PDF Uncertainties in Top Production at the LHC

Elements for a discussion

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MOTIVATION

Issues in standard PDF determinations

- Standard PDF determinations suffer of 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. Artificially 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?
- Large tolerances $\to$ Error blow-up by a factor $S = \sqrt{\Delta\chi^2/2.7}$
  $\to S_{\rm cteq} \sim 6$, $S_{\rm mstw} \sim 4.5$ both in input data and in PDFs
- Summary $\to$ Both the PDF input parametrization (and flavour assumptions) and the statistical treatment (value of $\Delta\chi^2$) need to be tuned to experimental data ....
- ... which implies that adding more data sometimes results in no error reduction or even an increase of PDF uncertainties (MSTW, CQ09G)

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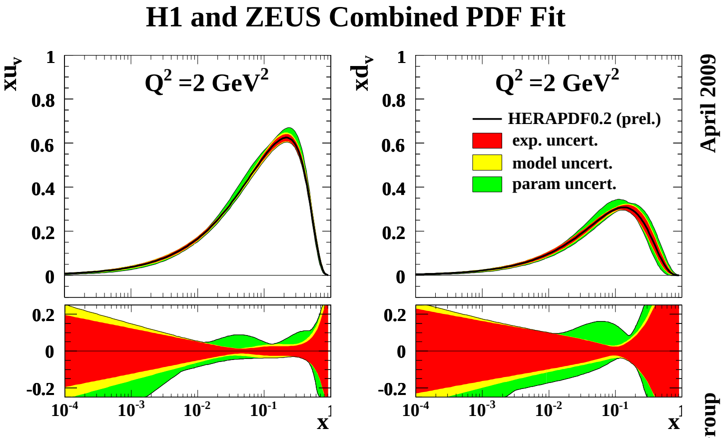
Issues in standard PDF determinations (II)

1. Recent analysys (Pumplin, arXiv:0904.2425) → No tension between datasets in the CTEQ analysis found which requires $\Delta\chi^2 = 100$ (reescaling experimental data by a factor 6)
2. The latest HERA0.2 PDF analysis (with $\Delta\chi^2 = 1$) leads to errors consistent with CTEQ (with $\Delta\chi^2 = 100$) only after accounting for (sizable) parametrization uncertainties.

Parametrization bias is a very important problem for a meaningful interpretation of PDF uncertainties!



THE NNPDF APPROACH

NNPDF collaboration

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[2] Dipartimento di Fisica, Università di Milano
[3] Physikalisches Institut, Albert-Ludwigs-Universität Freiburg
[4] Departament d'Estructura i Constituents de la Matèria, Universitat de Barcelona

The NNPDF approach

- Generate $N_{\rm rep}$ Monte Carlo replicas $F_i^{(\rm art)(k)}$ of the original data $F_i^{(\rm exp)}$
  Avoid gaussian/linearized assumptions

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

- Evolve each PDF parametrized with Neural Networks $\to$ Unbiased parametrization

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

- Minimization of χ^2 with Genetic Algorithms. + Dynamical Stopping:

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

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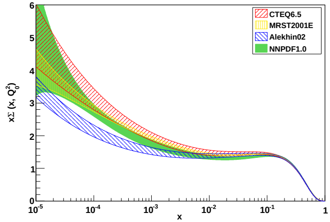
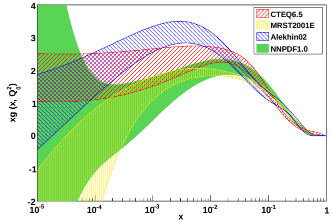
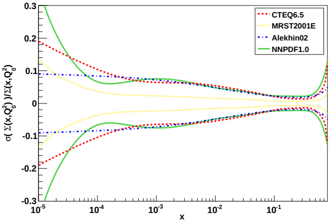
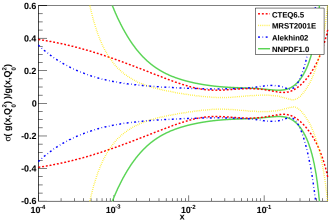
NNPDF1.0: First NNPDF parton set





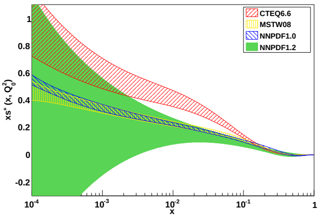
Note blow-up of uncertaities in extrapolation regions

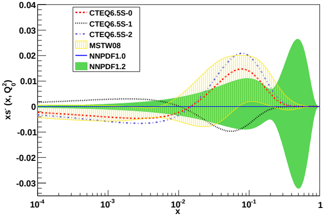


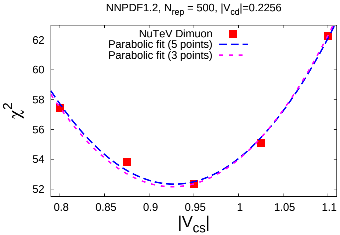


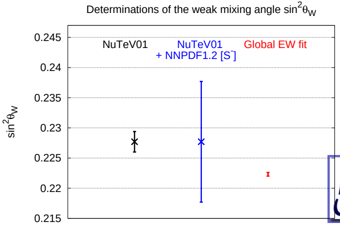
NNPDF1.2: Precision strange & EW parameters

Unbiased determination of the strange PDFs from NuTeV dimuons
Most precise ever direct determination of $|V_{cs}|$ + Nutev anomaly disapears from large uncertainties in $[S^-]$



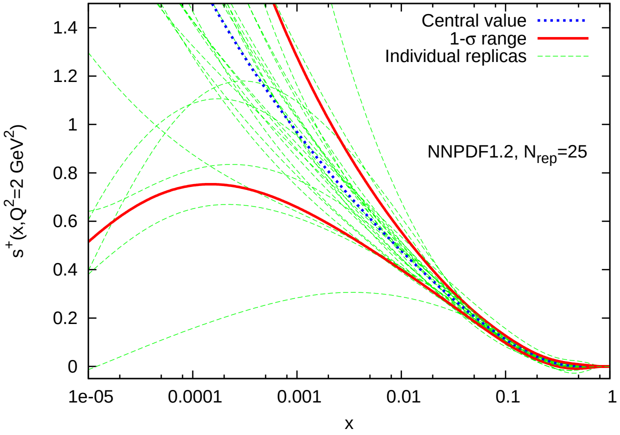






Neural networks: free from parametrization bias

Artificial neural network follow experimental data trends without any ad-hoc theoretical bias
Moderate spread in data region, blow up in extrapolation



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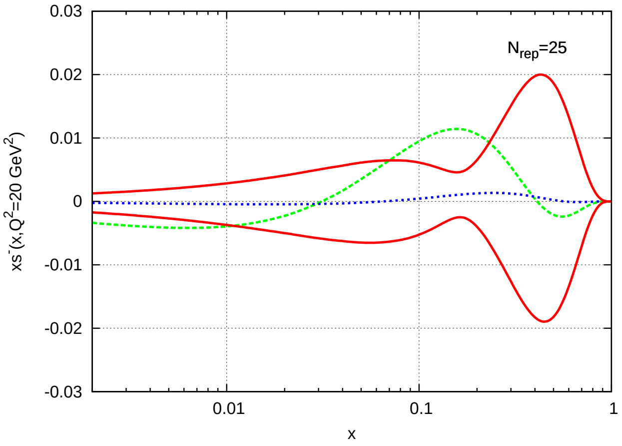
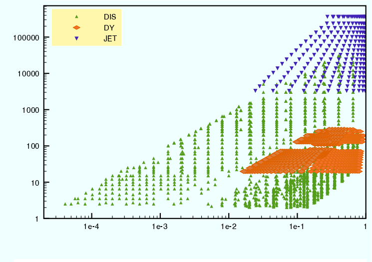
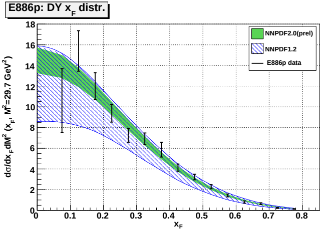
For S^- multiple nodes allowed if preferred by data (very difficult in the standard approach)

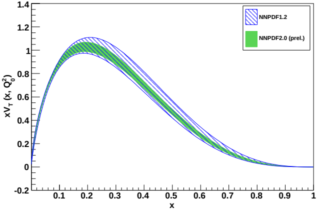


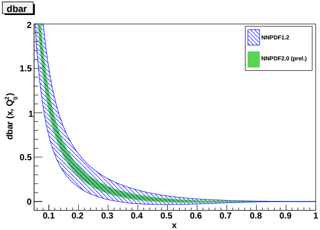
NNPDF2.0: Towards a global PDF analysis (Preliminary)!

PDF uncertainties reduced as expected from statistics without any modification of PDF parametrizations







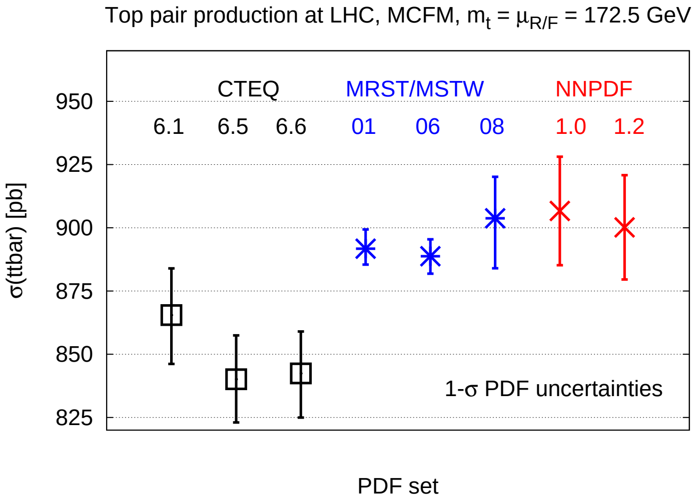


TOP QUARK PRODUCTION AND PDF UNCERTAINTIES

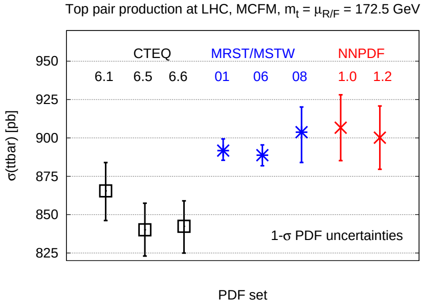
Beware: very preliminary results!!!

$\sigma^{\text{tot}}(t\bar{t})$ at the LHC

Compare results from different PDF sets (errors: 68% confidence levels)



$\sigma^{\mathrm{tot}}(t\bar{t})$ at the LHC



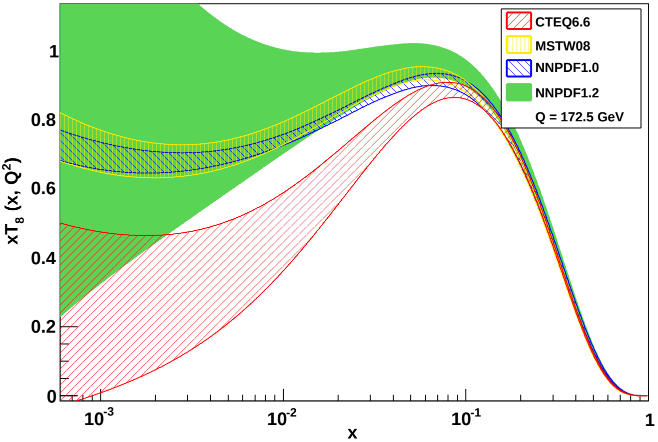
- Predictions from MTW08 and CTEQ6.6 still inconsistent
- NNPDF1.2 consistent with CTEQ6.1 (with ZM-VFN schemes for HQ)

1. Systematic downwards shift by $1-\sigma$ in CTEQ from 6.1 to 6.5/6.6 $\longrightarrow$ General Mass scheme for heavy quarks
2. Stability of central value MRST sets $\longrightarrow$ Despite change in HQ scheme which shifted $\sim 7\%$ $\sigma_{W/Z}$ in 2006!
3. Note sizable increase in PDF errors in MSTW08, despite using much more data $\longrightarrow$ Example of parametrization bias!

$\sigma^{\text{tot}}\,(t\bar{t})$ at the LHC

Some PDF combinations differ between MSTW08 and CTEQ6.6 (strangeness)

$$xT_8(x, m_t^2) = x\left(u + \bar{u} + d + \bar{d} - 2(s + \bar{s})\right)$$



Heavy quark production in hadronic collisions

The heavy quark pair production can be written

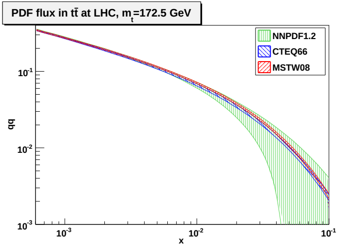
$$\sigma\left(S, m_H^2\right) = \frac{\alpha_s^2\left(\mu^2\right)}{m_H^2} \sum_{ij} \int_{\rho^H}^1 \frac{d\tau}{\tau} \Phi_{ij}\left(\tau, \mu\right) \widetilde{\sigma}_{ij}\left(\frac{\rho^H}{\tau}, \frac{\mu^2}{m_H^2}\right) \ , \rho^H = \frac{4m_H^2}{S}$$

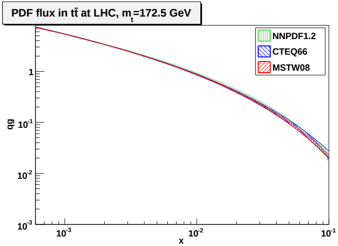
in terms of partonic fluxes

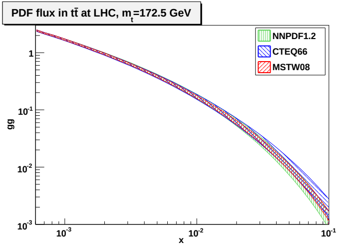
$$\Phi_{ij}\left(\tau, \mu\right) = \int_0^1 dx_1 \int_0^1 dx_2 q_i^{(A)}(x_1, \mu) q_j^{(B)}(x_2, \mu) \delta\left(x_1 x_2 - \tau\right)$$

at the LHC, for $m_t = 172.5$ GeV $\rightarrow \rho^H = 6 \cdot 10^{-4}$

PDF fluxes

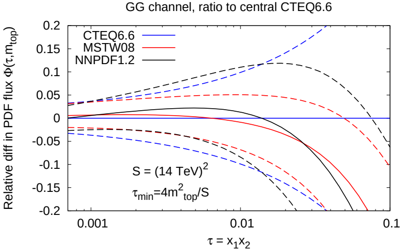


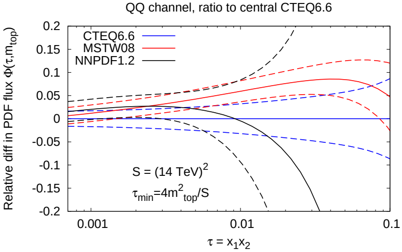


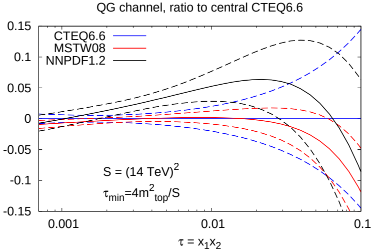


Dominance of the QG channel

PDF fluxes (II)







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2. Difficult to identify the source of the discrepancy at the PDF level ...
3. HQ scheme shifts cross-section by $\sim$ 1-σ in CTEQ. Is this result independent of the HQ prescription adopted?
4. Expect soon results from a NNPDF global fit with GM scheme $\longrightarrow$ Strong cross-check of the stability of the prediction for $\sigma\left(t\bar{t}\right)$ and its uncertainties.

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