Search for dark photon in four-lepton events via rare Z decay with the ATLAS detector

Mingyi Liu[1] | CLHCP2021

1. University of Science and Technology of China

Introduction

Motivation:

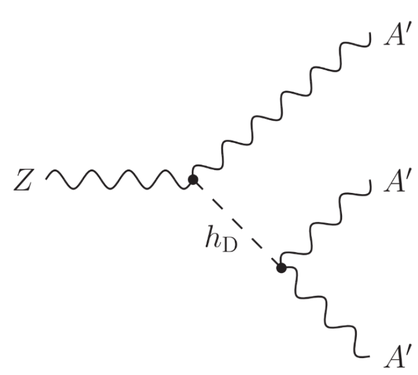
- ✓ Important candidate for the dark sector
- ✓ Hidden sector couplings and mass generation mechanisms

Gauge boson A' from $\mathbf{U(1)_D}$ couples to Z by kinetic mixing $\boldsymbol{\varepsilon}$

Whose mass generated from Dark Higgs h_D

$$\mathcal{L}_{int} \subset -\frac{1}{4}\widehat{B}_{\mu\nu}\widehat{B}^{\mu\nu} - \frac{1}{4}\widehat{Z}_{D\mu\nu}\widehat{Z}_D^{\mu\nu} + \frac{1}{2}\frac{\varepsilon}{cos\theta_W}\widehat{Z}_{D\mu\nu}\widehat{B}^{\mu\nu} + \frac{1}{2}m_{D,0}^2\widehat{Z}_D^{\mu}\widehat{Z}_{D\mu}$$

➢ New rare Z decay mode: $\boldsymbol{Z \rightarrow A' h_D}$



Assumptions:

- Br ($h_D \rightarrow A'\,A'$) = 100%
- A' is the lightest BSM particle
- Br ($A' \rightarrow SM\ f\ \bar{f}$) = 100%

Focusing on the on-shell cases:

$M_{A'}$ (10 ~ 40 GeV) < M_{hD} (20 ~ 70 GeV)

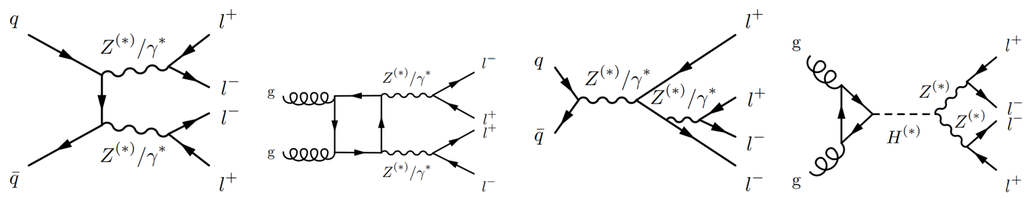
Decay rate for $Z \rightarrow A' + h_D \propto \boldsymbol{\alpha_D \varepsilon^2}$

Signal: 4l (e/μ, decayed from **on shell** A's) + X

SM Backgrounds

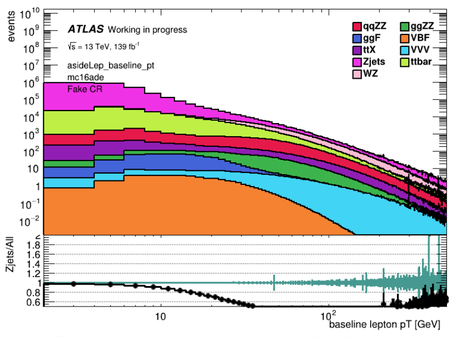
Prompt backgrounds:

- Inclusive Z/ZZ→4l, Higgs, tri-boson, ttXX



Non-prompt (fake) backgrounds:

- Fake leptons from Z+jets / tt / WZ, poor modeling
- Data driven fake factor method
  - ➢ Fake enriched (Z+jets) region defined to calculate fake factor
  - ➢ Apply fake factors to events with loose leptons



Validation region defined to check BKG modeling

Signal Region

Selections	Description
Trigger	Fire at least one of the unprescaled lepton trigger
$N_{lepton} \geq 4$	At least 4 leptons (e, μ)
From Z	For all OSSF Quadruplets, $m_{4l} < m_Z - 5GeV$
$N_{quad} \geq 1$	Has at least one OSSF Quadruplet If has more than one Quadruplet, choose the one with min $\lvert m_{l1l2} - m_{l3l4}\rvert$ Label the pair with larger mass as m_{l1l2}, the other one as m_{l3l4}
ΔR_{ll}	In the selected quadruplet, $\Delta R > 0.1(0.2)$ between SF (OF) leptons
On Shell	$m_{l3l4}/m_{l1l2} > 0.85$
J/ψ veto	In the selected quadruplet, the mass of OSSF pairs must be larger than 5GeV
$\Upsilon(bb)$ veto	The mass of OSSF pairs must be out of the Υ mass range $[m_{\Upsilon(1s)} - 0.7, m_{\Upsilon(3s)} + 0.75]$ GeV

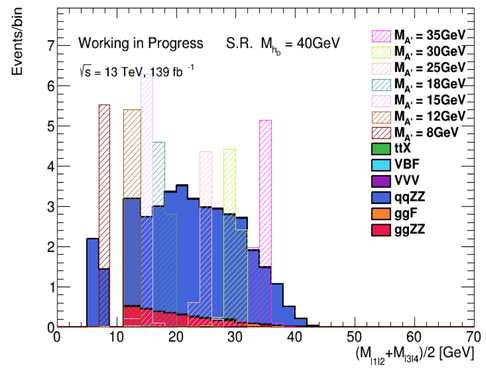
Signals (M_{hD} = 40 GeV) are under α_D = 0.1; $\varepsilon = 10^{-3}$

Discriminant $<M_{ll}>$

Yields (139fb^{-1}):

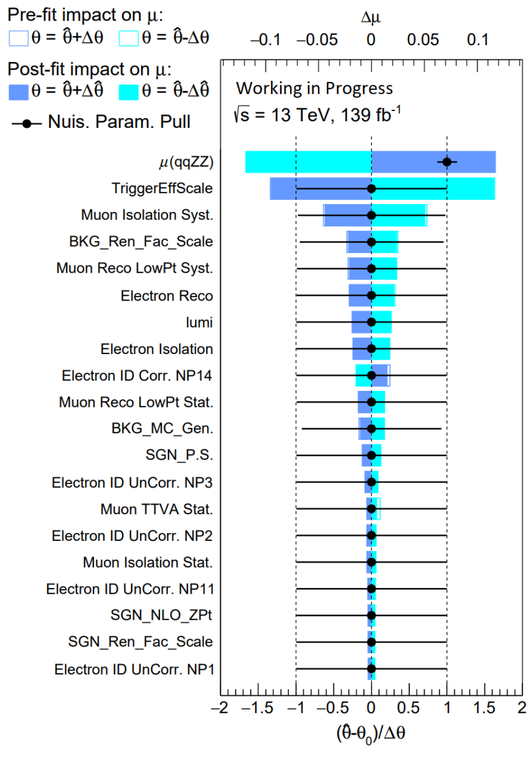
- qqZ/ZZ ~ 36
- ggZZ ~ 3
- Other BKGs << 1
- Signals ~ 7

Promising sensitivity!

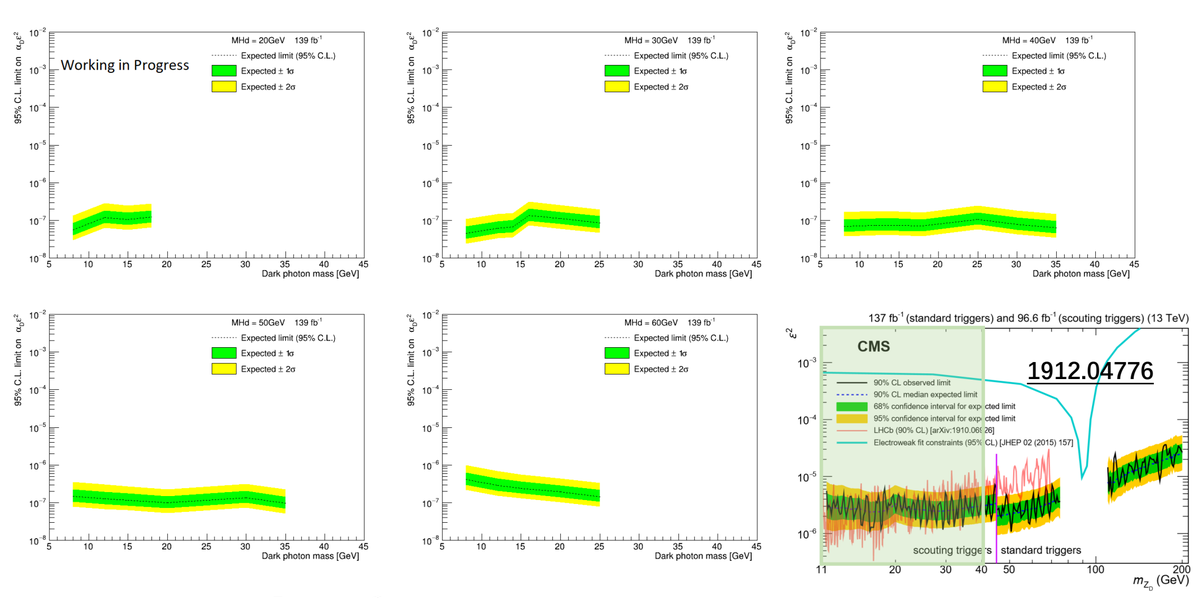


Uncertainties

- Statistical uncertainties
- Experimental systematics
  - ID, Isolation, Pt resolution
  - Pile up / Luminosity
  - Global trigger efficiency
  - …
- Theoretical systematics
  - QCD scale
  - PDF + α_S
  - Generator tune
  - Parton showering
  - High order Z Pt correction
  - …



Preliminary limit setting



- Asimov data fitting
- Upper limits

$\boldsymbol{\alpha_D\varepsilon^2 \sim 10^{-7}}$

Better than theory prediction

Comparable with limits set by CMS/LHCb