PROCEEDINGS OF SCIENCE

Status of ProtoDUNE-II

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The Deep Underground Neutrino Experiment (DUNE) is a long-baseline neutrino-oscillation experiment aiming to measure CP-violation and the neutrino mass ordering. The far detector consists of four 17-kt modules based on Liquid Argon Time Projection Chamber (LArTPC) technology. The technologies chosen for the first and second DUNE modules are tested with large-scale prototypes at the CERN Neutrino Platform. The first operation of the ProtoDUNE detectors (2018-2020) led to improvements in the design, construction, and assembly procedures of the LArTPCs foreseen for the DUNE modules.

The ProtoDUNE detectors have been updated and will take cosmic and beam data in 2024. ProtoDUNE-HD is equipped with the horizontal drift design (HD), formally known as 'Single Phase' and ProtoDUNE-VD uses the recently proposed vertical drift design (VD), an evolution of the previously 'Dual-Phase' design. This contribution reports the status of the two detectors as well as the first results from the data taking.

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1. Introduction

DUNE is a neutrino oscillation experiment currently being constructed in the United States. In DUNE, a beam of neutrinos will be generated at the Fermi National Accelerator Laboratory (FNAL) and directed toward massive detectors located 1300 km away in a mine at the Sanford Underground Research Facility (SURF) in South Dakota. These detectors will be filled with liquid argon. Near Detectors (ND) at FNAL will sample the beam near its production point. Two 770-ton prototypes at CERN, ProtoDUNE Horizontal Drift (HD) and Vertical Drift (VD), serve as testbeds for full-scale DUNE technology.

The DUNE physics program includes measuring the CP-violating phase (δ_{CP}) to determine if CP violation occurs, determining the neutrino mass ordering, identifying the octant of θ_{23}, observing supernova burst neutrinos, and measuring solar and atmospheric neutrinos [1].

2. ProtoDUNE-II at CERN

The CERN Neutrino Platform R&D facility is located in a test beam hall at the CERN Prévessin site as shown in Figure 1 (Left). This R&D facility enables the global neutrino community to design and prototype advanced neutrino detector technologies and was used for the first successful operation of large-scale DUNE prototypes in 2018. These results influenced the design, construction, and assembly procedures for the liquid Argon Time Projection Chambers (LArTPCs) intended for the DUNE's far detector modules. The ProtoDUNE detectors have been updated and are scheduled to collect cosmic and beam data in 2024-2025 (ProtoDUNE-II). The detectors incorporate new calibration techniques, such as a laser calibration system and a pulsed neutron source. ProtoDUNE-HD employs the Horizontal Drift (HD) design [2], while ProtoDUNE-VD utilizes the Vertical Drift (VD) design [3], which is an evolution of the earlier 'Dual-Phase' design. These developments are crucial for refining the technology and methodology for the DUNE experiment.

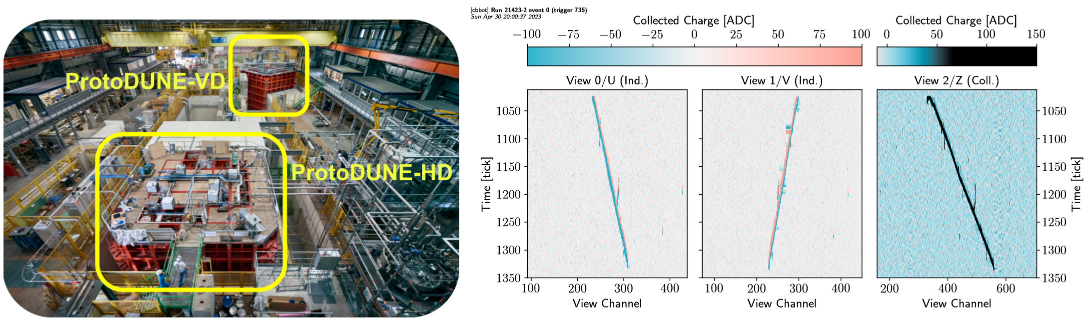

Figure 1: Left: ProtoDUNE-VD and ProtoDUNE-HD at the CERN neutrino platform. Right: Example of a muon track collected using a charge readout plane (CRP) prototype for the vertical drift technology

2.1 ProtoDUNE-HD

ProtoDUNE-HD consists of two drift volumes separated with a solid, planar cathode, each volume with a drift distance of 3.6 meters. The charge signals are readout using two anode plane assemblies (APAs) facing the cathode on each side. In addition, scintillation light signals are detected using upgraded X-ARAPUCA photon detection units [4]. The liquid argon (LAr) filling was completed on April 30, 2024, and the detector has been operational since May. The beam was turned on for commissioning and calibration on June 19, 2024. In addition, seven weeks of beam data have been collected during July, August and September. These data will be used to increase beam data statistics previously taken with protodune-SP [5], which is essential for cross section measurements, particle identification, calibration, and reconstruction efforts in preparation for the full-scale DUNE experiment.

2.2 ProtoDUNE-VD

ProtoDUNE-VD consists of two drift volumes separated by a semi-transparent cathode. The total active volume of the detector measures 6.8 meters in width, 3 meters in length, and 7 meters in height. The charge detection system is composed of four charge readout planes (CRPs) facing the cathode, with two located at the top and two at the bottom. The light detection system consists of 16 upgraded X-ARAPUCAs, distributed equally between the cathode and membrane sides. Each CRP has undergone extensive testing in a cold box facility to ensure reliability under final operational conditions. An example of a muon track collected by a CRP during a cold box test is shown in Figure 1 (Right). The liquid argon filling of ProtoDUNE-VD will start once data collection with ProtoDUNE-HD is completed, as it will re-use the same LAr. The transfer of LAr from ProtoDUNE-HD is expected to take place in October 2024, with data collection, including cosmics and beam data, scheduled to begin in early 2025.

3. Conclusions

Extensive research and development at the CERN Neutrino Platform over the past few years has been crucial for testing, validating, and optimizing the technologies for the DUNE far detector. The successful deployment and operation of large-scale DUNE prototypes provided valuable insights that informed design optimizations implemented in the ProtoDUNE-II prototypes. These prototypes are both equipped to collect additional beam data, which is essential to refine cross-section measurements, particle identification, calibration, and reconstruction techniques. ProtoDUNE-HD, which has been filled with LAr, is taking data since May 2024, and has collected seven weeks of beam data. In October 2024, the LAr will be transferred from ProtoDUNE-HD to ProtoDUNE-VD, allowing data taking to begin early 2025 in ProtoDUNE-VD. This second phase, ProtoDUNE-II, is critical for ensuring the success of the DUNE experiment and the advancement of neutrino liquid argon time projection chamber technologies.

References

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