New measurements of the spin-electron angular correlation in the decay of polarized neutrons

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Measurement of the correlation coefficient between the neutron spin and the β-electron momentum in neutron decay is a rather sensitive method of determining the ratio $\lambda = C_A/C_V$ of the fundamental weak-interaction constants. In addition, measurement of this quantity jointly with the results of other investigations make it possible to establish the limits of the possible deviations from the $V-A$ theory.

We report here a new measurement of the coefficient A of the spin-electron correlation in the decay of polarized neutrons.

The rate of electron counting by a detector placed near a beam of polarized eutrons is given by the expression

$$n_{1,2} = C(1 \pm \langle v/c \rangle_{\epsilon} \langle \cos\theta \rangle_{\Omega} PA) = C(1 \pm \beta k PA). \quad (1)$$

Here $n_{1,2}$ is the counting rate for the two polarization directions; $\beta = \langle v/c \rangle_{\epsilon}$ s the value of v/c averaged over the spectrum, $k = 1/\Omega_e \int_{\Omega} \cos\theta \, d\Omega_e$, where θ s the angle between the electron momentum and the polarization direction, and P is the degree of polarization.

Denoting the number of decay electrons registered at opposite neutron-spin lirections by N_1 and N_2, we obtain for the observed count asymmetry the expression

$$x = \frac{N_1 - N_2}{N_1 + N_2} = \beta k PA. \quad (2)$$

To separate cases when the k electrons are registered at a total (usually uite large) electron-detector count load, it becomes necessary to register he electrons in coincidence with the recoil protons. Expression (2) remains alid if $N_{1,2}$ is now taken to mean the number of registered coincidences.

It must be noted, however, that owing to the presence of a strong correlation etween the neutron spin and the antineutrino momentum, the distribution of he recoil protons in energy and angle changes with changing polarization irection.

Therefore, in order for the measurement result to be distorted, it is necesary either to take into account the influence of this factor by calculation, or else to ensure in some way that the recoil-proton registration efficiency is ndependent of the neutron spin direction. The best way is to register *all* the ecay protons.

This was first realized in 1970.[1]

The idea of the experiment was to separate that region of the beam from which the decay electrons are registered by means of a diaphragm placed beween the electron detector and the neutron beam, thereby ensuring complete registration of all the decay protons from this region.

This idea was preserved also in the present study.

The experimental setup was the same as in [1], although a number of modiications have been made in the 1970 installation. The entire electronic cir-uitry was done over. The protons were registered by a scintillation detector with a thin CsI(Tl) layer as the scintillator. The layer thickness was 80 μ g/cm^2 and exceeded only slightly the mean free path of electrons of energy 80 keV. A new method was used to select the proton-detector counts by means of the rise ime.[2]

The work was performed with the same beam of polarized neutrons of the RT-M reactor. Cobalt mirrors served as the polarizer. At a reactor power 6.5 MW, the polarized-neutron flux was $5 \cdot 10^7$ neut/sec through the beam cross section. The beam polarization was measured by the Stern-Gerlach method and amounted to $P = 0.733 \pm 0.024$. In the preparation for the measurements, a detailed analysis of the possible experimental errors was carried out.

	Electron energy 145 – 220 keV			Electron energy 220 – 780 keV		
	Value	Error	Contribution to error of A	Value	Error	Contribution to error of A
1. Asymmetry	0.04691	0.0048	0.0117	0.0558	0.0027	0.0055
2. Polarization				0.733	0.024	0.0037
3. $\beta = \langle v/c \rangle$	0.685	0.002	0.0034	0.814	0.0008	0.0001
4. $k = \langle \cos\theta \rangle$				0.861	0.005	0.0007
5. Correction for the electron scattering	0.0439	0.0003	0.0004	0.0257	0.0019	0.0002
6. Correction for the direct action of the measurement of the magnetic field	0.0213	0.0085	0.0010	0.0322	0.0125	0.0014
7. Possible error due to allowance for the edge regions		0.0085	0.0010		0.005	0.0003
	$A = -0.115 \pm 0.012$			$A = -0.115 \pm 0.007$		

To estimate some errors, a number of methodological experiments were performed, including measurements of the probability of registering electrons that experience scattering in the chamber, and experiments aimed at verifying the quality of the focusing system.

Checks were made on the correctness of the procedure of the background measurement, of the electron-detector calibration, etc. The small corrections that must be introduced into the results were estimated.

The delayed coincidences were counted at the two polarization directions separately for electron energies 145—220 and 220—780 keV. The coincidence counting rate six per minute was in both channels at a background/effect ratio ~ 0.12. Part of the background was connected with registration of a certain fraction of the instantaneous background coincidence in the window of the delayed coincidences, owing to the insufficiently good time resolution. Altogether, $2.1 \cdot 10^5$ decay events were registered in this measurement cycle.

The results and a summary of the principal errors are listed in the table.

For A we obtained the value $A = -0.115 \pm 0.006$. This yields the value $\lambda = C_A/C_V = -1.263 \pm 0.015$, which is in good agreement with the earlier measurements.[3-5]

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