SU(3) × SU(3) Symmetry and the Baryon–Meson Coupling Constants

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Abstract. In this paper we consider the relations between the coupling constants of a unitary octet of baryons with octets of pseudoscalar and singlet vector mesons. The analysis is based in the assumption that the breaking of the SU(6) symmetry for a vertex function with three external lines has a kinematic nature and is due to the presence of two independent four–dimensional energy–momentum vectors in lieu of one, as is the case for the self–energy of the particles when SU(6) symmetry is satisfied.

The requirement that the configuration of the system 4–momenta be invariant leads to the reduction of the SU(6) group to the group SU(3) × SU(3) × U, where the two SU(3) groups correspond to unitary transformations of quarks with different polarization directions along a preferred axis, while the group U corresponds to the usual spatial rotations about this axis. The 35- and 56–plet representations of the group SU(6), corresponding to mason and baryon supermultiplets, contain the following irreducible representations of the group SU(3) × SU(3):

$$(35) \to (3,3^*); (3^*,3); (8,1); (1,8); (1,1)$$
$$(56) \to (1,10); (10,1); (6,3); (3,6) \ . \tag{1}$$

It follows from (1) that the vertex $(56^*)(56)(35)$, when is invariant against SU(3)×SU(3) transformations, contains in the general case eight independent parity–conserving interaction constants.

If we confine ourselves to vertices which do not contain the (10), 1) (1, 10) (10, 1), and (10, 1) multiplets, which are classified as baryon resonances because the spin projection in these states is equal to 3/2, then the vertices of the interaction between the baryons proper and the mesons is characterized by four independent coupling constants in place of the eight constants in the case of SU(3) invariance.

The relations obtained by us for the coupling constants, which are valid for arbitrary values of the meson mass and off the mass shell, have the following form

$$G_C^D = \frac{\mu}{2m}(\frac{2}{3}G^D - G^F) \ , \tag{2}$$

$$G_C^F = -\frac{\mu}{2m}(\frac{5}{9}G^D + \frac{2}{3}G^F) \ , \tag{3}$$

$$G_M^D : G_M^F : G_M = 3 : 2 : 1 \ . \tag{4}$$

The upper index refers here to the type of coupling (F or D) of the meson octet, while the power index determines the character of the interaction of the vector mesons with the baryons (C — electric–charge, M — magnetic moment). In determining the coupling constants we started from the following normalization of the interaction variants;

$$\bar{U}\gamma_C U \qquad\qquad \text{pseudoscalar mesons}$$

$$\left.\begin{array}{ll} \frac{2m}{4m^2\mu^2}(eq)\bar{U}U & C-\text{interaction} \\ \bar{U}[e\gamma) - \frac{2m}{4m^2-\mu^2}(eq)]U & M-\text{interaction} \end{array}\right\}\text{vector mesons} \tag{5}$$

(e — polarization vector of the vector meson; $q = p_1 + p_2$; p_a and p_2 — four–dimensional baryon momenta) and from the usual definition of the F and D coupling.

Relations (2)–(4) are compatible with the relations obtained by (Gursey, Radicati and Pais (1964)) for the coupling constants only when the coupling constant G_C^D coincides with the analogous constant in the Dirac variant, i.e., when the meson mass or all the constants of the M–interaction are equal to zero.

It is interesting to note that in the case when $\mu = 0$ there is no C – interaction of the vector meson octet with baryons at all. As a result, the variants of the dynamic theory of strong interactions, in which, in analogy with electrodynamics, the minimum interaction of the vector mesons of zero mass with baryons is regarded as the main bare interaction, are not SU(3) $\times$ SU(3)–invariant[1]. An analogous paradox concerning the incompatibility of the minimal electromagnetic interaction and SU(6) invariance was noted by (Beg, Lee and Pais (1964)).

References

Beg, Lee and Pais (1964): Phys.Rev.Lett., **13**, 514.
Gursey, Radicati and Pais (1964): Phys.Rev.Lett., **13**, 299.
Ruhl, W. (1965): Phys.Lett. **14**, 350.

[1] Relationship (4) was recently obtained by (Ruhl (1965)) on the basis of a relativistic generalization of SU(6) transformation which he proposed.