Interplay between isoscalar and isovector correlations in neutron-rich nuclei†

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The interplay between isoscalar (IS) and isovector (IV) correlations has been an attractive and centrally placed topic in the study of nuclear structure. In the analysis of scattering data by IS particles such as α-particles it is often assumed that IS particles excite only IS strength. This assumption is generally incorrect if N̸=Z for the target nuclei. For example, in nuclei with neutron excess, IS operators excite IS moments, but for target nuclei with N̸=Z even-even nuclei isovector (isoscalar) strength may also be excited by IS particles.1) The exchange of the above roles of IS and IV excitations in the response is expected to be true as well. That is, IV operators may produce IS moments generally in nuclei with N̸=Z except for the case in which the IS moment corresponds to the center of mass motion.

To study this issue, we employ the self-consistent Hartree-Fock (HF) plus the random-phase approximation (RPA) with Skyrme interactions in neutron-rich oxygen isoyopes, simultaneously including both IS and IV interactions. The RPA response function is estimated in coordinate space to properly take into account the continuum effect for the IS compression dipole (ISCD) operator:2)

\[ D_{\mu}^{\lambda=1,\tau=0} = \sum_i \left( \frac{r_i^3 - 5}{3} \langle r_i^2 \rangle r_i \right) Y_{1\mu}(\hat{r}_i). \]  

(1)

Figure 1 shows the calculated RPA strength for the ISCD operator. We note the following points. (a) We very often obtain a large portion of ISCD strength in an energy interval several MeV above the threshold. This large strength appearing at an energy much lower than the energy of the ISCD giant resonance (GR), which is recognized as a very broad “resonance” found for Ex>24 MeV in Fig. 1, originates from the possible presence of occupied weakly bound low-ℓ neutron orbits together with the strong ℓ-dependence (r3) of the ISCD operator. (b) When IV interaction is included on top of IS interaction, the heights of many lower-lying IS peaks become lower and the peak energies may shift to slightly higher energies via the IV components contained in those IS peaks because of the repulsive nature of the IV interaction. (c) There are some peaks denoted by the solid curve, which may not be understood in the manner above (b). An example is the broad peak around 18.5 MeV in the solid curve. The IS peaks around 14.0 and 18.5 MeV have no trivial corresponding peaks in the dotted curve. The same behavior is also found in the response for the IV dipole operator interchanging the roles of IV and IS correlations; the IV dipole peak appears at approximately 14 MeV only when both IS and IV interactions are included in the RPA response. We may call the relatively broad peak around Ex = 14 MeV “pigmy resonance” because of its similarity to the isovector (isoscalar) resonance in the response of normal modes. In this study, it is explicitly shown in the scattering by isoscalar (isovector) particles on N̸=Z even-even nuclei isovector (isoscalar) strength may be populated in addition to isoscalar (isovector) strength.

References