ProtoDUNE Vertical Drift activities

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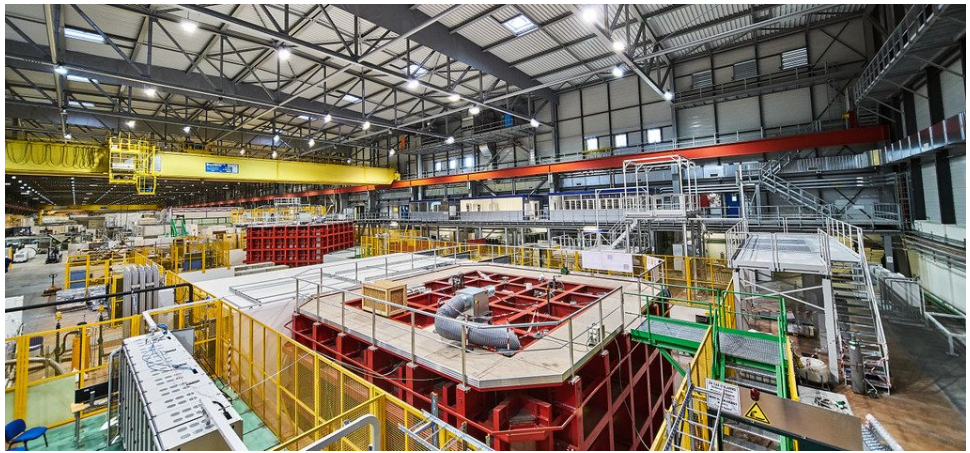
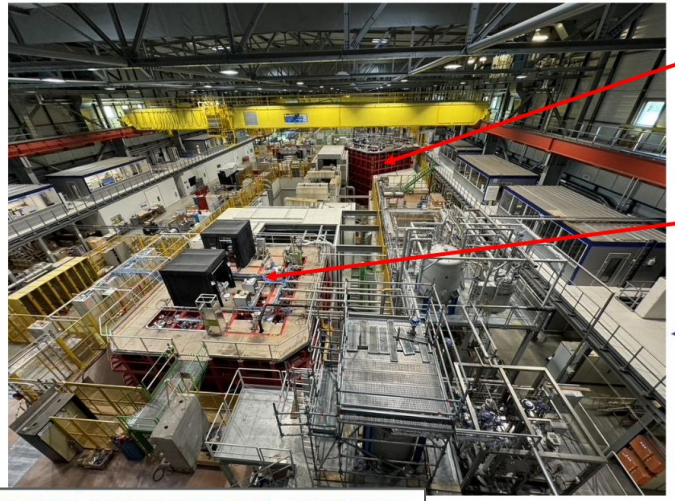


Overview

- Overview of **ProtoDUNE Vertical Drift**
- **The Photon Detection System** of ProtoDUNE-VD
- **Hardware** activities at CERN
- **Software** activities for the PDS of ProtoDUNE
- **Summer data taking** with ProtoDUNE-VD:
  - Definition of the optimal PDS configuration
  - 3 beam periods
- **Ongoing** activities
- **Future** plans

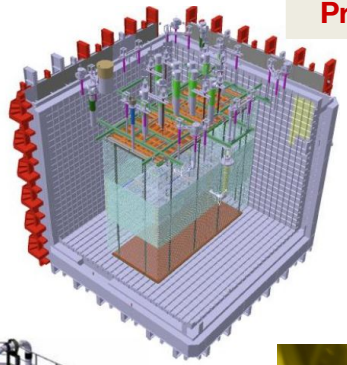
ProtoDUNE at CERN



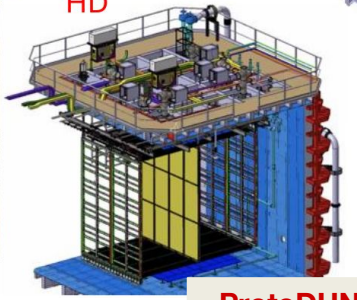
CERN NEUTRINO PLATFORM
@ EHN1

NP02
VD

NP04
HD

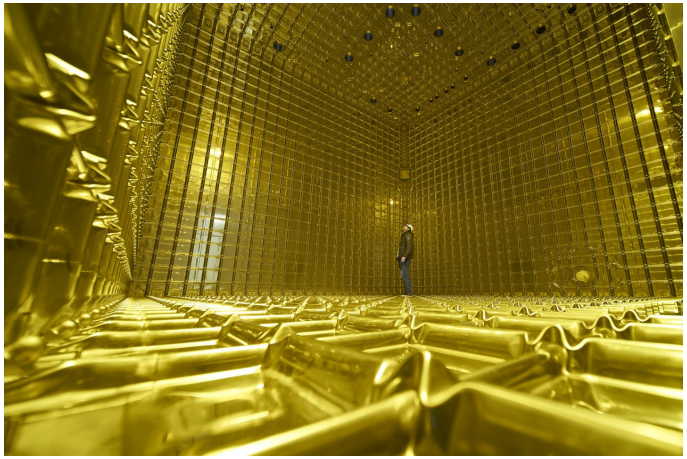


ProtoDUNE-VD



ProtoDUNE-HD

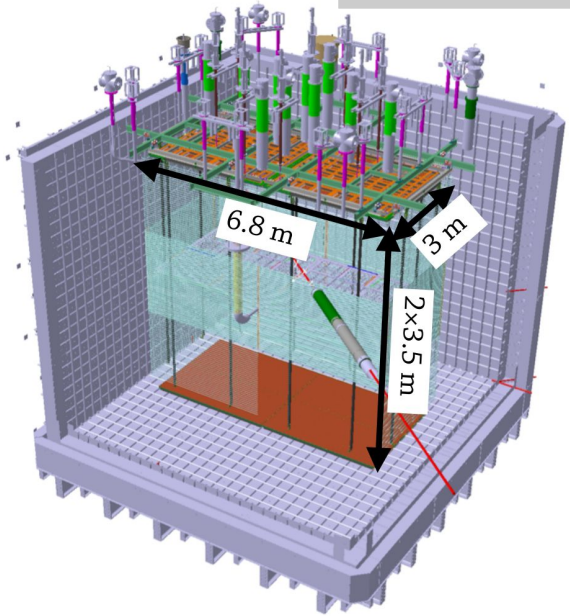
Talk from Gabriel Botogoske on ProtoDUNE-HD

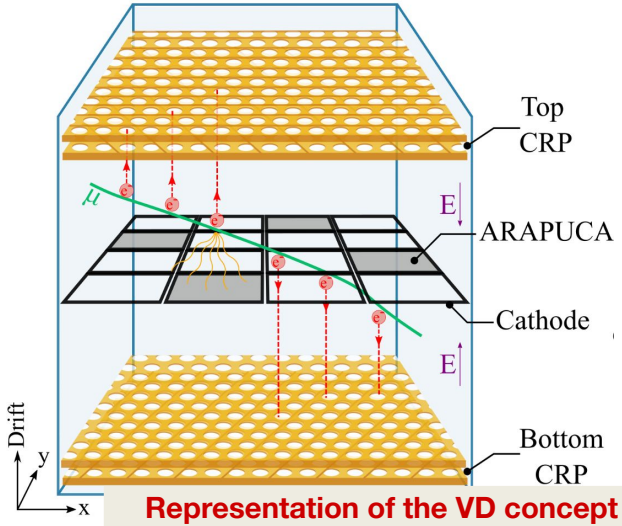


- 2 prototypes (~ 8 x 8 x 8 m3)
- 760 ton of LAr
- Time Projection Chamber (TPC)
- Photon Detector System (PDS)
- Cosmic-Ray Tagger

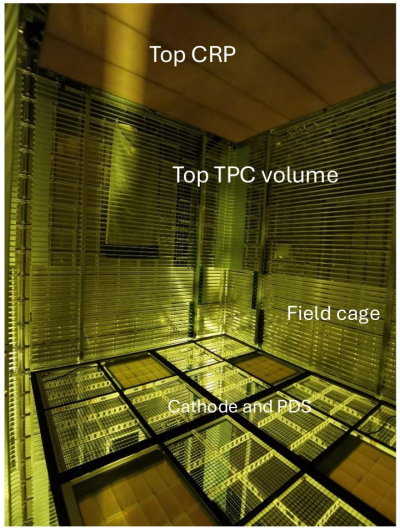
ProtoDUNE Vertical Drift

Second prototype but first module to be installed in South Dakota



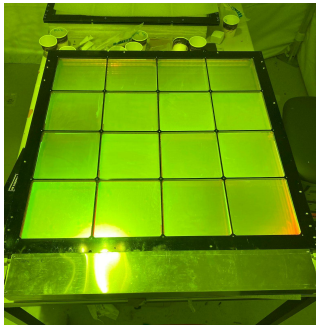


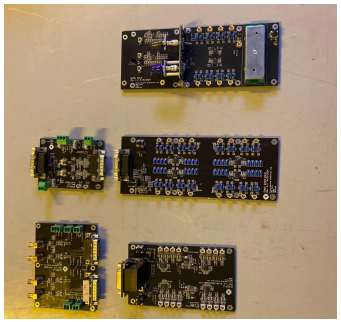
Representation of the VD concept not reproducing the real detector



- **2 vertical drift volumes** of 3.5 m each
- TPC made of 4 **Charge Readout Planes** (CRPs) - 2 top and 2 bottom: perforated PCB technology
- Horizontal cathode in the middle
- **Photon Detection System** (PDS) on the cathode and on the walls

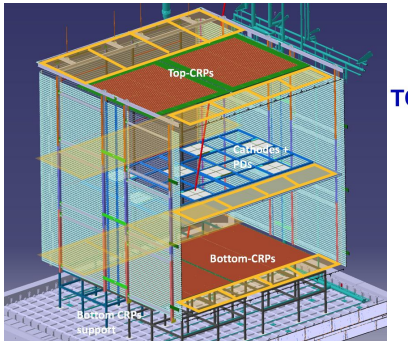
The PDS of ProtoDUNE-VD
X-Arapuca Megacell

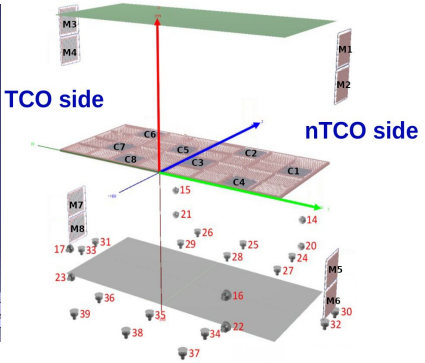




Pictures from VD-coldbox

- **Megacell X-ARAPUCA** (65 cm x 65 cm)
- 160 SiPMs (40 per side)
- Two channels: 80 SiPMs per channel
- 2 different SiPMs: Hamamatsu and FBK





ProtoDUNE-VD

- 16 Megacell X-ARAPUCAs
- 8 on the cathode
- 8 behind the field cage
- 160 SiPMs (40 per side)
- 20 PMTs installed outside the active volume

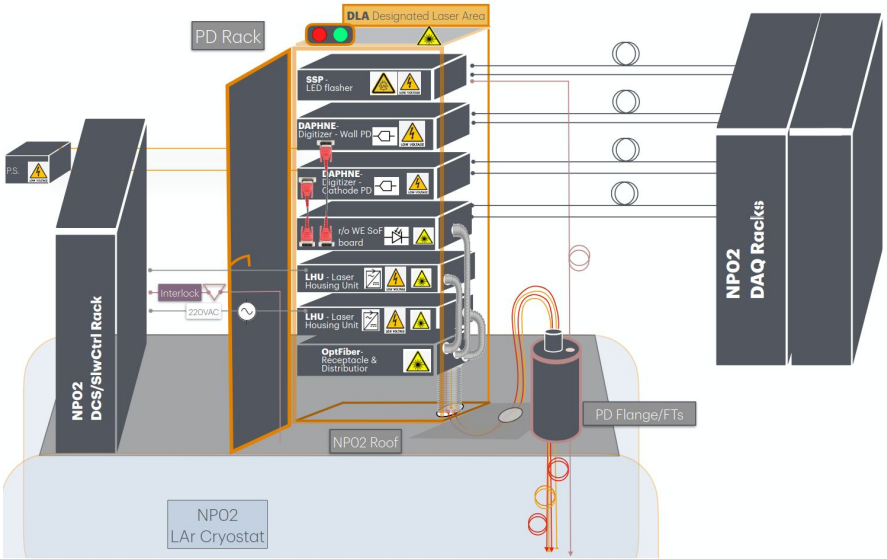
Far Detector 1 (FD1)

- 320 double-face X-ARAPUCAs on the Cathode
- 352 single-face X-ARAPUCAs on the walls

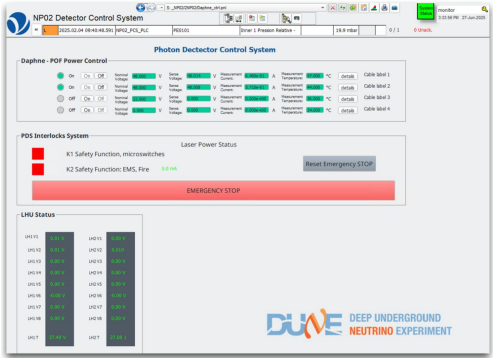
Hardware activities at CERN on ProtoDUNE-VD

- **Safety pause** do to an accident at the neutrino platform in January
- **Restart of lab activities** approved at the end of May
- Additional **CERN safety courses and safety inspections**

- Interlock
- Fiber crate
- Laser Housing Units
- Warm electronics / SoF box
- Calibration module
- 2 DAPHNE boards (digitizer)

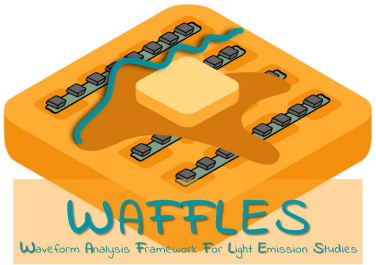


Remote detector control



Software activities at CERN

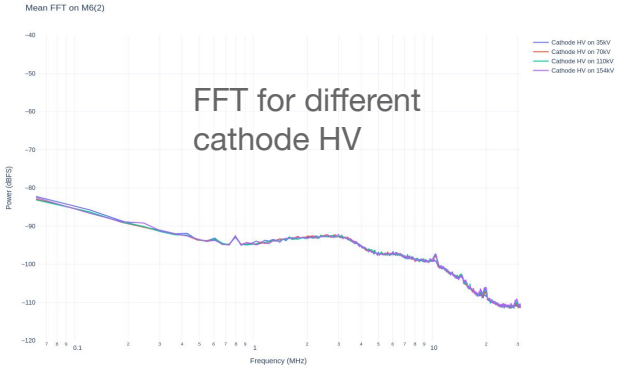
- **PDS-runner**: https://github.com/DUNE/PDS
  - Several tools developed for the PDS **data taking**
- **WAFFLES** (Waveform Analysis Framework for Light Emission Studies): https://github.com/DUNE/waffles
  - Initially developed for ProtoDUNE-HD, adapted for ProtoDUNE-VD and possibility to be used in the Far Detector
  - Framework to **process the data** taken with ProtoDUNE and perform several **analyses** related to the PDS
  - It includes beam trigger information, useful to perform PID

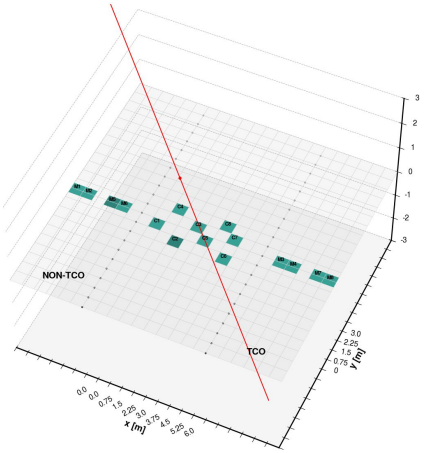


Data taking

- Several **PDS runs** taken (spreadsheet: [NP02 data taking]( ))
- Data available on lxplus at:
  - */eos/experiment/neutplatform/protodune/experiments/ProtoDUNE-VD/commissioning/*
- **Calibration** (LED intensity and mask scan, attenuators scan, trim (SiPM bias) scan, baseline set, SNR for all channels)
- **Noise studies**
- **Beam** data taking
- **Fast look** at beam data for monitoring purposes

More details in next talk from Henrique Souza





Beam tests

More details in next talk from Henrique Souza

Three beam periods:

1. **July 9th to 16th** - dedicated to beam and beam instrumentation commissioning
   a. **Beam Trigger-DAQ** development/synchronization - with **PDS**
   b. Confirmed that PDS could see the beam (data used for developing fast analysis)
   c. **PDS commissioning**
2. **July 30th to August 13th** - **PDS data taking and commissioning**
   a. First optimized PDS configuration
   b. The PDS was used to advance the beam trigger
3. **August 20th to September 10th**
   a. Definition of **PDS final configuration**
   b. PDS only runs until end of August
   c. Data taking with **TPC and PDS** from end of August to end of beam

After the beam - ongoing activities

- Data taken during the **cathode HV ramp down and ramp up**:
  - Steps of 20 kV ramp down with 10 minutes wait + 5 minutes data collection
  - Steps of 10 kV ramp up with 5 minutes wait + 5 minutes data collection
  - Only PDS because of short data taking time
  - Plan for another similar data taking with PDS+TPC, larger steps, longer acquisition time
- **Periodic calibration membranes and cathode** - once or twice per week if detector available
- **PMT calibration** - work in progress
- Analysis of **beam data with PDS+TPC** - work in progress
- Several **analyses** (SPE integral, signal shape, saturation, …) - work in progress

Future plans: a full agenda

- **Periodic calibration membranes and cathode** to monitor detector stability
- **CRT installation** - to be done soon
- Combined **PDS-TPC data taking with CRT** trigger
- **Low-energy calibration**: high SPE amplitude to increase sensitivity to low energy events
- **Calibration system validation** for the FD design: how many PDS modules can we calibrate with one LED?
- **Xenon doping** - December
- Test with **Pulse Neutron Source** - January/February
- Additional **data analysis** to study detector performance (time resolution, trigger studies, beam data …)
- Continue operations until **March 2025**

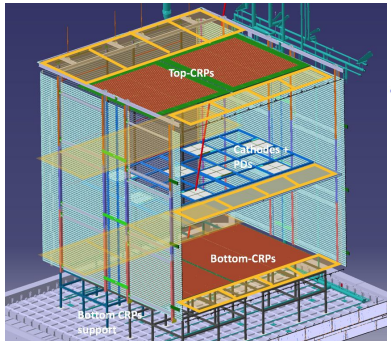
Conclusions

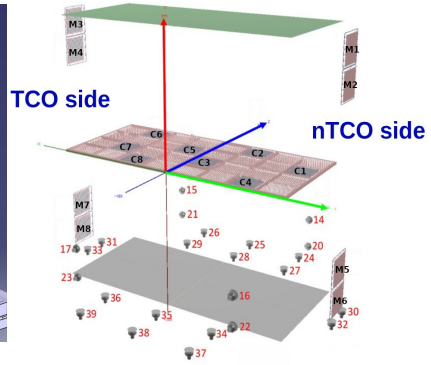
- The ProtoDUNE-VD operations successfully restarted after the safety pause
- Hardware implementations and software developments
- Huge effort for **PDS calibration**:
  - Definition of optimized configuration for the beam data taking
  - More than 800 runs processed
- PDS **successful data taking over three beam periods**
  - Several PDS-only data collected
  - Full detector (PDS + TPC) integration from the end of August
- First results from preliminary analyses
- More data taking ongoing and to be done in the next months
- Plenty of data to analyze

Thanks to Flavio, Manuel, Valeria, Esteban, Biswaranjan, Jaime, Halit, Gloria, Vlada, Alex, Jacob, Vojtech, Wei, Laura I., Gemma, Sabrina, Nilay, Francesco T., Anselmo, Andrea, Marco R. and the DAQ and NP02 team

BACKUP

The PDS of protoDUNE-VD





protoDUNE-VD

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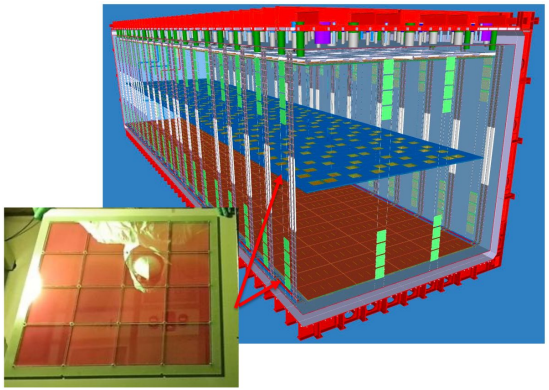


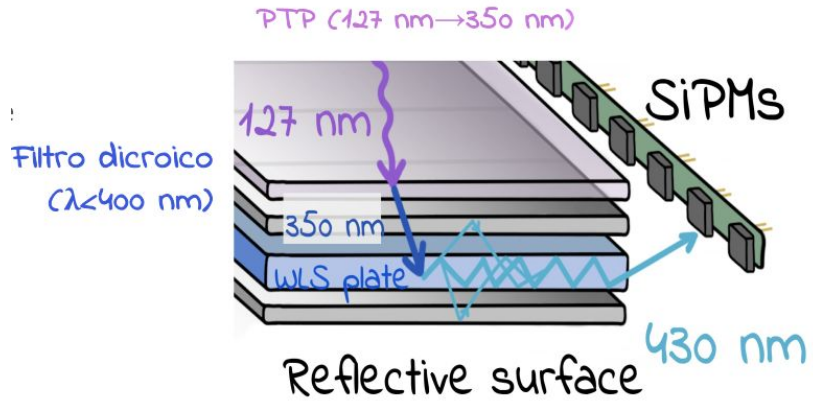
Preparing for the Far Detector

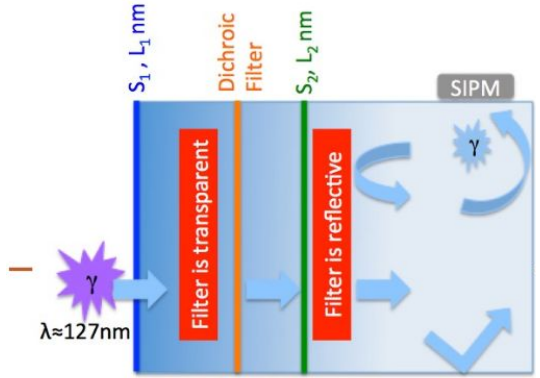
Far Detector 1 (FD1)

- Cathode (300 kV)
  - 80 cathode modules
  - 4 X-ARAPUCA Megacell double-faced per cathode module
  - 320 double-face X-ARAPUCAs in total
- Walls
  - Behind the transparent (70%) field cage
  - 320 at long walls
  - 32 short walls
  - 352 single-face X-ARAPUCAs

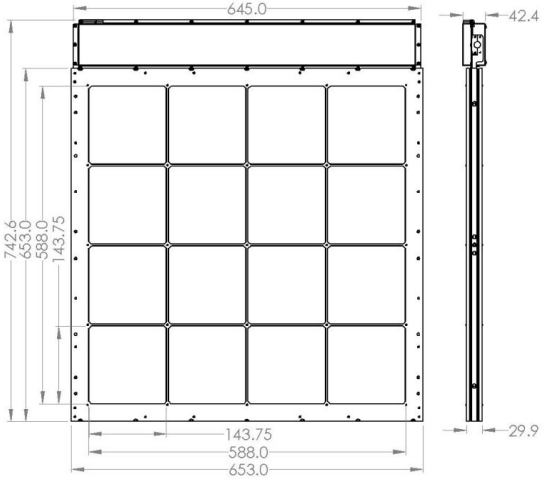
The Photon Detection System (PDS)
X-Arapuca

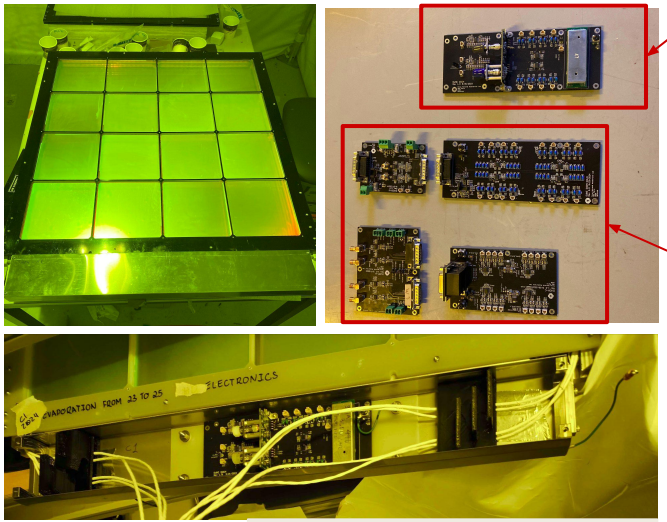
- **PTP (P-terphenyl layer)**
  Converts the LAr scintillation light
  λ=128 nm → λ=350 nm
- **Dichroic filter**
  Transparent to light with λ < 400 nm
  → the PTP converted light can enter
  Reflective for λ > 400 nm
- **Wavelength shifter bar (WLS bar)**
  Converts the incoming light to λ = 430 nm
  → the light is trapped
- **Silicon PhotoMultipliers (SiPM)**
  Light detection





The PDS of protoDUNE-VD
X-Arapuca Megacell





Pictures from VD-coldbox

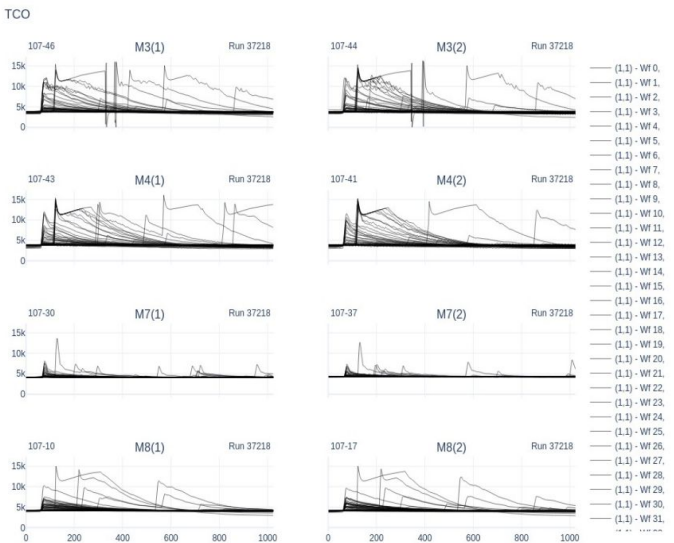
Power over Fiber (PoF) and **Signal over Fiber (SoF)** technology for cathode modules

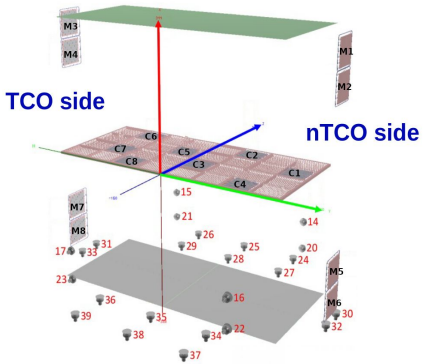
HD-style and VD-style electronics for wall modules

- **Megacell X-ARAPUCA** (65 cm x 65 cm)
- 160 SiPMs (40 per side)
- Two channels: 80 SiPMs per channel

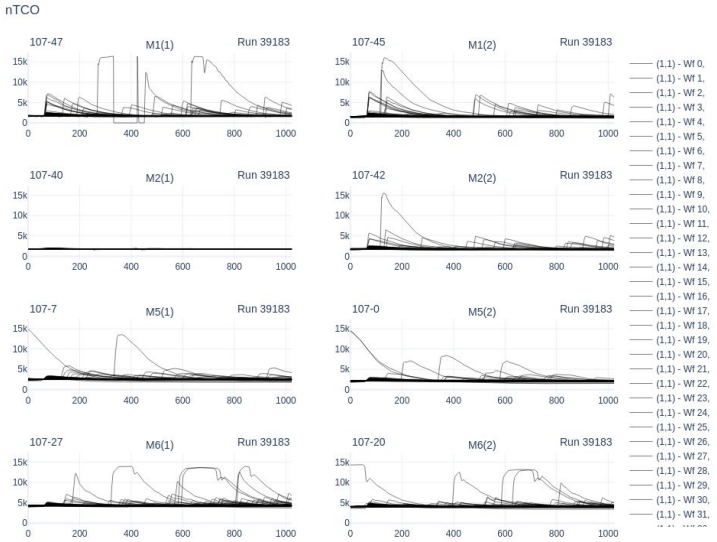
Signals from the wall PDS modules

Membranes (wall modules) TCO side



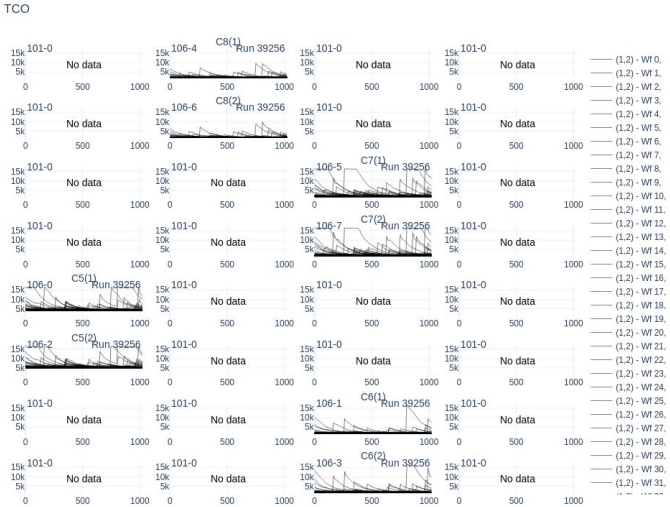


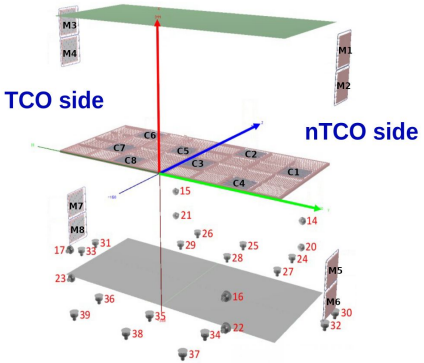
nTCO side



Signals from the cathode PDS modules

Cathode TCO side





nTCO side