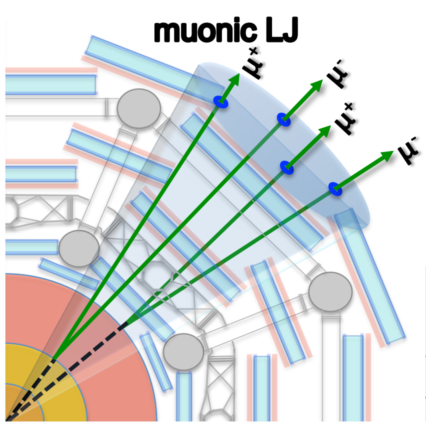
137th LHCC Meeting Open Session – CERN, Genève, February 2019

Trigger and search prospects for dark-photons decaying to displaced collimated jets of muons at HL-LHC with the ATLAS detector

Introduction

Dark sector models which predict the existence of dark photon are a probe of New Physics and a challenge for the ATLAS muon trigger system. The typical signature is a displaced boosted object that can decay to collimated structures containing pairs of muons (lepton-jets, LJ), the model is presented in Figure 1. ATLAS triggers are optimized to select prompt events and very inefficient in the selection of displaced objects. Critical features in triggering these events are: **low p_T threshold**, **small muons angular separation** and **large impact parameters**.
Two new algorithms at the first trigger level (L0) are studied to improve selection of displaced dark photon. These will be used in the sensitivity prospects for Run-3 and High Luminosity LHC.



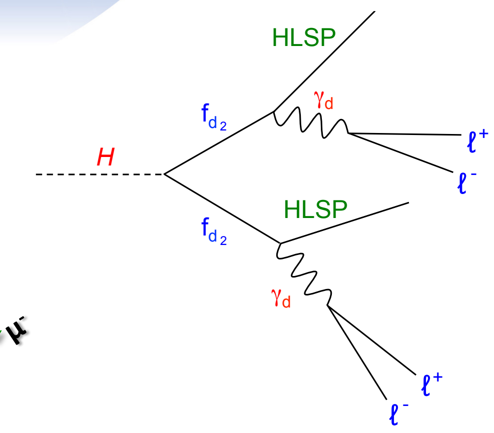


Fig.1 – The **FRVZ** benchmark model [1] describes a general interaction between SM and Dark Sectors, in which the Higgs (125 GeV) decays in a hidden sector fermion, finally producing two back-to-back muonic LJs.

New L0_muon_scan trigger

Boosted dark photon scenario, out-going muons are highly collimated and Run-2 trigger efficiency is limited by the Muon Spectrometer region of interest (RoI) granularity $\eta \times \varphi = 0.2 \times 0.2$.

Muon_scan:

- RoI search for multiple muon candidates
- Lower p_T selection without increasing significantly the rate

New trigger selection is defined by the logical OR of a single muon L0 p_T = 20 GeV and a multi-muon L0 p_T = 10 GeV trigger.
Results for the benchmark model are shown in Fig. 2. An overall improvement up to 7% w.r.t the standard single muon L0 p_T = 20 GeV selection is achieved on the benchmark sample.

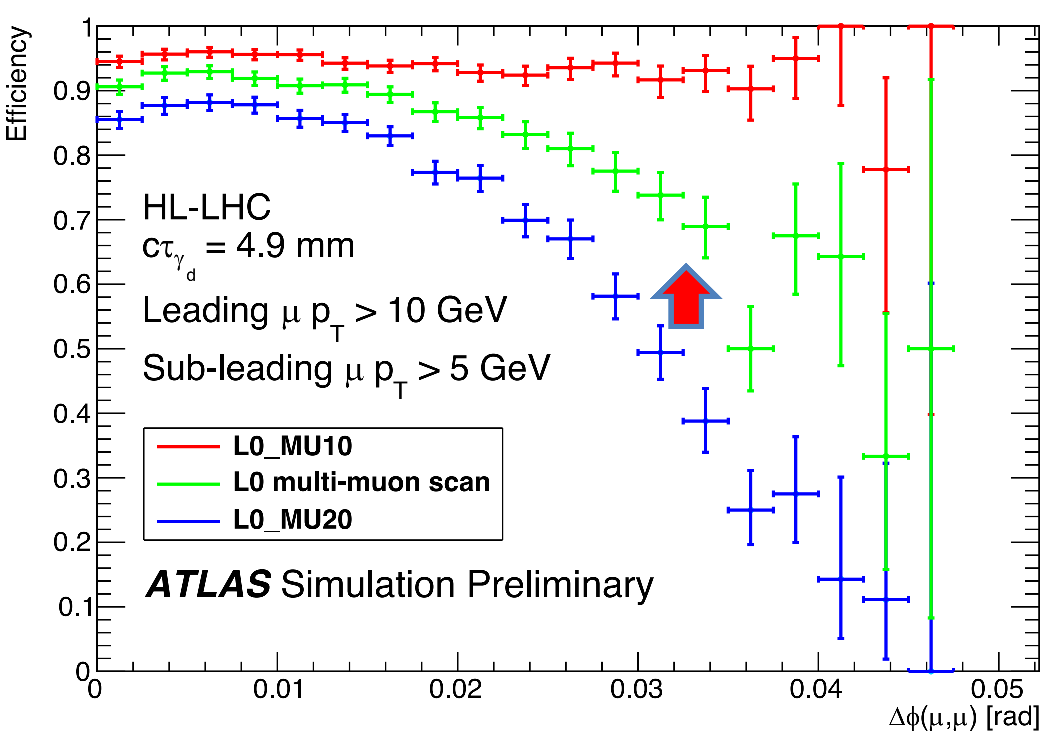


Fig.2 – Efficiency for different trigger selections as a function of the opening angle of the two muons of the dark photon decay. Single muon selection with p_T = 20 GeV threshold (blue), p_T = 10 GeV threshold (red) and L0_multi_muon (green) [2].

New L0_sagitta_muon trigger

Resolved scenario, the out-going displaced muons are open and may not point to the IP. The Run-2 L0 trigger has a tight constraint on IP pointing.

Sagitta_muon:

- Low p_T muon trigger to select high p_T non-pointing muons
- Sagitta measurement to confirm high p_T non-pointing muons

High p_T non-pointing muons are thus selected requiring a L0 muon trigger with p_T = 5 GeV threshold and a sagitta selection for p_T = 20 GeV.
By adding the sagitta_muon to the standard p_T = 20 GeV single muon selection, a 20% improvement in efficiency is achieved on the benchmark model, results are presented in Fig.3.

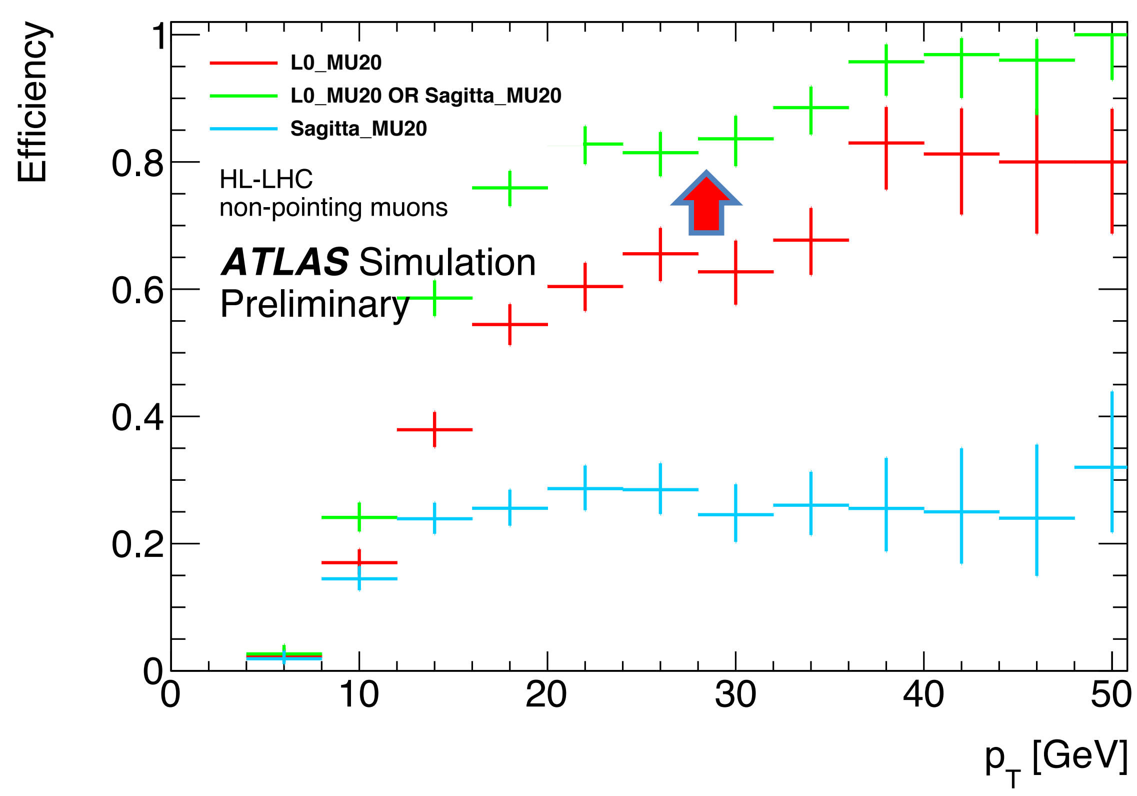


Fig.3 – Trigger efficiency comparison for the new L0_sagitta_muon with p_T = 20 GeV threshold (cyan), the single muon p_T = 20 GeV threshold (red) and the logical OR of the two (green) as a function of the muon transverse momentum [2].

HL-LHC sensitivity

The expected sensitivity of the displaced LJ search after Run-3 and HL-LHC is based on the 2015 Run-2 ATLAS analysis [3].

- Backgrounds from QCD multijets and cosmic ray muons.
- Dominant uncertainties arising from pile-up ~20%.

Results for Run 3, HL-LHC and HL-LHC with trigger improvements are presented in Table 1.
The exclusion limits are interpreted in the context of the vector portal model and presented in Fig. 4, assuming a Higgs decay branching fraction to the hidden sector of 1%.

Excluded $c\tau$ [mm] muonic-muonic	Run-2	Run-3	HL-LHC	HL-LHC w/ L0 muon-scan
BR(H $\rightarrow 2\gamma_d + X$)=10 %	$2.2 \leq c\tau \leq 111$	$1.15 \leq c\tau \leq 435$	$0.97 \leq c\tau \leq 553$	$0.97 \leq c\tau \leq 597$
BR(H $\rightarrow 2\gamma_d + X$)=1 %	-	$2.76 \leq c\tau \leq 102$	$2.18 \leq c\tau \leq 142$	$2.13 \leq c\tau \leq 148$

Tab.1 – Ranges of γd cτ excluded at 95% C.L. for H → $2\gamma_d$ + X assuming BR(H → $2\gamma_d$ + X) = 10% and BR(H → $2\gamma_d$ + X) = 1% and dark photon mass of 400 MeV [2].

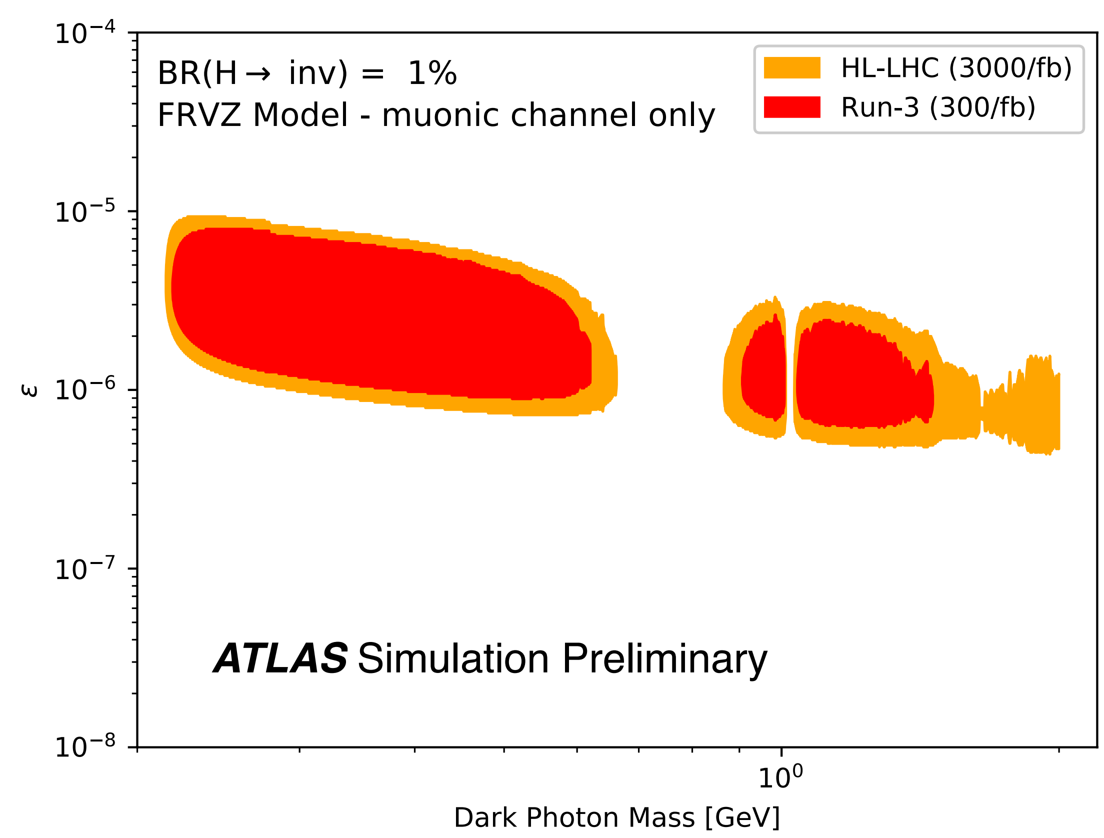


Fig.4 – Exclusion contour plot in the plane defined by the γ_d mass and the kinetic mixing parameter ε, that drives the interaction between the hidden sector and the SM. Two different scenarios are shown assuming a Higgs decay branching fraction to the hidden sector of 1% [2].

[1] A. Falkowski, J. T. Ruderman, T. Volansky, J.Zupan - 'Hidden Higgs Decaying to Lepton Jets' - JHEP 1005:077,2010
[2] ATLAS Collaboration - 'Search prospects for dark-photons decaying to displaced collimated jets of muons at HL-LHC' - ATLAS-PHYS-PUB-2019-002
[3] ATLAS Collaboration - 'Search for long-lived neutral particles decaying into displaced lepton jets in proton--proton collisions at $\sqrt{s}$= 13 TeV with the ATLAS detector' - ATLAS-CONF-2016-042

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ATLAS EXPERIMENT