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A Simulation Study of Neutrino-Induced Backgrounds in the Intermediate Water Cherenkov Detector for Hyper-Kamiokande

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In the Hyper-Kamiokande experiment, controlling systematic uncertainties is essential to achieve the projected precision of long-baseline neutrino oscillation measurements. To constrain uncertainties associated with neutrino interaction cross sections, the Intermediate Water Cherenkov Detector (IWCD) is being developed as a movable water Cherenkov detector located 870 m from J-PARC along the direction of Hyper-Kamiokande. By changing its vertical position, the IWCD can observe neutrinos under different flux and energy conditions, enabling precise measurements of neutrino interaction cross sections in the sub-GeV region. For such measurements, understanding beam-induced background events is essential. Neutrinos interacting with the surrounding soil and reinforced concrete structures can mimic signal events if they produce secondary particles that enter the Inner Detector (ID) without Cherenkov light being detected in the Outer Detector (OD). Another source of background events is pile-up, where multiple neutrino interactions take place within a few tens of nanoseconds due to the combination of the intense 1.3 MW neutrino beam and materials surrounding the detector.

In this study, Monte Carlo simulations using the SandSim and WCSim software packages were performed to evaluate detector responses to neutrino-induced backgrounds and pile-up events in the IWCD. I quantitatively evaluated the contribution of background events arising from interactions outside the ID to the ID event candidates and investigated their characteristics. This study will be utilized for optimization of the OD configuration and establish effective event-selection criteria by investigating background events that cannot be vetoed by the OD.

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