Letters to the Editor

SINGULARITY IN THE PHOTOPRODUCTION OF π^0 MESONS NEAR THRESHOLD

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Submitted to JETP editor July 20, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **41**, 1688-1689 (November, 1961)

THE analysis of the experimental data on photoproduction of π^0 mesons on protons in the near-threshold energy region [1] has revealed a number of disagreements with conclusions derived on the basis of one-dimensional dispersion relations. [2] The difficulties discussed in [1] in dealing with the photoproduction process on the basis of dispersion relations (a study of this question will be published separately) are, however, to some extent removed by the uncertainties arising from the imprecise estimates of the dispersion integrals. In the analysis of photoproduction in the region of angles $\theta = 0°$, in which the largest discrepancies appeared previously, [1] we have discovered an interesting effect which shows the sensitivity of the differential π^0-photoproduction cross section to slight changes in the dispersion integrals.

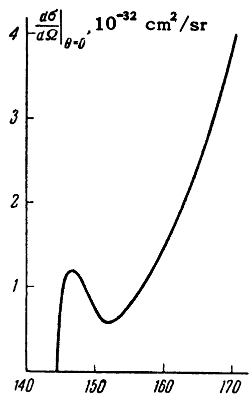
Consider the photoproduction cross section at zero degrees:

$$\frac{d\sigma}{d\Omega}\bigg|_{\theta=0°} = \frac{q}{k}\,|F_1(q^2, \theta=0°) - F_2(q^2, \theta=0°)|^2, \quad (1)$$

where q and k are the momenta of the meson and photon in the barycentric frame, and F_1 and F_2 are invariant photoproduction amplitudes. [2] It follows from the analysis of the existing experimental data that ($\omega = \sqrt{1+q^2}$; we set throughout $\hbar = \mu = c = 1$)

$$(F_1 - F_2)_{\theta=0°} = \left[\sqrt{k\omega}(-0{,}3 + 0.7q) + i\cdot 2.41\cdot\frac{2}{3}(a_1 - a_3)\right.$$
$$\left.\times\left(1 - \frac{q^2}{3\omega^2}\right)\sqrt{qq_+}\right]\cdot 10^{-2}, \quad (2)$$

from which it is obvious that at $q_0^2 \approx 0.18$ one has $\mathrm{Re}\,(F_1 - F_2)_{\theta=0°} = 0$ so that the cross section is determined entirely by the small imaginary part of the amplitude, related to the rescattering of charged mesons (a_T is the S-wave scattering length of mesons on nucleons in the state of isotopic spin $\frac{1}{2}T$, $a_1 - a_3 = 0.245$, [3] and q_+ is the momentum of the π^+ meson). It can be seen from the figure that the cross section for photoproduction at zero degrees, calculated from Eqs. (1) and (2), goes through a sharp minimum in the appropriate energy region of the photons. This characteristic behavior of the cross section is, according to the estimates of Ustinova, [4] not substantially changed by the singularities connected with the threshold of the reaction $\gamma^+ + p \to n + \pi^+$.



A similar behavior of the cross section follows from rigorous dispersion relations. [2] The calculation of the dispersion integral in this case was performed on the basis of the same assumptions as in [1], with however a careful analysis of the high-energy fall of the p ($\frac{3}{2}$, $\frac{3}{2}$) resonance and without an expansion in powers of cos θ. The calculations gave $q_0^2 = 0.12$ in good agreement with the experimental indications.

From what has been said and from Eq. (2) it follows that a) the location of the minimum in the cross section depends critically on the size of the dispersion integral and, consequently, on possible contributions from the high-energy region and from the $\pi\pi$ interaction; b) the magnitude of the cross section at the minimum determines the difference of the S-wave scattering lengths of pions $a_1 - a_3$, measured in this region of q^2 only indirectly.

To illustrate the first conclusion let us see what would be the effect on the photoproduction of a $\pi\pi$ interaction (see, e.g., [5]). If the parameter characterizing the contribution of the $\pi\pi$ interaction takes on the values $\Lambda/e = 2$ or -2, then $\mathrm{Re}\,(F_1 - F_2)_{\theta=0°}$ vanishes at $q_0^2 \approx 0.05$ and ≈ 0.30 respectively, making the agreement between calculations and experiment worse. A similar effect is obtained if the dispersion integral is changed by 20—30%.

The presence of the indicated effect should make itself strongly felt in the ratio

$[(d\sigma_{dd}/d\Omega)/(d\sigma/d\Omega)]_{\theta=0°}$, where $d\sigma_{dd}/d\Omega$ is the cross section for the process $\gamma + d \rightarrow d + \pi^0$. In the impulse approximation we have for this ratio

$$\left[\frac{d\sigma_{dd}}{d\Omega} \Big/ \frac{d\sigma}{d\Omega}\right]_{\theta=0°} = \frac{8}{3}\left|\frac{V}{V+S}\right|^2 I^2, \qquad (3)$$

where V and S stand for the isovector and isoscalar parts of the photoproduction amplitude, and $I^2 \approx 1$ is the deuteron formfactor. In the region $q \approx q_0$, where $|V + S|$ is small, $d\sigma_{dd}/d\Omega$ depends critically on the value of S, and a study of this ratio may provide information on both S-wave photoproduction of π^0 mesons on neutrons and on the $\pi\pi$ interaction, since the latter is connected to the two-pion intermediate state which contributes only to S. In this way the study of the indicated singularity may give rise to valuable information about the parameters of pion physics at low energies.

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Translated by A. M. Bincer
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NEW TYPE OF QUANTUM OSCILLATIONS IN THE ULTRASONIC ABSORPTION COEFFICIENT OF ZINC

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Submitted to JETP editor July 20, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **41**, 1689-1691 (November, 1961)

A great deal of attention has recently been directed to the study of the electron structure of metals by ultrasonic means. In the case in which $\kappa l \gg 1$ (κ is the wave vector of the sound, l is the mean free path length of the electrons) oscillations in the absorption coefficient α were observed in a comparatively weak magnetic field perpendicular to the vector $\boldsymbol{\kappa}$. These oscillations are due to the coincidence of the cyclotron radius of the electron orbit with an integral number of sound wavelengths.[1,2] The theory of this phenomenon has been considered by V. L. Gurevich[3] and Kaner,[4] who gave the connection between the absorption coefficient and the energy spectrum of the conduction electrons. The quantum oscillations of the absorption coefficient in the perpendicular field were observed experimentally in bismuth and zinc.[5,6] Gurevich, Skobov, and Firsov,[7] predicted the existence of a new quantum effect—gigantic oscillations of the absorption coefficient. The predicted oscillations arise in a non-perpendicular field (in particular, in a longitudinal one) if the following conditions are satisfied:

$$\zeta \gg \hbar\Omega \gg kT, \qquad \varkappa l = \sqrt{\zeta/kT}$$

(ζ is the chemical potential and Ω the cyclotron frequency of the electrons). Both conditions are satisfied at helium temperatures. The frequency of the ultrasound is 100—200 Mc/sec and higher for sufficiently pure metals with only slightly occupied electron bands.

With the aim of observing this phenomenon, we set up experiments in a longitudinal magnetic field ($\mathbf{H} \parallel \boldsymbol{\kappa}$) of intensity up to 35 koe. Single crystals of zinc prepared by zone refining were used. The purity of the samples is characterized by a residual resistance $R_{4.2}/R_{300} = 3 \times 10^{-5}$.

The dependence of $\alpha - \alpha_0$ on the reciprocal of the magnetic field is shown in Fig. 1 (α and α_0 are the absorption coefficients in the field and in the absence of a field, respectively). The wave vector $\boldsymbol{\kappa}$ and the vector **H** were directed along the $[10\bar{1}0]$ axis of the crystal; the frequency of the ultrasound was 220 Mc/sec. The absorption coefficient increases markedly with increase in the magnetic field intensity, and in a field $H \sim 10$ koe oscillations appear, the amplitude of which increases rapidly. The period of the oscillations in the inverse field is $\Delta H^{-1} = (0.204 \pm .005) \times 10^{-5}$