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Note on the nonleptonic hyperon decays in SU(3)

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Using an s-u-channel–symmetric weak Hamiltonian ($8 \oplus 27$) and assuming intermediate states to be nonexotic, we obtain most of the observed features, such as the $\Delta I = 1/2$ rule and the Lee-Sugawara sum rule, for parity-violating (pv) as well as parity-conserving (pc) decays of $(1/2)^+$ hyperons. In addition two sum rules $\Sigma_+^+ = 0$ and $\sqrt{2}\, \Sigma_+^+ - \Sigma_0^+ = \sqrt{3}\Lambda_-^0$ in pv and pc modes, respectively, are also obtained, which are well satisfied experimentally. For $\Omega^- \to \Xi + \pi$ decays, however, the $\Delta I = 1/2$ rule does not follow. Recent CERN data on this mode do indicate about 20% violation of the $\Delta I = 1/2$ rule.

INTRODUCTION

The current × current weak Hamiltonian does not automatically guarantee the most striking feature of nonleptonic decays, namely the approximate $\Delta I = \frac{1}{2}$ rule for $|\Delta S| = 1$ decays of $J^P = \frac{1}{2}^+$ baryons. Use of duality arguments has been quite successful in this matter. In the duality arguments of Nussinov and Rosner,[1] only the nonexotic spurion gets enhanced, which in the Hamiltonian language means octet enhancement of the SU(3) weak Hamiltonian. Kawarabayashi and Kitakado[2] have derived the $\Delta I = \frac{1}{2}$ rule and the Lee-Sugawara relation for nonleptonic decays of hyperons (including Ω^-), based on the $s(u)$-t-channel duality and the absence of exotic resonances. However, similar arguments run into difficulty when applied to the nonleptonic decays of charmed hadrons.[3] Moreover, even in the uncharmed sector, recent data[4] on Ω^- decays do not favor the $\Delta I = \frac{1}{2}$ rule.

This leads one to an interesting question, whether the basic features of nonleptonic decays of hyperons could be obtained using less restrictive conditions than those imposed by $s(u)$-t-channel duality. The purpose of the present note is not so much as to reexamine the applicability of duality to nonleptonic decays, but rather to suggest the possibility of reproducing essentially all the important aspects of the data in the case of uncharmed $\frac{1}{2}^+$ baryons and Ω^- using a much weaker assumption than that of the $s(u)$-t-channel duality.

Bajaj, Kaushal, and one of the present authors (M.P.K.)[5] were able to obtain the hypothesis of octet dominance for parity-violating (pv) decays of $\frac{1}{2}^+$ baryons in the s channel just with the absence of exotic intermediate states. We extend those considerations to the t and u channels also and observe that the nonexoticity of the intermediate states yields octet dominance in these channels, too. However, for parity-conserving (pc) decays, no useful result follows. Therefore, we employ an additional assumption, namely the s-u-channel symmetry of the weak Hamiltonian. This symmetry was discussed earlier by Kohara and Nishijima[6] in the context of on-mass-shell unsubtracted dispersion relations, when applied to pc nonleptonic decays. It may be mentioned that they, apart from certain other assumptions, invoke octet dominance of the weak Hamiltonian. We neither assume octet dominance nor duality in our attempt to deduce the observed features of parity-violating as well as parity-conserving decays of $\frac{1}{2}^+$ baryons. Furthermore, in our considerations, the $\Delta I = \frac{3}{2}$ component may contribute appreciably to $\Omega^- \to \Xi\pi$ decays, as demanded by the experimental data.[4]

Besides CP invariance, we essentially make two assumptions: (i) Only the eigenamplitudes corresponding to the nonexotic particle states contribute to the transitions[7] and (ii) that the weak Hamiltonian is symmetric with respect to exchange of s and u channels. The latter essentially amounts to requiring that identical reduced matrix elements appear in s and u channels. This assumption has already been arrived at by Kohara and Nishijima[6] in the case of weak decays. Following the method described in Ref. 5, and starting with the most general symmetric weak Hamiltonian ($8 \oplus 27$), we notice that the assumption (i) is enough to generate octet dominance in all three s, t, and u channels for the pv mode, and so $\Delta I = \frac{1}{2}$ relations and the Lee-Sugawara sum rule follow. Looking into the s- and u-channel contributions for $\frac{1}{2}^+ \to \frac{1}{2}^+ + 0^-$ decays, all the decay amplitudes are found to be proportional to Σ_+^+, which is nearly zero experimentally. In fact, using assumptions (ii) we do get $\Sigma_+^+ = 0$ in the SU(3) framework.[8] As a matter of fact, in the present model, the s-u channels are forbidden to contribute to pv decays, —a result which is in full accord with the conclusions obtained from duality arguments[1] and current algebra.[8]

In the case of pc modes, it is well known that the experimentally satisfied Lee-Sugawara sum rule does not follow even from an octet-dominant weak Hamiltonian without additional dynamical assumptions.[6] We find that mere s, u symmetry of the Hamiltonian [assumption (ii)] gives the Lee-Sugawara relation

$$\sqrt{3}\,\Sigma_0^+ - \Lambda_-^0 = 2\,\Xi_-^-$$

$$(10.68 \pm 1.26 = 13.42 \pm 0.76)\,,$$

in all three channels. This relation has also been obtained by Kohara and Nishijima.[6] Further limiting the intermediate states to be nonexotic, we obtain a new sum rule in s and u channels, i.e.,

$$\sqrt{2}\,\Sigma_+^+ - \Sigma_0^+ = \sqrt{3}\,\Lambda_-^0$$

$$(14.91 \pm 0.82 = 17.61 \pm 0.41)\,,$$

which is satisfied to the same extent[9] as the Lee-Sugawara sum rule. We may therefore conclude that the contributions from the t channel are small.[10] We also notice that the contributions from the 27 components of the weak Hamiltonian are forbidden in the s as well as in the u channels, thereby yielding octet dominance in these channels.

Extending our considerations to Ω^- decays, we find that in the case of $\frac{3}{2}^+ \to \frac{3}{2}^+ + 0^-$ decays, the nonexoticity of intermediate states makes the Ω^- decay amplitudes vanish in the s and the u channel for pv as well as for pc modes. From the t channel we obtain octet dominance for the pv decays and so the $\Delta I = \frac{1}{2}$ rule, i.e.,

$$\langle \Xi^{*0}\,\pi^- \,|\, \Omega^-\rangle = -\sqrt{2}\,\langle \Xi^{*-}\,\pi^0 \,|\, \Omega^-\rangle\,;$$

since the t-channel contributions in the pc mode are supposed to be small, we expect the parity-conserving $\Omega^- \to \Xi^*\pi$ mode to be suppressed.

This, of course, amounts to the vanishing of the asymmetry parameters, the observation of which therefore would tell us about the t-channel contribution.

The situation for the $\frac{3}{2}^+ \to \frac{1}{2}^+ + 0^-$ decay mode is quite different. Here CP invariance gives no constraints. If we assume that pv Ω^- decays arise predominantly through the t channel, as happens in the case of $\frac{1}{2}^+ \to \frac{1}{2}^+ + 0^-$ and $\frac{3}{2}^+ \to \frac{3}{2}^+ + 0^-$ decays, then the weak Hamiltonian $(8 \oplus 27)$ forbids $\Omega^- \to \Lambda K^-$ decay. So the asymmetry parameter $\alpha(\Omega_K^-)$ is predicted to be zero,[11] which is consistent with the experimental value, $\alpha(\Omega_K^-) = 0.06 \pm 0.14$, observed in a recent CERN experiment.

For the $\Omega^- \to \Xi\pi$ mode we get the $\Delta I = \frac{1}{2}$ rule, i.e., $\Omega_-^- = -\sqrt{2}\,\Omega_0^-$ only in the s channel. Thus in our considerations the $\Delta I = \frac{3}{2}$ component of the weak Hamiltonian is allowed to contribute to the $\Omega^- \to \Xi\pi$ decays through the t and/or u channels. The $\Omega^- \to \Lambda K^-$ decay obviously cannot arise through the $\Delta I = \frac{3}{2}$ piece. The recent CERN data[4] on Ω^- decays indeed support our result. Branching fractions for Ω^- decays are observed to be

$$\Lambda K^- : \Xi^0\pi^- : \Xi^-\pi^0$$
$$= (67.0 \pm 2.2) : (24.6 \pm 1.9) : (8.4 \pm 1.1)\,,$$

which clearly indicates about 20% violation of the $\Delta I = \frac{1}{2}$ rule in $\Omega^- \to \Xi\,\pi$ decays.

To briefly recount our results, we find that the absence of exotic intermediate states and s-u-channel symmetry of the weak Hamiltonian basically reproduce almost all the important observed features of nonleptonic decays of $\frac{1}{2}^+$ baryons and of Ω^-. Extension of these ideas to charmed-baryon decays is in progress.

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[1]S. Nussinov and J. Rosner, Phys. Rev. Lett. 23, 1266 (1969).

[2]K. Kawarabayashi and S. Kitakado, Phys. Rev. Lett. 23, 440 (1969).

[3]J. Ellis, M. K. Gaillard, and D. V. Nanopoulos, Nucl. Phys. B100, 313 (1975); M. K. Gaillard, B. W. Lee, and J. L. Rosner, Rev. Mod. Phys. 47, 277 (1975); J. Ellis Acta Phys. Austriaca Suppl. 14, 143 (1975).

[4]J. Gaillard, results of CERN experiment presented at the Sixth Trieste Conference on Elementary Particle Physics, 1978 (unpublished).

[5]J. K. Bajaj, V. Kaushal, and M. P. Khanna, Phys. Rev. D 10, 3076 (1974).

[6]Y. Kohara and K. Nishijima, Prog. Theor. Phys. 47, 648 (1972); 46, 348 (1971).

[7]J. L. Rosner, Phys. Rev. Lett. 21, 950 (1968); D. P. Roy and M. Suzuki, *ibid.* 28B, 558 (1969); H. J. Lipkin, Nucl. Phys. B9, 349 (1969); J. Mandula *et al.*, Phys. Rev. Lett. 22, 1147 (1969); M. Suzuki, *ibid.* 22, 1217 (1969); 22, 1413(E) (1969).

[8]Earlier this result had been obtained in higher spin symmetry considerations such as SU(6) and current algebra, with the assumption of octet dominance [see S. P. Rosen and S. Pakvasa, in *Advances in Particle*

Physics, edited by R. L. Cool and R. E. Marshak (Interscience, New York, 1968), Vol. 2].

[9]Decay-amplitude values are taken from Particle Data Group, Rev. Mod. Phys. 48, S243 (1976).

[10]But through the t channel, the $\Delta I = \frac{3}{2}$ piece of the weak Hamiltonian may appear. Recent $\Xi^0 \rightarrow \Lambda \pi^0$ data obtained [G. Bunce *et al.*, Phys. Rev. D 18, 633 (1978)] indicate a large violation of $\Delta I = \frac{1}{2}$ rule.

[11]Two of us have obtained the null asymmetry parameter $\alpha(\Omega_K^-)$ in the $SU(8)_W$ framework [Ramesh C. Verma and M. P. Khanna, Pramara 11, 333 (1978)].