# Unitarity Test of PMNS Matrix with Precision Measurements

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In the past decades, our understanding of neutrinos, one of the fundamental particles in the standard model, has been dramatically advanced. Neutrinos not only have non-zero masses, their mass eigenstates are also not identical as the flavor eigenstates. The relation between these two eigenstates can be described by the **Pontecorvo–Maki–Nakagawa–Sakata** (**PMNS**) mixing matrix. After 20 years of efforts, the measurement of the PMNS matrix is finally progressing from the exploration stage to the precision stage. In particular, with the current and next generation neutrino oscillation experiments, the unitarity tests of the PMNS matrix become feasible. This research will focus on the precision measurements of the third neutrino mixing angle $\sin^2 2\theta_{13}$. By comparing $\sin^2 2\theta_{13}$ value measured through reactor electron anti-neutrino disappearance experiments with that measured through electron neutrino appearance (from a muon neutrino beam) experiments, one can strongly constrain the potential new physics beyond the 3-flavor neutrino standard model. We will i) implement innovative methods to reduce systematic uncertainties thus improve the ultimate $\sin^2 2\theta_{13}$ precision from the Daya Bay experiment, ii) study various systematic uncertainties including the detection efficiencies in the liquid Argon time projection chamber and the nuclear effects of the neutrino interaction cross section in LBNE. The latter effort will also benefit the determination of neutrino mass hierarchy and the measurement of CP phase in LBNE.