NNPDF at NNLO and LHC phenomenology

Maria Ubiali

on behalf of the NNPDF Collaboration:

R. D. Ball, V. Bertone, F. Cerutti, L. Del Debbio, S. Forte,
A. Guffanti, J. I. Latorre, J. Rojo, M.U.

Institut für Theoretische Teilchenphysik und Kosmologie, RWTH Aachen University,
D-52056 Aachen, Germany

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PDF4LHC workshop, DESY, Hamburg

Outline

* Progress in the NNPDF analysis
  - NNPDF2.1 at NNLO
  - NNPDF2.1 at LO

* LHC phenomenology at NNLO
  - Higgs total cross-section
  - $t\bar{t}$ total cross-section
  - Vector boson production

* Inclusion of the LHC data in the NNPDF analysis
  - The effect of the LHC W lepton asymmetry data
  - Combination with the Tevatron W lepton asymmetry data
  - The NNPDF2.2 NLO set

* Conclusion and outlook

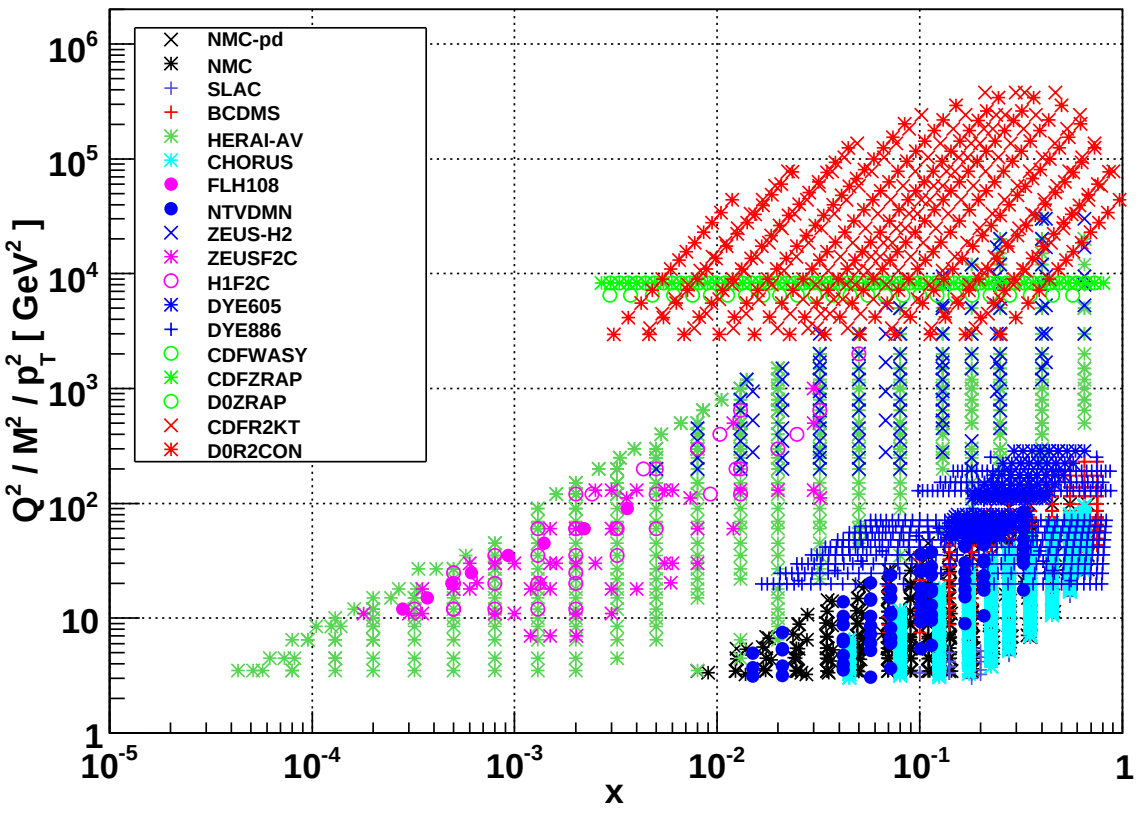
Outline

NNPDF2.1 at NNLO

Experimental data

* Same dataset as in NNPDF2.1 NLO [Nucl.Phys. B849 (2011)]

NNPDF2.1 dataset



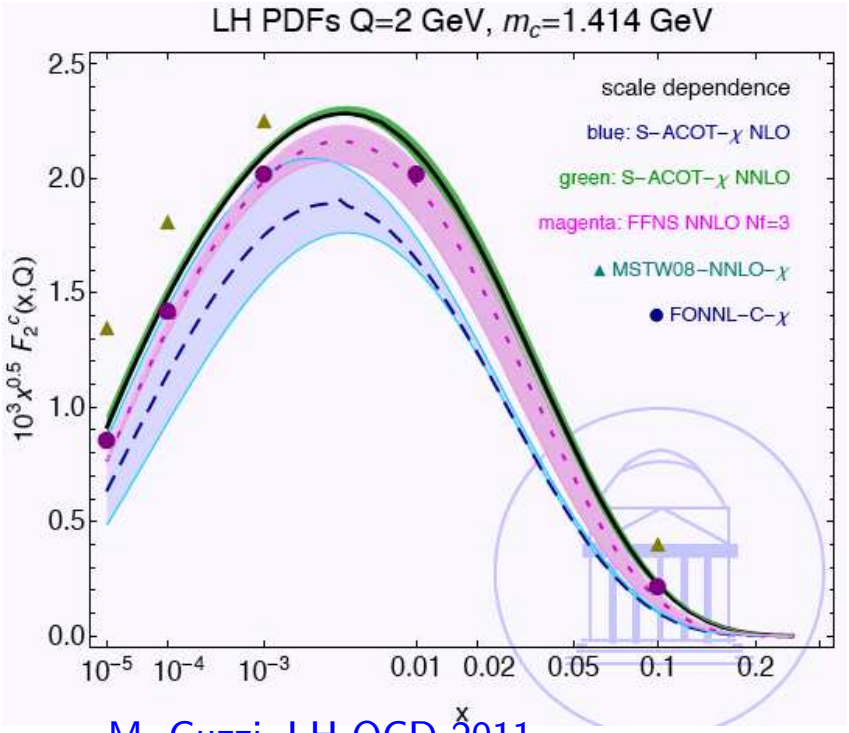
1. Fixed Target DIS
2. Combined HERA–I data
3. HERA F_2^c (looser cuts)
4. Fixed Target DY
5. Tevatron W and Z production
6. Tevatron jet production

$Q^2 > 3$ GeV^2
$W^2 > 12.5$ GeV^2

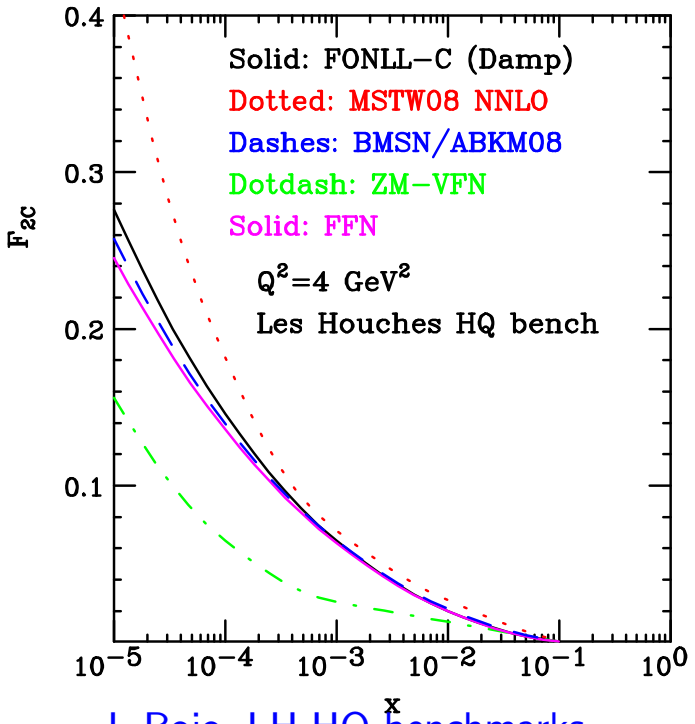
NNPDF2.1 at NNLO

Theoretical treatment

* Heavy quark mass effects treated in the FONLL-C General Mass VFN scheme [ArXiv:1001.2312]: NNLO massless matched to $\mathcal{O}(\alpha_s^2)$ massive contributions.
* NNLO fast evolution for PDFs and DIS observables in the FastKernel framework



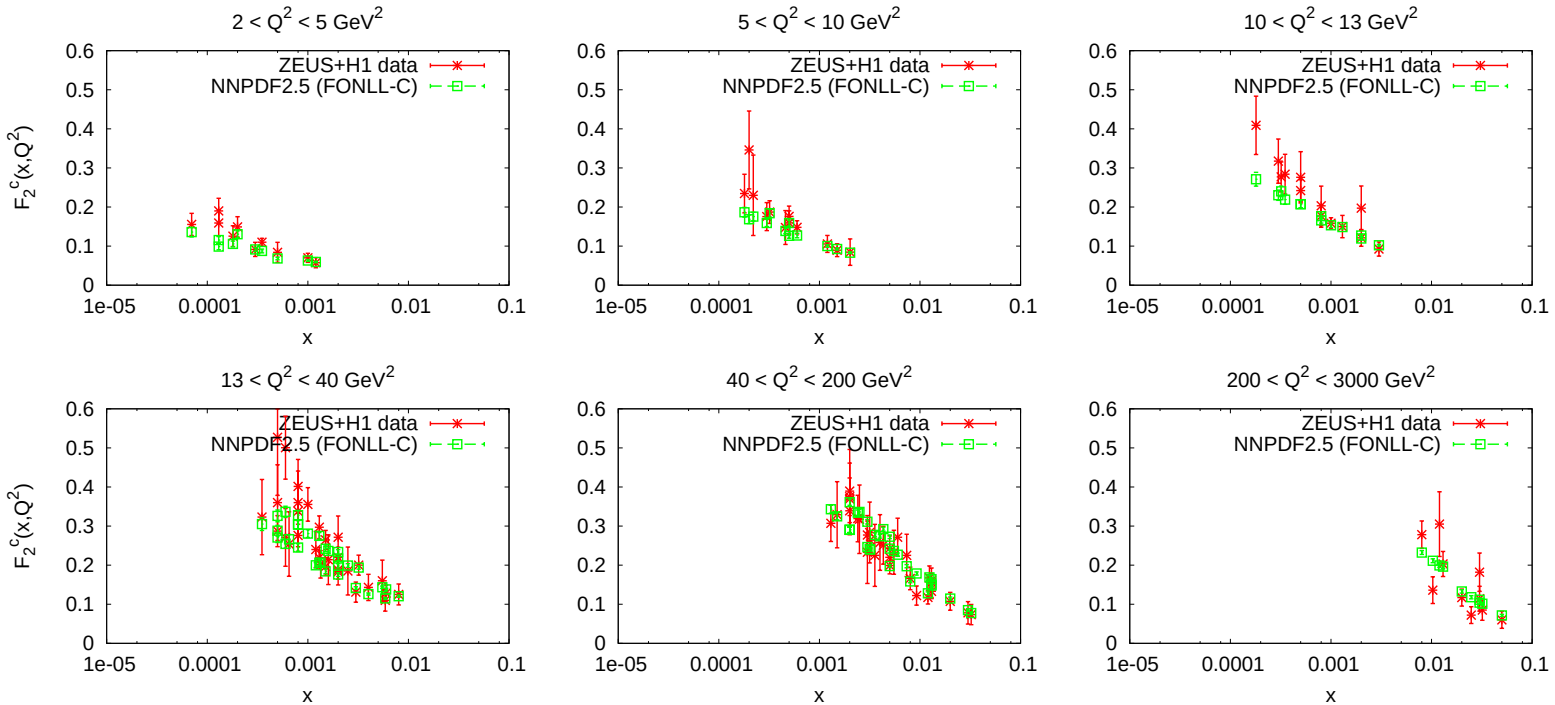
M. Guzzi, LH QCD 2011



J. Rojo, LH HQ benchmarks

NNPDF2.1 at NNLO

Theoretical treatment

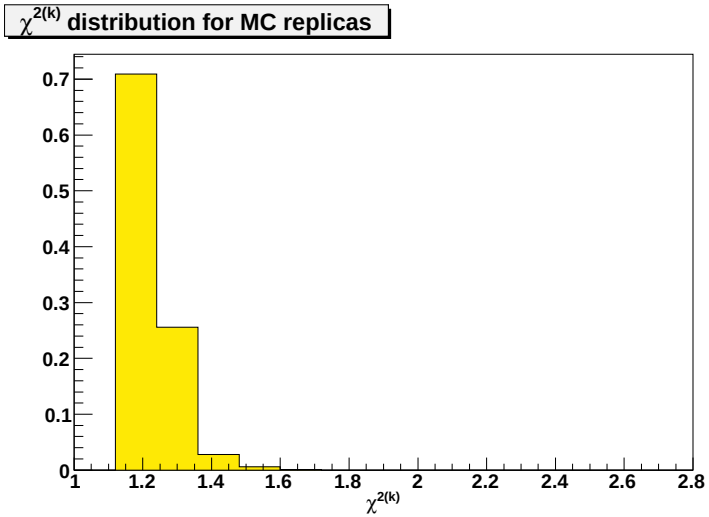


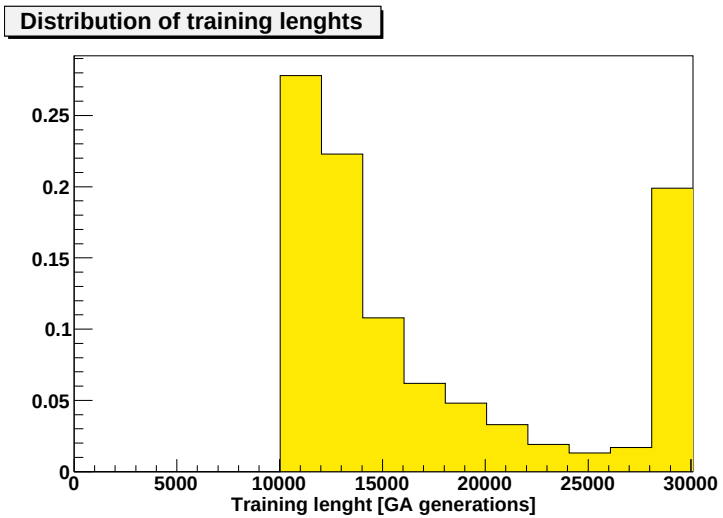
- HERA combined F_2^c dataset constrain small-x gluon
- Good description of ZEUS and H1 F_2^c data without any tuning of the GM-VFN

$$\chi^2_{F_2^c} = 1.1$$

NNPDF2.1 at NNLO

Results: the NNLO fit



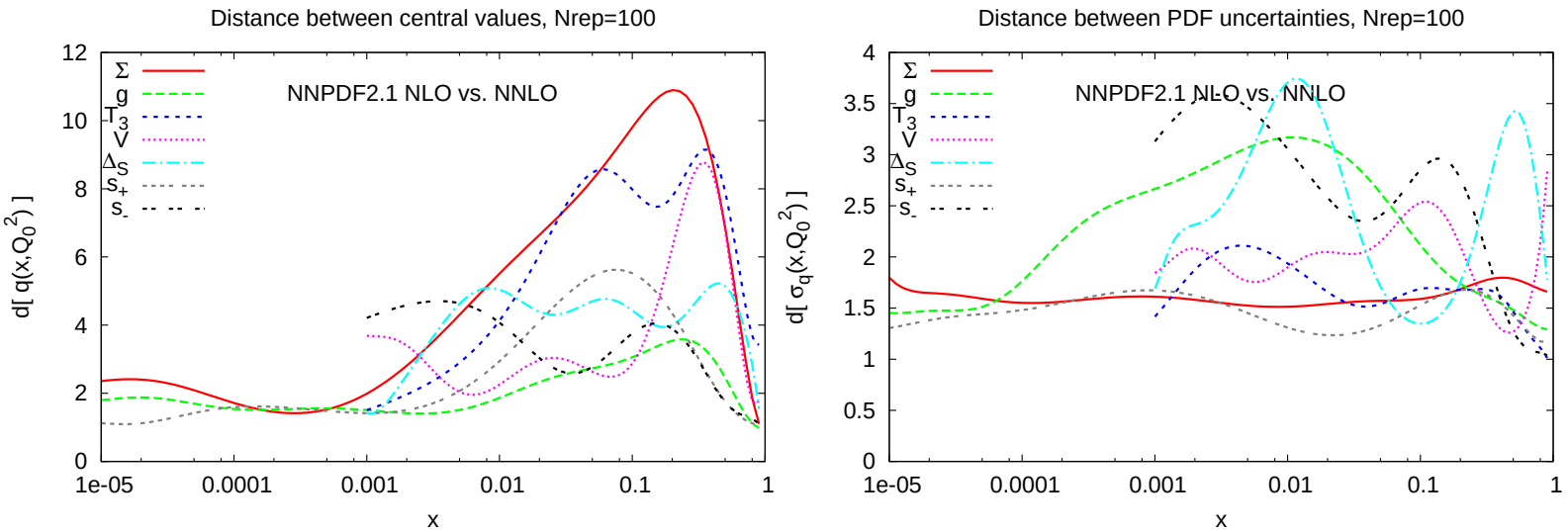


	NNLO	NLO
$\chi^2_{\rm tot}$	**1.16**	**1.16**
$\langle E\rangle \pm \sigma_E$	2.22 ± 0.07	2.24 ± 0.09
$\langle E_{\rm tr}\rangle \pm \sigma_{E_{\rm tr}}$	2.19 ± 0.09	2.22 ± 0.11
$\langle E_{\rm val}\rangle \pm \sigma_{E_{\rm val}}$	2.27 ± 0.10	2.28 ± 0.12
$\langle {\rm TL}\rangle \pm \sigma_{\rm TL}$	$(17 \pm 7)\ 10^3$	$(16 \pm 6)\ 10^3$
$\left\langle \chi^{2(k)}\right\rangle \pm \sigma_{\chi^2}$	1.23 ± 0.05	1.25 ± 0.09
$\left\langle \sigma^{(\rm exp)}\right\rangle_{\rm dat}$ (%)	11.9	11.3
$\left\langle \sigma^{(\rm net)}\right\rangle_{\rm dat}$ (%)	3.2	4.4

* NNLO fit quality and features very similar to NLO
* χ^2 of individual experiments does not significantly improves/deteriorate
* Slightly higher number of replicas requires longer training
* Verified stability of results when longer traning is performed

NNPDF2.1 at NNLO

Results: NNLO partons

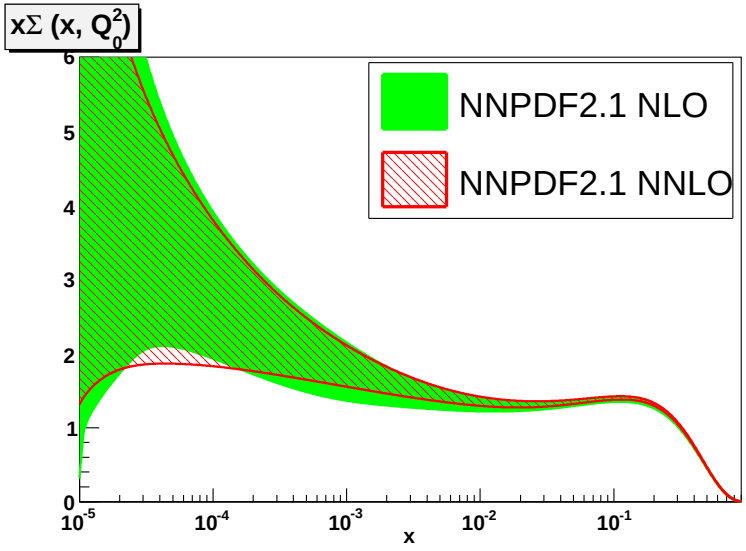


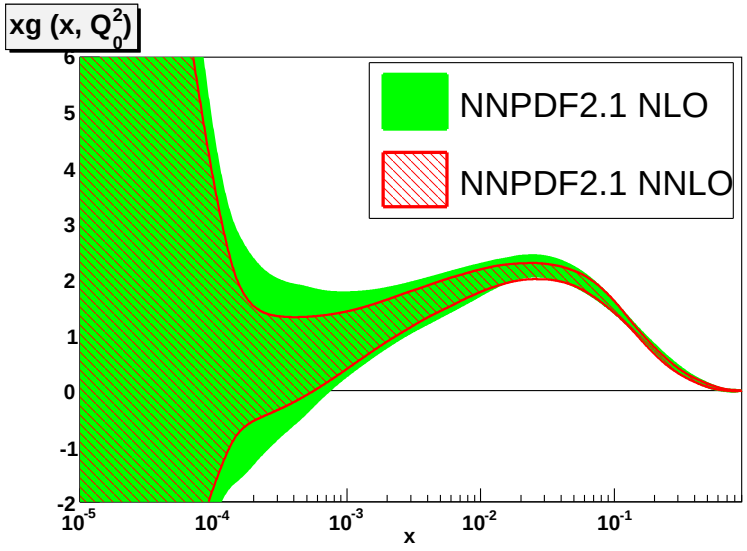
* NNLO fit quality and features very similar to NLO
* Larger shift in central values for small-medium x quarks and antiquarks
* Error bands very stable from NLO to NNLO: change within 1σ

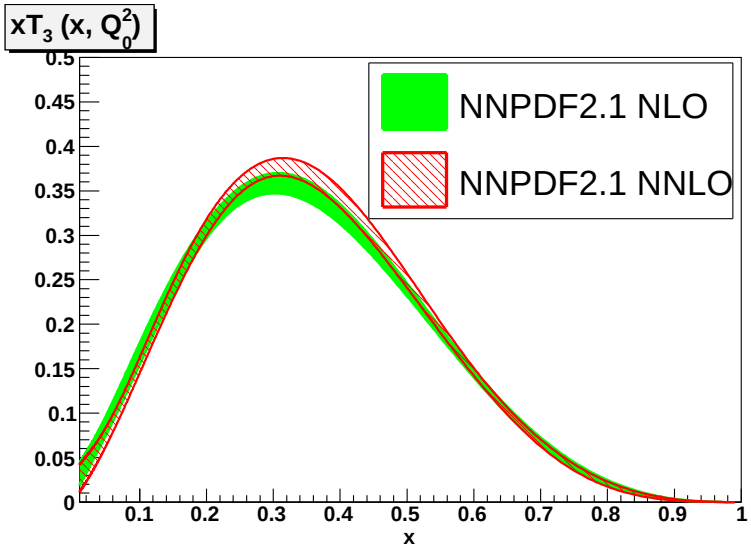
  statistically equivalent fits $d \sim 1$, inequivalent but consistent at the $n\sigma$ level $d < n7$

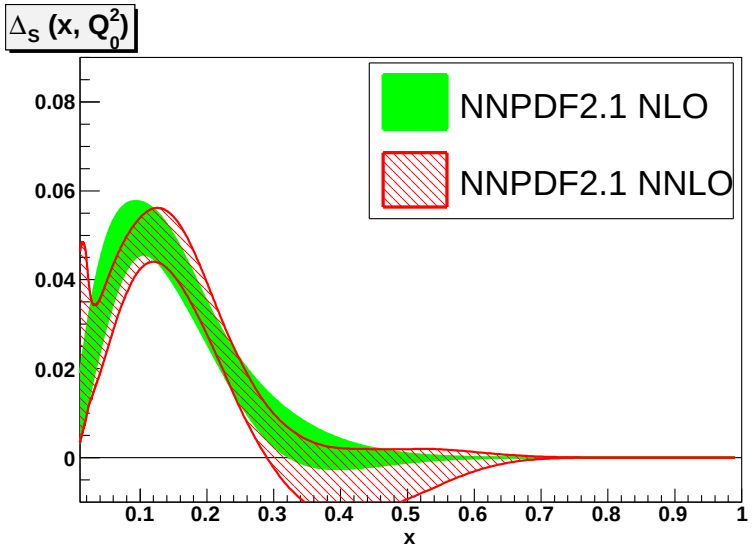
NNPDF2.1 at NNLO

Results: NNLO partons



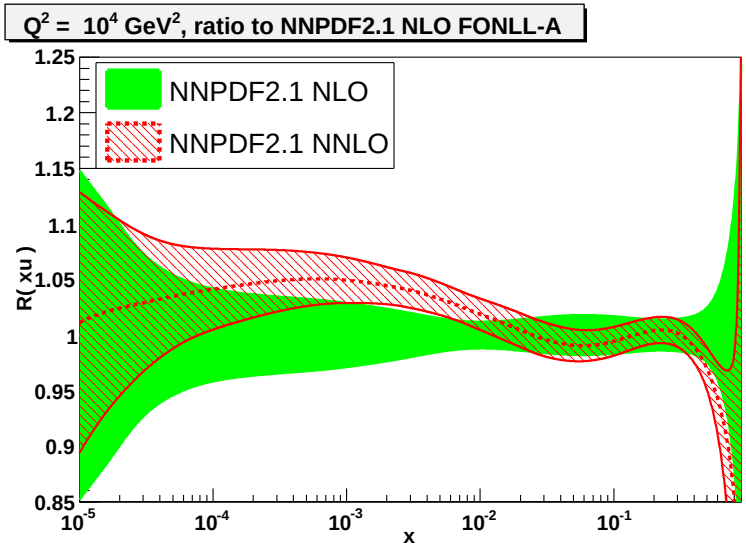


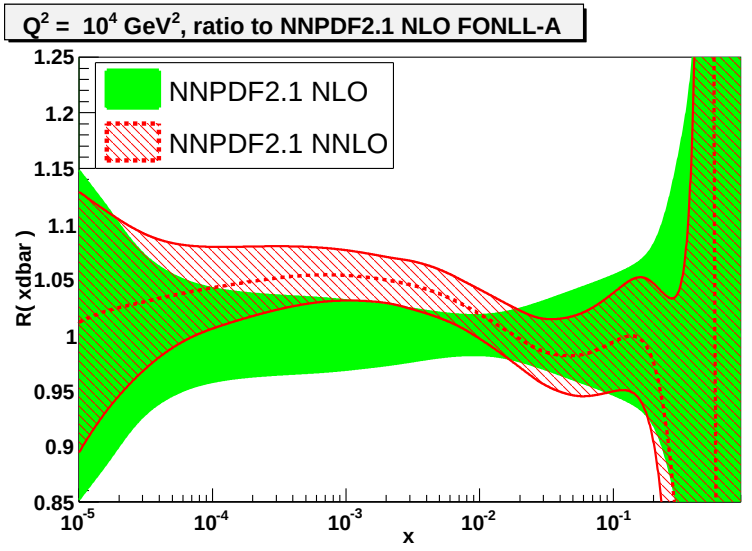


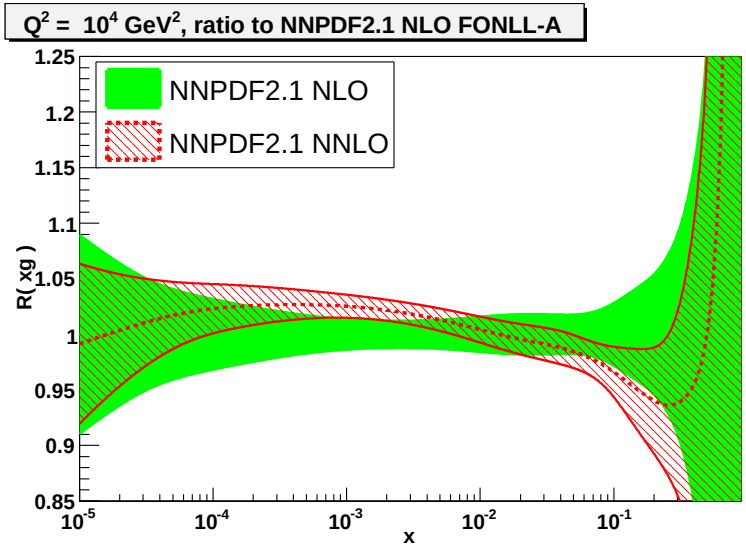


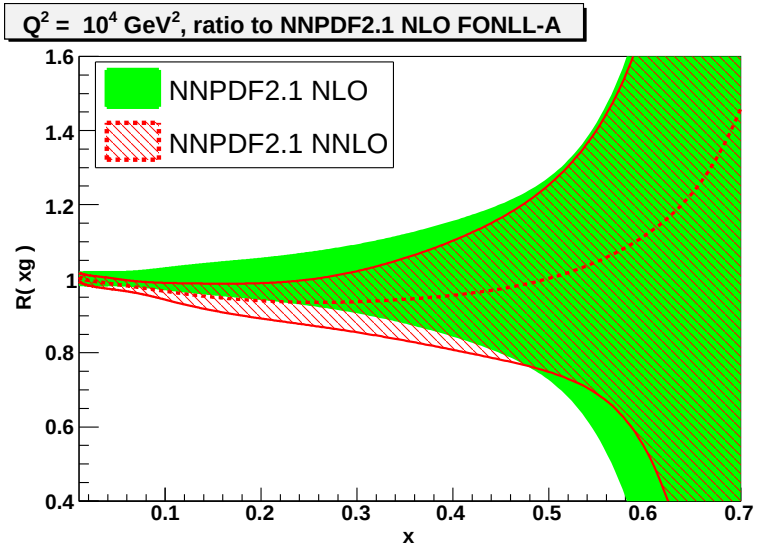
NNPDF2.1 at NNLO

Results: NNLO partons



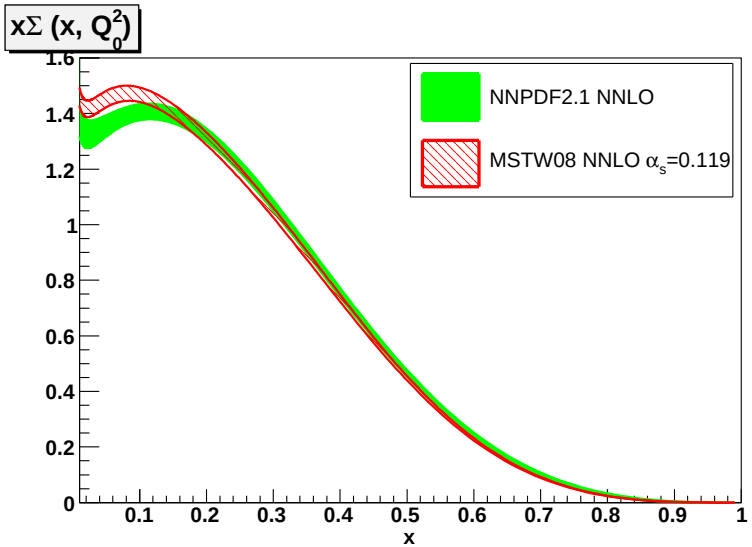


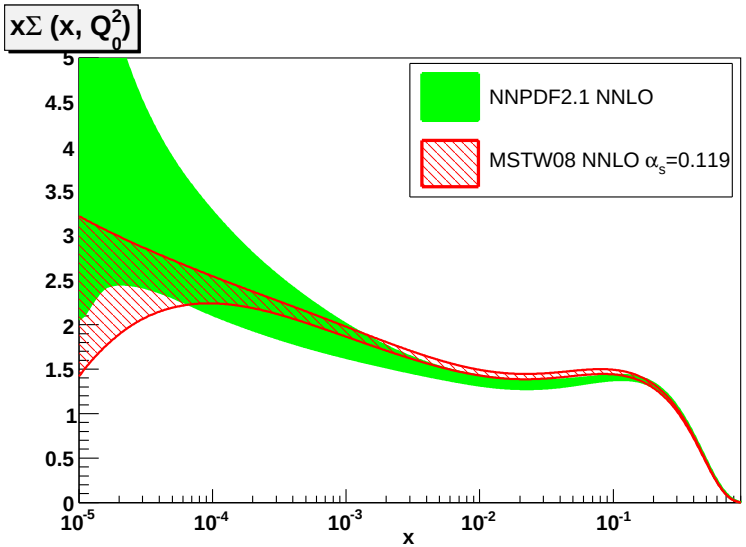


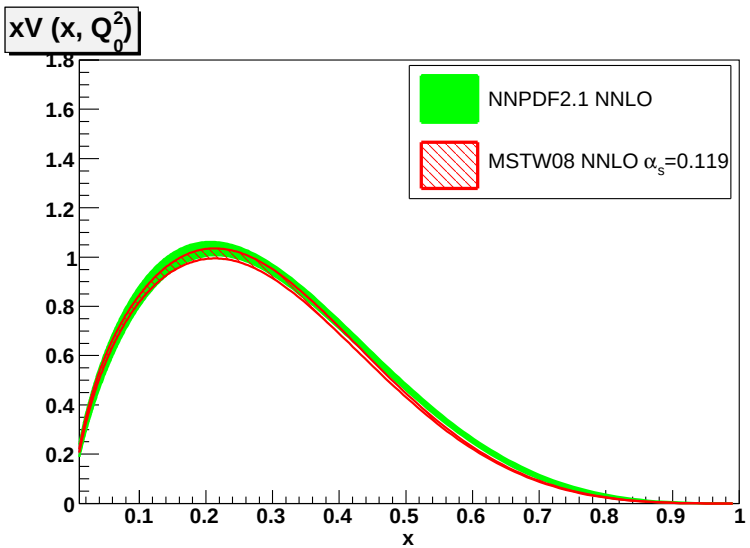


NNPDF2.1 at NNLO

Results: comparison to MSTW08



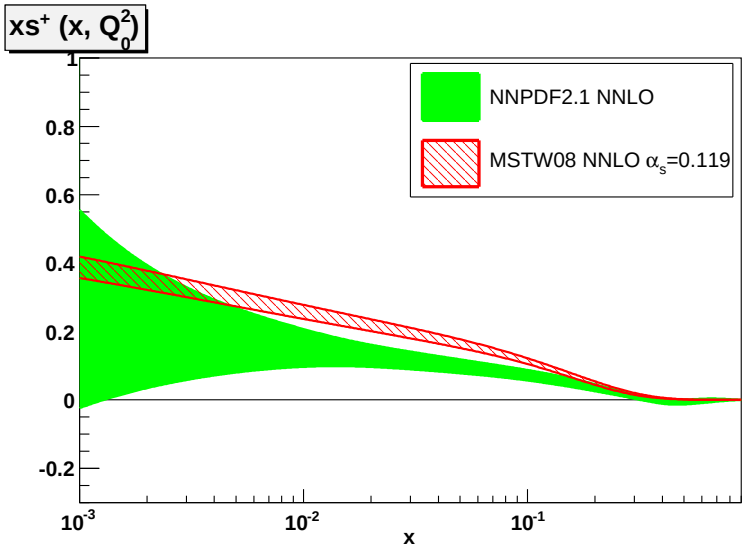


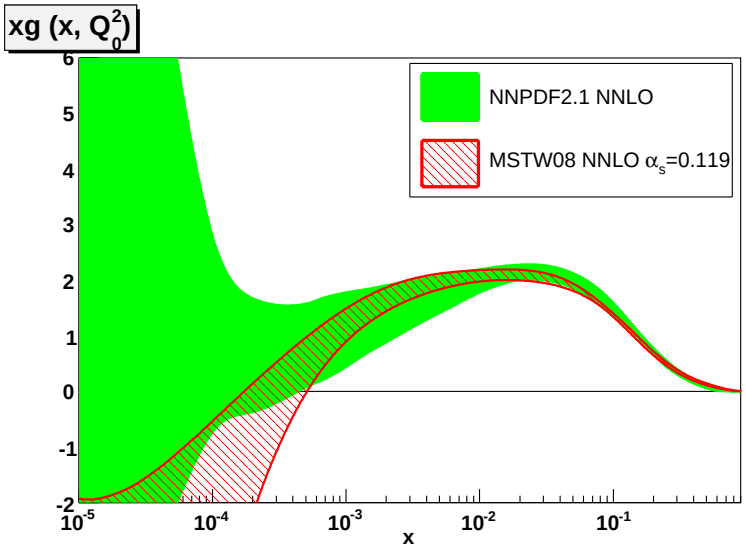


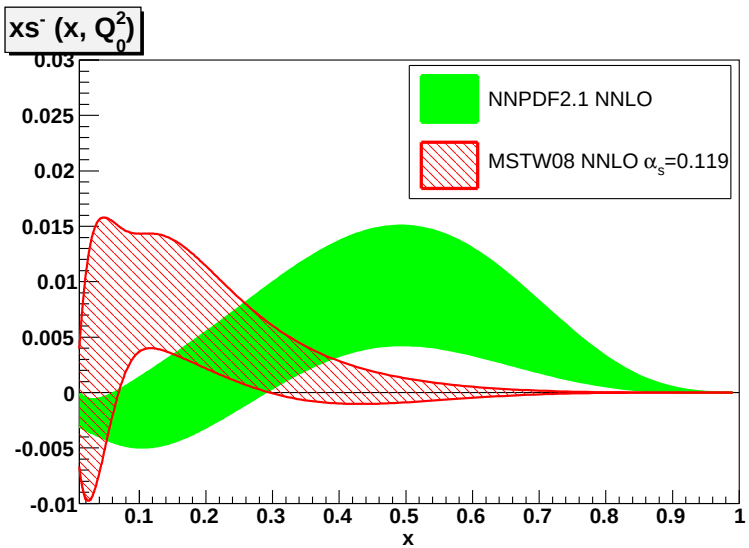
- Comparison to MSTW08 with same value for $\alpha_s(M_Z^2)$
- Reasonable agreement for most PDFs combinations
- NNPDF fit exhibits a more stable small-x gluon and larger singlet uncertainty in extrapolation region
- Flexible parametrization of strangeness

NNPDF2.1 at NNLO

Results: comparison to MSTW08







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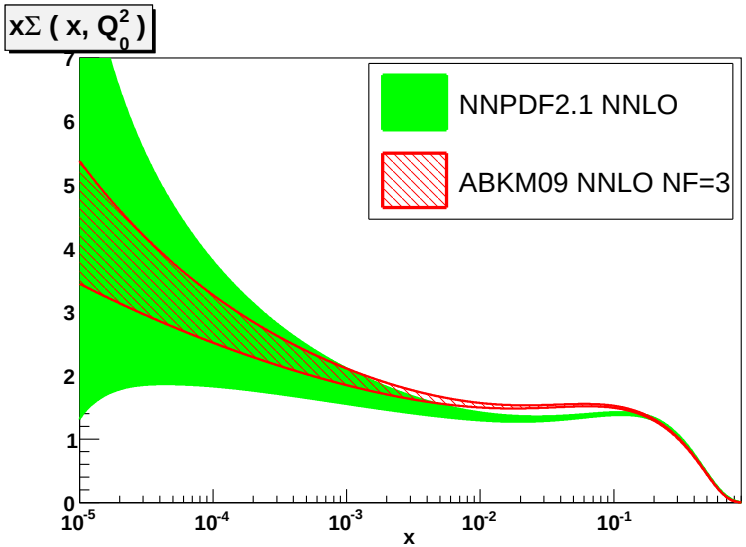
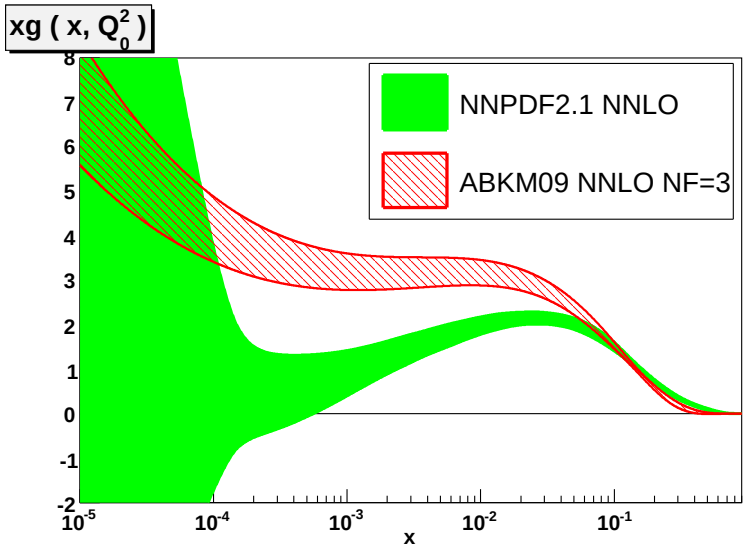
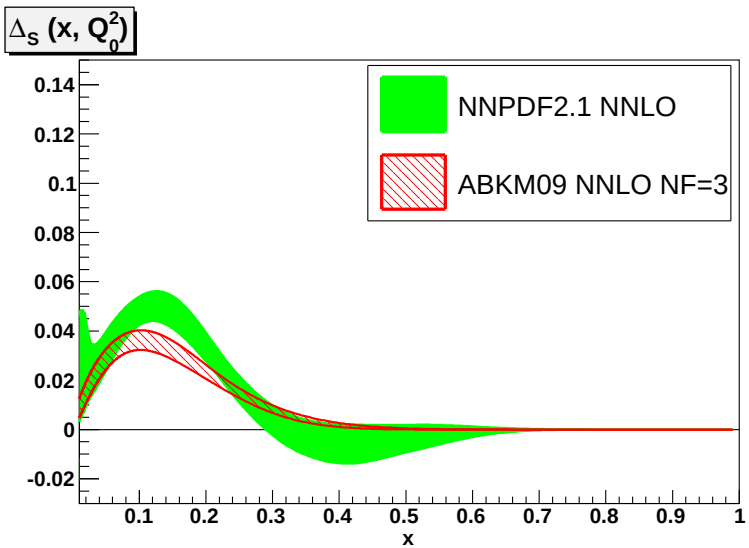
- Reasonable agreement for most PDFs combinations
- NNPDF fit exhibits a more stable small-x gluon and larger singlet uncertainty in extrapolation region
- Flexible parametrization of strangeness

NNPDF2.1 at NNLO

Results: comparison to ABKM





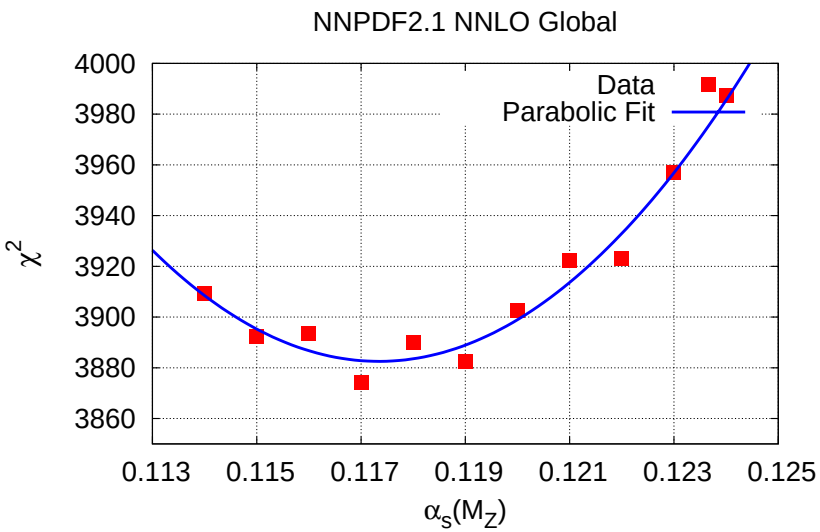


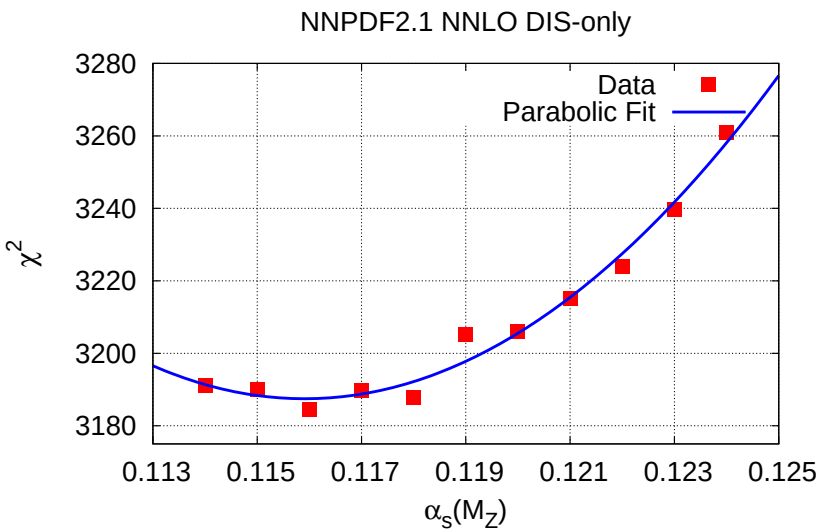
- Comparison with other NNLO parton determination
- Worse agreement than with MSTW08 NNLO
- Here:
  $\alpha_s(M_Z)_{\mathrm{ABKM}} = 0.1135$

$\alpha_S(M_Z)$ from NNLO analysis (preliminary)

	$\alpha_s\,(M_Z)$
NNPDF2.1 NLO	$0.1191 \pm 0.0006^{\rm stat}$
NNPDF2.1 NLO DIS–only	$0.1177 \pm 0.0009^{\rm stat}$
NNPDF2.1 NNLO (prel)	$0.1172 \pm 0.0006^{\rm stat}$
NNPDF2.1 NNLO DIS–only (prel)	$0.1160 \pm 0.0010^{\rm stat}$

- Preliminary NNPDF NNLO analysis
- Only 100 replicas
- NNLO value of $\alpha_s(M_Z^2)$ still compatible with PDF average
- $\alpha_s^{\rm PDG}\,(M_Z) = 0.1184 \pm 0.0007$





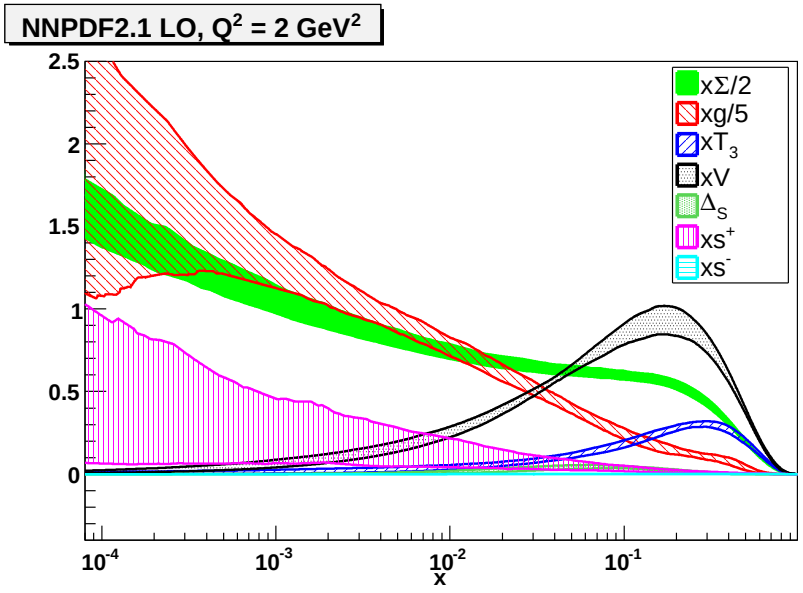
Outline

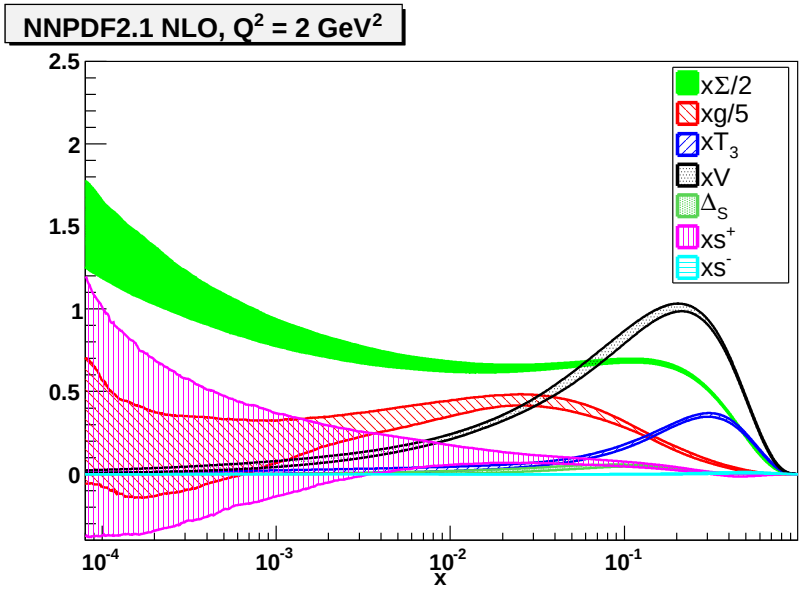
NNPDF2.1 at LO

The Leading Order fit

- Leading Order fit to match LO predictions and LO MC event generators
- PDFs positively defined
- Four fits with $\alpha_s(M_Z)$= 0.119/0.130 and with/without momentum sum rules imposed

PDF set	$\alpha_s(M_Z)$	Momentum SR
NNPDF2.1 LO	0.119	Yes
NNPDF2.1 LO	0.130	Yes
NNPDF2.1 LO*	0.119	No
NNPDF2.1 LO*	0.130	No





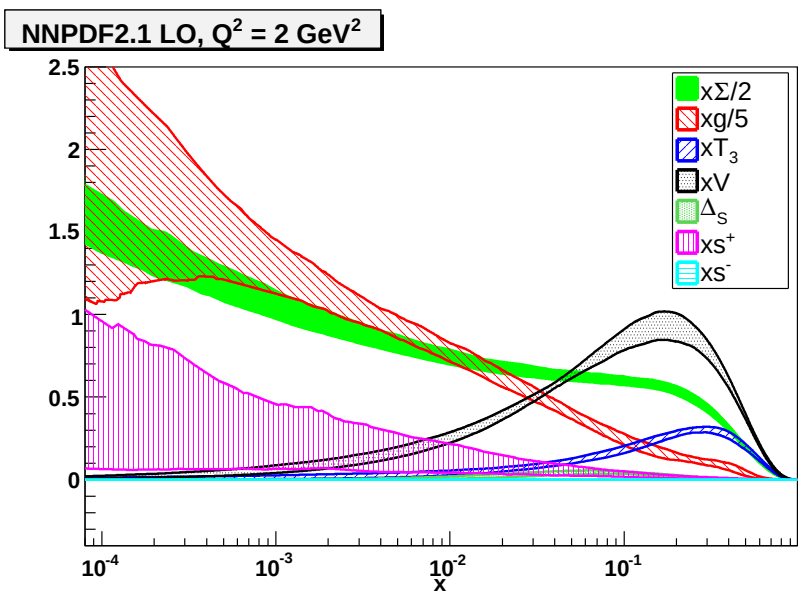
68% C.L. error bands

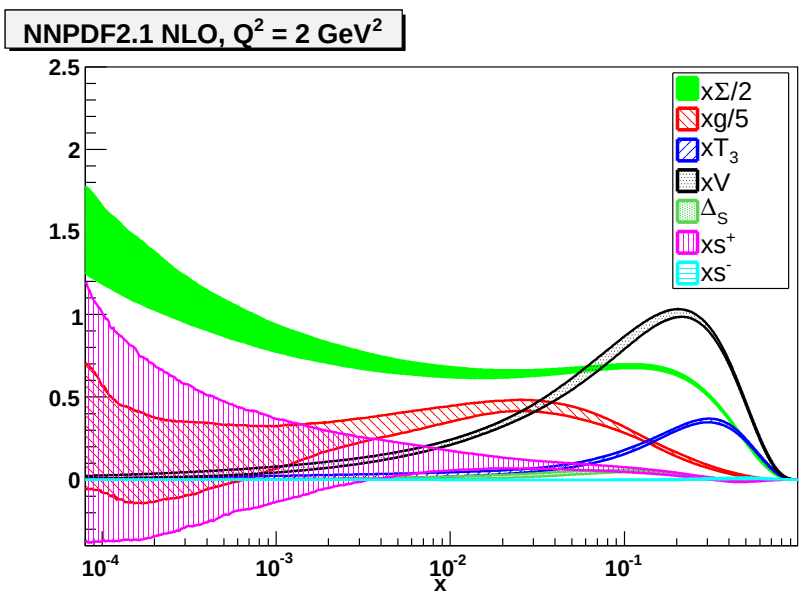
NNPDF2.1 at LO

The Leading Order fit

- Poorer quality of the fit $\chi^2_{\rm LO} \sim 1.7$ due to inaccuracy of LO theory
- Same quality for *LO* and *LO** fits: no advantage in changing $\alpha_s(M_Z^2)$ or relaxing momentum sum rules

PDF set	$\alpha_s(M_Z)$	Momentum SR
NNPDF2.1 LO	0.119	Yes
NNPDF2.1 LO	0.130	Yes
NNPDF2.1 LO*	0.119	No
NNPDF2.1 LO*	0.130	No

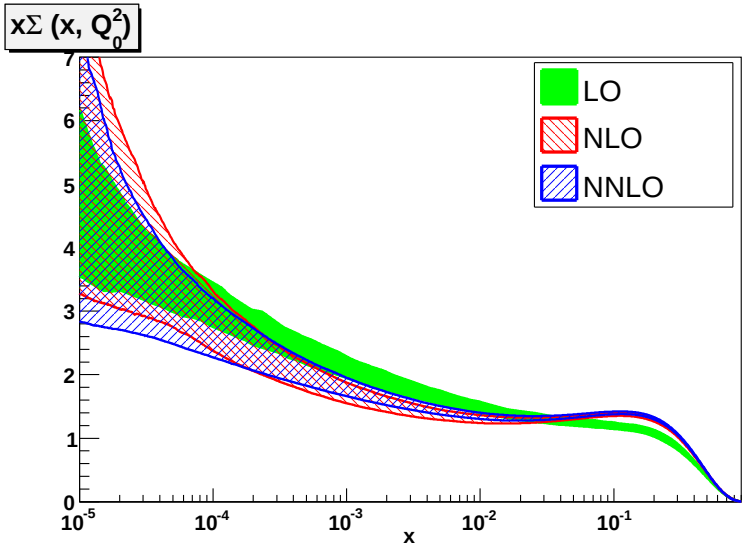


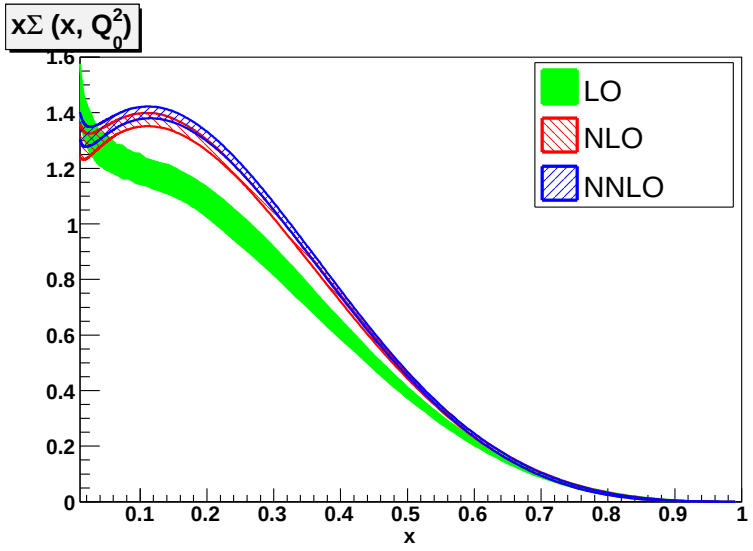


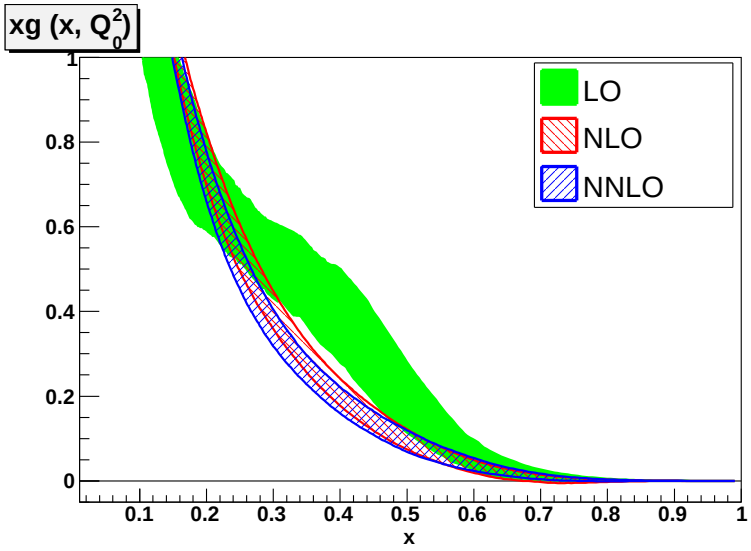
68% C.L. error bands

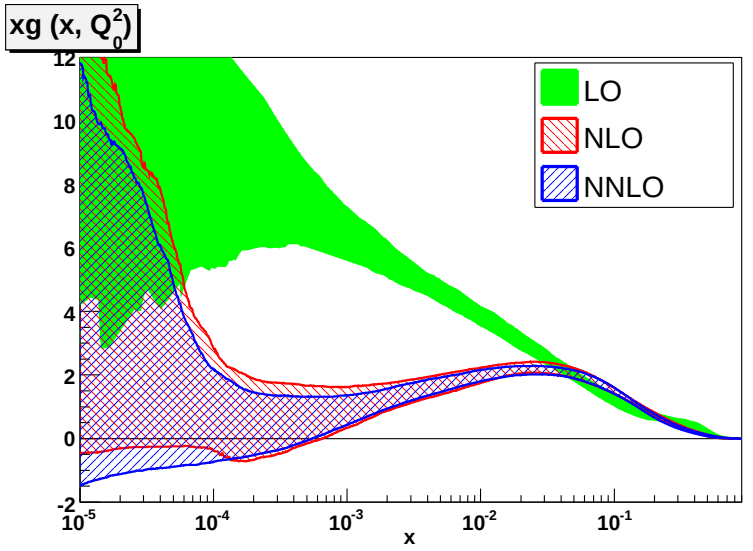
NNPDF2.1 at LO

LO fit and perturbative stability



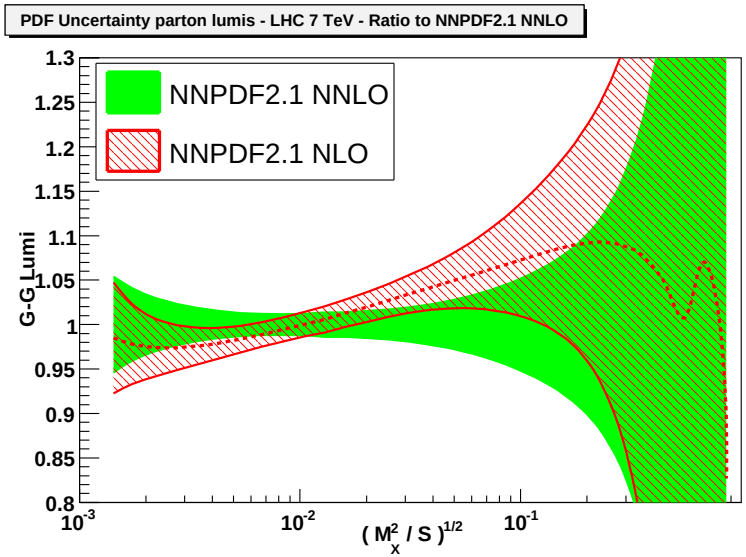


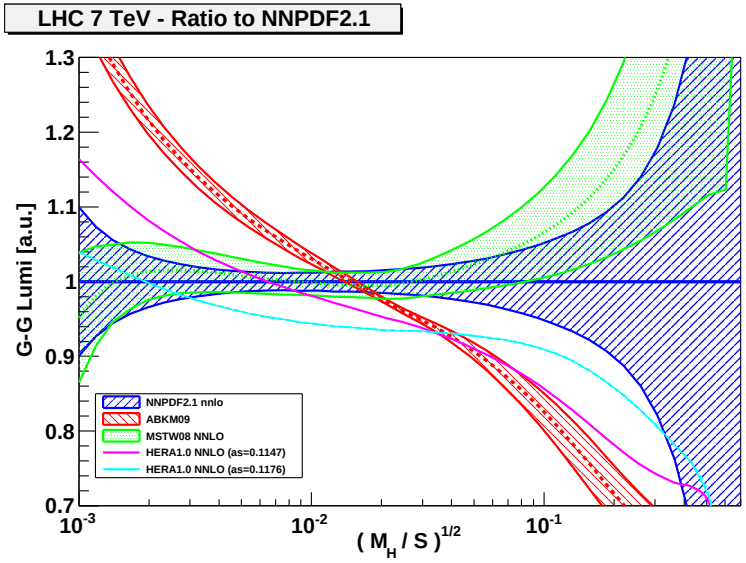


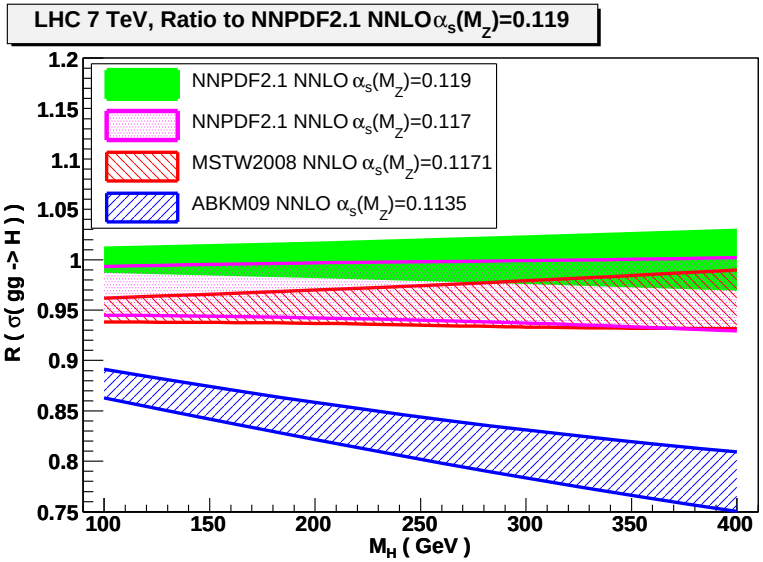


Outline

LHC phenomenology
Higgs cross section



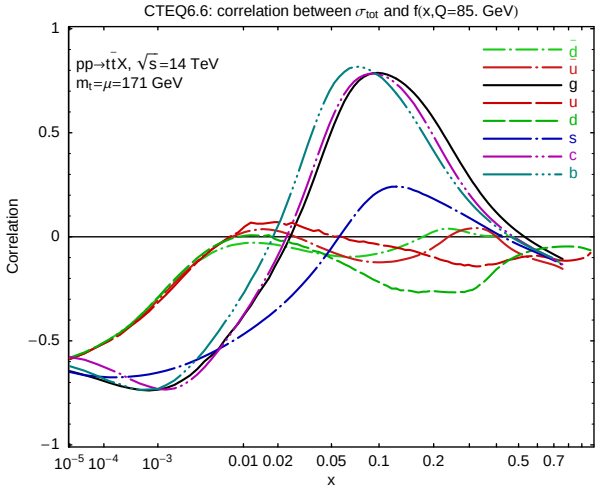




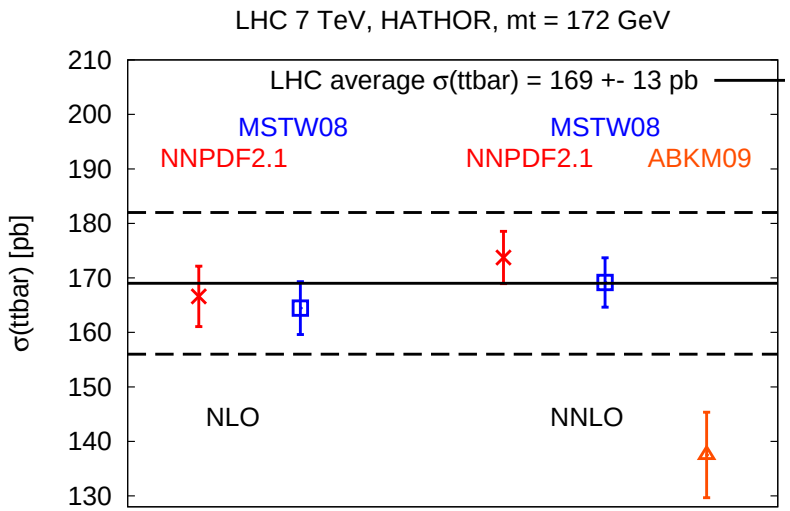
- NNLO Higgs cross-section prediction
- Good agreement between MSTW08 and NNPDF2.1 NNLO global fits
- Comparison meaningful and good agreement only at common value of α_s

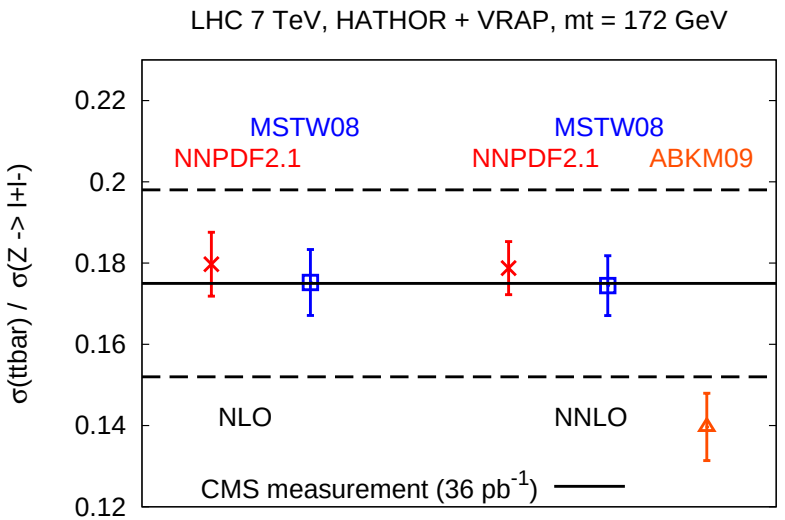
LHC phenomenology
$t\bar{t}$ production

Nadolsky et al, ArXiv:0802.0007

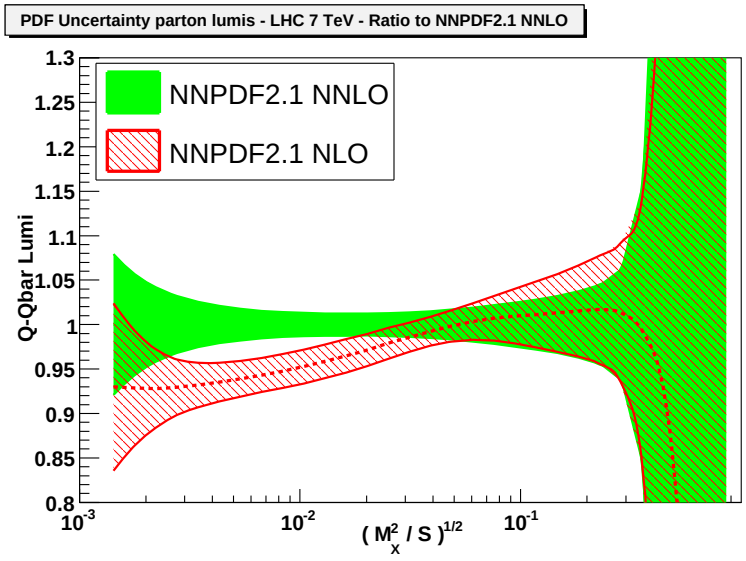


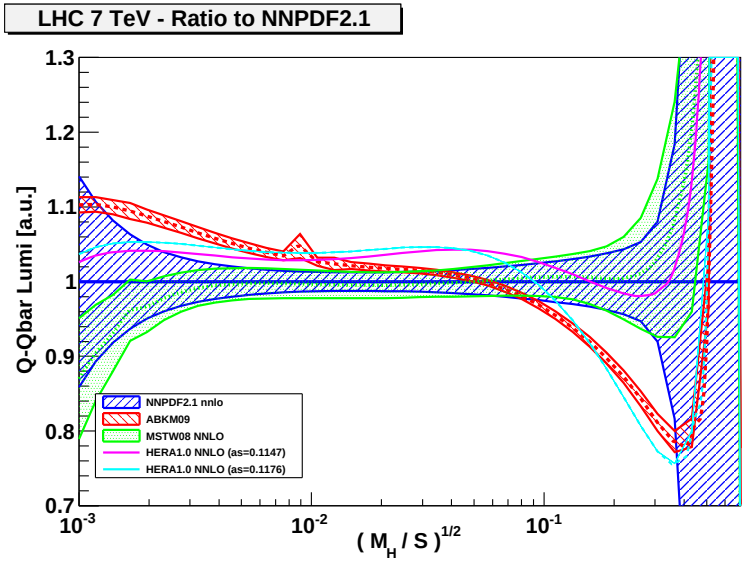
- $\sigma_{t\bar{t}}$ correlated to all PDFs
- $\sigma_{t\bar{t}}$ sensitive probe of gluon
- Gluon strongly correlated to α_s
- Here $\alpha_s(M_Z)$ =0.119 (NNPDF),
  0.1135 (ABKM), 0.11707 (MSTW08)

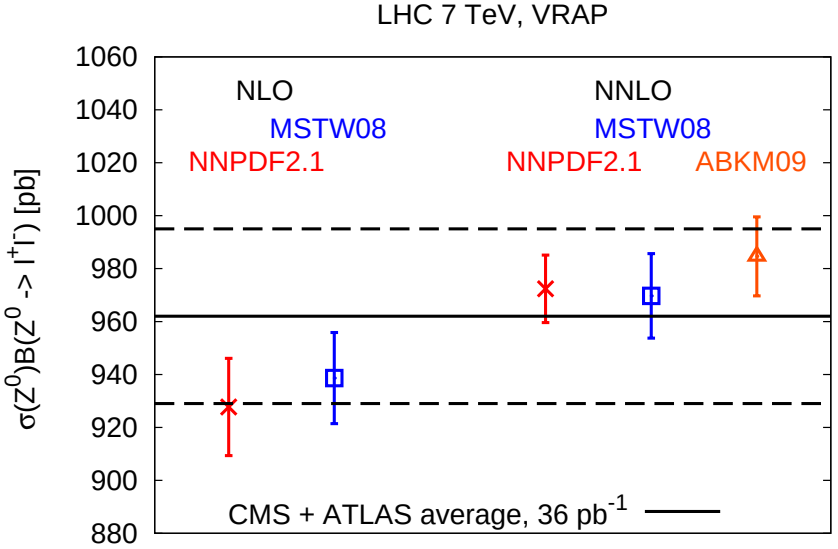




LHC phenomenology
W and Z boson production

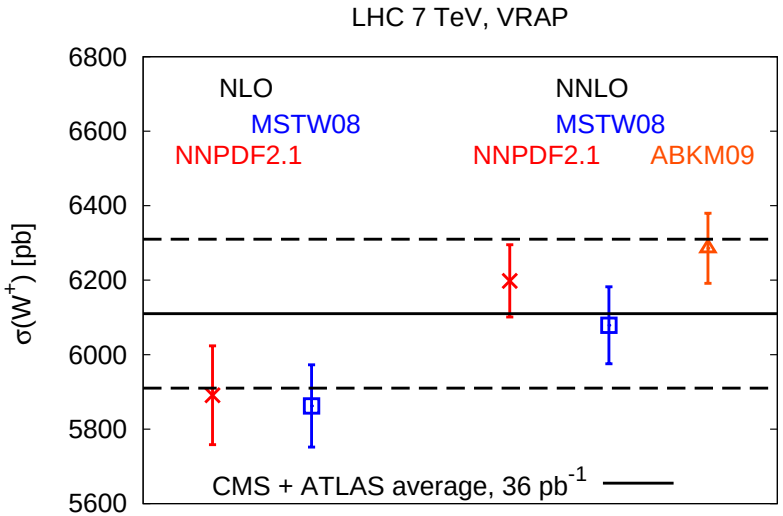


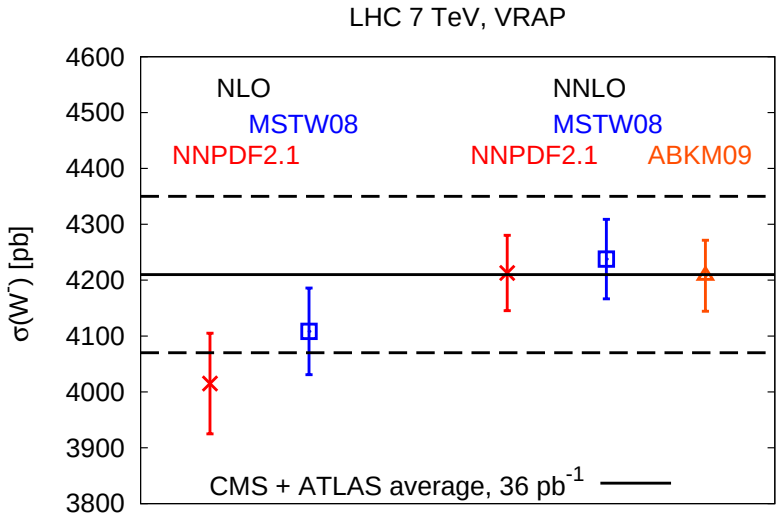


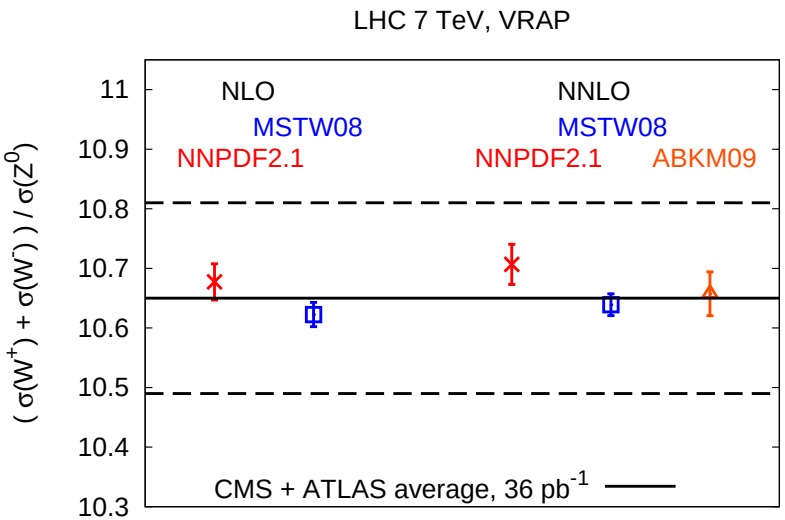


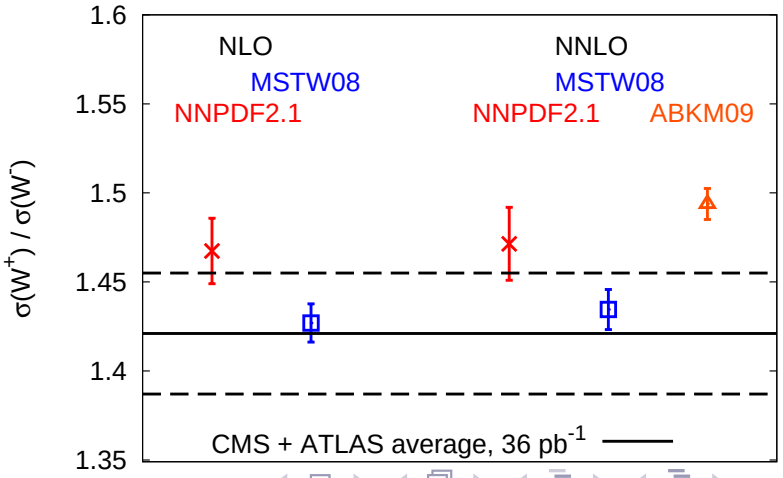
- Cross section for EW gauge boson production
- Harder light quark distribution from NLO to NNLO: upward shift in predictions
- Increasingly precise LHC measurements can discriminate between PDF sets!

LHC phenomenology
W and Z boson production









Outline

Reweighting

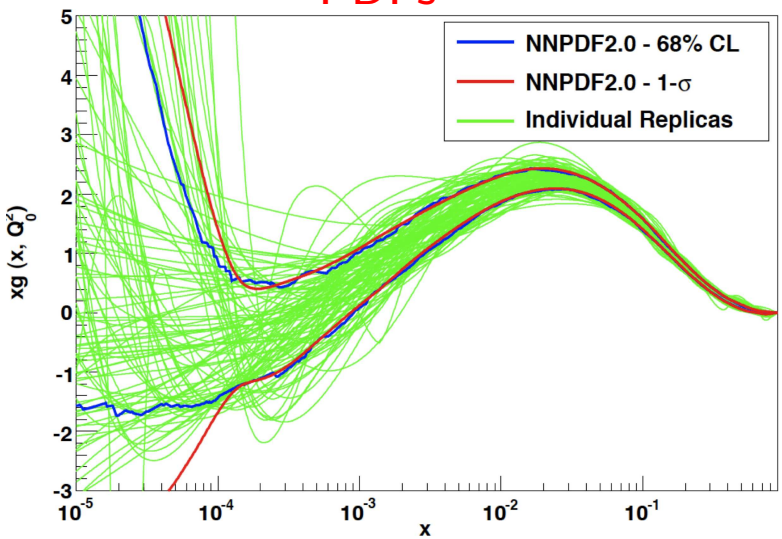
Adding new information without refitting

* The $N_{\rm rep}$ reps of a NNPDF fit give the probability density in the space of PDFs
* Expectation values for observables are Monte Carlo integrals
* One can study the effect of adding new data in the fit without refitting

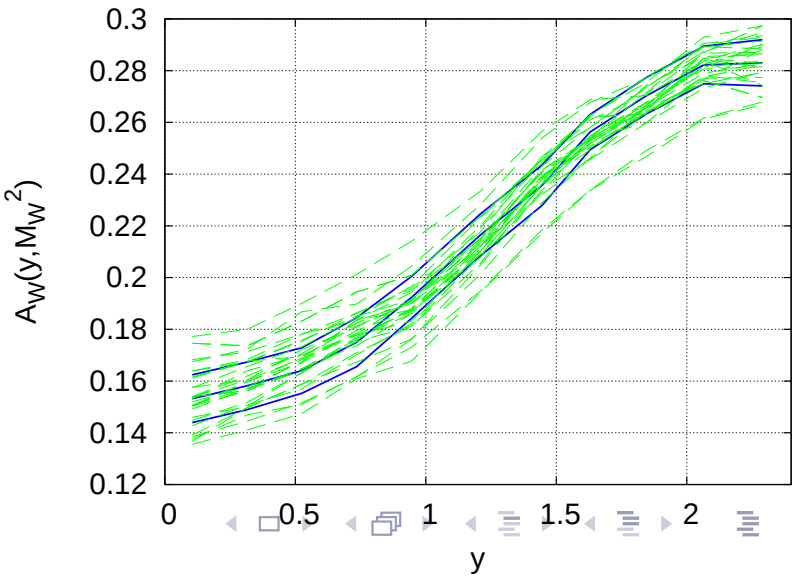
$$\langle \mathcal{F}[f_i(x)] \rangle^{\rm UW} = \int [\mathcal{D}f_i]\, \mathcal{F}[f_i(x)] \mathcal{P}[f_i(x)] = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} \mathcal{F}[f_i^{(k)}(x)]$$

$$\langle \mathcal{F}[f_i(x)] \rangle^{\rm RW} = \int [\mathcal{D}f_i]\, \mathcal{F}[f_i(x)] \mathcal{P}_{\rm new}[f_i(x)] = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k \mathcal{F}[f_i^{(k)}(x)]$$

PDFs



Observables

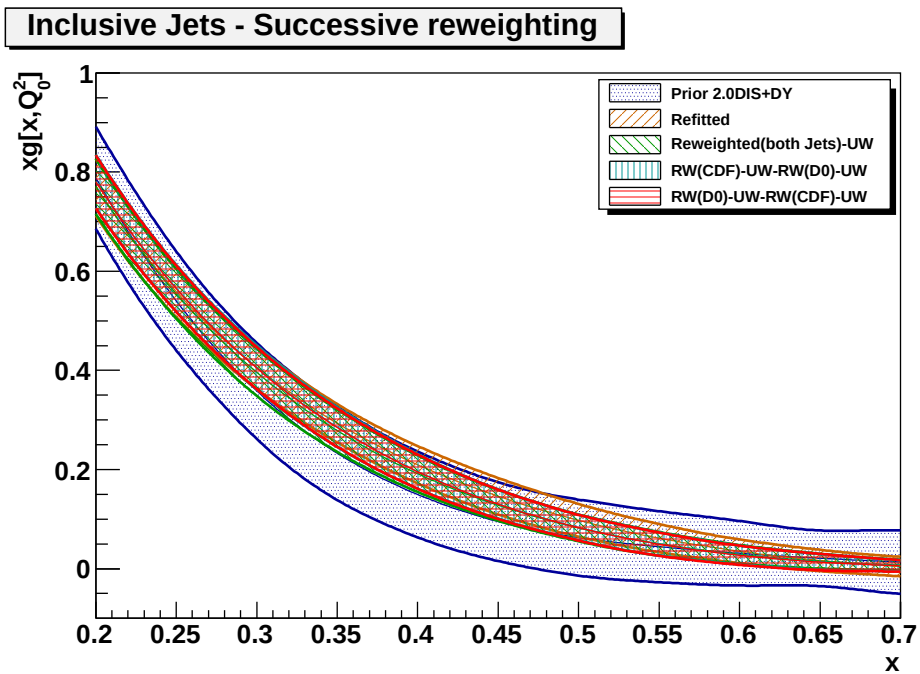


Reweighting

Adding new information without refitting

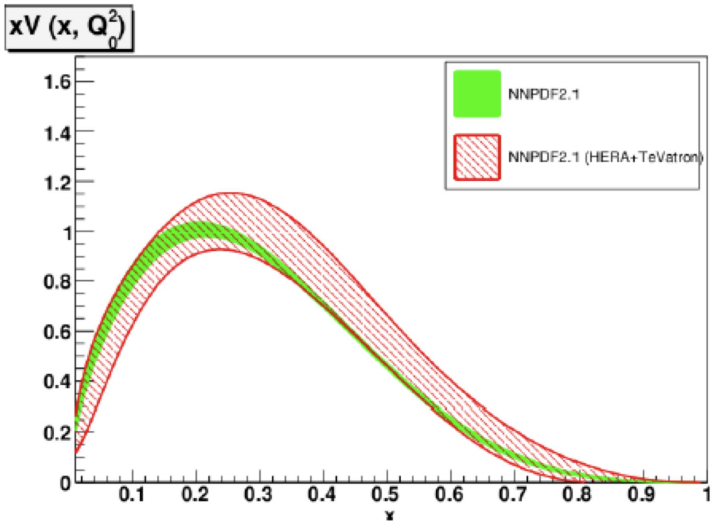
* The $N_{\rm rep}$ reps of a NNPDF fit give the probability density in the space of PDFs
* Expectation values for observables are Monte Carlo integrals
* One can study the effect of adding new data in the fit without refitting

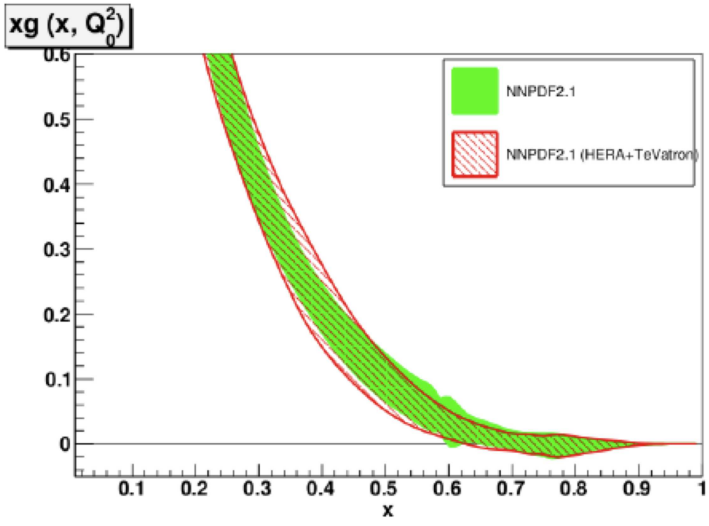
* Easy to use with any Monte Carlo PDF set, even with Hessian sets (see LHCb studies)
* No need of PDF fitting collaborations! (se D'Enterria's work on direct photon)
* From reweighted set one can obtain unweighted fit as good as the initial importance sampling set
* Commutativity tests ✓



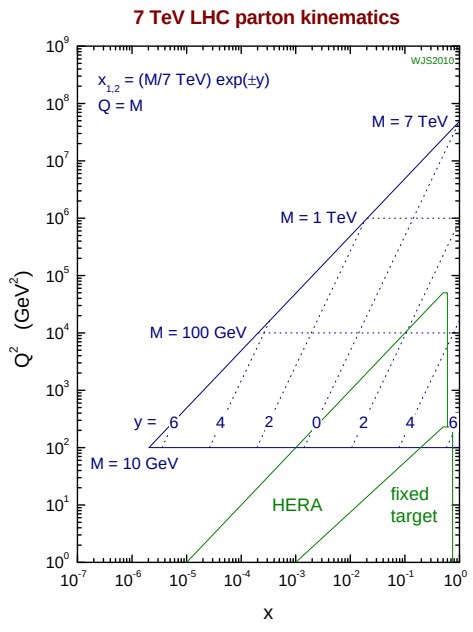
Motivation

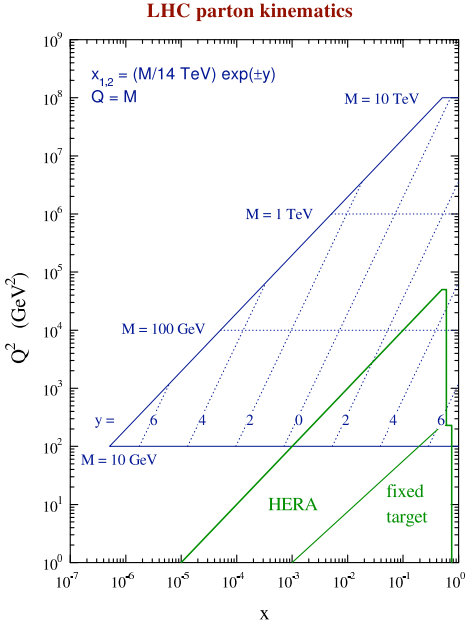
Towards a pure collider fit





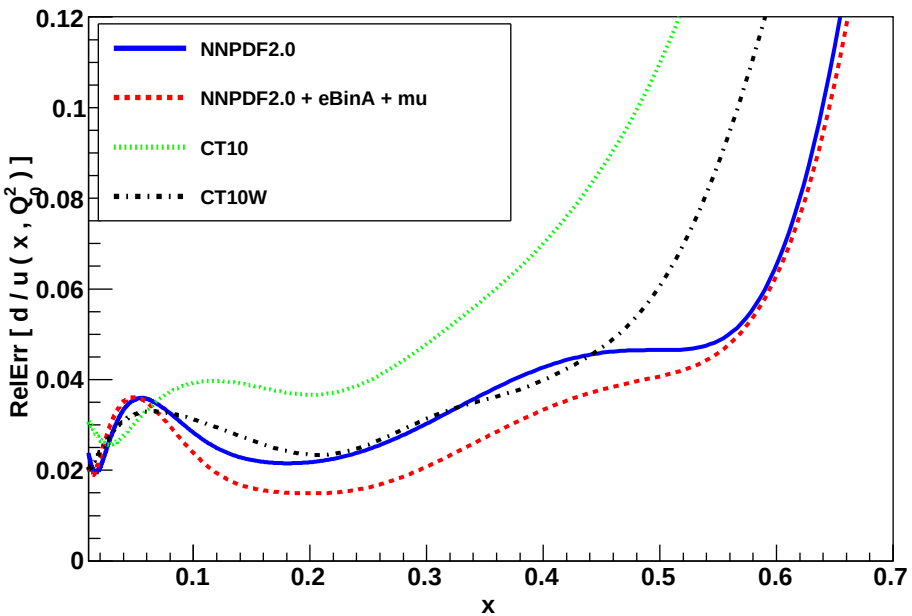
- No fixed target data $\rightarrow$ no low-energy trouble
- Is it possible to get rid of these data without losing accuracy?
- HERA+Tevatron:
  - Good accuracy for gluon
  - Loss of accuracy for flavor separation
- What about LHC?

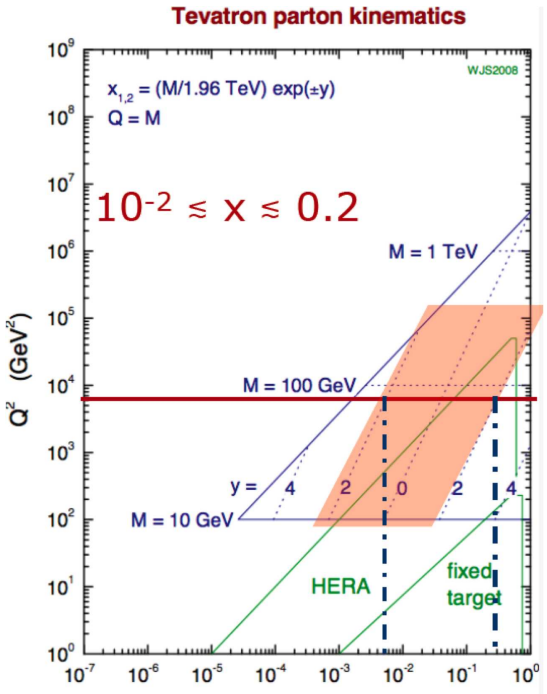




Increasing PDF precision
Tevatron W lepton asymmetry

- CDF W asymmetry data [ArXiv:0901.2169] included in NNPDF2.1 analysis
- D0 lepton asymmetry data included by reweighting [ArXiv:1012.0836]
- Muon asymmetry [ArXiv:0709.4254] and electron asymmetry [ArXiv:0807.3367]





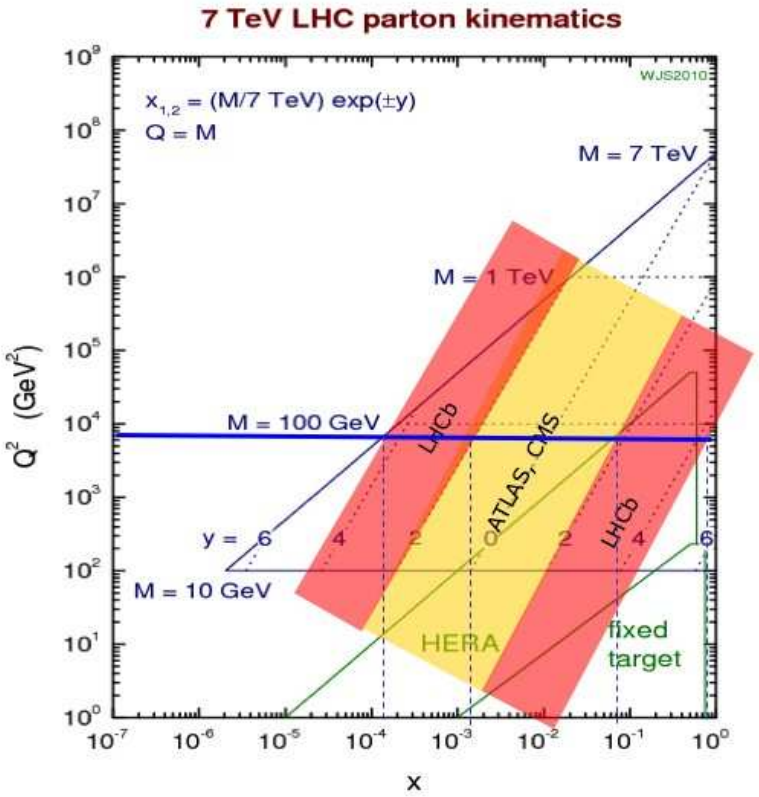
- Inclusive data (in p_T^l) are compatible with global fit
- Can be included at the same time and reduce significantly uncertainty on light quark in medium-large-x region
- Exclusive bins (25 GeV $< p_T^e <$ 35 GeV and $p_T^e >$ 35 GeV)) are problematic

Increasing PDF precision
The W lepton asymmetry data at LHC

$$A_W^l = \frac{\sigma(pp \to W^+ \to l^+\nu_l) - \sigma(pp \to W^- \to l^-\bar{\nu}_l)}{\sigma(pp \to W^+ \to l^+\nu_l) + \sigma(pp \to W^+ \to l^-\bar{\nu}_l)}$$

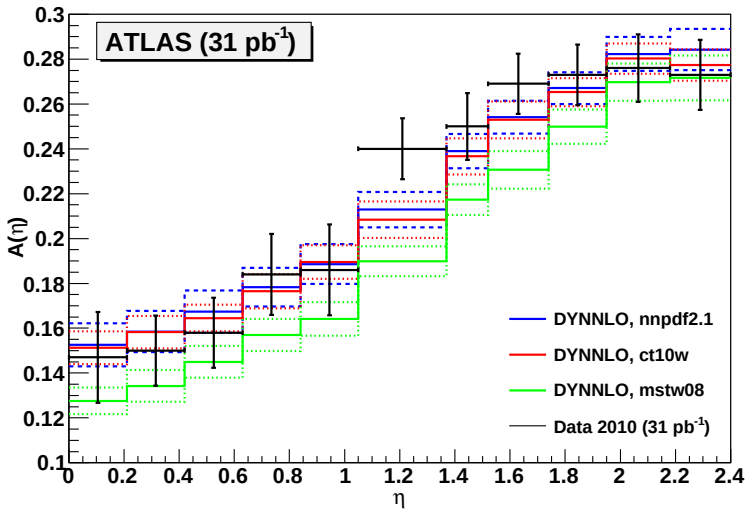
- ATLAS: muon charge asymmetry (31pb^{-1}) [ArXiv:1103:2929]
- CMS: muon charge asymmetry (36pb^{-1}) [ArXiv:1103:3470]
- LHCb: preliminary forward W muon charge asymmetry (16.5pb^{-1}), nor corrected for FSR

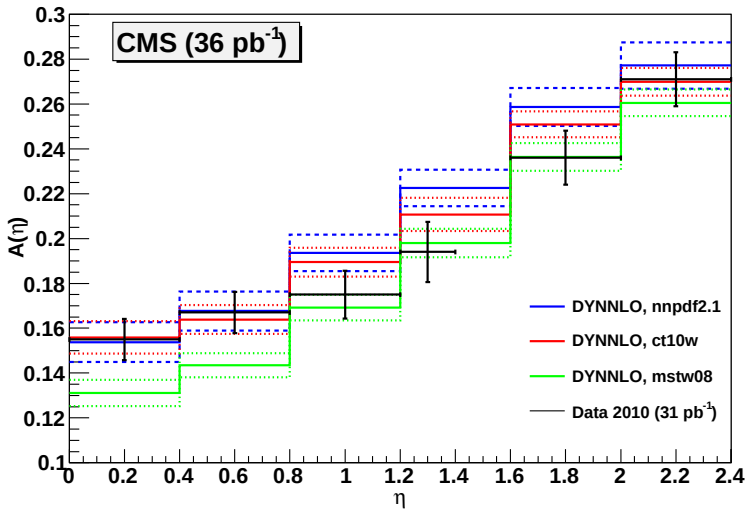
$$A_W^l \sim \frac{u(x_1, M_W^2)\bar{d}(x_2, M_W^2) - d(x_1, M_W^2)\bar{u}(x_2, M_W^2)}{u(x_1, M_W^2)\bar{d}(x_2, M_W^2) + d(x_1, M_W^2)\bar{u}(x_2, M_W^2)}$$



Increasing PDF precision

The W lepton asymmetry data at LHC





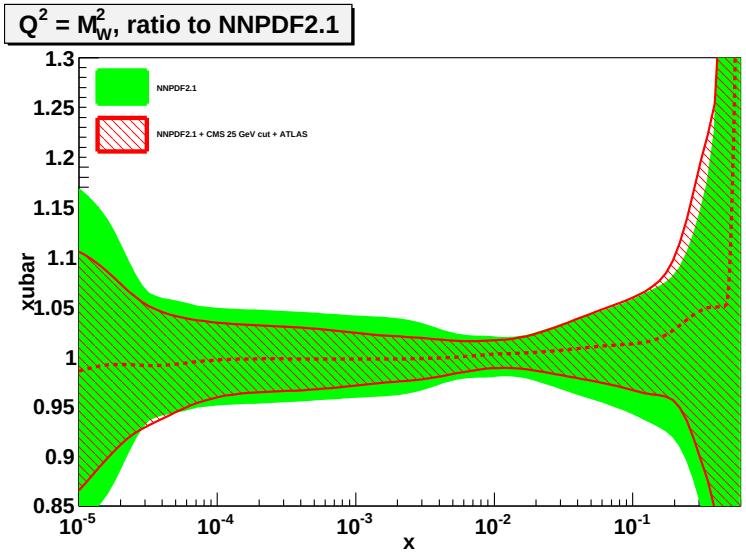
Predictions computed with DYNNLO code at NLO

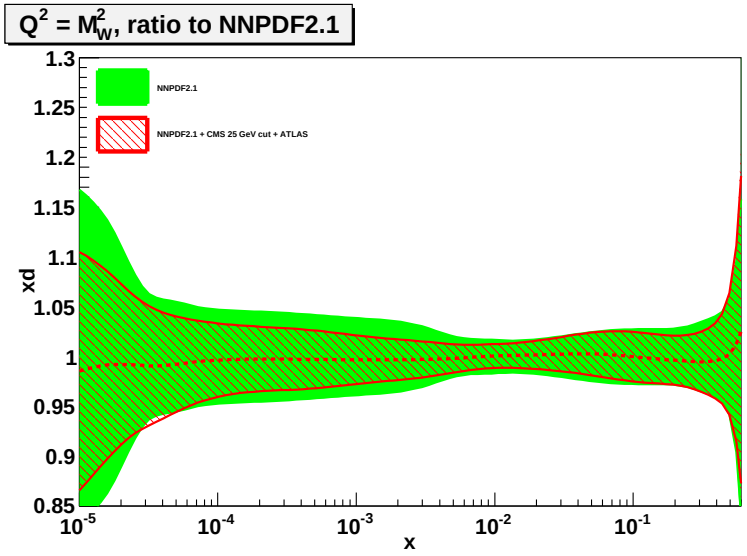
[ArXiv:0903.2120]

χ^2/d.o.f.	NNPDF2.1	CT10w	MSTW08
ATLAS	0.7	0.8	3.2
CMS e^- $p_T > 25$ GeV	1.9	0.8	2.4
CMS e^- $p_T > 30$ GeV	1.7	1.2	2.5
CMS μ $p_T > 25$ GeV	1.3	0.5	1.1
CMS μ $p_T > 30$ GeV	0.8	0.6	1.3

Increasing PDF precision

Inclusion of the LHC W lepton asymmetry data (PRELIMINARY)





- ATLAS and CMS data compatible with data included in global analysis
- The provide important constraint to PDFs in the small medium-x region
- Significant uncertainty reduction

ATLAS

$N_{\rm eff} = 928$, $\chi^2_{\rm d.o.f.} : 0.69 \to 0.65$

CMS ($p_T^l > 25$GeV)

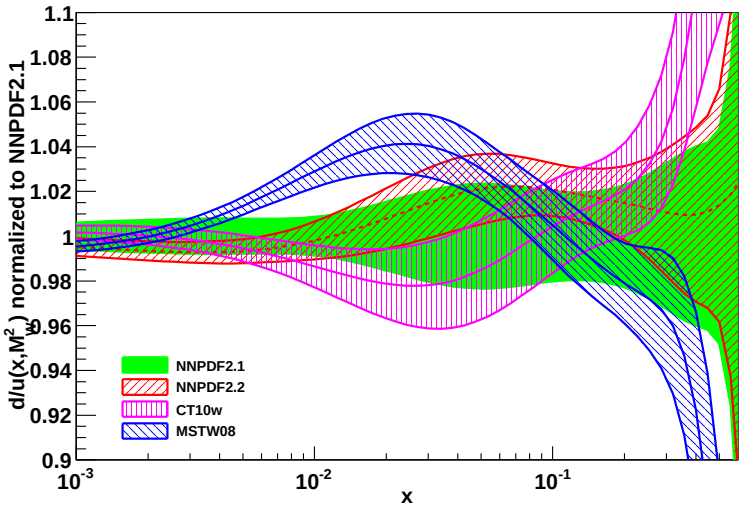
$N_{\rm eff} = 554$, $\chi^2_{\rm d.o.f.} : 1.41 \to 0.74$

CMS ($p_T^l > 30$GeV)

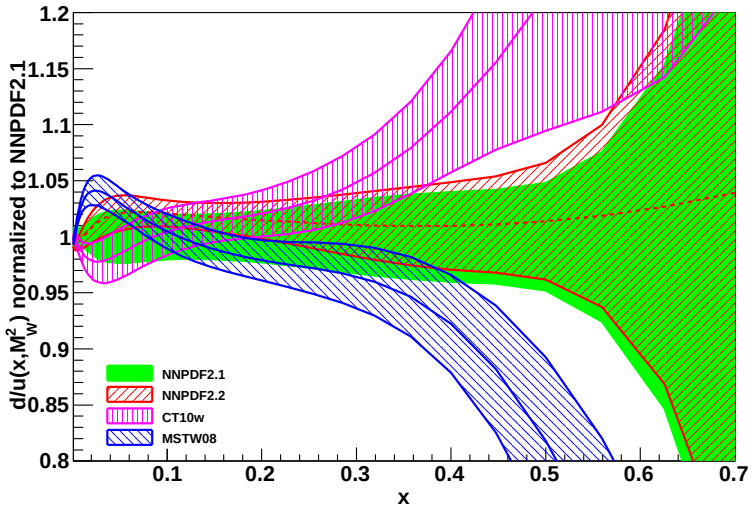
$N_{\rm eff} = 717$, $\chi^2_{\rm d.o.f.} : 0.98 \to 0.72$

Increasing PDF precision
Combining Tevatron and LHC data (PRELIMINARY)

LOG scale

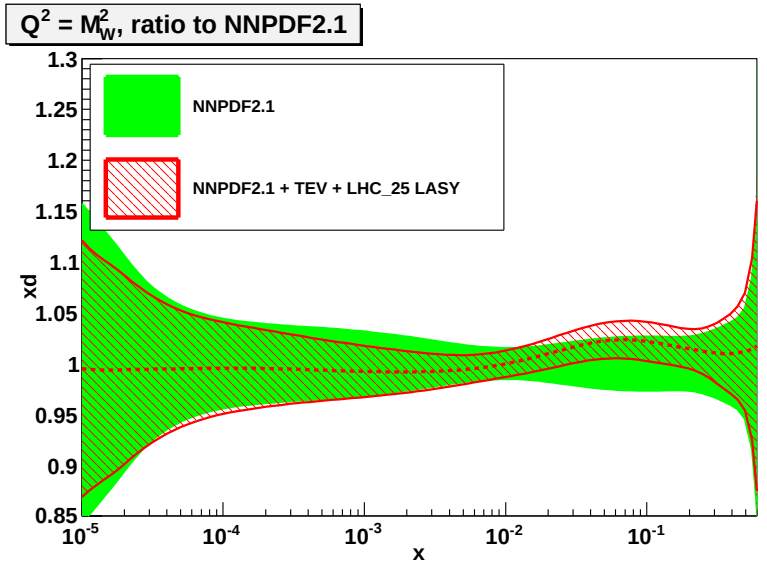


LIN scale



ATLAS+CMS_25+D0mu+D0el_20

$N_{\rm eff} = 196$, $\chi^2_{\rm d.o.f.} : 2.18 \rightarrow 0.86$

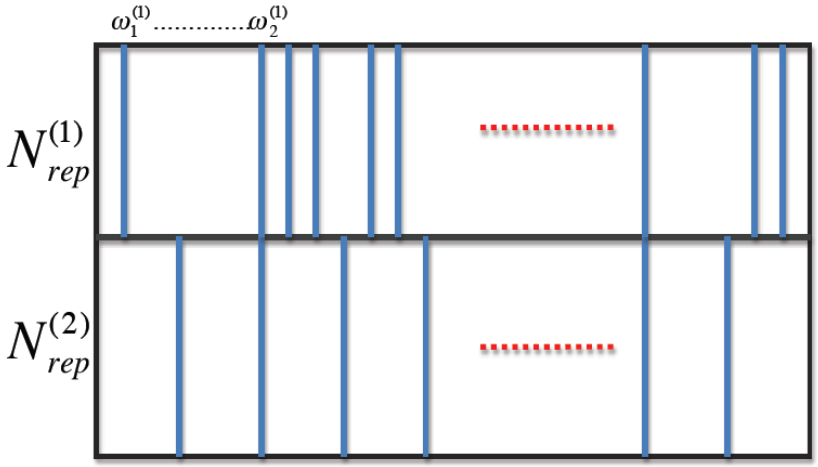


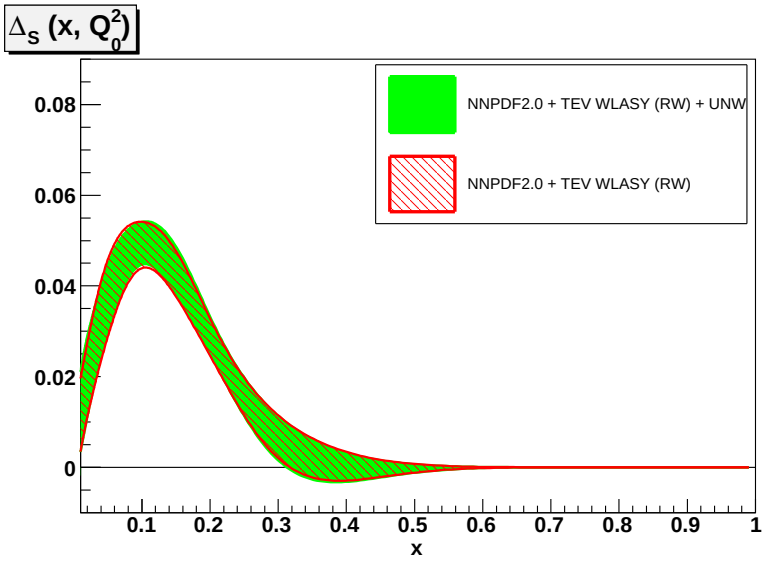
- Possible to add them at the same time!
- Reduction of medium-small x uncertainty and shift in central value driven by the LHC data,
- Uncertainty reduction in medium-large x driven by Tevatron data

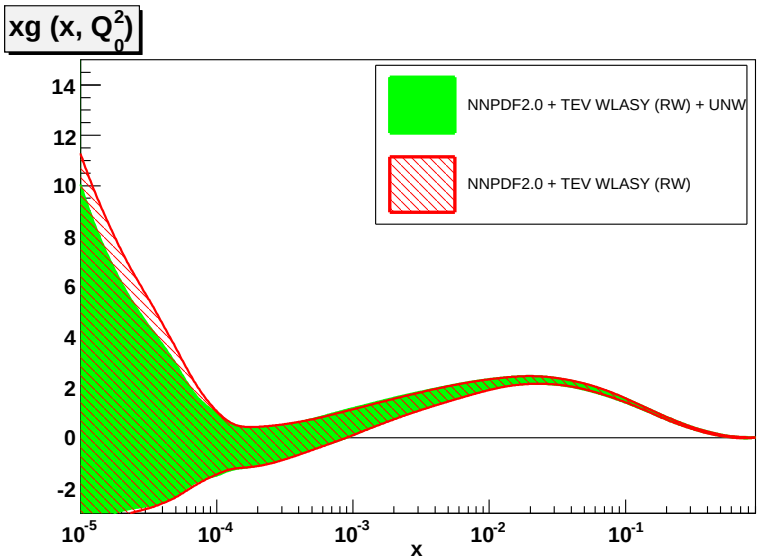
The NNPDF2.2 parton set

Inclusion of theLHC data

- From reweighted set it is possible to construct unweighted set to be used with LHAPDF interface
- Reweighted-unweighted PDFs statistically equivalent if $N_{\rm eff}$ is large enough
- NNPDF2.2 is the first PDF analysis including LHC data







Summary and outlook

- The NNLO and LO PDF analyses based on the NNPDF2.1 data set are now available!

  `http://sophia.ecm.ub.es/nnpdf/nnpdf2.htm`

  ...already in LHAPDF 5.8.6b4

- Stability of PDFs upon inclusion of NNLO corrections
- Ready to be used for LHC phenomenology!
- The early LHC data have already a significant impact in reducing PDF uncertainty
- NNPDF2.2 first PDF analysis including LHC data
- Avalaible by the end of summer in LHAPDF.
- Much more to come as new LHC data are published and added by reweighting!

  ...STAY TUNED!

BACKUP

FONLL scheme

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.

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

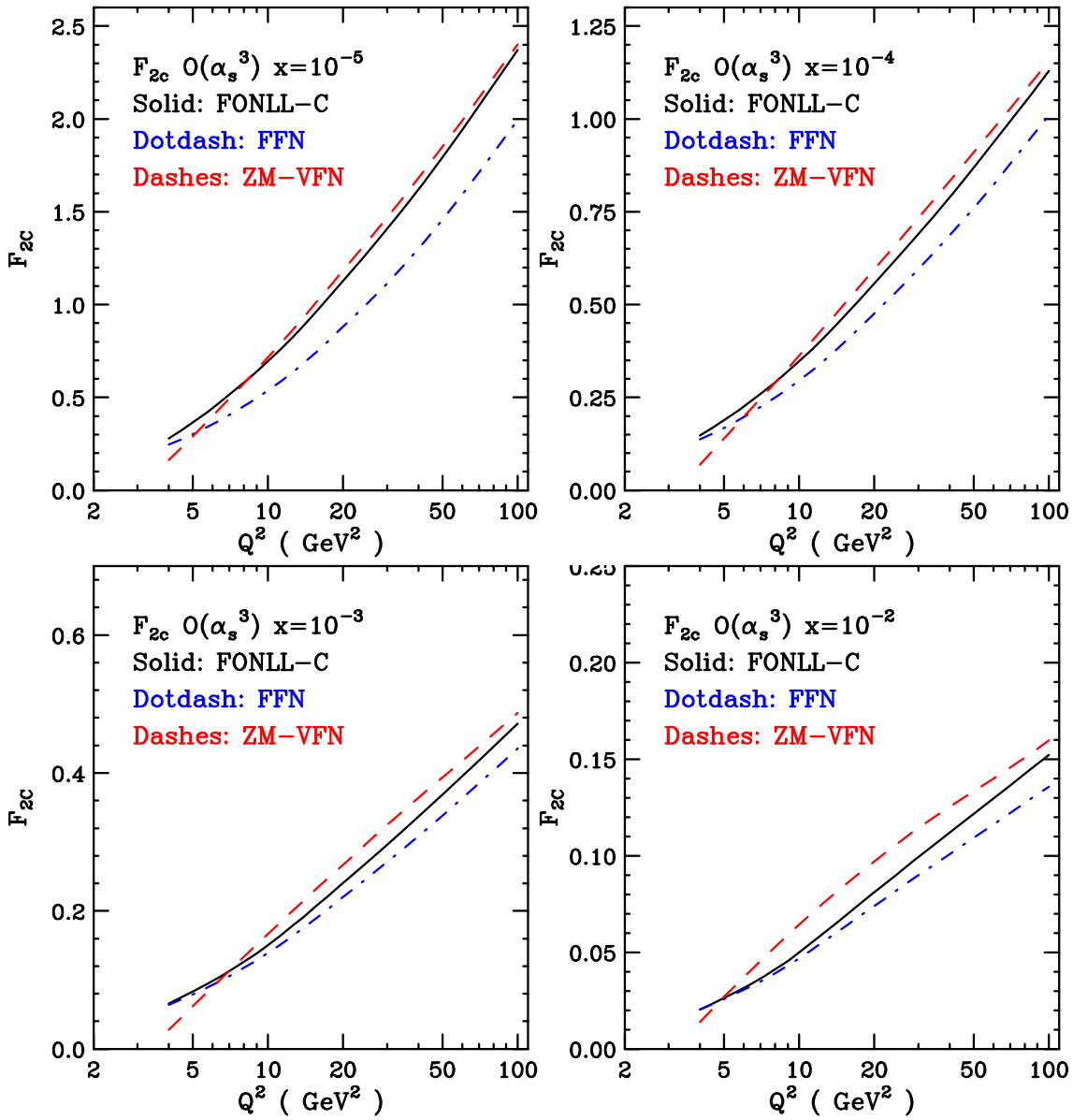
where

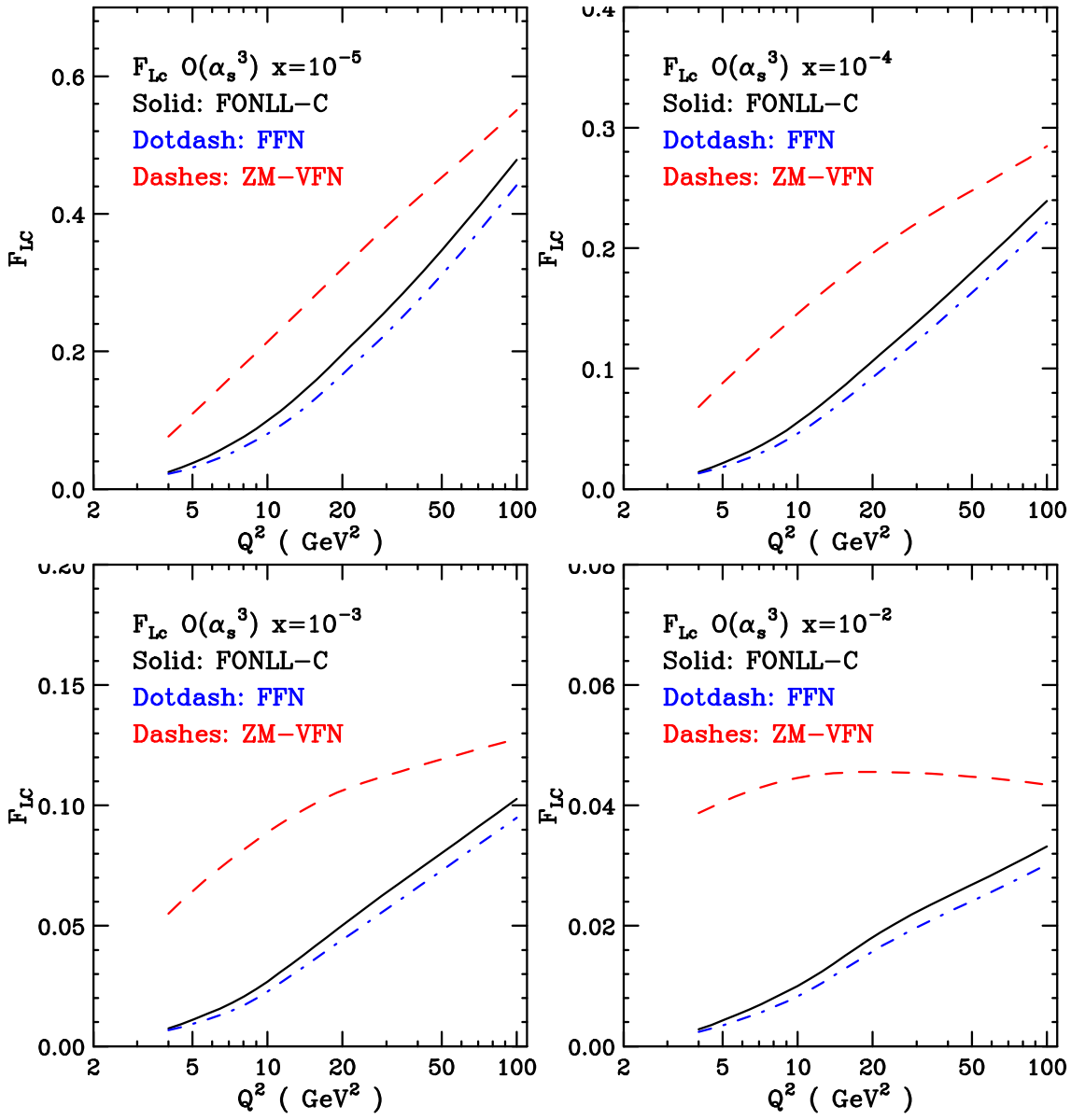
$$\mathcal{D}(Q^2) = \theta(Q^2 - m_h^2)\left(1 - \frac{m_h^2}{Q^2}\right)^2 \;\; ; \;\; F^{(d)} \equiv \left[F^{(n_l+1)}(x,Q^2) - F^{(n_l,0)}(x,Q^2)\right]$$

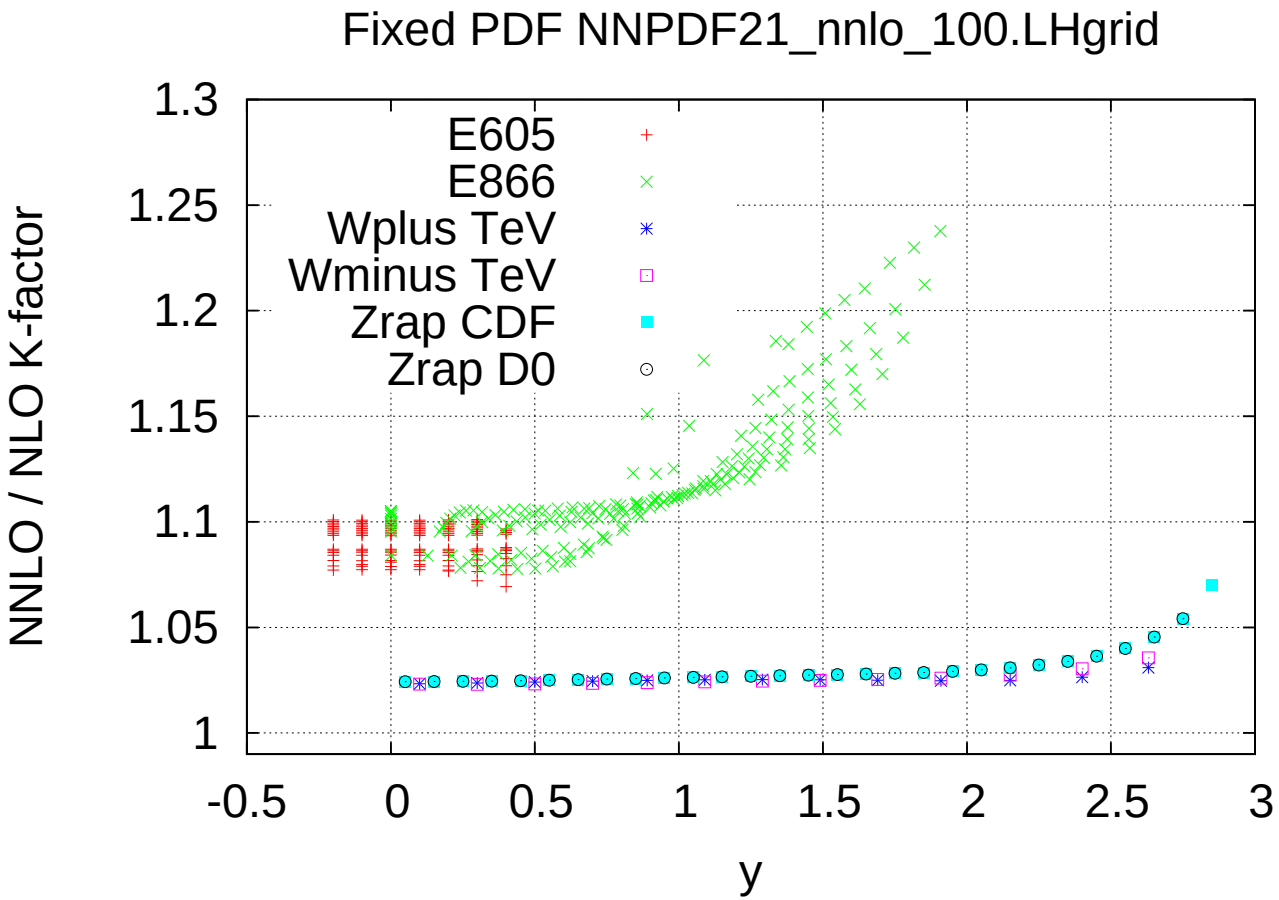
with

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

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


F_{2c} $O(\alpha_s^3)$ x=10^{-5}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{2c}
Q^2 (GeV^2)
F_{2c} $O(\alpha_s^3)$ x=10^{-4}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{2c}
Q^2 (GeV^2)
F_{2c} $O(\alpha_s^3)$ x=10^{-3}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{2c}
Q^2 (GeV^2)
F_{2c} $O(\alpha_s^3)$ x=10^{-2}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{2c}
Q^2 (GeV^2)

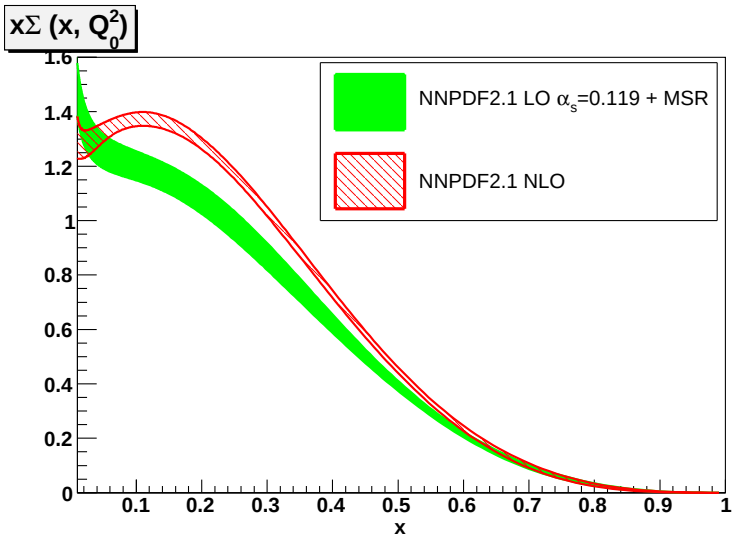

F_{Lc} $O(\alpha_s^3)$ x=10^{-5}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{LC}
Q^2 (GeV^2)
F_{Lc} $O(\alpha_s^3)$ x=10^{-4}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{LC}
Q^2 (GeV^2)
F_{Lc} $O(\alpha_s^3)$ x=10^{-3}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{LC}
Q^2 (GeV^2)
F_{Lc} $O(\alpha_s^3)$ x=10^{-2}
Solid: FONLL−C
Dotdash: FFN
Dashes: ZM−VFN
F_{LC}
Q^2 (GeV^2)

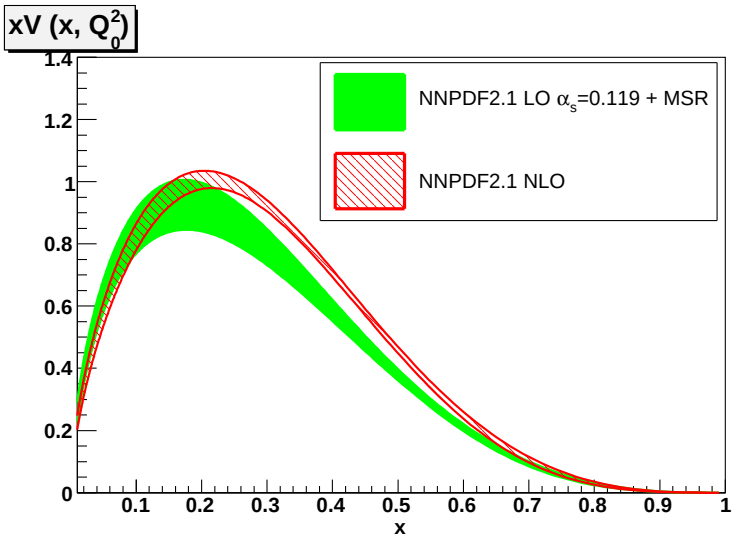

Fixed PDF NNPDF21_nnlo_100.LHgrid
NNLO / NLO K-factor
y
E605
E866
Wplus TeV
Wminus TeV
Zrap CDF
Zrap D0
1.3
1.25
1.2
1.15
1.1
1.05
1
-0.5
0
0.5
1
1.5
2
2.5
3

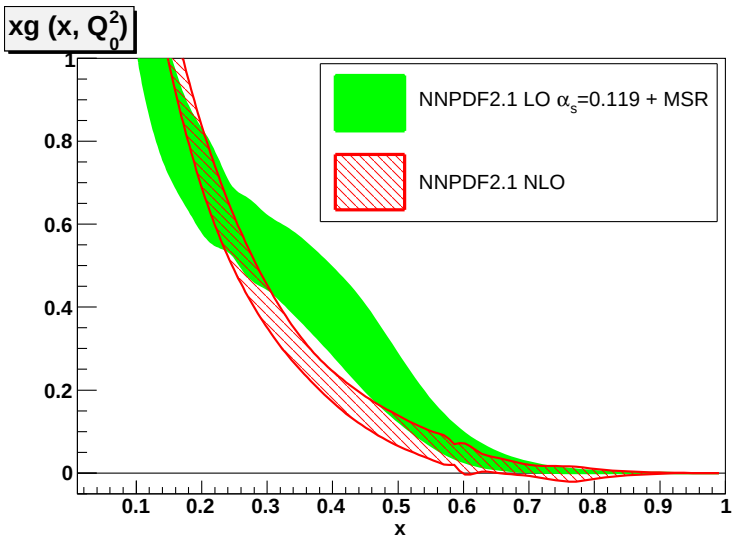
LO fit

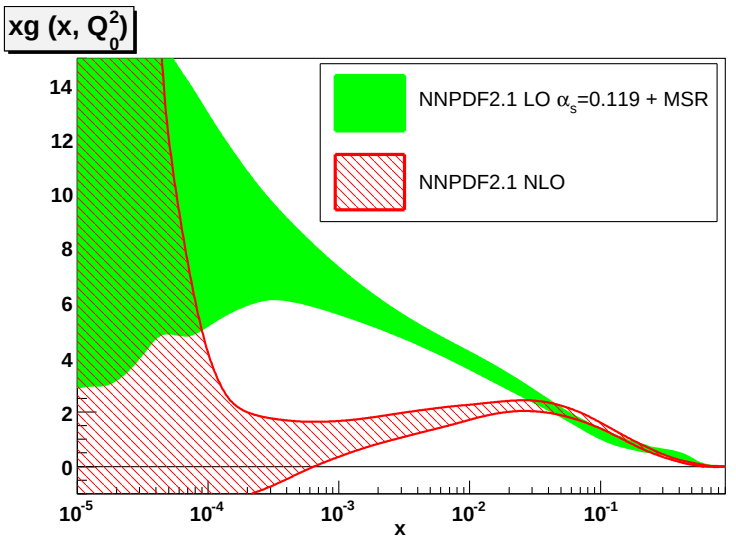
	NLO	LO α_s =0.119	LO* α_s =0.119	LO α_s =0.130	LO* α_s =0.130
Total χ^2	1.16	1.74	1.76	1.68	1.74
Total $\langle\chi^2\rangle$	1.25 ± 0.07	1.95 ± 0.21	1.89 ± 0.22	1.95 ± 0.19	1.94 ± 0.18
NMC-pd	0.97	1.43	1.13	1.18	1.12
NMC	1.72	2.05	1.68	1.74	1.72
SLACK	1.29	3.77	3.00	2.91	2.70
BEDIMS	1.24	1.87	1.82	1.76	1.75
HERAI-AV	1.07	1.70	1.55	1.58	1.59
CHORUS	1.15	1.51	1.67	1.53	1.67
NTVDMN	0.45	0.69	0.71	0.71	0.78
ZEUS-H2	1.29	1.51	1.42	1.43	1.44
ZEUSF2C	0.78	1.75	1.26	1.56	1.34
H1F2C	1.51	1.77	2.00	1.81	2.02
DYE605	0.85	1.86	2.02	1.70	1.83
DYE886	1.26	1.99	2.52	2.59	3.11
CDFWASY	1.83	1.80	2.50	2.16	2.29
CDFZRAP	1.64	2.88	3.89	2.08	2.58
D0ZRAP	0.59	1.07	1.29	0.87	1.02
CDFR2KT	0.96	2.60	3.22	2.45	2.76
D0R2CON	0.83	1.18	1.56	1.17	1.35
$[M]$	1	1	1.16 ± 0.03	1	1.09 ± 0.03

LO fit

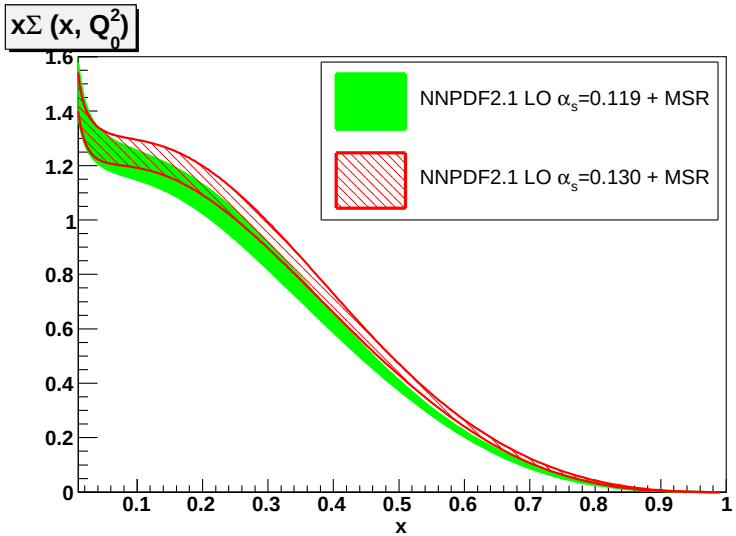

xΣ (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 NLO
x

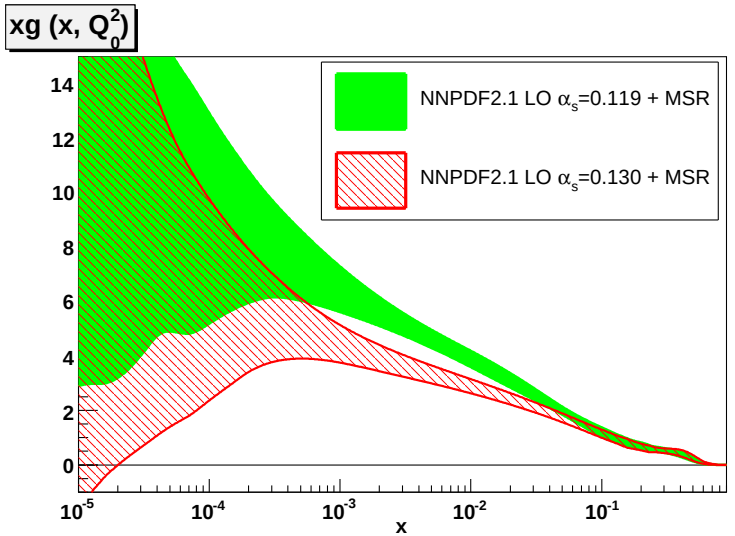

xV (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 NLO
x

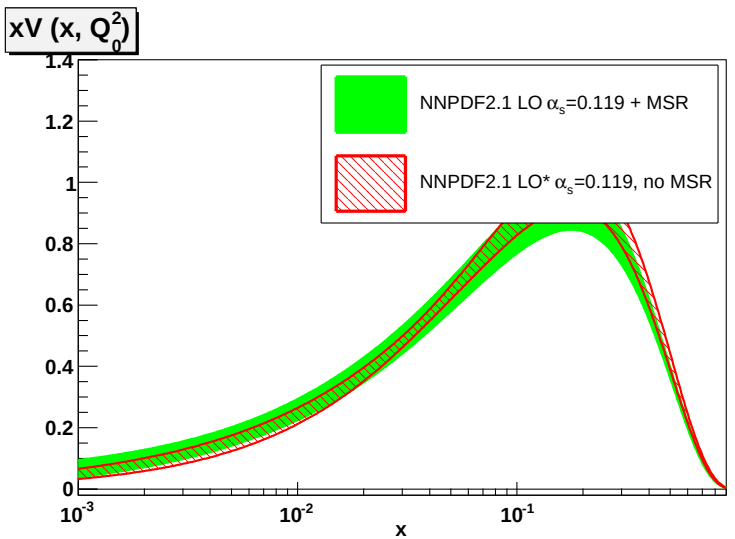

xg (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 NLO
x

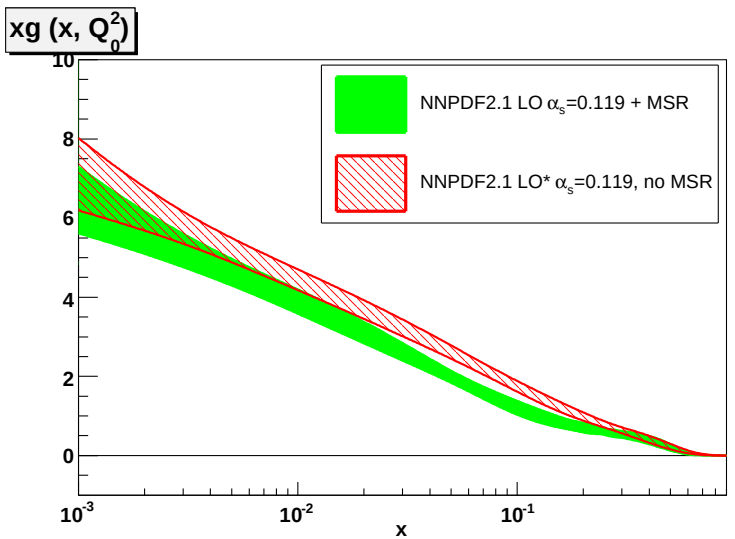

xg (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 NLO
x

LO fit

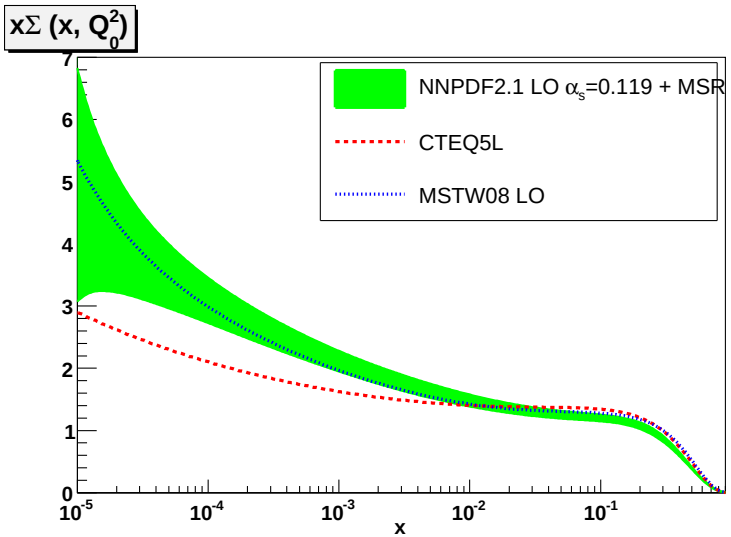

xΣ (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 LO α_s=0.130 + MSR
x

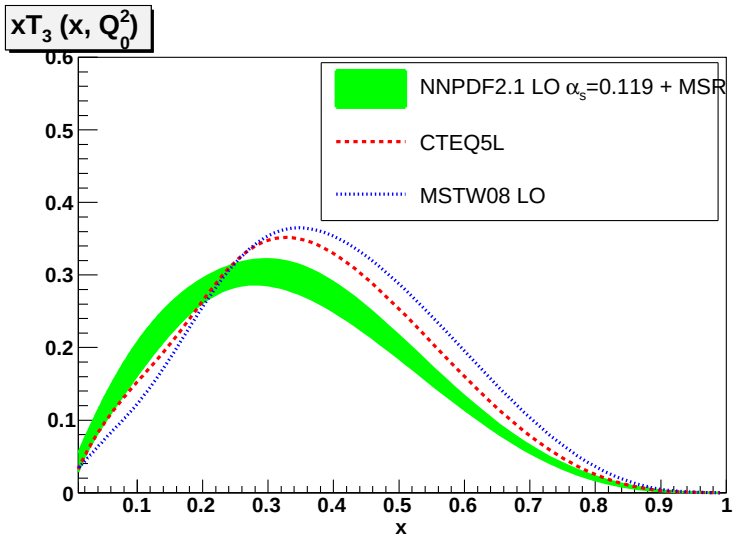

xg (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 LO α_s=0.130 + MSR
x

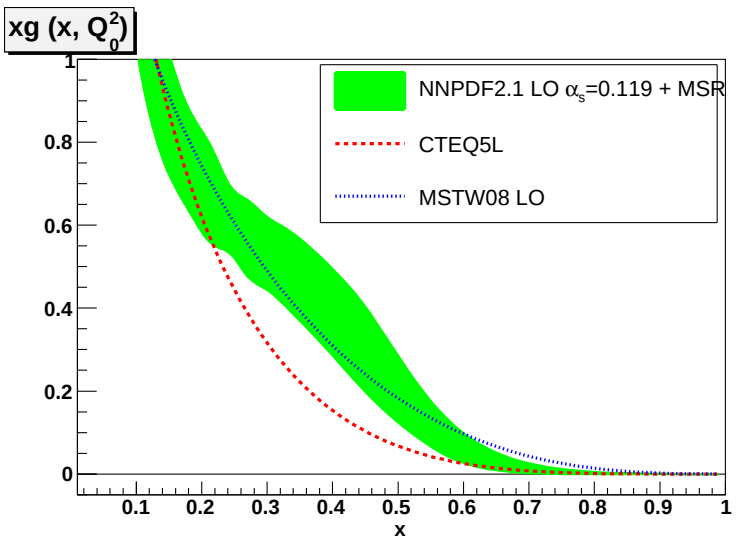

xV (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 LO* α_s=0.119, no MSR
x

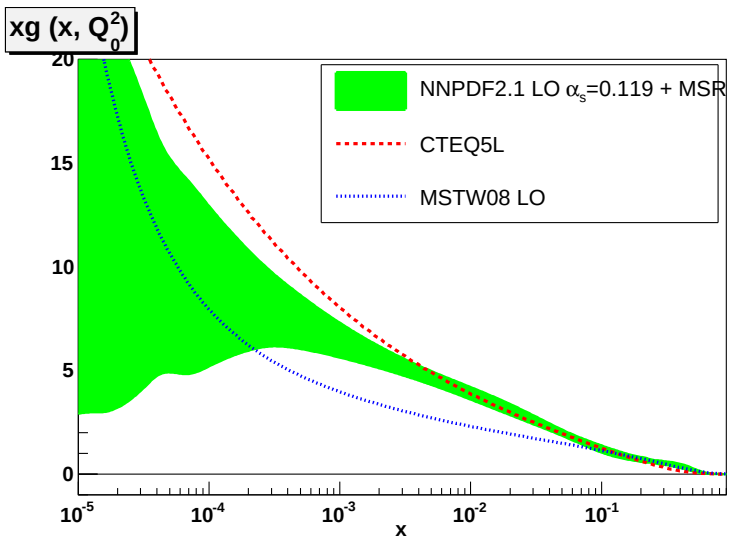

xg (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
NNPDF2.1 LO* α_s=0.119, no MSR
x

LO fit

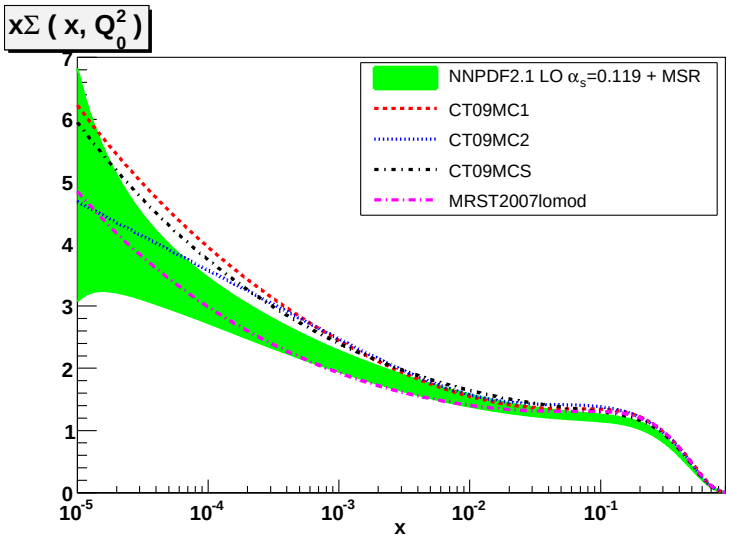

xΣ (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
CTEQ5L
MSTW08 LO
x

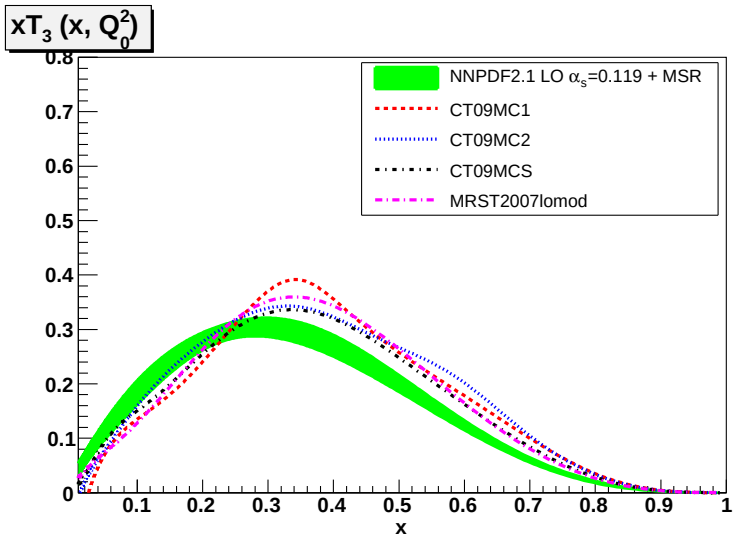

xT$_3$ (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
CTEQ5L
MSTW08 LO
x

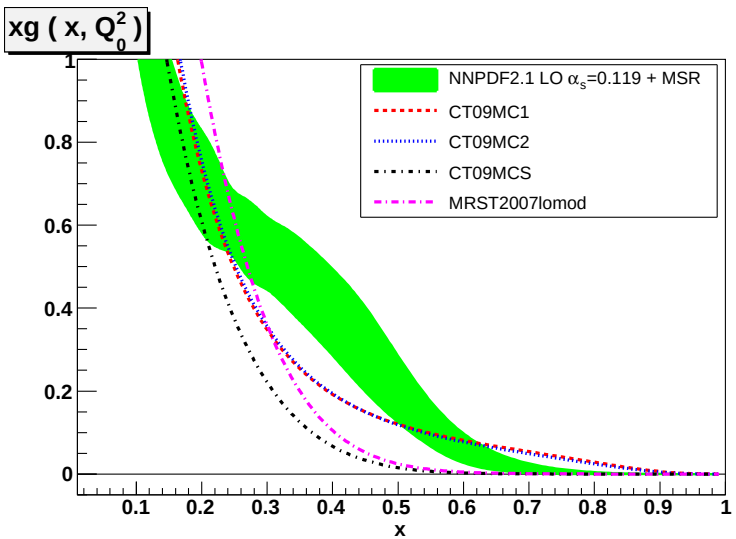

xg (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
CTEQ5L
MSTW08 LO
x


xg (x, Q$_0^2$)
NNPDF2.1 LO α_s=0.119 + MSR
CTEQ5L
MSTW08 LO
x

LO fit


$x\Sigma\ (x, Q_0^2)$
NNPDF2.1 LO α_s=0.119 + MSR
CT09MC1
CT09MC2
CT09MCS
MRST2007lomod
x


$xT_3\ (x, Q_0^2)$
NNPDF2.1 LO α_s=0.119 + MSR
CT09MC1
CT09MC2
CT09MCS
MRST2007lomod
x


$xg\ (x, Q_0^2)$
NNPDF2.1 LO α_s=0.119 + MSR
CT09MC1
CT09MC2
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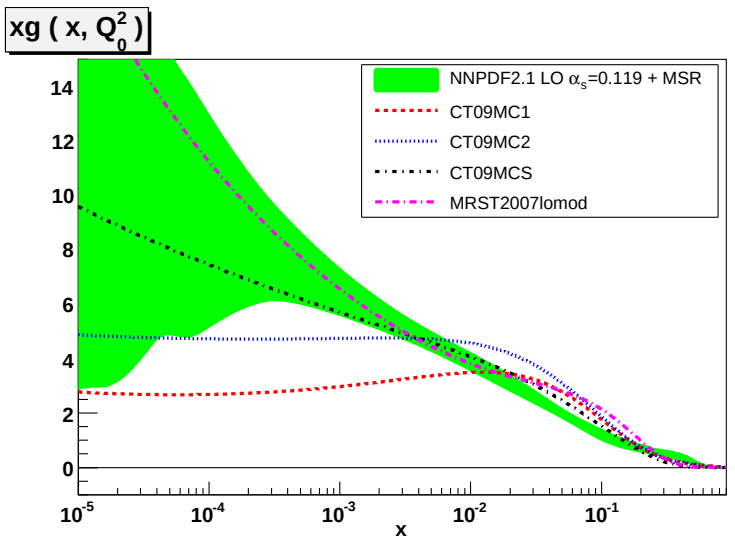
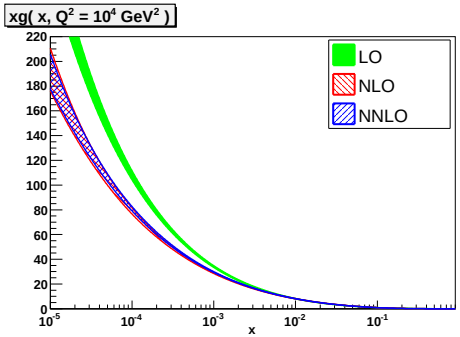
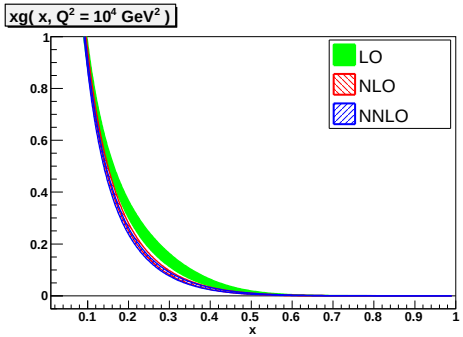
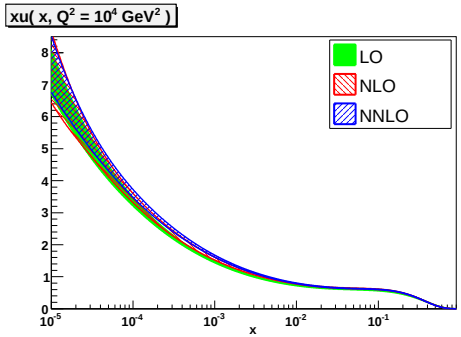
x

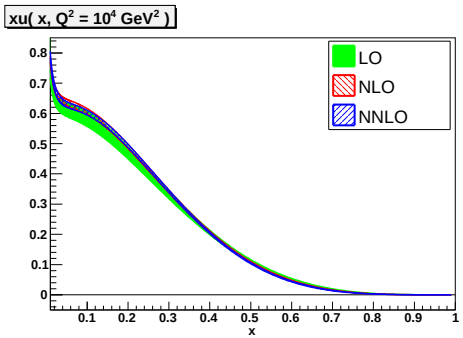

$xg\ (x, Q_0^2)$
NNPDF2.1 LO α_s=0.119 + MSR
CT09MC1
CT09MC2
CT09MCS
MRST2007lomod
x

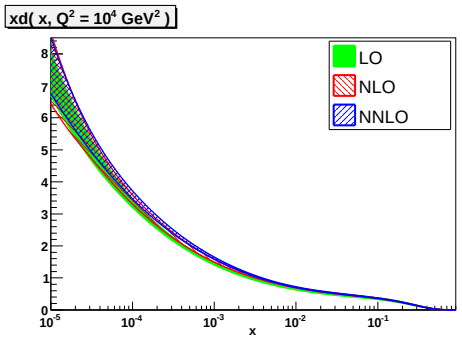
Perturbative convergence

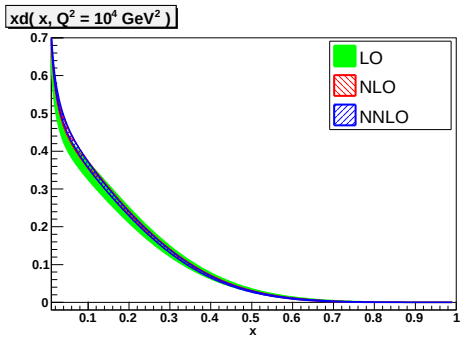


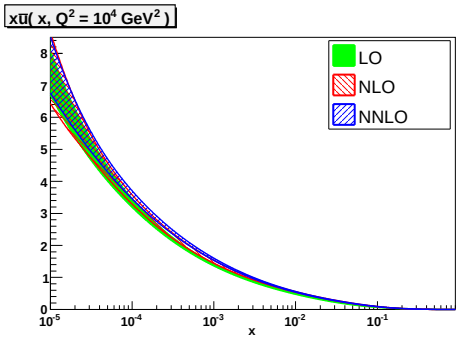


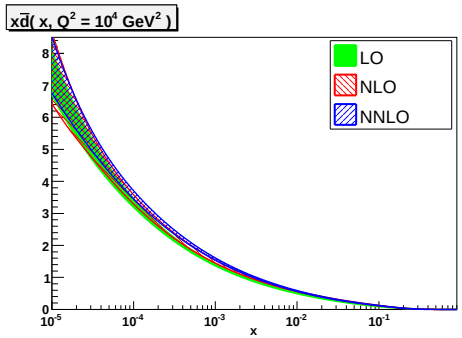




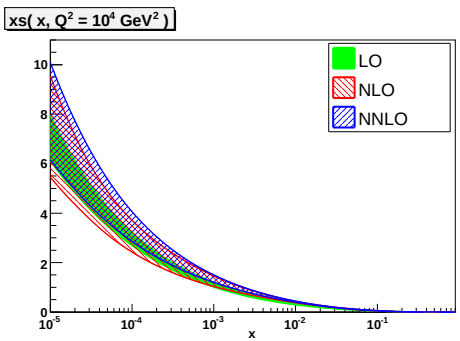


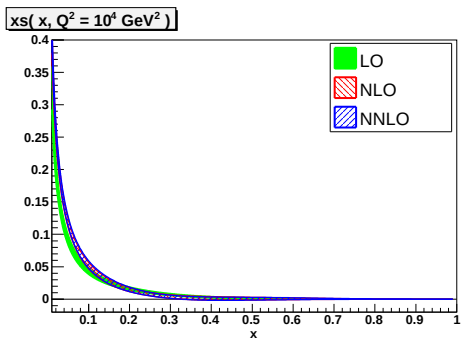


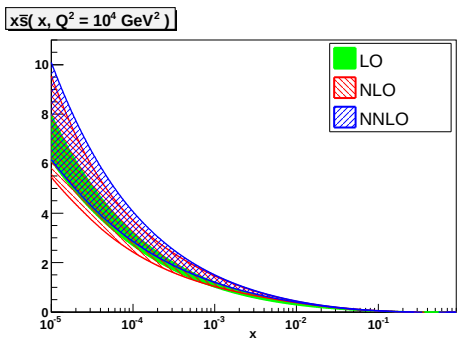


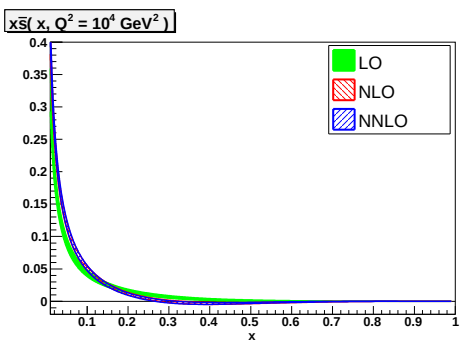


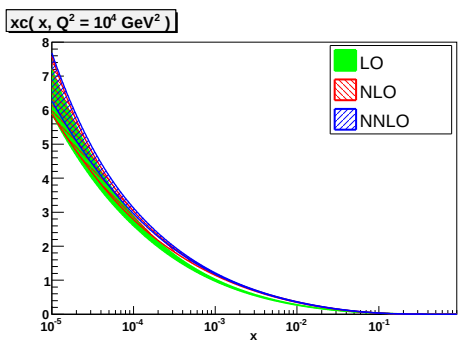
Perturbative convergence

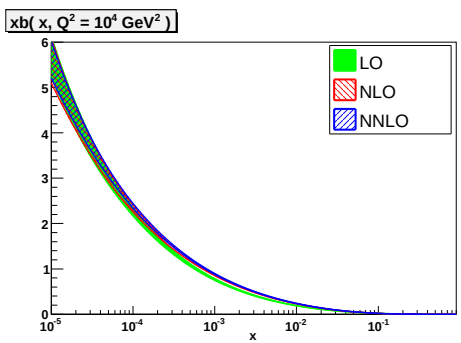




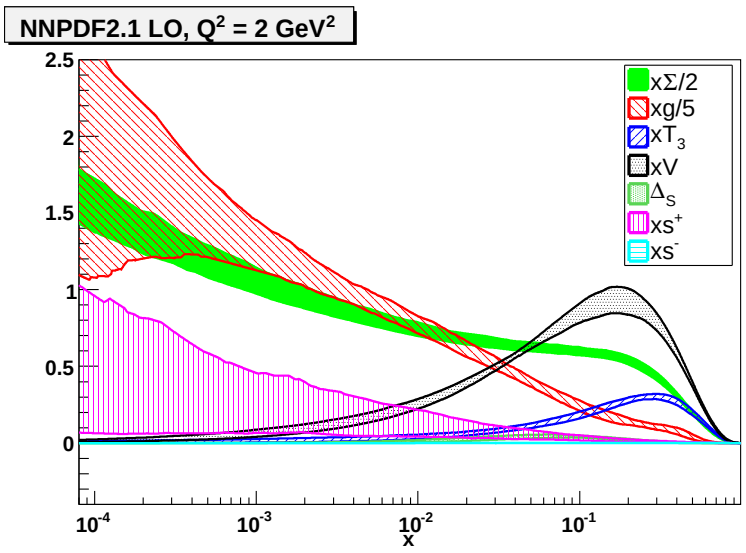


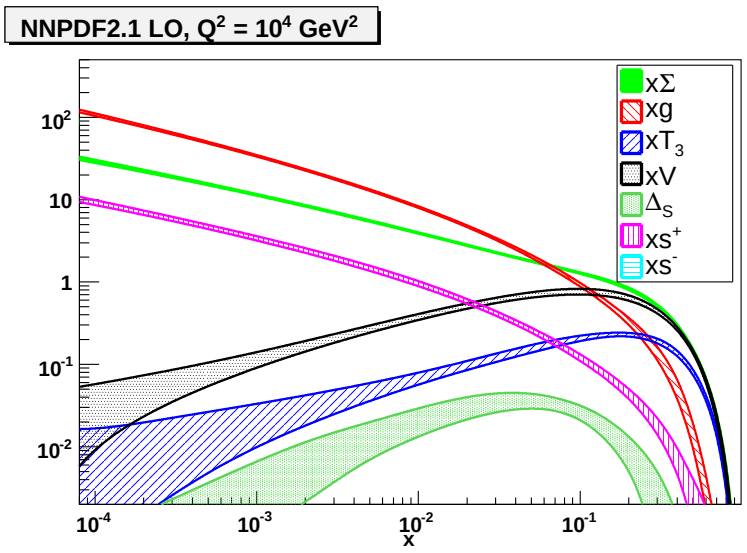




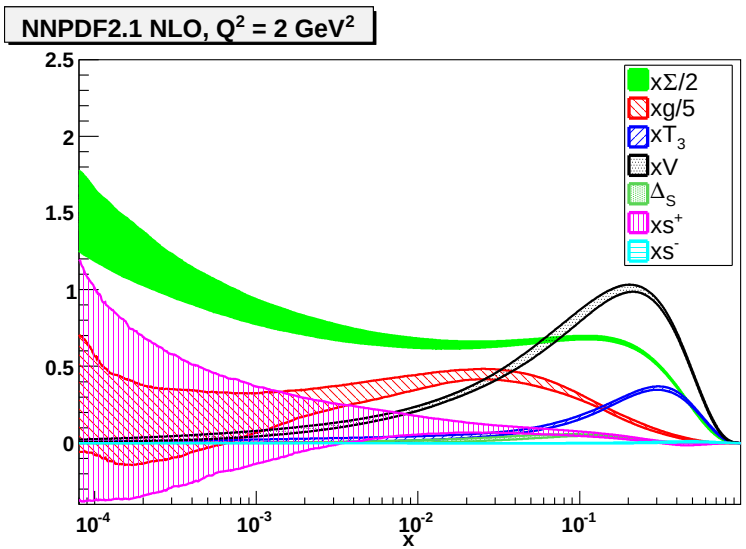


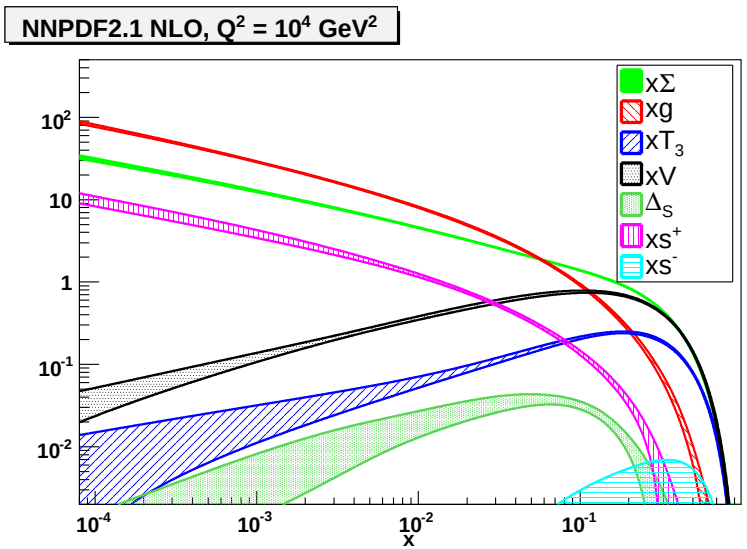
Perturbative convergence



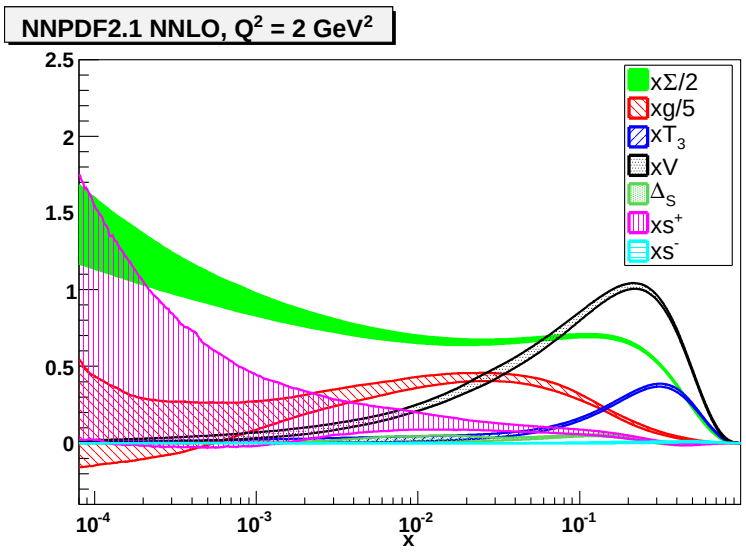


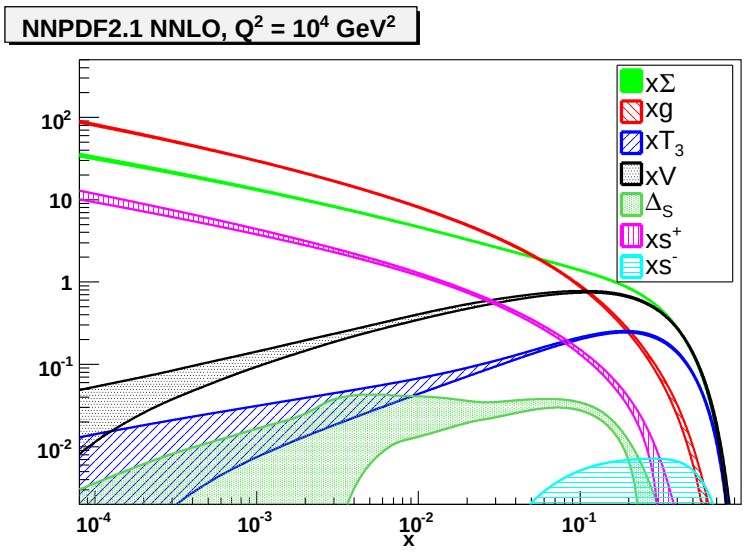
Perturbative convergence





Perturbative convergence





Reweighting
Bayesian inference

* The $N_{\rm rep}$ reps of a NNPDF fit give the probability density in the space of PDFs
* Expectation values for observables are Monte Carlo integrals

$$\begin{aligned}\langle \mathcal{F}[f_i(x)]\rangle &= \int [\mathcal{D}f_i]\,\mathcal{F}[f_i(x)]\mathcal{P}[f_i(x)] \\ &= \frac{1}{N_{\rm rep}}\sum_{k=1}^{N_{\rm rep}} \mathcal{F}[f_i^{(k)}(x)]\end{aligned}$$

as well as for errors, correlations ...

* We can assess the impact of including new data in the fit by updating the probability density distribution: $\mathcal{P}_{\rm new}$ is conditional to both the new and the "old" data

$$\int [\mathcal{D}f_i]\,\mathcal{F}[f_i(x)]\mathcal{P}_{\rm new}[f_i(x)] = \frac{1}{N_{\rm rep}}\sum_{k=1}^{N_{\rm rep}} w_k \mathcal{F}[f_i^{(k)}(x)]$$

$$w_k = \frac{[\chi^2(y,f_k)]^{\frac{n_{dat}-1}{2}} e^{-\frac{\chi^2(y,f_k)}{2}}}{\sum_{i=1}^{N_{\rm rep}} [\chi^2(y,f_i)]^{\frac{n_{dat}-1}{2}} e^{-\frac{\chi^2(y,f_i)}{2}}}$$