Impact of LHC data on (NN)PDFs

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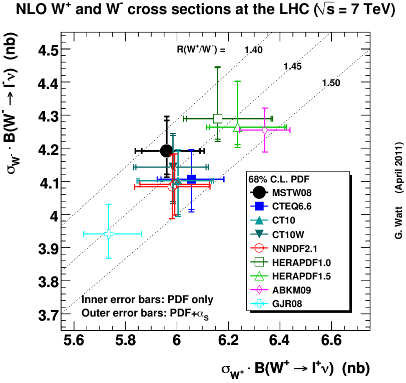
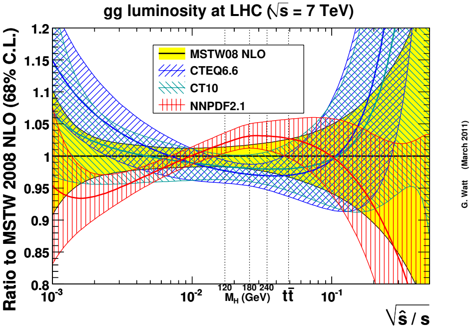
XLVInd Rencontres de Moriond
La Thuile, Aosta valley, Italy
March 10th -March 17th, 2012

Parton distributions for the LHC

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

- Need to have a reliable determination of PDFs for LHC physics.
- An accurate estimation of PDF uncertainties is crucial.



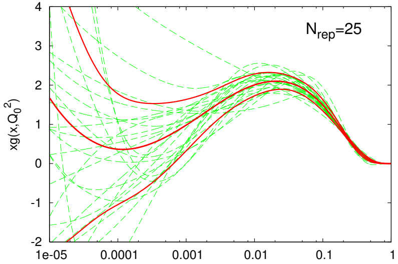


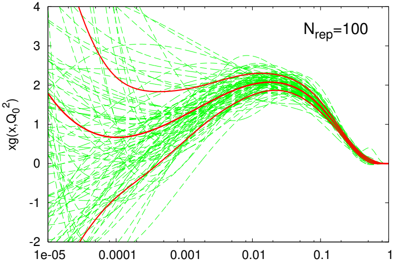
G. Watt [hep-ph/1106.5788]

NNPDF approach to parton fitting

- 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.

$$\langle \mathcal{O} \rangle = \frac{1}{N} \sum_{k=1}^{N} \mathcal{O}[f_k] \,. \qquad \mathrm{Var}[\mathcal{O}] = \frac{1}{N} \sum_{k=1}^{N} (\mathcal{O}[f_k] - \langle \mathcal{O} \rangle)^2 .$$

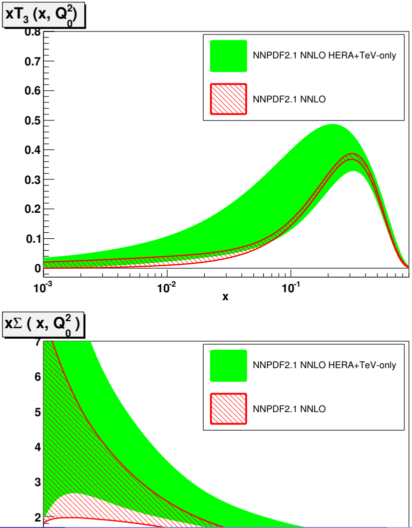




NNPDF collider only fits

Target: An NNPDF Fit based only upon collider data

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



Including new experimental data

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

- Full Refit

Tools: APPLgrid/FastNLO projects → MC Weights on an interpolation grid

$$W = \sum_p \sum_{l=0}^{n_{\rm sub}} \sum_{i_{y_1}} \sum_{i_{y_2}} \sum_{i_\tau} W^{(p)(l)}_{i_{y_1}, i_{y_2}, i_\tau} \left(\frac{\alpha_s\left(Q^{2^{(i_\tau)}}\right)}{2\pi} \right)^p F^{(l)}\left(x_1^{(i_{y_1})}, x_2^{(i_{y_1})}, Q^{2^{(i_\tau)}}\right)$$

Fast ... but can we get faster? → combine weight tables with FastKernel evolution:

$$E^\tau_{\alpha\beta jk} = \int_{x_\alpha}^1 \frac{dy}{y} \Gamma_{ij}\left(\frac{x_\beta}{y}, Q_0^2, Q_\tau^2\right) \mathcal{I}^{(\beta)}(y).$$

$$f_i(x_\alpha, Q_\tau^2) = \sum_j^{N_{\rm pdf}} R_{ij} N_j(x_\alpha, Q_\tau^2) = \sum_\beta^{N_x} \sum_{j,k}^{N_{\rm pdf}} R_{ij} E^\tau_{\alpha\beta jk} N_k^0(x_\beta).$$

Combined Weight-Evolution tables

- More of the calculation is precomputed
- Smaller flavour basis at initial scale

$$W = \sum_{\alpha,\beta}^{N_x} \sum_{i,j}^{N_{\rm pdf}} \sigma_{\alpha\beta ij} N_i^0(x_\alpha) N_j^0(x_\beta)$$

Including new experimental data

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

- Full Refit $\rightarrow$ Work in progress!
- Reweight existing Monte Carlo parton set. Giele, Keller [hep-ph/9803393]

If the new data is statistically independent of the data in the prior set:

$$\mathcal{P}_{\rm new}(f) = \mathcal{N}_\chi \mathcal{P}(\chi^2|f)\,\mathcal{P}_{\rm old}(f),$$

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

Weights determined by statistical inference

$$w_k = \mathcal{N}_\chi \mathcal{P}(\chi^2|f_k) = \frac{(\chi^2_k)^{(n-1)/2} e^{-\frac{1}{2}\chi^2_k}}{\frac{1}{N}\sum_{k=1}^{N}(\chi^2_k)^{(n-1)/2} e^{-\frac{1}{2}\chi^2_k}}\,.$$

Number of effective replicas reduced after reweighting:

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

R. D. Ball *et al.* Nucl. Phys. B **849** 112 [arXiv:1012.0836].

Application: NNPDF2.2 Parton Set .

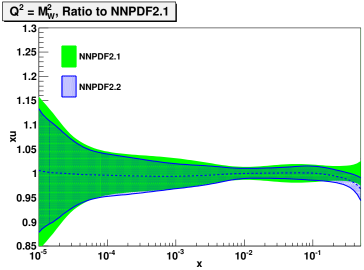
New data added by reweighting NNPDF2.1 Fit: W leptonic charge asymmetry.

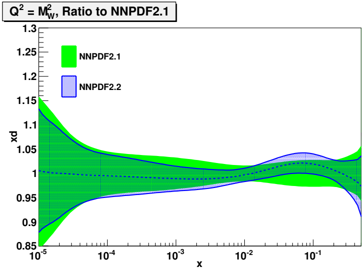
R. D. Ball *et al*, Nucl. Phys. B **855** 608 [arXiv:1108.1758] .

Defined in terms of $W^{\pm} \to l^{\pm}\nu_l$ differential cross-sections $d\sigma_{l^{\pm}}/d\eta_l$

$$A_W^l = \frac{d\sigma_{l^+}/d\eta_l - d\sigma_{l^-}/d\eta_l}{d\sigma_{l^+}/d\eta_l + d\sigma_{l^-}/d\eta_l},$$

- ATLAS μ charge asymmetry. [arXiv:1103.2929]
- CMS $e+\mu$ charge asymmetry. [arXiv:1103.3470]
- D0 $e+\mu$ charge asymmetry. [arXiv:0709.4254]





Updated LHC Data

- LHC data in NNPDF2.2 now superseded
  - Full covariance matrix available for the ATLAS W and Z rapidity distributions.
  - Higher integrated luminosity 234 pb^{-1} data for CMS muon asymmetry.
- Additional LHC Data
  - 36 pb^{-1} Inclusive jet measurements (Full covariance matrix for ATLAS).
  - 36 pb^{-1} LHCb Z rapidity distribution, W lepton asymmetry.
  - 840pb^{-1} CMS W electron asymmetry with full covariance matrix.
  - 4.67fb^{-1} CMS Inclusive jet measurement.

χ^2 to electroweak vector boson production data

Dataset , χ^2	NNPDF2.1	MSTW08	ABKM09	JR09	HERAPDF1.5
ATLAS W/Z Rapidity	2.7	3.6	3.6	5.0	2.0
CMS μ asym + Z Rap	2.0	3.0	2.8	3.6	2.8
LHCb W asym + Z Rap	0.8	0.7	1.2	0.4	0.6

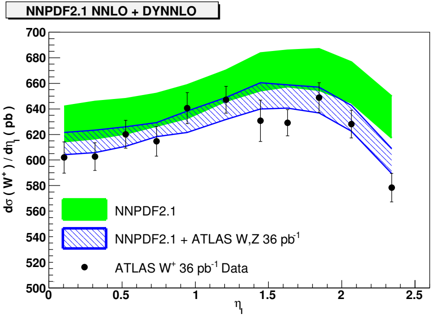
χ^2 to inclusive jet data

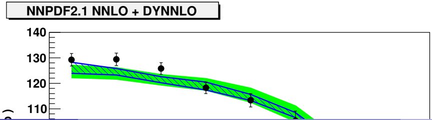
Dataset, χ^2	NNPDF2.1	MSTW08	ABKM09	JR09	HERAPDF1.5
ATLAS Incl. Jets $R = 0.4$	0.93	1.18	1.41	1.63	1.21
ATLAS Incl. Jets $R = 0.6$	1.38	1.31	1.46	1.88	1.43

Impact of LHC EW vector boson data - ATLAS

Preliminary reweighting results

Dataset	χ^2	$\chi^2_{\rm rw}$	$N_{\rm eff}$
ATLAS	2.7	1.2	16
ATLAS W^+ 36 pb^{-1}	5.7	1.5	17
ATLAS W^- 36 pb^{-1}	2.5	1.0	205
ATLAS Z 36 pb^{-1}	1.8	1.1	581

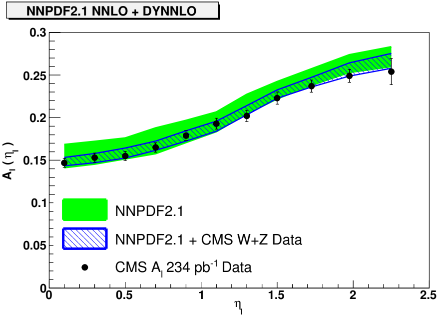


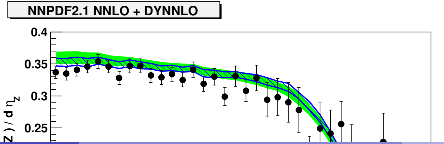


Impact of LHC EW vector boson data - CMS

Preliminary reweighting results

Dataset	χ^2	$\chi^2_{\rm rw}$	$N_{\rm eff}$
CMS	2.0	1.2	56
CMS Z rapidity 36 pb^{-1}	1.9	1.4	223
CMS muon asymmetry 234 pb^{-1}	2.0	0.4	200

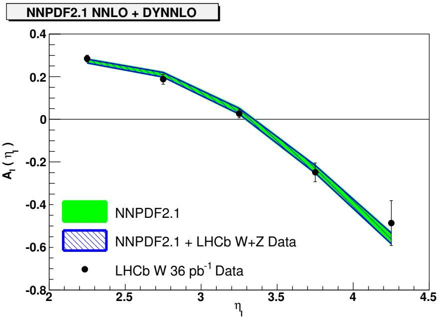


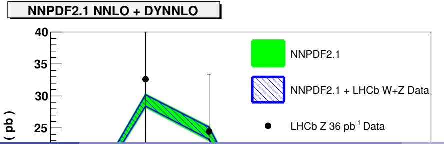


Impact of LHC EW vector boson data - LHCb

Preliminary reweighting results

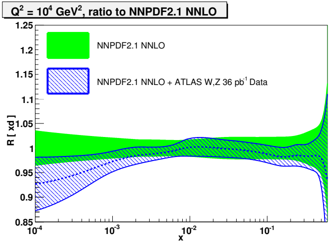
Dataset	χ^2	χ^2_{rw}	N_{eff}
LHCb	0.8	0.8	972
LHCb Z rapidity 36 pb^{-1}	1.1	1.0	962
LHCb W lepton asymmetry 36 pb^{-1}	0.8	0.5	961

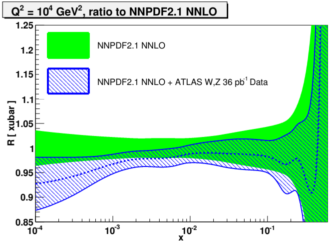




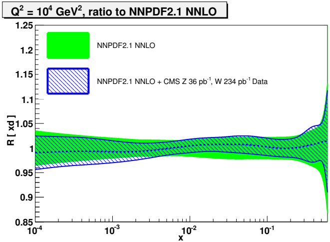
Impact of LHC EW vector boson data

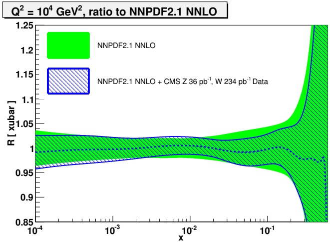
Ratio of d, $\bar{u}$ PDFs reweighted with ATLAS data to NNPDF2.1





Ratio of d, $\bar{u}$ PDFs reweighted with CMS data to NNPDF2.1

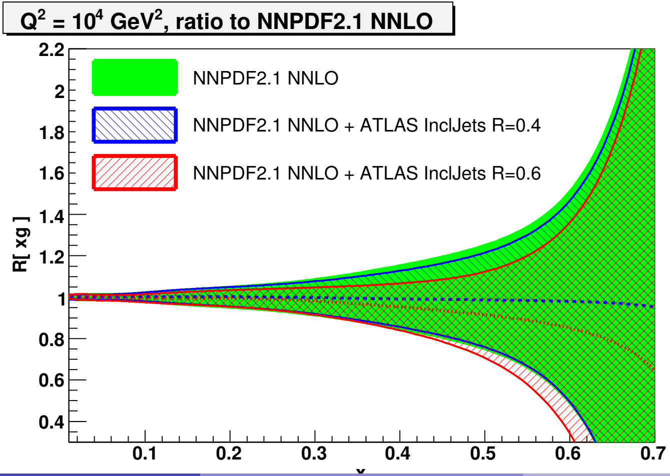




Impact of ATLAS inclusive jet data

Preliminary reweighting results

Dataset	χ^2	χ^2_{rw}	N_{eff}
NNPDF2.1 NNLO + ATLAS Incl. Jets $R = 0.4$	0.93	0.91	904
NNPDF2.1 NNLO + ATLAS Incl. Jets $R = 0.6$	1.42	1.24	610



Summary

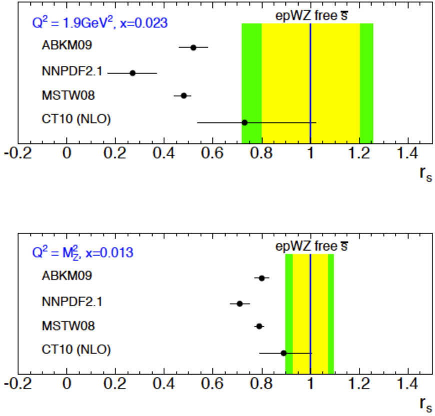
- NNPDF Parton Sets
  - Neural Network parametrisation of PDFs.
    Redundant parametrisation for an unbiased fit.
  - Monte Carlo uncertainty determination.
    Faithful representation of the experimental uncertainties.
- Bayesian Reweighting
  - Powerful technique for including new data into existing parton fits.
    Fast assessment of data impact.
- Impact of LHC data
  - ATLAS W/Z measurements:
    Substantial constraints, particularly from W^+ data.
  - CMS W/Z measurements:
    Less constraining $\rightarrow$ full covariance matrix is unavailable.
  - LHCb W/Z measurements:
    Data does not yet provide significant constraint upon PDFs.
  - ATLAS inclusive jet measurements:
    Moderate constraint upon gluon PDF.

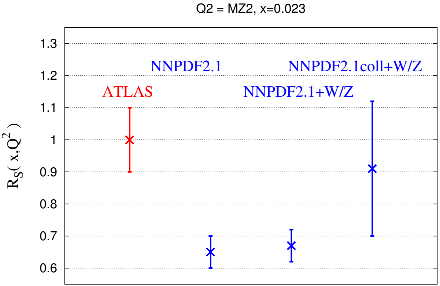
LHC data already providing significant constraints on parton distributions.

BACKUPS

ATLAS Determination of R_s

Ratio of strange to non-strange PDFs from a HERA + ATLAS W/Z production fit.





- No discrepancy observed with Rs for NNPDF collider +W/Z only fit

NNPDF2.1NLO/NNLO reweighted with ATLAS jets