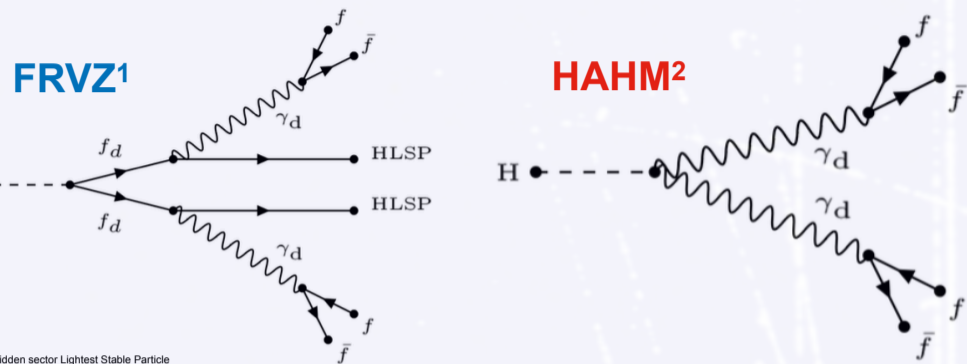


# Search for light long-lived neutral particles that decay to collimated pairs of leptons or light hadrons with the ATLAS detector and the full Run-II Data at LHC



## 1 - Dark photons



- Dark sector weakly coupled to the Standard Model (SM)
- Dark Photon ( $\gamma_D$ ) from Higgs portal, decaying through vector portal to leptons or light hadrons
- Investigate gluon-gluon Fusion (ggF) and Higgs associated production with a W boson (WH)

$$\mathcal{L} \propto \epsilon \epsilon \gamma_D^\mu J_\mu^{em} \quad \text{CT} = \frac{1}{\Gamma_{\gamma_D}^{tot}} \propto \frac{1}{\epsilon^2 m_{\gamma_D}}$$

- $\epsilon$  = coupling parameter between SM and Hidden Sector
- Small  $\epsilon \rightarrow$  long lived  $\gamma_D$
- Light and boosted LLP  $\rightarrow$  Collimated pair of leptons/hadrons: "Dark Photon Jets" (DPJ)

## 4 - Event selection

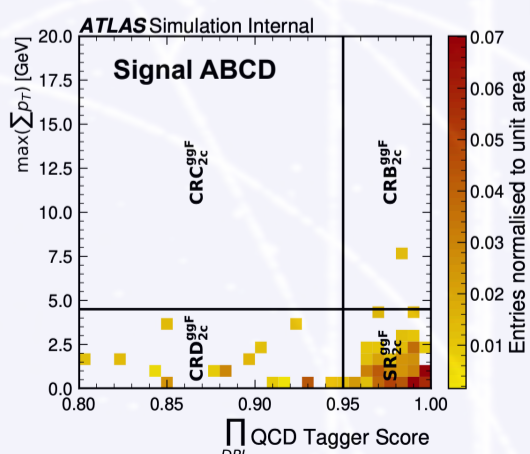
- ggF:**
- dedicated LLP triggers
  - prompt lepton veto
- WH:**
- triggering on prompt lepton from W decay
  - missing transverse energy ( $E_{T^{miss}}$ ) cut
  - transverse mass ( $m_T$ ) cuts
  - b-jet veto

- Per-DPJ type & number selection leads to have **six orthogonal channels**
- $SR_{2\mu}^{ggF}, SR_{2c}^{ggF}, SR_{c+\mu}^{ggF}$
- $SR_{1c}^{WH}, SR_{2c}^{WH}, SR_{c+\mu}^{WH}$

## 5 - Background estimate

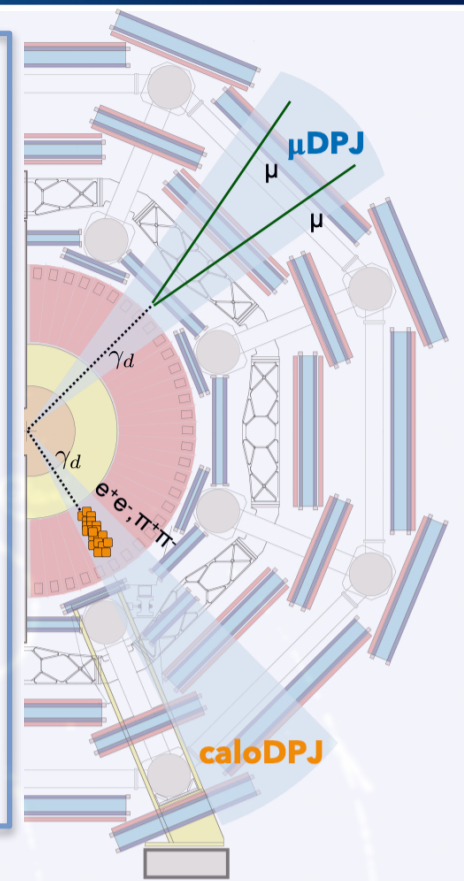
- multijet:** data-driven ABCD method
- cosmic-ray muons:** estimated in empty bunch-crossings (DNN + residuals subtracted)
- Beam Induced Background:** reduced to negligible level

- the number of events in the signal region are estimated as:  
 $N_A = N_B \times N_D / N_C$
- background event distribution can be factorized in a plane of two uncorrelated variables



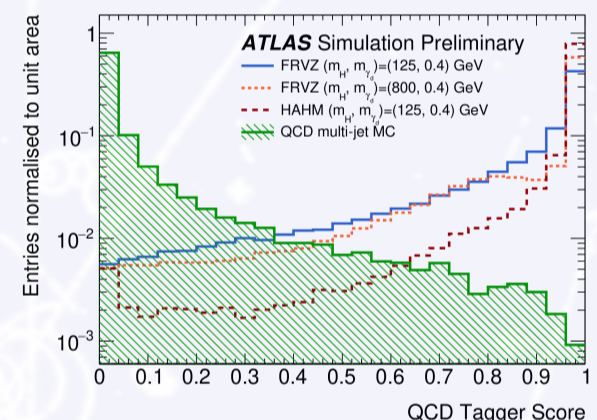
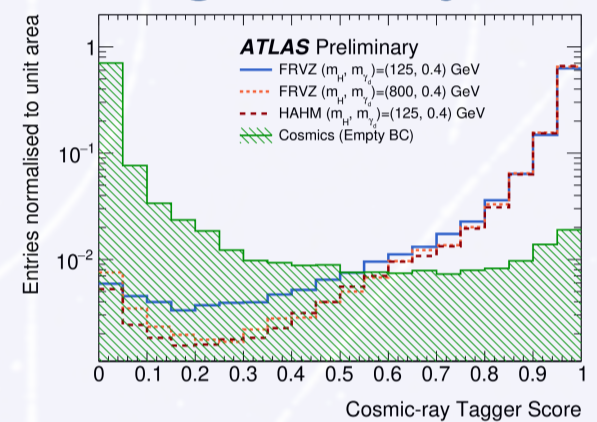
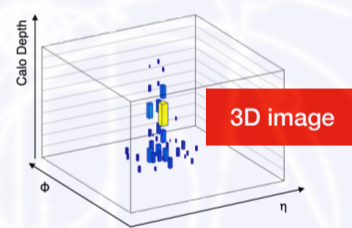
## 2 - DPJ Reconstruction

- $\mu$ DPJ:**
  - Close-by muons in the Muon Spectrometer (MS), no jets or tracks in the Inner Detector (ID)
  - Main background: cosmic-ray muons
- caloDPJ:**
  - a.k.a cDPJ, resulting from  $\gamma_D$  decaying to electrons or light hadrons
  - Displaced and narrow jets with most of the energy released in the Hadronic Calorimeter (HCAL)
  - Main background: rare multijet events



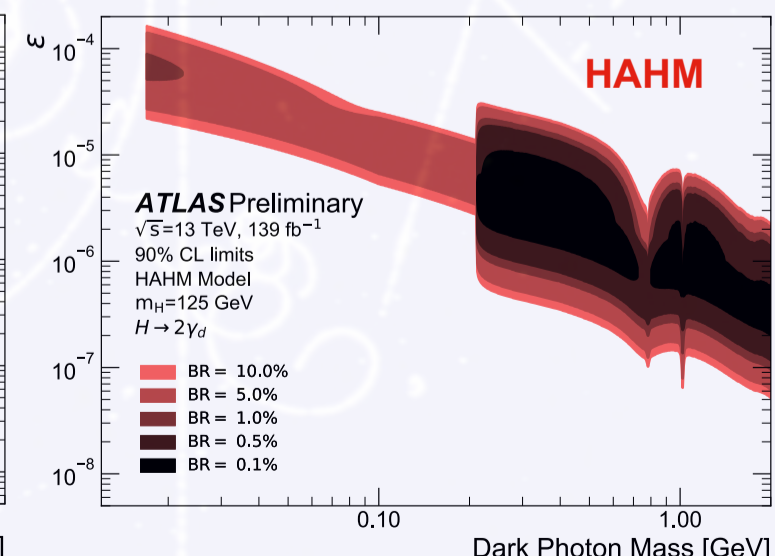
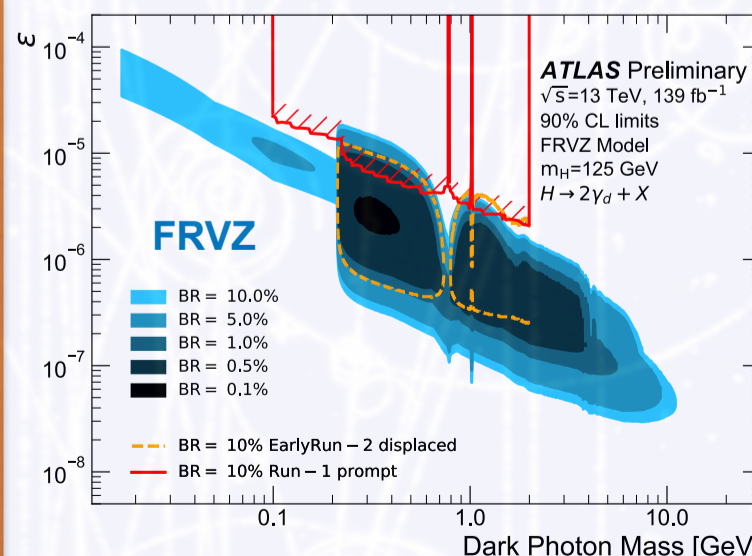
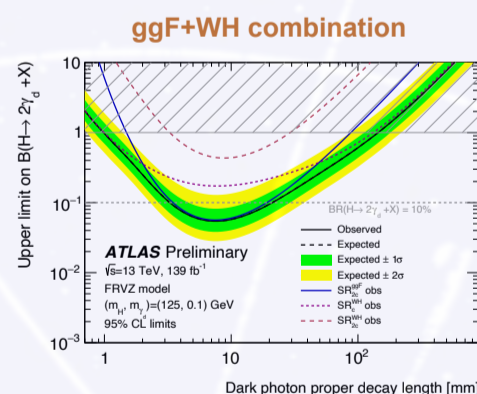
## 3 - Neural Network (NN) taggers for background rejection

- Cosmic-ray background: **per-muon Deep NN (DNN) tagger** exploiting timing, angular direction and impact parameter info
- multijet background: **per-jet Convolutional NN tagger exploiting 3D images** produced using angular direction and calorimeter cluster informations
- One of the first use in ATLAS searches of a CNN based tagger trained on low-level inputs



## 6 - Results

- First exclusion of fully electronic decays of the  $\gamma_D$**  allowing to probe previously uncovered regions of the phase space:  $m_{\gamma_D} < 2m_\mu$
- WH+ggF combination:** first search for light long-lived neutral particles decaying to collimated pairs of fermions at ATLAS exploiting the associated production mode
- First interpretation into HAHM models**



[1] A. Falkowski, J. T. Ruderman, T. Volansky, J. Zupan (FRVZ) - 'Hidden Higgs Decaying to Lepton Jets' - JHEP 1005:077, 2010  
 [2] 'Hidden Abelian Higgs Model (HAHM)' - D. Curtin, R. Essig, S. Gori and J. Shelton - 'Illuminating dark photons with high-energy colliders' - JHEP 10.1007, 2015  
 [3] 'Search for light long-lived neutral particles that decay to collimated pairs of leptons or light hadrons in pp collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector' - ATLAS-CONF-2022-001