NNPDF Status and Future Plans

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On behalf of the NNPDF collaboration:

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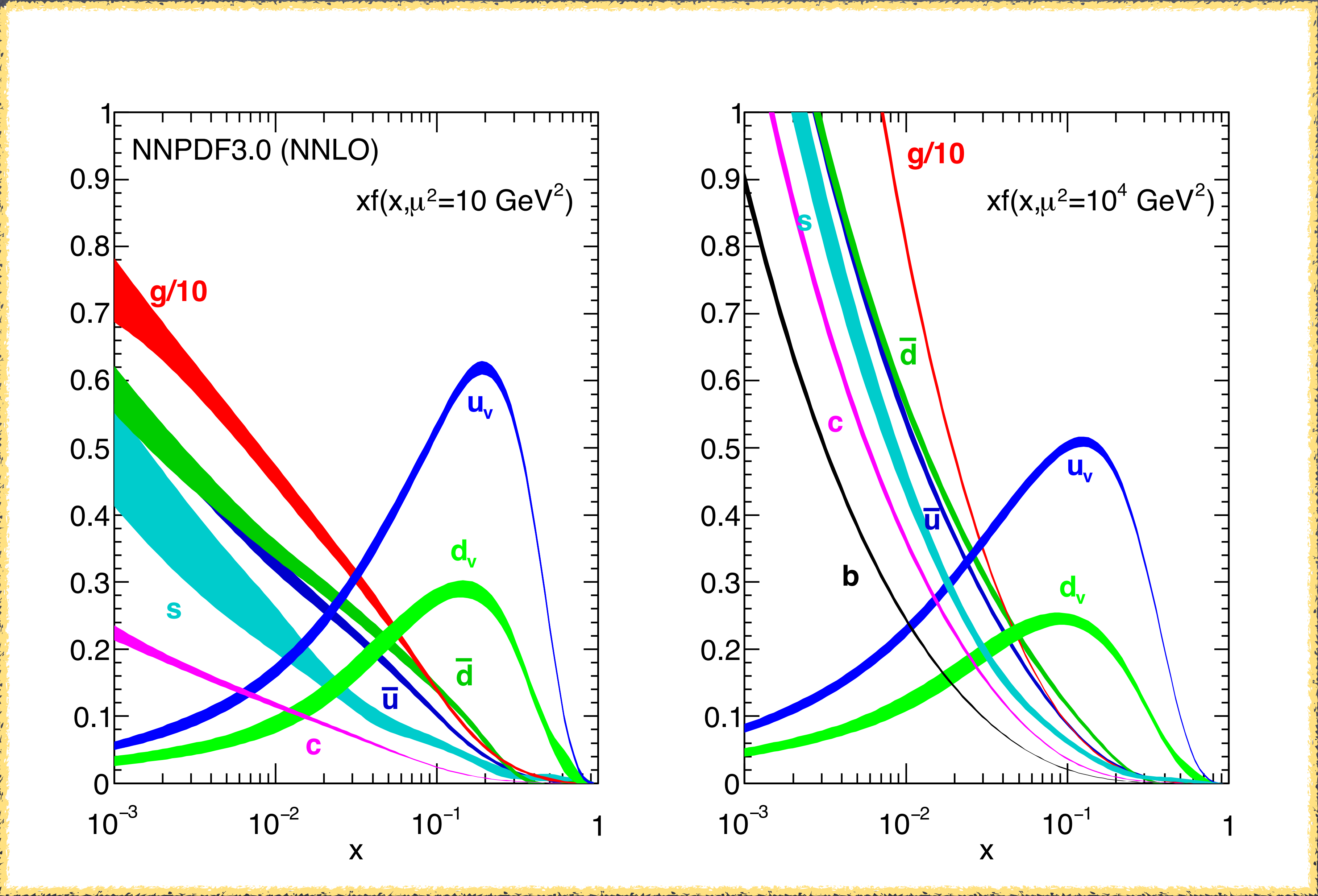
NNDPF3.0

NNPDF Collaboration, JHEP 1504 (2015) 040



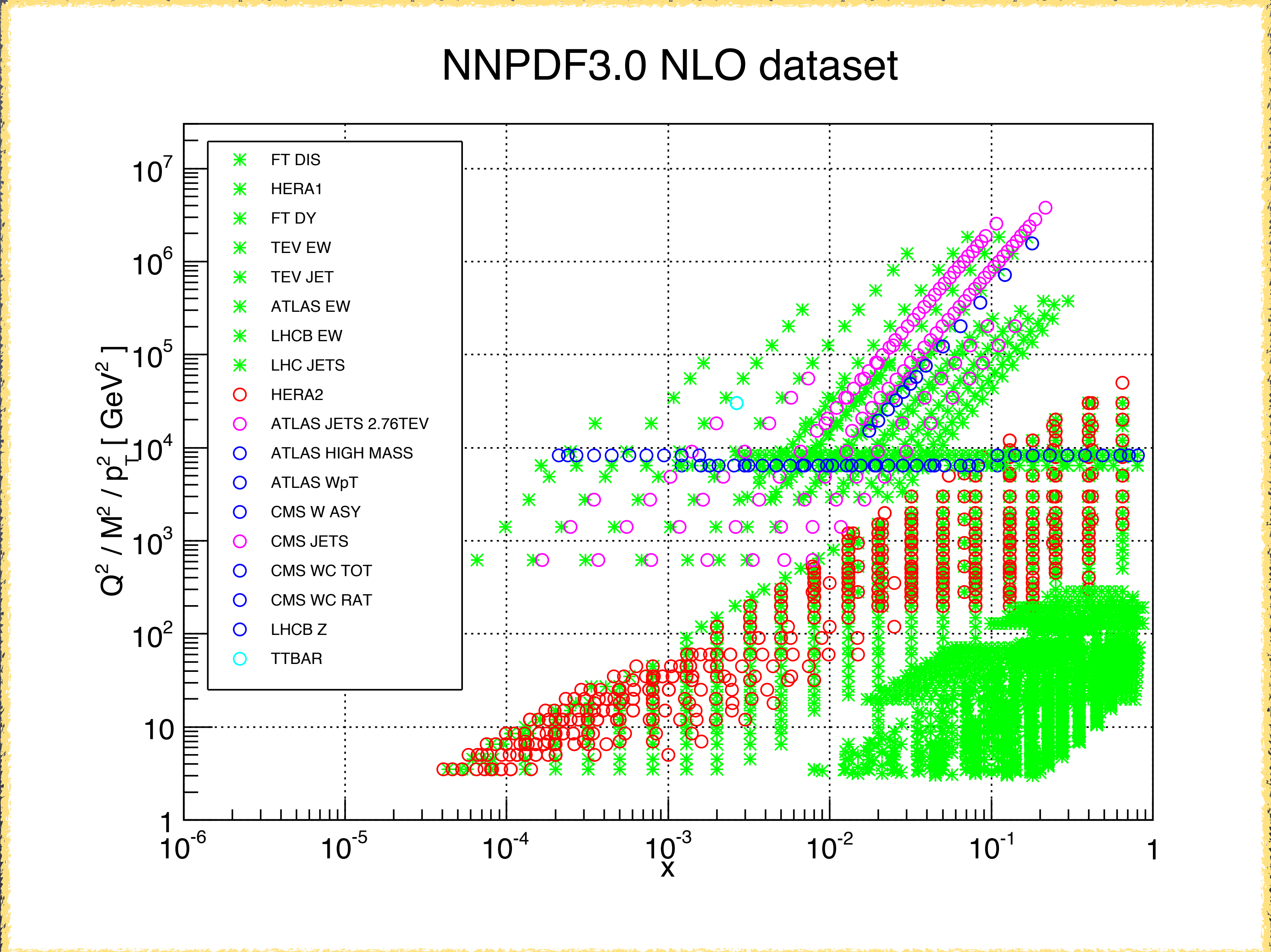
- New PDF set released last November
- LO, NLO and NNLO sets with different values of α_s and different datasets available from LHAPDF

NNPDF3.0

NNPDF3.0 Dataset

New in NNPDF3.0

- HERA: HERA II ZEUS+H1 structure functions, HERA charm production
- ATLAS: 2.76TeV Jets, high-mass Drell-Yan, W pT, top total cross section
- CMS: W muon asymmetry, double- differential Drell-Yan, jets, W+c, top total cross section
- LHCb: Z rapidity



Total Dataset: 4276/4078 (NLO/NNLO)

NNDPF3.0

NNPDF3.0 Dataset

- New code, completely rewritten in C++: focus on efficiency and modularity; easier to include new data and to upgrade theory
- Optimisation of the Genetic Algorithm: new mutation strategy exploiting NN structure in order to obtain better fits in a shorter amount of time
- Generalised PDF parametrisation: fits can now be performed in any arbitrary input PDF basis
- Lookback stopping: improved cross-validation which prevents the fit from stopping too early while still protecting against over-learning
- Optimisation of positivity constraints covering a wider range of observables over a larger kinematic range
- First PDF set validated by a Closure Test

NNDPF3.0

Closure Testing

Validation and optimisation of fitting strategy by fitting to pseudo-data generated using known PDFs

Define underlying physical law based on chosen PDF set (MSTW, NNPDF, CT etc.)

↓

Generate random pseudo-data using underlying law and experimental covariance matrix

↓

Perform (NN)PDF fit

↓

Compare results obtained from fit to underlying law

PDFs with Threshold Resummation

M. Bonvini, S. Marzani, J. Rojo, LR, M. Ubiali et al, arXiv:1507.01006

Motivation

- Logarithmic contributions in fixed order perturbative calculations become large in some kinematic regions, thus spoiling the perturbative expansions
- Large-x resummation: logarithmic enhancement appears close to threshold, $x \to 1$
- Resummed calculations provide the state of the art accuracy for many processes at LHC
- Inconsistent use of fixed order PDFs with resummed partonic cross sections can lead to inaccurate predictions
- One needs resummed PDFs to be able to provide a consistent calculation

PDFs with Threshold Resummation

Threshold Resummation in a nutshell

$$\sigma(x, Q^2) = x \int_x^1 \frac{dz}{z} \mathcal{L}\left(\frac{x}{z}, Q^2\right) \frac{\hat{\sigma}(z, Q^2, \alpha_s)}{z}$$

Convolution integral diagonalised in Mellin space

$$\sigma(N, Q^2) = \mathcal{L}(N, Q^2)\sigma_0(N, Q^2)C(N)$$

Double logarithmic enhancement due to soft gluon emission

$$C(N) = 1 + \sum_{n=1}^{\infty} \alpha_s^n \sum_{k=0}^{2n} c_{nk} \ln^k N + \mathcal{O}(1/N)$$

N-soft approximation

Exponentiation

$$C(N) = g_0(\alpha_s) \exp\left[\frac{1}{\alpha_s} g_1(\alpha_s \ln N) + g_2(\alpha_s \ln N) + \alpha_s g_3(\alpha_s \ln N) + \dots\right]$$

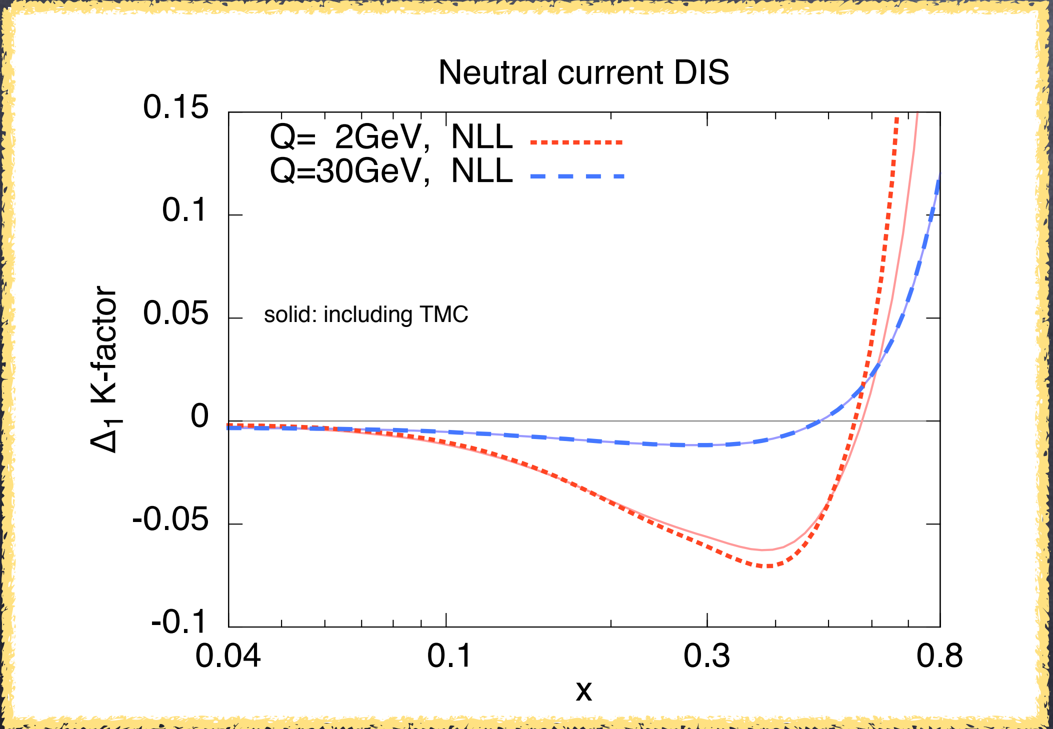
The functions g_i resum $\alpha_s^n \ln^n N$ to all orders

PDFs with Threshold Resummation

Threshold Resummation in DIS and DY

- TROLL (TROLL Resums Only Large-x Logarithms) computes threshold-enhanced terms up to N^{3}LL' accuracy(http://www.ge.infn.it/~bonvini/troll/)
- Consistent match with fixed order
- TROLL delivers $\Delta_j K_{N^nLL}$

$$\sigma_{N^jLO+N^kLL} = \sigma_{N^jLO} + \sigma_{LO} \times \Delta_j K_{N^kLL}$$



Target Mass Corrections at Next to Leading Twist

PDFs with Threshold Resummation

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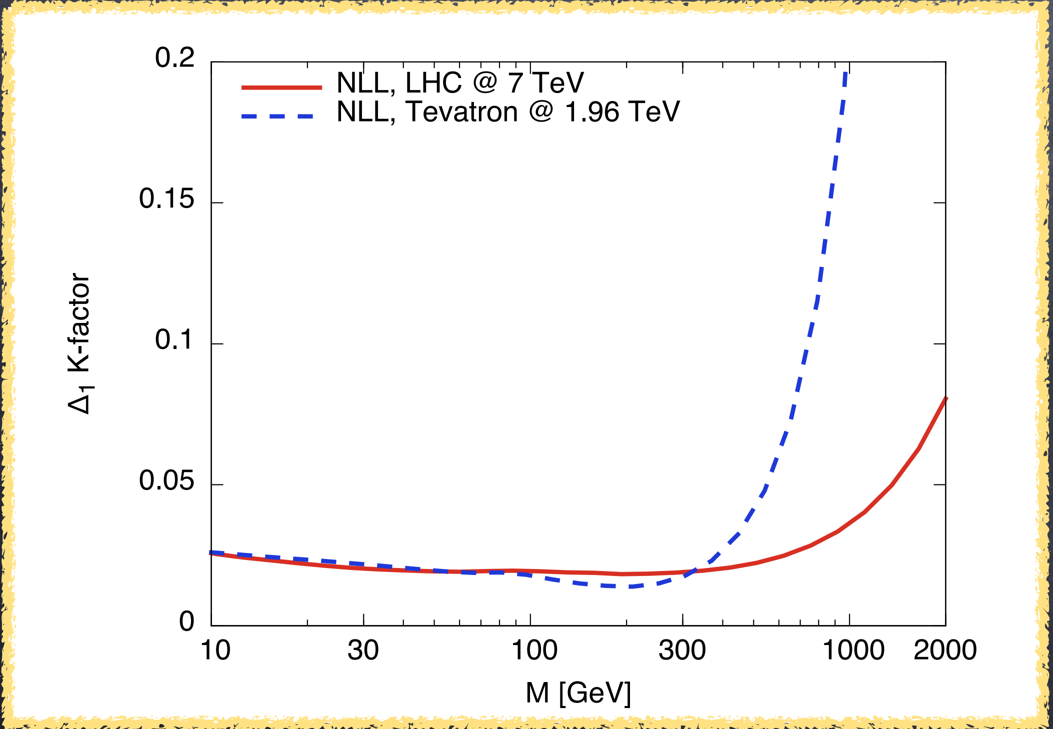

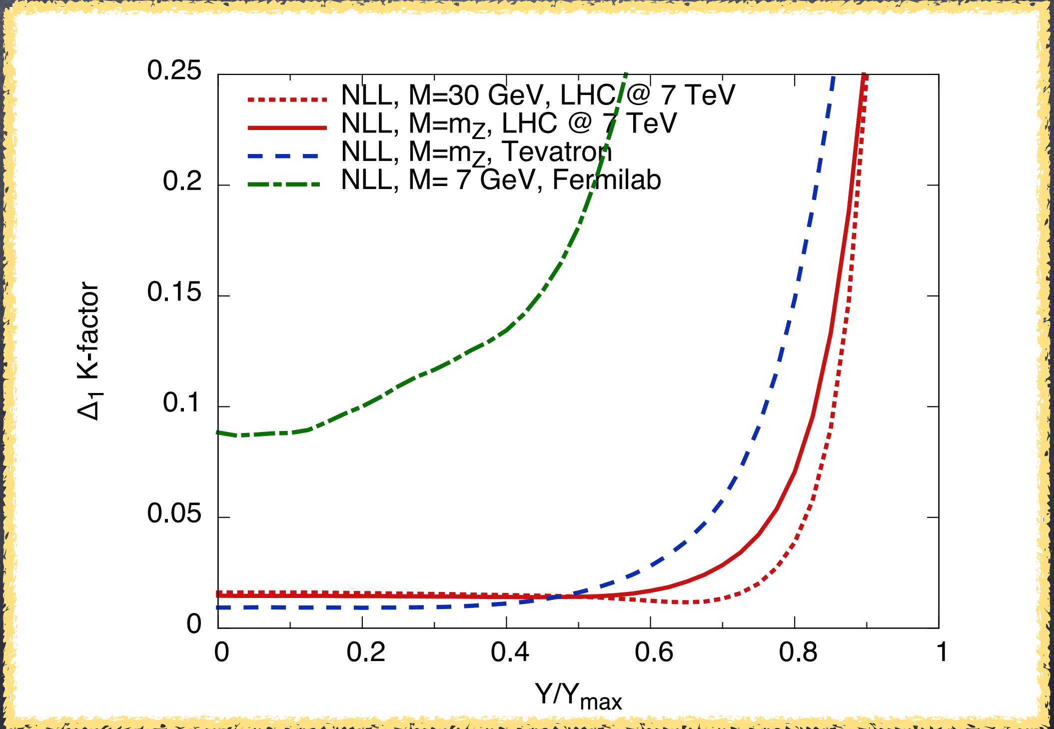

PDFs with Threshold Resummation

NNPDF3.0res Dataset

Experiment	Observable	Ref.	NNPDF3.0 global (N)NLO	NNPDF3.0 DIS+DY+top (N)NLO [+(N)NLL]
NMC	$\sigma_{\rm dis}^{\rm NC}, F_2^d/F_2^p$	[114, 115]	Yes	Yes
BCDMS	F_2^d, F_2^p	[116, 117]	Yes	Yes
SLAC	F_2^d, F_2^p	[118]	Yes	Yes
CHORUS	$\sigma_{\nu N}^{\rm CC}$	[119]	Yes	Yes
NuTeV	$\sigma_{\nu N}^{\rm CC,charm}$	[120]	Yes	Yes
HERA-I	$\sigma_{\rm dis}^{\rm NC}, \sigma_{\rm dis}^{\rm CC}$	[121]	Yes	Yes
ZEUS HERA-II	$\sigma_{\rm dis}^{\rm NC}, \sigma_{\rm dis}^{\rm CC}$	[122–125]	Yes	Yes
H1 HERA-II	$\sigma_{\rm dis}^{\rm NC}, \sigma_{\rm dis}^{\rm CC}$	[126, 127]	Yes	Yes
HERA charm	$\sigma_{\rm dis}^{\rm NC,charm}$	[128]	Yes	Yes
DY E866	$\sigma_{\rm DY,p}^{\rm NC}, \sigma_{\rm DY,d}^{\rm NC}/\sigma_{\rm DY,p}^{\rm NC}$	[129–131]	Yes	Yes
DY E605	$\sigma_{\rm DY,p}^{\rm NC}$	[132]	Yes	Yes
CDF Z rap	$\sigma_{\rm DY,p}^{\rm NC}$	[133]	Yes	Yes
CDF Run-II k_t jets	$\sigma_{\rm jet}$	[134]	Yes	No
D0 Z rap	$\sigma_{\rm DY,p}^{\rm NC}$	[135]	Yes	Yes
ATLAS Z 2010	$\sigma_{\rm DY,p}^{\rm NC}$	[136]	Yes	Yes
ATLAS W 2010	$\sigma_{\rm DY,p}^{\rm CC}$	[136]	Yes	No
ATLAS 7 TeV jets 2010	$\sigma_{\rm jet}$	[137]	Yes	No
ATLAS 2.76 TeV jets	$\sigma_{\rm jet}$	[138]	Yes	No
ATLAS high-mass DY	$\sigma_{\rm DY,p}^{\rm NC}$	[139]	Yes	Yes
ATLAS W p_T	$\sigma_{\rm DY,p}^{\rm CC}$	[140]	Yes	No
CMS W electron asy	$\sigma_{\rm DY,p}^{\rm CC}$	[141]	Yes	No
CMS W muon asy	$\sigma_{\rm DY,p}^{\rm CC}$	[142]	Yes	No
CMS jets 2011	$\sigma_{\rm jet}$	[143]	Yes	No
CMS $W+c$ total	$\sigma_{\rm DY,p}^{\rm NC,charm}$	[144]	Yes	No
CMS 2D DY 2011	$\sigma_{\rm DY,p}^{\rm NC}$	[145]	Yes	Yes
LHCb W rapidity	$\sigma_{\rm DY,p}^{\rm CC}$	[146]	Yes	No
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ATLAS CMS top prod	$\sigma(t\bar{t})$	[148–153]	Yes	Yes

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PDFs with Threshold Resummation

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medium & large-x gluon

quark-flavour separations

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~3000 Data Points

Accuracy competitive with global fit, except for large-x gluon

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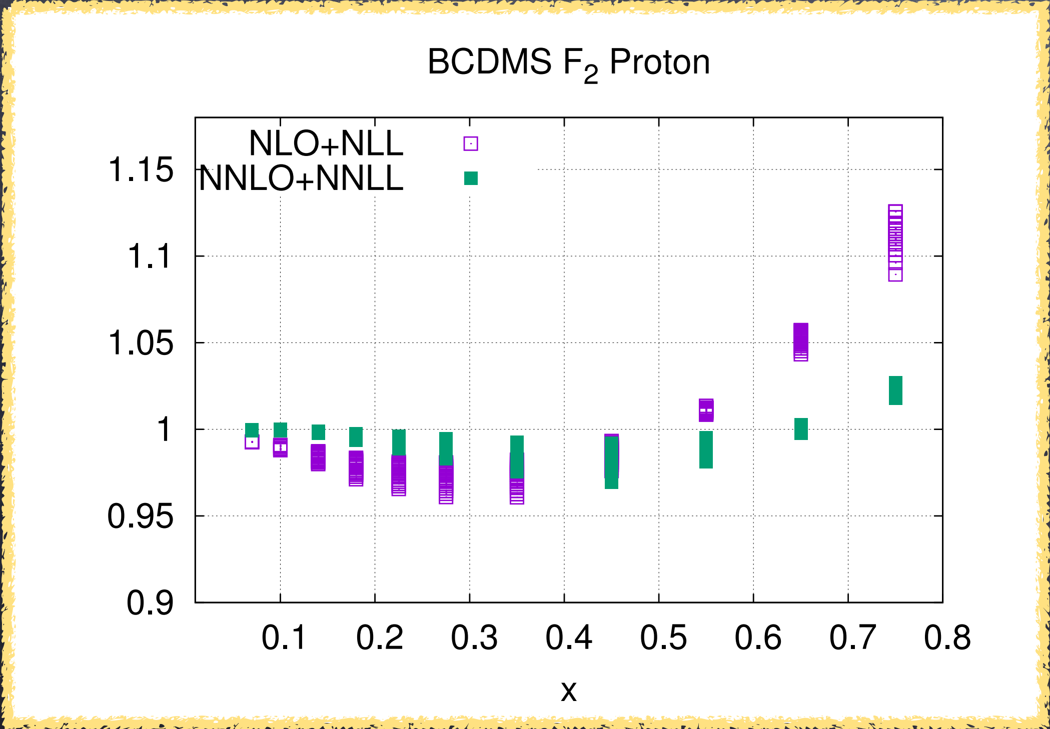
PDFs with Threshold Resummation

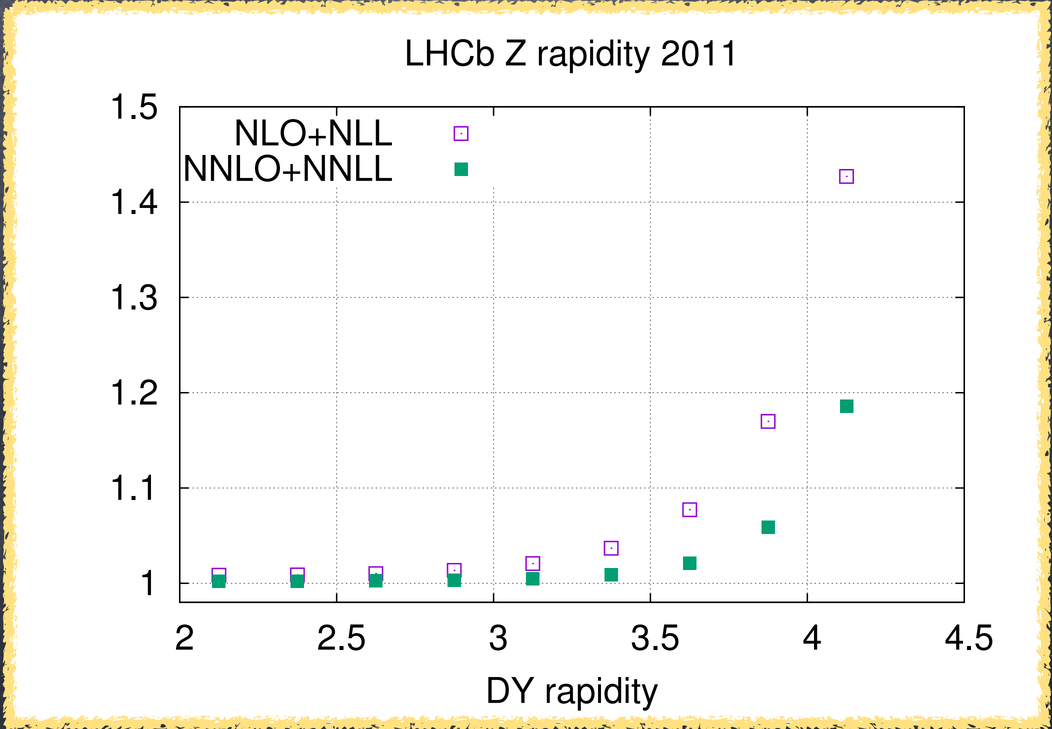
K-factors

- Effect of resummation included supplementing fixed order computation with K-factors

$$K^{N^kLO+N^kLL} = \frac{\sigma^{N^kLO+N^kLL}}{\sigma^{N^kLO}}$$

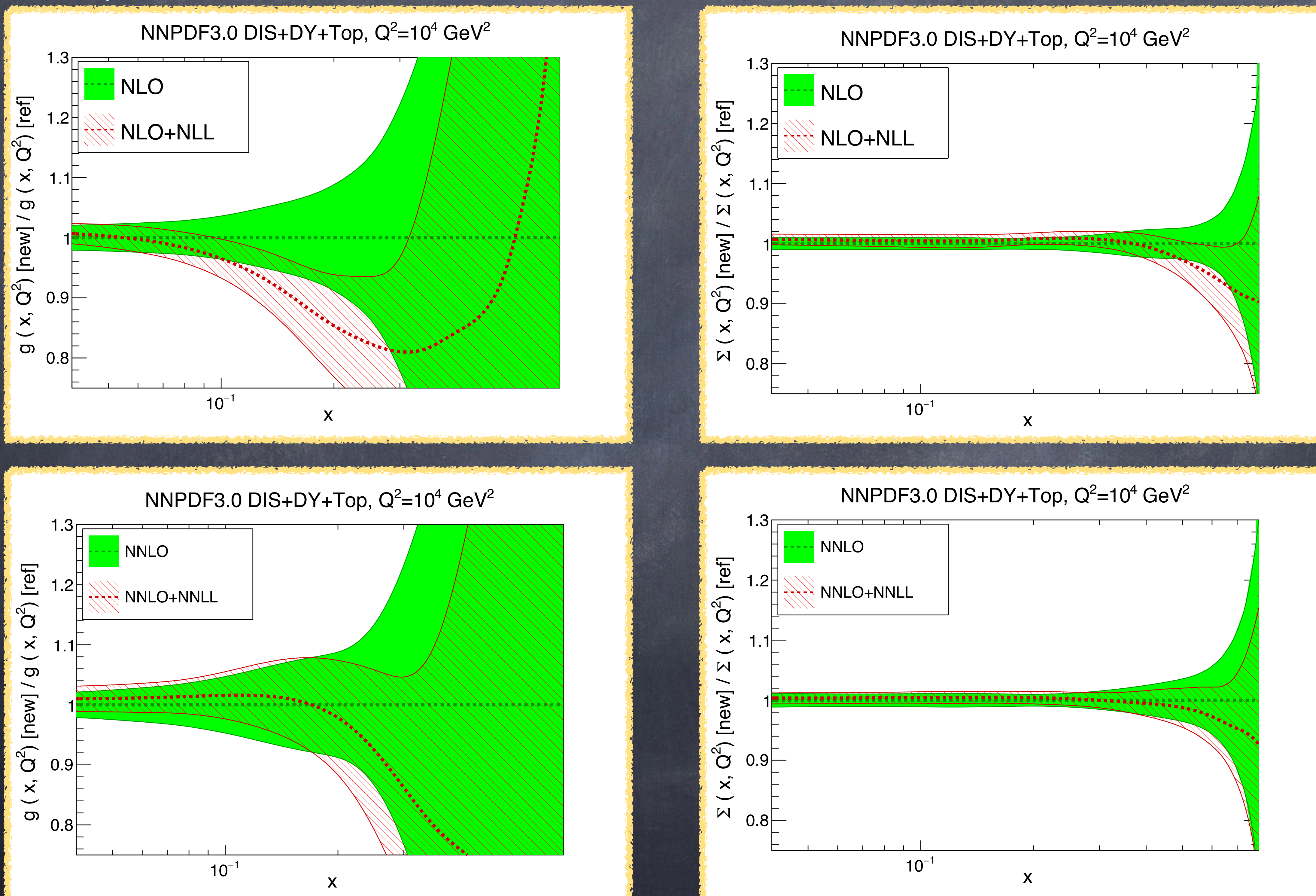
- Re-iteration of the fits to ensure convergence





PDFs with Threshold Resummation

Comparison with Baseline Fits



PDFs with Threshold Resummation

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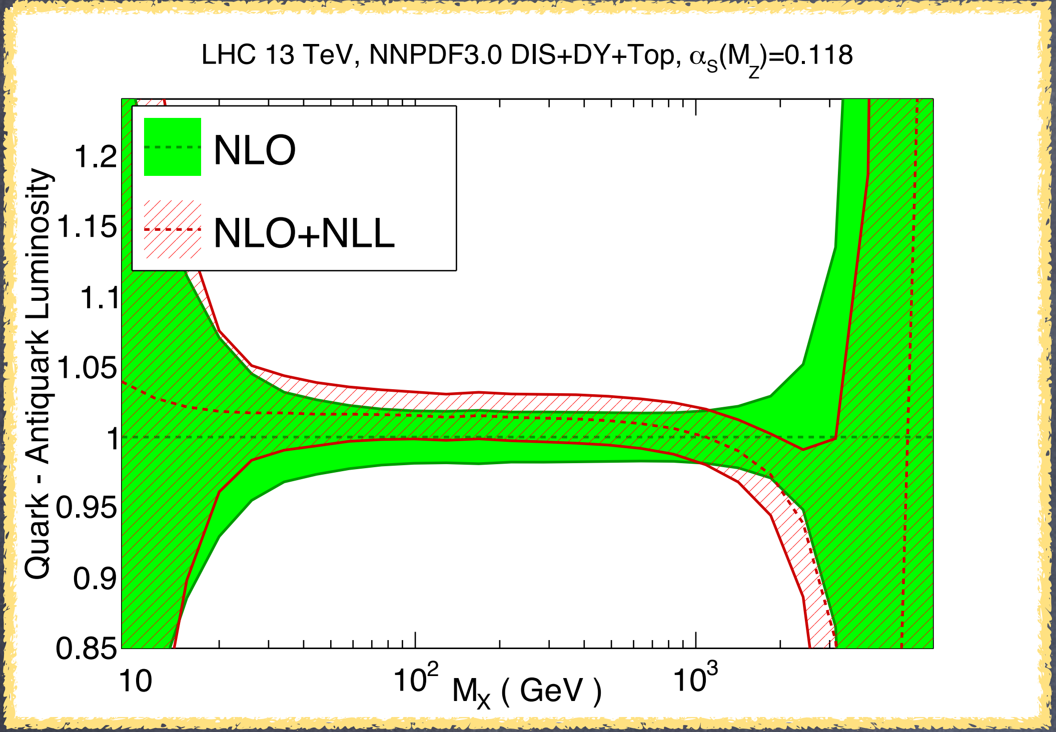
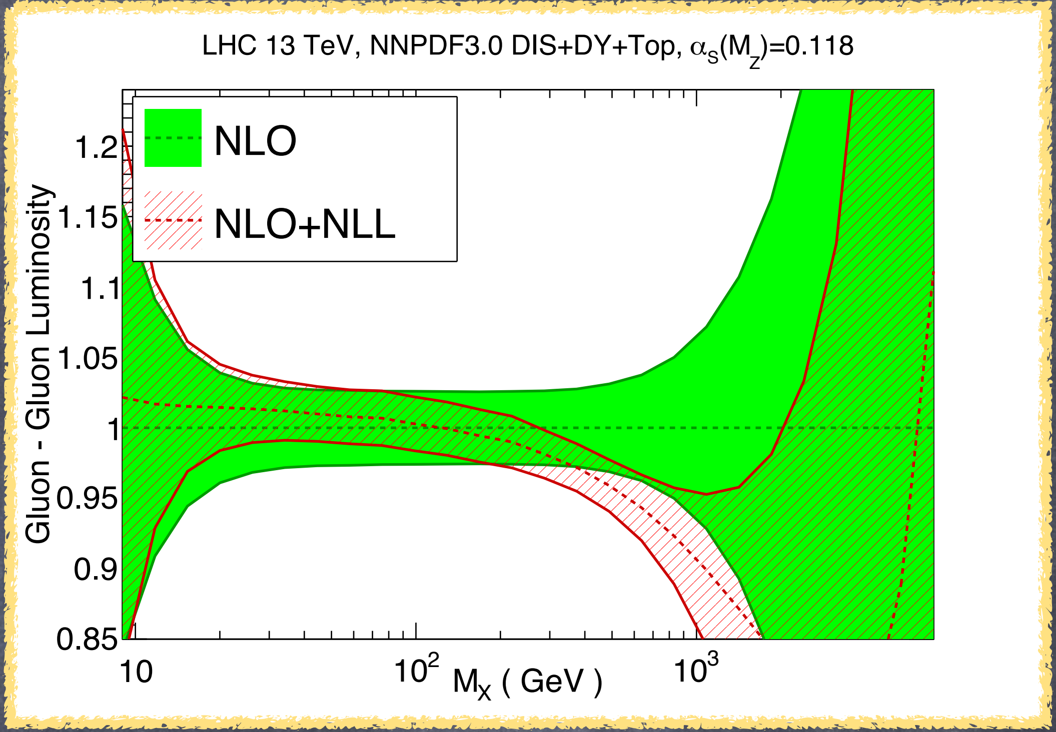
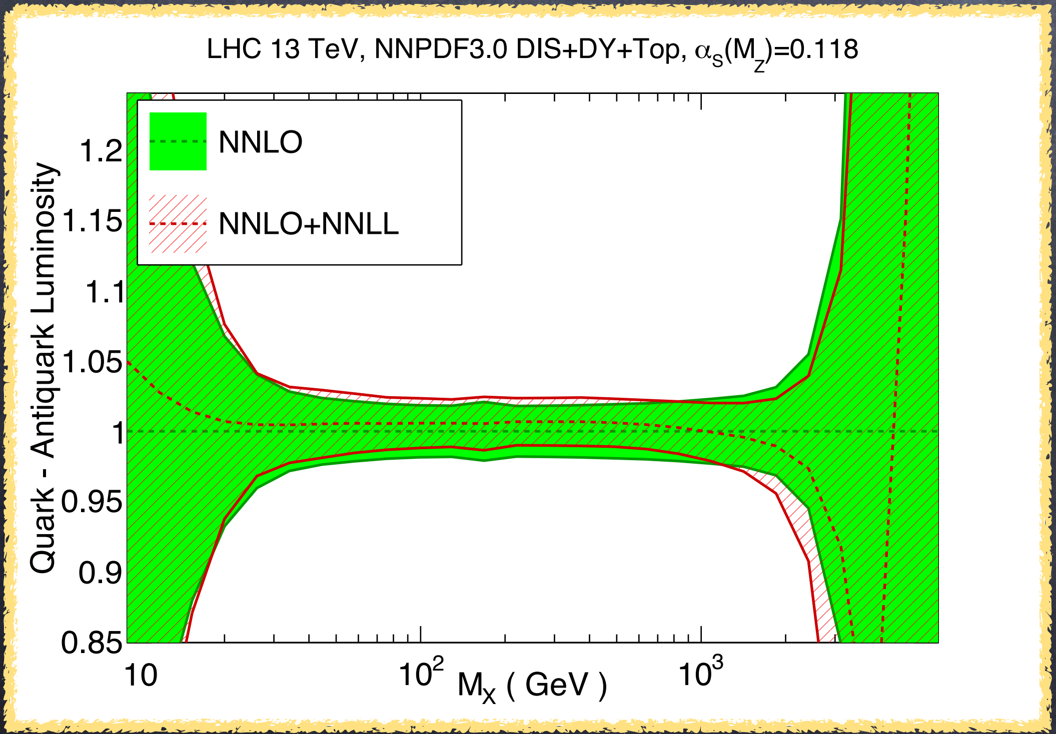
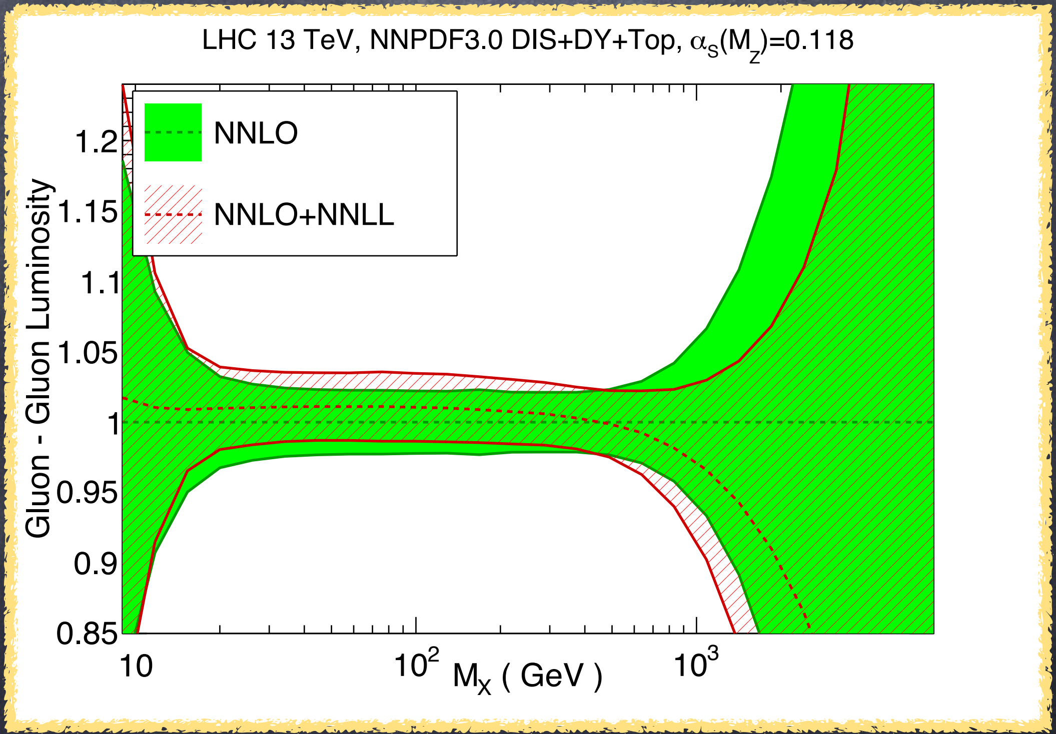


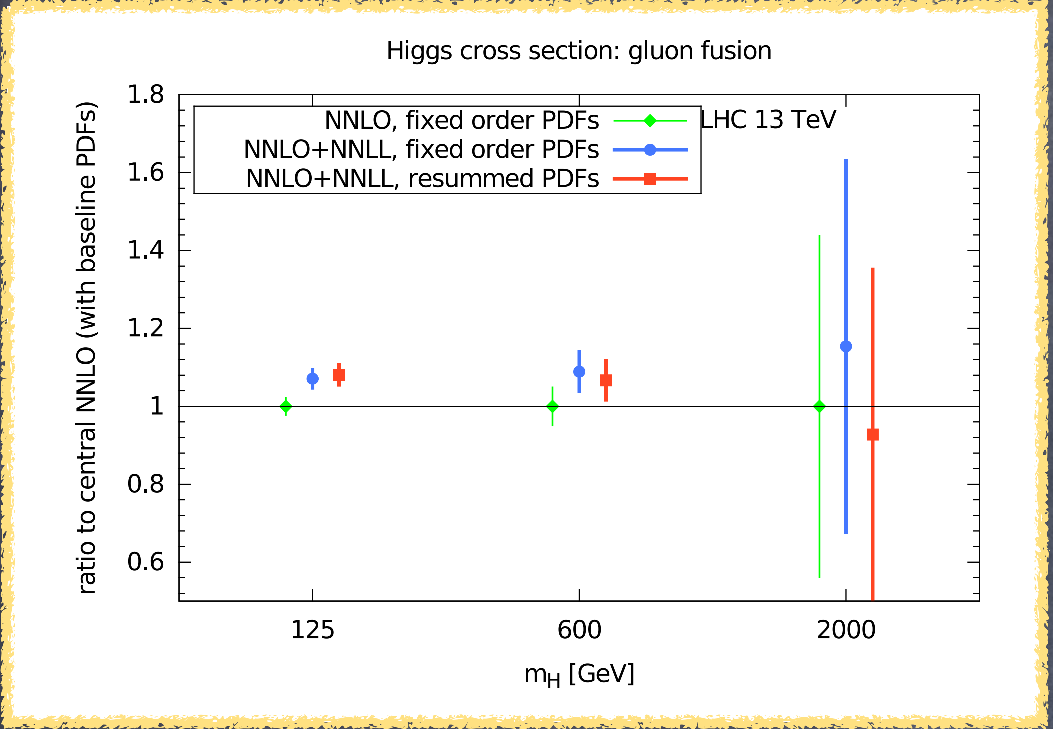


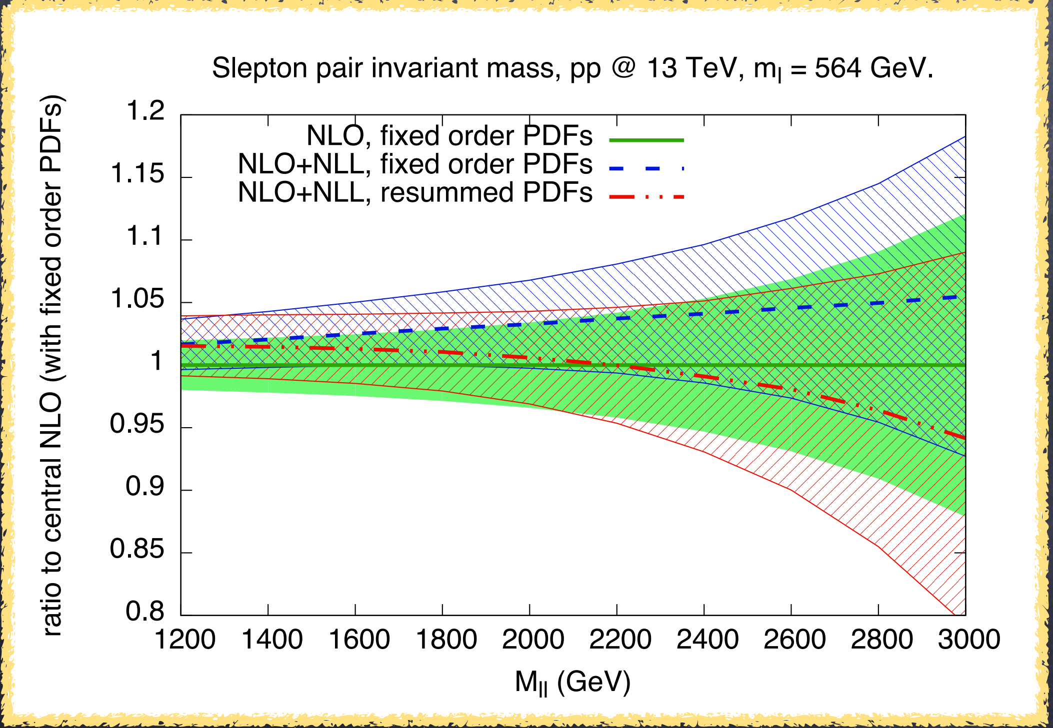




PDFs with Threshold Resummation

Phenomenology



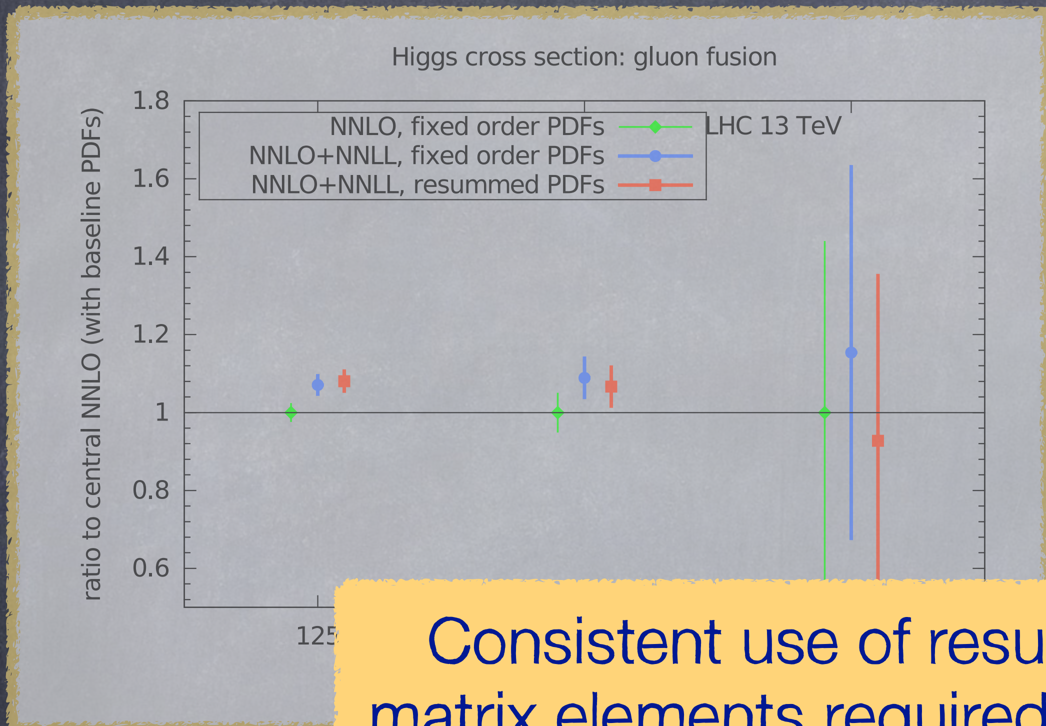


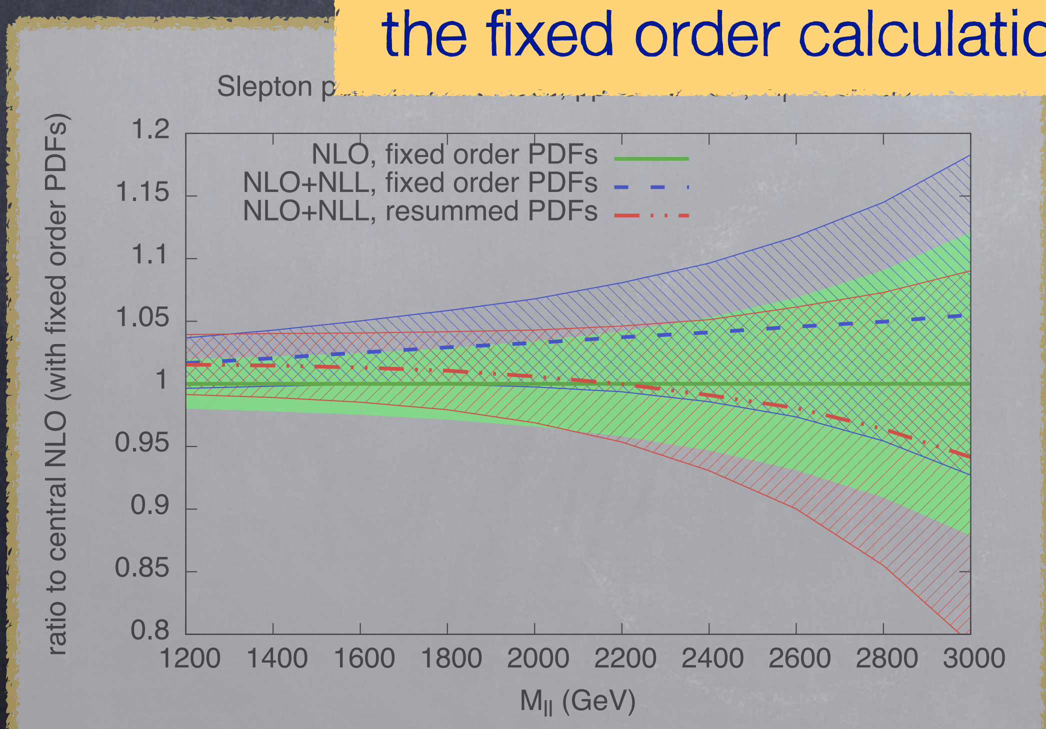
- SM Higgs not affected by resummation of PDFs
- m_H ~600 GeV cancellation of 1/2 of the enhancement
- m_H~2 TeV NNLO+NNLL with resummed PDFs similar to FO PDFs (larger uncertainty)

- 2-5% enhancement NLO+NLL calculation with FO PDFs
- 1-2% enhancement NLO+NLL calculation with resummed PDFs only of M_{ll}<2000 GeV
- At higher masses suppression of NLO+NLL calculation with resummed PDFs

PDFs with Threshold Resummation

Phenomenology





Consistent use of resummation in the PDFs and matrix elements required: resummed result closer to the fixed order calculation at large invariant masses

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PDFs with Threshold Resummation

Threshold Resummation: Summary

- First ever (global) fit of PDFs with threshold resummation
- PDFs reduced in the large-x region; at intermediate values of x quark PDFs slightly enhanced (sum rule); negligible effects at x<0.01
- Inclusion of resummation in PDFs compensates the enhancement from resummation in partonic cross sections for when M_X is large
- Importance of using consistently the same perturbative order in all components when calculating hadronic cross sections: consistent resummed calculations might be closer to fixed order results
- Limitations: larger uncertainties do to reduced dataset. Methodology enables to have truly global resummed PDFs when calculations for missing processes will be available

NNPDF Developments

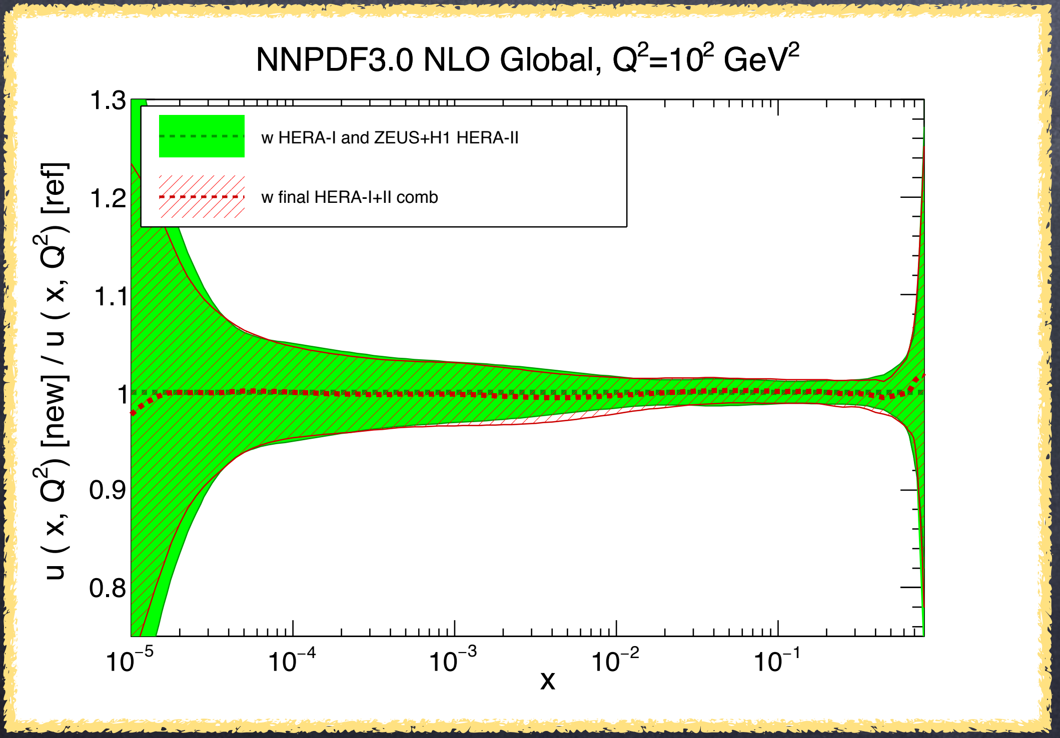
New Experimental Data

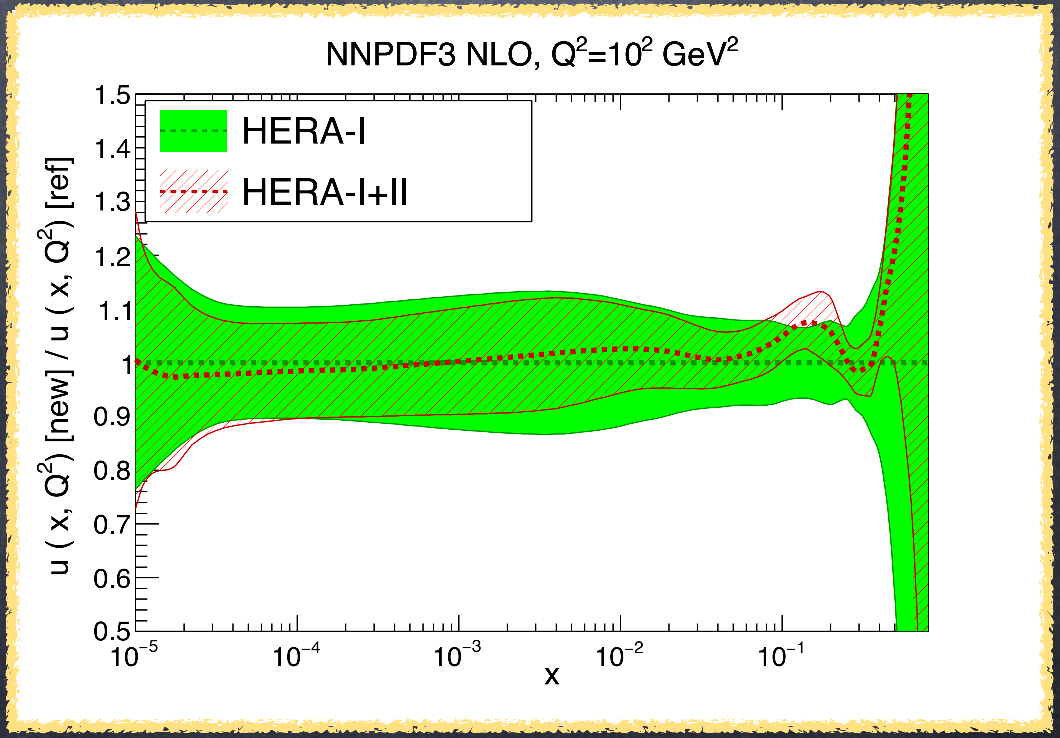
- HERA II HERA II legacy data
- D0 W asymmetry
- ATLAS low-mass DY, prompt photon, W+c, Z pt, top rapidity, inclusive jets 7 TeV
- CMS Z pt, top rapidity, double differential DY 8 TeV
- LHCb W, Z rapidity

NNPDF Developments

New Experimental Data: HERA II Data Impact

- NNPDF3.0 already includes all published data from HERA-II from H1 and ZEUS
- Impact of HERA legacy data on NNPDF3.0 negligible
- Rather substantial impact of HERA II data on HERA I-only fit





NNPDF Developments

New Experimental Data: HERA II Data Impact

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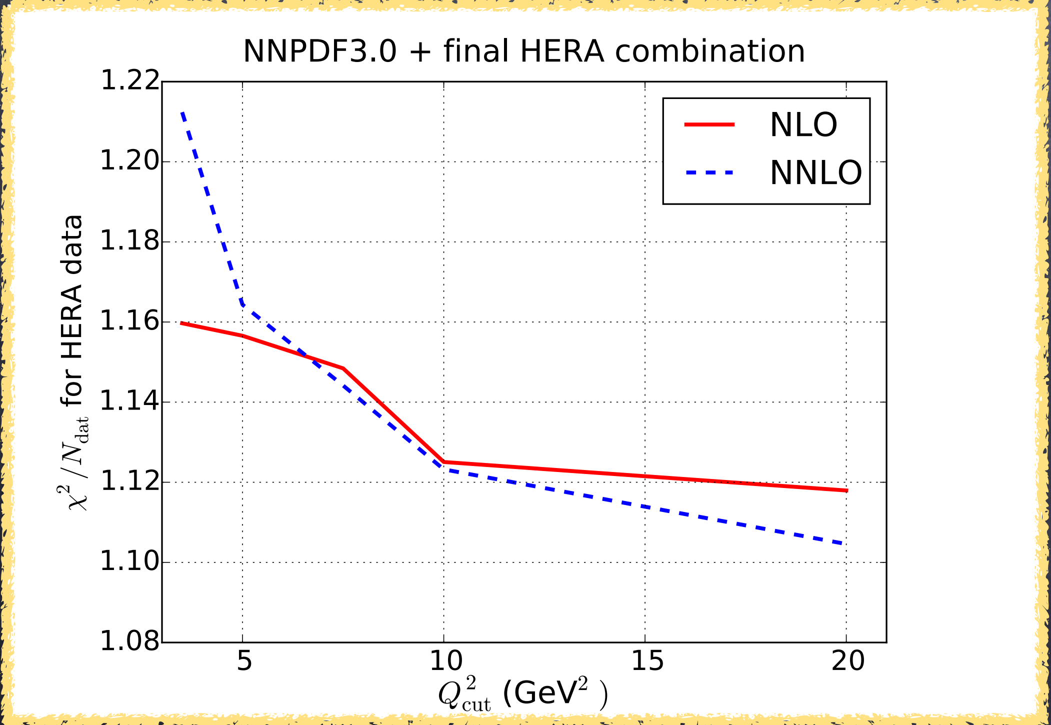
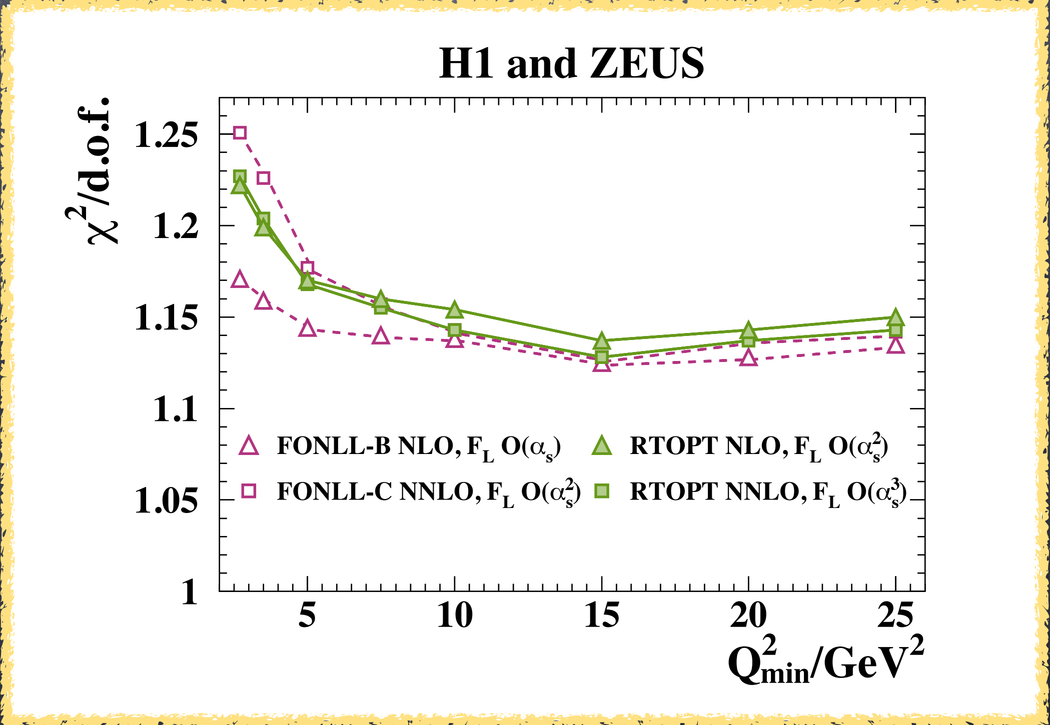
- Impact of HERA legacy data on NNPDF3.0 negligible
- Rather substantial impact of HERA II data on HERA I-only fit
- χ^2 vs Q^2_{cut} may indicate the need for small-x resummation





A.M.Cooper-Sarkar arXiv:1507.03849

NNPDF Developments

- ✓ Integration of APFEL in NNPDF with APFELcomb: straightforward inclusion in the NNPDF fits of new theory developments (resummations, IC, scale variations…)
- ✓ NNPDF3.0res with threshold resummation
- ☐ NNPDF3.x with new data, MSbar running masses
- ☐ NNPDF3.x with small-x resummation
- ☐ NNPDF3.x with fitted charm PDF (M. Bonvini’s talk)
- ☐ NNPDF3.xQED: precision determination of the photon PDF from LHC data
- ☐ NNPDF4.0 (?) with theoretical uncertainties on PDFs

NNDPF

NNPDF methodology: a short recap

- Each PDF parameterised by a Neural Network (NN): default 2-5-3-1 architecture, 37 parameters
- Minimisation performed using Genetic Algorithms (GA) to find best-fit PDFs
- Best fit through cross-validation method (no noise fitting)

- Capture the PDF uncertainties by using a Monte Carlo approach
- Monte Carlo representation of covariance matrix trough pseudo-data replicas
- PDF replica set is fitted to each pseudo-data replica
- Set of PDF replicas can be used to compute any set of observables

NNPDF Plans

Heavy Quarks Treatment

- Extension of FONLL GM-VFN scheme to include MSbar running masses and intrinsic charm (IC)
- Moderate but not negligible effect in the pole → MSbar mass when keeping the same numerical value of the charm mass fixed
- Intrinsic charm discussed in M. Bonvini's talk