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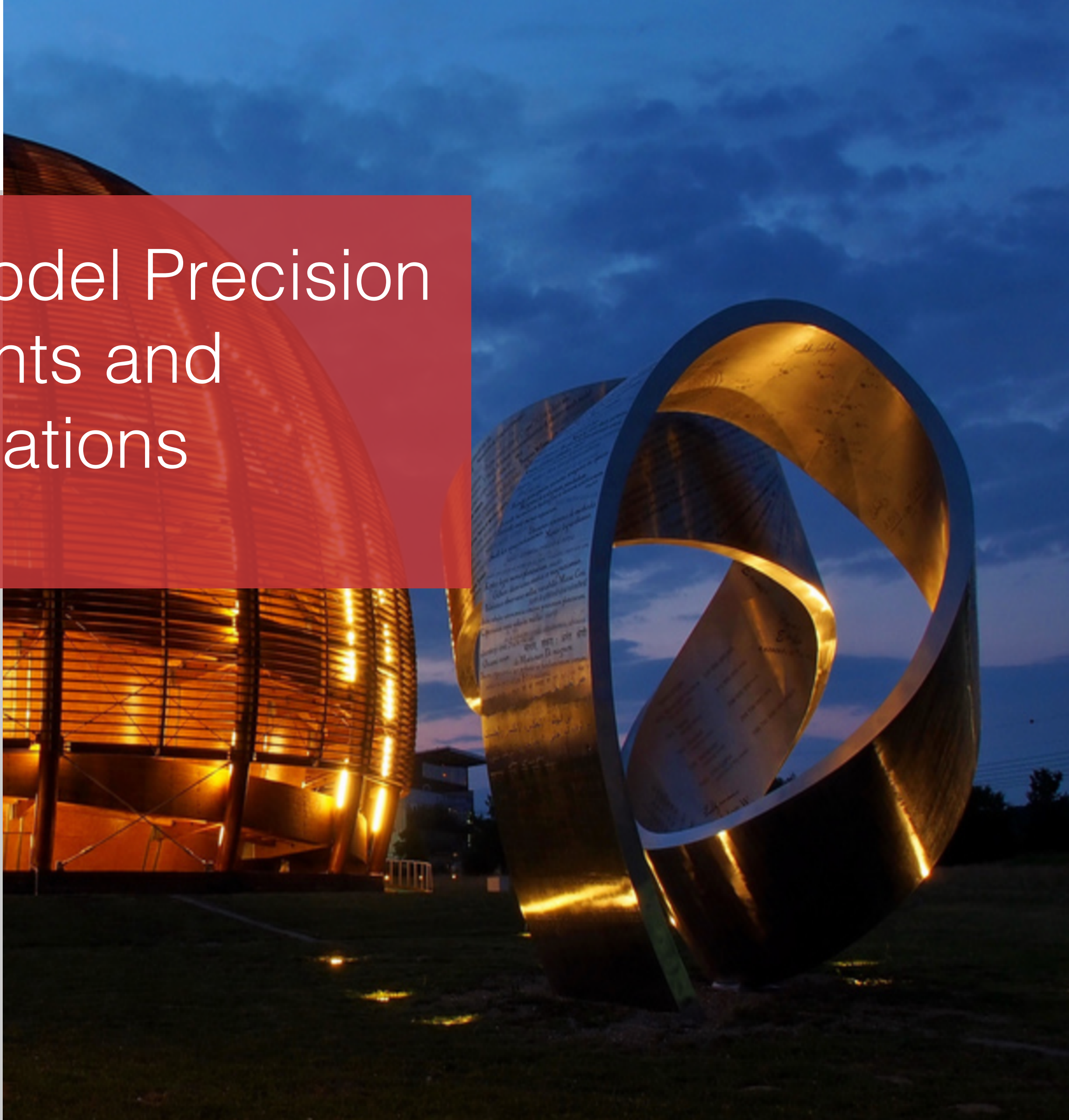
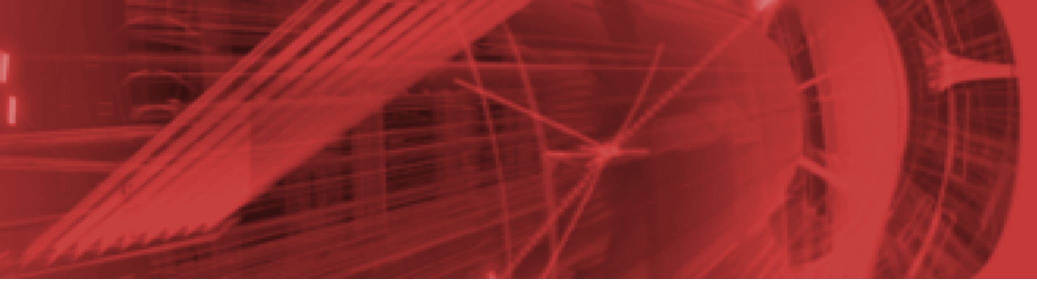


Standard Model Precision Measurements and Theory Limitations

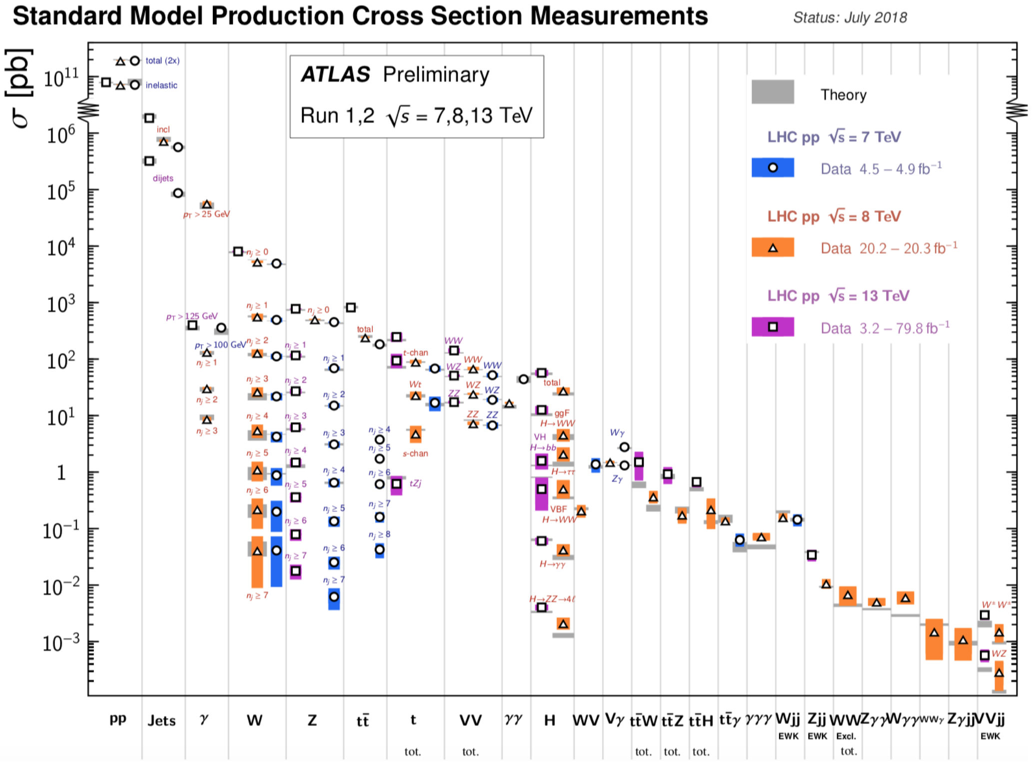
Matthias Schott

Where do we stand

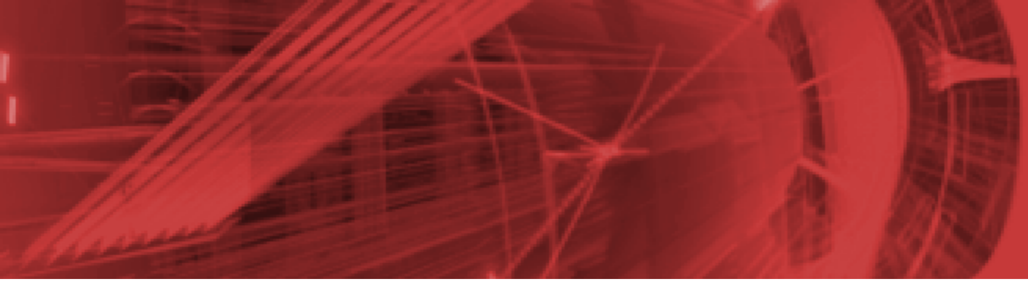


Where do we stand?

- **Disclaimer:** I will focus on ATLAS measurements and will only talk about (ATLAS) SM physics (due to by personal bias).
  - General conclusions hold also for the Higgs-sector as well as CMS
  - Nearly all LHC Run-1 measurements are published and first Run-2 precision measurements become available.



- Many differential/inclusive cross-section measurements are known at sub-percent precision, i.e. are better than the theory predictions



Theory limitations on measurements

- We measure cross-sections in fiducial volumes, defined on MC truth level close to the detector level selection
  - E.g.: W boson selection: 1 isolated lepton (p_T>20 GeV, eta<2.5), E_T^{Miss}>25 GeV, m_T>40 GeV

- Cross-Section typically evaluated by a counting experiment

- If the bin width is sufficiently small, then the C-factor is nearly independent from the underlying MC prediction
  - Most SM cross-section measurements are therefore not limited by theory

Number of background-subtracted data events

$$\frac{d\sigma}{dX}(i) = \frac{N_{\mathrm{sig}}^{(i)}}{\Delta X^{(i)}\ \mathscr{L}\ \epsilon_{\mathrm{trigger}}\ C_{\mathrm{unfolding}}^{(i)}}$$

Width of bin *i*

Corrections for detector resolution, reconstruction and selection efficiencies

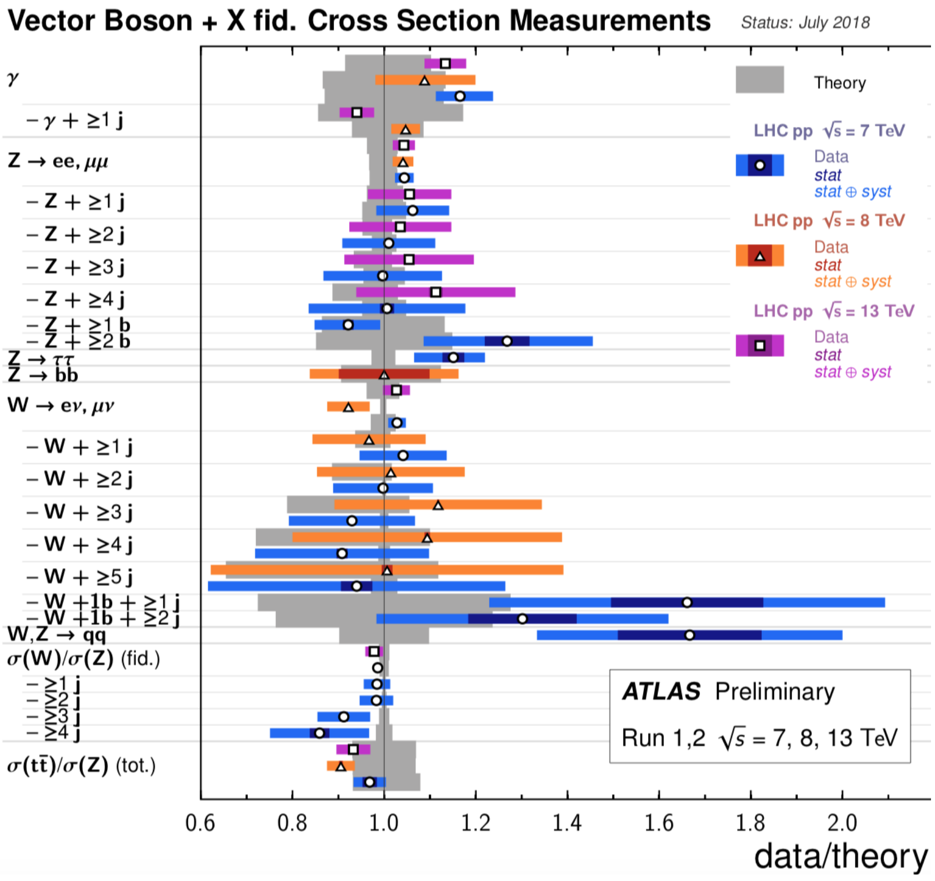
(From Brigitte Vachon (McGill))

Where are we limited?

- Theory limitations play a role in precision measurements of SM parameters:
  - m_{Top}, m_W, Sin^2theta
- We are limited when interpreting our measurements in terms of new physics
  - EFTs: We assume SM (i.e. the predictions) and the derive limits on EFTs by comparing prediction with data
    - If the predictions are wrong, our limits are wrong
- We are limited when interpreting our measurements in terms of SM (e.g. PDF Fits)
  - Examples: Interpretation of Jet cross-sections, PDF-Fits of high precision measurements
- Myth: we need high precision predictions of SM processes since they are backgrounds for searches
  - In general this is not the case, since we always use control- and validation regions for nearly all backgrounds which might have problems in the modelling

What will I discuss today?

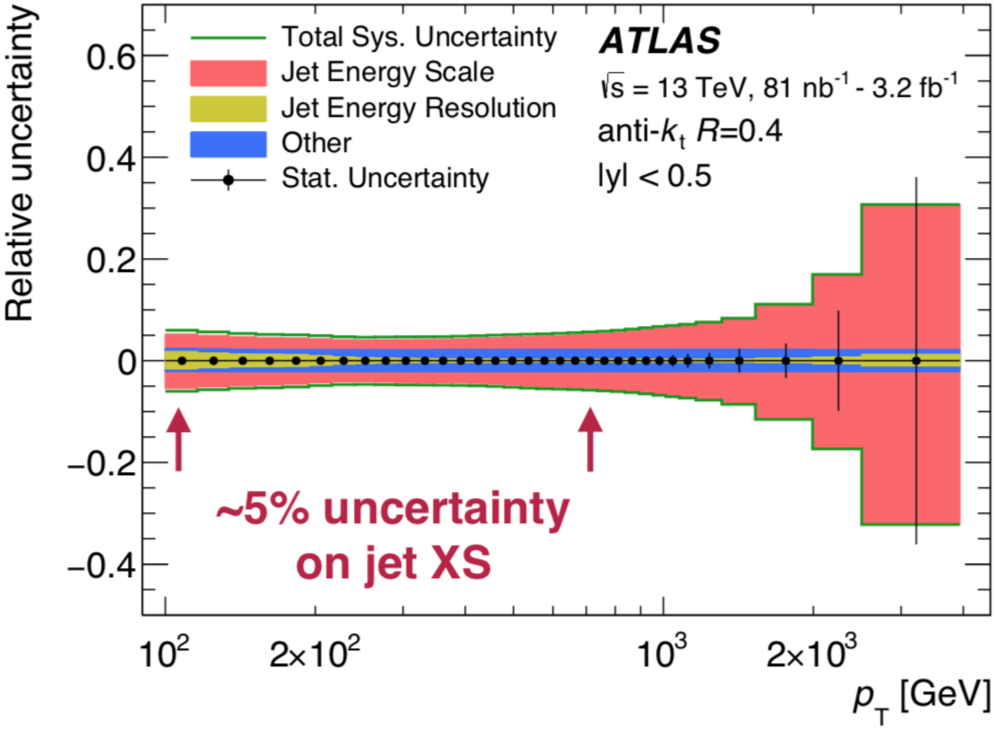
- Results on the jets and photons and their problems when comparing to theory predictions
- Some thoughts on scale choices
- The latest results of multi-boson measurements and discrepancies between predictions (and measurements)
- Limitations of electroweak precision measurements



Vector Bosons, Photons and Jets

Detector Jets

- Jets formed from calorimeter energy deposits using anti-kt algorithm
- Jet energy scale and resolution calibrated with MC-based methods and in situ data-to-MC corrections
- JES/JER are dominant experimental uncertainties
- Unfold data to hadron-level, correcting for detector effects
- Pythia-based transfer matrix



~5% uncertainty on jet XS

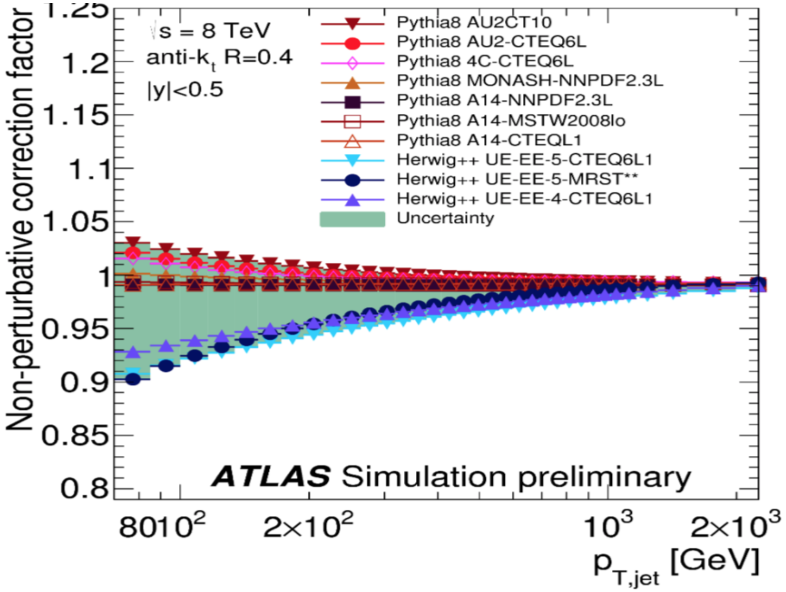
JES/JER uncertainty on 13 TeV XS

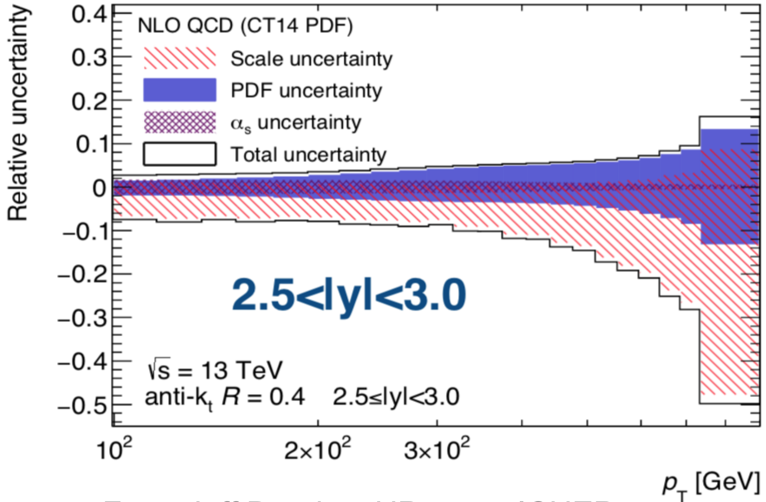
From Jeff Dandoy, UPenn at ICHEP

Theory predictions

- Theoretical prediction of Matrix Element from NLOJET++ interfaced with various PDFs
  - Non-perturbative corrections
  - (hadronization, underlying event)
  - from Pythia & Herwig tunes
  - Large spread between Pythia8 & Herwig++ taken as uncertainty

- Uncertainties
  - PDF - Propagated using variations for each PDF set
  - αs - Tunable parameter in PDFs varied according to PDF4LHC recommendations
  - Factorization / renormalization scales - 0.5 < $\mu_{R,F}$ < 2.0:
    - Dominant theory uncertainty!

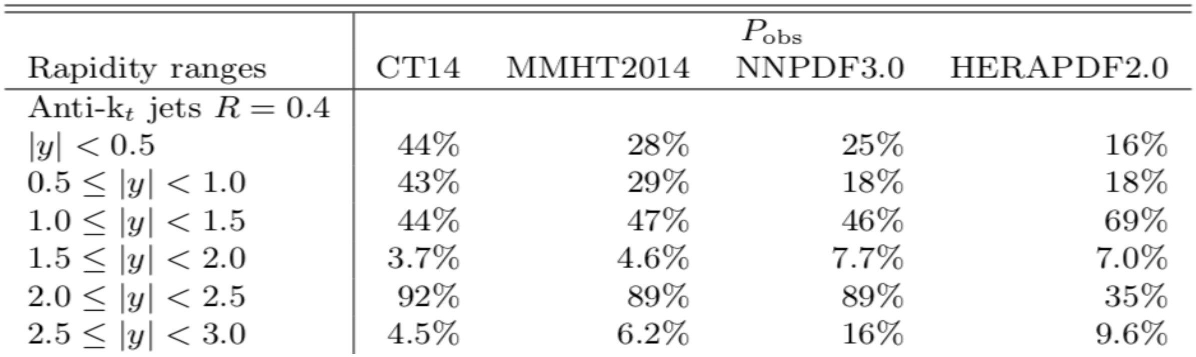




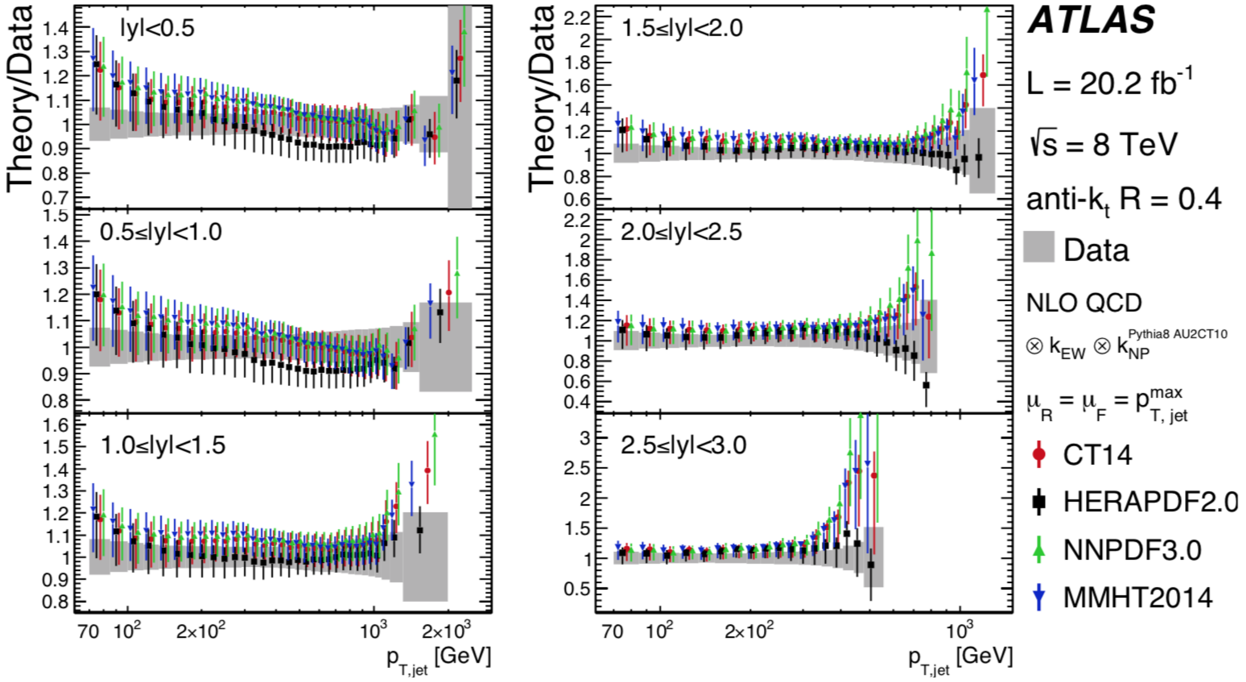
From Jeff Dandoy, UPenn at ICHEP

Inclusive & Dijet Cross-Section

- 8 TeV Inclusive: JHEP 09 (2017) 020
  - CT14, HERAPDF20, NNPDF30, MMHT14
  - Significant slopes at low-medium and medium-high pT
  - Good fit agreement within |y| bins, but poor inclusively (P^{obs} ≪10^{-3})



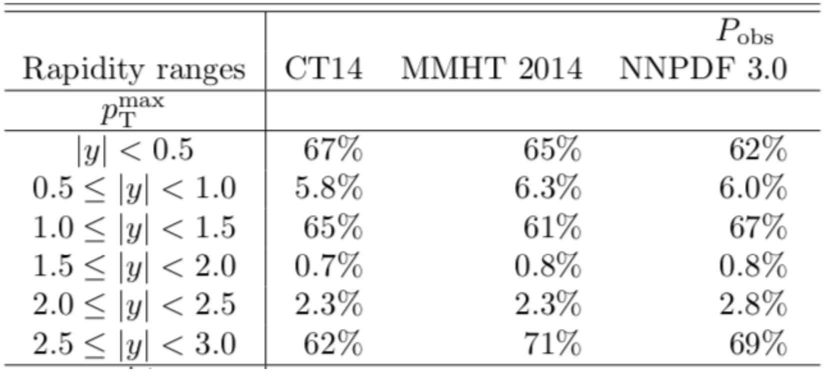
	P_{obs}			
Rapidity ranges	CT14	MMHT2014	NNPDF3.0	HERAPDF2.0
Anti-k_t jets $R = 0.4$				
$\lvert y \rvert < 0.5$	44%	28%	25%	16%
$0.5 \leq \lvert y \rvert < 1.0$	43%	29%	18%	18%
$1.0 \leq \lvert y \rvert < 1.5$	44%	47%	46%	69%
$1.5 \leq \lvert y \rvert < 2.0$	3.7%	4.6%	7.7%	7.0%
$2.0 \leq \lvert y \rvert < 2.5$	92%	89%	89%	35%
$2.5 \leq \lvert y \rvert < 3.0$	4.5%	6.2%	16%	9.6%



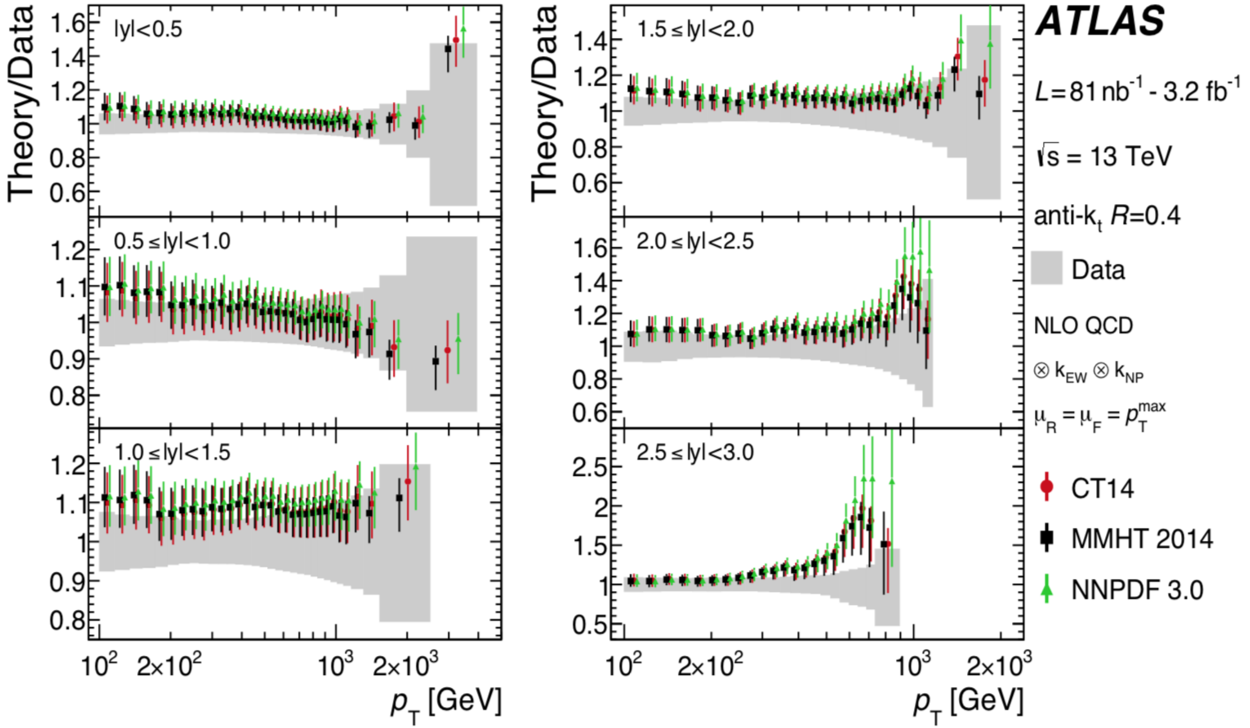
From Jeff Dandoy, UPenn at ICHEP

Inclusive & Dijet Cross-Section

- 13 TeV Inclusive & Dijet: JHEP 05 (2018) 195
  - CT14, MMHT2014, NNPDF3.0
  - 100 GeV to 3.5 TeV
  - Conclusions unchanged from 8 TeV



Rapidity ranges	P_{obs}		
$p_{\text{T}}^{\text{max}}$	CT14	MMHT 2014	NNPDF 3.0
$\|y\| < 0.5$	67%	65%	62%
$0.5 \leq \|y\| < 1.0$	5.8%	6.3%	6.0%
$1.0 \leq \|y\| < 1.5$	65%	61%	67%
$1.5 \leq \|y\| < 2.0$	0.7%	0.8%	0.8%
$2.0 \leq \|y\| < 2.5$	2.3%	2.3%	2.8%
$2.5 \leq \|y\| < 3.0$	62%	71%	69%



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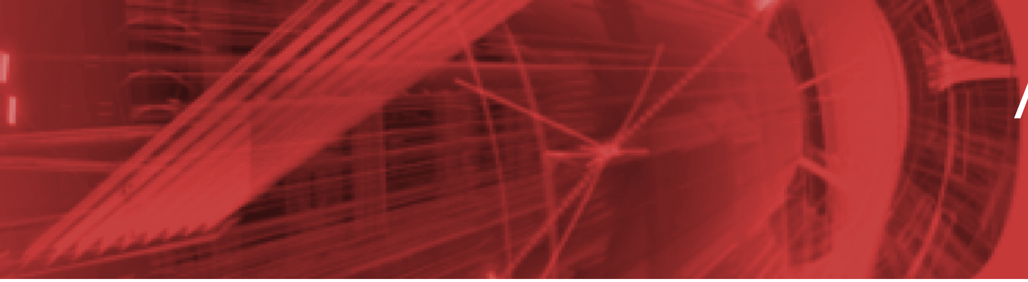


Alternative correlation schemes

- Data-theory tension in inclusive measurements at 8 & 13 TeV
  - Not localized in |y|, no central-forward tension

$\mu_{R,F}$

χ^2/dof all $|y|$ bins	CT14	MMHT 2014	NNPDF 3.0	HERAPDF 2.0	ABMP16
p_T^{max}	419/177	431/177	404/177	432/177	475/177
p_T^{jet}	399/177	405/177	384/177	428/177	455/177

- Potential culprit: 2-point systematics have unknown correlations
  - Comparison of 2 MC generators (non-perturbative corrections) or variations for uncertainties (theory scale uncertainty) - several for JES

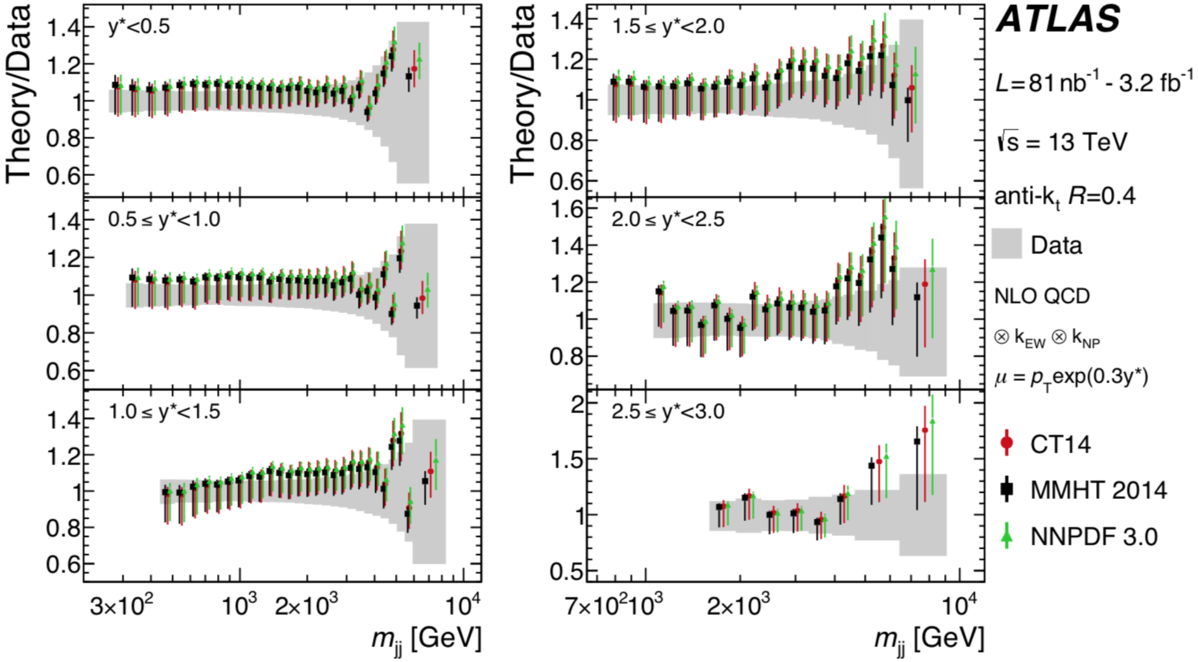
- Explored 18 alternative correlation scenarios to split 2-point systematics
- smoothly by pT and |y|
  - Can improve χ2 substantially - 58 units for 13 TeV CT14 result
  - But all justifiable de-correlation scenarios still give small p-values
  - Potential breakdown in 2-point systematic assumptions (phase-space dependence) or incomplete theoretical descriptions

From Jeff Dandoy, UPenn at ICHEP

DiJet Cross-Section Measurements

- 2-jet system as a function of mjj and y* (centrality)
- 300 GeV to 9 TeV
- Good data-theory agreement for most PDFs

y^* ranges	P_{obs} CT14	MMHT 2014	NNPDF 3.0	HERAPDF 2.0	ABMP16
$y^* < 0.5$	79%	59%	50%	71%	71%
$0.5 \leq y^* < 1.0$	27%	23%	19%	32%	31%
$1.0 \leq y^* < 1.5$	66%	55%	48%	66%	69%
$1.5 \leq y^* < 2.0$	26%	26%	28%	9.9%	25%
$2.0 \leq y^* < 2.5$	43%	35%	31%	4.2%	21%
$2.5 \leq y^* < 3.0$	45%	46%	40%	25%	38%
all y^* bins	8.1%	5.5%	9.8%	0.1%	4.4%



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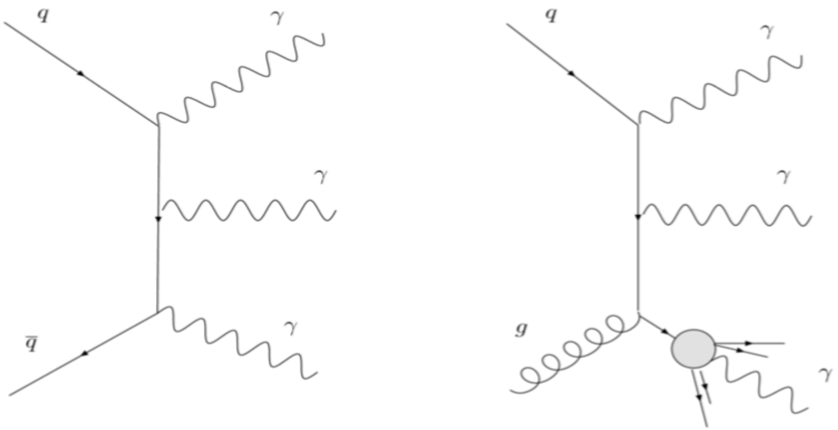
Some personal remarks

- The CMS Jet data does not show this tension, however, CMS adjusted the correlation scenario so that a good compatibility with the predictions are achieved.

- The scale choice in an inclusive jet measurement is not well defined (since also N-jet final states are considered)
  - Once there is a good scale-choice available (e.g. di-jet events), the tension to theory disappears
  - Maybe inclusive jet observables are not the ideal choice and some theory input on what to measure might be useful

Photon Measurements (1/2)

- Only one example (arXiv:1712.07291) since we are missing here predictions: pp → γγγ + X
  - Rare process: At LO contribution is order α^3_{EM} .
  - Complementary phase space to inclusive and di-photon production.



- Study topology and kinematics of individual photons, pairs of photons and three-photon system (13 kinematic variables).
  - Main background: electron and jet mis-identification.
  - Electron mis-identified as a photon
    - Estimated from eeγ, eeγγ, eνγγ MC events (LO Sherpa).
    - Mis-ID rate corrected to match measurement in Z→ee data.
  - Jet mis-identified as a photon
  - 2D sideband applied to account for all combinations of photons meeting or failing to meet the tight identification or isolation criteria.

From Brigitte Vachon, McGill at ICHEP

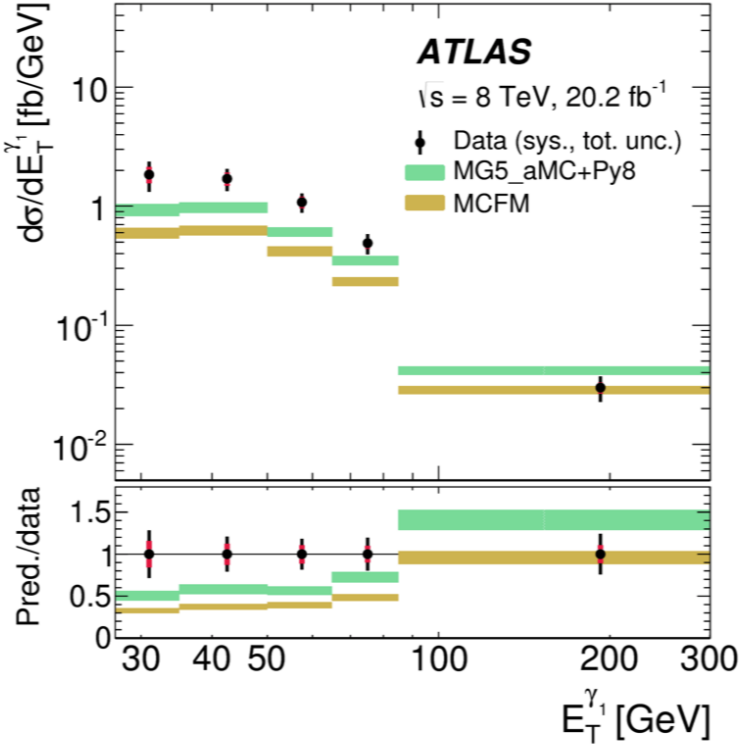
Photon Measurements (2/2)

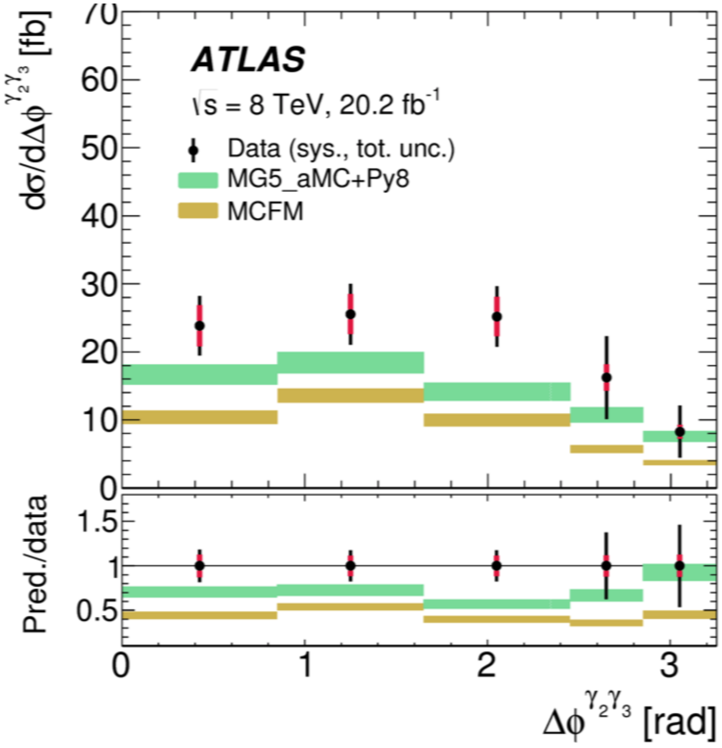
- NLO predictions underestimate measured cross- section by ~ x1.5-2.
  - NLO fails to describe regions of low ET.
  - Addition of PS to NLO improves agreement.

$$\boxed{\sigma_{\text{meas}} = 72.6 \pm 6.5\,(\text{stat.}) \pm 9.2\,(\text{syst.})\ \text{fb}}$$

$$\sigma_{\text{NLO}} = 31.5\,^{+3.2}_{-2.5}\ \text{fb}\,(\text{MCFM})$$

$$\sigma_{\text{NLO+PS}} = 46.6\,^{+5.7}_{-3.6}\ \text{fb}\,(\text{MadGraph5\_aMC@NLO})$$





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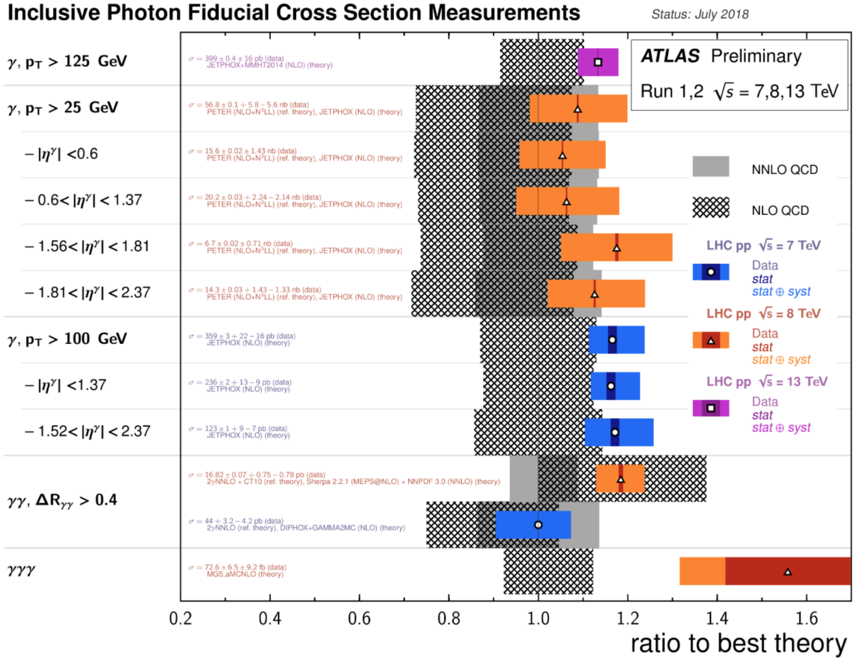
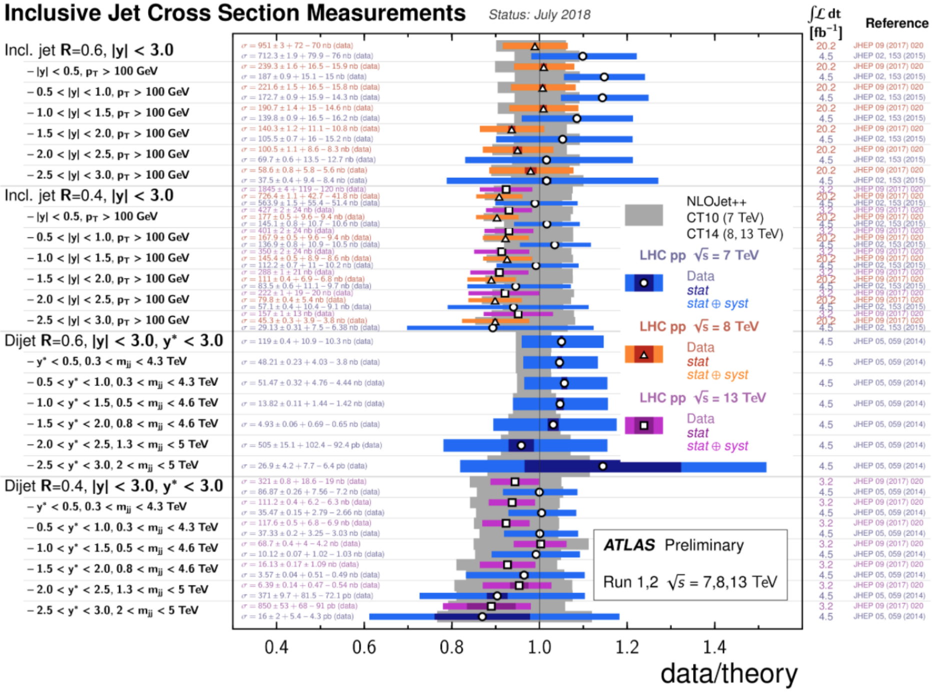
Some thoughts on Scale Choices

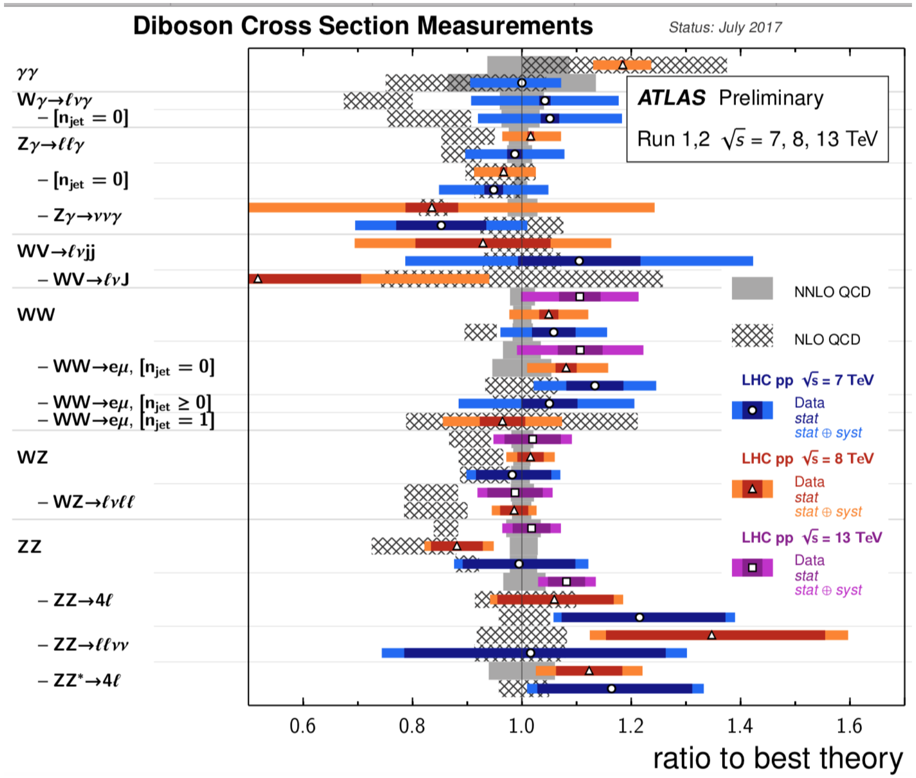
NLO vs. NNLO for photons and jets

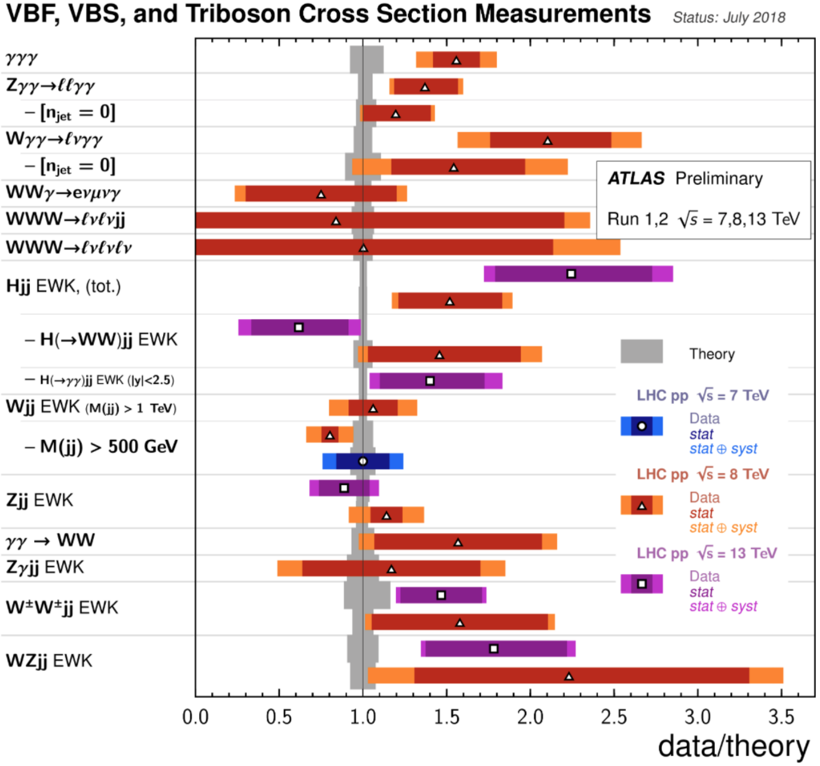




- We observe a quite good agreement to NLO predictions for the inclusive jet/photon cross-sections
  - Moreover, the NNLO predictions seems to be within the scale-variated NLO predictions

Electroweak processes





- Depending on the processes, we observe significant tensions between the prediction and theory
  - sometime presumably due to missing higher order
- We observe large changes when going from NLO to NNLO

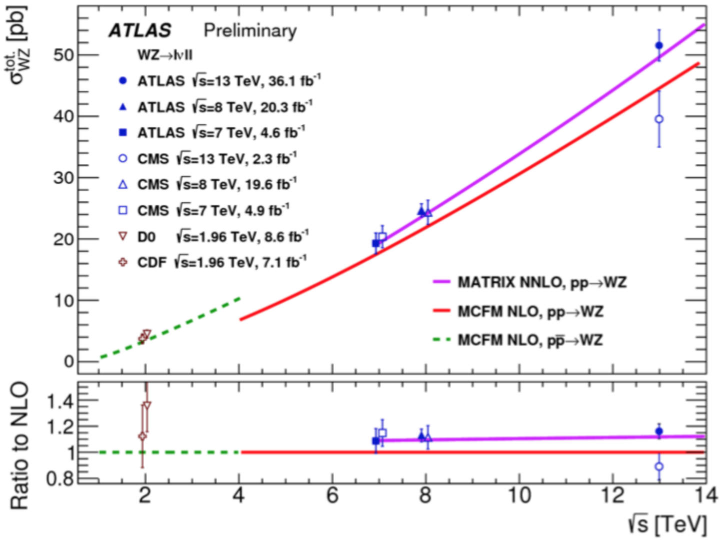
Some general thoughts and questions

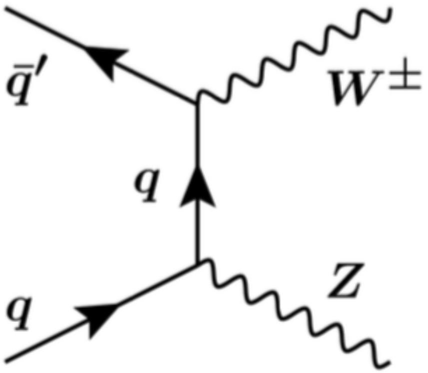
- We see (sometimes) very large differences between NLO and NNLO predictions, which are not covered by the usual scale variations (also for cases we no new channels open up)
  - To which extend can we trust NLO/NNLO predictions in the first place
  - Do we need a new paradigm how to evaluate missing higher order corrections,
    - E.g.: taking the full difference between (n-1)NLO to nNLO to estimate the uncertainty for missing (n+1)NLO
      - Similar to electroweak corrections?
    - The answer might be processes related, so a “handbook” of missing higher order corrections would be noce

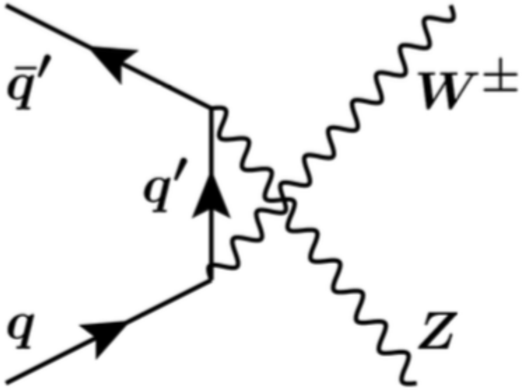
Testing the Electroweak Sector

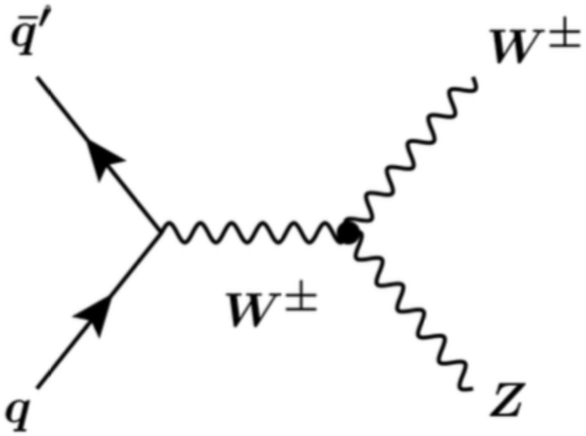
Example of a typical DiBoson Measurement: WZ

- W±Z cross section and gauge boson polarisation (ATLAS-CONF-2018-034)
  - Probe gauge structure of SM
  - Sensitive to aTGCs / EFTs
  - Precise measurements of differential and total cross sections
  - Polarisation of W and Z bosons





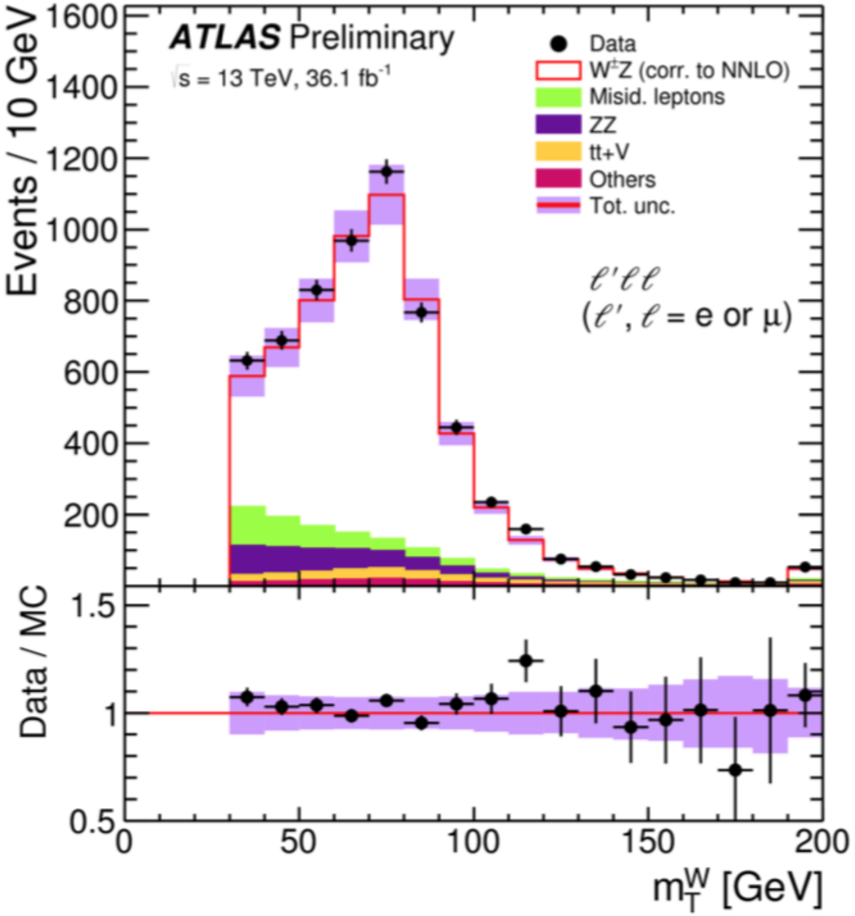




From Rustem Ospanov, USCTC at ICHEP

Signal Selection and Modelling (WZ)

- Trilepton fiducial region
  - Select Z leptonic decay
    - p_T>15, 80<mll<100
  - Select W leptonic decay
    - p_T>15, mT>30
- Signal modelling
  - Model W±Z with PowhegBox at NLO in QCD
  - Shower with Pythia 8.210 and CTEQ6L1PDF
  - Shower with Herwig to estimate uncertainty
- Theory predictions
  - NNLO QCD W±Z cross sections with MATRIX Apply particle-to-parton level corrections



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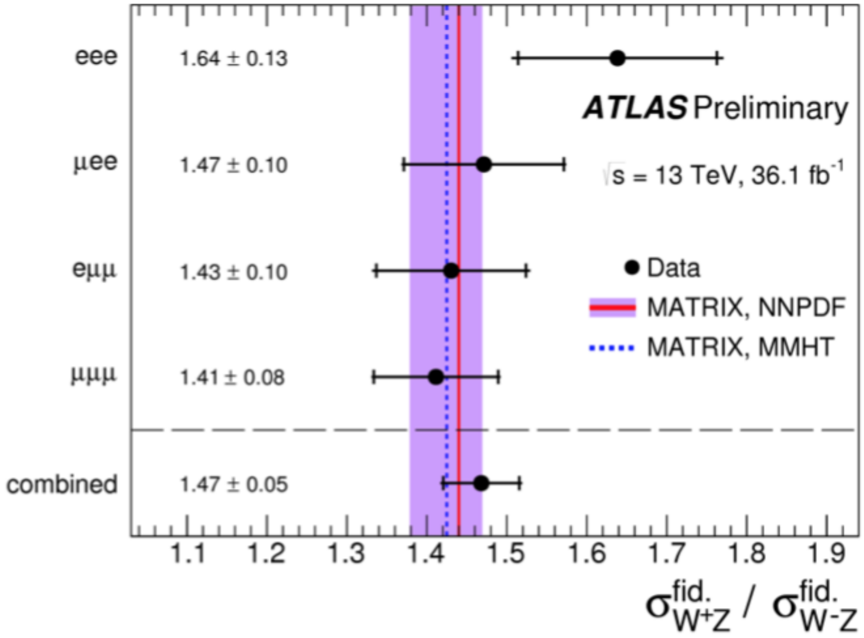
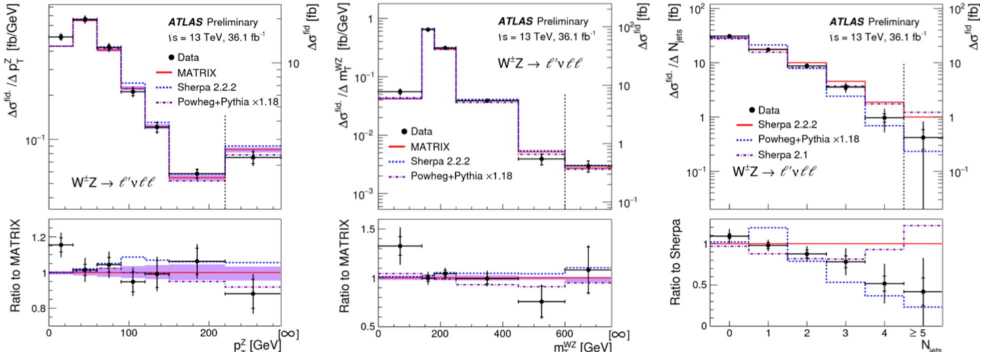
Results (WZ)

- Measured inclusive cross-section
  - σ_{WZ}=63.7±1.0(stat)±2.3(stat) ±0.3(mod)±1.5(lumi)
  - In good agreement with prediction (Matrix): σ_{WZ}=61.5±1.4fb
  - Precision on Ratio measurement similar to theory prediction
- Unfolded single differential cross sections for $p_T(Z)$, M_{WZ}, N_{jets}
  - Can be used to constain aTGCs and EFTs (also by people outside of ATLAS)
  - Crucial to get differential predictions correct in order to derive correct limits!





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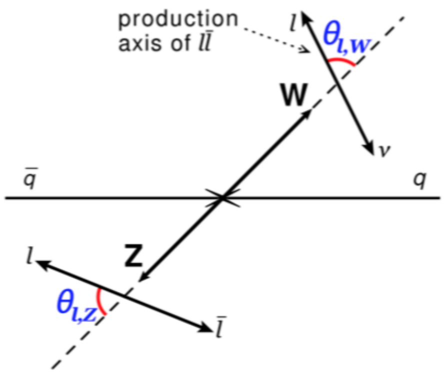
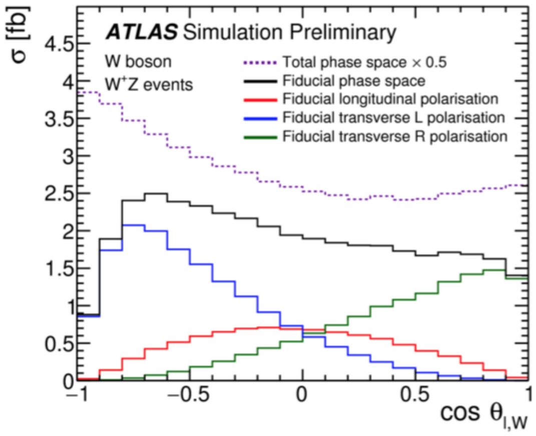
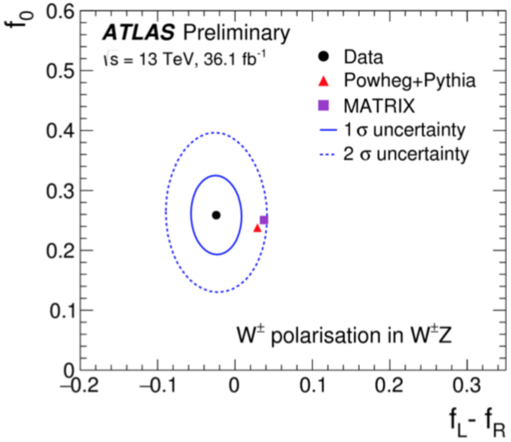
Polarization (WZ)

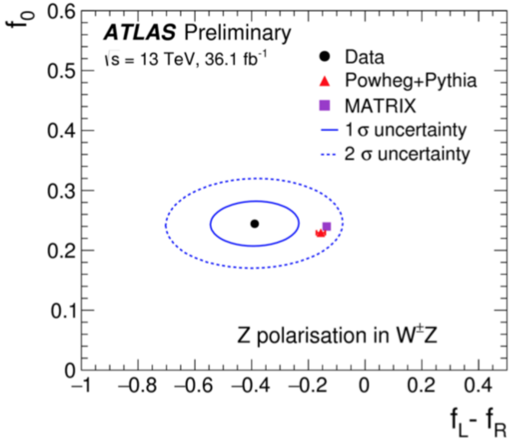
- Measure W /Z polarisation using lepton angular distributions
  - f_0, f_L and f_R define the longitudinal, transverse-left handed and transverse-right handed helicity fractions at Born
  - Template fit of $q_l \cdot \cos\theta_{l,W}$ and of $\cos\theta_{l,Z}$ distributions
    - m_W constraint to solve for missing $p_z(\nu)$





- Same story: Crucial to get all differential distributions (includir polarizations) correct
  - Soon we will have much more differential distributions available with high statistics





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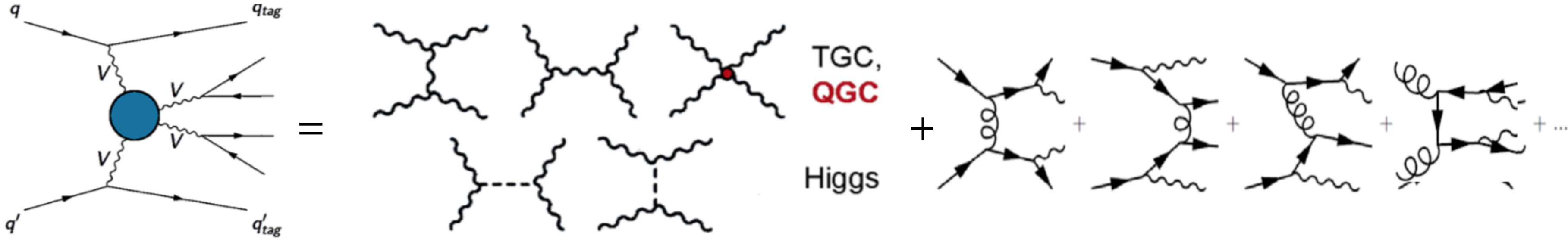
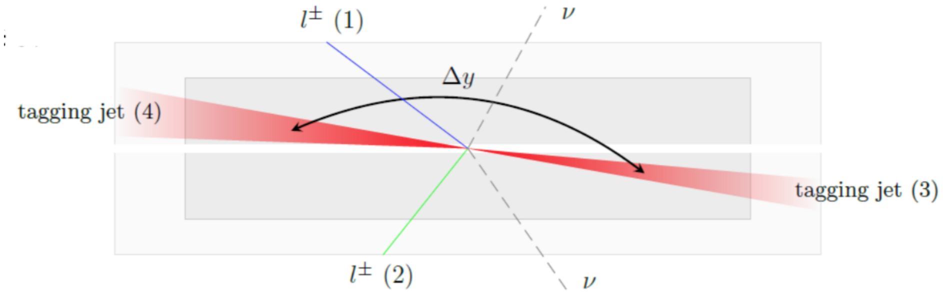
Electroweak Poduction of WZ (1/3)

- VV → VV provides insight into EWSB mechanism, access to quartic couplings:



(EW production) (strong production)

- Experimental Signature of VBS processes

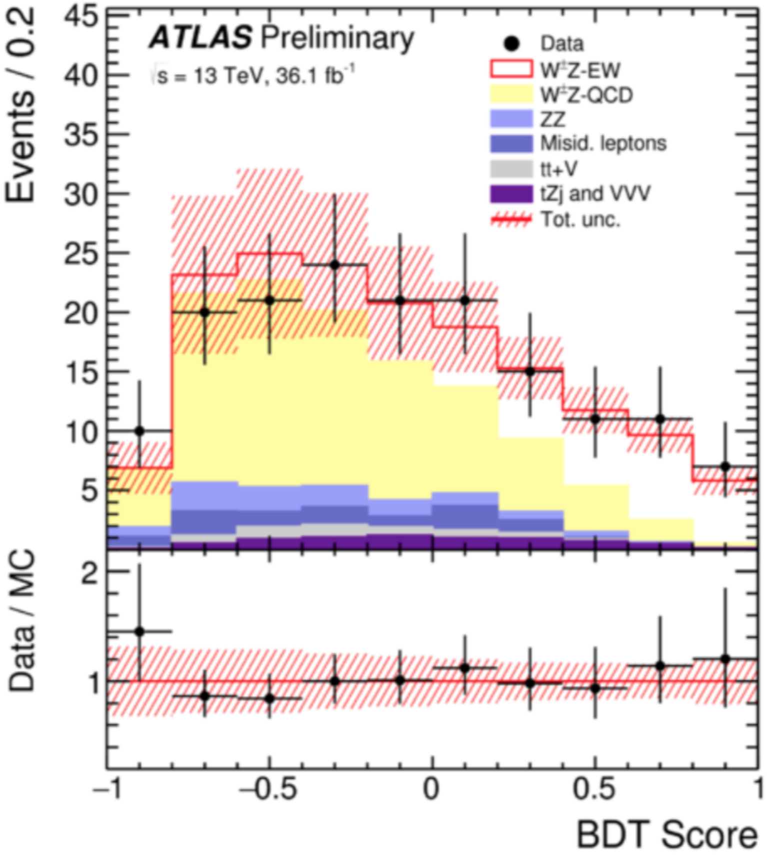


- Side remark: QCD background processes (e.g. Z+jets) for VBS/VBF typically do not describe data

From Marc-Andre-Pleier, BNL at ICHEP

Electroweak Poduction of WZ (2/3)

- Signal Selection
  - 3 isolated leptons (e or μ), MET (via mT) as WZ incl.
  - VBS signal region (SR): ≥ 2 jets, $p_T > 40$ GeV , $m_{jj} > 500$ GeV, b-jet veto
  - BDT discriminant based on 15 variables reflecting VBS kinematics
  - Cross-Section extracted as "signal-strength" parameter in a combined fit of signal and background processes



- Post-fit background normalisations
  - $\mu_{WZ\text{-}QCD} = 0.60 \pm 0.25$
  - $\mu_{ttV} = 1.18 \pm 0.19$
  - $\mu_{ZZ} = 1.34 \pm 0.29$
  - $\mu_{EW} = 1.77 \pm 0.45$
  - Observed sign.: 5.6σ (3.3σ expected)

From Marc-Andre-Pleier, BNL at ICHEP

Electroweak Poduction of WZ (3/3)

- Extracted Fiducial cross section

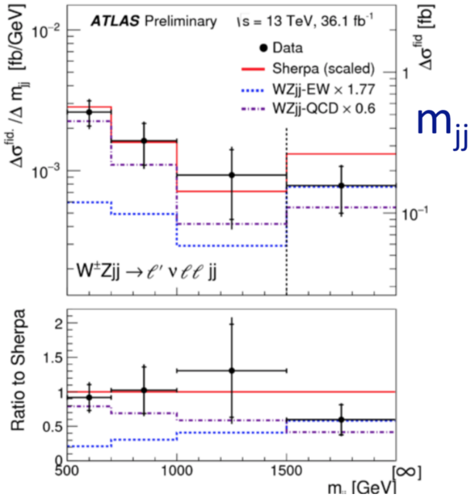
$$\begin{aligned}\sigma^{\text{fid., EW}}_{meas.} &= 0.57\ ^{+0.15}_{-0.14}\ \text{fb}\\ &= 0.57\ ^{+0.14}_{-0.13}\ (\text{stat.})\ ^{+0.05}_{-0.04}\ (\text{syst.})\ ^{+0.04}_{-0.03}\ (\text{th.})\ \text{fb}\,.\end{aligned}$$

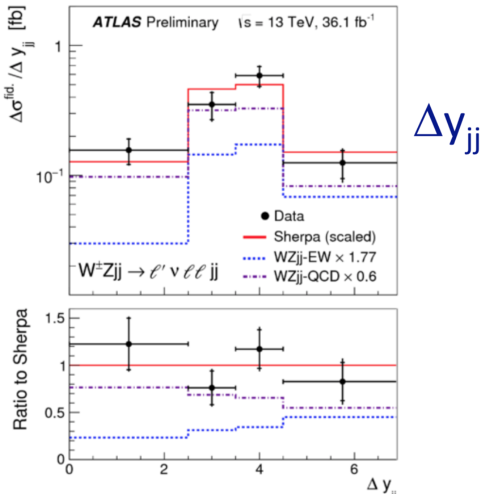
- Compared to two theory predictions (LO)

$$\sigma^{\text{fid., EW th.}}_{\text{Sherpa}} = 0.321 \pm 0.002\,(\text{stat.}) \pm 0.005\,(\text{PDF})^{+0.027}_{-0.023}\,(\text{scale})\ \text{fb} \qquad \sigma^{\text{fid., EW th.}}_{\text{MadGraph}} = 0.366 \pm 0.004\,(\text{stat.})\ \text{fb}$$

  - Significant discrepancies + HO missing

- Differential cross-sections extracted in SR (mjj > 500 GeV), i.e. include QCD induced production
  - Compared to normalized Sherpa predictions for WZjj (QCD + EW)

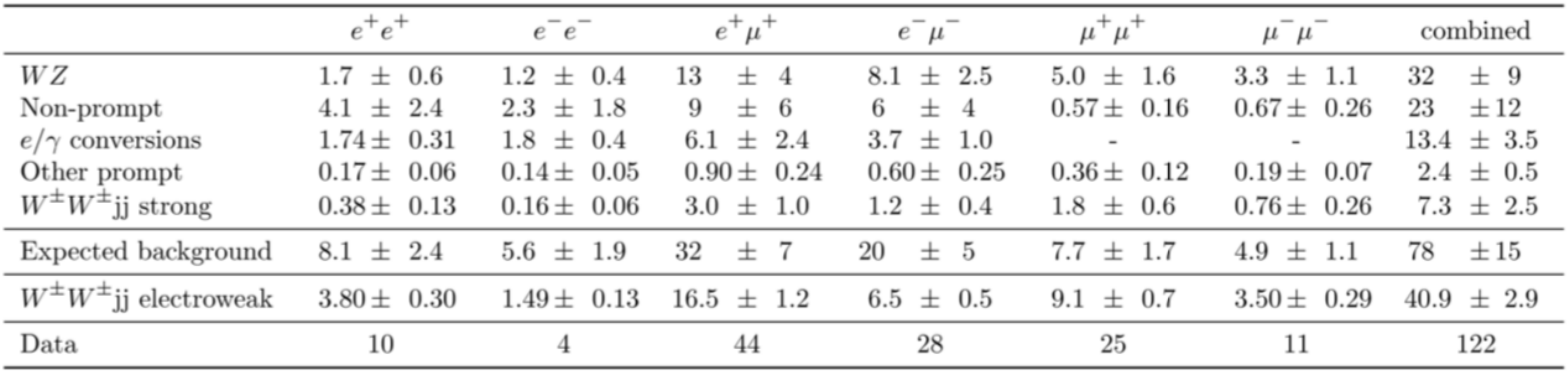




From Marc-Andre-Pleier, BNL at ICHEP

Electroweak Poduction of same sign WW (1/2)

- Experimental selection
  - Isolated well reconstructed same-sign dilepton events (e or μ)
  - Veto third lepton to suppress WZ and veto b-jets to suppress tt̄
  - Require Emiss > 30 GeV and VBS jet selections
- Backgrounds and exp. uncertainty:
  - WZ background is normalised from trilepton control region with 8% uncertainty
  - Fake lepton background measured from control regions with 50-90% uncertainty
    - Dominant experimental uncertainty
  - Other irreducible backgrounds are from Monte-Carlo simulation



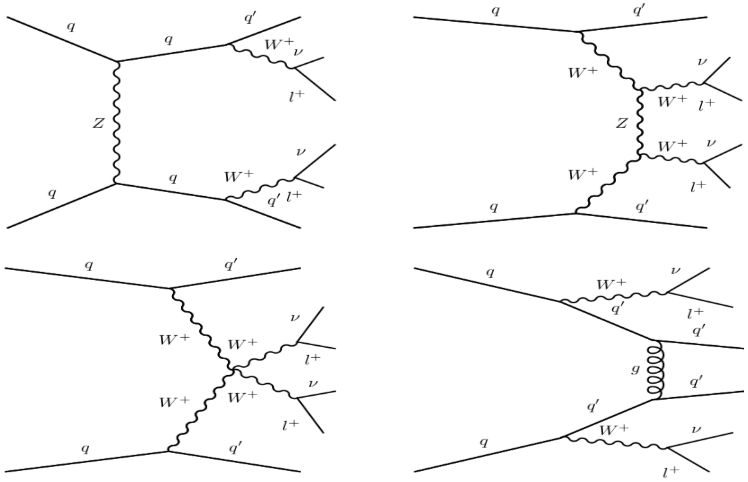
	e^+e^+	e^-e^-	$e^+\mu^+$	$e^-\mu^-$	$\mu^+\mu^+$	$\mu^-\mu^-$	combined
WZ	1.7 ± 0.6	1.2 ± 0.4	13 ± 4	8.1 ± 2.5	5.0 ± 1.6	3.3 ± 1.1	32 ± 9
Non-prompt	4.1 ± 2.4	2.3 ± 1.8	9 ± 6	6 ± 4	0.57 ± 0.16	0.67 ± 0.26	23 ± 12
e/γ conversions	1.74 ± 0.31	1.8 ± 0.4	6.1 ± 2.4	3.7 ± 1.0	-	-	13.4 ± 3.5
Other prompt	0.17 ± 0.06	0.14 ± 0.05	0.90 ± 0.24	0.60 ± 0.25	0.36 ± 0.12	0.19 ± 0.07	2.4 ± 0.5
$W^\pm W^\pm$jj strong	0.38 ± 0.13	0.16 ± 0.06	3.0 ± 1.0	1.2 ± 0.4	1.8 ± 0.6	0.76 ± 0.26	7.3 ± 2.5
Expected background	8.1 ± 2.4	5.6 ± 1.9	32 ± 7	20 ± 5	7.7 ± 1.7	4.9 ± 1.1	78 ± 15
$W^\pm W^\pm$jj electroweak	3.80 ± 0.30	1.49 ± 0.13	16.5 ± 1.2	6.5 ± 0.5	9.1 ± 0.7	3.50 ± 0.29	40.9 ± 2.9
Data	10	4	44	28	25	11	122

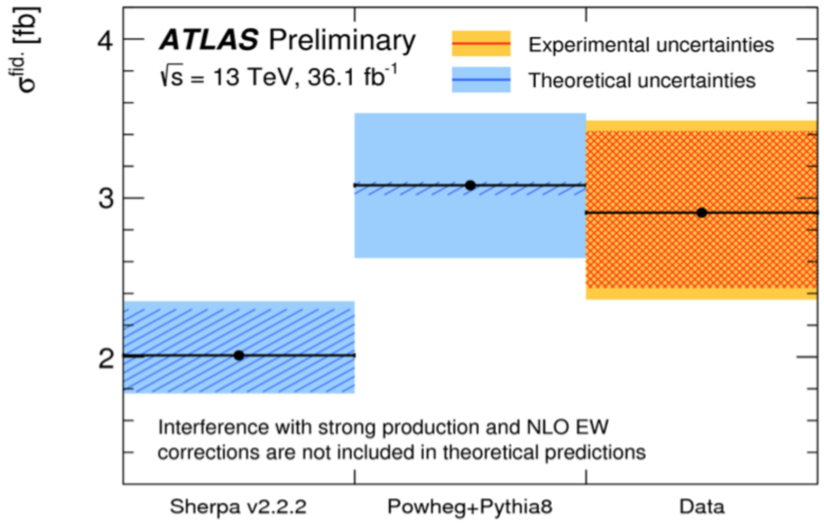
From Rustem Ospanov, USCTC at ICHEP

Electroweak Poduction of same sign WW (2/2)

- Observed (expected with Sherpa) significance is 6.9σ (4.6σ)
  - Measured fiducial cross section
    - $\sigma_{fid} = 2.95 \pm 0.49\ (stat.) \pm 0.23\ (sys.)$fb
    - σ_{fid} includes $W^{\pm}W^{\pm}jj$ electroweak plus interference with $W^{\pm}W^{\pm}jj$ strong
    - $W^{\pm}W^{\pm}jj$ strong production with exactly four EW vertices subtracted as background

- Predicted fiducial cross sections:
  - PowhegBox: σfid = 3.08±0.45
  - Sherpa: σfid = 2.01±0.28
    - Large difference due to scale choice? Under investigation
  - NLO electroweak corrections (−16% for Sherpa) and interference (+6%) are not include

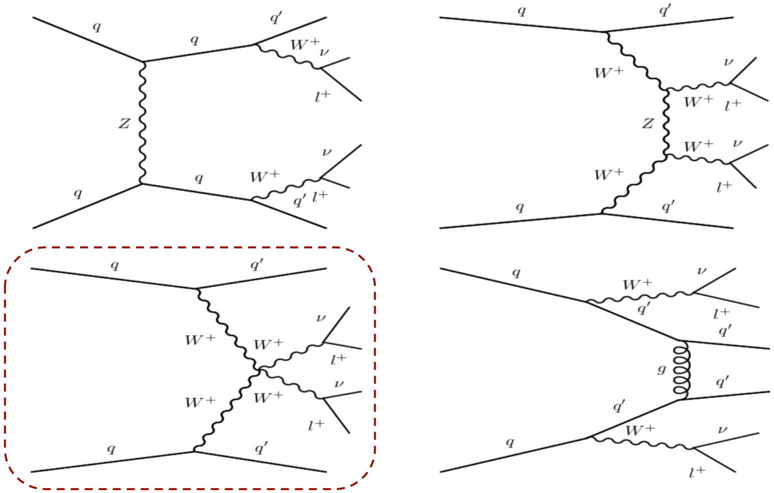


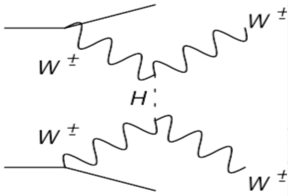


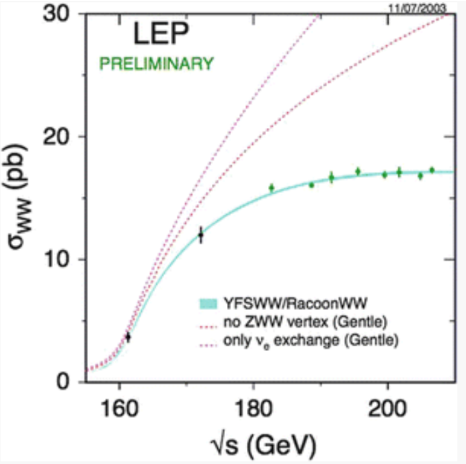
From Rustem Ospanov, USCTC at ICHEP

General thoughts on Electroweak Production

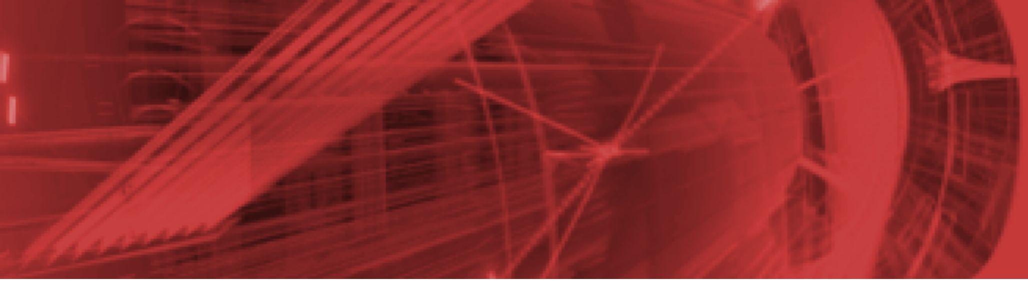
- Is there a way to test, if we are really seeing quadratic gauge couplings of the SM
    - The impact of a few diagrams (e.g. Higgs) can be estimated in a gauge invariant way
    - Clearly we cannot separate some the diagrams due to gauge invariance
    - Any ideas for a way forward (to get a plot similar to the famous LEP plots)?
- Electroweak corrections become sizeable for many VBS, VBF and triboson processes
    - But we are missing an estimation for many processes





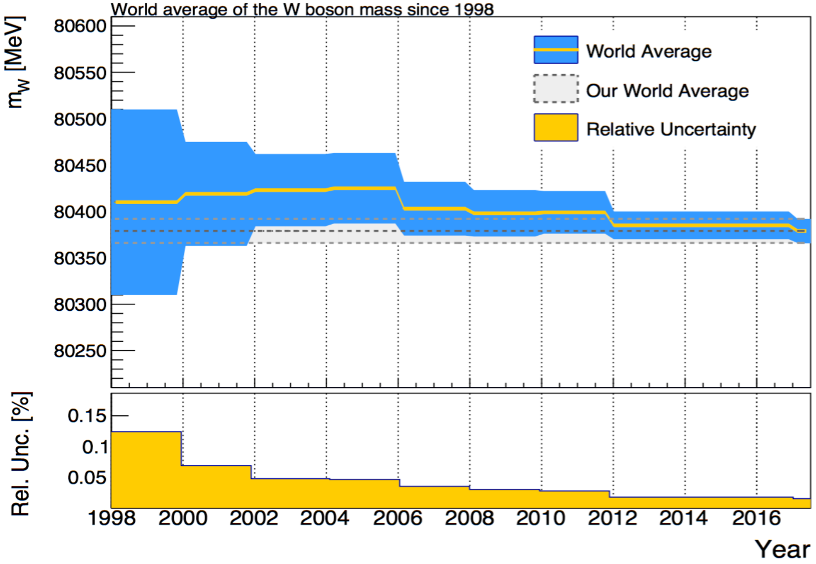


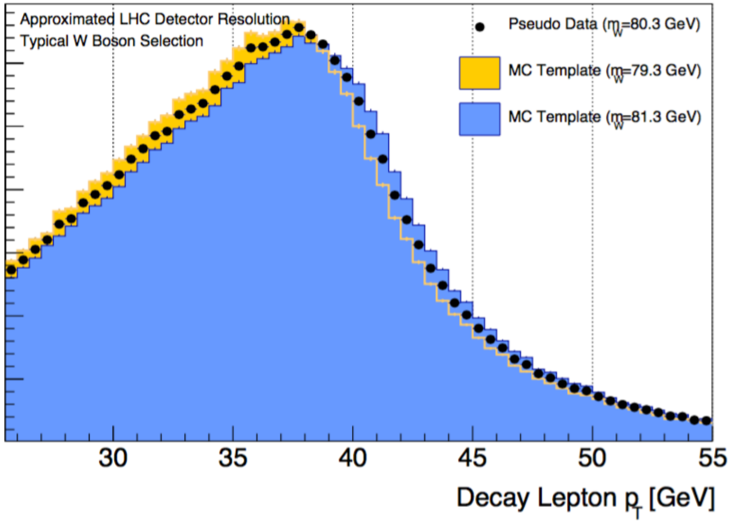
Electroweak Precision Measurements



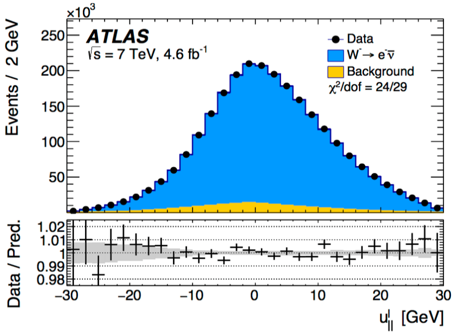
Measurement of the W Boson Mass (1/4)

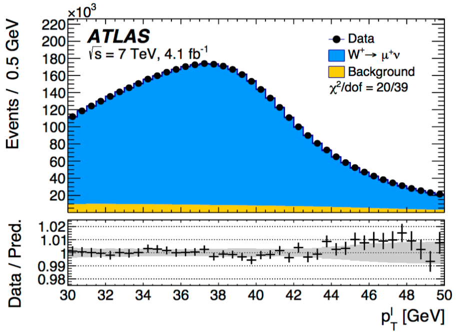
- Last round of measurements of m_W already published in 2012
  - CDF+D0: Δm_W=15 MeV
  - Latest update by ATLAS in 2016: Δm_W=19 MeV
- Basic measurement approach: Template fit method
- Requires perfect modelling of detector response and physics modelling
  - $p_T(W)$
  - Angular coefficients
  - EWK corrections
  - PDFs

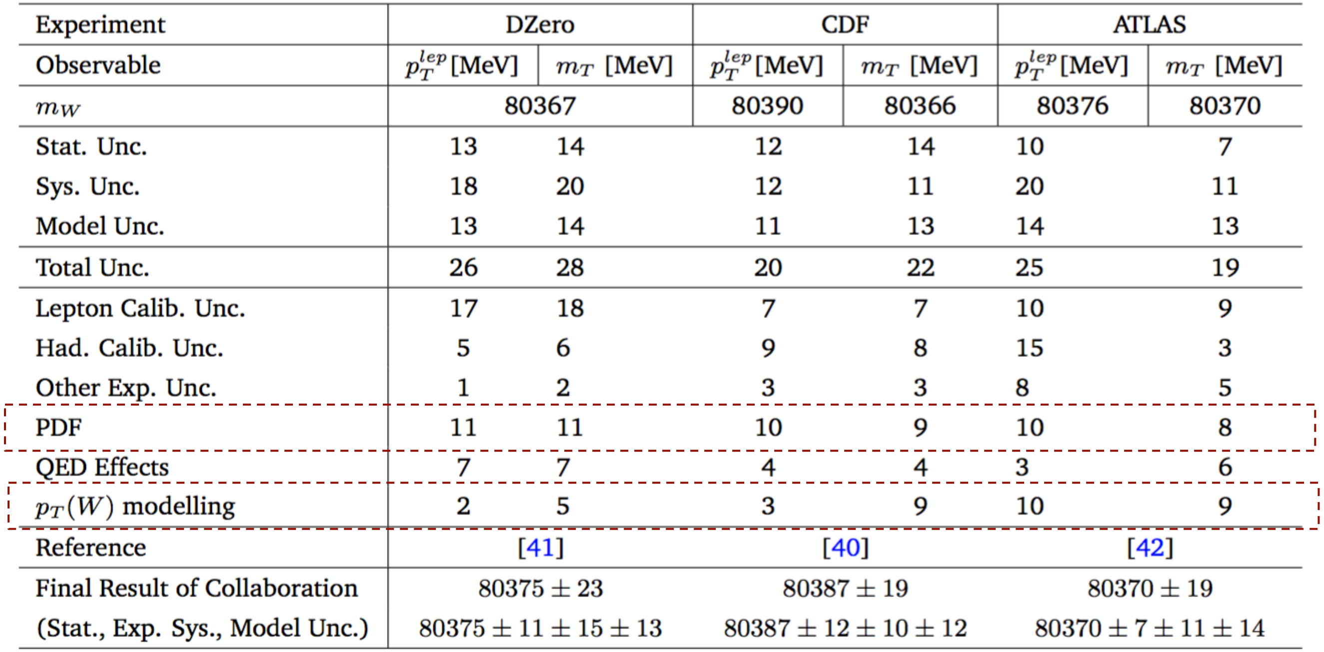




Measurement of the W Boson Mass (2/4)





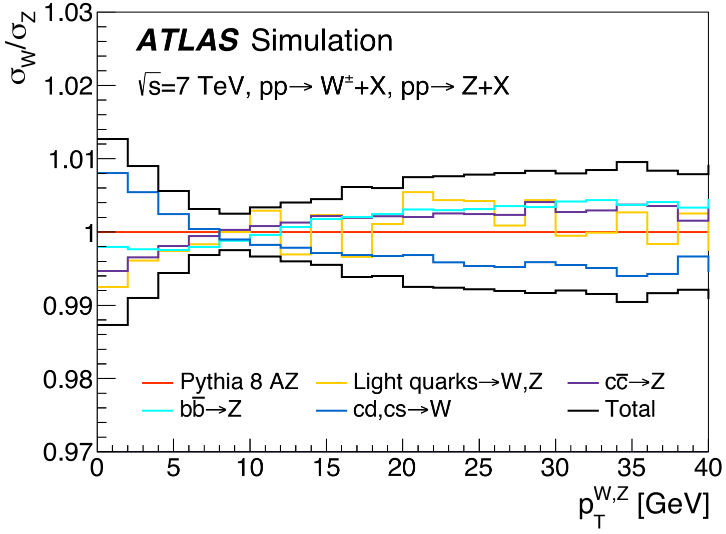


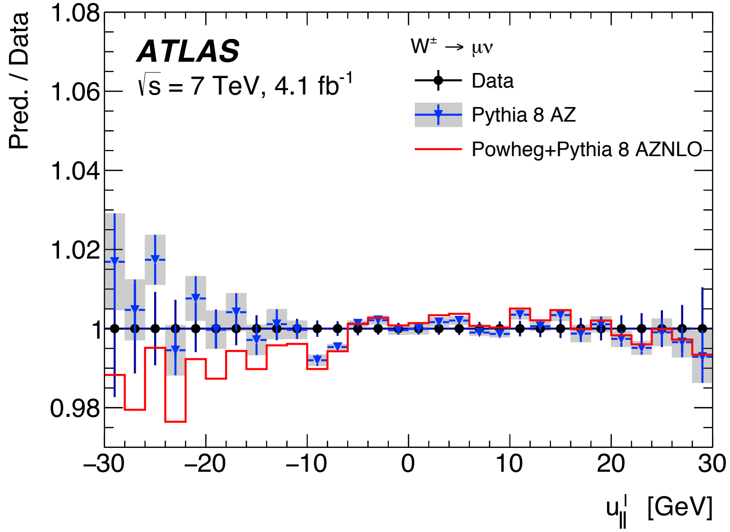
Experiment	DZero		CDF		ATLAS	
Observable	p_T^{lep} [MeV]	m_T [MeV]	p_T^{lep} [MeV]	m_T [MeV]	p_T^{lep} [MeV]	m_T [MeV]
m_W	80367		80390	80366	80376	80370
Stat. Unc.	13	14	12	14	10	7
Sys. Unc.	18	20	12	11	20	11
Model Unc.	13	14	11	13	14	13
Total Unc.	26	28	20	22	25	19
Lepton Calib. Unc.	17	18	7	7	10	9
Had. Calib. Unc.	5	6	9	8	15	3
Other Exp. Unc.	1	2	3	3	8	5
PDF	11	11	10	9	10	8
QED Effects	7	7	4	4	3	6
$p_T(W)$ modelling	2	5	3	9	10	9
Reference	[41]		[40]		[42]	
Final Result of Collaboration	80375 ± 23		80387 ± 19		80370 ± 19	
(Stat., Exp. Sys., Model Unc.)	$80375 \pm 11 \pm 15 \pm 13$		$80387 \pm 12 \pm 10 \pm 12$		$80370 \pm 7 \pm 11 \pm 14$	

- Most sensitive measurement from the m_T distributions at Tevatron, but from the p_T distribution at ATLAS (pile-up!)
  - Much larger dependence on $p_T(W)$ modelling for ATLAS
- Largest uncertainties due to PDFs but different origin
  - acceptance effects for Tevatron, but polarization effects at LHC

Measurement of the W Boson Mass (3/4) – $p_T(W)$

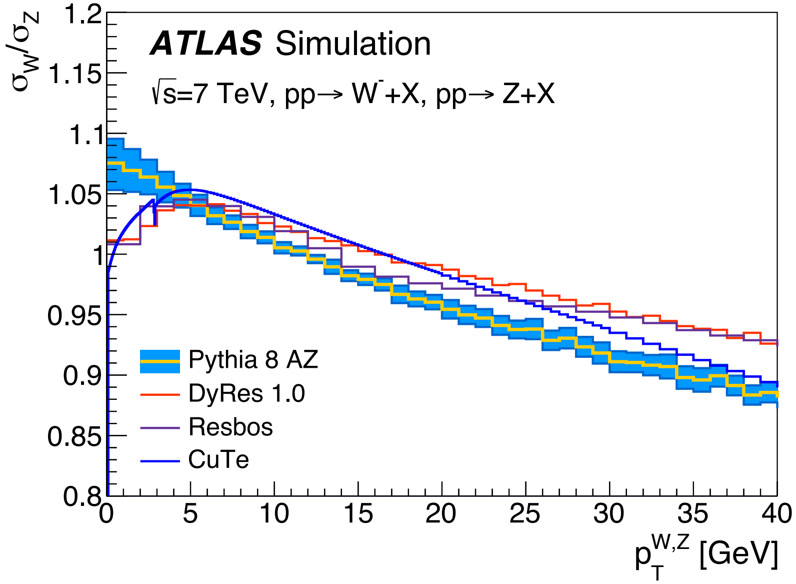
- Uncertainties from exp. $p_T(Z)$ unc. and theory unc. on the W/Z p_T ratio
- Heavy-flavour-initiated (HFI) production introduce decorrelation
  - bb/cc→Z accounts for 3-6%
  - cs→W is ~20% of W production
  - HFI addressed with
    - charm mass variations
    - decorrelating the PS between light and HFI processes
- Central prediction and uncertainty validated with the recoil distribution
  - end up with compatible central value and similar uncertainties compared to "model approach"

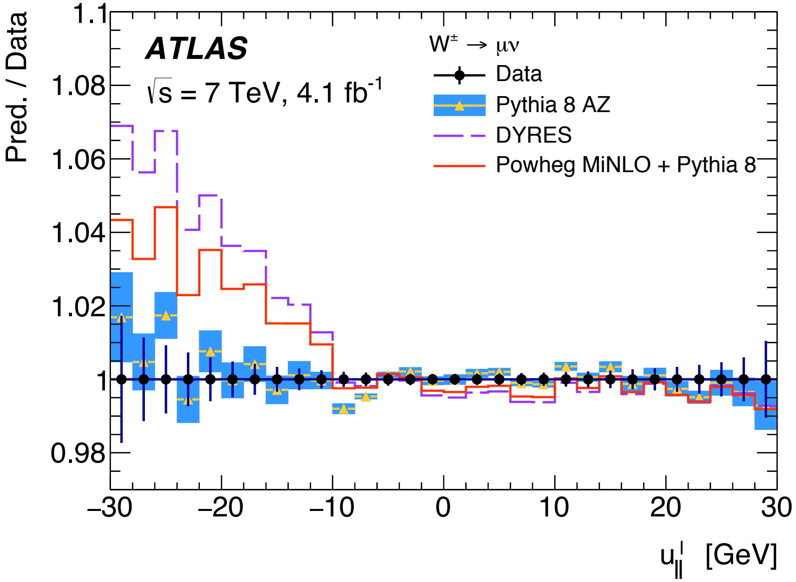




Measurement of the W Boson Mass (4/4) – $p_T(W)$

- Theoretically more advanced calculations were also attempted
  - DYRES (and other resummation codes : ResBos, CuTe)
  - Powheg MiNLO + Pythia8
- All predict a harder $p_T(W)$ spectrum for given $p_T(Z)$ distribution
  - Behaviour is disfavoured by data (comparison of $u_{||}$ distribution)



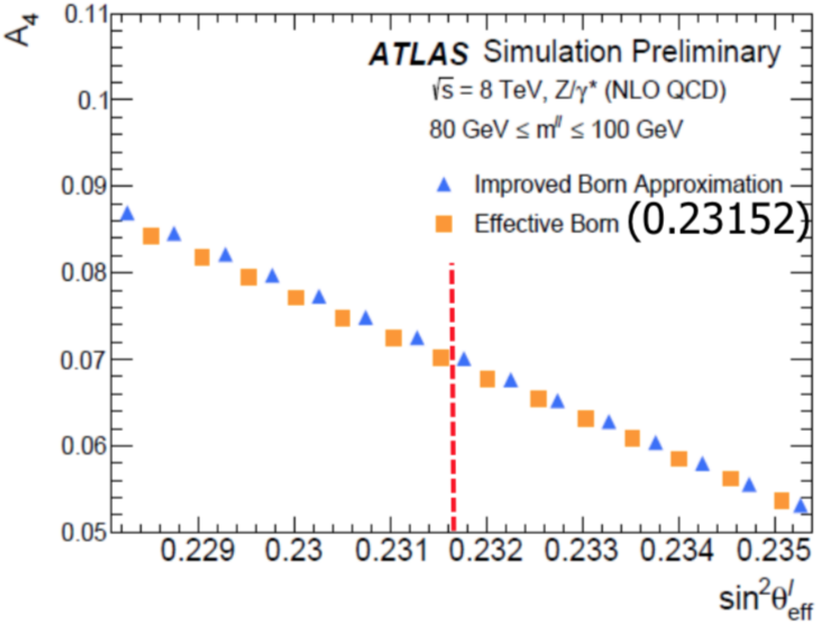


Measurement of $\sin^2\theta_W$ (1/2)

- Latest ATLAS result based on the measurement of the A4 angular coefficient

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

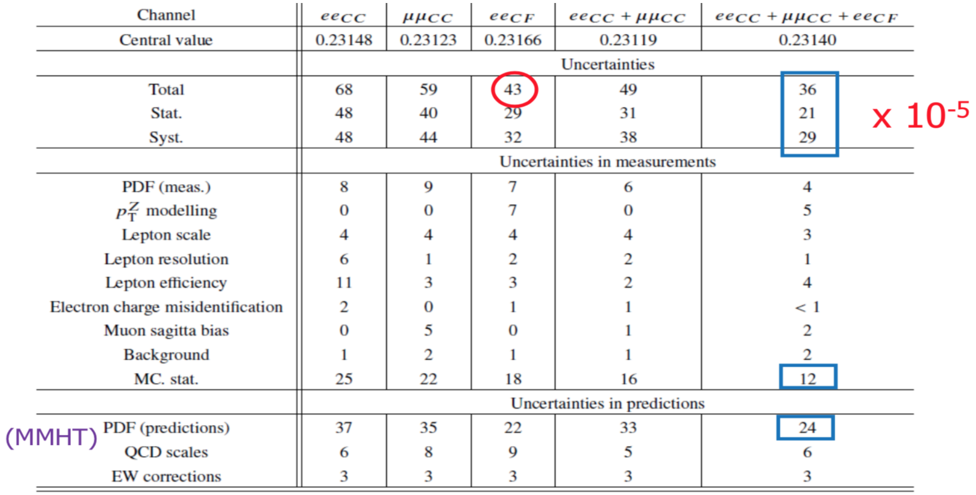
- Using three analysis channels
  - Muons ($y_Z<2.4$)
  - Central electrons ($y_Z<2.4$)
  - 1-forward, 1-central electron ($y_Z<3.6$)
- Profiling PDFs during fit of sin2theta



From Manuella Vincter, Carlton at ICHEP

Measurement of $\sin^2\theta_W$ (2/2)

- Contributions of the different channels to the measurement of $\sin^2\theta_{eff}$



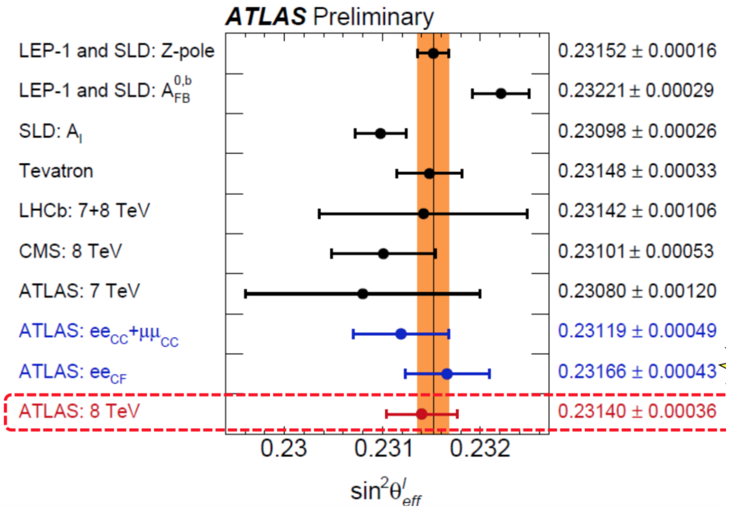
Channel	ee_{CC}	$\mu\mu_{CC}$	ee_{CF}	$ee_{CC} + \mu\mu_{CC}$	$ee_{CC} + \mu\mu_{CC} + ee_{CF}$
Central value	0.23148	0.23123	0.23166	0.23119	0.23140
	Uncertainties				
Total	68	59	43	49	36
Stat.	48	40	29	31	21
Syst.	48	44	32	38	29
	Uncertainties in measurements				
PDF (meas.)	8	9	7	6	4
p_T^Z modelling	0	0	7	0	5
Lepton scale	4	4	4	4	3
Lepton resolution	6	1	2	2	1
Lepton efficiency	11	3	3	2	4
Electron charge misidentification	2	0	1	1	< 1
Muon sagitta bias	0	5	0	1	2
Background	1	2	1	1	2
MC. stat.	25	22	18	16	12
	Uncertainties in predictions				
PDF (predictions)	37	35	22	33	24
QCD scales	6	8	9	5	6
EW corrections	3	3	3	3	3

x 10^{-5}

(MMHT)

- eeCF is most precise though it has only 1.5M events
  - compared to 13.5M eeCC + μμCC
- Measurement uncertainty 36 x 10-5
- data stat and PDF uncertainty roughly equal. MC stats next largest uncertainty

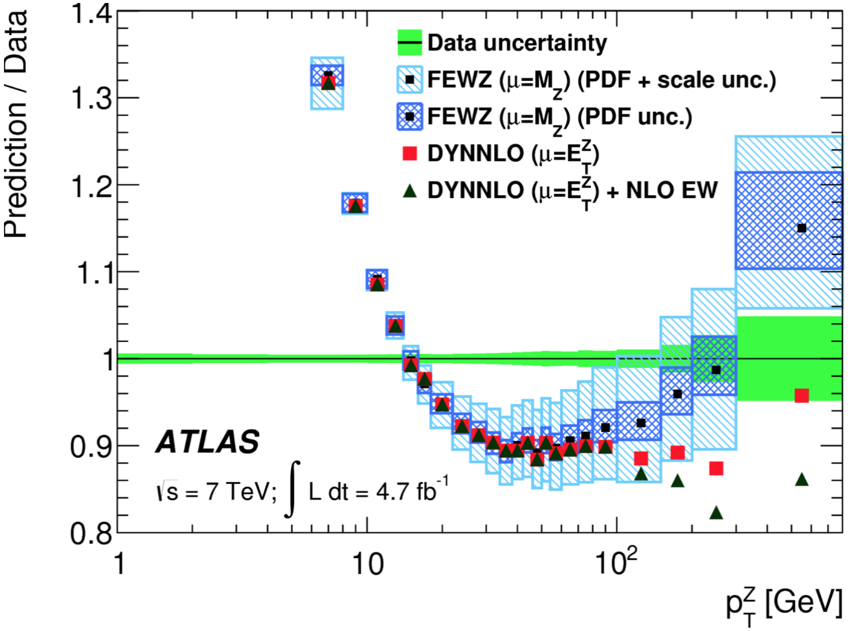
- Competitive measurement from a hadron collider

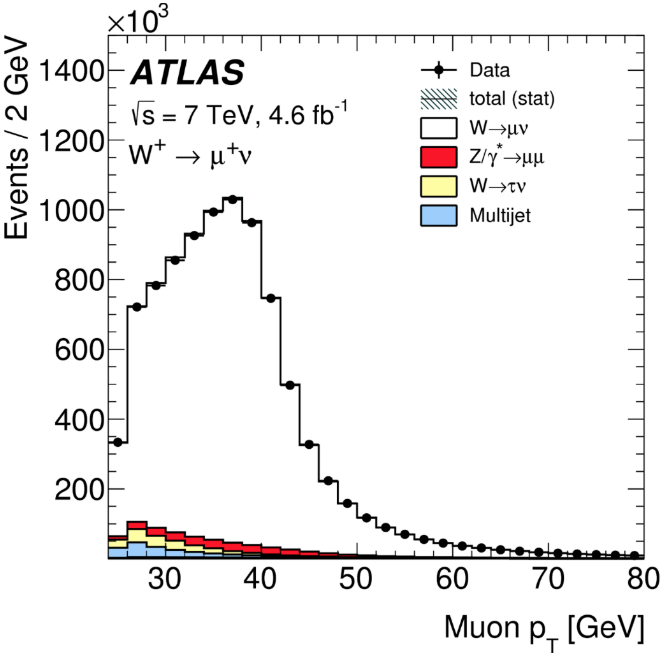


- adds consistency to the landscape!
- Still expect significant improvements for the final results, since we can add the A_{FB} based measurement

From Manuella Vincter, Carlton at ICHEP

Some remarks on PDFs profilling and fitting

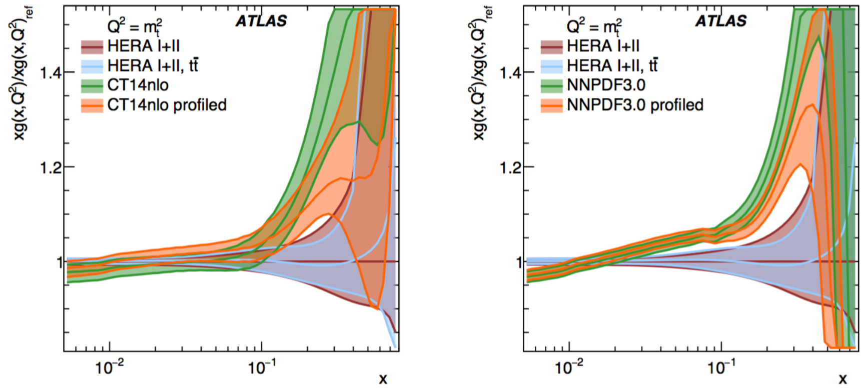


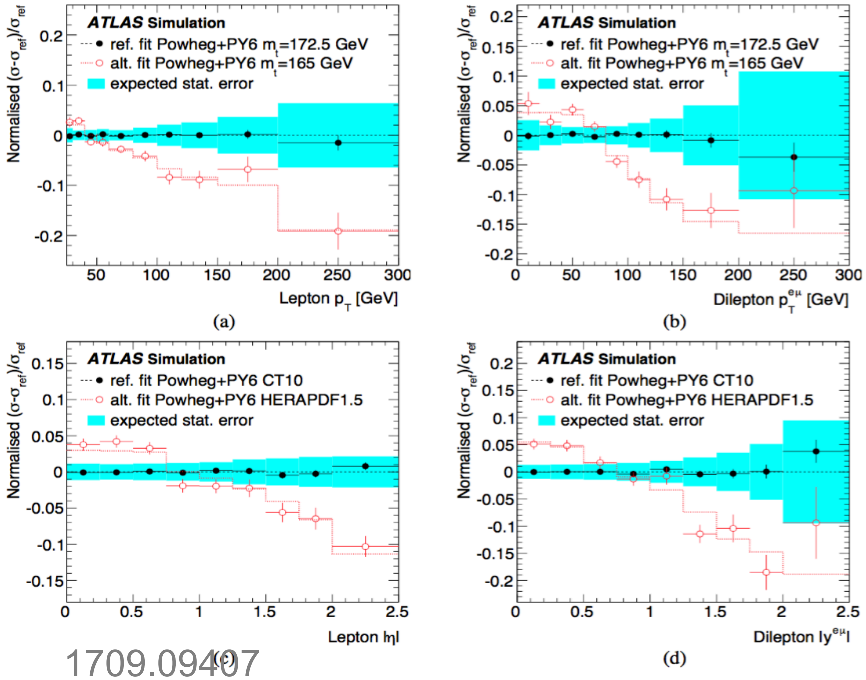


- When fitting / profiling PDFs, we use fiducial cross-section measurements and NNLO prediction
  - NNLO predictions do not describe the resummation/PS part of the vector boson spectra, i.e. this leads to a bias towards the lepton pT and thus the fiducial definition
  - Would need to have a resummed / NNLO+PS PDF Fit

Top Pole-Mass Measurements

- Absolute and normalised differential cross-section measurements, in the di-leptonic eμ pair channel with one or two b-tagged jets at 8 TeV
    - Constrain gluon PDFs
    - normalised lepton p_l and dilepton $p_{e\mu}$, $m_{e\mu}$, p_e+p_μ and E_e+E_μ distributions are sensitive to pole-mass of the top-quark
- Compare with fixed order prediction at NLO (MCFM) and extract
    - m_{top} = 173.2 ± 0.9 (stat) ± 0.8 (sys) ± 1.2 (model) GeV
    - much higher statistics for full run-2 and comparison to NNLO predictions might lead to uncertainty below 1 GeV





(a) (b) (c) (d)

1709.09407

Some Further Thoughts

Some Further Thoughts on SM measurements with Theory Limitations

- Also thanks to Dr. Ulla Blumenschein (Queen Mary, London)

- Missing higher orders are limiting the alpha_s measurement via jet measurements
  - https://arxiv.org/abs/1707.02562
  - Totally dominated by scale variations

- Vector boson fusion W/Z production is limited by modelling the QCD Z+2jets production even after exploiting a control region
  - see page 14 in https://arxiv.org/pdf/1709.10264.pdf

- Several examples in the Higgs-production: e.g. VH(->bb)
  - SM backgrounds are co-dominating with b-tagging efficiencies, see Table8:
    - https://cds.cern.ch/record/2630338/files/ATLAS-CONF-2018-036.pdf
  - Also ttH has a dominating component from tt+HF:
    - https://arxiv.org/pdf/1806.00425.pdf

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Summary

- While most SM measurements are not limited by missing higher orders, we need higher order corrections to interpret our data in the context of BSM
- Measurement of precision observables (mW, mTop) require indeed a better theoretical understanding of differential distributions
- A guidelines on scale-choices, adequat observables and uncertainties due to missing higher orders is highly welcome