The *W* lepton asymmetry and PDFs: From the Tevatron to the LHC

Juan Rojo

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DIS 2011 workshop, Newport News, VA, 12/04/2011

Outline

In this talk (Joint SF+EWK session):

- The Tevatron lepton asymmetry data and PDFs
- PDFs with LHC data: the impact of CMS and ATLAS lepton asymmetry measurement

In the morning talk:

- Towards NNLO NNPDFs and NNLO Higgs production
- The impact of NMC data in Higgs production
- Precision NLO determination of $\alpha_S\left(M_Z^2\right)$ from NNPDF2.1

In tomorrow's talk (Joint SF+HQ session):

- The impact of heavy quark mass effects on PDFs
- Implications for LHC phenomenology

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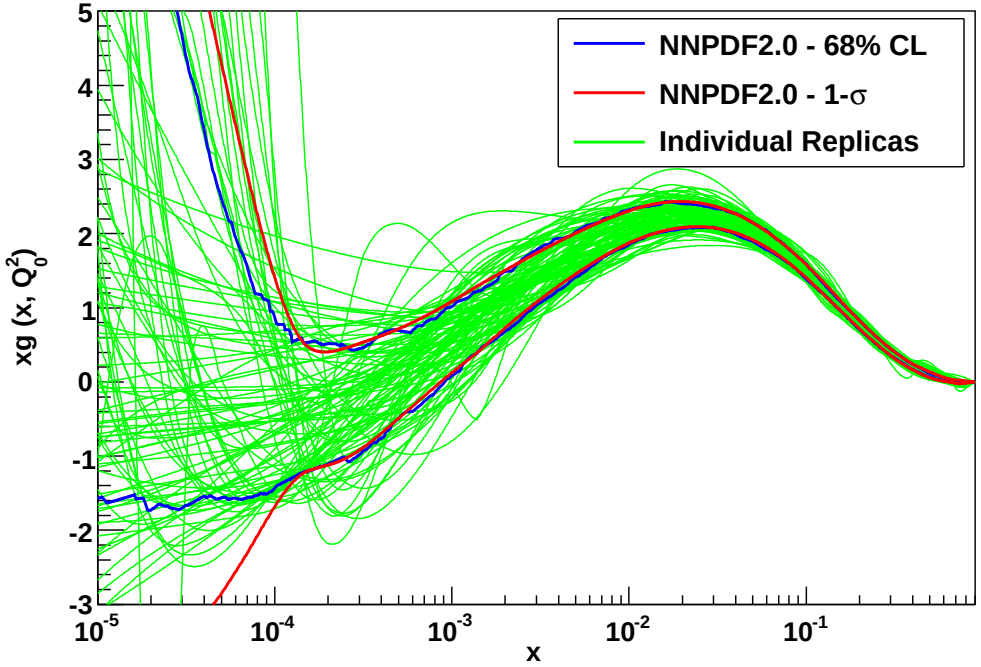
BAYESIAN PDF REWEIGHTING

arXiv:1012.0836, NPB in press

PDF Reweighting

- For a PDF set based on the Monte Carlo method, the PDF probability distribution is provided by a set of N **replicas**
  Compute any general observable of the PDFs $\mathcal{O}[f]$ by importance sampling

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



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- Update the initial probability with addition of new data using **Bayesian Inference**

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

$$w_k \propto \left(\chi_k^2\right)^{n/2-1} e^{-\chi_k^2/2}$$

Advantages of PDF reweighting:

- Very fast method, fully equivalento to refitting
- Only input $\rightarrow \chi_k^2$ for each of the Monte Carlo replicas
- Determine impact on PDFs and observables without refitting

PDF Reweighting: Statistical checks

- Effective number of replicas

$$\ln\left(N_{\rm eff}\right) \equiv \frac{1}{N}\sum_{k=1}^{N} w_k \ln\left(N/w_k\right)$$

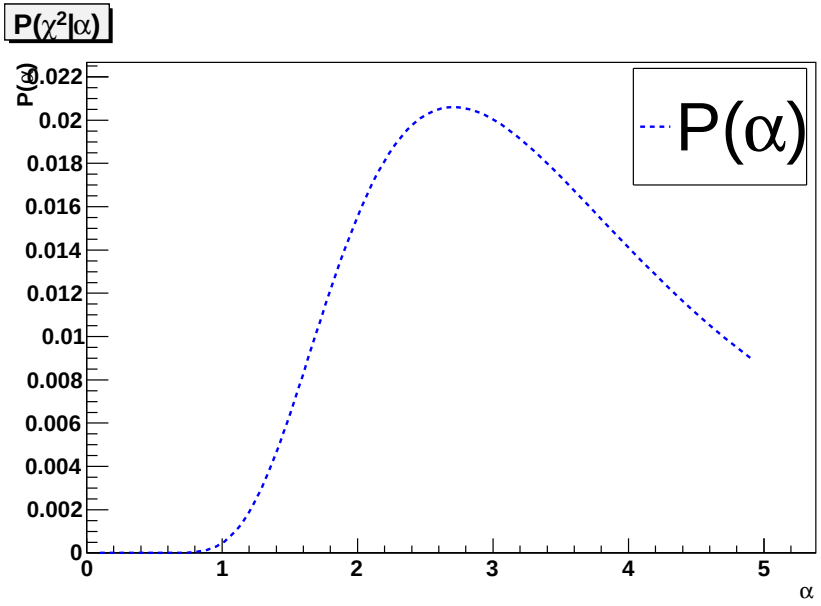
$N_{\rm eff} \ll N \rightarrow$ Very constraining data or tension with global fit

- Probability distribution of rescaled covariance matrix

$$P\left(\alpha\right) = \frac{\mathcal{N}}{\alpha}\sum_{k=1}^{N} w_k\left(1\right) w_k\left(\alpha\right) \quad , \qquad w_k\left(\alpha\right) \equiv \left(\chi_k^2/\alpha\right)^{n/2-1} e^{-\chi_k^2/\alpha/2}$$

$P\left(\alpha\right)$ peaked at $\alpha \sim 1 \rightarrow$ Data consistent with global fit

$P\left(\alpha\right)$ peaked at $\alpha \gg 1 \rightarrow$ Experimental uncertainties underestimated and/or tension with global fit



THE TEVATRON W ASYMMETRY DATA AND GLOBAL PDF ANALYSIS

arXiv:1012.0836, NPB in press

The Tevatron W lepton asymmetry

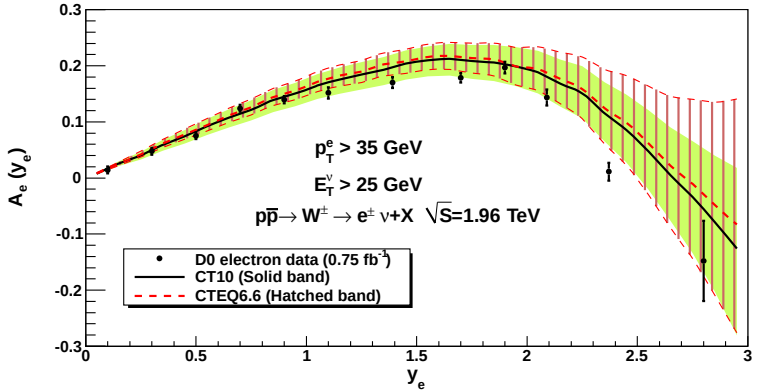
- Accurate Run-II Tevatron data on the $p\bar{p} \to W^{\pm} \to l^{\pm}\nu$ asymmetry available

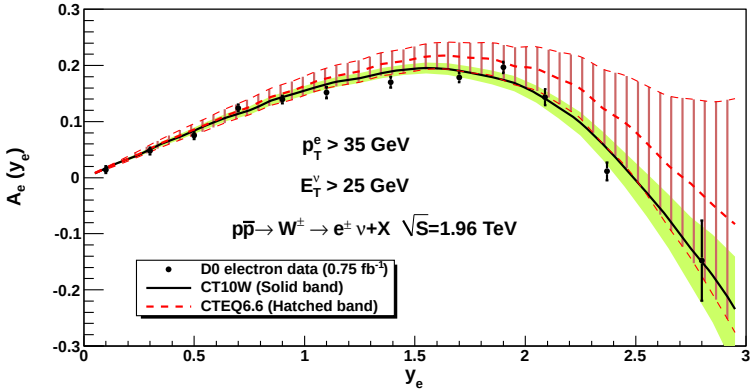
$$A_\ell(y_\ell) = \frac{d\sigma(W^+)/dy_\ell \; - \; d\sigma(W^-)/dy_\ell}{d\sigma(W^+)/dy_\ell \; + \; d\sigma(W^-)/dy_\ell}$$

- Some groups (CT10, MSTW) report tension with other datasets, specially DIS deuteron data. Problem with deuteron nuclear corrections?
- CT10 produced two sets, CT10 and CT10W, with and without D0 W asy data (arXiv:1007.2241)

ℓ	Cut (GeV)	Points	χ^2 CT10	CT10W
e	$p_T^\ell > 25$	12	79.5	**25.3**
e	$25 < p_T^\ell < 35$	12	20.7	**25.5**
e	$p_T^\ell > 35$	12	91.4	**26.5**
μ	$p_T^\ell > 20$	9	8.3	**13.5**

What do we do with Tevatron Wasy data?





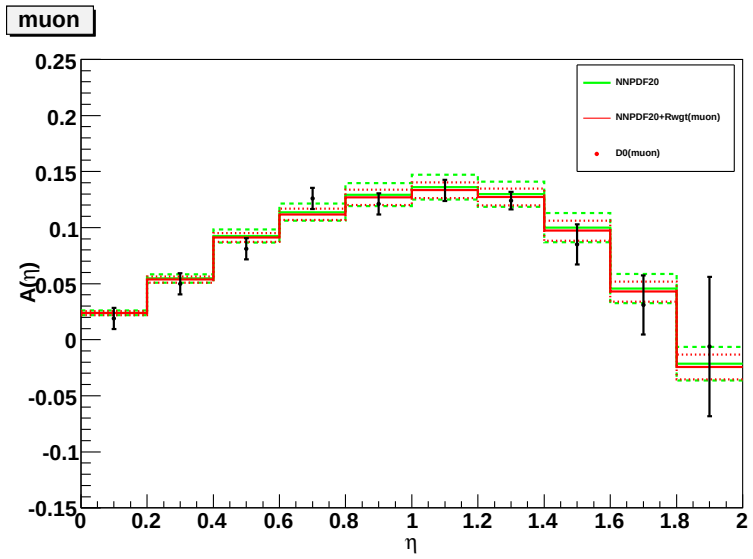
CT10W: large weight for all D0 datasets
Worse fit quality for other datasets (NMC, BCDMS)

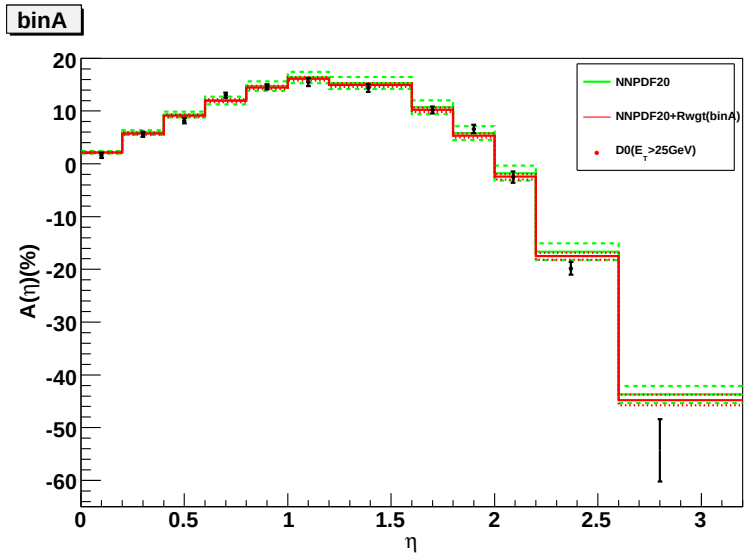
The Tevatron W lepton asymmetry

- Accurate Run-II Tevatron data on the $p\bar{p} \to W^{\pm} \to l^{\pm}\nu$ asymmetry available
- Some groups report tension with other datasets, specially DIS deuteron data. Problem with deuteron nuclear corrections?
- NNPDF analysis (Published D0 data): D0 $\mu + e$ inclusive data (not binned in p_t^l) perfectly consistent with global fit, reduction in valence PDF uncertainty + no tension exclusive to deuteron data found

Set	χ^2	$\chi^2_{\rm rw}$	$\chi^2_{\rm tot}$
D0 μ ($E_T > 20$ GeV)	0.62	**0.51**	1.14
D0 e bin A ($E_T > 25$ GeV)	2.12	**1.55**	1.13
D0 μ + e bin A	1.44	**1.11**	1.13
D0 e bin B ($25 < E_T < 35$ GeV)	4.75	**1.12**	1.16
D0 e bin C ($E_T > 35$ GeV)	5.06	**2.51**	1.16

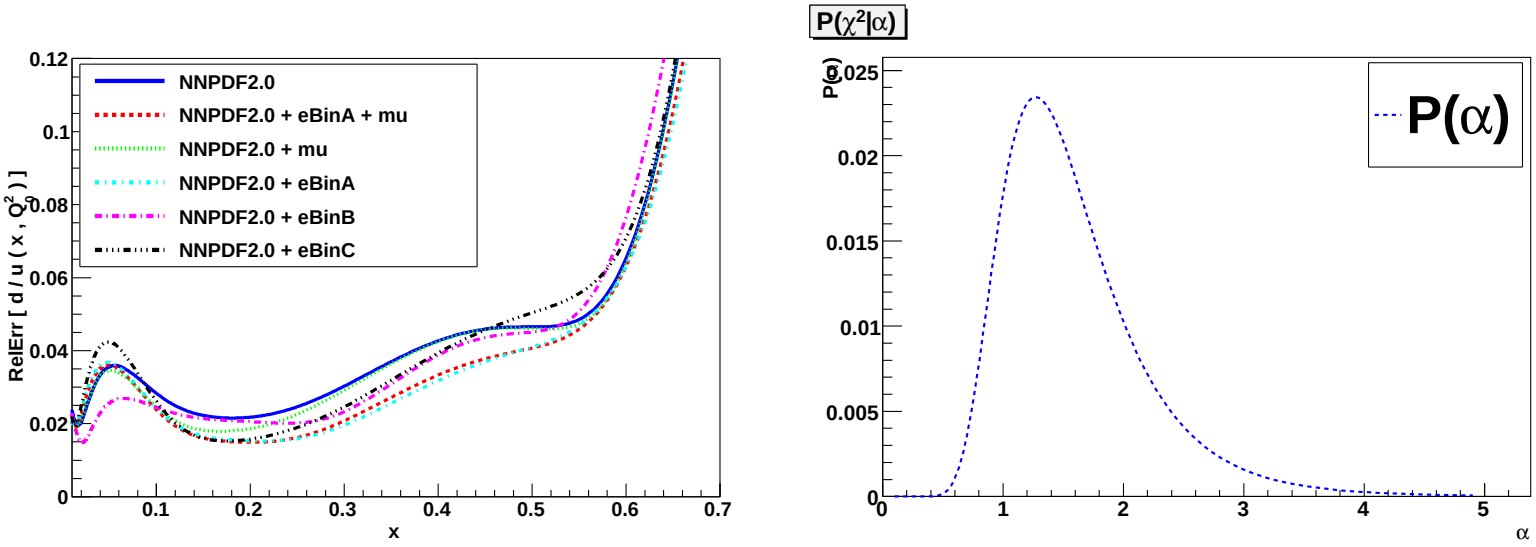
TeV W asy data: useful constrains on PDFs
No issues with DIS deuteron data, but care with systematics for exclusive p_T^e data





The D0 W asymmetry datasets

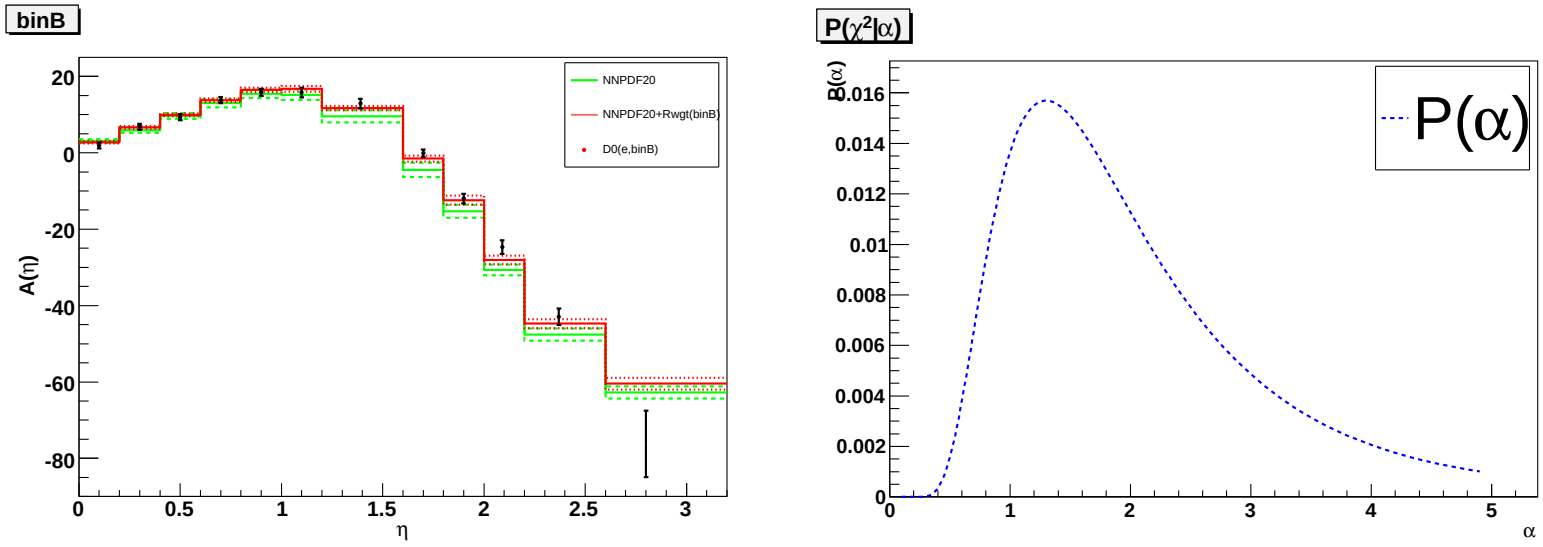
D0 muons + electrons $p_t \geq 25$ GeV



- Fully consistent with global analysis
- Good fit quality to the combined inclusive e and μ data
- Constraints on large-x valence PDF

The D0 W asymmetry datasets

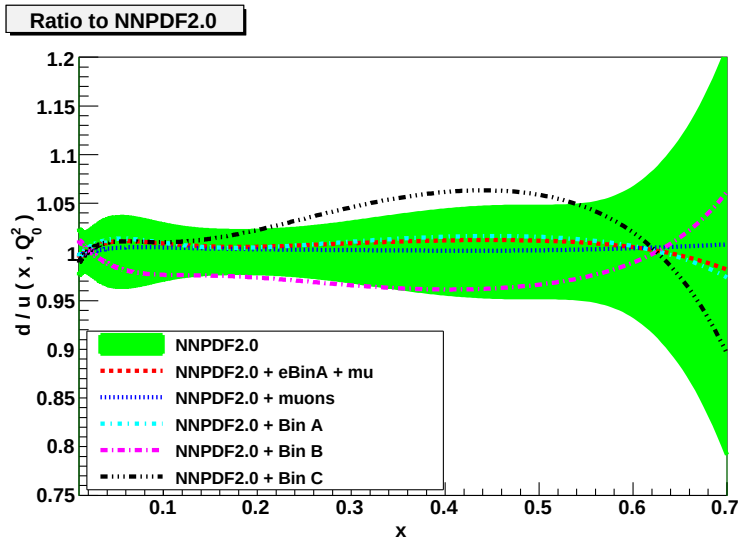
D0 electrons $25 \leq p_t \leq 35$ **GeV**

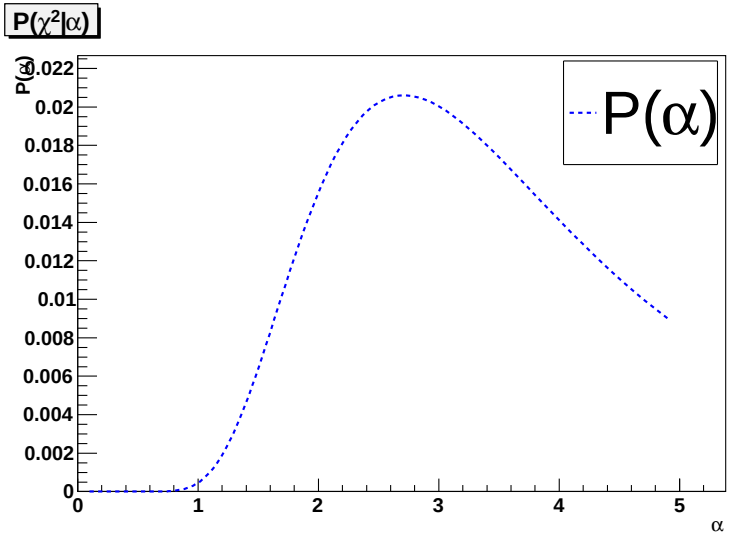


- Good χ^2 when included in the fit
- Tension with other datasets – but no particular tension with deuteron data

The D0 W asymmetry datasets

D0 electrons $p_t \geq 35$ GeV





- $P(\alpha)$ peaked at $\alpha \sim 3$ → Internal inconsistency (underestimated uncertainties?)
- Inconsistent with $25 \leq p_t \leq 35$ GeV data → Pull PDFs in opposite directions
- Tension with other experiments in global fit

Impact of D0 W asymetry in global PDF fit

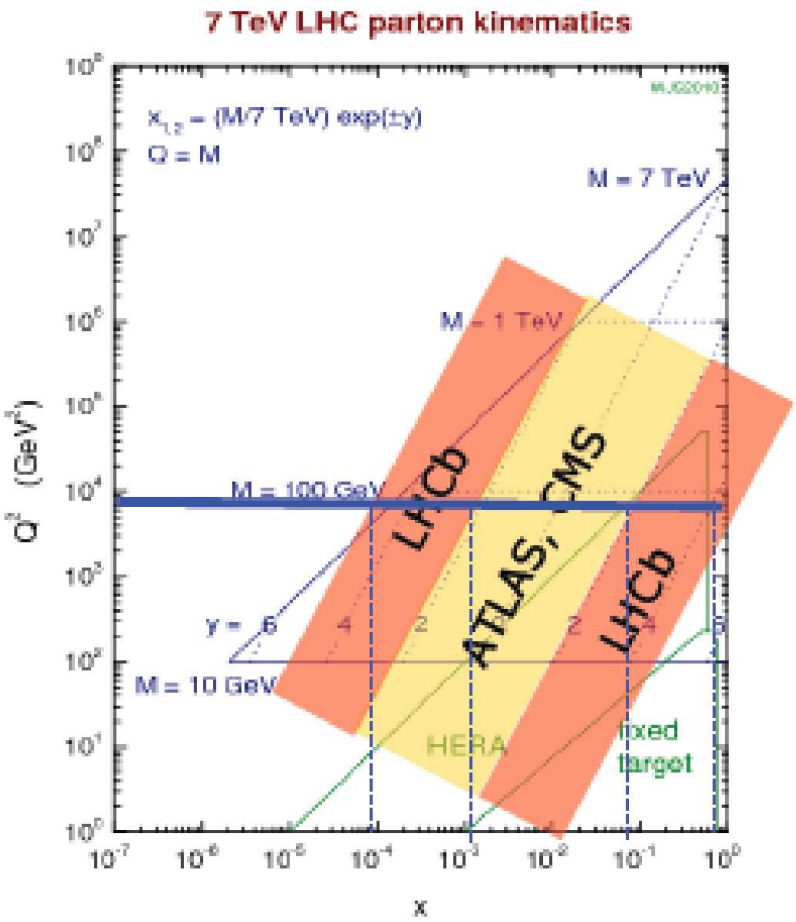
Set	$\chi^2_{2.0}$	$\chi^2_{2.0+\mu}$	$\chi^2_{2.0+\mathrm{binA}}$	$\chi^2_{2.0+\mathrm{binA}+\mu}$	$\chi^2_{2.0+\mathrm{binB}}$	$\chi^2_{2.0+\mathrm{binC}}$
NMC-pd	0.99	0.98	0.98	0.98	0.97	**1.13**
NMC	1.72	1.72	1.69	1.70	1.72	1.72
SLACp	1.55	1.55	1.53	1.54	1.50	**1.63**
SLACd	1.12	1.12	1.07	1.09	1.05	**1.24**
BCDMSp	1.35	1.35	1.33	1.34	**1.41**	1.35
BCDMSd	1.16	1.16	1.16	1.16	**1.24**	1.14
DYE886p	1.31	1.32	1.29	1.30	1.28	**1.36**
DYE886r	0.83	0.79	**0.67**	0.71	**1.08**	0.72
CDFWASY	1.88	1.88	**1.78**	1.82	**2.05**	**1.60**
CDFZRAP	1.74	1.77	1.75	1.77	**1.37**	**1.97**
CDFR2KT	1.02	1.02	0.95	0.97	**1.21**	0.93
D0R2CON	0.86	0.86	0.84	0.84	**0.91**	0.84
TOTAL	1.14	1.14	1.13	1.13	**1.16**	**1.16**

- D0 inclusive $\rightarrow$ Consistent with global PDF fit
- D0 exclusive $\rightarrow$ Tension with global fit, not restricted to deuterium data

PDFs WITH LHC DATA: THE W LEPTON ASYMMETRY MEASUREMENTS

J. Rojo, PDF4LHC 03/11
M. Ubiali, CERN EWK WG workshop 04/11
Paper in preparation

The W lepton asymmetry at the LHC



M. Ubiali, CERN EWK WG 04/11

ATLAS, CMS and LHCb have measured the W lepton asymmetry
We have analyzed the impact of PDFs of the LHC data:

- ATLAS muons (31 pb^{-1}) (arxiv:1103.2929)
- CMS electrons + muons (36 pb^{-1}) (arxiv:1103.3470)
- LHCb muons (preliminary, not discussed here)

The W lepton asymmetry at the LHC

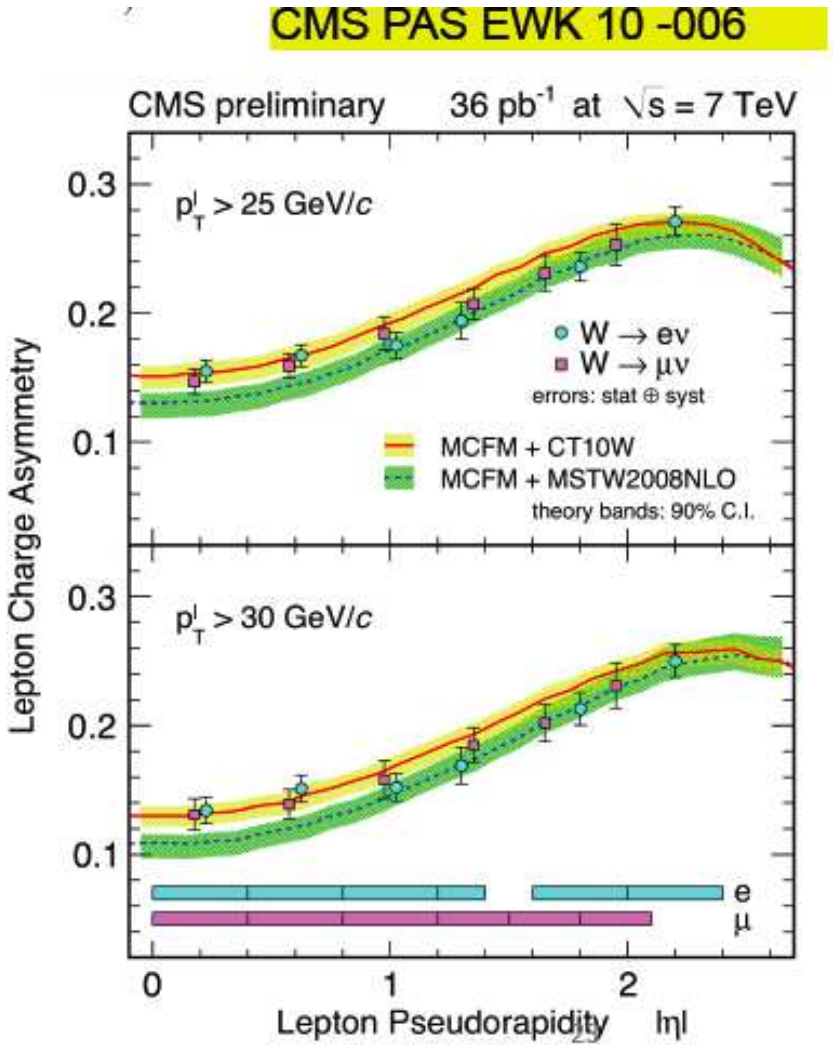
- LHC data on the $pp \to W^{\pm} \to l^{\pm}\nu$ asymmetries available from ATLAS, CMS and LHCb

$$A_\ell(y_\ell) \equiv \frac{d\sigma(W^+)/dy_\ell \; - \; d\sigma(W^-)/dy_\ell}{d\sigma(W^+)/dy_\ell \; + \; d\sigma(W^-)/dy_\ell}$$

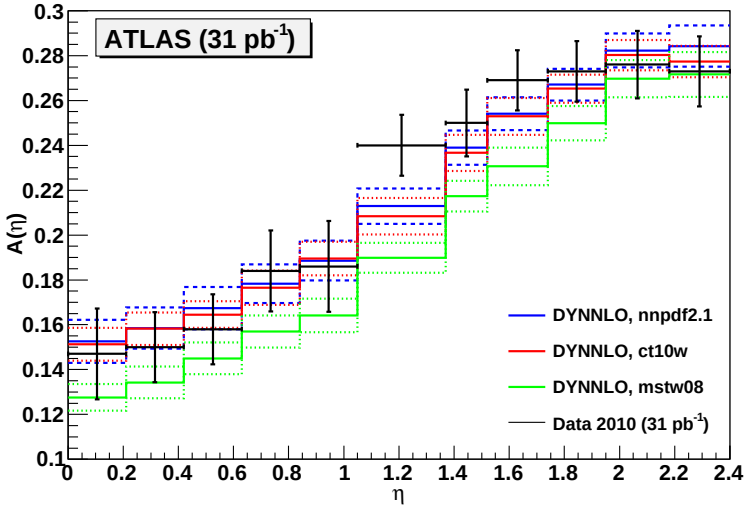
- The W asymmetry at the LHC sensitive to light (anti)quarks for $x \in [10^{-3}, 0.1]$ for ATLAS/CMS (larger and smaller-x from LHCb)

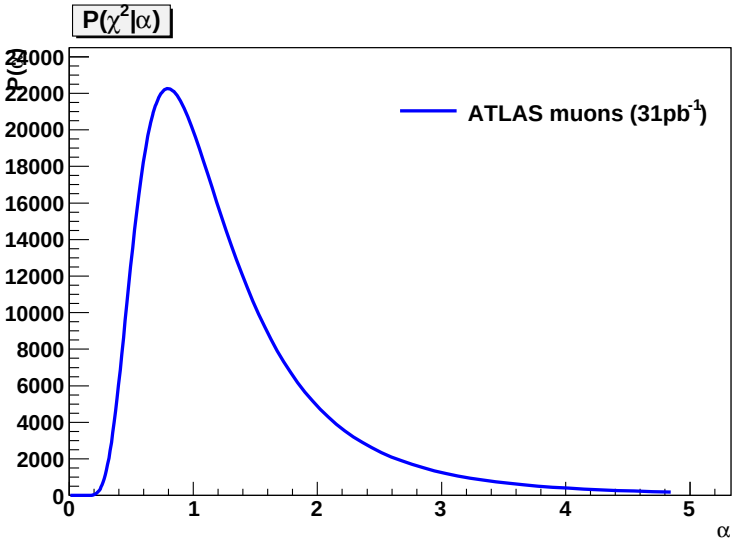
$$A_\ell(y_\ell) \sim \frac{u(x_1)\bar{d}(x_2) - d(x_1)\bar{u}(x_2)}{u(x_1)\bar{d}(x_2) + d(x_1)\bar{u}(x_2)}$$

First constrains on PDFs from LHC data?



Impact of ATLAS W lepton asymmetry

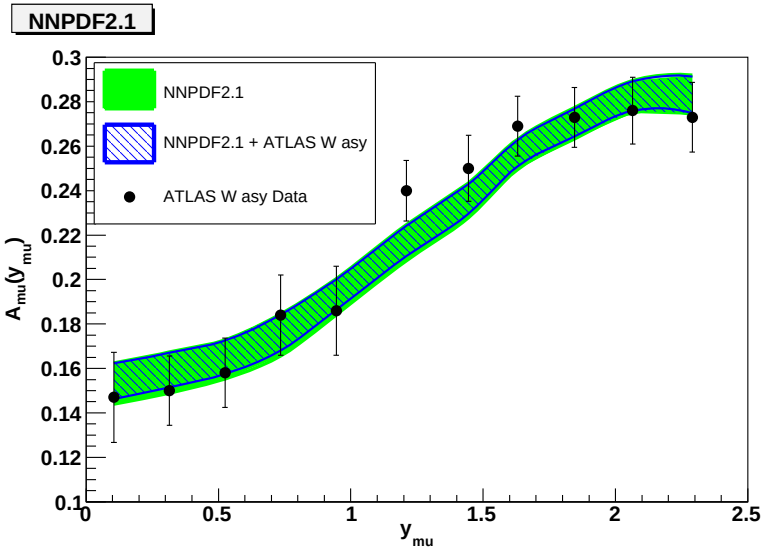


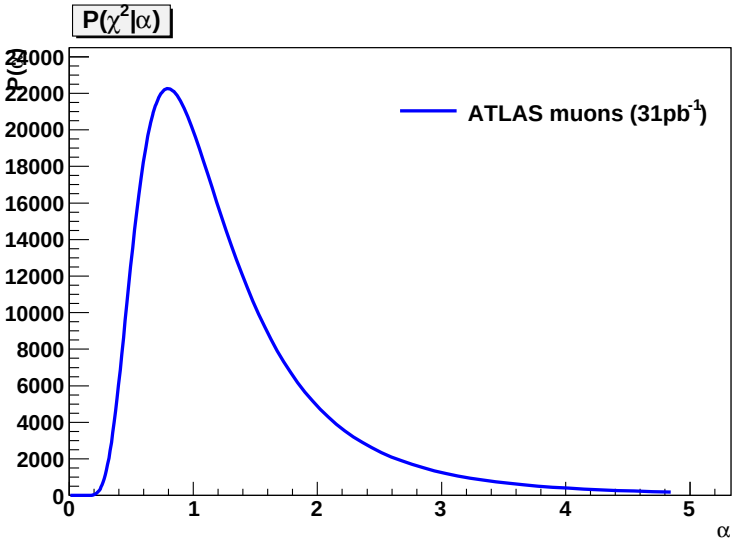


$N_{\rm eff} = 93$ $\quad$ $N_{\rm rep} = 100$

	CT10W	MSTW08	NNPDF2.1	NNPDF2.1+ATLAS
ATLAS data	**0.81**	**3.25**	**0.68**	0.63

Impact of ATLAS W lepton asymmetry





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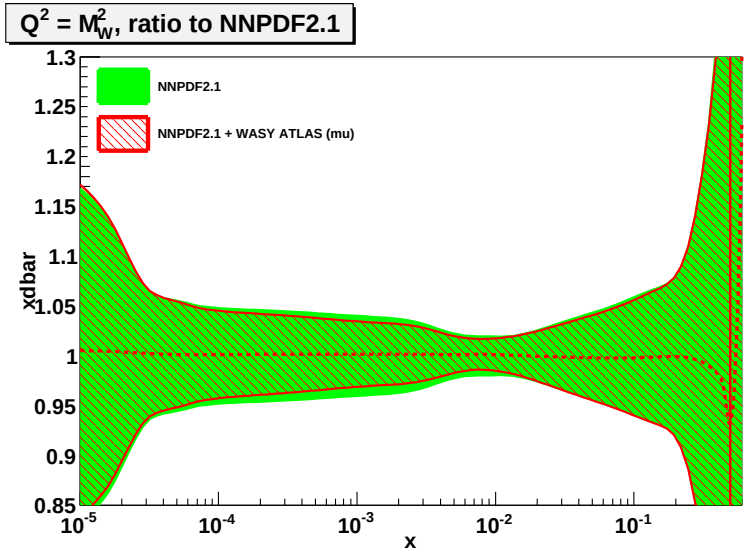
ATLAS data	**0.81**	**3.25**	**0.68**	0.63

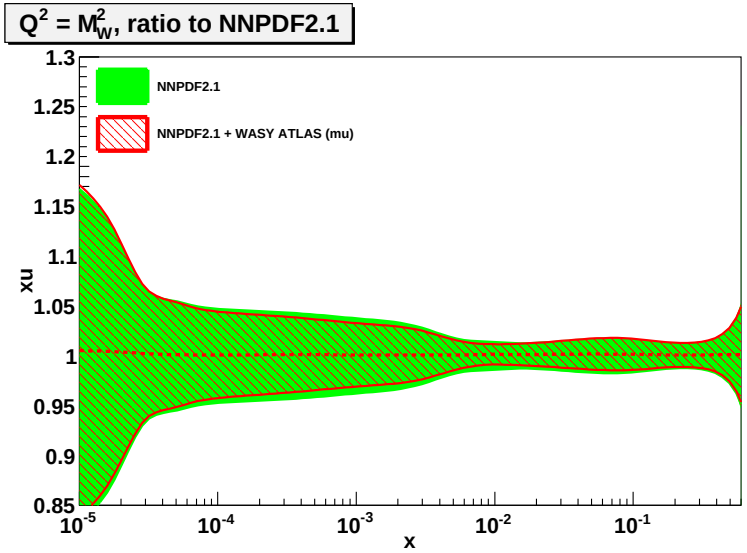
- NNPDF2.1 best description of ATLAS data - before including in fit
- CT10W similar to NNPDF2.1, MSTW08 poor fit quality

Impact of ATLAS W lepton asymmetry

$\bar{d}(x, Q^2)$ $\bar{d}(x, Q^2)$

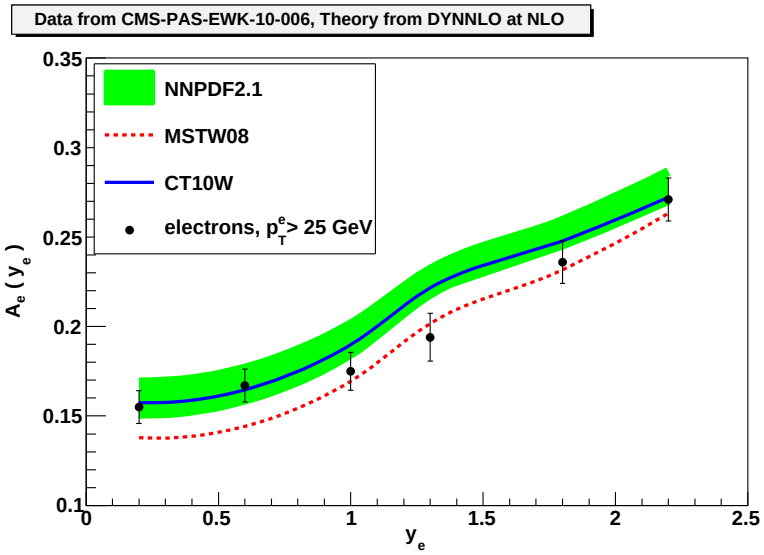


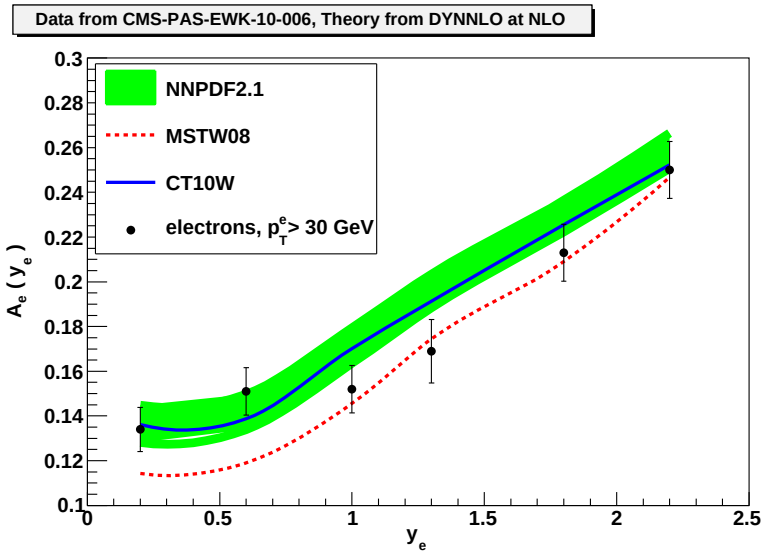
$u(x, Q^2)$



Reduction of PDF uncertainties ($\sim 15 - 20\%$) for medium and small-x quarks

Impact of CMS W lepton asymmetry

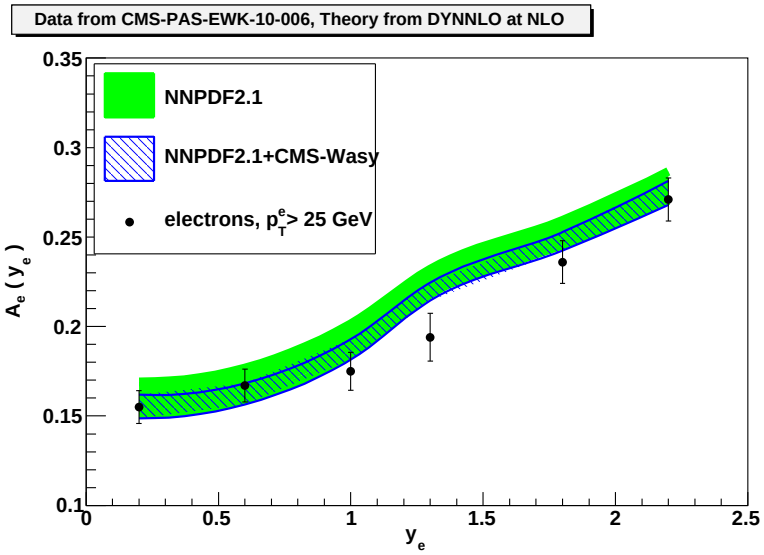


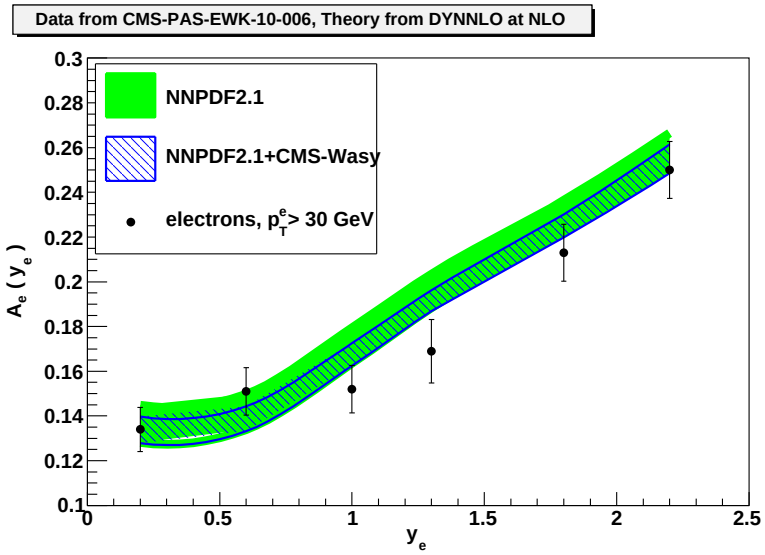


$$N_{\rm rep} = 100$$

	CT10W	MSTW08	NNPDF2.1
CMS data $p_t^l \geq 25$ GeV, electrons	0.8	2.4	1.9
CMS data $p_t^l \geq 30$ GeV, electrons	1.2	2.5	1.7
CMS data $p_t^l \geq 25$ GeV, muons	0.5	1.1	1.3
CMS data $p_t^l \geq 30$ GeV, muons	0.6	1.3	0.8
CMS data $p_t^l \geq 25$ GeV, el+mu	0.7	1.8	1.6
CMS data $p_t^l \geq 30$ GeV, el+mu	0.8	1.9	1.2

Impact of CMS W lepton asymmetry





$N_{\rm eff} = 53 \qquad N_{\rm rep} = 100 \ (p_t \geq 25\,{\rm GeV})$

$N_{\rm eff} = 68 \qquad N_{\rm rep} = 100 \ (p_t \geq 30\,{\rm GeV})$

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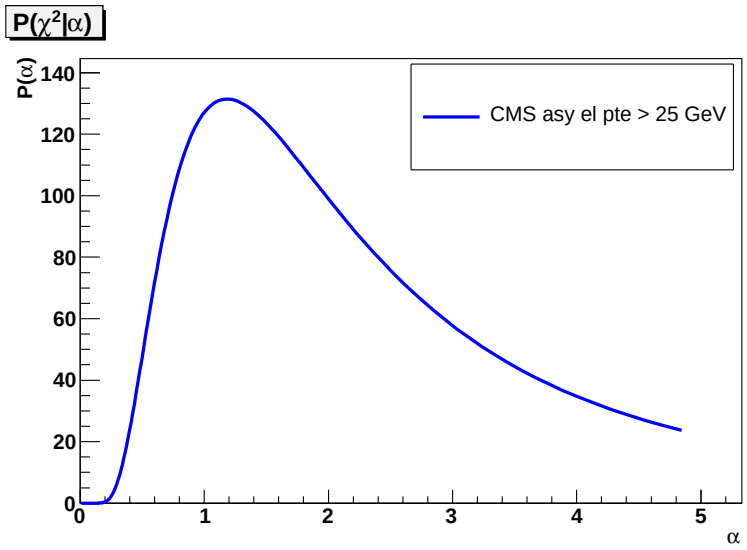
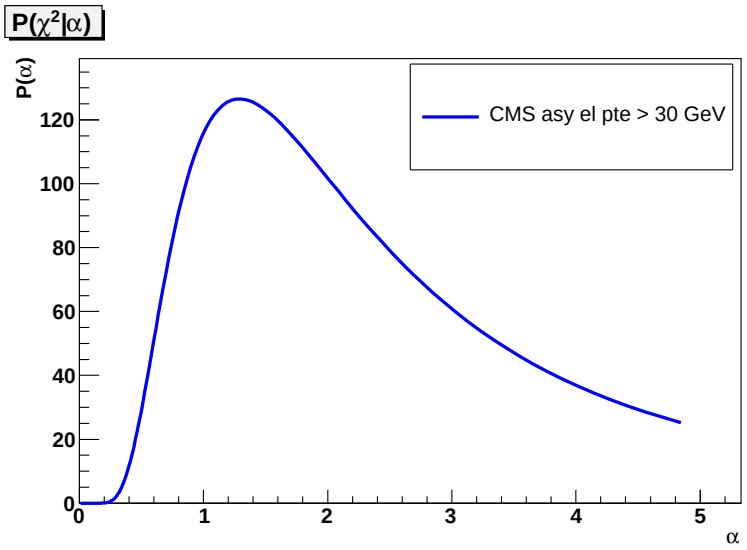
Impact of CMS W lepton asymmetry





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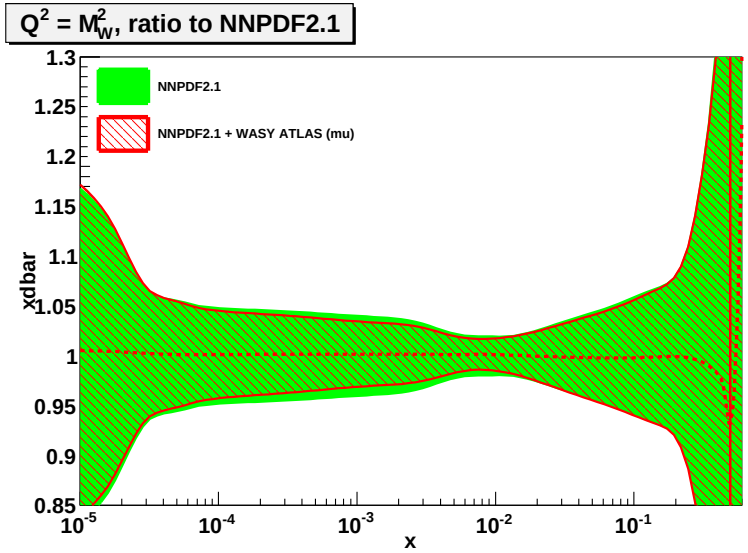
	CT10W	MSTW08	NNPDF2.1	NNPDF2.1+CMS
CMS data $p_t^l \geq 25$ GeV, el+mu	0.7	1.8	**1.6**	**0.9**
CMS data $p_t^l \geq 30$ GeV, el+mu	0.9	1.9	**1.2**	**0.9**

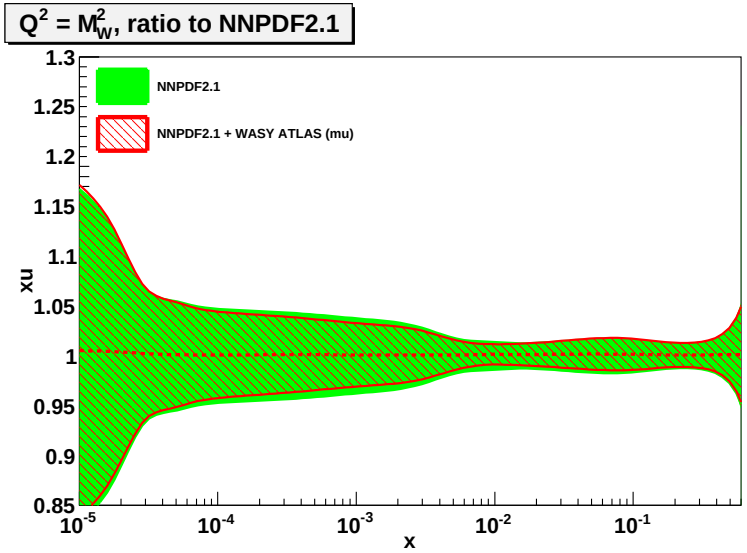
- Excellent description of CMS data once included in PDF fit
- CMS data perfectly consistent with global PDF fit data

Impact of CMS W lepton asymmetry

$\bar{d}(x, Q^2)$ $\bar{d}(x, Q^2)$

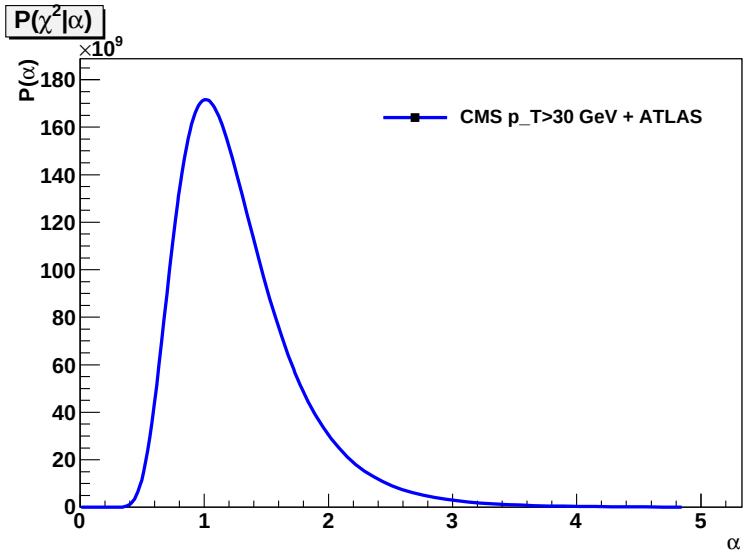


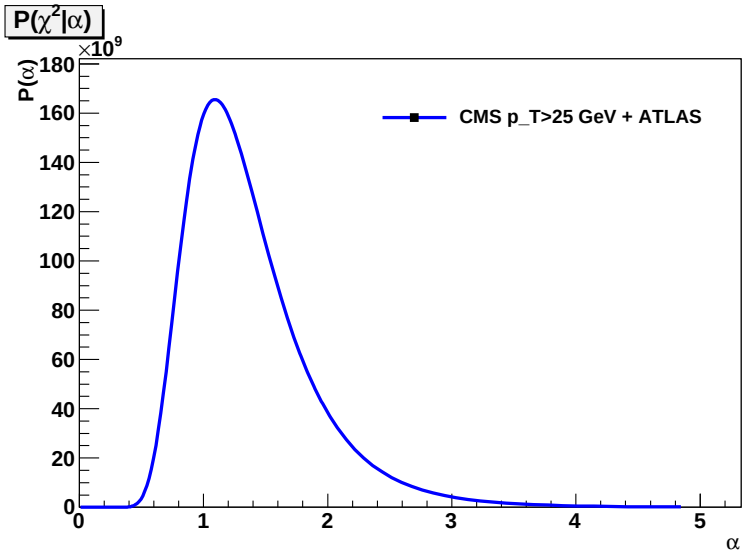
$u(x, Q^2)$



- Reduction of PDF uncertainties ($\sim 40 - 50\%$) for medium and small-x quarks
- More severe constrains on PDFs than ATLAS data

Impact of CMS+ATLAS W lepton asymmetry





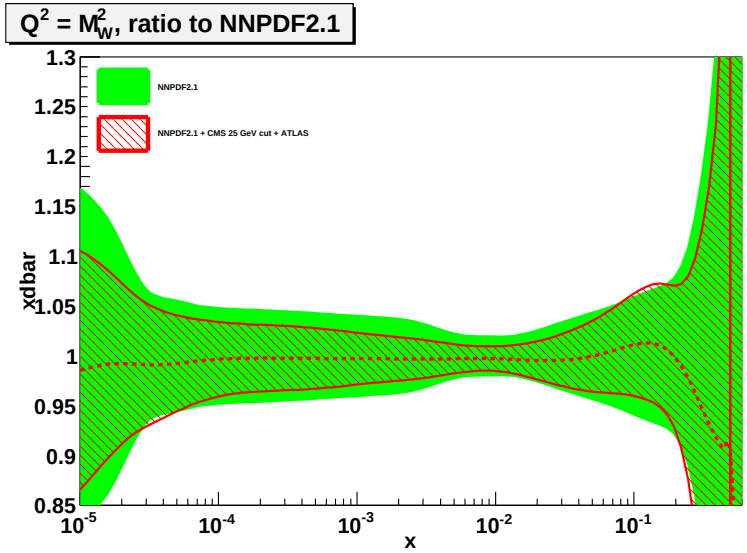
$N_{\rm eff} = 68/78$ $(p_t^l \geq 25\,{\rm GeV}/30\,{\rm GeV})$ $\qquad N_{\rm rep} = 100$

	NNPDF2.1	NNPDF2.1+ATLAS+CMS
ATLAS+CMS data	1.0	0.9

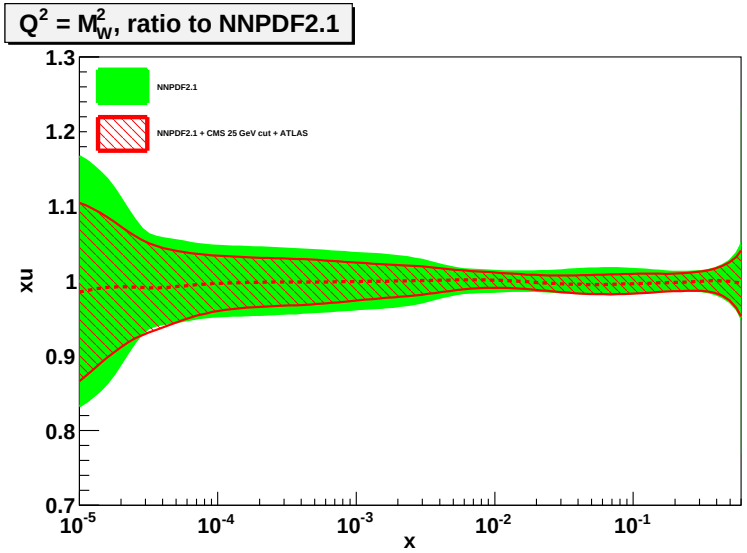
ATLAS and CMS measurements perfectly compatible

Impact of CMS+ATLAS W lepton asymmetry

$\bar{d}(x, Q^2)$ $\bar{d}(x, Q^2)$



$u(x, Q^2)$



- Reduction of PDF uncertainties ($\sim 30 - 40\%$) for medium and small-x light (anti)quarks
- CMS data more constraining than ATLAS

Summary

- Bayesian reweighting is a powerful tool to easify quantify impact of new data into PDFs
- The D0 inclusive W asymmetry data $\rightarrow$ Consistent with global PDF fit, constrain large-x valence quarks
- Exclusive D0 bins $\rightarrow$ Inconsistent with the global fit and among them + internal consistency issues
- No tension exclusive to DIS deuterium data found
- The ATLAS and CMS W lepton asymmetry data constraint small-x sea quarks $\rightarrow$ First PDF constraints from LHC data
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Thanks for your attention!

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EXTRA MATERIAL