DETERMINATION OF THE $\gamma\pi\rho$ INTERACTION CONSTANT

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From the point of view of checking on the predictions of the unitary symmetry hypothesis it is of interest to obtain information on the probability of the radiative ρ-meson decay $\rho \to \pi + \gamma$. At present, however, there are no direct data on this decay. Considerable interest is therefore attached to attempts of an indirect determination of the $\gamma\pi\rho$ interaction constant, Λ, especially from data on single photoproduction of pions from nucleons.

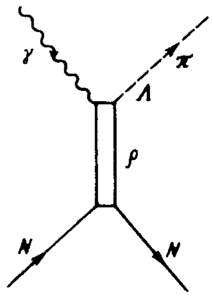

Fig. 1

The influence of the $\gamma\pi\rho$ interaction on the photoproduction processes are described by the diagram of Fig. 1, which characterizes the contribution of the ρ meson to the photoproduction amplitudes. This contribution can be separated by comparing the experimental data with theoretical calculations based on rigorous results of quantum field theory - one-dimensional dispersion relations [1]. In such an analysis, an important role is played by an estimate of the accuracy with which the dispersion integrals are calculated, since the uncertainty in integrals may imitate the contribution of the ρ meson to the photoproduction amplitudes. The purpose of this paper is (i) to find for the photoproduction processes a differential characteristic for which the theoretical uncertainties are minimal or nil, and (ii) analyze the corresponding experimental data for the purpose of determining the constant Λ.

To avoid the uncertainties connected with the imaginary parts of the photoproduction amplitudes, we confine ourselves to a consideration of the near-threshold region of photon energies 1).

Along with ρ meson, a contribution to the photoproduction amplitudes is made by the subtraction constant A of the process $\gamma + \pi \to \pi + \pi \to N + \tilde{N}$. Let us consider the quantity

$$\Delta = \frac{1}{2}\sqrt{\frac{k}{q}}\left[\sqrt{\frac{d\sigma}{d\Omega}(0^\circ)} - \sqrt{\frac{d\sigma}{d\Omega}(180^\circ)}\right], \quad (1)$$

where k is the photon momentum in the c.m.s. The contribution of the subtraction constant A to the value of Δ is greatly suppressed by kinematic multipliers. This is connected with the fact that Δ is a combination of the amplitudes of pion photoproduction in the P state, whereas A makes the main contribution to the S-wave amplitude. We shall henceforth neglect the contribution of the subtraction constant.

The diagram of Fig. 1 contributes only to the isoscalar pion photoproduction amplitude F^0. We therefore determine Λ from data on the photoproduction of charged pions on nucleons, the amplitudes of which are expressed in terms of F^0 and the isovector amplitude F^- as follows:

$$F(\pi^+) = \sqrt{2}\,(F^0 + F^-),$$
$$F(\pi^-) = \sqrt{2}\,(F^0 - F^-). \qquad (2)$$

The dispersion relations for the combination of the amplitudes Δ^0 have the following structure

$$\Delta^0 = P^0 + I^0 + D, \qquad (3)$$

where P^0 is the pole term, I^0 is the dispersion integral, and D the contribution of the ρ meson. The pole term P^0 was calculated using a value $f^2 = 0.080$ for the pion-nucleon constant. In the calculation of I^0, account was taken of the imaginary parts of the nonresonant S- and P-wave photoproduction amplitudes, which were calculated on the basis of the static dispersion relations with account of corrections of order $1/M$ (M - nucleon mass) [2] and the known πN-scattering phase shifts [3]. This part of the calculations may contain appreciable uncertainties (~100% of I^0). However, it is indeed for Δ^0 that the contribution of I^0 is negligible (~2%). The quantity Δ^0 can therefore be used for a reliable determination of the $\gamma\pi\rho$-interaction constant.

To find Δ^0 we used our data [4] on the differential cross sections of the process $\gamma + p \to n + \pi^+$, and also data on the angular dependence of the ratio $d\sigma^-/d\sigma^+ = d\sigma(\gamma + n \to p + \pi^-)/d\sigma(\gamma + p \to n + \pi^+)$. To find the cross sections $d\sigma^+/d\Omega$ at 0° and 180°, the experimental cross sections were approximated by expressions of the type

$$(1 - \beta\cos\theta)^2 \frac{d\sigma}{d\Omega}(\theta) = \sum_{i=0}^{n} a_i \cos^i\theta, \qquad (4)$$

and the value of (4) at the pole $\cos\theta = 1/\beta$ (β = pion velocity) was included among the experimental points. For negative pions, the cross sections $d\sigma^-/d\Omega$ were determined by multiplying the cross sections $d\sigma^+/d\Omega$ by the ratio $d\sigma^-/d\sigma^+$ obtained by approximating the experimental values of $(d\sigma^-/d\sigma^+)\theta$ by expressions of the type

$$d\sigma^-/d\sigma^+(\theta) = \sum_{i=0}^{n} b_i \cos^i\theta, \qquad (5)$$

and by including among the experimental points the value 1.00 ± 0.05 at the pole $\cos\theta = 1/\beta$. The cross sections obtained for the angles 0° and 180° were used to determine by means of formula (1) the values of $\Delta(\pi^+)$ and $\Delta(\pi^-)$ from which Δ^0 was obtained with the aid of (2).

The obtained value of Δ^0 is shown in Fig. 2 by the dashed line, and the interval of the experimental standard deviations is shown shaded. The same figure shows the theoretical curves. It can be seen from the figure that the experimental values of Δ^0 deviate systematically from those predicted by the one-dimensional dispersion relations ($\Lambda = 0$). If this systematic deviation is attributed to the contribution of the ρ meson to Δ^0, then a χ^2 analysis yields $\Lambda = (0.2 \pm 0.2)ef$, where $e^2 = 1/137$ and $f^2 = 0.08$. If we use the correspondence between Λ and the width $\Gamma_{\rho\pi\gamma}$ of the ρ-meson radiative decay [5], the results of our analysis yield

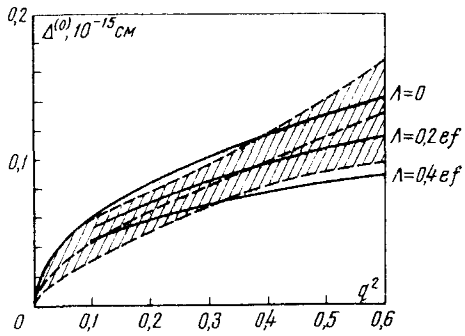

Fig. 2

$$\Gamma_{\rho\pi\gamma} = \left(0.07 \begin{smallmatrix}+0.25 \\ -0.07\end{smallmatrix}\right) \text{ MeV}. \qquad (6)$$

This does not contradict the value $\Gamma_{\rho\pi\gamma} = 0.12$ MeV predicted by the unitary-symmetry hypothesis [5].

The errors in (6) are due principally to experimental uncertainties. Therefore refinement of the differential cross sections of the processes $\gamma + p \to n + \pi^+$ and $\gamma + n \to p + \pi^-$ in the near-threshold region of energy can yield more definite information on the constant Λ. To obtain data on the latter process it is necessary to study further the processes $\gamma + d \to p + p + \pi^-$ and $\pi^- + p \to n + \gamma$.

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[1] A. A. Logunov, A. N. Tavkhelidze, and L. D. Solovjov, Nucl. Phys. 4, 427 (1957); G. F. Chew, M. L. Goldberger, F. E. Low, and Y. Nambu, Phys. Rev. 106, 1345 (1957).

[2] L. D. Solov'ev, JETP 33, 801 (1957), Soviet Phys. JETP 6, 617 (1958).

[3] J. Hamilton and W. S. Woolcock, Revs. Mod. Phys. 35, 737 (1963).

[4] M. I. Adamovich, V. G. Larionova, A. I. Lebedev, S. P. Kharlamov, and F. R. Yagudina, DAN SSSR 158, 309 (1964), Soviet Phys. Doklady 9, 792 (1965).

[5] V. A. Meshcheryakov, L. D. Solov'ev, and F. T. Tkebucheva, JINR Preprint R-2171, 1965.

1) The meson c.m.s. momentum in the near-threshold energy region is $q \lesssim 1$ (we use $\hbar = m = c = 1$).