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[1] See, e.g., V. L. Ginzburg, Progress in Elementary Particles and Cosmic Ray Physics (North Holland Publishing Company, Amsterdam, 1958), Vol. 4, p. 337.

[2] C. L. Critchfield, E. P. Ney, and S. Oleksa, Phys. Rev. 85, 461 (1952).

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DIRECT Ξ DECAY AND MUONIUM-ANTIMUONIUM TRANSITIONS

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It now seems certain that the mass difference between $K_{(1)}^0$ and $K_{(2)}^0$ is quite small ($|\delta m| < 10^{-5}$ ev with 95% confidence[1]). Okun' and Pontecorvo[2] discuss a connection between δm and the existence of $\Delta S = 2$ weak interactions. They show how such an interaction, if as strong as the $\Delta S = 1$ weak interactions, *might* lead to a mass splitting of the order of electron volts. Indeed, if the $\Delta S = 2$ interaction were absent, a mass difference between the neutral K mesons arises only at second order in the weak interaction and the theoretical estimate, $\delta m^{(2)} \approx 10^{-5}$ ev, agrees with experiment. But suppose L_w (the weak-interaction Lagrangian) includes a $\Delta S = 2$ term (which would permit direct decays of cascade hyperons, i.e., $\Xi^- \to n + \pi^-$, $\Xi^0 \to n + \pi^0$, and $\Xi^0 \to p + \pi^-$). The first order mass splitting, $\delta m^{(1)}$, is equal to twice the matrix element, $M = \langle K^0 | L_w | \bar{K}^0 \rangle$. Noting that $M = \langle \bar{K}^0 | L_w | K^0 \rangle = \langle K^0 | C^{-1} L_w C | \bar{K}^0 \rangle$, where C is the charge-conjugation operator,[3] we find that only the part of the $\Delta S = 2$ coupling which is even under C contributes to $\delta m^{(1)}$. Hence, a $\Delta S = 2$ weak interaction which is odd under C does not lead to a large $K_{(1)}^0$, $K_{(2)}^0$ mass splitting. The small measured value of δm implies nothing about the $\Delta S = 2$, C-odd interaction, but only requires that the $\Delta S = 2$, C-even interaction is no more than 10^{-5} as strong as $\Delta S = 1$ weak interactions.

Assume that a $\Delta S = 2$ interaction odd under C exists with similar strength as ordinary $\Delta S = 1$ weak interactions [the four-Fermion coupling, $G(\bar{\Lambda}\gamma_\lambda n)(\bar{\Lambda}\gamma_\lambda\gamma_5 n) + \text{H.c.}$, is one example[4]]. From CP invariance it follows that any such interaction is also odd under P. Consequently, the effective interaction responsible for direct decay of Ξ into a nucleon and a pion is invariant under space reflection for some assignment of relative Ξ, n parity. The absence of a large δm, although failing to forbid direct Ξ decay, implies that such modes (if they occur at all) cannot display asymmetries (i.e., they "conserve parity"). No direct decays of Ξ have yet been seen. However, existing experimental evidence that direct decay is absent is exceedingly slight.

An identical argument relates the appearance of muonium-antimuonium transitions to the possible existence of interactions permitting $e^- + e^- \to \mu^- + \mu^-$.[5-7] At first sight, looking for spontaneous transitions between muonium and antimuonium seems a more sensitive experiment than the direct search (utilizing, for example, the clashed electron beams soon to be available at Stanford University). But transitions between the 1S states of muonium and antimuonium are generated only by that part of the ($e^- + e^- \to \bar{\mu} + \bar{\mu}$ permitting) interaction which is even under C. To prove this, merely read for $\langle K^0 |$ and $\langle \bar{K}^0 |$ in the first paragraph, the 1S state of muonium and of antimuonium. The interaction $(\bar{\mu}\gamma_\lambda e)(\bar{\mu}\gamma_\lambda\gamma_5 e)$ + H.c., odd under C, could hardly be detected by looking for the muonium-antimuonium transitions it fails to induce. It could be found directly (by charge-exchange scattering of muons on electrons, or by $e^- + e^- \to \mu^- + \mu^-$), or possibly, by searching for nondegenerate transitions between states of muonium and antimuonium in the presence of external electromagnetic fields.

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[1] F. Muller et al., Phys. Rev. Letters 4, 418 (1960).

[2] L. Okun' and B. Pontecorvo, J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 1587 (1957) [translation: Soviet Phys.—JETP 5, 1297 (1957)].

[3] Actually L_w leads to no violation of either C or P invariance to any order. It is invariant under a charge-conjugation (or parity-reversing) operation which includes a factor of i in the behavior of Λ relative to n. In this note, however, C and P are chosen with customary phases (e.g., real K-meson parity) and L_w is odd under either C or P.

[4] This coupling arises in a partially-symmetric model of weak interactions. S. Glashow (to be published).

[5] B. Pontecorvo, J. Exptl. Theoret. Phys. (U.S.S.R.) 33, 549 (1957) [translation: Soviet Phys.—JETP 6, 429 (1957)].

[6] S. Glashow, Nuovo cimento (to be published).

[7] G. Feinberg and S. Weinberg, invited paper at 1960 Winter Meeting of the American Physical Society at Berkeley, California.

ERRATUM

ANGULAR DISTRIBUTION OF LYMAN-α RADIATION EMITTED BY H (2S) ATOMS IN WEAK ELECTRIC FIELDS, William Lichten [Phys. Rev. Letters 6, 12 (1961)].

On page 12, line 7 from the bottom, read "In the present case $J=\frac{1}{2}$, $m=\pm\frac{1}{2}$, ..."