Electroweak Measurements with the ATLAS Detector

Lake Louise Winter Institute 2015

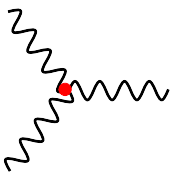
Philip Sommer
on behalf of the ATLAS Collaboration

Albert-Ludwigs-Universität Freiburg

16. - 21.02.2015

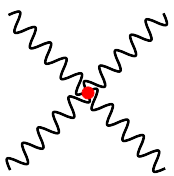
Introduction

- test of the electroweak (EW) sector of the Standard Model at the TeV scale
- probe triple and quartic gauge boson self-interactions
- probe QCD calculations



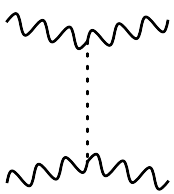
TGC

- measurement of electroweak parameters
- diboson production
- EW production of single vector bosons



QGC

- triboson production
- EW diboson production

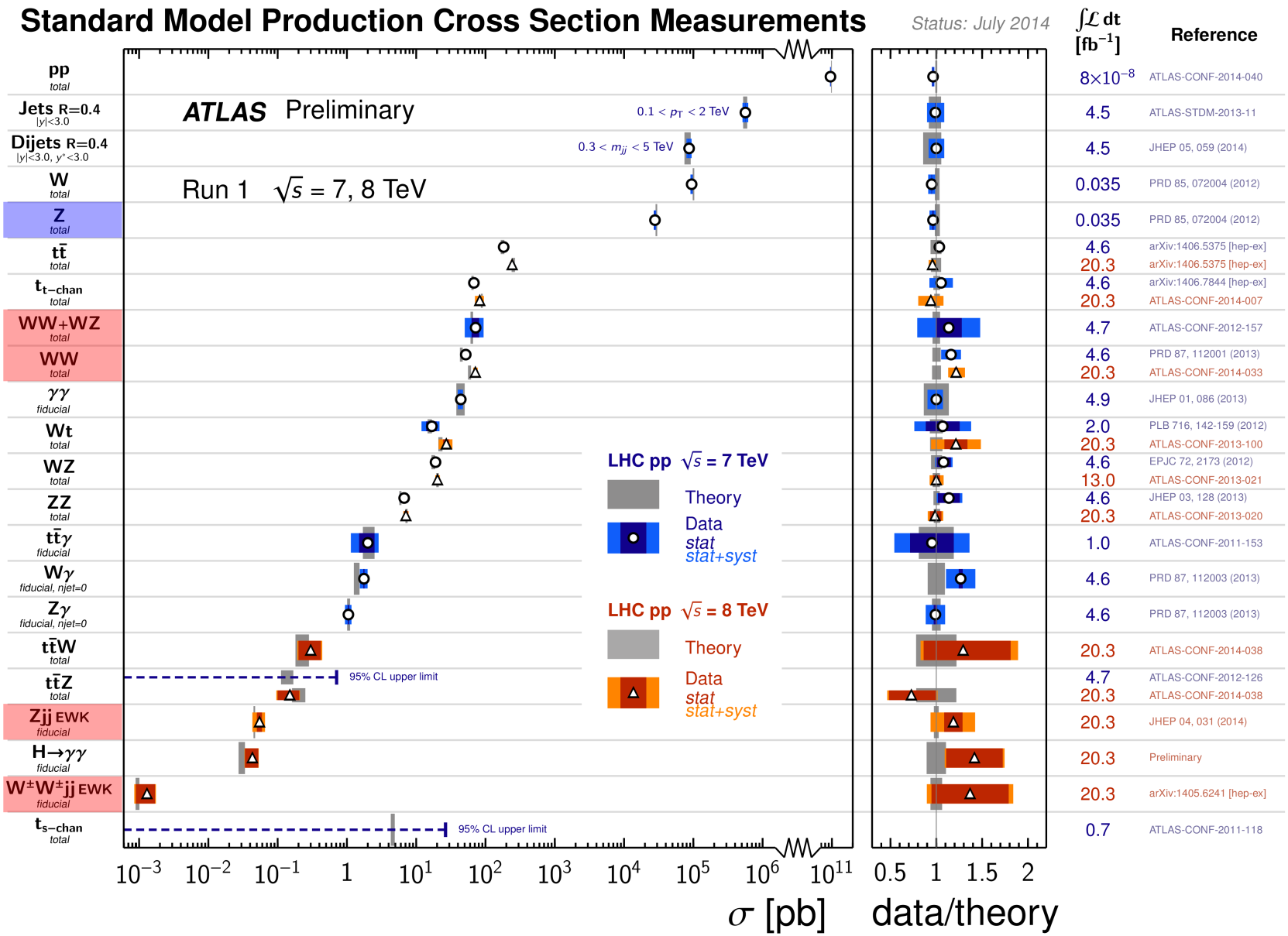


EWSB

- needed for a consistent EW theory
- no explicit Higgs measurements in this talk

- search for anomalous triple and quartic gauge couplings

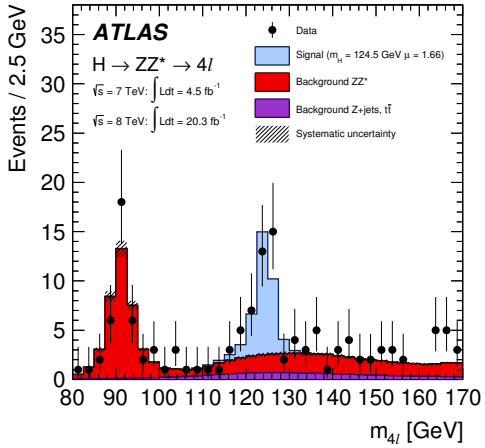
Outline

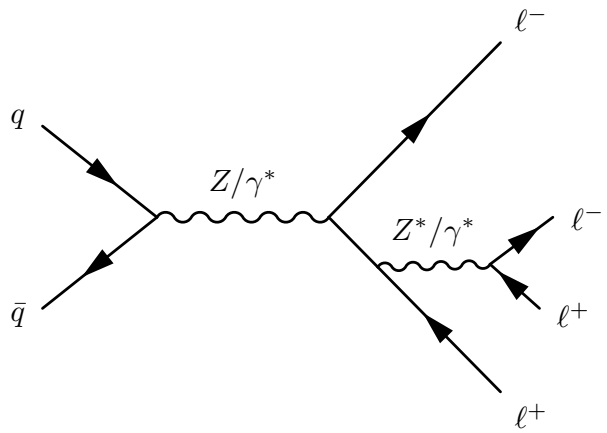

Standard Model Production Cross Section Measurements
Status: July 2014
ATLAS Preliminary
Run 1 $\sqrt{s}$ = 7, 8 TeV
0.1 < p_T < 2 TeV
0.3 < m_{jj} < 5 TeV
LHC pp $\sqrt{s}$ = 7 TeV
Theory
Data
stat
stat+syst
LHC pp $\sqrt{s}$ = 8 TeV
Theory
Data
stat
stat+syst
95% CL upper limit
95% CL upper limit
$\int \mathcal{L}\,dt$ [fb^{-1}]
Reference
pp total 8×10^{-8} ATLAS-CONF-2014-040
Jets R=0.4 |y|<3.0 4.5 ATLAS-STDM-2013-11
Dijets R=0.4 |y|<3.0, y*<3.0 4.5 JHEP 05, 059 (2014)
W total 0.035 PRD 85, 072004 (2012)
Z total 0.035 PRD 85, 072004 (2012)
tt̄ total 4.6 arXiv:1406.5375 [hep-ex]
20.3 arXiv:1406.5375 [hep-ex]
t t-chan total 4.6 arXiv:1406.7844 [hep-ex]
20.3 ATLAS-CONF-2014-007
WW+WZ total 4.7 ATLAS-CONF-2012-157
WW total 4.6 PRD 87, 112001 (2013)
20.3 ATLAS-CONF-2014-033
γγ fiducial 4.9 JHEP 01, 086 (2013)
Wt total 2.0 PLB 716, 142-159 (2012)
20.3 ATLAS-CONF-2013-100
WZ total 4.6 EPJC 72, 2173 (2012)
13.0 ATLAS-CONF-2013-021
ZZ total 4.6 JHEP 03, 128 (2013)
20.3 ATLAS-CONF-2013-020
tt̄γ fiducial 1.0 ATLAS-CONF-2011-153
Wγ fiducial, njet=0 4.6 PRD 87, 112003 (2013)
Zγ fiducial, njet=0 4.6 PRD 87, 112003 (2013)
tt̄W total 20.3 ATLAS-CONF-2014-038
tt̄Z total 4.7 ATLAS-CONF-2012-126
20.3 ATLAS-CONF-2014-038
Zjj EWK fiducial 20.3 JHEP 04, 031 (2014)
H→γγ fiducial 20.3 Preliminary
W±W±jj EWK fiducial 20.3 arXiv:1405.6241 [hep-ex]
t s-chan total 0.7 ATLAS-CONF-2011-118
10^{-3} 10^{-2} 10^{-1} 1 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{11}
σ [pb]
0.5 1 1.5 2
data/theory

Resonant $Z \to 4\ell$ cross-section

Phys. Rev. Lett. 112, 231806 (2014)

- SM test of a rare decay process
- resonant $Z \to 4\ell$ used to calibrate $h \to 4\ell$ measurements





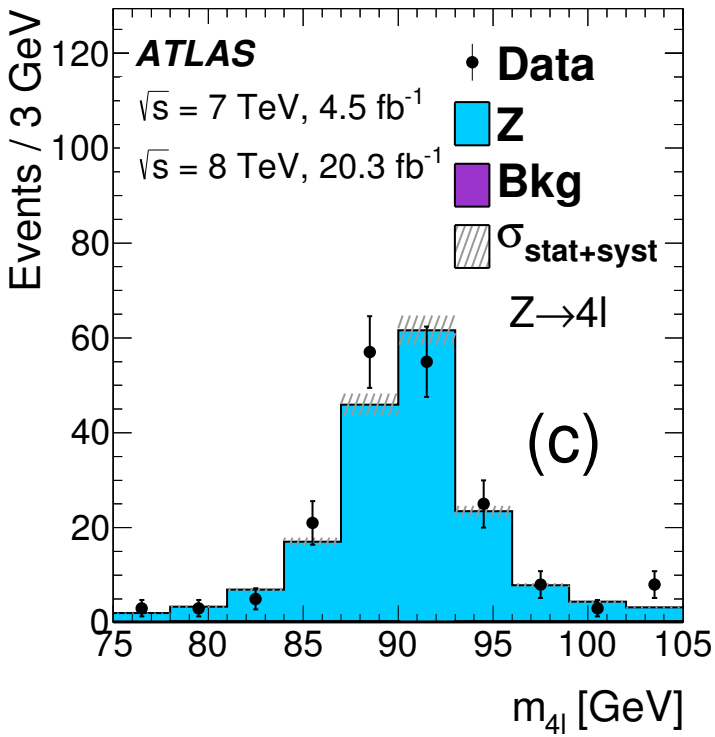
- determined cross-section and BR($Z \to 4\ell$)

$$\frac{\mathrm{BR}(Z \to 4\ell)}{\mathrm{BR}(Z \to 2\mu)} = \frac{\sigma^{\mathrm{meas.}}_{4\ell}}{\sigma^{\mathrm{meas.}}_{4\mu}} (1 - f_t)$$

with correction factor f_t for t-channel contributions

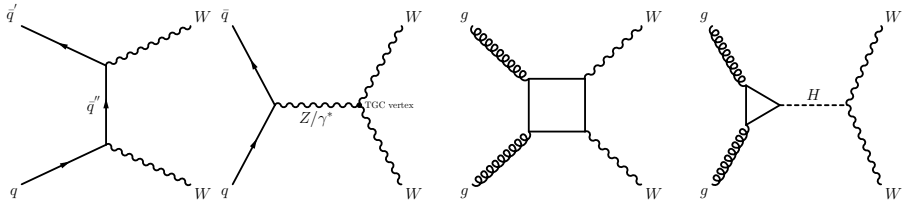
	$\sqrt{s}$	measured value	theory prediction
BR	7 TeV	$2.67 \pm 0.62(\mathrm{stat.}) \pm 0.14(\mathrm{syst.}) \times 10^{-6}$	$3.33 \pm 0.01 \times 10^{-6}$
	8 TeV	$3.33 \pm 0.27(\mathrm{stat.}) \pm 0.11(\mathrm{syst.}) \times 10^{-6}$	
	combined	$3.20 \pm 0.25(\mathrm{stat.}) \pm 0.12(\mathrm{syst.}) \times 10^{-6}$	
$\sigma^{\mathrm{fid.}}$ [fb]	7 TeV	$76 \pm 18(\mathrm{stat.}) \pm 4(\mathrm{syst.}) \pm 1.4(\mathrm{lumi})$	90.0 ± 2.1
	8 TeV	$107 \pm 9(\mathrm{stat.}) \pm 4(\mathrm{syst.}) \pm 3(\mathrm{lumi})$	104.8 ± 2.5

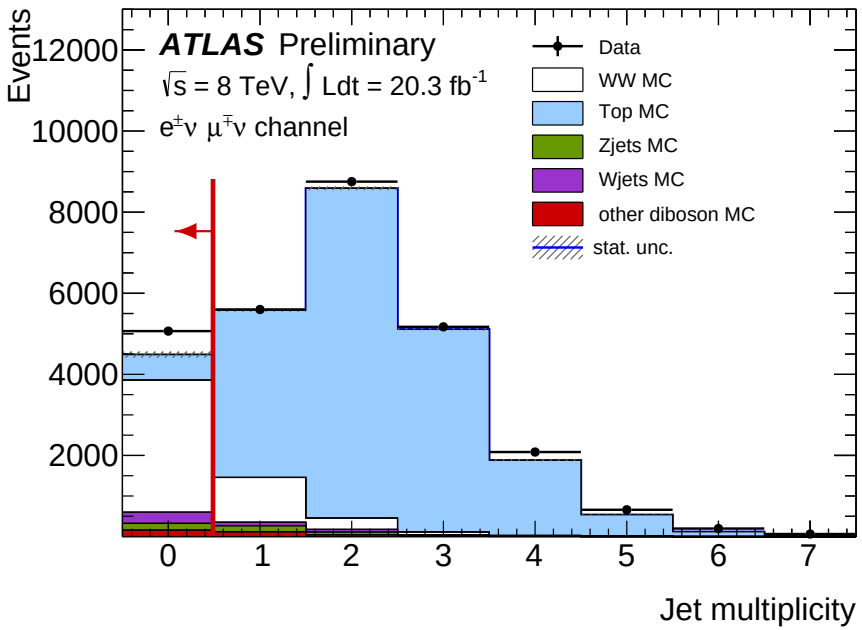
- measurement dominated by statistical uncertainty
- good agreement with theory prediction



$W^+W^- \to \ell\nu\ell\nu$ cross-section

- very hard selection-criteria on $E_{\mathrm{T}}^{\mathrm{miss}}$ and a jet-veto to suppress $t\bar{t}$ background
- dominant uncertainty due to jet-veto





- measured cross-section at 8 TeV is 2.1σ higher than NLO calculation
- enhancement of total cross-section by $\sim 10\%$ from NNLO arXiv:1408.5243
- enhancement of fid. cross-section by taking into account resummation effects arXiv:1407.4537,arXiv:1407.4481,arXiv:1407.4745

$\sqrt{s}$	$\int \mathcal{L}dt$ [fb^{-1}]	Measured total cross-section [pb]	Theory [pb]	
7 TeV	4.6	$51.9 \pm 2.0(\mathrm{stat.}) \pm 3.9(\mathrm{syst.}) \pm 2.0(\mathrm{lumi})$	$44.7^{2.1}_{-1.9}$	
8 TeV	20.3	$71.4 \pm 1.2(\mathrm{stat.})^{5.0}_{-4.4}(\mathrm{syst.})^{2.2}_{2.1}(\mathrm{lumi})$	$58.7^{3.0}_{-2.7}$	incl. Higgs

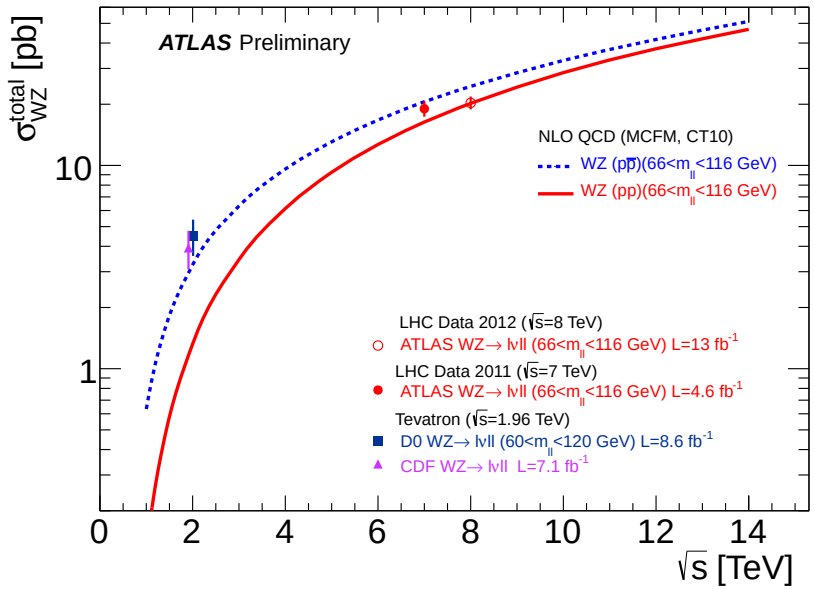
WZ and ZZ cross-sections

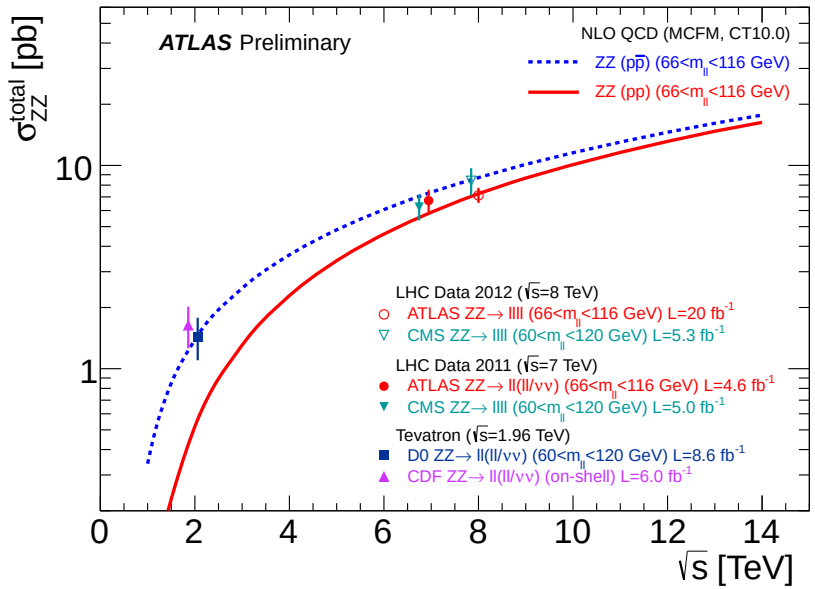
$WZ \to \ell\nu\ell\ell$
ATLAS-CONF-2013-021

- measurement at 7 and 8 TeV in fully leptonic final state

$ZZ \to 4\ell$ & $ZZ \to \ell\ell\nu\nu$ (7TeV)
ATLAS-CONF-2013-020

- measurement at 7 and 8 TeV in fully leptonic final state and in $2\ell 2\nu$ for 7 TeV
- contributions from $h \to ZZ \to 4\ell$ suppressed due to kinematic selection



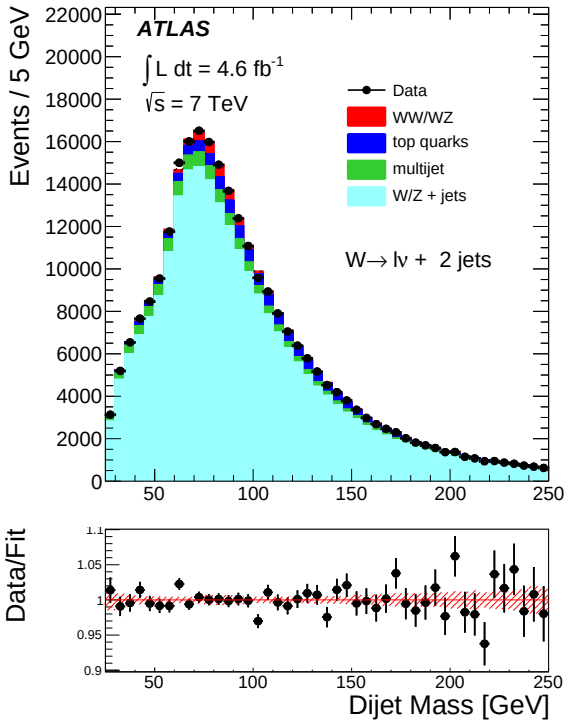


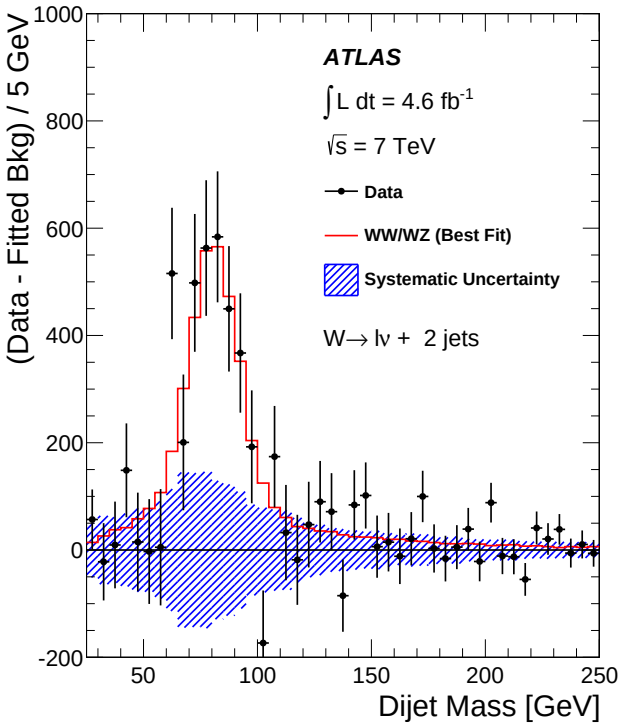
- both measurements in agreement with theory prediction
- WZ and $ZZ \to 4\ell$ analyses do *not* rely on a jet veto

$WW/WZ \to \ell\nu jj$ cross-section

JHEP01(2015)049

- new, final 7 TeV result
- measurement of combined WW/WZ cross-section in semi-leptonic final state
- 89% background from W+jets



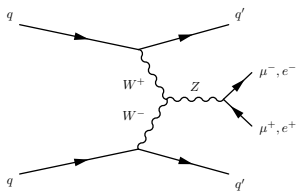


- signal yield extracted from a fit to m_{jj} distribution
- large m_{jj} range allows to constrain the W+jets rate in signal free regions
- the observed significance is 3.4σ
- $\sigma_{\text{tot}} = 68 \pm 7(\text{stat.}) \pm 19(\text{syst.})$ pb, compared to $\sigma_{\text{tot}}^{\text{theo.}} = 61.1 \pm 2.2$ pb
- with large uncertainties from W+jets modelling and jet uncertainties

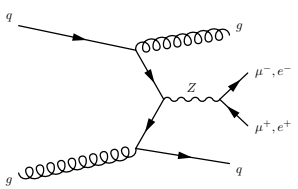
Electroweak Zjj production (VBF)

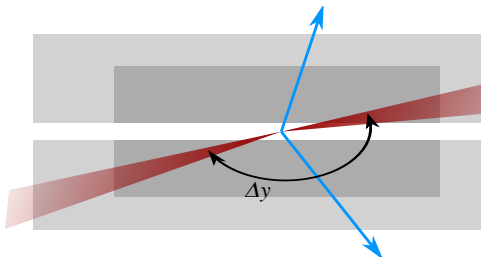
JHEP01(2014)031

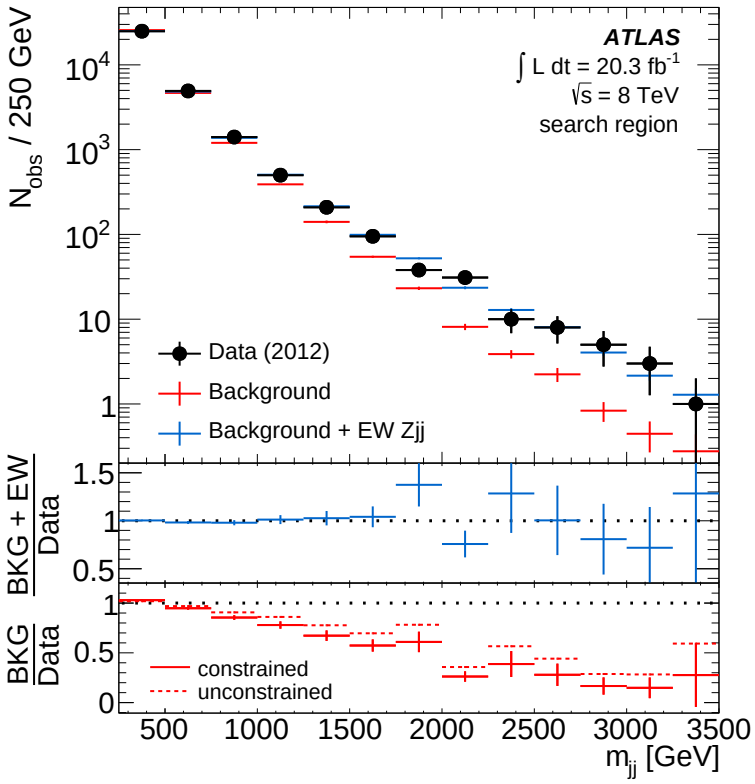
EW production



strong production







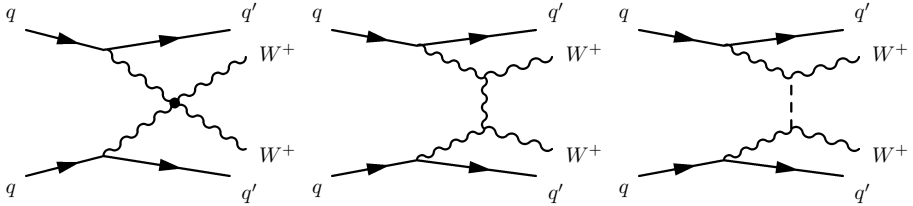
- strong production dominates by far
- enhance EW production by exploring VBF topology with two high m_{jj} jets with rapditiy gap
- (strong) background template constrained by data-driven technique, electroweak production extracted in *EW* enriched category
- strong-production-only hypothesis rejected at $> 5\sigma$

selection	Measured fiducial cross-section [fb]	POWHEG
$m_{jj} > 250$ GeV	$54.7 \pm 4.6(\text{stat.})^{9.8}_{-10.4}(\text{syst.}) \pm 2.5(\text{lumi})$	$46.1 \pm 0.2(\text{stat.})^{+0.3}_{-0.2}(\text{scale}) \pm 0.8(\text{PDF}) \pm 0.5(\text{model})$
$m_{jj} > 1$ TeV	$10.7 \pm 1.9(\text{stat.}) \pm 1.9(\text{syst.}) \pm 0.3(\text{lumi})$	$9.38 \pm 0.05(\text{stat.})^{+0.15}_{-0.24}(\text{scale}) \pm 0.24(\text{PDF}) \pm 0.09(\text{model})$

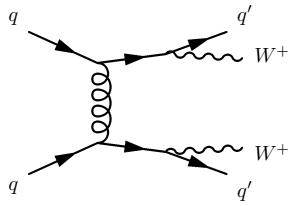
Electroweak *WWjj* production (VBS)

Phys. Rev. Lett. 113, 141803

- EWSB needed to unitarise VV scattering at $Q^2 \sim 1$ TeV
- key process to study the SM nature of EWSB, most promising at LHC is *same-sign* $W^{\pm}W^{\pm}$ scattering

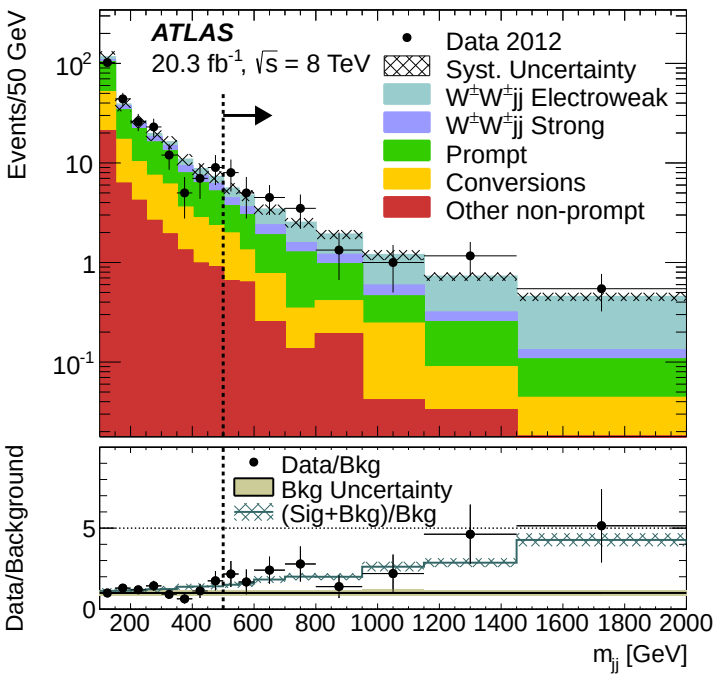


electroweak production in t-channel

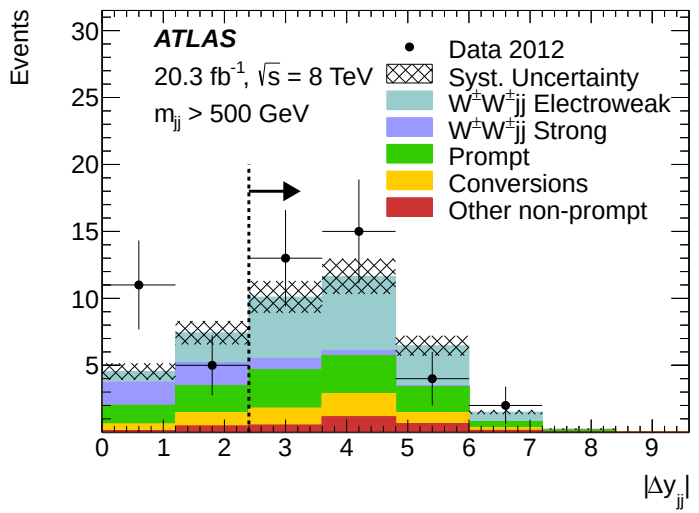


strong production

measurement of EW + strong production selected at high m_{jj}

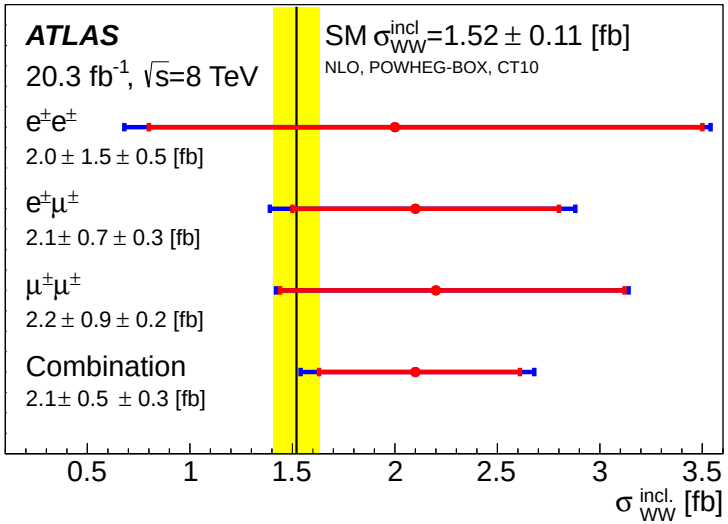


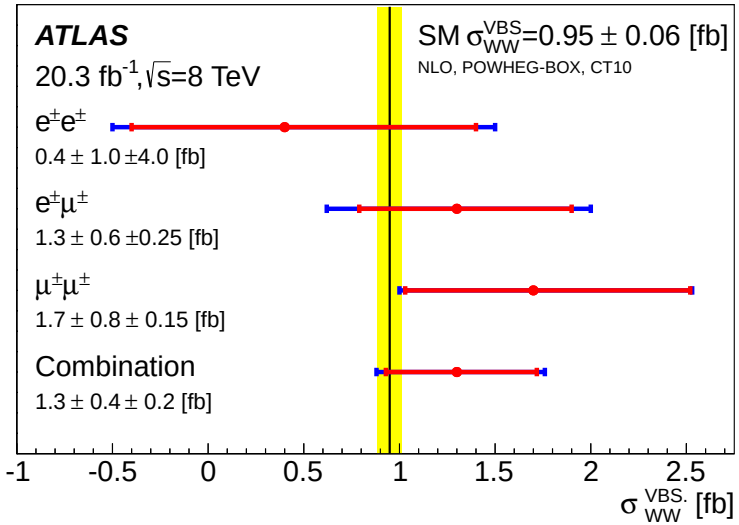
additional category enhanced in VBS by cutting on $|\Delta y_{jj}|$ in addition



prompt: prompt leptons from multilepton processes
conversions: photon conversions and charge mis-ID

Electroweak *WWjj* production (VBS)





- a total of 34 candidate events in VBS region

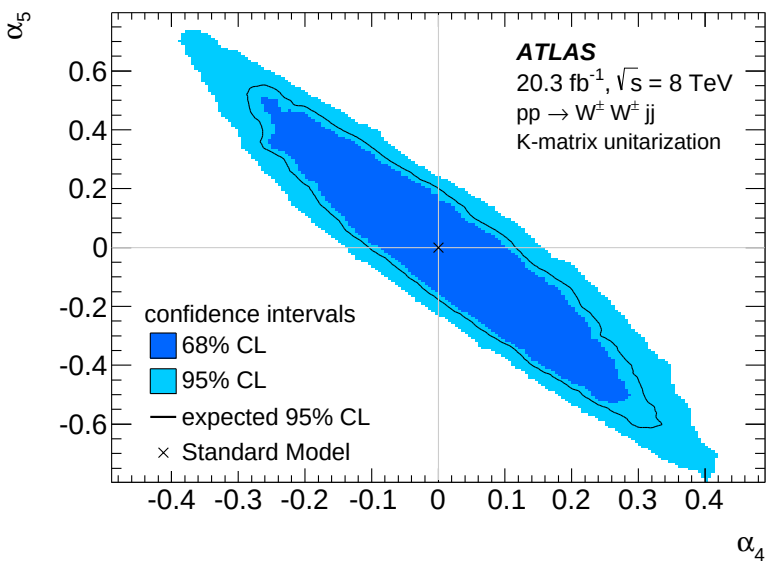
	measurement	POWHEG+PYTHIA8 prediction
	inclusive category	
cross-section [fb]	$2.1 \pm 0.5(\text{stat}) \pm 0.3(\text{syst})$	1.5 ± 0.11
significance	4.5σ	3.4σ
	VBS category	
cross-section [fb]	$1.3 \pm 0.4(\text{stat}) \pm 0.2(\text{syst})$	0.95 ± 0.06
significance	3.6σ	2.8σ

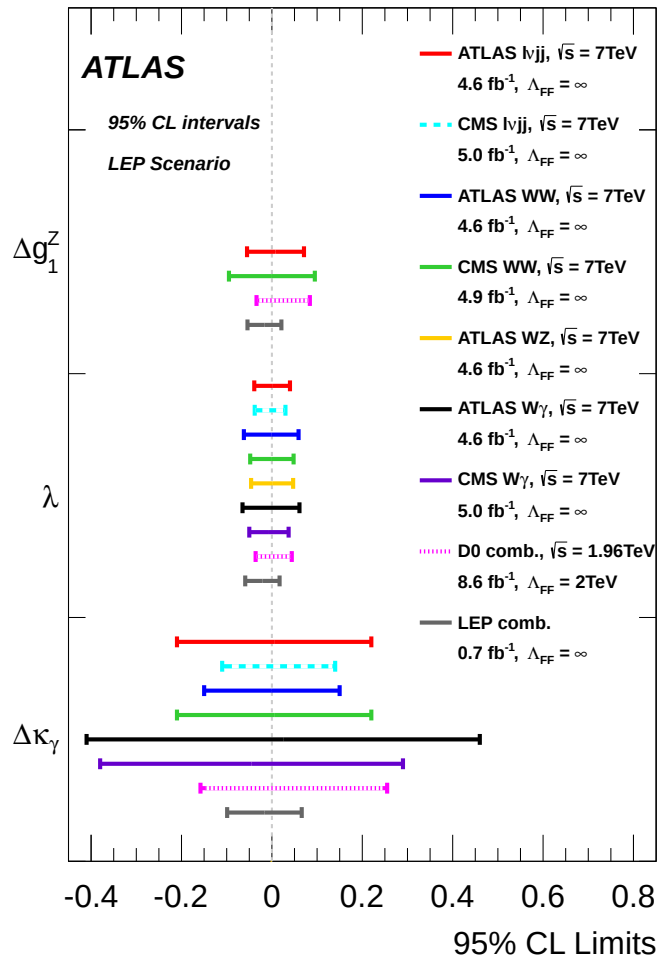
- measured cross-sections slightly higher but in agreement with theory prediction
- **first evidence for a *VVVV* vertex**

Anomalous Gauge Couplings

- place model independent limits on BSM physics in the EW sector
- parametrised in anomalous couplings

- limits on aTGC couplings from 7 TeV analyses, with new limits from $WW \to \ell\nu jj$
- WWZ and $WW\gamma$ limits becoming comparable to LEP
- measurement of WW scattering allows for setting limits on anomalous quartic couplings
- first limits on α_4, α_5 from $W^{\pm}W^{\pm}$
  (for notation see e.g. Phys. Rev. D 22, 200)





Summary

- measurement of diboson processes with accuracy of a few percent
- mostly good agreement with theory predictions
- theoretical and experimental work ongoing to understand WW discrepancy

- measurement of very rare processes become available:
- rare $Z \rightarrow 4\ell$ decay process
- evidence for VV scattering processes
- observation of electroweak Z production

- placed limits on aTGC and aQGC

- many run I results at 8 TeV about to come out before start of run II
- diboson differential distributions, triboson processes