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Microscopic description of pygmy dipole resonance in neutron-rich Ca isotopes

The structure of exotic neutron-rich nuclei is one of the main science drivers in contemporary nuclear physics research. An attention has been devoted to effects of varying the ratio between the proton Z and neutron N numbers on different nuclear structure characteristics of nuclei deviated from their valley of β-stability. One of the phenomena associated with the change in N/Z ratios is the pygmy dipole resonance (PDR). One of the successful tools for describing the PDR is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived from Skyrme energy density functionals (EDF). Such an approach can describe the properties of the low-lying states reasonably well by using existing Skyrme interactions. Due to the anharmonicity of the vibrations there is a coupling between one-phonon and more complex states. The main difficulty is that the complexity of calculations beyond standard QRPA increases rapidly with the size of the configuration space, and one has to work within limited spaces. Using a finite rank separable approximation for the residual particle-hole interaction derived from the Skyrme forces one can overcome this numerical problem.

As an illustration, we study the properties of the low-lying dipole states in the even-even nuclei $^{40-58}$Ca. Using the same set of the EDF parameters we describe available experimental data for ^{40,44,48}Ca and give the prediction for $^{50-58}$Ca. In particular, there is an impact of the coupling between one- and two-phonon states on low-energy $E1$ strength of ^{40,44,48}Ca. We predict a strong increase of the summed $E1$ strength below 10 MeV, with increasing neutron number from ^{48}Ca.

Primary authors: Dr ARSENYEV, Nikolay (Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research); Dr SEVERYUKHIN, Alexey (Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research); Prof. VORONOV, Victor (Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research); Prof. GIAI, Nguyen Van (Institut de Physique Nucleaire, CNRS-IN2P3, Universite Paris--Sud)

Presenter: Dr ARSENYEV, Nikolay (Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research)

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