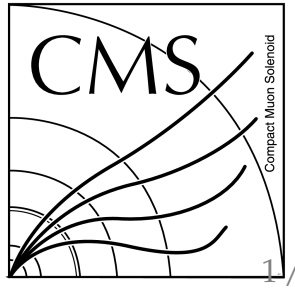
Status Of Single W/Z Measurements in the ATLAS and CMS Experiments

Precision Theory for Precise Measurements at LHC and Future Colliders - PrecisionVietnam

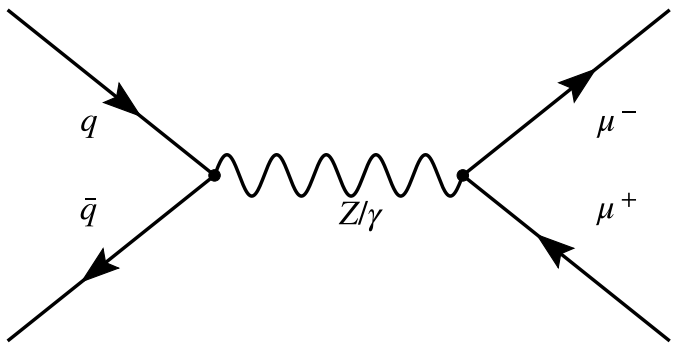
Vince Croft On behalf of ATLAS and CMS

September 26, 2016



MOTIVATING SINGLE W/Z MEASUREMENTS

- Didn't we already measure the W and Z at LEP?
- How can we perform precision measurements at a Hadron collider?
- Aren't they just backgrounds to other processes and calibration tools?

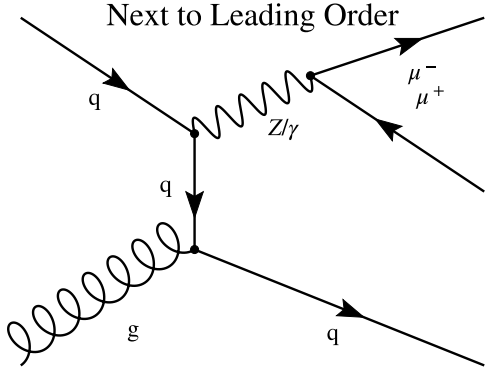


LOTS TO LEARN FROM Z AND W

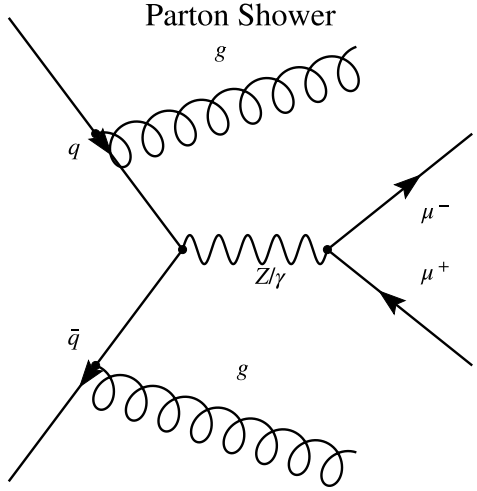
- Test perturbative QCD
- Constrain proton PDFs
- Assess parton shower effects
- Evaluate approaches in MC

- Z angular coefficients
- Anomalous Triple Gauge Coupling
- New Particles?

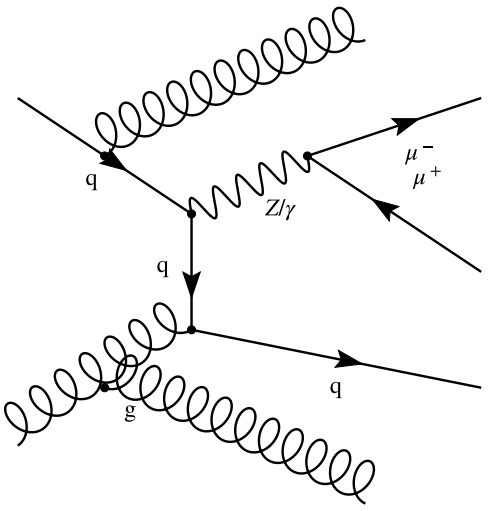
Next to Leading Order



Parton Shower



Next to Leading Order and Parton Shower



W/Z PRODUCTION MEASUREMENTS

- First measurements with 13TeV data
- Experimental Uncertainty for Early 13TeV data:
  - $< 3\%$ for W
  - $< 1\%$ for Z
- With higher precision we can constrain NNLO QCD calculations and EW corrections.

- Ratios are powerful tools:
  - Mitigates ~2% lumi uncertainty
  - W/Z ratio constrains strange quark sea
  - W^+/W^- sensitive to difference of valence quark flavour.
    - Very high prescision measurement
    - Provides large constraints on PDFs

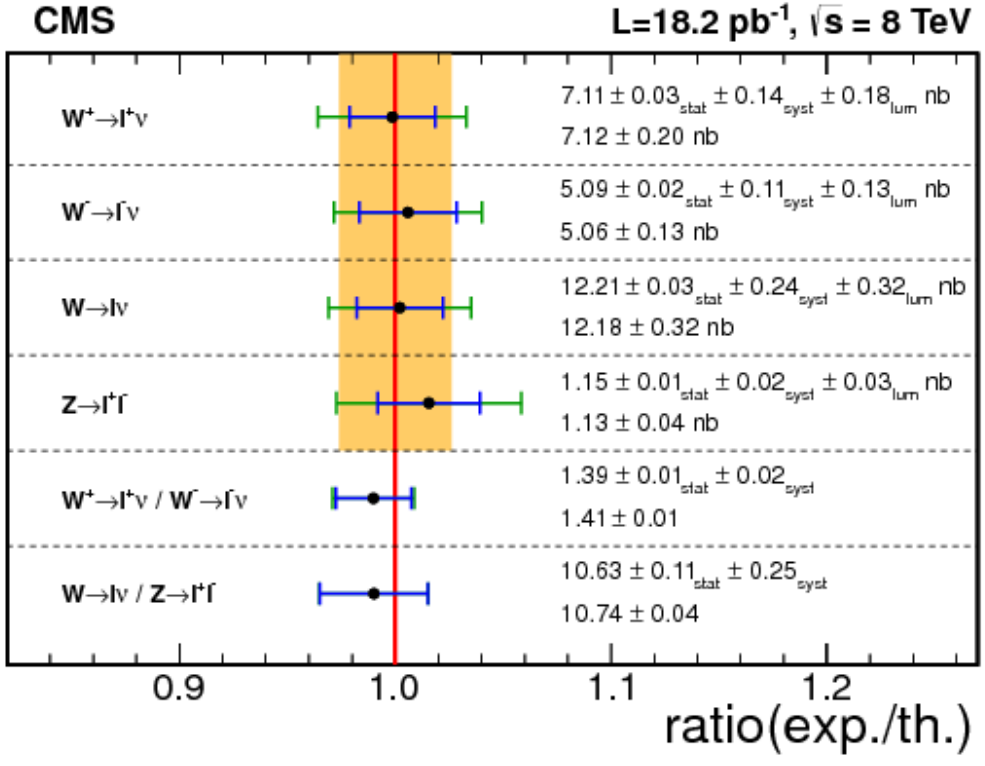
W/Z-BOSON PRODUCTION CROSS SECTIONS AT $\sqrt{(s)} = 8$ TEV

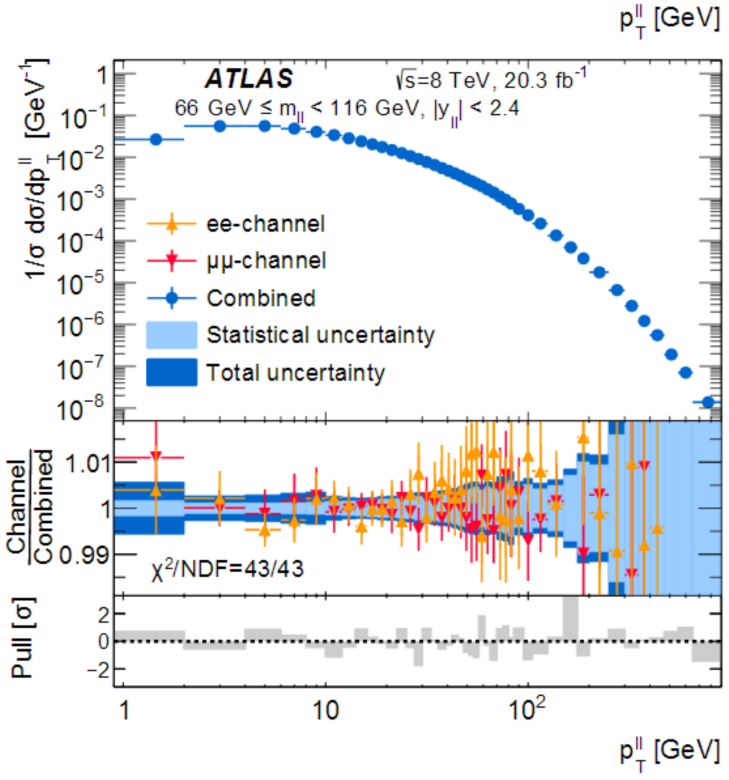
CMS@8 TeV: Phys.Rev.Lett.112(2014)191802

$\sigma(Z \to \ell\ell) = 1138pb \pm 0.07\%$ (stat) $\pm 2.2\%$ (theo) $\pm 2.6\%$ (lumi)

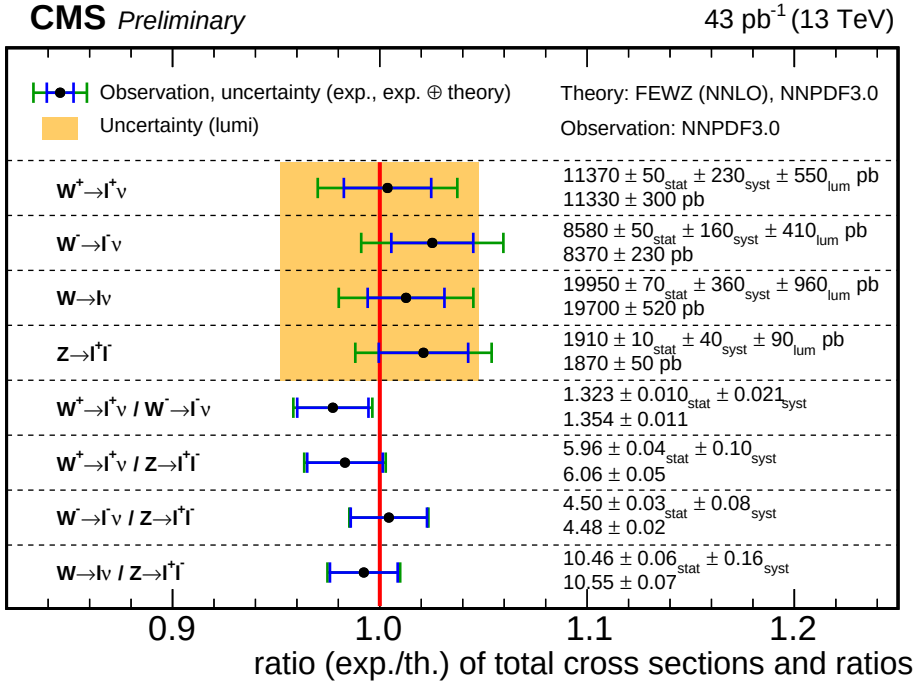
ATLAS@8 TeV: (Fiducial $66 < m_{\ell\ell} < 115$GeV) Eur.Phys.J.C (2016)76:291

$\sigma(Z \to \ell\ell) = 537.10pb \pm 0.03\%$ (stat) $\pm 0.45\%$ (syst) $\pm 2.8\%$ (lumi)



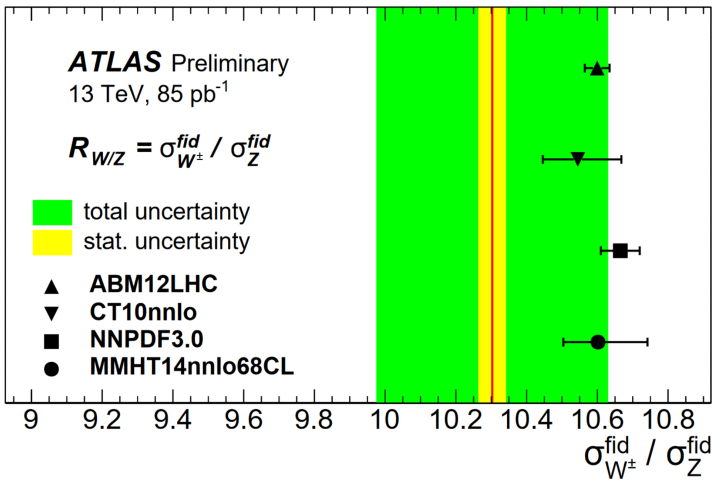


W/Z-BOSON PRODUCTION CROSS SECTIONS AT $\sqrt{(s)} = 13$ TEV



CMS-PAS-SMP-15-004

- Begin to discriminates between PDFs



Phys.Lett.B 759(2016)601

CMS@13 TeV: CMS-PAS-SMP-15-011

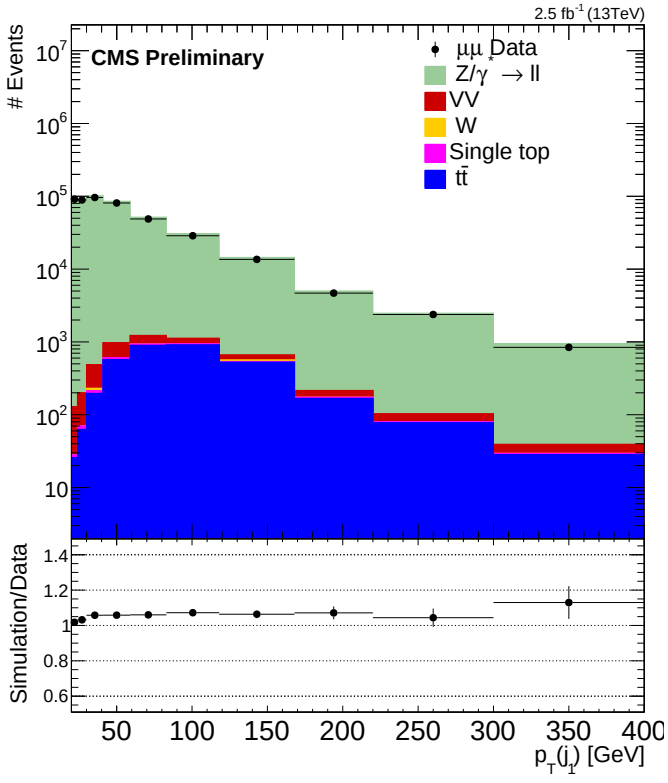
$\sigma(Z \to \ell\ell) = 1870pb \pm 0.1\%\ \text{(stat)}\ \pm 1.9\%\ \text{(syst)}\ \pm 2.7\%\ \text{(lumi)}$

ATLAS@13 TeV: Phys.Lett.B 759(2016)601

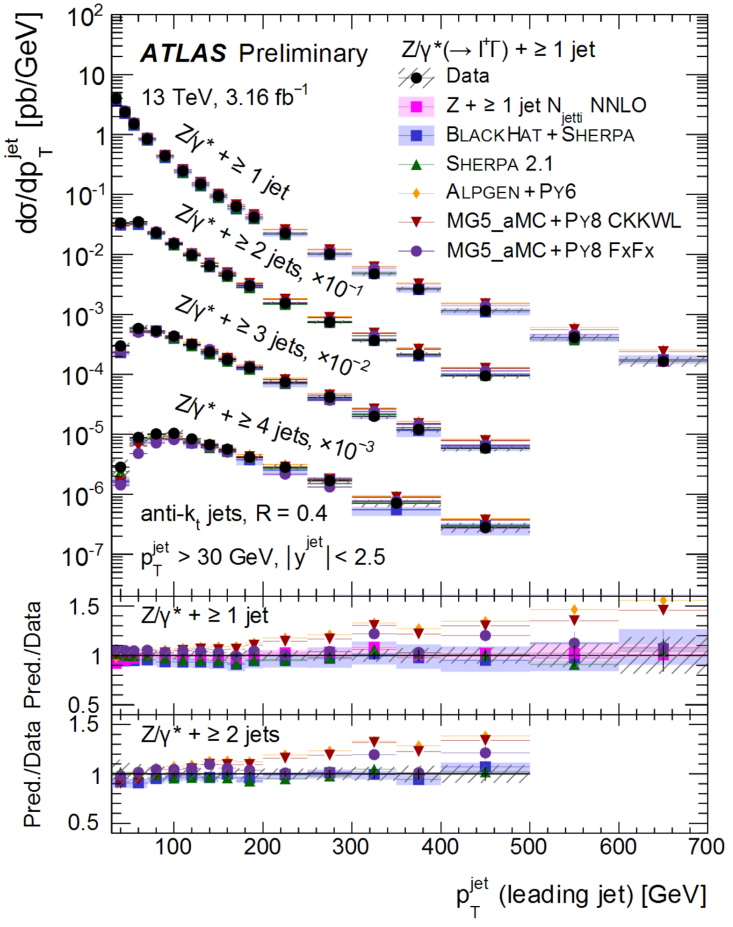
$\sigma(Z \to \ell\ell) = 1981pb \pm 0.007\%\ \text{(stat)}\ \pm 1.9\%\ \text{(syst)}\ \pm 2.1\%\ \text{(lumi)}$

Z + JETS RESULTS AT $\sqrt{s}$=13TEV

- Ratios of cross-sections njets
- cross-section as function of kinematic variables.
- Calculations at NNLO
- Several generators (ATLAS)



SMP-15-010

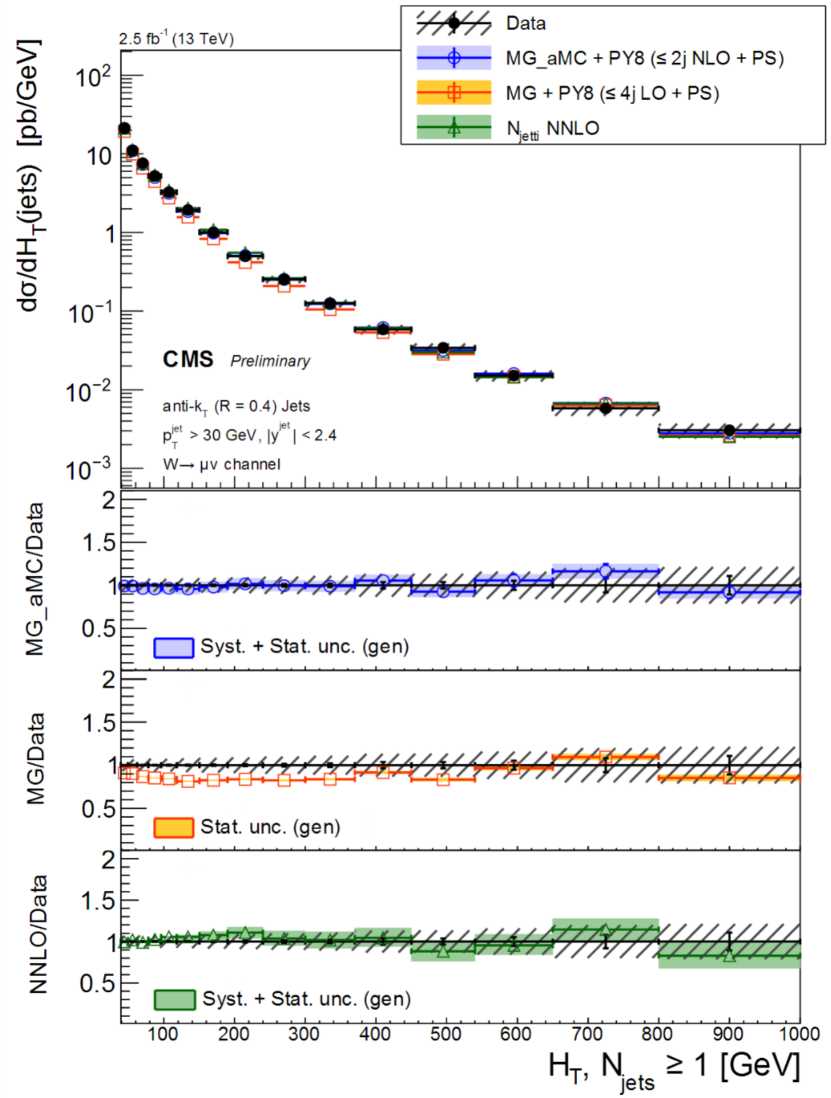


ATLAS-CONF-2016-046

Precision ranges from approximately 3% to 20%

CMS W + JETS AT $\sqrt{s}$ =13TEV

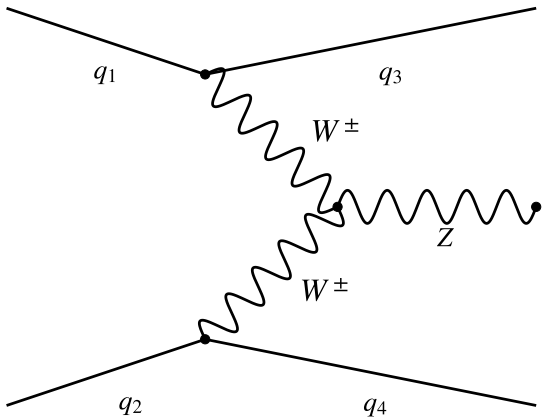
CMS-PAS-SMP-16-005



- More events!
- Cross sections up to 5 Jets
- Cross sections as function of kinematic distributions
- Predictions for H_T, jet p_T and y
- several generators considered
- Compared with NNLO theory calculations
- Agreement with SM.
- Excellent baseline for MC production

EW W/Z + DI-JET PRODUCTION

- Test the gauge sector of SM
- Electroweak vector boson fusion (VBF) is an important process for measuring particle properties
- Important for VBF production studies of Higgs boson

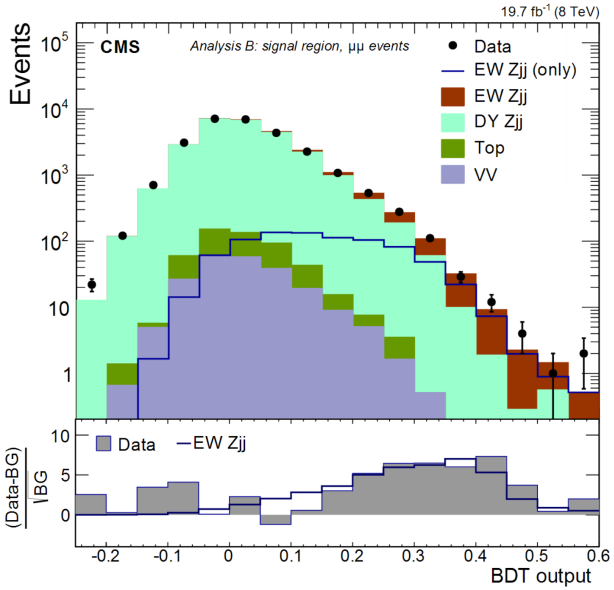


- roughly ten times lower cross sections than QCD production.

- Central boson
- 2 highly separated jets with high m_{jj}
- low central hadronic activity

EW W/Zjj Results at $\sqrt{s}$=8 TeV

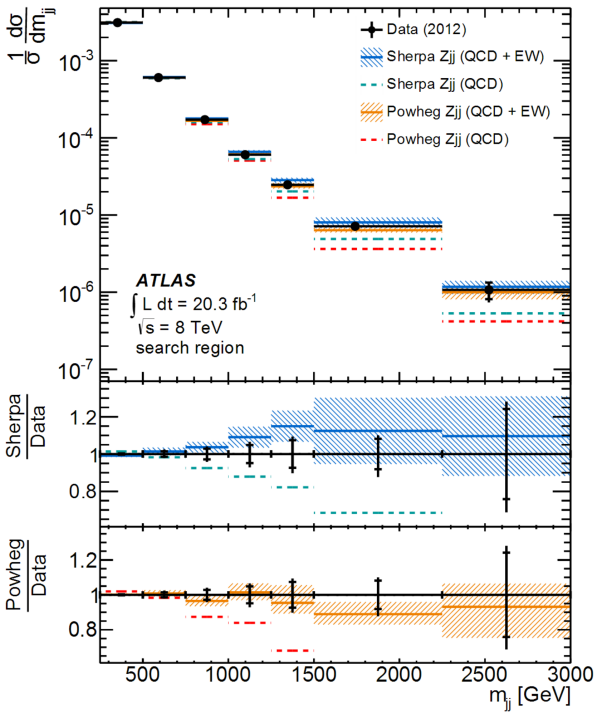
Zjj CMS Eur. Phys.J.C (2015)75:66



$\sigma_{EW}^{Zjj}(M_{jj} > 120GeV) =$

$174 \pm 8.6\%(\text{stat}) \pm 22\%(\text{syst})\text{fb}$

Zjj ATLAS JHEP 04(2014)031

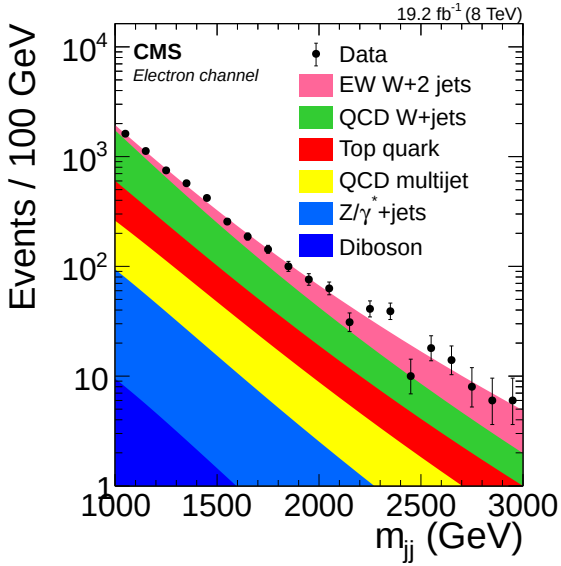


$\sigma_{EW}^{Zjj}(M_{jj} > 250GeV) =$

$54.7 \pm 8.4\%(\text{stat}) \pm 36.9\%(\text{syst}) \pm$

$2.7\%(\text{lumi})\text{fb}$

Wjj CMS SMP-13-012 - JHEP



$\sigma_{EW}^{Wjj}(M_{jj} > 1TeV) = 0.42 \pm$

$9.5\%(\text{stat}) \pm 21\%(\text{syst}) \pm 2.4\%(\text{lumi})\text{fb}$

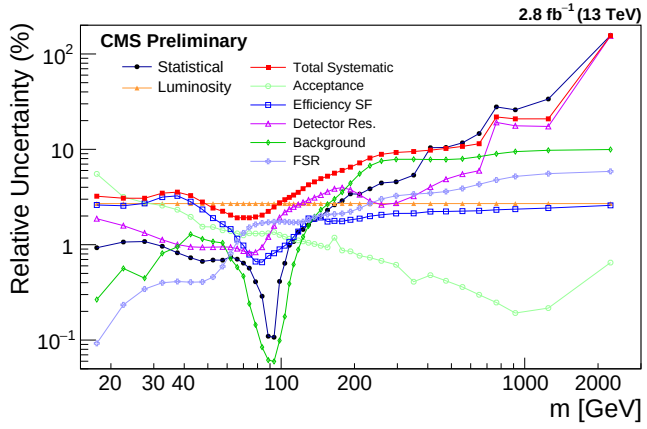
Good agreement with SM predictions!

PHOTON INDUCED DILEPTON PRODUCTION

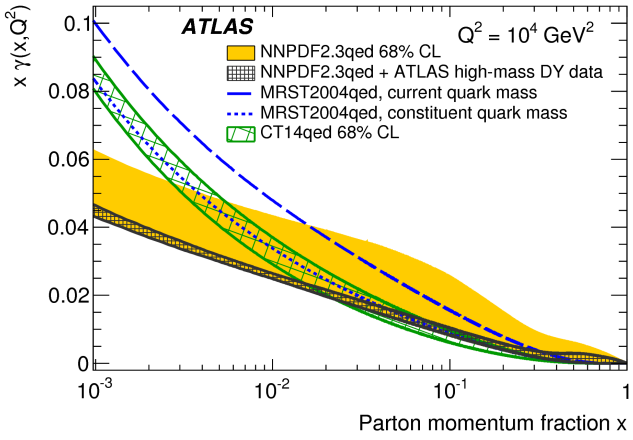
SEE ALSO TALK FROM LUCIAN HARLAND-LANG IN PDF SESSION

- OffShell DY measurements:
  - $q\bar{q} \to \gamma \to \ell\ell$
  - Possibility to also Measure the rate of photon induced process $\gamma\gamma \to \ell\ell$
  - Sensitive to new physics such as Z′
  - Large statistics allow measurements at high invariant masses
- Double Diffractive Dilepton Cross-section.
  - Sensitive to PI corrections
  - measurement of γ PDF

$$\frac{d}{dm_{\ell\ell} d|y_{\ell\ell}|}$$



CMS-PAS-SMP-16-009



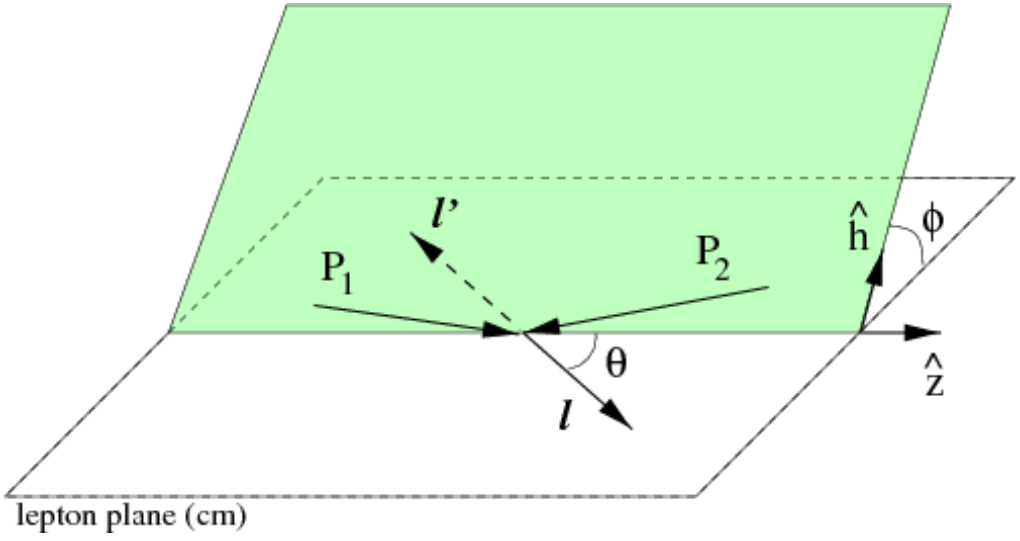
JHEP 08(2016)009

ANGULAR COEFFICIENTS IN COLLINS-SOPER (CS) FRAME

- Test QCD predictions to all orders α_s
- Include all Spin-correlations
- Sensitive to various SM parameters such as Z polarisation.

Differential cross section for:

$$pp \to Z/\gamma * + X \to \ell^+\ell^- + X$$

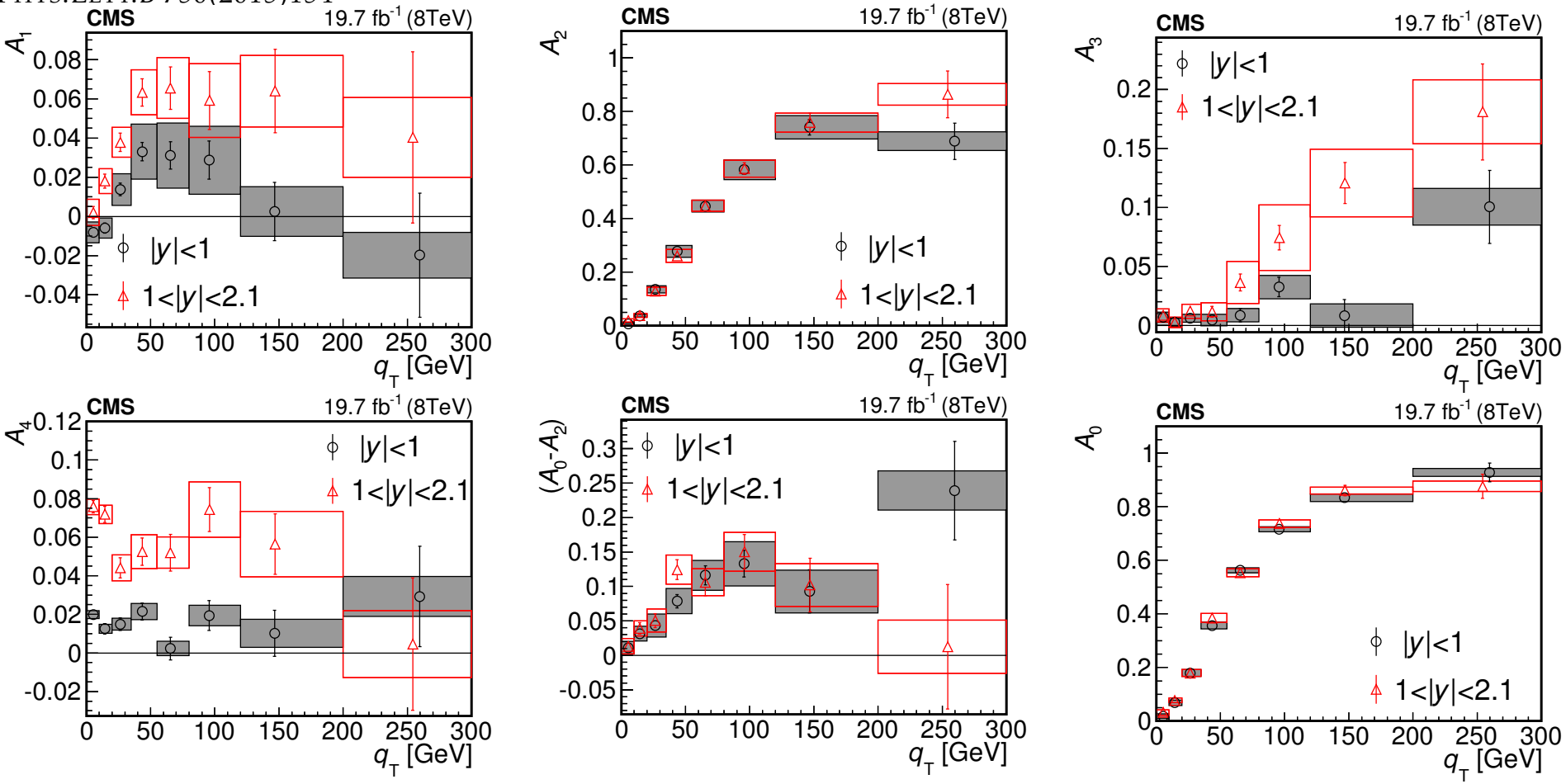


$$\frac{d\sigma}{dp_T^Z dy^Z dm^Z d\cos\theta d\phi} =$$

$$\frac{3}{16\pi}\frac{d\sigma^{U+L}}{dp_T^Z dy^Z dm^Z}\left\{(1+\cos^2\theta) + \Sigma_{i=0}^{7} A_i(p_T^Z, y^Z, m^Z)\cdot P_i(\cos\theta,\phi)\right\}$$

CMS RESULTS AT 8TEV

PHYS.LETT.B 750(2015)154

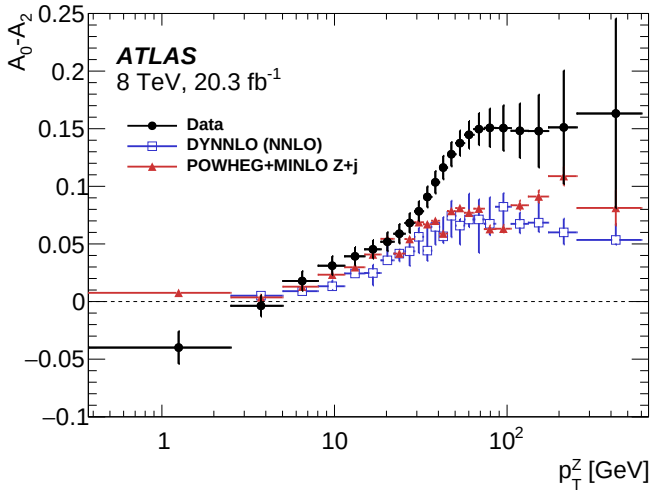


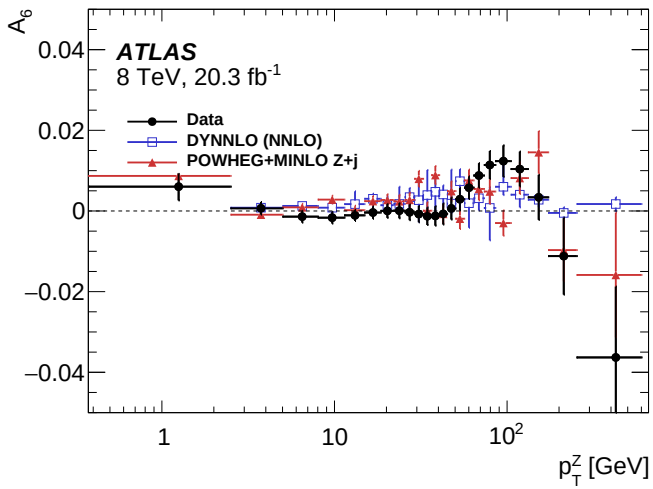
- Mostly stat dominated (even with 10^6 events)
- $A_0 - A_2$ larger than NNLO expectations.
- A_5, A_6, A_7 are predicted to be 0 at NLO

ATLAS RESULTS AT 8TEV

JHEP08(2016)159

- Angular Distributions sculpted by fiducial acceptance
- Polynomials are 'folded' into reconstruction space.
  - Simulate acceptance, efficiency and resolution
  - 3D folding in p_T^{ll} and CS angles.
- Fit folded templates to measured distributions
- Normalised in $p_T(Z)$





- A_5, A_6, A_7 have contributions at large p_T^Z
- Higher order effects measured using this method.

SUMMARY

Conclusions

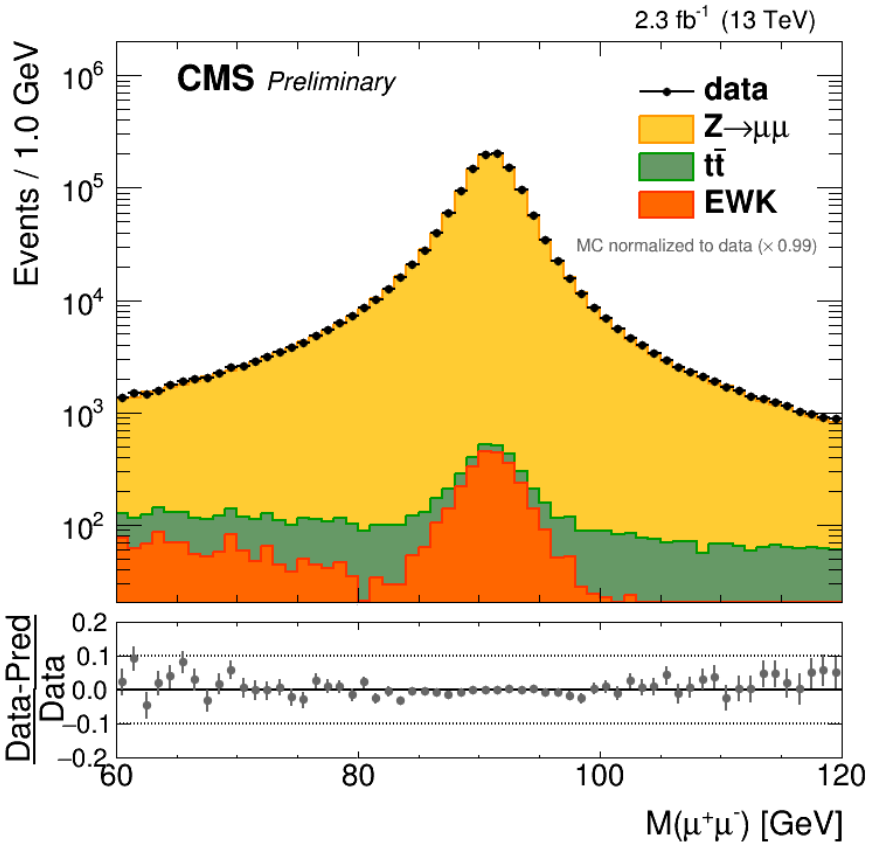
- Measurements of single Z/W processes are very well motivated at LHC.
- Parton Shower Modeling, Higher Order Calculation PDFs are still actively changing fields.
- Early 13 TeV results have already been produced with high precision
- Precision still dominated by 8TeV measurements

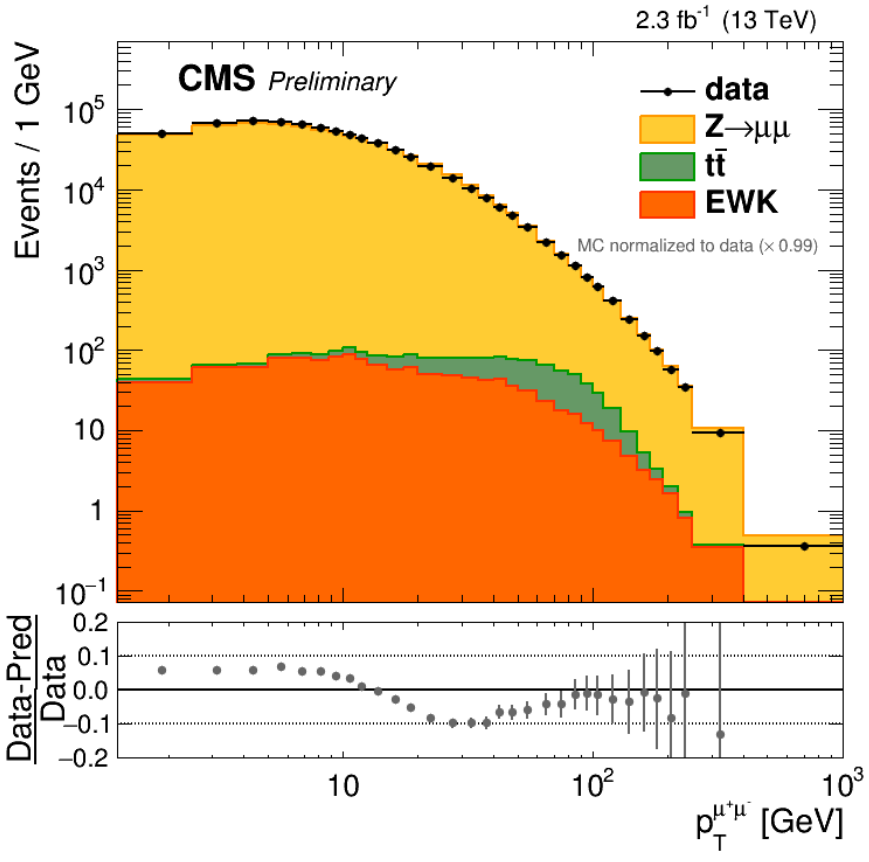
Outlook

- Further development of including heavy flavour jets (e.g. V+HF)
- Multidifferential cross section measurements (large impact on PDFs)
- Taus?

Additional Plots for consideration

Measurements of inclusive and differential Z boson production cross sections with CMS

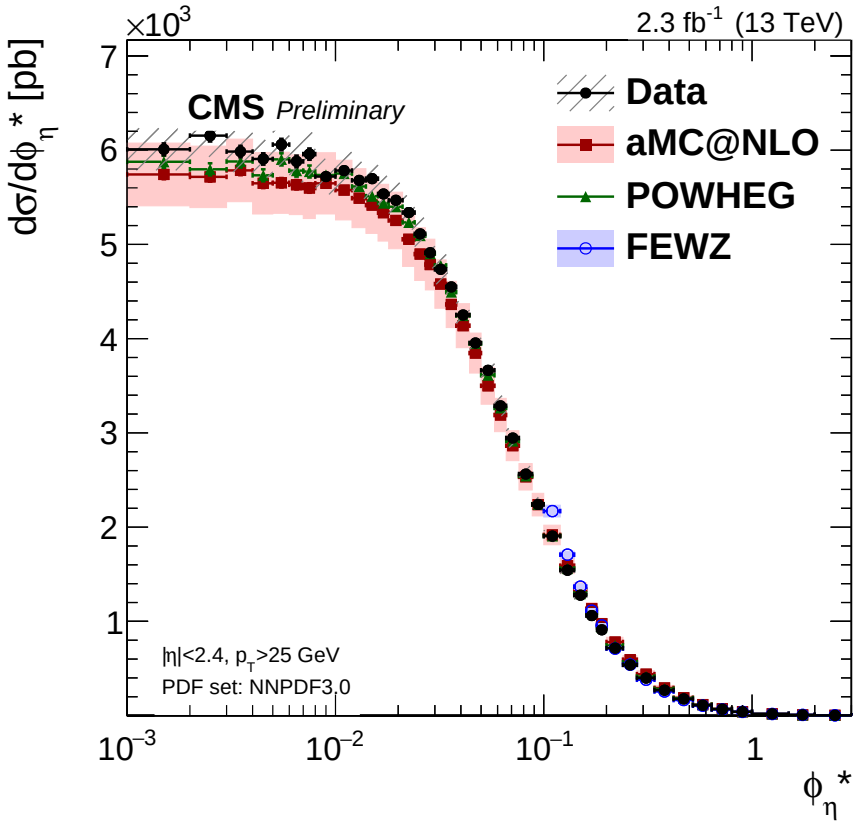


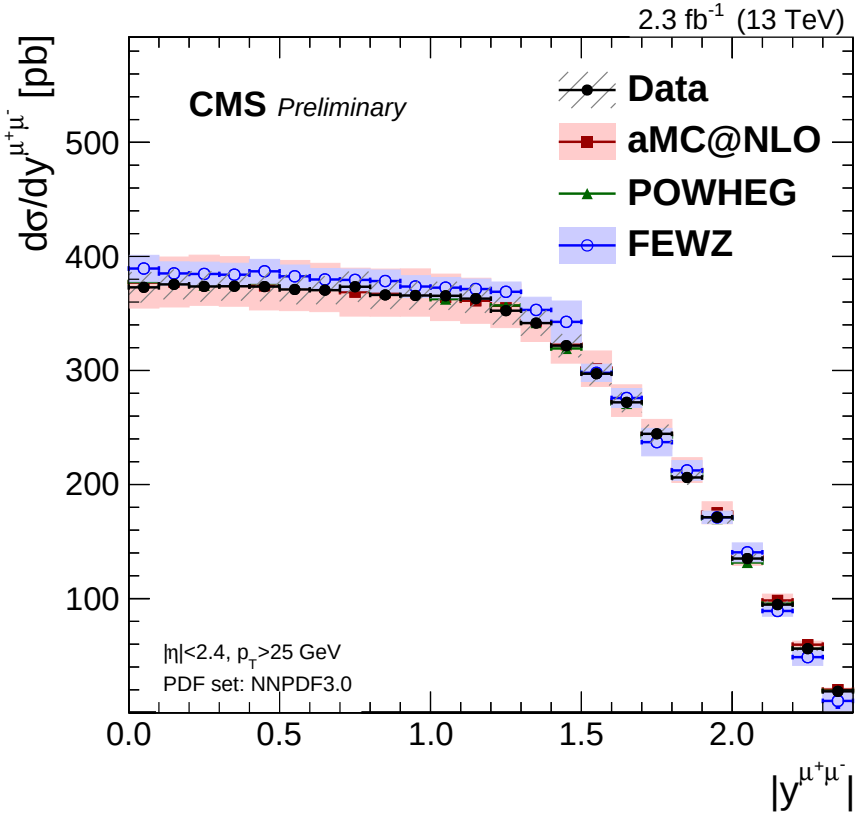


CMS-PAS-SMP-15-011

Additional Plots for consideration

Measurements of inclusive and differential Z boson production cross sections with CMS

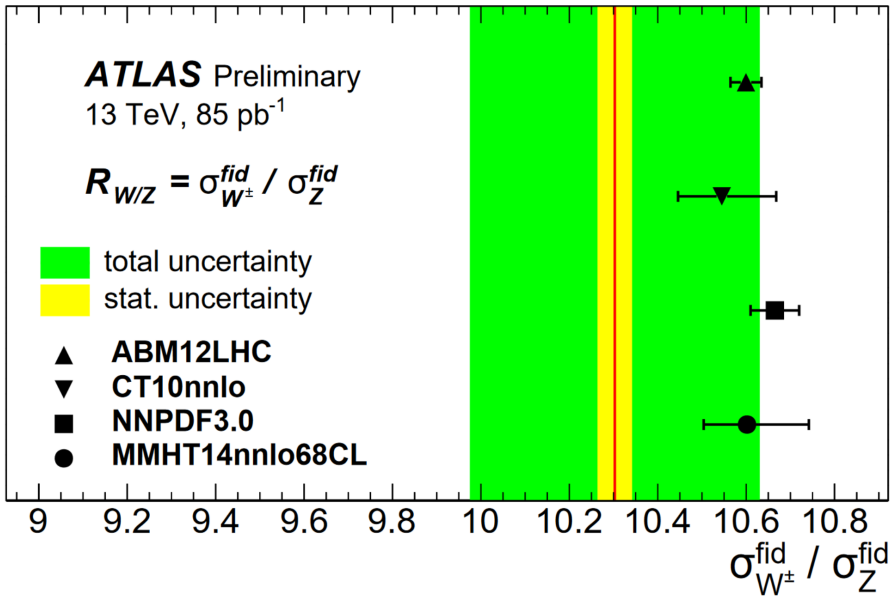


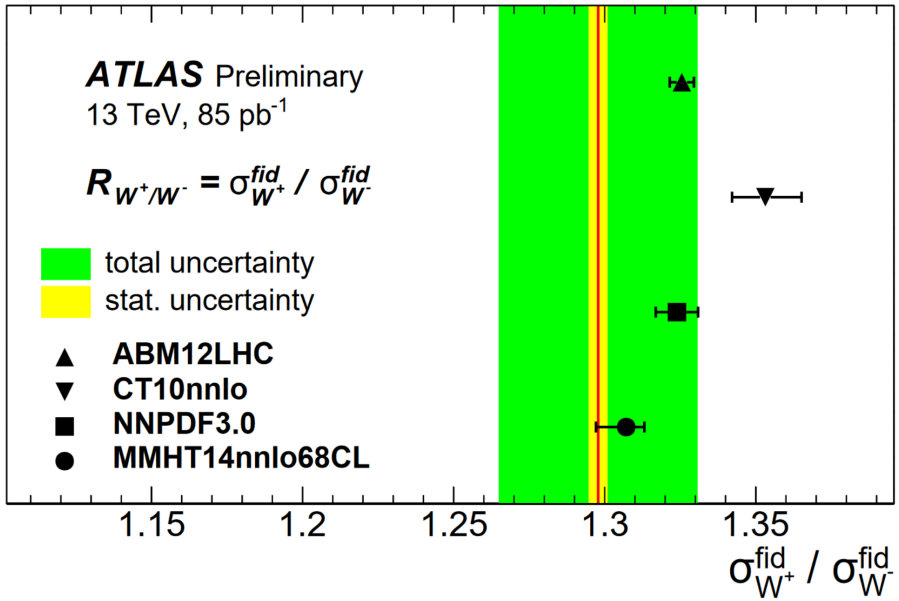


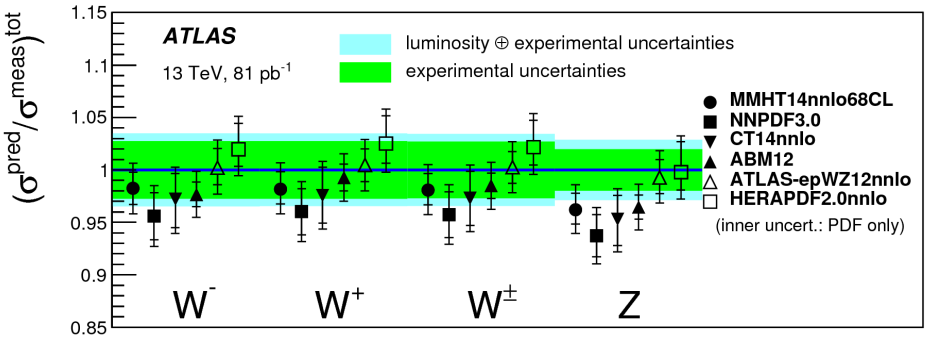
CMS-PAS-SMP-15-011

Additional Plots for consideration

WZ cross sections at 13 TeV with ATLAS



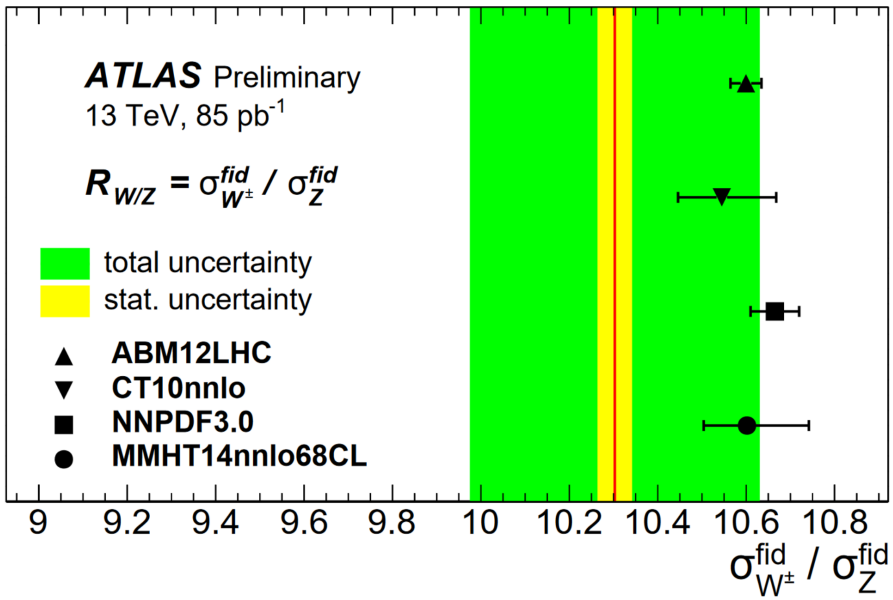


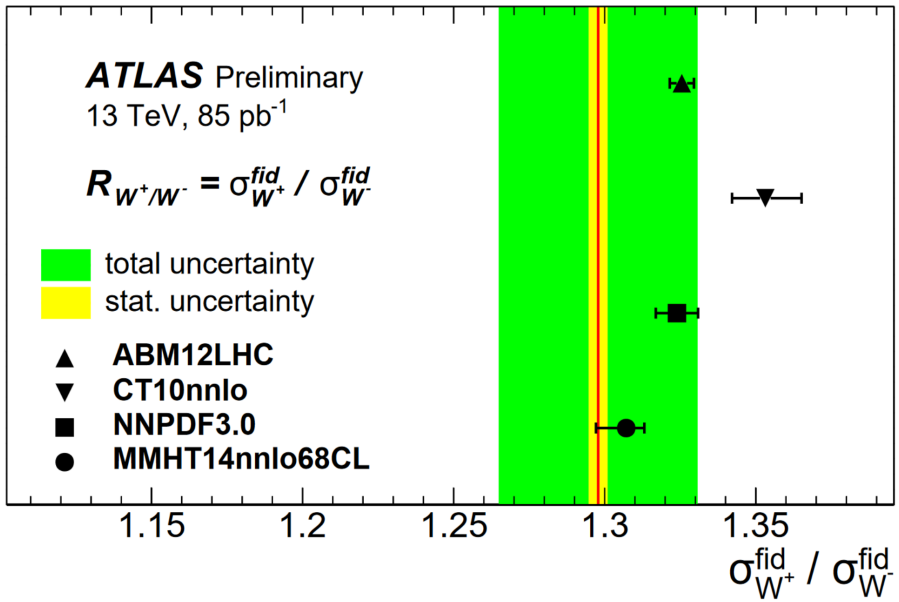


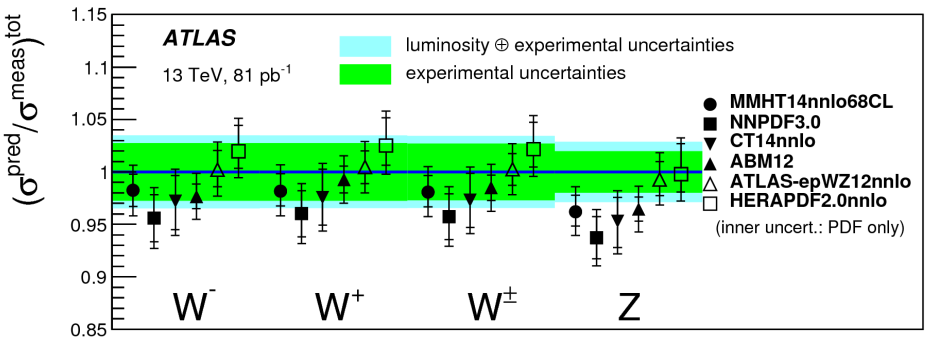
Phys.Lett.B 759 (2016) 601

Additional Plots for consideration

WZ cross sections at 13 TeV with ATLAS







Phys.Lett.B 759 (2016) 601

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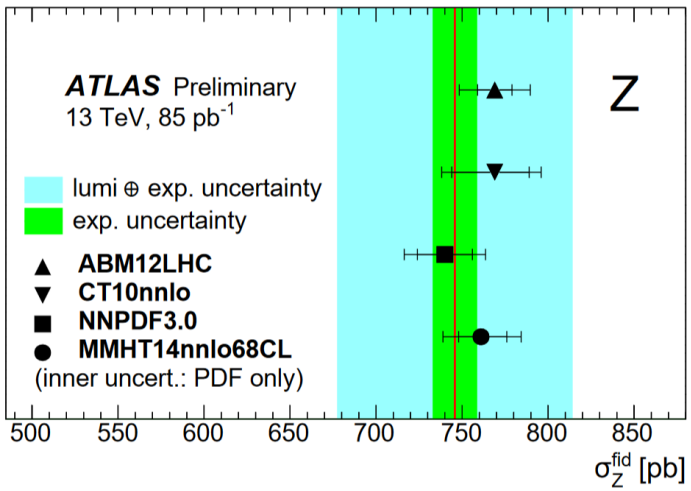

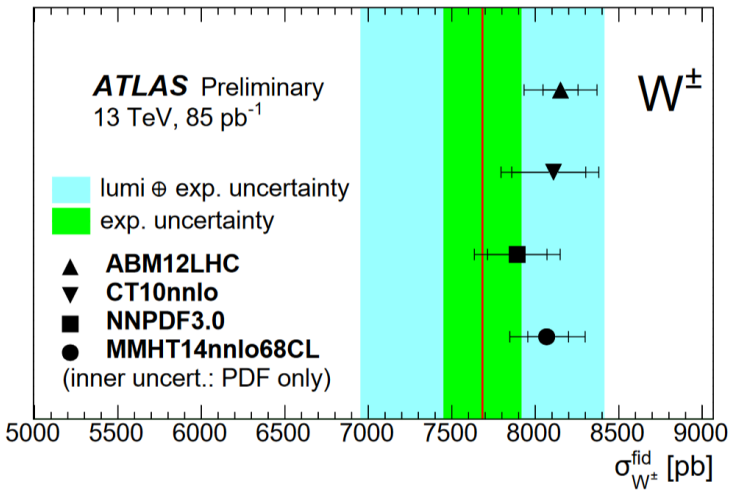

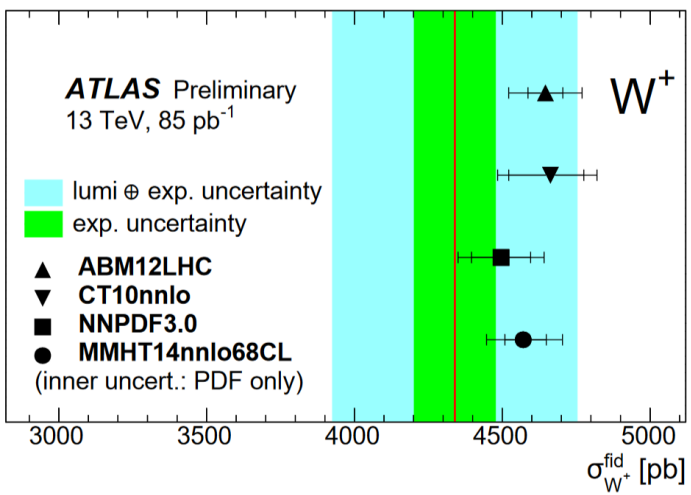

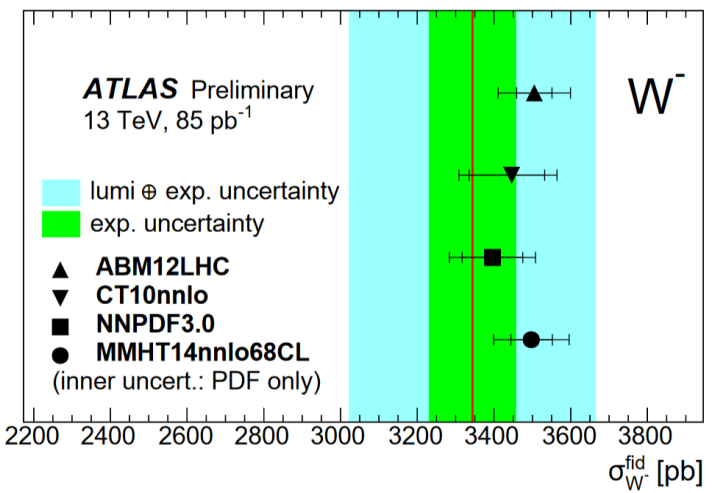

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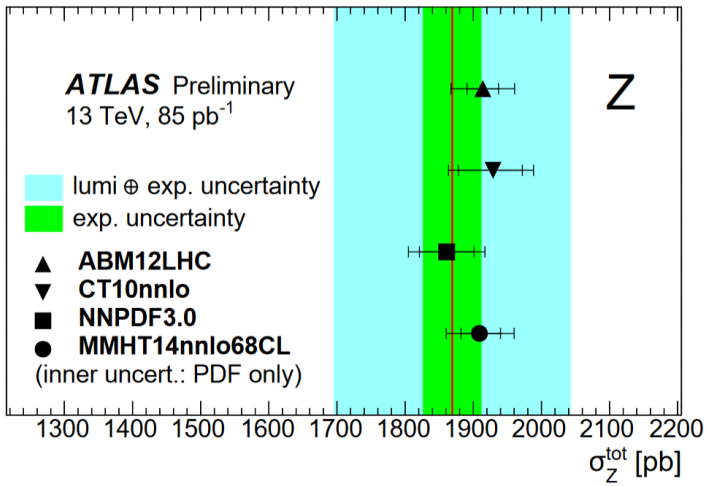
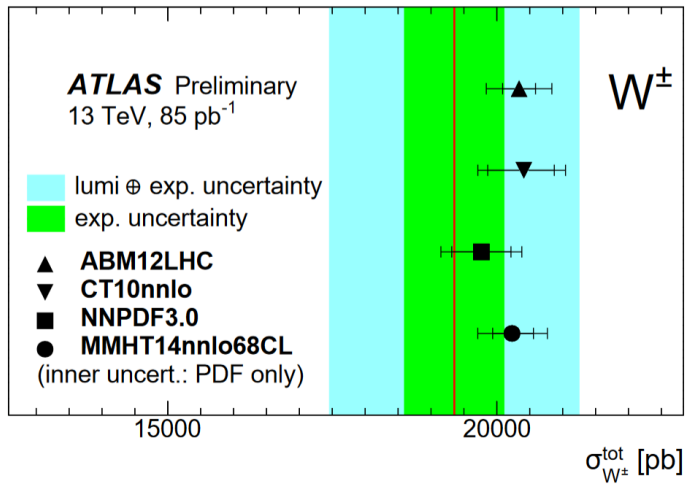
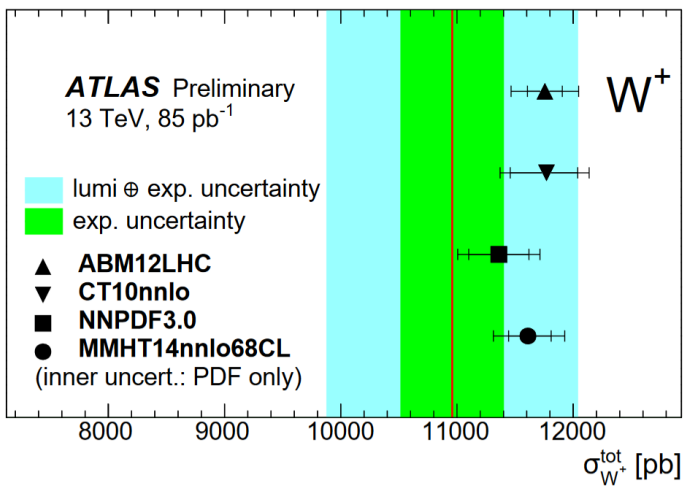
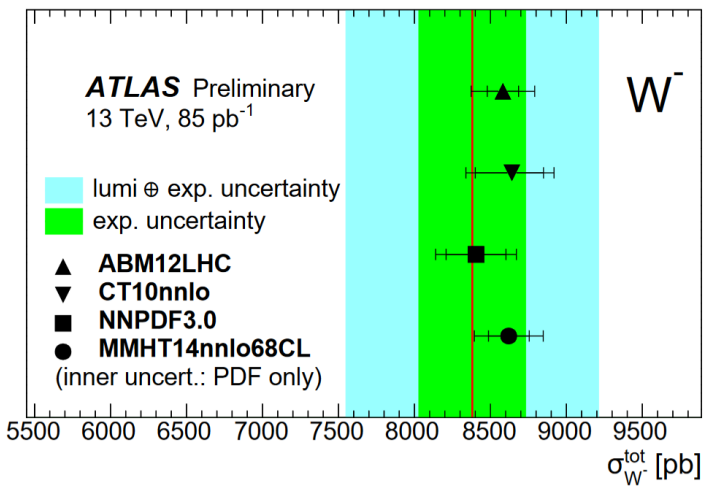
Additional Plots for consideration

WZ cross sections at 13 TeV with ATLAS









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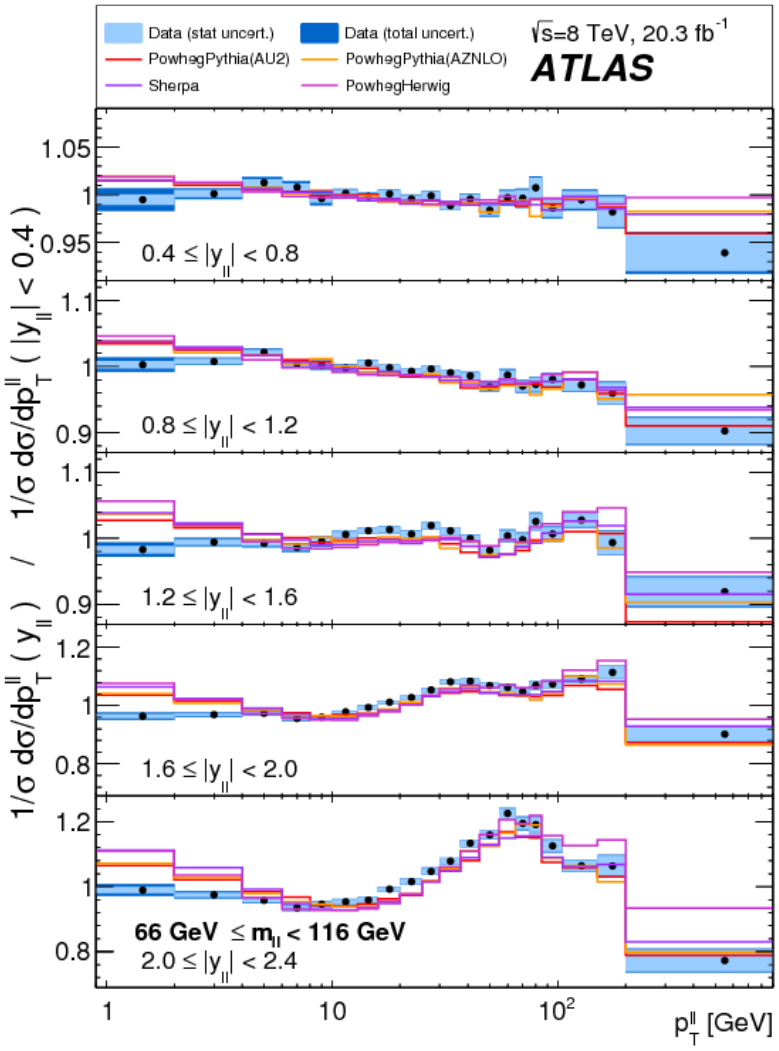
Additional Plots for consideration

ATLAS Cross-section at 8TeV

- Several different rapidity ranges are considered
- The MC generator performace is considered in each range.
- The range above and below the mass peak is also considered.



Additional Plots for consideration

ATLAS Z+jets at 13TeV additional Plots