Impact of Heavy Quark Masses on PDFs and LHC Phenomenology

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on behalf of

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MORIOND QCD
La Thuile, March 25, 2011

Overview

- The NNPDF Approach
- The NNPDF2.1 set
- Implications for LHC Phenomenology
- Recent NNPDF Developments
- Conclusion and Outlook

References:

arXiv:1101.1300v2
arXiv:1002.4407v2 - Nucl. Phys. B 838(2010)136-206
arXiv:1001.2312v2 - Nucl. Phys. B 834(2010)116
arXiv:1102.3182v1

Which is the usual approach?

- PDFs determined assuming some fixed functional form (MSTW, CTEQ):

$$f(x) \sim x^{\alpha}(1-x)^{\beta}$$

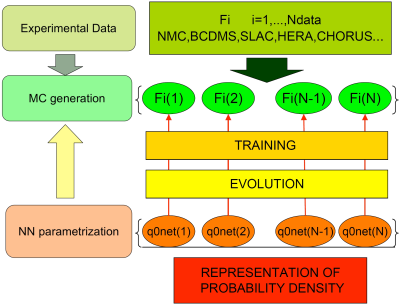
- PDFs uncertainties determined by propagation of errors on parameters (Hessian method)

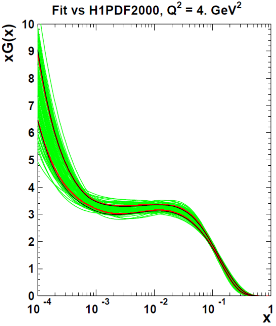
Number of parameters needed: $20 - 26$

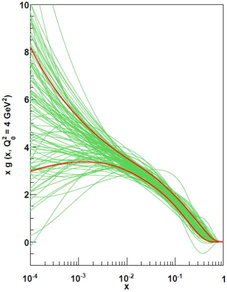
NNPDF Approach

NNPDF COLLABORATION

- Monte Carlo generation: textbook methods to evalutate statistical properties:
  $\langle \mathcal{F}[f(x)] \rangle = \frac{1}{N_{rep}} \sum_1^{N_{rep}} \mathcal{F}[f^{(k)}(x)]$
  $\sigma_{\mathcal{F}[f(x)]} = \sqrt{\langle \mathcal{F}[f(x)]^2 \rangle - \langle \mathcal{F}[f(x)] \rangle^2}$





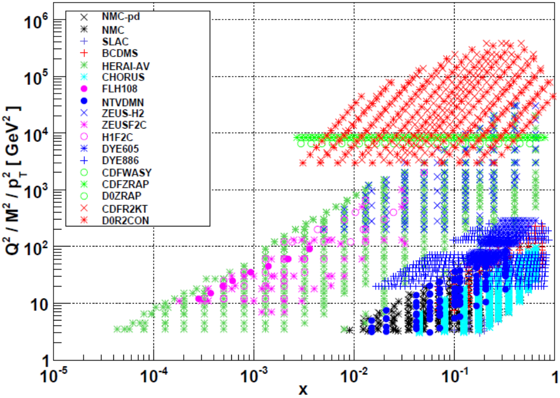


- Neural Network technology: universal unbiased interpolant, very redundant parametrization

O(300) parameters

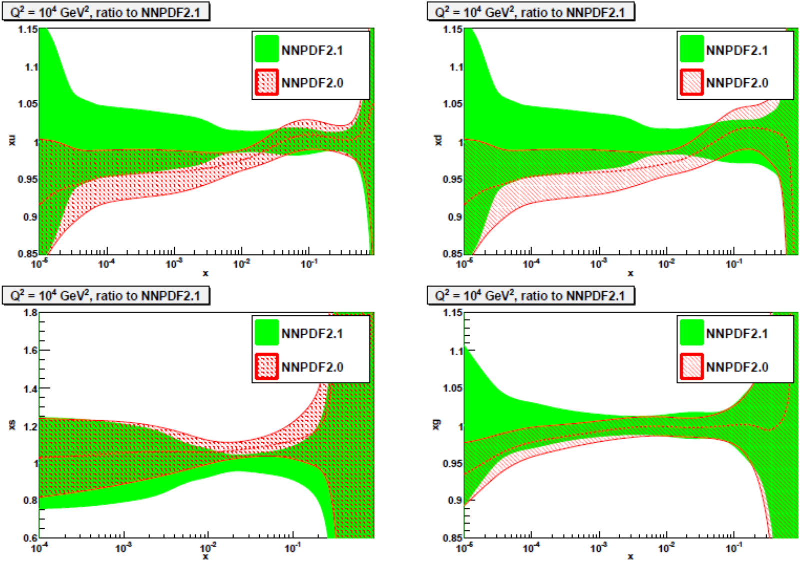
Main features:

- FONLL-A general mass scheme
- Included all relevant hard-scattering datasets: fixed target DIS, HERA, fixed target DY, Tevatron W/Z, Tevatron jets

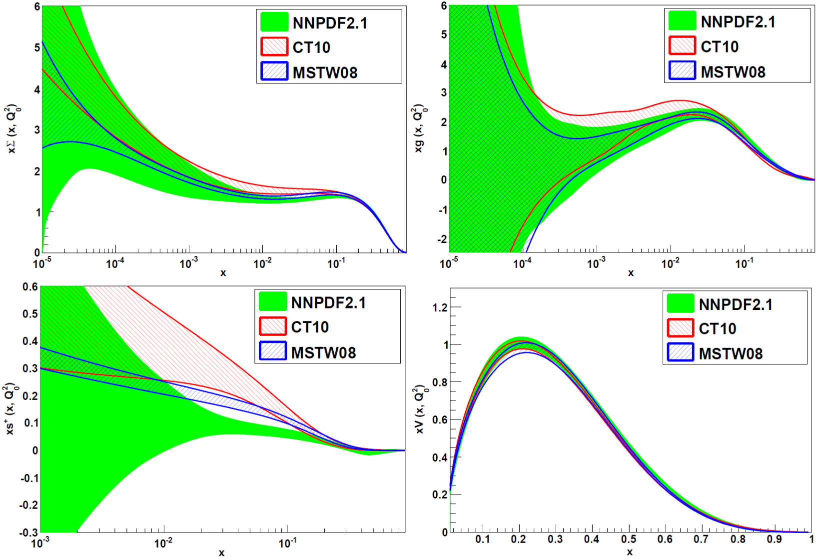


- Included ZEUS and H1 F_2^c charm data
- DY FastKernel $\rightarrow$ Exact DY NLO QCD

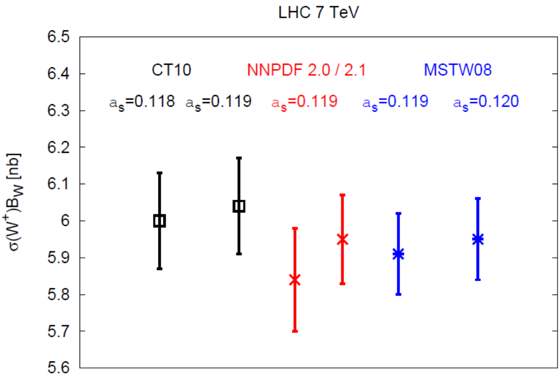
- NNPDF2.1 (General Mass) vs NNPDF2.0 (Zero Mass):



- NNPDF2.1 vs CT10/MSTW08:



- LHC standard candles: observables at $\sqrt{s}$ =7 TeV



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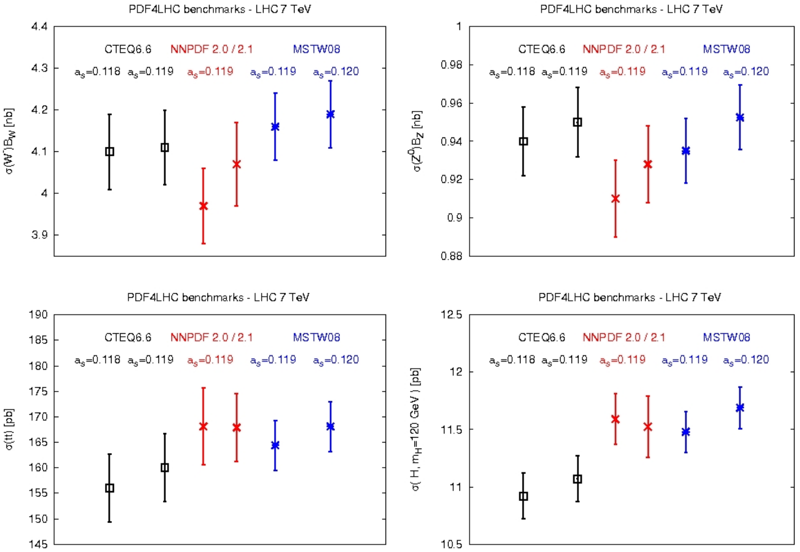
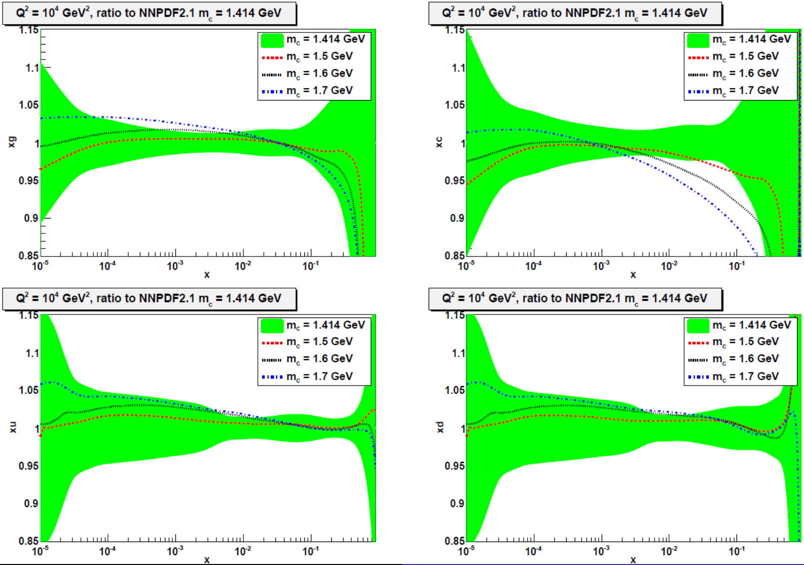
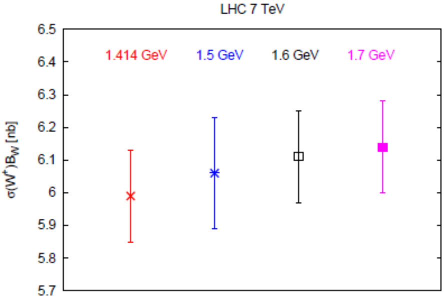


- NNPDF2.1 with m_c variations (default: $m_c^2 = 2GeV^2$):

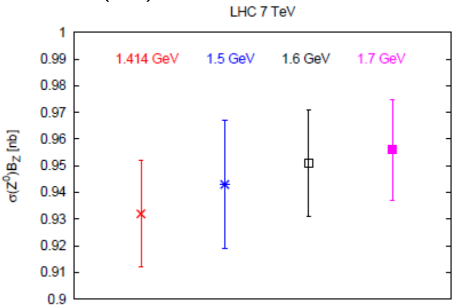


- Observables with m_c variations (default: $m_c^2 = 2 GeV^2$):

$\sigma(W^+)$

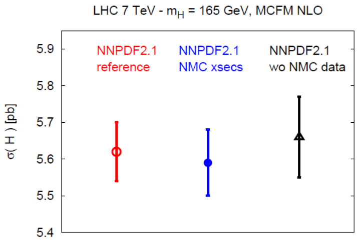


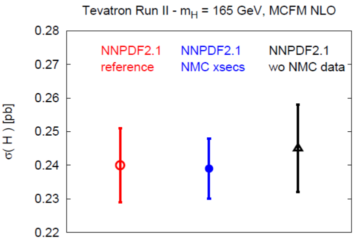
$\sigma(Z^0)$



Effects of charm mass variations smaller than PDF errors for $m_c \in [1.4, 1.7]$

- ABKM report a 3(1)–σ shift at NNLO (NLO) on the Higgs production cross section in gluon fusion at the LHC (and Tevatron) (arXiv:1101.5261)
- Claim is different use of fixed target DIS NMC data: as structure functions (MSTW, NNPDF, CT) or as cross sections (ABKM)





- NNPDF finds negligible impact of the treatment of NMC data for Higgs production, both at NLO (arXiv:1102.3182) and at NNLO – even removing NMC altogether has moderate effect

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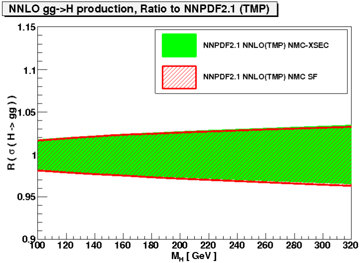

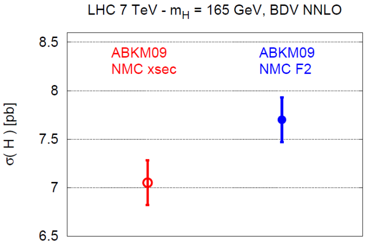

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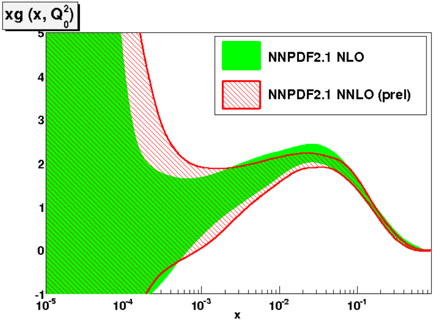
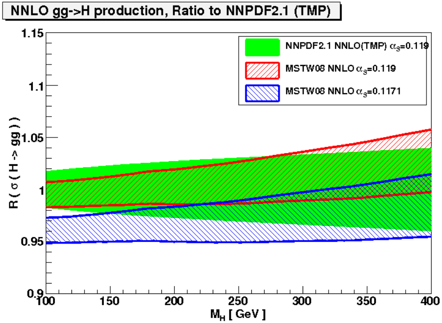
- Preliminary NNPDF2.1 NNLO results:
  based in the FONLL-C general mass scheme





NNPDF and MSTW in agreement for NNLO Higgs production

Conclusion and Outlook

- NNPDF2.1 parton set is presented
- Heavy quark mass effects have been implemented through the FONLL-A GM scheme
- Differences betweeh GM and ZM predictions for LHC observables at most 1-sigma PDF errors
- Dependence of parton sets on m_c variations has been studied
- Standard candles at LHC are computed at NLO: agreement ($W^{\pm}$,Z^0) and marginal agreement ($t\bar{t}$,H) with results from CT10 and MSTW08
- NNPDF2.1 NNLO = full NNLO NNPDF parton fit
  $\rightarrow$**on the go**

Conclusion and Outlook

NNPDF
COLLABORATION

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Thank you for your attention!

BACKUP SLIDES

FastKernel Framework

Evolution:

- Need to solve DGLAP eqns to evolve from the initial parametrisation scale Q_0^2 to the experimental one:

$$\frac{df_i(x,Q^2)}{d\ln Q^2} = \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{dy}{y} P_{ij}\left(y,\alpha_s(Q^2)\right) f_j\left(\frac{x}{y},Q^2\right)$$

- Modified evolution kernels are pre-computed in Mellin space and then stored:

$$\tilde{\Gamma}_k(N,\alpha_s(Q^2),\alpha_s(Q_0^2)) = \sum_{j=1}^{N_{pdf}} C_j(N,\alpha_s(Q^2))\Gamma_{jk}(N,\alpha_s(Q^2),\alpha_s(Q_0^2))$$

$$F(x,Q^2) = \sum_{k=1}^{N_{pdf}} \tilde{\Gamma}_k(x,\alpha_s(Q^2),\alpha_s(Q_0^2)) \otimes f_k(x,Q_0^2)$$

- Convolution is sped up using interpolating polynomials

First fast and accurate computation of DY processes and of collider weak boson production

FONL GM Scheme

How do we treat a heavy flavour in QCD processes?

If $Q^2 \gg m_h \Rightarrow \overline{\text{MS}}$ scheme with n_f flavours

- masses are neglected
- DGLAP evolution and α_s running with n_f flavours

If $Q^2 \ll m_h \Rightarrow$ decoupling scheme with n_l light flavours

- heavy quarks are neglected
- DGLAP evolution and α_s running with n_l flavours
- CWZ prescription (Collins, Wilczek, Zee 1978):
  $\rightarrow$ the $\overline{\text{MS}}$ for light flavours
  $\rightarrow$ a zero momentum subtraction for heavy flavour graphs

FONLL scheme:

Cacciari, Greco, Nason, JHEP 05 (1998) 007; FONLL paper

use the massless scheme, replace terms that are known in the massive scheme with the exact massive result.

Then common terms are subtracted.

$$F^{\mathrm{FONLL}}(x,Q^2) \equiv \mathcal{D}(Q^2)F^{(d)}(x,Q^2) + F^{(n_l)}(x,Q^2)$$

where

$$\mathcal{D}(Q^2) = \theta(Q^2 - m_h^2)\left(1 - \frac{m_h^2}{Q^2}\right)^2 \;\; ; \;\; F^{(d)} \equiv \left[F^{(n_l+1)}(x,Q^2) - F^{(n_l,0)}(x,Q^2)\right]$$

with

$$F^{(n_l,0)}(x,Q^2) = x\int_x^1 \frac{dy}{y} \sum_{i=q,\bar{q},g} B_i^{(0)}\left(\frac{x}{y}, \frac{Q^2}{m^2}, \alpha_s^{(n_l+1)}(Q^2)\right) f_i^{(n_l+1)}(y,Q^2)$$

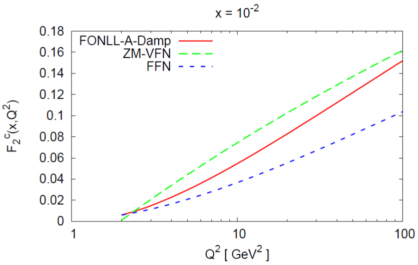
$$\lim_{m\to 0}\left[B_i\left(x, \frac{Q^2}{m^2}\right) - B_i^{(0)}\left(x, \frac{Q^2}{m^2}\right)\right] = 0$$

FONLL GM Scheme

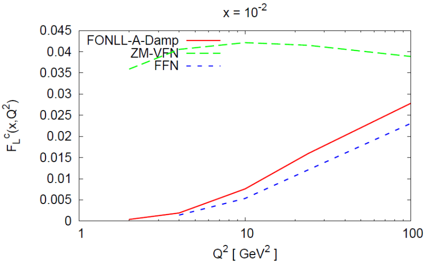
All the relevant charm structure function $F_2^c(x, Q^2)$ data from the H1 and ZEUS experiments at HERA are included:

- we consider this structure function for our benchmarks
- the FONLL expression smoothly interpolates between the FFN scheme near threshold and the massless scheme at large Q^2, also thanks to the damping factor

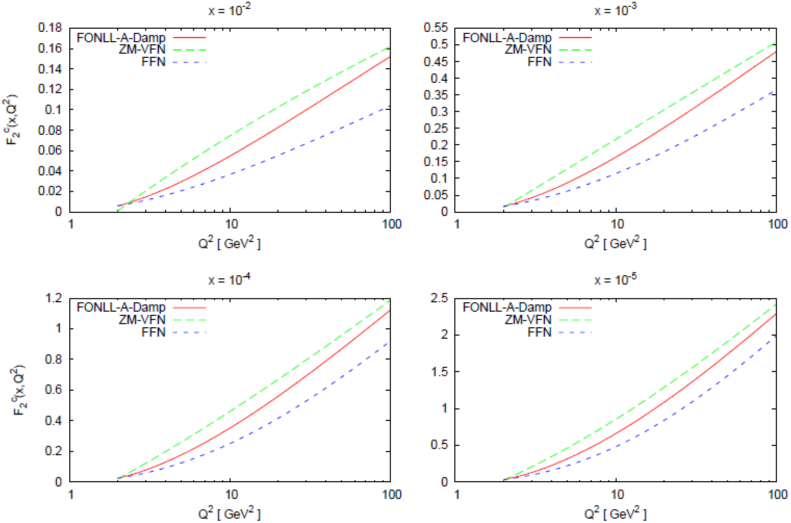
F_2^c



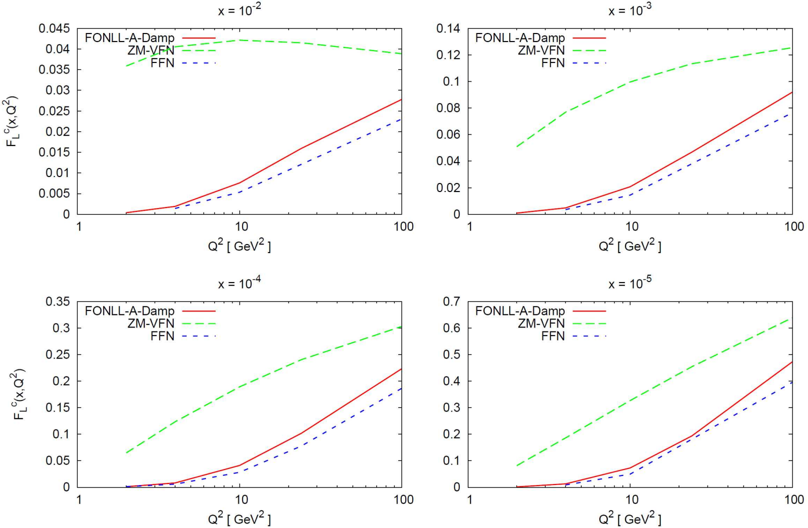
F_L^c



F_2^c Schemes Comparison



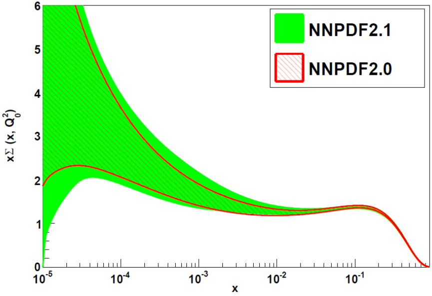
F_L^c Schemes Comparison



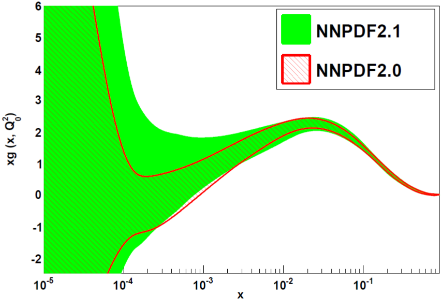
Comparison NNPDF2.1 vs NNPDF2.0 (massless):

- for the singlet sector PDFs

Singlet PDF

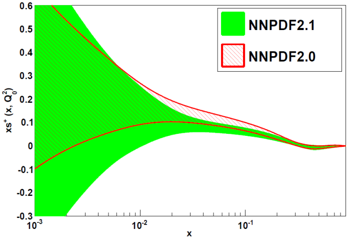


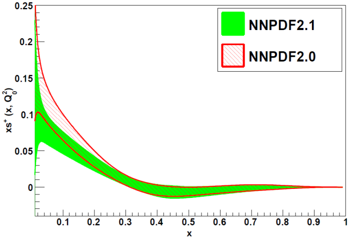
Gluon PDF



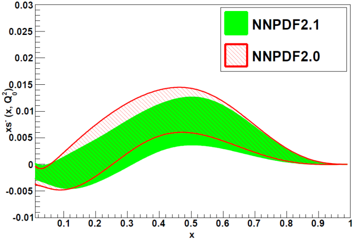
- for the non-singlet sector PDFs

Strange





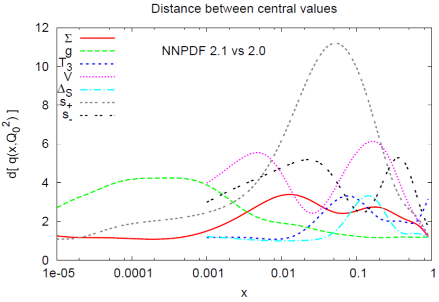
Strange Asymmetry

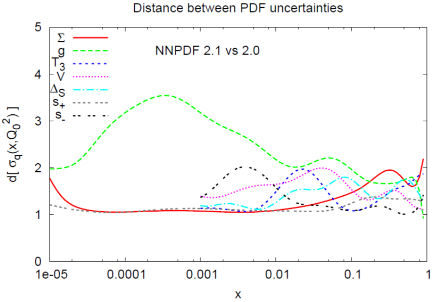


Distances between NNPDF2.0 and NNPDF2.1 sets are computed according to our definition:

$$d^2(\langle q^{(1)}\rangle, \langle q^{(2)}\rangle) = \frac{(\langle q^{(1)}\rangle_{(1)} - \langle q^{(2)}\rangle_{(2)})^2}{\sigma^2_{(1)}[\langle q^{(1)}\rangle] + \sigma^2_{(2)}[\langle q^{(2)}\rangle]}$$

- The two sets do not come from the same underlying distributions
- All PDFs are consistent at the one-σ level but the strangeness (90% C.L.)

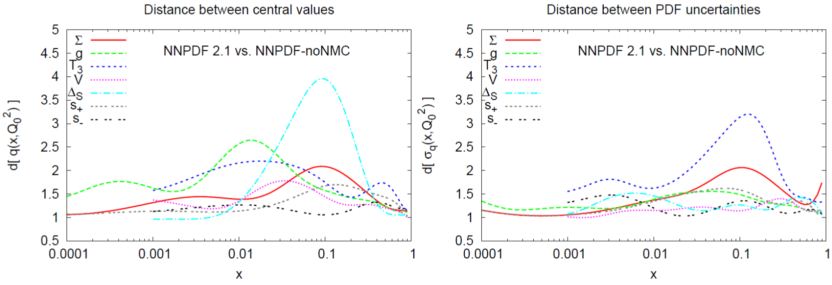




NNPDF COLLABORATION

It's reasonable to argue that NMC cross-section data should be used instead of structure function data:

- Comparison between standard NNPDF2.1, NNPDF2.1 with NMC cross-section data and NNPDF2.1 wo NMC data



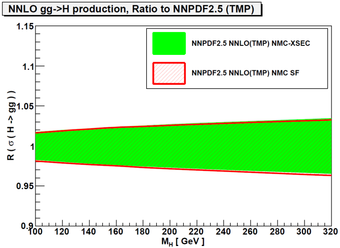
Differences well below the one-σ level

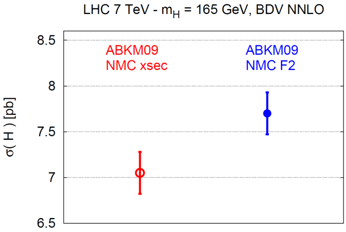
…from J.Rojo's talk at PDF4LHC Workshop (CERN, March 7)

- ABKM report a 3(1)–σ shift at NNLO (NLO) on the Higgs production cross section in gluon fusion at the LHC (and Tevatron) (arXiv:1101.5261)
- Claim is different treatment of fixed target DIS NMC data: used as structure functions (MSTW, NNPDF, CT) or cross sections (ABKM) → Origin of ABKM/MSTW discrepancy?

$$\tilde{\sigma}(x, y, Q^2) = F_2(x, Q^2)\left(2 - 2y + y^2 / \left[1 + R\left(x, Q^2\right)\right]\right) + TMCs$$

- NNPDF finds negligible impact of the treatment of NMC data for Higgs production, both at NLO (arXiv:1102.3182) and at NNLO – even removing NMC altogether has moderate effect





The treatment of NMC data has negligible impact on collider Higgs production
Also at NNLO