UPDATE FROM NNPDF

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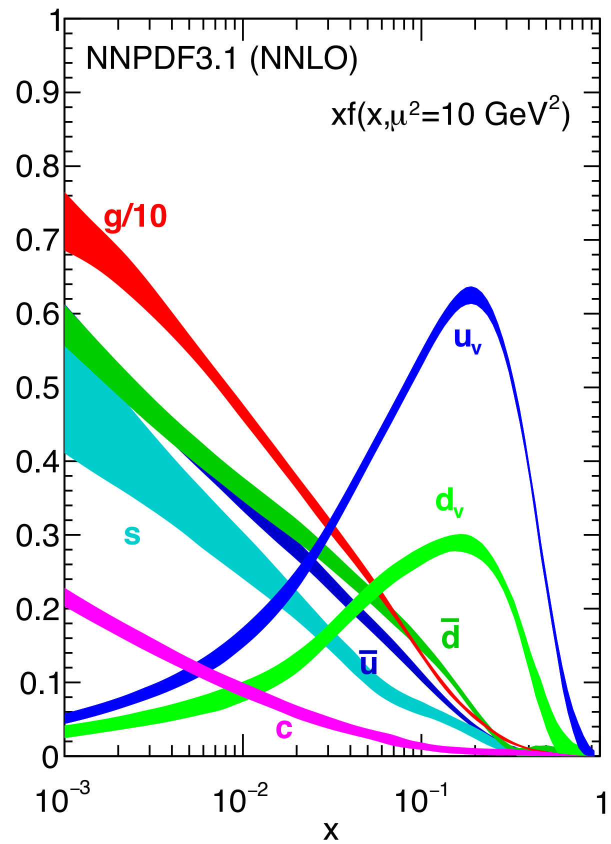
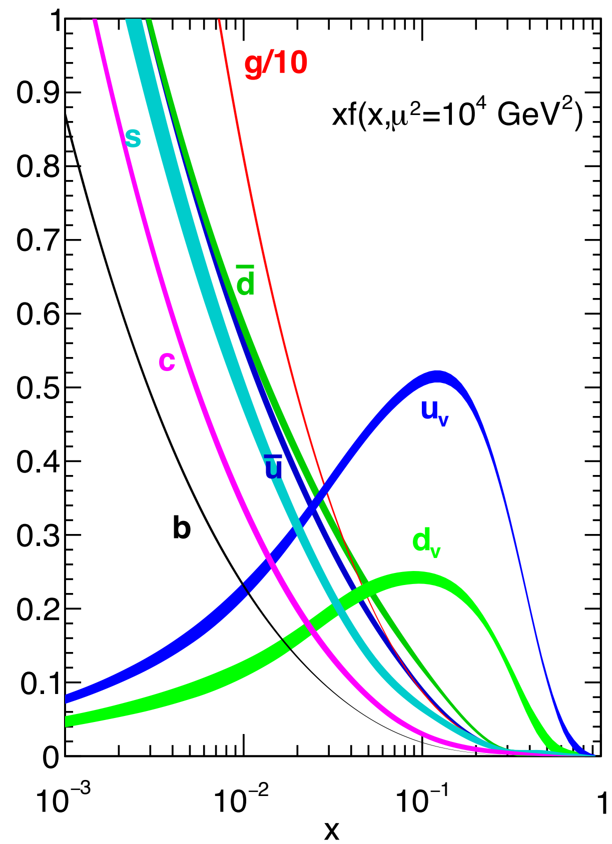
DIS 2018

Kobe, 17/04/18

CURRENT GLOBAL FIT STATUS





*Last release: **NNPDF3.1***
[1706.00428]

- *Broad dataset inc. LHC measurements*
- *Statistically validated methodology*

Theoretical developments for NNPDF3.1

- NNLO Results

$t\bar{t}$ Czakon, Heymes, Mitov [1511.00549], [1606.03350]

$W/Z\ pT$ Boughezal *et al*, Gehrmann et al[1504.02131], [1507.02850]

Inc. Jets Currie *et al* [1310.3993] [1611.01460]

- Fitted/intrinsic charm Ball *et al* [1510.02491], [1605.06515]

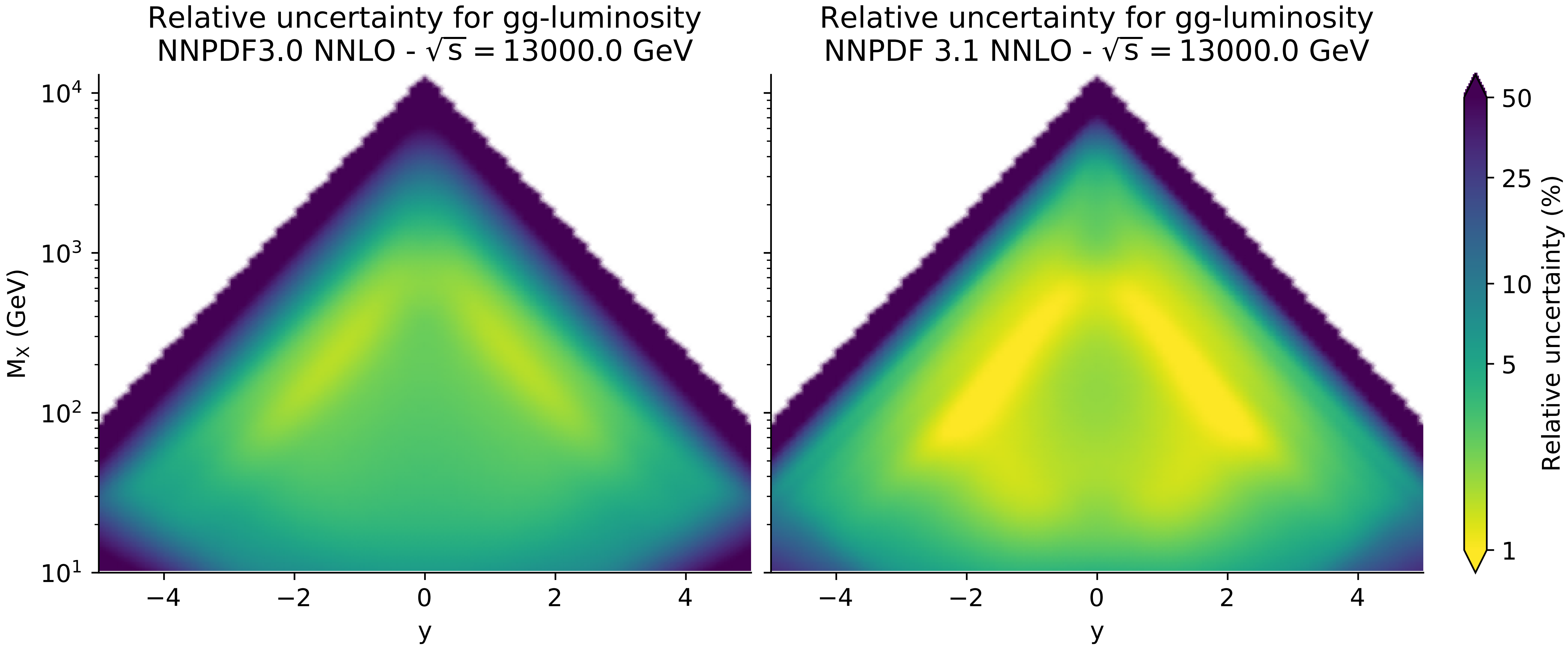
NEW DATA IN NNPDF3.1

Measurement	Data Taking	Target PDF
Combined HERA inclusive data	Run I+II	quark singlet and gluon
D0 legacy W asymmetries	Run II	quark flavor separation
ATLAS inclusive W, Z rap 7 TeV	2011	strangeness
ATLAS inclusive jets 7 TeV	2011	large-x gluon
ATLAS low-mass Drell-Yan 7 TeV	2010+2011	small-x quarks
ATLAS Z pT 7,8 TeV	2011+2012	medium-x gluon and quarks
ATLAS and CMS tt differential 8 TeV	2012	large-x gluon
CMS Z (pT,y) 2D xsecs 8 TeV	2012	medium-x gluon and quarks
CMS Drell-Yan low+high mass 8 TeV	2012	small-x and large-x quarks
CMS W asymmetry 8 TeV	2012	quark flavor separation
CMS 2.76 TeV jets	2012	medium and large-x gluon
LHCb W,Z rapidity dists 7 TeV	2011	large-x quarks
LHCb W,Z rapidity dists 8 TeV	2012	large-x quarks

(Table thanks to J. Rojo)

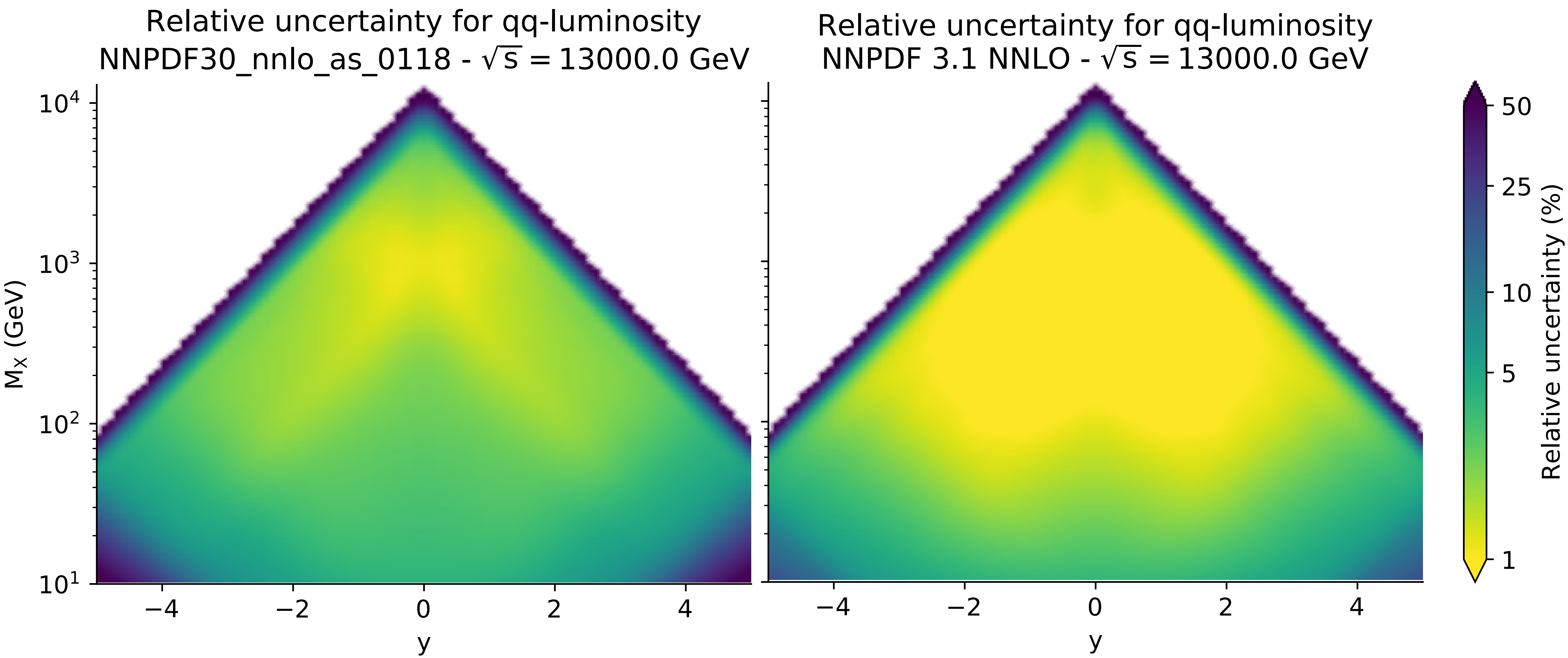
NNPDF3.1 GLOBAL - PHENOMENOLOGY (GG)

Significant reduction in uncertainties across the kinematic range



NNPDF3.1 GLOBAL - PHENOMENOLOGY (QQ)

QQ Uncertainties decrease *despite* greater parametrisation freedom

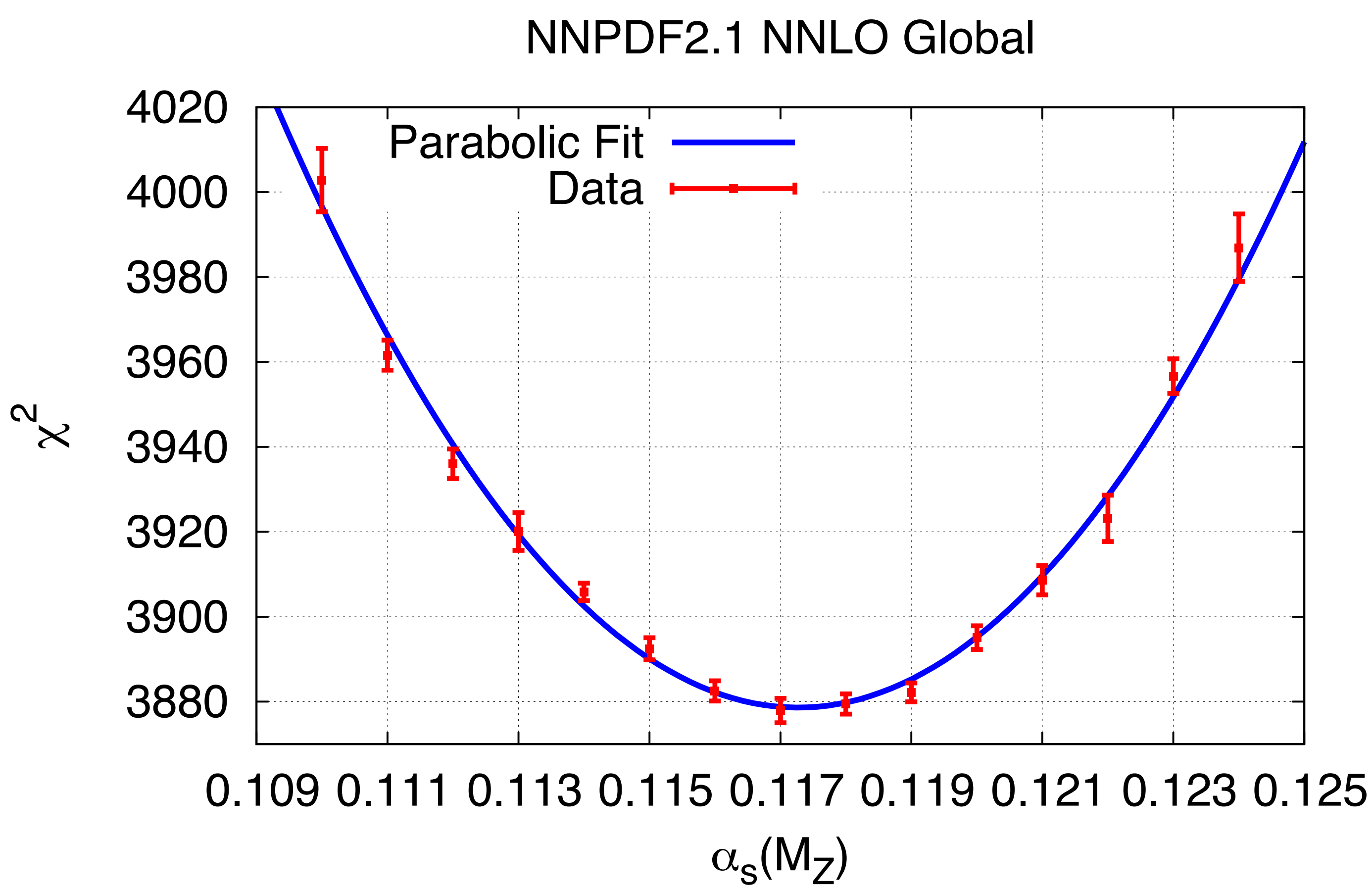


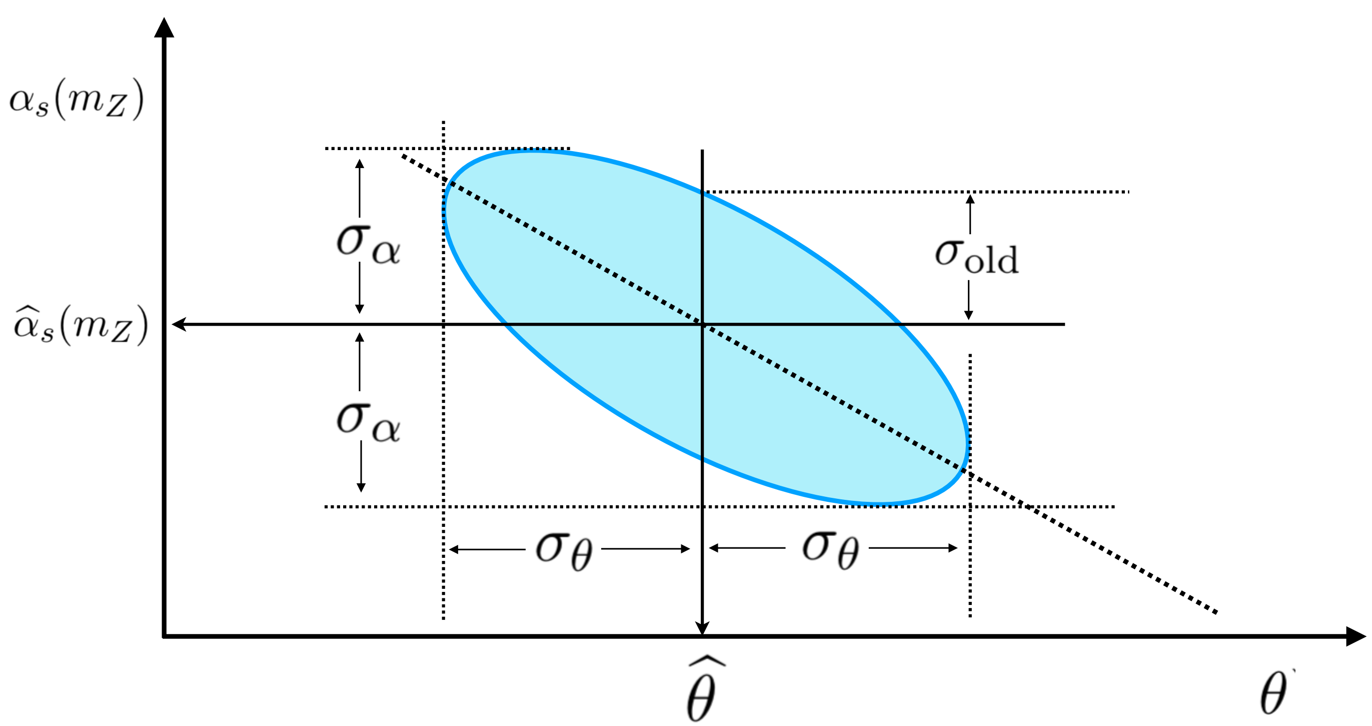
Uncertainties often towards the percent level

There are other sources of uncertainty to worry about

DETERMINING ALPHAS FROM A GLOBAL FIT

[1802.03398]





Previous NNPDF determination Based on a scan of NNPDF2.1

[1110.2483]

Measure the χ^2 of best fit PDF parameters as a function of α_S

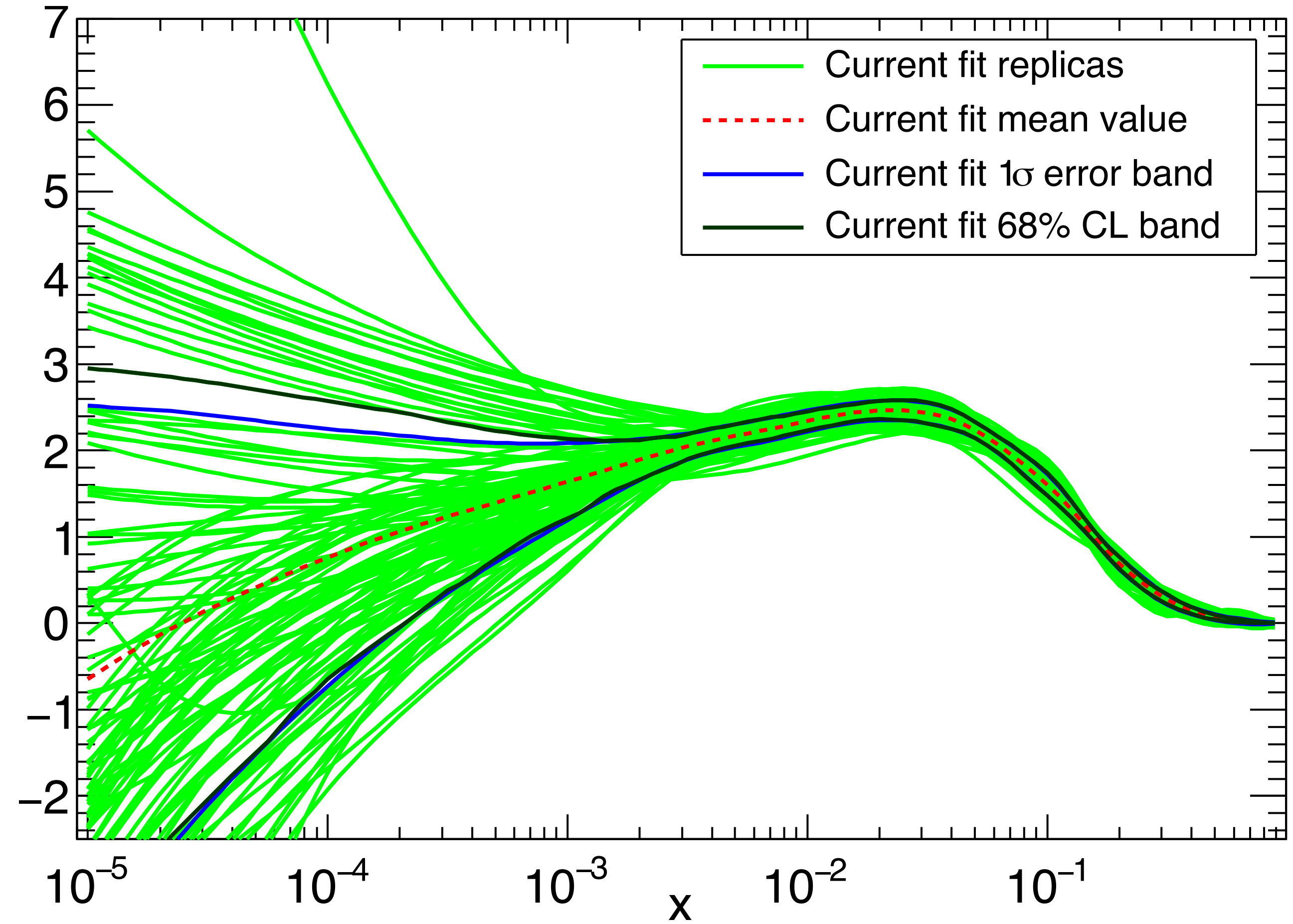
Neglects correlations with PDF fit parameters (θ) - important when experimental uncertainties are small

Ideally one should minimise PDFs and α_S simultaneously

NNPDF FITS ARE EXPENSIVE

Monte Carlo uncertainties

- PDFs are formed by *ensembles*: Fits to independent, equally likely samples (replicas) of the input dataset
- Each result requires 100/1000 statistically independent analysis runs



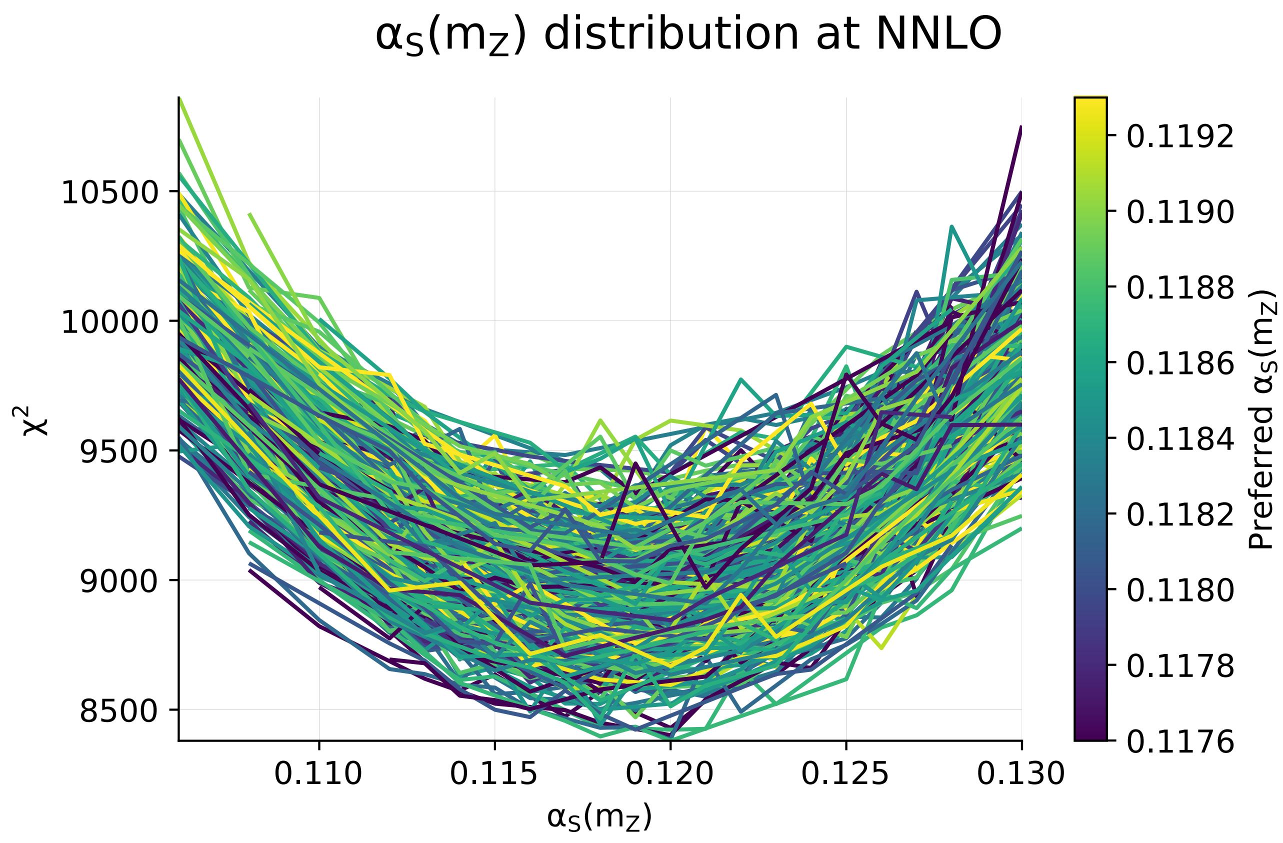
Fitting a large dataset only possible making use of pre-computed tables

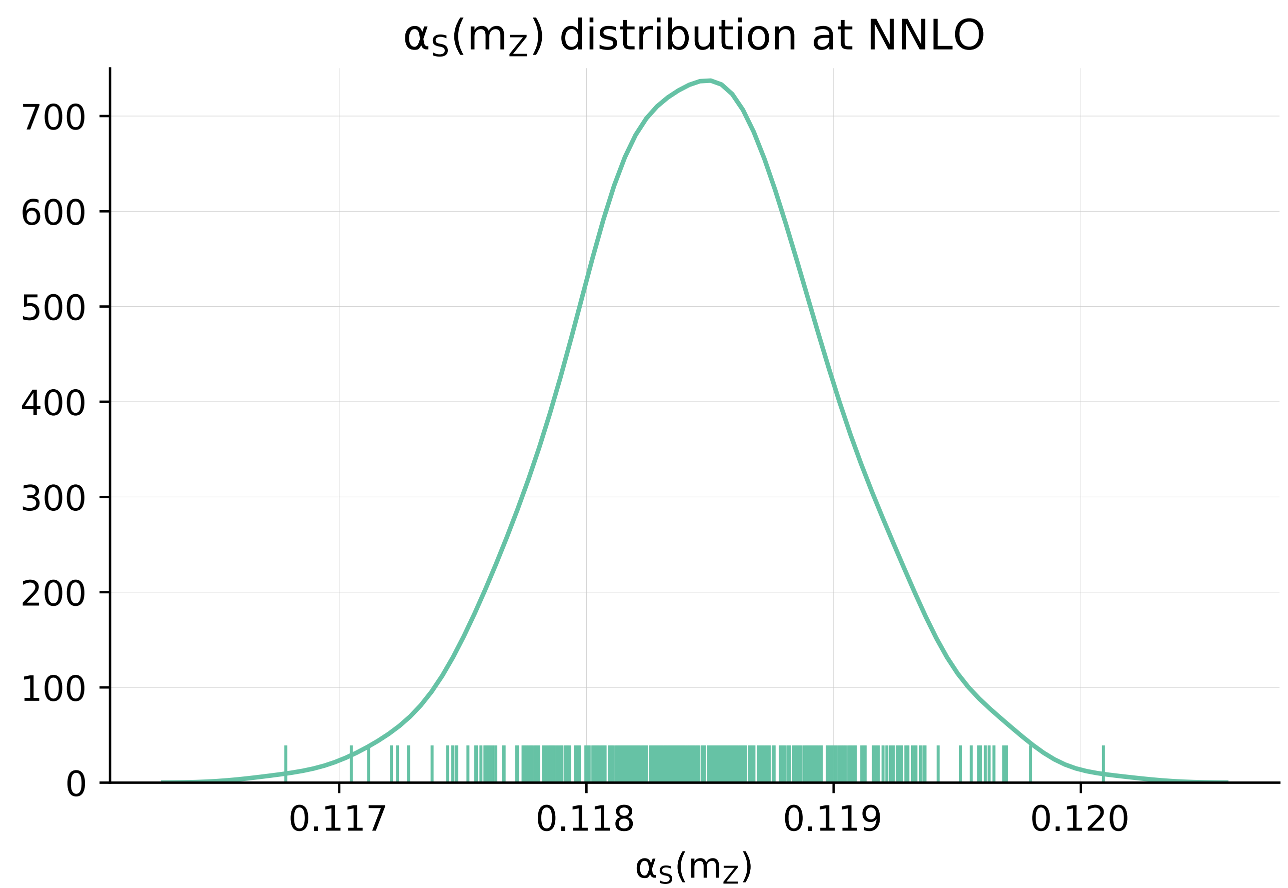
$$\sigma_{pp\to X} = \sum_{i,j}\int_0^1 dx_1 dx_2\ f_i(x_1,Q^2)\ f_j(x_2,Q^2)\ \sigma_{ij\to X}\left(x_1,x_2,Q^2\right)$$

$$\longrightarrow \quad \sigma = \sum_{i,j}^{n_f}\sum_{\alpha,\beta}^{n_x} W_{ij\alpha\beta}\ f_i(x_\alpha,Q_0^2) f_j(x_\beta,Q_0^2)$$

THE CORRELATED REPLICA METHOD

How can we take into account PDF/ α_S correlations in a 'MC' way?



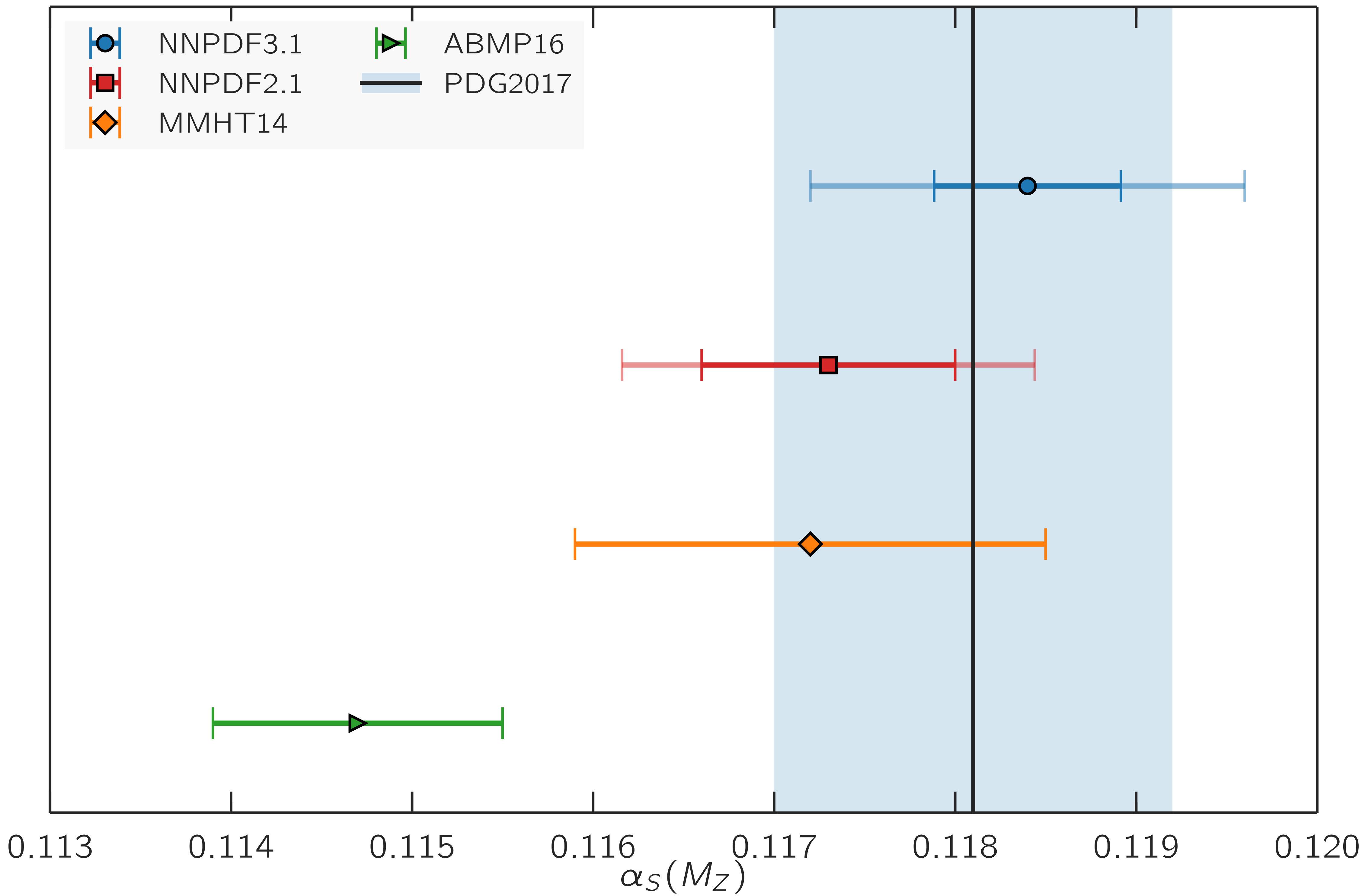


- For each data sample (replica) perform a scan in α_S
- Each replica has a preferred value of α_S (the minimum of each parabola)
- These preferred values form a **MC distribution**

RESULTS

[1802.03398]

$$\alpha_s^{\rm NNLO}(m_Z) = 0.1185 \pm 0.0005^{\rm exp} \pm 0.0001^{\rm meth} \pm 0.0011^{\rm th} = 0.1185 \pm 0.0012 \ (1\%)$$



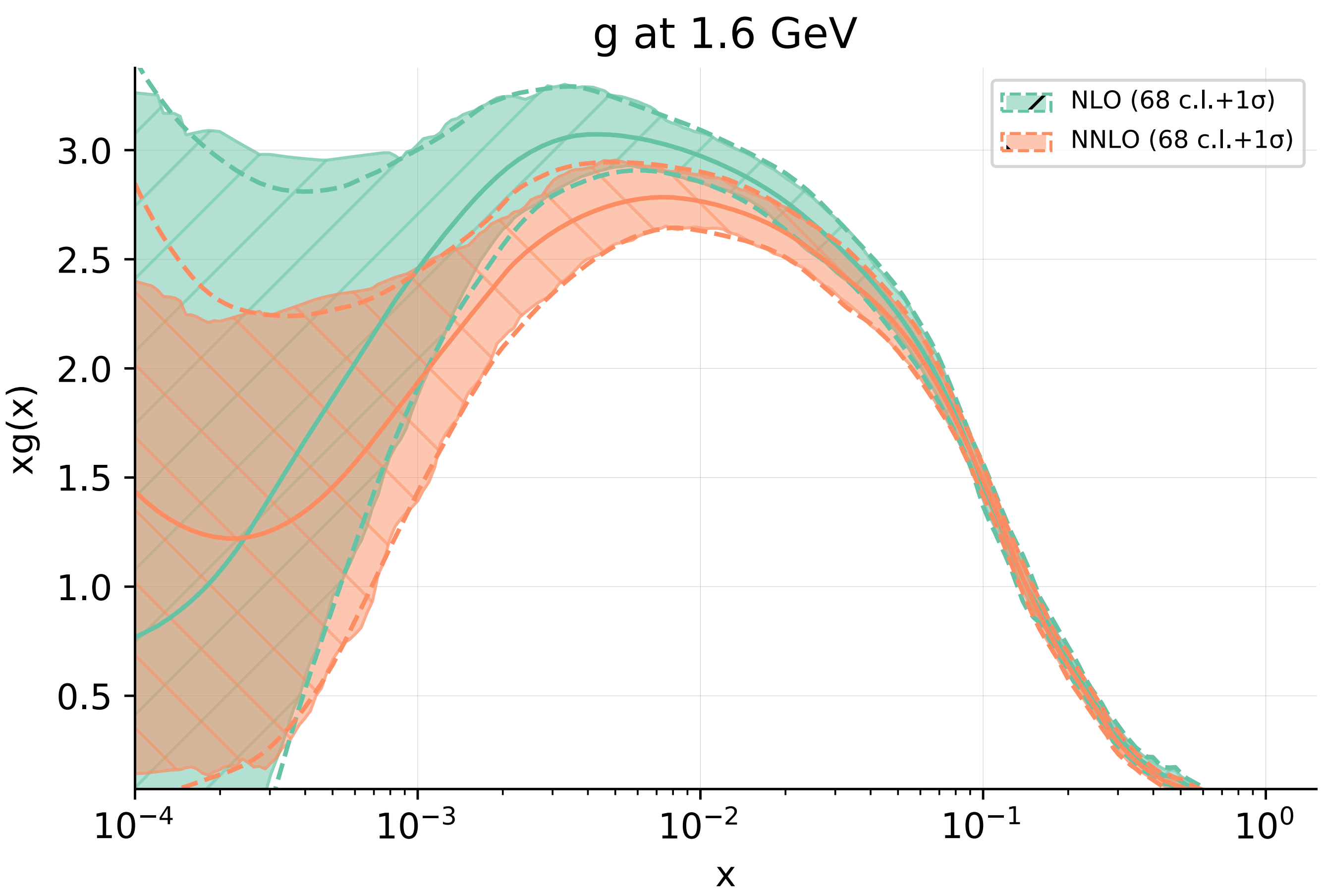
THEORETICAL UNCERTAINTIES IN PDF FITS

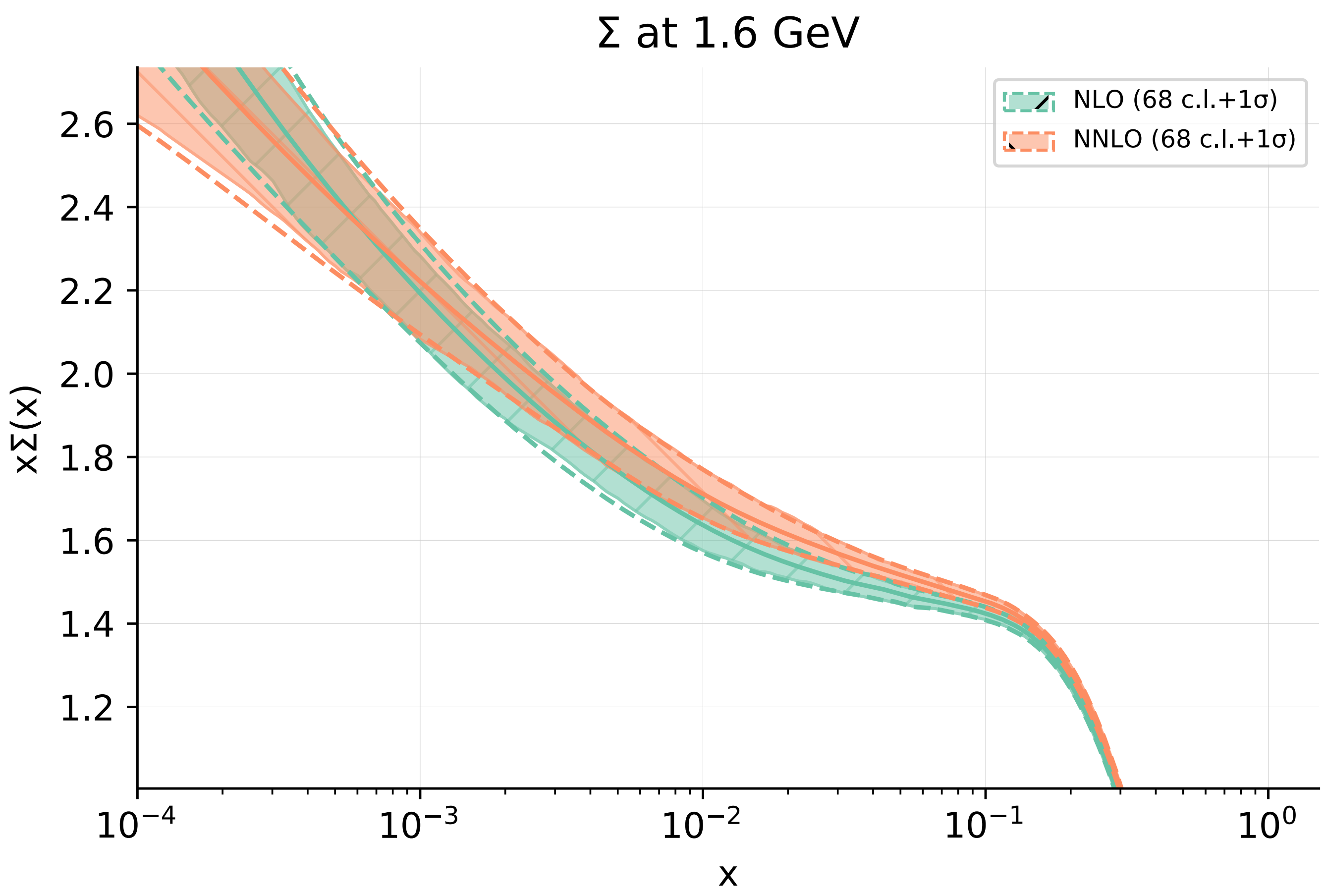
PDF uncertainties often represent only experimental and procedural factors

Parametric uncertainties due to e.g strong coupling straightforward to handle

A more difficult question

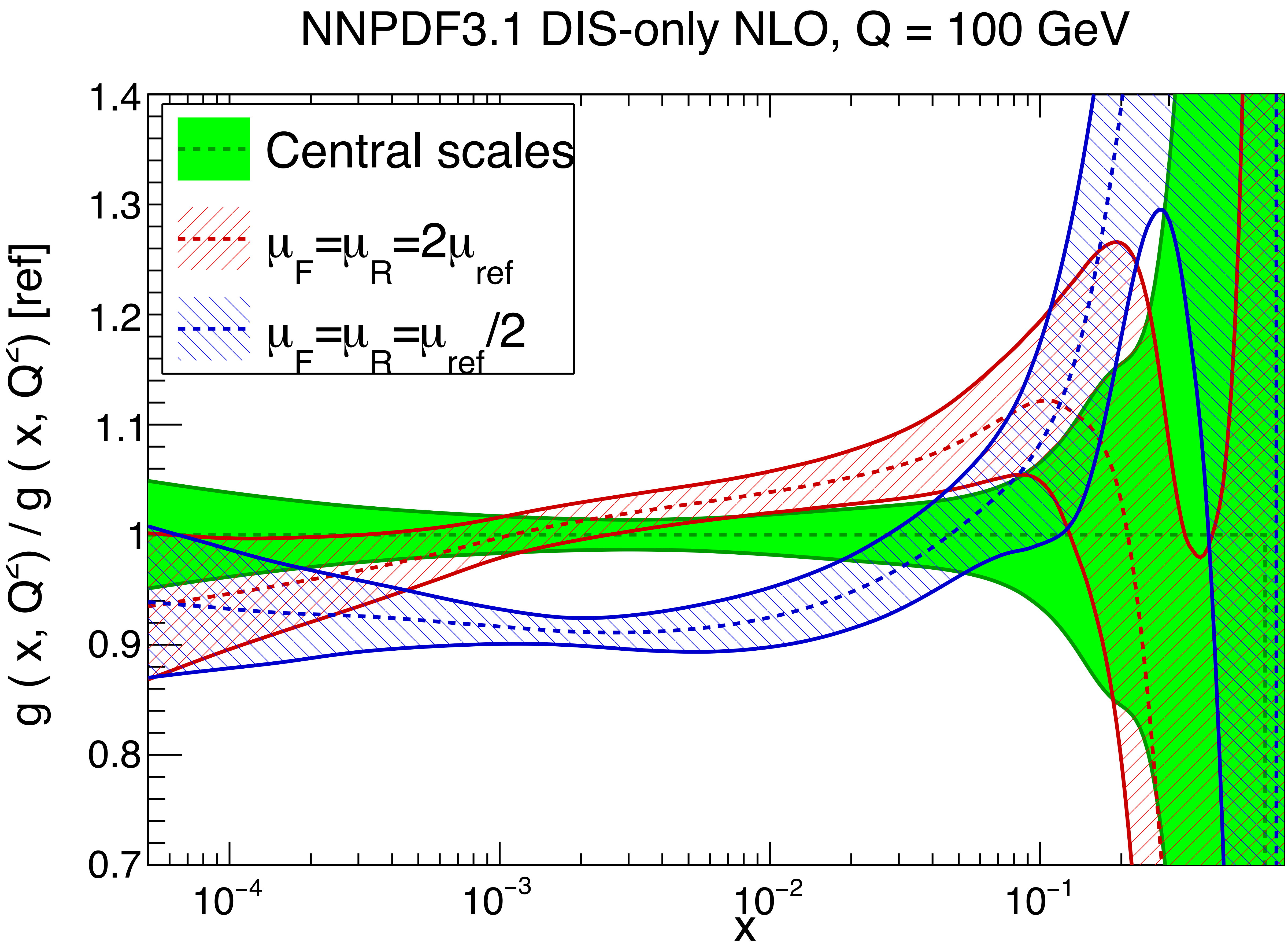
How can we estimate uncertainties due to missing higher orders?





At NLO - measure difference between fits at different perturbative orders

FITS WITH SCALE VARIED THEORY



THEORETICAL UNCERTAINTIES IN PDF FITS

Can we build a theoretical 'covariance matrix'?

For a set of predictions for an observable at a central scale

$$\mathcal{O}_i(\mu_R, \mu_F), \quad (0 < i < N_{\mathrm{dat}})$$

Consider shifts due to three-point scale variations

$$\Delta_i^+ = \mathcal{O}_i(\mu_R, \mu_F) - \mathcal{O}_i(2\mu_R, 2\mu_F),$$
$$\Delta_i^- = \mathcal{O}_i(\mu_R, \mu_F) - \mathcal{O}_i(\mu_R/2, \mu_F/2)$$

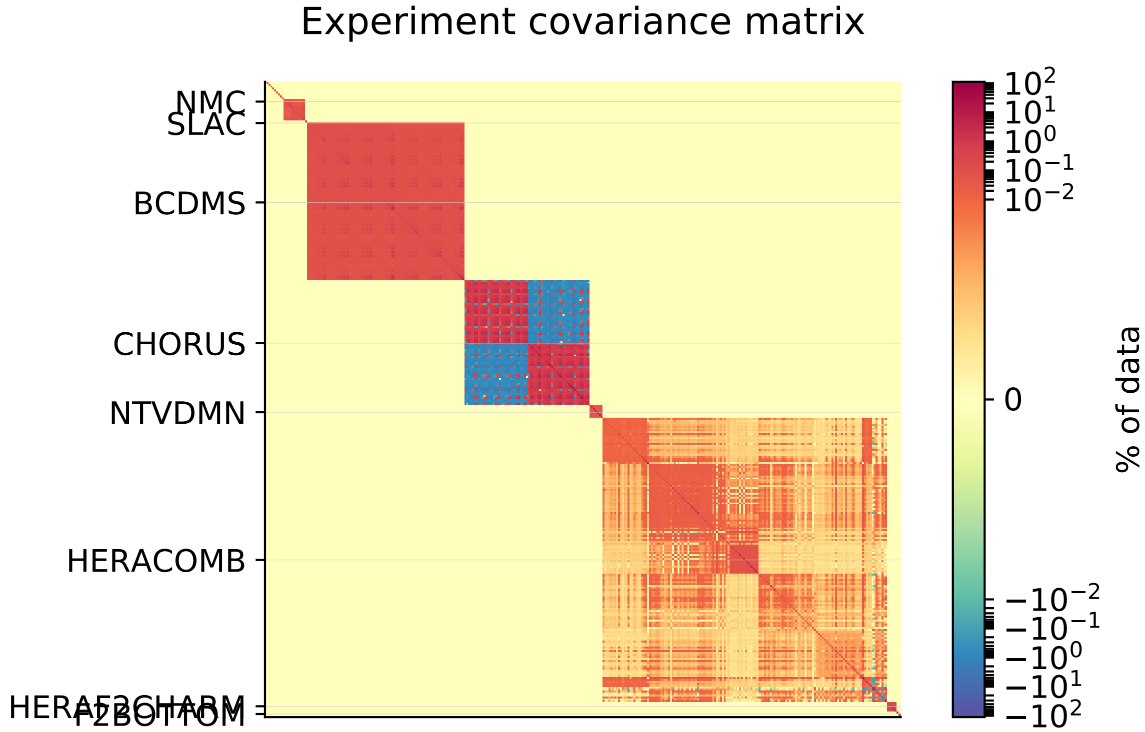
One can then construct a theory 'covariance'

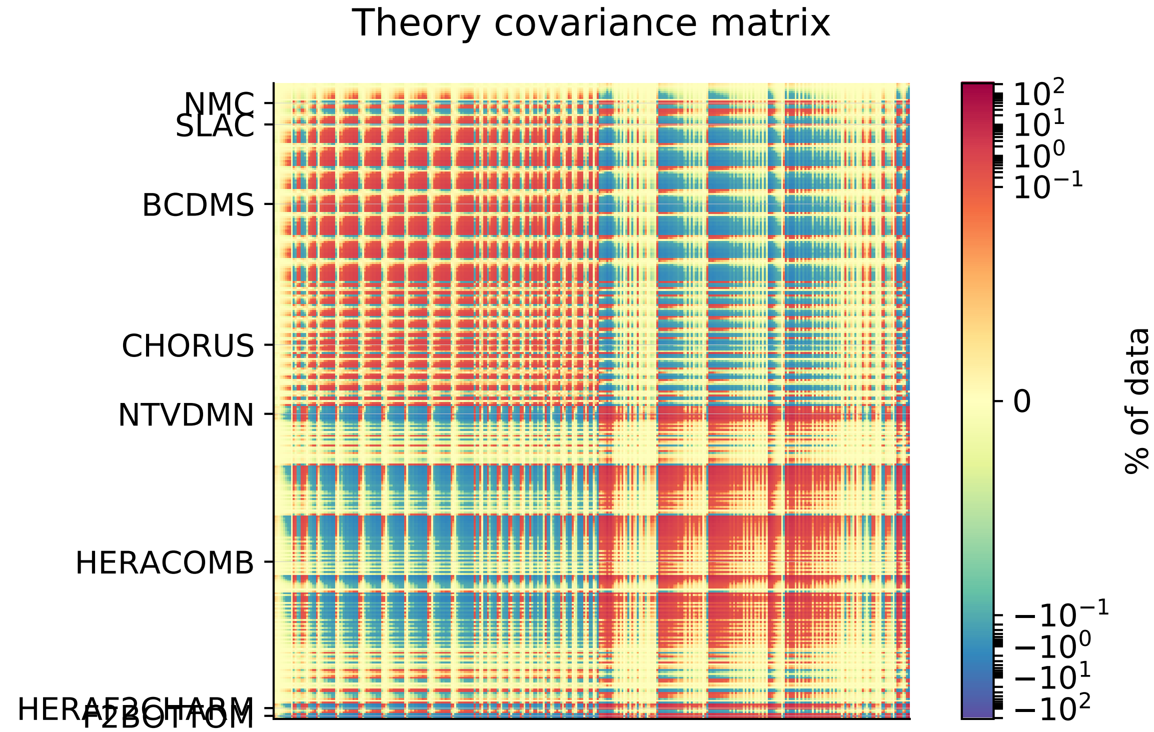
$$\mathrm{Cov}_{\mathrm{Th}}[\mathcal{O}_i, \mathcal{O}_j] = \Delta_i^+ \Delta_j^+ - \Delta_i^- \Delta_j^-$$

To be added to the experimental matrix

$$\mathrm{Cov}_{\mathrm{Total}} = \mathrm{Cov}_{\mathrm{Th}}[\mathcal{O}_i, \mathcal{O}_j] + \mathrm{Cov}_{\mathrm{Ex}}[\mathcal{O}_i, \mathcal{O}_j]$$

THEORY UNCERTAINTIES





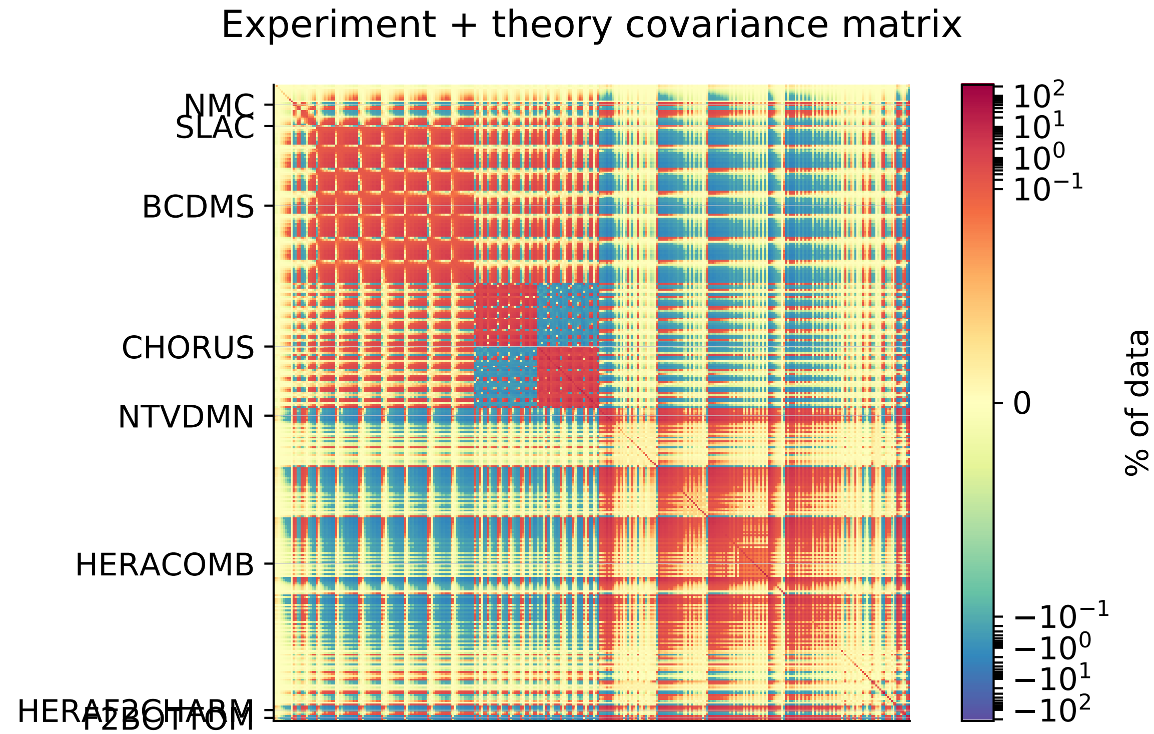
Very preliminary

Combined covariance for DIS sets

In progress

How do these matrices influence the fit?

How do they compare to scale-varied fits?

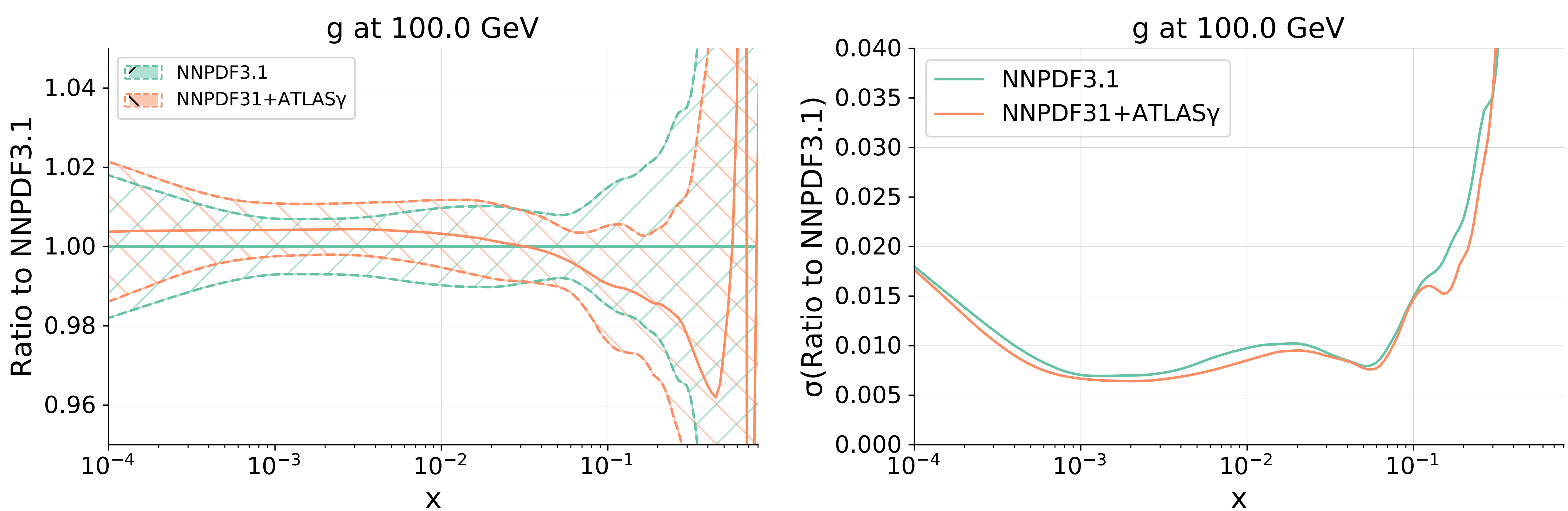


PATH TO NNPDF 4.0 – NEW DATA

Datasets/processes under consideration for NNPDF 4.0

DIS	13TeV Standard Candles	New processes
HERA c. F_2^c, F_2^b	Inclusive jets	2/3-jets
NOMAD $\mu\mu$	W/Z production	Prompt photon
CHORUS $\mu\mu$	High-Mass DY	Single top
JLAB S.Fs	top-pair production	D-meson

Impact of ATLAS prompt photon studied in J. Campbell *et al* [1802.03021]

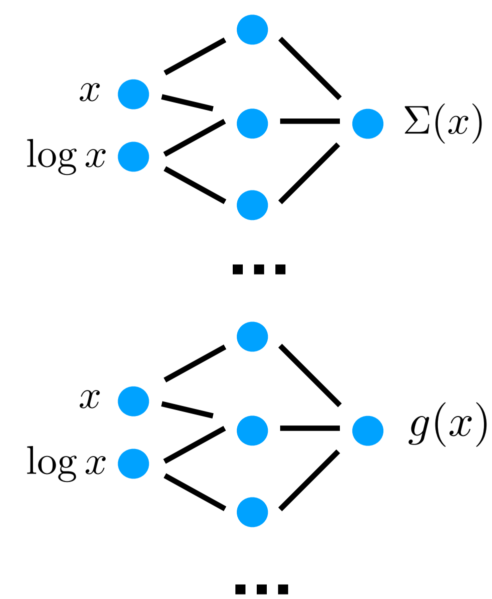


PATH TO NNPDF 4.0 – METHODOLOGY

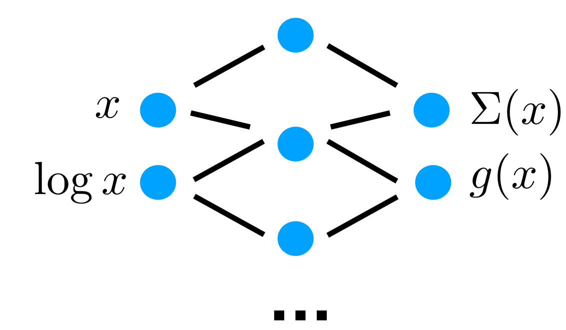
As our dataset gets larger, it's important to assess our methodology

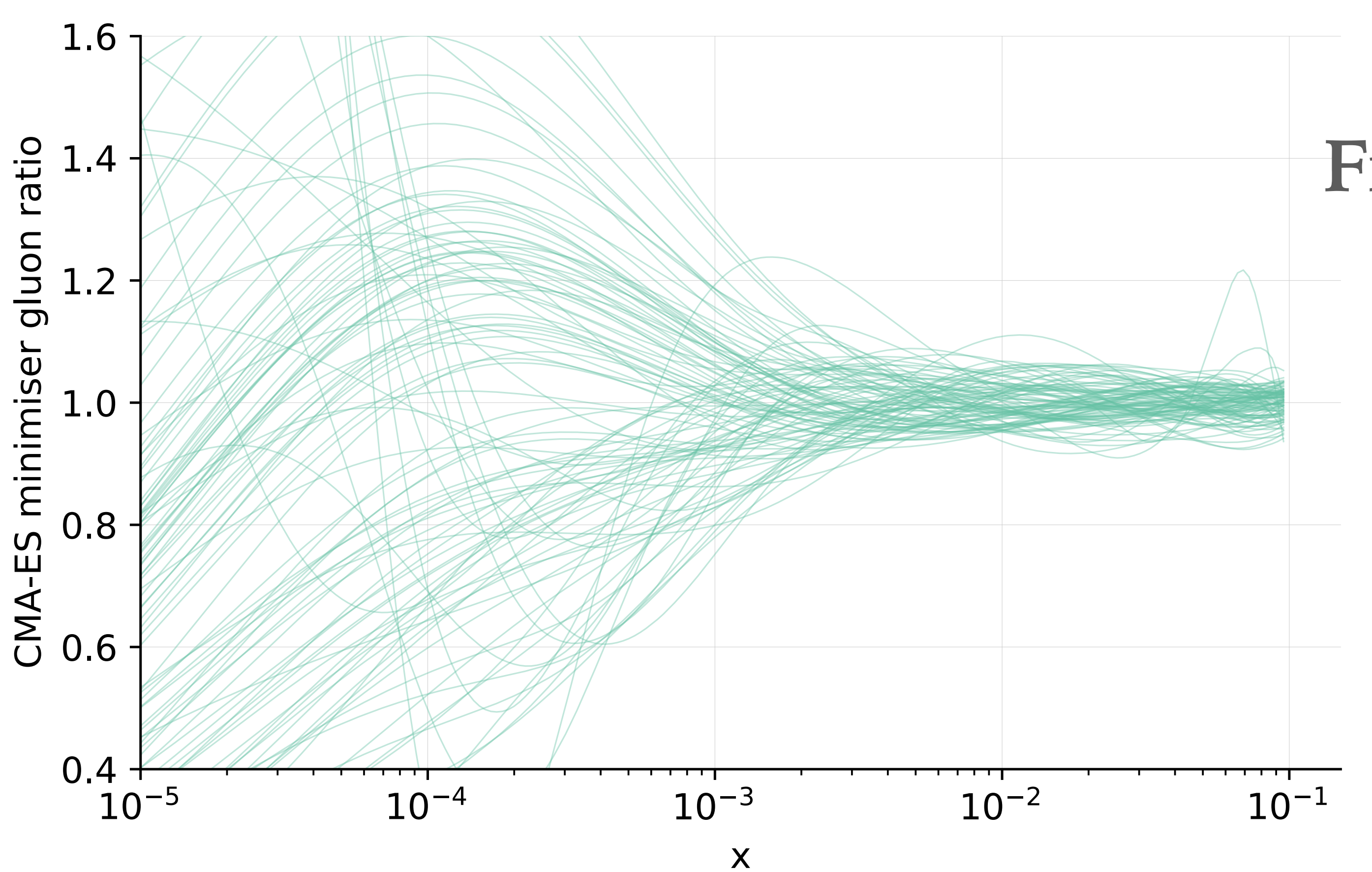
A large dataset with a flexible parametrisation presents a complex optimisation problem

Our parametrisation is flexible to minimise bias, but can it be made more *efficient*?



vs





Fits are computationally expensive

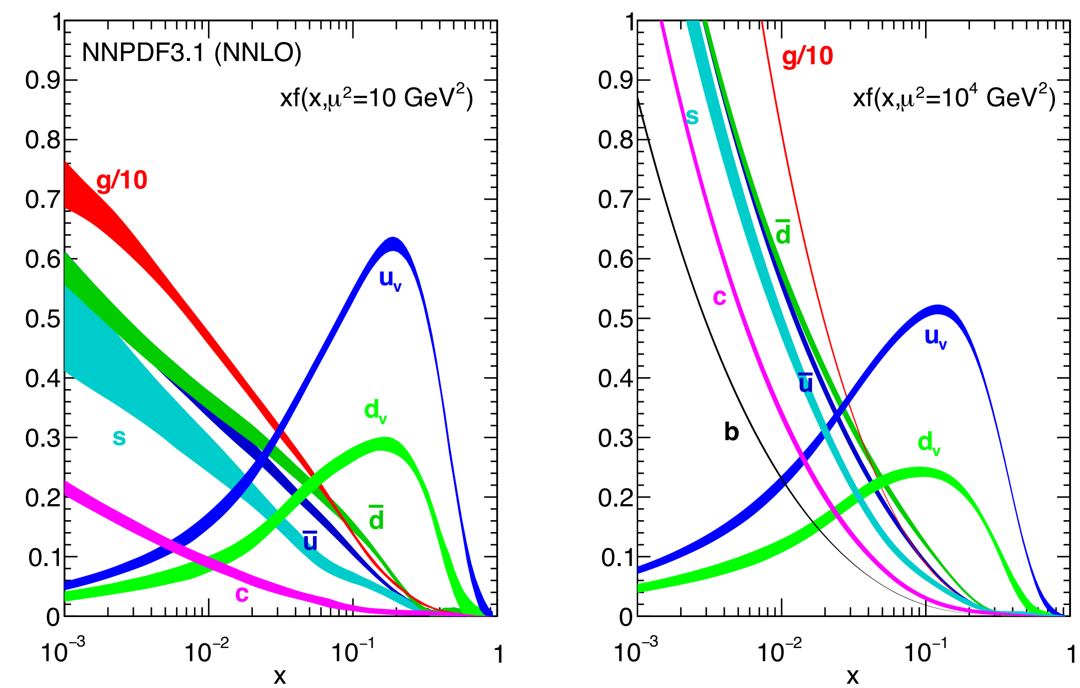
Can modern optimisation tools help?

- *Evolutionary Strategies*
- *Analytical gradients*

SUMMARY

NNPDF3.1: released June 2017

- NNPDF3.1sx *October 2017*
- NNPDF3.1luxQED *December 2017*
- NNPDF α_S *January 2018*



The path to NNPDF4.0

- **New data**

  Almost 40 new datasets due to be investigated

- **Theory uncertainties**

  How can we best represent PDF uncertainties due to MHO corrections?

- **Methodology**

  How can our fitting procedure keep pace with the dataset?

BACKUPS

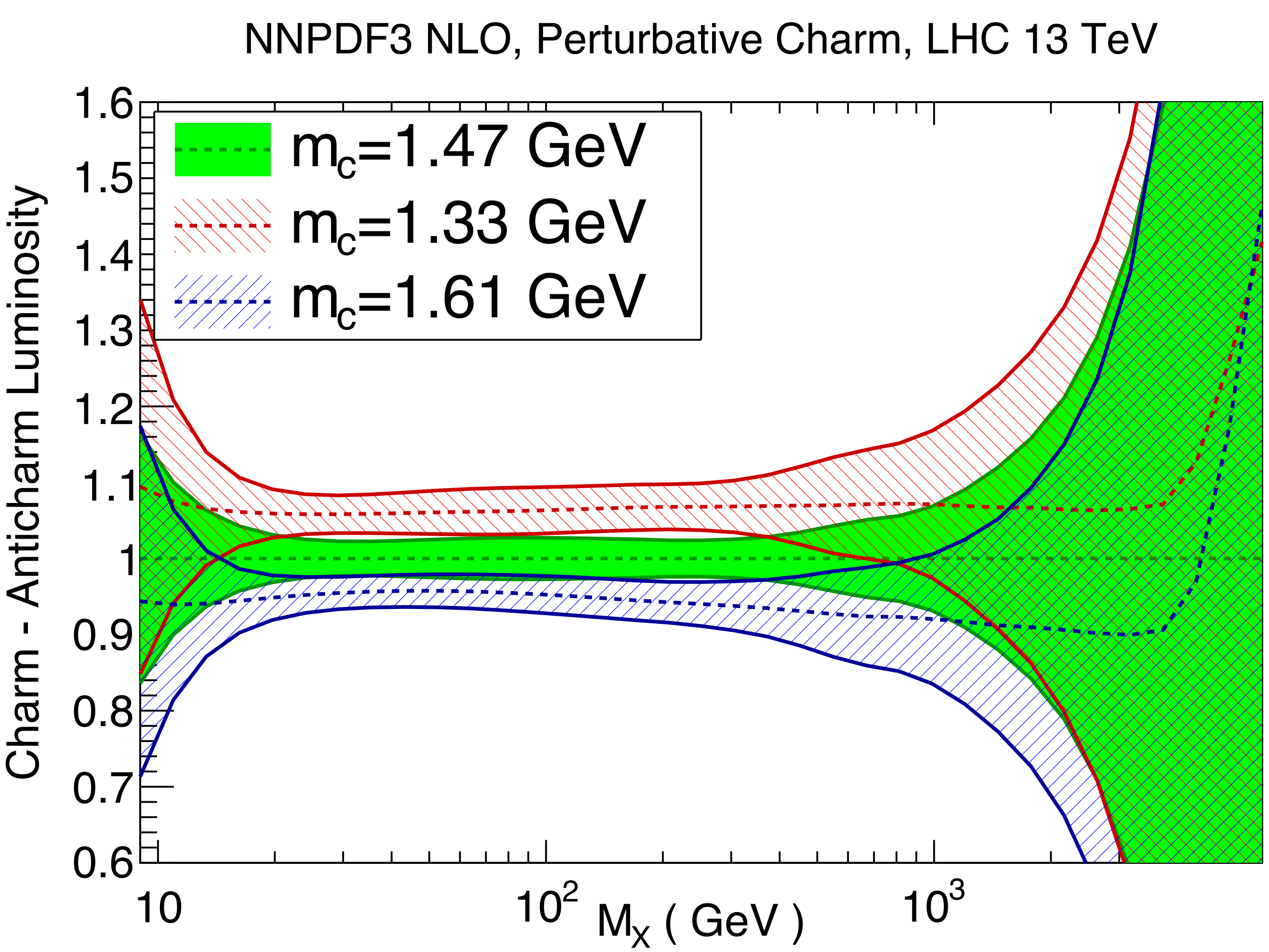
INTRINSIC CHARM

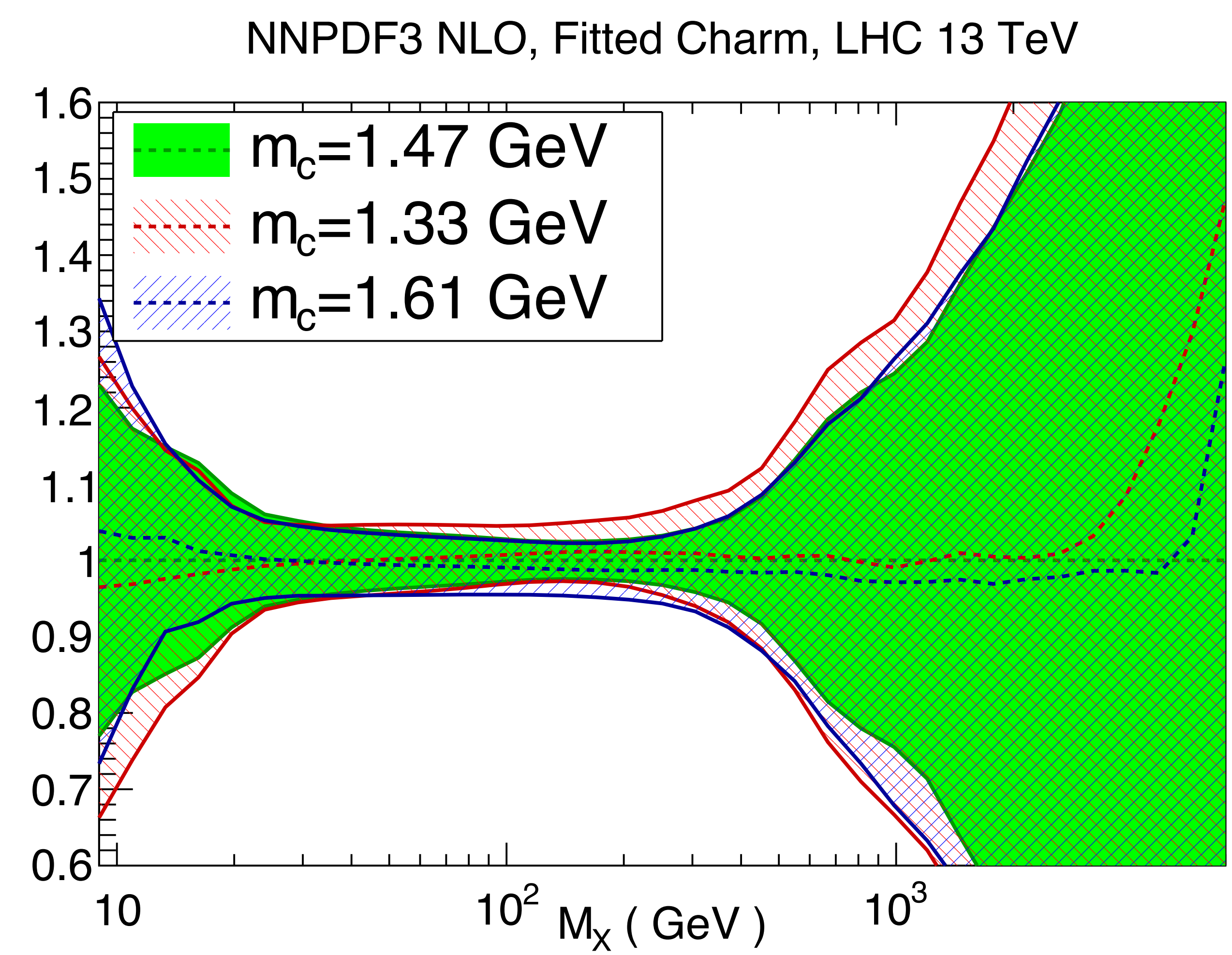
- The charm PDF is a **borderline** perturbative object

Most PDF fits assume that charm is generated perturbatively by evolution

Such an assumption can lead to a disproportionate influence of the charm mass

Relaxing this assumption by fitting charm can stabilise results





[1605.06515]

NNPDF FITS ARE EXPENSIVE

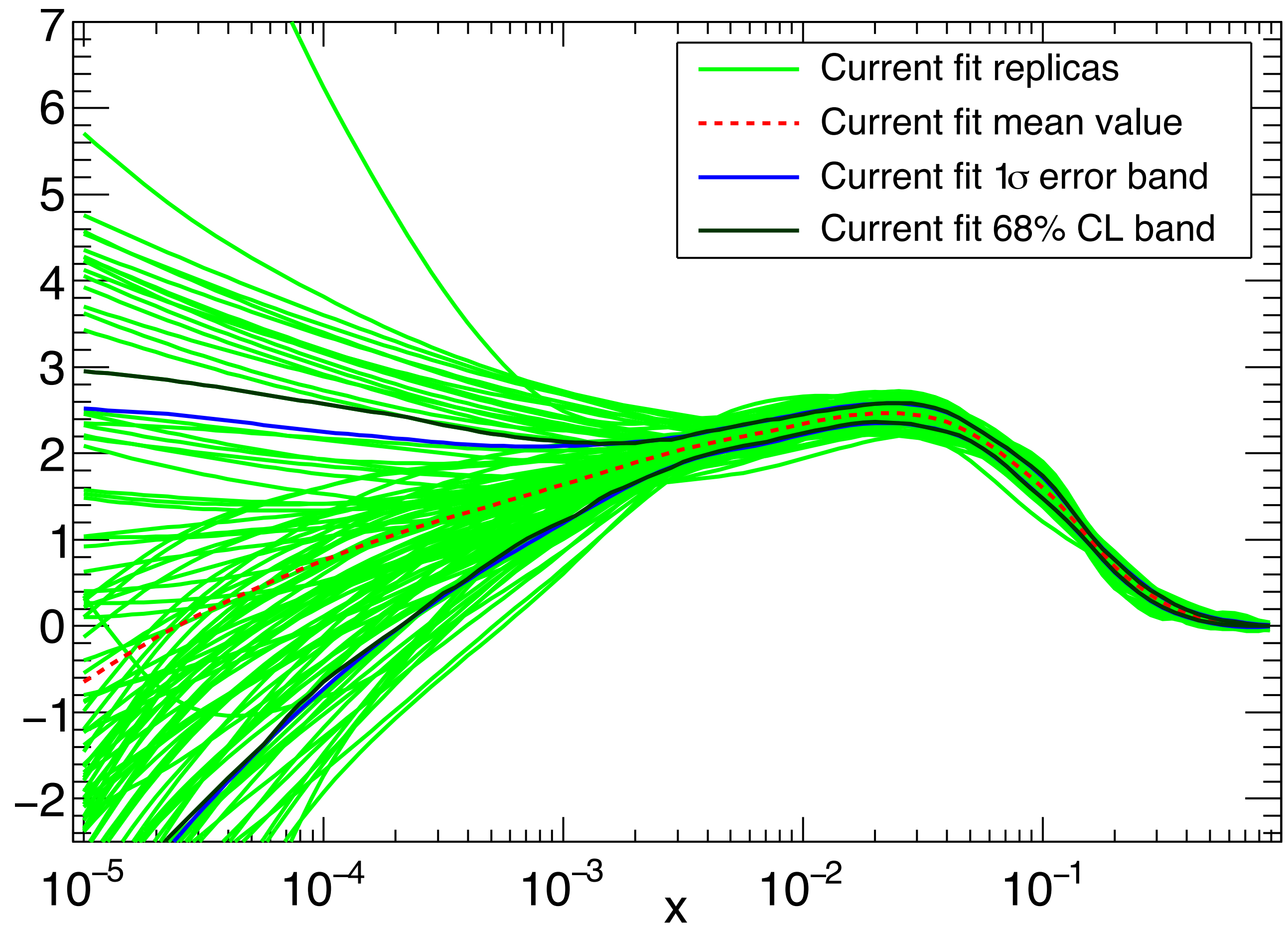
Several procedural factors conspire to make NNPDF fits particularly demanding

Monte Carlo uncertainties

➤ *PDFs are formed by **ensembles:***
Each result requires 100/1000 statistically independent analysis runs

Neural Network parametrisation

➤ *Standard gradient descent is **difficult:***
Minimisation by Genetic Algorithm
- typically 50,000 generations



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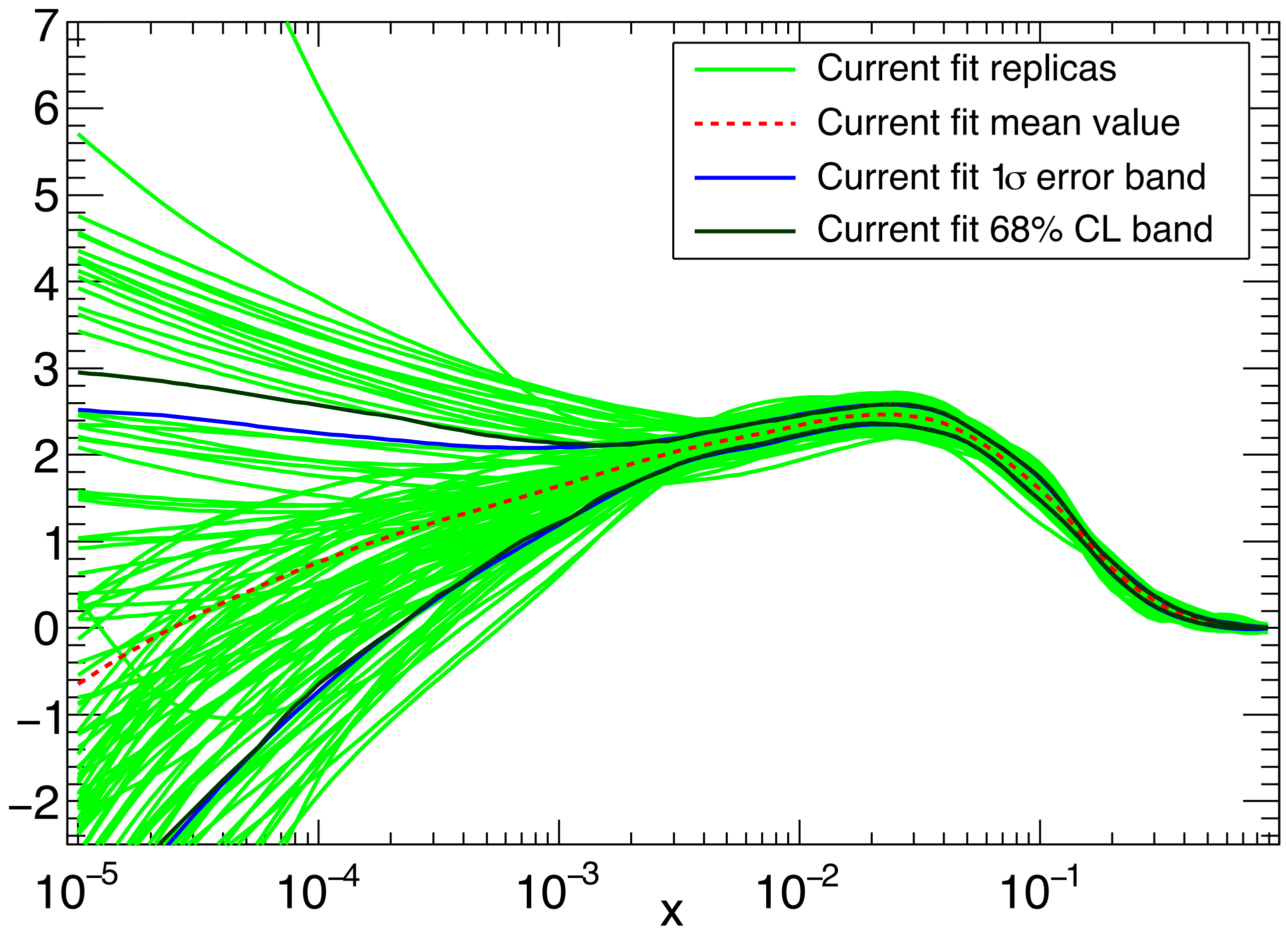
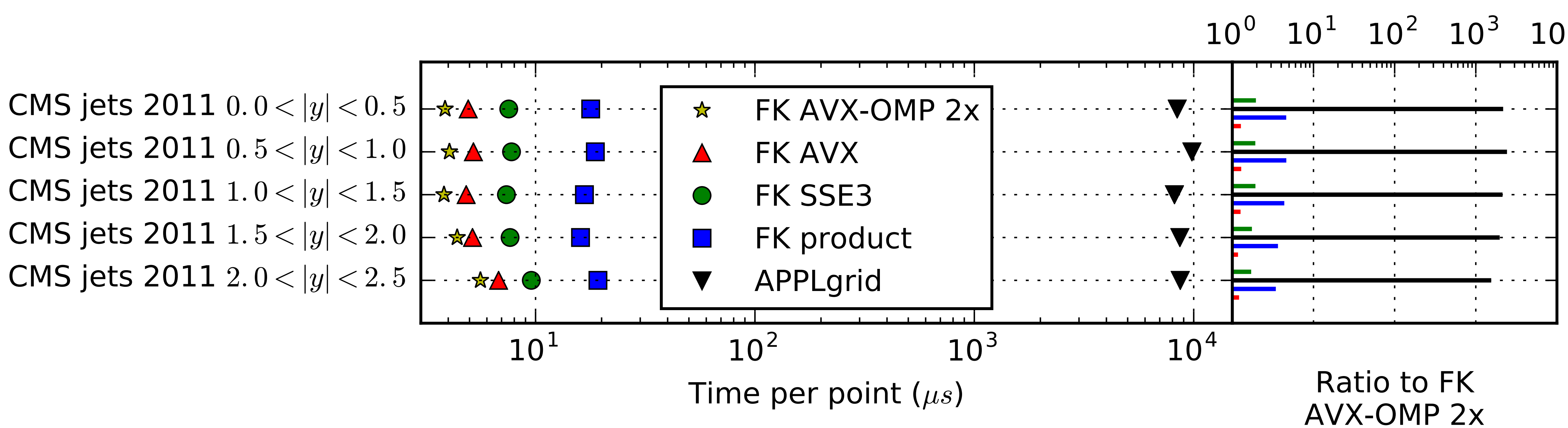
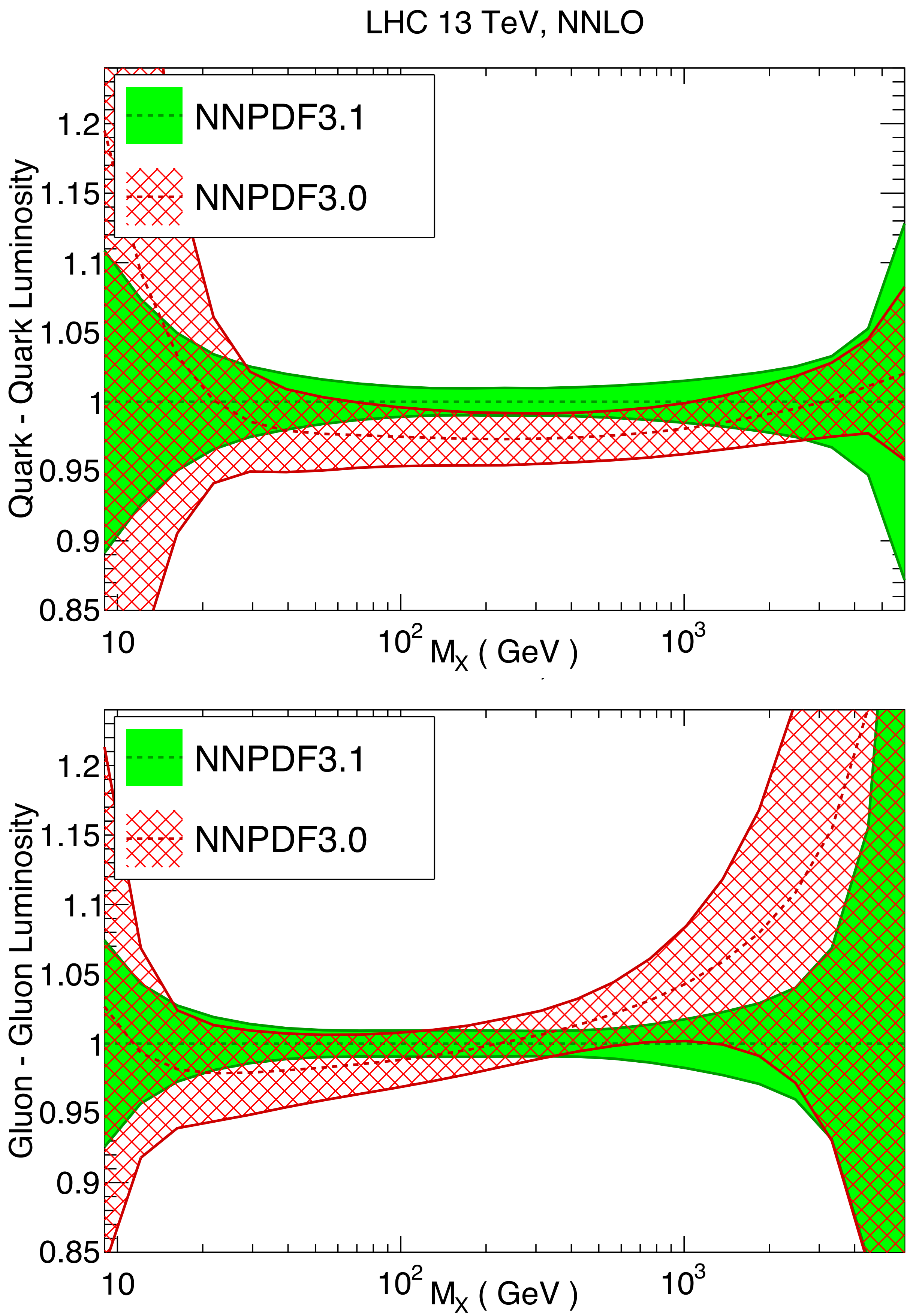




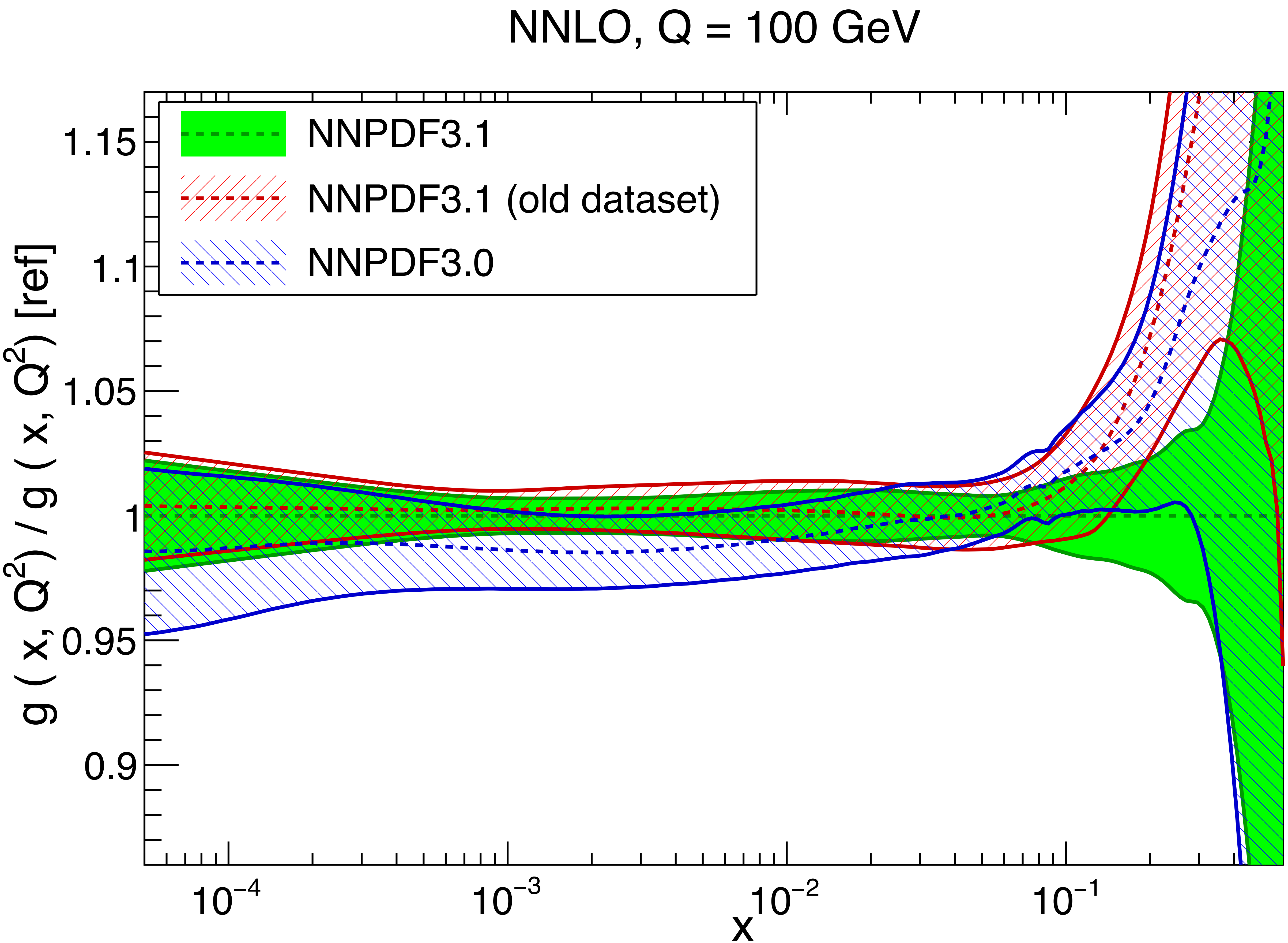
NNPDF3.1 GLOBAL FIT RESULTS



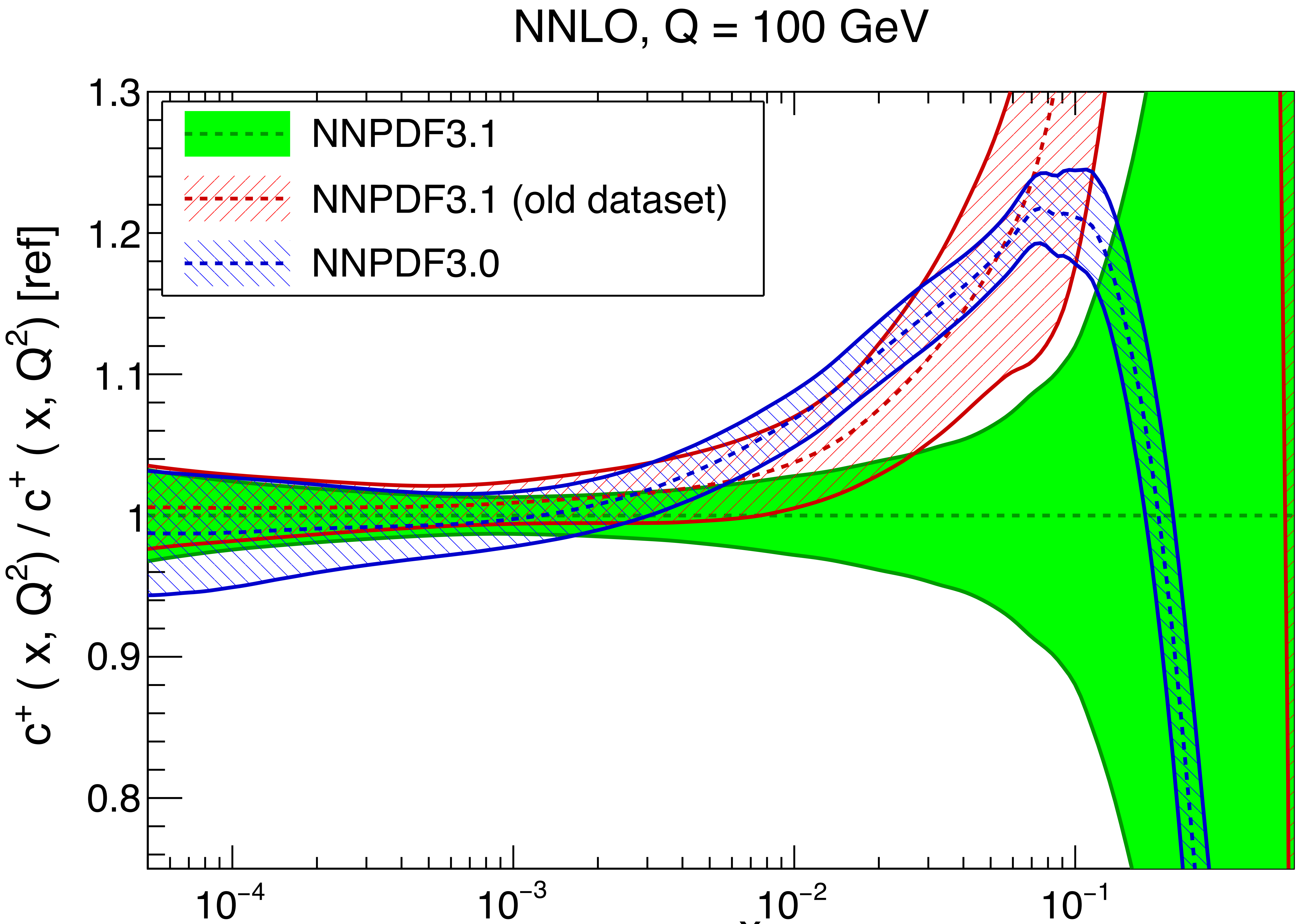
Fit Quality

χ^2	3.1 NNLO	3.0 NLO
HERA	1.16	1.14
ATLAS	1.09	1.37
CMS	1.06	1.20
LHCb	1.47	1.61
TOTAL (FC)	1.148	1.168
TOTAL (PC)	1.187	1.197

NNPDF3.1 GLOBAL FIT RESULTS – DATA VS METHODOLOGY

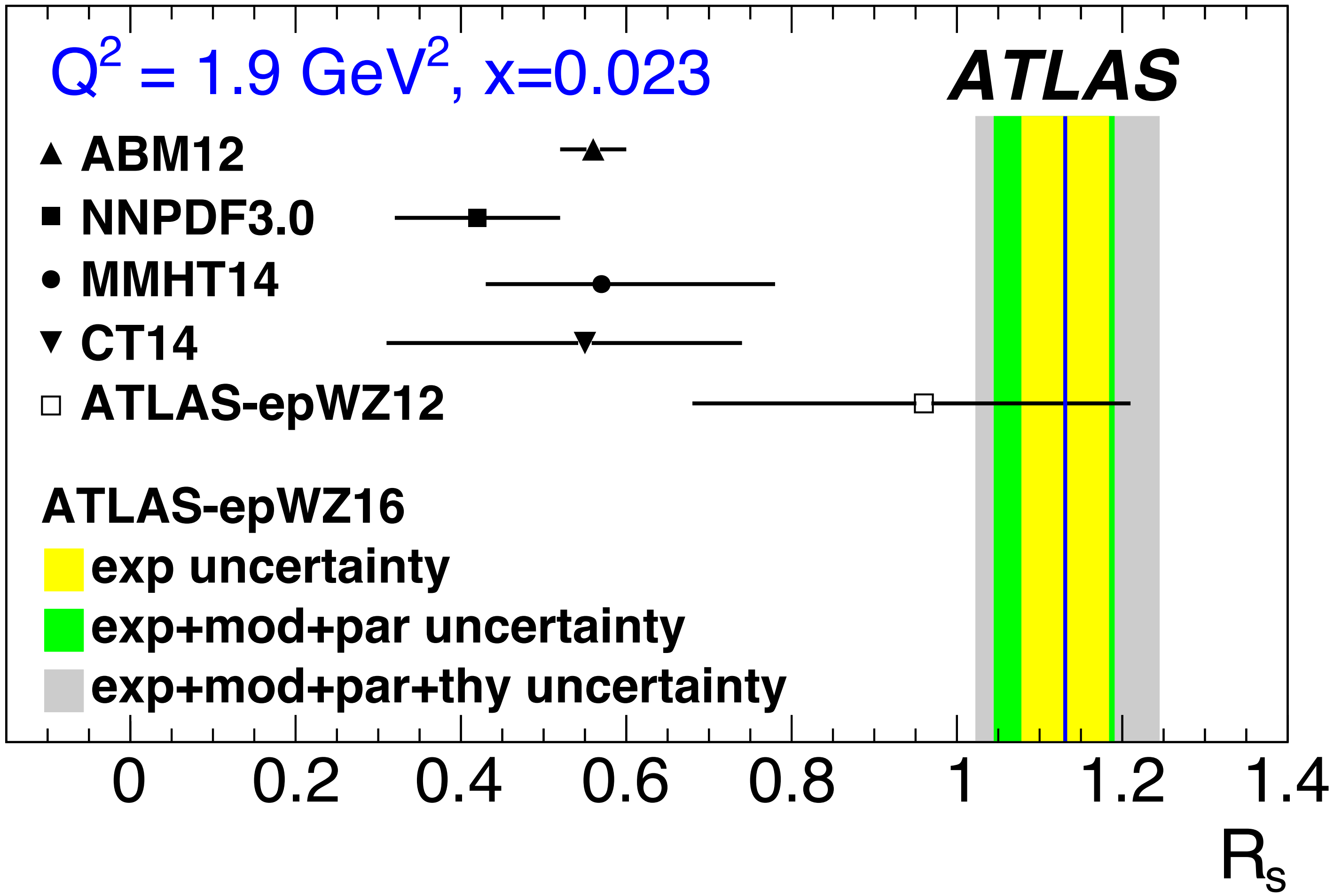


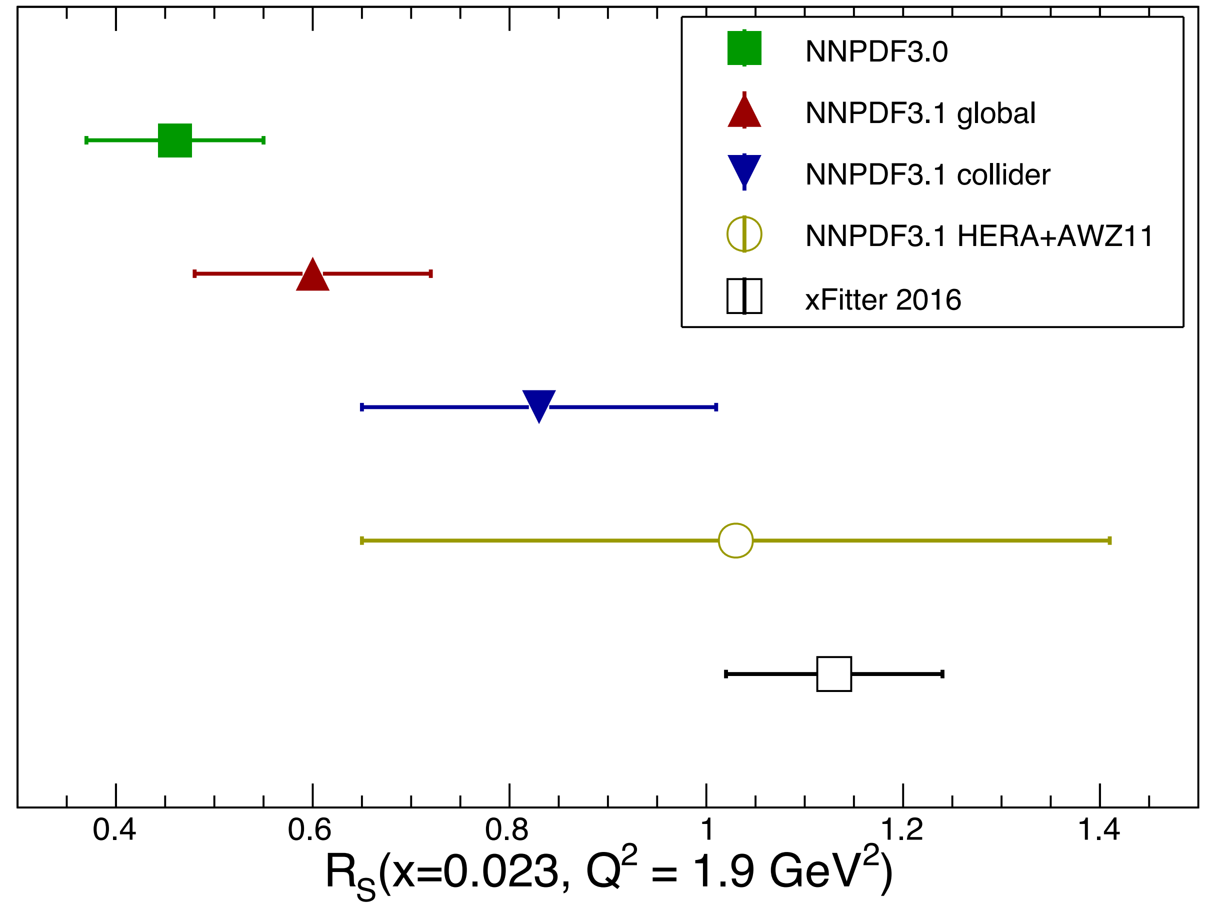
NNPDF3.1 GLOBAL FIT RESULTS - DATA VS METHODOLOGY



THE STRANGENESS PUZZLE

$$R_s(x,Q^2) = \left[s(x,Q^2)+\bar{s}(x,Q^2)\right] / \left[\bar{u}(x,Q^2)+\bar{d}(x,Q^2)\right]$$





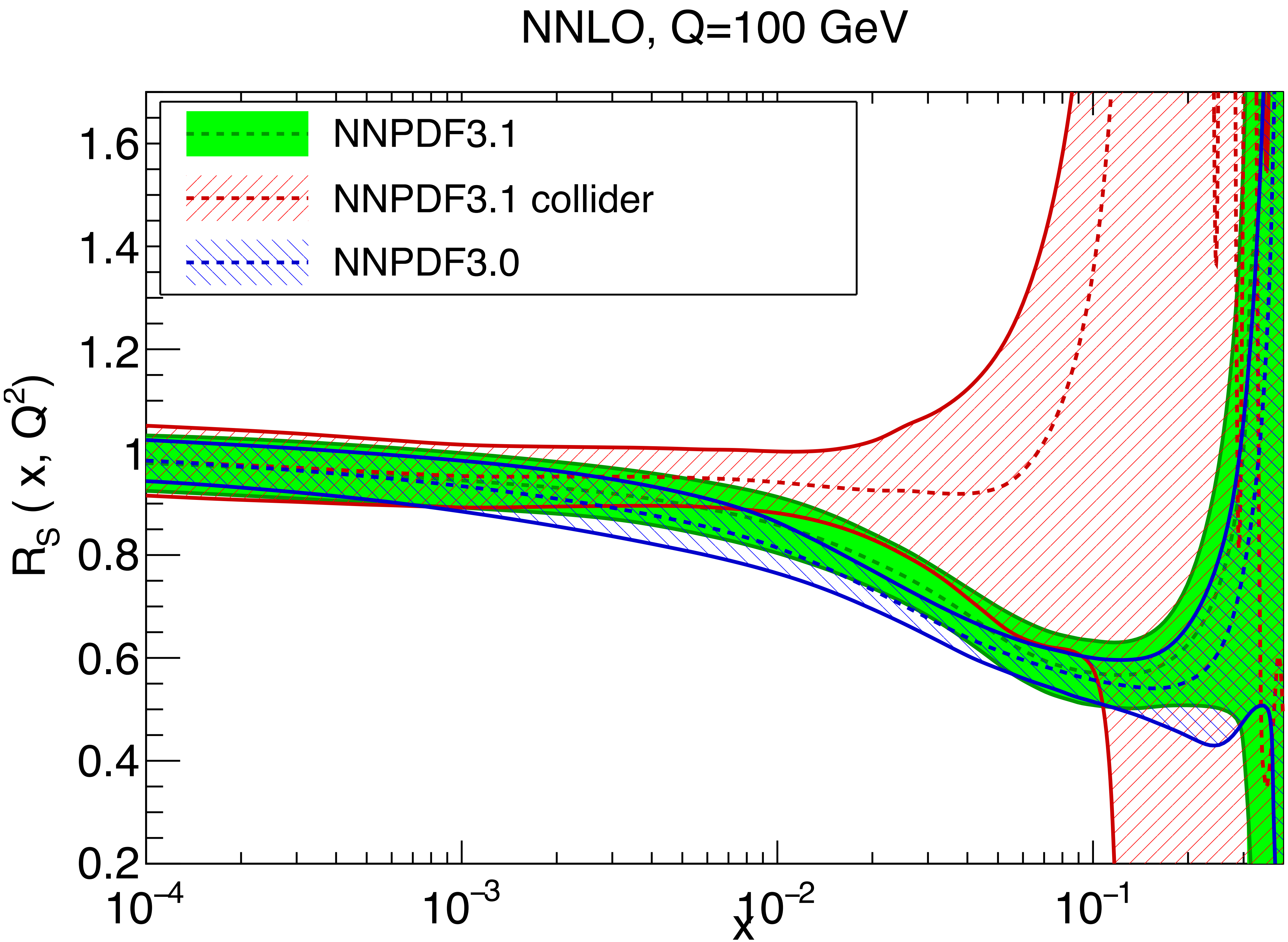
Tension in strangeness between global fits and xFitter persists in NN3.1

	NNPDF3.1 Global	NNPDF3.1 Collider
ATLAS 2011 W/Z	2.14	1.55
ATLAS 2010 W/Z	0.96	0.92
NuTeV dimuon	0.82	26.5

Driven by disagreement between collider data and neutrino DIS

THE STRANGENESS PUZZLE

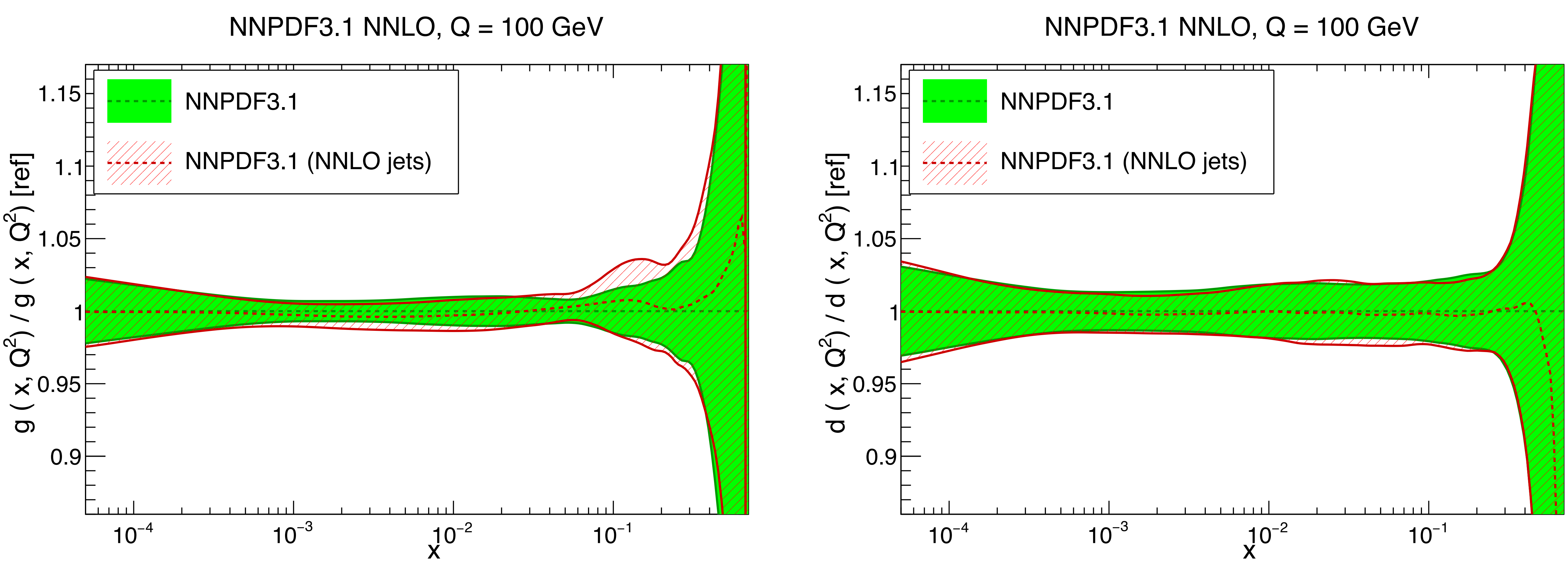
$$R_s(x,Q^2) = \left[s(x,Q^2) + \bar{s}(x,Q^2)\right] / \left[\bar{u}(x,Q^2) + \bar{d}(x,Q^2)\right]$$



INCLUSIVE JET DATA AT NNLO

While the full NNLO calculation for inclusive jet production has been finalised, exact K-factors for several of the jet datasets were not available at time of publication

Therefore for NNLO fits, the jet data was included at NLO accuracy, but with an additional uncertainty determined by NLO scale variation



Reliability verified by comparison against fit with available NNLO corrections