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POSSIBLE FORMAL SYMMETRY BETWEEN MUON AND ELECTRON (*)

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The possibility of a formal symmetry between muon and electron is investigated on the assumption that such particles have identical interactions and that they differ only in rest mass. If weak interactions are excluded, there is a symmetry property of the Lagrangian that is related to μ-e exchange. To this end, one can introduce a unitary operator S such that $S\psi S^{-1} = \sigma_1 \psi$ where ψ is a vector in e-μ space (which we call lepton space, or L space) and σ_1 is a Pauli matrix. It can be seen that if electromagnetic interactions are minimal, the total Lagrangian (excluding weak interactions) can be put in a form exhibiting symmetry under the S transformation (L symmetry). If one tries however to extend the validity of such a symmetry to include also the weak interactions, one finds that there are no symmetric descriptions if electrons and muons are coupled identically in weak interactions and if only one neutrino exists. But it is possible to find symmetric descriptions if there are two neutrinos, one, ν_e coupled to the electron, and one, ν_μ, coupled to the muon.

According to general principles one expects that a selection rule corresponds to the existence of the above formal symmetry. It is easily seen that S can be taken as a Hermitian operator, with eigenvalues ± 1. If L symmetry is satisfied one can divide all states into those with eigenvalue $+1$ and those with eigenvalue -1. States of one type cannot go into states of the other type. This conservation law forbids a muon from transforming into an electron (unless other particles with S quantum numbers, such as ν_e or ν_μ, are emitted or absorbed).

We may call it the " law of muonic number conservation ". The quantum number S is a multiplicative (not an additive) quantum number. One can assign $S = +1$ to μ and ν_μ, $S = -1$ to e and ν_e and then reactions such as $\mu \to e + \gamma$, $\mu \to e + \nu_e + \bar{\nu}_e$, $\mu + p \to e + p$, etc. would be forbidden. However, reactions such as $e^+ + e^+ \to \mu^+ + \mu^+$ would not be forbidden from this conservation law alone (but of course there would be no reason for their existence). The present theory, modified to include two neutrinos, satisfies L symmetry. One may consider this conclusion as a formal argument favoring the two neutrino hypothesis. The selection rules of the present theory are however stronger than those implied by L symmetry. They correspond to the existence of a gauge transformation implying the existence of an " additive " (instead of multiplicative) quantum number, which would forbid for instance the above mentioned reaction ($e^+ + e^+ \to \mu^+ + \mu^+$).

DISCUSSION

FEINBERG : I would like to add one comment with regard to the possibility that Gatto mentioned about having a multiplicative rule forbidding $\mu^+ \to e^+ + \gamma$. Such a rule, if it existed, might allow the process that he mentioned, 2 positrons going to 2 muons. It would also allow charge exchange in muonium, that is, the process $(\mu^+ e^-)$ going to $(\mu^- e^+)$ when the particles are bound together. In that particular case the situation is quite similar to the K^0-$\bar{K}^0$ conversion except that in this case one might think conceivably that it would happen to lowest order in the weak interaction rather than second order. Now if

(*) See also Phys. Rev. Letters **5**, p. 114 (1960).

one could make muonium in vacuum and study its properties, then an estimate was done a number of years ago by Pontecorvo indicating that perhaps one in ten thousand muoniums would make a transition to antimuonium in such a way that it would decay giving a fast electron instead of a fast positron. On the other hand if muonium is formed in a solid, then the energy levels of muonium are no longer equal because of the electric fields that are present. Then the transition rate is much lower and probably this process is completely unobservable. In the case of muonium formed in a gas the situation is somewhat ambiguous. However, estimates done by Weinberg indicate that if the coupling constant is of the order of the weak interaction perhaps the detection of muonium$\leftrightarrow$antimuonium transitions is not completely beyond the limit of what one can do.