



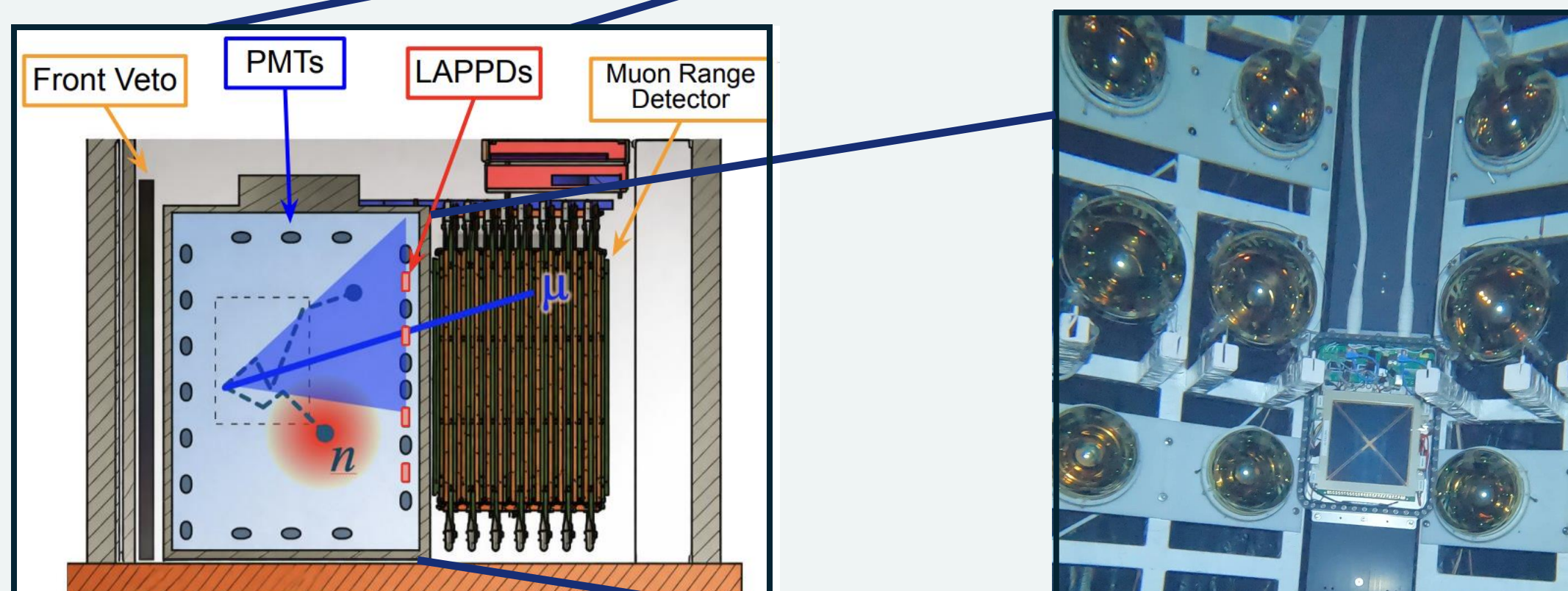
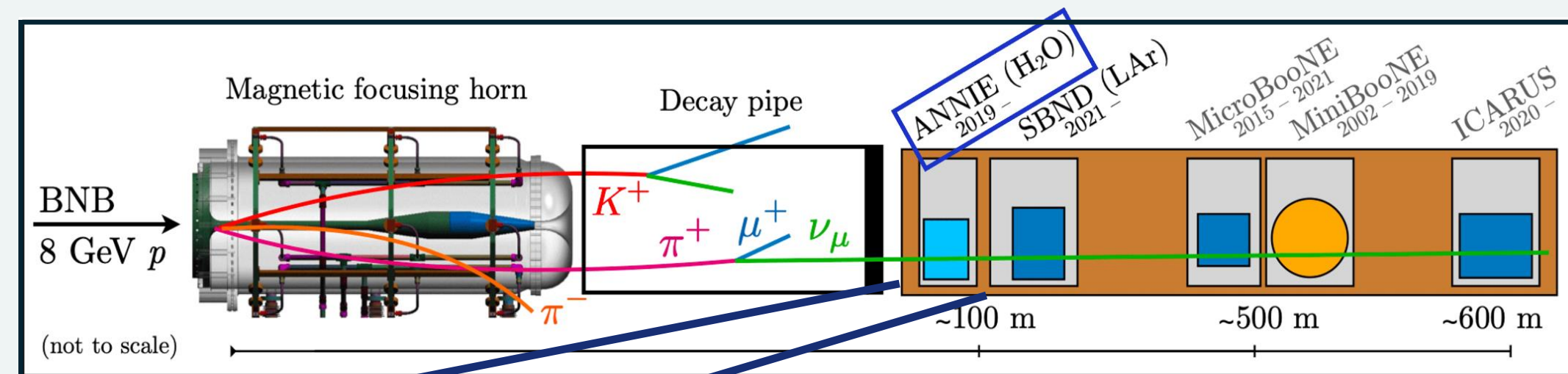
Neutrino Interactions observed with Large Area Picosecond Photodetectors in ANNIE

† Mohammad Adil Aman, Florida State University,
on behalf of the ANNIE Collaboration

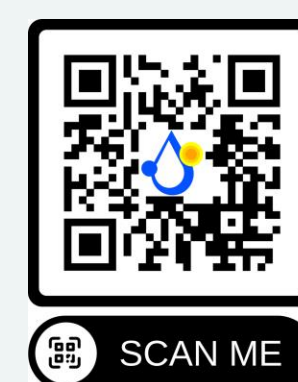
FERMILAB-POSTER-26-0112-V
† Mohammad Adil Aman : ma23f@fsu.edu

1. ANNIE : Accelerator Neutrino Neutron Interaction Experiment

- ANNIE is a 26-ton gadolinium-loaded water-based neutrino detector located at Fermilab, ~ 110 m downstream of the Booster Neutrino Beam (BNB).

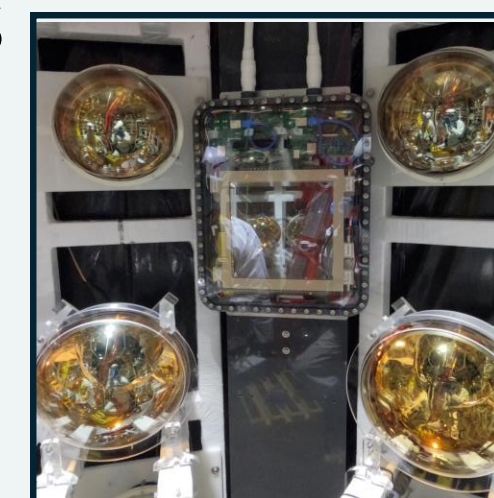


- ANNIE utilizes LAPPDs along with the conventional PMT array as LAPPDs provides picosecond-level timing and sub-cm spatial resolution, enabling precise neutrino interaction vertex reconstruction beyond the capabilities of PMTs alone.



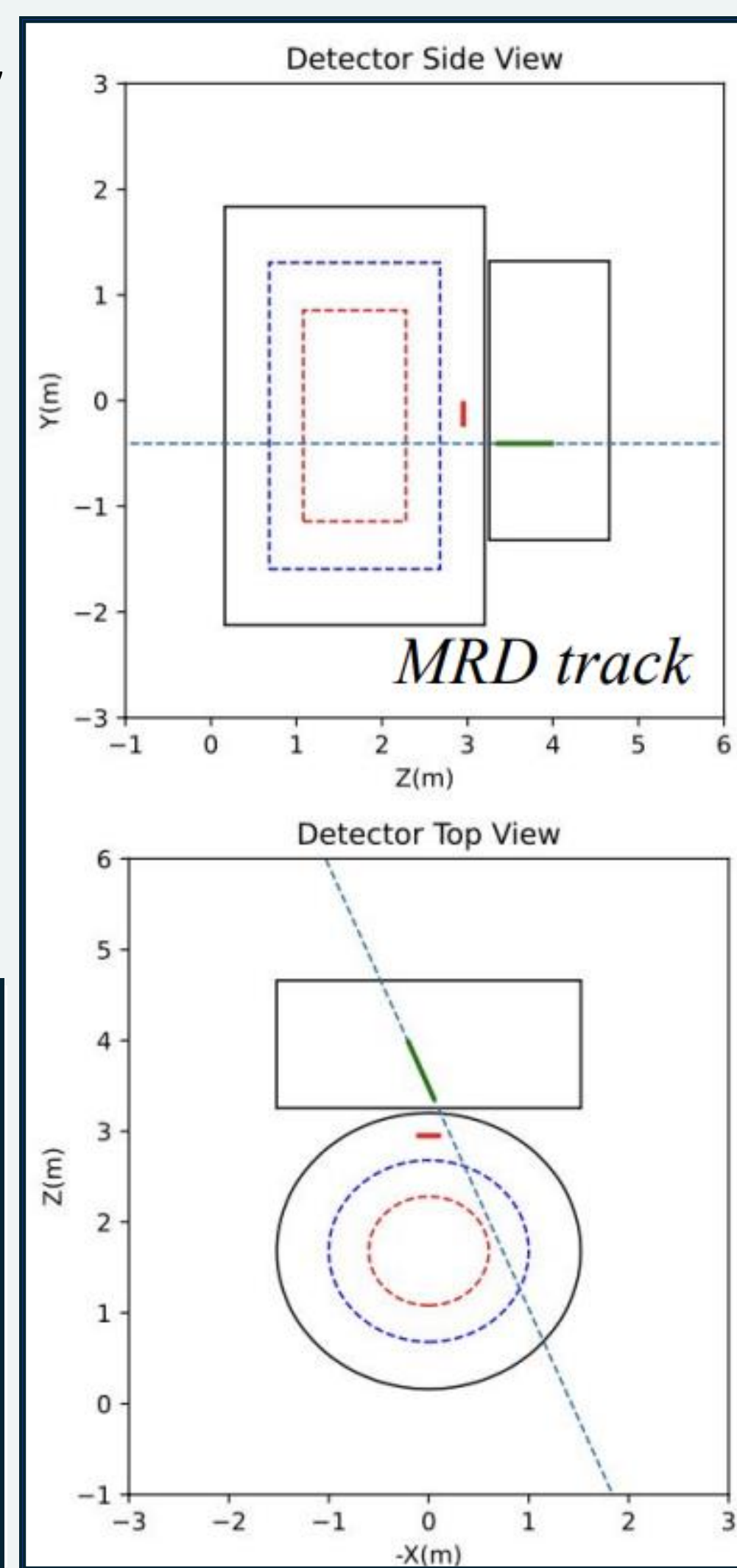
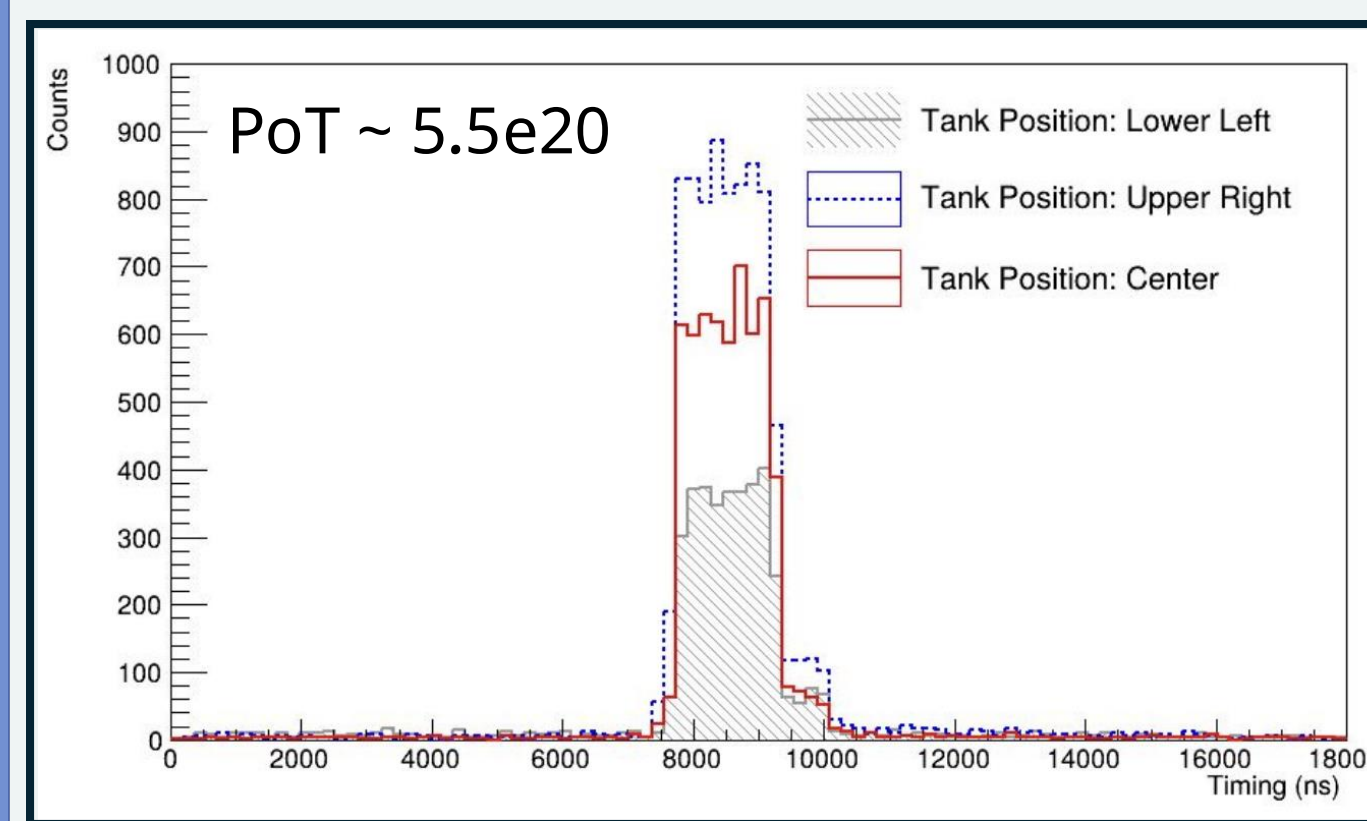
3. LAPPDs in ANNIE

- ANNIE uses INCOM-manufactured LAPPDs feature a 20x20 cm² active area, 60–100 ps time resolution, ~20% quantum efficiency with ~90% uniformity, and dark count rates as low as 150 Hz/cm².



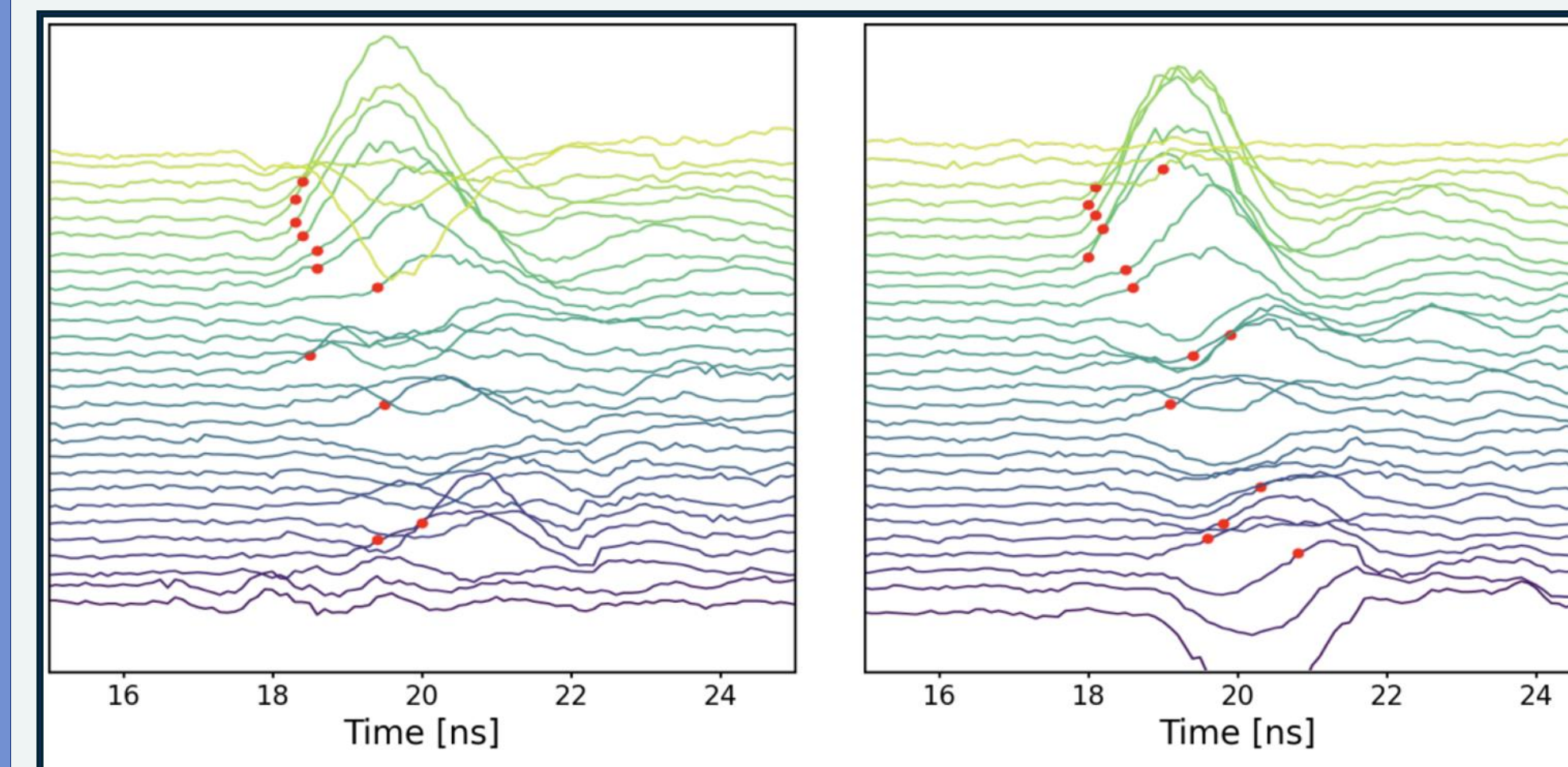
- The ANNIE event display combines PMT Cherenkov light, the MRD-reconstructed muon track, and the LAPPD position to visualize charged-current neutrino interactions

- The BNB delivers neutrinos in discrete 1.6 μs-long spills, within which multiple LAPPDs trigger autonomously; applying high-quality cluster cuts isolates beam-correlated events (*below*).



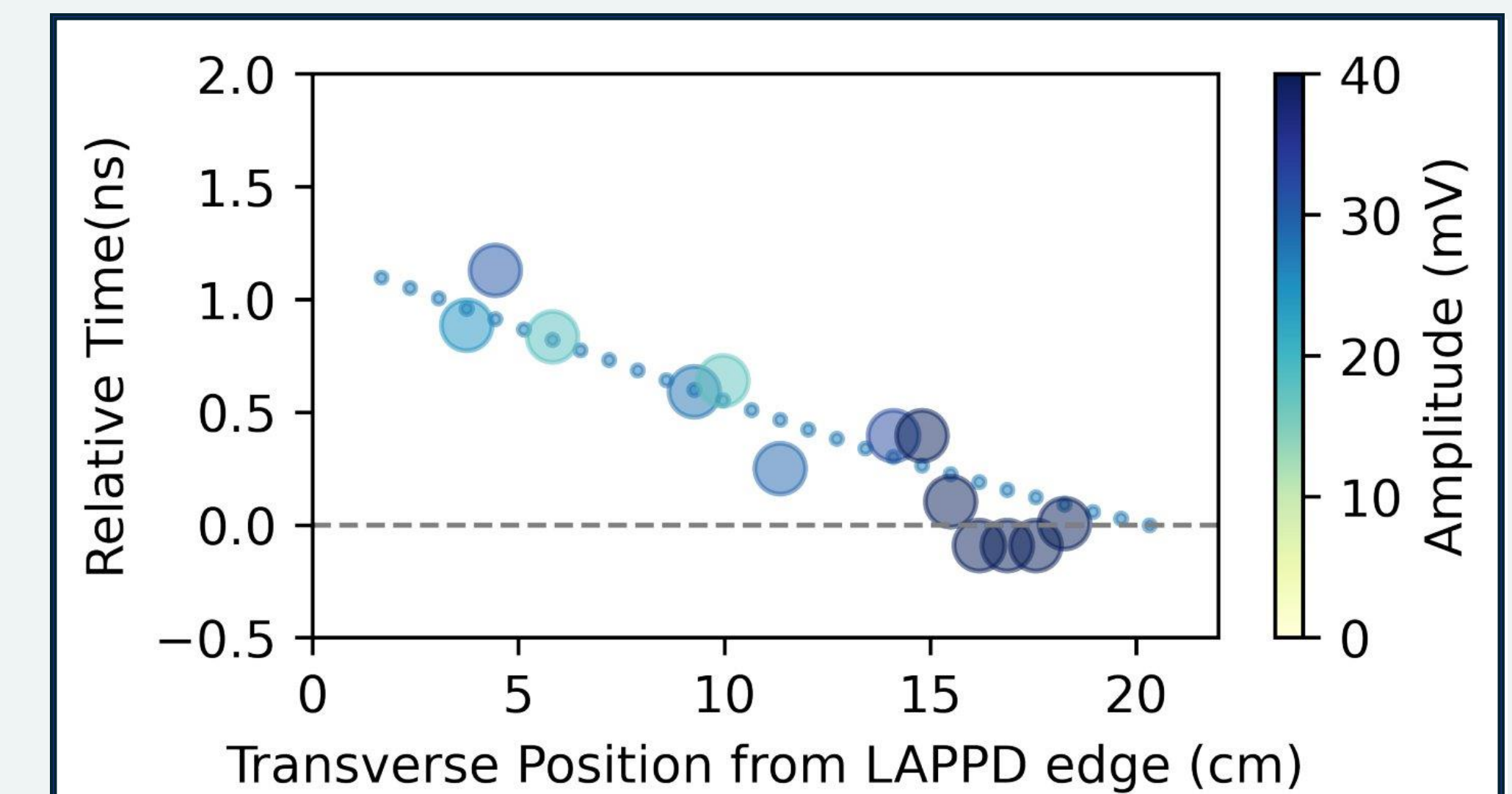
5. First Light from Beam Neutrinos on an LAPPD in ANNIE

- We present the first detection of neutrino-induced Cherenkov light with an LAPPD, marking a milestone toward next-generation picosecond-timing photosensors in large-scale high energy physics experiments.



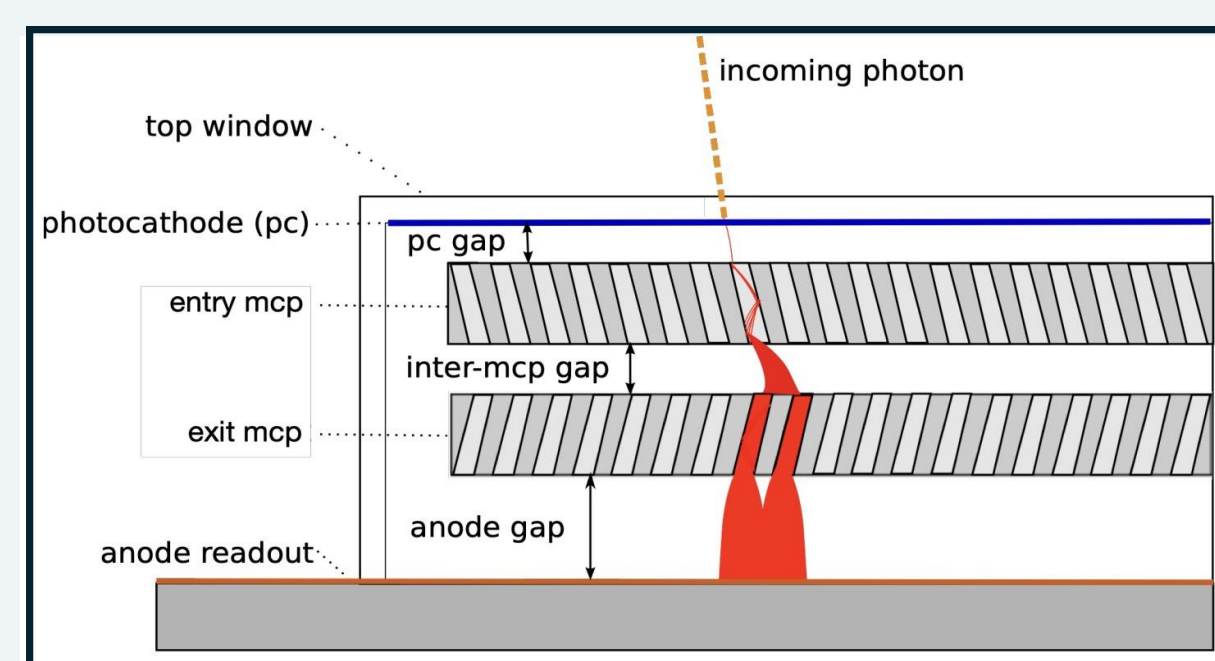
- ANNIE achieved the first deployment of an LAPPD in a running neutrino experiment via a custom waterproof module (PAL) with fast digitization and precision timing.
- The LAPPD waveforms (*on the left*) reveal a Cherenkov light timing gradient consistent with MRD-reconstructed muon track predictions, demonstrating spatio-temporal reconstruction with a single photosensor

- The LAPPD's picosecond timing and sub-cm position resolution map the Cherenkov cone with sufficient precision to constrain the muon track — and hence the neutrino interaction vertex — far beyond what conventional PMTs allow.
- (*On the right*) Relative photon arrival times show a clear gradient matching MRD-based muon track predictions.



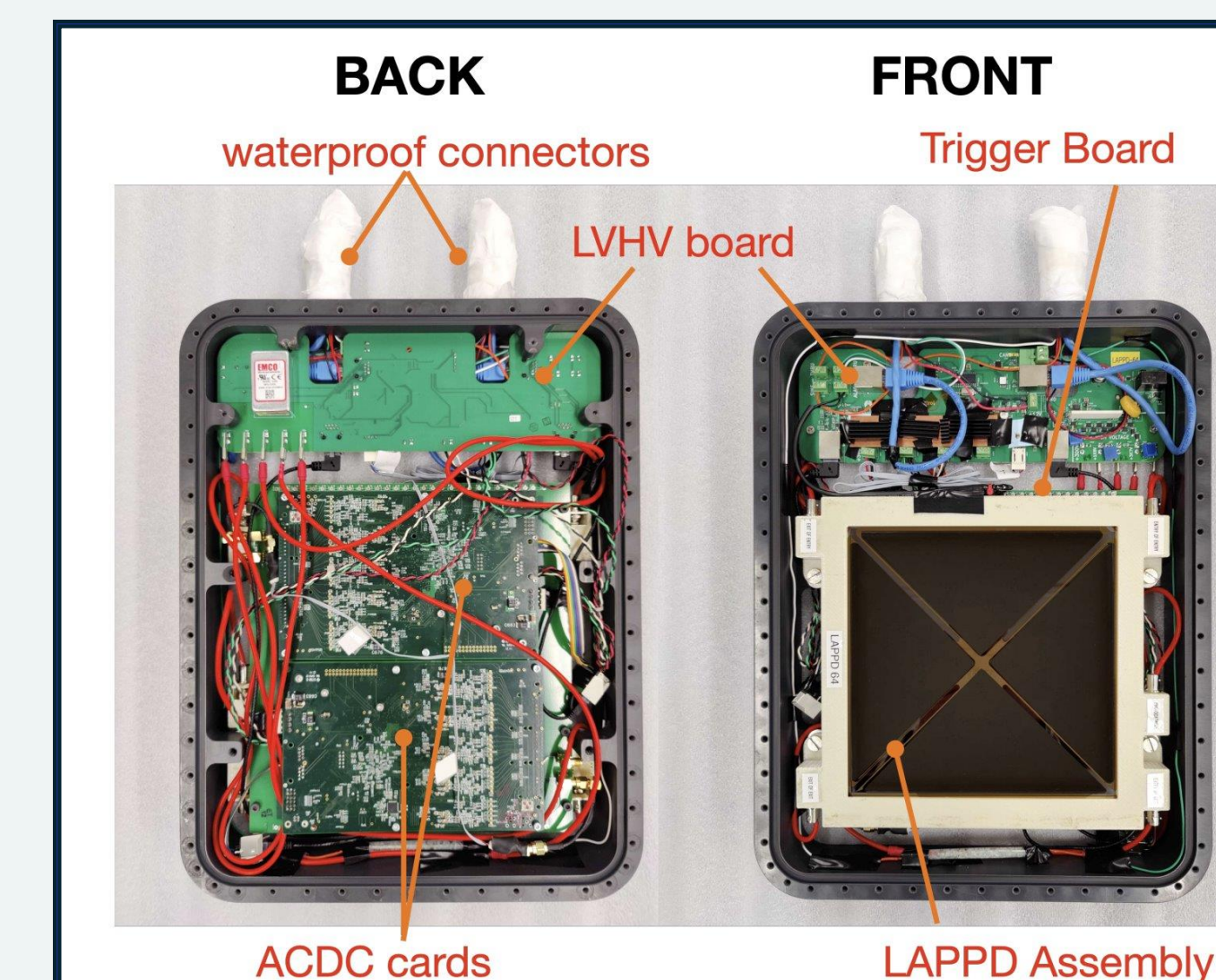
2. Large Area Picosecond Photodetector (LAPPD)

- LAPPDs are a novel technology offering picosecond temporal resolution and sub-cm spatial precision, surpassing conventional PMTs.
- LAPPDs use two MCPs (~1 kV) beneath a photocathode that converts photons into photoelectrons.



4. Packaged ANNIE LAPPD (PAL)

- To utilize the fast timing, the LAPPDs contain fast-electronics together inside a waterproof module
- The PAL is a waterproof module housing the LAPPD, ACDC readout cards for digitization, trigger board, and LVHV board for power and slow controls, enclosed within a PVC sidewall between a steel backplate and UV-transparent acrylic window.



Conclusion

- Multiple LAPPDs have been deployed in the ANNIE detector, providing the first use of this technology in a running particle physics experiment.
- These results establish a critical foundation for future ANNIE physics goals, including scintillation-Cherenkov separation using Water-based Liquid Scintillator (WbLS).
- Future upgrades to Generation II LAPPDs will further enhance timing and spatial performance

