function, where ϵ is the π^- kinetic energy divided by 50 Mev. Since we only have knowledge of the shapes of f_0 and f_1 in the region of small ϵ, they must be given the same normalization in this region if the test is to be a comparison of one shape against another:

$$\int_0^{0.2} f_0 \rho d\epsilon = \int_0^{0.2} f_1 \rho d\epsilon,$$

where $\rho(\epsilon)$ is the phase space. For $f_0=1$, $f_1=8.42\epsilon$. The relative probability of spin 1 to spin zero is then

$$\frac{P_1}{P_0}=\prod_{i=1}^{92}\frac{f_1(\epsilon_i)}{f_0(\epsilon_i)}=10^{-4.0}. \tag{1}$$

It should be emphasized that this factor of $10^{4.0}$ against spin 1 is an underestimate of the odds against spin 1 (or any odd spin). This is because above 10 Mev the shape f_1 is normally expected to depart appreciably from the data (the data are close to isotropic in ϵ). The most generous one can be toward spin 1 is to assume that f_1 is a perfect fit to the data above 10 Mev and that it goes as p^2 from 0 to 10 Mev. This is exactly what was done in Eq. (1). A momentum dependence faster than $n=2$ would give an even worse fit. The above procedure was repeated using only the data below 5 Mev (31 events). This should be a weaker test because now f_1 is permitted to be a good fit all the way down to 5 Mev. In this case the normalizations are $f_0=1$ and $f_1=16.7\epsilon$ which gave odds of 24 to 1 against f_1.

The effect of Coulomb enhancement should not appreciably alter the p^2 dependence of spin 1. As has been pointed out,[11,12] the entire low-energy region of the spectrum might be boosted up as much as 10%. In fact one might expect the enhancement factor to increase with p in this energy region.[13] Such a Coulomb-corrected f_1 would give a worse fit than the f_1 used in Eq. (1). When the energy region 0 to 10 Mev is considered by itself, the relativistic corrections are negligible and have not been made. Over this region the nonrelativistic phase space is proportional to the relativistic phase space to within 1%. The result given by Eq. (1) still holds if one employs an arbitrary mixture of both parity states. Such mixing would make odd spin an even worse fit. Corrections for detection bias would also increase the odds against spin 1.

The conclusion is that it is extremely unlikely that the τ meson has spin 1 or any odd value. Spins 0 and 2 are both quite consistent with the data and there seems to be no way to distinguish them by means of a Dalitz-type analysis alone.[2] If there is only one K meson, it most probably has either spin 0 or 2. The continued absence of the mode $K^+\rightarrow\pi^++\gamma$ is evidence against spin 2.[14]

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Energy Dependence of the Asymmetry in the Beta Decay of Polarized Muons*

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In an earlier report, we described experiments which established the existence of polarized muons in momentum-selected cyclotron pion beams.[1] These experiments also established the angular distribution of positrons arising from polarized muon decay to be of the form

$$f(\theta)=1+a\cos\theta, \tag{1}$$

and gave preliminary evidence for the behavior of the asymmetry parameter, a, as a function of positron energy. We present here additional results on the energy dependence as deduced from measurements of the asymmetry (peak to valley) as a function of positron range in carbon. Comparison is made with the predictions of the two-component neutrino theory.[2] Larsen, Lubkin, and Tausner[3] have employed these results to determine the additional parameters of a four-component neutrino theory.[4]

The experimental arrangement is identical with that described in reference 1 except that, for points of very large carbon thickness, three counters were used in the electron detection telescope in order to reduce background and to decrease the importance of higher order radiative effects. To minimize systematic errors, the current in the precession coil was alternated regularly between +170 ma and −170 ma to give peak-to-valley ratios of the resulting positron counting rate. That is,

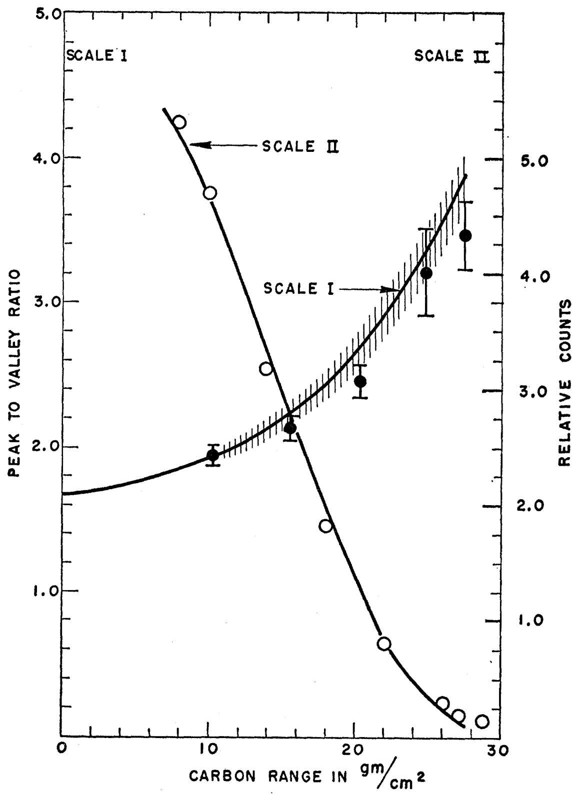

FIG. 1. Scale I: Variation of peak-to-valley (P/V) counting rate ratio with range of carbon traversed by muon decay positrons. We plot $P/V=(1.90r-0.10)/(1.90-0.10R)$ from (4), where r is the observed ratio. The solid curve isthe resolution-folded two-component neutrino theory prediction. The cross-hatching indicates the uncertainty introduced by the resolution curves. Scale II: The range of positrons from unpolarized muon decay. The solid curve is the resolution-folded Michel curve for $\rho=0.75$.

these currents are designed to produce a mean muon precession of $\pm 90°$ from the initial longitudinally polarized state and so have the muon spins pointing alternately toward and away from the electron detection telescope. Thus from (1) we determine

$$P/V=(1+a)/(1-a). \tag{2}$$

The oberved P/V ratios must be corrected for the angular extension of the counters and for the finite interval of counting time (gate width) during which muons continue to precess. The gate-width correction (which includes the muon lifetime) is by far the most important effect and is obtained by evaluating the integral:

$$\left.\begin{matrix}P'\\V'\end{matrix}\right\}=\int_{t_1}^{t_2} e^{-t/\tau}\{1+a\cos[\theta_0-\gamma(\pm H)t]\}dt, \tag{3}$$

where t_1 is the delay (0.77 μsec) introduced electronically between the coincidence count signalling the stopping of a muon in the target and the start of the gate which activates the electron detector. The duration of the gate is t_2-t_1; the muon mean life is τ (22.2 μsec). In (3), γ is the muon gyromagnetic ratio and H the applied magnetic field. The result, from (3), is

$$\left.\begin{matrix}P'\\V'\end{matrix}\right\}=1\pm a', \tag{4}$$

where $a'=0.90a$. In (4) we have also made the small additional correction for angular aperture. The corrected results are plotted in Fig. 1. Here we also plot the range curve of positrons from unpolarized muons obtained by allowing the pion beam to stop in the target. The horizontal scale is measured from the mid-point of the one-inch thick carbon target.

An extrapolation of the data to zero thickness gives for the full integrated spectrum:

$$a=-0.26\pm 0.02 \tag{5}$$

for the Nevis "85-Mev" muon beam[1] stopping in carbon.

We have attempted to compare the data with the predictions of the two-component neutrino theory.[2] This theory predicts, for the decay $\mu^+\to e^+ +\nu+\bar{\nu}$, an energy dependence of the form

$$f(\theta,x)=2x^2[(3-2x)+(1-2x)a_0\cos\theta], \tag{6}$$

where x is positron energy measured in units of the spectrum end point (52.9 Mev). We have set $a_0=\xi B$, where ξ is, in the Lee-Yang notation, the relative amplitude for decay through the two opposite parity states and B is the unknown fractional polarization of the muon beam at decay. To compare with experiment, a_0 is adjusted to the experimental result at 10.4 g/cm². Then, the prediction of the two-component theory appears as

$$\left.\begin{matrix}P\\V\end{matrix}\right\}=1\pm a_0\frac{\int_0^1 K(R,x)x^2(1-2x)dx}{\int_0^1 K(R,x)x^2(3-2x)dx}, \tag{7}$$

where R is the thickness of carbon used (the abscissa in Fig. 1) and $K(R,x)$ is a resolution function which represents the detection efficiency of our counter telescope for positrons of energy x, when a traversal of R g/cm² of carbon is required. These functions were provided by Garwin and Oxley[5] by using a duplicate of our geometry and monochromatic positrons from the Chicago betatron. A test of the sensitivity of the results to the exact form of the resolution functions was made by using Monte Carlo calculations.[6] The largest uncertainties occur at very large values of R where the sensitivity to possible nonuniform muon distribution in the target is greatest. As a test of the accuracy of the resolution unfolding, the unpolarized spectrum was compared with a Michel $\rho=0.75$ spectrum[7] (the solid curve in Fig. 1, Scale II). The good fit also served as a check on the horizontal scale. The peak-to-valley

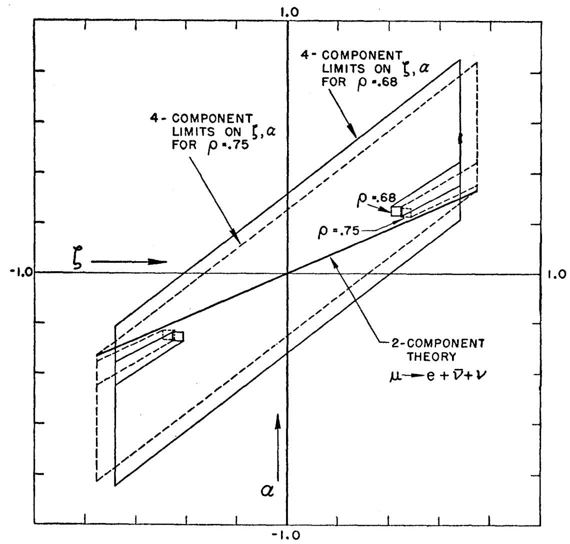

FIG. 2. Comparison of experimental values of α, ζ, with theoretical limits, from Larsen, Lubkin, and Tausner.[3] The direct empirical parameters α', ζ' for $\rho=0.68$, $\rho=0.75$ are represented by the little rectangles. The actual parameters α, ζ are larger in absolute value because of depolarization effects. The first quadrant applies if the μ's are polarized in the direction back to the parent π, the third quadrant if they are polarized opposite to this direction.

ratios of (7) are compared as a solid line with experiment in Fig. 1. The contribution of the distribution function uncertainty is indicated by the cross-hatching on the two-component curve. We judge the results to be a rather successful prediction of the two-component theory. Radiative corrections[8] amount to of the order of 1% in this method of analyzing the data. A more quantitative test of the two-component theory may be made by evaluating the additional parameters of the four-component theory. Larsen, Lubkin, and Tausner[3] find, instead of (6), the distribution

$$f(\theta,x)=Ax^2\{(1-x)+(2/9)\rho(4x-3)+[\alpha(1-x)+(2/9)\zeta(4x-3)]\cos\theta\}, \quad (8)$$

where α and ζ are the new parameters. The comparison with experiment is made in Fig. 2 which was prepared by these authors. Here too, resolution effects may account for the small deviation from two-component theory.

The data permit a determination of $a_0=\xi B$. Integration of (6) from $x=0$ to $x=1$ gives $f(\theta)=1-\frac{1}{3}a_0\cos\theta$. We find from (5)

$$\xi B=0.79\pm0.06. \quad (9)$$

In the two-component theory $|\xi|\leq 1$ and hence $B\gtrsim 0.80$. This is consistent with the two-component prediction that, in the decay $\pi\rightarrow\mu+\nu$, the muons are formed in a state of complete polarization. Independent of the two-component theory, the observation of $P/V>3$ (Fig. 1) and the restriction $|a|<1$ in (1) leads to $B\gtrsim 0.50$.

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Determination of the Sign of the He^3 Nuclear Magnetic Moment*

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WE have made a direct comparison between the signs of the proton and the He^3 nuclear magnetic moments. The result is that the proton and He^3 have nuclear magnetic moments of opposite sign. Since the sign of the proton moment is known to be positive,[1] the He^3 moment is therefore negative as predicted[2] from the odd neutron configuration and previously inferred from optical hyperfine spectra data.[3]

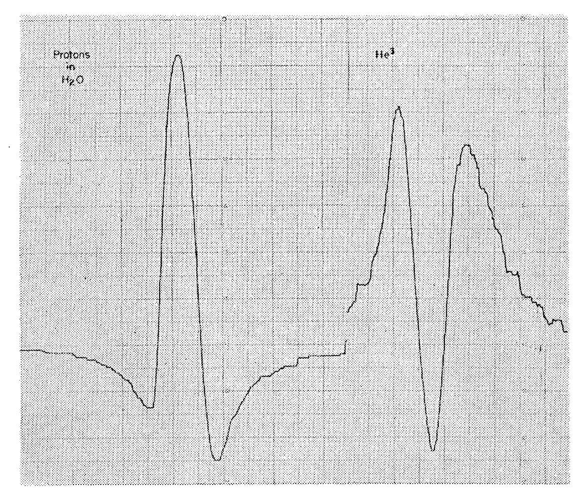

FIG. 1. Nuclear induction dispersion derivative signals of H^1 and He^3.