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The Large-Aperture Photodetector for Improved Water Cherenkov Detector Performance

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Newly designed photodetectors with a large 50-cm aperture were developed for future neutrino experiments. About twenty thousand R12860 photomultiplier tubes (PMTs) with a box-and-line dynode, manufactured by Hamamatsu Photonics, were selected for the next-generation water Cherenkov detector, Hyper-Kamiokande. Operation is scheduled to begin in 2028 with the world's largest 260k metric tons of ultra-pure water toward various physics topics on neutrinos and nucleon decays.

The improved performance of the photodetector enables the construction of a deeper water tank, with twice the strength against high hydrostatic pressure. It provides higher physics sensitivity through half the timing resolution and twice the detection efficiency for a single photoelectron, as well as a uniform response under varied magnetic fields and light-injection positions. A long-term stability was confirmed using a 200-ton water tank at EGADS (Evaluating Gadolinium's Action on Detector Systems), and a 50k-ton water at Super-Kamiokande.

The properties of the PMTs over six years of production since 2020 are assured with a continuous quality monitoring system using two 8-PMT measurement rooms with temperature control, two 100-PMT measurement rooms for dark noise stability monitoring, 16-PMT measurement setup for aging checks, and visual inspection in preparation for the installation in 2027. Furthermore, various studies to investigate the performance dependency on environmental properties were performed to suppress detection uncertainties.

I will present the overall achievements in performance improvements and quality assurance during production for the successful operation of Hyper-Kamiokande observation.

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