CM-P00056863

A MODEL FOR THE VIOLATION OF THE

$$|\Delta \vec{I}| = \frac{1}{2} \text{ RULE IN } K_{13} \text{ DECAYS}$$

AND ITS EXPERIMENTAL IMPLICATIONS

C. Bouchiat, J. Nuyts, J. Prentki

CERN-Geneva

There have recently been some experimental evidence for a violation of the $|\Delta \vec{I}| = \frac{1}{2}$ rule in the non-leptonic decays of the Ξ hyperons and K mesons ¹⁾. In the Ξ decay the triangle relationship of Gell-Mann and Rosenfeld which follows from $|\Delta \vec{I}| = \frac{1}{2}$ is not well satisfied, the inconsistency being between two and three standard deviations.

Concerning the $K_{\pi 3}$ decay, Crawford was able, by a combination of results coming from two different experiments, to give an experimental value for the rate of decay of K_2^0 into $\pi^+ \pi^- \pi^0$:

$$\Gamma_2(+ - 0) = (1.44 \pm 0.43) 10^6 \text{ sec}^{-1}. \quad (1)$$

Without any assumption about the symmetry of the three-pion final state, the $|\Delta \vec{I}| = \frac{1}{2}$ relates $\Gamma_2(+ - 0)$ to the rate of decay of K^+ into $\pi^+ \pi^0 \pi^0$ ²⁾:

$$\Gamma_2(+ - 0) = 1.032 \times 2 \Gamma_+(+ 0 0) = (2.87 \pm 0.23) 10^6 \text{ sec}^{-1}. \quad (2)$$

If the experimental result is taken seriously, it means that quite a large $|\Delta \vec{I}| = \frac{3}{2}$ amplitude is present in $K_{\pi 3}$ decay. The experimental value of the $\frac{\tau}{\tau'}$ branching ratio and the Dalitz plots of τ and τ' exclude the possibility of a large $|\Delta \vec{I}| = \frac{5}{2}$ amplitude but, as is well-known, tell us nothing about a possible $|\Delta \vec{I}| = \frac{3}{2}$ amplitude.

In this note we would like to propose a mechanism which may explain the observed deviations from the $|\Delta \vec{I}| = \frac{1}{2}$ rule in $K_{\pi 3}$ decay without assuming that the weak interaction Hamiltonian for non-leptonic decay of strange particles does contain an isospin $\frac{3}{2}$ term. This mechanism is in fact an enhancement of the electromagnetic corrections to the amplitude of K_2^0 decay due to the presence of η_0 with a mass very close to the mass of K. This model, however, cannot give corrections sufficiently important to explain the present situation in Ξ decays. If the experimental result were confirmed, this model would no longer give a natural explanation of the $|\Delta \vec{I}| = \frac{3}{2}$ contribution.

Recent evidence³⁾ for the decay of η_0 ($I = 0$) into two γ rays implies that the G parity of the η_0 is $+1$. The Dalitz plot of the decay into 3π suggests a 0^{-+} assignment. On the other hand, the experiment of Chretien et al.³⁾ indicates that the decay rates $\Gamma(\eta \rightarrow 2\gamma)$ and $\Gamma(\eta \rightarrow \pi^+ \pi^- \pi^0)$ are of the same order of magnitude. The decay amplitudes for $\eta \rightarrow 2\gamma$ and $\eta \rightarrow \pi^+ \pi^- \pi^0$ should both be of the order of α where α is the fine structure constant. However, $\eta \rightarrow 2\gamma$ is favoured by phase space by a factor of the order of three hundred. Then, unless the 2γ decay is somehow inhibited, one is forced to admit that the η - 3π coupling constant $\lambda_{\eta\pi\pi}$ should be of the order of 10α . A similar result is obtained from an estimate of the rate of the $\eta \rightarrow 2\gamma$ decay by a perturbation calculation (the experiment of Chretien et al. suggests that the η_0 nucleon and π_0 nucleon coupling constants are of the same order of magnitude).

Let us now consider the process described by the graph of Fig. 1

Fig. 1

in which the K_2^0 is converted by a $|\Delta \vec{I}| = \frac{1}{2}$ weak interaction into a virtual η_0 which decays into $\pi^+ \pi^- \pi^0$ in an $I = 1$ state. This amplitude is clearly a mixture of $|\Delta \vec{I}| = \frac{1}{2}$ and $|\Delta \vec{I}| = \frac{3}{2}$ amplitudes. Since the masses

of the η_0 and K_2^0 are very close to each other ($m_{K_2^0} = 500$ MeV ; $m_{\eta_0} = 550$ MeV) we expect a strong enhancement coming from the η_0 propagator ^{*}). To make a more quantitative analysis, let us write the decay amplitude for the K^+ into $\pi^+ \pi^0 \pi^0$:

$$\langle K^+ | T | \pi^+ \pi^0 \pi^0 \rangle = G_{K\pi} f(m_K, \omega_a, \omega_b, \omega_+) \frac{1}{4 \sqrt{m_K \omega_a \omega_b \omega_+}} \quad (3)$$

where f is normalized in such a way that

$$f(m_K, \frac{m_K}{3}, \frac{m_K}{3}, \frac{m_K}{3}) = 1. \quad (4)$$

Assuming only the validity of the $|\Delta I| = \frac{1}{2}$ rule, Sawyer and Wali ²⁾ have shown that the amplitude for the decay mode $K_2^0 \rightarrow \pi^+ \pi^- \pi^0$ is given by

$$\langle K_2^0 | T | \pi^+ \pi^- \pi^0 \rangle = G_{K\pi} f(m_K, \omega_+, \omega_-, \omega_0) \frac{1}{4 \sqrt{m_K \omega_+ \omega_- \omega_0}} \quad (5)$$

The similarity observed experimentally between the Dalitz plots of ω and η decays strongly suggests that the structure of the decay amplitudes for K and η is determined only by the final state interactions ⁵⁾. We can then write down the decay amplitude of the process $\eta \rightarrow \pi^+ \pi^- \pi^0$ in the following way

$$\langle \eta | T | \pi^+ \pi^- \pi^0 \rangle = \lambda_{\eta\pi} f(m_K \approx m_\eta, \omega_+ \omega_- \omega_0) \frac{1}{4 \sqrt{m_\eta \omega_+ \omega_- \omega_0}} \quad (6)$$

^{*}) A similar mechanism for the θ^+ decay, involving the still hypothetical meson, has been proposed by Feinberg and Pais ⁴⁾.

where $\lambda_{\eta\pi}$ is the dimensionless constant already introduced. We can now write down the contribution of the graph of Fig. 1 to the amplitude of the decay mode $K_2^0 \rightarrow \pi^+ \pi^- \pi^0$

$$G_{K\pi} f_{K\eta} \frac{m_K^2}{m_K^2 - m_\eta^2} \lambda_{\eta\pi} f(m_K, \omega_+ \omega_- \omega_0) \frac{1}{4 \sqrt{m_\eta \omega_+ \omega_- \omega_0}} \quad (7)$$

where the effective $K\eta$ coupling constant has been written as $G_{K\pi} f_{K\eta} \frac{m_K^2}{m_K^2 - m_\eta^2}$, $f_{K\eta}$ being a dimensionless quantity which is reasonably expected to be of the order of unity. The correction coming from the η virtual transition is simply obtained by multiplying the K_2^0 decay amplitudes given by the $|\Delta I| = \frac{1}{2}$ rule by the factor $1 - x$, where

$$x = f_{K\eta} \frac{m_K^2}{m_K^2 - m_\eta^2} \lambda_{\eta\pi} \quad (8)$$

In particular, formula (2) has to be replaced by :

$$\Gamma_2(+ - 0) = 1.032 \times 2 \Gamma_+(+ 0 0) \frac{1}{(1-x)^2} \quad (9)$$

The experimental value of $\Gamma_2(+ - 0)$, Eq. (1), yields $x = 0.30$ or $x = 1.70$. The reasonable solution $x = 0.30$ gives a value of 0.06 for the product $f_{K\eta} \lambda_{\eta\pi}$ which is compatible with $f_{K\eta}$ of the order of unity and $\lambda_{\eta\pi}$ of the order of 10^{-2} .

The model under discussion has some important experimental implications which can easily be tested.

- 1) Due to the enhancement factor

$$\frac{\frac{m_K^2}{2} - \frac{m_\eta^2}{2}}{m_\eta^2 - m_K^2} \approx 5$$

it is reasonable to assume that the dominant term in the $K_2^0 \rightarrow 2\gamma$ decay is given by the graph of Fig. 2

Fig. 2

It follows that the branching ratio between the 2γ and $\pi^+ \pi^- \pi^0$ decay modes of the K_2^0 *) is

$$\frac{\Gamma(K_2^0 \rightarrow 2\gamma)}{\Gamma(K_2^0 \rightarrow \pi^+ \pi^- \pi^0)} = \frac{\Gamma(\eta \rightarrow 2\gamma)}{\Gamma(\eta \rightarrow \pi^+ \pi^- \pi^0)} \left(\frac{x}{1-x} \right)^2 \approx 20\% . \quad (10)$$

*) The phase space corrections are manifestly of the order of a few percent.

Such a large branching ratio is not excluded experimentally and we would like to stress the importance of an experimental study of $K_2^0 \rightarrow 2\gamma$.

- 2) Another simple prediction of this model is that the branching ratios

$$\frac{\Gamma_{+}^{++-}}{\Gamma_{+}^{+00}} \quad \text{and} \quad \frac{\Gamma_{2}^{+-0}}{\Gamma_{2}^{000}}$$

remain roughly those predicted by a $|\Delta \vec{I}| = \frac{1}{2}$ rule.

- 3) A further prediction is the branching ratio of $K_2^0 \rightarrow \pi^+ \pi^- \gamma$ in terms of the still unknown branching ratio of $\eta \rightarrow \pi^+ \pi^- \gamma$, given by a formula analogous to (10).

- 4) Finally, there is no reason that a mechanism involving a virtual η meson should affect the predictions of the $|\Delta \vec{I}| = \frac{1}{2}$ rule in the non-leptonic decays of the Σ hyperon. It is then quite clear that if the strong violation observed recently in Σ decay were confirmed, this mechanism would not be the dominant effect and the idea of a weak Hamiltonian with the transformation properties of an isospinor would probably have to be given up.

R E F E R E N C E S

- 1) F.S. Crawford, Proceedings of the 1962 International Conference on High Energy, p. 828. (A complete list of references is given).
- 2) R.F. Sawyer, K.C. Wali, Nuovo Cimento 17, 938 (1960).
- 3) M. Chretien et al., Phys. Rev. Letters 9, 127 (1962).
- 4) G. Feinberg, A. Pais, Phys. Rev. Letters 8, 341 (1962).
- 5) M.A. Baqi Beg, Phys. Rev. Letters 9, 67 (1962) ;
G. Barton, S.P. Rosen, Phys. Rev. Letters 8, 414 (1962) ;
D. Berley, D. Colley, J. Schultz, Columbia University preprint.