Evolution of 2^+_γ Wave-functions and Gamma-stiffness in Well-deformed Rare Earth Nuclei

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Recently, the extended consistent-Q formalism (ECQF) of the Interacting Boson model was used to map the structural evolution of deformed rare-earth Gd, Dy, Er, Yb and Hf isotopes [1] within the IBA symmetry triangle. It was found that towards mid-shell the Gd, Dy and Er isotopes, while being well-deformed rotors, show a tendency of being less gamma-rigid, while the Yb and Hf isotopes become more gamma-rigid towards mid-shell.

It is the purpose of our investigation [2] to provide some insight into the particular features of those IBA trajectories for the well-deformed rare-earth nuclei. We show that for these nuclei the different structural evolution can be understood on the basis of some basic features of the quasiparticle structure of the gamma-vibrational band.

Within the framework of RPA calculations using a quasiboson approximation based on the Nilsson model we determine the 2^+_γ wave functions consisting of a linear combination of two quasiparticle excitations from the ground state by means of the $Q_{2\pm2} = r^2 Y_{2\pm2}$ operator. The pairing residual interaction is included by modifying the interaction matrix elements and by transforming Nilsson single-particle energies to quasiparticle energy levels.

In a next step, the distributions of two-quasiparticle components are quantified allowing to distinguish if a gamma-vibrational state contains only a few major or many small two-quasiparticle components, respectively.

This is shown in Fig. 1 and 2 where the separate distribution functions for neutrons S_ν and protons S_π are plotted against the neutron number for several even-even rare earth nuclei. A value of S closer to one indicates that the wave function is mainly carried by a few dominant components, whereas a value close to zero results from a wave function which is equally distributed on all components. Additionally the fraction f_ν of the neutrons in the wave function is displayed.

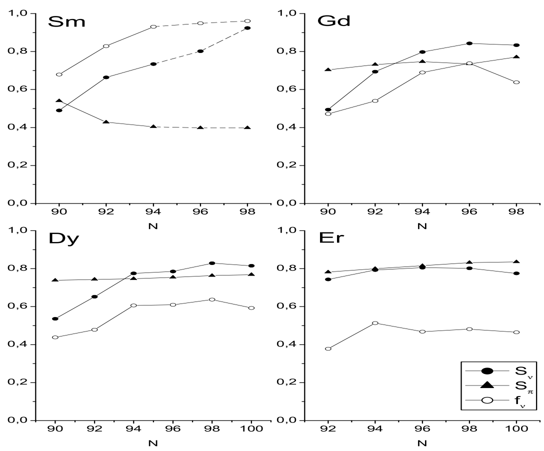

Fig. 1: Distribution functions and neutron fraction of the wave function for Sm, Gd, Dy and Er isotopes

According to IBA fits by Scholten et al. [3] the well-deformed Sm nuclei are the most gamma-rigid nuclei considered in this study. In our calculation the extreme rigidity of the Sm nuclei with growing neutron number is mainly due to the extreme dominance of the neutrons in the wave function. The oscillation of the neutrons is strongly damped through the strong proton-neutron interaction with the almost non-participating protons.

In IBA calculations [1] Gd and Dy isotopes show a reduced gamma-rigidity with increasing neutron number. Our calculation yields for the protons the presence of only a few dominant components in the wave function. As moving along the isotopic chain S_ν rises to higher values indicating that also only a few basis states dominate the neutron part of the wave function. This is the reason why the Gd and Dy isotopes become more gamma-soft. Moreover in opposite to Sm the wave function is more or less equally distributed to protons and neutrons for all isotopes. All Er nuclei show a similar value of the distribution functions S_ν and S_π like Gd and Dy isotopes with high neutron number and the wave function is perfectly balanced between neutrons and protons. This correlates well with the gamma-softness of the Er isotopes in the IBA calculations.

For Yb and Hf there is a significant difference in behavior not only in contrast to the Gd, Dy and Er isotopes but also between themselves. S_π is small for Hf and yields high values for all Yb nuclei. Thus Hf is in general more gamma-rigid than Yb. Indeed the Yb isotopes show a trend towards gamma-softness for N=92-100 while for N=102,104 the S_ν drops dramatically leading to an increased gamma-rigidity. This behavior is reflected in the IBA calculations. For N=94-98 Hf isotopes the increasing fraction of the neutrons f_ν in the wave function leads to gamma-rigidity which even increases with the drop of S_ν for N=100,102. The peak of S_π for N=104 leads to a small increase in gamma-softness. Even this subtle feature correlates with the IBA results [1].

References

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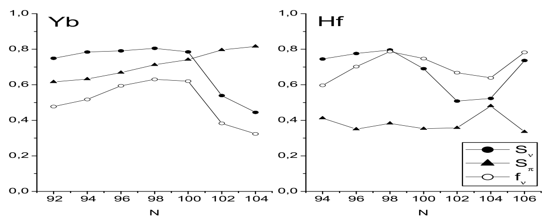

Fig. 2: Distribution functions and neutron fraction of the wave function for Yb and Hf isotopes