UDC 539.17

PROTON, π- AND K^+-MESON SCATTERING ON ^{7}LI NUCLEUS WITHIN THE FRAMEWORK OF GLAUBER THEORY

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Within the framework of the Glauber multiple scattering theory, differential cross sections of proton π- and K-mesons scattering off the ground state and inelastic scattering to the first excited state of ^{7}Li nucleus have been calculated. Wave functions of the nucleus have been taken in the cluster αt-model. Sensitivity of calculated characteristics to the wave functions of α- and t- clusters and their relative motion has been considered. Different multiplicities of scattering and rescattering from the clusters of ^{7}Li nucleus have been taken into account and their contributions to the cross sections have been demonstrated. Comparison to the experimental data has been carried out.

Keywords: Glauber theory, cluster αt-model, π- and K-mesons, wave functions, multiplicities.

Up-to-date experimental proton scattering data on ^{7}Li obtained at Indiana University [1] for incident proton energy E_p=200 MeV and scattering data of $\pi^\pm$-mesons with energy E_π =164 MeV obtained at Paul Scherrer Institute [2] gave a new impact for studying of nuclear structure and interaction mechanism.

Within the framework of Glauber multiple scattering theory, differential cross sections (DCSs) of elastic and inelastic (at level $J^\pi=1/2^-$, E^*=0.48 MeV) hadron scattering from ^{7}Li nucleus have been calculated at several values of incident particle energy and a comparison with available experimental data has been carried out. We have used cluster αt wave functions (WFs) [3] calculated in deep potentials with forbidden states.

Fig.1 shows the dependence of DCS on the type of ^{7}Li WFs (cluster and oscillator) for various sorts of incident particles: π-mesons (*a*), protons (*b*) and K^+-mesons (*c*).

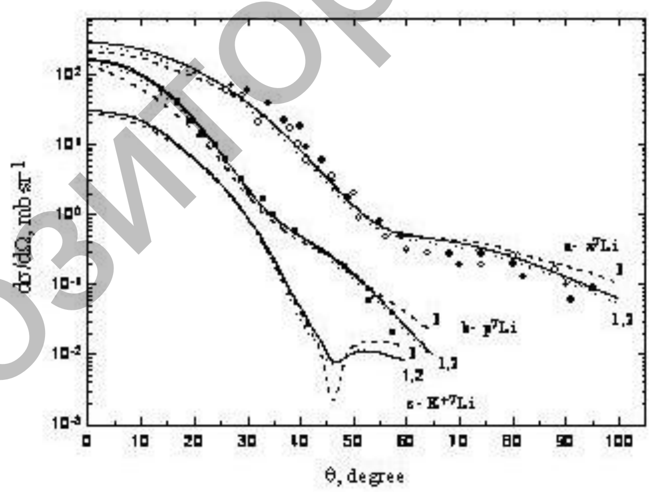


Fig.1. Dependence of DCS on various types of ^{7}Li WFs for various sorts of incident particles: *a* – π-mesons at E_π=164 MeV, *b*- protons at E_p=200 MeV, *c*- K^+-mesons at E_K=230 MeV. Curves 1 and 2 are the calculation with cluster WFs, curve 3 - with R_{31} oscillator WF. Experimental data for proton scattering are taken from [1] and for π-meson scattering (open dots (π^+),solid dots (π^-)) - from [3]

What are the differences and similarities between these WFs? All the WFs selected have a single node located near r=1.7 fm. In cluster αt-model WFs have been calculated with forbidden state potentials in Woods-Saxon potential form (DCS with this WF is curve 1) or with potentials in Buck-Gaussian form (DCS with one is curve 2). These WFs well reproduce static characteristics, electromagnetic formfactors and they do not differ much in absolute value and form. R_{31} oscillator WF (DCS with it is curve 3) differs from other ones in behavior far from the nucleus center: it falls down much faster, i.e. similar to any other oscillatory function it has rapidly decreasing asymptotic and it does not describe real behavior of WF. Therefore, oscillator WF values near the first maximum are about 40 percent greater than cluster ones. As it was mentioned above, K^+-mesons are the weakest among all strongly interacting particles, and therefore at the same fixed energy they can penetrate deeper inside the nucleus than protons and π-mesons. Curves 1 and 2 are located close to each other in all figures. In what range does curve 3 differ most from the first two? In cases *a* and *b* it differs at small ($\theta<20°$) and large ($\theta>60°$) scattering angles. The difference in behavior of curves is noticeable at small scattering angles, since the interaction of protons and π-mesons with nucleons takes place in nucleus periphery, i.e. where cluster and oscillator WFs differ much. Large distances in WFs correspond to small transferred momenta, that is to small scattering angles. At large angles (at small distances in WF), a difference appears due to the following factors: correlation effects are not considered in oscillator model and the fact that diffraction theory is limited by the region of small scattering angles. In case of *c*, the difference in behavior of curves (1,2) and (3) becomes apparent at large scattering angles, since K^+-meson scattering deep inside the nucleus is less vulnerable to asymptotic, and different behavior of WF does not affect cross section behavior. Let us point out, that the absolute value of cross section for π-meson and proton scattering is considerably greater than for K^+-scattering.

Fig.2*a* and 2*b* demonstrate the following regularities: as energy increases, the diffraction minimum shifts to the region of smaller scattering angles and for $\theta=0^0$ cross section absolute value slightly rises.

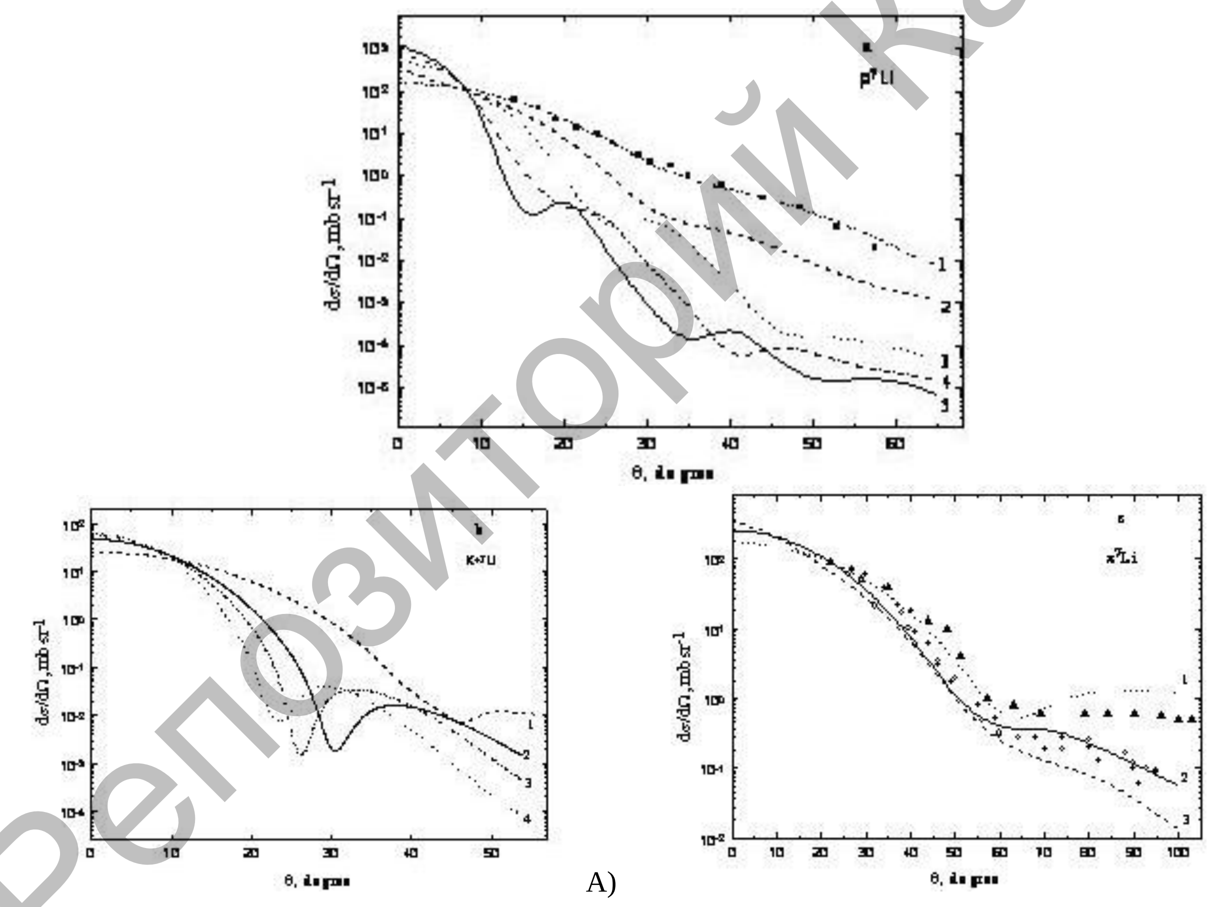
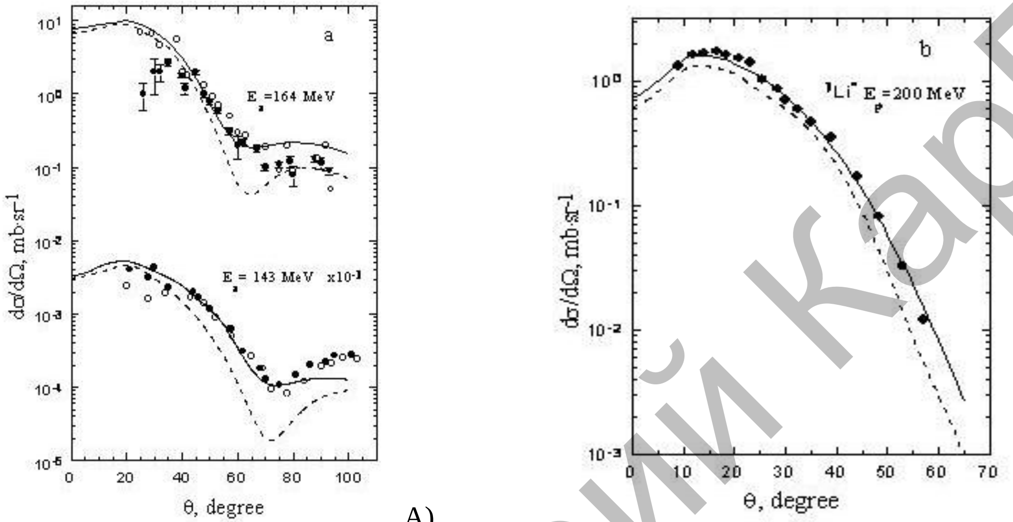


Fig.2. CS for elastic scattering of protons (*a*), K^+-(*b*), and π-mesons(*c*) at different energies of incident particles. In fig.2*a* curves 1,2,3,4,5 correspond to E=200, 400, 600,800 and 1000 MeV, in fig.2*b* curves 1,2,3 and 4 correspond to E_K=230, 375, 468 and 534 MeV, in fig.2*c* curves 1,2 and 3 correspond to E_π=143, 164 and 240 MeV. Experimental data in fig.2*a* are taken from [1] and in fig.2*c*- from [2,3]

The minimum inward shift occurs because of the fact that for K^+A and pA scattering the position of minimum is approximately a constant value in dependence on transferred momentum q. Therefore, as energy rises, the minimum shifts to the region of smaller scattering angles, because increasing of k is compensated by decreasing of θ, as shown in formula $q = 2k\sin\dfrac{\theta}{2}, k = \sqrt{\varepsilon^2 - m^2}$, where $\vec{q} = \vec{k} - \vec{k}'$ is the transferred momentum, θ is the scattering angle. Fig.2*c* shows DCS of π-meson scattering, as it illustrates that cross section minimum does not shift and remains within the region of $\theta \approx 60^0$. It is connected with a presence of dominating wide resonance channel Δ_{33} (≈100 MeV) in this region and the absence of open channels below the threshold of π-meson birth. Fig.3 shows the behavior of DCSs for inelastic (at level $J^{\pi}=1/2^-$, $E^*=0.48$ MeV) scattering of π-mesons (*a*) and protons (*b*). DCSs have been calculated for both types of ^{7}Li WFs cluster (solid curve) and oscillator (dash curve).



A) B)

Fig.3. DCS for inelastic scattering of incident π-mesons (*a*) and protons (*b*). Solid and dash curves are the calculation with both cluster and oscillator WFs. Experimental data in fig.3*a* are taken from [2,3] and in fig.3*b*- from [1]

The differences in calculations with these WFs are more noticeable for inelastic scattering than for the elastic one. In case of excitement of the first nucleus level, ^{7}Li WF consists of $\Psi_{31}(R)$ component (its contribution is 98%), this means that its radial part is the same as for the ground state (the difference consists in spin-orbital part). As these WFs are not orthogonal, the deep minimum are not observed for $\theta=0^0$.

Based on calculations, the following conclusions may be formulated.

1. Protons and π-mesons are more sensitive to the different behavior of target-nucleus WFs since their scattering takes place in nucleus periphery, whereas scattering of K^+-mesons occurs mainly in internal region.

2. In case of protons and K^+-mesons, as energy increases, the diffraction pattern of cross section increases and diffraction minima shift to the region of smaller scattering angles. It does not take place for π-mesons with energies under 200 MeV and the minimum is localized near $\theta \sim 60^0$.

3. In cases of elastic and inelastic hadron scattering, the calculation with cluster WFs well describes experimental data than with oscillator one, since the latter falls down much faster than cluster WFs, i.e. similar to any other oscillatory WF it has rapidly decreasing asymptotic, and because of that nucleon correlations are not considered in oscillator potential.

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