

The Module-0 Demonstrator

First test of ProtoDUNE-ND Module [1]

See below for info on DUNE and ND-LAr
Results

- 60 million collected cosmic ray events over an 8 day time span in March 2021
- Test of cryogenics, data acquisition, trigger and timing infrastructure on a smaller version of the final TPC ArgonCube Module with successful light and charge matching
- Exceeded the necessary requirement of $E_{\text{drift}} = 0.5 \text{ kV/cm}$

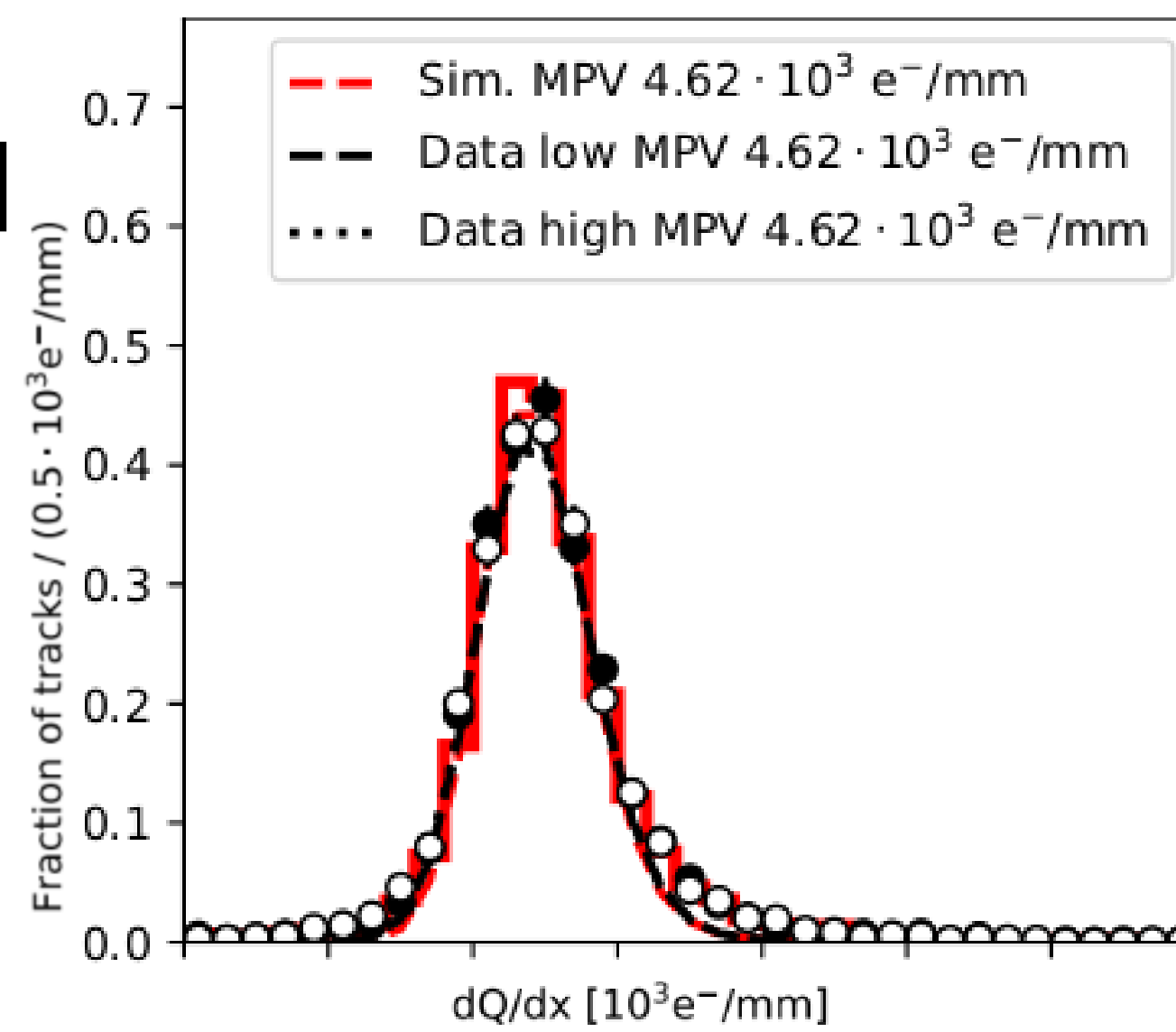


Figure 1: dQ/dx measured for a 100mm track segment for a low threshold (black dots), and a high threshold run (white dots)

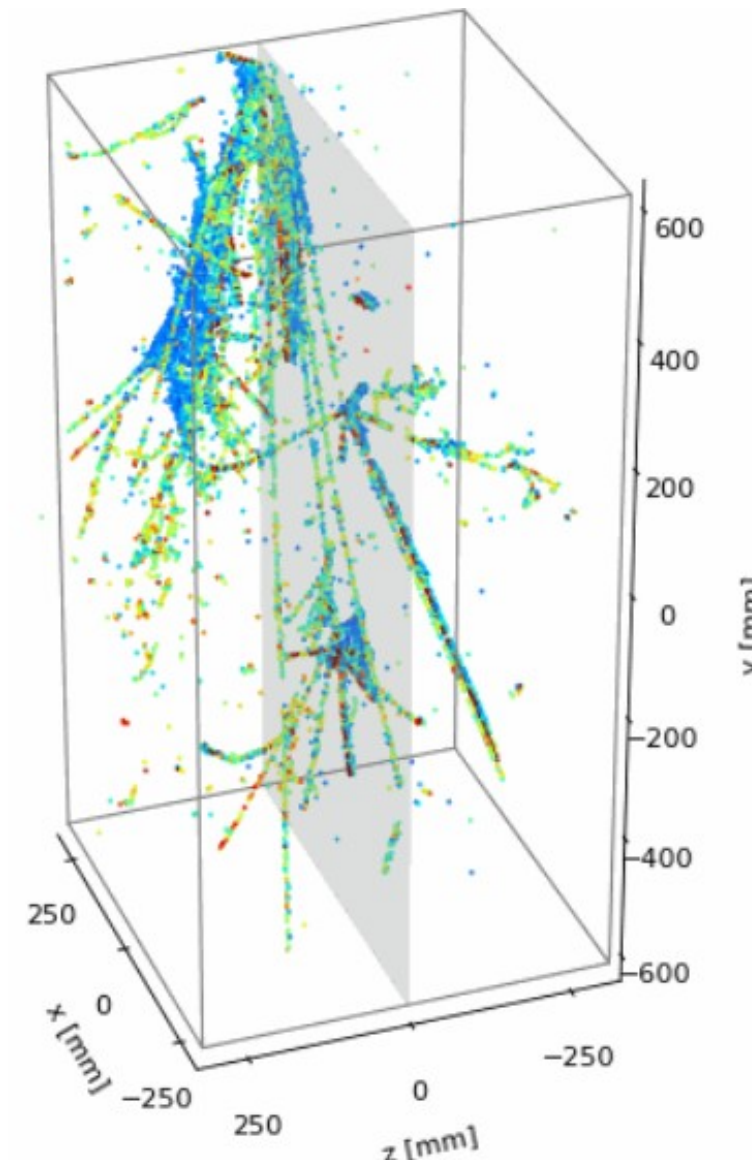


Figure 2: Observed multi-prong shower

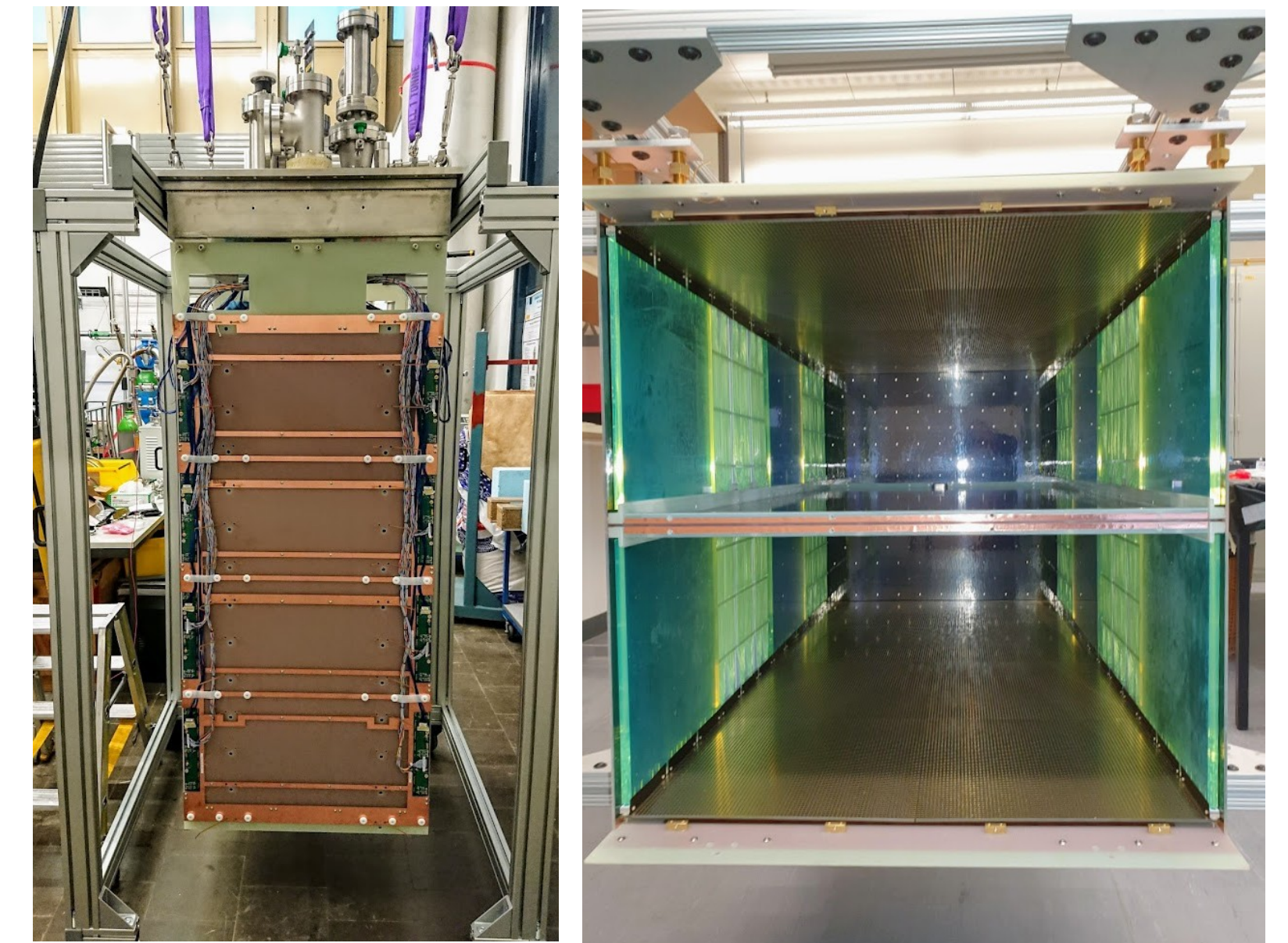


Figure 3: Top view of the two TPCs of Module 0 (right) and side view of the outer G10 shell with connected detector electronics (left)

ArgonCube TPC Module Liquid Argon Time Projection Chamber [2]

- Field structure with resistive shell (Dupont DR8) allows for modular design
- $V_{\text{drift}} = 25 \text{ kV}$, $E_{\text{drift}} = 0.5 \text{ kV/cm}$

Detection Systems

- Charge detected by system with LArPix Chip (see box Charge Detection)
- Light detected by ArCLight and LCM (See box Light Detection)

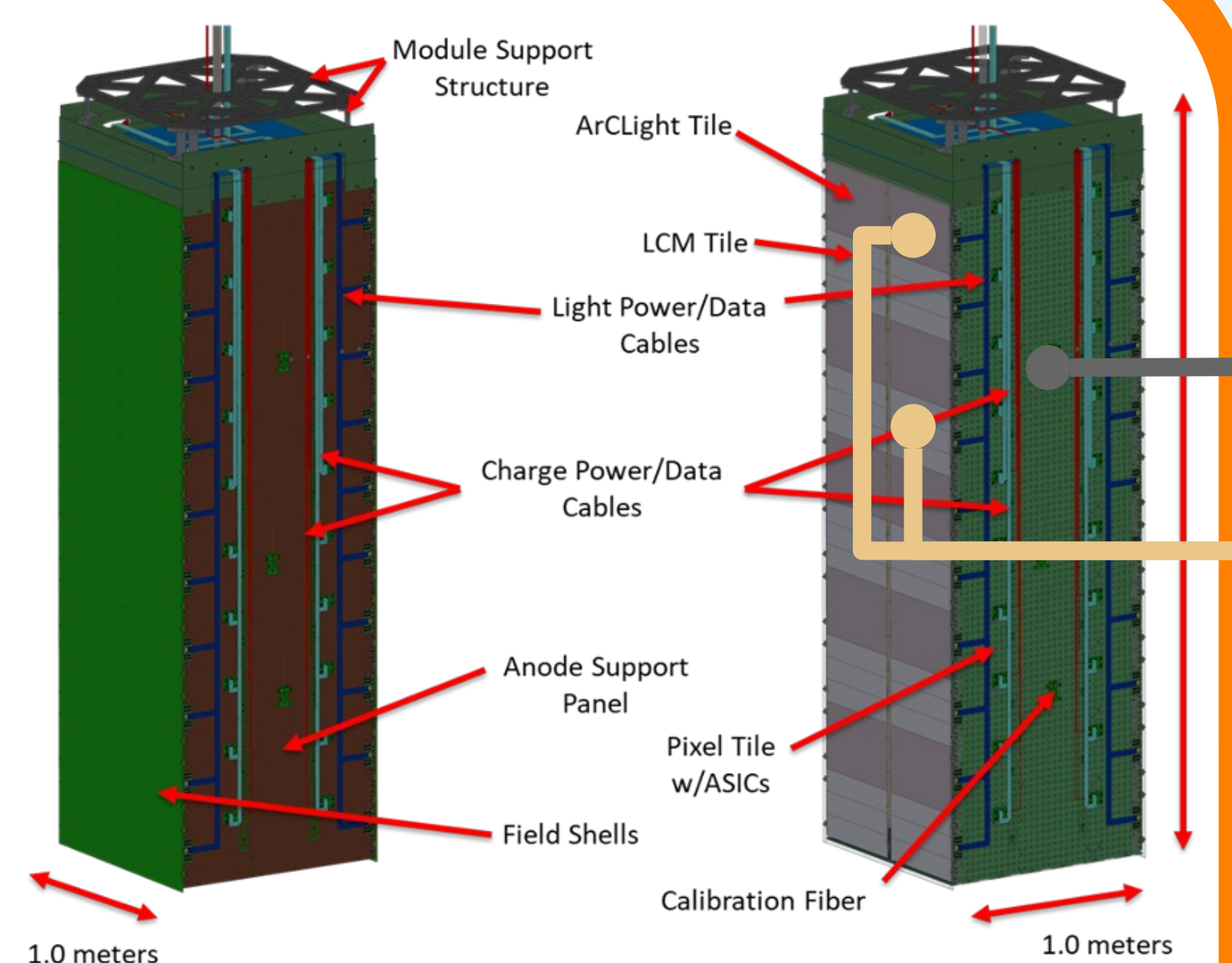


Figure 4: Illustration of an ArgonCube LArTPC Module

Light Detection Light Collection Module (LCM) & ArCLight [4,5]

- Fully dielectric, large area light detectors
- **ArCLight**: WLS* plastic+dicroic mirror+TPB**
- **LCM**: WLS* Fiber+TPB**



Figure 7: ArCLight tile (left) and three LCM tiles (right), as assembled within the Module-0 structure.

*WLS: Wavelength Shifter **tetraphenyl butadiene

ND-LAr Liquid Argon Near Detector [2,3]

- Contains 35 modules of $1\text{m} \times 1\text{m} \times 3\text{m}$
- **Modular design**
- Allows for tracking of 10-100 interactions per beam spill.
- Single modules can be accessed or replaced with minimal effort
- Short electron drift length and therefore achievable LAr purity requirements

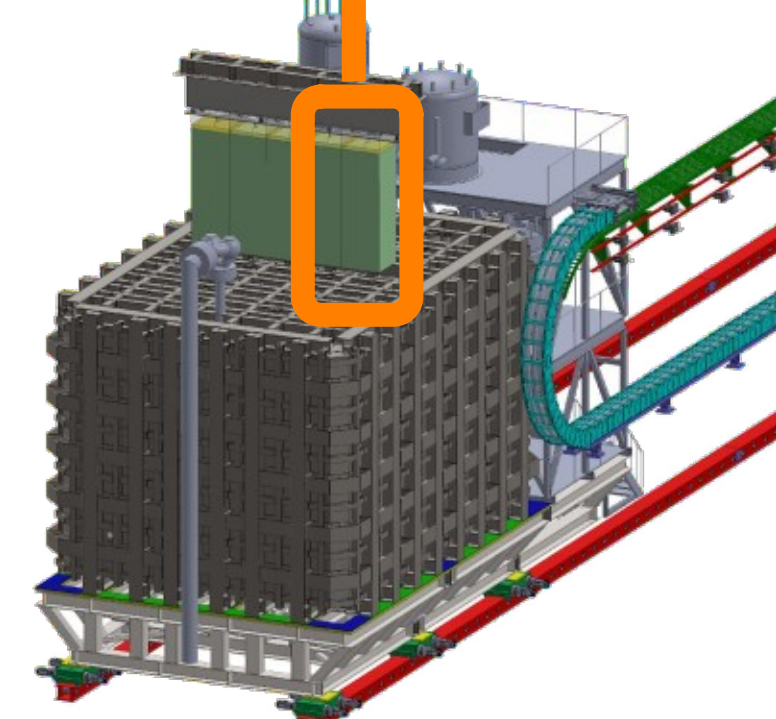


Figure 5: Preliminary Liquid Argon Near Detector design

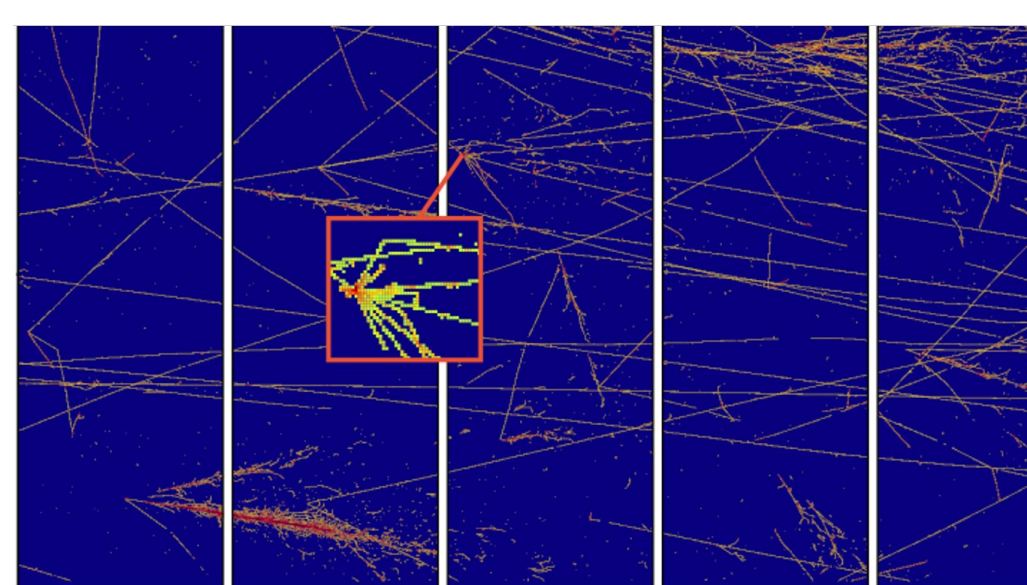


Figure 6: Simulated event in ND-LAr.

DUNE Deep Underground Neutrino Experiment [7]

- High-intensity neutrino beam: 1.2 – 2.4 MW
- **Primary science goals**
- Neutrino oscillation measurements
- Search for proton decay
- Supernova neutrino bursts

Charge Detection Charge Detection System with LArPix Chip [6]

- Low power, low noise, cryogenics compatible
- 78.4 k pixel channels in Module-0
- Continuous self-triggering, 100% up time
- Unambiguous 3D imaging of the LAr TPC ionization tracks

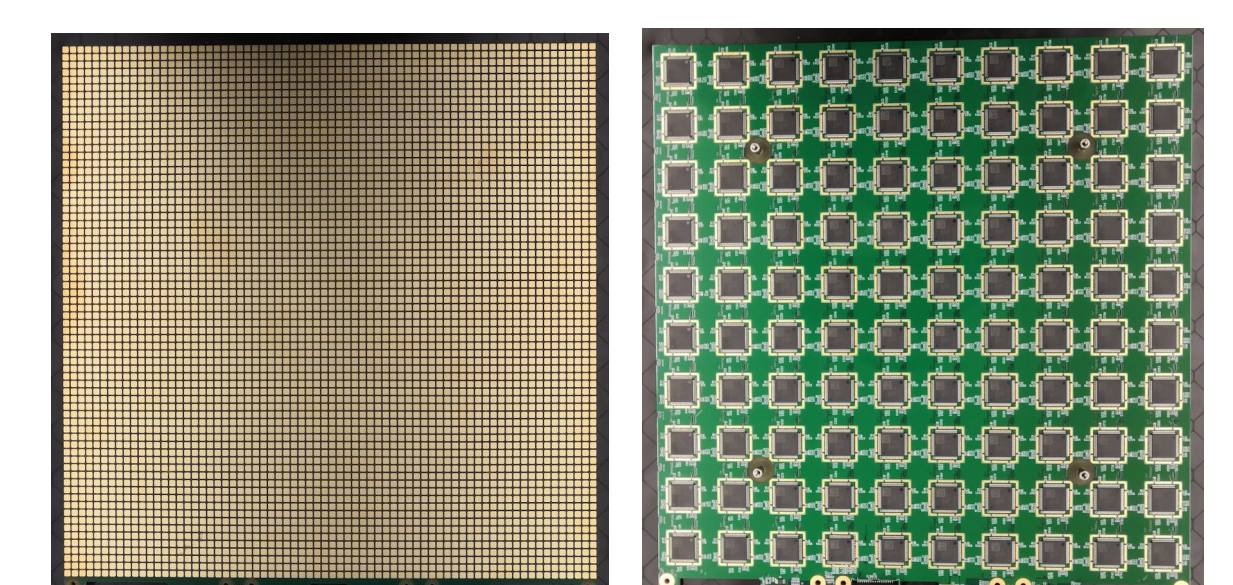
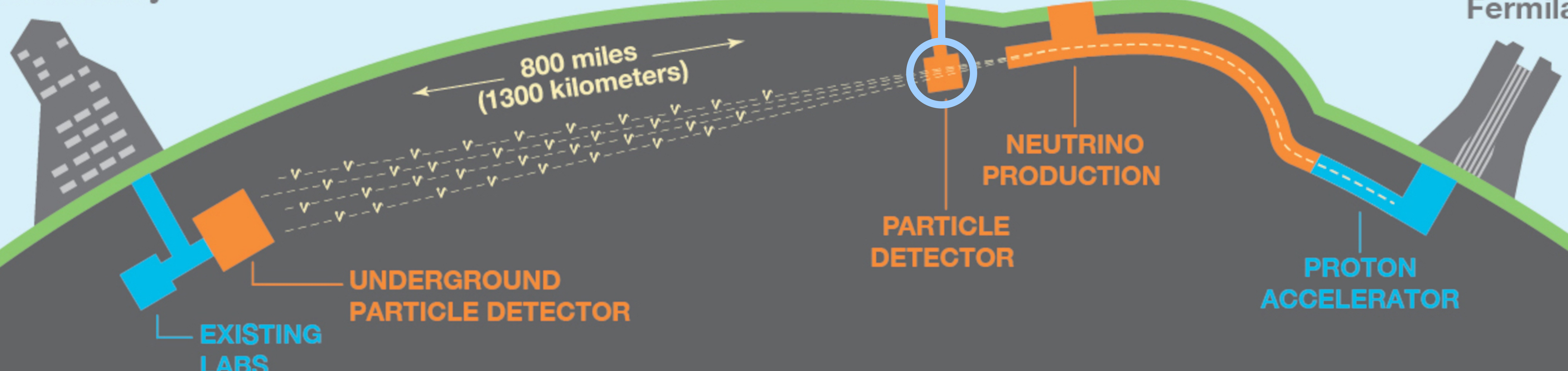


Figure 8: LArPix tile front side (left) and back side (right)

Sanford Underground Research Facility

Fermilab



[1] DUNE Collaboration, Performance of a modular ton-scale pixel-readout liquid argon 4 Time Projection Chamber (in preparation)
[2] N. Anfinov et. al., Letter of Intent: ArgonCube: A Modular Approach for Liquid Argon TPC Neutrino Detectors for Near Detector Environments (2018)
[3] J. Strait et. al., Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE): Coceptual Design Report, Vol. 3. LBNF-doc-10689 (2015)
[4] N. Anfinov et. al., Development of the Light Collection Module for the Liquid Argon Time Projection Chamber (LArTPC) (2020)
[5] M. Auger et. al., ArCLight – A Compact Dielectric Large-Area Photon Detector, Instruments 2018, 2, 3.
[6] D. A. Dwyer et. al., LArPix: Demonstration of low-power 3D pixelated charge readout for liquid argon time projection chambers
[7] A. D. Sakharov, Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe (1966)