Exotic weak decays of atomic nuclei

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The various neutrino-oscillation experiments have verified the existence of the neutrino mass by accurate determination of the squared mass differences of the mass eigenstates of the neutrino. The oscillations of solar and atmospheric neutrinos create two different scales of mass differences and lead to three different interpretations in terms of neutrino-mass hierarchies: degenerate, normal and inverted. Determination of the absolute neutrino mass is still lacking and much effort is being invested in expensive high-resolution neutrino experiments based on weak-interaction decays of atomic nuclei. The most intriguing of these processes is the nuclear double beta decay which not only can access the absolute mass scale and the hierarchy of the neutrinos but also can reveal if the neutrino is its own antiparticle, the so-called Majorana neutrino. Also beta decays of various nuclei are used or are being considered as means of accessing the elusive neutrino mass.

Since atomic nuclei are used as probes of the neutrino properties one needs to understand well the nuclear-structure part of the involved decay processes. The neutrinoless double beta decay is a well understood process in particle physics and recent advances have been made in pinning down the values of the associated nuclear matrix elements. At present a few experiments are running and several large-scale next-generation experiments are in the R&D phase to measure these decays.

During last few years experimental attention has been directed to a new interesting possibility to access the neutrino properties, namely the neutrinoless double electron capture (0vECEC). In particular, it has been speculated that the resonant 0vECEC could be detected due to its potential million-fold resonant enhancement relative to the double-positron emitting processes. The resonant 0vECEC is not yet well understood from the nuclear-, particle- or atomic-physics points of view. Recent advances in determination of the decay Q values by the Penning atom-trap techniques help in determination of the magnitudes of the potential resonant enhancements. These measurements together with nuclear-structure calculations and atomic data have recently been used to analyze a few potential cases for the resonant enhancement.

At the same time rare beta decays with low Q values can also be used to determine the magnitude of the neutrino mass. Recently one of such decays, the ^{115}In decay to the first excited state in ^{115}Sn was carefully analyzed by combining nuclear-structure calculations with accurate mass measurements with Penning-trap technique and half-life measurements in the HADES underground laboratory. The associated Q value of the decay turned out to be world-record-setting low and our analysis points to strong interference of atomic effects with nuclear effects for such rare weak decays with ultra-low Q values.