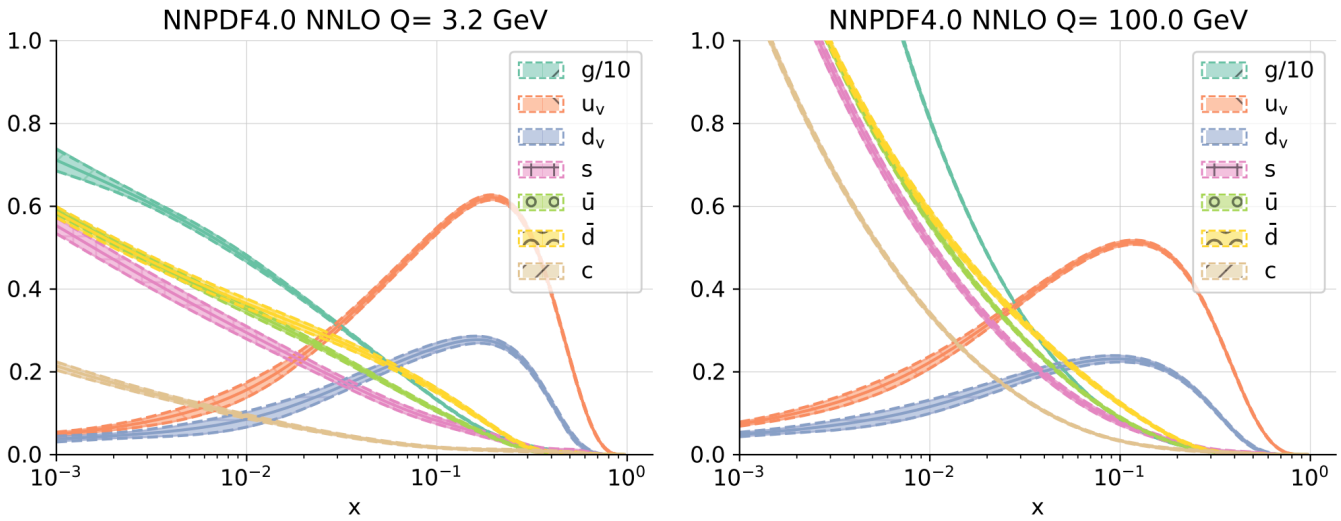
# The NNPDF4.0 global analysis of proton structure

**Juan Rojo,** VU Amsterdam & Nikhef

**ATLAS Standard Model Plenary Meeting**

**7th October 2021**



# NNPDF4.0:
# Setup & Validation

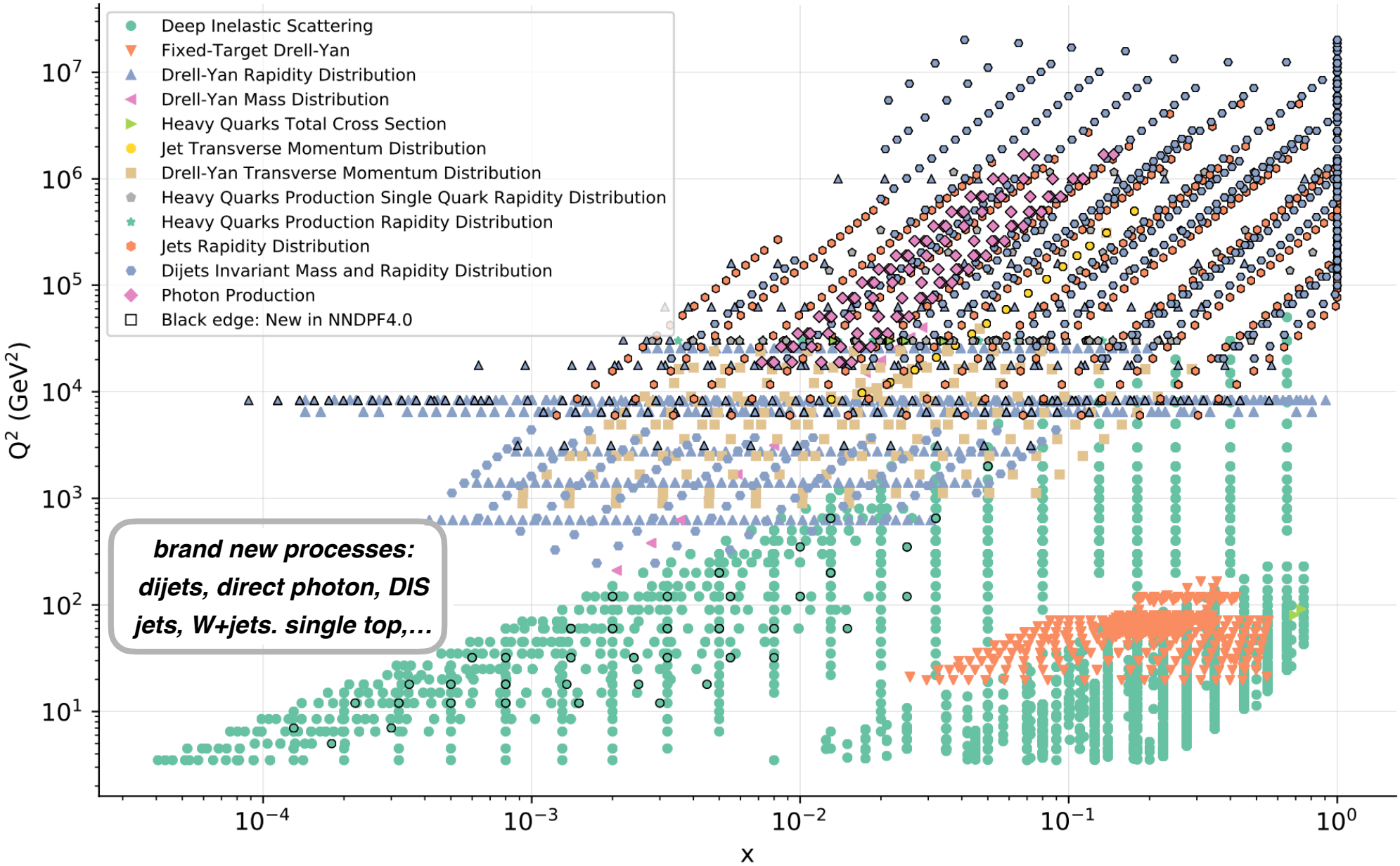
# The path to NNPDF4.0

Collaborative progress towards extending data, theory and methodology

| | | |
|---|---|---|
| 06/2017 | **NNPDF3.1** | [EPJ C77 (2017) 663] |
| 10/2017 | NNPDF3.1sx: PDFs with small-$x$ resummation | [EPJ C78 (2018) 321] |
| 12/2017 | NNPDF3.1luxQED: consistent photon PDF à la luxQED | [SciPost Phys. 5 (2018) 008] |
| 02/2018 | NNPDF3.1+ATLASphoton: inclusion of direct photon data | [EPJ C78 (2018) 470] |
| 12/2018 | NNPDF3.1alphas: $\alpha_s$ from a correlated-replica method | [EPJ C78 (2018) 408] |
| 12/2018 | NNPDF3.1nuc: heavy ion nuclear uncertainties in a fit | [EPJ C79 (2019) 282] |
| 05/2019 | NNPDF3.1th: missing higher-order uncertainties in a fit | [EPJ C79 (2019) 838; ibid. 931] |
| 07/2019 | Gradient descent and hyperoptimisation in PDF fits | [EPJ C79 (2019) 676] |
| 12/2019 | NNPDF3.1singletop: inclusion of single top $t$-channel data | [JHEP 05 (2020) 067] |
| 05/2020 | NNPDF3.1dijets: comparative study of single- and di-jets | [EPJ C80 (2020) 797] |
| 06/2020 | Positivity of $\overline{\mathrm{MS}}$ PDFs | [JHEP 11 (2020) 129] |
| 08/2020 | PineAPPL: fast evaluation of EW$\times$QCD corrections | [JHEP 12 (2020) 108] |
| 08/2020 | NNPDF3.1strangeness: assessment of strange-sensitive data | [EPJ C80 (2020) 1168] |
| 11/2020 | NNPDF3.1deu: deuteron uncertainties in a fit | [EPJ C81 (2021) 37] |
| 03/2021 | Future tests | [arXiv:2103.08606] |
| 2021 | **NNPDF4.0** | **September 2021** |

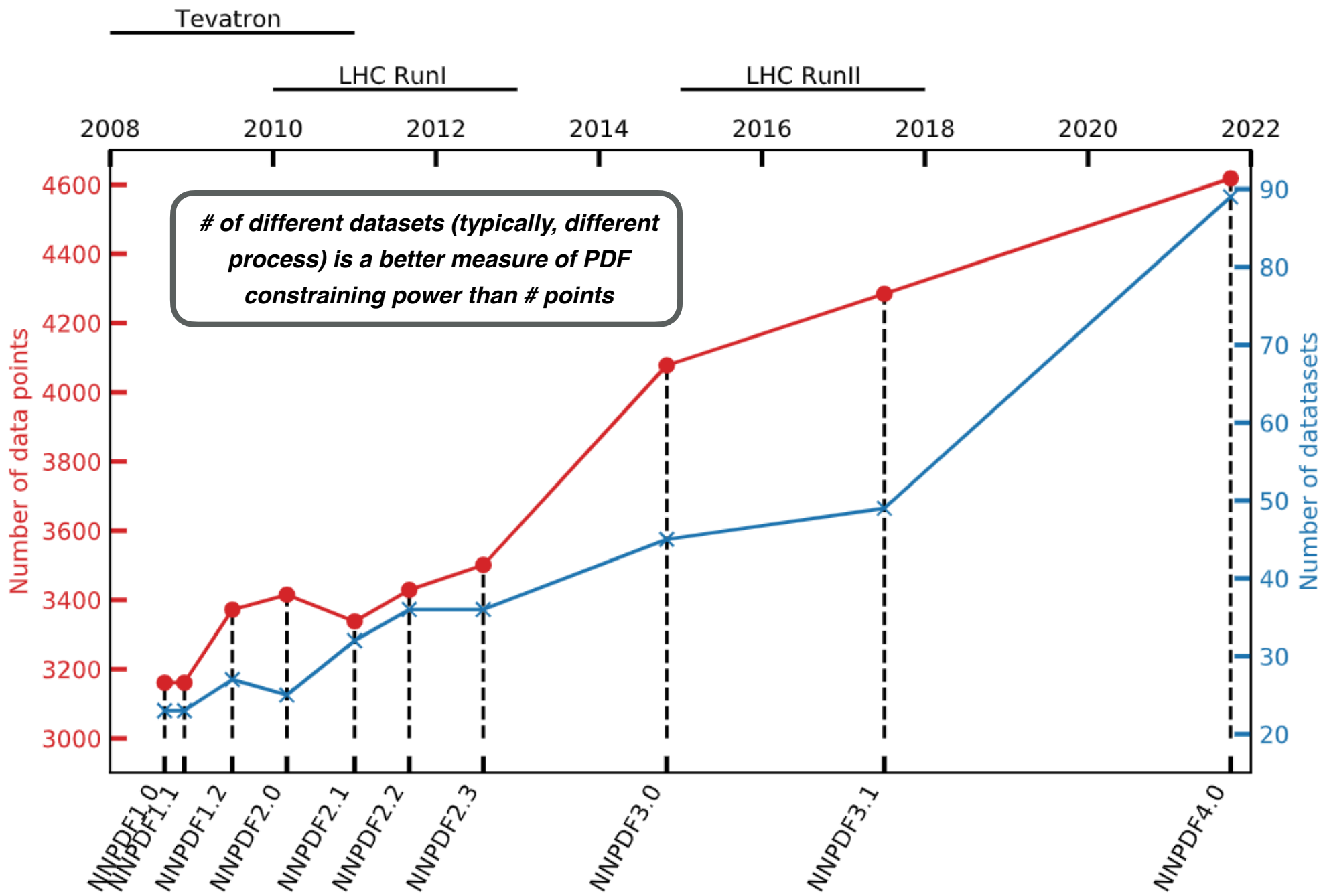
Culmination of extensive efforts from the last four years!

# The NNPDF4.0 dataset



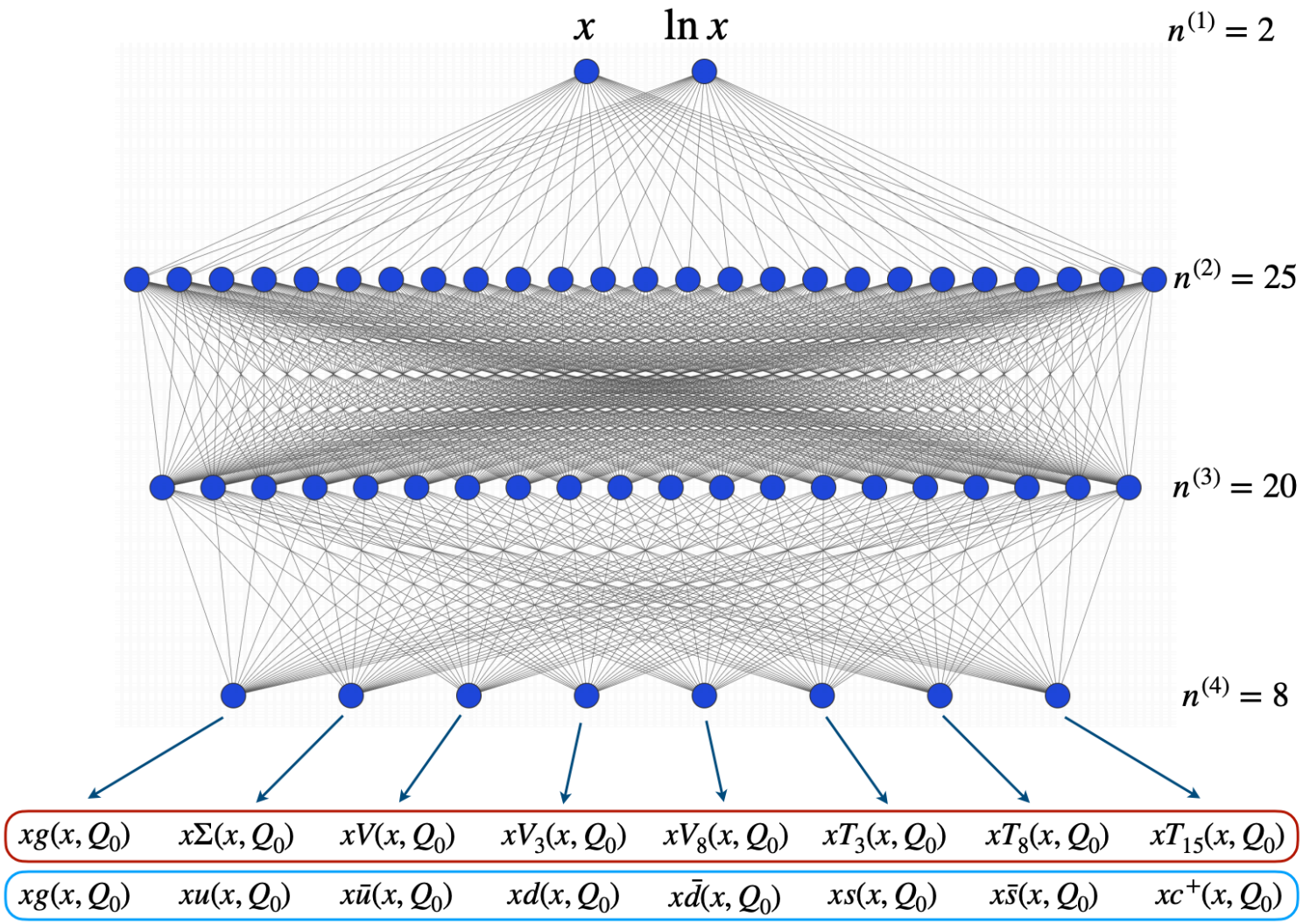

$\mathcal{O}(50)$ data sets investigated; $\mathcal{O}(400)$ data points more in NNPDF4.0 than in NNPDF3.1

# From NNPDF1.0 to NNPDF4.0



# Improved fitting methodology

- ☑ **Stochastic Gradient Descent** via TensorFlow for NN training
- ☑ Automated model **hyperparameter optimisation:** NN architecture, minimiser, learning rates …
- ☑ Validation with **future tests** (forecasting new datasets) and **closure tests** (data based on known PDFs)




***evolution basis***

***flavor basis***

PDFs should be independent of **parametrisation basis!**

# Improved fitting methodology

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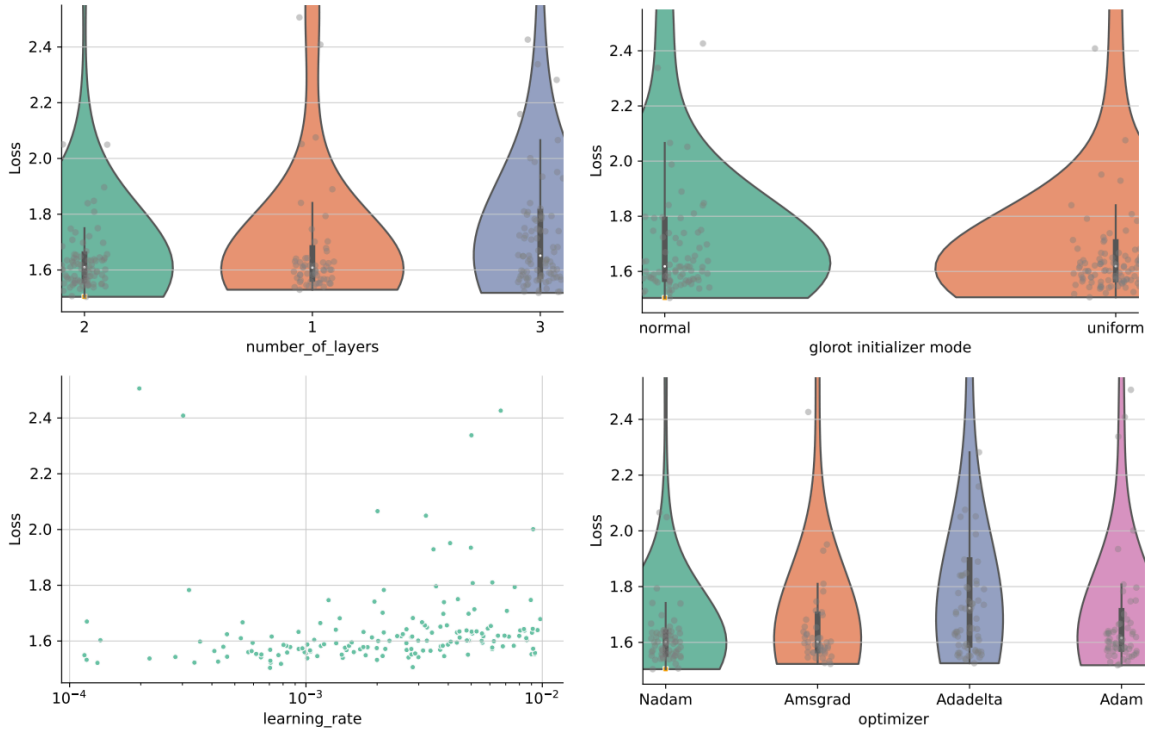
***Loss (``average")***

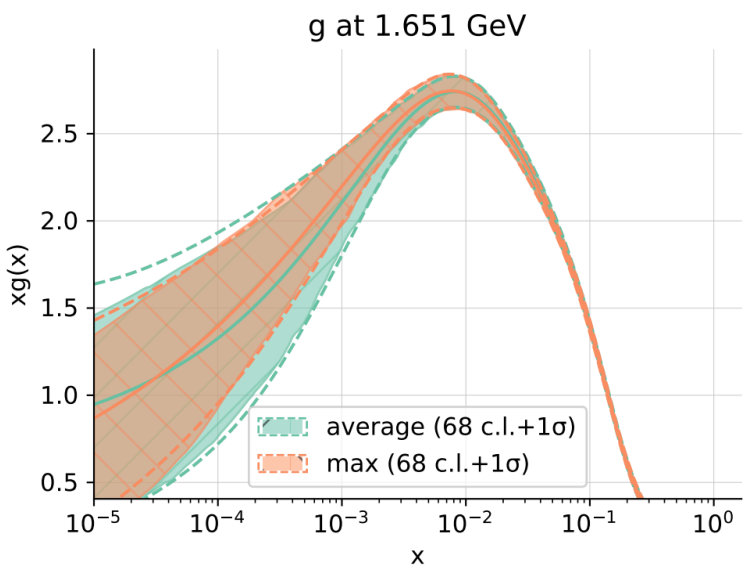
***ML model hyperparams***

$$\hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}\in\boldsymbol{\Theta}} \left( \frac{1}{n_{\rm fold}} \sum_{k=1}^{n_{\rm fold}} \chi_k^2(\boldsymbol{\theta}) \right)$$

***Loss (``max")***

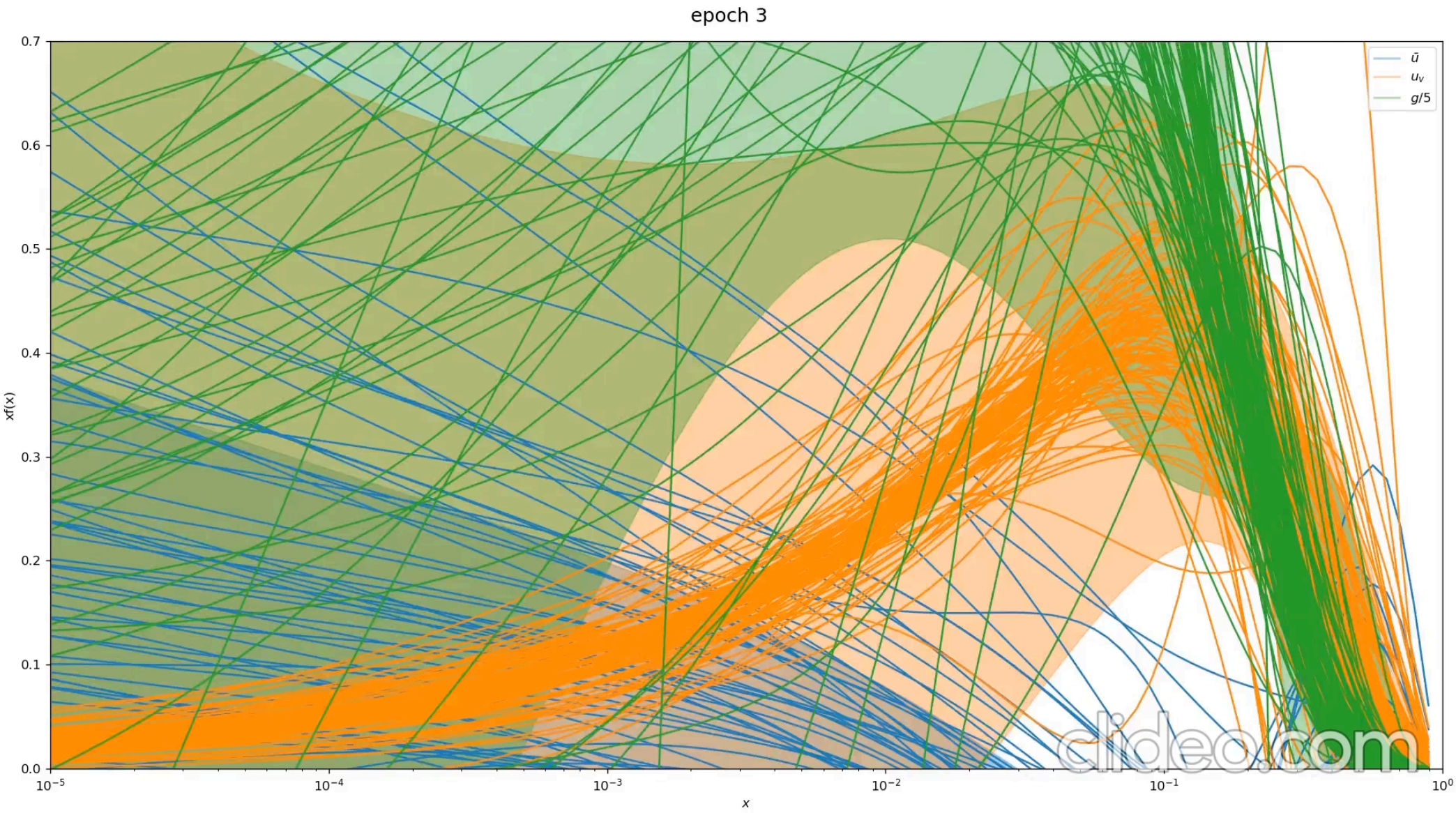
$$L = \max\left(\chi_1^2, \chi_2^2, \chi_3^2, \ldots, \chi_{n_{\rm fold}}^2\right)$$




***Stability wrt hyperopt loss function***

# Improved fitting methodology




Illustrating the outcome of **SGD minimisation** (band: standard deviation over the MC replicas)

# Closure and future tests

## *Closure tests*

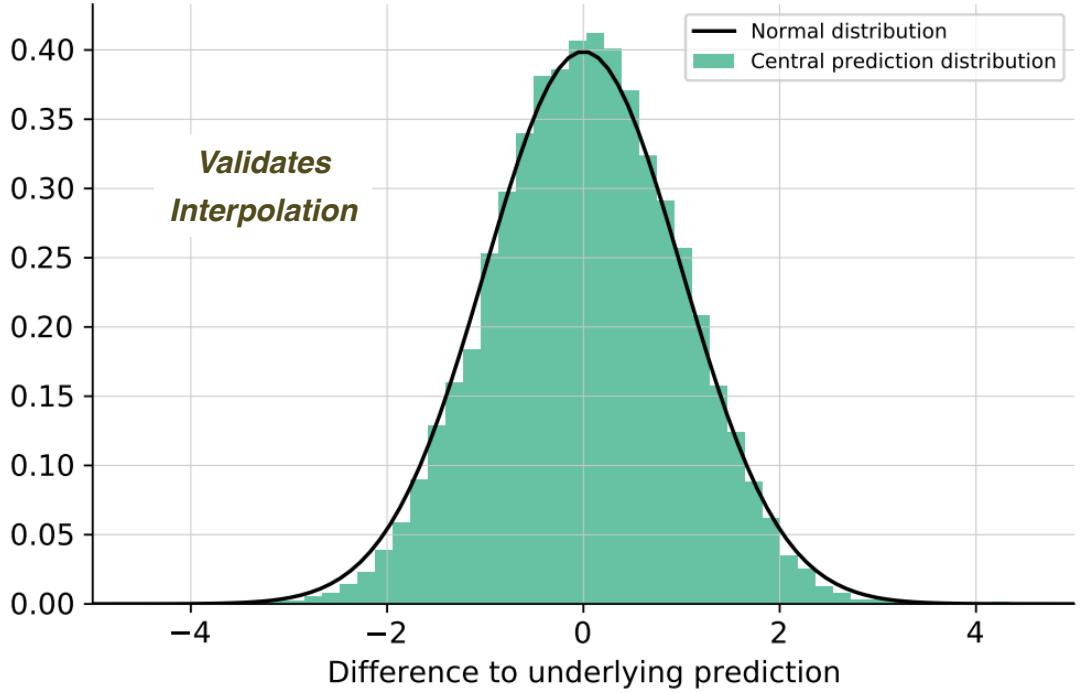
Generate **toy data** based on some known PDF, check *a posteriori* that the **true underlying law is reproduced** within errors

*mean NN prediction* *true central value*

*generate many toys*

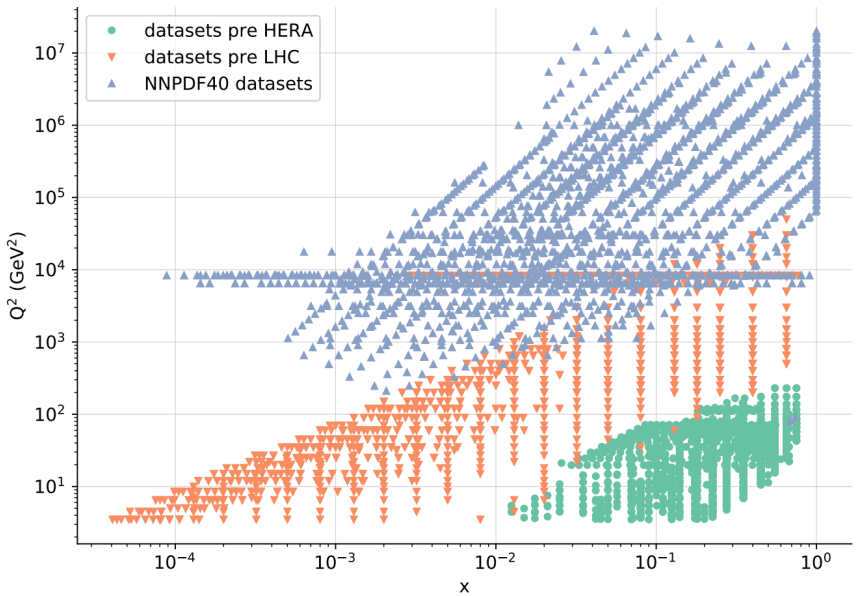
$$\delta_i^{(l)} \equiv \frac{\left(\mathbf{E}_\epsilon\left[g_i\right]^{(l)} - f_i\right)}{\sigma_i^{(l)}}$$

*data index* *PDF uncertainty*



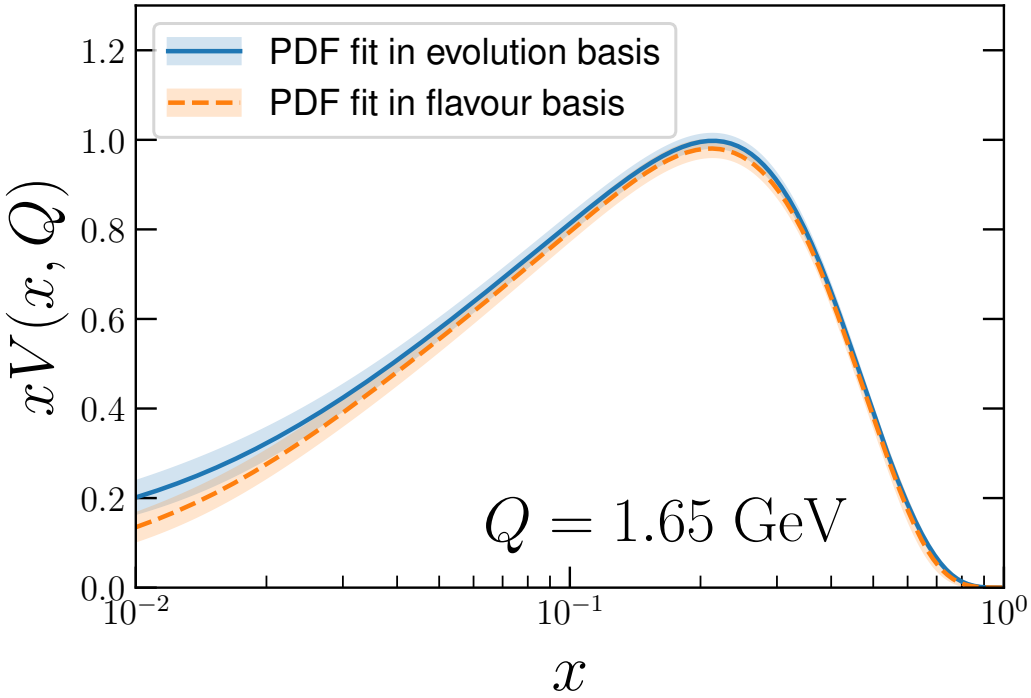

## *Future tests*

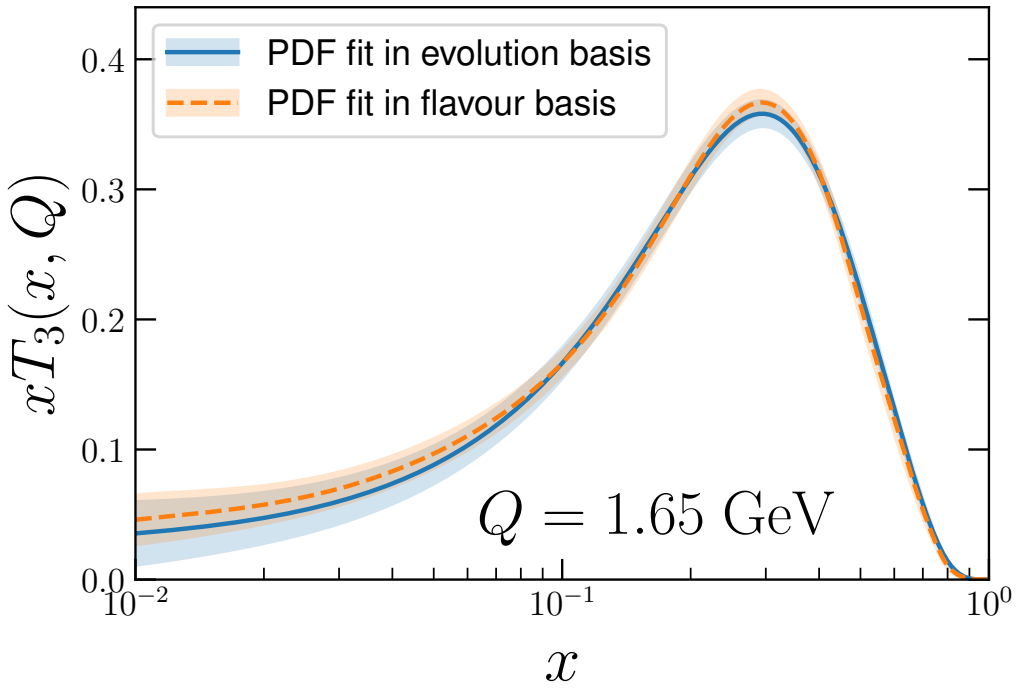
Fit data restricted to specific kinematic regions, then verify **succesful extrapolation**




| Process | $\chi^2$ pre-HERA | $\chi^2$ pre-LHC | $\chi^2$ Global |
|---|---|---|---|
| Fixed target NC DIS | 1.05 | 1.18 | 1.23 |
| Fixed target CC DIS | 0.80 | 0.85 | 0.87 |
| Fixed target Drell-Yan | 0.92 | 1.27 | 1.59 |
| HERA | *27.20* (**1.23**) | 1.22 | 1.20 |
| Collider Drell-Yan (Tevatron) | *5.52* (**1.02**) | 0.99 | 1.11 |
| Collider Drell-Yan (LHC) | *18.91* (**1.31**) | *2.63* (**1.58**) | 1.53 |
| Top quark production | *20.01* (**1.06**) | *1.30* (**0.87**) | 1.01 |
| Jet production | *2.69* (**0.98**) | *2.12* (**1.10**) | 1.26 |

# Parametrisation basis independence




***evolution basis PDF parametrisation:***

$$xV(x, Q_0) \propto \mathrm{NN}_V(x)$$

$$xT_3(x, Q_0) \propto \mathrm{NN}_{T_3}(x)$$

Radically different strategies to parametrize the **quark PDF flavour combinations** lead to identical results: ultimate test of **parametrisation independence**

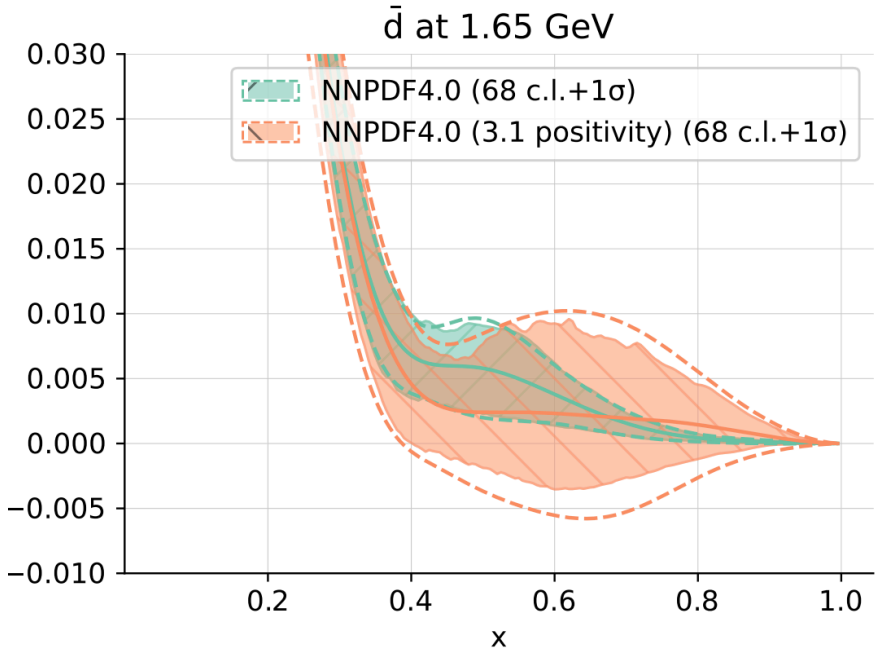
***first time ever!***

***flavour basis PDF parametrisation:***

$$xV(x, Q_0) \propto \left(\mathrm{NN}_u(x) - \mathrm{NN}_{\bar{u}}(x) + \mathrm{NN}_d(x) - \mathrm{NN}_{\bar{d}}(x) + \mathrm{NN}_s(x) - \mathrm{NN}_{\bar{s}}(x)\right)$$

$$xT_3(x, Q_0) \propto \left(\mathrm{NN}_u(x) + \mathrm{NN}_{\bar{u}}(x) - \mathrm{NN}_d(x) - \mathrm{NN}_{\bar{d}}(x)\right)$$

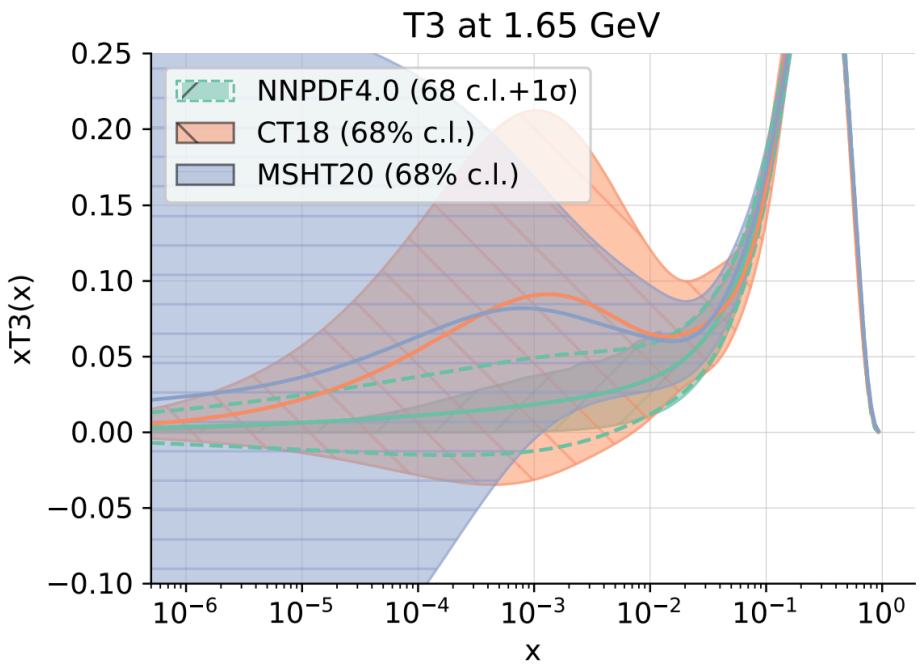
# Positivity and integrability

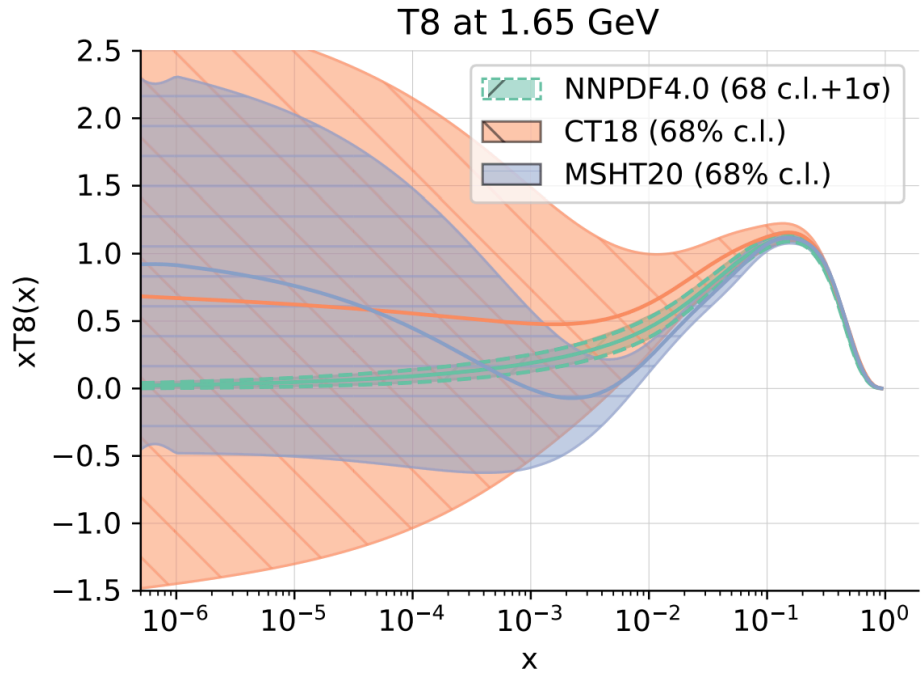



- MSbar PDFs have been shown to satisfy **positivity** requirements at all orders: **reduce large-*x* uncertainties**

- The non-singlet quark triplet and octet should be *integrable* (e.g. Gottfried sum rule): r**educe small-*x* uncertainties**

$$T_8 = (u + \bar{u}) + \left(d + \bar{d}\right) - 2\,(s + \bar{s})$$



# A ML open-source QCD fitting framework

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September 1, 2021

Software | Open Access

## NNPDF/nnpdf: An open-source machine learning framework for global analyses of parton distributions

Richard D. Ball; Stefano Carrazza; Juan M. Cruz-Martinez; Luigi Del Debbio; Stefano Forte; Tommaso Giani; Shayan Iranipour; Zahari Kassabov; Jose I. Latorre; Emanuele R. Nocera; Rosalyn L. Pearson; Juan Rojo; Roy Stegeman; Christopher Schwan; Maria Ubiali; Cameron Voisey; Michael Wilson

This version is used for producing all the publicly released fits for NNPDF4.0.

Preview

nnpdf-4.0.3.zip

! The previewer is not showing all the files

| | |
|---|---|
| NNPDF-nnpdf-1229126 | |
| .ciscripts | |
| build-deploy-linux.sh | 1.1 kB |
| build-deploy-osx.sh | 966 Bytes |
| deploy-documentation.sh | 878 Bytes |
| .github | |
| workflows | |
| rules.yml | 3.4 kB |
| .gitignore | 5.0 kB |
| .pylintrc | 15.1 kB |
| .travis.yml | 3.6 kB |
| CMakeLists.txt | 9.2 kB |

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**Publication date:**
September 1, 2021

**DOI:**
DOI 10.5281/zenodo.5362229

The full **NNPDF machine learning fitting framework** has been publicly released open source, together with extensive documentation and user-friendly examples

# A ML open-source QCD fitting framework

NNPDF

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## The NNPDF collaboration

The NNPDF collaboration performs research in the field of high-energy physics. The NNPDF collaboration determines the structure of the proton using contemporary methods of artificial intelligence. A precise knowledge of the so-called **Parton Distribution Functions (PDFs)** of the proton, which describe their structure in terms of their quark and gluon constituents, is a crucial ingredient of the physics program of the Large Hadron Collider of CERN.

## The NNPDF code

The scientific output of the collaboration is freely available to the publi through the arXiv, journal repositories, and software repositories. Along with this online documentation, we release the NNPDF code used to produce the latest family of PDFs from NNPDF, NNPDF4.0. The code is made available as an open-source package together with the user-friendly examples and an extensive documentation presented here.

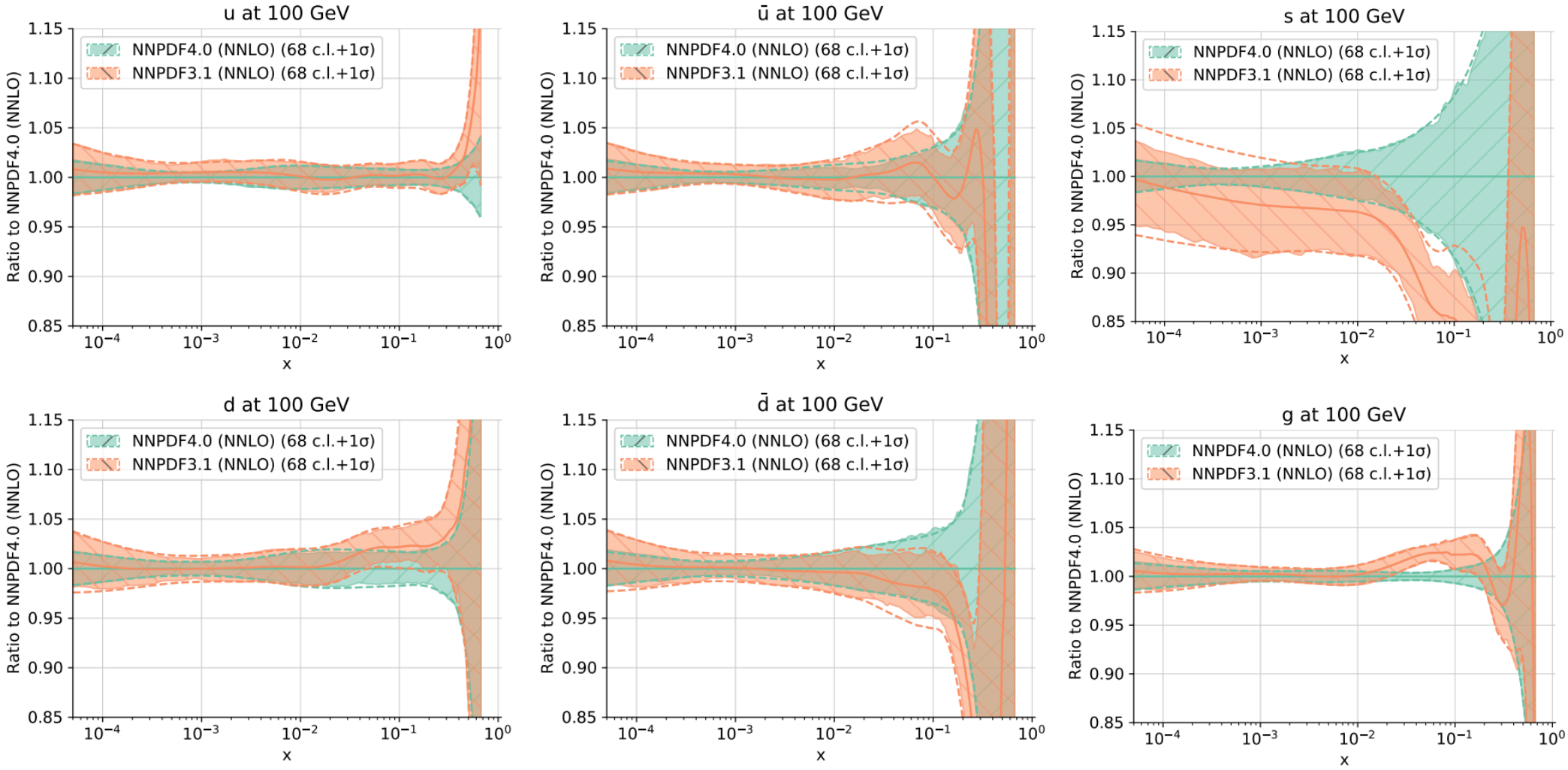
The code can be used to produce the ingredients needed for PDF fits, to run the fits themselves, and to analyse the results. This is the first framework used to produce a global PDF fit made publicly available, enabling for a detailed external validation and reproducibility of the NNPDF4.0 analysis. Moreover, the code enables the user to explore a number of phenomenological applications, such as the assessment of the impact of new experimental data on PDFs, the effect of changes in theory settings on the resulting PDFs and a fast quantitative comparison between theoretical predictions and experimental data over a broad range of observables.

If you are a new user head along to Getting started and check out the Tutorials.

Opportunities for many studies within the **LHC experimental community**: looking forward to suggestions and starting new collaborations!

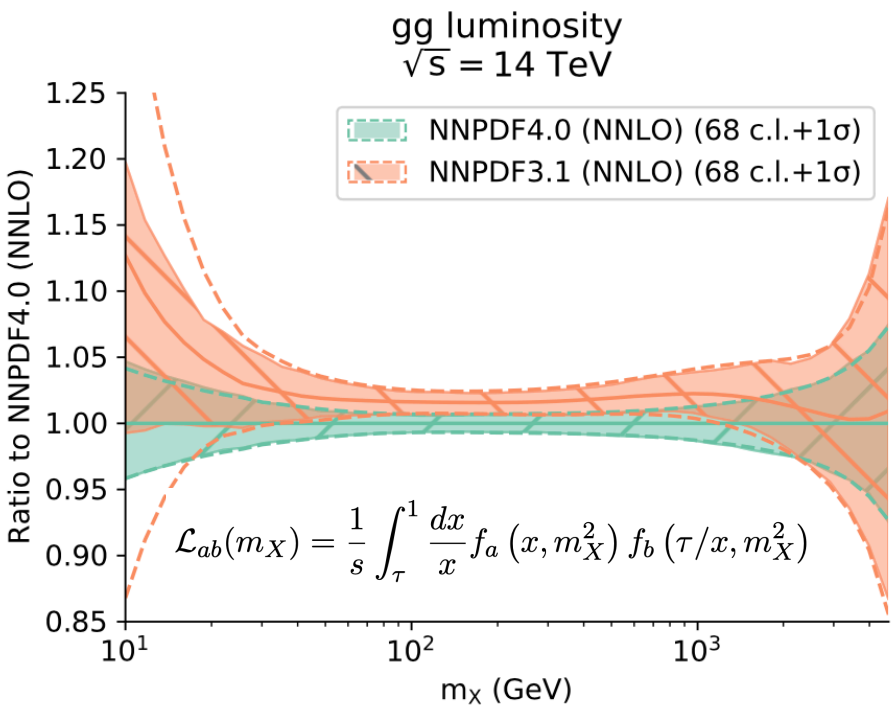
# NNPDF4.0: Results

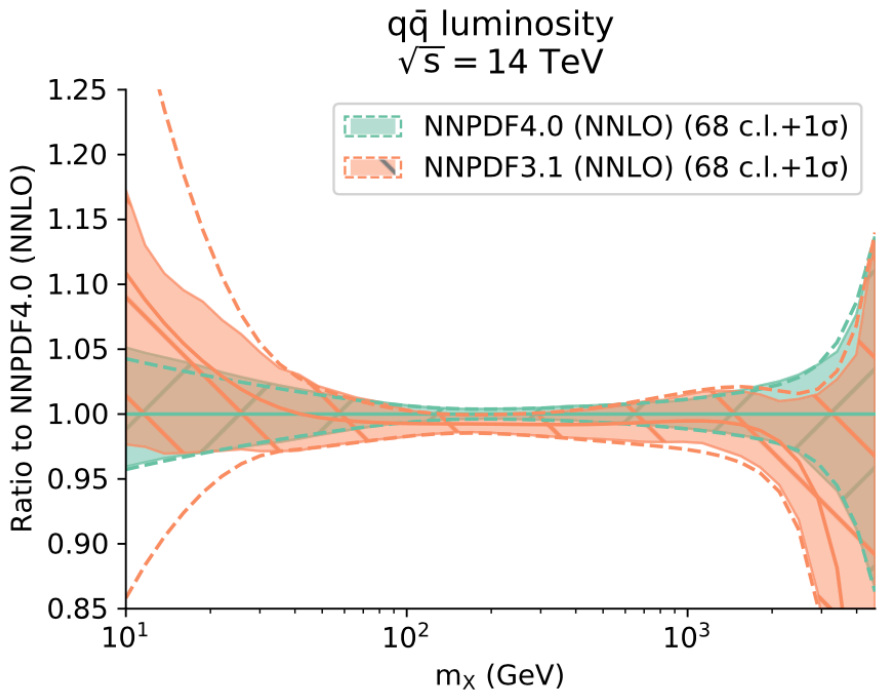
# Comparison with NNPDF3.1

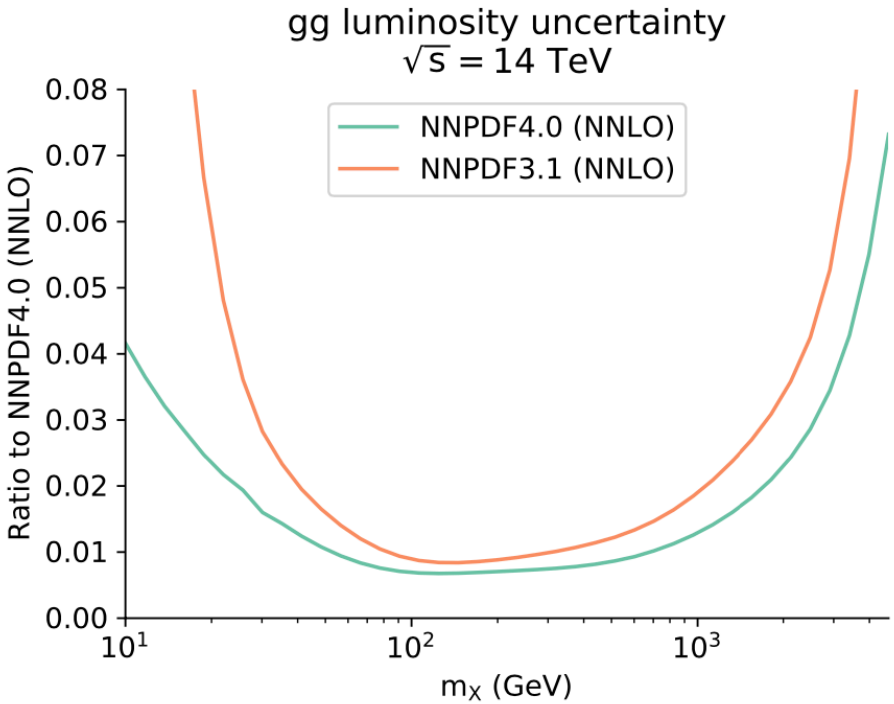


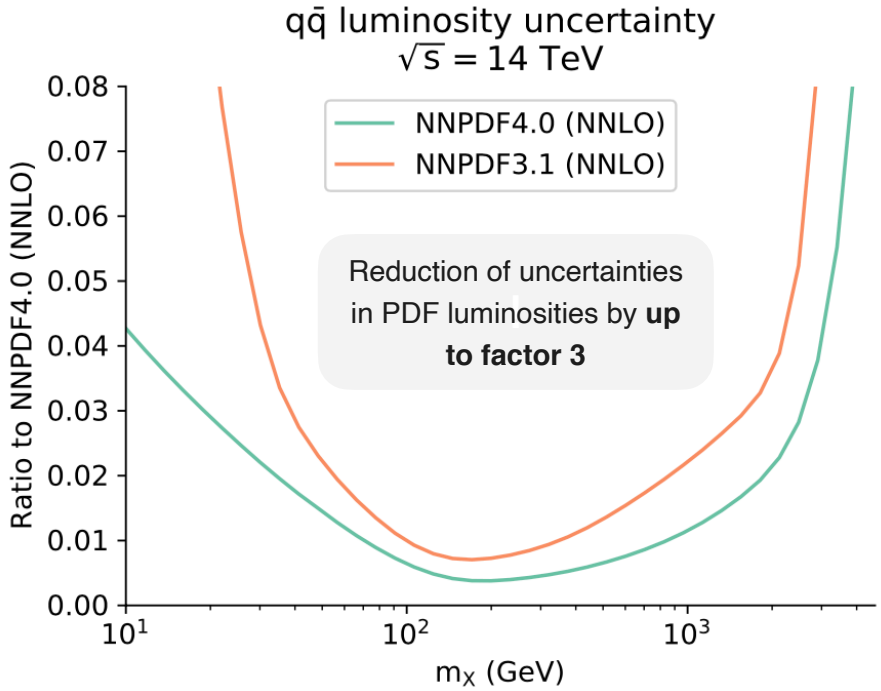

- **Good agreement** with NNPDF3.1 within uncertainties, with NNPDF4.0 being more precise
- Differences can be traced back to the **impact of specific datasets** (e.g. dijets for large-*x* gluon) or improvements in **theory calculations** (e.g. NNLO corrections in dimuon DIS for strangeness)

# Comparison with NNPDF3.1

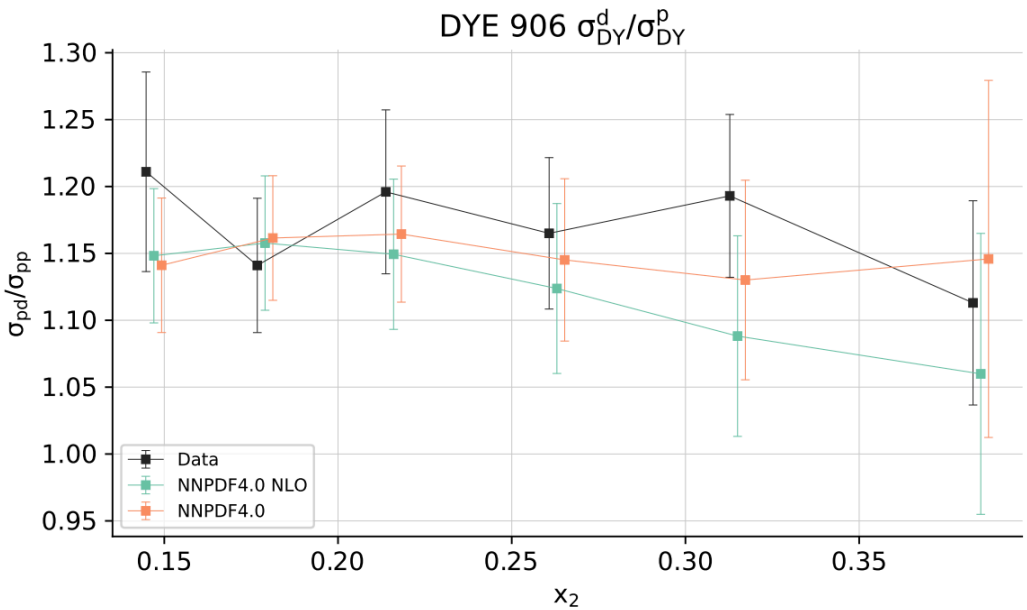


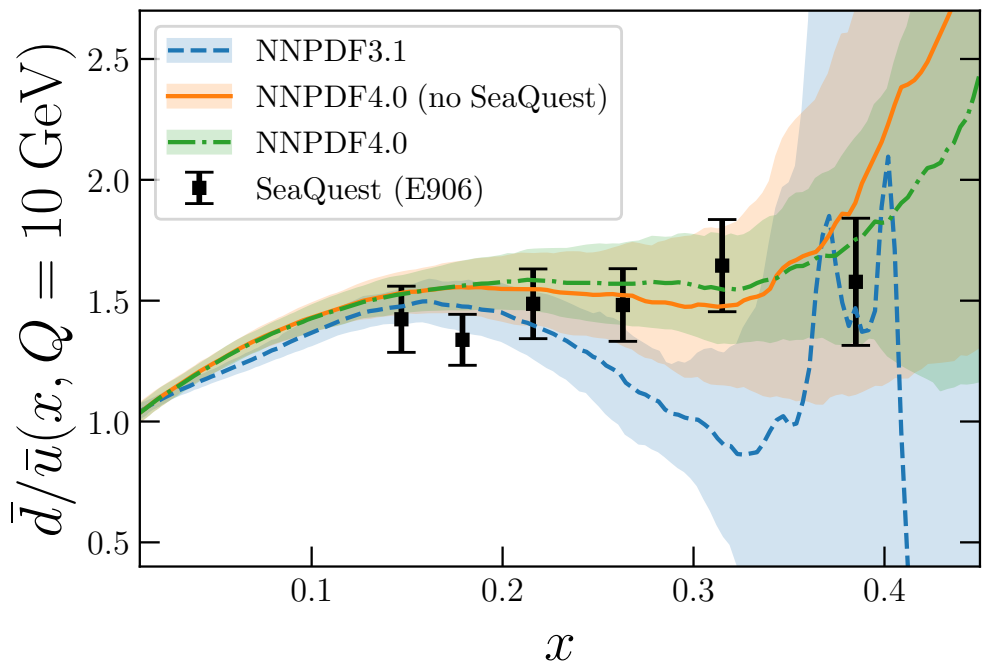



# Antimatter asymmetry



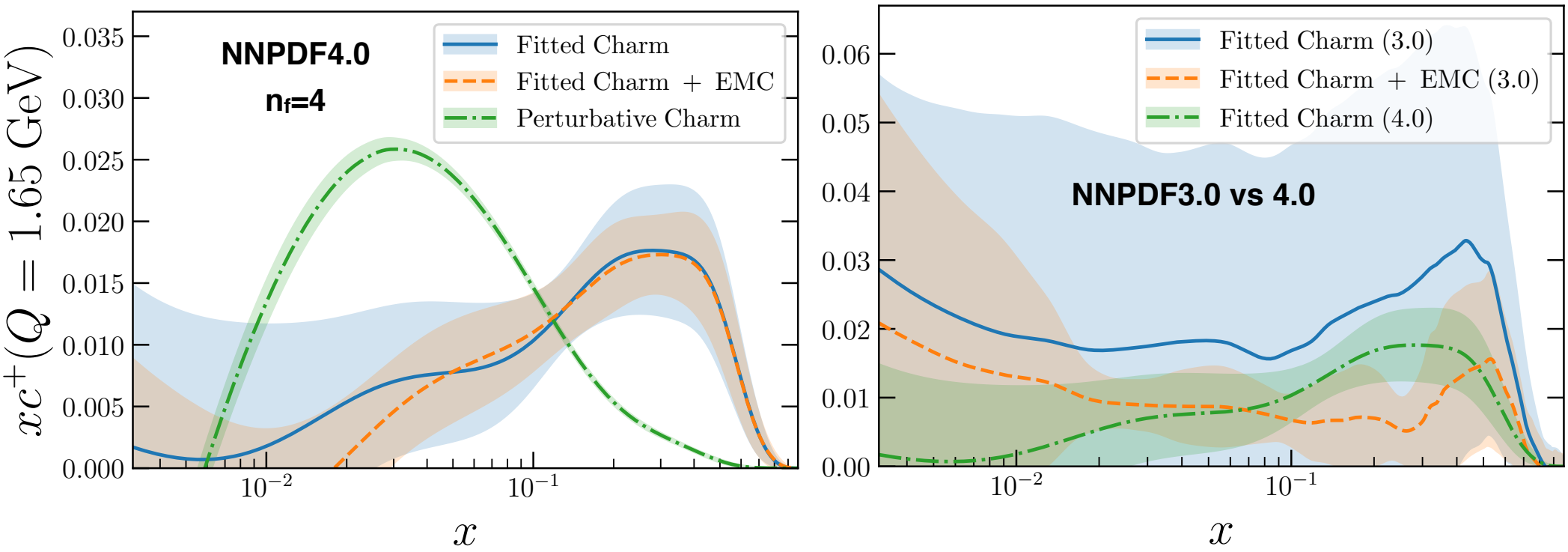

- The recent SeaQuest measurement claims evidence for **quark sea (`proton antimatter”) asymmetry**

$$\frac{\sigma_{\mathrm{DY,deuterium}}}{\sigma_{\mathrm{DY,hydrogen}}} \approx 1 + \frac{\bar{d}_p(x_t)}{\bar{u}_p(x_t)}$$

***with many caveats!***

- Actually, SeaQuest further confirms the **global fit prediction**, which agrees with it even when not included
- Already well described by **NNPDF3.1** within uncertainties

# Intrinsic charm

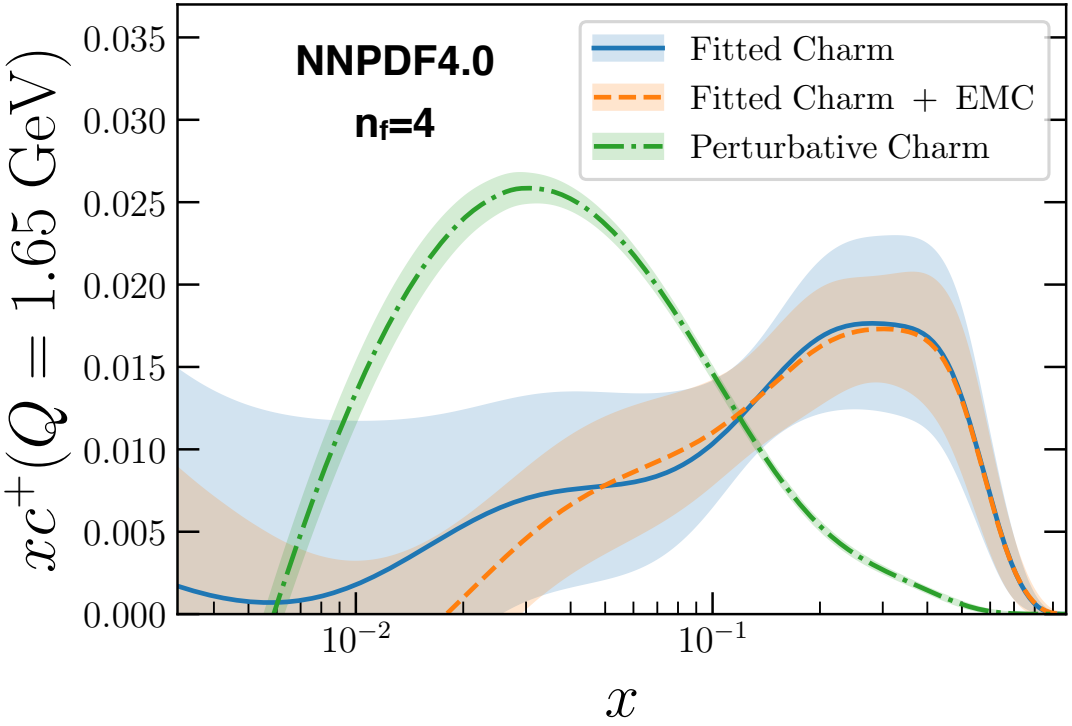


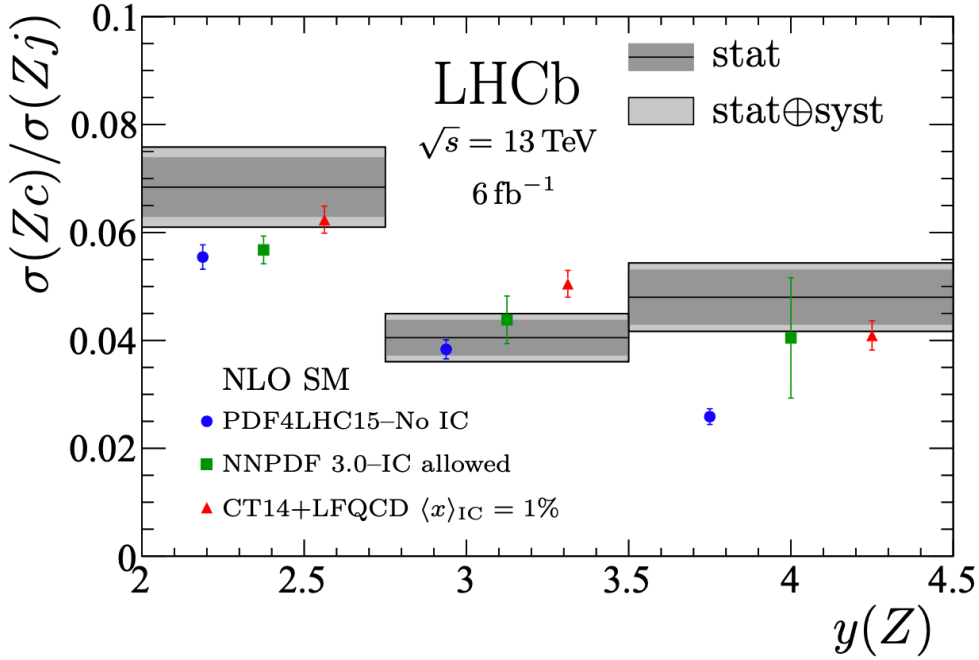

- ☑ Increasing evidence for **non-perturbative charm component** within the proton, robust upon conversion to the **3FNS** via backwards evolution and matching conditions (WIP)

- ☑ Bulk of constraints provided by new **precision LHC data**, complemented by fixed-target DIS

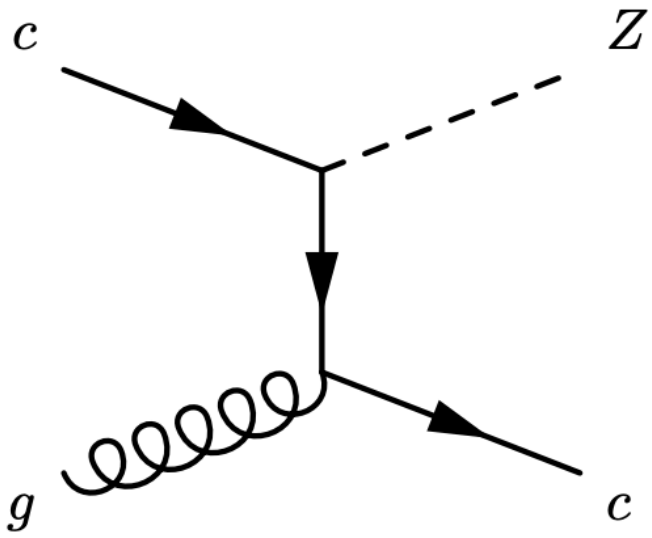
- ☑ As opposed to previous studies, impact of the **EMC charm measurements** mild now. Information provided by EMC $F_2^c$ consistent with latest collider data

# Intrinsic charm

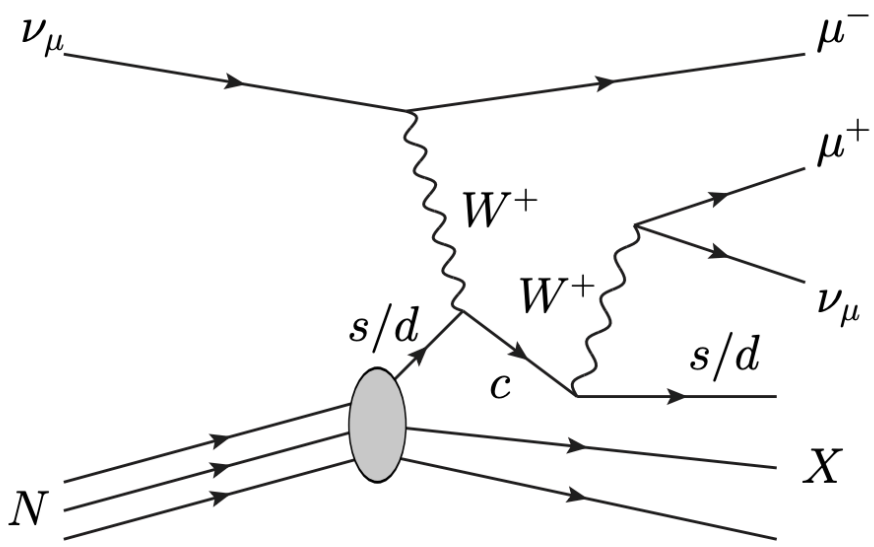



Consistent with recent LHCb measurements of **enhanced Z+charm production** in the forward region

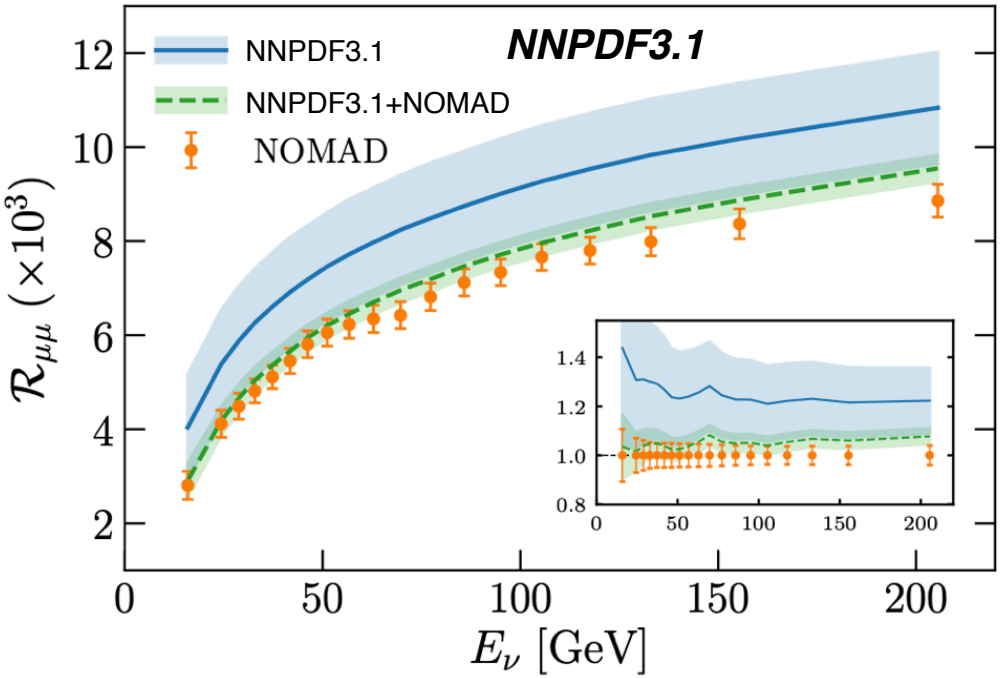


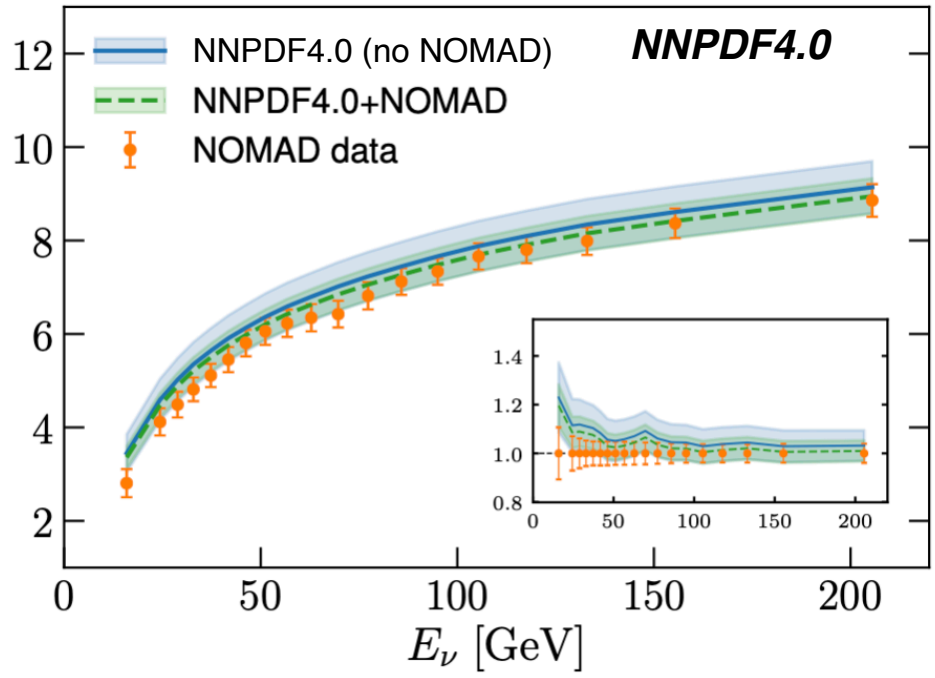
# The strangest proton




- ☑ NOMAD dimuon DIS data sensitive to **strangeness** via charged-current scattering
- ☑ Fitting NOMAD had large impact on the strangeness in NNPDF3.1, now in NNPDF4.0 the **no-NOMAD fit** is already spot on the data

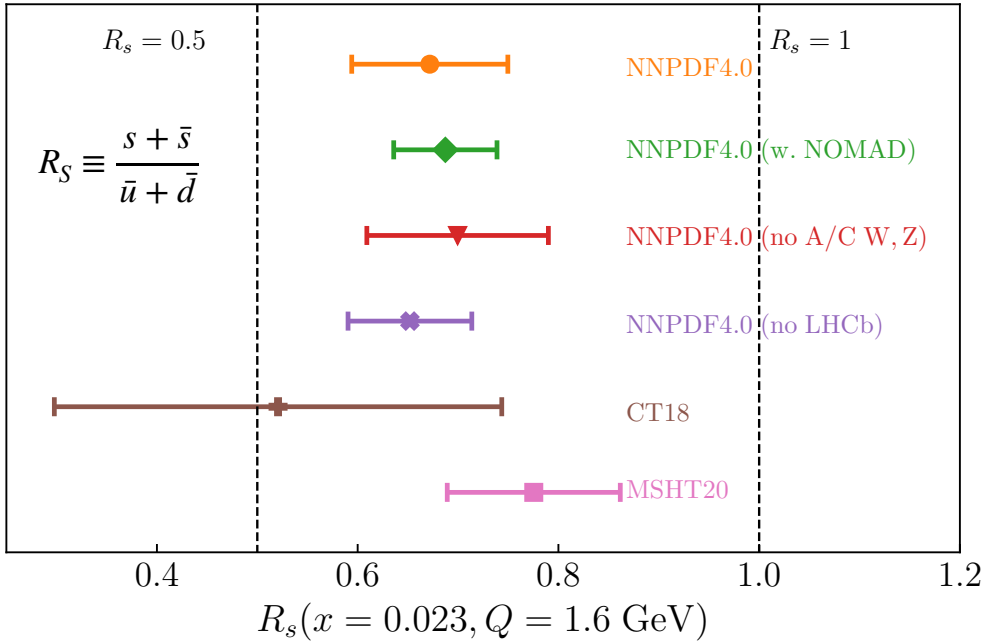
***Excellent consistency of global dataset***

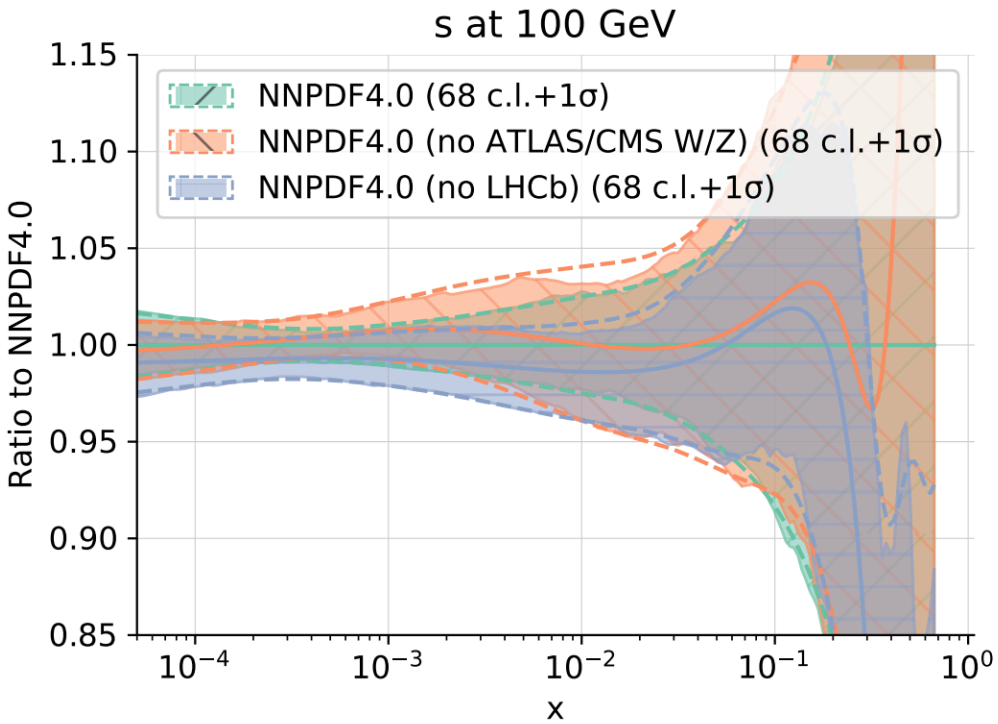


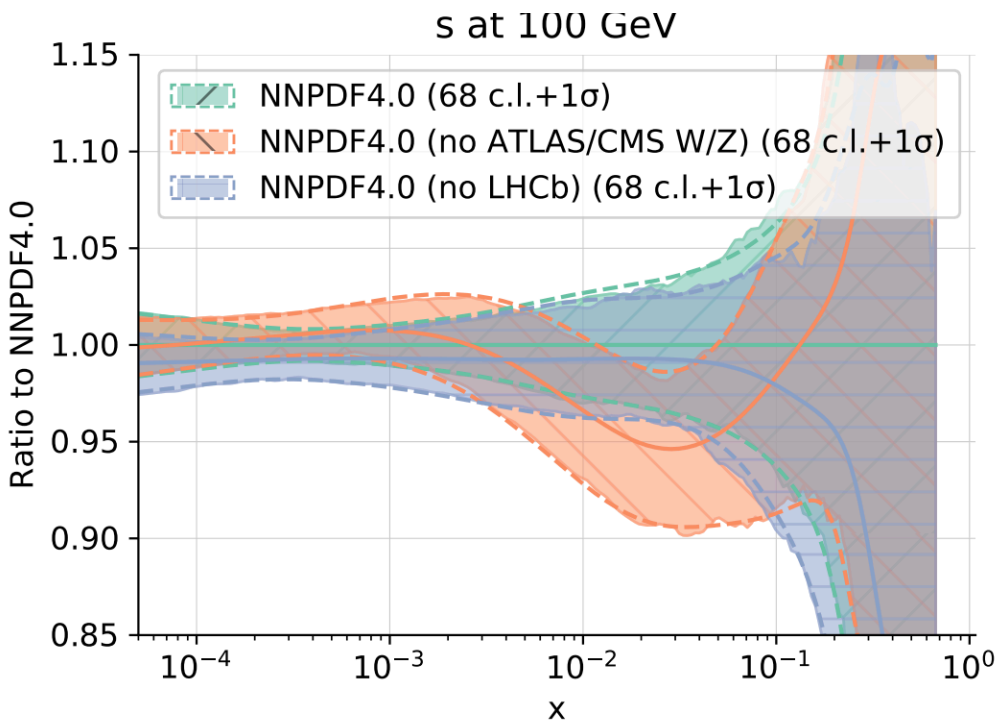



# The strangest proton

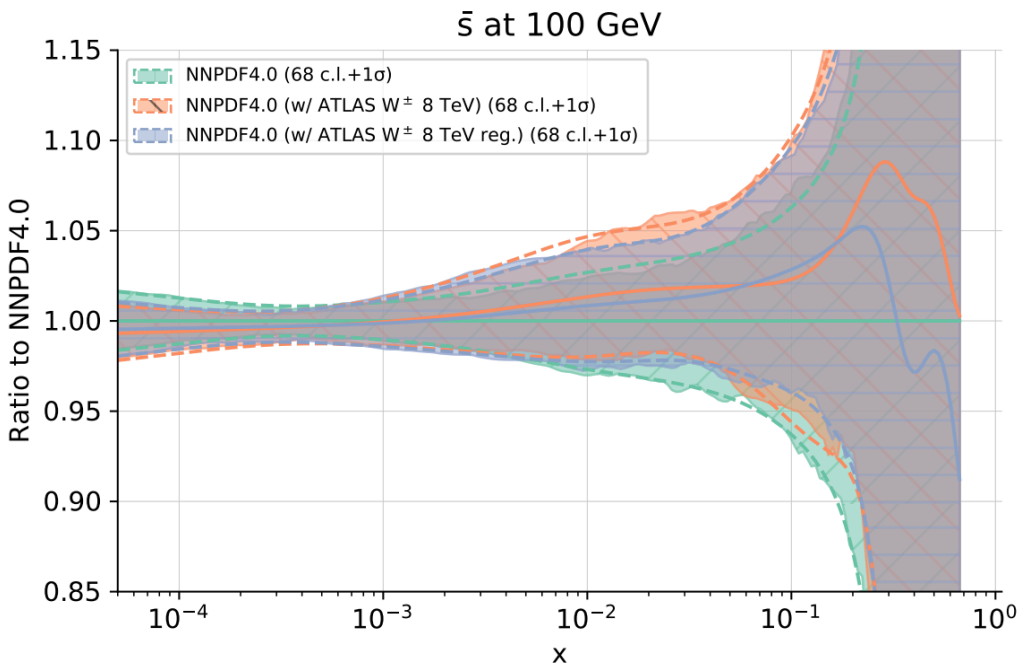
- The LHC **inclusive *W, Z* production** data are also sensitive probes of the proton strangeness
- Fit results stable, within uncertainties, when either **ATLAS/CMS** or **LHCb *W, Z*** data are removed
- **No tension** between LHC and DIS neutrino data observed

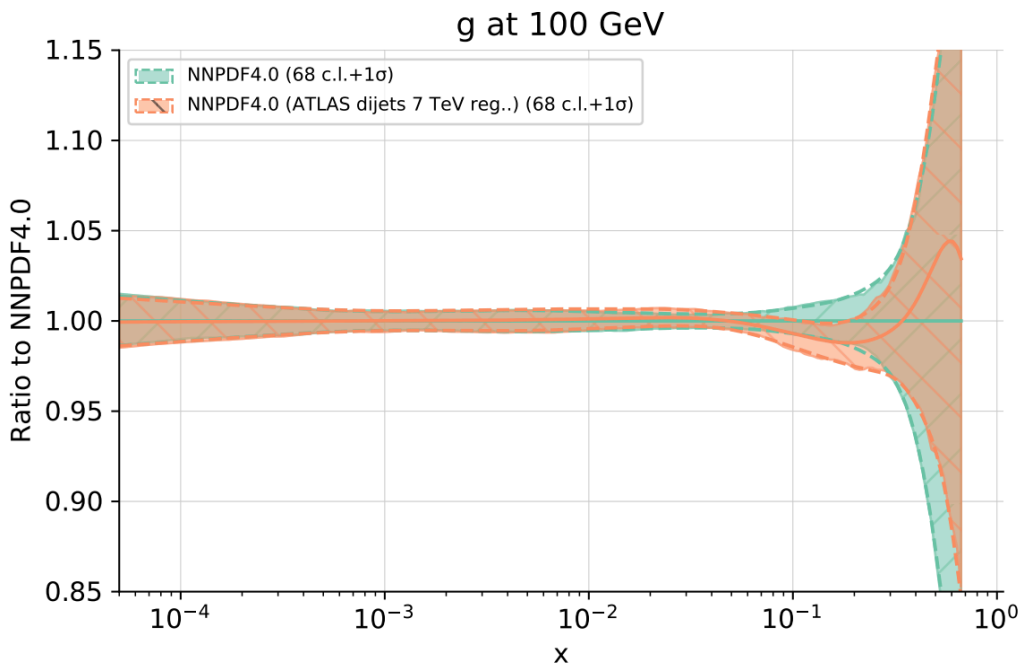


# Impact of decorrelation models



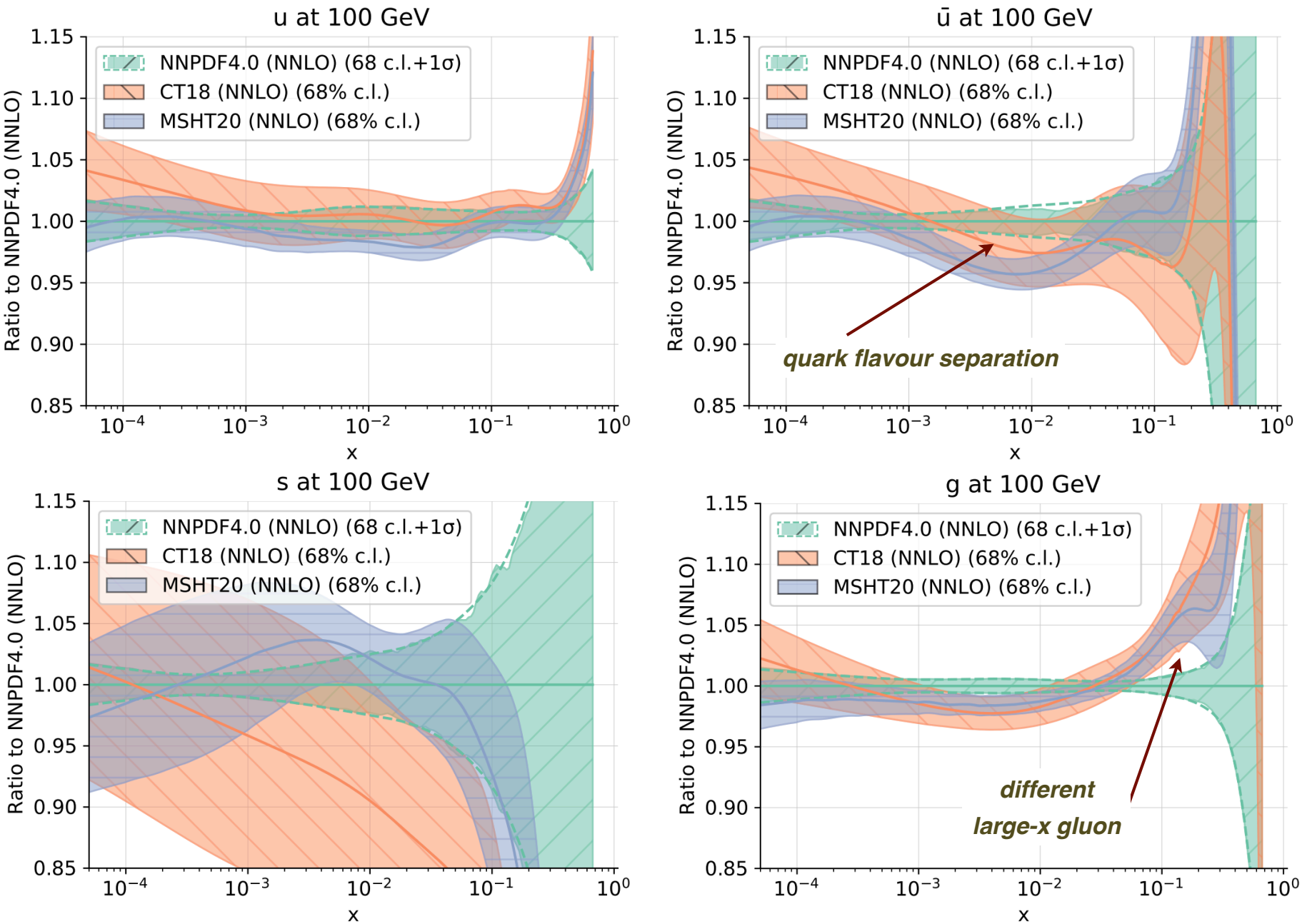

- ☑ Certain datasets exhibit covmats where **small changes in correlations** lead to **large impact in χ²**
- ☑ Assess impact in fit by transforming the original covmat into a matrix with the same eigenvectors but with **clipped eigenvalues** below some cut-off: **stable PDFs** with much lower **χ²**

| Dataset | $N_{\rm dat}$ | $Z_{\rm orig}$ | $\chi^2_{\rm orig}$ | $\chi^2_{\rm reg}$ |
|---|---|---|---|---|
| ATLAS $W, Z$ 7 TeV CC ($\mathcal{L} = 4.6$ fb$^{-1}$) | 46 | 9.01 | 1.89 | 0.93 |
| ATLAS $W$ 8 TeV (*) | 22 | 11.28 | 3.50 | 1.15 |
| CMS dijets 7 TeV | 54 | 4.70 | 1.81 | 1.73 |
| ATLAS dijets 7 TeV | 90 | 9.93 | 2.14 | 0.92 |
| CMS 3D dijets 8 TeV (*) | 122 | 4.47 | 1.50 | 0.92 |

# Phenomenology

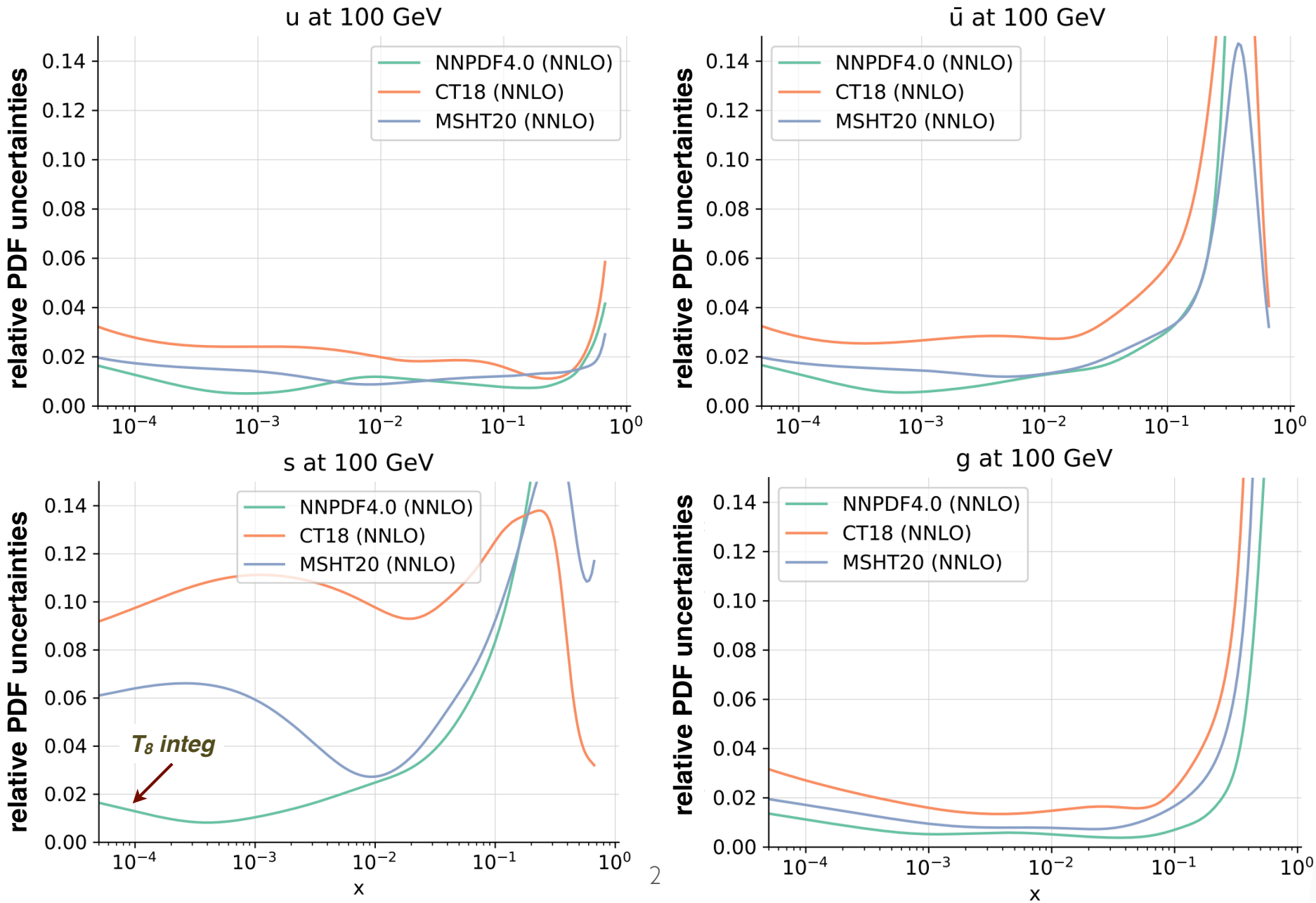
# Comparison between global fits

reasonable agreement with CT18, and MSHT20, different pattern of PDF uncertainties



# Comparison between global fits

different **pattern of PDF uncertainties** … $\delta_{\rm PDF}(\rm CT) \gtrsim \delta_{\rm PDF}(\rm MSHT) \gtrsim \delta_{\rm PDF}(\rm NNPDF)$



# Comparison between global fits

… follows pattern of **input datasets**

$$\delta_{\rm PDF}({\rm CT}) \gtrsim \delta_{\rm PDF}({\rm MSHT}) \gtrsim \delta_{\rm PDF}({\rm NNPDF})$$

| Data set | Ref. | NNPDF3.1 | NNPDF4.0 | ABMP16 | CT18 | MSHT20 |
|---|---|---|---|---|---|---|
| ATLAS $W, Z$ 7 TeV ($\mathcal{L} = 35$ pb$^{-1}$) | [51] | ✓ | ✓ | ✓ | ✓ | ✓ |
| ATLAS $W, Z$ 7 TeV ($\mathcal{L} = 4.6$ fb$^{-1}$) | [52] | ✓ | ✓ | ✗ | (✓) | ✓ |
| ATLAS low-mass DY 7 TeV | [53] | ✓ | ✓ | ✗ | (✓) | ✗ |
| ATLAS high-mass DY 7 TeV | [54] | ✓ | ✓ | ✗ | (✓) | ✓ |
| ATLAS $W$ 8 TeV | [79] | ✗ | (✓) | ✗ | ✗ | ✓ |
| ATLAS DY 2D 8 TeV | [78] | ✗ | ✓ | ✗ | ✗ | ✓ |
| ATLAS high-mass DY 2D 8 TeV | [77] | ✗ | ✓ | ✗ | (✓) | ✓ |
| ATLAS $\sigma_{W,Z}$ 13 TeV | [81] | ✗ | ✓ | ✓ | ✗ | ✗ |
| ATLAS $W$+jet 8 TeV | [93] | ✗ | ✓ | ✗ | ✗ | ✓ |
| ATLAS $Z$ $p_T$ 7 TeV | [259] | (✓) | ✗ | ✗ | (✓) | ✗ |
| ATLAS $Z$ $p_T$ 8 TeV | [63] | ✓ | ✓ | ✗ | ✓ | ✓ |
| ATLAS $W + c$ 7 TeV | [83] | ✗ | ✓ | ✗ | (✓) | ✗ |
| ATLAS $\sigma_{tt}^{\rm tot}$ 7, 8 TeV | [65] | ✓ | ✓ | ✓ | ✗ | ✗ |
| ATLAS $\sigma_{tt}^{\rm tot}$ 7, 8 TeV | [260–265] | ✗ | ✗ | ✓ | ✗ | ✗ |
| ATLAS $\sigma_{tt}^{\rm tot}$ 13 TeV ($\mathcal{L} = 3.2$ fb$^{-1}$) | [66] | ✓ | ✗ | ✓ | ✗ | ✗ |
| ATLAS $\sigma_{tt}^{\rm tot}$ 13 TeV ($\mathcal{L} = 139$ fb$^{-1}$) | [134] | ✗ | ✓ | ✗ | ✗ | ✗ |
| ATLAS $\sigma_{tt}^{\rm tot}$ and $Z$ ratios | [266] | ✗ | ✗ | ✗ | ✗ | (✓) |
| ATLAS $t\bar{t}$ lepton+jets 8 TeV | [67] | ✓ | ✓ | ✗ | ✓ | ✓ |
| ATLAS $t\bar{t}$ dilepton 8 TeV | [89] | ✗ | ✓ | ✗ | ✗ | ✓ |
| ATLAS single-inclusive jets 7 TeV, R=0.6 | [73] | ✓ | (✓) | ✗ | ✓ | ✓ |
| ATLAS single-inclusive jets 8 TeV, R=0.6 | [86] | ✗ | ✓ | ✗ | ✗ | ✗ |
| ATLAS dijets 7 TeV, R=0.6 | [148] | ✗ | ✓ | ✗ | ✗ | ✗ |
| ATLAS direct photon production 8 TeV | [100] | ✗ | (✓) | ✗ | ✗ | ✗ |
| ATLAS direct photon production 13 TeV | [101] | ✗ | ✓ | ✗ | ✗ | ✗ |
| ATLAS single top $R_t$ 7, 8, 13 TeV | [94, 96, 98] | ✗ | ✓ | ✓ | ✗ | ✗ |
| ATLAS single top diff. 7 TeV | [94] | ✗ | ✓ | ✗ | ✗ | ✗ |
| ATLAS single top diff. 8 TeV | [96] | ✗ | ✓ | ✗ | ✗ | ✗ |

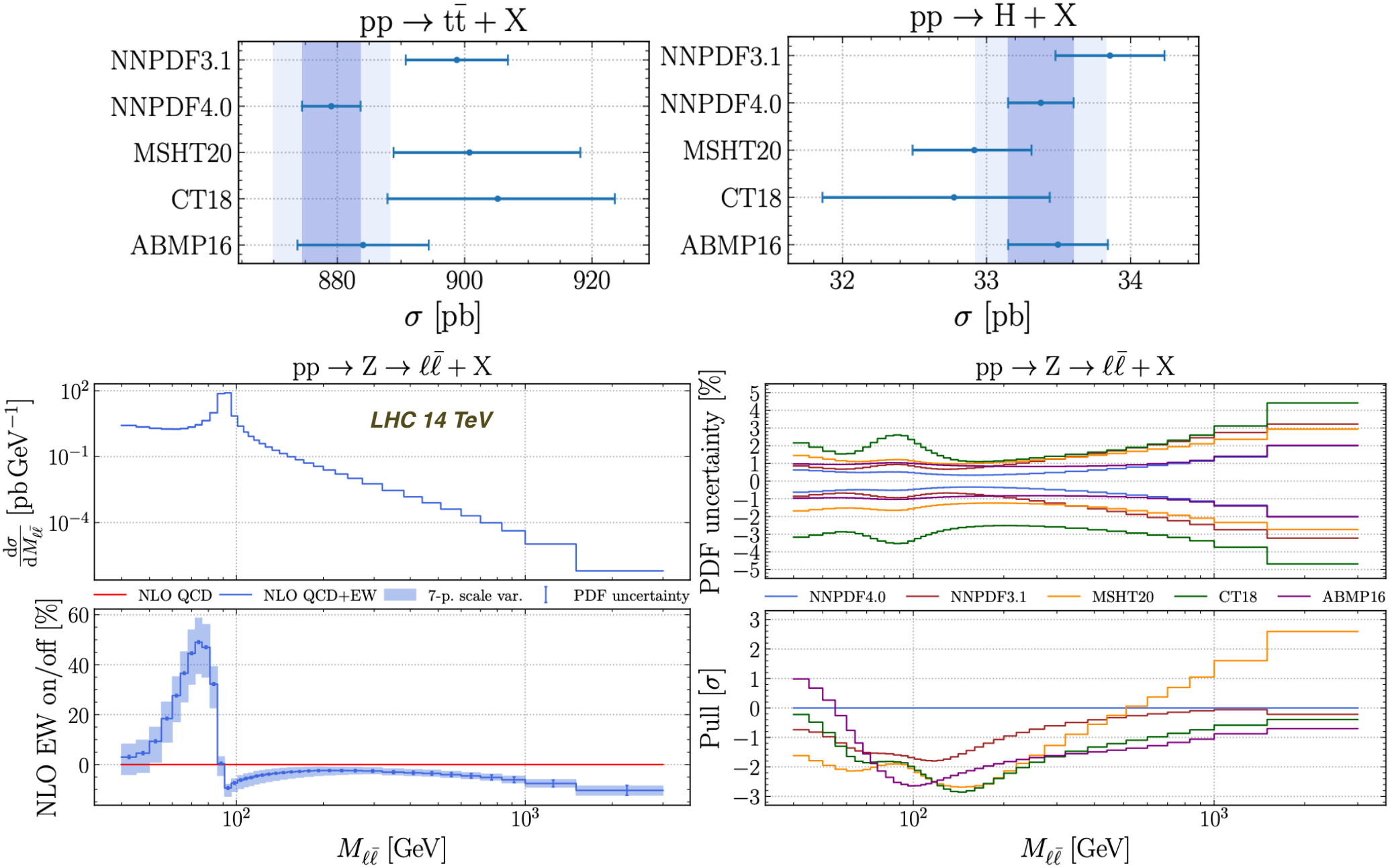
| Data set | Ref. | NNPDF3.1 | NNPDF4.0 | ABMP16 | CT18 | MSHT20 |
|---|---|---|---|---|---|---|
| CMS $W$ asym. 7 TeV ($\mathcal{L} = 36$ pb$^{-1}$) | [267] | ✗ | ✗ | ✗ | ✗ | ✓ |
| CMS $Z$ 7 TeV ($\mathcal{L} = 36$ pb$^{-1}$) | [268] | ✗ | ✗ | ✗ | ✗ | ✓ |
| CMS $W$ electron asymmetry 7 TeV | [55] | ✓ | ✓ | ✗ | ✓ | ✓ |
| CMS $W$ muon asymmetry 7 TeV | [56] | ✓ | ✓ | ✓ | ✓ | ✗ |
| CMS Drell-Yan 2D 7 TeV | [57] | ✓ | ✓ | ✗ | (✓) | ✓ |
| CMS Drell-Yan 2D 8 TeV | [269] | (✓) | ✗ | ✗ | ✗ | ✗ |
| CMS $W$ rapidity 8 TeV | [58] | ✓ | ✓ | ✓ | ✓ | ✓ |
| CMS $W, Z$ $p_T$ 8 TeV ($\mathcal{L} = 18.4$ fb$^{-1}$) | [270] | ✗ | ✗ | ✗ | (✓) | ✗ |
| CMS $Z$ $p_T$ 8 TeV | [64] | ✓ | ✓ | ✗ | (✓) | ✗ |
| CMS $W + c$ 7 TeV | [76] | ✓ | ✓ | ✗ | (✓) | ✓ |
| CMS $W + c$ 13 TeV | [84] | ✗ | ✓ | ✗ | ✗ | (✓) |
| CMS single-inclusive jets 2.76 TeV | [75] | ✓ | ✗ | ✗ | ✗ | ✓ |
| CMS single-inclusive jets 7 TeV | [147] | ✓ | (✓) | ✗ | ✓ | ✓ |
| CMS dijets 7 TeV | [74] | ✗ | ✓ | ✗ | ✗ | ✗ |
| CMS single-inclusive jets 8 TeV | [87] | ✗ | ✓ | ✗ | ✓ | ✓ |
| CMS 3D dijets 8 TeV | [149] | ✗ | (✓) | ✗ | ✗ | ✗ |
| CMS $\sigma_{tt}^{\rm tot}$ 5 TeV | [88] | ✗ | ✓ | ✗ | ✗ | ✗ |
| CMS $\sigma_{tt}^{\rm tot}$ 7, 8 TeV | [146] | ✓ | ✓ | ✗ | ✗ | ✗ |
| CMS $\sigma_{tt}^{\rm tot}$ 8 TeV | [271] | ✗ | ✗ | ✗ | ✗ | ✓ |
| CMS $\sigma_{tt}^{\rm tot}$ 5, 7, 8, 13 TeV | [68, 272–280] | ✗ | ✗ | ✓ | ✗ | ✗ |
| CMS $\sigma_{tt}^{\rm tot}$ 13 TeV | [69] | ✓ | ✓ | ✓ | ✗ | ✗ |
| CMS $t\bar{t}$ lepton+jets 8 TeV | [70] | ✓ | ✓ | ✗ | ✗ | ✓ |
| CMS $t\bar{t}$ 2D dilepton 8 TeV | [90] | ✗ | ✓ | ✗ | ✓ | ✓ |
| CMS $t\bar{t}$ lepton+jet 13 TeV | [91] | ✗ | ✓ | ✗ | ✗ | ✗ |
| CMS $t\bar{t}$ dilepton 13 TeV | [92] | ✗ | ✓ | ✗ | ✗ | ✗ |
| CMS single top $\sigma_t + \sigma_{\bar{t}}$ 7 TeV | [95] | ✗ | ✓ | ✓ | ✗ | ✗ |
| CMS single top $R_t$ 8, 13 TeV | [97, 99] | ✗ | ✓ | ✓ | ✗ | ✗ |
| CMS single top 13 TeV | [281, 282] | ✗ | ✗ | ✗ | ✗ | (✓) |

| Data set | Ref. | NNPDF3.1 | NNPDF4.0 | ABMP16 | CT18 | MSHT20 |
|---|---|---|---|---|---|---|
| LHCb $Z$ 7 TeV ($\mathcal{L} = 940$ pb$^{-1}$) | [59] | ✓ | ✓ | ✗ | ✗ | ✓ |
| LHCb $Z \to ee$ 8 TeV ($\mathcal{L} = 2$ fb$^{-1}$) | [61] | ✓ | ✓ | ✓ | ✓ | ✓ |
| LHCb $W$ 7 TeV ($\mathcal{L} = 37$ pb$^{-1}$) | [283] | ✗ | ✗ | ✗ | ✗ | ✓ |
| LHCb $W, Z \to \mu$ 7 TeV | [60] | ✓ | ✓ | ✓ | ✓ | ✓ |
| LHCb $W, Z \to \mu$ 8 TeV | [62] | ✓ | ✓ | ✓ | ✓ | ✓ |
| LHCb $W \to e$ 8 TeV | [80] | ✗ | (✓) | ✗ | ✗ | ✗ |
| LHCb $Z \to \mu\mu, ee$ 13 TeV | [82] | ✗ | ✓ | ✗ | ✗ | ✗ |

| | |
|---|---|
| ✓ | in baseline dataset |
| ✗ | not considered |
| (✓) | impact assessed but excluded from baseline |

# LHC phenomenology

extensive comparisons between global PDF fits for **inclusive** and **differential LHC cross-sections**



# Summary and outlook

- The global NNPDF4.0 fit achieves **high accuracy** in an unprecedentedly broad kinematic range, thanks so its **extensive dataset** combined with **deep-learning optimisation models**

- Its faithfulness in representing PDF uncertainties is completely validated by **closure tests**, **future tests**, and **parametrisation basis independence**

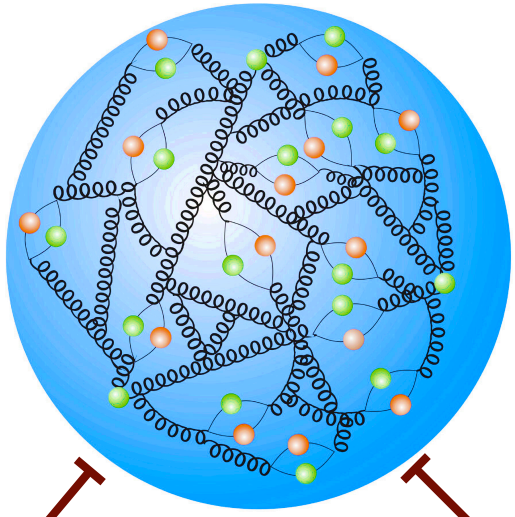
- In addition to implications for **LHC precision physics**, NNPDF4.0 sheds light on aspects of proton structure from **light antiquark asymmetries** to **strangeness** and **intrinsic charm**

- The current level of PDF uncertainties challenges the accuracy of theoretical predictions and demand an increased effort towards the systematic inclusion in the fit of **theoretical uncertainties** (nuclear, higher orders, SM parameters, . . . ) and **higher-order QCD** (including N3LO) **and EW corrections**

- Full NNPDF software framework is now **open source** and welcoming contributions!

# Extra Material

# Why Nucleon Structure?



***Address fundamental questions about the strong nuclear force***

origin of mass and spin in QCD, heavy quark content, 3D imaging, gluon-dominated matter, nuclear modifications

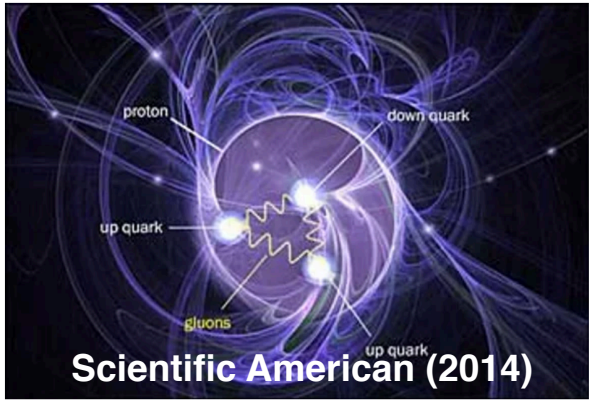
***Provide predictions for particle, nuclear, and astro-particle experiments***

LHC, Electron Ion Collider, RHIC, IceCube, AMBER, COMPASS, Auger, …

# Why Nucleon Structure?

THE SCIENCES

## Proton Spin Mystery Gains a New Clue




*Non-zero gluon polarisation*


*Intrinsic Charm*

The proton keeps surprising us as an endless source of **fundamental discoveries**

QUANTUM PHYSICS

## Decades-Long Quest Reveals Details of the Proton's Inner Antimatter

27

*Twenty years ago, physicists set out to investigate a mysterious asymmetry in the proton's interior. Their results, published today, show how antimatter helps stabilize every atom's core.*

*Antimatter asymmetry @ SeaQuest*

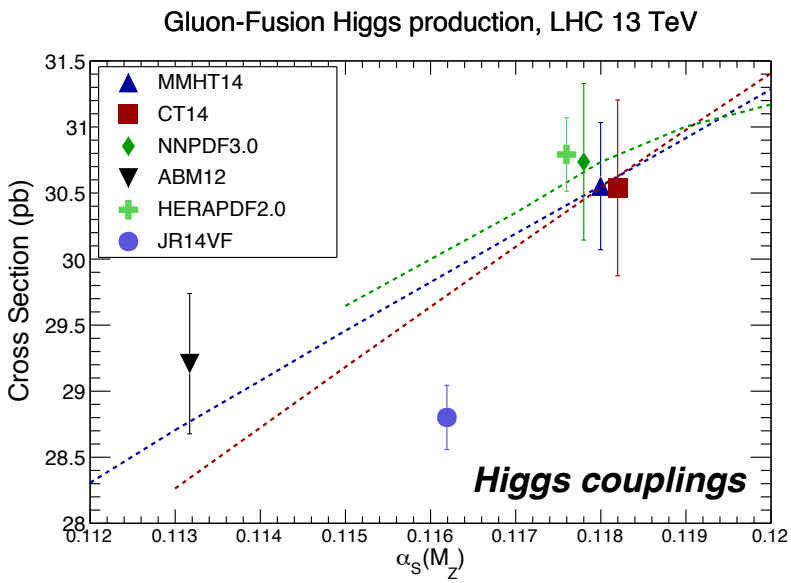

## After 40 years of studying the strong nuclear force, a revelation

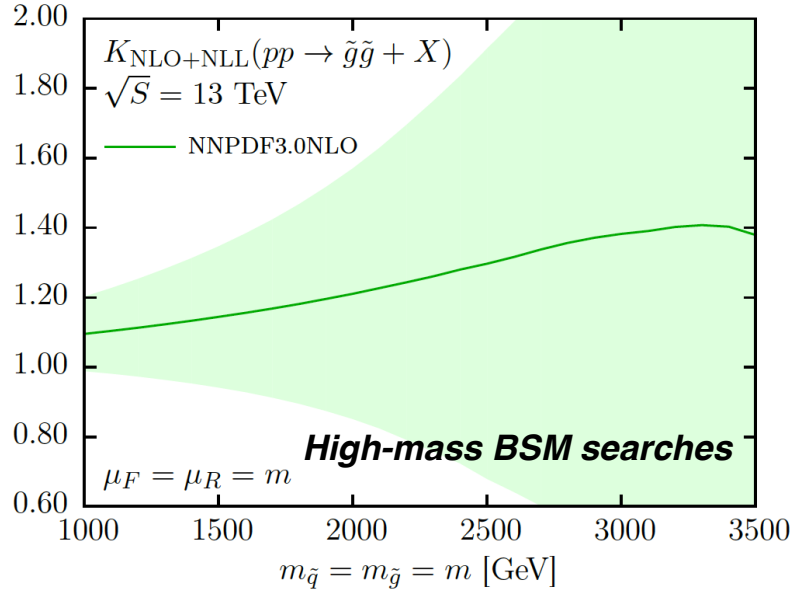
*BFKL dynamics*

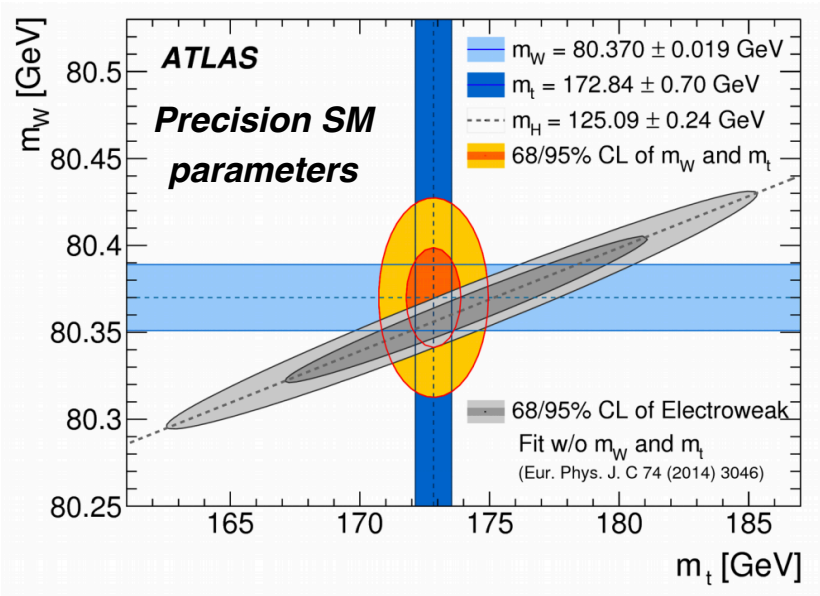
**This was the year that analysis of data finally backed up a prediction, made in the mid 1970s, of a surprising emergent behaviour in the strong nuclear force**

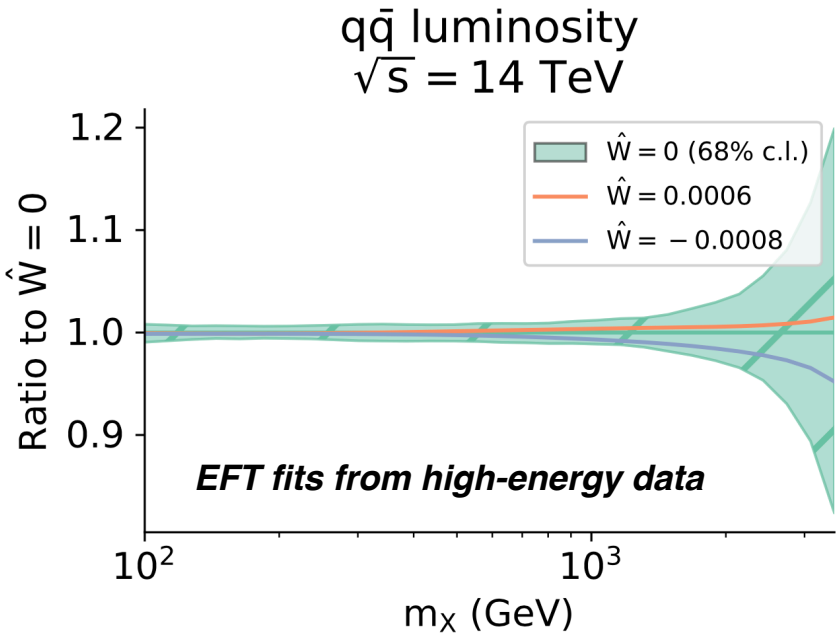
# PDFs for precision LHC physics

PDF uncertainties are limiting factor in **theoretical interpretation** for many LHC analysis



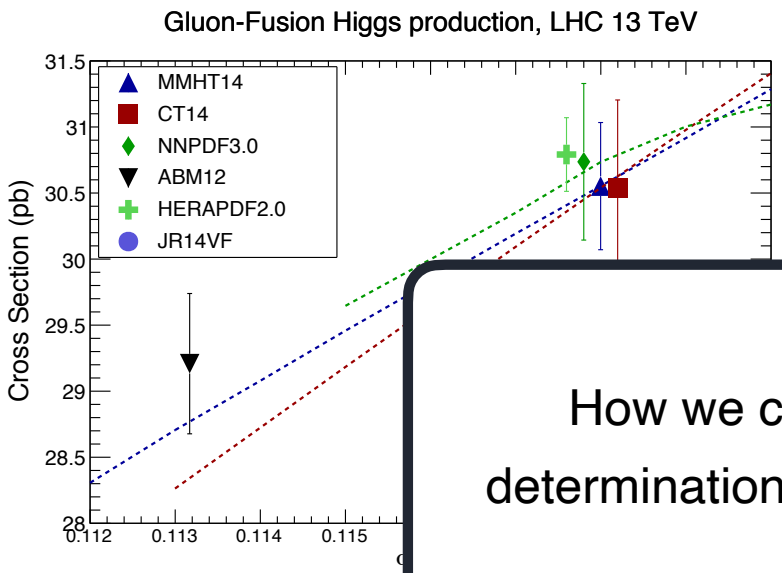



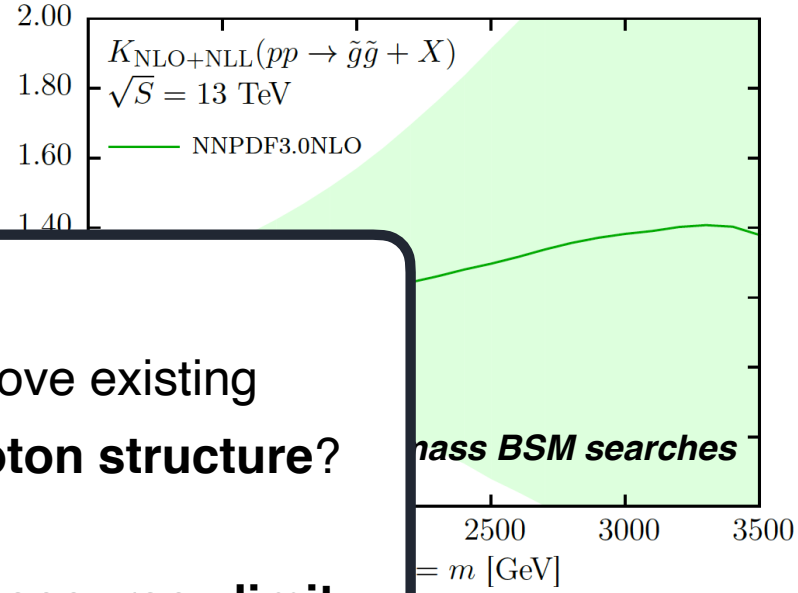



# PDFs for precision LHC physics

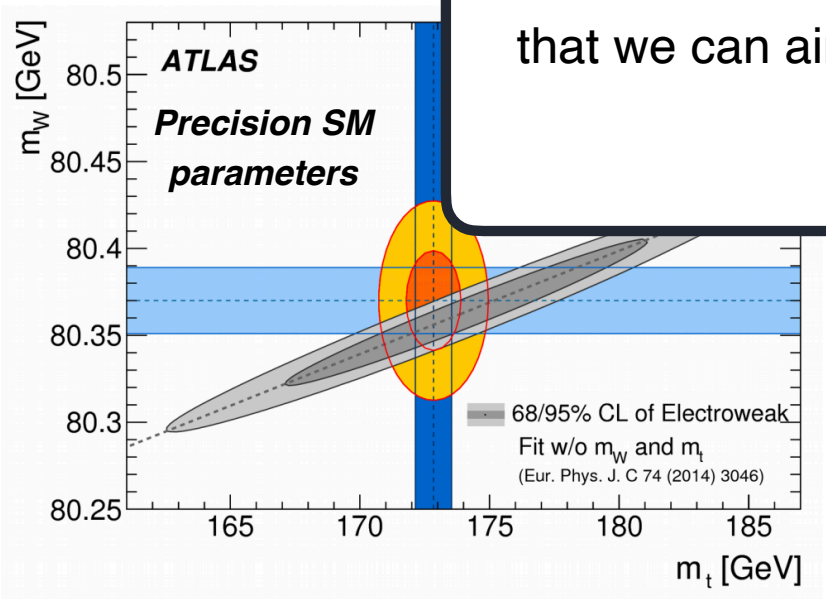
PDF uncertainties are limiting factor in **theoretical interpretation** for many LHC analysis

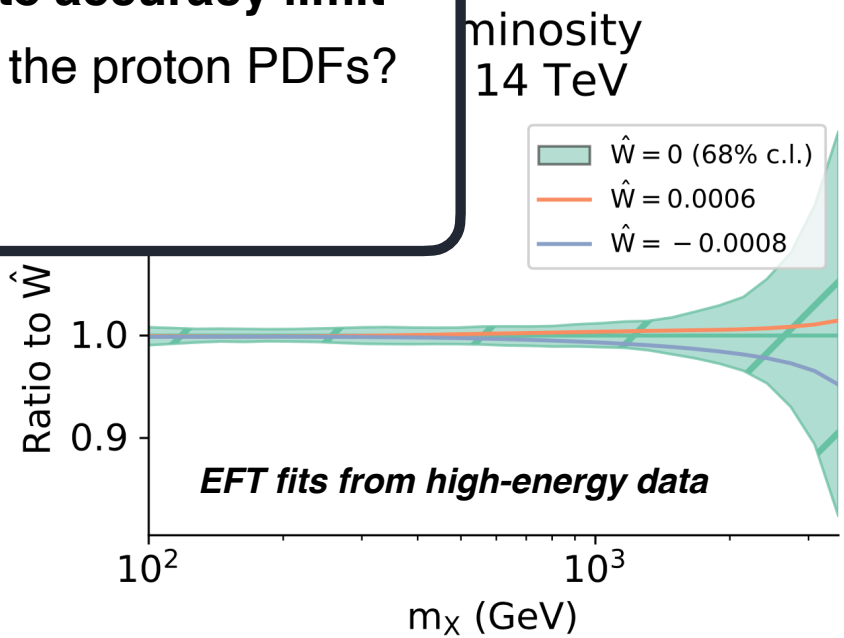


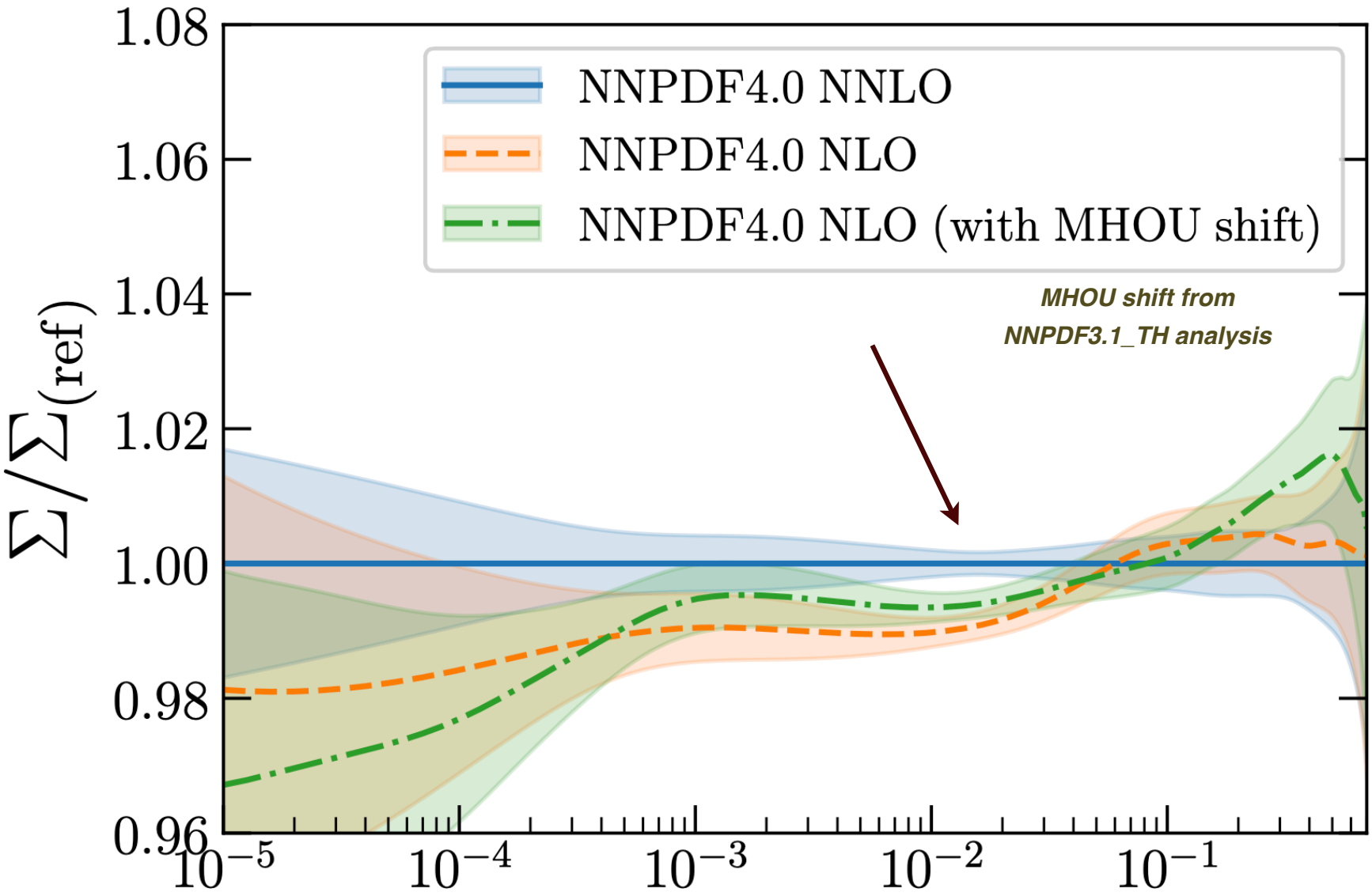

How we can improve existing determinations of **proton structure**?

What is the **ultimate accuracy limit** that we can aim for the proton PDFs?



# Missing higher order QCD uncertainties




Certainly NLO, but also **likely NNLO PDFs**, underestimate uncertainties without MHOUs

State-of-the-art LHC pheno demands both **NNLO PDFs with MHOUs** and **N3LO PDFs**: WIP!