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Towards symmetry-unrestricted Skyrme-HFB: MOCCa and its applications

The concept of intrinsic symmetry breaking is central to the mean-field description of nuclei: it allows for the inclusion of correlations beyond the indepent-particle picture at modest computational cost. Restriction of the rotational symmetry to one Cartesian axis (instead of three) is a prime example of intrinsic symmetry breaking in many mean-field approaches; limiting rotational symmetry this way gives acces to the description of axial deformations. While in many applications axial (and to a lesser extent, triaxial) deformations are considered, there remain a number of significant additional symmetries that are assumed to be conserved in many approaches. These assumptions are usually made for two reasons: every conserved intrinsic symmetry eases the computational burden and facilitates the physical interpretation of the results. However, an important downside of conserving additional symmetries is the limitation of the variational space and a loss of generality: the description of exotic geometries is often impossible. An example is reflection symmetry: while assumed to be conserved in many cases, it is necessarily broken for nuclear configurations exhibiting octupole or tetrahedral deformation. With the advent of tracking-γ-ray spectroscopy, experiments become more and more able to resolve the rich structure of rotational bands in numerous nuclei. More and more data becomes available on bands that are associated in a mean-field context with exotic geometries of the nucleus. To provide a satisfactory mean-field description of such bands, only allowing for axial (or even triaxial) deformations is not sufficient. To improve the description of such states, we have developed a new framework for self-consistent mean-field calculations, using effective Skyrme interactions in a coordinate-space representation. The MOCCa code is a generalization of the principles of the EV8 code, allowing its user for significant freedom concerning symmetry assumptions of the nuclear configuration and a more general treatment of pairing correlations. Breaking signature symmetry in particular presents a new frontier for nuclear density functional theory. Without such assumption, the orientations of various angular momenta at play in the nucleus are no longer restricted by symmetry. This freedom opens up the possibility to study various exotic rotational phenomena such as wobbling excitations and octupole rotational bands, as well as treat quasiparticle excitations in both even and odd-mass nuclei on a more general level. I will first introduce MOCCa and the principles it is built on, highlighting the physical and practical motivations for its construction. Afterwards, I will touch upon past and present challenges when dealing with signature symmetry, specifically with respect to the treatment of pairing, including a discussion on how to solve the Skyrme-HFB equations without any conserved antilinear symmetry. Finally, I will present a set of recent results obtained within this framework, specifically focusing on the freedom obtained by releasing signature symmetry, specifically when dealing with (the rotation of) odd nuclei.

Mercredi 14 Feb. 2018, 11h30

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