PROCEEDINGS OF SCIENCE

Demonstration of a novel, ton-scale, pixel-readout LArTPC for the DUNE near detector

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The Deep Underground Neutrino Experiment (DUNE) will be using optically separated liquid argon time projection chambers in the Near Detector (ND) complex to cope with the high event pile-up. DUNE ND-LAr 2x2 (ProtoDUNE-ND) is a prototype experiment for these modules. The capabilities of this detector, including the performance of the charge and light readout systems, the signal matching between the two, the detector purity, and the response uniformity, have been demonstrated with two ton-scale prototypes operated at the University of Bern. They acquired large samples of cosmic ray data by detecting ionization charge through a true 3D pixel-based charge readout, and scintillation light through advanced high-coverage photon detection systems, the Light Collection Modules (LCM) and the light traps called ArCLights. The main results from the analysis of these data sets, as well as the overall status of the ND-LAr detector and the role of ProtoDUNE-ND in DUNE, are presented in this poster.

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1. The Module-0 Demonstrator

The DUNE Near Detector and its prototype program, ProtoDUNE-ND, both are modular liquid argon time projection chambers (LArTPCs). The Module-0 Demonstrator is the first of four modules installed in the ProtoDUNE-ND.

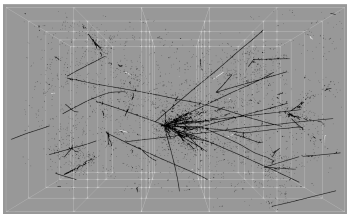

Figure 1: A beam spill in the liquid argon near detector. The black tracks are energy deposits with less than 10 MeV but sufficient energy for ionization charge to be collected at the pixel planes. The white tracks are fast-neutron induced recoiling proton tracks, with an energy greater than 10 MeV. The white lines indicate the 35 modules [1].

The modular design for both detectors is chosen mainly to be able to associate fast neutron-induced energy deposits to a neutrino vertex. There are 10-100 interactions per beam spill expected. Figure 1 shows a simulated beam spill in the ND-LAr [1].

Module-0 is a $0.7\times0.7\times1.4\text{m}^3$ TPC which was assembled and tested at the University of Bern. The module itself is again divided into two smaller TPCs as shown in Figure 2. It has a resistive shell (Dupont DR8) that allows for a modular design [2].

The two light collection detectors are the ArCLights (ACL) produced in Bern [6], and light collection modules (LCM) built in JINR [5]. Both are fully dielectric large area light detectors placed inside the E-field. ArCLights have a wavelength-shifting plastic. On top of that lies a dichroic mirror coated with tetraphenyl butadiene (TPB). Both detectors have dimensions of $30\times28\times1\text{cm}^3$ inside the DUNE-ND 2x2 demonstrator module.

On top and bottom in Figure 2 one sees the two anode pixel planes. The pixel planes have a dimension of $0.3\times0.3\text{m}^2$. The backside of the pixel plane is shown in Figure 3 on the left. The 100 LArPix Chips from Berkeley are visible. On the right side of Figure 3 one sees the 70×70 pixels on the plane from the front with a pixel-size of 4.43cm [7].

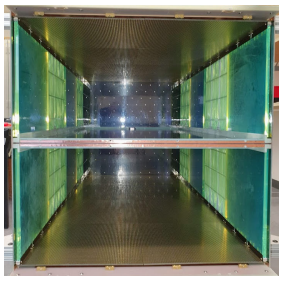

Figure 2: Top view of Module-0 with the cathode plane in the middle and two charge planes on top and bottom. The light detection modules flank both sides.

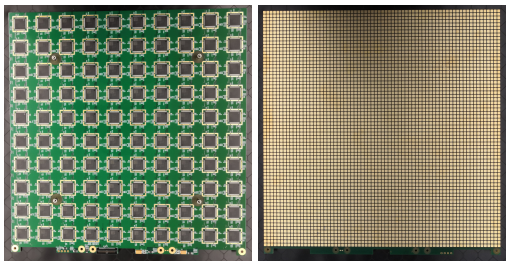

Figure 3: The front side of a charge collection plane on the right with 4900 pixels and on the left side the pixel plane from the back [3].

2. Results of Module-0 Test

Module 0 collected over 60 million cosmic ray events during its eight days of data-taking, as seen in Figure 4. The detector ran with a total of 78.4k working pixel channels, which took event data as exemplified in Figure 5. In the process, the cryogenics system and data acquisition infrastructure were successfully tested [3]. Figure 6 shows the dQ/dx measurement for low and high threshold runs. The electron lifetime factor corrects the amount of charge reaching the anode. DUNE's primary science goals are to measure the CP-violating phase of the leptonic sector and determine the neutrino mass ordering through neutrino oscillation measurements [4].

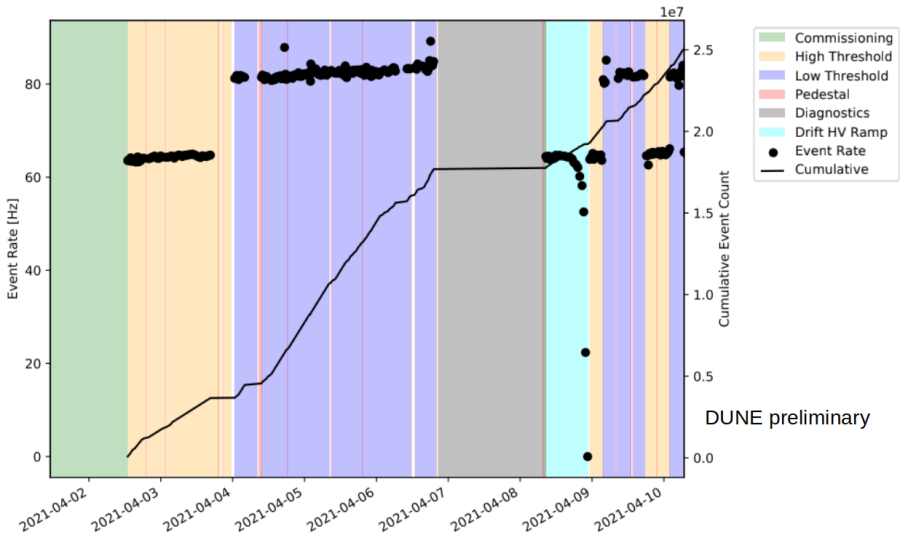

Figure 4: The event rate over the 8 day run as a function of time with respect to charge readout operating condition [3].

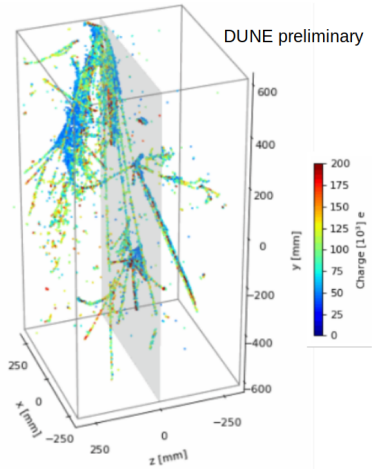

Figure 5: Multi-Prong Shower induced by cosmic ray within Module-0. The grey plane denotes the cathode [3].

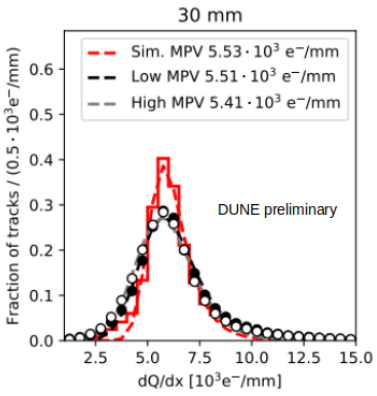

Figure 6: dQ/dx measurment for track segments of length 30 mm with low threshold runs (black dots), and high threshold runs (white dots) [3].

References

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