Dark photon models in ATLAS

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Portals to new physics

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

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

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 $Z_D$ 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)

$$J_{Z_D}^\mu = 0$$

- Light mediator mass $\rightarrow$ dark photon coupling to EM current suppressed by epsilon

$$M_{Z_D} \ll M_W$$
Vector portal only: kinetic mixing dominant

$$pp \rightarrow \gamma_d \rightarrow 2l$$

Vector portal + Higgs portal: Higgs mixing dominant

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

$$pp \rightarrow h \rightarrow ZZ_d \rightarrow 4l$$

$$pp \rightarrow h \rightarrow Z_d Z_d \rightarrow 4l$$

$$pp \rightarrow Z \rightarrow Z_d h_d \rightarrow Z_d Z_d Z_d$$

$$pp \rightarrow h \rightarrow \text{dark shower}$$
Low-mass models

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

Search:

prompt lepton-jets:
JHEP02(2016)062

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

BRs vary with the mass

Dark-SUSY https://arxiv.org/abs/0901.0283
Higher mass models

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

OR

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: \( m_{h_D} > 2m_{A'} \)

\[ pp \rightarrow Z \rightarrow A'h_D \rightarrow A'A'A' \]

Partially on shell decay: \( m_{A'} < m_{h_D} < 2m_{A'} \)

\[ pp \rightarrow Z \rightarrow A'h_D \rightarrow A'A'f\bar{f} \]
choose some benchmark parameters of

• DM mass
• dark photon mass
• dark photon coupling to SM fermions

and study the production cross section at the LHC (relating to internal parameters: A mass & couplings, DM-dark photon coupling…)

Parameters to consider?

New search in ATLAS, parameters to focus on:
• bound state mass > 100 GeV
• dark photon mass ~ 10-300 MeV
• epsilon ~ 10^{-5}-10^{-4}

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

Search:
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?