Effects of Coulomb and isospin symmetry breaking interactions on neutron-skin thickness†

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If the isospin symmetry of strong interaction is fully valid, the charge symmetry and charge independence of a nuclear interaction hold. However, the isospin symmetry of atomic nuclei is partially broken owing to the isospin symmetry breaking (ISB) terms of nuclear interaction together with the Coulomb interaction. The charge symmetry breaking (CSB) term of nuclear interaction mainly originates from the mass difference between protons and neutrons and π^0-η and ρ^0-ω meson-exchange processes, and the charge independence breaking (CIB) term of nuclear interaction mainly originates from the mass difference between π^0 and $\pi^\pm$.[1] These two terms are defined as $v_{\rm CSB} \equiv v_{nn} - v_{pp}$ and $v_{\rm CIB} \equiv v_{pn} - (v_{nn} + v_{pp})/2$, respectively.

The Coulomb interaction breaks the isospin symmetry of the atomic nuclei as well.[2,3] The effects of the isospin symmetry breaking are, in general, measured as a net effect, while the Coulomb interaction plays a major role. To disentangle the effects of the isospin symmetry breaking on the basis of experimental data, quantities that are sensitive to the ISB interaction or Coulomb one need to be investigated. Hence, sensitivity studies on the Coulomb and the ISB terms of nuclear interactions are essential.

We aim to conduct a complete sensitivity analysis of the nuclear equation of state and neutron-skin thickness considering the Coulomb and ISB terms. In the previous study,[4] we discussed the effect of ISB terms on the charge radii difference of mirror nuclei $\Delta R_{\rm ch}$, which may be correlated to the density dependence, (*i.e.*, the slope parameter) of the symmetry energy L.[5,6] Similarly, herein, we analyze different quantities related to isospin symmetry breaking, *i.e.*, the neutron-skin thickness and the mass differences of mirror nuclei.

To analyze the ISB contribution, the ISB terms of the SAMi-ISB energy density functional (EDF)[7] are considered on top of the SAMi EDF and SAMi-J family.[8] The correlations between ΔR_{np} and the slope parameter L are illustrated in Fig. 1 for four different EDFs: SAMi without ISB, with CSB only, with CIB only, and with both CSB and CIB. For a given value of ΔR_{np}, the difference between extracted $L + L^{\rm CIB} + L^{\rm CSB}$ without any ISB terms and that with all ISB terms is 11.1 MeV. Here, L, $L^{\rm CIB}$, and $L^{\rm CSB}$ denote the slope parameters of the symmetry energy originating from the no ISB, CIB, and CSB terms, respectively.

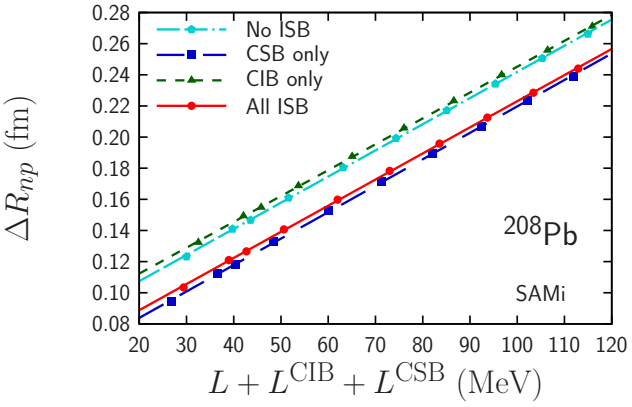

Fig. 1. Correlations between $L + L^{\rm CIB} + L^{\rm CSB}$ and ΔR_{np} without the ISB terms, only with the CSB term, only with the CIB term, and with the all ISB terms. The ISB terms of the SAMi-ISB EDF are considered on top of the SAMi EDF and SAMi-J family.

Using $L^{\rm CIB} = 2.3$ MeV and $L^{\rm CSB} = -3.2$ MeV obtained by the SAMi-ISB EDF, the extracted value of L changes by 12.0 MeV with or without the ISB terms. Thus, the ISB contributions (in particular, the CSB term) to the L parameter may not be negligible. In contrast to the case of the charge-radii difference of mirror nuclei $\Delta R_{\rm ch}$, the effect on L is less because the CIB and CSB effects are in opposite directions in ΔR_{np} for $N > Z$ nuclei, whereas they are coherent in $\Delta R_{\rm ch}$.

The magnitude of the ISB effect discussed here depends on the strengths of CSB and CIB interactions. Therefore, precisely determining their strengths is crucial.

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