SMALL ANGLE PROTON ELASTIC SCATTERING ON ^{4}He, ^{6}He and ^{8}He AT THE ENERGY OF 0.7 GeV IN INVERSE KINEMATICS

(S-105 experiment, GSI)

G. D. Alkhazov, M. N. Andronenko, A. V. Dobrovolsky, G. E. Gavrilov, A. V. Khanzadeev, G. A. Korolev, A. A. Lobodenko, D. M. Seliverstov, N. A. Timofeev, A. A. Vorobyov, V. I. Yatsoura, T. Beha[1]), K.-H. Behr[1]), A. Brunle[1]), K. Burkhard[1]), P. Egelhof[1]), C. Fischer[1]), H. Geissel[1]), H. Irnich[1]), G. Münzenberg[1]), F. Nickel[1]), W. Schwab[1]), T. Suzuki[1]), P. Lorenzen[2]), M. Mutterer[2]), S. R. Neumaier[2]), P. Singer[2]), J. P. Theobald[2])

[1]) *Gesellschaft für Schwerionenforschung, Darmstadt, Germany*
[2]) *Institut für Kernphysik, Technische Hochschule, Darmstadt, Germany*

One of the most exciting events in nuclear physics in recent years was the discovery of light neutron-rich nuclei (such as ^{8}He, ^{11}Li, ^{14}Be) with extended neutron distribution surrounding the nuclear core. To study nuclear density distributions of nuclei one uses elastic proton-nucleus scattering which can be described accurately by the diffractive multiple scattering theory [1]. This method can also be applied to study unstable nuclei by measuring proton elastic scattering in inverse kinematics using radioactive beams and a proton target. Futhermore, theoretical estimates show that proton scattering in the region of small momentum transfer is rather sensitive to the halo densities [2].

This experiment on elastic proton scattering was performed at the heavy ion synchrotron of GSI Darmstadt with secondary ^{4,6,8}He beams from the fragment separator at the incident kinetic energy of ~0.7 GeV/u. The experimental setup is shown in Fig.1.

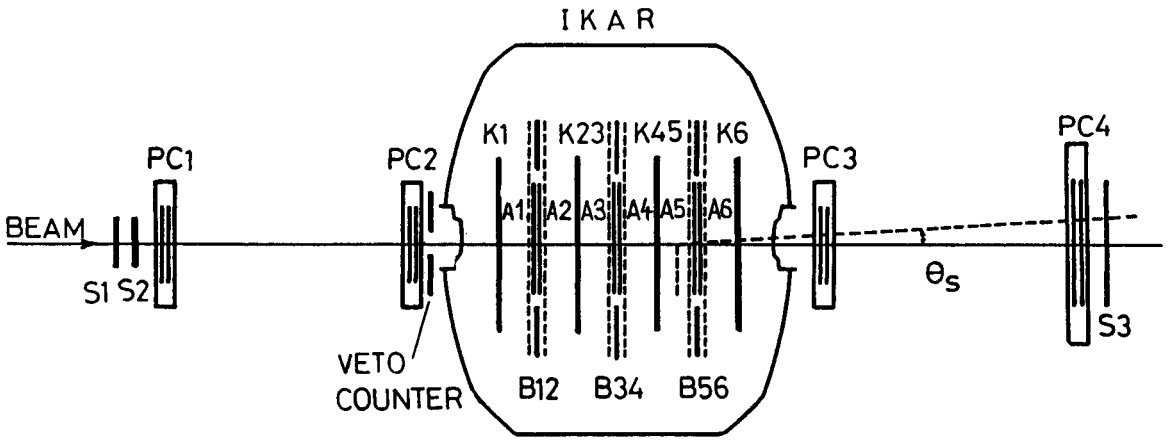

Fig.1. Experimental setup: IKAR – ionization chamber with cathodes K1-K6, anodes A1-A6 and B1-B6; PC1-PC4 – multiwire proportional chambers; S1-S3, veto counter – scintillation counters

Beam particles interacted with protons inside hydrogen filled ionization chamber IKAR which served as a gas target and a recoil detector at the same time. IKAR had been developed at PNPI to study small angle hadron elastic scattering [3–5]. It operates at 10 bar pressure and consists of 6 gridded ionization chambers. Each cell contains a cathode, a grid, and an anode plate divided into two rings (A and B). Signals from the various electrodes of IKAR were registered by flash-type ADCs. A tracking detector consisting of 4 multiwire proportional chambers permitted to measure the scattering angle Θ_s of the incident particle. A set of scintillation counters was used to trigger the system and to identify the incident particles in mass and charge via TOF and dE/dx.

The signals from IKAR allowed to determine precisely the energy T_R of recoil protons, or their energy loss ΔT_R in case they left the active volume, and to reconstruct the interaction vertex in the grid-cathode space. To correct for background events the correlation of the proton recoil energies measured in IKAR with the values evaluated from the scattering angle Θ_s of the incident projectile was used. The measured differential cross sections are presented in Fig.2. The absolute normalization is estimated with an accuracy of about 3%. In the case of ^{4}He an excellent overall agreement with data of [6] is attained.

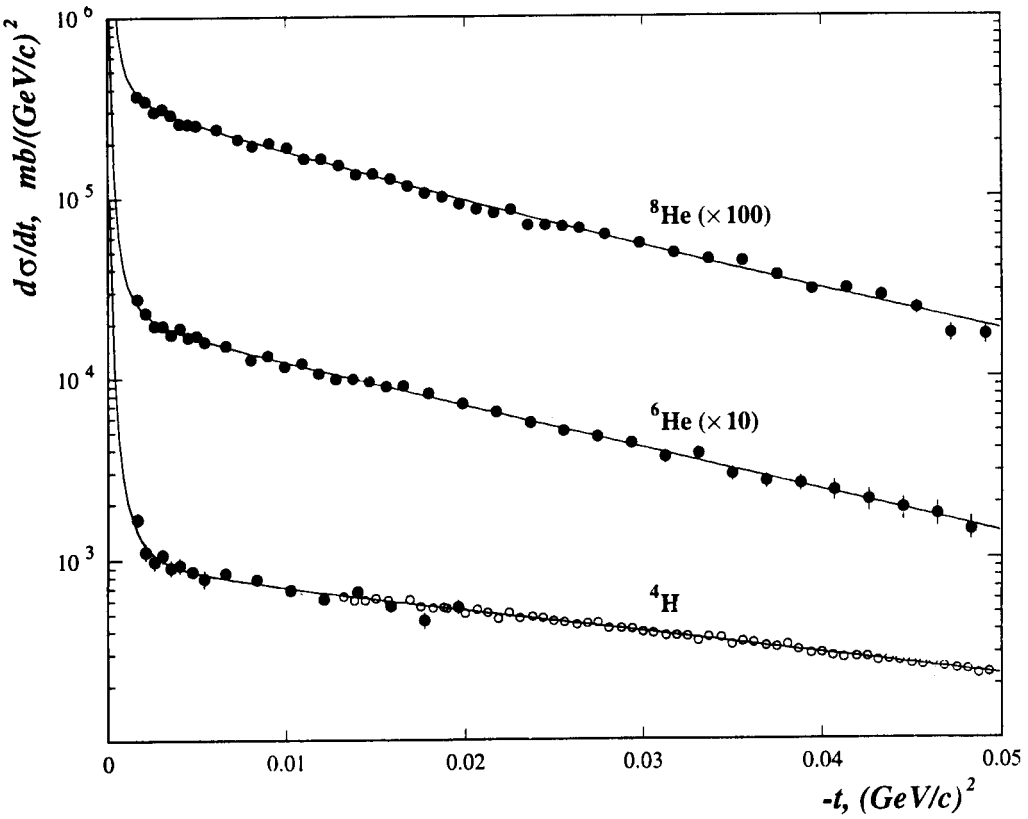

Fig.2. Absolute differential cross section $d\sigma/dt$ versus the four momentum transfer squared $\mid t \mid$ for p^{4}He, p^{6}He and p^{8}He elastic scattering (full dots) measured in the present experiment. Open dots show the result of p^{4}He scattering measured in direct kinematics with a proton beam [6]. Plotted lines present one of the versions obtained by calculations with the Glauber multiple scattering theory

To deduce the parameters of the nuclear density distributions from the measured cross sections, the Glauber multiple scattering theory was applied. Calculations were made with phenomenological one-body-density point distributions of Gaussian type to determine their root mean square radii $< r^2 >^{1/2}$ by fitting the measured cross sections.

One of the versions obtained by calculations with the Glauber multiple scattering theory is shown in Fig.2. The p^{4}He cross section is well described using a single Gaussian distribution for the density with $< r^2 >^{1/2}$ = 1.49±0.02 fm which corresponds to the nuclear charge radius determined from electron scattering [7]. For p^{6}He and p^{8}He scattering a better description of the data is obtained by using a nuclear matter distribution which is parametrized by 2 Gaussians, one describing the distribution of the core nucleons, and the other describing the distribution of the skin (halo) neutrons. For p^{6}He case the values of $< r^2 >_c^{1/2}$ = 1.95±0.10 fm for core nucleons and $< r^2 >_s^{1/2}$ = 2.88±0.27 fm for skin (or halo) neutrons thus obtained correspond to the average $< r^2 >_{av}^{1/2}$ = 2.30±0.06 fm. The values for p^{8}He scattering are: $< r^2 >_c^{1/2}$ = 1.68±0.07 fm, $< r^2 >_s^{1/2}$ = 3.04±0.09 fm, $< r^2 >_{av}^{1/2}$ = 2.46±0.04 fm. The indicated errors are statistical only. The present status of the analysis is in agreement with the existence of a neutron skin in ^{6}He and ^{8}He. The analysis of the measured cross sections using other density parametrizations and the work on estimation of the errors in extracted density parameters due to some possible systematical uncertainties are in progress. Further measurements of neutron-rich lithium and beryllium isotopes with the same experimental techniques are in preparation.

REFERENCES

1. *Alkhazov G.D. et al.* //Phys.Rep., 1978. **V.42.** P.89.
2. *Alkhazov G.D., Lobodenko A.A.* //Pisma Zh.Eksp.Teor.Fiz., 1992. **V.55.** P.377.
3. *Vorobyov A.A. et al.* //Nucl.Instr.Methods, 1974. **V.119.** P.509.
4. *Dobrovolsky A.V. et al.* //Nucl.Phys., 1983. **V.B214.** P.1.
5. *Burg J.P. et al.* //Nucl.Phys., 1981. **V.B187.** P.205.
6. *Grebenjuk O.G. et al.* //Nucl.Phys., 1989. **V.A500.** P.637.
7. *Ottermann et al.* //Nucl.Phys., 1985. **V.A436.** P.688.

THE PROBLEM OF NUCLEAR CHARGE RADIUS DETERMINATION FOR ^{11}Li BY LASER SPECTROSCOPY

A. E. Barzakh, V. P. Denisov

At present light nuclei near the neutron drip line attract much attention owing to their large neutron radii inferred from the anomalous total reaction cross sections for such nuclei as ^{11}Li,^{14}Be,^{17}B on various targets. This fact is considered as manifestation of a neutron halo. A neutron halo conception was supported by the subsequent experiments on the fragmentation and electromagnetic dissociation of ^{11}Li.

Nevertheless, there is no direct measurements of the size of this halo and the available estimations are model-dependent, though the sizes of the neutron halo and the charge radius are of crucial importance for understanding the ^{11}Li structure.