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Abstract

Full Text

PHYSICS

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RELATIONS BETWEEN PHOTOPRODUCTION AMPLITUDES IN THE UNITARY-SYMMETRY MODEL

1. Starting from the assumption that the strong interactions are invariant under SU_3 transformations, Levinson et al. ([1]) obtained a number of relations between the amplitudes of various meson photoproduction processes. In doing so, however, they did not take into account the moderately strong interaction that violates unitary symmetry. In the present communication we establish relations between meson photoproduction amplitudes with this interaction taken into account.

We consider the following processes

$$\begin{array}{ll} \gamma+p\to n+\pi^+, & \gamma+p\to K^0+\Sigma^+, \\ \gamma+p\to \Sigma^0+K^+, & \gamma+p\to \pi^0+p, \\ \gamma+p\to \Lambda+K^+, & \gamma+p\to \eta+p, \\ \gamma+\Sigma^+\to \Sigma^0+\pi^+, & \gamma+\Sigma^+\to \pi^0+\Sigma^+, \\ \gamma+\Sigma^+\to \Lambda+\pi^+, & \gamma+\Sigma^+\to \eta+\Sigma^+, \\ \gamma+\Sigma^+\to \Xi^0+K^+, & \gamma+\Sigma^+\to \overline{K}^0+p. \end{array}$$

Since the U-spin structure of the corresponding reactions in both columns is the same, it is sufficient to consider only the left column.

Let us introduce the amplitudes corresponding to the formation of neutral baryons with $U=0$ and $U=1$,

$$\begin{gathered} f_1=\langle\gamma p\mid n\pi^+\rangle, \\ f_2=\langle\gamma p\mid {}^1/{}_2(\Sigma^0-\sqrt{3}\Lambda),K^+\rangle, \qquad f_2'=\langle\gamma p\mid {}^1/{}_2(\sqrt{3}\Sigma^0+\Lambda),K^+\rangle, \\ f_3=\langle\gamma\Sigma^+\mid {}^1/{}_2(\Sigma^0-\sqrt{3}\Lambda),\pi^+\rangle, \qquad f_3'=\langle\gamma p\mid {}^1/{}_2(\sqrt{3}\Sigma^0+\Lambda),\pi^+\rangle, \\ f_4=\langle\gamma\Sigma^+\mid \Xi^0K^+\rangle. \end{gathered} \tag{1}$$

Next decompose the final states in (1) into states $\mid U,\nu\rangle$ with definite values of the total U-spin and its third projection ν:

$$| n\pi^+\rangle = | {}^3/_2, {}^1/_2 + \rangle \sqrt{2} \mid {}^1/_2, {}^1/_2\rangle,$$

$$| {}^1/_2(\Sigma^0 - \sqrt{3}\Lambda), \pi^+\rangle = \sqrt{2} \mid {}^3/_2, -{}^1/_2\rangle + \mid {}^1/_2, -{}^1/_2\rangle,$$

$$| \Xi^0 K^+\rangle = | {}^3/_2, -{}^1/_2\rangle - \sqrt{2} \mid {}^1/_2, -{}^1/_2\rangle,$$

$$| {}^1/_2(\Sigma^0 - \sqrt{3}\Lambda), K^+\rangle = \sqrt{2} \mid {}^3/_2, {}^1/_2\rangle - \mid {}^1/_2, {}^1/_2\rangle.$$

Taking into account that the moderately strong interaction transforms, with respect to the U-spin subgroup, as $S + V_3$ (S is a scalar, V_3 the third projection of a vector), while the electromagnetic interaction transforms as S, and using the known relation

$$\langle U\nu \mid S + V_3 \mid U'\nu'\rangle = \delta_{\nu\nu'}\delta_{UU'}\varphi_s + \delta_{\nu\nu'}(U'\nu'\, 10 \mid U\nu)\varphi_V(U, U'), \tag{3}$$

where φ_S and φ_V do not depend on ν, we represent the amplitudes f_i in the form

$$f_1 = \sqrt{2}\varphi_S + \sqrt{2}\varphi_V({}^1/_2, {}^1/_2) + \varphi_V({}^1/_2, {}^3/_2),$$

$$f_2 = -\varphi_S - \varphi_V({}^1/_2, {}^1/_2) + \sqrt{2}\varphi_V({}^1/_2, {}^3/_2),$$

$$f_3 = \varphi_S - \varphi_V({}^1/_2, {}^1/_2) + \sqrt{2}\varphi_V({}^1/_2, {}^3/_2), \tag{4}$$

$$f_4 = -\sqrt{2}\varphi_S + \sqrt{2}\varphi_V({}^1/_2, {}^1/_2) + \varphi_V({}^1/_2, {}^3/_2).$$

whence

$$f_1 - f_4 = \sqrt{2}\,(f_3 - f_2). \tag{5}$$

This relation, valid in first order of perturbation theory with respect to the moderately strong interaction, does not depend on the specific mechanism of the reactions under consideration.

2. Let us now make the assumption that the reactions under consideration are described by pole diagrams corresponding to the exchange of a particle (more precisely, a state) with a definite value of the U-spin. In this case we obtain new relations between the amplitudes f_i, which depend on the U-spin of the intermediate state.

Fig. 1

Figure 1: Fig. 1

Let us first consider the case in which exchange of a state with $U = 0$ takes place (see diagrams A_1, A_2; the shaded squares denote the moderately strong interaction, taken into account in first order of perturbation theory, B^+, B^0 denote baryons, and M^+ a meson). If the moderately strong interaction is not taken into account, then we obtain the relations:

$$f_1 = f_2 = f_3 = f_4 = 0, \qquad f_2' = f_3' = 0. \tag{6}$$

Fig. 1

Let us now include the moderately strong interaction. If this inclusion is made at the lower vertex (diagram A_1), then the relations (6) hold. If, however, the moderately strong interaction is included at the upper vertex (diagram A_2), then we arrive at the relations

$$f_1 = f_4 = 0, \qquad f_2 = f_3, \qquad f_2' = f_3'. \tag{7}$$

For the sum of diagrams A_1 and A_2 these relations also hold.

If for the intermediate state $U = 1$, then, with the moderately strong interaction switched off, the relations

$$f_1 = -\sqrt{2} f_2 = \sqrt{2} f_3 = -f_4, \qquad f_2' = f_3' = 0, \tag{8}$$

hold, and they do not change when the moderately strong interaction is included at the lower vertex. When this interaction is included at the upper vertex, we obtain the relations

$$f_1 + f_4 = f_2 + f_3 = 0, \qquad f_2' = f_3', \tag{9}$$

which are also valid for the sum of diagrams A_1 and A_2 (with $U = 1$).

For diagrams corresponding to exchange of a state with $U = \frac{1}{2}$, no new relations arise in comparison with (5).

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1. C. A. Levinson, H. I. Lipkin, S. Meshkov, *Phys. Lett.*, **7**, 81 (1963).

Note: Figure translations are in progress. See original paper for figures.