Cross-Section Measurement of Z(νν)γ in the ATLAS Detector

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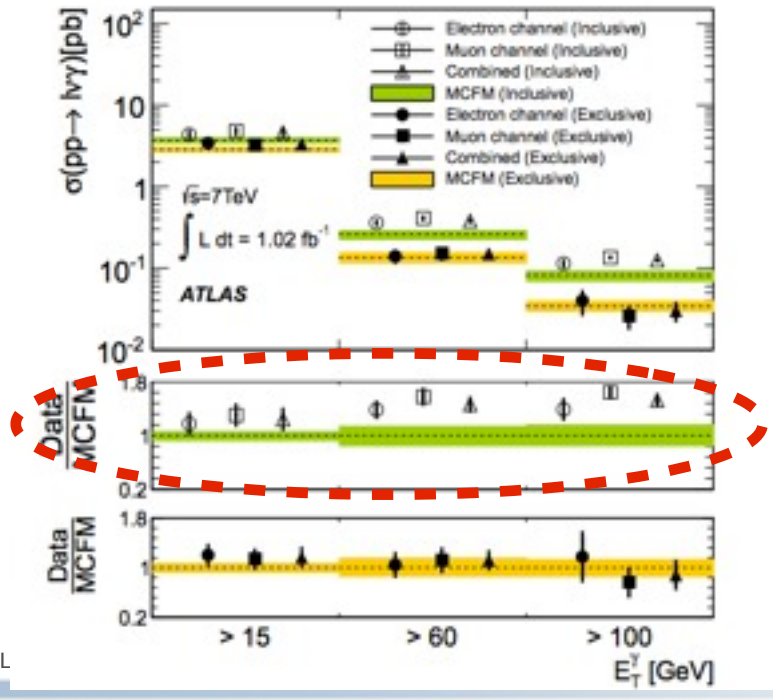
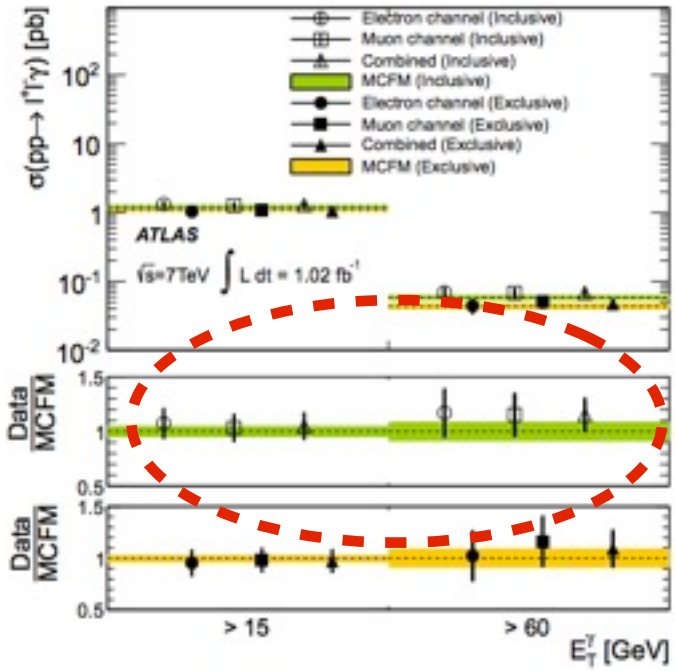
Why Bother?

- It has been used as a background for exotic photon + met analyses
  - but (!) Hadn't been measured at ATLAS before
- If we can collect a pure sample Z(νν)ɣ events can help constrain limits on aTGC more than Z(ll)ɣ
- Hints from previous Z(ll)ɣ and W(lν)ɣ analysis looked intriguing





Data Sample and Kinematic Cuts

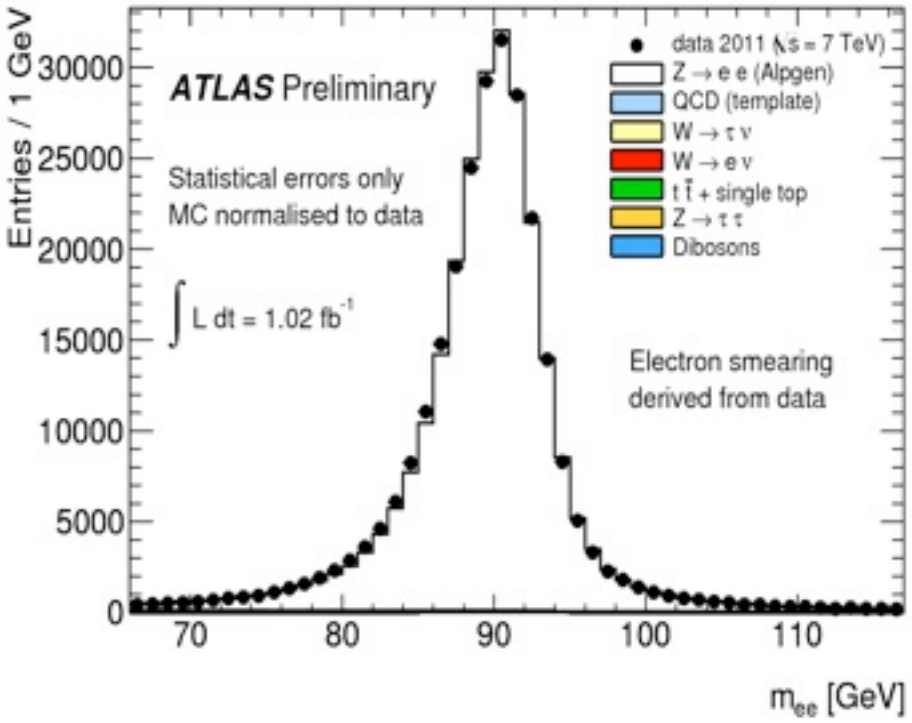
- Used full 7 TeV dataset = 4.64/fb
- Lowest energy, non-prescaled single photon trigger:
  - photon with ET > 80 GeV
- Photon Cut: ET > 100 GeV
  - Chosen to be consistent with Wɣ and Z(ll)ɣ aTGC limit studies
- Exactly 0 electrons, and exactly 0 tight muons
- Require Missing ET > 90 GeV

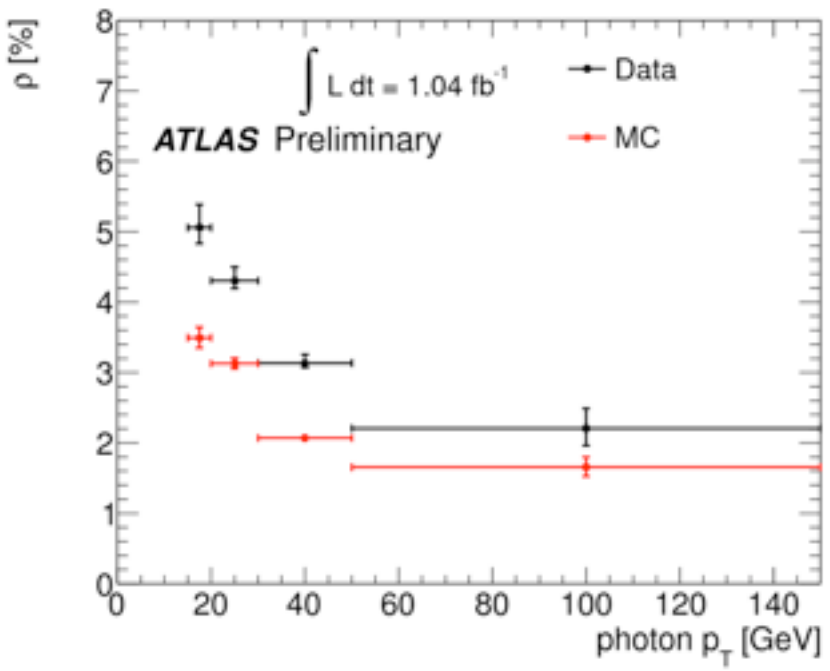
- **Two Largest SM backgrounds:**
  - W(eν): electron is misidentified as a photon
  - W(lν)ɣ: do not detect the charged lepton
  - Z(νν)+jets: jet -> photon

- **Performed two simultaneous measurements:**
  - Requiring exactly 0 jets (exclusive), and any νmber of jets (inclusive)

Measuring the W(eν) background

- Know that electrons can and do fake photons
- Get a handle on this looking for Z(ee) events reconstructed as Z(eɣ)
- Need at least one electron or the photon to have ET > 100 GeV
- Use two regions for the higher ET object |eta| < 1.37 and 1.52 < |eta| <2.47

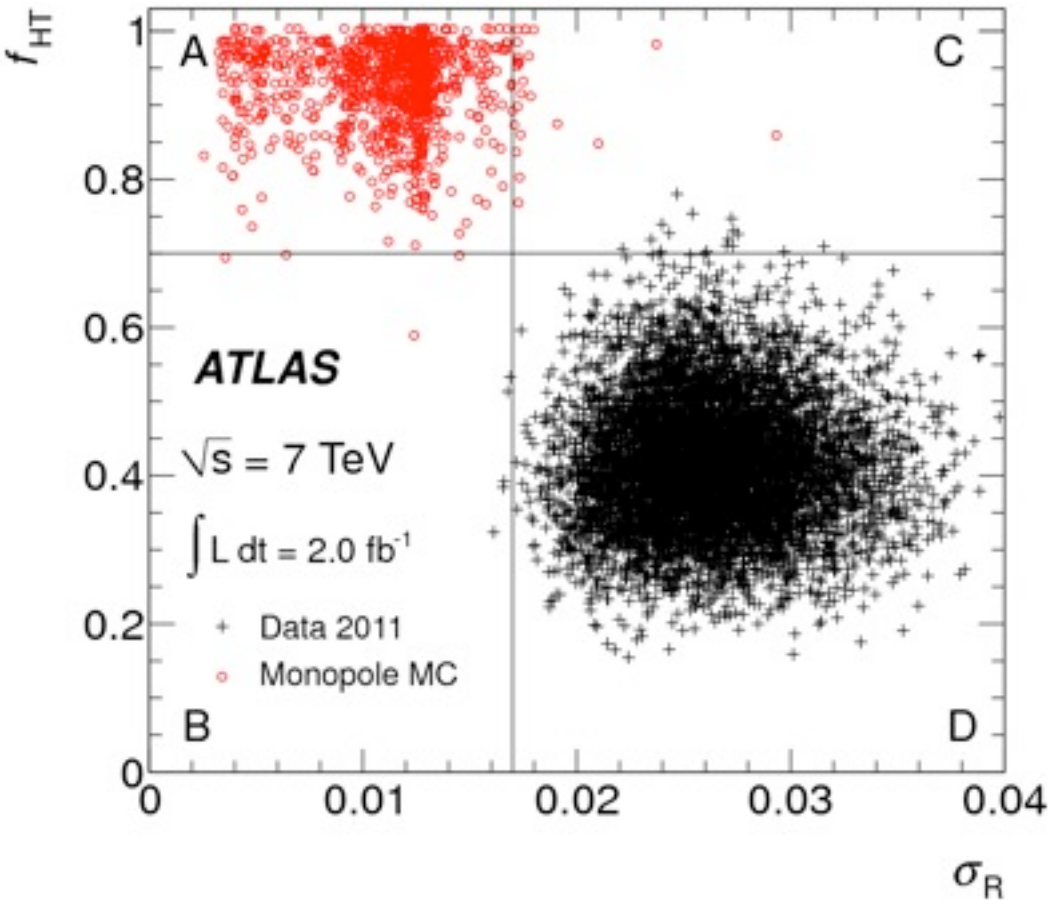




2% for the central region, and 6% for the forward region

Jets misidentified as photons

- Can construct a 2-D grid:
- tight and (loose and !tight) and isolation energies
- Assessing the amount of Z(νν) +jets -> photon + MET
- Can calculate the amount in A = B*C/D * correlation
- correlation factor comes from Z(νν)+jets MC
- A,B,C, and D corrected from SM processes with real photons
  - γ+jets, Wγ, Z(ll)γ, ...

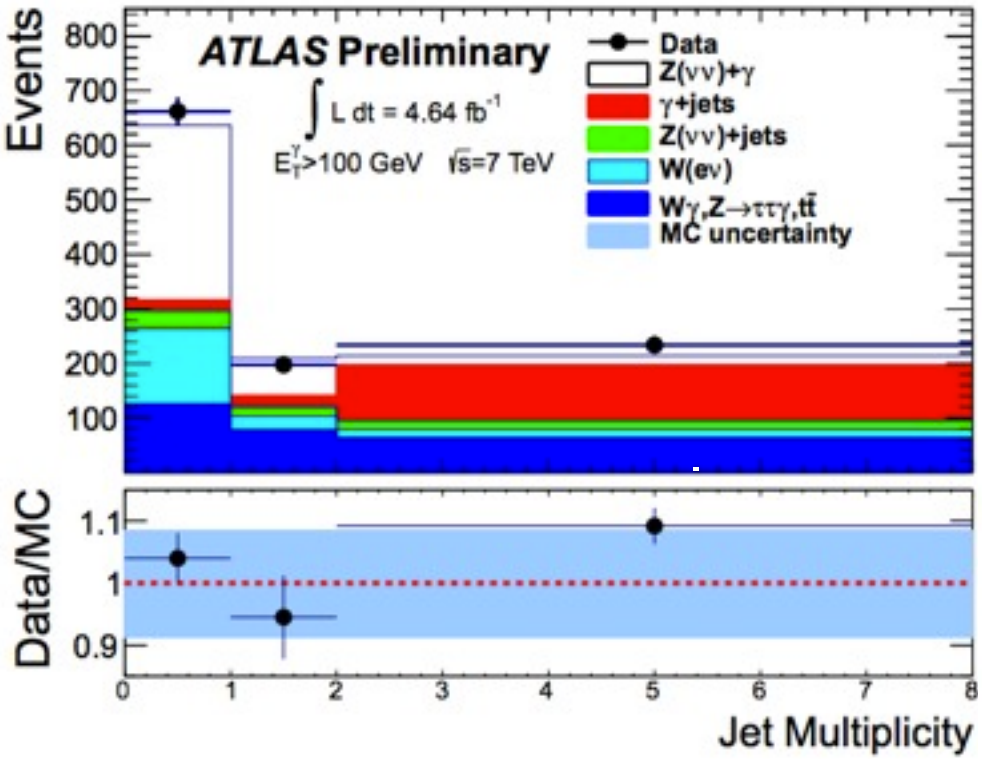


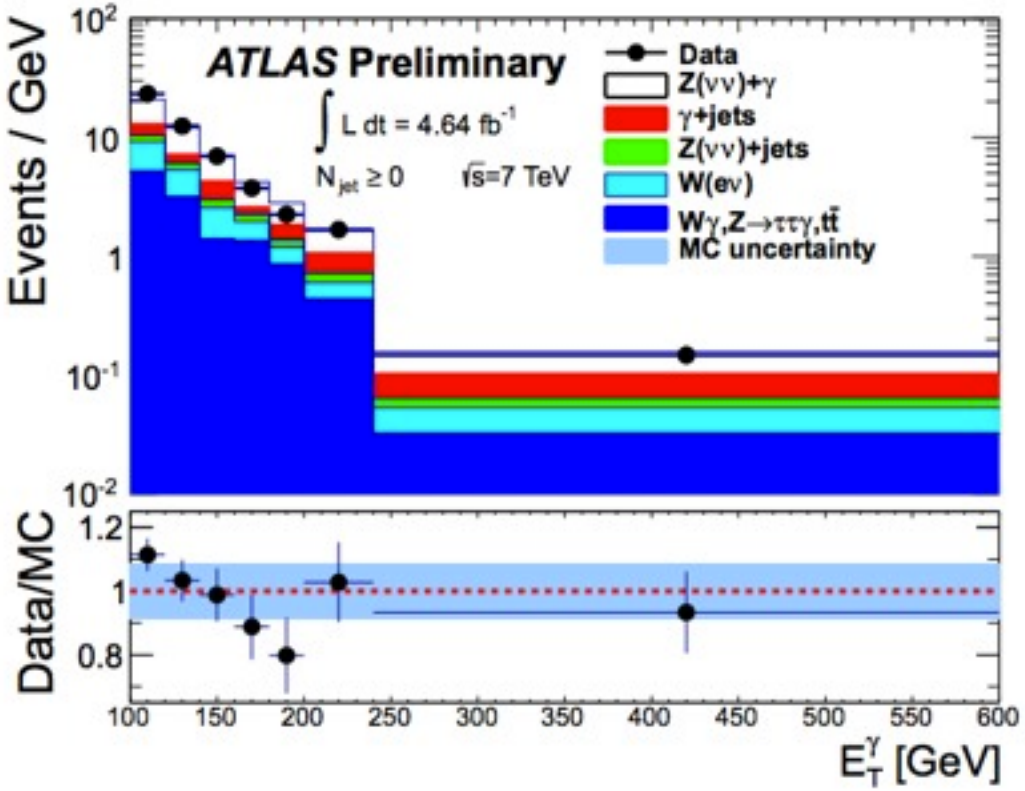
This plot has nothing to do with photons!

Putting Everything Together in Tables

background	$pp \to \nu\bar{\nu}\gamma$ $N_{jet} \geq 0$	$pp \to \nu\bar{\nu}\gamma$ $N_{jet} = 0$
$N_{Z\gamma}^{\text{obs}}$	1094	662
$W \to e\nu$	$171 \pm 2 \pm 17$	$132 \pm 2 \pm 13$
$Z \to \nu\bar{\nu}$+jet	$70 \pm 13 \pm 14$	$29 \pm 5 \pm 3$
$W\gamma$	$273 \pm 14 \pm 18$	$133 \pm 10 \pm 11$
γ+jet	$140 \pm 18 \pm 26$	$19 \pm 7 \pm 11$
$Z(\to \tau\tau)\gamma$	$11.7 \pm 0.7 \pm 0.9$	$6.5 \pm 0.6 \pm 0.6$
$t\bar{t}$	$11 \pm 1.2 \pm 1.0$	$0.9 \pm 0.6 \pm 0.1$
$N_{Z\gamma}^{\text{sig}}$	$417 \pm 33 \pm 39$	$342 \pm 23 \pm 21$

How does data compare to simulation?





Inclusive jets sample, very good agreement

If there was aTGC we'd expect large contribution at high photon ET... so we set limits

Measured cross sections in fiducial phase space

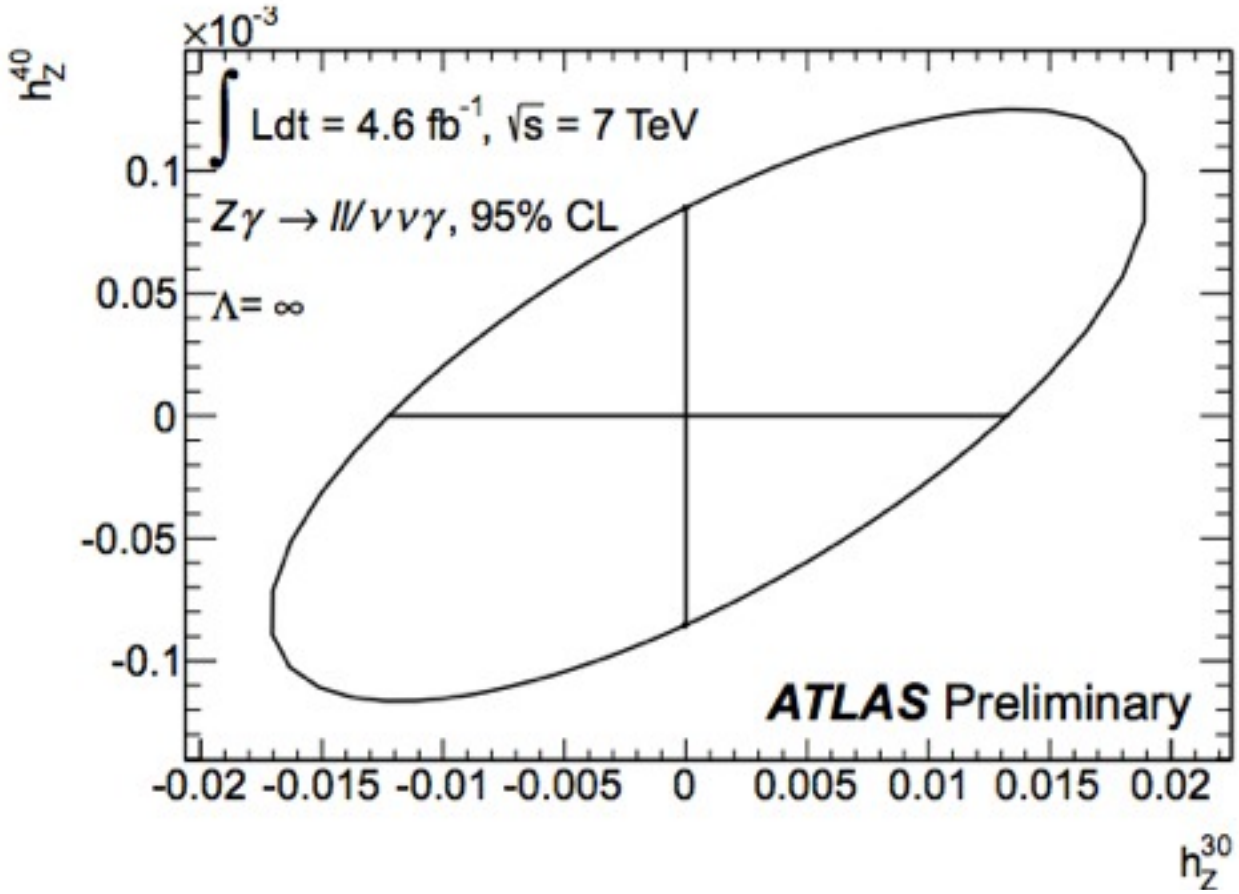
- Zɣ measurements are all consistent with MCFM predictions
- Wɣ measurements are still a bit higher than NLO predictions

	$\sigma^{\text{ext-fid}}$[pb]	$\sigma^{\text{ext-fid}}$[pb]
	Measurement	MCFM Prediction
	$N_{jet} \geq 0$	
$e\nu\gamma$	$2.70 \pm 0.12 \pm 0.33$	1.96 ± 0.17
$\mu\nu\gamma$	$2.77 \pm 0.12 \pm 0.37$	1.96 ± 0.17
$l\nu\gamma$	$2.74 \pm 0.09 \pm 0.34$	1.96 ± 0.17
$e^+e^-\gamma$	$1.28 \pm 0.06 \pm 0.13$	1.18 ± 0.05
$\mu^+\mu^-\gamma$	$1.30 \pm 0.05 \pm 0.11$	1.18 ± 0.05
$l^+l^-\gamma$	$1.29 \pm 0.04 \pm 0.11$	1.18 ± 0.05
$\nu\bar{\nu}\gamma$	$0.130 \pm 0.013 \pm 0.013$	0.156 ± 0.012
	$N_{jet} = 0$	
$e\nu\gamma$	$1.75 \pm 0.11 \pm 0.23$	1.39 ± 0.13
$\mu\nu\gamma$	$1.72 \pm 0.10 \pm 0.22$	1.39 ± 0.13
$l\nu\gamma$	$1.73 \pm 0.07 \pm 0.21$	1.39 ± 0.13
$e^+e^-\gamma$	$1.05 \pm 0.05 \pm 0.12$	1.06 ± 0.05
$\mu^+\mu^-\gamma$	$1.03 \pm 0.04 \pm 0.10$	1.06 ± 0.05
$l^+l^-\gamma$	$1.04 \pm 0.03 \pm 0.10$	1.06 ± 0.05
$\nu\bar{\nu}\gamma$	$0.109 \pm 0.010 \pm 0.011$	0.115 ± 0.009

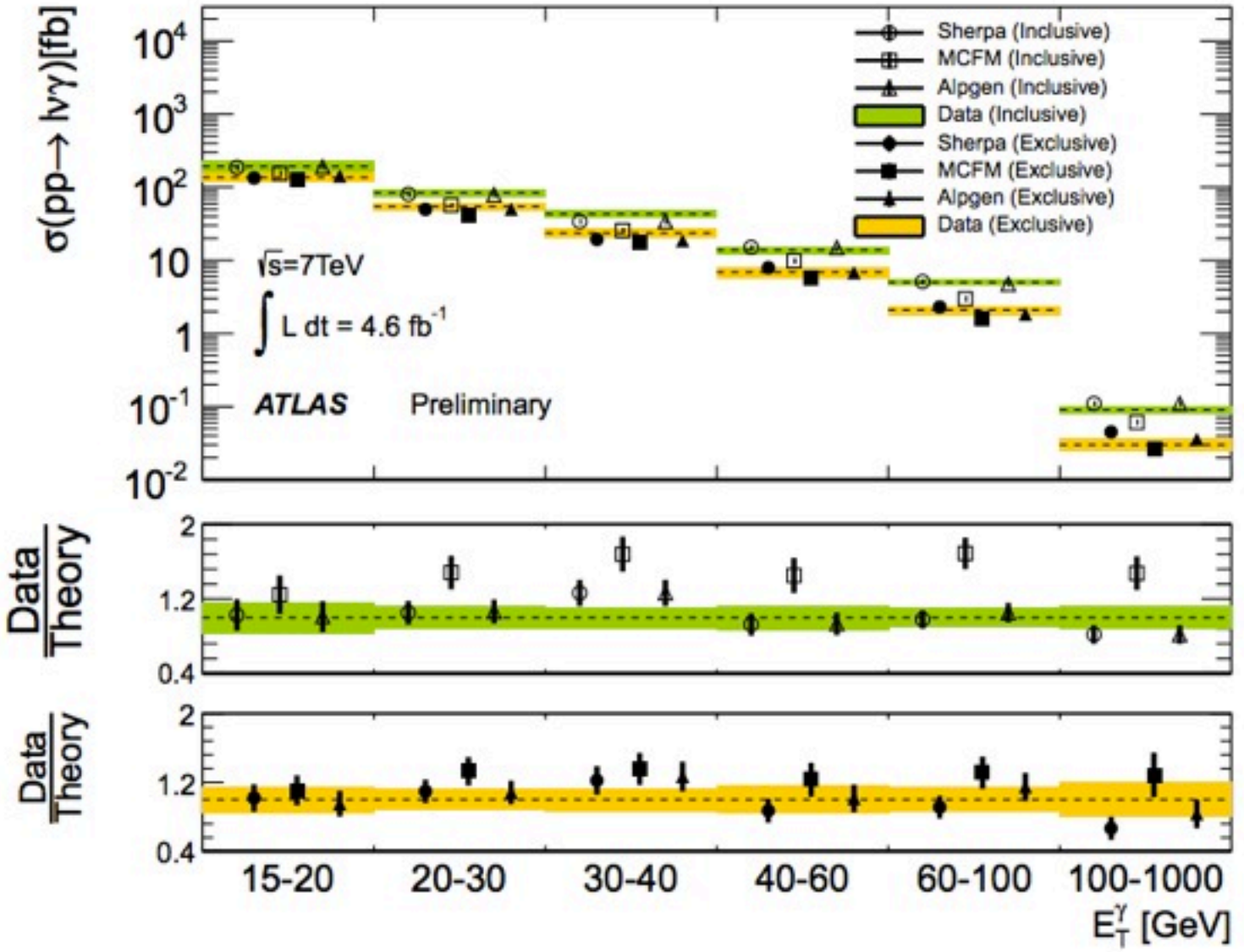
Limit Setting on aTGC

	Measured	Expected
processes	$pp \to \nu\nu\gamma$ and $pp \to l^+l^-\gamma$	
Λ	∞	∞
h_3^γ	(-0.015, 0.016)	(-0.017, 0.018)
h_3^Z	(-0.013, 0.014)	(-0.015, 0.016)
h_4^γ	(-0.000094, 0.000092)	(-0.00010, 0.00010)
h_4^Z	(-0.000087, 0.000087)	(-0.000097, 0.000097)
Λ	3 TeV	3 TeV
h_3^γ	(-0.023, 0.024)	(-0.027, 0.028)
h_3^Z	(-0.018, 0.020)	(-0.022, 0.024)
h_4^γ	(-0.00037, 0.00036)	(-0.00043, 0.00042)
h_4^Z	(-0.00031, 0.00031)	(-0.00037, 0.00036)

anomalous triple gauge couplings 2-D limits



Unfolded W(lν)γ cross sections



Conclusions

- Wɣ and Zɣ cross sections have been measured in both inclusive and exclusive jet multiplicity
- See very good agreement between Zɣ and theoretical predictions
- Wɣ cross sections are measured to be a bit higher than MCFM predictions
- Have set strong limits on size of anomalous triple gauge couplings
- Improvements to selection and analysis have been identified