Carter, Harvey, and Hughes, Phys. Rev. **96**, 113 (1954); Karriker, Marshak, and Newson, Bull. Am. Phys. Soc. Ser. II, **2**, 33 (1957).
[3] Schiffer, Davis, and Prosser, Bull. Am. Phys. Soc. Ser. II, **2**, 60 (1957); Schiffer, Lee, Davis, and Prosser, Phys. Rev. **107**, 547 (1957), this issue.
[4] B. Margolis and V. F. Weisskopf, Phys. Rev. **107**, 641 (1957), following letter.

Proton-Width Strength Function*

B. Margolis, *Department of Physics, Columbia University, New York, New York*

AND

V. F. Weisskopf, *Department of Physics and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts*

(Received May 13, 1957)

THE ratio $\bar{\Gamma}_n^0/\bar{D}$ of the reduced neutron width divided by the level distances, when averaged over low-lying resonance levels (usually referred to as neutron-strength function), shows a characteristic behavior as a function of A with maxima near $A_n\simeq 55$ and $A_n\simeq 170$. These maxima come from the establishment of standing waves within the nucleus when

$$K_nR=(n+\tfrac{1}{2})\pi,\quad K_n=(2mV_n/\hbar^2)^{\frac{1}{2}},\qquad (1)$$

where K_n is the wave number of the incoming particle within nuclear matter for particles with zero incident energy; V_n is the depth of the nuclear potential well for neutrons which, in first order, is considered constant over the nucleus.

Similar maxima should occur for the proton strength function $\Gamma_p^0/\bar{D}$, as was pointed out by Schiffer and Lee.[1] In this case Γ_p^0 is the reduced proton width, which is the actual width corrected for Coulomb penetration and reduced to a fixed energy. However, the potential well V_p for protons is different from V_n on two accounts. It is less deep than the well for neutrons, and the part which comes from the electrostatic force has a characteristic variation with the radial coordinate r. We have, in fact, $V_p=V_p^0-[\frac{3}{2}-\frac{1}{2}(r^2/R^2)](Ze^2/R)$, where V_p^0 is the depth without Coulomb force. The average value of V_p over the nucleus is $\bar{V}_p=V_p^0-(6/5)(Ze^2/R)$. Maxima in $\bar{\Gamma}_p^0/\bar{D}$ should occur whenever

$$\hbar^{-1}\int_0^R(2mV_p)^{\frac{1}{2}}dr \approx\left(\frac{2m}{\hbar^2}\right)^{\frac{1}{2}}\left(V_p^0-\frac{4}{3}\frac{Ze^2}{R}\right)^{\frac{1}{2}}R=\left(n+\frac{1}{2}\right)\pi.$$

We therefore get for protons an equation similar to (1) with

$$K_p=\left[\frac{2m}{\hbar^2}\left(\bar{V}_p-\frac{2}{15}\frac{Ze^2}{R}\right)\right]^{\frac{1}{2}}.$$

We obtain a simple estimate of $\bar{V}_p$ and V_n from the separation energies S_n and S_p of neutrons or protons. The following relation must hold: $T_F+S=\bar{V}$, where T_F is the kinetic energy on top of the Fermi distribution: $T_F=[(9/2)\pi]^{\frac{2}{3}}(\hbar^2/2mr_0^2)(n/2A)^{\frac{2}{3}}=C(n/2A)^{\frac{2}{3}}$. Here m is the mass of a nucleon, r_0 is given by $R=r_0A^{\frac{1}{3}}$, and n is the number of protons or neutrons, respectively. Hence, we get

$$\bar{V}_p/V_n=[(T_F)_p+S_p]/[T_F]_n+S_n],$$

and from this formula

$$\frac{K_p}{K_n}=\left[\frac{C(n_p/2A)^{\frac{2}{3}}+S_p-(2/15)(Ze^2/R)}{C(n_n/2A)^{\frac{2}{3}}+S_n}\right]^{\frac{1}{2}}.\qquad (2)$$

The ratio of the values of A at which maxima occur is then given by $(A_p/A_n)=(K_n/K_p)^3$.

Expression (2) can be roughly evaluated for nuclei $55<A<70$ by putting $r_0=1.2$ ($C=83.3$ Mev), $S_p\approx S_n\approx 8$ Mev, $(n_p/2A)=0.225$ and $(n_n/2A)=0.275$. We then get $(A_p/A_n)=1.24$, and, with the well-known value of $A_n\approx 55$, we expect $A_p\approx 68$. According to these rough estimates the next maximum can be expected near $A_p\approx 230$. Recent measurements by Schiffer and Lee[1] seem to bear out the prediction of a maximum near $A=68$.

* This work was supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] J. P. Schiffer and L. L. Lee [Phys. Rev. **107**, 640 (1957)], preceding letter.

Electron-Neutrino Angular Correlation in the Positron Decay of Argon 35*

W. B. Herrmannsfeldt, D. R. Maxson,† P. Stähelin,‡ and J. S. Allen

Department of Physics, University of Illinois, Urbana, Illinois

(Received May 28, 1957)

THE positron-neutrino angular correlation coefficient has been measured for the decay of A^{35}. Since this decay occurs mainly through the Fermi matrix element,[1] the correlation should be sensitive to the ratio of the two Fermi coupling constants $|g_V^2|/|g_S^2|$. Two different experiments have been carried out, and in each case, the results have shown that the vector interaction is dominant.

A^{35} has a half-life of 1.8 sec and decays by the emission of positrons with a maximum kinetic energy of 4.9 Mev into its mirror nucleus Cl^{35}. Although most of the beta transitions go to the ground state of Cl^{35}, about 7% of the decays go through beta transitions to the first two excited levels of Cl^{35} which then decay by emission of gamma rays.[1]

The A^{35} was produced by the reaction $S^{32}(\alpha,n)A^{35}$ in a target of gaseous SF_6. A steady stream of SF_6 carried the radioactive A^{35} through a pipe line to the apparatus outside the shielding walls of the cyclotron.

The carrier gas was frozen out in a liquid nitrogen trap. After purification in a calcium furnace, a small fraction of the original A^{35} reached the source volume of the recoil spectrometer, where the total gas pressure was kept below 3×10^{-5} mm Hg during most of the runs.

In the first experiment, we used, with minor improvements, the apparatus in which the positron-neutrino angular correlation coefficient on Ne^{19} had been measured.[2] For A^{35} we have obtained, with the same method, an angular correlation coefficient $\lambda=+0.9 \pm 0.3$.

In the second experiment, the energy spectrum of negative recoil ions was measured without any selection of the direction of positron emission. The recoil energy was measured with two electrostatic spectrometers in series. A weak magnetic field was superimposed on the electric field of the first spectrometer, in order to prevent electrons from traversing the two spectrometers in succession. The performance of the spectrometers was tested with an electron gun and with an ion gun. A differential pumping system, based on small apertures in the three focal planes of the spectrometers, reduced the amount of radioactive gas reaching the ion detector, and thus diminished the background. For the measurement of the remaining background, a repulsive potential was applied to a grid between the source volume and the first spectrometer.

The recoil spectrum from the second experiment and the theoretically predicted spectrum shapes for different values of λ are shown in Fig. 1. The theoretical curves have been corrected for the finite resolution of the spectrometers and for the presence of the low-intensity branches in the decay of A^{35}. In order to compute the second correction it was necessary to make an assumption about the interaction type in the beta transitions to the excited levels. The shapes of the recoil energy spectra are not very sensitive to the type of interaction

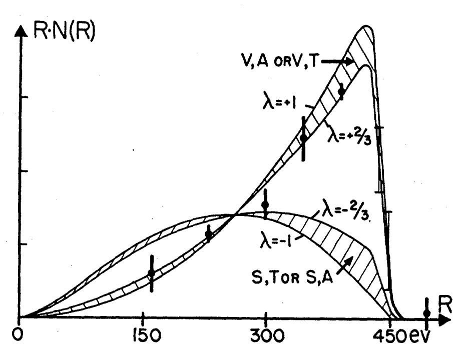

FIG. 1. The distribution of recoil ions as observed in the second experiment with A^{35} is plotted as a function of the recoil energy R. The curves are computed distributions for different values of the angular coefficient. For any combination of vector (V) with axial vector (A) and tensor (T) interaction, one expects a distribution in the upper shaded band, while for scalar (S) with axial vector (A) and tensor (T) interaction the spectrum should fall on the lower band.

because each recoil spectrum is smeared out by the recoil momentum of the following γ ray. The curves in Fig. 1 have been computed for axial vector interaction in the low-intensity branches. The use of the tensor instead of the axial vector interaction would raise the middle region of the curves by about 1%. Since the shell model suggests spins $\frac{1}{2}$ and $\frac{5}{2}$ for the first two excited states of Cl^{35}, a scalar or vector interaction would be ruled out by the spin change. The best least-squares fit of the corrected theoretical curves to the experimental data yields for the ground state transition an angular correlation coefficient $\lambda=+0.70$ with a standard error ±0.17.

The result that $\lambda>\frac{1}{3}$ in both experiments implies the existence of a vector interaction independently of any assumption about nuclear matrix elements. For any of the interaction pairs SA, ST, AV, or TV one expects λ to depend only on the ratio of the Fermi to Gamow-Teller transition probabilities. This ratio may be deduced from the known ft values of the 0^+-0^+ transitions in O^{14}, Al^{26}, and Cl^{34} and from the ft value of A^{35}, since one can assume that the Fermi matrix element for the 0^+-0^+ transitions is, within about 10%, twice the Fermi matrix element of the mirror transition $A^{35}-Cl^{35}$. Conservative limits for the errors of the involved ft values lead to an upper limit of 25% for the Gamow-Teller contribution to the total decay probability. The corresponding limits of λ and also the experimental values of λ are plotted in the upper half of Fig. 2. A comparison between the experimental results and the computed values shows that, in the decay of A^{35}, at least two-thirds of the Fermi interaction is of the vector type.

In view of this rather unexpected result, a review of the existing data on the angular correlation coefficient of the positron emitter Ne^{19} may be interesting. For comparison with the A^{35} results, the experimental values[2–4] and the theoretical limits of λ for Ne^{19} are plotted in the lower half of Fig. 2. It is evident, that in the case of Ne^{19}, the experimental values of λ are in agreement with either the S, T or A, V combination of interactions. However, the accurate measurements of Rustad and Ruby[5] show that $\lambda=+0.34\pm0.13$ for the He^6 decay which indicates that the tensor interaction is

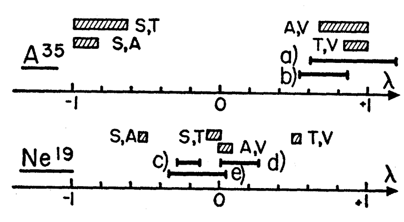

FIG. 2. Comparison of experimental values for the angular correlation coefficient in A^{35} and Ne^{19} with predicted limits for different combinations of two of the interaction invariants S, V, A, or T. The experimental values are taken from (a) first experiment, (b) second experiment, (c) reference 2, (d) reference 3, and (e) reference 4.

dominant in this transition. Thus, there is an apparent inconsistency between the experiments on the negatron decay of He^6 and the positron decays of Ne^{19} and A^{35}.

We wish to express our gratitude to Dr. J. Weneser for many stimulating discussions concerning the interpretations of our results.

* Supported in part by the Office of Naval Research.

† Now at the Department of Physics, Princeton University, Princeton, New Jersey.

‡ Assisted by the Swiss National Science Foundation.

[1] Kistner, Schwarzschild, and Rustad, Phys. Rev. **104**, 154 (1956).
[2] Maxson, Allen, and Jentschke, Phys. Rev. **97**, 109 (1955).
[3] M. L. Good and E. J. Lauer, Phys. Rev. **105**, 213 (1957).
[4] W. P. Alford and D. R. Hamilton, Phys. Rev. **105**, 673 (1957).
[5] B. M. Rustad and S. L. Ruby, Phys. Rev. **97**, 991 (1955).

Parity and Electron Polarization: Møller Scattering*

H. Frauenfelder, A. O. Hanson, N. Levine, A. Rossi, and G. DePasquali

University of Illinois, Urbana, Illinois

(Received May 27, 1957)

Lee and Yang's proposal that parity may not be conserved in weak interactions,[1] and the subsequent experimental confirmation[2–4] require a careful and complete reinvestigation of beta decay. The measurement of the electron polarization for various electron and positron decays seems to be a valuable tool in this respect.

In a recent letter,[5] we reported on an experiment in which we first transformed the longitudinal polarization of electrons from Co^{60} into a transverse one by means of an electrostatic field and then used Mott scattering to determine the transverse polarization. Similar experiments have since been communicated by other groups.[6–8]

The methods based on Mott scattering possess two weak points: (1) these are not effective for positrons, and (2) the scattering in the analyzer foil introduces errors which are difficult to evaluate accurately. Hence we searched for another way of observing the electron polarization and we report here on a measurement using Møller scattering.[9,10] The cross section for Møller scattering depends strongly on the relative orientation of the spins of the incident and target electron.[11] The dependence is most pronounced for collisions where the electrons possess equal energies after the scattering. For electrons, the cross section for such scattering with the spins parallel, σ_+, is much smaller than that for the spins antiparallel, σ_-, at all energies. For positrons, the spin dependence is small at low energies and approaches that for electrons at high energies ($\sigma_+/\sigma_- \rightarrow \frac{1}{8}$).

Detection of one of the electrons only is not practical since Rutherford scattering is much stronger and masks the desired effect. Simultaneous observation of both electrons, however, allows one to pick out the desired Møller scattering events. The idea of the present experiment is thus to use two counters and to record coincidences, accepting only electrons in a defined energy range. Assuming that one selects electrons with about equal energies and that a fraction f of the electrons in the scatterer is polarized, one may write

$$\delta \equiv 2(C_p - C_a)/(C_p + C_a) = 2f \cos\alpha\, P(1-\epsilon)/(1+\epsilon),$$

where C_a and C_p represent the number of coincidences when the electron momentum and the polarizing magnetic field in the scattering foil are antiparallel and parallel, respectively; α is the angle between the polarization in the foil and the direction of the incident beam; ϵ is the ratio σ_+/σ_-; and P is the polarization of the electrons from the source.

This method of observing the polarization is to a large extent free of the two restrictions mentioned above on Mott scattering. Positrons and electrons can be investigated. Plural scattering in the analyzer foil is less disturbing since two of the properties of both of the scattered electrons are selected, namely their energies and their angles. If one of the electrons suffers an excessive scattering, the event will not be recorded.

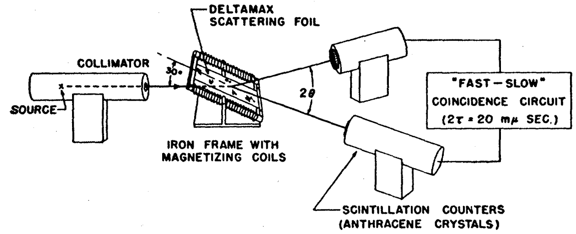

Fig. 1. Schematic drawing of the arrangement used to determine the longitudinal polarization of electrons by means of Møller scattering.

The experimental arrangement is shown schematically in Fig. 1. The scatterer consists of a magnetized Deltamax foil[12] having a thickness of 2.7 mg/cm^2 and an induction of 15 000 gauss ($f = 0.055 \pm 0.004$) which is placed at an angle α of ± 30 degrees with the electron beam. The electron collimator and the scatterer were placed in a helium atmosphere in order to reduce the undesired scattering in the air. As a check on the reality of the results with the Deltamax foil, an aluminum foil (5 mg/cm^2) was placed in the same field of seven oersteds and the coincidences were found to show no dependence on the direction of the magnetic field.

Some experimental results are summarized in Table I. From these data, the following conclusions can be drawn.

1. Møller scattering is well suited to measure the longitudinal polarization of electrons emitted in beta decay. In contrast to the conventional method,[5–8] the