Shallow and diffuse spin-orbit potential for proton elastic scattering from neutron-rich helium isotopes at 71 MeV/nucleon†

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Strong spin-orbit coupling in atomic nuclei plays an important role in nuclear structure and reactions. Its manifestation in neutron-rich nuclei has attracted extensive interest, since a number of experimental results suggest a change in the shell structure that could be explained by a reduction in the spin-orbit splitting. On the other hand, there has been no experimental study on how the spin-orbit coupling is modified in nuclear reactions. Spin asymmetry in proton–nucleus scattering is a prominent manifestation of the spin-orbit coupling in nuclear reactions. The spin-orbit term in the optical model potential is generally expressed by a derivative of the density distribution[1–3)]. It would be interesting to probe the nature of the spin-orbit potential for a nucleus with a very diffuse surface.

In order to investigate the effect of the exotic density distribution on the spin-orbit potential, we measured the vector analyzing powers for proton elastic scattering from ^{6}He and ^{8}He at 71 MeV/nucleon at RIPS beamline at RI Beam Factory using the solid polarized proton target specially constructed for the RI-beam experiment [4)]. To determine the spin-orbit potentials, we performed a phenomenological optical model analysis using the ECIS79 code. For the function of the potential, we used a standard Woods-Saxon form factor with a Thomas-type spin-orbit term. We search for a parameter set that reproduces both the $d\sigma/d\Omega$ and A_y data. Details of the fitting procedure and obtained parameters can be found in Refs.[5,6)].

The characteristics of the spin-orbit potential is discussed in terms of the r.m.s. radius of the potential $\langle r_{ls}^2\rangle^{1/2} = \sqrt{\int r^2 V_{ls}(r)d\boldsymbol{r}/\int V_{ls}(r)d\boldsymbol{r}}$ and the amplitude of $rV_{ls}(r)$ at the peak position. Here, r is the distance from the center-of-mass of ^{6,8}He and $V_{ls}(r)$ is the spin-orbit potential. Figure 1(a) shows the mass-number dependence of the $\langle r_{ls}^2\rangle^{1/2}$ values for the spin-zero nuclei. The closed circles show the potentials locally obtained for each nucleus. The dashed and dot-dashed curves represent the global optical potentials[7,8)]. We can see that the $\langle r_{ls}^2\rangle^{1/2}$ values of ^{6}He and ^{8}He are remarkably larger than the systematics. Moreover, it is interesting to find a close similarity between the behavior of $\langle r_{ls}^2\rangle^{1/2}$ and the matter radius r_m, plotted as the open squares in Fig. 1(a). This indicates the particular sensitivity of the spin-orbit interaction to the nuclear surface structure.

Figure 1(b) displays the amplitude of $rV_{ls}(r)$ at the peak position. The peak amplitudes for ^{6}He and ^{8}He are considerably smaller than the standard values of 3.5–5.5 MeV fm. From these results, it is concluded that the spin-orbit potentials between a proton and neutron-rich ^{6}He and ^{8}He nuclei are considerably shallower and more diffuse than the global systematics of nuclei along the stability line. This is considered to be a consequence of the diffuse density distribution of these neutron-rich isotopes.

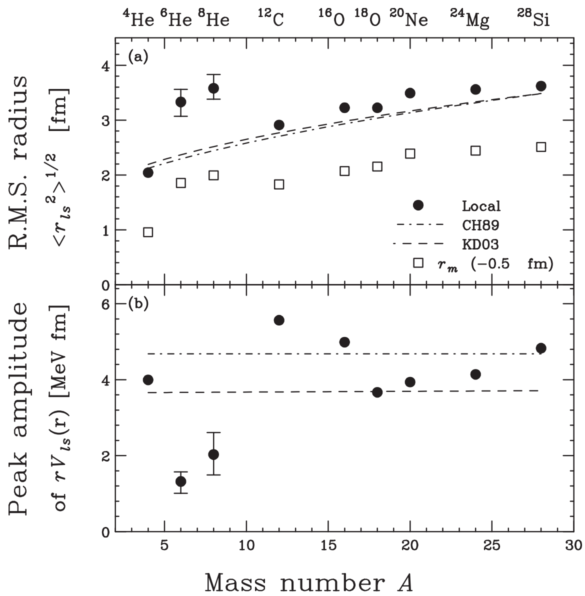

Fig. 1. See text for details. The symbols for r_m are shifted vertically by −0.5 fm to prevent overlap.

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