ANALYSIS OF ELASTIC AND INELASTIC SCATTERING OF HADRONS FROM ^{6}Li NUCLEUS AT INTERMEDIATE ENERGIES

IBRAEVA E.T., ZHUSUPOV M.A., SANPHIROVA A.V.

Institute of Nuclear Physics, National Nuclear Center Almaty, Kazakhstan

Studing of elastic and inelastic hadron scattering from nuclei for hadron energies of about hundreds MeV gives an important information about nuclear structure and interaction mechanisms. It is especially interesting to compare processes of hadron scattering from the same target-nucleus for different incident particles (protons, π^+- and K^+-mesons), since they interact with nucleons in a different manner. For example, K^+-mesons interact with nucleons weakly without making any well-established resonance, that gives a chance to use kaons as a nuclear probe as a test of reaction dynamics and nuclear structure. On the contrary, interaction of protons, π^+-mesons with the nucleus takes place in nucleus periphery, since these hadrons practically do not penetrate deep inside the nucleus due to the strong absorption.

Within the framework of Glauber multiple scattering theory differential cross sections (DCS) of proton, π^+- and K^+-meson elastic and inelastic scattering from ^{6}Li nucleus have been calculated in the range of incident particle energies from 0.164 to 0.534 GeV. The target-nucleus wave functions (WF), calculated with realistic interaction potentials, have been considered in α2N three-particle model [1].

In diffraction theory, the matrix element of hadron scattering on nucleus may be written as:

$$\langle \Psi_f | \Omega | \Psi_i \rangle = \frac{ik}{2\pi} \int d^2\rho \exp(i\vec{q}\vec{\rho}) \langle \Psi_f | \Omega(\vec{\rho}_1, \ldots \vec{\rho}_6) \delta(\vec{R}_6) | \Psi_i \rangle, \qquad (1)$$

In our calculations of DCS we use three-body WF with the following interaction potentials. Model 1: Nα is the Sack-Biedenharn-Breit potential (SBB), NN is the Reid potential with a soft core (RSC); model 2: Nα is the potential with even-odd splitting, taking into account the nucleon exchange between clusters with different masses, NN is the RSC potential. Configuration of WF is determined by the quantum numbers λ l L S, where l is the angular momentum of the relative motion of an α-particle and two-nucleon center of mass, λ is the angular momentum of two-nucleon relative motion, L and S are total orbital angular momentum and total spin of the nucleus.

For WF of the ground state $J^{\pi}=1^{+}$ we restricted with two configurations: λ=l=L=0, S=1 (S-wave) and λ=2, l=0, L=2, S=1 (D-wave). S-wave dominates in WF of ^{6}Li ground state (>90%), while D-wave gives a small contribution (from 3 to 7%) in dependence on a choice of interaction potentials. WF can be written in the form:

$$\Psi_i = \Psi_L^{(\lambda l)} = \Psi_S^{(00)} + \Psi_D^{(20)}. \quad (2)$$

In WF calculations for $J^{\pi} = 3^{+}$ state we take into account the following configurations: λ=0, l=2, L=2 (D_L – component with the weight of 73-74%) and λ=2, l=0, L=2 (D_λ – component with the weight of 22-25%).

$$\Psi_f = \Phi_{M_J}^{(\lambda 1)} = \Phi_{M_J}^{(02)} + \Phi_{M_J}^{(20)}. \quad (3)$$

The final expression for DCS can be written in the form:

$$\frac{d\sigma}{d\Omega} = \frac{1}{2J+1} \sum_{M_J M_J'} \left| \left\langle \Psi_f \left| \Omega \right| \Psi_i \right\rangle \right|^2. \quad (4)$$

As contribution of various WF components into DCS is different, then DCS in case of elastic scattering may be written as:

$$\frac{d\sigma}{d\Omega} = \frac{1}{3}\left\{ \left| \left\langle \Psi_S^{(00)} \left| \Omega \right| \Psi_S^{(00)} \right\rangle \right|^2 + \frac{6}{5}\left[\left| \left\langle \Psi_D^{(20)} \left| \Omega \right| \Psi_S^{(00)} \right\rangle \right|^2 + 2\left| \left\langle \Psi_D^{(20)} \left| \Omega \right| \Psi_S^{(00)} \right\rangle \right|^2 \right] + \left| \left\langle \Psi_D^{(20)} \left| \Omega \right| \Psi_D^{20} \right\rangle \right|^2 \right\}, \quad (5)$$

and in case of inelastic scattering:

$$\frac{d\sigma}{d\Omega} = \frac{7}{15}\left\{ \left| \left\langle \Phi_{M_J=0}^{(02)} \left| \Omega \right| \Psi_S^{(00)} \right\rangle \right|^2 + 2\left| \left\langle \Phi_{M_J=2}^{(00)} \left| \Omega \right| \Psi_S^{(00)} \right\rangle \right|^2 + \left| \left\langle \Phi_{M_J=0}^{(20)} \left| \Omega \right| \Psi_S^{(00)} \right\rangle \right|^2 + 2\left| \left\langle \Phi_{M_J=2}^{(20)} \left| \Omega \right| \Psi_D^{20} \right\rangle \right|^2 \right\}. \quad (6)$$

Fig.1 shows the dependence of DCSs on the model of ^{6}Li WFs for incident protons (a), π^{+}-(b), and K^{+}-(c) mesons. Curves 1 and 2 represent calculations with WFs in the models 1 and 2 respectively.

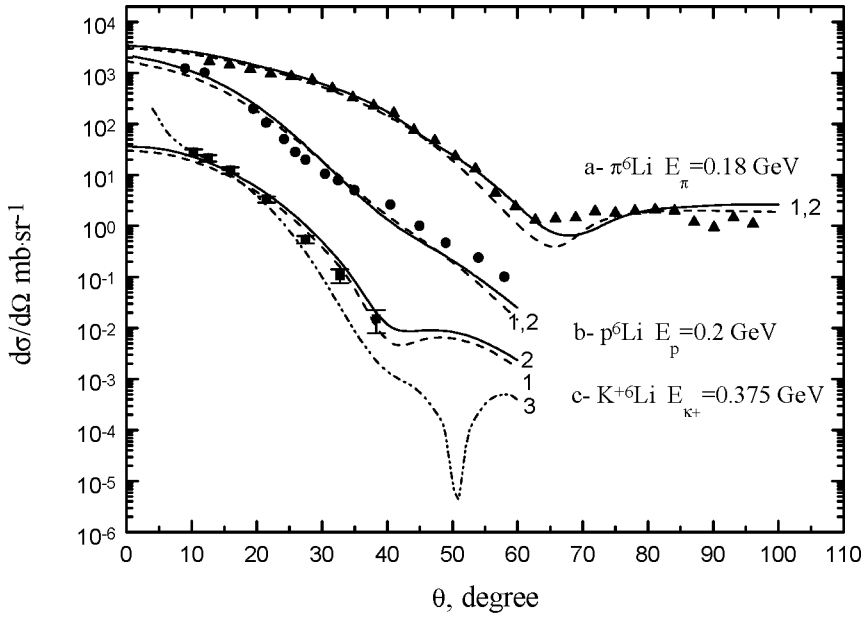


Fig.1 DCSs for elastic hadron scattering at different energies: π^+- (a), protons(b) and K^+- (c) mesons. Curves 1 and 2 are the calculation with WFs in both models 1 and 2. Curves 3 is the calculation in DWIA [2]. Experimental data in all figures for p, π^+-and K^+-mesons have been taken from [4,5], [3] and [2].

Comparison of curves 1 and 2 shows that cross sections, calculated with different types of WFs, do not differ much in the range of small angles. The difference in behavior of curves is noticeable in the region of diffraction minimum and at large scattering angles. Curve 2 corresponding to the greater contribution of D-wave into WFs locates closer to the experimental data than curve 1. Calculations by other authors are also adduced here. Curve 3 represents calculations in DWIA model taken from paper [2]. In spite of the fact that in DWIA model it was taken into account both types of scattering central and quadruple noncentral, Glauber theory predictions agree with the experimental data for K^+-mesons better (curve 2) than those in the optical model (curve 3). The difference in behavior of curves 1 and 3 appears at large scattering angles since diffraction theory is limited by the region of small scattering angles and for lack of any experimental data for this angle range.

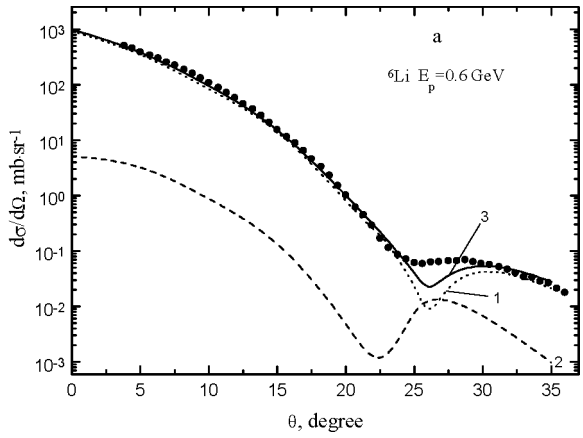


Fig.2 DCSs in dependence on contribution of S- and D-waves into WF for incident protons (a), π^+-(b), and K^+-(c) mesons. Curves 1 and 2 correspond to S- and D-wave contribution, respectively. Curve 3 is their summarized contribution.

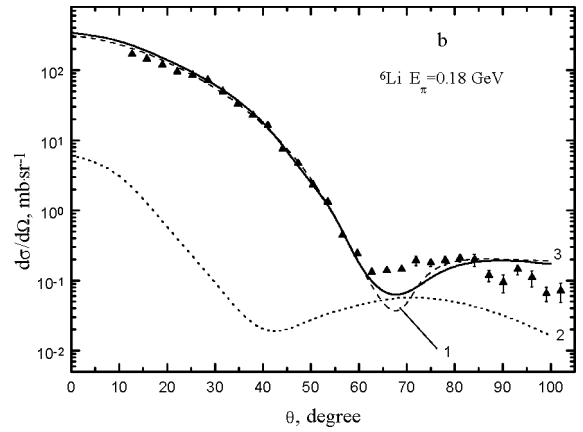
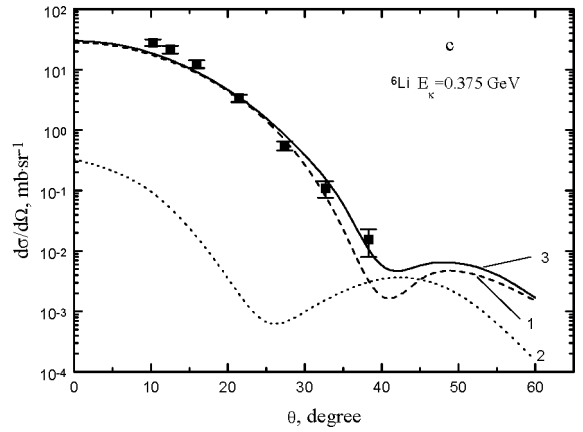
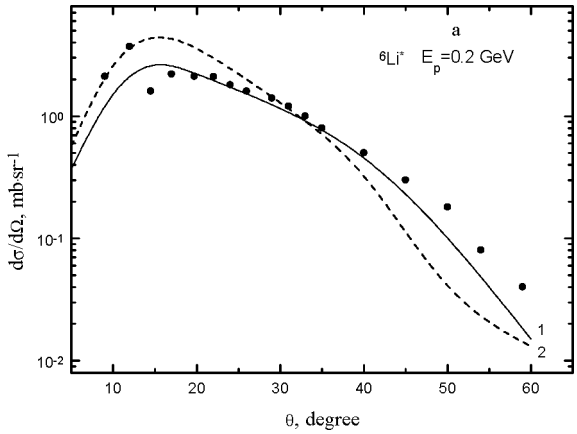
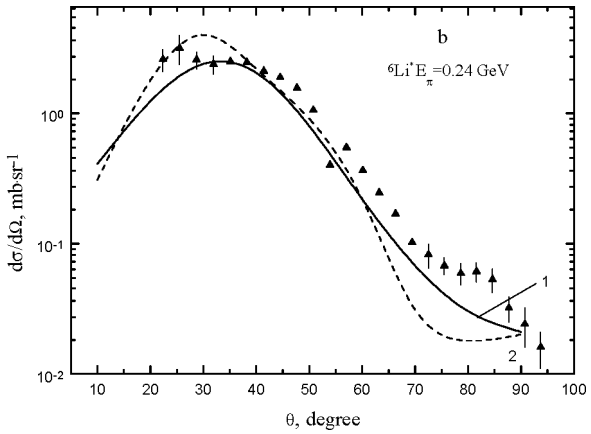


Fig.2 shows the behavior of DCSs in dependence on contribution of S-(the first term of formula (5)) and D-(the second and third terms of formula (5)) WF components for incident protons (a), π^+-(b), and K^+-(c) mesons. As it is shown that at zero angle, DCS for D-component is by about two factors of ten smaller than those for S-component. However, DCS minimum for D-component (curve 2) is shifted to the region of smaller scattering angles and its second maximum coincides with the minimum of curve 1 and partially fills it in the resulting curve 3.







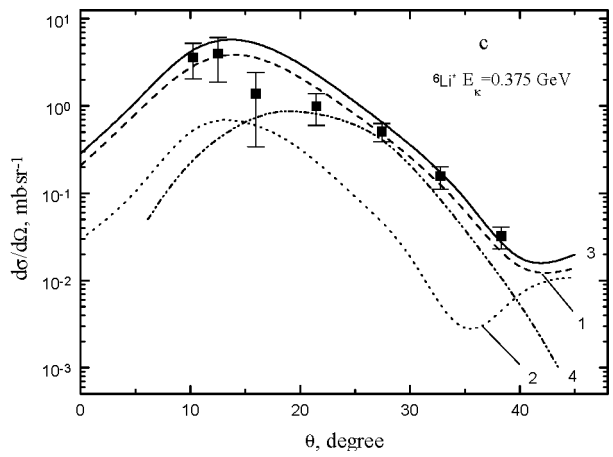


Fig.3 DCSs for inelastic scattering of protons (a), π^+- (b) and K^+- mesons (c) onto the level $J^\pi=3^+$ $E^*=2.18$ MeV with ^{6}Li WFs in model 2. The description of curves has given in the text.

Fig.3a,b illustrate DCSs calculated with both models of ^{6}Li WFs cluster (curve 1) and oscillatory (curve 2). The oscillatory WF is not in agreement with the experimental data. This means that it has rapidly decreasing asymptotic and it does not describe real behavior of WF. Protons and π-mesons are more sensitive to the different behavior of target-nucleus WFs since their scattering takes place in nucleus periphery, i.e. where cluster and oscillator WFs differ much. Scattering of K^+-mesons occurs mainly in the internal region of the nucleus and therefor different behavior of WFs does not affect cross section behavior.

In case of (c), curves 3 and 4 are calculation with two different WF components: Ψ^{02} (the first and the second terms of formula (6)) and Ψ^{20} (the third and the fourth terms of formula (6)). The contribution of the first component is three times greater than the second one. The first component (curve 3) gives the dominant contribution and the second (curve 4) contributes at large scattering angles. Curve 1 represents their total contribution into the cross section.

Based on our calculations we have made the following conclusions:

1. Glauber diffraction theory adequately describes DCSs of elastic and inelastic scattering from ^{6}Li for different types of particles in the wide range of incident particle energies.
2. WFs in three-particle cluster models calculated with realistic interaction potentials make it possible to evaluate the matrix element analytically. As a result, precision of DCS description in diffraction theory is not lower and sometimes is even higher than that in DWIA.
3. The role of the minor component (D-wave) in WF of ^{6}Li ground state is found to be significant. In spite of the fact that it practically does not contribute to DCS due to its small absolute value, it leads to negligible increasing in DCS just in the angle region where DCS major component reaches minimum.

REFERENCES

1. V.I. Kukulin, V.N. et al., Nucl. Phys. A586,151 (1995).
2. R.A. Michael et al., Phys. Lett. B382, 29 (1996); R.E. Chrien, R. Sawafta, R.J. Peterson et al., Nucl. Phys. A625, 251(1997)
3. L.E. Antonuk, D. Bovet, E. Bovet et al., Nucl. Phys. A451, 741(1986).
4. C.W. Glower, C.C. Foster, P. Schwandt et al., Phys. Rev. C 41, 6, 2487 (1990).
5. G. Bruge et al., Journ. De Phys. 40, 635 (1979).