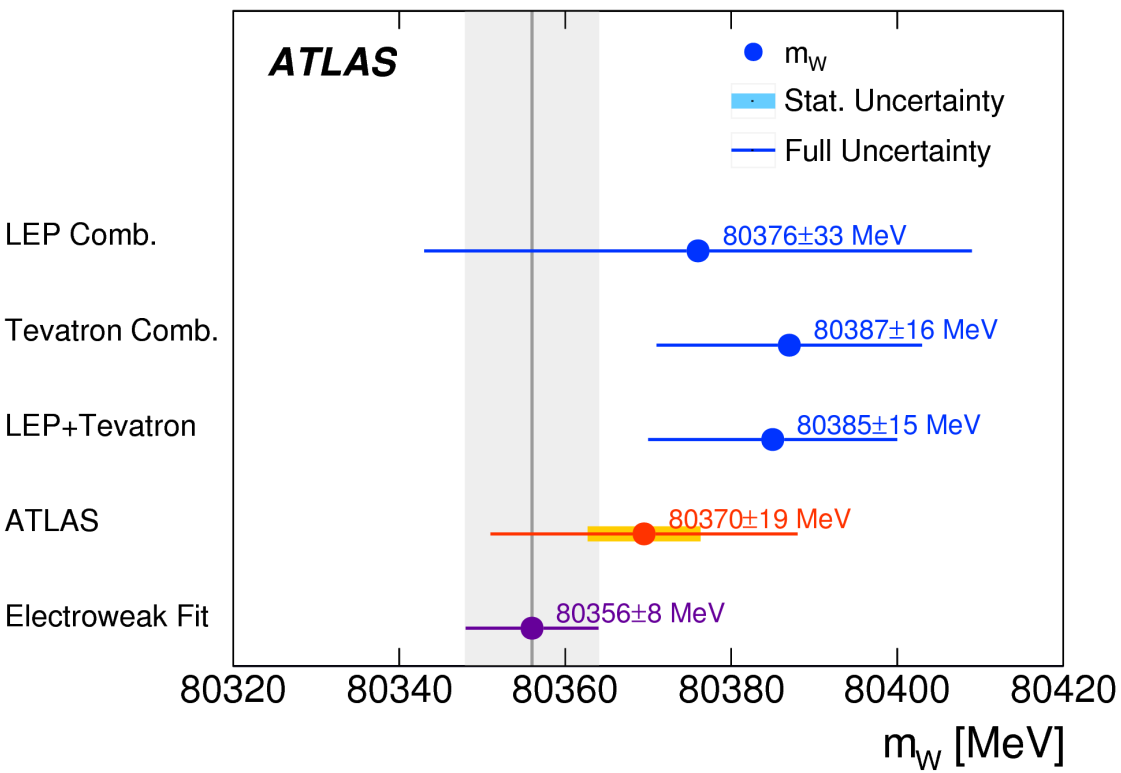
LHC-Tevatron Combination

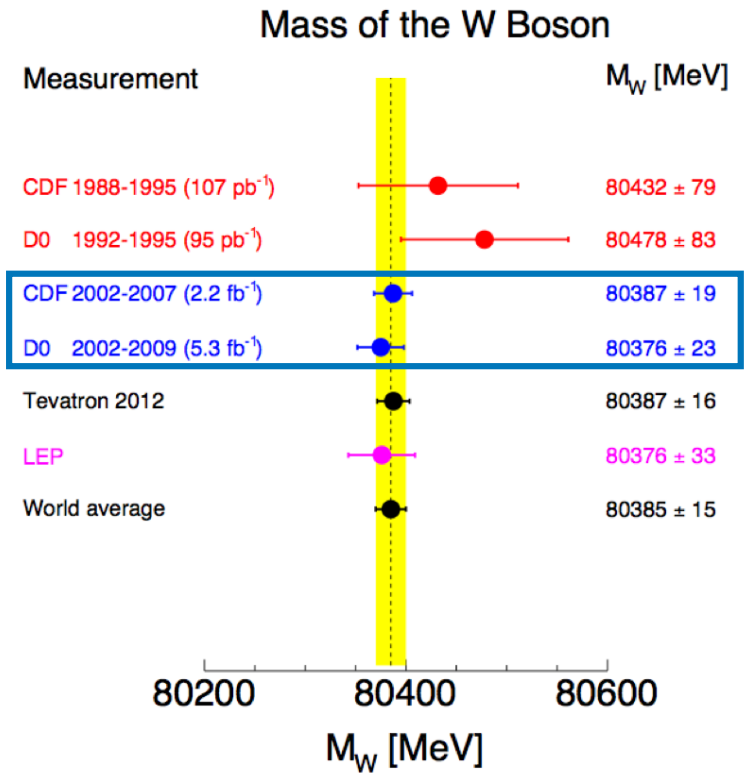
N. Andari, W. Ashmanskas, G. Belletini, M. Boonekamp, G. Chiarelli, C. Hays,
A. Kotwal, J. Kretzschmar, J. McFayden, J. Stark, D. Toback, K. Vellidis

https://indico.cern.ch/category/3290/ discussion on LHC / Tevatron combinations of mW

LHC EW Precision workshop
14/11/2018

Introduction





Aim: provide a new world average value combining the existing public results
(no change or improvement in the individual results is foreseen)

Uncertainty correlation

Stat and Experimental uncertainties: decorrelated
Theory-related uncertainties: correlations to be evaluated

EW

ATLAS

Decay channel	$W \to e\nu$		$W \to \mu\nu$	
Kinematic distribution	p_{T}^{ℓ}	m_{T}	p_{T}^{ℓ}	m_{T}
δm_W [MeV]				
FSR (real)	< 0.1	< 0.1	< 0.1	< 0.1
Pure weak and IFI corrections	3.3	2.5	3.5	2.5
FSR (pair production)	3.6	0.8	4.4	0.8
Total	4.9	2.6	5.6	2.6

CDF

Source	Uncertainty
Lepton energy scale and resolution	7
Recoil energy scale and resolution	6
Lepton tower removal	2
Backgrounds	3
PDFs	10
$p_T(W)$ model	5
Photon radiation	4
Statistical	12
Total	19

QCD

ATLAS

W-boson charge	W^+		W^-		Combined	
Kinematic distribution	p_{T}^{ℓ}	m_{T}	p_{T}^{ℓ}	m_{T}	p_{T}^{ℓ}	m_{T}
δm_W [MeV]						
Fixed-order PDF uncertainty (PDF)	13.1	14.9	12.0	14.2	8.0	8.7
AZ tune (pTW)	3.0	3.4	3.0	3.4	3.0	3.4
Charm-quark mass (pTW)	1.2	1.5	1.2	1.5	1.2	1.5
Parton shower μ_{F} with heavy-flavour decorrelation	5.0	6.9	5.0	6.9	5.0	6.9
Parton shower PDF uncertainty	3.6	4.0	2.6	2.4	1.0	1.6
Angular coefficients (Ai)	5.8	5.3	5.8	5.3	5.8	5.3
Total	15.9	18.1	14.8	17.2	11.6	12.9

Uncertainty correlation

All non-common uncertainties are obviously decorrelated

- The uncertainty from polarisation coefficients was estimated at the Tevatron and found to be negligible ~0.5 MeV

- No explicit uncertainty in the Tevatron results for the extrapolation from pTZ to pTW

- pTZ tune uncertainty dominated by stat uncertainties

==> Therefore pTW modelling uncertainties can be taken fully decorrelated

EW uncertainties agreed to take them as fully correlated between the different experiments.

PDF uncertainties

Dominant uncertainty in both measurements

ATLAS: CT10 for central value + uncertainties + envelope with CT14, MMHT
uses constraints from pTZ data : consider only PDF-induced variations on the pTW/pTZ ratio

Tevatron: CTEQ6.6 for central value; CTEQ6.6 + MSTW2008 for uncertainties.
—> no envelope of different PDF uncertainties taken into account. Difference between CTEQ6.6 and MSTW2008 quoted to be 6 MeV but not considered. No pTZ constraint used.

—> decorrelate uncertainty quoted in ATLAS from the envelope = 3.8 MeV and decorrelate the uncertainty for the parton shower PDF uncertainty.

PDF uncertainties

How to estimate remaining correlations?

- Update the published measurements with a common choice of a PDF set, compute shifts and correlations—> Tevatron: update ResBos interfaced to more recent PDF sets. Recent preliminary studies from Tevatron show that the PDF uncertainties do not depend on the tool used to evaluate them, switch to MC@nlo or Powheg. ATLAS: transmit PDF variations using reweighting of the event kinematics (pT,y,Ai)

- Emulate the published measurements: smear truth-level distributions using simplified parameterisations to mimic detector effects

Emulation approach

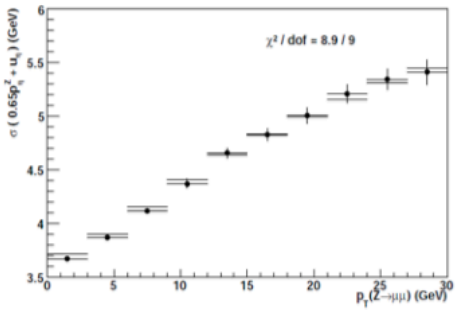
Use Powheg to simulate 1.96 TeV pp-bar and 7 TeV pp with a baseline PDF: CT10
Compute PDF weights for CTEQ6.6, CT14, MMHT, NNPDF3.1

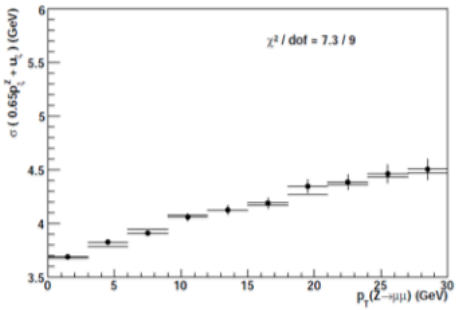
Mimic recoil and lepton resolution effects through a smearing approach of the truth level distributions to the one published in the measurements (done by eye for now)

Official repository to upload histograms for more exact smearing:
https://gitlab.cern.ch/lhcewkwg/lhcewkwg-precisionEW/mwcombinations

- CDF

1.96 TeV

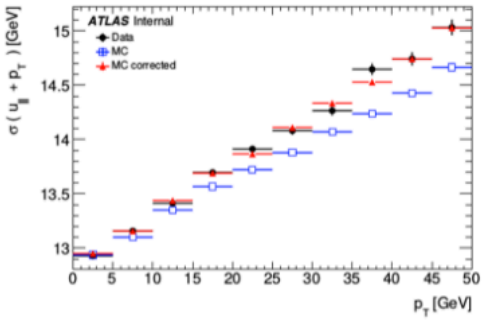


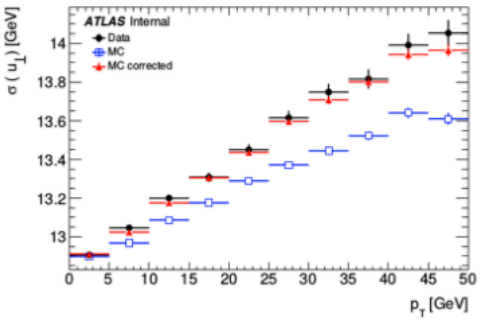


u_{PAR} u_{PERP}

- ATLAS

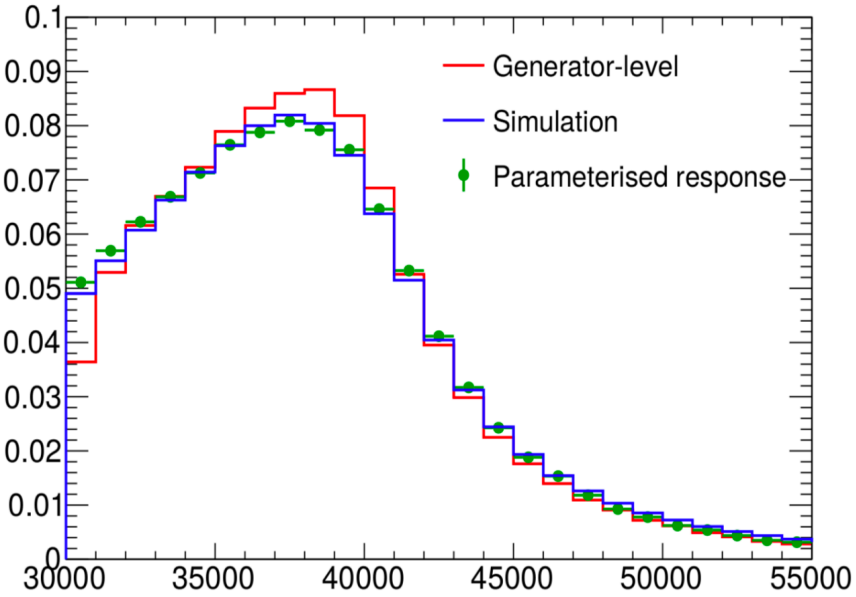
7 TeV,
<μ>~9

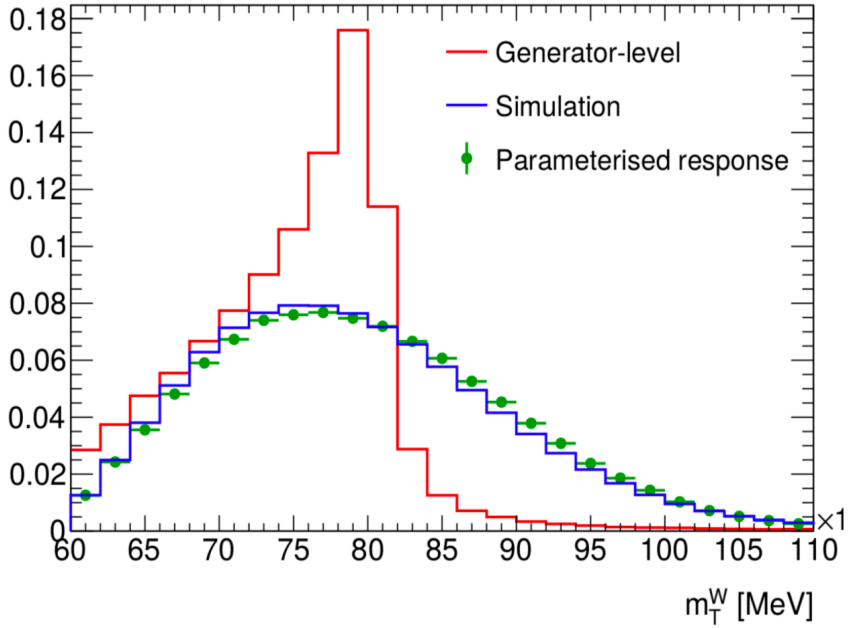




Validation of the recoil smearing

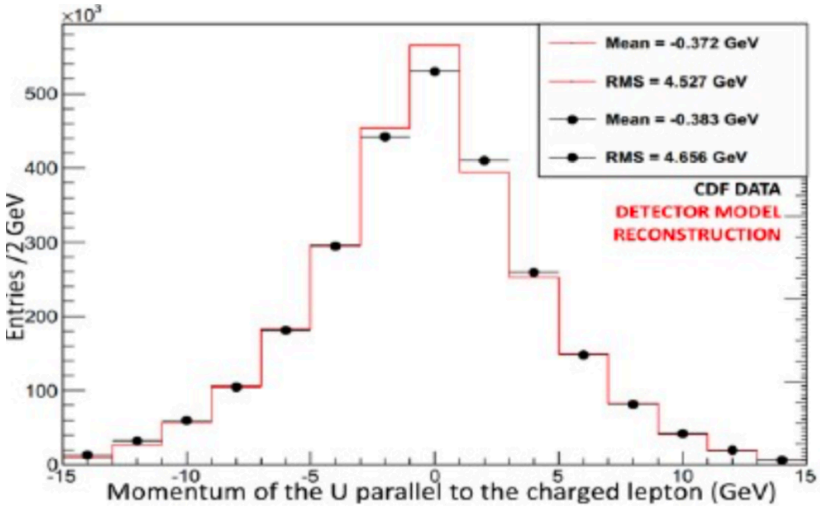
Not perfect agreement but reasonable for a first check

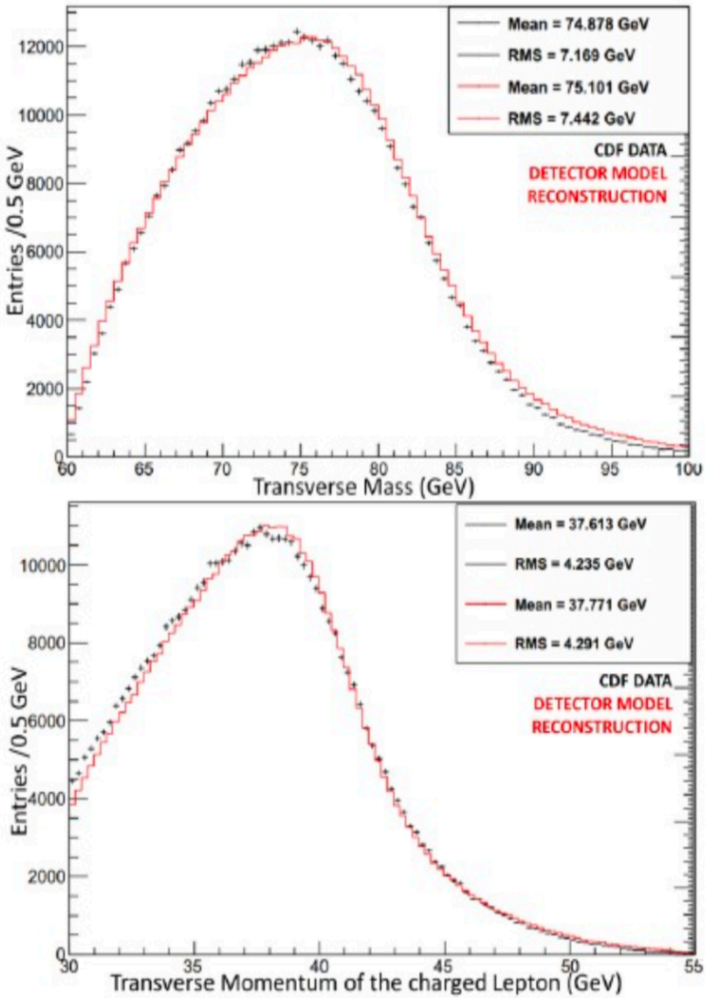




Parameterised CDF simulation

Parametric simulation based on that used for mW

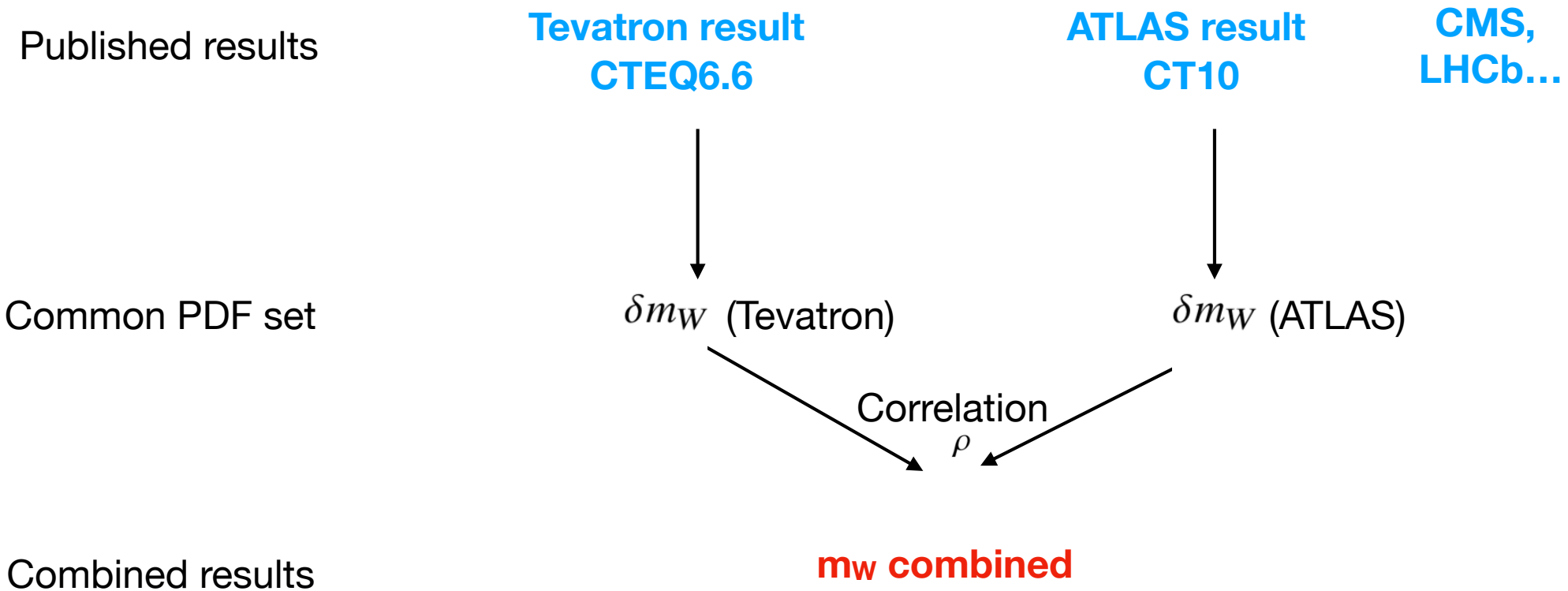




Reasonable estimate of PDFs (based on comparisons to full fast simulation used for CDF)

Old study based on Powheg + Pythia —> update to Madgraph + Pythia and improve smearing

Results to be updated with these parameterisations



Selection cuts

CDF	ATLAS
$30<p_t^{l,\nu}<55$ GeV, $60<m_T<100$ GeV, $u_T<15$ GeV, $\|\eta\|<1$	$p_t^{l,\nu}>30$ GeV, $m_T>60$ GeV, $u_T<30$ GeV, $\|\eta\|<2.4$

pTl observable

Correlations

Preliminary

CT10	1.	2.	3.	4.
1. W^+ 2 TeV	1	0.99	0.26	0.51
2. W^- 2 TeV	0.99	1	0.31	0.52
3. W^+ 7 TeV	0.26	0.31	1	-0.23
4. W^- 7 TeV	0.51	0.52	-0.23	1

CTEQ6.6	1.	2.	3.	4.
1. W^+ 2 TeV	1	1	0.37	0.45
2. W^- 2 TeV	1	1	0.36	0.46
3. W^+ 7 TeV	0.37	0.36	1	-0.42
4. W^- 7 TeV	0.45	0.46	-0.42	1

Few % stat uncertainties to be evaluated on the correlations

Around 50% correlation also observed using MadGraph NLO (Chris Hays)

mT observable

Correlations

Preliminary

CT10	1.	2.	3.	4.
1. W^+ 2 TeV	1	0.99	0.19	0.55
2. W^- 2 TeV	0.99	1	0.22	0.56
3. W^+ 7 TeV	0.19	0.22	1	-0.30
4. W^- 7 TeV	0.55	0.56	-0.30	1

CTEQ6.6	1.	2.	3.	4.
1. W^+ 2 TeV	1	1	0.32	0.50
2. W^- 2 TeV	1	1	0.31	0.52
3. W^+ 7 TeV	0.32	0.31	1	-0.42
4. W^- 7 TeV	0.50	0.52	-0.42	1

Few % stat uncertainties to be evaluated on the correlations

Shifts (MeV)

Preliminary

CT10—> CTEQ6.6	p_T^{l+}	p_T^{l-}	m_T^+	m_T^-
7 TeV eta 1	-4.0	-6.3	-7.7	-3.8
7 TeV eta 2	-12.6	-1.5	-16.8	-1.8
7 TeV eta 3	-17.7	+8.6	-15.5	+9.9
7 TeV eta 4	-11.1	+16.4	-11	+12.6

CTEQ6.6—> CT10	p_T^{l+}	p_T^{l-}	m_T^+	m_T^-
2 TeV	+8.4	+8.4	+7.3	+6.8

Stat uncertainties and m_W values

Assume: mW = 80387 for Tevatron and mW = 80370 for ATLAS

CDF

Distribution	W-boson mass (MeV)	χ^2/dof
$m_T(e, \nu)$	$80\,408 \pm 19_{\text{stat.}} \pm 18_{\text{syst.}}$	52/48
$p_T^{\ell}(e)$	$80\,393 \pm 21_{\text{stat.}} \pm 19_{\text{syst.}}$	60/62
$p_T^{\nu}(e)$	$80\,431 \pm 25_{\text{stat.}} \pm 22_{\text{syst.}}$	71/62
$m_T(\mu, \nu)$	$80\,379 \pm 16_{\text{stat.}} \pm 16_{\text{syst.}}$	58/48
$p_T^{\ell}(\mu)$	$80\,348 \pm 18_{\text{stat.}} \pm 18_{\text{syst.}}$	54/62
$p_T^{\nu}(\mu)$	$80\,406 \pm 22_{\text{stat.}} \pm 20_{\text{syst.}}$	79/62

Combine e/mu —> 13.67 (pTl) and 12.24 (mT)
pTl+: 19.33 , pTl-: 19.33, mT+: 17.31, mT-: 17.31

Different categories for electrons and muons but similar stat uncertainties.

For now assume muons uncertainties and divide by sqrt(2) except for 1.2<|eta|<1.8 take muon only

ATLAS

Channel m_T-Fit	m_W [MeV]	Stat. Unc.	Muon Unc.	Elec. Unc.	Recoil Unc.	Bckg. Unc.	QCD Unc.	EW Unc.	PDF Unc.	Total Unc.
$W^+ \to \mu\nu, \lvert\eta\rvert < 0.8$	80371.3	29.2	12.4	0.0	15.2	8.1	9.9	3.4	28.4	47.1
$W^+ \to \mu\nu, 0.8 < \lvert\eta\rvert < 1.4$	80354.1	32.1	19.3	0.0	13.0	6.8	9.6	3.4	23.3	47.6
$W^+ \to \mu\nu, 1.4 < \lvert\eta\rvert < 2.0$	80426.3	30.2	35.1	0.0	14.3	7.2	9.3	3.4	27.2	56.9
$W^+ \to \mu\nu, 2.0 < \lvert\eta\rvert < 2.4$	80334.6	40.9	112.4	0.0	14.4	9.0	8.4	3.4	32.8	125.5
$W^- \to \mu\nu, \lvert\eta\rvert < 0.8$	80375.5	30.6	11.6	0.0	13.1	8.5	9.5	3.4	30.6	48.5
$W^- \to \mu\nu, 0.8 < \lvert\eta\rvert < 1.4$	80417.5	36.4	18.5	0.0	12.2	7.7	9.7	3.4	22.2	49.7
$W^- \to \mu\nu, 1.4 < \lvert\eta\rvert < 2.0$	80379.4	35.6	33.9	0.0	10.5	8.1	9.7	3.4	23.1	56.9
$W^- \to \mu\nu, 2.0 < \lvert\eta\rvert < 2.4$	80334.2	52.4	123.7	0.0	11.6	10.2	9.9	3.4	34.1	139.9
$W^+ \to e\nu, \lvert\eta\rvert < 0.6$	80352.9	29.4	0.0	19.5	13.1	15.3	9.9	3.4	28.5	50.8
$W^+ \to e\nu, 0.6 < \lvert\eta\rvert < 1.2$	80381.5	30.4	0.0	21.4	15.1	13.2	9.6	3.4	23.5	49.4
$W^+ \to e\nu, 1,8 < \lvert\eta\rvert < 2.4$	80352.4	32.4	0.0	26.6	16.4	32.8	8.4	3.4	27.3	62.6
$W^- \to e\nu, \lvert\eta\rvert < 0.6$	80415.8	31.3	0.0	16.4	11.8	15.5	9.5	3.4	31.3	52.1
$W^- \to e\nu, 0.6 < \lvert\eta\rvert < 1.2$	80297.5	33.0	0.0	18.7	11.2	12.8	9.7	3.4	23.9	49.0
$W^- \to e\nu, 1.8 < \lvert\eta\rvert < 2.4$	80423.8	42.8	0.0	33.2	12.8	35.1	9.9	3.4	28.1	72.3
p_T-Fit										
$W^+ \to \mu\nu, \lvert\eta\rvert < 0.8$	80327.7	22.1	12.2	0.0	2.6	5.1	9.0	6.0	24.7	37.3
$W^+ \to \mu\nu, 0.8 < \lvert\eta\rvert < 1.4$	80357.3	25.1	19.1	0.0	2.5	4.7	8.9	6.0	20.6	39.5
$W^+ \to \mu\nu, 1.4 < \lvert\eta\rvert < 2.0$	80446.9	23.9	33.1	0.0	2.5	4.9	8.2	6.0	25.2	49.3
$W^+ \to \mu\nu, 2.0 < \lvert\eta\rvert < 2.4$	80334.1	34.5	110.1	0.0	2.5	6.4	6.7	6.0	31.8	120.2
$W^- \to \mu\nu, \lvert\eta\rvert < 0.8$	80427.8	23.3	11.6	0.0	2.6	5.8	8.1	6.0	26.4	39.0
$W^- \to \mu\nu, 0.8 < \lvert\eta\rvert < 1.4$	80395.6	27.9	18.3	0.0	2.5	5.6	8.0	6.0	19.8	40.5
$W^- \to \mu\nu, 1.4 < \lvert\eta\rvert < 2.0$	80380.6	28.1	35.2	0.0	2.6	5.6	8.0	6.0	20.6	50.9
$W^- \to \mu\nu, 2.0 < \lvert\eta\rvert < 2.4$	80315.2	45.5	116.1	0.0	2.6	7.6	8.3	6.0	32.7	129.6
$W^+ \to e\nu, \lvert\eta\rvert < 0.6$	80336.5	22.2	0.0	20.1	2.5	6.4	9.0	5.3	24.5	40.7
$W^+ \to e\nu, 0.6 < \lvert\eta\rvert < 1.2$	80345.8	22.8	0.0	21.4	2.6	6.7	8.9	5.3	20.5	39.4
$W^+ \to e\nu, 1,8 < \lvert\eta\rvert < 2.4$	80344.7	24.0	0.0	30.8	2.6	11.9	6.7	5.3	24.1	48.2
$W^- \to e\nu, \lvert\eta\rvert < 0.6$	80351.0	23.1	0.0	19.8	2.6	7.2	8.1	5.3	26.6	42.2
$W^- \to e\nu, 0.6 < \lvert\eta\rvert < 1.2$	80309.8	24.9	0.0	19.7	2.7	7.3	8.0	5.3	20.9	39.9
$W^- \to e\nu, 1.8 < \lvert\eta\rvert < 2.4$	80413.4	30.1	0.0	30.7	2.7	11.5	8.3	5.3	22.7	51.0

mW uncertainties (MeV)

2 TeV CTEQ6.6	p_T^{l+}	p_T^{l-}	m_T^+	m_T^-	pT&mT
Stat	19.7	19.3	17.3	17.3	9.4*
PDF	14.8	15.9	11.9	11.9	12.9
Total	24.3	25.0	21.0	21.0	16.0

PDF uncertainties here scaled from 90 to 68%CL with 1.645; however in Tevatron results it is scaled from MSTW2008 with 2.15 —> 10 MeV in agreement with the published result

2 TeV CT10	p_T^{l+}	p_T^{l-}	m_T^+	m_T^-	pT&mT
Stat	19.3	19.3	17.3	17.3	9.7*
PDF	16.6	18.1	13.2	13.4	14.3
Total	25.5	26.5	21.8	21.9	17.3

** to be updated with proper stat correlation between pT and mT*

mW uncertainties (MeV)

7 TeV CTEQ 6.6	p_T^{l+} Eta 1	p_T^{l-} Eta 1	p_T^{l+} Eta 2	p_T^{l-} Eta 2	p_T^{l+} Eta 3	p_T^{l-} Eta 3	p_T^{l+} Eta 4	p_T^{l-} Eta 4	m_T^{+} Eta 1	m_T^{-} Eta 1	m_T^{+} Eta 2	m_T^{-} Eta 2	m_T^{+} Eta 3	m_T^{-} Eta 3	m_T^{+} Eta 4	m_T^{-} Eta 4	pT& mT
Stat	15.6	16.5	17.8	19.7	23.9	28.1	24.4	32.2	20.6	21.6	22.7	25.8	30.2	35.6	28.9	37.0	6.8
PDF	23.4	22.9	27.1	20.4	25.6	23.1	18.4	24.8	27.4	24.5	25.4	20.2	21.2	24.3	20.0	30.9	8.4
Total	28.2	28.2	32.4	28.4	35.0	36.4	30.5	40.6	34.3	32.7	34.0	32.8	36.9	43.1	35.2	48.3	10.8

7 TeV CT10	p_T^{l+} Eta 1	p_T^{l-} Eta 1	p_T^{l+} Eta 2	p_T^{l-} Eta 2	p_T^{l+} Eta 3	p_T^{l-} Eta 3	p_T^{l+} Eta 4	p_T^{l-} Eta 4	m_T^{+} Eta 1	m_T^{-} Eta 1	m_T^{+} Eta 2	m_T^{-} Eta 2	m_T^{+} Eta 3	m_T^{-} Eta 3	m_T^{+} Eta 4	m_T^{-} Eta 4	pT& mT
Stat	15.6	16.5	17.8	19.7	23.9	28.1	24.4	32.2	20.6	21.6	22.7	25.8	30.2	35.6	28.9	37.0	7.4
PDF	32.9	29.8	31.3	24.6	28.8	25.2	25.9	26.2	37.1	30.4	26.3	25.3	25.1	27.2	29.8	35.1	10.0
Total	36.4	34.0	36.0	31.5	37.4	37.8	35.6	41.5	42.4	37.3	34.8	36.1	39.3	44.8	41.5	51.0	12.5

mW combined uncertainties (MeV)

Very preliminary

2 TeV + 7 TeV eta	CT10	CTEQ6.6
m_W	80376.3	80371
Stat	6.49	6.06
PDF	9.71	8.30
Stat+PDF	11.68	10.28

Conclusion

- Ongoing discussions between ATLAS and CDF in two meetings
- Machinery in place for the combination and evaluation of PDF uncertainties
- Reupdate results with the parameterisations from Tevatron
- Evaluate the correlations and the mW combined value and uncertainty for other PDF sets. Agreed on CT14, MMHT, and NNPDF3.1.