Electroweak Physics at the LHC

Experimental status and prospects

13 October 2014

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Introduction

Motivation for EW physics program at the LHC

EW as background for searches

- The validation and improvement of theory predictions is crucial to increase the sensitivity of BSM searches

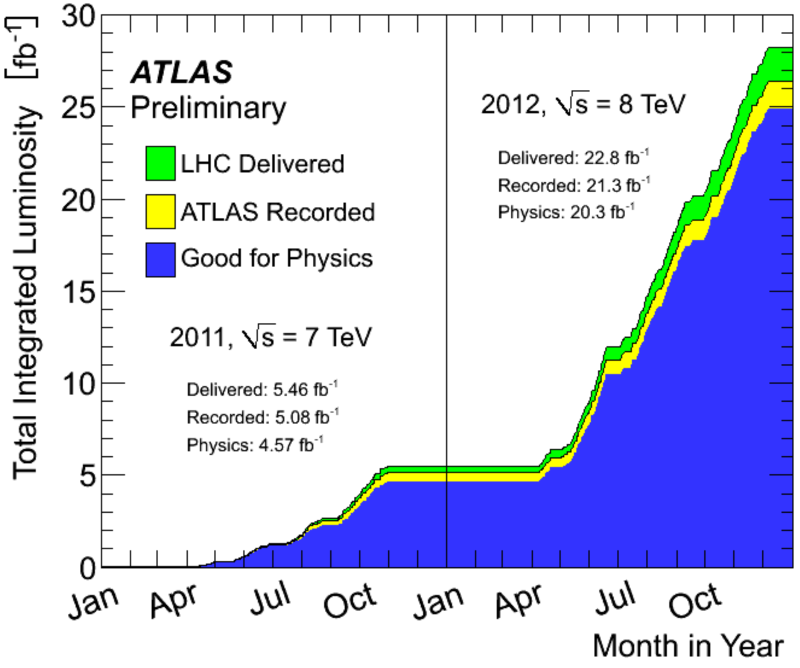
SM parameters

- Precise determination of fundamental EW parameters of the SM: M_W, θ_W, Γ_W

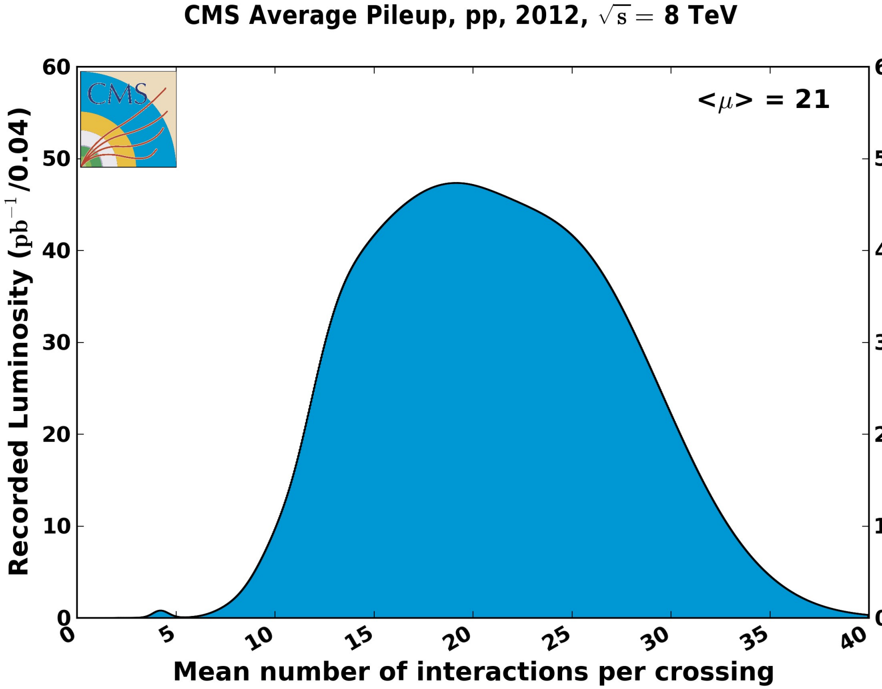
Cross sections

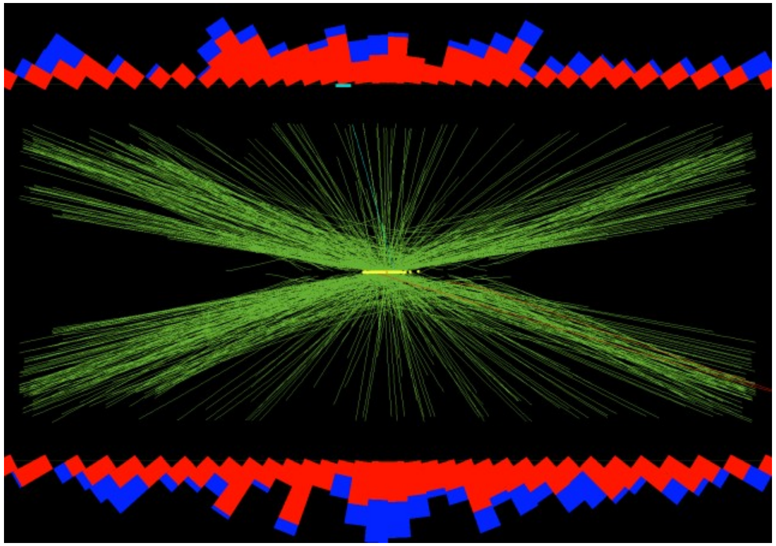
- Higher center-of-mass energy, and larger integrated luminosity, allow to test the SM in new corners of phase space, and in more complex final states

LHC in Run 1



- Excellent collider performance in terms of recorded luminosity



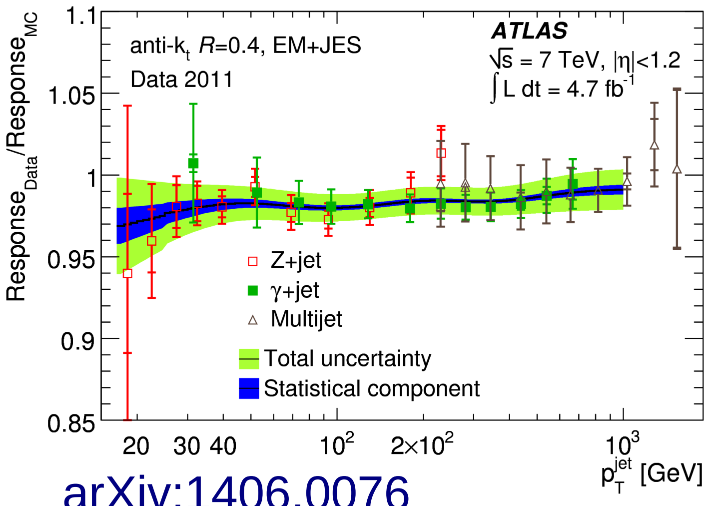


CMS event with 78 pile-up vertices

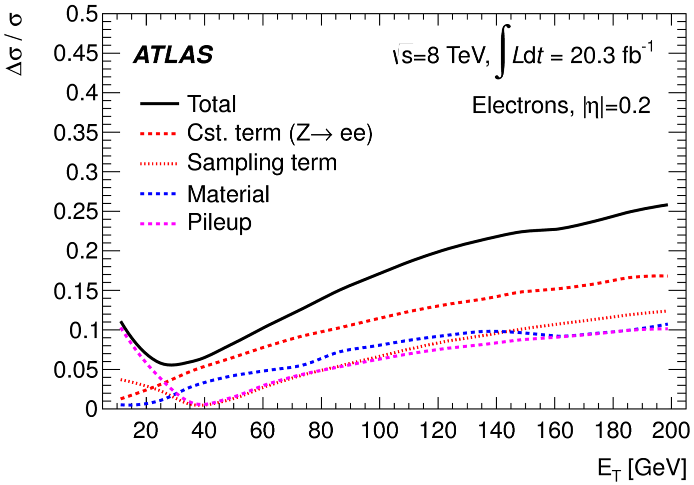
- Large number of average pp interactions per bunch crossing

→ Good for discoveries, but very challenging for EW precision physics with missing E_T, jets in the final state

Detector performances



arXiv:1406.0076



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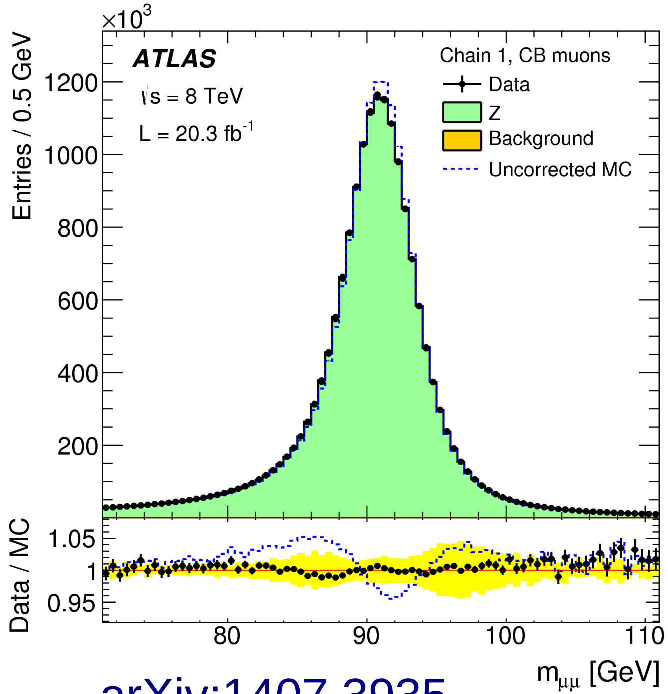


arXiv:1407.3935

- EW physics play a crucial role also in the detector calibration:
  - M_Z is used to calibrate the electromagnetic calorimeter, the muons and the tracking
  - Z events are used to evaluate leptons trigger and ID efficiencies
  - Z+jets events are used to calibrate the jet energy scale

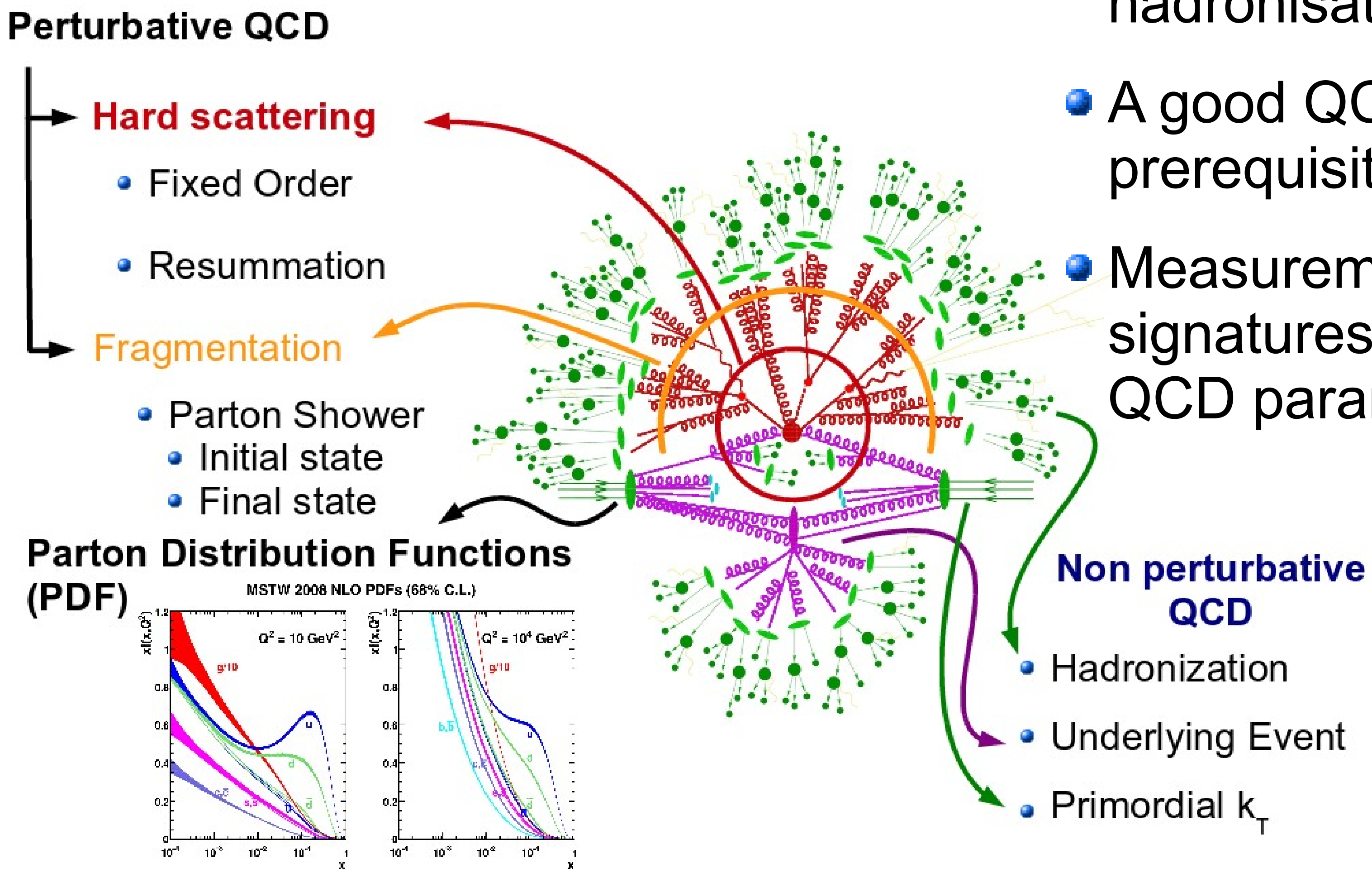
Excellent ATLAS and CMS detector performances allow a successful EW physics program

EW and QCD

Collinear factorization

$$\sigma_{pp\rightarrow X} = \Sigma_{i,j} \int dx_1 dx_2 f_i^p(x_1,\mu) f_j^p(x_2,\mu) \times \sigma_{ij\rightarrow X}$$

- EW physics at hadron colliders cannot forget about QCD: almost every EW observable is influenced by PDF, Underlying event, hadronisation
- A good QCD model is a prerequisite for EW physics
- Measurements of clean EW signatures help to constrain QCD parameters and models



Perturbative QCD

Hard scattering

- Fixed Order
- Resummation

Fragmentation

- Parton Shower
  - Initial state
  - Final state

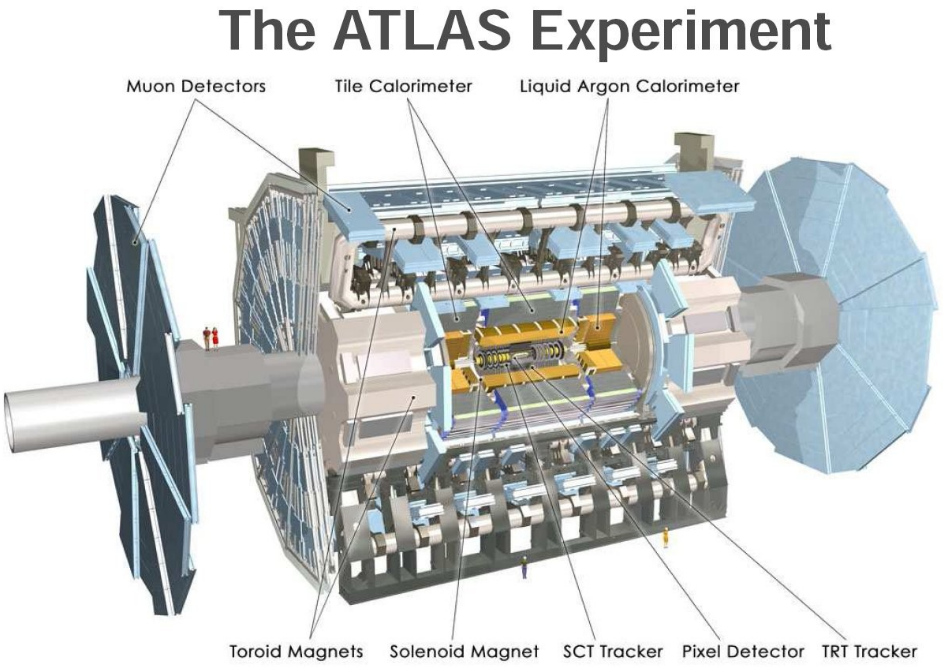
Parton Distribution Functions (PDF)

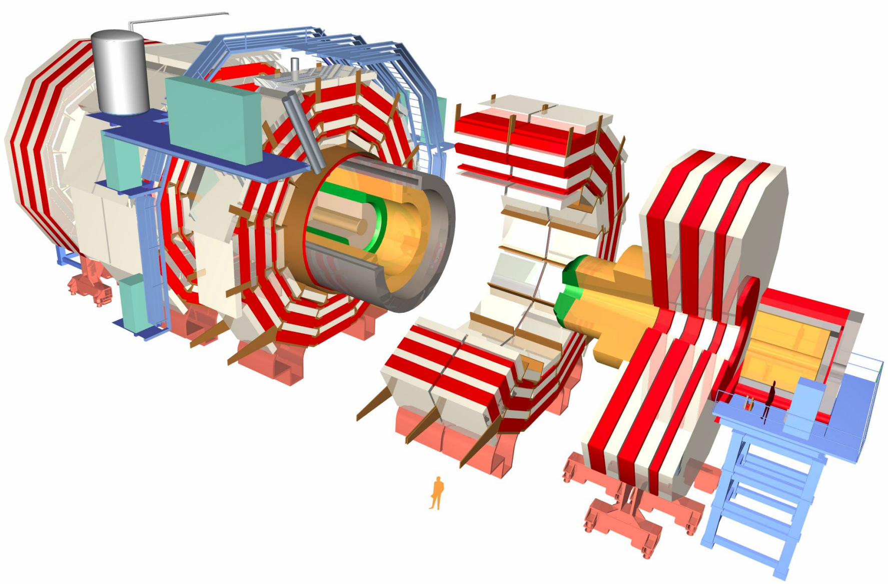
Non perturbative QCD

- Hadronization
- Underlying Event
- Primordial k_T

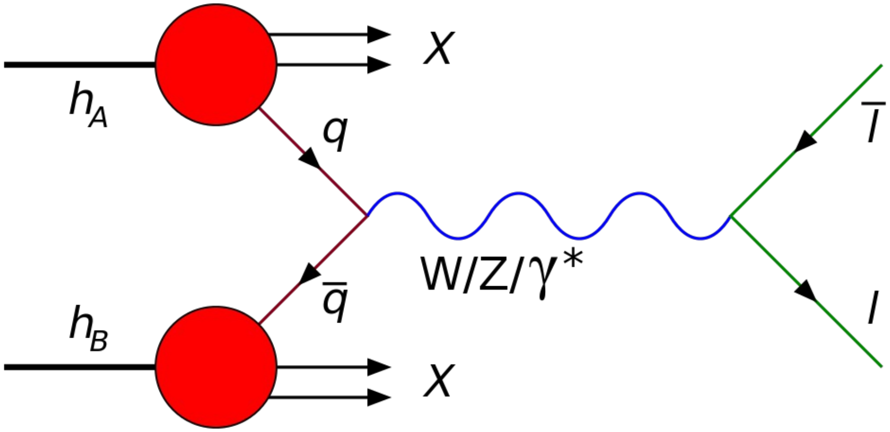
EW measurements at LHC - Overview

- Single vector boson production and Drell-Yan processes
- Diboson production, vector boson fusion, vector boson scattering
- Measurements of EW parameters: W mass and weak-mixing angle
- Prospects



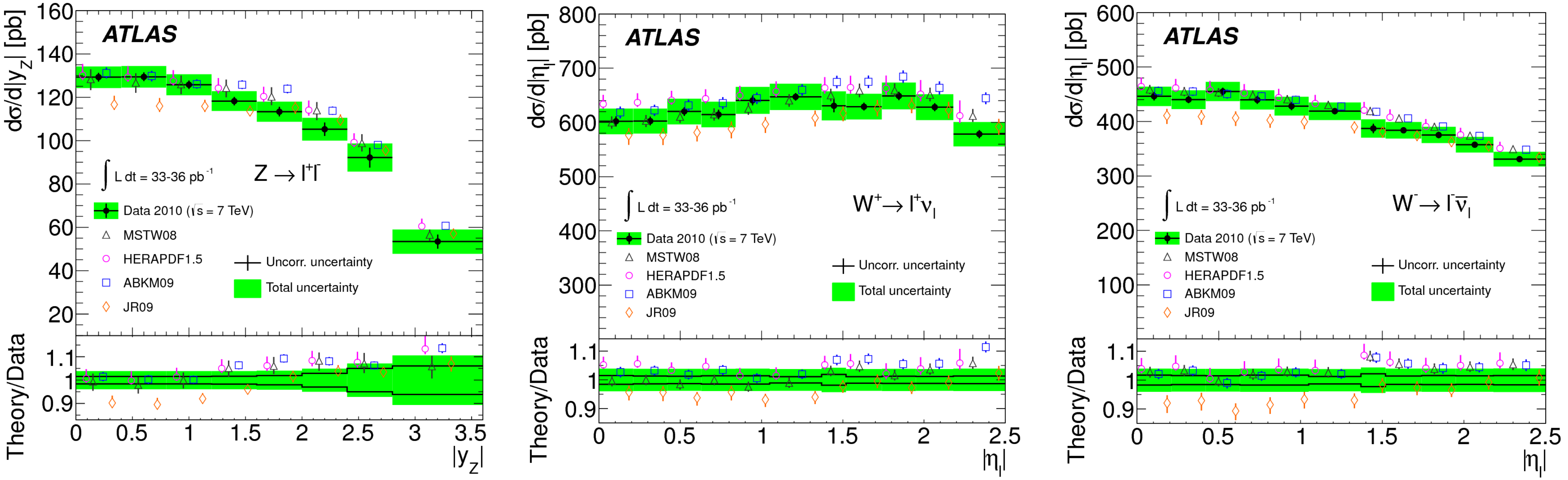


•Single vector boson production and Drell-Yan



- W, Z inclusive production
- W asymmetry
- High mass, low mass Drell-Yan
- Z → 4 leptons

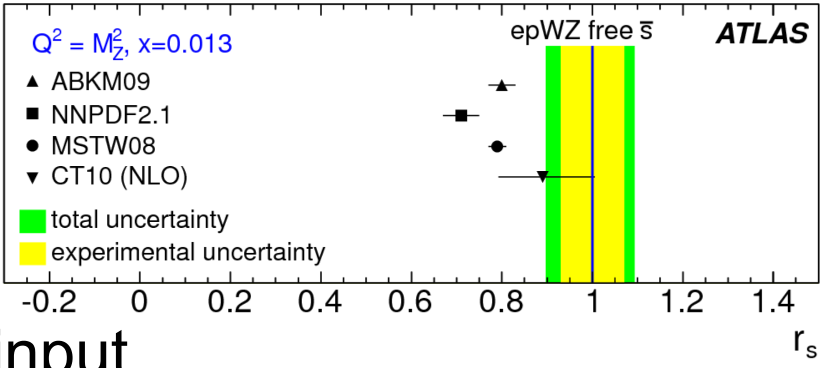
W, Z/γ* production cross section



- Measurement of W, Z cross sections provide important constraints on PDF

Phys. Rev. D85, 072004 (2012)

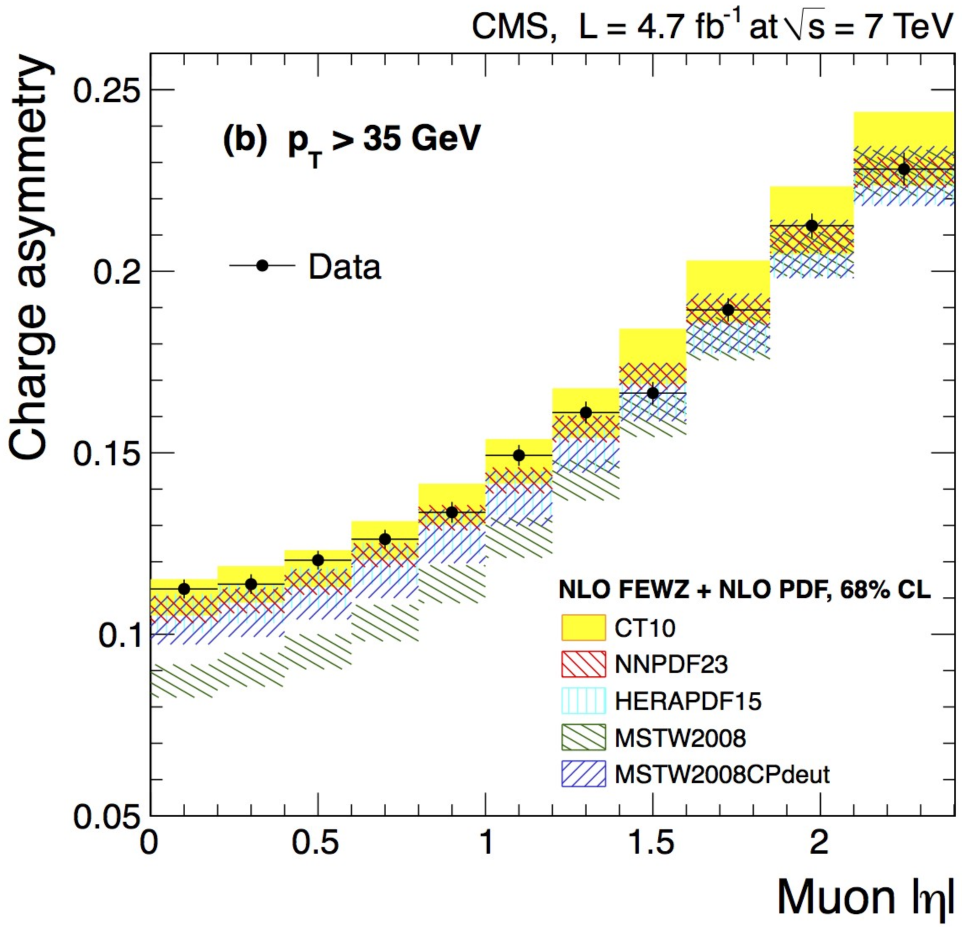
- EW theory is an essential ingredient for the interpretation of the measurements
  - Inclusion of NLO EW corrections
  - Modelling of QED FSR
  - Photon induced processes
  - Choice of the EW-scheme for the SM input parameters of the predictions



Phys.Rev.Lett. 109 (2012) 012001

W lepton η asymmetry

- Sensitive to down quark valence PDF
- Helps to reduce the PDF uncertainty for the measurement of the W mass
- Measurement already included in the latest PDF fits



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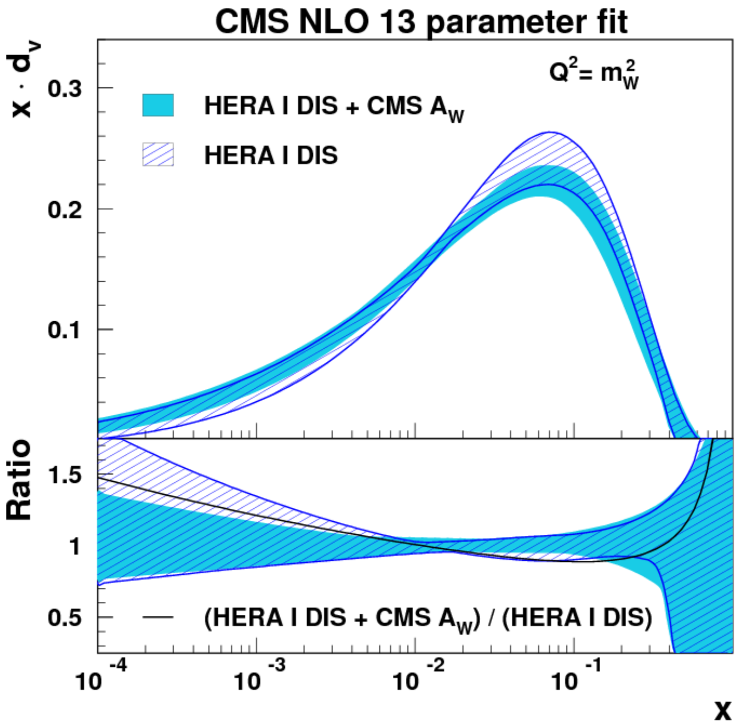
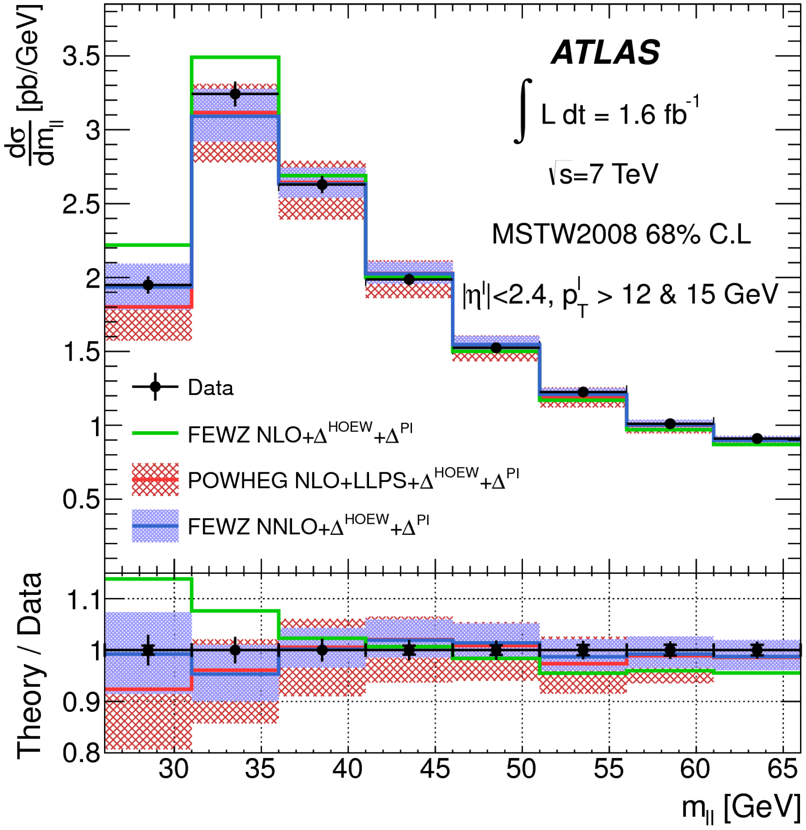


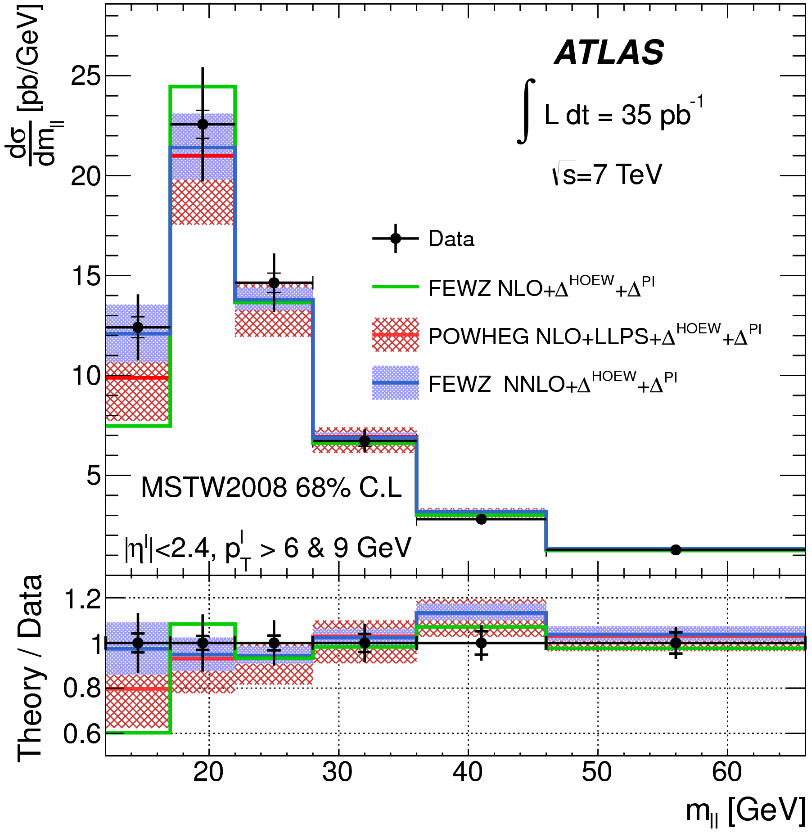
Low mass Drell-Yan

- Comparison to NLO, NNLO (FEWZ) and NLO+PS (POWHEG) predictions
- Careful inclusion of Higher Order EW corrections (SANC and FEWZ)
  - Photon Induced
  - Weak corrections
  - ISR and FSR QED radiation

JHEP 06 (2014) 112

- Probe $q\bar{q}$ coupling to γ^*
- Complementary to measurements near the Z mass peak

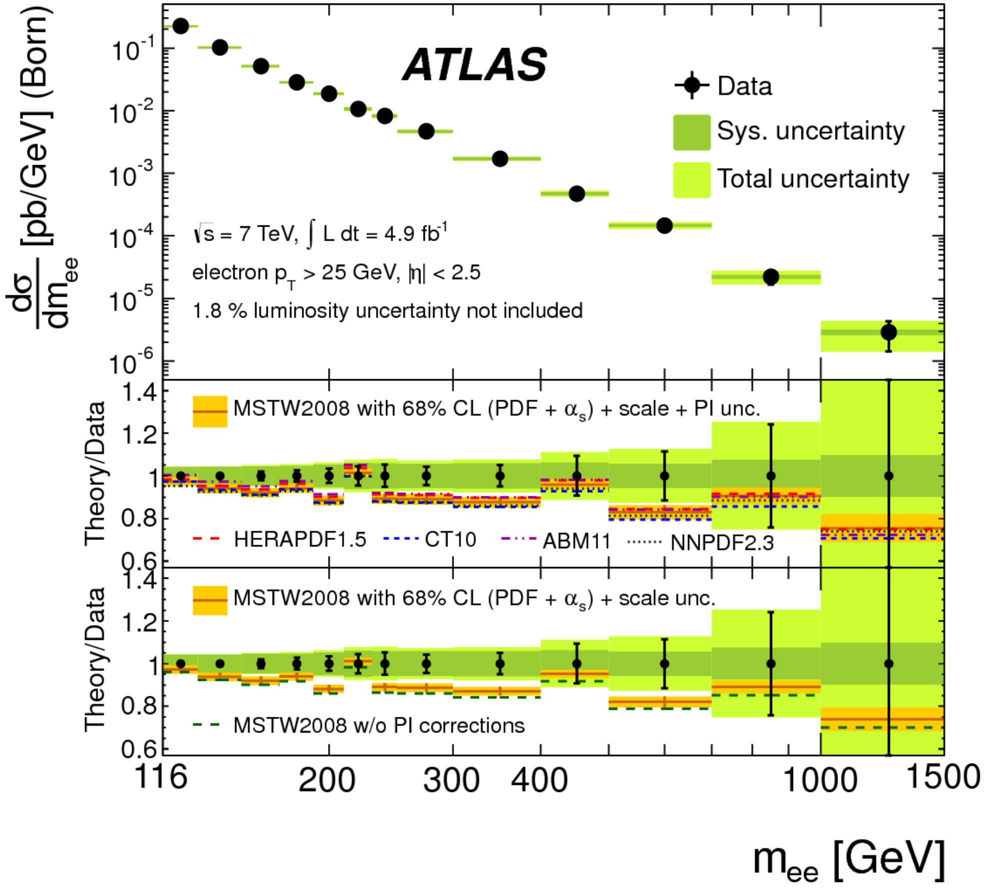


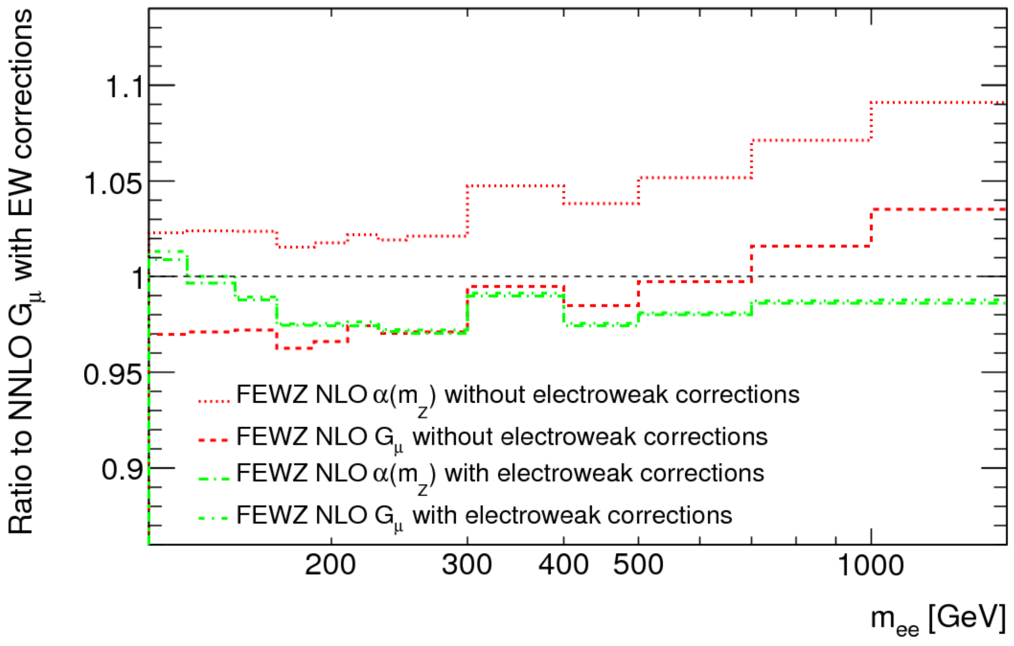


High mass Drell-Yan

- Background for Z' searches
- Sensitive to u-quark d-quark PDF at high Bjorken-x
- Significant NLO EW and photon induced corrections

Phys. Lett. B 725 (2013) 223-242

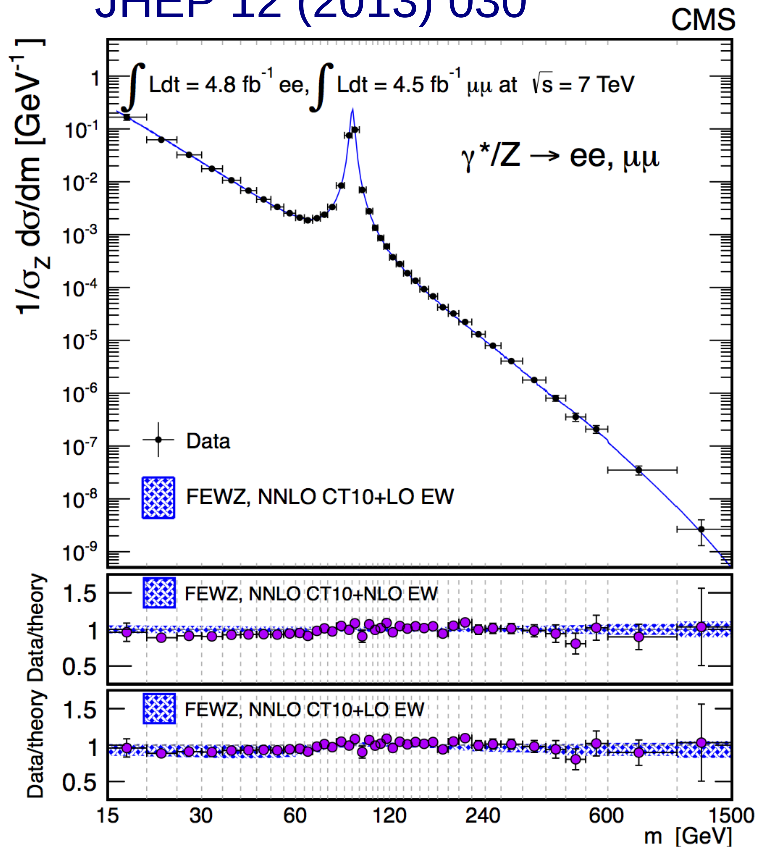




- Inclusion of NLO EW corrections largely reduce the dependence on the EW scheme for the input parameters

Dilepton invariant mass

JHEP 12 (2013) 030



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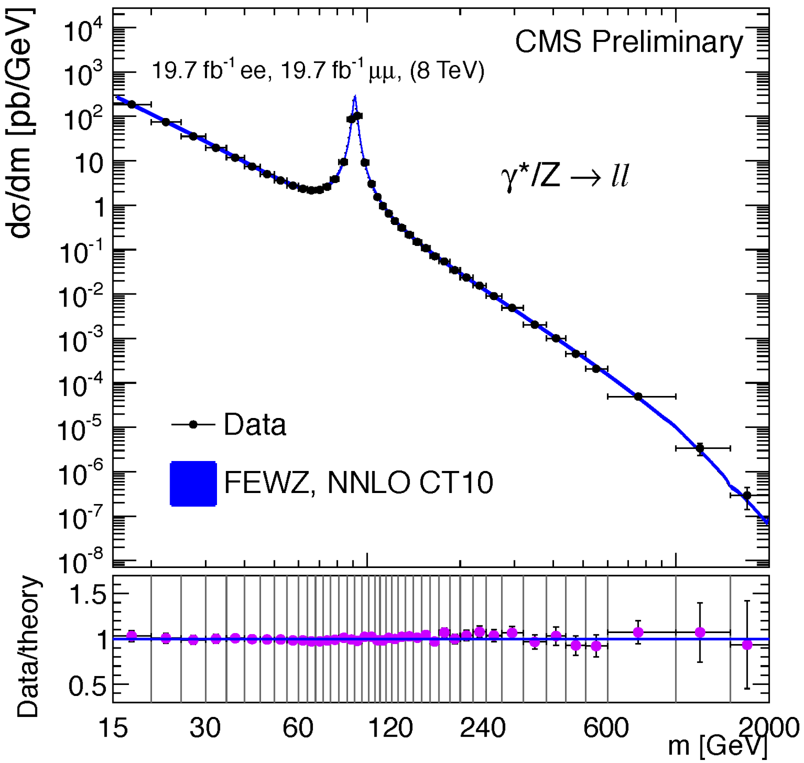
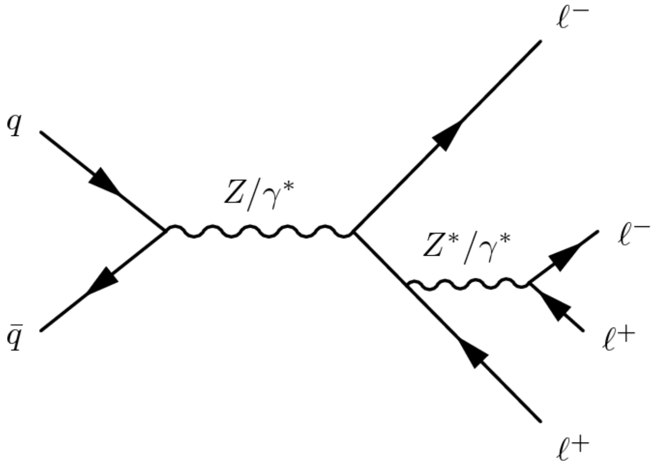


- Stringent test of
  - NNLO QCD
  - NLO EW
  - Detector calibration
  - ID efficiencies

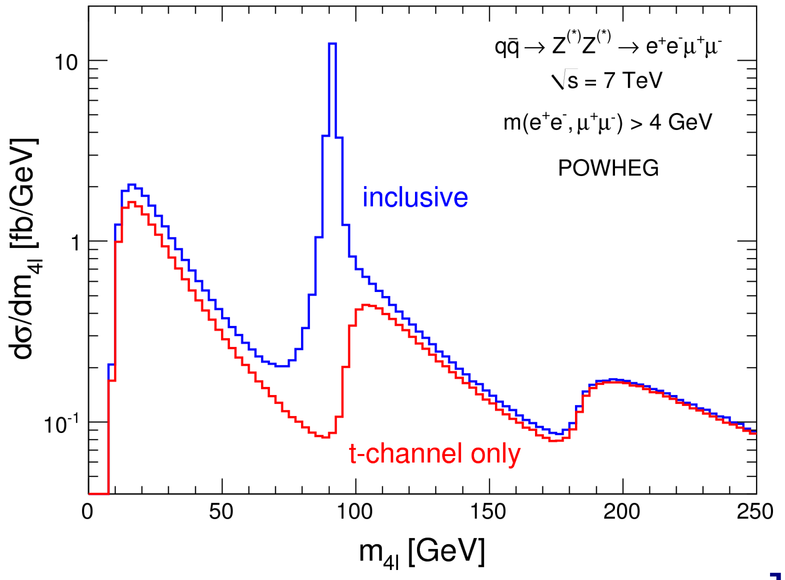
- Full spectrum of Drell-Yan dilepton invariant mass from 15 GeV to 2 TeV
- Cross section spans ten orders of magnitude

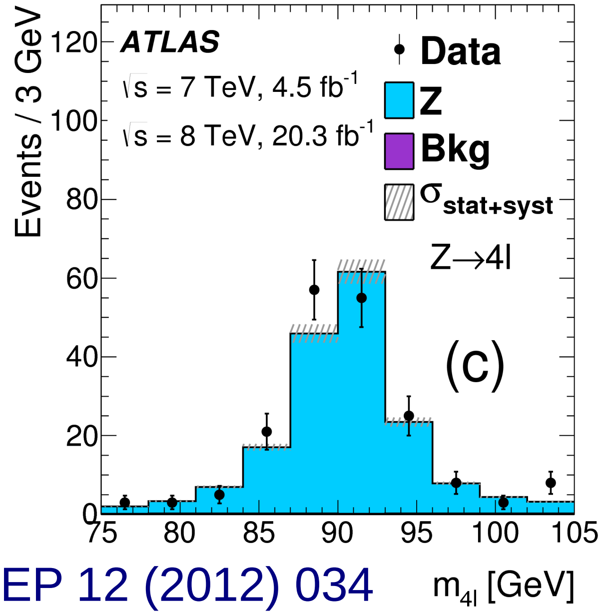
$Z \rightarrow 4$ leptons

Phys. Rev. Lett. 112, 231806 (2014)



- Resonant and non-resonant production



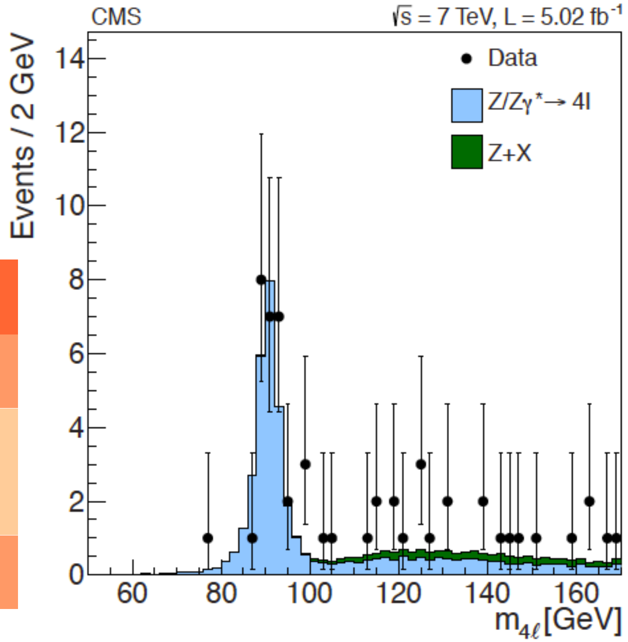


- Cross check lepton energy calibration for M_H in $H \rightarrow 4l$

- Non-resonant production is subtracted to measure BR($Z \rightarrow 4l$)

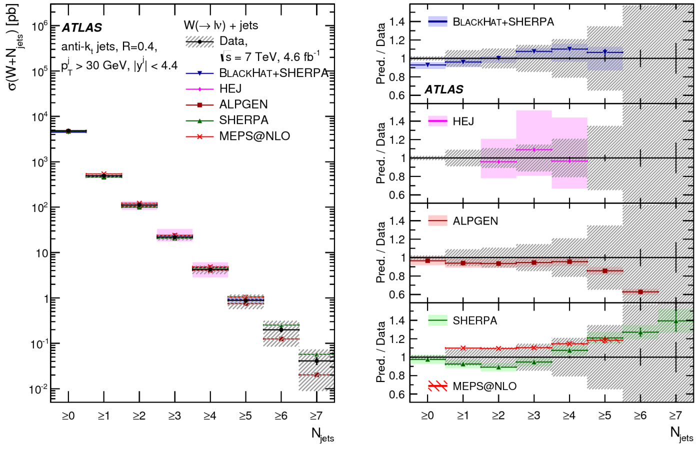
BR($Z \rightarrow 4l$) x 10^6	Data	Theory
ATLAS 7+8 TeV	3.30 ± 0.25(stat) ± 0.13(syst)	3.33 ± 0.01
ATLAS (extrapol. to CMS)	4.31 ± 0.34(stat) ± 0.17(syst)	4.50 ± 0.01
CMS 7 TeV	4.2 ± 0.9(stat) ± 0.2(syst)	4.45

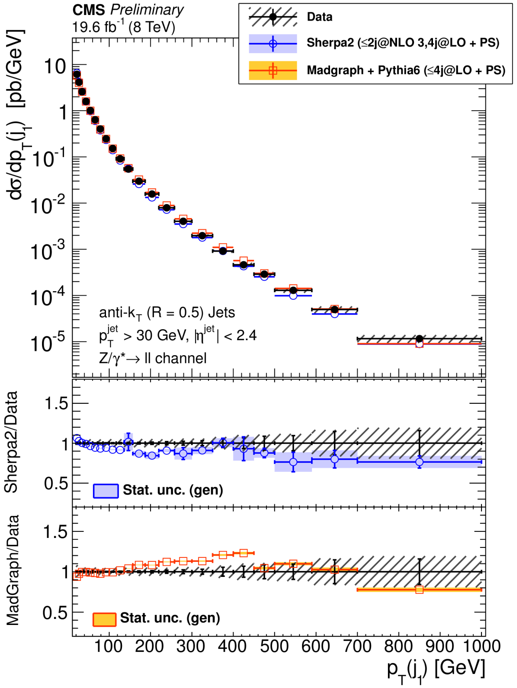
JHEP 12 (2012) 034

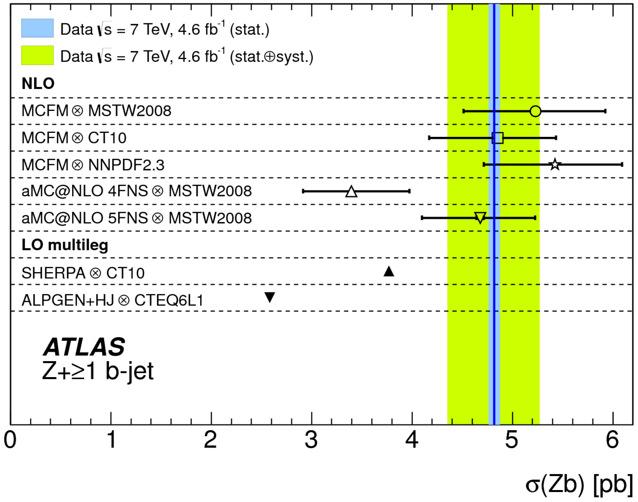


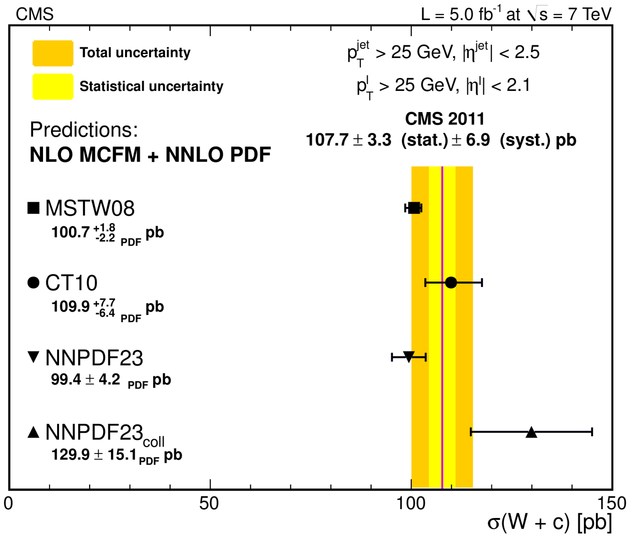
V + jets, V + heavy flavour jets

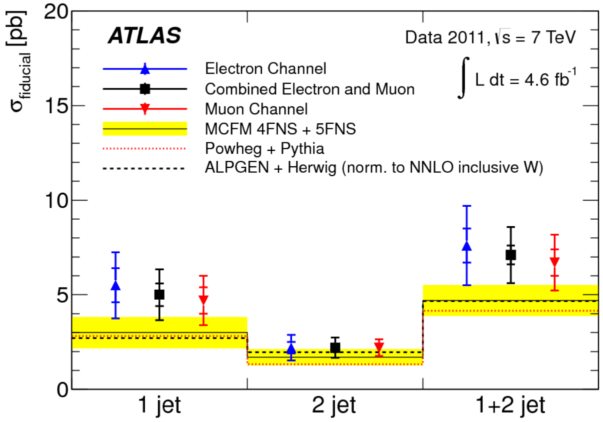
- Several Z + jets, W + jets measurements, provide stringent tests of perturbative QCD predictions

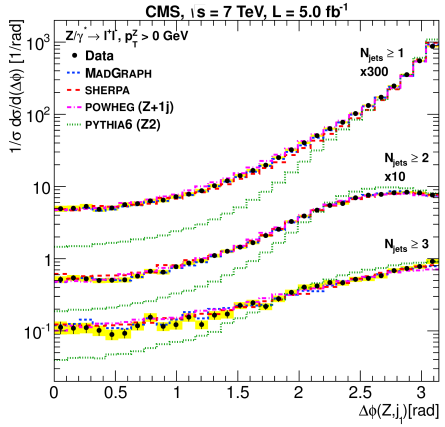






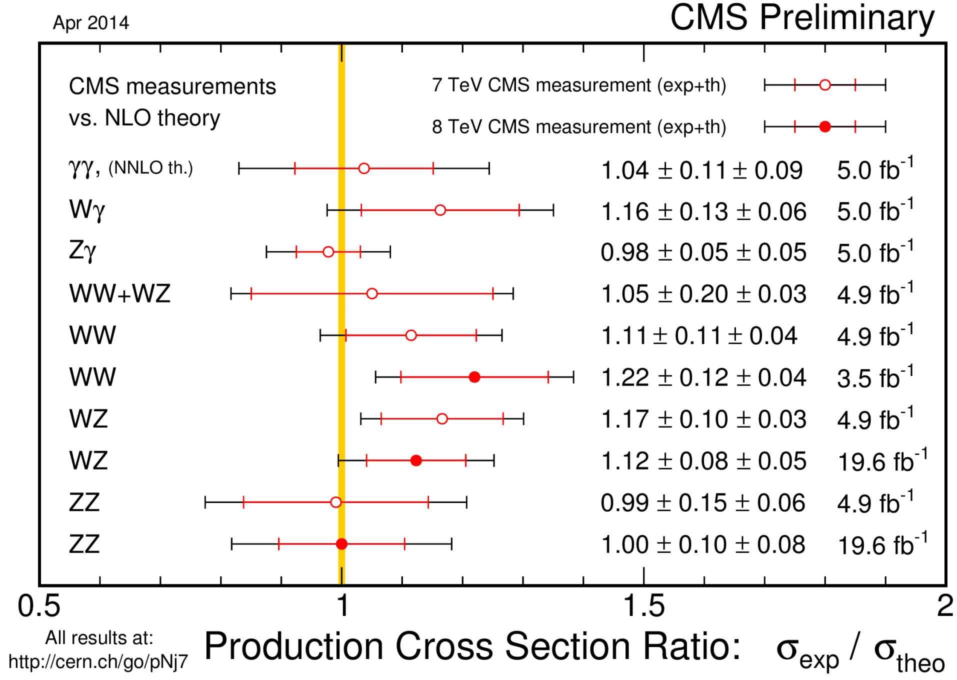


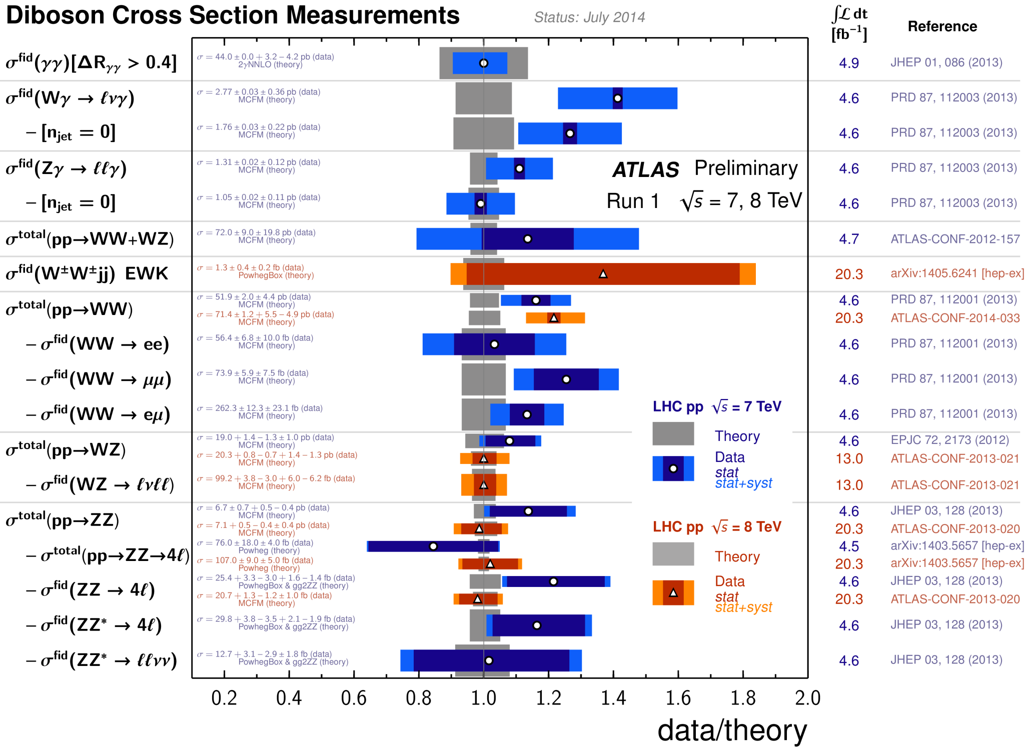




Diboson production and EW V+jets

- WW, WZ, and ZZ
- $pp \to l\nu\gamma$, $pp \to ll\gamma$, $pp \to \nu\bar{\nu}\gamma$
- $W^{\pm}W^{\pm}jj$ and Zjj EW production

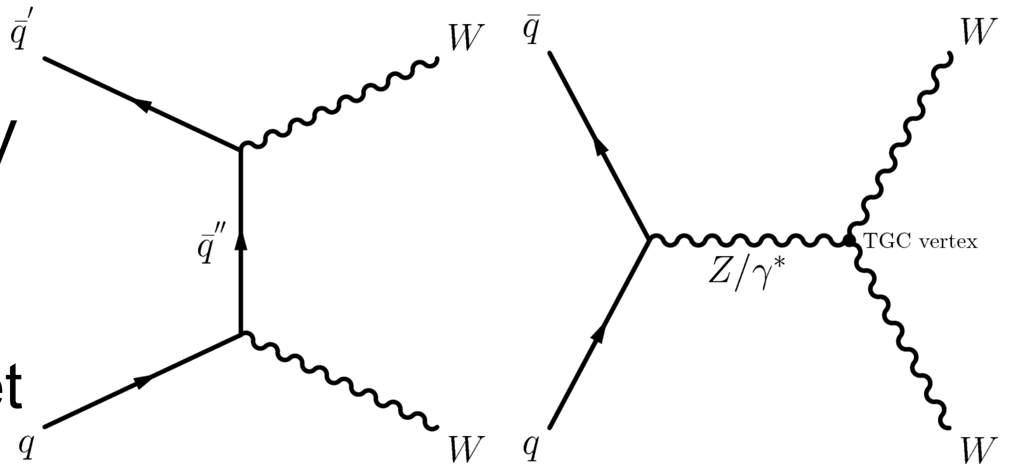


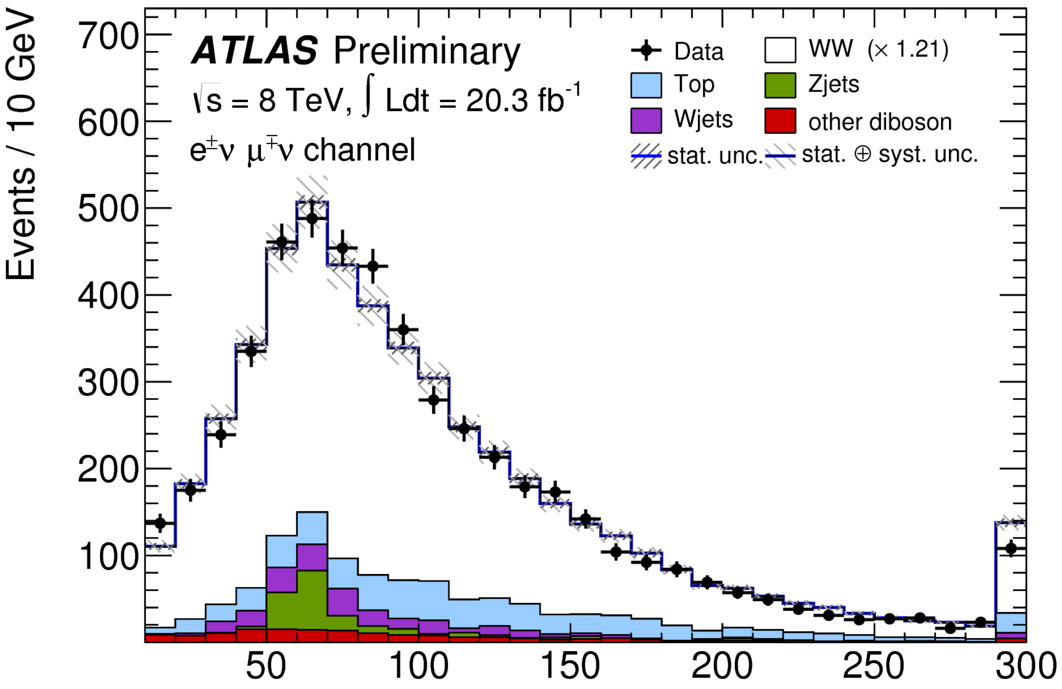


- Test of SM
- Background for higgs
- Probe of new physics: triple gauge couplings and diboson resonances

WW production cross section

- Signature: two leptons (e, μ) and missing E_T, jet veto p_T > 25(30) GeV
- Main background: W/Z + jets
- Dominant systematic uncertainty: jet energy scale and resolution for jet veto requirement





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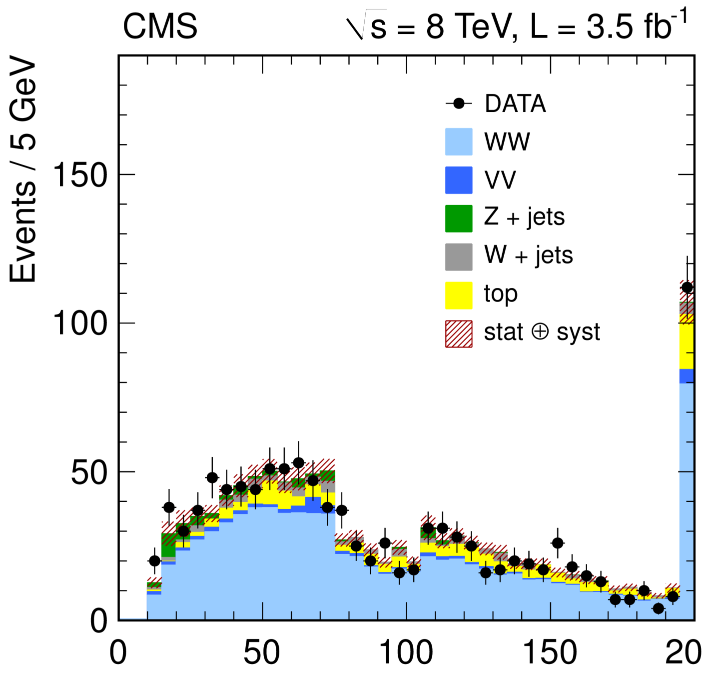

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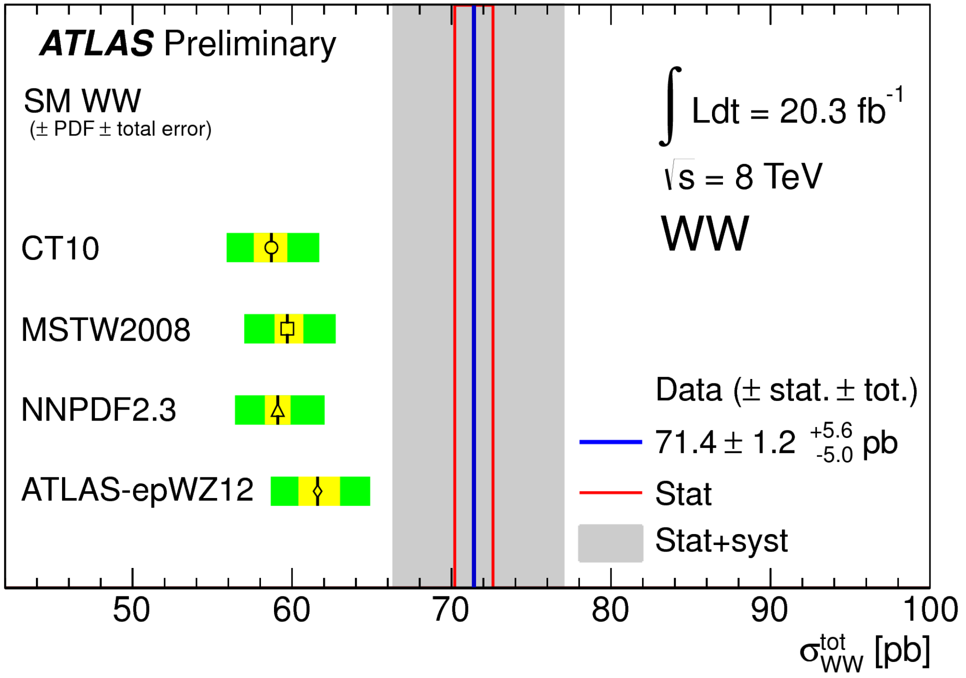
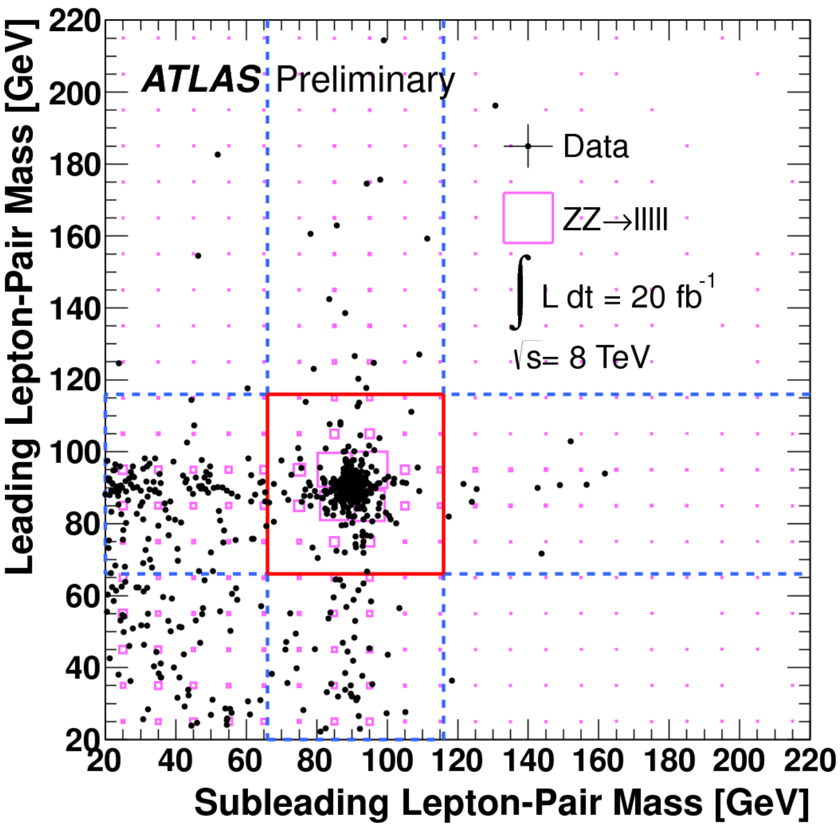
WW production cross section

8 TeV	$\sigma(pp\rightarrow WW)$	Stat	Syst	Lumi	NLO QCD
CMS	69.9 pb	2.8 pb	5.6 pb	3.1 pb	57.3+2.4-1.6 pb
ATLAS	71.4 pb	1.2 pb	+5.0-4.4 pb	+2.2-2.1 pb	58.7+3.0-2.7 pb

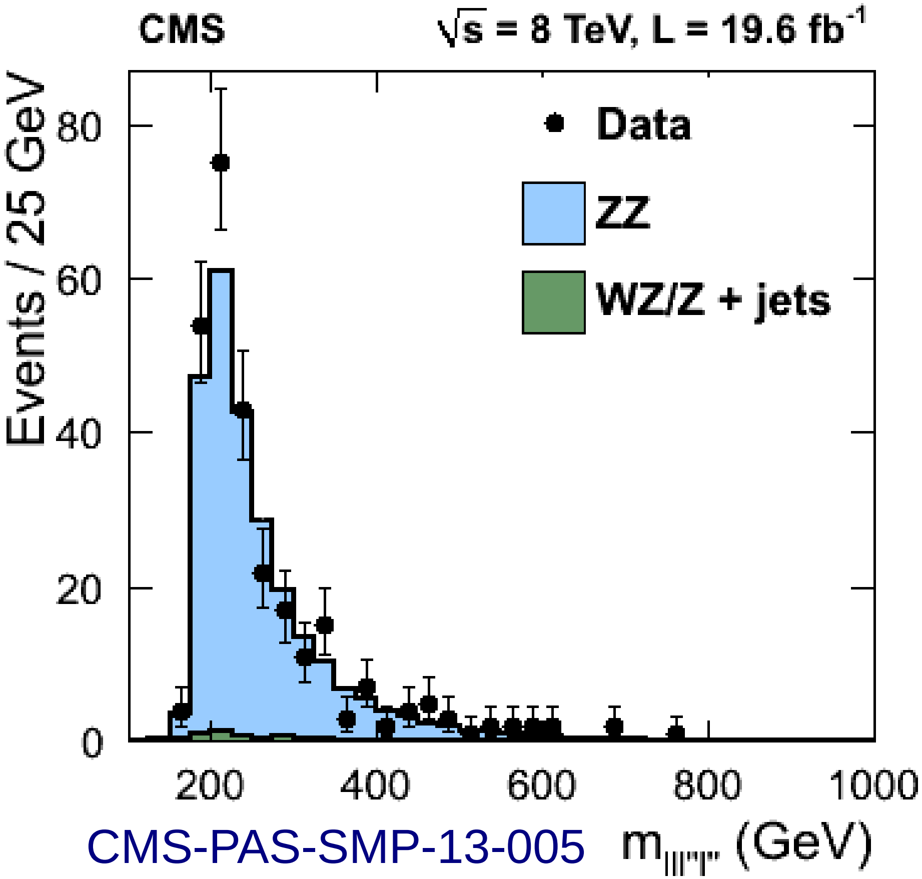
- Measured cross sections above NLO QCD prediction (~2σ)
- Good agreement between ATLAS and CMS
- PDF uncertainty cannot account for the data-theory disagreement
- NLO scale variations may underestimate MHOU when a jet veto is required
- Possible significant contribution from NNLO corrections



ZZ production cross section



ATLAS-CONF-2013-020

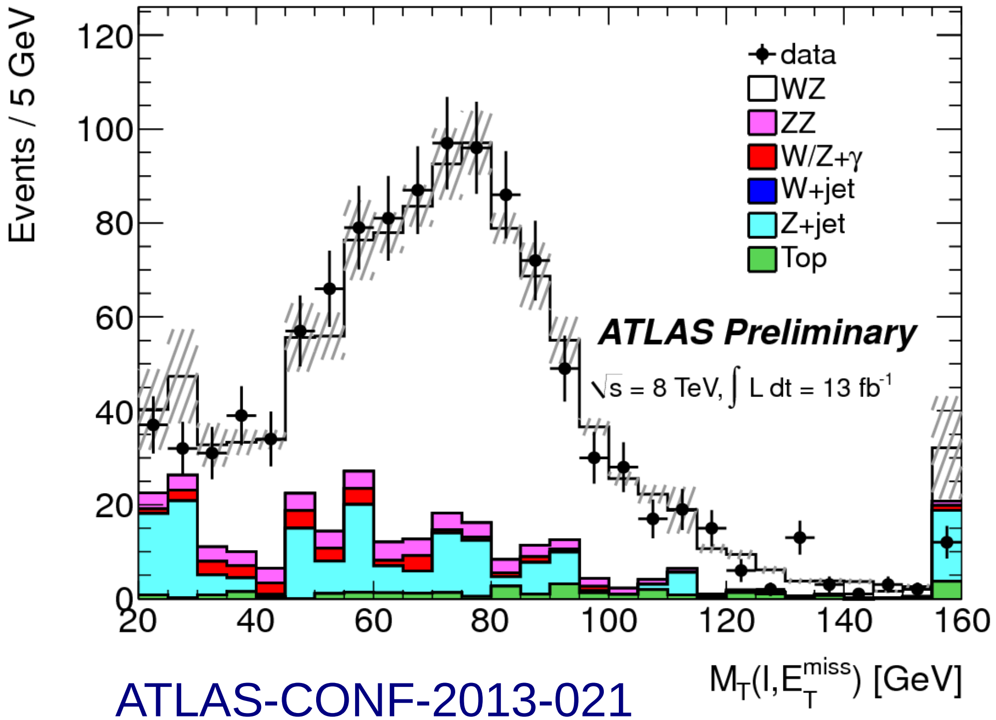


CMS-PAS-SMP-13-005

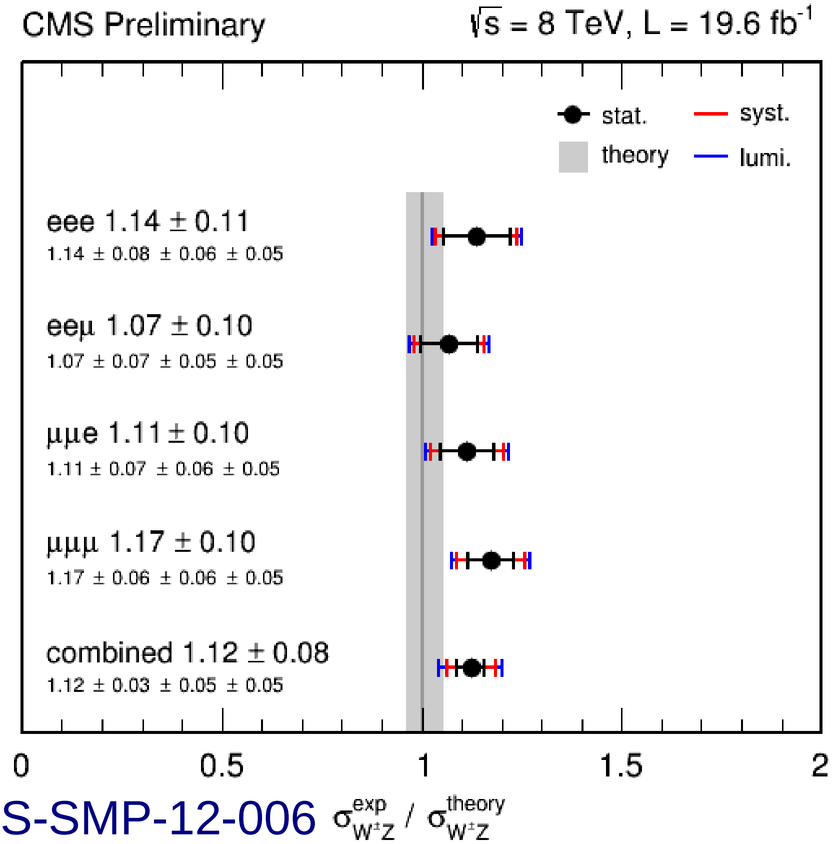
8 TeV	σ(pp→ZZ)	Stat	Syst	Lumi	NLO QCD
CMS	7.7 pb	0.5 pb	+0.5-0.4 pb	0.2 pb	7.7+-0.6 pb
ATLAS	7.1 pb	0.5 pb	0.3 pb	0.2 pb	7.2+-0.3 pb

- Good agreement with NLO QCD

WZ production cross section



ATLAS-CONF-2013-021

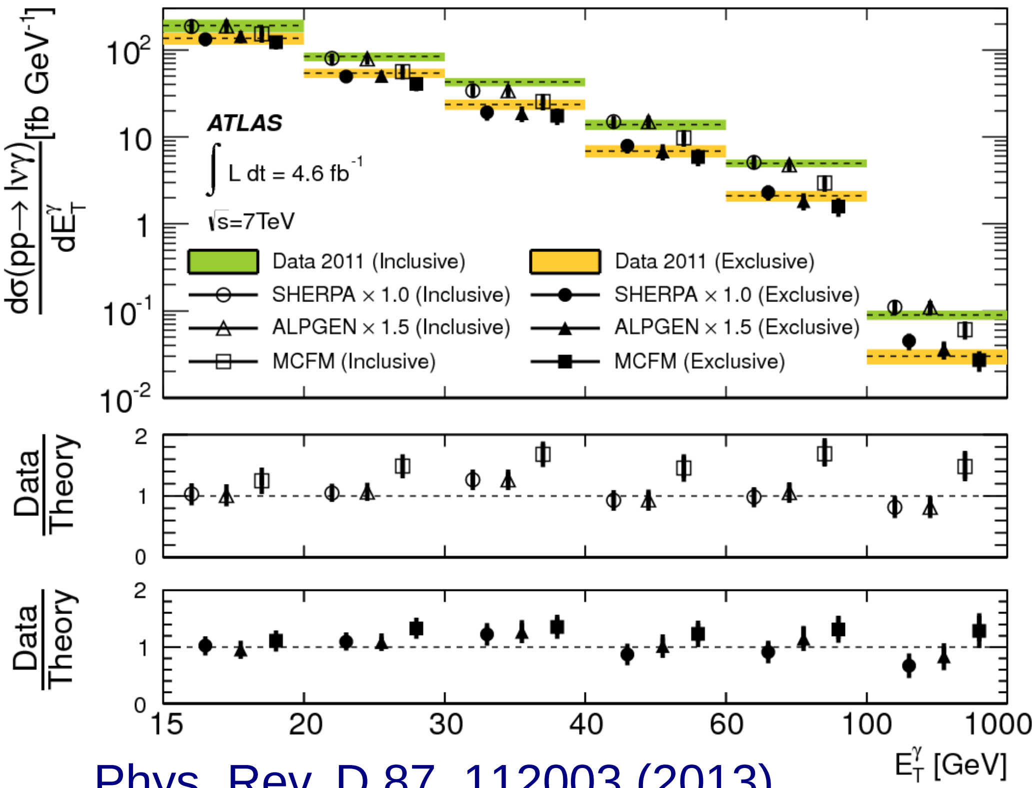


CMS-PAS-SMP-12-006

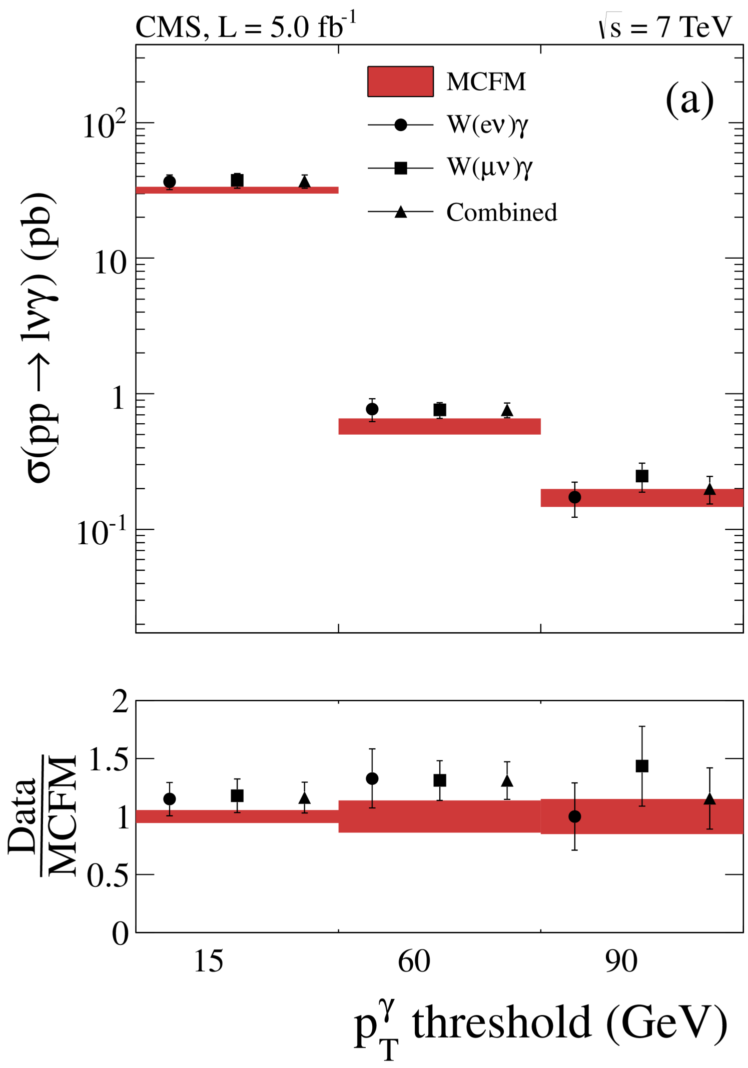
8 TeV	σ(pp→WZ)	Stat	Syst	Lumi	NLO QCD
CMS	24.6 pb	0.8 pb	1.1 pb	1.1 pb	21.9+1.2-0.9 pb
ATLAS	20.3 pb	0.8 pb	1.2 pb	0.7 pb	20.3+-0.8 pb

- Good agreement with NLO QCD

pp → lνγ cross section



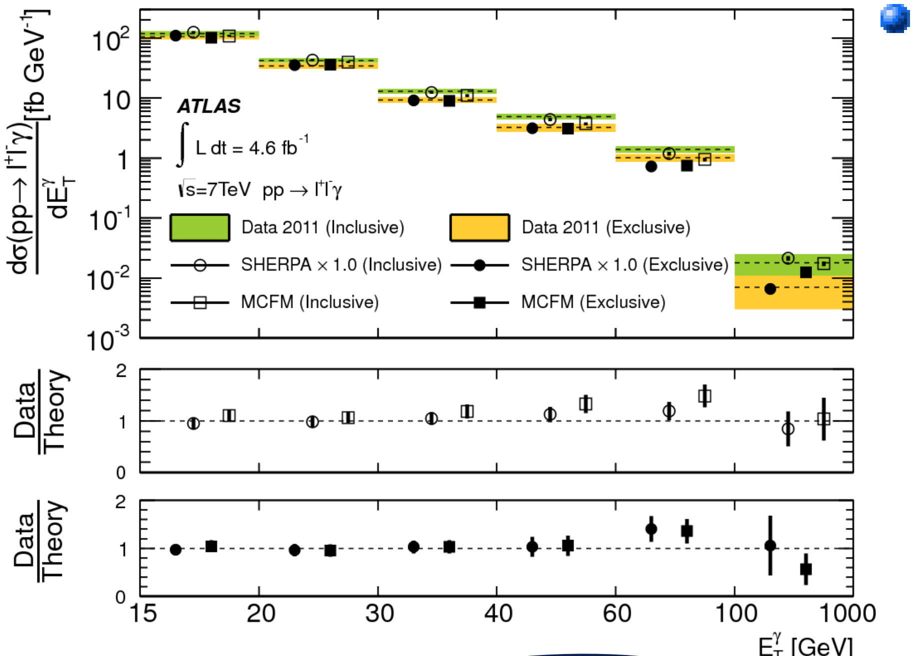
Phys. Rev. D 87, 112003 (2013)



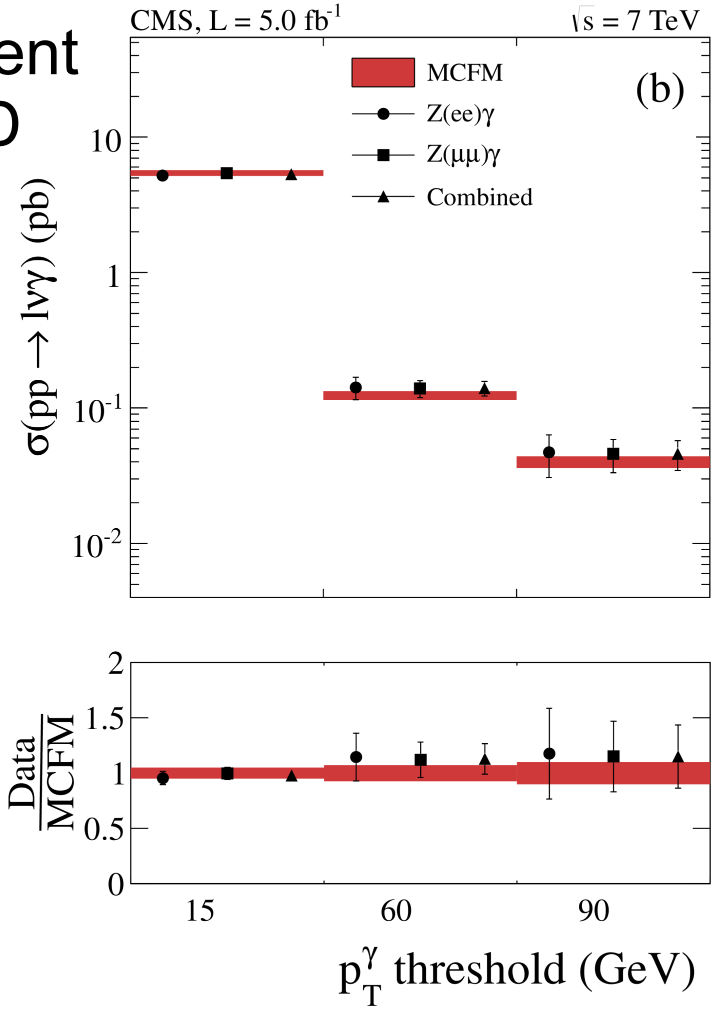
Phys. Rev. D 89 (2014) 092005

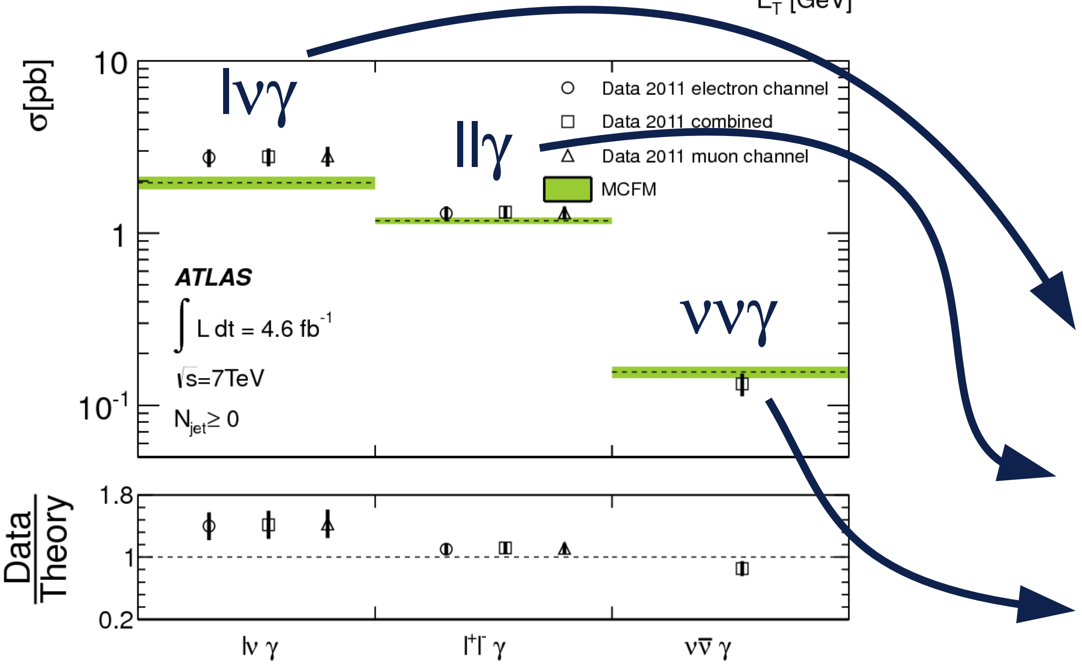
- MCFM NLO QCD prediction lower than the data
- Alpgen and Sherpa in reasonable agreement with data
- Jet veto improves agreement between data and NLO QCD

pp → llγ, ννγ cross sections



- Good agreement with NLO QCD

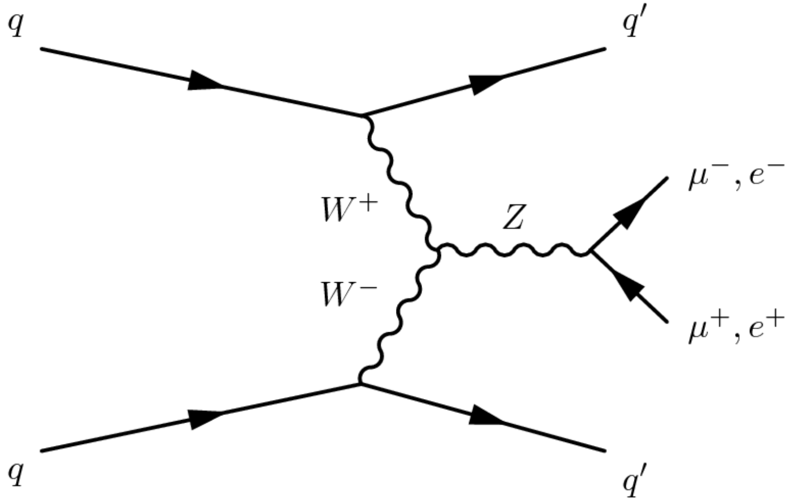




- ISR+FSR+W-strahlung
- ISR+FSR
- ISR

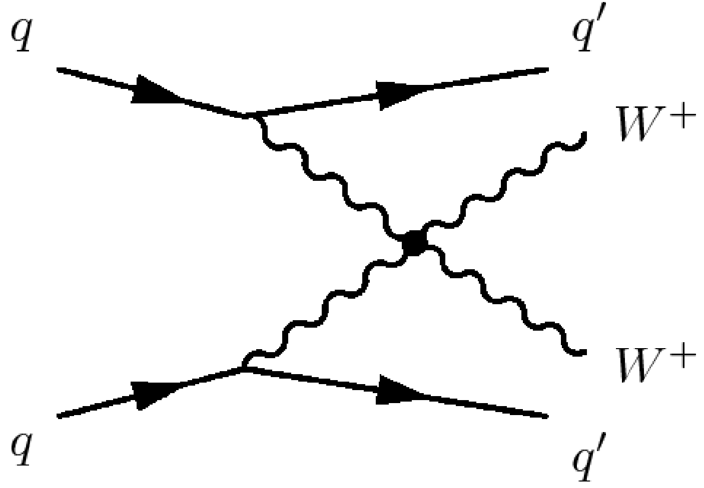
VBS and VBF

Vector Boson Fusion (VBF)



$$\sigma^{\mathrm{fid}}(Zjj - \mathrm{Electroweak}) = 46.1 \pm 1.0 \text{ fb}$$

Vector Boson Scattering (VBS)

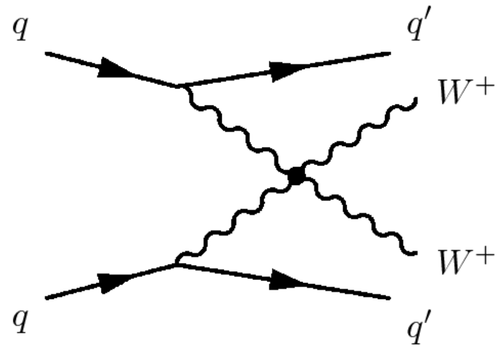


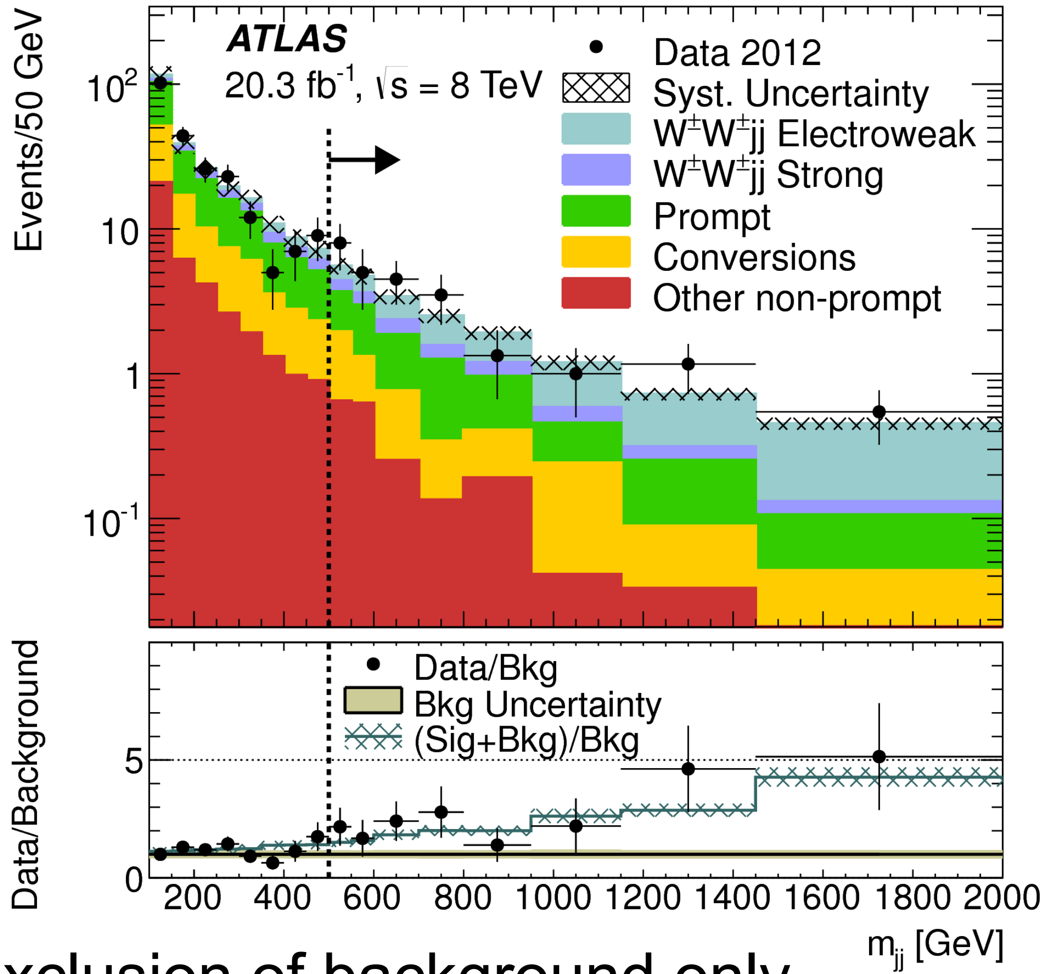
$$\sigma^{\mathrm{fid}}(W^{\pm}W^{\pm}jj) = 0.95 \pm 0.06 \text{ fb}$$

- Rare Standard Model processes
- Insight on Electroweak symmetry breaking: $W_L W_L \rightarrow W_L W_L$ violates unitarity without a SM Higgs
- Sensitive to triple/quartic gauge couplings

- Distinguish:
  - electroweak production $O(\alpha^4)$ at LO
  - QCD production $O(\alpha^2\alpha_s^2)$ at LO

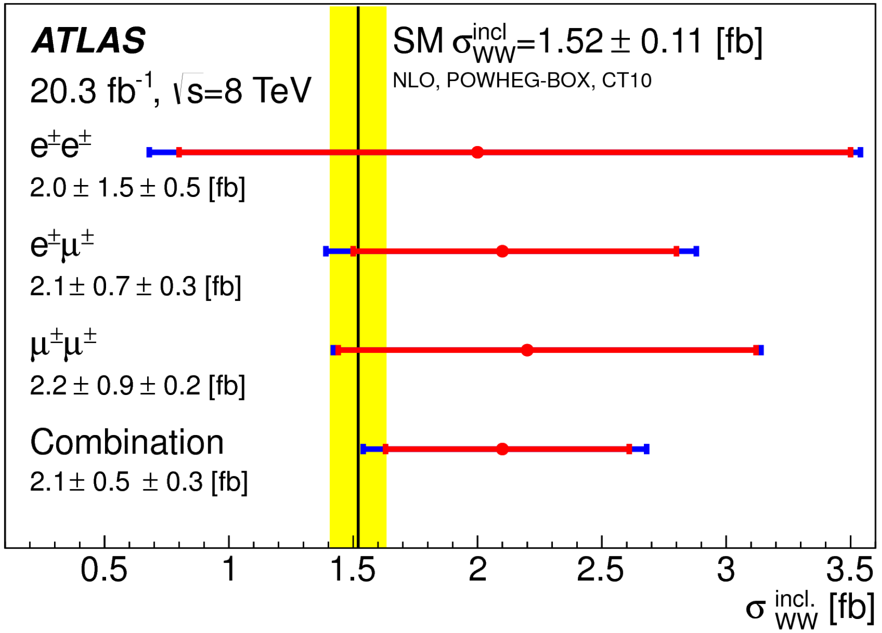
$W^{\pm}W^{\pm}$ jj production cross section





- Select high M_{jj} and Δy region to enhance electroweak production

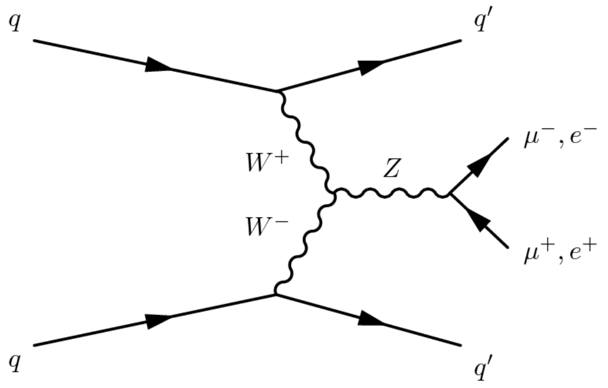
Phys. Rev. Lett. 113, 141803 (2014)

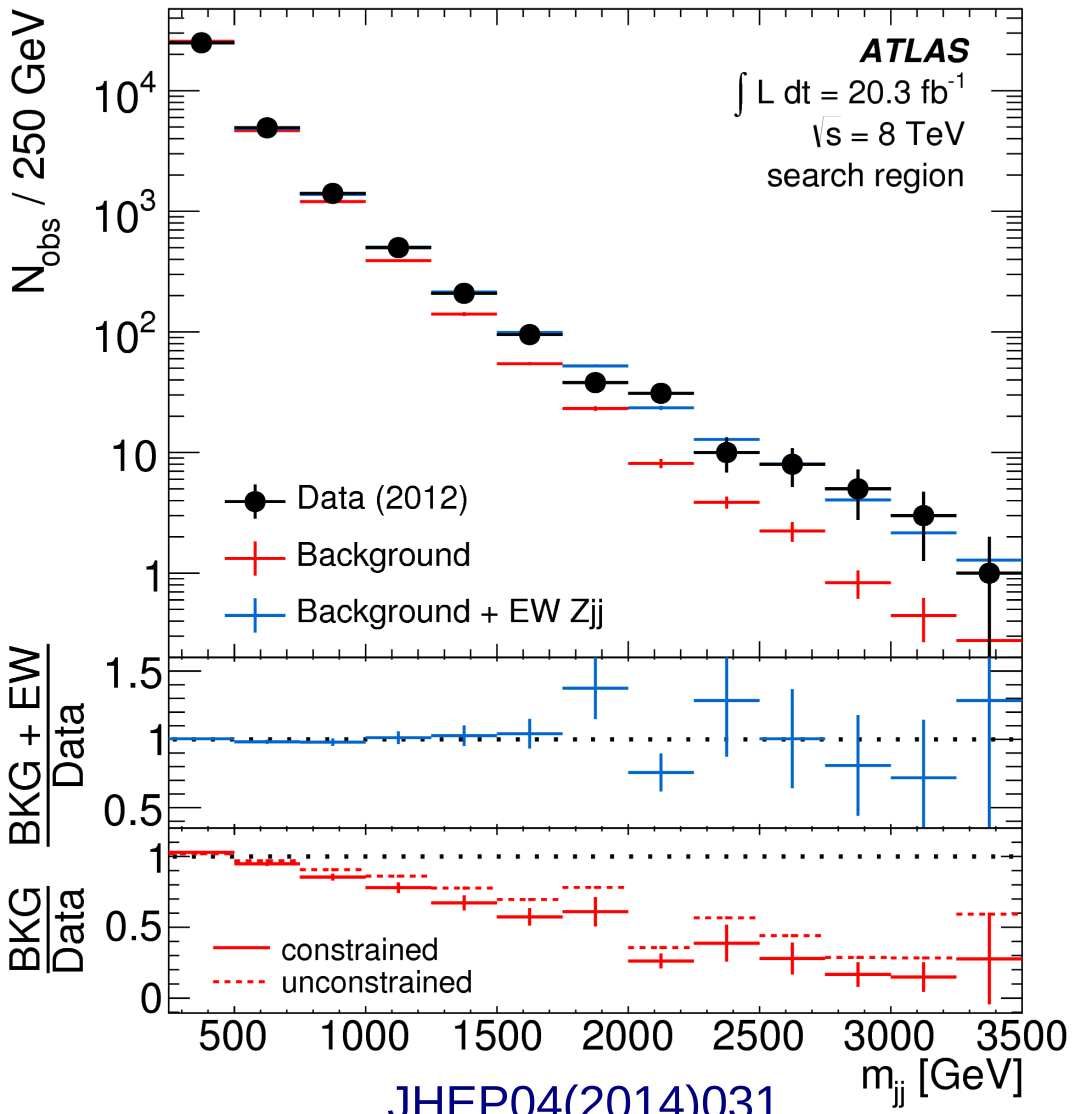


- Exclusion of background only hypothesis
  - ATLAS: 4.5σ ewk+qcd, 3.6σ ewk
  - CMS: 2.0σ ewk+qcd, 1.9σ ewk

CMS-PAS-SMP-13-015

Zjj Vector Boson Fusion (VBF)





JHEP04(2014)031

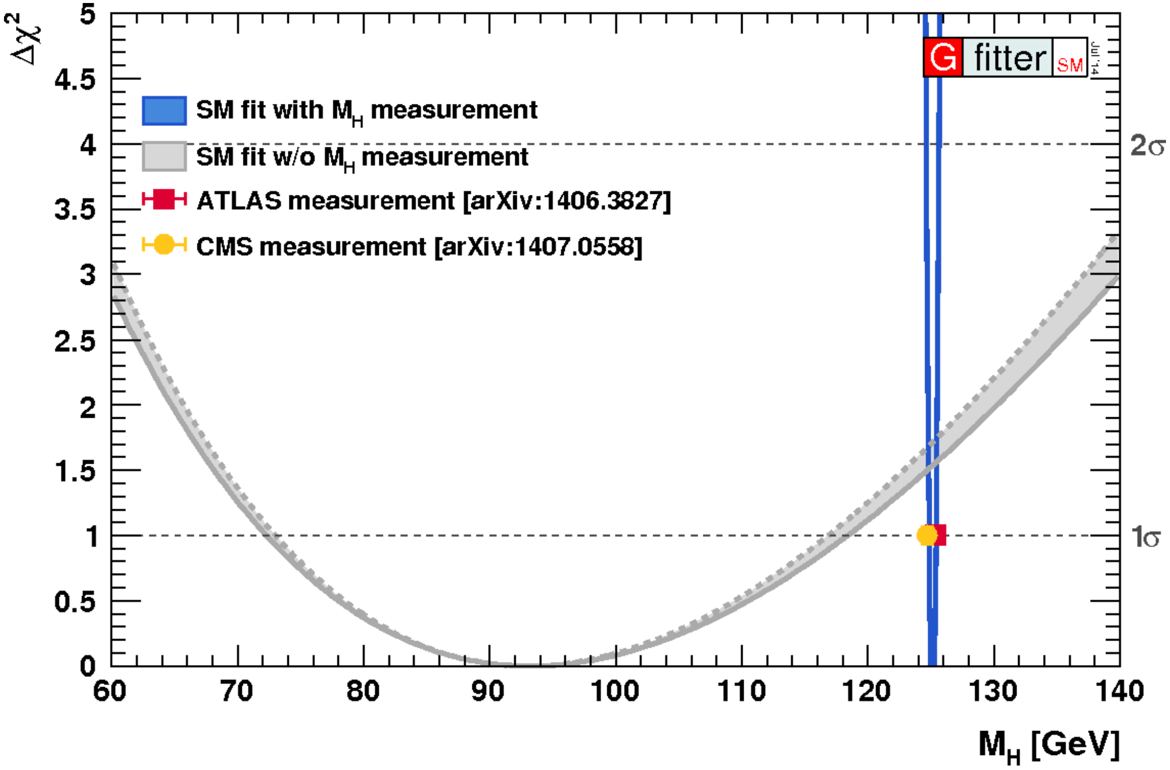
- Fit M_{jj} in signal region to extract electroweak component
- Background only hypothesis excluded at greater than 5σ significance

$$\sigma^{\rm fid}_{\rm ewk}(Zjj) = 55 \pm 5({\rm stat}) \pm 10({\rm syst})\ {\rm fb}$$

$$\sigma^{\rm theory}(Zjj) = 46.1 \pm 1.0\ {\rm fb}$$

EW precision measurements

- W mass
- Z mass (for calibration)
- Weak-mixing angle θ_W

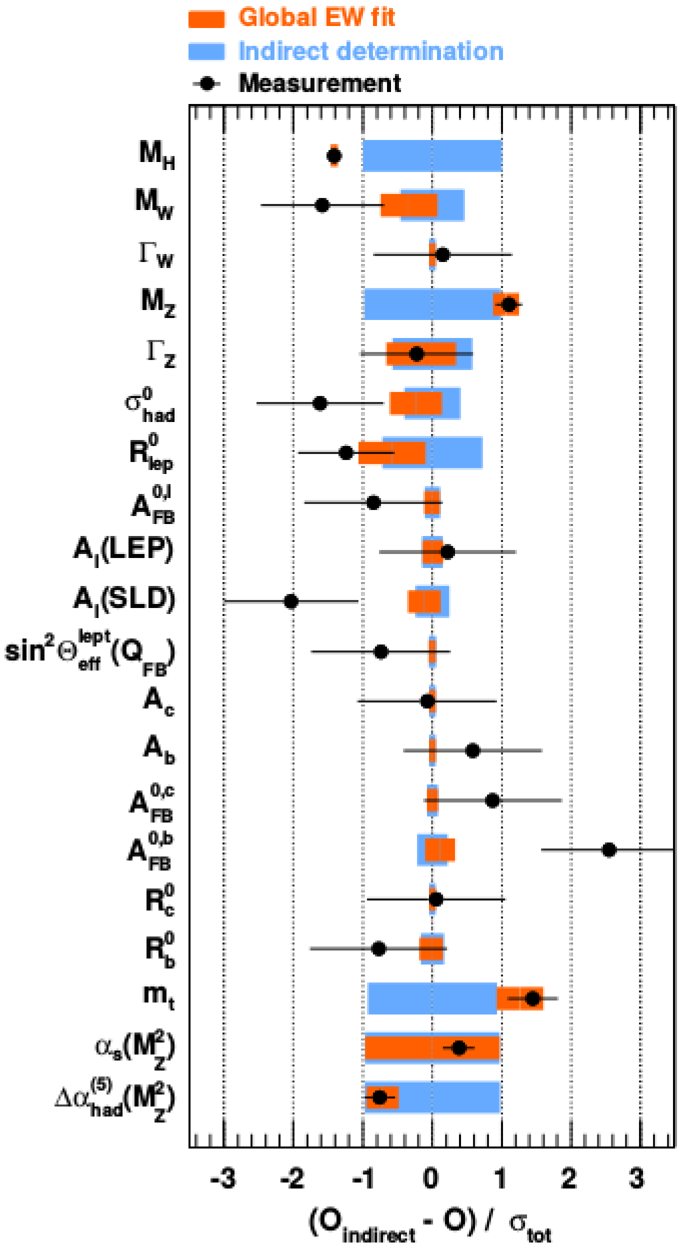


EW precision measurements

- After the measurement of the Higgs mass, all the free parameters of the Standard Model are known
- Relations between electroweak observables can be predicted (almost) at 2-loop level

Precise measurements of the EW parameters allow

- Stringent test of self consistency of the SM
- Look for hints of BSM physics



Eur.Phys.J. C74 (2014) 3046

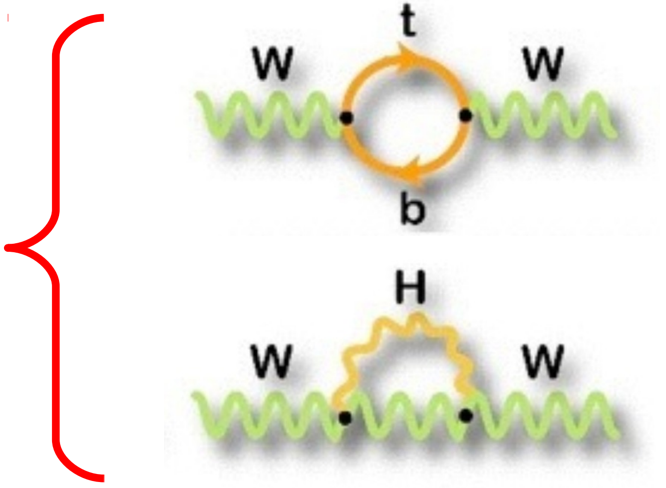
Measurement of the W mass

A milestone of the LHC physics program

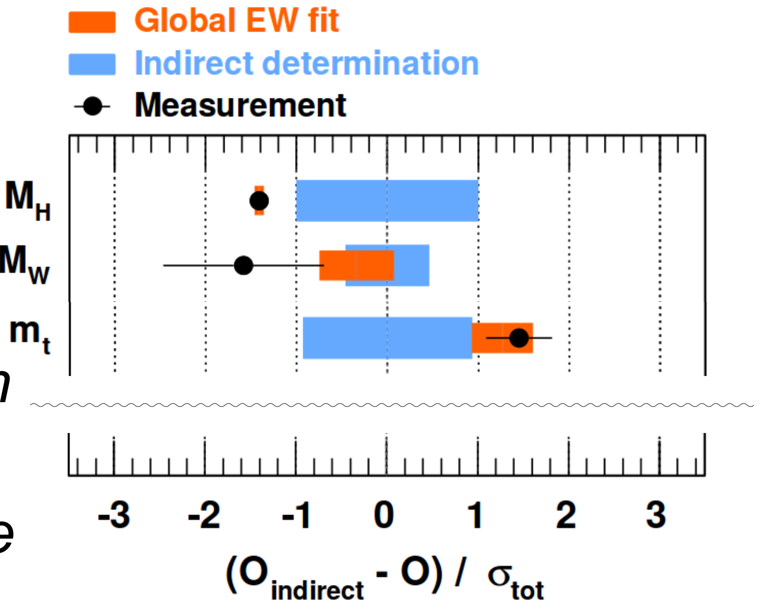
The EW sector of the SM, relates M_W to α, G_F, and $\sin^2\theta_W$

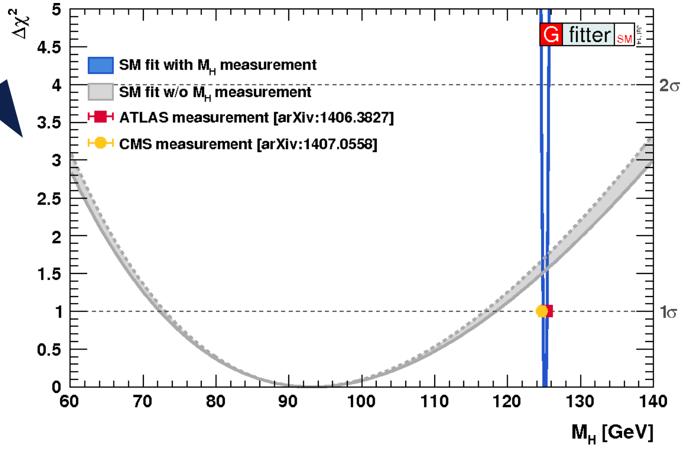
$$M_W^2 = \frac{\pi \boxed{\alpha_{EM}}}{\sqrt{2}\,\boxed{G_F}\,\boxed{(1-M_W^2/M_Z^2)}\,(1-\boxed{\Delta r})}$$

Radiative corrections Δr are dominated by Top and Higgs loops



- The relation between M_{top}, M_H and M_W provides a stringent test of the SM
- The comparison between the measured M_H and the predicted M_H is sensitive to new physics



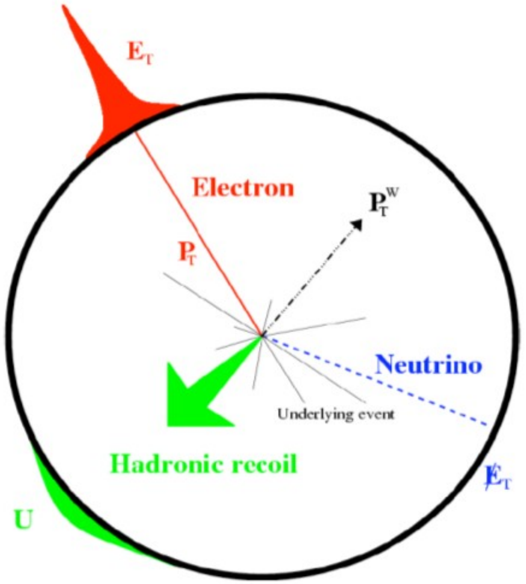


Indirect determination of M_W (±8 MeV) is more precise than the experimental measurement

Call for $\delta M_W^{exp} < 10$ MeV

Methodology for the W mass extraction

- Event selection: W leptonic decay
  W → l ν, l = e, μ
- The full kinematic of the W decay cannot be reconstructed, since the longitudinal momentum of the neutrino is unknown



Traditional analyses are based on a template fit extraction from observables sensitive to M_W

Lepton transverse momentum	p_T^l
W transverse mass	$M_T = \sqrt{2 \cdot p_T^l p_T^\nu \cdot (1 - \cos\Delta\phi(l,\nu)}$
Neutrino transverse momentum (from hadronic recoil)	p_T^ν

More sophisticated analysis techniques suggest simultaneous measurements of W and Z observables TS2008-022

Eur.Phys.J. C69 (2010) 379-397

→

In the same spirit, a common strategy of template fits analyses is to use Z → ll events to constraint both experimental and theory systematics

W mass measurement at the LHC

- The M_W measurement at the LHC follows a strategy similar to the Tevatron
- Important differences:
  - Higher pile-up environment → affect hadronic recoil calibration
  - Potentially larger theoretical uncertainties due to pp instead of $p\bar{p}$ collisions
  - W^+ and W^- production is not symmetric → Require a charge dependent analysis

Most precise observables for the M_W extraction

p_T^l	M_T
Observable does not depend on hadronic recoil, smaller experimental uncertainty	Depends on hadronic recoil measurement, expected larger experimental uncertainties
Larger theory uncertainty due to higher order QCD, p_T^W modelling, PDF, W polarisation, charm mass	M_T is quite stable wrt perturbative QCD corrections, smaller PDF uncertainties, smaller non-perturbative QCD uncertainties

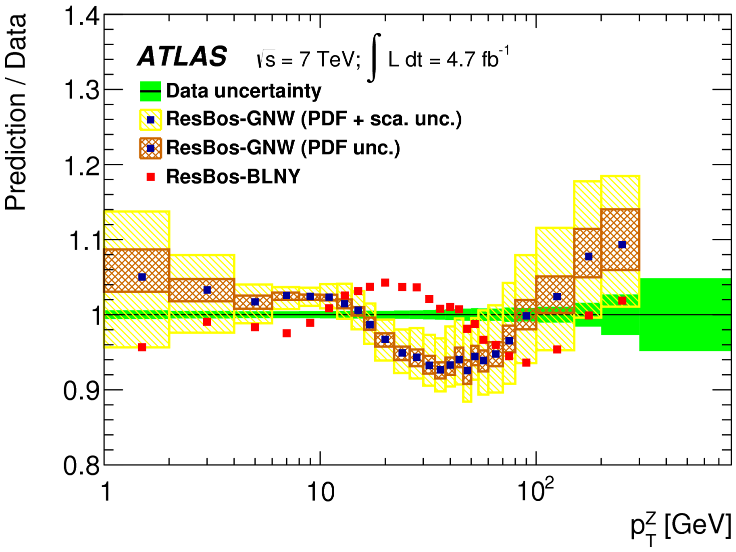
M_W extraction is likely to be limited by theoretical uncertainties

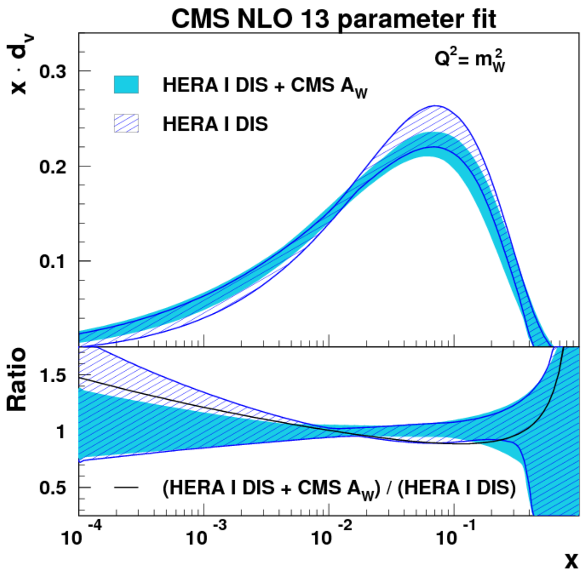
Final balance between theory and exp uncertainties will depend on pile-up mitigation algorithms

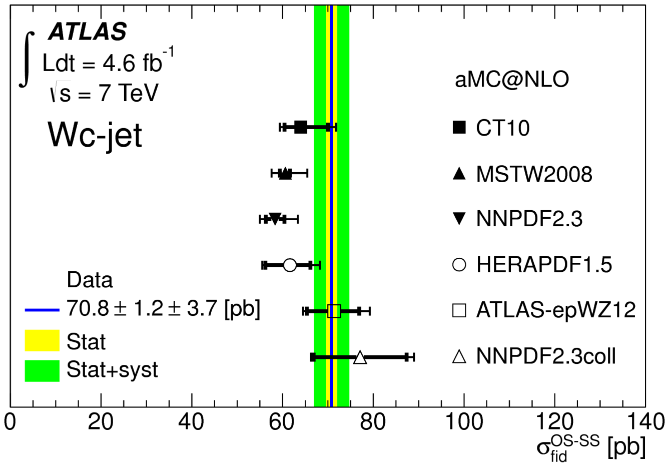
Constrain M_W theory uncertainties at the LHC

ATLAS and CMS are performing measurements of alternative W, Z observables to control the theoretical models and reduce the uncertainties on the measurement of M_W

Theory uncertainties	Measurements which can provide constraints to the theoretical models
p_T^W modelling	p_T^W, p_T^Z
PDF	W asymmetry, Z rapidity, W + charm







Z mass measurement at the LHC

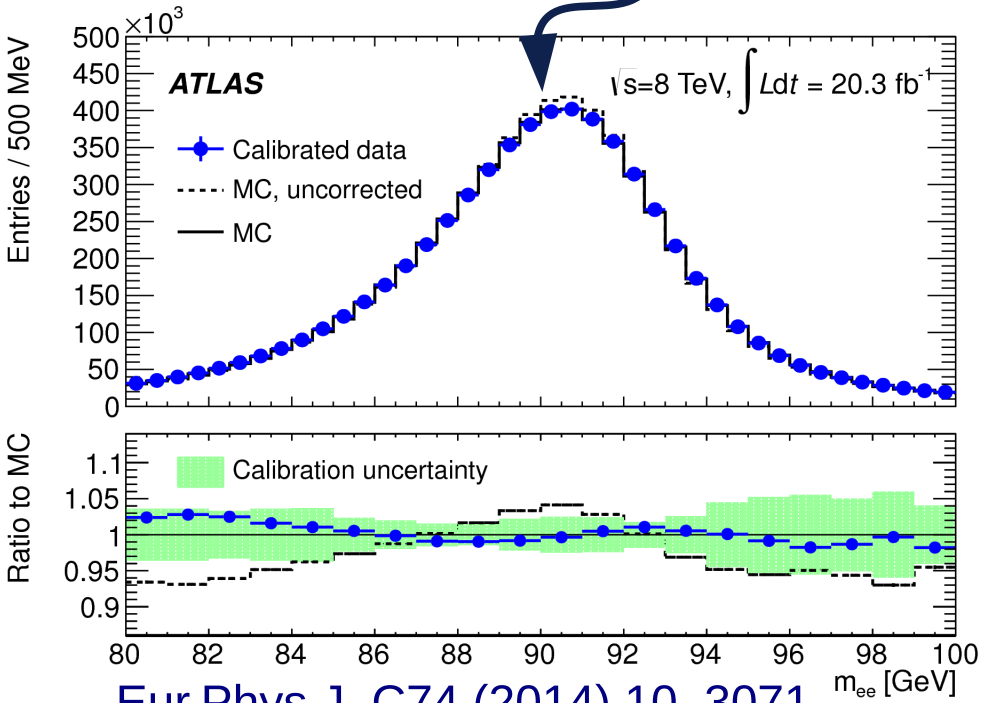
A first step towards the measurement of M_W at the LHC is the measurement of M_Z

Test the methodology of the M_W extraction:

→ Neglect one of the two leptons, extract M_Z from p_T^l and hadronic recoil

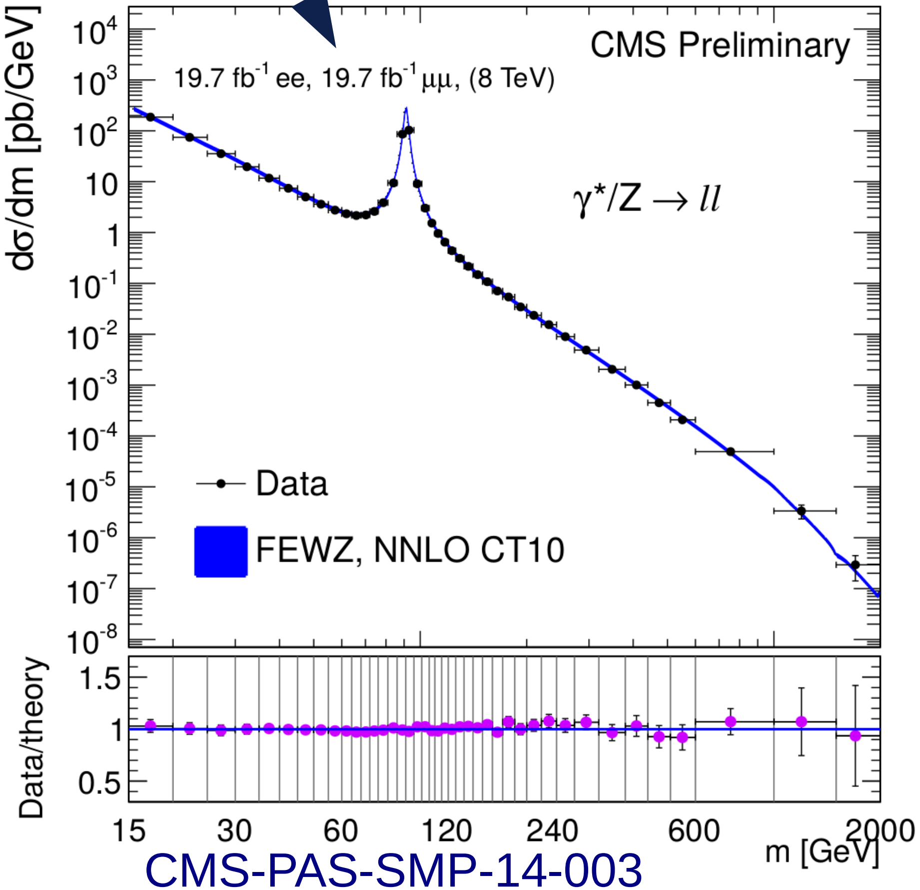
The lepton energy scale is calibrated by comparing the reconstructed M_Z to the LEP measurement of M_Z

Electron calibration from Z → ee invariant mass



Eur.Phys.J. C74 (2014) 10, 3071

$Z/\gamma^* \to$ ll lineshape measurement

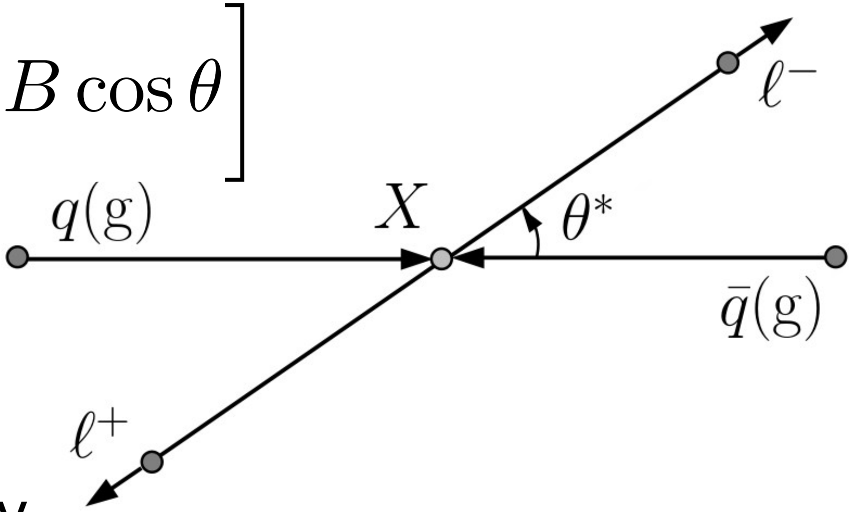


CMS-PAS-SMP-14-003

Z forward-backward asymmetry and θ_W

The Drell-Yan production cross section as function of the scattering angle θ

$$\frac{d\sigma}{d\cos\theta} = \frac{4\pi\alpha^2}{3s}\left[\frac{3}{8}(A(1+\cos^2\theta) + B\cos\theta\right]$$



- Coefficients A and B depend on the weak mixing angle θ_W
- Linear term in cos(θ) gives rise to non-vanishing forward-backward asymmetry

↳ $$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

$$\sigma_F = \sigma(\cos\theta > 0)$$
$$\sigma_B = \sigma(\cos\theta < 0)$$

$B \propto s - m_Z^2$ ➡ A_{FB} changes sign at the Z pole

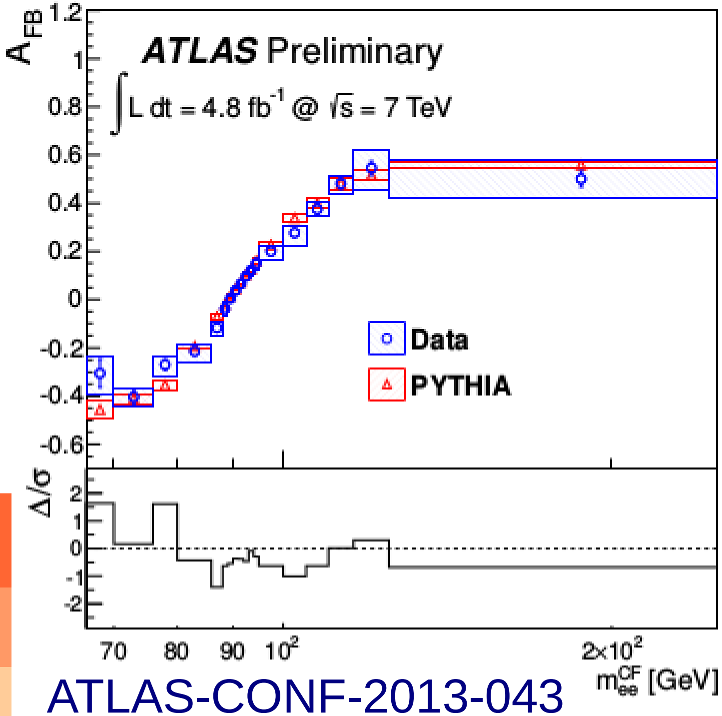
The direction of the incoming quark is unknown

- Only valence quarks determine a detectable asymmetry
- Asymmetry is diluted, effect related to PDF
- Use θ* scattering angle, defined in the Collins-Soper frame

Measurement of weak-mixing angle θ_W

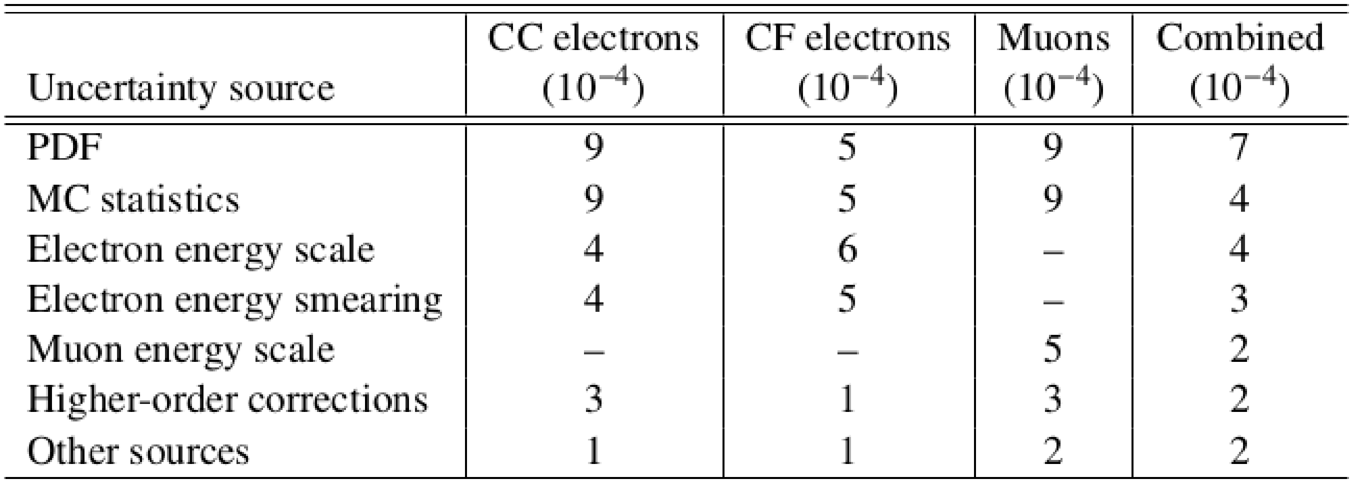
- ATLAS: θ_W extracted from template fits to Z AFB as a function of dilepton invariant mass M_{ll}
- CMS: multivariate likelihood technique, θ_W extracted from M_{ll}, $\cos(\theta_W)$, y_{ll}

	$\sin^2(\theta_W^{eff})$
ATLAS 7 TeV 4.8 fb^{-1}	0.2297 ± 0.0004(stat) ± 0.0009(syst)
CMS 7 TeV 1.1 fb^{-1}	0.2287 ± 0.0020(stat) ± 0.0025(syst)
LEP+SLD	0.23153 ± 0.00016



ATLAS-CONF-2013-043

Phys. Rev. D 84, 112002 (2011)

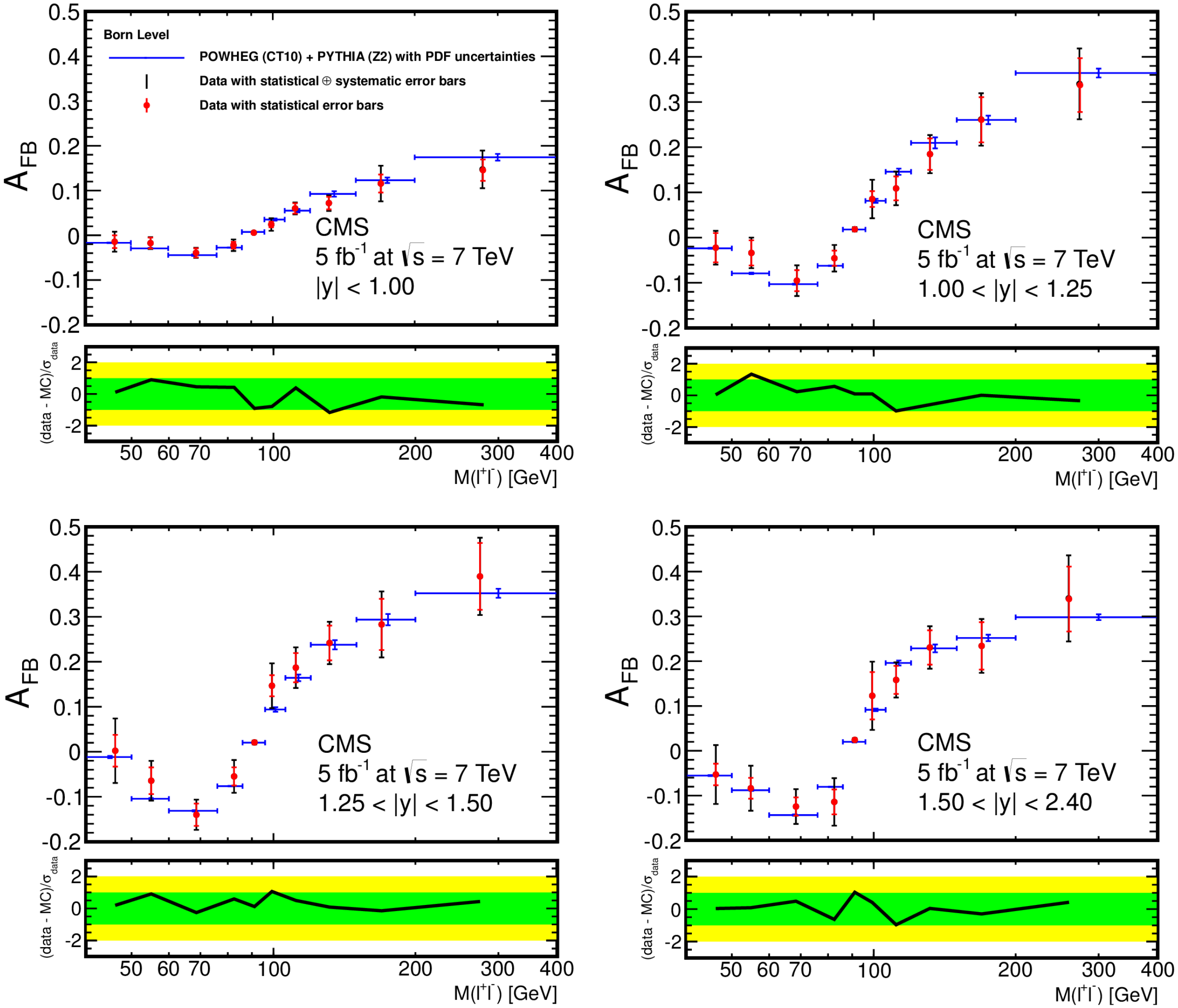


Uncertainty source	CC electrons (10^{-4})	CF electrons (10^{-4})	Muons (10^{-4})	Combined (10^{-4})
PDF	9	5	9	7
MC statistics	9	5	9	4
Electron energy scale	4	6	–	4
Electron energy smearing	4	5	–	3
Muon energy scale	–	–	5	2
Higher-order corrections	3	1	3	2
Other sources	1	1	2	2

- Still 10 times worst than LEP+SLD
- ATLAS measurement limited by PDF uncertainty

Unfolded Z forward-backward asymmetry

- CMS published also Z AFB asymmetries unfolded to particle-level
- ATLAS measurement will follow soon
- Easier to extract a combined measurement of θ_W, accounting for correlation of PDF uncertainties



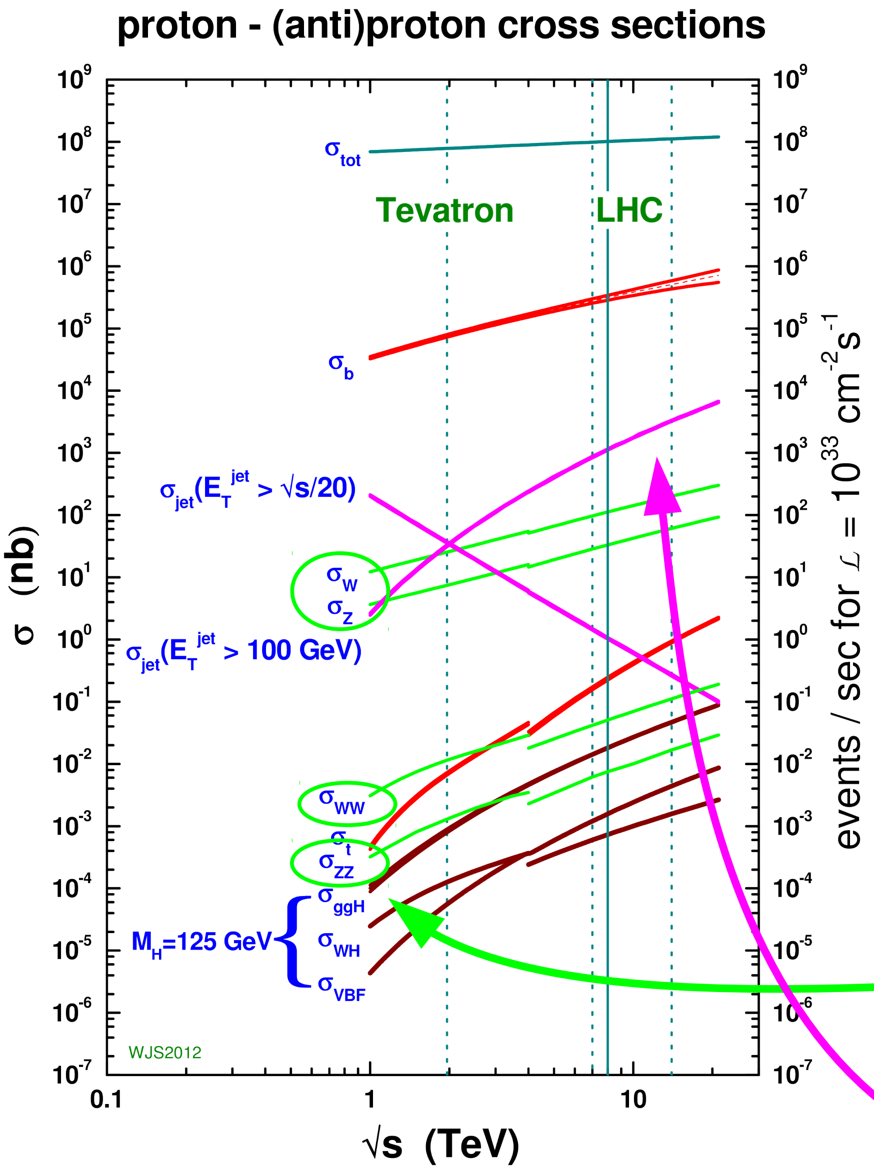
Phys. Lett. B 718 (2013) 752

- Allows to reinterpret the measurements once better PDF will be available

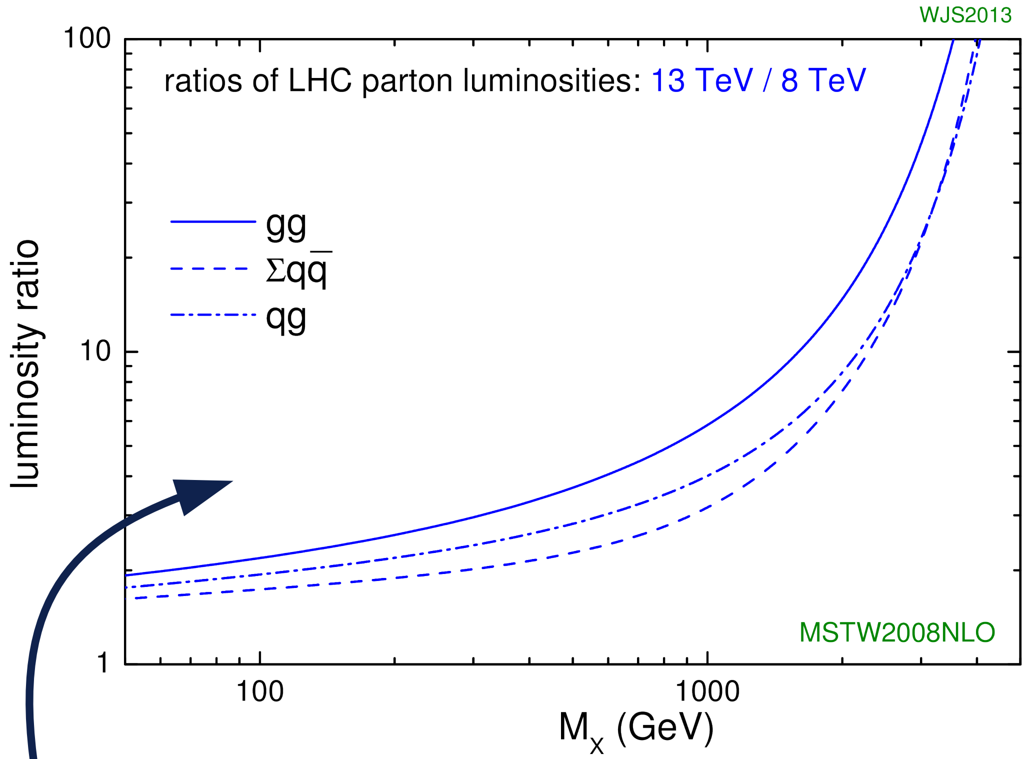
Prospects for EW measurements at the LHC

- EW in LHC Run 2
- New challenges → EW sudakov in V+jets, $t\bar{t}$, dijets
- New (perspectives on old) observables → angular coefficients A_i, extract θ_W from A_4, W/Z ratios and Γ_W
- New ideas → reconstruct W rapidity

LHC Run 2 at 13 TeV



W.J. Stirling, private communication

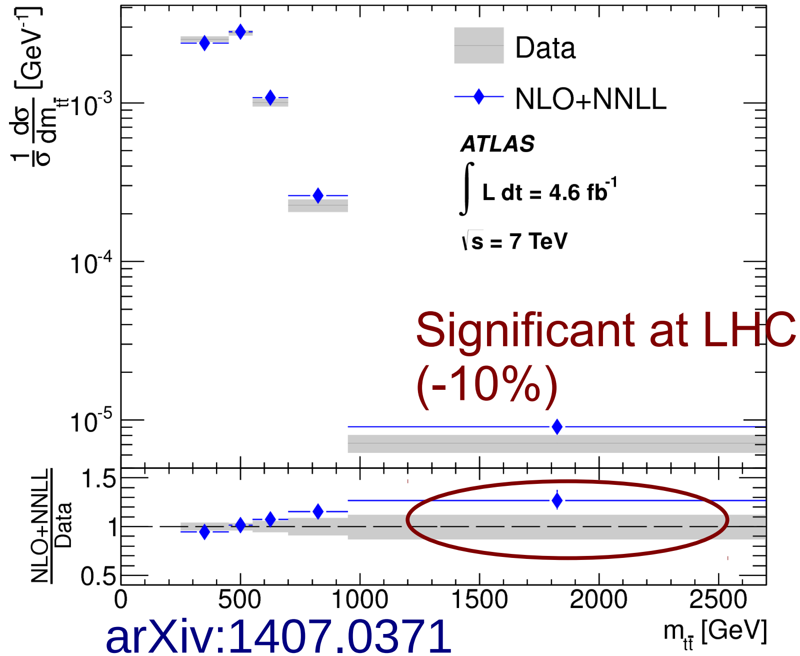


- Larger $q\bar{q}$ luminosities, but even larger gg luminosities
- Higher EW cross sections, but much higher QCD background

New challenges - Electroweak large Sudakov logs

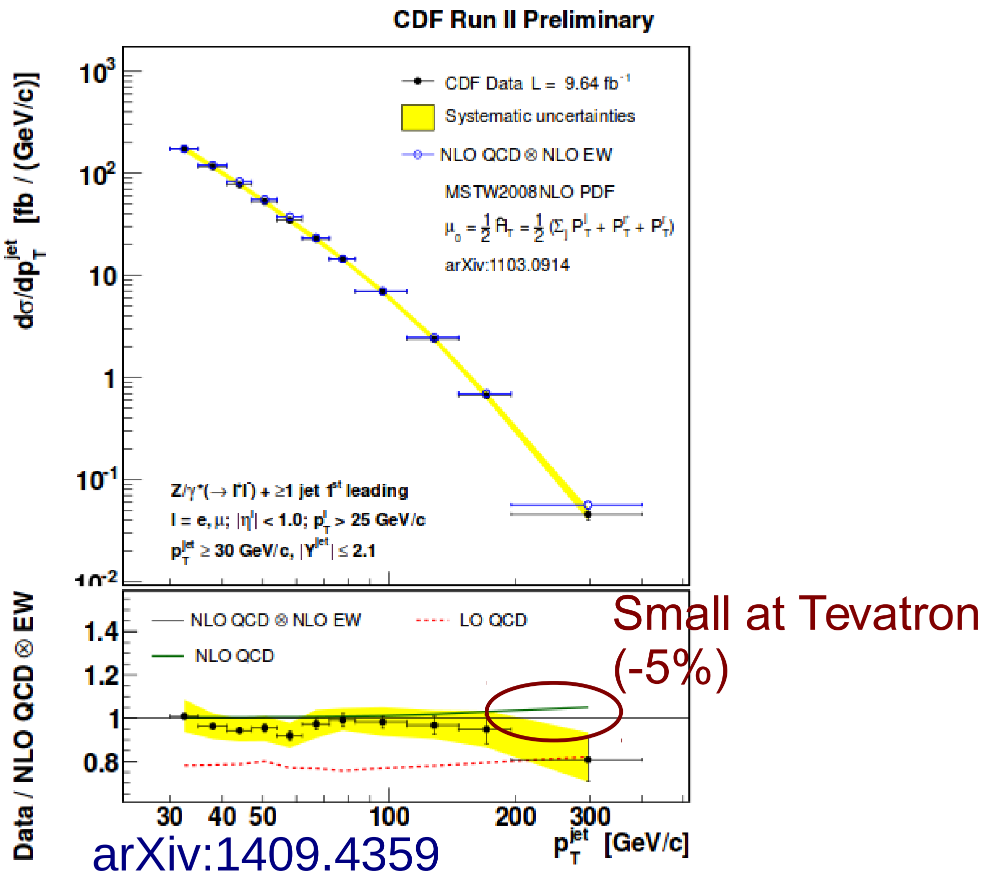
Usually negative corrections

$$\propto log^2\left(\frac{M_V^2}{Q^2}\right)$$



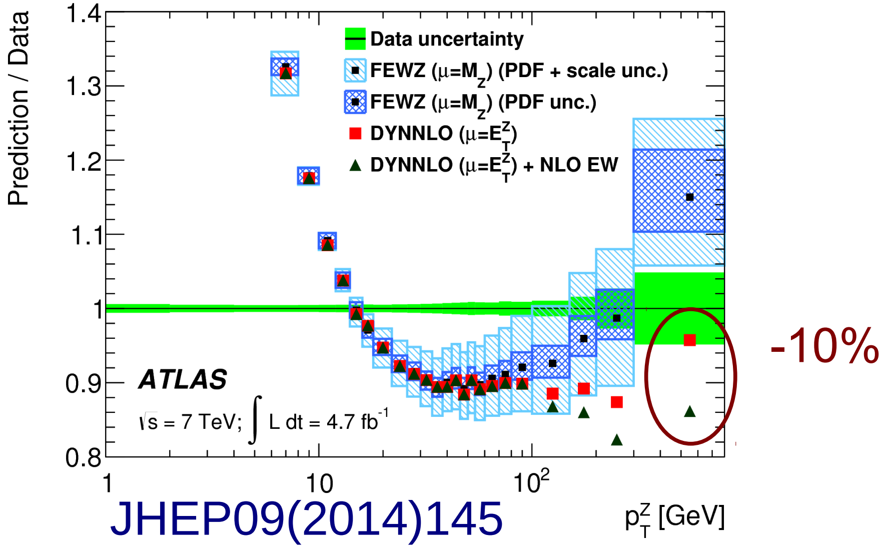
Significant at LHC (-10%)

arXiv:1407.0371



Small at Tevatron (-5%)

arXiv:1409.4359



-10%

JHEP09(2014)145

- NLO EWS corrections will become more important at higher Q^2
- Many calculations already available, need to include NLO EW corrections into MC programs and QCD predictions

W, Z polarization coefficients

- Set of 8 observables: angular coefficients A_i → ratio of helicity cross sections
- A_i are functions of the leptons kinematic $A_i(p_T^{ll}, y^{ll}, M^{ll})$
- A_i coeffiicients can be calculated form MC sample with moments method

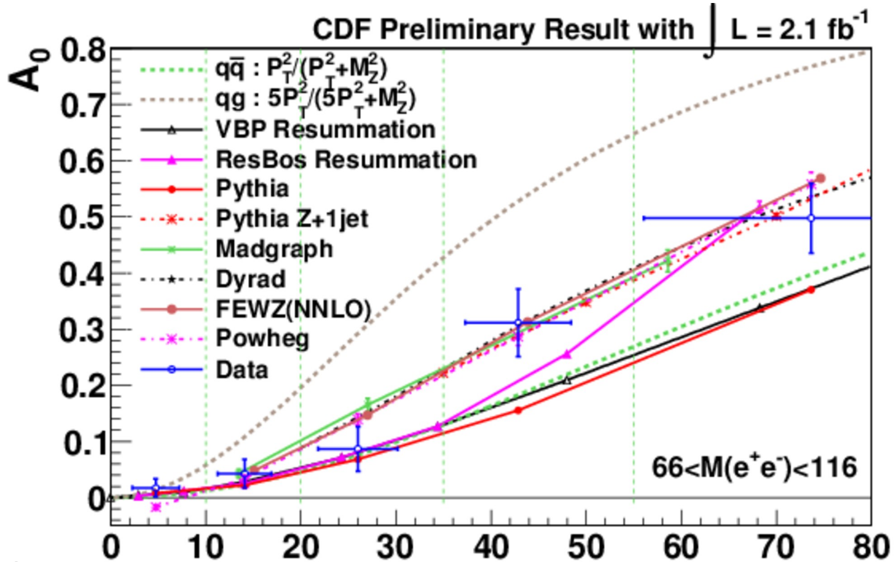
$$\langle m \rangle = \frac{\int d\sigma(p_T, y, \theta, \phi)\; m \; d\cos\theta\, d\phi}{\int d\sigma(p_T, y, \theta, \phi)\; d\cos\theta\, d\phi}$$

- A_i can be measured precisely for Z, the W measurement is more challenging
  - Related to boson polarization, V-A coupling
  - Provide insight into QCD and EW dynamics
  - Stringent test of predictions and MC generators
- A_0-A_4 coefficients measured at CDF
- Precise measurements at the LHC of A_0-A_7 can discriminate between different predictions

$$\frac{dN}{d\Omega} \propto \boxed{(1+\cos^2\vartheta)} + A_0\,\frac{1}{2}\,(1-3\cos^2\vartheta) + A_1\,\sin 2\vartheta\cos\varphi + A_2\,\frac{1}{2}\,\sin^2\vartheta\cos 2\varphi + A_3\,\sin\vartheta\cos\varphi + A_4\,\boxed{\cos\vartheta} + A_5\,\sin^2\vartheta\sin 2\varphi + A_6\,\sin 2\vartheta\sin\varphi + A_7\,\sin\vartheta\sin\varphi\,.$$

LO terms

Phys.Rev. D50 (1994) 5692
Nucl.Phys. 387 (1992) 3



Phys. Rev. Lett. 106, 241801 (2011)

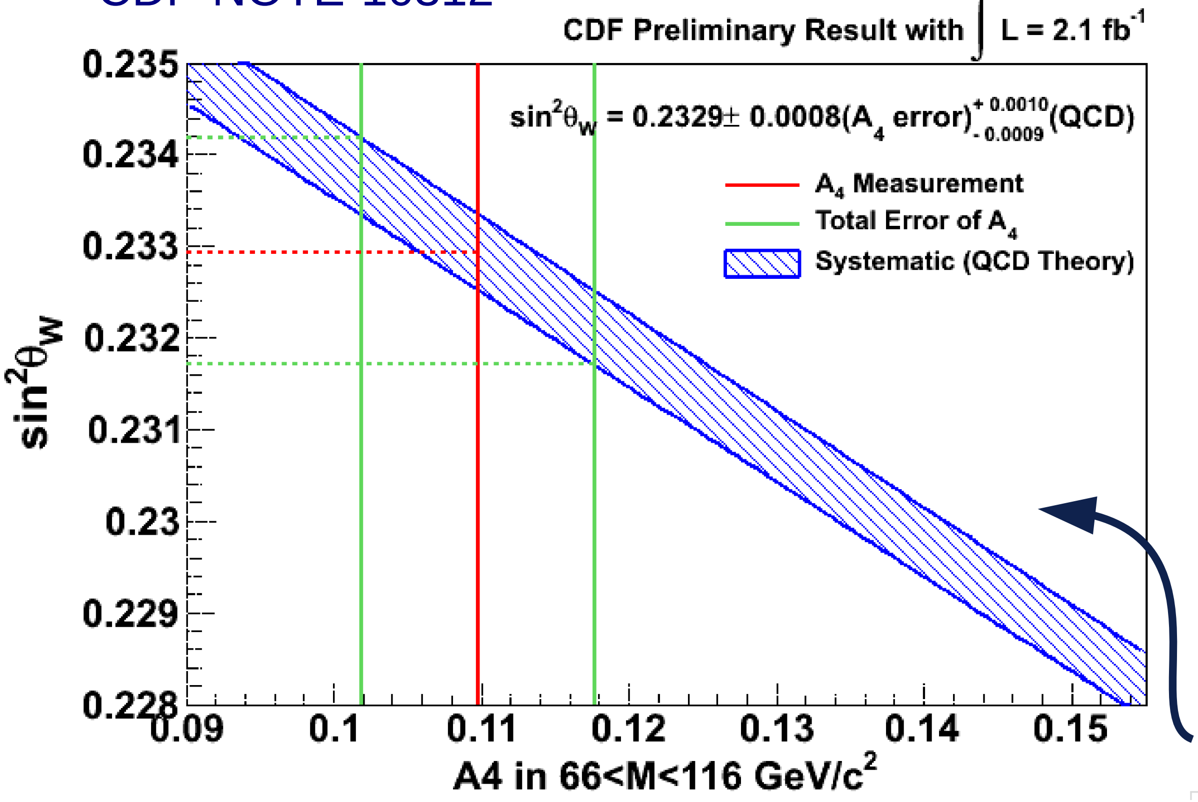
New (perspectives on old) observables

- Angular coefficient A_4 can be used to extract the weak-mixing angle θ_W

$$\frac{d\sigma}{d\cos\theta} = \frac{4\pi\alpha^2}{3s}\left[\frac{3}{8}\left(A(1+\cos^2\theta)+\boxed{B\cos\theta}\right]\right.$$

$$\begin{aligned}\frac{dN}{d\Omega} \propto\ & (1+\cos^2\vartheta) + \\ & A_0\ \frac{1}{2}\ (1-3\cos^2\vartheta) + \\ & A_1\ \sin 2\vartheta\cos\varphi + \\ & A_2\ \frac{1}{2}\ \sin^2\vartheta\cos 2\varphi + \\ & A_3\ \sin\vartheta\cos\varphi + \\ & \boxed{A_4\ \cos\vartheta} + \\ & A_5\ \sin^2\vartheta\sin 2\varphi + \\ & A_6\ \sin 2\vartheta\sin\varphi + \\ & A_7\ \sin\vartheta\sin\varphi\,.\end{aligned}$$

CDF-NOTE-10312

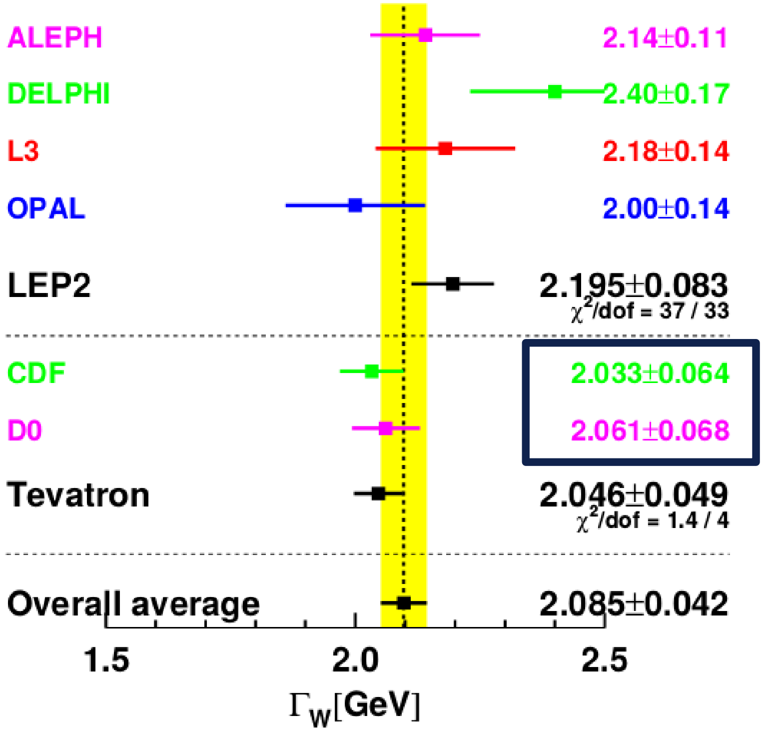


- Could be less sensitive to dilution effects
- Need good control of QCD predictions

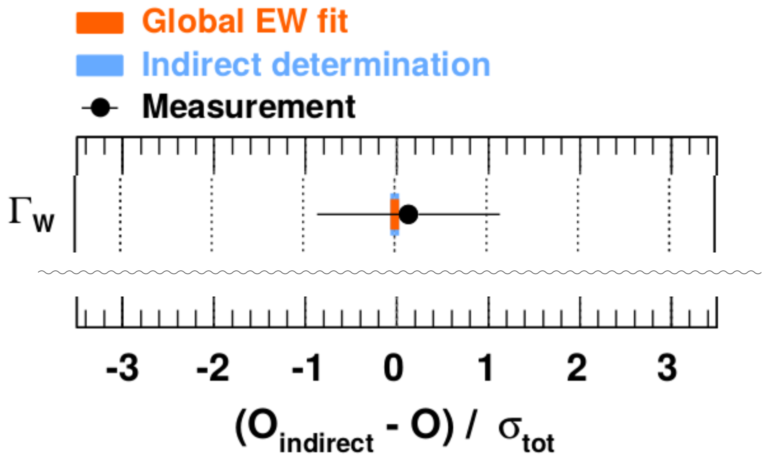
W/Z ratios and Γ_W

- Indirect determination of Γ_W is far more precise than measurement

Phys.Rev. D86 (2012) 010001

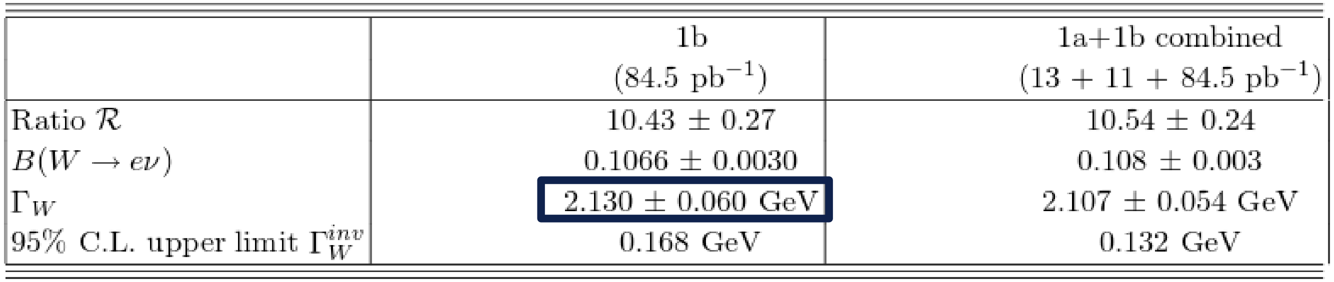


- Naive extraction: no uncertainties from PDF and from the choice of the EW scheme



- Γ_W is measured at the Tevatron from W M_T, with similar techniques as M_W

- Γ_W was extracted in Tevatron Run 1 from the W/Z ratio by D0

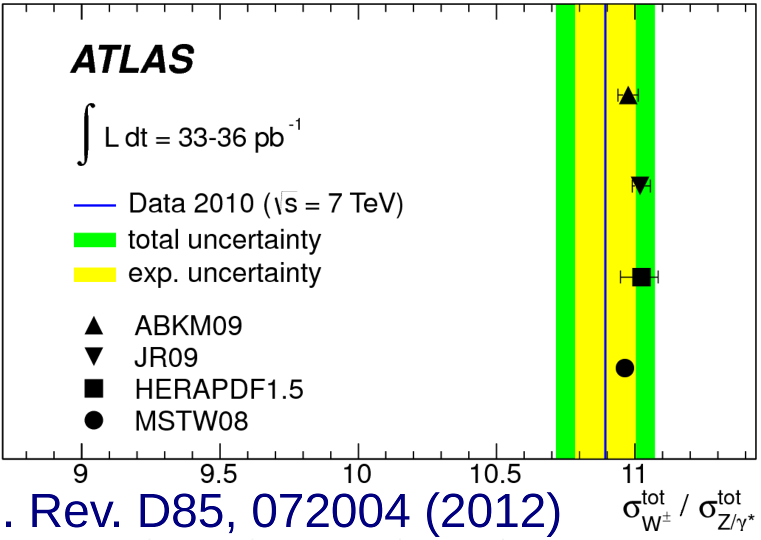


	1b (84.5 pb^{-1})	1a+1b combined (13 + 11 + 84.5 pb^{-1})
Ratio $\mathcal{R}$	10.43 ± 0.27	10.54 ± 0.24
$B(W \to e\nu)$	0.1066 ± 0.0030	0.108 ± 0.003
Γ_W	2.130 ± 0.060 GeV	2.107 ± 0.054 GeV
95% C.L. upper limit Γ_W^{inv}	0.168 GeV	0.132 GeV

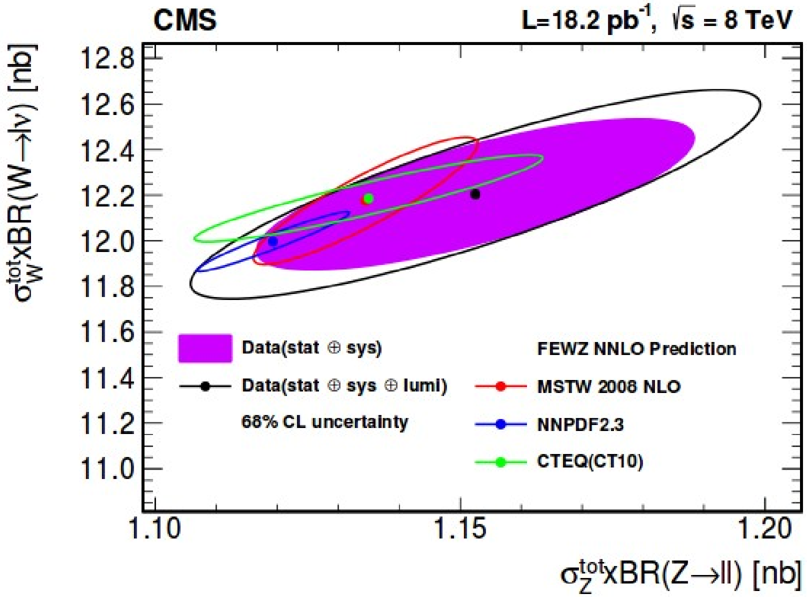
Phys.Rev.D61:072001,2000

W/Z ratios and Γ_W

- LHC experiments have measured W/Z ratios, but it is not straightforward to interpret them in terms of Γ_W
- Need to account for PDF uncertainties, and for the non trivial interplay with other EW and CKM parameters



Phys. Rev. D85, 072004 (2012)



Phys. Rev. Lett. 112 (2014) 191802

$$\mathcal{A}_W(p_{T,l}, \eta_l) = \frac{\Sigma_{W^+}(p_{T,l}, \eta_l) - \Sigma_{W^-}(p_{T,l}, \eta_l)}{\Sigma_{W^+}(p_{T,l}, \eta_l) + \Sigma_{W^-}(p_{T,l}, \eta_l)},$$

$$\mathcal{A}_Z(y_{ll}, p_{T,ll}, p_{T,l}, \eta_l) = \frac{\Sigma_{Z^+}(y_{ll}, p_{T,ll}, p_{T,l}, \eta_l) - \Sigma_{Z^-}(y_{ll}, p_{T,ll}, p_{T,l}, \eta_l)}{\Sigma_{Z^+}(y_{ll}, p_{T,ll}, p_{T,l}, \eta_l) + \Sigma_{Z^-}(y_{ll}, p_{T,ll}, p_{T,l}, \eta_l)},$$

$$\mathcal{R}_{WZ}(p_{T,l}, \eta_l) = \frac{\Sigma_{W^+}(p_{T,l}, \eta_l) + \Sigma_{W^-}(p_{T,l}, \eta_l)}{\Sigma_{Z^+}(p_{T,l}, \eta_l) + \Sigma_{Z^-}(p_{T,l}, \eta_l)}, \text{and}$$

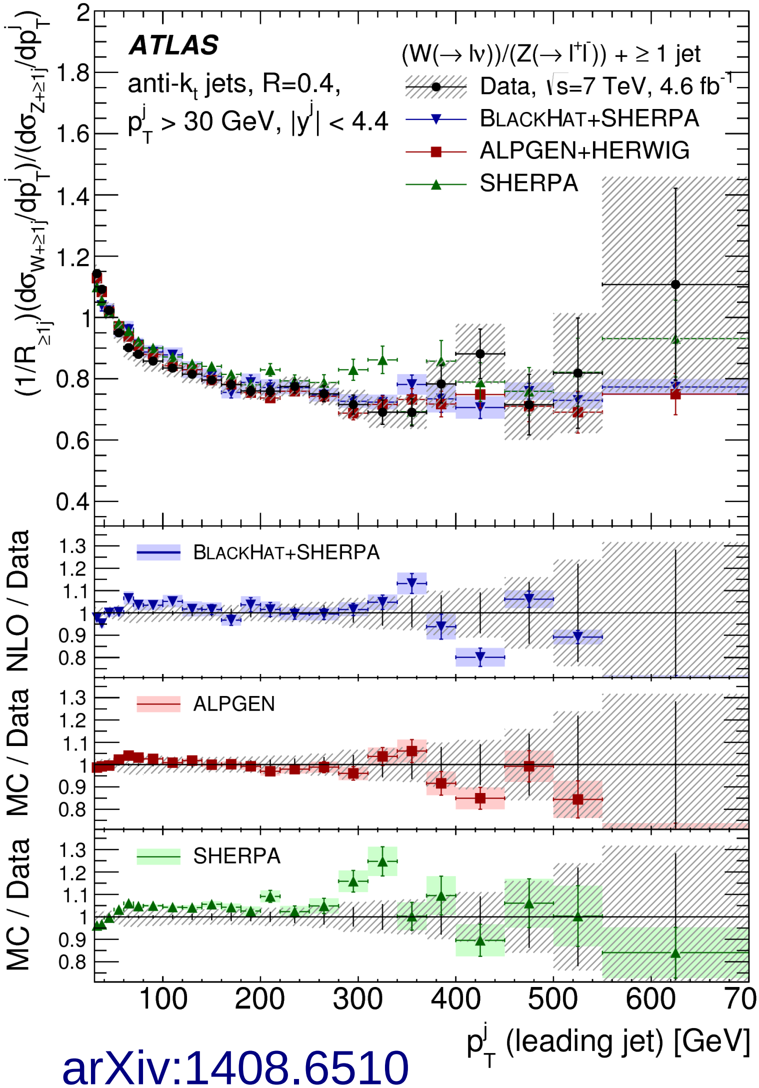
$$\mathcal{R}_Z^{\mathrm{norm}}(p_{T,ll}, y_{ll}) = \frac{\Sigma_Z(p_{T,ll}, y_{ll})}{\Sigma^{\mathrm{norm}}_{l^+l^-}},$$

- Suggested set of 4 ratio and asymmetry observables to disentangle M_W, Γ_W and PDF at the LHC

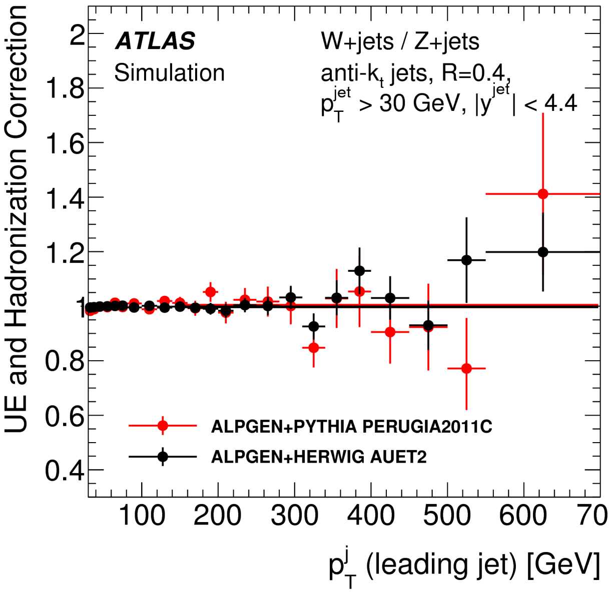
Eur.Phys.J. C69 (2010) 379-397

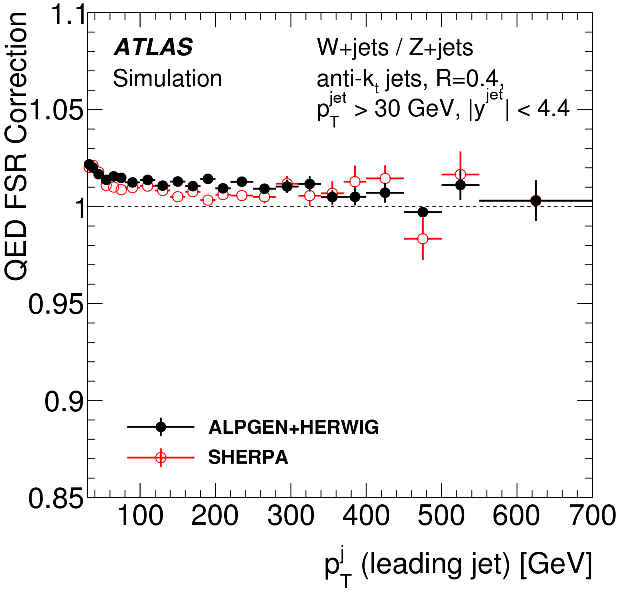
W/Z + jets ratio

- New precise observable measured at the LHC: W+jets / Z+jets ratio
- Useful for data-driven background determination
- Sensitivity to PDF and non-perturbative QCD mostly cancel out in the ratio
- Some sensitivity to QED FSR corrections



arXiv:1408.6510

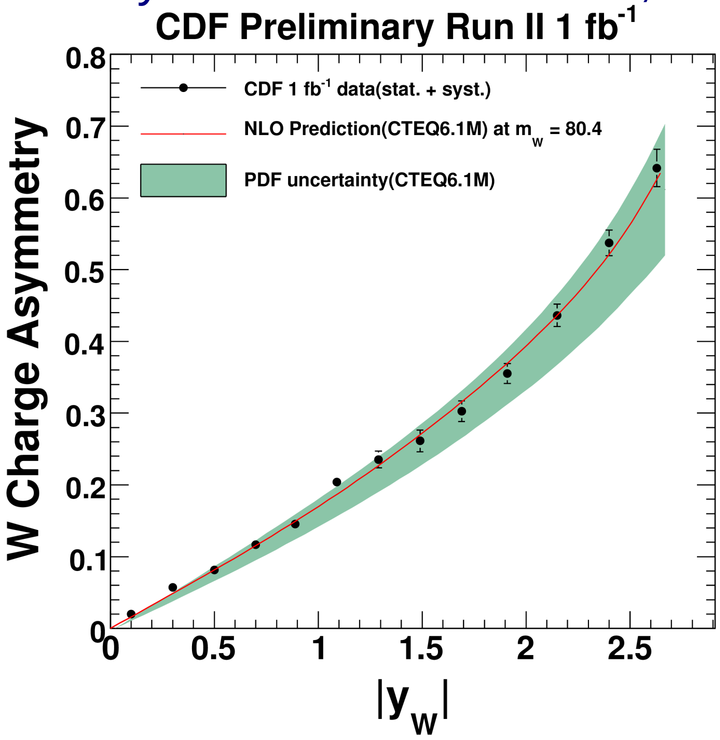




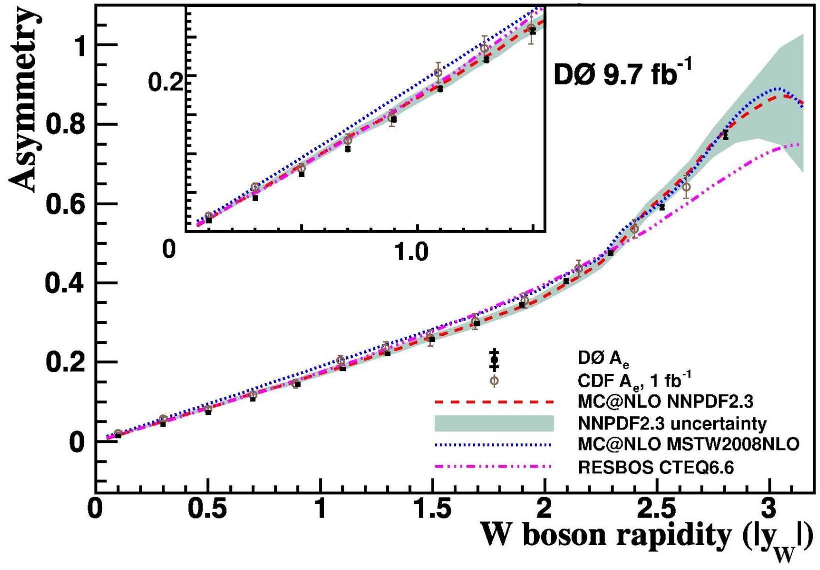
Potential sensitivity to EW physics not yet explored

Reconstruct W rapidity

Phys.Rev.Lett.102:181801,2009



Phys. Rev. Lett. 112, 151803 (2014)



- CDF and D0 have used the W mass constraint to determine the longitudinal momentum of neutrino, and reconstruct the W rapidity
- Similar and also more complex methods can be exploited to improve the precision of W measurements

- The challenge for the experiments is how to keep systematic uncertainties under control with such techniques

Summary and conclusions

- Large variety of cross sections measurements have been performed at the LHC in Run I
- EW precision measurements at the LHC are difficult, but nonetheless very important. They provide a stringent test of the SM, and an insight into BSM physics complementary to direct searches
- Electroweak physics at the LHC is an active and exciting field, Run 2 represents a challenge and a great opportunity