

# PDF uncertainty correlation

## *Effect on $mW$ measurement and 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

Based on:

- HL-LHC  $m_W$  PUB note: <https://cds.cern.ch/record/2643352>
- Work in progress for  $m_W$  combination with Tevatron: [https://indico.cern.ch/event/766590/contributions/3205397/attachments/1752668/2840437/Andari\\_ws\\_14112018.pdf](https://indico.cern.ch/event/766590/contributions/3205397/attachments/1752668/2840437/Andari_ws_14112018.pdf)

LHC Electroweak WG meeting  
13/12/2018

## PDF uncertainties and correlations

Baseline MC used: Powheg+Pythia 8 CT10 nnlo

PDF variations are applied as [event weights on the generator level](#), calculated internally in Powheg as the ratio of the event cross sections predicted by CT10 and alternative PDF sets:

- CT10, CTEQ6.6, MSTW2008 used in publications
- CT14, MMHT2014, NNPDF31: current PDF sets
- HL-LHC, LHeC: future PDF sets

Different energies 2, 5, 7, 13 TeV (pp-bar for 2 TeV)

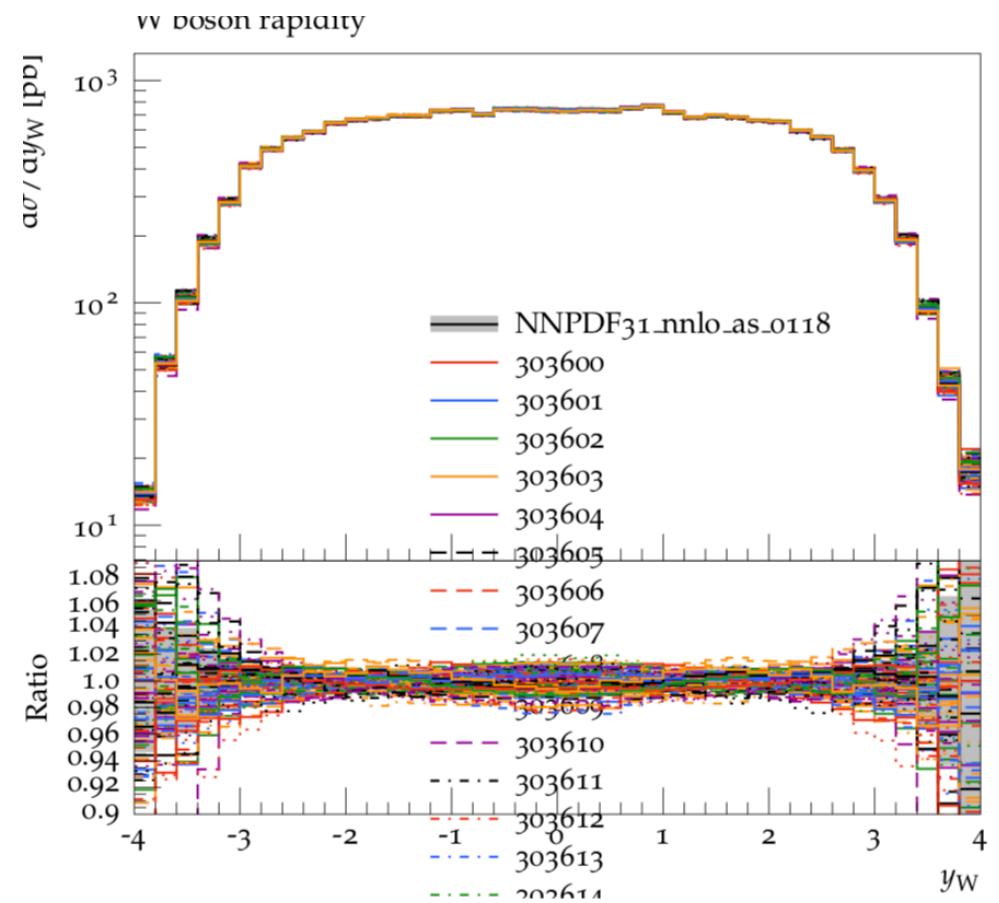
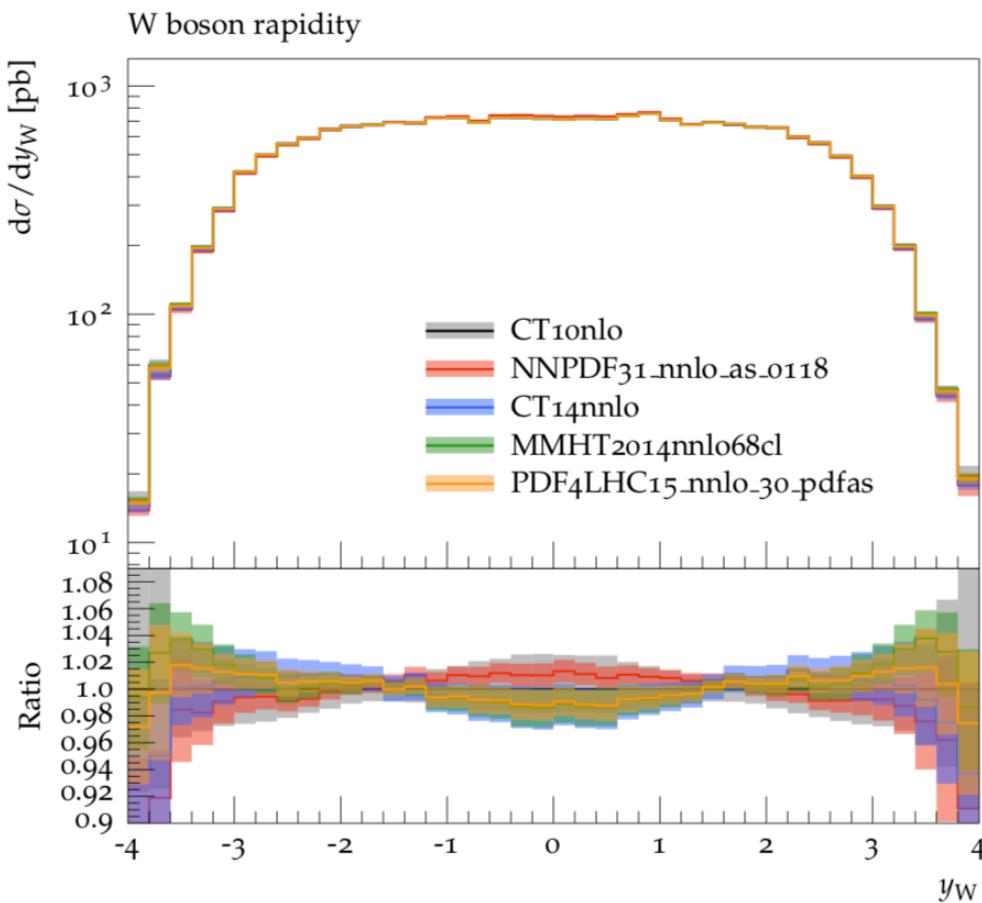
$$\delta m_{W\alpha}^+ = \left[ \sum_i \left( \delta m_{W\alpha}^i \right)^2 \right]^{1/2} \quad \text{if } \delta m_{W\alpha}^i > 0, \quad \delta m_{W\alpha}^- = \left[ \sum_i \left( \delta m_{W\alpha}^i \right)^2 \right]^{1/2} \quad \text{if } \delta m_{W\alpha}^i < 0,$$

Where i runs for the uncertainty sets

$$\rho_{\alpha\beta} = \frac{\sum_i \delta m_{W\alpha}^i \delta m_{W\beta}^i}{\delta m_{W\alpha} \delta m_{W\beta}}$$

[Correlation of PDF uncertainties](#) between different categories alpha and beta

# Samples



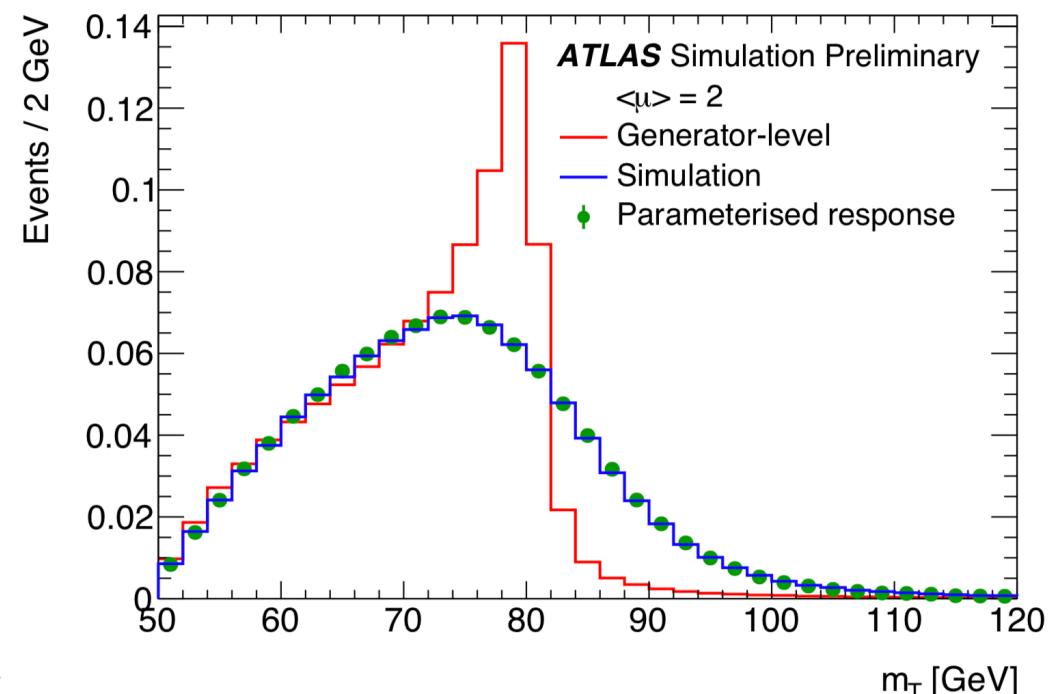
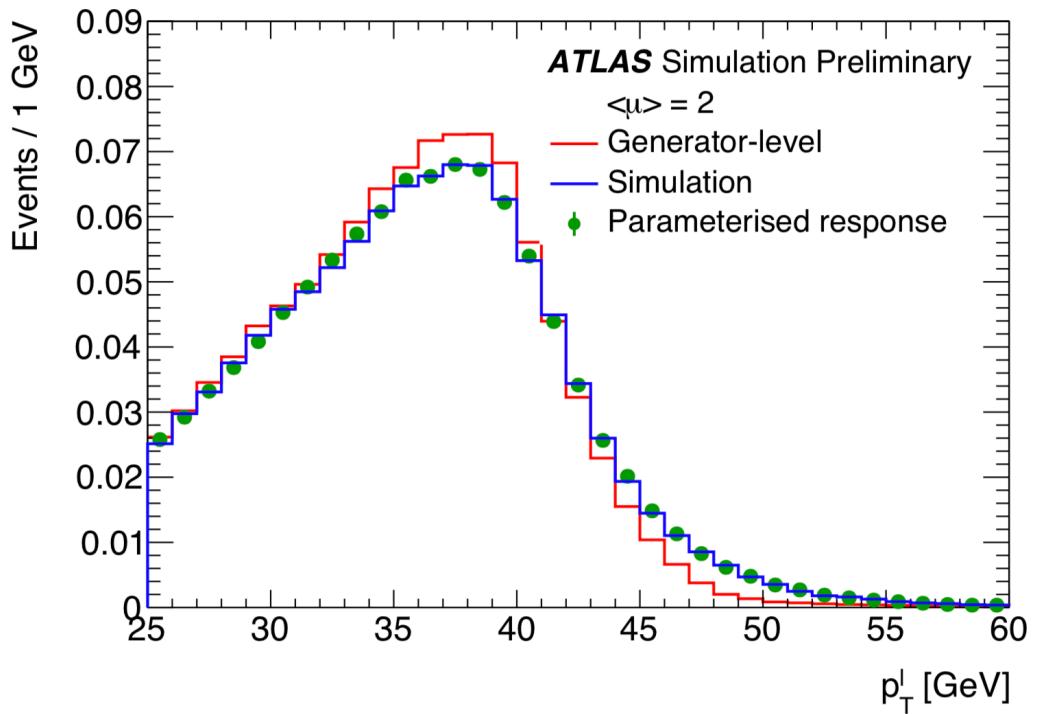
Powheg+Pythia8 signal samples Wenu: different PDF variation, different PDFsets

# Detector effects

Methodology: - smear truth level input distributions using simplified parameterisations to mimic detector effects.

$$\begin{aligned}\sigma_e(E_\ell) &= a(|\eta_\ell|)\sqrt{E_\ell} \oplus b(|\eta_\ell|) \oplus c(|\eta_\ell|) \cdot E_\ell, \\ \sigma_\mu(p_T^\ell) &= r_0(|\eta_\ell|) \oplus r_1(|\eta_\ell|) \cdot p_T^\ell, \\ \sigma_{u_T}(p_T^W, s) &= q_0 \cdot (s/s_0)^\alpha + q_1 \sqrt{p_T^W};\end{aligned}$$

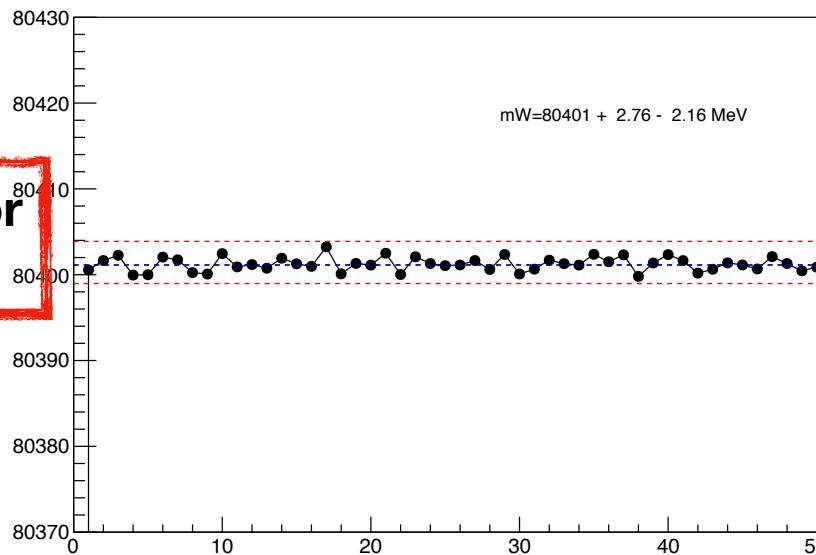
- Construct mW templates, vary PDFs, check impact on mW



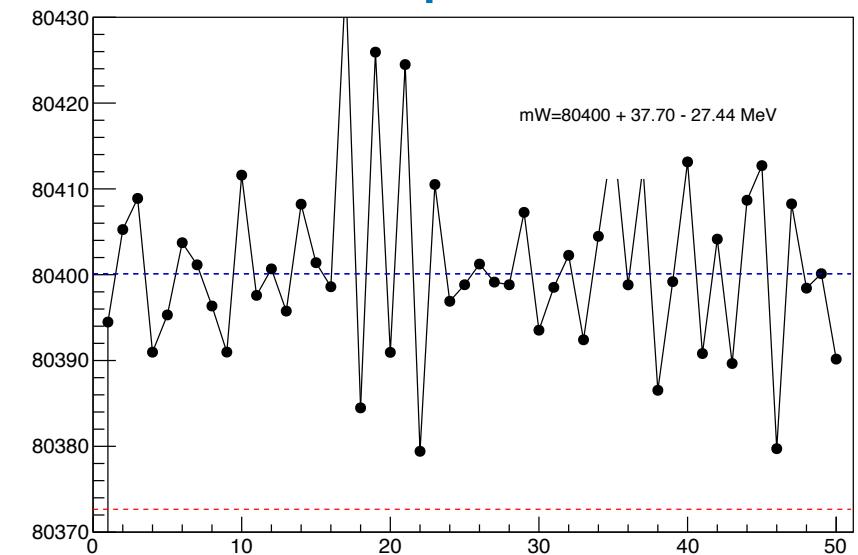
# Example of PDF effects (CT10nnlo)

mT

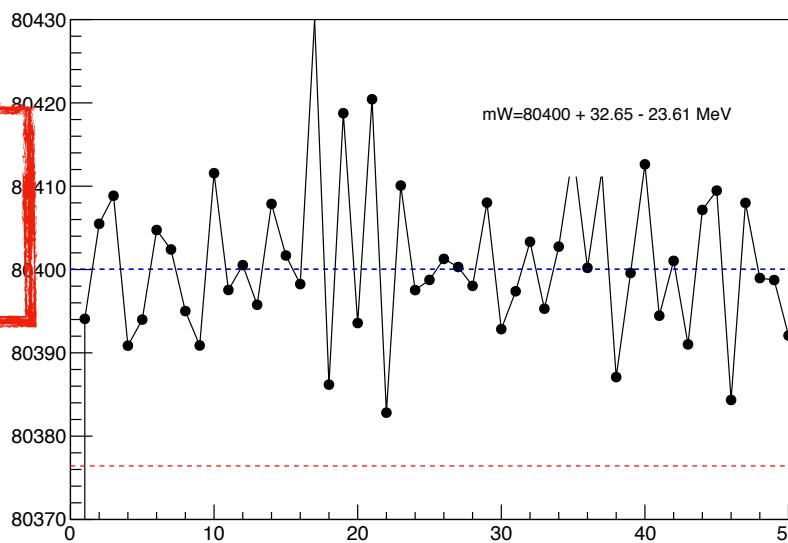
Generator  
Level



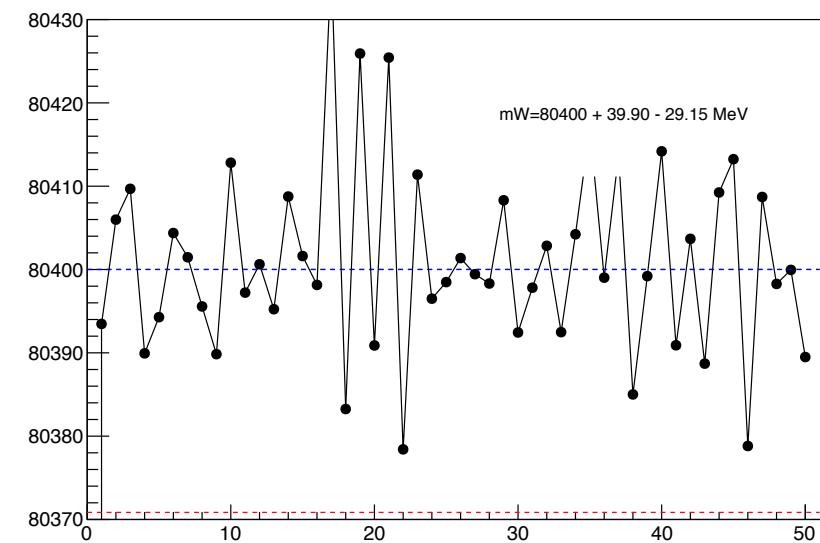
pT<sub>I</sub>



After  
detector  
effects



$mW = 80400 + 39.90 - 29.15 \text{ MeV}$

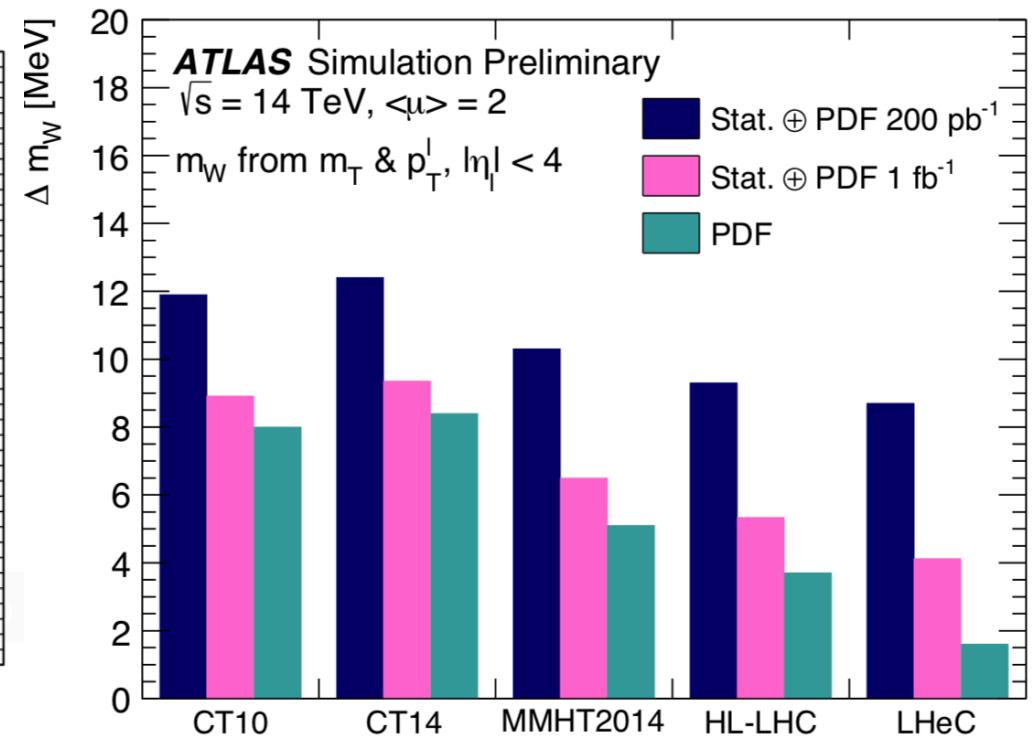
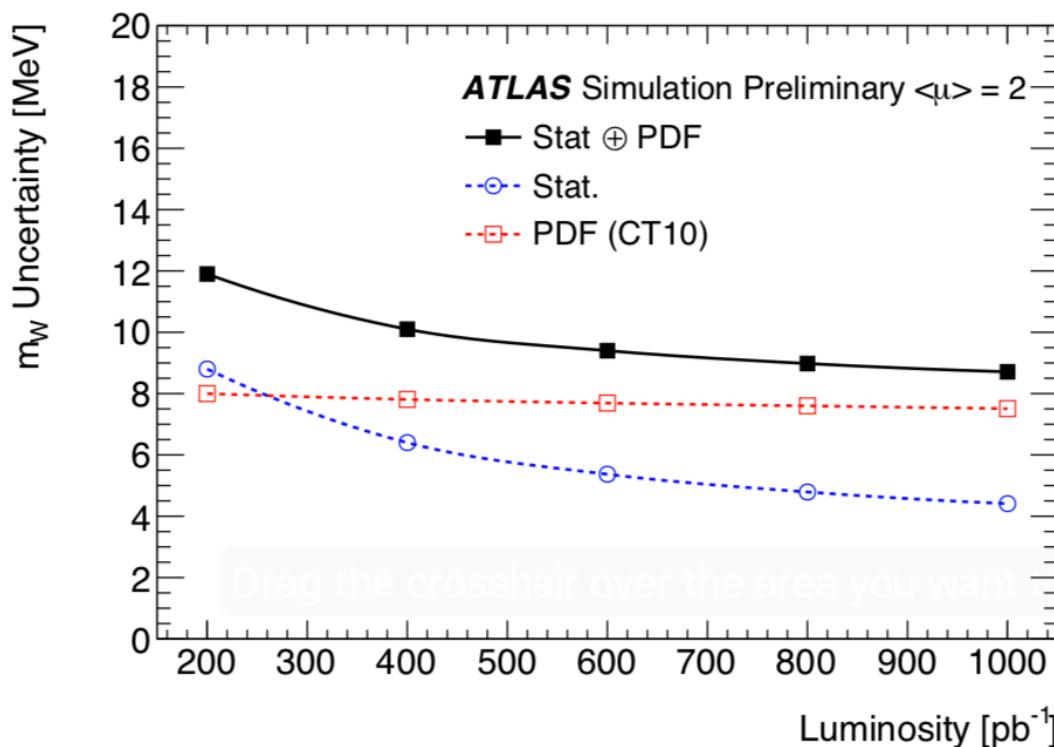


Factor 10 between born and smeared for mT, small effect from smearing on pT<sub>I</sub>

**HL-LHC/HE-LHC**

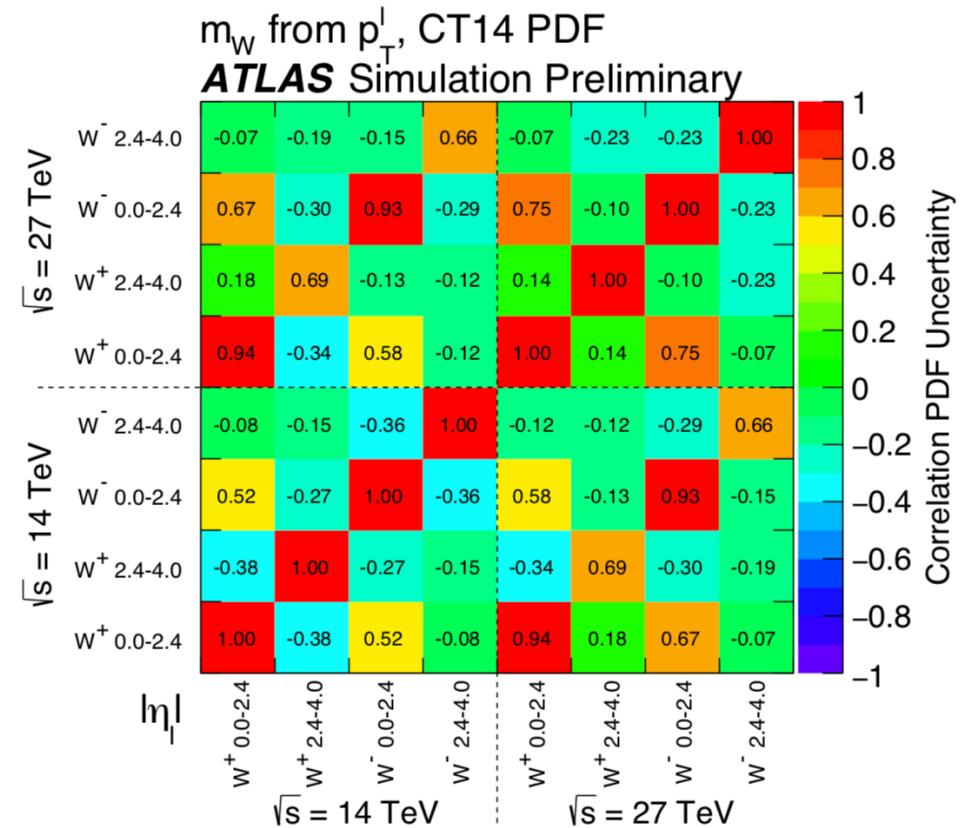
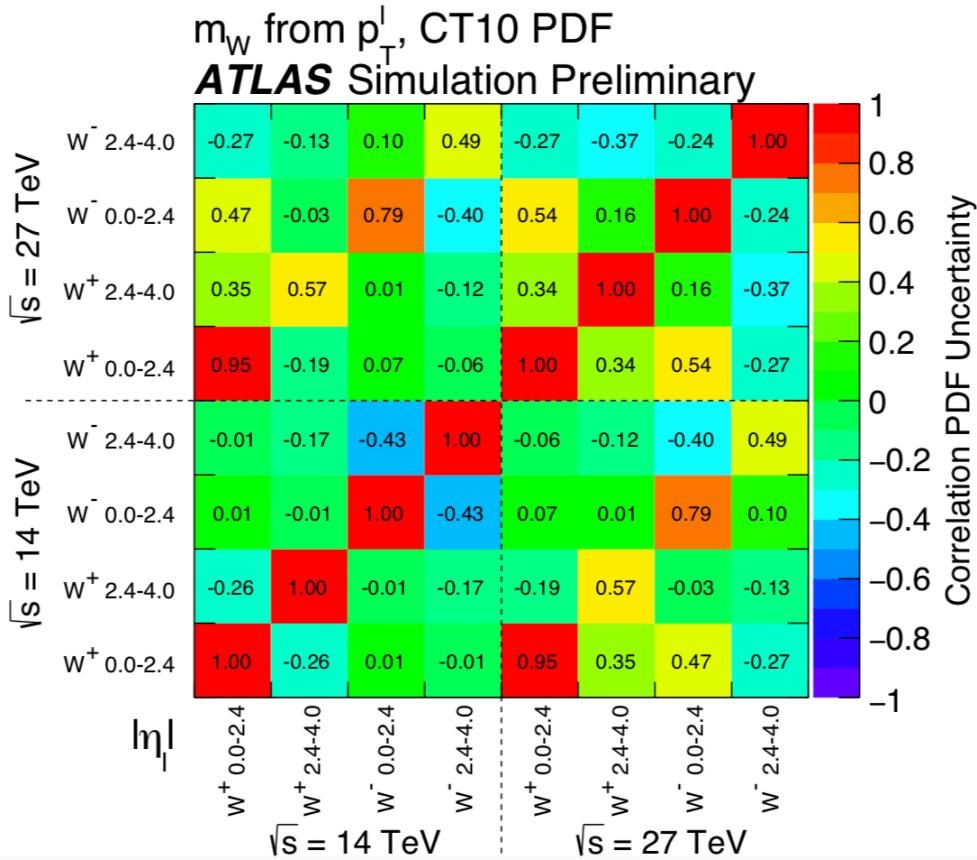
# PDF uncertainties

Consider pp collision data at low pile-up at the HL-LHC and HE-LHC benefiting from the [extended acceptance of the tracking detector](#) (ITk) up to  $|\eta| \sim 4$ .



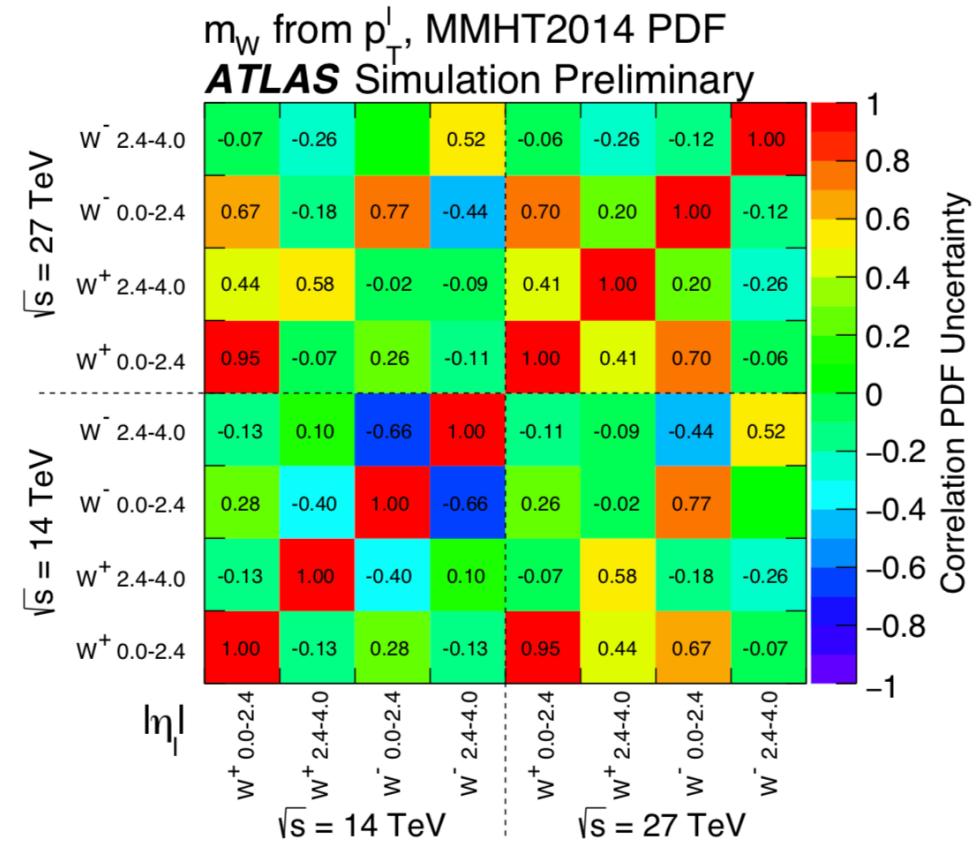
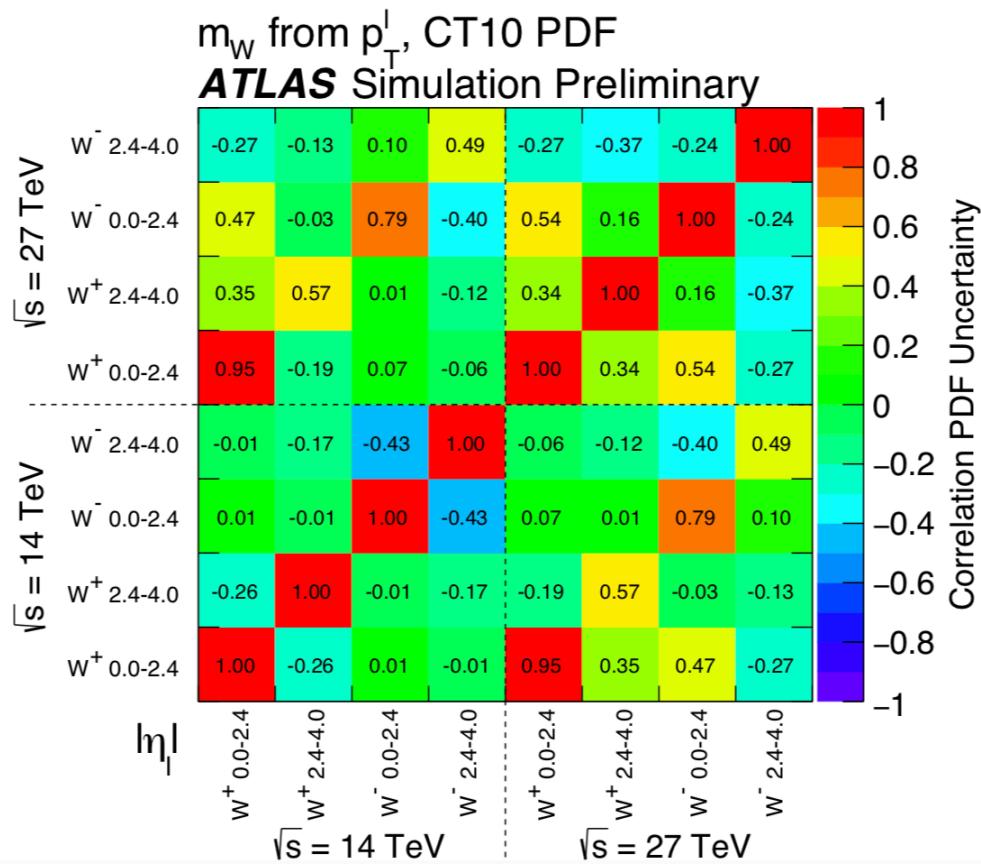
CT10 and CT14 sets have similar uncertainties, MMHT2014 30% lower. HL-LHC PDF sets provide a reduction by a factor of 2 compared to CT10. The LHeC PDF sets reduce the uncertainty by a factor 5-6 compared to CT10.

# PDF uncertainty correlations in CT10 and CT14



Similar general behaviour. Slightly stronger anti-correlation between 0-2.4 and 2.4-4 ( $W^+$  13 TeV) in CT14 (-0.38 instead of -0.26). But main difference positive correlation between  $W^+$  and  $W^-$  for  $\eta < 2.4$  (0.52 instead of 0.01)

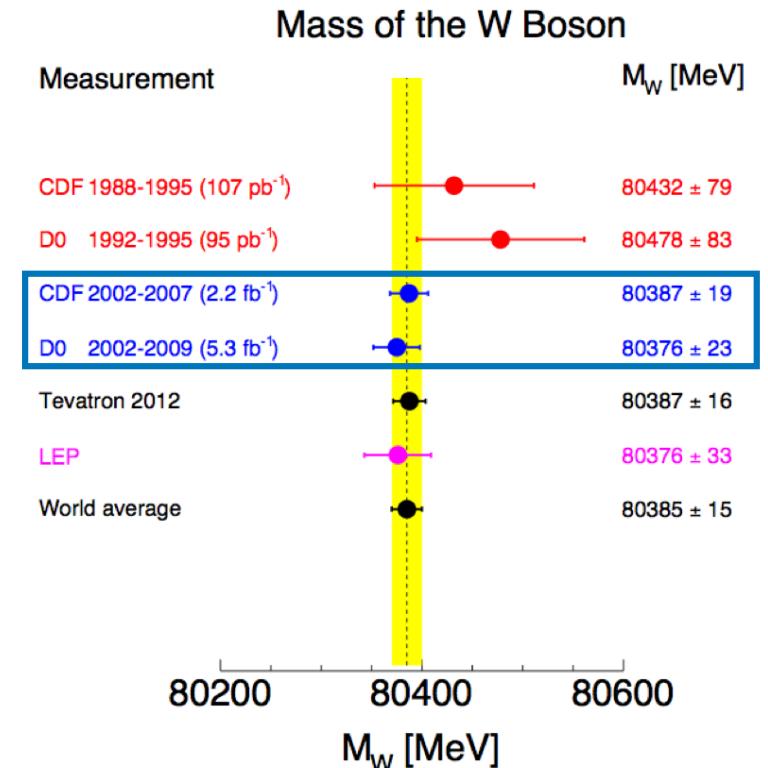
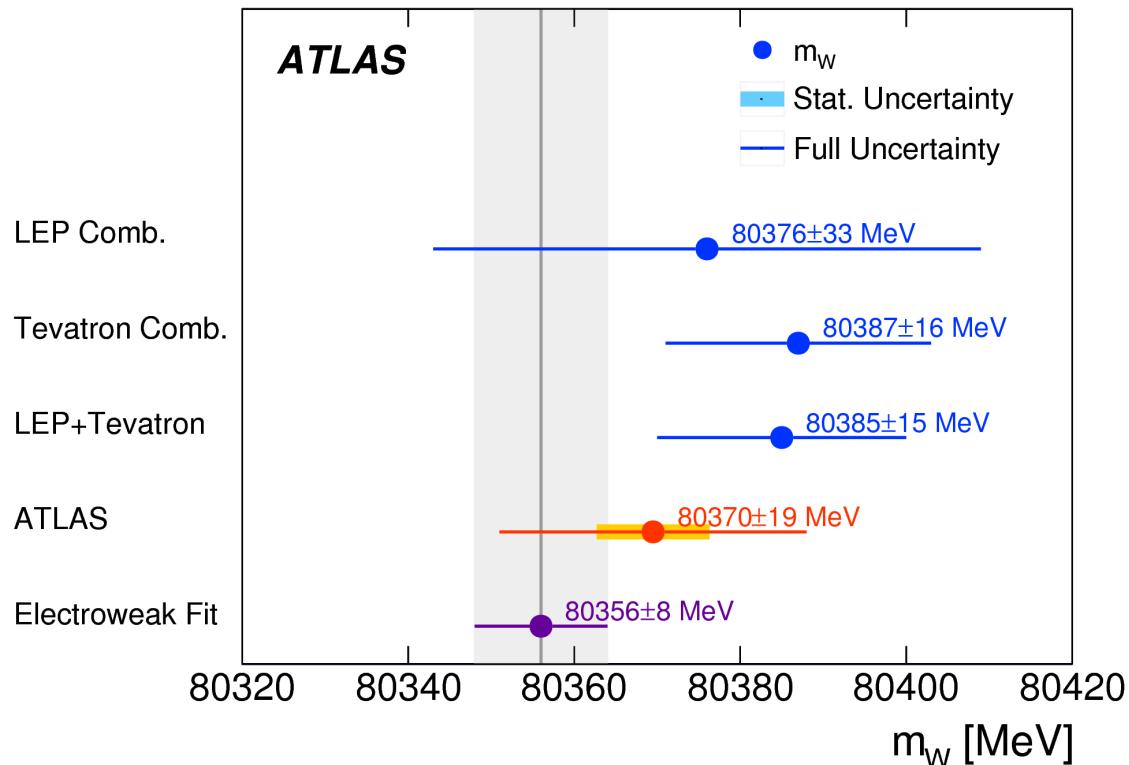
# PDF uncertainty correlations in CT10 and MMHT2014



Similar general behaviour. Weaker anti-correlation between 0-2.4 and 2.4-4 ( $W^+$  13 TeV) in MMHT14 (-0.13 instead of -0.26). But main difference positive correlation between  $W^+$  and  $W^-$  for  $\eta < 2.4$  (0.28 instead of 0.01)

## **ATLAS-Tevatron combination**

# ATLAS-Tevatron combination



Aim: provide a new world average value combining the existing public results

Published results

Tevatron result  
CTEQ6.6

ATLAS result  
CT10

CMS,  
LHCb...

Common PDF set

$\delta m_W$  (Tevatron)

$\delta m_W$  (ATLAS)

Correlation  
 $\rho$

Combined results

**mw combined**

**Selection cuts**

CDF

$30 < p_t^{l,v} < 55 \text{ GeV}$ ,  
 $60 < m_T < 100 \text{ GeV}$ ,  
 $u_T < 15 \text{ GeV}$ ,  $|\eta| < 1$

ATLAS

$p_t^{l,v} > 30 \text{ GeV}$ ,  
 $m_T > 60 \text{ GeV}$ ,  
 $u_T < 30 \text{ GeV}$ ,  $|\eta| < 2.4$

## 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.

*Will quote combined values for various PDF set; final envelope to be defined*

## 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 ( $pT, y, A_i$ )
- Emulate the published measurements: smear truth-level distributions using simplified parameterisations to mimic detector effects

# Emulation approach

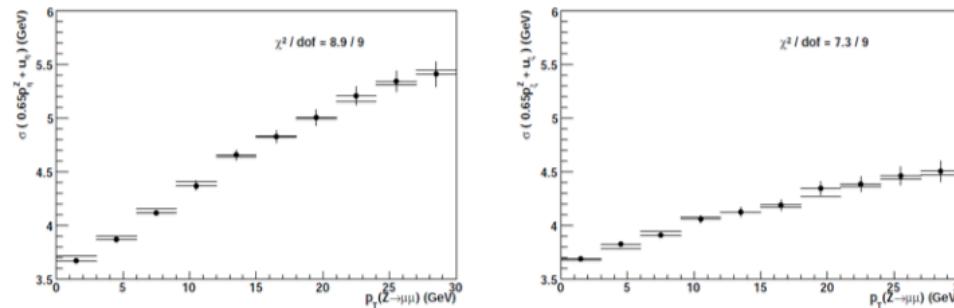
Use Powheg to simulate 1.96 TeV pp-bar and 7 TeV pp with a baseline PDF: CT10  
Compute PDF weights for CTEQ6.6, CT14, MMHT, NNPDF3.1

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/lhcnewwg/lhcnewwg-precisionEW/mwcombinations>

- CDF

1.96 TeV

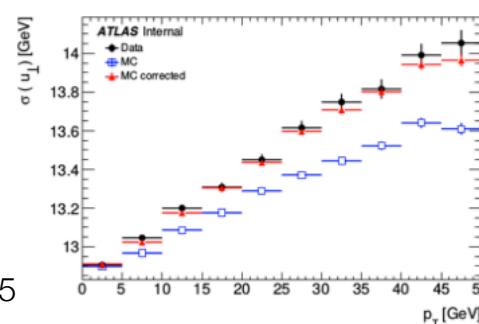
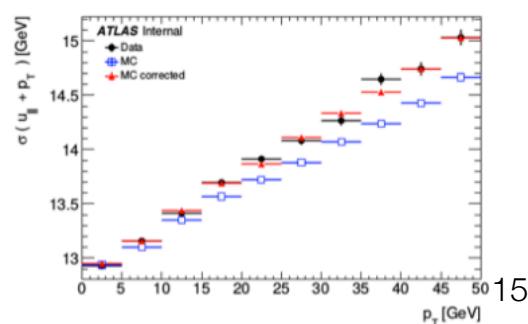


$u_{\text{PAR}}$

$u_{\text{PERP}}$

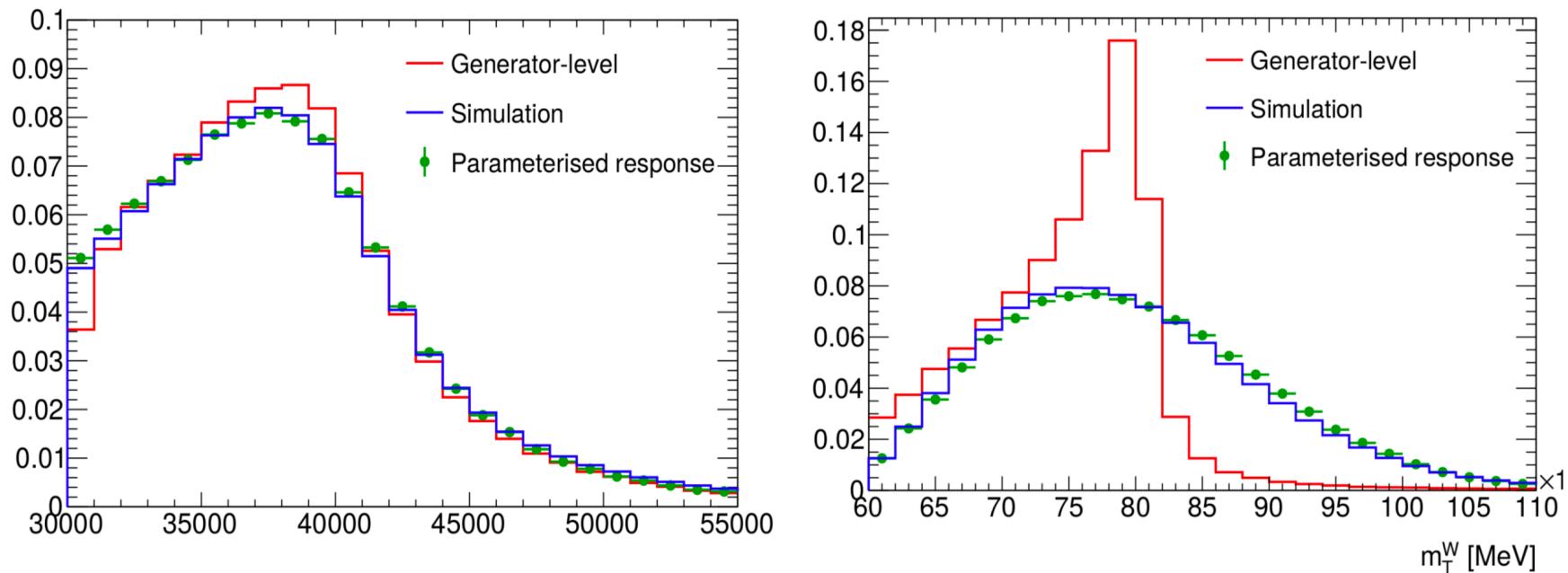
- ATLAS

7 TeV,  
 $\langle \mu \rangle \sim 9$



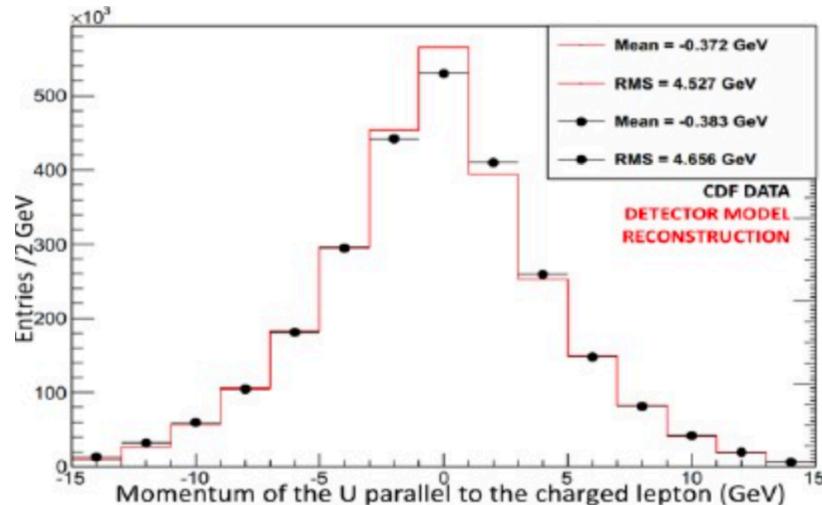
# Validation of smearing corrections for ATLAS at 7 TeV

Not perfect agreement but reasonable for a first check



# Parameterised CDF simulation

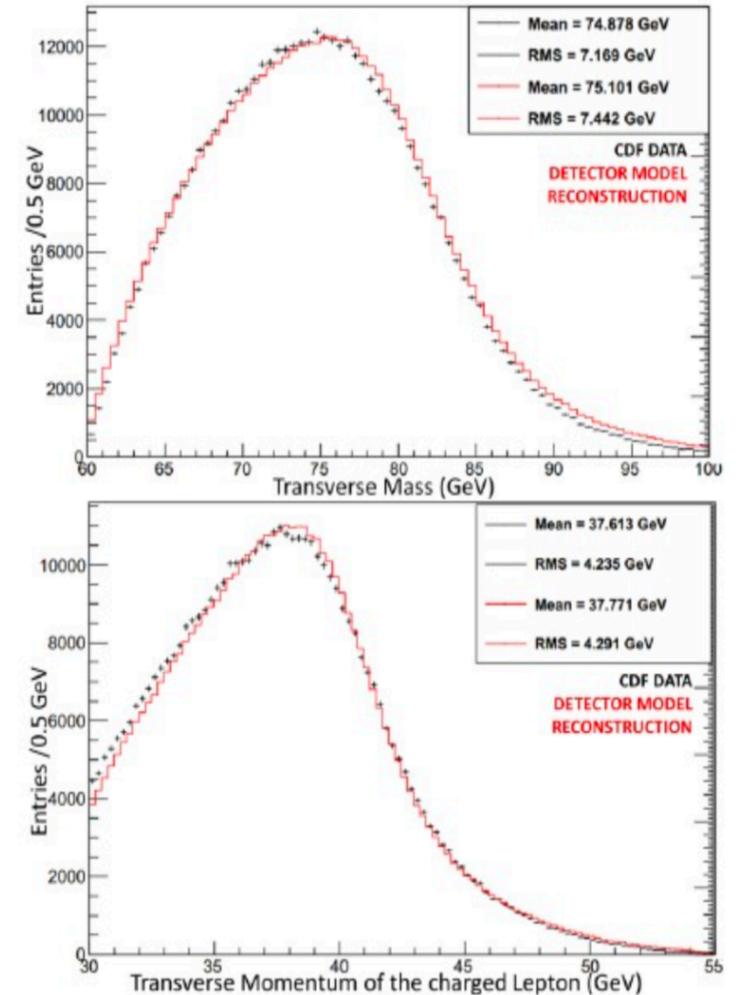
Parametric simulation based on that used for mW



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



pTl observable

Correlations  
Preliminary

CT10	1.	2.	3.	4.
1. W <sup>+</sup> 2 TeV	1	0.99	0.26	0.51
2. W <sup>-</sup> 2 TeV	0.99	1	0.31	0.52
3. W <sup>+</sup> 7 TeV	0.26	0.31	1	-0.23
4. W <sup>-</sup> 7 TeV	0.51	0.52	-0.23	1

CTEQ6.6	1.	2.	3.	4.
1. W <sup>+</sup> 2 TeV	1	1	0.37	0.45
2. W <sup>-</sup> 2 TeV	1	1	0.36	0.46
3. W <sup>+</sup> 7 TeV	0.37	0.36	1	-0.42
4. W <sup>-</sup> 7 TeV	0.45	0.46	-0.42	1

W<sup>+</sup> pp-bar 2 TeV more correlated to W<sup>-</sup> pp 7 TeV than to W<sup>+</sup> (effects from different x?)

Few % stat uncertainties to be evaluated<sup>8</sup> on the correlations

mT observable

**Correlations**  
**Preliminary**

CT10	1.	2.	3.	4.
1. W <sup>+</sup> 2 TeV	1	0.99	0.19	0.55
2. W <sup>-</sup> 2 TeV	0.99	1	0.22	0.56
3. W <sup>+</sup> 7 TeV	0.19	0.22	1	-0.30
4. W <sup>-</sup> 7 TeV	0.55	0.56	-0.30	1

CTEQ6.6	1.	2.	3.	4.
1. W <sup>+</sup> 2 TeV	1	1	0.32	0.50
2. W <sup>-</sup> 2 TeV	1	1	0.31	0.52
3. W <sup>+</sup> 7 TeV	0.32	0.31	1	-0.42
4. W <sup>-</sup> 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

**Large shifts observed +8 MeV going from CTEQ6.6 to CT10**

## Stat uncertainties and mw values

Assume:  $m_W = 80387$  for Tevatron and  $m_W = 80370$  for ATLAS

### CDF

Distribution	$W$ -boson mass (MeV)	$\chi^2/\text{dof}$
$m_T(e, \nu)$	$80\,408 \pm 19_{\text{stat}} \pm 18_{\text{syst}}$	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  $e/\mu \rightarrow 13.67$  ( $pT$ ) and  $12.24$  ( $mT$ )  
 $pT+$ : 19.33 ,  $pT-$ : 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

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

## mW uncertainties (MeV)

<b>2 TeV CTEQ6.6</b>	$p_T^{l+}$	$p_T^{l-}$	$m_T^+$	$m_T^-$	$pT\&mT$
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

<b>2 TeV CT10</b>	$p_T^{l+}$	$p_T^{l-}$	$m_T^+$	$m_T^-$	$pT\&mT$
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)

<b>7 TeV CTEQ 6.6</b>	$p_T^{l+}$ 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	$m_T^{l+}$ Eta 1	$m_T^{l-}$ Eta 1	$m_T^{l+}$ Eta 2	$m_T^{l-}$ Eta 2	$m_T^{l+}$ Eta 3	$m_T^{l-}$ Eta 3	$m_T^{l+}$ Eta 4	$m_T^{l-}$ Eta 4	<b><math>p_T \&amp;</math> <math>m_T</math></b>
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

<b>7 TeV CT10</b>	$p_T^{l+}$ 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	$m_T^{l+}$ Eta 1	$m_T^{l-}$ Eta 1	$m_T^{l+}$ Eta 2	$m_T^{l-}$ Eta 2	$m_T^{l+}$ Eta 3	$m_T^{l-}$ Eta 3	$m_T^{l+}$ Eta 4	$m_T^{l-}$ Eta 4	<b><math>p_T \&amp;</math> <math>m_T</math></b>
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

In agreement with the published result (worse because no pTZ constraint is yet applied)

## mW uncertainties (MeV)

2 TeV pT&mT	CTEQ6.6 /1.645	CT10 /1.645	MSTW2008 90%	MSTW2008 68%
Stat	9.4*	9.7*	10.1*	9.2*
PDF	12.9	14.3	20.3	9.4
Total	16.0	17.3	22.7	13.1

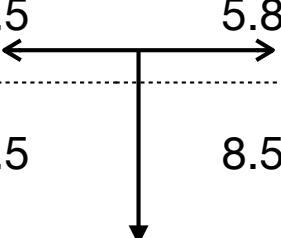
**2.16**

**Compatible with the scaling factor from Tevatron 2.15**

If scaled by 2.16, CTEQ6.6 number will be 9.82 compatible with MSTW2008 and with the published Tevatron result

## mW uncertainties (MeV)

7 TeV pT&mT	CTEQ6.6 /1.645	CT10 /1.645	MSTW2008 90%	MSTW2008 68%
Stat	6.8	7.4	7.1	6.1
PDF	8.4	10.0	11.5	5.8
Total	10.8	12.5	13.5	8.5

  
**1.98**

MSTW PDF uncertainties: 1.7 factor smaller than CT10 for 7 TeV

# Correlations

## Preliminary

MSTW	1.	2.	3.	4.
1. W <sup>+</sup> 2 TeV	1	1	0.04	0.66
2. W <sup>-</sup> 2 TeV	1	1	0.08	0.62
3. W <sup>+</sup> 7 TeV	0.04	0.08	1	-0.48
4. W <sup>-</sup> 7 TeV	0.66	0.62	-0.48	1
CT10	1.	2.	3.	4.
1. W <sup>+</sup> 2 TeV	1	0.99	0.26	0.51
2. W <sup>-</sup> 2 TeV	0.99	1	0.31	0.52
3. W <sup>+</sup> 7 TeV	0.26	0.31	1	-0.23
4. W <sup>-</sup> 7 TeV	0.51	0.52 <sub>26</sub>	-0.23	1

Loss of correlation between W<sup>+</sup> 2 and 7 TeV with MMHT while still present for W-

## Conclusions

- Machinery in place for the combination and evaluation of PDF uncertainties
- Smearing procedure in place to estimate PDF uncertainties (important effect for mT, factor of 10 difference between Born-level and emulated reco-level)
- Different W+/- correlations between different PDF sets observed
- Stronger correlation between W+ 2 TeV and W- 7 TeV observed
- MSTW2008 scaling factor 2.15 different from CT10 1.645 reproduced

## Next steps

- Reupdate results with the parameterisations from Tevatron
- Improve the parameterisations for ATLAS 7 TeV
- Evaluate the correlations and the mW combined value and uncertainty for other PDF sets. Agreed on CT14, MMHT, and NNPDF3.1. Define an envelope uncertainty.

## **Backup slides**

# PDF uncertainty correlations

Channel	$\eta_\ell$ range	$\sqrt{s}$ [TeV]		1.	2.	3.	4.	5.	6.	7.	8.
$W^+$	0–2.4	14	1.	1	-0.26	0.01	-0.01	0.95	0.35	0.47	-0.27
$W^+$	2.4–4	14	2.	-0.26	1	-0.01	-0.17	-0.19	0.57	-0.03	-0.13
$W^-$	0–2.4	14	3.	0.01	-0.01	1	-0.43	0.07	0.01	0.79	0.10
$W^-$	2.4–4	14	4.	-0.01	-0.17	-0.43	1	-0.06	-0.12	-0.40	0.49
$W^+$	0–2.4	27	5.	0.95	-0.19	0.07	-0.06	1	0.34	0.54	-0.27
$W^+$	2.4–4	27	6.	0.35	0.57	0.01	-0.12	0.34	1	0.16	-0.37
$W^-$	0–2.4	27	7.	0.47	-0.03	0.79	-0.40	0.54	0.16	1	-0.24
$W^-$	2.4–4	27	8.	-0.27	-0.13	0.10	0.49	-0.27	-0.37	-0.24	1

Channel	$\eta_\ell$ range	$\sqrt{s}$ [TeV]		1.	2.	3.	4.	5.	6.	7.	8.
$W^+$	0–2.4	14	1.	1	-0.38	0.52	-0.08	0.94	0.18	0.67	-0.07
$W^+$	2.4–4	14	2.	-0.38	1	-0.27	-0.15	-0.34	0.69	-0.30	-0.19
$W^-$	0–2.4	14	3.	0.52	-0.27	1	-0.36	0.58	-0.13	0.93	-0.15
$W^-$	2.4–4	14	4.	-0.08	-0.15	-0.36	1	-0.12	-0.12	-0.29	0.66
$W^+$	0–2.4	27	5.	0.94	-0.34	0.58	-0.12	1	0.14	0.75	-0.07
$W^+$	2.4–4	27	6.	0.18	0.69	-0.13	-0.12	0.14	1	-0.10	-0.23
$W^-$	0–2.4	27	7.	0.67	-0.30	0.93	-0.29	0.75	-0.10	1	-0.23
$W^-$	2.4–4	27	8.	-0.07	-0.19	-0.15	0.66	-0.07	-0.23	-0.23	1

Channel	$\eta_\ell$ range	$\sqrt{s}$ [TeV]		1.	2.	3.	4.	5.	6.	7.	8.
$W^+$	0–2.4	14	1.	1	-0.13	0.28	-0.13	0.95	0.44	0.67	-0.07
$W^+$	2.4–4	14	2.	-0.13	1	-0.40	0.10	-0.07	0.58	-0.18	-0.26
$W^-$	0–2.4	14	3.	0.28	-0.40	1	-0.66	0.26	-0.02	0.77	0.00
$W^-$	2.4–4	14	4.	-0.13	0.10	-0.66	1	-0.11	-0.09	-0.44	0.52
$W^+$	0–2.4	27	5.	0.95	-0.07	0.26	-0.11	1	0.41	0.70	-0.06
$W^+$	2.4–4	27	6.	0.44	0.58	-0.02	-0.09	0.41	1	0.20	-0.26
$W^-$	0–2.4	27	7.	0.67	-0.18	0.77	-0.44	0.70	0.20	1	-0.12
$W^-$	2.4–4	27	8.	-0.07	-0.26	0.00	0.52	-0.06	-0.26	-0.12	1

# Uncertainty correlation

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

**EW**

**ATLAS**

	$W \rightarrow e\nu$		$W \rightarrow \mu\nu$	
	$p_T^\ell$	$m_T$	$p_T^\ell$	$m_T$
$\delta m_W$ [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	
	$p_T^\ell$	$m_T$	$p_T^\ell$	$m_T$	$p_T^\ell$	$m_T$	$p_T^\ell$	$m_T$
$\delta m_W$ [MeV]								
Fixed-order PDF uncertainty	<b>PDF</b>		13.1	14.9	12.0	14.2	8.0	8.7
AZ tune		<b>pTW</b>	3.0	3.4	3.0	3.4	3.0	3.4
Charm-quark mass			1.2	1.5	1.2	1.5	1.2	1.5
Parton shower $\mu_F$ 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	<b>Ai</b>		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.