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Comprehensive Characterization of Photomultiplier Tubes for Next-Generation Neutrino Detectors at the CAPACITY Laboratory

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The precise characterization of photomultiplier tubes (PMTs) is critical for the advancement of next-generation neutrino detection experiments. At the CAPACITY laboratory, we have developed dedicated measurement setups to investigate the quantum efficiency (QE) and performance of PMTs with diameters of up to 20 inches. Our system enables radial and surface scans of the photocathode with three translational and two angular degrees of freedom, allowing for high-resolution QE mapping and controlled variation of the incident light angle.

These measurements are conducted across the ultraviolet (UV) to near-infrared (NIR) spectral range, utilizing both continuous light sources and picosecond pulsed lasers at six distinct wavelengths.

In addition to QE characterization, we have conducted systematic studies on the effects of intense light exposure and elevated temperatures on photocathode degradation. The temporal evolution of QE post-exposure is analyzed to assess long-term stability. Furthermore, we employ an absorption spectroscopy setup to monitor, in real time, the diffusion of cesium within the PMT glass bulb—an essential process linked to photocathode degradation.

For large-scale performance evaluation, we use a dedicated dark box to test up to 62 PMTs simultaneously. Each PMT is equipped with the digital base developed for the KM3NeT experiment. In this setup, time-over-threshold (TOT) signals, generated by laser illumination of the PMTs, enable precise assessment of timing resolution and dark noise characteristics. This work plays a key role in completing the KM3NeT neutrino telescope and optimizing the performance of its detection units for deep-sea neutrino observations.

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