SCATTERING OF NEUTRINOS BY ELECTRONS

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IMPROVEMENTS in experimental techniques have made it possible to determine cross sections on the order of $10^{-44} - 10^{-45}$ cm^2 in reactions dealing with the absorption of neutrinos by protons or Cl^{37} (see Refs. 1 and 2), and have led to the hope that these experiments will be repeated in the near future for the purpose of measuring the scattering of neutrinos by electrons. Up to now, experiments carried out to determine the magnetic moment of the neutrino have led to negative results. According to Ref. 3, σ_μ, the cross section for ν—e scattering, is less than 7.5×10^{-40} cm^2/electron, which leads to a value of μ, the magnetic moment of the neutrino, of less than $10^{-7}\mu_B$ (μ_B is the Bohr magneton). On the other hand, theoretical estimates of Thirring and Houtermans[4] yield $\mu \sim 10^{-10}\mu_B$.

The purpose of the present note is to show the possibility of ν—e scattering through a direct 4-fermion interaction $\bar{e}e\nu\bar{\nu}$. The cross section for such scattering may be of the same order of magnitude as σ_μ and can even exceed it. If the incident neutrino has energy E, and the recoil electron has energy W (in units of mc^2), the scattering cross section has the form

$$d\sigma_E(W) = \frac{m^2}{8\pi\hbar^4}\frac{dW}{E^2}\Big\{|g_S|^2(W^2+WE) + g_P^2 W^2 + 2|g_V|^2[W^2 - W(2E+1) + 2E^2] + 2|g_A|^2[W^2 - W(2E-1)+2E^2] + 2|g_T|^2[W^2 - W(4E+1)+4E^2] + 2\mathrm{Re}(2g_V g_A^* + g_S g_T^* + g_P g_T^*)(W^2 - WE)\Big\}. \quad (1)$$

The total effective cross section

$$\sigma_f = \int_0^\infty \rho(E)\,dE \int_0^{2E^2/(2E+1)} d\sigma_E(W) \quad (2)$$

is obtained by averaging over the energy distribution of the incident neutrinos $\rho(E)$. Assuming as in Ref. 5 that $\rho(E) \sim \exp[-E^2/2(\Delta E)^2]$ we find for $\Delta E = 3.8$

$$\sigma_f = 0.05\,(m^2/\hbar^4)\,g^2,$$
$$g^2 = |g_S|^2 + 0.5|g_P|^2 + 5|g_V|^2 + 6|g_A|^2 + 9|g_T|^2 - 2.5\,\mathrm{Re}(2g_V g_A^* + g_S g_T^* + g_P g_T^*). \quad (3)$$

If one assumes the usual value of the universal Fermi interaction constant $g = 3 \times 10^{-49}$ erg-cm^3, then

$$\sigma_f = 3.5 \cdot 10^{-45}\ \mathrm{cm}^2. \quad (4)$$

This value is 5 times larger than the cross section $\sigma_\mu \sim 7.5 \times 10^{-46}$ cm^2, corresponding to $\mu \sim 10^{-10} \times \mu_B$.

An interaction of this type may generally also take place in the scattering of a neutrino by a nucleon. Formula (1) may be used as above to obtain a cross section of the same order of magnitude, however, it is practically impossible to observe ν—n and ν—p scattering because of the small recoil energy of the nucleons.

Nonconservation of parity leads to modifying (1) and (3) as follows:

$$g_i g_j^* \to g_i g_j^* + g_i' g_j'^* - \eta(g_i g_j'^* + g_i' g_j^*),$$

where η is the longitudinal polarization of the neutrino beam.

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