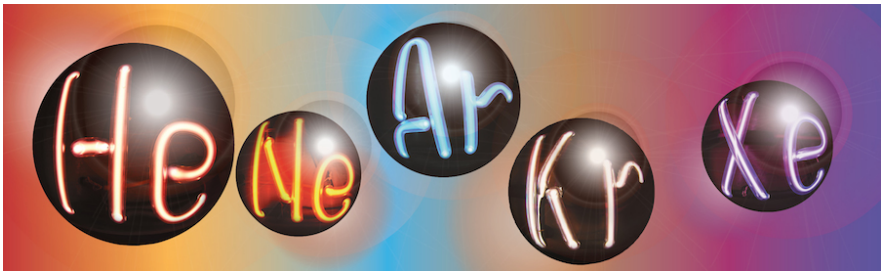

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Simulation Framework for the APEX Advanced Photon Detection System in Liquid Argon Test Apparatus

The Deep Underground Neutrino Experiment aims to explore fundamental neutrino properties and probe for physics beyond the Standard Model. DUNE's deployment involves constructing four large liquid argon time projection chambers, each utilizing a scintillation photon detection system for interaction timing, astrophysical triggering, and calorimetry. For modules 3 and 4, a detailed simulation is underway for a two-ton liquid argon test apparatus dedicated to evaluating "APEX"—an advanced PDS concept. To study several aspects associated with the unique operating conditions of the scintillation sensing devices under development, we implemented a comprehensive Monte Carlo simulation detailing the setup's geometry, optical properties, and particle interactions. The simulation records the essential physical data required for electronic readout digitization. This work presents findings on the apparatus's capability to determine signal-to-noise ratio, single photo-electron pulse shapes, and timing characteristics (rise and decay times). Finally, we discuss the platform's utility for evaluating detection efficiency, optimizing electronic dynamic range, and assessing how various parameter choices impact device performance.

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