1 GeV PROTON SCATTERING ON ^{11}Li NUCLEI

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In recent years one of the most interesting events in nuclear physics was the discovery of nuclei which have a neutron halo. These nuclei have a very unusual shape. In contrast with all previously known nuclei, which have a fairly thin surface layer of nuclear matter, these newly discovered nuclei have a neutron halo, whose size is several times the size of the core of the nucleus. These neutron-excess nuclei, which fall right at the boundary of nuclear stability, have been a subject of a large number of studies, both experimental and theoretical. Although the existence of a neutron halo in a nucleus ^{11}Li and in certain other exotic nuclei is now a solidly established fact, the accurate halo radius measurements are still to be done.

The most reliable information on the distribution of nuclear matter has been found from elastic scattering of intermediate energy protons. The use of protons with energies of 800–1000 MeV as probes to study nuclei proved to be successful because at these energies the scattering can be described by the theory of diffractive multiple scattering, which relates the measured cross sections to the nuclear densities of interest in a quite unambiguous way. This method can also be used in inverse kinematics to study unstable nuclei. Recently we proposed the experiments of this sort on fast beams of light exotic nuclei with the help of the IKAR recoil-nucleus detector [1, 2].

The present work is devoted to the question how sensitive the differential elastic proton-nucleus scattering cross sections are to the nucleon distributions of exotic nuclei with a neutron halo. The consideration of the problem is carried out for the particular case of proton scattering on ^{11}Li nuclei at 1 GeV. The cross sections are calculated using the Glauber theory of multiple scattering and the cluster-orbital model for the ^{11}Li nucleus.

It follows from the performed analysis that the scattering from the halo contributes to the small angle scattering region (Fig.), for the particular case of proton scattering on ^{11}Li this region being limited by the proton recoil energy $T < 5$ MeV. Cross sections in this region are sensitive to the size of a neutron halo whereas the behaviour of the cross sections at larger values of T is mainly determined by a size and a shape of a core. Hence, analyzing the shape of the cross section, one can obtain information on the radius of the halo as well as on the radius of the core. It has been shown that the differential cross section slope parameter depends on the root-mean-square radius of the neutron halo and practically does not depend on the shape of the halo distribution. This means that the root-mean-square radius of the neutron halo may be determined in an almost model independent way.

It follows also from the calculations that the direct effect in the cross sections from the halo neutron correlations connected with the shadowing of one neutron by another one for realistic range of correlations is negligible small. However, these correlations influence the center of mass motion of the core, so that in accurate cross section calculations they should be taken into account.

As is known, ^{11}Li is a deformed nucleus. Since its spin is more than 1/2, it means that the differential cross section minima are filled with the contribution from scattering on the quadrupole density component. The extent of this filling may be used to determine the value of the nuclear matter deformation.

We conclude that the proton elastic scattering at the intermediate energy is a promising tool to study neutron halo nuclei.

The results of the calculations are published in [3 - 5].

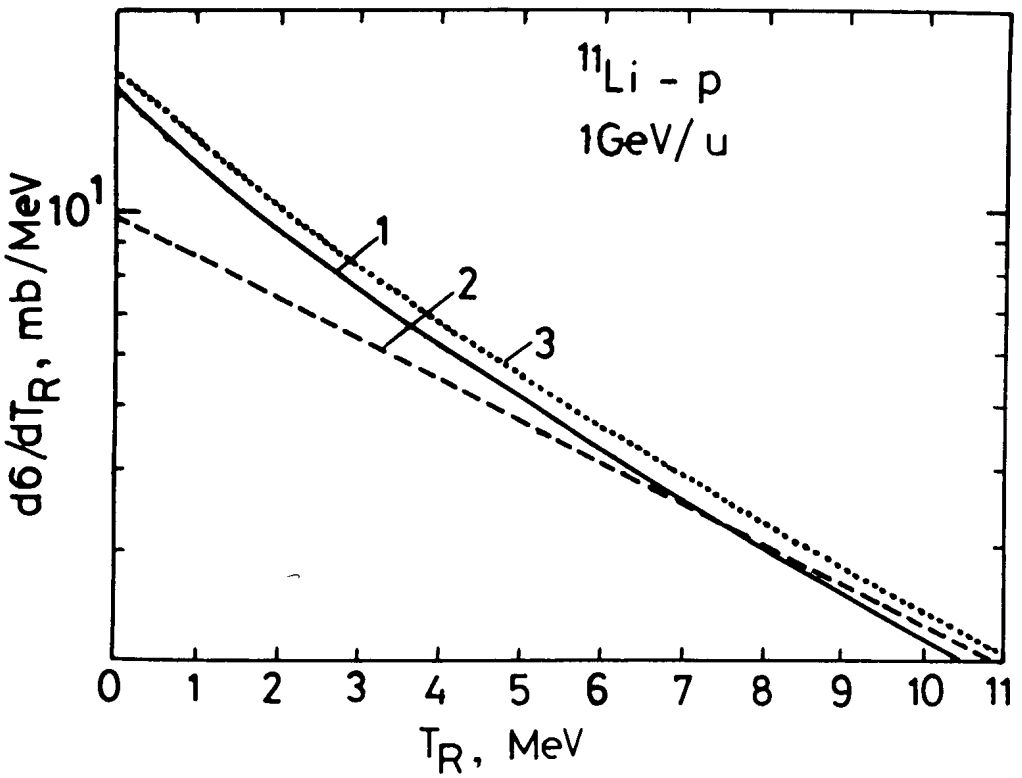

Fig. Calculated differential cross sections for elastic scattering of protons on ^{11}Li nuclei at 1 GeV in inverse kinematics as function of recoil proton energy (Coulomb interaction is switched off). Curves 1-3 correspond to taking into account all Glauber terms (1), contribution of scattering only from core (2) and sum of contributions of scattering from core and from halo (3). (For the halo radius 6.8 fm)

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