Event characterization of dark bosons via exotic Higgs decays with final states of displaced dimuons in high luminosity era of the LHC

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Introduction

Higgs is a key to new physics and can be the portal to BSM including dark matter (DM) particles such as dark vector Z_D and dark Higgs h_D bosons. The sensitivity of the Large Hadron Collider (LHC) to the dominant exotic Higgs decays with a final state of multiple displaced dimuons by 1 – 7500 mm is investigated in this presentation.

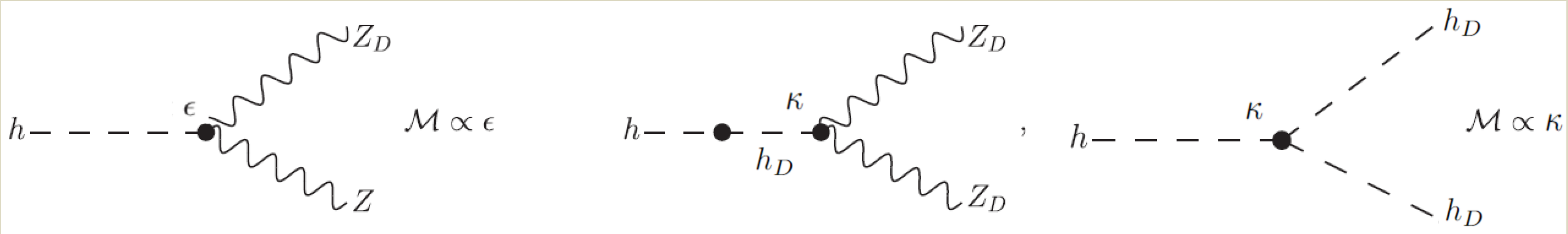

Figure 1: Feynman diagrams for the dominant exotic Higgs decays via the kinetic mixing (left) and Higgs mixing (middle and right).

Keys of acronyms:

SM Higgs boson = h
Dark Higgs boson = s = h_D
Dark vector boson = Z_D
Kinetic mixing parameter = ϵ
Higgs mixing parameter = κ

The current samples are generated by applying Monte Carlo (MC) simulation using the framework of MadGraph5_aMC@NLO v2.7.2 with Hidden Abelian Higgs Model (HAHM) [1].

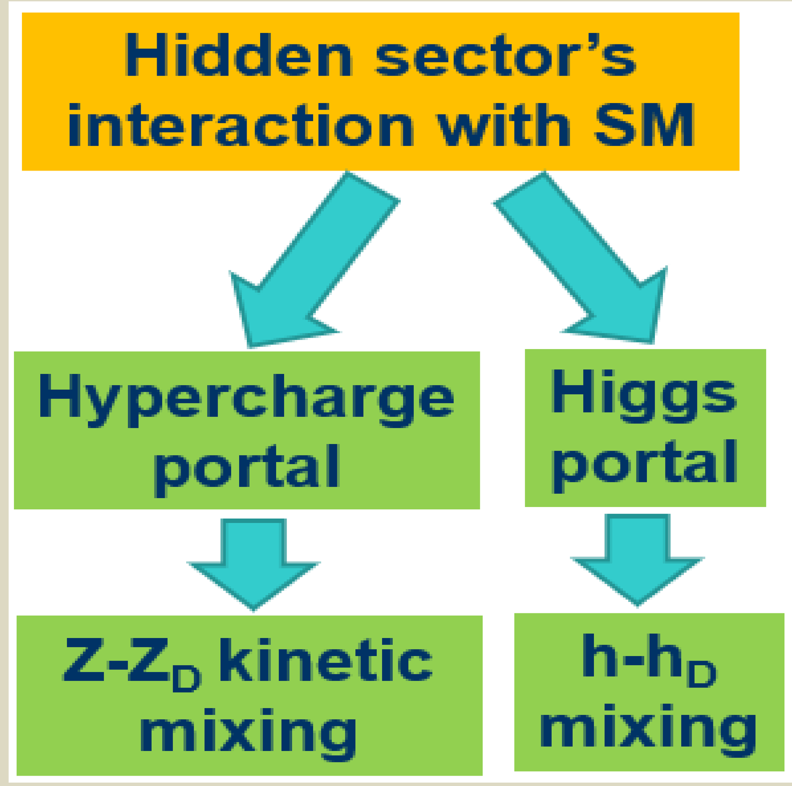

Figure 2: Portals and mixings through which the dark sector can interact with the Standard Model (SM).

Sensitivity of the LHC in Run 2, Run 3, and HL-LHC to various exotic Higgs decays

The SM Higgs with mass of m_h = 125.09 GeV is assumed to be produced at the LHC through the production channels of ggF, VBF, VH (i.e., Wh, Zh, lvh, llh, vvh, tth, and th with a production cross section of 55.88 and 63.06 pb for 13 and 14 TeV, respectively, calculated to either NLO QCD, N^{2}LO QCD, or N^{3}LO QCD combined or not combined with NLO EW depending on the production channel, see Ref. [2]. The top left and top middle panels of Fig. 3 were produced for ggF only in Ref. [3].

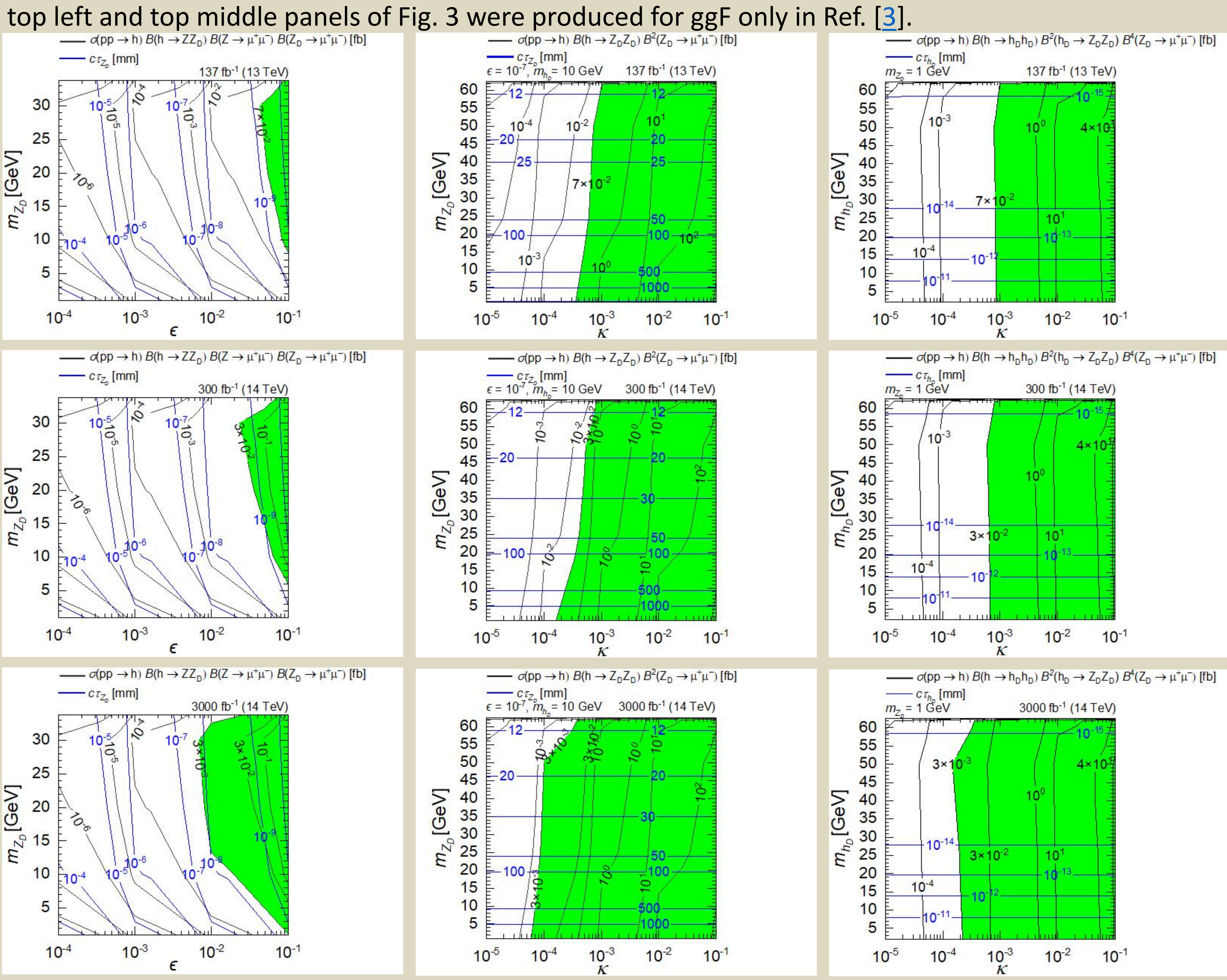

Figure 3: MC simulations showing the contour lines of total cross section (black) and $c\tau_{ZD}$ (or $c\tau_{hD}$) (blue) for the exotic Higgs decays h→ZZ_D→2μ⁺2μ⁻ (left column), h→Z_DZ_D→2μ⁺2μ⁻ (middle column), and h→h_Dh_D→$4Z_D$→4μ⁺4μ⁻ (right column) in a scan over the ϵ-m_{ZD}, the κ-m_{ZD}, and the κ-m_{hD} planes, respectively, for Run 2 (top row), Run 3 (middle row), and HL-LHC (bottom row) of the LHC for which sensitivity regions are shaded in green.

Lifetime of Z_D and impact on the decay width of W boson by the hidden sector via h -> Z_DZ_D

The decay length of Z_D ($c\tau_{ZD}$) is fully described by the scan over the ϵ-m_{ZD} plane and inversely proportional to the 2nd power of ϵ, while a smaller m_{ZD} decays to a fewer number of particles and hence has a narrower decay width and longer $c\tau_{ZD}$ as seen in Fig. 4 (top panel). It is noted that the decay width of W boson (Γ_W) is found to change slightly by ~2% in the scan over the ϵ-m_{ZD} plane where it is maximal for the highest m_{ZD} and largest ϵ, and *vice versa*, see Fig. 4 (bottom panel).

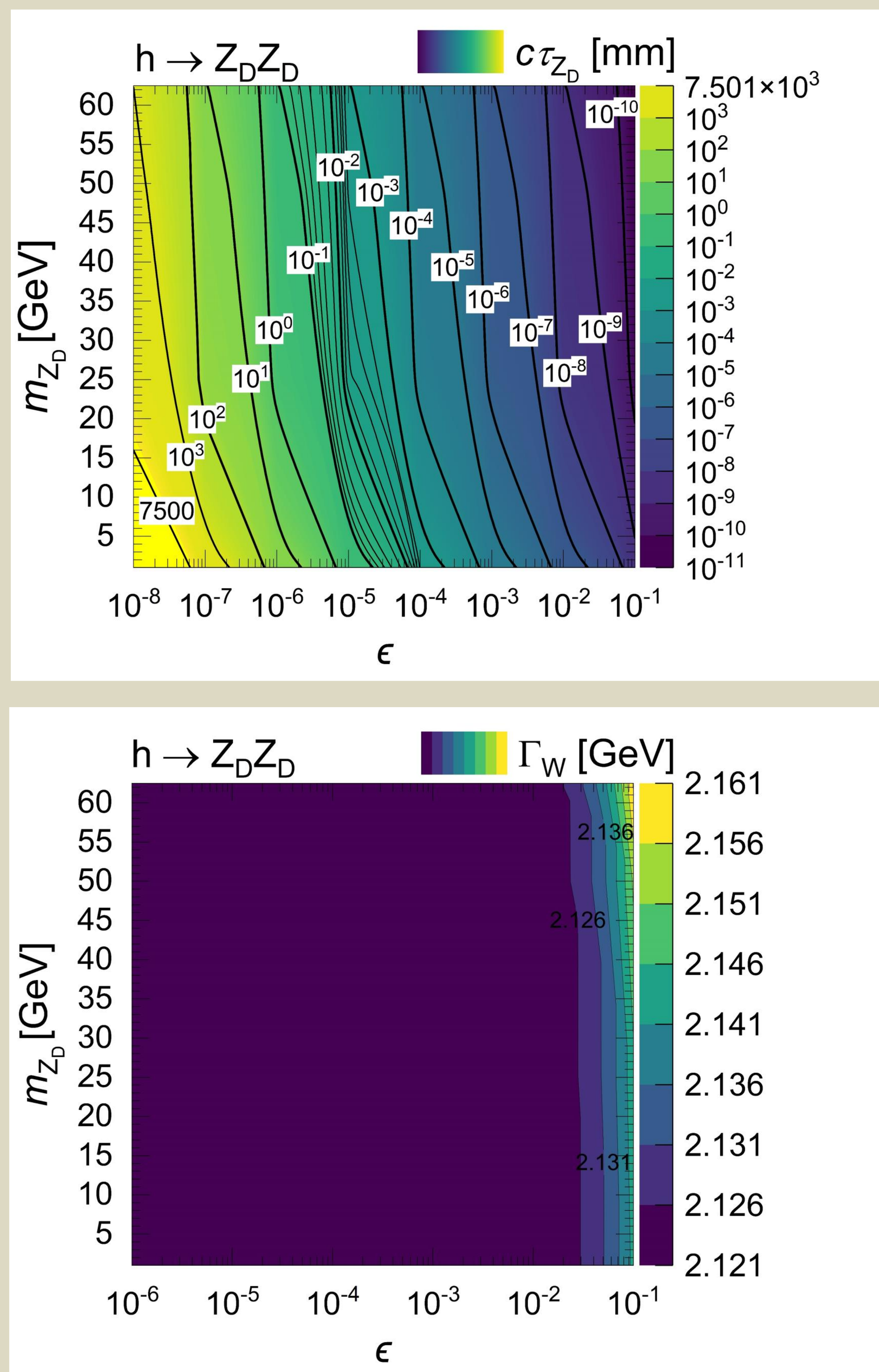

Figure 4: MC simulation of $c\tau_{ZD}$ (top) and Γ_W (bottom) as scanned over the ϵ-m_{ZD} plane for the decay h→Z_DZ_D.

Conclusion

(1) The LHC is found to be more sensitive to the two exotic Higgs decays h→Z_DZ_D→2μ⁺2μ and h→h_Dh_D→$4Z_D$→4μ⁺4μ⁻ (irrespective of the mass acquired by Z_D and h_D, respectively, and of the integrated luminosity) than h→ZZ_D→2μ⁺2μ⁻ through which the LHC is sensitive to certain regions of mass acquired by Z_D based on the integrated luminosity. New constraints on KM and HM parameters are obtained for h→Z_DZ_D→2μ⁺2μ as down to κ = 3.5 × 10⁻⁴ in Run 2, 1.5 × 10⁻⁴ in Run 3, and 6.0 × 10⁻⁵ in HL-LHC. These constraints for h→h_Dh_D→$4Z_D$→4μ⁺4μ⁻ are found to be down to κ = 8.5 × 10⁻⁴ in Run 2, 6.5 × 10⁻⁴ in Run 3, and 2.0 × 10⁻⁴ in HL-LHC. As for h→ZZ_D→2μ⁺2μ , the constraints obtained are down to ϵ = 4.0 × 10⁻² for m_{ZD} range of 8.5 – 33.8 GeV in Run 2, ϵ = 2.0 × 10⁻² for m_{ZD} range of 6.0 – 33.8 GeV in Run 3, and ϵ = 7.0 × 10⁻³ for m_{ZD} range of 1.0 – 33.8 GeV in HL-LHC.

(2) The LHC is found to be sensitive to the production of prompt or long-lived Z_D's (10⁻¹⁰ – 7500 mm depending on ϵ and m_{ZD}) via the decay mode h→Z_DZ_D→2μ⁺2μ⁻, while it is sensitive only to the production of prompt Z_D's (10⁻¹⁰ – 10⁻⁸ mm) and prompt h_D's (10⁻¹⁵ – 10⁻¹⁰ mm) via the decay modes h→ZZ_D→2μ⁺2μ and h→h_Dh_D→$4Z_D$→4μ⁺4μ⁻, respectively.

References

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