Status Report from NNPDF

Juan Rojo

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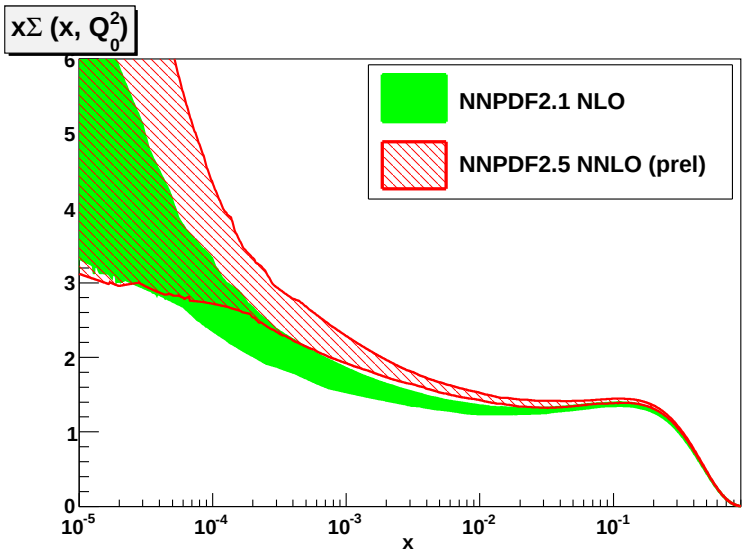
Outline

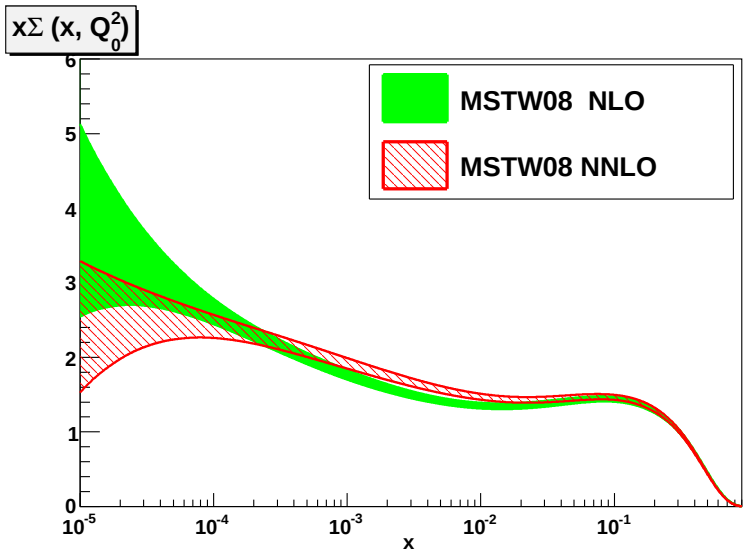
- Towards NNLO NNPDFs and NNLO Higgs production
- PDFs with LHC data: the CMS lepton asymmetry measurement
- The impact of NMC data in Higgs production
- Precision NLO determination of $\alpha_S\left(M_Z^2\right)$ from NNPDF2.1

THE NNPDF2.5 NNLO SET: FIRST (PRELIMINARY) RESULTS

NNPDF@NNLO

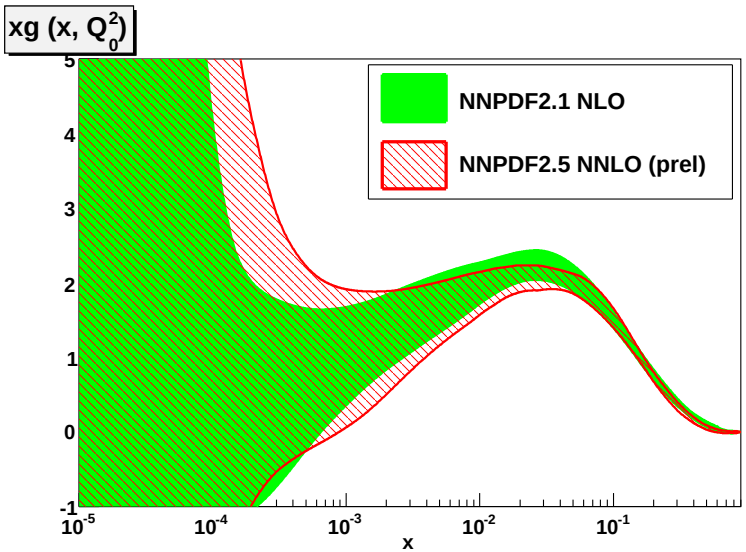
- NNPDF2.5: (preliminary) unbiased NNLO global analysis
- Same dataset as in NNPDF2.1 (arXiv:1101.1300). FONLL-C for DIS structure functions
- Impact of NNLO: Harder small-x sea quarks (same trend as MSTW08)

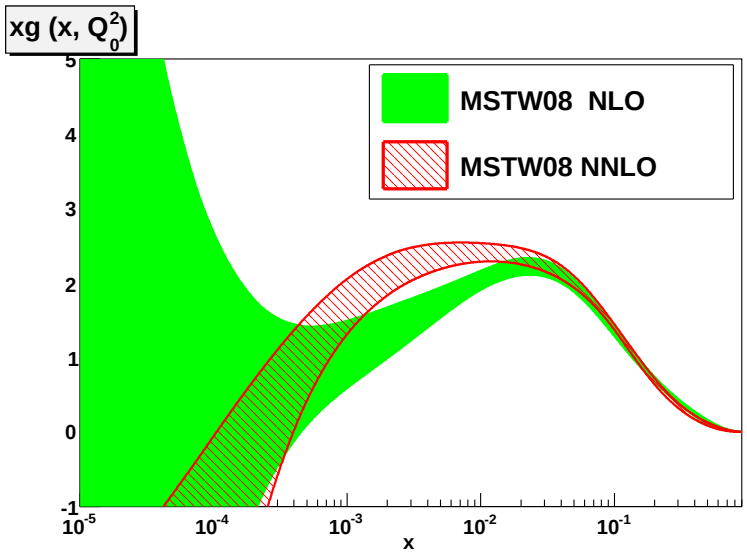




NNPDF@NNLO

- NNPDF2.5: (preliminary) NNLO global analysis
- Same dataset as in NNPDF2.1, FONLL-C for DIS structure functions
- Impact of NNLO: Stable small-x gluons (opposite to MSTW08)

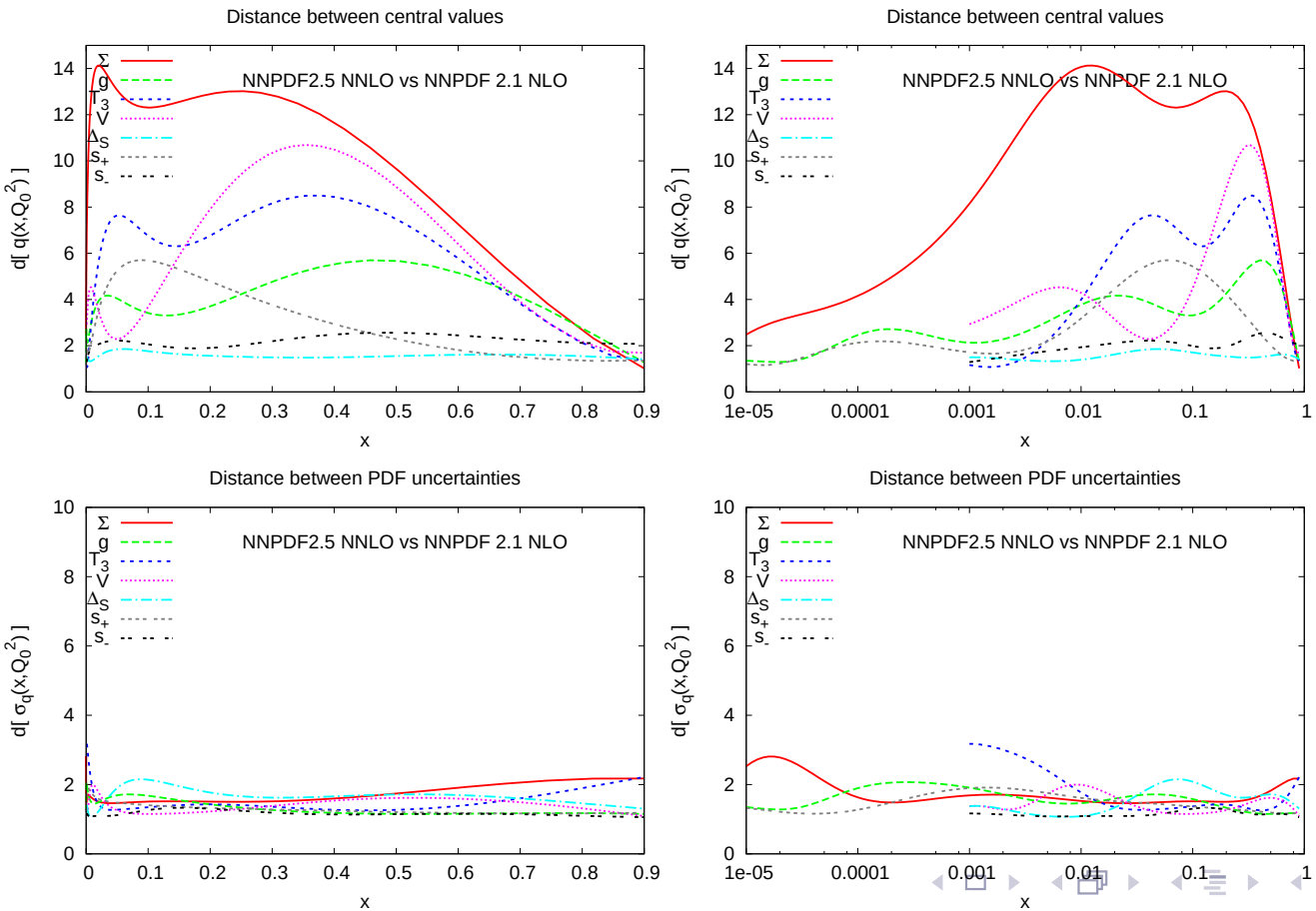




NNLO NNPDFs almost ready for LHC phenomenology

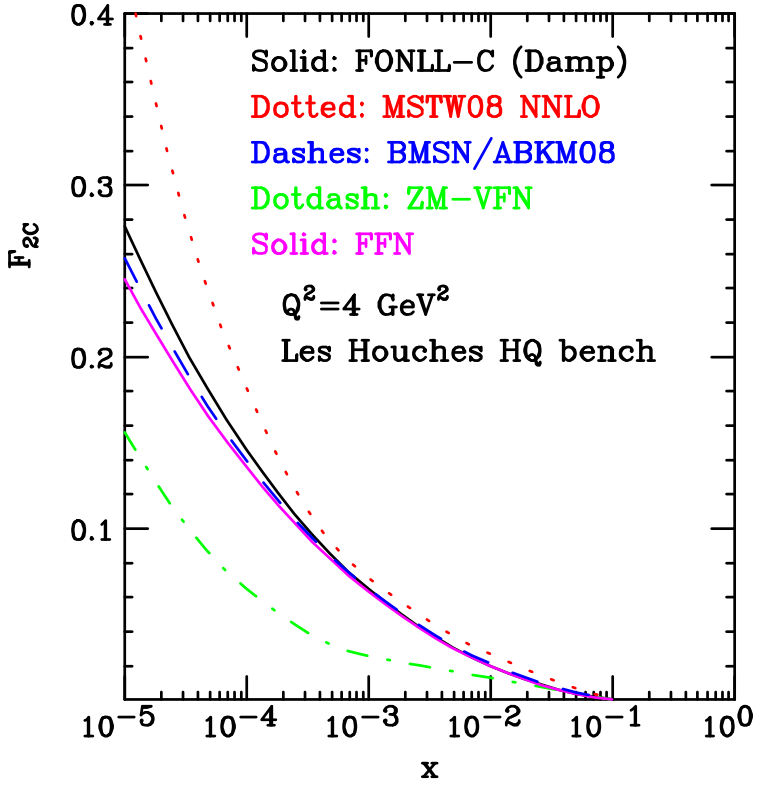
NNPDF@NNLO

- NNPDF2.5: (preliminary) NNLO global analysis
- Same dataset as in NNPDF2.1 (arXiv:1101.1300). FONLL-C for DIS structure functions
- Impact of NNLO: Central values shift by $\leq 1, 1.5$–σ, PDF uncertainties unchanged

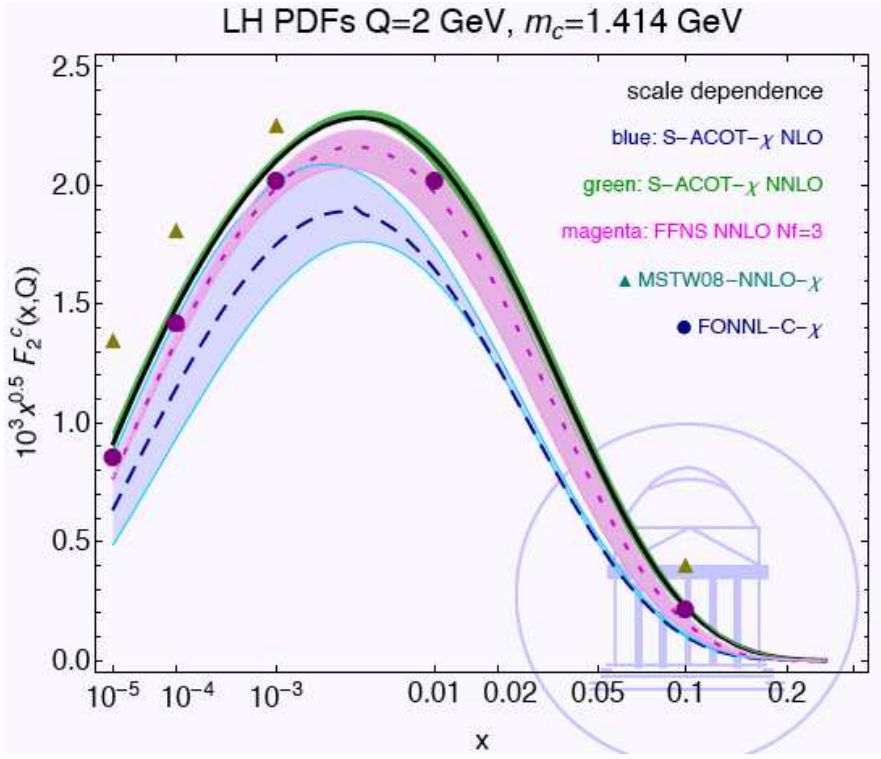


The FONLL-C GM-VFN scheme

- NNPDF2.5 based on the FONLL-C GM-VFN scheme for NNLO DIS structure functions (arxiv:1001.2312)
- S-ACOT-χ NNLO (used in CT NNLO) expected to be close FONLL-C-χ (reasonable numerical agreement)

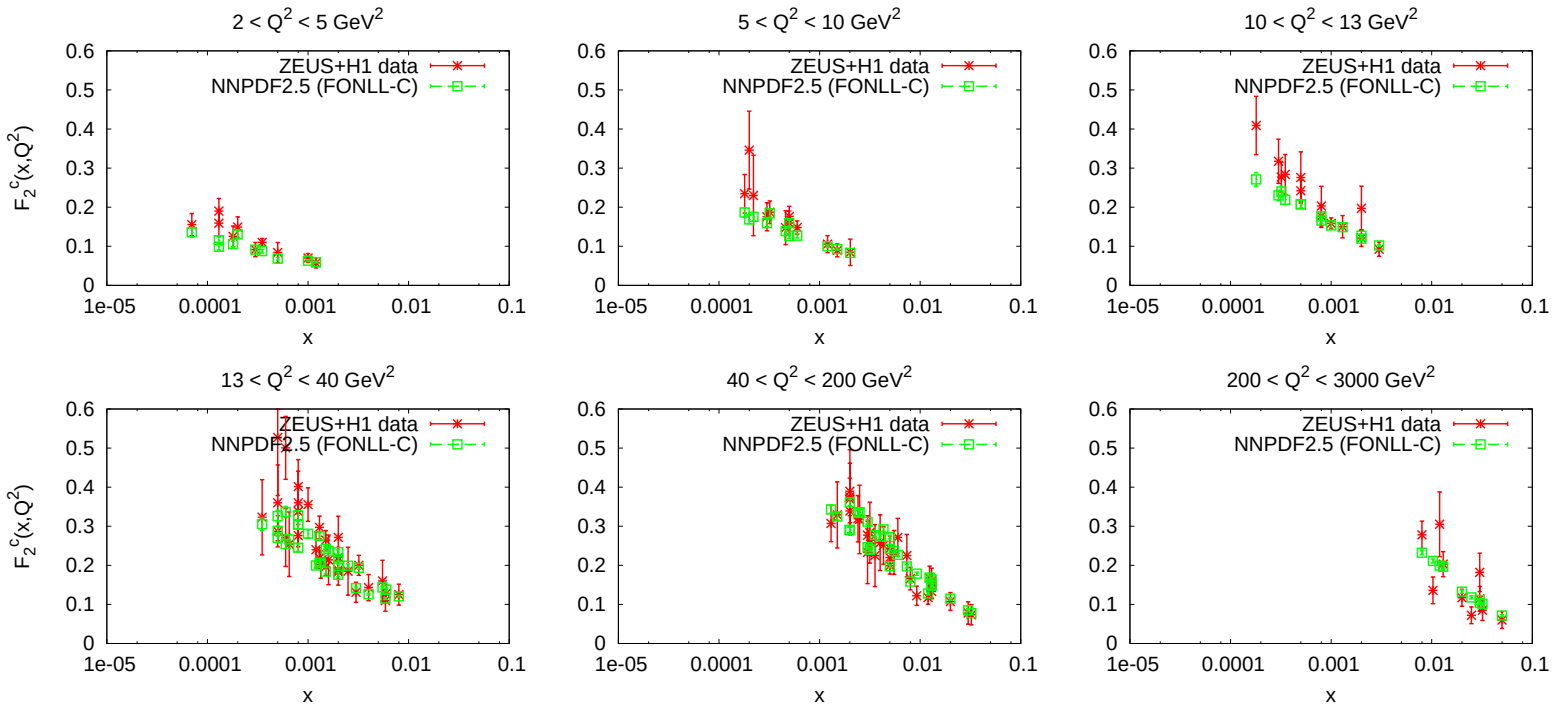


J. Rojo, LH HQ benchmarks



M. Guzzi, LH QCD 2011

HERA F_2^c data

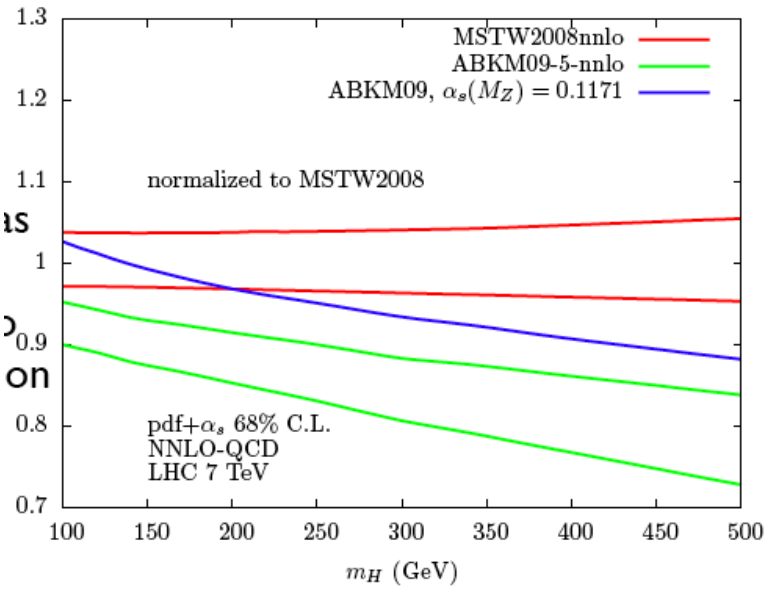


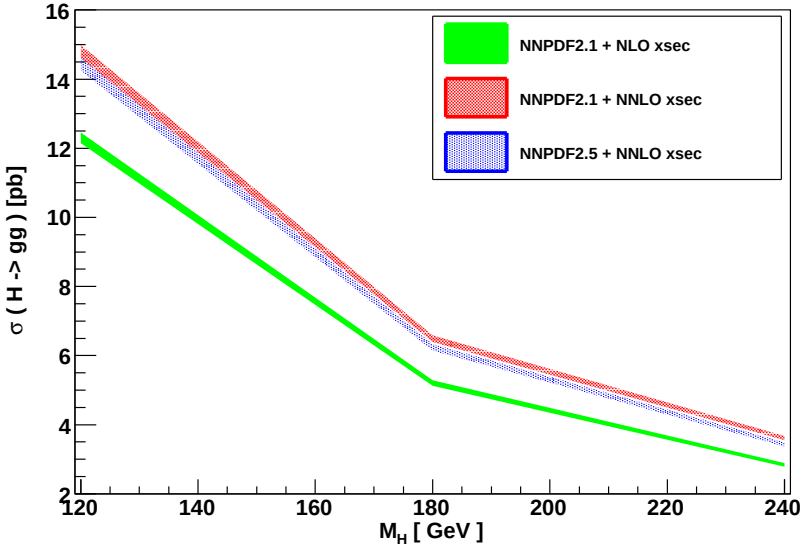
- FONLL-C-Damp $\longrightarrow$ Excellent description of ZEUS and H1 F_2^c data
- $\chi^2_{F_2^c} = 1.04$ (without any tuning of the GM-VFN)
- HERA combined F_2^c dataset $\longrightarrow$ constraints for small-x gluon

PDFs and Higgs production

The Higgs production $gg \longrightarrow H$ cross section depends (on decreasing order of importance)

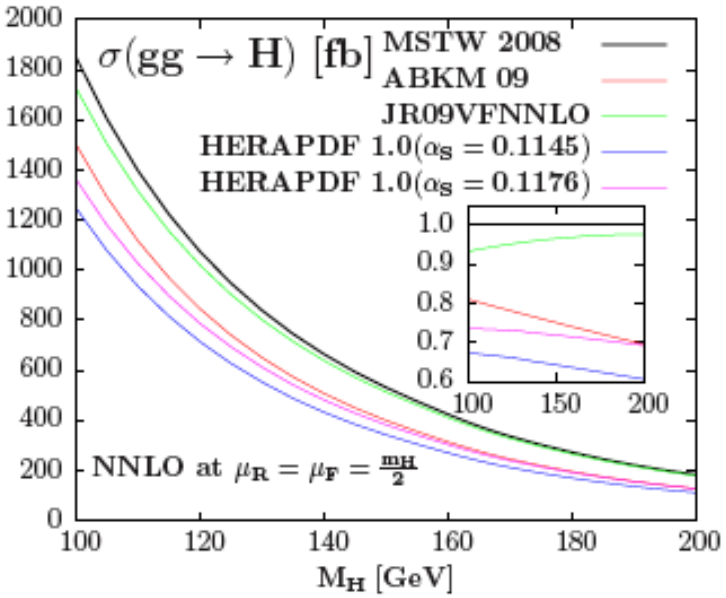
1. The matrix element
2. The value of α_s used in the matrix element
3. The PDF set

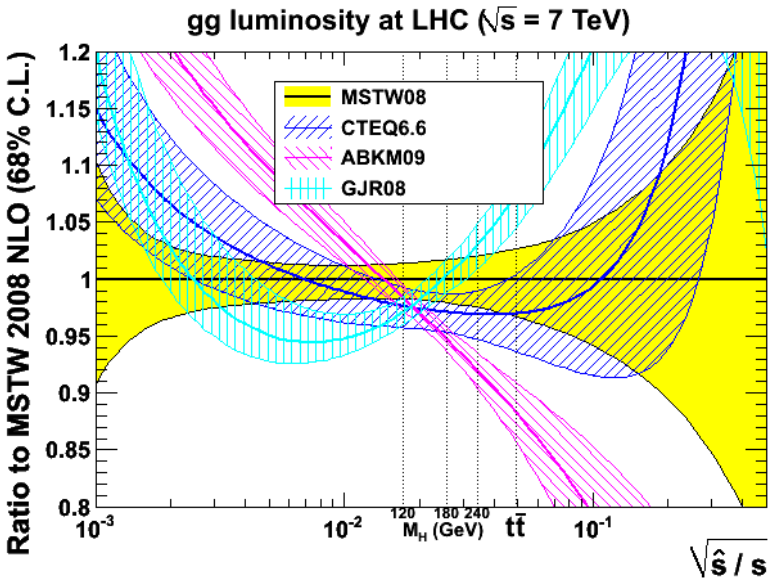




PDFs and Higgs production

- The Tevatron reports SM Higgs exclusion bounds of $158 \leq M_H \leq 175$ GeV 95% C.L., theory prediction used MSTW 2008 NNLO
- Challenged by Djoaudi et al. (arXiv:1101.1832): ABKM09 and HERAPDF lead to cross sections smaller by $\sim$ 20–50% due to both smaller α_s ($\alpha_s^{\rm ABKM} = 0.1135$, $\alpha_s^{\rm MSTW} = 0.1171$) and smaller gg lumi





The Tevatron excluded mass range should be reopened?

PDFs and Higgs production

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- ... ABKM09 and HERAPDF do not include Tevatron Run II jet data

χ^2 Description of CDF Run-II inclusive jet data

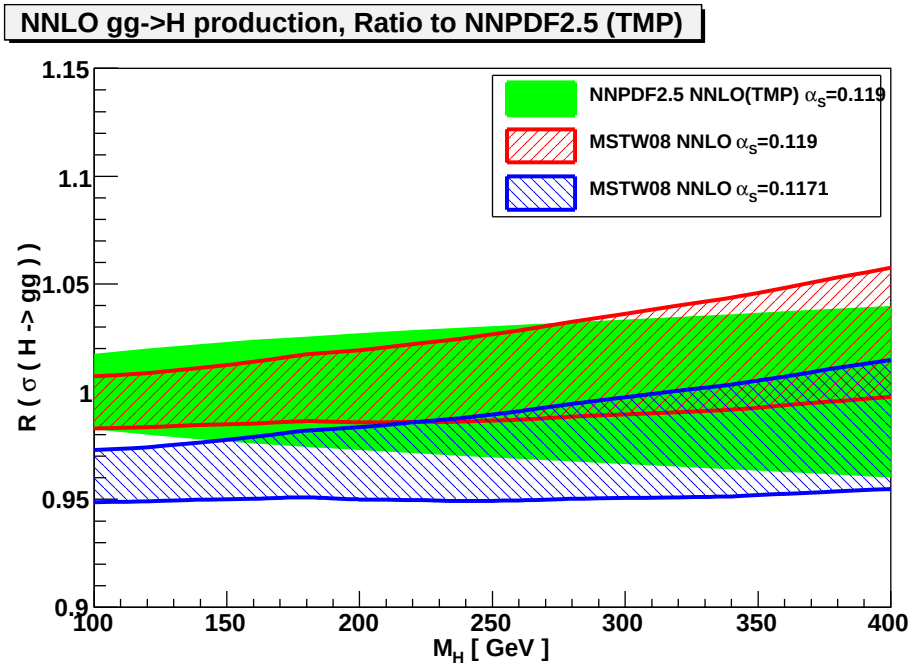
NNLO PDF	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.39 (0.42)	0.69 (0.44)	0.97 (0.48)
HERAPDF1.0 ($\alpha_S = 0.1145$)	2.64 (0.36)	2.15 (0.36)	2.20 (0.46)
HERAPDF1.0 ($\alpha_S = 0.1176$)	2.24 (0.35)	1.17 (0.32)	1.23 (0.31)
ABKM09	2.55 (0.82)	2.76 (0.89)	3.41 (1.17)

G. Watt, Les Houches QCD 2011

NNLO Non-global PDF sets: non–optimal description of jet data
Is the Tevatron jet data the real origin of the differences?

PDFs and Higgs production

- The Tevatron reports SM Higgs exclusion bounds of $158 \leq M_H \leq 175$ GeV 95% C.L., theory prediction used MSTW 2008 NNLO
- Challenged by Djoaudi et al. (arXiv:1101.1832): ABKM09 and HERAPDF lead to cross sections smaller by $\sim$ 20–50%.
- Two NNLO global fits, MSTW08 and NNPDF2.5, are in reasonable agreement



NNPDF2.5/MSTW08 agree for the NNLO Higgs at $\pm 5\%$

Better agreement with common $\alpha_s\,(M_Z)$
Crucial to compare results at same α_s

Global vs. Non-Global PDF sets

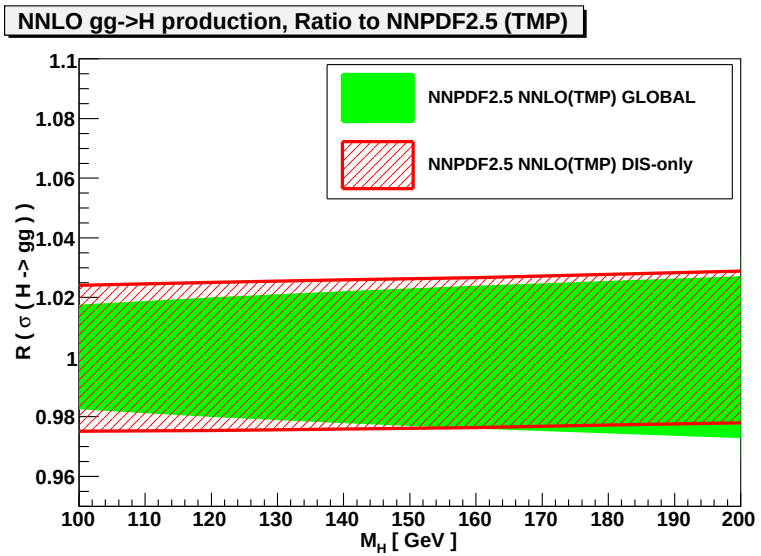
- Differences between PDF sets more subtle than *global* vs *non-global*
- NNPDF2.5 NNLO DIS–only $\rightarrow$ Excellent agreement for $\sigma(H)$ as compared to global fit
- Agreement also for Run II Tevatron jets (not included for DIS–only fit)

NNPDF DIS–only reproduces TeV jet data and agrees with global PDF predictions for $\sigma(H)$ Flexible and unbiased PDF parametrization important to achieve this

Description of Tevatron Run II jets:

$$\chi^2_{\mathrm{CDF,global}} = 0.72 \qquad \chi^2_{\mathrm{CDF,dis}} = 0.81$$

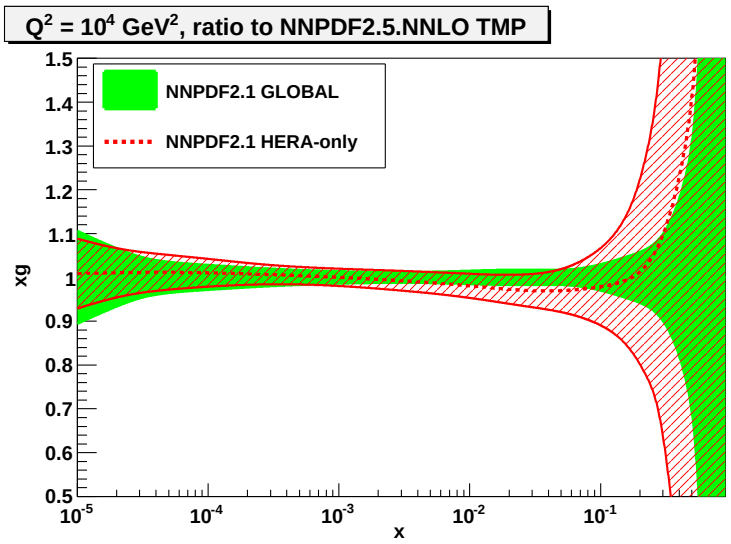
$$\chi^2_{\mathrm{D0,global}} = 0.99 \qquad \chi^2_{\mathrm{D0,dis}} = 1.01$$



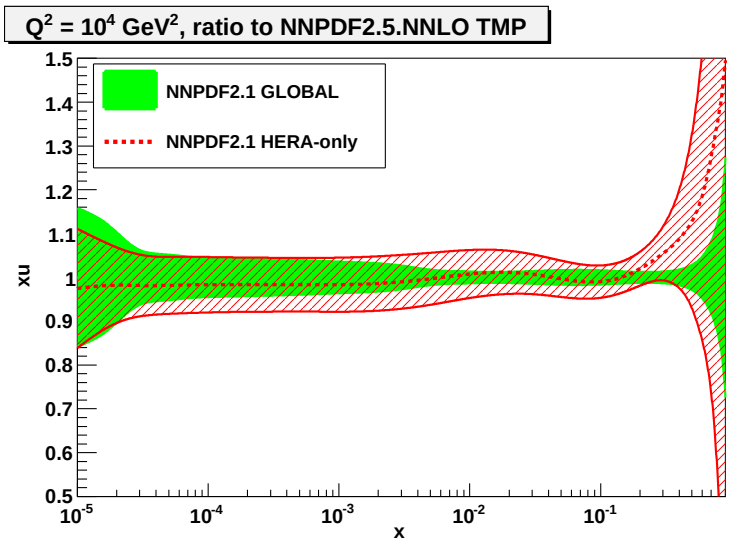
HERA only PDF sets

- HERAPDF is **not** the only PDF set based on HERA data only ...
- NNPDF21-HERA-only $\longrightarrow$ Same as NNPDF2.1 but with HERA only data
- HERA data $\longrightarrow$ Most of constrains from gluon and small-x quarks in global fit

$$xg(x, M_W^2)$$



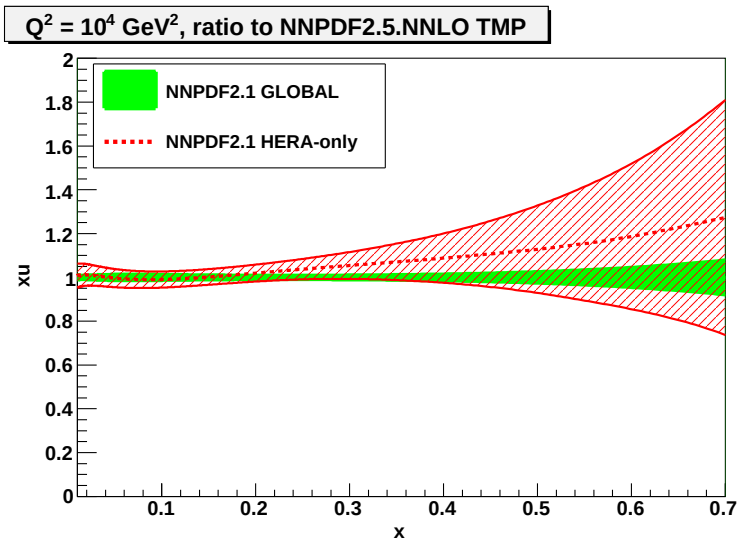
$$xu(x, M_W^2)$$



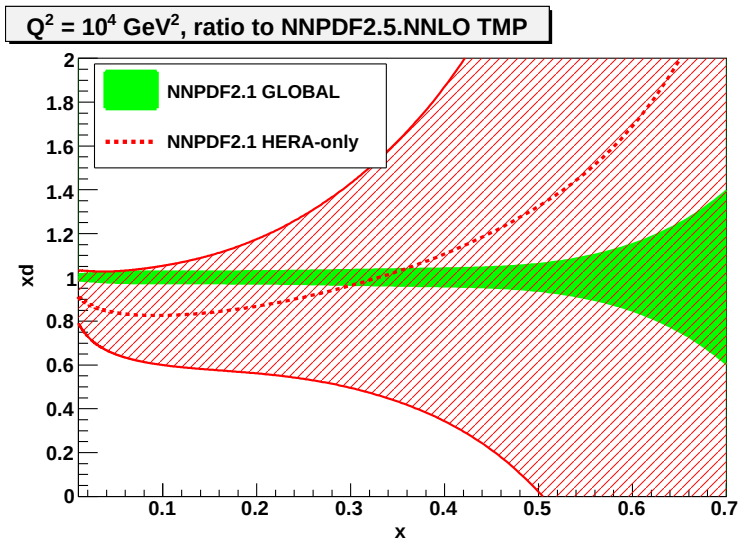
HERA only PDF sets

- HERAPDF is **not** the only PDF set based on HERA data only ...
- NNPDF21-HERA-only $\longrightarrow$ Same as NNPDF2.1 but with HERA only data
- HERA-only fit $\longrightarrow$ Increased PDF errors at large–x as compared to global fit

$$xu(x, M_W^2)$$



$$xd(x, M_W^2)$$



No systematic discrepancy between HERA-only and global fit
(questioned by potential deuteron nuclear corrections, CTEQ-JLAB, arXiv:1102.3686)

PDFs WITH LHC DATA: THE CMS LEPTON ASYMMETRY MEASUREMENT

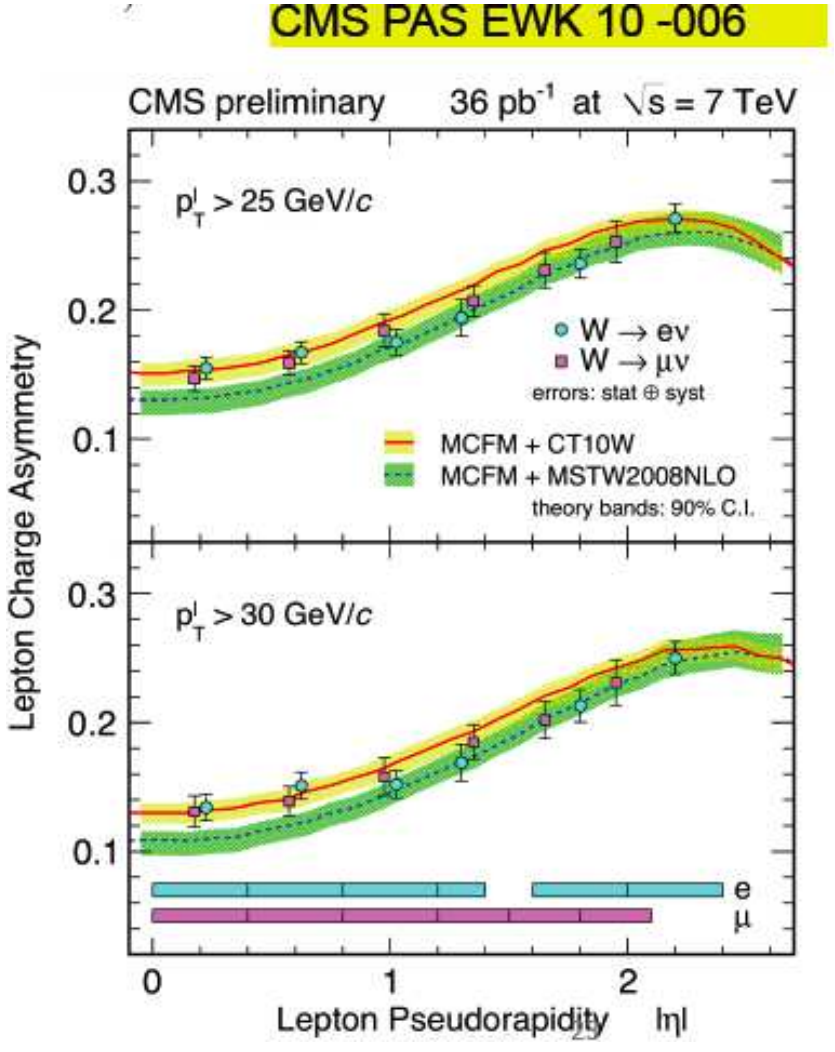
The W lepton asymmetry at the LHC

- Accurate Run-II Tevatron data on the $p\bar{p} \to W^{\pm} \to l^{\pm}\nu$ asymmetry available

$$A_\ell(y_\ell) = \frac{d\sigma(W^+)/dy_\ell - d\sigma(W^-)/dy_\ell}{d\sigma(W^+)/dy_\ell + d\sigma(W^-)/dy_\ell}$$

- NNPDF (arXiv:1012.0836): D0 $\mu + e$ inclusive data (not binned in p_t^l) perfectly consistent with global fit, reduction in valence PDF uncertainty, no tension exclusive to deuteron data found
- Related studies by CT (arXiv:1007.2241) and MSTW (arXiv:1006.2753)
- Now precise LHC measurements also available from CMS (CMS PAS EWK 10 -006) and ATLAS

First constrains on PDFs from LHC data?



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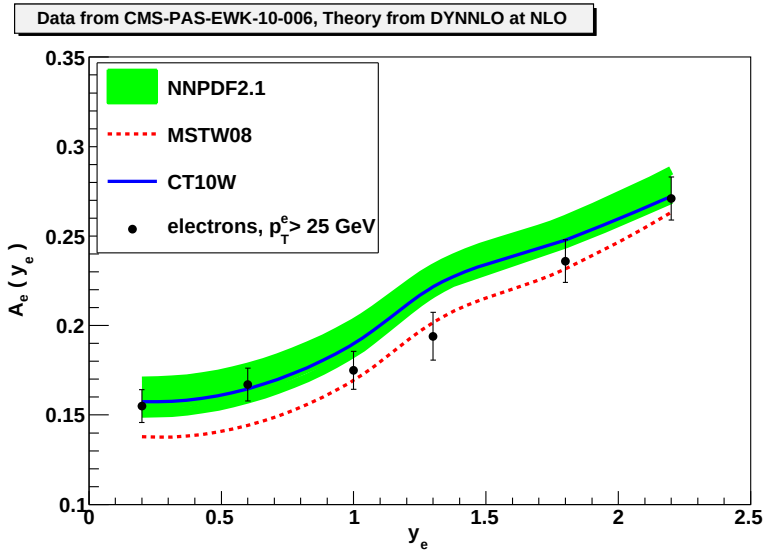
- CMS measurement (CMS PAS EWK 10 -006): e and μ asymmetries with two cuts $p_T^l \geq 25$ GeV and $p_T^l \geq 30$ GeV
- Compare CMS data with predictions from DYNNLO at NLO
  Discriminating power on PDF sets



Preliminary Results

$\chi^2/N_{\rm dat}$ (el)	$p_T^l \geq 25$ GeV	$p_T^l \geq 30$ GeV
NNPDF2.1	**1.8**	1.6
MSTW08	**1.8**	2.3
CT10W	**1.2**	1.3

The three PDFs sets: decent description of CMS data with $p_T^e \geq 25$ GeV

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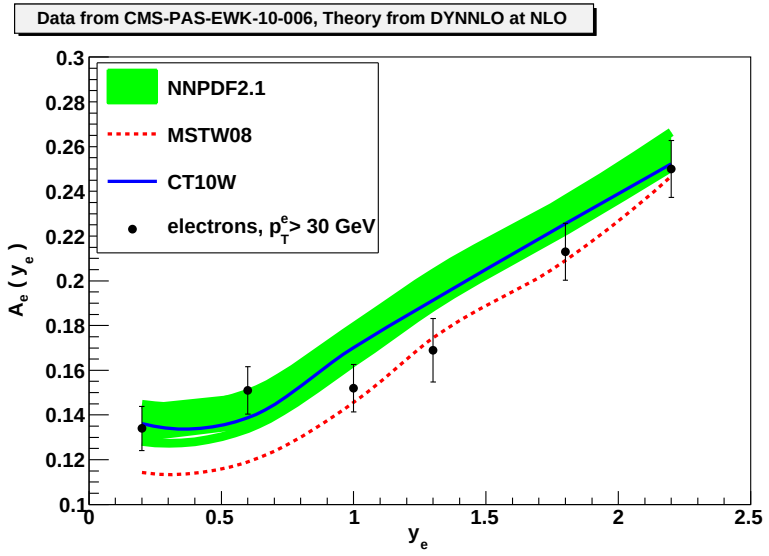

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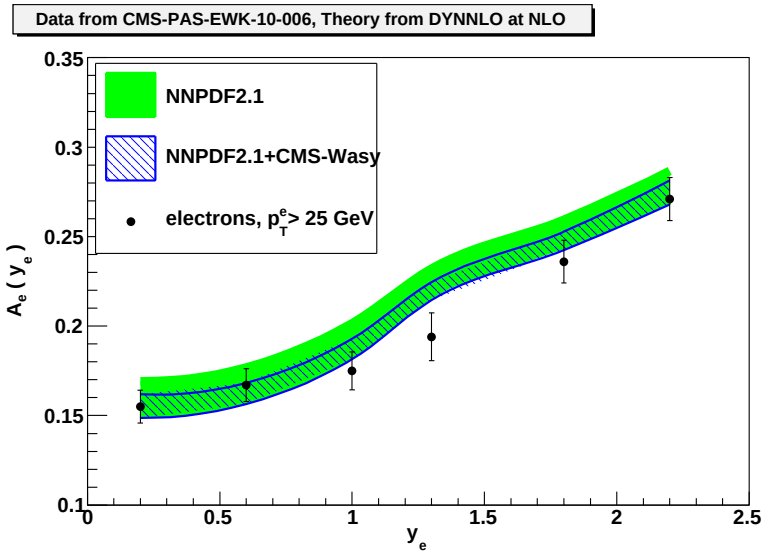
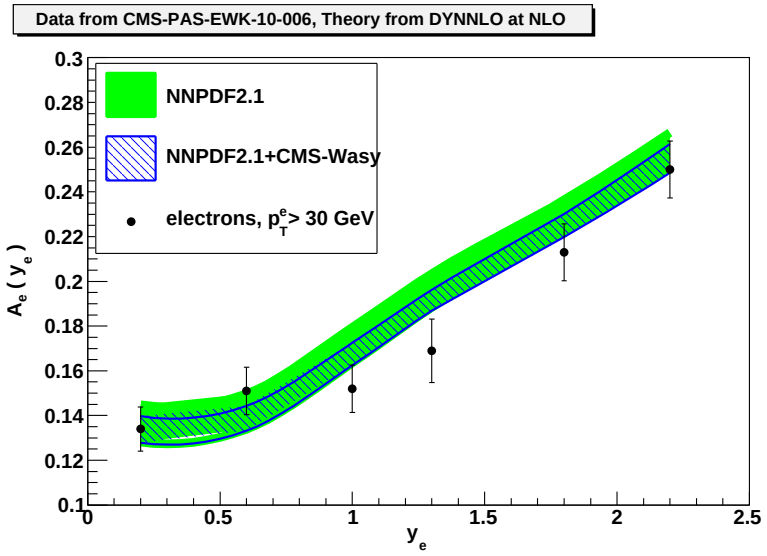
The three PDFs sets: decent description of CMS data with $p_T^e \geq 30$ GeV

FIRST LHC CONSTRAINS ON PDFs?
YES, REDUCED PDF ERRORS ON SEA QUARKS!

Impact of CMS Wasy data on PDFs





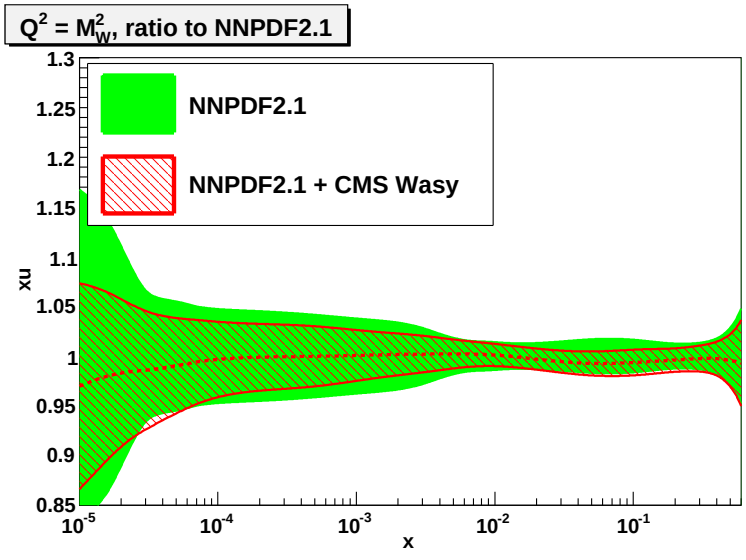
- CMS Wasy data have been included in the NNPDF2.1 PDF set
- The data/theory agreement improves when CMS data included

$\chi^2/N_{\rm dat}$ (el)	$p_T^l \geq 25$ GeV	$p_T^l \geq 30$ GeV
NNPDF2.1	**1.8**	**1.6**
NNPDF2.1 + CMS-Wasy	**1.05**	**1.15**

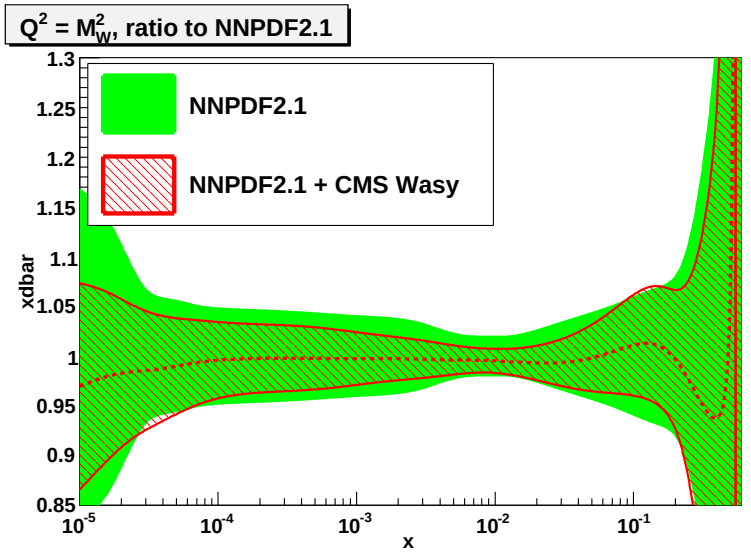
- CMS data fully consistent with global PDF fit

Impact of CMS Wasy data on PDFs

$xu(x, M_W^2)$



$x\bar{d}(x, M_W^2)$



Sea quark PDF uncertainties reduced at medium and small-x

CMS Wasy data: first LHC constrains on PDFs

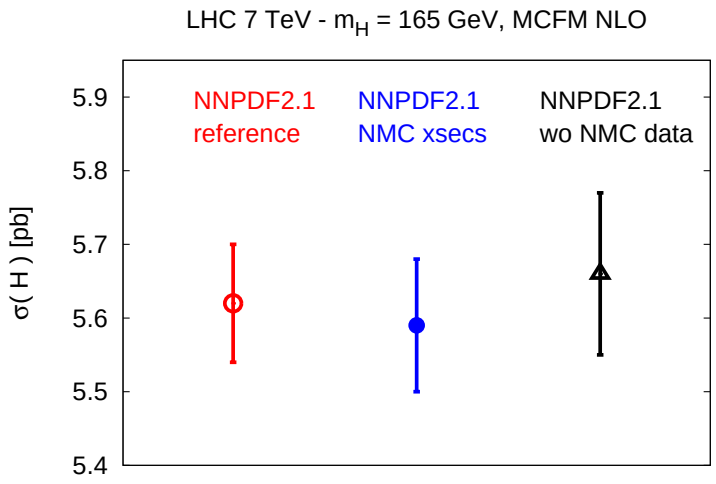
THE IMPACT OF NMC DATA ON PDFs AND HIGGS PRODUCTION AT HADRON COLLIDERS

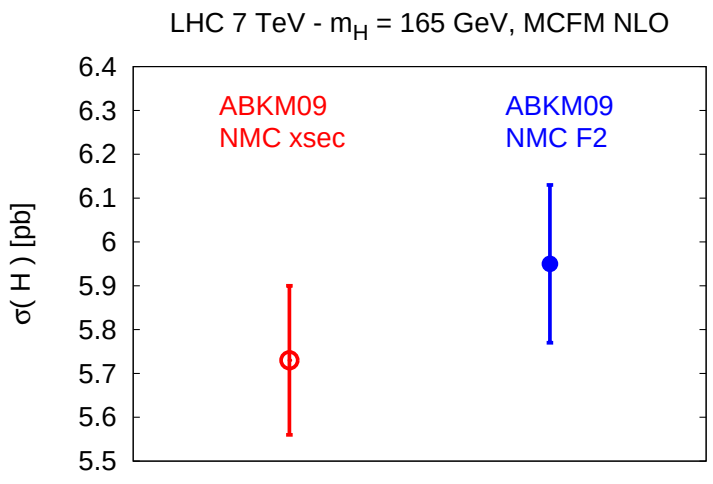
NMC data and Higgs production

- 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) $\longrightarrow$ Origin of ABKM/MSTW discrepancy?

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

- 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





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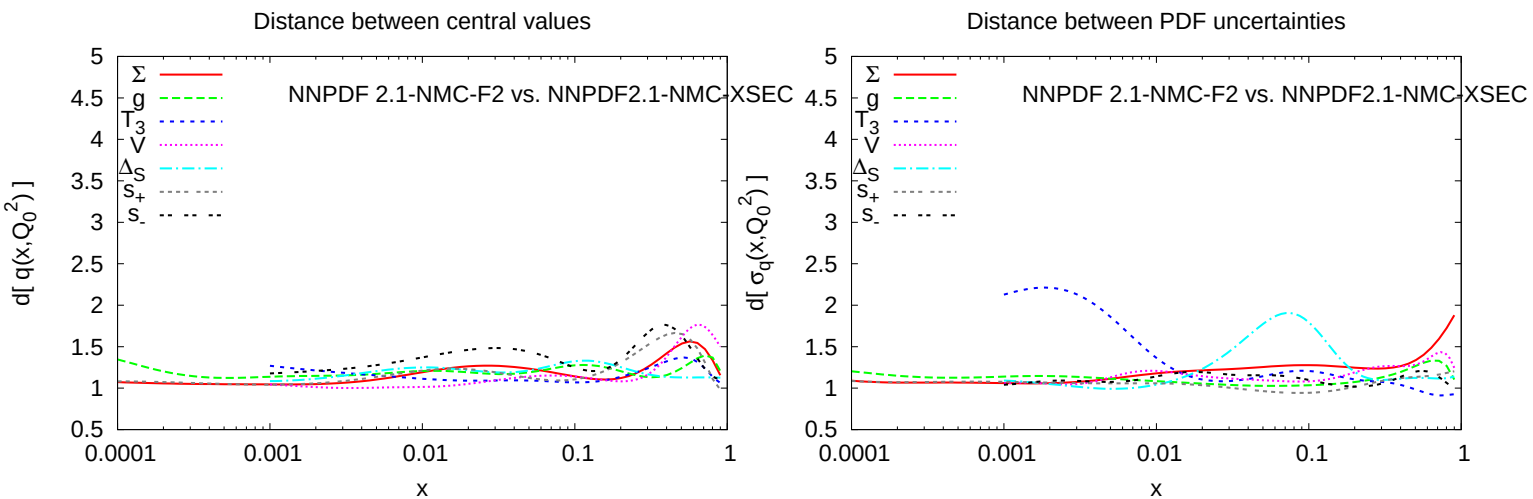

Statistical distances between NNPDF2.1 NMC-F2 and NNPDF2.1 NMC-XSEC

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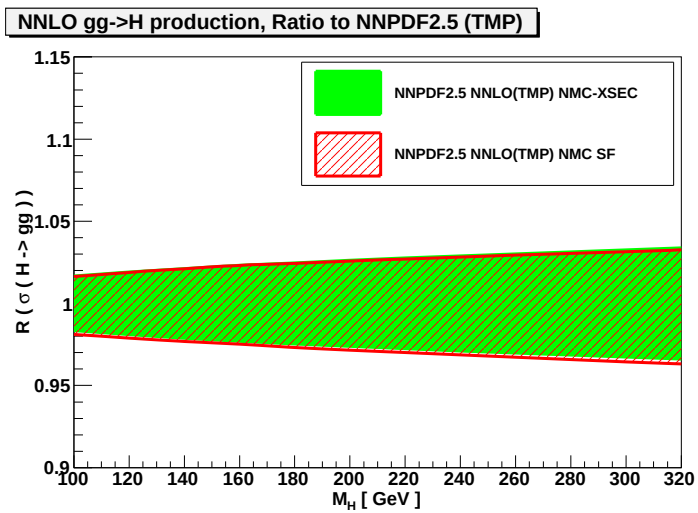

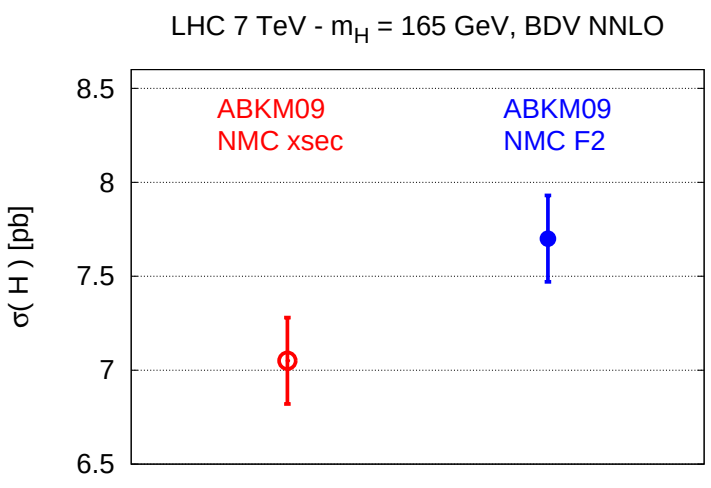

The treatment of NMC data has negligible impact on collider Higgs production
Also at NNLO

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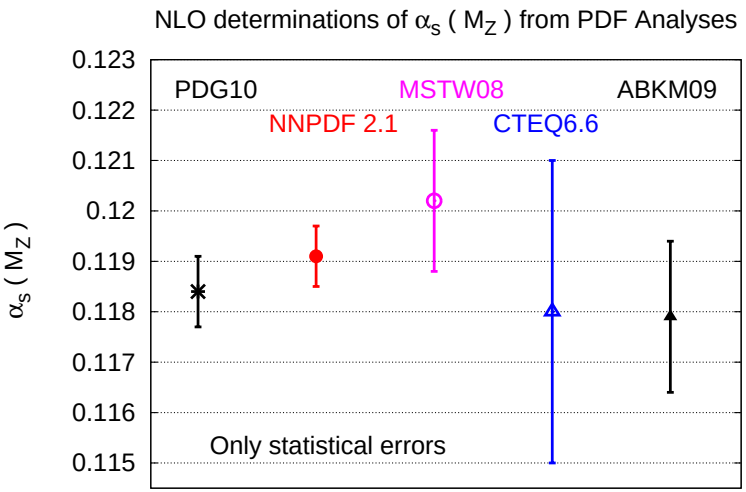
$\alpha_s(M_Z)$	$\alpha_s(M_Z)$ with $\sigma_{\rm NMC}$	$\alpha_s(M_Z)$ with $F_2^{\rm NMC}$
NLO	0.1179(16)	0.1195(17)
NNLO	**0.1135(14)**	0.1170(15)
NNLO $+F_L$ at $O(\alpha_s^3)$	0.1122(14)	0.1171(14)

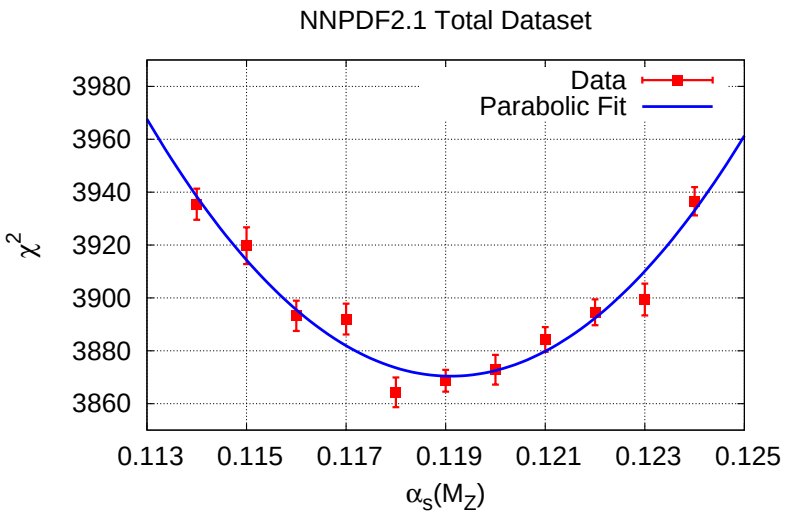
NMC *may* gave an impact on $\alpha_s(M_Z)$ determinations from PDF fits
Only affects LHC Higgs XS if PDG $\alpha_s(M_Z) = 0.1184 \pm 0.0007$ value not trusted

DETERMINATION OF $\alpha_s(M_Z)$ FROM AN UNBIASED GLOBAL PARTON ANALYSIS

$\alpha_s(M_Z)$ from PDF analysis

- Good: Small statistical errors from large dataset
- Bad: Bias from PDF parametrization? Dependence on dataset?
- NLO: reasonable agreement, NNPDF2.1 smallest statistical uncertainties without theoretical bias
- PDG10 average: $\alpha_s^{\rm PDG}\,(M_Z) = 0.1184 \pm 0.0007$, $\alpha\,(M_Z)^{\tau+\rm EW} = 0.1206 \pm 0.0012$

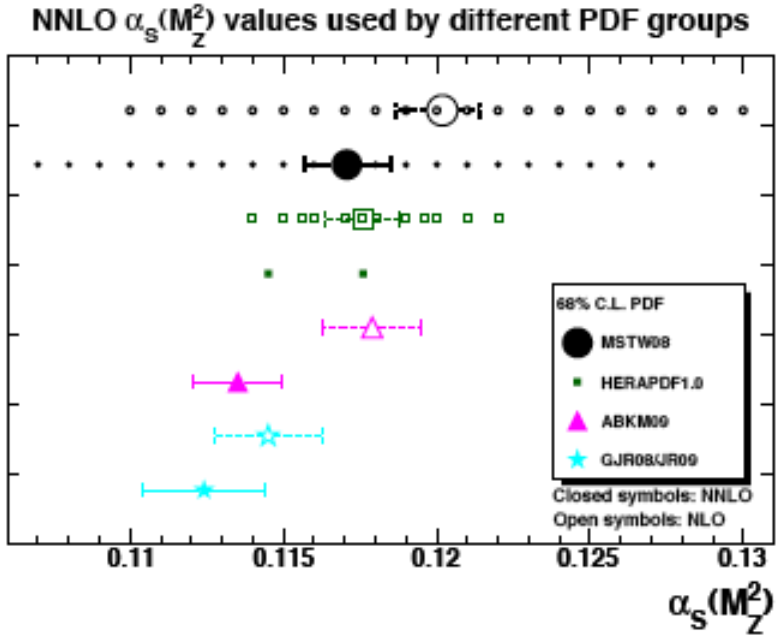




N.B.: CT, NNPDF and MSTW provide PDF sets for a wide range of $\alpha_s\,(M_Z)$ values

$\alpha_s(M_Z)$ from PDF analysis

- Good: Small statistical errors from large dataset
- Bad: Bias from PDF parametrization? Dependence on dataset?
- Large spread in NNLO α_s values from PDF fits
  $\rightarrow$ Hints of breakdown of perturbative expansion?
  $\rightarrow$ DIS not the best place to determine $\alpha_s\,(M_Z)$?
- Is it meaningful to use $\alpha_s\,(M_Z) = 0.1135$ in LHC phenomenology?

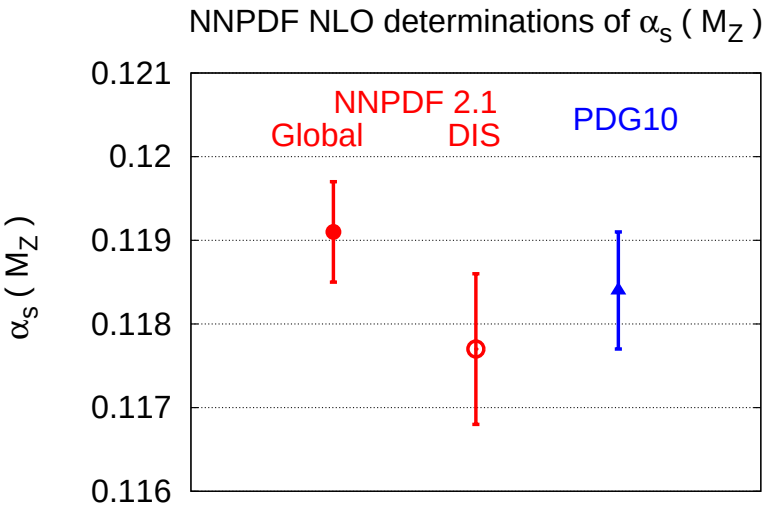


G. Watt 2011

Crucial to provide PDF sets with varying $\alpha_s\,(M_Z)$
This includes $\alpha_s^{\rm PDG}\,(M_Z)$ for reliable LHC phenomenology

Dataset dependence of $\alpha_s(M_Z)$ in PDF fits

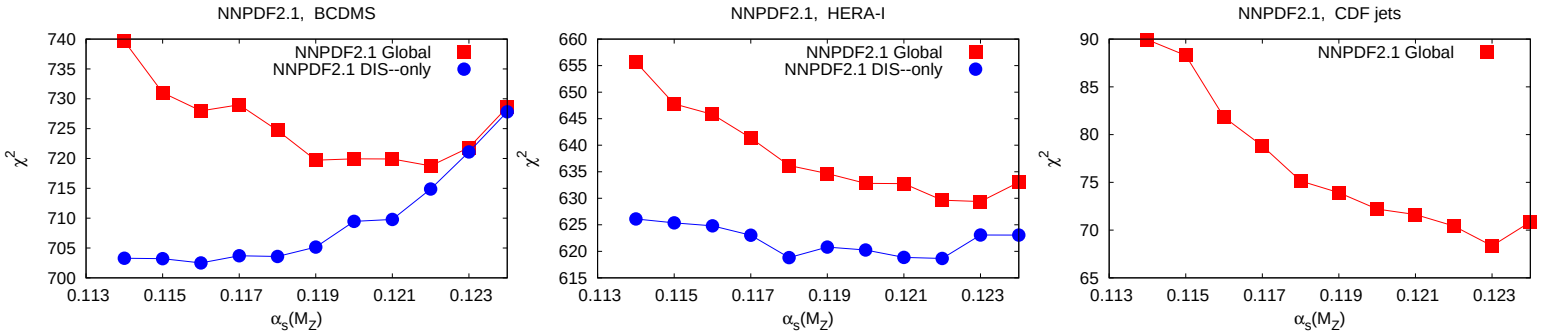
	$\alpha_s(M_Z)$
NNPDF2.1	$\mathbf{0.1191 \pm 0.0006^{stat}}$
NNPDF2.1 DIS–only	$\mathbf{0.1177 \pm 0.0009^{stat}}$
NNPDF2.0	0.1168 ± 0.0007^{stat}
NNPDF2.0 DIS–only	0.1145 ± 0.0010^{stat}



- Do DIS data prefer a smaller value of α_s?
  Perhaps, but not much smaller, compatible with global fit and with higher uncertainties
- Theoretical uncertainties likely dominant (*Ex.* $\Delta\alpha_s^{\rm HQ} \sim 0.002$)

Anyway, this is to be kept separated to which $\alpha_s(M_Z^2)$ should used in LHC phenomenology!

$\alpha_s\,(M_Z)$ for individual experiments



- BCDMS in a DIS–only fit sometimes has runaway direction at small $\alpha_s\,(M_Z)$, absent in the global fit
- HERA rather flat in α_s in DIS–only fit
- Tevatron jet experiments exclude small $\alpha_s\,(M_Z)$ values

Interplay between DIS and hadronic data important

Summary

- NNPDF2.5 will be the first NNPDF NNLO PDF set
- The NNLO Higgs cross section in reasonable agreement with NNPDF2.5 and MSTW08 (also in DIS–only fit)
- CMS lepton asymmetry data provide the first ever LHC constraints on PDFs
- Differences in the treatment of NMC have negligible impact on PDFs and Higgs production within NNPDF
- $\alpha_s(M_Z)$ determined at NLO from NNPDF2.1: compatible with PDG average, reduced statistical uncertainties, theory errors dominant

Thanks for your attention!

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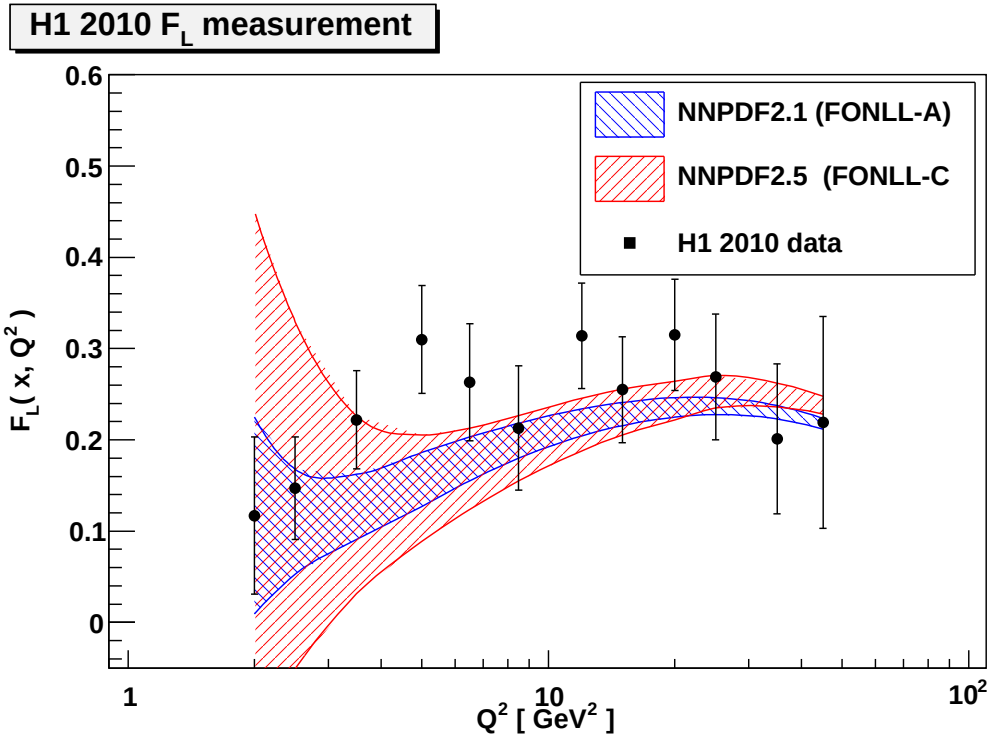
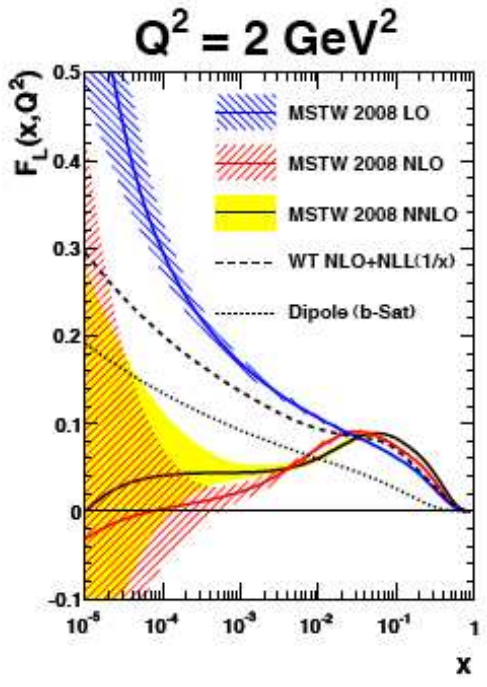
Thanks for your attention!

EXTRA MATERIAL

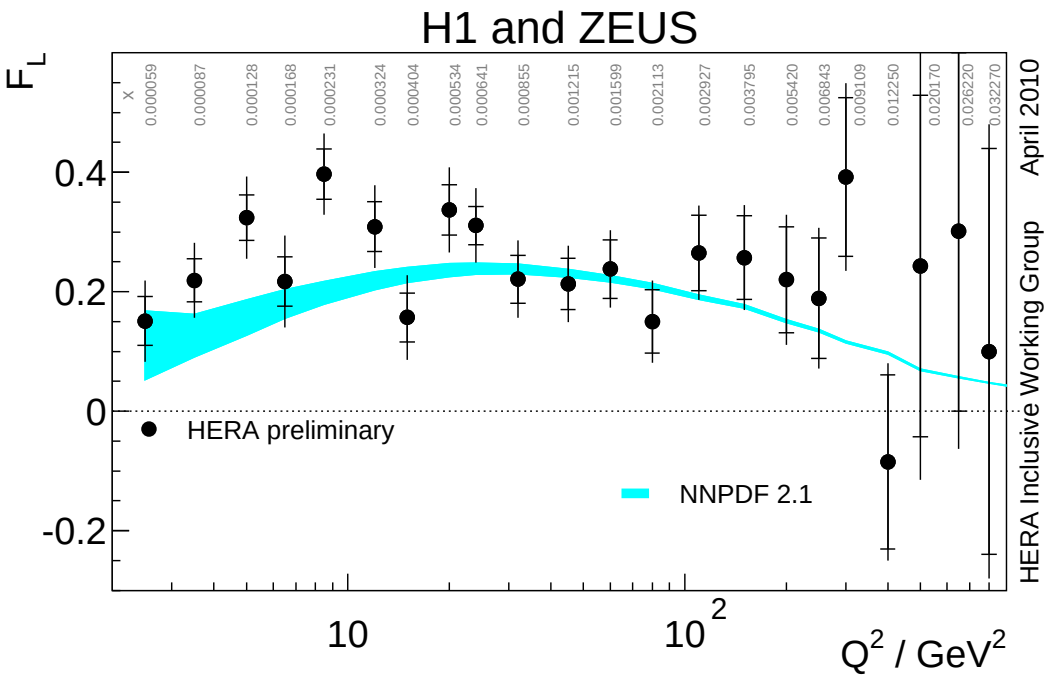
Perturbative stability of $F_L(x, Q^2)$





- Stability of F_L expected from the small-x gluon stability from NLO to NNLO
- NNPDF $F_L(x, Q^2)$ positive by construction at all orders
  MSTW allows $F_L \leq 0$ at low scales

Perturbative stability of $F_L(x, Q^2)$



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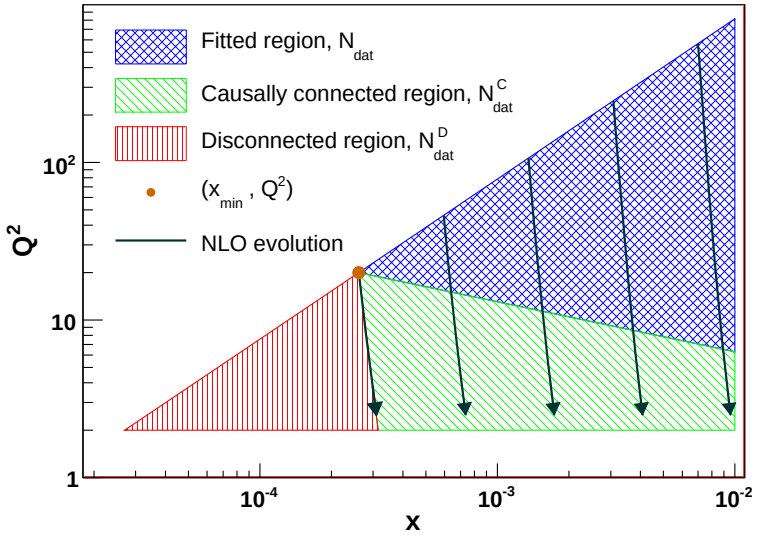
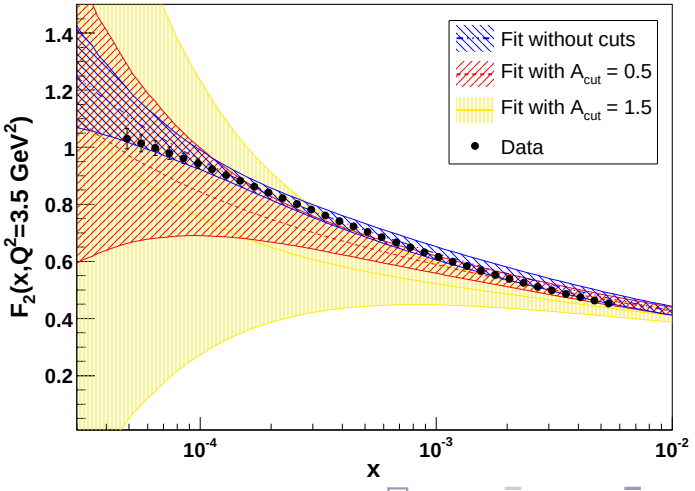
  MSTW allows $F_L \leq 0$ at low scales

NNPDF2.1 NLO and 2.5 NNLO $\rightarrow$ Good description of HERA combined F_L
$F_L(x, Q^2)$ is positive and perturbative stable at small-x

A new QCD regime in HERA data?

- Deviations from NLO DGLAP in small-x small-Q^2 HERA-I data have been reported
- NNPDF finds that small–x and Q^2 data cannot be recovered by backwards DGLAP evolution when excluded from global PDF fit (arXiv:0910.3143,1007.5405)
- Prediction: NNLO should be worse than NLO for small-x HERA





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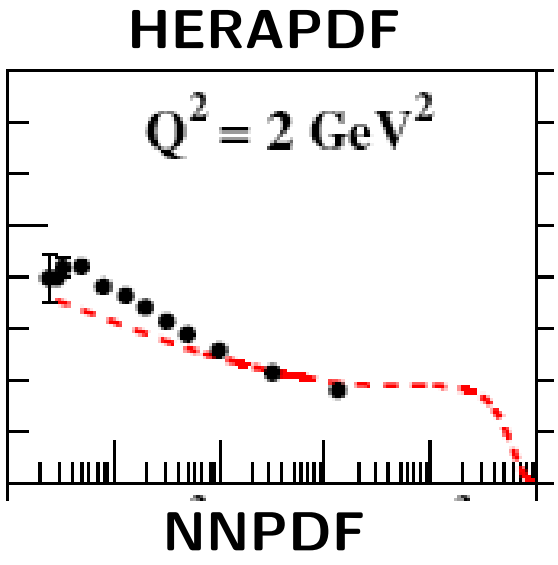
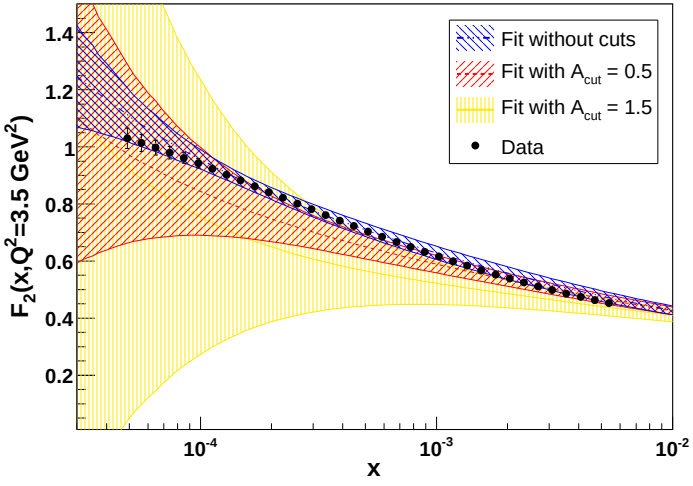
- Independent confirmation from HERAPDF (H1 prelim-10-044)



$\alpha_S(M_Z)$	NNLO fits	without low energy data
0.1176	$\Delta\chi^2$	64
0.1145	$\Delta\chi^2$	49



New QCD regime: Non–linear dynamics?
High–energy resummation?

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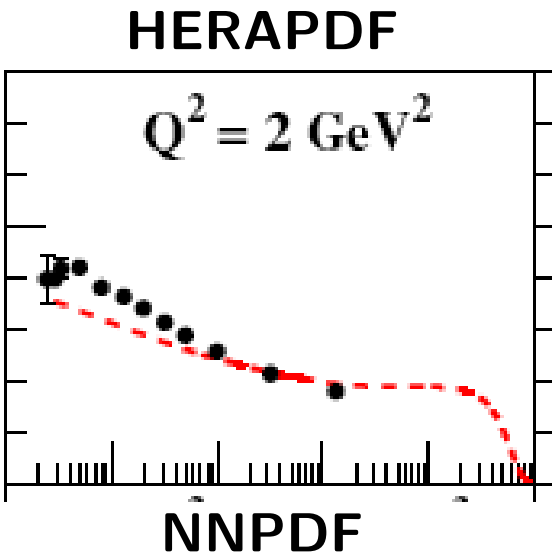
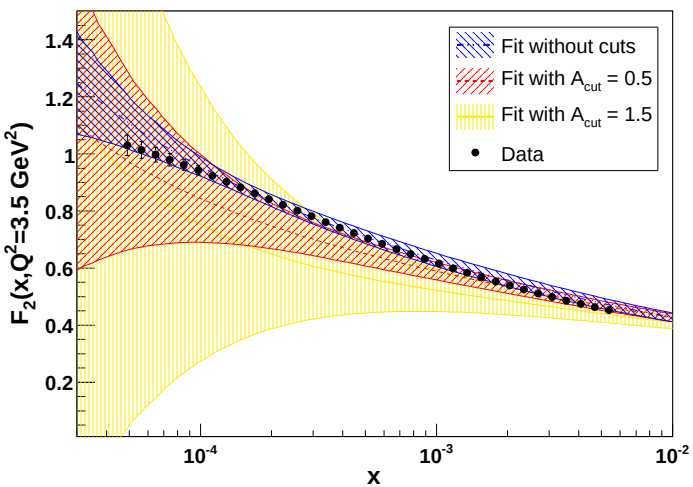
- NNPDF2.5: Decrease in fit quality to HERA-I NC e^+ data:

$$\text{NNLO}: \chi^2 = 1.33\,, \quad \text{NLO}: \chi^2 = 1.24$$

New QCD regime: Non–linear dynamics?
High–energy resummation?





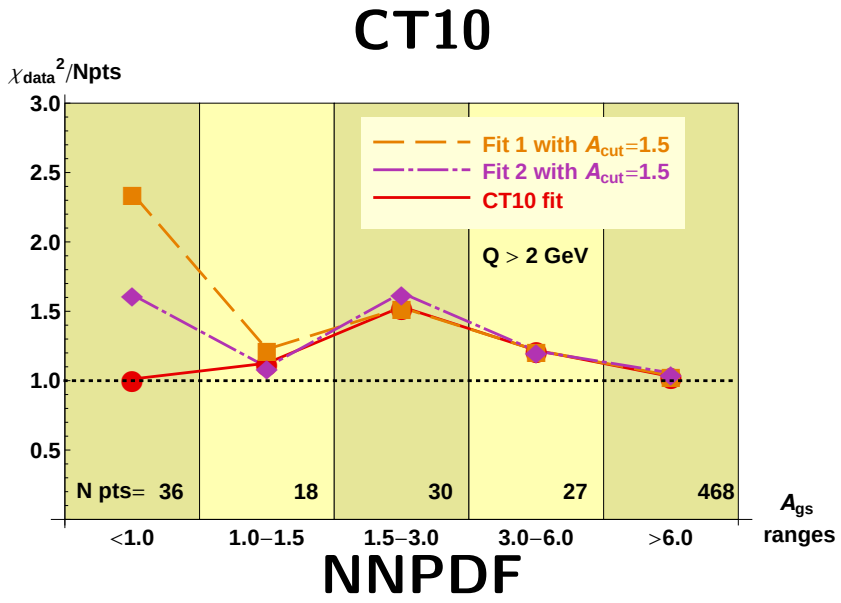
A new QCD regime in HERA data?

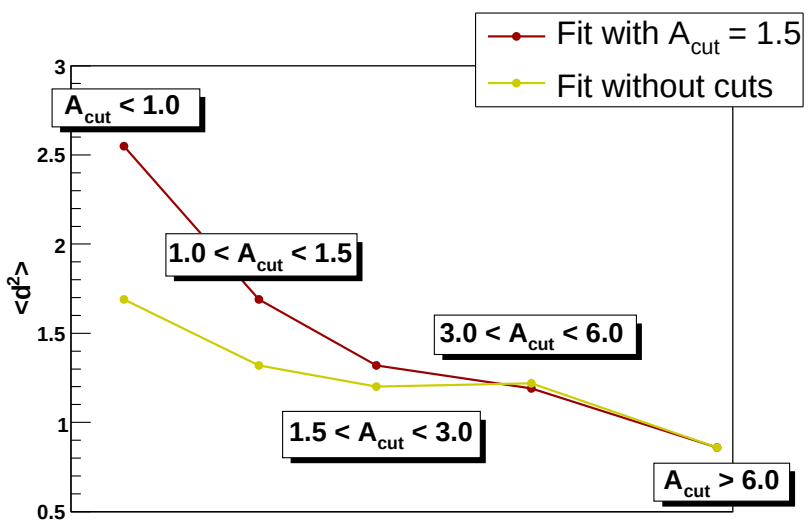
- Prediction: NNLO should be worse than NLO for small-x HERA
- MSTW08: Slight improvement in fit quality to HERA-I NC e^+ data:

$$\mathrm{NNLO}, \alpha_s = 0.1171 : \chi^2 = 0.75 \ ,$$
$$\mathrm{NLO}, \alpha_s = 0.1202 : \chi^2 = 0.81$$

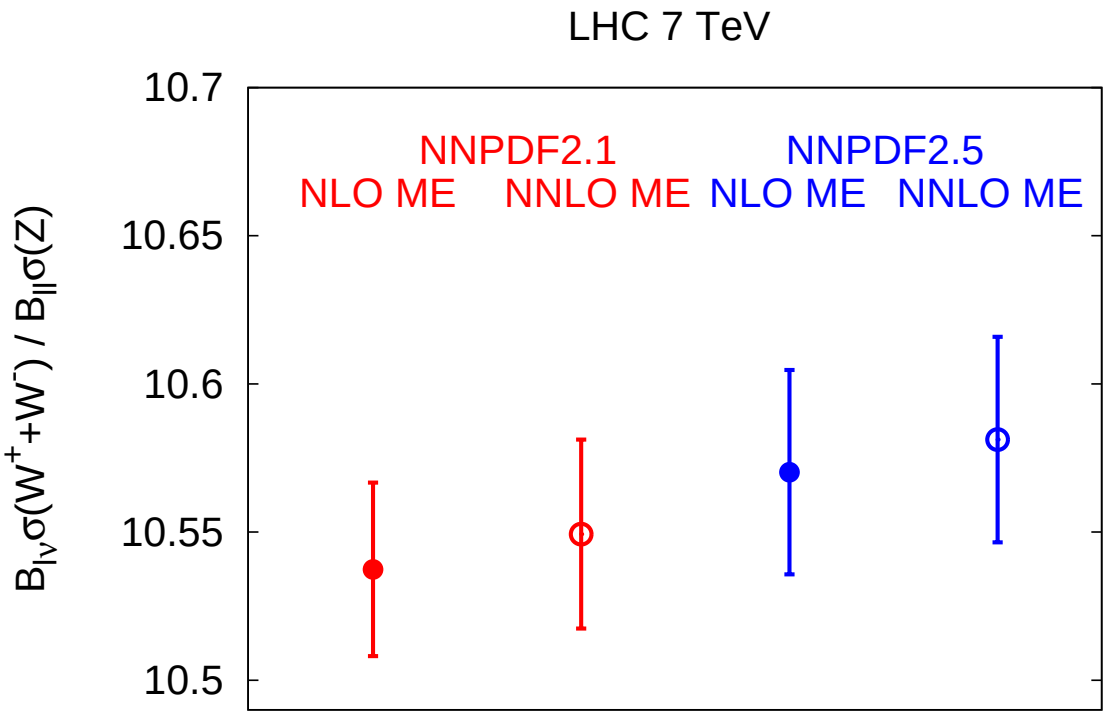
  arXiv:1006.2753 + R. Thorne, priv. comm.
  But systematics added in quadrature: at this level, correlations might play a role
  Should we compare at fixed $\alpha_s\,(M_Z)$?
- CT10: Partial evidence, but restricted to few functional forms (arXiv:1007.2241)

New QCD regime: Non–linear dynamics?
High–energy resummation?





The W/Z ratio



- Impact of NNLO Matrix Element (ME) corrections minimal
- Moderate shift from NNLO PDFs
- Golden benchmark observable?

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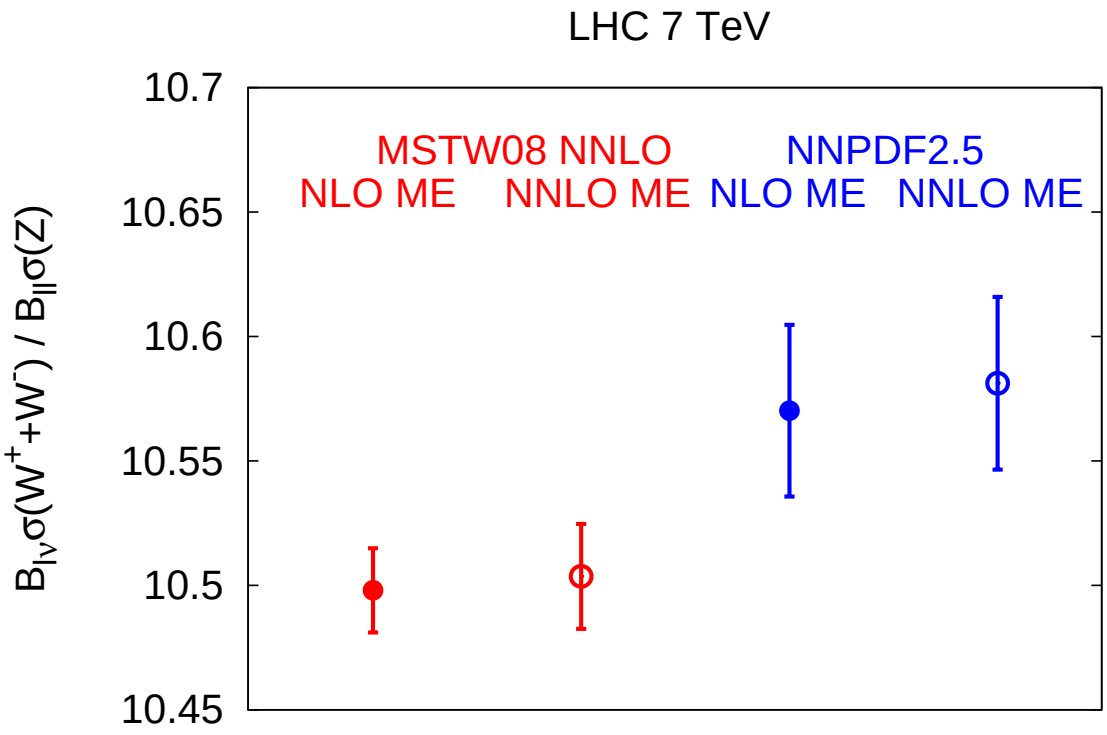

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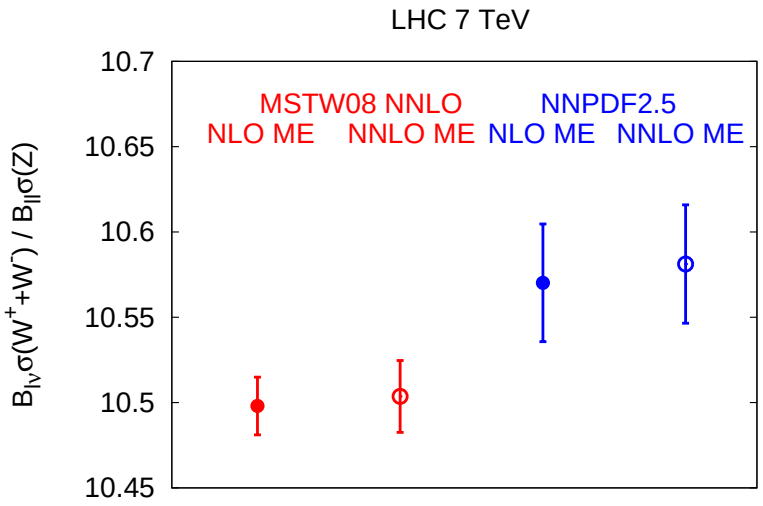

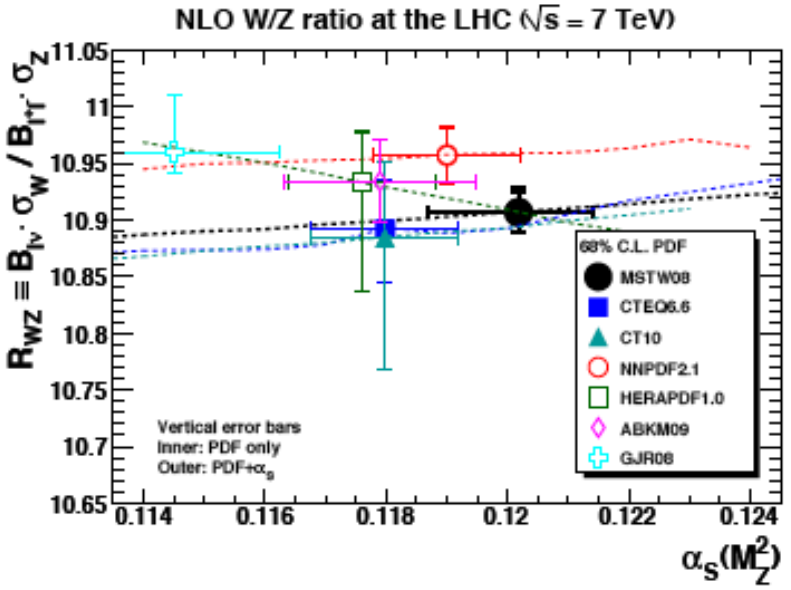

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LHC data will have (or has now) discrimination power

The PDG Global $\alpha\,(M_Z)$ average

The 2009 PDG $\alpha_s\,(M_Z)$ average is (S. Bethke, arxiv:0908.1135)

$$\alpha\,(M_Z) = 0.1184 \pm 0.007$$

Preliminary 2011 average (S. Bethke, alphas2011 workshop)

$$\alpha\,(M_Z) = 0.1187 \pm 0.006\ , \qquad \chi^2 = 8/8\,(\mathrm{ndof})$$

	Process	Q [GeV]	$\alpha_s(Q)$	$\alpha_s(M_{Z^0})$	excl. mean $\alpha_s(M_{Z^0})$	std. dev.
new →	τ-decays	1.78		0.1209 ± 0.0014	0.1182 ± 0.0010	1.6
	DIS $[F_2]$	2 - 170	–	0.1142 ± 0.0023	0.1190 ± 0.0011	1.9
	DIS [e-p → jets]	6 - 100	–	0.1198 ± 0.0032	0.1186 ± 0.0007	0.4
	$Q\overline{Q}$ states	7.5	0.1923 ± 0.0024	0.1183 ± 0.0008	0.1192 ± 0.0009	0.7
	Υ decays	9.46	$0.184^{+0.015}_{-0.014}$	$0.119^{+0.006}_{-0.005}$	0.1187 ± 0.0006	0.1
	e^+e^- [JADE]	14 - 44	–	0.1172 ± 0.0051	0.1187 ± 0.0006	0.3
	e^+e^- [ew prec. data]	91.2	0.1193 ± 0.0028	0.1193 ± 0.0028	0.1186 ± 0.0007	0.2
→	e^+e^- [LEP, A+O]	91 - 208	–	0.1220 ± 0.0034	0.1186 ± 0.0006	0.6
→	$p\bar{p}$ D0 incl. jets		–	0.1161 ± 0.0045	0.1187 ± 0.0006	0.6

The PDG Global $\alpha(M_Z)$ average

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$$\alpha(M_Z) = 0.1184 \pm 0.007$$

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$$\alpha(M_Z) = 0.1187 \pm 0.006\ , \qquad \chi^2 = 8/8\,(\mathrm{ndof})$$

To be conservative, take average of the result from τ–decays: fully inclusive, $\mathcal{O}(\alpha_s^4)$

$$\alpha(M_Z)^{\tau} = 0.1209 \pm 0.0014$$

and the result from the global electroweak fit (if this is wrong also M_W is ...)

$$\alpha(M_Z)^{\mathrm{EW}} = 0.1193 \pm 0.0028$$

for an average

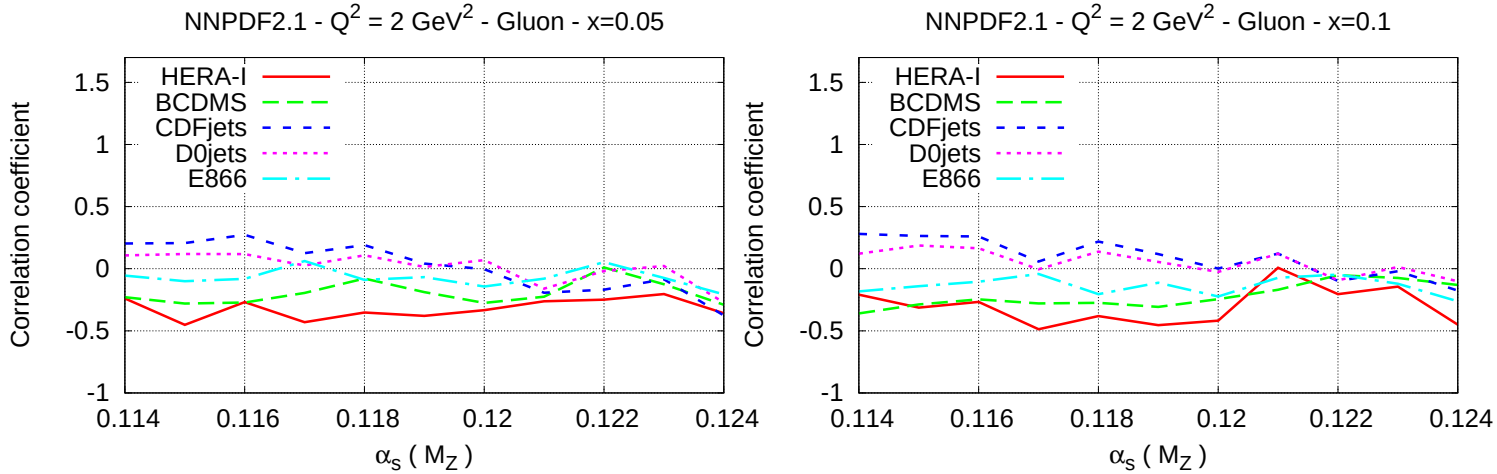
$$\alpha(M_Z)^{\tau+\mathrm{EW}} = 0.1206 \pm 0.0012$$

Low values of $\alpha_s(M_Z)$ from PDF fits with small uncertainties difficult to reconcile with the most theoretically sound α_s determinations

PDF sets should be provided for a range of $\alpha_s(M_Z)$ values
The sensitivity of PDF fits to $\alpha_s(M_Z)$ is an interesting problem, but by construction the accuracy of $\alpha_s(M_Z)$ from PDFs is worse than the global average

PDFs-χ^2 Correlation

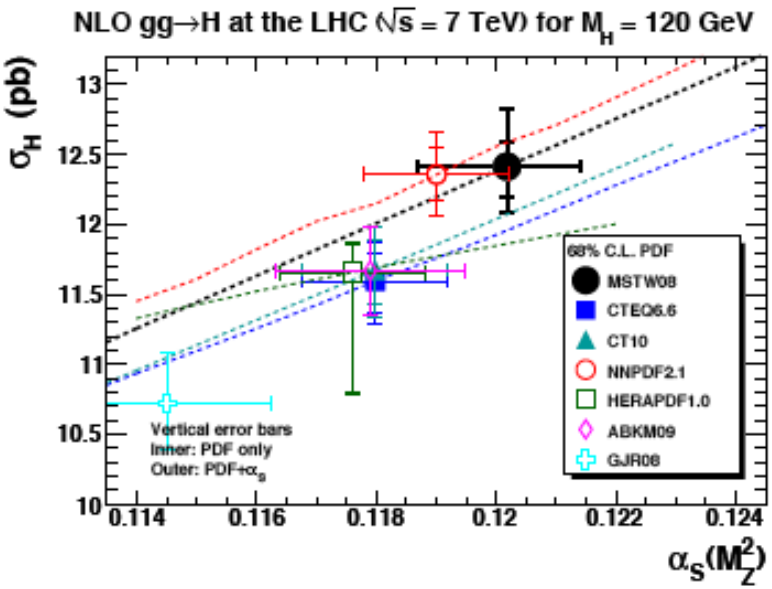
$$\rho\left[\chi^2_j\left(\alpha_s\right), g_{\alpha_s}\left(x,Q^2\right)\right]_j = \frac{\left\langle \chi^{2(k)}_j\left(\alpha_s\right) g^{(k)}_{\alpha_s}\left(x,Q^2\right)\right\rangle_{\rm rep} - \left\langle \chi^{2(k)}_j\left(\alpha_s\right)\right\rangle_{\rm rep}\left\langle g^{(k)}_{\alpha_s}\left(x,Q^2\right)\right\rangle_{\rm rep}}{\sigma_{\chi^2(\alpha_s)}\sigma_{g_{\alpha_s}}}$$

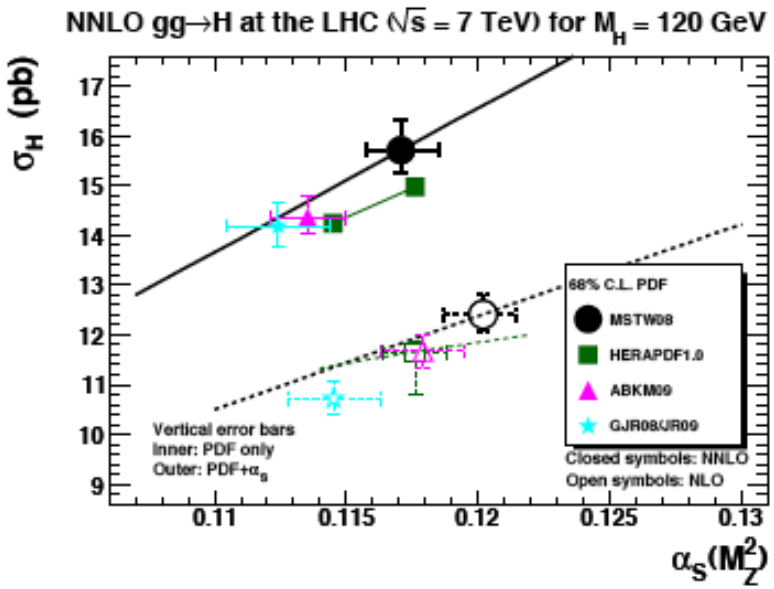


- Compute correlation between χ^2 and PDFs
- Large correlations $\longrightarrow$ Runaway direction
- Opposite sign correlations $\longrightarrow$ Data pulling in opposite directions
- At low $\alpha_s = 0.114$ DIS has a runaway direction stabilized by gluon

NNLO benchmarking

- The PDF4LHC NLO benchmark exercise was very useful to understand similarities and differences between PDF sets
- Also basis for the definition of the interim PDF4LHC recommendation
- Preliminary results for the NNLO benchmark by G. Watt (LH QCD 2011) $\rightarrow$ Towards new NNLO PDF4LHC recipee?
- NNPDF can contribute with the (preliminary) NNPDF2.5 NNLO predictions. CT?





How do global PDF sets compare at NNLO?