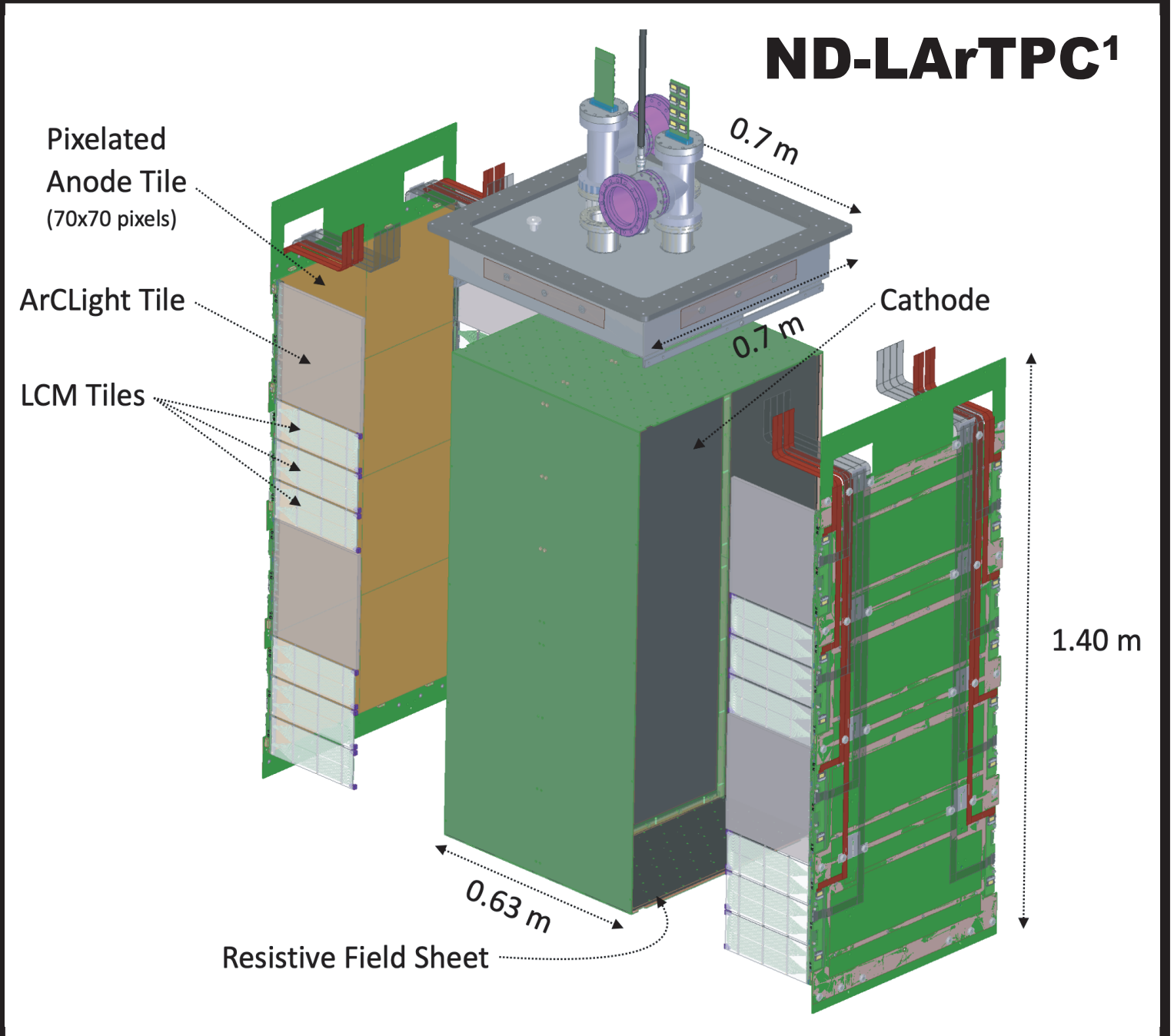
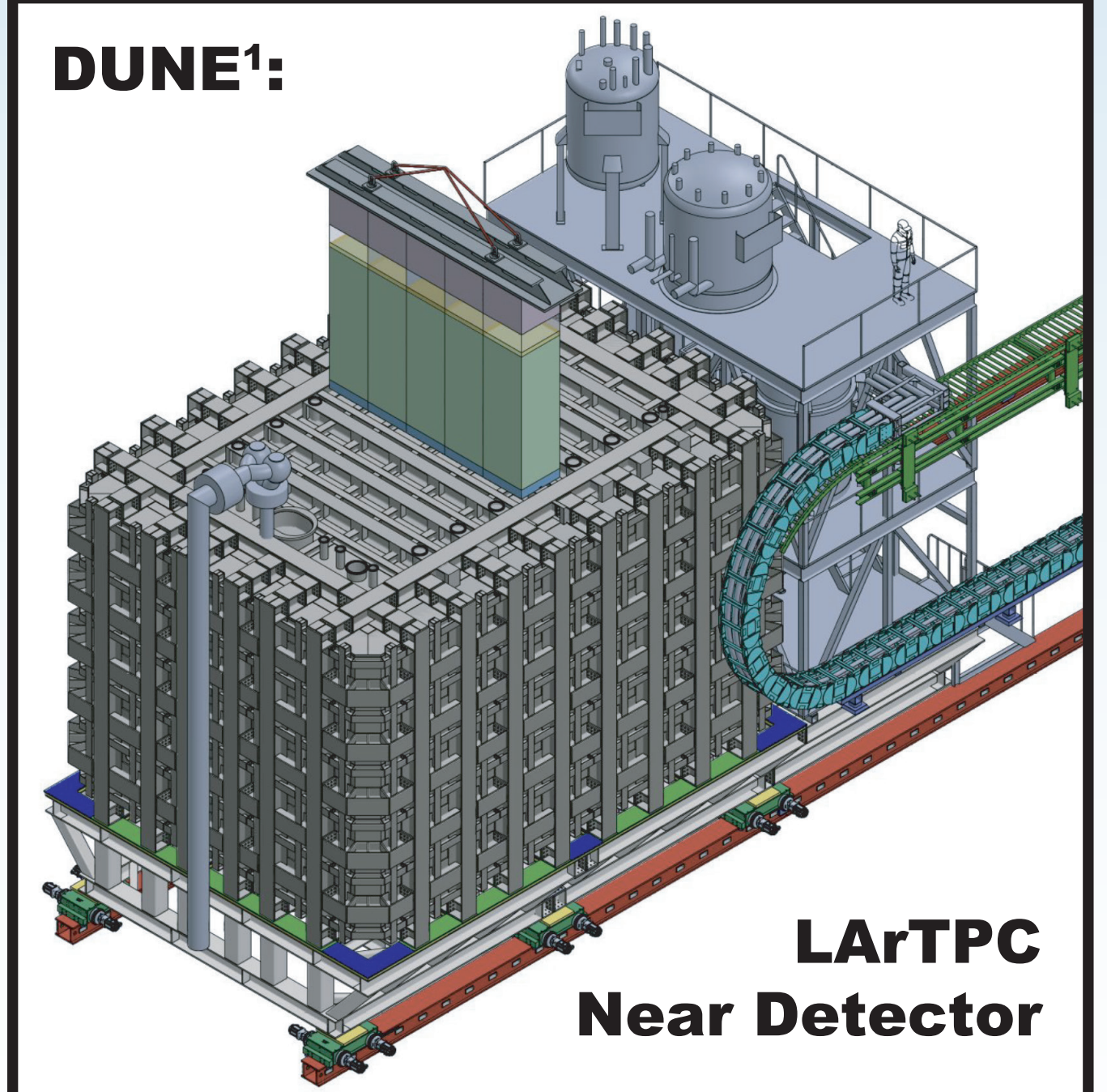


2x2 Demonstrator: High-Coverage Light Readout System in a Novel LArTPC

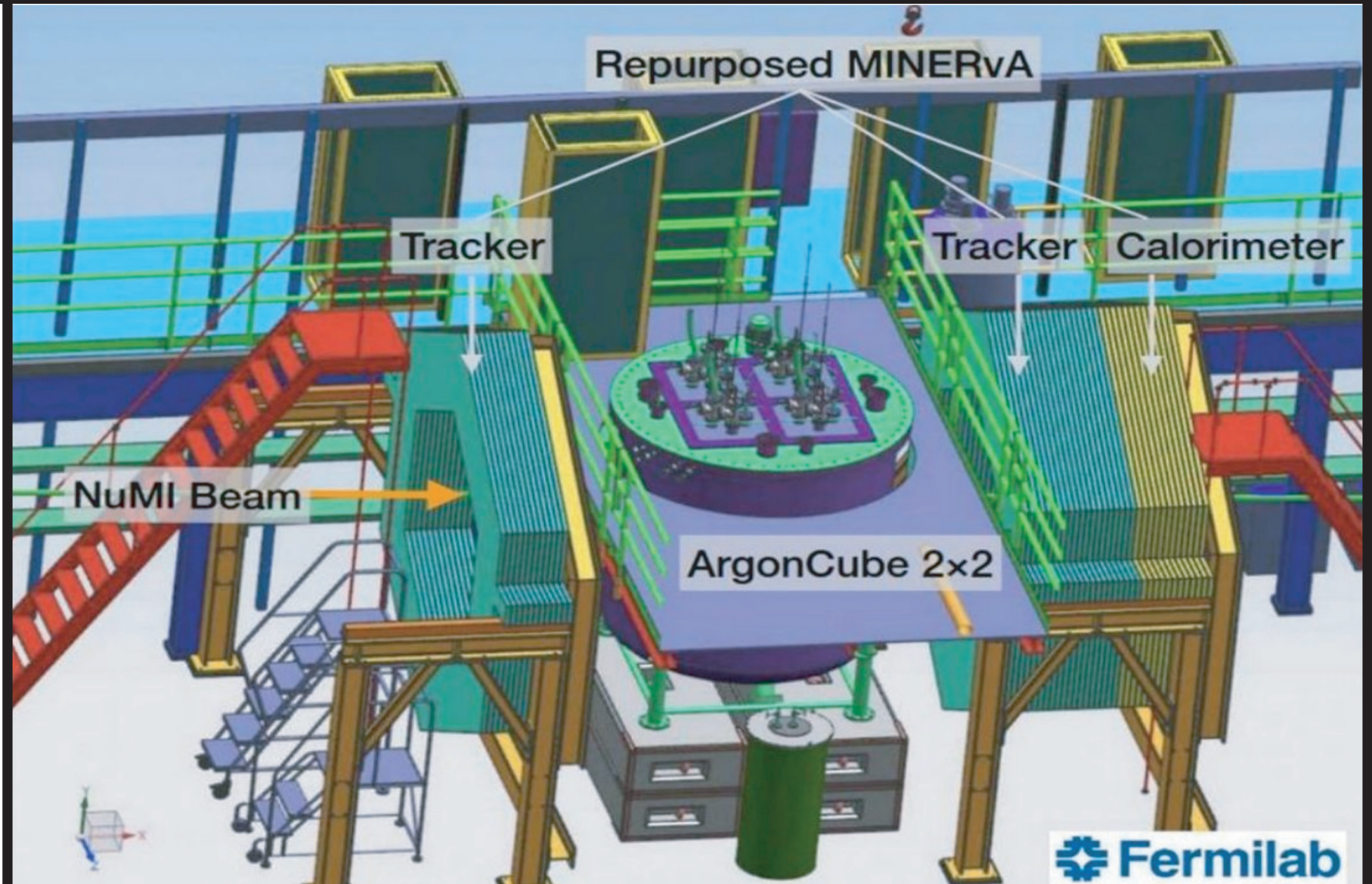
Angela J. White | ajwhite@uchicago.edu



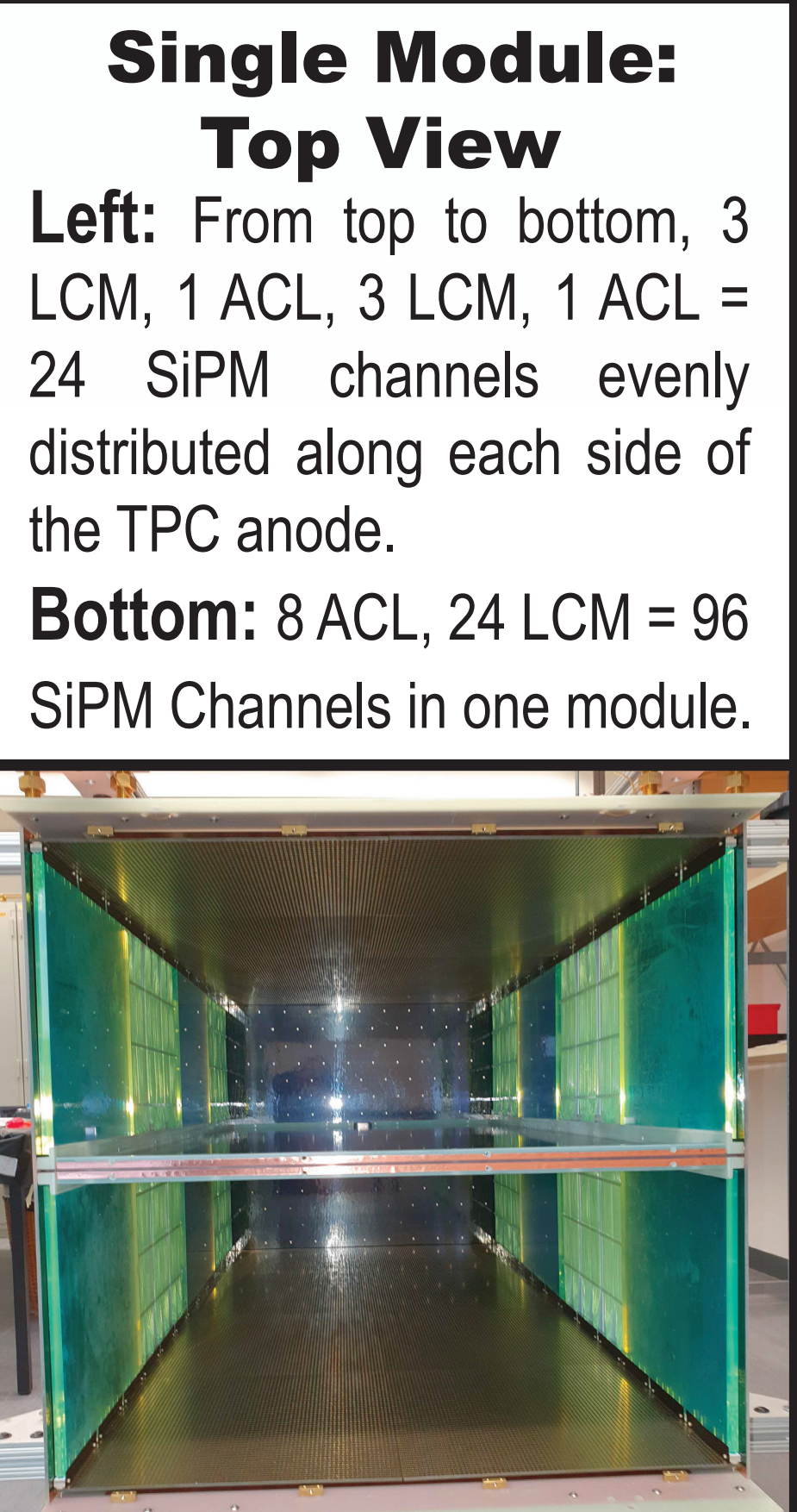
The Deep Underground Neutrino Detector (DUNE):



DUNE is a **long-baseline** Liquid Argon Time Projection Chamber (**LArTPC**) **neutrino oscillation experiment**. Its near detectors, located at Fermi National Laboratory, will **constrain systematic errors** on far detector measurements. The **2x2 Demonstrator**, a novel proof of concept prototype for the ND LArTPC, has a **modular TPC** design that **mitigates event pileup** in a **high-occupancy** nearline beam environment, further aided by a **native 3D pixelated** charge readout and a **30% coverage**, low profile light readout. This will be the first large-scale LArTPC to utilize pixels in place of wire planes.



2x2 Demonstrator¹: 104m belowground, four modular LArTPCs sit between muon tracking MINERVA planes, centered in a **muon anti-neutrino beam**.

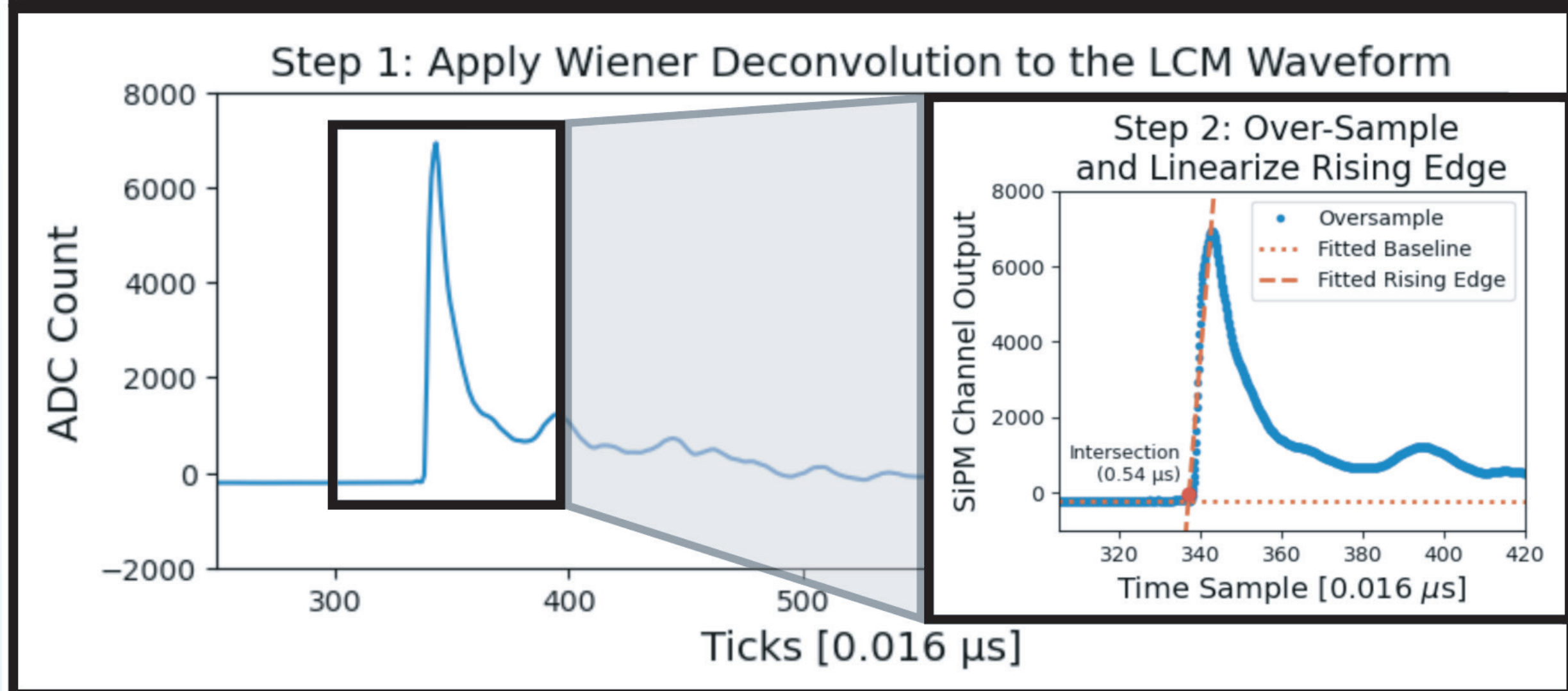
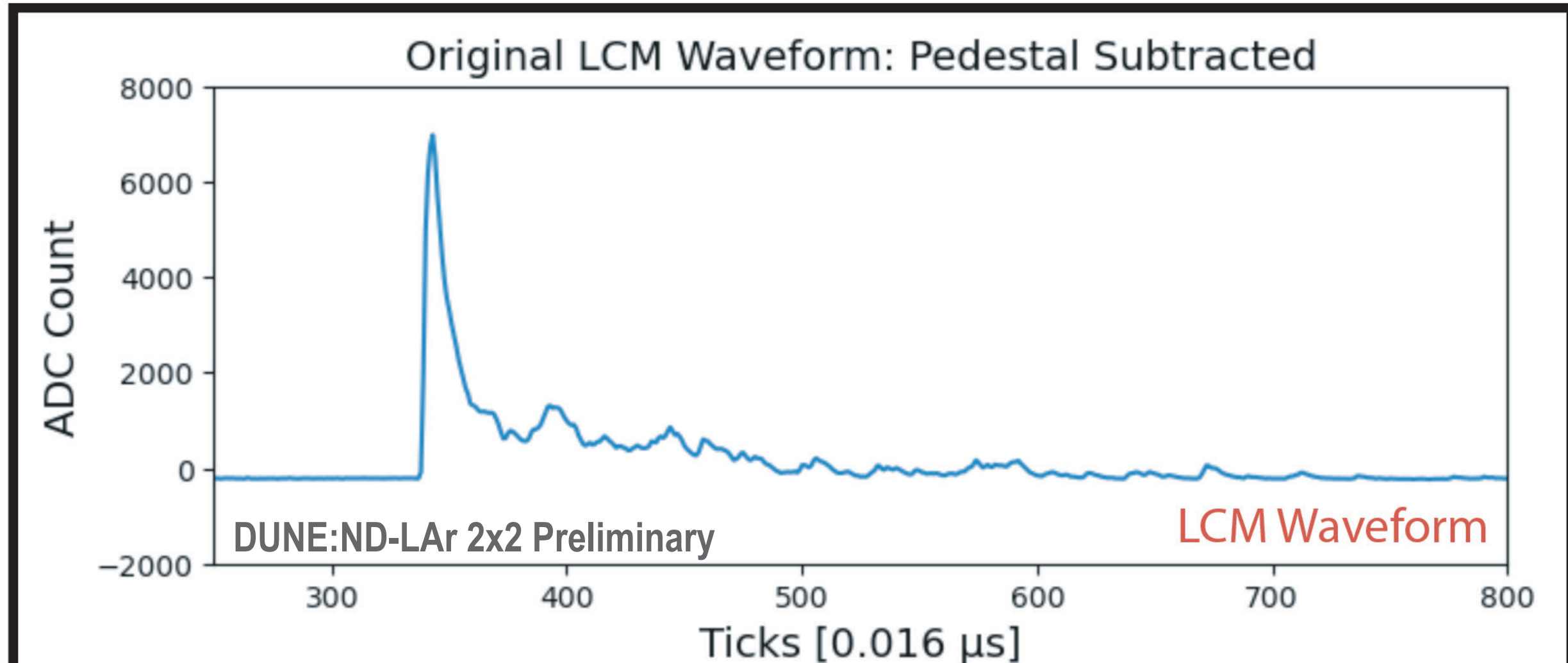
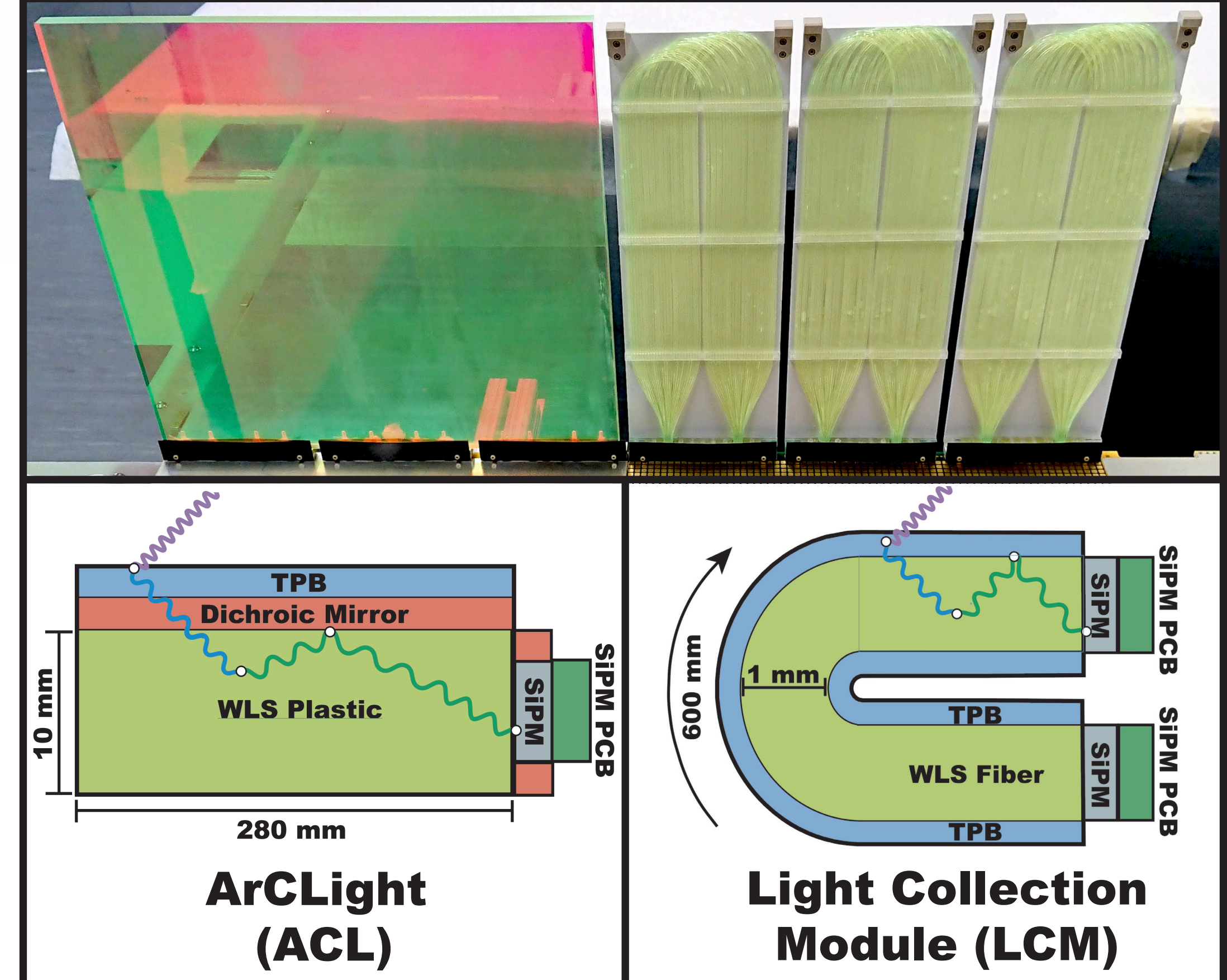


Light Readout System (LRS) Design:

The 2x2 Demonstrator LRS utilizes 384 Hamamatsu S13360-6050PE silicon photomultipliers (**SiPMs**) and two alternating types of **dielectric light trap**:

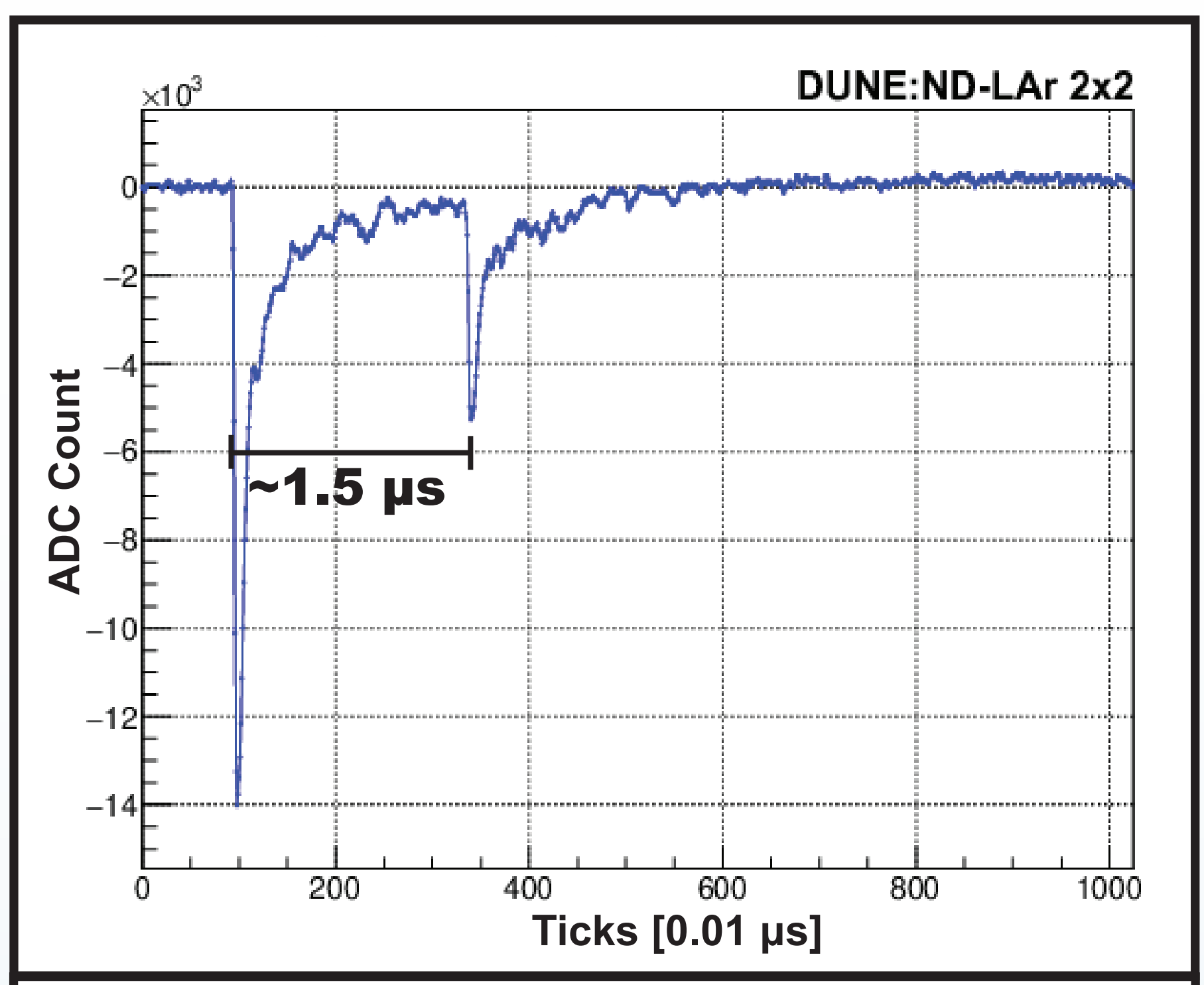
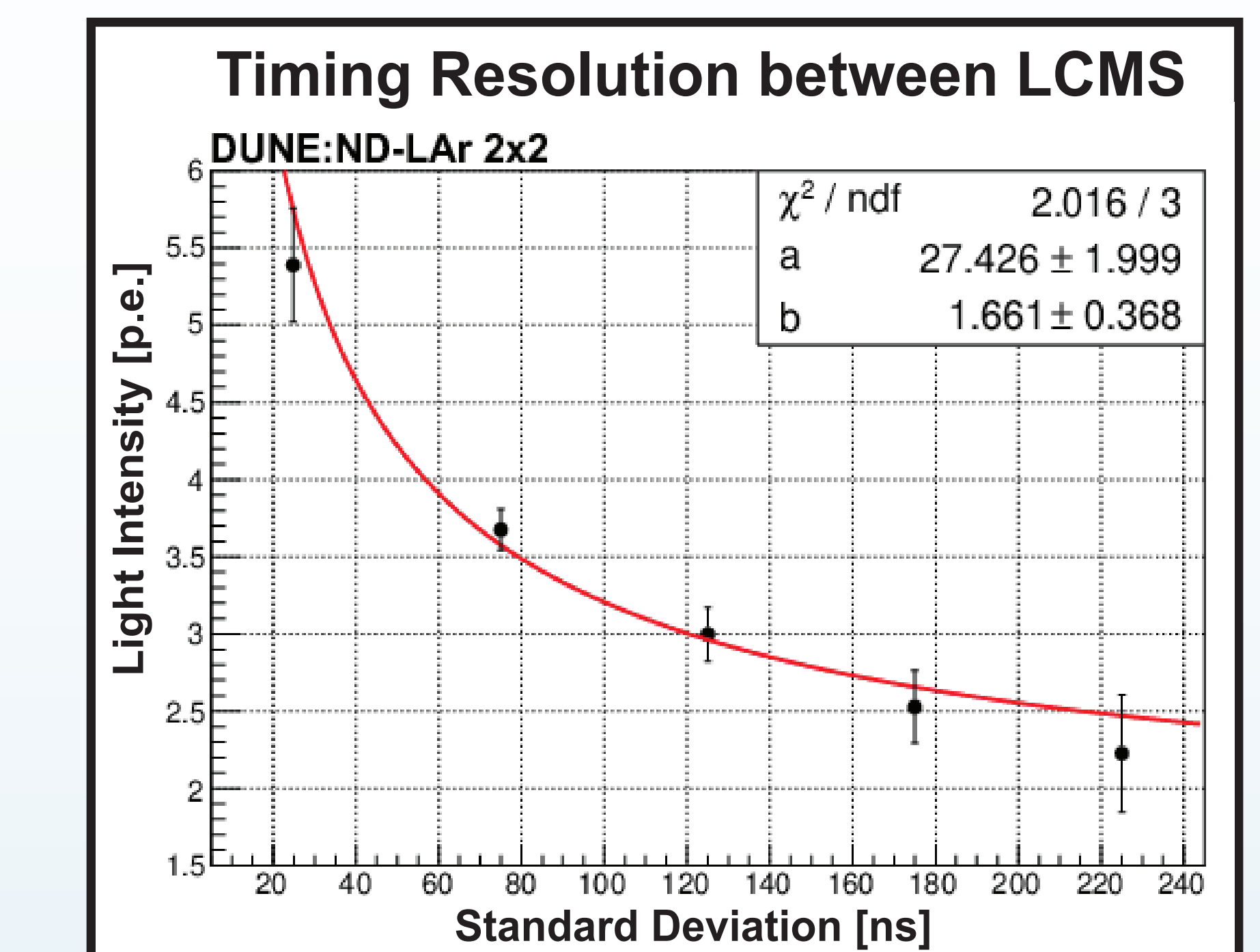
ArCLight³ (ACL)
Dimension: 30cm x 50cm x 1cm
Channels: 6 SiPM Channels distributed evenly along anode edge
Strengths: Spatial Resolution

Light Collection Module⁴ (LCM)
Dimension: 10cm x 50cm x 1cm
Channels: 2 SiPM channels distributed evenly along anode edge, coupled by wavelength shifting fiber
Strengths: Timing resolution, higher photon detection efficiency



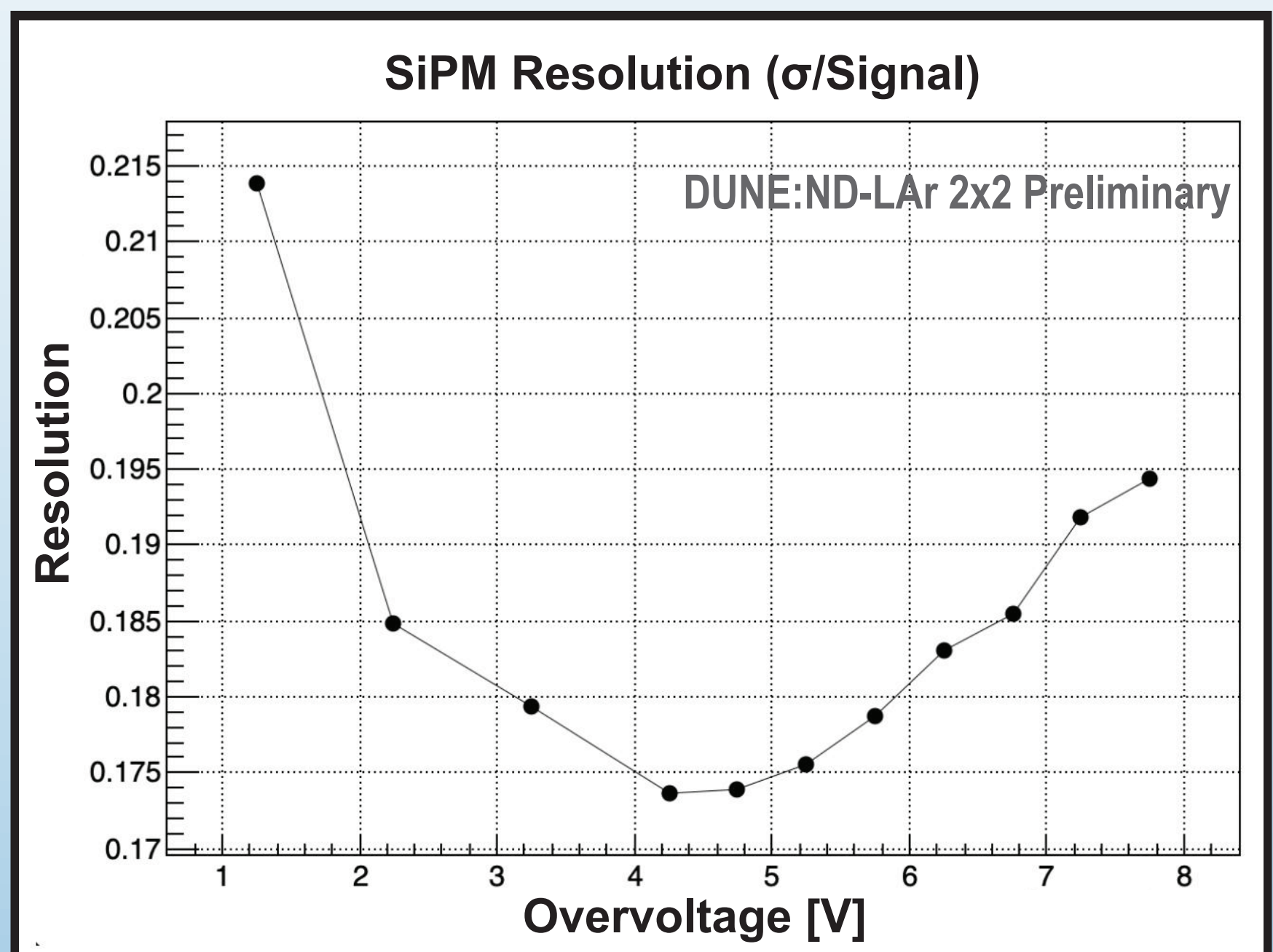
Timing Resolution and Charge-Light Matching:

LCM channel pairs coupled to the same WLS fiber will record light peaks occurring at the same time tick, within a range of error; this defines the LRS **timing resolution**. **Right:** precise timing of an LCM peak determined via oversampling. **Below²:** Timing differentials between coupled LCM channels across various peak amplitudes.

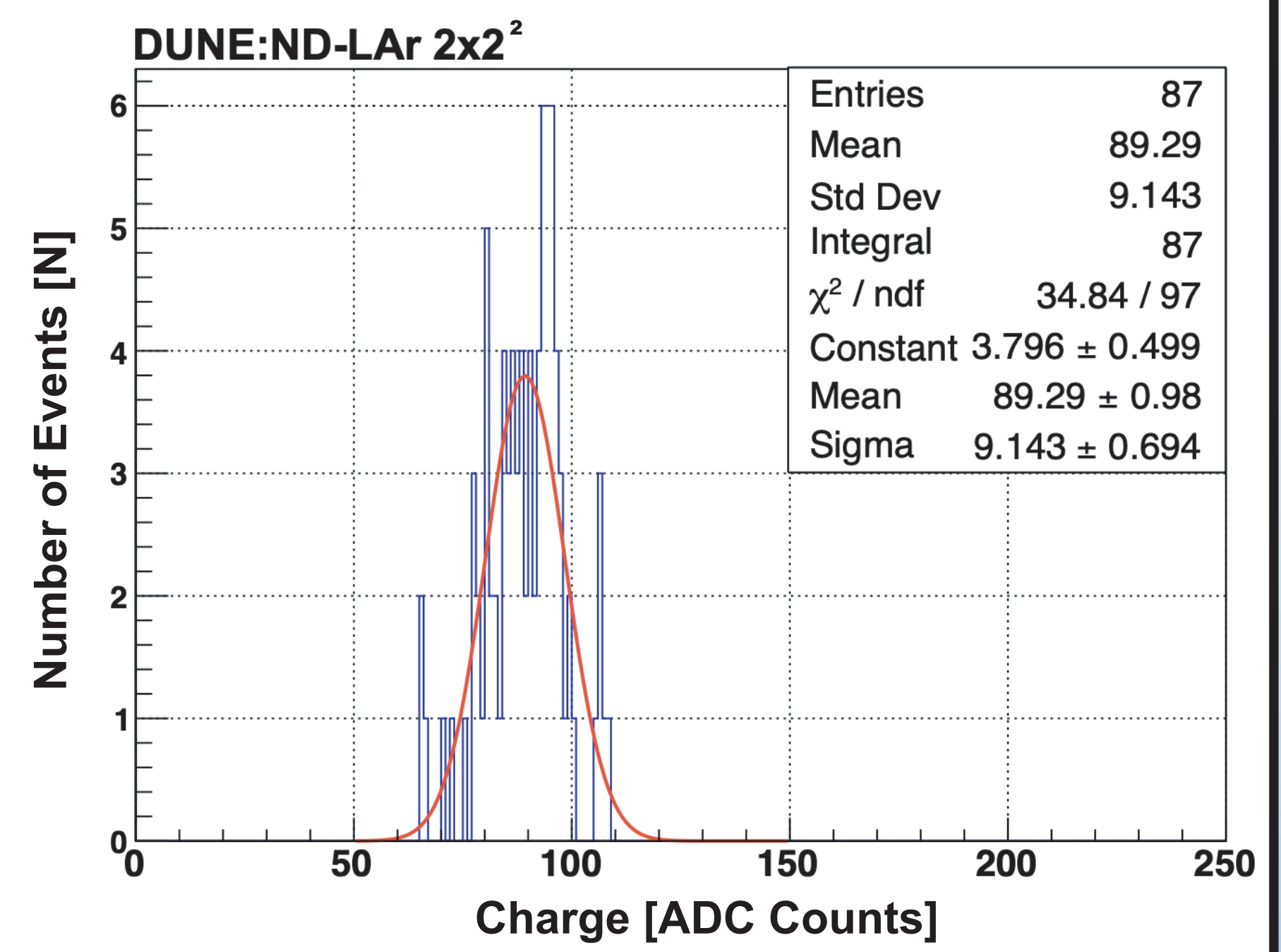
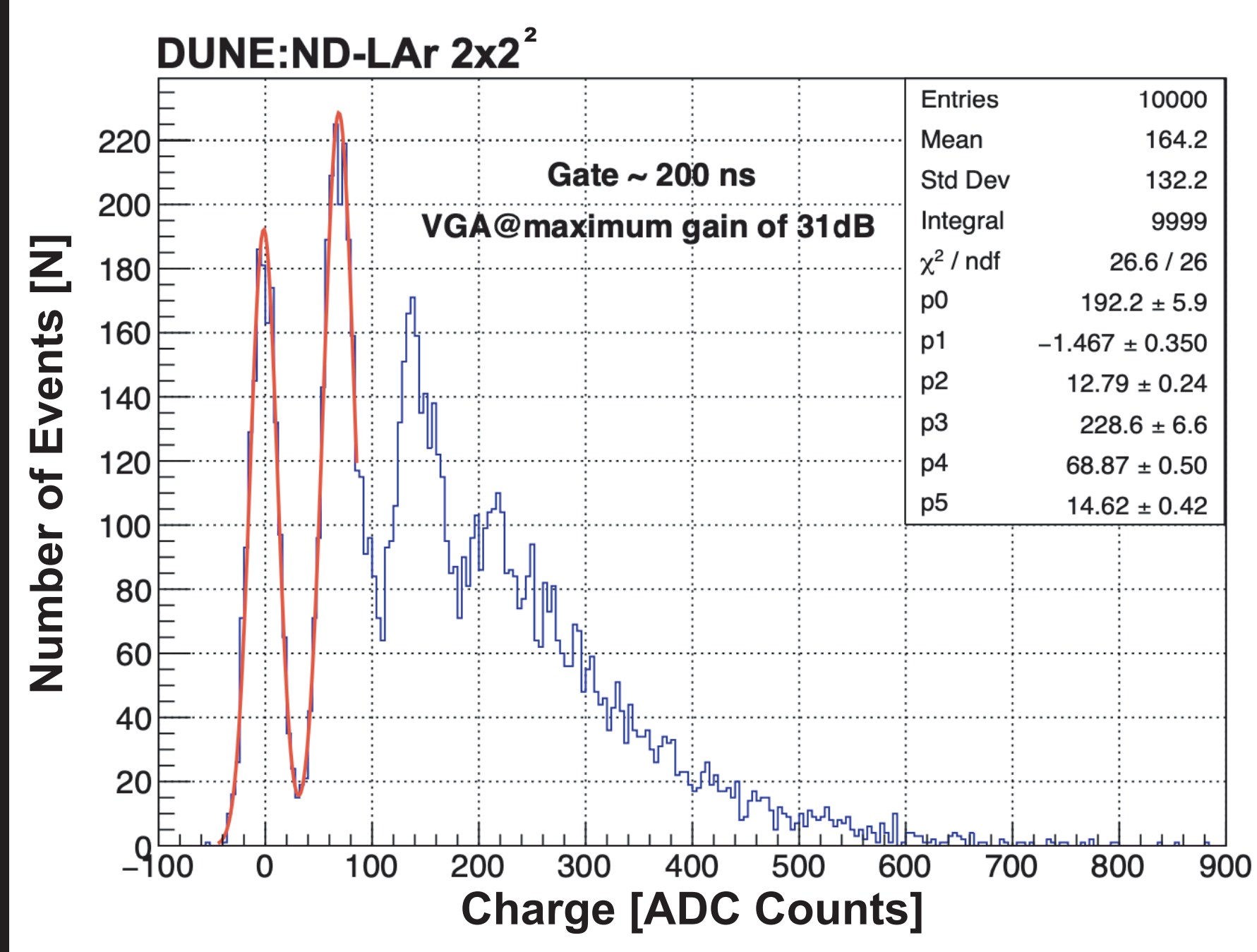


Stopping muons² with Michel electrons can be identified using just the light readout. The muon and electron peak separation is determined by the muon lifetime, which follows an exponential distribution with a mean of 2.2 μs—a clear signature given ns-scale resolution.

Calibrating Channel Gain/Resolution:



LEDs positioned at the top and bottom of each TPC are **flashed** or fed a sustained current while SiPM channels operate over a range of overvoltages. In this way, **overvoltage** is **optimized** for each channel, and channel **uniform gain** can be applied across the entire detector.



References

¹ DUNE Collaboration. Deep Underground Neutrino Experiment (DUNE) Near Detector Conceptual Design Report. Instruments 2021, 5. <https://doi.org/10.3390/instruments5040031>.

² DUNE Collaboration. Performance of a Modular Ton-Scale Pixel-Readout Liquid Argon Time Projection Chamber. 2024. <https://doi.org/10.48550/arXiv.2403.03212>.

³ Auger; et al. ArCLight—A Compact Dielectric Large-Area Photon Detector. Instruments 2018, 2. <https://doi.org/10.3390/instruments2010003>.

⁴ Anfimov; et al. Development of the Light Collection Module for the Liquid Argon Time Projection Chamber (LArTPC). Journal of Instrumentation 2020, 15, C07022–C07022. <https://doi.org/10.1088/1748-0221/15/07/c07022>.