ELECTROMAGNETIC INTERACTIONS IN THE QUARK MODEL

A. M. Baldin
Joint Institute for Nuclear Research
Submitted 16 February 1966
ZhETF Pis'ma 3, No. 7, 265-268, 1 April 1966

The applications of SU(6) symmetry to electromagnetic interactions are based, as is well known, on the natural assumption that the electromagnetic current is transformed in accordance with the representation 35. However, if we use model representations concerning the quark structure of the particles, then the current operator can be assigned a more concrete form. In the present paper we obtain and discuss several relations that do not follow from SU(6) symmetry, but have a sufficiently general character.

A Lagrangian for the interaction between mesons and quarks was written out even in the first papers on SU(6) symmetry [1]. We shall henceforth be interested only in that part of the Lagrangian which is due to pseudoscalar mesons

$$\frac{g}{\mu}\, i(\sigma\nabla)^{a}_{b}[F^{B}_{A} - \tfrac{1}{3}\delta^{B}_{A}\, F^{C}_{C}]P^{A}_{B} \qquad \begin{matrix}(a,\ b = 1,\ 2)\\ (A,\ B = 1,\ 2,\ 3)\end{matrix} \tag{1}$$

Here g is the coupling constant, F_λ the generators of the SU(3) group, σ the Pauli matrices, P_λ the wave functions of the meson field, and μ the meson mass (the value of μ will be discussed later).

In such an approach the mesons are regarded as external fields. Formula (1) is a static limit, and corresponds to a large quark mass. The coupling constant g can be determined by averaging (1) over the baryon wave functions.

If we assume μ equal to the pion mass, we obtain for g the formula

$$\frac{g^2}{4\pi} = \frac{g}{25}\,\frac{f^2}{4\pi} \simeq 0.03,^{1)}$$

where f is the constant of $NN\pi$ interaction.

Approximately the same value is obtained for the coupling constants from a consideration of the $\rho \to \pi + \pi$ decay width. We introduce the electromagnetic interaction by starting from the gauge invariance requirement: $\nabla \to \nabla - i\hat{e}A$, where $\hat{e}$ is the operator of the meson electric charge. From (1) we obtain the direct or catastrophic interaction:

$$\frac{g}{\mu}(\sigma A)[F^{B}_{A} - \tfrac{1}{3}\delta^{B}_{A}\, F^{C}_{C}]\hat{e}\, P^{A}_{B} = \hat{\mathcal{D}}. \tag{2}$$

As in the case of the Kroll-Ruderman theorem, this interaction should play the main role in processes with slow mesons, i.e., in photoproduction of mesons in the near-threshold region,

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in radiative decays of resonances, etc. Equation (2) yields not only relations between the probabilities of the processes, but also the absolute values of these probabilities.

The cross section for the photoproduction of the mesons in the c.m.s. (in our model) is of the form

$$\frac{d\sigma}{d\Omega} = \frac{q}{k}\frac{E_1 E_2}{W^2}|\langle\mathcal{D}\rangle|^2 = \alpha\frac{q}{k} \qquad (\alpha \approx \text{const}). \tag{3}$$

Here q and k are the three-dimensional momenta of the meson and the photon respectively, E_1 and E_2 are the total energies of the baryon before and after the collision, and $W = k + E_1$ is the total energy; $\langle\mathcal{D}\rangle$ is obtained with the aid of well-known fully-symmetrical functions of the baryon 56-plet.

The results of the calculations of α are summarized in the table, together with the experimental data of [2-4].

$\gamma + p$ reactions

	1	2	3	4	5	6	7
Final state	πn	$\Delta^{++}\pi^-$	$\Delta^0 + \pi^+$ $\pi^- + p$	$\Delta^+\pi^0$	ΛK^+	$\Sigma^0 K^+$	$\Sigma^{0*} K^+$
$\alpha_{theor} \times 10^{-30}$, cm^2	17	14	$\frac{1}{9}$ 14	0	0.5	$\frac{1}{27}$ 0.5	0
$\alpha_{exp} \times 10^{-30}$, cm^2	15.0 ± 0.5	16 ± 1	$\lesssim 2$	-	0.5 ± 0.05	$\lesssim 0.1$	-

$\gamma + n$ reactions

	8	9	10
Final state	$\pi^- + p$	$\Sigma^- K^+$	$\Sigma^{-*} K^+$
$\alpha_{theor} \times 10^{-30}$, cm^2	17	0.03	0.26
$\alpha_{exp} \times 10^{-30}$, cm^2	20 ± 1	-	-

The value of μ in formula (2) was set equal to the K-meson mass for K mesons and to the pion mass for pions.

The threshold cross sections for the photoproduction of π^0 and K^0 in such a model are equal to zero. The only one of these cross sections actually measured, $\gamma + p \to p + \pi^0$, is approximately 50 times smaller than that of $\gamma + p \to \pi^0 + n$.

We see from the table that the agreement with experiment is much better than expected. In particular, the model explains the experimentally observed [4] sharp differences between the angular distributions in the reactions $\gamma + p \to \Sigma^0 + K^+$ and $\gamma + p \to \Lambda + K^+$, and the large ratio of the $\gamma + p \to \Delta^{++} + \pi^-$ and $\gamma + p \to \Delta^0 + \pi^0$ cross sections. Considerable interest attaches to a detailed experimental verification of the ratio of the squares of the matrix elements of the K-meson photoproduction reactions:

$$|\mathcal{D}_5|^2 : |\mathcal{D}_6|^2 : |\mathcal{D}_9|^2 : |\mathcal{D}_{10}|^2 = \frac{3}{2} : \frac{1}{18} : \frac{1}{9} : \frac{8}{9}. \tag{4}$$

This ratio does not depend on either f or μ.

We have carried out similar calculations of the ratio of the probabilities of the decays of the vector particles $[W(V \to P + P + \gamma)]/[W(V \to P + P)]$, and these ratios do not depend on g/μ, but there are no experimental data on the decays $V \to P + P + \gamma$. The ratios presented thus serve as a check on the model and, for the time being, agree well with experiment. It is interesting to note that the predictions of the model contradict the predictions of the naive dipole model of meson photoproduction (see the table and formula (4)).

The author thanks S. B. Gerasimov, A. B. Govorkov, and A. A. Komar for useful discussions.

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1) Thus, the coupling constant g is sufficiently small to be able to consider this interaction by means of perturbation theory in the quark model.

PARITY NONCONSERVATION IN RADIATIVE TRANSITION OF Lu^{175}

V. M. Lobashov, V. L. Nazarenko, L. F. Saenko, L. M. Smotritskii, and G. I. Kharkevich
A. F. Ioffe Physico-technical Institute, USSR Academy of Sciences
Submitted 29 January 1966
ZhETF Pis'ma 3, No. 7, 268-274, 1 April 1966

We have investigated the circular polarization of the γ quanta of Lu^{175}, resulting from weak nucleon-nucleon interaction. We investigated the 396-keV $9/2^- \to 7/2^+$ γ transition with multipolarity E1 + M2, going to the ground state of the Lu^{175} nucleus. A favorable circumstance in this case is the fact that the $9/2^+$ state, which should mix in with $9/2^-$ as the result of the weak interaction, is located nearby. This is the 113-keV $9/2^+$ level, from which a γ transition of a multipolarity M1 + E2 goes to the ground state. Thus, the probability of the main (E1) and admixture (M1) transitions is known [1], and from this we can obtain the enhancement factor R = 50.

The possibility of determining the enhancement factor, or at any rate its lower limit, from the experimental data was the stimulus for the investigation of Lu^{175}.

The circular polarization was measured by the procedure of forward Compton scattering from magnetized iron with a resonance method of separating and storing the periodic signal. The apparatus used was the same as in [2].

In order to exclude more reliably the interfering factors, such as the magnetostriction changes of the polarimeter dimensions and the inductive pick-up during the instant of reversal of polarimeter magnetization, we turned off the signal during the magnetization reversal time. The period of signal storage in a pendulum filter was reduced to 3 hours. The measurement