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

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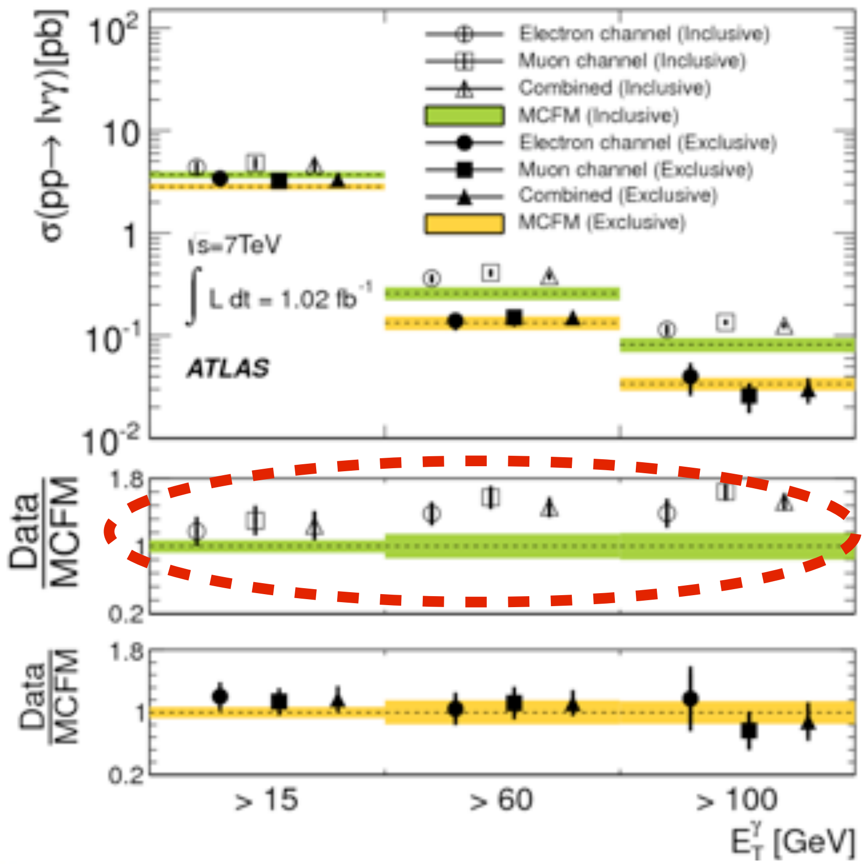
Why Bother?

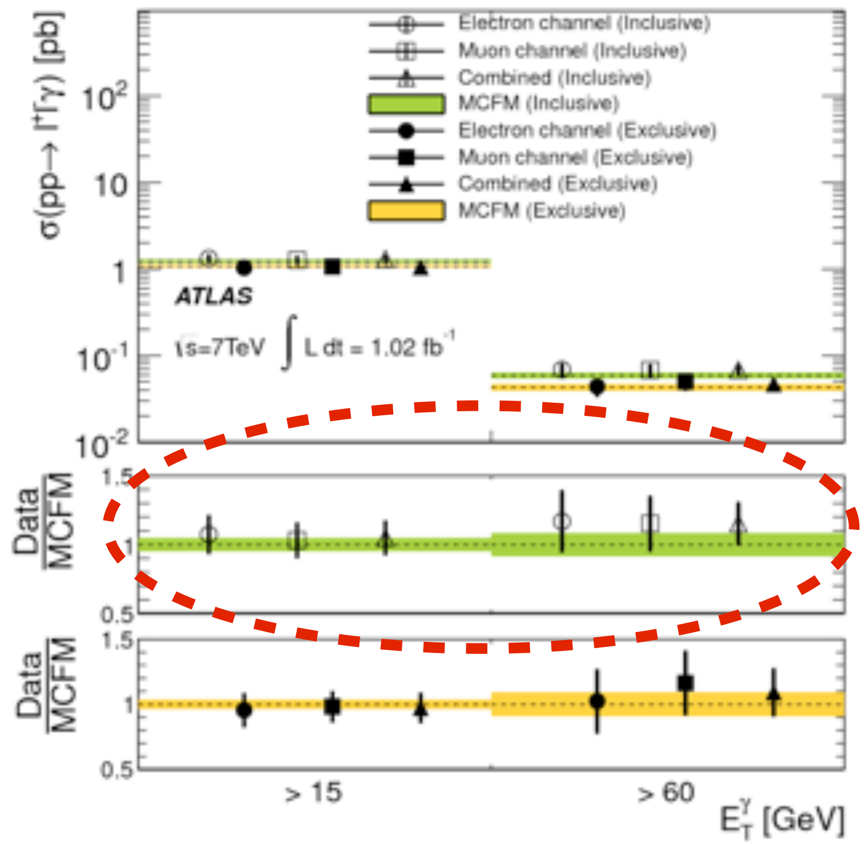
- It has been used as a background for exotic photon + met analyses
  - but (!) Hadn't been measured at ATLAS before
- If we can collect a pure sample Z(νν)ɣ events can help constrain limits on aTGC more than Z(ll)ɣ
- Small W(lν) ɣ excess over predictions from previous Z(ll)ɣ and W(lν)ɣ analysis
- Is the excess just Wɣ? Or did we not have enough Zɣ events?

Wɣ

Incl.

0 jet





Zɣ

Incl.

0 jet

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Data Sample and Kinematic Cuts

- Used full 7 TeV dataset = 4.64 fb^{-1}
- Lowest energy, non-prescaled single photon trigger:
  - photon with $E_T > 80$ GeV
- Photon Cut: $E_T > 100$ GeV
  - Chosen to be consistent with Wɣ and Z(ll)ɣ
- Exactly 0 electrons, and exactly 0 muons
- Require Missing $E_T > 90$ GeV
  - Negative vector sum of all energy deposits

- **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 number of jets (inclusive)

Putting Everything Together in Tables

	$\nu\bar{\nu}\gamma$ $N_{\text{jet}} \geq 0$	$\nu\bar{\nu}\gamma$ $N_{\text{jet}} = 0$
$N_{Z\gamma}^{\text{obs}}$	1094	662
$W(e\nu)$	$171 \pm 2 \pm 17$	$132 \pm 2 \pm 13$
$Z(\nu\bar{\nu})$+jets, multi-jet	$70 \pm 13 \pm 14$	$29 \pm 5 \pm 3$
$W\gamma$	$238 \pm 12 \pm 37$	$104 \pm 9 \pm 24$
γ+jets	$168 \pm 20 \pm 42$	$26 \pm 7 \pm 11$
$Z(\tau^+\tau^-)\gamma$	$11.7 \pm 0.7 \pm 0.9$	$6.5 \pm 0.6 \pm 0.6$
$t\bar{t}$	$11 \pm 1.2 \pm 1.0$	$0.9 \pm 0.6 \pm 0.1$
$N_{Z\gamma}^{\text{sig}}$	$420 \pm 42 \pm 60$	$360 \pm 29 \pm 30$

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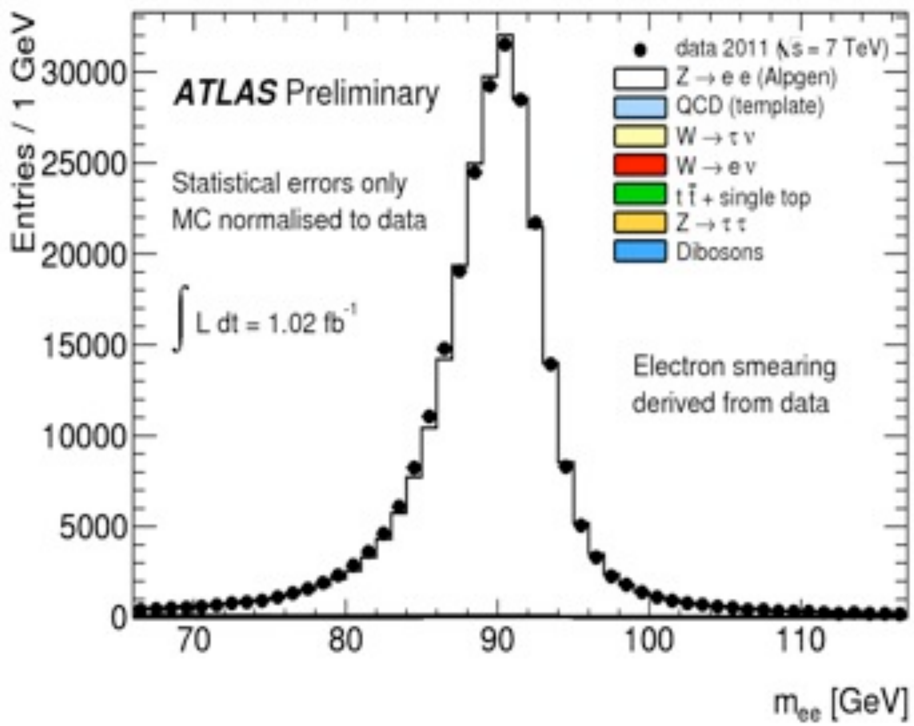
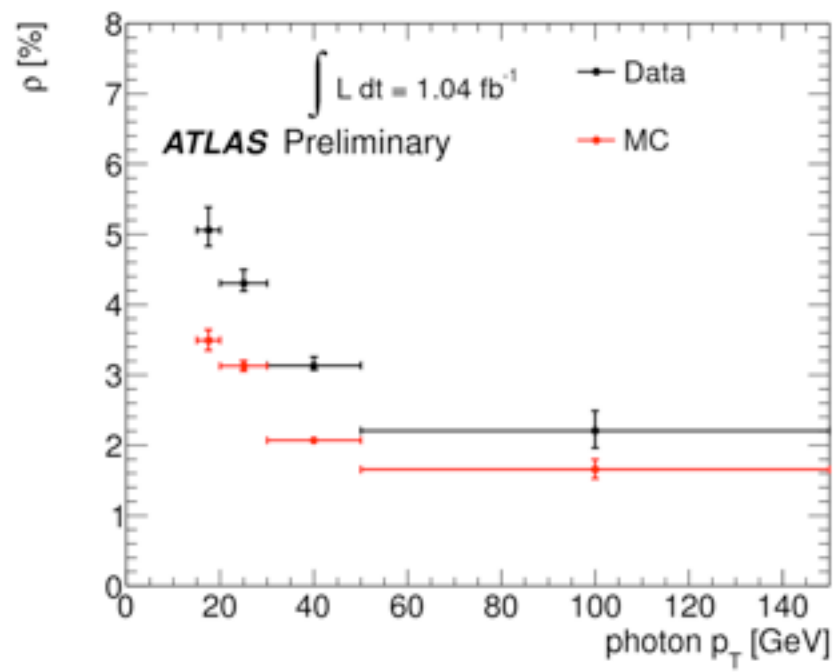
Data-Driven

Measuring the W(eν) background

- Know that electrons can and do fake photons
- Z(ee) events reconstructed as Z(eɣ) gives a perfect control sample
- Need at least one electron or the photon to have $E_T > 100$ GeV
- Use two regions for the higher E_T object $|\eta| < 1.37$ and $1.52 < |\eta| < 2.47$

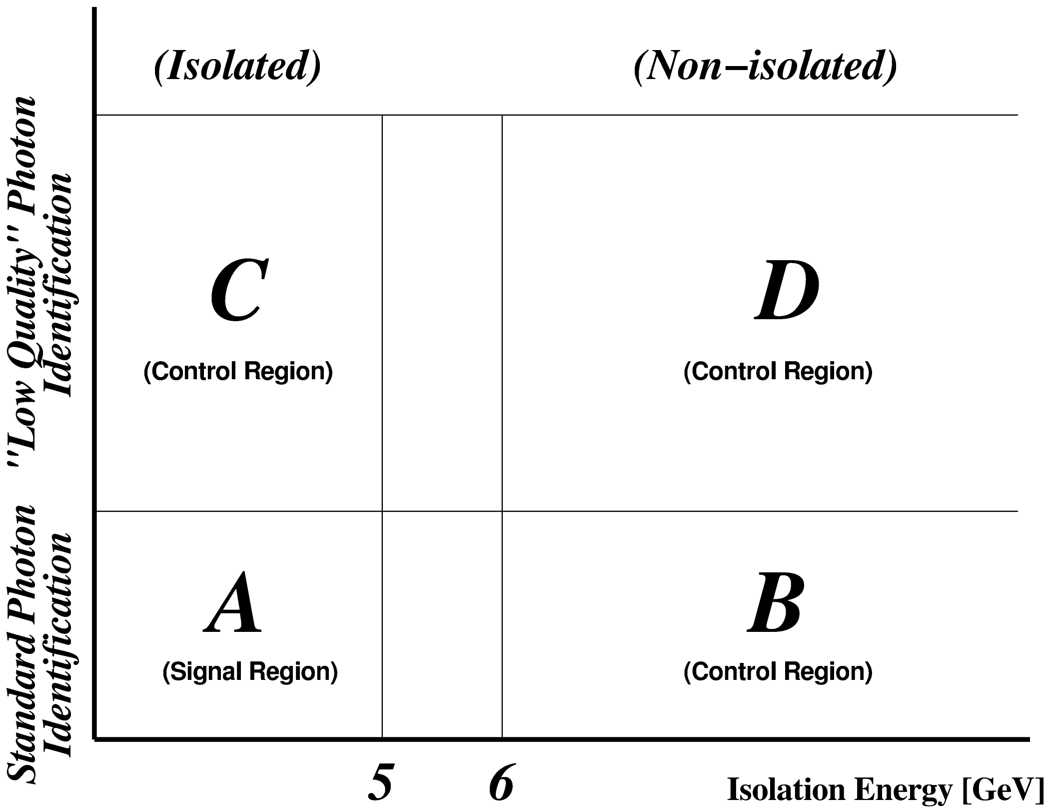




2% for the central region, and 6% for the forward region

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, ...



Use a region with large statistics to extrapolate into a signal region

Measured cross sections in fiducial phase space

	$\sigma^{\text{ext-fid}}$[pb] Measurement	$\sigma^{\text{ext-fid}}$[pb] MCFM Prediction
	$N_{\text{jet}} \geq 0$	
$e^+e^-\gamma$	1.30 ± 0.03 (stat) ± 0.13 (syst) ± 0.05 (lumi)	1.18 ± 0.05
$\mu^+\mu^-\gamma$	1.32 ± 0.03 (stat) ± 0.11 (syst) ± 0.05 (lumi)	1.18 ± 0.05
$\ell^+\ell^-\gamma$	1.31 ± 0.02 (stat) ± 0.11 (syst) ± 0.05 (lumi)	1.18 ± 0.05
$\nu\bar{\nu}\gamma$	0.133 ± 0.013 (stat) ± 0.020 (syst) ± 0.005 (lumi)	0.156 ± 0.012
	$N_{\text{jet}} = 0$	
$e^+e^-\gamma$	1.07 ± 0.03 (stat) ± 0.12 (syst) ± 0.04 (lumi)	1.06 ± 0.05
$\mu^+\mu^-\gamma$	1.04 ± 0.03 (stat) ± 0.10 (syst) ± 0.04 (lumi)	1.06 ± 0.05
$\ell^+\ell^-\gamma$	1.05 ± 0.02 (stat) ± 0.10 (syst) ± 0.04 (lumi)	1.06 ± 0.05
$\nu\bar{\nu}\gamma$	0.116 ± 0.010 (stat) ± 0.013 (syst) ± 0.004 (lumi)	0.115 ± 0.009

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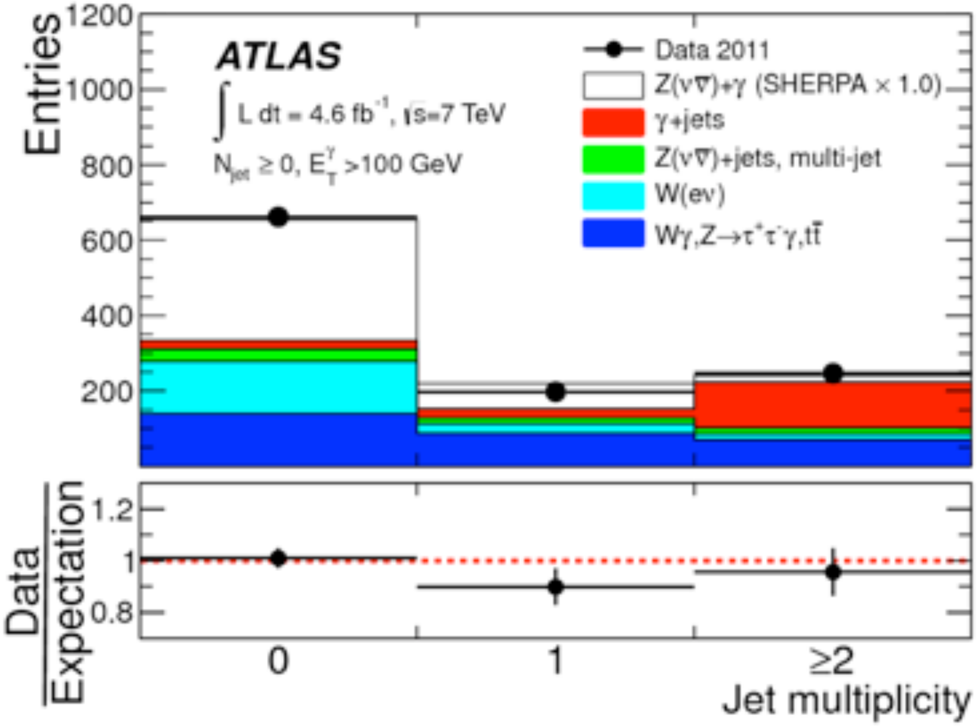
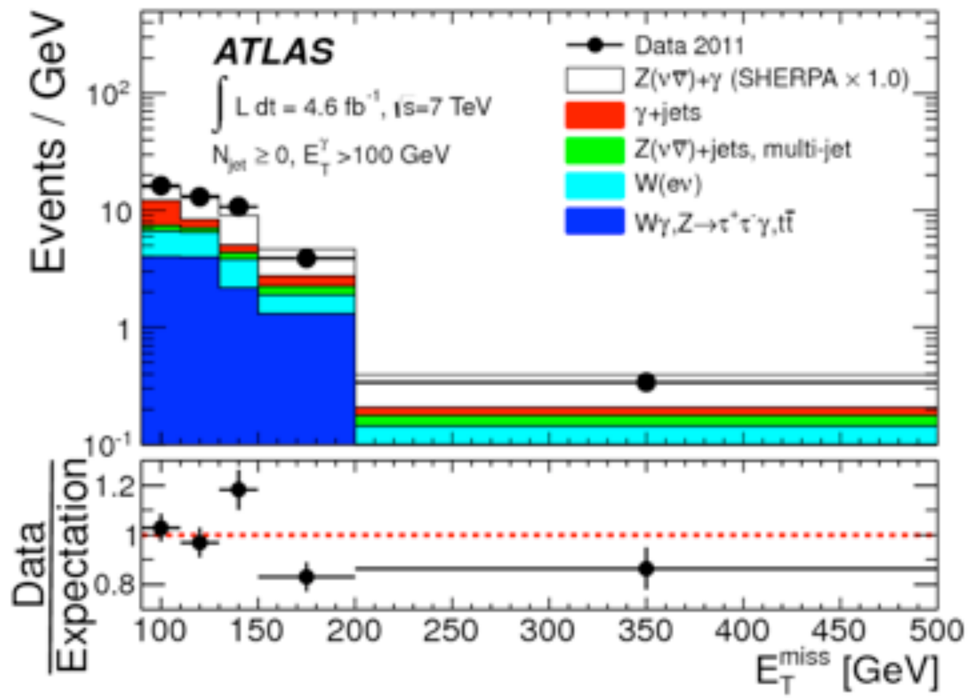
- Zɣ measurements are all consistent with MCFM predictions

How does data compare to simulation?





Inclusive jets sample, shows agreement

Agreement in the Missing E_T sample

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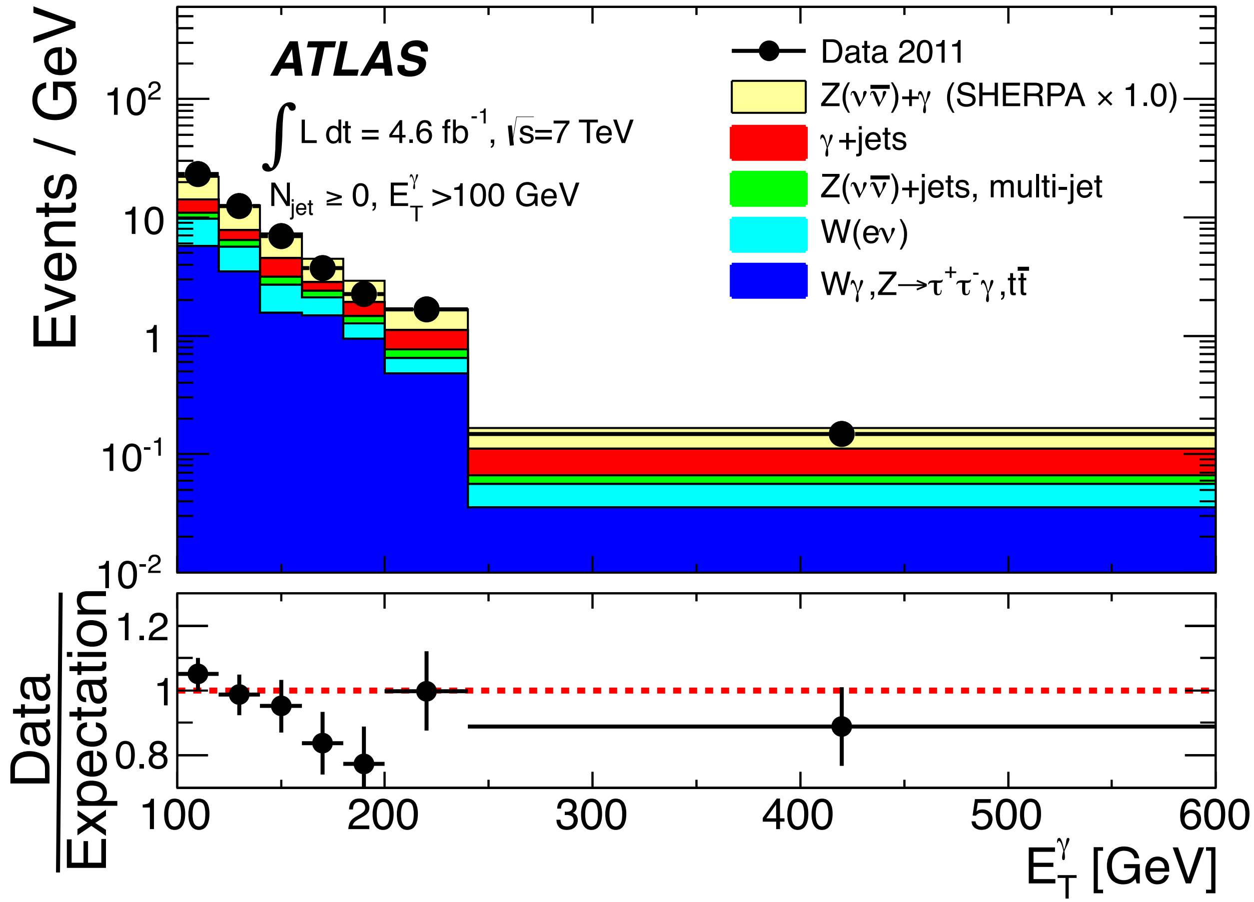
Photon E_T in the $Z(\nu\nu)\gamma$



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Conclusions

- $Z\gamma$ cross sections have been measured in both inclusive and exclusive jet multiplicity
- See very good agreement between $Z\gamma$ and theoretical predictions
- Improvements to selection and analysis have been identified

1-Dimensional 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)

$$h_3^V(s) = h_3^V/(1+\hat{s}/\Lambda^2)^3 \text{ and } h_4^V(s) = h_4^V/(1+\hat{s}/\Lambda^2)^4$$

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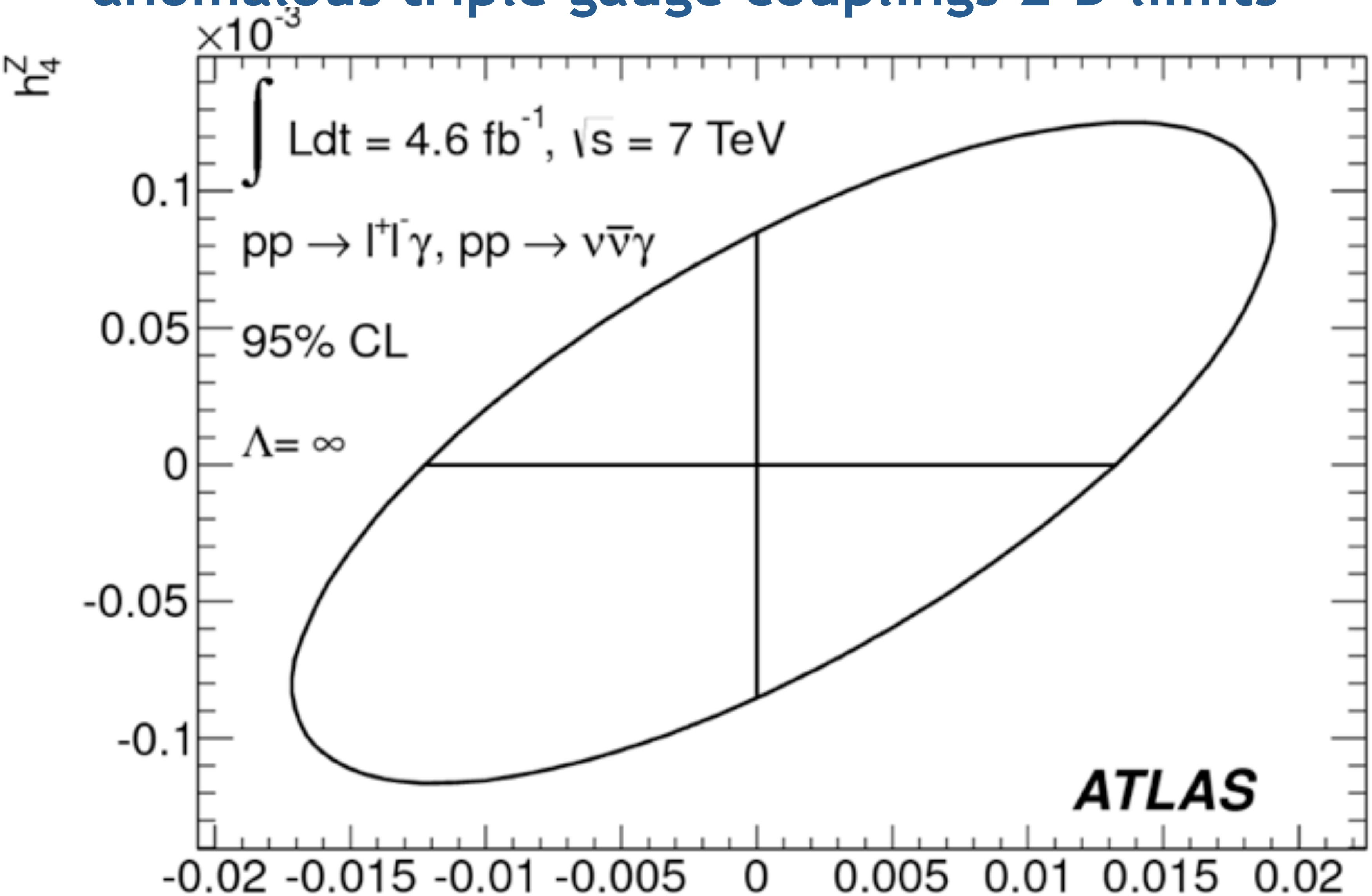
anomalous triple gauge couplings 2-D limits



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