# MidTermReview

Leonardo Favilla

DEEP UNDERGROUND NEUTRINO EXPERIMENT


# Neutrino oscillations

The primary objective of DUNE is to study lon-baseline neutrino oscillations

## Origin of Matter

Could neutrinos be the reason that the universe is made of matter rather than antimatter? By exploring the phenomenon of neutrino oscillations, DUNE seeks to revolutionize our understanding of neutrinos and their role in the universe.

## Unification of Forces

With the world's largest cryogenic particle detector located deep underground, DUNE can search for signs of proton decay. This could reveal a relation between the stability of matter and the Grand Unification of forces, moving us closer to realizing Einstein's dream.

## Black Hole Formation

DUNE's observation of thousands of neutrinos from a core-collapse supernova in the Milky Way would allow us to peer inside a newly-formed neutron star and potentially witness the birth of a black hole.

A neutrino beam will be generated using the proton accelerator complex at Fermilab. The location in deep underground would allow detection of neutrinos of astrophysical origin (and possibly other rare underground phenomena) in a lower energy range (10-100 MeV) compared to beam neutrinos (1-10 GeV)

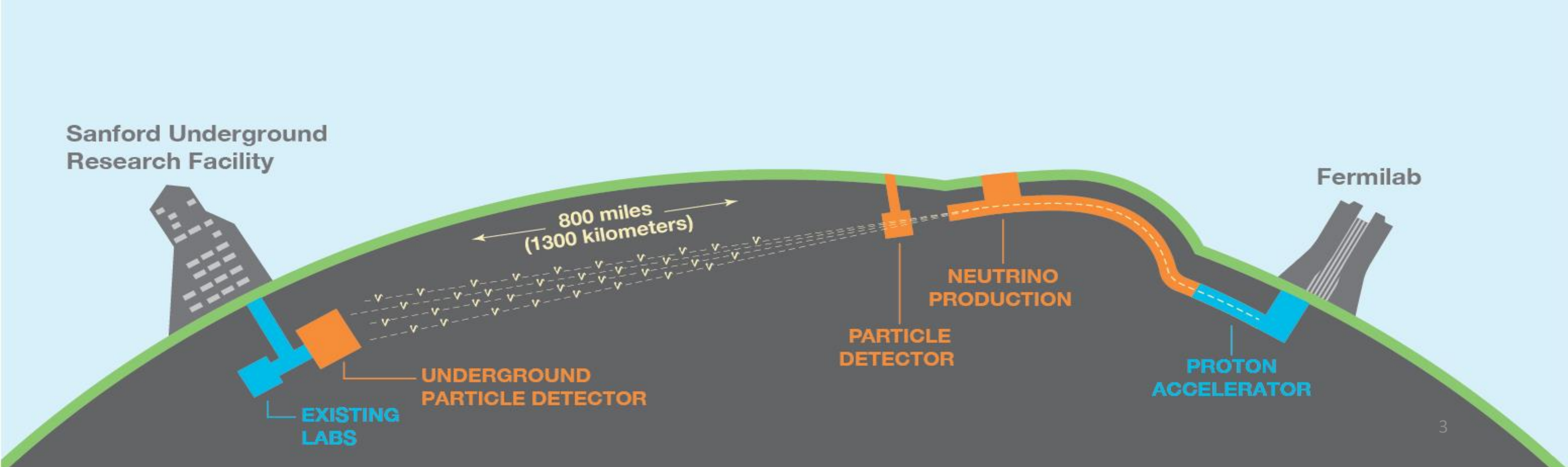
The Near **Detector (ND):** located at Fermilab, characterizes and monitors the beam

The Far **detector (FD)**: the largest and most technologically advanced liquid-argon neutrino detector

An underground cavern is currently under construction, to contain **4 detector modules**. At least two of these will be use **Liquid Argon Time Projection Chambers (LArTPC)**

(FD-1) will be a **Horizontal Drift (HD)** LArTPC

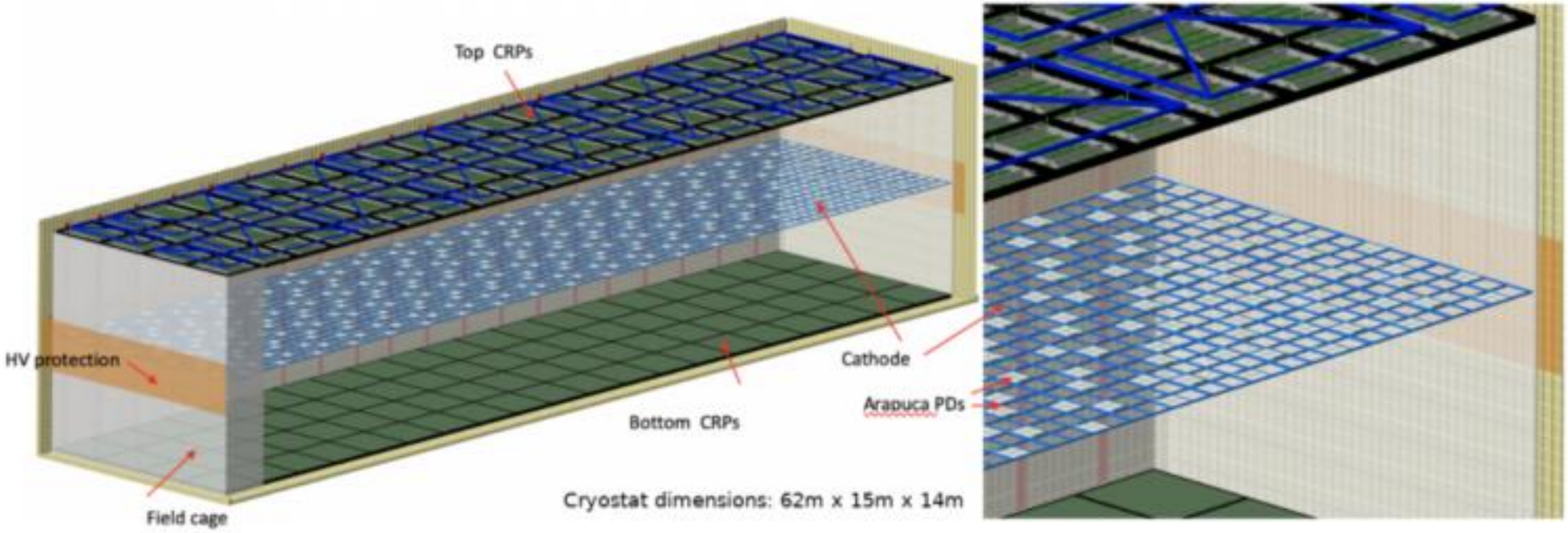
(FD-2) will be a **Vertical Drift (VD)** LArTPC



# VD-LArTPC

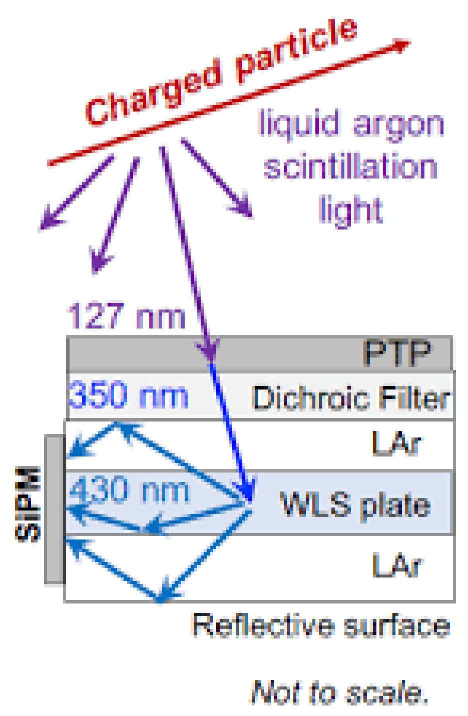
Charge generated by **ionization** is drifted towards a set of grids which allows the reconstruction of particles' trajectories inside the chamber. Argon **scintillation light** is also collected providing **fast timing** information used in event time reconstruction, precise calorimetric energy reconstruction and efficient triggering capability, and to reduce energy threshold and study low-energy neutrino interactions (e.g. SuperNova neutrinos)

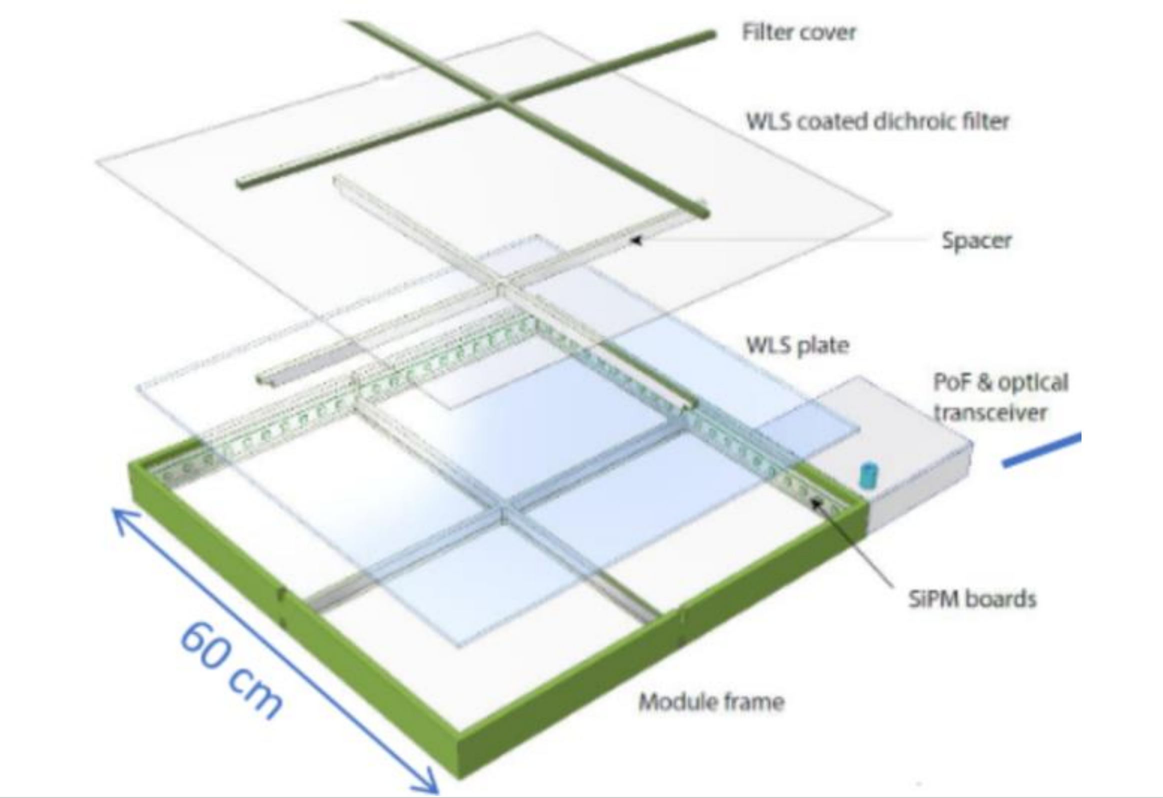
Divided into two volumes by a central horizontal cathode, each volume will have its own anode plane, parallel to the cathode, where electrons will be collected by **Charge Readout Planes**.



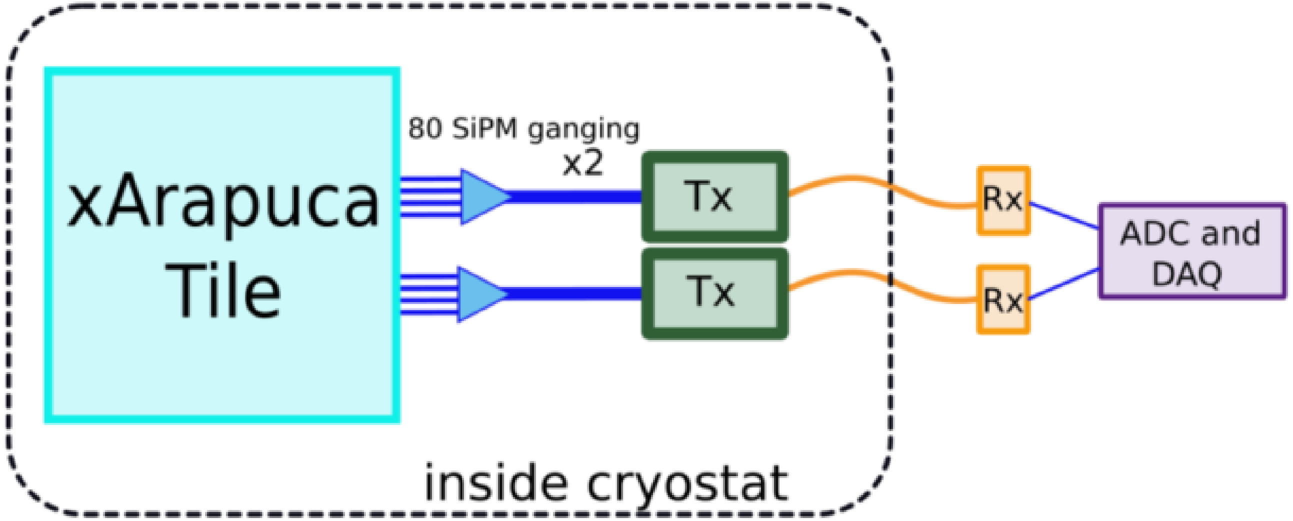
# PDs

- This **Photon Detection System (PDS)** will use large 60 x 60 cm2 **X-Arapucas,** a box with highly reflective internal walls and with a set of wavelength shifters and a dichroic filter designed to trap photons on the inside of the device so they can be detected by silicon photomultipliers (SiPM)



# PoF & SoF




**Analog Optical Transmitter** inside the cryostat to bring the signal produced by PDs to a **Receiver** and **Digitizer**, both placed in warm

**Power** will be supplied **over fiber**. The light of a high-power laser will be transmitted using multi-mode fibers to a photovoltaic power converter placed inside the cryostat and close to the photo-sensors.

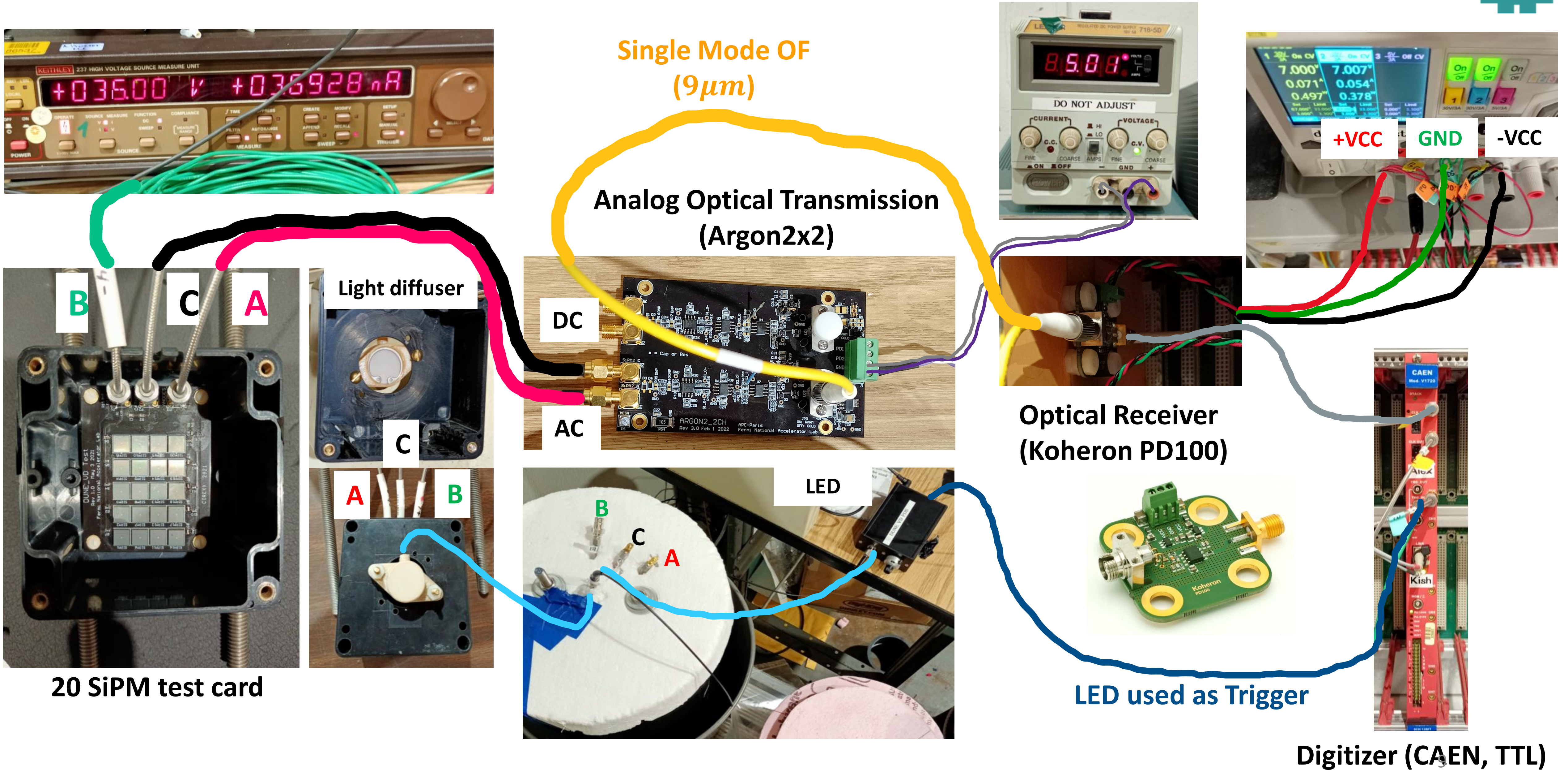
Fermilab is leading the development of the **Power Delivery Over Fiber** (**PoF**) and front-end electronics for **Analog** and **Digital Optical Signal Transmission** (**SoF**).
Dedicated R&D and test facility is in operation at the FNAL Proton Assembly Building (PAB)

# Main Aim

Characterization of silicon photomultipliers (SiPMs) and their aggregated read-out, optimization of the analog optical readout electronics, SoF and PoF

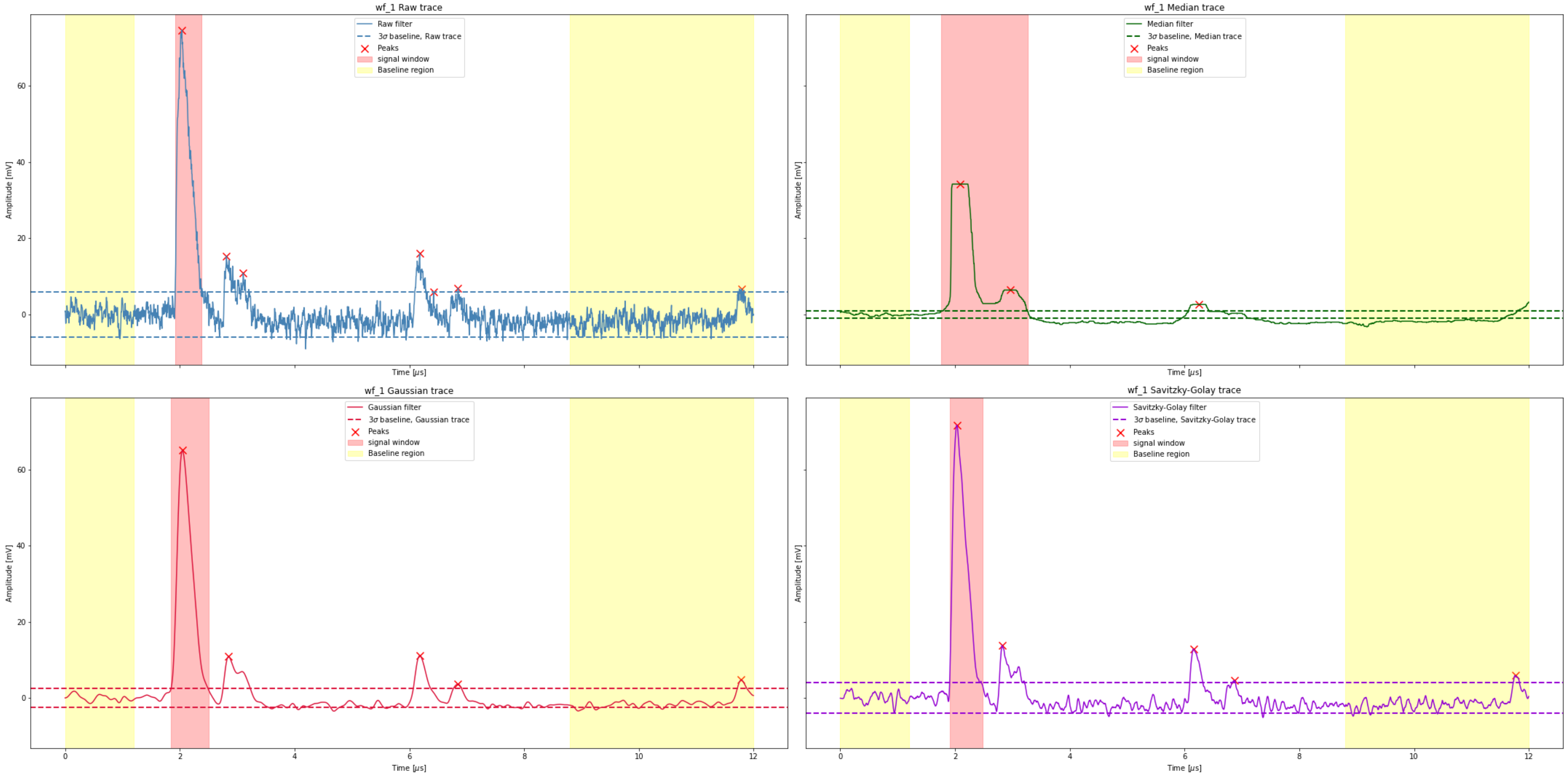
# Experimental Setup

# Test schematic



# Example of waveform (mean bsl subtracted)

The signals in this test were by LED flashes (with the SiPM board in liquid Argon bath)




3 high frequency digital filters:

- **Median**
- **Gaussian**
- **Savitzky-Golay**

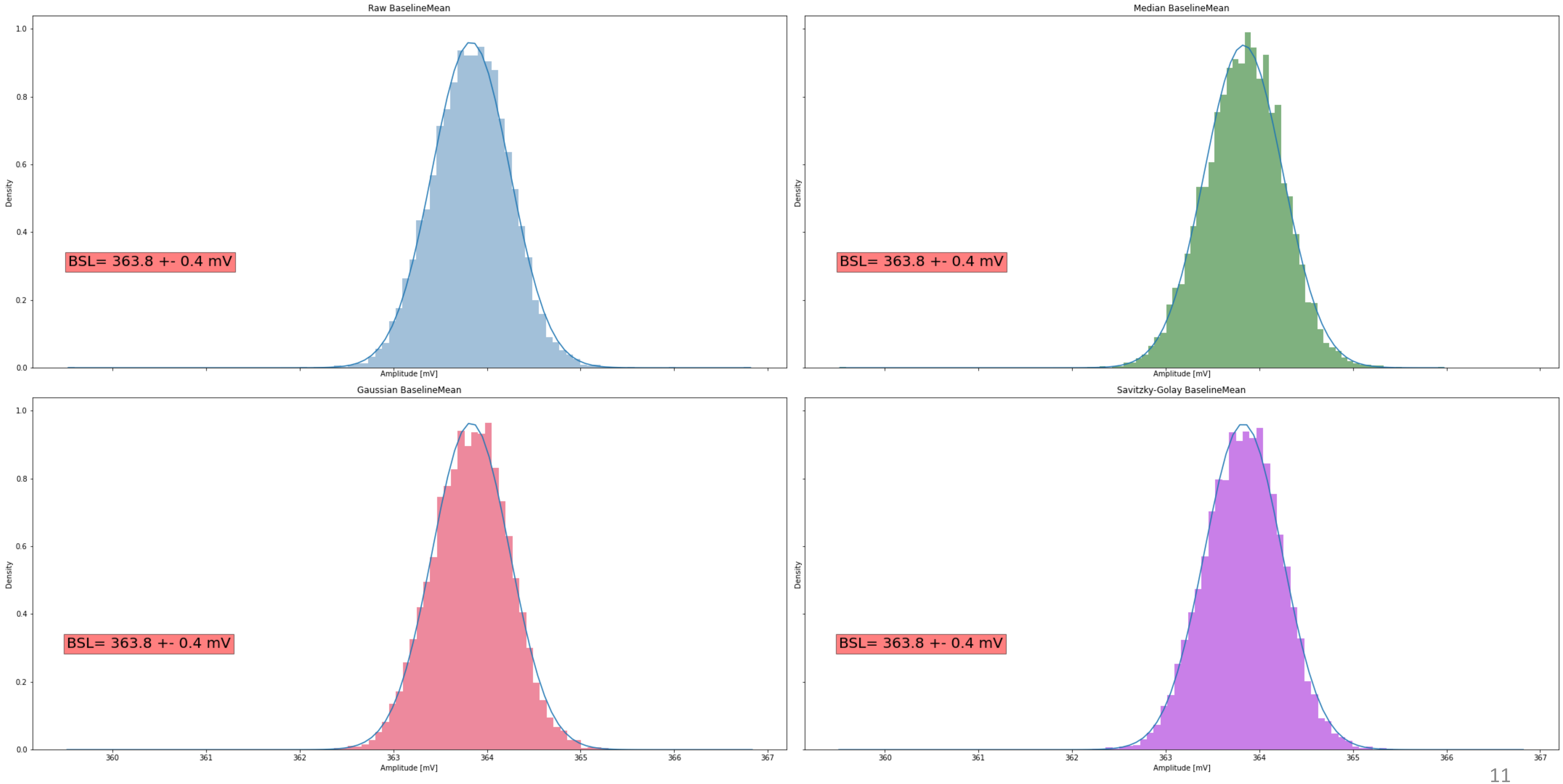
Algorithm to find peaks (calibration with high intensity laser, sensitive to single p.e.)

thr = 2.5*sigma_bsl

Already scaled down by baseline value (mean in first 300 samples)

# Mean Baseline distribution

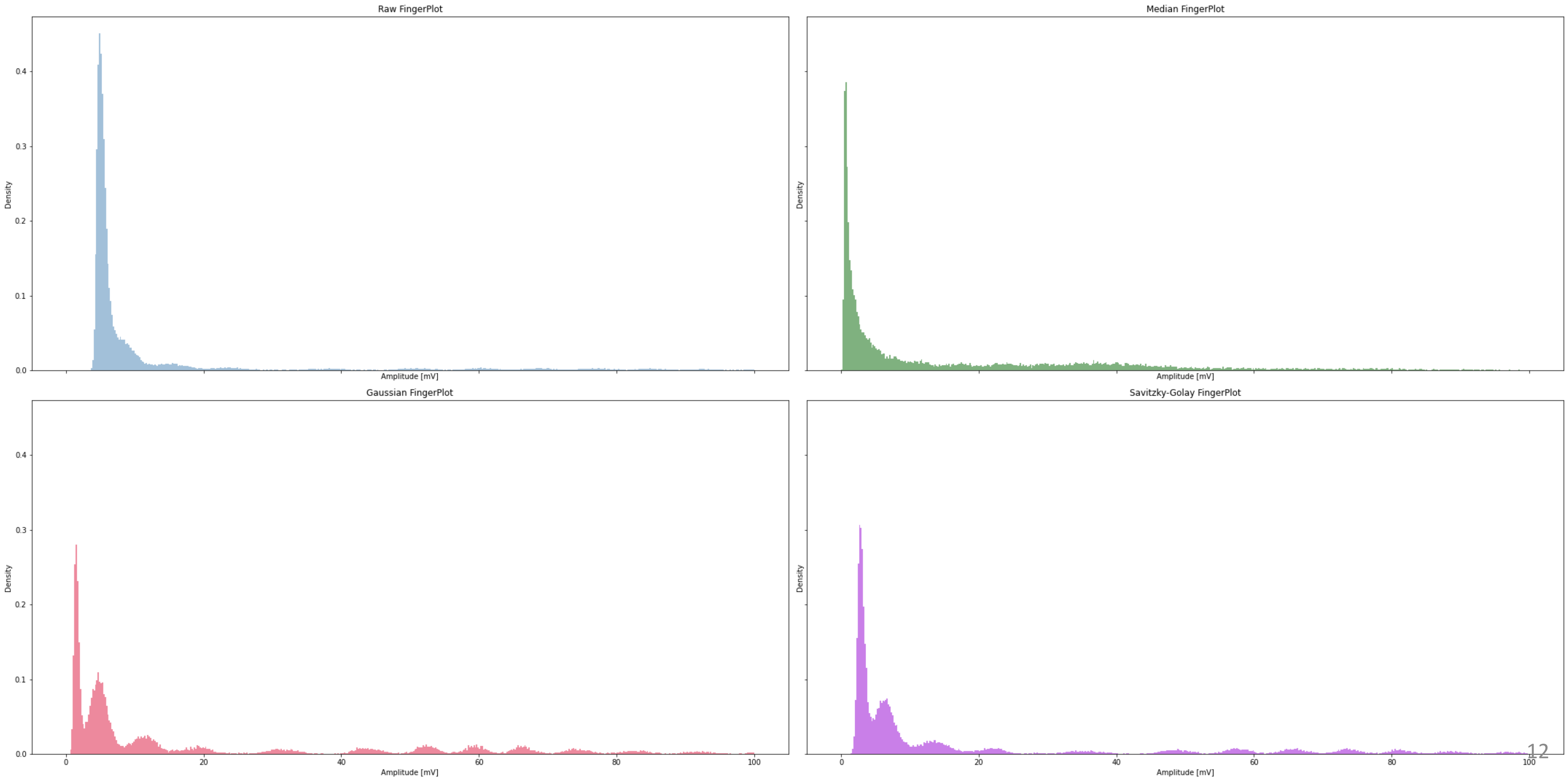
10k events



# Finger Plot (peaks heights)

10k events,
0-100mV

For each event (waveform) we consider the heights of all peaks found, and make an histogram across all the events, obtaining the so called «**Finger Plot**»



# Summary

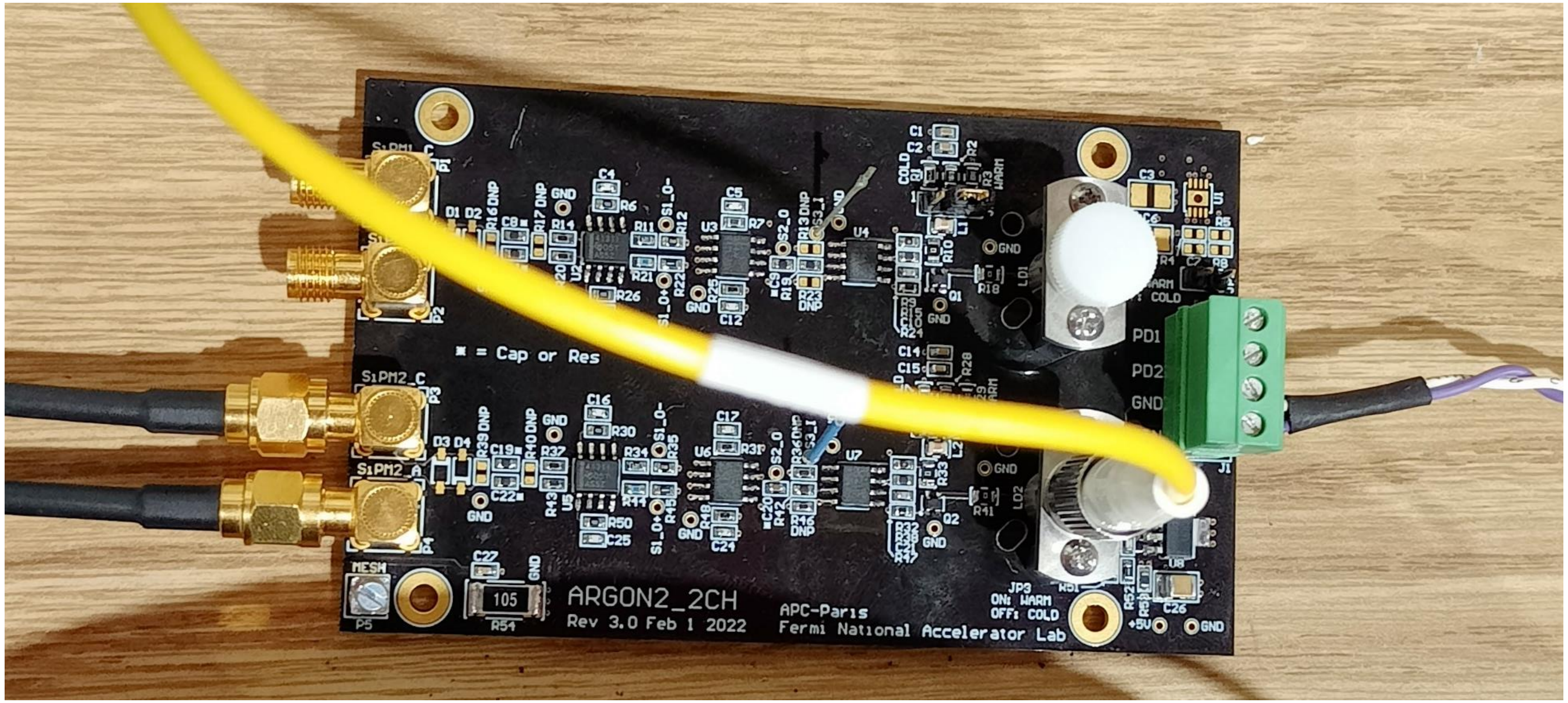
1. Prepared the experimental setup;
2. Tested all the electrical and optical components;
3. Acquired first set of data;
4. Started working on data analysis, creating a code able to: read all the waveforms acquired, plot them, apply 3 different digital filters to reduce high-frequency noise, calculate the baseline and subtract it, calculate the window to integrate the highest peak for each wf (integration needed for the charge but not done yet), plot the histogram of the peaks' heights in order to obtain the so called «Finger Plot» (there are some problems related to the peaks that I need to verify in the following weeks taking more data and optimizing the script).

# Future Plan

1. Try with thr = 3*sigma_bsl
2. Take more data but with low LED intensity;
3. Fit the Finger Plot (peaks heights) and get means and sigmas of peaks;
4. Calculate the mean and the sigma of the SPE peak;
5. Calculate **SNR** (Signal to Noise Ratio) as: $\frac{\mu_{SPE}}{\sigma_{BSL}}$;
6. Calculate **Resolution** to SPE as: $\frac{\sigma_{SPE}}{\mu_{SPE}}$ ;
7. Compare several types of SiPMs, coming from different vendors.
8. Analog readout boards in different configurations

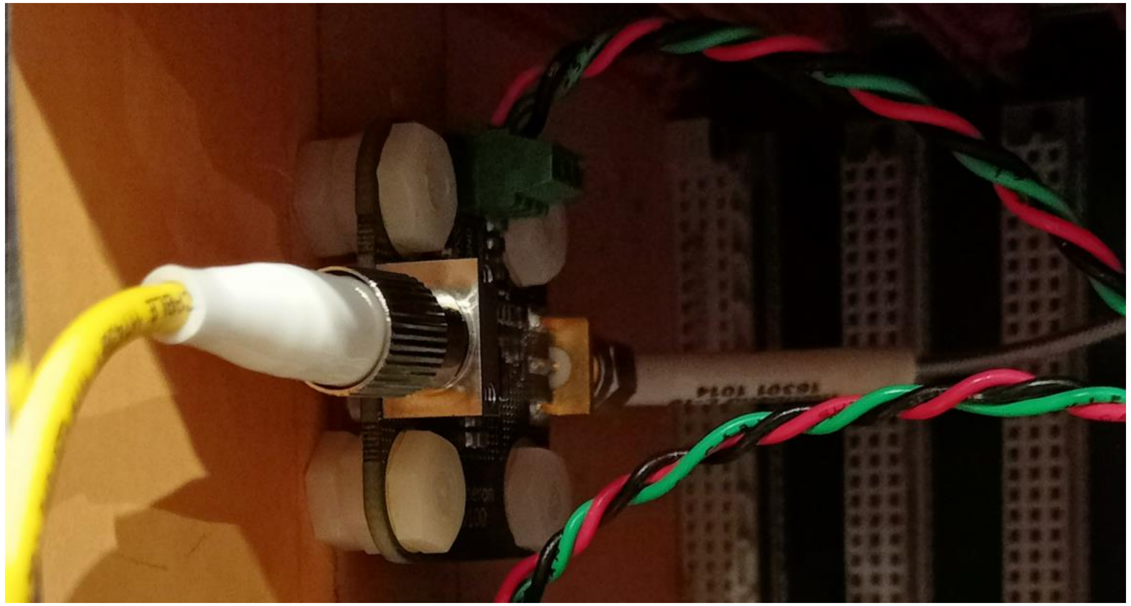
# Thanks for the attention

# Analog Optical Transmission (Argon2x2)




It amplifies and converts an analog signal (in this case coming from the SIPM board) into a light signal, that goes throguh the (yellow) fiber

# Optical Receiver (Koheron PD100)




It receives the optical signal coming from the **Analog Optical Transmission (Argon2x2)** and converting it into an analog electrical signal, ready to be acquired by an ADC