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Machine-Learning-Assisted $\nu/\bar{\nu}$ Discrimination in Atmospheric Neutrino Events for CP-Violation Sensitivity in a 20-kton Liquid Scintillator Detector

Although large liquid scintillator detectors are primarily designed for reactor antineutrino measurements, their large fiducial volume and excellent energy resolution also enable the observation of atmospheric neutrino interactions. We investigate the potential of machine-learning-assisted event classification to achieve statistical neutrino–antineutrino discrimination in atmospheric neutrino samples. A classifier is developed using GENIE-simulated charged-current interactions in the 0.1–4.0 GeV energy range and detector-smeared leptonic and hadronic observables, including reconstructed inelasticity, neutron multiplicity, visible lepton energy, visible hadronic energy, and event-topology variables. The resulting classifier achieves a preliminary AUC of 0.78 for neutrino-enriched and antineutrino-enriched samples. The additional neutrino–antineutrino discrimination improves sensitivity to matter effects and CP-violating oscillation asymmetries, yielding a preliminary CP-violation sensitivity approaching 2σ for favorable values of δ_{CP} in a 10-year atmospheric-neutrino exposure. Sensitivities are evaluated using an Asimov dataset and a binned χ^2 likelihood framework incorporating liquid scintillator detector smearing and atmospheric-neutrino systematic uncertainties.

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