S

SEARCH FOR DYNAMICAL ENHANCEMENT IN THE PARITY-CONSERVING SU_3 NON-INVARIANT BARYON-MESON COUPLINGS

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In a recent series of publications, Dashen and Frautschi have developed an S matrix perturbation theory [1),2)]. Several calculations using this technique have been performed, dealing with medium strong, electromagnetic and weak interaction problems [3),4),5)].

We would like to report here on some results about parity-conserving, SU_3 non-invariant baryon-meson couplings.

As already emphasized by Dashen and Frautschi [see especially Ref. [2)]], the dynamical enhancement, if any, obtained in this method is due only to SU_3 conserving strong interactions, and is therefore "universal", i.e., independent of the particular driving term under consideration. In the problem we are interested in here, this means that the calculations are the same for medium strong, electromagnetic, or parity-conserving weak violations of SU_3 at the baryon-pseudoscalar meson vertices.

One postulates first that the baryon octet B and the $\frac{3}{2}^+$ decimet Δ are obtained, in the limit of exact SU_3 symmetry, as dynamical poles in the corresponding channels of B+P scattering (P is the pseudoscalar octet). This constitutes the unperturbed situation of the problem.

One then switches on the perturbation, which is here a parity-conserving, but SU_3 violating, interaction. As a result, the 8 degenerate poles of the baryon octet and the 10 ones of the $\frac{3}{2}^+$ decimet will be split ; furthermore, their residues will be modified, and in particular they will "leak" into representations which originally had no poles.

The Dashen-Frautschi method treats these modifications in first order. The enhancement argument comes from the fact that the perturbed crossed B and Δ poles react on the direct ones [see Ref. [4)]]. But Dashen and Frautschi [4)] have given arguments which make plausible that the perturbation of coupling constants in the crossed channel has little influence on the position of the poles in the direct one. As a consequence, they were able to show, using the static approximation, that mass differences transforming like an octet member are enhanced with respect to those behaving like 27 [4)].

Parity-violating weak $\bar{B}BP$ couplings also showed octet enhancement [5], under very general hypotheses such as CP conservation and the current × current theory for the driving terms.

The case of parity-conserving couplings is somewhat more complicated because of the following reasons :

1) Δ exchange has a strong influence on $\bar{B}BP$ vertices, so that one is forced to treat the $\bar{\Delta}BP$ ones simultaneously.

2) When one considers the scattering

$$\left(B_j + P_k\right)_{P_{1/2}} \longrightarrow \left(B_\ell + P_m\right)_{P_{1/2}} \qquad (1)$$

(j, k, ℓ, m being SU_3 indices), the perturbation of the residue at the baryon pole is, in first order, of the form

$$\sum_i \left[f_{ijk}\, \delta f_{i\ell m} + f_{i\ell m}\, \delta f_{ijk} \right]$$

where f and δf are the SU_3 conserving and violating constants, respectively. This means that, when considering the influence of the crossed B pole on the direct B or Δ ones, one finds two terms corresponding to a possible violation at each vertex (the same is of course true for the crossed Δ pole) ; it turns out that these two terms behave quite differently when one expands the coupling constants in irreducible representations of SU_3.

3) If one writes the effective $\bar{B}BP$ Hamiltonian in the form

$$H = \sum_{ijk} \left(f_{ijk} + \delta f_{ijk}\right) \overline{B_i}\, (i\gamma_5)\, B_j\, P_k \qquad (2)$$

CP conservation requires that [6]

$$\delta f_{ijk} = (-1)^k \, \delta f_{ji-k} \tag{3}$$

Now, when one expands the δ f's by combining first the two baryons, relation (3) remains simple. Supposing for simplicity that we deal with the isospin conserving medium strong interactions, we will write

$$\delta f_{ijk} = \sum_{\beta, N} (-1)^i \begin{pmatrix} 8 & 8 & \beta \\ -i & j & -k \end{pmatrix} \begin{pmatrix} \beta & 8 & N \\ -k & k & 0,0,0 \end{pmatrix} \delta f^N_\beta \tag{4}$$

and Eq. (3) will take the form [8)]

$$\delta f^N_\beta = \xi_3 (8 \otimes 8 ; \bar{\beta}) \, \xi_1 (8 \otimes 8 ; \beta) \, \xi_3 (\bar{\beta} \otimes 8 ; N) \, \delta f^N_{\bar{\beta}} \tag{5}$$

But the evaluation of the dynamical factors relating the crossed and direct vertices is simple in another basis, namely when the expansion is taken as :

$$\delta f_{ijk} = \sum_{\alpha, N} (-1)^i \begin{pmatrix} 8 & 8 & \alpha \\ j & k & i \end{pmatrix} \begin{pmatrix} 8 & \alpha & N \\ -i & i & 0,0,0 \end{pmatrix} \delta \bar{f}^N_\alpha \tag{6}$$

One has then to compute the recoupling coefficients which give the δf^N_β's in terms of the $\delta \bar{f}^N_\alpha$'s.

Using the static approximation, we have calculated the matrix relating the coupling constants of the crossed channel to those of the direct one. When the coupling constants are expanded in irreducible representations of SU_3, this matrix takes a block-diagonal form, each block corresponding to a definite SU_3 representation N. One has then to diagonalize these matrices, and look for eigenvalues near 1, which can produce an enhancement.

The results are as follows :

a) For $N = 1$, the matrix is a 3×3 one (two parameters come from the $\bar{B}BP$ couplings, the third one from $\bar{\Delta}BP$). If one takes $\lambda = \frac{1}{3}$ (λ is the unperturbed F to D ratio), one finds the eigenvalues 0.83, -0.09 and -0.65.

b) For $N = 8$, the $\bar{\Delta}BP$ vertex depends on four independent constants, the $\bar{B}BP$ one on only five, due to Eq. (3). The largest eigenvalue of the corresponding 9×9 matrix (calculated numerically) is 0.92 for $\lambda = \frac{1}{3}$, the next one being 0.65.

c) For $N = 27$, one also has to deal with a 9×9 matrix (four parameters coming from $\bar{B}BP$ and five from $\bar{\Delta}BP$). The two largest eigenvalues were calculated to be 0.86 and 0.67 for $\lambda = \frac{1}{3}$ [11].

These results could be considered as rather gratifying for medium strong interactions. In fact, a fit of the $\frac{3}{2}^+$ resonance widths within the octet dominance hypothesis, although giving a relation in fair agreement with experiment [12], was not completely satisfactory because the SU_3 violating constants seemed to come out of the same order as the SU_3 conserving one [10].

But the situation is rather bad if one turns to the parity conserving weak interactions. Since both 8 and 27 are enhanced, the $\Delta I = \frac{1}{2}$ rule for the non-leptonic hyperon decays does not come out as a result of this calculation, in contrast with what happened in the parity non-conserving case [5].

However, this might not be the whole story. We have recalled above that the perturbation of the coupling constants in the crossed channel does not strongly influence the mass differences. The converse, however, is not true : mass shifts might give an important term in the equations for the coupling constants. These mass shifts are much larger for $N = 8$ than for $N = 27$. It could very well happen (especially for medium strong interactions, where the driving terms are unknown) that the true driving terms are small against the contribution of mass shifts, i.e., that the apparent driving terms are essentially in an octet.

Of course, this is a purely qualitative and speculative statement and is not proved by the above considerations.

A more detailed analysis of the calculations and results will be given elsewhere.

REFERENCES AND FOOTNOTES

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6) The notations are those defined, for instance, in Ref. [7].

7) J.J. de Swart, Rev.Mod.Phys. 35, 916 (1963).

8) It is well known, for instance, that a $\bar{B}BP$ vertex transforming like a member of an octet depends on five parameters, and not on eight, as would be the case if the two baryons were different [9),10)].

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11) The quoted eigenvalues remain practically unchanged if λ is varied from $\frac{1}{3}$ to $\frac{2}{3}$.

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