The Significance of the Quasiparticle-Phonon Model for the Study of Nuclear Structure and Nuclear Reactions

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A theoretical method based on the energy-density functional theory and the quasiparticle-phonon model, including up to three-phonon configurations, has been developed. The main advantages of the method are that it includes a self-consistent mean field and multi-configuration mixing, which are found to be crucial for systematic studies of nuclear low-energy excitations, pygmy and giant resonances in a unified manner. In particular, the theoretical approach has proven very successful in predicting new excitation modes, namely the pygmy quadrupole resonance, which has also been observed experimentally. A systematic comparison between QRPA and multiphonon QPM calculations in different nuclei shows that the behavior of the γ-strength function at low energies is influenced by the competition between static and dynamic effects. The former effect is related to the mean field, while the latter represents the coupling of single-particle states with more complex excitations related to the polarization of the nucleus. In the case of the dipole excitations, these effects lead to a redistribution and fragmentation of the electric dipole strength at low energies, with particular emphasis on the neutron one-particle-one-hole components of the dipole state vectors. The latter have been identified as doorway states common to the neutron and γ channels in (n,γ) reactions. As doorway states, the 1^- QRPA excited states of the pygmy dipole resonance contain mainly neutron one-particle-one-hole configurations, which are expected to strongly influence the (n,γ) cross sections and thus influence isotope production in explosive stellar environments. This work is partially supported by the ELI-RO-RDI-2024-AMAP project.