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NON CONSERVATION OF PARITY AND THE UNIVERSAL FERMI INTERACTION *

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The recent suggestion of Lee and Yang [1] that parity might not be conserved in weak interactions has lead to experimental work which have not only verified this conjecture both for β-decay [2] and for μ-decay [3] but also brought new information on the Fermi interactions. The fact that the experimental results are in very good agreement with the 2-component neutrino theory [4] has been interpretated as an indication of the valididy of this theory. However the interaction which lead to the correct results for the μ-decay [5] is of the form A + V in the charge exchange ordering $(\bar{u}_+ \nu)(\bar{e}\,\nu)$ in contradistinction to the interaction

$$\alpha S + T + \beta P \qquad (|\alpha| \sim 1 \, ; \beta \sim + 1) \qquad (1)$$

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needed for β-decay [6] (usual ordering: ($\overline{P}$ N)($\overline{e}$ ν)). This might be an indication of the non validity of the Universal Fermi Interaction. Indeed Lee and Yang [7] have proved on very general grounds that the experimental results definitively exclude the U.F.I. if we accept the following postulates:

1. Conservation of the number of light particles.

2. Validity of the two component theory with only one kind of neutrino (and of antineutrino).

The idea of the U.F.I. is however so appealing and simplifying that one should try to keep it even if one or both of these postulates should be discarded. Feynman [3] has indeed pointed out to a possibility of recovering the U.F.I. by the use of Majorana neutrinos and appropriate projection operators

$$P_{\pm} = \frac{1}{2} (1 \pm \gamma_5) \qquad (2)$$

conveniently used so to reproduce the experimental results. In this case both postulates 1 and 2 are violated and unless the operators $P_{\pm}$ are used only for the light particles (Feynman choses to assotiate them to the charged particles) the tensor interaction is killed also for β-decay in disagreement with the experience.

We wish to point out another possibility which is not only more symmetrical but violates only postulate 2. This is done by assumming that there are two kinds of neutrino ν_e and ν_μ of opposite spirality which are assotiated to the electron and μ-mesons in the same way as the neutron is assotiated to the proton. Thus we have the following pairs of "particles" [9]:

$$(P, N) ; (e_{+} , \nu'_{e}) ; (\mu_{+} , \nu'_{\mu}) \qquad (3)$$

$$P_{-} \nu_{e} = \nu_{e} ; \quad P_{+} \nu_{\mu} = \nu_{\mu} \qquad (4)$$

The Universal Interaction should be written as a sum for all pairs of particles of interactions of the type

$$(\bar{\psi}^{r}_{+} O \psi^{r}_{o}) (\bar{\psi}^{s}_{o} O \psi^{s}_{+}) + h. c. \qquad (5)$$

Also we take for the direct $\pi - \mu$ interaction:

$$\pi_{+} \bar{\mu}_{+} \nu'_{e} + h. c. \qquad (6)$$

(and not $\pi_{+} \bar{\mu}_{+} \nu'_{\mu}$) which correspond to the fact that we have $\pi_{+} \bar{\Sigma}_{+} N$ + h. c. for Σ_{+} decay (Σ_{+} and N belonging to different pairs). Interaction (6) is the same as the one used by Lee and Yang and lead to μ_{-} s with spin pointing back in the $\pi - \mu$ -decay.

Now we shall prove that if we take the interaction (5) as

$$S + P - T \qquad (7)$$

(which correspond to S + P + T in the β-decay ordering, being thus compatible with (1)) the same energy spectrum and angular distribution for μ-decay as with the Yang Lee interaction results from the interaction:

$$(\bar{\nu}_{\mu} \mu_{-}) (\bar{e} \nu_{e}) + h. c. \qquad (S + P - T) \qquad (8)$$

This equivalence can be easily shown if we use the ordering $(\bar{\nu}'_e \mu_-)(\bar{e} \nu'_\mu)$ for which (8) take the form

$$(\bar{\nu}'_e \mu_-)(\bar{e} \nu'_\mu) \quad \text{(scalar)} \qquad (9)$$

while the Yang-Lee interaction becomes

$$(\bar{\nu}'_e \mu_-)(\bar{e} \nu'_e) \quad \text{(scalar)} \qquad (10)$$

It is clear from the comparison of (9) and (10) that if the polarization of the electron is not measured no difference can be detected for the spectrum. Indeed the ρ factor, angular and energy distribution will be the same [10] for (9) and (10) except that the electron will come out in (9) polarized oppositely to its velocity instead of in the same direction as in (10). Measurement of the polarization of the electron in μ-decay should decide between the two theories.

It should be mentioned that the U.F.I. (5), (7) has the special feature of being symmetrical in the exchange both of "particles" and of "antiparticles", on which grounds it has been proposed before [11].

Direct application of the U.F.I. (5), (7) to decay and μ-capture are inpaired by the fact that they correspond to bare particles. For interactions with actual nucleons such as in β-decay and μ-capture emission and reabsorption of virtual π mesons result in different renormalizations of the S, T and P coupling constants which become different [12]. The difference between S and T couplings has been indeed observed in β-decay [13], and is in good agreement with the assumption of equal S, T couplings for bare nucleon interactions **. However as it is not well known how large are these differences we shall quote a few results of our Universal Interaction which should be approximately valid if the renormalized couplings are not much different from the unrenormalized ones:

1. The λ factor proposed by Michel [15] is equal to 1.33 in reasonable agreement with the experimental value 1.16 $\pm$ 0.12 [16].

2. For β-decay interaction which is here

$$(\bar{P}\ N)\ (\bar{e}\ \nu_e) + h.\ c. \qquad (S + P + T) \tag{11}$$

we obtain no angular (P,e) correlation.

3. The μ-capture interaction which is here

$$(\bar{P}\ N)\ (\bar{\mu}_-\ \nu_\mu) + h.\ c. \qquad (S + P + T) \tag{12}$$

leads to the fact that neutrons from μ-capture in Hydrogen will come out polarised in the direction of the polarization of μ_-;

4. Interaction (12) leads also to the angular correlation of the neutrons in μ-capture in Hydrogen:

$$1 + \vec{n} \cdot \vec{p}_N / E_N \tag{13}$$

where $\vec{n}$ is the polarisation vector for μ_-, $\vec{p}_N$ and E_N being the momentum and energy of the neutron.

Conclusions 2-4 are easily verified if the interactions are written in the ordering:

$$(\bar{N}\ P_-\ \mu_-)(\bar{\nu}_\mu\ P) \qquad \text{(scalar)} \tag{14}$$

$$(\bar{N}\ P_+\ e)(\bar{\nu}_e\ P) \qquad \text{(scalar)} \tag{15}$$

Finally it seems worthwhile to mention that in contradistinction to the Yang-Lee theory which can lead to the decay

$$\mu \longrightarrow e + \gamma \tag{16}$$

the present theory gives vanishing probability for this process.

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5. T.D. Lee (private communication).

6. H.M. Mahmoud and E.J. Konopinski, Phys. Rev. 88, 1266, 1952 (and references therein quoted).

7. T.D. Lee, communication to the Seventh International Conference on High Energy Nuclear Physics, Rochester, April 1957.

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9. In (3), (4) we use primes for neutrino "particles" to conform with the usual notation of β-decay. For the present purpose it is not necessary to include the hyperon pairs.

10. After this work was acomplished we received a pre-print of a paper by T. Kinoshita and A. Sirlin in which a class of interactions is show to give the same result as in Yang-Lee theory for μ-decay. Our interaction (8) seems to be the only one of this class suitable for the Universal interaction. These results have been also obtained by E.M. Ferreira (to be published in An. Acad. Bras. Ci.).

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