NEUTRINOLESS DOUBLE BETA DECAY WITHIN THE INTERACTING SHELL MODEL

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Estructura nuclear

The state of the art Interacting Shell Model (ISM) calculations of the Nuclear Matrix Element (NME) for the neutrinoless double beta decay ($0\nu\beta\beta$ decay) will be presented. To study such a decay is very important due to the implications an experimental observation of the process would have: one the one hand, it would proof neutrinos to be Majorana particles, this is, its own antiparticles, allowing for such a lepton number violating process. On the other hand, it would provide insight, together with the NME, into the absolute neutrino masses. Only the differences between mass states are known to date [1].

A number of topics regarding the NMEs will be covered. First of all, the approximations necessary to perform such a challenging calculation will be exposed: the terms kept in the hadronic current, the parametrization of the nucleon size via dipole form factors, the inclusion of short range correlations in the calculation and the closure approximation will be explained. Furthermore, the advantages (full variety of correlations within the model space) and drawbacks (small valence space) of the ISM will be presented. With all these ingredients, the results of the NMEs obtained within the ISM and their estimated uncertainties will be shown [2,3], along with these obtained by other methods such as the quasiparticle random phase approximation, the interacting boson model or beyond mean field self-consistent calculations.

Then, in order to understand better the behaviour of the NME and the operator, and differences between the above methods, we will study the role of correlations in this process. First, the role of pairing correlations will be studied, with the result that the NME is favoured by the decay of nucleons coupled to J=0 into protons also coupled to J=0. This means that the NME is expected to be maximal between two superfluid nuclei. Also the evolution of the NME as a function of the maximum seniority (number of pairs not forming J=0 pairs) allowed in the father and daughter wavefunctions will be shown, stressing the importance of keeping high seniority components in the calculation [4].

Afterwards, the role of quadrupole correlations will be studied. Studying the ficticious transitions between mirror nuclei, and extending this study to realistic nuclei, we see that the NMEs are reduced whenever there is a difference in deformation between the mother and daughter nuclei. When both have the same deformation, the NME is larger in the case of both being spherical nuclei, but the drop in the NME is not as large in the equally deformed case as in the one with different deformations. These results are shown to be common to the two neutrino double beta decay, second order beta process analogue to $0\nu\beta\beta$ decay but where two neutrinos are emitted [5].

Finally, we will explore the role of the neutrino mass in the $0\nu\beta\beta$ process. This is relevant because in some particle physics models such as seesaw models heavy neutrinos are responsible for the masses of the light neutrinos of the Standard Model and could also contribute to the amplitude of the decay (the usual contribution to the decay rate is that of the light neutrinos of the Standard Model). We find scenarios where the Standard Model decay rate can be increased by these heavy neutrino contributions. This result could be used to reconcile the unconfirmed experimental claim of $0\nu\beta\beta$ decay [6] and recent cosmology observations [7], which are not compatible if only the contribution of the light neutrinos of the Standard Model are considered [3].

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