W+Z Physics with ATLAS and CMS

DRAFT1.1-20.9.11
The talk has 20+5min and there are further LHC talks too/before.
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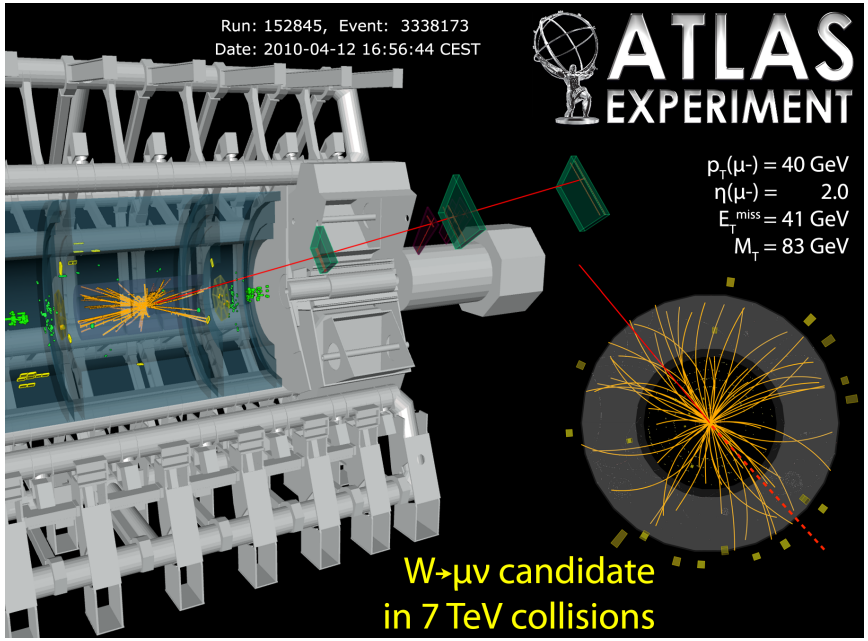
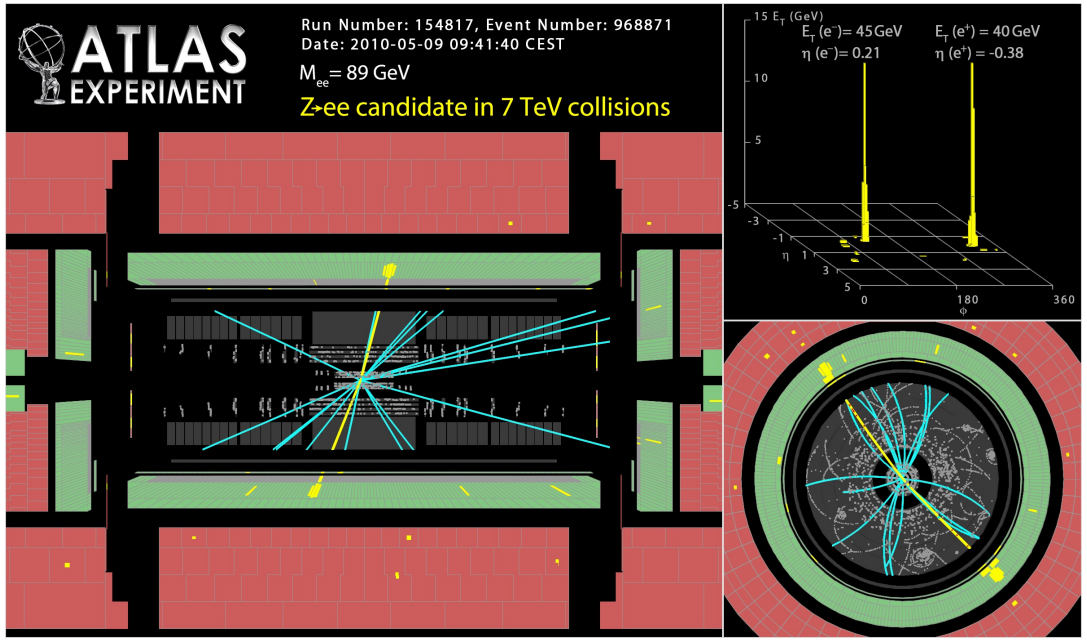
For the ATLAS and CMS Collaborations

International Symposium on Multiparticle Dynamics, ISMD11, Hiroshima, Japan, 26.9.2011

W and Z events in ATLAS

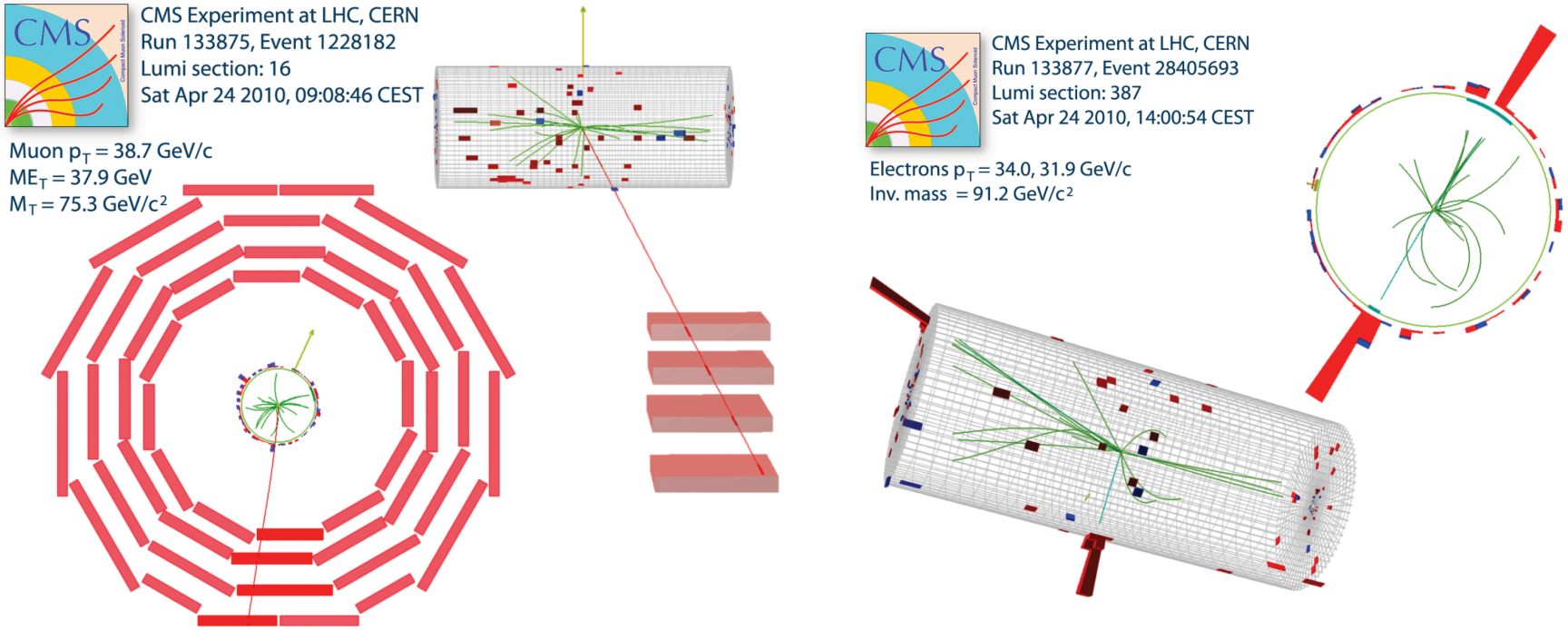




Clear signature, copious: about 1M $W^{\pm}$ and 100k Z in e+μ per 1fb^{-1} luminosity

$p_T^l > 20$ GeV, $p_T^\nu > 25$ GeV, $m_T > 40$ GeV $p_T^l > 20$ GeV, $66 < M_{ll} < 116$ GeV $|\eta_l| < 2.5$ ($|\eta_e| < 4.9$)

W and Z events in CMS



Clear signature and as copious as in ATLAS..

$p_T^l > 25$ GeV, $p_T^\nu > 25$ GeV, $|\eta_l| < 2.1$, $m_T > 40$ GeV $p_T^l > 25$ GeV, $60 < M_{ll} < 120$ GeV, $|\eta_l| < 2.1$

why W+Z with the LHC?

ATLAS-CONF-2011-011

Old "folklore"

$$\mathcal{L} = \frac{\mu_{vis} n_b f_r}{\sigma_{vis}} \qquad \mathcal{L} = \frac{n_b f_r n_1 n_2}{2\pi \Sigma_x \Sigma_y} \qquad \sigma_{vis} = \mu_{vis}^{MAX} \frac{2\pi \Sigma_x \Sigma_y}{n_1 n_2}$$

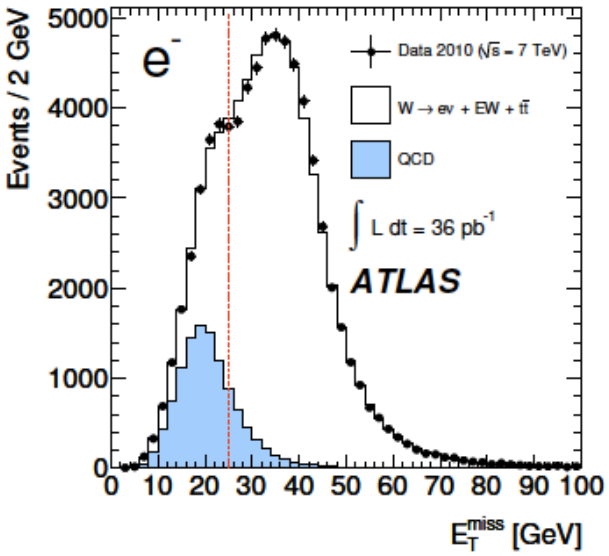
1. Monitor the Luminosity

Beam separation scan (accurate to ATLAS 3.4%, CMS 4.0% in 2010)

2. Understand Detector: Calibration, alignment, MET:

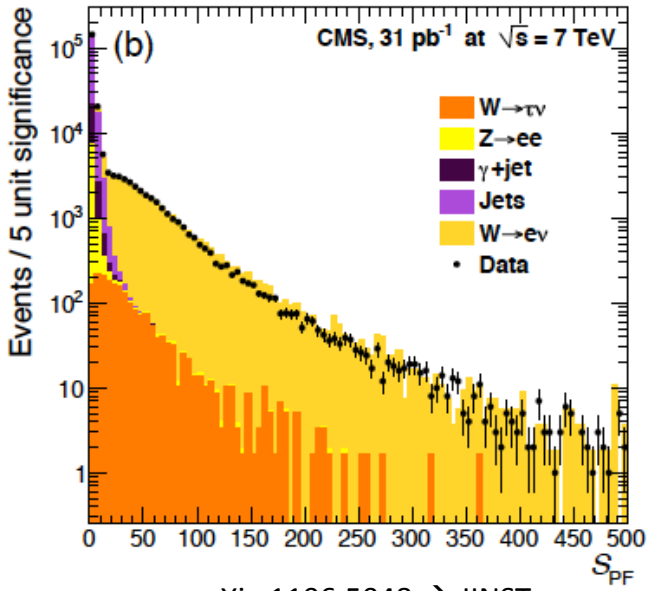
Uncertainty Source	$\delta\mathcal{L}/\mathcal{L}$
Statistical	$< 0.1\%$
Bunch charge product	3.1%
Beam centering	0.1%
Emittance growth and other non-reproducibility	0.4%
Beam position jitter	0.2%
Length scale calibration	0.3%
Absolute ID length scale	0.3%
Fit model	0.2%
Transverse correlations	0.9%
μ dependence	0.6%
Long-term consistency	0.5%
Total	3.4%

from new ATLAS WZ paper:



arXiv:1109:xxxx → PRD

from recent CMS MET paper:



arXiv:1106:5048 → JINST

why W+Z with the LHC?

Present Reasons

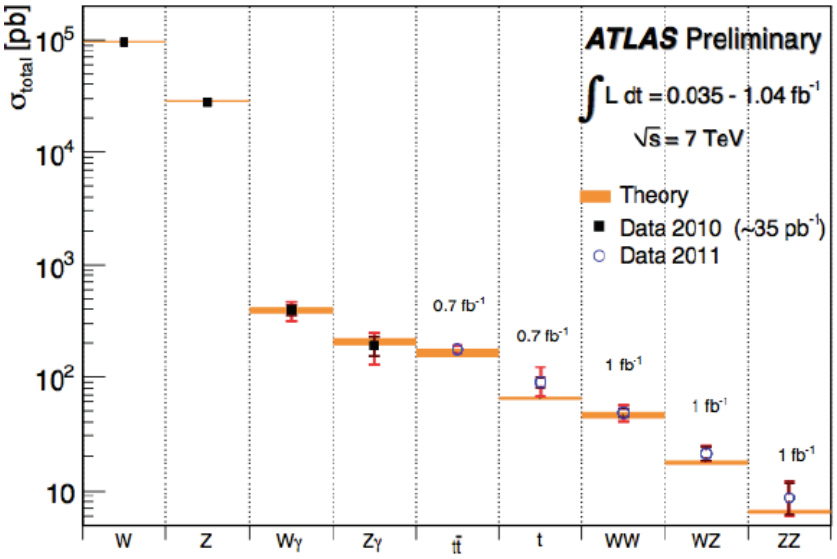
1. Constrain Parton Densities [dσ/dy,η,WZ+c,b]
2. Explore QCD in new kinematic domain [p_T(W,Z), WZ+jets]
3. Perform precision electroweak measurements [Pol_W,$\sin^2\Theta$,TGC]
4. H → WW and H→ ZZ→ 4l and H → ττ as Z → ττ

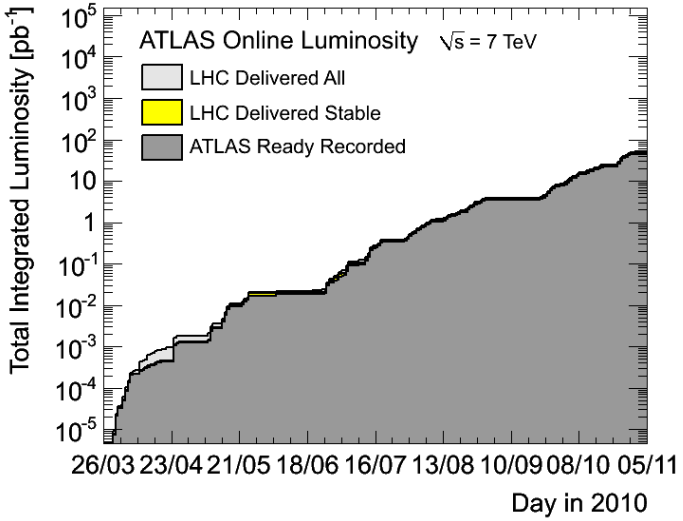
Here: focus on new high precision inclusive WZ cross section data and present first results on W+c,b and $p_T^{Z,W}$

- W,Z + jets: S.Shimizu (ATLAS), A.Hinzmann (CMS)
- With high statistics, genuine electroweak measurements will become more precise
- Higgs: C.Bini (ATLAS), G.Schott (CMS)
- τ Physics: S.Dhaliwal (ATLAS)

WZ Cross Sections with ATLAS and CMS

Total cross sections





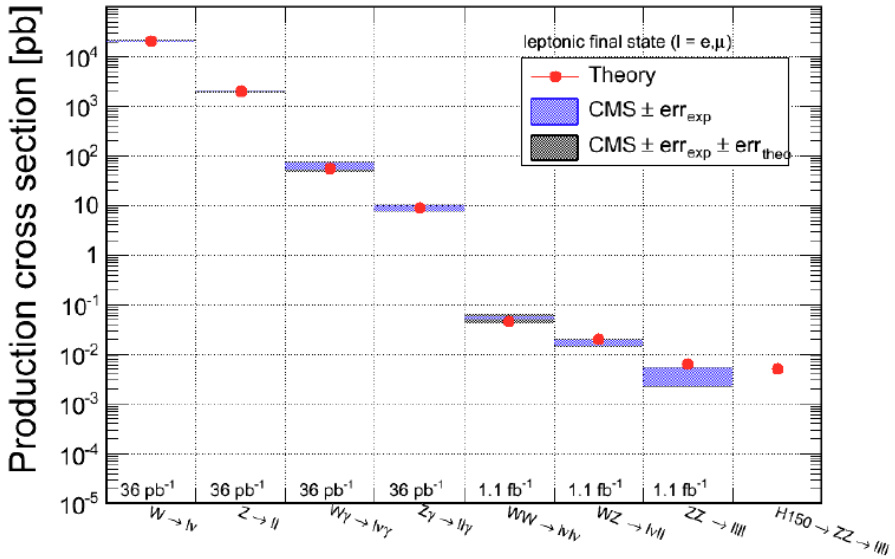
2010

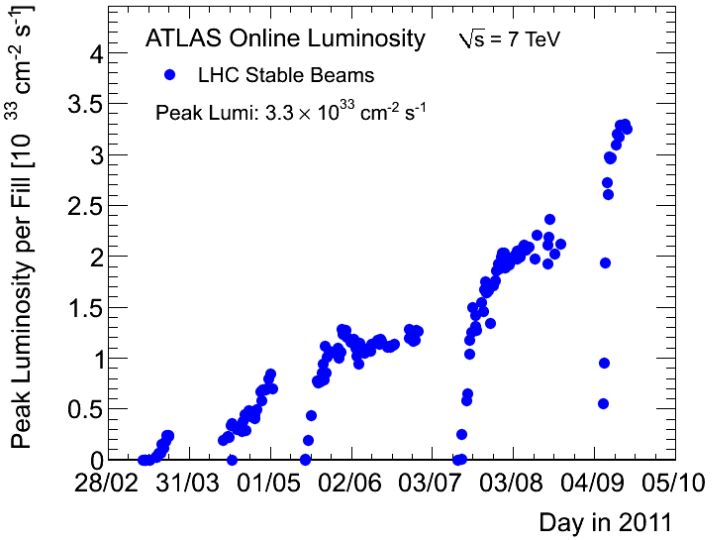
→Current publications

differential W,Z cross sections

35pb^{-1}: 270k W$^{\pm}$ 24k Z (in e+μ decay channels)

Total cross sections * Branching fracctions





2011

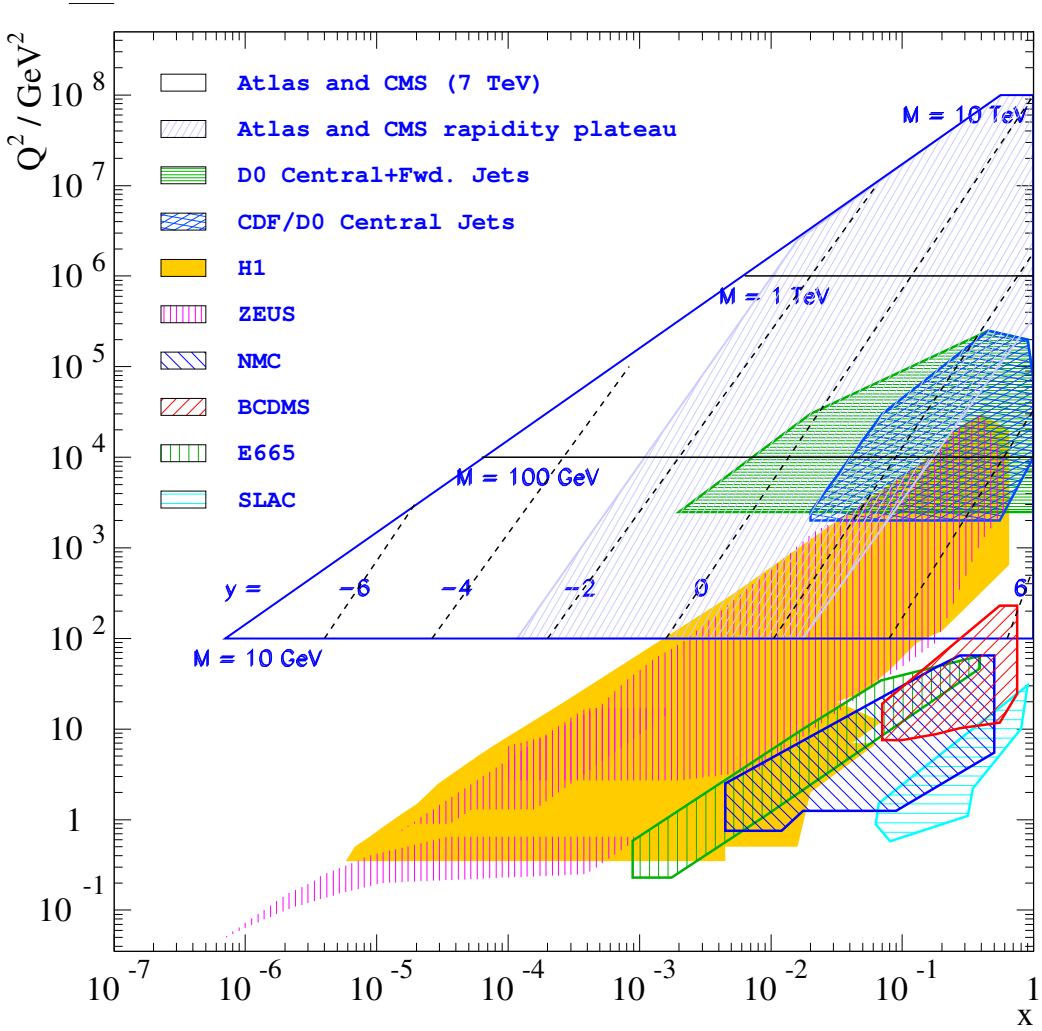
2d-differential W,Z cross sections

Precise associate cross sections

Note HUGE L_{peak}

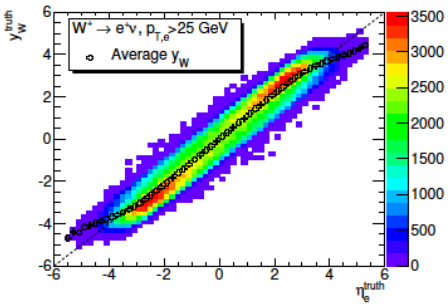
So far ATLAS and CMS collected 3.1 fb^{-1} each

Drell-Yan and Deep Inelastic Scattering



$$Q^2 = M^2$$

$$x_{1,2} = \frac{M}{2E_p} e^{\pm y}$$



for W use pseudo rapidity

$$\frac{d^2\sigma}{dMdy} = \frac{4\pi\alpha^2(M)}{9} \cdot 2M \cdot P(M) \cdot \Phi(x_1, x_2, M^2)$$

P:propagator

Z (NC) channel $\Phi_Z = \sum_q (v_q^2 + a_q^2) F_{q\bar{q}}$

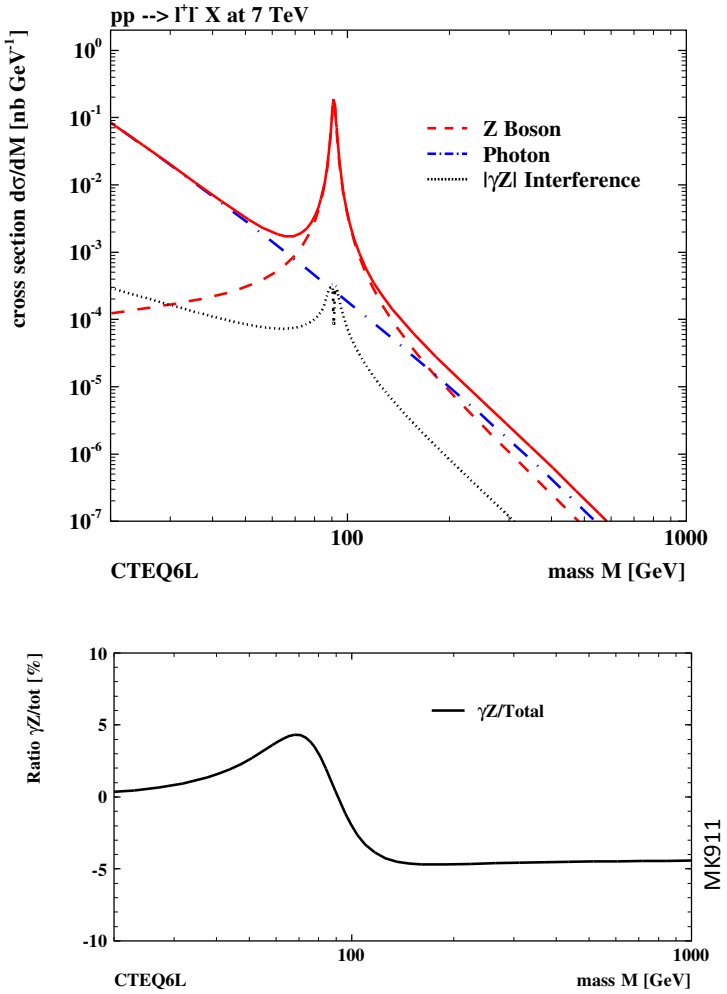
$$F_{q\bar{q}} = x_1 x_2 \cdot [q(x_1, M^2)\bar{q}(x_2, M^2) + \bar{q}(x_1, M^2) q(x_2, M^2)]$$

W$^{\pm}$ (CC) channel

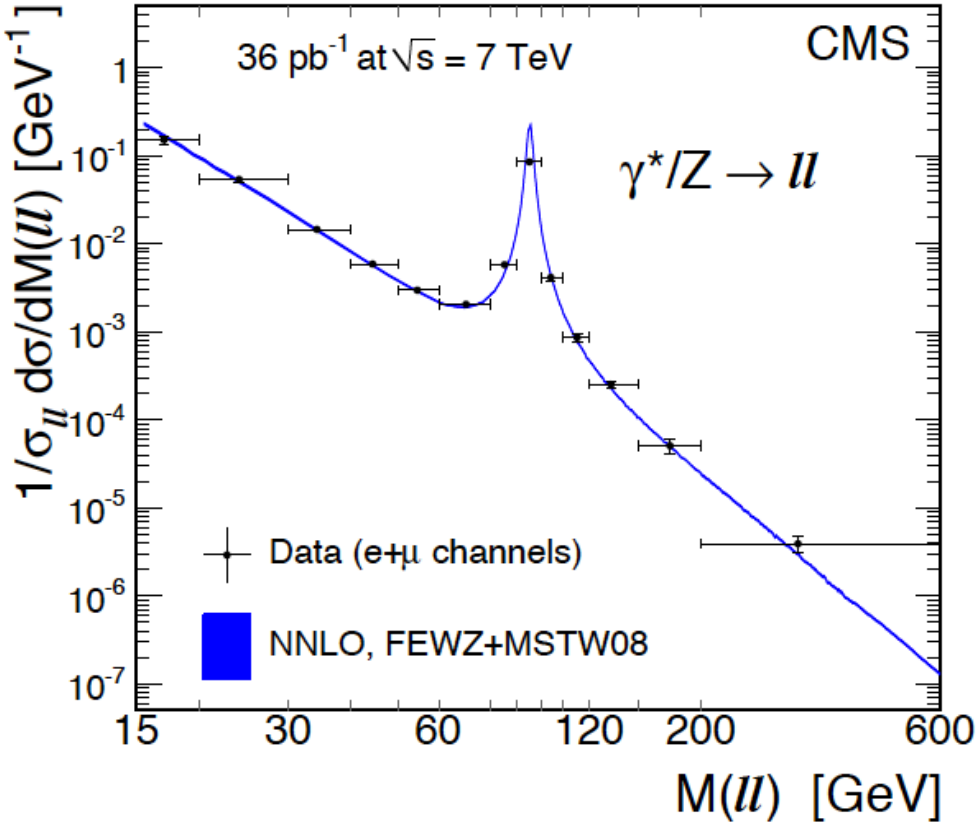
$$\Phi_{W^+} = x_1 x_2 [U_{ud}^2(u_1\bar{d}_2 + u_2\bar{d}_1) + U_{cs}^2(c_1\bar{s}_2 + c_2\bar{s}_1) + U_{us}^2(u_1\bar{s}_2 + u_2\bar{s}_1) + U_{cd}^2(c_1\bar{d}_2 + c_2\bar{d}_1)]$$
$$\Phi_{W^-} = x_1 x_2 [U_{ud}^2(\bar{u}_1 d_2 + \bar{u}_2 d_1) + U_{cs}^2(\bar{c}_1 s_2 + \bar{c}_2 s_1) + U_{us}^2(\bar{u}_1 s_2 + \bar{u}_2 s_1) + U_{cd}^2(\bar{c}_1 d_2 + \bar{c}_2 d_1)],$$

New constraints to PDFs
low mass to access low x

Drell-Yan Spectrum in Neutral Currents



Low and high mass dominated by Z production
γZ interference +- 5% left and right from Z peak



CMS: arXiv:1108.0566 (August 2011)

Normalised DY spectrum measured with 2010 data to 6% (~20GeV), 3% (Z peak) and 20% at highest M

$M_{Z'}$ > 2.xx TeV (ATLAS), 2.yy TeV (CMS)

Total W+Z Cross Sections in l=e,μ Decay Mode

ATLAS

	$\sigma_W^{\text{tot}} \cdot \text{BR}(W \to \ell\nu)$ [nb]			
	sta	sys	lum	acc
W^+	$6.048 \pm 0.016 \pm 0.072 \pm 0.206 \pm 0.096$			
W^-	$4.160 \pm 0.014 \pm 0.057 \pm 0.141 \pm 0.083$			
$W^\pm$	$10.207 \pm 0.021 \pm 0.121 \pm 0.347 \pm 0.164$			
	$\sigma_{Z/\gamma^*}^{\text{tot}} \cdot \text{BR}(Z/\gamma^* \to \ell\ell)$ [nb] $66 < m_{\ell\ell} < 116$ GeV			
	sta	sys	lum	acc
Z/γ^*	$0.937 \pm 0.006 \pm 0.009 \pm 0.032 \pm 0.016$			

66<M<116 GeV

arXiv:1109:xxxx → PRD

$6.04 \pm 0.02\,(\text{stat.}) \pm 0.06\,(\text{syst.}) \pm 0.08\,(\text{th}) \pm 0.24\,(\text{lumi.})$

$4.26 \pm 0.01\,(\text{stat.}) \pm 0.04\,(\text{syst.}) \pm 0.07\,(\text{th}) \pm 0.17\,(\text{lumi.})$

$10.30 \pm 0.02\,(\text{stat.}) \pm 0.10\,(\text{syst.}) \pm 0.10\,(\text{th}) \pm 0.41\,(\text{lumi.})$

CMS

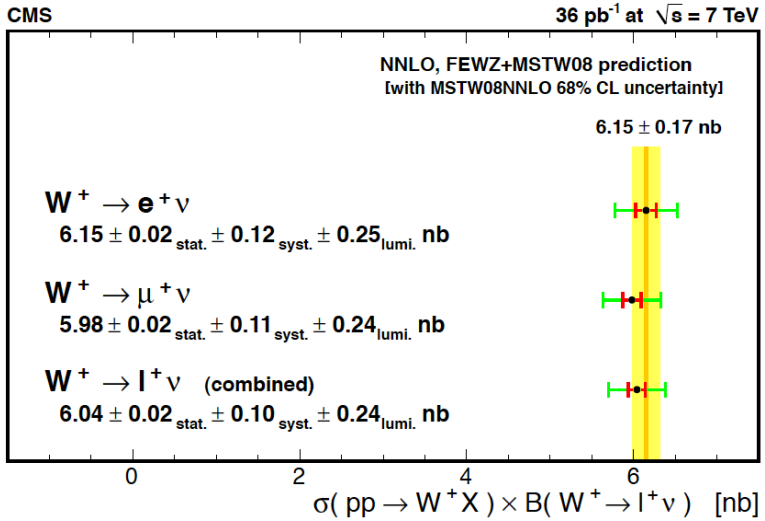
$0.974 \pm 0.007\,(\text{stat.}) \pm 0.007\,(\text{syst.}) \pm 0.018\,(\text{th}) \pm 0.039\,(\text{lumi.})$

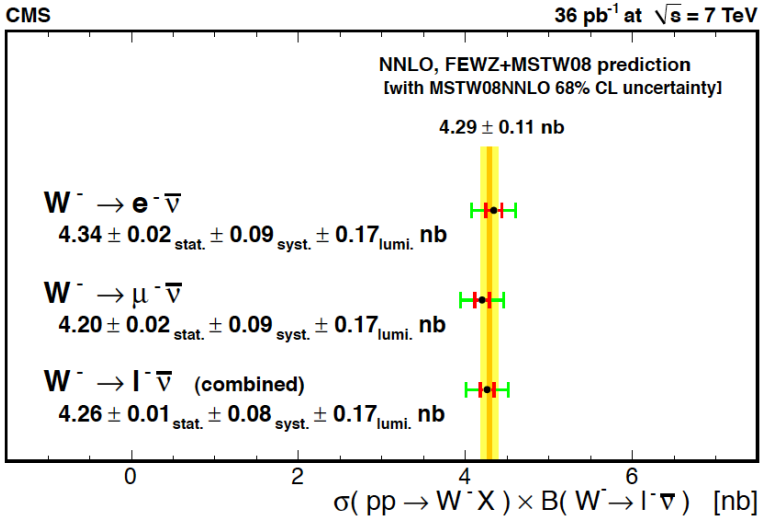
60<M<120 GeV

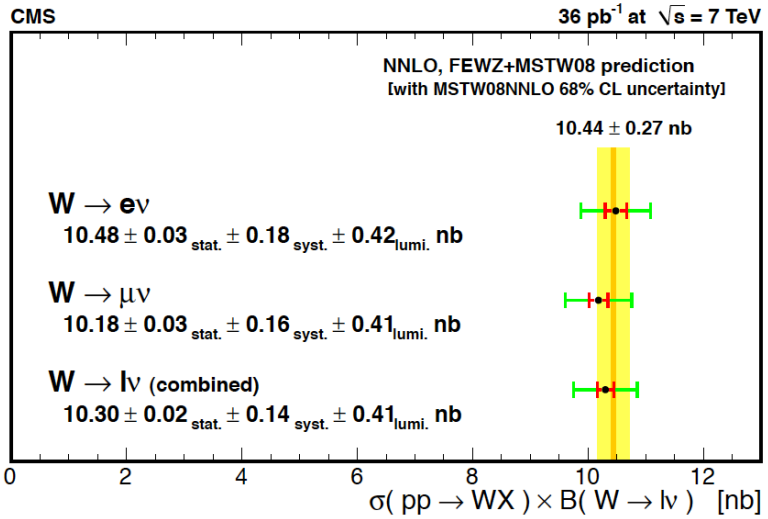
arXiv:1107:4789 → JHEP

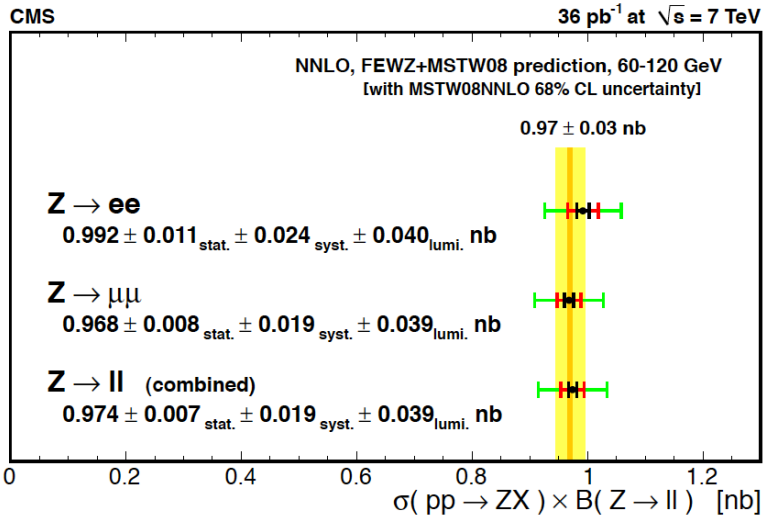
Electron and muon, ATLAS and CMS data are consistent.
Cross sections measured to 1% systematic uncertainty.
Acceptance uncertainty (1-2%) due to extrapolation to full phase space.

Total WZ Cross Sections vs NNLO Thy - CMS



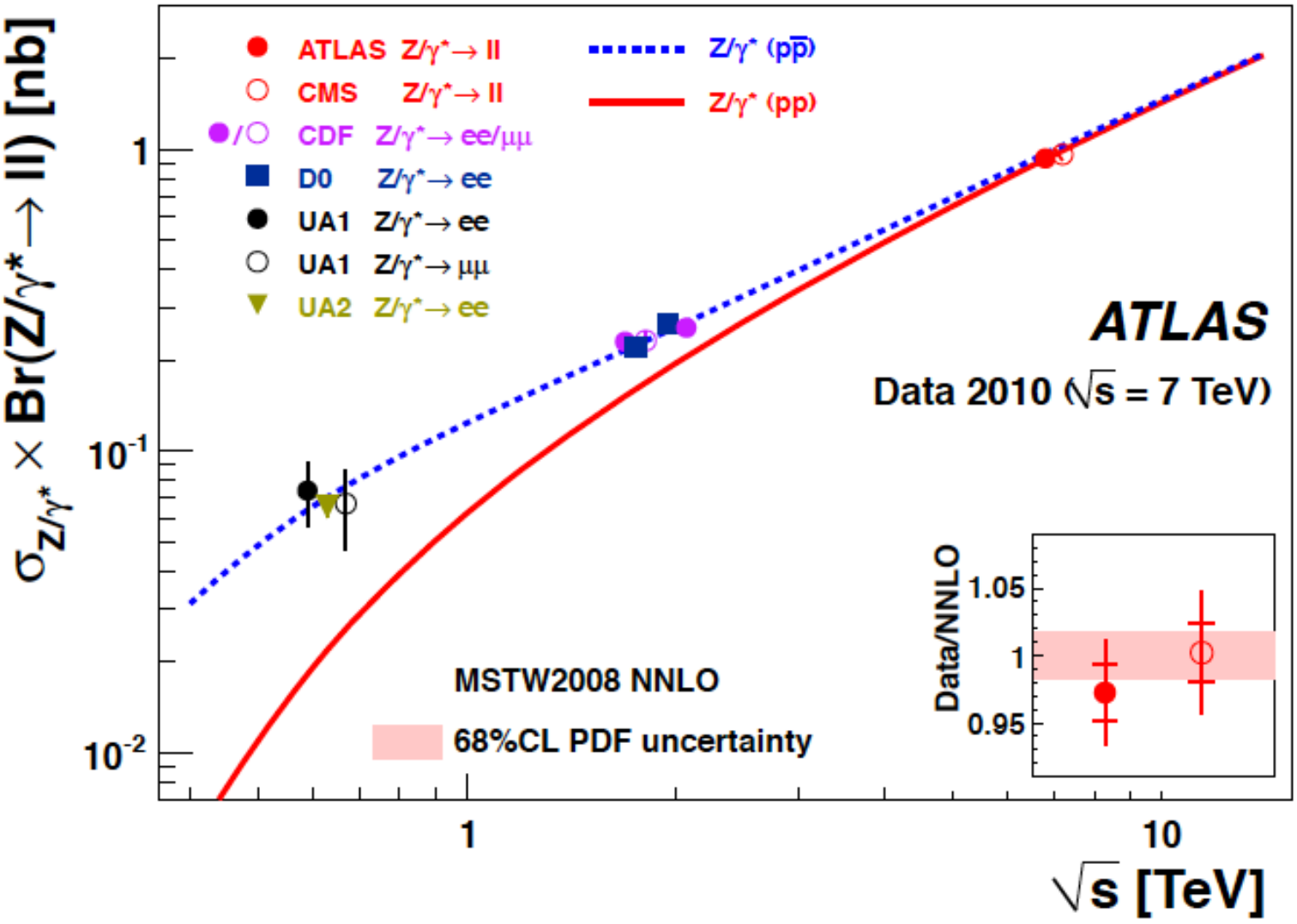




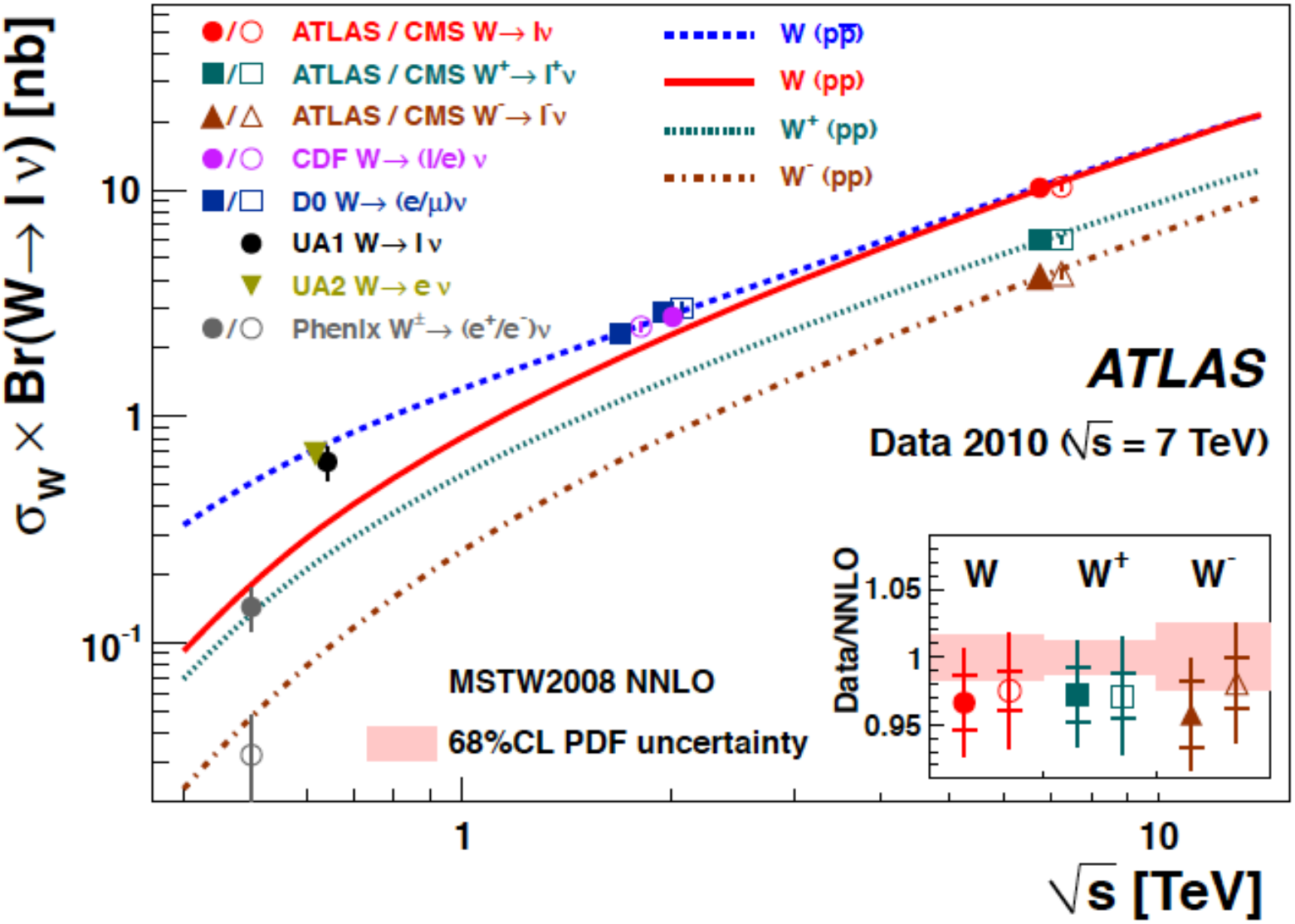


Good agreement with NNLO (FEWZ+MWST08). Exp uncertainty dominated by Luminosity

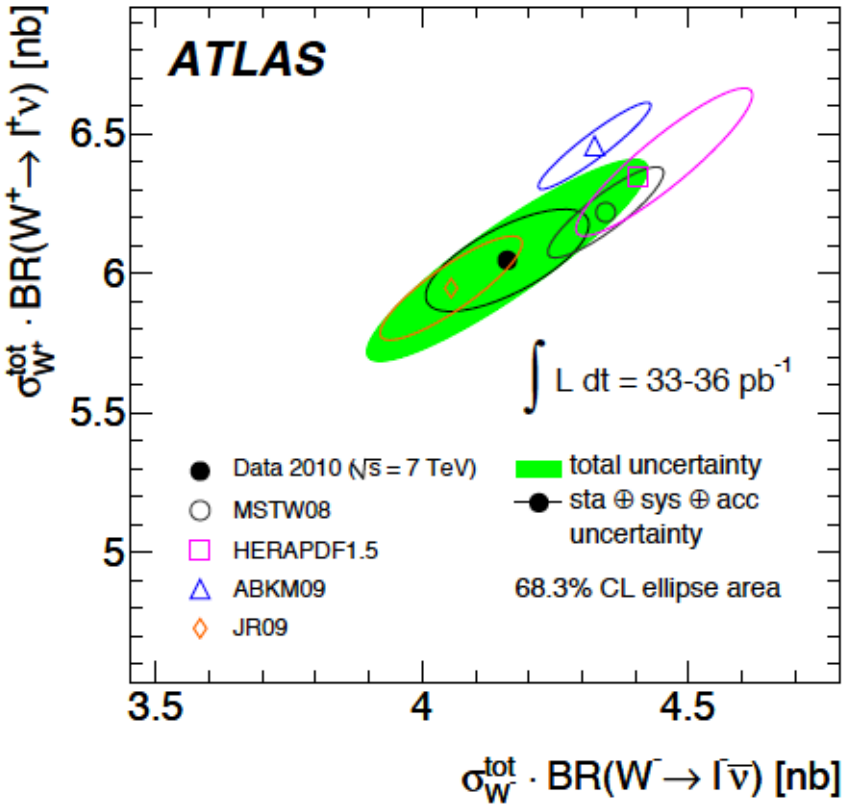
Total Z→ll Cross Sections vs √s=2E$_p$

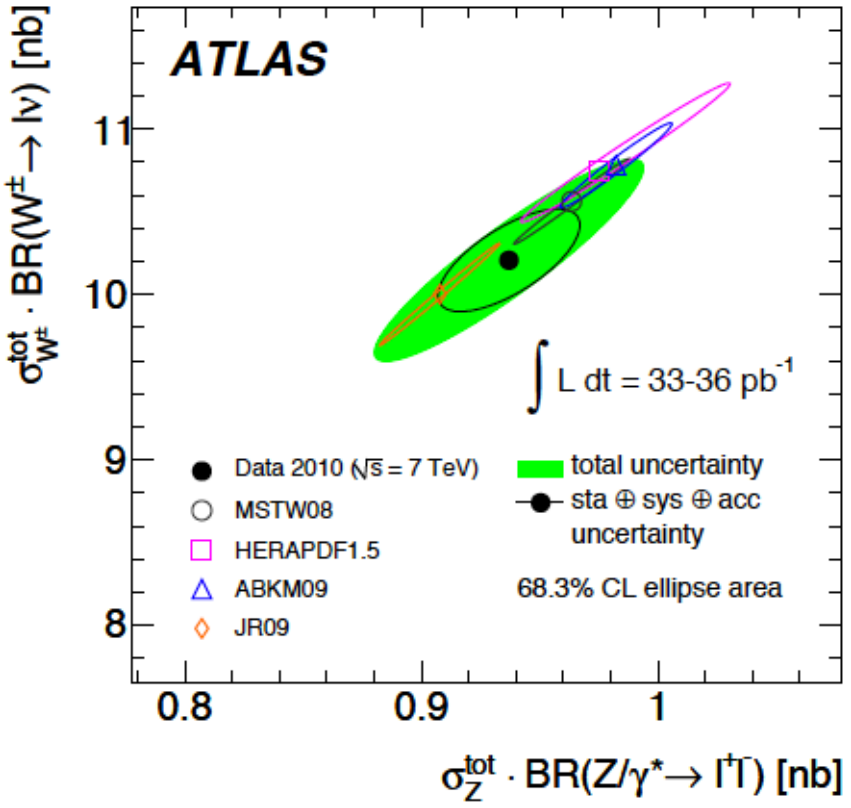


Total W→lν Cross Sections vs √s=2E$_p$



Total W-Z Cross Sections



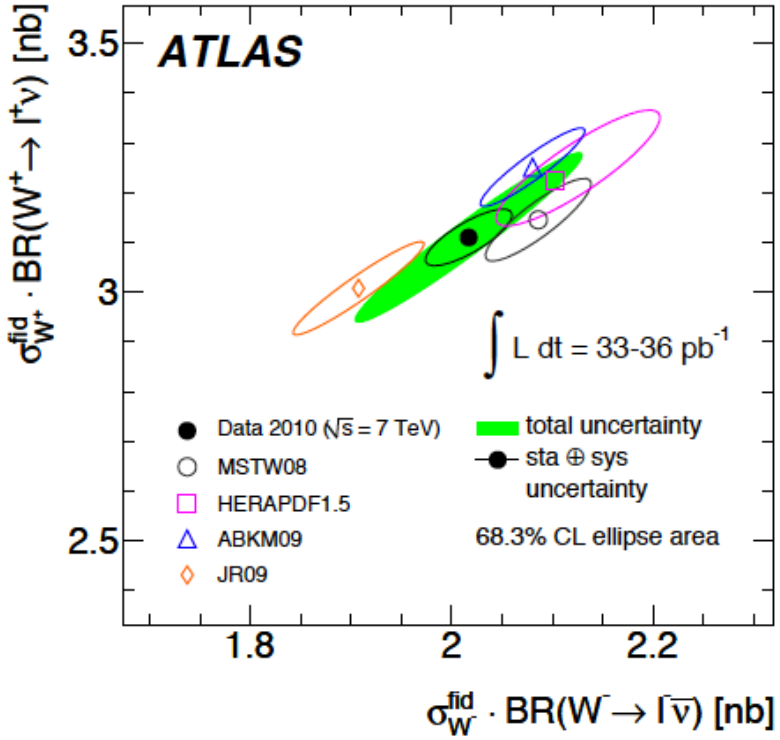


Experimental correlation of cross sections dominated by luminosity.
Theoretical correlations dominated by PDF correlations,
e.g. W/Z for symmetric sea is about constant → very slim ellipses

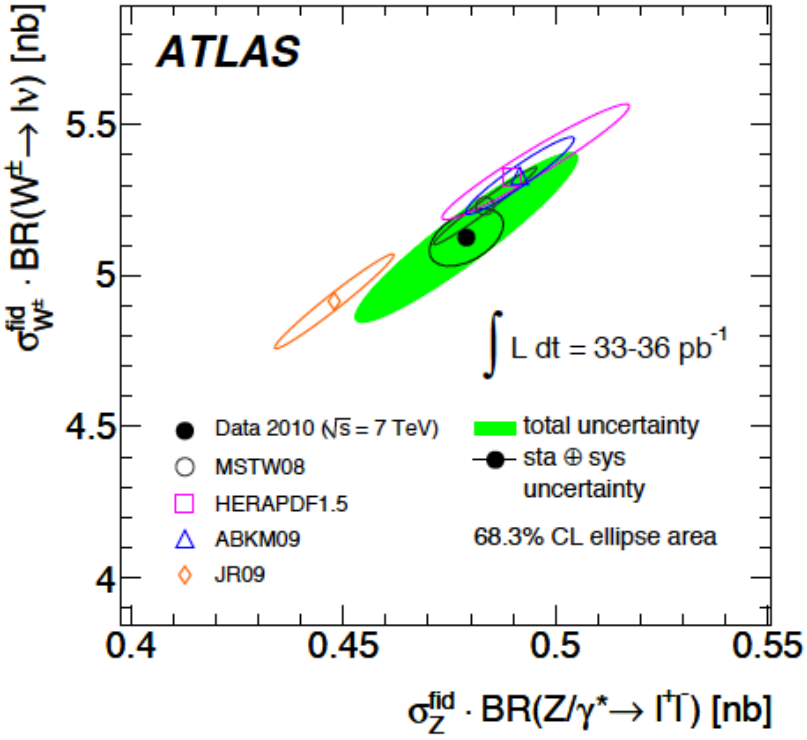
arXiv:1109:xxxx → PRD

Integrated W-Z Cross Sections (in fiducial regions)

$|\eta_\ell| < 2.5$, $p_{T,\ell} > 20$ GeV,
$p_{T,\nu} > 25$ GeV and $m_T > 40$ GeV



$|\eta_\ell| < 2.5$, $p_{T,\ell} > 20$ GeV
and $66 < m_{\ell\ell} < 116$ GeV

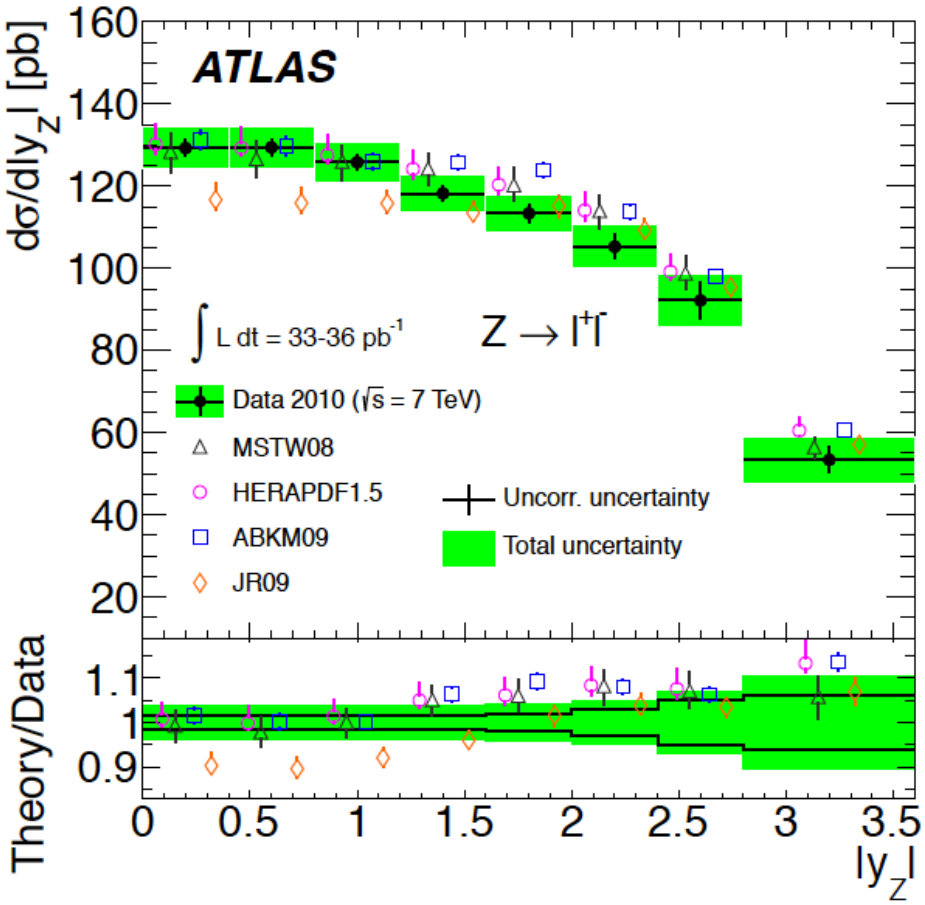


Measurement uncertainty reduced as acc (thy) error becomes negligible. Theory errors taken as 68% for ellipse. PDF uncertainties only, which are defined differently by fit groups. Comparison to NNLO required (and possible with FEWZ and DYNNLO used) to reduce scale uncertainty effect.

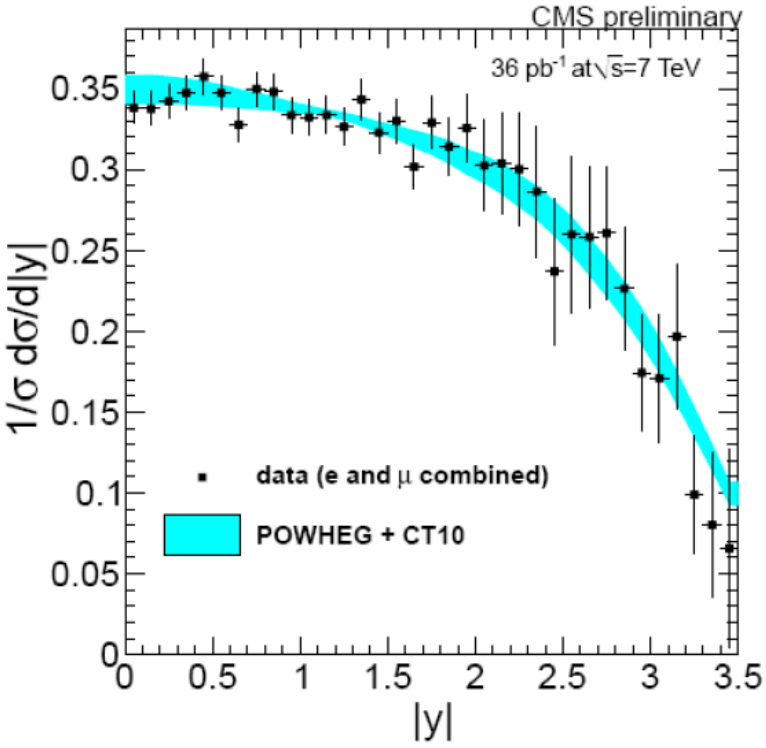
arXiv:1109:xxxx → PRD

Cf also recent NNPDF NNLO paper (August11)

Differential Z Cross Section



Absolute differential cross section measurement
Experimental precision 2-6% plus 3.4% for L
Compared to NNLO in fiducial region. JR09 low at central rapidity. Visible sensitivity to PDF's

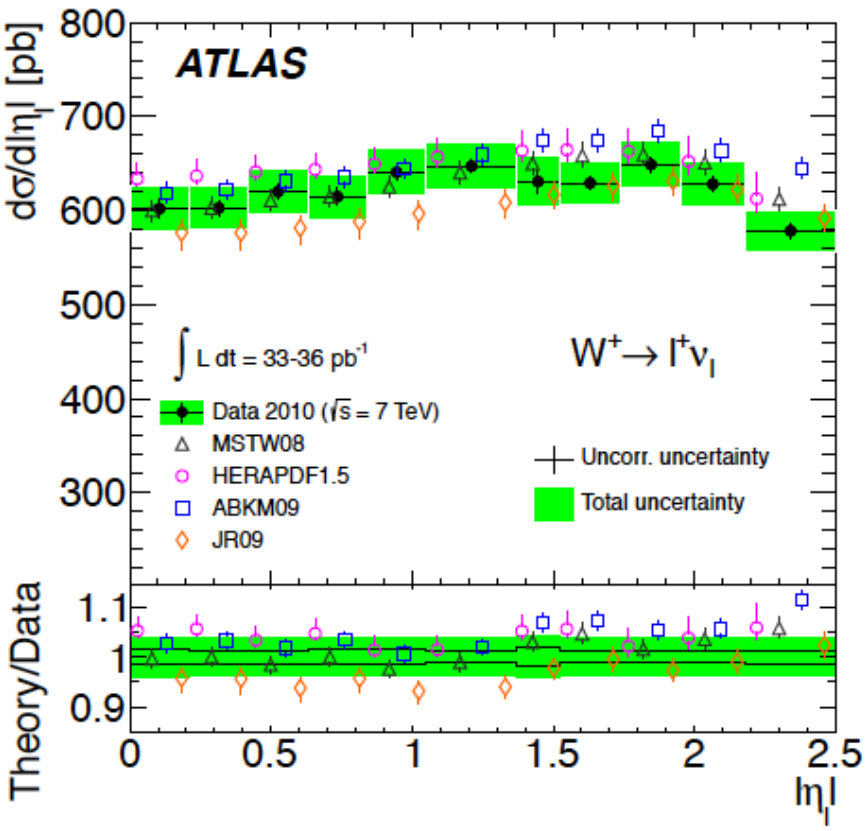


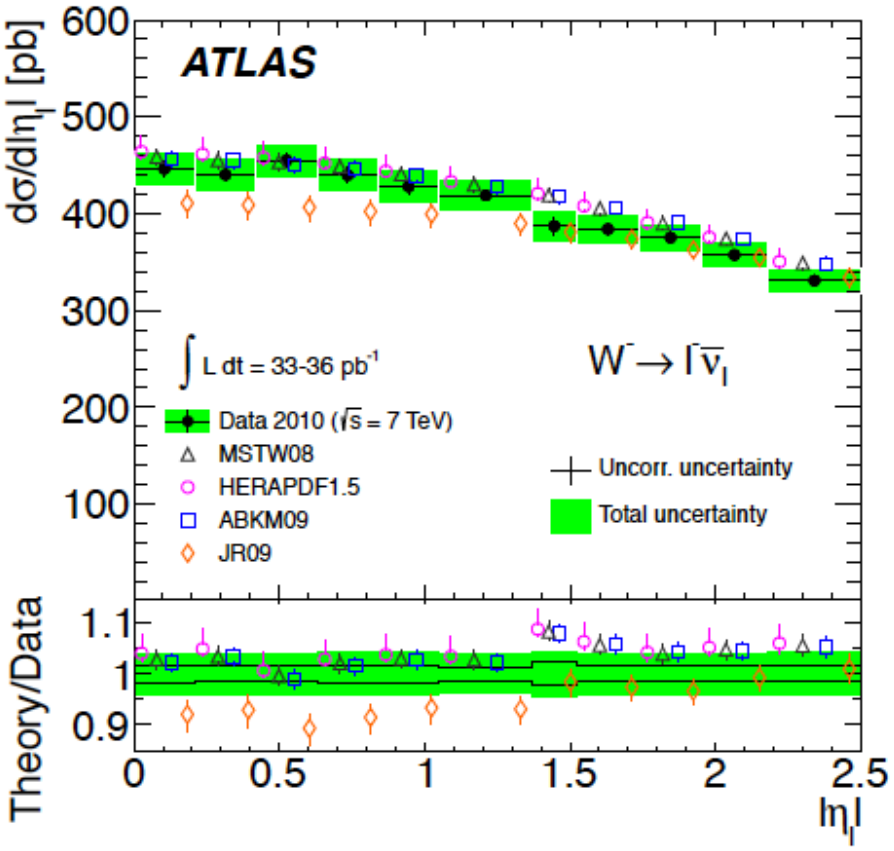
Shape comparison of y_Z with NLO (POWHEG, CT10)

CMS PAS EWK 10-010 (March 2011)

arXiv:1109:xxxx → PRD

Differential W^+ and W^- Cross Sections

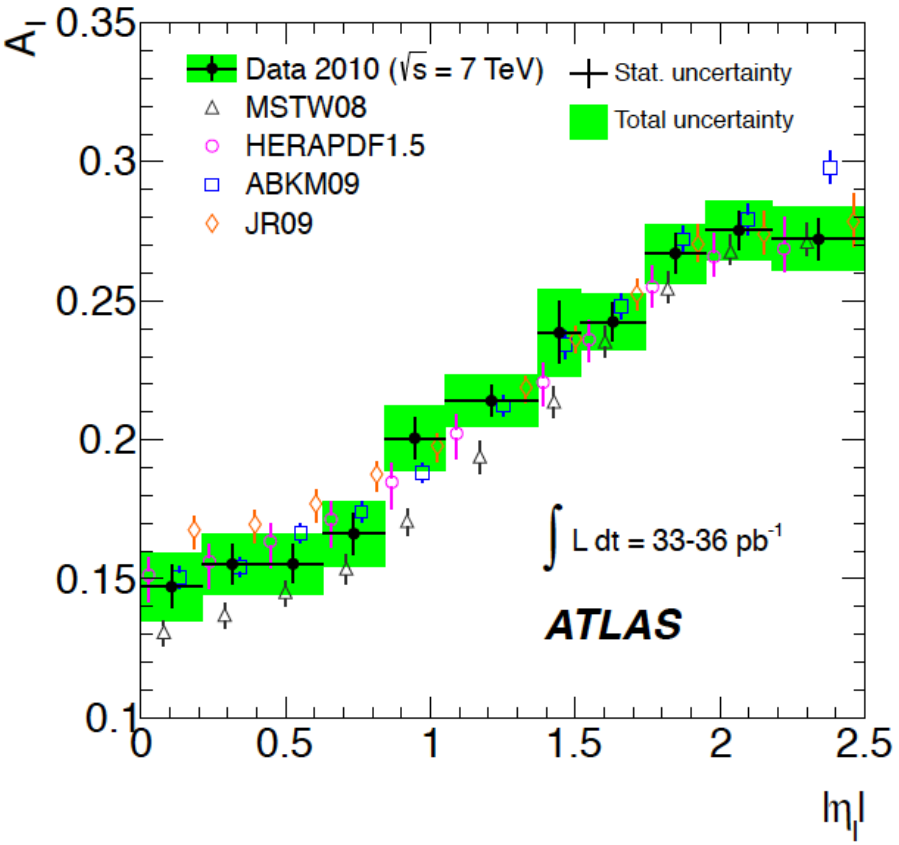


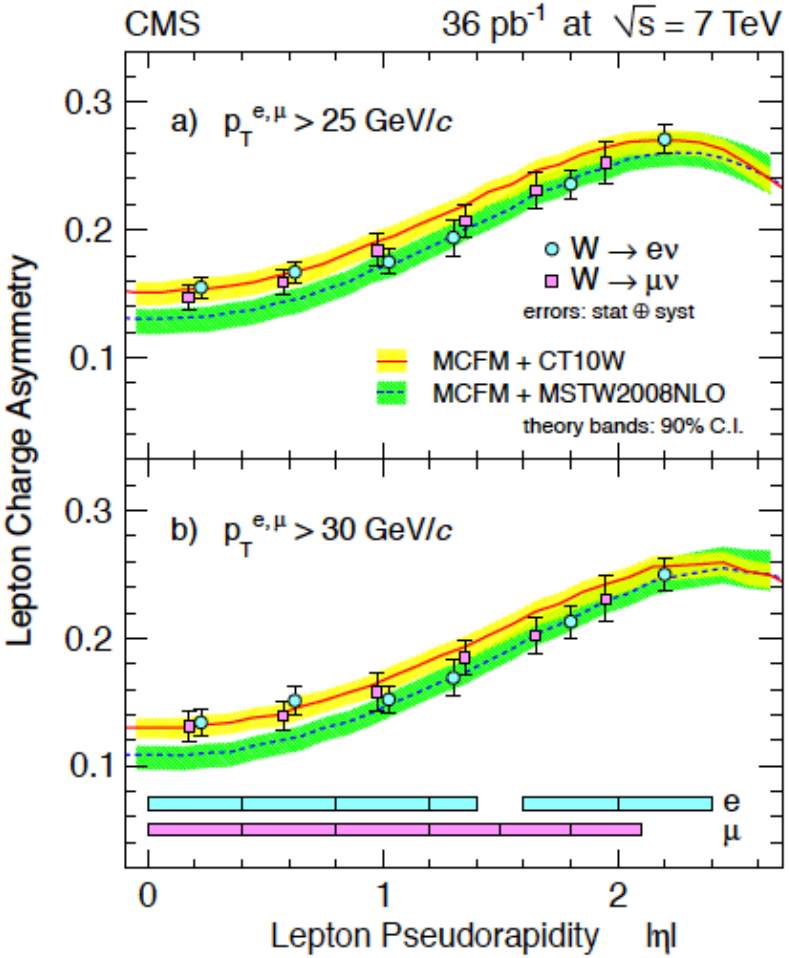


2% precise measurement over full range of pseudorapidity, in fiducial region
comparison with NNLO (FEWZ/DYNNLO), as for Z: no weak corrections applied.
Sensitivity to PDFs apparent (JR09 low at low η, ABKM09 high at large η)

arXiv:1109:xxxx → PRD

W Charge Asymmetry



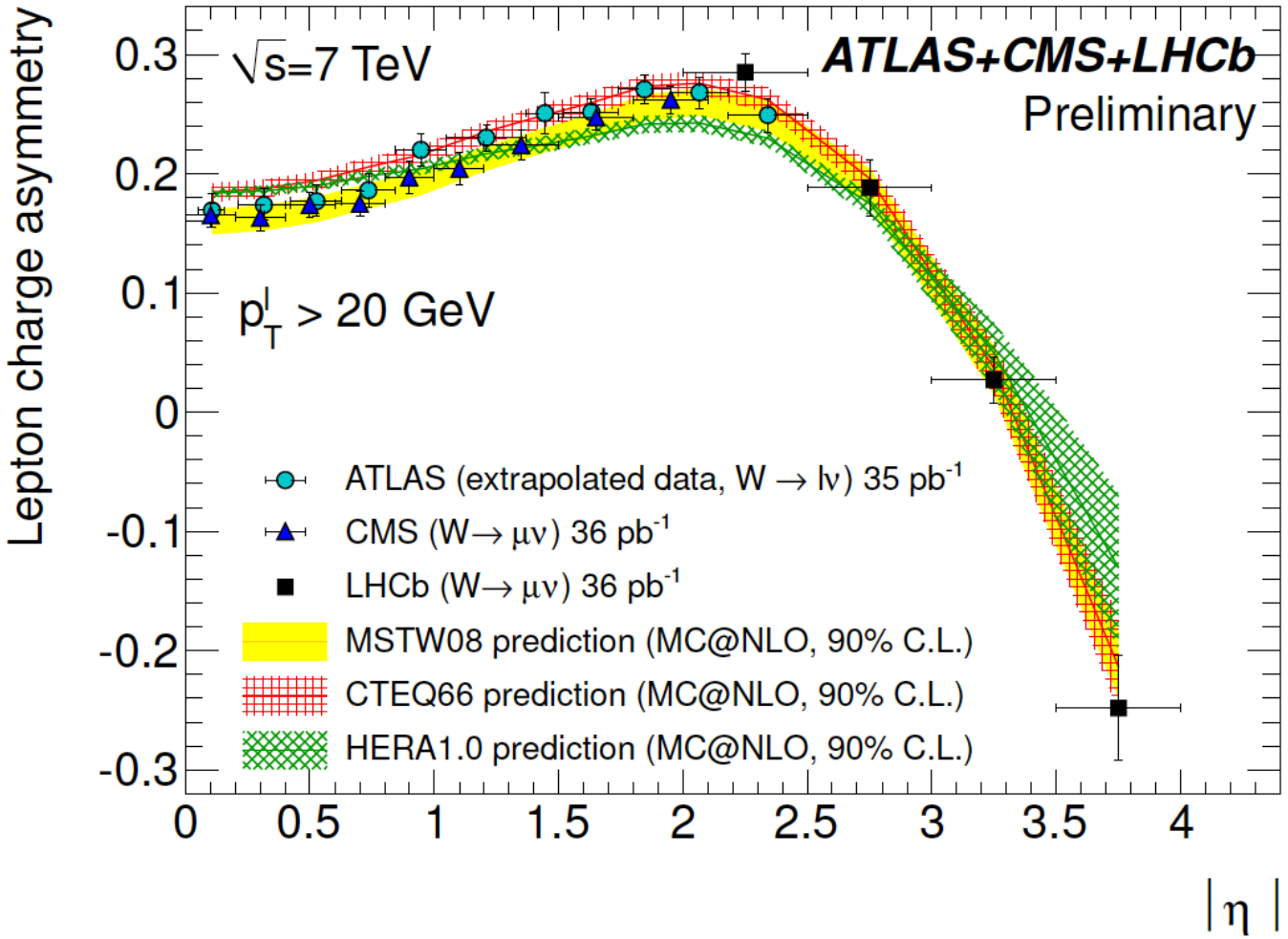


Electron and muon information combined
Less information than in separate cross sections and their correlations (here ABKM09 appears to be best, cf previous slide)

CMS: separate e – μ comparison
Good agreement with NLO PDFs

arXiv:1109:xxxx → PRD

W Charge Asymmetry from LHC

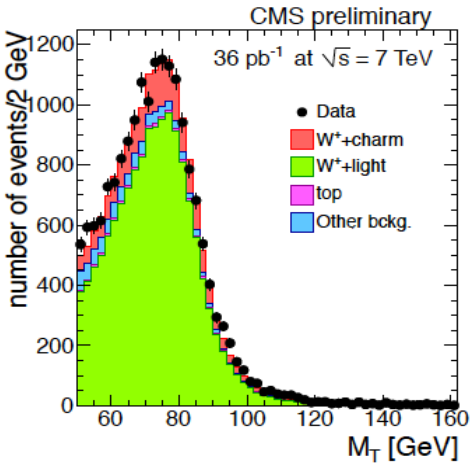


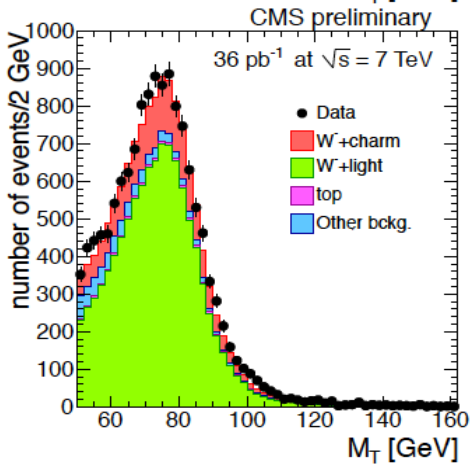
Asymmetries evaluated for full phase space (with $p_T^l > 20$ GeV) for comparison of 3 experiments. LHCb extending most forward. Theory to NLO with 90% CL.

ATLAS-CONF-2011-129 (August 2011)

First Measurement of W+c

Sensitivity to (anti) strange distribution





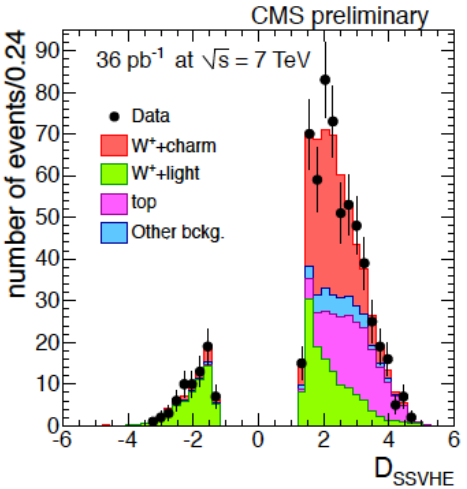
W →μν
Lifetime tag
Measure:

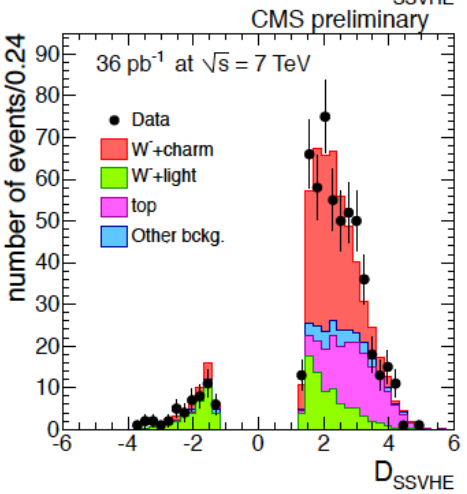
$R_c^{\pm}$ = (W⁺+cbar)/(W⁻+c)
R_c = (W+c)/(W+jet)

$$R_c^{\pm} = 0.92 \pm 0.19\ (stat.) \pm 0.04\ (syst.)$$
$$R_c = 0.143 \pm 0.015\ (stat.) \pm 0.024\ (syst.)$$

MCFM (CT10)	MCFM (MSTW08)	MCFM (NNPDF21)
$0.915^{+0.006}_{-0.006}$	$0.881^{+0.022}_{-0.032}$	0.902 ± 0.008
$0.125^{+0.013}_{-0.007}$	$0.118^{+0.002}_{-0.002}$	0.103 ± 0.005

CMS PAS EWK-11-013

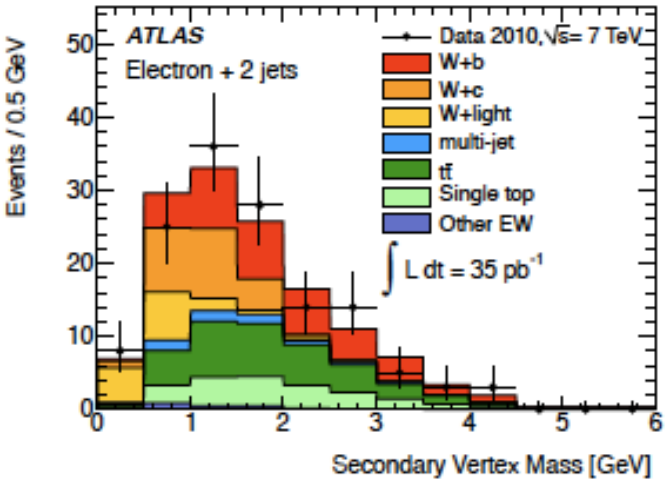


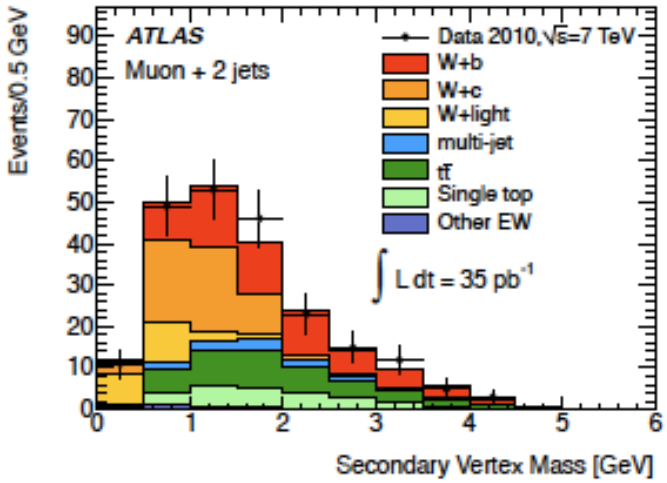


Transverse mass in W+1 jet

SSVHE: 2nd vtx with >= 2 tracks

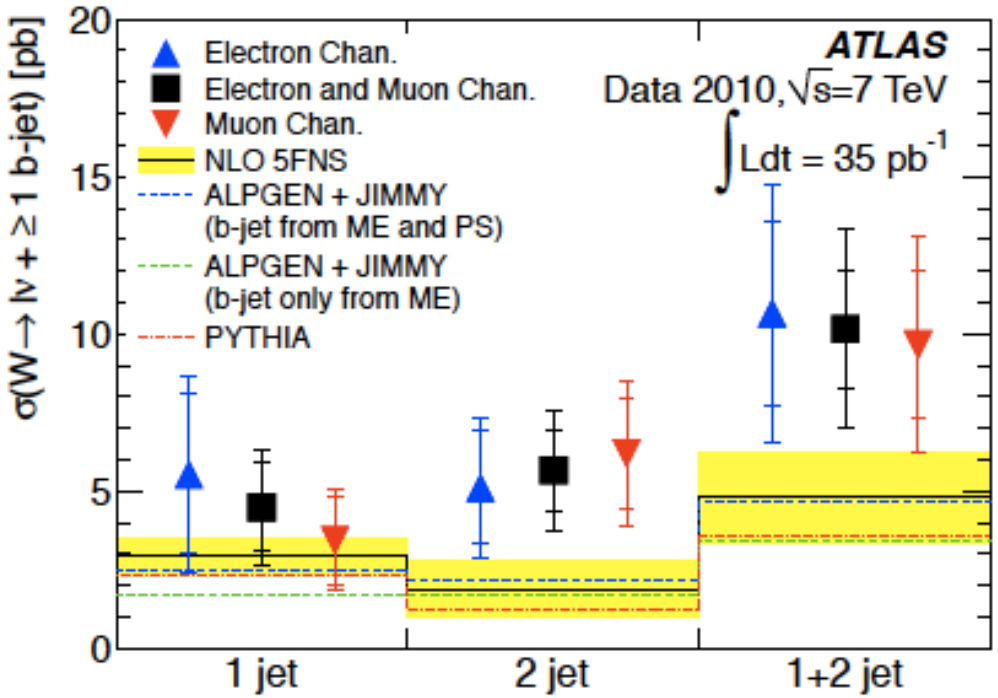
First Measurement of W+b





arXiv:1109:1470 → PLB

NLO QCD + heavy quarks in the initial state

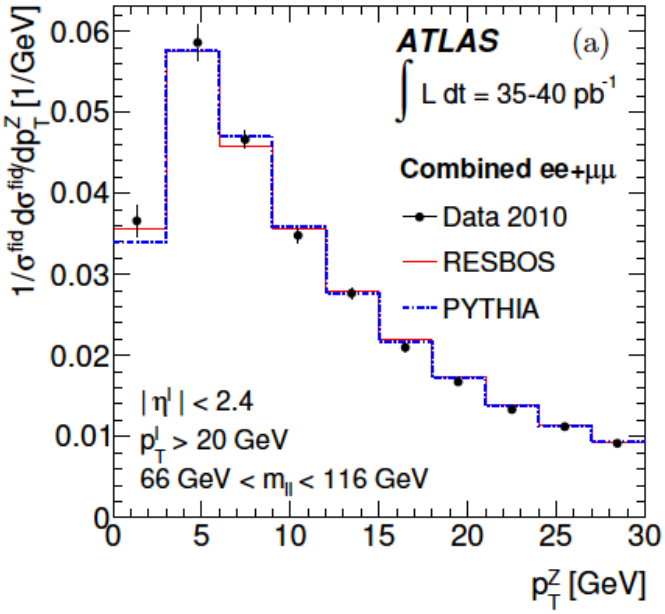


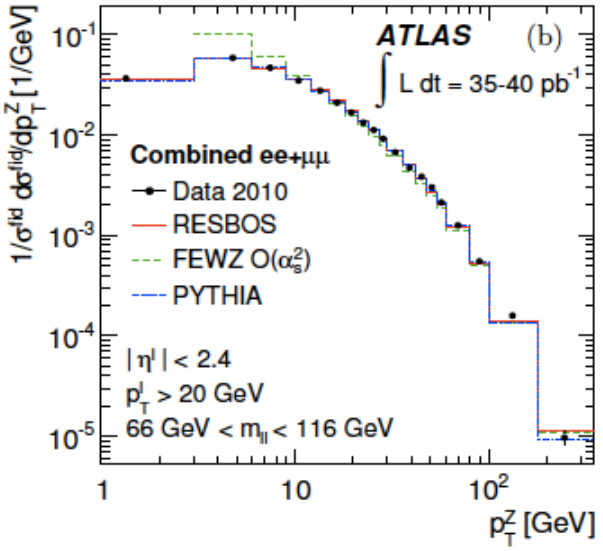
CDF: 2.9σ above thy

[**First** measurement of b .. PRL 104(2010)131801]

ATLAS: 1.5σ above but consistent

p_T^Z





Unfolded cross section vs p_T^Z

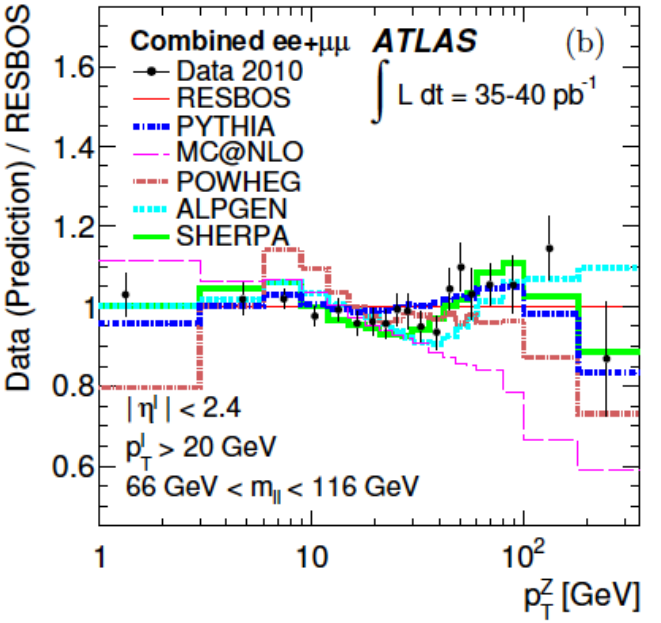
Low p_T:multiple soft g radiation and non-perturbative effects (MC tuning region)

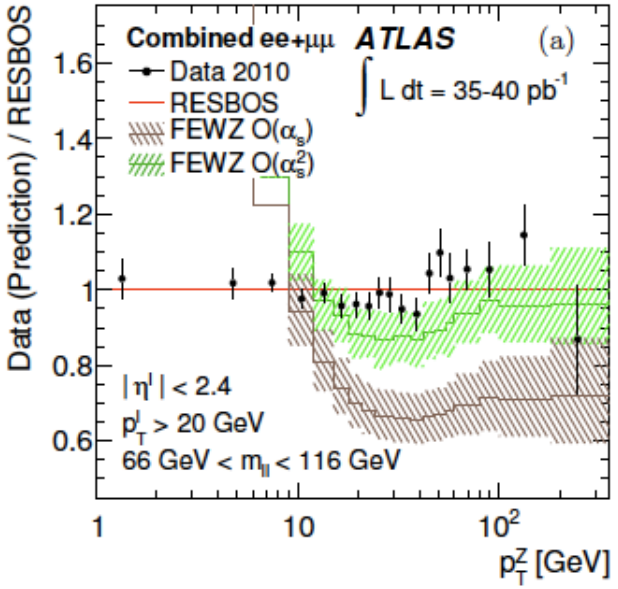
RESBOS, SHERPA, ALPGEN ok
PYTHIA with ATLASMC10 ok too.

POWHEG low, FEWZ divergent..
MC@NLO different shape

High p_T: pQCD test, multijets

FEWZ to α_s^2 ok for p_T> 10 GeV

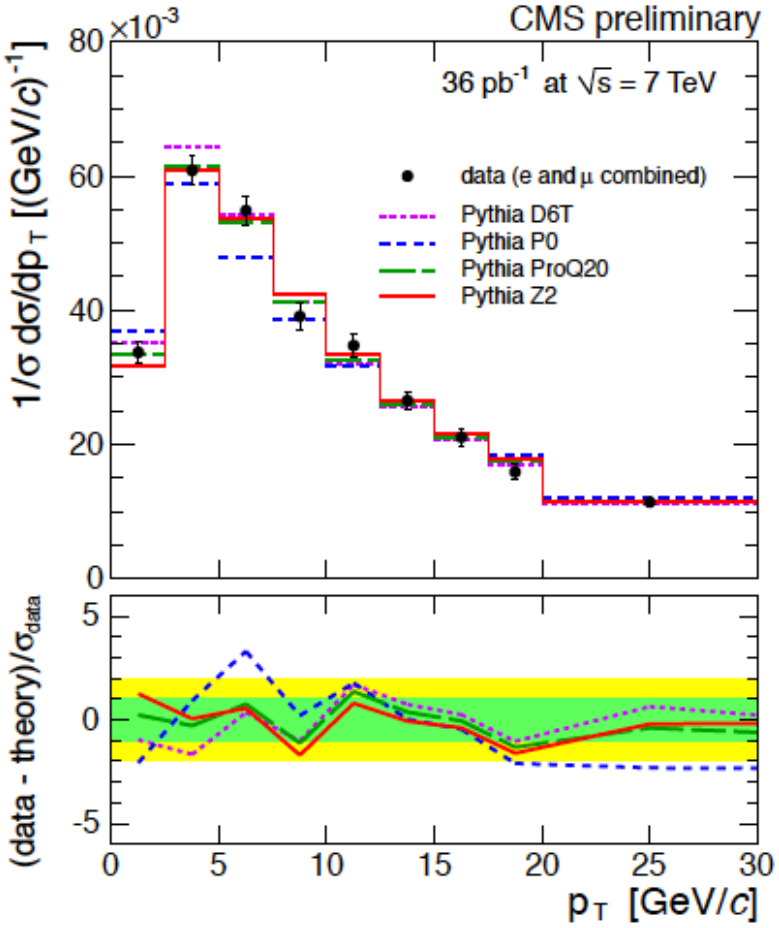


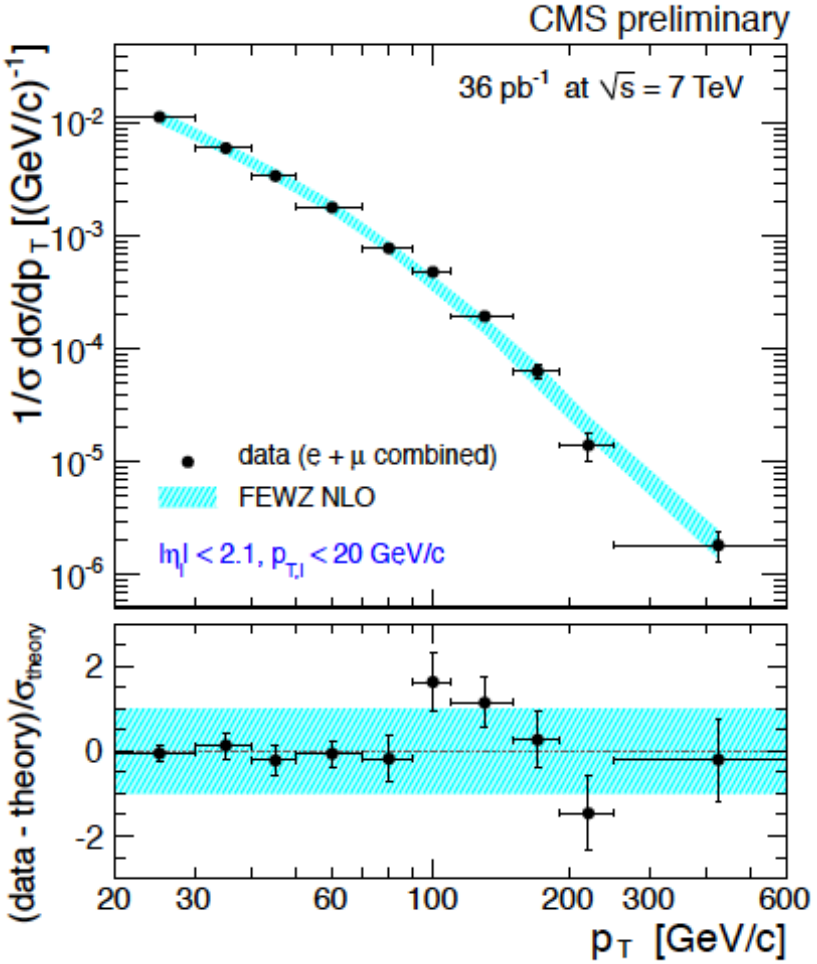


ATLAS

arXiv:1107:2381 subm to PLB

p_T^Z



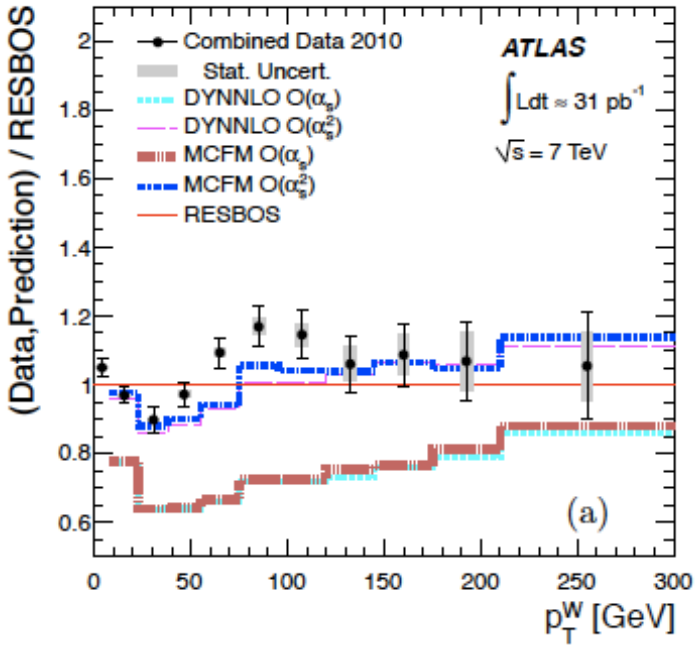


PYTHIA tunes vs Z transverse momentum
POWHEG found low at low p_TZ too (as ATLAS)

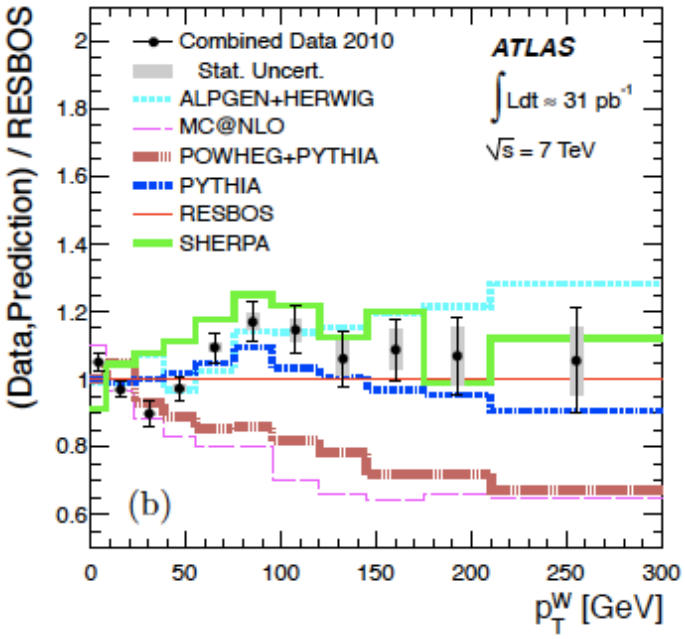
Shape of p_T^Z distribution in agreement with FEWZ at $O(\alpha_s)$ at high transverse momentum

CMS PAS EWK 10-010 (March 2011)

p_T^W



Needs α_s^2

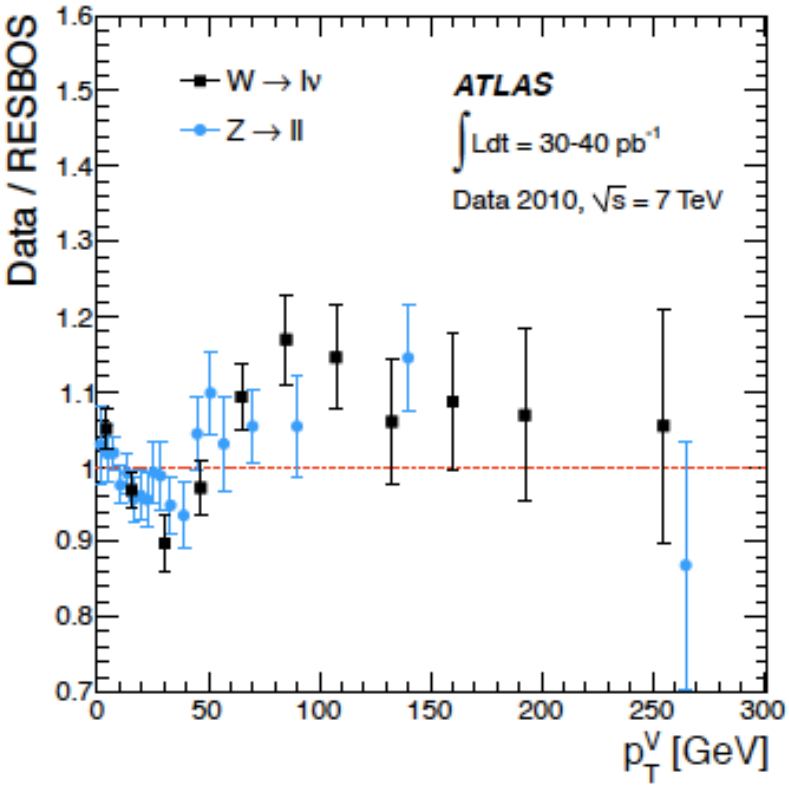


MCs Similar to p_T^Z

RESBOS, SHERPA, ALPGEN ok
PYTHIA with ATLASMC10 ok too.

POWHEG low, FEWZ divergent..
MC@NLO different shape

Comparison of W and Z p_T



p_T^W from had. recoil
i.e. $E_{calo} - E_l$
p_T^Z from lepton pair

A step towards M_W …

arXiv:1108:6308 subm to PRD

Summary

To be written

backup

W Polarisation

$\sin^2\Theta$

ww