McGill
Department of Physics

Search for a fermiophobic Charged Higgs through low-mass $W^{\pm}\gamma$ resonances with the ATLAS detector

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Sections

Introduction

Event Selections

Invariant mass reconstruction

Background Estimations

- Fake treatment
  - $e \to \gamma$ fakes
  - Jets faking photons
- Overall Background

Conclusion

Introduction

- After the discovery of the scalar Higgs, speculations are raised of a more complicated Higgs sector.
- The Georgi-Machacek (GM)* Model is one such model with $H_5^0, H_5^{\pm}, H_5^{\pm\pm}$
- $H_5^{\pm}$ decays fermiophobically, to $W^{\pm}Z$ or $W^{\pm}\gamma$, if $m_{H3} > m_{H5}$.
- There have been ATLAS searches* for $H_5^{\pm} \to W^{\pm}Z$ with $m_{H_5} > 200$ GeV.
- Our analysis focuses on resonances below 200 GeV where the $W^{\pm}\gamma$ decay channel dominates.

*GM model paper link

*ATLAS search

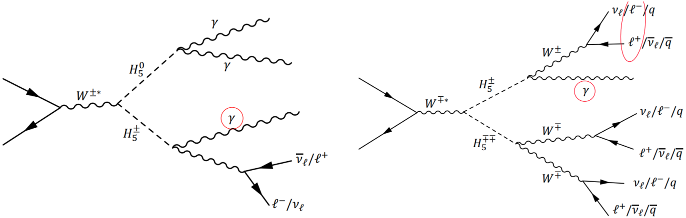

Figure 1

- Searching final states of $l + \nu_l + \gamma + X$. Try to stay model independent.
- Simulation samples are generated with
  - $s_H \stackrel{\text{def}}{=} \frac{2\sqrt{2}v_\chi}{v} = 10^{-4}$, WZ final states are suppressed by s_H^2

Event selections

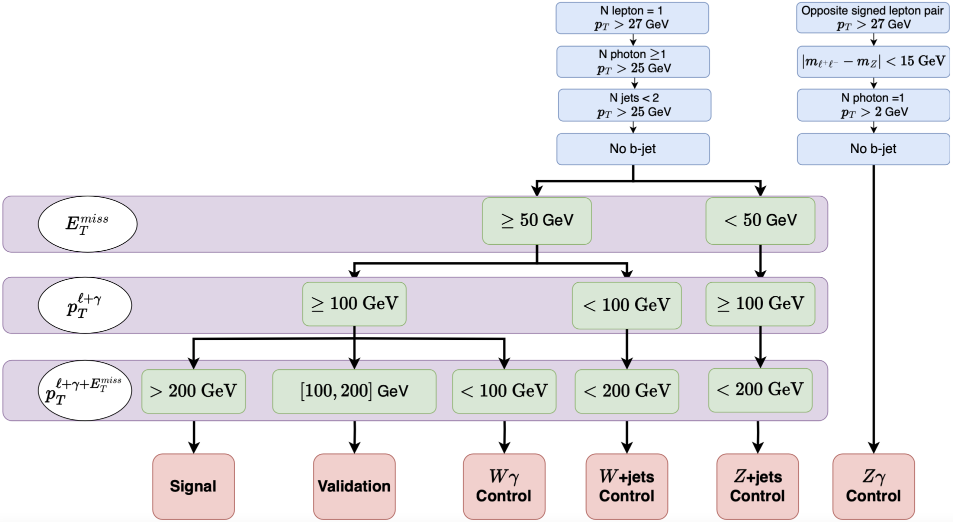

Figure 2: Event selections.

Building neutrino momentum

- Infer the neutrino momentum by assuming the W boson is on-shell:

$$m_{\ell\nu} = \sqrt{(E^{\nu} + E^{\ell})^2 - (\mathbf{p}^{\nu} + \mathbf{p}^{\ell})^2} = m_W$$

$$\text{where } E_{\nu} = \sqrt{p_x^{\nu 2} + p_y^{\nu 2} + p_z^{\nu 2}}$$

- $\mathbf{p}_{\mathbf{T}}^{\nu}$ is modelled by $\mathbf{p}_{\mathbf{T}}^{\nu} \approx \mathbf{E}_{\mathbf{T}}^{\text{miss}}$, p_z^{ν} is the only unknown.
- The smaller solution is picked in case of two real solutions
- In case of complex solution, we minimize the following constraint:

$$C(p_x^{\nu}, p_y^{\nu}, p_z^{\nu}) = \sum_{i=x,y} c_i (p_i^{\nu} - E_i^{\text{miss}})^2 + c_z (p_z^{\nu} - \Re(p_z^{\nu,\mathbb{C}}))^2 + c_m (m_{\ell\nu} - m_W)^2$$

where $\Re(p_z^{\nu,\mathbb{C}})$ is the real part of the original complex solution

- Resonance recovered.

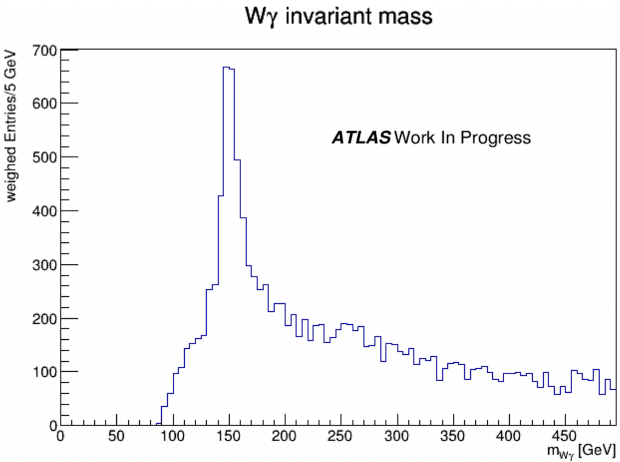

Figure 3: Reconstructed invariant masses of the charged Higgs.

$e \rightarrow \gamma$ fakes

- Estimate the fake rate of e $\rightarrow \gamma$ using the following regions:

Region	$N_\ell(> 27\text{ GeV})$	$N_\gamma(> 27\text{ GeV})$	$N_{\text{jets}}(> 25\text{ GeV})$	$N_{\text{b-jets}}$
ee	2	0	> 1	0
$e\gamma$	1	1	> 1	0

Table 1: $e\gamma$ control regions. $N_{\text{jets}} > 1$ is required to keep orthogonality.

- Slice them in bins of p_T and η of e and γ.
- Perform a fit to extract the "signal" (resonance) part
- Fake rate is given by:

$$FR_{e\rightarrow\gamma}(p_T, \eta) = \frac{N_{e\gamma}^{sig}}{N_{ee}^{sig}}$$

- An example of the $m_{e\gamma}$ in the bin of 27 GeV $< p_T^\gamma <$ 35 GeV and $|\eta| < 0.6$.

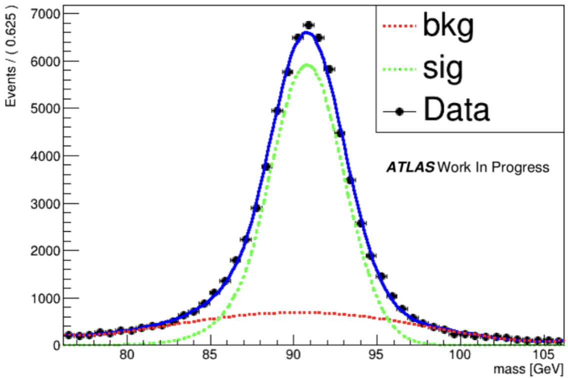

Figure 4: Z mass resonance in the $e\gamma$ channel.

- Fake rate is close to Monte Carlo (MC) simulation: $\frac{FR_{\text{data}}}{FR_{\text{MC}}} \approx 1$
- MC is used with fake rate ratio as corrections.

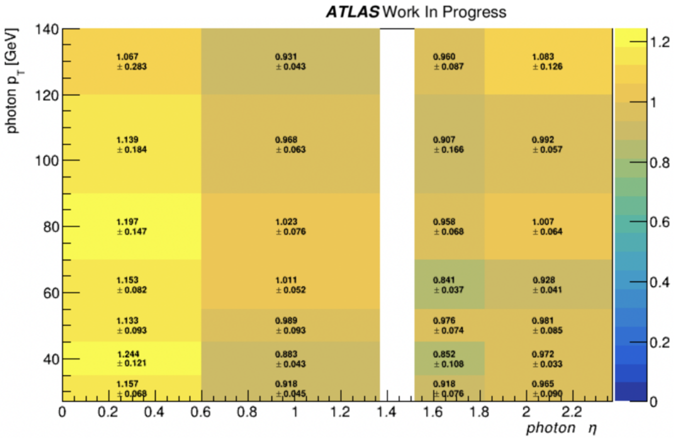

Figure 5: 2D fake rate ratios.

Jets faking photons

- The template fit method was used to model the jets faking photons.
- Data-driven estimate of fakes is based on the **Isolation Energy** (E_{Iso}^{γ}):

$$E_{\text{Iso}}^{\gamma} = E_T^{\gamma,\text{topo40}} - 0.022 \cdot p_T^{\gamma}$$

  where topoEt40 ($E_T^{\gamma,\text{topo40}}$) is the energy deposited within $R = 0.4$ of the photon in the $\eta - \phi$ plane.
- Templates are fitted to the observed E_{Iso}^{γ} distribution to form an estimate of the fake contribution.

Jets faking photons

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$$E_{\text{Iso}}^{\gamma} = E_T^{\gamma,\text{topo40}} - 0.022 \cdot p_T^{\gamma}$$

  where topoEt40 ($E_T^{\gamma,\text{topo40}}$) is the energy deposited within $R = 0.4$ of the photon in the $\eta - \phi$ plane.

- Real and fake templates are obtained from MC and data.

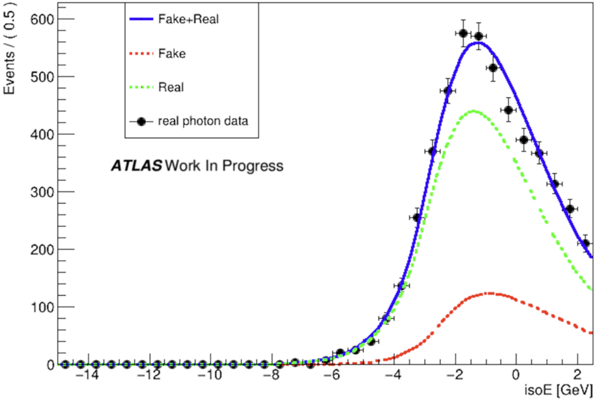
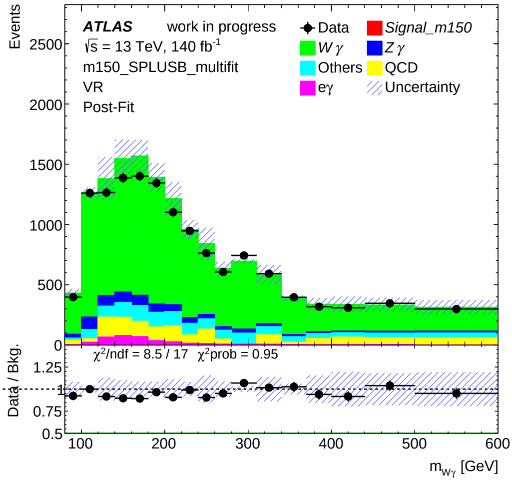


Figure 6: Template fit in the $W\gamma$ control region. 140 GeV $< m^{\ell+\gamma+E_T^{\text{miss}}} <$ 160 GeV in

Results

- Reviewing results internally. Looking to unblind within the year.



Conclusion

- This analysis is going to be the first to search for charged Higgs with $W\gamma$ resonance below 200 GeV.
- Higgs mass is reconstructed by inferring neutrino momentum from W-decay.
- Backgrounds are modeled by MC. Processes with misidentified objects are modeled by data-driven methods.
- Good agreement between MC and data in control regions.
- Data in the signal region is expected to be unblinded this year.

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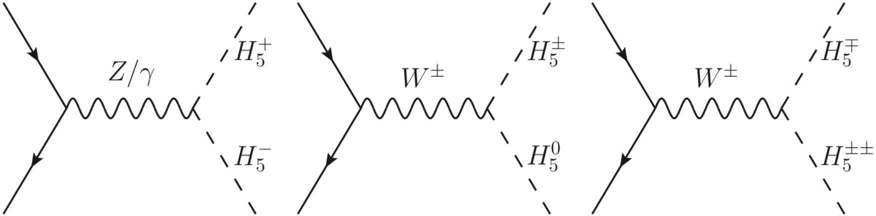
Thank you for your attention

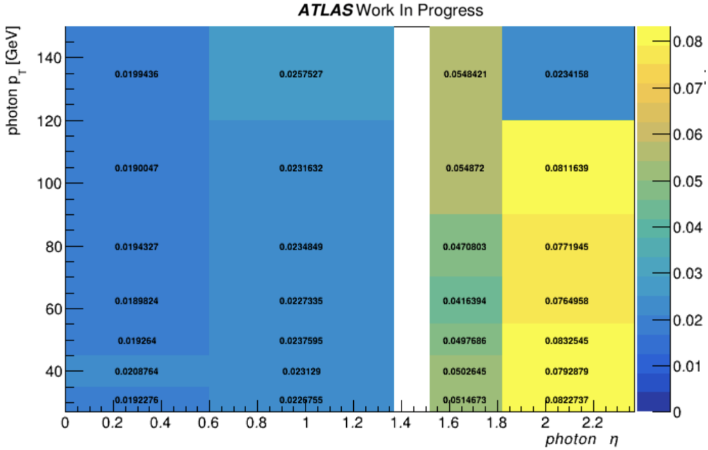
Additional Slides

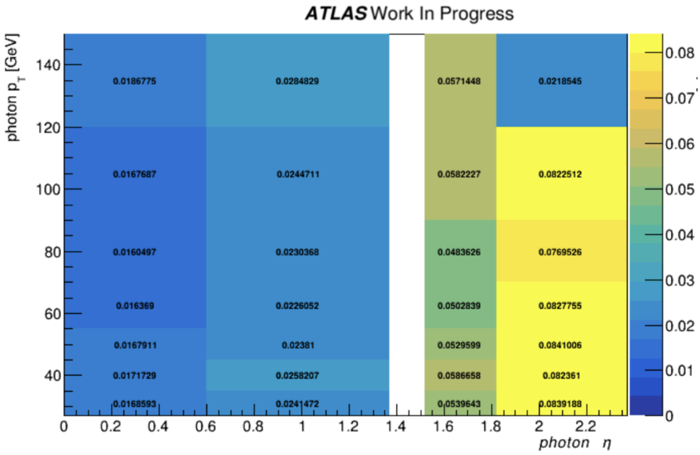
- $H_5^{\pm} H_5^0$ and $H_5^+ H_5^-$ are the signal processes being considered
- $H_5^{\pm} H_5^{\mp\mp}$ is too complicated due to three massive bosons contributing to the final state

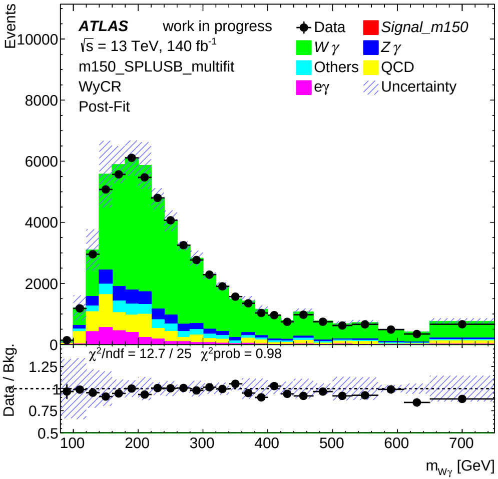


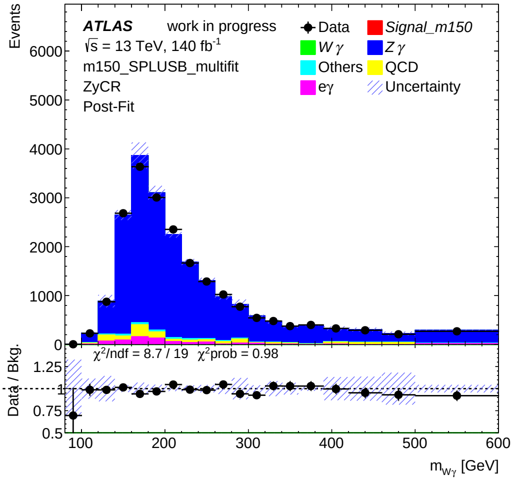
- Simulation samples are generated with
  - $s_H \stackrel{\text{def}}{=} \frac{2\sqrt{2}v_\chi}{v} = 10^{-4}$, WZ final states are suppressed by s_H^2
  - $100\ \text{GeV} < m_{H_5} \leq 200\ \text{GeV}$, in 10 GeV intervals

Fake Rate data

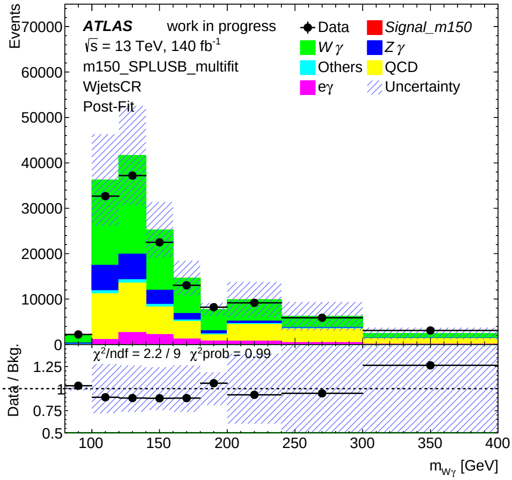


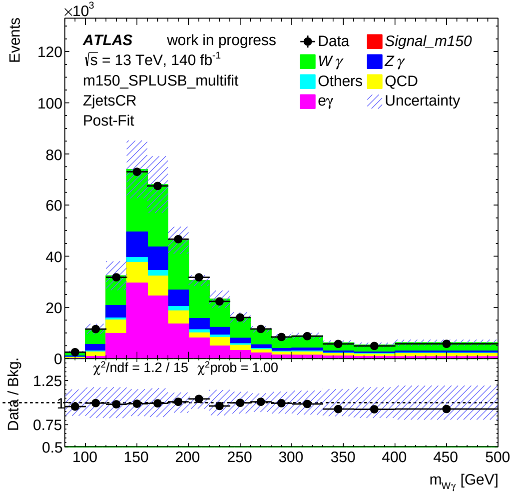

ATLAS Work In Progress
photon p_T [GeV]
photon η
0.0186775
0.0284829
0.0571448
0.0218545
0.0167687
0.0244711
0.0582227
0.0822512
0.0160497
0.0230368
0.0483626
0.0769526
0.016369
0.0226052
0.0502839
0.0827755
0.0167911
0.02381
0.0529599
0.0841006
0.0171729
0.0258207
0.0586658
0.082361
0.0168593
0.0241472
0.0539643
0.0839188


ATLAS work in progress
√s = 13 TeV, 140 fb-1
m150_SPLUSB_multifit
WyCR
Post-Fit
Data
Signal_m150
W γ
Z γ
Others
QCD
eγ
Uncertainty
Events
χ2/ndf = 12.7 / 25 χ2prob = 0.98
Data / Bkg.
mWγ [GeV]


ATLAS work in progress
√s = 13 TeV, 140 fb⁻¹
m150_SPLUSB_multifit
ZyCR
Post-Fit
Data
Signal_m150
W γ
Z γ
Others
QCD
eγ
Uncertainty
Events
6000
5000
4000
3000
2000
1000
0
χ²/ndf = 8.7 / 19 χ²prob = 0.98
Data / Bkg.
1.25
1
0.75
0.5
100
200
300
400
500
600
m_Wγ [GeV]

Results


ATLAS work in progress
√s = 13 TeV, 140 fb⁻¹
m150_SPLUSB_multifit
WjetsCR
Post-Fit
Data
Signal_m150
W γ
Z γ
Others
QCD
eγ
Uncertainty
Events
χ²/ndf = 2.2 / 9 χ²prob = 0.99
Data / Bkg.
m_Wγ [GeV]


ATLAS work in progress
√s = 13 TeV, 140 fb-1
m150_SPLUSB_multifit
ZjetsCR
Post-Fit
Data
Signal_m150
W γ
Z γ
Others
QCD
eγ
Uncertainty
×10^3
Events
χ2/ndf = 1.2 / 15 χ2prob = 1.00
Data / Bkg.
m_Wγ [GeV]