Parton distributions with LHC data

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

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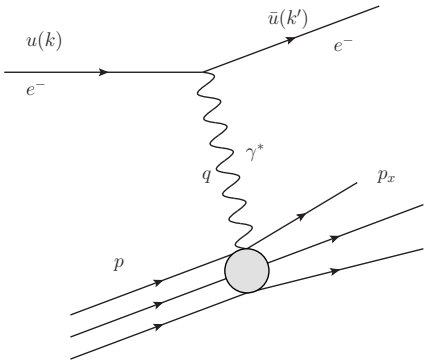
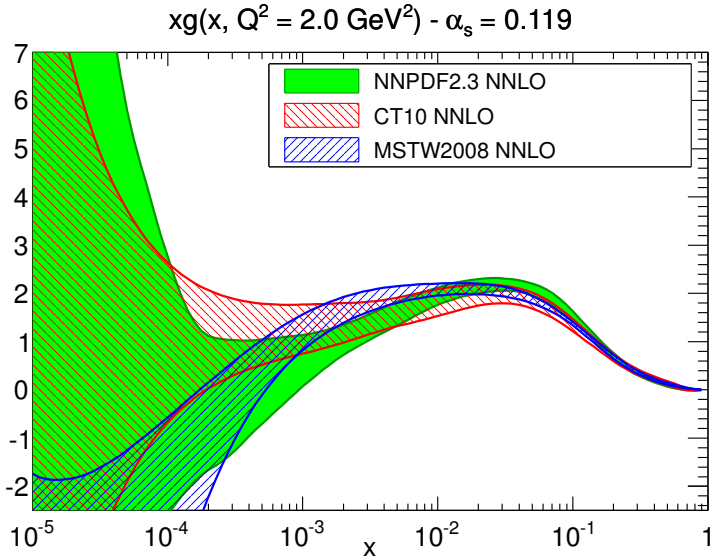
What about PDFs?

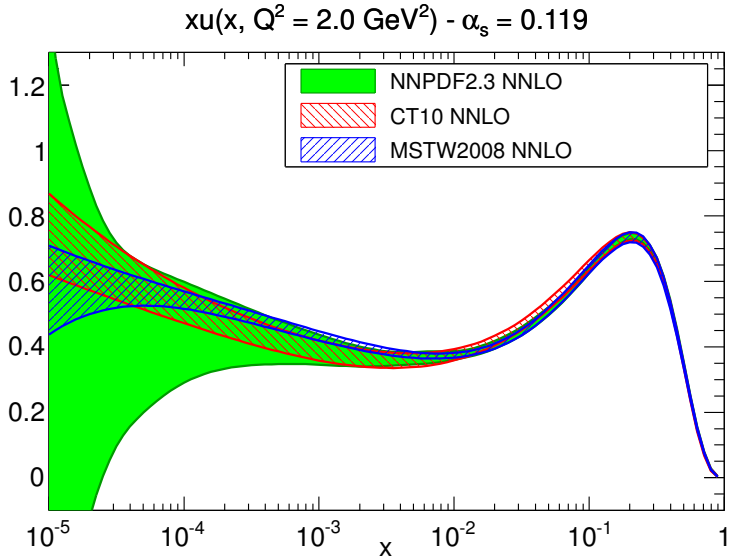
PDF definition:

- 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 $Q^2 = 2.0\,\mathrm{GeV}^2$:





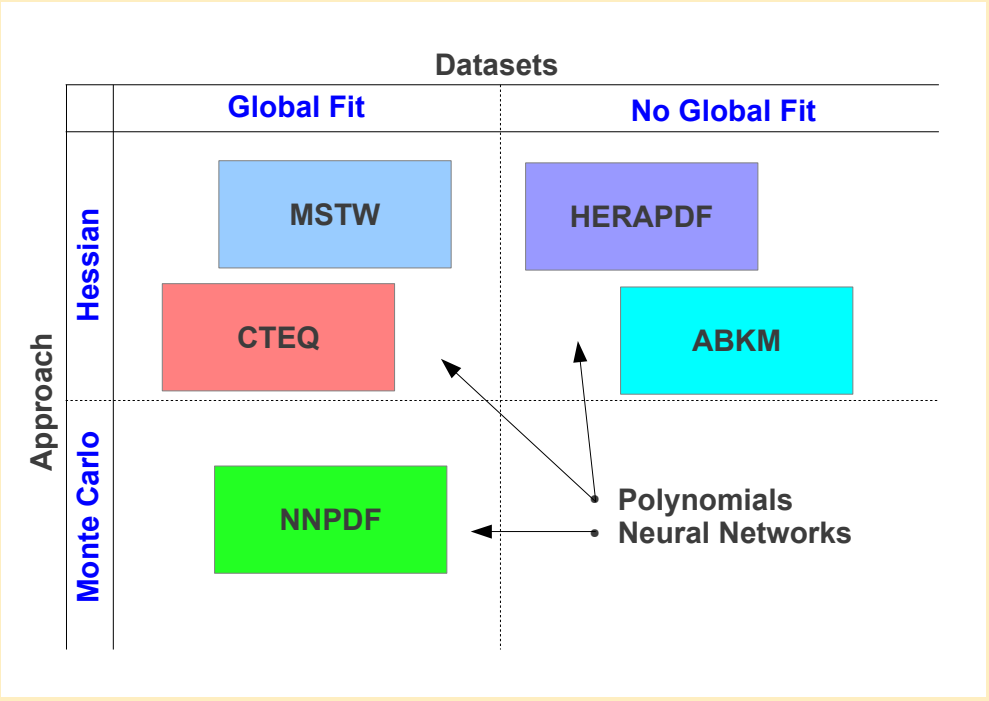
PDFs on the market...

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

- Global fits: DIS + DY + JET data

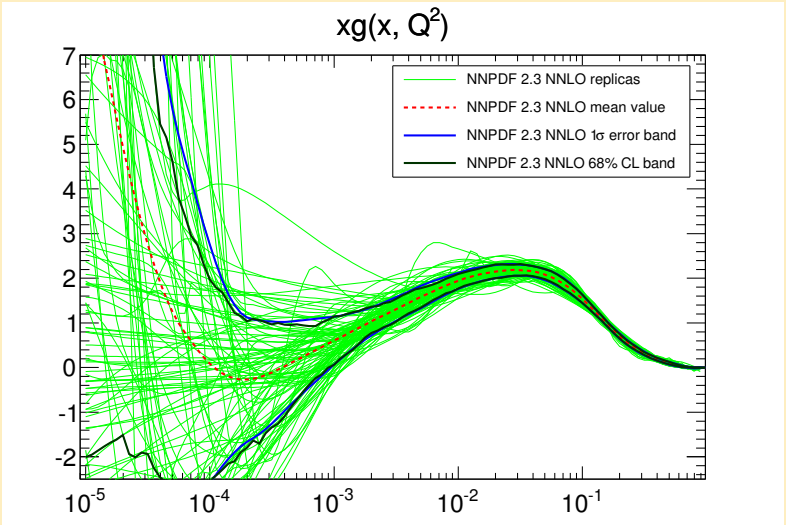
Some examples:

- 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:**



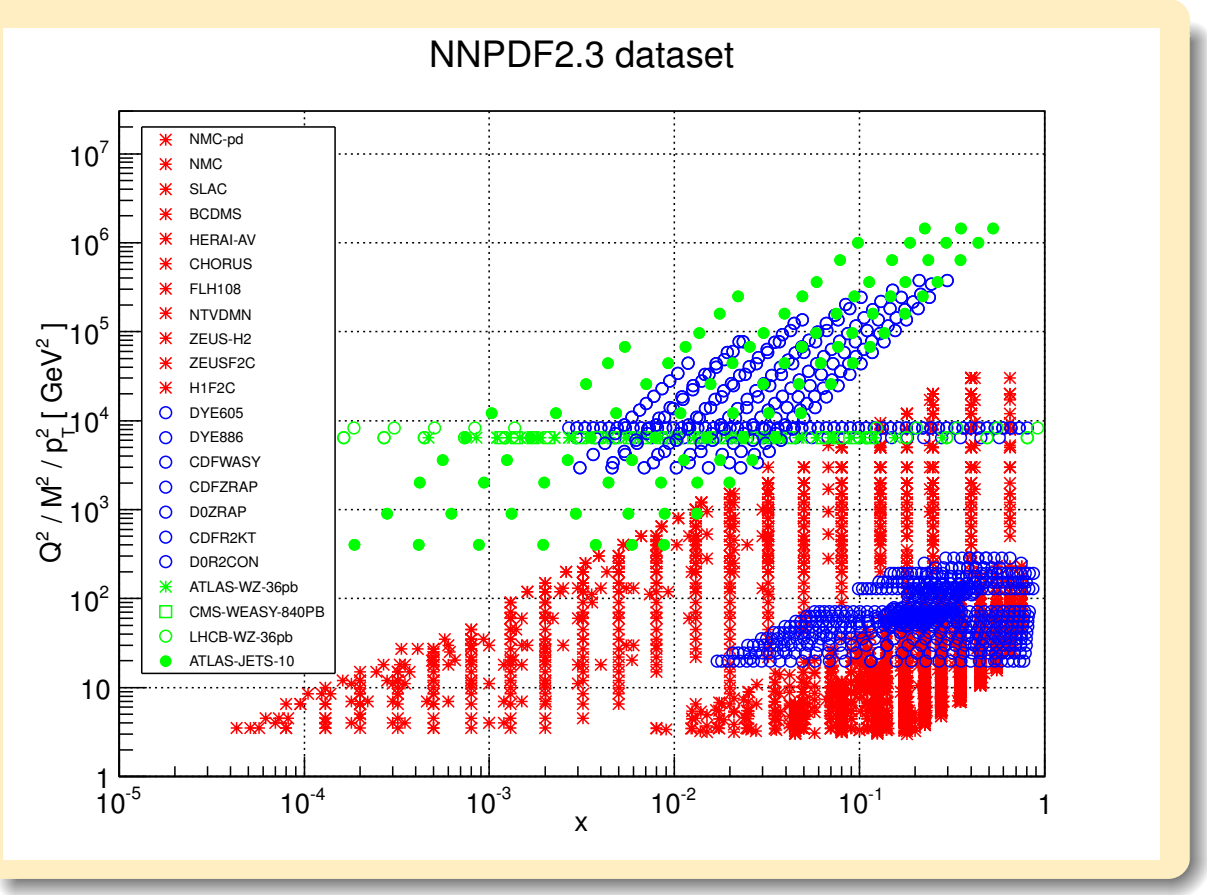
MC approach:

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

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

NNPDF2.3 dataset

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



ATLAS:

- inclusive jets
- W/Z lepton rapidity distributions

CMS:

- W lepton asymmetry

LHCb:

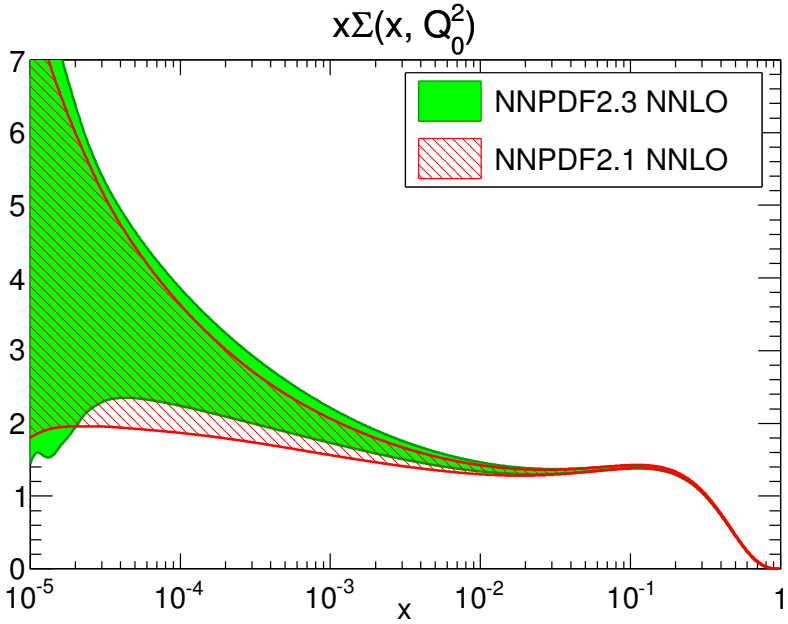
- W/Z rapidity distributions

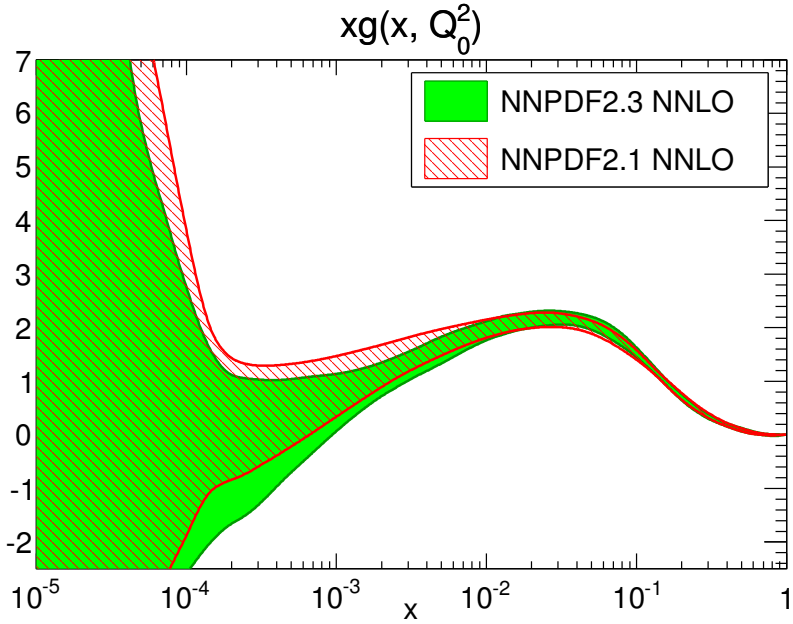
- **3506 data points** in the NNLO fit: **56** LHC W/Z, **90** LHC Jets

(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 $Q^2 = 2.0\,\mathrm{GeV}^2$:

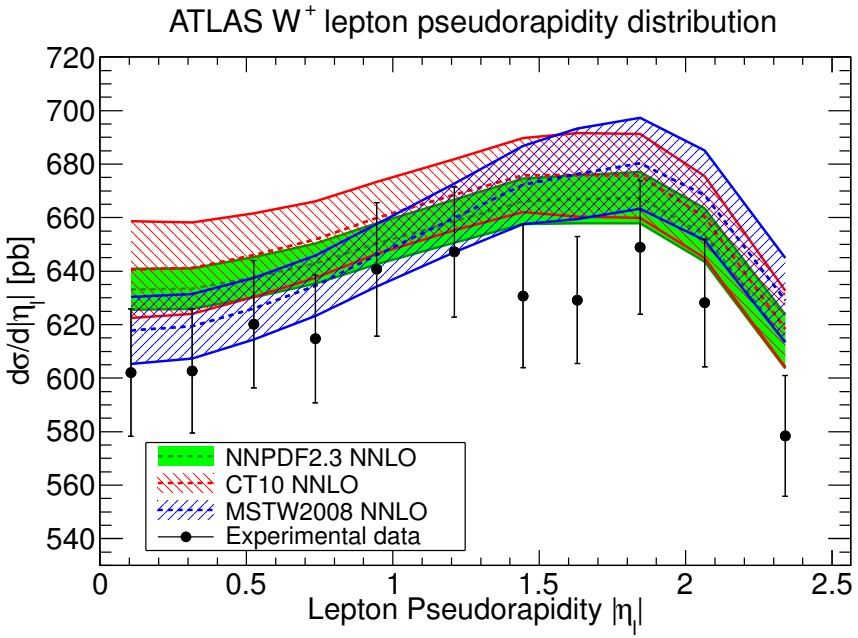


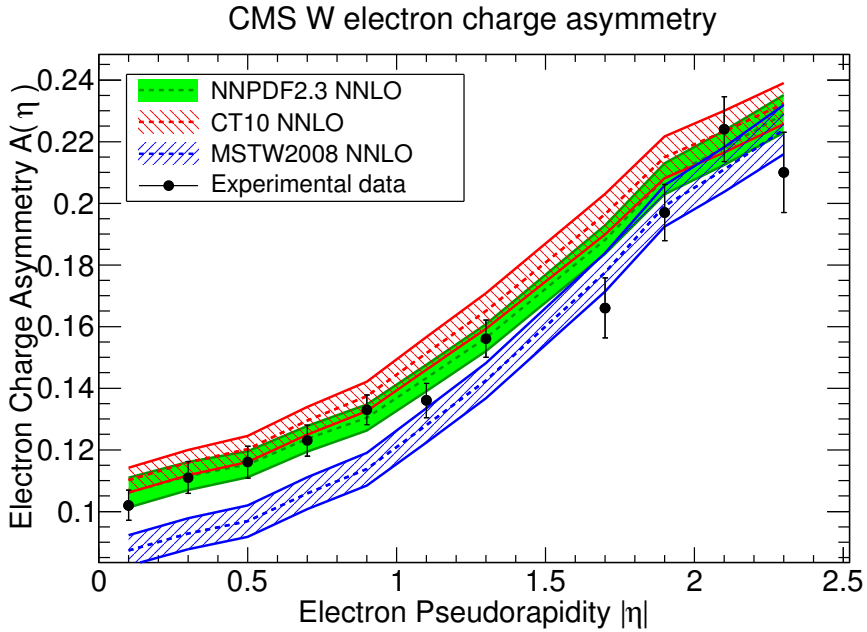


- **NNPDF2.1 = no LHC data**. Fit also available at NLO.
- LHC data reduces uncertainties and improves the χ^2:

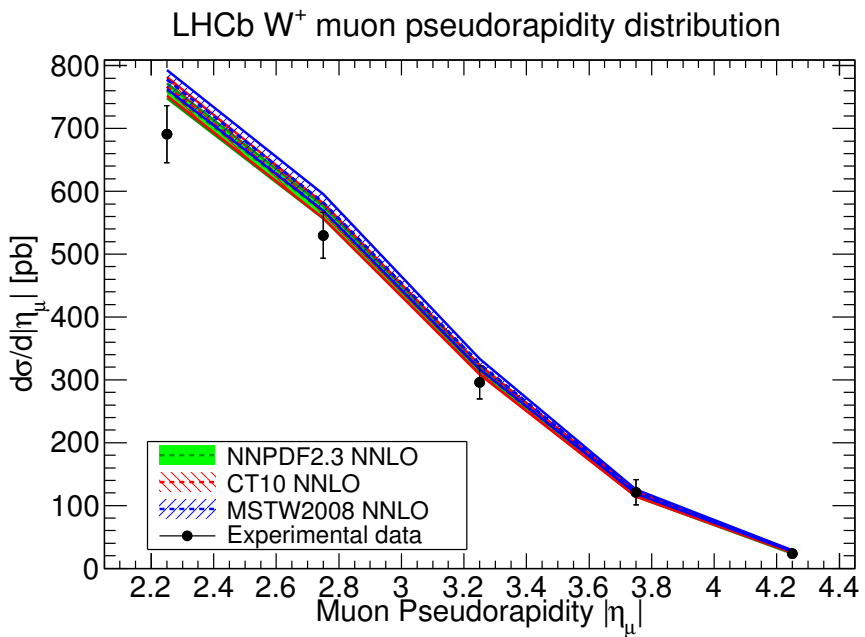
	NNPDF2.1		NNPDF2.3	
Order	NLO	NNLO	NLO	NNLO
Total χ^2	1.145	1.167	1.121	1.153

LHC observables (preliminary)





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**

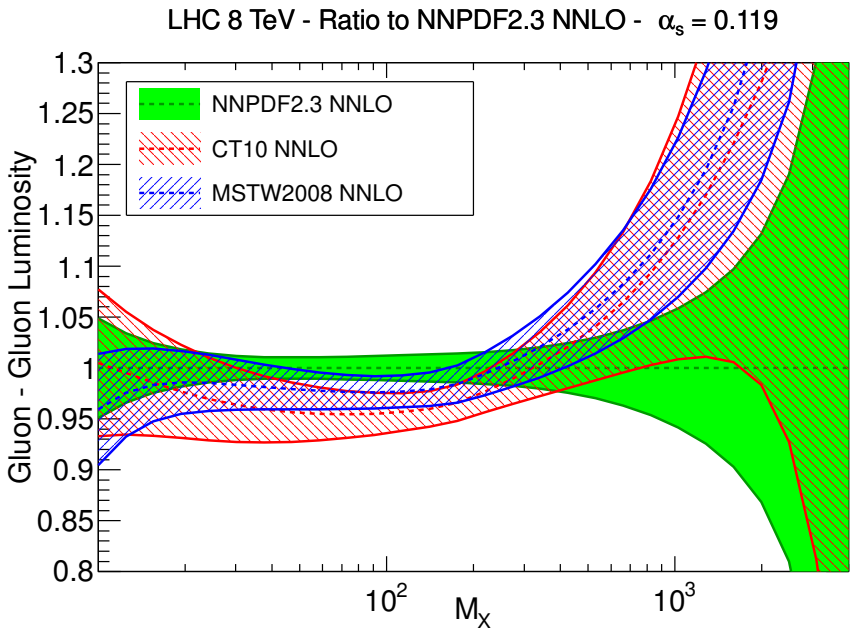


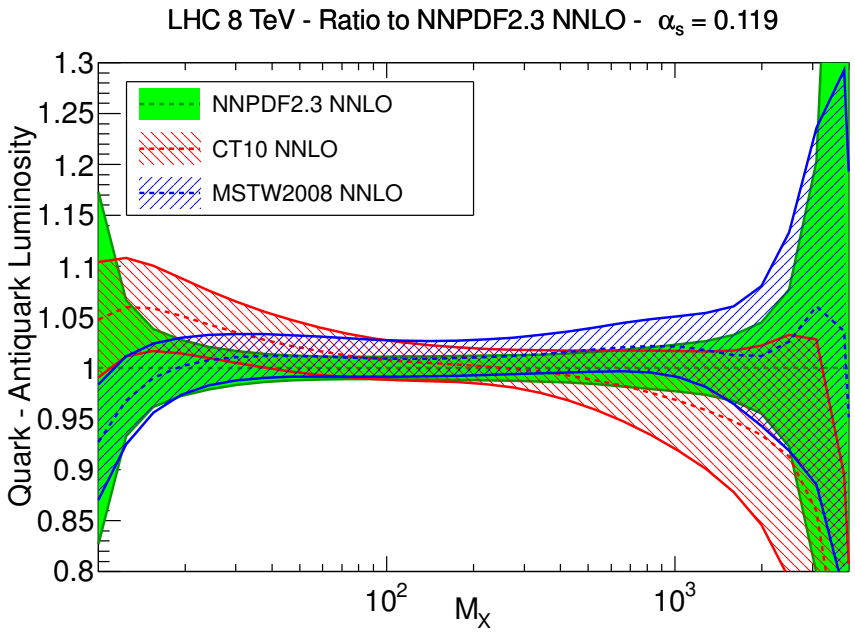
Luminosities (preliminary)

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)

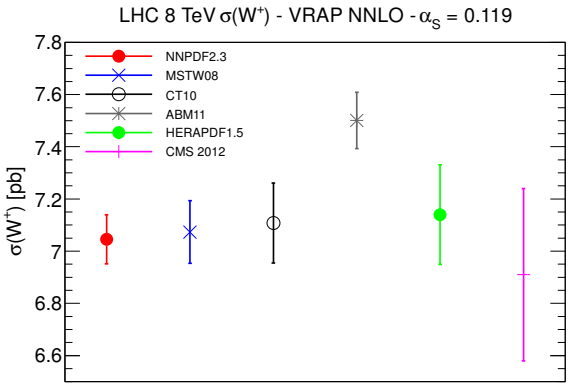


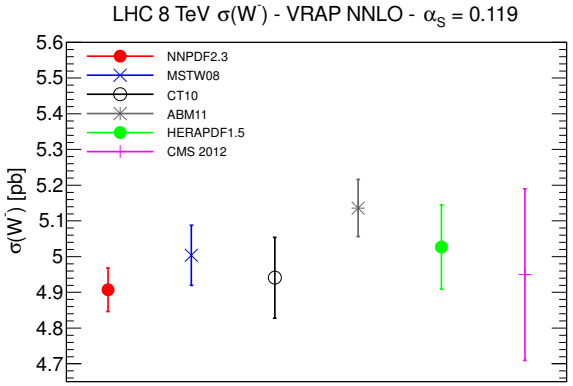


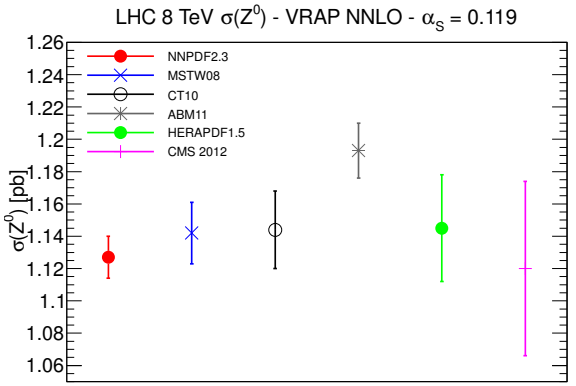
- All luminosities **are reasonably compatible** for between **global PDF sets**.

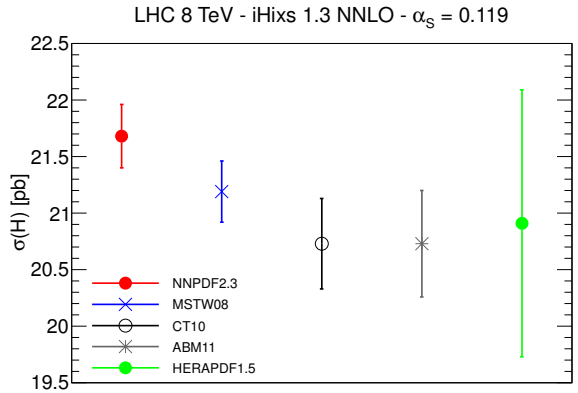
Phenomenology at 8 TeV (preliminary)

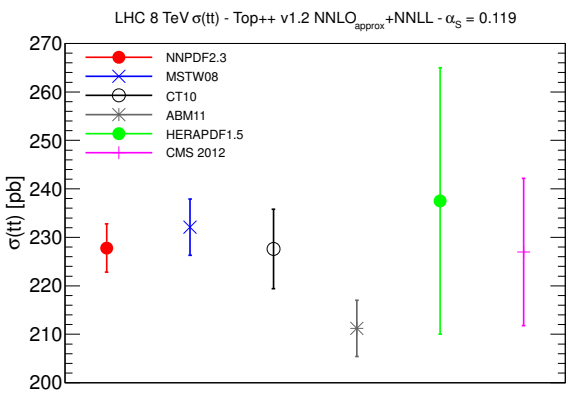
- Cross sections calculated with: Vrap, Top++, iHixs at 8 TeV.











- **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. Paper in preparation with all the benchmark comparison results, SC and Juan Rojo (CERN)
4. Invite you to try **NNPDF2.3**!

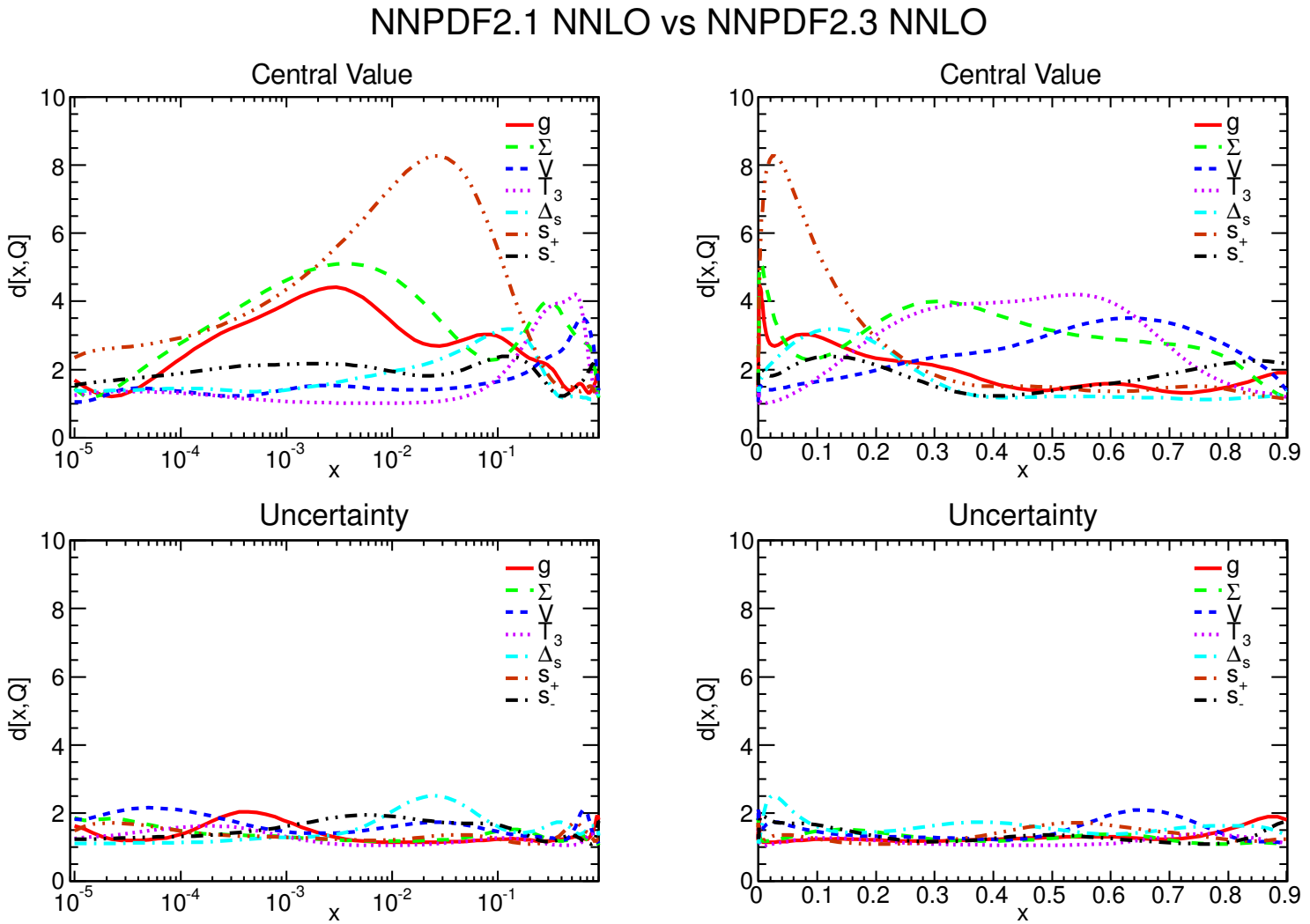
For further information, tutorials and Mathematica interface visit:

http://nnpdf.hepforge.org/

- Near future: EW corrections to PDFs...

BACKUP SLIDES

Distances between 2.3 and 2.1



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 (DYNNLO)
- NNLO corrections to inclusive JET implement using FastNLO (hep-ph/0609285)
  - approximated NNLO corrections based on threshold resummation.

Data sets

- 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

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

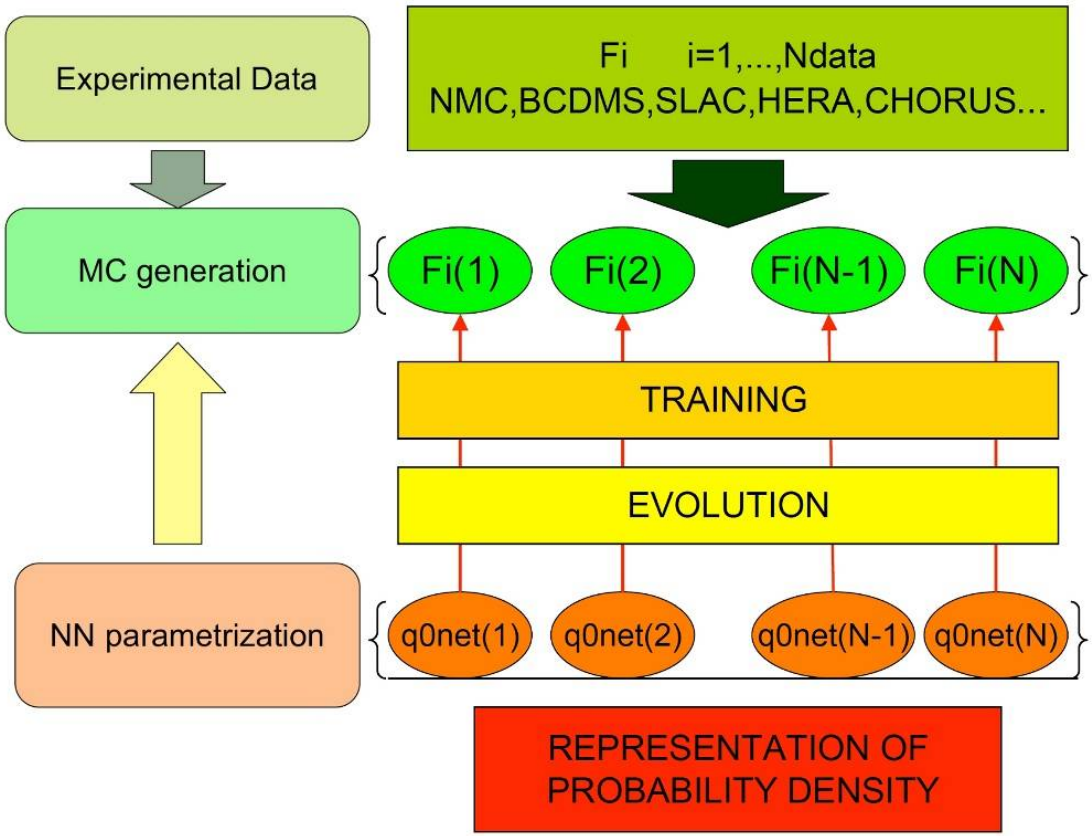
- LHCb W, Z rapidity distribution

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

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



MC generation

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

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

where r_k is the Gaussian random numbers, σ_N quadratic sum of normalization errors and σ_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