Di-Boson production Cross Section at LHC

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On behalf of the ATLAS and CMS collaborations

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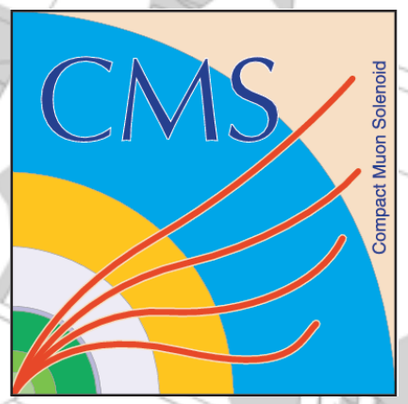
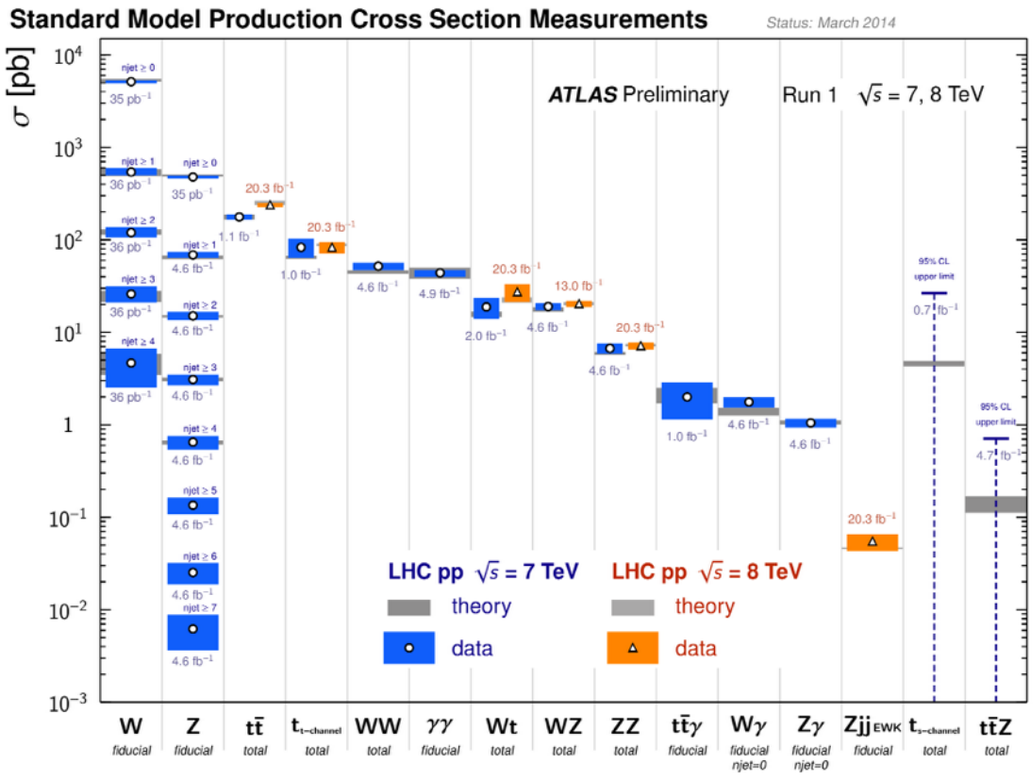
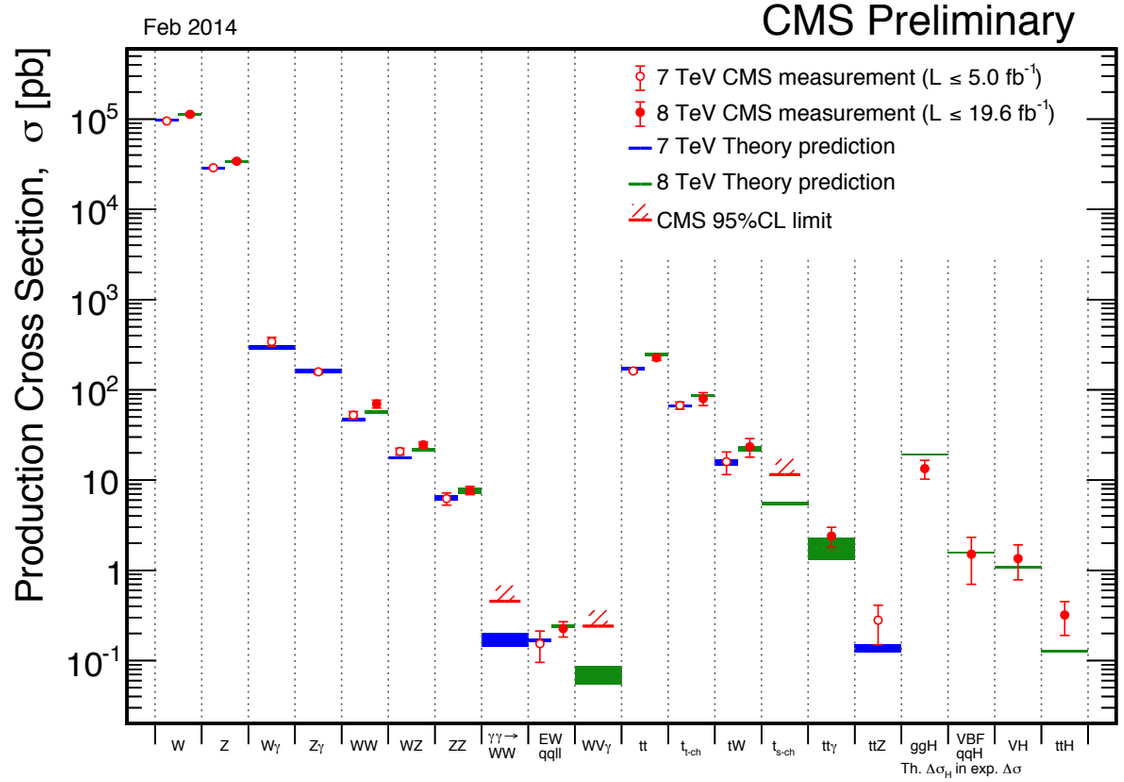


Di-boson physics at LHC

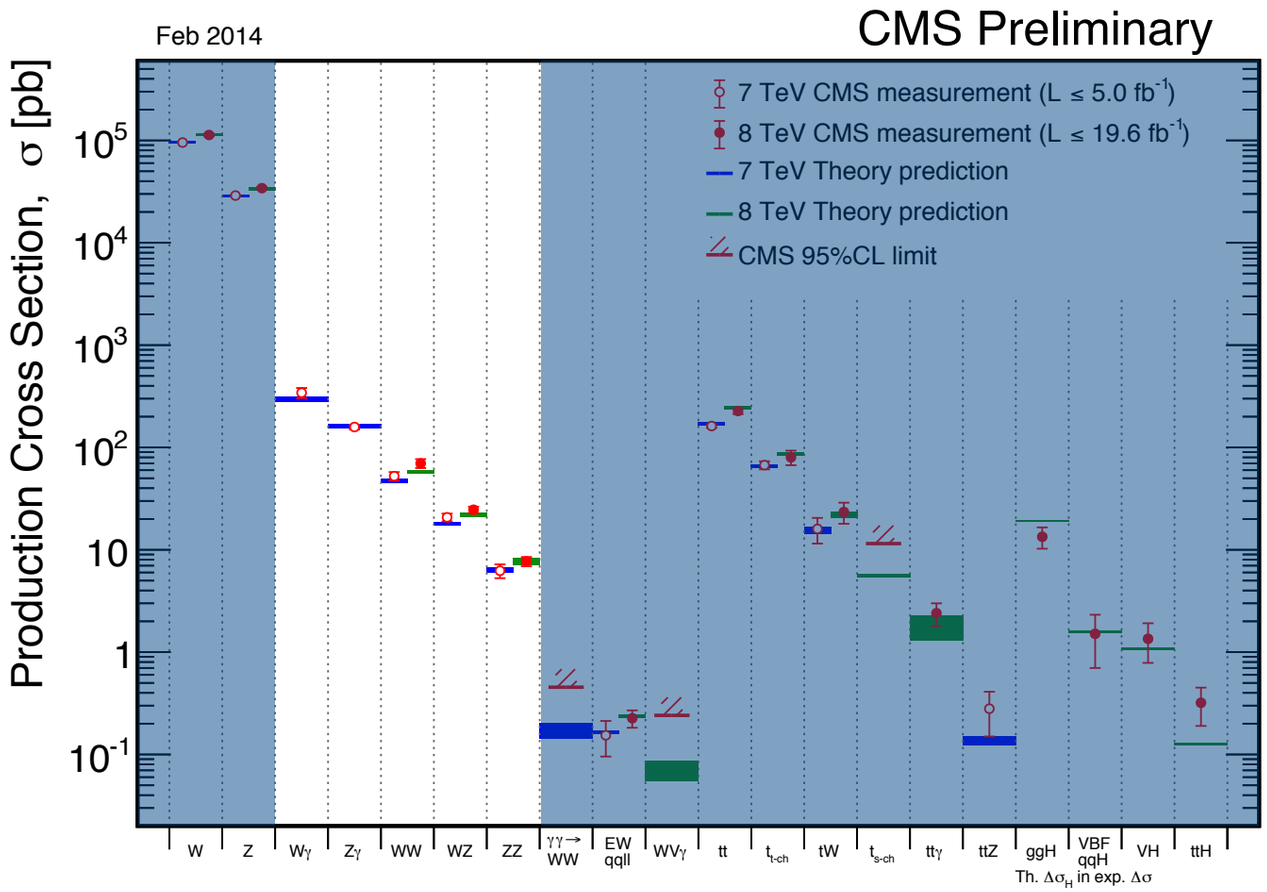




- various di-bosons processes are accessible at LHC
- measurement important to test the SM but also as di-boson processes are an irreducible background for Higgs boson searches
- di-bosons processes also sensitives to self-interaction between gauge bosons → direct test of the non abelian structure of (SU(2)xU(1)) gauge symmetry

Overview

- cross section measurement takes advantage of rather clean final states: photon and leptonic decays of W and Z → signatures will be isolated high p_T photon and leptons and missing E_T
- backgrounds: Top, other bi-boson, V+jets, V+γ,γ+jets
- if possible, use of data driven estimations



In this talk, cross section measurement in following channels:

- γγ
- Wγ→lνγ, Zγ→llγ
- WW→lνlν
- WZ→lνll
- ZZ→llll, ZZ→llνν
- VZ→Vbb
- Z→4l
- $W^{\pm}jW^{\pm}j$→lνlνjj

γγ cross section at 7 TeV

ATLAS: JHEP01(2013)086
CMS: CMS-PAS-SMP-13-001

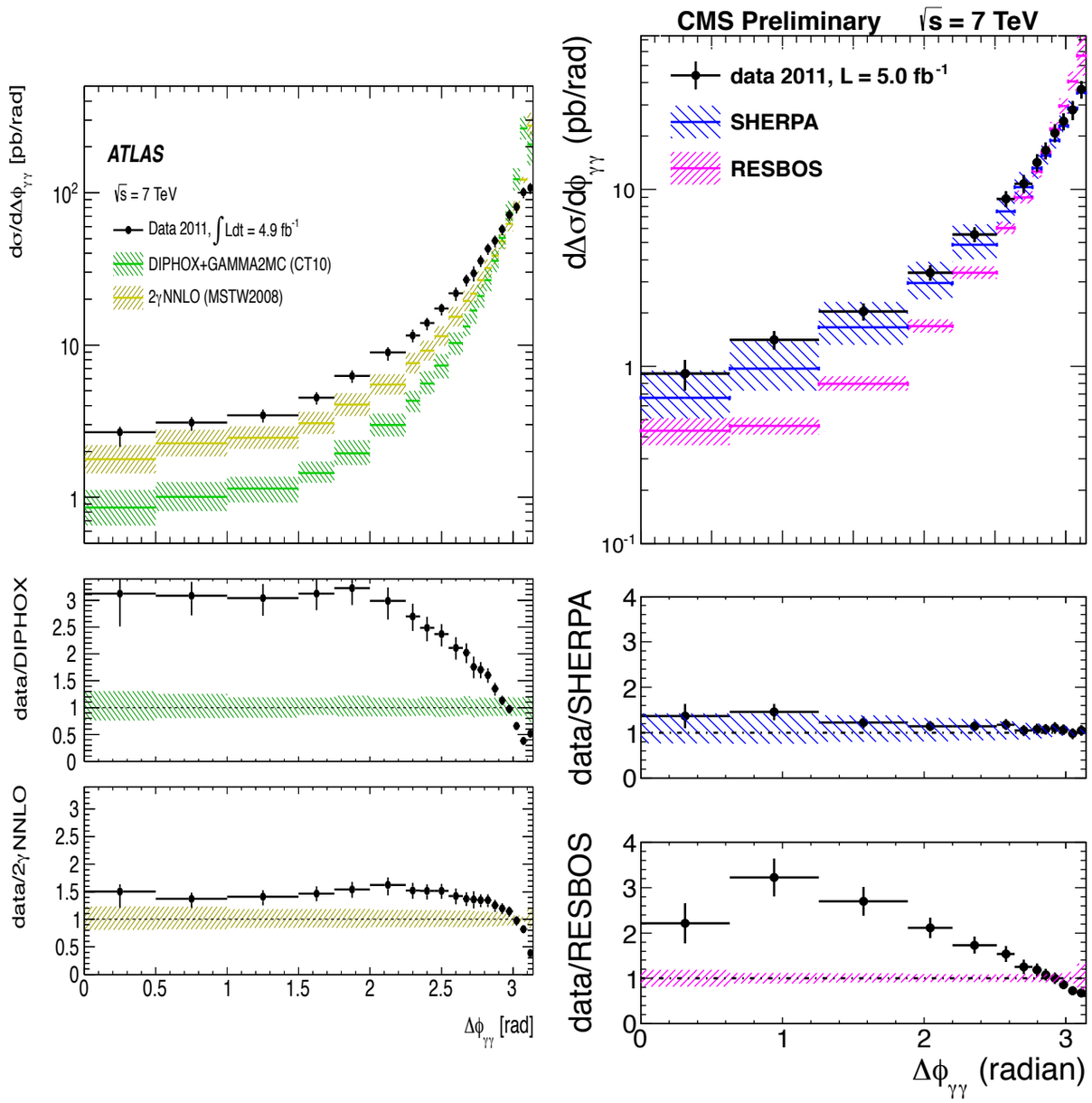
signal:
- 2 isolated photons

background:
- γ+jet and multi-jets, with 1 or 2 jets faking a photon
- subtracted using data driven methods

acceptance cuts:

in ATLAS:
- $p_{T,\gamma 1} > 25$ GeV/c, $p_{T,\gamma 2} > 22$ GeV/c, $\Delta R_{\gamma\gamma} > 0.4$
- $|\eta|<1.37$, $1.52<|\eta|<2.37$

in CMS:
- $p_{T,\gamma 1} > 40$ GeV/c, $p_{T,\gamma 2} > 24$ GeV/c, $\Delta R_{\gamma\gamma} > 0.45$
  →asymmetric phase space to enhance sensitivity to higher order diagrams
- $|\eta|<1.44$, $1.57<|\eta|<2.5$



Measurement:

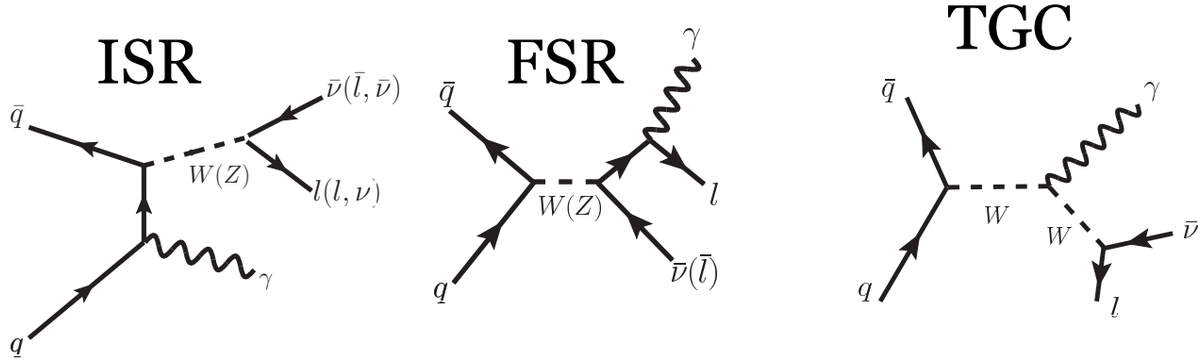
	Measurements (pb)	2γNNLO Prediction (pb)
ATLAS 4.9 fb^{-1}	$44.0^{+3.2}_{-4.2}$	44^{+6}_{-5}
CMS 5.0 fb^{-1}	16.8 ± 0.2 (stat.) ± 1.8 (syst.) ± 0.4 (lumi)	$16.2^{+1.5}_{-1.3}$

- NNLO prediction with 2 γNNLO shows better agreement that NLO from RESBOS and DIPHOX+GAMMA2MC
- SHERPA LO shows a reasonable agreement

Wγ/Zγ cross section

ATLAS: Phys. Rev. D 87, 112003 (2013)
CMS: CERN-PH-EP-2012-376

diagrams:

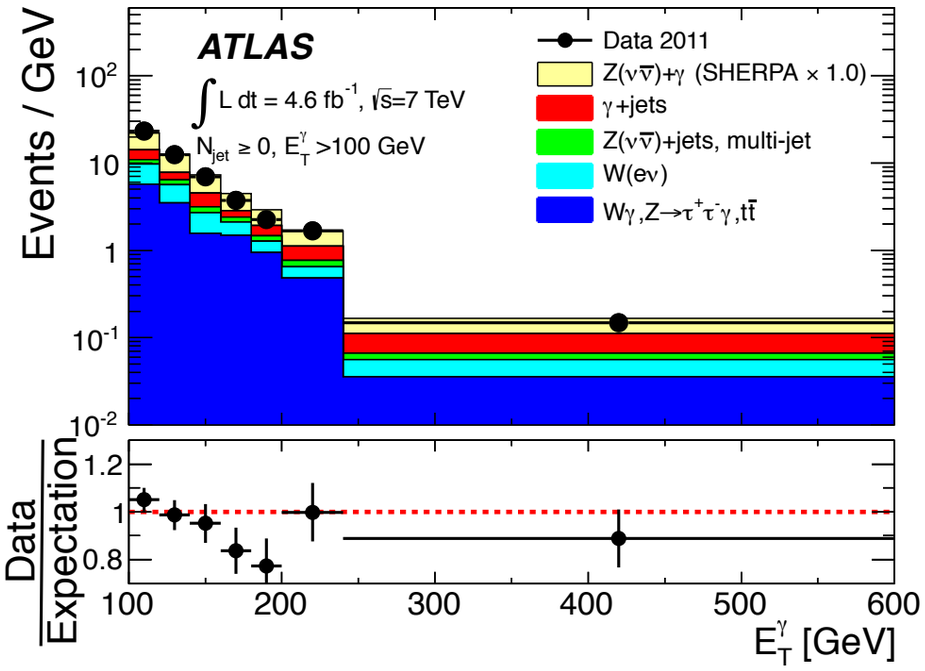


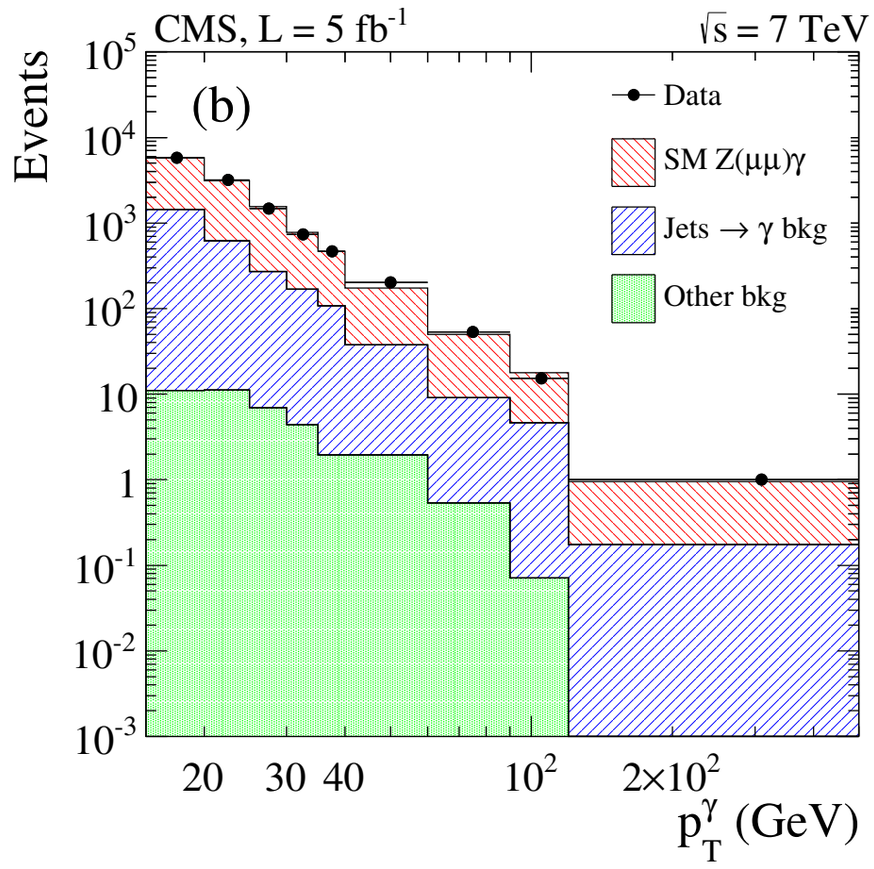
channels:

- Wγ→lνγ:
  - 1 well identified lepton (μ or e)
  - 1 photon (E_T > 15 GeV)
  - large missing E_T
  - veto 3rd lepton
- Zγ→l^+l^-γ:
  - 2 leptons of same flavor and opposite sign
  - M_{ll} > 40 GeV in ATLAS (50 GeV in CMS)

+ ΔR(l, γ)>0.7 in both channels

main background from W+jets and Z+jets estimated using data driven methods





Wγ/Zγ result at 7 TeV

ATLAS:

4.6 fb	Measurements (pb)	MCFM Prediction (pb)
Wγ	2.77 ± 0.03 (stat) ± 0.33 (syst) ± 0.14 (lumi)	1.96 ± 0.17
Zγ	1.31 ± 0.02 (stat) ± 0.11 (syst) ± 0.05 (lumi)	1.18 ± 0.05

CMS:

5.0 fb	Measurements (pb)	MCFM Prediction (pb)
Wγ	37.0 ± 0.8 (stat) ± 4.0 (syst) ± 0.8 (lumi)	31.8 ± 1.8
Zγ	5.33 ± 0.08 (stat.) ± 0.25 (syst.) ± 0.12 (lumi.)	5.45 ± 0.27

- Zγ cross sections in agreement with MCFM prediction whereas Wγ is between 1 and 2 σ higher
  - agreement back within 1 σ when including NNLO corrections (see Massimiliano Grazzini talk at Moriond QCD)
- cross section measurement with Njet=0 is also perform and show similar excess
- both result are limited by systematic uncertainty coming from background estimation

WW cross section

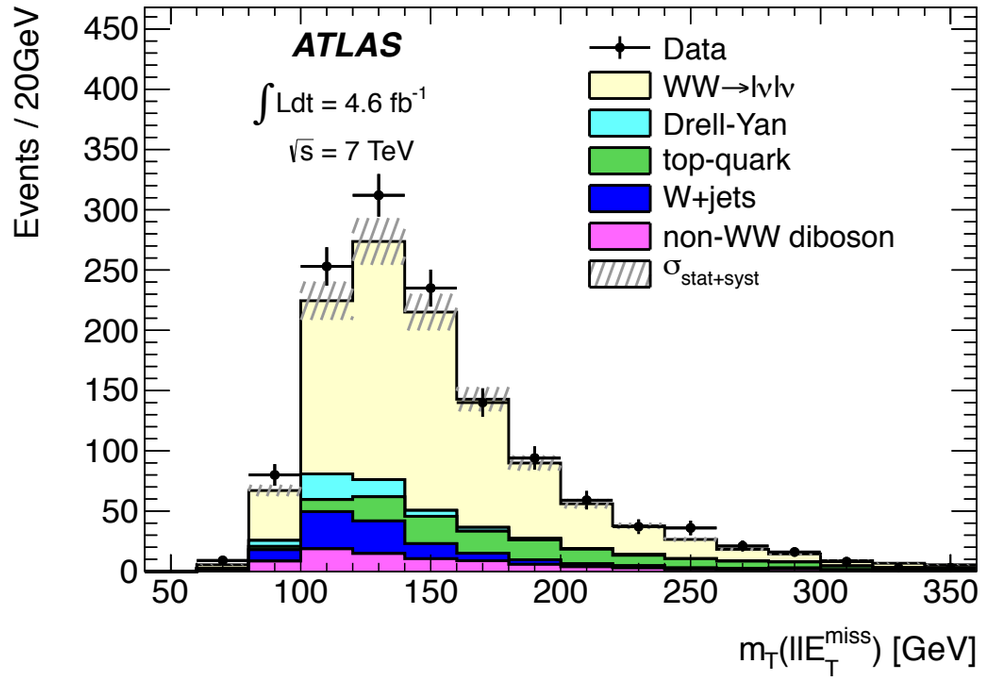
ATLAS: Phys. Rev. D 87, 112001 (2013)
CMS:Phys. Lett. B 721 (2013) 190–211

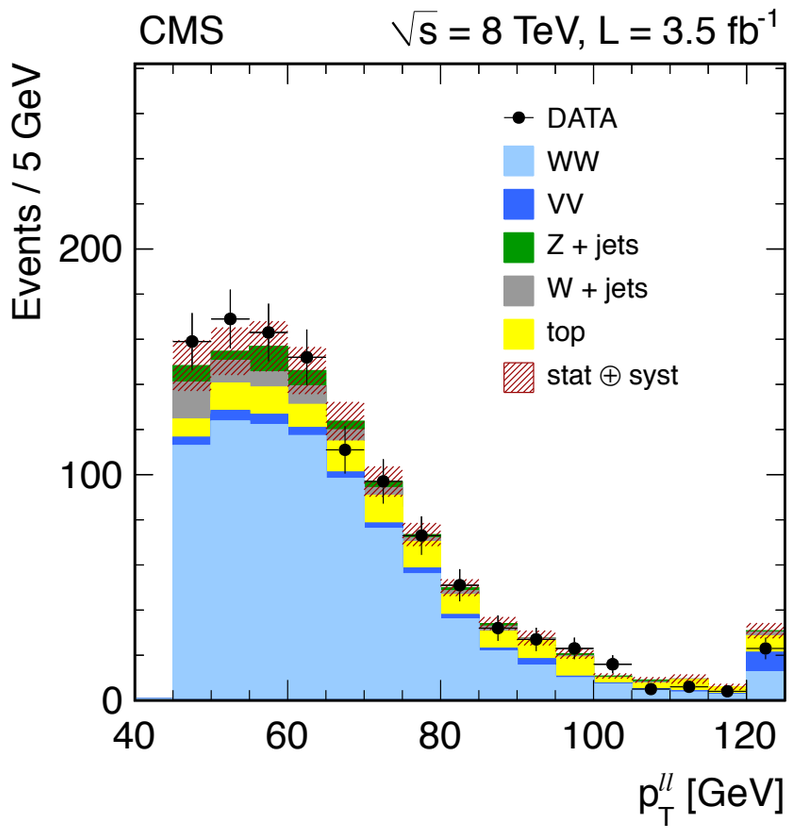
signal:
• 2 isolated leptons + missing ET

background:
• top, Drell-Yan, W+jets, other VV process

selection:
• 2 isolated leptons of pT > 20 GeV/c + veto of any 3rd lepton
• large missing E_T
• veto jets with p_T>30 GeV/c
• in same flavor di-lepton categories: Z veto + tighter cut on missing E_T

data driven estimation of ttbar and W+jet backgrounds

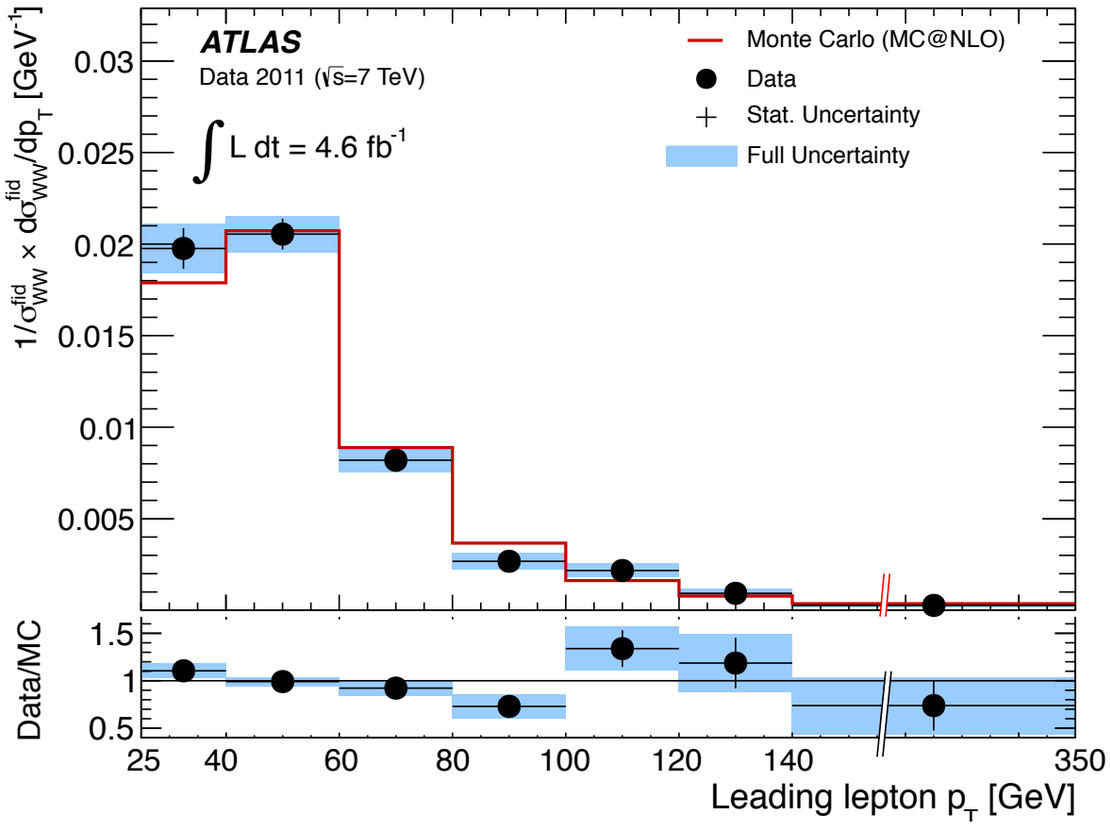




WW result

	Measurements (pb)	MCFM Prediction (pb)
ATLAS 4.6 fb^{-1} @ 7TeV	51.9 ± 2.0 (stat) ± 3.9 (syst) ± 2.0 (lumi)	$44.7^{+2.1}_{-1.9}$
CMS 3.5 fb^{-1} @ 8TeV	69.9 ± 2.8 (stat) ± 5.6 (syst) ± 3.1 (lumi)	$57.3^{+2.3}_{-1.6}$

- main contribution to systematics is error on jet veto efficiency
- measured cross section has a ~ 2 σ excess respect to MCFM prediction



- excess is more at low p_T
  → not consistant with an enhancement from TGC

measurement with full 2012 dataset in progress

WZ cross section

ATLAS: ATLAS-CONF-2013-021
CMS: CMS-PAS-SMP-12-006

signal and selection:

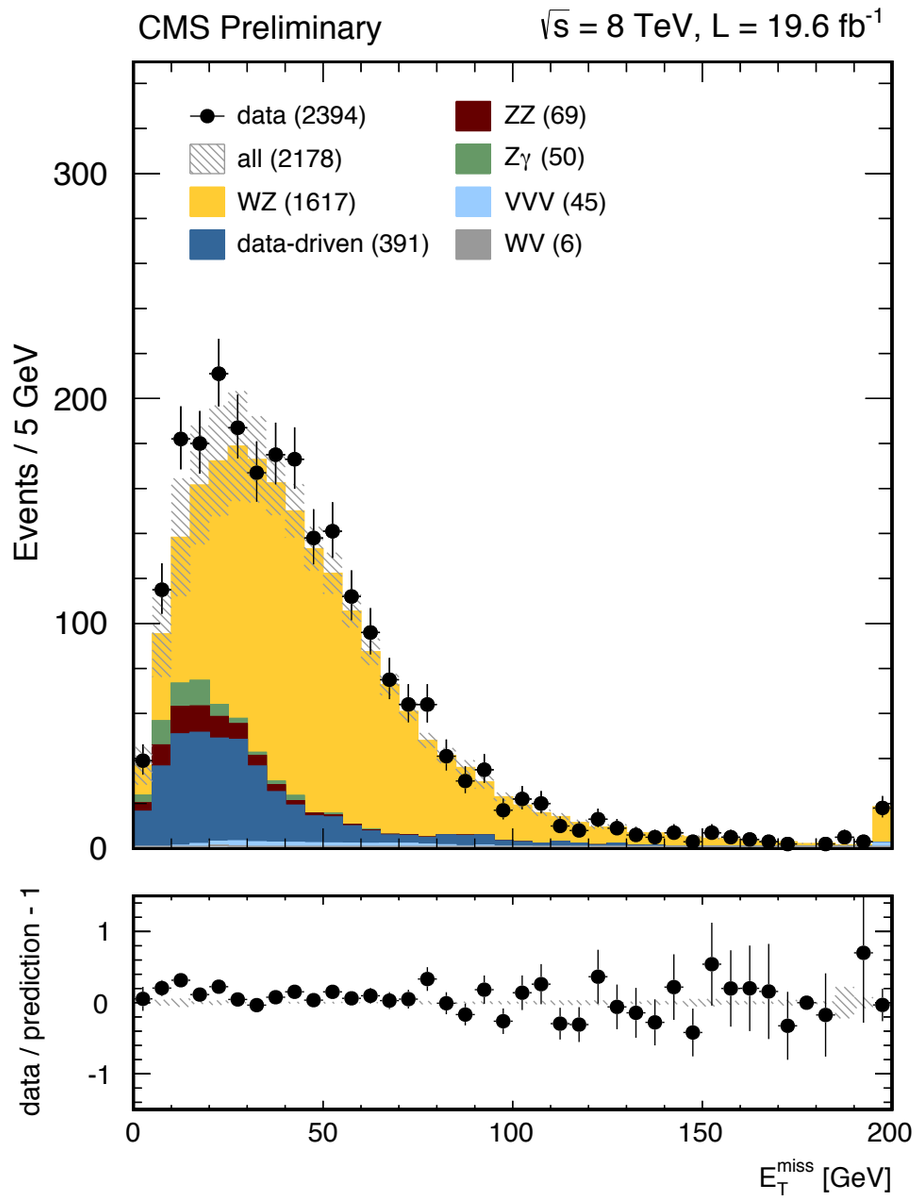
- 2 leptons from Z with pT > (10, 20)GeV
- |mll-mZ| < 10 GeV in ATLAS (15 GeV in CMS)
- W: 3rd lepton + missing Et
- cut on m_T (in ATLAS only)

background:

- Z+jets/γ, other di-bosons, top

systematics:

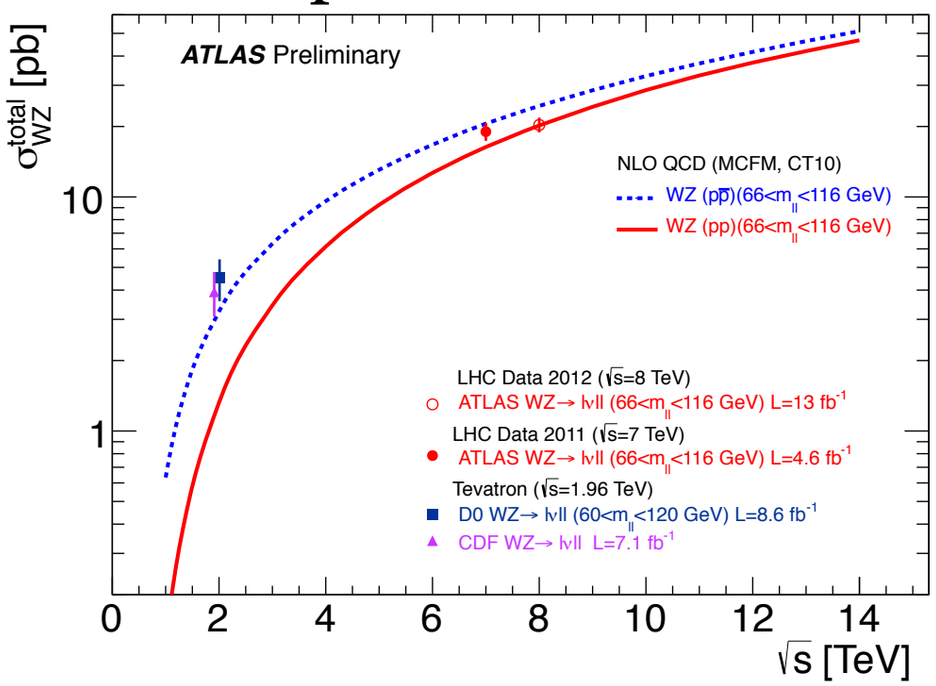
- coming from signal acceptance and background estimation

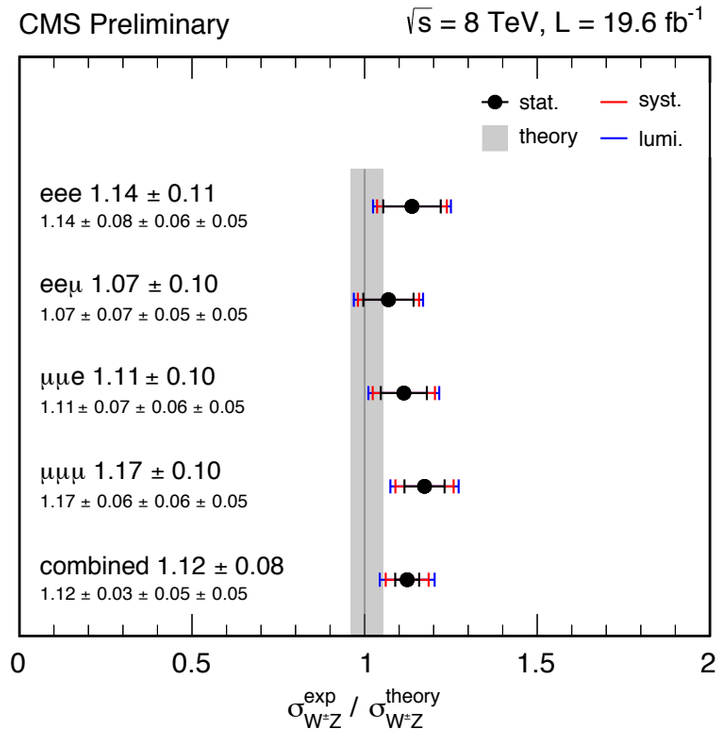


WZ results at 8 TeV

	Measurements (pb)	MCFM Prediction (pb)
ATLAS 13 fb^{-1}	$20.3^{+0.8}_{-0.7}(\text{stat})^{+1.2}_{-1.1}(\text{syst})^{+0.7}_{-0.6}(\text{lumi})$	20.3 ± 0.8
CMS 19.6 fb^{-1}	$24.61 \pm 0.76\ (\text{stat}) \pm 1.13\ (\text{syst}) \pm 1.08\ (\text{lumi})$	$21.91^{+1.17}_{-0.88}$

- agreement between ATLAS measurement and prediction
- from 1 to 1.5 σ excess respect to prediction in CMS
  - an excess of similar significance has been also measured with 7 TeV data in both experiments
- excess present in all channels





in CMS, charge ratio was measured:

$$\left(\frac{\sigma_{W^+Z}}{\sigma_{W^-Z}}\right)_{8\ \text{TeV}} = 1.81 \pm 0.12\ (\text{stat.}) \pm 0.03\ (\text{syst.})$$

SM expectation is 1.724 ± 0.003

ZZ in 4 leptons final state

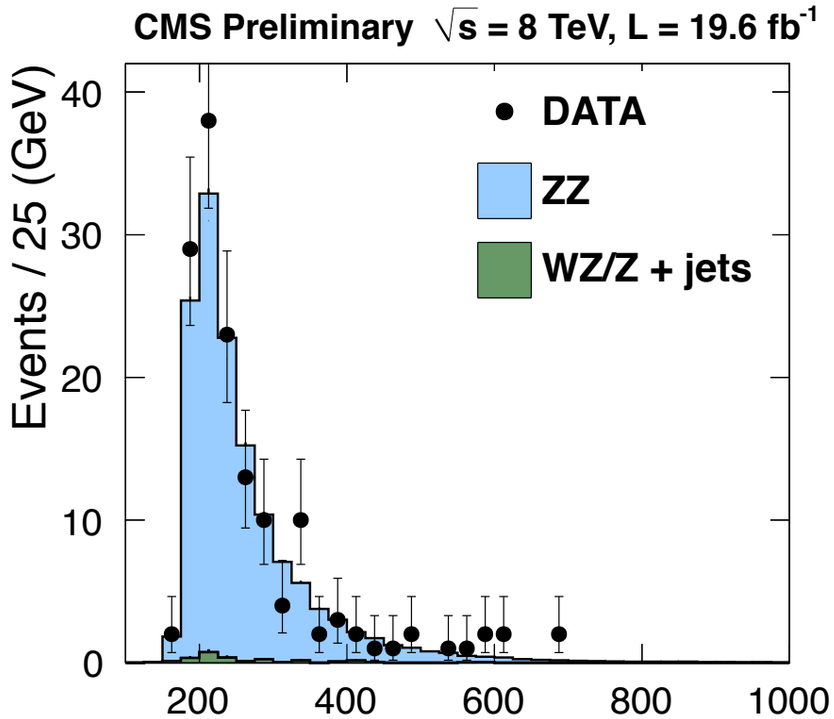
ATLAS: ATLAS-CONF-2013-020
CMS: CMS-PAS-SMP-13-005

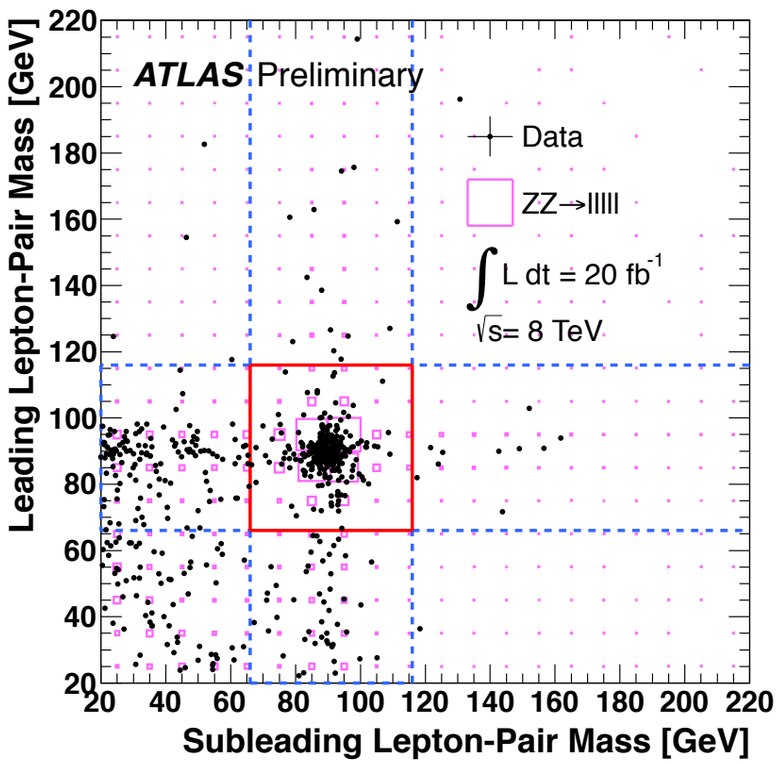
signal selection:

- 4 leptons (eeee, μμμμ, eeμμ) + llττ in CMS
- 66 GeV < m_{ll} <116 GeV in ATLAS
  60 GeV < m_{ll} <120 GeV in CMS

background:

- coming from V+j/γ, top, VV
- small in 4l channel (s/b≈14), larger in llττ channel (s/b≈1)

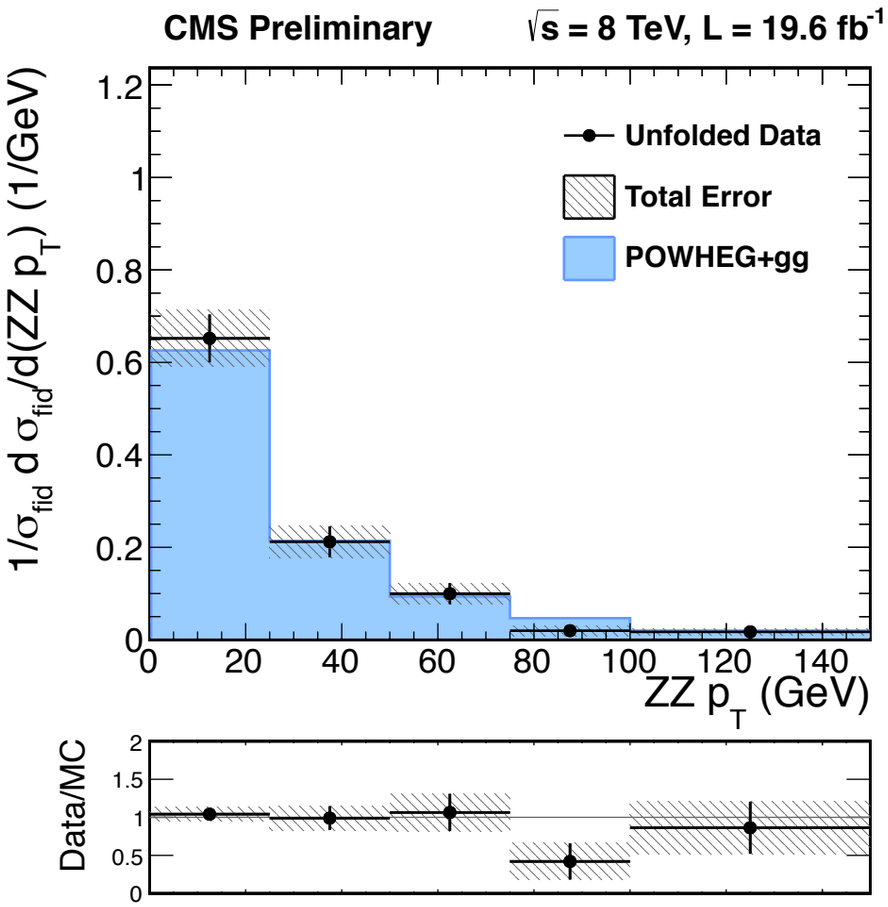


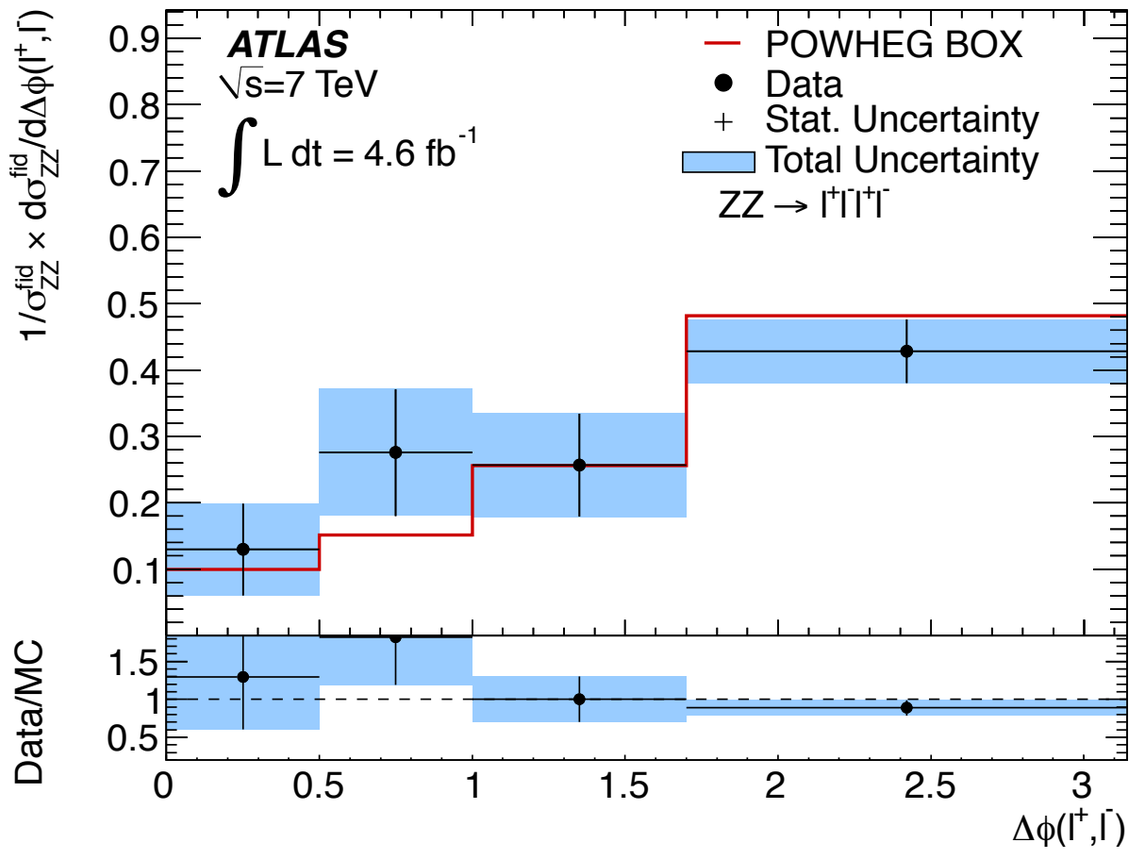


	Measurements (pb)	MCFM Prediction (pb)
ATLAS 20.0 fb^{-1}	$7.1^{+0.5}_{-0.4}$(stat) ± 0.3 (syst) ± 0.2 (lumi)	$7.2^{+0.3}_{-0.2}$
CMS 19.6 fb^{-1}	$7.7^{+0.5}_{-0.5}$(stat)$^{+0.5}_{-0.4}$(syst) ± 0.3 (lumi)	$7.7^{+0.6}_{-0.6}$

ZZ in 4 leptons final state

- differential cross section measurement has been performed





- good agreement between measurement and predictions

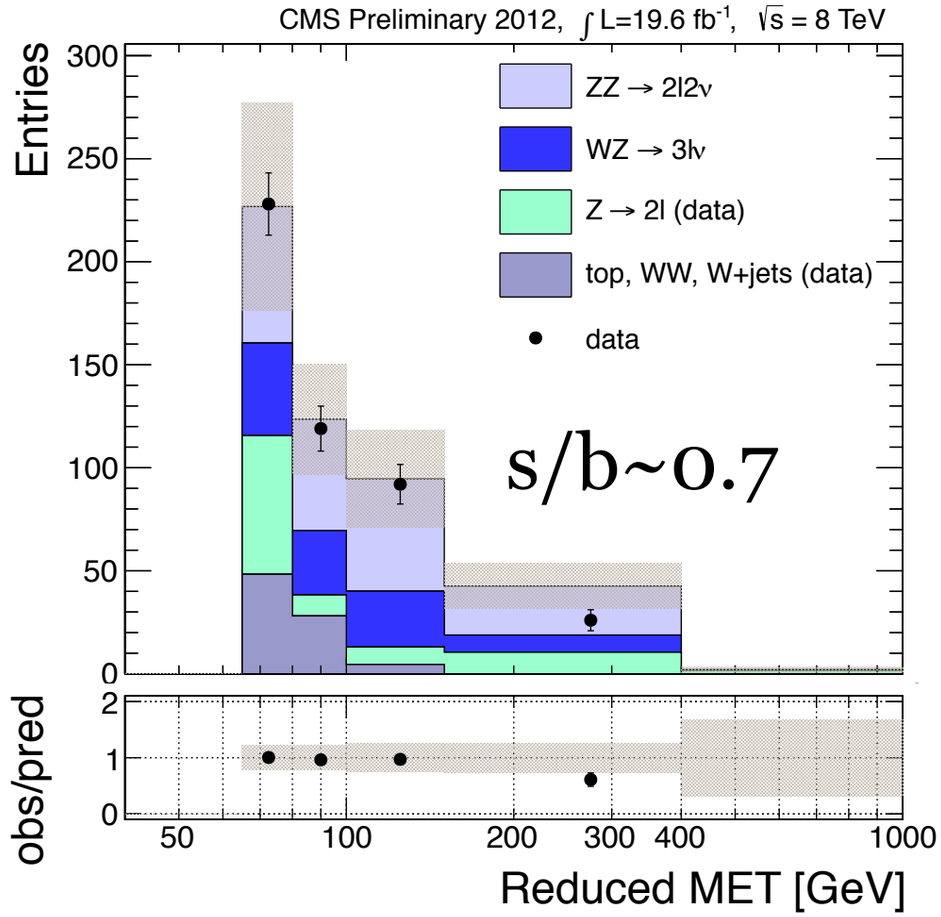
ZZ in 2l 2v final state

CMS: CMS-PAS-SMP-12-016

signal:
- 2 same flavor leptons + large missing E_T
- large BR but larger background
  →sensitive at large Z p_T

background:
- WZ, Z+j, WW, Top

selection: (CMS)
- 2 same flavor leptons of p_T > 20 GeV/c
- m_{ll} in 7.5 GeV/c² windows around M_Z
- $p_T(ll)$ > 45 GeV/c
- cut on missing E_T balance:
  0.4<MET/$p_T(ll)$ < 1.8
- reduced MET > 65 GeV
- veto jets with pT > 30 GeV/c
  (20 if b-jets)



	Measurements (pb)	MCFM Prediction (pb)
CMS 19.6 fb-1 @ 8TeV	$6.8^{+0.8}_{-0.8}(\text{stat})^{+0.8}_{-0.4}(\text{syst}) \pm 1.08\ (\text{lumi})$	$7.92^{+4.7\%}_{-3.0\%}$

fair agreement with theory

result from ATLAS combined with ZZ in 4l at 7TeV: JHEP03(2013)128

VZ with Z→bb decay

CMS: CERN-PH-EP-2014-022

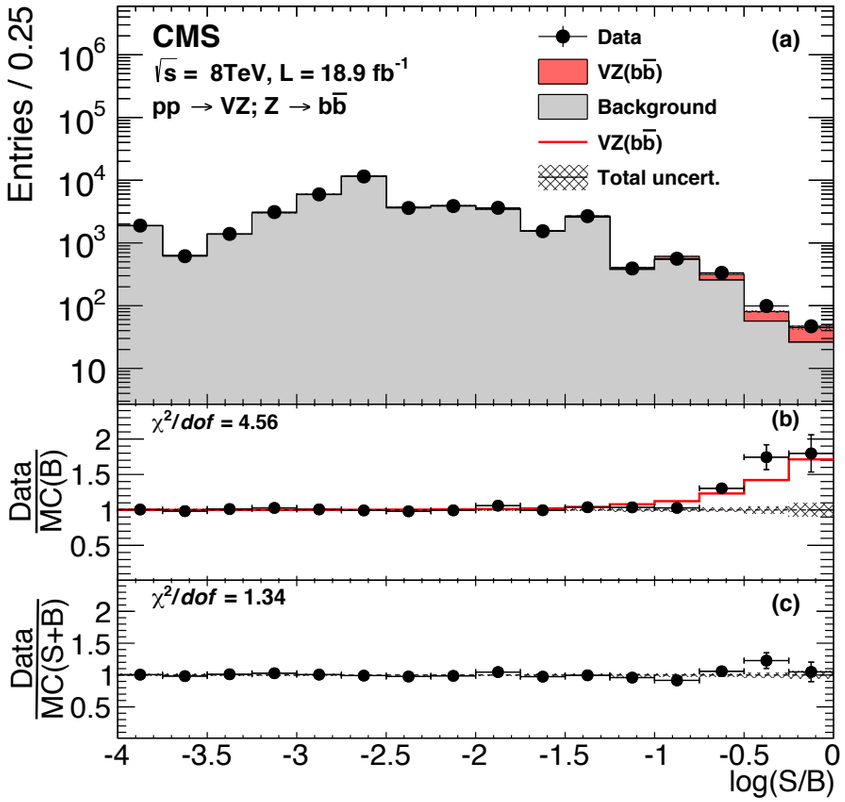
- adapted from H→bb search analysis where scalar boson is now considered as background

signal:
- 2 b jets from Z in bb decay
- V can be W→lν, Z→ll, Z→νν

background:
- large background from Z or W+jets

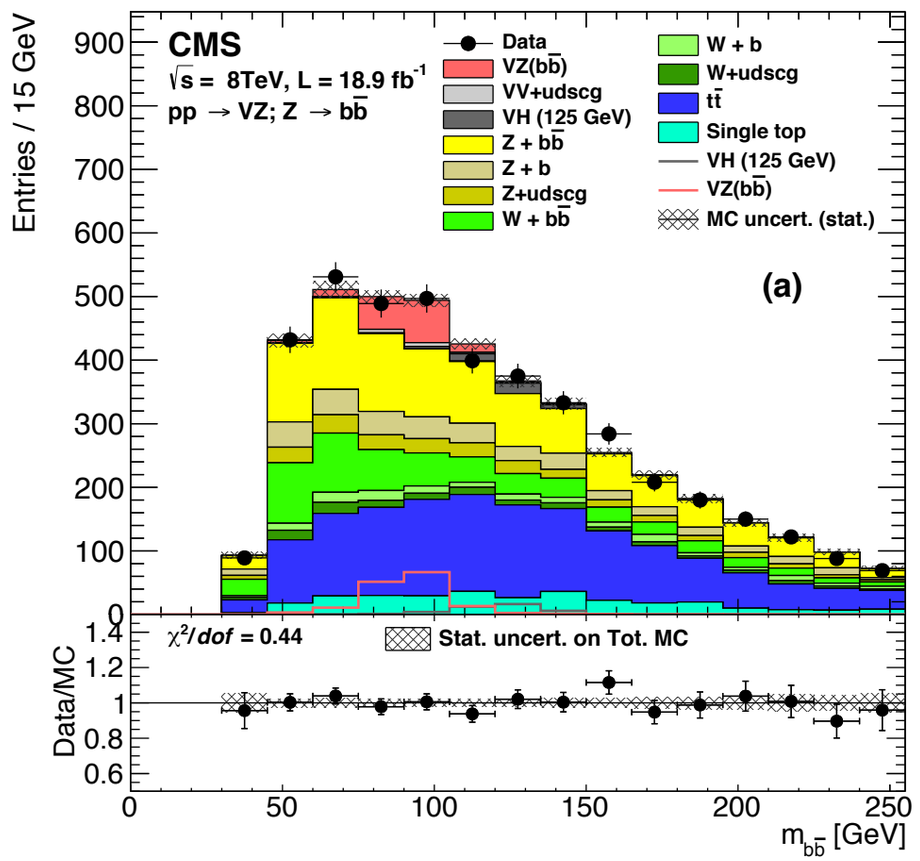
MVA analysis:

6.3 σ observation



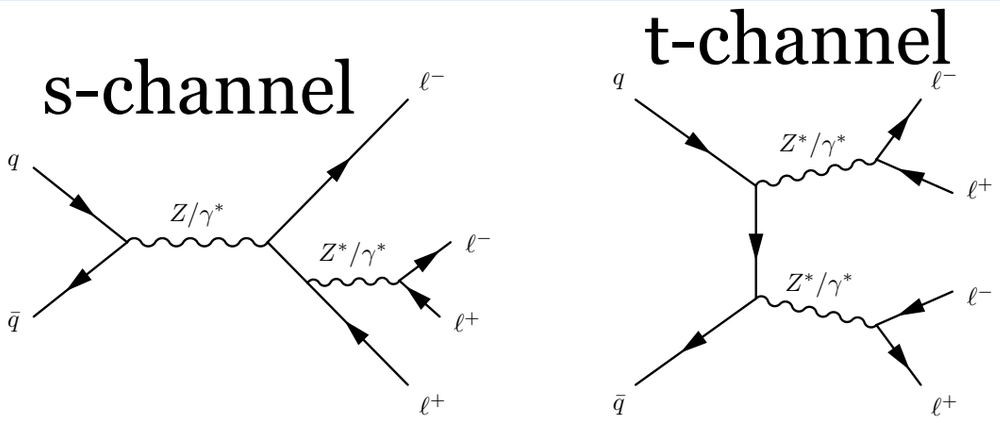
cut based analysis:

4.3 σ observation



Z→4l

ATLAS arXiv:1403.5657
CMS: CERN-PH-EP-2012-283



signal selection:

- 4 leptons of p_T > 20, 15, 8/10, 4/7 GeV/c
- m_{12} > 20 GeV/c², m_{34} > 5 GeV/c²
- 80 < m_{4l} < 100 GeV/c²

background:

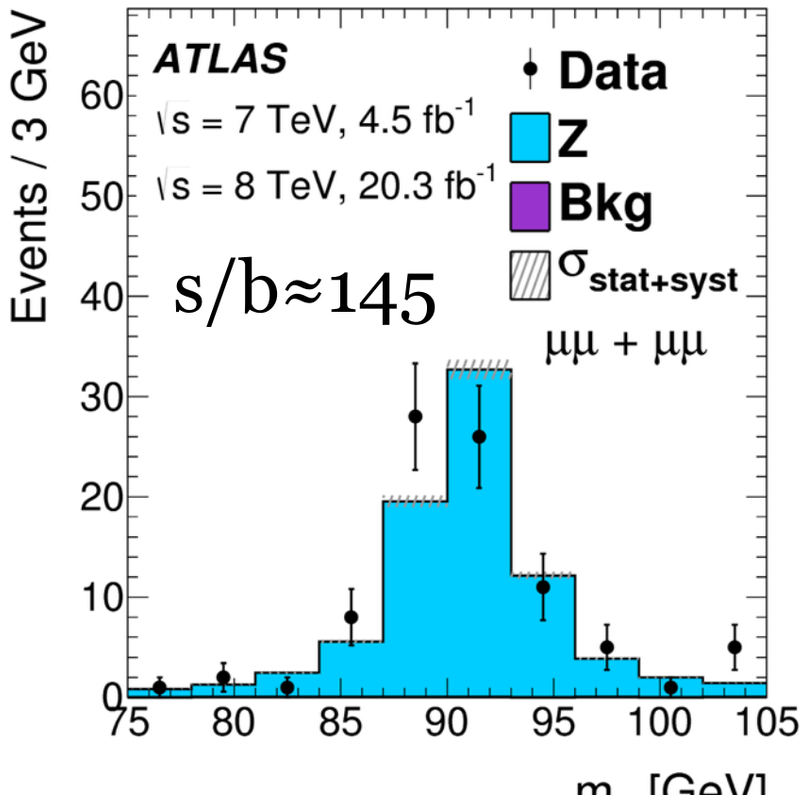
- small background coming from VV, Z+jets and top

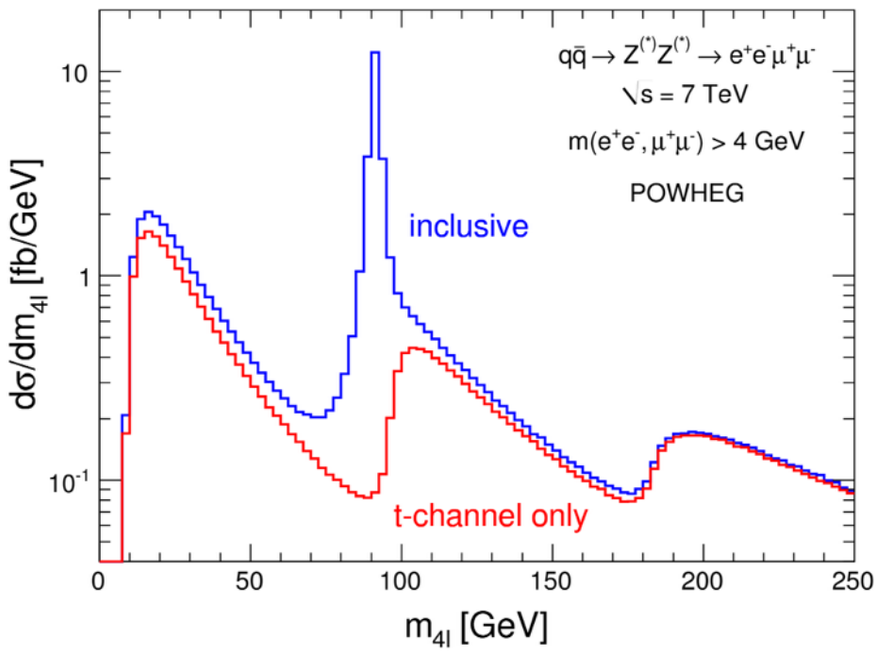
measured cross section:

- at 8 TeV in ATLAS: $\sigma_{Z\to 4l}$ = 107 ± 9 (stat) ± 4 (syst) ± 3 (lumi) fb
- SM prediction at 8 TeV is 104.8 ± 9 fb
- also measurement at 7TeV from ATLAS and CMS

Z→4l branching ratio (7 and 8 TeV):

- $\Gamma_{Z\to 4l}/\Gamma_Z = (3.20 \pm 0.25\ (stat) \pm 0.13\ (syst)) \times 10^{-6}$
- SM prediction was $(3.20 \pm 0.01) \times 10^{-6}$

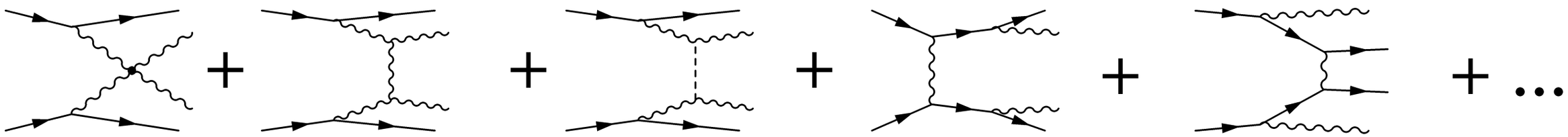




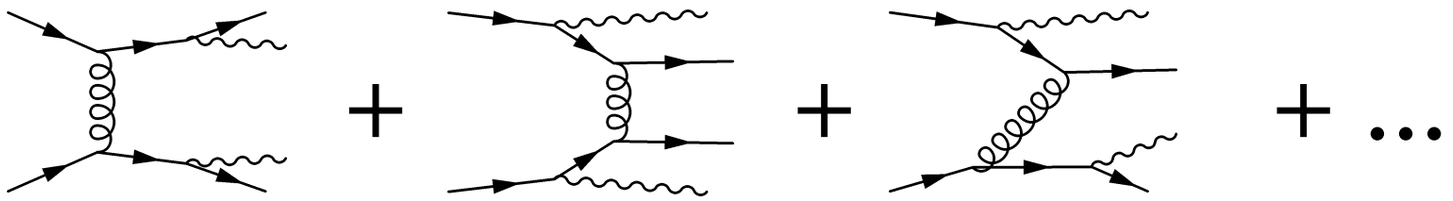
$W^{\pm}W^{\pm}jj \rightarrow l\nu l\nu jj$

ATLAS ATLAS-CONF-2014-013

electroweak $W^{\pm}W^{\pm}jj$ production:

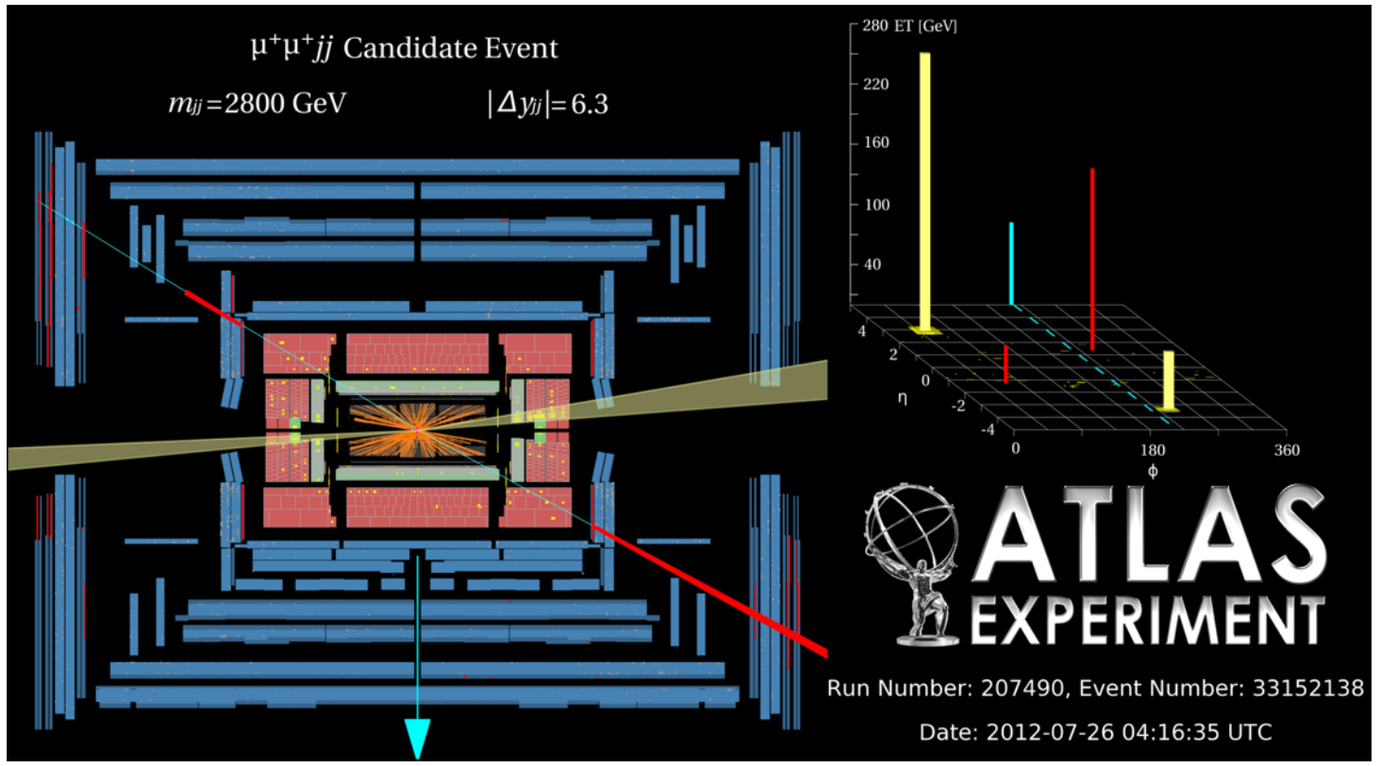


QCD $W^{\pm}W^{\pm}jj$ production:



signature:

- 2 central high-p_T leptons
- forward/backward jets (large mjj + well separated in y)



$W^{\pm}W^{\pm}jj \rightarrow l\nu l\nu jj$

signal selection:

- 2 same sign leptons (p_T > 25 GeV/c)
- at least 2 jets with p_T>30 GeV/c + veto b-jets
- missing E_T > 40 GeV
- cut on kinematic: mjj>50 GeV, $|\Delta y_{ij}|$ > 2.4

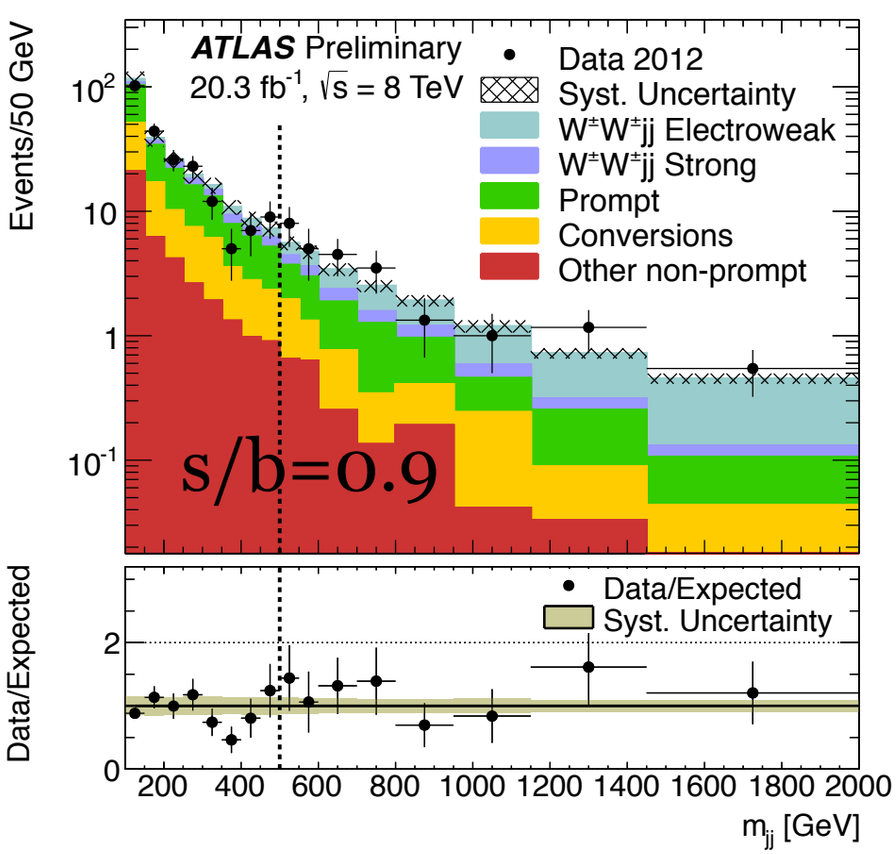
background:

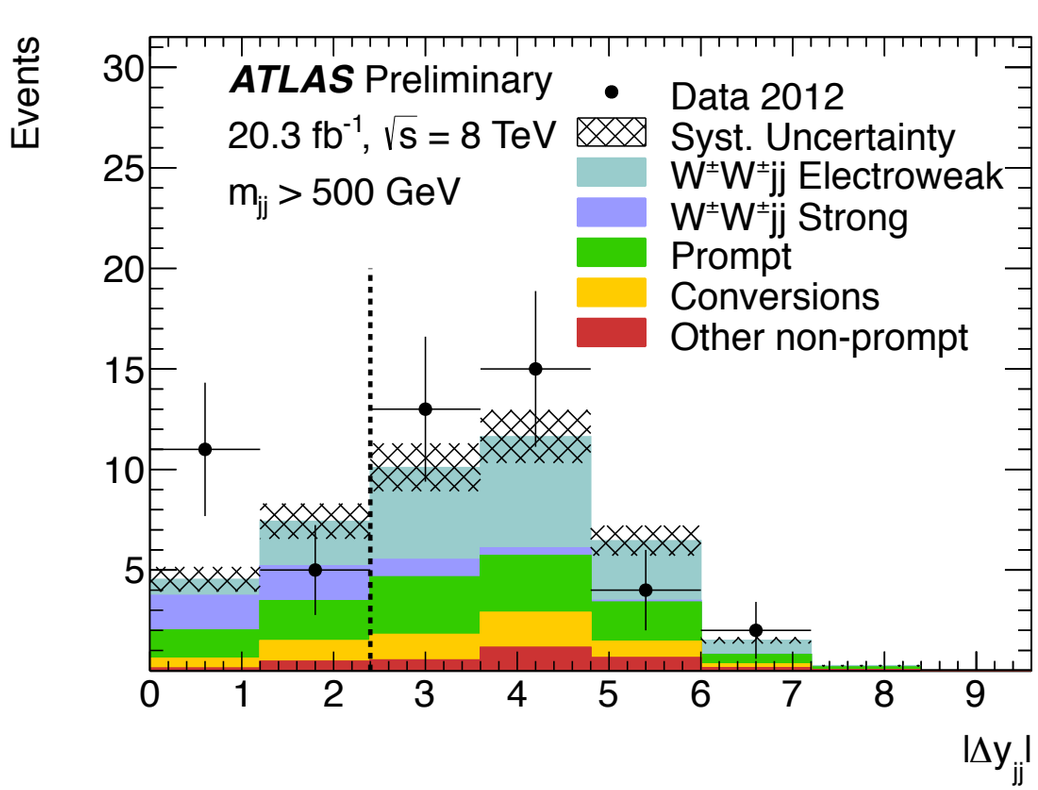
- main are WZ/γ*+jets, Wγ+jets

measured cross section:

- at 8 TeV: $\sigma^{EW}_{W^{\pm}W^{\pm}jj}$ = 1.3 ± 0.4 (stat) ± 0.2 (syst)
- SM prediction at 8 TeV (NLO) = 0.95 ± 0.06 fb

- evidence of EW W±W± jj production at 3.6 σ





Summary:

- cross section have been measured in many di-boson channels

- some excess have been observed in Wγ, WW and WZ channel, with significance < 2 σ
  → consideration of NNLO contribution should help to understand it

- evidence of vector boson scattering

- limit can be placed on anomalous couplings: see Nenad Vranjes talk.