Study of the reaction $(\gamma,\pi^\circ p)$ on Li^6, C^{12} and O^{16} nuclei for a wide range of momentum transfers

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The cross sections of reaction $(\gamma,\pi^\circ p)$ on Li^6 C^{12} nuclei were measured in the 0–600 MeV/c range of momentum transfer to the residual nucleus. For large values of momenta, cross section values disagree with calculations carried out within the framework of a shell model and a model of quasi-free meson photoproduction on nuclei.

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Scattering of high-energy particles on atomic nuclei with resulting knock-on nucleons constitutes a useful means of studying the shell structure of nuclei and also of effects that lead to deviation from the shell structure.[1,2] Especially interesting for obtaining additional information on short-range dynamic correlations (SDC) in nuclei[3–5] are experimental data in the region of large momentum transfers to the residual nucleus. However, experimental cross sections of reactions with knock-on nucleons are, as a rule, in the region of small momenta.

In this work we investigate the $(\gamma,\pi^0 p)$ reaction on Li^6, C^{12} and O^{16} nuclei at the maximum bremsstrahlung energy of 450 MeV. The π^0-mesons were detected experimentally in coincidence with protons and in a coplanar geometry. The angle and energy of π^0-mesons were fixed ($\Theta_\pi = 67 \pm 2°$, $E_\pi = 300 \pm 16$ MeV), as well as the proton energy detection thresholds ($T_p > 21 \pm \frac{3}{4}$MeV for the C^{12} nucleus and $T_p > \pm \frac{2}{3}$MeV for Li^6 and O^{16} nuclei). Reaction yields (cross sections per equivalent γ-ray) were measured as a function of the outgoing proton angle in the interval 40–150° (the momentum imparted to the residual nucleus varies in this case from 0 to 600 MeV/c). Photoproduction of mesons on nucleons from the various nuclear shells was unresolved. Measurements were carried out on the Tomsk electron synchrotron. π^0-mesons were identified using a setup for the detection of neutral mesons by their γ-ray decay using total-absorption Čerenkov spectrometers.[6] The proton detection channel included a scintillation counter with a polyethylene absorber in front of it. To check the apparatus we measured the reaction cross section on hydrogen by the "difference" method (on polyethylene and oxygen). The results coincided within experimental error with measurements of other authors on liquid hydrogen. Detailed features of the setup and processing of experimental data are described in Ref. 7.

Figure 1 shows cross sections of the $(\gamma,\pi^0 p)$ reaction as a function of the proton angle of emission. The lower scales correspond to momentum transfer to residual nucleus (P_R) averaged over the detected proton spectrum. Calculations of cross sections were carried out within the framework of a quasi-free meson photoproduction model and in the impulse approximation.[8] The interaction of the π^0-meson and proton with the residual nucleus was considered in the framework of the optical model using

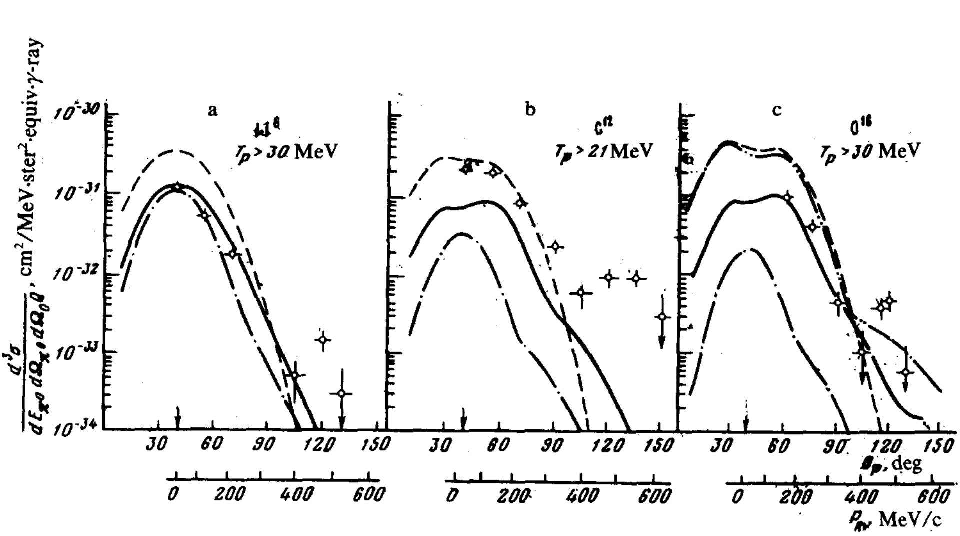

FIG. 1. Dependence of reaction cross section on the proton angle of emission: O—experiment, with total measurement errors;---- —calculations using plane waves; —— final state interactions taken into account; —·—·—effect of S-shell shown separately; —··—··—calculations with momentum distribution from Ref. 3 with allowance for correlation by the Jastrow model. Oscillator parameters $\alpha_s = \alpha_p = 115$ MeV/sec for Li^6 nucleus,[12] 120 MeV/sec for C^{12} and 113 MeV/sec for O^{16}.[13] Arrow indicates angle of proton emission in the case of reaction $\gamma + p \to \pi^0 + p$.

the eikonal approximation.[8,9] Harmonic oscillator model nuclear wave functions were assumed. In the case of the Li^6 nucleus three sets of oscillator parameters were considered: 1) $\alpha_p = \alpha_s = 97$ MeV/sec;[10] 2) $\alpha_p = 50$ MeV/sec, $\alpha_s = 108$ MeV/sec;[11] and 3)$\alpha_p = \alpha_s = 115$.[12] Subscripts P and S indicate affiliation to the $1P$ or $1S$ nuclear shell. Cross section calculations in which the first two sets of parameters were used disagree with the experiment over the entire interval of the proton emission angles. A more satisfactory agreement is obtained with the third set up to $P_R \sim 350$ MeV/c. In the case of the O^{16} nucleus calculations agree fairly well with experiment in the region of small P_R. The calculated reaction cross section on the C^{12} nucleus is considerably below the experimental value, the divergence possibly occurring for reasons which are not nearly as significant for the Li^6 and O^{16} nuclei because of the higher proton detection threshold: a) taking account of final-state interactions using the eikonal approximation is unjustified for $T_p \sim 20$ MeV; b) the model fails to take into account processes of a partial or total breakup of the nucleus which is accompanied by the emission of protons with an energy above the threshold.

Thus, calculations for the Li^6 and O^{16} nuclei in the shell model with oscillator wave functions and in the quasi-free meson photoproduction model satifactorily describe the experimental values of cross section up to $P_R \sim 350$ MeV/c. In the region of large momentum transfer qualitatively-different behavior of reaction cross sections is observed. The dotted curve in the figure shows the cross section of a reaction on the O^{16} nucleus without allowing for final-state interactions, but including SDC. Clearly, allowing simultaneously for final-state interactions and SDC may lead to an improved agreement with the experimental results. In particular, the question of the nature of the reaction mechanism in the case of larger momentum transfers to the residual nucleus remains open.[14]

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[1]G. Jacob and Th.A.J. Maris, Rev. Mod. Phys. **45**, 6 (1973).
[2]V.M. Kolybasov, G.A. Leksin and I.S. Shapiro, Usp. Fiz. Nauk **113**, 239 (1974) [Sov. Phys. Usp. **17**, 381 (1975)].
[3]A. Malecki, Fisica Nucleare Intermedia, LNF-75/3 (R), Frascati, 1975, p. 18; A. Malecki, Lett. al Nuovo Cim. **8**, 16 (1973).
[4]R.J. Jibuti and R.Ya. Keserashvili, Phys. Lett. **57B**, 433 (1975).
[5]R.Ya. Kezerashvili, Sb. Mnogochastichnye aspekty teorii legkikh yader (Coll. Many-body Aspects of the Theory of Light Nuclei) Tbilisi, Metsniereba, 96 (1978).
[6]G.N. Dudkin *et al.* Prib. Tekh. Eksp. No. 2, 64 (1973).
[7]V.N. Eponeshnikov, Yu.F. Krechetov and V.N. Padalko, Izv. AN SSSR, Ser Fiz. **42**, 1552 (1978).
[8]J.M. Laget, Nucl. Phys. **A194**, 81 (1972).
[9]R.M. Frank, J.Z. Cammel and K.M. Watson, Phys. Rev. **101**, 891 (1956).
[10]T.W. Donnely and J.D. Walecka, Phys. Lett. **B44**, 330 (1973).
[11]Yu.P. Antuf'ev, V.L. Agranovich, V.S. Kuz'menko, I.I. Miroshnichenko and P.V. Sorokin, Pis'ma Zh. Eksp. Teor. Fiz. **16**, 77 (1972); Yu.P. Antuf'ev, V.L. Agranovich, V.S. Kuz'menko and P.V. Sorokin, ibid. **16**, 339 (1972) [JETP Lett. **16**, 52 (1972), **16**, 240 (1972)].
[12]E.L. Kuplennikov *et al.* Voprosy atomnoĭ nauki i tekhniki, ser. fizika vysokikh energii i atomnogo yadra (Problems of Atomic Science and Technology, Ser. Physics of High Energies and Atomic Nucleus) No. 1(**3**), 72 (1973).
[13]V.Yu. Gonchar *et al.*, Ukr. Fiz. Zh. **22**, 2059 (1977).
[14]V.A. Karmanov and I.S. Shapiro, EChAYa **9**, 327 (1978).