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Multilayer Coating Simulations for Enhanced Photon Detection in Particle and Astroparticle Physics

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Photon detection efficiency (PDE) is a critical parameter in semiconductor and vacuum photodetectors used in particle and astroparticle physics experiments. Enhancing PDE in the relevant wavelength range and suppressing background photons are essential for optimizing experimental performance. Reflectance and transmittance at the photodetector surface, typically estimated using Fresnel's law, are key factors influencing PDE. However, the actual surface of silicon photomultipliers (SiPMs), particularly those without resin coating, resembles a multilayer structure due to the presence of SiO_2 and Si_3N_4 layers, making a simple two-media boundary model insufficient. To accurately model and improve SiPM PDE across different wavelengths, simulations of interference effects are required. Beyond photodetectors, multilayer coatings are also applied to other optical components such as Winston cones and telescope mirrors, which are crucial for detecting more signal photons, such as blue Cherenkov photons. These simulations necessitate the integration of both photon tracking (ray tracing) and multilayer analysis. While Geant4 and ROOT-based simulator for ray-tracing (ROBAST) are widely used for optical photon tracking in this field, they lack built-in multilayer simulation functionality. To address this gap, we have extended ROBAST to incorporate multilayer simulation capabilities, enabling unified ray-tracing and multilayer analysis within a single framework. This contribution presents the newly developed functionality in ROBAST and provides simulation examples from gamma-ray and cosmic-ray telescopes.

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