Sensitivity to decays of long-lived dark photons at the ILC

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I. INTRODUCTION

Searches for light, weakly coupled particles are an important component of the physics program at present and future colliders. New hidden or dark sectors around the electroweak scale which are weakly coupled to the Standard Model (SM) through mediators are well motivated by numerous theoretical and observational considerations, including naturalness, dark matter, and electroweak baryogenesis. A classic benchmark for a potential vector-boson mediator between the SM and dark sector is the hypothetical dark photon, γ_D, which interacts with the SM through kinematic mixing with the weak hypercharge field B with coupling strength ϵ. The dark sector could also have a dark Higgs boson, h_D, which in the general case will mix with the SM Higgs Boson [1]. This opens up a Higgs portal production mode for dark photons.

Prospects for sensitivity to γ_D and h_D production have mainly focused on prompt, leptonic decays of the γ_D for vector portal γ_D production when the mass of the dark photon is greater than about 1 GeV. For small enough ϵ ($\epsilon \lessapprox 10^{-5}$), the γ_D becomes long-lived, a mode which is accessible if Higgs portal production is also considered [1, 2]. The prospects for detection of long-lived particles produced via the Higgs portal at future linear colliders has been studied for displaced hadronic decays, focusing on CEPC and FCC-ee [3].

In this project, we aim to study the sensitivity for detection of long-lived dark photons at the ILC. Existing work on γ_D and h_D production at the ILC has focused on prompt di-muon decays of γ_D production and indirect constraints from measurements of the Higgs to invisible branching ratio [2, 4]. We aim to add the Higgs portal production mode and use the displaced decays of long-lived γ_D as a benchmark to study the detector performance for detection of displaced decays.

II. QUESTIONS TO STUDY

We plan to focus on the proposed ILC dataset of 2 ab^{-1} at $\sqrt{s} = 250$ GeV. We are interested to use truth-level signal simulation samples to explore the full acceptance available to the ILC detectors. To explore the expected detector performance, we aim to use a benchmark signal sample reconstructed with full simulation of the SiD detector. The nominal SiD vertex detector [5] comprises five barrels closed by four disks one each side, together with three more forward disks further along the beamline on each side. Barrels and disks are instrumented with Silicon pixels with 5 μm or better hit resolution [5]. Comparisons of truth-level acceptance and full simulation with the standard reconstruction will provide a benchmark for the efficiency of the default reconstruction, and potentially identify areas of reconstruction which could be improved for the identification of displaced decays. To complement the expected coverage of the HL-LHC and take advantage of the excellent vertexing of SiD and clean background environment, we will focus on signal scenarios with shorter lifetimes and/or lighter masses [3].

In addition to the potential acceptance and performance of the default reconstruction, it is interesting to study whether the timing constraints of the ILC detectors impose limitations on the detection of long-lived particles with moderate mass [6]. If time permits, we would like to explore potential backgrounds to the identification of a displaced vertex arising from the decay of a long-lived neutral particle, potentially including both physics and machine-induced sources, and analyze handles for the separation of signal and background.

[1] D. Curtin, R. Essig, S. Gori, and J. Shelton, Illuminating Dark Photons with High-Energy Colliders, JHEP **02**, 157, arXiv:1412.0018 [hep-ph].
[2] R. K. e. a. Ellis, *Physics Briefing Book: Input for the European Strategy for Particle Physics Update 2020*, Tech. Rep. arXiv:1910.11775 (Geneva, 2019) 254 p.
[3] S. Alipour-fard, N. Craig, M. Jiang, and S. Koren, Long live the higgs factory: Higgs decays to long-lived particles at future lepton colliders, Chinese Physics C **43**, 053101 (2019).
[4] J. de Blas, , *et al.*, Higgs boson studies at future particle colliders, Journal of High Energy Physics **2020**, 10.1007/jhep01(2020)139 (2020).
[5] H. Abramowicz *et al.*, The International Linear Collider Technical Design Report - Volume 4: Detectors, (2013), arXiv:1306.6329 [physics.ins-det].
[6] K. F. et al, Ilc study questions for snowmass 2021 (2020), arXiv:2007.03650 [hep-ph].

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