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Effects of three-nucleon force on nucleus-nucleus scattering

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How important is the three-nucleon force (3NF)? This is one of the fundamental subjects in nuclear physics. This long-standing subject essentially started with the two-pion exchange 3NF proposed by Fujita and Miyazawa. For light nuclei, attractive 3NFs were introduced to reproduce the binding energies. In symmetric nuclear matter, the empirical saturation point could not be reproduced only with two-nucleon force (2NF) and then repulsive 3NFs were introduced. There is thus no doubt that the 3NF plays an important role in nuclear many-body systems.

It is hard to define 2NF and 3NF clearly in a phenomenological way. This problem was solved by the chiral effective field theory (Ch-EFT), since it allows us to determine 2NF, 3NF and many-nucleon forces consistently and systematically. Recently, the roles of Ch-EFT 3NF have been analyzed in few-body systems and nuclear matter. In particular, the g-matrix interaction calculated from the Ch-EFT 2NF and 3NF well reproduce the saturation property in symmetric nuclear matter with no adjustable parameter.

Microscopic description of nucleon-nucleus and nucleus-nucleus scattering is another important subject in nuclear physics. In particular, it is necessary to construct an accurate microscopic reaction theory for scattering of unstable nuclei, in which any phenomenological approaches based on optical potentials are not available. The scattering can be described by the g-matrix folding model with the local-density approximation. In the framework, the 3NF effects appear through the density dependence of the g-matrix.

We aim to construct the microscopic reaction theory including the effects of Ch-EFT 3NF for scattering of stable and unstable nuclei. It is, however, not easy to construct a local form of the g-matrix interaction calculated from the Ch-EFT 2NF and 3NF, since the momentum cut-off is introduced. As an effective way of introducing the Ch-EFT 3NF effects, we modify the density dependence of the Melbourne g-matrix interaction constructed from the Bonn-B 2NF. This procedure is justified by the fact that in nuclear matter the g-matrix interaction calculated from the Bonn-B 2NF is close to that from the Ch-EFT 2NF. The Ch-EFT 3NF changes the folding potential less attractive and more absorptive, and consequently, the Ch-EFT 3NF yields better agreement with measured angular distributions of nucleus-nucleus elastic scattering.

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