NON-LEPTONIC DECAYS AND THE CHIRAL BAG MODELS

DUBRAVKO HORVAT

Zavod za fiziku, Elektrotehnički fakultet, University of Zagreb, Croatia, Yugoslavia

Nonleptonic hyperon decays have been analyzed using a chiral-bag model. The adopted theoretical formalism allows a comparison between the new and the old MIT-bag model approach. Chiral-bag model based theoretical predictions are not significantly different from the MIT-bag model based results.

1. Introduction

This paper is based on a particular scheme |1| which has used the MIT-bag model |2| but here it will be replaced by the chiral-bag quark model |3, 4|.

In the particular approach |1| s-wave hyperon decay amplitudes are approximated through a commutator term. The usage of PCAC is an essential ingredient in the calculation of the soft-pion amplitudes |5|

$$A^{c} = a_{B'B} = \langle B'|H_{W}^{eff}|B\rangle \qquad (1)$$

The effective Hamiltonian H_{W}^{eff} has been obtained by calculating QCD radiative corrections to the standard electroweak Hamiltonian |6|.

In the MIT-bag model |2| the axial-vector current is not conserved on the bag surface and the chiral symmetry is broken.

The chiral symmetry can be restored by introducing an elementary meson field coupled to quarks |3, 4|. As the chiral symmetry is spontaneously broken the PCAC condition can be incorporated into the MIT-bag model.

The weak currents in the effective weak Hamiltonian now have a quark piece inside the bag and a meson piece outside the bag in accordance with two phase model of hadrons.

The QCD-corrected effective weak Hamiltonian is of the form |6|:

$$H = \sqrt{2}\, G_F \sin \Theta_c \cos \Theta_c \sum_{i=1}^{6} c_i O_i \qquad (2)$$

Here O_i's are four quark local operators, made out of the left handed fields and c_i are the QCD enhancement coefficients.

Therefore one is dealing with a V-A combination of the vector-current V and the axial-vector current A. In the chiral-bag model both A and V currents contain "mesonic" parts outside the bag boundary. Static approximation for the meson field means that each field has a quark source inside the hadron, for example

$$\begin{aligned} \phi_a^M(\vec{r}) = {} & D_o^M\ (1/\mu_M r)\ \exp(-\mu_M r)\,(\tilde{\chi}_m^{\dagger} \lambda_a \chi_n) \cdot \\ & \cdot (\tilde{d}_m^c\ b_n^c + \tilde{b}_m^{c\dagger}\ d_n^c\ ) + D_1^M\ (1/\mu_M r + 1/\mu_m^2 r^2) \cdot \\ & \cdot \exp(-\mu_M r)\,(\tilde{\chi}_m^{\dagger} (\vec{\sigma}\ \vec{r}_v) \chi_n)(\tilde{b}_m^{c\dagger} b_n^c + \tilde{d}_m^c d_n^{c\dagger}) \end{aligned} \qquad (3)$$

Here $b^+(b)$ and $d^+(d)$ are creation (annihilation) operators for quarks (antiquarks) inside the hadron.

The calculation of matrix elements (1), i.e.

$$a_{B_f B_i} = \sqrt{2}\, G_F \sin \Theta_c \cos \Theta_c | c_1 \langle B_f | O_1^{(1)} | B_i \rangle + \ldots | \qquad (4)$$

allows only parts transforming as V·V or A·A to contribute. The quark flavours can be sources of the meson fields for instance

$$\begin{aligned} u\,\bar{u} &\longrightarrow \frac{\sqrt{6}}{6}\,\eta_8 + \frac{\sqrt{3}}{3}\,\eta_1 + \frac{\sqrt{2}}{2}\,\pi^o \\ s\,\bar{d} &\longrightarrow \overline{K^o} \end{aligned} \qquad (5)$$

This means that each axial-vector current has an addition of the derivative of the corresponding meson field:

$$<B_f|O_1^{(1)}|B_i>_{AA} = <B_f|O_1^{(1)}|B_i>_{AAq} + <B_f|O_1^{(1)}|B_i>_M \qquad (6)$$

Here, for instance for $(\bar{d}\ s)(\bar{u}\ u)$ combination:

$$<B_f|O_1^{(1)}|B_i>_{AAq} = <B_f|\int d^3x\ :\ (\bar{d}(x)s(x))_A(\bar{u}(x)u(x))_A: \\ |B_i>\Theta(R-x) \qquad (7a)$$

and

$$<B_f|O_1^{(1)}|B_i>_M \equiv \int (P_1+P_2+P_3)\cdot\Theta(x-R)\,d^3x \qquad (7b)$$

where, for instance

$$P_1 = \frac{\sqrt{6}}{6}<B_f|:(f_{\overline{K^0}}\partial_\mu\phi^{\overline{K_0}}\ f_{\eta_8}\partial^\mu\phi^{\eta_8}):|B_i>$$

By using a free-particle Klein-Gordon equation for the meson field $\phi(r)$ outside the bag, one finds

$$P_i = a_i f_\ell f_m <B_f|:\int_{r=R} r^2 d\Omega\,\phi^\ell\,\partial_r\phi^m:|B_i> + \\ + a_i f_\ell f_m \mu_m^2 <B_f|:\int r^2 dr\,d\Omega\,\phi^\ell\phi^m:|B_i> \qquad (8)$$

and the contribution (7a) corresponds formally to the old MIT-bag model based results |1|. However the quark wave functions under integration must be the chiral-bag model solutions.

The overall structure of the soft-pion amplitude is

$$a_{B_iB_f} = \sqrt{2}\,G_F \sin\Theta_c \cos\Theta_c\ \Sigma\ c_i\,[<B_f|O_i|B_i>_{VVq} + \\ +<B_f|O_i|B_i>_{AAq} + <B_f|O_i|B_i>_M] \qquad (9)$$

Expressions for various amplitudes $a_{B_iB_f}$ can be given in terms of integrals over quark and meson wave functions. Chiral-bag quark wave functions depend on the actual hadron H which is built from the quarks in question.

The current-algebra contribution A^c |5| to the s-wave hyperon nonleptonic decay amplitude is the best illustration of the differences between chiral-bag and MIT-bag models.

We have found two possible sets of model parameters to describe the chiral bag (confinement radii, m_s).

In Table 1 we display theoretical and experimental s-wave amplitudes which contain both current-algebra and separable contributions.

The overall picture is quite pleasing. The agreement with experimental values is as good as in the calculation based on the simple MIT-bag model |1|. The relative signs of the hyperon decay amplitudes are always reproduced correctly, if one excludes A (Σ^+_+) amplitude. This particular result is in complete agreement with the other chiral-bag model calculation|7|. Apart from A (Σ^+_+) even the relative magnitude of the various amplitudes are qualitatively correct.

TABLE 1

Amplitude x 10^6	R $R_1 = 4.58$ $R_2 = 5.65$	A^c	Separable	Tot. Our	Tot. Ref. |1|	Exp.
$A(\Lambda^o_-)$	R_1	0.25	0.03	0.28	0.21	0.32
	R_2	0.14	0.03	0.17		
$A(\Xi^-_-)$	R_1	-0.46	-0.06	-0.52	-0.43	-0.44
	R_2	-0.28	-0.06	-0.34		
$A(\Sigma^+_o)$	R_1	-0.42	-0.05	-0.47	-0.38	-0.32
	R_2	-0.25	-0.05	-0.30		
$A(\Sigma^-_-)$	R_1	0.43	0.02	0.45	0.49	0.42
	R_2	0.21	0.02	0.23		
$A(\Sigma^+_+)$	R_1	$3\cdot10^{-3}$	0	$3\cdot10^{-3}$	0	0.01
	R_2	$3\cdot10^{-3}$	0	$3\cdot10^{-3}$		

Hyperon nonleptonic decay amplitudes
Experimental values are from Ref |8|

References

|1| D.Tadić, J.Trampetić, Phys.Rev. D23 (1981) 144;

|2| A.Chodos, R.L.Jaffe, K.Johnson and C.B.Thorn, Phys. rev. D9(1974)3471;
T. De Grand, R.L.Jaffe, K.Johnson, J.Kiskis, Phys.Rev. D12(1975)2060;

|3| M.M.Musakhanov: preprint ITEP-179 (1980); A.W. Thomas, Adv.Nucl.Phys. 13, p.1. J.W.Negele, E.Vogt (eds.) New York: Plenum Press 1984; R.L. Jaffe: Lectures at the 1979 Summer School "Ettore Majorana", Vol.17, ed. A.Zichichi, New York: Plenum Press, 1982; F.Myhrer, G.E.Brown, Z.Xu, Nucl.Phys. A362 (1981) 317; G.E.Brown, M.Rho, Phys.Lett. 82B (1979) 177; G.E.Brown, M.RHO, V.Vento, Phys.Lett. 84B (1979) 383; M.V.Barnhill, W.K.Cheng, A.Halprin, Phys.Rev. D20 (1979)727; M.V. Barnhill, A.Halprin, Phys.Rev. D21 (1980) 1916; V.Vento, M.Rho, E.M. Nyman, J.H.Jun, G.E.Brown, Nucl.Phys. A345 (1980) 314; K.Saito, Progr. Theor.Phys. 71 (1984) 775;

|4| F.Myhrer, G.E.Brown, Z.Xu, Nucl.Phys. A362 (1981) 317; I.Hulthage, F.Myhrer, Z.Xu, Nucl.Phys. A364 (1981) 322; H.Høgaasen, F.Myhrer, Z. Phys. C21 (1983) 73;

|5| R.E.Marshak, Riazuddin, C.P.Ryan: Theory of weak interactions in particle physics. New York: Wiley Interscience 1969

|6| M.K.Gaillard, B.W.Lee, Phys.Rev.Lett. 33 (1974) 108; G.Altarelli, L. Maiani, Phys.Lett. 52B (1974) 351; A.A.Shifman, A.J.Vainshtein, V. Zaharov, Zh.Eksp.Teor.Fiz. 22 (1975)123; Sov.Phys. JETP 22, 55 (1975); ITEP Reports 64 and 65 (unpublished); Nucl.Phys. B120 (1977) 315; R.D.C.Miller, B.H.J.McKellar: Phys.Rep. 106 (1984) 169

|7| J.A.Oteo, S.Noguera: Orsay preprint IPNO/TH 85-7; P.Gonzales, S.Noguera, J.Bernabeu, V.Vento, Nucl.Phys. A423 (1984) 477;

|8| Review of Particle Properties: Phys.Lett. 111B (1982)