unlikely from these results that there exists any
S or V contribution as great as 10%: this result
is of course to be expected from the fact that
change in total isotopic spin is forbidden in Fermi
interactions. Examination of Fig. 2 shows that
the spin and parity of Li^8 cannot be 1^+ or 3^+,
except in the unlikely contingency that A and T
interactions contribute equally. We conclude that
Li^8 has spin and parity 2^+, and that the beta-de-
cay interaction is at least 90% Gamow-Teller.
These conclusions are essential to the elucida-
tion of the nature of the Li^8 beta-decay inter-
action as indicated by Barnes et al.[4]

[1] Christy, Cohen, Fowler, Lauritsen, and Lauritsen,
Phys. Rev. 72, 698 (1947).
[2] Lauterjung, Schimmer, and Maier-Leibnitz, Z.
Physik 150, 657 (1958).
[3] R. P. Feynman and B. Stech (private communication)·
M. Morita, Phys. Rev. Lett. 1, 112 (1958).
[4] Barnes, Fowler, Greenstein, Lauritsen, and Nord-
berg, following Letter [Phys. Rev. Lett. 1, 328(1958)] .

NATURE OF THE Li^8 BETA-DECAY INTERACTION *

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It has been established in the preceding Letter[1]
that the spin and parity of Li^8 are 2^+, and that
the beta decay to the 2^+ excited state of Be^8 pro-
ceeds at least 90% of the time by a Gamow-Teller
transition. With the spin sequence 2^+-2^+-0^+, a
measurement of the recoil momentum from the
electron and antineutrino, perpendicular to the
direction of the alpha break up, distinguishes
vector (V) and scalar (S) interactions from each
other and from axial vector (A) and tensor (T)
interactions, but does not allow a distinction be-
tween A and T.

The distinction between A and T can be made,
however, by a determination of the distribution
of recoil momenta along the alpha break-up di-
rection.[2] This component will generally be larg-
er when the electron and antineutrino are emitted
preferentially in the same direction (V and T),
and smaller in the opposite case (S and A). Theo-
retically, V and T give identical predictions for

the spin sequence 2^+-2^+-0^+, and S and A are
likewise indistinguishable.

In the present experiment, the Li^8 is produced
by bombarding a thin layer of Li^7 on a 0.005-inch
aluminum backing, with a deuteron beam pulsed
at 60 pulses per second. During the periods when
the beam is cut off, alpha particles following the
Li^8 beta decay are magnetically analyzed and
detected in a 0.002-inch thick CsI(Tl) crystal in
coincidence with electrons travelling perpendicu-
lar to the alpha direction, or alternatively anti-
parallel to the alpha direction. The electrons
are detected in collimated plastic scintillators
so that pulse-height analysis can be carried out
to select various ranges of electron energy. The
measured alpha-particle momentum spectra for
the two counter configurations, and for two dif-
ferent ranges of electron energy, are shown in
Figs. 1 and 2. Corrections to the experimental
data have been made for the He^+/He^{++} ratio and
for the momentum loss of the alpha particles in
escaping from the target.

To first order in p_β/p_α, the alpha-particle
spectrum observed for the perpendicular counter
configuration is just the spectrum in the rest
system of the Be^{8*} slightly broadened symmetri-
cally, for all interactions, by the antineutrino
momentum. Also to first order, the momentum
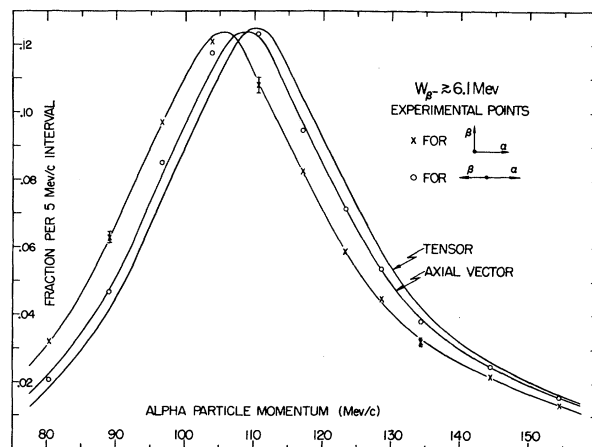of an alpha particle in the antiparallel configur-

FIG. 1. Alpha-particle momentum spectra obtained
in $\beta\alpha$-coincidence measurements on the decay of Li^8.
The crosses are experimental points for electrons
with $W_\beta \gtrsim 6.1$ Mev perpendicular to the observed alpha
particle; the open circles are for electrons with W
$\gtrsim 6.1$ Mev antiparallel to this alpha particle. Theo-
retical curves corrected for finite experimental re-
solution are shown for axial vector (or scalar) and
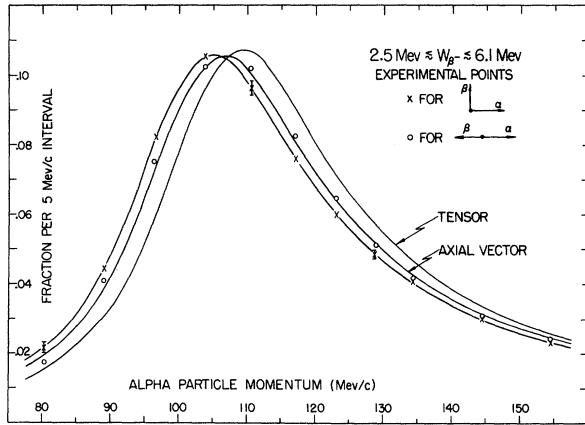tensor (or vector) interaction.

FIG. 2. Theoretical and experimental spectra as in Fig. 1 except for electrons with 2.5 Mev $\lesssim W_\beta \lesssim 6.1$ Mev.

ation is increased by an amount

$$\Delta p_\alpha = \tfrac{1}{2} (p_\beta - p_{\bar{\nu}} \cos\theta_{\bar{\nu}\alpha}), \qquad (1)$$

where p_β and $p_{\bar{\nu}}$ are the absolute magnitudes of the electron and antineutrino momenta. The theoretically predicted angular correlation for antineutrino and alpha particle is, for $\cos\theta_{\beta\alpha} = -1$,

$$W(\theta_{\bar{\nu}\alpha}) = 1 \pm \frac{v}{c} \cos\theta_{\bar{\nu}\alpha}, \qquad (2)$$

where the plus sign holds for A or S and the minus sign for T or V.[2,3] When the antineutrino momenta are averaged over all angles, with the angular correlation given by Eq. (2), and average magnitudes inserted for the electron and antineutrino momenta, the spectrum of the observed alpha particles in the antiparallel configuration will be shifted upwards on the average by

$$\langle \Delta p_\alpha \rangle = \tfrac{1}{2} \langle p_\beta \rangle \pm \tfrac{1}{6} \langle p_{\bar{\nu}} \rangle, \qquad (3)$$

where the plus sign holds for T or V and the minus sign for A or S. Since the measurements described in the preceding Letter[1] set upper limits for S and V, we are here interested in distinguishing A from T. To calculate $\langle p_\beta \rangle$ and $\langle p_{\bar{\nu}} \rangle$ we have assumed that the spectra of electron and antineutrino momenta in coincidence with alpha par-

ticles of energy E_α are given by the usual Fermi expression with an end-point energy $W_0 = (16.6 - 2E_\alpha)$ Mev.

The crosses in Fig. 1 give the experimental alpha-particle momentum spectrum for the perpendicular configuration, with a smooth curve drawn through the points. The other two curves in Fig. 1 are constructed from this smooth curve with the aid of Eq. (3), for electrons of total energy $W_\beta \gtrsim 6.1$ Mev. A small correction has been made for the beta counter pulse height resolution which was ~15% at 6.1 Mev. It is evident that the open circles, which give the measured spectrum for the antiparallel configuration, agree well with the axial vector prediction.

The curves in Fig. 2 are derived similarly for 2.5 Mev $\lesssim W_\beta \lesssim 6.1$ Mev. In addition to the resolution correction already mentioned, corrections have been made for high-energy electrons scattered from the collimator, as determined experimentally, and for the "tail" of small pulses always present in the pulse-height spectrum of high-energy electrons. Again, it is evident that the observed shifted spectrum agrees well with the axial vector prediction. A qualitative comparison of the results in Fig. 2 with those in Fig. 1 is instructive. A relatively large shift is expected for either A or T in the antiparallel curve of Fig. 1 since the antiparallel electron has the greater share of the decay energy and the shift is thus not very sensitive to the orientation of the low-energy antineutrino. The measurements show that the experimental arrangement was capable of measuring such a relatively large shift. On the other hand, the small shift in Fig. 2 shows the partial cancellation to be expected for the axial vector interaction between the antiparallel momentum of the low-energy electron and the average parallel component of momentum of the high-energy antineutrino.

A more quantitative comparison of the experimental shifts with the theoretically expected shifts may be made by correcting all shifts for their dependence on p_α and then averaging. Table I displays the average shifts, corrected to

Table I. Experimental and theoretical momentum shifts (Δp_α in Mev/c) (Corrected to $p_\alpha = 100$ Mev/c and averaged).

W_β	Axial vector		Tensor	
	Exp.	Theory	Exp.	Theory
$W_\beta \gtrsim 6.1$ Mev	3.55 ± 0.16	3.41	3.63 ± 0.17	5.18
2.5 Mev $\lesssim W_\beta \lesssim 6.1$ Mev	1.50 ± 0.08	1.51	1.60 ± 0.10	4.23
$W_\beta \lesssim 2.5$ Mev	2.61 ± 0.17	2.40	2.71 ± 0.17	4.67

$p_\alpha = 100$ Mev/c $(E_\alpha = 1.33$ Mev). The quoted errors are standard deviations of the mean values. It will be noted that the corrected experimental shifts differ only slightly for the two theoretical predictions.

The results show that the Li^8 beta decay proceeds by the axial vector interaction with an upper limit on the tensor interaction of approximately 10%. These results incidentally set a similar upper limit on the vector interaction but cannot exclude a large contribution from the scalar interaction. However, the preceding Letter sets an upper limit of 10% on this latter interaction. The two combined results establish the Li^8 decay as at least 90% Gamow-Teller and the Gamow-Teller portion as at least 90% axial vector.

Morita[3] has shown that the coefficient of the second term on the right-hand side of Eq. (2) is $-\frac{1}{3}$ for $J^\pi(Li^8) = 1^+$ and $+\frac{4}{7}$ for $J^\pi(Li^8) = 3^+$, so that the magnitude of the observed shifts exclude these possibilities as do the results of the preceding Letter. The conclusions of this and the preceding Letter are in accord with results reported on Li^8 by Lauterjung et al.[4] and on the nature of the Gamow-Teller interaction in He^6 as recently revised by Herrmannsfeldt et al.[5]

It is a pleasure to acknowledge our indebtedness to R. F. Christy, R. P. Feynman, M. Gell-Mann, and B. Stech for many helpful discussions.

[1] Lauritsen, Barnes, Fowler, and Lauritsen, Phys. Rev. Lett. 1, 326 (1958).

[2] R. P. Feynman and B. Stech (private communication).

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[4] Lauterjung, Schimmer, and Maier-Leibnitz, Z. Physik 150, 657 (1958).

[5] Herrmannsfeldt, Burman, Stähelin, Allen, and Braid, Phys. Rev. Lett. 1, 61 (1958).

CIRCULAR POLARIZATION OF EXTERNAL BREMSSTRAHLUNG PRODUCED BY BETA RAYS

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Beta particles longitudinally polarized on account of parity violation give rise to a circularly polarized external bremsstrahlung. This was shown by Goldhaber et al.[1] observing the transmission of the photons through magnetized iron. However, this method works only for photon energies above 600 kev. For smaller energies the polarization was measured by Galster and Schopper[2] using the forward scattering from magnetized iron. These results are in qualitative agreement with calculations[3,4] but a quantitative comparison has not yet been performed. The computations were done for monoenergetic electrons falling on a thin absorber whereas in all experiments the whole beta spectrum and thick absorbers were used. It will be shown here that even in this case a comparison with theory is possible as the diffusion of the electrons in the absorber has practically no influence on the polarization.

Cohen et al.[5] reported in one case a strong dependence of the circular polarization on the atomic number Z of the absorber. As this effect is rather unexpected we investigated it more carefully. The experimental setup was the same as that used in a former experiment.[2] The bremsstrahlung was produced by beta particles of $Sr^{90}+Y^{90}$ in absorbers of different Z and the photons were scattered from magnetized iron. The relative change in counting rate ϵ on reversing the magnetization was measured for different photon energies. The results are represented in Fig. 1. There is no indication of Z dependence
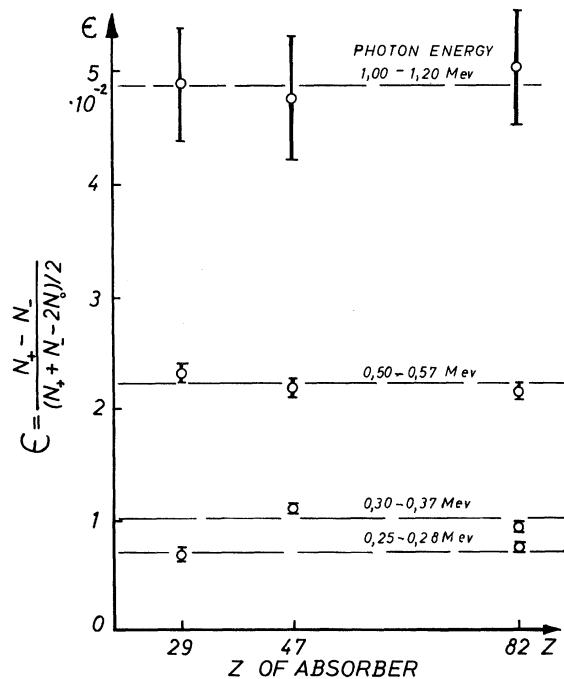

FIG. 1. The relative change in counting rate ϵ on reversal of magnetization as a function of the atomic number Z of absorber. Source: $Sr^{90} + Y^{90}$.