Searching for long-lived particles at the LHC: Fifth workshop of the LHC LLP Community

27 May 2019, 09:00 → 29 May 2019, 17:30 Europe/Zurich

Dark photon models in ATLAS

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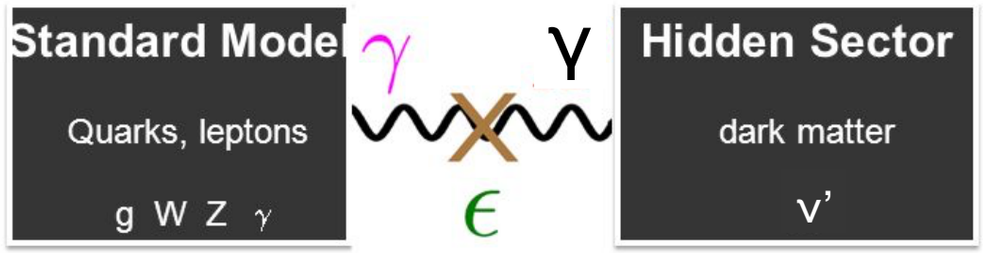
https://arxiv.org/abs/1412.0018

Portals to new physics

Vector portal:
add U(1)' gauge group—> 'dark' boson which mixes with SM photon

kinetic mixing parameter

$$\mathcal{L} \subset -\frac{1}{4}\hat{B}_{\mu\nu}\hat{B}^{\mu\nu} - \frac{1}{4}\hat{Z}_{D\mu\nu}\hat{Z}_D^{\mu\nu} + \frac{1}{2}\frac{\epsilon}{\cos\theta}\hat{Z}_{D\mu\nu}\hat{B}^{\mu\nu} + \frac{1}{2}m_{D,0}^2\hat{Z}_D^{\mu}\hat{Z}_{D\mu}$$



Higgs portal:
Scalar singlet—> spontaneous symmetry breaking of U(1)' and mixing with SM Higgs

$$V_0(H,S) = -\mu^2|H|^2 + \lambda|H|^4 - \mu_S^2|S|^2 + \lambda_S|S|^4 + \kappa|S|^2|H|^2$$

Dark photon

After diagonalising, you have a mostly dark photon ZD mass eigenstate, a mostly Z eigenstate, and two scalars: one mostly SM higgs and one mostly dark higgs

Minimal:

- No charging SM fields under extra U(1)

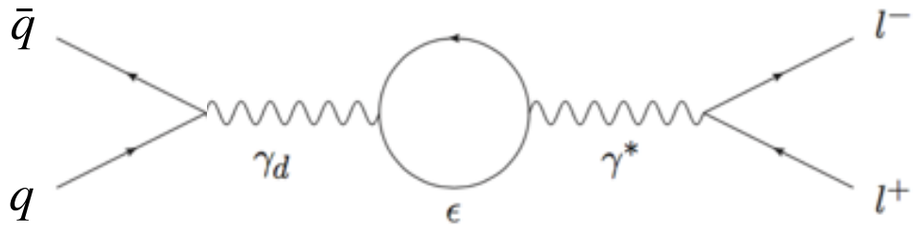
$$J^{\mu}_{Z_D} = 0$$

- Light mediator mass —> dark photon coupling to EM current suppressed by epsilon

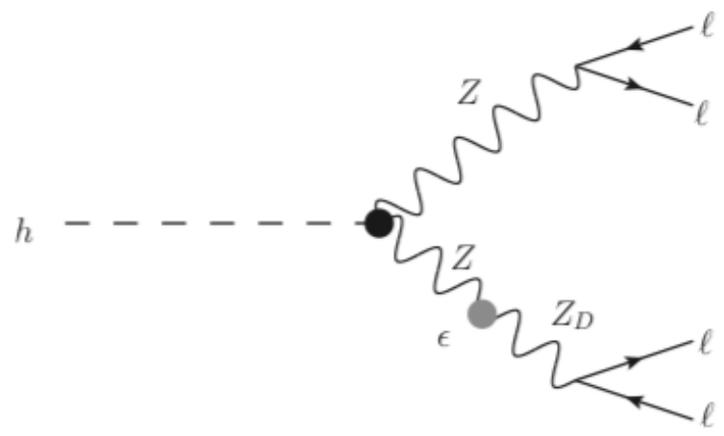
$$M_{Z_D} \ll M_W$$

Production

Vector portal only:
kinetic mixing dominant

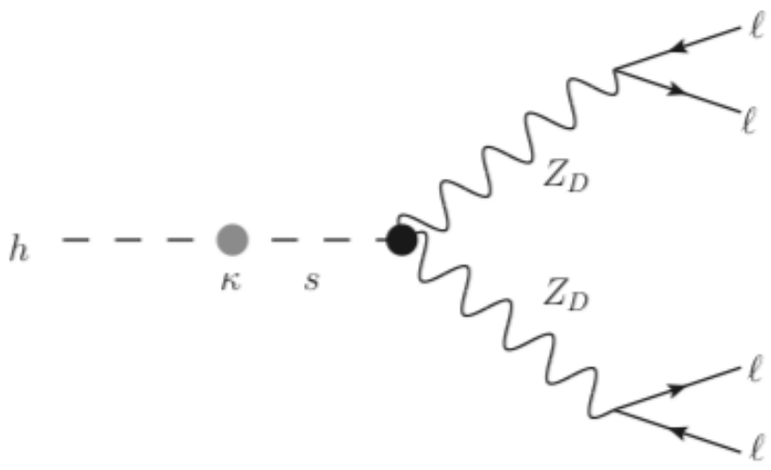


$$pp \to \gamma_d \to 2l$$



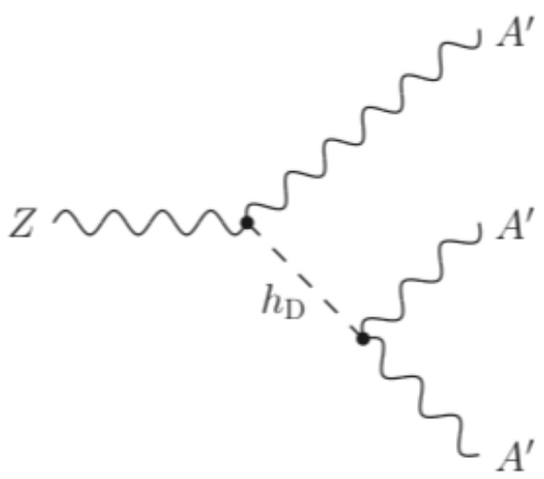
$$pp \to h \to ZZ_d \to 4l$$

Vector portal + Higgs portal:
Higgs mixing dominant

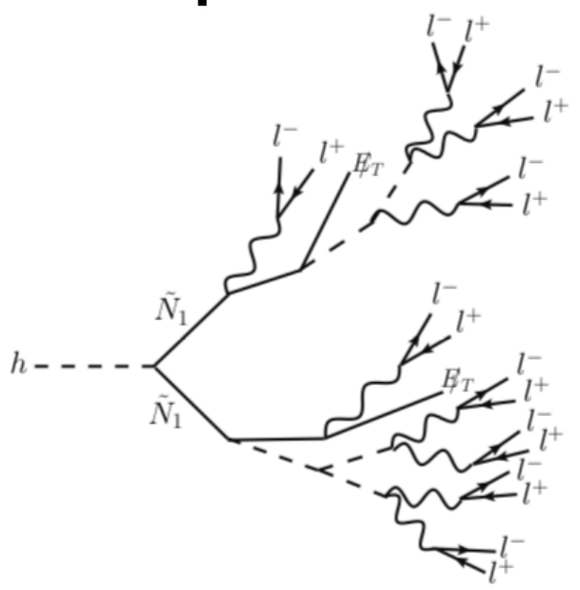


$$pp \to h \to Z_d Z_d \to 4l$$

If Higgs mixing, the 'large' Higgs cross section allows to probe small epsilon events



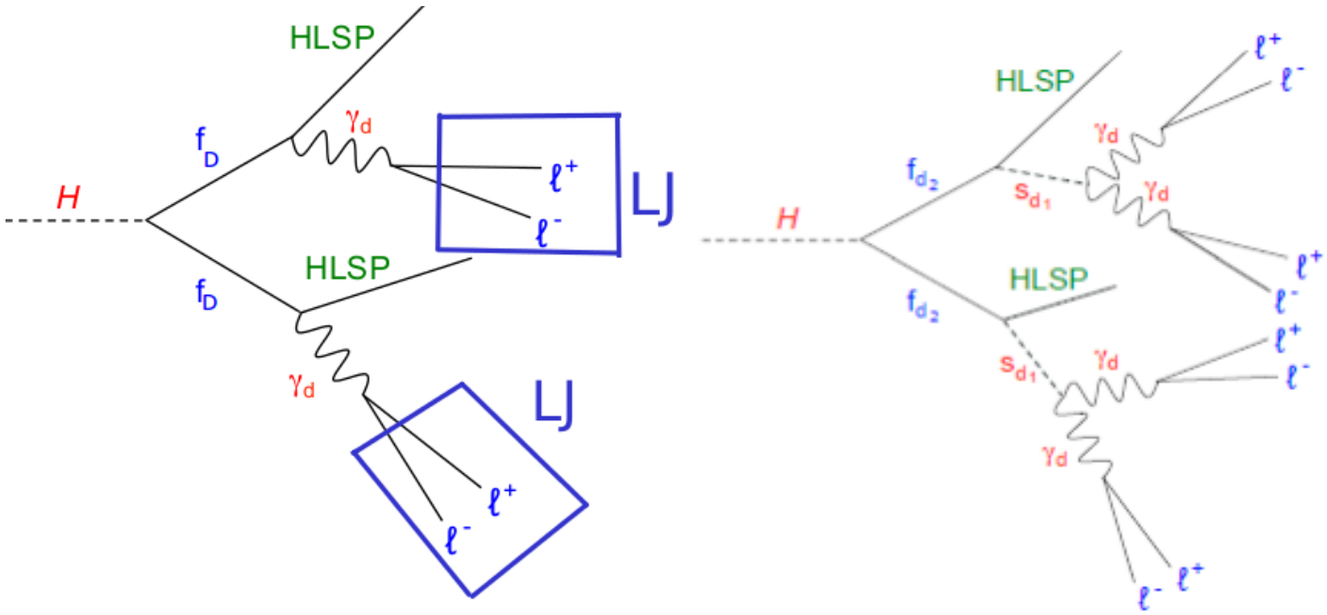
$$pp \to Z \to Z_d h_d \to Z_d Z_d Z_d$$



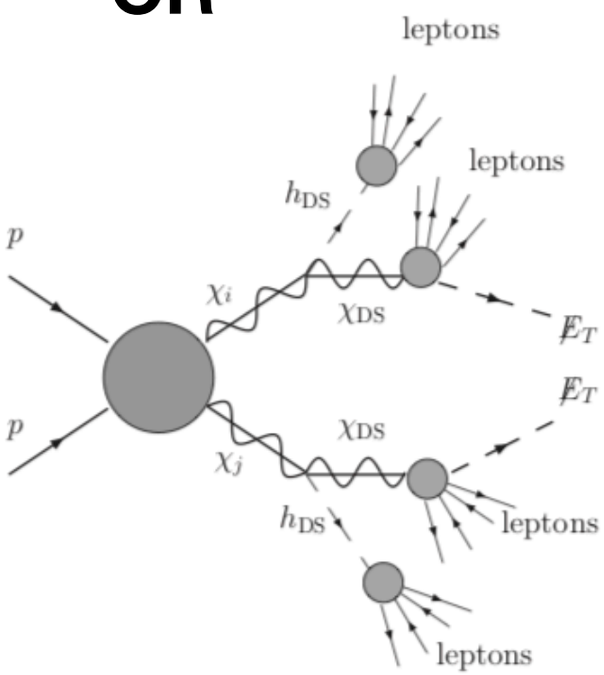
$$pp \to h \to dark\ shower$$

Low-mass models

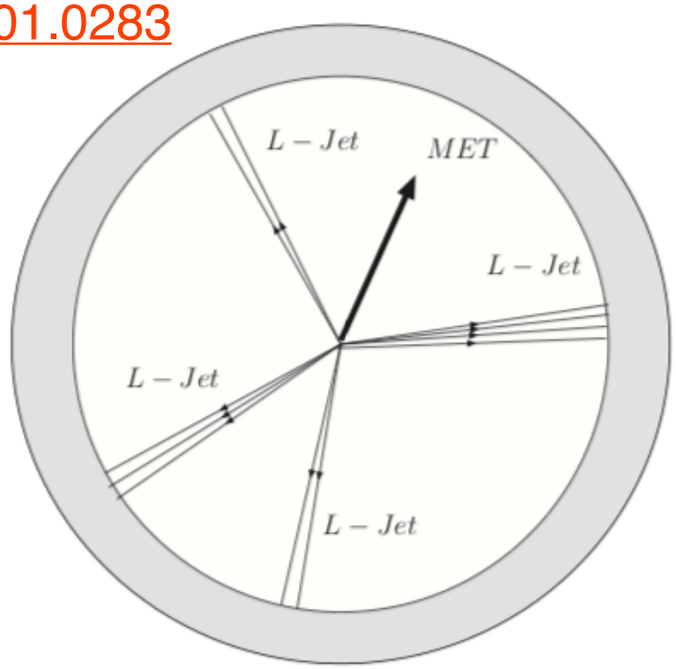
Falkowsky, Ruderman, Volansky, Zupan [FRVZ] arXiv:1002.2952



OR



Dark-SUSY https://arxiv.org/abs/0901.0283



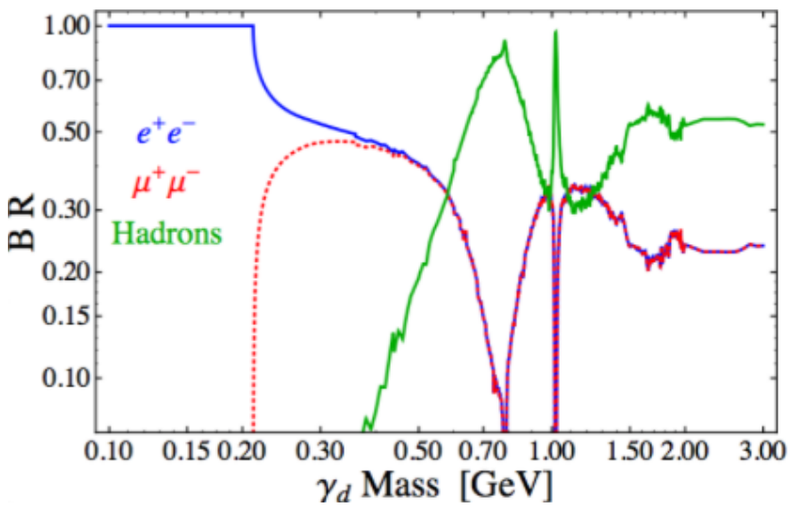
Search:

prompt lepton-jets:
JHEP02(2016)062

displaced lepton-jets:
ATLAS-CONF-2016-042

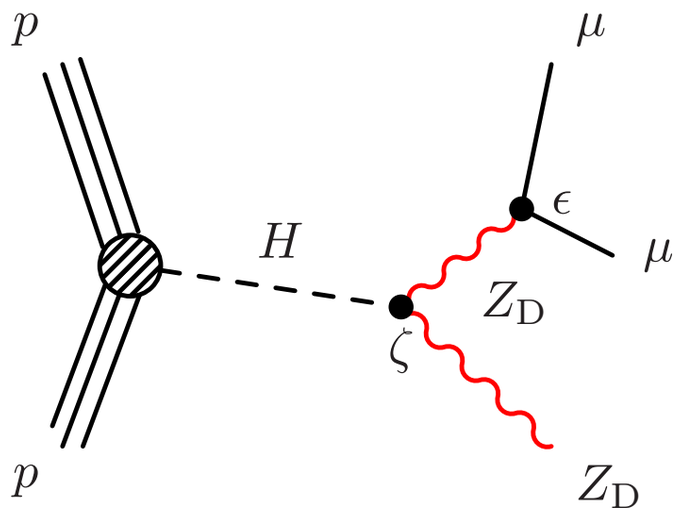
BRs vary with the mass

γ_d **Branching Ratio**



frvz MadGraph

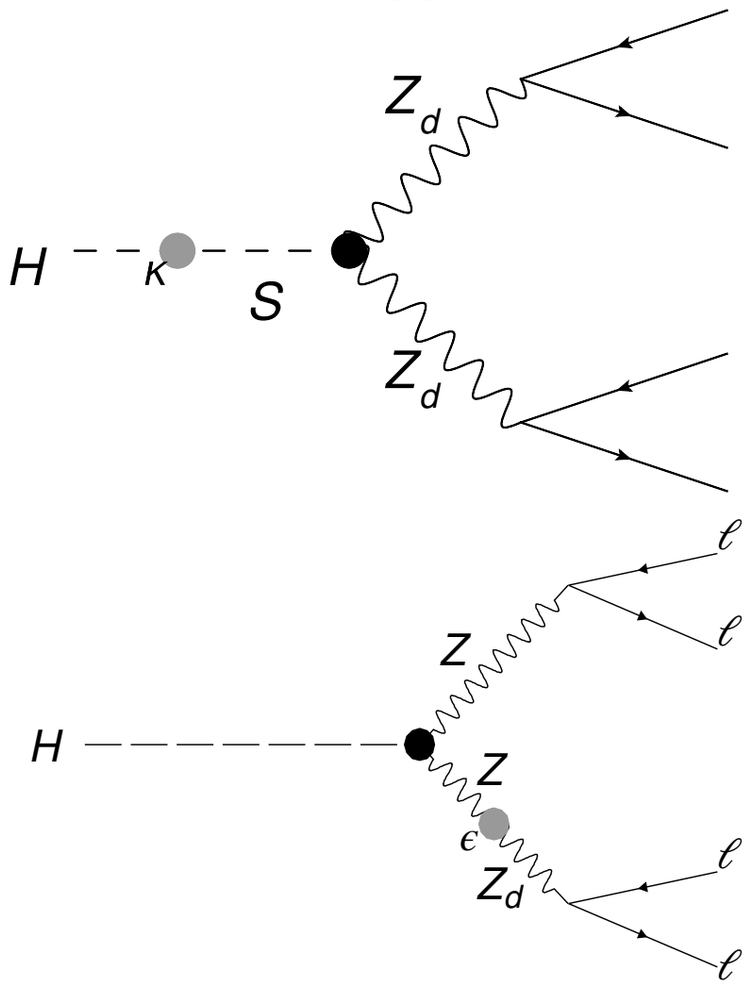
Higher mass models



Search:

Non collimated muons (displaced di-muons): Phys. Rev. D 99, 012001

OR



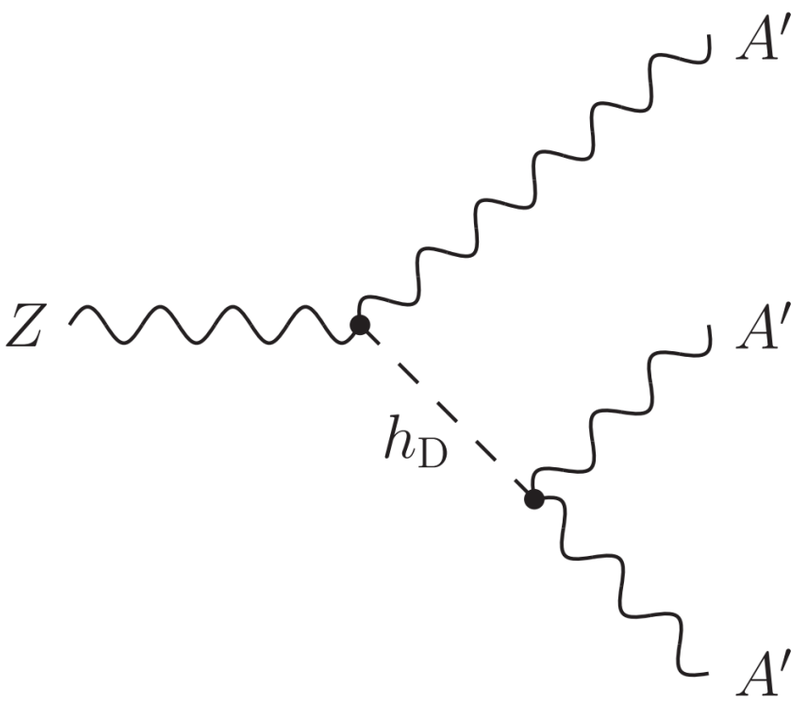
Search:

H to ZdarkZdark or ZZdark search in the 4 leptons final state: JHEP 06 (2018) 166

Both use HAHM MadGraph
—> hahm_mg

Higher mass models II

https://arxiv.org/abs/1710.07635v2



`Search:`

Z to Zdark and Hdark search in 4 leptons + ff: New entry!

`Modified HAHM MadGraph`

Full on shell decay: $m_{h_D} > 2m_{A'}$

$$pp \to Z \to A'h_D \to A'A'A'$$

Partially on shell decay: $m_{A'} < m_{h_D} < 2m_{A'}$

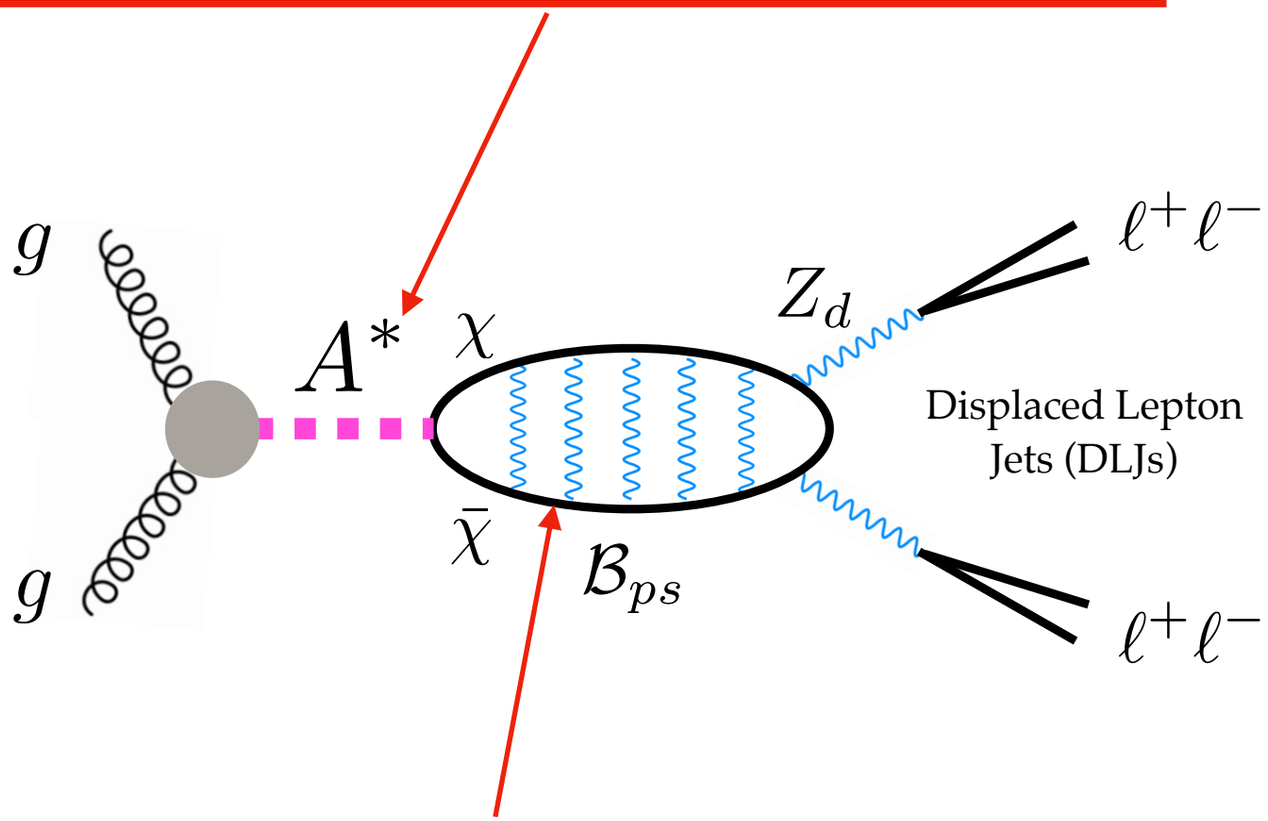
$$pp \to Z \to A'h_D \to A'A'f\bar{f}$$

siDM model

self-interacting DM

1811.05999

Heavy pseudo-scalar mediator (off shell)



Dark Fermion bound state

`Search:`

back-to-back dLJs with invariant mass = 2DM mass

New search in ATLAS, parameters to focus on:

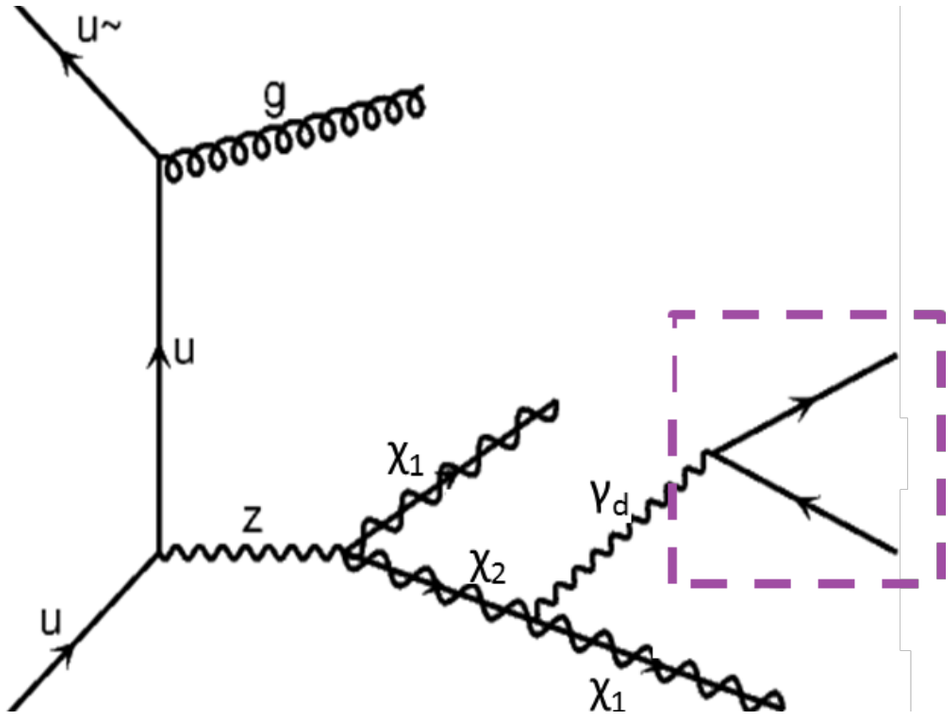
- **bound state mass > 100 GeV**
- **dark photon mass ~ 10-300 MeV**
- **epsilon ~ 10^{-5}-10^{-4}**

`siDM MadGraph`

iDM model

inelastic dark matter

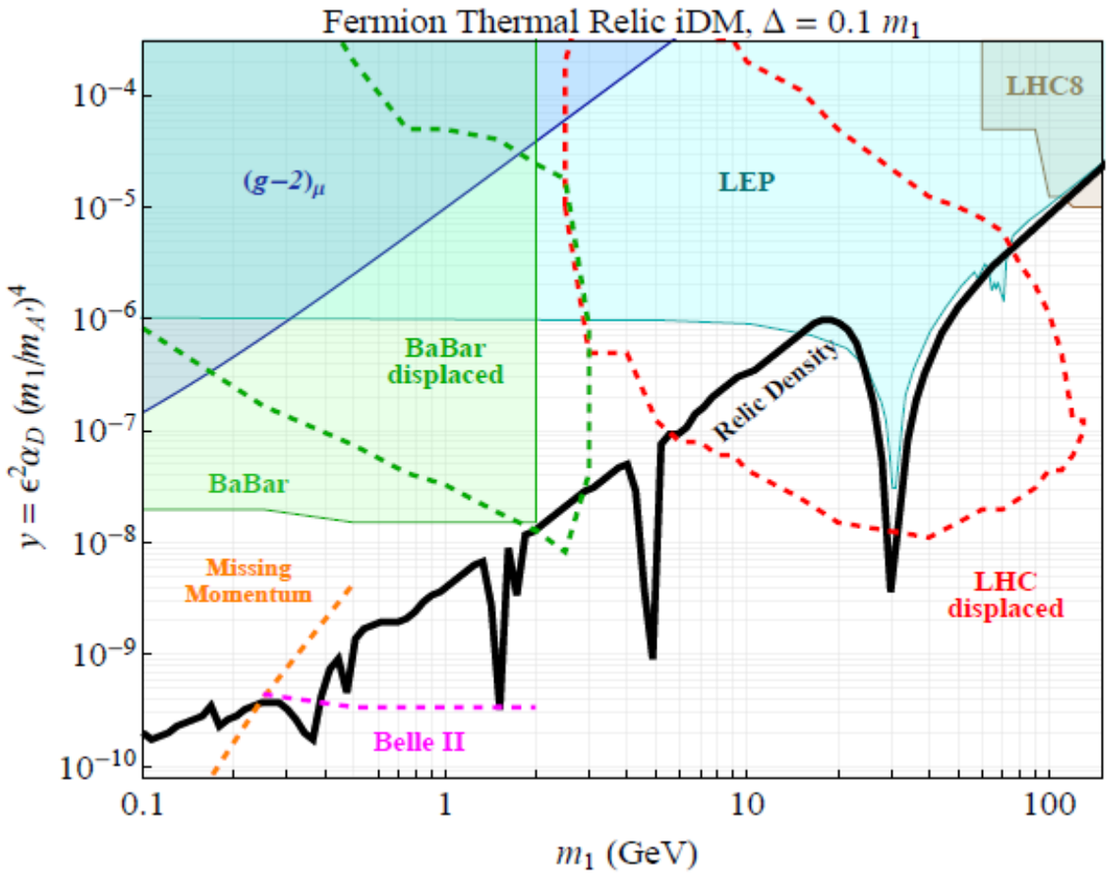
arXiv:1508.03050



DM fermion, mass eigenstates with dominantly off-diagonal interactions

Search:

Only one LJ (+ prompt jet)

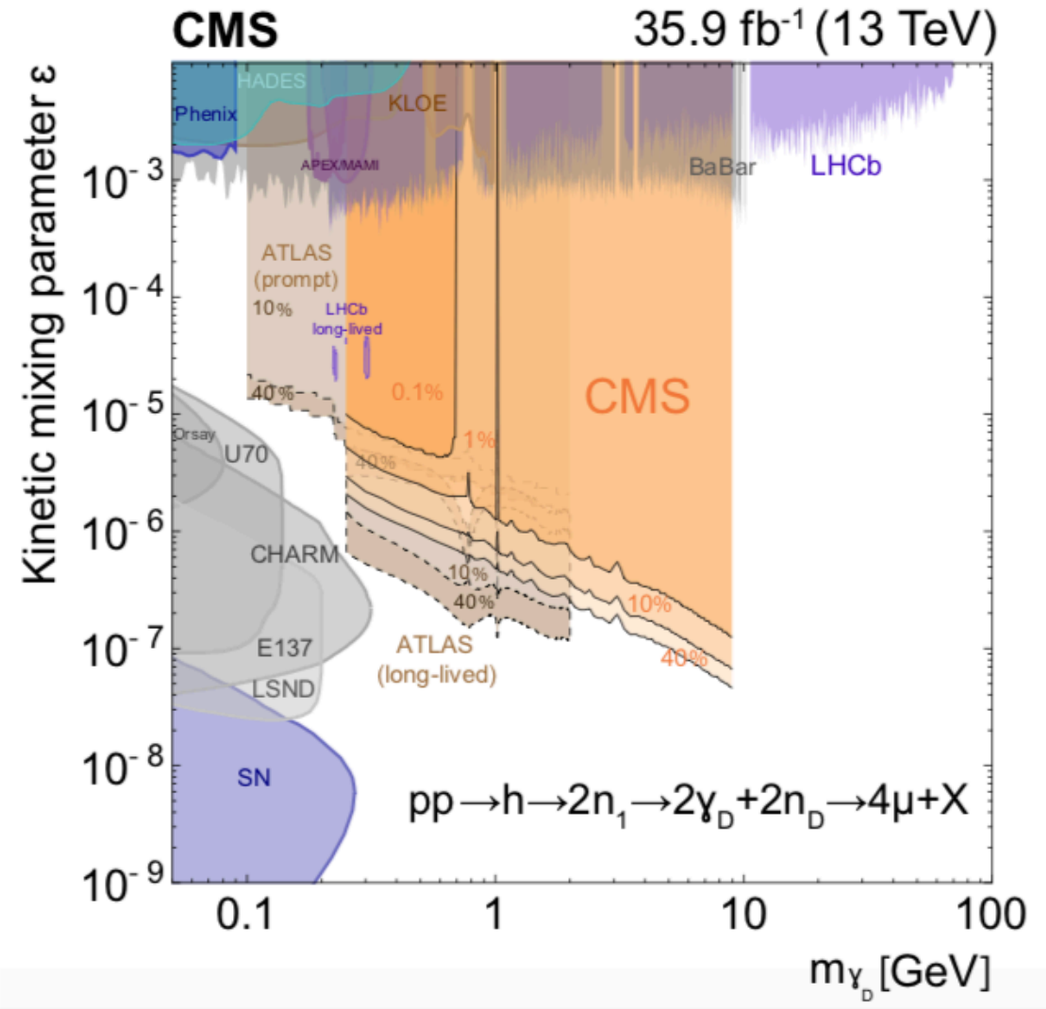


iDM MadGraph

Discussion

- **ATLAS and CMS are most sensitive to models with Higgs mediated production of dark photons: a possible common benchmark should reflect this**

- **Sensitivity to pure vector portal production only via DY processes, good sensitivity only for prompt decays and intermediate dark photon masses (above few GeV)**

- **Most of the analyses so far based on HAHM simplified models**

- **Would be possible to pick a common benchmark to put next to our currently used models?**