Study of variables in the search for long-lived dark photons that decay into muonic Lepton jets with the ATLAS detector

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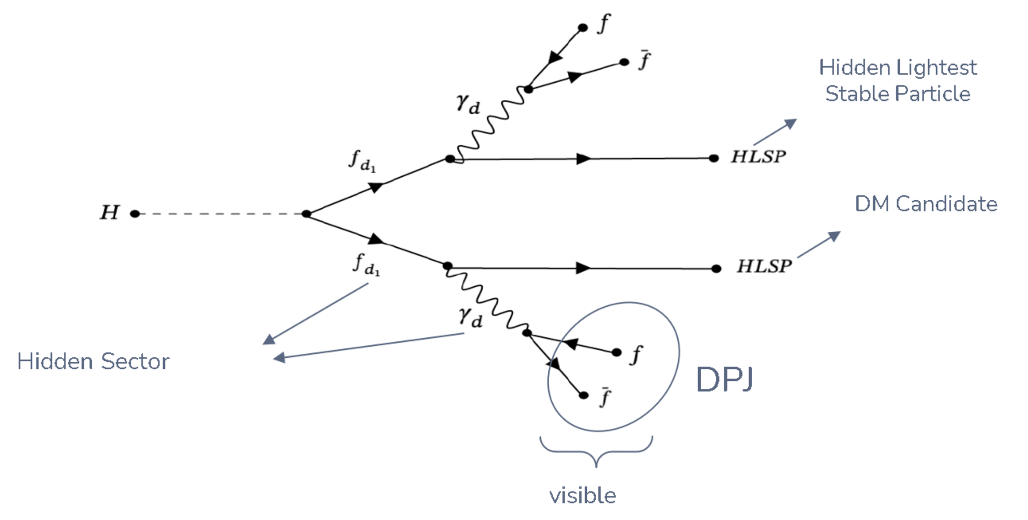
Introduction

- The Standard Model (SM) successfully describes fundamental particles and their interactions but does not account for dark matter (DM), which constitutes a significant part of the universe. Understanding DM remains one of the main challenges in modern physics.
- The Large Hadron Collider (LHC) allows testing physics beyond the SM by searching for new phenomena, including long-lived particles (LLPs). This study analyzes simulated data from Run 2 of higgs boson decays through the Falkowski-Ruderman-Volansky-Zupan (FRVZ) model, where the Higgs was produced via Vector Boson Fusion (VBF).
- This project focuses on improving the identification of muonic dark photon jets (DPJs), which are predicted to emerge from hidden-sector decays. The analysis is performed using a cut-based selection, focusing specifically on missing transverse energy (E_{Tmiss}). By refining the E_{Tmiss} cut, we aim to maximize signal efficiency while effectively suppressing background events, improving the prospects for detecting DPJs in ATLAS.

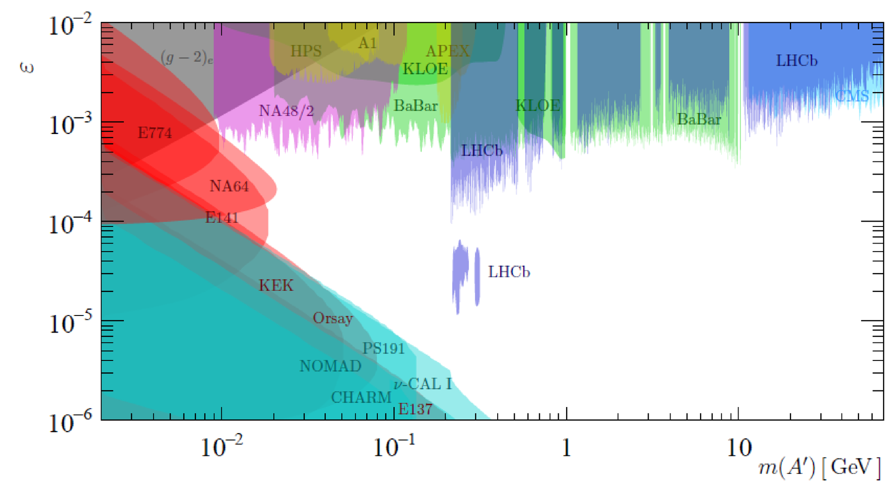
Model FRVZ

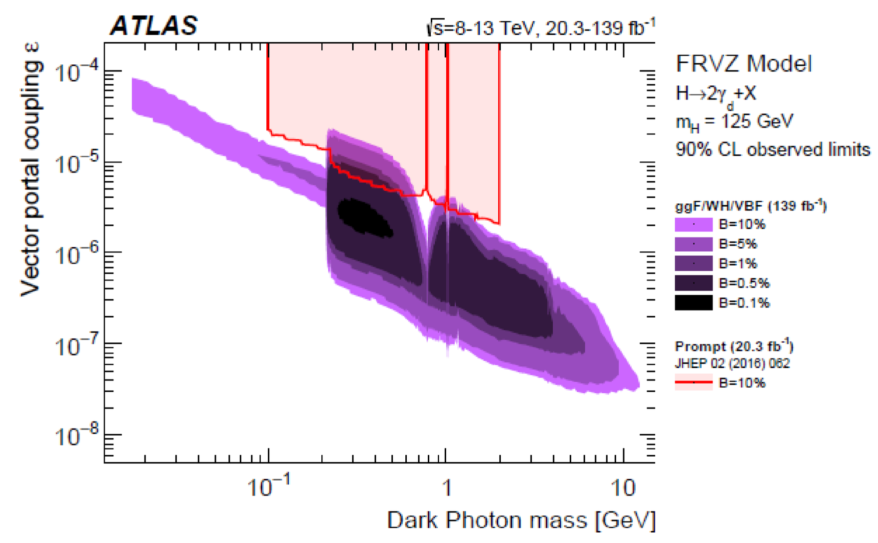


$$L_{mixing} = \frac{\epsilon}{2} B^{\mu\nu} b_{\mu\nu} \quad (1)$$

⇒ **With ϵ as the mixing parameter**

"State of the Art"

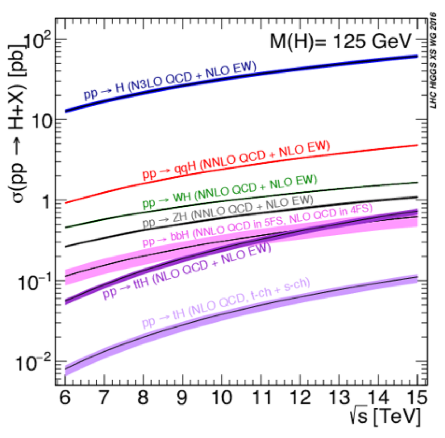


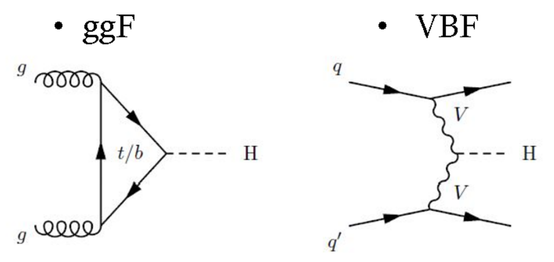


$$\tau \propto \left[\frac{10^{-4}}{\epsilon}\right]^2 \left[\frac{100\text{MeV}}{m_{\gamma d}}\right]^2 \quad (2)$$

- ϵ and $m_{\gamma d}$ are free parameters.

Higgs Production Channels

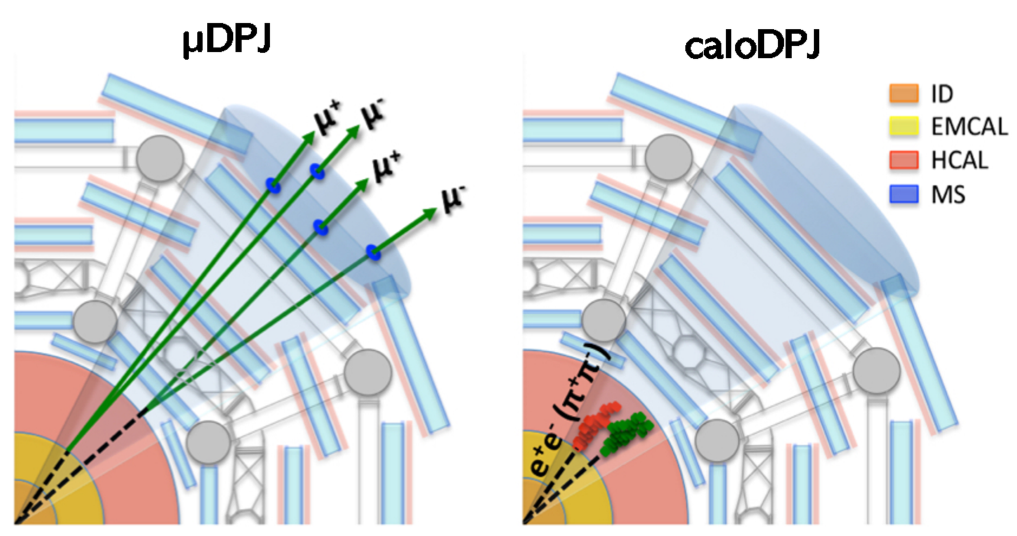




The simulations in this analysis are based on the FRVZ model, where the Higgs boson is produced via VBF.

We set the dark photon to be LLP

Displaced Jets



2 DPJ

- μDPJ
- caloDPJ
- μDPJ + caloDPJ

The muons appear collimated in the Muon Spectrometer (MS) with a minimum angular separation, leaving no coincident traces in the Inner Detector and no energy deposits in the calorimeters.

Cuts, Cutflow, E_{Tmiss}, Significance and Efficiency

Signal Region (SR)	
VBF filter	Jets ≥ 2 $\Delta\eta_{jj} > 3.0$ $m_{jj} > 1000\,GeV$
Max. $\lvert\Delta\phi(jet, jet)\rvert$	< 2.5
Lepton veto	Number of signal muons = 0 Number of signal electrons = 0
B-jet veto	No b-jets
Muonic DPJ	Leading DPJ type = muonic
Trimuon OR Narrow Scan OR E_{Tmiss} Trigger	True
E_{Tmiss}	$> 225\,GeV$
μDPJ isGood	== 1
Min. DPJ1 centrality μ	> 0.7

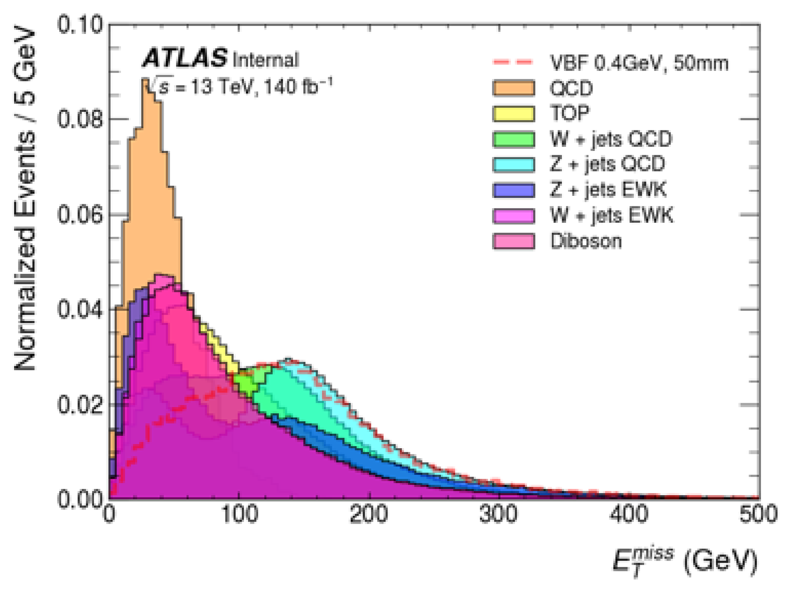
Filter	$c\tau = 50$ mm	Bkg	Total Significance
VBF filter	2738.81	1.13×10^{10}	0.0258
$\lvert\Delta\phi(\text{jet}, \text{jet})\rvert < 2.5$	2183.21	3.35×10^{9}	0.0377
Lepton veto	2181.16	3.35×10^{9}	0.0377
B-jet veto	2132.77	3.26×10^{9}	0.0374
MET trigger	1600.80	7.66×10^{7}	0.1829
$E_{\text{Tmiss}} > 225$ GeV	312.87	7.94×10^{4}	1.1093
Muonic Type lead	61.56	49.02	7.5370
μDPJ isGood	53.32	44.13	6.9104
Centrality μDPJ	31.60	0.362	14.9421

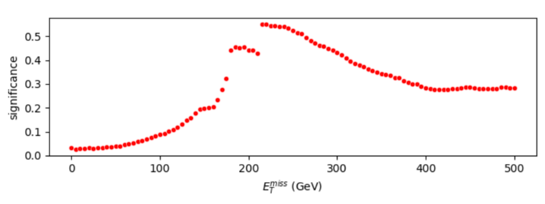
$$\sigma = \sqrt{2 \cdot \left((N_{\text{sgn}} + N_{\text{bkg}}) \cdot \ln\left(1 + \frac{N_{\text{sgn}}}{N_{\text{bkg}}}\right) - N_{\text{sgn}} \right)} \quad (3)$$

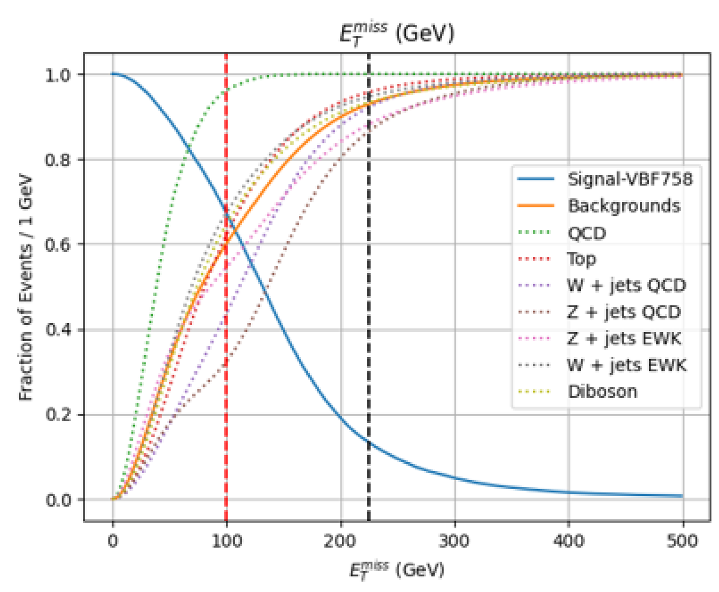
$$\text{Efficiency} = \frac{\text{Events passing cut}}{\text{Total VBF events}} \quad (4)$$

$$\text{Background Rejection} = 1 - \text{Background Efficiency} \quad (5)$$

Results







Filter	$c\tau = 50$ mm	Background	Total Significance
VBF filter	2738.81	1.13×10^{10}	0.0258
$\lvert\Delta\phi(\text{jet}, \text{jet})\rvert$	2183.21	3.35×10^{9}	0.0377
Lepton veto	2181.16	3.35×10^{9}	0.0377
B-jet veto	2132.77	3.26×10^{9}	0.0374
MET trigger	1600.80	7.66×10^{7}	0.1829
$E_{\text{Tmiss}} > 100$ GeV	1431.75	1.86×10^{7}	0.3319
Muonic Type lead	356.02	206.47	20.3822
μDPJ isGood	306.84	182.91	18.7362
Centrality μDPJ	194.49	1.51	38.9823

The significance plot shows why the baseline E_{Tmiss} cut is set at 225 GeV. However, E_{Tmiss} was scanned to optimize efficiency, leading to an optimal cut at 100 GeV. This adjustment increased the total significance, but its interpretation is limited since all background events are removed, making analysis inconclusive.

Acknowledgements

I would like to express my gratitude to my colleagues in the High Energy Physics (HEP) group for their continuous support and collaboration. Additionally, I extend my thanks to the ATLAS Collaboration for providing the framework and resources that made this research possible.

References

[1] A. Collaboration, "Search for light long-lived neutral particles from higgs boson decays via vector-boson-fusion production from pp collisions at $\sqrt{s} = 13$ tev with the atlas detector," *Eur. Phys. J. C*, vol. 84, p. 650, 2023.

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