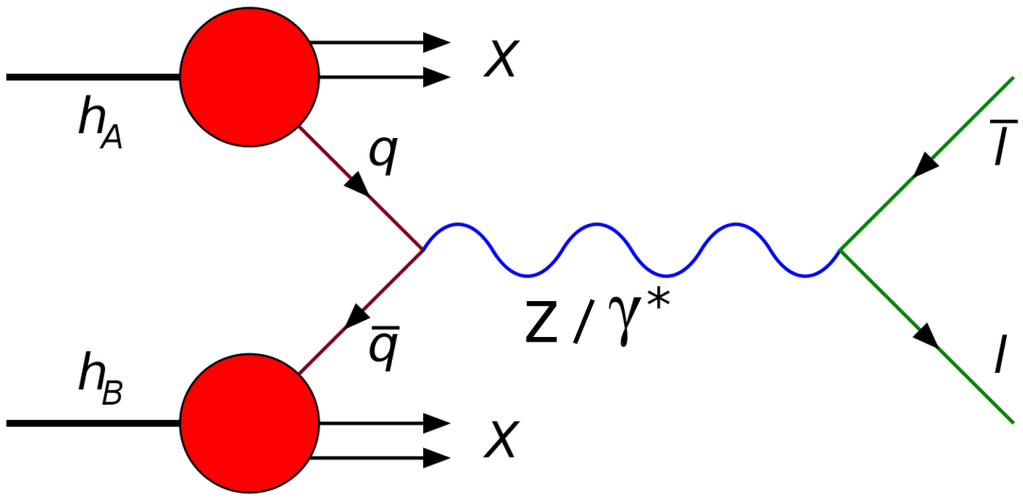
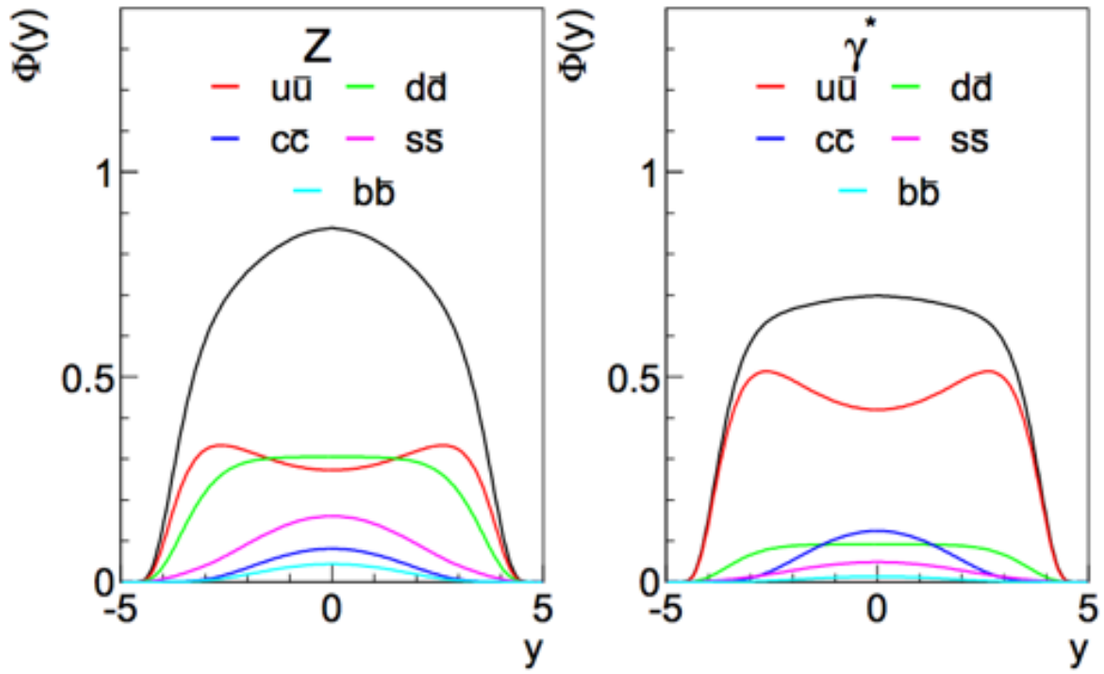
Measurements of inclusive and differential Drell–Yan cross sections with the ATLAS detector at 8 and 13 TeV

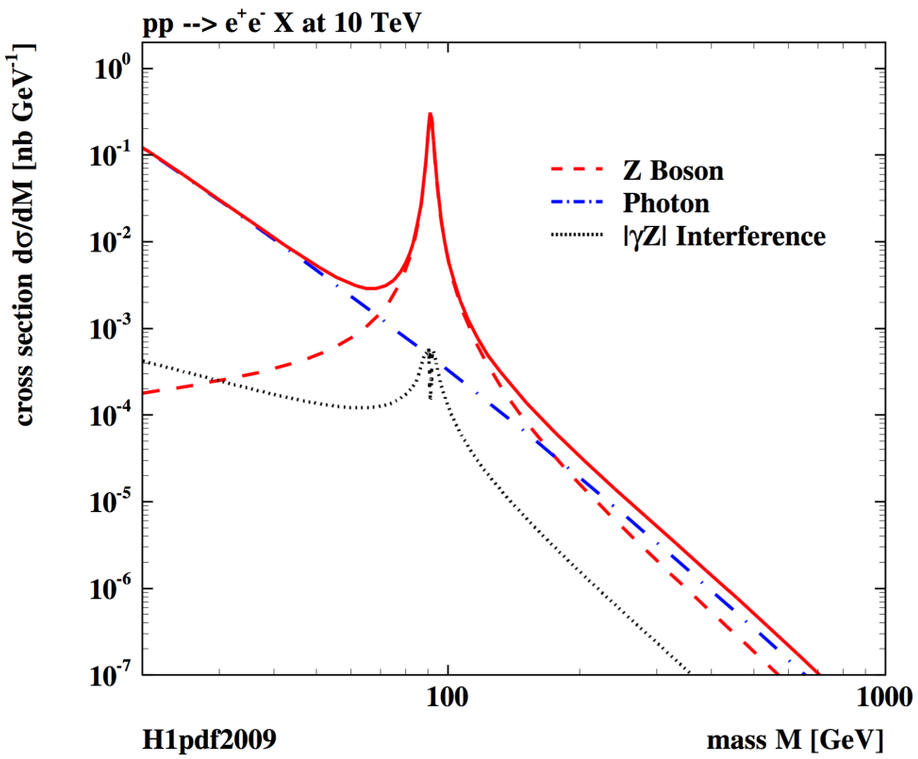
Trofymov Artur on behalf of the ATLAS Collaboration

Low-x 2016, Gyöngyös, 09.06.2016

Introduction

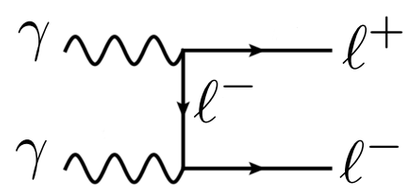






Drell-Yan processes:

- Allows the extraction of the structure functions of the beam hadrons
- Provides a precision test of pQCD
- Different sensitivity to up-type, down-type quarks and antiquarks near and outside Z peak (γ^* dominates outside)
- Sensitive to the photon PDF through the photon-induced (PI) process ($\gamma\gamma \to \ell\ell$):

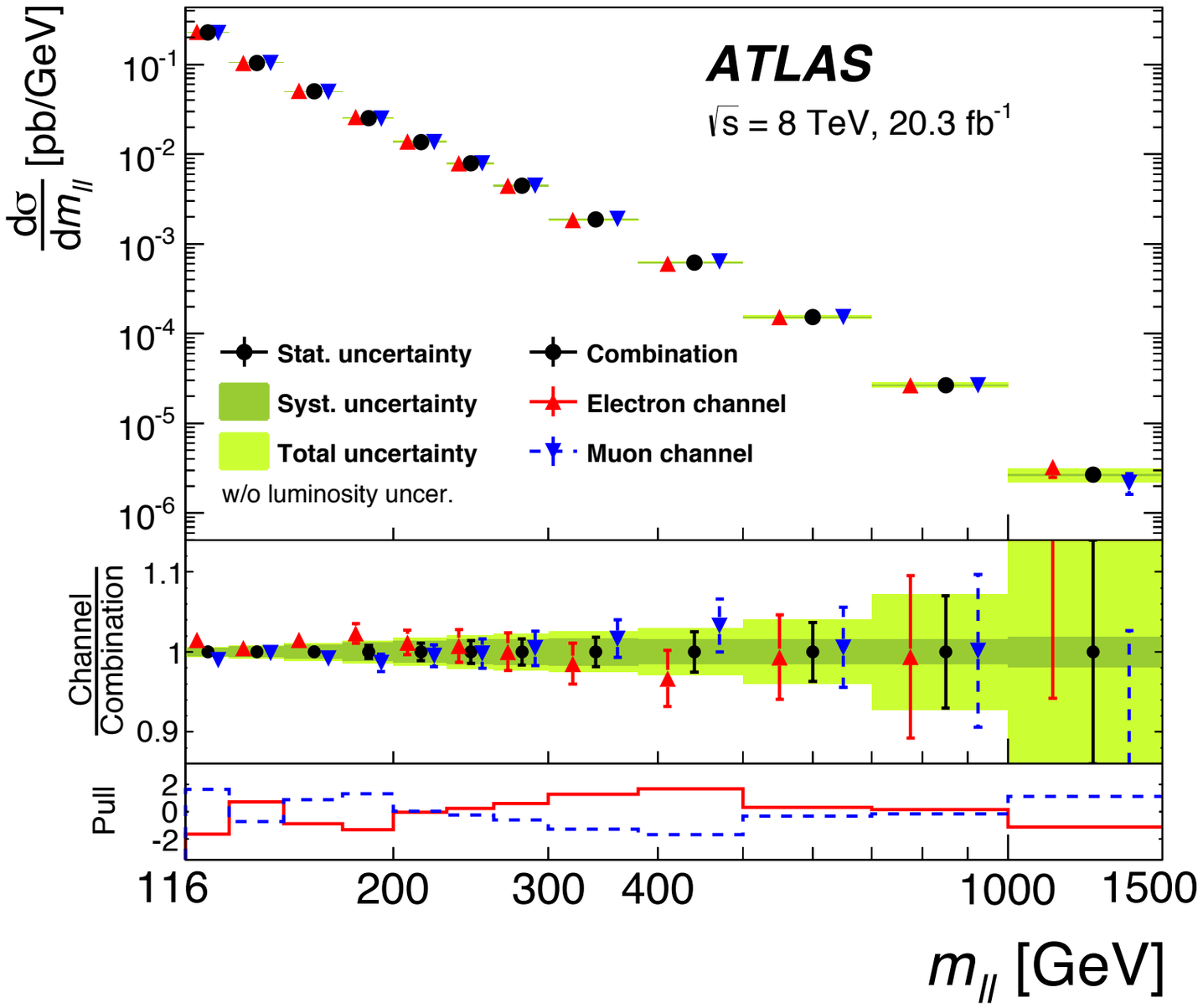


- Cross section ratios measurements are powerful tools to constrain PDFs and benefit from the cancellation of some experimental uncertainties

High mass Drell-Yan at 8 TeV

Measurement motivation:

- Offers constraints on the large *x* anti-quark PDFs
- Sensitive to the photon PDF (expected to contribute at large $|\Delta\eta_{\ell\ell}|$, small $|y_{\ell\ell}|$, large $m_{\ell\ell}$



Submitted to: JHEP, arXiv:1606.01736

Dominant background contribution

- Top ($t\bar{t}$ and Wt)
- Multi-jet
- Diboson (WW, WZ, ZZ)

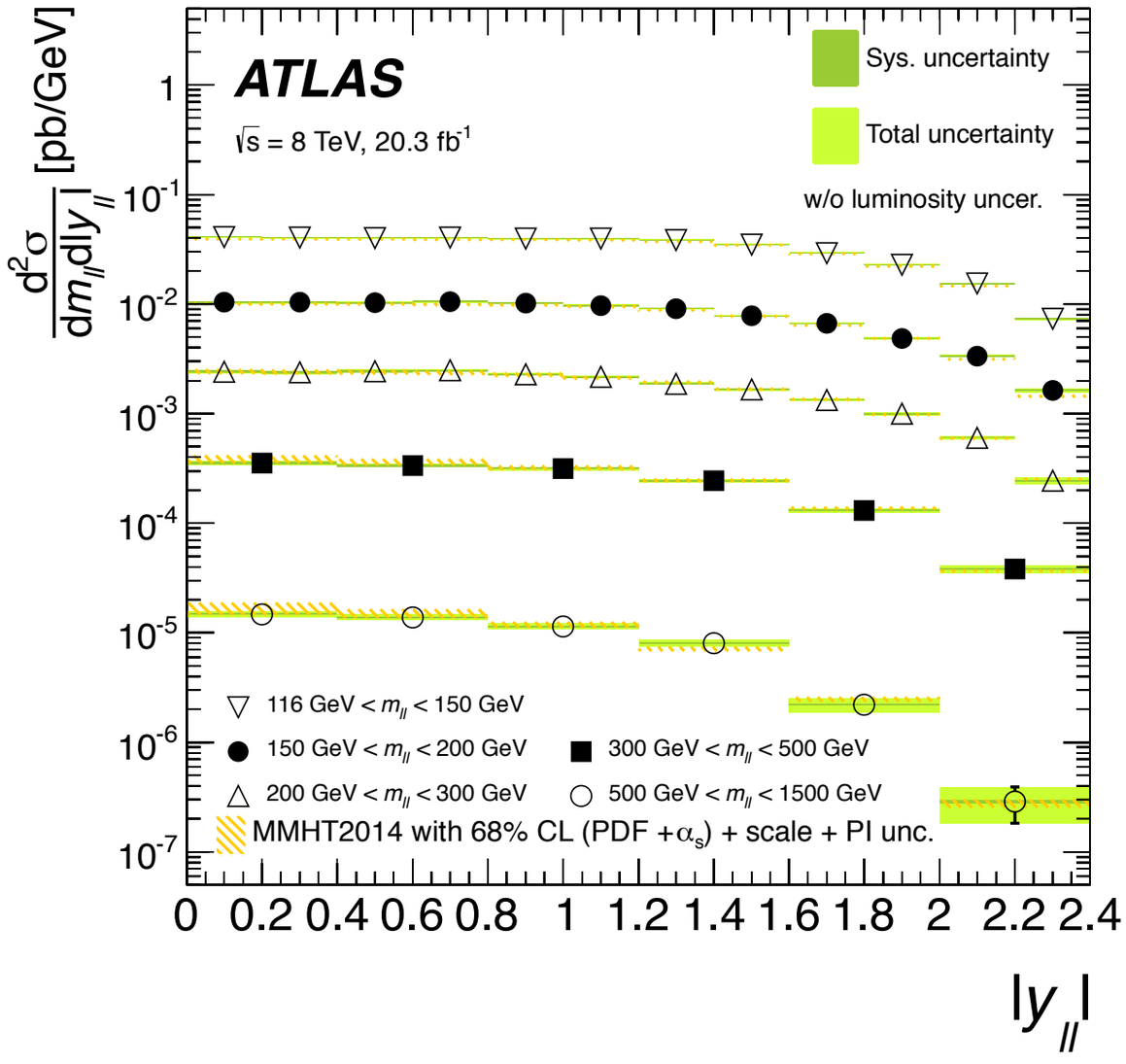
Photon-induced process contribution:
1% (except high $m_{\ell\ell}$ and large $\Delta\eta_{\ell\ell}$ region)

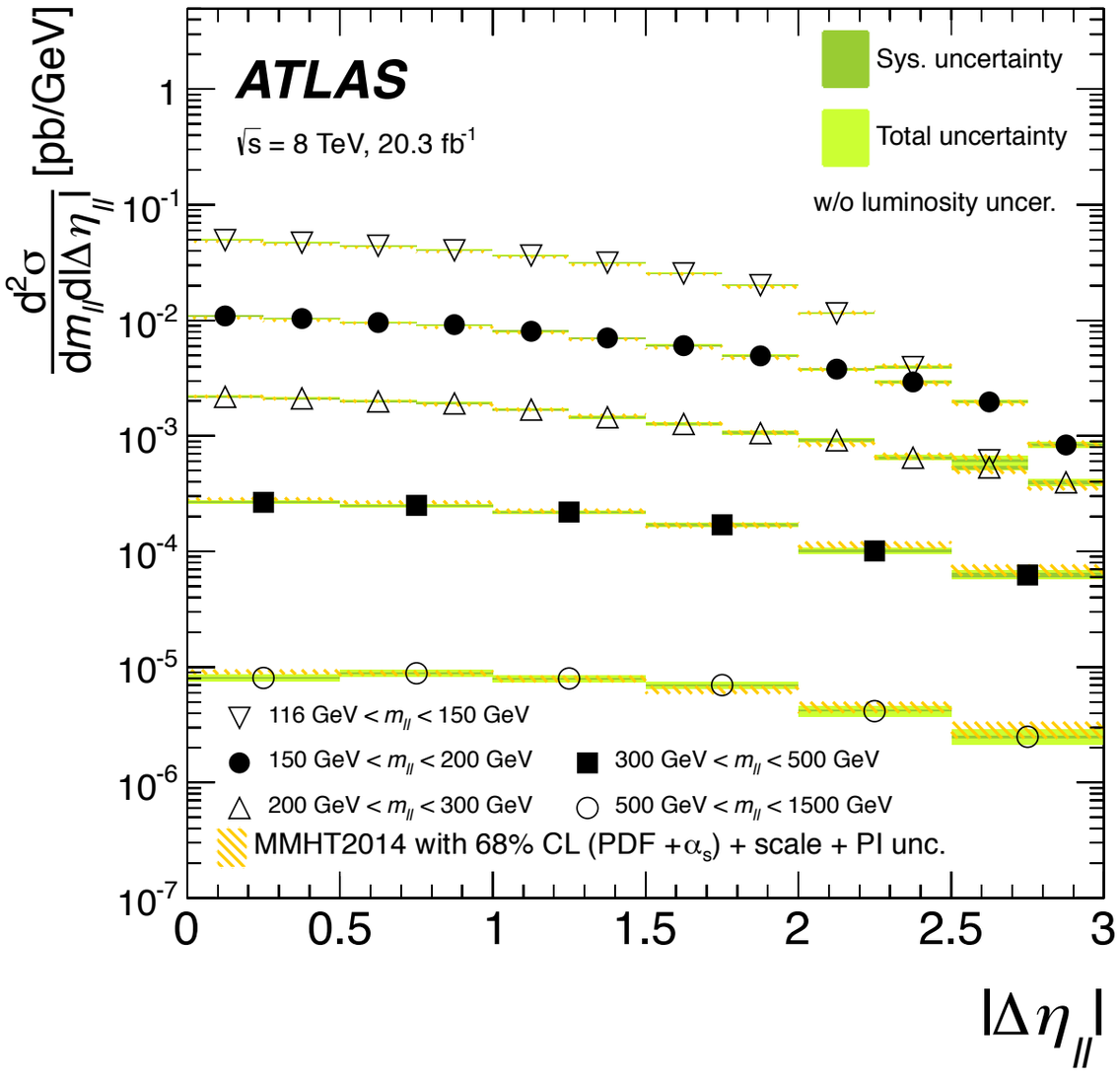
Dominant systematic uncertainty sources

- Top background estimation
- Multi-jet background estimation
- Electron energy scale
- Muon reco. efficiency correction
- Muon momentum scale calibration

High mass Drell-Yan at 8 TeV

- Double-differential cross sections:





→ **Good agreement between data and predicted results**

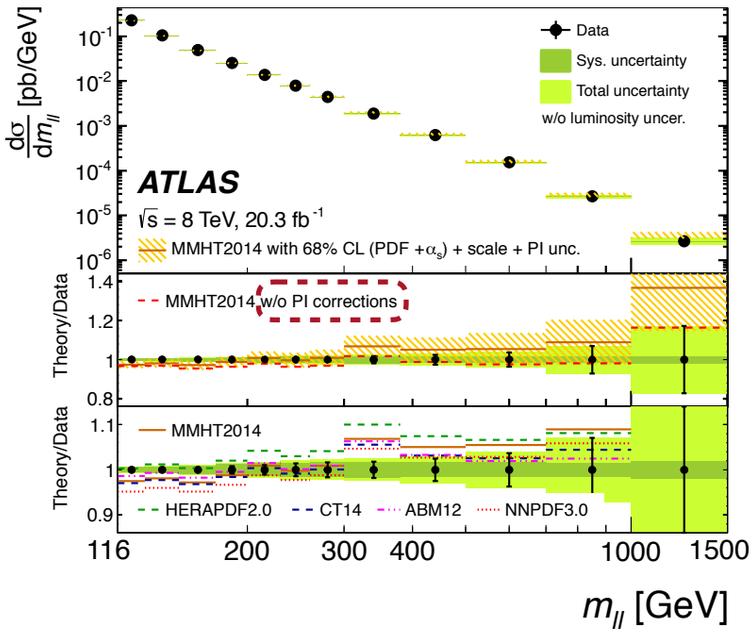
- Combined fiducial cross section at **Born** level compared to NNLO pQCD calculations
- Theoretical predictions are calculated with FEWZ 3.1 using MMHT14 PDF set

arXiv:1606.01736

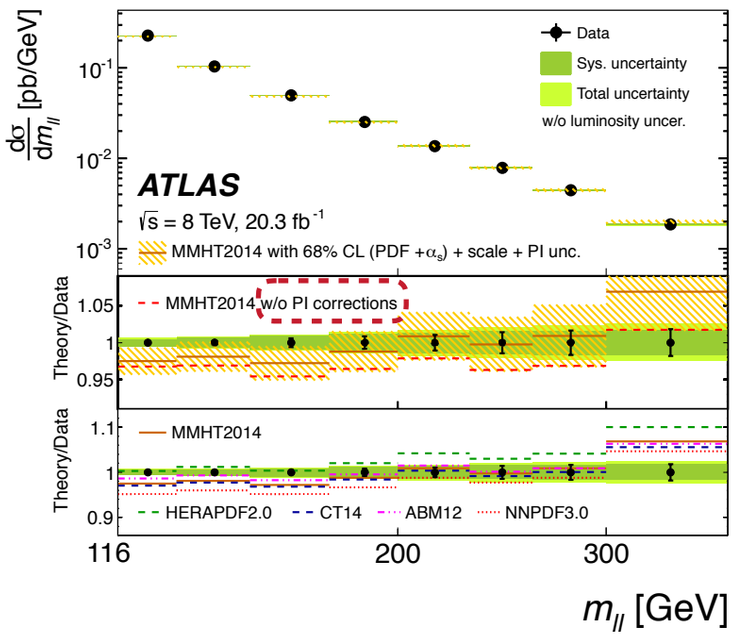
High mass Drell-Yan at 8 TeV

Single-differential cross section

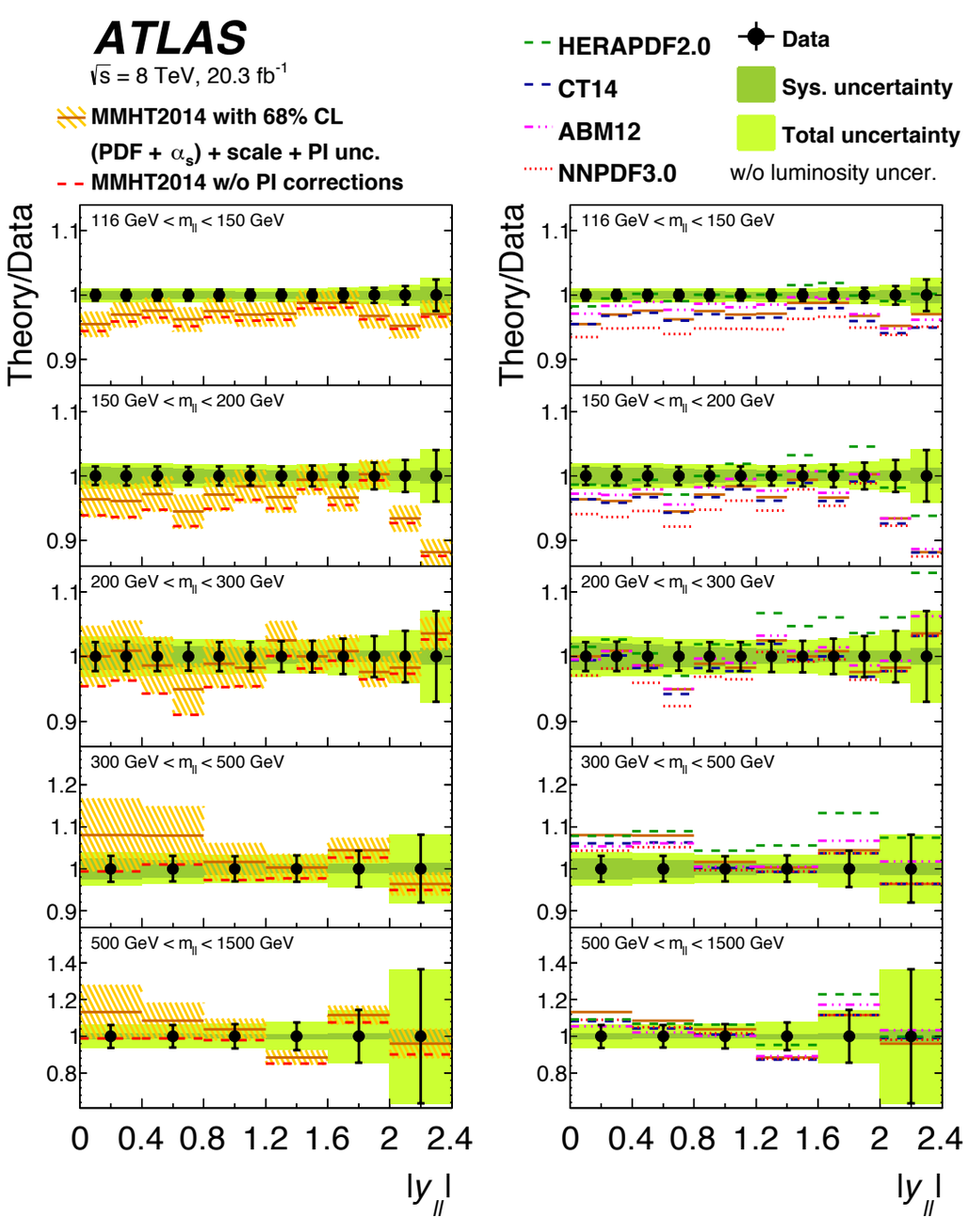
full window



restricted range



Ratio of theoretical calc. to combined double-differential cross section

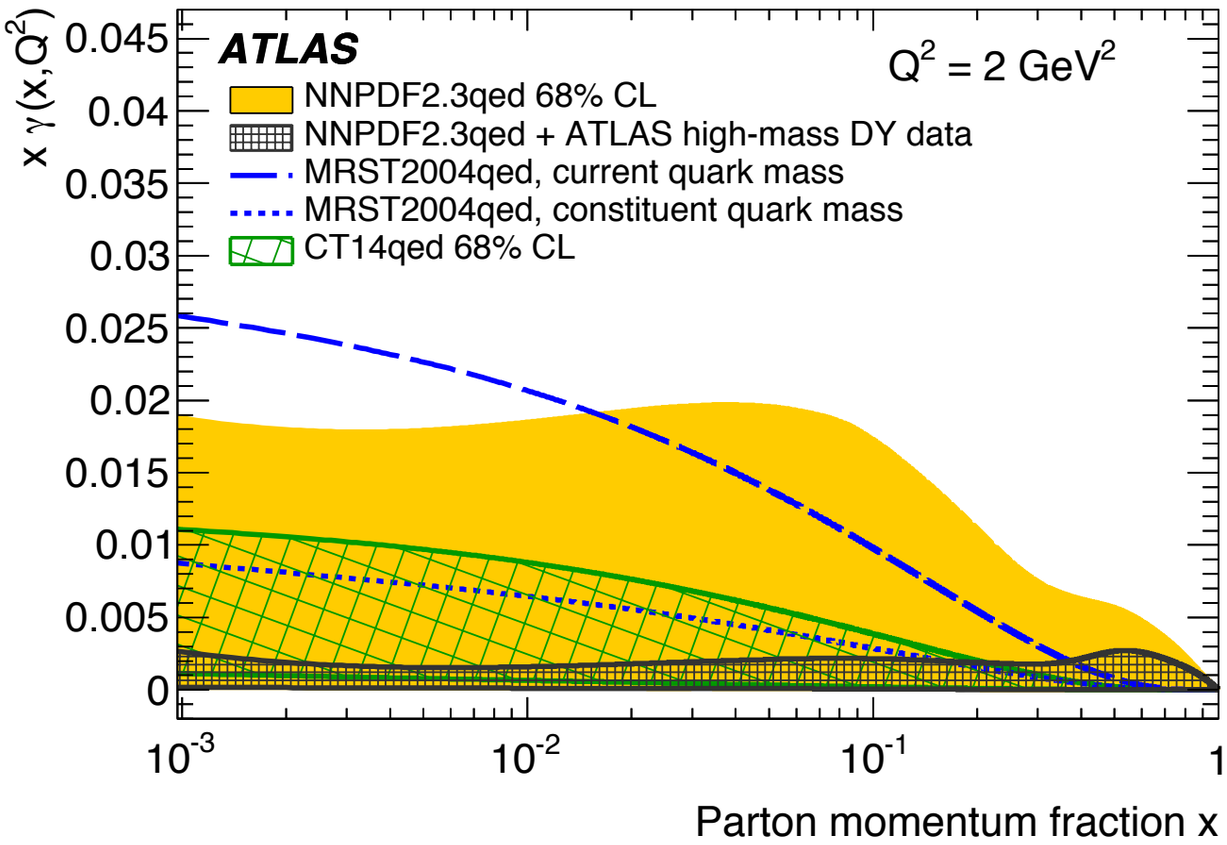


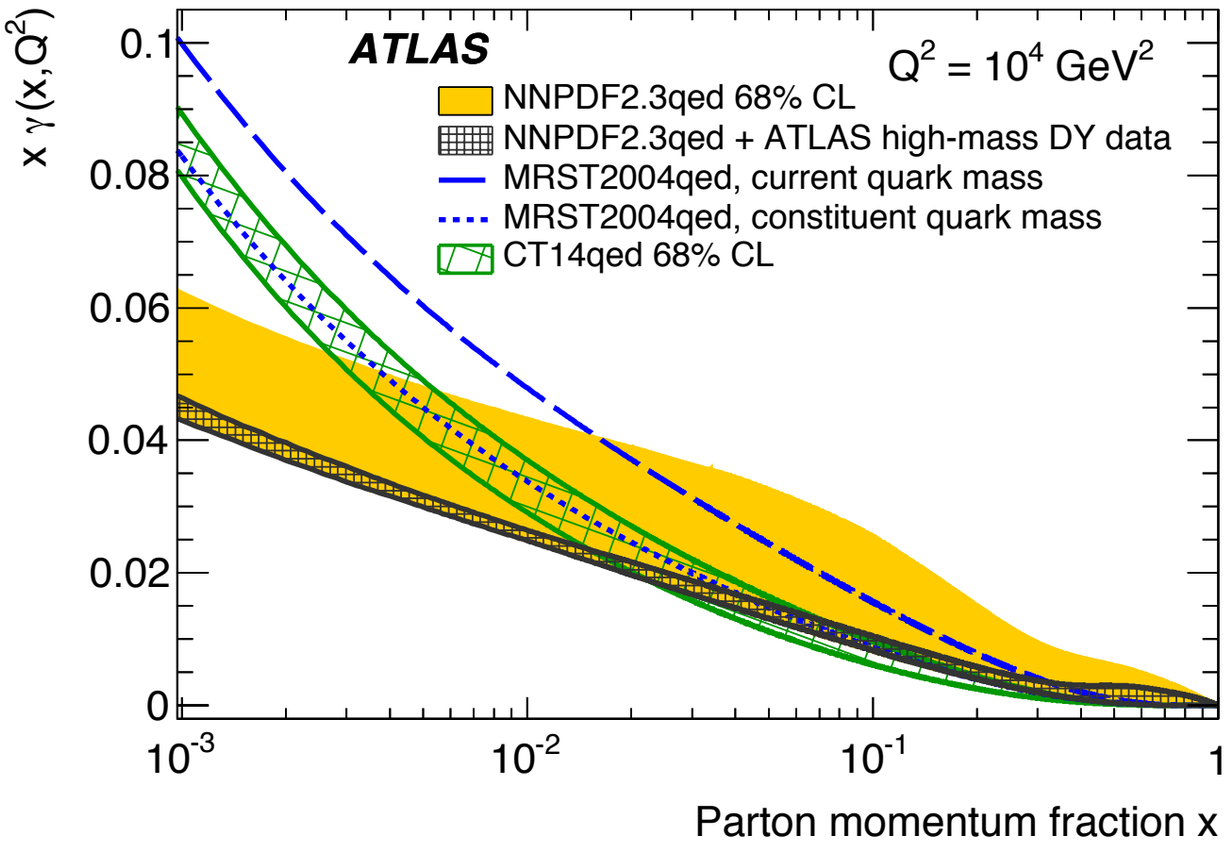
- Contribution of non-resonant PI process included. Estimated at LO using photon PDF.
  - → Reaches 15%
  - → In the region where PI contribution is large the PI uncertainty dominates the total uncertainty band
- At low mass, the differences between the predictions are larger than the total uncertainty of the measurement
  - → **Potential to constrain PDFs**

arXiv:1606.01736

High mass Drell-Yan at 8 TeV

Impact of the measured results on photon PDF sets





- **Bayesian reweighing was used** for MC replica representing NNPDF2.3qed photon PDF (to get impact of the data on PDF set)

  $\longrightarrow$ Based on χ^2 minimization (replicas not describing well get smaller weight assigned)

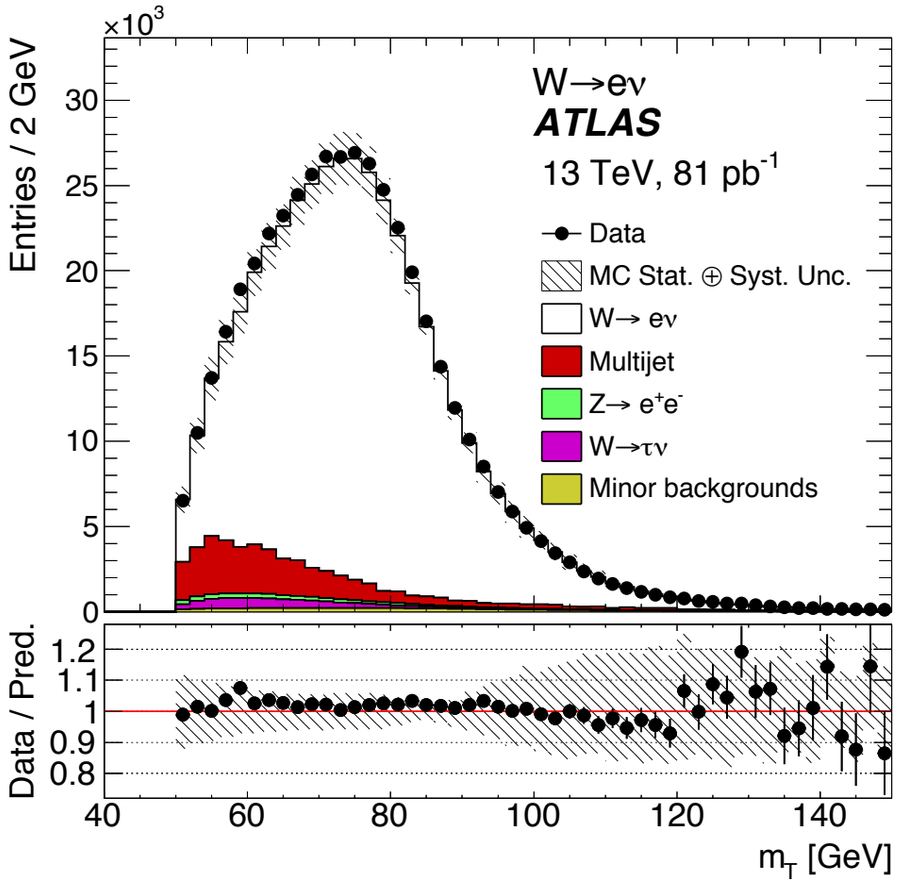
- Shaded area indicates new PDF after inclusion of the data
- **Large reduction of the uncertainty confirms the strong sensitivity of this data to the photon PDF**

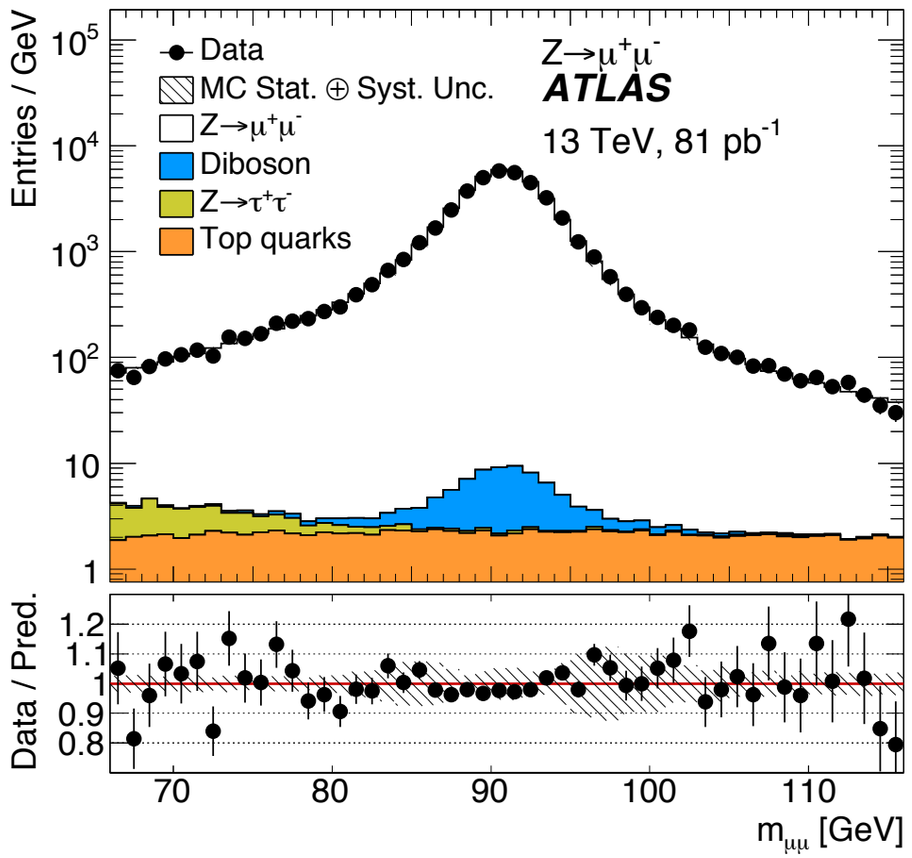
arXiv:1606.01736

W and Z Cross Sections Measurements at 13 TeV

- Measurements are performed using data collected at $\sqrt{s} = 13\ TeV$ corresponding to an integrated luminosity of $81 pb^{-1}$
- Cross section ratios measurements benefit from the **cancellation of luminosity, some experimental uncertainties,** and are powerful tools to **constrain PDFs**

$\longrightarrow$ W,Z analysis selections are **fully synchronised** to maximise the cancellation





- **Fiducial volume defined at the Born-level:**

$p_T^\ell > 25\ GeV \qquad |\eta^\ell| < 2.5 \qquad p_T^\nu > 25\ GeV$

$66 < m_{\ell\ell} < 116\ GeV \qquad m_T^W > 50\ GeV$

Dominant background contribution:

Z channels: $t\bar{t}$ **W channels:** Multi-jet

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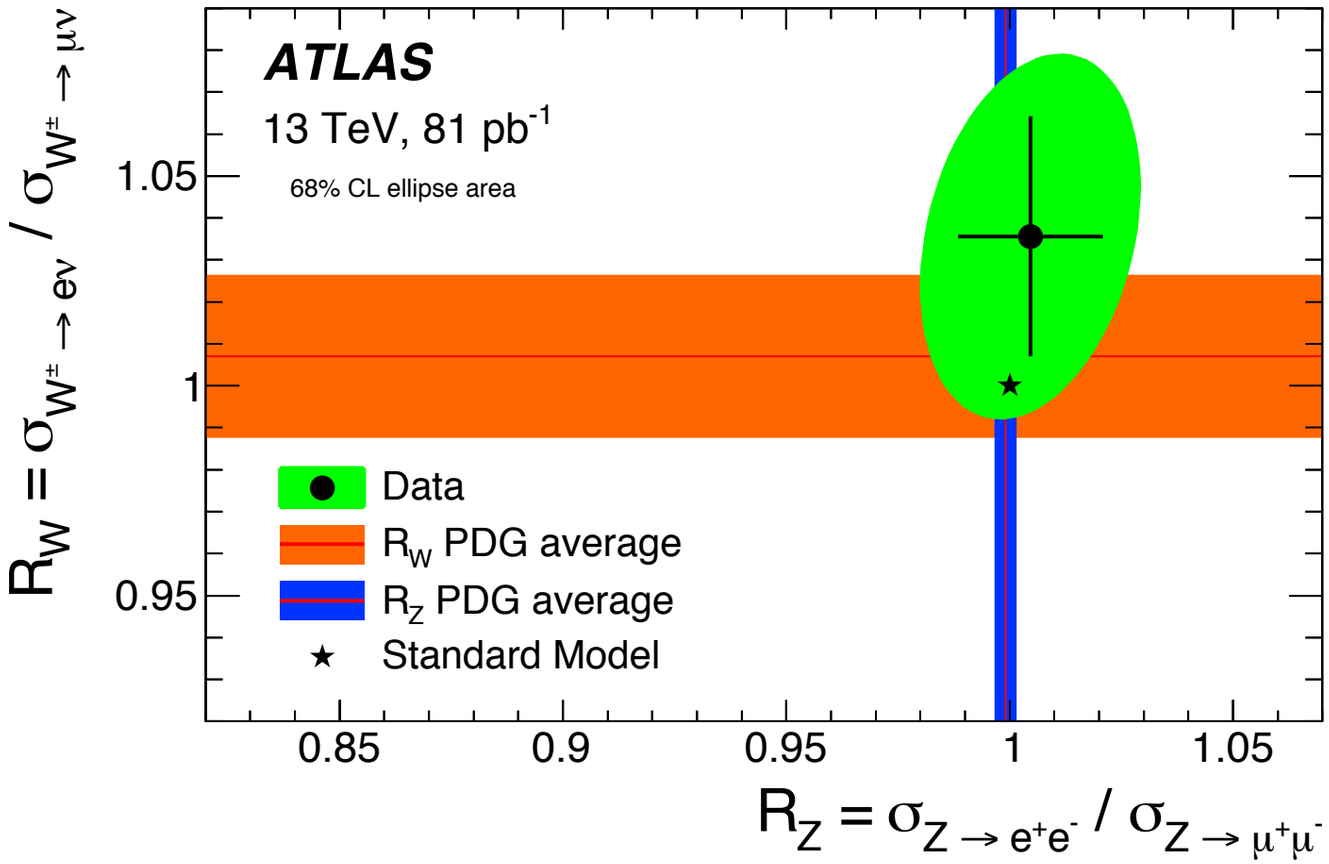
W and Z Cross Sections Measurements at 13 TeV

Lepton universality



- Provide a **test for both channels** before combining
- Rw and Rz evaluated taking into account correlations in the systematic uncertainties

→ Lepton reconstruction and identification are naturally uncorrelated between electron and muon channel

→ EWK bkg. sources are treated as uncorrelated between *W* and *Z* channels and 100% correlated for different *W* and *Z* channels.

Correlation coefficients

	W^-	W^+	Z
W^-	1	0.93	0.18
W^+		1	0.19
Z			1

- Combination of the W^+, W^- and *Z* fiducial cross sections is performed to improve the precision
- Combination is performed with HERAverager tool
- Results agree well with Standard Model expectations

arXiv:1603.09222

W and Z Cross Sections Measurements at 13 TeV

- Total and fiducial cross-sections (**combined results**):

→ Electron and muon channels are combined at Born level using χ^2 minimization technique
The combination yields a good $\chi^2/N_{d.f.}$ = 3.0 / 3

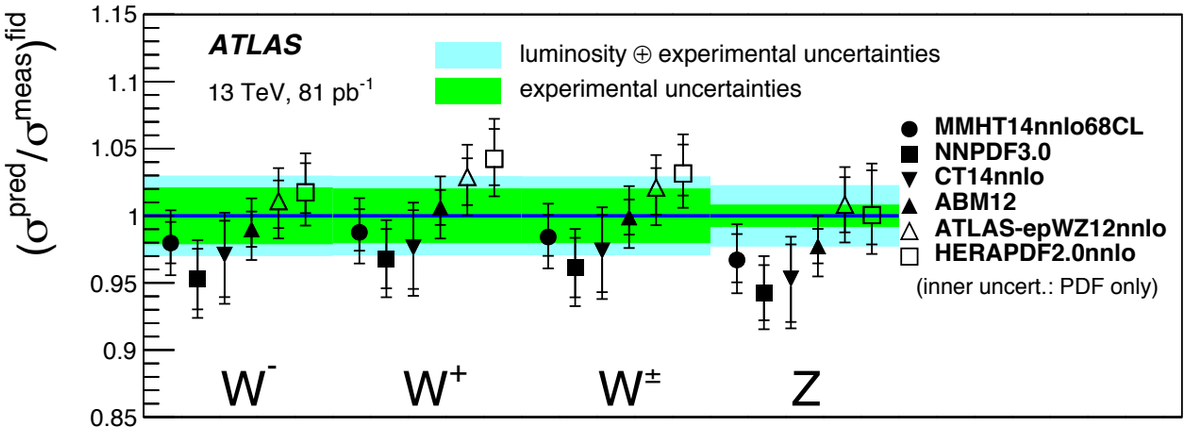
Fiducial cross sections

Channel	value (pb) ± stat (pb) ± syst (pb) ± lumi (pb)
W^-	3497.9 ± 6.2 ± 72.7 ± 73.5
W^+	4530.8 ± 7.1 ± 90.7 ± 95.1
$W^\pm$	8028.7 ± 9.5 ± 160.7 ± 168.6
Z	778.6 ± 2.8 ± 5.6 ± 16.4

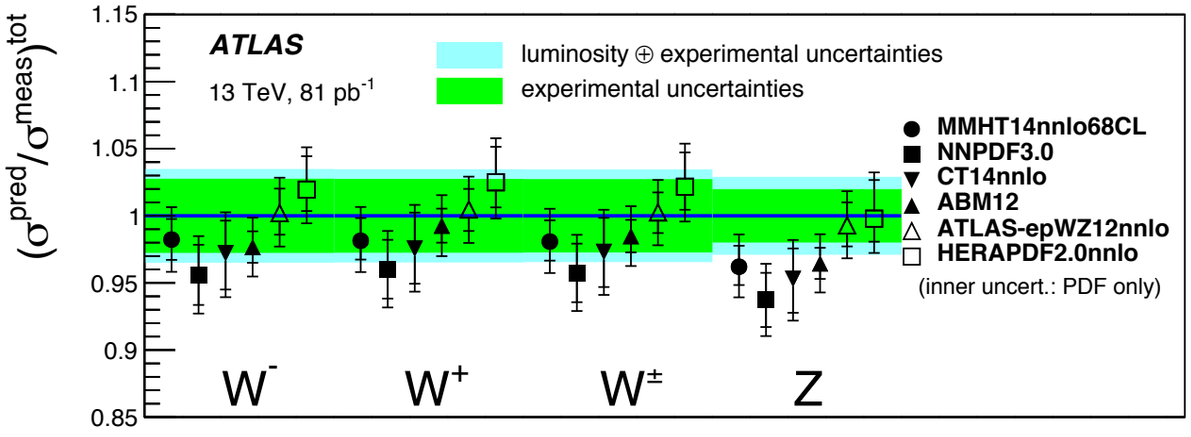
Total cross sections

Channel	value (pb) ± stat (pb) ± syst (pb) ± lumi (pb)
W^-	8788.7 ± 15.7 ± 239.3 ± 184.6
W^+	11829.8 ± 18.6 ± 320.7 ± 248.4
$W^\pm$	20639.3 ± 24.4 ± 555.6 ± 433.4
Z	1981.2 ± 7.0 ± 38.1 ± 41.6

Fiducial cross sections ratios (predicted to measured)



Total cross sections ratios (predicted to measured)



- DYNNLO1.5 is used for the central values of the predictions

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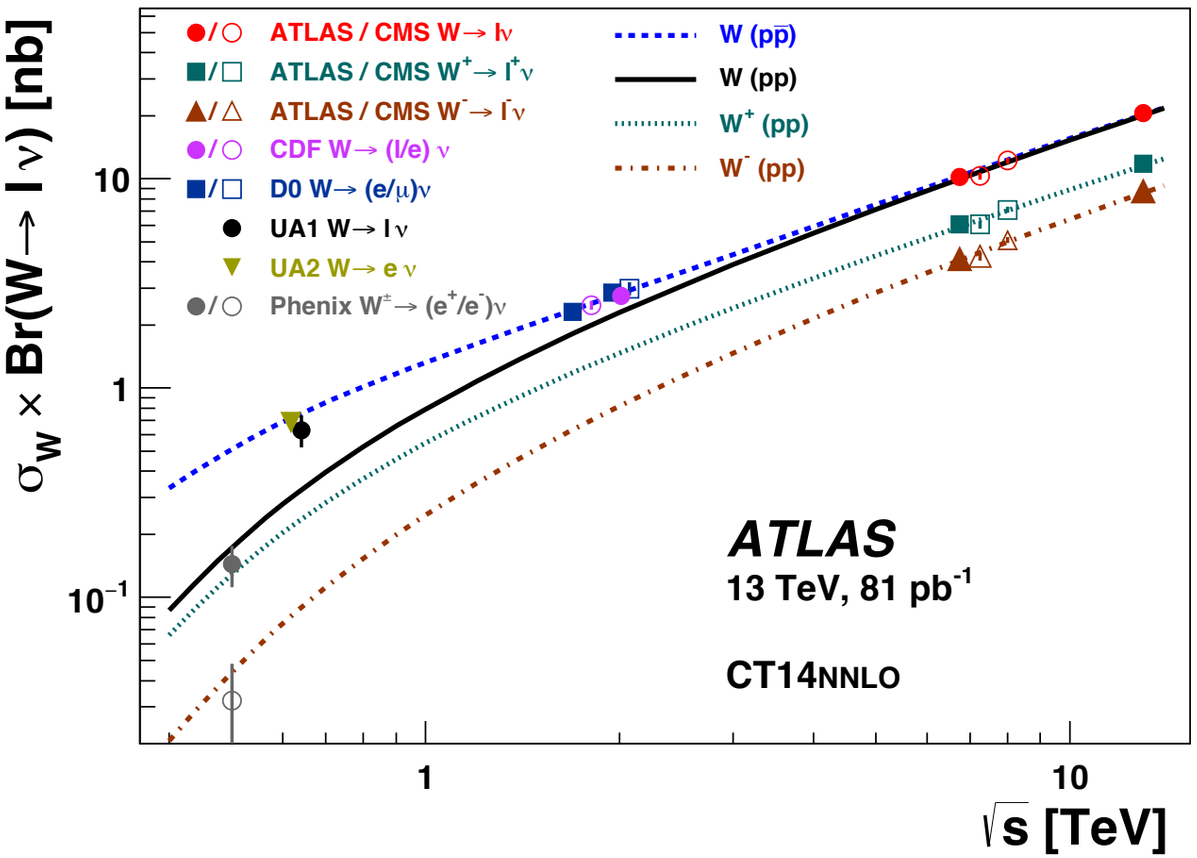
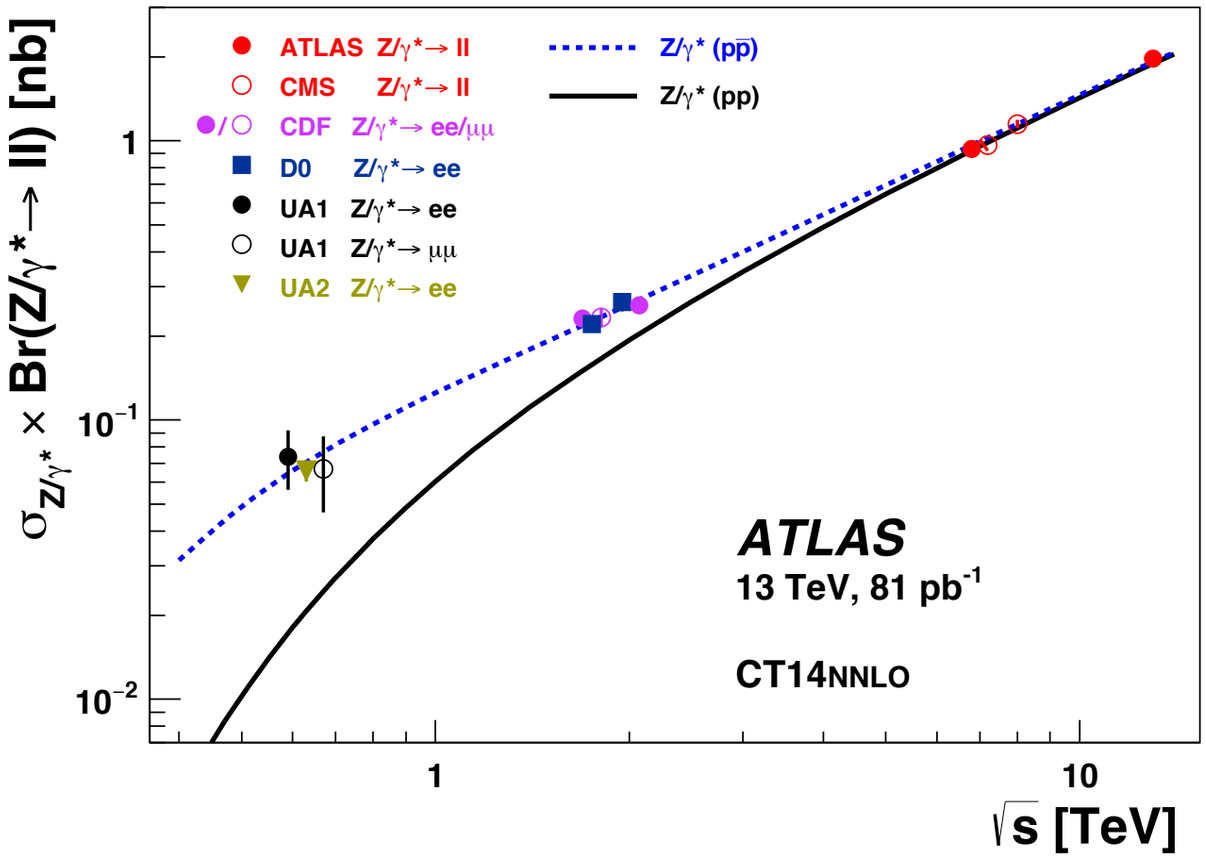
W and Z Cross Sections Measurements at 13 TeV

$\sigma_W \times Br(W \to l\nu)$



$\sigma_Z \times Br(Z/\gamma^* \to ll)$



- Measured energy dependence of the total W and Z production cross sections is in good agreement with theoretical predictions
- NNLO QCD and NLO EW predictions calculated using CT14nnlo PDF with the FEWZ
- All data points displayed with their total uncertainty
- Theoretical uncertainties on the cross section predictions are not shown

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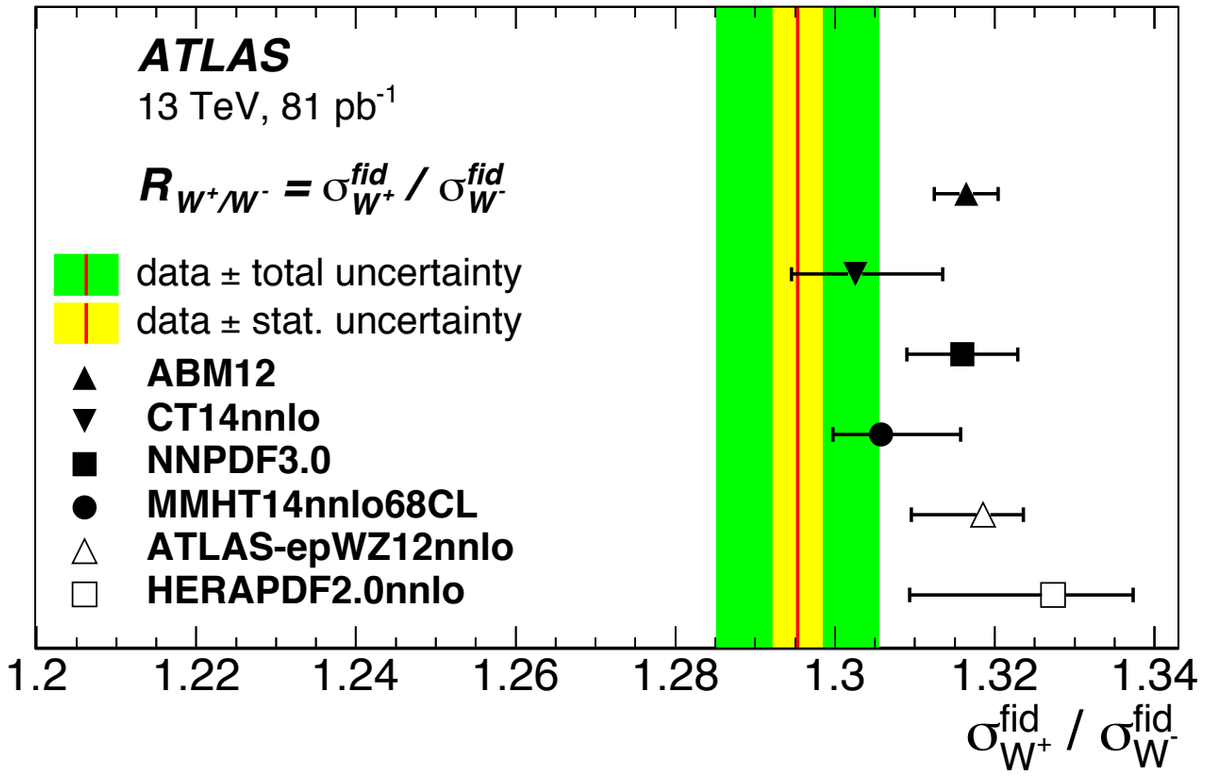
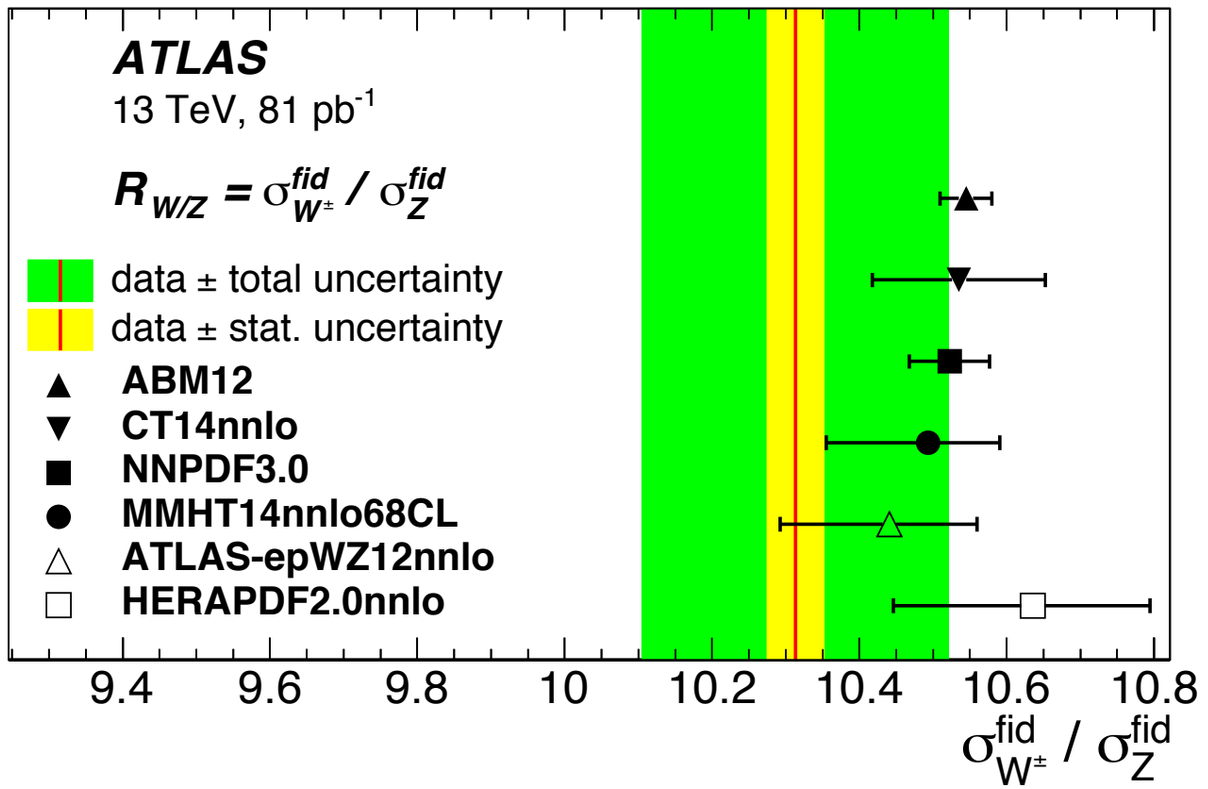
W and Z Cross Sections Measurements at 13 TeV

- **Fiducial cross-sections ratios:**





- Complete **cancellation of luminosity uncertainty** and partial cancellation of **lepton-ID and trigger systematic**
- W^+ to W^- cross sections ratio is sensitive to the difference of u_v and d_v valence-quark distributions at low Bjorken-x
- $W^\pm$ to Z ratio is sensitive to **strange-quark** distribution
- Dominant source of uncertainty in W^+ to W^- ratio is from **uncorrelated part of multi-jet bkg**.
- Dominant source of uncertainty in $W^\pm$ to Z is **multi-jet bkg. and jet energy scale/resolution**

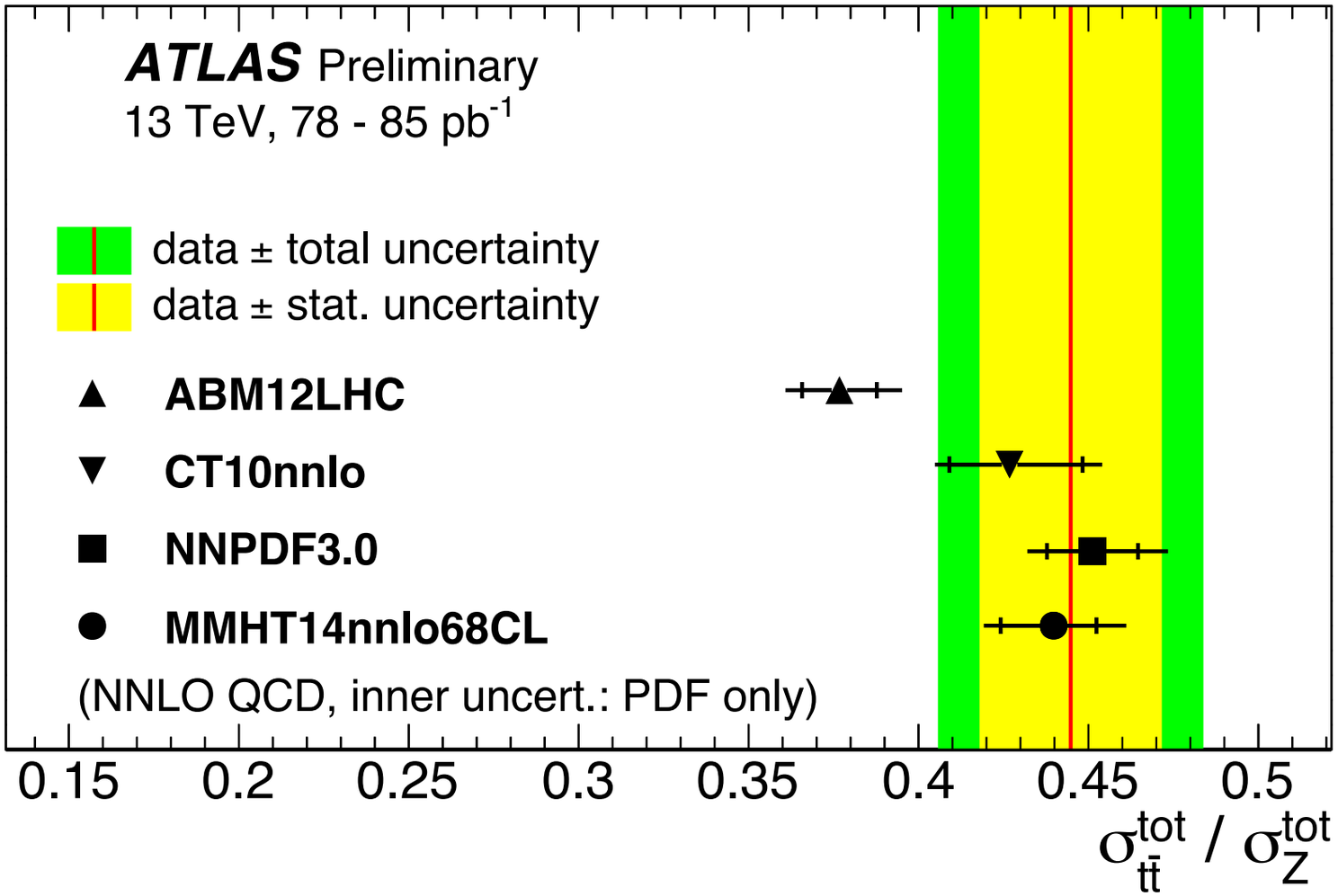
arXiv:1603.09222

$t\bar{t}$ / Z Cross Sections Ratio at 13 TeV

- $t\bar{t}$ production dominated by gg process while Z production is more sensitive to $q\bar{q}$

$\longrightarrow$ $R_{t\bar{t}/Z}$ **provide constraints on the ratio of gluon to sea-quark parton distributions in the proton**

- **Total cross-sections ratio:** $R_{t\bar{t}/Z} = \dfrac{\sigma_{t\bar{t}}}{0.5\left(\sigma_{Z\to ee} + \sigma_{Z\to\mu\mu}\right)}$



$$R_{t\bar{t}/Z} = 0.445 \pm 0.027(stat) \pm 0.028(syst) = 0.445 \pm 0.039$$

Uncertainty cancellation

Uncertainty (%)	$\sigma_{Z\to ee}$	$\sigma_{Z\to\mu\mu}$	$\sigma_{t\bar{t}}$	$R_{t\bar{t}/Z}$
Data statistics	0.5	0.5	6.0	6.0
$t\bar{t}$ NLO modelling	-	-	2.2	2.2
$t\bar{t}$ hadronisation	-	-	4.5	4.5
Initial/final state radiation	-	-	1.2	1.2
Parton distribution functions ($t\bar{t}$, Wt)	-	-	1.4	1.4
Single-top modelling	-	-	0.5	0.5
Single-top/$t\bar{t}$ interference	-	-	0.1	0.1
Single-top Wt cross-section	-	-	0.5	0.5
Diboson modelling	-	-	0.1	0.1
Diboson cross-sections	-	-	0.0	0.0
Z+jets extrapolation	-	-	0.2	0.2
Electron energy scale/resolution	0.2	-	0.2	0.1
Electron identification	3.8	-	3.2	1.3
Electron charge identification	0.8	-	-	0.4
Electron isolation	1.0	-	1.1	1.2
Muon momentum scale/resolution	-	0.1	0.1	0.0
Muon identification	-	0.9	0.5	0.1
Muon isolation	-	0.5	1.1	1.1
Lepton trigger	0.5	1.1	0.8	0.7
Jet energy scale	-	-	0.3	0.3
Jet energy resolution	-	-	0.1	0.1
b-tagging	-	-	0.3	0.3
Misidentified leptons	-	-	1.4	1.4
Pileup modelling	0.9	0.9	-	0.9
Z acceptance	1.5	1.5	-	1.5
Z backgrounds	0.1	0.1	-	0.1
Analysis systematics	4.4	2.3	6.7	6.3
Integrated luminosity	9.0	9.0	10.0	1.0
Total uncertainty	10.0	9.3	13.5	8.8

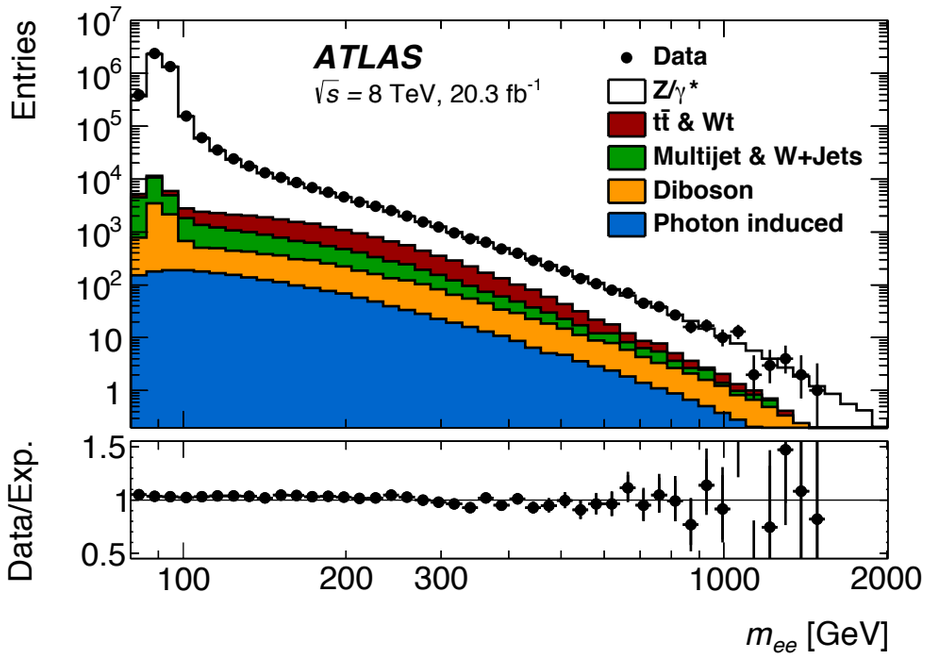
ATLAS-CONF-2015-049

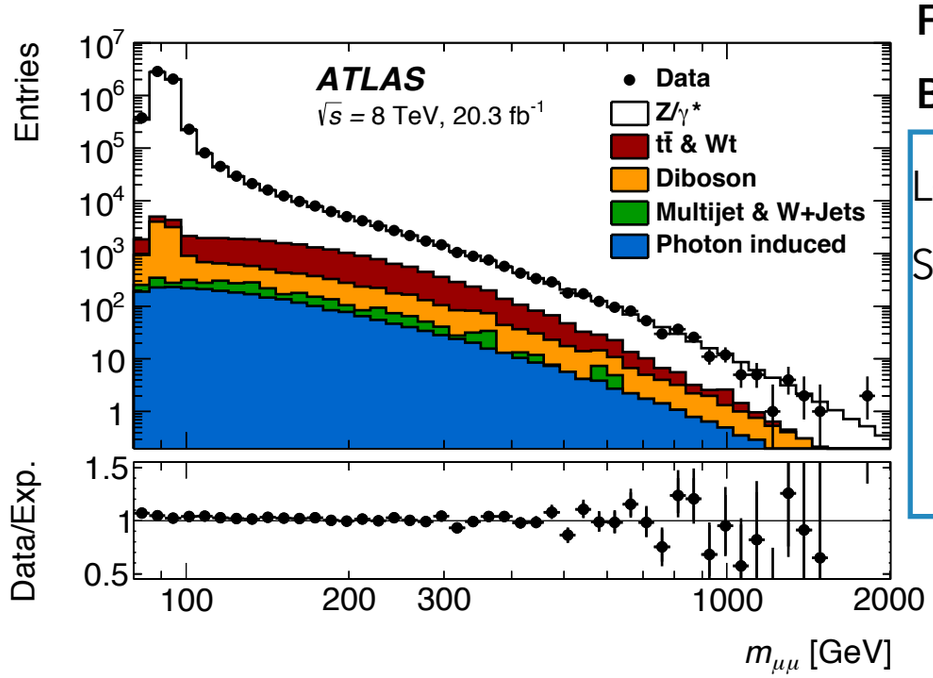
Summary

- **High mass DY measurement at 8 TeV:**
  - Combined cross sections achieve an experimental **precision of better than 1%** at low $m_{\ell\ell}$, excluding the overall luminosity uncertainty of 1.9%
  - Theoretical uncertainties arising from PDFs are found to be larger than the measurement uncertainties, indicating **potential for proton PDF constraints**
  - Bayesian reweighting (using data) method showed **dramatic reduction of the uncertainties on the photon PDF**
- **W / Z cross sections ratio:**
  - Extracted with a precision of few % (cancellation of several experimental uncertainties and luminosity uncertainty)
  - The measurements agree well with the predictions and the experimental precision is comparable to the PDF uncertainties (**potential constraining power**)
- **$t\bar{t}$ / Z cross sections ratio:**
  - Provides constrain on the ratio of gluon to sea-quark parton distribution

Backup slides

High mass Drell-Yan at 8 TeV





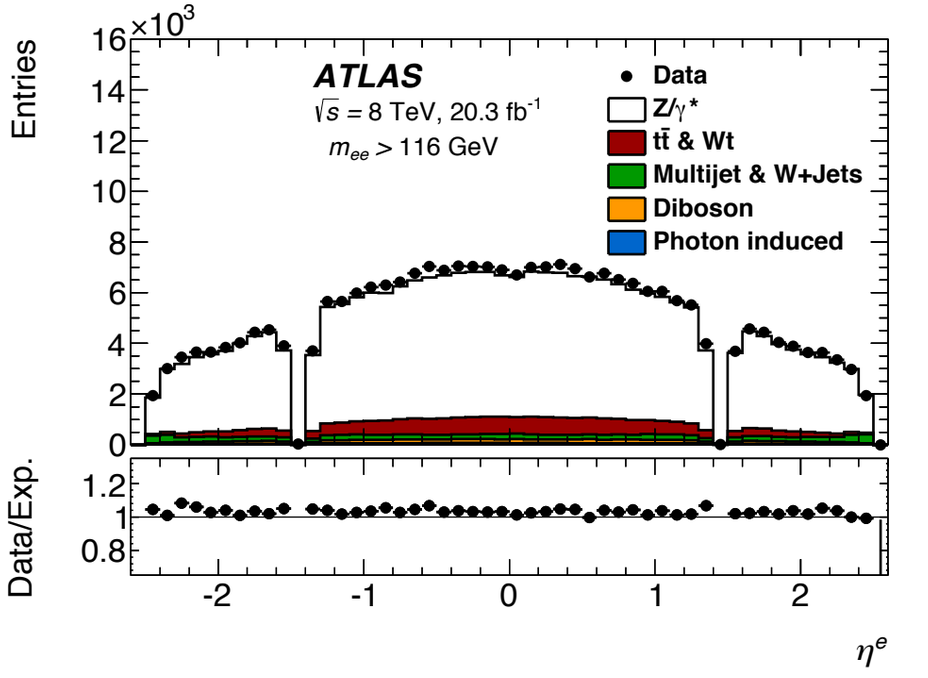
Fiducial volume defined at the Born-level:

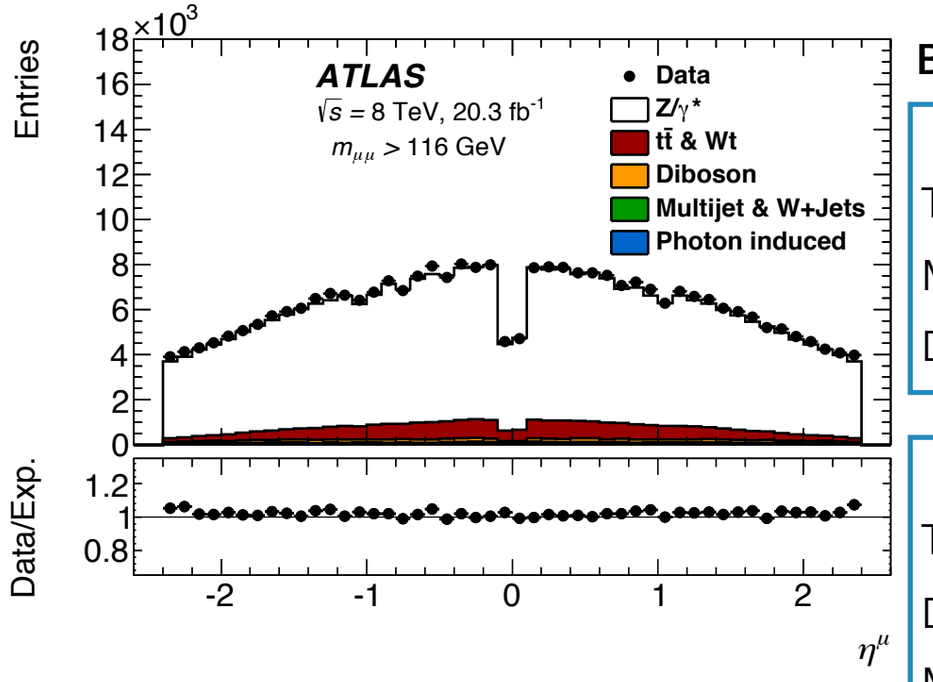
Leading lepton: $p_T^\ell > 40\ GeV$

Subleading lepton: $p_T^\ell > 30\ GeV$

$$|\eta^\ell| < 2.5$$

$$116 < m_{\ell\ell} < 1500 GeV$$





Background contribution:

Electron channel

Top quark: 9%

Multijet: 4%

Diboson: 2%

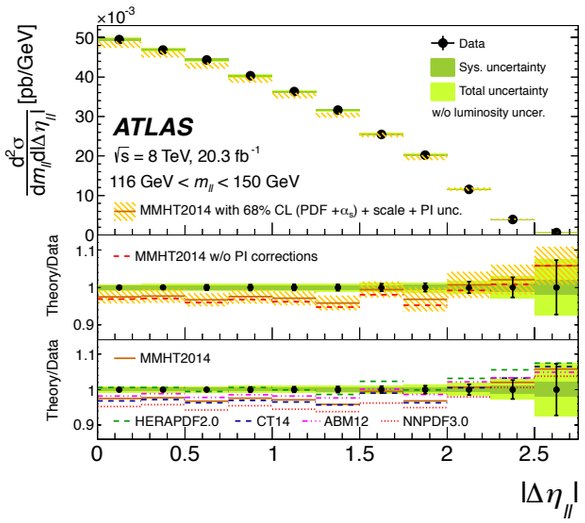
Muon channel

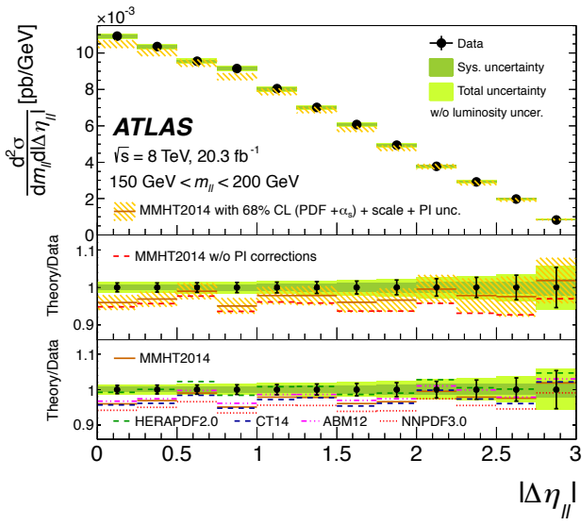
Top quark: 9%

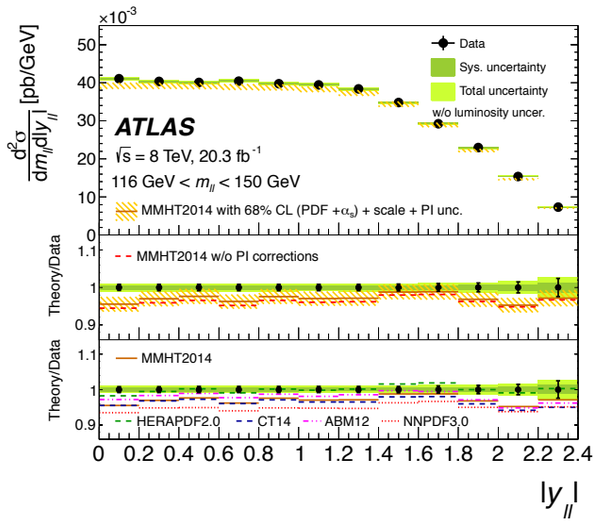
Diboson: 2%

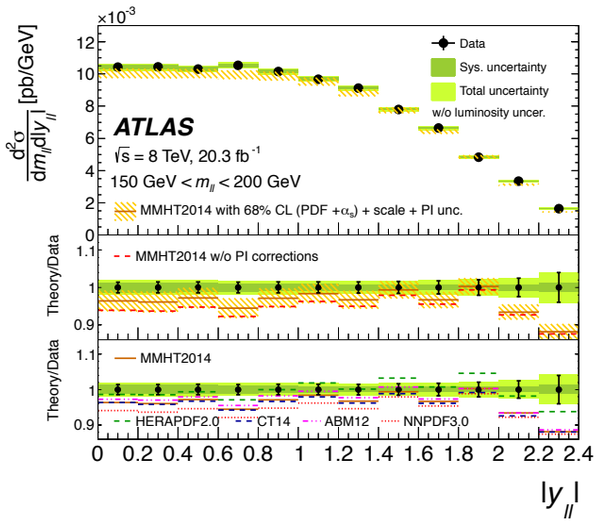
Multijet: < 1%

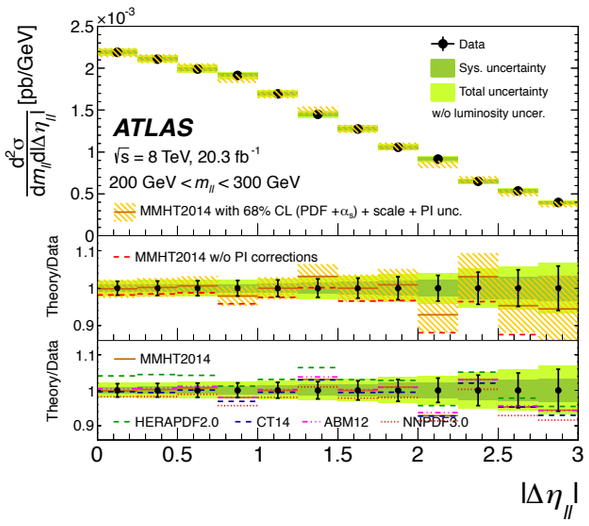
High mass Drell-Yan at 8 TeV

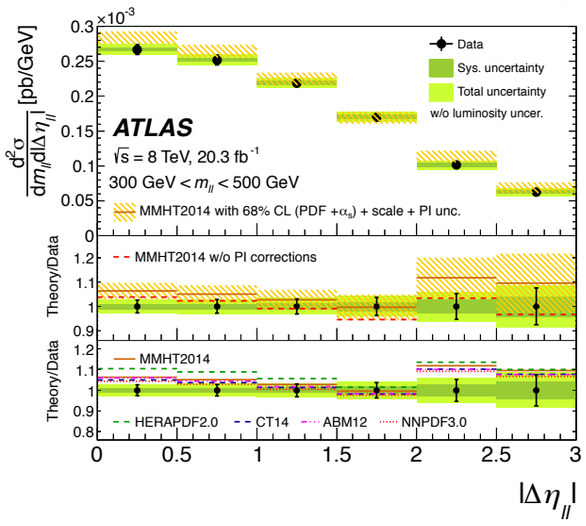


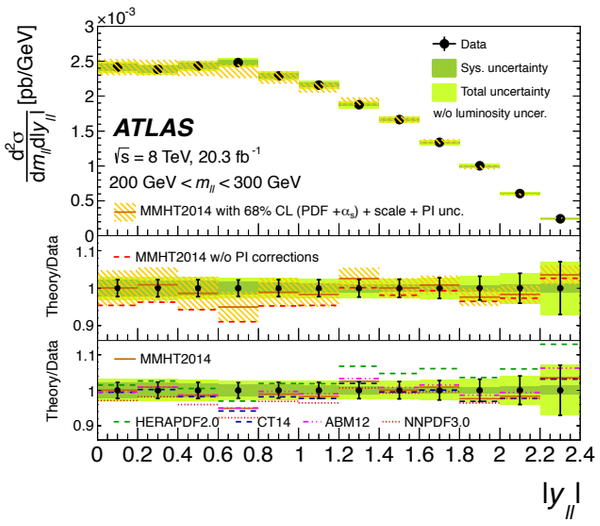


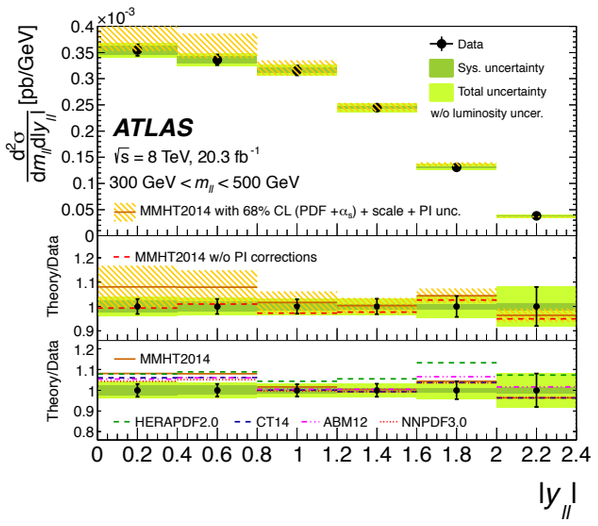


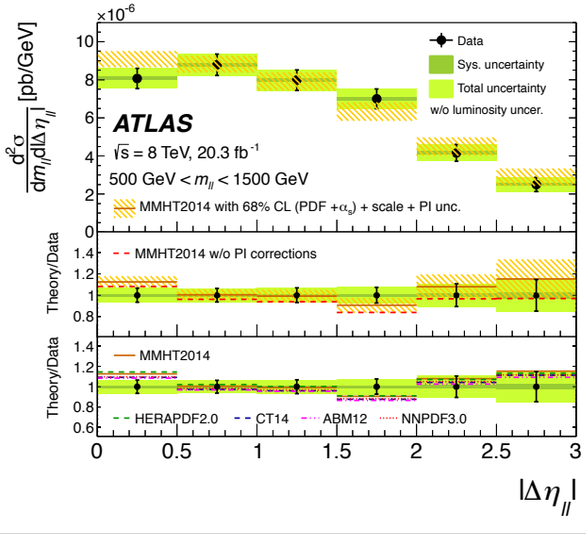


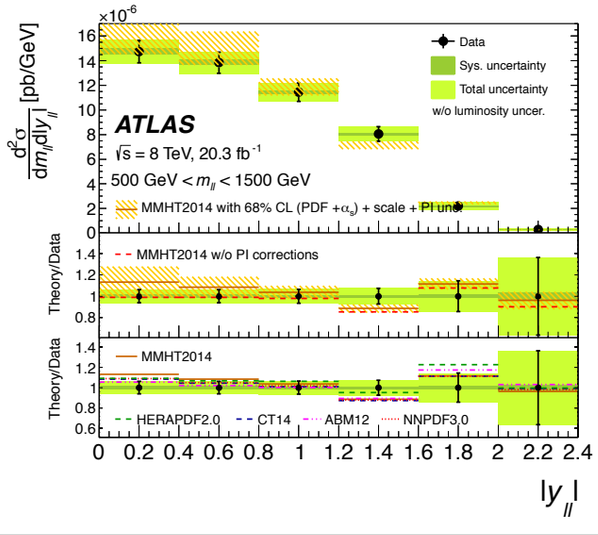












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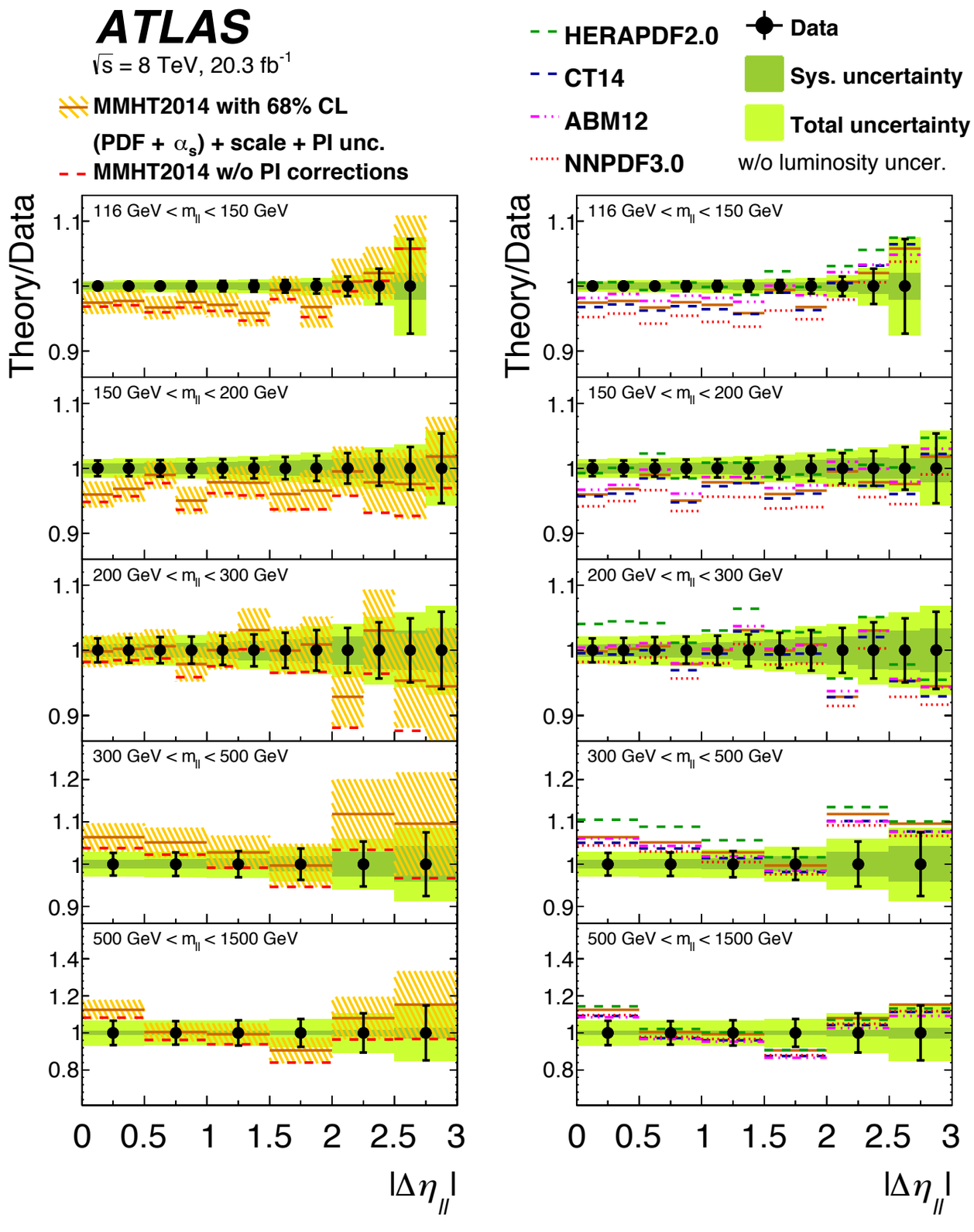

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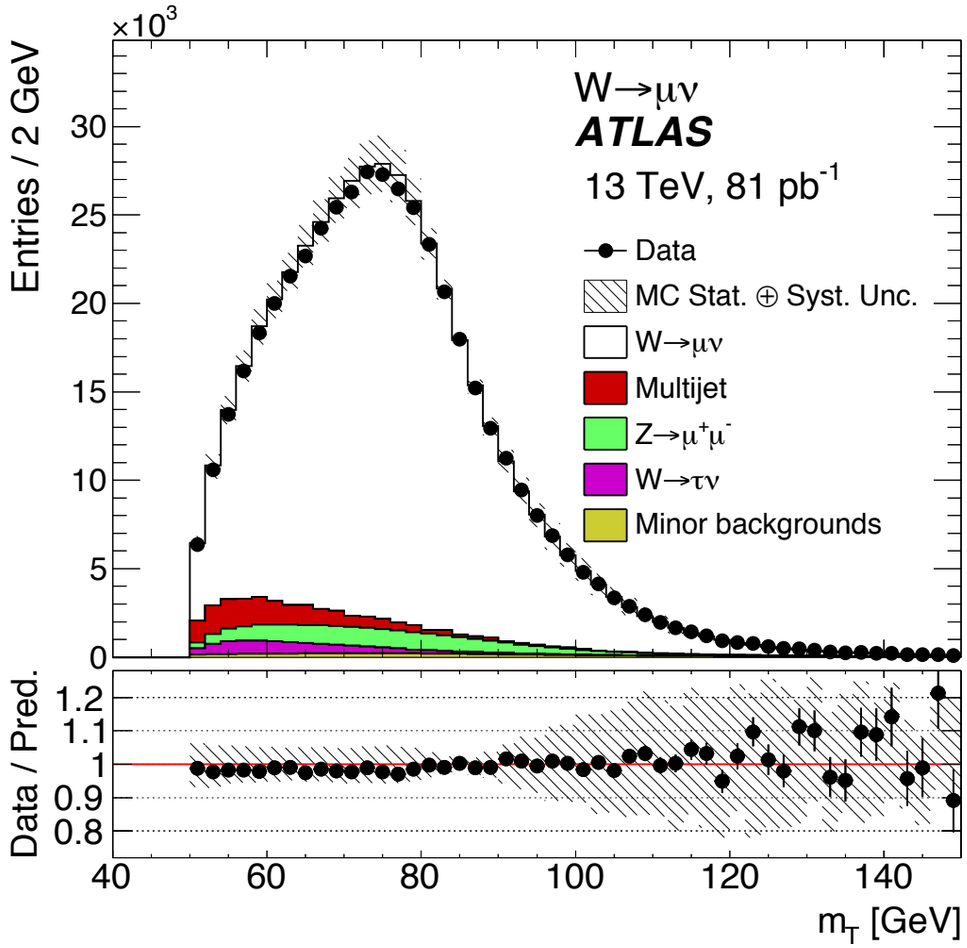
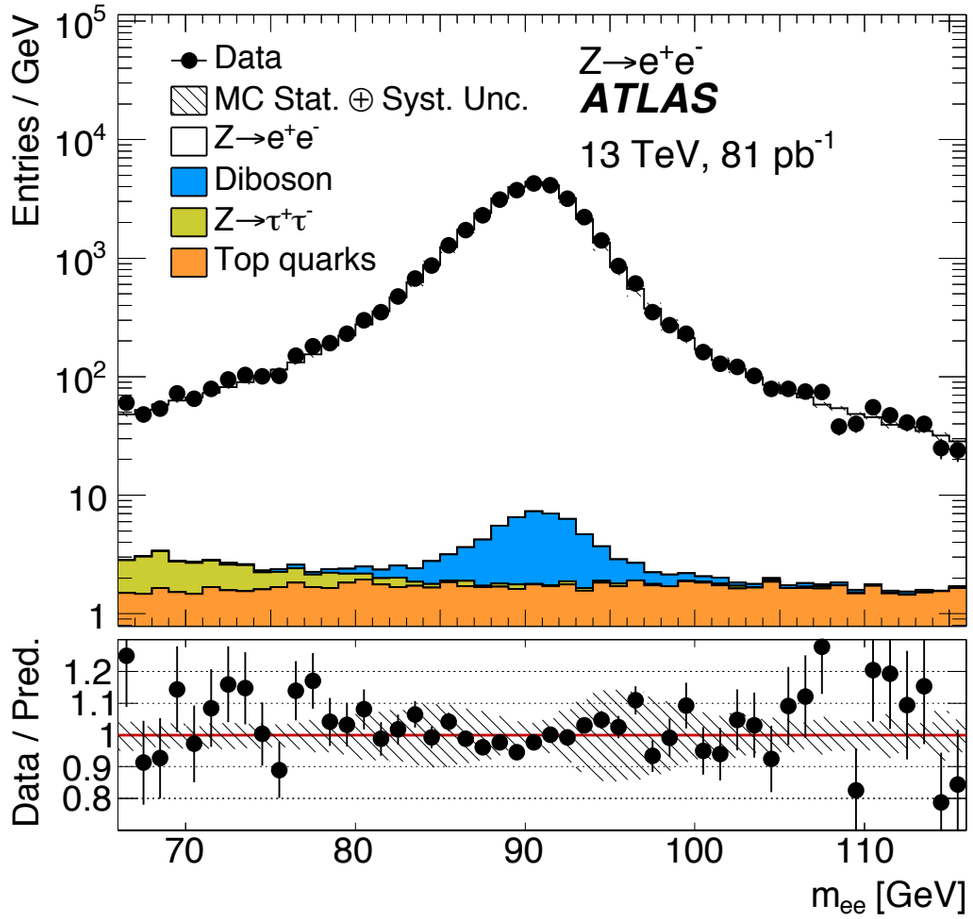




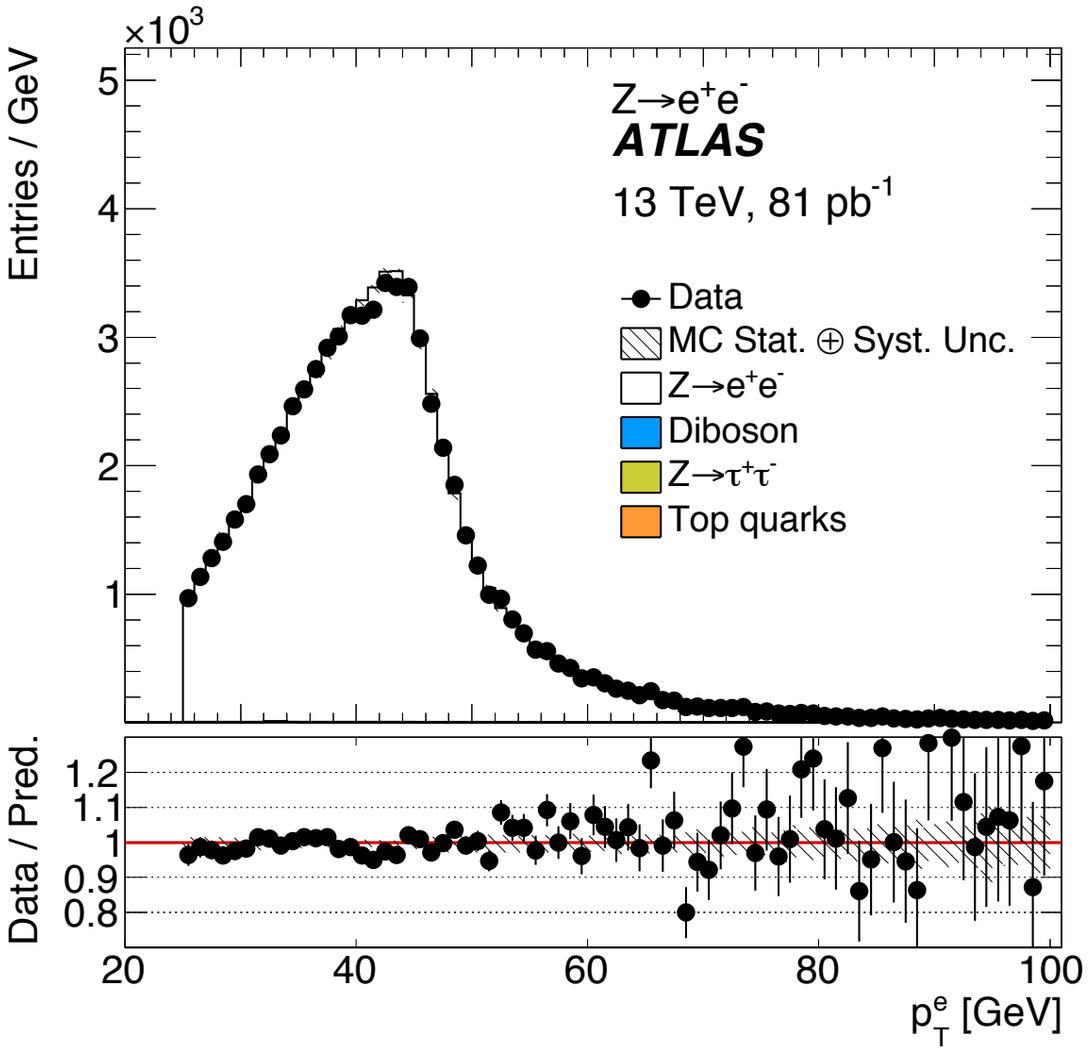
Z channels : $t\bar{t}$ - 0.24% for electron and muon channels

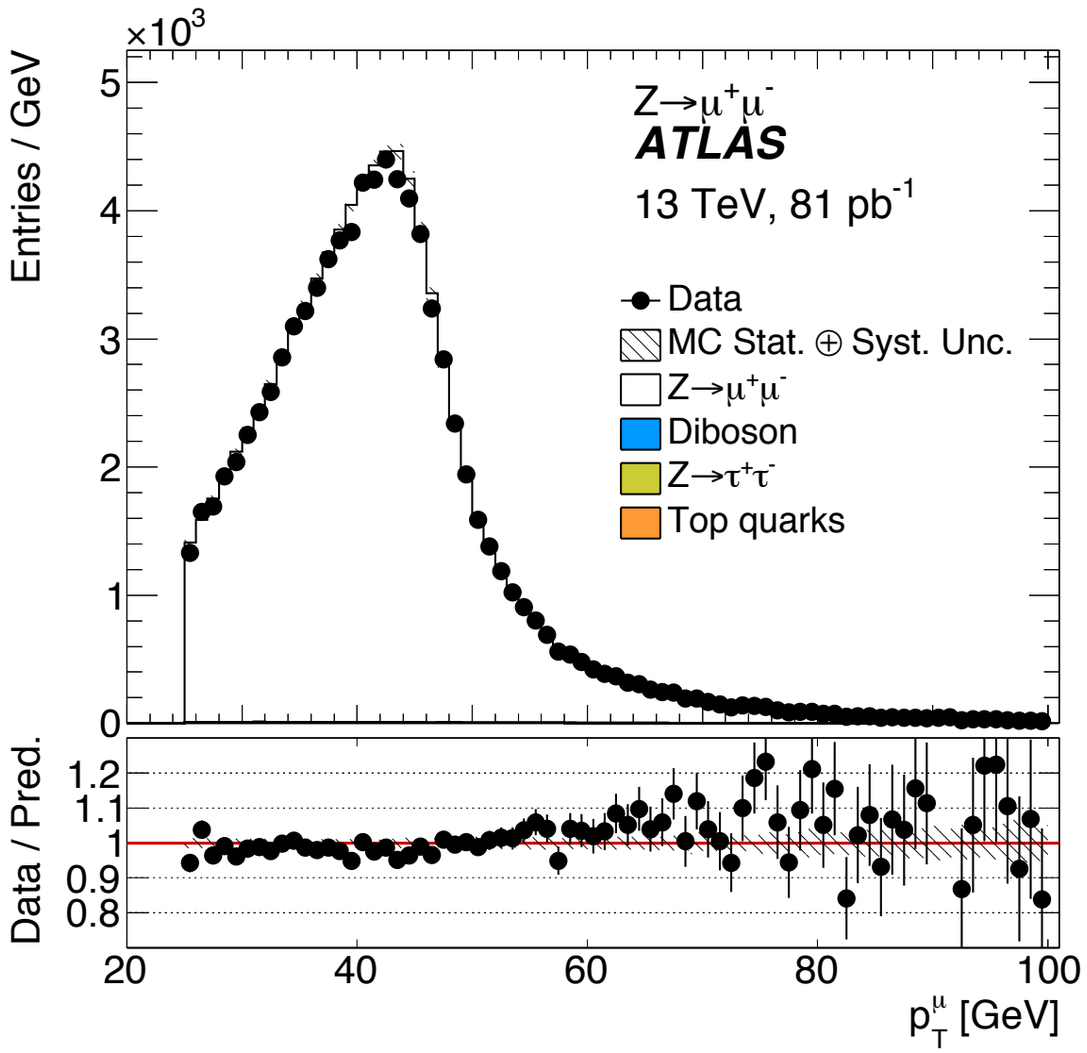
W channels multi-jet:

8% and 10% for W^+ and W^- in electron channel

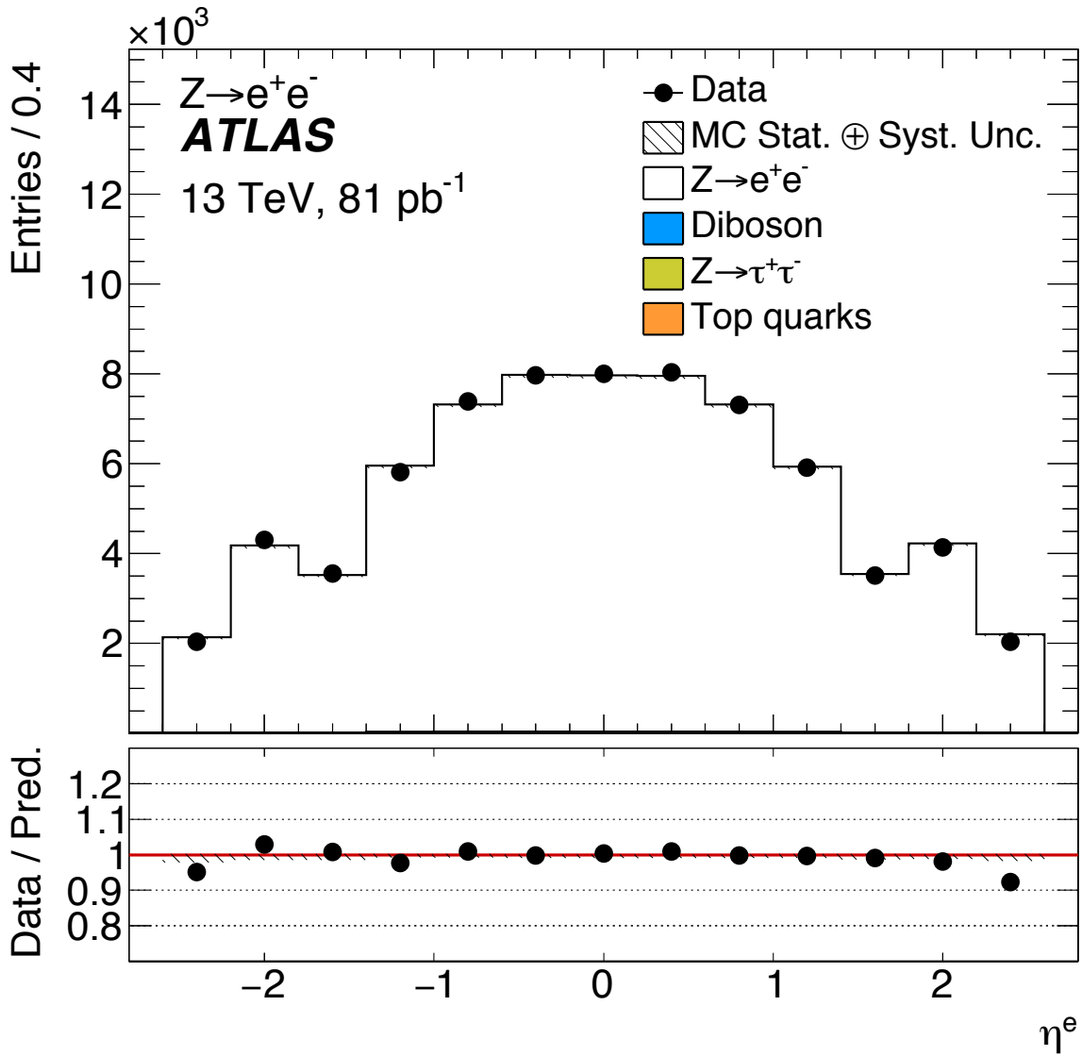
3.5% and 4% for W^+ and W^- in muon channel

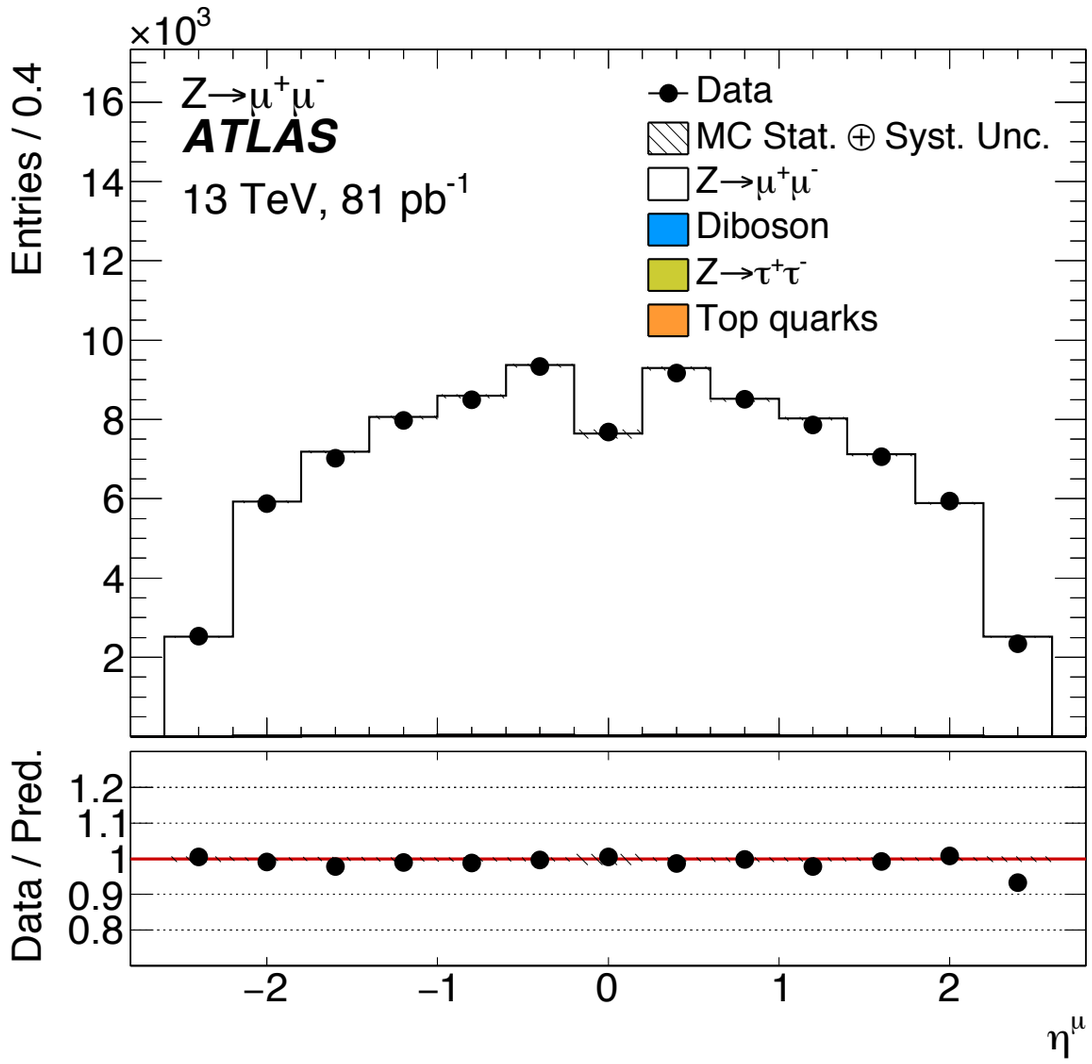
W and Z Cross Sections Measurements at 13 TeV





W and Z Cross Sections Measurements at 13 TeV





W and Z Cross Sections Measurements at 13 TeV

	W^+	W^-	Z
	Electron channel (value ± stat ± syst ± lumi)		
Signal events	228060 ± 510 ± 4920 ± 200	177890 ± 450 ± 6110 ± 180	34865 ± 187 ± 7 ± 3
Correction C	0.602 ± 0.012	0.614 ± 0.012	$0.552\ ^{+0.006}_{-0.005}$
σ^{fid}[nb]	4.68 ± 0.01 ± 0.14 ± 0.10	3.58 ± 0.01 ± 0.14 ± 0.08	0.781 ± 0.004 ± 0.008 ± 0.016
Acceptance A	0.383 ± 0.007	0.398 ± 0.007	0.393 ± 0.007
σ^{tot}[nb]	12.23 ± 0.03 ± 0.42 ± 0.27	9.00 ± 0.02 ± 0.39 ± 0.20	1.987 ± 0.011 ± 0.041 ± 0.042
	Muon channel (value ± stat ± syst ± lumi)		
Signal events	237720 ± 520 ± 2210 ± 410	183180 ± 460 ± 2520 ± 360	44706 ± 212 ± 9 ± 4
Correction C	0.653 ± 0.012	0.650 ± 0.012	0.711±0.008
σ^{fid}[nb]	4.50 ± 0.01 ± 0.09 ± 0.10	3.48 ± 0.01 ± 0.08 ± 0.08	0.777 ± 0.004 ± 0.008 ± 0.016
Acceptance A	0.383 ± 0.007	0.398 ± 0.007	0.393 ± 0.007
σ^{tot}[nb]	11.75 ± 0.03 ± 0.33 ± 0.27	8.75 ± 0.02 ± 0.25 ± 0.20	1.977 ± 0.009 ± 0.041 ± 0.042

- **Cross-section definition:** $\sigma^{tot} = \frac{\sigma^{fid}}{A} = \frac{N-B}{A \cdot C \cdot \mathcal{L}}$
- **Main systematic sources:**

$Z \to ee, \mu\mu$: lepton reco. and id. (0.9%)

$W^{\pm} \to e^{\pm}\nu, \mu^{\pm}\nu$: jet energy scale and resolution (~ 1.7%)