Monopole-effects on symmetric and antisymmetric couplings of protons and neutrons

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As a general feature of two-fluid quantum systems, excited states in atomic nuclei can be constructed in a proton-neutron symmetric or mixed-symmetric way. In near vibrational nuclei the building block of mixed-symmetric states is the one-phonon quadrupole-collective isovector valence-shell excitation $2^+_1\text{ms}[1]$. In a most simple picture, such states can be understood to be generated by mixing unperturbed proton and neutron phonons via the residual proton-neutron interaction [2]. Therefore the study of mixed-symmetric states delivers direct information on the residual proton-neutron interaction in the valence shell and provides a tool to explore the evolution of the residual interaction towards e.g. extreme values of isospin.

In the framework of the generalized seniority scheme we present a simple expression for the valence proton-neutron interaction $V_{pn}$ in atomic nuclei near closed shells consisting of a monopole and a quadrupole term. The monopole component of the residual interaction is approximated by double differences of binding energies only. We show that the energetic splitting between the lowest lying $J^\pi=2^+$ states of symmetric and mixed-symmetric character in even-$A$ nuclei is well reproduced in almost all experimentally known cases (see Fig. 1 for one example), including nuclei where the effective number of valence particles is put to zero at subshells. The only free parameter, the quadrupole strength parameter $\kappa$ turns out to be surprisingly constant in the mass region $A=50$ to $A=150$, yielding a good approximation for absolute values of $V_{pn}$ near closed shells. We show applications on new data from neutron scattering with monoenergetic neutrons on the nuclei $^{68,70}\text{Zn}$ where an unusual abrupt drop in the excitation energy of the mixed-symmetric components is found towards the possible subshell at $N=40$. We draw conclusions on the minimal repelling of the lowest-lying symmetric and mixed-symmetric $2^+_1$ states in even-$A$ nuclear systems.