NNPDF2.3 Parton Distributions

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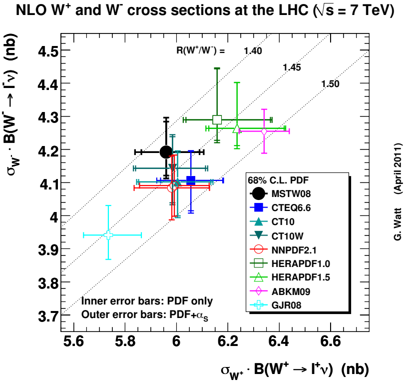
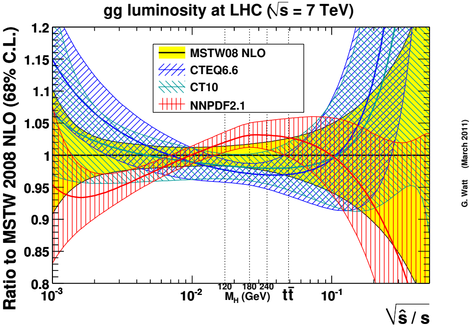
QCD 2012, Montpellier
Monday 2nd July 2012

Parton distributions for the LHC

$$\sigma_X = \sum_{a,b} \int_0^1 dx_1 dx_2 f_a(x_1, Q^2) f_b(x_2, Q^2) \sigma_{q_a q_b \to X} \left(x_1, x_2, Q^2\right)$$

- A reliable determination of parton distributions is vital for LHC physics.





G. Watt [hep-ph/1106.5788]

Parton distribution fitting

Standard approach

- Choose some functional form with a few free parameters for the PDFs at an initial scale, typically

$$f(x, Q_0^2) = ax^b(1-x)^c(1+...)$$

- Determine PDF uncertainties by linear error propagation, often with the use of a **tolerance** criterion.

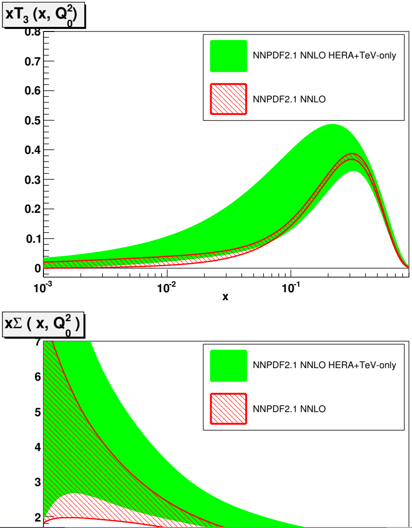
NNPDF approach

- Use of Neural Networks as unbiased and extremely flexible interpolators.
  - Each PDF has 37 free parameters to vary in the fit.
  - Total of 259 free parameters minimises parametrisation bias.
- Monte Carlo approach to uncertainty estimation.
  - Perform an independent NN fit upon an ensemble of artificial data sets.
  - Ensemble of PDF replicas faithfully represent the uncertainty in the original experimental data without the need for a tolerance criterion.

NNPDF collider only fits

Target: An NNPDF Fit based only upon collider data

- Free of contamination from higher twists
- No nuclear corrections required



Including new experimental data - reweighting

How can we add new LHC data to an existing parton set?

- Reweight existing Monte Carlo parton set.

Each replica in the set is assigned a weight based upon it's χ^2 to the new data.

$$\langle\mathcal{O}\rangle_{\mathrm{new}} = \frac{1}{N}\sum_{k=1}^{N} w_k \mathcal{O}[f_k], \qquad w_k \propto (\chi^2_k)^{(n-1)/2} e^{-\frac{1}{2}\chi^2_k}$$

- Application: NNPDF2.2 Parton Set [arXiv:1012.0836]
  LHC Electroweak data added by Bayesian Reweighting

However, reweighting method is impractical for large/constraining data sets.
Number of effective replicas reduced after reweighting:

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

Including new experimental data - refitting

How can we efficiently include LHC data into a full refit?
Tools: APPLgrid/FastNLO projects

- Precompute and store MC Weights on an interpolation grid

$$\sigma = \sum_p \sum_{l=0}^{N_{\mathrm{sub}}} \sum_{\alpha,\beta}^{N_x} \sum_{\tau}^{N_Q} W_{\alpha\beta\tau}^{(p)(l)} \left(\frac{\alpha_s\left(Q^2_\tau\right)}{2\pi} \right)^p F^{(l)}\left(x_\alpha, x_\beta, Q^2_\tau\right) \tag{1}$$

PDF Evolution in the FastKernel method is a similar procedure,

$$f_i(x_\alpha, Q^2_\tau) = \sum_\beta^{N_x} \sum_j^{N_{\mathrm{pdf}}} A^\tau_{\alpha\beta ij} N^0_j(x_\beta)$$

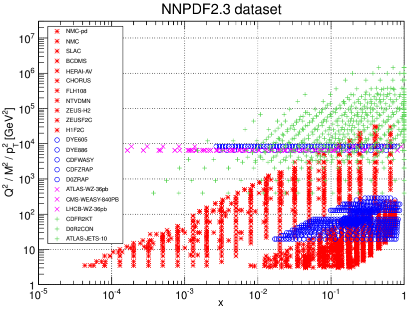
Idea: Combine weight grids with evolution grids

$$\sigma = \sum_{\alpha,\beta}^{N_x} \sum_{i,j}^{N_{\mathrm{pdf}}} \sigma_{\alpha\beta ij} N^0_i(x_\alpha) N^0_j(x_\beta)$$

- Precomputing all Q^2 dependence leads to extremely efficient calculations.

NNPDF2.3 - LHC Data

- The NNPDF2.3 dataset contains all LHC data with published correlation matrices
  - 36 pb^{-1} ATLAS Inclusive jet measurements [arxiv:1112.5141]
  - 35 pb^{-1} ATLAS W lepton and Z differential distributions [arxiv:1109.5141]
  - 37 pb^{-1} LHCb W lepton and Z differential distributions [arxiv:1204.1620]
  - 840 pb^{-1} CMS W electron asymmetry [arxiv:1206.2598]



Methodological Improvements

Improved dynamical stopping.
Expanded genetic algorithm minimisation.
Improved training/validation partitioning.

	NNPDF2.1		**NNPDF2.3**	
	NLO	NNLO	NLO	NNLO
Fit Quality	1.16	1.16	1.14	1.15

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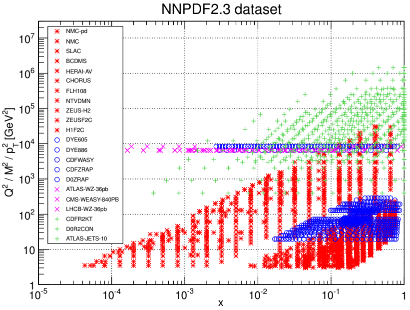

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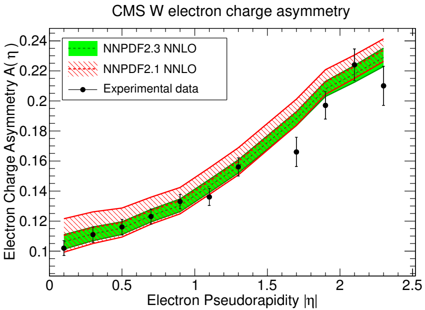
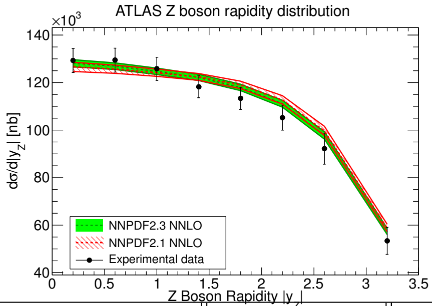
- Also in the NNPDF2.3 family
  - NNPDF2.3 noLHC: same dataset as NNPDF2.1, with improved methodology.
  - NNPDF2.3 Collider only: dataset restricted to HERA, Tevatron and LHC data.

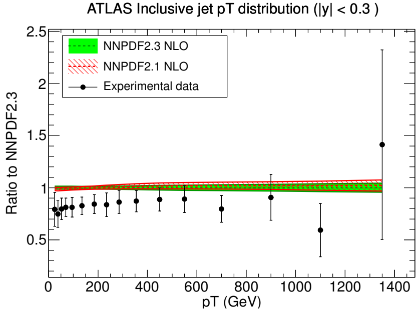
Impact of LHC EW vector boson data

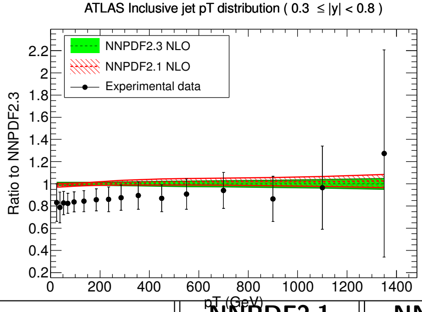




	NNPDF2.1	NNPDF2.3

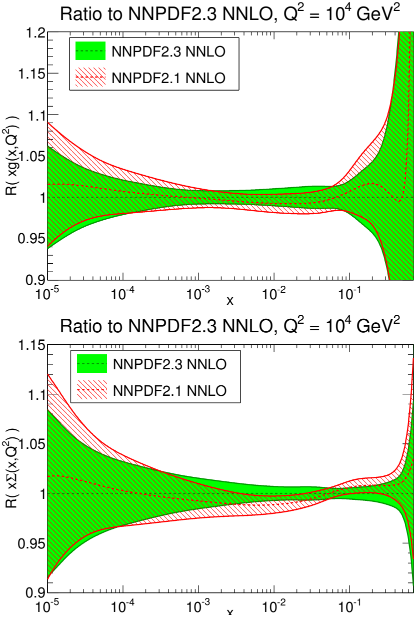
Impact of ATLAS inclusive jet data





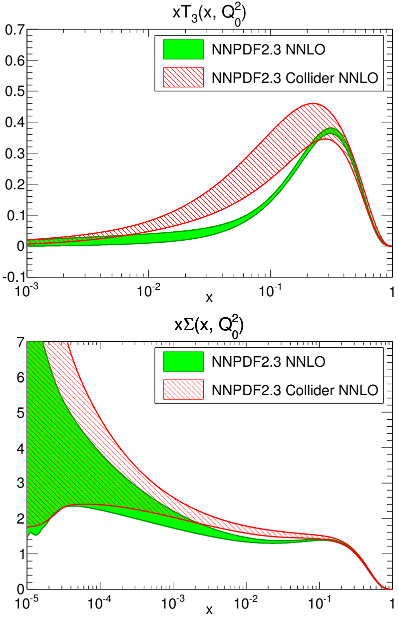
	NNPDF2.1	NNPDF2.3

NNPDF2.3 vs NNPDF2.1



PDF Uncertainty parton lumis - LHC 8 TeV - Ratio to NNPDF2.3 NNLO

Collider only PDFs with LHC data



Summary

LHC data in NNPDF2.3

- The NNPDF2.3 parton set is the new standard PDF set of the NNPDF collaboration.
- NNPDF2.3 provides a determination of parton distributions with a faithful representation of the experimental uncertainties, and without parametrisation bias.
- The FastKernel method is utilised to perform fully NLO QCD calculations, enabling the efficient inclusion of LHC electroweak boson production and inclusive jet datasets into an NNPDF fit.
- LHC data provides a valuable constraint upon PDFs, reducing the uncertainty in the gluon, and modifying the shape of the light quark pdfs.

BACKUPS

Determination of R_s

$$r_s(x, Q^2) = \frac{s(x, Q^2) + \bar{s}(x, Q^2)}{2\bar{d}(x, Q^2)}$$