is replaced by a reduced probability ("valley" rate) at the line center. The line width is limited by the breadth of the Fourier spectrum of the applied rf pulse, and the accuracy in measuring the magnetic moment, therefore, is ultimately limited for a given frequency by the finite lifetime of the muon (2.22 μsec).

To derive the magnetic moment, the magnetic field at the line center is measured by proton magnetic resonance absorption, errors due to hysteresis and influence on trajectories having been experimentally demonstrated to be negligible. The shape and central frequency of the rf spectrum are measured on a precision wave meter. The proton resonance oscillator and the wave meter are calibrated with the same crystal-checked frequency meter.

TABLE I. Muon g values under various conditions.[a]

Target material	Frequency Mc/sec	g value
CH_2	7.5	$+2.01\pm0.01$
$CHBr_3$	7.5	$+2.00\pm0.01$
Cu-(dust)	16	$+2.02\pm0.01$
Pb (in plastic)	16	$+2.00\pm0.01$
$CHBr_3$	16 (3 runs)	$+2.0064\pm0.0048$

[a] Errors are standard deviations which include uncertainty as to the location of line center and the distribution of stopping mesons over the volume of the sample.

The target material had to satisfy the following conditions: long magnetic relaxation time for the μ mesons, small average internal magnetic fields, high stopping power, sufficiently low conductivity to allow the magnetic field to penetrate and to provide sufficiently small damping to allow a 1.5-μsec ringing time. Bromoform ($CHBr_3$), a liquid of density 2.89 g/cm^3, gave the largest line depth in this apparatus and was used most frequently. In the Bromoform run of Fig. 2, the central rf frequency was $f_\mu = 16.164\pm0.005$ Mc/sec, and a conventional procedure for determining the line center yields a field value at resonance corresponding to the proton resonance frequency $f_p = 5.069\pm0.012$ Mc/sec. The uncertainty here arises from the estimation of the line center and from the field inhomogeneity over the sample.

We have observed the resonance at several frequencies and in polyethylene, powdered copper, and leaded plastic. Table I summarizes the data. The combined best value for the 16-Mc/sec $CHBr_3$ runs is given in (3) above. The correction for the diamagnetism of the liquid in the target cell is negligible compared to the line width which we have thus far achieved, while the Bloch-Siegert effect in the initial rf field of 50 gauss is approximately 0.01%. It is interesting to note that a lower limit to the muon mass exists from mesonic x-ray studies[7] which would give from (2)

$$g_{\mu+} \geqslant 2.0044\pm0.0048.$$

We are continuing these experiments with a new rf system designed to reach 140 Mc/sec at a dc field of approximately 10 000 gauss. This will give a full line width of approximately 0.2%, thereby allowing the considerable improvement in precision which is necessary in order to observe the anomalous contribution in (1).

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Polarization of Electrons in Muon Decay and the Two-Component Theory of the Neutrino*

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RECENTLY, Lee and Yang, Salam, and Landau have proposed independently a two-component theory of the neutrino.[1] The significance of this theory for muon decay has been studied on the basis of the general four-component theory.[2] The effect of the radiative correction has also been discussed.[2] In this note, we want to point out that the longitudinal polarization of an electron emitted from a muon at rest gives further information about the nature of the muon decay interaction in the two-component theory.

The muon decay is described in the two-component theory by a Hamiltonian

$$g_V(\bar{\psi}_\mu\gamma_\rho\psi_e)(\bar{\psi}_\nu\gamma_\rho\psi_\nu)+g_A(\bar{\psi}_\mu(-i\gamma_\rho\gamma_5)\psi_e)\times(\bar{\psi}_\nu(-i\gamma_\rho\gamma_5)\psi_\nu)+\text{H.c.}, \quad (1)$$

where ψ_ν satisfies

$$\gamma_5\psi_\nu = -\psi_\nu, \quad (2)$$

and H.c. is the Hermitian conjugate. Because of (2), the interaction can be expressed in the form

$$(\bar{\psi}_\mu\gamma_\rho[g_V+g_A\gamma_5]\psi_e)(\bar{\psi}_\nu\gamma_\rho\psi_\nu)+\text{H.c.}, \quad (3)$$

where $g_V+g_A\gamma_5$ may be written as

$$(g_V-g_A)\frac{1-\gamma_5}{2}+(g_V+g_A)\frac{1+\gamma_5}{2}. \quad (4)$$

Let us note that, in the case where the electron mass is negligible compared with its momentum, the operator

$\frac{1}{2}(1-\gamma_5)$ [or $\frac{1}{2}(1+\gamma_5)$] projects the electron wave function into the state in which the spin is parallel (or antiparallel) to the direction of motion. The probability of finding an electron in these states is determined by $|g_V-g_A|^2$ and $|g_V+g_A|^2$. Thus the electron will be partially polarized in general.

With the interaction (1), the spectrum of a decay electron with its spin parallel to the direction of motion is given by

$$dN_p \sim |g_V-g_A|^2[3-2x-(1-2x)\cos\theta]x^2dxd\Omega. \quad (5)$$

Here the muon is assumed to be at rest with its spin completely polarized. When the electron spin is antiparallel to its momentum, we obtain

$$dN_a \sim |g_V+g_A|^2[3-2x+(1-2x)\cos\theta]x^2dxd\Omega. \quad (6)$$

If one adds (5) and (6), one finds of course the well-known formula

$$dN \sim [3-2x+\xi(1-2x)\cos\theta]x^2dxd\Omega, \quad (7)$$

with

$$\xi=(g_V^*g_A+g_A^*g_V)/(|g_V|^2+|g_A|^2), \quad (8)$$

for the spectrum regardless of the spin direction of the electron.

When the muon is partially polarized, one obtains

$$dN_p^r \sim |g_V-g_A|^2[3-2x-r(1-2x)\cos\theta]x^2dxd\Omega, \quad (9)$$

and

$$dN_a^r \sim |g_V+g_A|^2[3-2x+r(1-2x)\cos\theta]x^2dxd\Omega, \quad (10)$$

instead of (5) and (6), where r is the degree of polarization of the muon at the moment of decay. One can therefore determine the muon polarization r by observing the angular dependence of longitudinally polarized electrons without requiring a knowledge of ξ.

Of particular interest is the case where either

$$g_V=-g_A, \quad (\xi=-1), \quad (11)$$

or

$$g_V=g_A, \quad (\xi=1), \quad (12)$$

holds. If the condition (11) is satisfied, Eqs. (6) and (10) vanish and thus the electron is fully polarized in the direction along its momentum. If (12) is satisfied, the electron is completely polarized in the opposite direction. It is remarkable that the polarization is complete in these cases for any energy and angle of the electron. It does not even matter whether the muon spin is polarized or not.

For $r=0$ and any ξ,

$$\frac{dN_p^0}{dN_a^0}=\frac{|g_V-g_A|^2}{|g_V+g_A|^2}=\frac{1-\xi}{1+\xi}. \quad (13)$$

Thus, for an unpolarized muon, the degree of longitudinal polarization of a decay electron is independent of energy and determines the asymmetry parameter ξ.

It should be noted that our argument is valid only insofar as the electron mass is negligible compared with its momentum.

The measurement of the electron polarization in muon decay may not be easy, but is certainly not impossible.[3] If one assumes the conservation of leptons, our formulas are valid for μ^- decay. Formulas for μ^+ decay are obtained by the substitution $g_V \to -g_V^*$, $g_A \to g_A^*$. θ is always the angle between the muon spin and the electron (or positron) momentum. The available experimental data[4] indicate that, when one averages over the angle θ, at least 88% of the positrons are polarized along the direction antiparallel to that of their motion.

Detailed calculations of the electron polarization using general parity-nonconserving interactions are being carried out. We would like to thank Mr. J. Sakurai for interesting discussions.

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