Structure of nuclear transition matrix elements for neutrinoless double-β decay

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The confirmation of flavour oscillation of neutrinos has already established that three massive neutrino species are sufficient to explain the observed atmospheric and solar neutrino puzzle. However, it is generally agreed that out of several possibilities, the observation of neutrinoless double beta $(\beta\beta)_{0\nu}$ decay can clarify a number of issues, namely the Dirac/Majorana nature of neutrinos, the origin of neutrino mass, absolute scale on neutrino mass, the possible hierarchy in the neutrino mass spectrum and CP violation in the leptonic sector.

The two neutrino double beta $(\beta\beta)_{2\nu}$ decay is an allowed process in the standard model of electroweak unification (SM). Presently, the $0^+ \rightarrow 0^+$ transition of $(\beta^-\beta^-)_{2\nu}$ decay has been experimentally observed in ten nuclei, out of 35 possible candidates. It is possible to extract accurate nuclear transition matrix elements (NTMEs) $M_{2\nu}$ from the observed half-lives of $(\beta^-\beta^-)_{2\nu}$ decay. A comparison between the theoretically calculated and experimentally extracted NTMEs provides a cross-check on the reliability of different nuclear models used for the study of nuclear $\beta\beta$ decay. On the other hand, the lepton number violating $(\beta\beta)_{0\nu}$ decay can occur in a number of gauge theoretical models, namely GUTs -left-right symmetric models and E(6)-, R_p-conserving as well as violating SUSY models, in the scenarios of leptoquark exchange, existence of heavy sterile neutrino, compositeness and Majoron models. Hence, it is a convenient tool to test the physics beyond the SM.

The shell model is the best choice for calculating the NTMEs. However, it is not possible to study the medium and heavy mass deformed nuclei in the shell model. Remarkably, the QRPA and its extensions have emerged as the most successful models in correlating single-β GT strengths and half-lives of $(\beta^-\beta^-)_{2\nu}$ decay. In spite of the spectacular success of the QRPA in the study of $\beta\beta$ decay, there is a need to include the deformation degrees of freedom in its formalism and developments in this direction are in progress. Moreover, it has become possible to understand the effects of deformation on the NTMEs in the projected Hartree-Fock-Bogoliubov (PHFB) model [1–3]. In the PHFB model, a number of issues regarding the structure of NTMEs, namely the effect of pseudoscalar and weak magnetism terms on the Fermi, Gamow-Teller and tensorial NTMEs and the role of finite size as well as short range correlations vis-a-vis the radial evolution of NTMEs will be discussed in the symposium.

References

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