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Nuclear charge-exchange excitations in localized covariant density functional theory

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Nuclear charge-exchange excitations are crucial to understand many important topics in nuclear physics, astrophysics, and particle physics, such as nuclear spin and isospin properties, effective nucleon-nucleon tensor interactions, neutron skin thickness, nuclear β-decay rates in r-process nucleosynthesis, unitarity of Cabibbo-Kobayashi-Maskawa matrix, etc.

The fully self-consistent descriptions of charge-exchange excitations in covariant density functional theory (CDFT) were achieved only recently [1] with the RPA based on the density-dependent relativistic Hartree-Fock (RHF) theory [2]. The characteristics of isobaric analog and Gamow-Teller resonances [2,3] as well as the fine structure of spin-dipole resonances [4] can be nicely understood by the delicate balance between the σ- and ω-meson fields via the exchange terms. Nevertheless, the RHF theory includes non-local potentials, which is much more involved than the conventional CDFT in the Hartree level. Therefore, it is also desirable to stay within the Kohn-Sham scheme and to find a covariant density functional based on only local potentials, yet keeping the merits of the exchange terms.

In Ref. [5], we proposed a new kind of RHF equivalent local covariant density functional. The corresponding isovector channels, which can be barely controlled in ground-states descriptions, are constrained by the Fock term effects of the RHF scheme. It is found that the charge-exchange excitations can be naturally reproduced in such localized framework. This retains the advantages of conventional CDFT models and provides proper descriptions of nuclear isovector properties.

In order to extend this approach to the deformed systems, one of the ongoing projects is the self-consistent relativistic RPA based on the above functionals with the finite amplitude method (FAM). The FAM provides an efficient way to find the RPA equation solutions, in particular, when the dimension of the matrix is huge as in the deformed case [6]. The feasibility of the FAM for CDFT has been demonstrated [7]. Meanwhile, it is shown that the effects of Dirac sea can be taken into account implicitly in the $\mathbf{r}$-space representation and the rearrangement terms due to the density-dependent couplings can be treated practically without extra computational costs.

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