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Precision neutrinoless $\beta\beta$ decay nuclear matrix elements and related $\gamma\gamma$ decays

Neutrinoless double-beta decay ($0\nu\beta\beta$) is a transition in nuclei where two neutrons simultaneously transform into two protons, accompanied by the emission of only two electrons [1]. This second-order process, if observed, would prove that neutrinos are Majorana particles (their own antiparticles), shed light on the existence of massive neutrinos, and help explain the predominance of matter over antimatter in the universe. The half-lives depend on the square of the nuclear matrix elements (NMEs), which must be computed since $0\nu\beta\beta$ has not been observed yet.

In this talk, we will discuss computations of the NMEs at the next-to-next-to-leading order (N^2LO) [2] corrections within the nuclear shell model framework. These calculations aim to reduce the uncertainty surrounding the NMEs. First, we will present the contribution of ultrasoft (low-momentum) neutrinos, which can be dominant in some scenarios involving light sterile neutrinos [3]. Then, we will present novel results for the full N^2LO NMEs, which have not yet been computed in the literature.

Finally, we study second-order electromagnetic double-magnetic dipole ($M1M1$) transitions due to the connection between $M1M1$ and $0\nu\beta\beta$ NMEs [4]. We compute the nuclear matrix elements for the following nuclei: ^{20}Ne, ^{48}Ti, ^{40}Ca, and ^{72}Ge using the nuclear shell model framework with different valence spaces and interactions. We estimate the quality of the results by comparing related calculations with data from first-order electromagnetic transitions, energy spectra, and recent double-gamma decay experiments [5].

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Abstract

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