Update on NNPDF parton distributions

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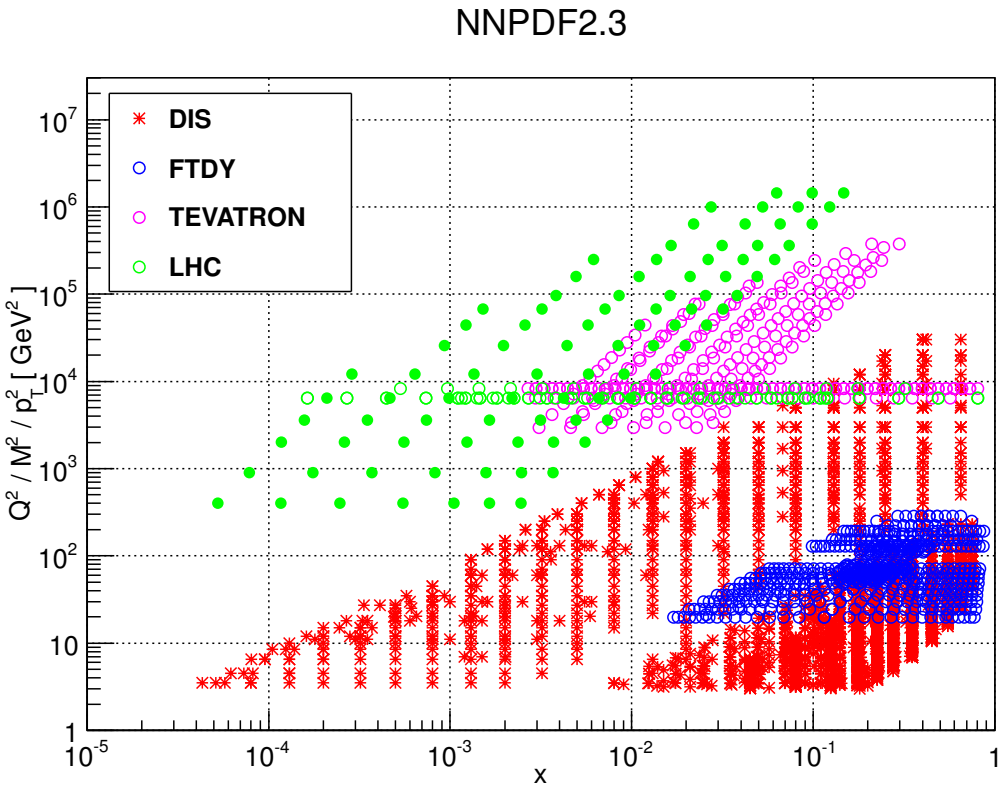
Current status of NNPDF determinations

- Most recent update: **NNPDF2.3** includes constraints from LHC data

New data in 2.3

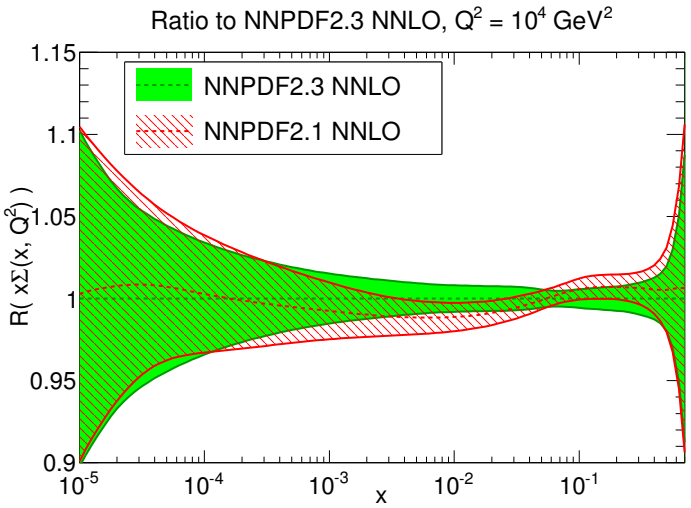
- **ATLAS 2010**
  Inclusive Jets,
  $W^{\pm}/Z$ rapidity distributions.
- **LHCb 2010**
  $W^{\pm}$ rapidity distributions.
- **CMS 2011**
  W lepton asymmetry.

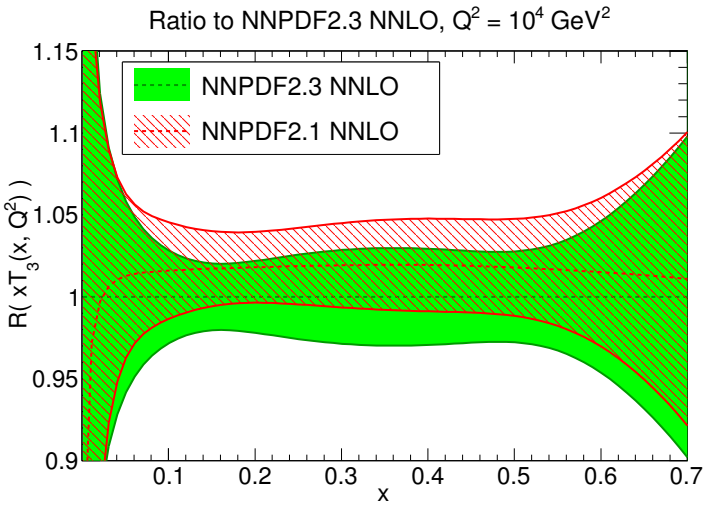


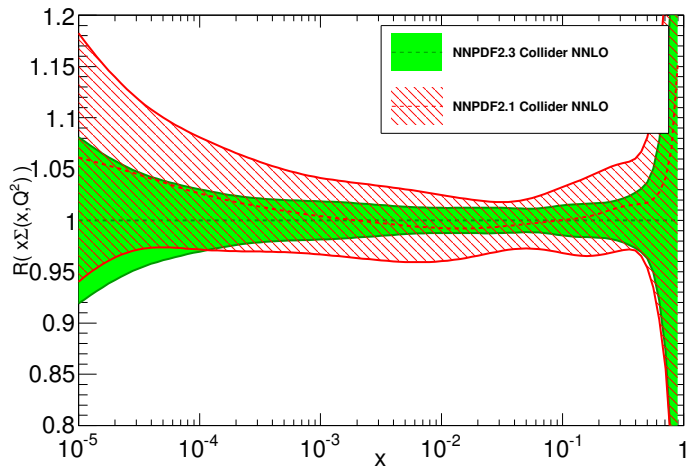
NNPDF2.3 Family

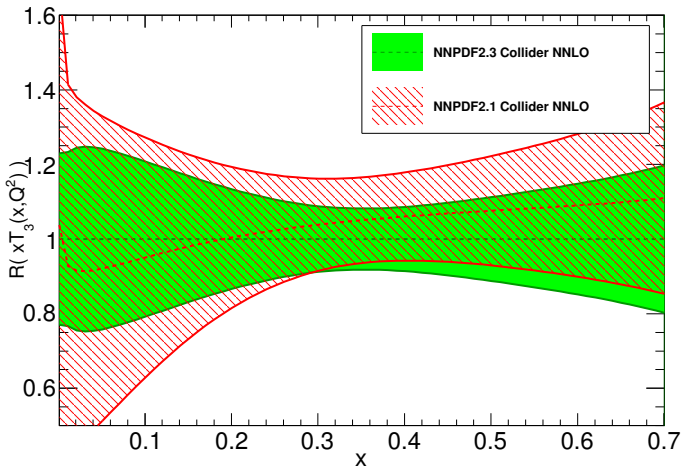
NNPDF2.3 - global dataset including LHC data.
NNPDF2.3 noLHC - global dataset without LHC data.
NNPDF2.3 Collider - HERA, Tevatron and LHC data only.

Constraints from LHC data





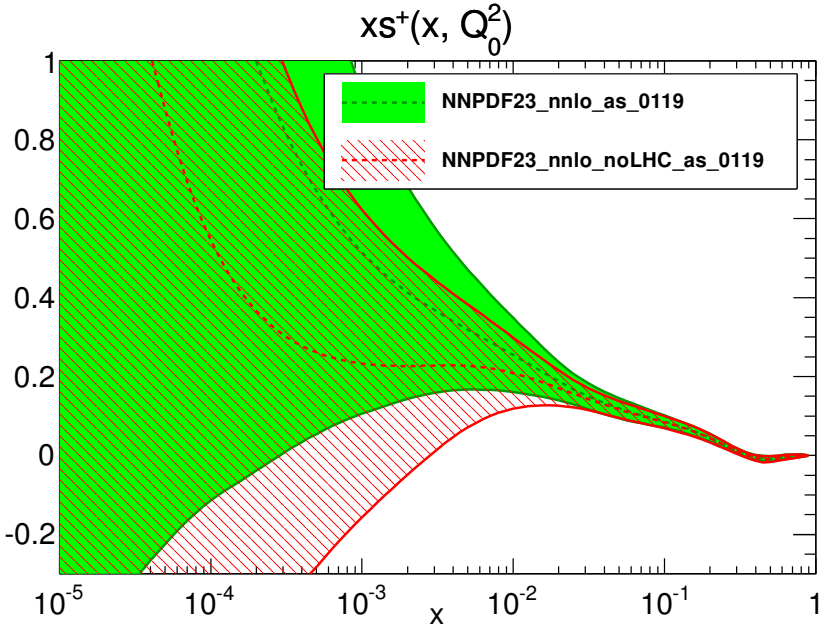


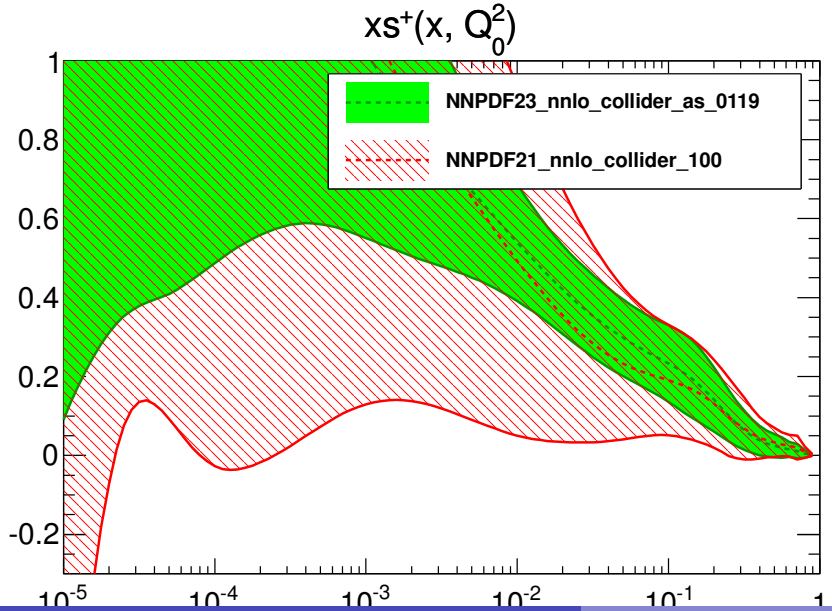


- LHC data generally demonstrates good consistency with the global dataset.
- Provides particularly large constraint for collider only PDFs.

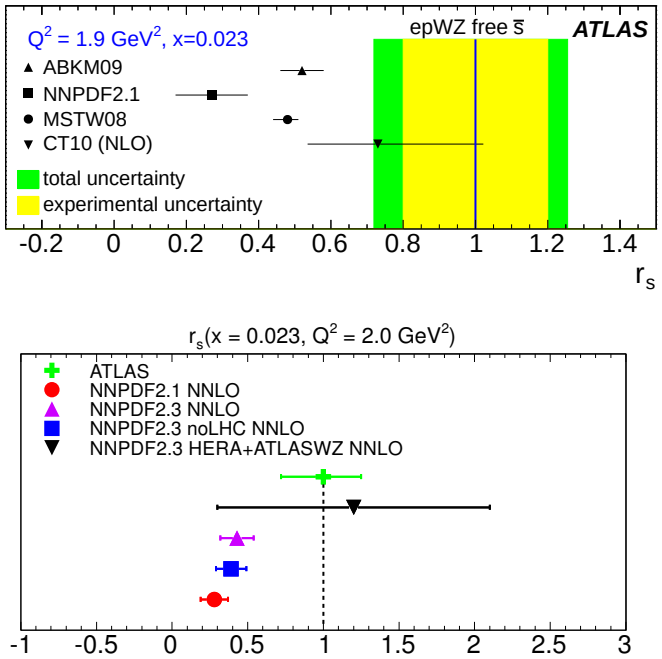
The strange content of the proton.

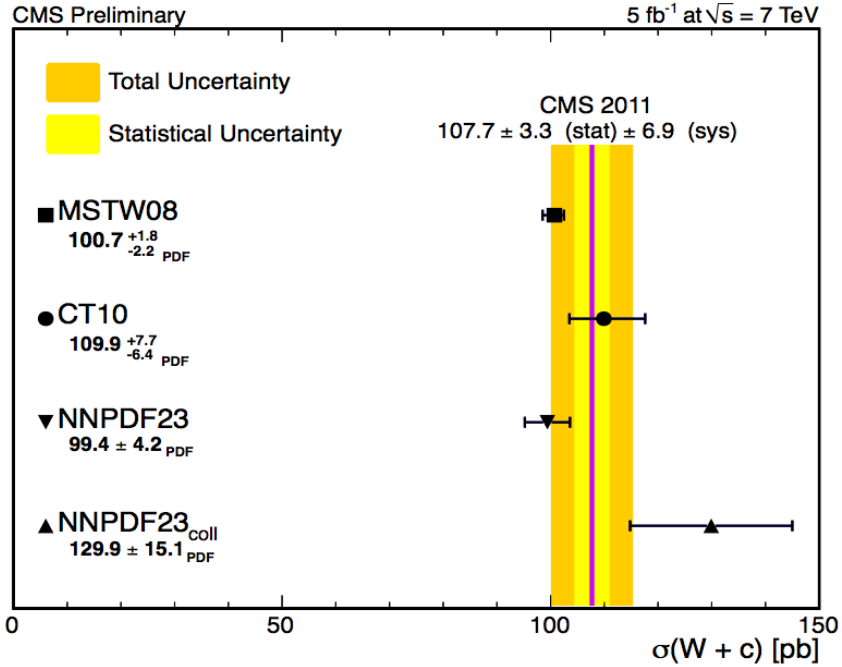
Strange distributions suffer from generally large uncertainties.





The strange content of the proton.





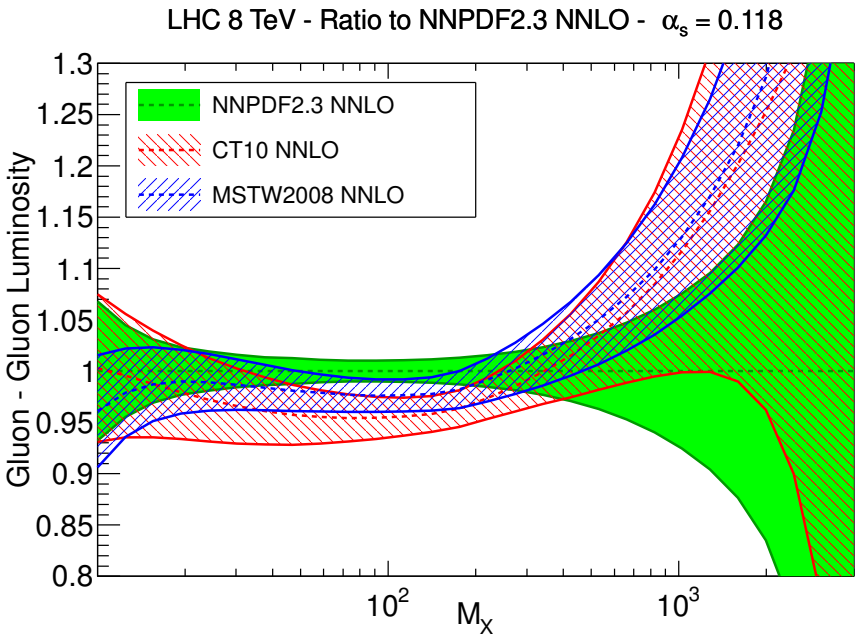
- NNPDF fit to HERA and ATLAS-WZ data finds central value consistent with ATLAS[1] determination of $r_s(x) = (s(x) + \bar{s}(x))/2d(x)$ within a large uncertainty.
- Recent CMS[2] measurement of $W + c$ consistent with strangeness in global fits. Slightly disfavours the larger strange sea in NNPDF2.3 Collider only, but consistent within uncertainties.

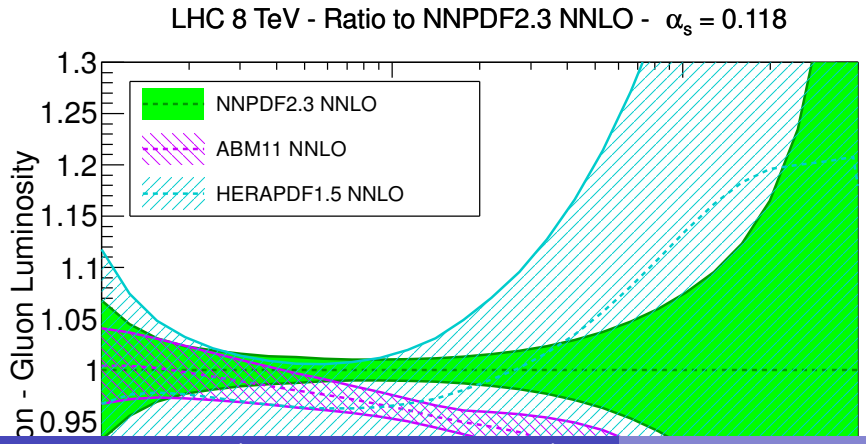
[1] arXiv:1203.4051
[2] CMS-SMP-12-002

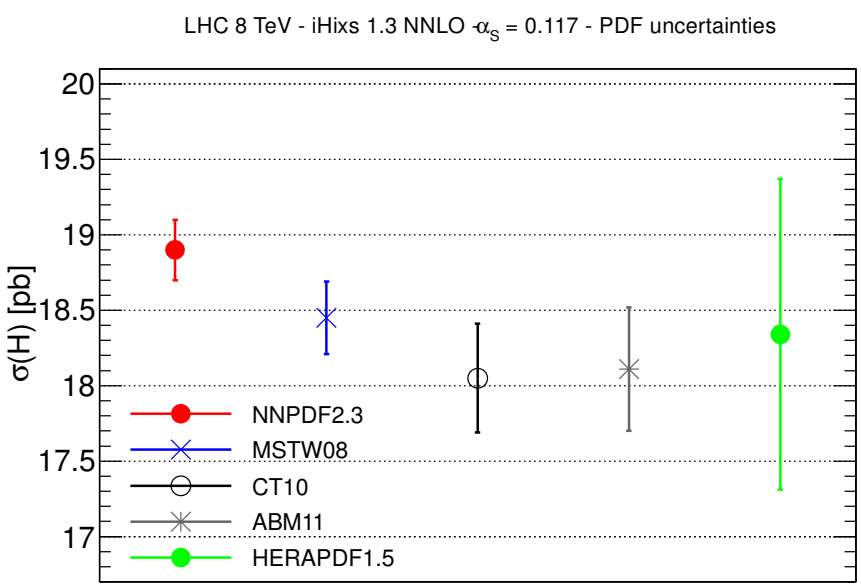
PDF Benchmarking

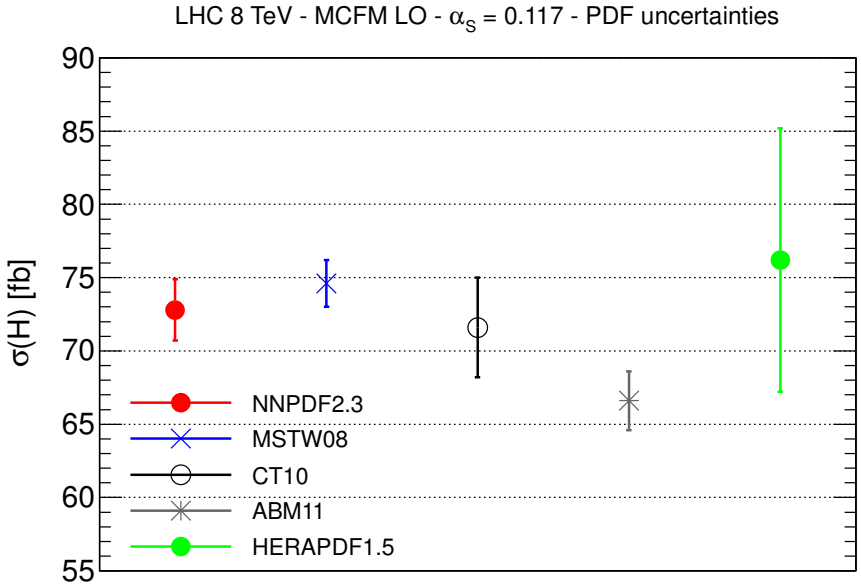
[arXiv:1211.5142] - Benchmark study of different PDF determinations.

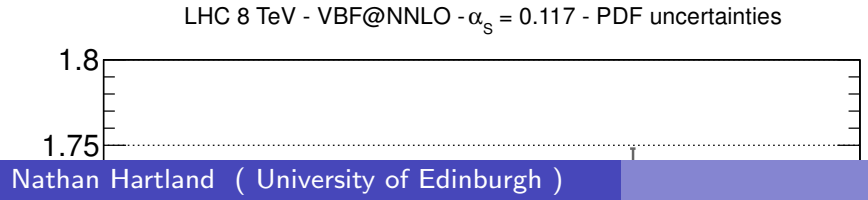
Detailed comparison at common α_S of the most up to date NNLO fits from the ABM, CT, HERAPDF, MSTW and NNPDF collaborations.






LHC 8 TeV - iHixs 1.3 NNLO - α_S = 0.117 - PDF uncertainties
σ(H) [pb]
20
19.5
19
18.5
18
17.5
17
NNPDF2.3
MSTW08
CT10
ABM11
HERAPDF1.5

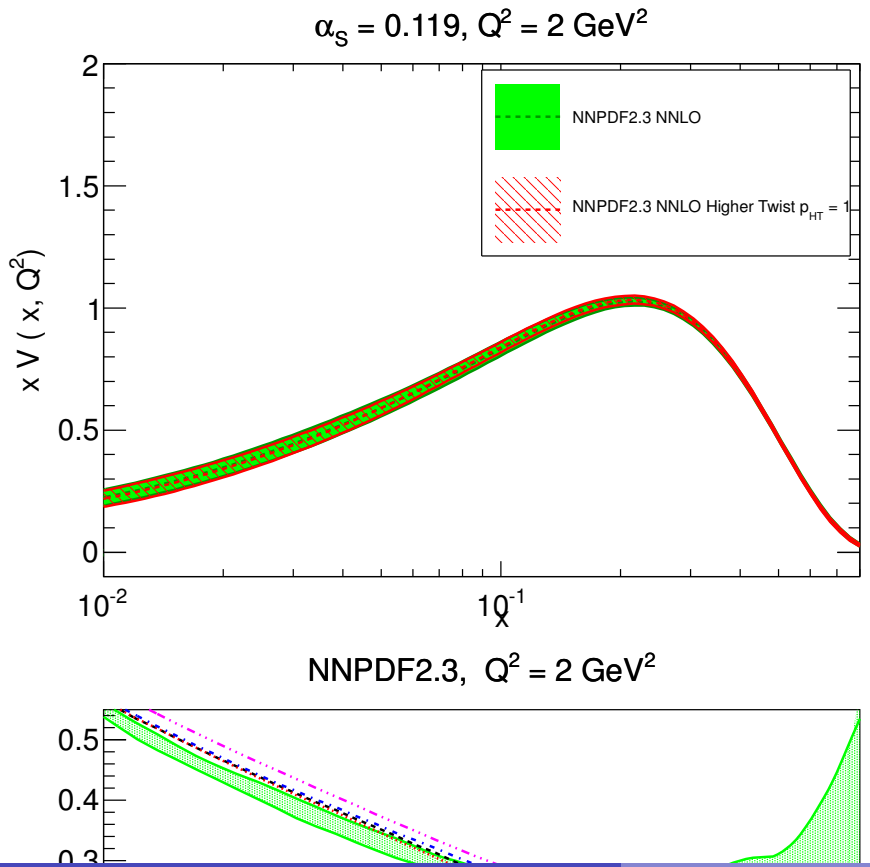

LHC 8 TeV - MCFM LO - α_S = 0.117 - PDF uncertainties
σ(H) [fb]
90
85
80
75
70
65
60
55
NNPDF2.3
MSTW08
CT10
ABM11
HERAPDF1.5


LHC 8 TeV - VBF@NNLO - α_S = 0.117 - PDF uncertainties
1.8
1.75

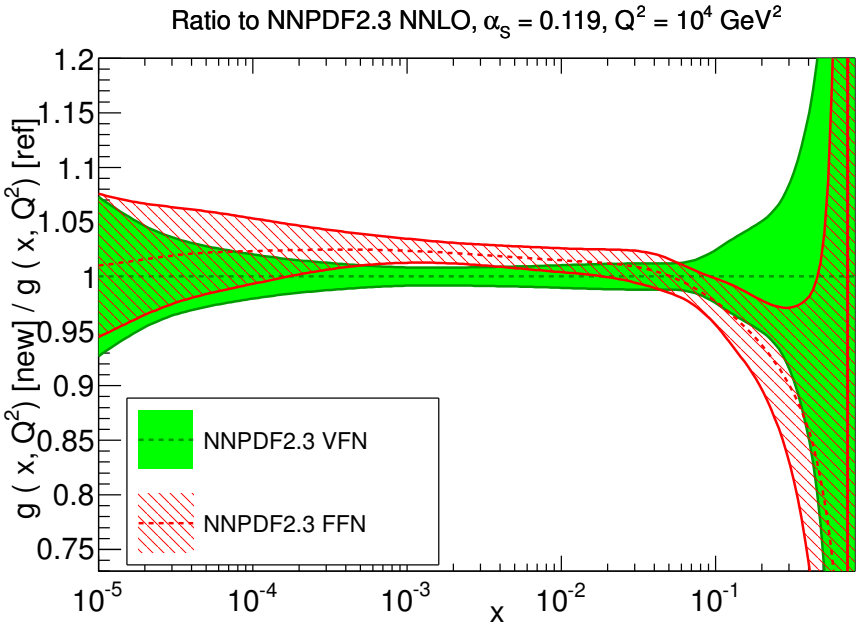
Theoretical uncertainties in PDF determination.

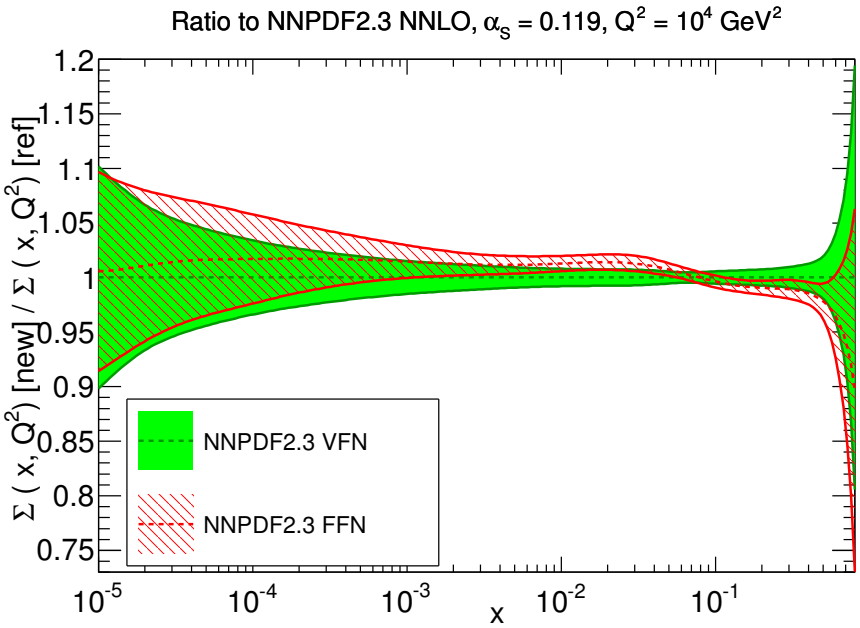
[arXiv:1303.1189] - NNPDF study of contributions to theoretical uncertainty.

- **Dynamical Higher Twist**
  NNPDF Fit with higher twist corrections (from ABM determination) indicates modest impact upon PDFs
- **Deuterium nuclear corrections**
  Potentially affects down quark, fitted from deuterium data. Impact is limited to the d/u ratio in the range $0.1 \leq x \leq 0.5$

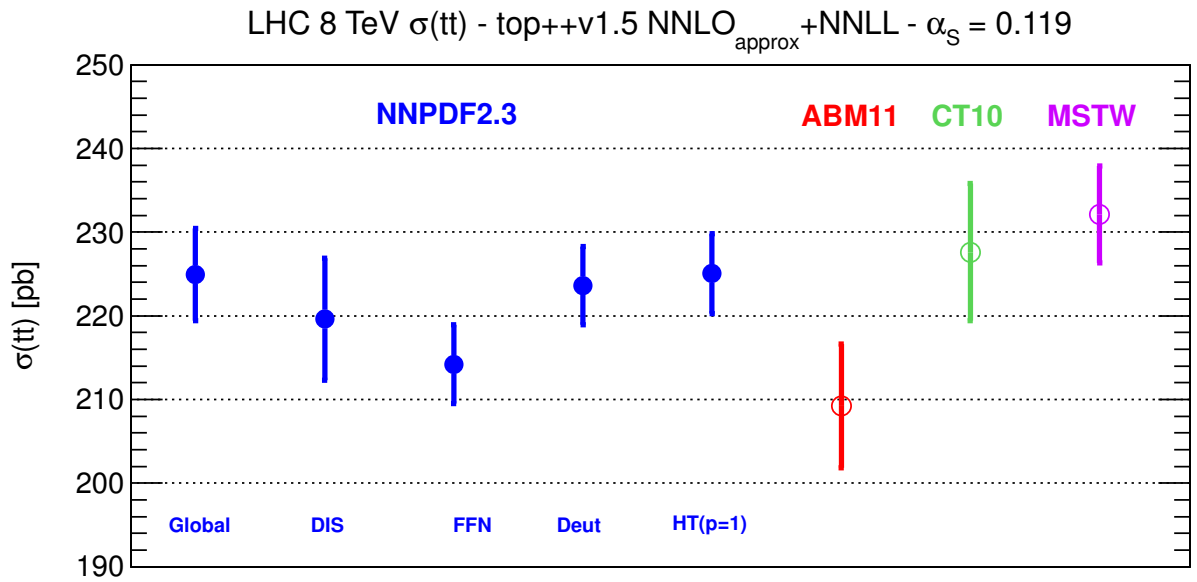


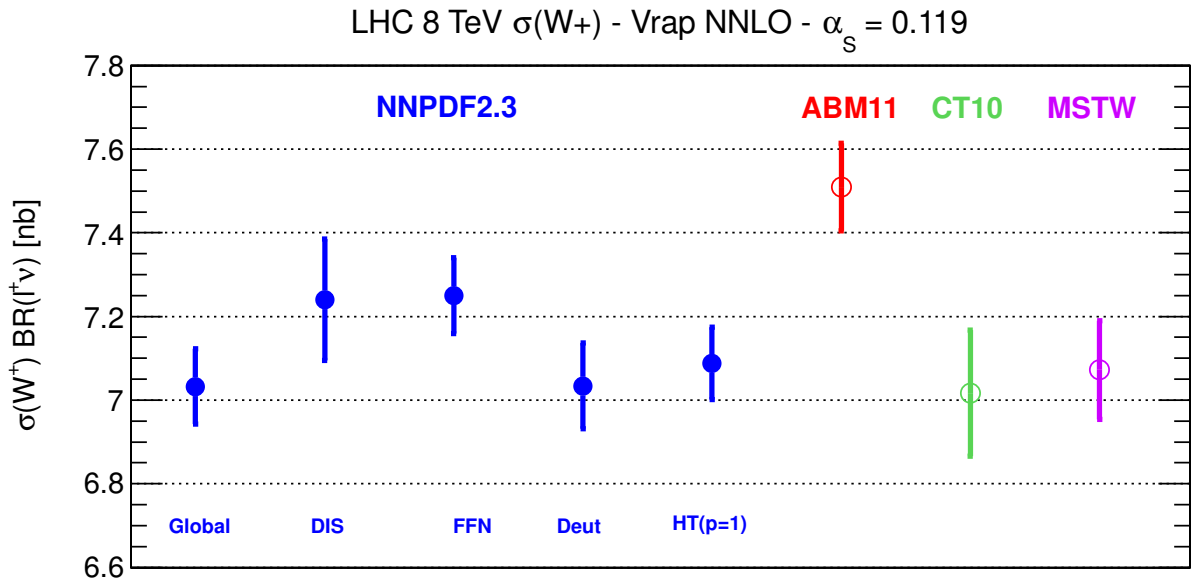
Impact of Flavour Number Scheme choice.





Impact of FFN Scheme





Towards NNPDF3.0

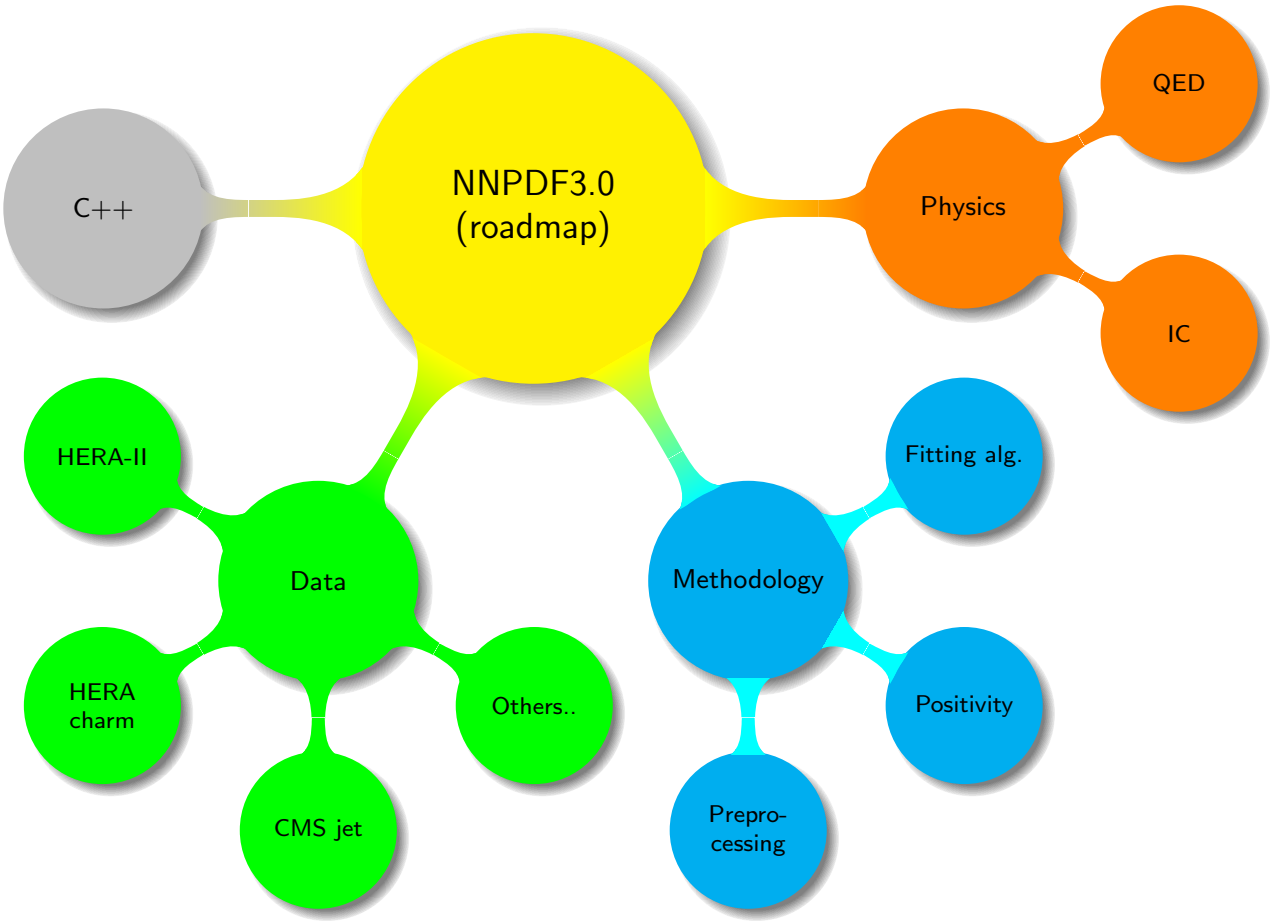
Challenges

- **Predictions for LHC data are computationally rather expensive.**
  - A fast fitting framework is required.
- **New datasets from the LHC and HERA are becoming available.**
  - The ability to rapidly implement and assess the impact of new data is vital.
- **Fitting methodology should be analysed in the light of new data.**
  - Is our current methodology doing the best job it can?

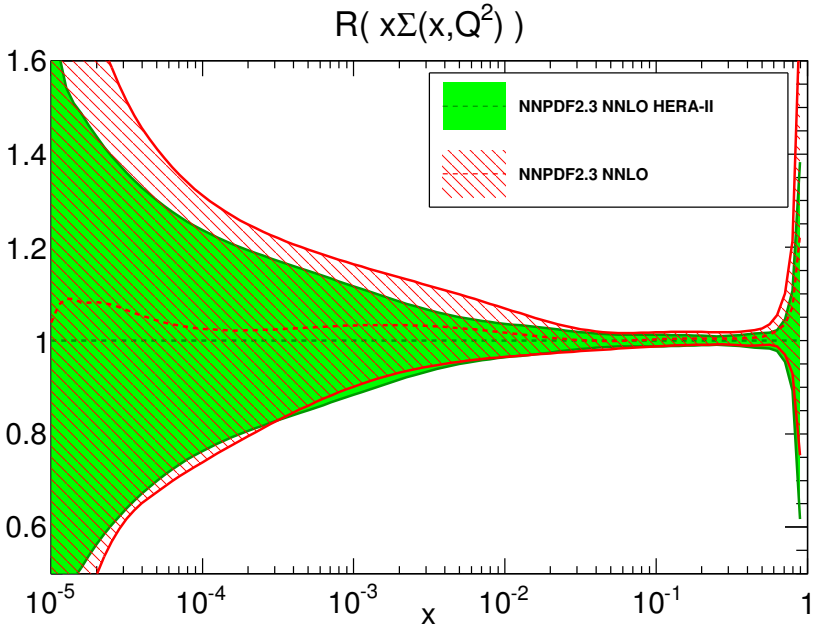
A new NNPDF code is under development, built from scratch to support rapid iteration.

- Faster fits means more aggressive minimisation, more scope for Methodological surveys.
- Code is written in modern C++ to aid flexibility and maintainability.
- Rewrite provides an in-depth cross check of the implementation.

Towards NNPDF3.0



New data - HERA-II DIS

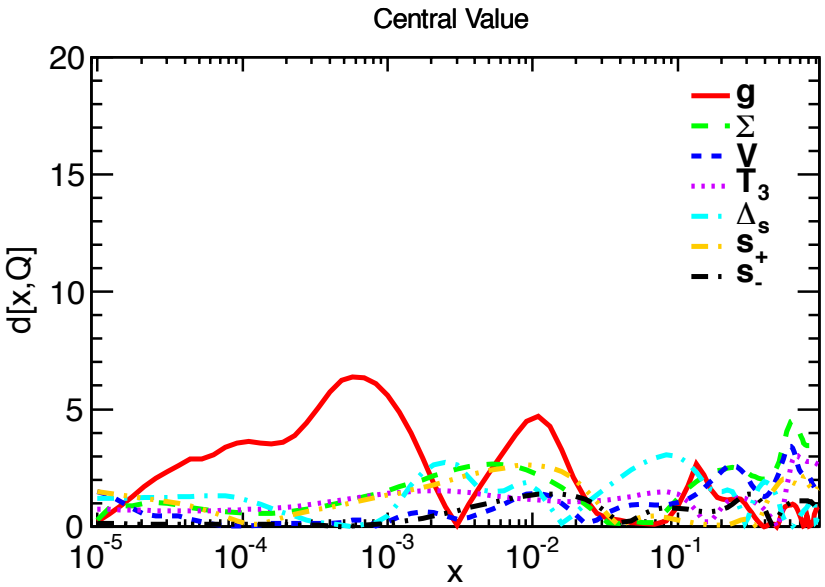


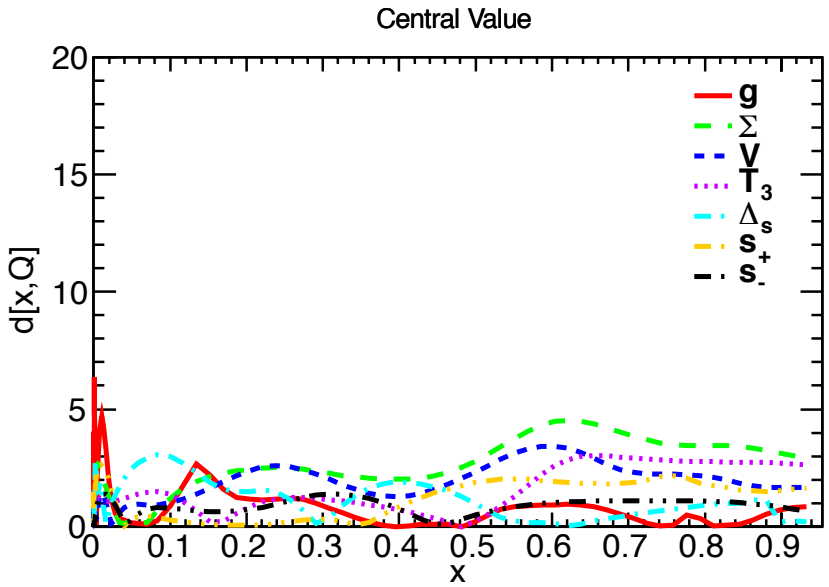
Preliminary Fits to HERA-II Inclusive DIS Datasets.

Large new DIS datasets from the ZEUS and H1 collaborations.

Over **600** new data points demonstrate excellent consistency in global fit, providing constraint particularly for the singlet PDF.

PDF distances demonstrate this consistency. A distance of $d = 10$ implies a shift by 1-σ.

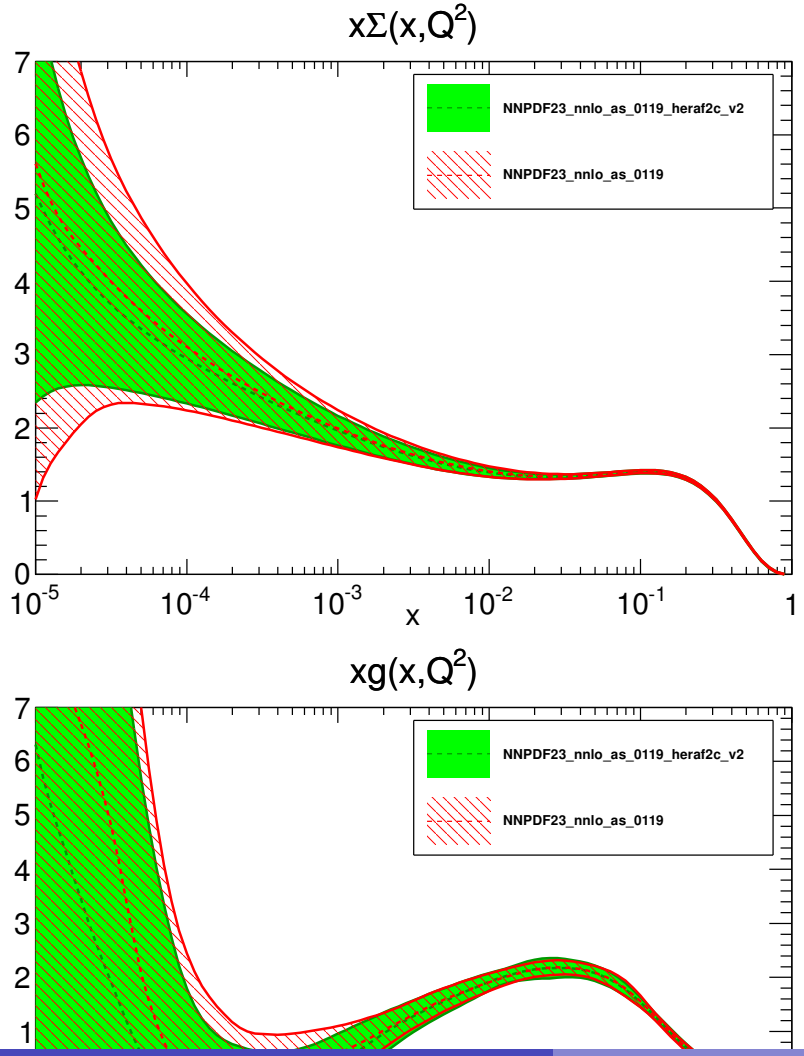




New data - HERA Combined F_c^2

[arXiv:1211.1182] - ZEUS and H1 Combination F_c^2 data.

Supersedes separate datasets used in previous NNPDF fits, providing additional information on data correlations.



Methodology: Closure tests

How do we ensure that our fit minimises *bias*?
Related studies by Thorne-Watt [arXiv:1205.4024]

Perform a **Closure Test**:

- **Generate artificial pseudo-data based upon a known PDF distribution.**
  Pseudodata generated according to NLO pQCD. Dataset is therefore free of internal inconsistencies.

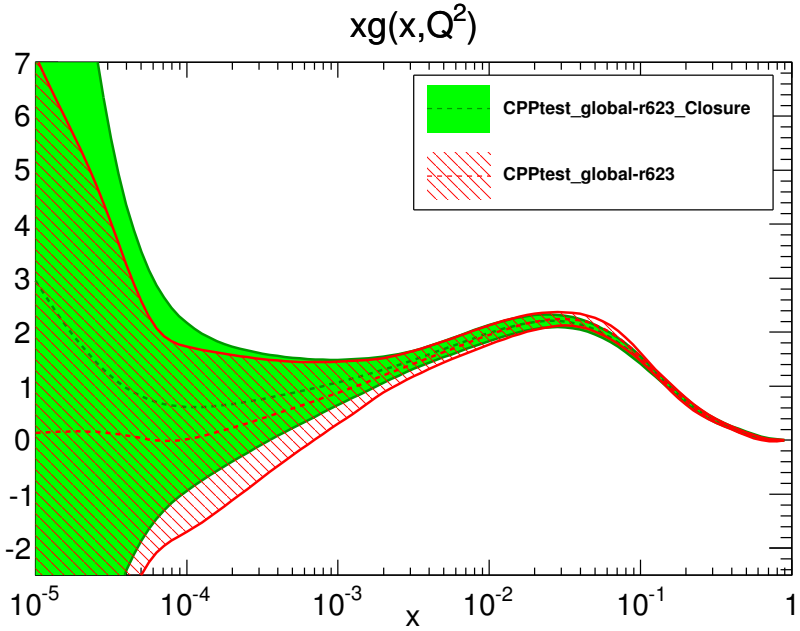
- **Simulate experimental noise in the pseudodata.**
  Data points perturbed according to multi-gaussian distribution defined by the experimental covariance matrix.

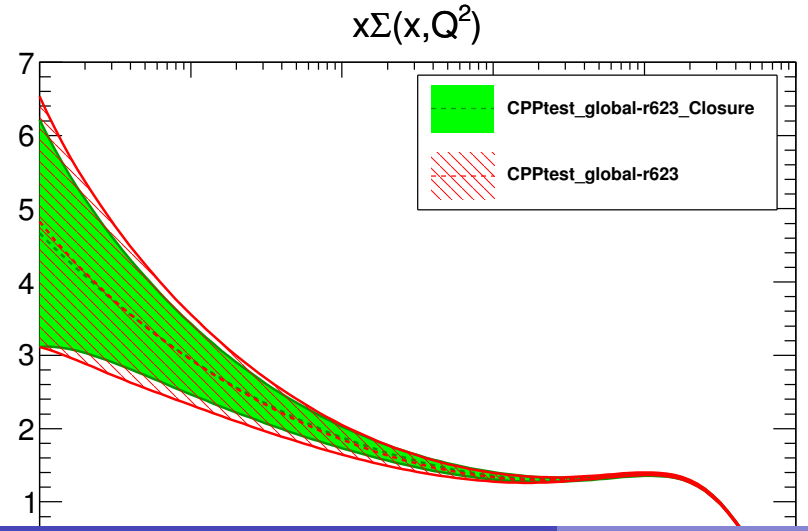
- **Perform a full PDF fit to the pseudo-dataset.**
  Closure fit should recover generating PDF up to the level of experimental uncertainty.

Methodology: Closure tests

Preliminary NNPDF closure test fits.

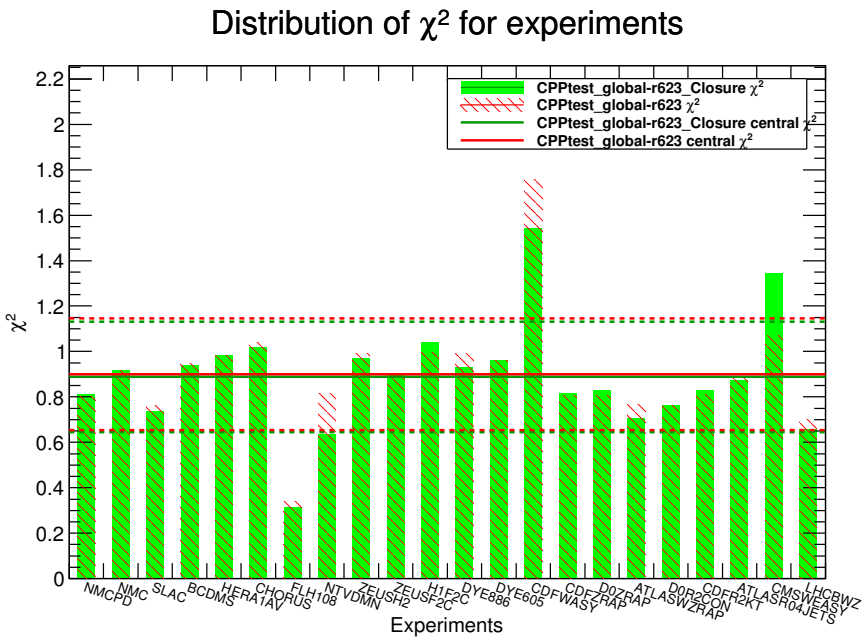
First closure tests performed with NNPDF C++ code to a NLO fit with a global dataset.



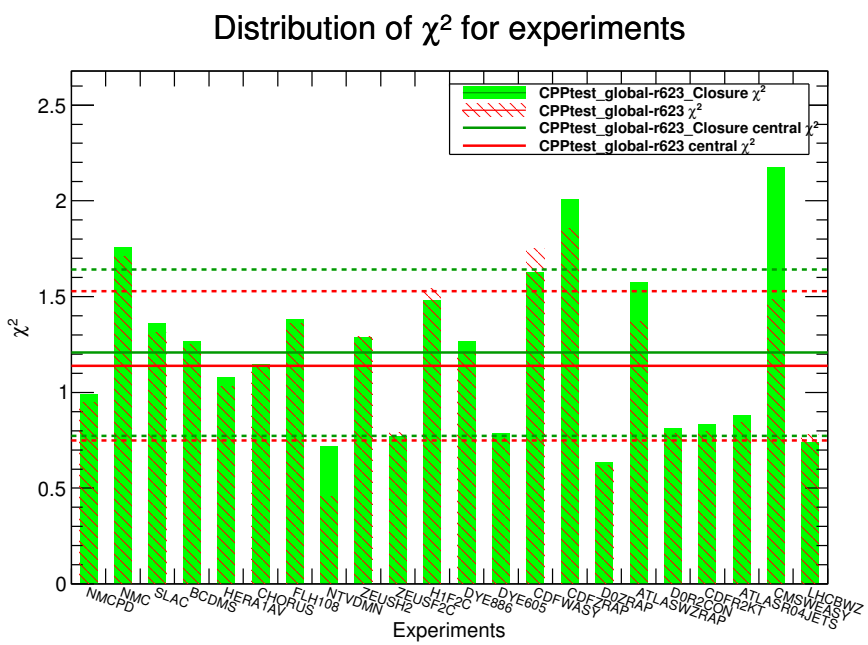


Preliminary closure tests - fit quality

Pseudodata



Experimental data



- The χ^2 value for each dataset is assessed both for the artificial pseudodata, and for the real experimental data.
- Closure test fit demonstrates self consistency of the NNPDF procedure.

Summary and Outlook

Current Status

- **NNPDF2.3**
  The NNPDF2.3 family of fits provide a determination of parton distribution functions with a global dataset, including a sizeable LHC contribution.

  Measurements from the LHC and HERA will provide interesting further constraints upon PDFs, particularly in collider only determinations.

Looking Forward

A great deal of progress in NNPDF determinations across many fronts.

- **Progress towards the next global NNPDF set**
  - New fitting framework developed from scratch in C++.
  - Preliminary methodological studies by Closure Testing.
  - Impact of new HERA combinations upon NNPDF2.3 studied.
  - Plenty of new data to come (e.g CMS Inclusive Jets, $W + c$).
- **New Results for PDFs with QED Corrections, and polarised NNPDFs**
  see talks by S.Carrazza, E.Nocera.

BACKUPS

Including new experimental data - reweighting

How can we add new LHC data to an existing parton set?

- Reweight existing Monte Carlo parton set.

Each replica in the set is assigned a weight based upon it's χ^2 to the new data.

$$\langle \mathcal{O} \rangle_{\rm new} = \frac{1}{N} \sum_{k=1}^{N} w_k \mathcal{O}[f_k], \qquad w_k \propto (\chi^2_k)^{(n-1)/2} e^{-\frac{1}{2}\chi^2_k}$$

- Application: NNPDF2.2 Parton Set [arXiv:1012.0836]
  LHC Electroweak data added by Bayesian Reweighting

However, reweighting method is impractical for large/constraining data sets.
Number of effective replicas reduced after reweighting:

$$N_{\rm eff} \equiv \exp\left(\frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k \ln(N_{\rm rep}/w_k) \right)$$

Including new experimental data - refitting

How can we efficiently include LHC data into a full refit?
Tools: APPLgrid/FastNLO projects

- Precompute and store MC Weights on an interpolation grid

$$\sigma = \sum_{p} \sum_{l=0}^{N_{\text{sub}}} \sum_{\alpha,\beta}^{N_x} \sum_{\tau}^{N_Q} W^{(p)(l)}_{\alpha\beta\tau} \left(\frac{\alpha_s\left(Q^2_\tau\right)}{2\pi} \right)^p F^{(l)}\left(x_\alpha, x_\beta, Q^2_\tau\right) \tag{1}$$

PDF Evolution in the FastKernel method is a similar procedure,

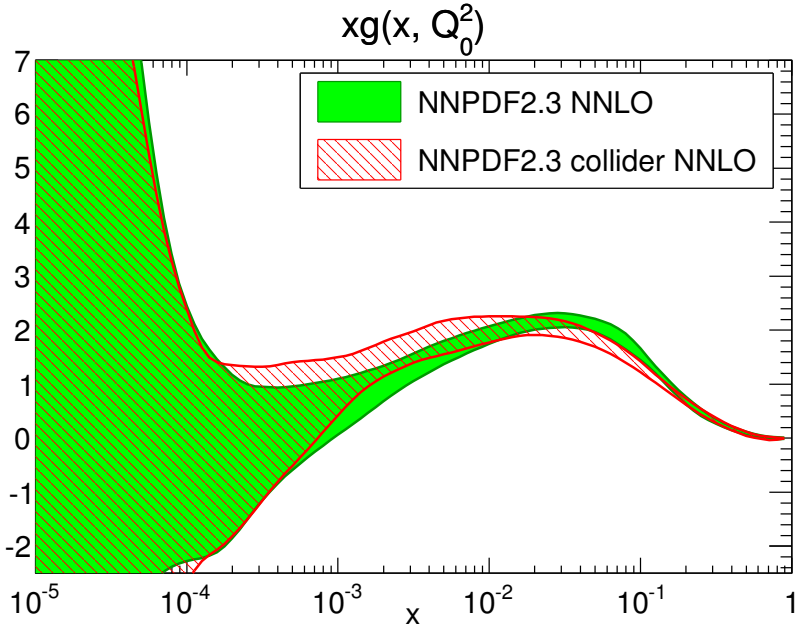
$$f_i(x_\alpha, Q^2_\tau) = \sum_{\beta}^{N_x} \sum_{j}^{N_{\text{pdf}}} A^{\tau}_{\alpha\beta ij} N^0_j(x_\beta)$$

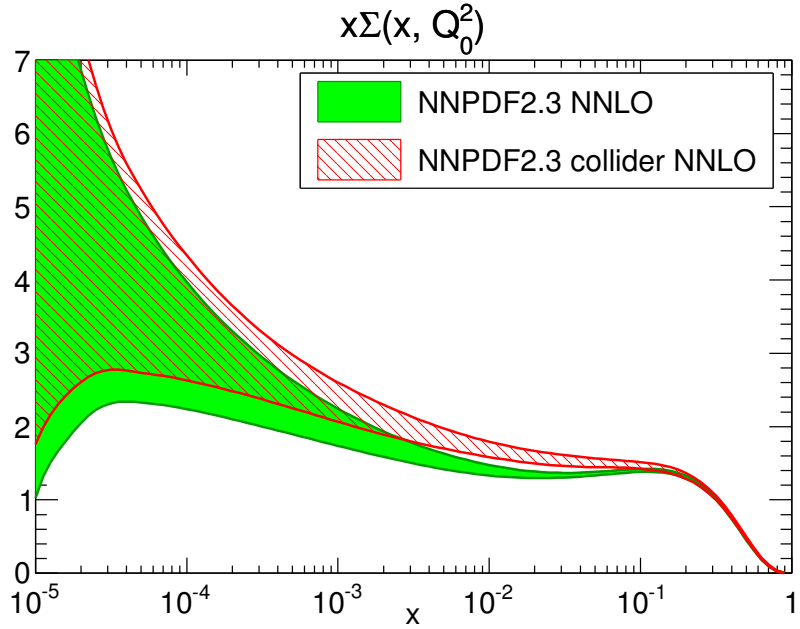
Idea: Combine weight grids with evolution grids

$$\sigma = \sum_{\alpha,\beta}^{N_x} \sum_{i,j}^{N_{\text{pdf}}} \sigma_{\alpha\beta ij} N^0_i(x_\alpha) N^0_j(x_\beta)$$

- Precomputing all Q^2 dependence leads to extremely efficient calculations.

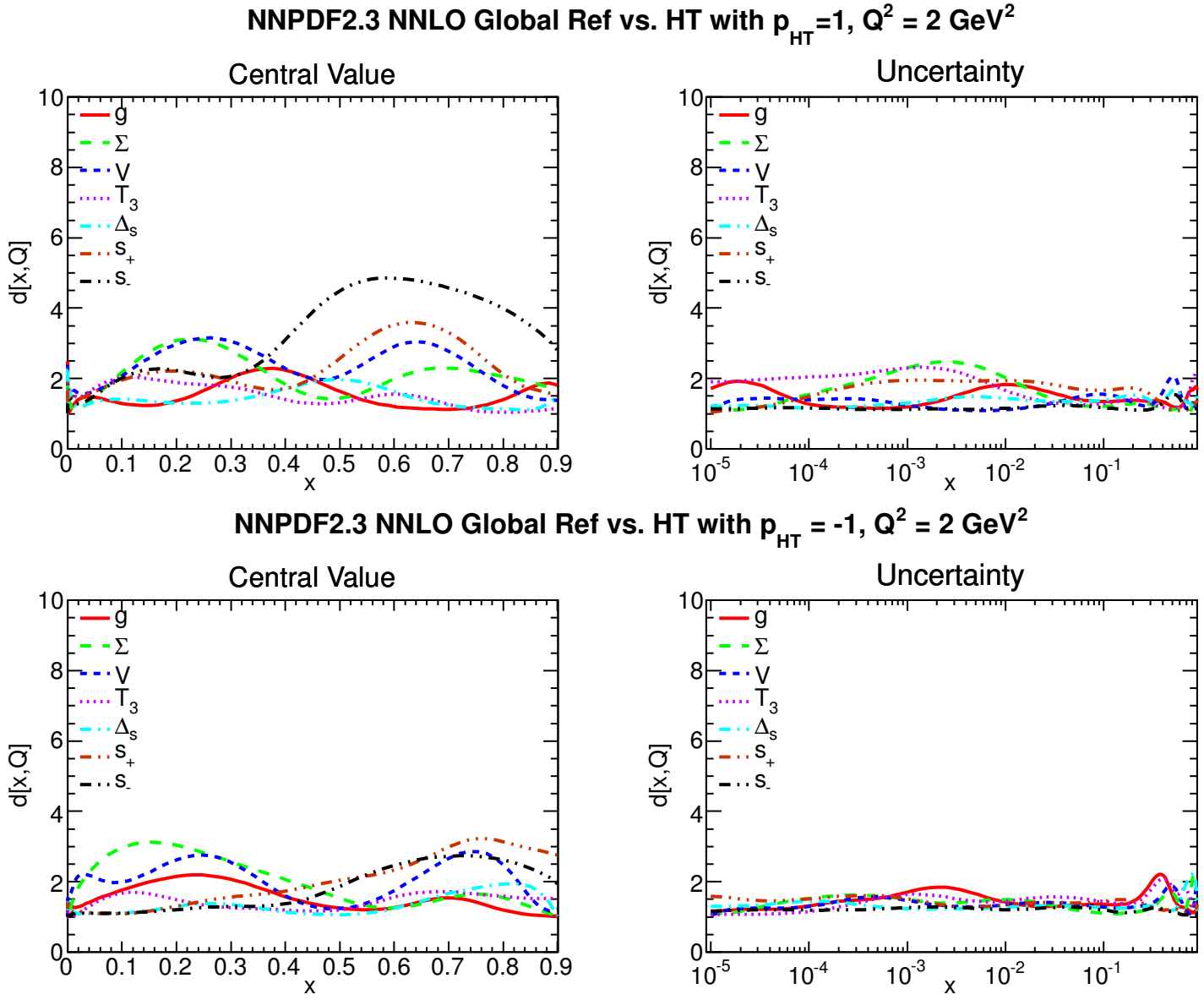
NNPDF2.3 Collider only vs NNPDF2.3



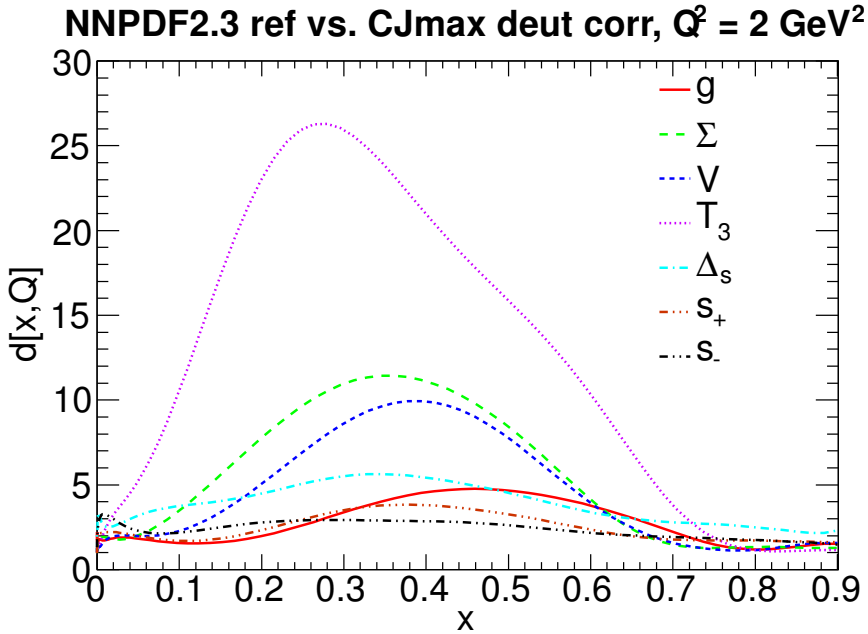


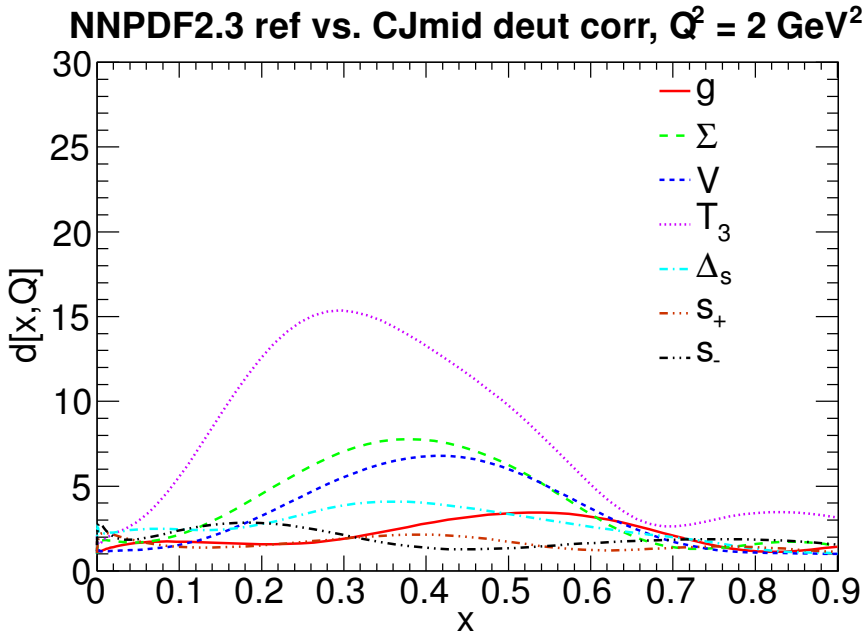
$xT_3(x, Q^2)$

Impact of HT upon NNPDFs



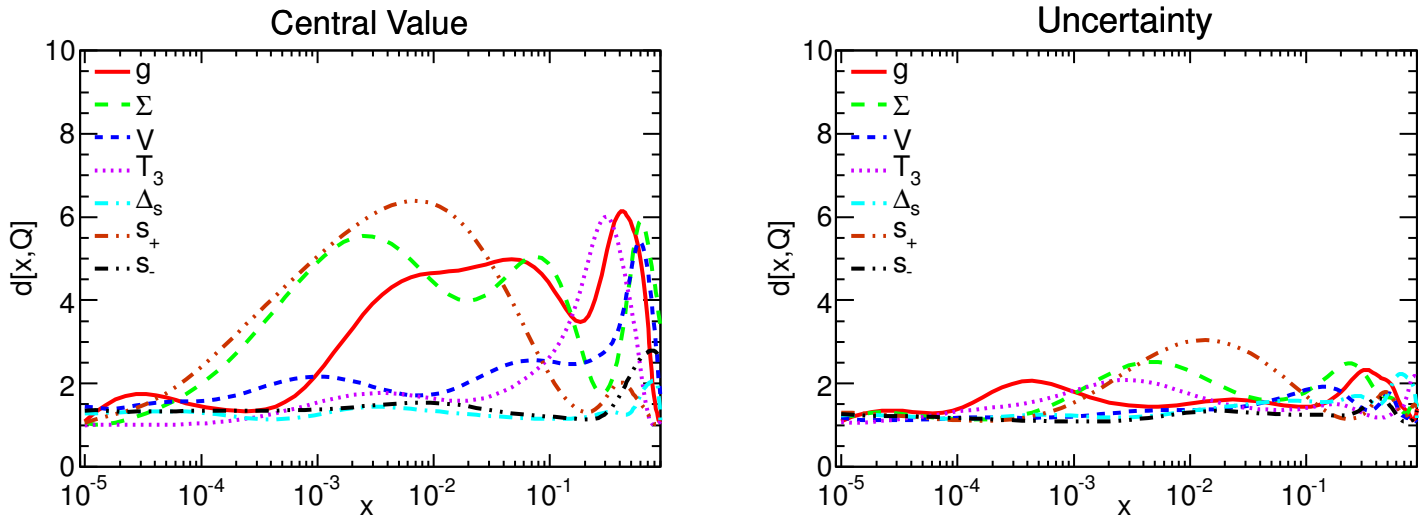
Impact of deuterium corrections upon NNPDFs





Impact of FFN Scheme

NNPDF2.3 NNLO Global VFN vs FFN, Q^2 = 2 GeV^2



NNPDF2.3 NNLO Global VFN vs. FFN, Q^2 = 10^4 GeV^2