PARTON DISTRIBUTIONS FROM HIGH-PRECISION COLLIDER DATA

Based on arXiv:1706.00428 with the NNPDF Collaboration

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DESY Hamburg, 29/09/17

Nikhef VU VRIJE UNIVERSITEIT AMSTERDAM NNPDF

PRECISION PDFS FOR LHC PHYSICS

Accurate parton distributions are a vital ingredient in pQCD predictions

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

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LHAPDF 6.2.1

(lhapdf.hepforge.org/pdfsets.html)

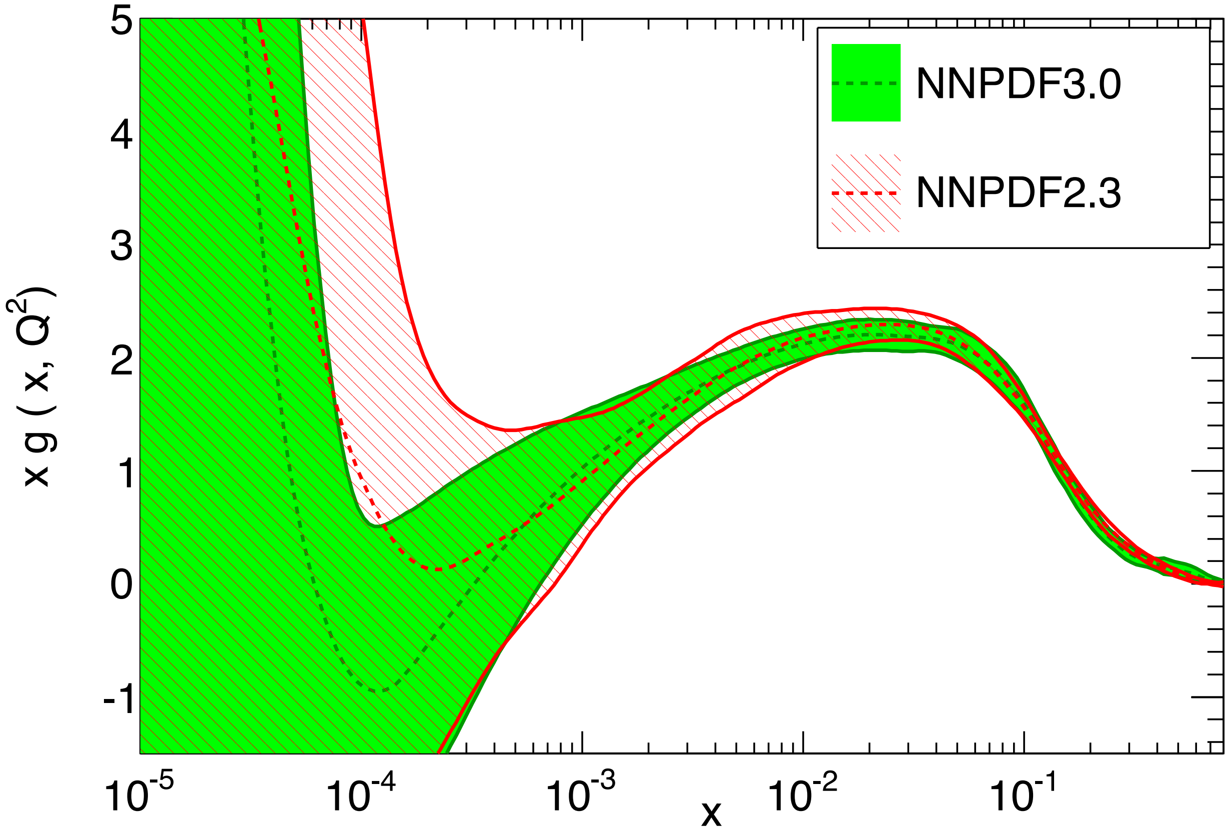
Main Page | Related Pages | Namespaces | Classes | Files | Examples

PDF sets

Official LHAPDF 6.2 PDF sets: currently 775 available, of which 773 are validated.

Plenty of options to choose from these days!

WHY ANOTHER PDF SET?



Last release: ***NNPDF3.0*** [1410.8849]

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

However - increasing precision in th + exp

PDF determinations must keep pace

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]**

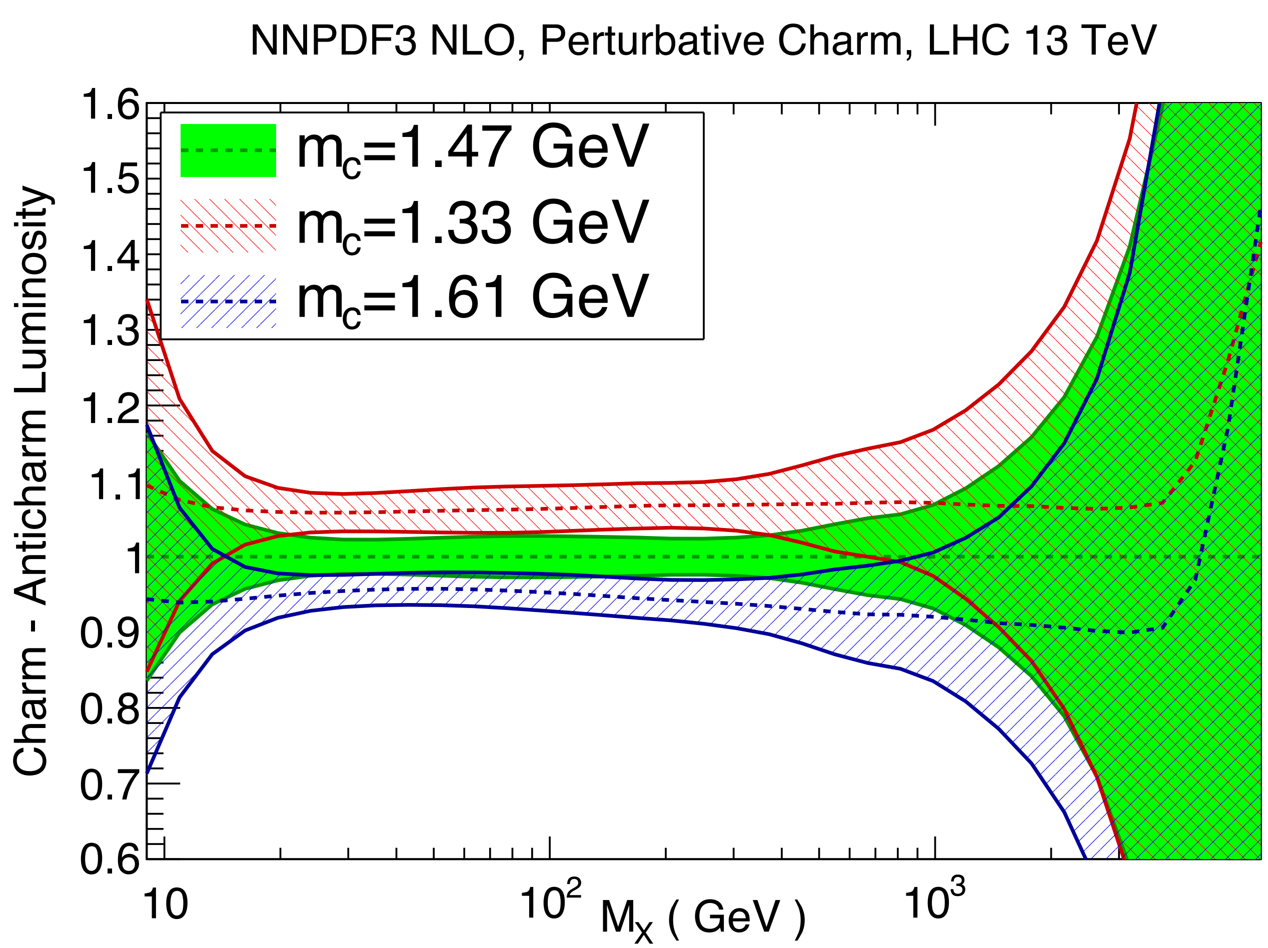
INTRINSIC CHARM

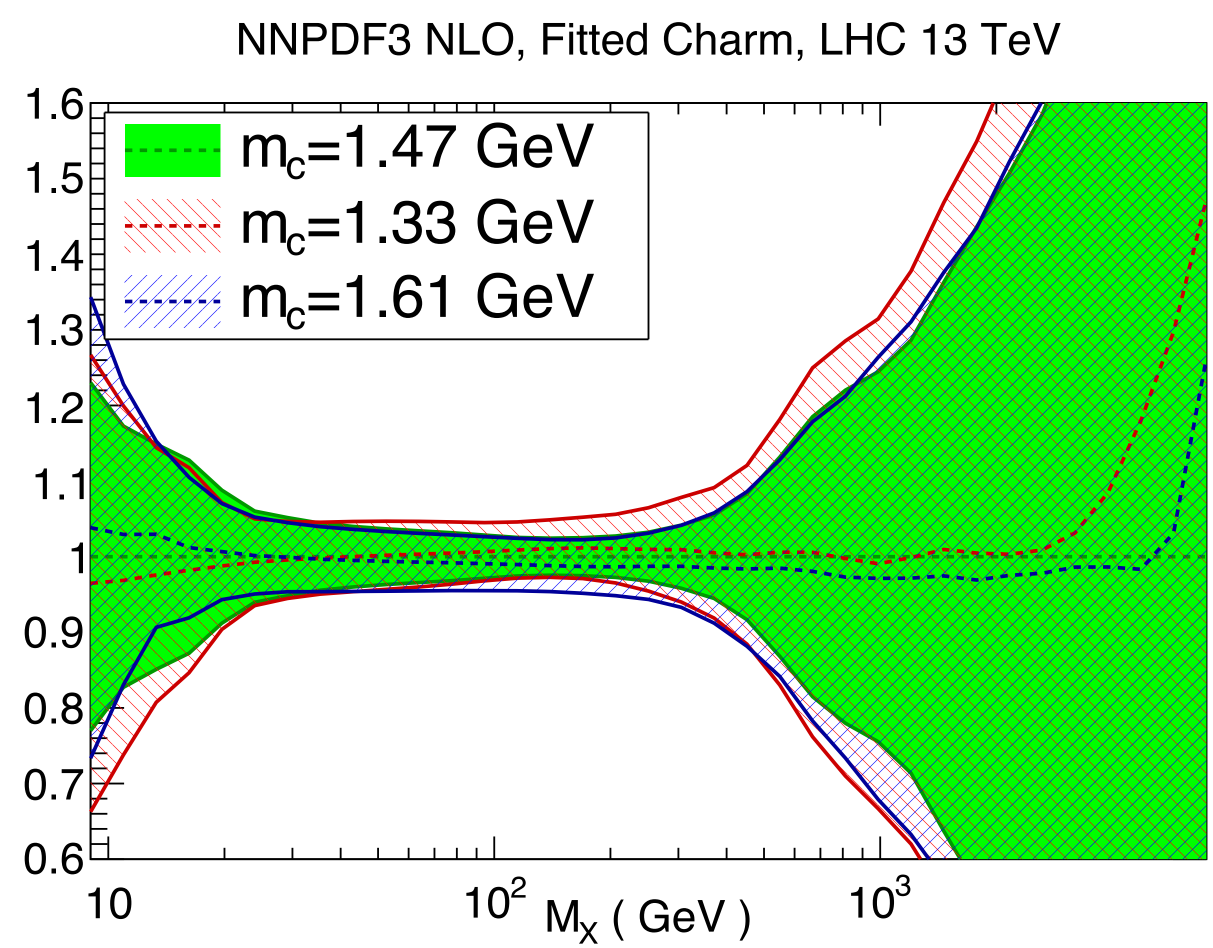
- The charm PDF is a **borderline** perturbative object

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





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

[1605.06515]

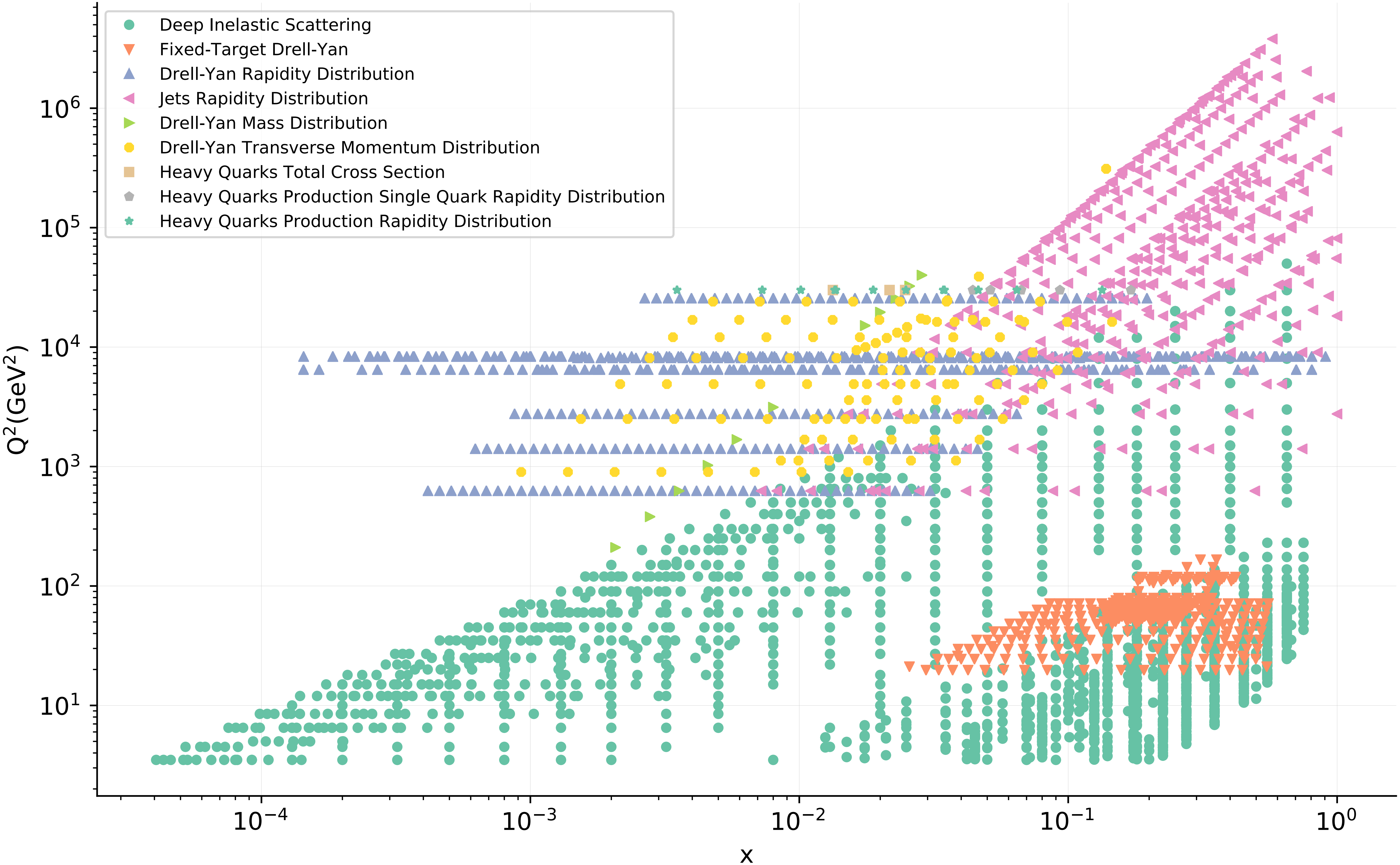
WHY ANOTHER PDF SET?

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

[13 TeV data reserved for comparison/future studies]

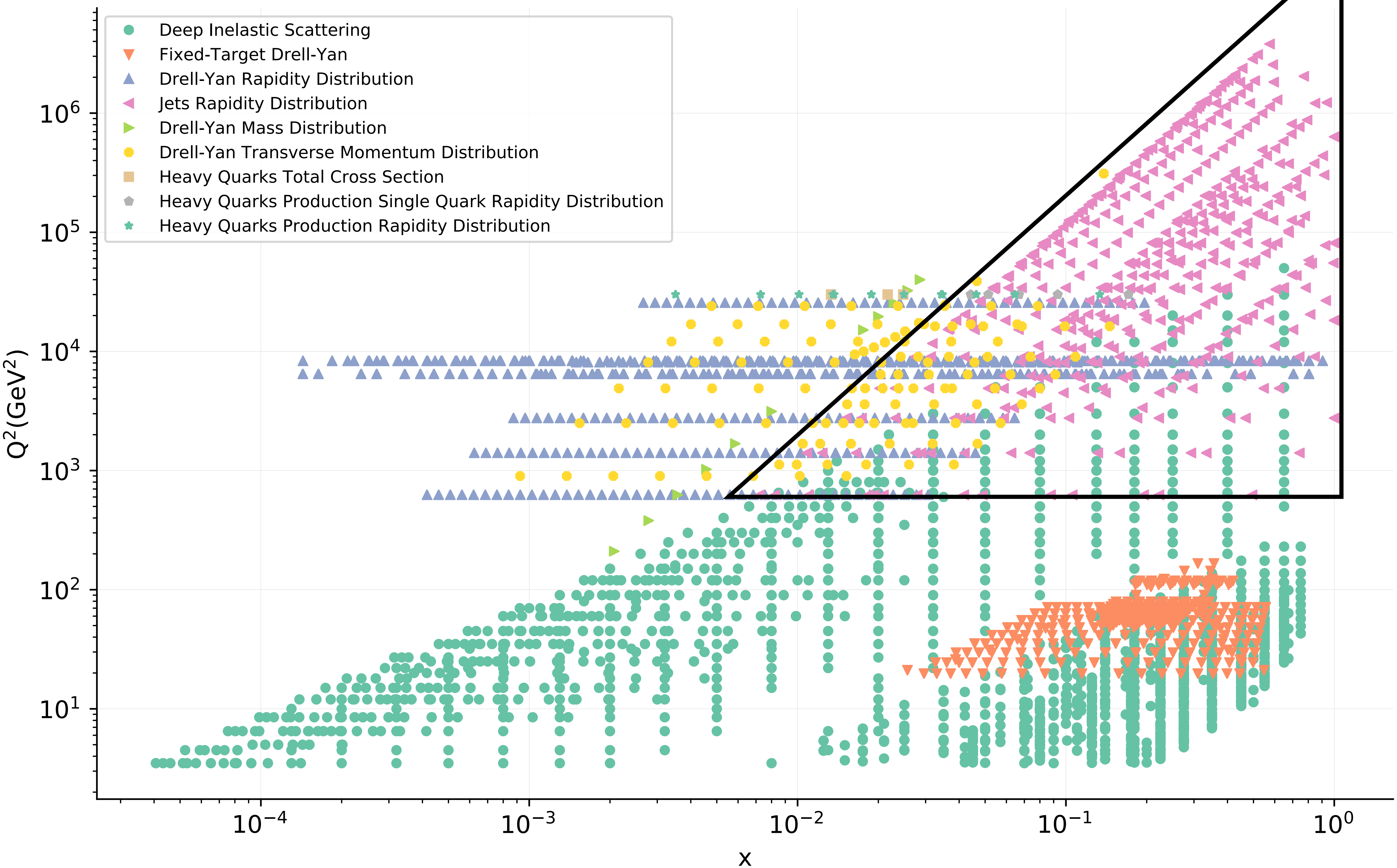
(Table thanks to J. Rojo)

THE DATA LANDSCAPE – NNPDF3.1 DATASET



Total of ***4285*** *points at NNLO*

THE DATA LANDSCAPE – NNPDF3.1 DATASET



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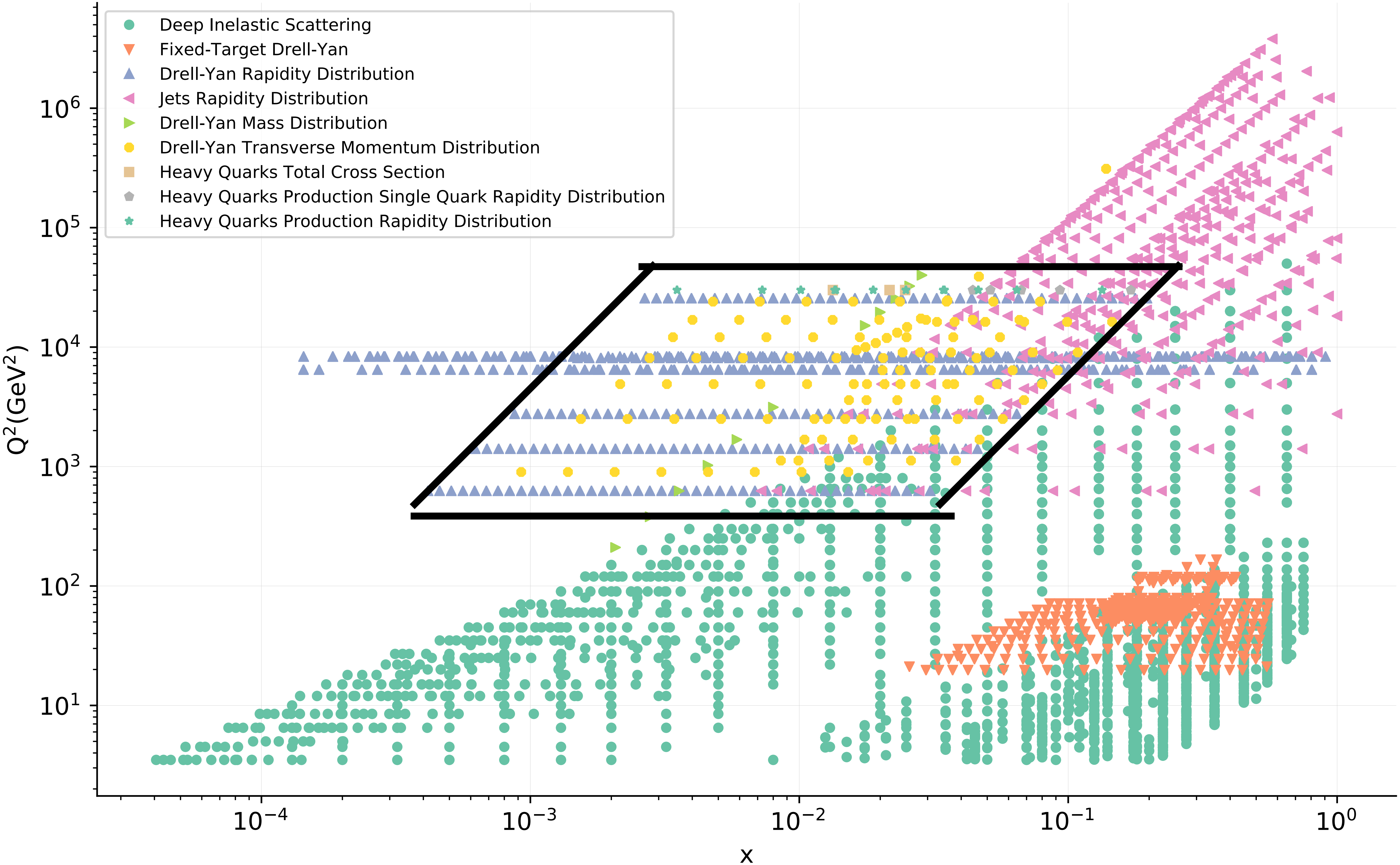

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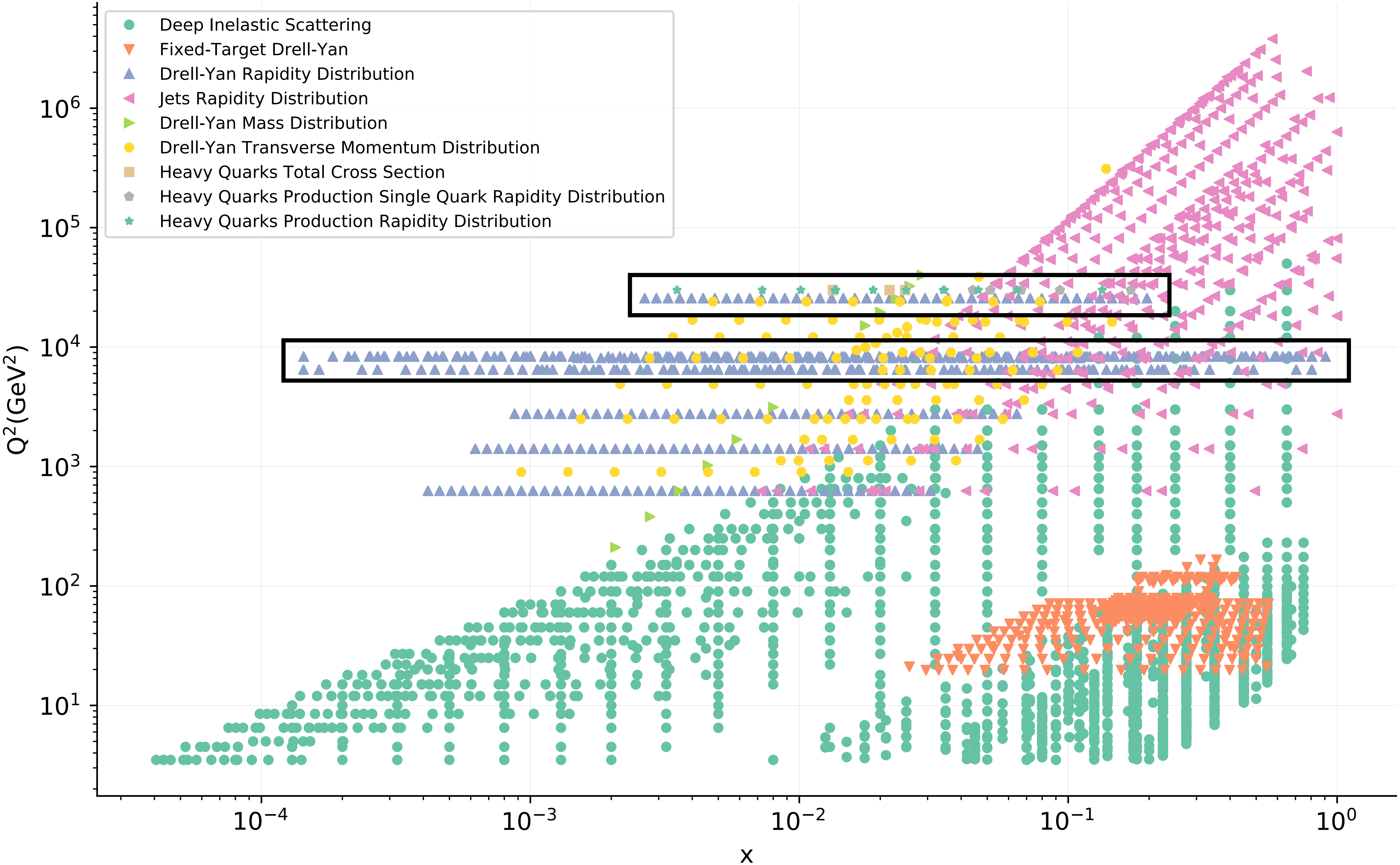

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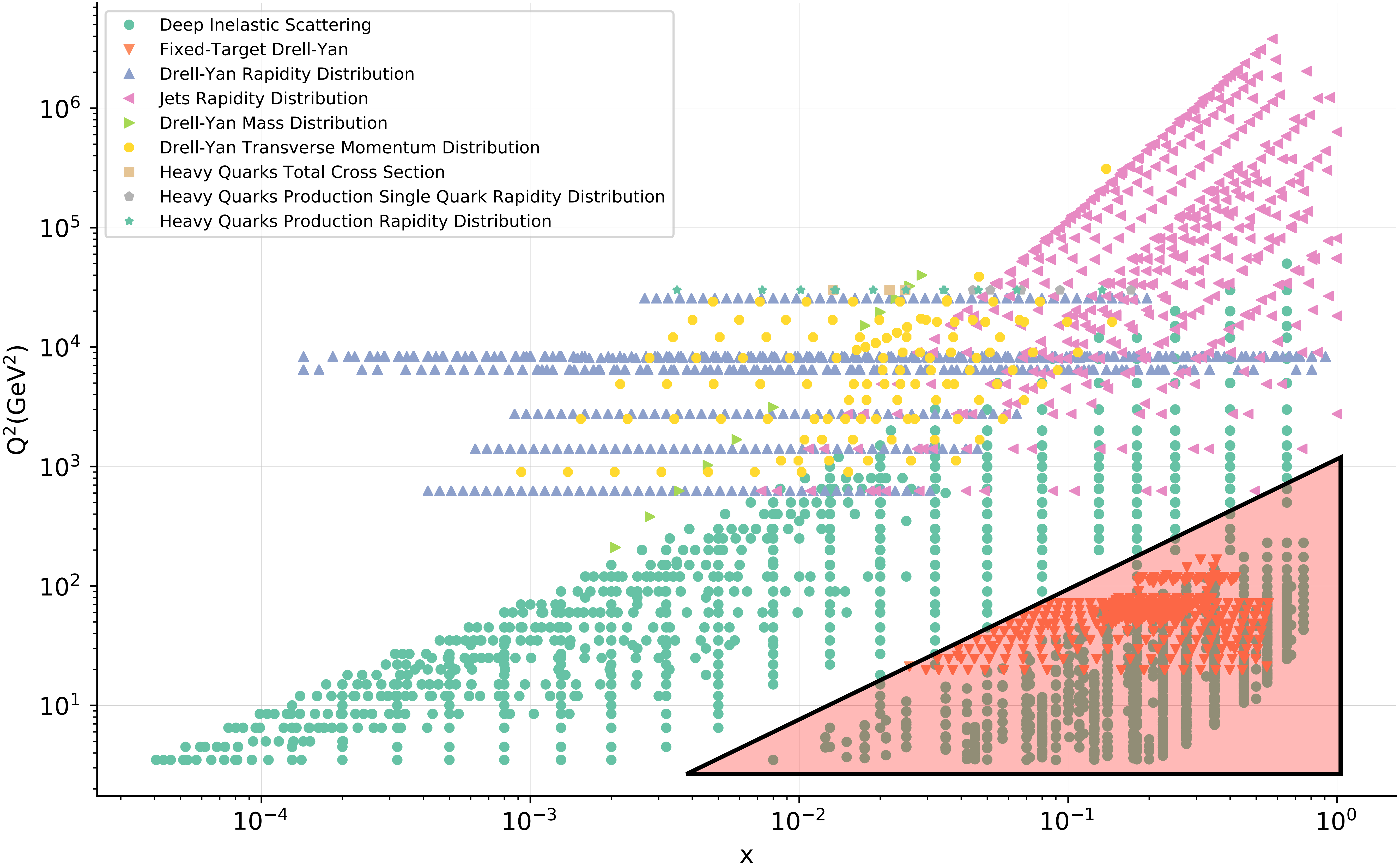

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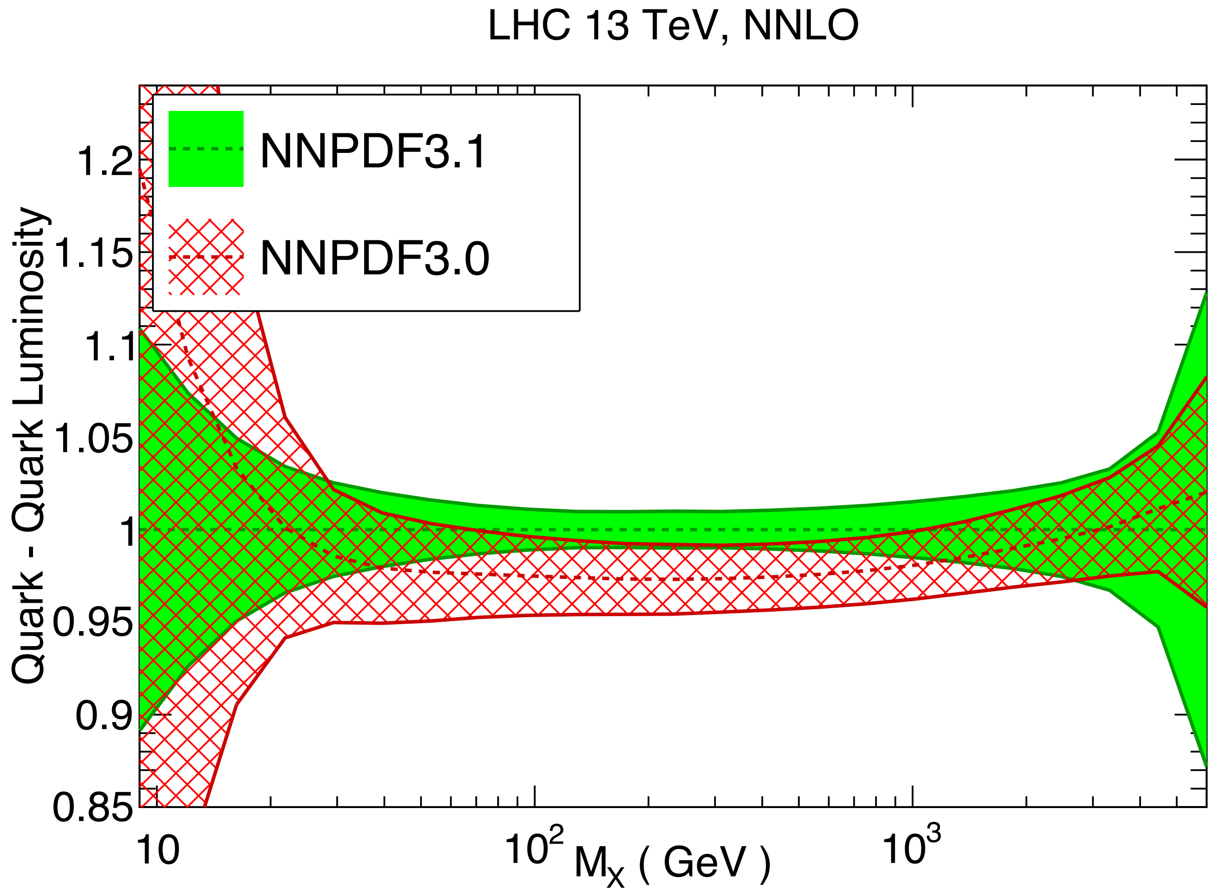
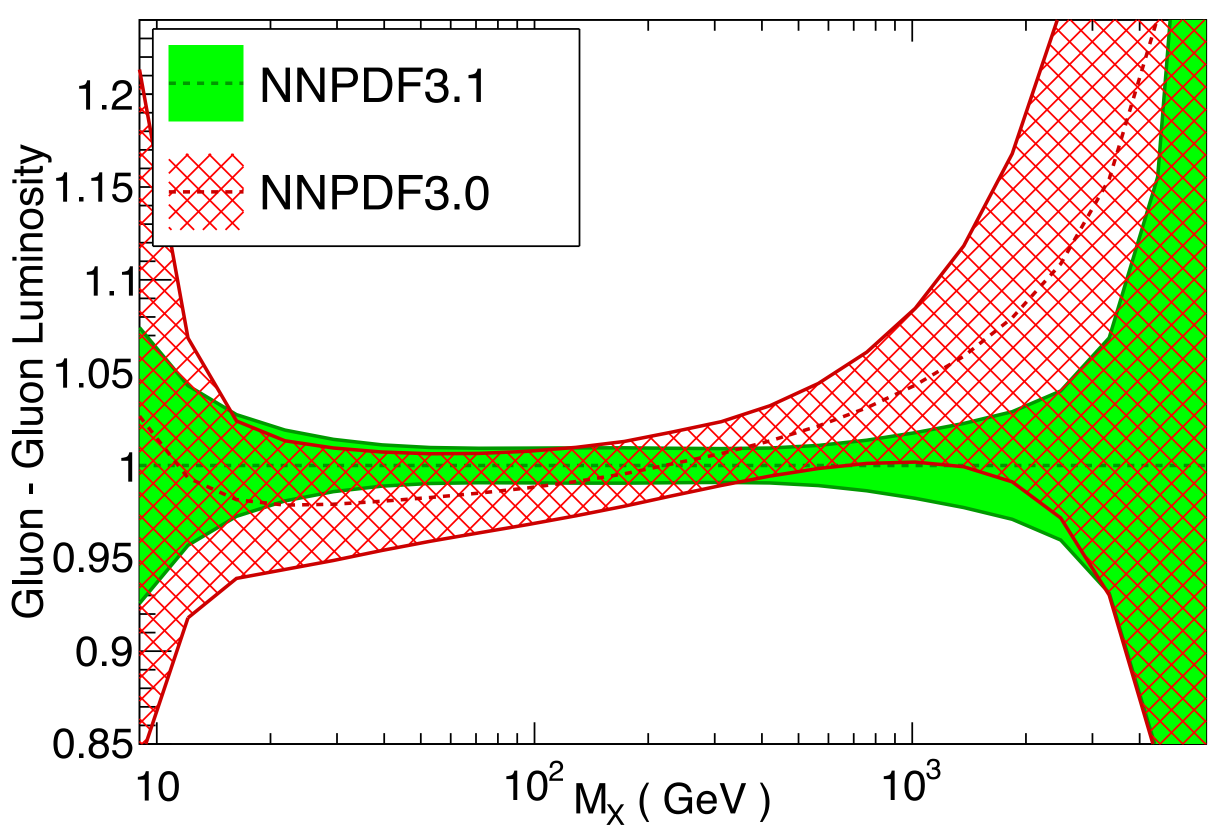
NNPDF3.1 GLOBAL FIT RESULTS

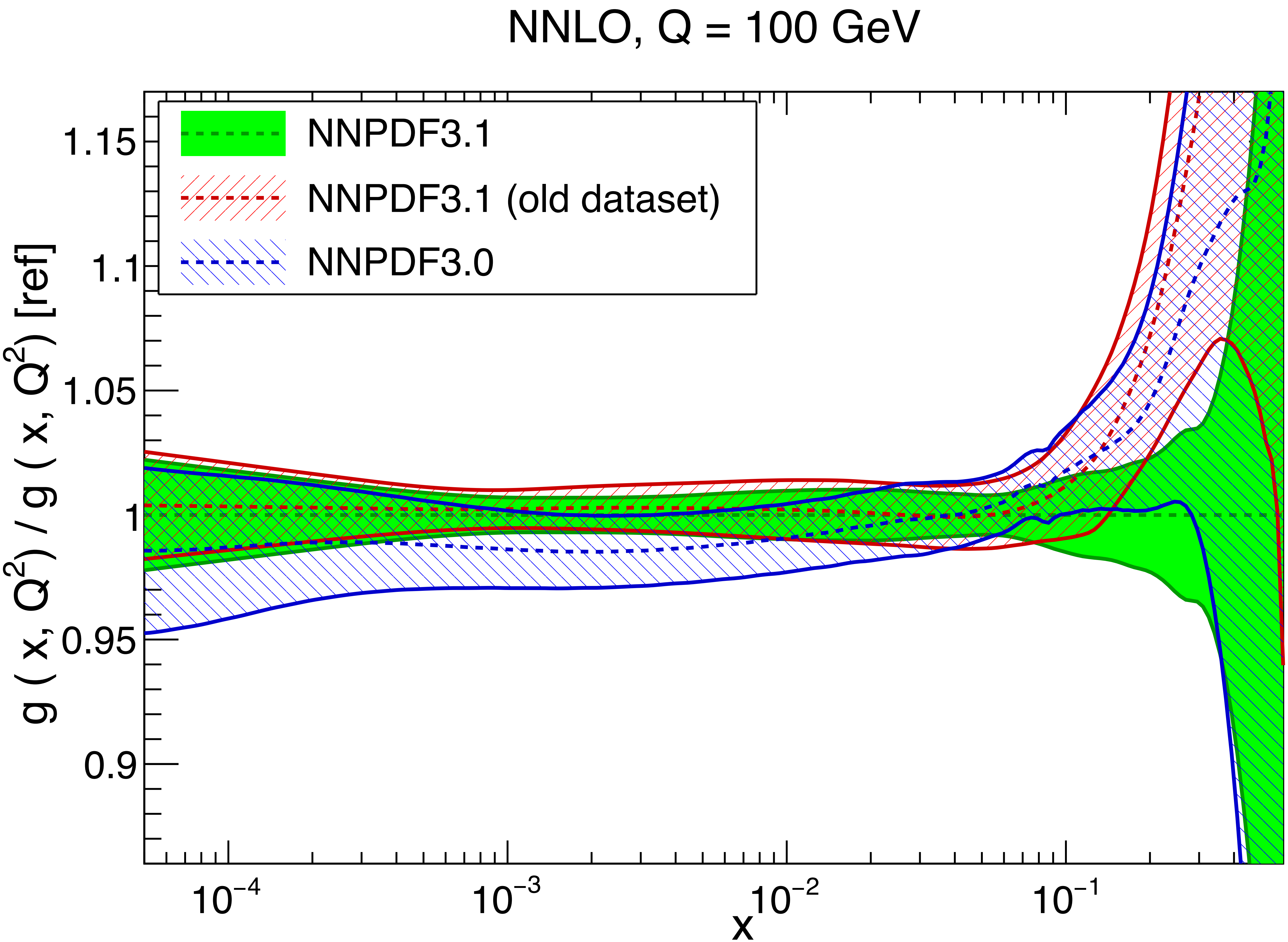




Fit Quality

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



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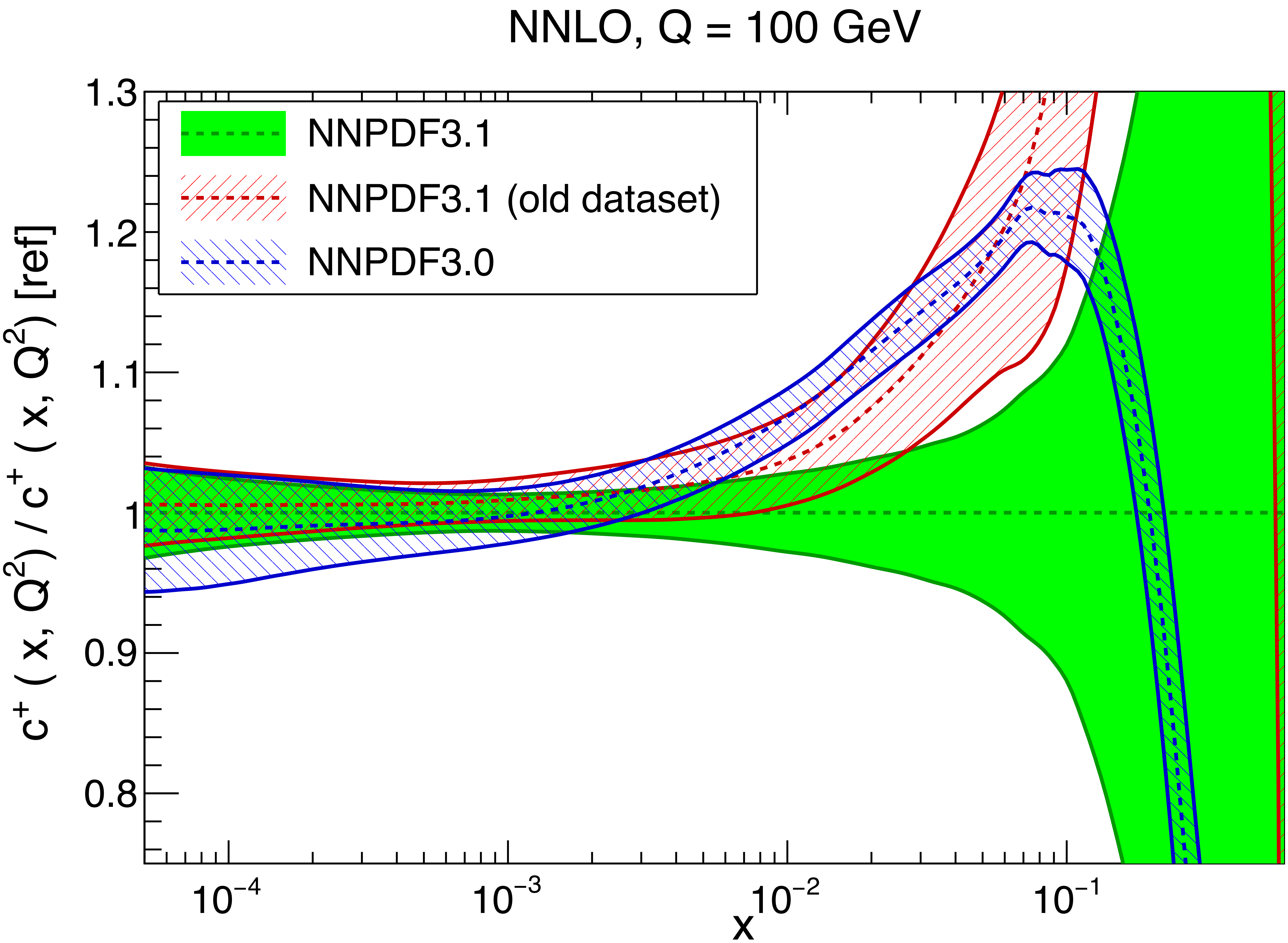
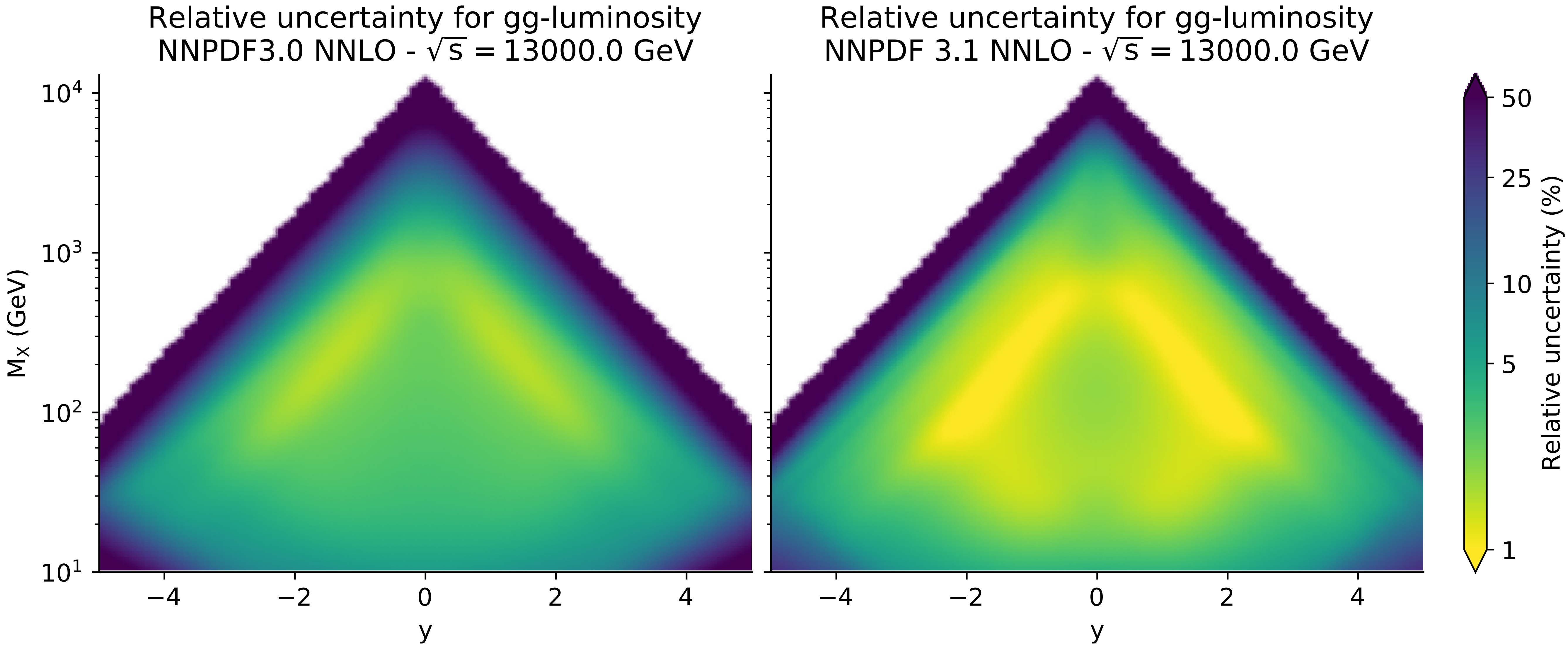
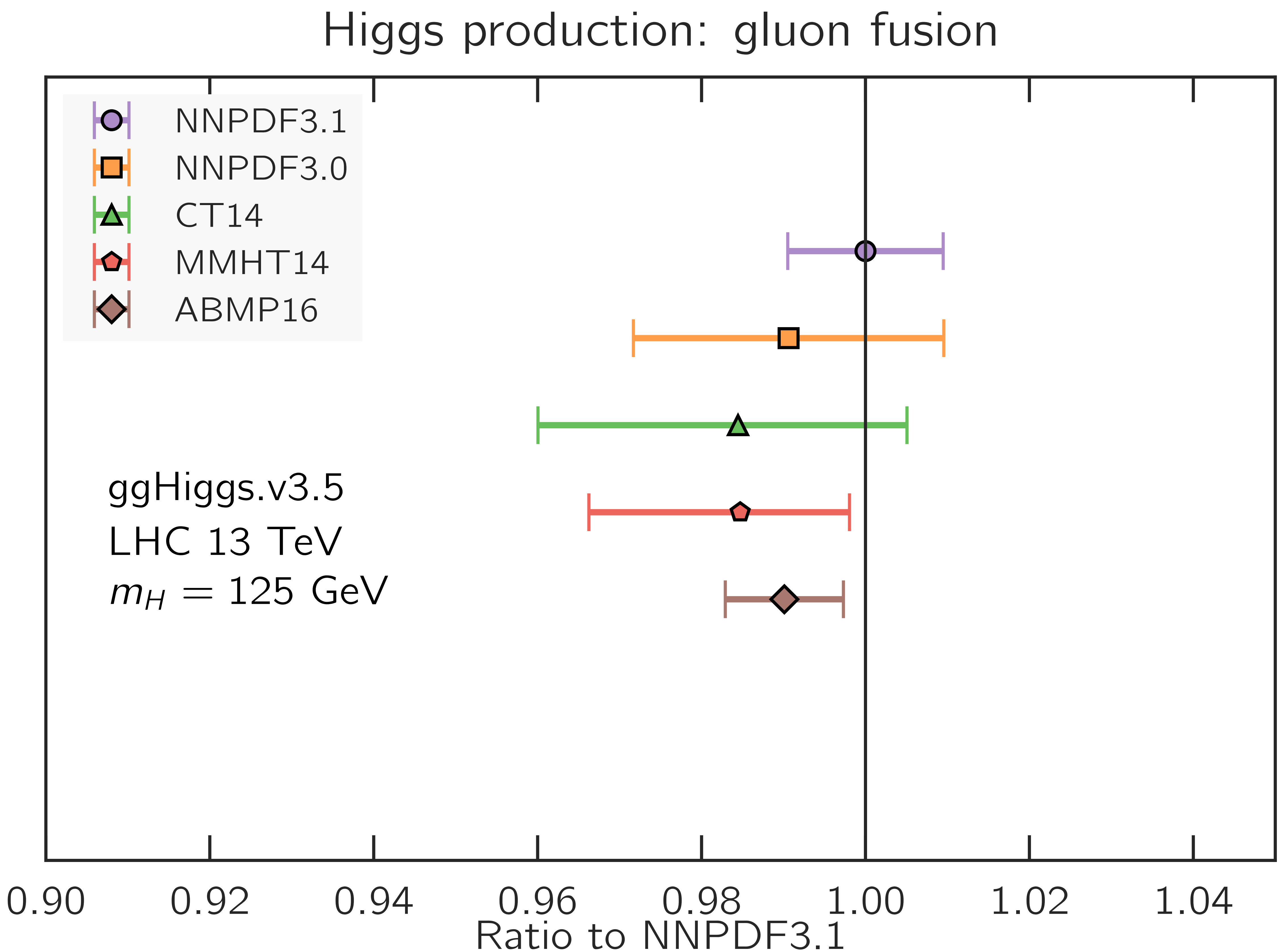


NNPDF3.1 GLOBAL - PHENOMENOLOGY (GG)

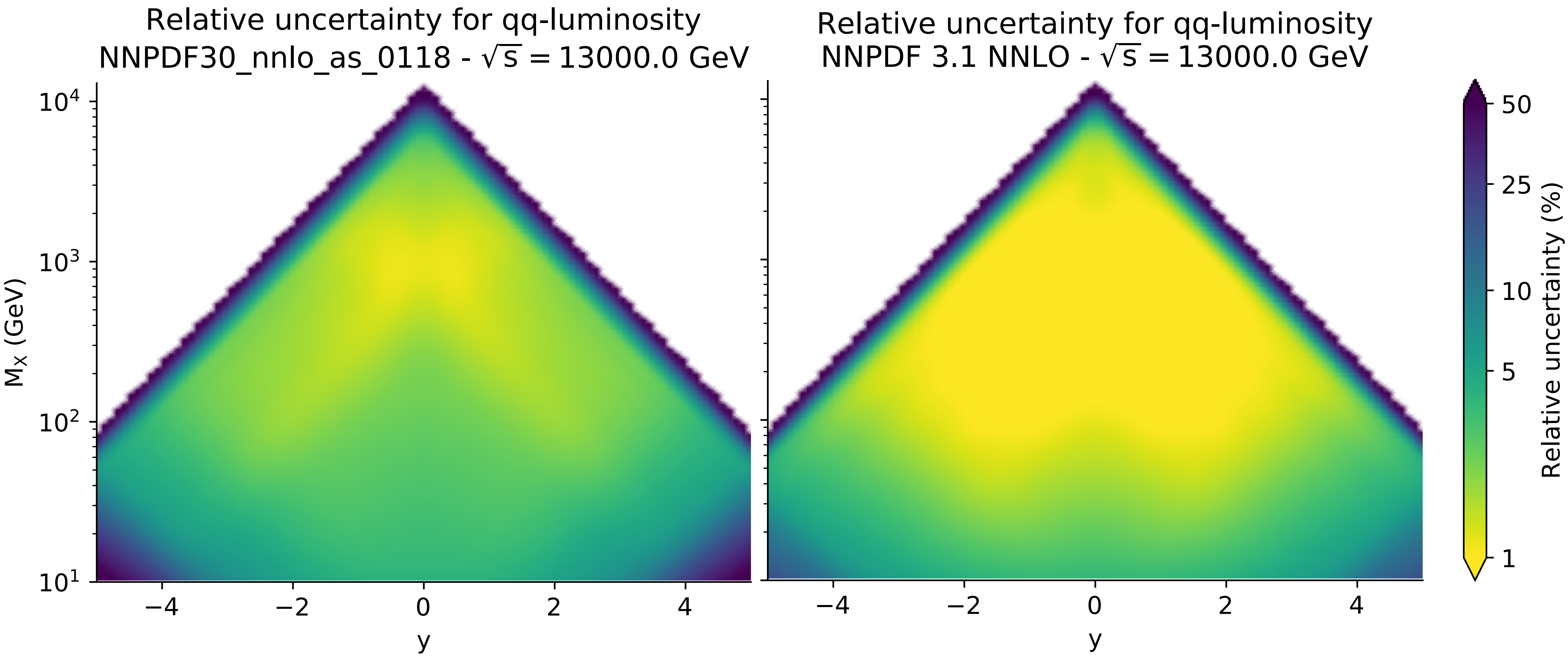


Significant reduction in uncertainties across the kinematic range

NNPDF3.1 GLOBAL - PHENOMENOLOGY (GG)



NNPDF3.1 GLOBAL - PHENOMENOLOGY (QQ)



QQ Uncertainties decrease *despite* greater parametrisation freedom

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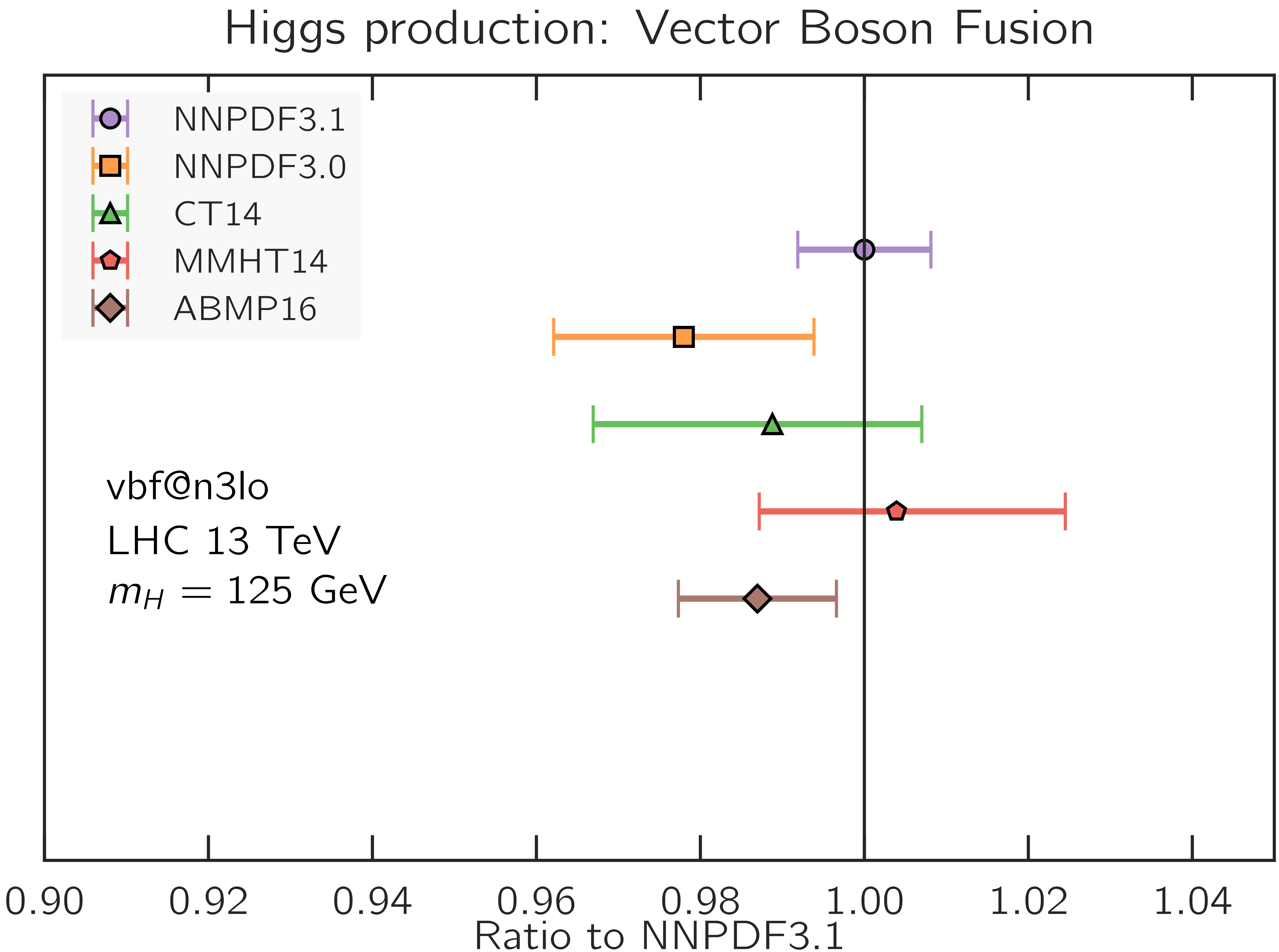
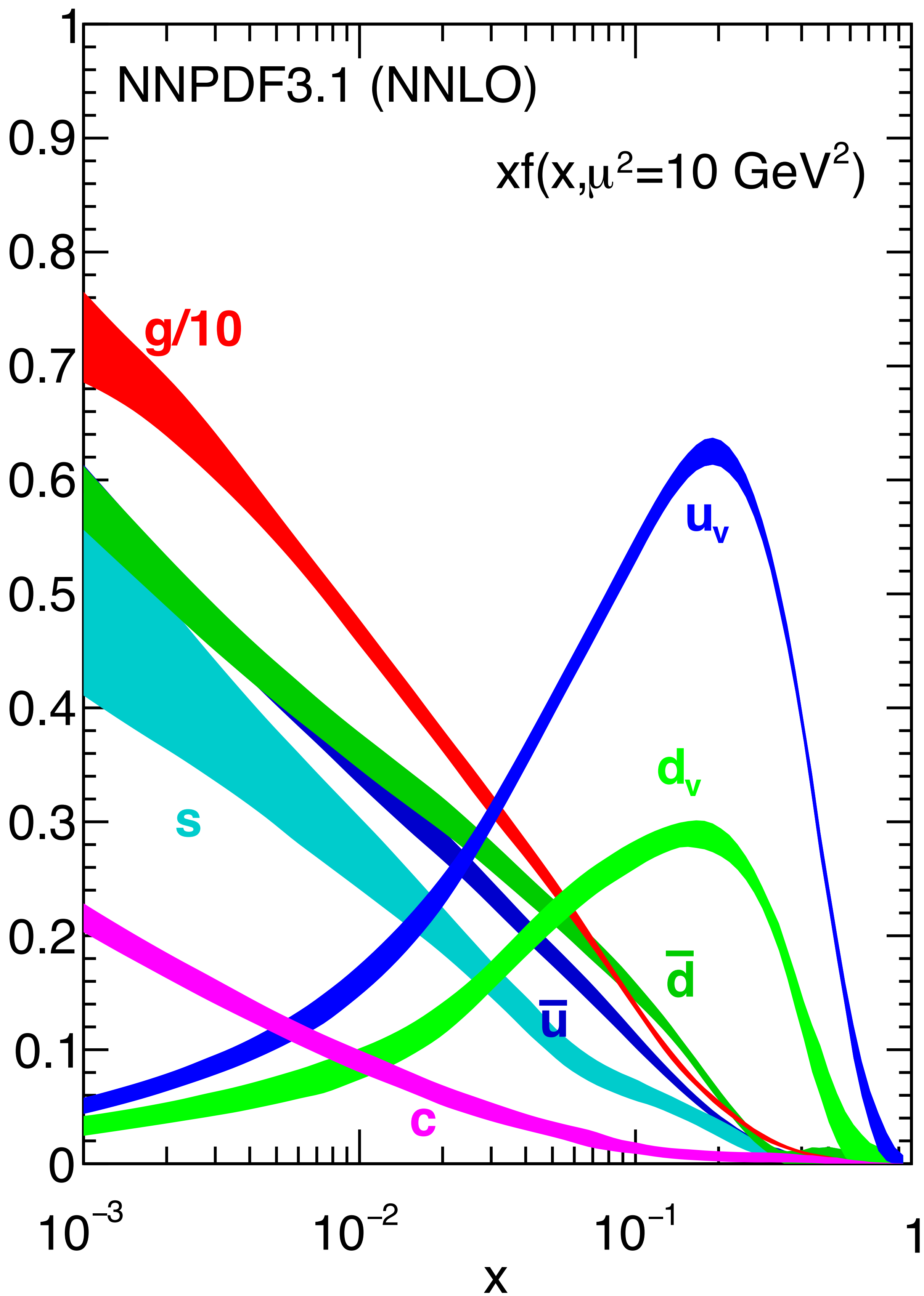


NNPDF 3.1



NNPDF3.1 PDFs now on LHAPDF

Up to date global dataset and restrictive sets

- *Collider-only / Proton-only and more*
- *Fitted and perturbative charm*
- *Wide range of α_S variations*

In the pipeline

- *α_S determination from global fit*
- *NNPDF3.1QED (LUX QED photon)*
- *NNPDF3.1sx (Small-x resummation)*

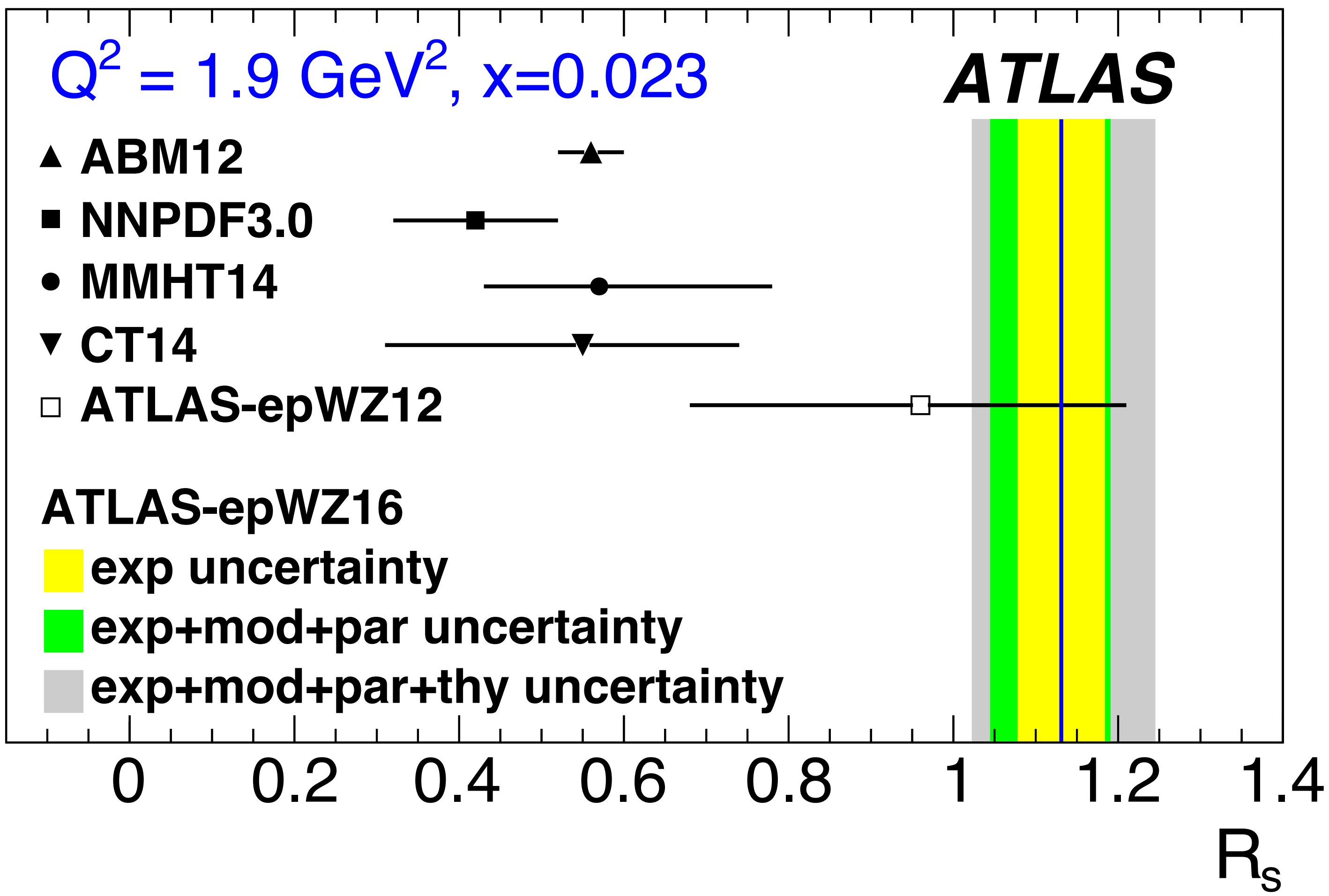
Fast approaching 1% precision

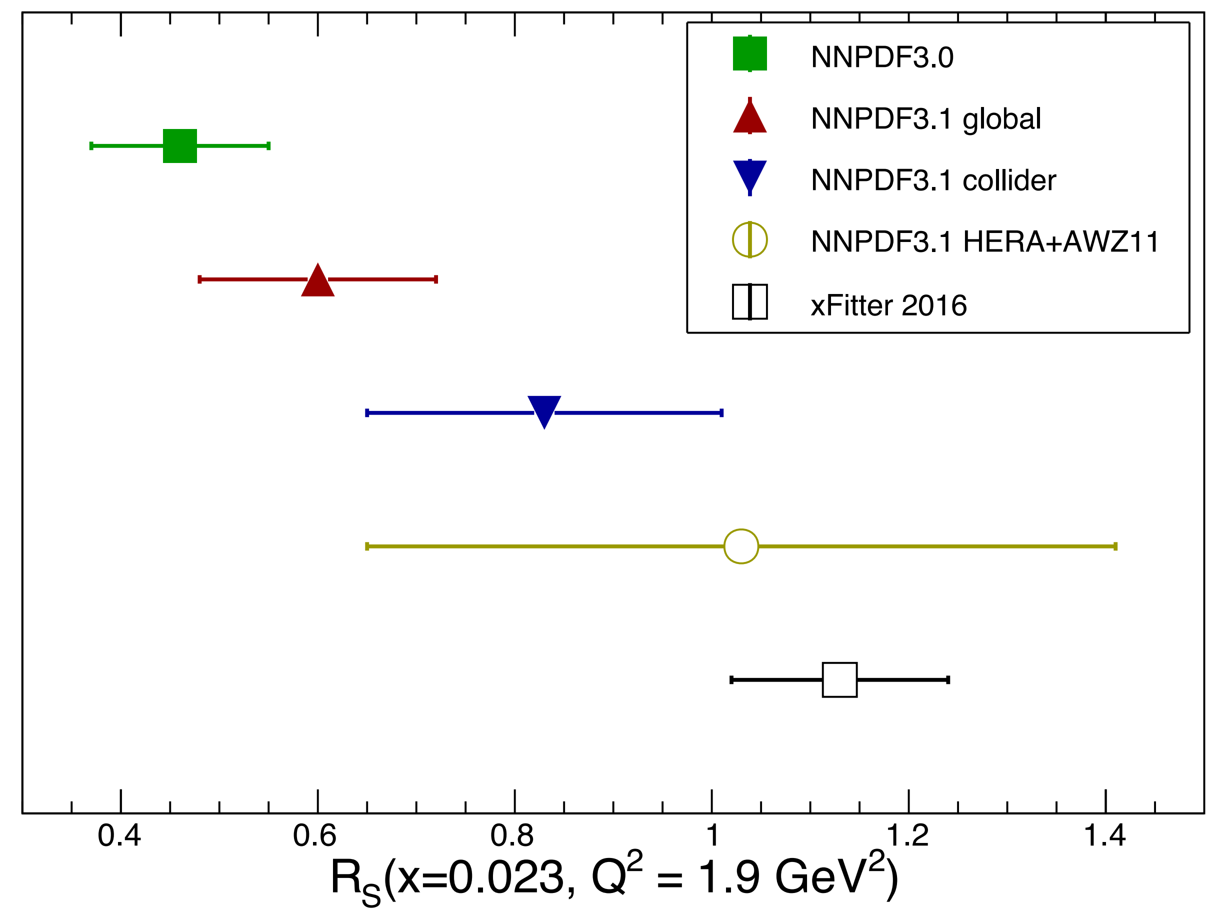
Better understanding of theory uncertainties will be important!

BACKUPS

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

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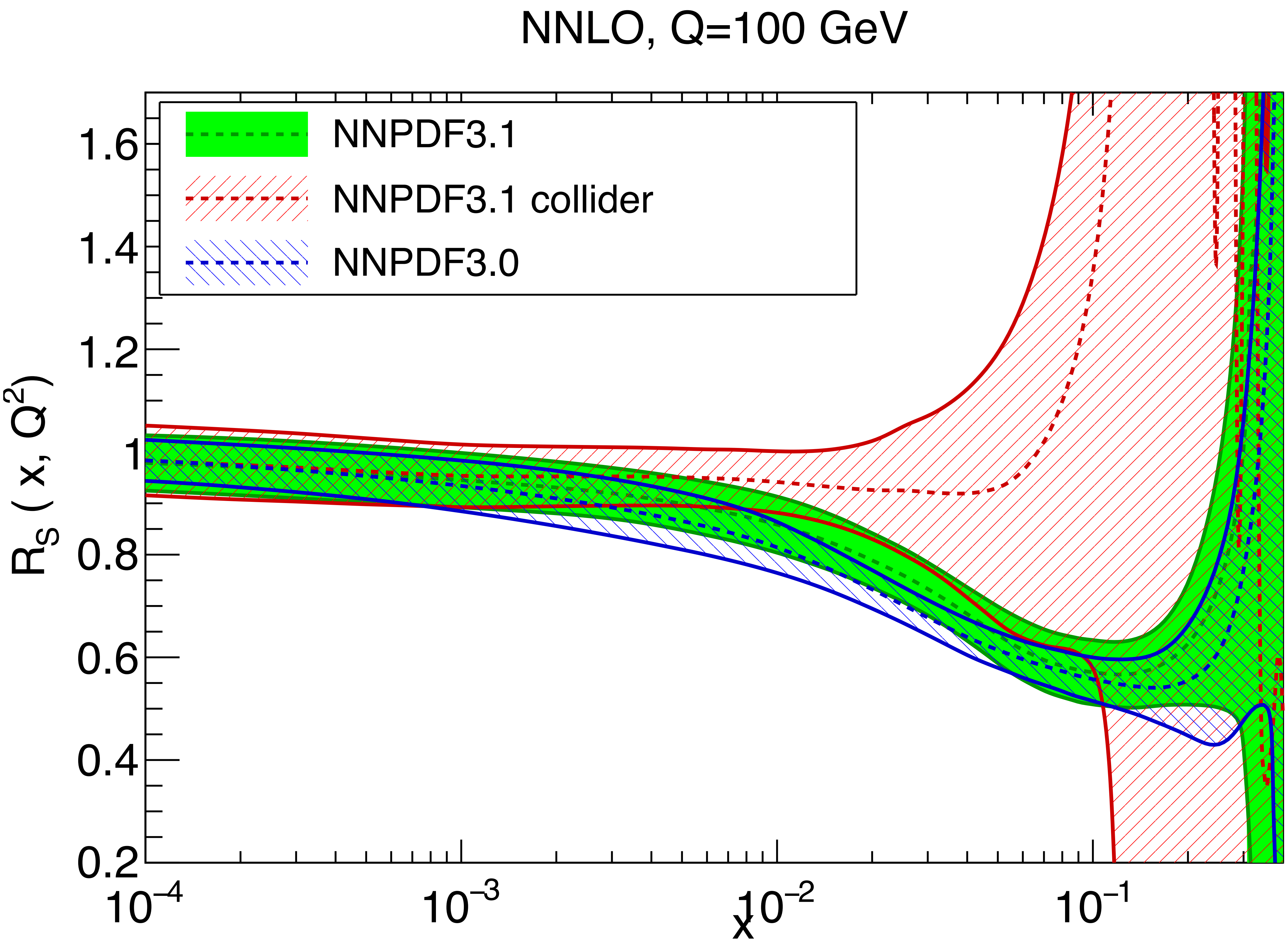
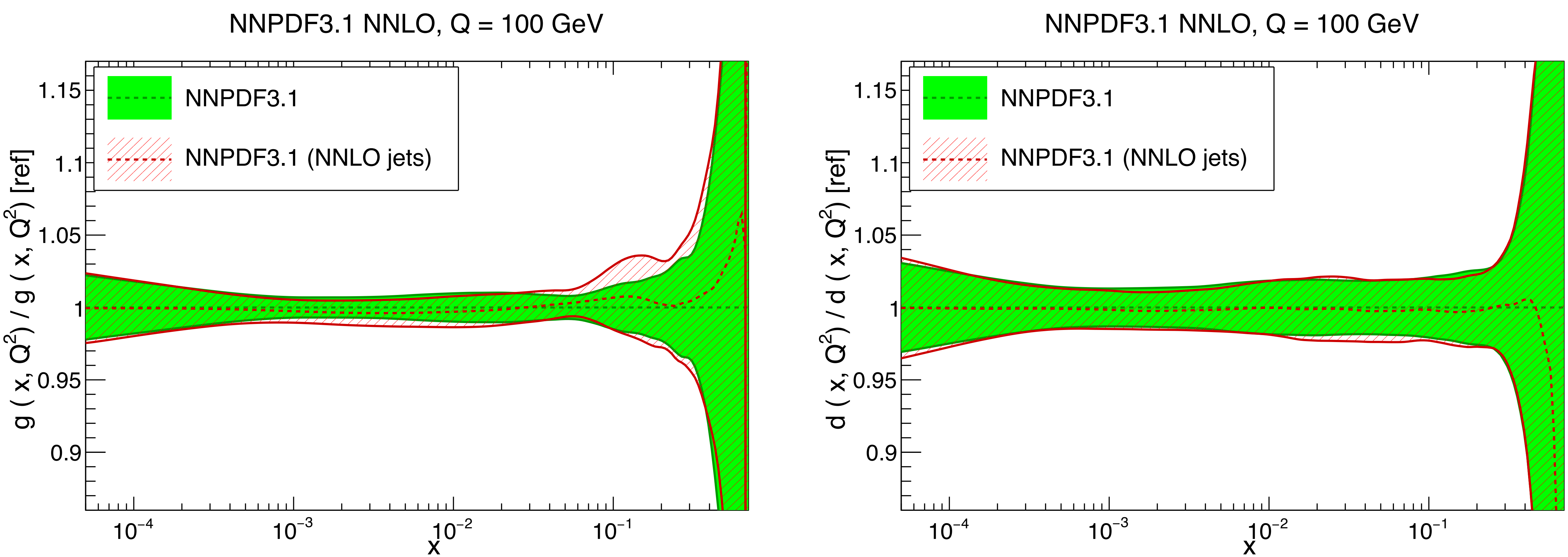


INCLUSIVE JET DATA AT NNLO

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

NNPDF FITS ARE EXPENSIVE

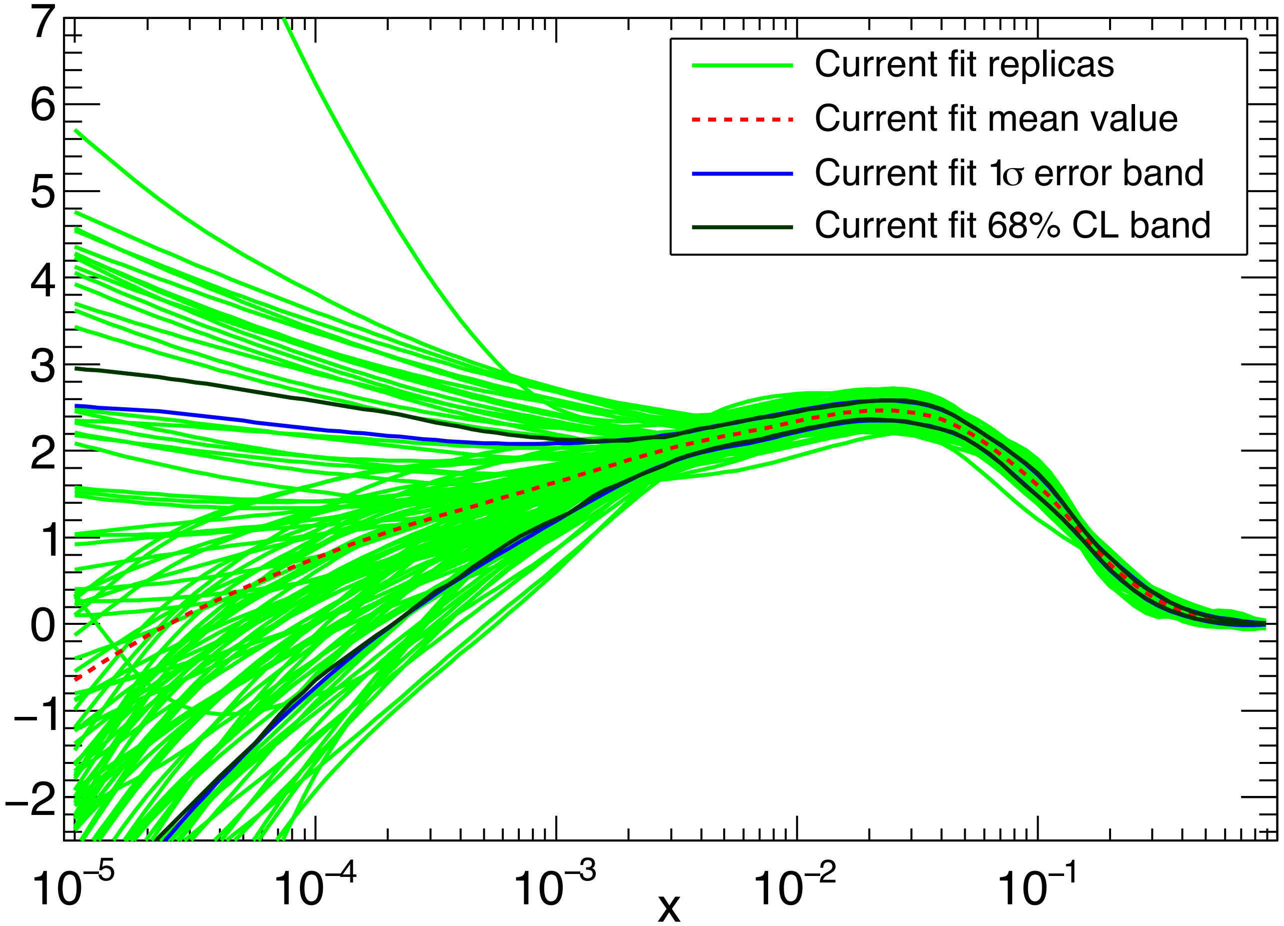
Several procedural factors conspire to make NNPDF fits particularly demanding

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*



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

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

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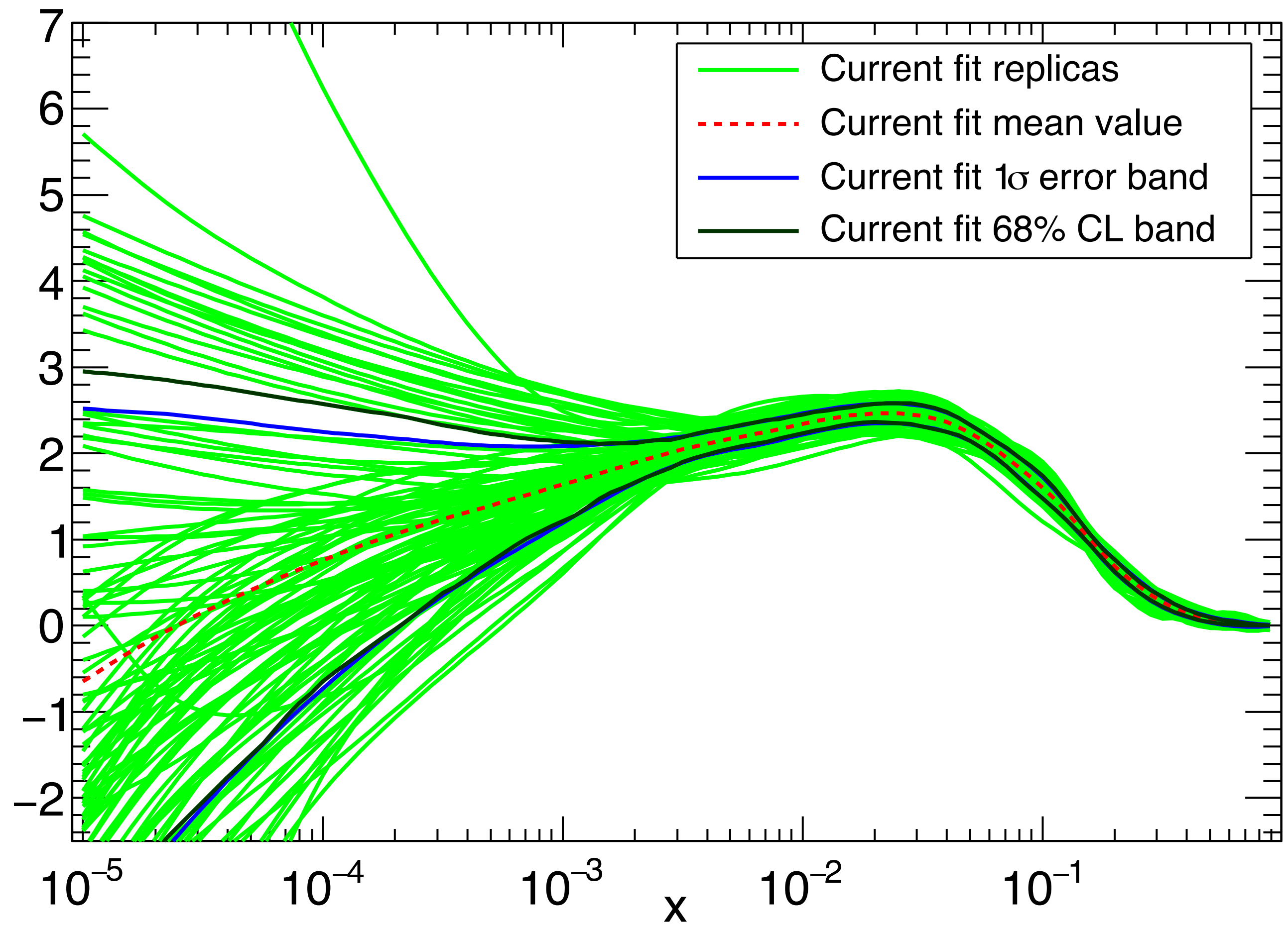

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