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 N≠Z for the target nuclei. For example, in nuclei with neutron excess, IS operators excite IS moments, but the strong neutron-proton forces may tend to maintain the local ratio of neutrons to protons. Then, the presence of neutron excess N>Z implies that IV moments 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 N≠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 neuron-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]

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

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 r-dependence (r^3) 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
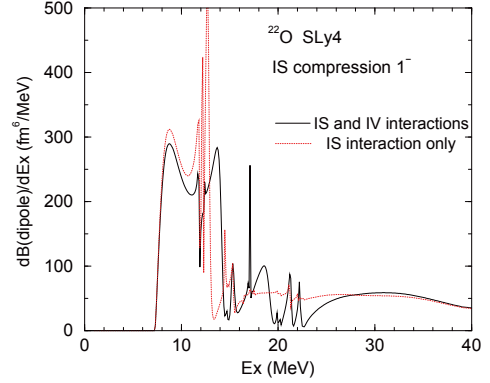

Fig. 1. RPA strength of the isoscalar compression dipole (ISCD) of ^{22}O calculated using the SLy4 interaction as a function of excitation energy (Ex). The solid curve expresses the strength obtained by including both IS and IV interactions in RPA, while the dotted curve expresses the strength obtained by including only the IS interaction.

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 MeVn 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 with both isoScalar and isoVector correlations ("iS-iV pigmy resonance"). The pigmy resonance is interpreted as neither the IS strength induced by a strong IV peak nor the IV strength induced by a strong IS peak, owing to the presence of neutron excess. It is a relatively broad resonance having an energy much lower than the energies of both IVD GR and ISCD GR, but it gathers the collectivity of low-lying IS and IV strengths. The strong neutron-proton interaction can be responsible for controlling the isospin structure of normal modes. In this study, it is explicitly shown that in the scattering by isoscalar (isovector) particles on N≠Z even-even nuclei isovector (isoscalar) strength in addition to isoscalar (isovector) strength may be populated.

References

1) A. Bohr, B. R. Mottelson, *Nuclear Structure* (Benjamin, Reading, MA, 1975).
2) I. Hamamoto, H. Sagawa, X. Z. Zhang, Phys. Rev. C **57**, R1064 (1998).