

Nuclear Matter Distributions of Neutron-Rich Li-Isotopes from Elastic Proton Scattering in Inverse Kinematics

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The method of proton elastic scattering at intermediate energies, which was already proven for the neutron-rich helium isotopes ^{6,8}He [1],[2] to be well suited for obtaining accurate and detailed information on nuclear matter distributions of halo nuclei, was recently applied for the investigation of the lithium isotopes ^{6,8,9,11}Li. Absolute differential cross sections $d\sigma/dt$ for small-angle Li-p elastic scattering were determined by an inverse-kinematics measurement using secondary Li-beams with $E \approx 0.7$ GeV/u from the SIS-FRS, and gaseous hydrogen as the proton target. The hydrogen filled ionization chamber IKAR served simultaneously as target and detector for recoil protons. Projectile scattering angles were measured precisely with multi-wire tracking detectors. Furthermore, a magnetic-rigidity analysis of the scattered particles was performed with the aid of the ALADIN magnet and a position sensitive scintillator wall behind for the separation of neutron break-up channels. For this purpose the entire experimental setup was installed at the Cave B.

The data analysis has fairly progressed within the year 2000. The (still preliminary) differential cross sections $d\sigma/dt$ for p^{9,11}Li scattering are displayed in Fig. 1 together with the cross section for p⁶Li scattering, the results of which were discussed already in the previous GSI annual report 1999.

For establishing the nuclear density distributions from the measured cross sections, the Glauber multiple scattering theory was applied. Calculations were performed using the basic Glauber formalism for proton-nucleus elastic scattering, and taking experimental data on the elementary proton-proton and proton-neutron scattering amplitudes as input. In the present analysis two different parametrizations for modelling the nuclear density distribution were used for the Glauber calculations, and the parameters were varied in order to obtain a best fit to the experimental cross sections. Both parametrizations applied assume the nuclei involved to consist of a core and two valence neutrons. A Gaussian distribution for the core, and either a Gaussian (GG) or a 1p-shell harmonic

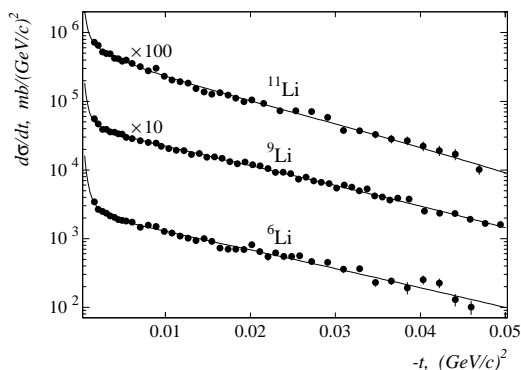


Figure 1. Absolute differential cross sections $d\sigma/dt$ versus the four momentum transfer squared t for p^{6,9,11}Li elastic scattering obtained from the present experiment. Full lines are the result of fits to the data performed on the basis of the Glauber multiple scattering theory.

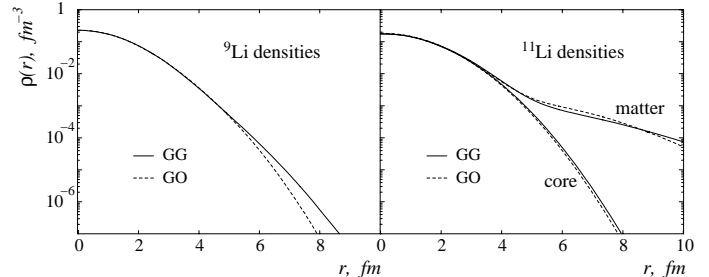


Figure 2. The nuclear matter and nuclear core density distributions $\rho(r)$ of ¹¹Li deduced from the present experimental data are compared with the nuclear matter density distribution of ⁹Li. Labels denote different parametrizations of phenomenological density distributions used in the analysis (see text).

oscillator-type density (GO) for the valence neutrons were used (for details see ref.[1]). The experimental data are comparably well described with both density parametrizations, with a reduced χ^2 around unity. Solid lines in Fig. 1 show the GG case as an example.

The nuclear matter distributions of ¹¹Li and ⁹Li deduced from the present data are displayed in Fig. 2. The radii obtained for the total matter, the core, and the halo distributions for ^{9,11}Li are given in Table 1 in comparison with those of ^{6,8}He from the previous experiment [1],[2]. It is obvious from the data that the matter distribution of ¹¹Li exhibits the by far most pronounced halo structure compared to all the other nuclei investigated, including ⁶He and ⁸He. This is also reflected in the deduced nuclear matter radius $R_m = 3.62$ (14) fm and the halo radius $R_h = 6.54$ (38) fm, the latter being more than twice as large as in ⁶He and ⁸He. A comparison of the nuclear matter and core distributions of ¹¹Li with the matter distribution deduced for ⁹Li, and the corresponding radii (Table 1), supports the generally accepted picture of ¹¹Li to consist of a ⁹Li core and a two-neutron halo.

Table 1: Summary of nuclear matter radii deduced for the helium isotopes ^{6,8}He [1],[2] and for the lithium isotopes ^{9,11}Li from the present experiment (please note that the results on the lithium isotopes are still preliminary). R_m denotes the total rms matter radius, R_c the core radius, and R_h the halo radius. The errors given include statistical and systematical uncertainties.

nucleus	R_m	R_c	R_h
⁶ He	2.30 (7)	1.88 (12)	2.97 (26)
⁸ He	2.45 (7)	1.55 (15)	3.08 (10)
⁹ Li	2.43 (7)	2.21 (10)	3.10 (28)
¹¹ Li	3.62 (14)	2.55 (12)	6.54 (38)

References

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