Determination of G_A/G_V from the set of three angular-correlation coefficients observed in the decay of the free neutron

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An equation relating $\lambda = G_A/G_V$ to the three angular-correlation coefficients yields the value $\lambda = -1.226 \pm 0.042$. The indicated error is determined entirely by the error in the measurements of the antineutrino-spin correlation. This quantity may thus be regarded as the result of a new measurement of λ, the first based on this correlation.

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Measurements of the angular correlations in the β decay of the free neutron can yield the ratio $\lambda = G_A/G_V$ of the axial vector and vector constants of the weak interaction, under the assumption that the constants are real in the $V-A$ version of the theory. The most effective approach in such a determination is to make use of the electron-spin correlation,

$$A = -2\,\frac{\lambda^2+\lambda}{1+3\lambda^2}\,. \tag{1}$$

In this case the errors $\Delta\lambda$ and λA are related by $\Delta\lambda \cong 2.6\Delta A$. If we take A to be the average of the two most accurate values,[1,2]

$$\bar{A} = -0.1136 \pm 0.0039, \tag{2}$$

we find

$$\lambda = -1.260 \pm 0.010\,. \tag{3}$$

It is less effective to use the electron-antineutrino angular correlation coefficient,

$$a = \frac{1-\lambda^2}{1+3\lambda^2}\,; \tag{4}$$

for it we have $\Delta\lambda \cong 3.3\Delta a$.

The most accurate measurement[3] yields

$$a = -0.1017 \pm 0.0051, \tag{5}$$

from which we find

$$\lambda = -1.259 \pm 0.017. \tag{6}$$

The most effective approach is to use the antineutrino-spin correlation,

$$B = 2\,\frac{\lambda^2-\lambda}{1+3\lambda^2}\,. \tag{7}$$

For it we have $\Delta\lambda \cong 11\Delta B$.

Substitution of the values

$$B = 1.00 \pm 0.030\,, \tag{8}$$

averaged over the two most accurate measurements,[4,5] into (7) yields

$$\lambda = -1.00 \pm 0.33\,. \tag{9}$$

The weak dependence of this coefficient on λ is the reason why measurements of B are ordinarily not used to find λ.

There is the interesting possibility of using all three coefficients jointly to determine λ. From (1), (4), and (7) we find

$$\lambda = \frac{a-1}{B+A}\,. \tag{10}$$

Analysis of (10) shows that in this case the accuracy of the λ determination and the errors in the measurements of A, a, and B are related in a more favorable way than for the quadratic relations discussed above [(1), (2), and (3)]:

$$\Delta\lambda = \frac{1}{B+A}\sqrt{(\Delta a)^2 + (\lambda\Delta A)^2 + (\lambda\Delta B)^2} \cong \sqrt{(1,06\,\Delta a)^2 + (1,33\,\Delta A)^2 + (1,33\,\Delta B)^2}\,. \tag{11}$$

If all three of the coefficients were measured with the same accuracy $\Delta = \Delta a = \Delta A = \Delta B$, the error in λ would be $\Delta\lambda \cong 2.3\Delta$. Substitution of the present values of A, a, and B (given above) into (10) and (11) yields

$$\lambda = -1.226 \pm 0.042 \tag{12}$$

The existing error in the measurements of B is the reason why the accuracy is poorer than in (3) and (6). It follows from (11) that the error $\Delta\lambda$ is due entirely to the error ΔB at the present accuracy of measurements of the angular-correlation coefficients. The value in (12) may thus be regarded as the result of a new measurement of the ratio $G_A.G_V$, the first in practice to be based on the value of the antineutrino-spin correlation coefficient. It thus becomes worthwhile to improve the accuracy of measurements of the antineutrino-spin correlation coefficient, if only to the level of ± 0.01; this improvement would make it possible to determine the ratio G_A/G_V within $\Delta\lambda = \pm 0.016$—an error comparable to that corresponding to the electron—antineutrino correlation.

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