Nuclear-Structure Related Issues of Double Beta Decays

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The results from the recent neutrino-oscillation measurements have shown that neutrinos have a non-zero mass. At present, the most practical way to access the absolute mass scale and Dirac/Majorana character of the neutrino, is to perform measurements of the neutrinoless double beta ($0\nu\beta\beta$) decays of atomic nuclei. The $0\nu\beta\beta$ decays and the two-neutrino double beta ($2\nu\beta\beta$) decays are among the slowest reactions in the nature. Both these modes have been studied carefully in the theoretical and experimental frameworks. However, currently only the $2\nu\beta\beta$ mode has been unambiguously confirmed by experiments.

One of the biggest challenges related to nuclear aspects of the double beta decay lies in the fact that most of the double-beta-decaying nuclei are medium-heavy or heavy nuclei. In the nuclear-structure description of double beta decay, the transition proceeds via the virtual states of the intermediate double-odd nucleus. For the $2\nu\beta\beta$ mode only the 1^+-states are active, whereas in the case of the $0\nu\beta\beta$ mode all the multipole states of the intermediate nucleus are active. A reliable description of the structure of these intermediate states is essential in the theoretical calculations due to the fact that the half-lives of the double beta decay have a strong dependence on their structure.

The structure of the intermediate states can be analyzed for example by performing electron capture or β-decay experiments. However, the drawback of these methods appears in the fact that they can be used only to probe the lowest J^π state, typically the ground state of the odd-odd intermediate nucleus. Other possible independent probes of the relevant nuclear-structure aspects are the charge-exchange reactions and nucleon-transfer reactions. Recently it has been suggested that ordinary muon capture (OMC) reaction could be used to investigate the structure of the intermediate nucleus and its excitated states. Due to the large mass of captured muon (roughly 100 MeV) the OMC reaction can lead to highly excitated states of the final nucleus. Yet an other proposed way to probe the nuclear wave functions are the neutrino-nucleus charged-current scatterings.

For the $2\nu\beta\beta$ and $0\nu\beta\beta$ decays to excited states the final-state wave function - a low-lying excited 2^+ or 0^+ state in an even-even nucleus - could be probed by analysis of the associated collectivity by M1 and E2 gamma decays.