General applicability of certain tests of the V-A theory of neutron decay

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By directly applying the radiative-correction theorem to the angular coefficients in the neutron beta decay, it is shown that the recently proposed relations for verifying the V-A theory of this decay are generally valid in a variety of cases.

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Yu.A. Mostovoĭ and A.I. Frank have recently proposed simple relations between the coefficients of the angular correlations in neutron decay. These relations can be used to establish the upper bounds of the possible contributions of the scalar and tensor interactions.

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At the present-day level of the measurement accuracy, it was found that although the V-A theory is well satisfied, one can still not exclude the possibility of a noticeable contribution of scalar and tensor interactions. This calls for more accurate measurements.

We wish to call attention to a theoretical aspect of the problem. In the derivations of the relations in[1], no account is taken at all of the influence of radiative corrections. In first-order approximation this is permissible, but if these relations are to improve the measurement results, it is necessary to take suitable account of the radiative corrections. Otherwise one can arrive at incorrect conclusions. We show below that the relations from[1] are valid independently of the radiative corrections and make it therefore possible to verify very accurately the V-A theory.

In the V-A theory of beta decay, the relations between the coefficients of the angular correlations, proposed by Mostovoĭ and Frank in[1] are the following:

$$F_1 = 1 + A - B - a = 0$$
$$F_2 = aB - A^2 - A = 0 \quad , \tag{1}$$

where

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

a is the coefficient of angular correlation between the momenta of the electron and neutrino, A is the coefficient of correlation between the neutrino spin and the electron momentum, B is the coefficient of correlation between the neutrino spin and the antineutrino momentum, and $\lambda = C_A/C_V$. C_V and C_A are the Fermi and Gamow-Teller constants. If scalar and tensor interactions are present, expressions (2) for the angular-correlation coefficients must be modified. In this case F_1 and F_2 in (1) are no longer equal to zero.

Our task of introducing radiative corrections to F_1 and F_2 is greatly simplified by using a theorem proved in[2]. This theorem established that in V-A theory the form of the expressions for the coefficients for the angular correlations (2) in neutron decay remains unchanged when one includes radiative corrections of first-order in the hyperfine-structure constant α, provided that two effective interaction constants C''_V and C''_A are introduced, and corrections of order αq and $a(E/M)\ln(M/E)$ can be neglected. Here, E is the energy of the radiated electron, M is the mass of the proton, and q is the 4-momentum transferred from the neutron to the proton. The proof of the theorem does not depend on the concrete model but takes into account the influence of the strong interactions or the existence of intermediate vector bosons for weak interactions.

In our case there is no need for exact expressions for C''_V and C''_A. The radiative corrections to the angular coefficient lead simply to replacement of C_V and C_A by C''_V and C''_A in Eqs. (2). That is to say,

$$a = \frac{1 - |\lambda^{**}|^2}{1 + 3|\lambda^{**}|^2}; \quad A = -2\,\frac{|\lambda^{**}|^2 + \mathrm{Re}\,\lambda^{**}}{1 + 3|\lambda^{**}|^2}; \quad B = 2\,\frac{|\lambda^{**}|^2 - \mathrm{Re}\,\lambda^{**}}{1 + 3|\lambda^{**}|^2}, \qquad (3)$$

where

$$\lambda^{**} = C_A^{**}/C_V^{**}.$$

It should now be noted that relations F_1 and F_2 as well as other expressions that connect any of the pairs of the angular coefficients that can be derived from them were obtained as a result of a functional dependence of a, A, and B only on λ, and their validity does not depend on the concrete value of λ. Inasmuch as for the angular coefficients we should actually use the equalitities (3), it is easy to conclude that the relations F_1 and F_2 are perfectly valid also after the radiative corrections of first order in α are included. In fact it can be stated that F_1 and F_2 are independent of radiative corrections of first order in α.

In conclusion it should be mentioned that the next higher order corrections to F_1 and F_2 are connected within the framework of the V-A theory with the 4-momentum transfer q. These corrections are of the order of one-tenth of one percent.[2] Thus, relations F_1 and F_2 are valid with high degree of accuracy and ensure relatively stringent restrictions when it comes to detecting the presence of scalar and tensor interactions.

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[1]Yu.A. Mostovoĭ and A.I. Frank, Pis'ma Zh. Eksp. Teor. Fiz. **24**, 43 (1976) [JETP Lett. **24**, 38 (1976)].
[2]A. Garcia, Model Independent Form of Certain Observables in Neutron Decay, to be published in Phys. Lett. B (1978).