Isovector density and isospin impurity in ^{40}Ca[†]

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Experimental charge densities have been studied by electron scattering experiments since the 1950s. Proton densities can be extracted from charge densities removing the proton finite-size effect. It has been shown in Ref. 1) that proton elastic scattering is quite useful to extract the neutron density from the angular distributions of cross sections and analyzing powers of polarized proton beams.

Charge symmetry breaking (CSB) and charge independence breaking (CIB) forces have been discussed in the context of isospin impurity effect on the superallowed Fermi decays. The quantitative information of isospin symmetry breaking (ISB) forces has been recently examined to calculate the binding energies of isodoublet and isotriplet nuclei and also the excitation energies of isobaric analogue states (IAS). This study introduces the Skyrme-type ISB interactions and study their effect on the IV density in ^{40}Ca.

The isovector density defined as the difference between neutron and proton densities as $\rho_{\rm IV} = \rho_n - \rho_p$ is plotted with a factor of $4\pi r^2$ (Fig. 1). The theoretical predictions of the isovector density are qualitatively different from the experimental results: the experimental result of the isovector density exhibits a peak at $r \sim 3.2$ fm, whereas the Hatree-Fock (HF) model with SAMi-J27 interaction predicts a peak at $r \sim 2.5$ fm with positive values (neutron excess) in the interior and negative values on the surface.

A strong correlation between the maximum of IV density and isospin impurity was reported in Ref. 2) with the correlation coefficient $r = 0.992$. The isospin impurity can be extracted from the peak height of the IV density when the proton and neutron densities are available experimentally. The experimental peak height of the IV density is 0.208 ± 0.066 fm^{-1} in Fig. 1. Then, the isospin impurity is then extracted from the correlation plot as

$$\varepsilon^2 = (0.928 \pm 0.586)\,\%. \tag{1}$$

This central value is about 50% larger than the value of RPA calculations without the ISB forces. From this value of the isospin impurity, the strength of CSB interaction s_0 is further obtained as $s_0 = -(8.80 \pm 16.0)$ MeV fm^3.

In summary, we studied the IV density of ^{40}Ca using the mean-field and particle-vibration coupling (PVC) models. We adopted the Skyrme SAMi-J model as the mean-field model. We observed a significant difference between the experimental and calculated IS densities in the interior part and also dilute density region of ^{40}Ca. This difference implies the modification of density distribution owing to the reduced occupation probabilities of single-particle states near the Fermi surface, which may be caused by many-body correlations beyond the mean-field model.

It was shown in Ref. 2) that the magnitude of the IV density significantly changes owing to the CSB interaction, whereas the CIB interaction exhibits no appreciable effect. It is found that the CSB interaction exhibits a strong linear correlation with the maximum of IV density and isospin impurity. Thus, the magnitude of IV density helps experimentally to determine the isospin impurity and the magnitude of CSB interaction. This characteristic of the IV density appears in general in $N = Z$ nuclei, ^{40}Ca, ^{80}Zr, and ^{100}Sn. The measurements of the IV density is desired to obtain the experimental information of the isospin impurity and the CSB interaction.

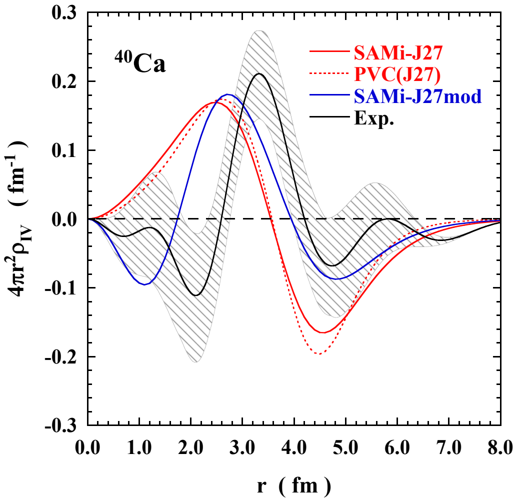

Fig. 1. IV densities multiplied by a factor of $4\pi r^2$ of ^{40}Ca calculated by the HF, modified HF and PVC models as well as the experimental IV density. The red (blue) solid and dashed curves denote the HF (modified HF) and PVC densities with SAMi-J27 (SAMi-J27mod) model, respectively. The occupation probabilities near the Fermi surface are optimized to fit the IS density in the case of modified HF. The experimental data are denoted with a black solid curve considering the experimental uncertainty depicted by the shaded area.

References

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