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Precision Neutrino Physics: Status and Outlook in the 3ν Paradigm

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We present an updated global analysis of the standard three-neutrino (3ν) framework, incorporating the latest oscillation and nonoscillation data available at the start of 2025. Notably, we report subpercent-level precision in the determination of the atmospheric mass-squared splitting, marking a significant milestone in neutrino oscillation physics. Our analysis reveals evolving constraints on the mass ordering, the CP-violating phase, and the θ23 octant, though current hints remain statistically inconclusive. Beyond oscillations, we update bounds on absolute neutrino mass observables from β-decay, neutrinoless double β-decay, and cosmology, with recent data pointing to potential tensions or novel physics within the ΛCDM paradigm. Looking forward, we highlight the pivotal role of the JUNO experiment, which is poised to deliver high-precision measurements of key oscillation parameters and provide an independent handle on the mass ordering. As the field transitions into the era of subpercent precision, resolving current ambiguities and ensuring robust control over shared systematics across experiments will be critical. These advances promise to deepen our understanding of the neutrino sector and may unveil new directions in particle physics and cosmology.

Collaboration you are representing

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