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Recent ATLAS measurements relevant for PDF fits

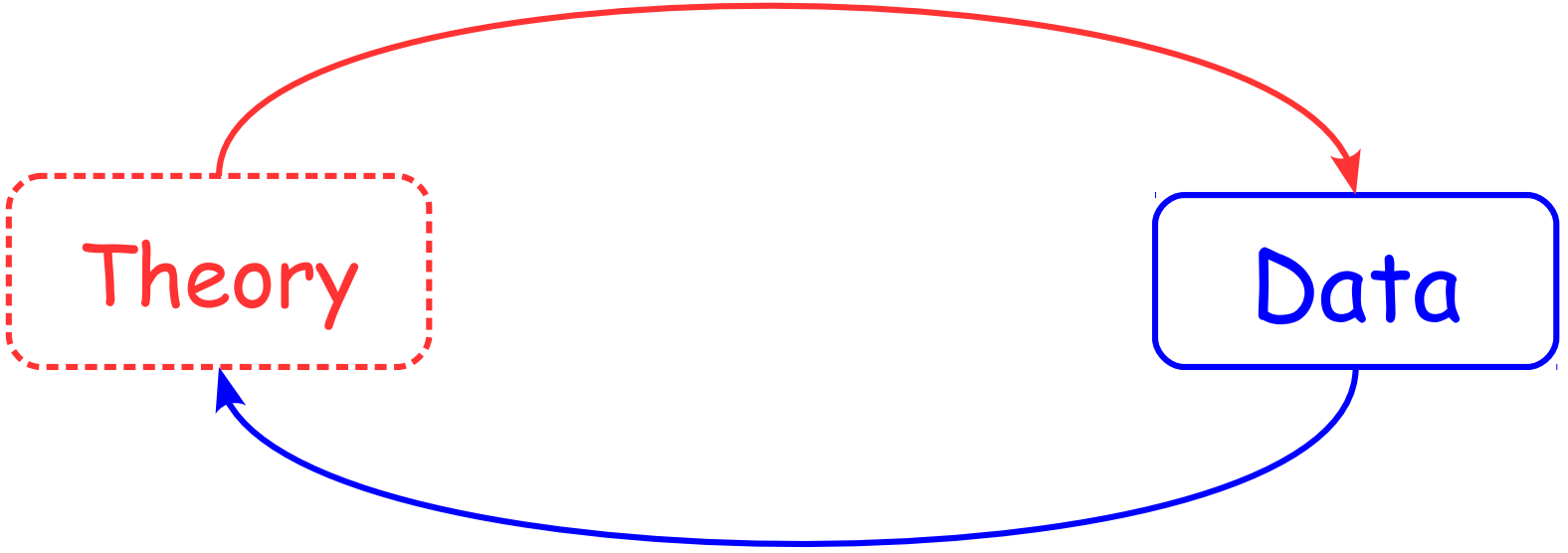
Misha Lisovyi on behalf of the ATLAS Collaboration

PDF4LHC

13.09.2016

Data-Theory interplay

Compare theory/model to check
our understanding with of Nature



Inputs to constrain parameters not
predicted by theory (e.g. PDFs)

Outline

- High-mass differential Drell-Yan cross sections @ 8 TeV (JHEP 1608 (2016) 009)
- Integrated fiducial W and Z cross sections and ratios @ 13 TeV (PLB 759 (2016) 601)
- Differential Z p_T and φ^*_η cross sections @ 8TeV (EPJC 76 (2016) 291)
- Differential tt cross sections in di-lepton and l+jets decay channels @ 7 and 8 TeV (arXiv:1607.07281, arXiv:1511.04716)

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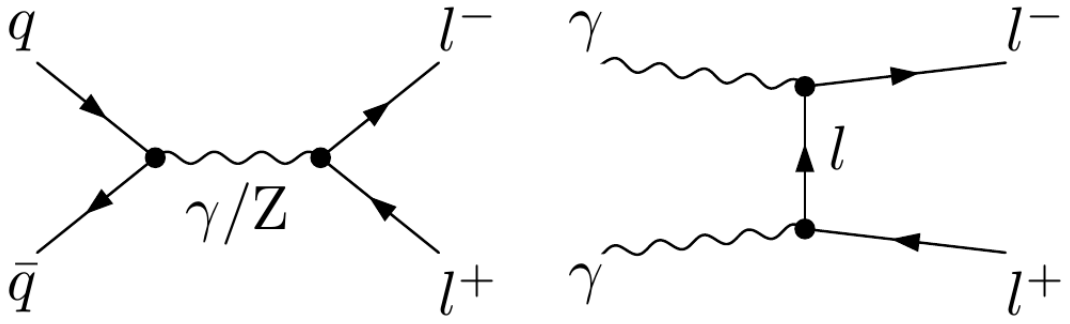
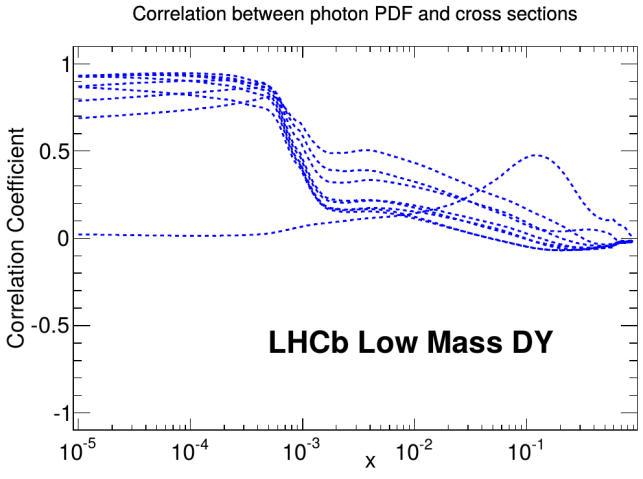
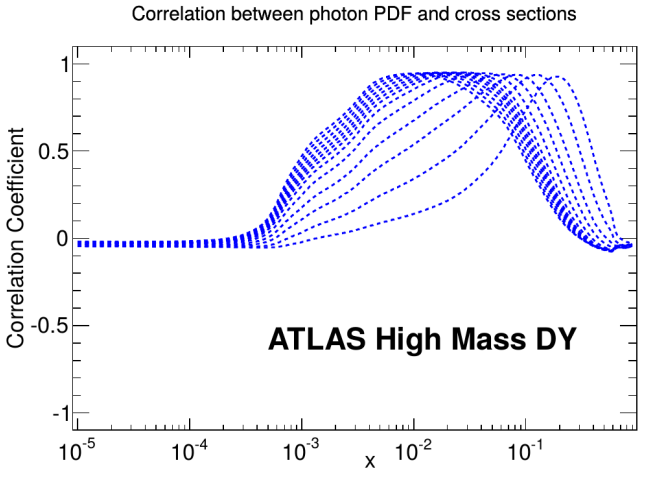
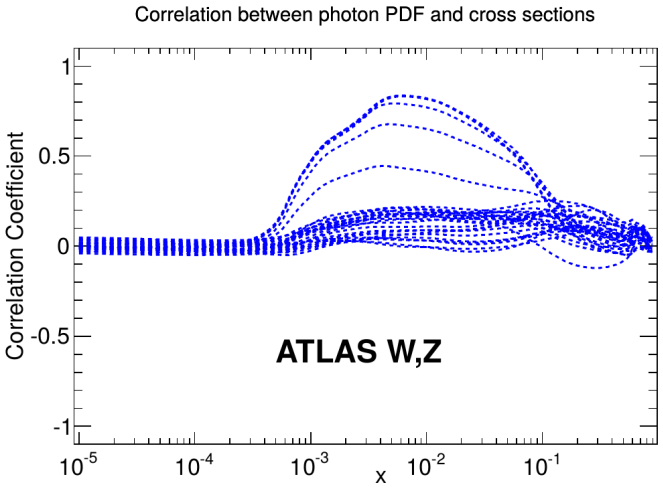
High-mass DY: motivation



- Sensitivity to EW and QCD corrections.
- Constraints on PDFs (in particular on γ): earlier 7 TeV data were used in NNPDF2.3_qed (NPB 877 (2013) 290).



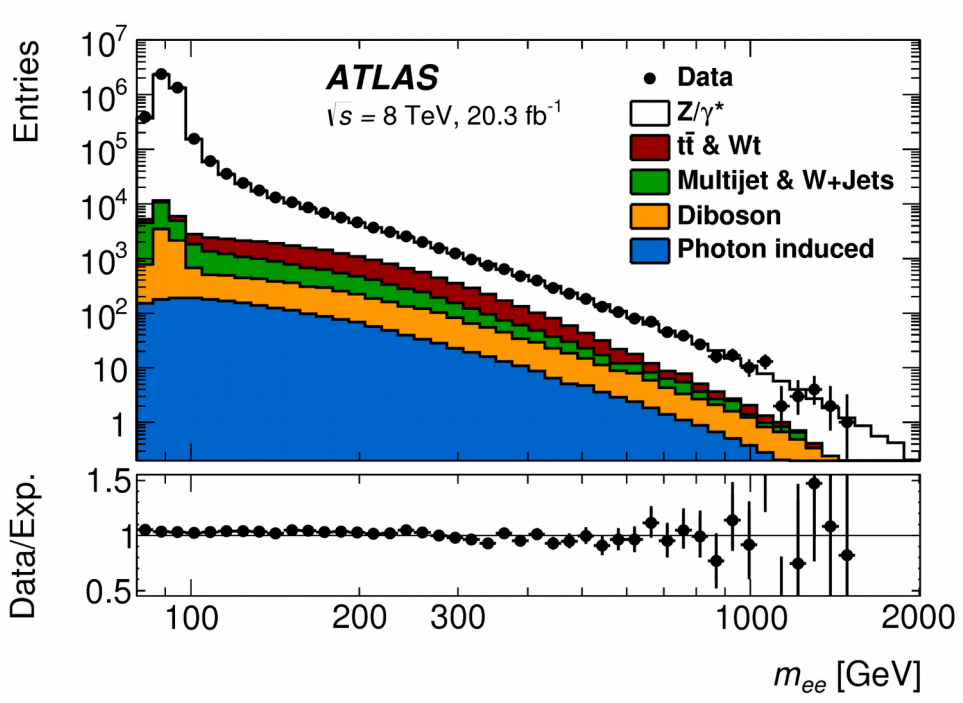




R. Ball et al., NPB 877 (2013) 290

Analysis overview

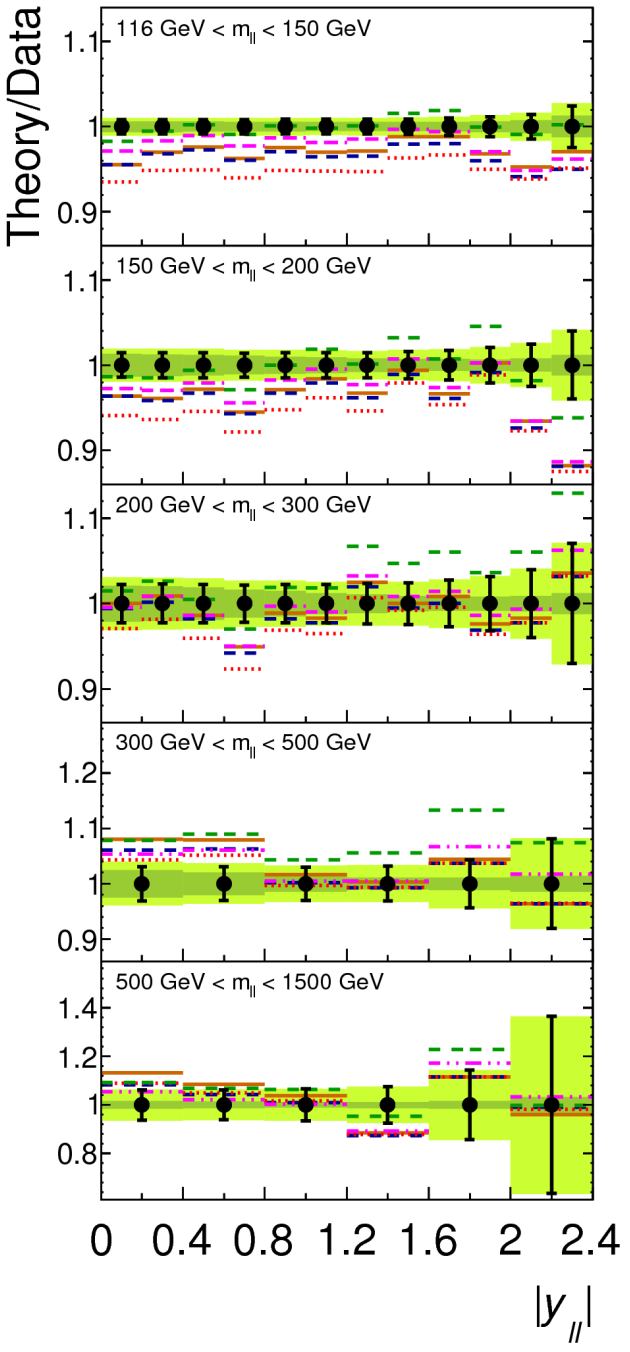
- p_T^l > 40(30) GeV
- $|\eta^l|$ < 2.5
- 116 < M < 1500 GeV

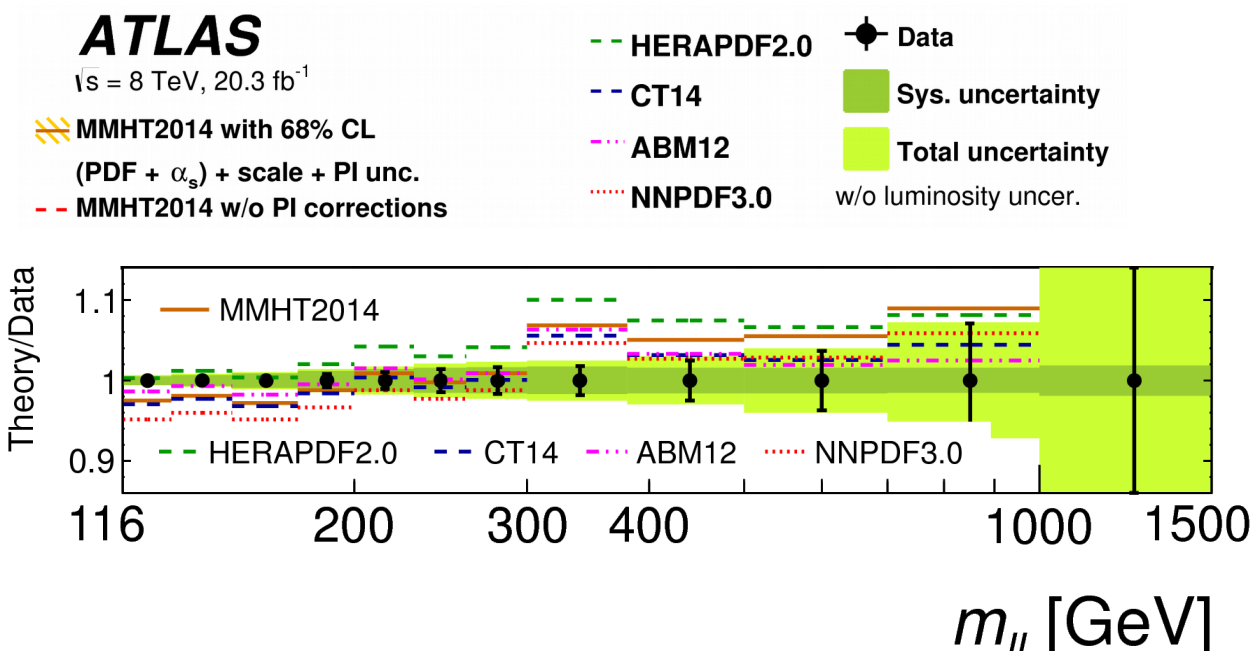


- Full 2012 sample: 20.3 fb^{-1}. --> Double-differential cross sections: $d\sigma/dM$, $d^2\sigma/dM/d|y_{ll}|$, $d^2\sigma/dM/d|\Delta\eta_{ll}|$
- Backgrounds: EW+top from MC and multijet data-driven.
- Bin-by-bin unfolding.
- Combine ee and μμ cross sections using HERAverager.

Comparison to predictions

JHEP 1608 (2016) 009



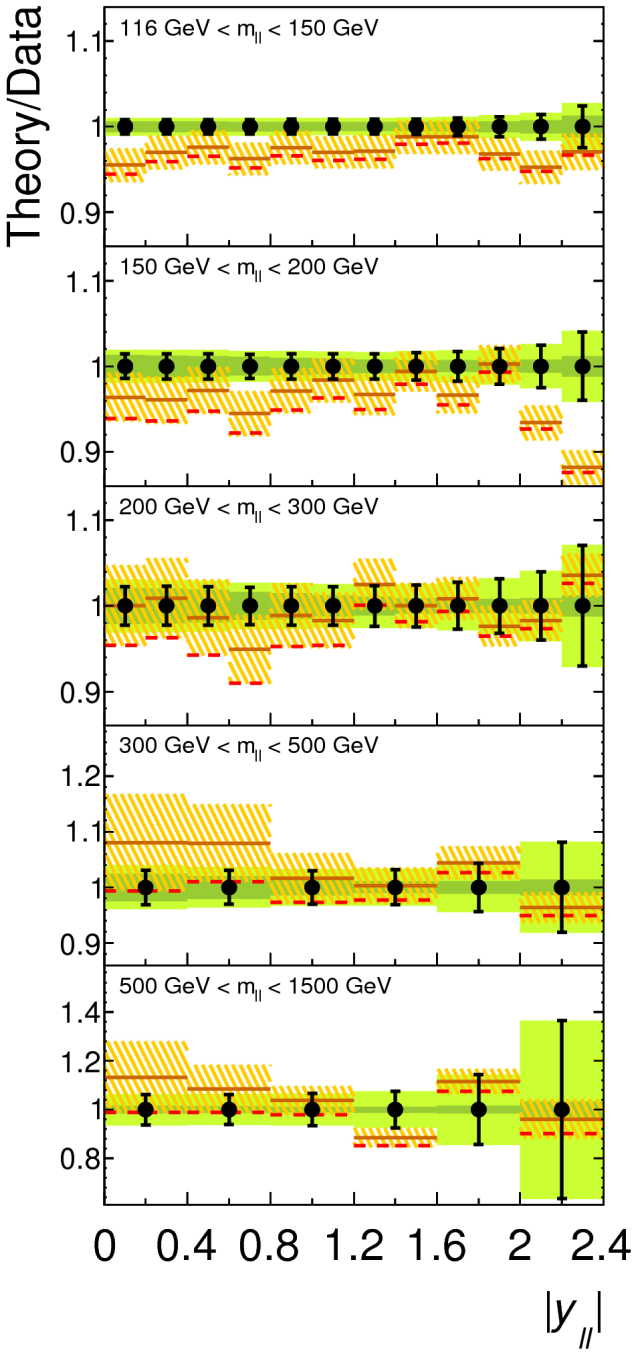


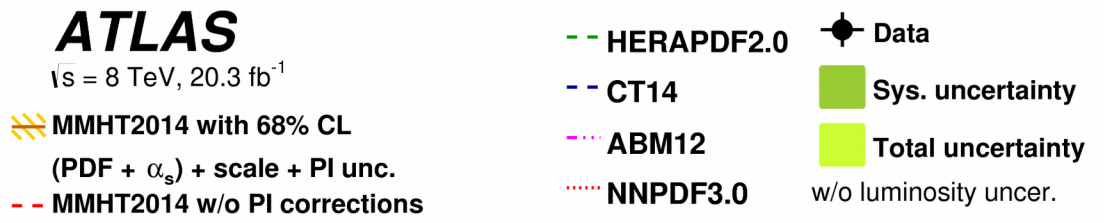
χ^2/ndof

	m_{ee}	$\lvert y_{ee}\rvert$	$\lvert\Delta\eta_{ee}\rvert$
MMHT2014	18.2/12	59.3/48	62.8/47
CT14	16.0/12	51.0/48	61.3/47
NNPDF3.0	20.0/12	57.6/48	62.1/47
HERAPDF2.0	15.1/12	55.5/48	60.8/47
ABM12	14.1/12	57.9/48	53.5/47

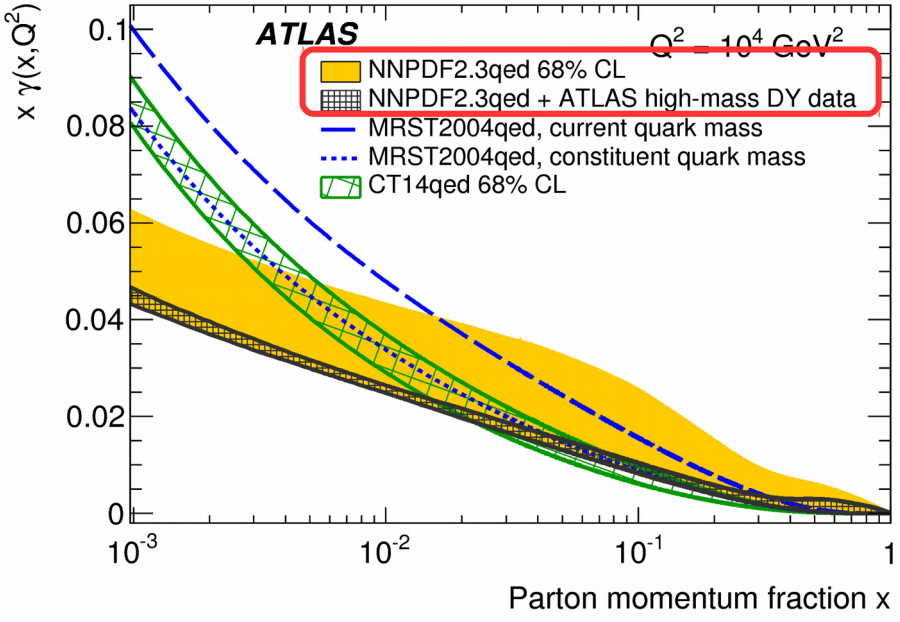
Photon PDF in proton

JHEP 1608 (2016) 009





- Bayesian reweighting of $q\bar{q}$ and $\gamma\gamma$ predictions based on NNPDF2.3qed to illustrate constraining power of the data.
- Significant sensitivity to the photon PDF.



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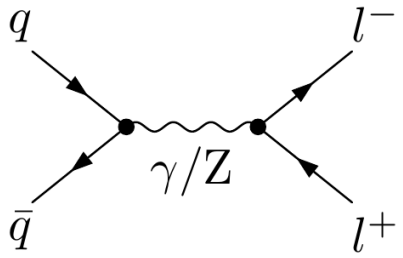
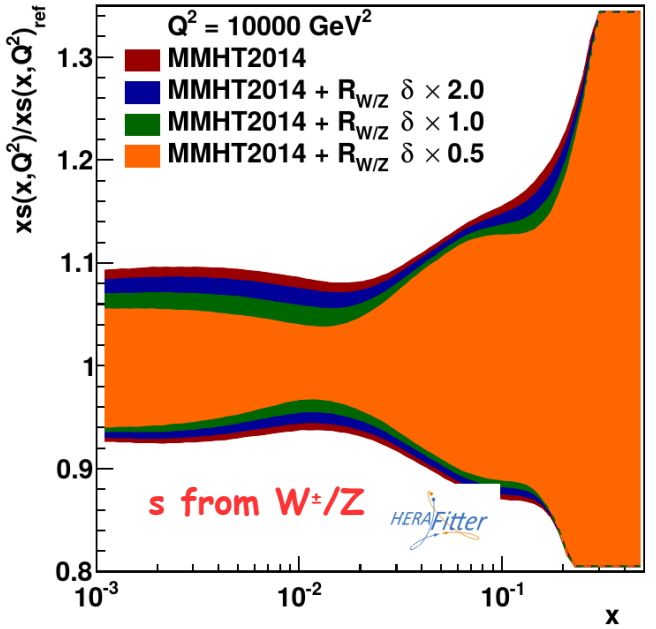
W,Z @ 13 TeV: overview

- Measure cross-section ratios: fully cancel lumi uncertainties and partially systematics.
- W/Z: 2% exp. precision adds constraint on strange PDF
- W^+/W^-: 2% contrains u_v-d_v PDF.

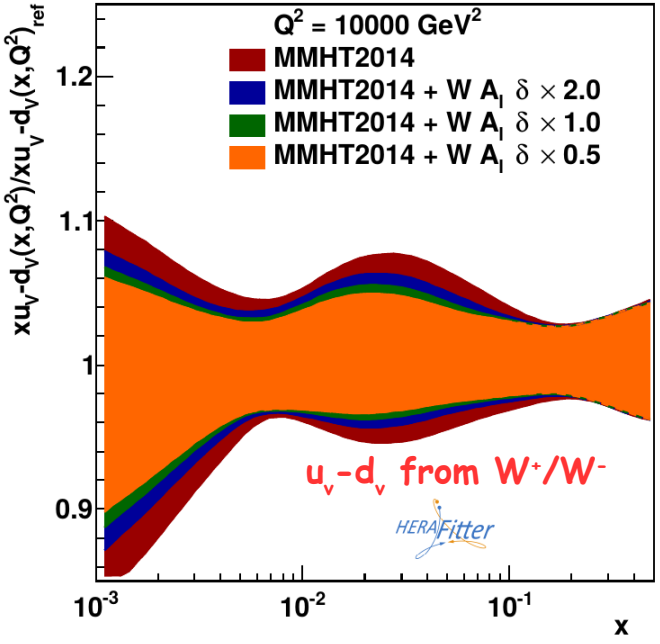


$W^{\pm}$:	Z:
• $p_T^l > 25$ GeV	• $p_T^l > 25$ GeV
• $\|\eta^l\| < 2.5$	• $\|\eta^l\| < 2.5$
• $p_T^\nu > 25$ GeV	• $66 < M < 116$ GeV
• $m_T > 50$ GeV	

81 pb^{-1} of 50ns datasample from 2015



PDF4LHC, J.Phys.G 42 (2015) 103103



Measurement precision

- Already systematics-limited!
- Dominating uncertainties:
- Z: lepton reconstruction;
- W: multijet and JES+JER

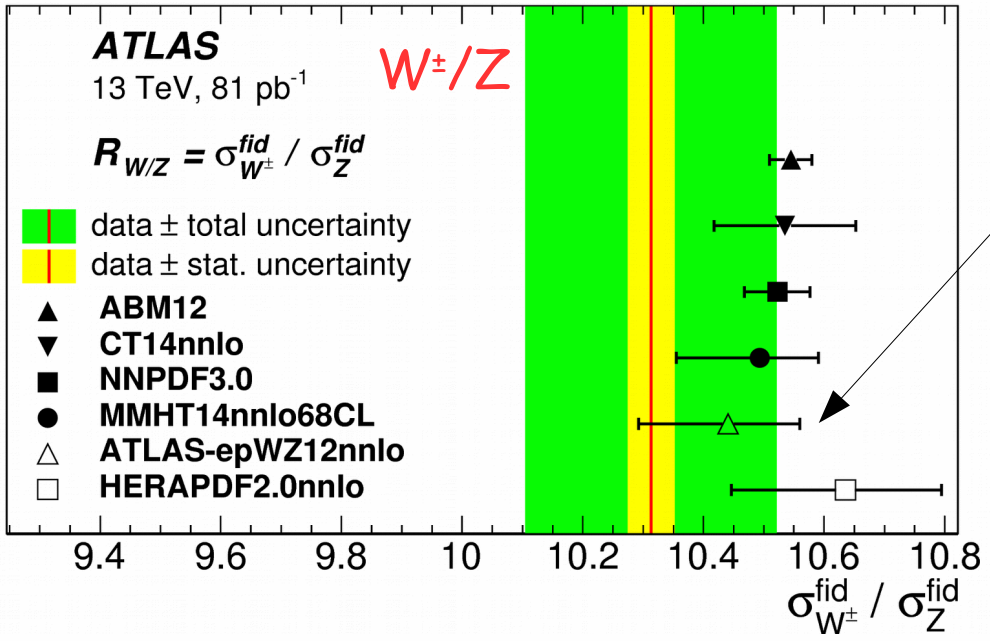
Z: ~1% (+2.1% lumi)

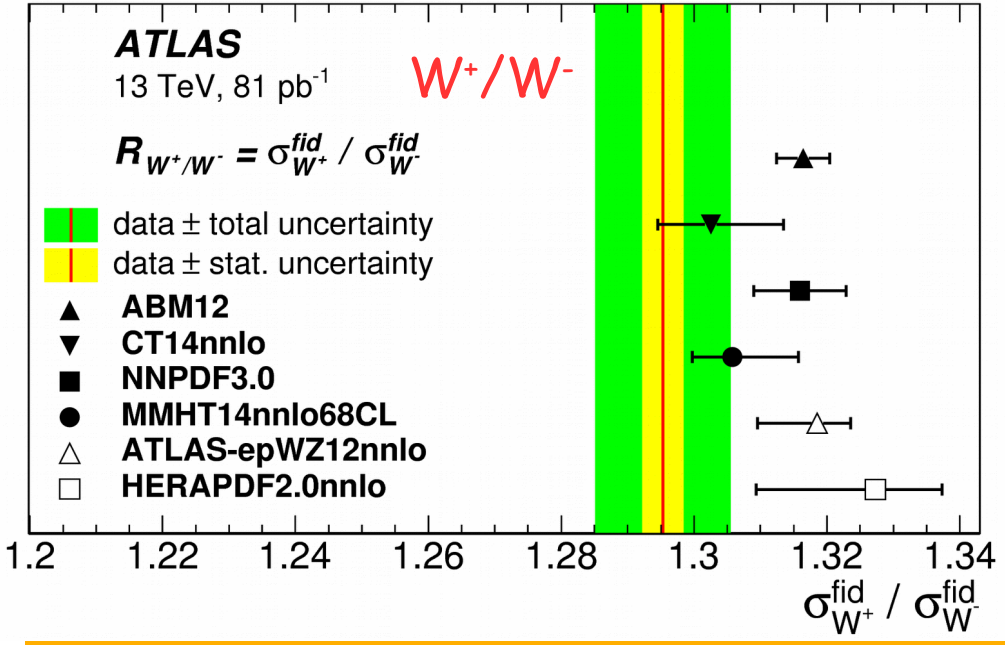
W: ~2% (+2.1% lumi)

$\delta C/C$ [%]	$Z \to e^+e^-$	$W^+ \to e^+\nu$	$W^- \to e^-\bar{\nu}$	$Z \to \mu^+\mu^-$	$W^+ \to \mu^+\nu$	$W^- \to \mu^-\bar{\nu}$
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
MJ	-	~3	~3	-	~1	~1
Statistical	0.5	~0.25	~0.25	0.5	~0.25	~0.25

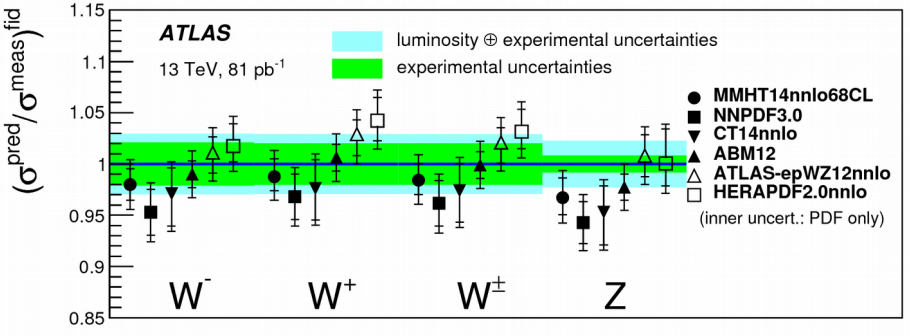
Results

PLB 759 (2016) 601





- Cross sections will constrain PDFs!
- W/Z: Enhanced strangeness observed using 7 TeV ATLAS data (ATLAS-epWZ12nnlo) is confirmed with the 13 TeV data.
- W^+/W^-: u_v-d_v PDF.



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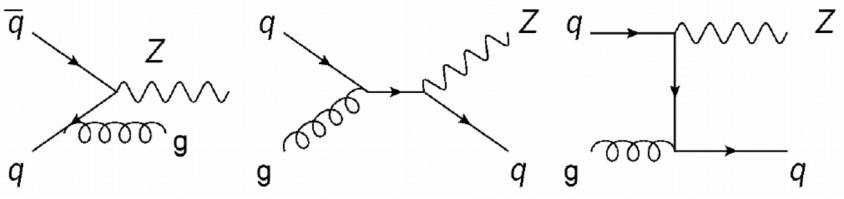
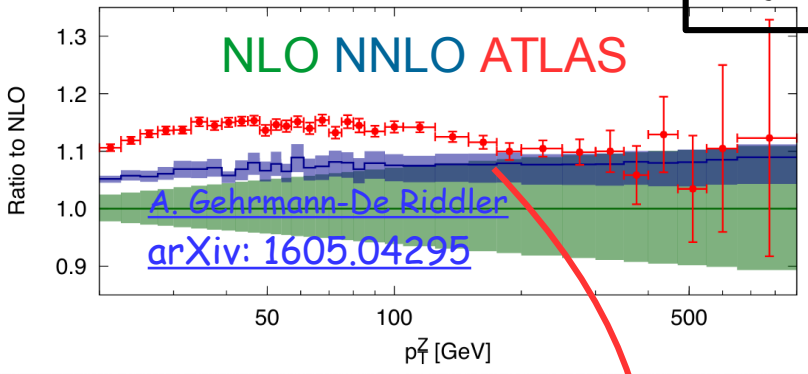
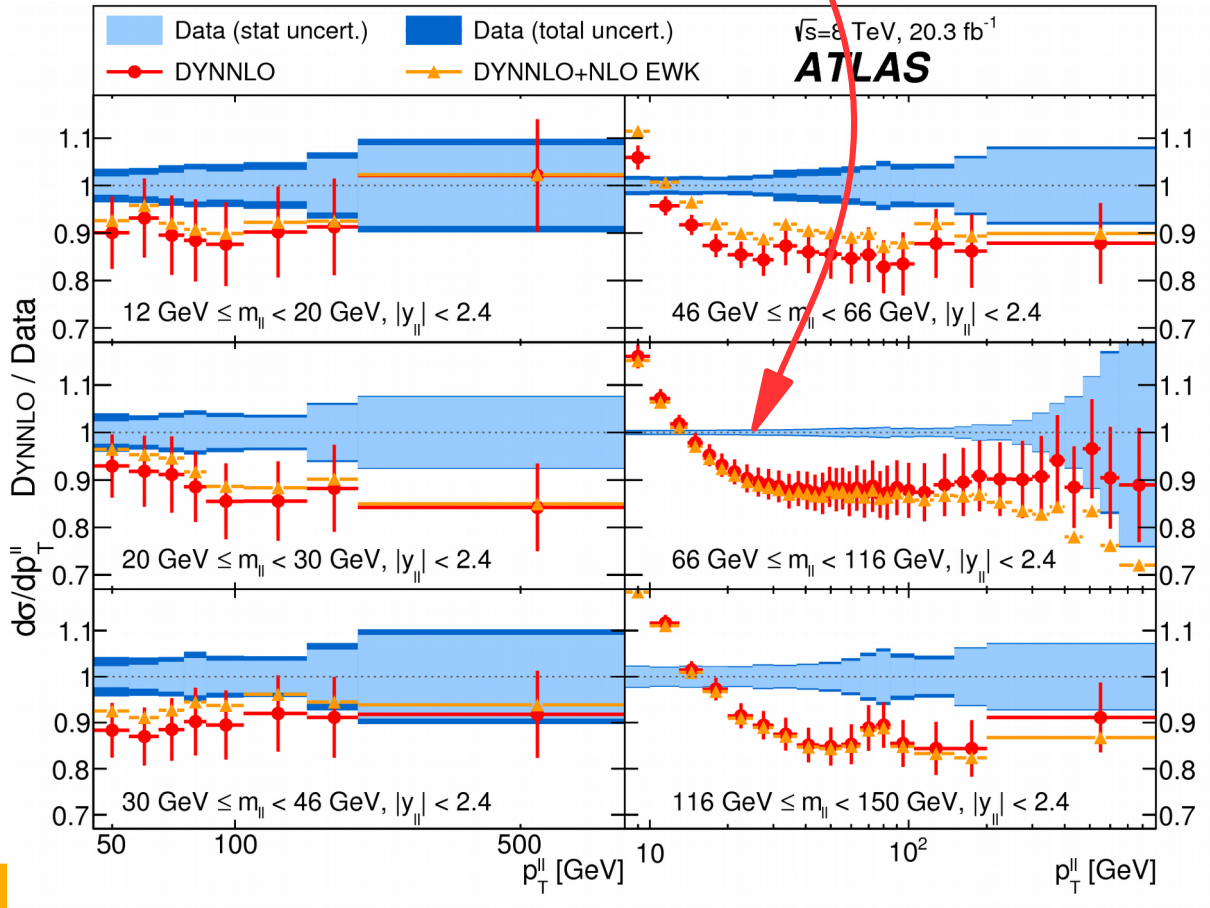
Z pT compared to $O(\alpha_s^2)$QCD

EPJC 76 (2016) 291





- High-pT region is sensivite to higher-order QCD (and EW) corrections.
- Recent $O(\alpha_s^3)$ corrections bring predictions closer to the data.
- The measurement has potential to be used for α_s extraction.



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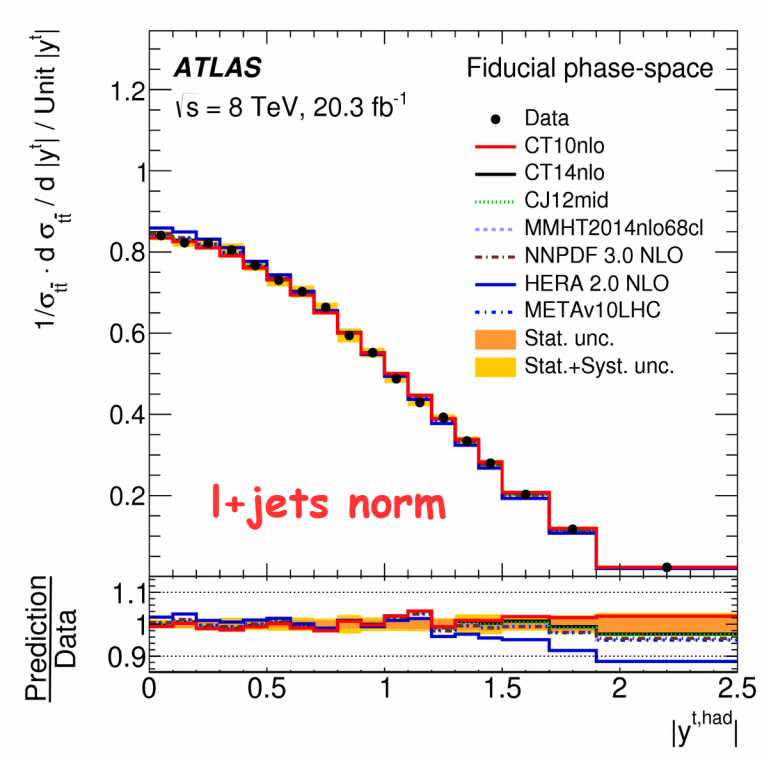
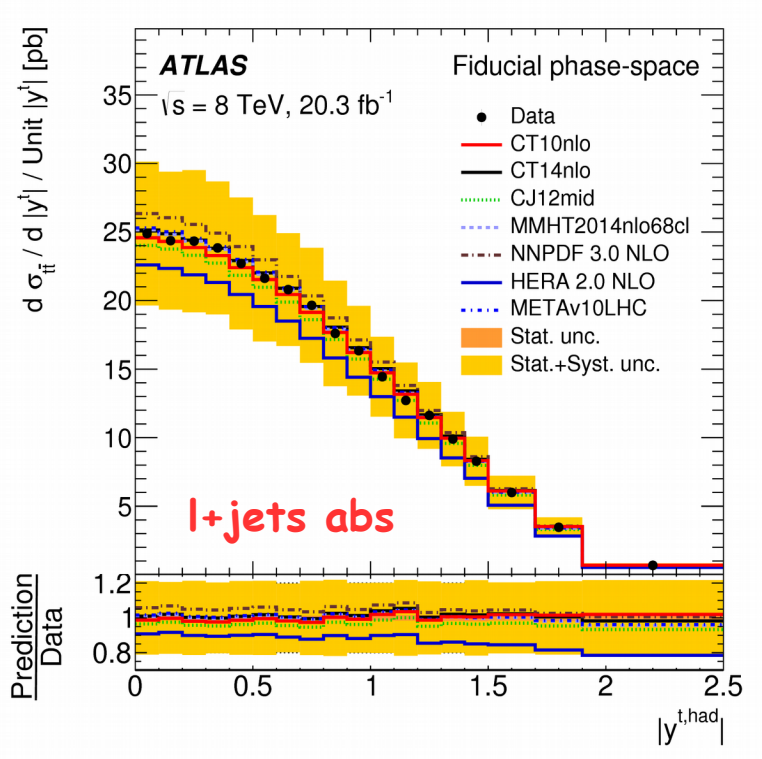
$t\bar{t}$ cross sections

- Tested description of various rapidity distributions by different PDFs.
- Potential to constrain gluon PDF?

arXiv:1511.04716

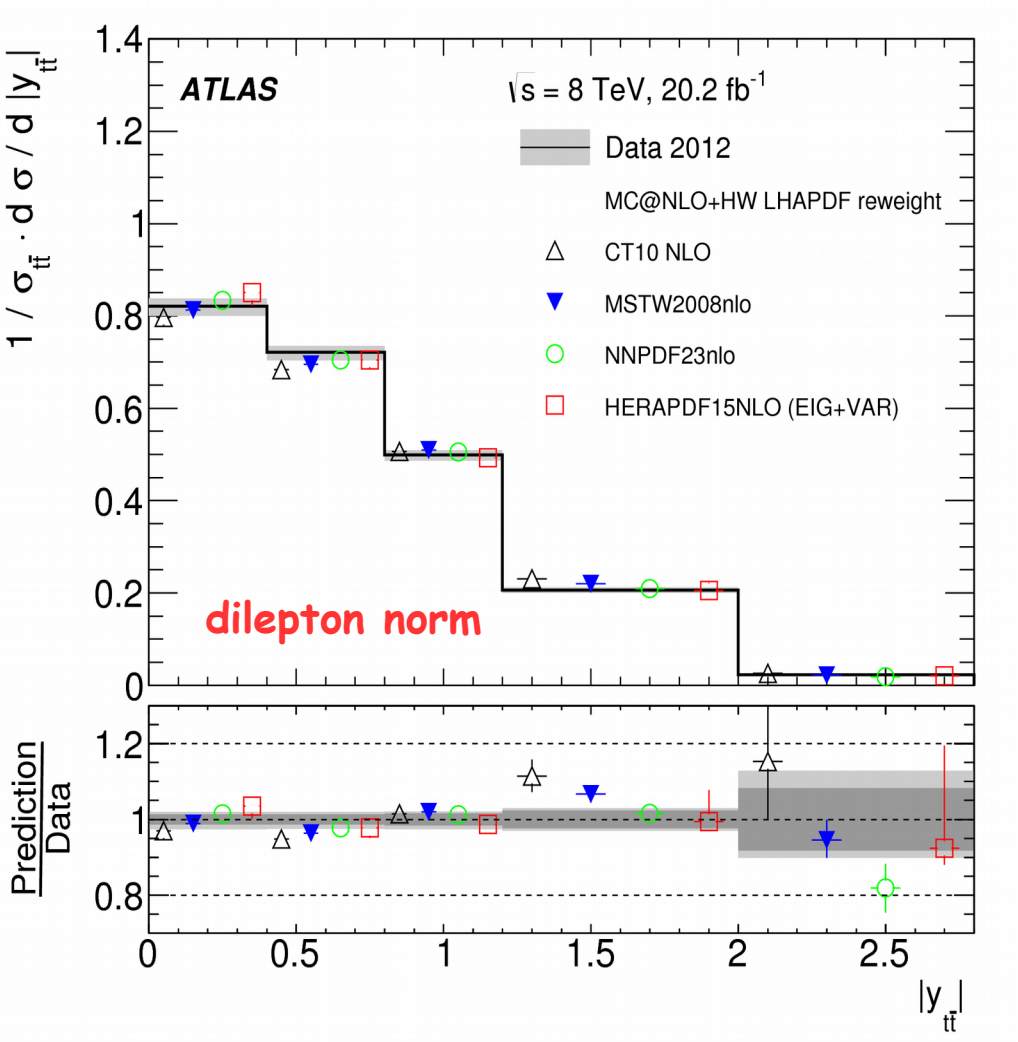




Variable	CT14nlo		CJ12mid		MMHT2014nlo68cl		NNPDF30nlo		CT10nlo		METAv10LHC		HERA20NLO	
	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value
$\lvert y^{tt}\rvert$	24/17	0.14	18/17	0.36	16/17	0.51	14/17	0.70	25/17	0.10	14/17	0.64	24/17	0.12
$\lvert y^{t,\mathrm{had}}\rvert$	15/17	0.60	13/17	0.71	14/17	0.66	12/17	0.79	13/17	0.75	13/17	0.71	26/17	0.08
$y^{t\bar{t}}_{boost}$	21/15	0.15	18/15	0.29	12/15	0.68	8.8/15	0.89	25/15	0.06	10/15	0.84	17/15	0.32

$t\bar{t}$ cross sections

arXiv:1607.07281



- NNPDF2.3nlo and HERAPDF1.5NLO provide better description of high values of $|y_{t\bar{t}}|$
- Potential to constrain gluon PDF?

Summary

- Many recent measurement useful for PDFs:
- Differential in M and y or Δη high-mass Drell-Yan cross sections @ 8 TeV: tests of QCD and EW corrections, constraints on photon PDF in the proton.
- Integrated W,Z cross sections @ 13 TeV: constraints on PDF with early 2015 data.
- Differential in p_T Z cross sections @ 8 TeV: test of QCD and potential for α_s fits.
- Differential tt cross sections @ 7 and 8 TeV: potential to contrain gluon PDF and α_s.
- All have been published, feel free to start using those!

Backup

Even more fun slides...

Analysis overview

$W^{\pm}$:

- $p_T^l > 25$ GeV
- $|\eta^l| < 2.5$
- $p_T^\nu > 25$ GeV
- $m_T > 50$ GeV

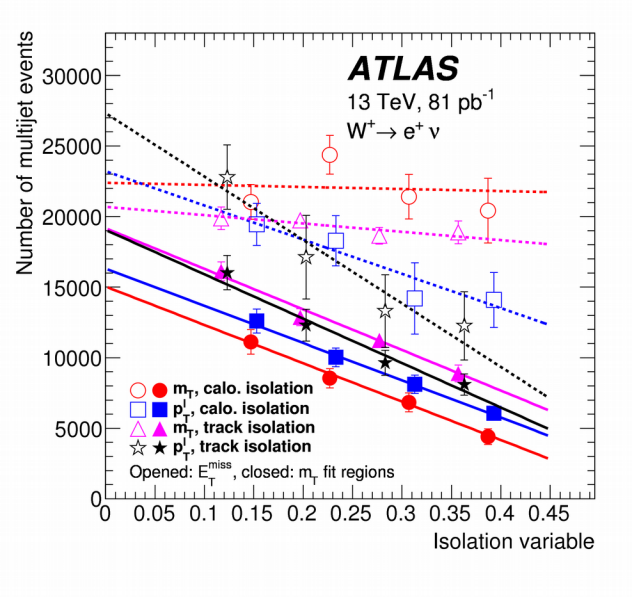
Z:

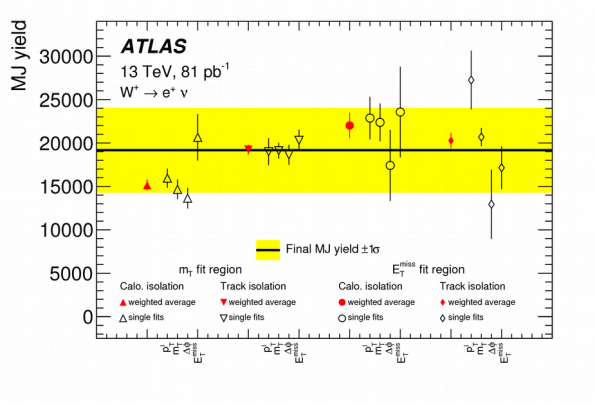
- $p_T^l > 25$ GeV
- $|\eta^l| < 2.5$
- $66 < M < 116$ GeV

$$\sigma^{fid}_{W,Z} \times BR(W,Z \to l\nu, ll) = \sigma^{tot}_{W,Z} \times BR(W,Z \to l\nu, ll) \cdot A_{W,Z} = \frac{N - B}{C_{W,Z} \cdot \mathcal{L}_{W,Z}}$$

- N: di-lepton signal candidates $W^{\pm}$~O(1M), Z~O(100k)
- B: estimated background candidates: EW+top from MC and data-driven multijet
- $C_{W,Z}$: corrections factor (1-bin unfolding)
- L: luminosity, 81 pb^{-1} ± 2.1%
- Combine ee and μμ cross sections using HERAverager (χ^2 minimisation treating correlated systematics as nuisance parameters)

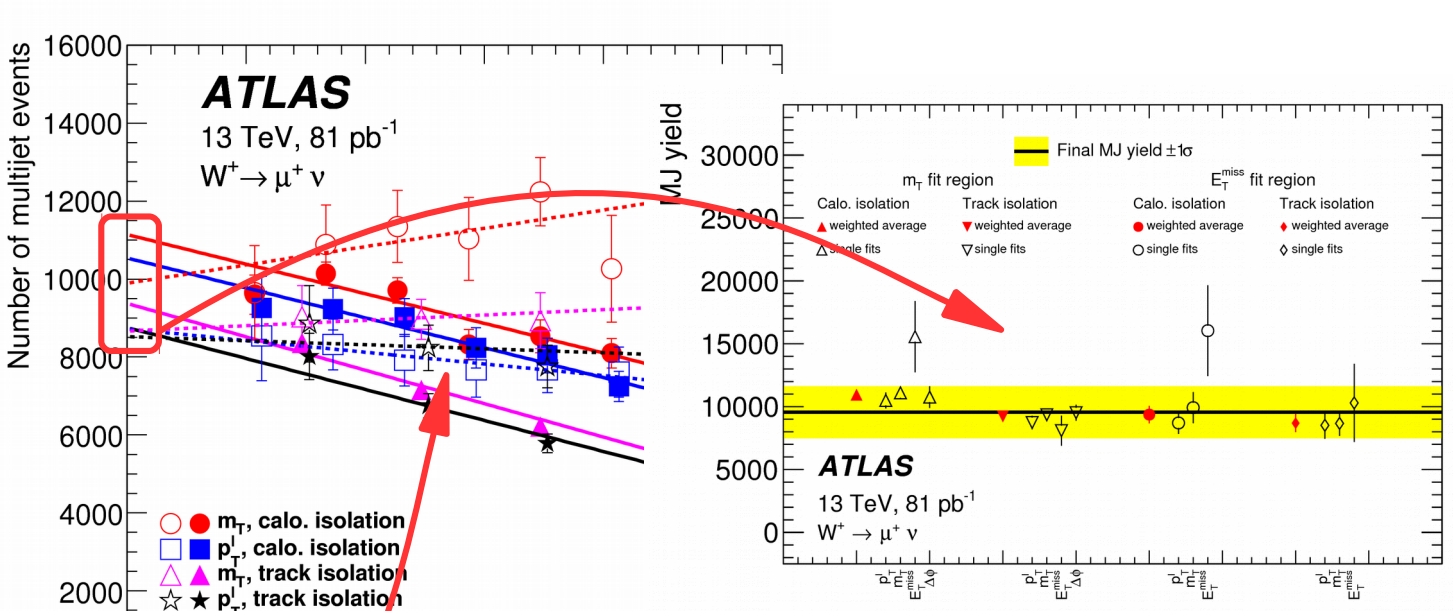
Multijet background

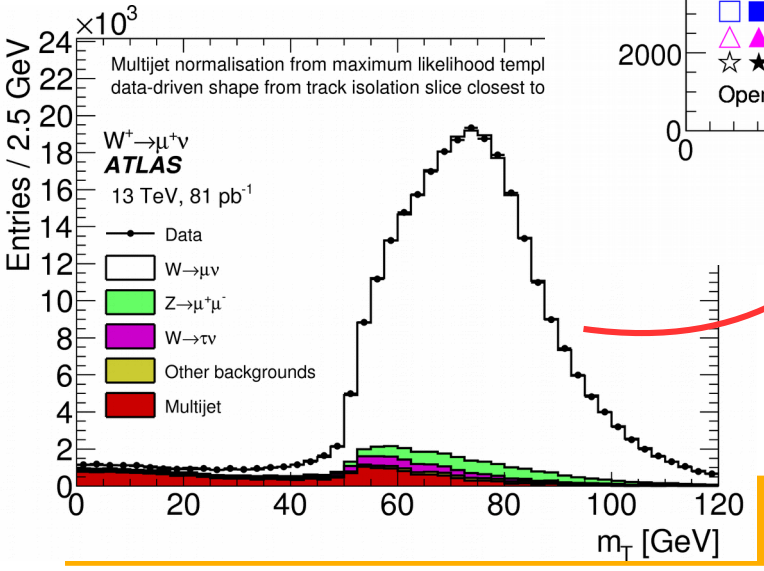




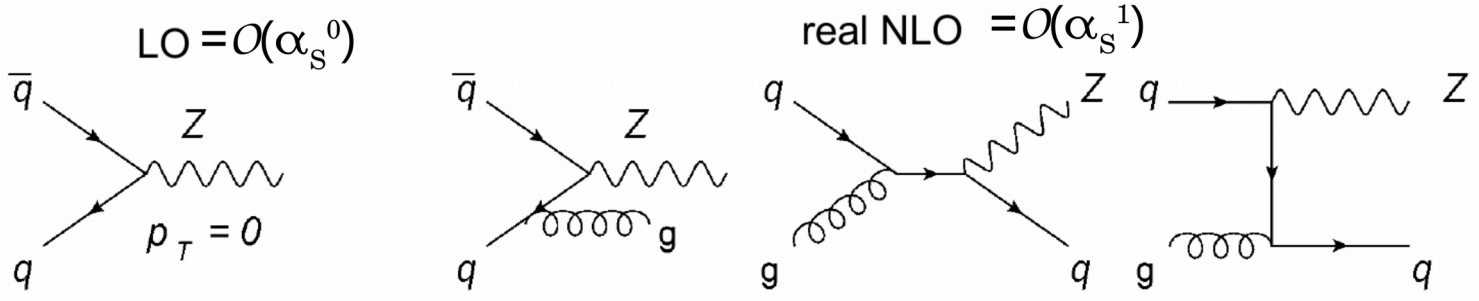
Multijet background

- Key: <u>isolated leptons from W and non-isolated from QCD</u>.
- Template fit in either of m_T, E_T^{miss}, p_T^l, $\Delta\varphi$ removing either m_T or E_T^{miss} cut for slices of calo- or track-based isolation. Extrapolated to the signal-like isolation topology.
- W -> ev: 9% ± 3%
- W -> μv: 4% ± 0.8%





Z p_T: motivation



- Measure p_T and φ^*_η distributions in Z-boson production:
  - Low p_T (multiple soft-gluon emissions): resummation up to NNLL (RESBOS), parton shower (PS) techniques, ME+PS with ME $O(\alpha_s)$.
  - High p_T (hard-gluon emission): fixed-order calculations up to $O(\alpha_s^2)$ (DYNNLO) and beyond...

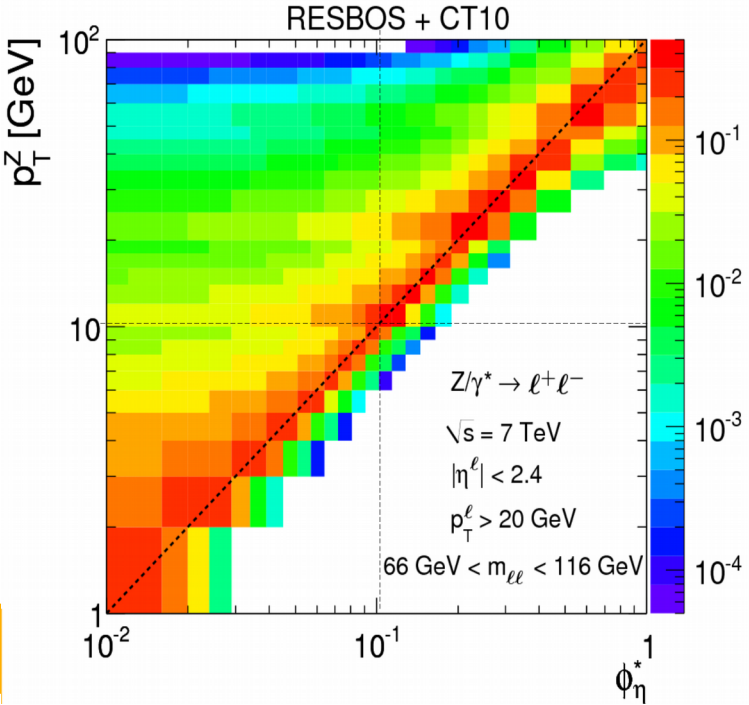
- At <u>low p_T measurements are limited by experimental resolution and uncertainties on momentum scale</u> --> Use φ^*_η, which depends on angular lepton measurements

$$\phi^*_\eta = \tan(\phi_{acop}/2) \times \sin(\theta^*_\eta)$$

$$\phi_{acop} = \pi - \Delta\phi(\ell,\ell)$$

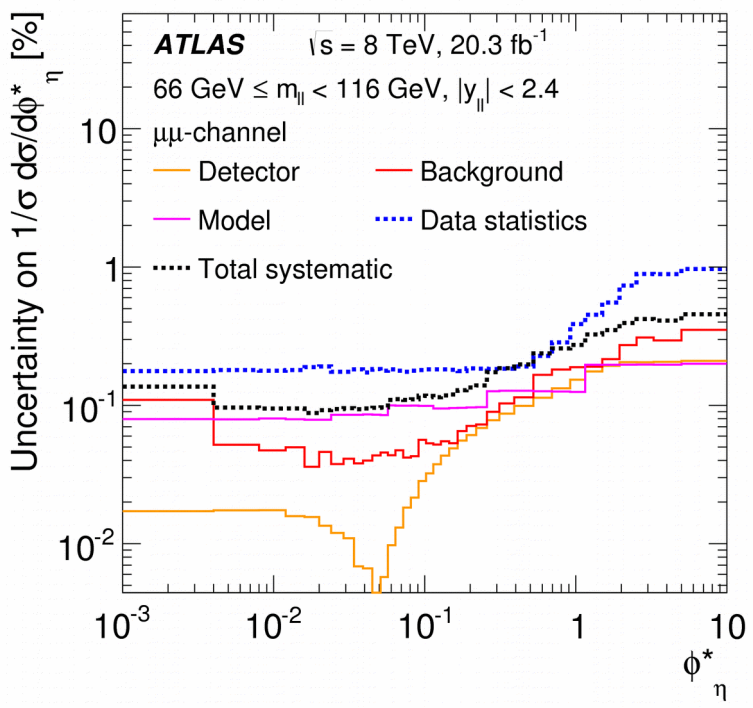
$$\cos(\theta^*_\eta) = \tanh[(\eta^- - \eta^+)/2]$$

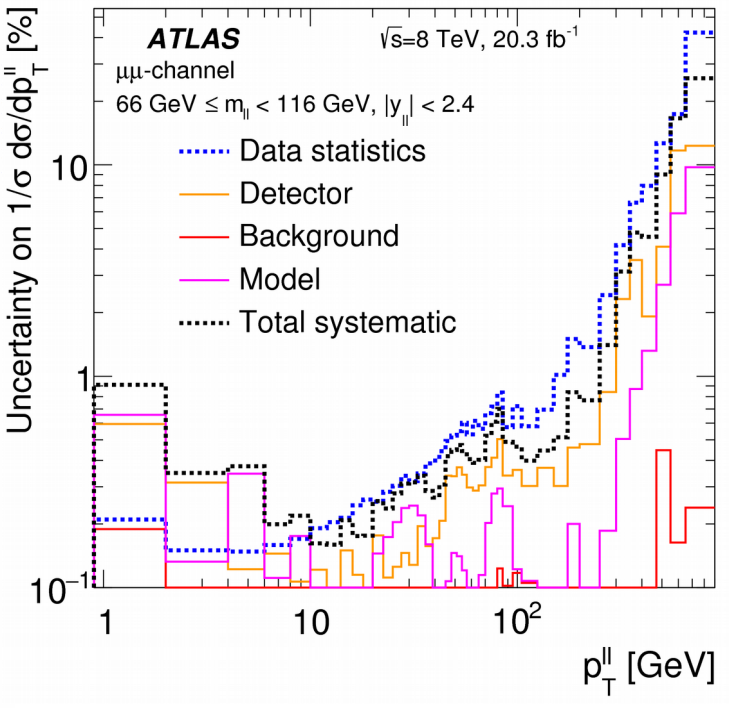
$\Phi^* \sim p_T/M_{ll}$



Analysis overview

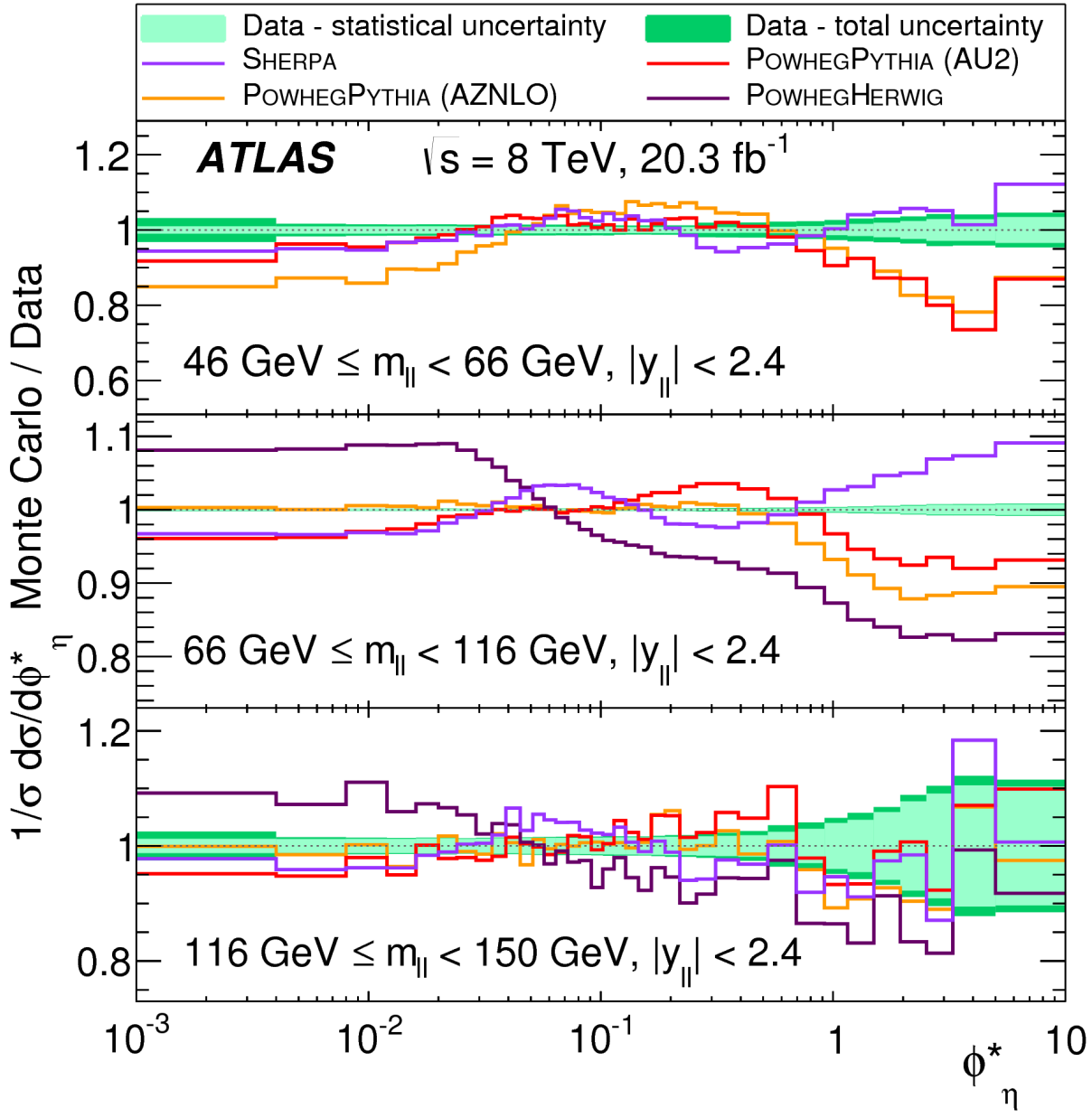
- $p_T^l > 20$ GeV
- $|\eta^l| < 2.4$
- $|y_{ll}| < 2.4$
- $12 < M < 150$ GeV





- Measure normalised cross sections (but also absolute as a function of p_T and integrated fiducial as a function of M) in M and y_{ll} slices.
- φ^*_η : concentrate on the low-p_T and medium-p_T regions.
- p_T: concentrate on the high-p_T region.
- Combine ee and μμ cross sections using HERAverager.

Comparison to MC



EPJC 76 (2016) 291

- The data have large constraining potential!
- Powheg+Pythia AZNLO was tuned to earlier 7 TeV Z p_T data (JHEP 09 (2014) 145). Good description in the phase space of the tune (66<M<116 GeV and pT<100 GeV), but fails at low masses.
- High mass is reasonably described by all but Powheg+Herwig.