Relations between the angular-correlation coefficients in neutron decay and verification of the *V-A* theory of beta decay

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It is shown that when the *V-A* theory of beta decay is satisfied, the correlation coefficients in the neutron decay should be connected by simple relations. Contemporary values of the correlation coefficients agree well with this requirement, but this does not exclude, as before, the possibility of a noticeable contribution from the scalar and tensor interactions.

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The simple connection between the angular-correlation coefficients in neutron decay, on the one hand, and the fundamental beta-decay constants on the other, makes it possible that the results of measurements of these coefficients can be used to verify the theory.

In the case of the two-component *V–A* theory, all the correlation coefficients are functions of the ratio of two fundamental constants: the Fermi constant and the Gamow-Teller constant.

The corresponding expressions are given by[1,2]

$$a = \frac{1-|\lambda|^2}{1+3|\lambda|^2}, \qquad B = 2\frac{|\lambda^2| - \mathrm{Re}\,\lambda}{1+3|\lambda|^2},$$

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

where a is the coefficient of the correlation between the electron and neutrino momentum, B is the coefficient of correlation between the spin of the neutrino and the antineutrino momentum, A is the coefficient of the correlation between the neutron spin and the electron momentum, and $\lambda = C_A/C_V$.

It follows therefore that the quantities a, A, and B are not independent, but are connected by two relations, which can be written in the form

$$\begin{aligned} 1 + A &= B + a \\ aB &= A^2 + A\,. \end{aligned} \tag{2}$$

From these equations we easily obtain expression connecting any pair of correlation coefficients.

We emphasize that these relations must be satisfied if the *V–A* theory is to be valid.

Coefficient	Correlation	Quality	Reference
A	$(\vec{\sigma}p_e)$	-0.114 ± 0.019	[3]
		-0.09 ± 0.05	[4]
		-0.115 ± 0.009	[5] with allowance for [3]
		-0.118 ± 0.010	[6]
		-0.110 ± 0.008	[7] with allowance for [3,5]
		-0.115 ± 0.006	[8]
B	$(\vec{\sigma}p_\nu)$	-0.88 ± 0.15	[3]
		-0.96 ± 0.4	[9]
		1.01 ± 0.05	[5]
		0.995 ± 0.035	[10]
a	$(p_e p_\nu)$	-0.091 ± 0.039	[11]
		-0.099 ± 0.010	[12]

A summary of the present-day data on the values of a, A, and B is contained in the table. From these data we can obtain the average universal values

$$A = -0.1139 \pm 0.0040, \quad B = 0.995 \pm 0.028, \quad a = -0.0985 \pm 0.0097.$$

Using these values, we can verify the satisfaction of relations (2). Denoting the values of the corresponding differences by F_1 and F_2, we obtain

$$F_1 = 1 + A - B - a = -0.01 \pm 0.03, \qquad (3)$$
$$F_2 = aB - A^2 - A = 0.002 \pm 0.010.$$

We can thus state that the contemporary values of the correlation coefficients in neutron decay are in splendid agreement with the requirements of the V–A theory. Expressions (3) can be used to estimate the possible contributions of the scalar and tensor interactions. To this end, the values of the correlation coefficients must be regarded as functions of all the coupling constants. If, as is customary, no doubt is cast on the complete parity violation in beta decay, i.e., if it is assumed that $(C_i) = (C'_i)$, where i stands for the A, S, V, and T variants, then these quantities are functions of the four coupling constants or of their three ratios. If the difference between the quantities $F_{1,2}$ and zero is designated by ϵ, then expressions of the type

$$F_{1,2}(\alpha, \beta, \lambda) \leqslant \epsilon, \text{ where } \alpha = C_S/C_V, \quad \beta = C_T/C_V, \quad \lambda = C_A/C_V$$

can be used to estimate α and β. Assuming the quantities to be equal to the experimental errors in (3), we obtain for different ratios of α and β

$$\alpha, \beta \leqslant 0.25 - 0.3.$$

We note that for the case $C_{S,T} = +C'_{S,T}$ we can use the experimentally deduced absence of a Fierz term to make much more accurate estimates.[13] However, if we assume $C_{S,T} = -C'_{S,T}$, then the Fierz term is identically equal to zero and the values of C_S and C_T can be estimated only from the quantitative relations between the results of different experiments on beta decay, such as in the procedure used above.

We see that in spite of the very good satisfaction of relation (2), which is a confirmation of the correctness of the *V-A* theory, it is still impossible to exclude the possibility of a sufficiently noticeable contribution of the scalar and tensor interaction variants. It seems useful therefore to improve further the accuracy of the measurements of the correlation coefficients in neutron decay, principally for the correlations with participation of antineutrinos.

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