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Effects of nucleon electric form factors to nuclear binding energy

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It is known that the nuclear interaction is much stronger than the Coulomb interaction, and thus the main contribution to the nuclear properties comes from the nuclear interaction. Nevertheless, the contribution from the Coulomb interaction to the properties is also important, since the Coulomb interaction and the isospin symmetry breaking terms of the nuclear interaction are entangled to each other in some particular nuclear properties, such as the superallowed β decay, the energy difference of the mirror nuclei and its Nolen-Schiffer anomaly, and the isobaric analog states. Although the Coulomb EDFs can be given fully theoretically, the Hartree-Fock-Slater or even Hartree approximation has been widely used.

The Coulomb EDFs are, in principle, written in terms of $\rho_{\rm ch}$, because the Coulomb interaction affects the charge itself instead of the point protons. Nevertheless, the protons and neutrons are assumed to be point particles, i.e., $\rho_{\rm ch} \equiv \rho_p$ is assumed in most of the self-consistent nuclear DFT. In Ref.~[1], for the first time, the finite-size effects of nucleons are implemented to the self-consistent steps of the Skyrme Hartree-Fock calculation. The electric form factors of both protons and neutrons are considered, which corresponds to the leading-order contribution of the finite-size effects. Also, other possible electromagnetic contributions, i.e.,~the vacuum polarization and electromagnetic spin-orbit interaction, are considered in the self-consistent steps. It is found that the neutron finite-size effect and the vacuum polarization are also non-negligible as well as the proton finite-size effect, and the corrections are comparable to the isospin symmetry breaking terms of the nuclear force. The mirror nuclei mass difference between ^{48}Ca and ^{48}Ni is reproduced within $300\,\mathrm{keV}$ accuracy once all the corrections to the Coulomb functional, the GGA, the nucleon finite-size effects, the vacuum polarization, and the electromagnetic spin-orbit term, are considered as well as the isospin symmetry breaking terms.

[1] T.Naito, X. Roca-Maza, G. Colò, and H. Liang. Phys. Rev. C **101**, 064311 (2020).

Field of your work

Theoretical nuclear physics

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