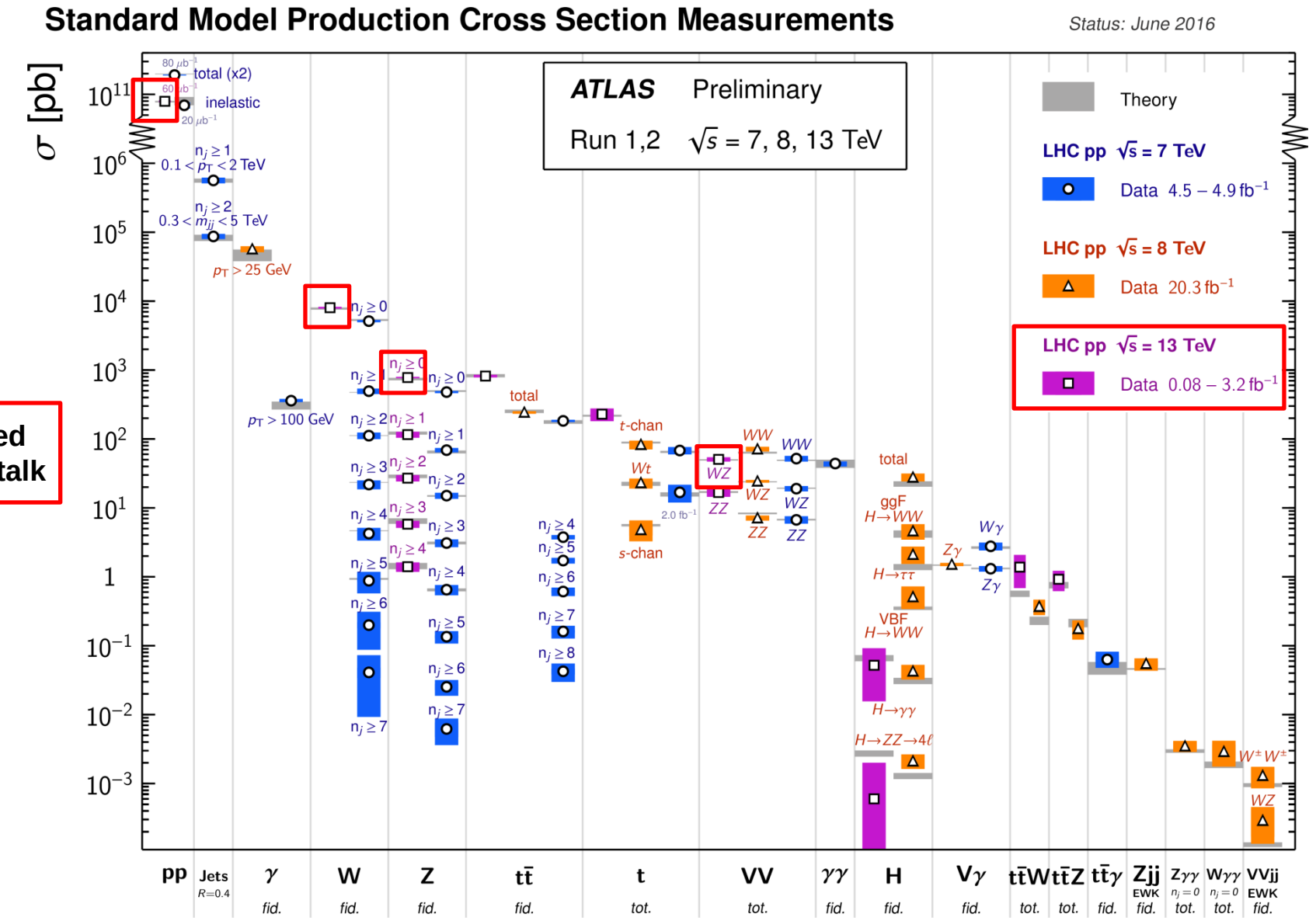
Recent ATLAS Standard Model results at 13 TeV

Mateusz Dyndal
(on behalf of the ATLAS collaboration)

4 July 2016

Outline

covered in this talk



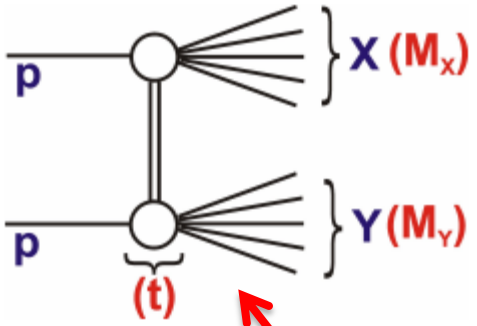
Outline

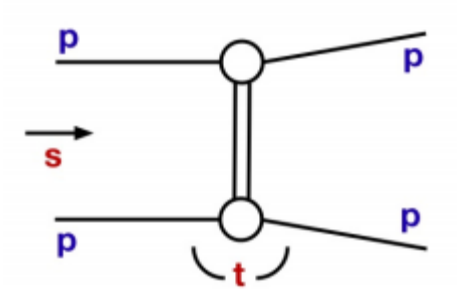
- Measurement of the Inelastic Proton-Proton Cross Section at 13 TeV
  - **arXiv:1606.02625**
  - Fiducial and total cross sections
- Measurement of $W^{\pm}$ and Z-boson production cross sections at 13 TeV
  - **arXiv:1603.09222**
  - Fiducial and total cross sections + ratios
- Measurement of $W^{\pm}Z$ boson pair-production cross section at 13 TeV
  - **arXiv:1606.04017**
  - Fiducial and total cross sections + ratios
  - N_{jet} differential cross sections
- **Results are updated for improved luminosity uncertainty (1.9 - 2.1%)**

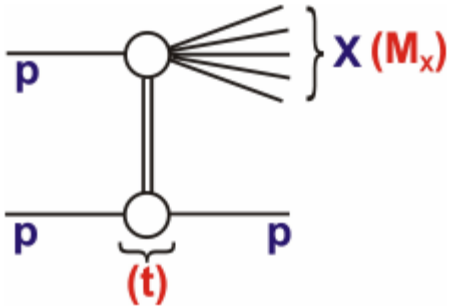
1. Inelastic pp Cross Section at 13 TeV

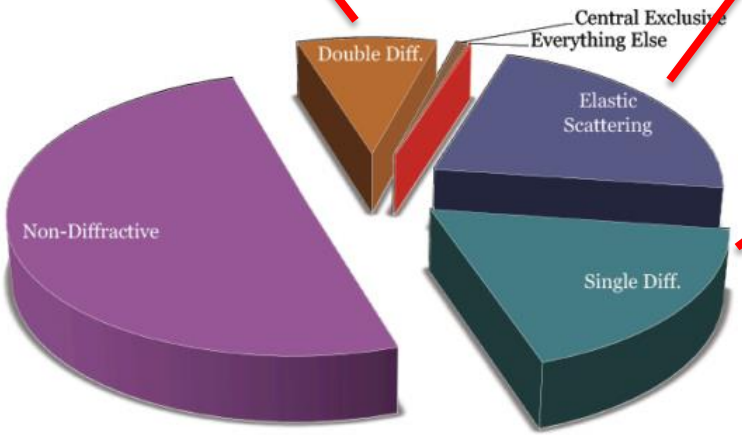
Inelastic pp Cross Section at 13 TeV

- **Total pp cross section decomposition**



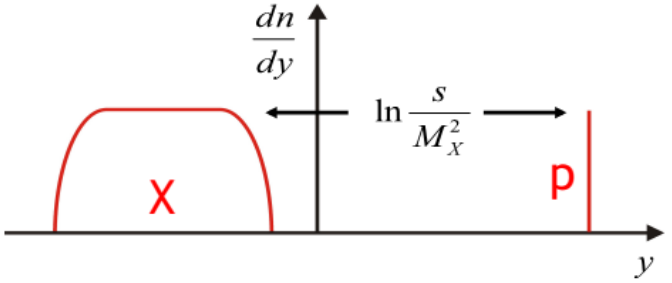






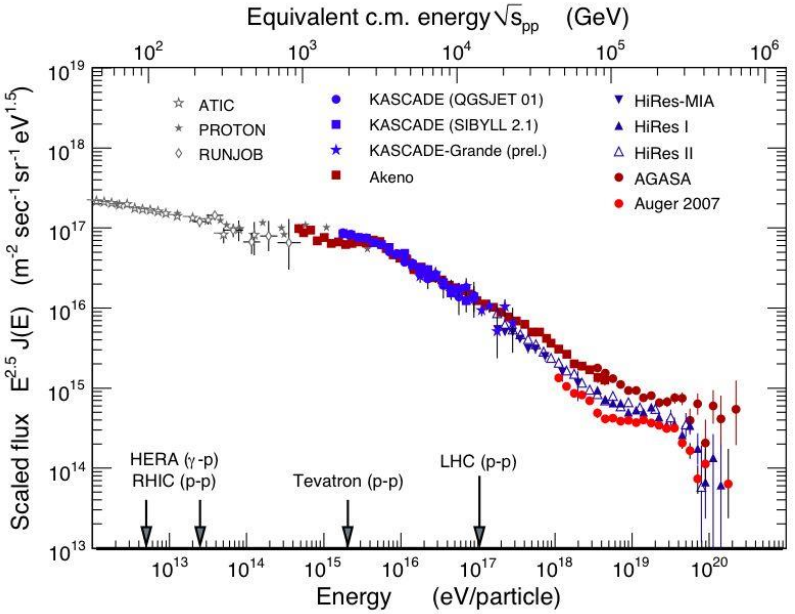
Rapidity gap kinematics: $\xi = \frac{M_X^2}{s}$

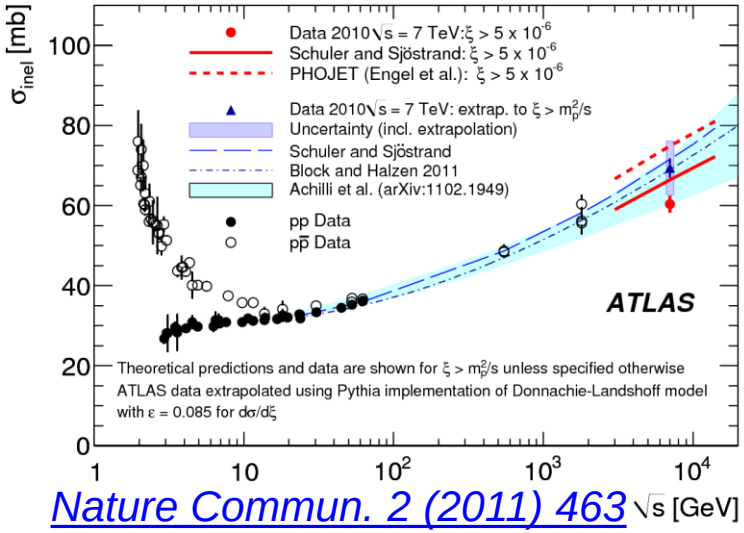
ξ variable is strongly correlated with empty rapidity regions: $\Delta\eta \approx -\ln\xi$



Inelastic pp Cross Section at 13 TeV

- **Motivation**
- Crucial quantity for understanding cosmic ray air showers (direct relation with total pp cross section)
- At LHC: pile-up modelling
- Idea for 13 TeV measurement: repeat 7 TeV procedure (MBTS) using short low pile-up run ($\mu \sim 10^{-3}$)

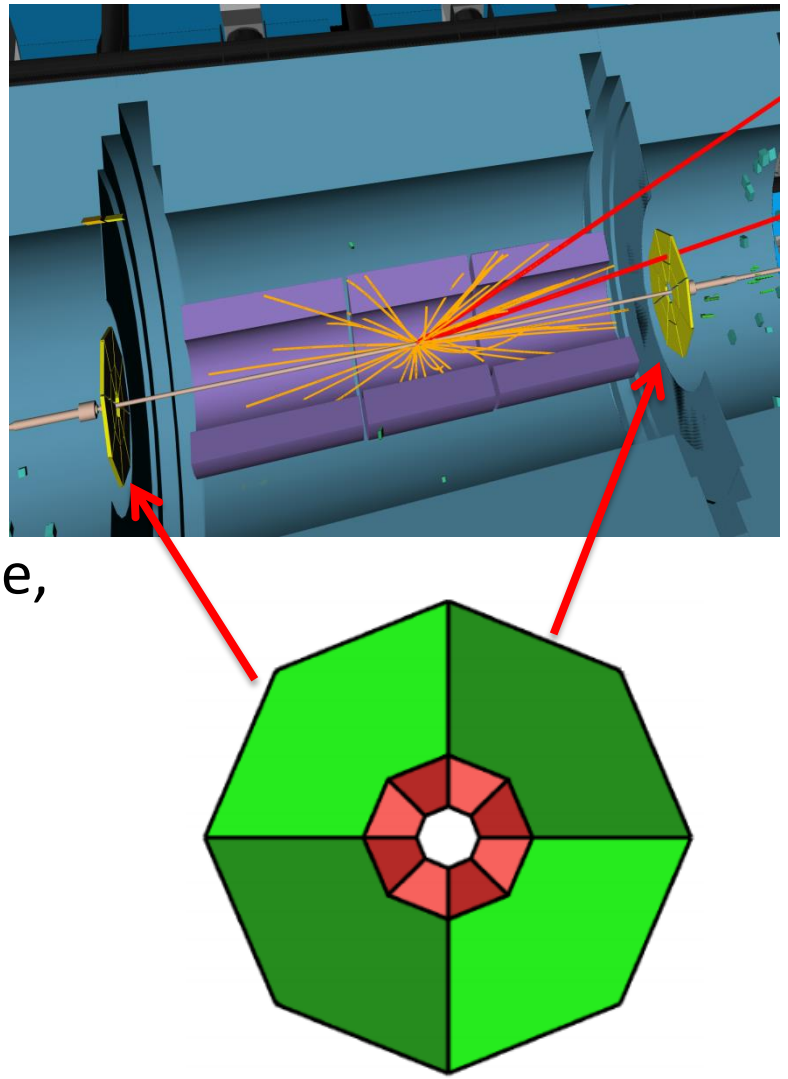




Nature Commun. 2 (2011) 463

Inelastic pp Cross Section at 13 TeV

- **MBTS detectors**

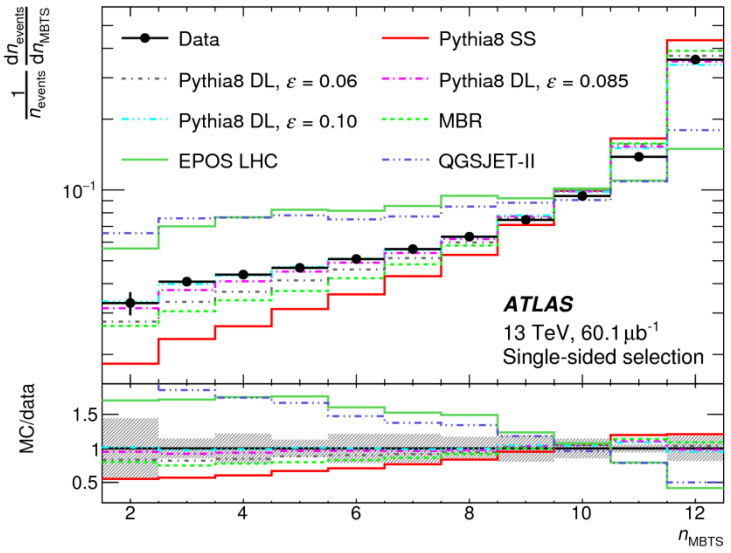


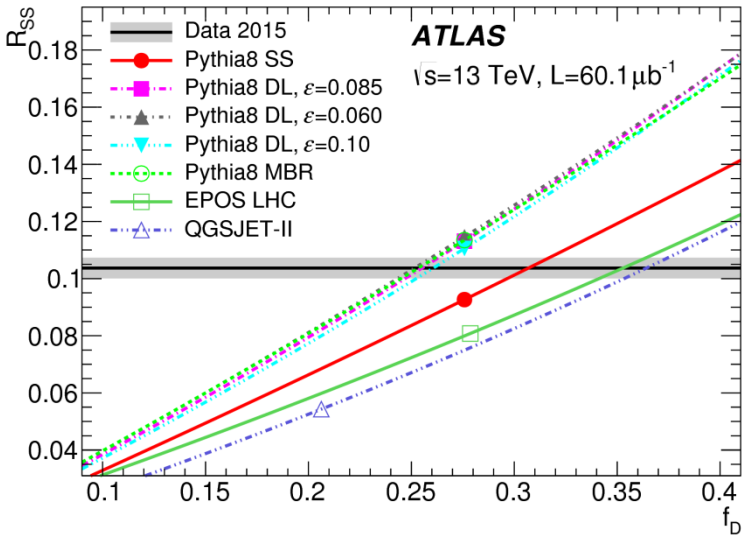
- Plastic scintillation counters
- Cover the region $2.1 < |\eta| < 3.8$
- Rebuilt for run-2:
  2 x 8-fold segmentation ->
  8-fold segmentation nearest beam-pipe,
  4-fold for further out
- Acceptance limit of MBTS
  corresponds to $\xi \sim 10^{-6}$
  -> **M_X > 13 GeV**
  -> MBTS 'sees' ~ 90% of all
  inelastic events
- Inclusive selection: ≥ 2 hits above a threshold of 0.15 pC

Inelastic pp Cross Section at 13 TeV

- **Diffractive MC models benchmarking**

- Additional single-sided selection (and the ratio of events wrt inclusive selection, R_{SS})
  -> sensitivity to SD events modelling
  -> constraining the f_D parameter:
  $f_D = (\sigma_{SD} + \sigma_{DD})/\sigma_{inel}$
  -> this is used to adjust the diffractive models
- f_D between 25% and 31% is favoured
- Pythia8 with DL pomeron flux is the baseline model for the analysis





Inelastic pp Cross Section at 13 TeV

- **Fiducial cross section extraction**

$$\sigma_{\text{inel}}^{\text{fid}}\left(\xi > 10^{-6}\right) = \frac{N - N_{\text{BG}}}{\epsilon_{\text{trig}} \times \mathcal{L}} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\text{sel}}}$$

Factor	Value	Rel. uncertainty
Number of events passing the inclusive selection (N)	4159074	–
Number of background events (N_{BG})	51187	±50%
Integrated luminosity [μb^{-1}] ($\mathcal{L}$)	60.1	±1.9%
Trigger efficiency (ϵ_{trig})	99.7%	±0.3%
MC correction factor (C_{MC})	99.3%	±0.5%

(updated!)

- N_{BG}: Dominated by beam-gas, radiation & activation; determined using non-colliding bunches
- ε_{trig} : estimated using ID tracks and Calo topoclusters
- $C_{MC} = (1\text{-}f)/\varepsilon_{sel}$: acceptance and migration correction (from MC)

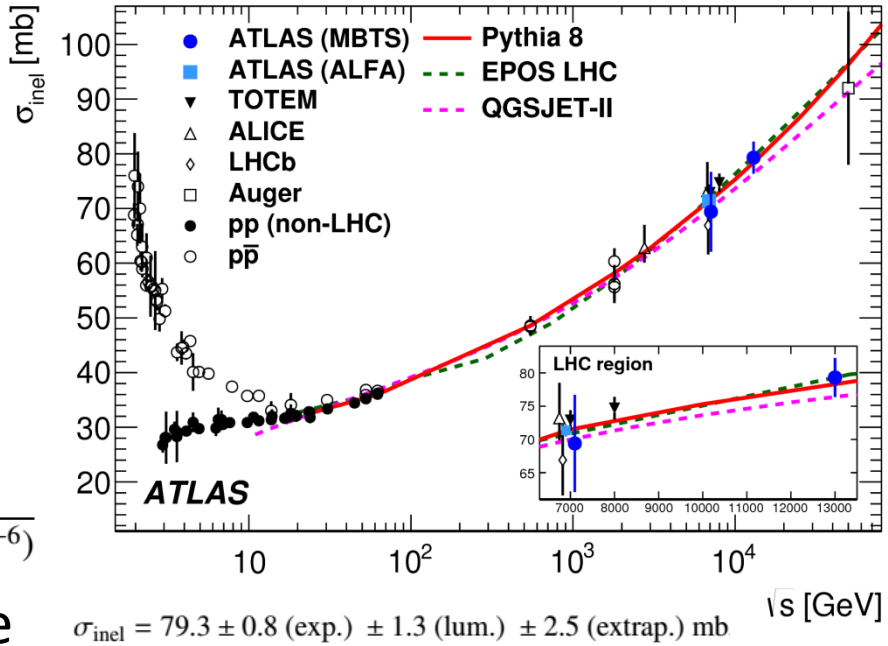
$$\sigma_{\text{inel}}^{\text{fid}} = 68.2 \pm 0.8\ (\text{exp.})\ \pm 1.3\ (\text{lum.})\ \text{mb}$$

Inelastic pp Cross Section at 13 TeV

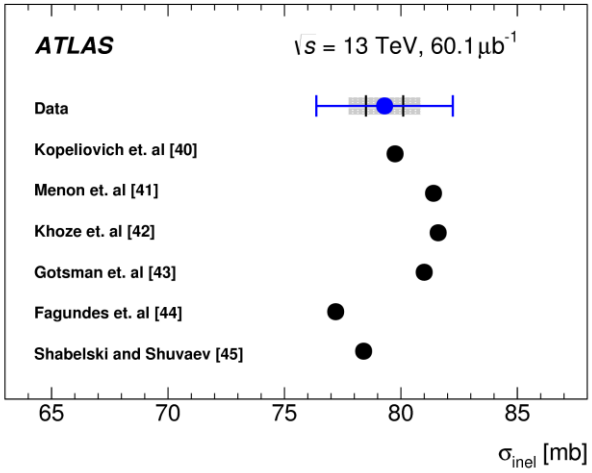
- **Total inelastic cross section estimation**
- Extrapolation in the region with $\xi < 10^{-6}$ uses constraints from 7 TeV measurements:

$$\sigma_{\text{inel}} = \sigma_{\text{inel}}^{\text{fid}} + \sigma^{7\text{ TeV}}(\xi < 5\times10^{-6}) \times \frac{\sigma^{\text{MC}}(\xi < 10^{-6})}{\sigma^{7\text{ TeV, MC}}(\xi < 5\times10^{-6})}$$

- Minimizes the model dependence (initially was done using MC models only)
- Result is consistent (within uncertainties) with various models predictions



$\sigma_{\text{inel}} = 79.3 \pm 0.8\,(\text{exp.}) \pm 1.3\,(\text{lum.}) \pm 2.5\,(\text{extrap.})$ mb

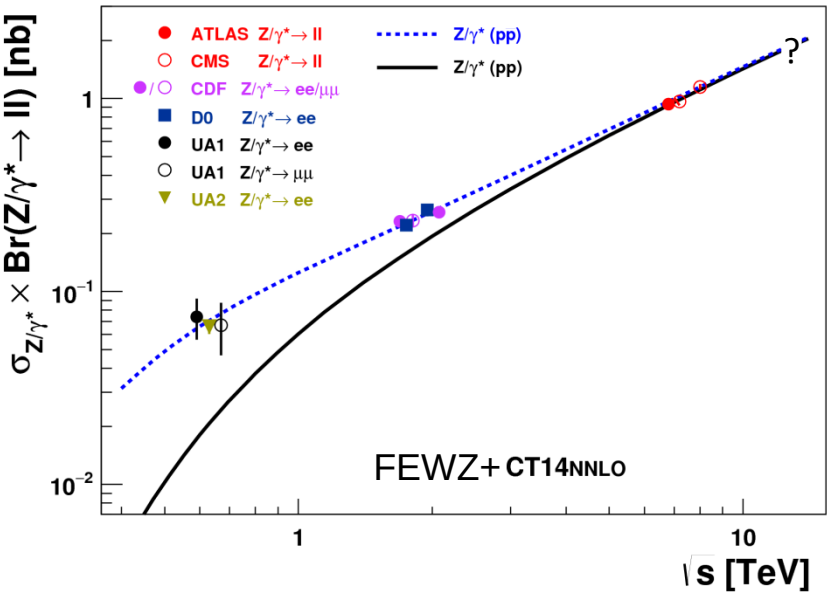


2. $W^{\pm}$ and Z-boson production at 13 TeV

$W^{\pm}$ and Z-boson production at 13 TeV

- **Motivation**

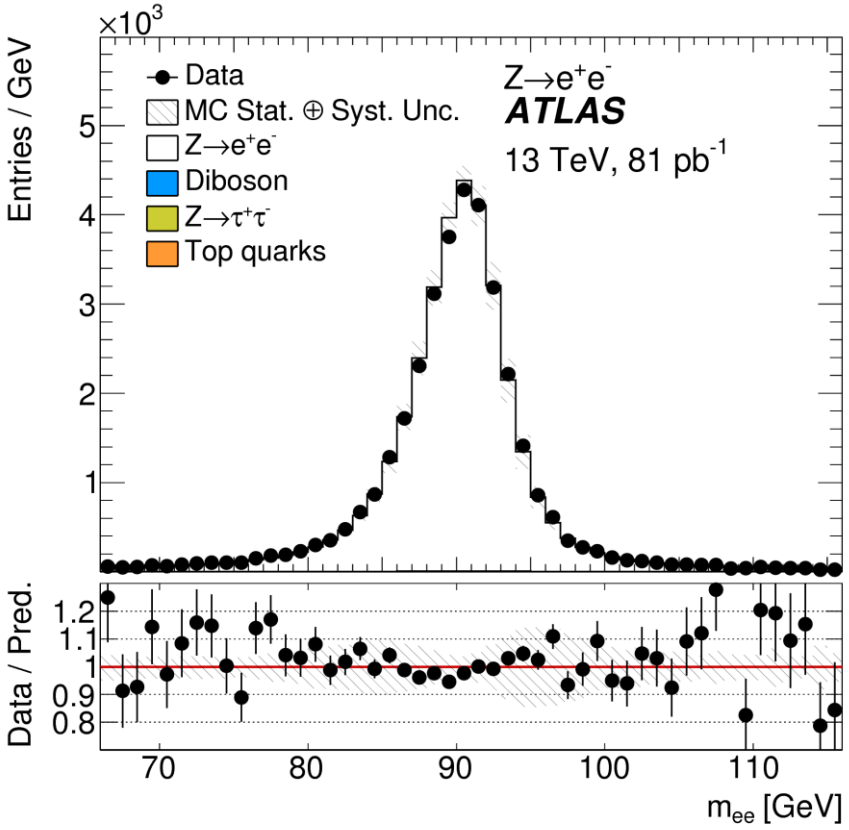
- (Relatively) large cross sections and leptonic final states
  - Clean experimental signature
  - High precision measurement possible, already with L_{int}= O(100pb^{-1})
- Good benchmark for the understanding of QCD and EW processes
  - Test models of parton dynamics at 13 TeV pp collisions
  - Cross section ratios benefit from cancellation of some experimental uncertainties -> tool for PDF constrains



$W^{\pm}$ and Z-boson production at 13 TeV

- **Event selection**

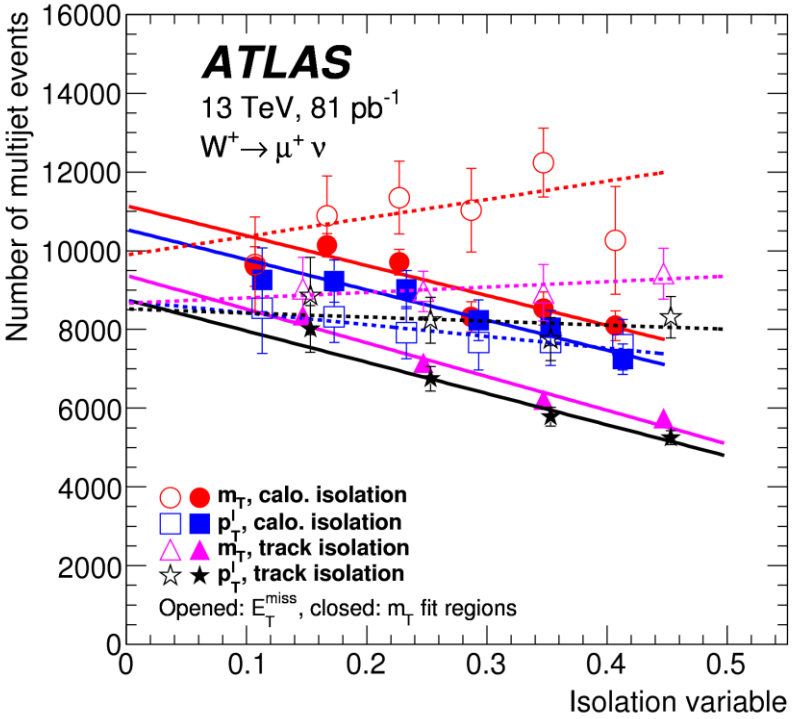
- Measurement is based on 81 pb^{-1} of 2015 data (50 ns collisions)
- Trigger and lepton selection
  - Synchronized between W and Z -> exp. uncertainty is reduced for cross section ratios
  - Single-lepton trigger is used
  - Lepton $p_T > 25$ GeV
  - Leptons isolated both in calorimeter and tracking
- W boson selection:
  - $Et_{miss} > 25$ GeV, $m_T > 50$ GeV
- Z boson: $66 < m_{ll} < 116$ GeV



$W^{\pm}$ and Z-boson production at 13 TeV

- **Background contributions**

- EW and top background:
  - Estimated from MC
  - W measurement:
    Z->ll (1-5%), W->τν (~2%) ttbar (~1%)
  - Z measurement:
    dibosons (~0.2%), ttbar (~0.3%)



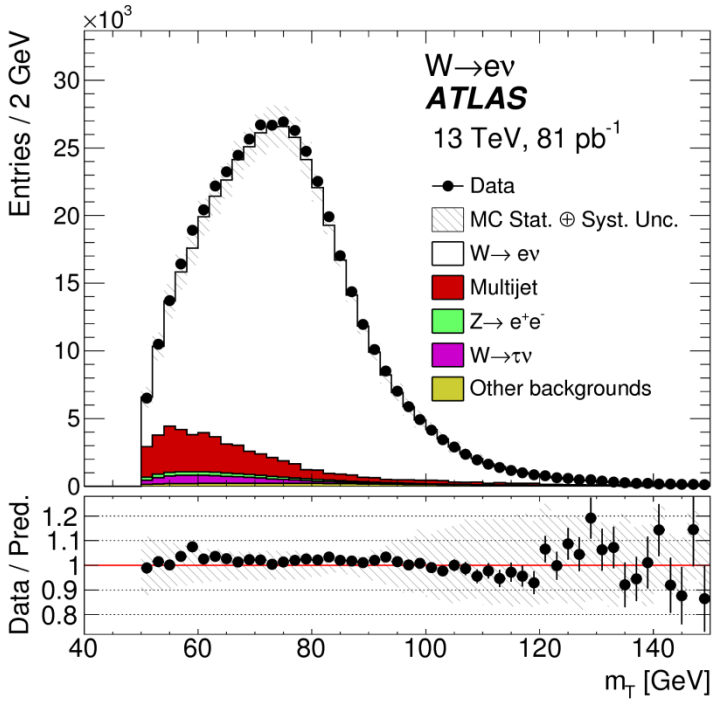
- Multijet background:
  - For Z analysis estimated from MC (< 0.1%)
  - Sizable contribution for W measurement (5-10%) -> data-driven approach
  - Templates are created by inverting the track- or calo-based isolation (sliced)
  - For each template fits to p_T^l or m_T are used to extract the normalization
  - Results are extrapolated to the "isolated" signal region
    (full procedure is done in Et_{miss} -relaxed or m_T -relaxed regions)

$W^{\pm}$ and Z-boson production at 13 TeV

- **Systematic uncertainties**

- Dominant uncertainty sources:
  - Multijet background modelling: up to 3.4% (W->eν) and 1.4% (W->μν)
  - JetEnergy Scale and Resolution 1.7% (W->lν)
  - Lepton reconstruction and identification (0.4 – 0.9%) depending on the channel

- Luminosity uncertainty: 2.1%
  (updated!)

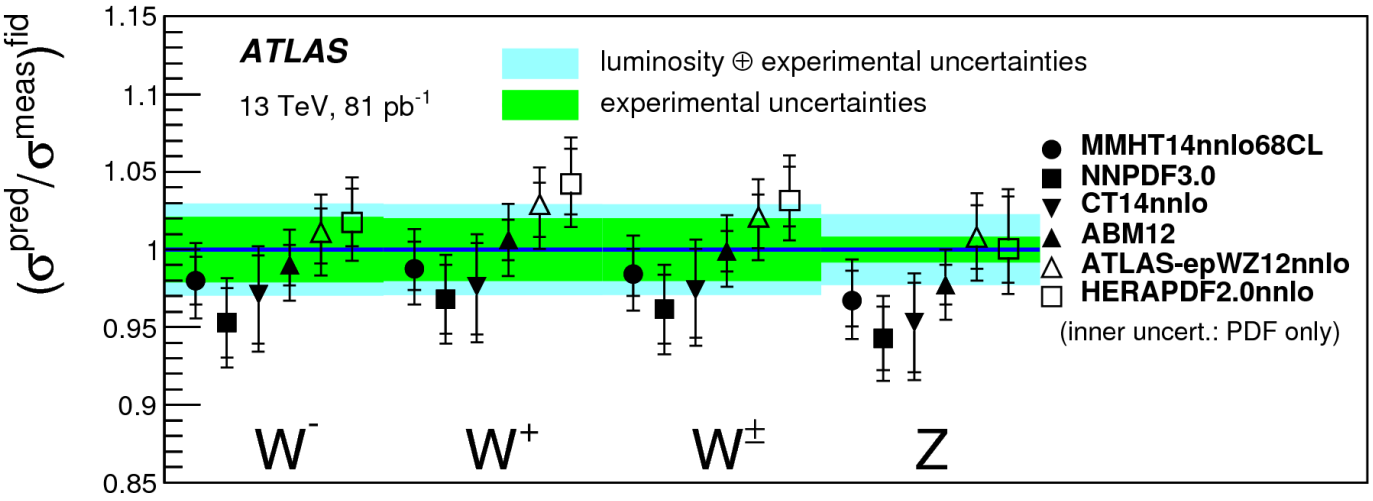


$\delta C/C$ [%]	$Z \to e^+e^-$	$W^+ \to e^+\nu$	$W^- \to e^-\bar{\nu}$	$Z \to \mu^+\mu^-$	$W^+ \to \mu^+\nu$	$W^- \to \mu^-\bar{\nu}$
Lepton trigger	0.1	0.3	0.3	0.2	0.6	0.6
Lepton reconstruction, identification	0.9	0.5	0.6	0.9	0.4	0.4
Lepton isolation	0.3	0.1	0.1	0.5	0.3	0.3
Lepton scale and resolution	0.2	0.4	0.4	0.1	0.1	0.1
Charge identification	0.1	0.1	0.1	–	–	–
JES and JER	–	1.7	1.7	–	1.6	1.7
$E_{\mathrm{T}}^{\mathrm{miss}}$	–	0.1	0.1	–	0.1	0.1
Pile-up modelling	< 0.1	0.4	0.3	< 0.1	0.2	0.2
PDF	0.1	0.1	0.1	< 0.1	0.1	0.1
Total	1.0	1.9	1.9	1.1	1.8	1.8

$W^{\pm}$ and Z-boson production at 13 TeV

- **Measured vs predicted cross sections**

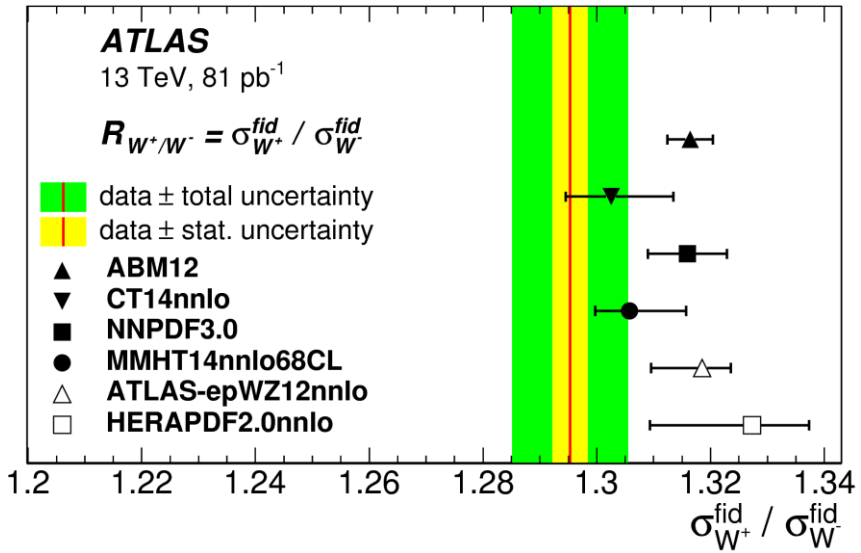
- Ratio of the predicted to measured fiducial cross section (for the combined e and μ channels) using various PDFs
- The measurements agree well with NNLO pQCD predictions (calculations include NLO EW corrections)

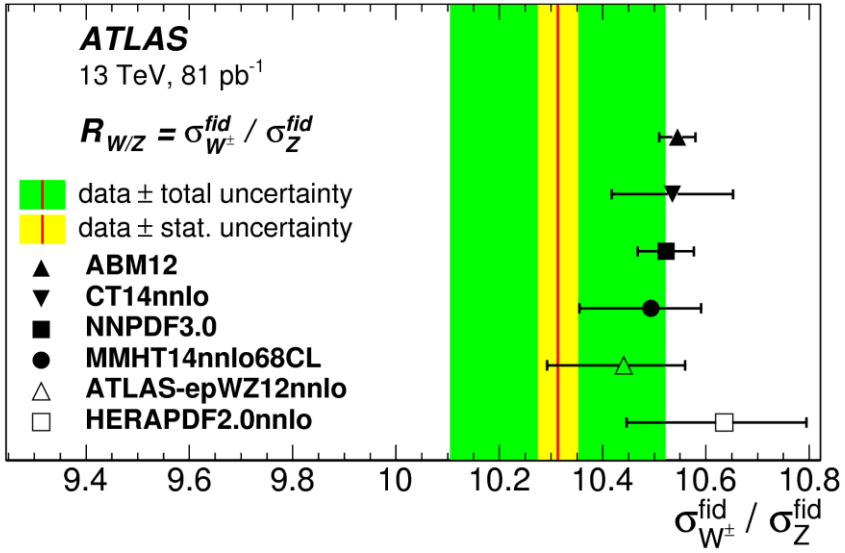


$W^{\pm}$ and Z-boson production at 13 TeV

- **Cross section ratios**

- Cancellation of lumi uncertainty
- Lepton identification and trigger systematics partly cancelled
- Data seem to favour lower $R_{W+/W-}$ and $R_{W/Z}$

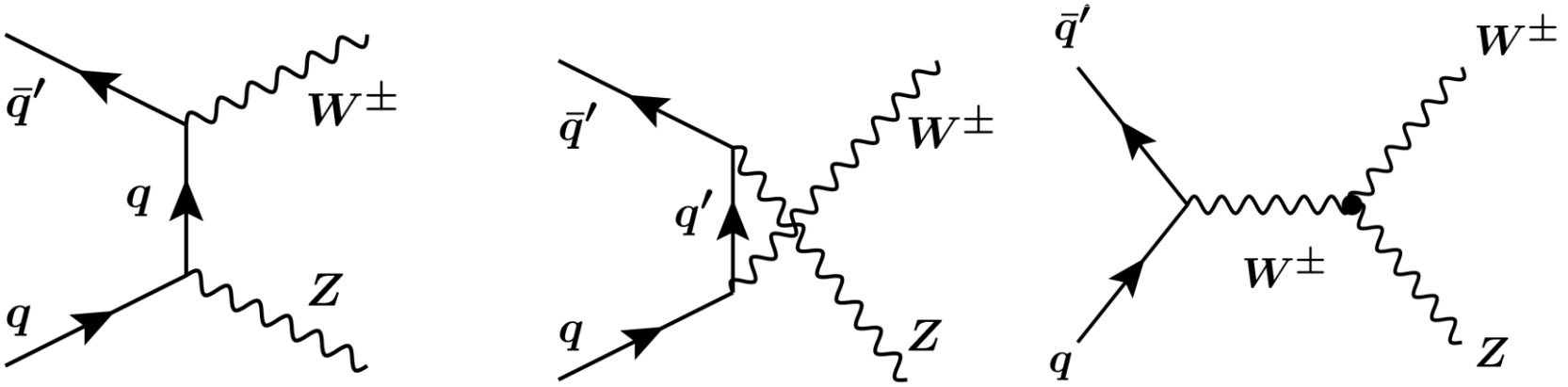




3. $W^{\pm}Z$ boson pair-production at 13 TeV

$W^{\pm}Z$ boson pair-production at 13 TeV

- **Motivation**

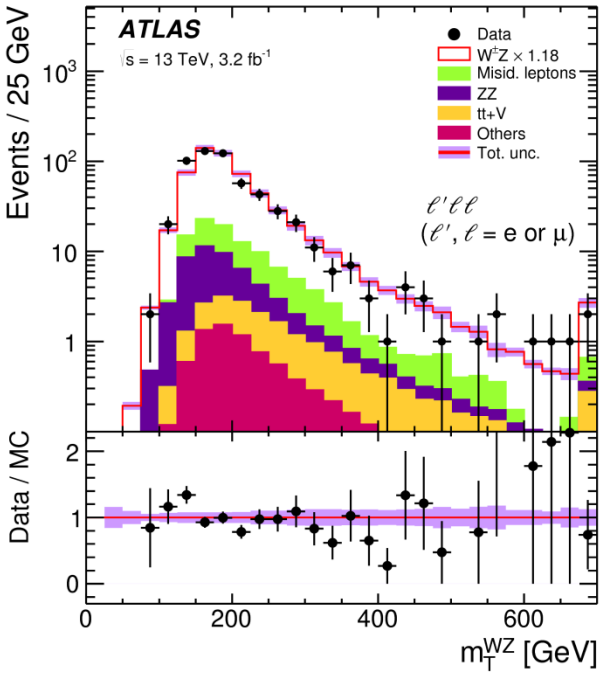


- Test of the electroweak gauge sector
- Test of perturbative QCD
- Search for new physics via anomalous triple gauge couplings
- Background for other processes (e.g. in BSM searches)

$W^{\pm}Z$ boson pair-production at 13 TeV

- **Measurement methodology**

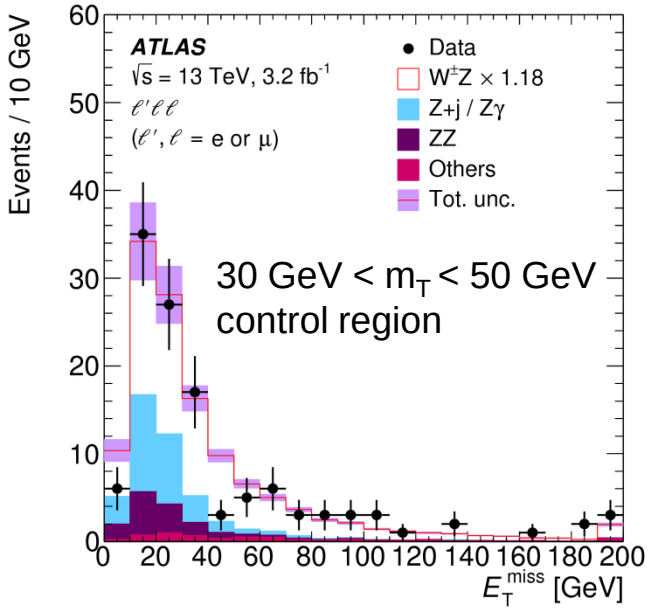
- WZ → lνll channel is exploited (eee, eeμ, μμe, μμμ)
- Measurement is based on 3.2 fb^{-1} of 2015 data (25 ns)
- Single-lepton triggers are used: 24 GeV (e) and 20 GeV (μ) thresholds
- Event selection: exactly 3 leptons
  - Z selection: 2 OS SF leptons with $p_T > 15$ GeV $|m_{ll} - m_Z| < 10$ GeV
  - W selection: remaining lepton $p_T > 20$ GeV, $m_T > 30$ GeV
  - ZZ veto: reject events with four leptons (fourth lepton $p_T > 7$ GeV)

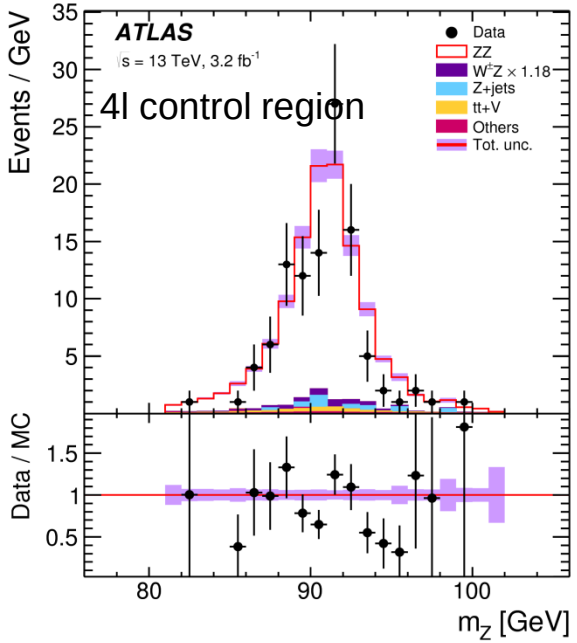


$W^{\pm}Z$ boson pair-production at 13 TeV

- **Backgrounds**

- Background ~20% dominated by misidentified leptons (Zj/Zγ) and ZZ production
- Fake leptons: data-driven estimate cross-checked with control regions
- ZZ: estimated using MC simulations

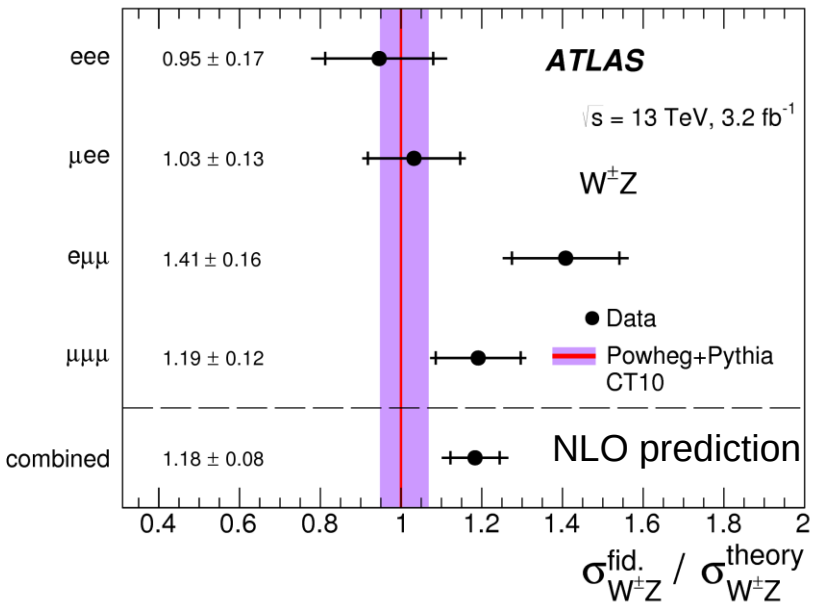


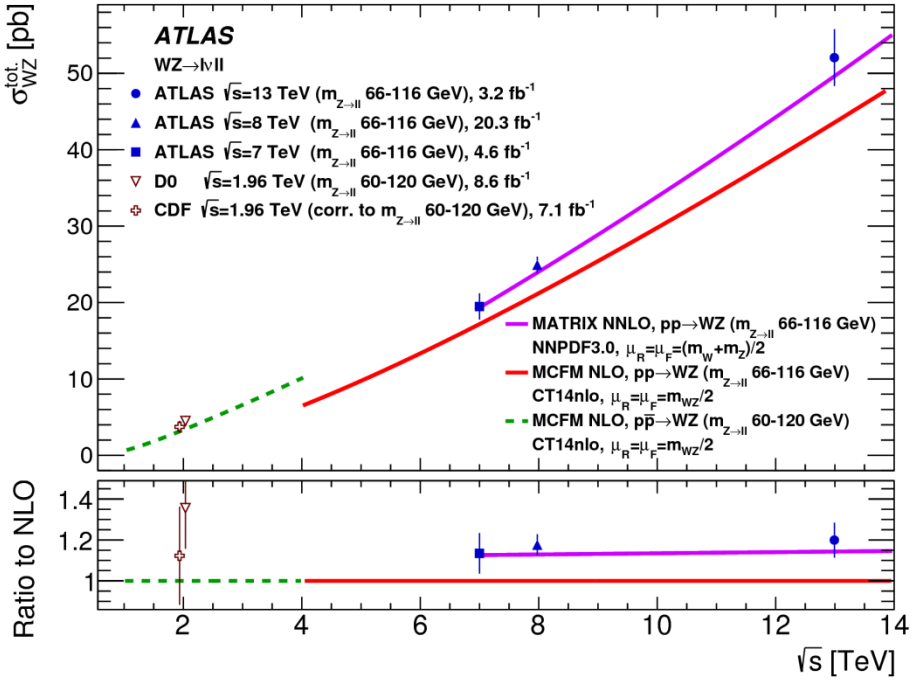


$W^{\pm}Z$ boson pair-production at 13 TeV

- **Cross section results**

- Currently a statistically limited measurement
- Dominant systematic from lepton misID background estimation
- Results compared to both NLO and NNLO predictions

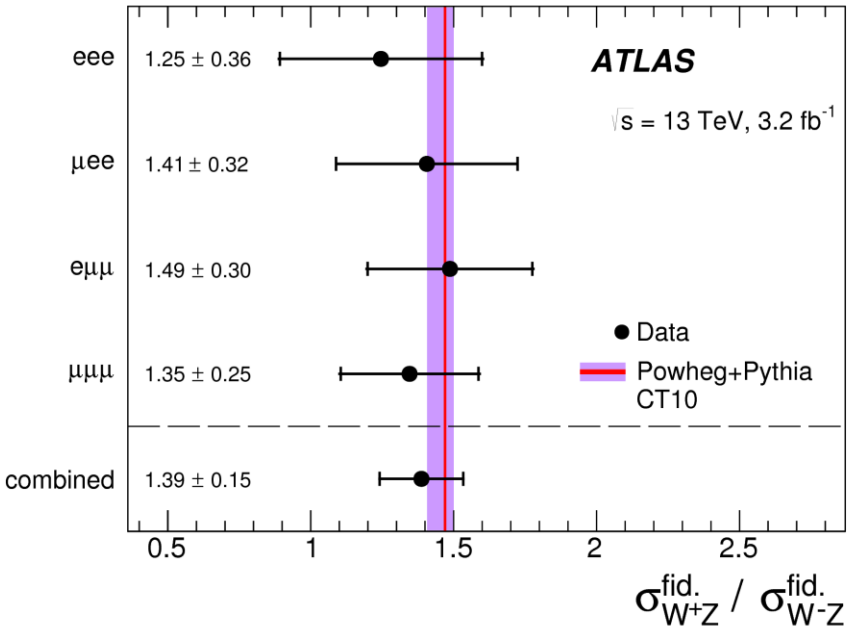




$W^{\pm}Z$ boson pair-production at 13 TeV

- **Cross section ratios**

- Most of the systematic uncertainties (especially the luminosity uncertainty) cancel in the ratio
- $W^{+}Z$ / $W^{-}Z$ ratio is PDF-sensitive



- 8 TeV / 13 TeV ratio is also provided:

$$\frac{\sigma^{\text{fid.,13 TeV}}_{W^{\pm}Z}}{\sigma^{\text{fid.,8 TeV}}_{W^{\pm}Z}} = 1.80 \pm 0.10\ (\text{stat.}) \pm 0.08\ (\text{sys.}) \pm 0.06\ (\text{lumi.})$$

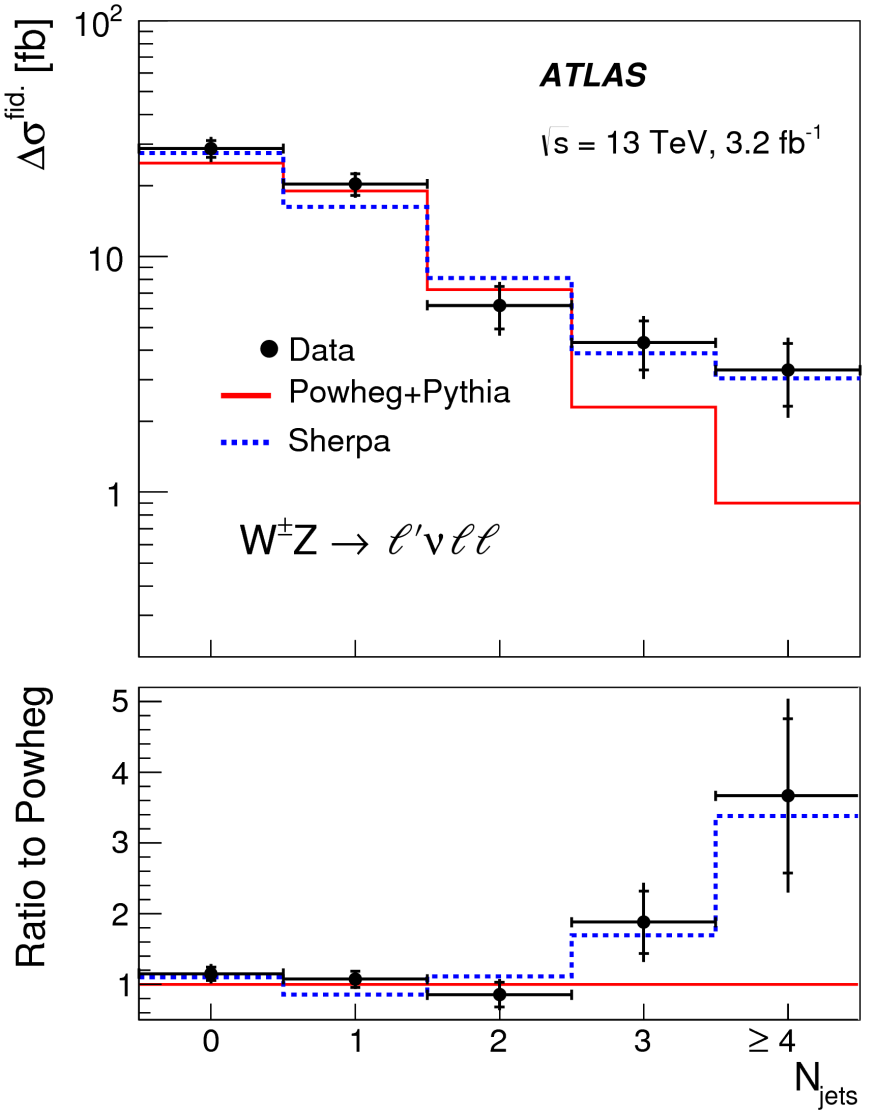
1.78±0.03 from POWHEG+PYTHIA

$W^{\pm}Z$ boson pair-production at 13 TeV

- **Additional jet multiplicity**

- Test of different MC models
- Jets are selected using anti-k_t algorithm (R=0.4) and have $p_T > 25$ GeV, $|\eta| < 4.5$

- Data in good agreement with Sherpa (up to 3 ME jets)
- Powheg: only leading jet at ME (higher jet multiplicities described by PS)



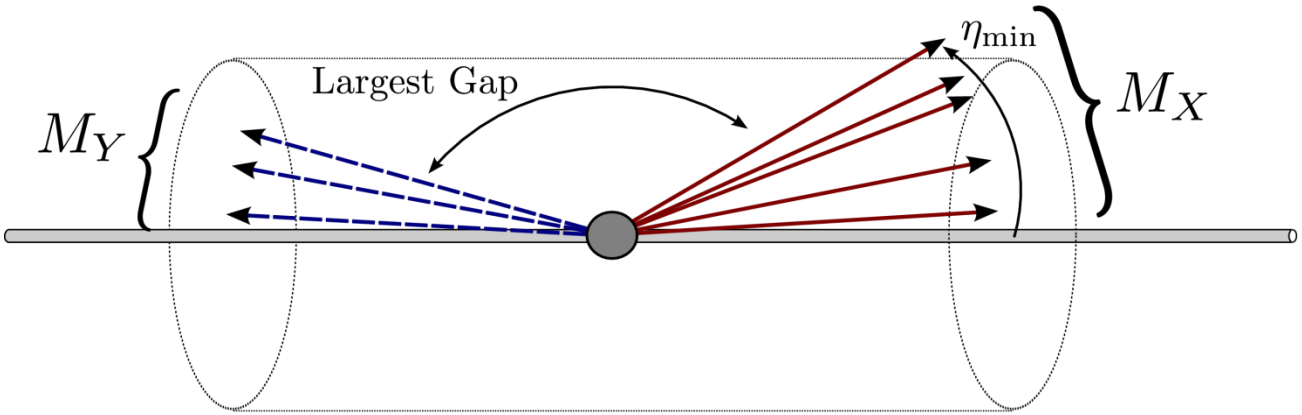
Summary

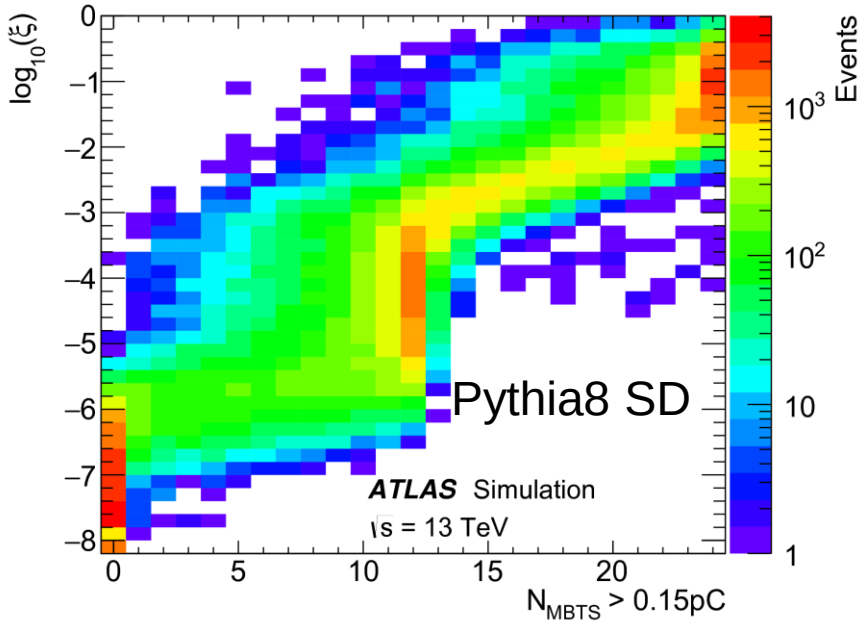
- Many new tests of QCD and Electroweak physics at 13 TeV were completed recently in ATLAS

- Possible improvements still possible
  - Inelastic cross section can be extracted from 13 TeV total cross section measurement with ALFA -> more precise method
  - Z production at 13 TeV: low- and high-mass DY + differential measurements possible with 2015 (+2016) high-statistics datasets
  - $W^{\pm}Z$ boson pair-production: more statistics needed, especially for improving aTGC studies / limits

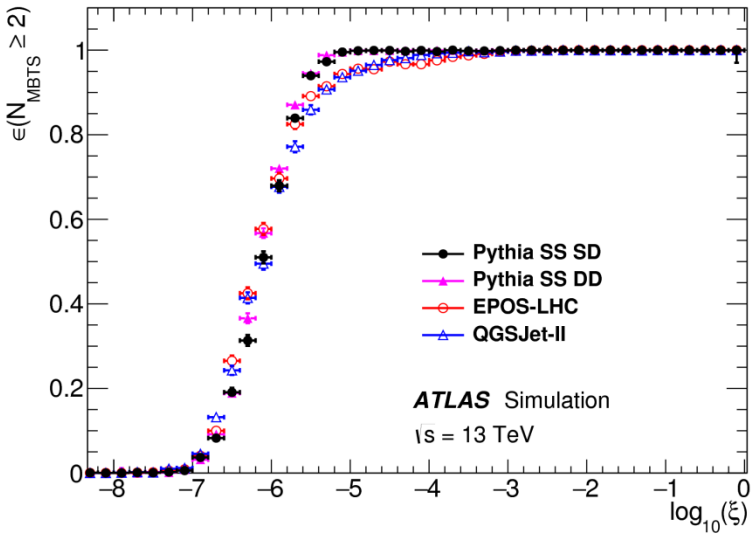
Backup

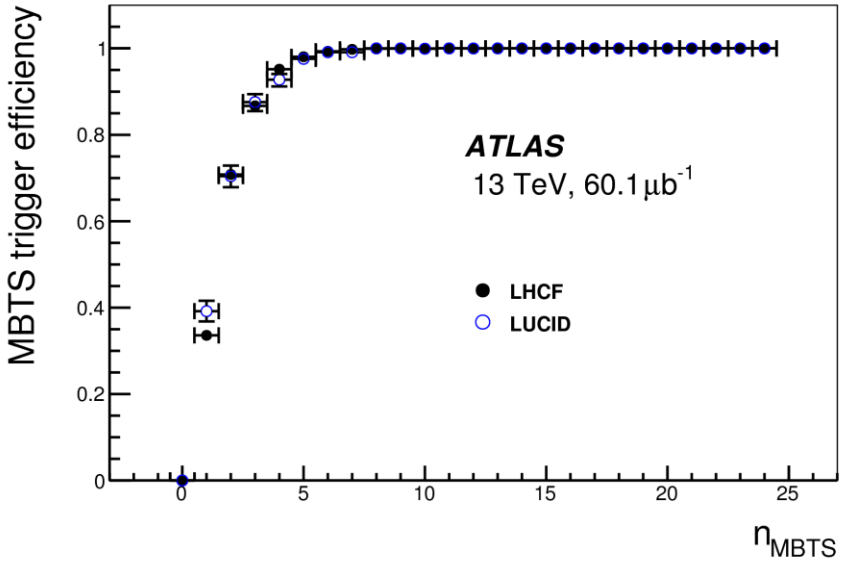
Inelastic pp Cross Section at 13 TeV



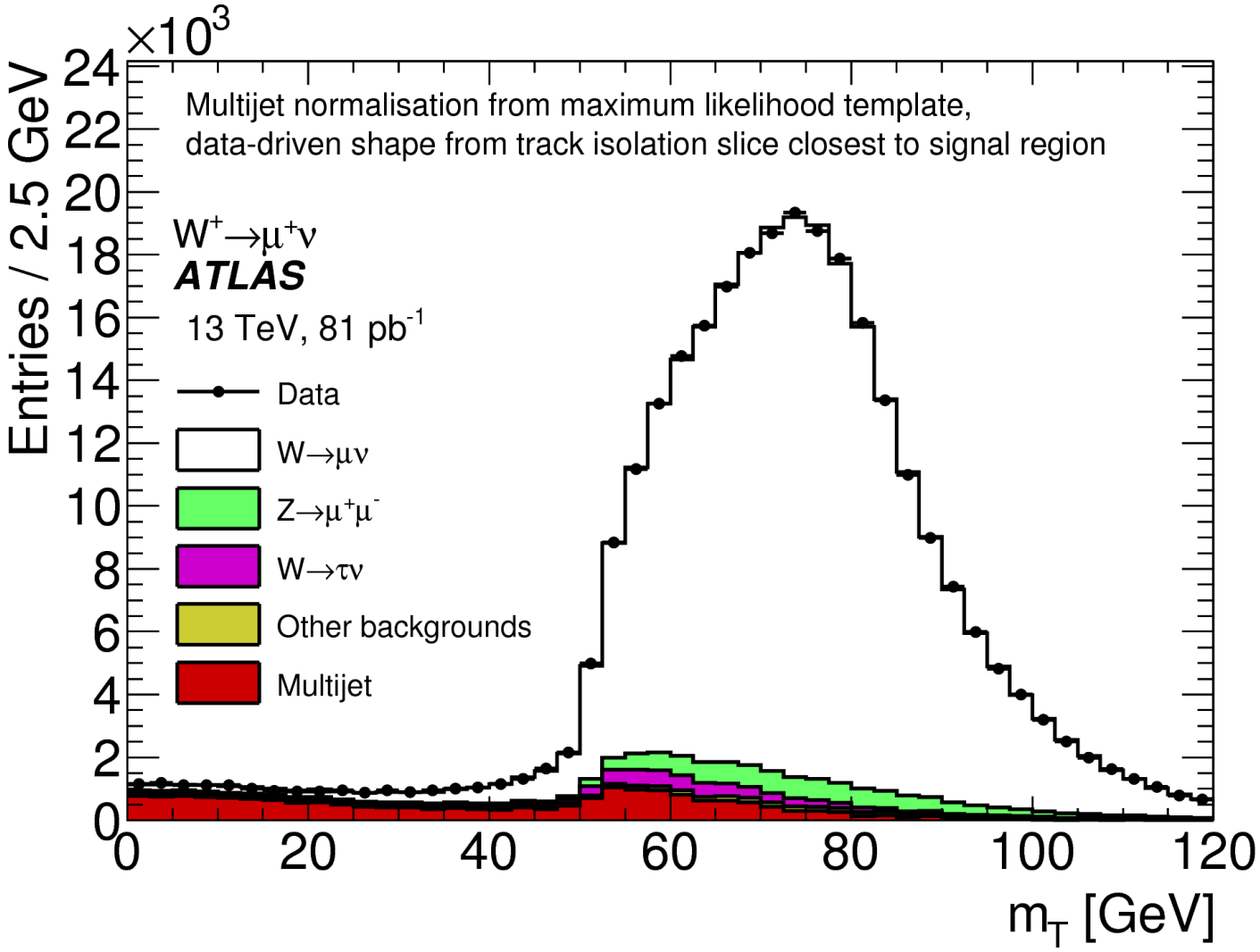


Inelastic pp Cross Section at 13 TeV





$W^{\pm}$ and Z-boson production at 13 TeV



$W^{\pm}Z$ boson pair-production at 13 TeV

Channel	eee	μee	$e\mu\mu$	$\mu\mu\mu$	All
Data	98	122	166	183	569
Total Expected	102 ± 10	118 ± 9	126 ± 11	160 ± 12	506 ± 38
WZ	74 ± 6	96 ± 8	97 ± 8	129 ± 10	396 ± 32
$Z+j$, $Z\gamma$	16 ± 7	7 ± 5	14 ± 7	9 ± 5	45 ± 17
ZZ	6.7 ± 0.7	8.7 ± 1.0	8.5 ± 0.9	11.7 ± 1.2	36 ± 4
$t\bar{t}+V$	2.7 ± 0.4	3.2 ± 0.4	2.9 ± 0.4	3.4 ± 0.5	12.1 ± 1.6
$t\bar{t}$, Wt, $WW+j$	1.2 ± 0.8	2.0 ± 0.9	2.4 ± 0.9	3.6 ± 1.5	9.2 ± 3.1
tZ	1.28 ± 0.20	1.65 ± 0.26	1.63 ± 0.26	2.12 ± 0.34	6.7 ± 1.1
VVV	0.24 ± 0.04	0.29 ± 0.05	0.27 ± 0.04	0.34 ± 0.05	1.14 ± 0.18

$W^{\pm}Z$ boson pair-production at 13 TeV