

Dipole moments of the tau-neutrino from the process $e^+e^- \rightarrow \nu\bar{\nu}\gamma$

M. A. Hernández-Ruíz^{a,b}, A. Gutiérrez-Rodríguez^c, C. P. Castañeda-Almanza^c, A. Espinoza-Garrido^c, A. Chubykalo^c

^aFacultad de Ciencias Químicas, Universidad Autónoma de Zacatecas, Apartado Postal 585, 98060 Zacatecas, Zac. México.

^bInstituto de Física, Universidad Autónoma de San Luis Potosí, Álvaro Obregón 64, Zona Centro, San Luis Potosí, S.L.P. 78000, México.

^cFacultad de Física, Universidad Autónoma de Zacatecas Apartado Postal C-580, 98060 Zacatecas, Zac. México.

Abstract

In the framework of a Simplest Little Higgs Model (SLHM), we calculate the total cross section for the reaction $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ and thereafter we get a limit on the characteristic energy scale of the model f , $f \geq 5.5 \text{ TeV}$, which in turn induces bounds on the anomalous Magnetic Moment (MM) and the Electric Dipole Moment (EDM) of the tau-neutrino. We consider initial-state radiation, and neglect W and photon exchange diagrams. The results are based on the data reported by the L3 Collaboration at LEP, and compare favorably with the limits obtained in other models, complementing previous studies on the dipole moments.

Keywords: Non-standard-model neutrinos, Electric and Magnetic Moments, Neutral Currents, Models beyond the standard model.

1. Introduction

In the Standard Model (SM) extended to contain right-handed neutrinos, the neutrino Magnetic Moment (MM) induced by radiative corrections is unobservable small, $\mu_\nu \sim 3 \times 10^{-19} (m_\nu/1 \text{ eV})$. Similarly, a neutrino Electric Dipole Moment (EDM) will point also to new physics and they will be of relevance in astrophysics and cosmology, as well as terrestrial neutrino experiments.

However, in order to improve the limits on the MM and the EDM of the tau-neutrino, in our calculation to the process $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ we consider initial-state radiation, in this way the bounds on the dipole moments are stronger than those evaluated in previous studies by other authors.

At higher s , near the Z_1 pole $s \approx M_{Z_1}^2$, the dominant contribution involves the exchange of a Z_1 boson. The dependence on the magnetic moment (μ_{ν_τ}) and the electric dipole moment (d_{ν_τ}) now comes from the radiation of the photon observed by the neutrino or antineutrino in the final state. We emphasize here the importance of the final state radiation near the Z_1 pole of a very energetic photon as compared to conventional Bremsstrahlung.

Our aim in the present work is to analyze the reaction $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ in the framework of the Simplest Little Higgs Model (SLHM) and we attribute an anomalous MM and an EDM to a massive tau-neutrino. This process serve to set limits on the tau-neutrino MM and EDM. First, using as an input the results obtained by the L3 collaboration [1] for the tau MM and EDM in the process $e^+e^- \rightarrow \nu\bar{\nu}\gamma$, we will set a limit on the SLHM energy scale f which is similar to that obtained through oblique corrections [2], as well as that obtained recently from the Z_1 leptonic decay. We then use this limit on f to get bounds on the electromagnetic dipole moments of the ν_τ . In this study, we take advantage of this fact to set limits on μ_{ν_τ} and d_{ν_τ} for various values of the characteristic energy scale f of the SLHM.

2. Cross Section of $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ in the Simplest Little Higgs Model

We calculate the total cross section for the reaction $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ using the neutral current lagrangian Refs. [3, 4] for the SLHM. A characteristic interesting from

Table 1: Limits on the μ_{ν_τ} magnetic moment and d_{ν_τ} electric dipole moment at 95% C. L. for different values of the characteristic energy scale of the model f . We have applied the cuts used by L3 for the photon angle and energy.

$f(\text{TeV})$	$\mu_{\nu_\tau}(10^{-6}\mu_B)$	$d_{\nu_\tau}(10^{-17}\text{e cm})$
1.5	[-2.550, 2.647]	[-4.918, 5.106]
5.2	[-2.688, 2.704]	[-5.185, 5.216]
5.6	[-2.690, 2.705]	[-5.189, 5.217]
7	[-2.694, 2.706]	[-5.196, 5.219]
10	[-2.698, 2.708]	[-5.204, 5.223]

this model is that is independent of the mass of the additional Z_2 heavy gauge boson and so we have the characteristic energy scale of the model f as the only additional parameter.

The MM, EDM and the characteristic energy scale of the simplest little Higgs model f give a contribution to the total cross section for the process $e^+e^- \rightarrow \nu\bar{\nu}\gamma$.

3. Results and Conclusions

In order to evaluate the integral of the total cross section as a function of the parameters of the simplest little Higgs model, that is to say, f , we require cuts on the photon angle and energy to avoid divergences when the integral is evaluated at the important intervals of each experiment.

The values obtained for this limit for several values of the f parameter are show in Table 1. So the previous analysis and comments can readily be translated to the EDM of the τ -neutrino with $\mu_{\nu_\tau} = 0$. The resulting limits for the EDM as a function of f also are shown in Table 1. The results obtained are in agreement with the literature [1, 5, 6, 7].

To see the dependence of the cross section $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ on the parameters f and μ_{ν_τ} , we plot the total cross section in Fig. 1 for the bounds of the scale of energy f and the magnetic moment μ_{ν_τ} given in Table 1. We can see that the cross section decreases as f increases. The surface also demonstrate that the effect of the SLHM to the cross section $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ is proportional to a factor of $1/f^2$. In Fig. 2 we summarize the respective limit contours for the dipole moments at the 95% C.L. in the $\mu_{\nu_\tau} - d_{\nu_\tau}$ plane for a characteristic energy scale of the model of 5.2 and 5.6 TeV.

In summary, we conclude that the estimated limits for the tau-neutrino magnetic and electric dipole moments in the context of a little Higgs model compare favorably

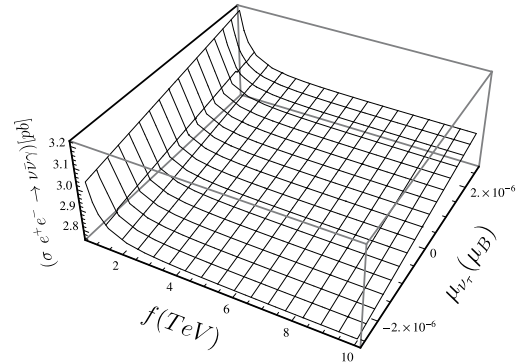


Figure 1: The total cross section for $e^+e^- \rightarrow \nu\bar{\nu}\gamma$ as a function of f and μ_{ν_τ} (Table 1).

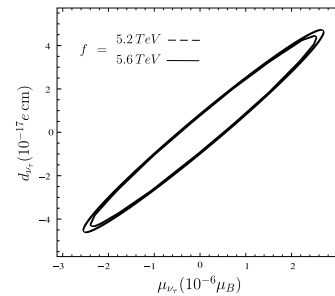


Figure 2: Limits contours at the 95% C.L. in the $\mu_{\nu_\tau} - d_{\nu_\tau}$ plane for $e^+e^- \rightarrow \nu\bar{\nu}\gamma$. The solid curves and the dashed curves are respectively for $f = 5.6 \text{ TeV}$ and $f = 5.2 \text{ TeV}$. We have used the cuts on the photon angle and energy from 44.5° to 135.5° and E_γ from 15 GeV to 100 GeV.

with the limits obtained by the L3 Collaboration, and complement previous studies on the dipole moments. In the limit $f \rightarrow \infty$ our limits takes the value previously reported in Ref. [5] for the SM. On the other hand, it seems that in order to improve these limits it might be necessary to study direct CP-violating effects. In addition, the analytical and numerical results for the total cross section have never been reported in the literature before and could be of some practical use for the scientific community.

References

- [1] L3 Collab. M. Acciarri, et al., *Phys. Lett.* **B412**, 201 (1997).
- [2] G. Marandella, C. Schappacher, A. Strumia, *Phys. Rev.* **D72**, 035014 (2005).
- [3] Alex G. Dias, et al., *Phys. Rev.* **D77**, 055001 (2008).
- [4] A. Gutiérrez-Rodríguez, *Mod. Phys. Lett.* **A25**, 703 (2010).
- [5] T. M. Gould and I. Z. Rothstein, *Phys. Lett.* **B333**, 545 (1994).
- [6] A. Gutiérrez, M. A. Hernández, M. Maya and A. Rosado *Phys. Rev.* **D58**, 117302 (1998).
- [7] A. Gutiérrez-Rodríguez, M. A. Hernández-Ruíz and A. Del Rio-De Santiago, *Phys. Rev.* **D69**, 073008 (2004).