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Abstract

Full Text

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PHOTOPRODUCTION OF π^+-MESONS ON HYDROGEN

(Presented by Academician V. I. Veksler on 27 VII 1964)

Thanks to the inclusion in the theory of the contribution to the photoproduction amplitudes of the resonant π–π interaction (ρ-meson), it became possible, by comparing experimental data with the theory, to obtain the constant $\Lambda_{\gamma\pi\rho}$ of such an interaction. In the present work the angular distribution of π^+-mesons from the reaction $\gamma + p \to \pi^+ + n$ was measured at $E_\gamma = 230$ MeV.

The experimental arrangement and the block diagram of the apparatus are shown in Fig. 1. The bremsstrahlung beam of the FIAN synchrotron, with a maximum energy of 264 MeV, was collimated and, after passing through a cleaning magnetic field, entered a vacuum pipe connected with the vacuum jacket of the liquid-hydrogen target. The target and the telescope registering mesons, consisting of three scintillation counters, were placed on a special platform, which moved along a circular rail relative to the axis of the appendix of the target filled with liquid hydrogen. The dose of γ-radiation was registered by three monitors with thin-walled ionization chambers, which were periodically calibrated with the aid of a quantameter. π^+-mesons of the required energy were selected by their range in the telescope, with their stopping in the 3rd counter, and were registered by their π–μ decay in it. The pulse of triple coincidences produced by a π^+-meson generated, of standard amplitude and duration ($1.2 \cdot 10^{-7}$ sec), "gates," which, when an appropriate time shift was introduced relative to the moment of the triple coincidences, admitted for registration pulses from the μ-mesons of the decay. In order to reduce the number of false starts of the "gates," discrimination of particles according to the magnitude of the energy left by them was carried out in the channels of the 2nd and 3rd counters.

For each of 6 angles the number of delayed coincidences N_μ was measured at several delays in the channel of triple coincidences. Analysis of the scatter of the individual values of N_μ relative to the mean value $\overline{N}_\mu$, obtained from several tens of measurements, revealed the presence of purely statistical fluctuations. The quantity $\overline{N}_\mu$ was recalculated to the number of π^+-mesons stopped in the 3rd counter, $\overline{N}_\pi$. The background, measured with an empty target, as well as the number of random coincidences, were in all cases negligibly small.

The differential cross section for photoproduction of π^+-mesons for a given angle

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Fig. 1. Schematic of the experiment and block diagram of the apparatus.

Figure 1: Fig. 1. Schematic of the experiment and block diagram of the apparatus.

in the center-of-mass system $(d\sigma/d\Omega)_{\text{c.m.}}$ is related to the quantity $\overline{N}_\pi$ by the relation

$$\overline{N}_\pi = \varepsilon \iint N_\gamma(E_\gamma)\,\Omega(E_\gamma, r)\left(\frac{d\sigma}{d\Omega}\right)_{\text{c.m.}} \frac{d\Omega_{\text{c.m.}}}{d\Omega_L}\,\eta(E_\gamma)\,\delta(E_\gamma)\,F(E_\gamma)\,\frac{dn}{d\nu}\,d\nu\,dE_\gamma,$$

where $\Omega(E_\gamma, r)$ is the efficiency function for the point target and the circular entrance aperture of the telescope, calculated on an electronic computer from the geometry of the experiment, the kinematics of the reaction, and the energy losses of π^+-mesons in the target and telescope; $N_\gamma(E_\gamma)$ is the bremsstrahlung spectrum, calculated on the basis of Schiff' s spectrum integrated over angles, taking into account the spread in the duration of the γ-beam; $d\Omega_{\text{c.m.}}/d\Omega_L$ is the coefficient for transforming solid angles from the c.m. system to the laboratory;

$dn/d\nu$ is the target-nucleus density; ε is the registration efficiency of the μ-meson decay setup; η, δ, F are the corrections, respectively, for in-flight decay, nuclear absorption, and multiple Coulomb scattering of π^+ mesons. Since the width of the working energy interval of the γ quanta was, for different measurement angles, from ± 3 to ± 8.5 MeV, in view of

Fig. 1. Schematic of the experiment and block diagram of the apparatus. K —lead collimators; $O.\ M.$—clearing magnet; $B.\ P.$—vacuum pipe; $Zh.\ V.\ M.$ —liquid-hydrogen target; T—telescope for registering π^+ mesons; M_1, M_2, M_3 —monitors of γ radiation; Φ—copper filter; $C.\ C.$—coincidence circuit; D_3—discriminator; $L.\ Z.$—delay line; $C.\ F.\ V.$—gate-forming circuit; $C.\ P.$—transmission circuit.

the weak dependence on E_γ of the quantities η, δ, F and $d\Omega_{\text{c.m.}}/d\Omega_{\text{L}}$, they were calculated for the mean values $\overline{E}_\gamma$. The corrections $\overline{\eta}$, $\overline{\delta}$ and $\overline{F}$ were calculated taking into account the slowing down of π^+ mesons in the telescope; the introduction of these corrections is associated with an error not exceeding 1-2%.

Table 1

$\theta_{\text{c.m.}}$, deg	$\overline{E}_\gamma$, MeV	ε	$\overline{\eta}$	$\overline{\delta}$	$\overline{F}$	$\overline{N}_\pi^*$	$\left(\frac{d\sigma}{d\Omega}\right)_{\text{c.m.}}$, μbarn**
38	231.5	0.72	0.885	0.790	0.900	85.8 ± 4.9	7.15 ± 0.34

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Fig. 2. Comparison of experimental differential cross sections with calculation results for: 1 $-\Lambda_{\gamma\pi\rho} = -0.5$; 2 -0; 3 $-+0.4$; 4 $-+0.6$; 5 $-+1.0$. Points are experimental data. Statistical errors are shown.

Figure 2: Fig. 2. Comparison of experimental differential cross sections with calculation results for: 1 $-\Lambda_{\gamma\pi\rho} = -0.5$; 2 -0; 3 $-+0.4$; 4 $-+0.6$; 5 $-+1.0$. Points are experimental data. Statistical errors are shown.

$\theta_{\text{c.m.}}$, deg	$\overline{E}_\gamma$, MeV	ε	$\overline{\eta}$	$\overline{\delta}$	$\overline{F}$	$\overline{N}_\pi^*$	$\left(\frac{d\sigma}{d\Omega}\right)_{\text{c.m.}}$, μbarn**
82	230.1	0.95	0.876	0.881	0.938	163.5 ± 4.9	11.30 ± 0.33
90	228.9	0.95	0.870	0.902	0.944	177.5 ± 5.0	12.10 ± 0.31
116	230.1	0.95	0.849	0.961	0.971	232.0 ± 8.1	12.75 ± 0.45
138	229.0	0.95	0.838	0.978	0.980	268.8 ± 8.2	14.64 ± 0.44
146	230.0	0.95	0.822	0.983	0.982	214.7 ± 5.3	13.66 ± 0.33

* $\overline{N}_\pi$ is referred to the standard number of monitor counts.
** Root-mean-square statistical errors are given.

The main results are summarized in Table 1. The absolute values of the cross sections may contain a systematic error ($\pm 5\%$), the principal contribution to which is made by the uncertainty in the value of the quantameter constant ($\pm 4\%$). A comparison of the differential cross sections obtained by us with the results of calculations carried out by A. I. Lebedev and S. P. Kharlamov on the basis of dispersion relations for various values of the $\gamma\pi\rho$ constant (Fig. 2) makes it possible to estimate the value of $\Lambda_{\gamma\pi\rho}$ (in units of e and f).

For this purpose a likelihood function was constructed, $\mathcal{L}(\Lambda) = \prod_i p(\theta_i, \Lambda)$, where $p(\theta_i, \Lambda)$ is the probability of comparing the given experimental

points with the theoretical curve for a definite value of Λ. From the position of the maximum and the half-width $\mathcal{L}(\Lambda)$, one obtains $\Lambda_{\gamma\pi\rho} = +0.56 \pm 0.15$. Comparison of the experimental data with the theoretical curve for $\Lambda_{\gamma\pi\rho} = +0.56$ gives a value of χ^2 lying outside the critical region for the 5% significance level.

The likelihood function for the case of experimental data with doubled errors gives $\Lambda_{\gamma\pi\rho} = +0.52 \pm 0.23$, while the discrepancy between theory and experiment still remains insignificant according to the χ^2 criterion.

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Fig. 2. Comparison of experimental differential cross sections with calculation results for:
1 $-\Lambda_{\gamma\pi\rho} = -0.5$; 2 -0; 3 $-+0.4$; 4 $-+0.6$;
5 $-+1.0$. Points are experimental data.
Statistical errors are shown.

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Note: Figure translations are in progress. See original paper for figures.

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