Microscopic calculations based on chiral two- and three-nucleon forces for proton- and ^{4}He-nucleus scattering

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One of the important issue in nuclear physics is understanding the effects of three-nucleon force (3NF) on nuclear reactions, finite nuclei, and infinite matter. Recently, chiral effective field theory (Ch-EFT) has made a theoretical breakthrough in this issue [1, 2]. Ch-EFT allows us to define two-, three-, and many-nucleon forces systematically. Another important issue is microscopic understanding of nucleon- and nucleus-nucleus optical potentials. The g-matrix folding model is a standard approach to obtaining the optical potential microscopically. In this work, new g matrix from chiral two-nucleon force (2NF) and 3NF is constructed by Brueckner-Hartree-Fock (BHF) method and we apply it to proton- and ^{4}He elastic scattering [3].

In the BHF method, the g matrix is obtained by solving Brueckner-Bethe-Goldstone equation. Since the direct treatment of the 3NF is so difficult even in infinite matter, we introduce an effective 2NF derived from 3NF with the mean-field approximation. For more convenience we derive the local g matrix with Gaussian form by keeping the on-shell and near-on-shell components consistent with the original ones. Applying the local g matrix to the folding model, we obtain the optical potentials for proton- and ^{4}He elastic scattering.

Figure 1 shows the differential cross sections $d\sigma/d\Omega$ and the vector analyzing power A_y for proton scattering on ^{40}Ca, ^{58}Ni, and ^{208}Pb targets at $E_{\rm in} = 65$ MeV, and $d\sigma/d\Omega$ for ^{4}He scattering on ^{58}Ni and ^{208}Pb targets at $E_{\rm in}/A_{\rm P} = 72$ MeV. The results of chiral g matrix with 3NF effects (solid lines) reproduce the measured $d\sigma/d\Omega$ and A_y without any adjustable parameters for each system. The effects of 3NF for proton scattering are small at forward and middle angles where the experimental data are available. On the other hand, the effects for ^{4}He scattering are clearly seen at middle angles, because the near-side and far-side of scattering amplitude [4] are decomposed well. We found that chiral 3NF makes the optical potentials less attractive and more absorptive, and these effects mainly originated in the 2π-exchange diagram in chiral 3NF.

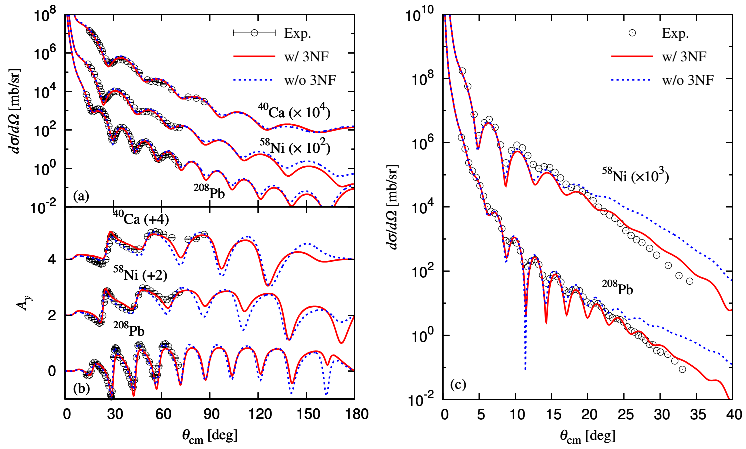

Figure 1: Angular distribution of (a) differential cross sections and (b) vector analyzing powers for proton elastic scattering at 65 MeV, and (c) differential cross sections for ^{4}He scattering at 72 MeV. The solid (dashed) lines represent the results of the chiral g matrix with (without) 3NF effects. Each cross section (vector analyzing power) is multiplied (shifted up) by the number in the figure. Experimental data are from Refs. [5, 6]

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