Sensitivity on the electromagnetic dipole moments of theτ-lepton at the CLIC

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Abstract

We established model independent bounds on the anomalous magnetic and electric dipole moments of the tau-lepton using the two-photon process $\gamma\gamma\to\tau^+\tau^-$ and, $\mathcal{L}$=10,50,100,300,500,1000,1500,2000,3000fb^{-1} of data collected with the future e^+e^- linear collider as the CLIC at $\sqrt{s}$=380,1500,3000 GeV and we consider systematic uncertainties ofδ_{sys} =0,3,5%. Precise bounds at 95% C. L. on the anomalous dipole moments to the tau-lepton $-0.00012\le a_\tau \le 0.00014$ and$|d_\tau(ecm)|=7.445\times 10^{-19}$ are set from our study. Our results show that the processes under consideration are a very good prospect for probing the dipole moments of the tau-lepton at the future e^+e^- linear collider at the$\gamma\gamma$ mode.

1 Introduction

In this work, using $\gamma\gamma\to\tau^+\tau^-$ reaction, we established model-independent sensitivity estimates on the dipole moments of the tau-lepton and, we improve the existing bounds on a_τ and d_τ. An interesting feature of these reactions is that they are extremely clean process because it has not interference with weak interactions, being a purely process of Quantum Electrodynamics (QED). Furthermore, the high center-of-mass energies proposed for the Compact Linear Collider (CLIC) makes of it an appropriate machine to probing the anomalous magnetic (MM) and electric dipole (EDM) moments which are more sensitive with the high energy and high luminosity of the collider.

2 Two-photon process $\gamma\gamma\to\tau^+\tau^-$

The model independent bounds on the electromagnetic dipole moments of theτ-lepton. The Feynman diagrams for this processes is given in Fig. 1

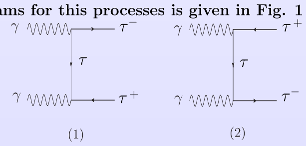

Figure 1: The Feynman diagrams for the process$\gamma\gamma\to\tau^+\tau^-$.

In order to determine the sensitivity on the MM and EDM of the τ-lepton, we calculate the total cross section of the reaction $\gamma\gamma\to\tau^+\tau^-$. The most general parametrization for the electromagnetic current between on-shellτ-lepton and the photon is given by [1]

$$\Gamma^\alpha_\tau = eF_1(q^2)\gamma^\alpha + \frac{ie}{2m_\tau}F_2(q^2)\sigma^{\alpha\mu}q_\mu + \frac{e}{2m_\tau}F_3(q^2)\sigma^{\alpha\mu}q_\mu\gamma_5 + eF_4(q^2)\gamma_5(\gamma^\alpha - \frac{2q^\alpha m_\tau}{q^2}), \quad (1)$$

where$e$is the charge of the electron,m_τ is the mass of theτ-lepton,$\sigma^{\alpha\mu}=\frac{i}{2}[\gamma^\alpha,\gamma^\mu]$represents the spin 1/2 angular momentum tensor and $q=p'-p$ is the momentum transfer. In the static (classical) limit the q^2-dependent form factors$F_{1,2,3,4}(q^2)$have interpretations for $q^2=0$: $F_2(0)=a_\tau$ its anomalous MM and $F_3(0)=\frac{2m_\tau}{e}d_\tau$ withd_τ its EDM.

The most promising mechanism to generate energetic photon beams in a linear collider is Compton backscattering. Compton backscattered photons interact with each other and generate the process $\gamma\gamma\to\tau^+\tau^-$. The spectrum of Compton backscattered photons is given by

$$f_\gamma(y) = \frac{1}{g(\zeta)}[1-y+\frac{1}{1-y} - \frac{4y}{\zeta(1-y)} + \frac{4y^2}{\zeta^2(1-y)^2}], \quad (2)$$

where

$$g(\zeta) = (1-\frac{4}{\zeta}-\frac{8}{\zeta^2})\log(\zeta+1) + \frac{1}{2} + \frac{8}{\zeta} - \frac{1}{2(\zeta+1)^2}, \quad (3)$$

with

$$y=\frac{E_\gamma}{E_e}, \quad \zeta=\frac{4E_0E_e}{M_e^2}, \quad y_{max}=\frac{\zeta}{1+\zeta}. \quad (4)$$

Here, E_0 and E_e are energy of the incoming laser photon and initial energy of the electron beam before Compton backscattering andE_γ is the energy of the backscattered photon. The maximum value of$y$ reaches 0.83 when$\zeta=4.8$.

The total cross section is given by,

$$\sigma = \int f_\gamma(x) f_\gamma(x) d\hat{\sigma} dE_1 dE_2. \quad (5)$$

2.1 Sensitivity on the $\tilde{a}_\tau$ and $\tilde{d}_\tau$ through $\gamma\gamma\to\tau^+\tau^-$ at the CLIC

For our numerical analysis of the total cross section $\sigma_{NP}(\gamma\gamma\to\tau^+\tau^-=)\sigma_{NP}(\sqrt{s},\kappa,\tilde{\kappa})$, and of the electromagnetic dipole moments of the τ-lepton, the free parameters are the center-of-mass energy $\sqrt{s}$, the integrated luminosity $\mathcal{L}$ of the CLIC, and the factors $\kappa$and $\tilde{\kappa}$. We Use theχ^2 funcion [2, 3, 4, 5]:

$$\chi^2 = \left(\frac{\sigma_{SM} - \sigma_{NP}(\sqrt{s},\kappa,\tilde{\kappa})}{\sigma_{SM}\delta}\right)^2, \quad (6)$$

where$\sigma_{NP}(\sqrt{s},\kappa,\tilde{\kappa})$is the total cross section including contributions from the SM and new physics, $\delta=\sqrt{(\delta_{st})^2+(\delta_{sys})^2}$,$\delta_{st}=\frac{1}{\sqrt{N_{SM}}}$ is the statistical error, δ_{sys} is the systematic error and N_{SM} is the number of signal expected events $N_{SM}=\mathcal{L}_{int}\times BR\times\sigma_{SM}$ where$\mathcal{L}_{int}$ is the integrated CLIC luminosity.

With all these elements taken into consideration, we made and presented a set of figures, which illustrate our results.

3 Results and Conclusion

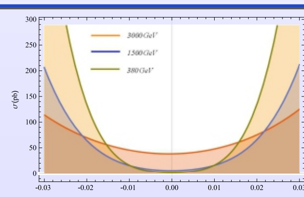

Figure 2: The total cross sections of the process$\gamma\gamma\to\tau^+\tau^-$ as a function ofF_2 for center-of-mass energies of $\sqrt{s}$= 380,1500,3000GeV.

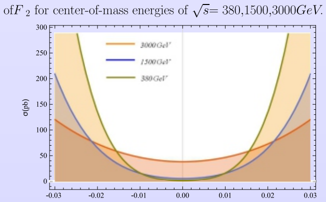

Figure 3: Same as in Fig. 2, but forF_3.

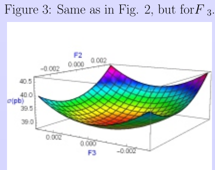

Figure 4: The total cross sections of the process$\gamma\gamma\to\tau^+\tau^-$ as a function ofF_2 andF_3 for center-of-mass energy of $\sqrt{s}$= 380GeV.

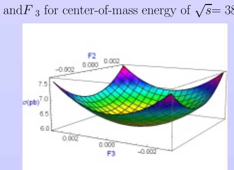

Figure 5: Same as in Fig. 4, but for $\sqrt{s}$= 1500GeV.

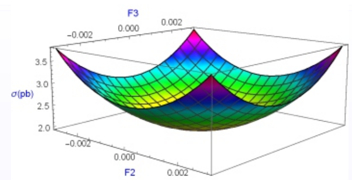

Figure 6: Same as in Fig. 5, but for $\sqrt{s}$= 3000GeV.

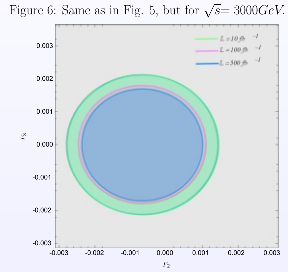

Figure 7: Bounds contours at the 95%$C.L.$in the ($F_2 - F_3$) plane for the process$\gamma\gamma\to\tau^+\tau^-$ with the$\mathcal{L}$= 10,100,500bf^{-1} and for center-of-mass energy of $\sqrt{s}$= 380GeV.

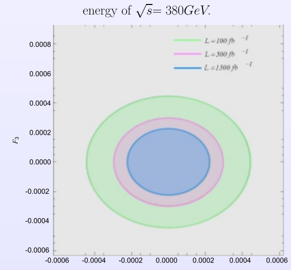

Figure 8: Same as in Fig. 7, but for$\mathcal{L}$= 100,500,1500bf^{-1} and for center-of-mass energy of $\sqrt{s}$= 1500GeV.

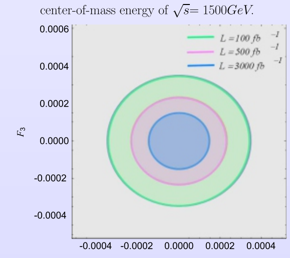

Figure 9: Same as in Fig. 7, but for$\mathcal{L}$= 100,500,3000bf^{-1} and for center-of-mass energy of $\sqrt{s}$= 3000GeV.

In conclusion, we have shown that the two-photon $\gamma\gamma\to\tau^+\tau^-$ process at the CLIC leads to an improvement in the existing sensitivity estimates on the $\tilde{a}_\tau$ and $\tilde{d}_\tau$. We present an optimistic scenario regarding the potencial precision, energy, and luminosity that may be achievable at the future e^+e^- colliders. For the process$\gamma\gamma\to\tau^+\tau^-$ we obtain 3.466×10^2 for the upper sensitivity and 0.764×10^2 for the lower sensitivity, showing an improvement when compared to the results published by the DELPHI and BELLE Collaborations [6, 7].

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