



Contribution ID: 186

Type: **Contributed talk**

Precision neutrinoless double-beta decay nuclear matrix elements and related double-gamma decays

Monday 8 July 2024 14:40 (20 minutes)

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 explain the predominance of matter over antimatter in the universe.

The half-lives depend on their square of a nuclear matrix element (NME) which has to be calculated due to the fact that $0\nu\beta\beta$ has not been measured yet.

In this talk we will discuss computations of the NMEs at the N2LO order (next-to-next leading order)[2] corrections within the nuclear shell model framework. These calculations aim to reduce the uncertainty surrounding the NMEs ($\mathcal{M}^{0\nu\beta\beta}$). 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 N2LO NMEs, which have not been computed yet in the literature.

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

[1] M. Agostini *et al.* Rev. Mod. Phys. **95**, 025002 (2023)

[2] L. Jokiniemi, D. Castillo, P. Soriano, J. Menéndez, in progress.

[3] W. Dekens *et al.*, arXiv:2402.07993.

[4] B. Romeo, J. Menéndez, C. Peña Garay. Phys. Lett. B **827**, 136965 (2022).

[5] D. Freire-Fernández *et al.*, arXiv:2312.11313.

session

I. Nuclear Structure and Reactions

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Session Classification: I. Nuclear Structure and Reactions