Scalable water-based scintillators (WbLS), large-area picosecond photodetectors (LAPPDs), and low-power SoC readout for future neutrino detectors

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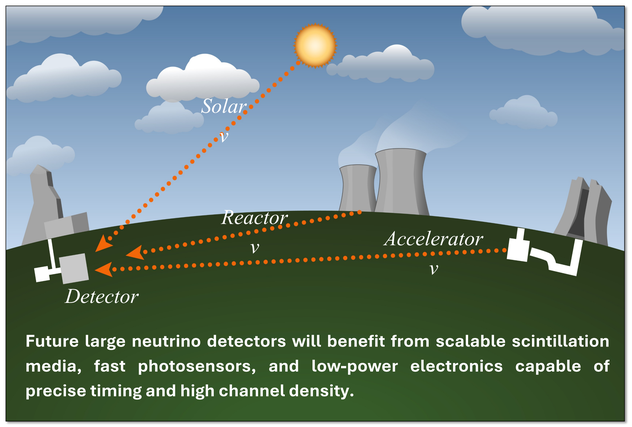
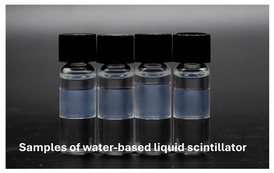


Future large neutrino detectors will benefit from scalable scintillation media, fast photosensors, and low-power electronics capable of precise timing and high channel density.

Two complementary R&D thrusts at LLNL

Scalable WbLS

LAPPDs (gen 2) with SoC readout


Samples of water-based liquid scintillator


64-channel Large Area Picosecond Photodetector


32-channel system on a chip

These R&D address an emerging need in next-generation neutrino detectors: precise, scalable timing readout and tunable scintillation media that can enable discrimination between Cherenkov and scintillation photons in WbLS. While motivated by long-baseline and reactor-antineutrino applications, the technologies are broadly applicable to rare-event searches and nuclear security–relevant radiation detection.

Acknowledgements

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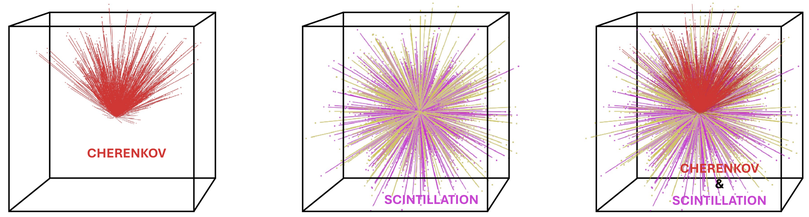
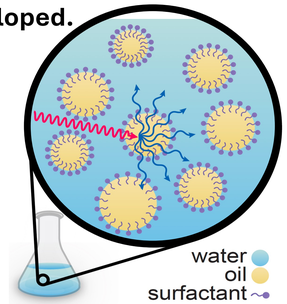
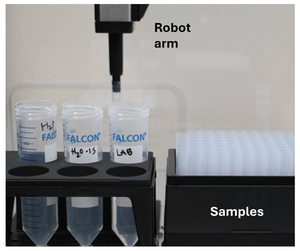
WATER-BASED LIQUID SCINTILLATORS with AUTOMATION

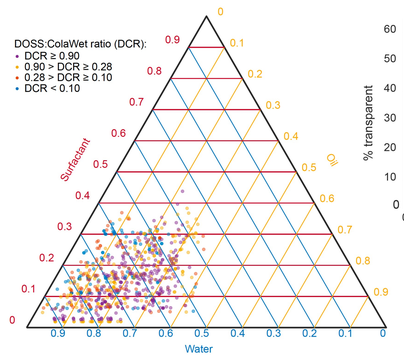


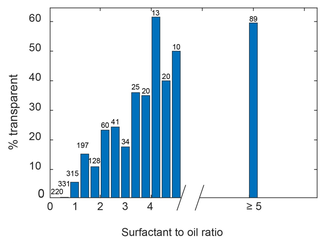
An automated, data-driven workflow for the synthesis and characterization of water-based liquid scintillators (WbLS) has been developed.



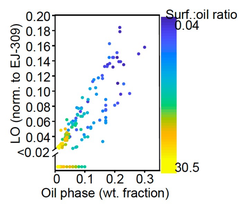


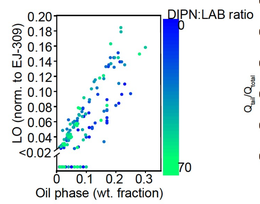
The system varies oil, surfactant, and water content to formulate and optimize WbLS, and has been used to synthesize and evaluate more than one thousand samples.

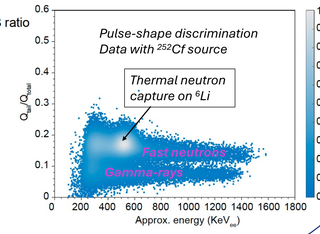




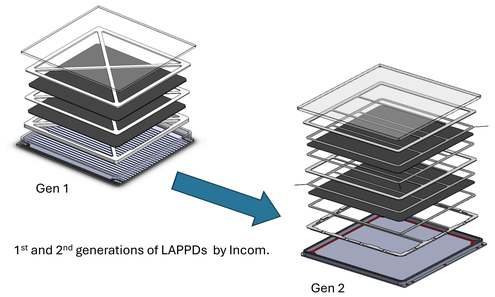
The automated platform reduces optimization time, enables statistically meaningful structure–property correlations, and supports rapid iteration toward application-specific WbLS, including formulations with dopants and pulse-shape discrimination capabilities.

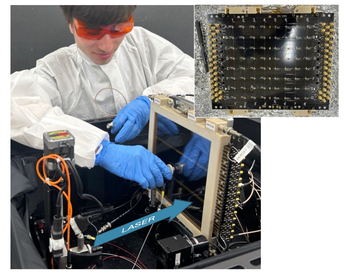




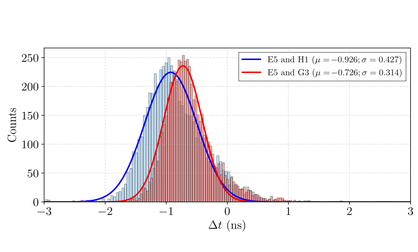


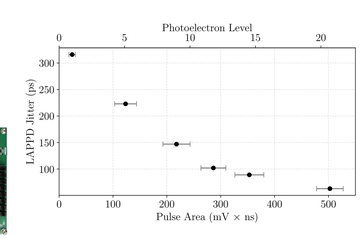
LARGE AREA PICOSECOND PHOTODETECTORS with SYSTEMS on a CHIP



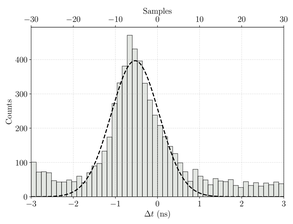


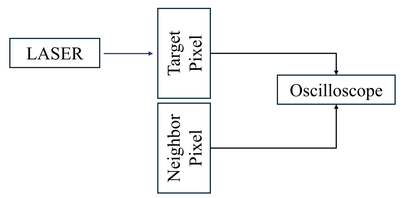
The initial integration and timing characterization of second-generation Large Area Picosecond Photodetectors (LAPPD Gen 2) with commercial multi-channel system-on-a-chip waveform digitizers from Nalu Scientific, in particular the 4-channel 10-GSa/s AARDVARC platform:

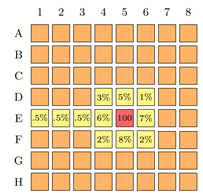


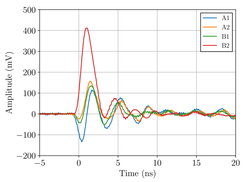


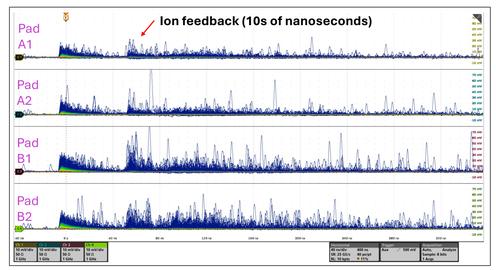
Using picosecond laser measurements, we demonstrate sub-100-ps-level timing performance and evaluate cross-talk and stability at the single-photon level, illustrating the potential of this scalable readout for large-area photosensor arrays.











- **New SoC integrated**
- **Temporal and special resolution measurement automated**
- **Ion feedback and electron backscatter characterized**
- **Ion feedback and electronic cross talk model developed**

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