PDF benchmarking for precision physics

S. Glazov, 18 Dec 2019, LHC EW meeting

Motivation: sin2 thetaW using different PDFs

	CT10	CT14	MMHT14	NNPDF31
$\sin^2\theta^{\ell}_{\mathrm{eff}}$	0.23118	0.23141	0.23140	0.23146
	Uncertainties in measurements			
Total	39	37	36	38
Stat.	21	21	21	21
Syst.	32	31	29	31

- ATLAS preliminary measurement of sin2 thetaW shows visible PDF dependence
- Do we need to take the difference in results as an extra uncertainty ?

Alternative experimental analyses

The situation is very similar to a typical experimental measurement in which multiple approaches can be used for analysis of the same quantity, e.g.

- Alternative selection criteria (“cut variation”)
- Alternative MC for corrections
- Alternative analyses strategies, different groups.

Normal experimental procedure would be to

- Check consistency of the approaches (need to know uncorrelated error). If measurements are
  - consistent: pick the best, or combine (if correlation can be trusted)
  - Inconsistent: continue working. In extreme undesirable cases take difference as an extra uncertainty (“two point uncertainty”)

→ Understanding of the correlations is essential to measure consistency

Correlations for PDF

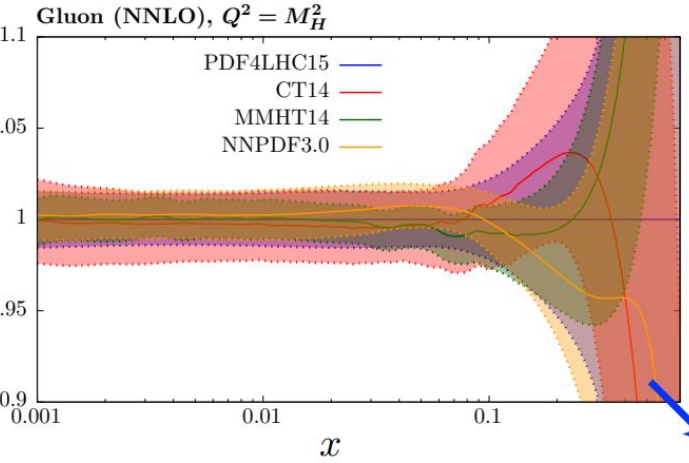
PDFs determined by different groups (ABMP, CTEQ-TEA, MMHT, NNPDF, ...) are expected to be correlated due to:

- Common data samples used (e.g. HERA combined data)
- Similar theory predictions (NNLO DGLAP, NNLO coefficient functions, often identical APPLgrids)

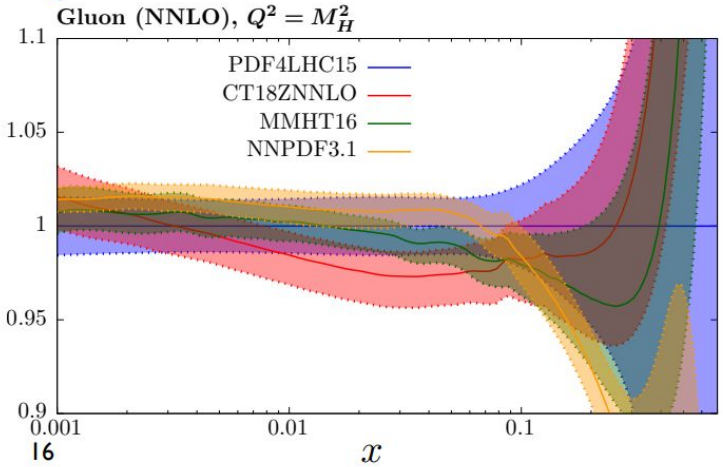
However, there are significant differences due to:

- Different parameterisation, minimization procedure/loss function (NNPDF), different assumptions for poorly constraint PDFs
- Different input data, data tension treatment (e.g. dynamic tolerance)
- Different theory predictions (e.g. FFNS of ABMP, resummation corrections), different theory uncertainty treatment

Towards PDF4LHC20



- Spread between groups has in some regions **increased**! Not always straightforward picture of ever decreasing PDF errors.



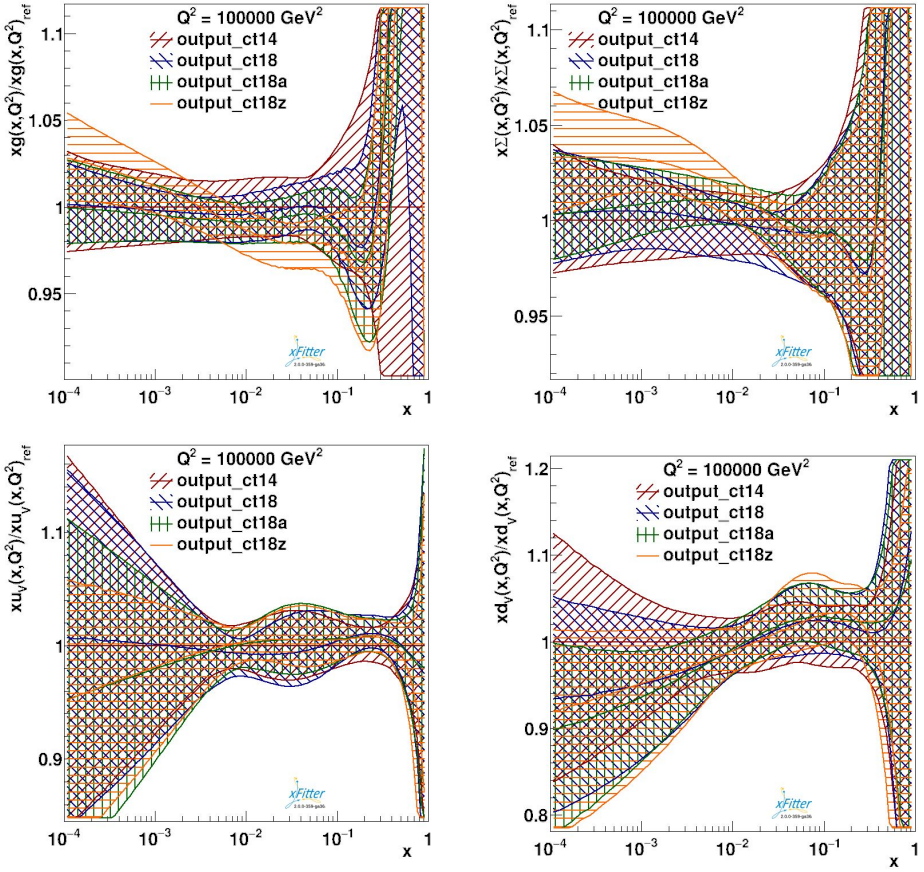
- To understand this: detailed **benchmarking** + combination essential (and planned).
- Note: updated 'MMHT19' release coming soon.

L. Harland-Lang, UPHC workshop

16

- Extensive benchmarking studies for PDF4LHC15 combination, lead to convergence of the predictions for gluon PDF
- With new developments results from different groups seem to start diverging again

CTEQ-TEA18 sets



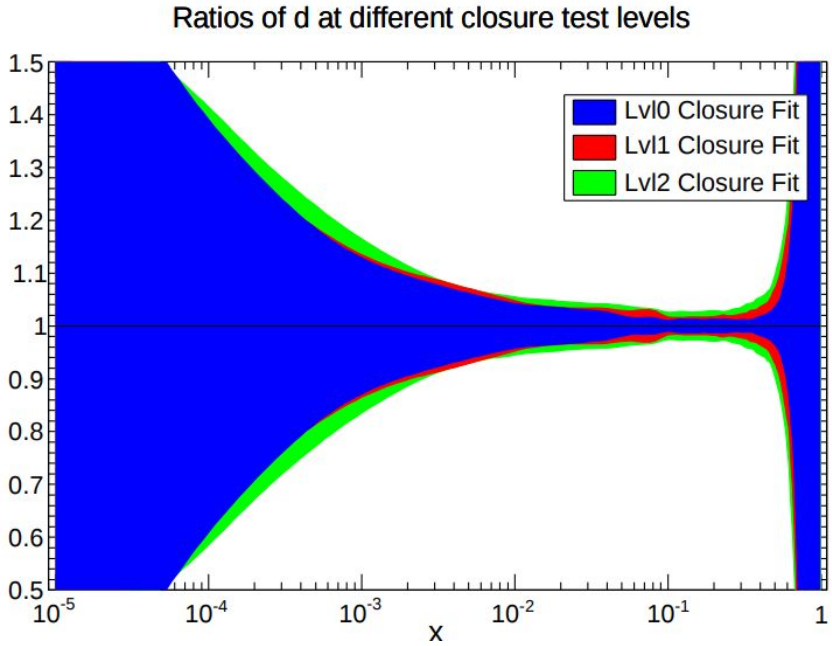
Significant vs uncertainties variation of PDFs within CT18 analysis:

CT18Z differs from CT18 by:

- Addition of ATLAS 7 TeV W/Z data and removal of CDHSW data
- Different m_c = 1.4 vs m_c=1.3 (suppresses charm vs u)
- Different factorisation scale for low x DIS (“effective resummation”, affects gluon/sea ratio)

arXiv:1908.11394

NNPDF3.0 closure tests



arXiv:1410.8849

Extensive test of PDF uncertainty decomposition by NNPDF using “closure tests”.

- Closure L0 test uses ideal data, probes extrapolation uncertainties/information loss
- Closure L1 test fits to fluctuated data, probes additional parameterisation uncertainties
- Closure L2 test emulates full NNPDF procedure, probes additional data uncertainties

“An important general conclusion is that data uncertainties are not dominant anywhere, and thus a PDF determination that does not include the extrapolation and functional components will underestimate the overall PDF uncertainty”

Probing the correlation

- Correlations due to common data used in the PDF analyses can be probed using toy MC method: same toys to be used by different PDF groups, to measure the correlation of the central fits.
- Increased tolerances can be also accommodated in toy MC method.
- One can start with the data samples with the most constraining power on PDFs: HERA combined, DY from fixed target, LHC and Tevatron → set to be defined soon.
- However since significant “extrapolation” uncertainty is driven by uncertainties in the flavour decomposition (since data are sensitive to particular flavour combinations), a care is needed to take sufficient data sample.

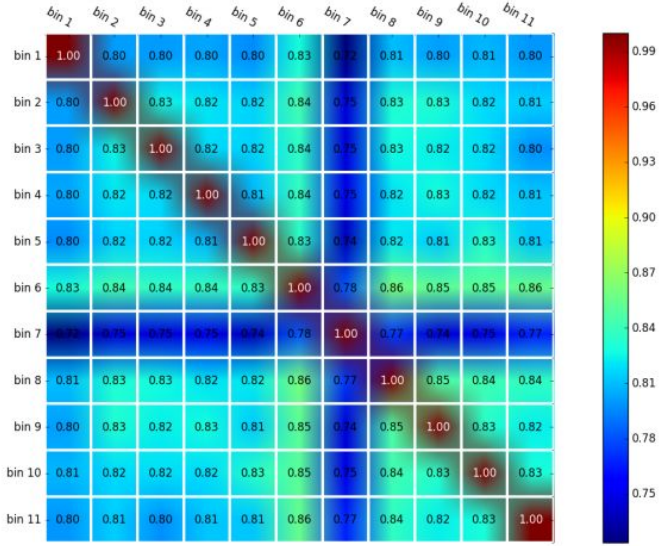
Tools for the correlation measurement

- Use xFitter as a baseline tool for toy generation
  - Large database of included processes (several missing sets, e.g. LHCb DY added for the test)
  - Toy generation built in for both nuisance parameter and covariance matrix-based uncertainties
  - Common data format for different samples, known to PDF groups
- Prepare scripts for toys generation and validation. Store the toys in a common repository
- Together with PDF groups, prepare scripts to convert toys for fits
- PDF groups are to perform fits using toys (central fit only)

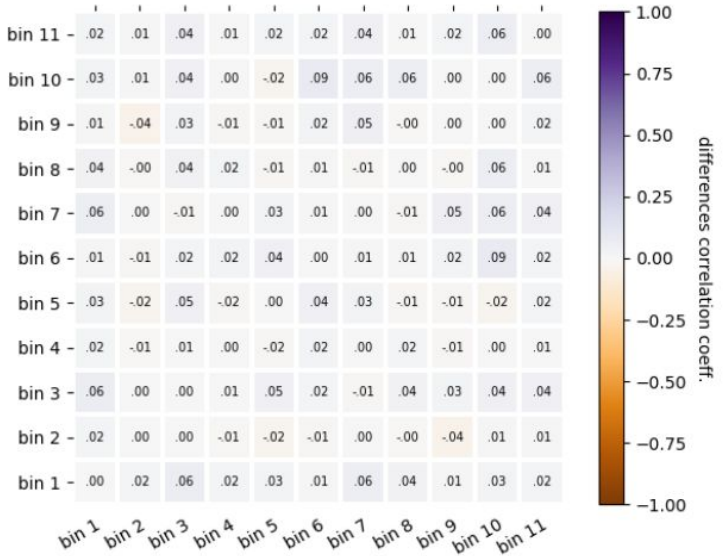
Validation of the toys

From ATLAS 1612.03016

Covariance matrix from the toys



Difference covariances from the data uncertainties and as built from the toys



S. Amoroso, S. Mikhalcov, V. Novik (LHC EW, 1 July 2019)

Status

- Validated toys for ATLAS W/Z 2011, HERA-combined data. Other DY data to be added.
- Toys converted to CT format, validated for HERA data. Will run tests using existing toys over the holiday break
- Conversion tool for HERA for ABM is provided
- MMHT converges on the final fit configuration, will run using toys after that

→ Hope to have first go through the complete procedure for CT by the end of the year. This will check technical details of the procedure.

Next steps

- Extend the toy sample from “testing” to “minal required”
- Fits for all PDF groups (ABM, CT, MMHT, NNPDF, ...)
- Data replicas are to be stored publicly, to measure correlations vs existing sets
- Possibly a “methodological” publication based on first results using minimal required data set.