



# Report experimental activities Second Year

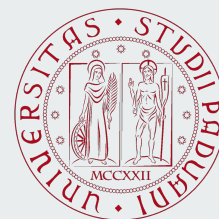
Gabriel Botogoske

Supervisor: Francesco di Capua  
Co Supervisor: Ettore Segreto

UNIPD & INFN Sezione di Napoli



18/09/2025



UNIVERSITÀ  
DEGLI STUDI  
DI PADOVA

# ABOUT ME



Electronic Engineer - UTFPR - Curitiba/Brazil  
Master in Physics - UNICAMP - Campinas/Brazil

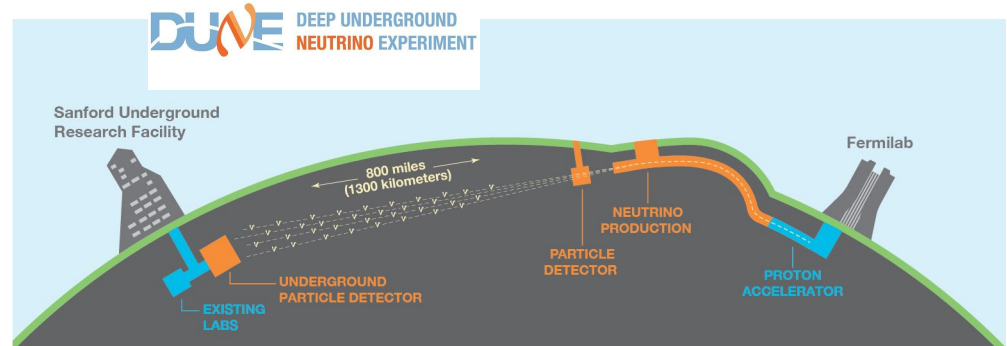
Università di Padova - since 2023

Working place: Napoli, **Università degli Studi di Napoli Federico II**

- Supervisor: Francesco di Capua
- **Dottorato Nazionale in Tecnologie per la ricerca fondamentale in Fisica e Astrofisica**
- **Curriculum: Rivelatori, laser e ottica**



**DUNE - Deep Underground Neutrino Experiment**  
Neutrino oscillation experiment

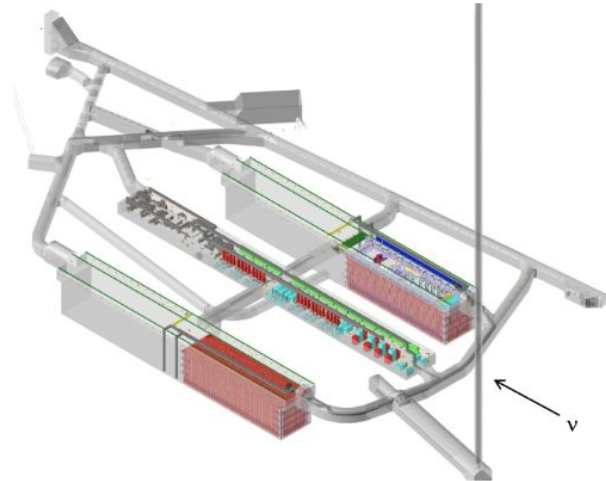


# Deep Underground Neutrino Experiment (DUNE)

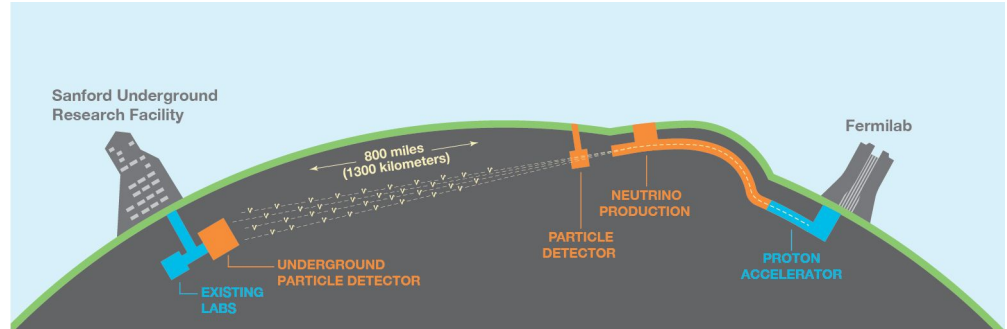
Next generation international neutrino oscillation experiment

## GOALS

- Determine CP violation in leptonic sector
- Neutrino mass hierarchy
- Proton Decay
- Study of supernova neutrinos
- Others Beyond Standard Model searches



- Neutrino Beam: from 1.2 up to 2.1 MW proton beam  
→ muonic neutrinos from 0.5 to 5 GeV
- Near Detector (ND): Characterize the Neutrino Beam
- Far Detector: 1300 km from ND, 4 modules



**4 LArTPCs of 17 kton each and 1.5 km underground**

- Phase I :

**FD1 - Horizontal Drift LArTPC**

**FD2 - Vertical Drift LArTPC**

- Phase II :

**FD3 - Vertical Drift LArTPC \***

**FD4 - To be decided**

# ProtoDUNE-HD Light Yield Analysis

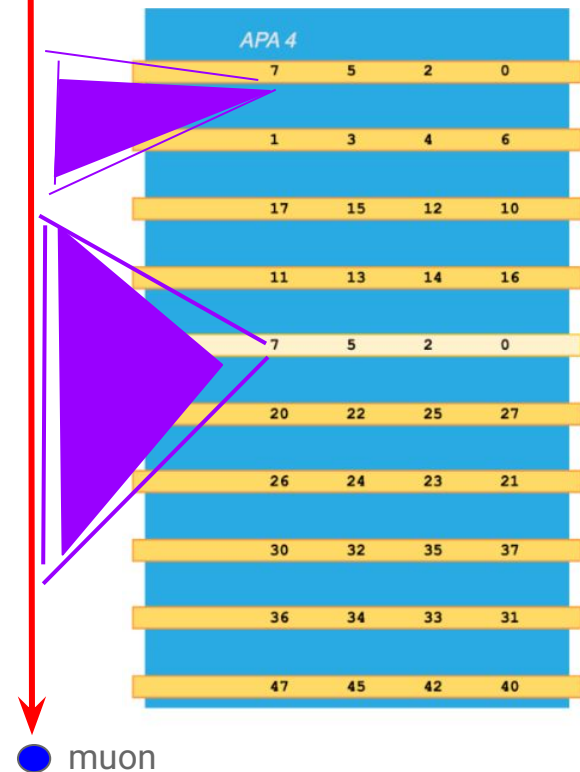
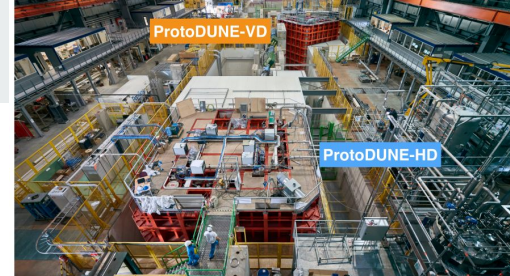
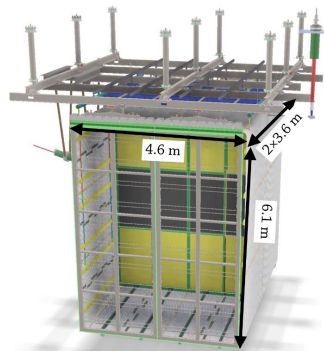
ProtoDUNE is a LArTPC build at CERN to do test and validate the technologies and choices made for FD-HD

→ Select muons that crosses the detector

Expect more light on the middle channels in relation to the top bottoms channels

→ Similar Behaviour on neighbour channels

- 0.28 kton fiducial LAr
- 4 APAs
- Data acquisition finished at 2024

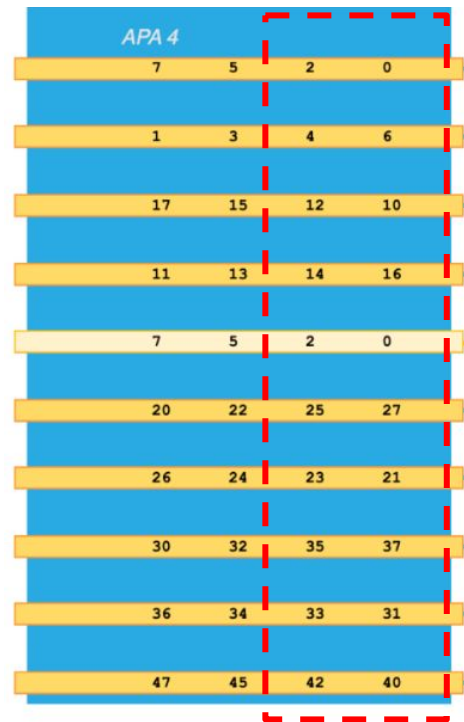
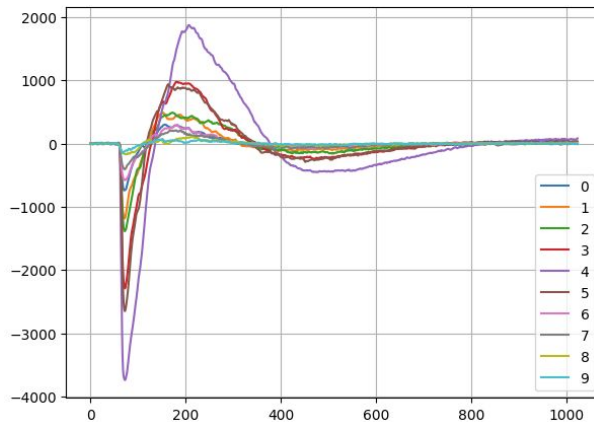
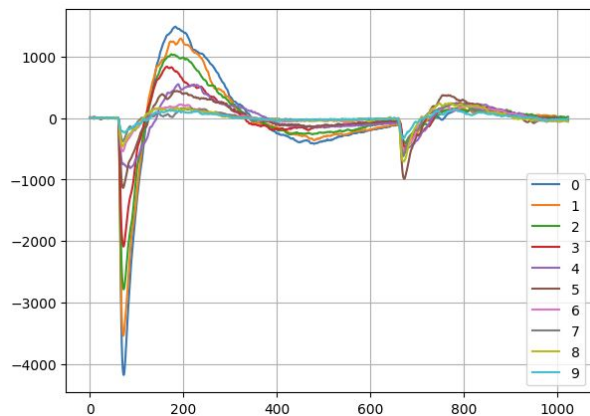


# SELECTION OF EVENTS ( Detecting flashes)

→ Selection of events recorded in 20 channels in a window of 5 units of timestamp

**NOTE:**( the trigger is counted in the UNIX time with a unit of 16 ns)

Examples of events:



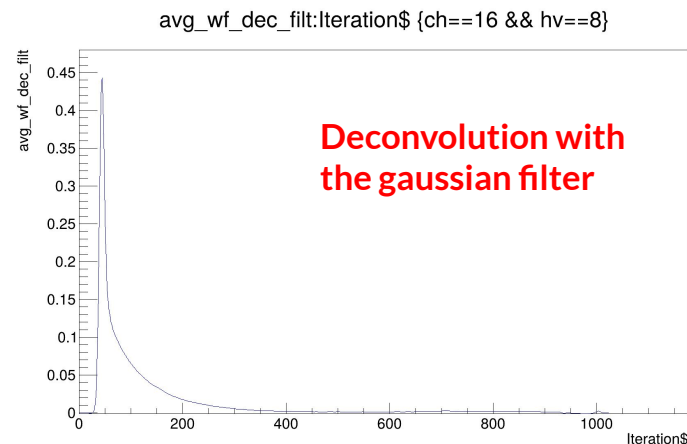
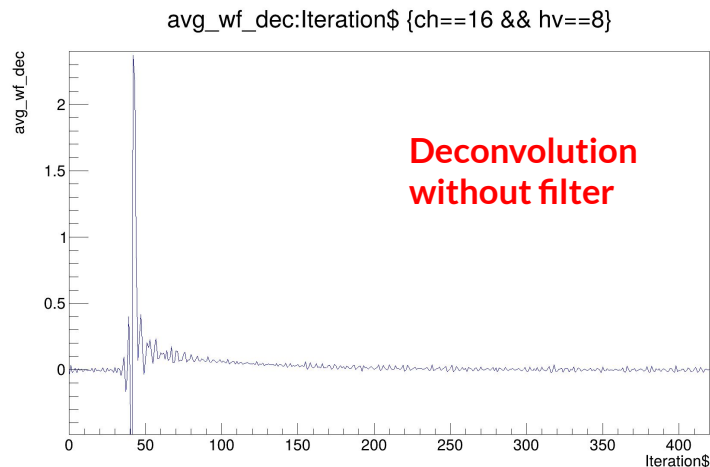
# DECONVOLUTION AND AVERAGE

The signal readout  $v(t)$  is to the convolution of light response  $L(t)$  with the impulse response of the system  $[h(t)]$  (with take in account electronics + SiPM + X-ARAPUCA WLS)  $v(t) = h(t) * L(t)$

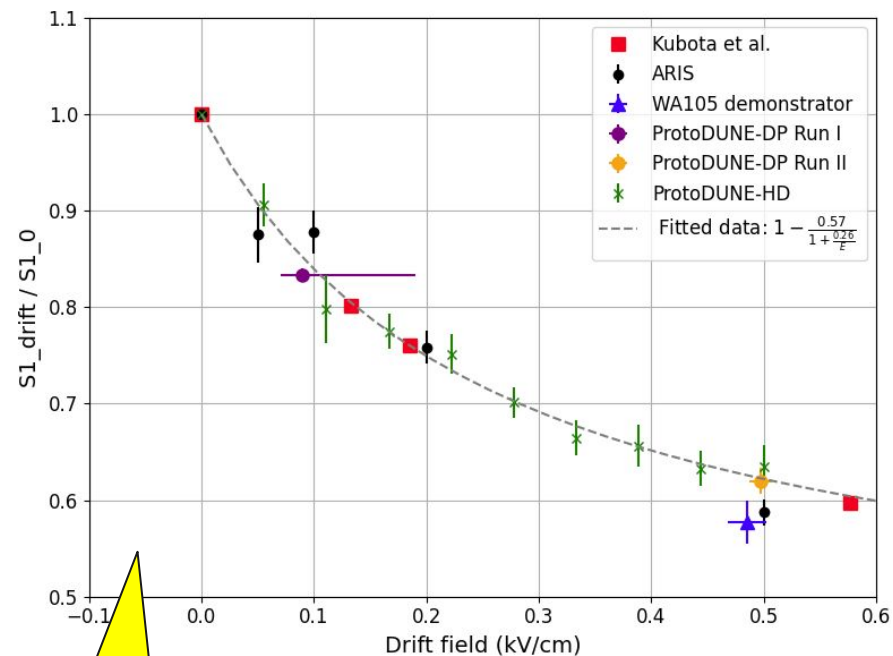
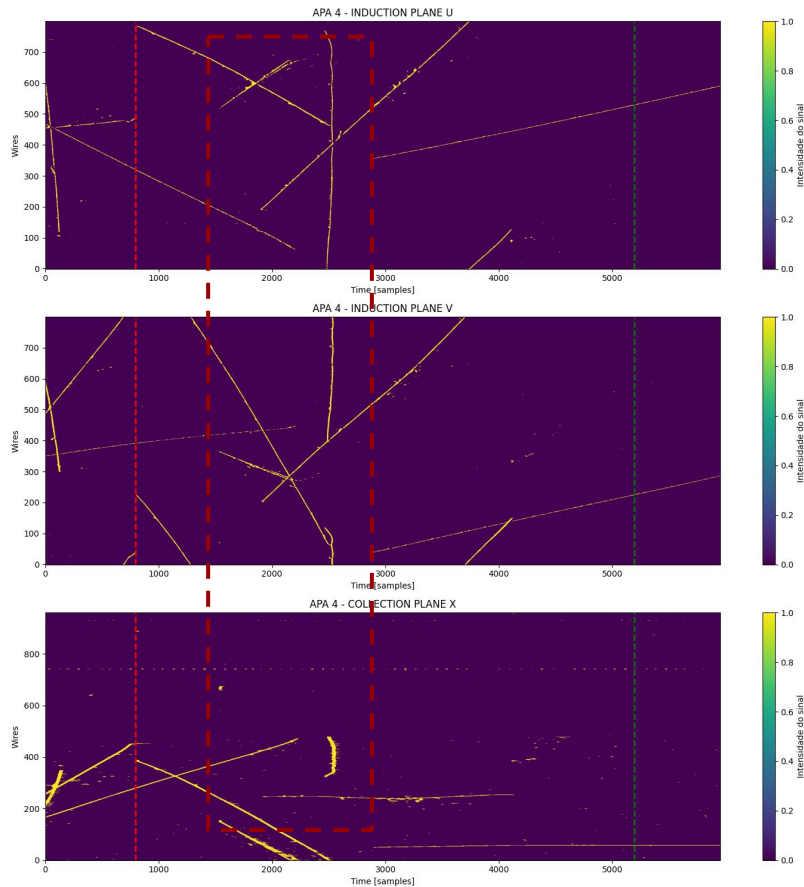
The templates (which are the response of the spe) can be obtained from the finger plots calibration:

To get the  $L(t)$ : Deconvolution  $\rightarrow$  Discrete fourier Transform  $\rightarrow L[f] = V[f] * G[f] / H[f]$

Where  $G[f]$  is a gaussian filter



# LIGHT YIELD VS ELECTRIC FIELD



$$\frac{S}{S_o} = 1 - \frac{B}{1 + \frac{\kappa}{|E_D|}}$$

$$k = (0.26 \pm 0.06) \text{ kV/cm}$$

$$B = 0.57 \pm 0.06$$

A Paper on the PDS validation with ProtoDUNE-HD is currently in preparation.

# FD3 - POWER

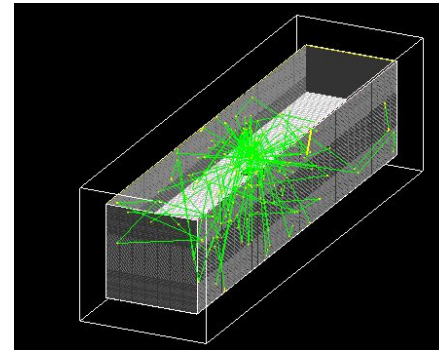
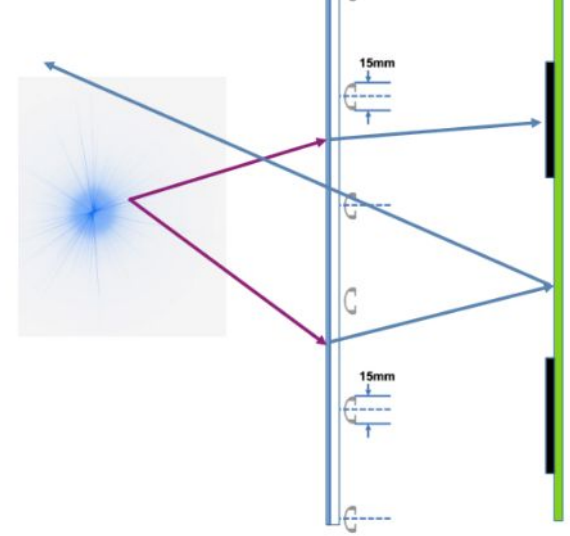
Is a proposed idea for FD3 detector, using PEN in the field cage to create a large VETO system



Main features:

- LArTPC Vertical Drift
- Use of PEN (Polyethylene Naphthalate) as wls covering the field cage + acrylic
- Use of large matrix SiPMs (of the order about hundreds of  $\text{cm}^2$ ): SiPMs VUV and visible light sensitive

Working in the simulation of the detector using GEANT4



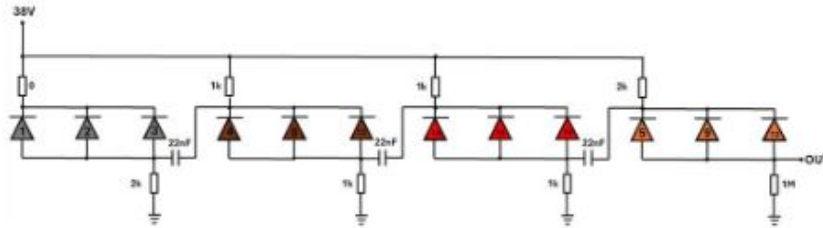


# FD3 - POWER

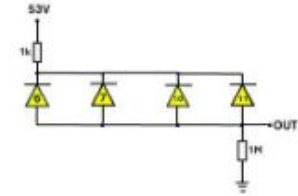
Also worked on validating and developing the electronics board for the future prototype.

**12 VIS SiPMs:** 3 SiPMs are passively parallel-ganged; each triplet is then passively series-ganged.

**4 VUV SiPMs:** 4 SiPMs are passively parallel-ganged

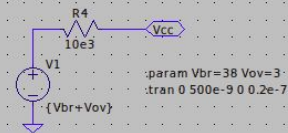
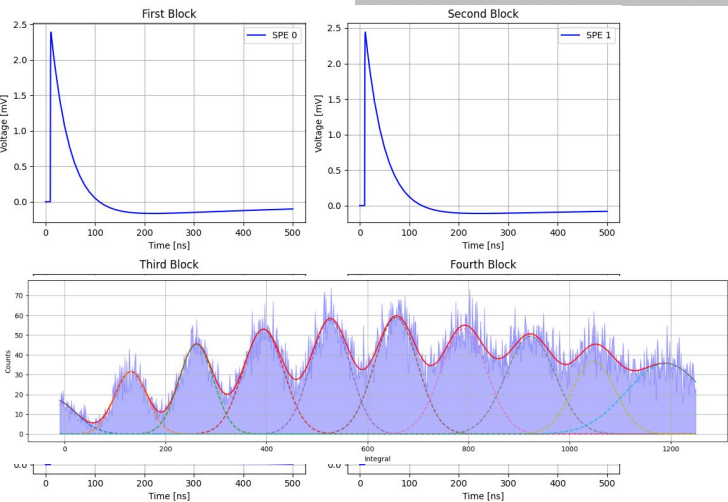
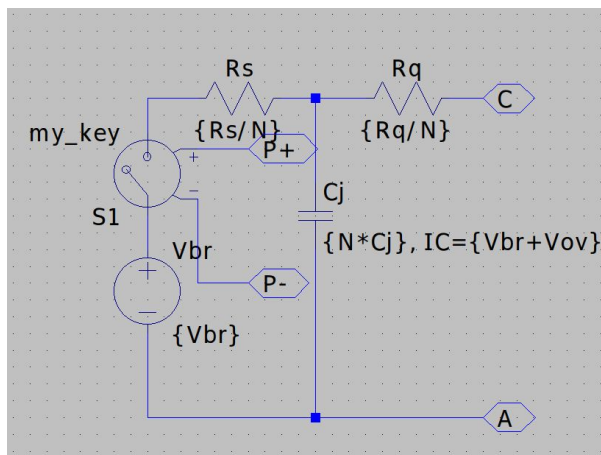


|   |   |    |    |
|---|---|----|----|
| 1 | 5 | 9  | 13 |
| 2 | 6 | 10 | 14 |
| 3 | 7 | 11 | 15 |
| 4 | 8 | 12 | 16 |

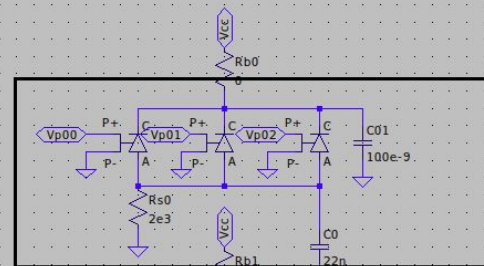
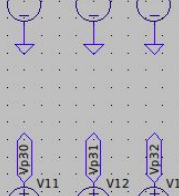
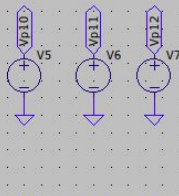
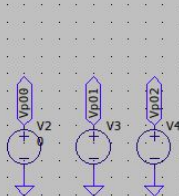


# Spice Simulation

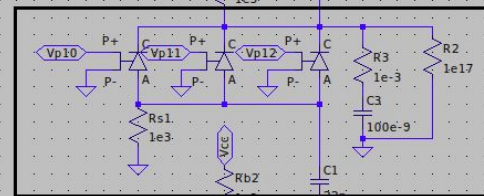
SiPM model:



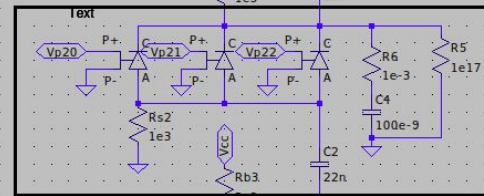
.param Vbr=38 Vov=3  
.tran 0 500e-9 0 0.2e-7



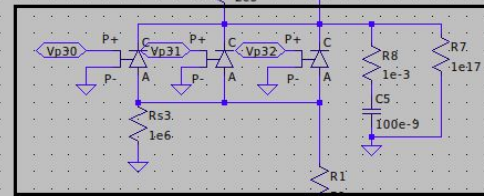
1  
group



2  
group



3  
group



4  
group

# FUTURE WORK - FLASH MATCHING FOR MUONS

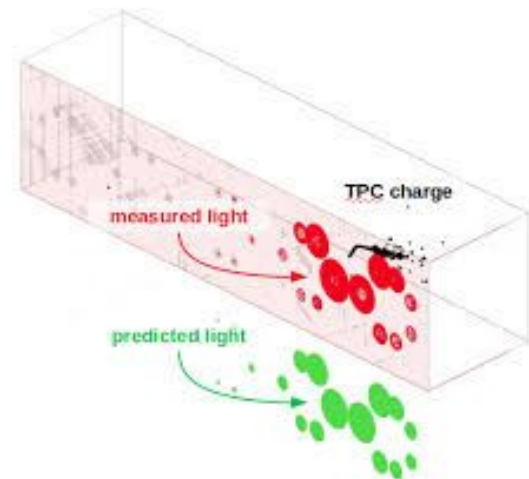
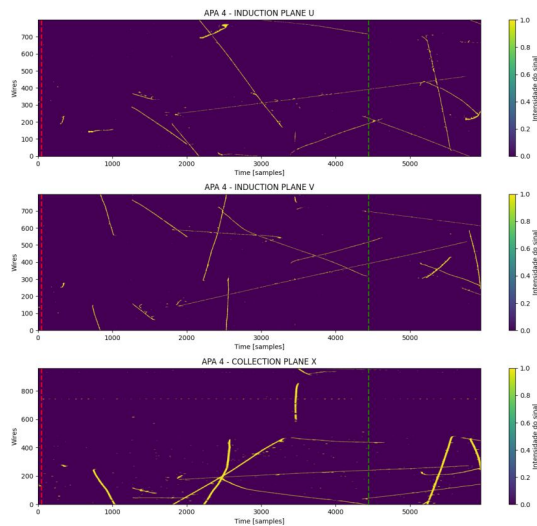
When particles cross the LArTPC it realises charge and light

CHARGE → Tracks in the wires

LIGHT → Hits on the optical detector detectors → A collection of hits around is a flash

The problem is associated a track with a flash without an external trigger

If matched: increase energy resolution,  $t_0$  determination and more ...



# FUTURE WORK - FLASH MATCHING FOR MUONS

Develop a flash matching algorithm for ProtoDUNE-HD for muon particles

Tools: LArSOFT  
What is LArSoft?



I learned how to use it in my second year, as planned in my first-year schedule

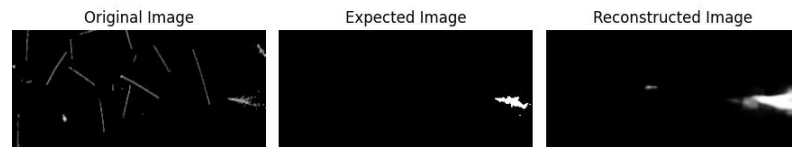
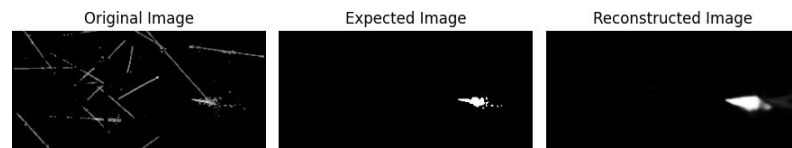
A toolkit to facilitate simulation, reconstruction and analysis of events from liquid-argon TPC-based detectors

1 step: develop a classical matching algorithm and validate with Monte Carlo analysis

2 step: apply the algorithm to real data and study cosmic data

3 step: develop a machine learning algorithm and compare with the first algorithm

To learn how use neural network tools, I developed a convolutional neural network to select neutrinos event on a LArTPC



# Schools, conferences ( 2 year )

## Participations:

- **Participation in the 9th UK LArTPC Software and Analysis Workshop** in Edinburgh, Scotland, from 28/10/2024 to 31/10/2024.
- **Participation in the school *Theory Meets Experiments: "Neutrinoless Double Beta Decay: The Experimental Programme and Its Fundamental and Nuclear Theory Connections"*** in Florence, Italy, from 11/11/2024 to 22/11/2024.
- **TECH-FPA PhD Retreat 2025 in L'Aquila, Italy** from 17/02/2025 to 21/02/2025
- **XIV International Conference on New Frontiers in Physics**, from 17/07/2025 to 31/07/2025 in Kolymbari, Greece – Presented the talk: *DUNE Photon Detection System Validation with ProtoDUNE-HD*.
- Invited to give a talk and lectures about LArSoft at the **"Neutrino Brazilian School"** from 06/08/2025 to 08/08/2025 in Curitiba, Brazil. The talk was titled: *"The Mystery of the Nature of the Neutrino: Exploring  $0\nu\beta\beta$  through the LEGEND Experiment"*.
- **DarkSide Young Academy:** 02/21/24 to 02/24/24 in Naples
- **15th International Neutrino Summer School 2024:** 06/03 to 06/14 in Bologna
- **LIDINE 2024: Light Detection In Noble Liquids:** 08/26 to 08/28 in São Paulo/BRAZIL. I present a talk named: DUNE Photon Detection System

## Classes:

- **Machine learning for physics** – approved
- **Rare event search with Time Projection Chamber** -- approved
- **Simulation of Optical Photon Propagation** – need to schedule exam

## First year courses:

- Cryogenics sensors for astroparticle physics - approved
- Cabling and Shielding for low noise applications - approved
- Vacuum Technologies - approved



# Schools, conferences ( 2 year )



- **List of published papers/proceedings**

DUNE Photon Detection System, DUNE Collaboration, G. Botogoske for the collaboration. (Jun 19, 2025)

Published in: *JINST* 20 (2025) 06, C06034

## **Collaboration DUNE papers:**

The DUNE Phase II Detectors. DUNE Collaboration Adam Abed Abud(CERN), Mar 29, 2025. e-Print: 2503.23293 [physics.ins-det]

The DUNE Science Program. DUNE Collaboration Adam Abed Abud (CERN) et al. (Mar 29, 2025). e-Print: 2503.23291 [hep-ex]

DUNE Software and Computing Research and Development. DUNE Collaboration Adam Abed Abud (CERN) et al. (Mar 31, 2025). e-Print: 2503.23743 [physics.data-an]

European Contributions to Fermilab Accelerator Upgrades and Facilities for the DUNE Experiment.

DUNE .Collaboration Adam Abed Abud (CERN) et al. (Mar 31, 2025). e-Print: 2503.23744 [physics.acc-ph]

Spatial and temporal evaluations of the liquid argon purity in ProtoDUNE-SP. DUNE Collaboration Saeed Abbaslu(IPM, Tehran) et al.(Jul 11, 2025). Published in: *JINST* 20 (2025) P09008

## Thesis Title: Characterization of Light–Charge Matching in Liquid Argon TPC with ProtoDUNE data



- Summary of performed activities ( **second year activities** )
  - PDE of MEGACELL: Finalization of the paper
  - ProtoDUNE HD analysis – Light Yield vs Electric Field at CERN , paper expected at the end of the year
  - Simulations using Geant4 and PSPICE for POWER detector (proposed FD3 DUNE) and electronics
  - Learned how to use LArSOFT
  - Schools, conferences and lessons
- Future activities
  - Study of flash-matching algorithm for PROTODUNE-HD
  - Study of Liquid Argon Scintillation properties
  - Analysis of POWER setup
  - Thesis finalization

# MUITO OBRIGADO!!!!