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Underlying structure of collective bands of nuclei and self-organization mechanism.

The interplay between the single-particle states and the collective modes has been one of the central subjects of nuclear physics since the very beginning. If the single-particle aspect is too strong, for instance, with a large gap between relevant orbits, it suppresses the collective mode. Thus, the single-particle states and the collective modes have been considered to counteract each other, and the former behaves as a resistance against the latter. However, an opposing idea has arisen recently. The nuclear force is characterized by components driving a given collective mode, like the quadrupole interaction for the ellipsoidal shape and, in addition, by the monopole component that can reduce the resistance against collective modes. The energies of single-particle orbits can thus be optimized for a given mode with favorable configurations. In fact, the monopole components of the central and tensor forces show strong orbital dependences, and can shift single-particle energies effectively depending on the configurations of other nucleons. This mechanism can be interpreted as a quantum self-organization, and is consistent with the general self-organization concept. Its effect can be seen in the quantum phase transition of Zr isotopes [1], and more generally in the shape evolution in Sm isotopes as well as the band structure of ^{154}Sm. The state-of-the-art Monte Carlo Shell Model calculations with reasonable interactions produce properties of these nuclei in good agreement with experiments. The monopole-controlled optimization is shown to be essential: if it is switched off, this good agreement disappears. One of the striking results is that contrary to the traditional idea, side bands of strongly deformed nuclei may not be beta or gamma vibration of the ellipsoidal shape, but can be consequences of many-body correlations due to nuclear forces, beyond the liquid drop model. A textbook example of ^{166}Er shows that its key properties are reproduced by the shell-model solution obtained around a triaxial minimum with strong gamma-instability, including the relatively strong 0_1^+, 2_2^+ E2 excitation. Prospects over heavy nuclei and fission processes and possible experimental challenges will be discussed.

[1] T. Otsuka, Y. Tsunoda, et al., arXiv: 1907.10759 [nucl-th].

Mercredi 23 Octobre 2019,

11h30

IPN, Bât. 100, Salle A015