BOSON-PAIR TERMS OF THE CHARGED CURRENT IN THE SCHIZON THEORY OF WEAK INTERACTIONS *

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Abstract

The immediate consequences of the introduction of strangeness conserving as well as non-conserving charged currents involving bosons only have been considered in the light of the intermediate schizon theory of weak interactions. It is pointed out among others that Sugawara's $\bar{K}_1^0 \pi$ current has to be discarded if the interaction is via the intermediate boson.

1. Introduction

In the accepted formalism of weak interactions (Gatto 1959) in terms of current interacting with itself, one decomposes the current J_μ into different components $J_\mu = J_\mu^{(l)} + J_\mu^{(0)} + J_\mu^{(-1)} + J_\mu^{(+1)}$ corresponding respectively to lepton pairs, strangeness conserving baryon pairs ($\Delta S = 0$), strangeness non-conserving baryon pairs with $\Delta S = -1$ and $\Delta S = +1$. To forbid some unobserved decays the rule $\Delta Q = \pm 1$ is imposed on every pair (for a pair $A\bar{B}$ the charge transfer is $\Delta Q = Q_B - Q_A$; ΔS is similarly defined). In addition to these pairs of leptons and baryons one can include also pairs of bosons (Sugawara 1958, 1959). The pairs $(\pi^+\bar{\pi}^0)$ and $(K^+\bar{K}^0)$ satisfying $\Delta Q = -1$, $\Delta S = 0$ and the pairs $(K^+\pi^0)$ and $(K^0\pi^+)$ satisfying $\Delta S = \Delta Q = -1$ can be included. The inclusion of the first pair is a necessary consequence of the assumption that the vector part of the weak current is divergenceless.

Recently Lee and Yang (1960) have suggested that all weak interactions are transmitted through an intermediate boson field W (called schizon). They have shown that the observed $|\Delta \vec{I}| = 1/2$ rule and the small mass difference between K_1^0 and K_2^0 leads to the conclusion that there exists four W particles: $W^\pm$, W^0 and $\bar{W}^0$. A natural assignment of the isotopic spin transformation property of these W particles follows a dual scheme in which W's behave as an isotopic vector when coupled with strangeness conserving currents and as an iso-spinor when coupled with strangeness non-conserving currents. This statement remains true if we include the boson-pair terms. W behaves as an iso-vector when coupled with the strangeness conserving currents involving

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$(\pi\,\bar{\pi})$, and $(K\,\bar{K})$ terms and the interaction has the form $(\vec{\pi}\times\vec{\pi}),\ \vec{W}$ or $(\bar{K}\,\vec{\tau}\,K)\ \vec{W}$ in iso-space, while the coupling with the strangeness non-conserving current is of the form $(\bar{K}\ \vec{\tau}\ \vec{W})\ \pi$. The neutral field W^0 does not take part in these interactions as the $(\pi^0\,\bar{\pi}^0)$ current vanishes identically and $(\pi^+\,\pi^-)$ pair violates $\Delta\,Q = \pm 1$ rule. Similar argument holds for K-particle pair.

2. Consequences of the Assumption of Boson Currents

2.1 $(\pi\,\pi)$ current:

The charged W field is coupled with the pionic current in the following manner

$$f\left(\phi_0\,\frac{\partial\phi}{\partial x_\mu} - \phi\,\frac{\partial\phi_0}{\partial x_\mu}\right).\,W_\mu \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.1)$$

where ϕ and ϕ_0 are the charged and neutral pion fields respectively. The coupling constant $f \propto \sqrt{G}$ where G is the universal Fermi coupling constant. An immediate consequence of the above interaction is the direct decay of W into two pions:

$$W^{\pm} \rightarrow \pi^{\pm} + \pi^0, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.2)$$

with a life-time comparable to its leptonic mode of decay (decay rate $= \lambda \approx 8 \times 10^{16}$ sec^{-1}). Charge independence leads to $\lambda(W^+ \rightarrow \pi^+ + \pi^0) = \lambda(W^- \rightarrow \pi^- + \pi^0)$ but $\lambda(W^0 \rightarrow 2\pi^0) = 0$. The ratio of the decay rates,

$$R_1 = \frac{W \rightarrow 2\pi \text{ (without } \pi\,\pi \text{ current)}}{W \rightarrow 2\pi \text{ (by } \pi\,\pi \text{ current only)}} \approx 1.$$

Another interesting consequence is that the decay of pion into a pion and lepton proceeds as follows:

$$\pi^{\pm} \rightarrow \pi^0 + W^{\pm} \rightarrow e^{\pm} + \nu(\bar{\nu}) + \pi^0$$

which does not involve any strong processes. The decay rates according to the usual and present theory turn out to be of the same order. A cut-off mass, $1{\cdot}5\ m_p$, has been used. The transition rate of $W \rightarrow 3\pi$ will be the same as the same number of strong and weak constants are involved in both the cases. The same is true of the leptonic decay of W: The contribution of the $(\pi\,\pi)$ current will, therefore, be the same as that of the baryonic current in all the above decays.

In conclusion, we consider the electromagnetic decay of W. The contributions are again of the same order. We conclude, therefore, that in all the processes considered here the contribution of the $(\pi\,\pi)$ current is just as important as that of the baryonic current and hence justifies its inclusion.

2.2 $(K\ \bar{K})$ current:

As pointed out in section 1, the strangeness conserving $(K\ \bar{K})$ currents we can form are $(K^+\ \bar{K}_0)$ and $(K^-\ K^0)$ and the coupling with the W field leads to the decays,

$$K^0 \to K^+ + e^- + \bar{\nu},$$

which is analogous to the decay of $\pi^{\pm}$. This will have the decay rate of the same order as when the decay proceeds through baryon loops.

The following unobserved decay of K^+ is a consequence of this interaction:

$$K^+ \to W^+ + K^0 \to (\mu^+, e^+) + \pi^+ + \pi^- + (\nu', \nu).$$

The following decays are also possible for W, through the $(K\ \bar{K})$ current, if its mass is high enough:

$$W^+ \to K^+ + \bar{K}^0 \to K^+ + \pi^+ + \pi^- \to \mu^+ + \nu' + \pi^+ + \pi^-, \text{ etc.}$$

Here, again, charge independence leads to the equality of decay rates

$$\lambda(W^- \to K^- + K^0) = \lambda(W^+ \to K^+ + \bar{K}^0).$$

2.3 $(K\ \pi)$ current:

This current can be constructed both from a charged K and a neutral π and from a neutral K and a charged π. It may be noted that $K\ \pi$ current is not, however, divergenceless. Sugawara (1959) has pointed out that the former choice gives too rapid a decay of $K^+ \to \pi^0 + e^+ + \nu$ and hence has to be discarded. The same argument holds in the present case. So we have to construct a current with a neutral K and a charged pion, i.e. replace ϕ_0 in (2.1) by ϕ_{K^0} or $\phi_{\bar{K}^0}$ (or a combination of them). Sugawara has argued that if we demand CP-invariance of the interaction then we should choose $\phi_{K_1^0}$ rather than $\phi_{K_2^0}$, because the leptonic partial decay rates of K_1^0 calculated with this current is 10^8 sec^{-1}. This would be the same for K_2^0 if we had assumed $\phi_{K_2^0}$ instead of $\phi_{K_1^0}$, which contradicts the long life of K_2^0. If this argument is correct then the mass difference between K_1^0 and K_2^0 is $\sim G$ instead of G^2 as is experimentally observed (*see* Figs. 1 and 2).

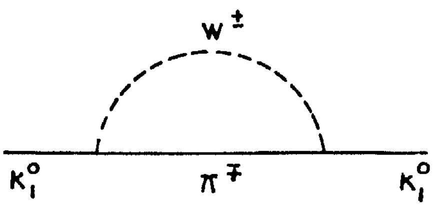

FIG. 1

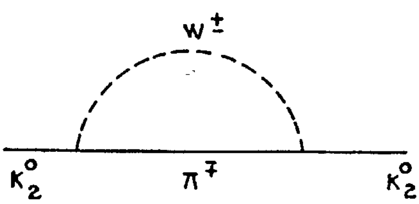

FIG. 2

Therefore we are led to discard the $(K_1^0\pi^+)$ current in the schizon theory. On the other hand the existence of the decay $\Lambda \rightleftarrows p + W^-$ in the schizon theory implies also the existence of the decay $\bar{K}^0 \rightleftarrows \pi^+ + W^-$ but not $K^0 \rightleftarrows \pi^+ + W^-$

(Lee and Yang 1960). Therefore the only allowed interaction is of the form $\sqrt{G}\,.\,(\bar{K}^0\pi^-)W^-$. This interaction also implies the following decays:

$$\begin{aligned}\bar{K}^0 \rightarrow \pi^+ + W^- &\rightarrow \pi^+ + \pi^- + \pi^0\\ &\rightarrow \pi^+ + e^- + \bar{\nu}\\ &\rightarrow \pi^+ + \mu^- + \bar{\nu}'\end{aligned}$$

which are the characteristic decays of the long-lived component of the neutral K meson.

Further decays due to $(K\pi)$ W interaction may be the following:

$$\bar{K}^0 \rightarrow \pi^+ + W^- \rightarrow \pi^+ + \pi^- + \gamma$$

which has a transition amplitude $\sim Gg_\pi e$,

$$\begin{aligned}\bar{K}^0 \rightarrow \pi^+ + W^- &\rightarrow \pi^0 + \pi^+ + e^- + \bar{\nu}\\ &\rightarrow \pi^0 + \pi^+ + \mu^- + \bar{\nu}', \text{ etc.}\end{aligned}$$

It should be noted that $\bar{K}^0$ cannot decay into $\pi^0 + \pi^- + e^+ + \nu$, etc.

The other consequence of the inclusion of these currents is that although

$$\begin{aligned}&\Sigma^- \rightarrow n + W^- \rightarrow n + e^- + \bar{\nu}\,,\\ &\Sigma^+ \not\rightarrow n + e^+ + \nu\,.\end{aligned}$$

It should also be noted that now all decays, in which

$\Delta S = 2$, are strictly forbidden. For example,

$$\Xi^- \rightarrow \bar{K}^0 + \Sigma^- \rightarrow \bar{K}^0 + n + W^- \not\rightarrow n + \pi^-$$

or

$$\Xi^0 \rightarrow \bar{K}^0 + \Lambda \rightarrow \bar{K}^0 + p + W^- \not\rightarrow p + \pi^-.$$

The latter case has been considered to be possible by Sugawara (1959).

3. Concluding Remarks

We have shown in the above sections how one can explain some of the decay schemes of mesons and hyperons by generalizing the universal weak V-A interactions incorporating the various possible divergence-free and non-free boson currents in the framework of intermediate boson (W particles) theory of weak interactions. Important consequence of this consideration is that it clearly demonstrates purely from the $(K_1^0 - K_2^0)$ mass difference argument that one should discard Sugawara's $(K_1^0\pi)$ current. This should be replaced by $K_0\pi^+$ current in the present formalism. Immediately one sees that in the present case the unwanted decay modes of Ξ particles violating strangeness selection rules are completely forbidden which were otherwise allowed by Sugawara's hypothesis. In addition some decay modes of K-mesons and hyperons which are as yet unobserved but allowed by the present formalism have been written down. Secondly various decay modes of W particles due to bosonic currents have been predicted. Some of these modes were already noted by Lee and Yang from the basis of the baryonic currents only.

References

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