Recent Wγ/Zγ measurements at ATLAS

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January 9 2013
Epiphany Conference, Cracow

Outline

- Motivation
- Standard Model $W\gamma/Z\gamma$ cross-sections
- Anomalous Triple Gauge Couplings
- BSM resonance searches

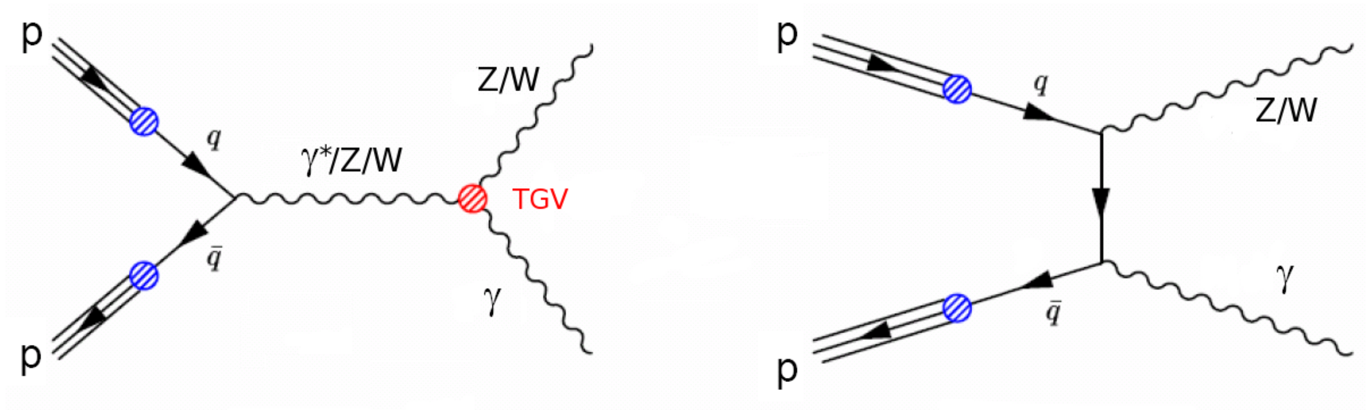
Motivation

Signature

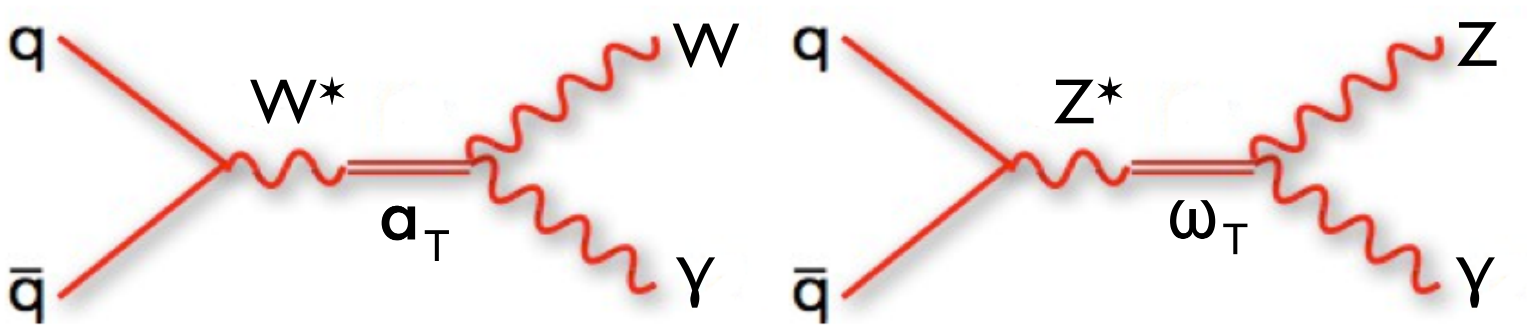
Associated production of a Z/W boson and a photon, where Z → ee/μμ/νν and W → eν/μν.

Physics

- Precision test of the Standard Model (SM)
  Triple Gauge Couplings (TGC)
  WWγ vertex (charged TGCs) and ZZγ / Zγγ vertices (neutral TGCs - forbidden in SM!)



- Search for vector resonances decaying to Zγ/Wγ (e.g. Techni-mesons):



Z(ee/μμ)γ, W(eν/μν)γ selection

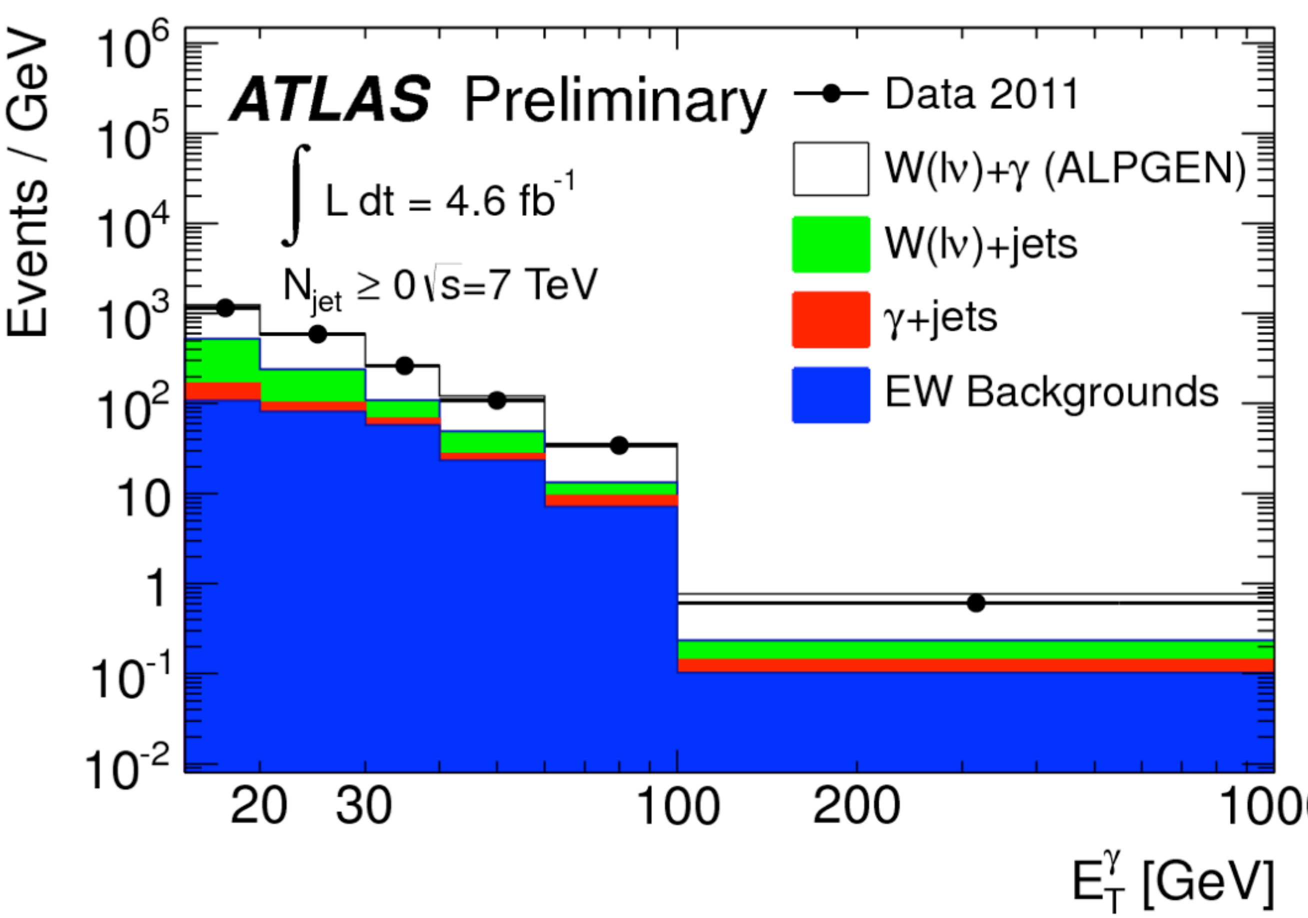
Signal definition

- $P_T(l)$ > 25 GeV
- $E_T(\gamma)$ > 15 GeV
- $\Delta R(l,\gamma)$ > 0.7
- Z(ee/μμ)γ: M_{ll}>40GeV
- W(eν/μν)γ: M_T>40GeV, E_T^{miss}>35GeV

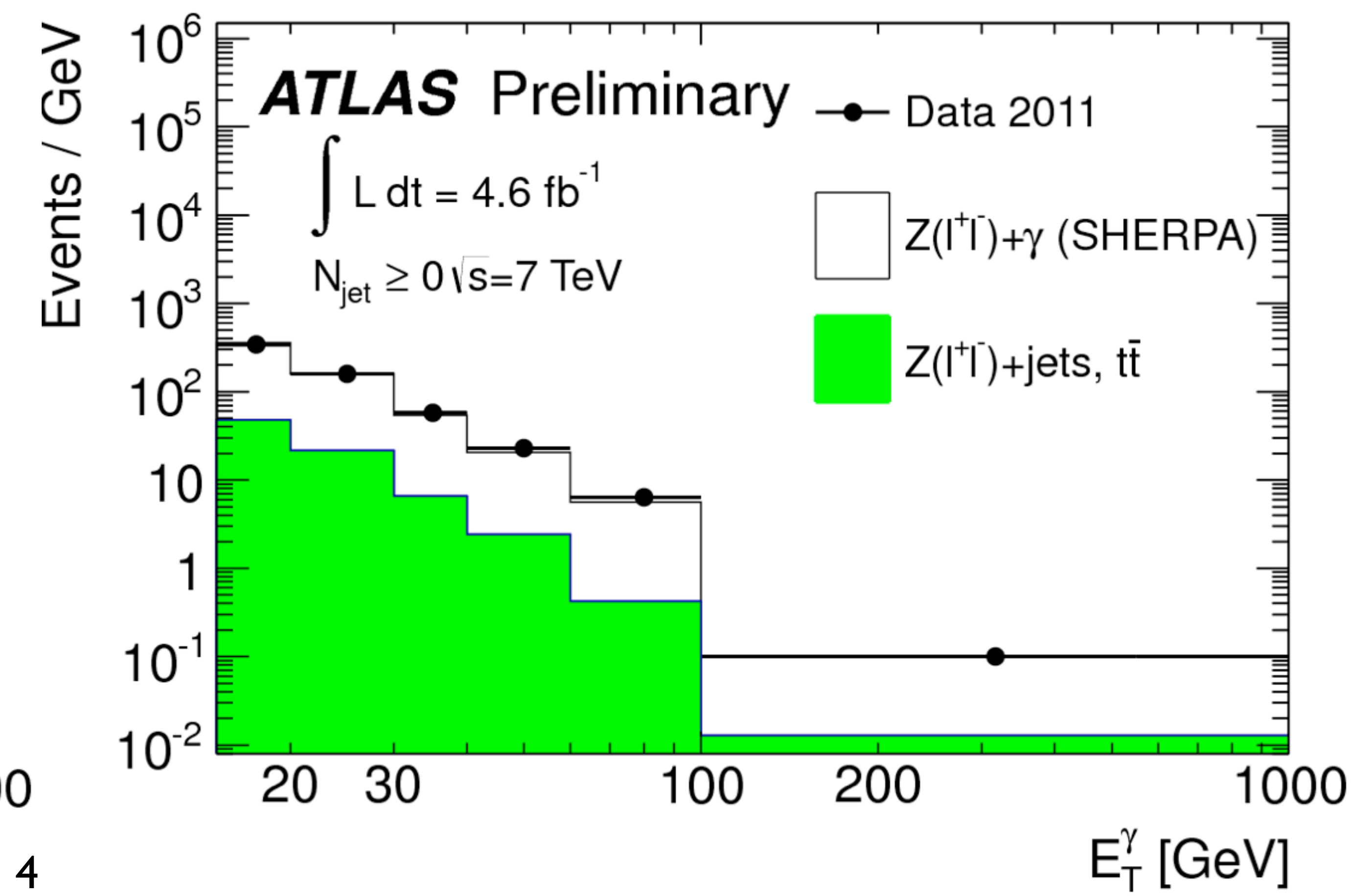
Background estimation

- Data driven methods for estimating W+jet, Z+jet, γ+jets.
- MC for EW (WW, ttbar, Z(ττ), W(τν), single top).

photon transverse energy (Wγ)



photon transverse energy (Zγ)



Z(νν)γ selection

- only used for the integrated cross section measurement.

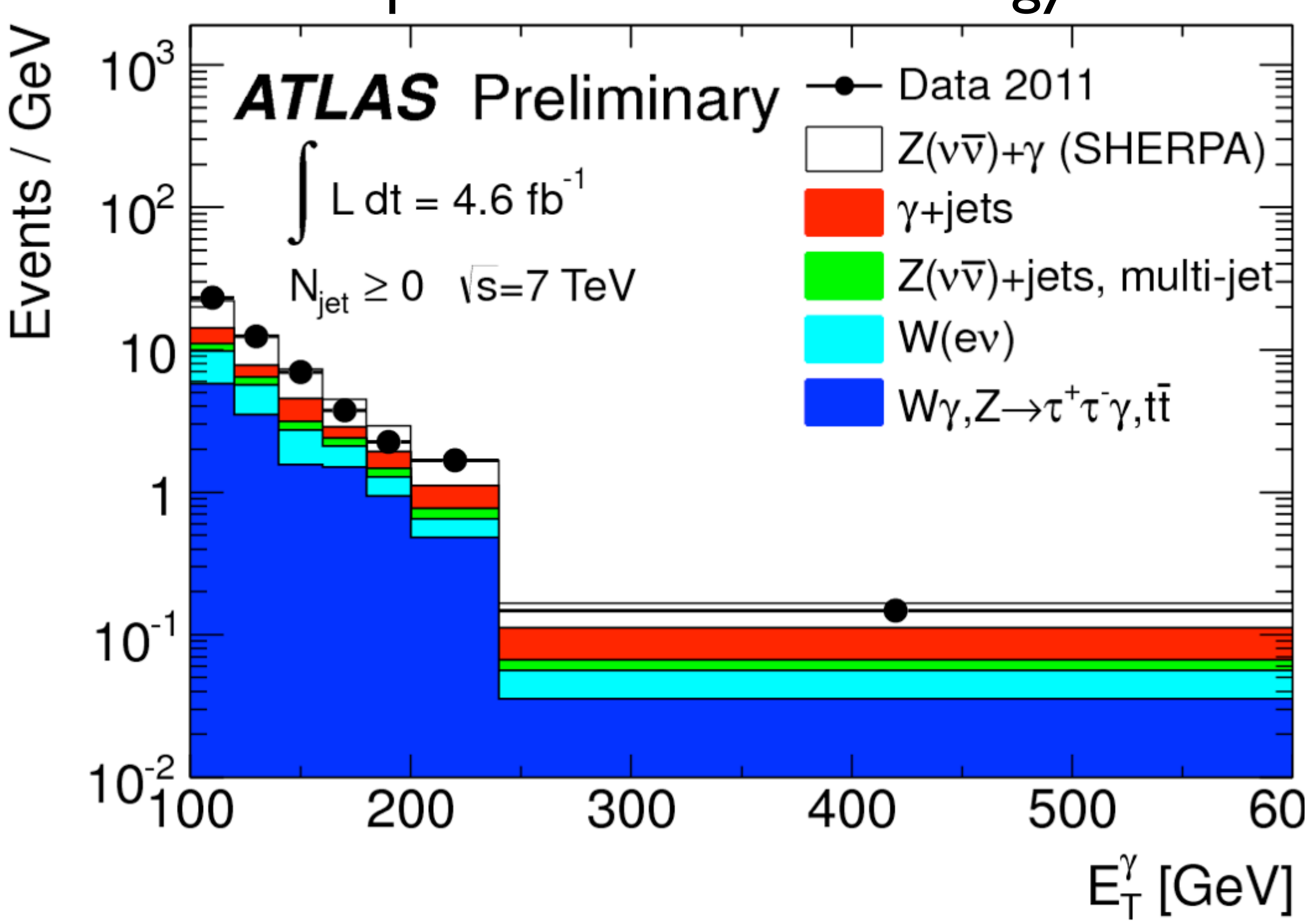
Signal definition

- $E_T(\gamma) > 100$ GeV
- $E_T^{miss} > 90$ GeV
- $\Delta\varphi(E_T^{miss},\gamma) > 2.6$
- $\Delta\varphi(E_T^{miss},\text{jet}) > 0.4$
- Electron and muon veto

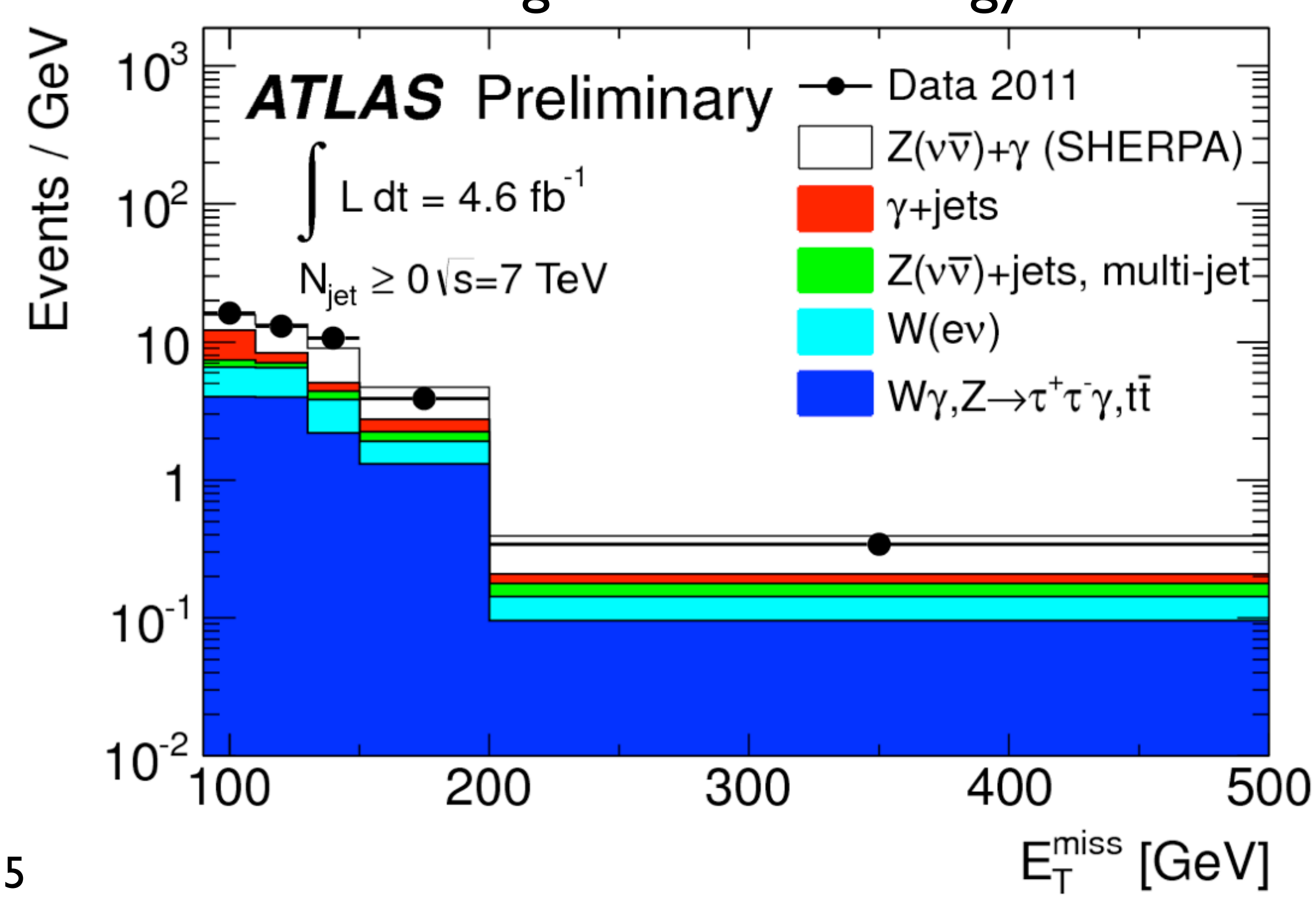
Background estimation

- Data driven methods for estimating γ+jets, Z(νν)+jets, multijets, W(eν)
- MC for Wγ, Z(ττ)γ, ttbar.

photon transverse energy



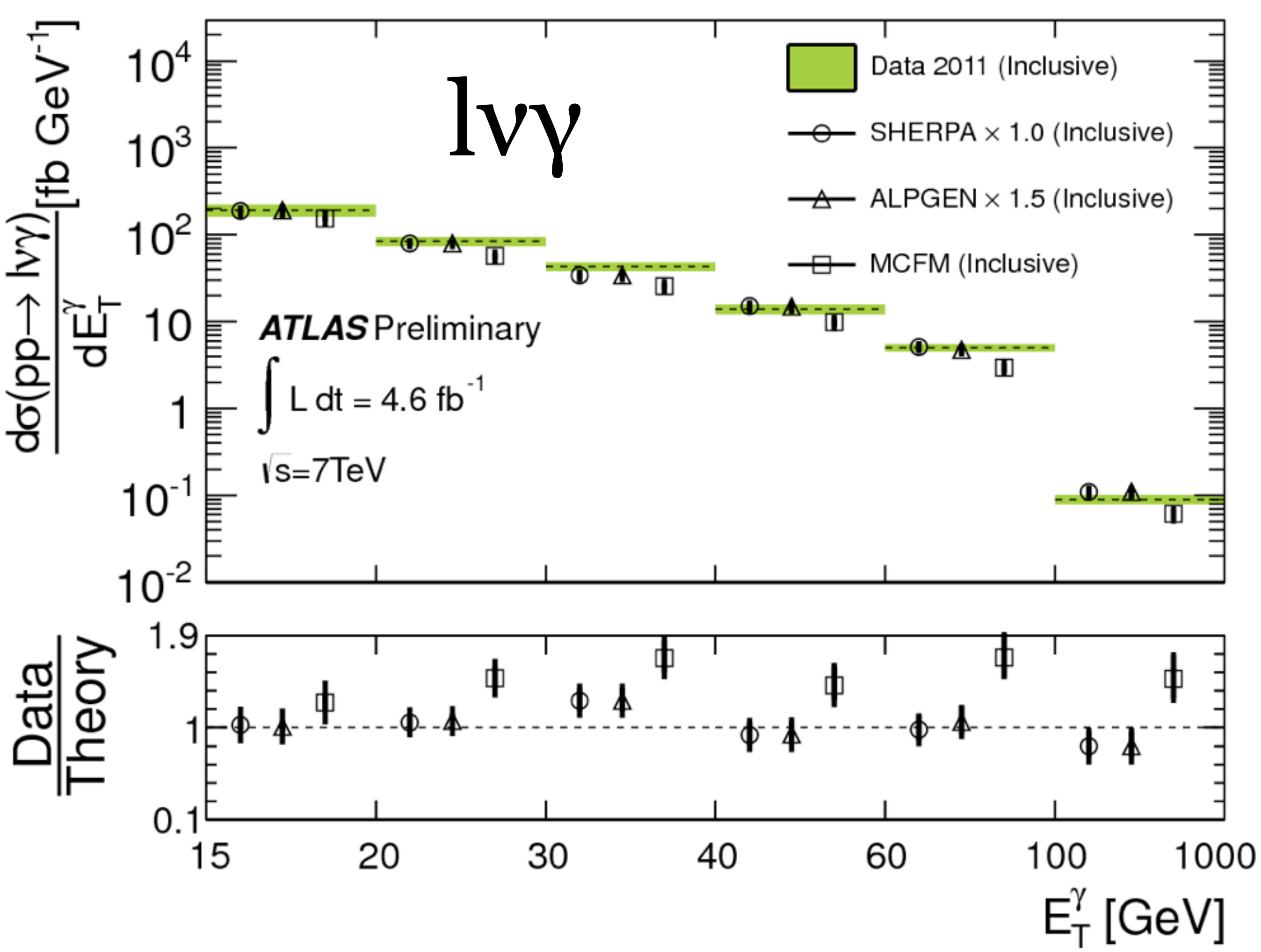
missing transverse energy

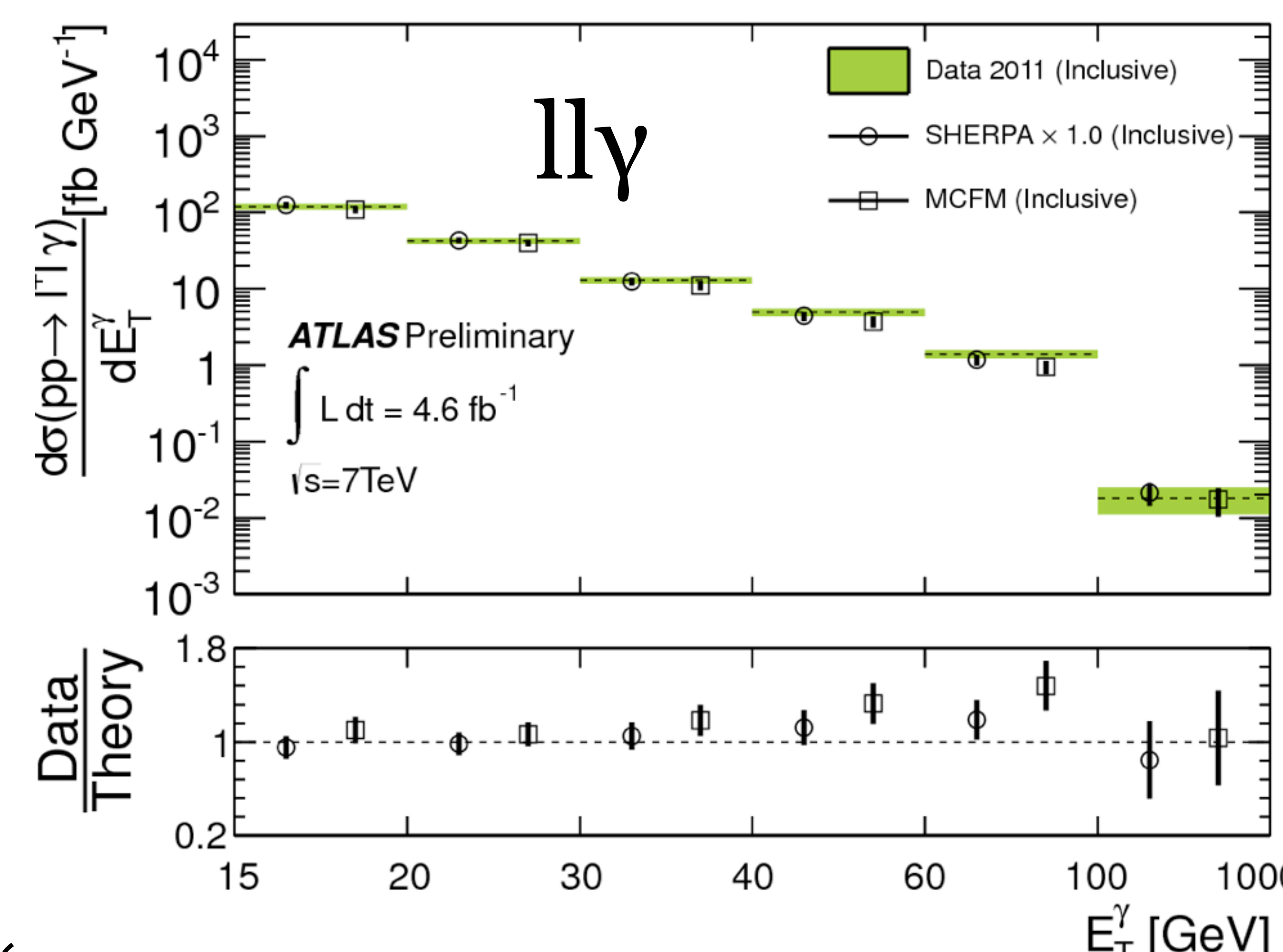


Inclusive results

- Multi-leg LO MC Sherpa/Alpgen is normalized to the observed yields and describe data better than NLO prediction from MCFM.
- Main systematic uncertainties: V+jet background estimate, photon ID efficiency.
- The table shows integrated fiducial cross sections with $E_T(\gamma)$ > 15 GeV for $Z(ll)\gamma$ and $W(l\nu)\gamma$, while $E_T(\gamma)$ > 100 GeV for $Z(\nu\nu)\gamma$.

Channel	Measurement (pb)	NLO (MCFM) pb
$l\nu\gamma$	2.77 ± 0.03 (stat) ± 0.33 (syst) ± 0.14 (lumi)	1.96 ± 0.17
$ll\gamma$	1.31 ± 0.02 (stat) ± 0.11 (syst) ± 0.05 (lumi)	1.18 ± 0.05
$\nu\nu\gamma$	0.133 ± 0.013 (stat) ± 0.020 (syst) ± 0.005 (lumi)	0.156 ± 0.012

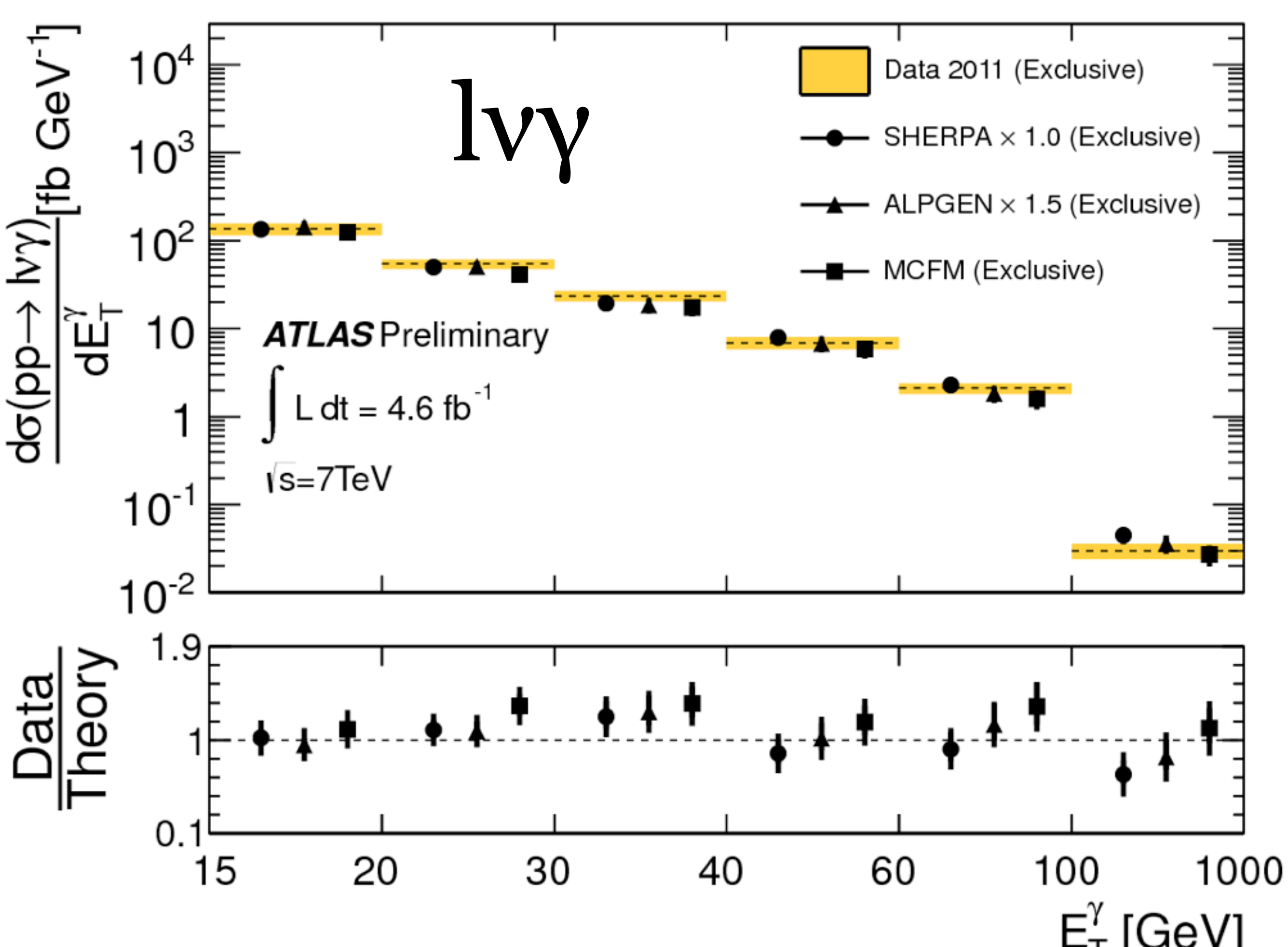


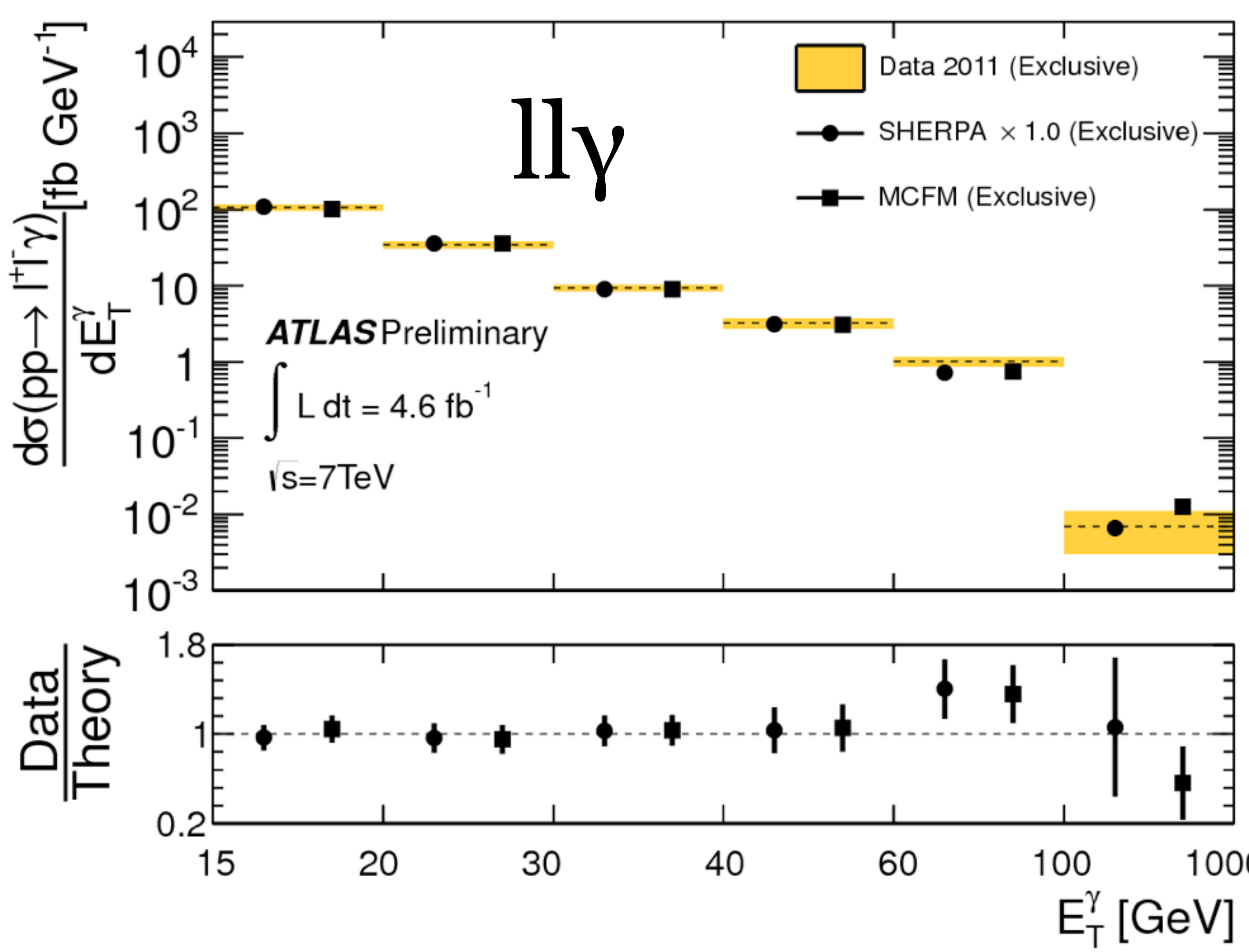


Zero jet results

- No jets with E_T > 30 GeV, $|\eta|$ < 4.4. Better agreement with NLO prediction.
- Main systematic uncertainties: V+jet backround estimate, photon ID efficiency.
- The table shows integrated fiducial cross sections with $E_T(\gamma)$ > 15 GeV for $Z(ll)\gamma$ and $W(l\nu)\gamma$, while $E_T(\gamma)$ > 100 GeV for $Z(\nu\nu)\gamma$.

Channel	Measurement (pb)	NLO (MCFM) pb
$l\nu\gamma$	1.76 ± 0.03 (stat) ± 0.21 (syst) ± 0.08 (lumi)	1.39 ± 0.13
$ll\gamma$	1.05 ± 0.02 (stat) ± 0.10 (syst) ± 0.04 (lumi)	1.06 ± 0.05
$\nu\nu\gamma$	0.116 ± 0.010 (stat) ± 0.013 (syst) ± 0.004 (lumi)	0.115 ± 0.009



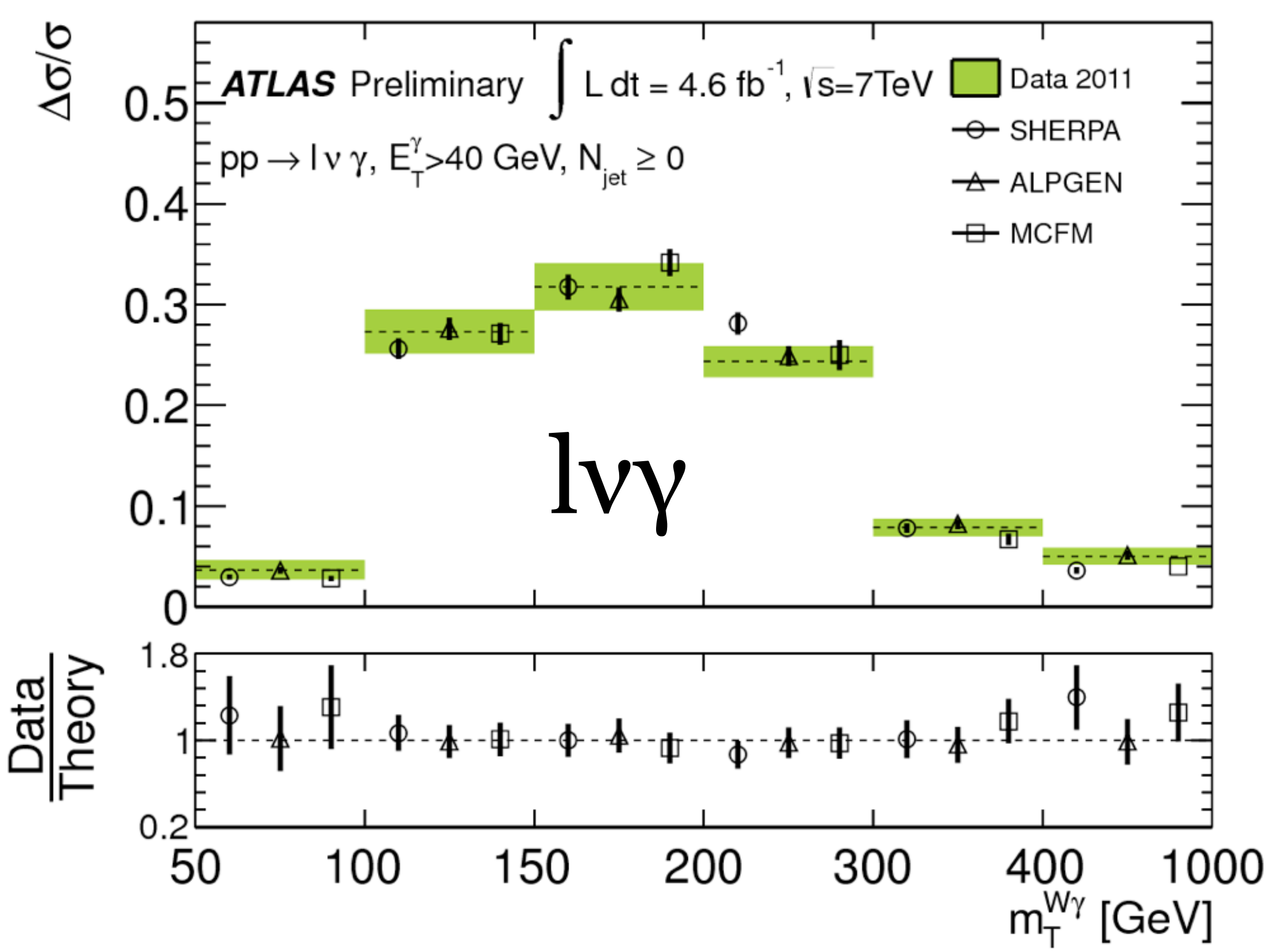


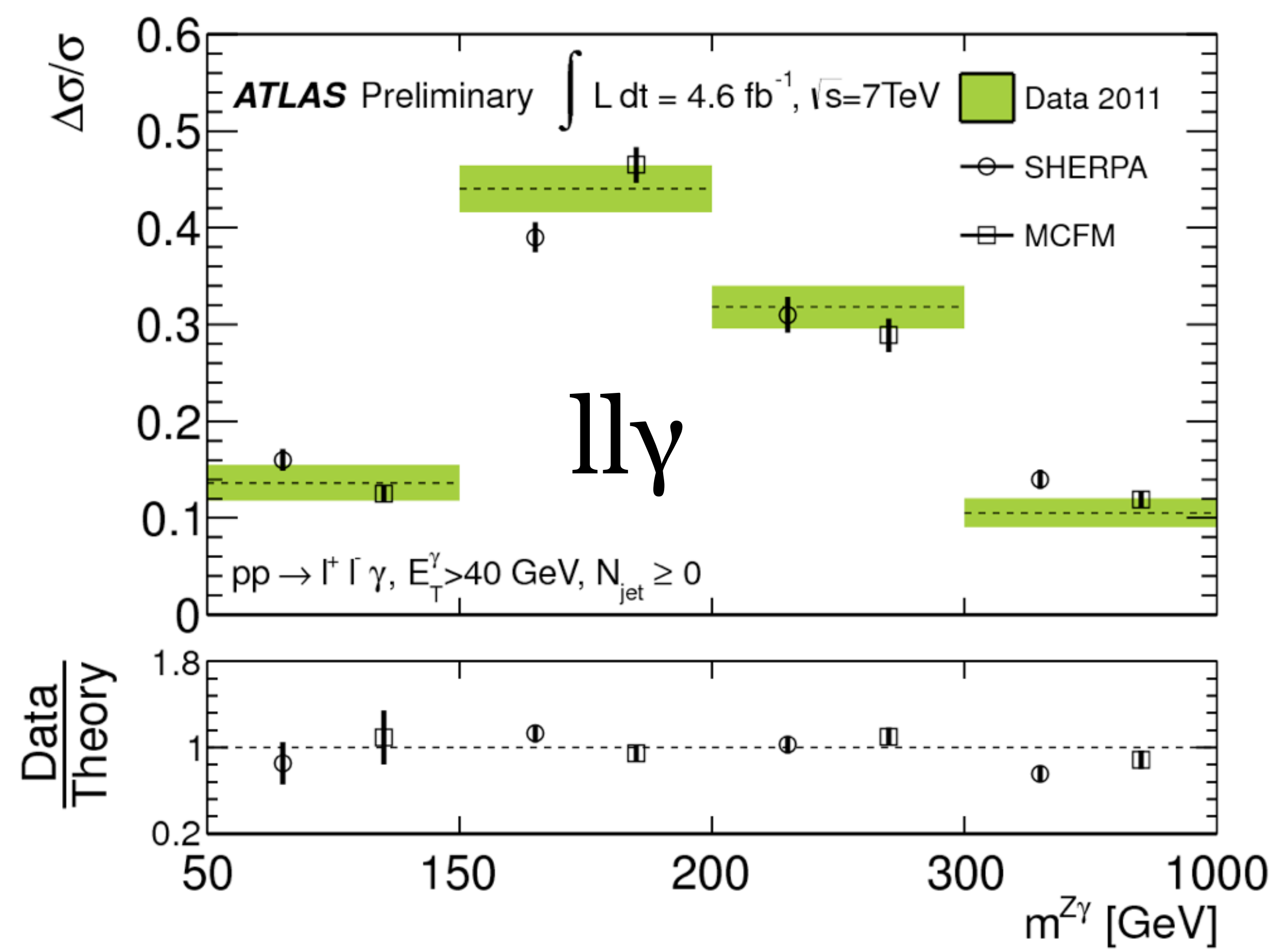
Differential cross section

The measured distributions are converted to the underlying particle level distributions by unfolding the effects of the experimental acceptance and resolution.

The plots show the inclusive normalized differential cross sections.

Observables for BSM resonance searches.





Triple Gauge Couplings

- Anomalous triple gauge couplings (aTGC) represent new interaction vertices or corrections to existing ones between SM electroweak bosons. This modifies the expected production rate of dibosons.
- Model independent parametrization via effective Lagrangians

  - Charged aTGCs for Wγ (CP conserving)

$$L = ie\Delta\kappa_\gamma W^\dagger_\mu W_\nu F^{\mu\nu} + ie\frac{\lambda_\gamma}{M_W^2} W^\dagger_{\sigma\mu} W^\mu{}_\nu F^{\nu\sigma}$$

  - Neutral aTGCs for Zγ (CP conserving)

$$L = \frac{-e}{M_Z^2}\left(\left(h_3^\gamma(\partial_\sigma F^{\sigma\rho}) + h_3^Z(\partial_\sigma Z^{\sigma\rho}\right) Z^\alpha \tilde{F}_{\rho\alpha} - \left(\frac{h_4^\gamma}{2M_Z^2}(\Box\partial^\sigma F^{\rho\alpha}) + \frac{h_4^Z}{2M_Z^2}(\Box + M_Z^2)\partial^\sigma Z^{\rho\alpha}\right) Z_\sigma \tilde{F}_{\rho\alpha}\right)$$

- Unitarity is preserved by introducing energy dependent form factor

$$\alpha(\hat{s}) = \frac{\alpha_0}{(1+\hat{s}/\Lambda^2)^n} \qquad \begin{array}{l} \Lambda = 6\text{TeV},\ n = 2 \quad \text{for } W\gamma, \\ \Lambda = 3\text{TeV},\ n = 3(h_3^\gamma), 4(h_4^\gamma) \quad \text{for } Z\gamma \end{array}$$

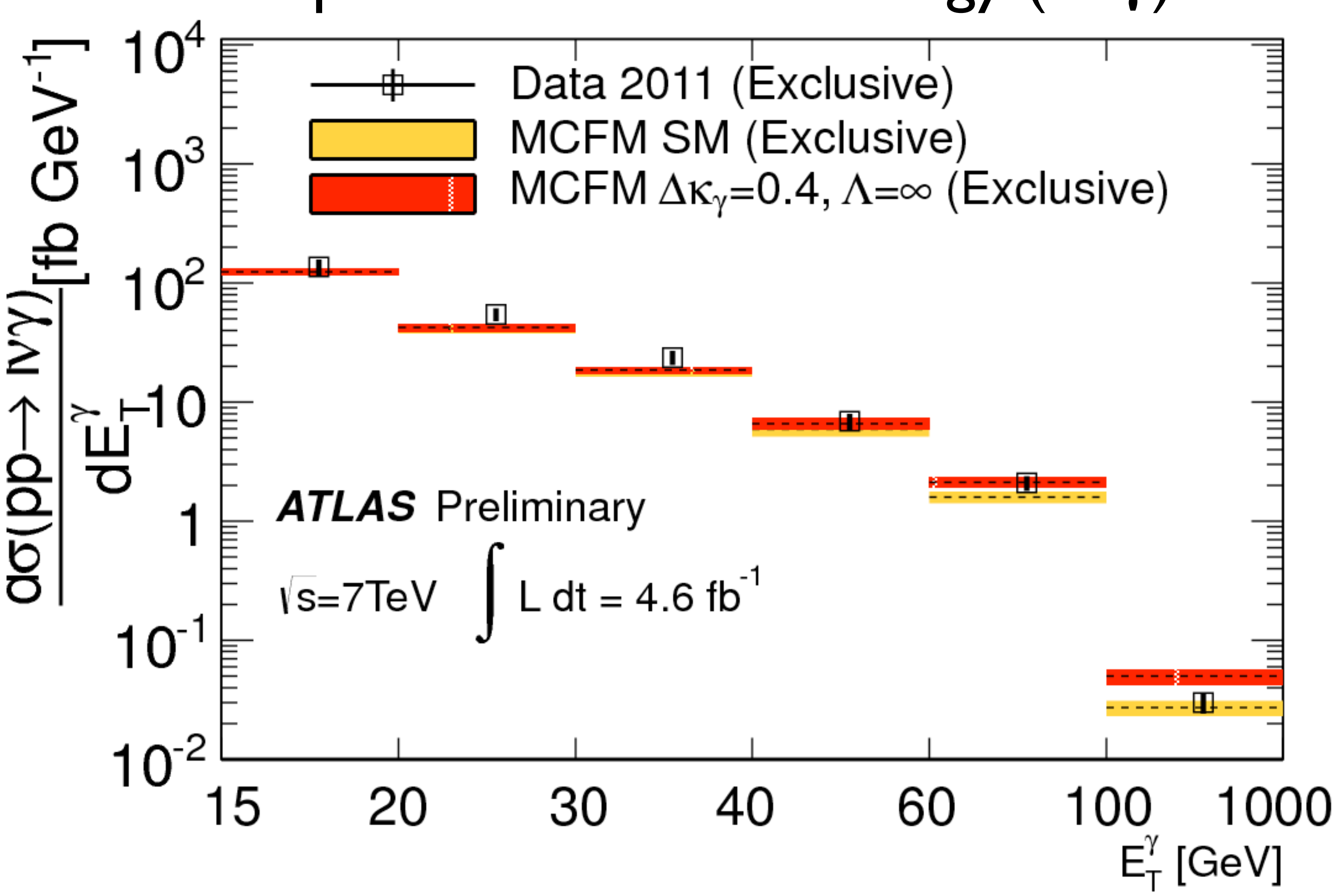
- Results are presented with/without form factor.

Triple Gauge Couplings

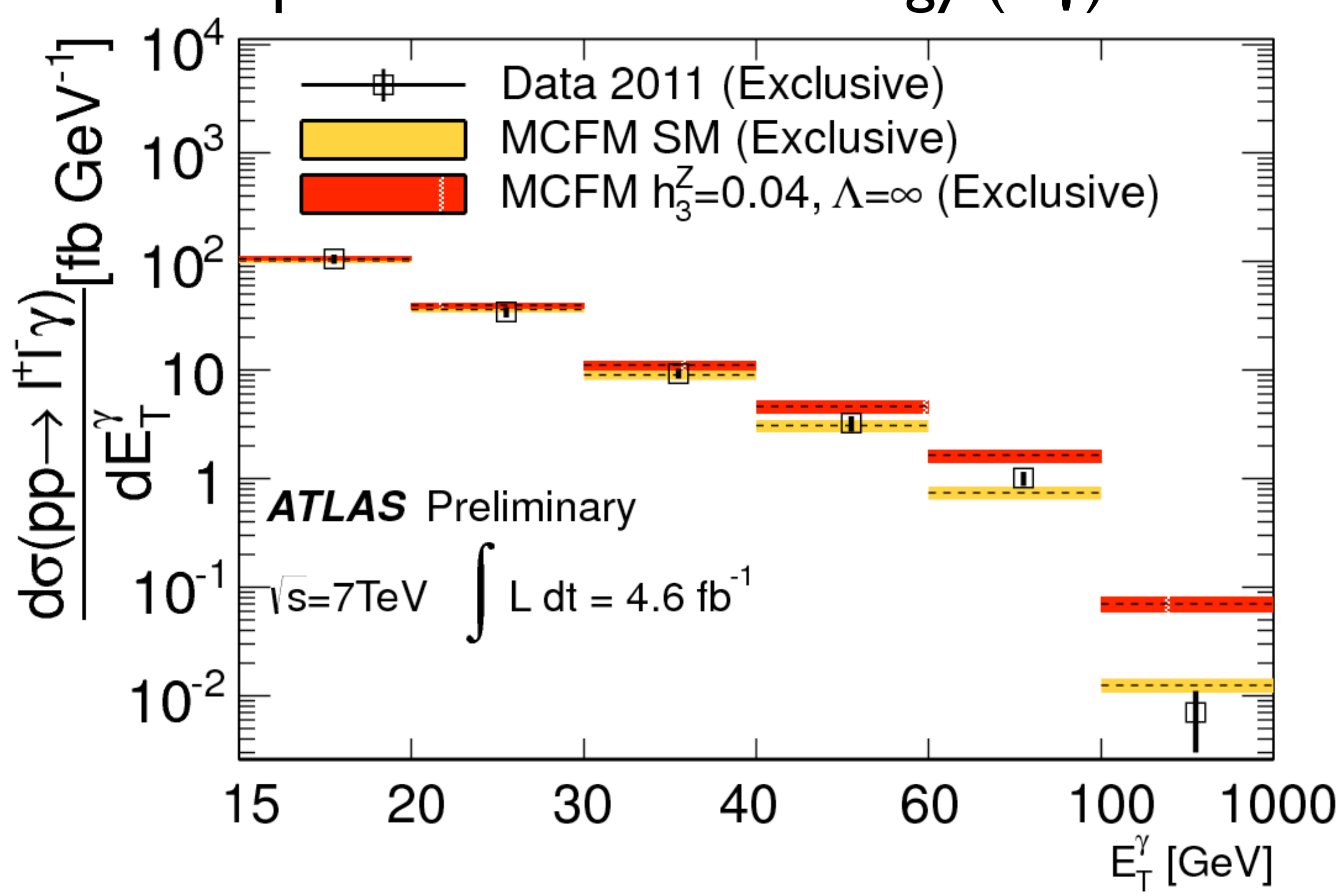
The signature of anomalous triple gauge couplings is enhanced differential cross section at high center-of-mass energies and large scattering angles.

The exclusive zero-jet distributions of photon transverse energy are used to extract information on aTGCs.

photon transverse energy (Wγ)



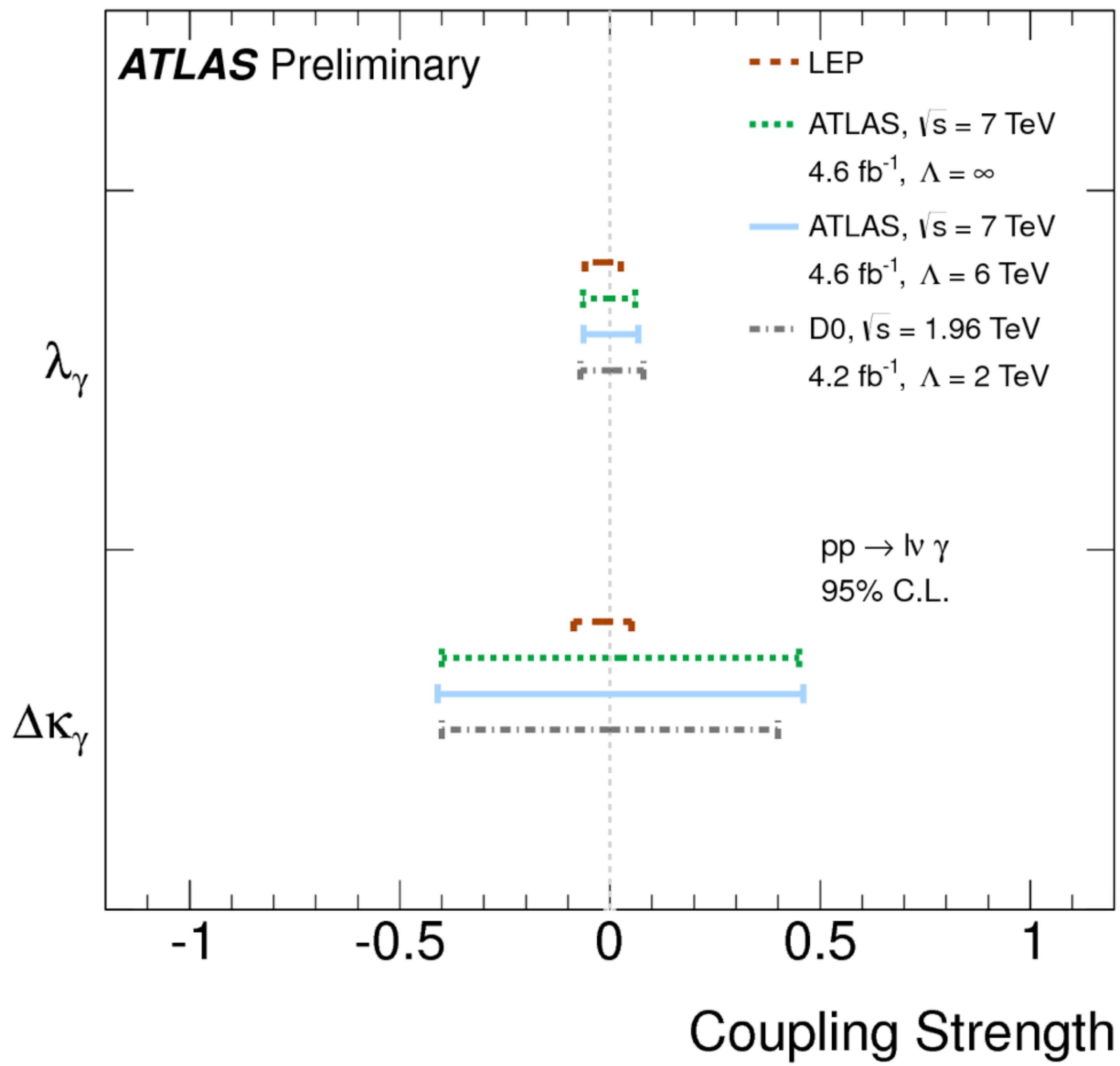
photon transverse energy (Zγ)



Wγ Triple Gauge Couplings

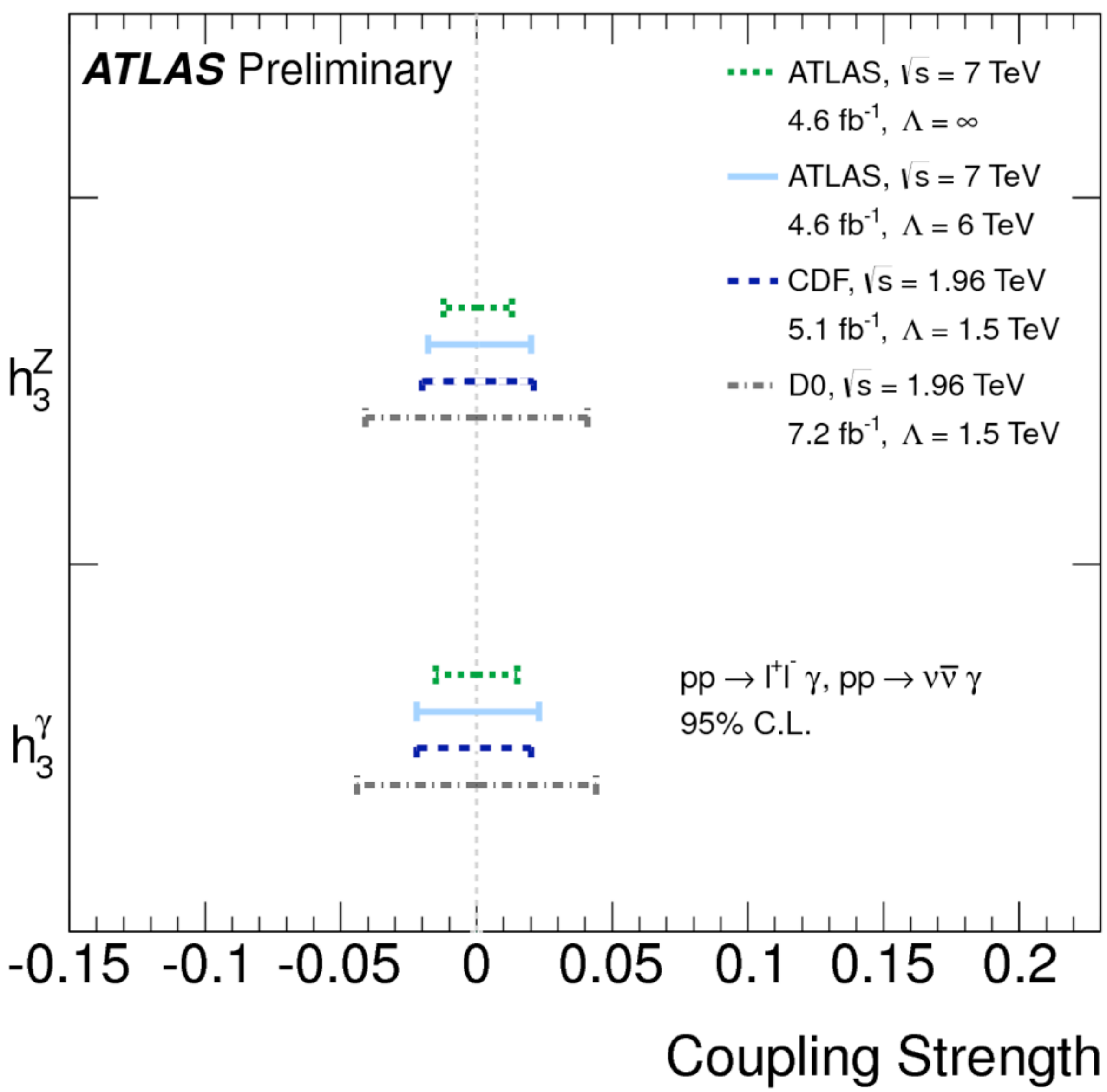
No deviations from SM predictions observed.

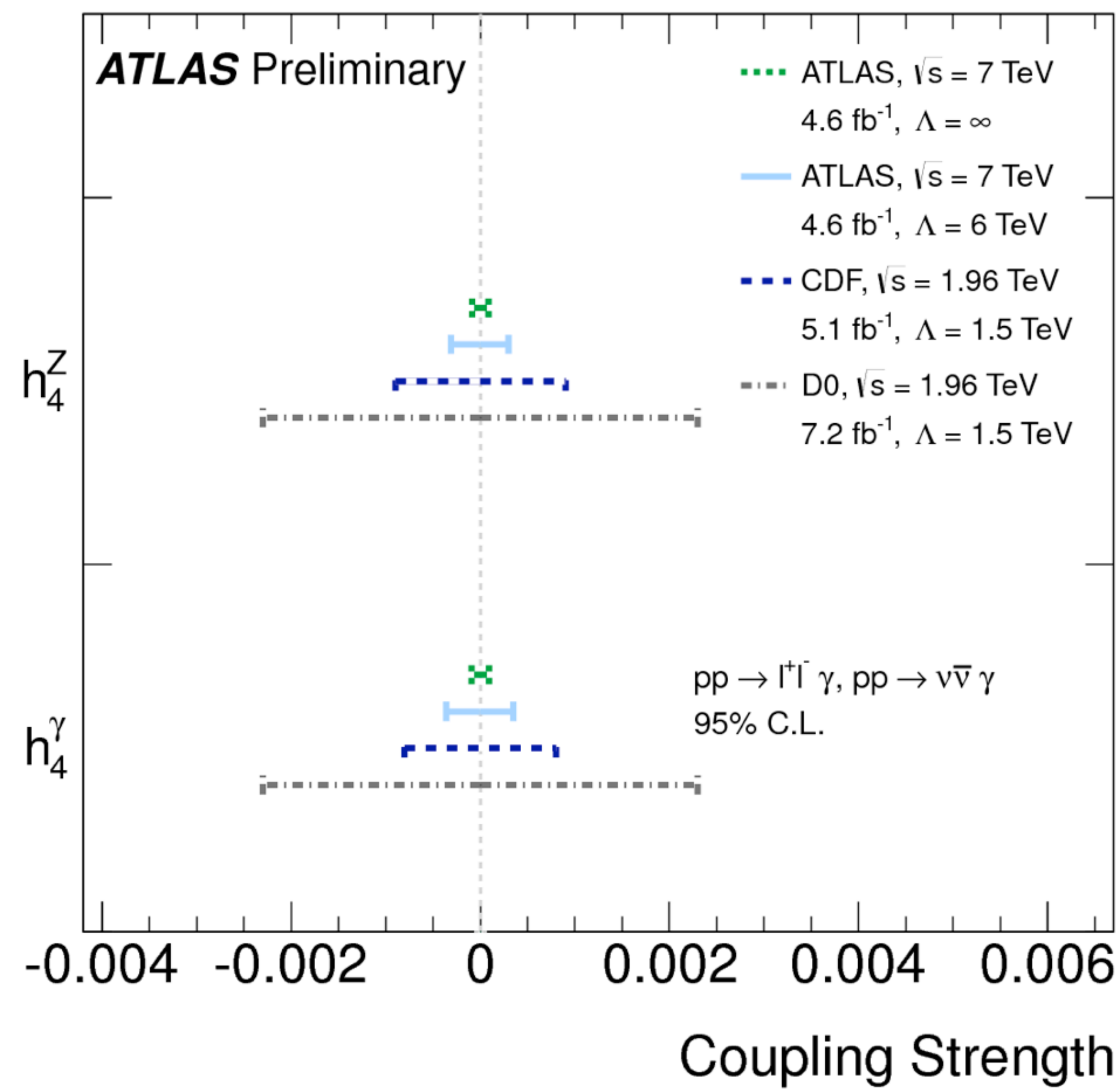
Limits are comparable to LEP and Tevatron results, but with different form factors.



Zγ Triple Gauge Couplings

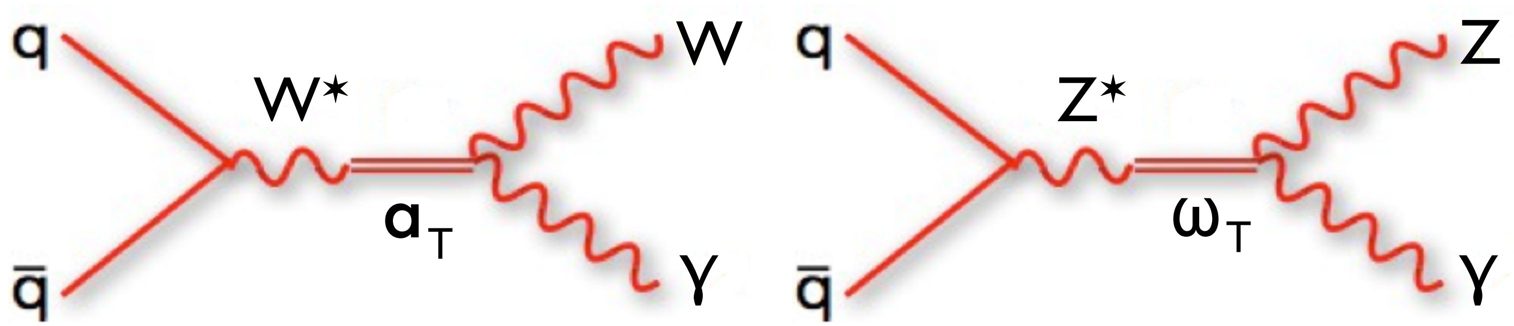
No deviations from SM predictions observed.
Limits are comparable to Tevatron results, but with different form factors.





BSM resonance searches

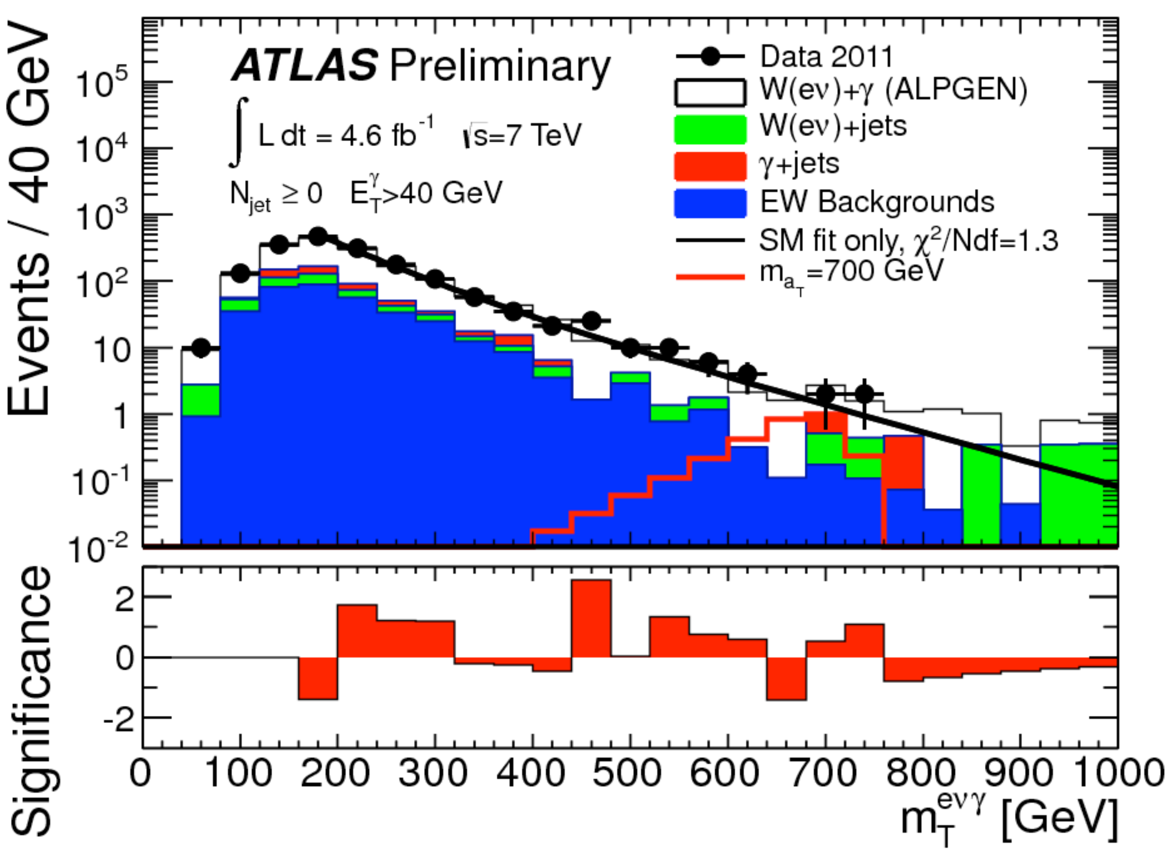
Probe physics beyond the SM: Low-scale Technicolor resonances a_T and ω_T

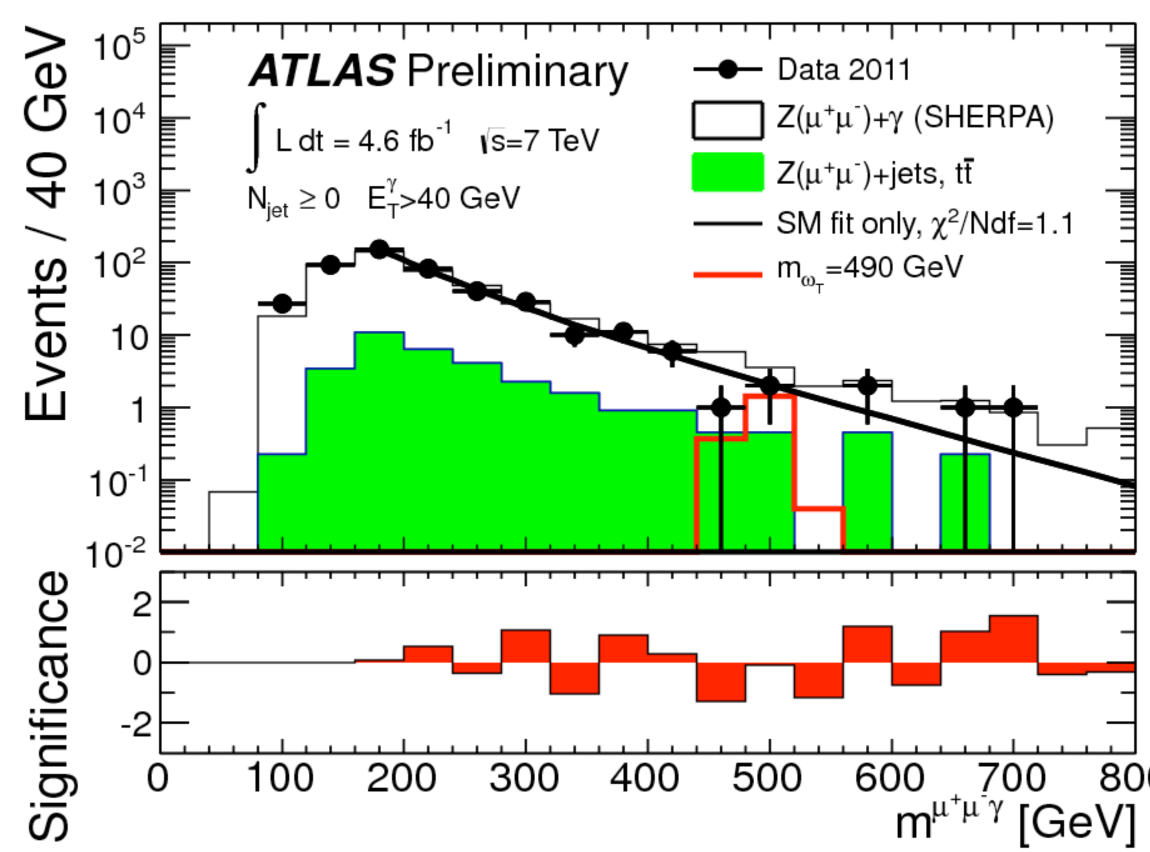


Limits on Techni-meson masses (observed/expected):

a_T > 703/619 GeV

ω_T > 494/483 GeV





Summary

- Cross sections measurements performed for $W(e\nu/\mu\nu)\gamma$ and $Z(ee/\mu\mu/\nu\nu)\gamma$ using 4.6 fb^{-1} of data collected with the ATLAS detector.
- Exclusive zero jet cross sections agree with Standard Model NLO predictions (MCFM).
- Both inclusive and exclusive cross sections agree with Standard Model predictions from multi-leg MC generators (ALPGEN/SHERPA).
- The measurements of exclusive zero-jet $Z\gamma$ and $W\gamma$ are used to constrain aTGCs.
- Inclusive $Z\gamma$ and $W\gamma$ events are used to set limits on low-scale Technicolor resonances a_T and ω_T.
- The results of the low-scale Technicolor resonances are the first ones reported for $W\gamma$ final state and the most stringent for $Z\gamma$.