News from NNPDF

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PDF4LHC Working Group Meeting
CERN, 27/10/2015

Recent NNPDF studies (and related work)

Since the last PDF4LHC meeting ….

- Inclusion of the **legacy HERA** combined dataset
  JR, arXiv:1508.07731, ICHEP15 proceedings
- Inclusion of new measurements from **ATLAS, CMS and LHCb**
  NNPDF, in preparation
- NNPDF3.0 fits with **intrinsic charm**, and associated theory calculations
  NNPDF, in preparation + Ball, Bertone, Bonvini, Forte, Groth-Merrild, JR, Rottoli, arXiv:1510.00009
- NNPDF3.0 fits with **threshold resummation** ,and implications for high-mass SUSY xsecs
  Bonvini, Marzani, JR, Rottoli, Ubiali, Ball, Bertone, Carrazza, Hartland, arXiv:1507.01006
- Impact of **LHCb charm data in small-x gluon**, and implications for neutrino astronomy
  Gauld, JR, Rottoli, Talbert, arXiv:1506.08025, + Sarkar, in preparation
- Parton Distributions in a **doped VFN scheme**
  Bertone, Carrazza, JR, arXiv:1509.04022
- **Specialised Minimal PDF sets**
  Carrazza, Forte, Kassabov, JR, in preparation

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This talk

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- Specialised Minimal PDF sets
  Zahari's talk in the afternoon
  Carrazza, Forte, Kassabov, JR, in preparation

Towards NNPDF3.1: New experimental data

New LHC experimental data

ATLASLOMASSDY11	ATLAS low mass Drell-Yan dilepton production 7 TeV, 1.6 fb $^{-1}$
ATLASPHT11	ATLAS isolated photon production 7 TeV, 4.6 fb $^{-1}$
ATLASZPT47FB	ATLAS Z pt distribution 7 TeV, 4.7 fb $^{-1}$
ATLAS1JET11	ATLAS inclusive jet production 7 TeV, 5 fb $^{-1}$
ATLASTTB11	ATLAS ttbar differential distributions, 7 TeV, 4.6 fb^{-1}
ATLASWPCTOT11	ATLAS W+charm production 7 TeV, 4.6 fb $^{-1}$
CMSDY2D12	CMS Drell-Yan double-differential distribution 2012 dataset, 8 TeV
CMSTTB12	CMS ttbar differential distributions, 8 TeV
CMSZDIFF12	CMS pt and rap differential distributions 2012 dataset, 8 TeV
HERACOMB	Combined HERA I+II inclusive dataset
D0WMASY	D0 W muon asymmetry final results
D0WEASY	D0 W electron asymmetry final results
LHCBWMURAP11	LHCb W-> mu nu rapidity distributions from 2011
LHCBZERAP11	LHCb Z -> e+e- rapidity distributions 2011, 8 TeV
LHCBZMURAP11	LHC Z-> mu mu rapidity distribution 2011, 7 TeV

ATLAS low mass DY data: **Implemented**

ATLAS Z pt: **Implemented**
NNLO calculation now available

ATLAS 2011 jets: **Implemented**
Covariance matrix definition?

Work in progress, in various degrees of progress, for **all experiments in this list**

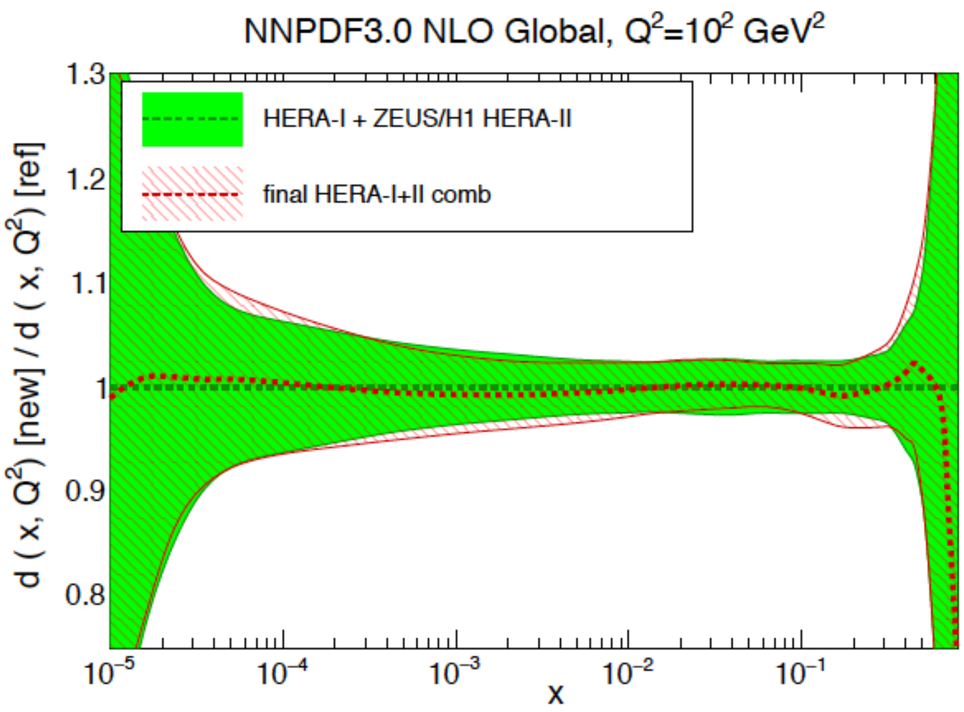
Legacy HERA data: **Implemented**

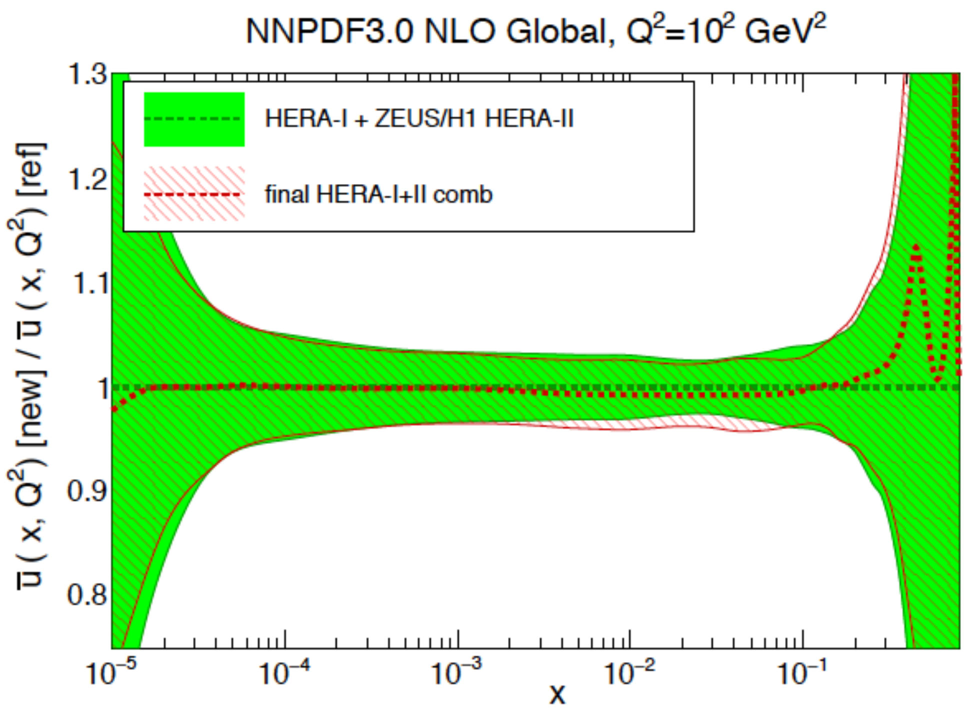
Legacy Tevatron electroweak measurements
Impact studied in recent HERAfitter analysis
Implementation in progress

New LHCb forward DY data: **Implemented**

Final HERA legacy dataset

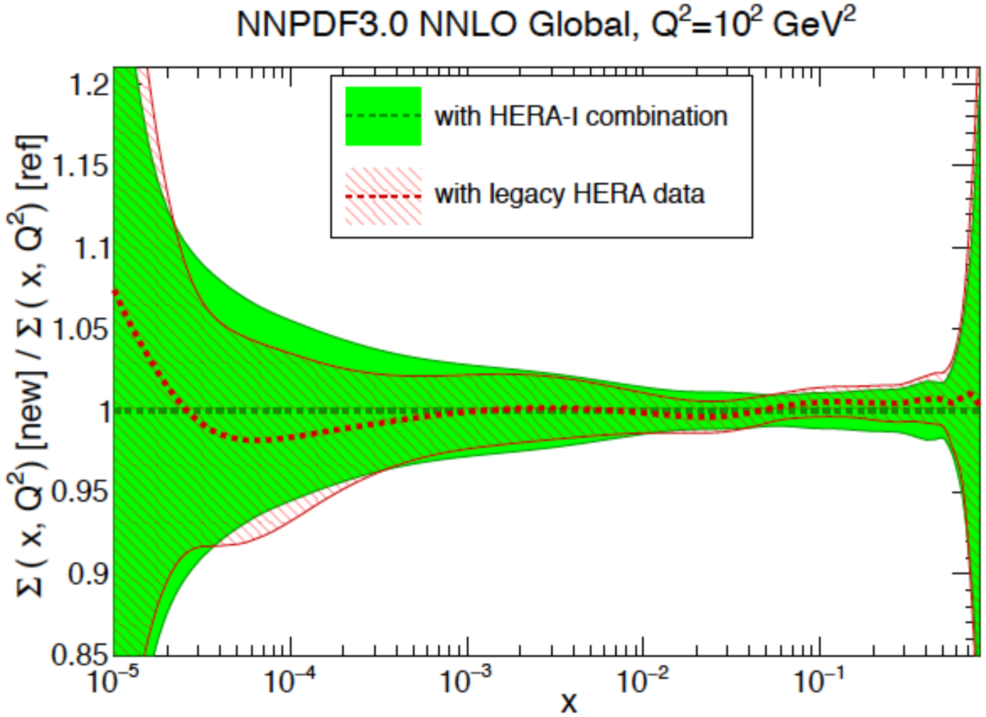
- The **legacy HERA inclusive combination** has been added to NNPDF3.0 in various ways
- **NNPDF3.0** already included all published **HERA-II measurements** from H1 and ZEUS,
- When replacing individual HERA-II data with **combined dataset**, we find **very minor impact on PDFs**

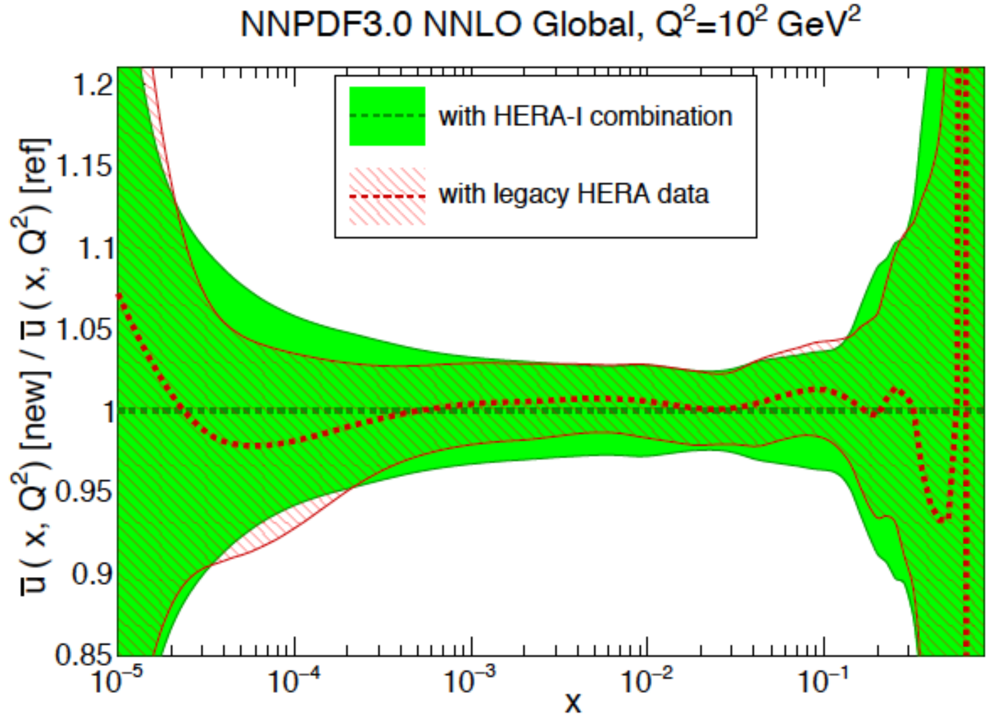




Final HERA legacy dataset

- The **legacy HERA inclusive combination** has been added to NNPDF3.0 in various ways
- If we compare a NNPDF3.0 fit without **any HERA-II data** with the corresponding fit with the legacy combination, find good consistency and a moderate reduction of PDF uncertainties



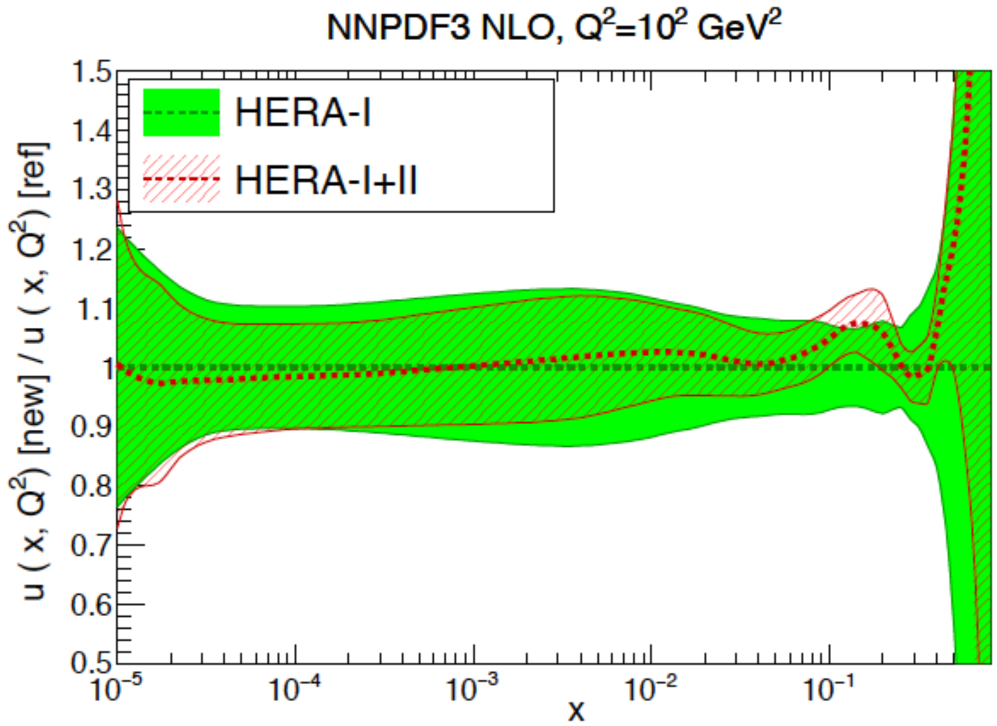


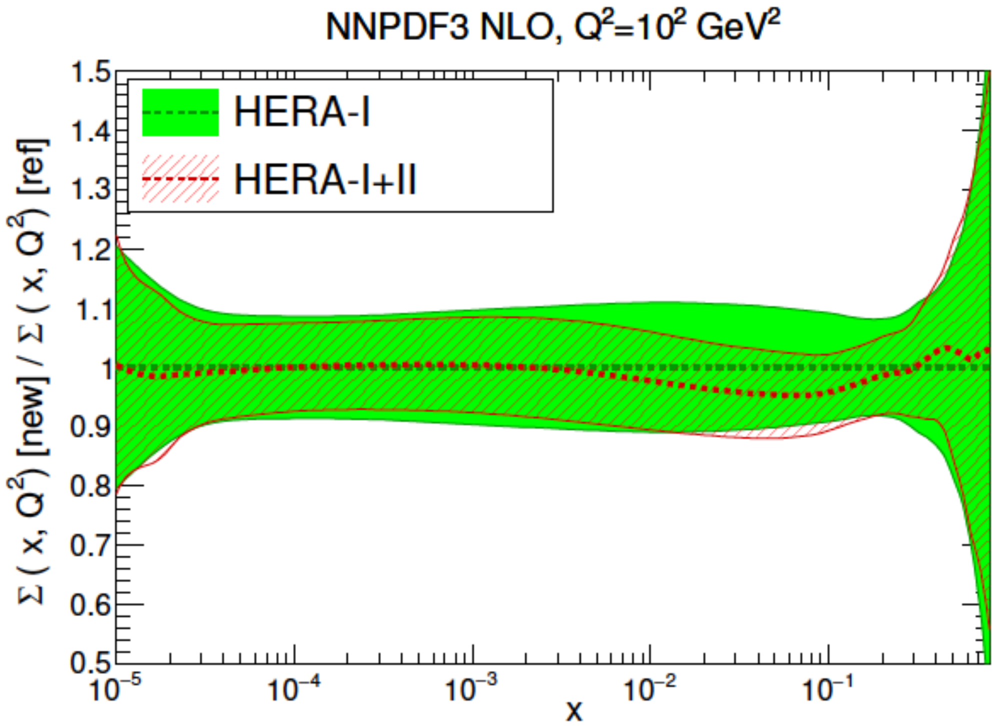
→ Including HERA-II measurements useful to **reduce PDF uncertainties** in various flavours

Results consistent with the corresponding MMHT study **arXiv:1508.0661**

Final HERA legacy dataset

- The **legacy HERA inclusive combination** has been added to NNPDF3.0 in various ways
- If we compare a NNPDF **HERA-I-only fit** with the **HERA-I+II-only fit**, the reduction of PDF uncertainties is even more marked (same conclusions as in the **HERAPDF2.0 analysis**)

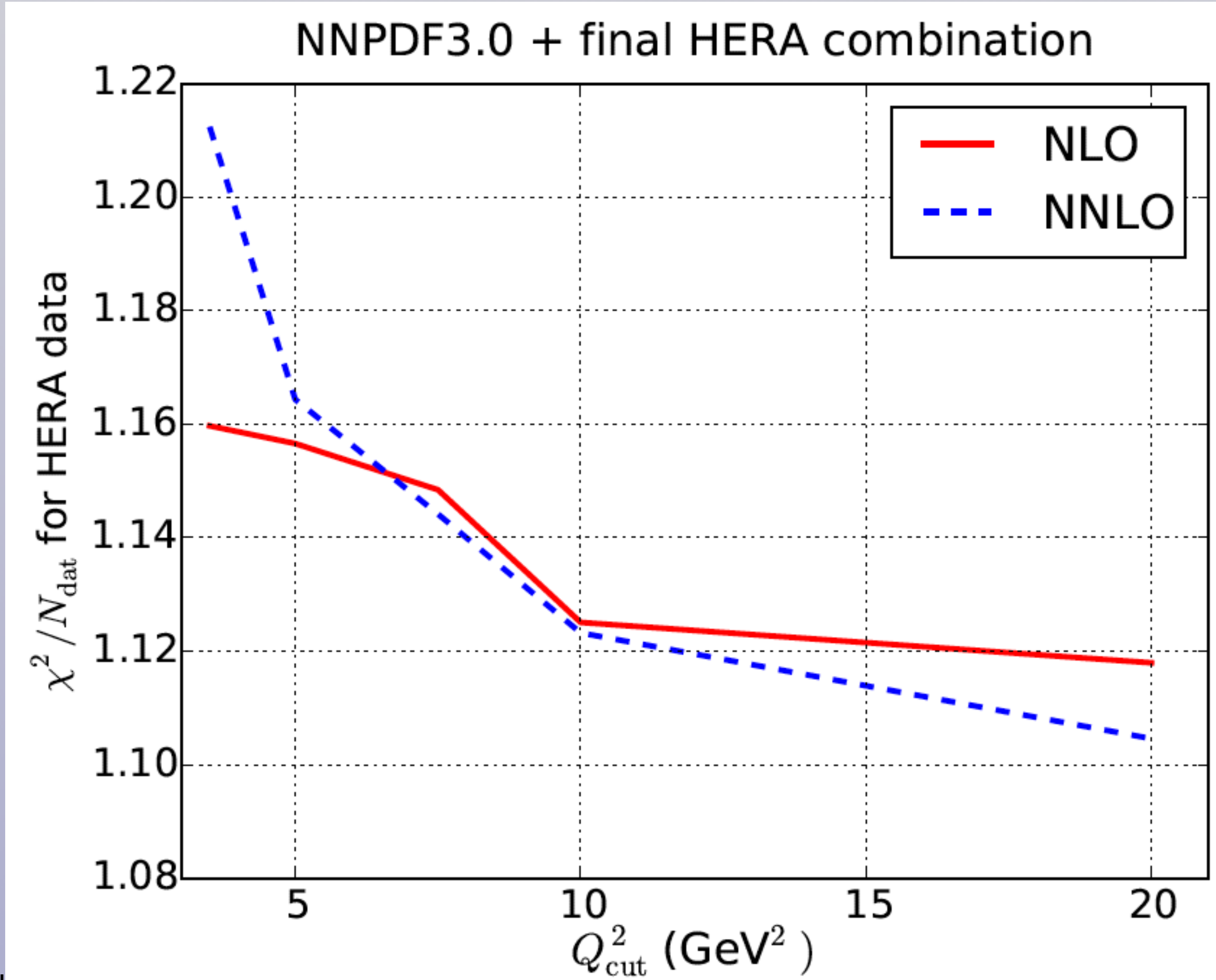




Including HERA-II measurements useful to **reduce PDF uncertainties** in various flavours

Tension at small-x?

- Fit quality somewhat improves if **low-x, low-Q² data removed**, specially at NNLO
- However for **$Q^2_{cut} \geq$ 7.5 GeV²** the NNLO quality always better than NLO
- Related to **BFKL-like effects at small-x**? To investigate using **small-x (high-energy) resummed fits**



Including the ATLAS 2011 jet data

- **ATLAS inclusive jet production** from 2011 recently available from **HepForge**
- **NLO theory from NLOjet++/APPLgrid**, with **p_T^{jet} as central scale**
- **Information about how to treat systematic errors not available**: explore two assumptions about **the experimental covariance matrix**: treat all systematics either as fully correlated or as fully uncorrelated
- Non-perturbative and electroweak corrections included in the theory calculation

ATLAS1JET11 all systematic uncertainties uncorrelated

ATLAS		333	1.13781
	ATLASWZRAP36PB	30	1.17809
	ATLASR04JETS36PB	90	1.01606
	ATLASR04JETS2P76TEV	59	1.36090
	ATLASZHIGHMASS49FB	5	1.97278
	ATLASWPT31PB	9	1.17594
	ATLAS1JET11	140	0.57488

The **theory/data comparison** depends strongly on assumptions in the **construction of experimental covariance matrix**

ATLAS1JET11 all systematic uncertainties fully correlated

ATLAS		333	2.17935
	ATLASWZRAP36PB	30	1.18827
	ATLASR04JETS36PB	90	1.01396
	ATLASR04JETS2P76TEV	59	1.37073
	ATLASZHIGHMASS49FB	5	2.00097
	ATLASWPT31PB	9	1.17049
	ATLAS1JET11	140	3.02404

ATLAS 2011 jets lead to reduction on **large-x gluon PDF uncertainties,** but need input about correct treatment of systematics

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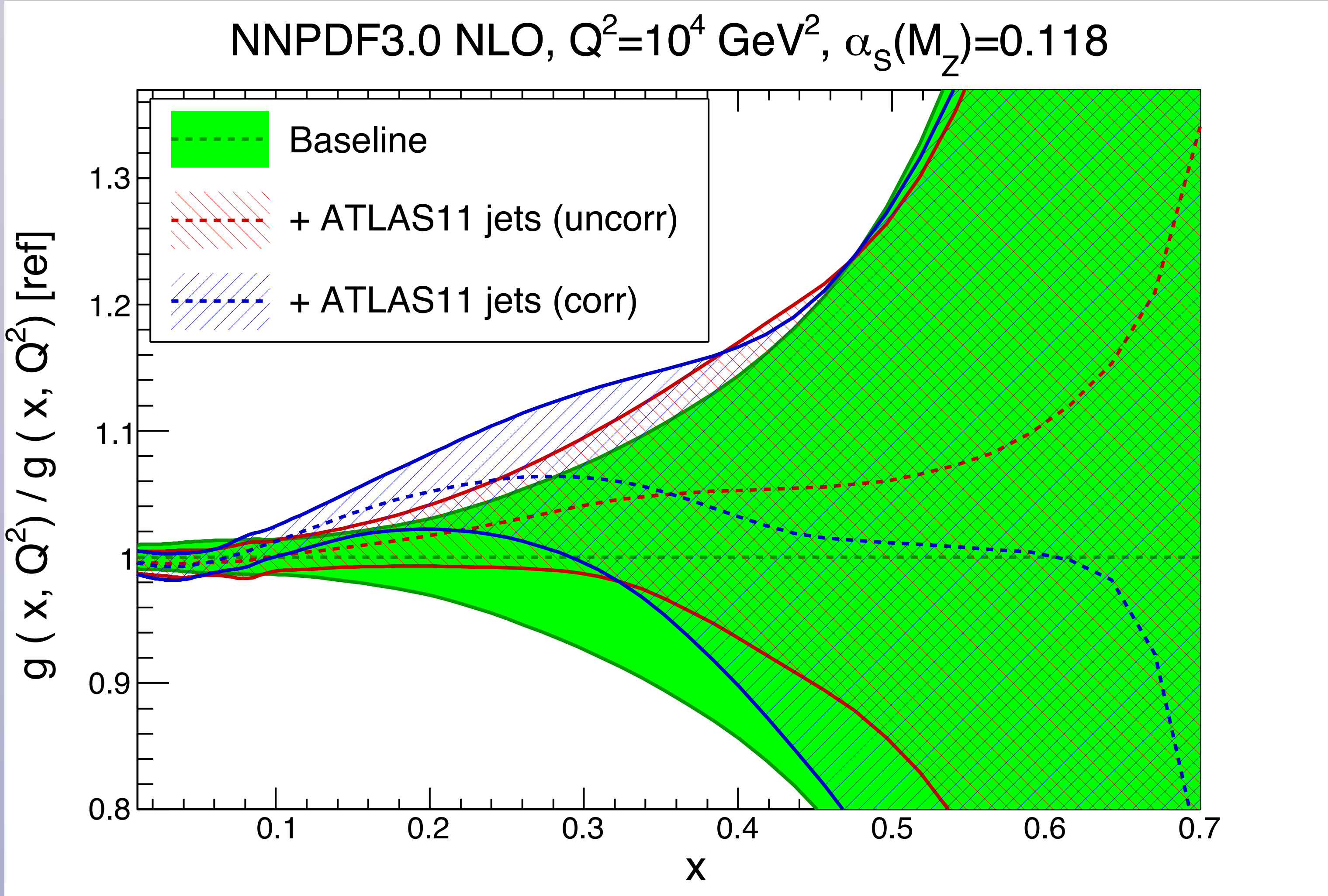

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ATLAS 2011 jets lead to reduction on **large-x gluon PDF uncertainties,** but need input about correct treatment of systematics

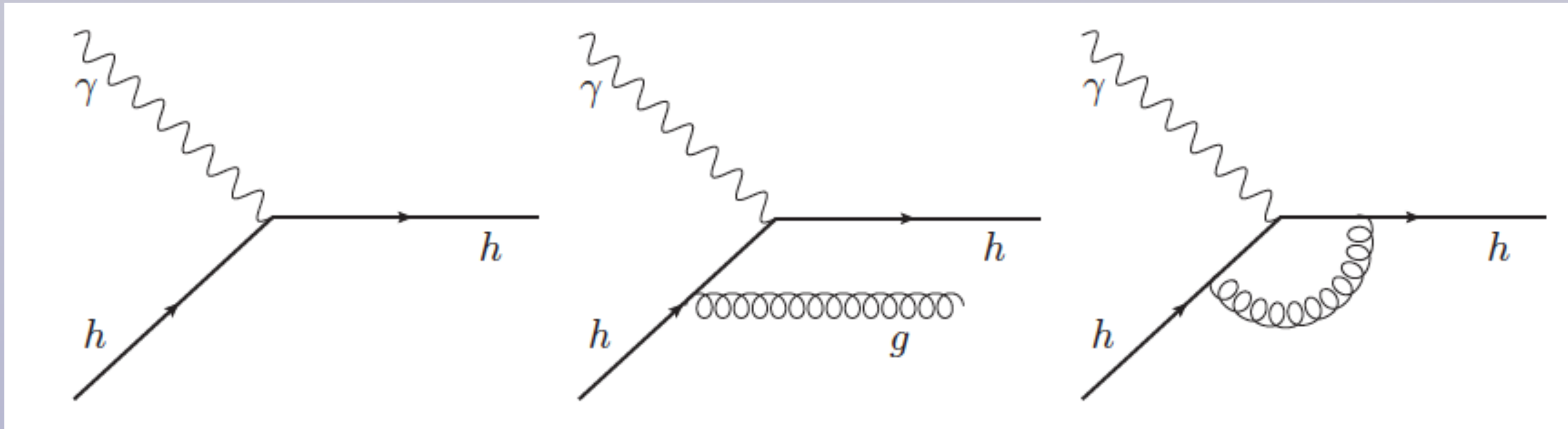
NNPDF fits with intrinsic charm

Ball, Bertone, Bonvini, Forte, Groth-Merrild, JR, Rottoli, arXiv:1510.01009
Ball, Bonvini, Rottoli, arXiv:1510.02491
NNPDF, in preparation

FONLL with a fitted charm PDF

- The motivation **to fit a charm PDF** is two-fold:
  - ☑ Stabilise the dependence of **GM-VFN calculations** with respect to **value of the charm mass**
  - ☑ Quantify the possible **non-perturbative charm component in the proton**

- Not enough to only add **a new fitted PDF at the input scale**: FFN and GM-VFN scheme calculations need to be modified to account for genuinely **new contributions: massive charm-initiated processes**



- Coefficient functions for NC and CC **charm-initiated contributions in the massive scheme** up to NLO have been computed, but NNLO not available yet

Hoffmann and Moore 83
Kretzer and Schienbein 98

FONLL with a fitted charm PDF

- The original FONLL structure functions can be modified to account for **massive charm-initiated contributions**

$$F(x,Q^2) = F^{\mathrm{FLNR}}(x,Q^2) + \Delta F(x,Q^2)$$

- The new piece to be added to the **FONLL charm structure functions** is

$$\begin{aligned}\Delta F_h(x,Q^2) = \sum_{i=h,\bar{h}} \Bigg\{ \Big[\left(C_i^{(3),0}\left(\frac{Q^2}{m_h^2}\right) - C_i^{(4),0} \right) \\ + \alpha_s^{(4)}(Q^2)\left(C_i^{(3),1}\left(\frac{Q^2}{m_h^2}\right) - C_i^{(4),1} \right) \Big] \\ - \alpha_s^{(4)}(Q^2) C_i^{(3),0}\left(\frac{Q^2}{m_h^2}\right) \otimes \left(K_{hh}^{(1)}(m_h^2) + P_{qq}^{(0)} L \right) \Bigg\} \otimes f_i^{(4)}(Q^2) \\ - \alpha_s^{(4)}(Q^2) \sum_{i=h,\bar{h}} \left(C_i^{(3),0}\left(\frac{Q^2}{m_h^2}\right) - C_i^{(4),0} \right) \otimes P_{qg}^{(0)} L \otimes f_g^{(4)}(Q^2) + \mathcal{O}(\alpha_s^2)\end{aligned}$$

- This correction **vanishes at large Q²** (since massless scheme unaffected by new contributions) and is **numerically tiny for a perturbative generated charm** (use equations of motion)

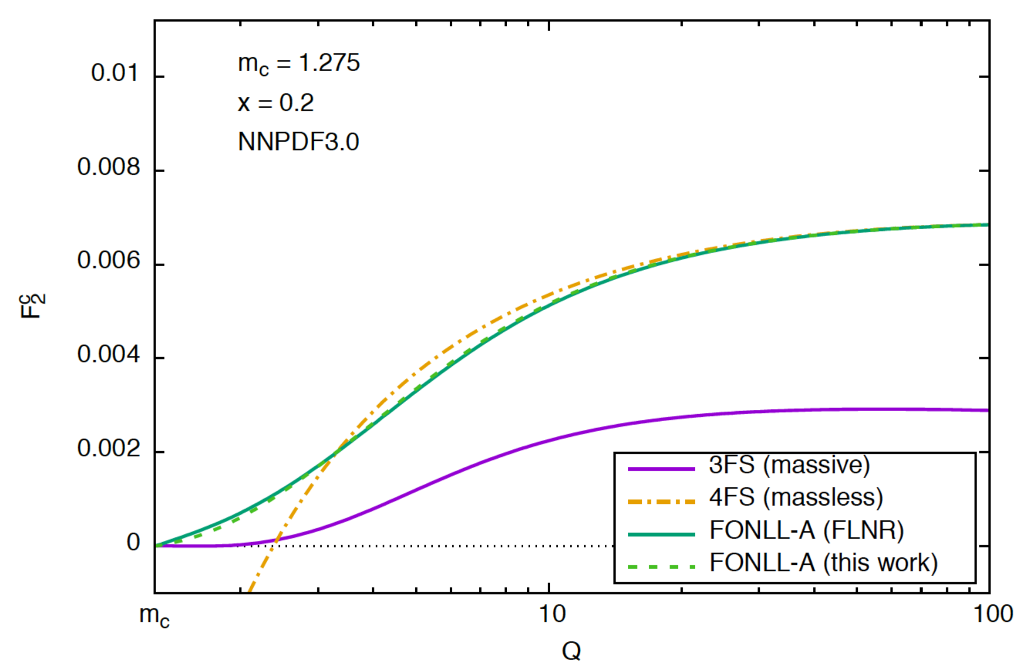
$$\begin{aligned}f_h^{(3)} = f_h^{(4)}(Q^2) \\ - \alpha_s^{(4)}(Q^2)\left(K_{hh}^{(1)}(m_h^2) + P_{qq}^{(0)} L \right) \otimes f_h^{(4)}(Q^2) - \alpha_s^{(4)}(Q^2) L P_{qg}^{(0)} \otimes g^{(4)}(Q^2) + \mathcal{O}(\alpha_s^2)\end{aligned}$$

FONLL with a fitted charm PDF

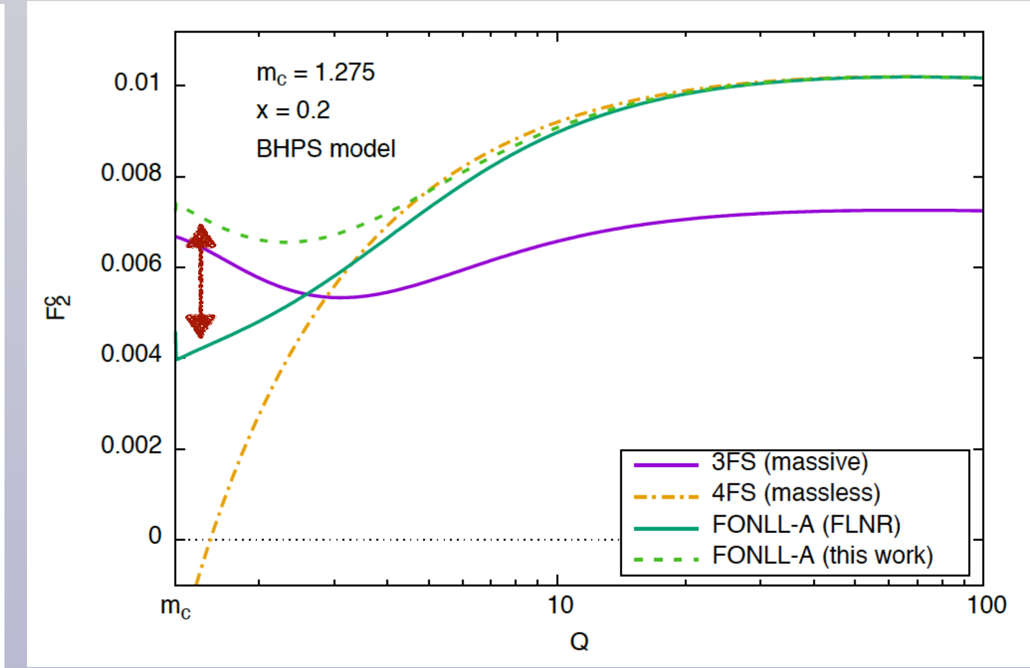
$$F(x,Q^2) = F^{\mathrm{FLNR}}(x,Q^2) + \Delta F(x,Q^2)$$

``This work"* *``FLNR"

Perturbatively generated charm PDF



Charm PDF from BHPS model, 0.5% mom fract



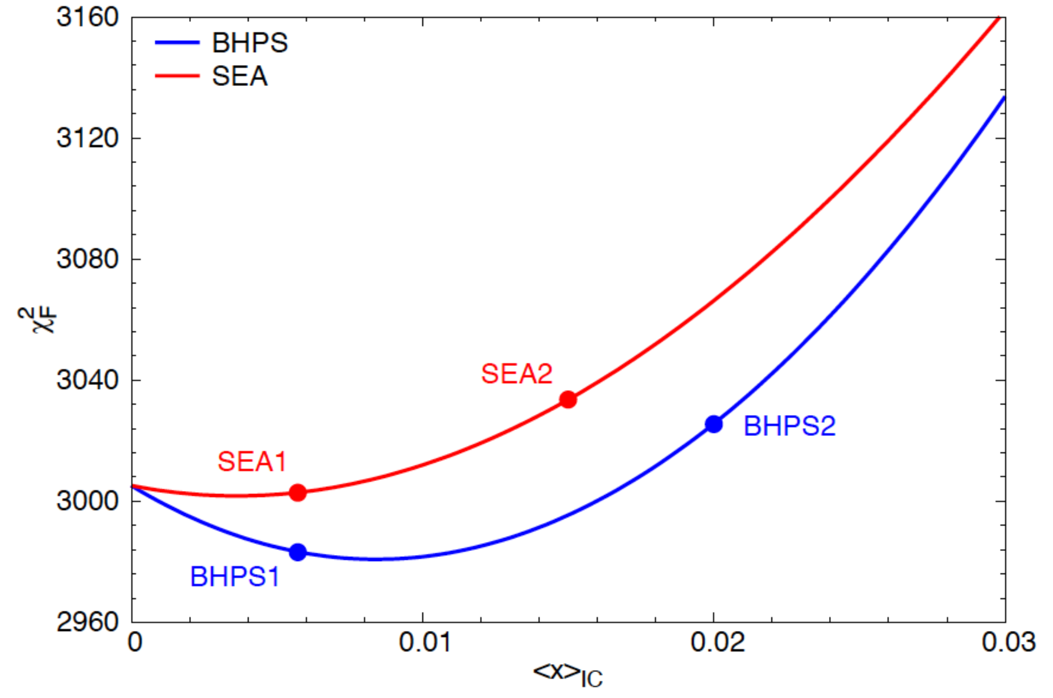
$$f_c^{(3)}(x) = f_{\bar{c}}^{(3)}(x) = A\,x^2[6x(1+x)\ln x + (1-x)(1+10x+x^2)]\,.$$

- For a **dynamically generated charm**, the new contributions have tiny numerical effects
- For **BHPS-like fitted charm**, substantial differences close to threshold at low scales

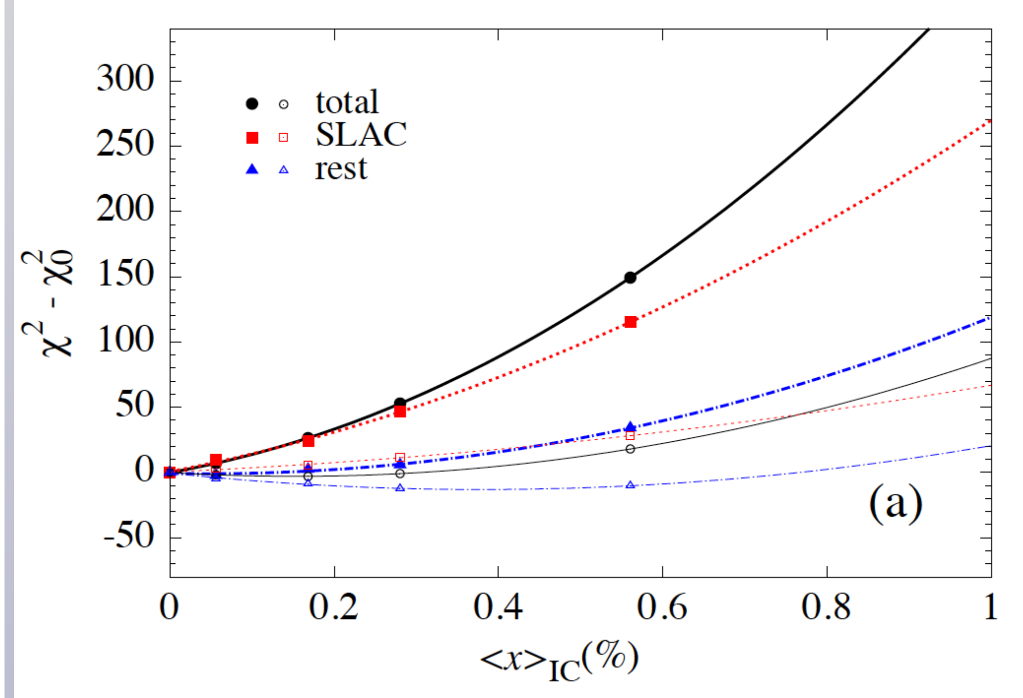
→ Use of **generalized GM-VFN scheme** crucial for any **realistic fit with charm PDFs**

Previous global PDF fits with IC

CT10 IC fit, arXiv:1309.0025



JLAB IC fit, arXiv:1408.1708

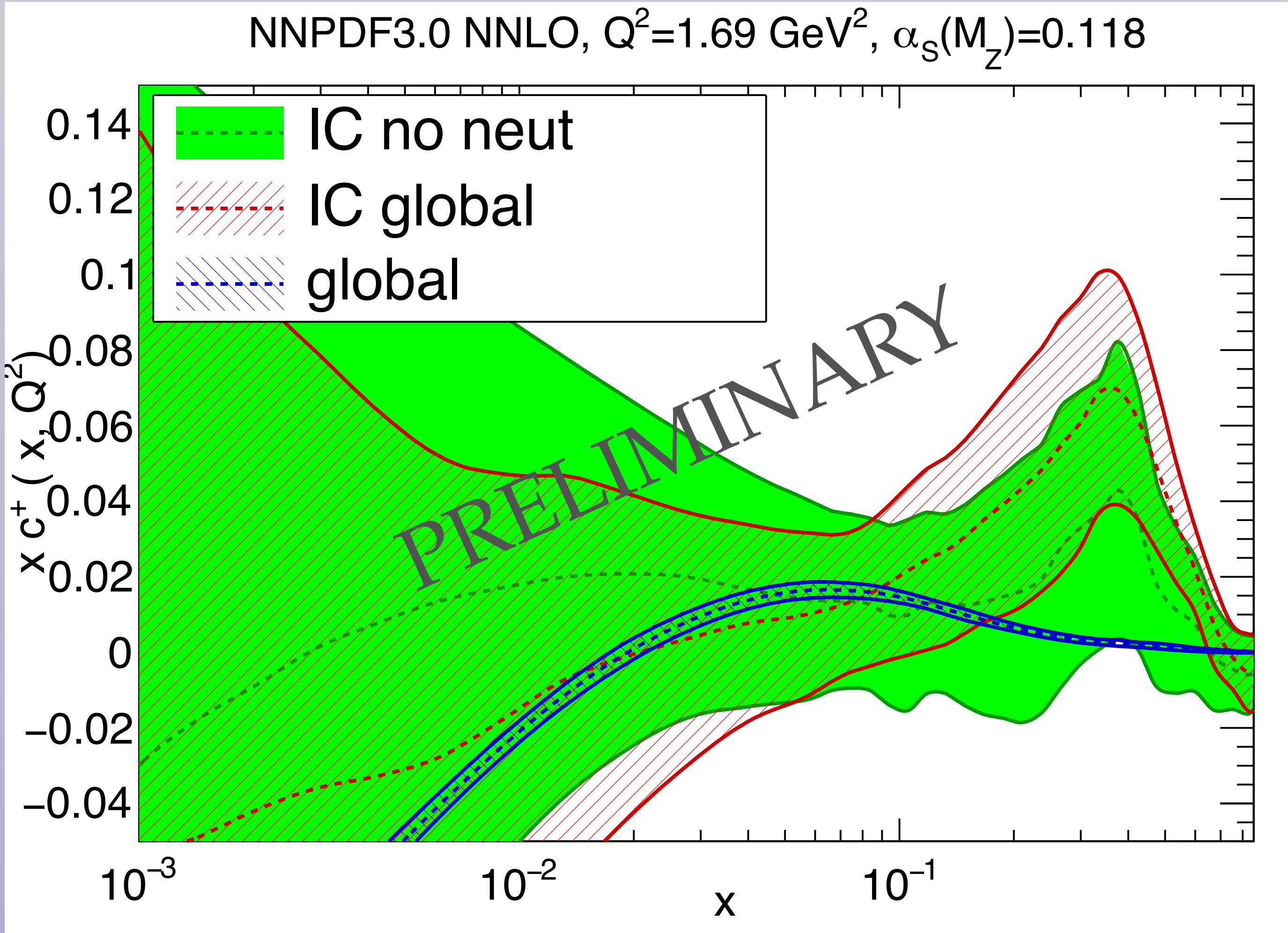


- Fitted charm with **standard S-ACOT structure functions,** without massive charm-initiated terms
- **Sizable charm** still allowed in global fit, though results depend on the **specific choice of model for fitted charm**, as well as **value of tolerance, $\Delta\chi^2$=100**

- Fitted charm in the **FFN scheme,** with massive charm-initiated terms
- Claims very stringent bounds on IC, also depends on **choice of tolerance (in this case $\Delta\chi^2$=1)**

NNPDF3.0 fits with intrinsic charm

- Currently exploring how **NNPDF3.0 fits** are modified if **$c^+(x,Q_0)$ is also fitted**
- Initial exploratory study: use **FLNR FONLL expressions** for the DIS structure functions but also fit a charm PDF (as done in the **CTEQ-IC fits**)
- Very preliminary results for fitted charm indicate that there might be room in the global fit for a **relatively large charm contribution**, though with sizeable dependence on the **choice of fitted dataset**



$\langle xc^+ \rangle$ = (2.6 +- 1.3)%

$\langle xc^+ \rangle$ = (1.3 +- 1.4)%

For any robust conclusion, need to implement **modified FONLL structure functions** with **massive charm-initiated contributions**

Work in progress

Summary and outlook

Working in different directions to improve the NNPDF global analysis:

- Included the **legacy HERA combined dataset**

- Included **new measurements** from ATLAS, CMS and LHCb, and studied their constraints on NNPDF3.0

- NNPDF3.0 fits with **intrinsic charm** should become available very soon. Study their implications for **LHC phenomenology**

- Not discussed here: NNPDF fits with **running heavy quark masses**, and the associated determination of **$m_c(m_c)$**

- Also, ongoing work towards NNPDF fits with **high energy resummation.** Relation with the tension with the **low-Q^2 HERA combined data?**