Diboson Production and aTGCs from ATLAS

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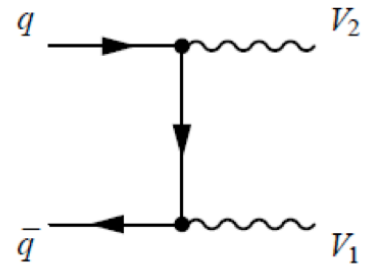
On behalf of the ATLAS Collaboration

Motivation

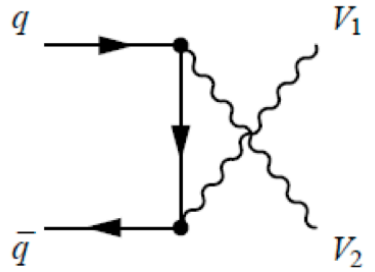
Cross-section measurements

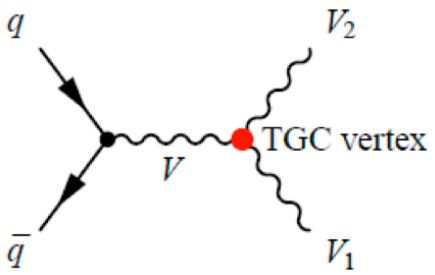
- Backgrounds to new physics searches
- Sensitive to new particles decaying into dibosons:
  - Technicolor, SUSY, W', Z', Higgs
- Standard Model *requires* something interesting at ~ TeV scale in WW scattering process



Triple Gauge Coupling Studies

- Vector boson self-interactions fundamental prediction of standard model gauge symmetry
  - Couplings not yet well measured
- Sensitive to new physics
  - New, heavy particles that couple to vector bosons, compositeness of the bosons



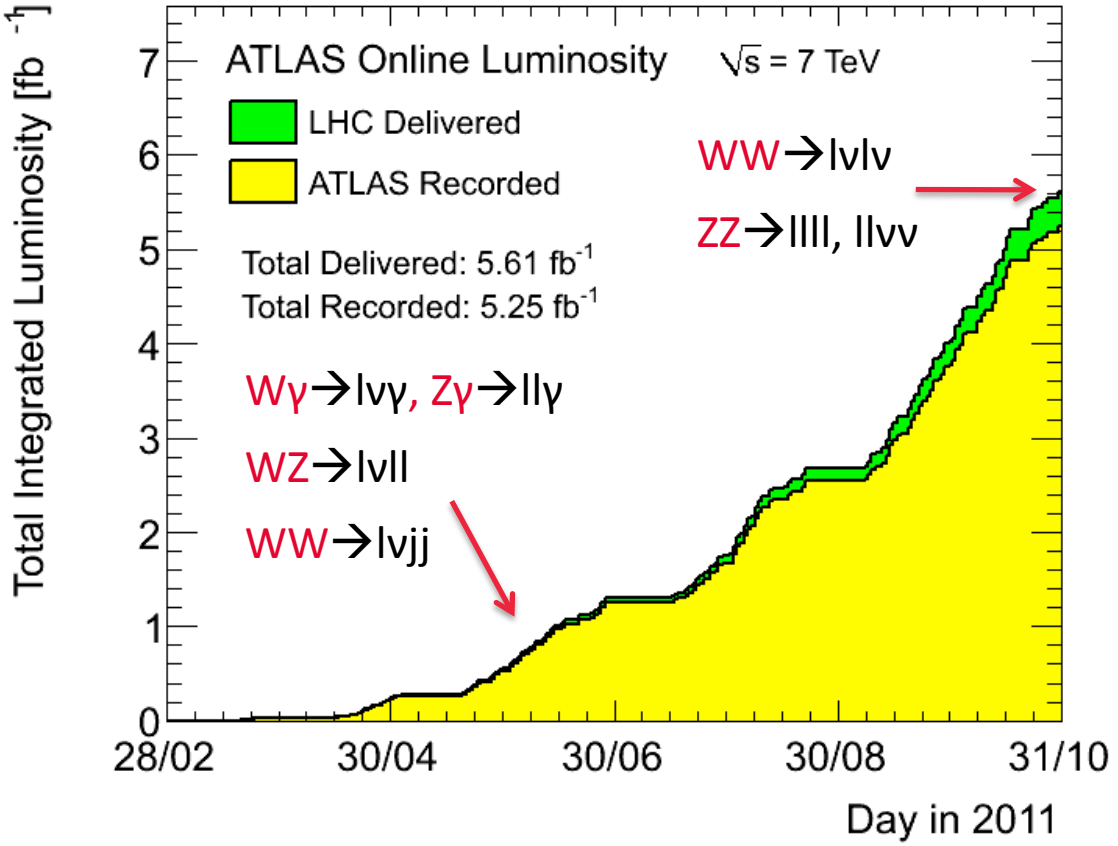


Overview

Dibosons: small σ (~ 1 – 100 pb)

- Early measurements made in fully leptonic mode = clean signal
- Moving toward higher branching ratios, with higher bkgs
- Measure total and fiducial σ

All analyses with 2011, √s = 7 TeV data



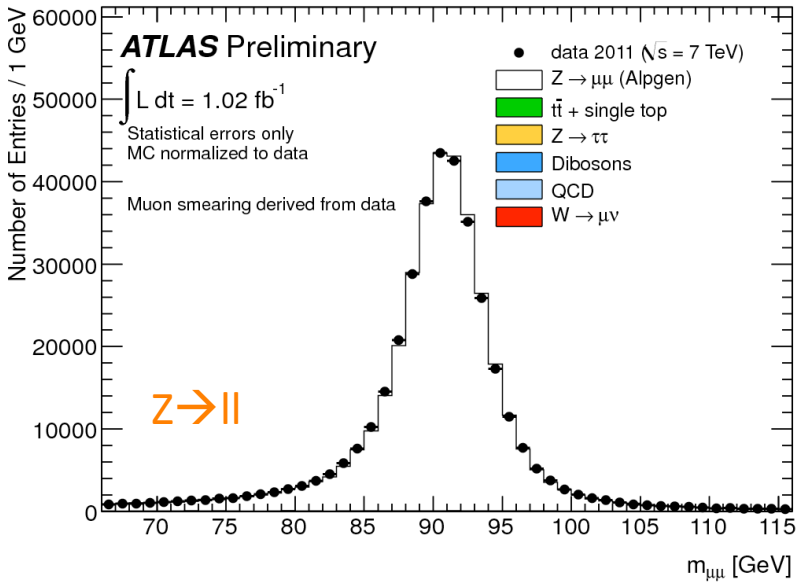
W and Z selection

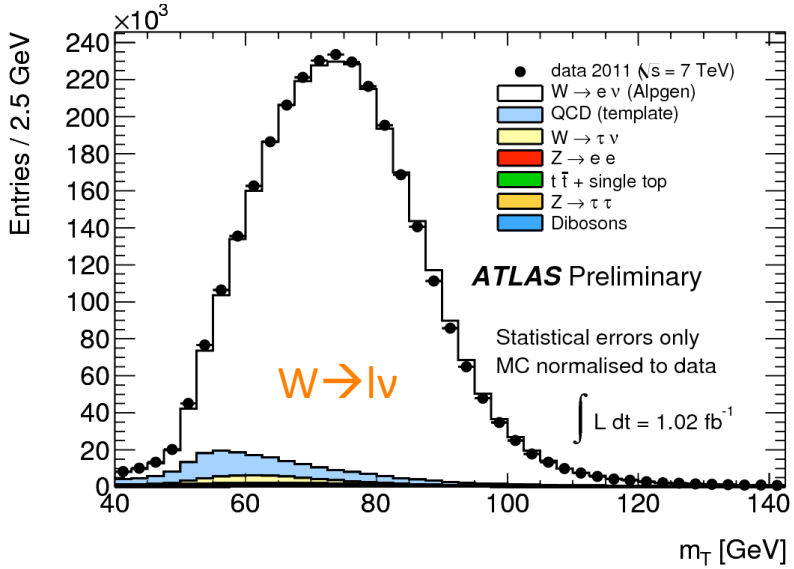
Lepton selection:

- p_T > 7-20 GeV
- Single lepton trigger
- trigger lepton p_T > 20, 25 GeV
- track + calo based isolation
- $|\eta| < 2.5$

Z selection:

- 2 same-flavor, opp charge iso. leptons
- Invariant mass within 10-25 GeV of Z





ME_T selection:

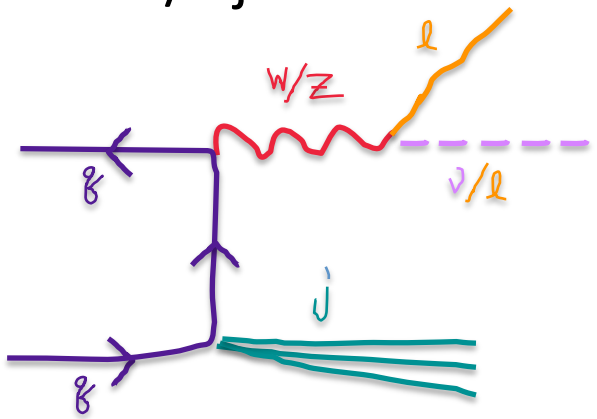
- Based on jets, leptons, and calo clusters
- $|\eta| < 4.5$

W selection:

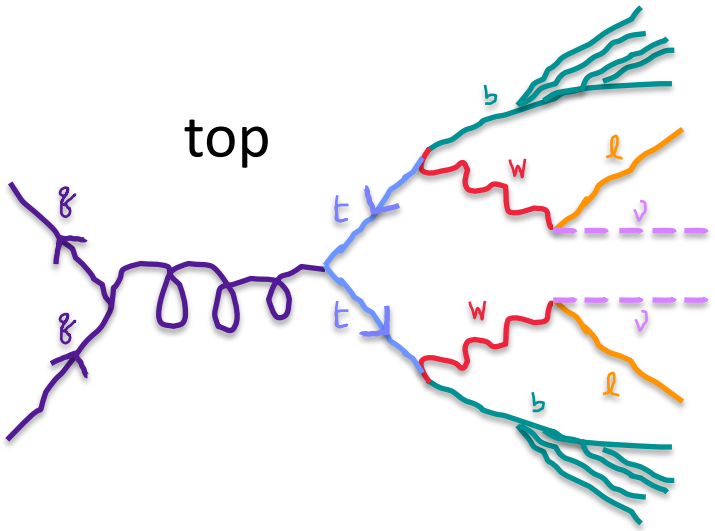
- 1 isolated lepton
- ME_T > 25-45 GeV
- WM_T > 20, 40 GeV

Common Backgrounds to Dibosons

W/Z jets



top



W/Z + jets and top:

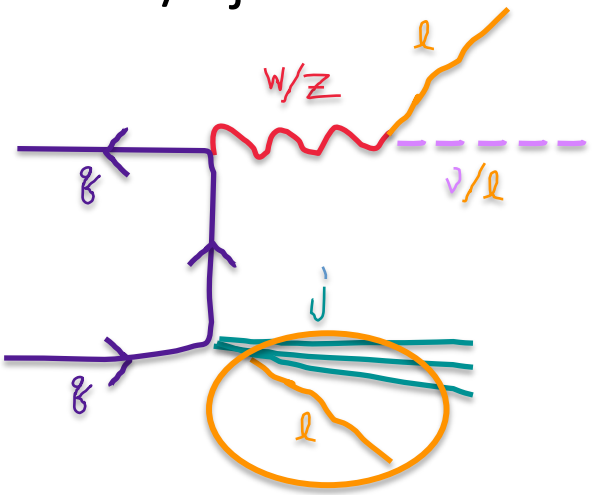
- major backgrounds to all diboson analyses
- estimated mostly from data

Diboson backgrounds:

- Wγ, Zγ, WW, WZ, ZZ backgrounds to each other
- estimated mostly from MC

Backgrounds: W/Z + jets

W/Z jets



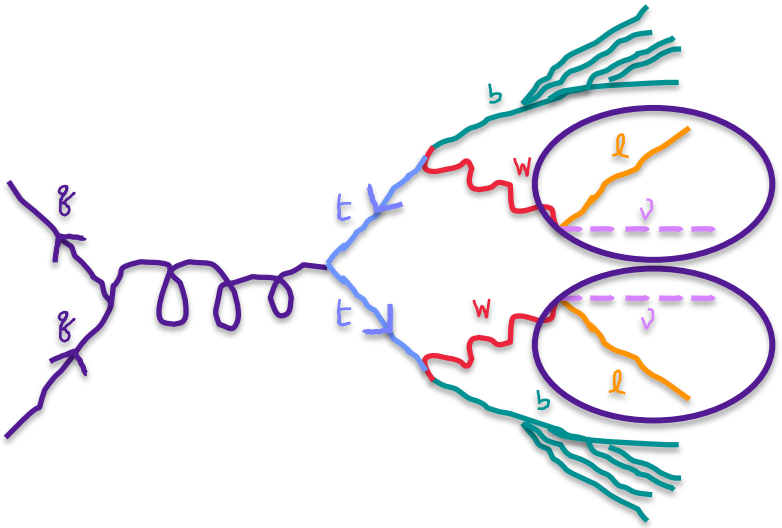
W/Z + jet backgrounds:

1 or 2 real, isolated leptons
Missing transverse energy
Jet can produce fake or real lepton or photon

Backgrounds estimated in data by measuring probability of jet producing lepton, photon

Backgrounds: top

Top background to WW→lνlν & ZZ→llνν:



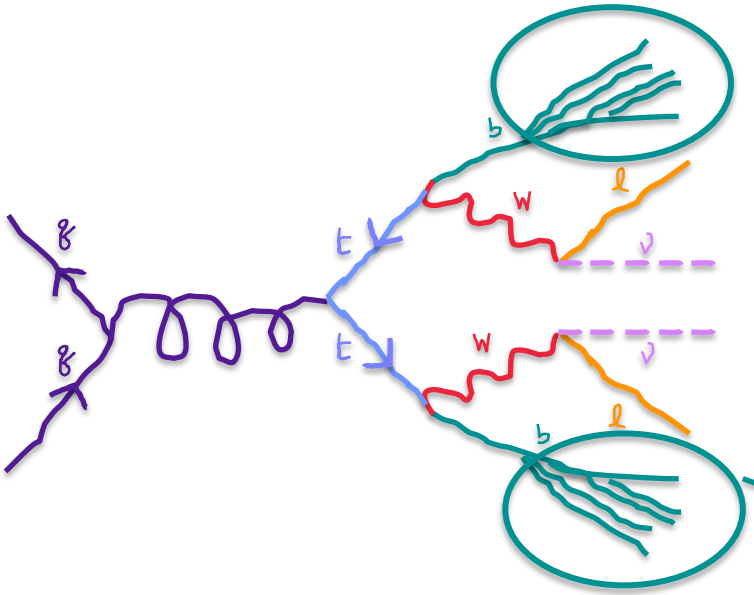
2 real, isolated leptons

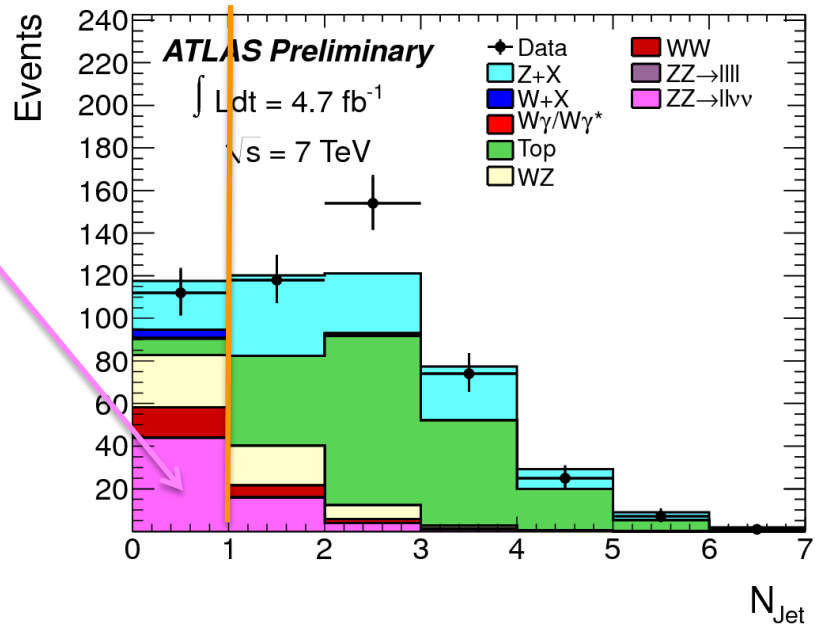
Missing transverse energy

Backgrounds: top

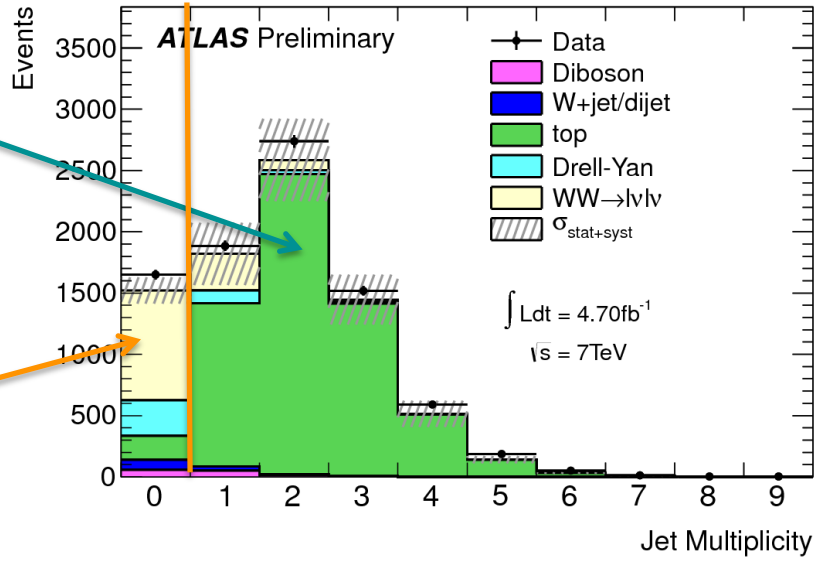
Reduce top bkg by cutting on N_{jets}

ZZ→llvv signal in 0 jet bin





WW→lvlv signal in 0 jet bin



WW→lνlν

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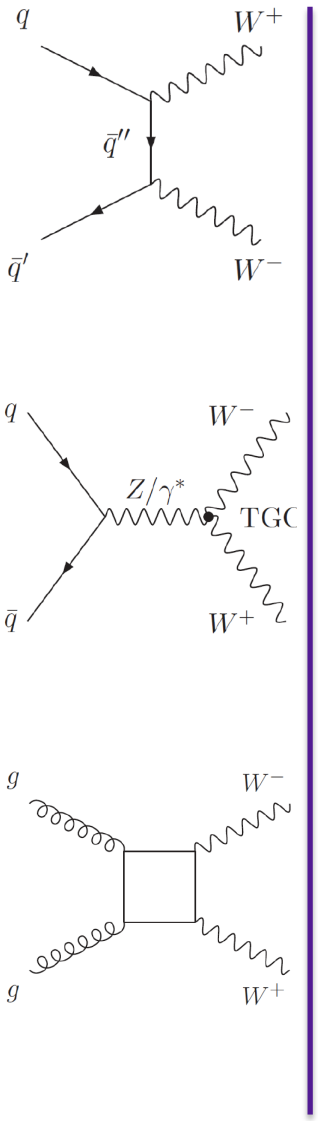


Selection highlights

- Exactly 2 leptons with opp. charge, $p_T > 20$ GeV
- Z veto
- Jet veto ($p_T > 25$ GeV or b-jet $p_T > 20$ GeV)
- $M_{ll} > 15$, $M_{e\mu} > 10$ GeV
- $MET_{rel} > 55,50,25$ GeV (μμ,ee,eμ)

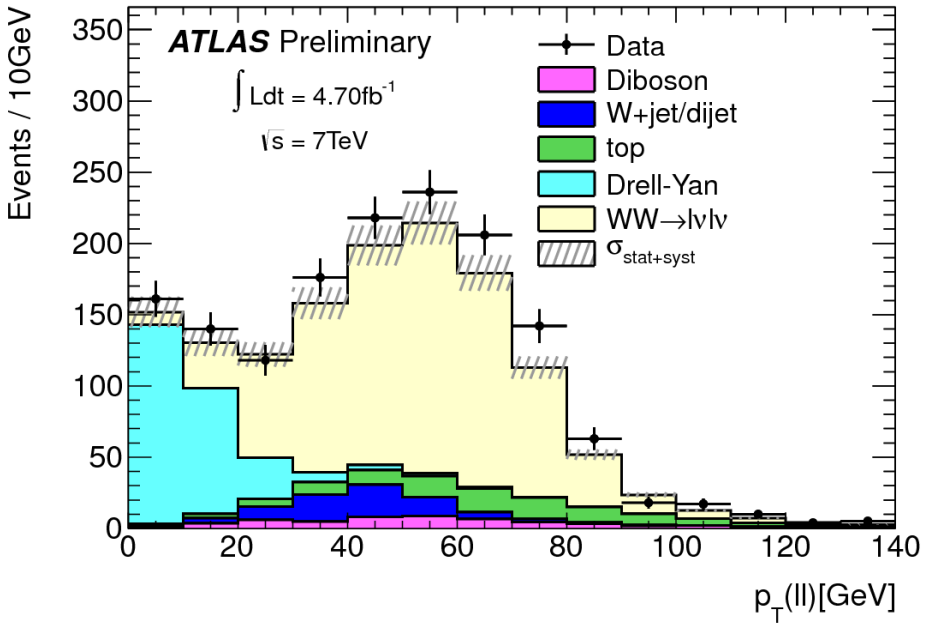
Dominant uncertainty from data driven bkg estimates

Good agreement between experiment and theory

σ_{total} measured = 53.4 ± 2.1 (stat) ± 4.5 (sys) ± 2.1 (lumi) pb

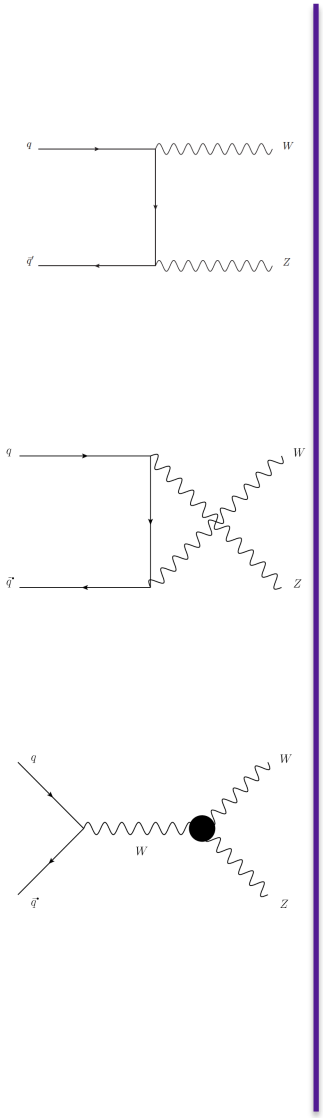
SM NLO prediction σ_{total} = 45.1 ± 2.8 pb

Dilepton pT after all cuts



WZ→lνll

Phys. Lett. B709 (2012) 341-357



Selection highlights

- At least 3 leptons p_T > 15 GeV
- Z candidate
- W candidate

Dominant uncertainty statistical

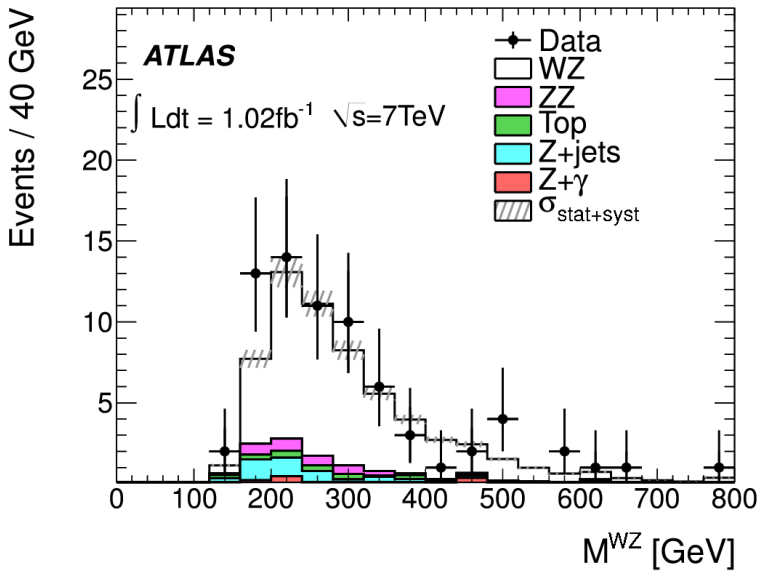
Good agreement between experiment and theory

σ_{total} measured: $20.5^{+3.1}_{-2.8}$(stat) ± 1.4 (syst) $^{+0.9}_{-0.8}$(lumi) pb

SM NLO prediction σ_{total} : $17.3^{+1.3}_{-0.8}$ pb

$\sigma_{fiducial}$ measured: 102^{+15}_{-14}(stat) ± 7 (syst) ±4 (lumi) fb

Transverse mass of WZ candidates



Fiducial truth volume

- $p_T^{\mu} > 15$ GeV/c
- $|\eta^{\mu}| < 2.5$
- $p_T^{e} > 15$ GeV/c
- $|\eta^{e}| < 2.5$
- $p_T^{\nu} > 25$ GeV/c
- $|M_{ll} - M_{Z\ \mathrm{Pole}}| < 10$ GeV/c^2
- $M_T^{W} > 20$ GeV/c^2

ZZ→llll

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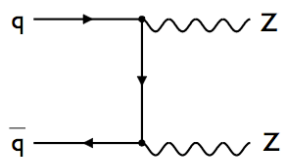
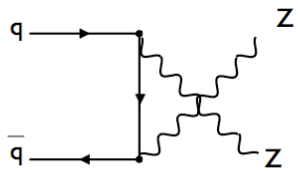
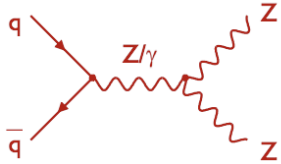






Selection highlights

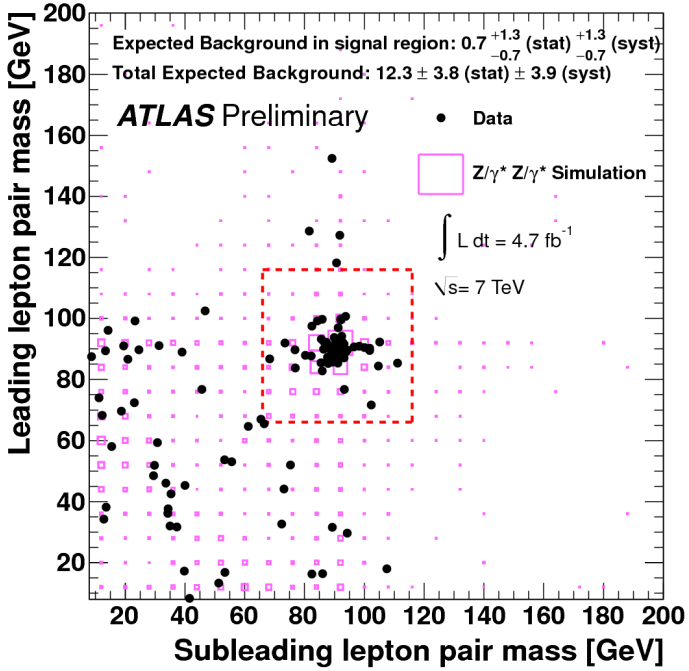
- 4 leptons pT > 7 GeV, leading lepton pT > 20, 25 (μ,e)
- 2 Z candidates

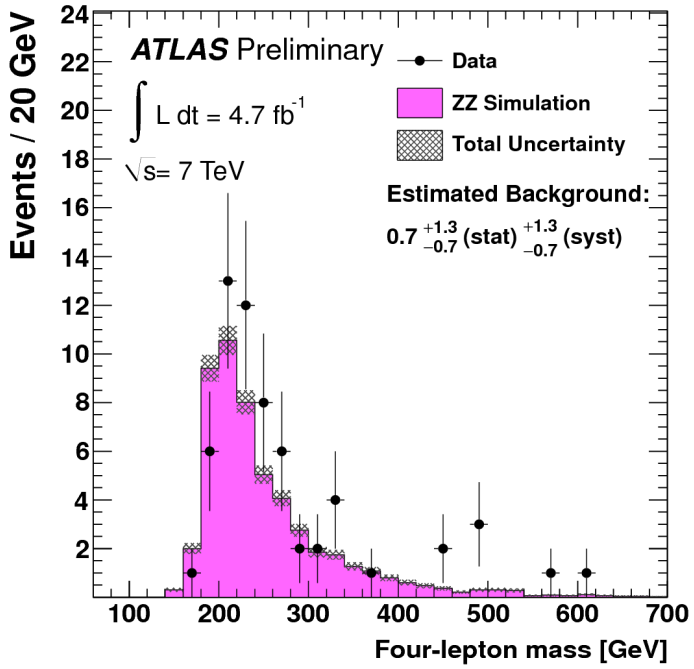
σ_{total} measured: $7.2^{+1.1}_{-0.9}$(stat) $^{+0.4}_{-0.3}$(syst) ± 0.3(lumi) pb

SM NLO prediction σ_{total} : $6.5\ ^{+0.3}_{-0.2}$ pb

Dominant uncertainty statistical

Good agreement between experiment and theory





ZZ→llνν

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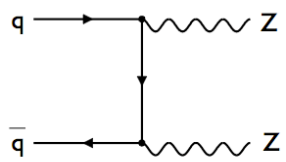
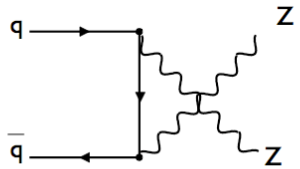
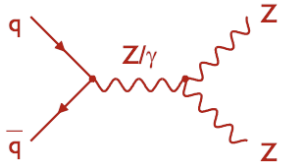






Exclusive Cross section measurement

Selection highlights

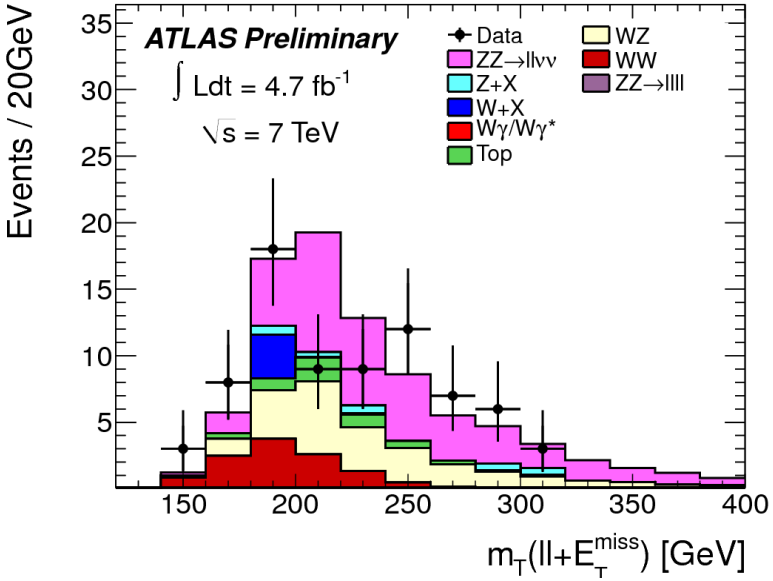
- 2 leptons pT > 20 GeV
- Z→ll candidate
- Axial MET > 80 GeV
- Jet veto (p_T > 25 GeV)

σ_{total} measured: $5.4^{+1.3}_{-1.2}$(stat) $^{+1.4}_{-1.0}$(syst) ± 0.2(lumi) pb

SM NLO prediction σ_{total} : $6.5\ ^{+0.3}_{-0.2}$ pb

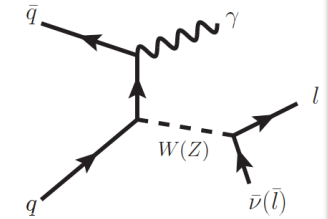
Equal statistical and systematic uncertainties

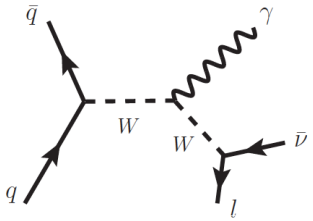
Good agreement between experiment and theory



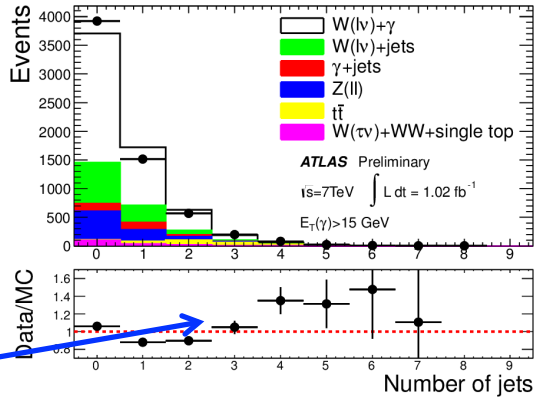
Wγ/Zγ

Selection highlights
- W or Z candidate
- Converted or unconverted γ with
  - p_T > 15 GeV
  - absolute calo isolation
- ΔR(l,γ) > 0.7



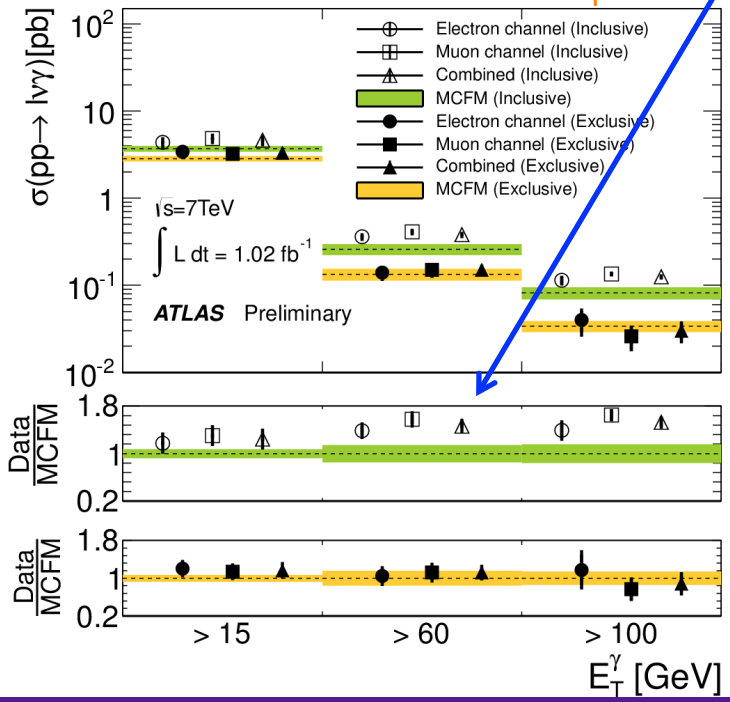


N jets in selected Wν events

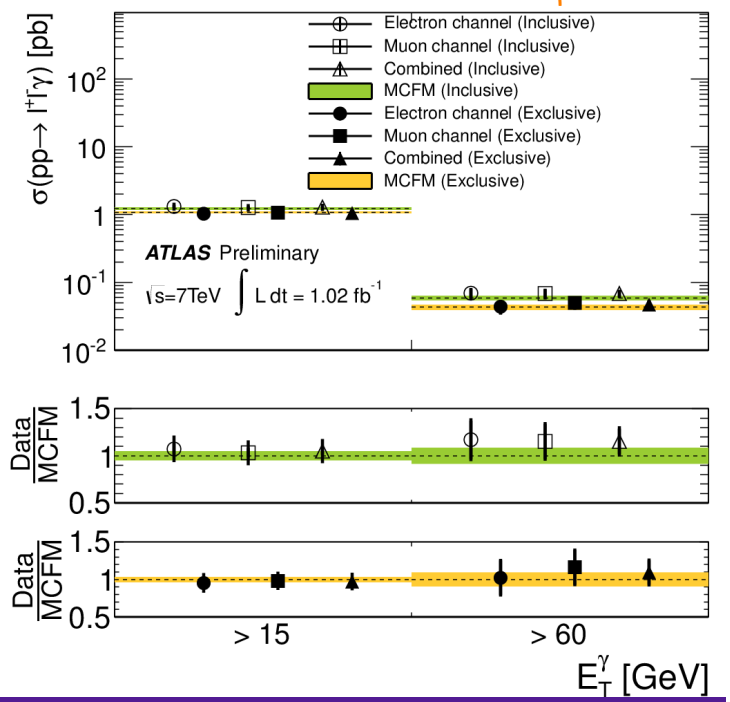


Good agreement for exclusive measurement and MCFM prediction
Inclusive comparison: Need NLO W/Z γ + 0,1,2,3… parton calculation

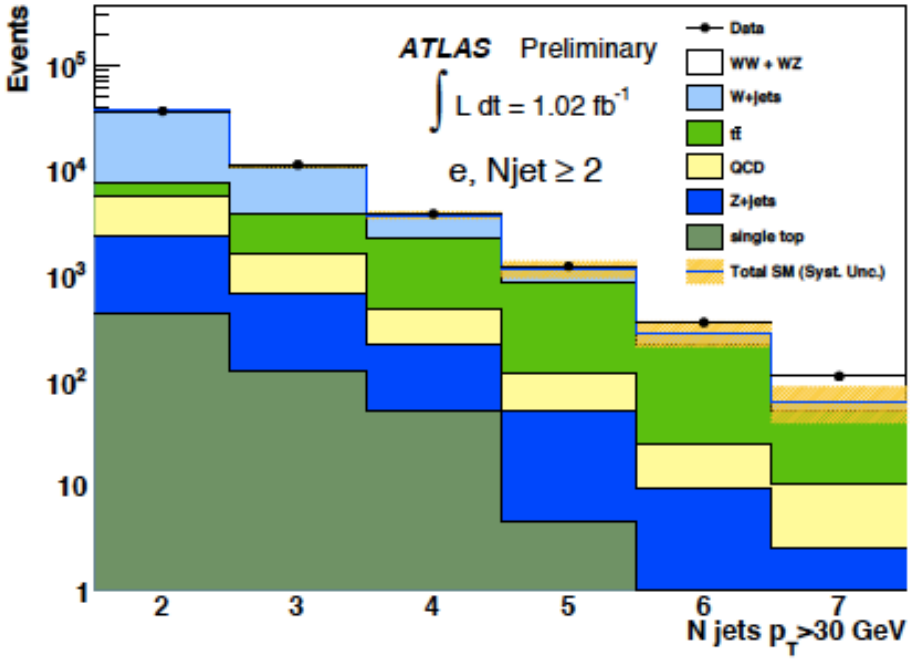
Inclusive and exclusive σ for Wγ

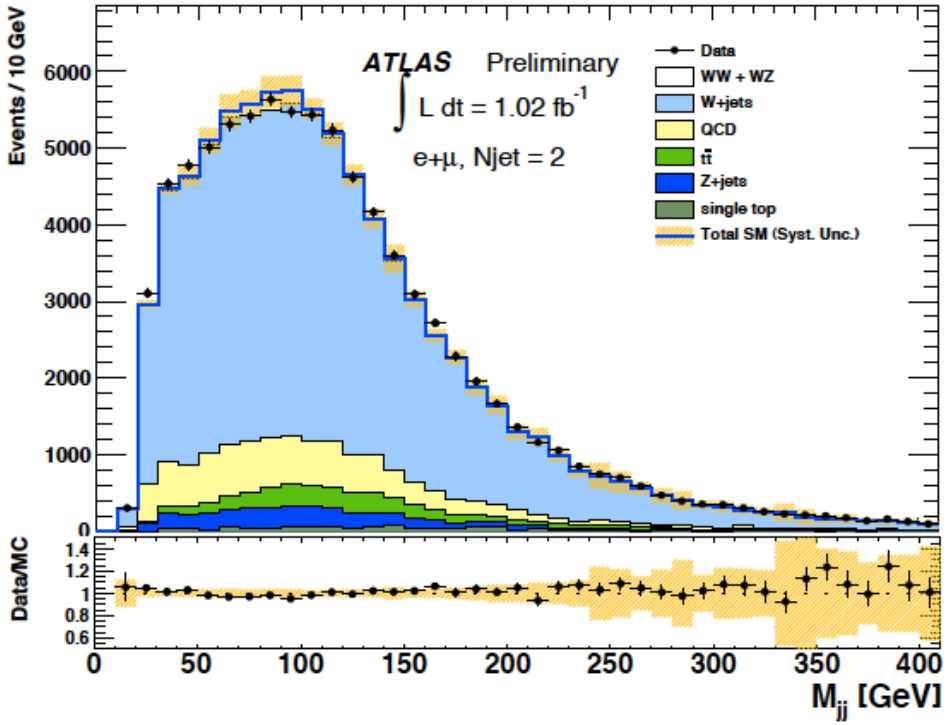


Inclusive and exclusive σ for Zγ



Semileptonic WW→lνjj Analysis ATLAS-CONF-2011-097



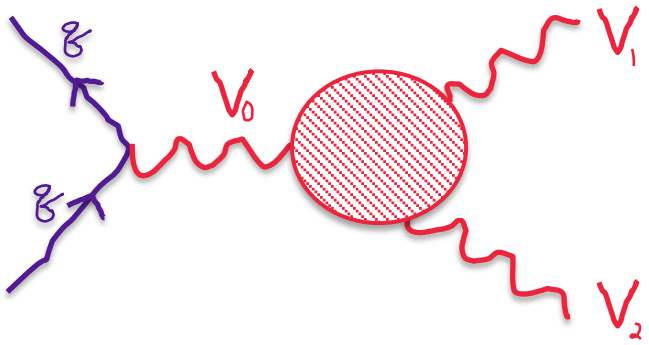


Harder at the LHC than at the Tevatron

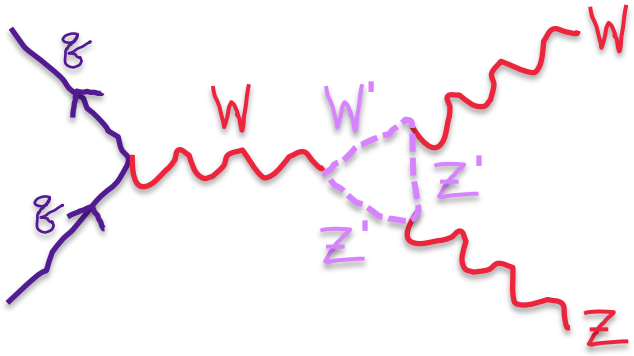
Cross section scaling from Tevatron to LHC:

- W + (n ≥ 2) jets: from 22 to 440 pb [CDF, ATLAS meas.]
- WW/WZ →lνqq: from 3.7 to 15.3 pb [MCFM prediction]

anomalous Triple Gauge Couplings

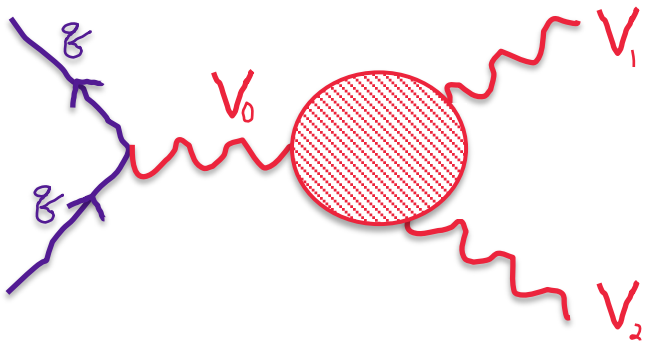


anomalous Triple Gauge Couplings



Example: W', Z' could be SUSY, Technicolor, Higgs…

anomalous Triple Gauge Couplings



The effective Lagrangian for model independent triple gauge couplings can be expressed as:

$$\frac{\mathcal{L}_{WWV}}{g_{WWV}} = i\left[g_1^V(W^\dagger_{\mu\nu}W^\mu V^\nu - W_{\mu\nu}W^{\dagger\mu}V^\nu) + \kappa^V W^\dagger_\mu W_\nu V^{\mu\nu} + \frac{\lambda^V}{m_W^2}W^\dagger_{\rho\mu}W^\mu_\nu V^{\nu\rho}\right] \quad \text{(WW, WZ)}$$

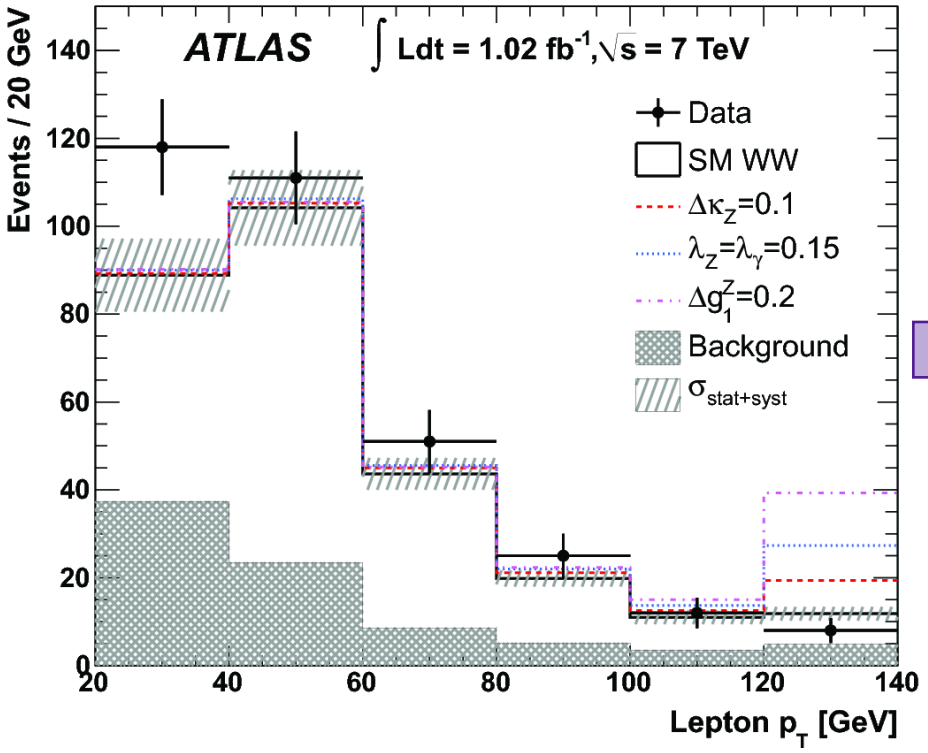
$$\mathcal{L}_{VZZ} = -\frac{e}{M_Z^2}\left[f_4^V(\delta_\mu V^{\mu\beta})Z_\alpha(\delta^\alpha Z_\beta) + f_5^V(\delta^\sigma V_{\sigma\mu})Z^{\mu\beta}Z_\beta\right] \quad \text{(ZZ)}$$

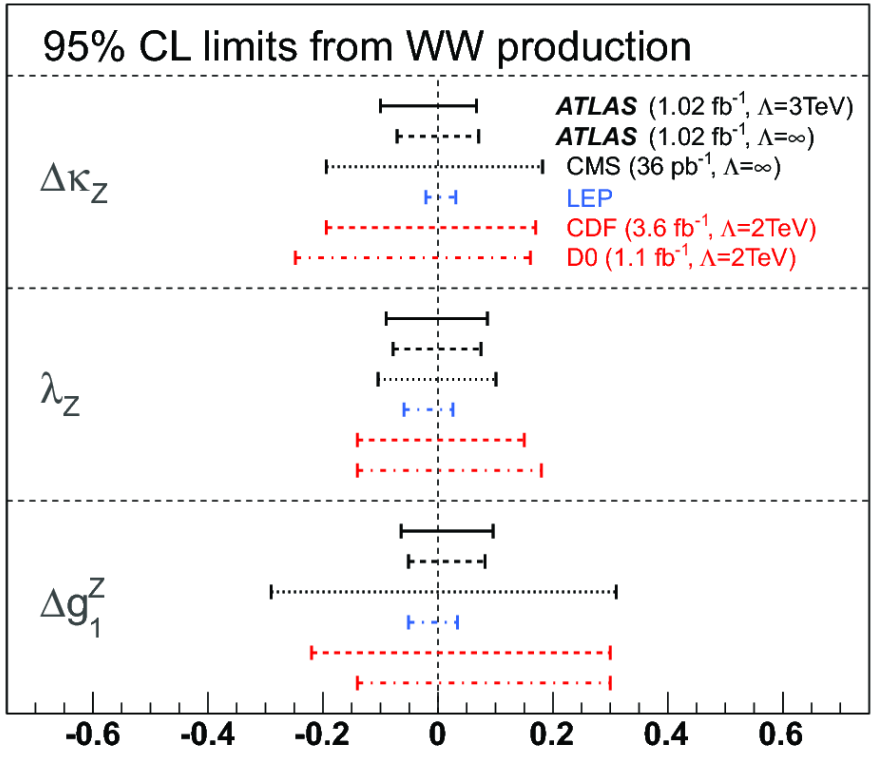
In the Standard Model:

- $g_1^V = \kappa^V = 1$ (set limits on $\Delta g = g - 1$, $\Delta\kappa = \kappa - 1$)
- $\lambda^V = f_4^V = f_5^V = h_3^V = h_4^V = 0$

WW->lvlv aTGC results

ATLAS-STDM-2011-24



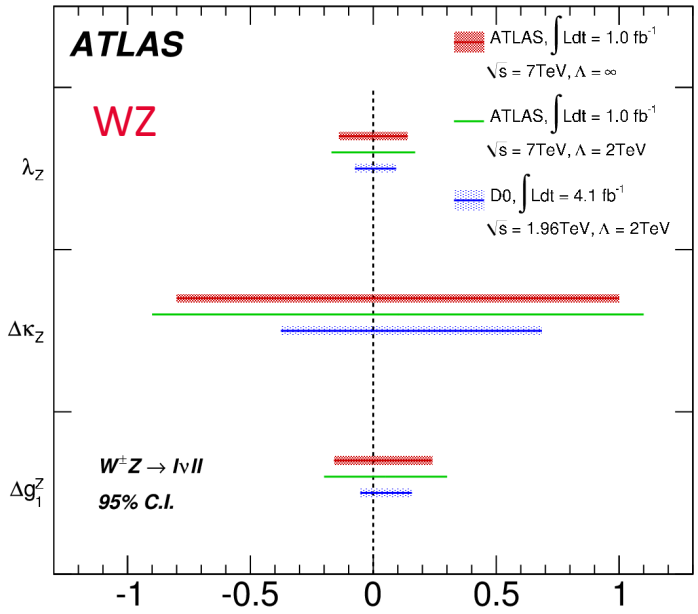


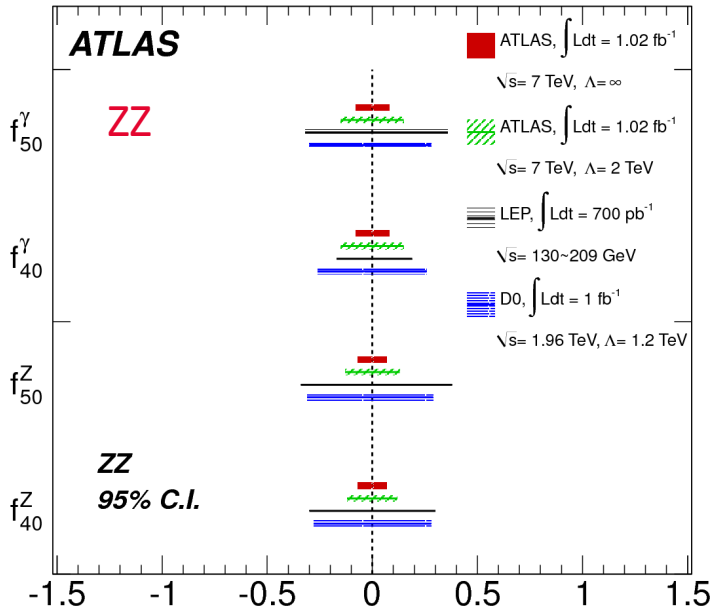
WW limits

- Limits set using leading lepton p_T spectrum
- ATLAS limits tighter than TeVatron limits

Wγ, Zγ, WZ, ZZ aTGC results

ATLAS-STDM-2011-25
ATLAS-STDM-2011-36



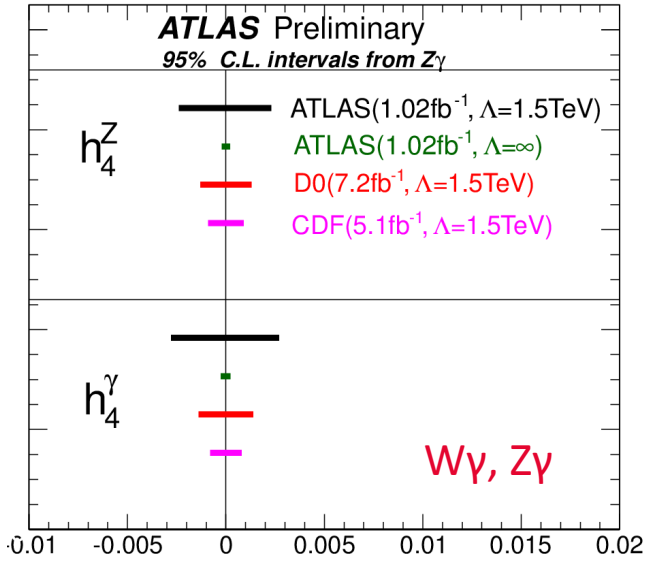


WZ, ZZ limits

- Limits set using total cross section

Wγ, Zγ limits

- Limits set using exclusive cross-section (no jets) at high E_T^γ
- ATLAS aTGC limits most stringent for h_3 and h_4



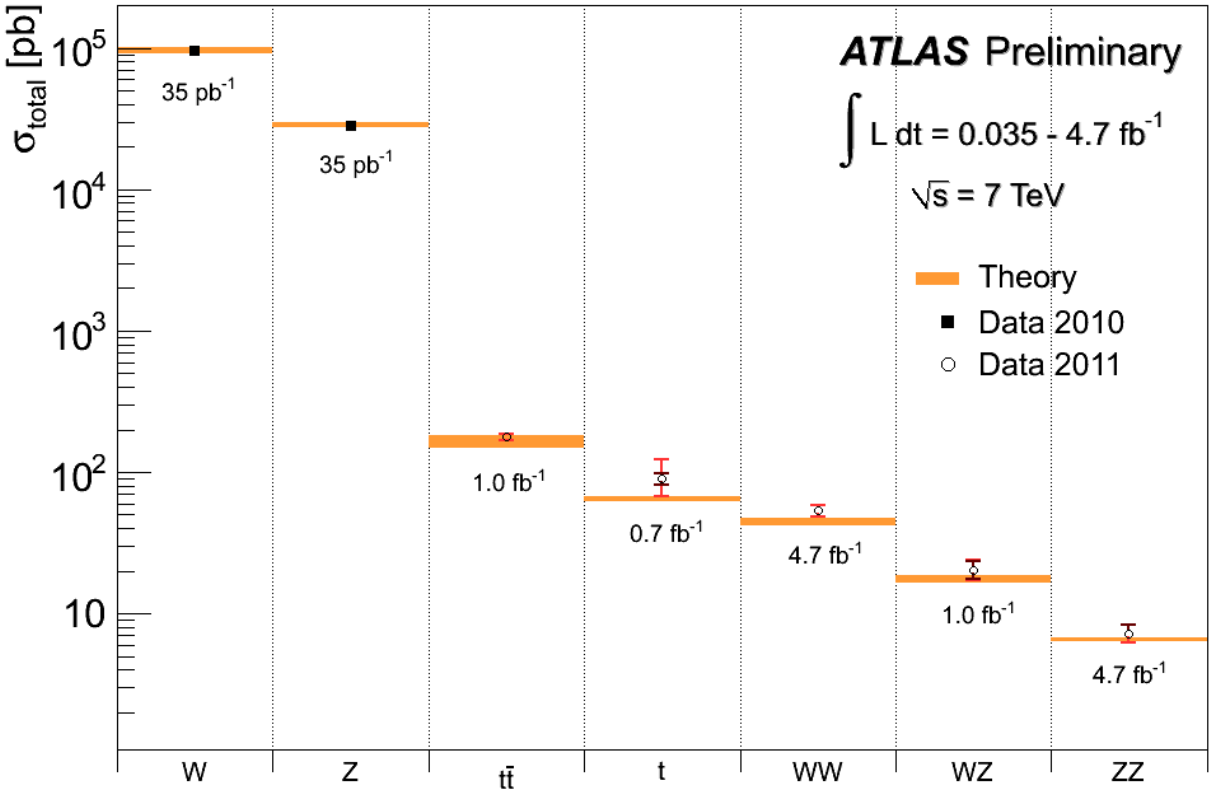
Summary and Outlook

Summary

- All Diboson cross sections measured at 7 TeV and agreement with SM within uncertainty
- Most stringent aTGC limits in many channels

Outlook

- Look for updated results coming soon – use of differential distributions will improve aTGC limits for WZ, ZZ analyses
- Looking forward to analyzing the 2012 data – many, many thanks to the LHC for 1 fb^{-1} already and hopefully much more soon!



Backup

WW→lνlν

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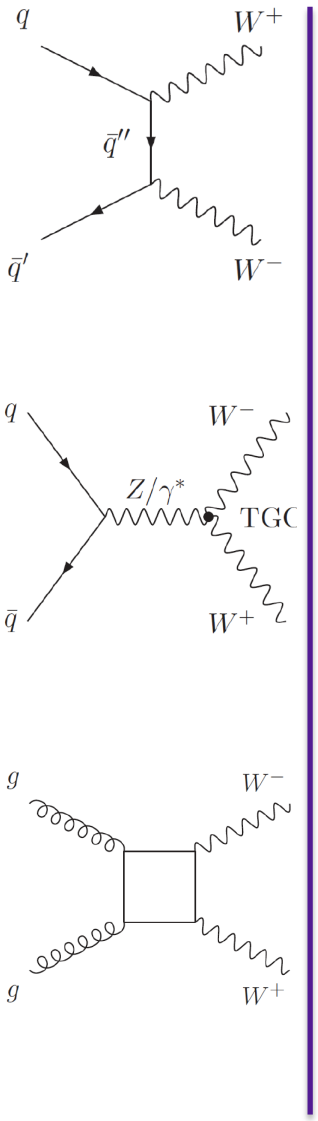
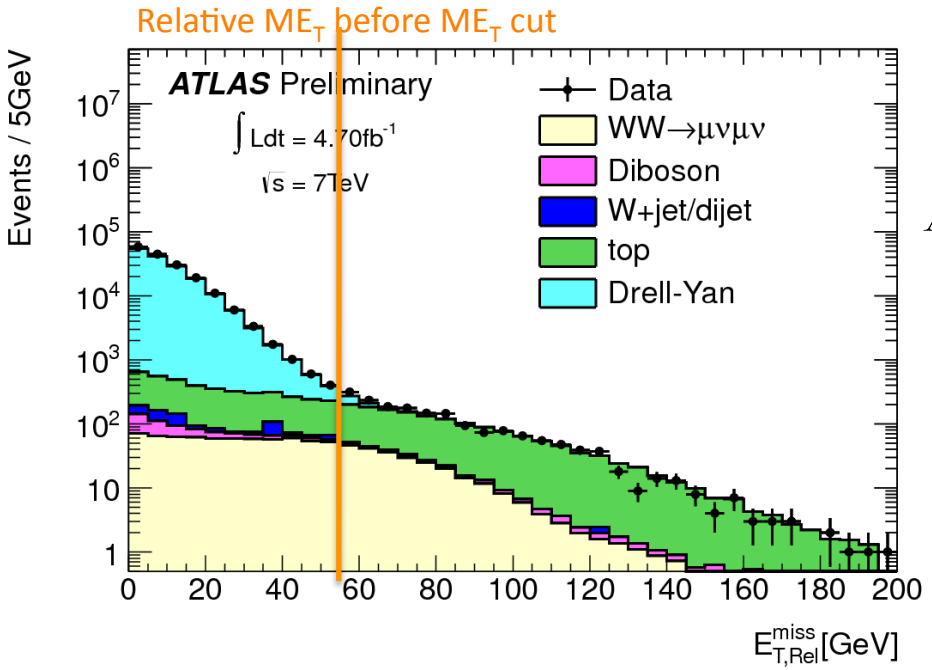
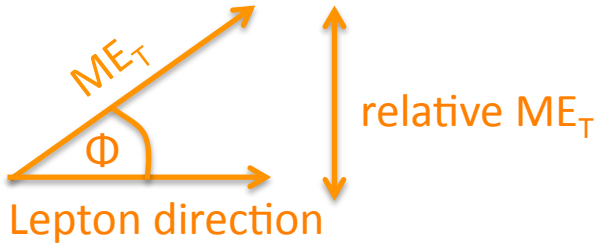




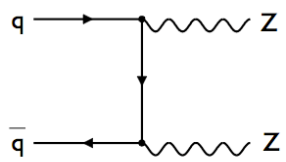
To reduce Z background, WW uses ME$_T$ relative to nearest lepton

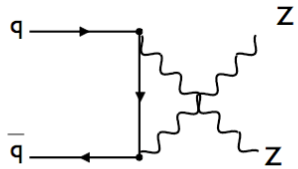
$$MET_{rel} = \sin(\Delta\phi) * MET \ for \ \phi < 90°$$

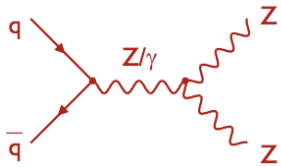


ZZ→llνν

ATLAS-CONF-2012-027



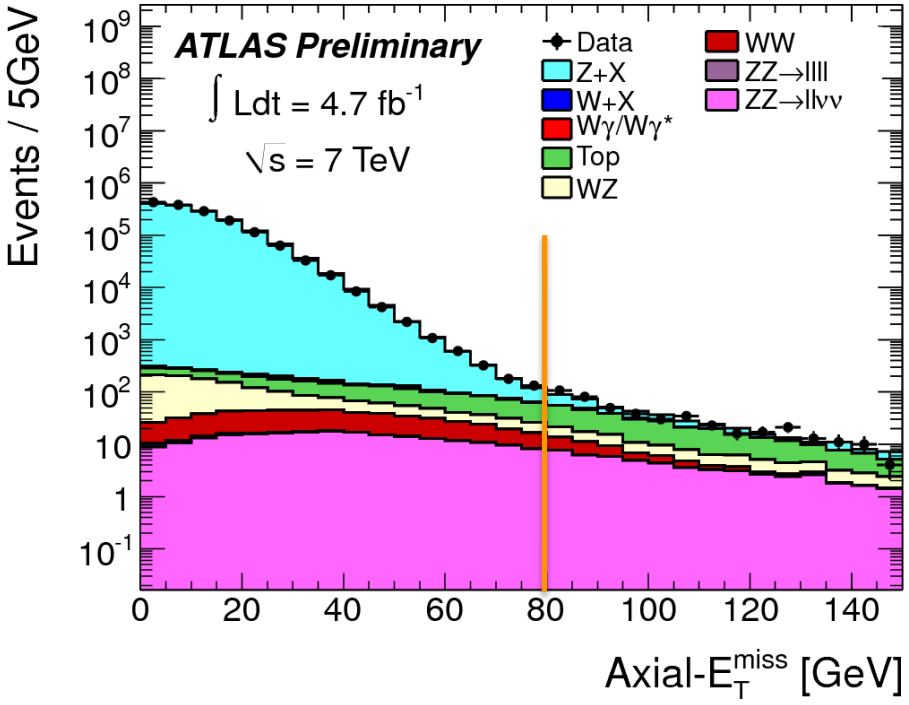




Exclusive Cross section measurement

Selection highlights

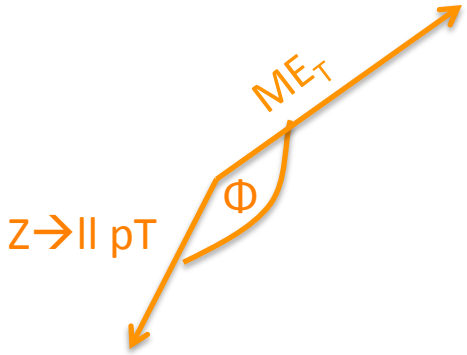
- 2 leptons pT > 20 GeV
- Z→ll candidate
- Axial MET > 80 GeV
- Jet veto (p_T > 25 GeV)



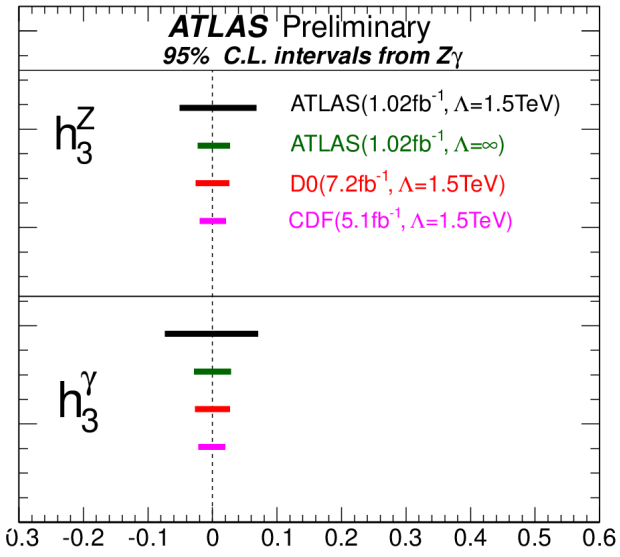
To enhance signal,

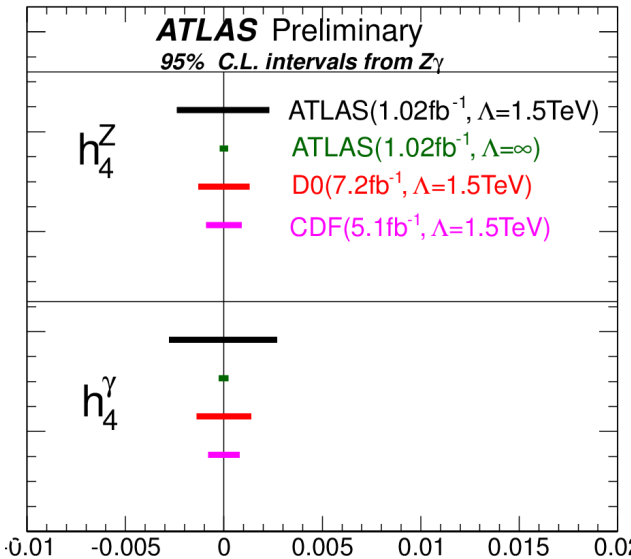
ZZ uses ME_T relative to p_T of Z→ll

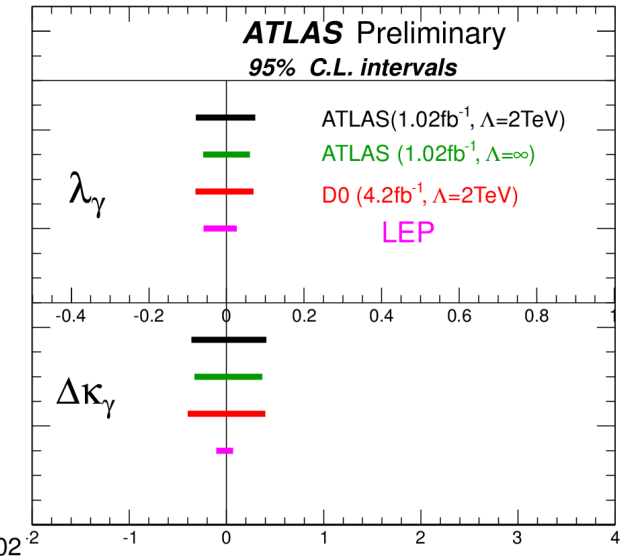
$$ME_{T\,axial} = \cos(\Delta\varphi(\vec{ME}_T, \vec{p}_T^{\,ll}) * ME_T$$



Wγ, Zγ aTGC Full Results







Wγ, Zγ limits

- Limits set using exclusive cross-section (no jets) at high E_T^γ
- ATLAS aTGC limits most stringent for h_3 and h_4