Title

THE K| DECAY MODES AND THE QUESTION OF TIME REVERSAL OF WEAK INTERACTIONS

Author

Gatto, R.

Publication Date

1957-01-31

UCRL 3658
c. 2

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

UNIVERSITY OF CALIFORNIA
Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

THE K^0 DECAY MODES AND THE QUESTION OF TIME REVERSAL OF WEAK INTERACTIONS

R. Gatto

January 31, 1957

Printed for the U. S. Atomic Energy Commission

THE K^0 DECAY MODES AND THE QUESTION OF TIME REVERSAL OF WEAK INTERACTIONS*

R. Gatto†

Radiation Laboratory
University of California
Berkeley, California

January 31, 1957

Recent experiments[1] have shown the existence of weak interactions which violate parity (P) and charge conjugation (C) conservation. It is not known so far whether time reversal (T) is also violated in weak interactions. We shall assume that C, P, and T are conserved in strong and electromagnetic interactions and we shall derive some physical consequences -- to be compared with experiment -- of the assumption that weak interactions are invariant under time reversal.

From Lüders-Pauli theorem[2] if T is conserved the product CP (which we shall denote by L) is also conserved, and the reverse also holds. Let us assume that L is conserved in strong, electromagnetic, and alsoin weak iteractions. The operator L must satisfy the equations

$$LL^{+} = 1, \qquad L^{+} = (-)^{N} L \tag{1}$$

$$LP - (-)^{N}PL = 0, \quad LC - (-)^{N}CL = 0 \tag{2}$$

$$[L, Q]_{+} = 0, \quad [L, N]_{+} = 0, \quad [L, S]_{+} = 0 \tag{3}$$

where Q, N, S are the operators for the charge, for the heavy particle number, and for the strangeness respectively. We may expect selection rules due to conservation of L for systems with Q=0, N=0, and S=0. A K^0, and a $\bar{K}^0$, will not be eigenstates of L, but the superpositions

$$K_1^0 = 1/\sqrt{2}\,(K^0 + \bar{K}^0), \quad K_2^0 = 1/\sqrt{2}\,(K^0 - \bar{K}^0) \tag{4}$$

will be eigenstates of L with different eigenvalue. (From Eq. (1) it follows that for systems with N=0 the eigenvalues of L are ±1). From the assumed L conservation K_1^0 and K_2^0 will decay into states with different L and exhibit different lifetimes. Therefore K^0 and $\bar{K}^0$ shall be regarded as mixtures of K_1^0 and K_2^0 with coefficients, obtained from Eq. (4), which are still the same

---

* This work was performed under the auspices of the U.S. Atomic Energy Commission.

† On leave of absence from Istituto di Fisica dell'Università di Roma.

parity of $2\pi^0$

as for the case of absolute C conservation, discussed by Gell-Mann and Pais.[3]

A system of two pions will have L=1. (This can be seen as follows. In the limit $H_{weak} = 0$, C and P are separately conserved, and, for a system of two pions, $L = CP = (-)^l(-)^l = 1$ for every value l of the relative angular momentum. However, if H_{weak} is assumed to conserve L, the conclusion holds at any order in H_{weak}). Therefore only the component with L = 1 of the K^0 (or $\bar{K}^0$) mixture will be able to decay into two pions. It is known experimentally that the short-lived component decays into two pions. Therefore, if L is conserved, the long-lived component cannot decay into two pions. Decay into $e^-\pi^+\gamma$ and $e^+\pi^-\bar{\gamma}$ will not be forbidden for any of the two components on the basis of L conservation alone. The branching ratio for the decay of the long lived component into $e^-\pi^+\gamma$ and into $e^+\pi^-\bar{\gamma}$ must be equal to unity if L conservation holds. (However, e^-/e^+ = does not necessarily mean that T is conserved since it also follows in the case that the mass difference between the long-lived and the short-lived component is negligible.)[4] A $3\pi^0$ system with total angular momentum zero (for simplicity we confine the discussion to the case of spin zero for the K and we assume angular momentum conservation in weak interactions) will have L = -1. Therefore only the long-lived component will be able to decay into $3\pi^0$. For a $\pi^+\pi^-\pi^0$ system we denote by (l, l') the state for which l is the relative $\pi^+\pi^-$ angular momentum and l' the angular momentum of π^0 with respect to the $\pi^+\pi^-$ center of mass. The states of total angular momentum zero are: (0, 0), (2, 2), . . . for which L = -1, and (1, 1), (3, 3). . . for which L = +1. Decay into states of the first group will be forbidden for the short-lived component, decay into states of the second group will be forbidden for the long-lived one. Therefore decay into 3π would be very infrequent for the short-lived component, for which 2π decay is allowed, $3\pi^0$ decay would be forbidden, and $\pi^+\pi^-\pi^0$ decay without centrifugal barrier would also be forbidden. The decay curve for K^0 (or $\bar{K}^0$) would be the sum of two exponentials corresponding to the K_1 and K_2 lifetimes. However an interference term may occur in the decay rate into a $e\pi\gamma$ state with specified charges, in a similar way as discussed by Treiman and Sachs[5] for the case of absolute C conservation. Particular effects which only depend on the existence of the mixture, as those discussed by Pais and Piccioni,[6] will occur in a similar way.

The foregoing conclusions follow from the assumption that L is conserved in weak interactions, which is equivalent to the assumption that weak interactions are invariant under time reversal. We have shown, in particular, that it follows from such assumption that the long-lived component of the K^0 mixture must never decay into two pions, and that its branching ratio for decay into $e^-\pi^+\gamma$ and into $e^+\pi^-\bar{\gamma}$ must be unity.

Can short comp. go into e, π, ν yes – but
what holds it back? phase space?

REFERENCES

1. Wu, Ambler, Hudson, and Heyward, Phys. Rev. (in the press)
   Garwin, Ledermann, and Weinrich, Phys. Rev. (in the press)
2. G. Lüders, Dan Mat. Fys. Medl. 28, N. 5 (1954)
   W. Pauli, in "Niels Bohr and the Development of Physics", London 1955.
3. M. Gell-Mann and A. Pais, Phys. Rev. 97, 1387 (1955).
4. T. D. Lee, R. Oehme and C. N. Yang, Phys. Rev. (in the press)
5. S. B. Treiman and R. G. Sachs, Phys. Rev. 103, 1545 (1956).
6. A. Pais and O. Piccioni, Phys. Rev. 100, 1487 (1955).