QCD @ LHC 2012

20th-24th August 2012 at Michigan State University

NNPDF 2.3
Parton densities with LHC data

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NNPDF Methodology
Main ingredients

- **Monte Carlo** determination of **uncertainties**
  - **No** need to rely on **linear propagation** of errors
  - Possibility to test the impact of **non-gaussianly** distributed uncertainties
  - Possibility to test for **non-gaussian behaviour** of uncertainties of fitted PDFs
- Parametrization of PDFs using **Neural Networks**
  - Provide an **unbiased parametrization**
- Determine the **best fit** PDFs using **Cross-Validation**
  - Ensures **proper fitting**, avoiding overlearning

NNPDF Methodology
... in a Nutshell

- **Generate** N_{rep} **Monte Carlo replicas** of the experimental data, taking into account all experimental correlations

- **Fit** a set of Parton Distribution Functions, parametrized at the initial scale using Neural Networks, to each replica

- **Expectation values** for observables are then given by

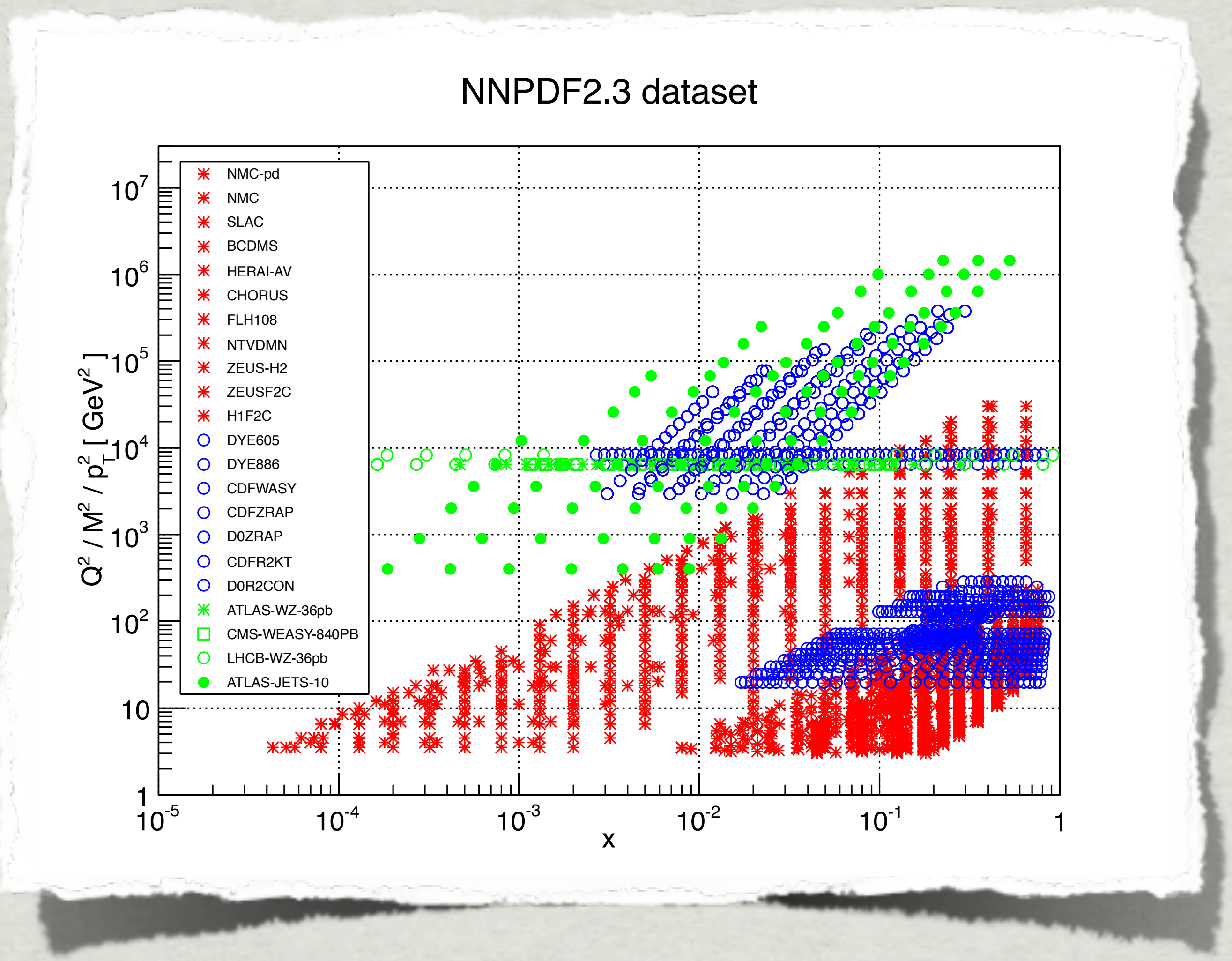
$$\langle \mathcal{F}[f_i(x,Q^2)] \rangle = \frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} \mathcal{F}\left(f_i^{(net)(k)}(x,Q^2) \right)$$

.... and corresponding formulae are used to compute uncertainties, correlations, etc.

NNPDF2.3
Dataset

- NNPDF2.3 dataset includes **relevant LHC data** for which the **full covariance matrix** is available
  - ATLAS Inclusive Jets, 36 pb^{-1} (arXiv:1112.6297)
  - ATLAS W/Z lepton rapidity distributions, 36 pb^{-1} (arXiv:1109.5141)
  - CMS W lepton asymmetry, 840 pb^{-1} (arXiv:1206.2598)
  - LHCb W/Z rapidity distributions, 36 pb^{-1} (arXiv:1204.1620)

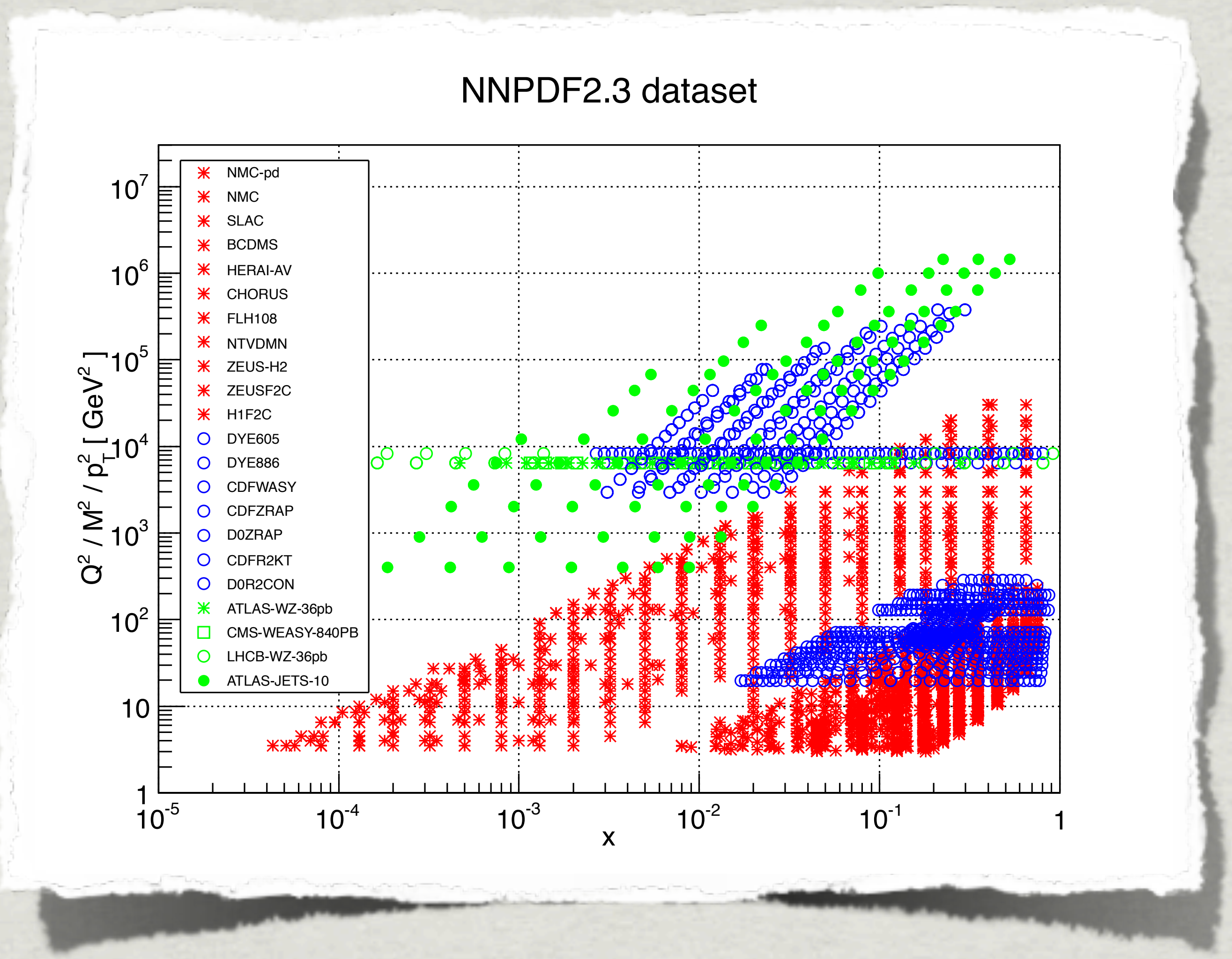
NNPDF2.3
Dataset



Experiment	Data
Fixed Target DIS	1952
HERA DIS	834
Fixed Target DY	318
Tevatron W/Z	70
Tevatron Jets	186
LHC W/Z	56
LHC Jets	90

3506 data points
(in the NNLO global fit)

NNPDF2.3
Dataset



Experiment	Data
Fixed Target DIS	1952
HERA DIS	834
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Tevatron W/Z	70
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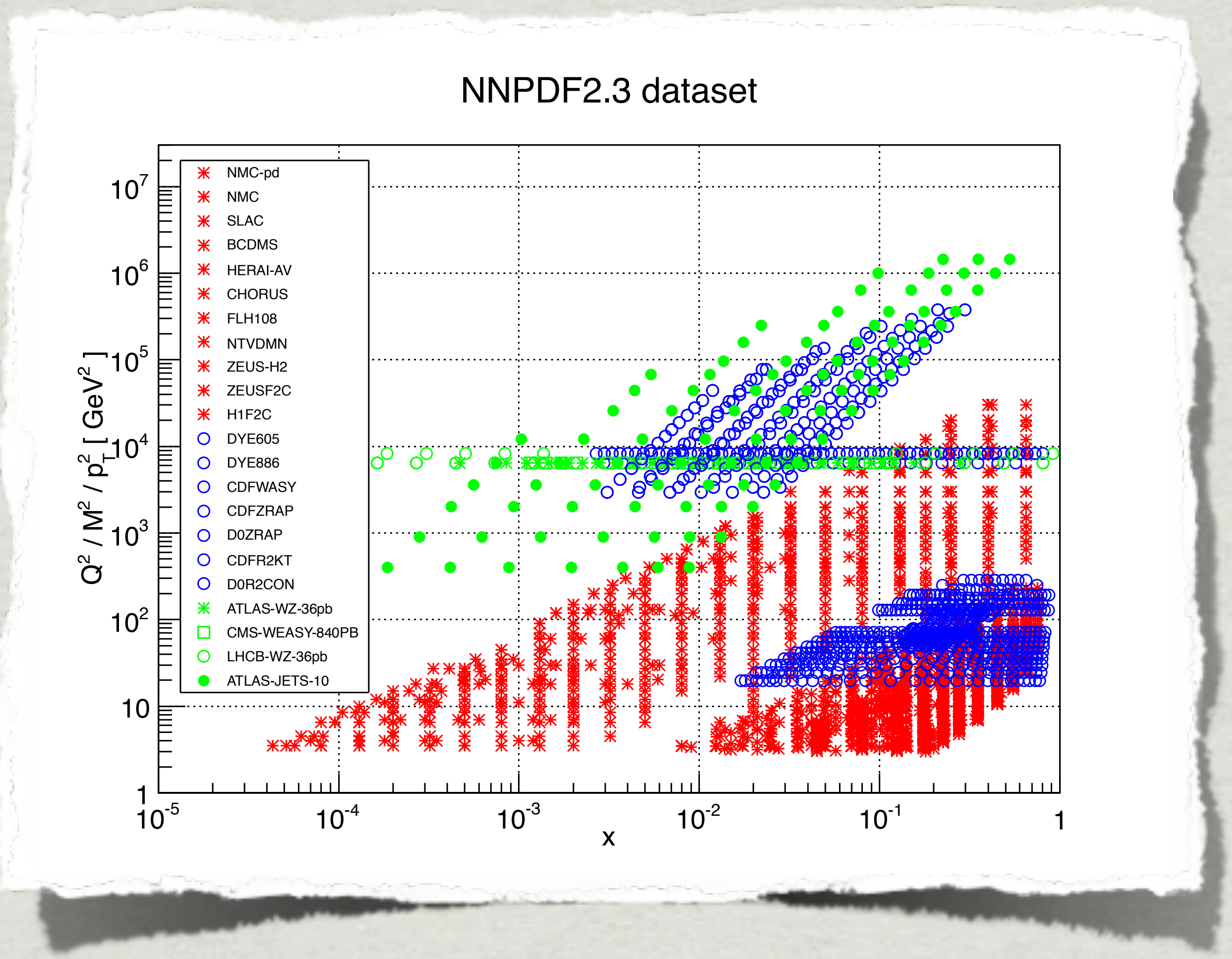
3360 data points
(in the NNLO noLHC fit)

NNPDF2.3
Dataset



Experiment	Data
Fixed Target DIS	1952
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Tevatron W/Z	70
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LHC W/Z	56
LHC Jets	90

1236 data points
(in the NNLO collider fit)

NNPDF2.3
Methodological Improvements

- Inclusion of higher order corrections to hadronic processes is very intensive from a computational point of view
- Combination of FastKernel method for PDF evolution with APPLgrid/ FastNLO tables (**FK**) gives a substantial speed-up in computation of observables during the fit
- More **advanced minimization** studies allowed by fast computation of observables
  - **larger number** of maximum genetic algorithm **generations** allowed
  - **increased** number of **mutants** and **mutations** per generation
  - retraining of **outlier** replicas
    (defined as replicas which do not stop and have a χ^2 more than 4-sigma away from the average)

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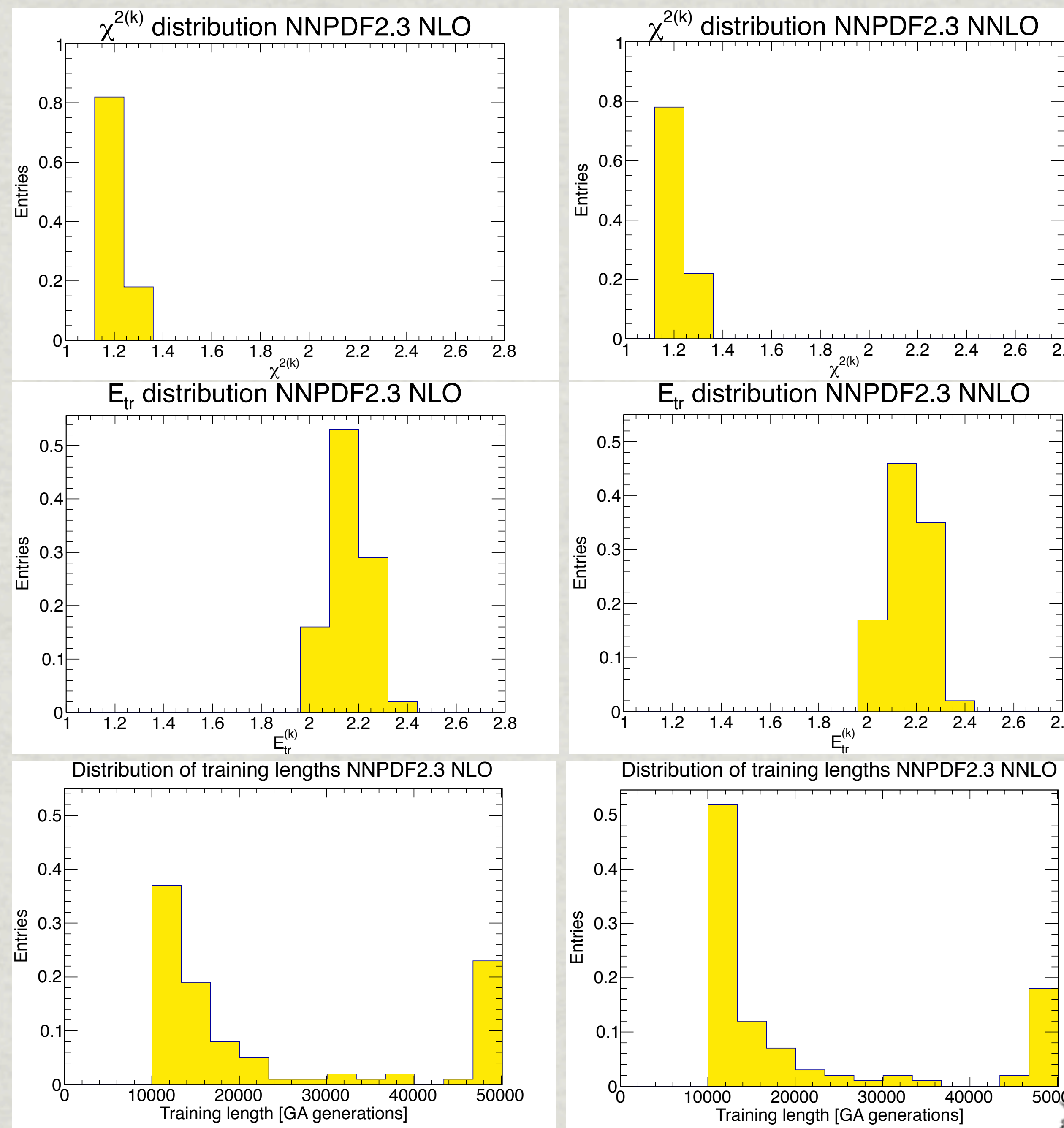
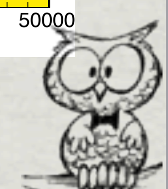
Results - Statistical features of the fit

NNPDF2.3		
	NLO	NNLO
$\chi^2_{\rm tot}$	1.137	1.150
$\langle E \rangle \pm \sigma_E$	2.19 ± 0.07	2.21 ± 0.06
$\langle E_{\rm tr} \rangle \pm \sigma_{E_{\rm tr}}$	2.16 ± 0.08	2.17 ± 0.08
$\langle E_{\rm val} \rangle \pm \sigma_{E_{\rm val}}$	2.23 ± 0.10	2.26 ± 0.09
$\langle {\rm TL} \rangle \pm \sigma_{\rm TL}$	$(24 \pm 15)\ 10^3$	$(22 \pm 15)\ 10^3$
$\langle \chi^{2(k)} \rangle \pm \sigma_{\chi^2}$	1.21 ± 0.05	1.22 ± 0.05
$\langle \sigma^{(\rm exp)} \rangle_{\rm dat} (\%)$	12.1	12.2
$\langle \sigma^{(\rm net)} \rangle_{\rm dat} (\%)$	3.0	3.0
$\langle \rho^{(\rm exp)} \rangle_{\rm dat}$	0.18	0.18
$\langle \rho^{(\rm net)} \rangle_{\rm dat}$	0.40	0.49



- Overall fit quality comparable (better an NLO) with previous NNPDF fits
- Distribution of replicas χ^2, and training lengths confirms the good fit quality



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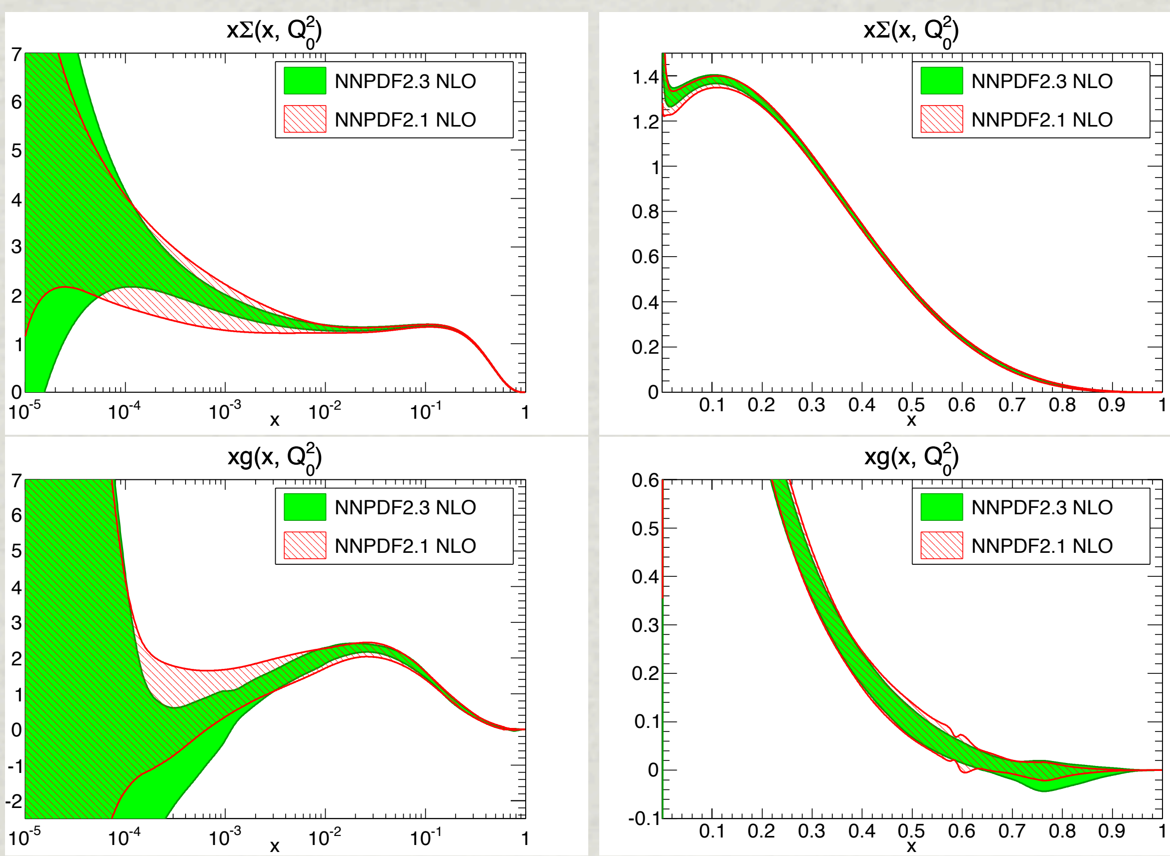
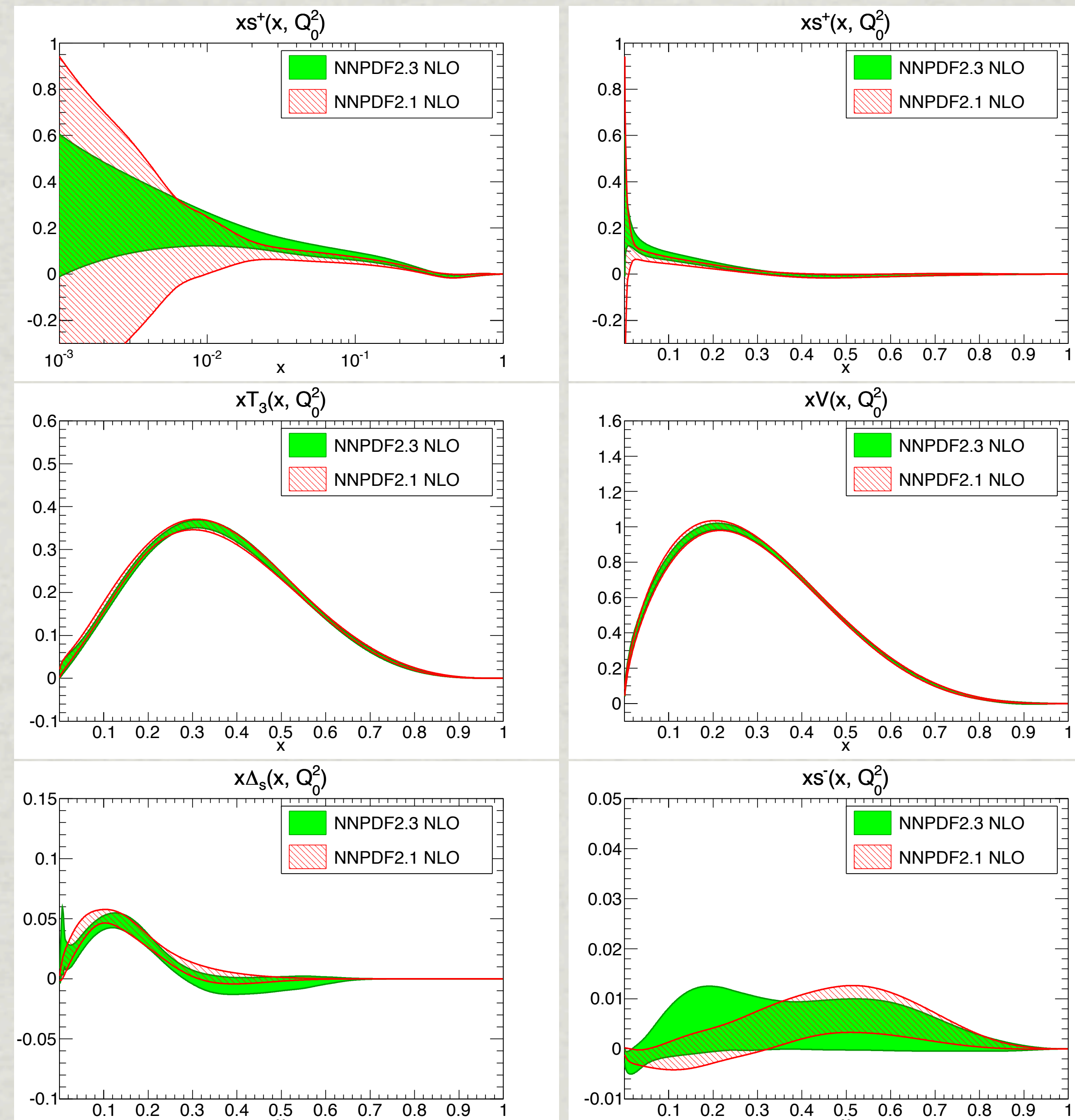
NNPDF2.3
Results - Parton Distributions (NLO)

- Detailed comparison with NNPDF2.1
  - addition of LHC data
  - improved minimization
  - corrected error in dimuon cross-section (moderate effect on strangeness)





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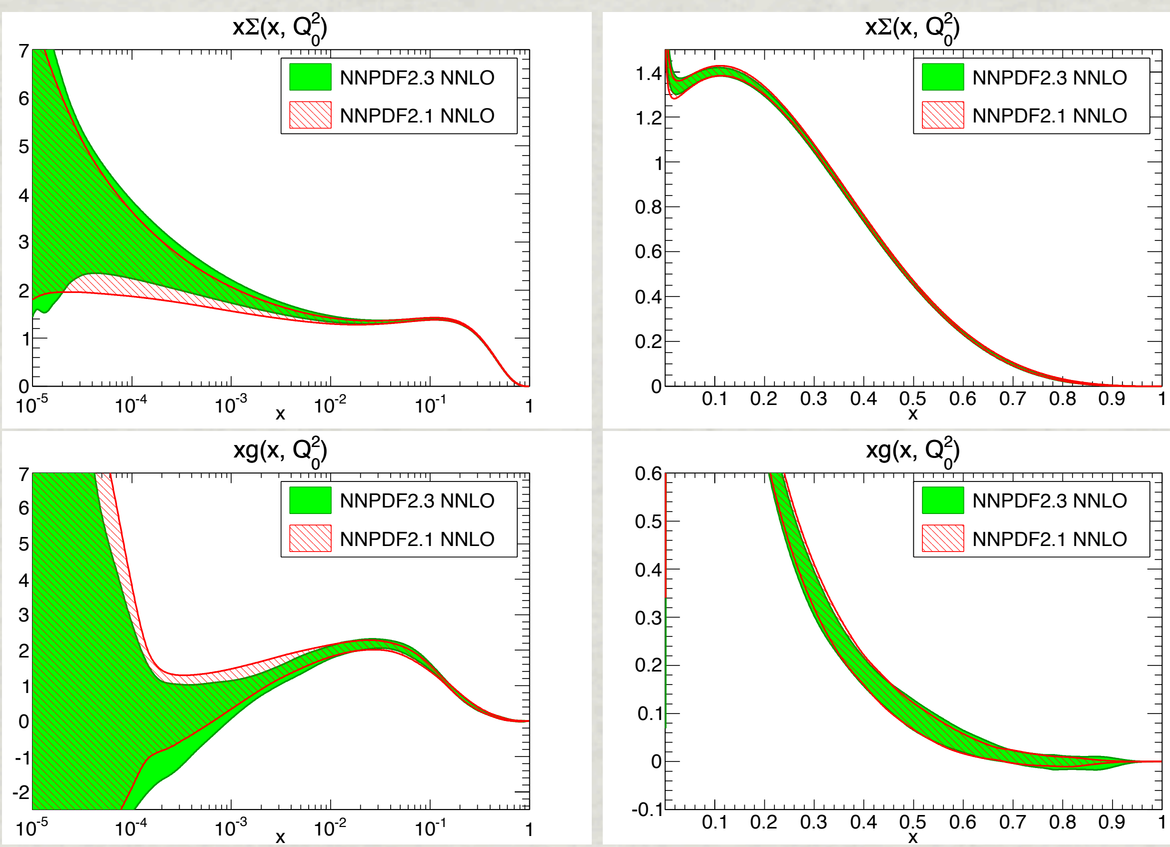

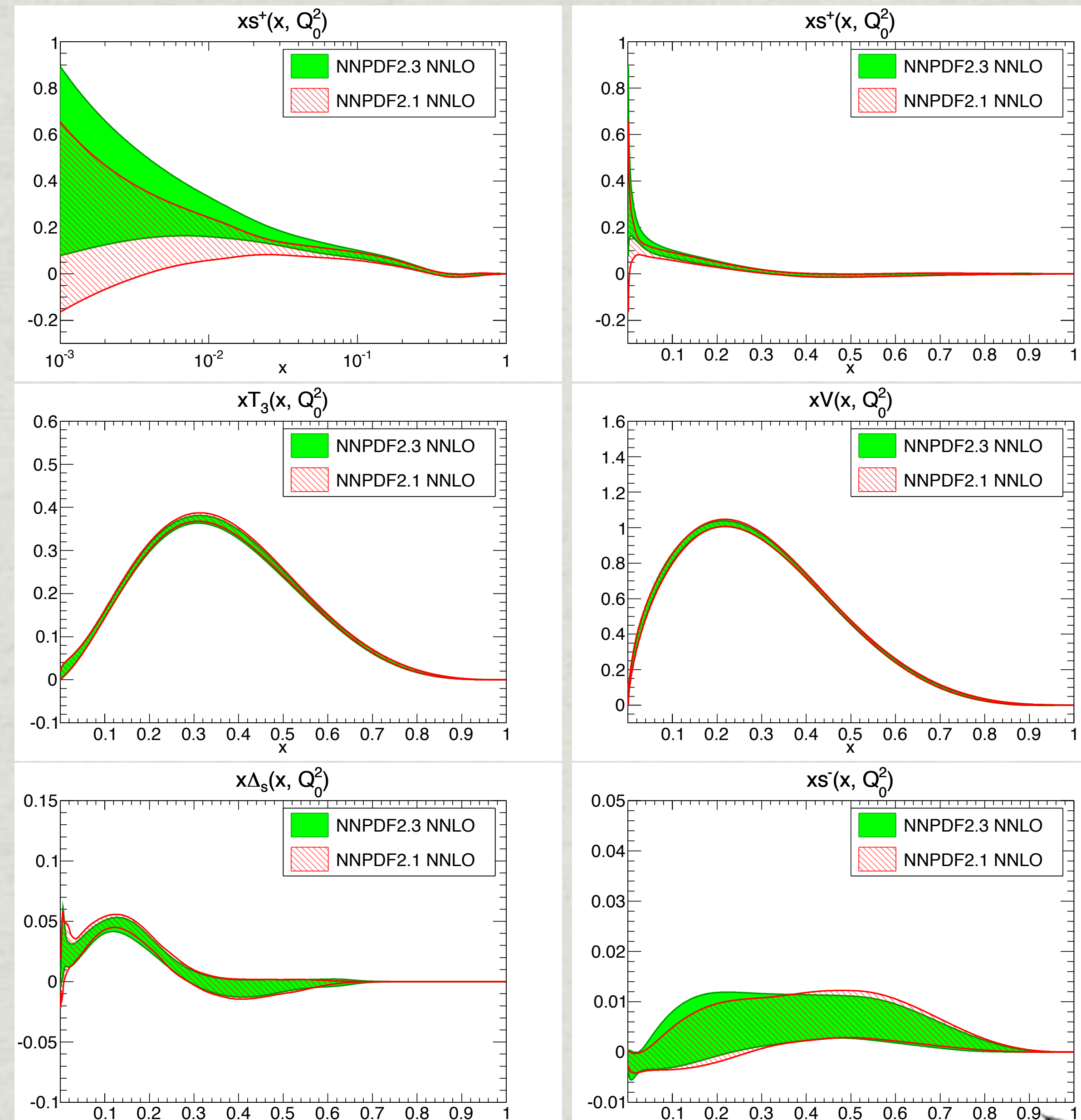

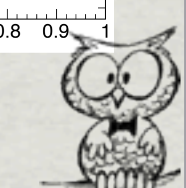

NNPDF2.3

Results - Data description

	NNPDF2.1		NNPDF2.3							
	Global		Global Fit		Global RW		noLHC		Collider	
Experiment	NLO	NNLO	NLO	NNLO	NLO	NNLO	NLO	NNLO	NLO	NNLO
Total	1.145	1.167	1.121	1.153	1.116	1.153	1.101	1.147	1.018	1.034
NMC-pd	0.97	0.93	0.93	0.94	0.93	0.94	0.93	0.94	[4.72]	[5.03]
NMC	1.68	1.58	1.61	1.57	1.59	1.56	1.59	1.56	[1.86]	[1.87]
SLAC	1.34	1.04	1.26	1.02	1.24	1.00	1.28	1.04	[1.80]	[1.48]
BCDMS	1.21	1.29	1.19	1.29	1.21	1.29	1.20	1.28	[1.81]	[2.08]
CHORUS	1.10	1.08	1.10	1.06	1.10	1.06	1.09	1.07	[1.93]	[1.81]
NTVDMN	0.70	0.50	0.45	0.55	0.45	0.59	0.42	0.48	[28.51]	[22.61]
HERAI-AV	1.04	1.04	1.00	1.01	1.00	1.02	1.01	1.03	0.97	0.98
FLH108	1.34	1.23	1.28	1.20	1.29	1.20	1.29	1.21	1.33	1.25
ZEUS-H2	1.21	1.21	1.20	1.22	1.21	1.22	1.20	1.22	1.30	1.32
ZEUS F_2^c	0.75	0.81	0.82	0.90	0.83	0.90	0.81	0.86	0.73	0.77
H1 F_2^c	1.50	1.44	1.58	1.52	1.63	1.53	1.58	1.49	1.34	1.30
DYE605	0.94	1.09	0.88	1.02	0.86	1.04	0.85	1.07	[11.12]	[4.56]
DYE886	1.42	1.76	1.28	1.62	1.25	1.59	1.24	1.61	[4.44]	[4.63]
CDF W asy	1.87	1.63	1.54	1.70	1.56	1.69	1.45	1.66	1.17	1.16
CDF Z rap	1.77	2.42	1.79	2.12	1.77	2.16	1.77	2.15	1.49	1.49
D0 Z rap	0.57	0.68	0.57	0.63	0.57	0.63	0.57	0.64	0.57	0.61
ATLAS W,Z	[1.58]	[2.22]	1.27	1.46	1.26	1.53	[1.37]	[1.94]	1.08	1.08
CMS W e asy	[2.26]	[1.45]	1.04	0.96	1.18	1.04	[1.50]	[1.37]	0.96	0.96
LHCb W,Z	[1.34]	[1.42]	1.21	1.22	1.19	1.21	[1.24]	[1.33]	1.22	1.29
CDF RII k_T	0.68	0.65	0.61	0.67	0.58	0.65	0.60	0.67	0.57	0.59
D0 RII cone	0.90	0.98	0.84	0.93	0.82	0.92	0.84	0.94	0.83	0.93
ATLAS jets	[1.65]	[1.48]	1.55	1.42	1.44	1.37	[1.57]	[1.45]	1.46	1.41

- **Overall quality** of the fit is **good**, with **no** signs of **strong tensions** among different datasets
- Good **consistency** of **refitting** and **reweighting** results

NNPDF2.3

The LHC data - Fit quality

- Compare the quality of the fit to LHC data before and after inclusion in the global fit
- Including LHC data in the fit improves the quality of their description, w/o deteriorating quality of the fit to other datasets
- Moderate impact of the LHC data, supporting consistency of the global fit framework
- Fit quality is comparable at NLO and NNLO, thought the former marginally better

NLO	NNPDF2.3 noLHC	NNPDF2.3
NMCpd	0.93	0.93
NMC	1.59	1.61
SLAC	1.28	1.26
BCDMS	1.20	1.19
HERA-I	1.01	1.00
CHORUS	1.09	1.10
NuTeV	0.42	0.45
DYE605	0.85	0.88
DYE866	1.24	1.28
CDFWASY	1.45	1.54
CDFZRAP	1.77	1.79
D0ZRAP	0.57	0.57
ATLAS-WZ	1.37	1.27
CMS-WEASY	1.50	1.04
LHCb-WZ	1.24	1.21
CDFR2KT	0.60	0.61
D0R2CON	0.84	0.84
ATLAS-JETS-2010	1.57	1.55

NNPDF2.3

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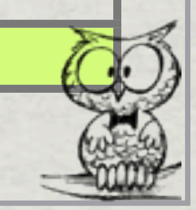

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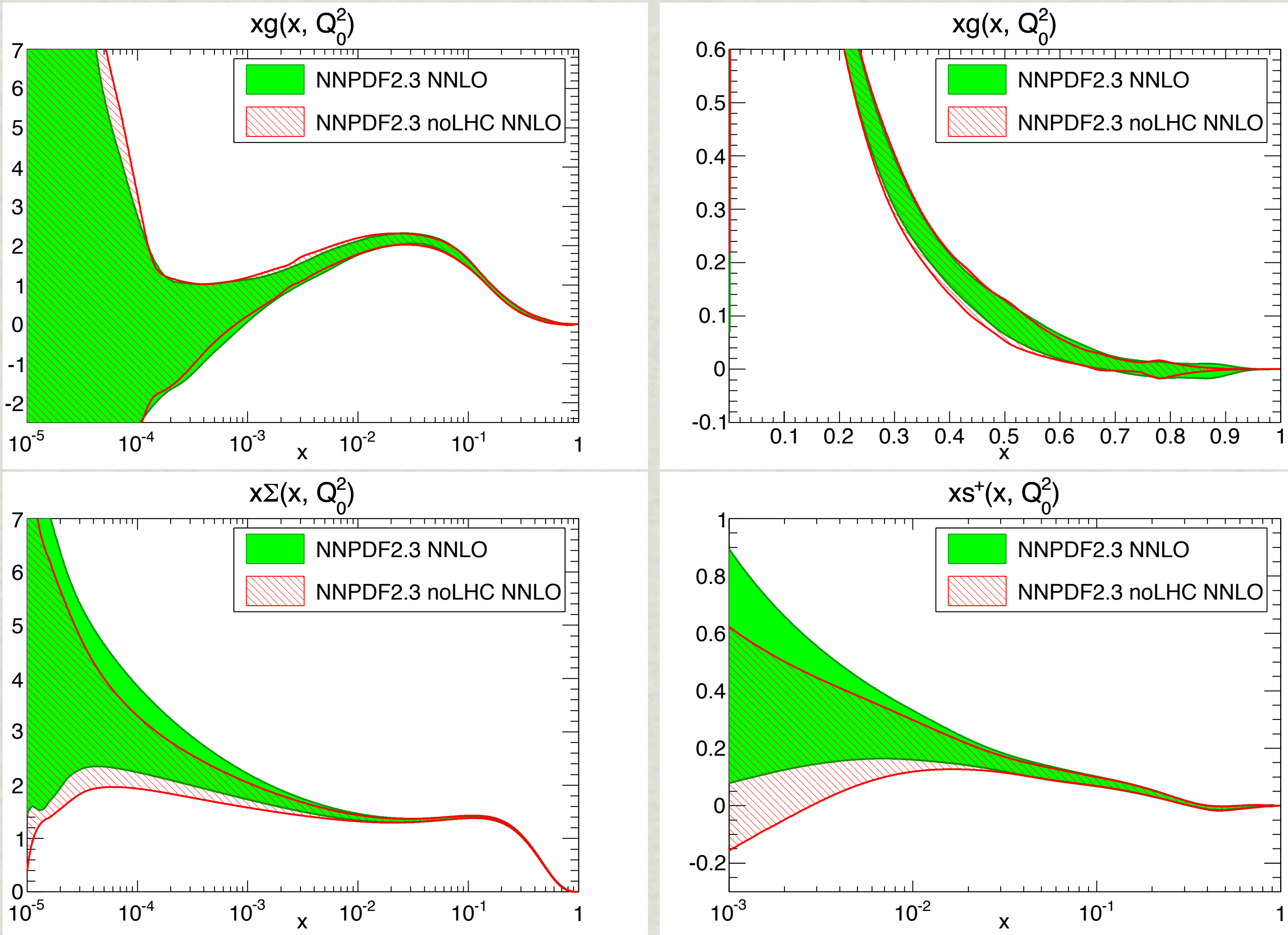
The LHC data - PDF comparison

- Moderate impact of LHC data on extracted PDFs
- Largest impact on singlet quark and strange distribution
- Effect is at most half a sigma shift in central values



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The LHC data - Observables

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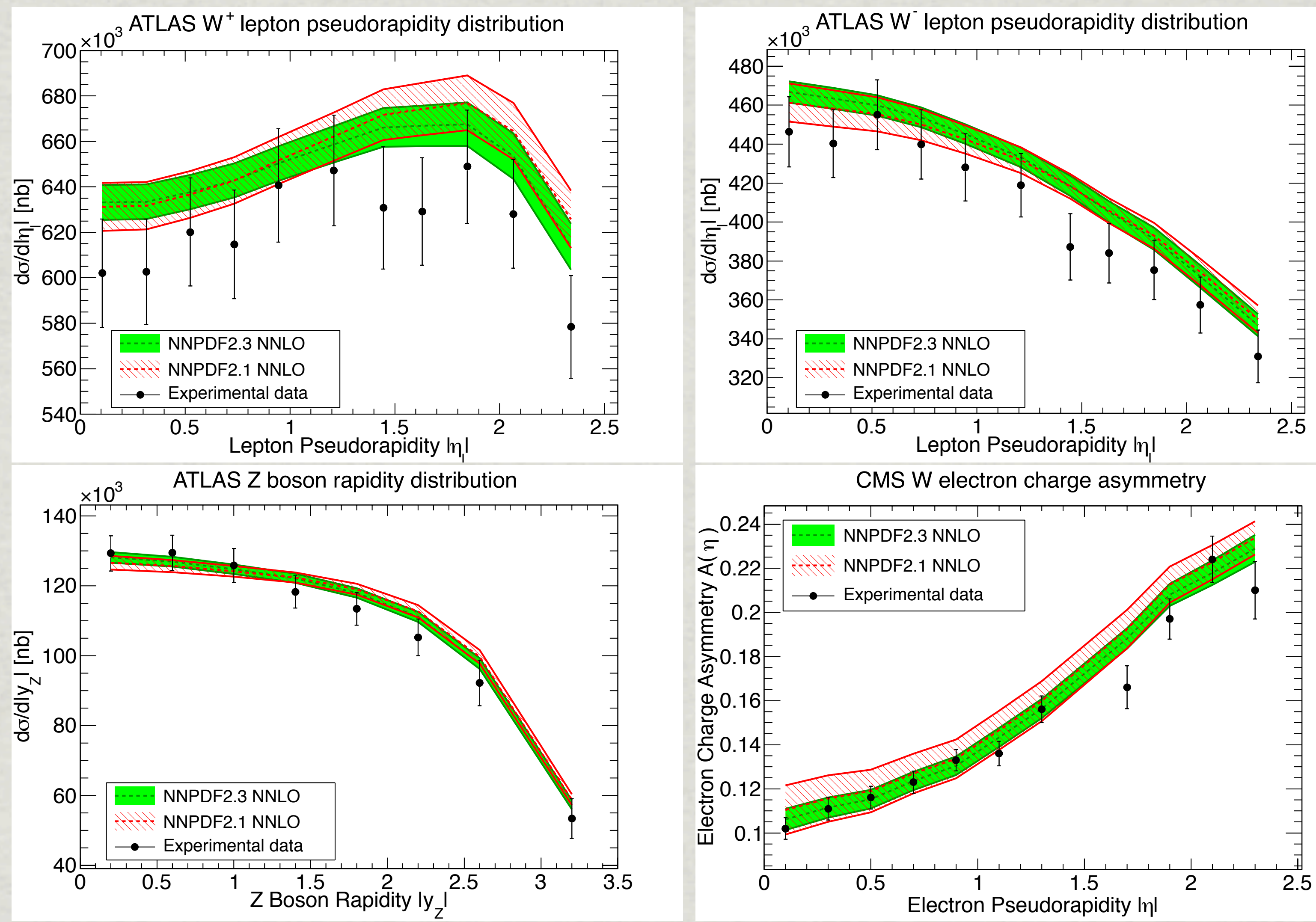
- Fit to LHC data already acceptable before including them in the fit
- Very good description of LHC datasets after inclusion in the NNPDF2.3 fit
- Substantial reduction in the uncertainties on the observable predictions



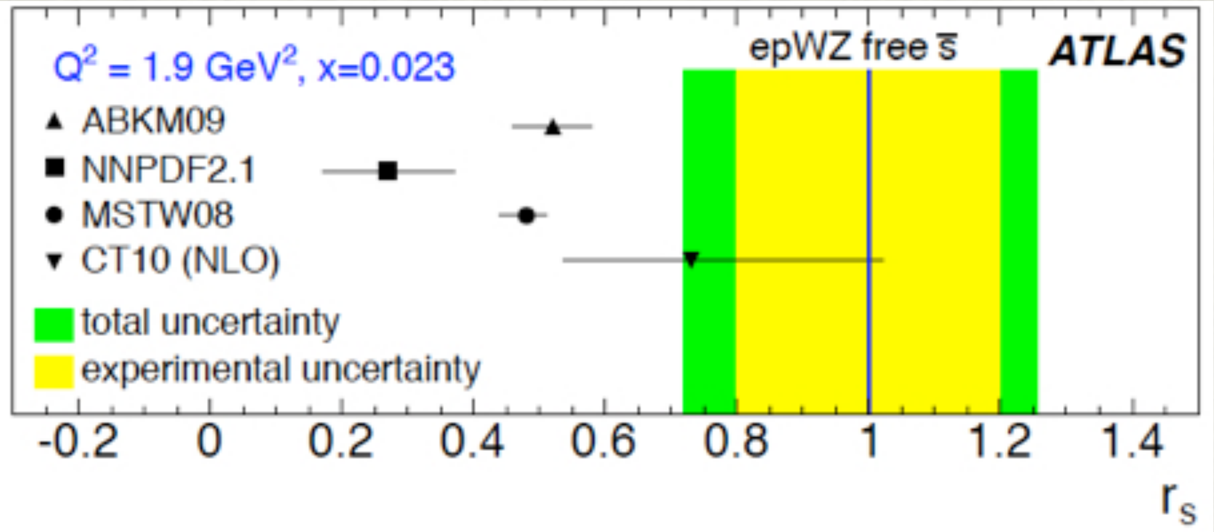
NNPDF2.3

The LHC data - a "strange" story

- ATLAS recently presented evidence for a larger than thought strange distribution at low Q2 and x, leading to a value for

$$r_s(x,Q^2) = \frac{s(x,Q^2)+\bar{s}(x,Q^2)}{2\bar{d}(x,Q^2)} \approx 1 \quad \text{(for } Q^2\text{=1.9 GeV}^2 \text{ and x=0.023)}$$

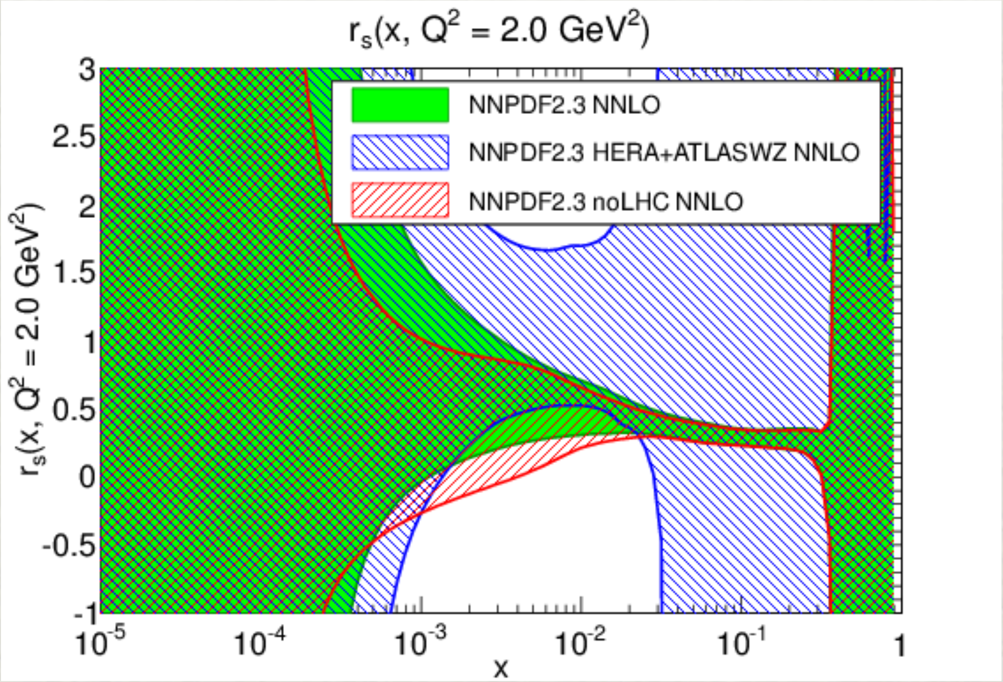
  which disagrees at two sigma level with the NNPDF2.1 prediction
- The ATLAS analysis is based on a fit combining the HERA-I data with the ATLAS W/Z rapidity distribution data

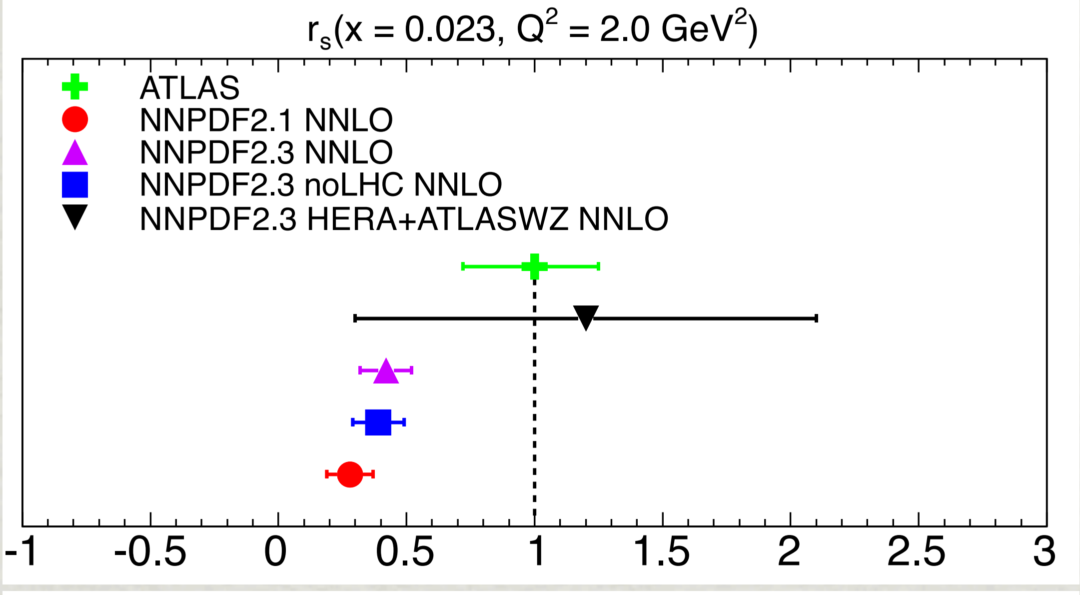


- In order to check the ATLAS claim we produced a version of the NNPDF2.3 fit based on the same dataset used in the ATLAS study

NNPDF2.3

The LHC data - a “strange” story





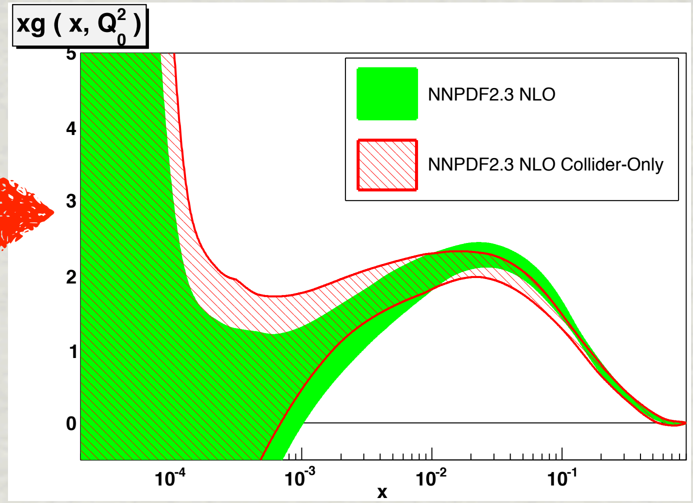
- Strangeness in NNPDF2.3 somewhat larger than NNPDF2.3noLHC in the range $10^{-3}<x<10^{-1}$, though still compatible within errors shows minor small impact of LHC data
- Determination from HERA+ATLAS dataset yields r_s~1 but has much larger uncertainties (substantially larger than ATLAS determination)

NNPDF2.3

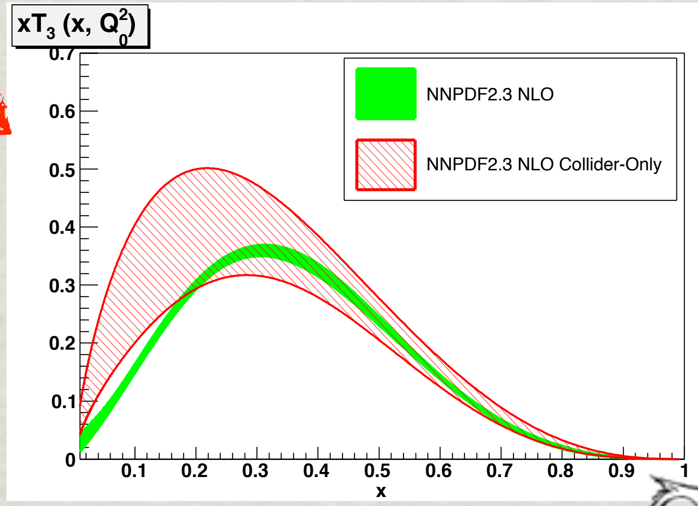
Collider fit - are we there yet?

It is the fit we would love to have

- Only **high energy data**: minimize the effects of higher-twist contributions
- Only **proton data**: no assumptions based on models for nuclear corrections



- **Gluon distribution** is very **well constrained** both at small-x (HERA) and large-x (Tevatron/LHC jets)
- PDF combinations sensitive to **light flavour separation** have **substantially larger uncertainties** (missing constraints from fixed target DIS/DY data)

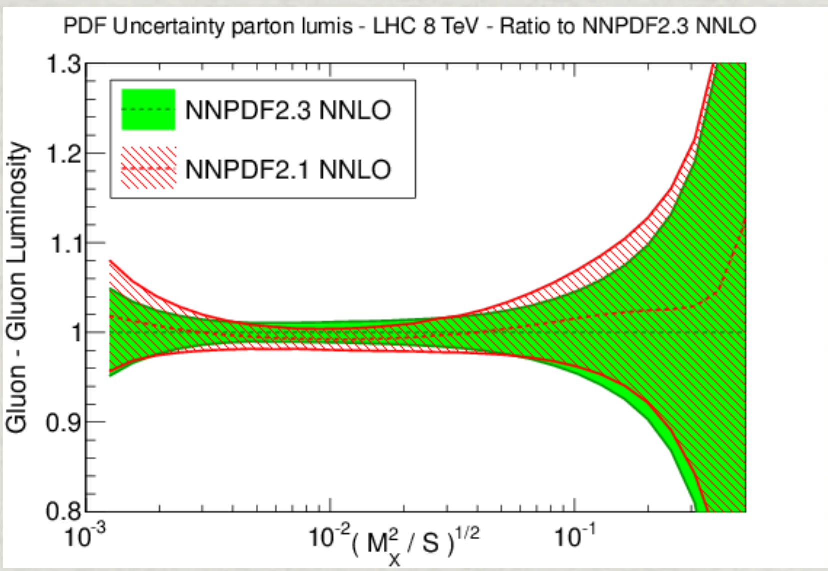


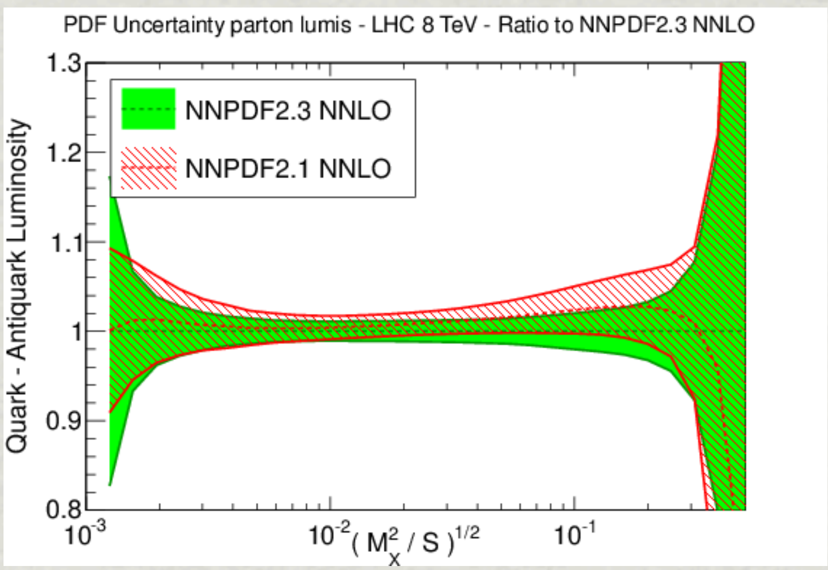
- **Uncertainties** on **"fixed target" observables** are still unacceptably **large**
- Improvement with respect to NNPDF2.1 collider fit thanks to inclusion LHC data
- **...** things can only get better with more LHC data coming (W+c, low mass DY, photons, high pt Z/W ...)

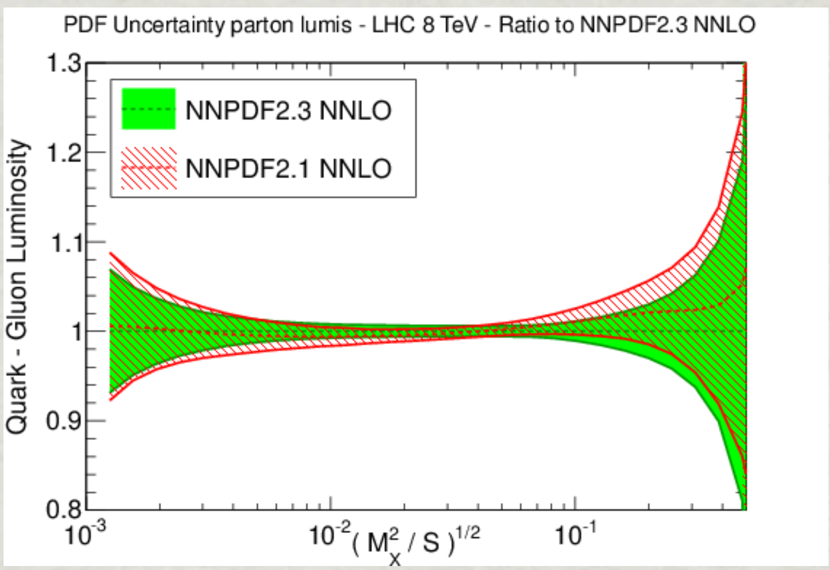
NNPDF2.3

Phenomenology - parton luminosities

$$\Phi_{ij}\left(M_X^2\right) = \frac{1}{s}\int_\tau^1 \frac{dx_1}{x_1} f_i\left(x_1, M_X^2\right) f_j\left(\tau/x_1, M_X^2\right)$$



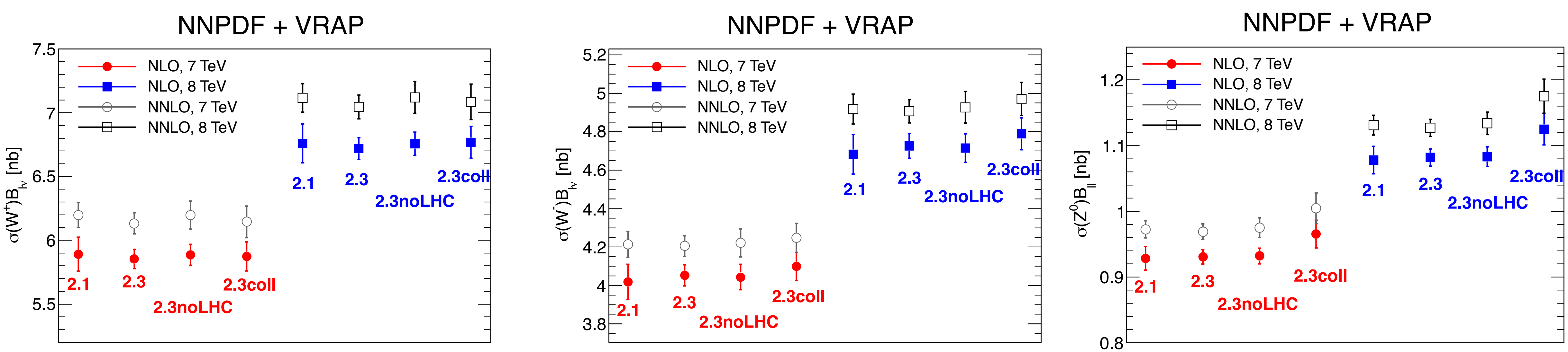




- Reduction in uncertainty on gluon-gluon luminosity for larger final state invariant masses when going from NNPDF2.1 to NNPDF2.3
- NNPDF2.3 quark-antiquark luminosity at large invariant masses somewhat smaller than NNPDF2.1

NNPDF2.3

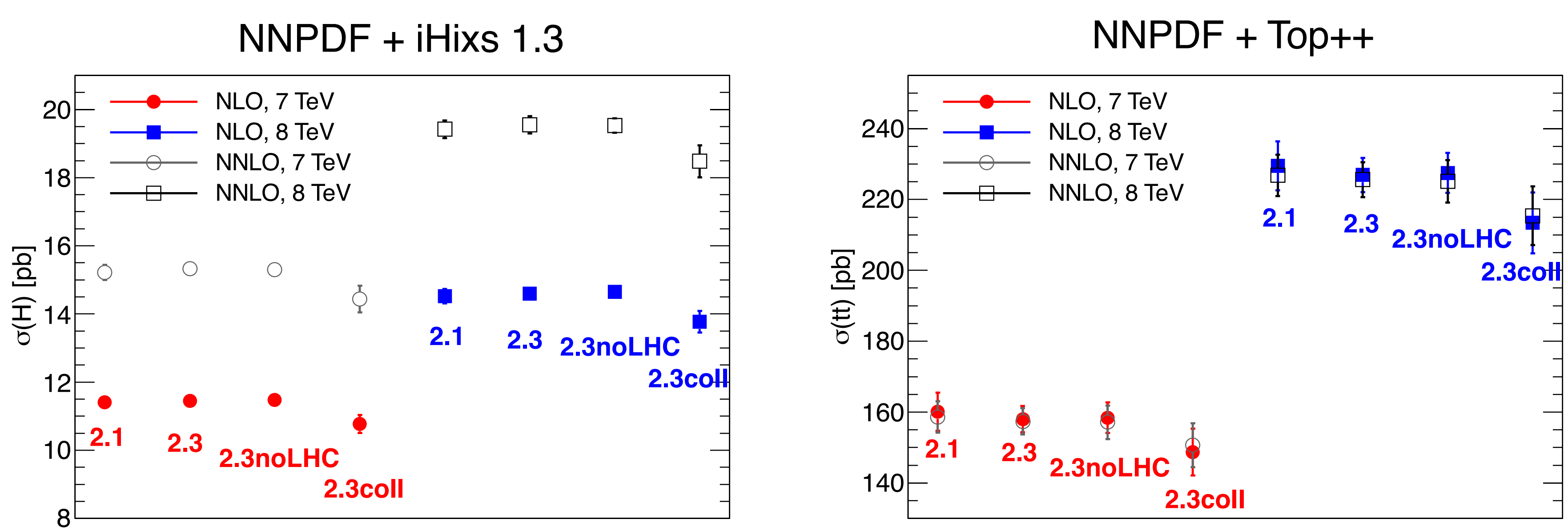
Phenomenology - W/Z production



- Mostly sensitive to quark parton luminosities
- Predictions from NNPDF2.3 sets are compatible with each other and with predictions obtained using the NNPDF2.1 global set
- Largest differences with collider only fit, although the latter has larger uncertainties

NNPDF2.3

Phenomenology - top/Higgs production



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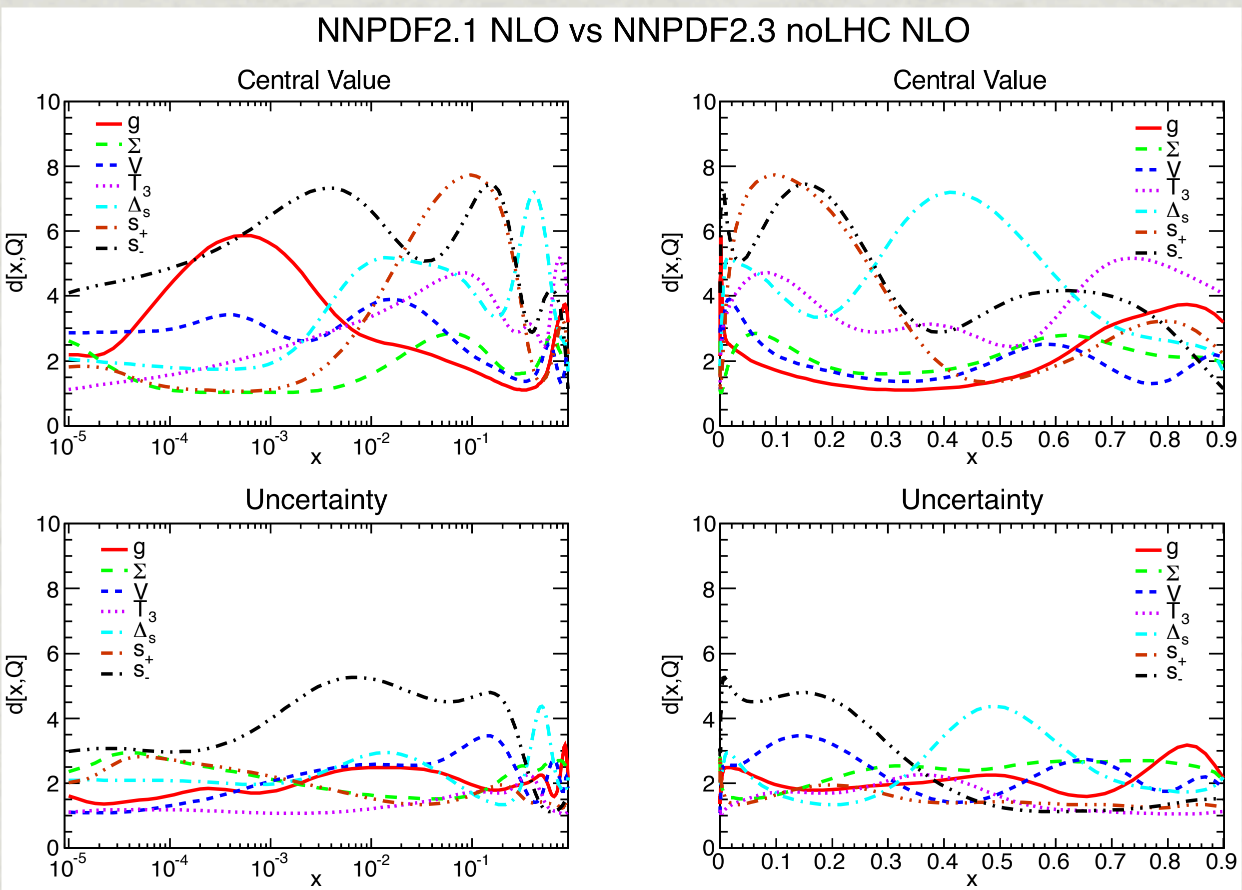
NNPDF2.3
Conclusions

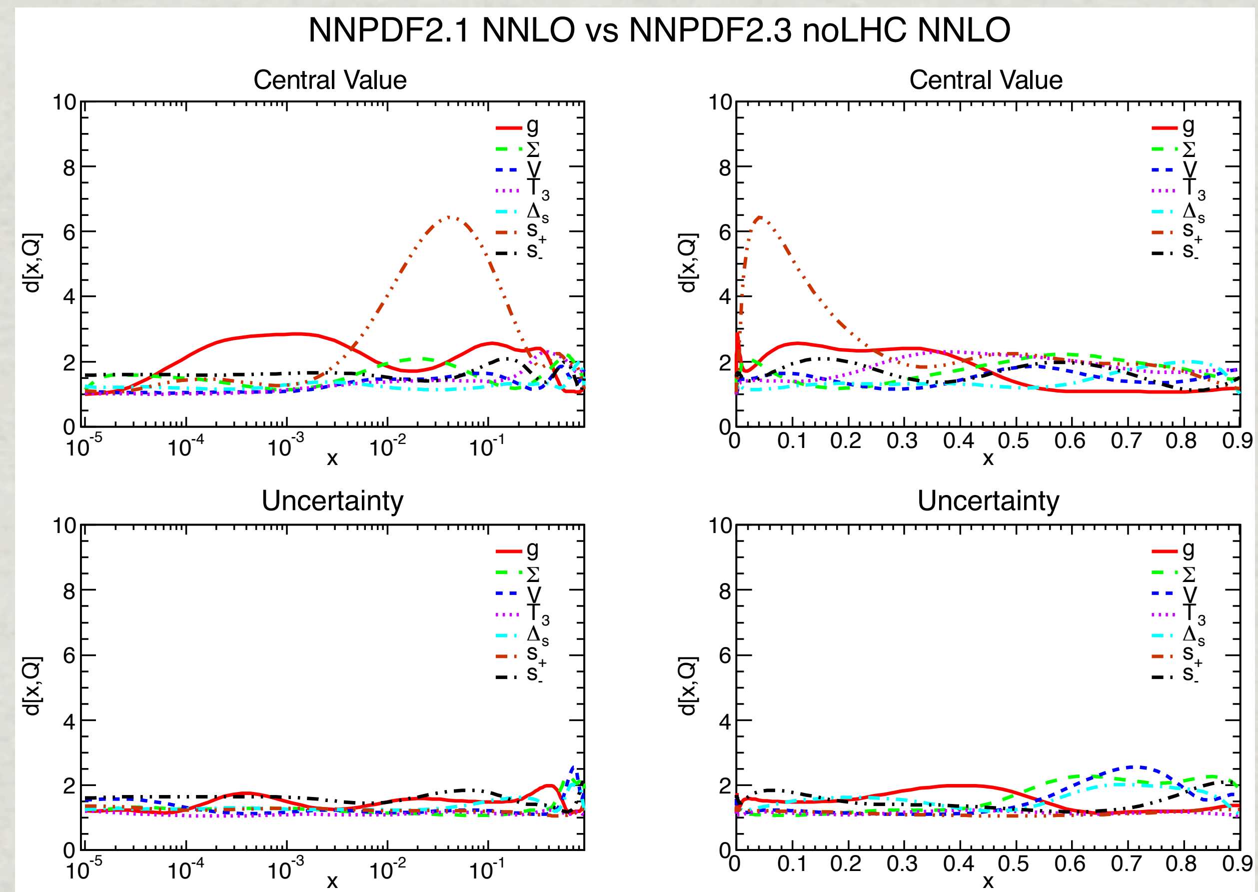
- NNPDF2.3 is the **first PDF** fit including **LHC data**
- **Development of the FastKernel** method allowed for **faster observables computation** and **improvements** in the **fitting** methodology
- Impact of LHC data is small but non-negligible
- **Collider fit not yet competitive** with global fit, but more data are coming
- ... we look forward to include more and more LHC data as they become available

Backup Slides

Distances

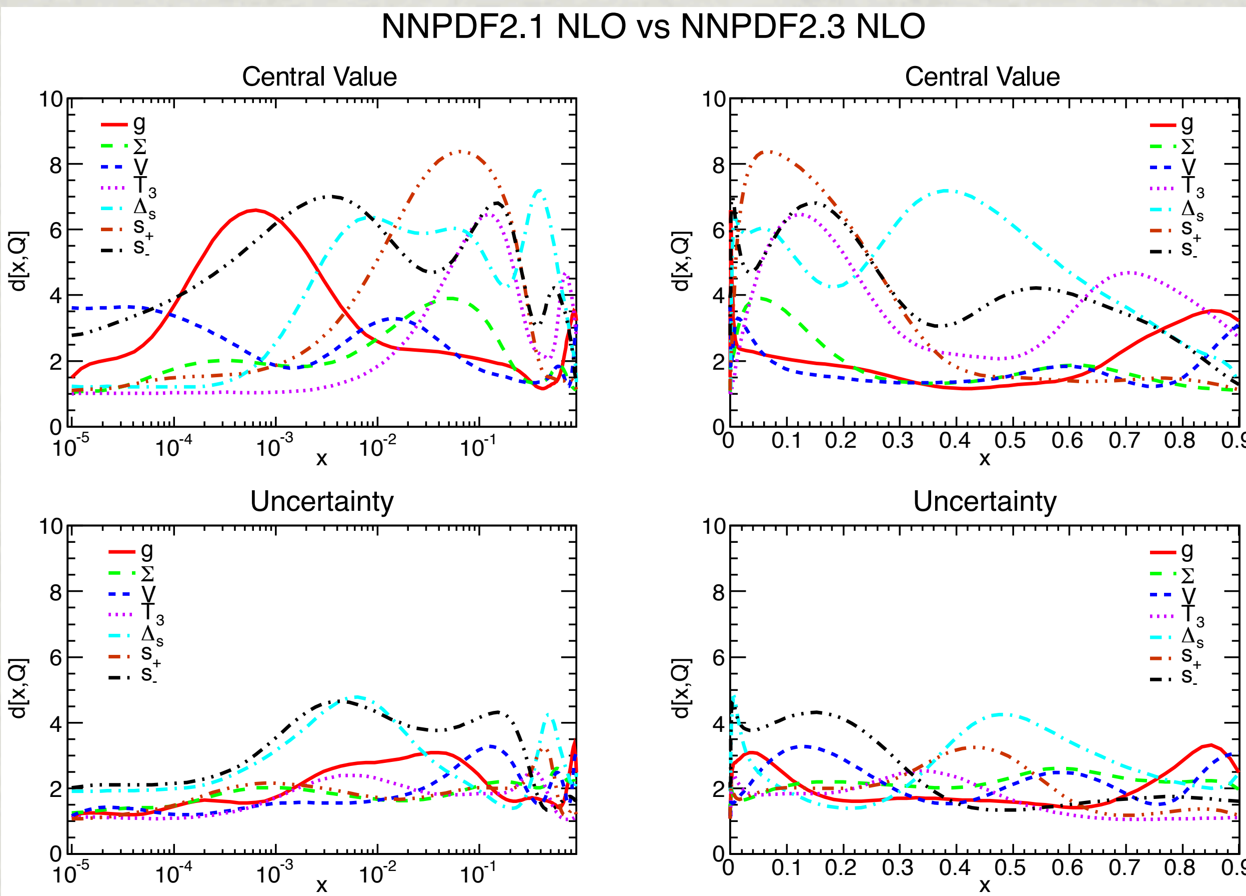
NNPDF2.3noLHC vs. NNPDF2.1

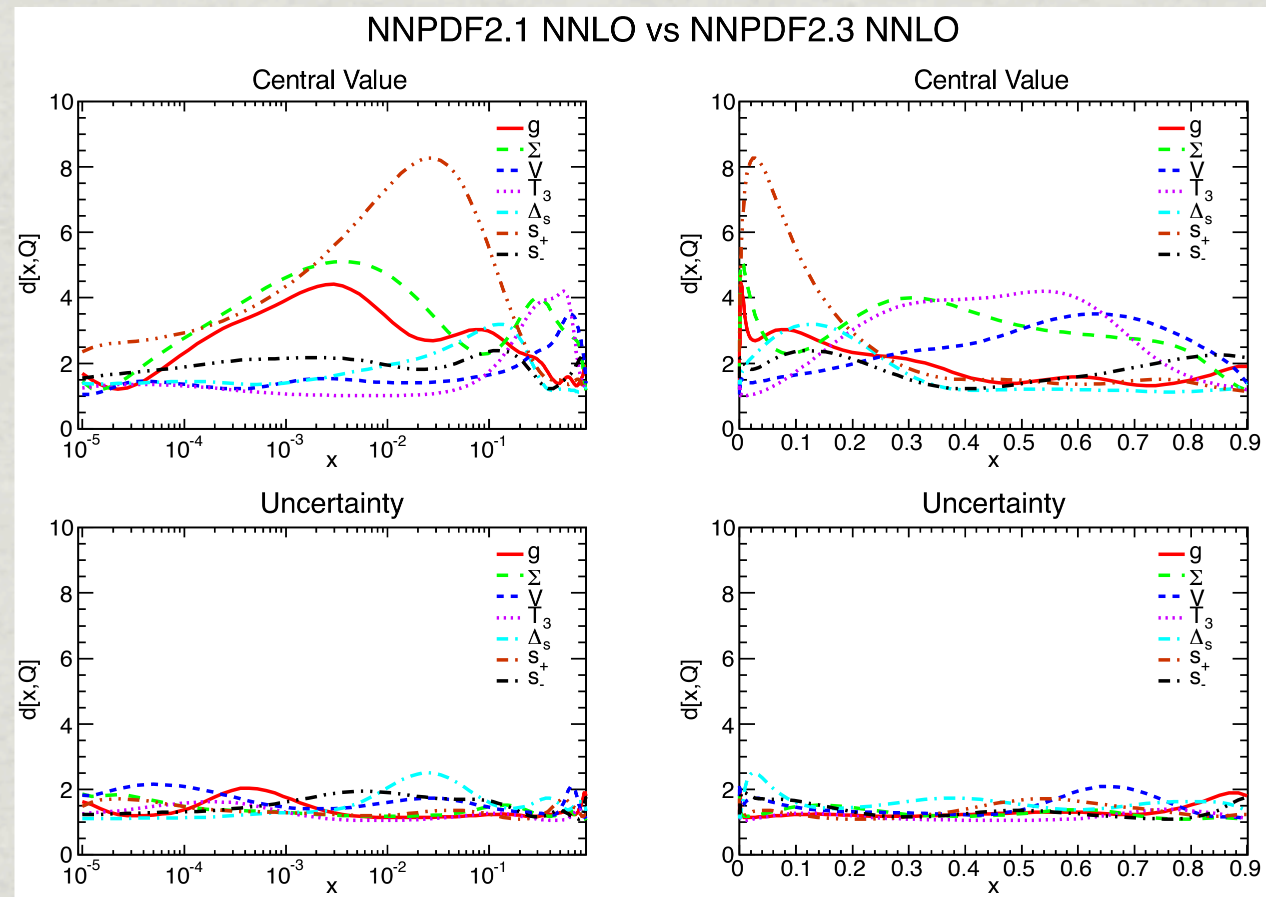




- d~1 corresponds to statistically equivalent fits
- d = 10 indicates that a 1σ difference

Distances
NNPDF2.3 vs. NNPDF2.1





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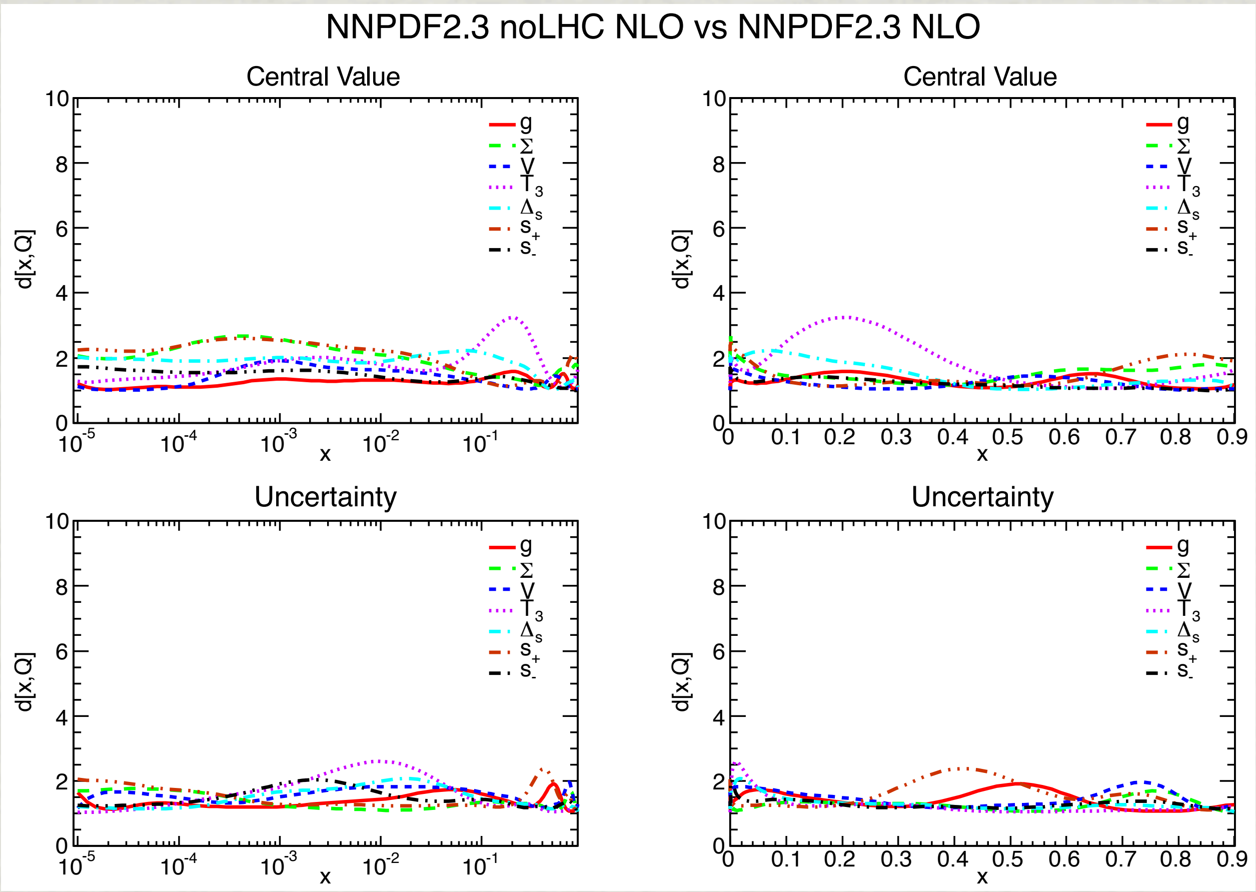
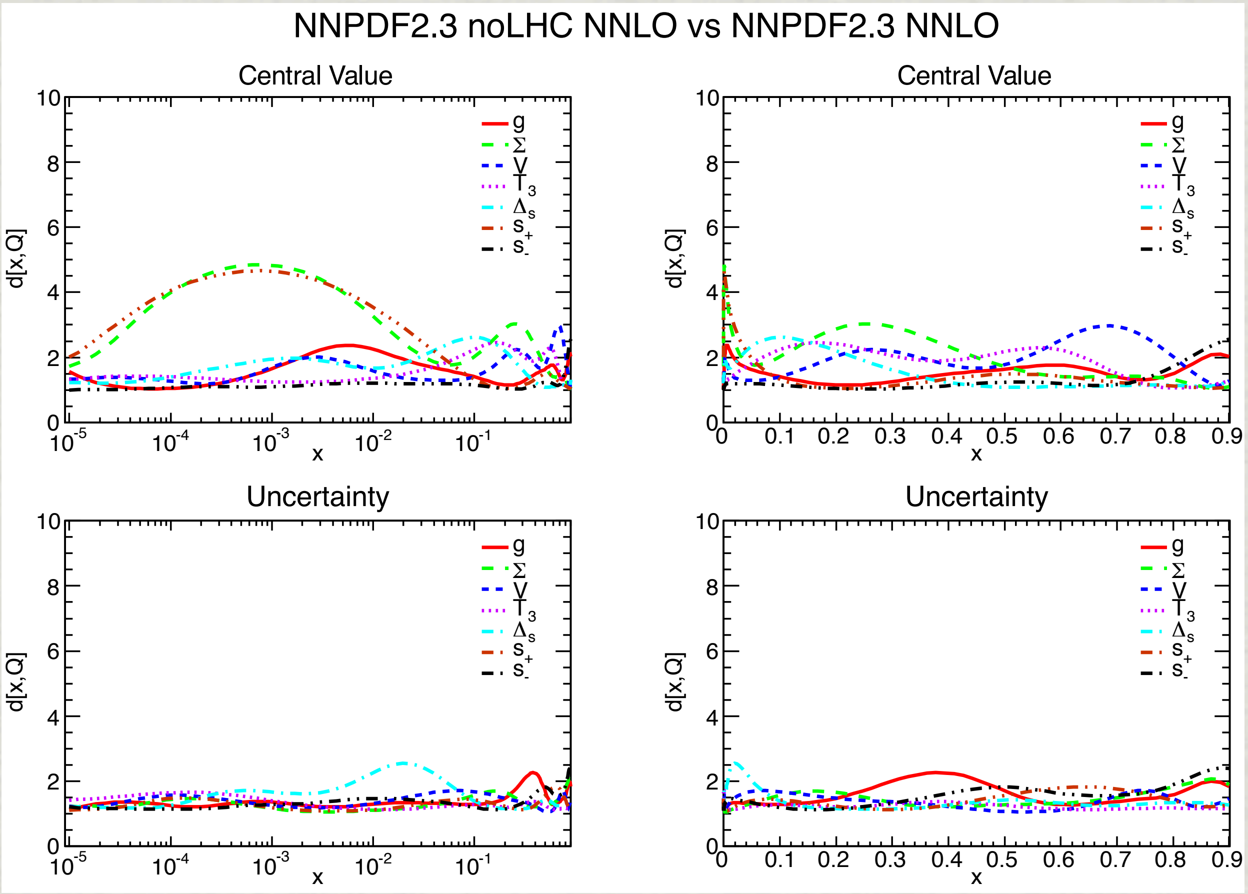
Distances

NNPDF2.3noLHC vs. NNPDF2.3





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