Proton polarization in the reactions $(\gamma,p\pi^0)$ and $(\gamma,p\pi^-)$ on the ^{12}C nucleus

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Results are presented of the measurement of the energy dependence of the proton polarization in the reactions $(\gamma,p\pi^0)$ and $(\gamma,p\pi^-)$ on ^{12}C. The measurements were made by registering the pions and protons in coincidence. No strong influence of the interaction in the final state on the proton polarization was observed. The proton polarization in the reaction $(\gamma,\ p\pi^-)$ agrees with the predictions of Walker's analysis, and no reversal of its sign in the region of the second (πN) resonance was observed.

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The overwhelming number of experiments on the photoproduction of pions on nuclei, for photon energies < 1 GeV, were made by registering one of the secondary particles of the reaction. The results of these experiments are values averaged over a number of variables that are not fixed, and for this reason are not critical to various theoretical models. Therefore, further development of the ideas concerning the processes of photoproduction of pions on nuclei calls for more detailed experimental investigations, in which the reaction channel is determined and as many kinematical variables as possible are fixed. Then experiments include the study of the photoproduction of pions, accompanied by the knocking out of the protons from the nucleus,

$$\gamma + A \to A' + p + \pi^{0(-)}. \tag{1}$$

In the processes (1), if they are compared with the corresponding processes on a free nucleon

$$\gamma + p \to p + \pi^0 \tag{2}$$

and

$$\gamma + n \to p + \pi^-, \tag{3}$$

then one of the possible results of the influence of the nuclear structure is the change of the polarization of the recoil protons. In the approximation of the photoproduction of pions on quasifree nucleons of the nucleus, as shown in[1], the difference between the proton polarizations in the corresponding processes (1), (2), and (3) should be connected with interaction in the final state. Thus, measurement of the depolarizing effects in the process (1) serves as a check on the proposed model of meson photoproduction on nuclei and explains the role of the nuclear structure. Notice should also be taken of the small number of experimental data[2,3] and the contradictary nature of the theoretical predictions[4,5] of the energy dependence of the polarization of the protons in the photoproduction of π^- mesons. On the other hand, an estimate of the depolarizing effects, obtained from measurement of the polarization of the protons in the photoproduction of π^0 mesons in the processes (1) and (2) makes it possible to use the results of the measurement of the proton polarization in the photoproduction of π^- mesons on medium nuclei to obtain information on the proton polarization in the process (3).

We have measured, for the first time, the proton polarization in the processes (1) on ^{12}C by registering the π^0 and π^- mesons in coincidence with the proton. Preliminary results of the measurements using part of the experimental material were published in[6]. The measurements were performed with the γ-ray beam of the Tomsk synchrotron. The apparatus was arranged in accordance with the kinematics of the investigated processes on the free nucleon for a pion emission angle $\theta_\pi^* \approx 90°$ in the c. m. s. The protons were registered with a telescope consisting of scintillation counters and four wide-gap chambers with polyethylene plates in the working volume,[7] and having a solid angle 3.8 msr. The energy of the protons before and after the scattering was measured by the time of flight over a distance 3.1 m and by the range. The decay photons from the π^0 meson and the π^- mesons were registered with a total-absorption spectrometer[7] and a scintillation counter.

To check on the apparatus, we measured the differential cross section of the process (2) for ten values of the photon energy in the range 460—875 MeV and $\theta_\pi^* \approx 90°$. An estimate of the contribution of the background processes was made by measuring the yields of the investigated reactions for complanar and noncomplanar arrangement of the apparatus.[8]

Approximately 186 000 events were registered in the experiment. Rejection based on a number of criteria[6] left 899 events of π^0-meson photoproduction and 710 events of π^--meson photoproduction. For these events, the proton kinetic energy T at the instant of scattering had a value in the range (90—260) MeV, and the polar scattering angle was in the range $[6-(26-0.026)T]°$. The polarization of the protons was calculated by the maximum-likelihood method. The results are shown in Figs. 1 and 2. The statistical measurement errors were taken to amount to one standard deviation, which was determined from the form of the likelihood function. The measurements for $E_\gamma = 0.53$, 0.58, and 0.63 were carried out at a maximum bremsstrahlung spectrum energy $E_e = 0.7$, for $E_\gamma = 0.675$, 0.725, at $E_e = 0.7$ and for $E_\gamma = 0.775$ and 0.82 at $E_e = 0.9$ (the values of E_γ and E_e are given here in GeV). The resolution of the apparatus with respect to the energy of the incident photons was calculated by the Monte Carlo method with allowance for the characteristics of the apparatus and the value of E_e. For an immobile target nucleon, the resolution ranges from ± 30 MeV for $E_\gamma = 0.53$ GeV to ± 60 MeV for $E_\gamma = 0.82$ GeV, and for a Gaussian

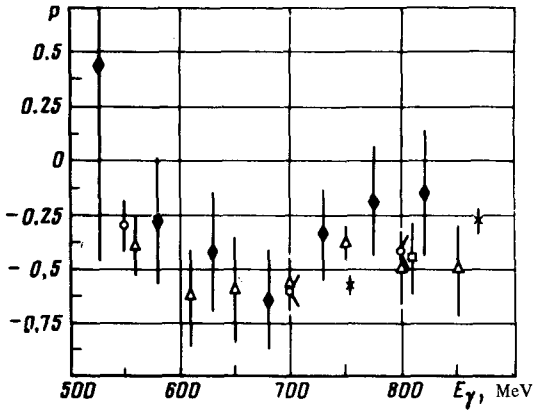

FIG. 1. Energy dependence of the proton polarization in the reaction $(\gamma, p\pi^0)$ for $\theta_\pi^* \approx 90°$ in the c. m. s. of the (πN) system: □, △, ×, ○—compilation of the results obtained in experiments with an H_2 target,[2] ♦—result of present work.

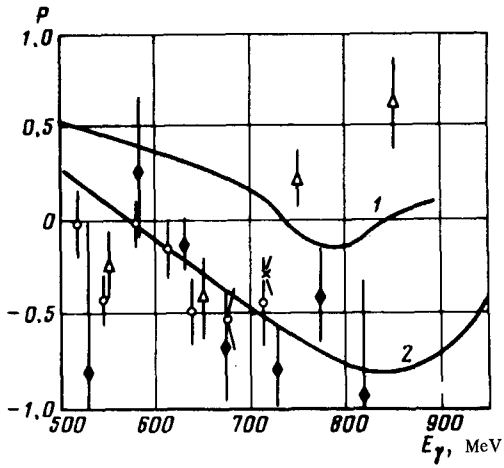

FIG. 2. Energy dependence of the proton polarization in the reaction (γ, p, π^-) for $\theta_\pi^* \approx 90°$ in the c. m. s. of the (πN) system: □, ×—compilation of data obtained in experiments with a D_2 target[2]; △—data extracted from an investigation of the (γ, p) reaction on ^{12}C [3]; ♦—our present results: 1 and 2—theoretical calculations of[4] and[5], respectively.

target-nucleon momentum distribution, with a distribution parameter $\alpha = 122$ MeV/c, the resolution with respect to the effective energy of the incident photons lies in the range ±(80—100 MeV). The systematic measurement error, due principally to the false asymmetry and to the uncertainty of the analyzing ability of the inelastic (pC) scattering, does not exceed 20—25%.

Comparison of the results in Fig. 1 shows that the proton polarization in the reactions $(\gamma, p\pi^0)$ is the same on free and bound protons. Consequently no strong depolarizing influence of the nucleon binding in the carbon nucleus or of the interaction in the final state is observed.

The data obtained for the π^--meson photoproduction process (Fig. 2) are in better agreement with the predictions of the phenomenological analysis,[4] while the prediction of the analysis[5] based on the dispersion relations are not confirmed. No changes were observed in the polarization in the region of the second (πN) resonance obtained in[3] from the results of the measurement of the polarization of photoprotons emitted from the ^{12}C nucleus at angles 41° in the lab.

In conclusion, we are grateful to the co-authors of[61] for taking part in the initial stage of the work.

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