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Theoretical Constraints and Their Implications for Neutrinoless Double-β Decay Probes

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Next-generation neutrinoless double beta decay ($0\nu\beta\beta$) experiments are poised to achieve sensitivities that fully explore the inverted mass hierarchy (IH) parameter space and begin probing the normal mass hierarchy (NH) region, marking a significant advancement in the search for Majorana neutrinos, revealing the absolute neutrino mass scale, and lepton number violation [1, 2]. Achieving this long-sought discovery is plausible provided that theoretical ambiguities, especially in the nuclear matrix elements, the axial-vector coupling, and phase space contributions, are negligible or if the underlying physics favors the most optimistic scenario. Conversely, if the axial-vector coupling constant is subject to maximal quenching, nuclear matrix elements assume the lowest values predicted by nuclear models, and nature follows a most conservative scenario, then even probing the IH region would represent a formidable challenge and will demand extraordinary experimental sensitivity [3]. We present a detailed quantitative analysis of how theoretical limitations, including nuclear and particle physics inputs, shape the experimental outlook for $0\nu\beta\beta$ decay. Our findings highlight that reducing theoretical uncertainties will require both refined nuclear modeling and dedicated measurements, essential for sharpening the predictions of future $0\nu\beta\beta$ searches.

References:
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[2] M. K. Singh, H. B. Li, H. T. Wong et al., Projections of discovery potentials from expected background, Phys. Rev. D 109, 032001 (2024); https://doi.org/10.1103/PhysRevD.109.032001
[3] M. K. Singh, S. Karmakar, H. B. Li, H. T. Wong, et al., Impact of theoretical constraints in the sensitivity estimation for neutrinoless double beta decay, Int. J. Mod. Phys. A (2025); https://doi.org/10.1142/S0217751X25500502

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