Objective:
The goal of this work is to search for a long-lived dark boson \( Z_D \) 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 = \( h_D \)
- Kinetic mixing = \( KM \)
- Dominant = \( ON \)
- Higgs mixing = \( HM \)
- Negligible = \( OFF \)
Scan over the kinetic mixing parameter $\epsilon$

**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 very likely that $Z_D$ is produced at the LHC via $h \rightarrow 2Z_D$ and $h \rightarrow ZZ_D$ for any strength of KM.

Production cross section of $Z_D$ via $h \rightarrow ZZ_D$ is higher by one order of magnitude than that via $h \rightarrow 2Z_D$ for the highest possible mass of $Z_D$ (33.8 GeV for $h \rightarrow ZZ_D$ and 62 GeV for $h \rightarrow 2Z_D$).

It is likely that $Z_D$ is measured indirectly via $h \rightarrow 2Z_D \rightarrow 2\mu^+2\mu^-$ for any strength of KM if HM is ON (an acceptance of 100% is assumed).

For $Z_D$ to be measured indirectly via $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$, the KM strength must be $\geq 10^{-1}$ (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.
How the expected lifetime and cross section of $Z_D$ change with each for the two decay modes

Prompt/long-lived $Z_D$ is very likely to be produced via $h \rightarrow 2Z_D$ and measured indirectly via $h \rightarrow 2Z_D \rightarrow 2\mu^+2\mu^-$ at the LHC if HM is ON.

Cross section of $Z_D$ is not a function of $\tau_{Z_D}$ but rather, they both are impacted by KM strength.

Prompt/long-lived $Z_D$ is very likely to be produced via $h \rightarrow ZZ_D$ at the LHC for any KM strength.

Only prompt $Z_D$ is likely to be measured indirectly via $h \rightarrow ZZ_D \rightarrow 2\mu^+2\mu^-$ at the LHC if KM strength $\geq 10^{-1}$. 

Tamer Elkafrawy – LHCP2021 Conference – June 10, 2021
References

For the UFO model used to produce the current samples:


For the current project:


5) The current presentation of LHCP2021 can be downloaded from (https://indico.cern.ch/event/905399/contributions/4335593/).