Eur. Phys. J. C (2021) 81:664
https://doi.org/10.1140/epjc/s10052-021-09466-1

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

Probing anomalous quartic $\gamma\gamma\gamma\gamma$ couplings in light-by-light collisions at the CLIC

S.C. İnan[1,a], **A.V. Kisselev**[2,b]

[1] Department of Physics, Sivas Cumhuriyet University, 58140 Sivas, Turkey
[2] Division of Theoretical Physics, A.A. Logunov Institute for High Energy Physics, NRC "Kurchatov Institute", Protvino 142281, Russia

Received: 12 January 2021 / Accepted: 21 July 2021 / Published online: 29 July 2021

Abstract The anomalous quartic neutral couplings of the $\gamma\gamma\gamma\gamma$ vertex in a polarized light-by-light scattering of the Compton backscattered photons at the CLIC are examined. Both differential and total cross sections are calculated for e^+e^- collision energies 1500 GeV and 3000 GeV. The helicity of the initial electron beams is taken to be ± 0.8. The unpolarized and SM cross sections for the same values of helicities are also estimated. The 95% C.L. exclusion limits on two anomalous photon couplings ζ_1 and ζ_2 are calculated. The best bounds on these couplings are found to be 6.85×10^{-16} GeV^{-4} and 1.43×10^{-15} GeV^{-4}, respectively. The results are compared with the exclusion bounds obtained previously for the LHC and HL-LHC. It is shown that the light-by-light scattering at the CLIC, especially the polarized, has a greater potential to search for the anomalous quartic neutral couplings of the $\gamma\gamma\gamma\gamma$ vertex.

1 Introduction

In the Standard Model (SM), the trilinear gauge couplings (TGCs) [1,2] and quartic gauge couplings (QGCs) [3–6] are completely defined by the non-Abelian $SU(2)_L \times U(1)_Y$ gauge symmetry. These couplings have been accurately tested by experiments. A possible deviation from the electroweak predictions can give us important information on probable physics beyond the SM.

Anomalous TGCs and QGCs can be studied in a model independent way in the framework of the effective field theory (EFT) via Lagrangian [7–10]

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{(6)} + \mathcal{L}_{(8)}. \tag{1}$$

The Lagrangian $\mathcal{L}_{(6)}$ contains dimension-6 operators. It generates an anomalous contribution to the TGCs and QGCs. Let us underline that the lowest dimension operators that modify the quartic gauge interactions without exhibiting two or three weak gauge boson vertices are dimension-8. The Lagrangian $\mathcal{L}_{(8)}$ is a sum of dimension-8 genuine operators,

$$\mathcal{L}_{(8)} = \sum_i \frac{c_i}{\Lambda^4} \mathcal{O}_i^{(8)}, \tag{2}$$

where Λ is a mass-dimension scale associated with new physics, and c_i are dimensionless constants. This Lagrangian induces anomalous deviation to the QGCs. It is assumed that the new interaction respects the local $SU(2)_L \times U(1)_Y$ symmetry which is broken spontaneously by the vacuum expectation value of the Higgs field Φ. CP invariance is also imposed. It means that $\mathcal{L}_{(8)}$ is invariant under the full gauge symmetry. As a result, the electroweak gauge bosons can appear in the operators $\mathcal{O}_i^{(8)}$ only from covariant derivatives of the Higgs doublet $D_\mu \Phi$ or from the field strengths $B_{\mu\nu}$, $W^a_{\mu\nu}$.

There are three classes of dimension-8 operators. The first one contains just $D_\mu \Phi$. It leads to non-standard quartic couplings of massive vector bosons, $W^+W^-W^+W^-$, W^+W^-ZZ and $ZZZZ$. The second class contains two $D_\mu \Phi$ and two field strength tensors. The third class has four field strength tensors only. The dimension-8 operators of the last two classes induce the anomalous quartic neutral couplings of the vertices $\gamma\gamma\gamma\gamma$, $\gamma\gamma\gamma Z$, $\gamma\gamma ZZ$, γZZZ, and $ZZZZ$. A complete list of dimension-8 operators which lead to anomalous quartic neutral gauge boson couplings is presented in [11–13]. In particular, the effective Lagrangian of the operators $\mathcal{O}_i^{(8)}$ which contributes to the anomalous quartic couplings of the vertex $\gamma\gamma\gamma\gamma$ looks like

$$\mathcal{L}_{\text{QNGC}} = \frac{c_8}{\Lambda^4} B_{\rho\sigma} B^{\rho\sigma} B_{\mu\nu} B^{\mu\nu} + \frac{c_9}{\Lambda^4} W^a_{\rho\sigma} W^{a\rho\sigma} W^b_{\mu\nu} W^{b\mu\nu} + \frac{c_{10}}{\Lambda^4} W^a_{\rho\sigma} W^{b\rho\sigma} W^a_{\mu\nu} W^{b\mu\nu} + \frac{c_{11}}{\Lambda^4} B_{\rho\sigma} B^{\rho\sigma} W^a_{\mu\nu} W^{a\mu\nu}$$

[a] e-mail: sceminan@cumhuriyet.tr
[b] e-mail: alexandre.kisselev@ihep.ru (corresponding author)