Isovector Quadrupole Excitations of the Nuclear Valence Shell studied in Projectile Coulomb Excitation[1]

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Atomic nuclei are examples of mesoscopic two-fluid quantum systems the physics of which is determined by three generic aspects: the many-body property (collectivity), the quantum nature (shell structure), and the two-fluid character (isospin degree of freedom). The mutual balance between these aspects might be studied by investigating phenomena that reflect these three aspects equally well, such as collective isovector excitations of the valence shell of heavy nuclei. Those nuclear excitations have been modeled, for instance, within the framework of the proton-neutron interacting boson model (IBM-2) in terms of Mixed-Symmetry States (MSSs) and examples have been found experimentally, *e.g.*, the $J^\pi = 1^+$ scissors mode of deformed nuclei [1] or one- and two-phonon structures with mixed symmetry in vibrational nuclei [2].

In recent years, our knowledge on MSSs of vibrational nuclei has been expanded rapidly, partly because of new combinations of experimental techniques. That knowledge is still limited to stable nuclides because of tremendous experimental challenges for solidly identifying short-lived off-yrast MSSs. Their particular sensitivity to the effective proton-neutron interactions in the valence shell makes it desirable to study them in exotic nuclei, too. The advent of facilities that provide intense beams of radioactive ions offers now the opportunity to first investigate MSSs of heavy nuclei beyond β-stability.

We have previously demonstrated [3] the possibility to identify the quadrupole-collective one-phonon $2^+_{1,\mathrm{ms}}$ MSS using the technique of projectile Coulomb excitation. The full investigative power of this technique has recently been shown [4] using the example of the rare isotope ^{138}Ce. The experiments have been performed at the Argonne National Laboratory, IL, U.S.A. The ATLAS facility accelerated beams of ^{138}Ce and ^{136}Ce (with low natural abundances of 0.25% and 0.19%, respectively) to an energy of 3.5 MeV per nucleon with intensities of a few 10^9 pps. The ion beams bombarded a carbon target in the center of the Gammasphere detector array. Gamma radiation from projectile Coulomb excitation has been detected with Gammasphere in singles mode.

The data yield comprehensive information on the $E2$ excitation strength distributions to bound 2^+ states up to 2.6 MeV excitation energy and enable us to identify the one-phonon $2^+_{1,\mathrm{ms}}$ states amongst them from the $M1$ strength distributions to the 2^+_1 states. We can determine the size of an F-spin mixing matrix element for the first time directly from the properties of a state with predominant mixed-symmetry character. The observations suggest a *shell stabilization* mechanism for mixed-symmetry states that emphasizes their particular sensitivity to the underlying shell structure.

The feasibility of corresponding experiments with radioactive ion beams will be demonstrated.

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