Search for heavy resonance decaying to $Z/W/H + \gamma$ with the ATLAS detector

4th CLHCP workshop

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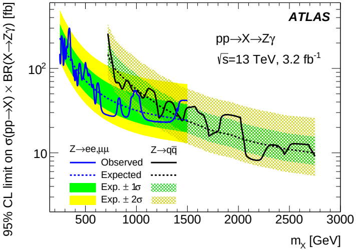
On behalf of the ATLAS Collaboration

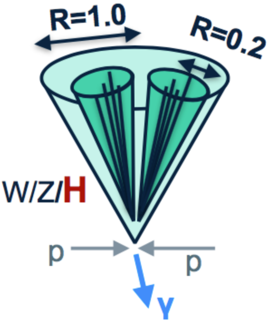
ATLAS EXPERIMENT

Phys. Rev. D 98, 032015

Introduction

- Search for heavy resonance decaying to $V/H + \gamma$:
  - Only consider the hadronic decay of V ($\mathcal{B} \sim 70\%$) and $H \to b\bar{b}$ decay mode ($\mathcal{B} \sim 58\%$)
  - Only use events in the boosted/merge region
  - Final state are fat jet ($R = 1.0$) and an energetic photon
- Different spin hypothesis signals are considered:
  - $X(J = 0) \to Z + \gamma$
    - ☞ Motivated by the extension of the Higgs sector
  - $X(J = 1) \to W/H + \gamma$
    - ☞ $W\gamma$ is induced by the HVT model. $H\gamma$ is induced by the HEL model
  - $qq/gg \to X(J = 2) \to Z + \gamma$
    - ☞ Higgs Characterisation model





Samples

- Data Sample: data collected by the ATLAS detector in 2015 and 2016, corresponding to $36.1\ fb^{-1}$
- Signal samples are produced with different mass and spin hypothesis, only considered NWA signals:

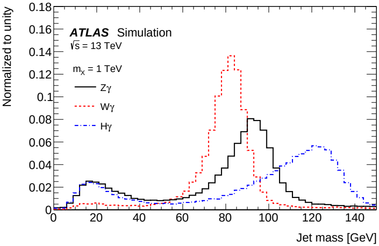
Channel	Generator	Spin	Production	V Polarization
$Z\gamma$	Powheg+Pythia8	0	gg→X	Transvers
$Z\gamma$	MadGraph+Pythia8	2	gg→X	Transvers
$Z\gamma$	MadGraph+Pythia8	2	qq→X	Transvers
$W\gamma$	MadGraph+Pythia8	1	qq→X	Longitudinal
$H\gamma$	MadGraph+Pythia8	1	qq→X	-

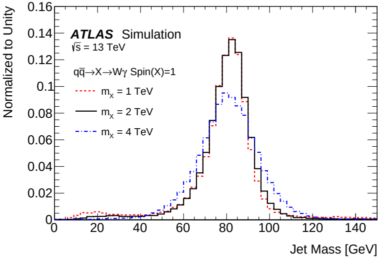
- Background samples:

Channel	Generator
γ+jets	Sherpa
SM W+γ	Sherpa
SM Z+γ	Sherpa
tt+γ(all hadronic and no all hadronic)	MadGraph + Pythia8

Object definition

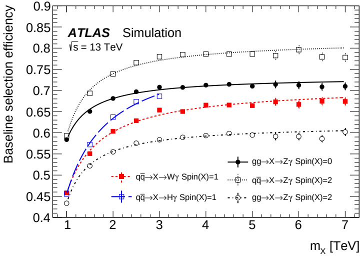
- Photon
  - $p_T > 250$ GeV and $|\eta| < 2.37$ (exclude crack region: $1.37 < |\eta| < 1.52$)
  - Satisfy *Tight* photon ID requirement and *Tight* calo-only isolation
- Jet
  - Anti-*kt* large-R jet ($R = 1.0$), Trimmed ($f_{cut} < 5\%$, $R_{sub} = 0.2$)
  - $p_T > 200$ GeV and $|\eta| < 2.0$
  - Boson tagger applied based on D_2 and m_J depending on signals
  - $n_{trk} < 30$ for $Z\gamma$ and $W\gamma$
  - Anti-*kt* $R = 0.2$ track jet are used to tag b-jet with MV2c10 algorithm @ 70% efficiency





Event selection

- Trigger: HLT_g140_loose
- One good PV with at lease two associated tracks
- At lease one photon in barrel calorimeter ($|\eta| < 1.37$)
- $\Delta R(J, \gamma) > 1.0$
- Events should present at lease one fat jet and one photon fulfilled the object definition
  ☞ The leading p_{T} objects are used to form $m_{J\gamma}$



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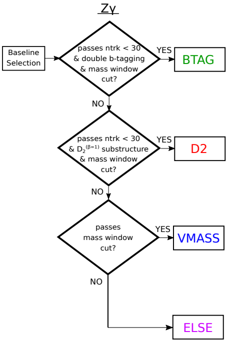
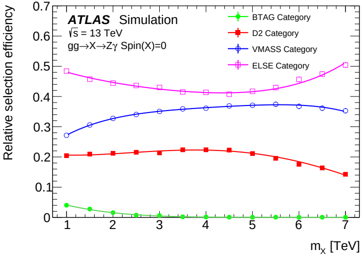
- Events are divided into different categories: BTAG , D2 , VMASS and ELSE



Selection	Event yield in each category (> 1 TeV)				
	Baseline	BTAG	D2	VMASS	ELSE
$Z\gamma$ search	60,237	25	784	5,569	53,859
$W\gamma$ search	60,237	—	661	5,216	54,360
$H\gamma$ search	60,237	59	—	—	—



Signal & Background Modelling

- Signals are modelled by the *CrystalBall+Gaussian* function

$$S(m_{J\gamma}) = f_C \cdot C(m_{J\gamma};\mu,\sigma_C,\alpha_C,n_C) + (1-f_C)\cdot \mathcal{G}(m_{J\gamma};\mu,\sigma_{\mathcal{G}})$$

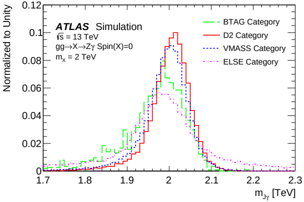
Where *CrystalBall* function can be written as:

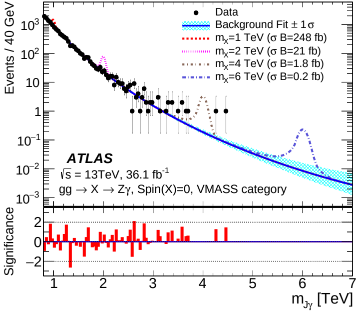
$$C(m_{J\gamma};\mu,\sigma_C,\alpha_C,n_C) = N_C \cdot \begin{cases} \exp\left(-\frac{(m_{J\gamma}-\mu)^2}{2\sigma_C^2}\right) & \frac{m_{J\gamma}-\mu}{\sigma_C} > -\alpha_C \\ \left(\frac{n_C}{\alpha_C}\right)^{n_C} \exp\left(-\frac{\alpha_C^2}{2}\right)\left(\frac{n_C}{\alpha_C}-\alpha_C-\frac{m_{J\gamma}-\mu}{\sigma_C}\right)^{-n_C} & \frac{m_{J\gamma}-\mu}{\sigma_C} \leq -\alpha_C \end{cases}$$

- Background are modelled as:

$$B(m_{J\gamma};p_i) = (1-x)^{p_1} x^{p_2+p_3\log(x)+p_4\log^2(x)+p_5\log^3(x)},\ x = m_{J\gamma}/\sqrt{s}$$

  - Different regions have different number of parameters for background

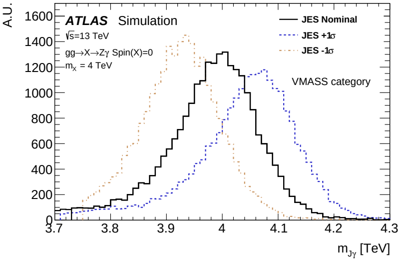




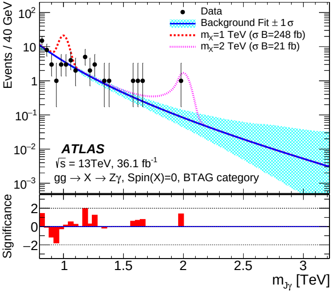
Systematic Uncertainties

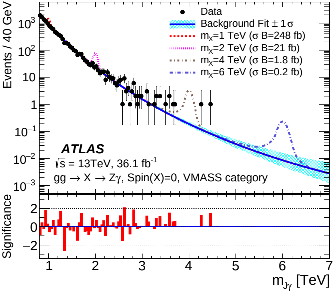
- Detector related systematic uncertainties are considered and their effects are categorized into three parts: impact on signal efficiency, signal peak position, and signal resolution.
- Theoretical uncertainties impacts on signal efficiency are also considered

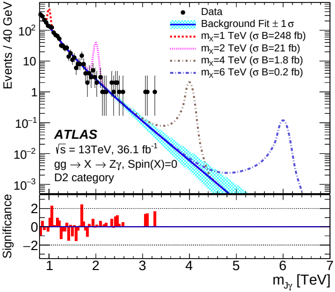
	Impact on normalization and efficiency [%]
Luminosity	2.1
Jet energy scale	2–6
Photon identification and isolation	0.5–1.5
Flavor tagging	10–20
n_{trk} associated with the jet	6
Jet mass resolution	3–6
scale and resolution	< 1
Pileup modeling	1–2
	Impact on signal peak position [
Jet energy and mass scale	1–3
Photon energy scale	< 0.5
	Impact on signal peak resolution
Jet energy resolution	5 ($m_X < 2.5$ TeV)–15 ($m_X > 2.5$ TeV)
Photon energy resolution	1–3
	Impact on acceptance
PDF	2–12
Parton shower	2

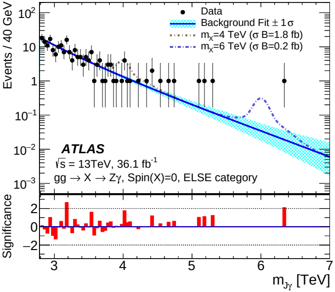


Results: distributions ($Z\gamma$)



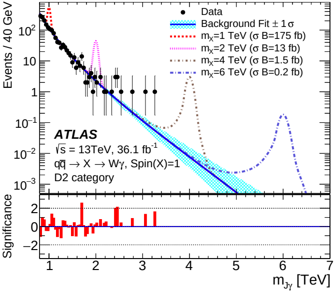


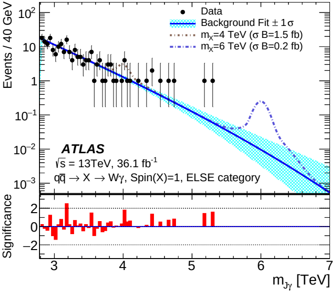


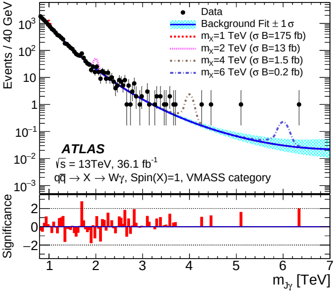


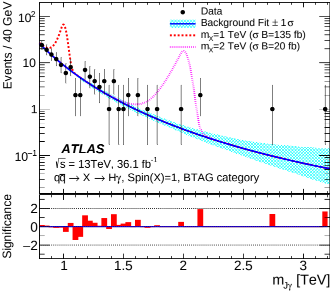
☞ Data are compatible with background only hypothesis. No significant excess observed.

Results: distributions ($W\gamma$ & $H\gamma$)









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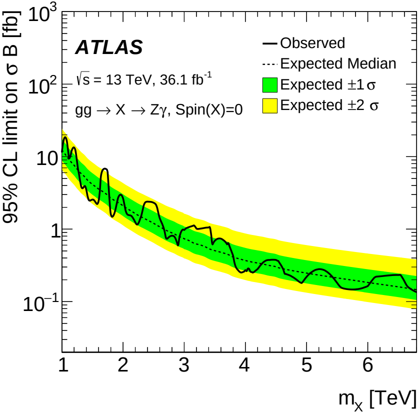
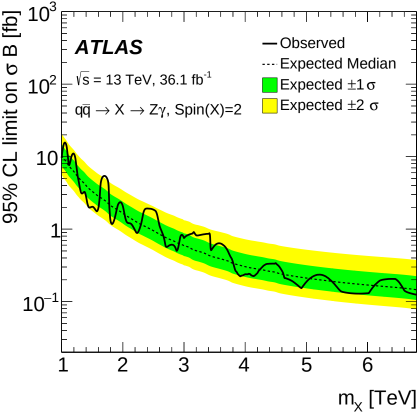
Cross section limits ($Z\gamma$)





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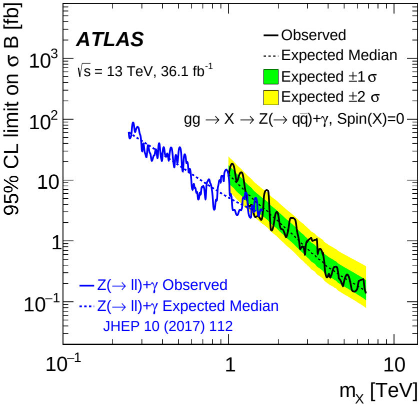

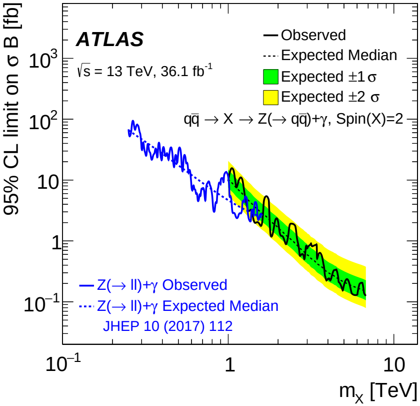

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- Hadronic channel results are compatible with leptonic results around 1 TeV
- Provide complementary results to leptonic $Z + \gamma$ search

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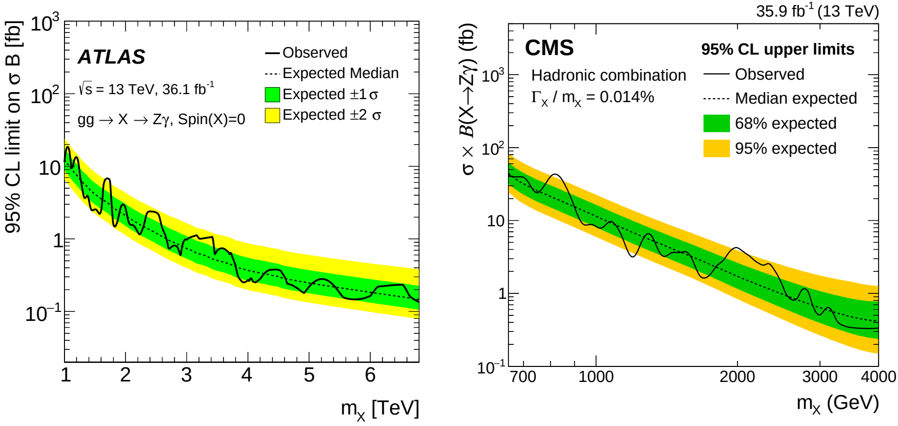

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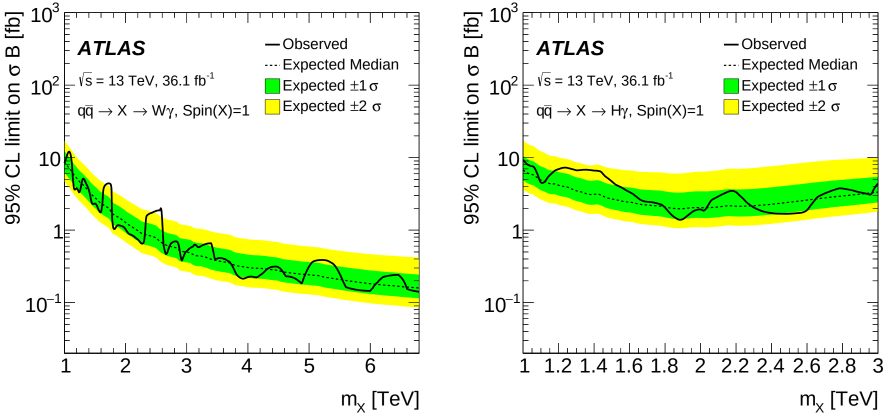
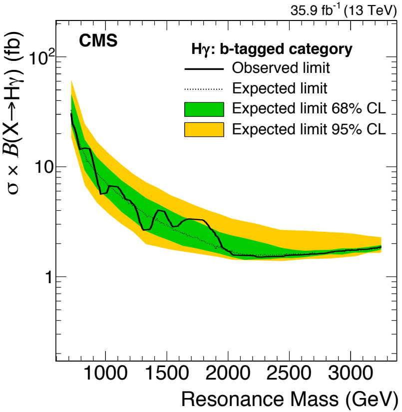
- Hadronic channel results are compatible with leptonic results around 1 TeV
- Provide complementary results to leptonic $Z + \gamma$ search
- Similar results compared to CMS (JHEP09(2018)148)

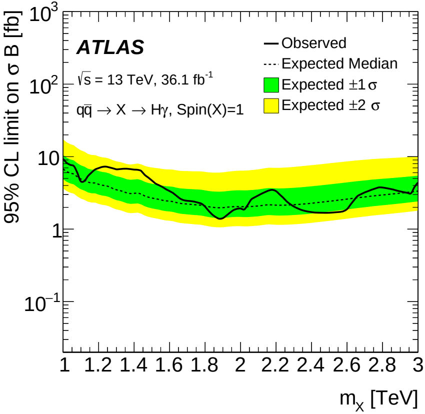
Cross section limits ($W\gamma$ & $H\gamma$)



- No significant excess observed

Cross section limits ($H\gamma$)





- No significant excess observed
- Similar results comparing to CMS btagged categories limits (CMS also defined untagged category) arXiv: 1712.03143

Summary

- A search for heavy resonance decaying to $Z/W/H + \gamma$ in hadronic final state using 36.1 fb^{-1} 13 TeV data is presented:
  - Large decay branching fraction ($\sim 70\%$) $\rightarrow$ relative more statistics in high mass region
  - Five different types of signals are considered depending on resonance spins and decay modes
  - Only consider boosted/merge regime where V/H decay products can be formed with a large-R jet
    $\rightarrow$ Boson tagger technique helps to reduce multi-jet background
  - Multiple categories are defined based on large-R jet quantities and flavour tagging requirements
  - No significant excess is observed in signal regions

Summary

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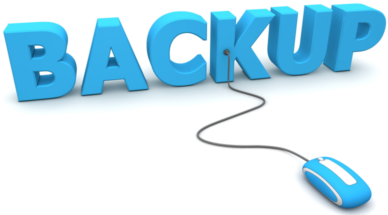
- Only used 1/4 run-II luminosity, more results are expected with full run-II data.


BACKUP