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APPARENT CP VIOLATION DUE TO A NEW VECTOR BOSON ⁺)

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Recently, experimental evidence has been found for an apparent decay mode of the K_2^0 into two pions ¹⁾. If this is confirmed, the implication would be that the CP invariance of weak interactions is violated, unless the decay has not occurred in a total vacuum ²⁾. We would like to examine here an alternative explanation to this experiment which is consistent with CP conservation, but implies the existence of a neutral boson of very small mass, which we call s .

We assume that the process observed is the transition ³⁾ $K_2^0 \rightarrow K_1^0 + s$, where s should have the following properties :

- 1) its mass m_s is smaller than Δ , the $K_2^0 - K_1^0$ mass difference ⁴⁾ ;
- 2) it is a vector particle, coupled to the strangeness current only, in a manner which preserves all strong selection rules (including strangeness and isotopic spin conservations) ;
- 3) it has isotopic spin $I_s = 0$ and strangeness $S = 0$.

One can in fact consider the approximate gauge invariance of the s field as the reflection of the approximate conservation of strangeness. The part of its coupling to the $K-\bar{K}$ current can be written

$$\mathcal{L}_{sK} = -j_{(K\bar{K})}^\mu s_\mu \quad (1)$$

where

$$j_{(K\bar{K})}^\mu \simeq -i \frac{g_s}{2} [\bar{K}(\partial^\mu K) - (\partial^\mu \bar{K})K]. \quad (2)$$

The divergence of this current is proportional to Δ . If we start with a particle s of zero bare mass, the non-conservation of strangeness in weak interactions induces automatically a small finite mass m_s which is presumably of the order of Δ .

With the coupling of Eq. (1), we can calculate the rate Γ_s of the reaction $K_2^0 \rightarrow K_1^0 + s$:

$$\Gamma_s = \frac{g_s^2}{4\pi} \left(\frac{k_s}{m_s} \right)^2 k_s, \quad (3)$$

where $k_s \simeq (\Delta^2 - m_s^2)^{\frac{1}{2}}$ is the momentum of the s particle. Calling Γ_2 the normal decay rate of K_2^0 , the experiment ¹⁾ yields

$$\Gamma_s \simeq 2 \cdot 10^{-3} \Gamma_2, \quad (4)$$

which implies $g_s^2/4\pi m_s^2 \simeq 10^{-5} \Delta^{-2}$. Assuming that m_s and Δ are of the same order of magnitude, we can obtain an estimate ⁵⁾ of g_s^2

$$\frac{g_s^2}{4\pi} \simeq 10^{-3} \frac{\Gamma_2}{\Delta} \simeq 10^{-5}. \quad (5)$$

In this case, it is appreciably weaker than electromagnetism, but still quite large compared to weak interactions or gravitation. This is the reason why we assume that s is coupled to strangeness and not to hypercharge in order to avoid strong long range forces in ordinary matter. Of course, there will be forces due to the virtual dissociation of nucleons into strange particles, exactly as the neutron has electromagnetic interactions due to its virtual dissociation into charged particles. However, since ordinary matter has zero total strangeness, the range of the induced forces will be of the order of the "strangeness radius" of nucleons, (i.e., resulting from dissociations such as $N \rightarrow \Sigma (\Lambda) + K$ or $N \rightarrow N + K + \bar{K}$, etc. ...). Similarly, we note that the direct transition $\Sigma^0 \rightarrow \Lambda^0 + s$ is forbidden by isotopic spin conservation.

EXPERIMENTAL IMPLICATIONS

The introduction of the s particle in order to save the CP invariance of weak interactions reminds one of the proposal for the existence of the neutrino, ~~which would conserve angular momentum conservation in β decay~~ (although the urgency may not seem so obvious now as it was then). It should be expected that direct observation of the s particle may be difficult at the present time. It implies, in any case, that no CP violation should be observed in the decay of other strange particles or in β decay. The regeneration of K_1^0 in the $K_2^0 \rightarrow K_1^0 + s$ transition can be distinguished experimentally from the coherent regeneration of K_1^0 in matter by the fact that the pions produced in the first process would not interfere with those produced in the second ⁶⁾. Another point which should be noted is that the apparent CP violation due to the emission of the s particle is not accompanied by an apparent violation of Lorentz invariance. In other words, the branching ratio Γ_s / Γ_2 does not depend on the momentum of the K_2^0 beam ⁷⁾.

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REFERENCES AND FOOTNOTES

- 1) J.H. Christenson, J.W. Cronin, V.L. Fitch and R. Turlay, Phys. Rev. Letters 13, 138 (1964).
- 2) Proposals have been made that the galaxy may give rise to a static potential which is responsible for a small $K_0 - \bar{K}_0$ mass difference.
J.S. Bell and J.K. Perring, Stanford Linear Accelerator Center preprint.
J. Bernstein, N. Cabibbo and T.D. Lee, CERN preprint.
J. Bjorken, private communication.
- 3) Preliminary experimental evidence indicates that $\Delta = m(K_2^0) - m(K_1^0) > 0$:
G. Meisner, R.L. Golden, B.B. Crawford and F.S. Crawford, UCRL 11018 and Proceedings of the International Conference on Fundamental Aspects of Weak Interactions, Brookhaven (1963), p. 67.
- 4) Δ is approximately equal to τ_1^{-1} , where τ_1 is the K_1^0 lifetime.
See, for example, T. Fujii, J.V. Jovanovich, F. Turkot and G.T. Zorn, Phys. Rev. Letters 13, 253 (1964).
- 5) The expansion parameter is either g_s or $g_s \frac{\Delta}{m_s}$, depending on whether weak interactions play a role, real or virtual, in the process or not. In cases where they do not enter, the current coupled to s particles is absolutely conserved, and the theory reduces to quantum electrodynamics. When weak interactions come into play, singularities proportional to m_s^{-1} appear, but they are multiplied by G^2 , where G is the weak interaction constant (Δ is, of course, proportional to G^2).
- 6) This seems the most feasible experiment to determine whether an additional neutral particle is emitted in the 2π decay of the K_2^0 . A similar idea has been suggested independently by Dr. C. Rubbia (private communication) and by J. Bernstein, N. Cabibbo and T.D. Lee, Ref. ²).

- 7) If it is assumed that the vector boson is coupled to hypercharge instead of strangeness, and that there is a $K_2 \rightarrow 2\pi$ transition due to the virtual field produced by our galaxy (see Ref. ²), its mass must be smaller than $\frac{1}{R}$, where R is the galactic radius. In principle, there still exists then the real process $K_2 \rightarrow 2\pi + s$, with a transition rate $\Gamma_{K_2 \rightarrow 2\pi + s} \simeq f^2 R^2 \Delta^3$, where f is the coupling constant to hypercharge. It is remarkable that the numerical estimate of f^2 from the observed rate ²⁾, assuming only virtual transition, (which depends on the galactic mass as well as the radius), implies a comparable rate of real transition, since $f^2 R^2 \simeq g_s^2 / m_s^2$. In this case one would expect the observed effect to have a velocity dependence of the type $a + b\gamma^2$. The contributions of the two terms a and b could also be distinguished by the coherence experiment mentioned above. One of us (M.L.) is indebted to Professor T.D. Lee for an interesting discussion on these points.