The Ninth Annual Conference on Large Hadron Collider Physics

FLORIDA TECH

Search for the dark boson through exotic Higgs decays

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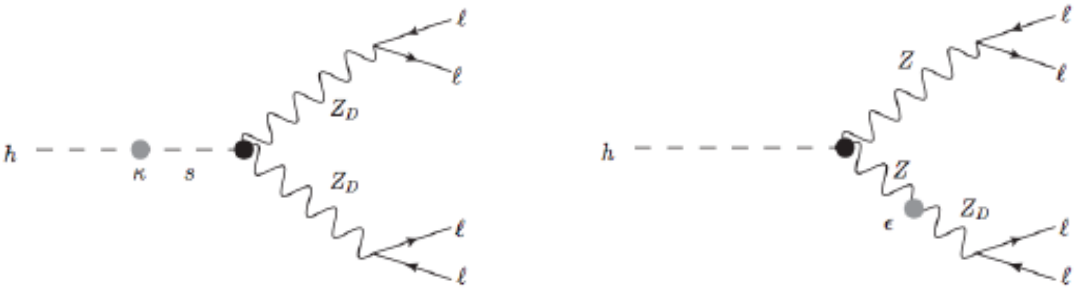
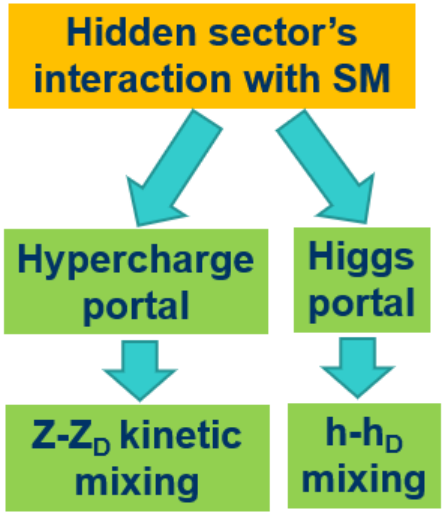
Objective:
The goal of this work is to search for a long-lived dark boson (on-shell) Z_D via the two exotic Higgs decays $h \rightarrow Z_D Z_D \rightarrow 2\mu^+ 2\mu^-$ and $h \rightarrow Z Z_D \rightarrow 2\mu^+ 2\mu^-$. We are interested in the final state of two dimuons, displaced by 1–7500 mm.



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



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

The exotic decay $h \rightarrow Z Z_D$ 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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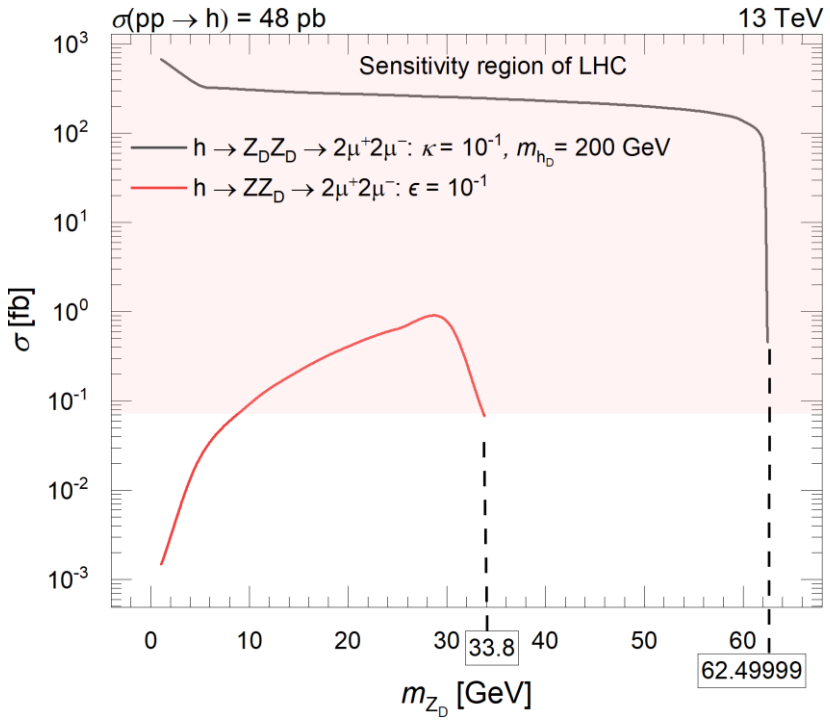
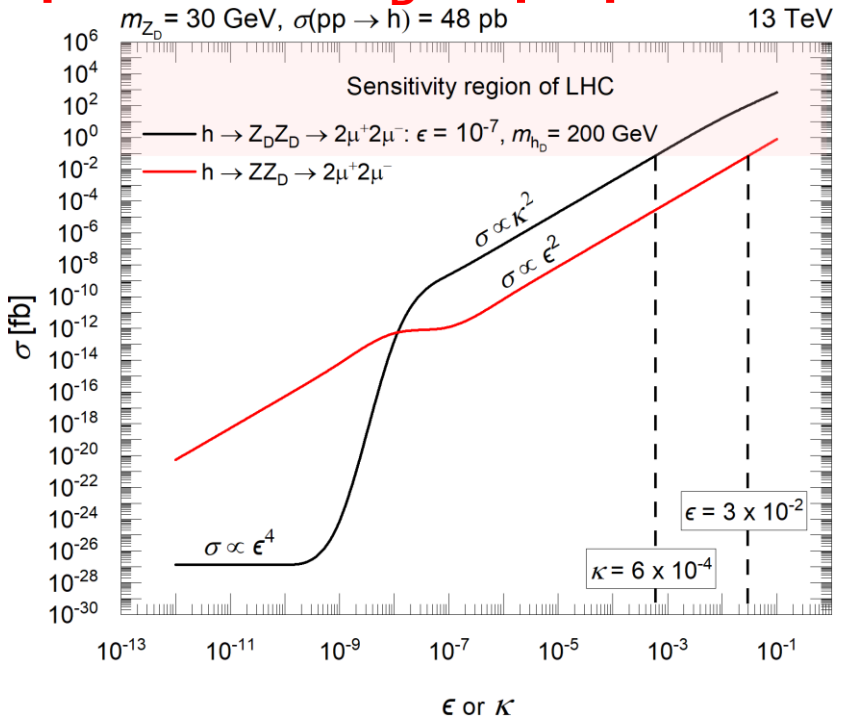
Expected total cross sections of Z_D in the scans of interest for h➔Z_DZ_D➔2μ⁺2μ⁻ and h➔ZZ_D➔2μ⁺2μ⁻





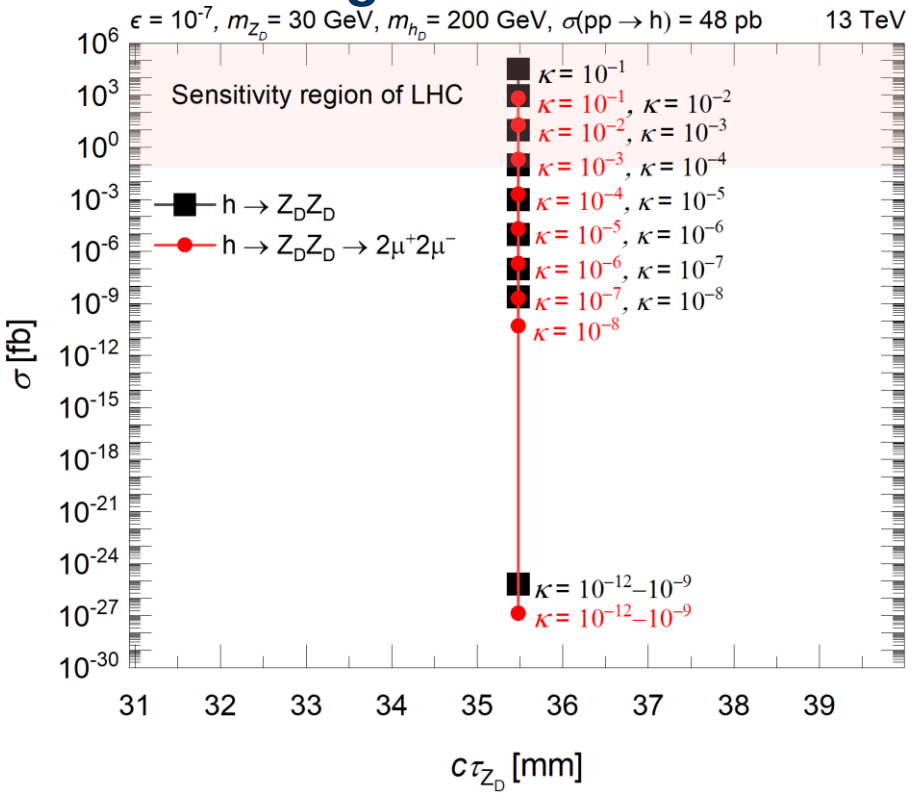
If 0.1 is taken as the highest possible value of ϵ and κ, the LHC in Run 2 is sensitive to measure Z_D indirectly via h➔Z_DZ_D➔2μ⁺2μ⁻ for m_{ZD} in the range of 1 – <62.5 GeV, and via h➔ZZ_D➔2μ⁺2μ⁻ for m_{ZD} > 10 GeV where an acceptance of 100% is assumed.

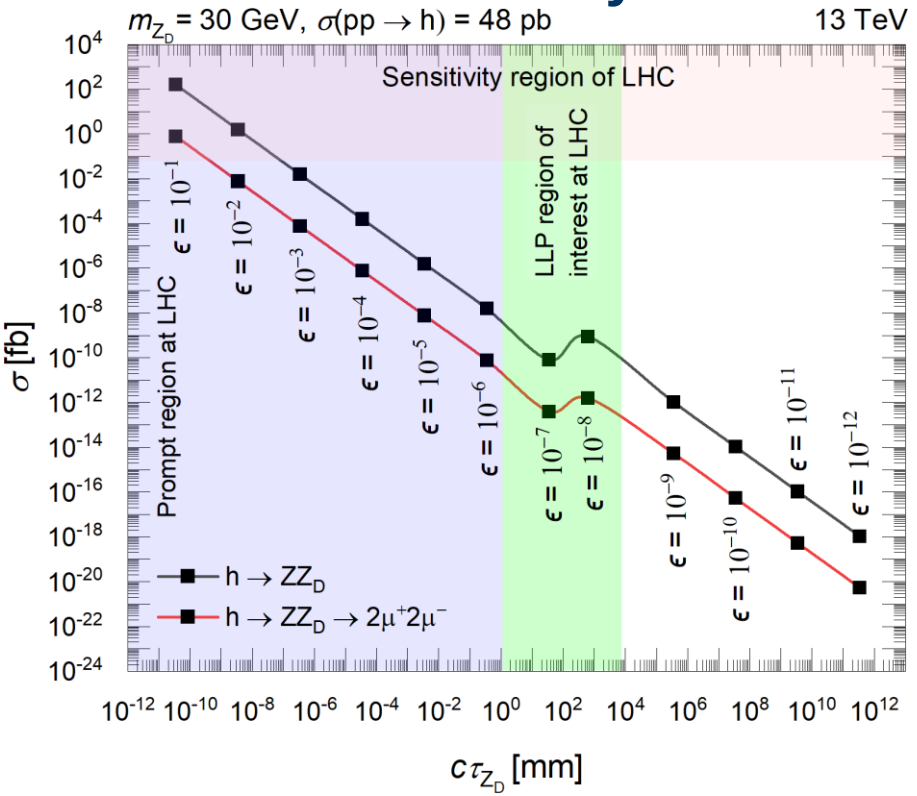
Abrupt decrease of total cross section is seen in the vicinity of the two thresholds of 62.5 and 33.8 GeV for h➔Z_DZ_D➔2μ⁺2μ⁻ and h➔ZZ_D➔2μ⁺2μ⁻, respectively.

If 0.1 is taken as the highest possible value of ϵ and κ and 30 GeV is chosen for m_{ZD}, then Z_D can be measured indirectly at the LHC in Run 2 via h➔Z_DZ_D➔2μ⁺2μ⁻ only if HM is dominant ($k \geq 6\text{x}10^{-4}$) and via h➔ZZ_D➔2μ⁺2μ⁻ only if KM is dominant ($\epsilon \geq 3\text{x}10^{-2}$) where an acceptance of 100% is assumed.

σ(pp➔h) = 48 pb for ggF production channel, calculated to N³LO QCD + NLO EW. The LHC is assumed to be sensitive down to 0.073 fb based on 10 events to be measured for L_{int} = 137 fb⁻¹.

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





LHC is sensitive to the indirect measurement of Z_D if HM is dominant where $k \geq 6\times10^{-4}$ has to be verified.

Lifetime of Z_D is unchanged for all expected production/total cross sections in the scan over HM parameter k in the range of 10^{-12}–10^{-1}. and cτ is tuned mainly by the value of ϵ (here, $\epsilon = 10^{-7}$) and slightly by Z_D mass (here, $m_{ZD} = 30$ GeV).

Only prompt (and not long-lived) Z_D can be measured indirectly via $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$ with a constraint of $\epsilon \geq 3\times10^{-2}$.

$c\tau_{ZD}$ is always inversely proportional to ϵ^2, while production/total cross section of Z_D is directly proportional to ϵ^2, which causes that production/total cross section of Z_D is inversely proportional to $c\tau_{ZD}$.

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/).