Experimental means to reduce theoretical uncertainties on M_W

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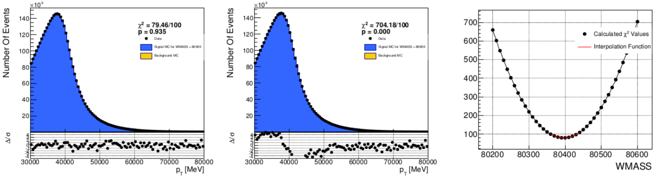
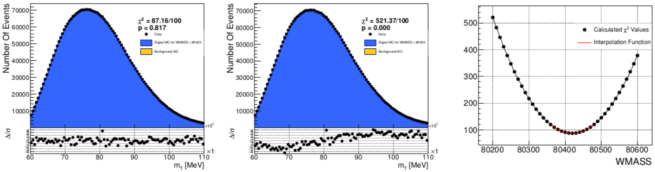
Measurement method

- The p_T^l, m_T^W are sensitive to precise M_W due to Jacobian peak:
$$p_T^l \sim M_W/2, m_T^W \sim m_W$$
- The p_T^l, m_T^W distributions are computed with MC for different M_W
- Each template is compared to data
- The value which maximizes binned likelihood agreement is prefered M_W



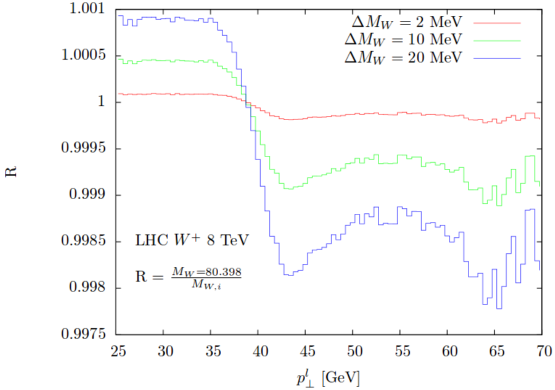
(a) p_T: Best fitting template (b) p_T: Worst fitting template (c) p_T: χ^2 distribution



- Sharper the Jacobian peak $\rightarrow$ better stat. precision of M_W

ptl sensitivity to M_W

- The p_T^l is most sensitive to M_W at LHC



A. Vicini et al.
Link

- PDF uncertainties that induce a change in p_T^l shape represent a systematic uncertainty on the M_W determination
- PDF uncertainties can be propagated to ΔM_W through the template fit method

PDF systematics with nominal PDFs

- CT10nnlo, central set for templates
- 25*2 orthogonal eigensets used as pseudo-data. Each pair corresponding to a $\pm 1\sigma$ variation of the corresponding fitted PDF parameter
- For each variation ($1 \leq i \leq 50$): $\Delta m_W^i = m_W^i - m_W^0$
- Total positive uncertainty: $\Delta m_W^2 = \sum_{\Delta m_W^i > 0} (\Delta m_W^i)^2$
- Total negative uncertainty: $\Delta m_W^2 = \sum_{\Delta m_W^i < 0} (\Delta m_W^i)^2$
- Symmetrized, linearized uncertainties ($0 \leq i \leq 24$):

$$\Delta m_W^i = (m_W^{2i+1} - m_W^{2i+2})/2 \qquad \Delta m_W^2 = \sum_i (\Delta m_W^i)^2$$

PDF systematics

Generator level(LHC 8TeV, CT10)

Vicini et al.

Selection criteria:

$p_T^l > 25 GeV$

$\not{E}_T > 25 GeV$

$|\eta| < 2.5$

With detector effects(LHC 7TeV, CT10nnlo)

→Smoothing Jacobian peak due to

- Energy resolution
- recoil resolution

Selection criteria:

$p_T^l > 30 GeV$

$\not{E}_T > 30 GeV$

$|\eta| < 2.4$

$p_T^W < 30 GeV, m_T^W > 60 GeV$

Template Fit

$29 GeV < p_T^l < 49 GeV$

↓

$W^+ : \delta_{PDF} = 29 MeV$

$W^- : \delta_{PDF} = 26 MeV$

$30 GeV < p_T^l < 50 GeV$

↓

$W^+ : \delta_{PDF} = 21.4 MeV$

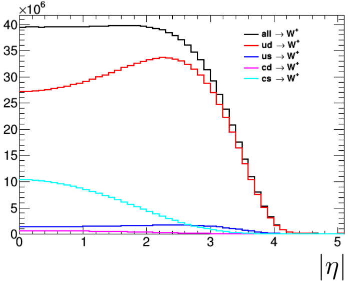
$W^- : \delta_{PDF} = 28.6 MeV$

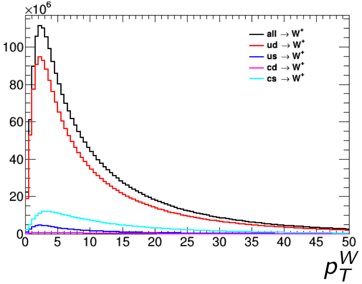
→ **How to improve?**

PDF uncertainty at the Tevatron: 10MeV(CDF) and 11MeV(D0)

Improving errors

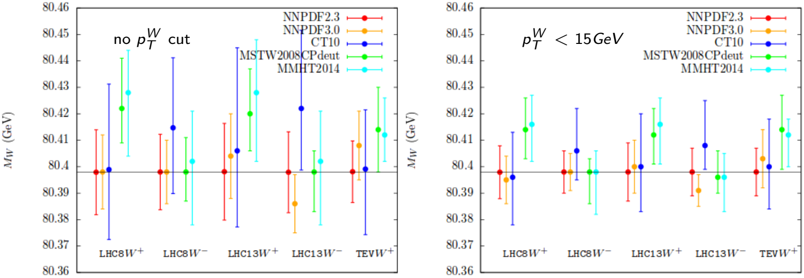
- Split W mass analyses selection into categories
- Recoil u and lepton pseudorapidity η are good for catigorization $\rightarrow$ PDF dependent
  - $\rightarrow$ W produced by sea quark - lepton with central $|\eta|$, by valence quark - forward leptons
  - $\rightarrow$ Less known *sc* contribution makes p_T^W to be harder
- Combine the PDF uncertainties from each category
  - $\rightarrow$ if not fully correlated, PDF error must be improved
- As alternative: one can use a category with least sensitivity to PDF(balanced with exp. error)





Expected improvemenets with p_T^W cut

- Studies are done for different PDF sets
- Approximate PDF reweighting: $w = \frac{f^{new}(x_1) \cdot g^{new}(x_2)}{f^{old}(x_1) \cdot g^{old}(x_2)}$
- Illustration of the PDF error improvement with $p_T^W < 15 GeV$ compared to no p_T^W cut
  - $\rightarrow$ Estimated PDF error $\sim 10 MeV$ for most advanced PDF set
  - $\rightarrow$ Difference larger between sets $\sim 20 - 30 MeV$
- PDF errors are bigger for W^+ than for W^-



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Expected improvemenets with η cuts

- Selection cuts: $p_T^l > 20GeV$, $\not{E}_T > 20GeV$, $p_T^W < 30GeV$
- m_T variable is used at reconstruction level: $\delta_{PDF}^{CT10} = 39MeV$ and $\delta_{PDF}^{CT10W} = 27MeV$
- η cuts: W^c : $|\eta| < 1.3$; W^f : $|\eta| > 1.6$

TABLE III: PDF errors on each sub-analysis, in MeV. Refer to Tab. II for errors on the naive analysis using all events.

	7 TeV		13 TeV	
	CT10	CT10W	CT10	CT10W
W_c^+	$^{+46}_{-32}$	$^{+39}_{-28}$	$^{+41}_{-30}$	$^{+36}_{-30}$
W_f^+	$^{+98}_{-102}$	$^{+68}_{-78}$	$^{+52}_{-52}$	$^{+41}_{-42}$
W_c^-	$^{+20}_{-14}$	$^{+17}_{-13}$	$^{+29}_{-23}$	$^{+27}_{-21}$
W_f^-	$^{+49}_{-57}$	$^{+37}_{-50}$	$^{+24}_{-35}$	$^{+19}_{-32}$

TABLE IV: Resulting error on the W mass after optimal sub-experiment weighting, in MeV.

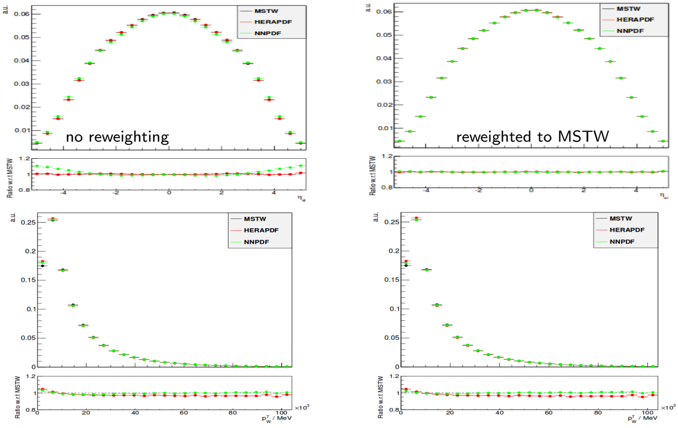
	CT10	CT10W
7 TeV	$^{+19}_{-12}$	$^{+15}_{-11}$
13 TeV	$^{+20}_{-22}$	$^{+17}_{-21}$

Z.Sullivan, S.Quackenbush Link

- Errors are larger for forward leptons compared to central, W^+ compared to W^-
- Improvement of about 60% from recombination

PDF reweighting

- PDF reweighted with $w = \frac{f^{new}(x_1) \cdot g^{new}(x_2)}{f^{old}(x_1) \cdot g^{old}(x_2)}$
- Works with η but does not recover p_T^W distribution



(a) No reweighting applied

(b) Reweighted to MSTW 2008

- We reweight the complete phase space in (p_T, Y) bins and A_i

Improving errors(ATLAS 7TeV)

- Break our analysis into $u < 15GeV$ and $15GeV < u < 30GeV$ bins, 4 lepton $|\eta|$ bins
- CT10nnlo PDF set, uncertainties are propagated with Hessian approach separately for each category

categories		$|\eta| < 0.8$	$0.8 < |\eta| < 1.4$	$1.4 < |\eta| < 2.0$	$2.0 < |\eta| < 2.4$
$p_T^W < 30GeV$	W^+	30.2	26.2	22.8	18.7
	W^-	34.4	32.1	31.6	37.4
$p_T^W < 15GeV$	W^+	29.9	26.2	22.8	19.1
	W^-	34.6	31.9	31.9	37.3
$15GeV < p_T^W < 30GeV$	W^+	31.3	26.5	23.5	18.8
	W^-	34.8	32.9	31.5	37.1

Table: PDF errors in each sub-analysis, in MeV

- Larger uncertainty for W^- compared to W^+(because of bigger fraction of *sc* that produce W)
- Smaller uncertaity for forward leptons

Improving errors(ATLAS 7TeV)

Summary Table

	Inclusive	4-eta	8-eta u	W+/W- 4 eta	W+/W- 8 eta-u
Stat Error	W+:7.8	W+: 7.8	W+: 7.7	5.8	5.8
	W-: 8.9	W-: 8.8	W-: 8.8		
Syst Error	W+: 21.4	W+: 18.3	W+: 18.4	18.1	18.2
	W-: 28.6	W-: 27.5	W-: 27.5		
Total Error	W+: 22.8	W+: 19.9	W+: 20.0	19.0	19.1
	W-: 30.0	W-: 28.9	W-: 28.9		

The gain in systematics is statistics dependent —> expected improvement of the pdf uncertainty with more statistics —> to do gain as a function of stat error

Effect of W,Z cross sections on the PDF uncertainties

- PDFs are constrained using new ATLAS data:
  - p_T^Z shape
  - W,Z cross-sections
- With new data the PDF uncertainties are reduced by $40 - 50\%$
- These are preliminary results

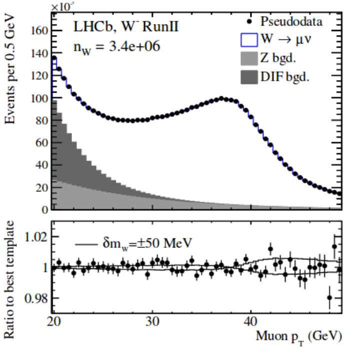
Uncertainty (MeV)		(pT,y)	Ai	Total
CT10	W+	17.5	14.4	21.4
	W-	19.2	15.9	28.6
CT10+ZPT	W+	12.1	13.9	18.8
	W-	13.1	15.4	24.2
CT10+ZPT+WZ	W+	8.6	9.8	11.8
	W-	9.0	11.0	17.1

Impact of forward muons in LHCb

- W mass measurement at the LHCb Link :
  - $\rightarrow$ based on p_T^μ, very forward muons $2 < |\eta| < 4.5$
  - $\rightarrow$ Able to select $W \rightarrow \mu\nu$ sample using knowledge about reconstructed muon
  - $\rightarrow$ Anti-correlated PDF uncertainties with those based on ATLAS and CMS

$$\delta_{\mathrm{PDF}} = \begin{pmatrix} \mathbf{G}^+ & 24.8 \\ \mathbf{G}^- & 13.2 \\ \mathbf{L}^+ & 27.0 \\ \mathbf{L}^- & 49.3 \end{pmatrix},$$

- Envelop of NNPDF3.0, MMHT2014 and CT10 sets is used
- $G^\pm$ are ATLAS/CMS PDF uncertainties(averaged in e and μ channels)
- $L^\pm$ are LHCb PDF uncertainties with forward muons
- Expected to increase precision of M_W at the LHC by factor 1.3 in the combination



Conclusions

- A few ways to reduce PDF uncertainties on the m_W measurement are considered
  - Tighter recoil cut
  - Different lepton $|\eta|$ regions
  - Recombination of each sub-analysis performed in $|\eta|$, recoil bins
- Results are compared to a few paper results
  - W^+/W^- PDF uncertainties $\rightarrow$ issue of PDF rewighting that does not catch p_T^W distribution?
- Small PDF errors reduction is found with recombination
- $40 - 50\%$ improvement taking into account new ATLAS data
- Expected m_W improvement with LHCb forward muons (but with Run2 data)

BACKUP