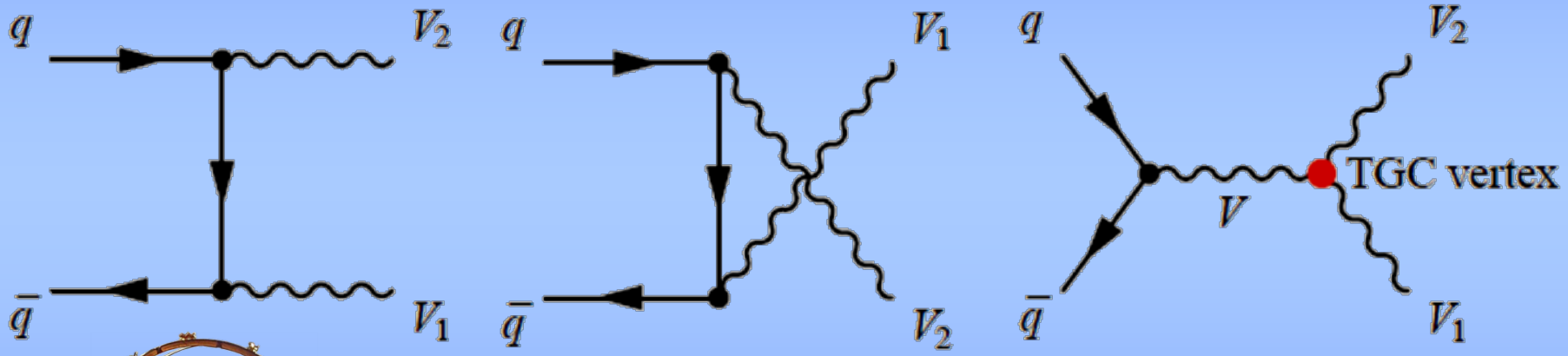
DiBoson Production Cross Section at Ecm=8 TeV

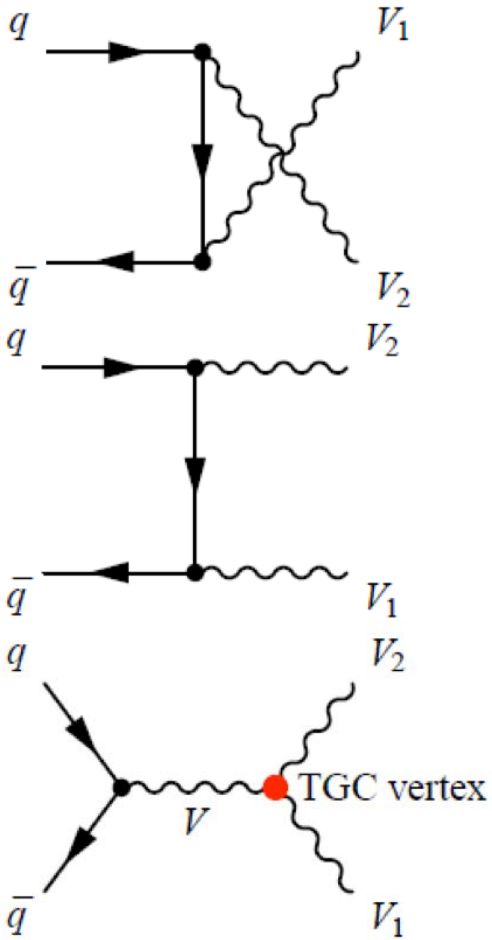


Marc-André Pleier

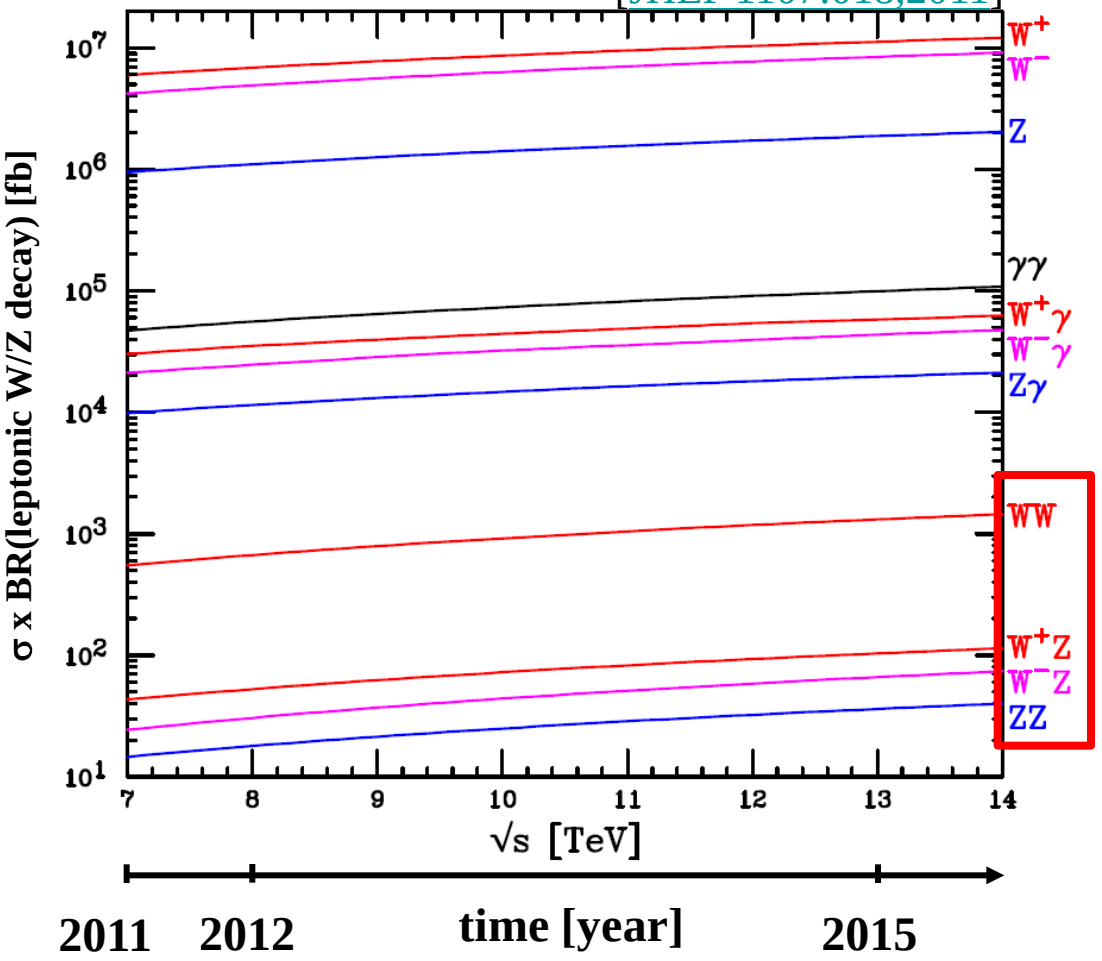
BROOKHAVEN
NATIONAL LABORATORY

DiBoson Production

Test SM predictions, probe new phenomena/aTGCs, background to Higgs



[JHEP 1107:018,2011]



DiBoson Analyses Overview

- Leptonic W/Z decay channels allow signal extraction from large BG (ℓ= e or μ)
- SM BR(W$\rightarrow \ell\nu$) = 0.108, BR(Z$\rightarrow \ell\ell$) = 0.03366
- Experimental signature: isolated high p_T leptons, MET if ν present
- Common backgrounds: Top, V+jets/γ, other diboson processes
- Data driven methods used where possible

Today's menu:

$WW \rightarrow \ell\nu\ell\nu$

$WZ \rightarrow \ell\nu\ell\ell$

$ZZ \rightarrow \ell\ell\ell\ell$

$ZZ \rightarrow \ell\ell\nu\nu$

$VZ \rightarrow Vbb$

Today's specials:

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

$Z \rightarrow 4\ell$

$WW \rightarrow \ell\nu\ell\nu$

[PLB 721 (2013) 190–211]

Main Preselection Cuts:

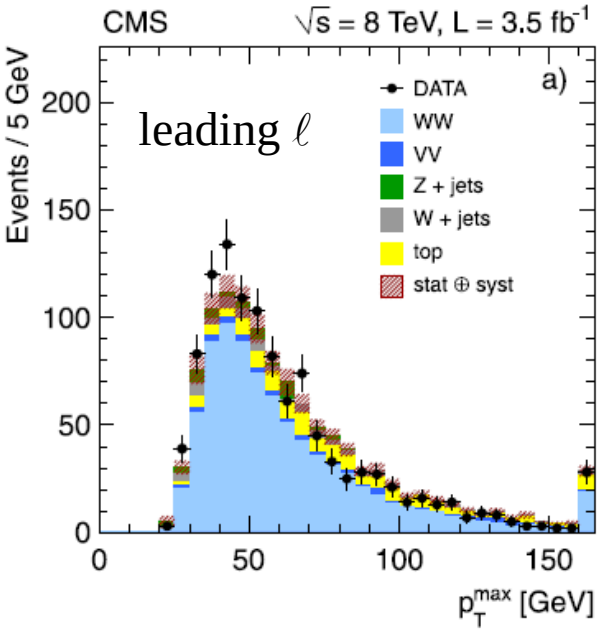
- $p_T(\ell) > 20$ GeV, 3rd ℓ veto >10 GeV
- No jets with $p_T > 30$ GeV, $|\eta| < 4.7$
- $MET_{rel} > 45/45/20$ GeV (ee, μμ, eμ)
- $|m_{\ell\ell}-m_Z| > 15$ GeV (ee, μμ)
- $m_{\ell\ell} > 12$ GeV (ee, μμ),
- $p_T(\ell\ell) > 45$ GeV

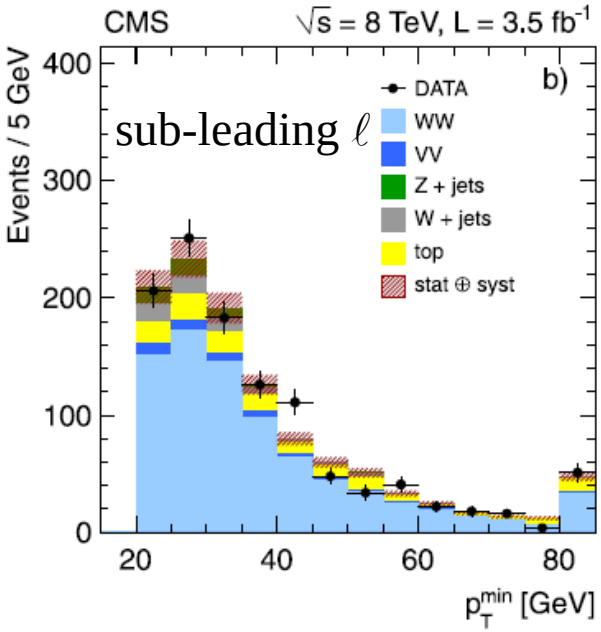
Major backgrounds: V+jets, Top, VV

- Expected S/B: ~2.5
- Main syst: jet veto efficiency

Measured total cross section:

- $\sigma_{WW} = 69.9 \pm 2.8(stat) \pm 5.6(syst) \pm 3.1(lum)$ pb.
- SM: σ_{WW} (NLO) = $57.3^{+2.3}_{-1.6}$ pb
  (Higgs contribution @ m_H 125 GeV: +4%)





$WZ \rightarrow \ell\nu\ell\ell$

[ATLAS-CONF-2013-021]

Preselection:

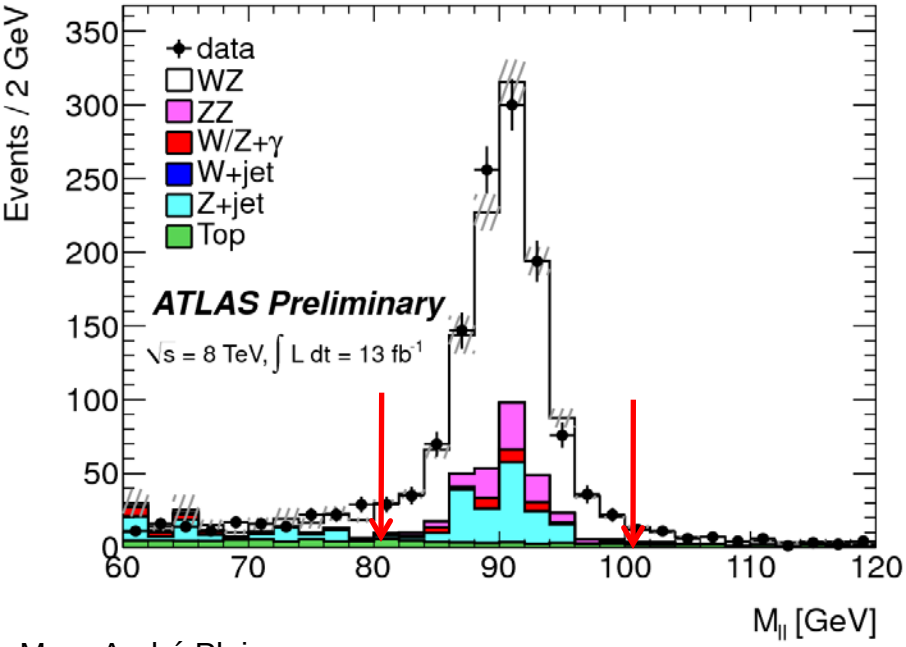
- Z: 2ℓ, $p_T > 15$ GeV,
- $|m_{\ell\ell} - m_Z| < 10$ GeV ,
- W: $3^{rd}\ell$, $p_T > 20$ GeV,
- MET > 25 GeV,
- $m_T > 20$ GeV

- Expected S/B: 3.0
- Main systs: reco acceptance, BG, lumi

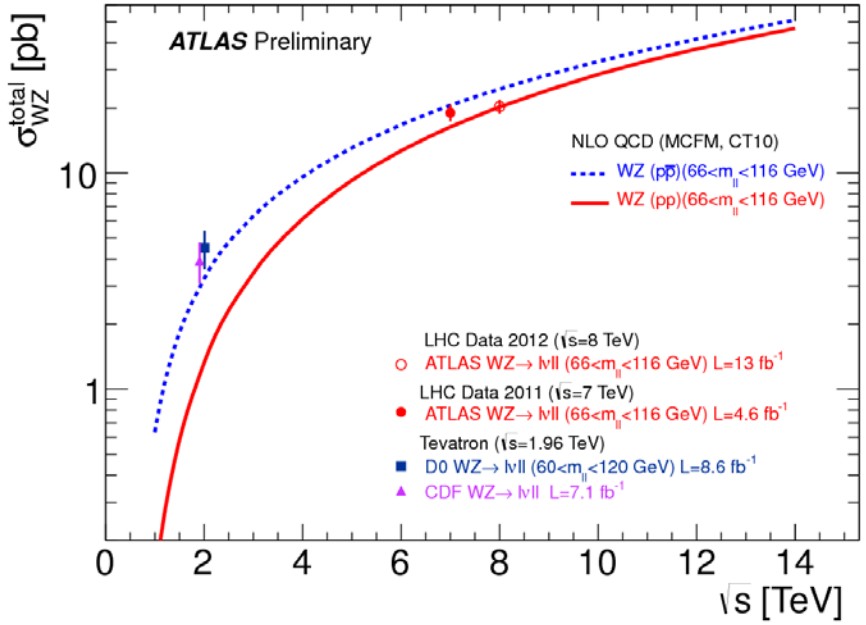
Measured total cross section:

- $\sigma_{WZ} = 20.3^{+0.8}_{-0.7}(stat)^{+1.2}_{-1.1}(syst)^{+0.7}_{-0.6}(lumi)$ pb
- SM: σ_{WZ} (NLO) = 20.3 ± 0.8 pb
- xsecs in common fid. vol. provided as well

Major backgrounds: Z+j/γ, ZZ, Top

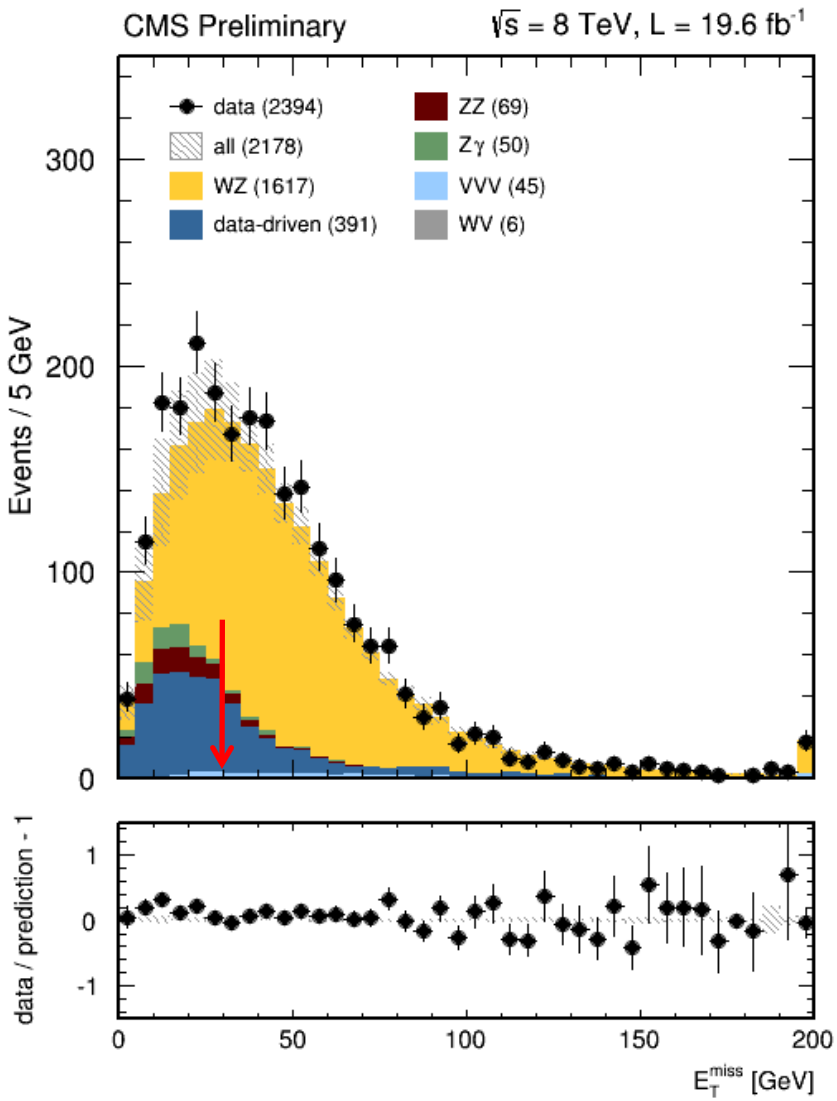


WZ xsec vs. center-of-mass energy :



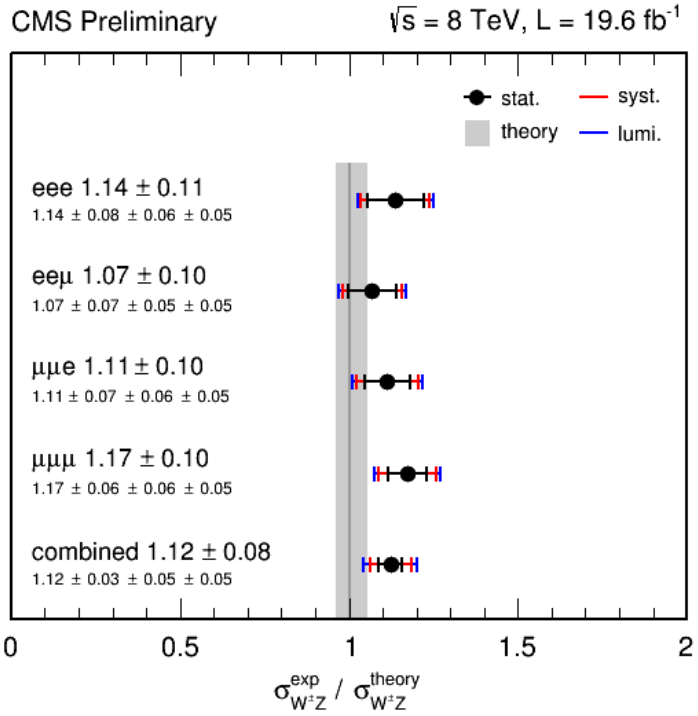
$WZ \rightarrow \ell\nu\ell\ell$ (II)

[CMS-PAS-SMP-12-006]



Measured total cross section (ratio):

- $\sigma_{WZ} = 24.6 \pm 0.8(\text{stat}) \pm 1.1(\text{syst}) \pm 1.1(\text{lumi})$ pb
- SM: σ_{WZ} (NLO) $= 21.9^{+1.2}_{-0.9}$ pb [71 GeV < m_Z < 111 GeV]
- $\left(\frac{\sigma_{W^+Z}}{\sigma_{W^-Z}}\right)_{8\ \text{TeV}} = 1.81 \pm 0.12\ (\text{stat.}) \pm 0.03\ (\text{syst.})$
- xsec ratio SM expectation: 1.724 ± 0.003



$ZZ \rightarrow \ell\ell\ell\ell$

[ATLAS-CONF-2013-020]

Preselection:

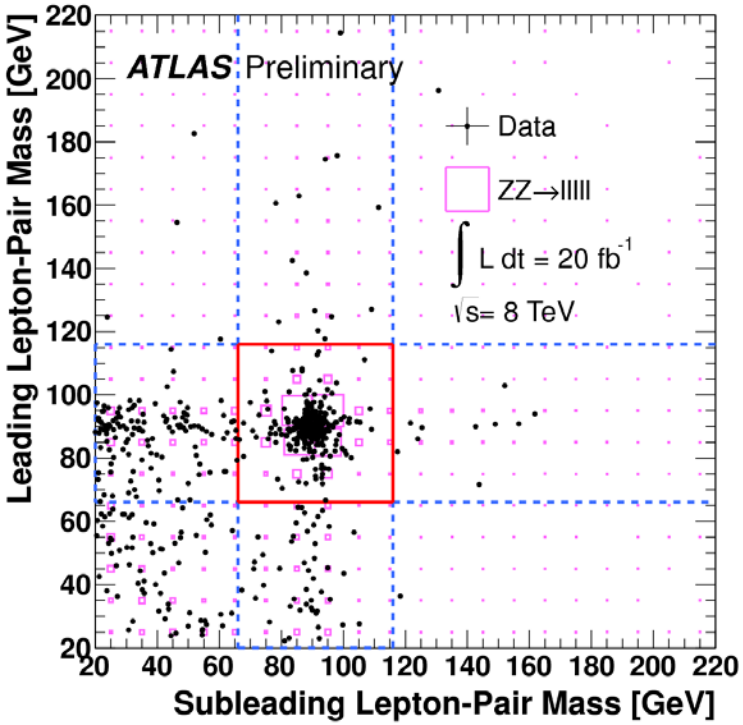
- four leptons with $p_T > 7$ GeV,
- trigger matched ℓ-$p_T > 25$ GeV,
- 66 GeV < $m_{\ell\ell}$ < 116 GeV (each pair)
- Expected S/B: ~14

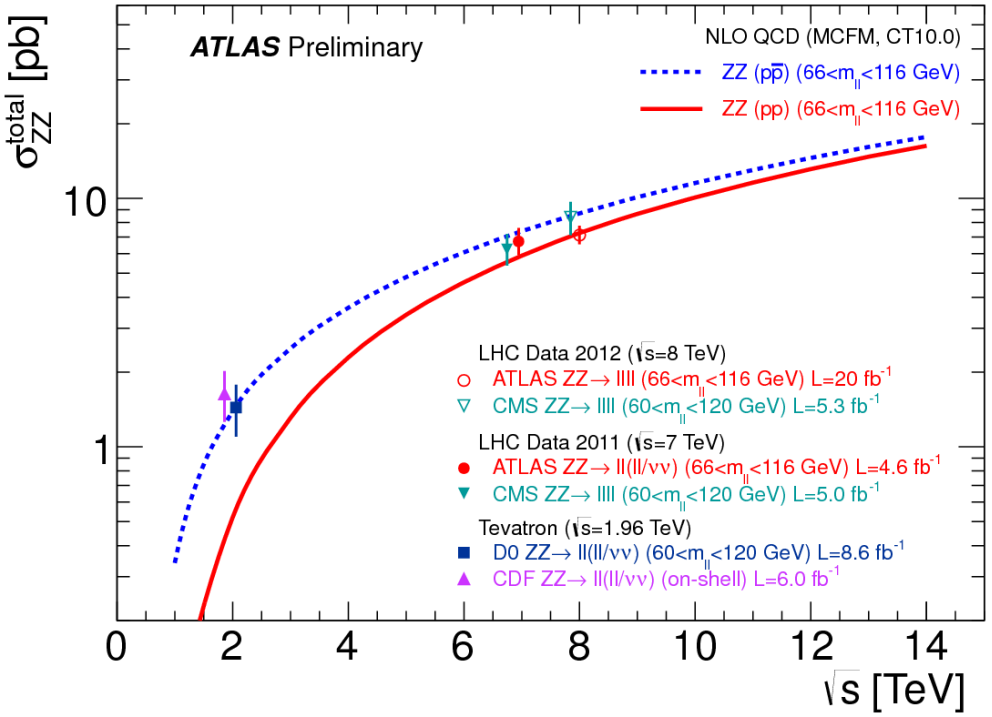
Major backgrounds: V+j/γ, top, VV

Measured total cross section:

- $\sigma_{ZZ} = 7.1^{+0.5}_{-0.4}(\text{stat}) \pm 0.3(\text{syst}) \pm 0.2(\text{lumi})$ pb
- SM: σ_{ZZ} (NLO) = $7.2^{+0.3}_{-0.2}$ pb (both Z's in mass window)
- xsecs in common fid. vol. provided as well

ZZ xsec vs. center-of-mass energy :



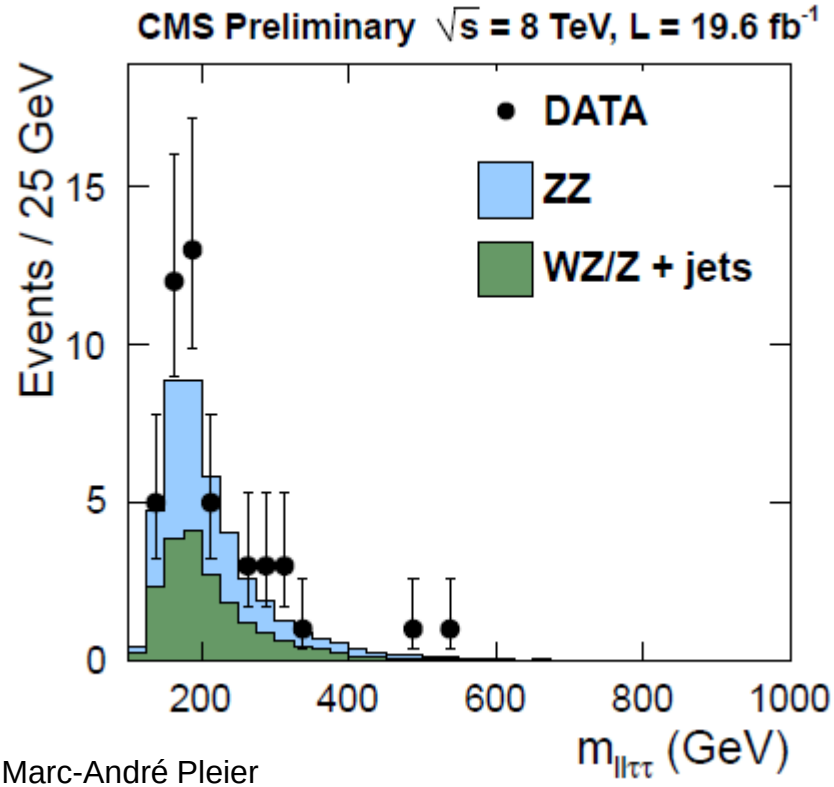


$ZZ \to \ell\ell\ell\ell$ (II)

[CMS-PAS-SMP-13-005]

Preselection:

- similar to ATLAS,
- 60 GeV < $m_{\ell\ell}$ < 120 GeV (each pair)
- **include Z→ττ for 2nd Z candidate**: 20/30 GeV < $m_{\tau\tau}$ < 90 GeV (eμ/other)
- Expected S/B for $\ell\ell$ ττ : ~1

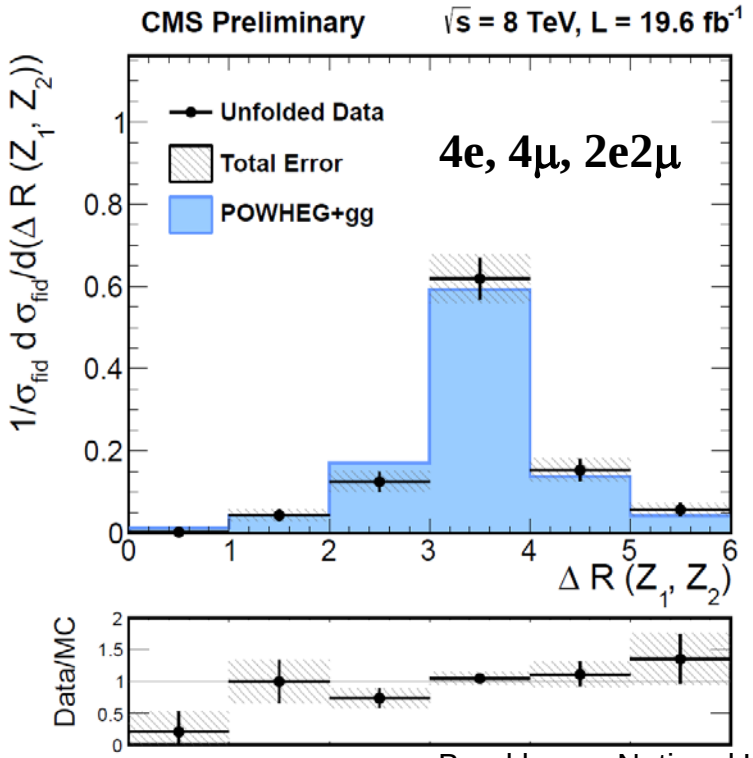


Measured total cross section:

- $\sigma_{ZZ} = 7.7^{+0.5}_{-0.5}(\text{stat})^{+0.5}_{-0.4}(\text{syst}) \pm 0.4(\text{theo}) \pm 0.3(\text{lumi})$ pb
- SM: σ_{ZZ} (NLO) = 7.7 ± 0.6 pb [Z's in mass window]
- Anom. coupling limits using m_{4l} dist:

$-0.004 < f_4^{\gamma,Z} < 0.004, \quad -0.005 < f_5^{\gamma,Z} < 0.005$

normalized differential fiducial xsec:



$ZZ \to \ell\ell\nu\nu$

[CMS-PAS-SMP-12-016]

Main preselection cuts:

- 2 same flavour leptons of $p_T > 20$ GeV
- $|m_{\ell\ell} - m_Z| < 7.5$ GeV , $p_T(\ell\ell) > 45$ GeV
- $0.4 < \text{MET}/\, p_T(\ell\ell) < 1.8$
- reduced MET > 65 GeV
- No (b-)jets w/ $p_T > (20)30$ GeV, $|\eta| < (2.4)\ 5$

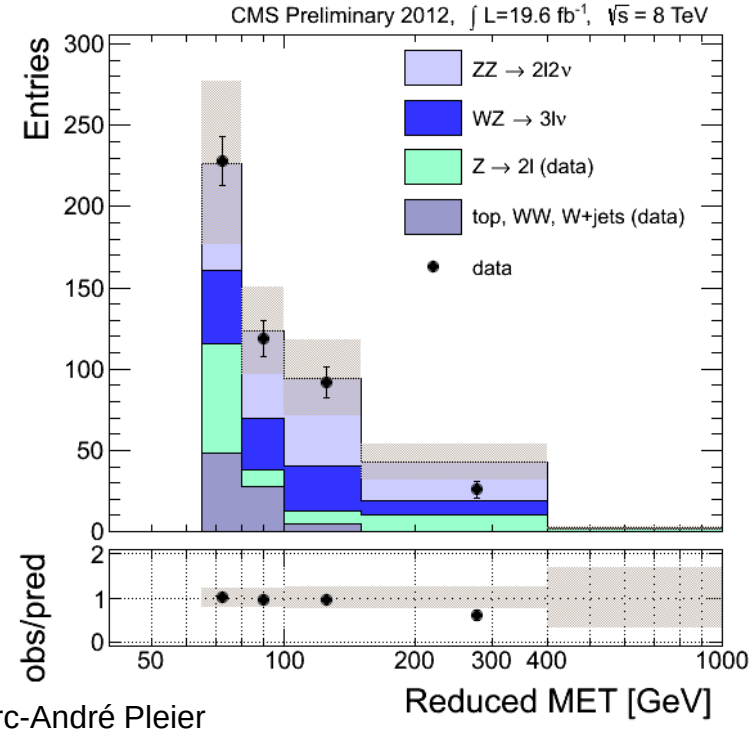
Major backgrounds: WZ, Z+j, WW, Top

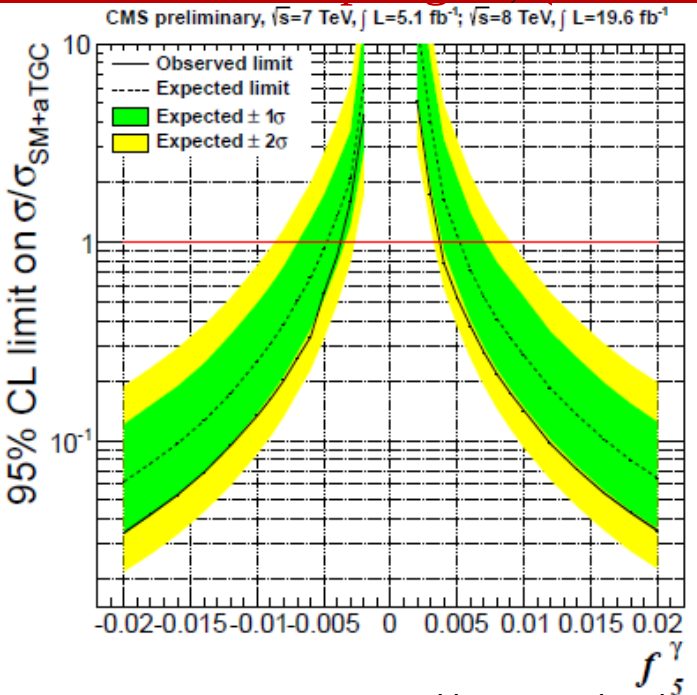
- Expected S/B: ~ 0.7
- Main systs: JES, BG shape/norm.

Measured cross section:

- $\sigma_{ZZ} = 6.8^{+0.8}_{-0.8}(\text{stat})^{+1.8}_{-1.4}(\text{syst}) \pm 0.3(\text{lumi})$ pb
- SM: $\sigma_{ZZ}(\text{NLO}) = 7.9^{+0.4}_{-0.2}$ pb [60 GeV < m_Z < 120 GeV]

Use $p_T(\ell\ell)$ distribution to set stringent limits on anom couplings $f^V_{4,5}$ (=0 in SM):





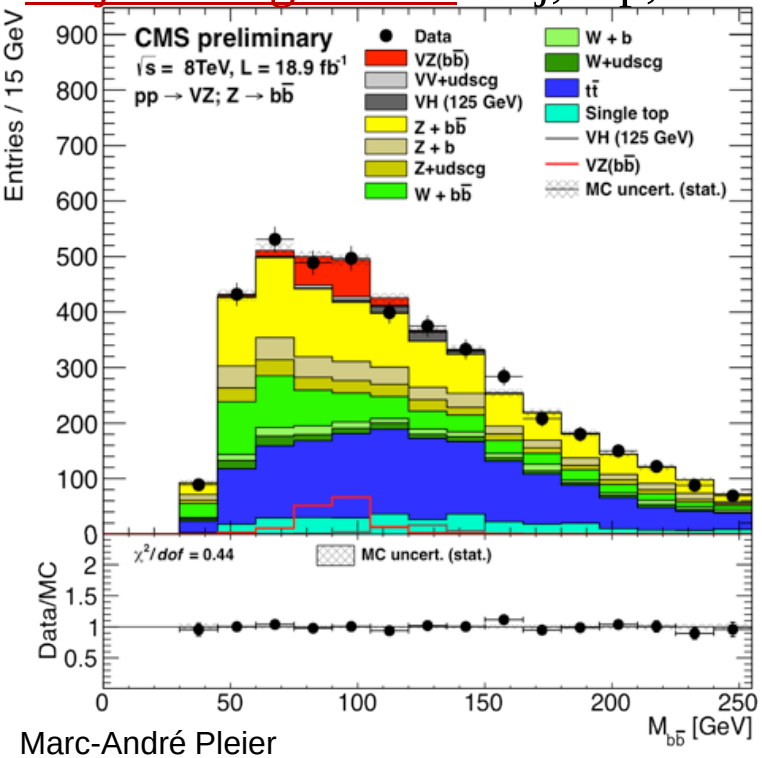
VZ →Vbb

[arXiv:1403.3047]
[CMS-PAS-SMP-13-011]

Basic Preselection:

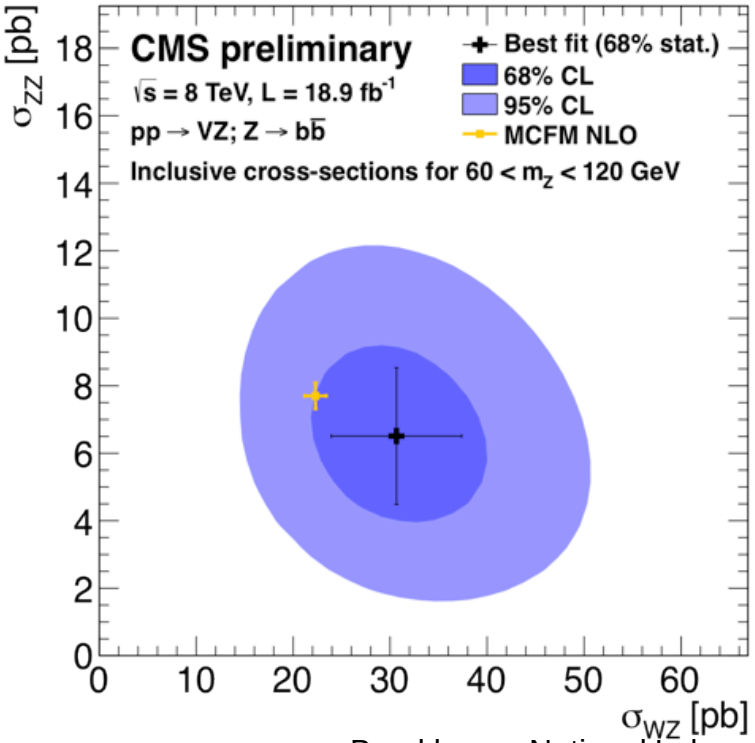
- 2 b-jets ($|\eta| < 2.5$), $m_{jj} < 250$ GeV
- $0\ell(Z \rightarrow \nu\nu)$: MET > 100 GeV
- $1\ell(W \rightarrow \ell\nu)$: MET > 45 GeV
- $2\ell(Z \rightarrow \ell\ell)$: 75 GeV < $m_{\ell\ell}$ < 105 GeV
- Fit of multivariate discriminant / m_{jj}

Major backgrounds: V+j, top, VH



Measured total cross section:

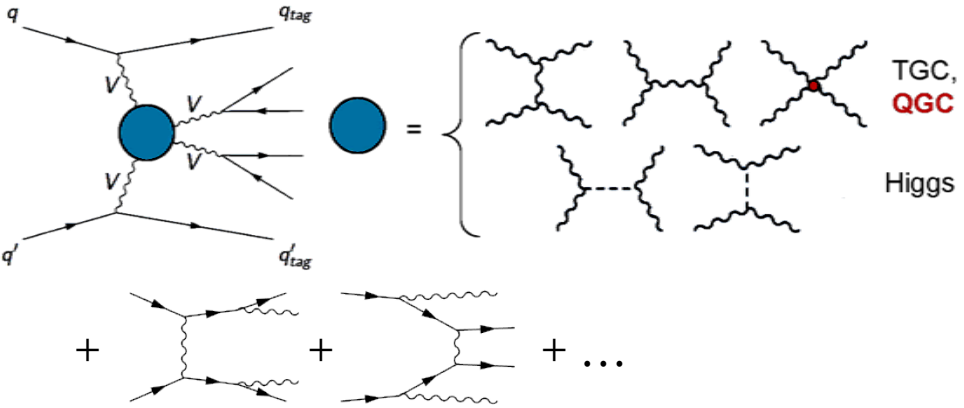
- $\sigma_{ZZ} = 6.5 \pm 1.7(\text{stat}) \pm 1.0(\text{syst}) \pm 0.9(\text{theo}) \pm 0.2(\text{lumi})$ pb
- $\sigma_{WZ} = 30.7 \pm 9.3(\text{stat}) \pm 7.1(\text{syst}) \pm 4.1(\text{theo}) \pm 1.0(\text{lumi})$ pb
- SM (NLO, 60 GeV < m_Z < 120 GeV):
  $\sigma_{ZZ} = 7.7 \pm 0.4$ pb, $\sigma_{WZ} = 22.3 \pm 1.1$ pb
- Fiducial xsecs ($p_T(V)$>100 GeV) also provided



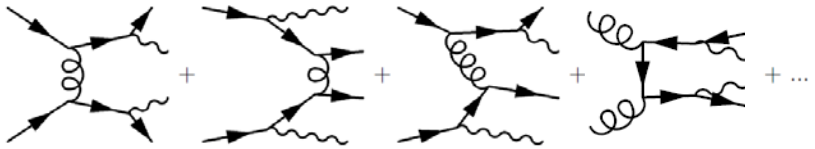
Vector Boson Scattering

• VV→VV provides insight into EWSB mechanism, access to quartic couplings:

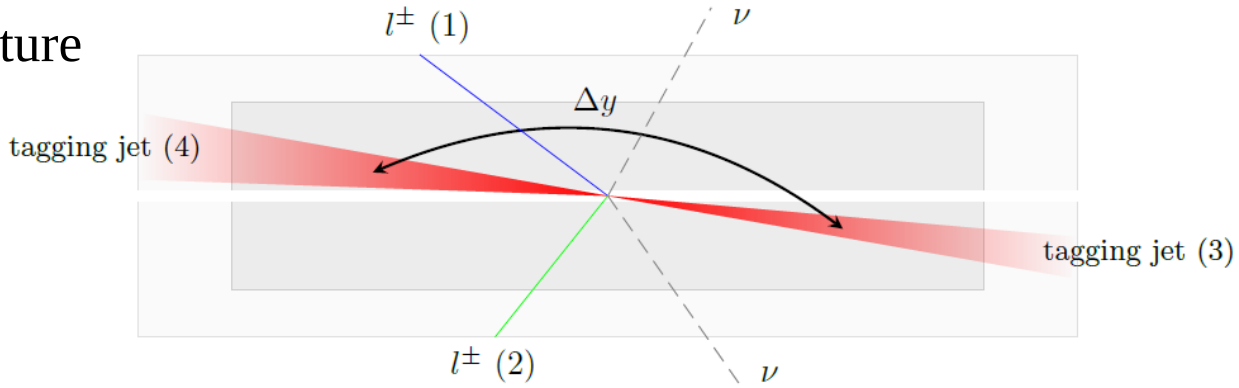
<u>electroweak VVjj production includes:</u>



<u>strong VVjj production includes:</u>



• Experimental signature ($W^{\pm}W^{\pm}$ example):



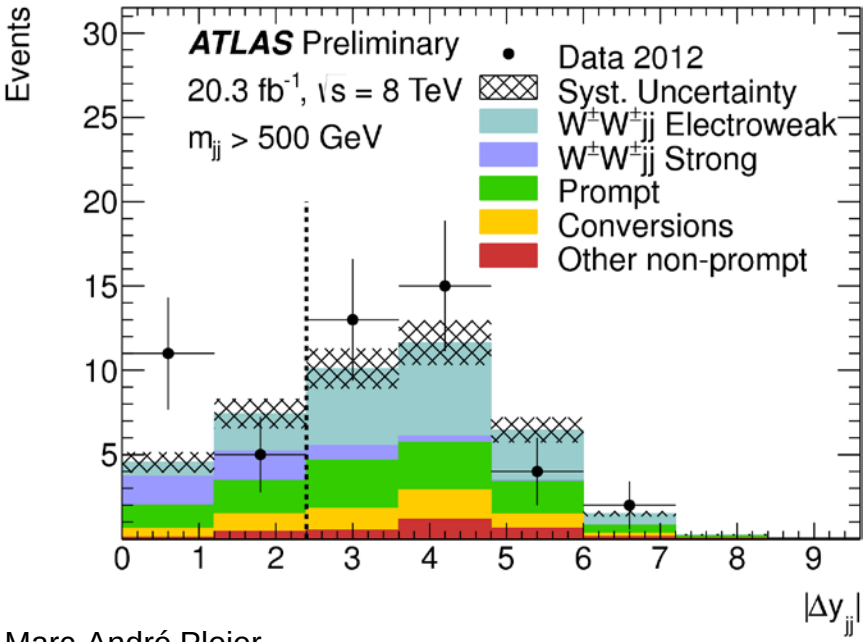
- 1,2 = Central, high-p_T charged leptons from V decays
- 3,4 = Forward/backward tagging jets (large m_{jj} and well separated in y)

$W^{\pm}W^{\pm}jj \rightarrow \ell\nu\ell\nu jj$ [ATLAS-CONF-2014-013]

Preselection:

- exactly 2 same-charge ℓ ($p_T > 25$ GeV)
- ≥ 2 jets, $p_T > 30$ GeV
- MET > 40 GeV, no b-jets
- $m_{jj} > 500$ GeV, $|\Delta y_{jj}| > 2.4$

Main backgrounds: prompt ℓ (WZ/γ^*+j), conversion (Wγ+j), non-prompt

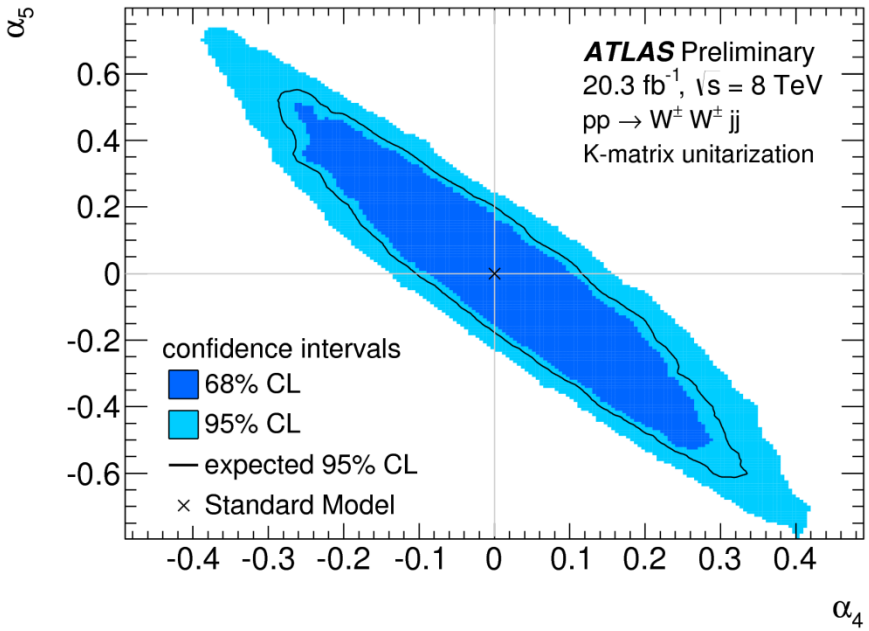


- Expected S/B: 0.9
- Main syst: WZ/γ^*+j norm. theo. uncert., JES

Measured EW fiducial cross section:

- $\sigma^{EW}_{W^{\pm}W^{\pm}jj} = 1.3 \pm 0.4(\text{stat}) \pm 0.2(\text{syst})$ fb
- SM: $\sigma^{EW}_{W^{\pm}W^{\pm}jj}(\text{NLO}) = 0.95 \pm 0.06$ fb
- 1st evidence (3.6 σ) for EW $W^{\pm}W^{\pm}jj$ prod.
- Access to WWWW vertex, derive

1st limits on anom. quartic couplings $\alpha_{4,5}$:



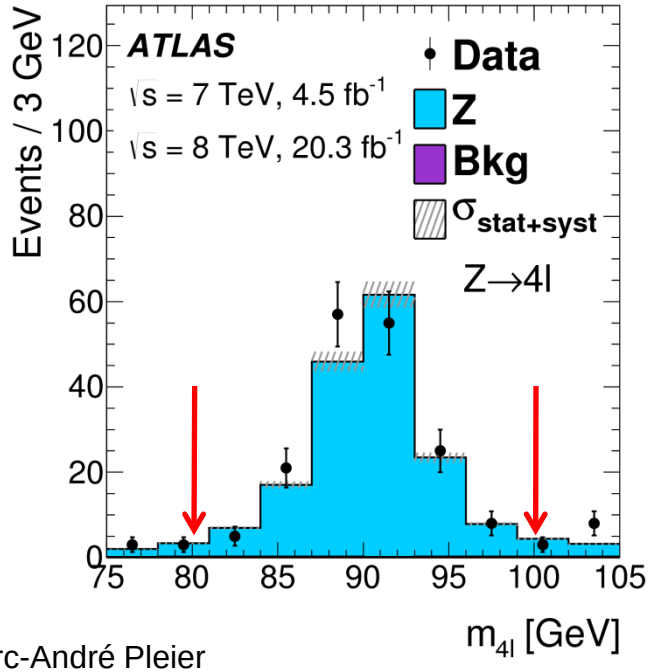
$Z \rightarrow 4\ell$

[arXiv:1403.5657]

Basic Preselection:

- four leptons with p_T> 4/7 GeV (μ/e),
- leading ℓ-p_T's > 20, 15, 8/10 GeV,
- m_{12} > 20 GeV, m_{34} > 5 GeV
- 4e, 4μ: $m_{\ell\ell}$ > 5 GeV
- 80 GeV < $m_{4\ell}$ < 100 GeV
- Expected S/B: ~145

Backgrounds: VV, Z+j, top



Measured total cross section: [$m_{\ell^+\ell^-}$ > 5GeV, 80 < $m_{4\ell}$ < 100GeV]

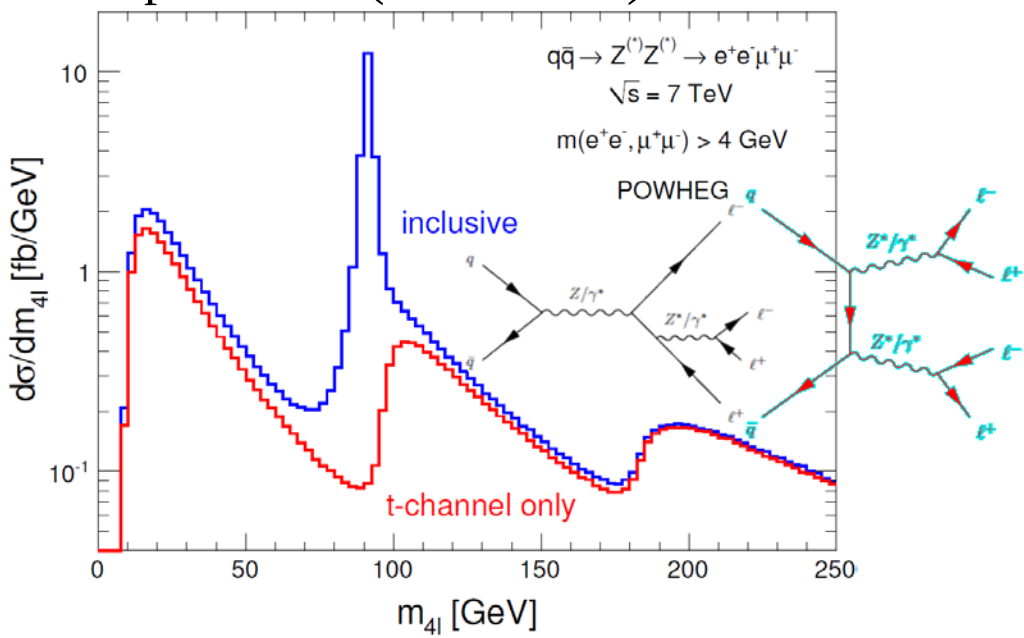
- $\sigma_{Z \rightarrow 4\ell}$ = 107 ± 9 (stat) ± 4 (syst) ± 3 (lumi) fb
- SM (NLO, 8 TeV): $\sigma_{Z \rightarrow 4\ell}$ = 104.8 ± 2.5 fb

Measured $Z \rightarrow 4\ell$ branching fraction (7&8 TeV):

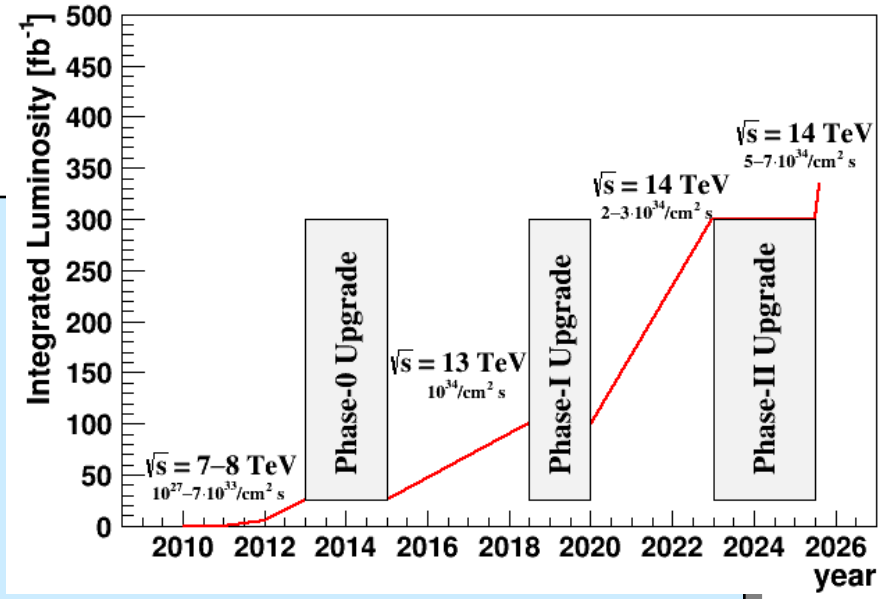
- subtract expected non-resonant contribs,
- normalize to $Z \rightarrow \mu\mu$ in same dataset:

$$\Gamma_{Z\to 4\ell}/\Gamma_Z = (3.20 \pm 0.25\ (\text{stat}) \pm 0.13\ (\text{syst})) \times 10^{-6}$$

- SM expectation: (3.33 ± 0.01)×10^{-6}



Summary



VV cross sections:

- Compatible with SM expectations
- Differential xsecs probe MC modelling

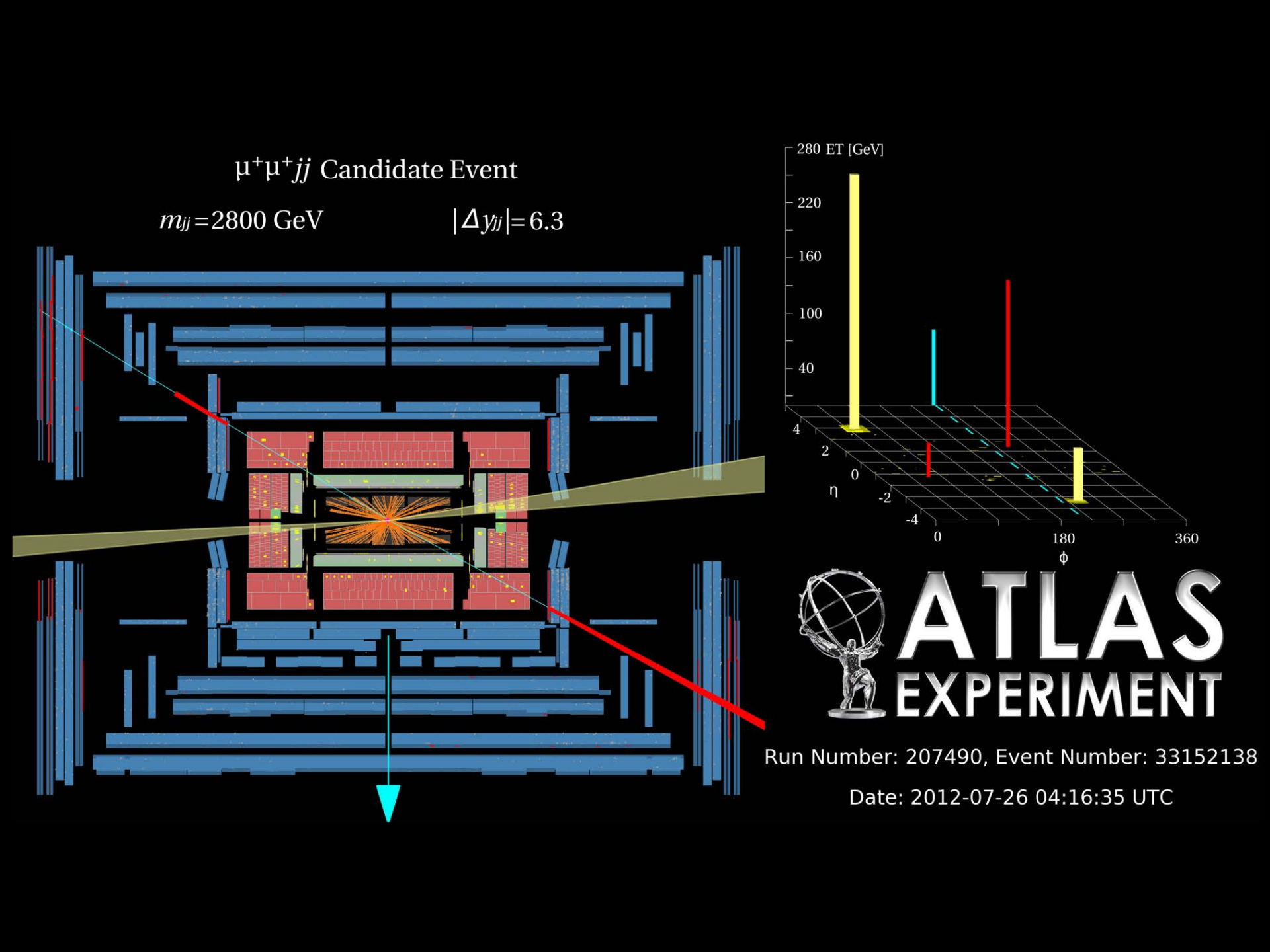
aGCs:

- Competitive limits obtained

Plans:

- 8 TeV publications in preparation for all VV
- Analyses for VBF/VBS/VVV are ramping up
- Working towards combination across channels (& experiments)
- Need for coherent NLO+PS MC for all analyses; NNLO QCD, NLO EW
- 13/14 TeV data will allow measurements of new rare processes, probe NP

dessert


μ⁺μ⁺jj Candidate Event
m_{jj} = 2800 GeV
$|\Delta y_{jj}|$ = 6.3
280 ET [GeV]
220
160
100
40
4
2
0
-2
-4
η
0
180
360
ϕ
ATLAS
EXPERIMENT
Run Number: 207490, Event Number: 33152138
Date: 2012-07-26 04:16:35 UTC