LETTERS TO THE EDITOR

FOURTH GENERATION OF FERMIONS AND THE MAGNETIC MOMENT OF THE NEUTRINO*

By H. Czyż, K. Kołodziej and M. Zrałek

Department of Theoretical Physics, Silesian University, Katowice**

(*Received November 26, 1987*)

We found that within the Glashow–Salam–Weinberg model with four generations of fermions one cannot obtain a big magnetic moment of the electron (muon, tau) neutrino.

PACS numbers: 13.10.+q, 13.40.Fn

There exist many various speculations on the magnetic moments of the neutrinos [1]. In the light of the recent papers [2] a big magnetic moment of the neutrino can explain the solar neutrino flux puzzle. In any case, whether it is true [2] or not [3] it is worth to investigate, what is the limit of the magnetic moment of the neutrino within the Glashow–Salam–Weinberg (GSW) model. In [4] the value

$$M_k = 3G_F m_e m \mu_B/(4\sqrt{2}\,\pi^2) \tag{1}$$

was found $\left(\text{with present data [5] it is equal to } 3.2\,\mu_B \frac{m}{1\text{ eV}}\right)$, but the authors assumed that there exist only three generations of leptons and they did not consider the possibility of the Kobayashi–Maskawa mixing between the lepton generations. In this letter we answer the question of the influence of the next generation of fermions with heavy charged lepton on the magnetic moment of the electron (muon, tau) neutrino. We assumed the Kobayashi–Maskawa mixing between electron (muon, tau) generation and the new one.

We have to use now the full formula for the magnetic moment of the neutrino as presented in [6]. To investigate big charged lepton masses we did not neglect terms of O (m_l^2/M_W^2) where m_l is the mass of the charged lepton of the next generation and M_W is the mass of the charged weak boson. Although the result in [6] is exact up to the one

---

* Work supported in part by the grant CPBP 01.03.

** Address: Zakład Fizyki Teoretycznej, Instytut Fizyki, Uniwersytet Śląski, Uniwersytecka 4, 40-007 Katowice, Poland.

loop corrections, it is useless for the numerical calculations, because of the big cancellations between different terms.

We have obtained an approximate formula in which we have neglected terms $O(m^2/M_W^2)$, where m is the neutrino mass but we have not neglected terms $O(m_l^2/M_W^2)$

$$M_n = -\frac{3mG_F}{8\sqrt{2}\,\pi^2}\sum_l |A_{ln}|\, m_e\{(-2+5b-b^2)/(1-b)^2+2b^2\ln b/(1-b)^3\}\mu_B, \quad (2)$$

where $b = m_l^2/M_W^2$, $\sum_l$ is the sum over charged leptons, A_{ln} is the KM matrix element, m_e is the electron mass.

Using the above formula we have obtained the following numerical results (Table I).

TABLE 1

Dependence of the neutrino magnetic moment on the mixing between generations and the ratio of the fourth generation charged lepton mass and charged boson mass (in units 10^{-19} μ_B $(m_\nu/1\ \mathrm{eV})$)

m_l^2/M_W^2	Mixing parameter $\|A_{ln}\|^2$					
	0.01	0.1	0.2	0.3	0.4	0.5
0.1	3.233	3.511	3.820	4.128	4.437	4.745
0.9	3.230	3.472	3.741	4.011	4.281	4.550
2	3.227	3.450	3.697	3.945	4.192	4.439
3	3.226	3.438	3.674	3.909	4.145	4.381
4	3.225	3.430	3.657	3.885	4.112	4.340
5	3.225	3.424	3.645	3.866	4.088	4.309
6	3.224	3.419	3.635	3.852	4.068	4.285
10	3.222	3.406	4.610	3.814	4.018	4.222
100	3.219	3.373	3.543	3.714	3.884	4.055
1000	3.218	3.364	3.526	3.688	3.850	4.012

We can easily see that there exists a visible influence of the fourth generation, which mixes with the known one and includes heavy charged lepton, on magnetic moments of the neutrinos of the known generations. However, all these changes are not big enough to alter the order of the magnitude of the considered value. Thus we can conclude that if a big (of order 10^{-11} μ_B for example) magnetic moment of the neutrino is measured in the planned experiments [7] we will be able to claim undoubtedly that the GSW model breaks down and we have to look for another gauge group or Higgs sector.

REFERENCES

[1] J. Liu, *Phys. Rev.* **D35**, 3447 (1987); S. N. Biswas, A. Goyal, J. N. Passi, *Phys. Rev.* **D28**, 671 (1983); and references therein.
[2] M. B. Voloshin, M. I. Vysotskii, *Yad. Fiz.* **44**, 845 (1986); L. B. Okun, *Yad. Fiz.* **44**, 847 (1986).
[3] A. O. Barut, M. Bozic, Trieste preprint IC/87/158.
[4] B. W. Lee, R. E. Shrock, *Phys. Rev.* **D16**, 1444 (1977).
[5] M. Aquilar-Benitez et al., *Phys. Lett.* **170B**, 1 (1986).
[6] H. Czyż, K. Kołodziej, M. Zrałek, *Acta Phys. Pol.* **B18**, 127 (1987).
[7] D. B. Cline, Wisconsin preprint WISC-EX-86-283.