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I. OTS

ON MASSLESS SPIN 3/2 NEUTRINOS WITH POSSIBLE NONMAXIMAL HELICITY STATES AND LEPTONIC DECAYS

I. OTS. VÕIMALIKE MITTEMAKSIMAALSETE SPIRAALSUSTEGA MASSITUTEST 3/2-SPINNIGA NEUTRIINODEST JA LEPTONLAGUNEMISTEST

И. ОТС. О БЕЗМАССОВЫХ НЕЙТРИНО СО СПИНОМ 3/2 С ВОЗМОЖНЫМИ НЕМАКСИМАЛЬНЫМИ СПИРАЛЬНОСТЯМИ И О ЛЕПТОННЫХ РАСПАДАХ

(Presented by H. Keres)

According to the conventional knowledge only maximal helicities can exist for zero-mass particles. This concept rests mainly on the works of E. P. Wigner [1,2] and S. Weinberg [3]. D. Miller was the first to point out that there may be exceptions from the accepted concepts. Analyzing the works mentioned above, he concluded that neither Wigner's nor Weinberg's theorems require throwing out nonmaximal helicity states when the curl formalism is used. The curl formalism guarantees that different helicities do not mix, and eliminates infinite contributions [4].

One may suppose that massless higher-spin particles with possible nonmaximal helicities, when taking part in reactions give quite different effects as compared with conventional particles.

The aim of this note is to present the calculation results for the effects of nonmaximal helicity states of massless spin 3/2 neutrino (ν_L) in the leptonic decay of a heavy spin 3/2 lepton

$$L \to l + \tilde{\nu}_l + \nu_L. \tag{1}$$

The final l lepton and its neutrino are ordinary spin 1/2 particles. The l neutrino is taken to be massless and the mass of the l lepton is neglected.

We find the energy-angular distribution of the final l lepton from the decay of arbitrarily oriented L lepton in the case when L neutrino has all possible helicity states — maximal and nonmaximal — and compare the results with those of an ordinary, maximal helicity case. For describing the spin 3/2 particles the Rarita-Schwinger formalism is used and in the case of massless spin 3/2 neutrino the curl formalism is added.

If we assume the l lepton current to be only of $V-A$ type, the L lepton current may be written as

$$L_\mu(k)\,(1+\alpha\gamma_5)\,\nu_L^{\mu\sigma}(q), \tag{2}$$

where

$$\nu_L^{\mu\sigma}(q) = q^\mu \nu^\sigma - q^\sigma \nu^\mu.$$

By calculating in the rest frame of the decaying particle and by using the density matrix [5]

$$\varrho_{ik}=\frac{\gamma_0+1}{4}\,(A_{ik}+B_{ikp}\gamma^p\gamma_5), \tag{3}$$

$$A_{ik}=-\frac{g_{ik}}{3}-\frac{i\varepsilon_{pik}t^p}{2}-\frac{t_{ik}}{4},$$

$$B_{ikp}=-\frac{i\varepsilon_{pik}}{6}+\frac{4g_{ik}t_p-g_{ip}t_k-g_{kp}t_i}{10}+\frac{i\varepsilon_{qik}t_p^q}{4}+\frac{3t_{pik}}{8}$$

for describing the orientation of L lepton; one will get the following distribution:

$$dw=\frac{G^2M_L^5}{24\,(2\pi)^4}\int d\Omega\int_0^{1/2}\{F_0(x,\alpha)+\tilde{F}_0(x,\alpha)+$$

$$+[F_1(x,\alpha)+\tilde{F}_1(x,\alpha)]\,t_in^i+[F_2(x,\alpha)+\tilde{F}_2(x,\alpha)]\,t_{ij}n^in^j+$$

$$+[F_3(x,\alpha)+\tilde{F}_3(x,\alpha)]\,t_{ijk}n^in^jn^k\}\,dx. \tag{4}$$

By $F_i(x,\alpha)$ and $\tilde{F}_i(x,\alpha)$ the invariant distribution functions accordingly in the maximal (—3/2, 3/2) and nonmaximal (—1/2, 1/2) helicity cases are given, the tensors t_i, t_{ij} and t_{ijk} are the first, second and third rank orientation tensors describing the spin state of the L lepton, and n_i being the unit vector along the l lepton momentum. x denotes the ordinary dimensionless energy variable. For further details see [5, 6].

For the two helicity configurations $\alpha=-1$ and $\alpha=1$ the invariant amplitudes are given as follows:

$$\begin{aligned}
F_0(x,-1)&=4x^2(3/8-x+7x^2/12-x^3/15),\\
F_1(x,-1)&=\frac{6x^2}{5}\,(-3/4+x+29x^2/30-2x^3/15),\\
F_2(x,-1)&=\frac{3x^2}{10}\,(x-17x^2/6+2x^3/3),\\
F_3(x,-1)&=\frac{3x^2}{40}\,(x^2+4x^3);
\end{aligned} \tag{5}$$

$$\begin{aligned}
\tilde{F}_0(x,-1)&=\frac{4x^2}{3}\,(1/4-x+4x^2/3-2x^3/3),\\
\tilde{F}_1(x,-1)&=\frac{4x^2}{5}\,(5/12-5x/3+2x^2-2x^3/3),\\
\tilde{F}_2(x,-1)&=-\frac{x^2}{3}\,(x^2-2x^3),\\
\tilde{F}_3(x,-1)&=-x^2(x^2/2-x^3);
\end{aligned} \tag{6}$$

$$\begin{aligned}
F_0(x,1)&=4x^2(1/2-5x/3+5x^2/3-2x^3/3),\\
F_1(x,1)&=\frac{2x^2}{5}\,(5-10x-2x^2+4x^3),\\
F_2(x,1)&=x^2(2x-5x^2+2x^3),\\
F_3(x,1)&=-\frac{3x^2}{2}\,(x^2-2x^3);
\end{aligned} \tag{7}$$

$$\tilde{F}_0(x,1)=\frac{4x^2}{3}\,(1/8-x/3+x^2/4-x^3/15),$$

$$\tilde{F}_1(x,1)=\frac{4x^2}{3}\,\left(-\frac{1}{24}+x/3-29x^2/60+x^3/15\right),$$

$$\tilde{F}_2(x,1)=-\frac{x^2}{5}\,(x/3-x^2/4-x^3/3), \tag{8}$$

$$\tilde{F}_3(x,1)=-\frac{x^2}{10}\,(x^2/4-x^3).$$

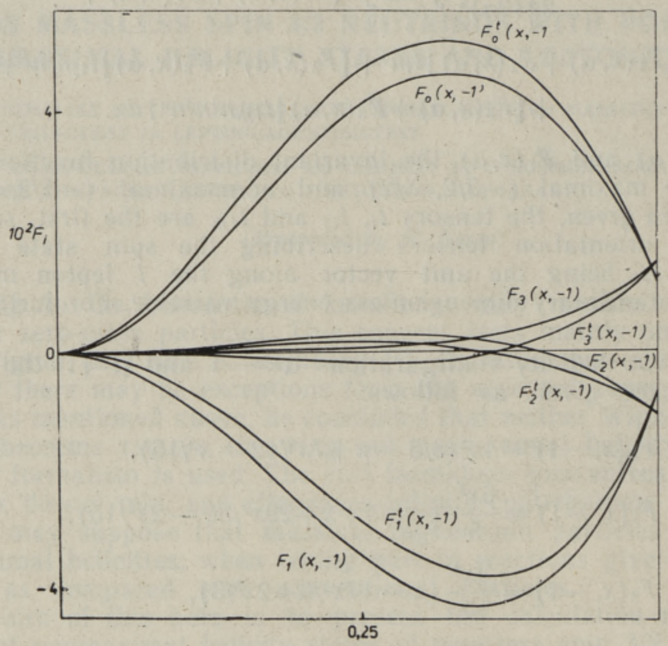

Fig. 1.

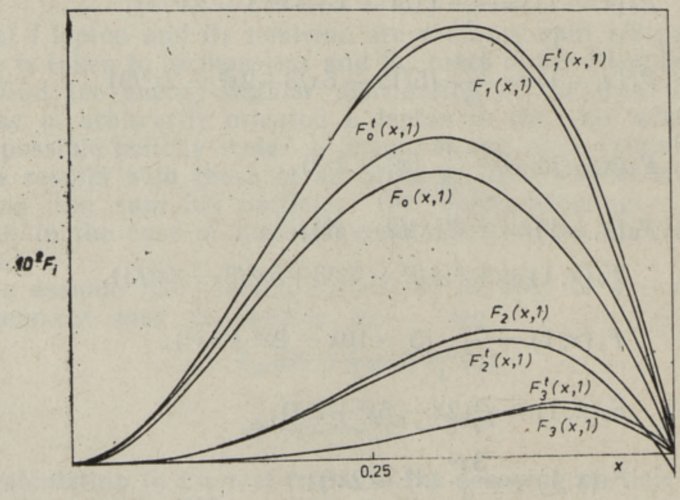

Fig. 2.

In Figs 1 and 2 the dependence of the invariant functions on the energy variable in the case of all possible helicity states

$$F_i^t(x, \pm 1) \equiv F_i(x, \pm 1) + \bar{F}_i(x, \pm 1),$$

and in the case when only maximal helicities contribute $(F_i(x, \pm 1))$, are given. One can see that these cases differ from each other, but not very drastically. So, for example,

$$\frac{\int F_0^t(x, \pm 1)\, dx}{\int F_0(x, \pm 1)\, dx} = 17/15.^* \tag{9}$$

The differences between the respective invariant functions describing the distribution from the various orientation moments of L lepton, are of the same order or less.

* This fact was already mentioned by D. Miller [4].

REFERENCES

1. *Wigner, E. P.* Ann. Math., **40** (1939).
2. *Wigner, E. P.* In: Theoretical Physics. Intern. Atomic Energy Agency, Vienna, 1963.
3. *Weinberg, S.* Phys. Rev., **B134**, 882—896 (1964).
4. *Miller, D.* SLAC-PUB-2713, Stanford, 1981.
5. *Ots, I.* Preprint F-9, Tartu, 1979.
6. *Отс И.* Изв. АН ЭССР. Физ. Матем., 28, № 2, 155—157 (1979).

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