Constraints on the neutron skin and the symmetry energy from the anti-analog giant dipole resonance in ^{208}Pb[†]

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Different experimental methods, either direct or indirect, have been proposed to extract the value of neutron-skin thickness in finite nuclei, that is, the difference between neutron and proton root-mean-square radii,

$$\Delta R_{np} \equiv \langle r^2 \rangle_n^{1/2} - \langle r^2 \rangle_p^{1/2}. \quad (1)$$

The neutron skin thickness has received much attention from both experimental and theoretical viewpoints because it is one of the most promising observables in nuclear structure for constraining the density dependence of symmetry energy around the nuclear saturation density. The symmetry energy plays an important role in understanding the mechanisms of different phenomena in nuclear physics and nuclear astrophysics. It directly affects the properties of exotic nuclei, dynamics of heavy-ion collisions, structure of neutron stars, and simulations of core-collapse supernova.

We investigate the impact of neutron skin thickness, ΔR_{np}, on the energy difference between the anti-analog giant dipole resonance (AGDR), E_{AGDR}, and isobaric analog state (IAS), E_{IAS}, in a heavy nucleus ^{208}Pb. The AGDR has $J^\pi = 1^-$, and $T = T_0 - 1$ with respect to the isospin of parent nucleus T_0. We employ a family of systematically varied Skyrme energy density functionals. The calculations are performed within the fully self-consistent Hartree-Fock (HF) plus charge-exchange random phase approximation (RPA) framework. We confirm a linear correlation with our microscopic approach and compare our results with available experimental data on ^{208}Pb in order to extract a preferred value for ΔR_{np} and, in turn, for the symmetry energy parameters. In Ref.[1)] (denoted as Exp1), the AGDR was separated from other excitations by means of the multipole decomposition analysis of the ^{208}Pb$(\vec{p}, \vec{n})$ reaction at a bombarding energy $T_p = 296$ MeV; the polarization transfer observables were quite instrumental in the separation of the non-spin flip AGDR from the spin-flip spin dipole resonance (SDR) in the multipole decomposition analysis. The energy difference between the AGDR and IAS was determined to be $E_{\mathrm{AGDR}} - E_{\mathrm{IAS}} = 8.69 \pm 0.36$ MeV. Another experimental measurement has been reported in Ref.[2)] (Exp2); the ^{208}Pb$(p, n\gamma p)$ ^{207}Pb reaction with a beam energy of 30 MeV was used to excite the AGDR and to measure its γ-decay to the isobaric analog state, coinciding with proton decay of the IAS. The energy difference between the AGDR and IAS was determined to be $E_{\mathrm{AGDR}} - E_{\mathrm{IAS}} = 8.90 \pm 0.09$ MeV. Averaging the results from two available experimental data, our analysis gives $\Delta R_{pn} = 0.236 \pm 0.018$ fm, $J = 33.2 \pm 1.0$ MeV and a slope parameter of the symmetry energy at saturation $L = 97.3 \pm 11.2$ MeV. Good agreement is obtained in comparing our new results of neutron-skin thickness and symmetry energy J with the values extracted using several different experimental methods within the error bars as shown in Fig. 1. In contrast, the extracted L value is somewhat larger than previously obtained values. Possible hints on whether model dependence can explain this difference are provided.

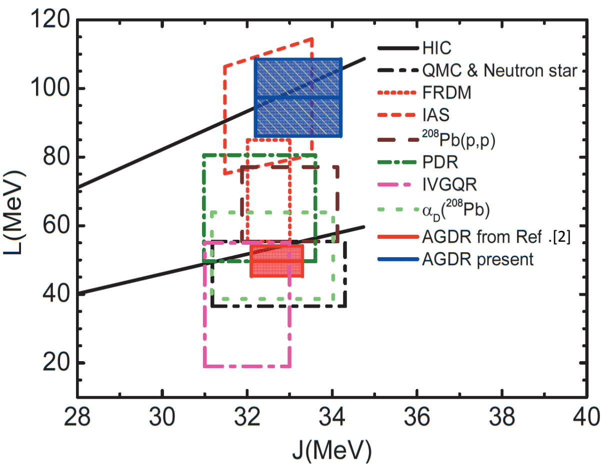

Fig. 1. (Color online) Values of the slope parameter L and symmetry energy J at the saturation density extracted in the current work compared with the values from other experimental data extracted using several different methods.

References
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