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Search for the dark boson through exotic Higgs decays

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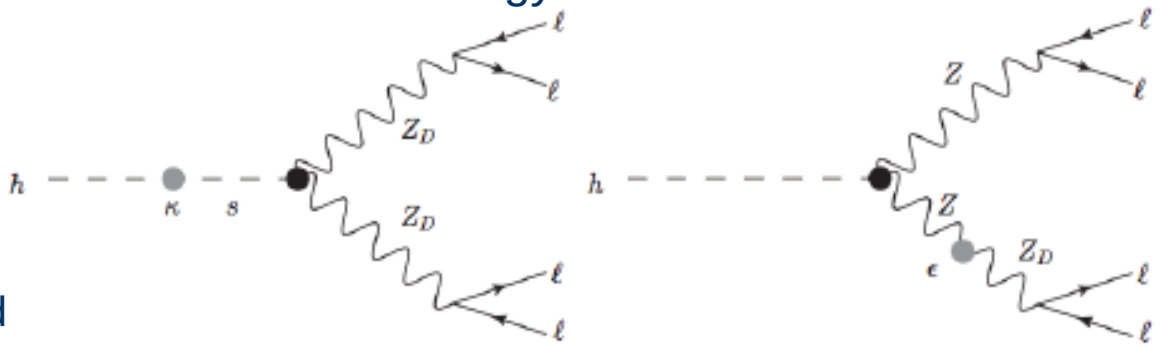
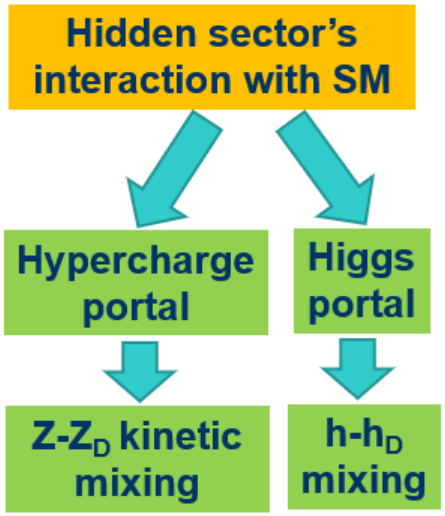
Objective:
The goal of this work is to search for a long-lived dark boson (on-shell) Z_D via the two exotic Higgs decays $h \rightarrow 2Z_D \rightarrow 2\mu^+2\mu^-$ and $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$. We are interested in the final state of two dimuons, displaced by 1–1000 mm.



Feynman diagrams for Higgs boson decay via Higgs mixing mechanism (left) or the kinetic mixing (right) [Ref. 2]



The exotic decay $h \rightarrow 2Z_D$ is induced if Higgs mixing (HM) dominates.

The exotic decay $h \rightarrow ZZ_D$ is induced if kinetic mixing (KM) dominates.

The current samples are generated by applying Monte Carlo simulation using the framework of MadGraph5_aMC@NLO v2.7.0.

Keys of acronyms used in this presentation:

Standard-Model Higgs boson = h
Dark Higgs boson = h_D
Dark boson = Z_D
Kinetic mixing = KM
Higgs mixing = HM
Dominant = ON
Negligible = OFF

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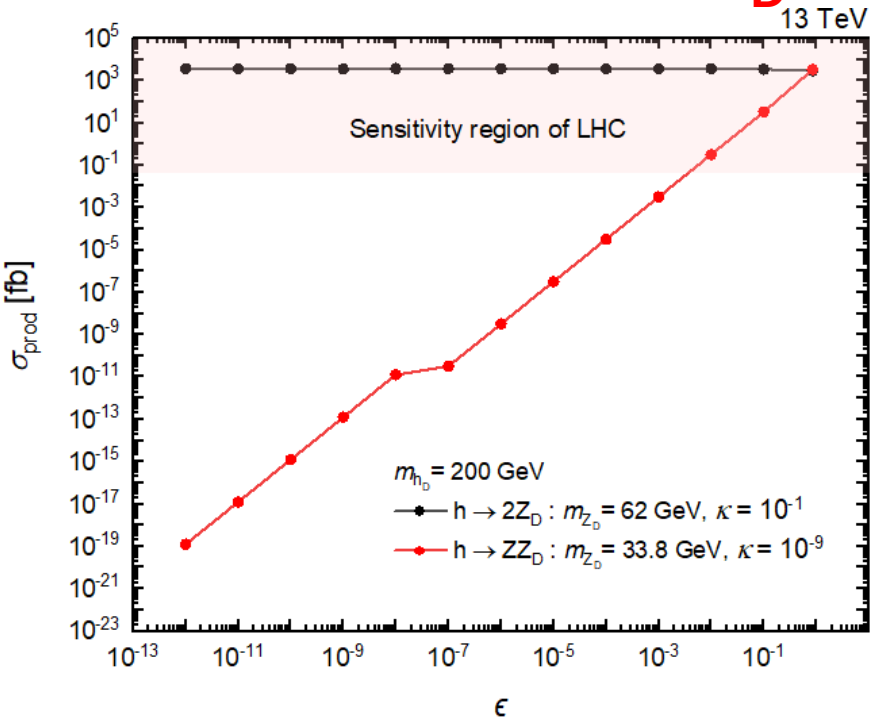
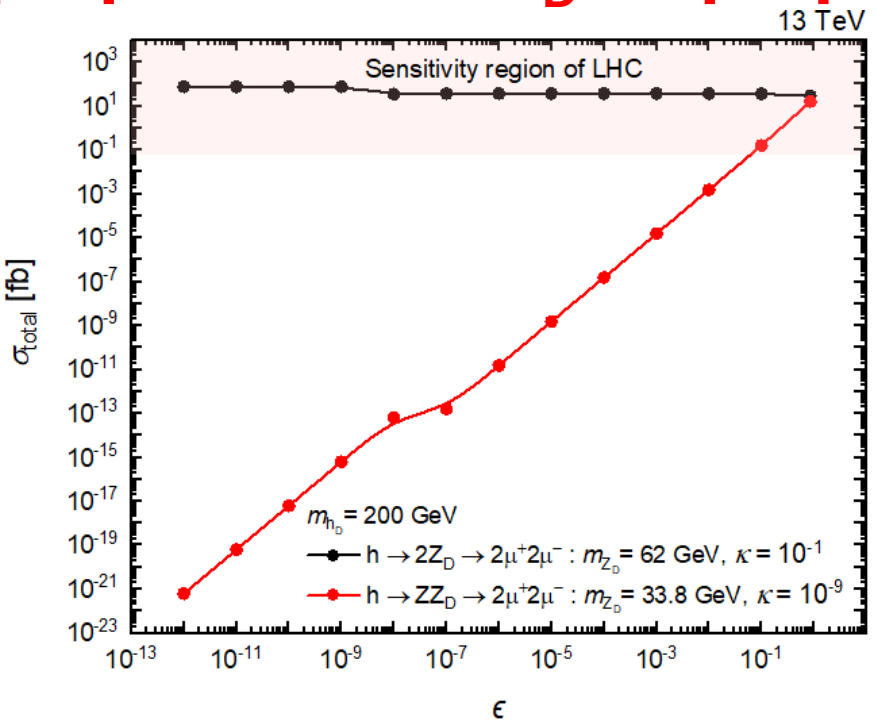
Expected production and total cross sections of Z_D at the LHC for $h \rightarrow 2Z_D \rightarrow 2\mu^+2\mu^-$ and $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$





It is likely that Z_D is produced at the LHC via $h \rightarrow 2Z_D$ for any strength of KM and via $h \rightarrow ZZ_D$ for KM strength $\geq 5 \times 10^{-3}$.

Production cross section of Z_D is highly impacted via $h \rightarrow ZZ_D$ and not impacted via $h \rightarrow 2Z_D$ by the KM strength.

It is likely that Z_D is measured indirectly via $h \rightarrow 2Z_D \rightarrow 2\mu^+2\mu^-$ for any strength of KM and via $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$ for KM strength $\geq 8 \times 10^{-2}$ (an acceptance of 100% is assumed).

Total cross section of Z_D is highly impacted via $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$ and not impacted via $h \rightarrow 2Z_D \rightarrow 2\mu^+2\mu^-$ by the KM strength.

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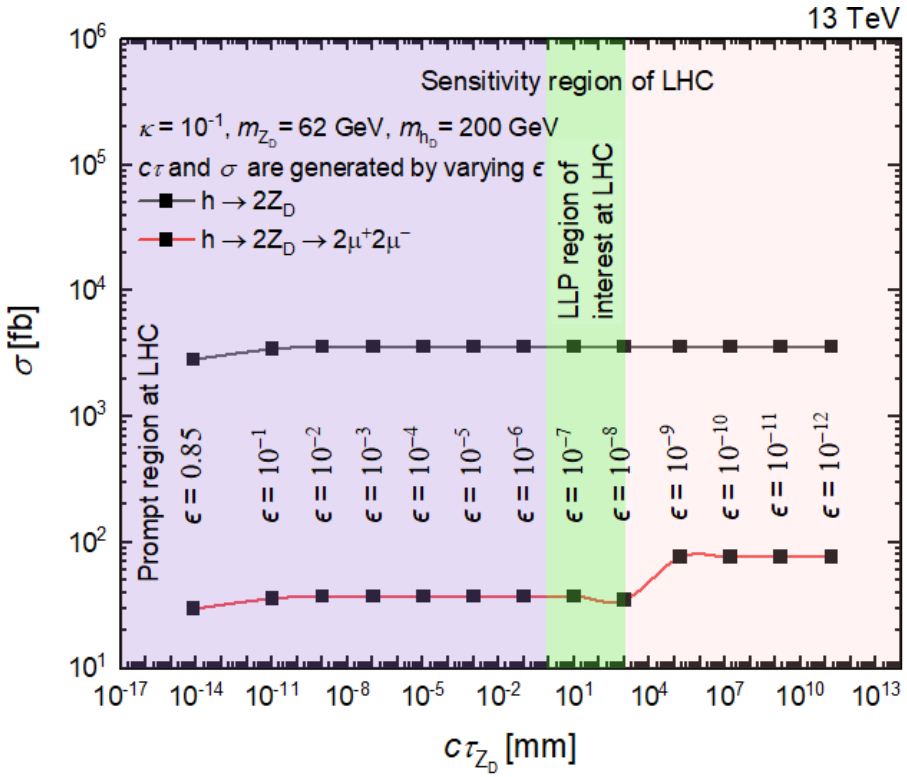
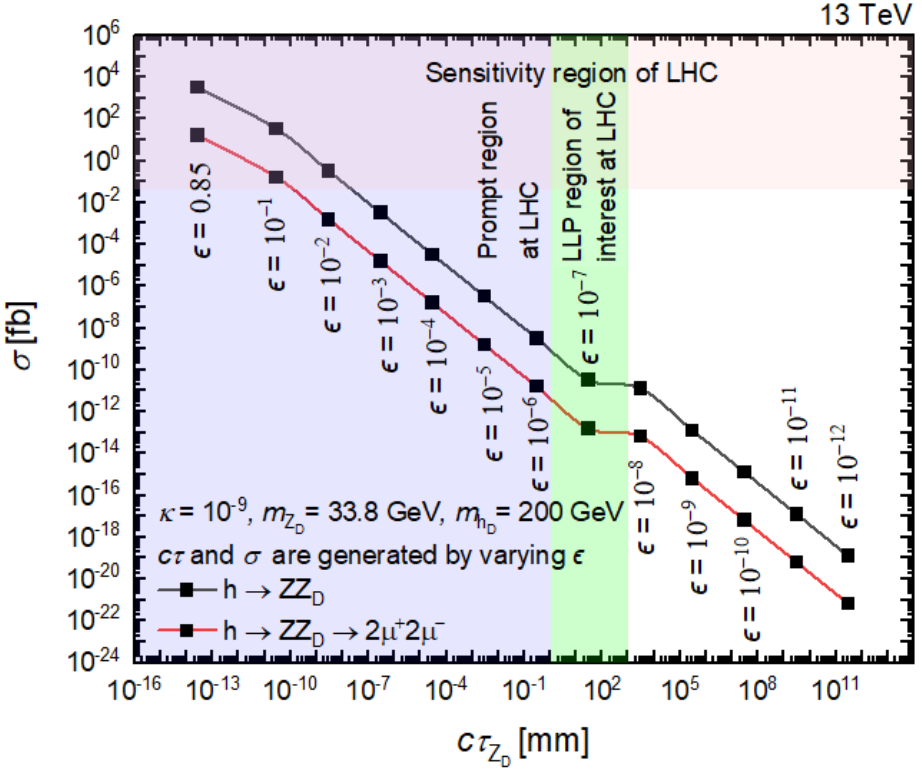
How the expected lifetime and cross section of Z_D change with each for the two exotic decays





Prompt/long-lived Z_D is likely to be produced at the LHC via $h \to 2Z_D$ and measured indirectly via $h \to 2Z_D \to 2\mu^+2\mu^-$ for any KM strength and for dominant HM strength.

Only prompt Z_D is likely to be produced at the LHC via $h \to ZZ_D$ for KM strength $\geq 8\times10^{-3}$ and measured indirectly via $h \to ZZ_D \to 2\mu^+2\mu^-$ at the LHC for KM strength $\geq 10^{-1}$.

References

For the UFO model used to produce the current samples:

1) "Exotic decays of the 125 GeV Higgs boson," David Curtin *et al.*, *Phys. Rev. D* **90**, 075004 (2014) (10.1103/PhysRevD.90.075004).
2) "Illuminating dark photons with high-energy colliders," David Curtin *et al.*, *Journal of High Energy Physics* **2015**, 157 (2015) (10.1007/JHEP02(2015)157).

For the current project:

3) “Study of Higgs and Vector Portals to Dark Matter," Tamer Elkafrawy *et al.,* APS April Meeting, April 17–20, 2021, (https://absuploads.aps.org/presentation.cfm?pid=19067).
4) “Modeling exotic Higgs decays to vector bosons with displaced dimuons in the final states”, T. Elkafrawy and M. Hohlmann, Searching for long-lived particles at the LHC and beyond: Ninth workshop of the LLP Community, May 25–28, 2021. (https://indico.cern.ch/event/980853/timetable/)
5) The current presentation of LHCP2021 can be downloaded from (https://indico.cern.ch/event/905399/contributions/4335593/).