$$\times\left\{\sum_{\nu\nu'} \rho^{a\lambda}_{\nu\nu'} \langle \nu i_\nu \| \hat{m}^p_\lambda - \hat{m}^n_\lambda \| \nu' i_{\nu'} \rangle + 0\left(\frac{1}{N-z}\right)\right\}, \tag{10}$$

where

$$\rho^{a\lambda}_{\nu\nu'} = (2i_a + 1)\sum_i C^{a*}_{\nu i} C^{a}_{\nu' i} (-1)^{i_i+\lambda+i_a+i_\nu} \begin{Bmatrix} i_i & i_a & i_\nu \\ \lambda & i_{\nu'} & i_a \end{Bmatrix} . \tag{11}$$

Thus, by investigating the analog-antianalog gamma transitions, we can obtain information concerning the structure of the nuclear states. The value of such information may be no less than that of the corresponding information obtained from nuclear reactions, since the uncertainty connected with the assumptions concerning the mechanism of the reaction does not arise in this case.

[1] J. D. Fox, Proc. Topical Symposium on Nuclear Structure, Tbilisi, 1967.
[2] G. Vorvopoulos, J.D. Fox, and B. Rosner, Phys. Rev. 177, 1789 (1969)
[3] P. M. Endt, Nuovo Cimento Suppl. 6, Ser. 1, 1071 (1968).
[4] S. Maripuu, Nucl. Phys. A123, 357 (1969).
[5] A. M. Lane, Nucl. Phys. 35, 676 (1962).
[6] A. B. Migdal,Teoriya konechnykh fermi-sistem i svoistv atomnykh yader (Theory of Finite Fermi Systems and Properties of Atomic Nuclei), Nauka, 1965.

CONCERNING ONE METHOD OF STUDYING RESONANCES IN MESON PHOTOPRODUCTION

V. A. Tsarev
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 26 November 1969
ZhETF Pis. Red. 11, No. 1, 65 - 67 (5 January 1970)

Recent progress in the study of πN scattering has led to the discovery of a number of new baryon resonances in the 1.5 - 3 GeV region. Attempts to observe these "new" resonances in the photoproduction of mesons on nucleons have so far not led to great success. Most of the resoances have not been observed at all (for example, $P_{11}(1470)$, $S_{31}(1640)$, $W_{11}(1710)$ etc.) and there are only slight indications of the presence of the others. This situation is most probably due primarily to the small contribution made by these resonances to photoproduction compared with the nonresonant background, and to the insufficiency of the experimental data. On the other hand, there may exist selection rules that forbid or suppress the manifestation of these resonances in photoproduction (thus, for example, the $P_{11} \to \gamma p$ transition is forbidden in the quark model [1]). This circumstance makes searches for resonances in photoproduction particularly interesting. A complete multipole analysis that would reveal resonances, in analogy with the phase-shift analysis of πN scattering, is made difficult by the presence of almost double the number of parameters (compared with πN scattering at the same value of the angular momentum) describing the photoproduction. In addition, we are lacking at present many of the data needed for such an analysis. As to the separation of the resonances only by observing the weak "humps" in the cross section, it is easily seen that the presence of a "hump" is not necessarily connected with the characteristic behavior of the resonant part of the multipole, namely with the passage of the real part through zero and with the maximum of the imaginary part at the resonance.

Starting from this, we propose for the study of resonances in the photoproduction of π^0, η, X, etc. mesons (i.e., mesons having a two-photon decay) a method based on measuring the cross section at small angles, when an important role is played by the contribution of the (real) amplitude of the production resulting from one-photon exchange (the Primakoff effect), interference with which makes it possible to separate the real and imaginary parts of the amplitude. (In some sense these measurements are analogous to polarization measurements.)

The amplitude of the Primakoff effect P can be written in the form

$$P = Y t^{-1} \epsilon^{\mu\nu\lambda\sigma} \bar{u}(p_2)[F_1\gamma_\mu + (2N)^{-1}F_2\sigma_{\mu\delta}(P_1 - P_2)\delta] u(p_1)\epsilon_\nu q_\lambda k_\sigma . \tag{1}$$

Here Y is the amplitude of the two-photon meson decay, and is connected with its lifetime τ by

$$Y = 8\sqrt{\pi/\tau\mu^3} \tag{2}$$

F_1 and F_2 are the nucleon form factors. By using (1) we can find the contributions of P to the invariant photoproduction amplitudes [2]:

$$P_1 = -YF_2/2N, \quad P_2 = YF_2/2Nt, \quad P_3 = 0, \quad P_4 = YF_1/t \tag{3}$$

and the expression for the cross section of the Primakoff effect is

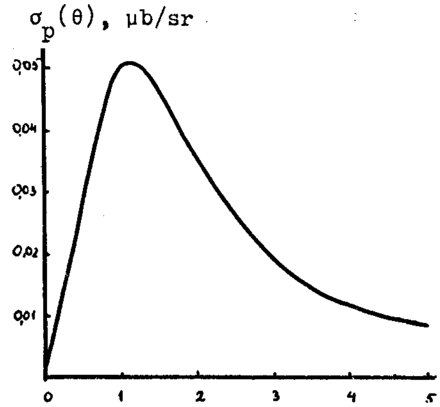
$$\sigma_P(\theta) = \sigma_0 \left[-\frac{g(t-\mu^2)^2}{8tW^2k}(F_1+F_2)^2 + \frac{kq^3\sin^2\theta}{t^2}\left(F_1^2 - \frac{t}{4N^2}F_2^2\right)\right], \tag{4}$$

$$\sigma_0 = \frac{e^2}{4\pi}\,\frac{Y^2}{8\pi} .$$

We note that (4) differs from the expression obtained in [3] in the form of the first term, which is significant in the small-angle region. By way of illustration, the figure shows the cross section σ_P for the production of π^0 mesons on protons at E = 1.1 GeV (the region of the $S_{11}(1710)$ resonance), calculated from formula (4) with $\tau_{\pi^0} = 0.9 \times 10^{-6}$ sec. (Detailed calculations of the interference effects, for the energies corresponding to the "new" resonances, will be published in our next paper.) The cross section σ_P has a sharp peak in the region of small angles ($\theta^* \sim 1°$) and decreases rapidly with increasing angle. This makes it possible to separate the contributions connected with P by measuring the cross section at $\theta \sim \theta^*$ and at angles $\sim 5 - 10°$, where the contribution of P is insignificant, thus yielding the magnitude and the sign of $\mathrm{Re}T_0$(assuming the sign of Y to be known [4]), and also the value of $\mathrm{Im}T_0$ from the condition $\sigma = (\mathrm{Re}T_0)^2 + (\mathrm{Im}T_0)^2$ (T_0 is the "nuclear" amplitude).

A simultaneous study of the energy dependences of $\mathrm{Re}T_0(E)$ and $\mathrm{Im}T_0(E)$ can serve as a method of investigating the resonances whose contributions can be separated either by concrete paramatrization or by simply assuming that the nonresonant background is sufficiently smooth and $\mathrm{Re}T_{res}(E') \simeq \mathrm{Im}T_{res}(E') \simeq \mathrm{Re}T_{res}(E_{res}) = 0$, where E' is the energy far from the resonant value E_{res}.

If a nucleus with zero spin is used as the target in lieu of the nucleon, then the analysis of the effect becomes simpler, since the cross section is determined in this case by only one amplitude.



It is of interest to note that the Primakoff effect should lead to a considerable enhancement of the polarization effects at small angles. Thus, the polarization of the recoil nucleons and the asymmtery of production on a polarized nucleon depend on the product of the helicity amplitudes H_4 and H_1 [5], having large contributions of the Primakoff effect, by the amplitude H_1, which is the largest of the "nuclear" amplitudes at small angles. The separation of the contribution of P to these effects makes it possible to determine the magnitude and sign of the imaginary part of H_2.

[1] R. G. Moorhouse, Phys. Rev. Lett. 16, 772 (1966).
[2] G. F. Chew, M. L. Goldberger, F. E. Low, and Y. Nambu, Phys. Rev. 106, 1345 (1957).
[3] V. M. Arutyunyan, Zh. Eksp. Teor. Fiz. 42, 1112 (1962) [Sov. Phys.-JETP 15, 768 (1962)].
[4] F. J. Gilman, Preprint SLAC-PUB-594, 1969.
[5] R. J. Walker, Phys. Rev. 182, 1729 (1969).

SECOND ORDER PHASE TRANASITIONS THAT ARE CLOSE IN TEMPERATURE

A. P. Levanyuk and D. G. Sannikov
Crystallography Institute, USSR Academy of Sciences

Submitted 1 December 1969
ZhETF Pis. Red. 11, No. 1, 68 - 70 (5 January 1970)

Experiments on phase transitions in solids frequently reveal cases of several transitions that are close in temperature (for example, Rochelle salt). In the present paper we consider the phases between which close transitions take place on a unified basis, regarding them as the result of distortions of one more symmetrical phase. This "protophase" need not necessarily be observed in the experiment. The description of the dynamic anomalies, obtained by such an approach, is more complete in the sense that a smaller number of components is needed than in the corresponding description based on a separate analysis of phase transitions in Landau's theory [1]. It turns out that the phase diagram has a characteristic singularity, in that it has a point at which four different phases are in contact.

The termodynamic potential Φ will be represented here in the form of a series in terms of two quantities η and ξ, which transform in accordance with one two-dimensional irreducible representation of the symmetry group of the protophase. Thus, η and ξ are components of a two-component parameter describing transitions with a lowering of the protophase symmetry

$$\Phi = \alpha(\eta^2 + \xi^2) + \beta_1(\eta^2 + \xi^2)^2 + \beta_2(\eta\xi)^2 + \delta(\eta\xi)^4. \quad (1)$$

Unlike the usual approach [1], in expansion (1) we take into account invariants not only of the second and fourth power, but also one of the invariants of eighth power, which turns out to be significant.

The conditions for the minimum of (1) correspond to the following four solutions: