THE UNIVERSITY of EDINBURGH

NNPDF

NNPDF3.0: PARTON DISTRIBUTIONS FOR THE LHC RUN II

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28th April 2015

DIS2015 Dallas, Texas

On behalf of the NNPDF collaboration:
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OUTLINE

- **NNPDF3.0:**
  - Methodology
  - Data
  - Closure testing
  - Results

- **Recent work:**
  - PDFs with threshold resummation
  - Towards NNPDF3.1

- **Summary**

NNPDF3.0

Edinburgh 2014/15
IFUM-1034-FT
CERN-PH-TH/2013-253
OUTP-14-11p
CAVENDISH-HEP-14-11

Parton distributions for the LHC Run II

The NNPDF Collaboration:
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Christopher S. Deans[1], Luigi Del Debbio[1], Stefano Forte[4], Alberto Guffanti[5],
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- **New PDF set** released last November
- arXiv:1410.8849, JHEP 04(2015)040
- **LO, NLO and NNLO sets** with different values of α_S and different datasets are available from **LHAPDF** (lhapdf.hepforge.org)

NNPDF APPROACH

- Parameterise parton distributions using **neural networks**
- Perform a **genetic algorithm** minimisation to find best-fit PDFs
- **Cross-validation** to prevent neural networks from over-learning
- Capture PDF uncertainties by generating set of **Monte Carlo replica PDFs**
- Fit using **large, global dataset**, including data from fixed target DIS and DY, HERA, Tevatron and LHC

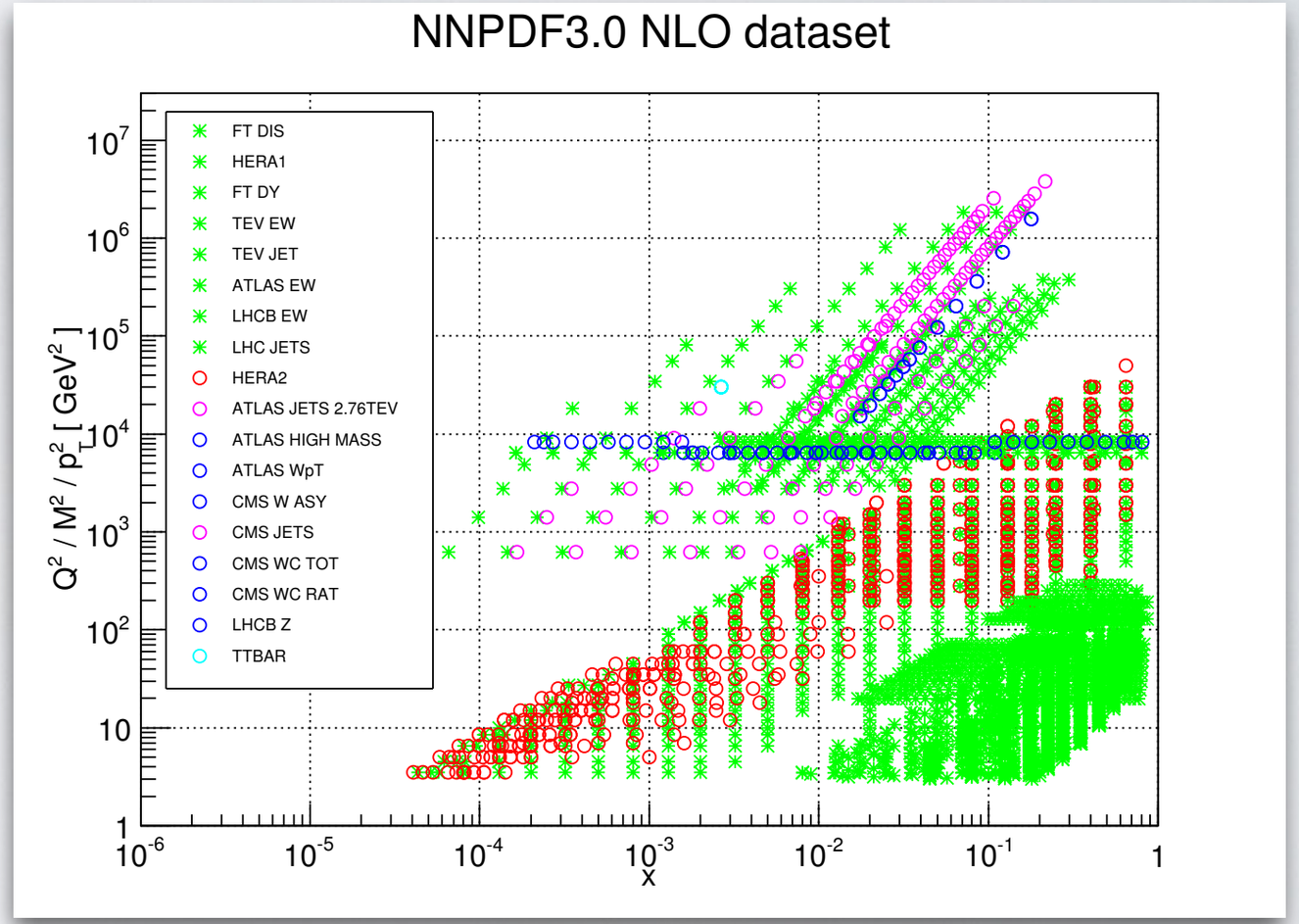
3.0 IMPROVEMENTS

- **New code** completely rewritten in C++, with new structure to improve efficiency and promote modularity between theory and fitting.
- **New mutation strategy** exploiting the structure of the neural networks to obtain a better fit results in a shorted amount of time.
- **Improved cross-validation** which prevents the fit from stopping too early while still protecting against over-learning.
- **New positivity constraints** covering a wider range of observables over a larger kinematic range.

NNPDF3.0: DATASET

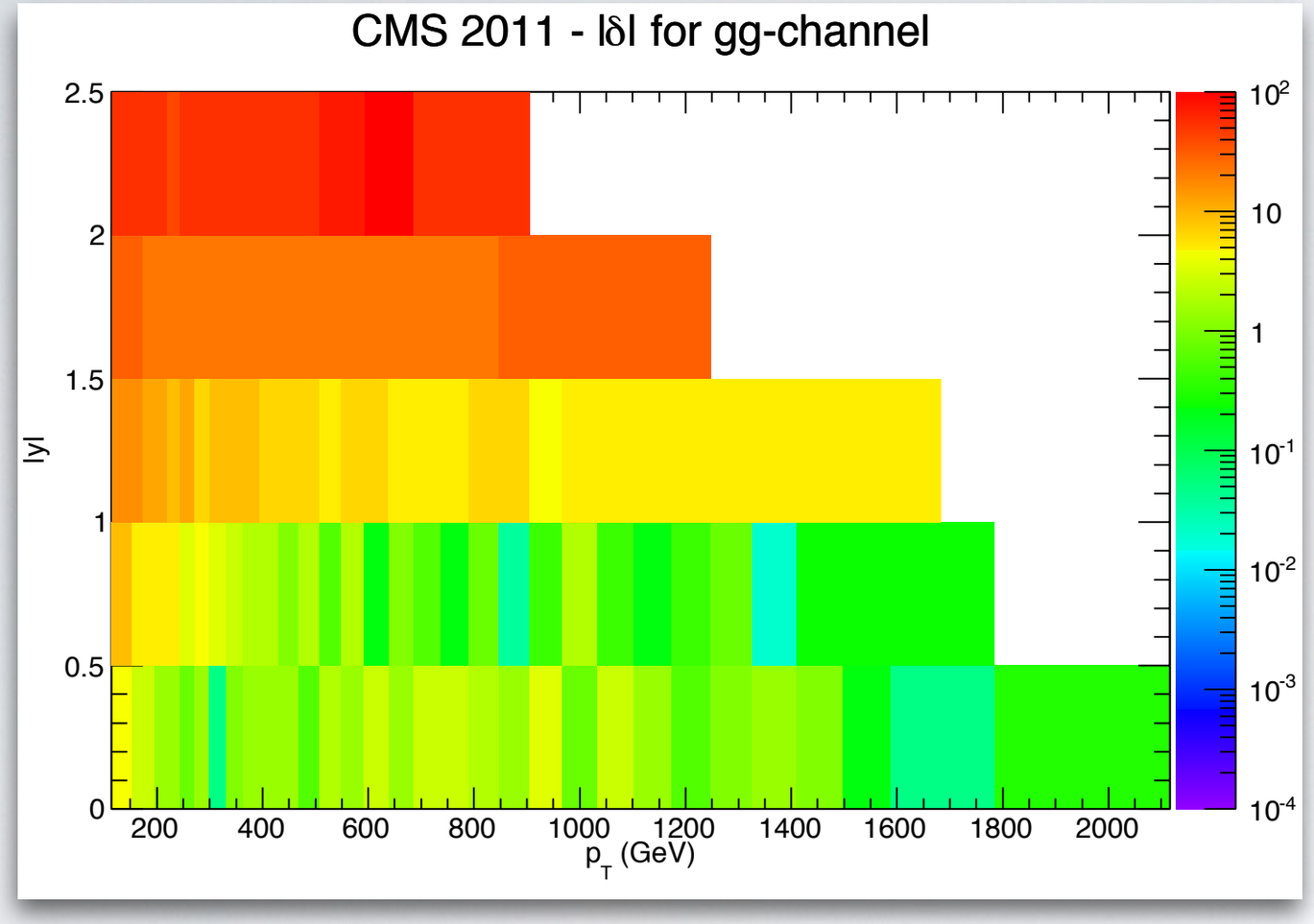
Large amount of new data included in the fit:

- **HERA**: HERA-II structure function data from H1 & Zeus, combined charm production data
- **ATLAS**: 2.76 TeV inclusive jet data, high-mass Drell-Yan and W pT distributions, top quark pair production total cross-section
- **CMS**: 7 TeV inclusive jet data, muon asymmetry, W+c production, double differential Drell-Yan distributions, top quark pair production cross-section
- **LHCb**: Z rapidity distribution



… plus data from NNPDF2.3

NNPDF3.0: THEORY

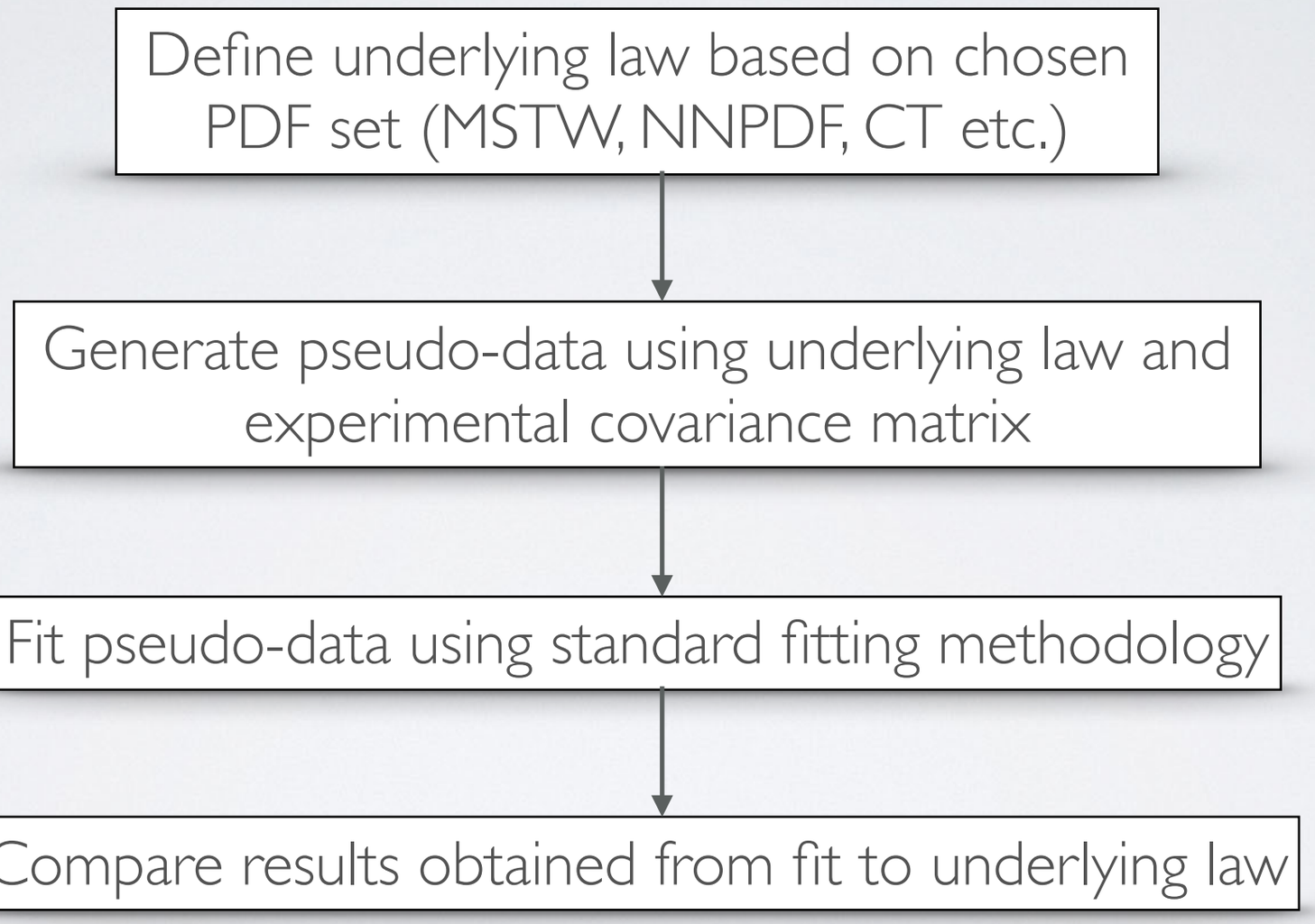


Percentage difference between approximate and exact calculation for gg channel

- Use fast interfaces at NLO (APPLgrid, FastNLO, aMCfast) to generate *FKtables*
- For NNLO fits, supplement NLO theory for hadron data with k-factors
- Jet data included at NNLO using threshold calculation in regions where the gg channel agrees with exact calculation (Pires et al.)
- Electroweak corrections from FEWZ3.1 for neutral current datasets included as additional factor

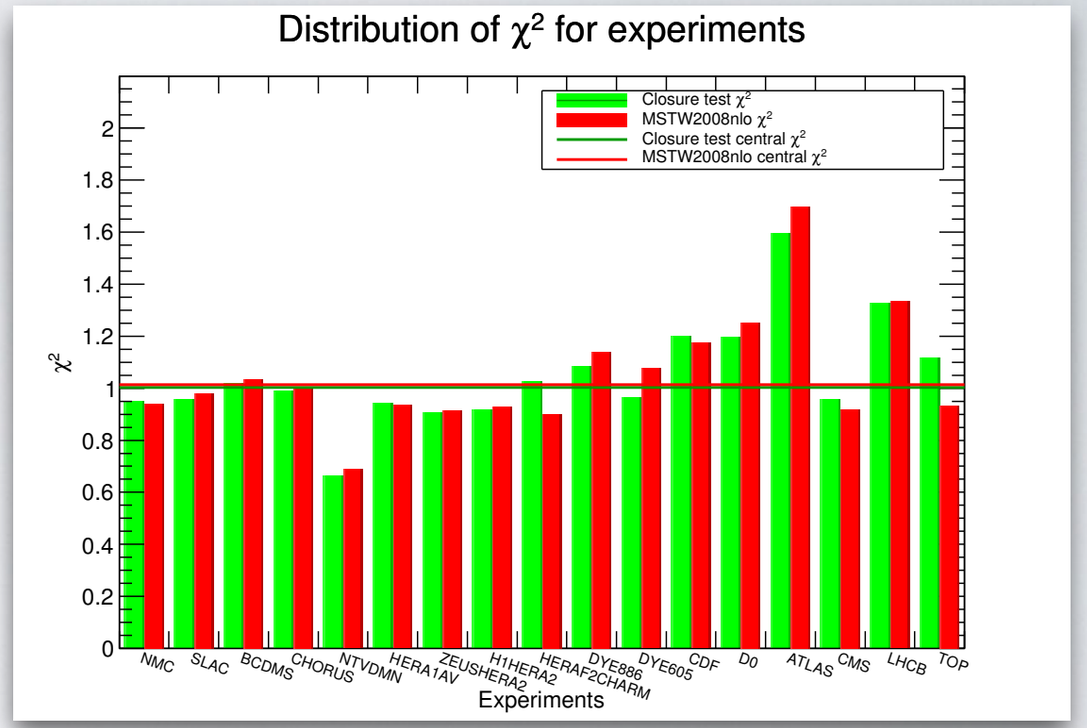
NNPDF3.0: CLOSURE TESTING

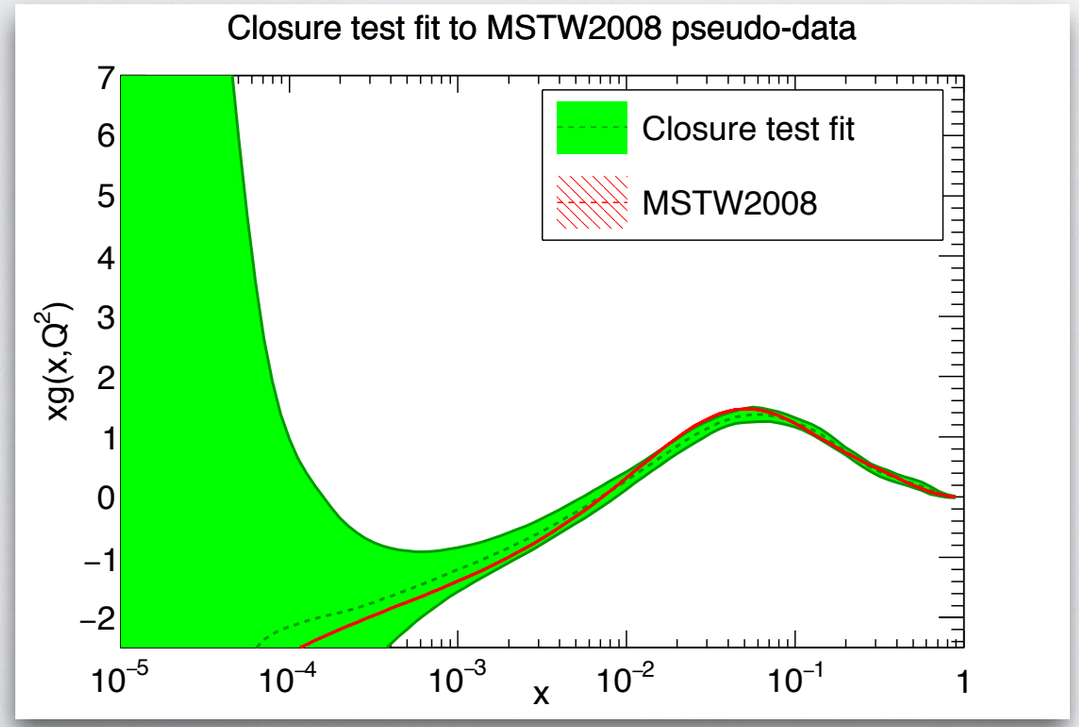
Validate methodology by fitting to pseudo-data generated using known PDFs

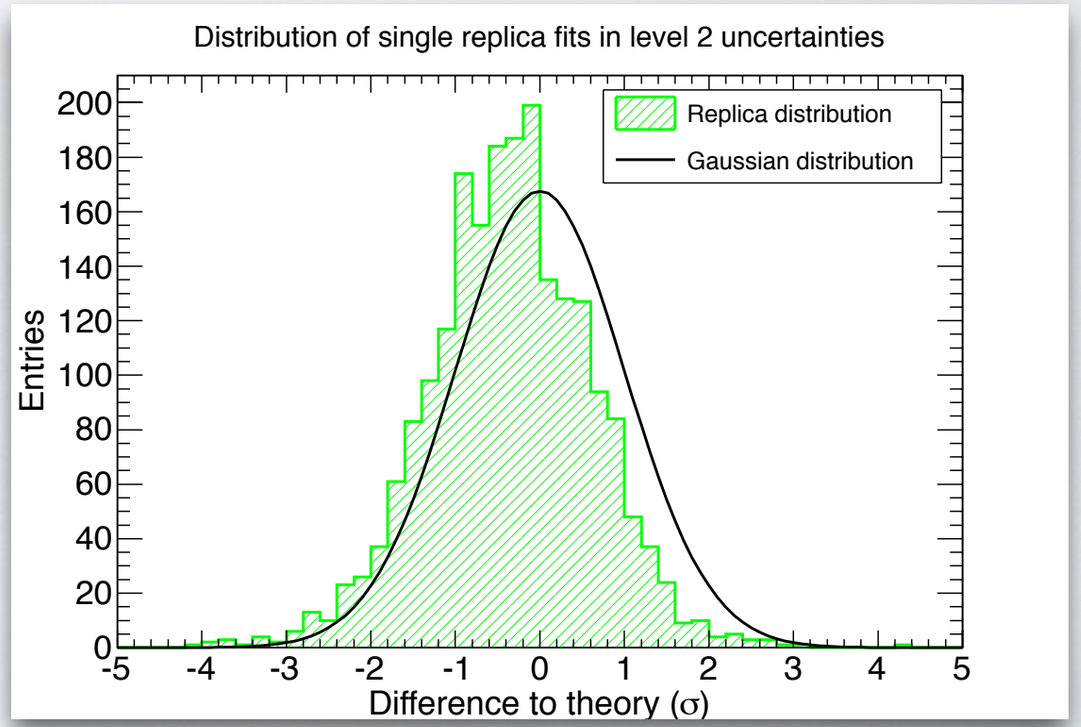


NNPDF3.0: CLOSURE TEST RESULTS

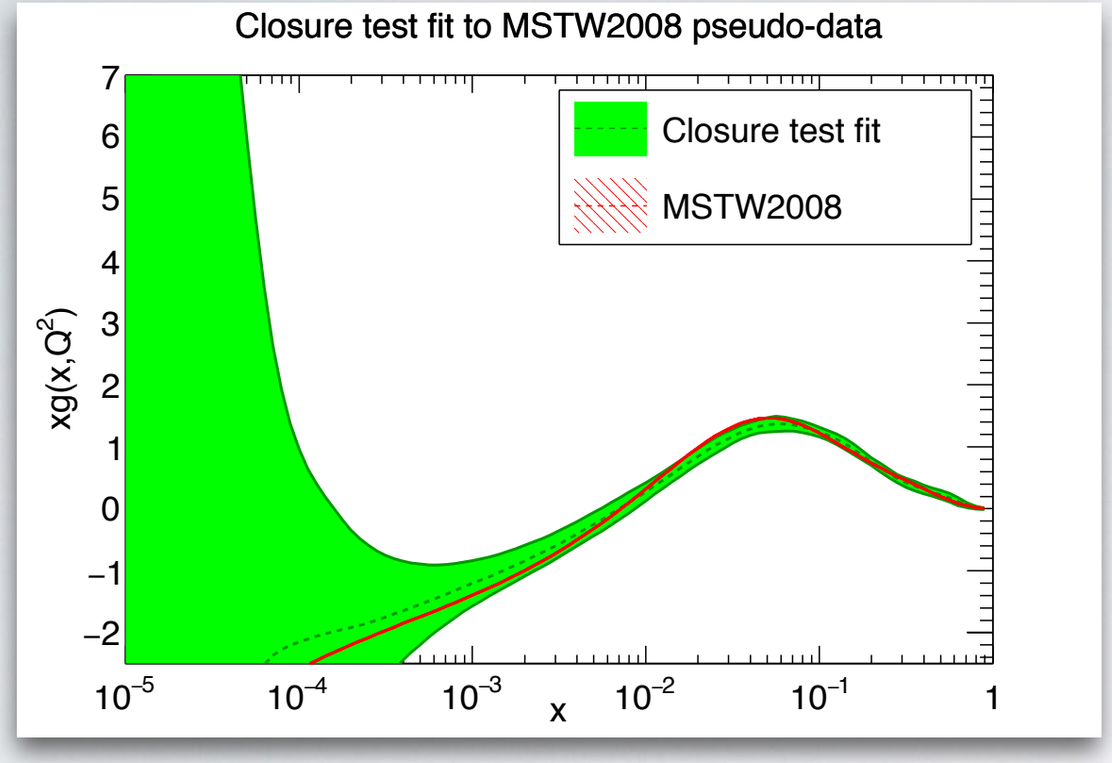
- Reproduce central χ^2 of input set to within 1% (Fit χ^2 =1.00, input χ^2=1.01)
- Additionally reproduce χ^2 of individual datasets (see right)
- PDF central values reproduced (with expected fluctuations)
- Theory within one sigma of fit central value in ~70% of fits.

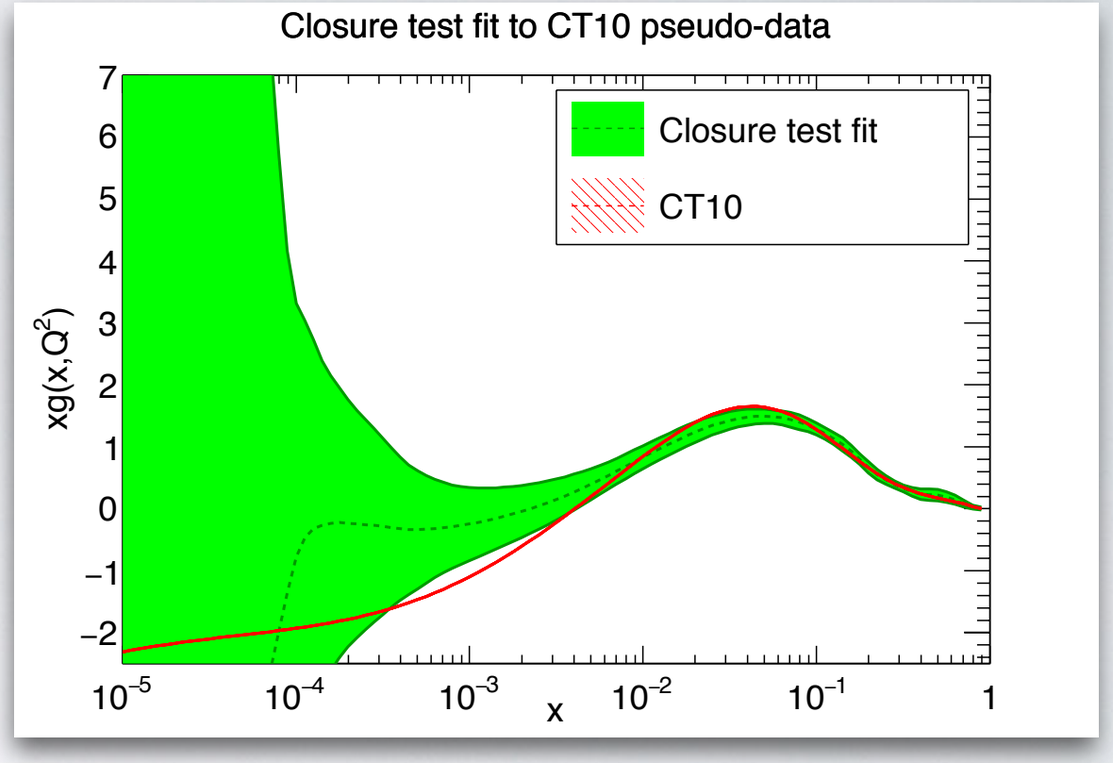


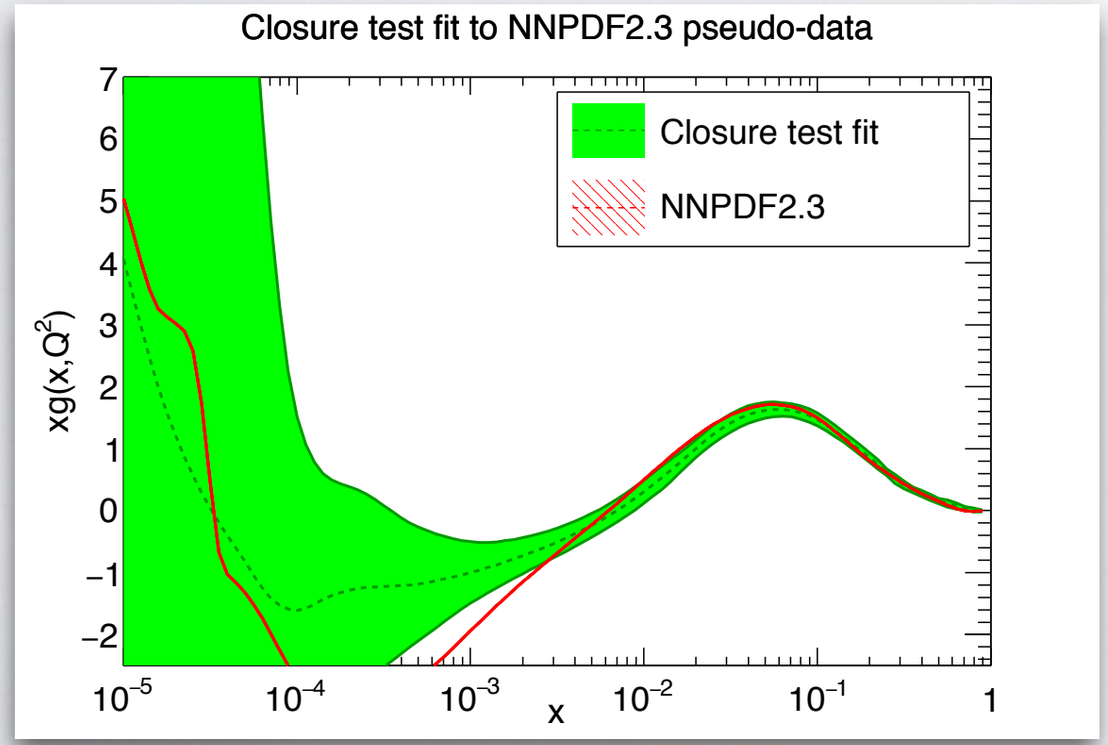


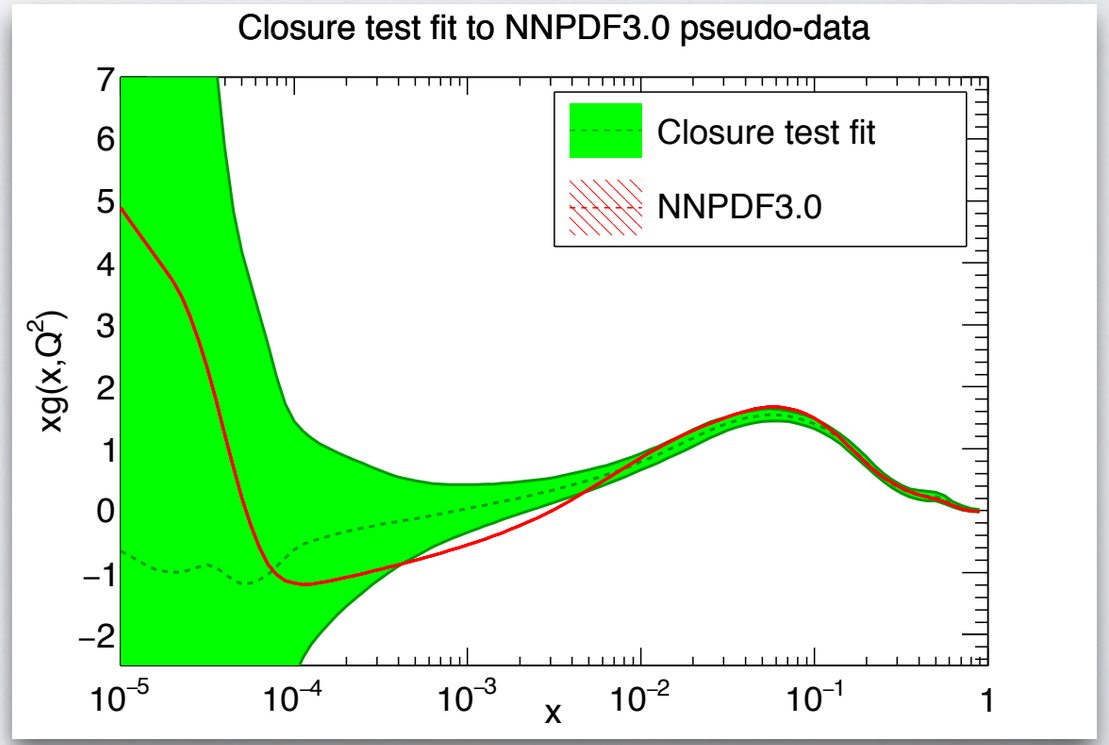


CLOSURE TEST PDFS



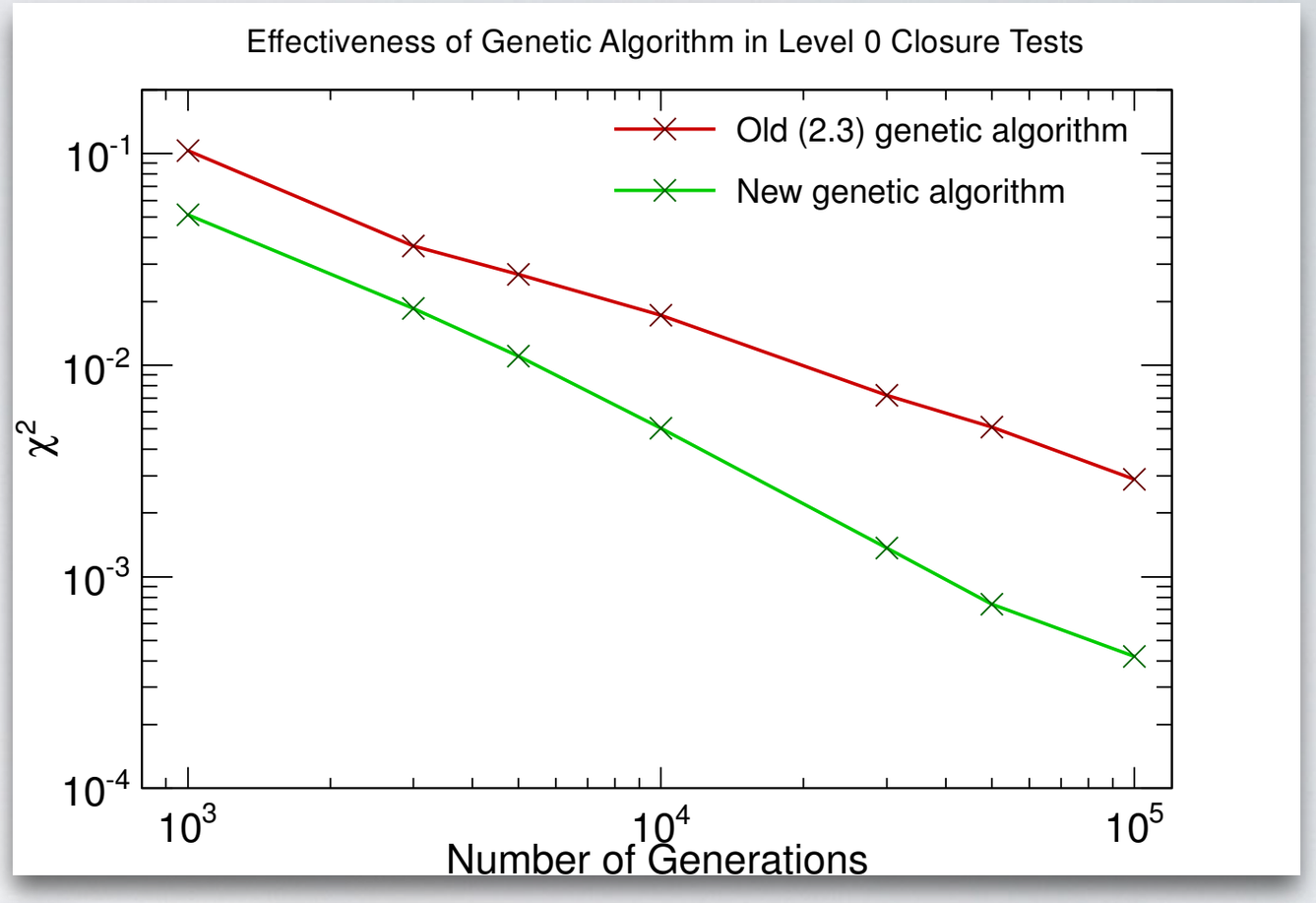


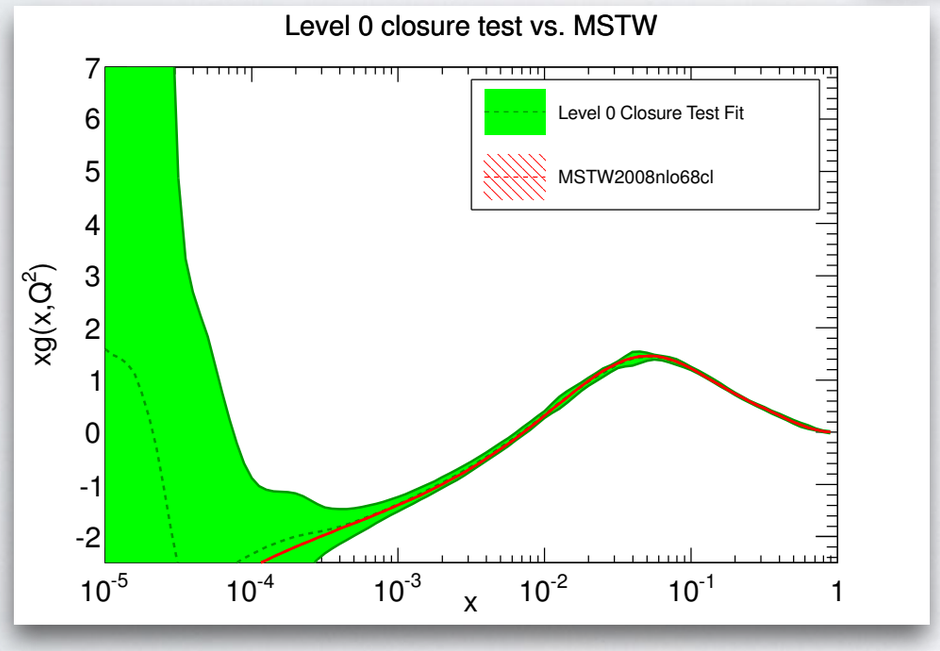


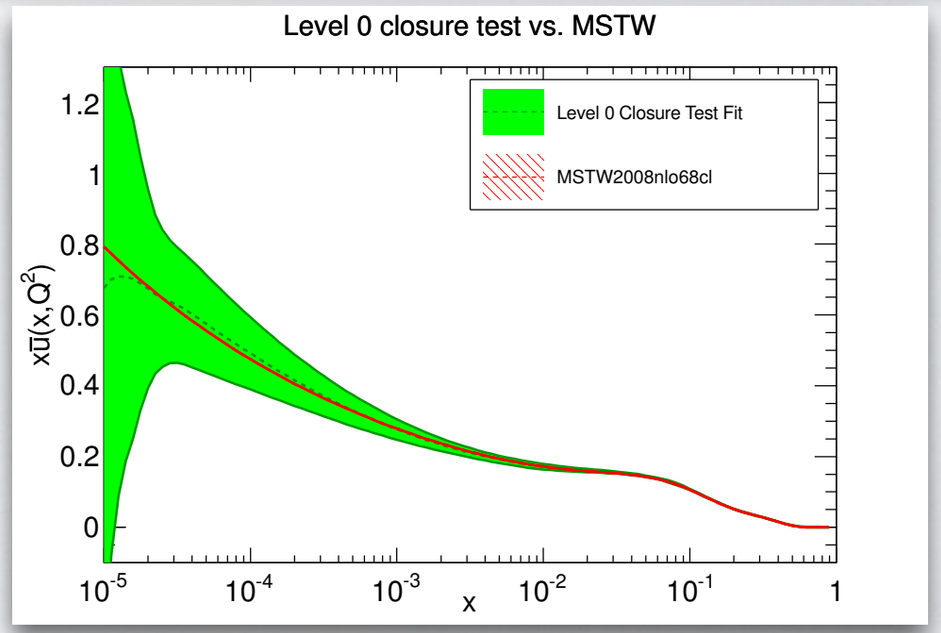


NNPDF3.0: NOISELESS CLOSURE TEST

- When generating closure test pseudo-data, it's possible to control level of noise
- Closure test with no noise provides test of basic fitting ability
- Ideal χ^2 of zero (expect slightly above for fixed length fit)

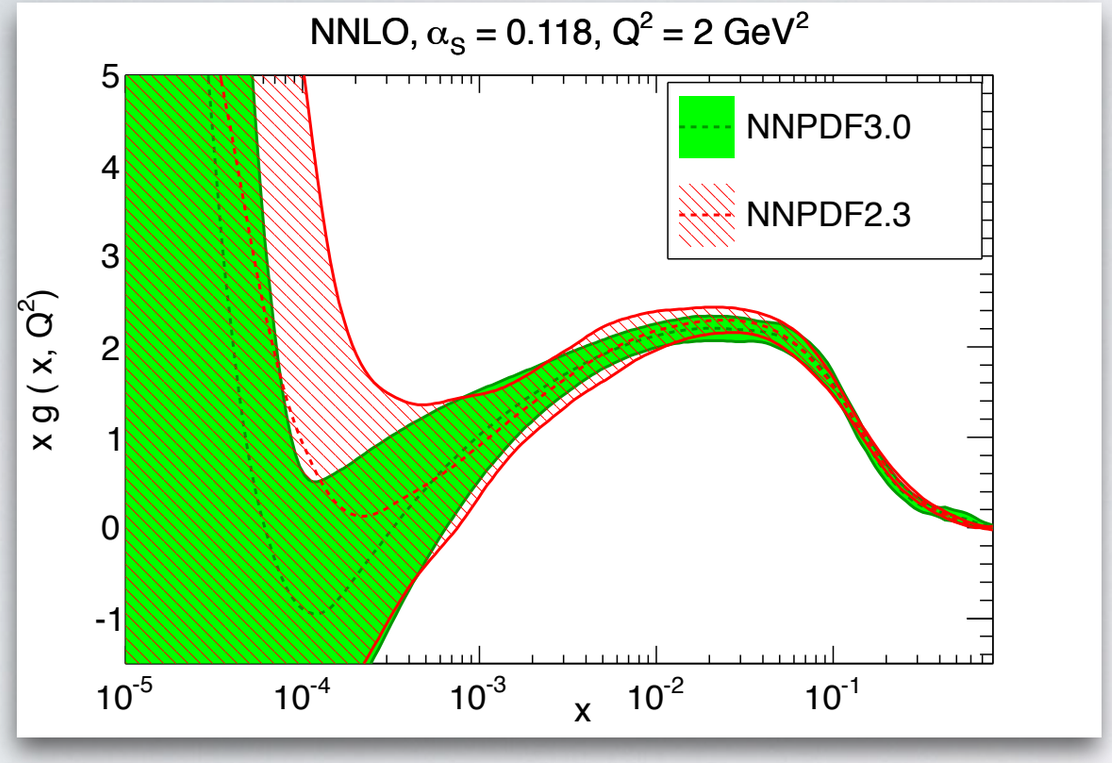


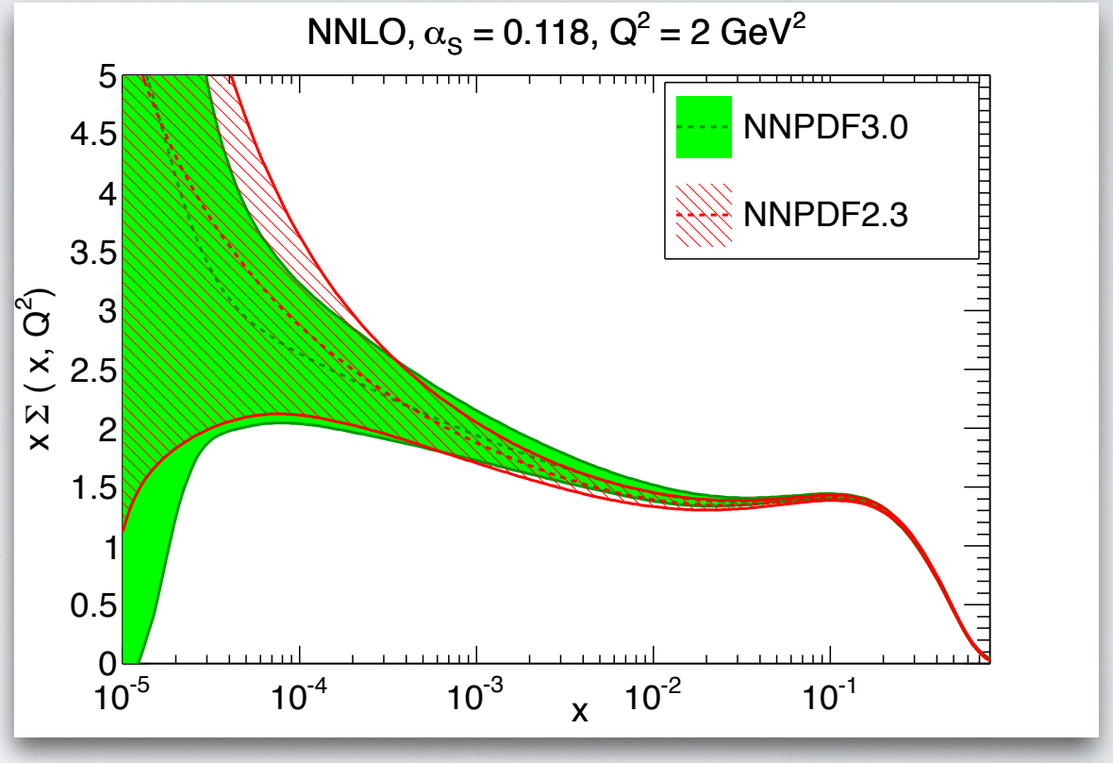


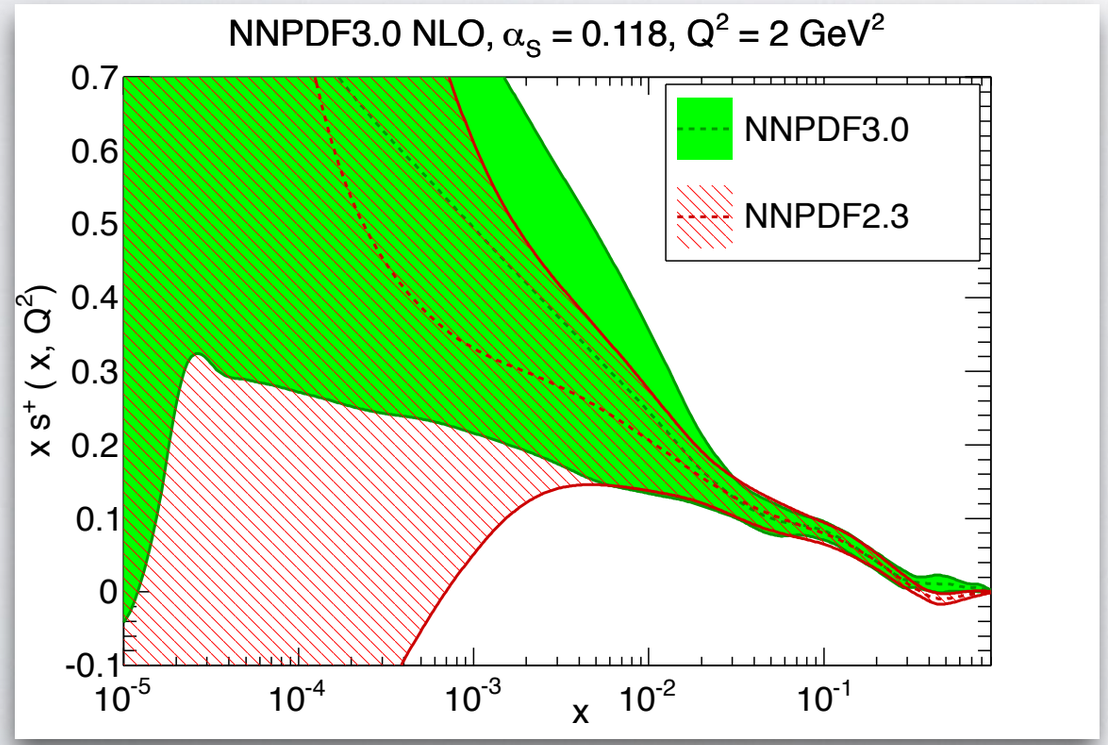


NNPDF3.0: RESULTS

NNPDF3.0 RESULTS: PDFS

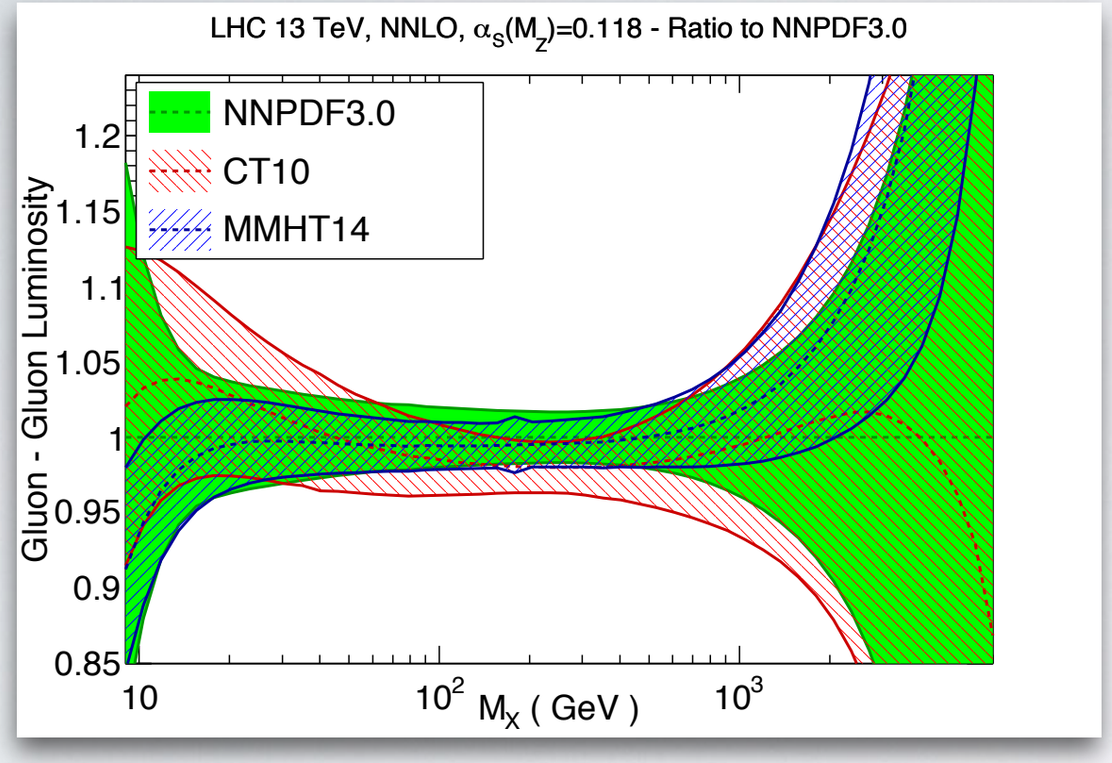


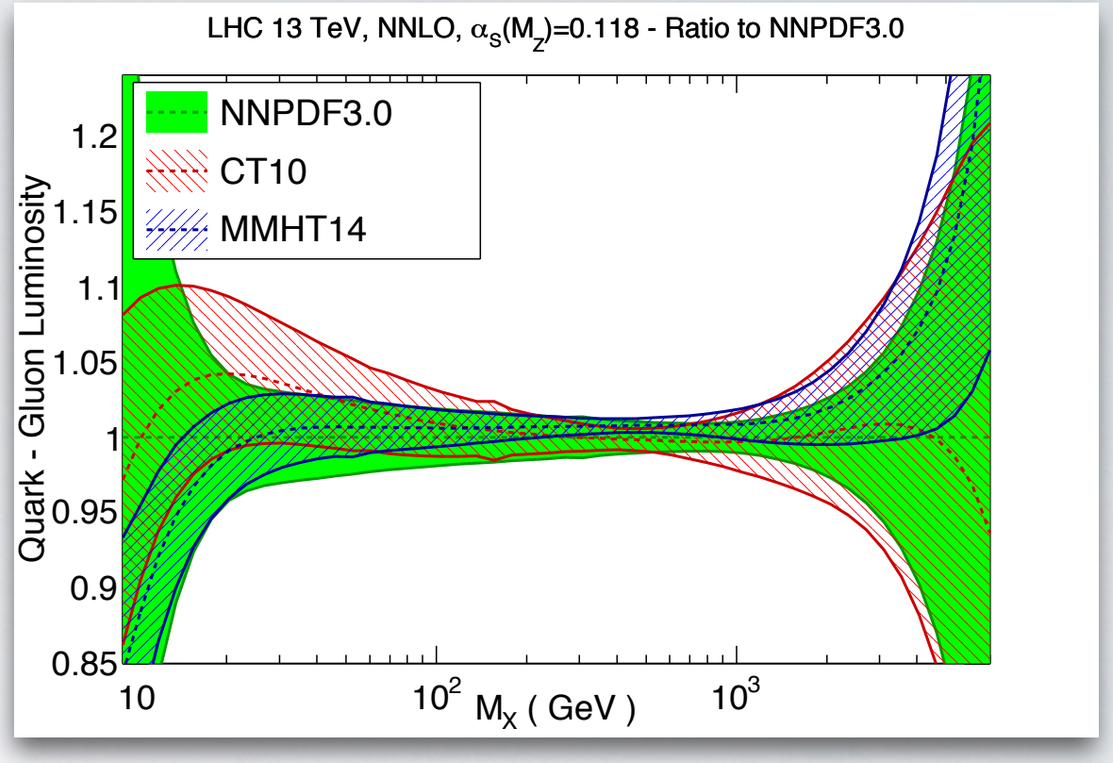


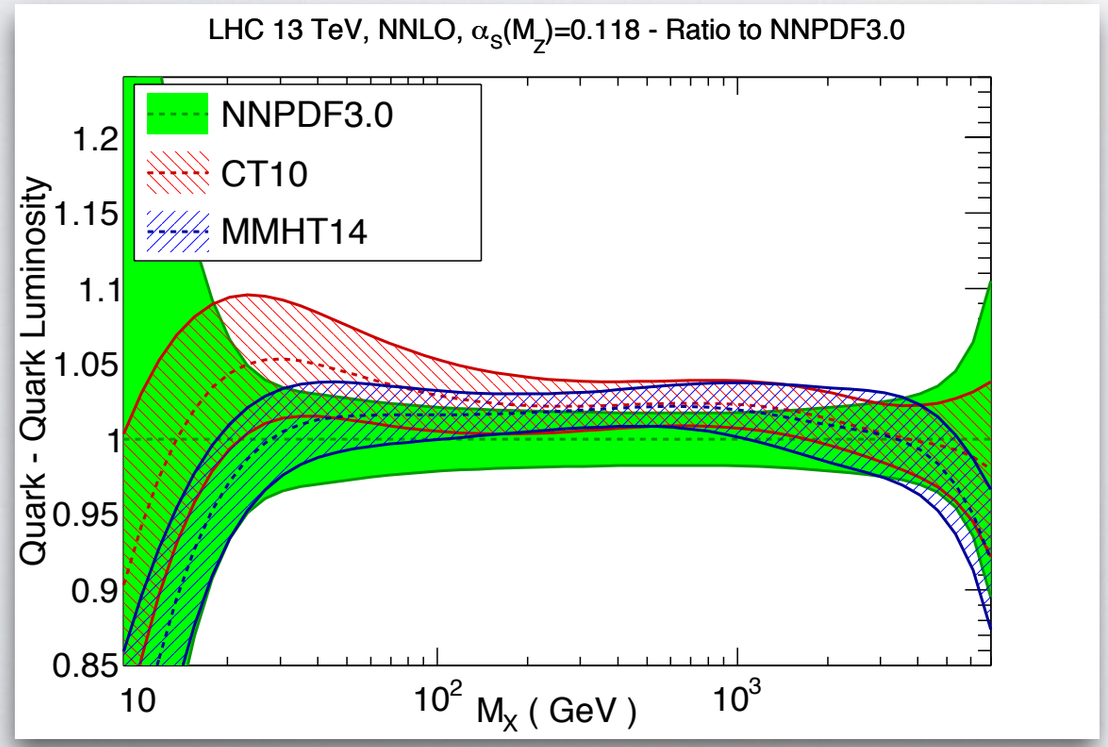


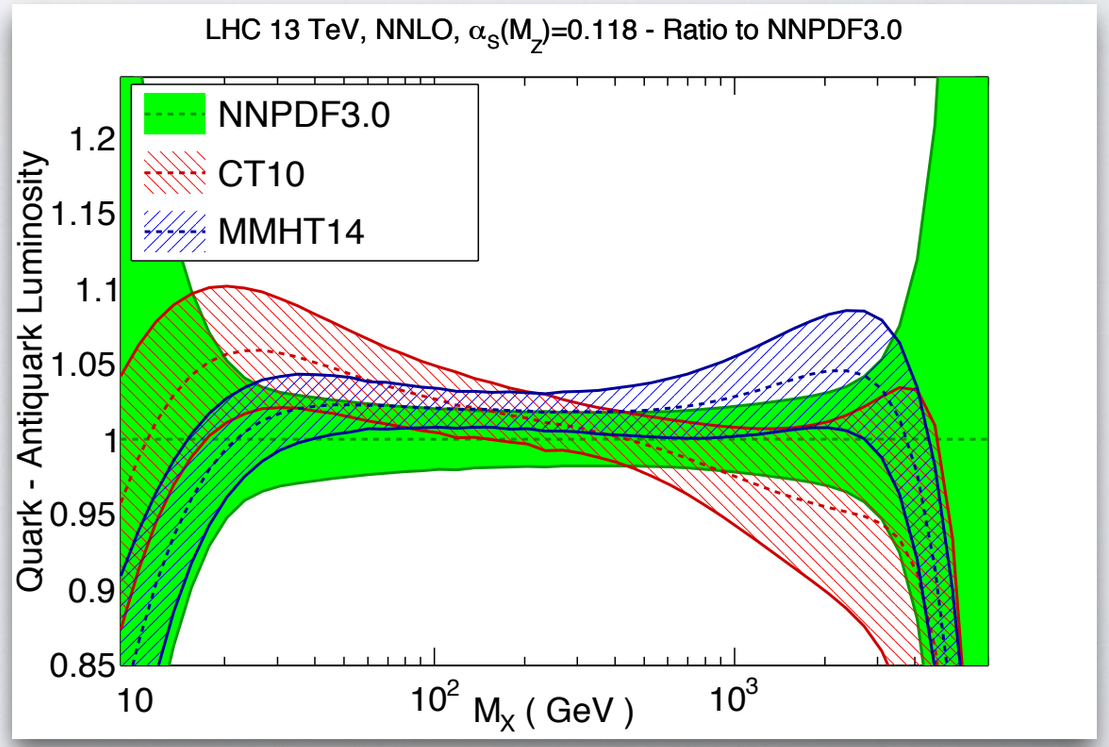
- General agreement with 2.3; differences of ~1σ due to new data/improved methodology
- Reduction of uncertainties in many PDFs
- Impact of extended positivity in s+

PDF LUMINOSITIES



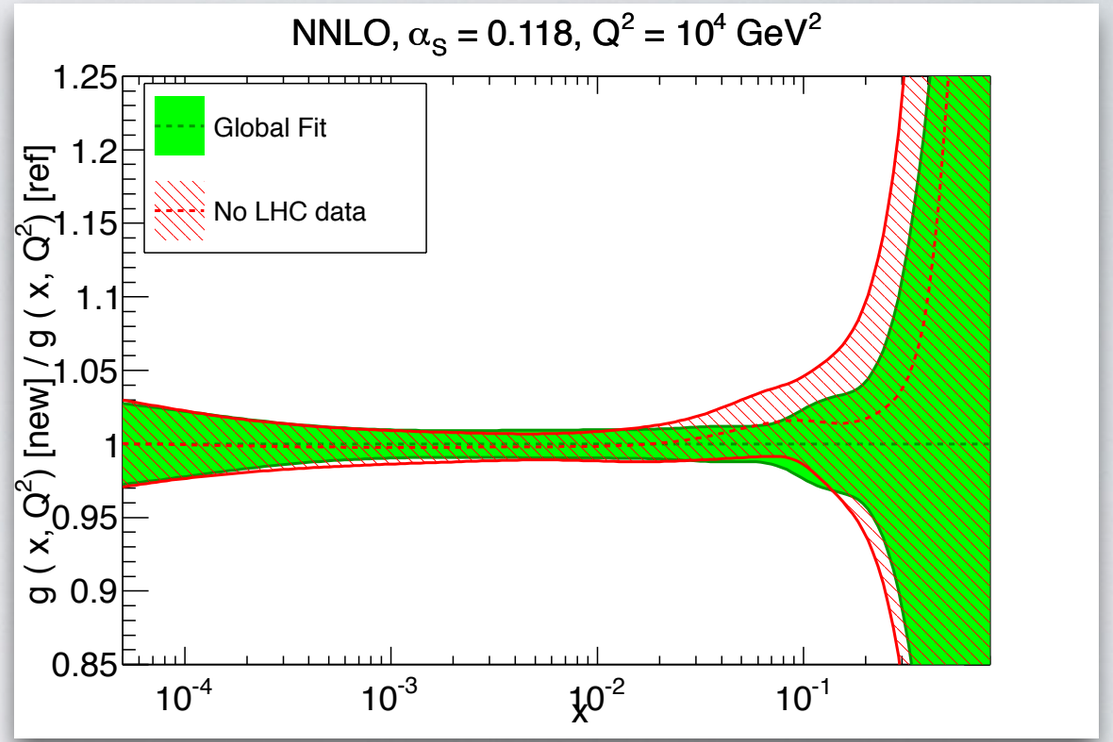


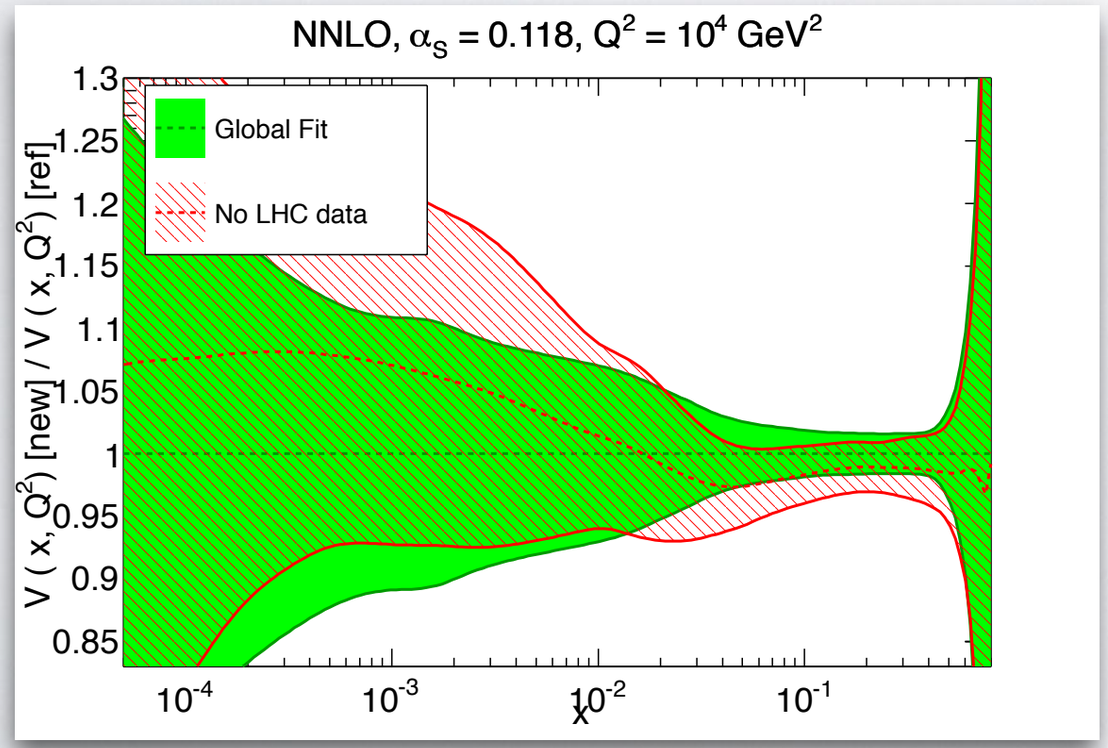


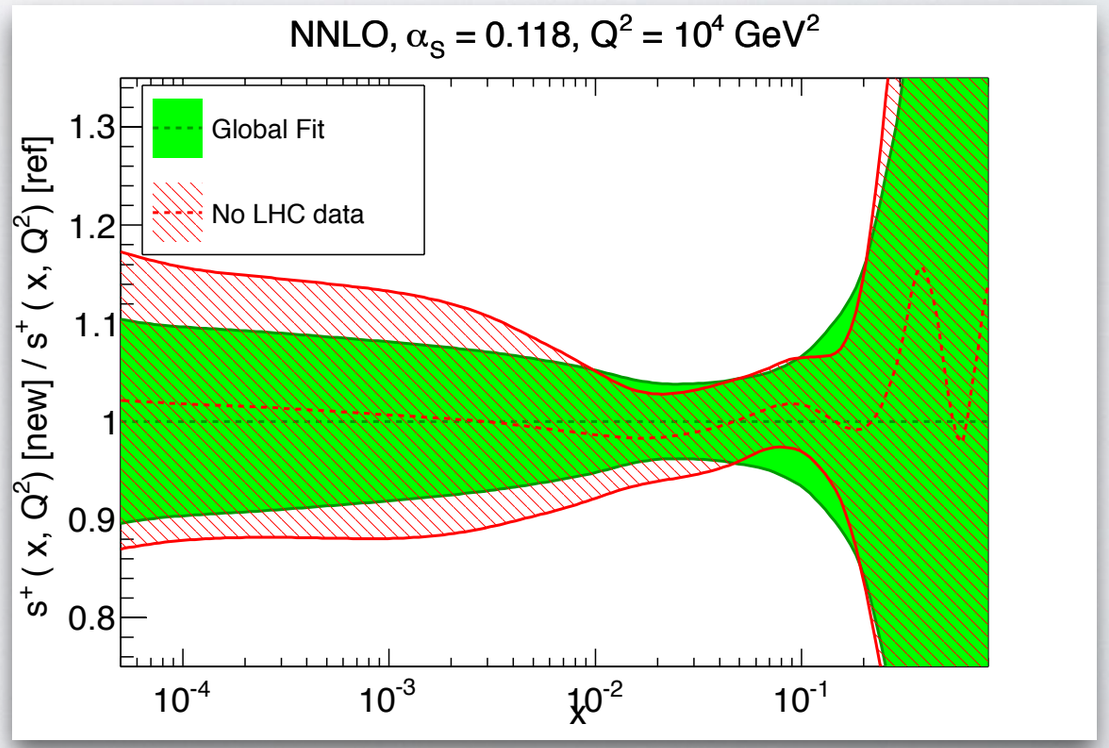


IMPACT OF LHC DATA

- Compare NNPDF3.0 fits with and without LHC data
- Reduction of uncertainties in large-x gluon, light-quarks
- Also available on LHAPDF: HERA-only, HERA+ATLAS, HERA+CMS, NoJet PDFs



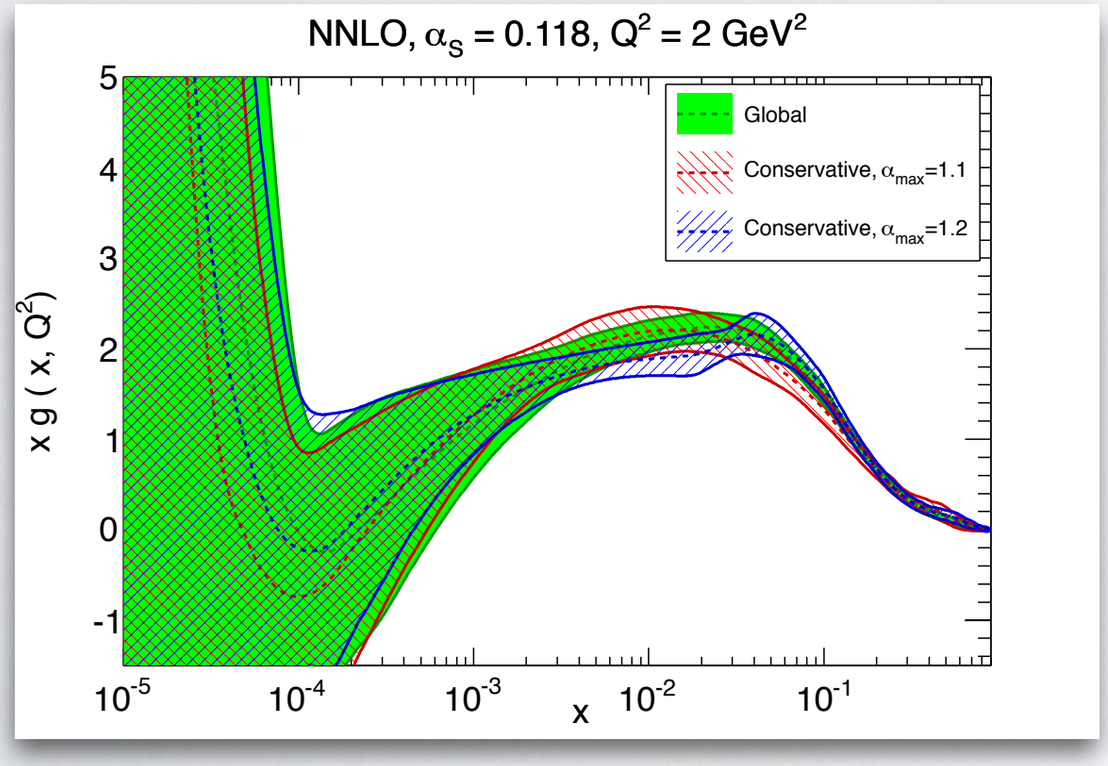




CONSERVATIVE DATASET PDFS

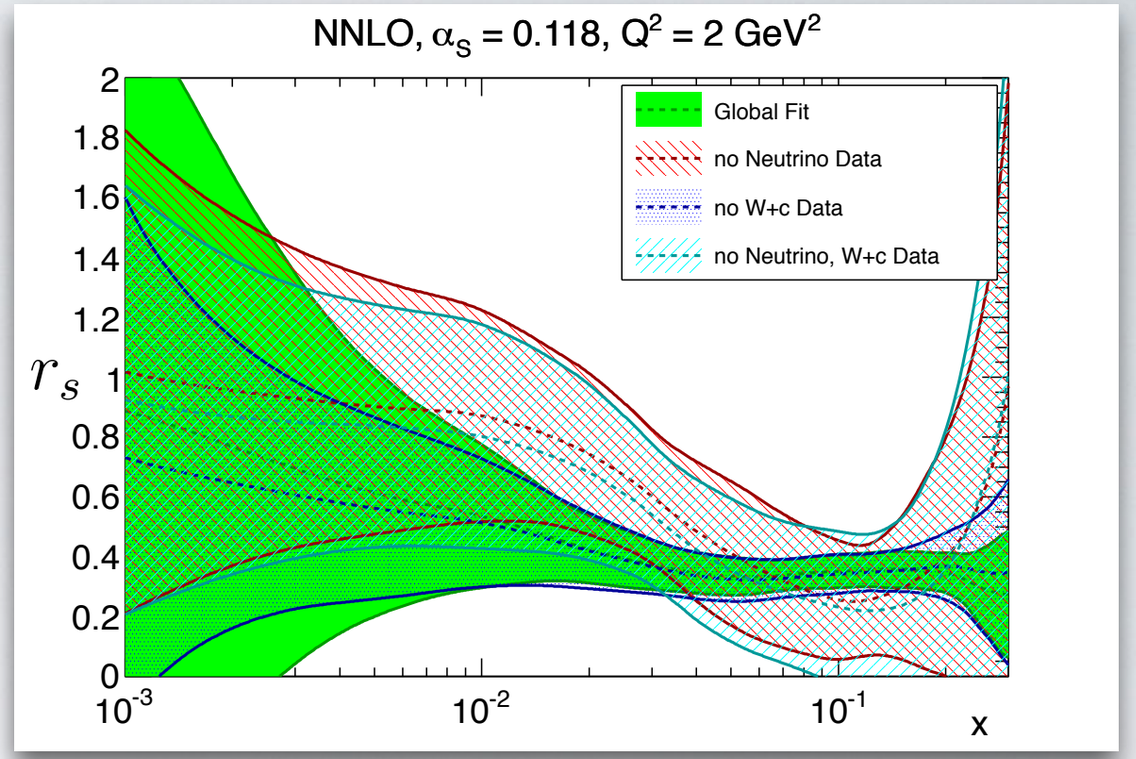
- PDFs generated by fitting reduced fully consistent dataset
- Consistency determined by calculating P(α) for each dataset, (see arXiv:1012:0836)
- Results compatible with global fit, with larger uncertainties

	$\alpha_{\max} = 1.1$		$\alpha_{\max} = 1.2$		$\alpha_{\max} = 1.3$		Global fit	
	$\chi^2_{\rm nlo}$	$\chi^2_{\rm nnlo}$	$\chi^2_{\rm nlo}$	$\chi^2_{\rm nnlo}$	$\chi^2_{\rm nlo}$	$\chi^2_{\rm nnlo}$	$\chi^2_{\rm nlo}$	$\chi^2_{\rm nnlo}$
Total	0.96	1.01	1.06	1.10	1.12	1.16	1.23	1.29
NMC d/p	0.91	0.91	0.89	0.89	0.88	0.89	0.92	0.93
NMC $\sigma^{\rm NC,p}$	-	-	-	-	-	-	1.63	1.52
SLAC	-	-	-	-	1.77	1.19	1.59	1.13
BCDMS	-	-	1.11	1.15	1.12	1.16	1.22	1.29
CHORUS	-	-	1.06	1.02	1.09	1.07	1.11	1.09
NuTeV	0.35	0.34	0.62	0.64	0.70	0.70	0.70	0.86
HERA-I	0.97	0.98	1.02	1.00	1.02	0.99	1.05	1.04
ZEUS HERA-II	-	-	-	-	1.41	1.48	1.40	1.48
H1 HERA-II	-	-	-	-	-	-	1.65	1.79
HERA $\sigma^{\rm c}_{\rm NC}$	-	-	1.21	1.32	1.20	1.31	1.27	1.28
E886 d/p	0.30	0.30	0.43	0.40	0.44	0.46	0.53	0.48
E886 p	-	-	1.18	1.40	1.27	1.53	1.19	1.55
E605	1.04	1.10	0.74	0.83	0.75	0.88	0.78	0.90
CDF Z rapidity	-	-	-	-	-	-	1.33	1.53
CDF Run-II k_t jets	-	-	1.01	2.01	1.04	1.84	0.96	1.80
D0 Z rapidity	0.56	0.61	0.62	0.71	0.60	0.69	0.57	0.61
ATLAS W, Z 2010	-	-	1.19	1.13	1.19	1.17	1.19	1.23
ATLAS 7 TeV jets 2010	0.96	1.65	1.08	1.58	1.10	1.54	1.07	1.36
ATLAS 2.76 TeV jets	1.03	0.38	1.38	0.36	1.35	0.35	1.29	0.33
ATLAS high-mass DY	-	-	-	-	-	-	2.06	1.45
ATLAS W p_T	-	-	-	-	-	-	1.13	-
CMS W electron asy	0.98	0.84	0.82	0.72	0.85	0.73	0.87	0.73
CMS W muon asy	-	-	-	-	-	-	1.81	1.72
CMS jets 2011	0.90	2.09	0.96	2.09	0.99	2.10	0.96	1.90
CMS $W + c$ total	-	-	-	-	-	-	0.96	0.84
CMS $W + c$ ratio	-	-	-	-	-	-	2.02	1.77
CMS 2D DY 2011	-	-	-	-	1.20	1.30	1.23	1.36
LHCb W rapidity	-	-	0.69	0.65	0.74	0.69	0.71	0.72
LHCb Z rapidity	-	-	1.23	1.78	1.11	1.58	1.10	1.59
$\sigma(t\bar{t})$	-	-	-	-	-	-	1.43	0.66

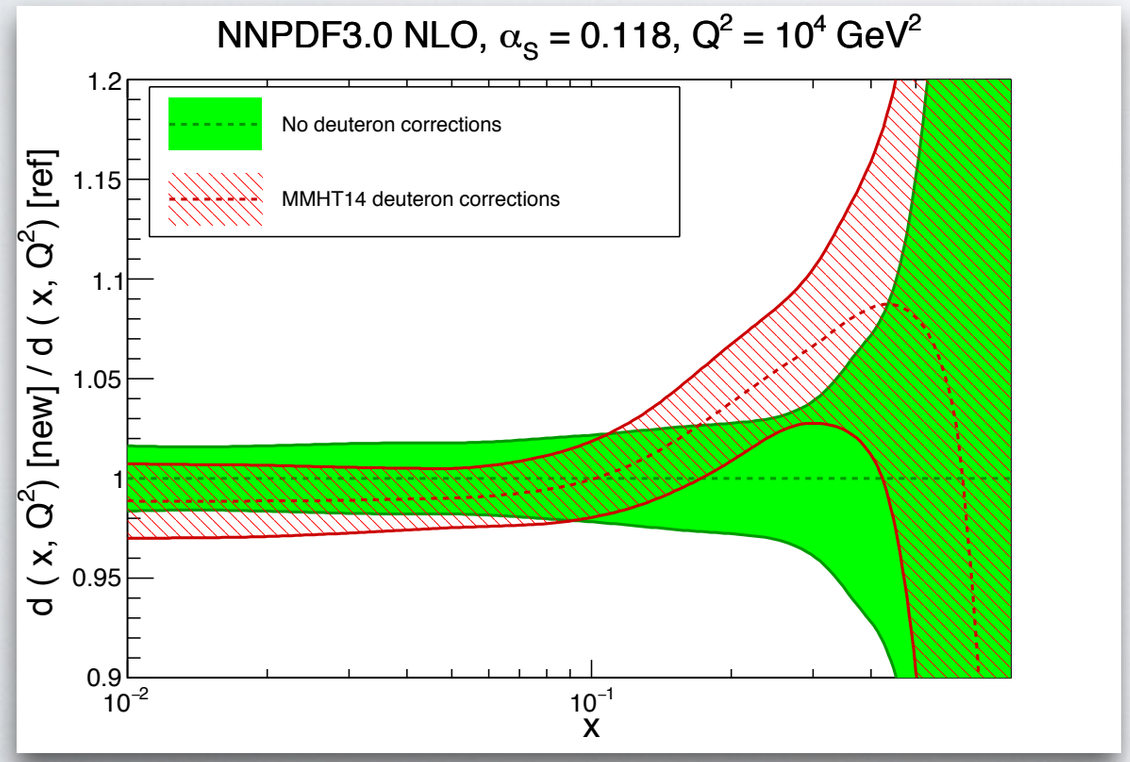


PROTON STRANGENESS

- CMS W+c and ATLAS WZ data provide information on strangeness content
- Fits with excluding different sets of relevant data find general agreement
- Shown: $r_s = \dfrac{s + \bar{s}}{\bar{u} + \bar{d}}$



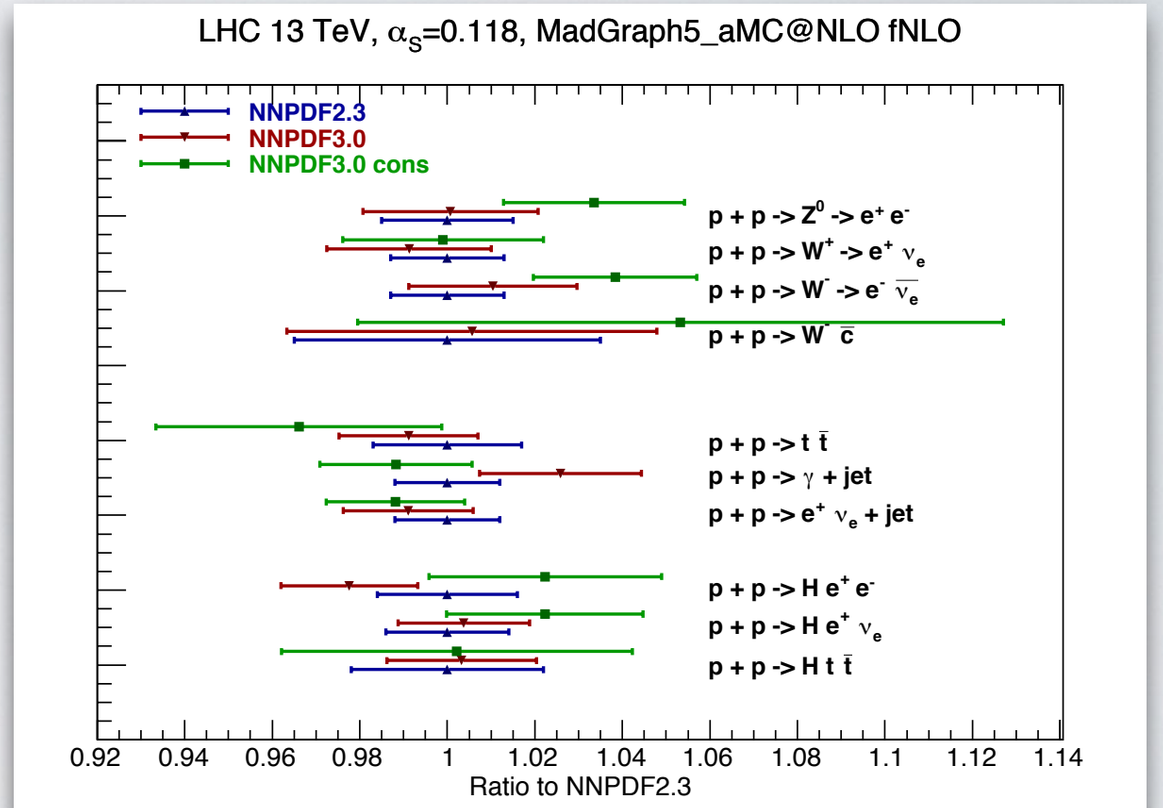
DEUTERON CORRECTIONS

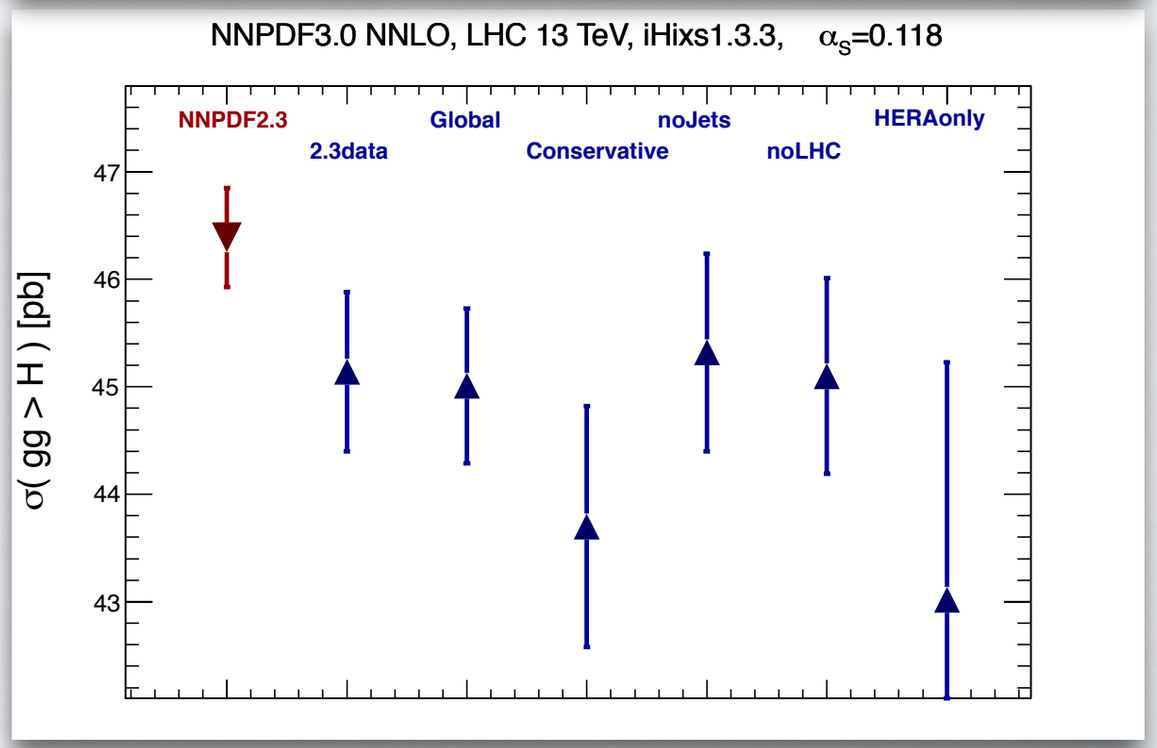


- NNPDF3.0 fit including deuteron corrections to fixed-target DIS and DY data (Thorne et al., arXiv:1412.3989)
- Non-negligible difference only for down PDF

LHC CROSS-SECTIONS

- Consistent results between 2.3 and 3.0 across many LHC observables
- Slightly larger uncertainties in general: due to improvements in methodology, better exploration of parameter space
- Decrease in ggH cross-section due to softer gg luminosity
- Again change is due to improved methodology, similar results for 3.0 global and 2.3data fits

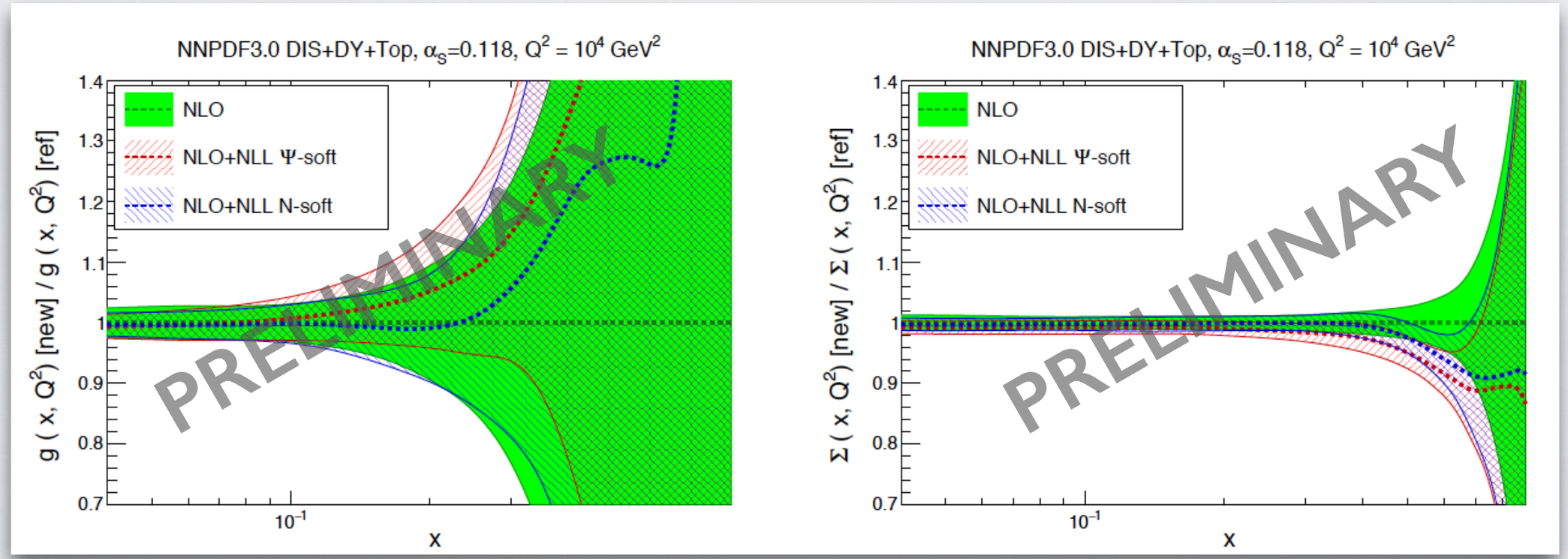




RECENT WORK

THRESHOLD RESUMMATION

- First PDF sets at NLO+NLL and NNLO+NNLL
- Soft-gluon resummation most relevant for DIS at large-x and Drell-Yan at forward rapidities
- Perform fit (plus baseline) with DIS, DY and top data — code not yet available for inclusive jet processes
- Preliminary results for NLO+NLL: shifts in quark and gluon at large-x, relevant for production of BSM particles



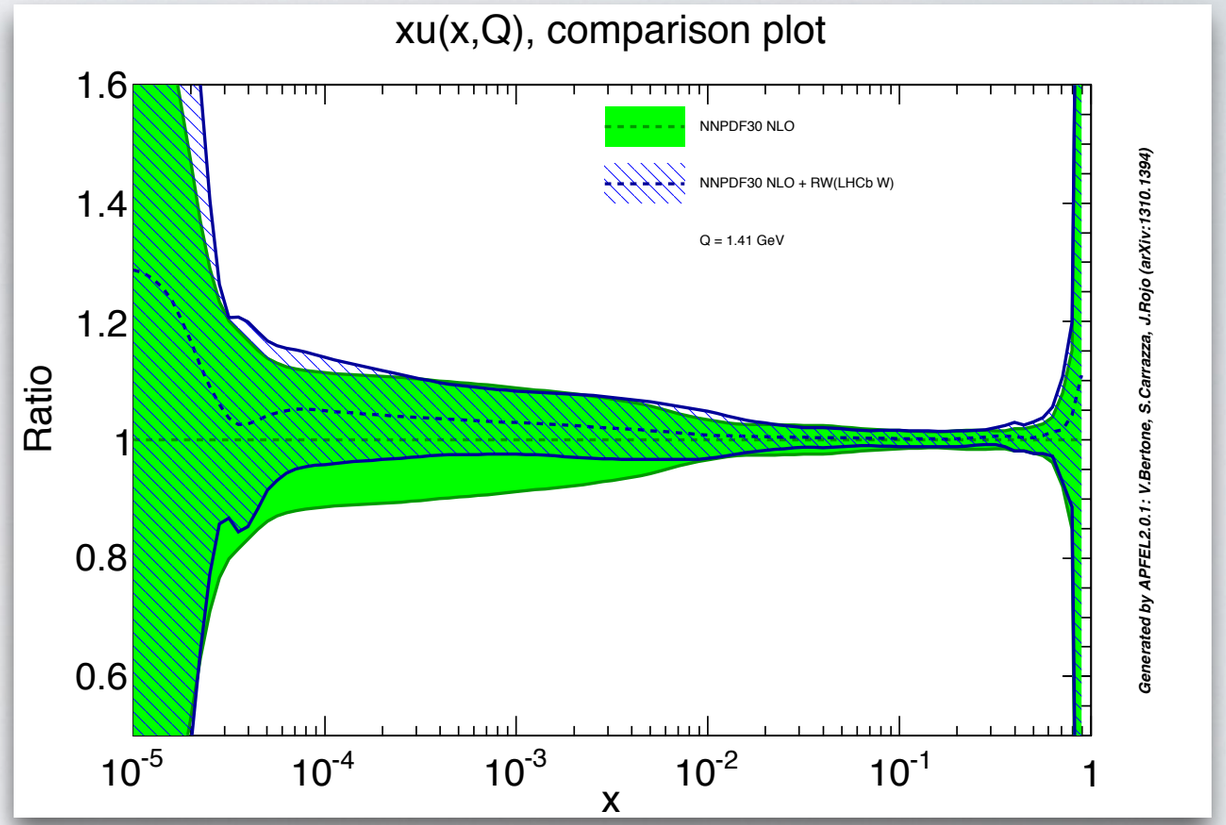
TOWARDS NNPDF3.1

- **New Data:** Final combined HERA results, Tevatron WZ, many new LHC processes incl. ATLAS 1,2,3-jet cross-sections, ATLAS top differential distribution, LHCb W, Z rapidity, CMS 8TeV Drell-Yan, ATLAS prompt photon

- **Running quark mass effects**

- **Fitted charm PDF:** parameterisation with 9 independent flavors

- PDF evolution and DIS cross-sections calculated in **APFEL**; optimised theory calculation in fit



NNPDF3.0 reweighted with LHCb W data

SUMMARY

- **NNPDF3.0:**
  - Next generation PDF set, available now on LHAPDF
  - Large amount of new data from HERA, ATLAS, CMS and LHCb
  - New theory: Electroweak corrections, top cross-sections, jet data at NNLO
  - Improved fitting methodology fully validated using closure tests

- **Looking ahead:**
  - First PDF set including NLL and NNLL soft-gluon resummation effects
  - NNPDF3.1: More LHC data, HERA combined dataset, running quark masses, Fitted charm PDF

- **Also available:**
  - NNPDF2.3QED: PDFs with QED evolution + photon, arXiv:1308.0598
  - NNPDFpol1.1: Polarised neural network PDFs, arXiv:1406.5539