STUDY OF POLARIZATION IN QUASI-ELASTIC BREAK-UP REACTION $^6Li(p,2p)^5He$ IN COMPLETE KINEMATICS AT 1 GeV

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Investigation of a few-body system has a great importance and becomes more actual in connection with searching for the effects of nuclear structure. Up to now this investigation has been carried out mainly in experiments where only cross sections of various reactions were measured. The new generation of the polarization experiments where the effects of clusterization in the nuclei were studied became available recently. As one of the results of these investigations [1] the significant spin effects on ^6Li were demonstrated over the wide energy and angular ranges. None of the theoretical calculations was able to reproduce the obtained data in details. It appears that the nucleus vector and tensor analyzing powers are more sensitive to the chosen nuclear wave function than to the details of the interaction. The polarization effects found on ^7Li, ^{13}C, ^{15}N are much smaller than on ^6Li in contradiction to the theoretical predictions. It was also found out that the vector analyzing power in the reactions on very light nuclei such as deuteron [2] is large and has a tendency of increasing with the energy.

Under these circumstances it seems very interesting to measure the polarization variables in the exclusive quasi-free $(p,2p)$ reaction on ^6Li at 1 GeV in order to reveal the effects of nucleus clusterization. With this purpose in mind we proposed to measure the polarization (P_2) of the low-energy protons produced in above mentioned reaction as well as the analyzing power (A_Z) in the reaction on polarized nuclear target. From these two observables we may obtain information on nuclear structure function $B_Z(k)$ and effective polarization of protons on nuclear shells $P_{eff}(k)$. The latter was predicted by *Maris Th. et al.* [3] as the result of absorption of the secondary protons and spin-orbit coupling in nuclear matter. It was shown that the predictions on the value of P_{eff} strongly correlate with the assumption on the nuclear wave function used in the calculations [4]. The same is true for the nuclear structure function $B_Z(k)$.

1. First experiment

In the experiment with unpolarized ^6Li target we measured the polarization (P_2) of the low-energy protons knocked out in the reaction $^6Li(p,2p)^5He$ at angle $\Theta_2 = 58^o$ from S- and P-shells of ^6Li nucleus. The measurements were performed at non-symmetric outgoing angles ($\Theta_1 = 15^o \div 22^o$, $\Theta_2 = 58^o$) of the secondary protons in the conditions of a coplanar quasi-free scattering geometry and a complete reconstruction of the reaction kinematics. It is known that for such a reconstruction at a given excitation of the residual nucleus (^5He) one needs to measure five kinematical variables. In this experiment we measured the momenta (K_1, K_2) of the secondary protons and their outgoing angles (Θ_1, Θ_2, Φ_1, Φ_2). Using the obtained values of K_i, Θ_i, Φ_i and the value of beam momentum K_0 it is possible to calculate

the nuclear proton separation energy ΔE and the residual nucleus momentum K_B. The latter in the impulse approximation is equal to the momentum of nuclear proton before the interaction ($\vec{K}_B = -\vec{K}$).

The experimental setup is presented in Fig.1. It consisted of proton beam magnetic channel, two-arm magnetic spectrometer, unpolarized ^6Li target (T_1), scintillation counter telescope ($M_1 \cdot M_2 \cdot M_3$) and ionization chamber (IC) for monitoring the incoming beam parameters. The two-arm magnetic spectrometer was used for registration of the secondary protons from the reaction $^6Li(p,2p)^5He$ and for measurements of their momenta and outgoing angles. Its low-energy arm (NES-spectrometer) was installed at fixed angle $\Theta_2 = 58^o$. Polarimeter located at the focal plane of the NES-spectrometer was used to measure the polarization (P_2) of the low-energy protons produced in the reaction $^6Li(p,2p)^5He$. It consisted of four proportional chambers and carbon analyzer (T_2). The main parameters of the two-arm magnetic spectrometer are presented below (Table).

2. First results

The results of investigation of the reaction $^6Li(p,2p)^5He$ are presented in Figs.2,3. First of them presents the energy loss spectrum which allows to estimate the obtained resolution of S- and P-shells of ^6Li. The results of measurement of the polarization P_2 for P- and S-shells of ^6Li in the region of the residual nucleus momenta up to 150 MeV/c are shown in Fig.3a. The measured value of the polarization in elastic pp-scattering is shown in the figure as a point at $K_B = 0$. The solid line in Fig.3a is the result of calculations of the polarization in the reaction $^6Li(p,2p)^5He$ in the impulse approximation.

The experimental data for P-shell (Fig.3a) display a smooth decrease of the polarization P_2 as the residual nucleus momentum increases. The behavior of the polarization P_2 for S-shell is more complicated and demonstrates a deep minimum near $K_B = 100$ MeV/c. This effect apparently is not connected with any systematical errors of the measurements because the S- and P-shell data were obtained simultaneously in the same experimental conditions. The off-line data analysis was also carried out using the same routine.

According to our data the mean value of the effective polarization in the region $50 \leq K_B \leq 150$ MeV/c for P-shell (Fig.3b) is equal to $\langle P_{eff} \rangle = -0.14$ [5]. The obtained sign of P_{eff} is the same as predicted in [4] in the framework of primitive cluster model of ^6Li nucleus $\left\{^6Li - (\alpha \overset{s}{+} d)\right\}$.

The nature of the behavior of the polarization P_2 for the case of scattering on the S-shell protons (Fig.3a) is not clear yet. It is impossible to explain it in terms of P_{eff}, its value being zero for S-shell of ^6Li nucleus in the framework of pure shell model. However assuming the existence of a significant $(d-d)$ clusterization in α-core of ^6Li one can expect to find a non-zero effective polarization in the region of inner momenta close to the node of the S-state radial wave function in relative motion of the clusters due to a noticeable admixture of the D-state in $(d+d)$ cluster structure of ^4He ($11 \div 15\%$ according to theoretical predictions). Another possible explanation is the presence of $^3H + p$ component in the P-state of relative motion which can also produce an effective polarization of the same sign.

The results of this experiment are under discussion now. We plan to continue the polarization measurements in the kinematic region where the product $(\vec{K}_B \cdot \vec{K}_0)$ has positive sign (Fig.3b).

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Table

Parameters of the Magnetic Spectrometers

Spectrometer	NES	MAP
Maximum particle momentum $(K/Z)^{max}$, GeV/c	1.0	1.7
Axial trajectory radius R, m	3.03	5.5
Deflection angle α, deg.	42.2	24.0
Dispersion in focal plane D, mm/%	16.0	22.0
Solid angle acceptance Ω, sr	$4.7 \cdot 10^{-3}$	$4.0 \cdot 10^{-4}$
Energy resolution (FWHM), MeV	~ 2.0	~ 1.5

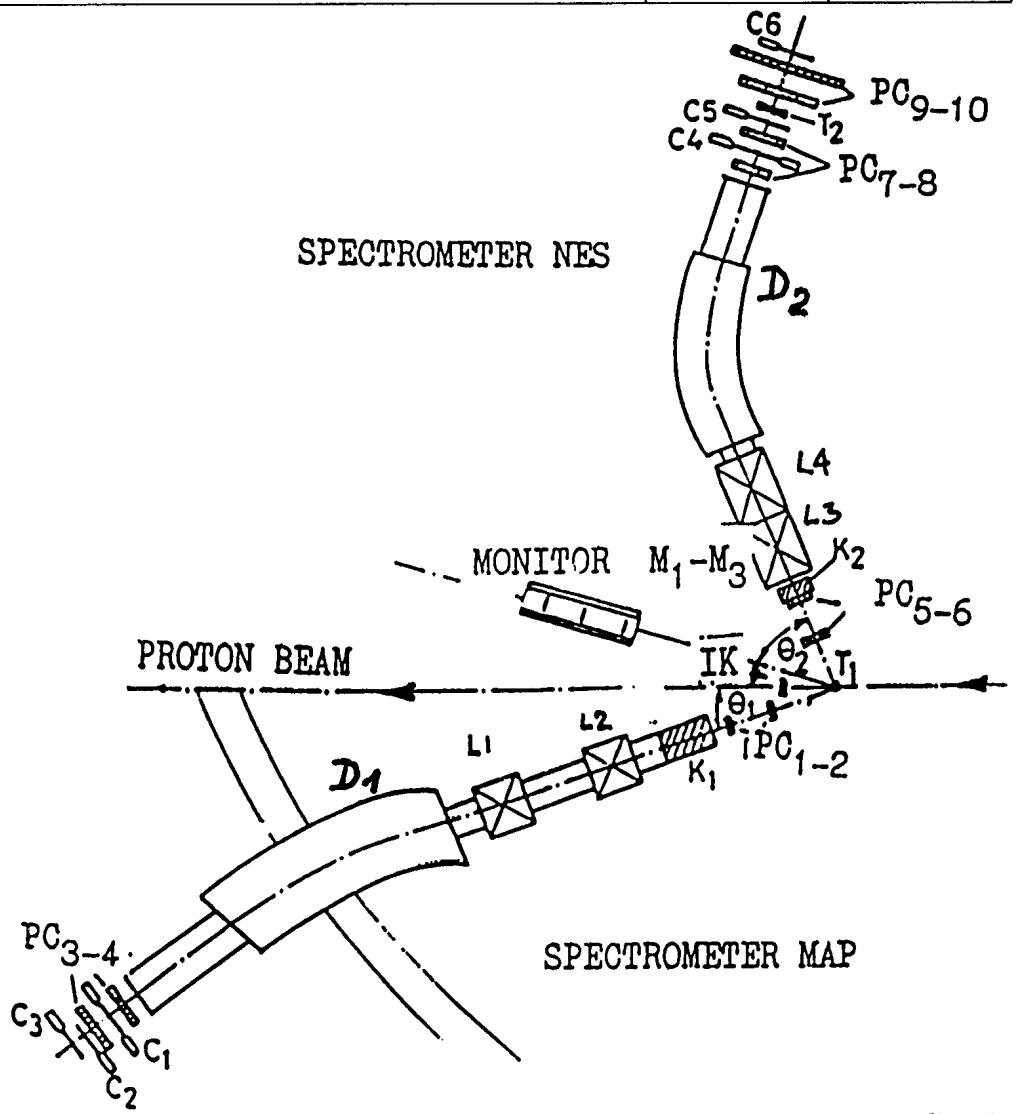

Fig.1. Experimental setup: $L_1 - L_4$ — quadrupoles; D_1, D_2 — magnets; IC — ionization chamber; C_1–C_6 — scintillation counters; PC_1–PC_{10} — proportional chambers; ^6Li target; T_2 — carbon analyzer of the polarimeter

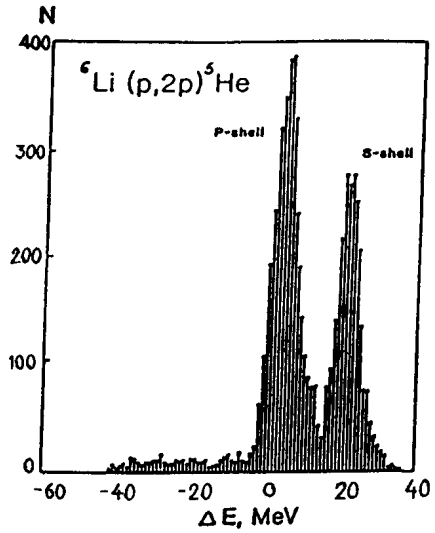

Fig.2. Nuclear proton separation energy spectrum for the reaction $^6Li(p,2p)^5He$ at 1 GeV

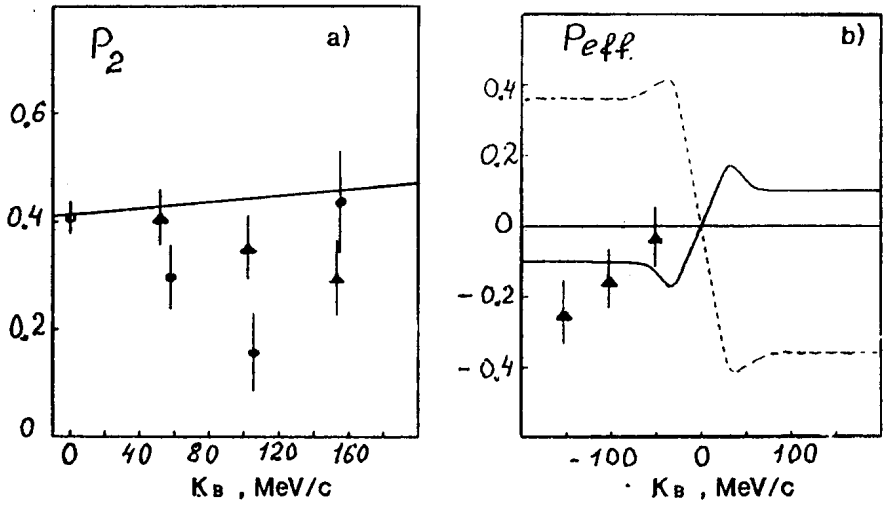

Fig.3. a) Polarization of the low-energy protons produced at angle $\Theta_2 = 58^o$ in the reaction $^6Li(p,2p)^5He$ at 1 GeV on protons of S-shell (○) and P-shell(△) of ^6Li. Point (□) is the polarization in elastic pp-scattering. Solid line shows impulse approximation predictions;
b) Effective polarization in the reaction $^6Li(p,2p)^5He$ for P-shell of ^6Li nucleus. Points (△) are the results of this experiment [5]. Solid and dashed curves represent the results of cluster- and shell-model calculations, respectively [4]. Sign of the residual nucleus momentum K_B corresponds to that of $(\vec{K_B} \cdot \vec{K_0})$ product

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