ONE PROPERTY OF LEPTON RADIATIONS EMITTED IN THE INTERACTION BETWEEN NEUTRINOS AND MATTER

G. V. SHISHKIN

Institute for Heat and Mass Exchange, Academy of Sciences, Belorussian S.S.R.

Submitted to JETP editor April 6, 1964

J. Exptl. Theoret. Phys. (U.S.S.R.) **47**, 1757-1758 (November, 1964)

It is shown that in a certain case the polarization properties of leptons produced in the interaction between neutrinos and matter (reactions of the type $\nu + N \to N' + L$) may not depend on the weak-interaction constant.

In view of the importance of the study of neutrino interactions, it is useful to note one interesting property of lepton radiations produced in "elastic" neutrino processes of the type

$$\nu + N \to N' + L. \tag{1}$$

Here ν —neutrino or antineutrino, N —target nucleon, N′ —product nucleon, and L —lepton[1].

Using the method of the theory of Dirac particles with oriented spin[2,3], we obtained the following expressions for the degrees of longitudinal and transverse polarizations of the produced leptons for the (V, A) variant of four-fermion interaction in the first perturbation-theory approximation.

For the degree of longitudinal polarization of the leptons

$$\begin{aligned} P_1 = s_\nu\{&G_V{}^+G_V(k/K+\cos\theta) + \rho s_\nu(G_V{}^+G_A + G_A{}^+G_V) \\ &\times [s_x\sin\theta + s_z(k/K+\cos\theta)] \\ &+ i\rho(G_V{}^+G_A - G_A{}^+G_V)s_y\sin\theta \\ &+ G_A{}^+G_A[3k/K - \cos\theta + 2\rho s_\nu s_x\sin\theta \\ &- 2\rho s_\nu s_z(k/K-\cos\theta)]\}W^{-1}. \end{aligned} \tag{2}$$

For the degree of transverse polarization of leptons polarized in the reaction plane, i.e., in the plane of the neutrino (antineutrino) and lepton momenta

$$\begin{aligned} P_2 = \frac{k_0}{K}\{&s_\nu G_\nu{}^+G_V\sin\theta - \rho(G_V{}^+G_A - G_A{}^+G_V) \\ &\times[s_x\cos\theta - s_z\sin\theta] - i\rho s_\nu(G_V{}^+G_A - G_A{}^+G_V)\, s_y\cos\theta \\ &- G_A{}^+G_A[s_\nu\sin\theta + 2\rho s_x\cos\theta - 2\rho s_z\sin\theta]\}\, W^{-1}. \end{aligned} \tag{3}$$

Finally, for the degree of transverse polarization of leptons polarized perpendicularly to the plane of the reaction

$$\begin{aligned} P_3 = \rho\frac{k_0}{K}\{&s_\nu(G_V{}^+G_A - G_A{}^+G_V)is_x \\ &- (G_V{}^+G_A + G_A{}^+G_V + 2G_A{}^+G_A)s_y\}W^{-1}. \end{aligned} \tag{4}$$

The normalization coefficient W is determined, apart from a factor coinciding with the probability of the process (1), by the following expression:

$$\begin{aligned} W = {}&G_V{}^+G_V\left(1+\frac{k}{K}\cos\theta\right) + \rho s_\nu(G_V{}^+G_A + G_A{}^+G_V) \\ &\times\left[s_x\frac{k}{K}\sin\theta + s_z\left(1+\frac{k}{K}\cos\theta\right)\right] \\ &+ i\rho(G_V{}^+G_A - G_A{}^+G_V)s_y\frac{k}{K}\sin\theta + G_A{}^+G_A \\ &\times\left[3 - \frac{k}{K}\cos\theta + 2\rho s_\nu s_x\frac{k}{K}\sin\theta\right. \\ &\left.- 2\rho s_\nu s_z\left(1-\frac{k}{K}\cos\theta\right)\right]. \end{aligned} \tag{5}$$

In (2)–(5), G_V and G_A are the coupling constants of the vector and axial-vector interactions; $K^2 = k^2 + k_0^2$, where $k = p/\hbar$, p —lepton momentum, $k_0 = m_0c/\hbar$, m_0 —lepton rest mass; θ —angle between the momenta of the neutrino (antineutrino) and the lepton; s_x, s_y, and s_z —projections of the unit vector in the direction of the nucleon-target polarization on the coordinate axes; $s_\nu = \pm 1$; ρ —degree of polarization of target nucleons. The Z axis is directed along the neutrino (antineutrino) momentum, and the XZ plane is the reaction plane. It is obvious from (2)–(5) that we can write down the spatial components of the lepton polarization vector[3,4] in the form

$$\xi_1 = KP_1, \quad \xi_2 = k_0P_2, \quad \xi_3 = k_0P_3. \tag{6}$$

It is curious to note the following interesting circumstance. If the field of the target-nucleons is completely polarized in the direction of the spin of the incoming neutrino (antineutrino), i.e., if the spins of the neutrino (antineutrino) and target nucleons are parallel ($\rho = 1$, $s_\nu = s_z$, $s_x = s_y = 0$ or $s_\nu s_z = 1$), then the lepton longitudinal and transverse polarizations, and consequently also the spatial components of the polarization vector of the leptons produced in the interaction (1), are independent of the weak-interaction constants G_V and G_A.

For the spatial components of the lepton polarization vector we have when $s_\nu s_Z = 1$

$$\xi_1 = s_\nu K \frac{k + K\cos\theta}{K + k\cos\theta}, \quad \xi_2 = s_\nu \frac{k_0^2 \sin\theta}{K + k\cos\theta}, \quad \xi_3 = 0. \quad (7)$$

In addition, in the case $s_\nu s_Z = 1$ it turns out that all the leptons are polarized. Indeed, using (6) and (7), we readily obtain for the fraction P_0 of the lepton polarized state

$$P_0 = 1 - \sqrt{P_1^2 + P_2^2 + P_3^2} = 0. \quad (8)$$

I take this opportunity to thank Professor B. Pontecorvo for consultation.

[1] B. Pontecorvo, JETP **37**, 175 (1959), Soviet Phys. JETP **10**, 1236 (1960).

[2] A. A. Sokolov, Vvedenie v kvantovuyu élektrodinamiku (Introduction to Quantum Electrodynamics), Fizmatgiz, 1958.

[3] A. A. Sokolov, Ann. Phys. **7**, 17 (1961).

[4] Sokolov, Loskutov, and Ternov, JETP **36**, 930 (1959), Soviet Phys. JETP **9**, 657 (1959).

Translated by J. G. Adashko
253