three π mesons. Such transitions are strictly forbidden because of a generalized Furry theorem, if we neglect electromagnetic interactions and assume as is customary that H_S is invariant with respect to C and to rotation in isotopic spin space.[4] This forbiddenness breaks down in the presence of electromagnetic interactions, but the effect on the branching ratios would be extremely small. From these arguments, however, it could not be concluded that the distribution of the three-π mode into τ and τ' would be the same for K^+ and K^-. Finally, equal spectra of the τ^+ and τ^- decay could not be predicted from TCP alone since H_S certainly will lead to a scattering of three π mesons.

The authors are indebted to Dr. Lee, Dr. Oehme, and Dr. Yang for having made available their papers[3] prior to publication, and to Dr. L. S. Rodberg for an interesting communication. One of us (G.L.) wishes to thank the U. S. Department of State for a Fulbright and Smith-Mundt grant and the Massachusetts Institute of Technology for its hospitality.

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[1] Wu, Ambler, Hayward, Hoppes, and Hudson, Phys. Rev. **105**, 1413 (1957); Garwin, Lederman, and Weinrich, Phys. Rev. **105**, 1415 (1957); J. I. Friedman and V. L. Telegdi, Phys. Rev. **105**, 1681 (1957). These experiments were reported as post-deadline papers at the New York Meeting of the American Physical Society, January, 1957.

[2] J. Schwinger, Phys. Rev. **82**, 914 (1951), and **91**, 713 (1953); G. Lüders, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **28**, No. 5 (1954); W. Pauli, in *Niels Bohr and the Development of Physics*, edited by W. Pauli (McGraw-Hill Book Company, Inc., New York, 1955). One of us (G.L.) wants to emphasize here again the importance of the role the other (B.Z.) played during all stages of the work that led to the theorem, both through personal discussions and through correspondence. In particular, the original formulation of the theorem, for parity-conserving interactions, was suggested by B.Z. in early 1953.

[3] Lee, Oehme, and Yang, Phys. Rev. **106**, 340 (1957); T. D. Lee and C. N. Yang, Phys. Rev. **105**, 1671 (1957).

[4] See, e.g., A. Pais and R. Jost, Phys. Rev. **87**, 871 (1952).

Parity and the Polarization of Electrons from Co[60]†

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LEE and Yang[1] recently proposed that parity may not be conserved in weak interactions and suggested various experiments to verify their hypothesis. Two of the experiments have since been performed with positive result—the asymmetry of the electron emission from aligned nuclei[2] and the polarization of muons.[3,4] In a second paper,[5] Lee and Yang discuss a two-component theory of the neutrino and consider some more experimental tests. Among these, they list the measurement of momentum and polarization of electrons emitted in beta decay. If parity is not conserved, the electrons should be longitudinally polarized. For tensor and scalar interaction, the degree of polarization is simply equal to (v/c).[6,7] We have found this polarization in the case of Co^{60}.

The observation of the expected longitudinal polarization of the electrons is difficult. However, by means of an electrostatic deflector, the longitudinal polarization can be transformed into a transverse one.[8] The transverse polarization can be measured by scattering the electrons with a thin foil of a high-Z material (Mott scattering). Because of the spin-orbit interaction, the elastically scattered electrons show a strong left-right asymmetry, especially at scattering angles between 90° and 150°.[9] From this measurable asymmetry, the initial longitudinal polarization can be calculated.

The experimental arrangement is housed in a cylindrical vacuum chamber of 30-cm diameter. The electrons from a Co^{60} source are deflected in a cylindrical electrostatic field (radius of curvature 6 cm) by about 108° and then impinge on the scattering foil. The left-right asymmetry of electrons scattered into the angular interval 95° to 140° is measured with two end-window Geiger counters (3.5 mg/cm^2 mica windows). Two electroplated Co^{60} sources are used, one of about 1 mC strength on aluminum (1.7 mg/cm^2), the other of 6 mC strength on a silver-covered rubber hydrochloride film (0.6 mg/cm^2). The electrostatic deflector is designed so that electrons of about 100-kev energy completely change their polarization from longitudinal to transverse. The scattering foils (0.05 mg/cm^2 gold, 0.15 mg/cm^2 gold, 1.7 mg/cm^2 aluminum, all backed by 0.9 mg/cm^2 Mylar) can be interchanged from the outside.

For an ideal arrangement, the left-right asymmetry in the counters would be $L/R=[1+Pa(\theta)]/[1-Pa(\theta)]$.[10] P is the initial longitudinal polarization of the electrons and $a(\theta)$ the polarization asymmetry factor after scattering by an angle θ in the analyzer foil. In the actual experiment, however, the determination of P from L/R involves corrections for (1) the asymmetry of the two counters, (2) the finite extension of scatterer and counters, and (3) incomplete transformation from longitudinal to transverse polarization. The first correction was performed experimentally by using the nearly isotropic scattering from aluminum foils; the second and third corrections were calculated in a first approximation. A correction for depolarization in the source and the analyzer was neglected completely.

The results of some runs are given in Table I. Even though these data are only very preliminary, some conclusions can be drawn.

TABLE I. The polarization of electrons from Co^{60}.

Electron energy kev	$\beta=v/c$	Gold scattering foil mg/cm^2	Left-right asymmetry L/R	Longitudinal polarization P
50	0.41	0.15	1.03±0.03	−0.04
68	0.47	0.15	1.13±0.02	−0.16
77	0.49	0.05	1.35±0.06	−0.40
77	0.49	0.15	1.30±0.09	−0.35

1. The violation of parity conservation is obvious. Every run (about five in addition to the ones shown in Table I) shows a definite left-right asymmetry.

2. The negative sign of the polarization P indicates that the beta particles are polarized in the direction opposite to their momentum. This conclusion agrees with the experiment of Wu *et al.*[2]

3. The values of P are not in disagreement with the two-component theory, which gives $P=-v/c$. The deviations, especially at lower energies, can easily be due to depolarization in the source and in the analyzer. More accurate measurements and further investigation of the corrections are required for a detailed comparison between theory and experiment.

We are very much indebted to Dr. J. Weneser for many illuminating discussions.

† Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

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[6] L. Landau (to be published).
[7] Jackson, Treiman, and Wyld (to be published).
[8] H. A. Tolhoek, Revs. Modern Phys. **28**, 277 (1956).
[9] N. Sherman, Phys. Rev. **103**, 1601 (1956).
[10] We use $P=(I_+-I_-)/(I_++I_-)$, where I_+ is the intensity of electrons polarized along their initial momenta and I_- is the intensity of electrons polarized in the opposite direction. We define "left" by $\mathbf{p}_3\cdot(\mathbf{p}_1\times\mathbf{p}_2)>0$, where $\mathbf{p}_1$, $\mathbf{p}_2$, and $\mathbf{p}_3$ are, respectively, the electron momenta immediately after emission from the source, before scattering from the analyzer, and after scattering from the analyzer.

μ-Meson Decay and the Two-Component Neutrino*

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It has been suggested[1] that nature takes advantage of the fact that the neutrino has mass zero and, therefore, describes it by a two-component wave function. This results in a violation of both parity conservation and charge-conjugation invariance, which is in agreement with recent experiments.[2]

The above authors then propose that the μ-meson decay takes place via the emission of an electron, a neutrino, and an antineutrino. This gives a Michel parameter of $\rho=\frac{3}{4}$. In addition, if one calculates the integrated asymmetry for all electrons from 0 to 10 Mev, the result is

$$B/F\equiv\text{back/front}=0.77,$$

where "back" means the number of electrons with energy between 0 and 10 Mev and making an angle between 90° and 180° with respect to the direction of the μ-meson spin. Similarly, "front" means electrons coming off at an angle between 0° and 90° with respect to the μ-meson spin. The above number is calculated assuming a maximum asymmetry.

The purpose of this note is to propose that, in addition to the above decay mode, the μ meson be allowed to decay simultaneously into an electron plus two neutrinos or two antineutrinos. The second two sets of interactions can be added if one will give up the conservation of light fermions in interactions involving two or more neutrinos.

The advantages of the above addition are twofold: (a) One can better fit the experimentally observed value for the Michel parameter which appears to be $0.60<\rho<0.67$. (b) Pless *et al.*[3] have carried out a preliminary investigation of the 0 to 10-Mev integrated asymmetry and find the back/front ratio $B/F=0.97\pm0.16$. If we assume that the number 0.97 will not vary much with improved statistics, one may obtain a better fit to this anticipated result.

Previously, the following interaction term has been considered,[1]

$$H'=\sum f_{V,A}\langle\bar{\psi}_e O_{V,A}\psi_\mu\rangle\langle\bar{\psi}_\nu O_{V,A}\psi_\nu\rangle+\text{c.c.},\tag{1}$$

where $O_{V,A}$ is γ_μ or $\gamma_5\gamma_\mu$ and ψ_ν is the two-component neutrino field, $\bar{\psi}_\nu=\psi_\nu^+\beta$, where ψ_ν^+ is the Hermitian conjugate of ψ_ν. The proposed additional terms would be[4]

$$H''=\sum_i g_i\langle\bar{\psi}_e O_i\psi_\mu\rangle\langle\bar{\psi}_\nu O_i\phi_\nu\rangle+\sum_i h_i\langle\bar{\psi}_e O_i\psi_\mu\rangle\langle\bar{\phi}_\nu O_i\psi_\nu\rangle+\text{c.c.}\tag{2}$$

In the above, $\phi_\nu=C(\bar{\psi}_\nu)^T$, where ψ_ν is still the two-component neutrino field, C is a Dirac operator so defined that $C^{-1}\gamma_\mu C=-\gamma_\mu^T$. The T refers to the transpose of the spinor indices only. Note that ϕ_ν is *not* the charge-conjugate wave function to ψ_ν. Nevertheless, the above interaction is invariant under proper Lorentz transformations and can be made invariant under time reversal by choosing all the coupling constants to be real. The second set of terms (involving h_i) will yield the same results as the first (involving g_i) and their inclusion will add nothing new to the following discussion. We shall, therefore, drop them.

One easily verifies that, for a two-component neutrino, O_i may be only 1 or γ_5. [The tensor vanishes because the components of ψ_ν anticommute with each other and $((C^{-1})^T\sigma_{\mu\nu})^T=(C^{-1})^T\sigma_{\mu\nu}$.]

Interactions (1) and (2) do not have any interference terms. Hence, the total number of electrons emitted per unit energy and solid angle is

$$dN=|A|dN_1+|B|dN_2,\tag{3}$$

where dN_1 is the number of electrons emitted with a neutrino and antineutrino, while dN_2 is the number emitted with two neutrinos. The normalization requires that,

$$|A|+|B|=1.\tag{4}$$