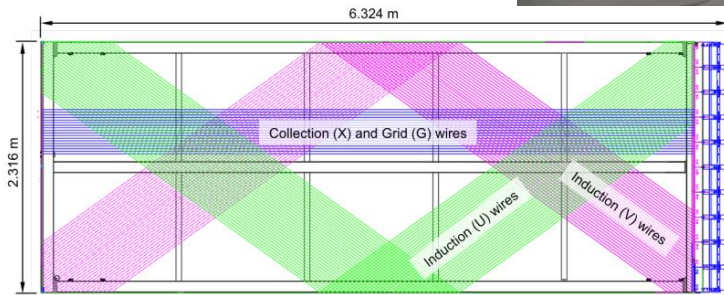
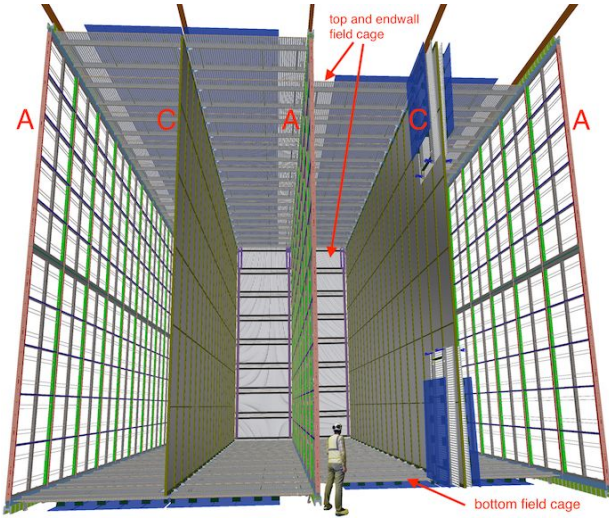
FD3 and FD4:

Vertical drift

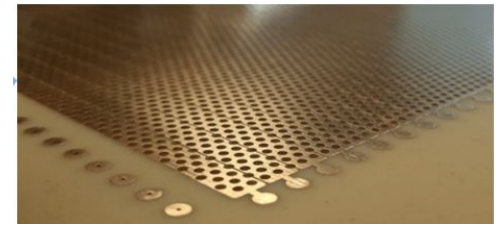
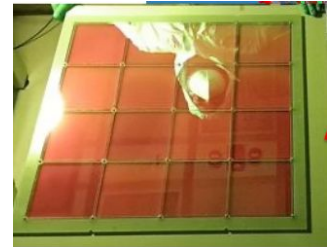
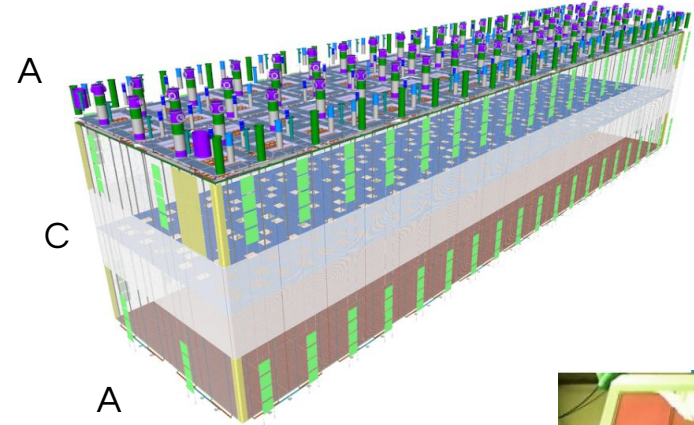


FD2-VD

# FD1-HD



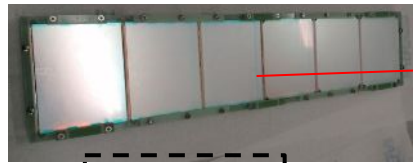
# FD2-VD



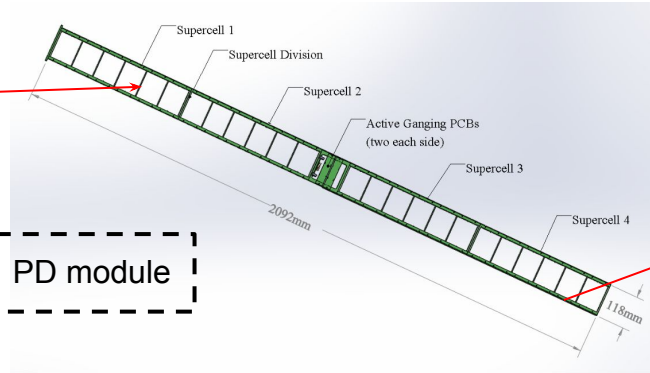
# PDS-HD

- 10 PD modules for APA → 1500 in total
- 1 PD module → 4 super cell X-ARAPUCA (49 cm x 10 cm)
- Inside the APA: not decrease the active volume

500 dual-face (middle anode)  
1000 single-face (edge anodes)



Supercell



PD module



APA

## SUPER CELL:

- EJ-286 WLS Light Bar (487 mm x 93 mm x 3.5 mm)
- 48 SiPMS per SUPERCCELL → 192 per PD module

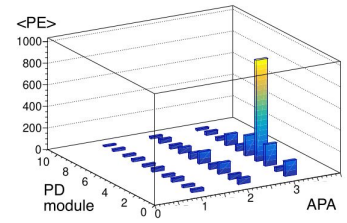
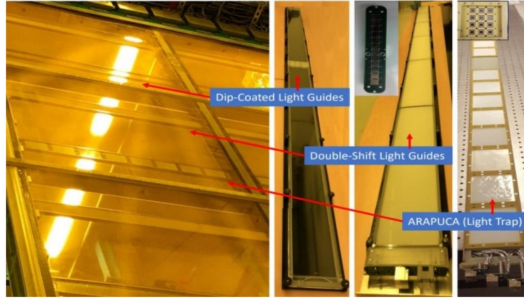
- 6 dichroic windows with a pTP layer



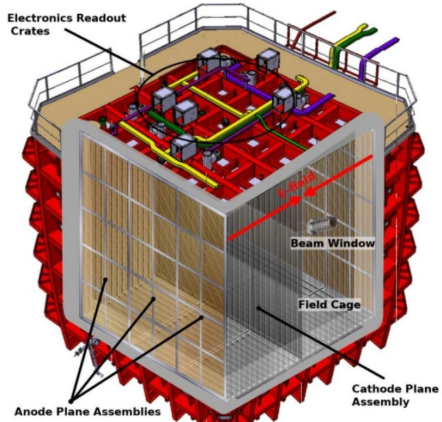
# Proto-DUNE HD @CERN

## Proto-DUNE SP

- 0.42 kton fiducial LAr
- 6 APAs

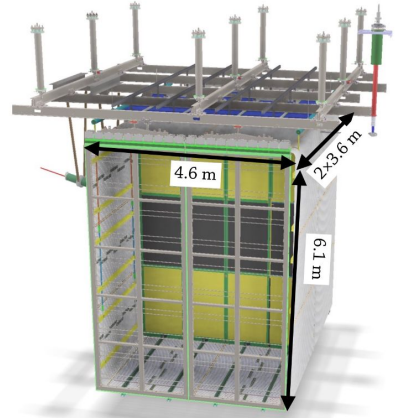


Successful



## Proto-DUNE HD

- 0.28 kton fiducial LAr
- 4 APAs
- Moved to X-ARAPUCA

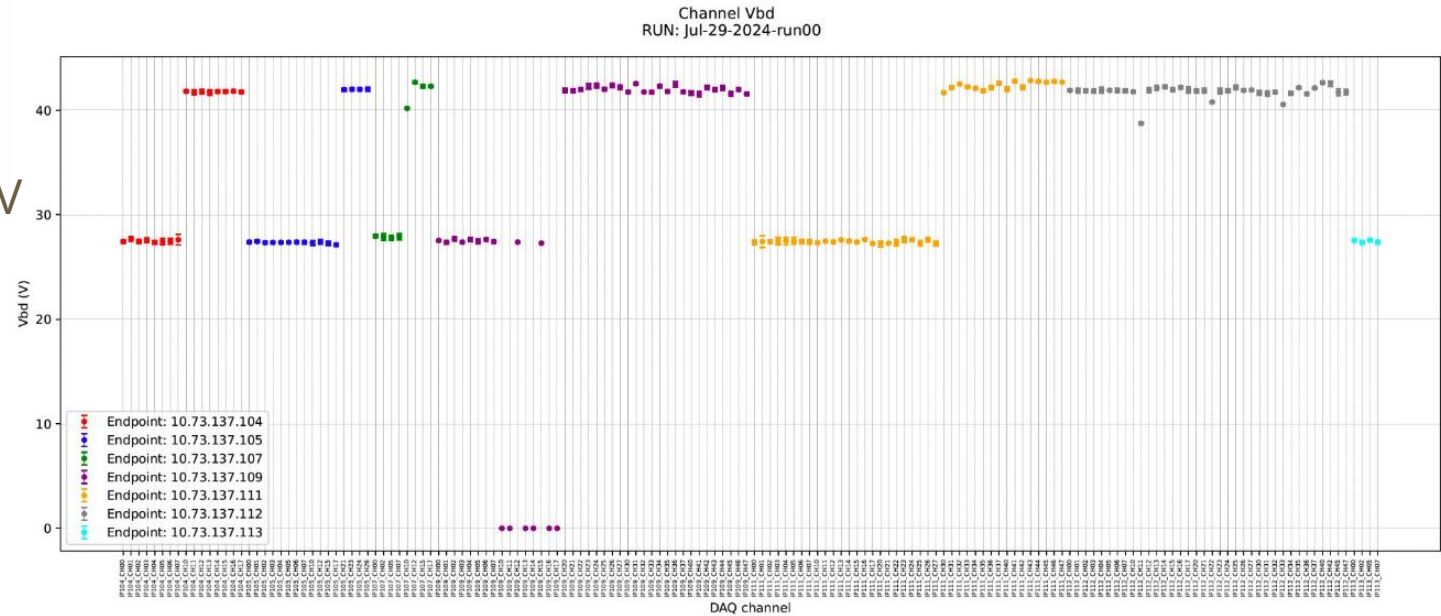
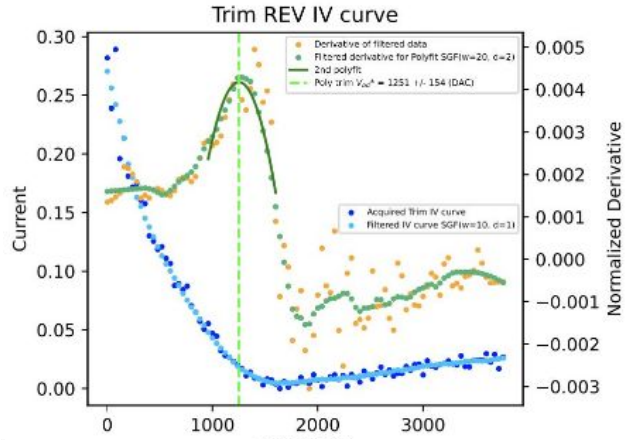


- 2 different WLS and SiPMs (Hamamatsu and FBK)
- APA 1- Full streaming mode
- APA 2-4: Self Trigger mode

# Breakdown Voltage

- Vbr is stable
- Vbr measured weekly
- Ensure same gain between channels

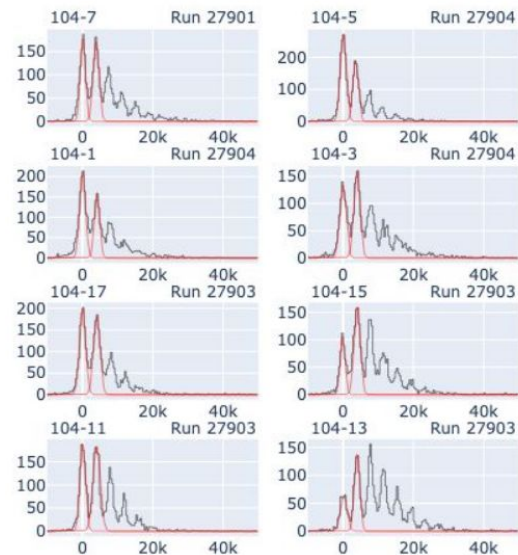
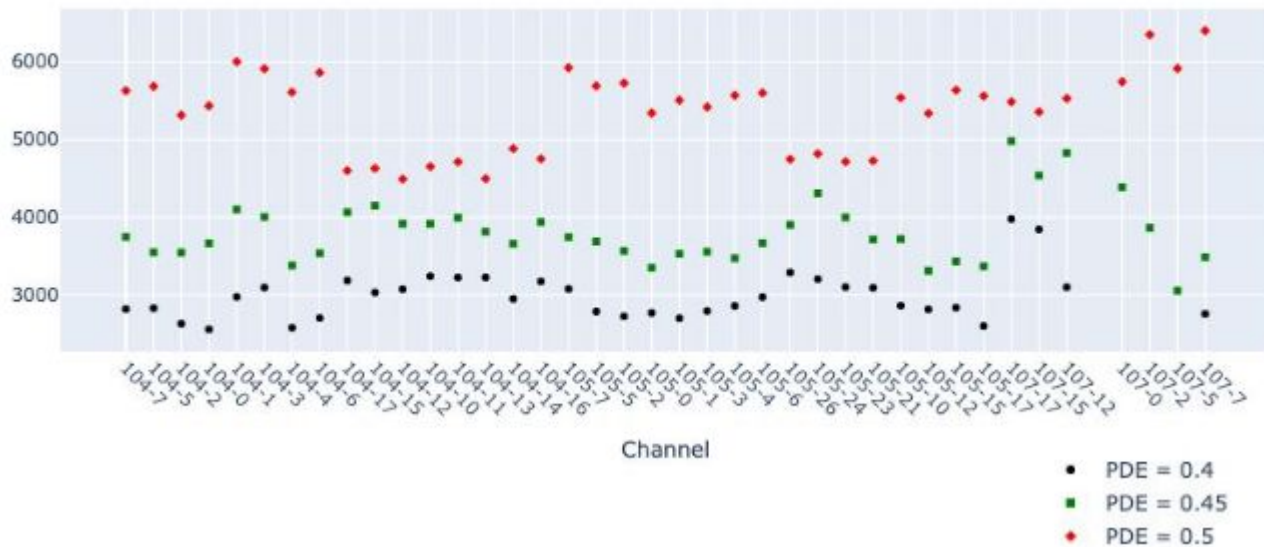
**OV**  
**Hamamatsu: 2.5 V**  
**FBK: 4.5 V**



# Single Photon Electron calibration - Gain

- 270 nm LED with 5 diffusers

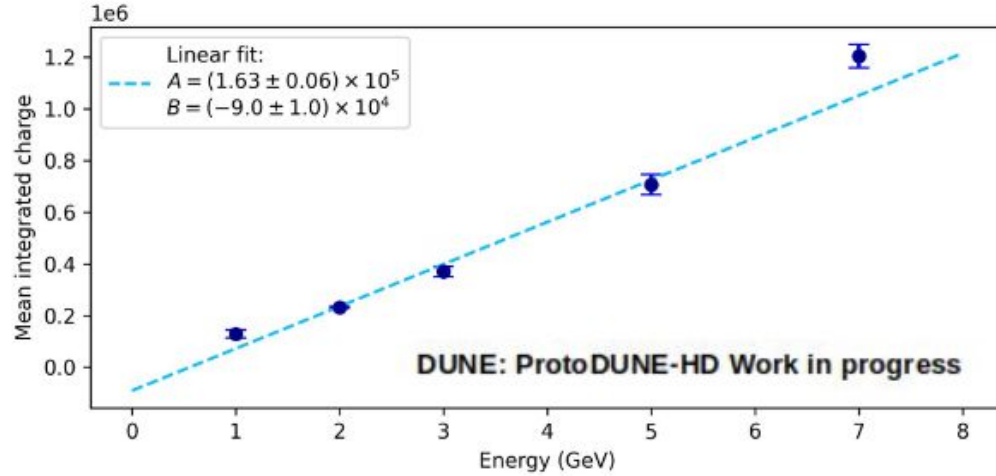
Gain per channel in APA 1



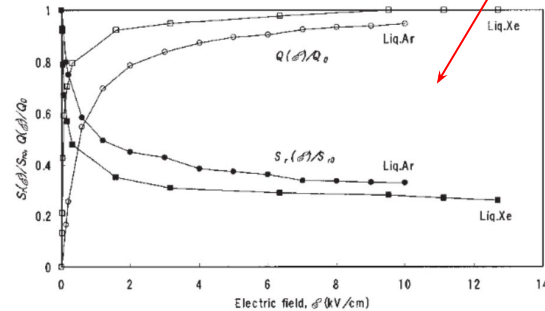
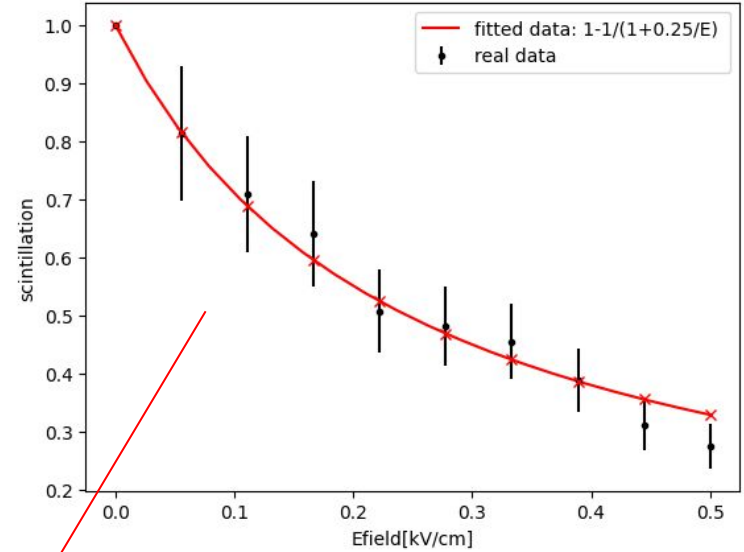


# Light Yield Studies

## Light Yield vs Beam energy



## Light Yield vs Electric Field

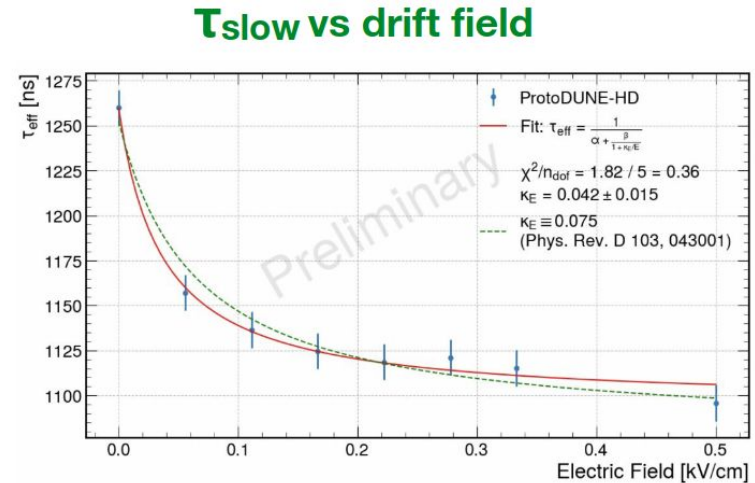
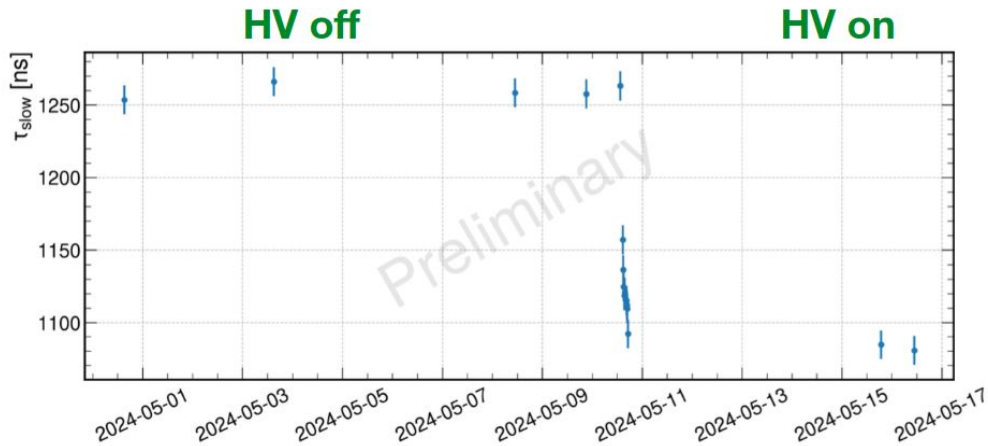
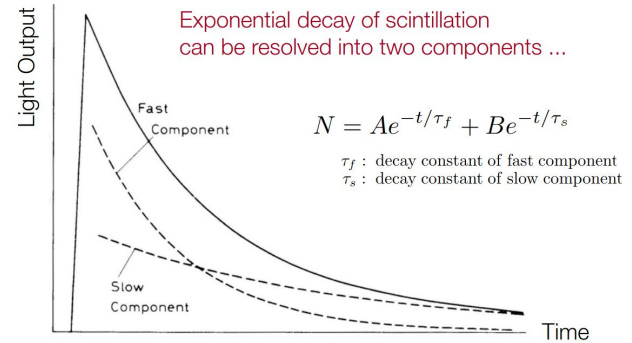


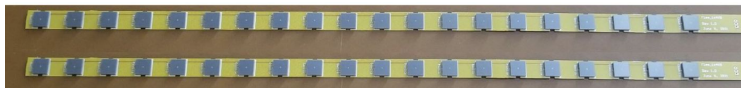
$$Q = \frac{1}{1 + k/E}$$
$$S = 1 - \frac{1}{1 + k/E}$$

Birk's  
Law

# Tau Slow Studies

→ The slow component is important to particle identification and nitrogen contamination





## MEGACELL X-ARAPUCA

- Dimension 65 cm x 65 cm
- One WLS slab (Glass to Power)
- 160 SiPMs (40 at each side)
- SiPM → 6 mm x 6 mm
- 16 dichroic filter per side
- 2 channels → 80 SiPMs/channel

### Cathode:

→ 80 cathode modules ( same size of CRP )

→ Each cathode model has 4 X-Arapuca Megacell double-faced

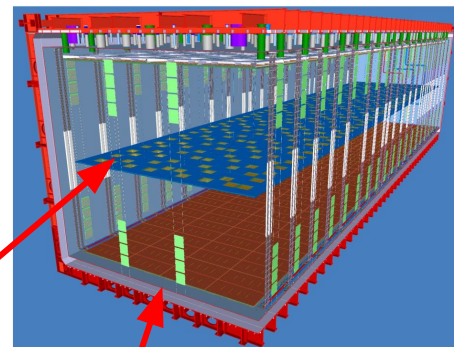
→ total: 320 double faced Megacell

### Walls:

→ Behind the field cage ( 70% transparent) on the four membrane walls

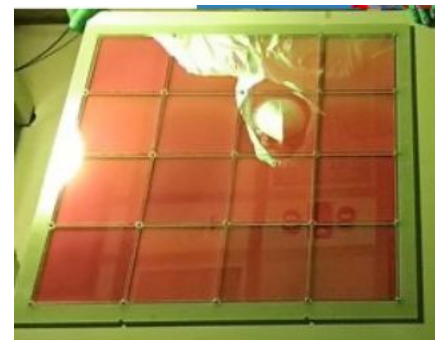
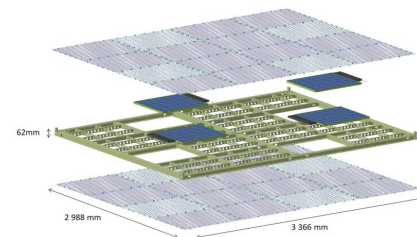
→ 320 at long walls (20 columns) + 32 short walls (4 columns)

= 352 single faced X-ARAPUCAs



Double face module

Single face module





# Proto-DUNE VD

## Proto-DUNE VD

→ 4 CRPs (2 on each anode) → 8 Cathode X-Arapucas  
+8 Membrane X-ARAPUCA

Goals:

- Test of X-ARAPUCA on HV cathode
- 70% field cage
- Test of SoF and PoF
- Xenon Doping

