DUNE detector

HEP instrumentation discussion

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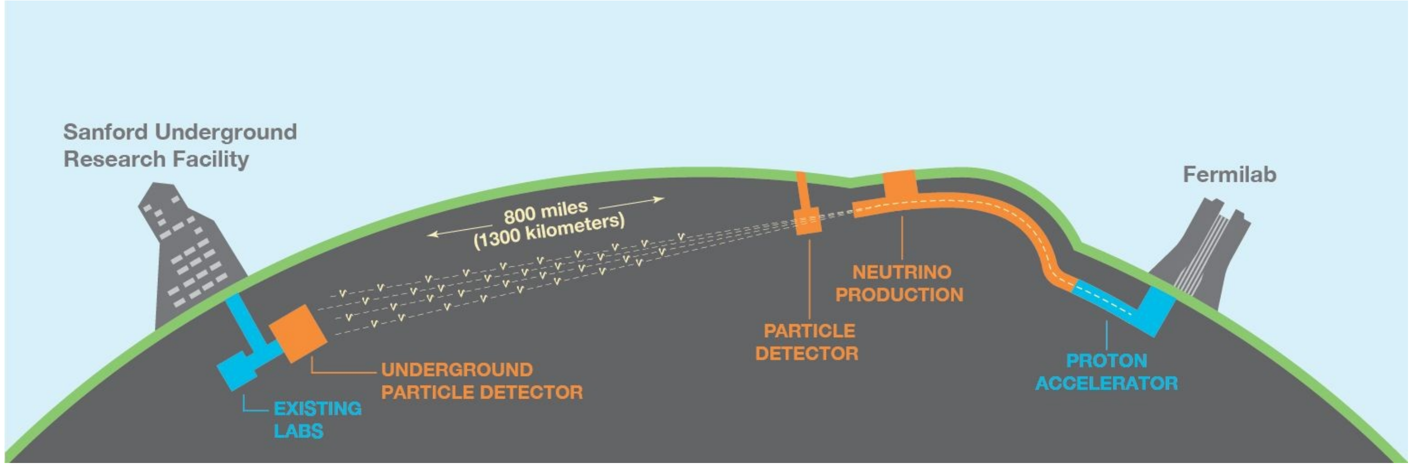
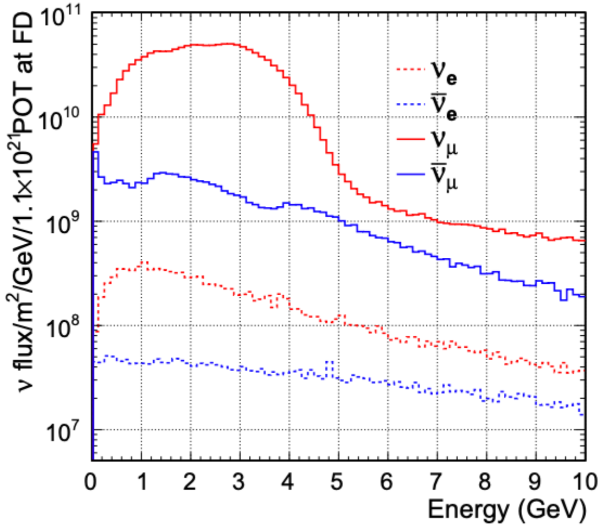
SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

Deep Underground Neutrino Experiment





Long baseline neutrino oscillation experiment. Using Liquid Argon Time Projection Chambers (LArTPCs).

Beam 120 GeV protons,10 μs spill, 1.4 Hz

Phase1 1.2 MW 20 kt FD
Phase2 2.2 MW 40 kt FD

Far Detector (FD)
1285 km from the first focusing
4x 10 kt fiducial mass LArTPCs, each 58x12x14 m^3
3.4 ν events per hour → simple (old tech)

Near Detector (ND)
574 m from the first focusing
150 t active mass 5x7x3 m^3
24 ν events/10 μs beam spill → lots of R&D

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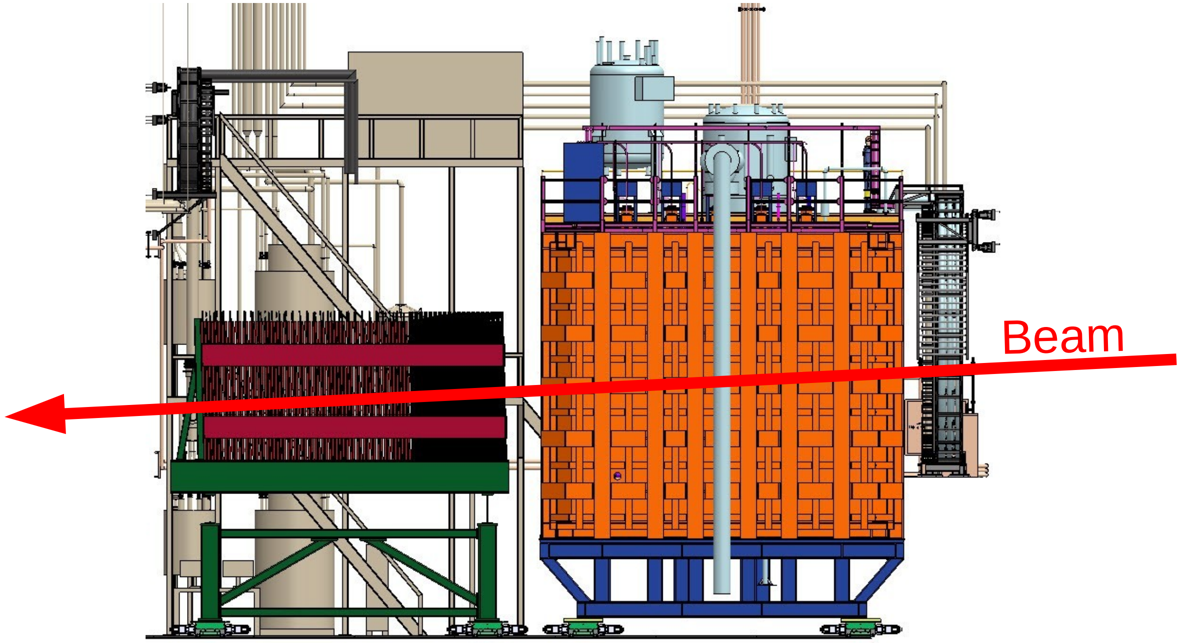
DUNE Near Detector

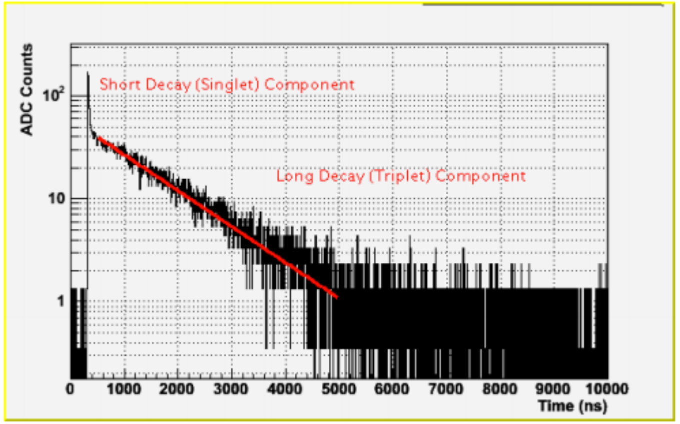
High-multiplicity environment means everything must be done to reduce pile up. MeV is priority, not meV.

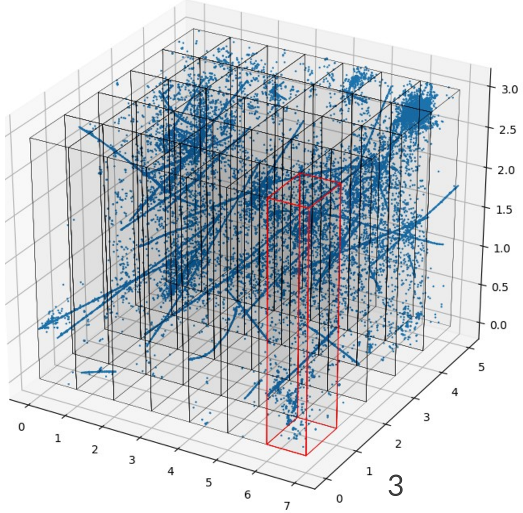
The detector is divided into a number of TPC modules (7x5) sharing a common cryostat.

Dimensions set for hadronic containment, relying on the spectrometer for muon momentum.

Short drift distances:
- Reduced Charge RO window (250 μs @ 0.5 m drift)
- Contained scintillation light (localized T0)
- Unambiguous pixelated charge readout



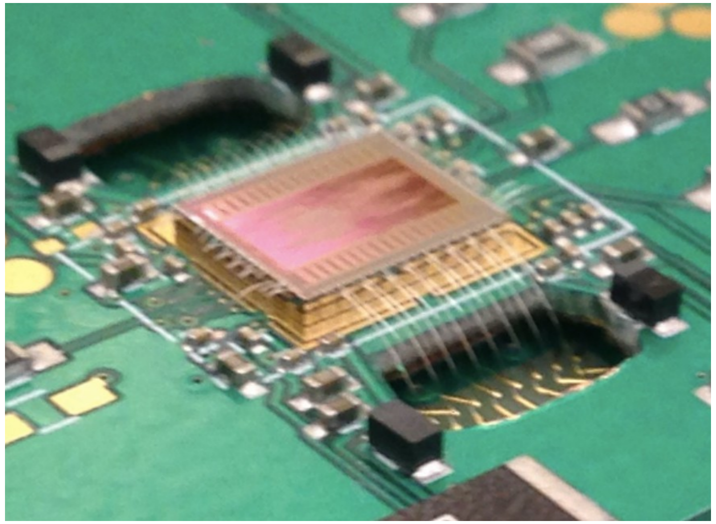


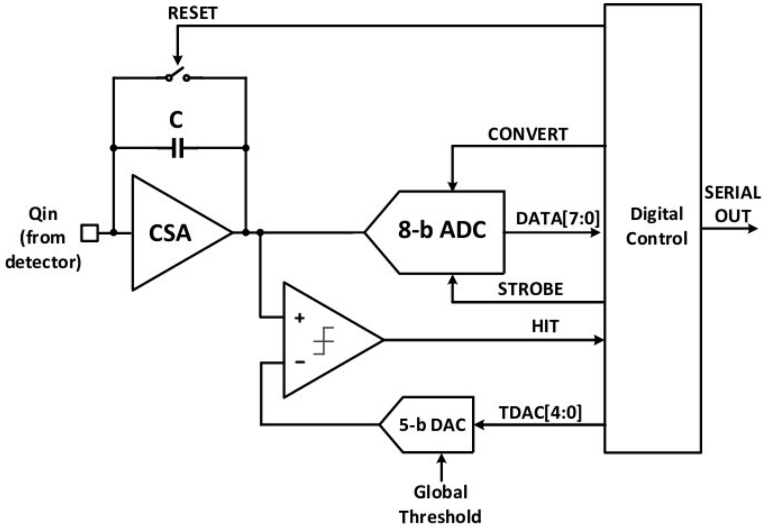


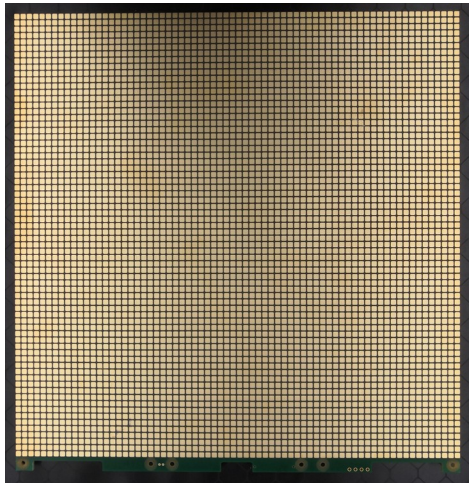
Unambiguous charge readout – Pixels!

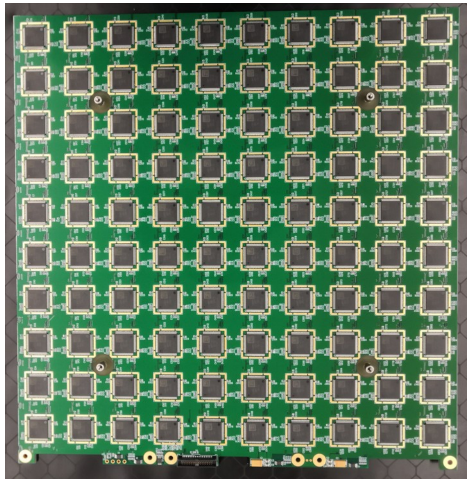
Pixels are not new to HEP, they are new to LArTPCs… Low-power cold amplification and digitization of every pixel is required for true 3D readout.

This was enabled by the LArPix ASIC, developed at LBNL, with support of Bern.
Power consumption per pixel: 62 μW (37 μW digital).
Data rate: O (0.1) MB/s/m2
NOT optimized for FD









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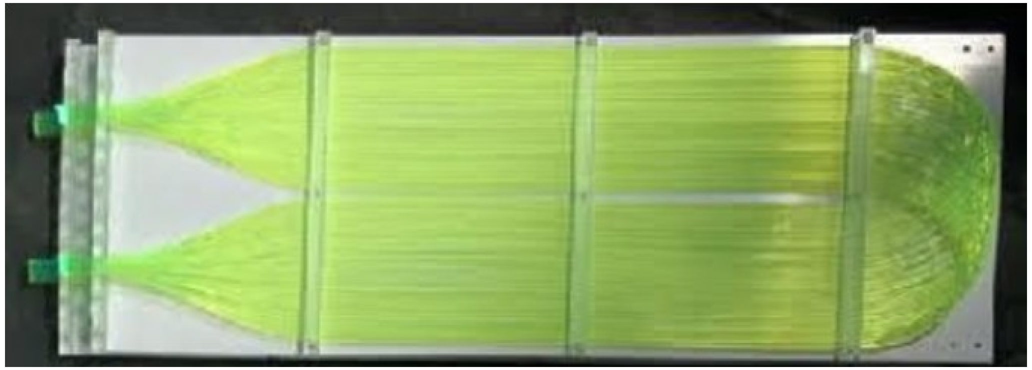
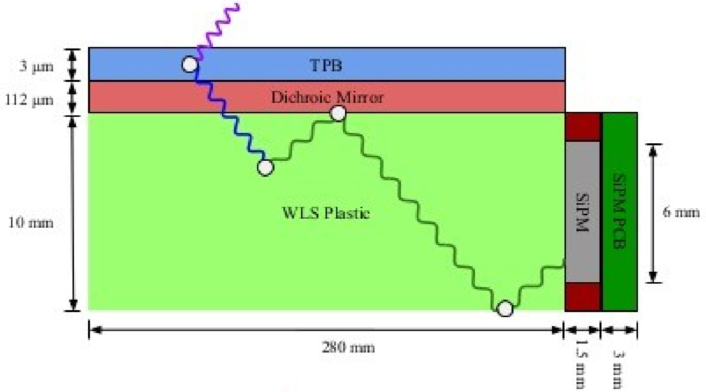
Dielectric light readout

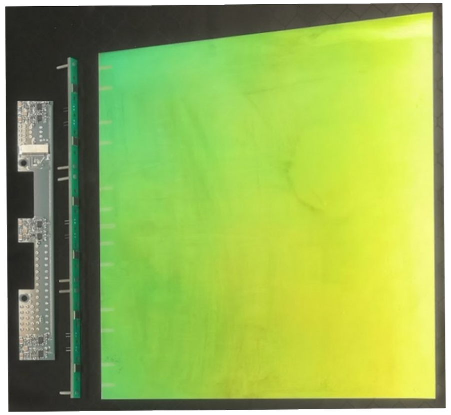
Typical light readouts are dielectric light traps coupled to SiPMs.

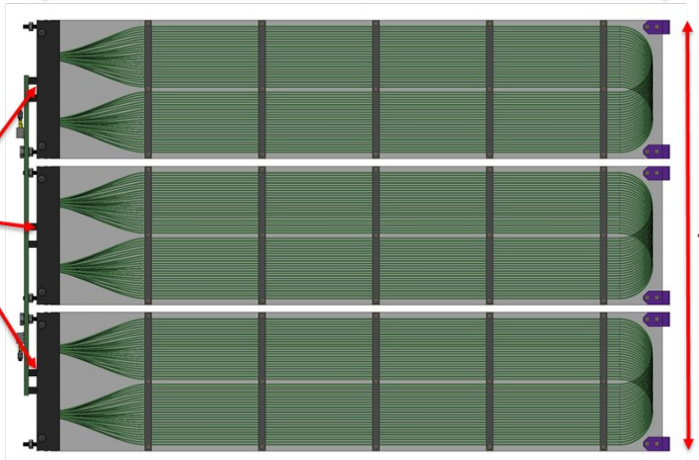
128 nm scintillation requires wavelength shifting to convert light to peak sensitivity for SiPMs (blue). Otherwise, SiPM coverage must be increased.

Cold pre-amplifiers are used, but still reliant on warm digitization. This is problematic for noise and signal feedthroughs.









What would be nice

Maximize active volume and improve time response.

Simplify construction - PCBs are easier to build with than wire planes. Especially at FD scale, where even focusing grids are as bad as wire planes.

Cold digitization of SiPM signals will make signal routing and feedthroughs easier. Will also reduce data rates and improve triggers.

Digital SiPMs would reduce cold component count and power consumption within the cryostat.

Improve timing by mitigating wavelength shifting – UV sensitive SiPMs

Increase SiPM coverage without reducing charge coverage – power over fiber has shown promising results for placing SiPMs within E-field instead of at anode.