PION PHOTOPRODUCTION ON NUCLEON NEAR THRESHOLD AND THE CONTRIBUTION FOR VECTOR-MESON EXCHANGE

G.M. Radutskii and V.A. Serdyutskii
Institute of Nuclear Physics, Electronics, and Automation of the Tomsk Polytechnic Institute
Submitted 8 February 1971
ZhETF Pis. Red. 13, No. 6, 288 - 290 (20 March 1971)

There is a large number of papers devoted to the effect of vector mesons in the photoproduction of pions on nucleons at the threshold [1 - 7].

We shall show that within the framework of the pole approximation in the dispersion relations and the hypothesis of vector dominance of electromagnetic interactions (VDM), which makes it possible to determine the constants of the vector-meson interactions $V\pi\gamma$ and VNN, it is impossible to obtain agreement with the experimental data on the magnitude of the multipole amplitude E_{0+}. The latter, as is well known, determines the differential cross section at threshold.

The pole contribution of the vector meson to the threshold photoproduction amplitude is ($\hbar = c = m_\pi = 1$)[1)]

$$\Delta E_{0+}(V) = \frac{\omega_t}{4\pi}\sqrt{\frac{m_N}{m_N+1}}\,\frac{f_{V\pi\gamma}\,g_{V1}}{1-2\omega_t-m_V^2}\left[\frac{g_{V2}}{g_{V1}}m_V^2 - 1 + \omega_t\right],$$

where the c.m.s. photon energy is

$$\omega_t = \frac{2m_N+1}{2(m_N+1)} = 0.935.$$

from the hypothesis that the ρ-meson interaction is universal it follows that

$$g_{\rho 1} = \frac{1}{2}f_\rho\ .\quad \frac{1}{4\pi}f_\rho^2 = 2.42 \pm 0.25\ [8],$$

and from SU(3) symmetry and the VDM we have

$$g_{\omega 1} = 3g_{\rho 1},\quad \frac{g_{\rho 2}}{g_{\rho 1}} = \frac{\kappa^V}{m_N},\quad \frac{g_{\omega 2}}{g_{\omega 1}} = \frac{\kappa^S}{m_N},\quad \kappa^V = 1.845,\quad \kappa^S = -0.065.$$

We take the constants $f_{V\pi\gamma}$ from [8]

$$f_{\rho\pi\gamma} = (0.126 \pm 0.009)e,$$

$$f_{\omega\pi\gamma} = (0.39 \pm 0.04)e.$$

We then obtain

---

1) A similar formula is obtained in Ball's method [1] if it is assumed that the form factors are dominated by the vector mesons.

$$\Delta E_{0+}^{(0)}(\rho) = (-0.19 \pm 0.01)\cdot 10^{-2},$$
$$\Delta E_{0+}^{(+)}(\omega) = (0.08 \pm 0.01)\cdot 10^{-2}.$$

For comparison, we present the values of the contributions of the nucleon Born terms:

$$\Delta E_{0+}^{(0)}(N) = -0.13\cdot 10^{-2},$$
$$\Delta E_{0+}^{(+)}(N) = -0.68\cdot 10^{-2}$$

and the experimental data of [7]:

$$E_{0+}^{(0)} = (-0.14 \pm 0.05)\cdot 10^{-2},$$
$$E_{0+}^{(+)} = (-0.06 \pm 0.09)\cdot 10^{-2}.$$

Thus, representation of the amplitudes of pion photoproduction on nucleons in the form of sums of the N-, π-, ρ-, and ω-pole contributions (the contribution of the Δ(1238) resonance at threshold is negligible) does not agree with experiment under the assumptions made by us concerning the interaction constants.

Let us compare our results with other estimates of the contributions of vector mesons to the pion photoproduction amplitude at low energies.

Donnachie and Shaw [3], following Ball's method [1], wherein the ρ-exchange effect is connected with the isovector form factors of the nucleon, have shown that this method does not result in a significant correction to the reaction cross section at the threshold, and that the constant $f_{\rho\pi\gamma}$ is small. On the other hand, by taking into account the well-known fact that the nucleon Born terms make too large a contribution to the reaction $\gamma + p \rightarrow p + \pi^0$, the authors of [5, 6] included the ω-meson pole as an additive increment of the nucleon pole term, regarding the ω-meson coupling constants as adjustment parameters. This enabled them to obtain agreement with experiment. The values given by them for these constants differ noticeably from those obtained from an analysis of NN scattering and the electromagnetic form factors of the nucleon.

In papers where current algebra is used to derive low-energy theorems for pion photoproduction, one presently obtains agreement with experiment for $E_{0+}^{(+)}$ by cancelling the nucleon contribution with the so-called non-pole contribution [9]. The results obtained for $E_{0+}^{(0)}$ are, however, incorrect, because the author of [9] arbitrarily discarded the ρ-meson contribution. Since the model used by him includes all the assumptions made by us (VDM, universality of ρ-coupling, SU(3), and pole approximation), the results presented above remain in force also in his model.

In our opinion, any model that takes into account the contribution of the vector mesons to the photoproduction amplitude should contain some dynamic mechanism that cancels out the large ρ-meson contribution.

The authors thank S.B. Gerasimov and A.I. Lebedev for a discussion of the results of this work.

[1] J.S. Ball, Phys. Rev. 124, 2014 (1961).
[2] G. Hohler and W. Schmidt, Ann. Phys. 28, 34 (1964).

[3] A. Donnachie and G. Shaw, Ann. Phys. 37, 333 (1966).
[4] A.I. Lebedev and S.P. Kharlamov, Preprint, Phys. Inst. USSR Acad. Sci., No. 69, 1967.
[5] F.A. Berends, A. Donnachie, and D.L. Weaver, Nucl. Phys. B4, 103 (1967).
[6] D.L. Weaver, Phys. Lett. 26B, 451 (1968).
[7] M.I. Adamovich, V.G. Larionova, A.I. Lebedev, S.P. Kharlamov, and F.R. Yagudina, Yad. Fiz. 11, 657 (1970) [Sov. J. Nuc. Phys. 11, 369 (1970)].
[8] M. Gourdin, Preprint CERN-TH, 1238 (1970).
[9] D.A. Wray, Nucl. Phys. B11, 27 (1969).

ANOMALOUS ABSORPTION OF SOUND NEAR THE FERROELECTRIC PHASE TRANSITION

V.I. Samulionis and V.F. Kunigelis
Vilnius State University
Submitted 8 February 1971
ZhETF Pis. Red. 13, No. 6, 291 - 293 (20 March 1971)

The absorption of ultrasonic waves (USW) near the phase transition in ferroelectrics has been the subject of a large number of experimental and theoretical papers [1 - 4]. Until recently, however, there was no good agreement between the experimental and theoretical temperature or frequency dependences of the anomalous USW absorption.

The temperature dependences of anomalous absorption, measured by us in SbSI [5], likewise agreed with the relaxation theories only very approximately [3, 4]. A theory that considered absorption due to the interaction of sound and polarization waves at the phase transition [6] was also unable to interpret well the experimental results, owing to the complexity of the mathematical derivations, although the orientation dependence of the anomalous absorption is explained in a paper to be published this year in Fiz. Tverd. Tela.

A general expression for the sound absorption coefficient,

$$\kappa \sim \omega^2 \mathrm{Re} \int_0^\infty < \delta X(t) \delta X(0) > \exp(-i\omega t)\, dt, \tag{1}$$

is contained in recent papers [7, 8] (ω is the frequency of the sound and δX describes the random force acting on the ultrasonic wave via the dipole-lattice interaction). In the case of an electrostriction coupling, the random force is proportional to the dipole-dipole interaction.

Applying formula (1), Kawasaki obtained the following relation for the USW absorption coefficient in the case of a phase transition in a ferromagnet [9]:

$$\kappa = A\omega^2 C^2(T)\left(\gamma + \frac{\lambda}{C(T)}\frac{\omega^2}{v_s^2}\right)^{-1}\left[1 + \omega^2 C(T) \Big/ \left(\gamma + \frac{\lambda}{C(T)}\frac{\omega^2}{v_s^2}\right)^2\right]^{-1}, \tag{2}$$

where $C(T)$ is the temperature dependence of the specific heat, v_s is the speed of sound, and A, γ, and λ are coefficients that depend weakly on the temperature. In the approximation of low USW frequencies, κ is proportional to the square of the specific heat:

$$\kappa = A\omega^2 C^2(T)/\gamma. \tag{3}$$

Since Kawasaki's calculations are fairly general, it was noted by Hatta et al. [10] that such an analysis can be used also in the case of anomalous absorption in $NaNO_2$. Unfortunately, they have not yet compared the temperature