WW production cross section at 13 TeV

at the ATLAS detector

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on behalf of the ATLAS collaboration

Electroweak Session

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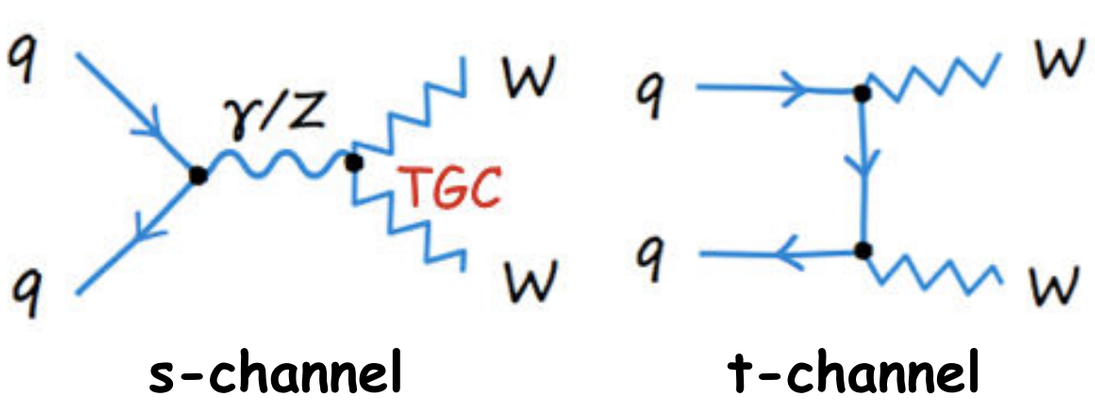
Introduction

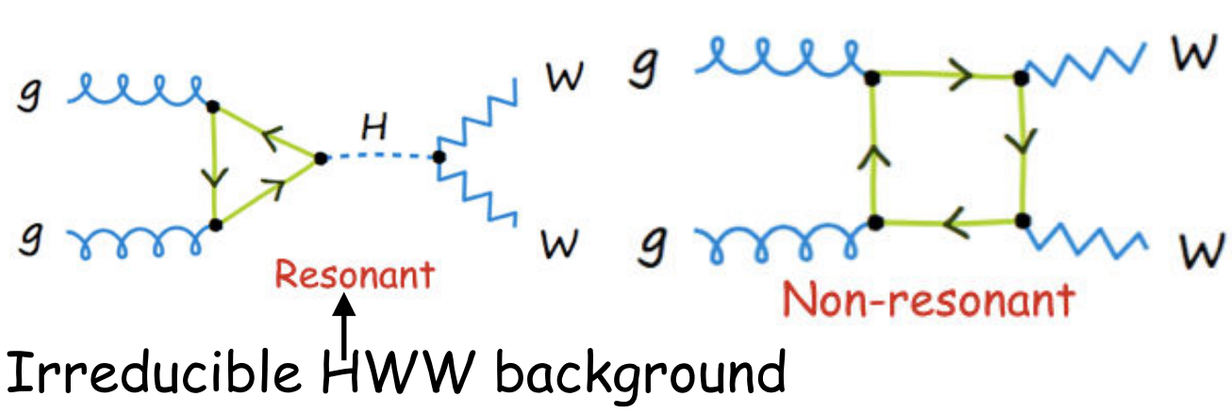
- Measurement of the fiducial/total W^+W^- cross section with 2015 data collected at the ATLAS detector (luminosity 3.16 fb^{-1}) [arXiv: 1702.04519, submitted to Phys. Lett. B.]

- Production processes

quark anti-quark processes (~87 %)



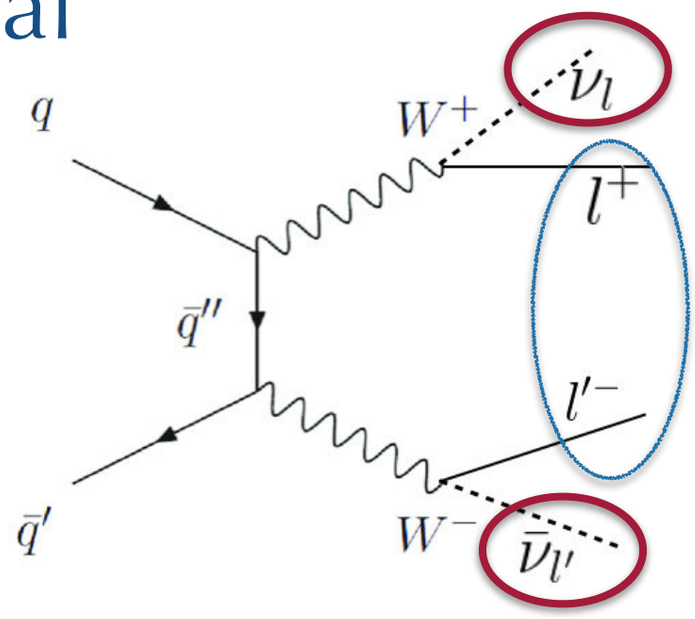
gluon gluon processes (~13%)



- Motivation
  - To understand electroweak physics of Standard Model
  - Sensitive to new physics (anomalous triple gauge couplings)
  - Important background for Higgs measurements ($H \rightarrow W^+W^-$)

Signal signature

Signal



Selecting WW events

- Two high energetic different flavor leptons
  - One $e^{\pm}\mu^{\mp}$ pair selected
- Large missing transverse momentum ($E_T$miss)
- Jet veto (no jet in the event)

Main backgrounds

Top and Drell-Yan (Z/γ +jets)

- **Transfer Factor approach**
- Normalization is obtained using dedicated orthogonal background control region and extrapolated to the signal region

W+jets and multijet(QCD)

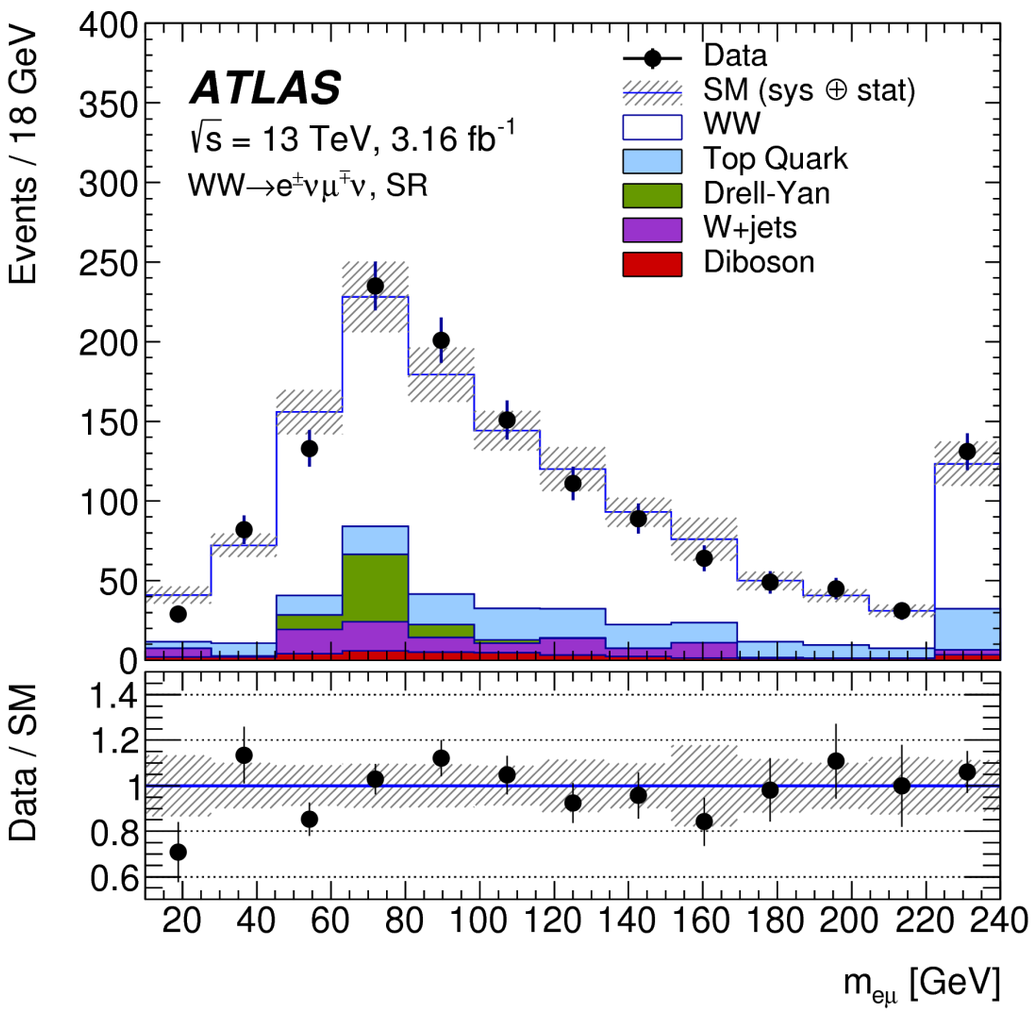
- **Data-driven Matrix Method**
- Efficiencies of real and fake (mis-identified) leptons to pass final event selection, are used to estimate the background contribution due to misidentified leptons

Other diboson (WZ/ZZ. V+γ)

- Estimated from Monte Carlo simulation

Determination of cross section

- Initial background estimates are then refined by a simultaneous likelihood fit over signal and control regions (Top and Drell-Yan)



1351 data events are observed in final event selection

Fiducial cross section definition

Likelihood fit results

$$\sigma_{fid} = \frac{N_{data} - N_{bkg}}{L.C_{WW}}$$

L : Luminosity 3.16 fb^{-1}

C_{WW} : Detector acceptance factor accounts for detector efficiencies and resolution

Total uncertainty is dominated by

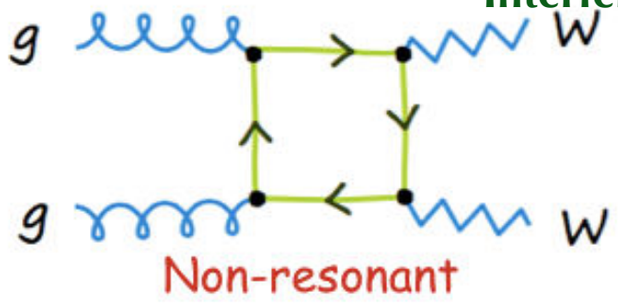
- Jet and E_T^{miss} related uncertainties
- Background estimations
- Data statistics

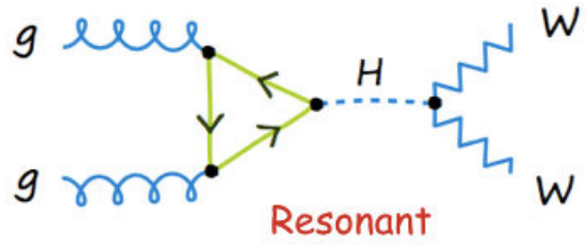
Theoretical predictions

quark anti-quark processes (~87 %)

gluon gluon processes (~13%)

Interference Neglected





$O(\alpha_s^2)$ (NNLO)

$O(\alpha_s^3)$ (NLO)

$O(\alpha_s^5)/O(\alpha_s^3)$ for total / fiducial cross section (N^3LO/NLO)

- WW production processes, known at different $O(\alpha_s)$ are combined to get the final total and fiducial cross section predictions, which we refer to as nNNLO+H
- Interference between gluon gluon (non-resonant and resonant) processes are neglected

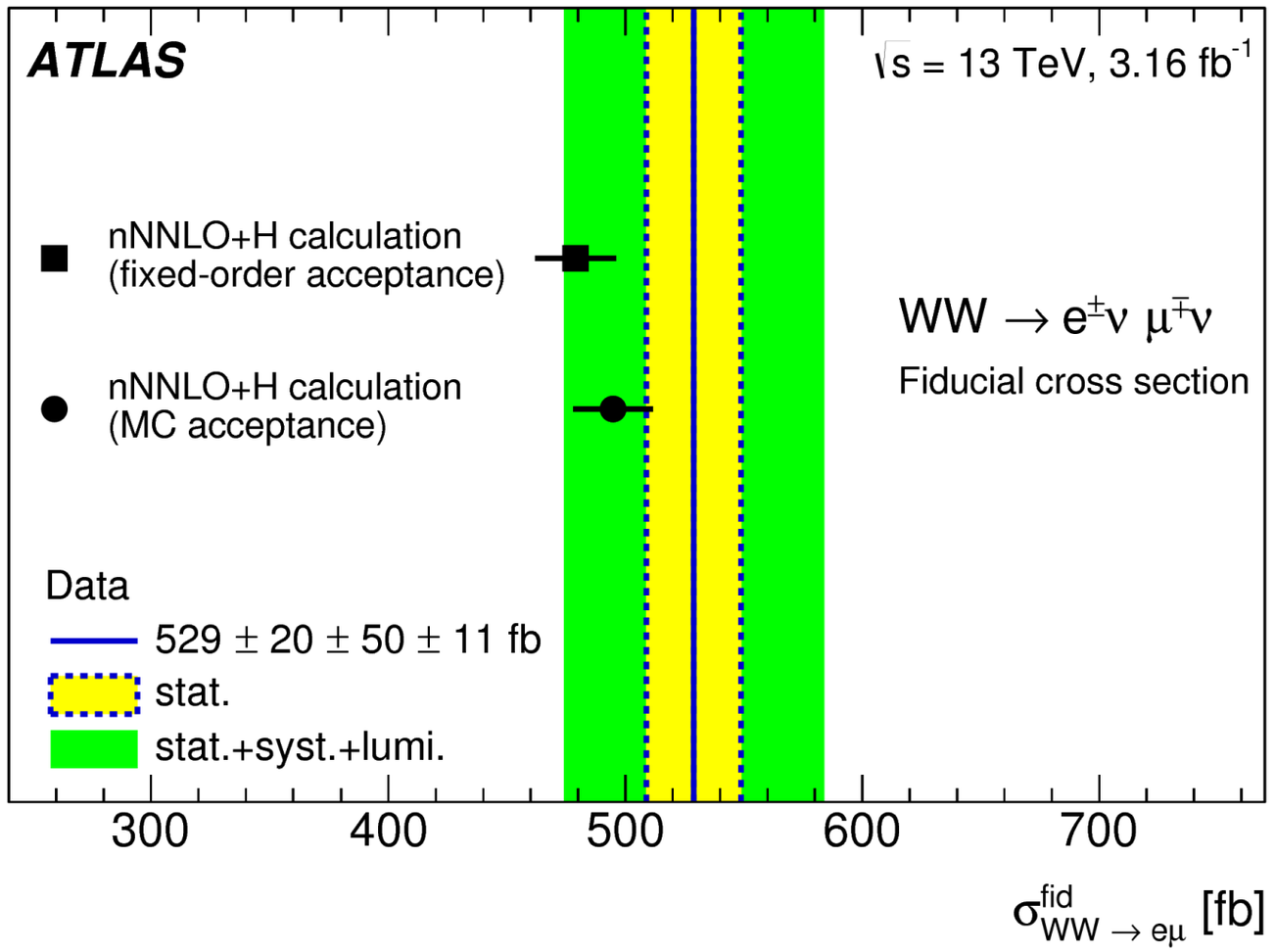
Results

Fiducial cross section

Predictions:

Acceptance factor going from total to fiducial phase space is calculated in two different ways

- Parton level prediction in fiducial phase space + parton to particle level corrections
- Acceptance factor based on MC shower generator (Powheg+Pythia8) × total cross section prediction



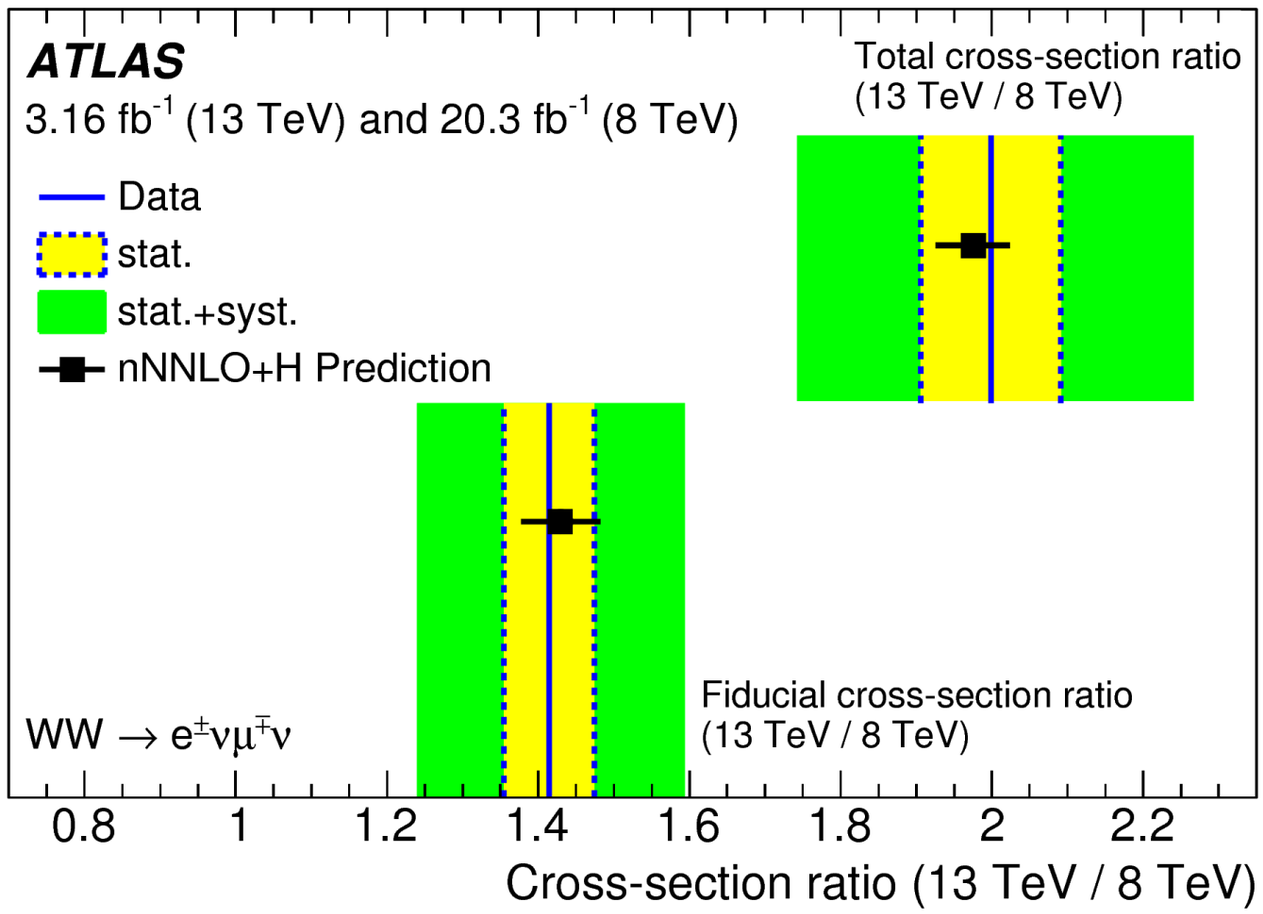
Summary

- Predictions are in very good agreement (no large corrections coming from higher orders in acceptance)
- Good agreement between predictions and measurements

Results

Cross section ratio measurement

Treating 8 TeV and 13 TeV measurements as uncorrelated



Summary

- Cross section ratio shows excellent agreement within large uncertainties

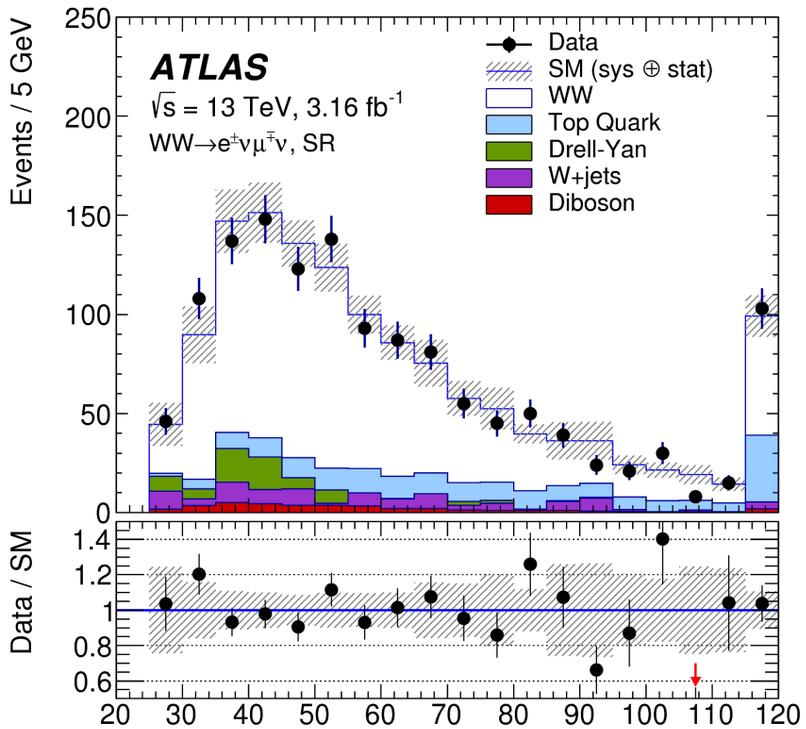
Thank You

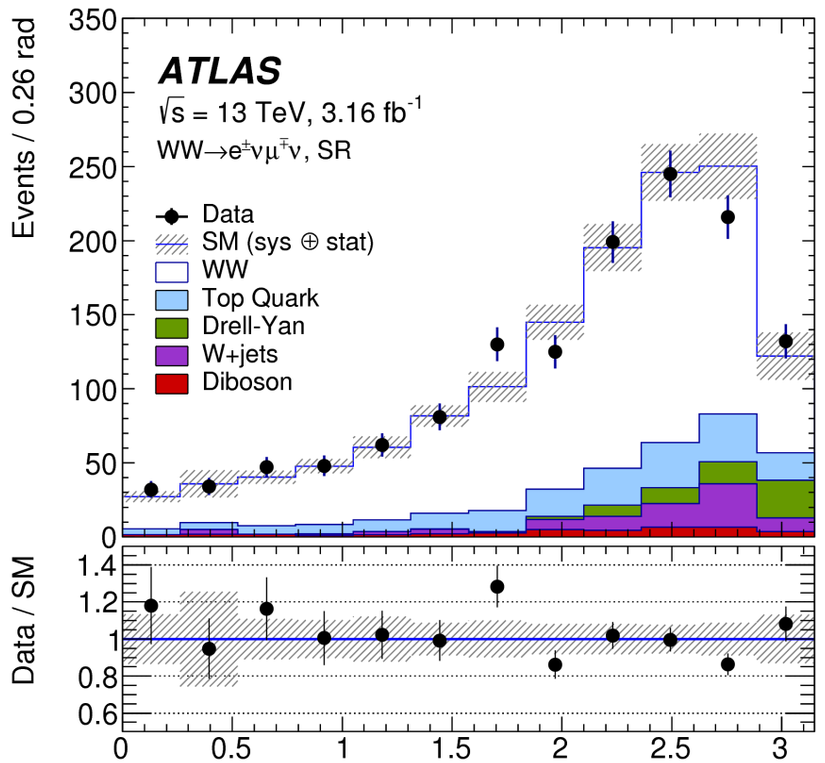
Backup

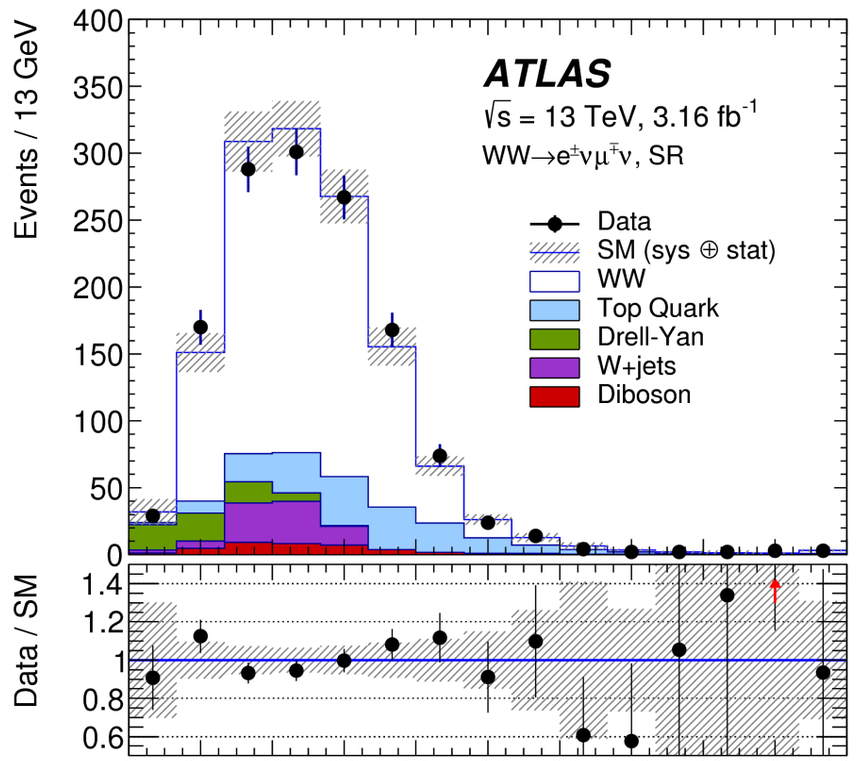
Event selection

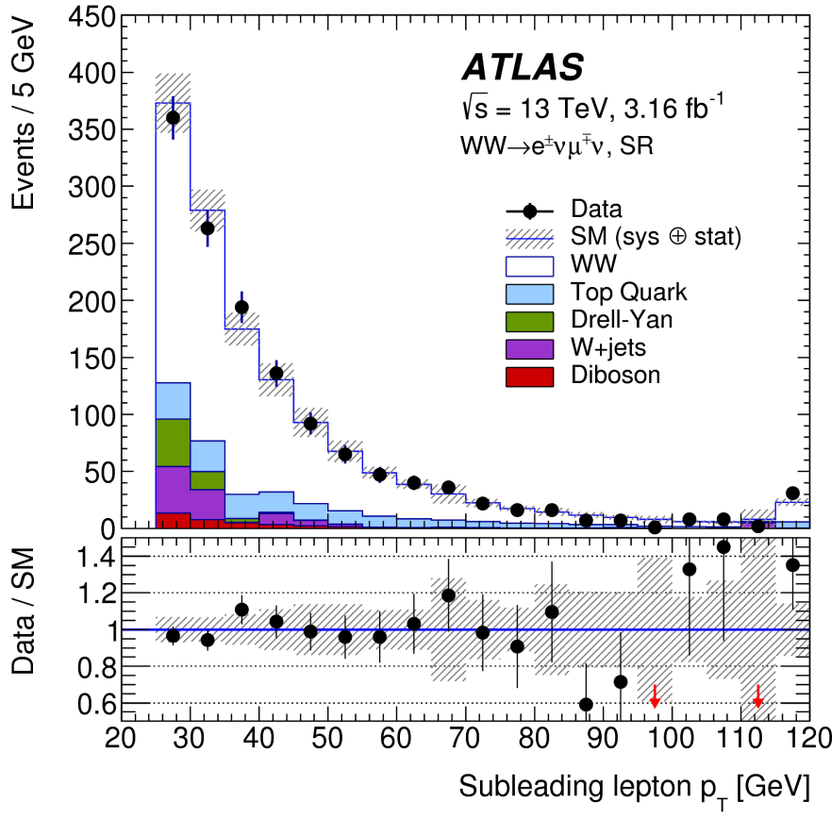
Selection requirement	Selection value
p_{T}^{ℓ}	> 25 GeV
η^{ℓ}	$\lvert\eta^{e}\rvert < 2.47$ (excluding $1.37 < \lvert\eta^{e}\rvert < 1.52$), $\lvert\eta^{\mu}\rvert < 2.4$
Lepton identification	Tight (electron), Medium (muon)
Lepton isolation	Gradient working point
Number of additional leptons ($p_{\mathrm{T}} > 10$ GeV)	0
$m_{e\mu}$	> 10 GeV
Number of jets with p_{T} >25(30) GeV, $\lvert\eta\rvert$ <2.5(4.5)	0
Number of b-tagged jets ($p_{\mathrm{T}} > 20$ GeV, 85% op. point)	0
$E_{\mathrm{T,\,Rel}}^{\mathrm{miss}}$	> 15 GeV
$p_{\mathrm{T}}^{\mathrm{miss}}$	> 20 GeV

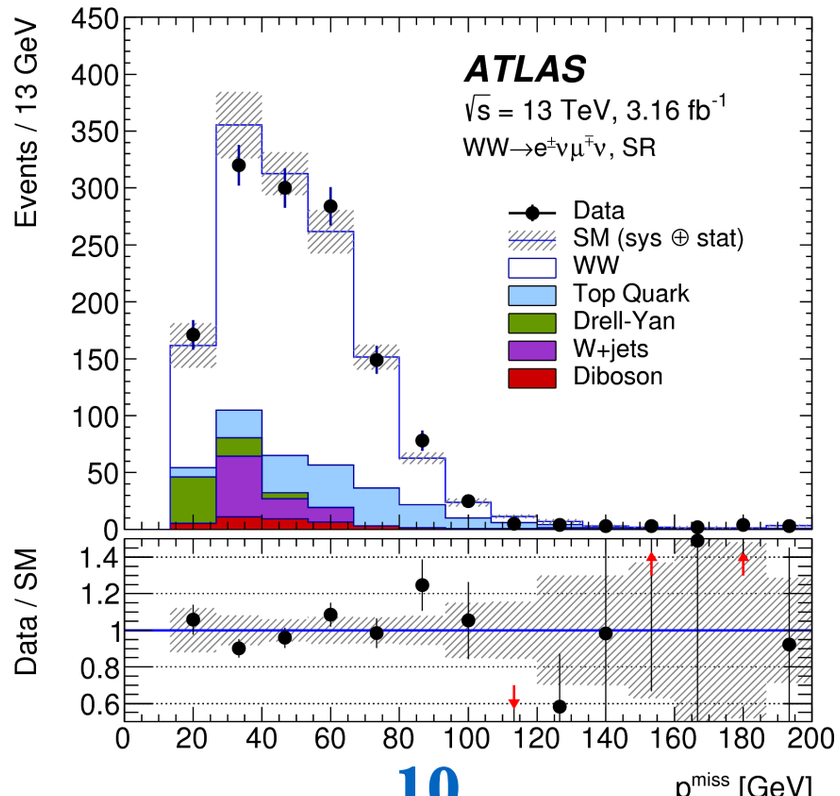
Data/MC comparisons in signal region

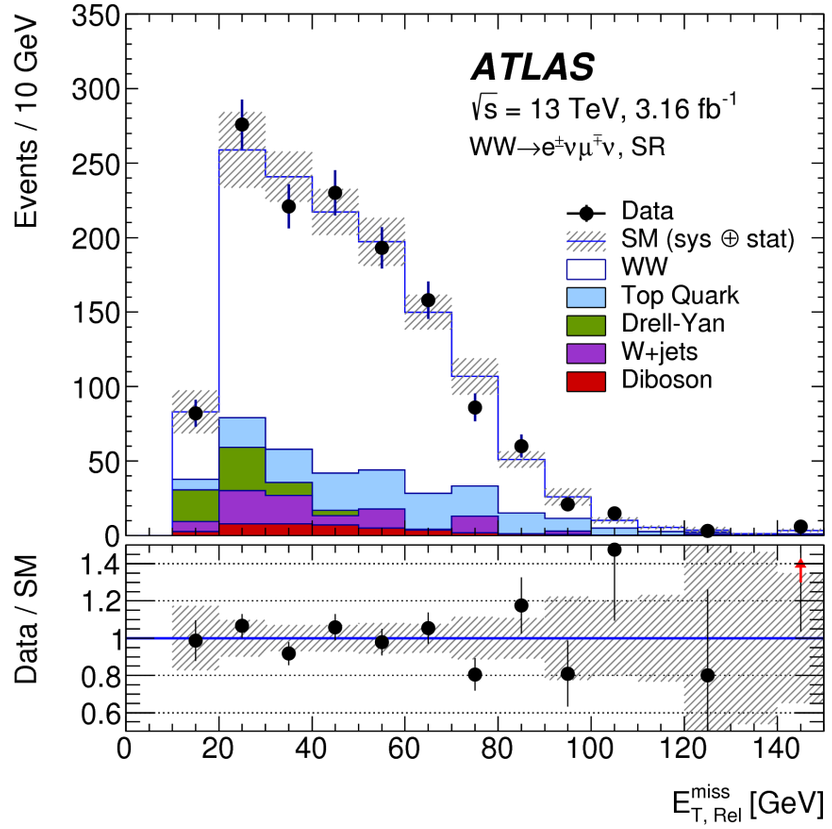






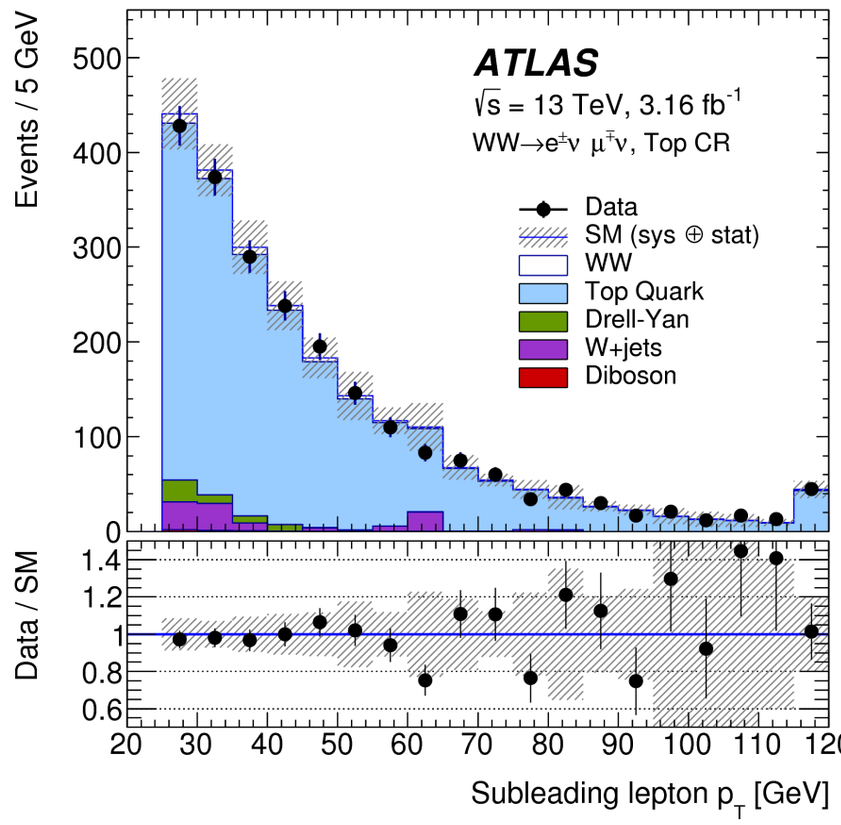


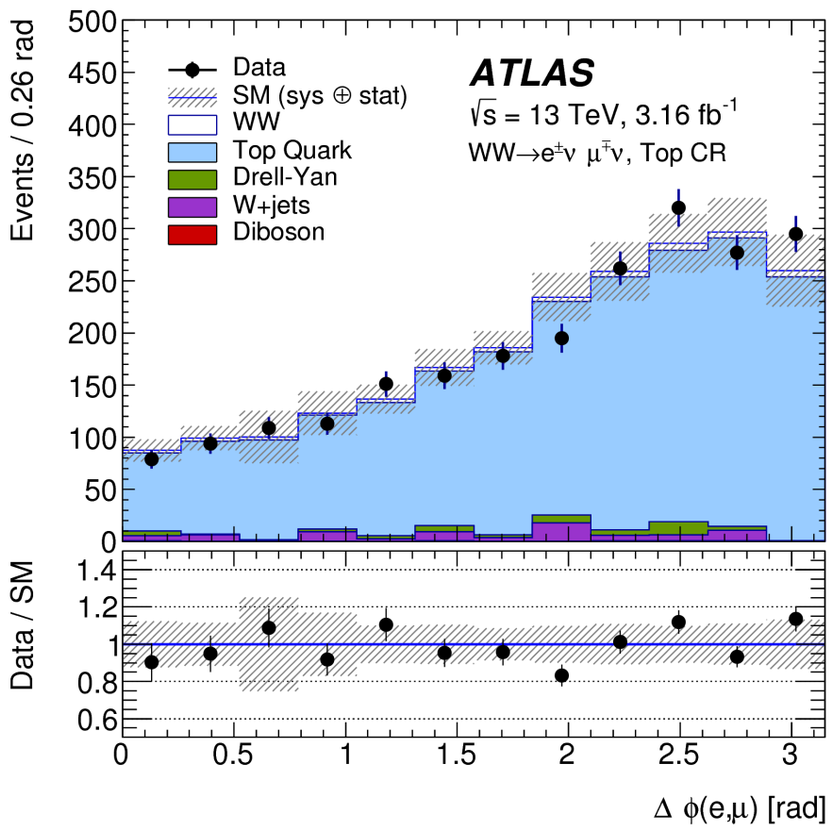




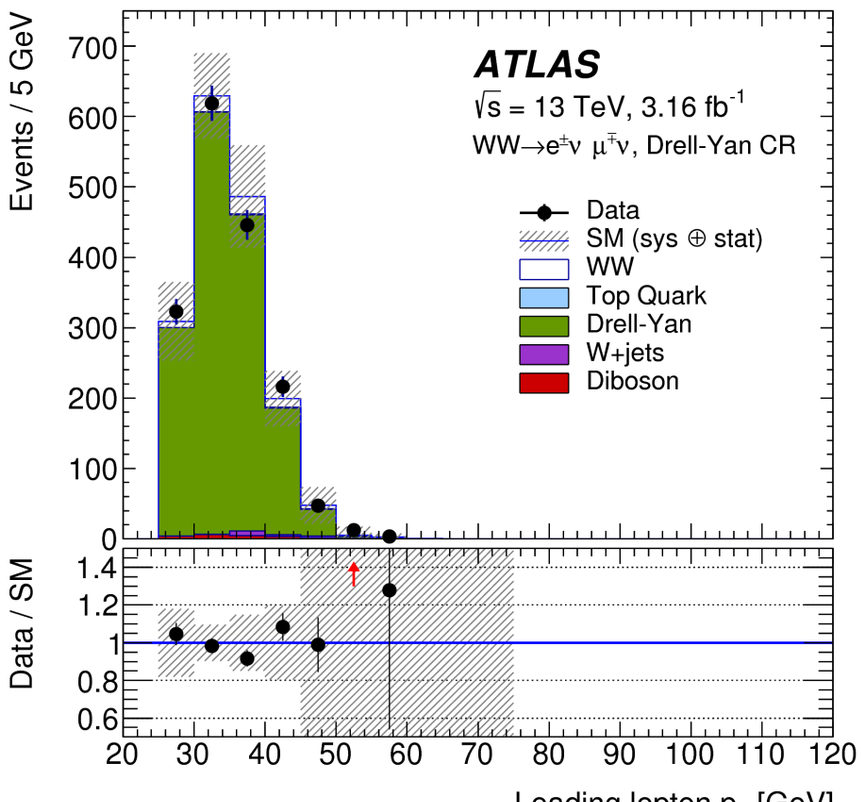
Data/MC comparisons in control regions

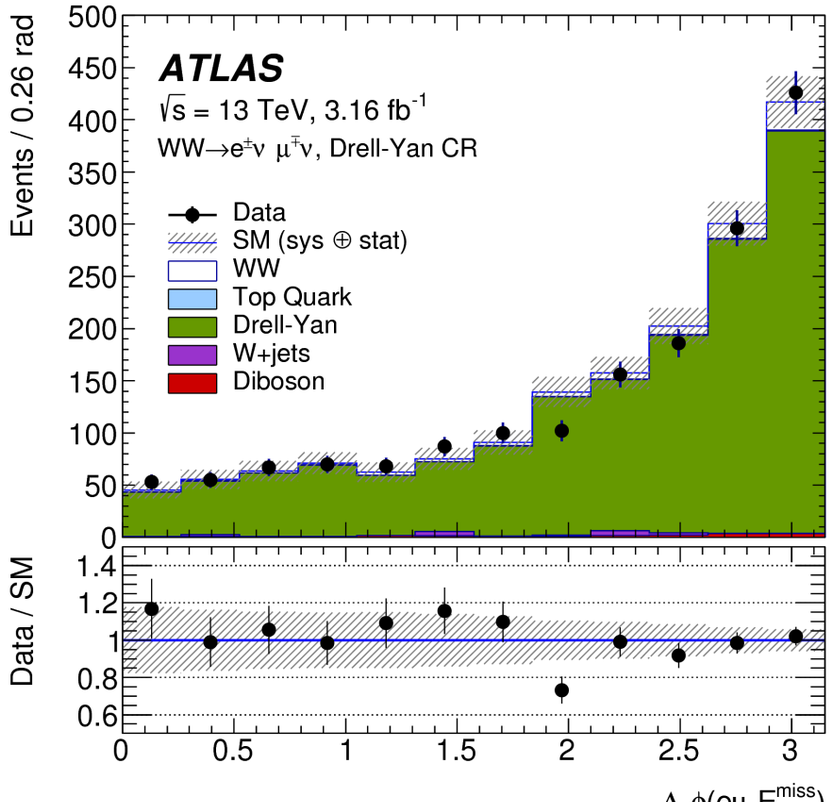
Top Control Region





Drell-Yan Control Region





Observed/estimated number of events

Process	Signal region	Top-quark control region	Drell–Yan control region
WW signal	997 ± 69	49 ± 12	75.3 ± 5.4
Drell–Yan	62 ± 23	49 ± 29	1568 ± 45
tt+single top	177 ± 33	2057 ± 81	3.5 ± 1.6
W+jets/multi-jet	78 ± 41	70 ± 55	0 ± 17
Other dibosons	38 ± 12	6.3 ± 3.5	19.2 ± 6.1
Total	1351 ± 37	2232 ± 47	1666 ± 41
Data	1351	2232	1666

Associated uncertainties

Sources of uncertainty	Relative uncertainty for $\sigma^{\text{fid}}_{WW\to e\mu}$
Jet selection and energy scale & resolution	7.3% ← Biggest
b-tagging	1.3%
$E_{\text{T}}^{\text{miss}}$ and $p_{\text{T}}^{\text{miss}}$	1.7%
Electron	1.0%
Muon	0.4%
Pile-up	0.9%
Luminosity	2.1%
Top-quark background theory	2.4%
Drell–Yan background theory	1.5%
W+jet and multi-jet background	3.8%
Other diboson backgrounds	1.1%
Parton shower	3.1%
PDF	0.2%
QCD scale	0.2%
MC statistics	1.2%
Data statistics	3.7%
Total uncertainty	11%

Object

Beam

Bkg

Corrections using MC

Statistics

Theoretical predictions

Fiducial phase space

Fiducial selection requirement	Cut value
p_{T}^{ℓ}	> 25 GeV
$\lvert\eta_{\ell}\rvert$	< 2.5
$m_{e\mu}$	> 10 GeV
Number of jets with $p_T > 25(30)$ GeV, $\lvert\eta\rvert < 2.5(4.5)$	0
$E_{\mathrm{T,\ Rel}}^{\mathrm{miss}}$	> 15 GeV
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 20 GeV

Total/fiducial cross section predictions

$pp \to WW$ sub-process	Order of α_{s}	$\sigma_{WW}^{\mathrm{tot}}$ [pb]	A [%]	$\sigma_{WW\to e\mu}^{\mathrm{fid}}$ [fb]
$q\bar{q}$ [9,13]	$\mathcal{O}(\alpha_{\mathrm{s}}^2)$	111.1 ± 2.8	16.20 ± 0.13	$422\ ^{+\ 12}_{-\ 11}$
gg (non-resonant) [33]	$\mathcal{O}(\alpha_{\mathrm{s}}^3)$	$6.82\ ^{+\ 0.42}_{-\ 0.55}$	$28.1\ ^{+\ 2.7}_{-\ 2.3}$	44.9 ± 7.2
$gg \to H \to WW$ [67][30]	$\mathcal{O}(\alpha_{\mathrm{s}}^5)$ tot. / $\mathcal{O}(\alpha_{\mathrm{s}}^3)$ fid.	$10.45\ ^{+\ 0.61}_{-\ 0.79}$	4.5 ± 0.6	11.0 ± 2.1
$q\bar{q}$ + gg (non-resonant) + $gg \to H \to WW$	nNNLO+H	$128.4\ ^{+\ 3.5}_{-\ 3.8}$	$15.87^{+\ 0.17}_{-\ 0.14}$	478 ± 17

Links to references: ref [9], ref [13], ref [33], ref [30], ref [67]