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PHOTOPRODUCTION OF NEUTRAL PIONS ON HYDROGEN AND DEUTERIUM AT LOW ANGLES

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THE previously described [1] experiments on the measurement of the ratio of the cross sections of the processes

$$\gamma + d \rightarrow \begin{cases} d+\pi^0 \\ n+p+\pi^0 \end{cases}, \qquad \gamma + p = p + \pi_0$$

in the near-threshold energy region were continued in the region of meson emission angles $\theta_\pi \sim 0°$.

Unlike the preceding experiments, we measured directly the differential cross section of these processes. The neutral pions were registered by the two decay gamma quanta using ordinary gamma telescopes, connected in a coincidence circuit. The efficiency of the telescopes was determined in a monochromatic high-energy photon beam [2]. The absolute measurements of the bremsstrahlung intensity were made with a quantometer [3].

The differential cross sections for the mean values of the primary photon energies κ and for the meson emission angle θ_π were determined as the ratio of the measured yield $Y(\alpha, \theta_1, \kappa)$ to the function determining the probability of registering the neutral pion. The latter is connected with the kinematics of the process, the characteristics of the apparatus and of the bremsstrahlung beam, and with the geometry of the experiment. Thus,

$$\frac{d\sigma}{d\Omega}(\bar{\varkappa}, \bar{\theta}_\pi) = Y(\alpha, \theta_1, \varkappa) \Big/ n \int_{\varkappa_{thr}}^{\varkappa_{max}} \int_{\Omega_\pi} N(\varkappa, \Omega_\pi) f(\varkappa)\, d\Omega_\pi\, d\varkappa; \quad (1)$$

here α and θ_1 are the angles which define the position of the telescopes, n is the number of nuclei per square centimeter of target, $f(\kappa)$ the bremsstrahlung spectrum, κ_{max} the maximum energy in the bremsstrahlung spectrum, κ_{thr} is the photon energy corresponding to the neutral-pion photoproduction threshold, and $N(\kappa, \Omega_\pi)$ the probability of registering a neutral pion emitted in a unit solid angle at an angle from θ to $\theta + \Delta\theta$ and produced by a photon with energy from κ to $\kappa + \Delta\kappa$. The average values of the energy κ and the cosine of the angle θ_π, to which the cross section pertained were calculated from the formulas

$$\bar{\varkappa} = \int_{\Omega_\pi} \varkappa N(\varkappa, \Omega_\pi)\, d\Omega_\pi \Big/ \int_{\Omega_\pi} N(\varkappa, \Omega_\pi)\, d\Omega_\pi,$$

$$\overline{\cos\theta_\pi} = \int_{\varkappa_{thr}}^{\varkappa_{max}} \cos\theta_\pi N(\varkappa, \Omega_\pi) f(\varkappa)\, d\varkappa \Big/ \int_{\varkappa_{thr}}^{\varkappa_{max}} N(\varkappa, \Omega_\pi) f(\varkappa)\, d\varkappa. \quad (2)$$

The integrals in the denominators of (1) and (2) determine, respectively, the probability of registration and the functions of the energy and angular resolution in the given experiment. These integrals are calculated analytically and by the Monte Carlo method on an electronic computer.

Table I lists the measured differential photoproduction cross sections of neutral pions on hydrogen and deuterium in the laboratory system. Only the statistical errors are indicated.

The measurement of the differential cross section for the angle $\theta_\pi \approx 90°$ was carried out by way of a control experiment. The cross section obtained therein for hydrogen agrees well with the results of other authors [4,5]. At the same time, the cross section for hydrogen in the angle region $\theta_\pi \sim 0°$, and also the ratio of the cross sections at angles close to 15° and 90° for $\kappa \approx 220$ MeV (second and fourth lines of the first column of Table I), clearly contradict the data obtained by Vasil'kov, Govorkov, and Gol'danskiĭ on the basis of an analysis of the experiment [4]. Our results

Table I. Differential cross sections for the photoproduction of neutral pions on hydrogen and deuterium

$\bar{\varkappa}$, MeV	$(d\sigma/d\Omega)_p$	$(d\sigma/d\Omega)_d$	$\overline{\cos\theta_\pi}$
	in 10^{-30} cm²/sr·photon·nucleus		
190	1.6 ± 0.2	5.0 ± 0.3	0.938
224	6.3 ± 0.3	15.3 ± 0.4	0.966
207	—	10.7 ± 0.4	0.063
218	5.5 ± 0.2	—	0.002

for hydrogen, however, are in satisfactory agreement with the results of Ball[6], who, unlike[4], took account of the contribution of the D wave.

The comparison of the theory with the experimental data for deuterium is simplified in many respects if the latter data are represented in the form of a ratio of the cross sections for the photoproduction of neutral pions on deuterium and on hydrogen. In Table II these data for the angles $\theta_\pi \sim 0°$ are compared with the ratios of the cross sections calculated in the impulse approximation. In Table II are given only the statistical errors, while all other possible experimental errors arising in the calculation of the ratio cancel out.

Table II. Ratio of cross sections for the photoproduction of neutral pions on deuterium and on hydrogen

$\bar{\varkappa}$, MeV	$\left(\frac{d\sigma_d}{d\sigma_p}\right)_{\text{exp}}$	$\left(\frac{d\sigma_d}{d\sigma_p}\right)_{\text{theor}}$	$\overline{\cos\theta_\pi}$
190	3.12 ± 0.40	2.28	0.938
224	2.43 ± 0.13	2.50	0.966
250[7]	2.34 ± 0.33	2.58	0.999

The theoretical ratios of the cross sections of the elastic photoproduction process on deuterium to the photoproduction cross section on hydrogen are calculated with greater rigor than in [1]. At angles $\theta_\pi \sim 0°$ the principal role is apparently played by the elastic photoproduction on deuterium. If we take into consideration the fact that the spin-independent part of the matrix element for photoproduction on a nucleon $|L|^2$ is proportional to $4\sin^2\theta_\pi$ and the spin-dependent part is $|K|^2 \sim (1+\cos^2\theta_\pi)$, and if we assume that $K_n = K_p$ and $L_n = L_p$, then we get in the impulse approximation

$$\frac{d\sigma_d^{\text{el}}}{d\sigma_p} = a\,\frac{8}{3}\,F^2(q)\,\frac{2+5\sin^2\theta_\pi}{2+3\sin^2\theta_\pi},$$

where a is a coefficient that depends on the momentum of the photon and the meson, and on the mass of the target nucleus in each of the processes, while $F(q)$ is the form factor of the deuteron.

It follows from Table II that for angles $\theta_\pi \sim 0°$ the experimental results are in good agreement with the theoretically calculated ratios for energies from approximately 200 to 250 MeV. This means that in these conditions the contribution of the inelastic process and of multiple scattering[8] lies within the experimental error. At energies below 200 MeV, the experimental result exceeds the theoretical value by more than two standard deviations. Taking into account the foregoing remark, we can assume that the existing discrepancy is connected with the contribution of the neutral pions produced by scattering with charge exchange of the π^0 mesons, inasmuch as it is known that at small energies $\sigma_\pm \gg \sigma_0$.

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SENSITIVITY OF LIQUID TO RADIATION

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A sensitivity of liquids to radiation was observed by Glaser, who showed that vapor bubbles can be produced in a liquid along the path of a charged particle. For this purpose the liquid must have a definite temperature and must be superheated in suitable fashion.

From the experiments described below, it follows that the liquid can be sensitive to radiation also in the nonsuperheated state, if at the instant of passage of the charged particles in the liquid the pressure is reduced with sufficient speed.