



1222-2022  
**800**  
ANNI



UNIVERSITÀ  
DEGLI STUDI  
DI PADOVA

**PhD course of National Interest in Technologies for  
Fundamental Research in Physics and Astrophysics**

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## Annual report

**Name and surname: Gabriel Botogoske**

**Cycle and a.a.: 39<sup>th</sup>**

**Supervisor: Francesco di Capua**

- Research activity carried out during the year**

Describe the aim of the project (very briefly), discuss the research activity carried out during the year mentioning the difficulties encountered until now and the actions taken to face them. 1 page max in total.

The goal of my project is to study different aspects of the DUNE Photon Detection System (PDS).

DUNE is an international long baseline neutrino oscillation experiment designed to probe CP violation in the neutrino sector, determine the neutrino mass hierarchy, and search for proton decay, as well as solar and supernova neutrinos, among other objectives. To detect neutrinos, DUNE will employ Liquid Argon Time Projection Chamber (LArTPC) technology and will consist of four Far Detectors of 17-kton of LAr each.

In order to test and validate the technologies that will be applied to the construction of the DUNE experiment in the United States, DUNE prototypes (ProtoDUNE) have been designed and operated at the CERN Neutrino Platform. The prototype of the first far detector module (ProtoDUNE-HD) was commissioned in 2024. I was part of the PDS team focusing on the validation of the PDS detector. In particular, I worked on studying the scintillation properties of liquid argon under different applied electric fields using cosmic muon data. The results, in agreement with previous experiments, indicate that with increasing electric field, fewer electrons recombine, leading to a significant reduction in light yield. In addition, new effects have been observed, which are currently under further investigation. A paper on the PDS validation with ProtoDUNE-HD, including my work, is currently in preparation.

Additionally, in my first year I analyzed data collected on 2024 in Liquid Argon test performed to measure the Photon Collection Efficiency of the Arapuca module of the PDS of the second DUNE Far detector. The result of this activity will be the subject of a paper in preparation.

In 2025, another DUNE prototype (ProtoDUNE-VD) began operating at CERN, where I started working on cosmic simulations and data analysis to understand the flux rate at the detector and to develop a trigger algorithm based on light information. In addition, I plan to develop a flash-matching algorithm to correlate the light signal with the charge signal, which is essential for both calorimetry and trigger applications. For most of these tasks, I relied on the LArSoft framework, a dedicated software suite for simulation and data analysis of LArTPCs. I spent some time learning how to use this tool effectively. My long-term goal is to compare “traditional” reconstruction codes with those based on Neural Networks.



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To gain the necessary expertise, I developed a machine-learning algorithm capable of selecting neutrino events in a LArTPC using charge data.

I am also part of a working group that has proposed a new detector concept, PoWER, intended for use in DUNE Phase II as the third Far Detector module. As part of this effort, I am scheduled to build a small prototype to validate the veto capabilities of the detector using PEN scintillator. For the setup, I contributed to the development and simulation of the amplifier that will be used for both types of SiPMs (UV and visible). Furthermore, using the knowledge acquired during my first year with Geant4, together with the lectures I attended in the second year, I plan to simulate the detector performance. Lastly, I am working on a small setup to determine the photon detection efficiency of SiPMs at different cryogenic temperatures.

- **List of attended courses and passed exams**

Second year courses:

- 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

- **List of attended conferences, workshops and schools, with mention of the presented talks**

- 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 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



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- 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

● **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**

**Date, 9 settembre 2025**

**Signature:** \_\_\_\_\_

**Seen, the supervisor**