Polarized light-by-light scattering at the CLIC induced by axion-like particles

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Abstract: In this study, light-by-light (LBL) scattering with initial polarized Compton backscattered photons at the CLIC, induced by axion-like particles (ALPs), is investigated. The total cross sections are calculated assuming *CP*-even coupling of the pseudoscalar ALP to photons. The 95% C.L. exclusion region for the ALP mass m_a and its coupling constant f is presented. The results are compared with CLIC bounds previously obtained for the unpolarized case. It is shown that the bounds on f for the polarized beams in the region $m_a = 1000-2000$ GeV with collision energy of 3000 GeV and integrated luminosity of 4000 fb^{-1} are on average 1.5 times stronger than the bounds for the unpolarized beams. Moreover, our CLIC bounds are stronger than those for all current exclusion regions for $m_a > 80$ GeV. In particular, they are more restrictive than the limits that follow from the ALP-mediated LBL scattering at the LHC.

Keywords: axion-like particles, light-by-light scattering, polarized beams, CLIC

DOI: 10.1088/1674-1137/abe0be

I. INTRODUCTION

The fine-tuning problem, known as the strong *CP* problem, is one of the open issues of the Standard Model (SM). It can be solved by introducing a spontaneously broken Peccei-Quinn symmetry [1, 2], which involves a light pseudoscalar particle, i.e., the QCD axion [3, 4]. This axion couples to the gluon field strength. Its phenomenology is determined by its low mass and very weak interactions. In particular, it could i) affect cosmology, ii) affect stellar evolution, iii) mediate new long-range forces, and iv) be produced in a terrestrial laboratory. At present, the QCD axion is regarded as a main component of the dark matter [5-7]. The solar axion [8, 9] was proposed to explain the excess in the low-energy electron recoil observed by the XENON1T Collaboration [10], given that its energy spectrum matches the excess.

An axion-like particle (ALP) is a particle having interactions similar to the axion. The origin of ALPs is expected to be similar but without the relationship between its coupling constant and mass. It means that the ALP mass can be treated independently of its couplings to the SM fields. The ALPs emerge in string theory scenarios [11-17], in theories with spontaneously broken symmetries [18, 19], or in the GUT [20]. All these models predict an ALP-photon coupling and, therefore, the electromagnetic decay of the ALPs in two photons. Experimental searches are mainly directed to ALPs to relax the coupling parameter [21].

Heavy ALPs can be detected at colliders in a light-by-light (LBL) scattering [22-27]. It was shown that LHC searches employing the proton tagging technique constrain the ALP masses in the region 0.5 – 2 TeV [25-28]. The current exclusion regions for the axion and ALP searches are shown in Fig. 1. The first evidence of the subprocess $\gamma\gamma \to \gamma\gamma$ was observed by ATLAS Colloboration [29, 30] and CMS Colloboration [31] in high-energy ultra-peripheral PbPb collisions. The phenomenological analysis of the exclusive and diffractive $\gamma\gamma$ production in PbPb scattering at the LHC and FCC was done in [32, 33]. The photon-induced process $pp \to p\gamma\gamma p \to p'\gamma\gamma p'$ at the LHC was studied in [34-36].

We recently investigated the virtual production of ALPs in LBL scattering at the compact linear collider (CLIC) [37, 38] with the initial unpolarized Compton backscattered (CB) photons [39]. The 95% C.L. exclusion regions for the ALP mass m_a and ALP-photon coupling f have been calculated. It turned out that our CLIC

Received 17 November 2020; Accepted 6 January 2021; Published online 4 February 2021

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