PDF4BSM
Parton Distributions in the Higgs Boson Era

Impact of new collider data in the NNPDF global analysis

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PDF4LHC Meeting
CERN, 13/09/2016

From the past ....

2015 Parton Distributions with threshold (soft gluon) resummation

2014 NNPDF3.0 global analysis & Closure Test validation

2013 NNPDF2.3QED and the photon PDF

2012 NNPDF2.3 global analysis

NNPDF ... to the future

05/2016 — **NNPDF3 fits with intrinsic charm**

Fall 2016 — **NNPDF3.1 global analysis** — *This talk*

NNPDF3.1QED fits

Updated determinations of $\alpha_S(M_Z)$ and $m_c(m_c)$ from the global PDF fit

PDF fits with small-x (BFKL) resummation

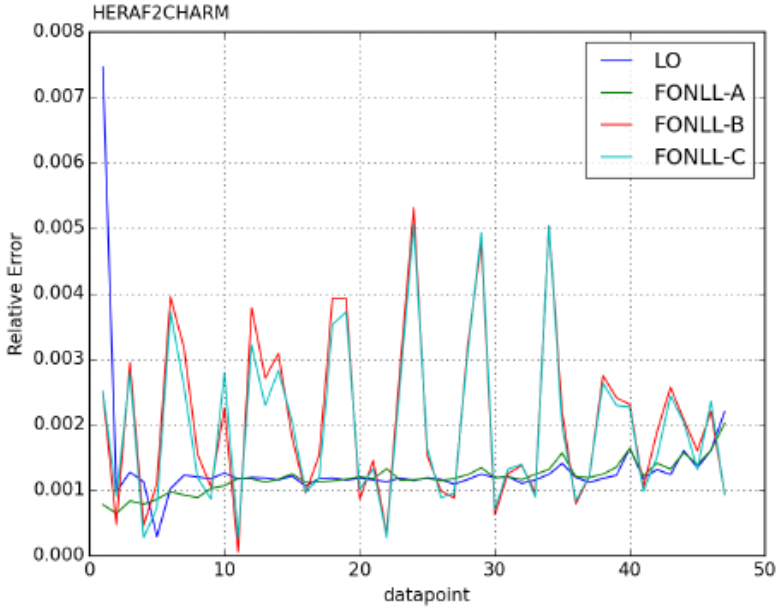
APFEL and APFELcomb

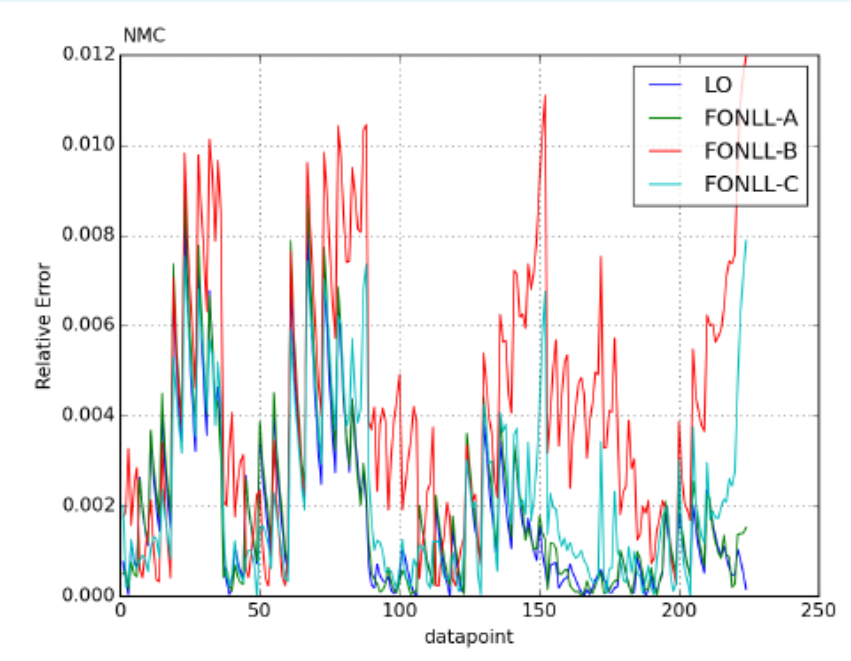
- Up to NNPDF3.0, PDF evolution and DIS structure functions were based on a (private) N-space code, **FKgenerator**

- From NNPDF3.1 we will adopt the public code **APFEL** for all theory calculations

- **Extensive benchmarking** between the two codes performed, as well ad with other codes like **HOPPET and OpenQCDrad**

- For hadronic observables, **APPLgrid** and **FastNLO** grids are pre-convoluted with PDF evolution kernels to optimise fit performance using a new tool, **APFELcomb** (to be publicly released)





Observable	APPLGRID	**APFELcomb**
W^+ production	1.03 ms	0.41 ms (2.5x)
Inclusive jet production	2.45 ms	20.1 μs (120x)

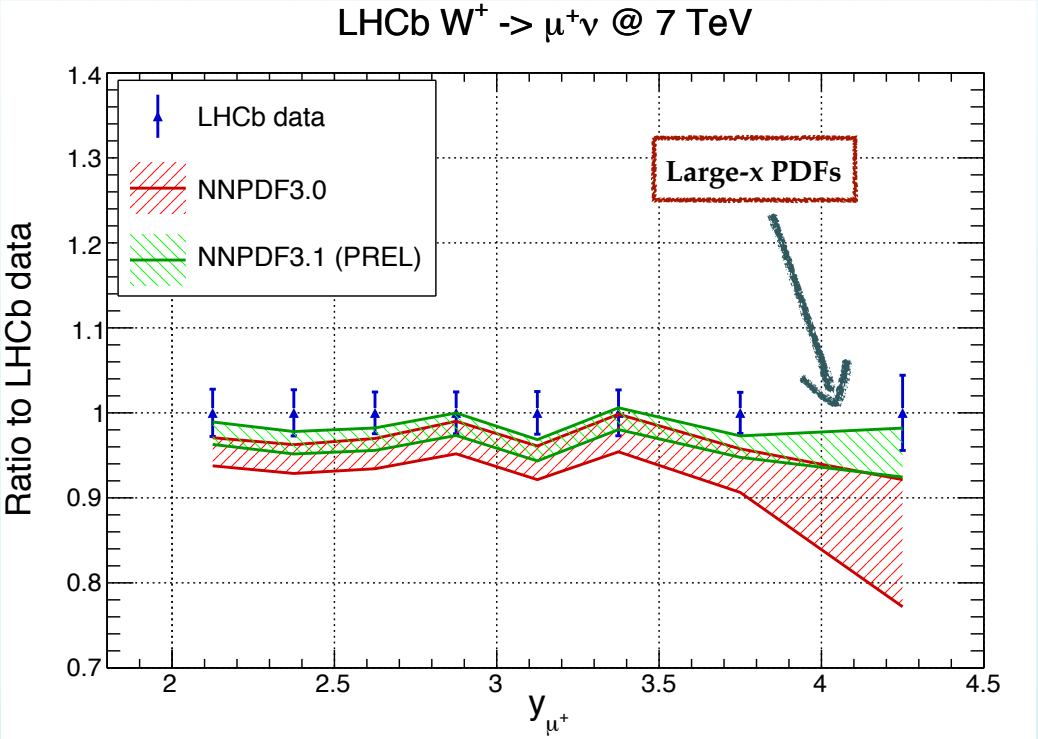
APFEL**: Bertone, Carrazza, Rojo, **arXiv:1310.06515
APFELcomb**: Bertone, Carrazza, Harland, **arXiv:1605.02070

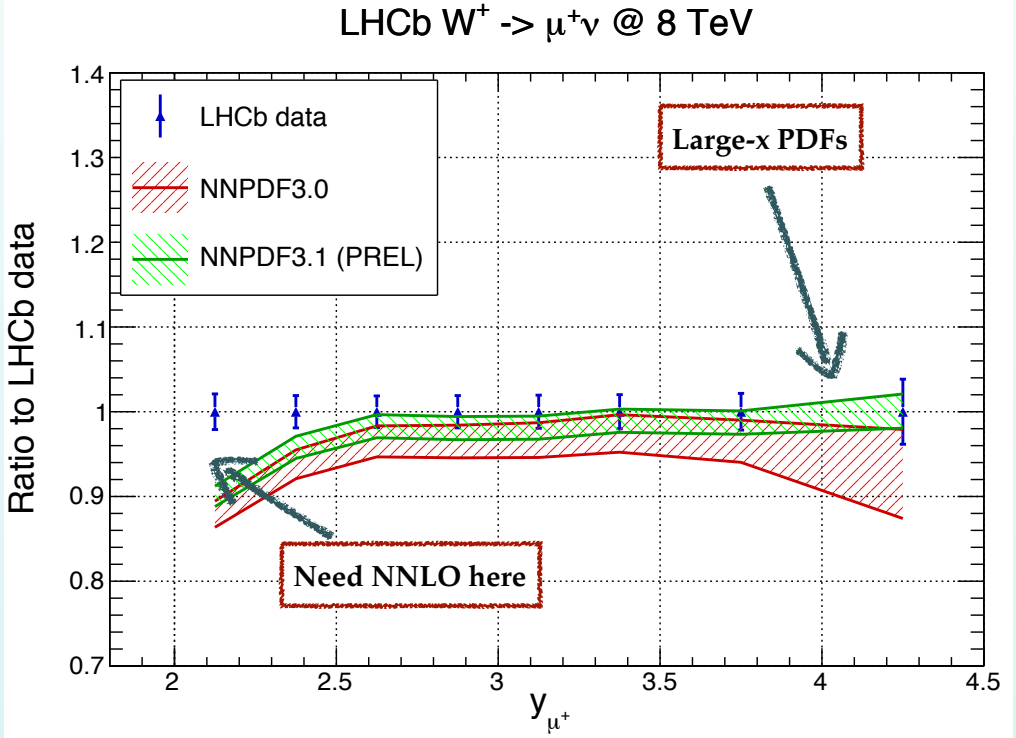
New datasets in NNPDF3.1

Measurement	Data taking	Motivation
LHCb W,Z rapidity dists 7 and 8 TeV	2011+2012	small-x and large-x quarks
D0 legacy W asymmetries	Run II	quark flavor separation
ATLAS inclusive jets 7 TeV	2011	large-x gluon
ATLAS low-mass Drell-Yan 7 TeV	2010+2011	small-x quarks
ATLAS Z pT 7,8 TeV	2011+2012	medium-x gluon and quarks
ATLAS and CMS tt differential 8 TeV	2012	large-x gluon
CMS Z (pT,y) 2D xsecs 8 TeV	2012	medium-x gluon and quarks
CMS Drell-Yan low+high mass 8 TeV	2012	small-x and large-x quarks
CMS W asymmetry 8 TeV	2012	quark flavor separation
CMS 8 TeV and 2.76 TeV jets Ratio	2012	medium and large-x gluon

LHCb Run I combination (muons)

- LHCb has provided their **combination of all Run I measurements on W -> μ ν and Z -> μ μ**
- Reasonable **description at NLO** for NNPDF3.1, significant **reduction of PDF uncertainties at large-x**
- **NNLO/NLO K-factors** can be large - compute them with **FEWZ** and **MCFM@NNLO**
- **LHCb 8 TeV electron data** also recently available



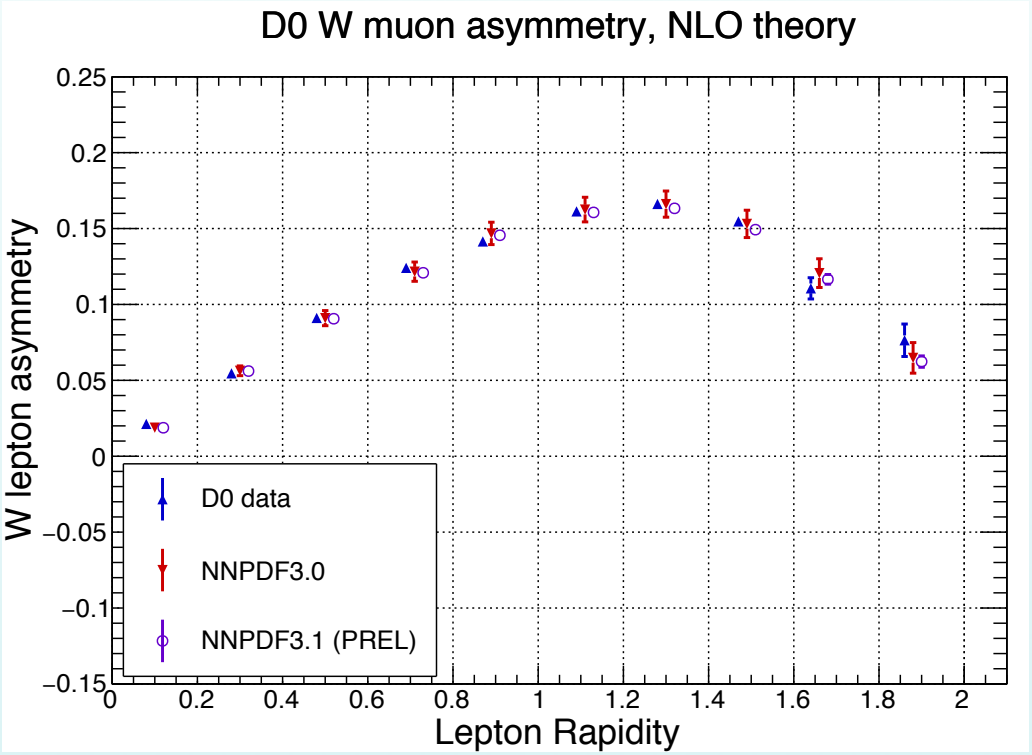


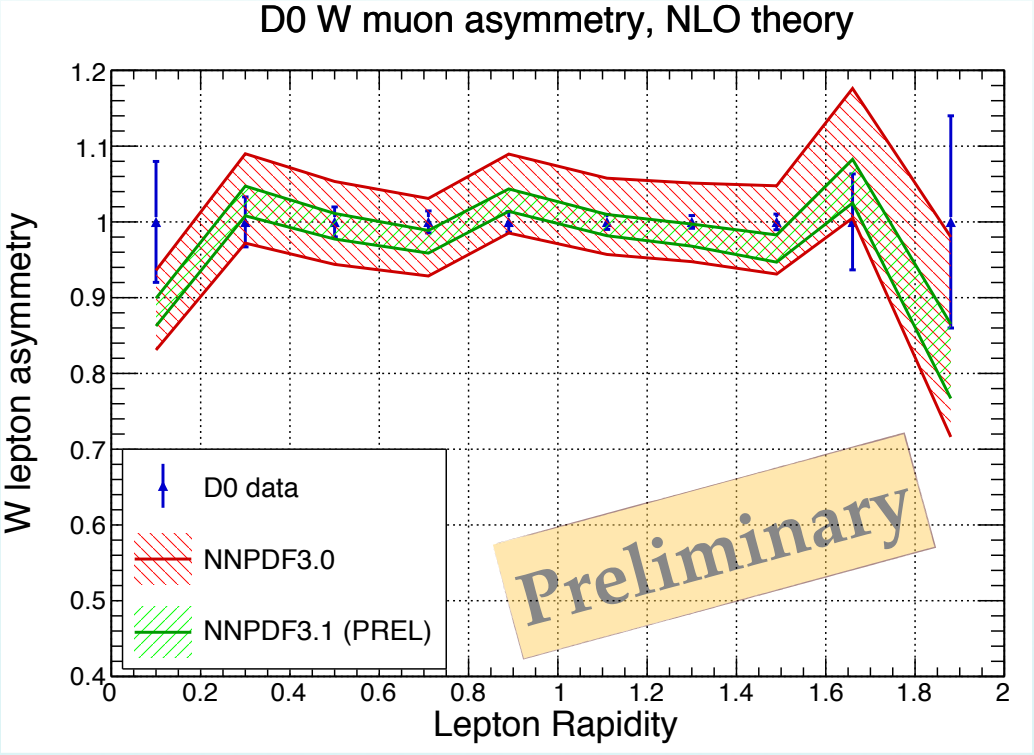
χ^2/N_{dat} (W+Z,NLO, 7 TeV) = 1.6

χ^2/N_{dat} (W+Z,NLO, 8 TeV) = 2.5

Tevatron legacy W asymmetries

- The **legacy Tevatron measurements on W asymmetries** based on the full dataset now available
- Consider only data at the **lepton level from D0** (exclude reconstructed W data from CDF)
- Good agreement with NNPDF3.1 NLO, substantial reduction of PDF uncertainties: **improved flavor separation**





χ^2/N_{dat} **(NLO, muon asy) = 1.3**

Tevatron legacy W asymmetries

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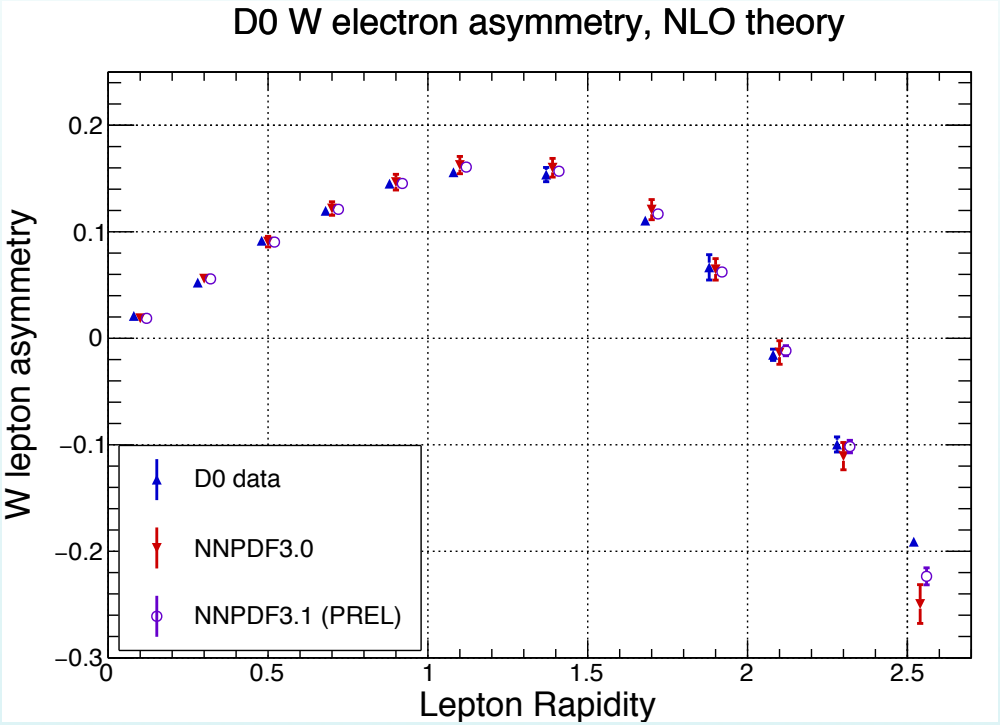
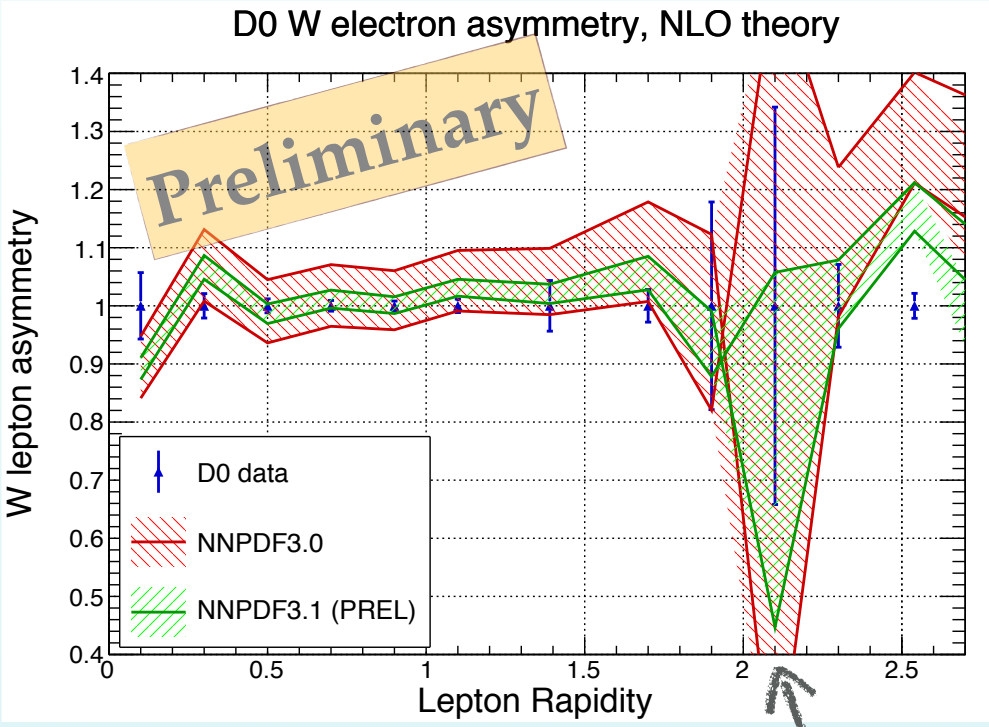




χ^2/N_{dat} **(NLO, electron asy) = 1.4**

asymmetry crosses zero

Fits with differential top quark pair data

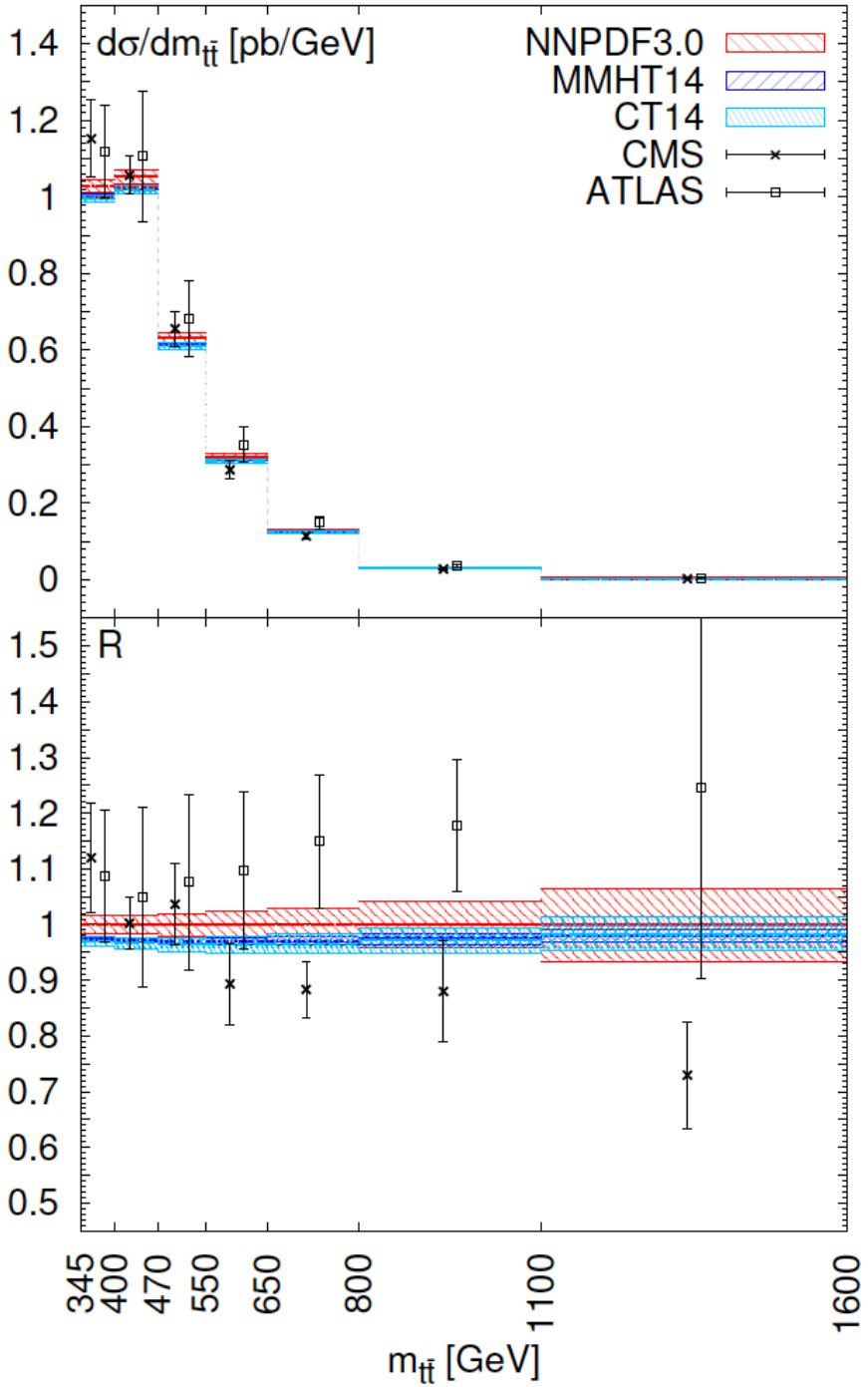
- The recent availability of **exact NNLO results** (*Czakon, Heines, Mitov, arxiv:1511.00549*) makes possible the inclusion of **top quark differential distributions** into the NNLO global analysis

- Exploit the most recent **8 TeV data from ATLAS and CMS** to constrain the **large-x gluon PDF**

- These datasets will be **integral part of NNPDF3.1:** complementary constraints to jet production

- Some **tension** between the ATLAS and CMS data observed: under investigation

M. Czakon, N. Hartland, A. Mitov, E. R. Nocera, JR, in preparation



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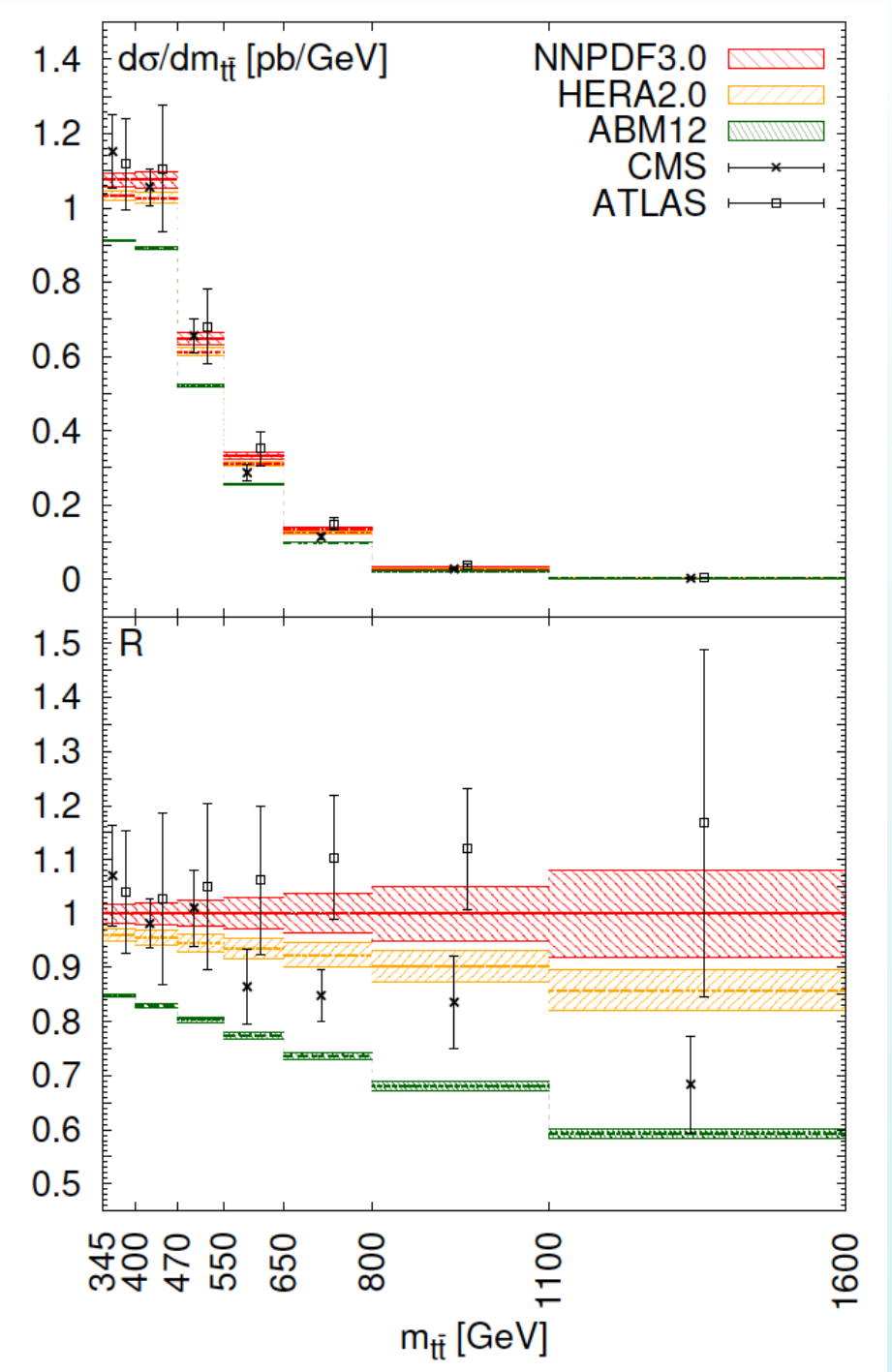


Fits with differential top quark pair data

Preliminary

Data set	Fit ID									
	1	2	3	4	5	6	7	8	9	10
ATLAS $d\sigma/dp_T^t$	2.12	2.13	**1.97**	2.08	2.07	2.20	1.98	2.15	2.17	2.11
ATLAS $d\sigma/dy_t$	0.68	0.64	0.61	**0.72**	0.55	0.63	0.74	0.60	0.62	0.69
ATLAS $d\sigma/dy_{t\bar{t}}$	0.56	0.55	0.52	0.90	**0.31**	0.47	1.01	0.36	0.25	0.44
ATLAS $d\sigma/dm_{t\bar{t}}$	0.71	1.08	0.95	0.91	0.97	**1.03**	0.89	1.11	1.22	1.15
ATLAS $(1/\sigma)d\sigma/dp_T^t$	4.06	7.38	4.28	6.06	5.22	6.37	**4.10**	6.97	6.52	7.38
ATLAS $(1/\sigma)d\sigma/dy_t$	3.09	1.89	1.79	3.25	1.54	1.82	3.19	**1.71**	1.49	1.74
ATLAS $(1/\sigma)d\sigma/dy_{t\bar{t}}$	2.04	1.34	1.27	3.15	0.66	1.53	3.85	1.01	**0.37**	1.71
ATLAS $(1/\sigma)d\sigma/dm_{t\bar{t}}$	1.80	3.16	2.83	2.38	2.79	3.30	2.49	3.35	4.20	**3.57**
ATLAS $\sigma_{t\bar{t}}$	3.29	**1.46**	1.93	2.74	2.84	2.82	**1.70**	**1.64**	**1.57**	**1.58**
CMS $d\sigma/dp_T^t$	12.0	7.85	**2.98**	9.51	8.32	9.84	5.53	7.35	5.51	6.73
CMS $d\sigma/dy_t$	3.59	3.65	3.97	**3.07**	4.48	4.16	3.24	3.90	4.93	4.12
CMS $d\sigma/dy_{t\bar{t}}$	1.10	0.88	0.88	0.98	**1.03**	1.06	0.90	0.99	1.16	1.09
CMS $d\sigma/dm_{t\bar{t}}$	5.91	4.02	4.42	4.73	4.42	**4.07**	4.67	3.93	3.44	3.72
CMS $(1/\sigma)d\sigma/dp_T^t$	3.30	3.94	2.84	3.67	3.08	3.44	**2.94**	3.60	2.98	3.67
CMS $(1/\sigma)d\sigma/dy_t$	3.65	4.47	4.53	3.52	5.02	4.68	3.53	**4.67**	5.98	5.05
CMS $(1/\sigma)d\sigma/dy_{t\bar{t}}$	1.18	1.23	1.20	1.37	1.20	1.29	1.54	1.32	**1.40**	1.46
CMS $(1/\sigma)d\sigma/dm_{t\bar{t}}$	9.94	7.31	7.86	8.60	7.89	7.23	8.47	7.12	6.16	**6.82**
CMS $\sigma_{t\bar{t}}$	4.15	**0.50**	1.38	1.49	1.60	1.99	**1.39**	**0.77**	**0.56**	**0.60**

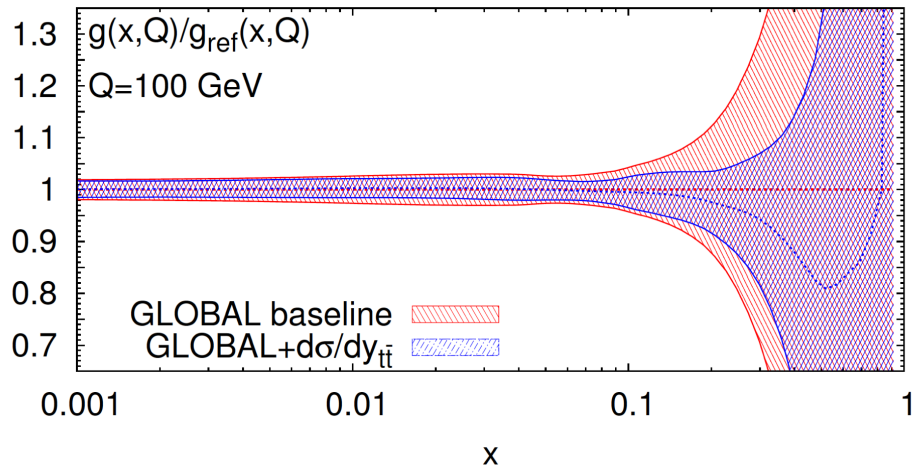
χ^2/N_{dat} for various combinations of top quark differential distributions added to the NNPDF3 global analysis

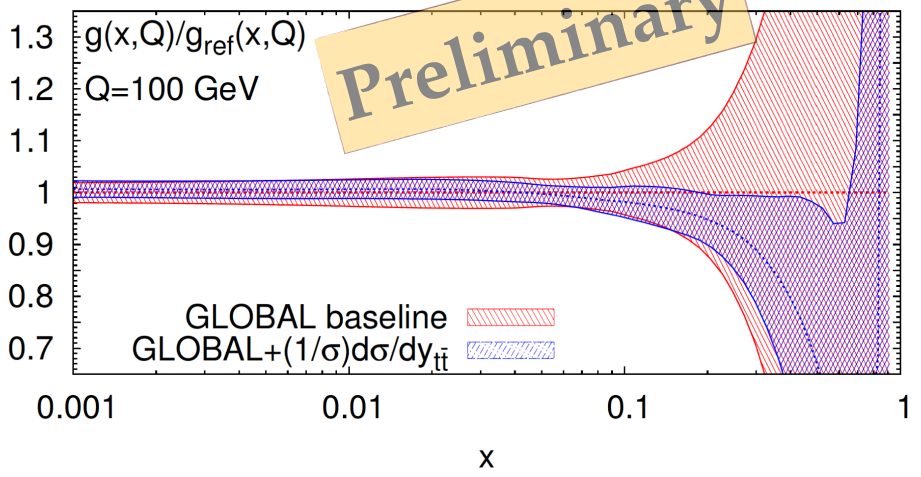
Some difficultly in fitting the CMS distributions at the same time as the ATLAS ones ….

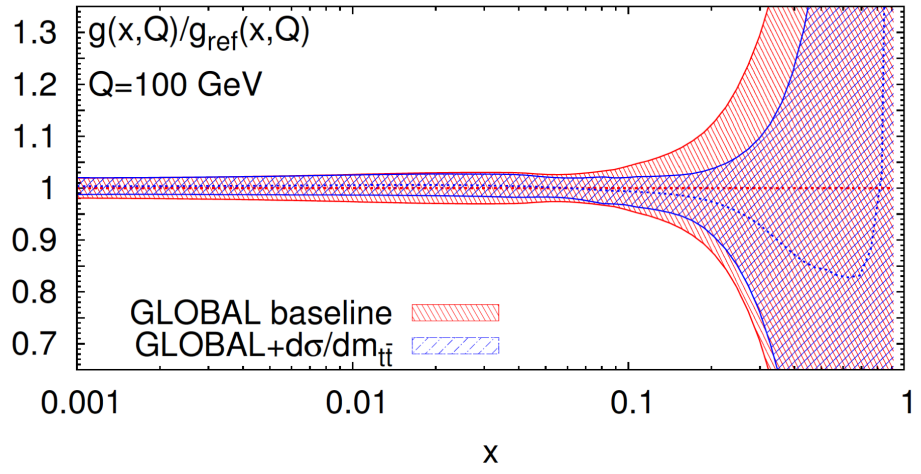
Poor description of the top transverse momentum distributions, both ATLAS and CMS

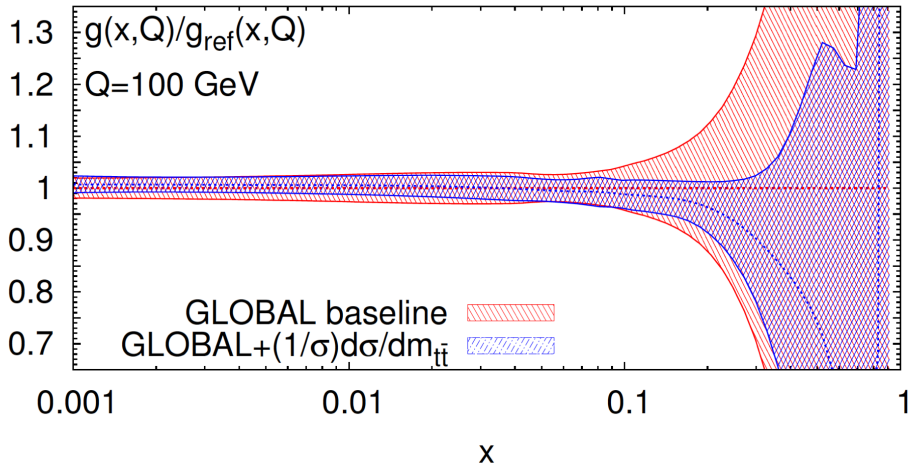
Fits with differential top quark pair data

Since **only one distribution per experiment** can be added at the same time in the global fit, need to determine the consistent choice which **maximizes the constrains on the large-x gluon**





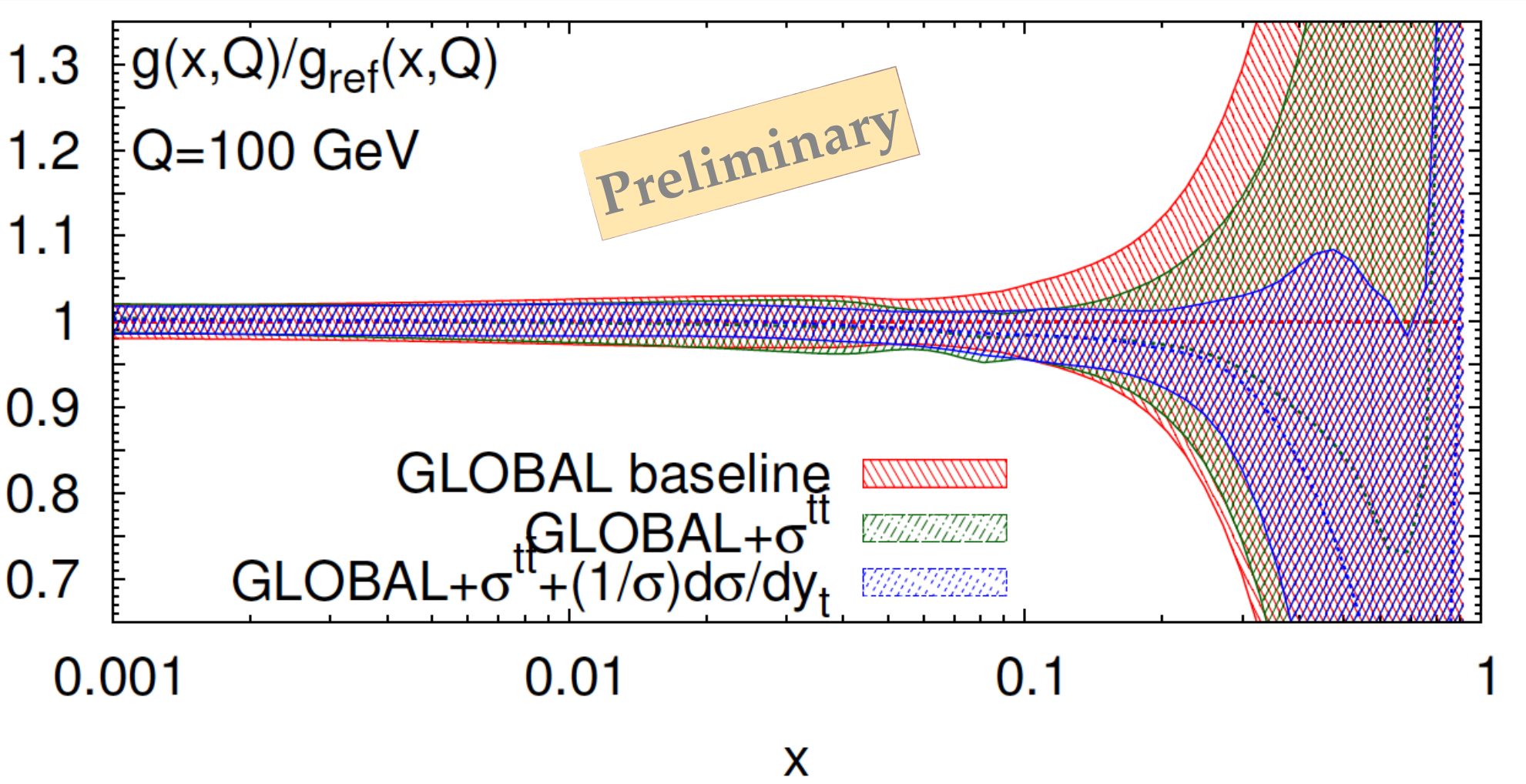




Significant constraints on **large-x gluon** from **global fit** without inclusive jet data (not available at NNLO)

Normalized distributions, supplemented by total inclusive cross-sections, exhibit more constraining power

Fits with differential top quark pair data



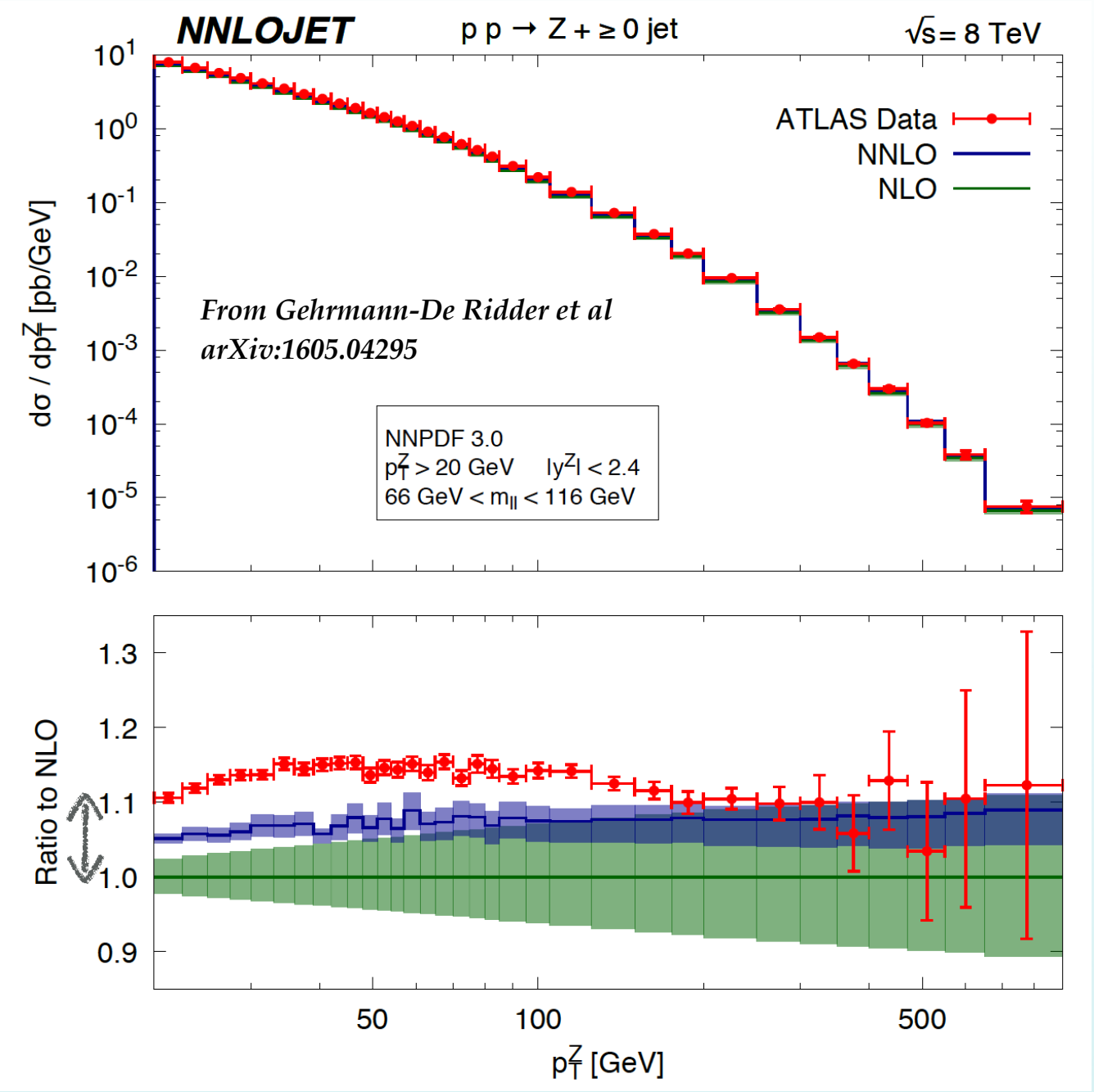
The additional constrains provided by the **normalized distributions** complement those of the **total cross-sections,** which to begin with are already quite useful (*Czakon, Mangano, Mitov, Rojo, arxiv:1303.7215*)

The Z p_T distribution at the LHC

High-precision, theoretically very clean process

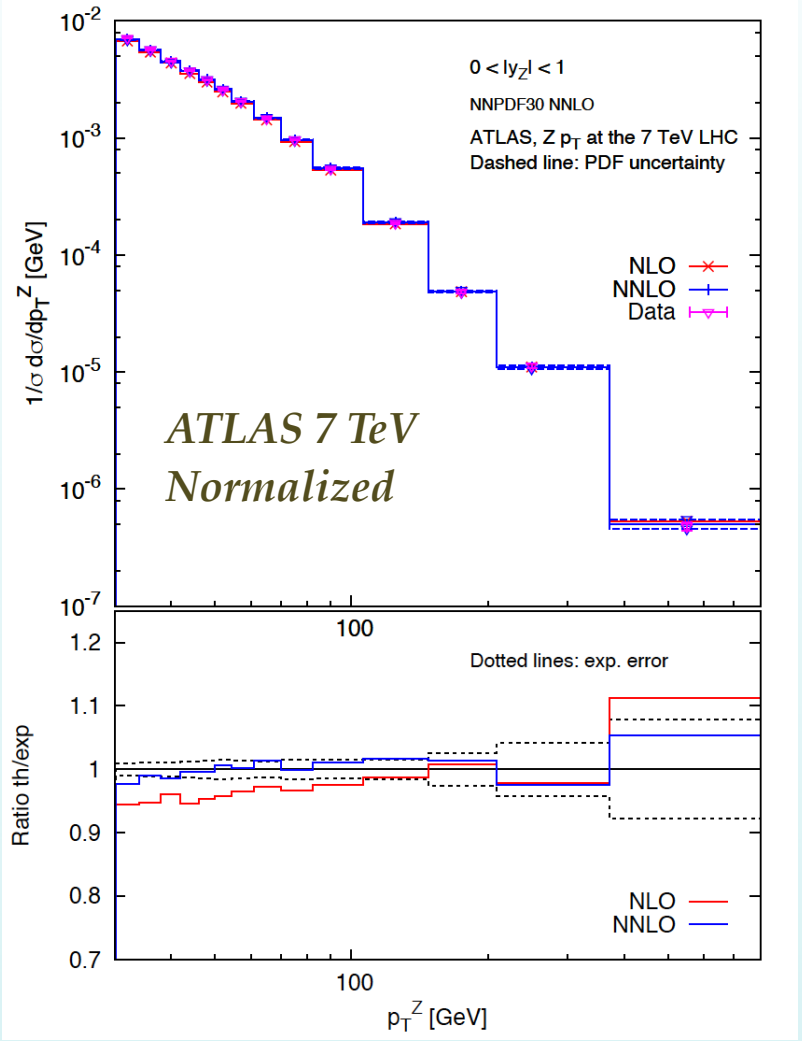
Comparison between **NNLO calculations** and **LHC data** with **NNPDF3.0**

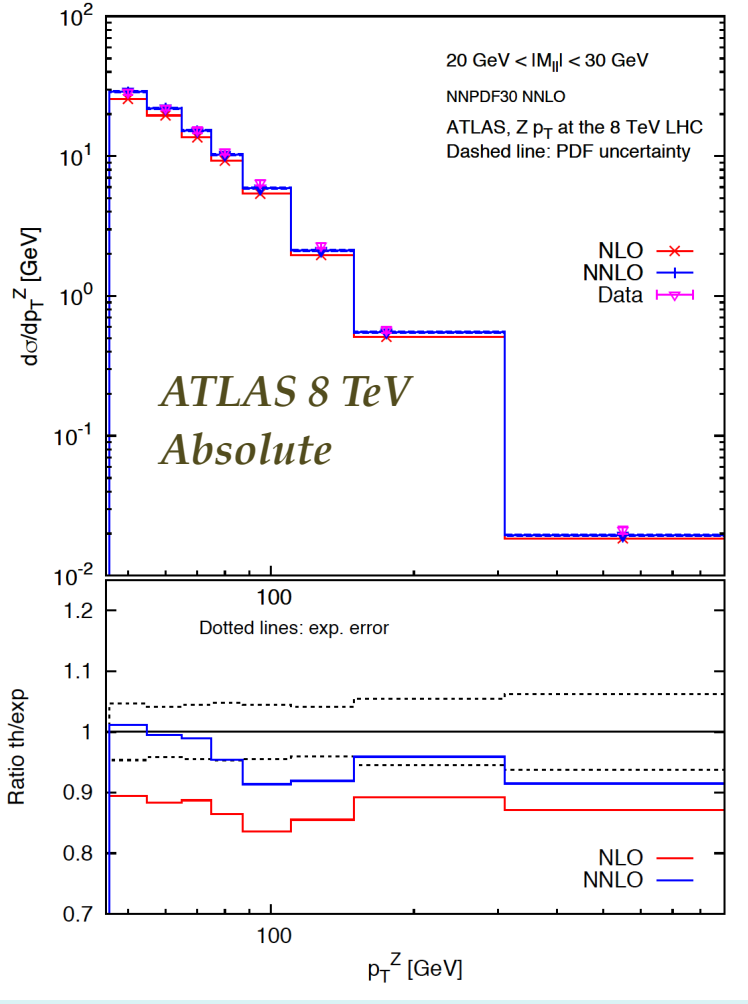
Some **tension for the unnormalized distributions** even at NNLO - it is a **PDF issue?**



The Z p_T distribution at the LHC

- In NNPDF3.1 we will include the **ATLAS 7 TeV** (arXiv:1406.3660) and **8 TeV** (arXiv:1512.02192) **Z p_T** distributions, as well as the corresponding **CMS 8 TeV data** (arXiv:1504.03511)
- Agreement between data and theory (fixed input PDF) **improves noticeably with NNLO corrections**

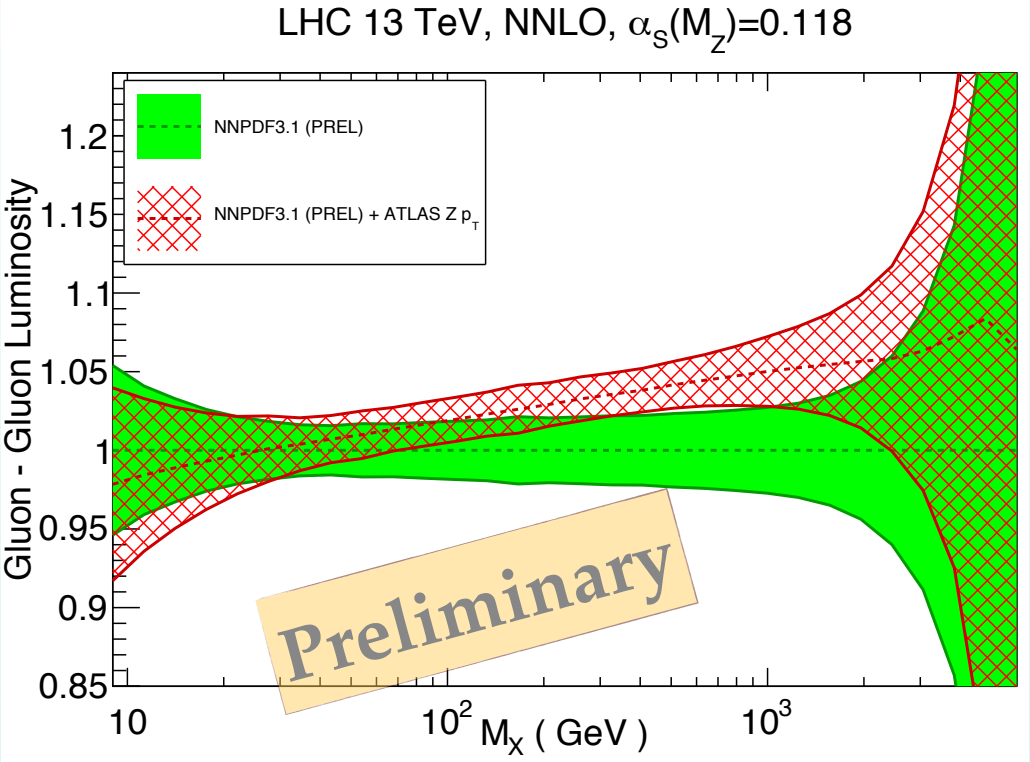


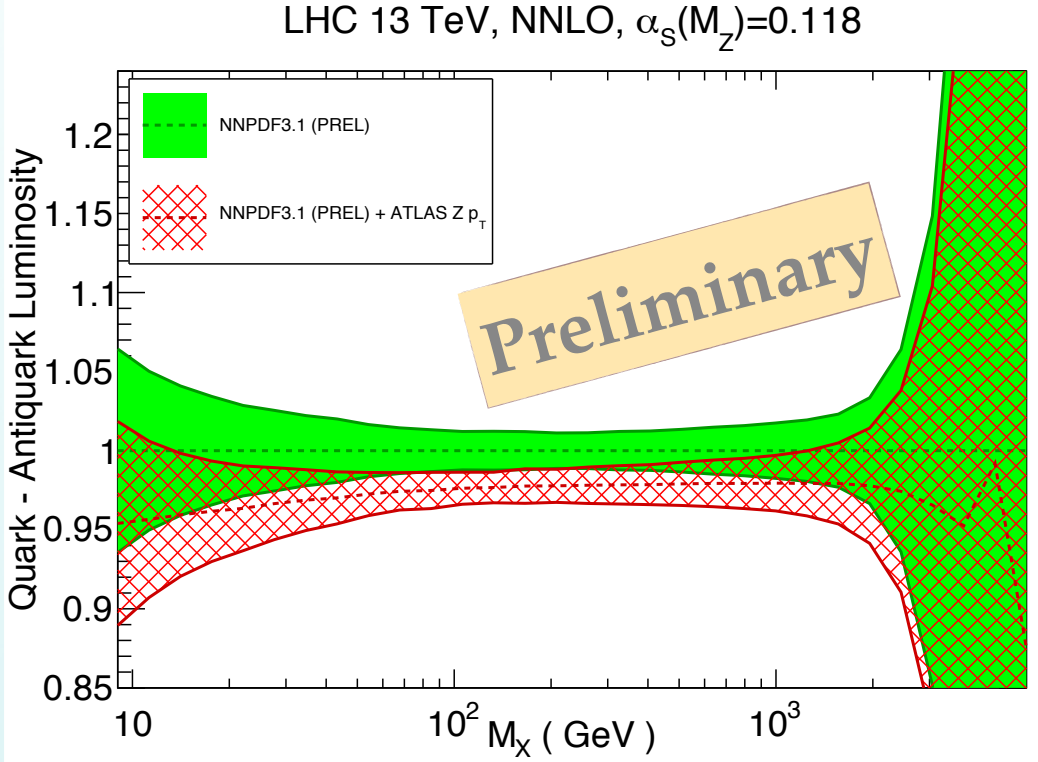


Theory calculations from R. Boughezal,A. Guffanti, F. Petriello and M. Ubiali, in preparation

The Z p_T distribution at the LHC

Preliminary NNPDF3.1 NNLO fits suggest a **sizeable impact** of the **LHC Z p_T data** on the PDFs

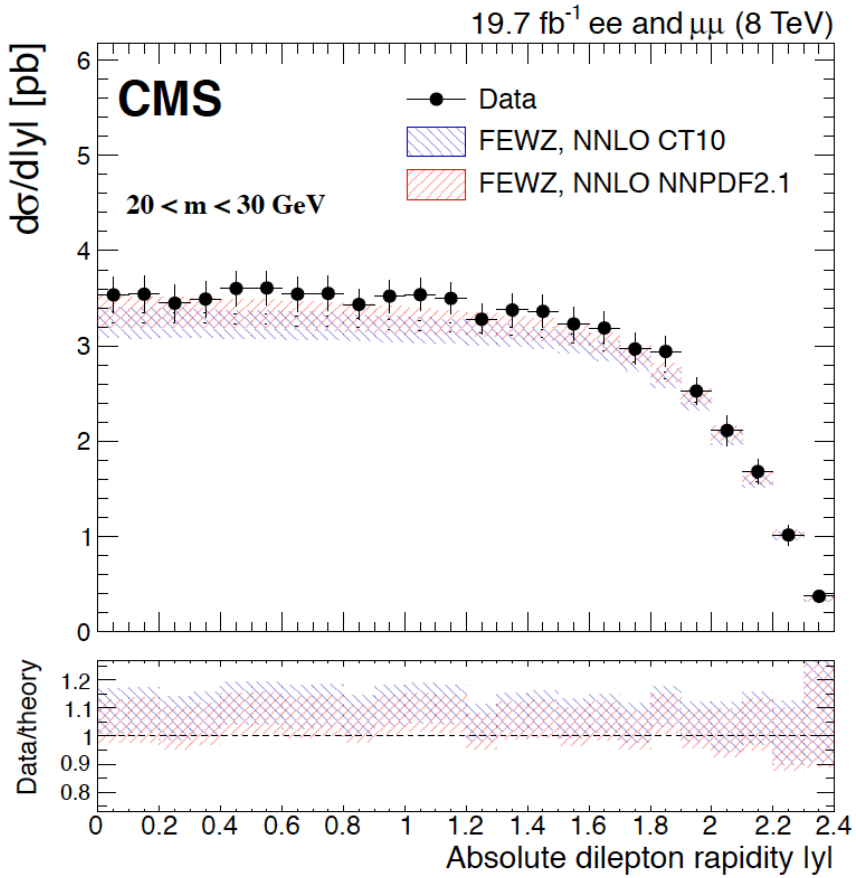


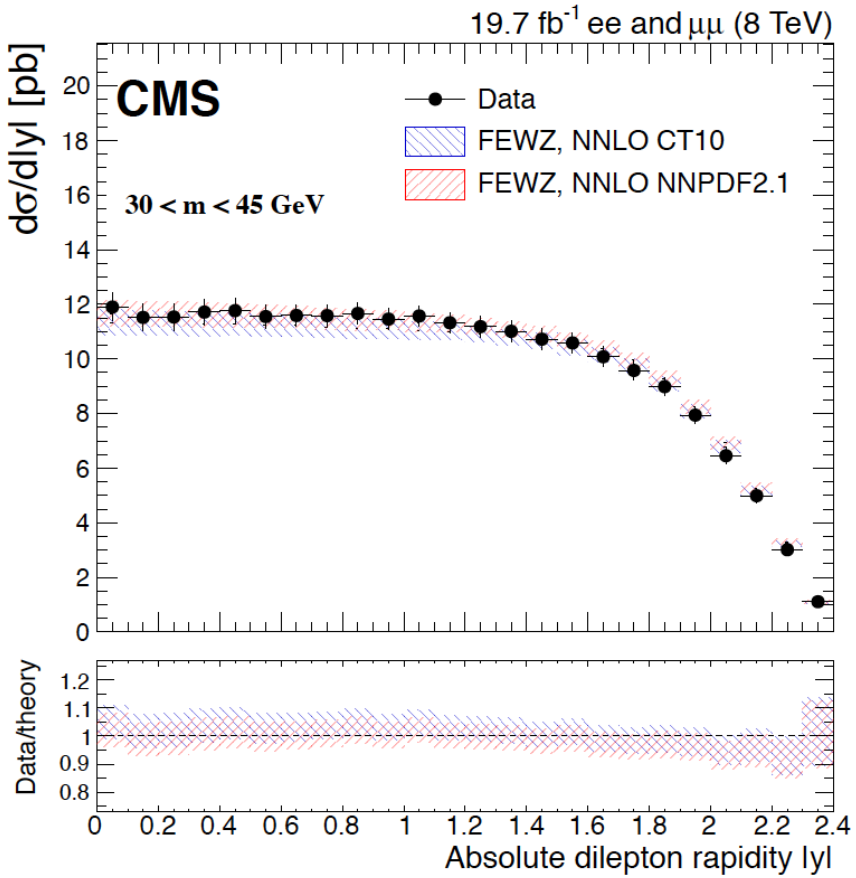


Including the LHC Z p_T data could be a **game-changer** in global NNLO PDF fits ……

CMS Drell-Yan 8 TeV (y_{ll},M_{ll}) data

- The CMS 7 TeV **Drell-Yan double-differential (y_{ll},M_{ll}) distributions** at 7 TeV are included in NNPDF3.0, and a **good data vs theory description** is achieved
- We are now investigating the information that can be obtained from **fitting the same data taken at 8 TeV,** which exhibits substantially reduced experimental uncertainties

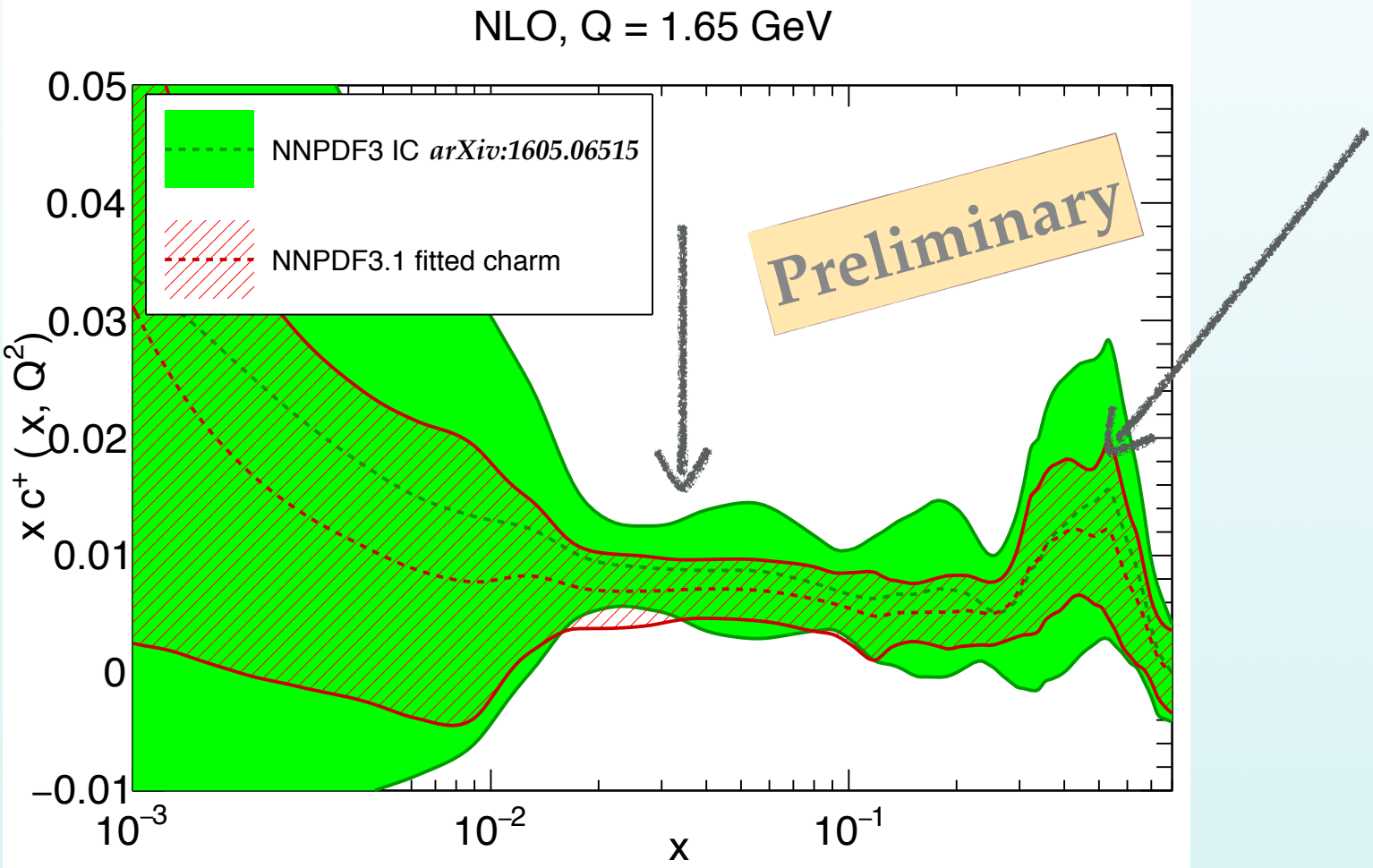




CMS, arXiv:1412.1115

Fitted charm stability

- The additional datasets included in NNPDF3.1, in particular the new Tevatron and LHCb measurements, further **constrain the charm PDF**
- Results are **nicely consistent** with those of the NNPDF3 IC paper, with **reduced PDF uncertainties**
- **Impact of EMC data** is now rather reduced when added on top of the NNPDF3.1 dataset



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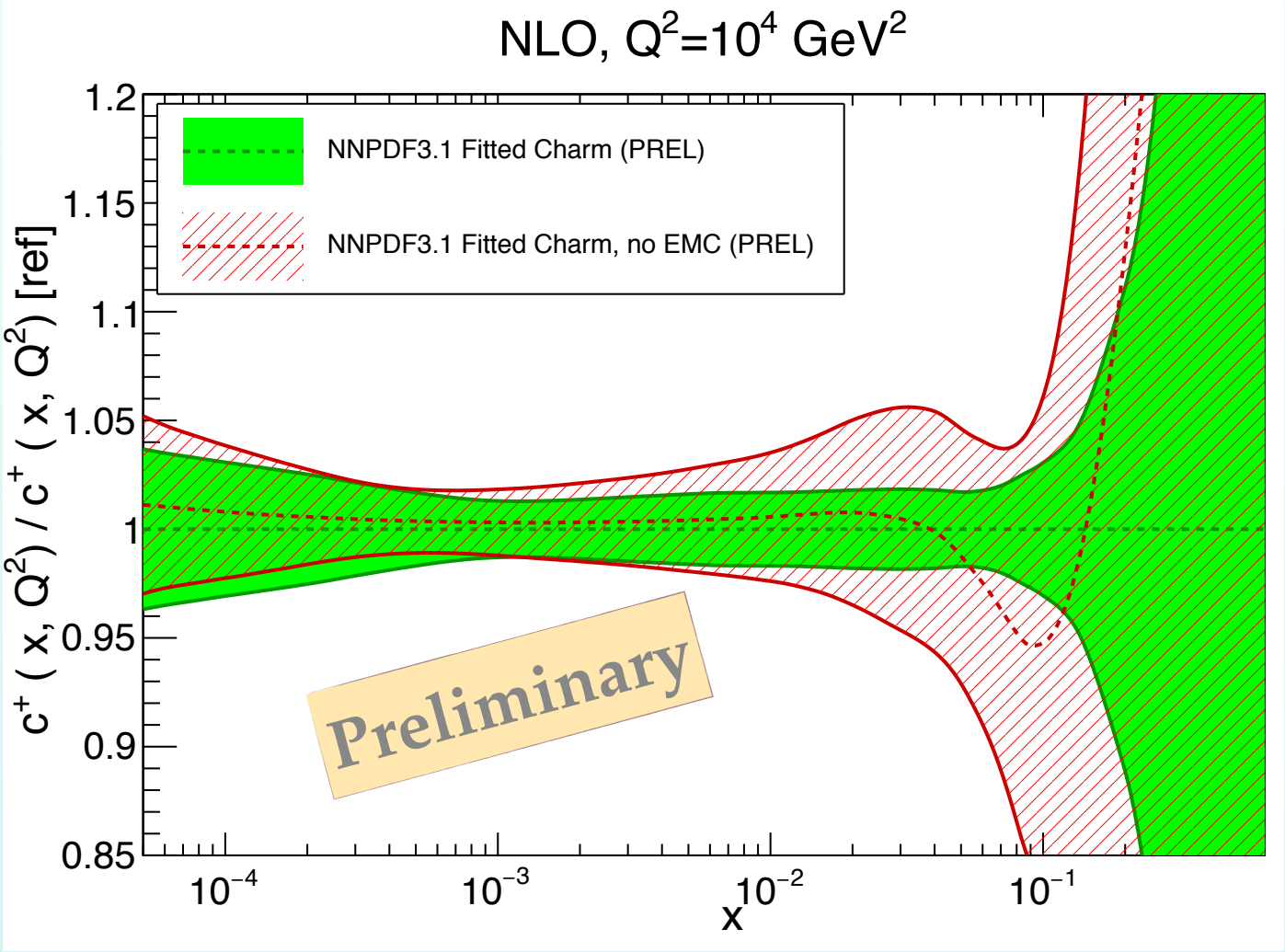
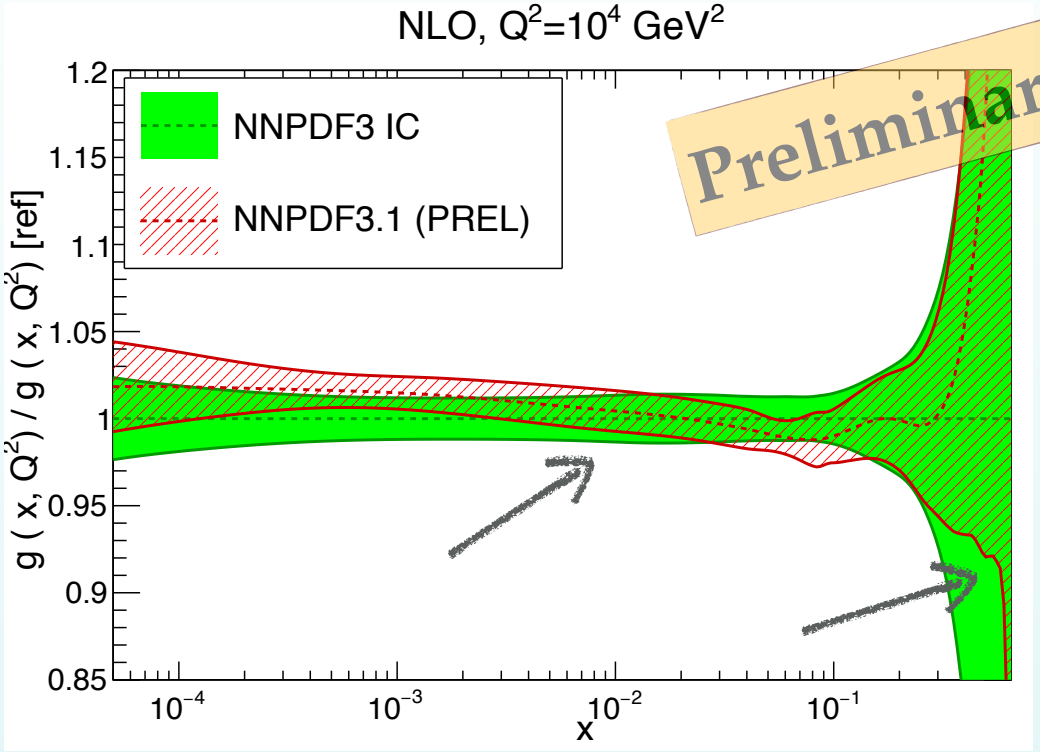
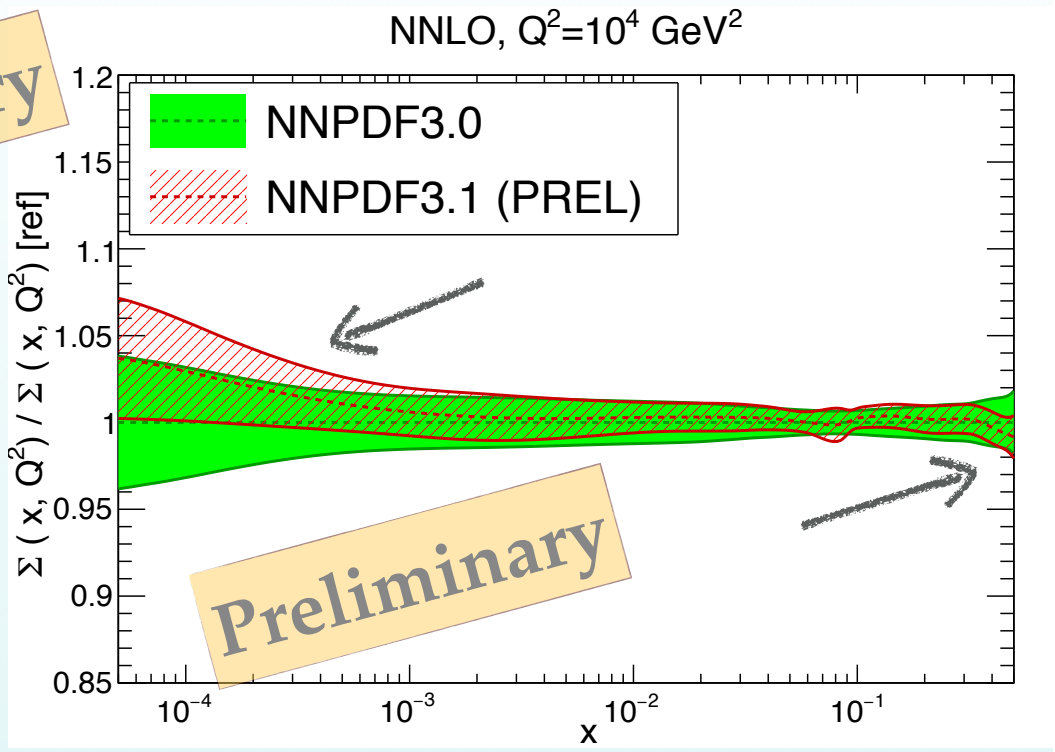


NNPDF3.1 vs NNPDF3.0





- Preliminary results indicate **qualitatively good stability** with respect to NNPDF3.0
- All PDFs exhibit **reduced PDF uncertainties** at large-x region
- Gluon and singlet PDFs reasonably stable
- **Improved light quark flavor separation** from all the new electroweak data from Tevatron and LHC

Summary and outlook

- **Several new datasets included**, from the HERA and Tevatron legacy data to precision LHC electroweak production measurements and top quark production differential distributions

- Preliminary results indicate in general good **stability with respect to NNPDF3.0,** with main differences being a **reduction of the large-x PDF uncertainties** and an **improved flavor separation**, relevant for precision electroweak production data at the LHC

- **Top quark differential distributions** provide stringent constraints on **NNLO large-x gluon**

- From **preliminary fits**, it seems that information on PDFs from the **Z transverse momentum** seems substantial, but more studies still required

- NNPDF3.1 with fitted charm **confirms and strengthens the conclusions of the NNPDF3 IC study** concerning the charm content of the proton

- Release of NNPDF3.1 foreseen before the end of the year!

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Thanks for your attention