Topics on structure of spherical nuclei and effective nucleonic interaction

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Several topics on nuclear structure will be discussed, by using the self-consistent mean-field calculations and the random-phase approximation (RPA) calculations on top of them. Particular focus is put on effective nucleonic interaction, which is the only input of these calculations. To clarify dependence and indication on the effective interaction, I restrict myself to spherical nuclei, in this talk.

1. Prediction of magic numbers [1]
Experiments using radioactive beams have disclosed that nuclear magic numbers are not always rigorous, depending on the proton (Z) and neutron (N) numbers. The tensor force has been pointed out to play a significant role in the Z- or N-dependence of the magic numbers [2]. Applying the so-called semi-realistic effective interaction [3], which contains realistic tensor force, we have predicted magic and submagic numbers in almost whole nuclear chart. The prediction with the M3Y-P6 interaction is compatible with the available experimental data with only a few exceptions.

2. Evidence for 3N LS interaction in isotope shifts [4, 5]
While origin of the ℓs splitting has not been established, it has recently been suggested [6, 7] that the three-nucleon (3N) interaction derived from the chiral effective field theory accounts for the missing part of the ℓs splitting. Incorporating the 3N LS interaction into the semi-realistic interaction, the kink of the isotope shifts in Pb at \( N = 126 \) is reproduced fairly well, without fictitious \( n1g_{9/2}-n0i_{11/2} \) degeneracy (or inversion of those orbits) that was indicated in the previous studies [8]. Moreover, almost equal charge radii between \( ^{40}\text{Ca} \) and \( ^{48}\text{Ca} \), which have been unable to reproduce in self-consistent calculations for decades, are successfully described. With the 3N LS interaction, a kink is newly predicted at \( N = 82 \) for the isotope shifts in Sn, giving an opportunity of further test of the present picture.

3. Constraining slope parameter of symmetry energy [9]
The slope parameter of the symmetry energy \( L \) is a key to understand structure of neutron stars. Although several physical quantities, which can be obtained from nuclear structure experiments, have been proposed to constrain \( L \), model- or interaction-dependence has not been investigated sufficiently. To constrain \( L \) with less model- or interaction-dependence, it is desired to apply observables that correlate well to \( L \), and degree of the correlation is often checked from the interaction-dependence. However, in investigating correlations of the quantities to \( L \), different interactions are used in some works while in others are interactions derived from a single interaction so as to keep certain properties. Furthermore, the number of nuclides are quite limited in the studies so far. We extensively study interaction- and nucleus-dependence of the correlations of the nuclear structure observables proposed so far, the neutron-skin thickness, the low-energy \( E1 \) cross section, the \( E1 \) polarizability \( \alpha_D \) and \( \alpha_D S_0 \) (\( S_0 \) represents the volume symmetry energy), in the Hartree-Fock (HF) and the HF+RPA calculations. It is found that the neutron-skin thickness and \( \alpha_D S_0 \) well correlate to \( L \) in e.g. \( ^{54}\text{Ca} \), \( ^{132,140}\text{Sn} \) and \( ^{208}\text{Pb} \), providing a possibility to constrain \( L \) up to \( \approx 10 \text{ MeV} \) accuracy.
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References