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PARITY CONSERVING AMPLITUDES OF HADRON DECAYS OF BARYONS IN THE $\tilde{U}(12)$ SYMMETRY SCHEME

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In a preceding letter [1] we reported the results of application of the $\tilde{U}(12)$ symmetry [2-4] to hadron decays of hyperons 1).

In the case of parity nonconserving amplitudes, the transformation properties of the weak spurion were fixed in this case in a perfectly natural and unique manner. It belonged to the representation 143 of $\tilde{U}(12)$, being a pseudoscalar and the sixth component of an SU(3) vector. As to the parity-conserving amplitudes, one can conceive with respect to the weak (scalar) spurion of at least two possibilities. If no condictions such as the Bargmann-Wigner equations are imposed on the spurion, the latter can belong to the representation 143. Such a possibility was considered by us in [1] (see also [5]), and we found that the relations obtained in this case for the parity-conserving amplitudes of hadron decays of baryons disagree with the experimental data.

We consider here the other possibility: the spurion enters on an equal basis as real particles with respect to the transformation properties of $\tilde{U}(12)$ symmetry. The lowest representations of $\tilde{U}(12)$ symmetry, containing a CP-even scalar, are 4212 and 5940 [6,7], and we shall use them to describe the weak spurion H. With respect to SU(3) symmetry, this spurion should be a sixth component of a vector.

In other words, the weak spurion belonging to the representation 4212 is of the form

$$H^{[A,B]}_{[C,D]} = (\gamma_5 C)_{\gamma\delta}(C^{-1}\gamma_5)^{\alpha\beta}\left[T^i_k\delta^j_\ell + T^j_\ell\delta^i_k + T^i_\ell\delta^j_k + T^j_k\delta^i_\ell\right] - \text{trace}$$

while the weak spurion transforming in accordance with the representation 5940 is given by

$$H^{\{A,B\}}_{\{C,D\}} = (\gamma_5 C)_{\gamma\delta}(C^{-1}\gamma_5)^{\alpha\beta}\left[T^i_k\delta^j_\ell + T^j_\ell\delta^i_k - T^i_\ell\delta^j_k - T^j_k\delta^i_\ell\right] - \text{trace}$$

Here T is the sixth component of the SU(3) vector (all symbols are the same as in [1]).

For the CP-invariant parity-conserving matrix element of hadron decays we can write

$$\begin{aligned} M_{\text{p.c.}} &= b_1\overline{\Psi}^{\{ABC\}}(p_2)\Phi^E_M(q)H^{\{MD\}}_{\{EA\}}\Psi_{\{BCD\}}(p_1) + \\ &+ b_2\overline{\Psi}^{\{ABC\}}(p_2)\left[\Phi^D_M(q)H^{\{ME\}}_{\{AB\}} + \Phi^M_A(q)H^{\{DE\}}_{\{MB\}}\right]\Psi_{\{CED\}}(p_1) + \\ &+ b_3\overline{\Psi}^{\{ABC\}}(p_2)\Phi^D_A(q)H^{\{EM\}}_{\{BC\}}\Psi_{\{DEM\}}(p_1) + \\ &+ b_4\,\overline{\Psi}^{\{ABC\}}(p_2)\Phi^E_M(q)H^{\{MD\}}_{\{EA\}}\Psi_{\{DBC\}}(p_1), \qquad (p_1 = p_2 + q) \end{aligned} \tag{1}$$

where b_i are invariant functions. A detailed analysis shows that for the pion decays of interest to us b_1 and b_4 appear only in the single combination $b_1 - b_4$, so that we effectively have three parameters: $b_1 - b_4$, b_2, and b_3.

For convenience let us determine the amplitudes of the decuplet-decuplet (D → DP), decuplet-octet (D → BP), and octet-octet (B → BP) transitions by the following normalization:

$$(D \to DP)_{p.c.} = (\frac{2M}{\mu} - 1)\,\frac{1}{M^2}\,(\mathcal{P}^2\delta_{\mu\nu} + 2q_\mu q_\nu)\bar{D}_\mu\gamma_5 D_\nu,$$

$$(D \to BP)_P = (\frac{m + M}{\mu} - 1)\frac{q_\mu}{m}\,\bar{B}D_\mu \qquad (2)$$

$$(B \to BP)_P = (\frac{2m}{\mu} - 1)\,\frac{2}{m^2}\,\bar{B}\gamma_5 B$$

(We point out that the sign in front of the unity in the first factors of (2) is opposite from that of the corresponding definitions in [1].) In (2) M is the "central" mass of the decuplet, while m and μ are corresponding quantities for the baryon and meson octets, and $\mathcal{P}^2 = (p_1 - p_2)^2$.

After rather cumbersome calculations we obtain the following connection between the parity-conserving amplitudes of hadron decays of baryons and the quantities b'_1, b'_2, and b'_3 which differ by constant factors from $b_1 - b_4$, b_2, and b_3 respectively:

$$\begin{aligned}
&(\Omega^- \to \Xi^{\circ *}\pi^-)_{p.c.} = \sqrt{3}b'_1,\\
&(\Omega^- \to \Xi^\circ\pi^-)_P = -4b'_1,\\
&(\Omega^- \to \Lambda K^-)_P = (4\sqrt{6})\kappa b_2,\\
&(\Xi^- \to \Lambda\pi^-)_P = (1/\sqrt{6})b'_1 - (2/\sqrt{6})b'_2,\\
&(\Sigma^+ \to p\pi^\circ)_P = -(1/3\sqrt{2})b'_1 + (3\sqrt{2})b'_2 + (1/\sqrt{2})b'_3,\\
&(\Sigma^+ \to n\pi^+)_P = 2b'_2 + b'_3,\\
&(\Sigma^- \to n\pi^-)_P = (1/3)b'_1 - b'_2,\\
&(\Lambda \to p\pi^-)_P = -(3/\sqrt{6})b'_1 + (5/\sqrt{6})b'_2 + (1/\sqrt{6})b'_3
\end{aligned} \qquad (3)$$

where $\kappa = (2m - \mu)/(m + M - \mu)$ is the quantity on the order of unity.

Eliminating b'_1, b'_2, and b'_3 from (3), we obtain in addition to the Gell-Mann--Rosenfeld triangle relation also the following relations between the parity-conserving amplitudes of hadron decays of hyperons:

$$4(\Omega^- \to \Xi^{\circ *}\pi^-)_{p.c.} = -\sqrt{3}(\Omega^- \to \Xi^\circ\pi^-)_P \qquad (4a)$$

$$(1/3)(\Omega^- \to \Xi^\circ\pi^-)_P + (1/\sqrt{6})\kappa^{-1}(\Omega^- \to \Lambda K^-)_P = -4(\Sigma^- \to n\pi^-)_P \qquad (4b)$$

$$24(\Xi^- \to \Lambda\pi^-)_P - \kappa^{-1}(\Omega^- \to \Lambda K^-)_P = (12\sqrt{6})(\Sigma^- \to n\pi^-)_P \qquad (4c)$$

$$(\sqrt{6})(\Lambda \to p\pi^-)_P + (6\sqrt{6})(\Xi^- \to \Lambda\pi^-)_P + 9(\Sigma^- \to n\pi^-)_P \qquad (4d)$$

Relation (42) coincides with (5a) of [1]. The remaining relations are new 2).

We see that (4d) strongly contradicts the experimental data, in spite of the great inaccuracy of the latter (for example, for the preferred solution (i) from [8], from the point of view of the results of SU(6) symmetry for the S amplitudes, the left side of (4d) is equal to (25.46 ± 1.86) and the right side to (7.60 ± 5.40). (4d) deviates from experiment even more for the solutions (ii)).

Together with the result obtained in [1,5], this means that within the framework of $\tilde{U}(12)$ symmetry there is no satisfactory description of the parity-conserving amplitudes of hadron decays of hyperons. It is possible that this circumstance is closely connected with the recently noted contradiction between $\tilde{U}(12)$ symmetry and experiment in polarization phenomena [9,10].

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1) After [1] went to press, a paper by Oehme [5] appeared, in which the relations obtained for the octet-octet transitions are exactly the same as ours. Oehme, however, confined himself to an examination of the indicated transitions, and he failed to notice the $\tilde{U}(12)$-symmetry deduction that all the hadron decays of the Ω^- hyperon proceed with parity conservation.

2) It must be noted that relations (2) - (4) correspond to neglecting the traces in the expressions for the spurions H. An account of the traces does not change the situation essentially, leading again to three effective parameters b''_i. However, it results in a "mismatching" of the form factors and in the appearance of multipliers on the order of unity (of the type of κ in (4) in the relations between the octet-octet amplitudes. Agreement with experiment for relation (4d) cannot be obtained with any sensible choice of the central mass.