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ND280++, the multi-ton upgrade of the magnetised near detector for the Hyper-Kamiokande high-statistics phase

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Hyper-Kamiokande will start collecting accelerator neutrino data in 2028 to search for leptonic CP violation. The largest systematic uncertainty, $\Delta(\sigma_{\nu_e}/\sigma_{\bar{\nu}_e})$, is related to the ratio between the electron neutrino and antineutrino cross section. A not proper modeling could generate an ambiguous asymmetry in the ratio between the $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation probabilities, thus leading to a bias in the measurement of the CP violating phase (δ_{CP}). Sensitivity studies show that the magnetised near detector (ND280) currently operating at the T2K experiment, and the intermediate water-Cherenkov detector (IWCD), together, constrain $\Delta(\sigma_{\nu_e}/\sigma_{\bar{\nu}_e})$ to about 4\%. Its reduction would lead to an improvement in the sensitivity down to $\delta_{CP} \sim 45^\circ$. Thus, Hyper-Kamiokande is developing the conceptual design of a second upgrade of ND280, called ND280++, envisaged for the high-statistics phase, after 2030, when the systematic uncertainty will become dominant. The detectors operating since the start of T2K in 2009, would be replaced with up to 10 tons of water and/or organic scintillator detectors and time projection chambers, aiming to a three times higher neutrino target mass and a large water content. The main goals of ND280++ are the collection of a high-statistics sample of ν_e and $\bar{\nu}_e$ interactions, the precision measurement of the neutrino cross section in water, the high-resolution reconstruction of the hadronic final state, down to below 200 MeV/c proton momenta. The ND280++ reference design will be presented and the status of the ongoing R&D, ranging from scintillating fibers, 3D segmented water-based liquid scintillator to highly segmented organic scintillator, will be reported. Finally, the results of the ongoing simulation studies of the ND280++ physics potential will be discussed.

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