The impact of Parton Distributions in determinations of M_W in hadronic colliders

Juan Rojo

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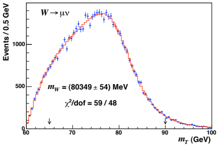
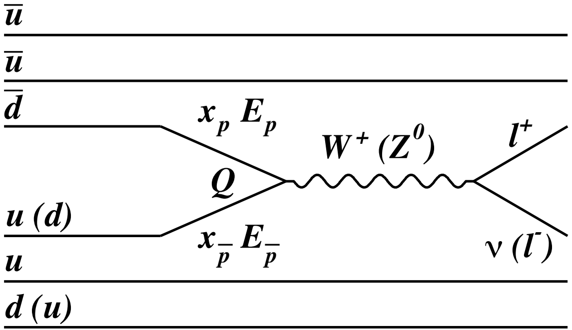


W mass workshop, 18/03/2009

PDFS IN M_W DETERMINATION

PDF dependence of W production

- At hadronic colliders, electroweak bosons (W/Z) are produced predominantly through $q_i\bar{q}_j$ scattering



PDF dependence of W production

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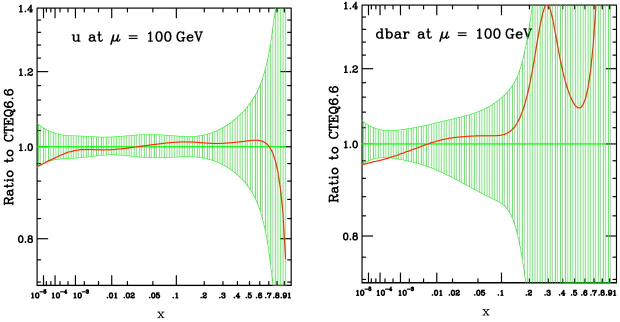
- The differential distributions, m_T^W, p_T^l, p_T^ν used to determine M_W are thus affected by (mostly quark) PDF uncertainties at $Q^2 = M_W^2$ (x-range depends on collider)
  M_W from shape of distributions $\rightarrow$ Reduced sensitivity to PDF normalizations



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- PDF uncertainties fully correlated between experiments and channels at same collider (Ex. CDF/D0) ?

PDF dependence of W production

PDF uncertainties contribution important at Tevatron

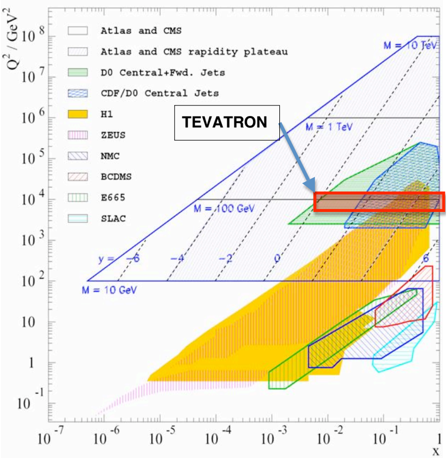
Estimations $\rightarrow$ $\delta_{M_W}^{\rm PDFs}\left(p_T^l\right) \sim 20$ MeV, $\delta_{M_W}^{\rm PDFs}\left(p_T^\nu\right) \sim 13$ MeV, $\delta_{M_W}^{\rm PDFs}\left(m_T^W\right) \sim 11$ MeV

CDF First Run II M_W measurement, Phys. Rev. D 77, 112001 (2008)

p_T Fit Uncertainties			
Source	$W \to \mu\nu$	$W \to e\nu$	Correlation
Tracker Momentum Scale	17	17	100%
Calorimeter Energy Scale	0	25	0%
Lepton Resolution	3	9	0%
Lepton Efficiency	6	5	0%
Lepton Tower Removal	0	0	0%
Recoil Scale	17	17	100%
Recoil Resolution	3	3	100%
Backgrounds	19	9	0%
PDFs	20	20	100%
W Boson p_T	9	9	100%
Photon Radiation	13	13	100%
Statistical	66	58	0%
Total	77	73	-

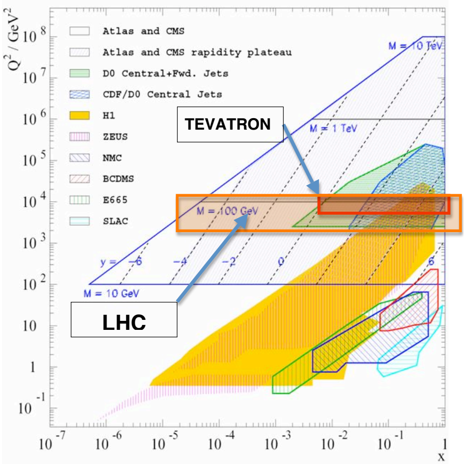
PDF dependence of W production

PDF effects are very different from Tevatron and LHC
Tevatron probes PDFs for $x \geq 10^{-3}$ ...



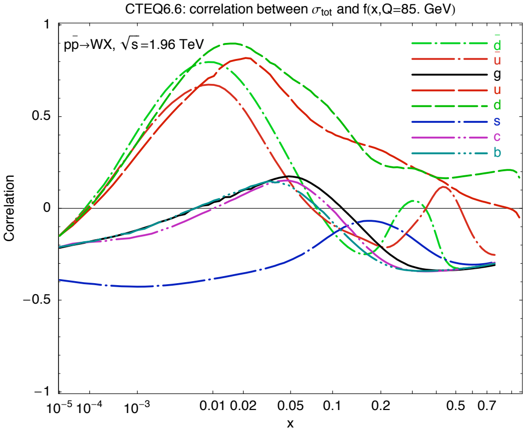
PDF dependence of W production

... while for LHC $x \geq 10^{-5}$ in W production
Small-x PDF evolution effects + larger PDF uncertainties



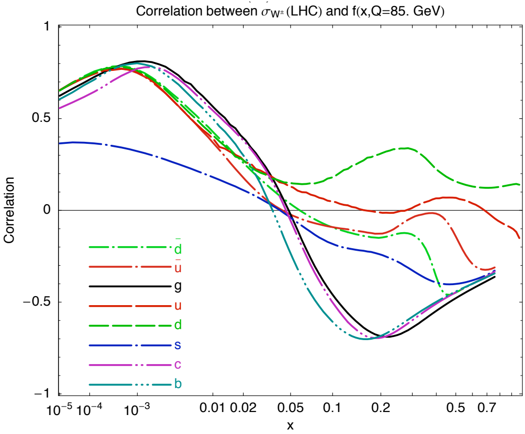
PDF dependence of W production

→ Small correlation at TeVatron between $\sigma(W^{\pm})$ and q_k $\left(x \le 10^{-3}, Q^2 = M_W^2\right)$ ...
(Nadolsky et al., CTEQ6.6 study)



PDF dependence of W production

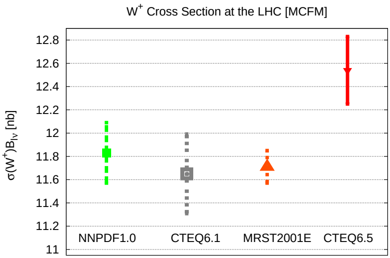
.. but sizable correlation at LHC between $\sigma(W^{\pm})$ and $q_k \left(x \leq 10^{-3}, Q^2 = M_W^2\right)$!
PDF effects for M_W determination, which are already important at TeVatron, could become dominant at the LHC

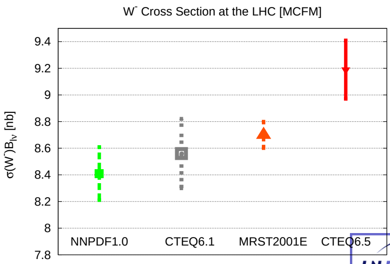


Recent developements in PDF analysis

1. CTEQ6.5/CTEQ6.6 (Phys.Rev.D78:013004,2008, JHEP 0702:053,2007)
   - General Mass treatment of heavy quark mass effects
   - Additional data sets, strange sector better determined
   - Study of phenomenological implications at colliders for W production

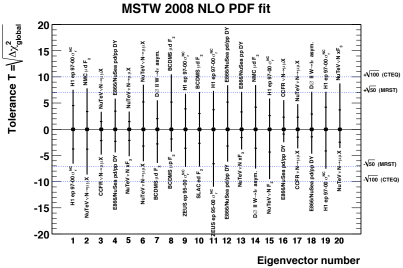
From ZM (CTEQ6.1) to GM (CTEQ6.6) $\rightarrow$ Sizable shift in $\sigma(W^{\pm})$ at LHC
Impact in M_W determination?

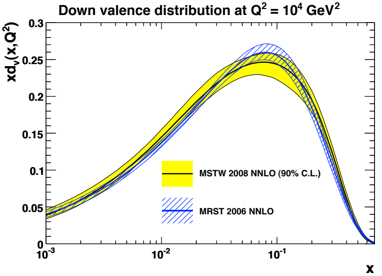




Recent developements in PDF analysis

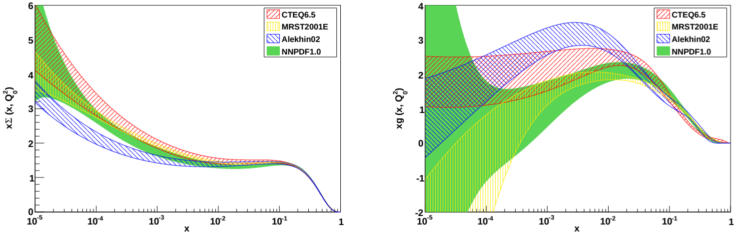
1. CTEQ6.5/CTEQ6.6
2. MSTW08 (arXiv:0901.0002)
   - New method for dynamical determination of tolerances T_i
   - Additional data sets, but PDF errors larger because enlarged PDF params.
   - Corrected wrong implementation of GM-VFN which affected all MRST sets before 2006 (including MRST2004QED)
   - Neglected experimental correlations in most datasets





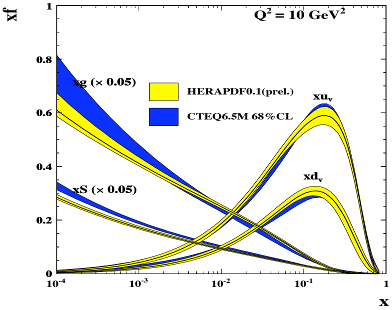
Recent developements in PDF analysis

1. CTEQ6.5/CTEQ6.6
2. MSTW08
3. NNPDF1.0 (Nucl.Phys.B809:1-63,2009), see later
   - Faithful determination of PDF errors from DIS data, ZM-VFN for HQ
   - Unbiased parametrizations (artificial neural networks)
   - No linear/gaussian approximations in error propagation



Recent developements in PDF analysis

1. CTEQ6.5/CTEQ6.6
2. MSTW08
3. NNPDF1.0
4. HERAPDF0.1 (arXiv:0901.2504)
   Reduced uncertainties at small-x from final combined HERA I data set
   Extremely restrictive parametrization (artificial error reduction?)



Recent developements in PDF analysis

1. CTEQ6.5/CTEQ6.6
2. MSTW08
3. NNPDF1.0
4. HERAPDF0.1
5. Others: AKP08, GJR08 (dynamical partons), ...

THE NNPDF APPROACH

The **NNPDF Collaboration**: R. D. Ball[1], L. Del Debbio[1], S. Forte[2], A. Guffanti[3], J. I. Latorre[4], A. Piccione[2], **Juan Rojo**[2], M. Ubiali[1]
[1]University of Edinburgh, [2] Università di Milano, [3]Albert-Ludwigs-Universität Freiburg, [4]Universitat de Barcelona

Issues in global PDF determinations

- Standard PDF determinations (CTEQ/MSTW) might be affected by several drawbacks:
  1. Fixed functional forms, $q_i(x, Q_0^2) = A_i x^{b_i} (1-x)^{c_i} (1 + \ldots)$.
     Are they flexible enough?
  2. Artificial large tolerances $\Delta\chi^2 \gg 1$
     Are they really needed due to incompatible data?
  3. Gaussian linear error propagation
     Is this really enough for all observables?
- Summary → Both the PDF input parametrization (and flavour assumptions) and the statistical treatment (value of $\Delta\chi^2$) need to be tuned to experimental data
- Situation not satisfactory, specially delicate to predict behaviour of PDFs in extrapolation regions like for the LHC at small-x
- Large tolerances → Error blow-up by a factor $S = \sqrt{\Delta\chi^2/2.7}$
  $\rightarrow S_{\rm cteq} \sim 6$, $S_{\rm mstw} \sim 4.5$ both in input data and in PDFs (B. Cousins, PDF4LHC)

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The NNPDF approach

- Generate $N_{\rm rep}$ Monte Carlo replicas $F_i^{(\mathrm{art})(k)}$ of the original data $F_i^{(\mathrm{exp})}$

$$F_i^{(\mathrm{art})(k)} = \left(1 + r_N^{(k)}\sigma_N\right)\left(F_i^{(\mathrm{exp})} + \sum_{p=1}^{N_{\rm sys}} r_p^{(k)}\sigma_{i,p} + r_i^{(k)}\sigma_{i,s}\right)$$

- Evolve each PDF parametrized with Neural Nets $q_\alpha^{(\mathrm{net})(k)}(x, Q_0^2)$

$$F_i^{(\mathrm{net})(\mathrm{k})}(x, Q^2) = C_{i\alpha}(x, \alpha(Q^2)) \otimes q_\alpha^{(\mathrm{net})(k)}\left(x, Q^2\right)$$

- Training: Minimize χ^2 using Genetic Algs. + Dynamical Stopping:

$$\chi^{2(k)} = \frac{1}{N_{\rm dat}} \sum_{i,j=1}^{N_{\rm dat}} \left(F_i^{(\mathrm{art})(k)} - F_i^{(\mathrm{net})(k)}\right)\left(\mathrm{cov}_{ij}^{-1}\right)\left(F_j^{(\mathrm{art})(k)} - F_j^{(\mathrm{net})(k)}\right)$$

- Set of trained NNs $\rightarrow$ Representation of the PDFs probability density

$$\left\langle \mathcal{F}\left[q_\alpha^{(\mathrm{net})}\right]\right\rangle = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} \mathcal{F}\left[q_\alpha^{(\mathrm{net})(k)}\right]$$

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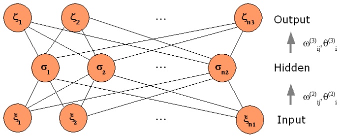
What are neural networks?

Each independent PDF at the initial scale $Q_0^2 = 2\mathrm{GeV}^2$ is parameterized by a multi-layered feed-forward neural network.



* Each neuron receives input from neurons in preceding layer.
* Activation determined by weights and thresholds according to a non linear function:

$$\xi_i = g\left(\sum_j \omega_{ij}\xi_j - \theta_i\right), \qquad g(x) = \frac{1}{1+e^{-x}}$$

In a simple case (1-2-1) we have,

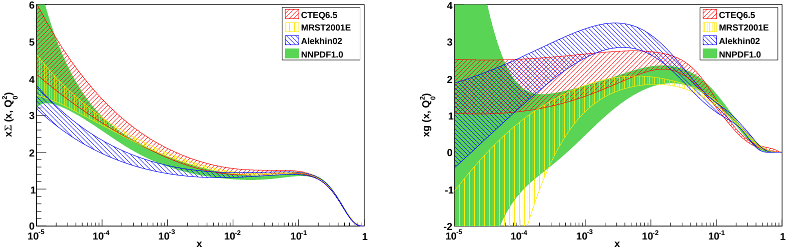
$$\xi_1^{(3)} = \frac{1}{1 + e^{\theta_1^{(3)} - \frac{\omega_{11}^{(2)}}{1+e^{\theta_1^{(2)} - \xi_1^{(1)}\omega_{11}^{(1)}}} - \frac{\omega_{12}^{(2)}}{1+e^{\theta_2^{(2)} - \xi_1^{(1)}\omega_{21}^{(1)}}}}}$$

7 parameters

...Just a convenient functional form which provides a redundant and flexible parametrization

Best fit to be independent of any assumptions in parametrization.

NNPDF: Results



- NNPDF1.0 → DIS data, ZM-VFN, 5 independent PDFs, $N_{\rm par} \sim 200$ free parameters (Nucl.Phys.B809:1-63,2009)
- NNPDF1.1 → Independent parametrizations for $s_{\pm}(x, Q_0^2)$ (arXiv:0811.2288)
- NNPDF1.2 → Strangeness determination from dimuon data (in progress)
- NNPDF2.0 → Global fit DIS + Drell-Yan + W/Z prod. + Jets (in progress)

PDFs AND M_W DETERMINATION
TOWARDS AN UPDATE

From kinematical distributions to M_W

New sets of PDFs with important updates → Timely to revisit the impact of PDF uncertainties in M_W determination at TeVatron and LHC

Strategy:

1. HORACE MC to generate the m_T^W distribution with recent PDF sets with uncertainties
2. Translate results into shifts of M_W due to PDFs, $\delta M_W^{\mathrm{PDFs}}$, with FITTER (See C. Carloni's talk)
3. Check distribution of M_W obtained from different PDF sets with uncertainties: Asymmetric/Non-gaussian effects? Shifts in M_W from different PDF sets compatible?

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New sets of PDFs with important updates → Timely to revisit the impact of PDF uncertainties in M_W determination at TeVatron and LHC

Strategy:

1. HORACE MC to generate the m_T^W distribution with recent PDF sets with uncertainties
2. Translate results into shifts of M_W due to PDFs, $\delta M_W^{\rm PDFs}$, with FITTER (See C. Carloni's talk)
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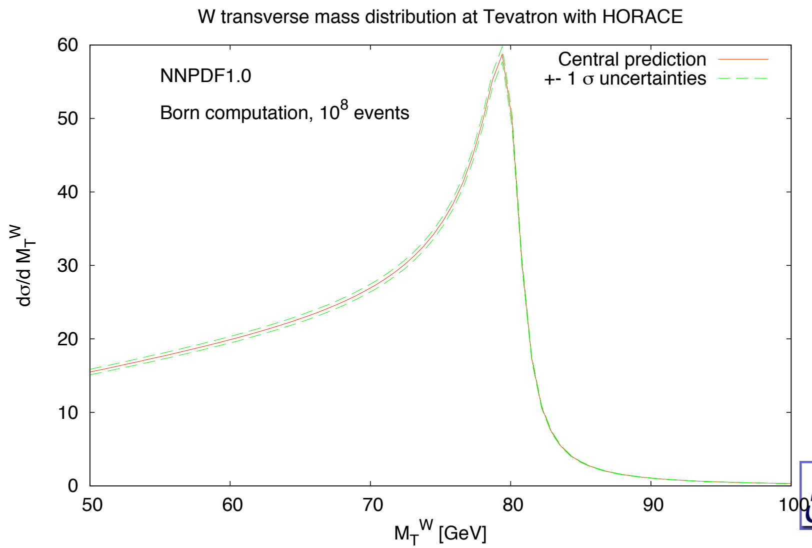
PDF dependence of M_T^W distribution - An update



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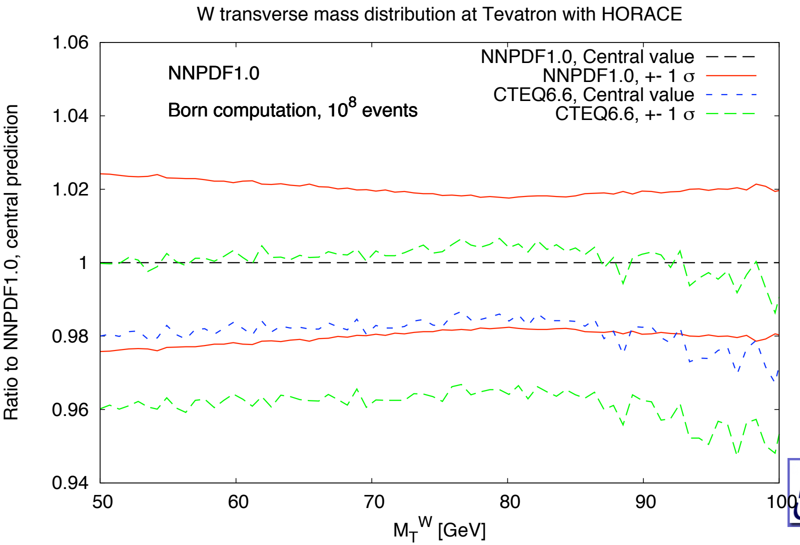

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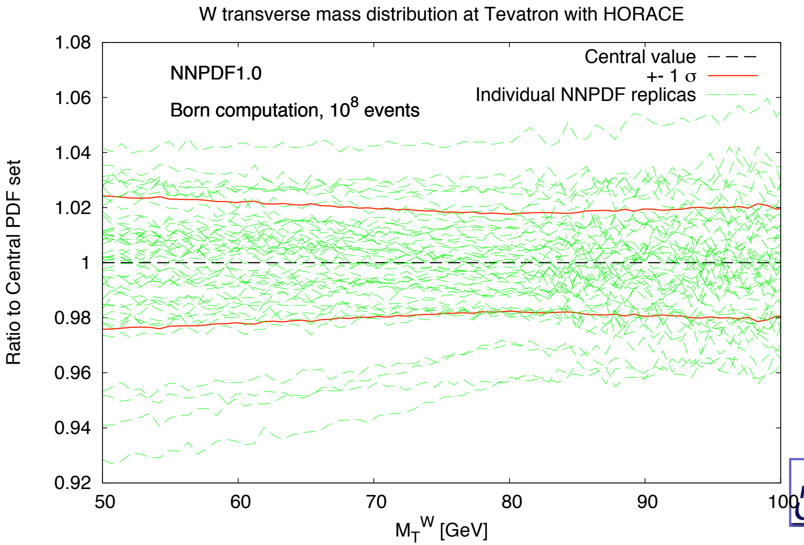

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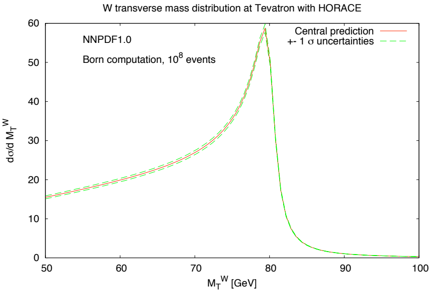
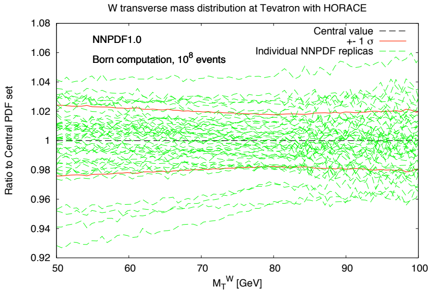


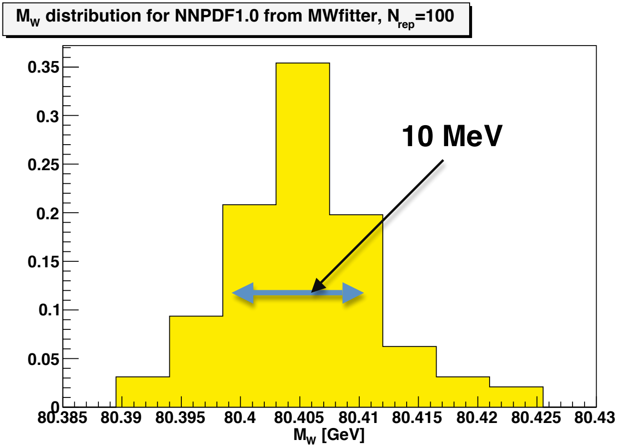


- Differences in shape and normalization in individual NNPDF replicas
- Determine M_W independently for each error PDF $M_W^{(k)}$ and compute uncertainties

$$\delta_{M_W}^{\mathrm{PDFs}}\Big|_{\mathtt{NNPDF}} = \left(\frac{1}{N_{\mathrm{rep}}-1} \sum_{k=1}^{N_{\mathrm{rep}}} \left(M_W^{(k)} - \langle M_W \rangle \right)^2 \right)^{1/2}$$

Effects in M_W determination - Preliminary

PDF uncertainty in m_T^W channel close to CDF estimate: $\delta_{M_W}^{\rm PDFs}\left(m_T^W\right) \sim 11$ MeV



Homework

This is not a conference but a **workshop** ....Thus we need to work!

1. Confirm FITTER results with higher accuracy templates
2. Generalize preliminary studies systematically to other PDF sets and other channels for M_W determination: p_T^l, p_T^ν
3. Study the (potentially different) situation at LHC
4. Single PDF set with photon PDF $\gamma(x, Q^2)$, MRST2004QED
   Need to update other sets (CTEQ/NNPDF) with QED effects?
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Now time for discussions!!

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