RWTH AACHEN UNIVERSITY

NNPDF collaboration

Implications of W charge asymmetry measurements for PDF fits

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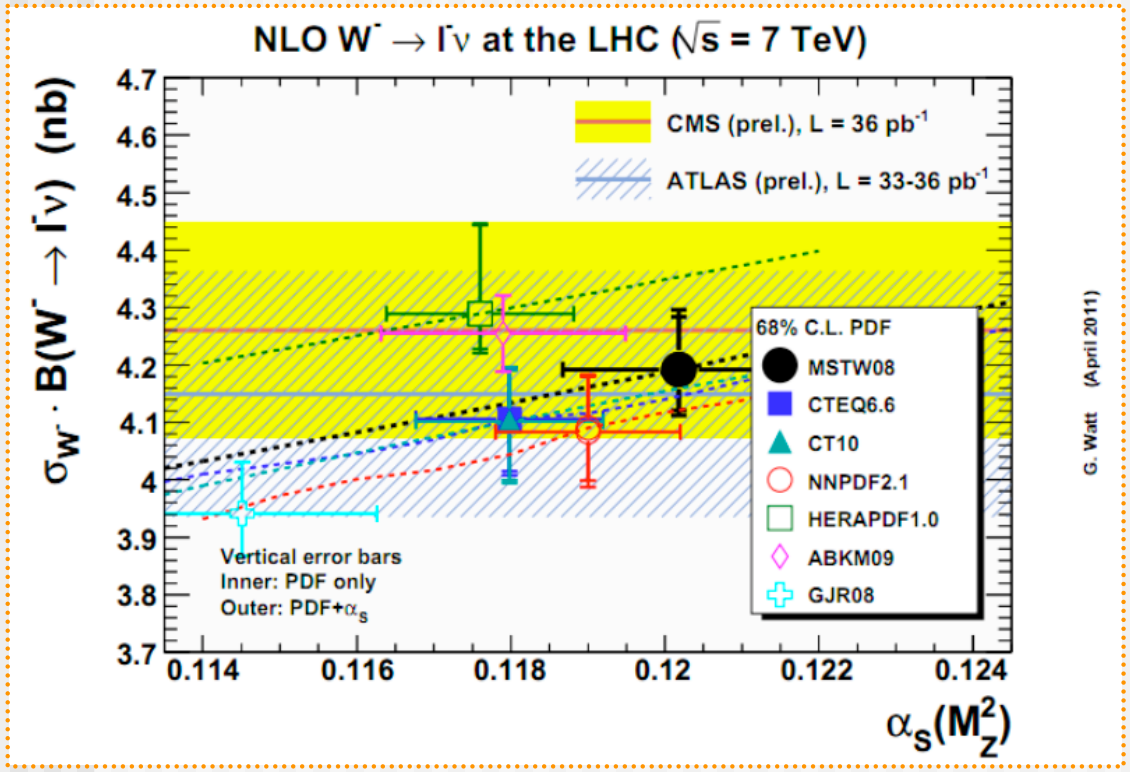
Summary

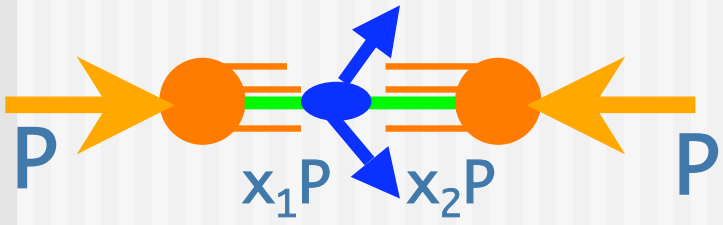
- Introduction
  - Parton Distribution Functions
  - LHC and PDF uncertainties
  - Reweighting techniques
- The W lepton charge asymmetry data
  - Effect of the Tevatron data on parton uncertainties
  - Effect of the LHC data (CMS and ATLAS) on parton uncertainties
  - A few more examples (Z rapidity distribution and W charm)
- Conclusion and outlook

LHC collisions
and PDFs uncertainty



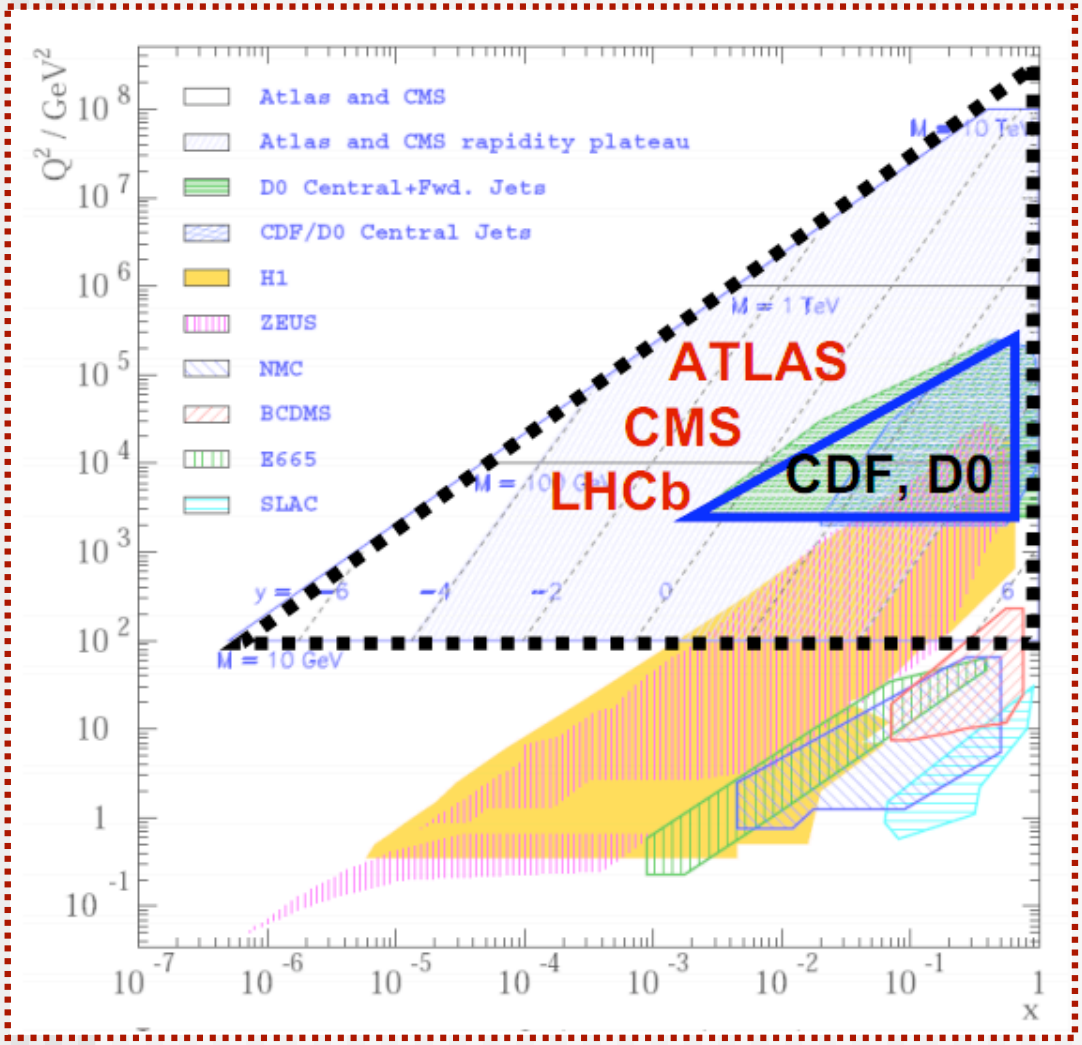
G. Watt, PDF4LHC

For many standard candle processes at the LHC theoretical uncertainty is dominated by PDF uncertainties



A reliable understanding of PDFs and of their associated uncertainties plays a crucial role in relating theory to experimental observation at the LHC.

LHC collisions
and PDFs uncertainty



V. Radescu, DIS2011

For many standard candle processes at the LHC theoretical uncertainty is dominated by PDF uncertainties

Can LHC data help in this direction by providing more info on PDFs and thereby reduce their uncertainties & discriminate between models?

Bayesian reweighting
and PDFs uncertainty

Is it possible to assess immediately the impact of the new LHC data without refitting?

Conventional PDF fits:
× Whenever add new data, need to do full refitting, tune parametrization and statistic treatment.
× Can be done only by PDF fitting collaborations themselves.

Monte Carlo method (NNPDF):
✓ Always uses the same "infinite" parametrization (no tuning to data).
✓ Provides Monte Carlo ensemble in space of PDFs: can add new data simply by updating probability.

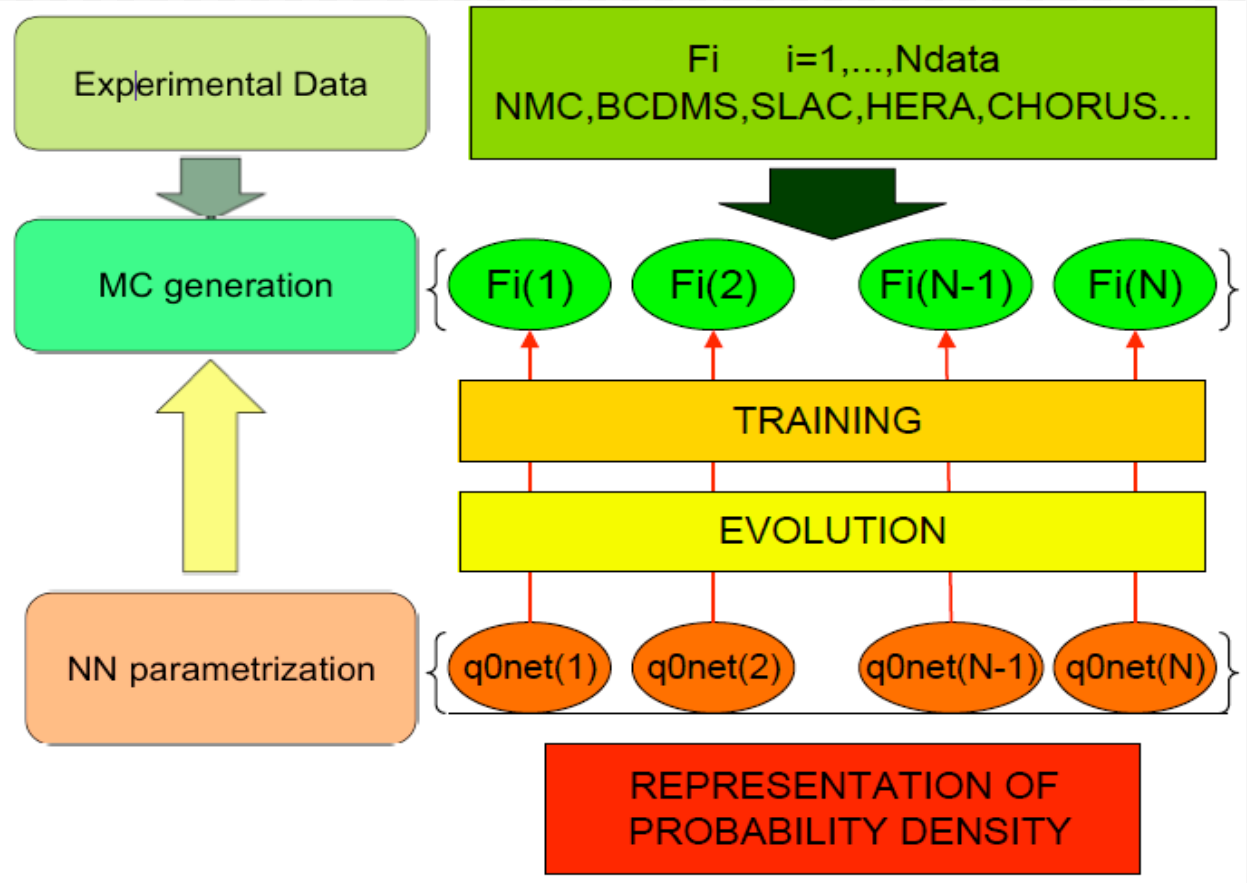
Bayesian Reweighting

Giele, Keller [hep-ph/9803393] ➔ NNPDF collaboration [ArXiv: 1012.0836]
✓ Can determine consistency, effect on PDF precision and shapes, impact on predictions on any other observable without refitting.
✓ Can be done quickly and easily by anybody (no need of PDF fitters): all you need to do is to compute the χ^2 to the new data for each error set.

Bayesian reweighting
The NNPDF2.1 parton set

➔ Probability density in the space of PDFs

$$\langle \mathcal{O} \rangle = \int \mathcal{O}[f]\,\mathcal{P}(f)\,Df = \frac{1}{N}\sum_{k=1}^{N} \mathcal{O}[f^{(k)}]$$



- Generate a Monte Carlo ensemble in space of data and project in space of PDFs
- "Infinite" neural network parametrization for PDFs at the initial scale (300 pars versus typical ~30 pars in polynomial fits)
- Cross-validation method to stop the fit dynamically
- Full NLO and GM-VFNS theory

Bayesian reweighting
The NNPDF2.1 parton set

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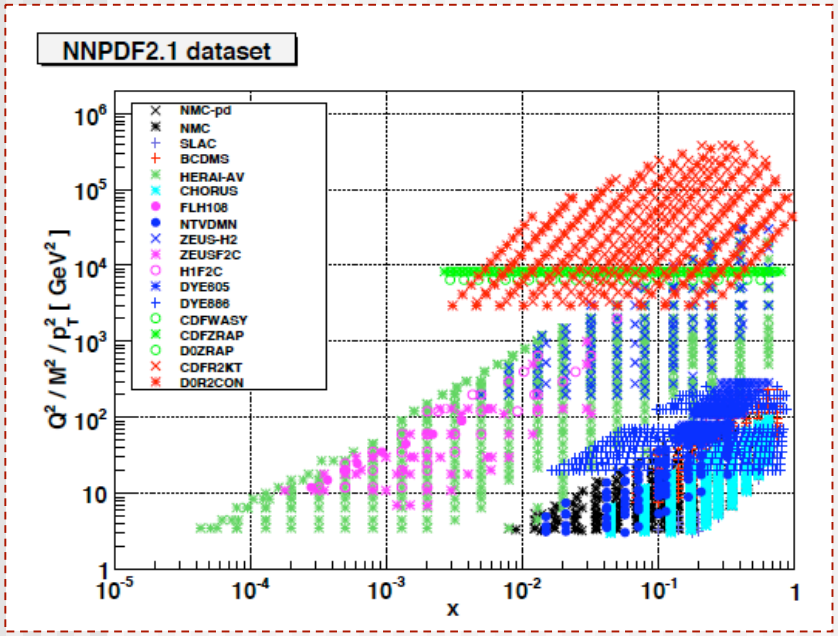
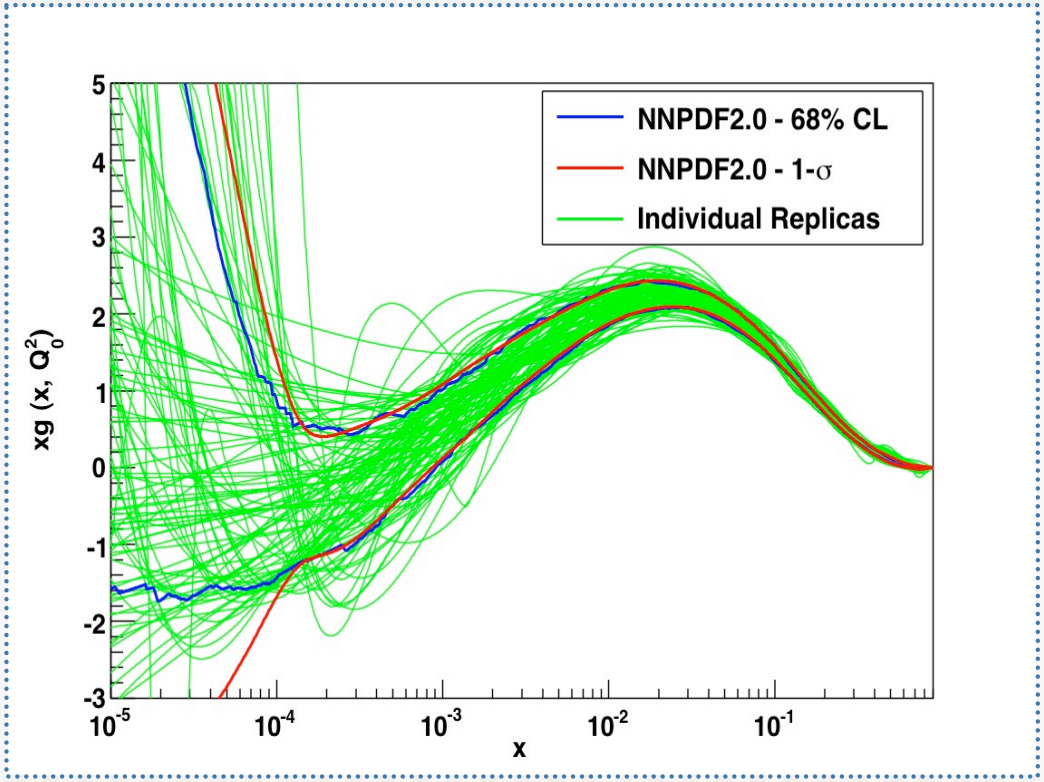




Bayesian reweighting
Update the (NN)PDFs

➔ Probability density in the space of PDFs (uniform sample)

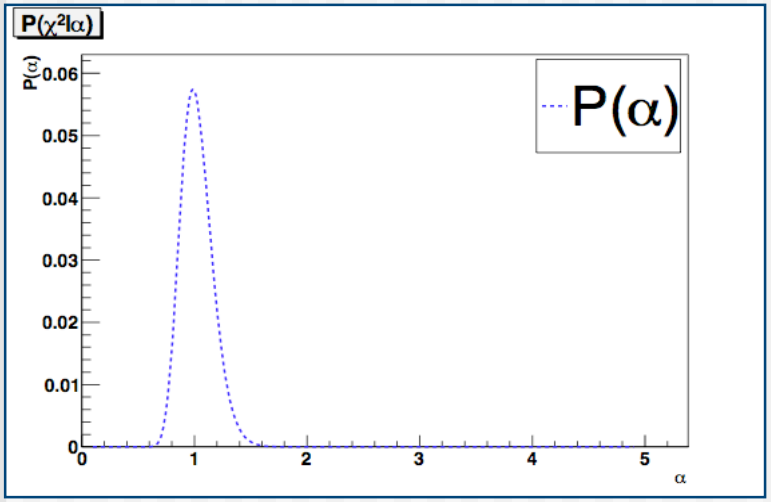
$$\langle \mathcal{O} \rangle = \int \mathcal{O}[f]\,\mathcal{P}(f)\,Df = \frac{1}{N}\sum_{k=1}^{N} \mathcal{O}[f^{(k)}]$$

➔ Probability density of PDFs conditional on both "old" and "new" data (weighted sample)

$$\langle \mathcal{O} \rangle_{\rm new} = \int \mathcal{O}[f]\mathcal{P}_{\rm new}(f)\mathcal{D}f = \frac{1}{N}\sum_{k=1}^{N} w_k \mathcal{O}[f^{(k)}]$$

$$w_k \propto (\chi^2_k)^{\frac{1}{2}(n-1)} e^{-\frac{1}{2}\chi^2_k}$$

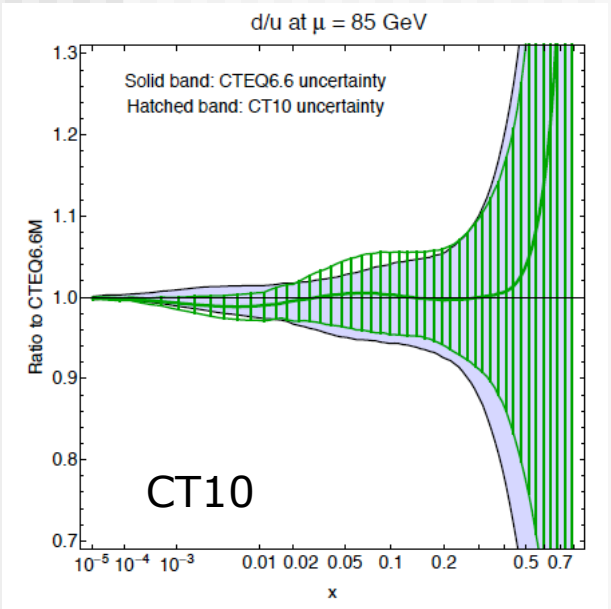
χ^2_k of the k^{th} replica to the NEW data

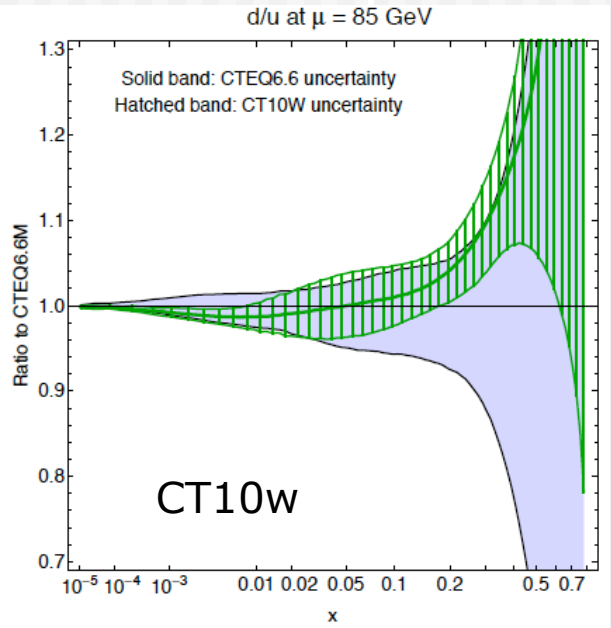


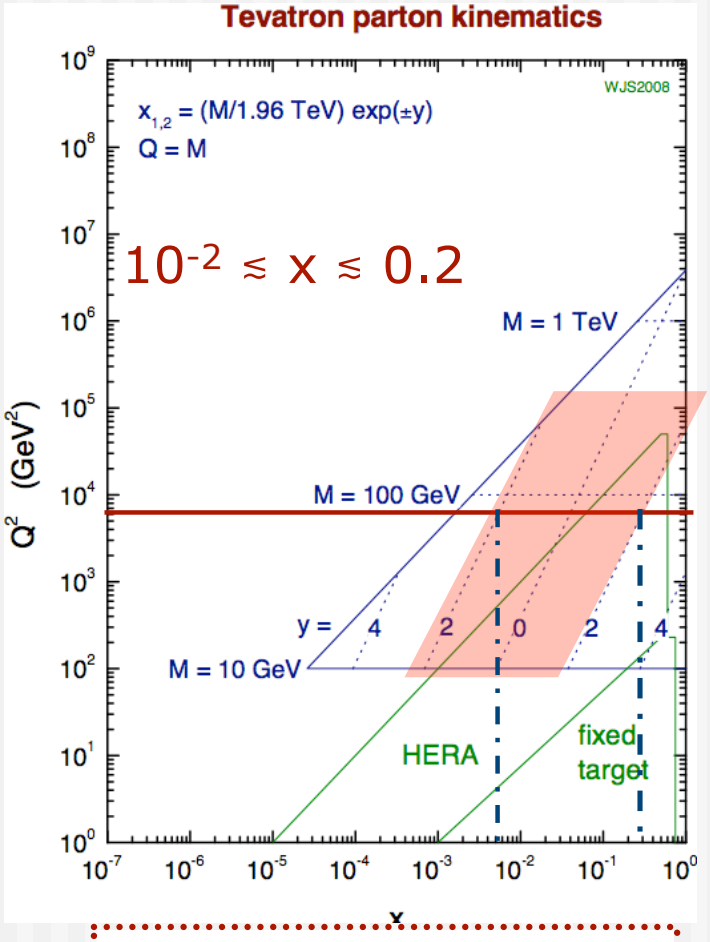
- Compute N_{eff} replicas: if N_{eff} << N new data are constraining or incompatible
- Compute P(α): if centered about 1 data are compatible, if far from one needs tolerance α to fit them along with old data (incompatible)

The W lepton asymmetry
Tevatron Run II

- ✓ CDF W charge asymmetry is fitted in NNPDF2.1 [ArXiv:0901.2169]
- ➔ D0 muon charge asymmetry in single p_T^{μ} bin [ArXiv:0709.4254]
- ➔ D0 electron charge asymmetry combined and separated p_T^{e} bins : [ArXiv: 0807.3367]







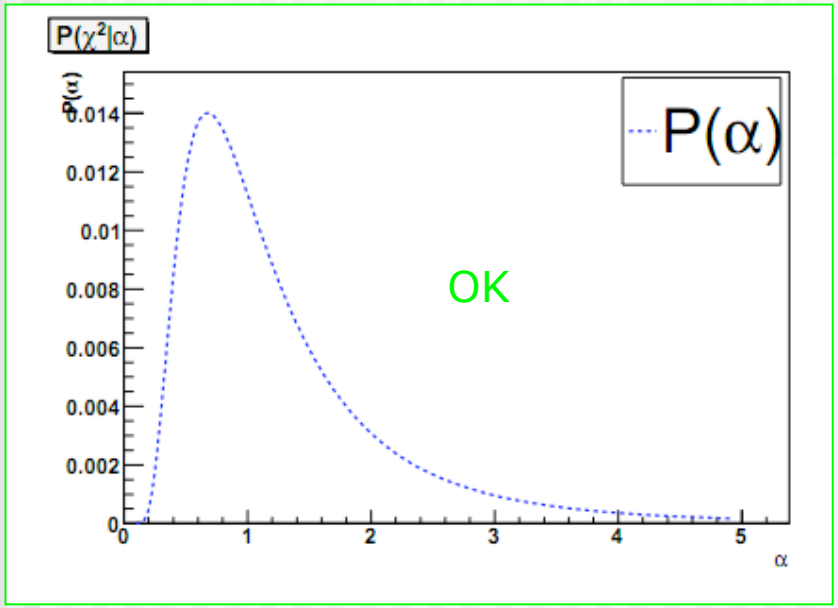
$$\frac{u(x_1)d(x_2) - d(x_1)u(x_2)}{u(x_1)d(x_2) + d(x_1)u(x_2)}$$

The W lepton asymmetry
Tevatron Run II

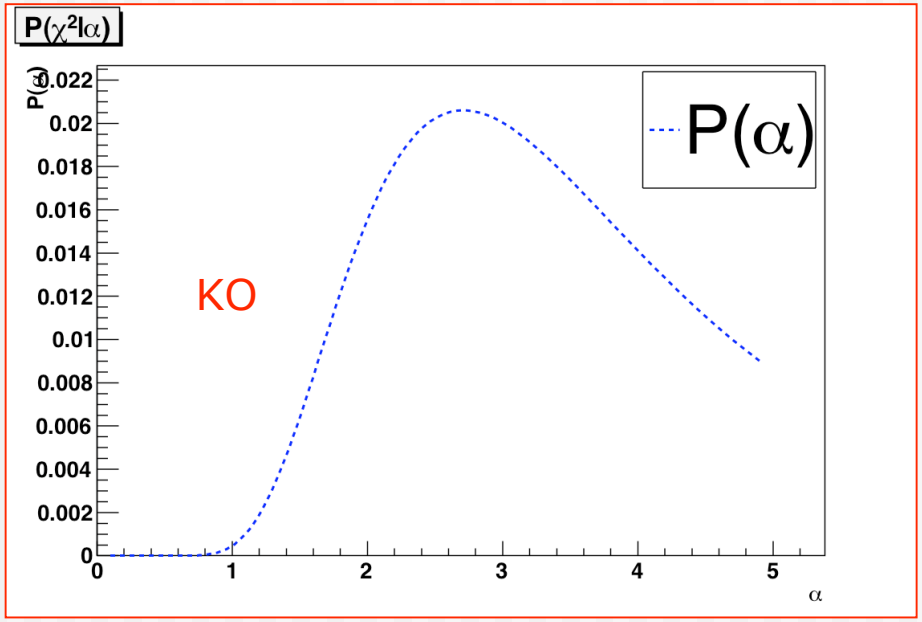
H. Schellman, DIS 2011

Reweighting analysis
[NNPDF, ArXiv:1012.0836]
✓ It is possible to include D0 lepton asymmetry inclusive data in global analyses: no need of producing separate sets
✓ Issues with exclusive bins

□ Need to encourage use of least sensitive observable – either a very inclusive lepton asymmetry or the W asymmetry itself



Inclusive bins in p^T_{muon}



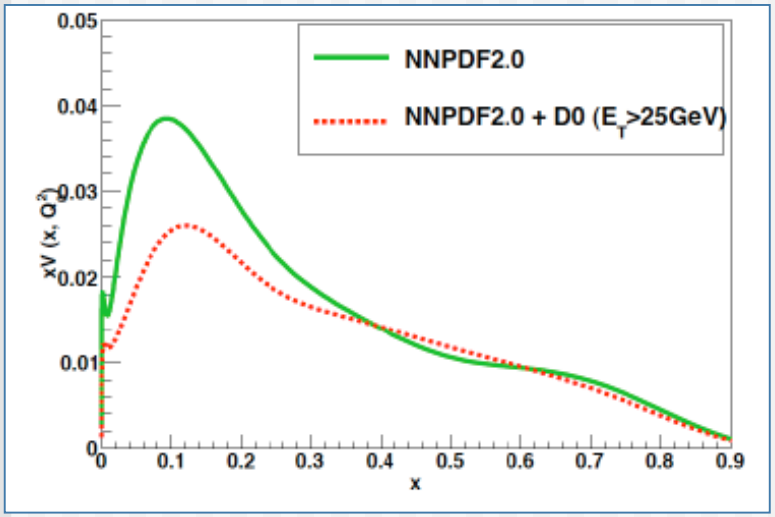
Exclusive bins in p^T_{el}

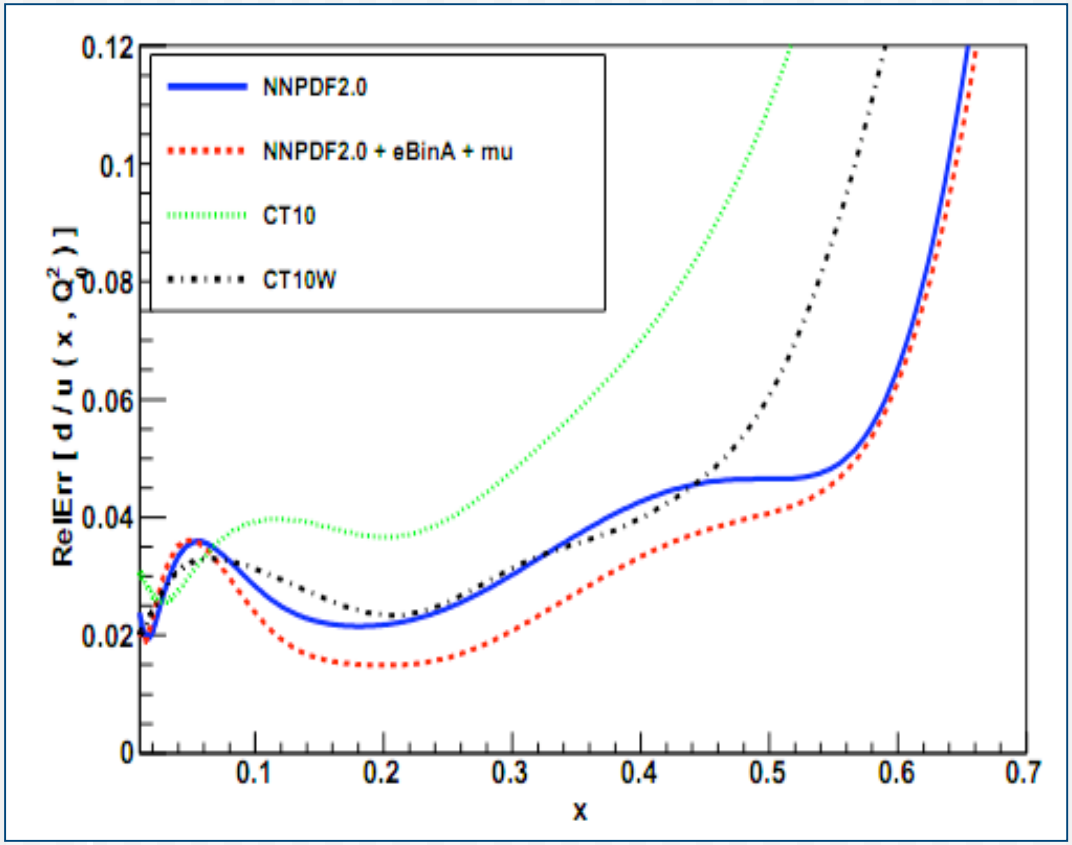
The W lepton asymmetry
Tevatron Run II

Reweighting analysis
[NNPDF, ArXiv:1012.0836]

✓ It is possible to include D0 lepton asymmetry inclusive data in global analyses: no need of producing separate sets

✓ Issues with exclusive bins





Reduction of the valence PDFs uncertainty and on the d/u ratio!

The W lepton asymmetry
LHC @ 7TeV measurements

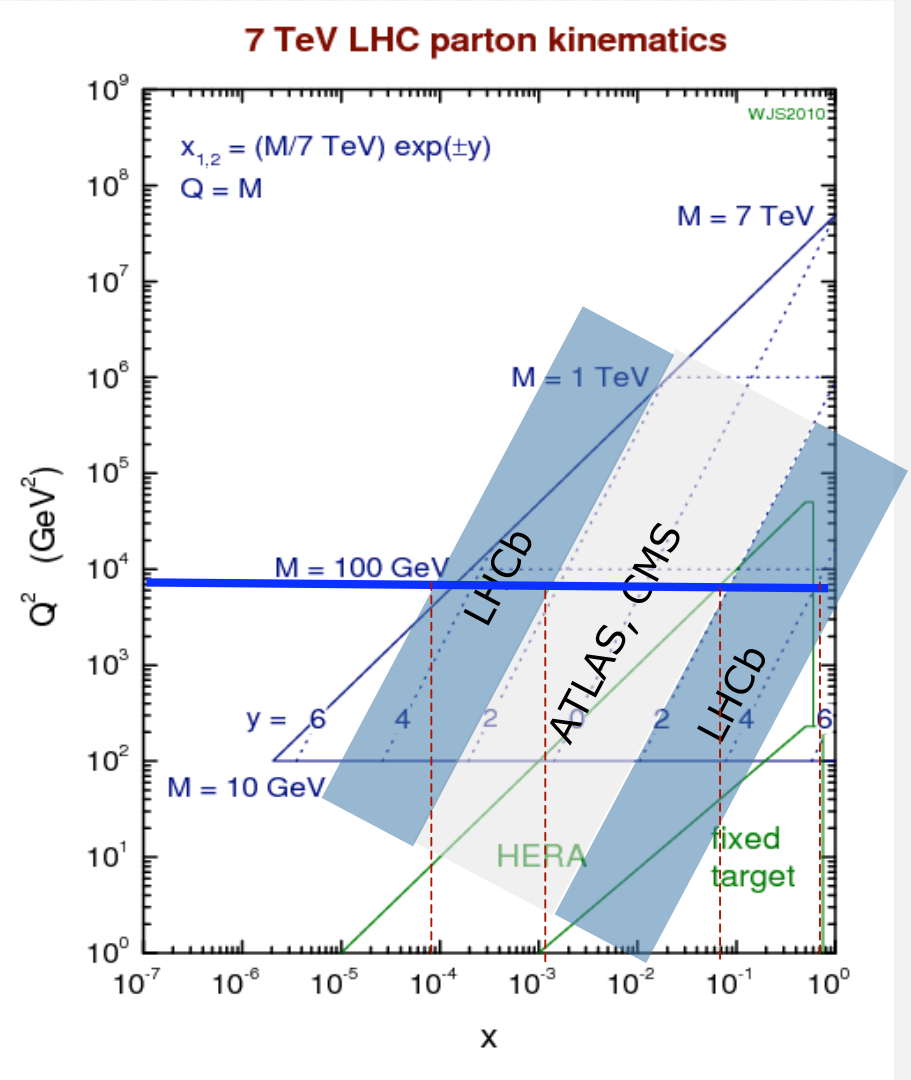
$$A_l = \frac{d\sigma(l^+)/dy(l^+) - d\sigma(l^-)/dy(l^-)}{d\sigma(l^+)/dy(l^+) + d\sigma(l^-)/dy(l^-)}$$

$$\frac{u(x_1)\bar{d}(x_2) - d(x_1)\bar{u}(x_2)}{u(x_1)\bar{d}(x_2) + d(x_1)\bar{u}(x_2)}$$

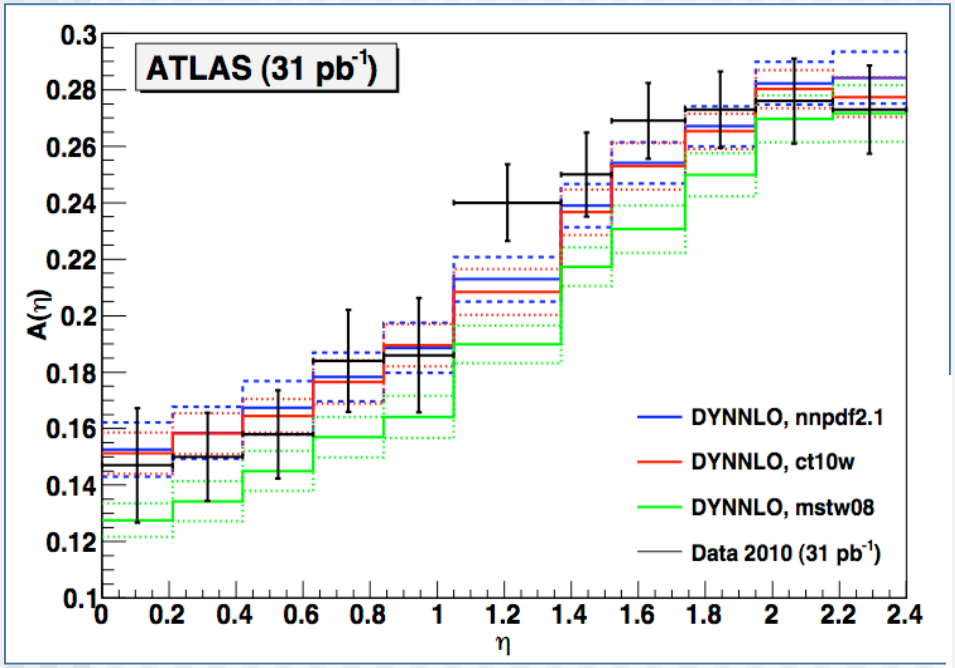
✓ **ATLAS:**
W muon charge asymmetry (31pb^{-1})
ArXiv: 1103.2929

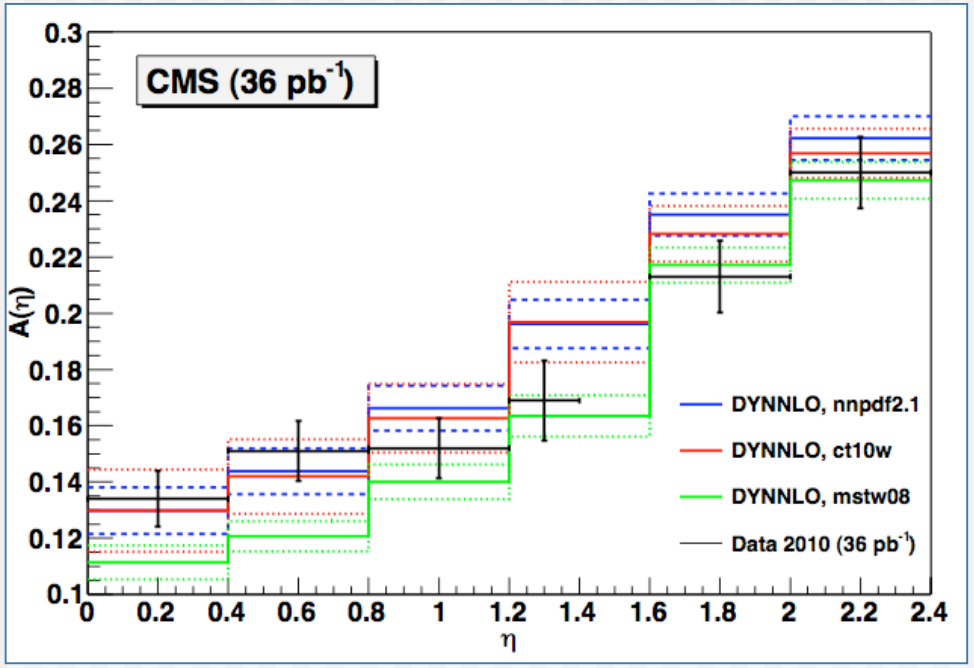
✓ **CMS:**
W muon and electron charge asymmetry (36pb^{-1})
ArXiv: 1103.3470

× **LHCb:**
Preliminary forward W muon charge asymmetry (16.5pb^{-1})
Not corrected for FSR radiation



The W lepton asymmetry
LHC @ 7TeV predictions

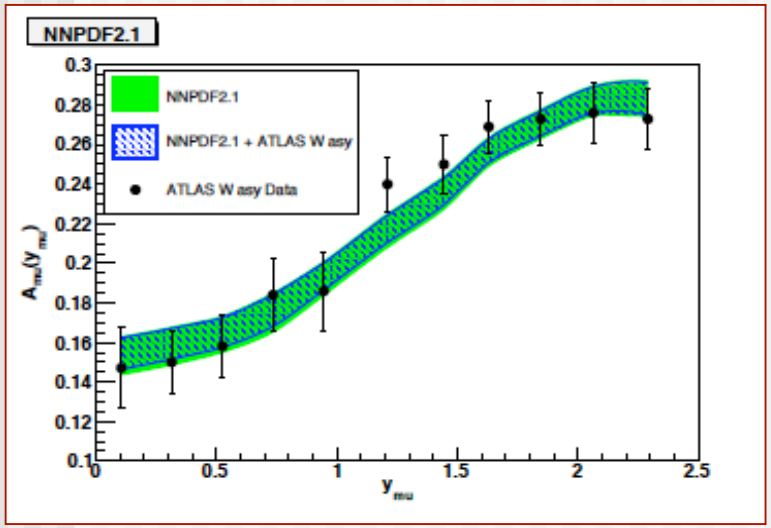


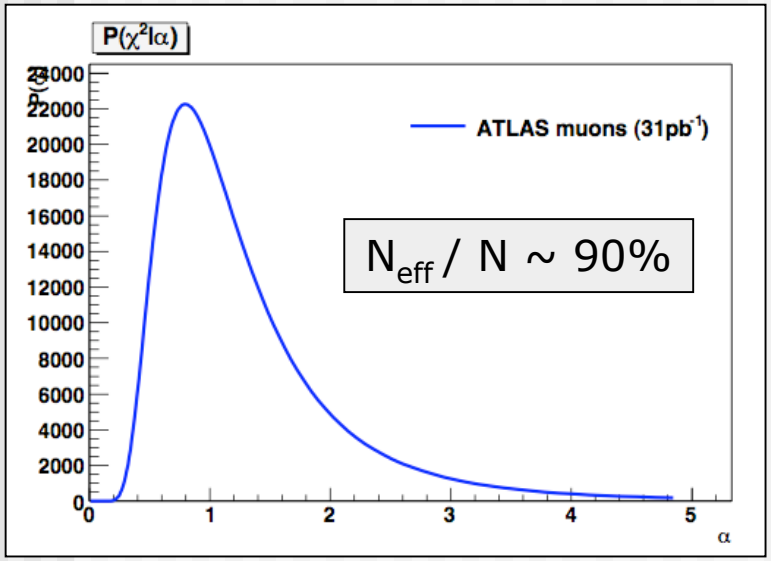


NLO theoretical predictions obtained with DYNNLO
[ArXiv: 0903.2120]

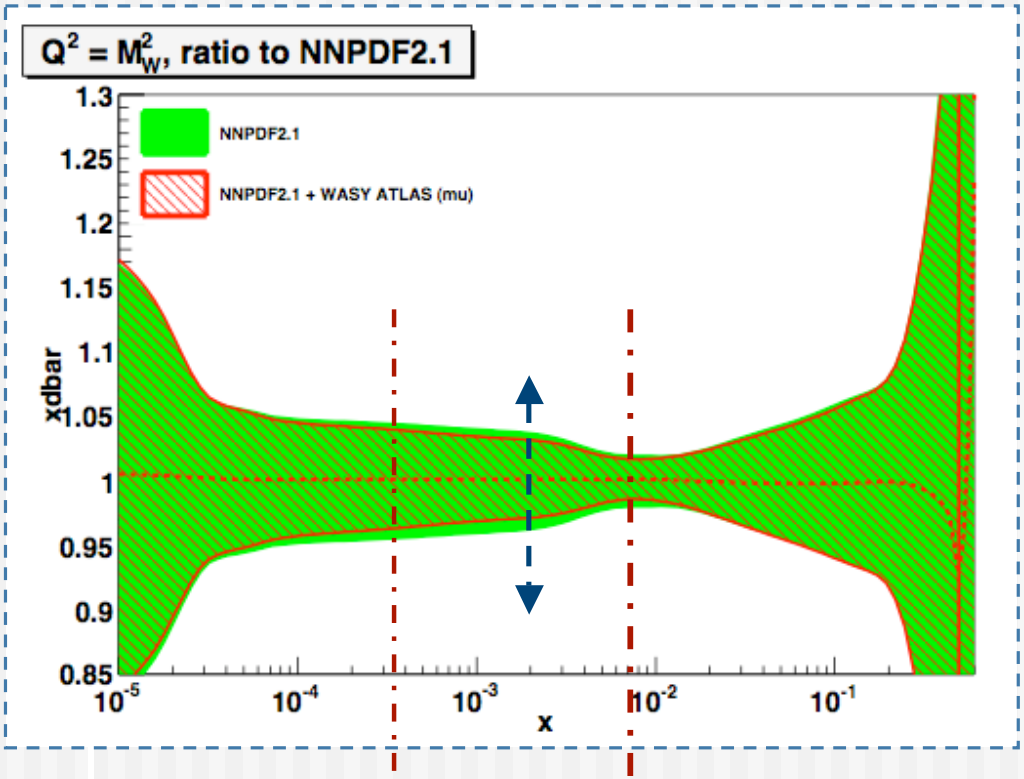
χ^2/d.o.f.	NNPDF2.1	CT10w	MSTW08
ATLAS(31pb^{-1}) muon $p_T > 20$ GeV	0.7	0.8	3.2
CMS(36pb^{-1}) electron $p_T > 25$ GeV	1.9	0.8	2.4
CMS(36pb^{-1}) electron $p_T > 30$ GeV	1.7	1.2	2.5
CMS(36pb^{-1}) muon $p_T > 25$ GeV	1.3	0.5	1.1
CMS(36pb^{-1}) muon $p_T > 30$ GeV	0.8	0.6	1.3

The W lepton asymmetry
LHC @ 7TeV, ATLAS data

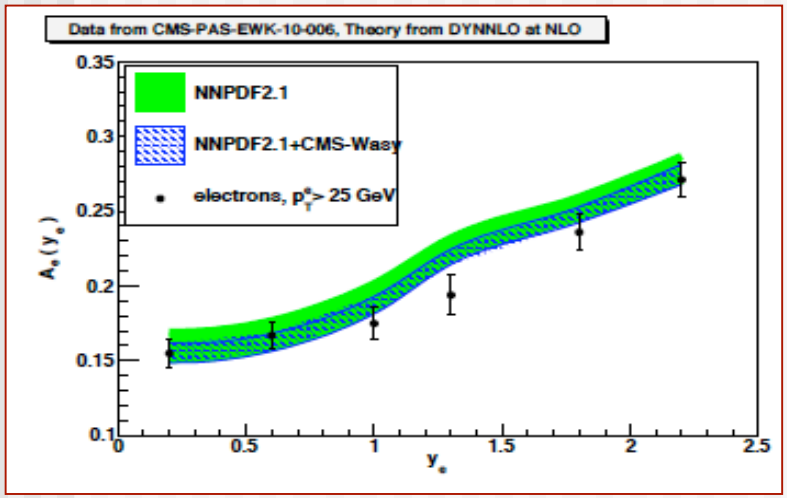


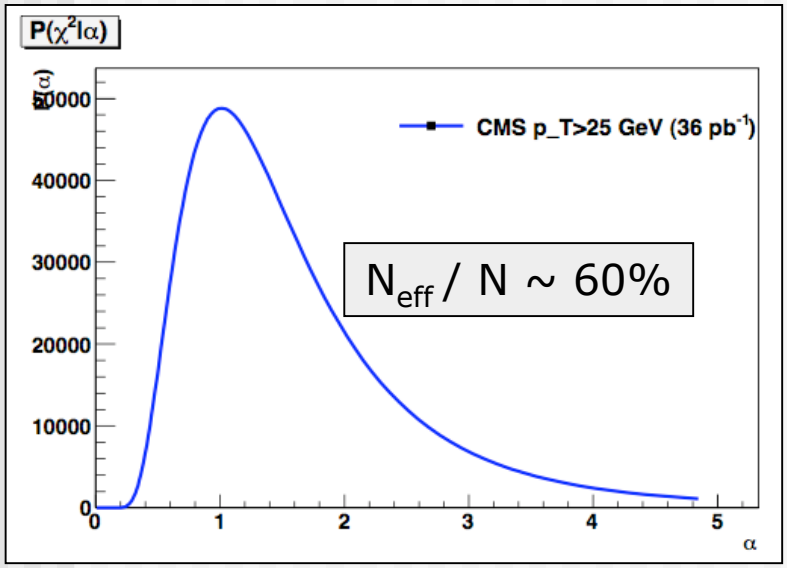


- Data compatible with data included in global PDF analysis
- Slight reduction of uncertainty at medium-small x for light (anti)quark

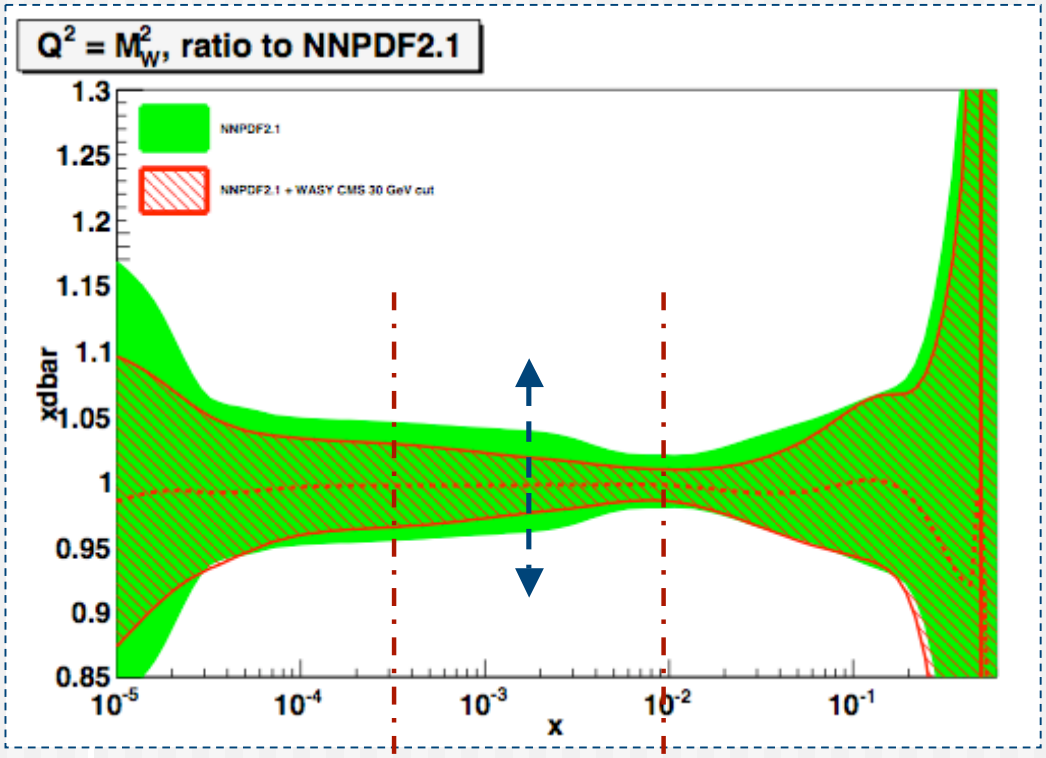


The W lepton asymmetry
LHC @ 7TeV, CMS data



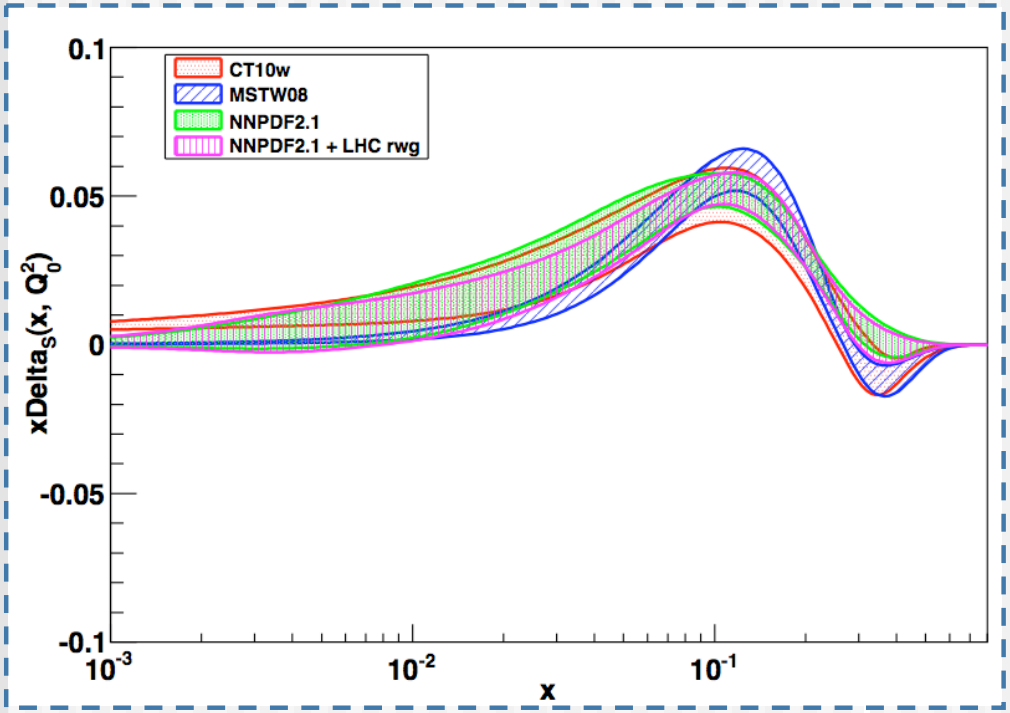


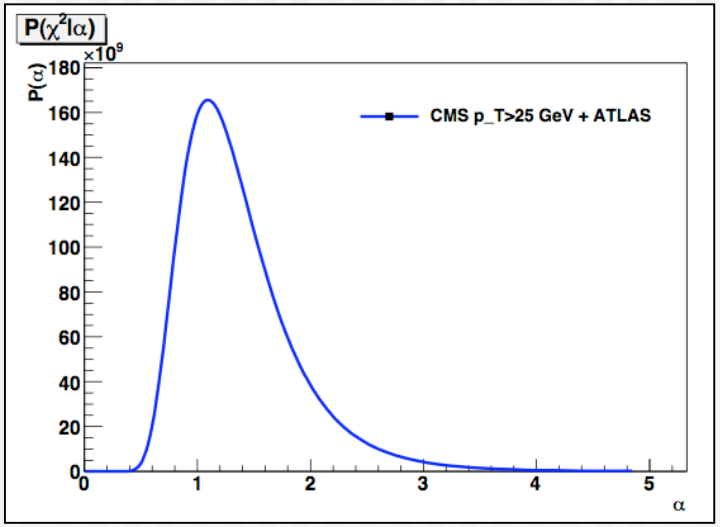
- Data compatible with data included in global PDF analysis
- Significant reduction of uncertainty at medium-small x for light (anti)quark



The W lepton asymmetry
LHC @ 7TeV, ATLAS & CMS data

Data/χ^2	NNPDF2.1	NNPDF2.1 + rwt SET
ATLAS + CMS $p_T^l > 25$ GeV	1.0	0.9
ATLAS + CMS $p_T^l > 30$ GeV	1.2	1.0

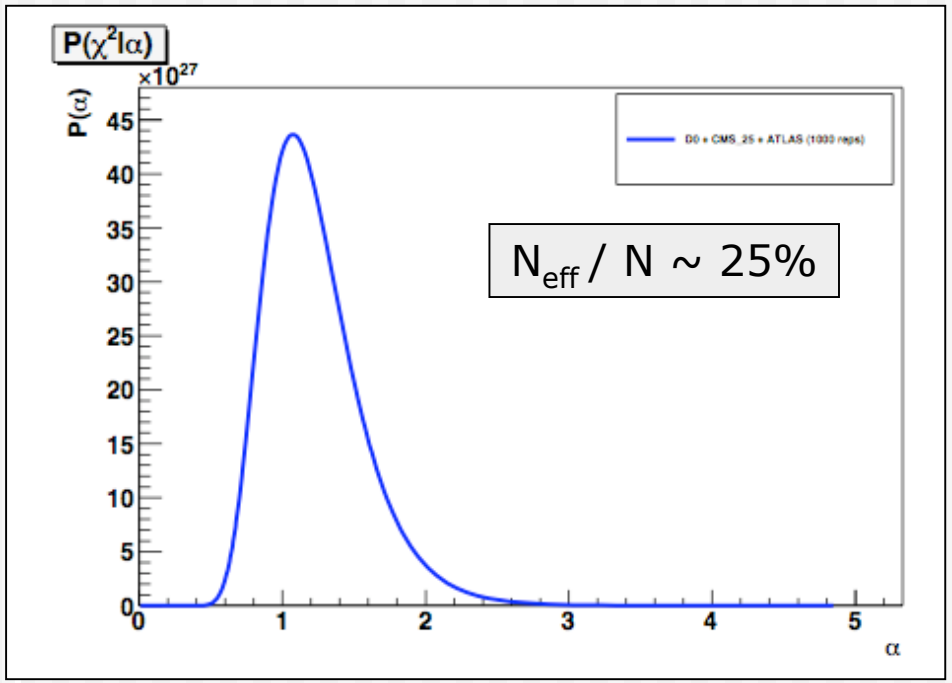




- ATLAS and CMS data can be added at the same time, no clear signs of tension
- CMS data are more constraining than ATLAS data.
- Inclusion of data in PDFs fits reduces uncertainty of more than 40% in the small-medium x region for light (anti)quark PDFs

The W lepton asymmetry
Can we combine Tevatron and LHC data?

	NNPDF2.1	NNPDF2.1 + TeV + LHC
χ^2	2.0	0.7



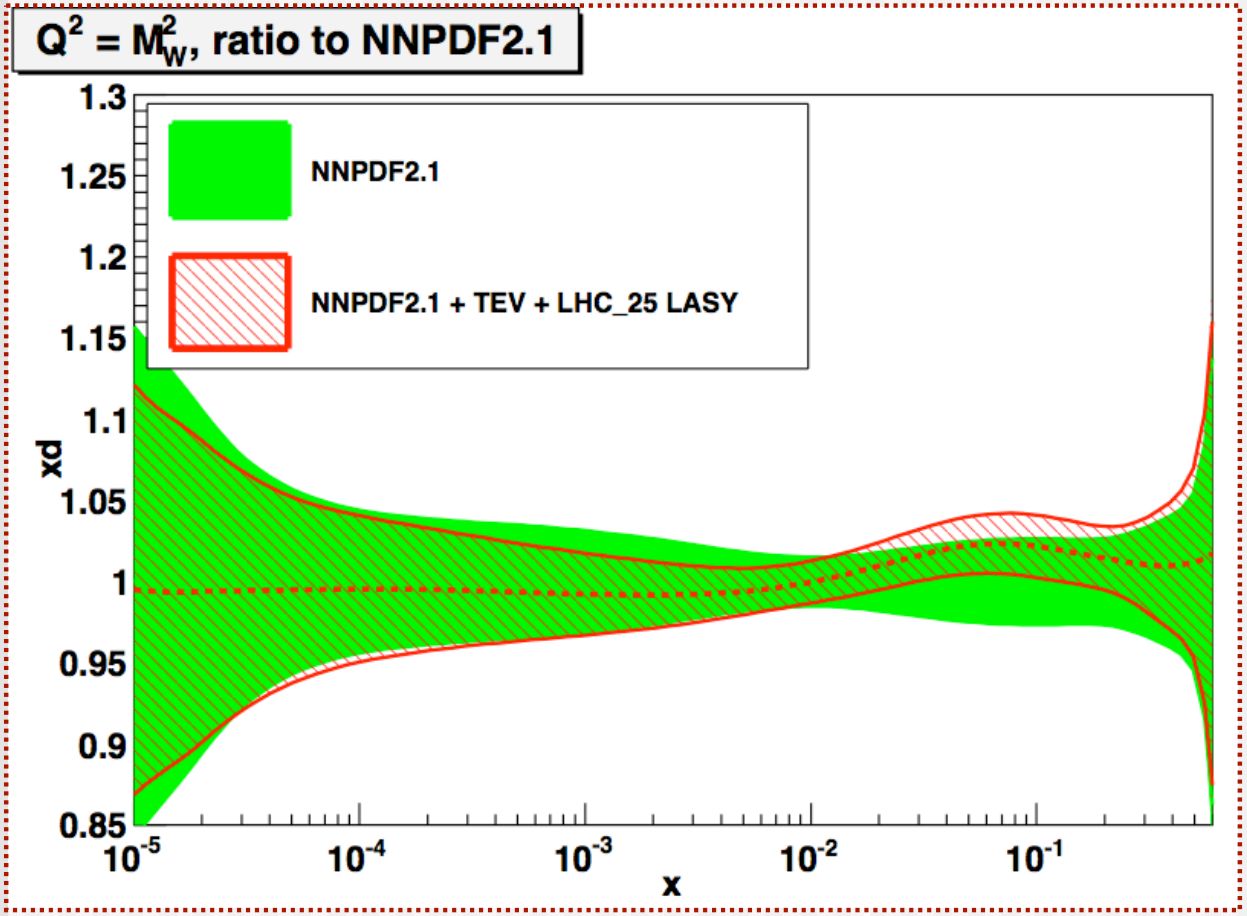
✓ YES data are very constraining on PDFs but compatible with data included in the global analyses

✓ After reweighting the reweighted set fits very well both Tevatron (D0 muon and D0 electron inclusive) and LHC (ATLAS and CMS) W lepton asymmetry data

✓ The description of W asymmetry from CDF does not deteriorate

What about the PDFs central values and PDFs uncertainty?

The W lepton asymmetry
Can we combine Tevatron and LHC data?



✓ Reduction of uncertainty of light quark and anti-quark PDFs in small-medium x region is driven by LHC data.

✓ Shift and reduction of uncertainty in light quark PDFs driven by D0 Tevatron data.

NNPDF2.2 parton set including these data is going to be available soon on LHAPDF

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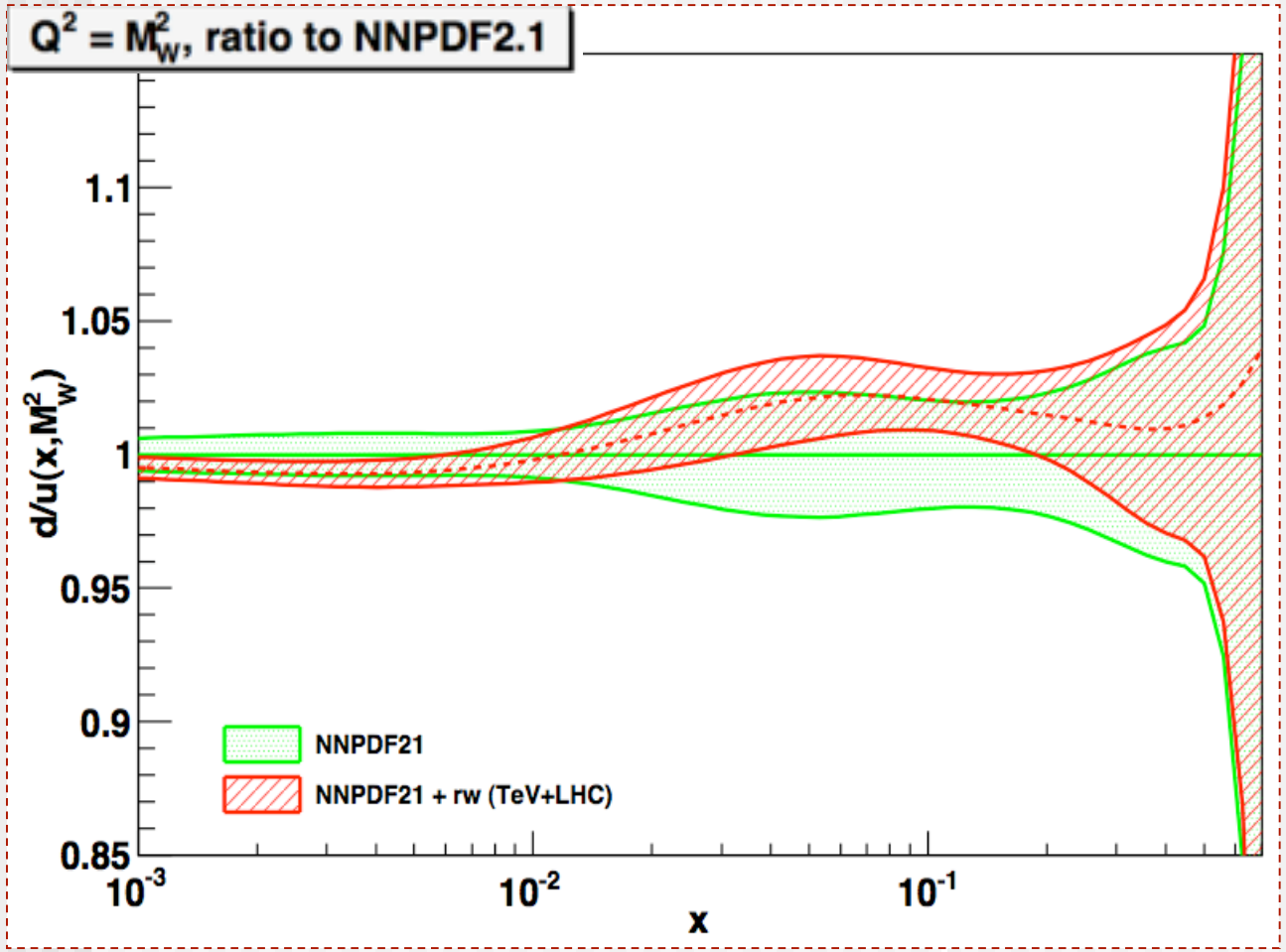
Can we combine Tevatron and LHC data?



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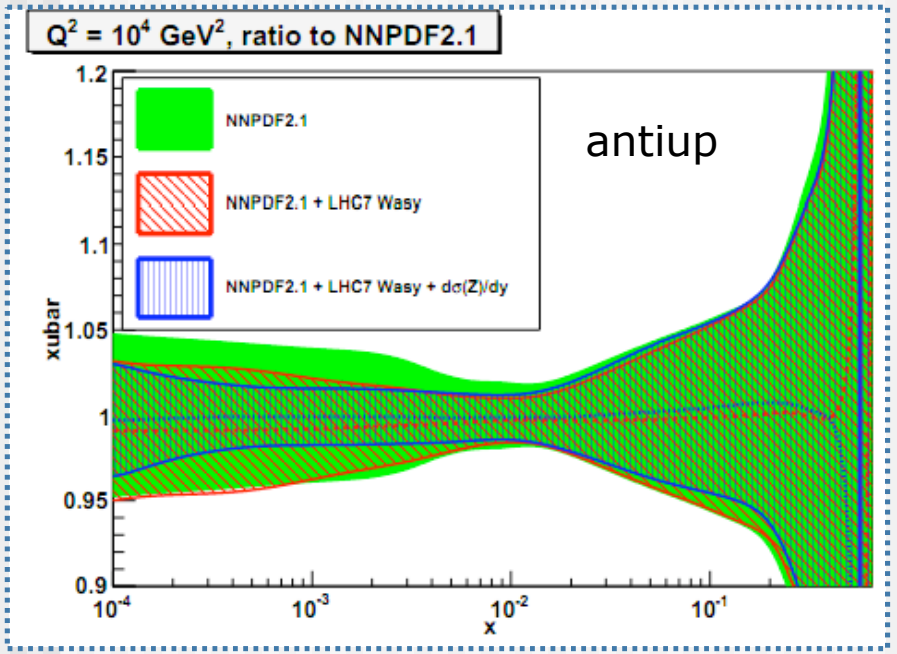
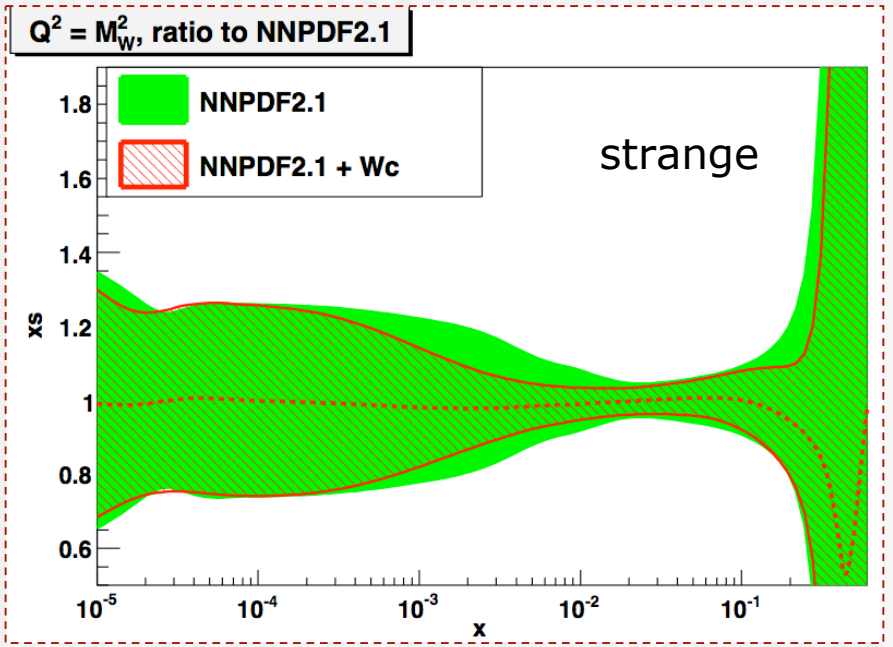
Future measurements
LHC pseudo-data analysis

- Generate pseudo-data fluctuating about predictions produced with NNPDF2.1 within a given % (statistical) uncertainty
- Check the effect of future measurements on PDF shapes



W asymmetry + Z rapidity distribution with 2% uncertainty



W-charm production, charm pseudo-rapidity distribution with 10% uncertainty

Conclusions and Outlook

✓ LHC data (and Tevatron) provide important constraint PDFs
- 40% in the small/medium-x region from ATLAS and CMS
- 20% in the medium-x region from D0
- NNPDF2.2 will include these info - available soon on LHAPDF!

✓ As statistics increases uncertainty can be further reduced and precise LHC data can discriminate among different PDF models

✓ Is NNPDF2.1 HERA + Tevatron + LHC (without fixed-target data) the future?
- Medium and large x gluon:
  - Prompt photon ✔
  - Precision jets data ✔
- Light flavors at medium and small x
  - Low-mass Drell-Yan ✔
  - Z rapidity distributions ✔
  - W asymmetries ✔ and polarized W ✔
- Strangeness and heavy flavors
  - Wc for strangeness ✔
  - Zc and γc for charm ✔
  - Zb for bottom ✔

Conclusions and Outlook

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- Strangeness and heavy flavors
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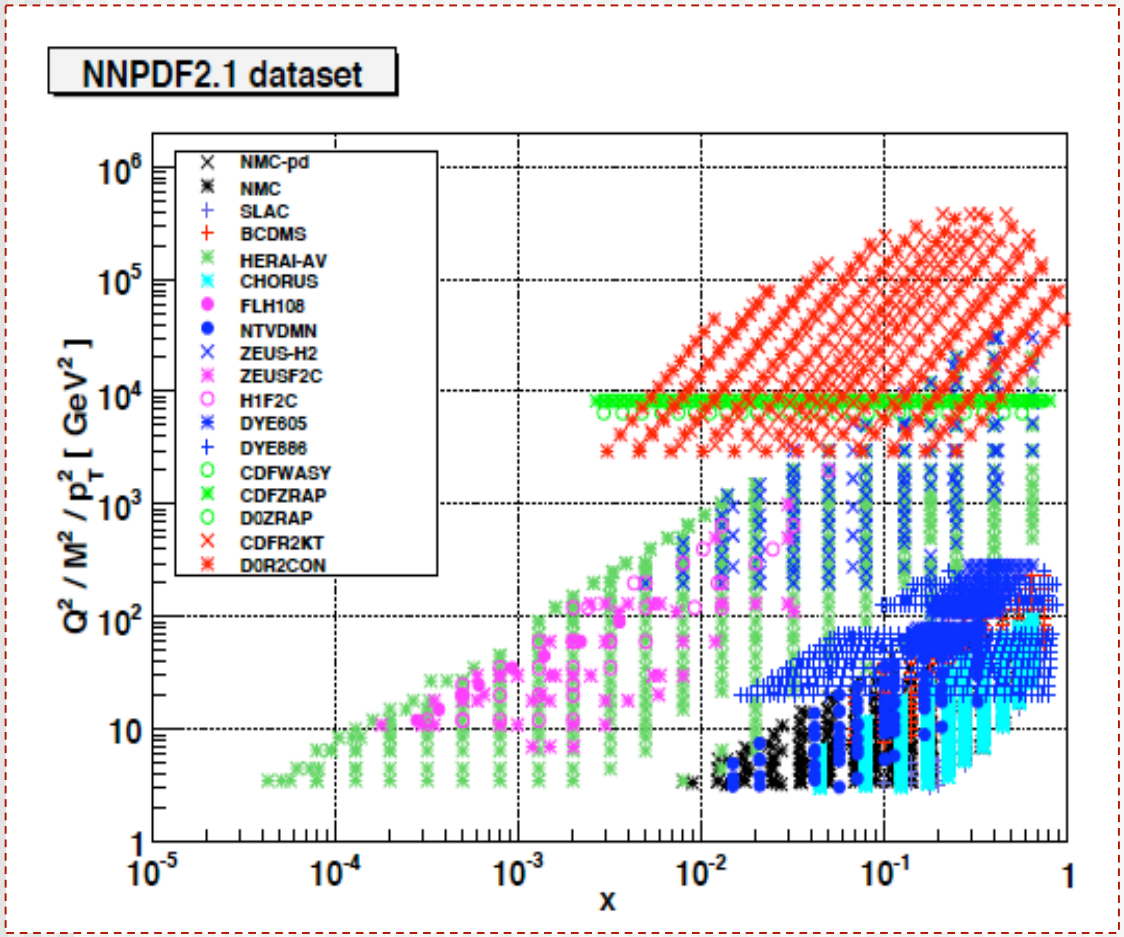
  - Zb for bottom ✔

THANKS FOR YOUR ATTENTION !!

BACKUP

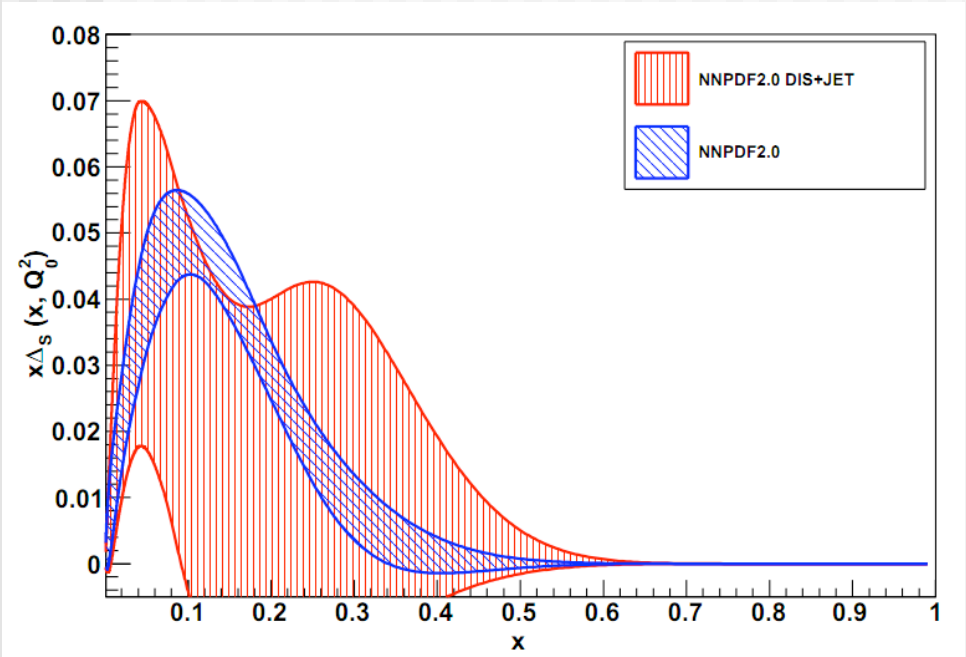
LHC collisions
and PDFs uncertainty

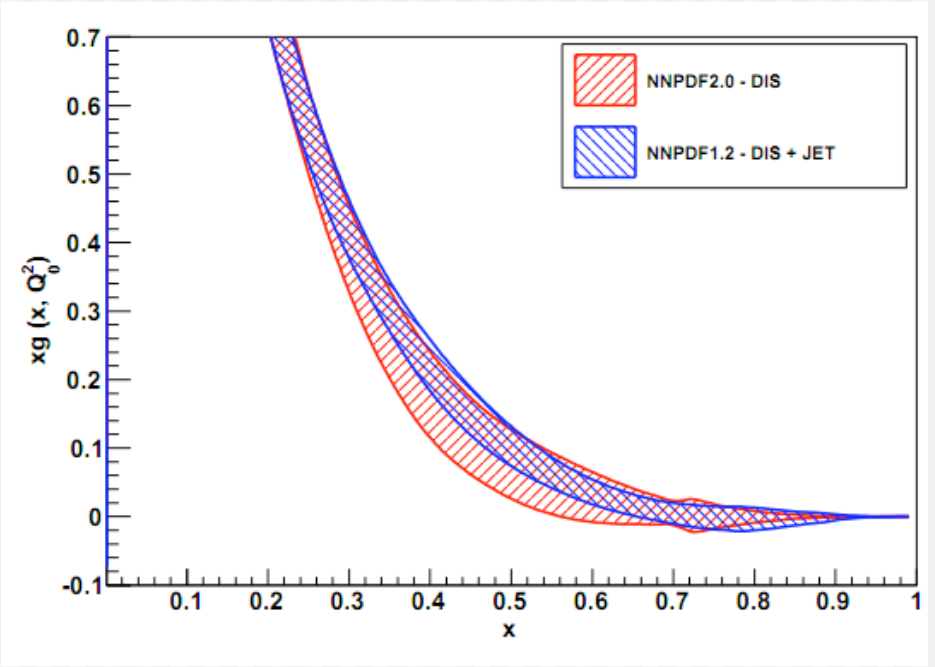


What data do constrain PDFs?

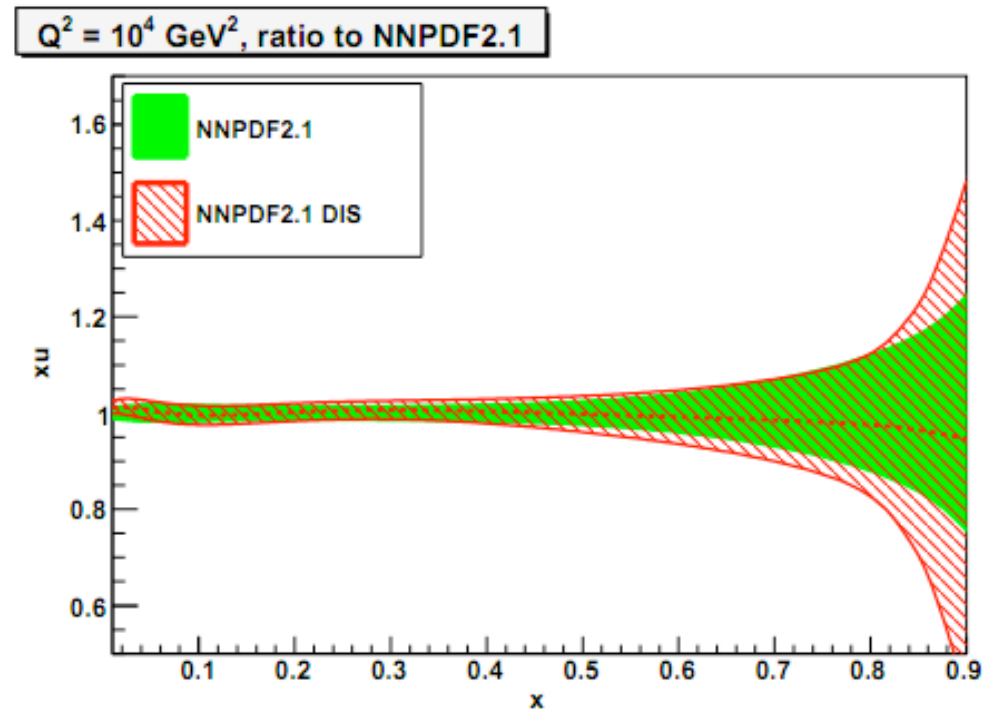
- DIS neutral and charged current data (singlet-triplet separation) + F_2^c,F_2^b
- Neutrino data, inclusive and charm tagged (strange and anti-strange)
- Drell-Yan data from fixed target (anti-up, anti-down separation)
- Vector boson production and asymmetries from Tevatron (up-down flavor asymmetries)
- Inclusive jet data (gluon)

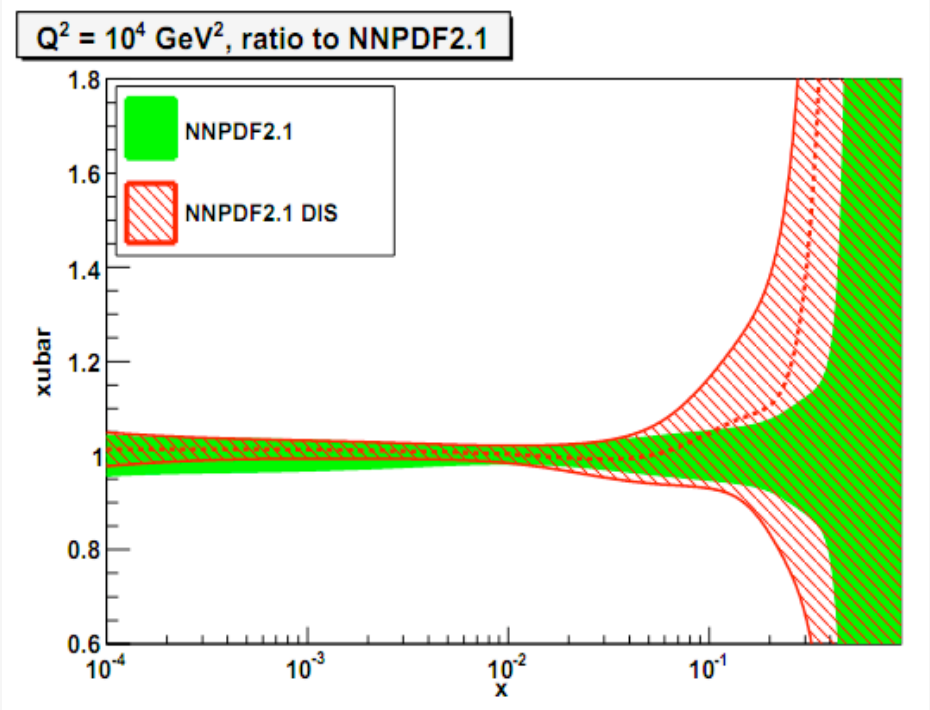
Backup


NNPDF2.0 DIS+JET
NNPDF2.0
$x\Delta_s(x, Q_0^2)$
x

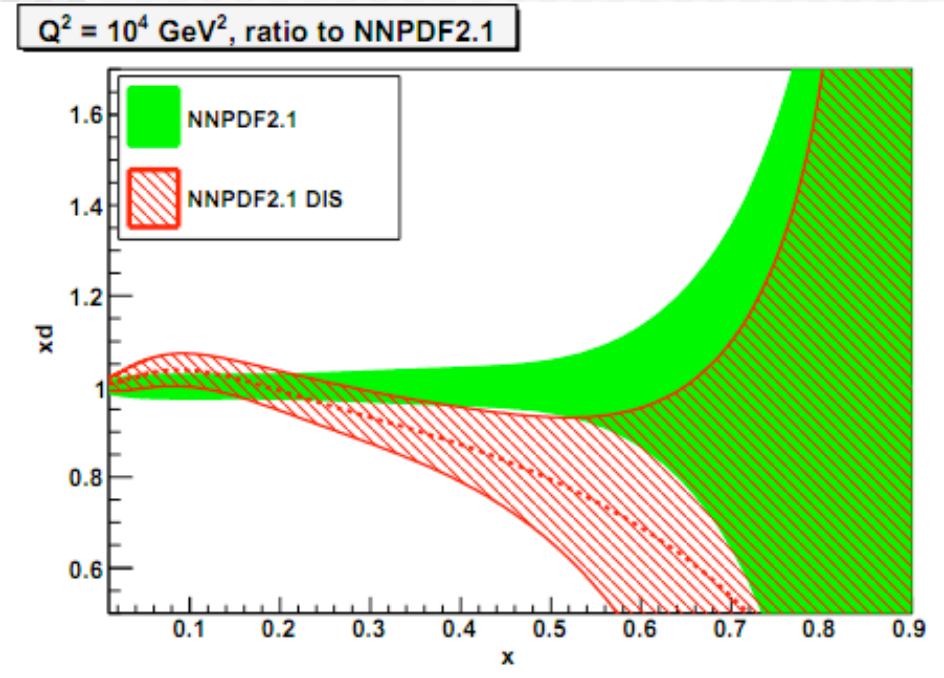

NNPDF2.0 - DIS
NNPDF1.2 - DIS + JET
$xg(x, Q_0^2)$
x

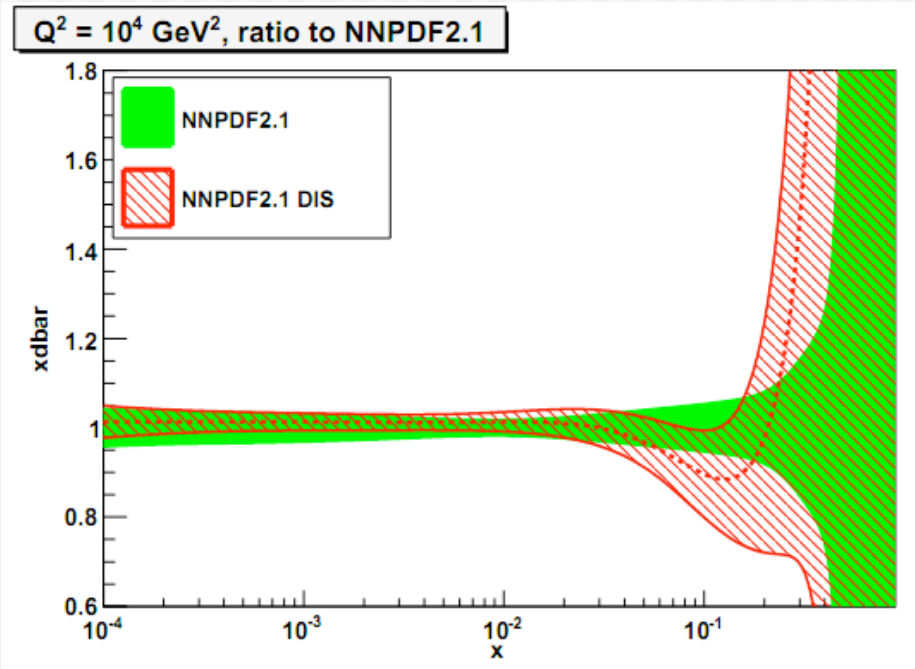
Backup


$Q^2 = 10^4$ GeV^2, ratio to NNPDF2.1
NNPDF2.1
NNPDF2.1 DIS
xu
x
1.6
1.4
1.2
1
0.8
0.6
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

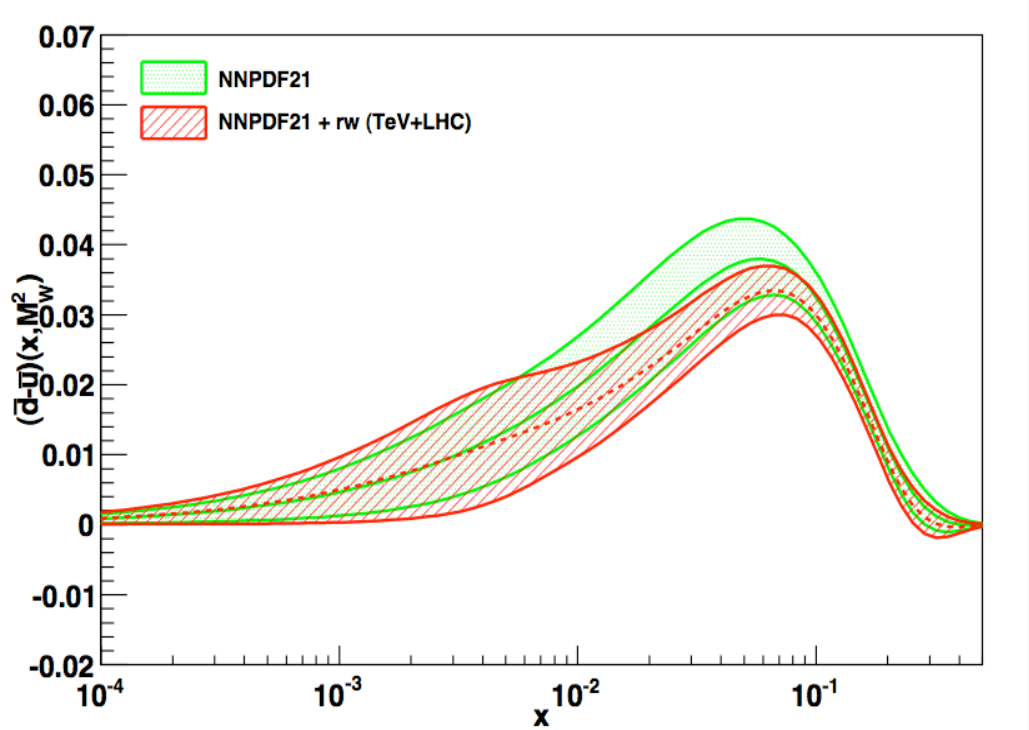

$Q^2 = 10^4$ GeV^2, ratio to NNPDF2.1
NNPDF2.1
NNPDF2.1 DIS
xubar
x
1.8
1.6
1.4
1.2
1
0.8
0.6
10^{-4}
10^{-3}
10^{-2}
10^{-1}

Backup


$Q^2 = 10^4$ GeV^2, ratio to NNPDF2.1
NNPDF2.1
NNPDF2.1 DIS
xd
x
1.6
1.4
1.2
1
0.8
0.6
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


$Q^2 = 10^4$ GeV^2, ratio to NNPDF2.1
NNPDF2.1
NNPDF2.1 DIS
xdbar
x
1.8
1.6
1.4
1.2
1
0.8
0.6
10^{-4}
10^{-3}
10^{-2}
10^{-1}

Backup


NNPDF21
NNPDF21 + rw (TeV+LHC)
$(\bar{d}-\bar{u})(x,M_W^2)$
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
10^{-4}
10^{-3}
10^{-2}
10^{-1}
x