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INTERMEDIATE VECTOR BOSON CORRECTIONS TO SPIN $^3/_2$ HEAVY LEPTON DECAY

I. OTS. VAHEPEALSEST VEKTORBOSONIST TINGITUD PARANDUSED $^3/_2$-SPINNIGA RASKE LEPTONI LAGUNEMISELE

И. ОТС. УЧЕТ ВЛИЯНИЯ ПРОМЕЖУТОЧНОГО ВЕКТОРНОГО БОЗОНА НА РАСПАД ТЯЖЕЛОГО ЛЕПТОНА СО СПИНОМ 3/2

(Presented by H. Keres)

Experimental data show conclusively that τ is a spin $^1/_2$ lepton. However, in nature there may still exist leptons with spins higher than $^1/_2$. In previous papers [1,2] the energy-angular distribution of final leptons from the leptonic decay of oriented spin $^3/_2$ heavy leptons was calculated. At that the heavy lepton neutrino was taken to be a massless spin $^1/_2$ particle and the decay process was supposed as local four-fermion interaction. But there are strong theoretical arguments in favour of the weak interaction being mediated by vector bosons. As the masses of intermediate bosons are expected to be rather high, of the order of 30—80 GeV, the intermediate boson corrections are significant only when decaying leptons are quite massive. So the modifications to the μ or τ decay spectra are not significant due to their small masses but in more massive lepton decay process they may play an important role.

In this paper we calculate the intermediate vector boson corrections to spin $^3/_2$ heavy lepton leptonic decay parameters, modifying them by terms of the order $\omega=M_L^2/M_W^2$ (M_L — mass of the decaying lepton, M_W — mass of the intermediate boson). Using the same lepton currents as in [1,2], one can give the Lagrangian of interaction between leptons and intermediate bosons for the decay processes

$$L^-\to l^-+\tilde{\nu}_l+\nu_L,\qquad L^+\to l^++\nu_l+\tilde{\nu}_L \tag{1}$$

as

$$\mathfrak{L}=g[\bar{l}\gamma^\mu(1-\gamma_5)\nu_l W_\mu^+ +\bar{\nu}_L(1-\alpha\gamma_5)L^\mu W_\mu^-]+\text{h.c.}, \tag{2}$$

where $\bar{l}$, ν_l and $\bar{\nu}_L$ are the field operators of final particles and $W_\mu^\pm$ are the field operators of intermediate bosons. For the description of the spin $^3/_2$ field L^μ the Rarita—Schwinger formalism is used. The interaction constant in Lagrangian (2) is connected with the local interaction constant, as usual,

$$g^2/M_W^2 = G/\sqrt{2}. \tag{3}$$

Using Lagrangian (2) the energy-angular distribution from the leptonic decay of oriented heavy leptons can be calculated by standard methods. We calculate it in the rest frame of the decaying lepton and neglect the mass of the final light lepton. In this case, for taking into account the intermediate boson effect of the order ω, all that is to be done differently as compared with local theory is to multiply the local theory squared transition matrix by factor

$$1+2\omega(1-q_0^L/M_L), \tag{4}$$

where by q_0^L the energy of L neutrino is denoted.

After taking the traces in squared transition matrix and integrating over the momenta of neutrino and antineutrino in the standard decay probability expression, one can write the energy-angular distribution of final leptons formally in the same way as in local theory:

$$dW^{\pm} = \frac{G^2 M_L^5}{24(2\pi)^4} \int d\Omega \int_0^{1/2} [\mathcal{F}_0(x,\alpha) \pm \mathcal{F}_1(x,\alpha) t_i n^i + \mathcal{F}_2(x,\alpha) t_{ij} n^i n^j \pm \mathcal{F}_3(x,\alpha) t_{ijk} n^i n^j n^k]\, dx, \tag{5}$$

where the upper sign describes the L^- decay and the lower one, the L^+ decay. n^i denotes the components of unit vector along the final lepton momentum and α is the real parameter from Lagrangian (2). For the determination of orientation tensors t_i, t_{ij} and t_{ijk} of the decaying spin $^3/_2$ lepton see [1]. Invariant amplitudes $\mathcal{F}_i(x,\alpha)$ are now divided into two parts

$$\mathcal{F}_i(x,\alpha) = F_i(x,\alpha) + \omega F'_i(x,\alpha). \tag{6}$$

The first part corresponds to the local theory and the second one to the intermediate boson corrections. They depend on energy variable $x=E/M_L$ (E — energy of final lepton) and parameter α as follows:

$$\begin{aligned} F_0(x,\alpha) &= x^2/3[(1+\alpha^2)(9-16x+4x^2)+2\alpha(8x-3)], \\ F_1(x,\alpha) &= x^2[(1+\alpha^2)(3-4x)-2\alpha(1-4x+4x^2/5)], \\ F_2(x,\alpha) &= x^2[(1+\alpha^2)(x-x^2)+2\alpha x], \\ F_3(x,\alpha) &= 3\alpha x^4. \end{aligned} \tag{7}$$

$$\begin{aligned} F'_0(x,\alpha) &= 4/3\, x^3[(1+\alpha^2)(5-9x+2x^2)+2\alpha(5x-2)], \\ F'_1(x,\alpha) &= 4x^3[(1+\alpha^2)(2-3x)-2\alpha(1-3x+2x^2/5)], \\ F'_2(x,\alpha) &= x^3[(1+\alpha^2)(1-2x^2)-2\alpha(1-4x)], \\ F'_3(x,\alpha) &= 6\alpha x^5. \end{aligned} \tag{8}$$

For the two-component ν_L (the cases $\alpha=\pm 1$) one can get from (7) and (8):

$$\begin{aligned} F_0(x,1) &= 4/3\, x^2(3-4x+2x^2), & F_2(x,1) &= 2x^3(2-x), \\ F_1(x,1) &= 4/5\, x^2(5-2x^2), & F_3(x,1) &= 3x^4. \end{aligned} \tag{9}$$

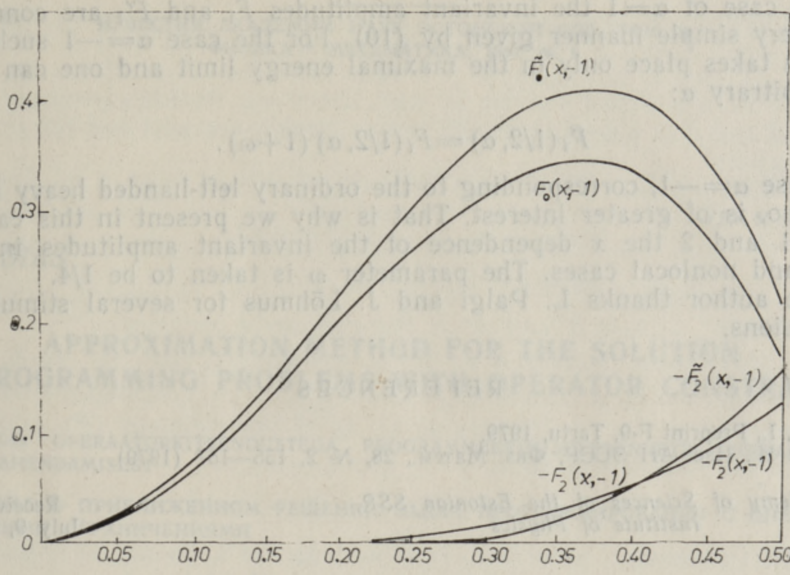

Fig. 1.

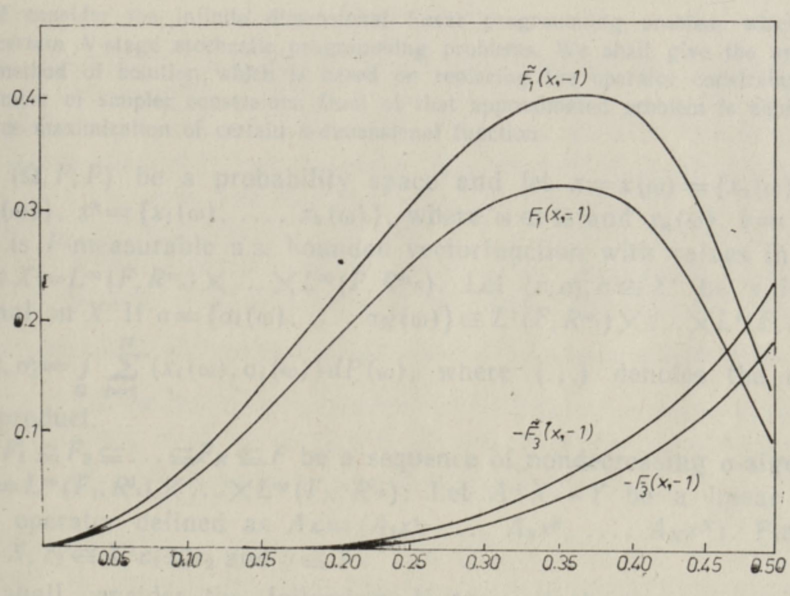

Fig. 2.

$$F'_i(x,1)=2xF_i(x,1),\quad i=0,\ 1,\ 2,\ 3. \tag{10}$$

$$F_0(x,-1)=8/3\,x^2(3-6x+x^2),\qquad F_2(x,-1)=-2x^4,$$

$$F_1(x,-1)=8/5\,x^2(5-10x+x^2),\qquad F_3(x,-1)=-3x^4. \tag{11}$$

$$F'_0(x,-1)=8/3\,x^3(7-14x+2x^2),\qquad F'_2(x,-1)=4x^3(1-2x-x^2),$$

$$F'_1(x,-1)=8x^3(3-6x+2x^2/5),\qquad F'_3(x,-1)=-6x^5. \tag{12}$$

In the case of $\alpha=1$ the invariant amplitudes F_i and F'_i are connected in a very simple manner given by (10). For the case $\alpha=-1$ such connection takes place only in the maximal energy limit and one can write for arbitrary α:

$$\bar{F}_i(1/2,\alpha)=F_i(1/2,\alpha)\,(1+\omega). \tag{13}$$

The case $\alpha=-1$, corresponding to the ordinary left-handed heavy lepton neutrino, is of greater interest. That is why we present in this case by Figs. 1 and 2 the x dependence of the invariant amplitudes in both local and nonlocal cases. The parameter ω is taken to be 1/4.

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