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Optical Simulations in the LEGEND-1000 Outer Argon Shielding

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The LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double-beta decay) project searches for neutrinoless double-beta decay in ^{76}Ge, aiming to operate at the ton-scale in its second phase (LEGEND-1000). The first phase, LEGEND-200, uses a light detection system to detect energetic events in the liquid argon shielding surrounding the ^{76}Ge crystals, taking advantage of argon's natural scintillation. The current baseline design of LEGEND-1000 has an inner liquid argon volume (comprised of "underground argon") with light detection instrumentation, and an outer liquid argon volume (comprised of "atmospheric argon"). This work investigates the possibility of adding light detection instrumentation to the outer liquid argon, for the purpose of identifying additional types of background signals, which can then be vetoed. This work includes two sets of Geant4-based simulations: one to model cosmic muon-induced neutron capture in the liquid argon of LEGEND-1000, and another to model scintillation light production and propagation. Inspired by a similar tool applied in GERDA and LEGEND-200, a three-dimensional optical map has been constructed from the scintillation simulations. This map has been built in a generalized fashion and can be applied to any well-defined set of light detection instrumentation placed along the neutron moderator of LEGEND-1000, allowing the same map to be used for multiple configurations. This work discusses the simulation production flow and the building of the optical map. It will also discuss the post-processing to apply the optical map to a LEGEND-1000 simulation data set, as well as showcase a set of plots for data analysis and optimization of the instrumentation.

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