

# Parton distributions with LHC data

NNPDF2.3 - arXiv:1207.1303 & PDF benchmark (preliminary)

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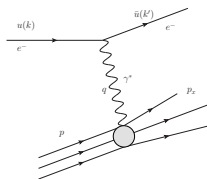
in collaboration with S. Forte, R. Ball, L. Del Debbio *et al.*



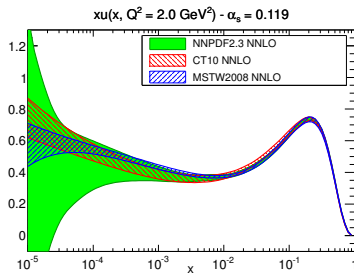
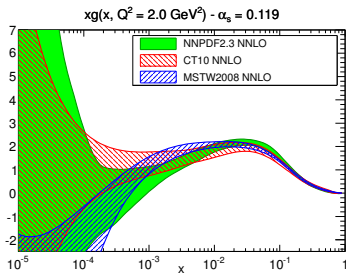
# What about PDFs?

## PDF definition:

- The **probability density** for finding a **parton** with a momentum fraction  $x$  at momentum transfer  $Q^2$ .
- PDFs are **fitted** from **experimental** data: DIS, Drell-Yan, EW production and Jets



- Examples of  $xg(x, Q^2)$  and  $xu(x, Q^2)$  at  $Q^2 = 2.0 \text{ GeV}^2$ :



# PDFs on the market...

- PDF sets are available in a common format interface at **LHAPDF**:

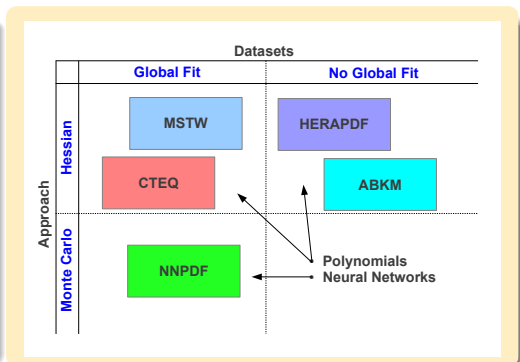


## LHAPDF the Les Houches Accord PDF Interface

- Global fits: DIS + DY + JET data

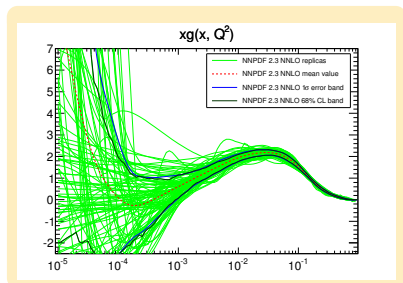
### Some examples:

- MSTW2008
- CTEQ/CT10
- NNPDF2.1/2.3
- ABKM/ABM11
- HERAPDF
- GJR
- others...



# The NNPDF methodology (Shortly)

- Why not a **standard approach** to PDF fitting?
  - ▶ **Bias associated** to the choice of functional form
- Generate **Monte Carlo replicas** of the experimental data
  - ▶ No need to rely on **linear propagation of errors**
- Fit PDFs using a set of **Neural Networks** on each replica
  - ▶ Neural Networks provide an **unbiased parametrization**
  - ▶ Parametrization: **7 independent PDFs**  $\Rightarrow$  **259 free parameters**
- Expectation values for **observables are Monte Carlo integrals:**



MC approach:

$$\langle \mathcal{O}[f] \rangle = \frac{1}{N} \sum_{k=1}^N \mathcal{O}[f_k]$$

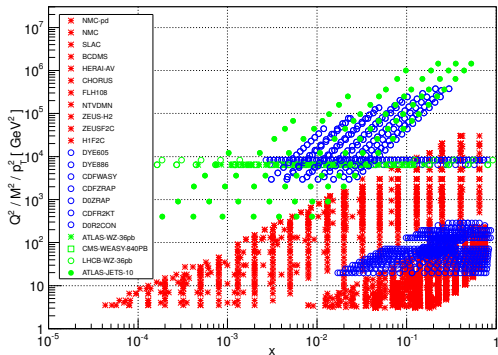
- ▶ for **observables, errors, correlations, etc.**



# NNPDF2.3 dataset

- **NNPDF2.3** dataset includes **LHC data** for which the full covariance matrix is available (●).

NNPDF2.3 dataset



## ATLAS:

- inclusive jets
- W/Z lepton rapidity distributions

## CMS:

- W lepton asymmetry

## LHCb:

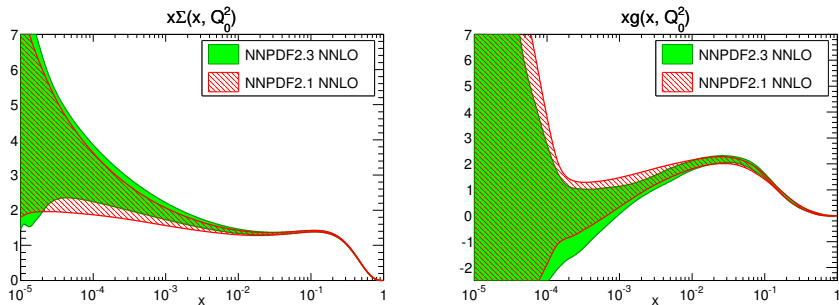
- W/Z rapidity distributions

- **3506 data points** in the NNLO fit: **56 LHC W/Z**, **90 LHC Jets**

(ATLAS jets arXiv:1112.6297, ATLAS W/Z arXiv:1109.5141, CMS Weasy arXiv:1206.2598, LHCb W/Z arXiv:1204.1620)

# Example of NNPDF2.3 PDF

- Example of NNLO PDFs at  $Q^2 = 2.0 \text{ GeV}^2$ :



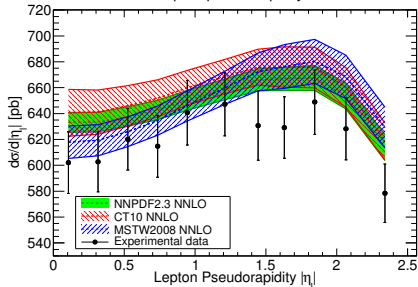
- **NNPDF2.1 = no LHC data.** Fit also available at NLO.
- LHC data reduces uncertainties and improves the  $\chi^2$ :

	NNPDF2.1		NNPDF2.3	
Order	<b>NLO</b>	<b>NNLO</b>	<b>NLO</b>	<b>NNLO</b>
Total $\chi^2$	<b>1.145</b>	<b>1.167</b>	<b>1.121</b>	<b>1.153</b>

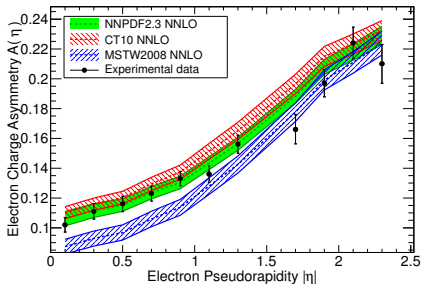


# LHC observables (preliminary)

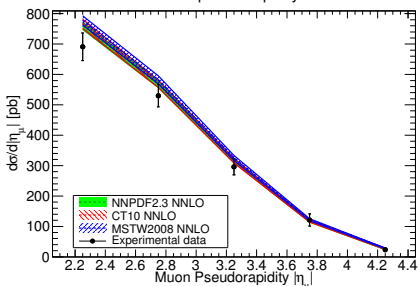
ATLAS  $W^+$  lepton pseudorapidity distribution



CMS  $W$  electron charge asymmetry



LHCb  $W^+$  muon pseudorapidity distribution



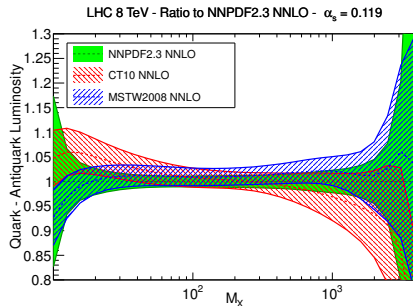
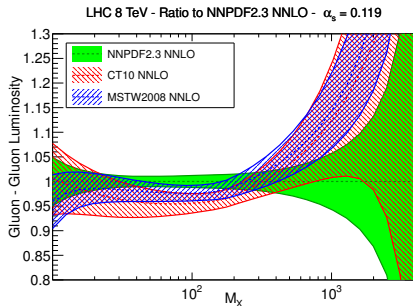
PDF Set	NNPDF2.3	MSTW08	CT10
ATLAS W, Z	1.5	3.2	1.2
CMS Weasy	0.8	3.8	1.8
LHCb W, Z	0.9	1.1	1.0
ATLAS jets	1.4	1.5	1.5

# Luminosities (preliminary)

**Luminosity** is defined as

$$\Phi_{ij}(M_X^2) = \frac{1}{s} \int_{\tau}^1 \frac{dx_1}{x_1} f_i(x_1, M_X^2) f_j(\tau/x_1, M_X^2), \quad \tau = \frac{M_X^2}{s}$$

- Preliminary results:  $gg$  and  $q\bar{q}$  luminosities at **8 TeV** (2012 runs)



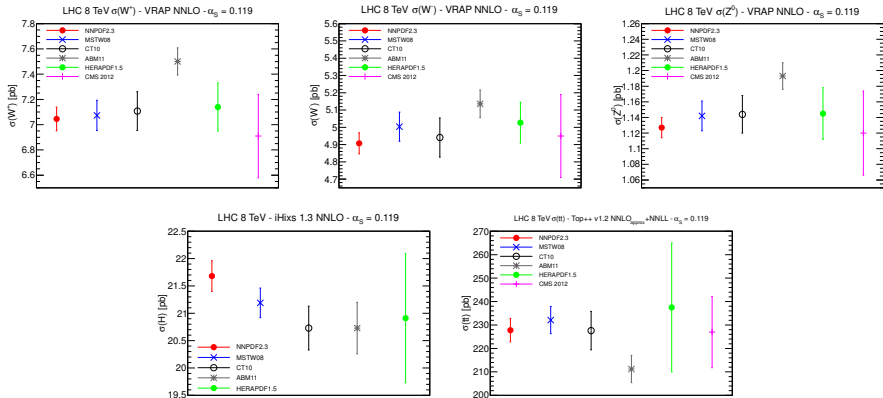
- All luminosities are reasonably compatible for between **global PDF sets**.





# Phenomenology at 8 TeV (preliminary)

- Cross sections calculated with: Vrap, Top++, iHixs at 8 TeV.



- **Good agreement** between all PDFs.
- **Waiting for Higgs cross-section measurements!**



# Conclusion

- 1 NNPDF2.3 is the **first PDF fit** including **LHC data**
- 2 Impact of LHC data is small but **non-negligible**
- 3 Invite you to try **NNPDF2.3!**

For further information, tutorials and Mathematica interface visit:

<http://nnpdf.hepforge.org/>

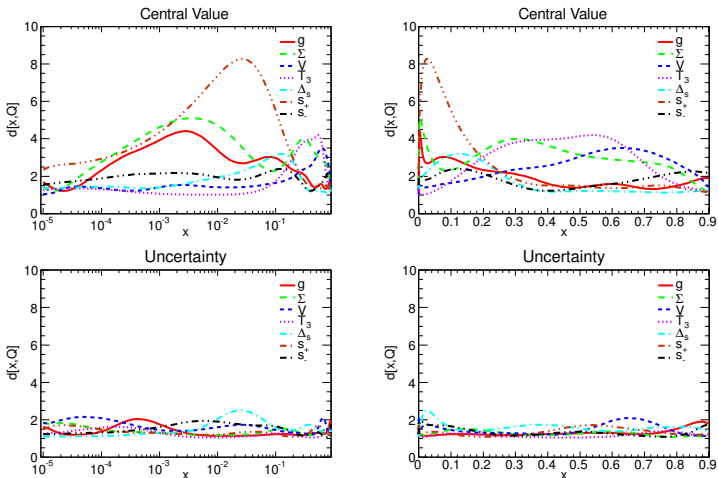


## BACKUP SLIDES



# Distances between 2.3 and 2.1

## NNPDF2.1 NNLO vs NNPDF2.3 NNLO



# Features

- Heavy quark mass effects included using the FONLL method up to NNLO, S. Forte et al., arXiv:1001.2312.
- FastKernel method for the inclusion of the higher order corrections  
The NNPDF Collaboration, arXiv:1002.4407
  - ▶ DIS up to NNLO
  - ▶ DY and JET up to NLO
- NNLO corrections to DY included by means of K-factors (DYNLO)
- NNLO corrections to inclusive JET implement using FastNLO (hep-ph/0609285)
  - ▶ approximated NNLO corrections based on threshold resummation.



- NLO/NNLO cuts

- ▶  $W^2 = Q^2(1-x)/x > 12.5 \text{ GeV}^2$
- ▶  $Q^2 > 3 \text{ GeV}^2$  + further cuts on  $F_2^c$

- ATLAS W, Z lepton rapidity distributions cuts

$$p_T^l \geq 20 \text{ GeV}, \quad p_T^{\nu} \geq 25 \text{ GeV}, \quad m_T < 40 \text{ GeV}, \quad |\eta_l| \leq 2.5$$

$$p_T^l \geq 20 \text{ GeV}, \quad 66 \text{ GeV} \leq m_{l+l-} \leq 116 \text{ GeV}, \quad \eta_{l+,l-} \leq 4.9$$

- CMS W electron asymmetry

$$p_T^e \geq 35 \text{ GeV}$$

- LHCb W, Z rapidity distribution

$$p_T^{\mu} \geq 20 \text{ GeV}, \quad 60 \text{ GeV} \leq m_{l+l-} \leq 120 \text{ GeV}, \quad 2.0 \leq \eta_{1,2}^{\mu} \leq 4.5$$

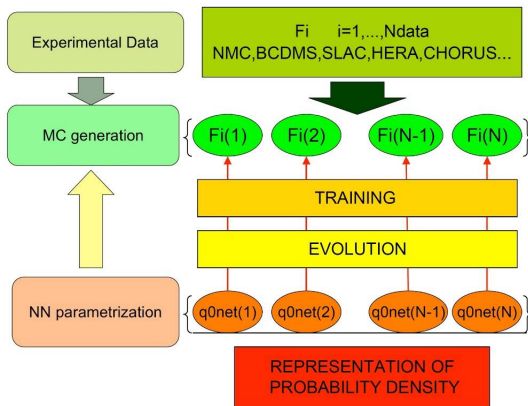


# NNPDF fit quality

	NNPDF2.1		NNPDF2.3							
	Global		Global Fit		Global RW		noLHC		Collider	
Experiment	NLO	NNLO	NLO	NNLO	NLO	NNLO	NLO	NNLO	NLO	NNLO
Total	1.145	1.167	1.121	1.153	1.116	1.153	1.101	1.147	1.018	1.034
NMC-pd	0.97	0.93	0.93	0.94	0.93	0.94	0.93	0.94	[4.72]	[5.03]
NMC	1.68	1.58	1.61	1.57	1.59	1.56	1.59	1.56	[1.86]	[1.87]
SLAC	1.34	1.04	1.26	1.02	1.24	1.00	1.28	1.04	[1.80]	[1.48]
BCDMS	1.21	1.29	1.19	1.29	1.21	1.29	1.20	1.28	[1.81]	[2.08]
CHORUS	1.10	1.08	1.10	1.06	1.10	1.06	1.09	1.07	[1.93]	[1.81]
NTVDMN	0.70	0.50	0.45	0.55	0.45	0.59	0.42	0.48	[28.51]	[22.61]
HERAI-AV	1.04	1.04	1.00	1.01	1.00	1.02	1.01	1.03	0.97	0.98
FLH108	1.34	1.23	1.28	1.20	1.29	1.20	1.29	1.21	1.33	1.25
ZEUS-H2	1.21	1.21	1.20	1.22	1.21	1.22	1.20	1.22	1.30	1.32
ZEUS $F_2^c$	0.75	0.81	0.82	0.90	0.83	0.90	0.81	0.86	0.73	0.77
H1 $F_2^c$	1.50	1.44	1.58	1.52	1.63	1.53	1.58	1.49	1.34	1.30
DYE605	0.94	1.09	0.88	1.02	0.86	1.04	0.85	1.07	[11.12]	[4.56]
DYE886	1.42	1.76	1.28	1.62	1.25	1.59	1.24	1.61	[4.44]	[4.63]
CDF W asy	1.87	1.63	1.54	1.70	1.56	1.69	1.45	1.66	1.17	1.16
CDF Z rap	1.77	2.42	1.79	2.12	1.77	2.16	1.77	2.15	1.49	1.49
D0 Z rap	0.57	0.68	0.57	0.63	0.57	0.63	0.57	0.64	0.57	0.61
ATLAS W,Z	[1.58]	[2.22]	1.27	1.46	1.26	1.53	[1.37]	[1.94]	1.08	1.08
CMS W e asy	[2.26]	[1.45]	1.04	0.96	1.18	1.04	[1.50]	[1.37]	0.96	0.96
LHCb W,Z	[1.34]	[1.42]	1.21	1.22	1.19	1.21	[1.24]	[1.33]	1.22	1.29
CDF RII $k_T$	0.68	0.65	0.61	0.67	0.58	0.65	0.60	0.67	0.57	0.59
D0 RII cone	0.90	0.98	0.84	0.93	0.82	0.92	0.84	0.94	0.83	0.93
ATLAS jets	[1.65]	[1.48]	1.55	1.42	1.44	1.37	[1.57]	[1.45]	1.46	1.41



# NNPDF mechanism





- The  $k^{\text{th}}$  MC replica ( $k=1, \dots, N_{\text{rep}}$ ) is generated according to

$$g^{(\text{art}),k}(x, Q^2) = (1 + r_{k,N}\sigma_N) \left[ g_1^{(\text{exp})}(x, Q^2) + r_{k,t}\sigma_t \right]$$

where  $r_k$  is the Gaussian random numbers,  $\sigma_N$  quadratic sum of normalization errors and  $\sigma_t$  total error (summing in quadrature statistical and systematic errors)



# Neural Networks

- Neural Networks are defined as

$$\xi_i^{(l)} = g \left( \sum_{j=1}^{n_{l-1}} \omega_{ij}^{(l-1)} \xi_j^{(l-1)} - \theta_i^{(l)} \right)$$

- $\omega_{ij}^{(l-1)}$  weights,  $\theta_i^{(l)}$  thresholds,  $i^{th}$  neuron,  $l^{th}$  layer, where  $g$  is the sigmoid activation function:

$$g(x) \equiv \frac{1}{1 + e^{-x}}$$

- Example: Neural network 1-2-1

$$\xi_1^{(3)} = \left\{ 1 + \exp \left[ \theta_1^{(3)} - \frac{\omega_{11}^{(2)}}{1 + e^{\theta_1^{(2)} - x\omega_{11}^{(1)}}} - \frac{\omega_{12}^{(2)}}{1 + e^{\theta_2^{(2)} - x\omega_{21}^{(1)}}} \right] \right\}^{-1}$$



# Genetic algorithm

