SOVIET PHYSICS JETP VOLUME 13, NUMBER 1 JULY, 1961

β-γ *POLARIZATION CORRELATION IN THE* β *DECAY OF* Sc^{46}

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Submitted to JETP editor June 22, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) 40, 10-12 (January, 1961)

The correlation between the β-ray transverse polarization and γ-ray circular polarization was measured. The degree of correlation is theoretically proportional to an interference term of the type Im (VT, SA). The experimental result indicates with statistical accuracy ~ 30% that the term is absent. This is not inconsistent with the present theory of β decay.

THE time-reversal invariance of β decay has been tested in several experiments. Direct experiments such as the determination of β - ν correlation in polarized-neutron decay and of β - γ correlation in oriented-nucleus decay indicate with accuracy of 15 — 30% that the β-interaction Hamiltonian does not include an imaginary part. The magnitude of the correlation in these experiments depends on the imaginary part of V, A interference terms. Since S- and T-interaction terms have so far not been excluded, it was of interest to perform a direct experiment in order to estimate the Im (VT, SA) term.

The verification of time-reversal invariance is known to require the measurement of pseudoscalar quantities with respect to time. Our experiment was devised to measure the pseudoscalar $P_\gamma \mathbf{k}_\gamma \times [\mathbf{p}_e \times \boldsymbol{\xi}_e]$, where P_γ is the circular polarization of the γ ray, $\mathbf{k}_\gamma$ is its momentum, and $\mathbf{p}_e$ and $\boldsymbol{\zeta}_e$ are the momentum and polarization of the β electron. The correlation between the transverse polarization of the electron and the circular polarization of the γ ray was measured. The experimental geometry is shown in Fig. 1.

The correlation coefficient in the case of allowed transitions is, according to Dolginov,[1]

$$K = -\frac{B_{1\sigma}}{|\xi|}\Big\{2\,\frac{v}{c}\,\mathrm{Im}\,(C_V C_T'^{*} + C_V' C_T^{*} - C_S C_A'^{*} - C_S' C_A^{*})\, M_F M_{GT}^{*}$$
$$-\frac{2\alpha Z}{E}\,\mathrm{Re}\,(C_S' C_T^{*} + C_S C_T'^{*} - C_V C_A'^{*} - C_V' C_A^{*})\, M_F M_{GT}^{*}$$
$$-\lambda_{j_1 j_0}\Big[\frac{v}{c}\,\mathrm{Im}\,(C_A C_T'^{*} + C_A' C_T^{*})\,|M_{GT}|^2$$
$$-\frac{\alpha Z}{E}\,\mathrm{Re}\,(C_T C_T'^{*} - C_A C_A'^{*})\,|M_{GT}|^2\Big]\Big\}, \qquad (1)$$

where

$$|\xi| = (|C_A|^2 + |C_A'|^2 + |C_T|^2 + |C_T'|^2)\,|M_{GT}|^2$$
$$+ (|C_S|^2 + |C_S'|^2 + |C_V|^2 + |C_V'|^2)\,|M_F|^2,$$

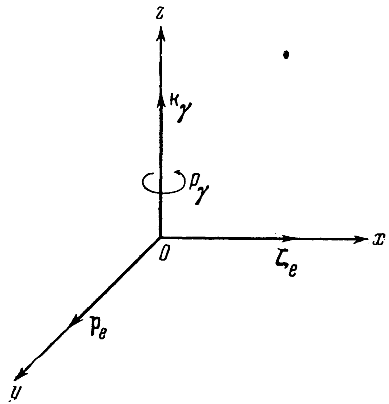

FIG. 1. Experimental geometry

$$B_{1\sigma} = \frac{j_1(j_1+1) - j_2(j_2+1) + I(I+1)}{2I(I+1)\sqrt{j_1(j_1+1)}},$$

$$\lambda_{j_1 j_0} = \frac{j_1(j_1+1) - j_0(j_0+1) + 2}{2\sqrt{j_1(j_1+1)}},$$

j_0 is the spin of the level from which β decay proceeds, and j_1 and j_2 are the spins of product-nucleus levels. The magnitude of the correlation obviously depends on the degree of interference between Gamow-Teller and Fermi matrix elements. We therefore used as our source the Sc^{46} nucleus, for which experiments on β-γ circular polarization correlation have indicated large interference of the matrix elements.

The correlation can obviously be determined in two ways: 1) by detecting γ rays with specified circular polarization in order to measure electron polarization; 2) by detecting β rays with specified polarization, to measure the circular polarization of γ rays. The second method is favored because the measurement of γ-ray circular polarization does not require any change of experimental geometry. Errors associated with instrumental asymmetry are thus excluded.

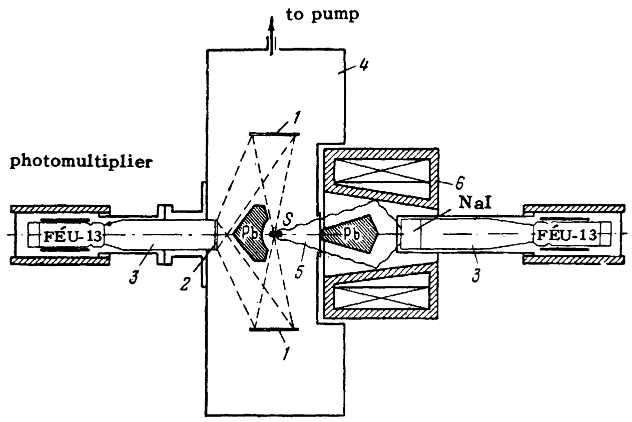

FIG. 2. Diagram of apparatus: S – source, 1 – electron scatterer, 2 – plastic scintillator, 3 – light pipes, 4 – vacuum chamber, 5 – γ-ray exit window, 6 – magnet of γ polarimeter,

The experimental arrangement is shown diagramatically in Fig. 2. Collimated electrons from the source S strike a 0.5-mg/cm^2 bismuth film, and after scattering at ~ 135° are registered by a scintillator combined with a light pipe and photomultiplier. Because of azimuthal asymmetry associated with Mott scattering, the beam of scattered electrons will be polarized in the $\mathbf{p}_1 \times \mathbf{p}_2$ direction, where $\mathbf{p}_1$ and $\mathbf{p}_2$ are the electron momentum before and after scattering, respectively.

Circular geometry was used to increase the counting rate. The circular polarization of γ rays was measured through forward Compton scattering on magnetized iron.[2] The photomultiplier outputs of the β and γ detectors were connected to a fast-slow coincidence scheme with $2\tau = 1.8 \times 10^{-8}$ sec. In order to avoid errors associated with changing sensitivity of the coincidence scheme, the magnetization of the γ-polarimeter magnet was reversed automatically every 3.5 minutes.

The measurements were used to calculate

$$\Delta = 2(I_1 - I_2)/(I_1 + I_2), \qquad I_{1,2} = R_{\text{coinc}} / R_\beta R_\gamma;$$

the subscripts 1 and 2 here pertain to the magnetic field directed away from and toward the source, respectively.

The correlation coefficient K was obtained from the formula

$$K = \Delta / P_\gamma P_\beta,$$

where P_γ and P_β are the efficiencies of the γ and β polarimeters.

We obtained $\Delta = +\ 0.15 \pm 0.11\%$, from which the correlation coefficient $K = 0.08 \pm 0.06$ was calculated. The sign corresponds to the notation in Dolginov's paper, and is the opposite of our previous convention in reference 3.

The efficiency P_β of the β polarimeter was determined from the known scattering geometry, extrapolating the azimuthal asymmetry coefficients from Sherman's tables[4] to Z = 83 (bismuth). We followed Wegener[5] in taking account of multiple scattering. The polarization efficiency P_γ of the γ polarimeter was also calculated from the scattering geometry.

The absence of instrumental asymmetry was checked by repeating the experiment with a thick (~ 5 mg/cm^2) scatterer. As a result of multiple electron scattering spin-associated azimuthal asymmetry here disappears, and the investigated effect should also disappear. The result $\Delta = -\ 0.03 \pm 0.09\%$ indicates the absence of instrumental asymmetry.

We used the value $|M_{GT}|/|M_F| = 2.2$ given in reference 2 for the interference of Gamow-Teller and Fermi matrix elements. From Eq. (1) we then obtain

$$K = +0.04 \quad \text{assuming} \quad \operatorname{Im}(VT,\ AS) = 0,$$

$$K = \begin{cases} +0.23 \\ -0.15 \end{cases} \quad \text{assuming maximum} \quad \operatorname{Im}(VT,\ AS).$$

Our result therefore agrees, with statistical accuracy ~ 30%, with the hypothesis that the Im (VT, AS) term is not present. This term can fail to appear not only because the interaction constants have no imaginary parts, but also because VT, AS interference terms are forbidden in the existing β-decay theory. Our results can therefore be regarded as an additional confirmation of the present theory of β decay.

As an independent check of our experimental procedure we performed experiments on the β-γ circular polarization correlation in the β decay of Sc^{46} and Co^{60}, obtaining results in agreement with those of other investigators.

We are indebted to A. Z. Dolginov for discussions and for his continued interest, and to O. M. Saltykovskiĭ, V. V. Andryukevich, and A. V. Kurakin for assistance with the apparatus and measurements.

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Translated by I. Emin
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