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Octupole correlations from a theoretical perspective

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Quadrupole deformation is a rather common characteristic of the ground state of atomic nuclei. It implies the breaking of rotational invariance and naturally yields to the useful concept of intrinsic states. The next relevant moment is the octupole one characterized by the breaking of reflection symmetry and pear-like shapes. Contrary to the quadrupole moment case, permanent octupole deformation in the ground state is rather scarce and it is only present in a few nuclei in the rare earth and the actinide regions. However, dynamical correlations around the reflection symmetric ground state are not negligible and therefore, octupole correlations are essential to describe the energy of low lying collective negative parity states and $E1$ and $E3$ transition strengths. They also have an impact on binding energies and derived quantities like nucleon separation energies. Among the theoretical models used to describe from different perspectives this phenomenon the mean field has proved to be a good candidate [1]. However, the dynamical character of octupole correlations in most of the nuclei imply the relevance of going beyond the mean field to improve the description. In our recent survey of octupole properties in even-even nuclei [2] the generator coordinate method (GCM) has been used to restore the broken reflection symmetry of octupole shapes and to take into account fluctuations on the octupole degree of freedom around reflection symmetric ground states. Realistic Energy Density Functionals (EDF) like various parametrizations of the Gogny EDF have been considered in the calculations (see also [3] for calculations with the recently proposed BCPM functional). The consistency among the results obtained with the different functionals give credit to the validity of our description and suggests that potential discrepancies with experiment have to be attributed to missing degrees of freedom.

In this talk, I will discuss the results obtained in [2,3] for excitation energies, transition strengths and ground state correlation energies of essentially all the relevant even-even nuclei. The comparison with available experimental data is quite reasonable all over the nuclear chart. However, systematic deviations are observed that point to missing degrees of freedom and deficiencies in the description. For instance, in Ref [4] the coupling between the quadrupole and octupole degree of freedom is considered in a few nuclei. The coupling seems to be small for the quadrupole deformed nuclei considered but a more systematic calculation covering spherical or near spherical nuclei is in order. The coupling to other degrees of freedom is being considered at present and preliminary results show the relevance of the coupling to pairing degrees of freedom.Systematic underestimation of the E3 strengths is also observed. We have focused on the validity of the rotational formula used to related intrinsic and laboratory frame quantities [5] and shown that the systematic underestimation can be traced back to the breaking of the rotational formula for near spherical systems. Systematic calculations considering angular momentum projection are very promising and substantially improve the comparison with experiment.

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