PDF Benchmarking

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I will discuss potential PDF benchmarking, outlining current exercises ongoing.

All discussions based on most recent sets, NNPDF3.1, CT18, MSHT2020 (PDFs final - article imminent), along with ABMP16 and HERAPDF2.0.

Updates due to inclusion of new, largely LHC (different amounts and choices for different groups) but also some HERA, Tevatron, data sets.

New PDF4LHC Benchmarking exercise

Fit to a subset of data such that all groups (CT, MSHT, NNPDF) fit it (very largely) the same way.

Make definition flexible enough that a decent set of constraints on all PDF flavours and combinations is achieved.

Use most conservative cuts applied by any group – avoid most questionable kinematic regions.

Overall list is surprisingly small.

Many data sets fit in some non-trivially different manner by one or all groups.

Many data sets only fit by two groups or even one.

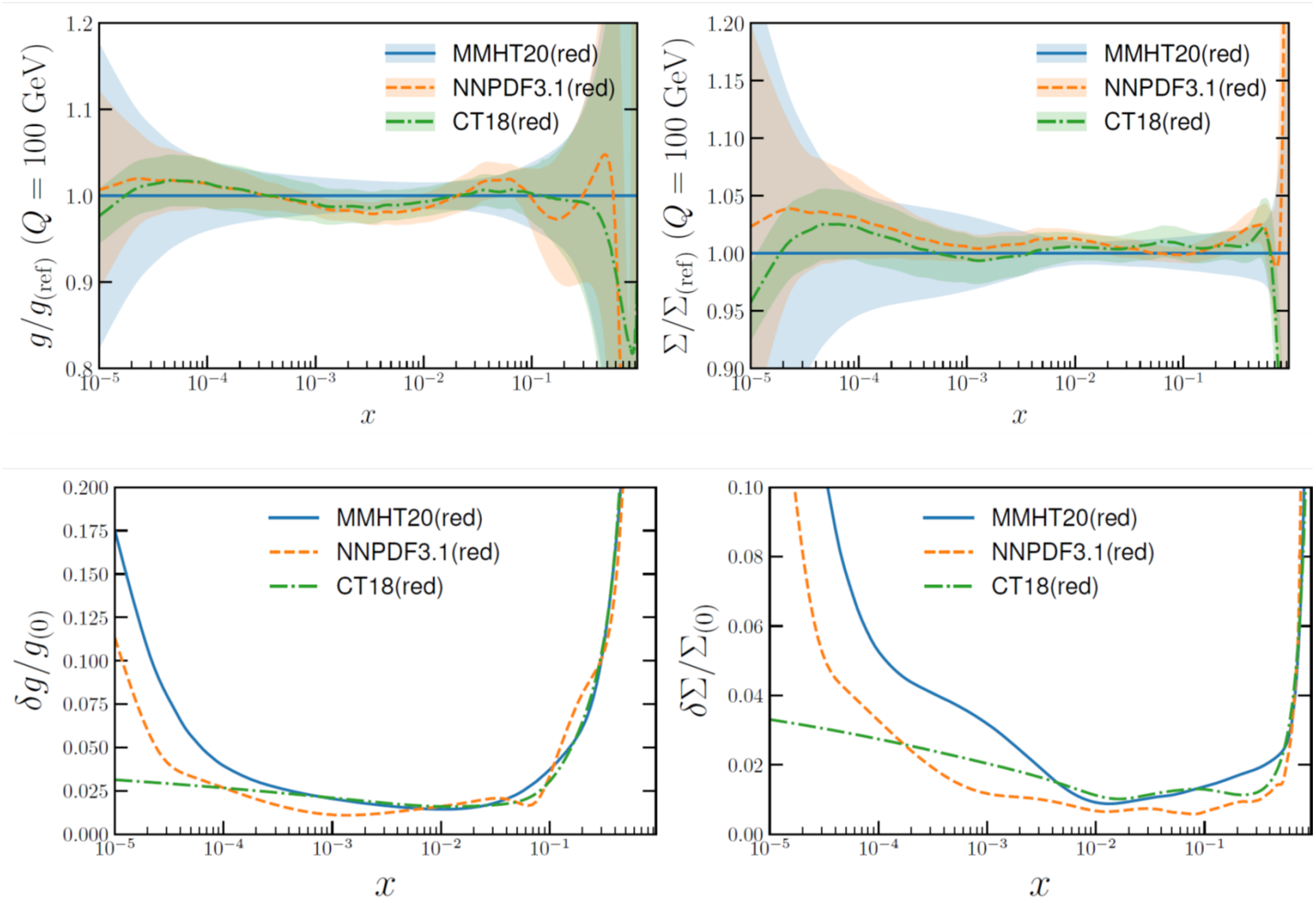
- NMC deuteron to proton ratio in DIS.
- NuTeV dimuon cross sections.
- HERA I + II inclusive cross sections from DIS.
- E866 fixed target Drell-Yan pd/pp data.
- D0 Z rapidity distribution.
- ATLAS W, Z 7 TeV rapidity distributions, only Z peak and not forward rapidity.
- CMS 7 TeV W asymmetry.
- CMS 8 TeV inclusive jet data.
- LHCb $7, 8$ TeV W, Z rapidity distributions.
- BCDMS proton and deuteron DIS (MSHT use averaged data).

Set as many theoretical procedural choices the same as possible. Again, can differ between groups.

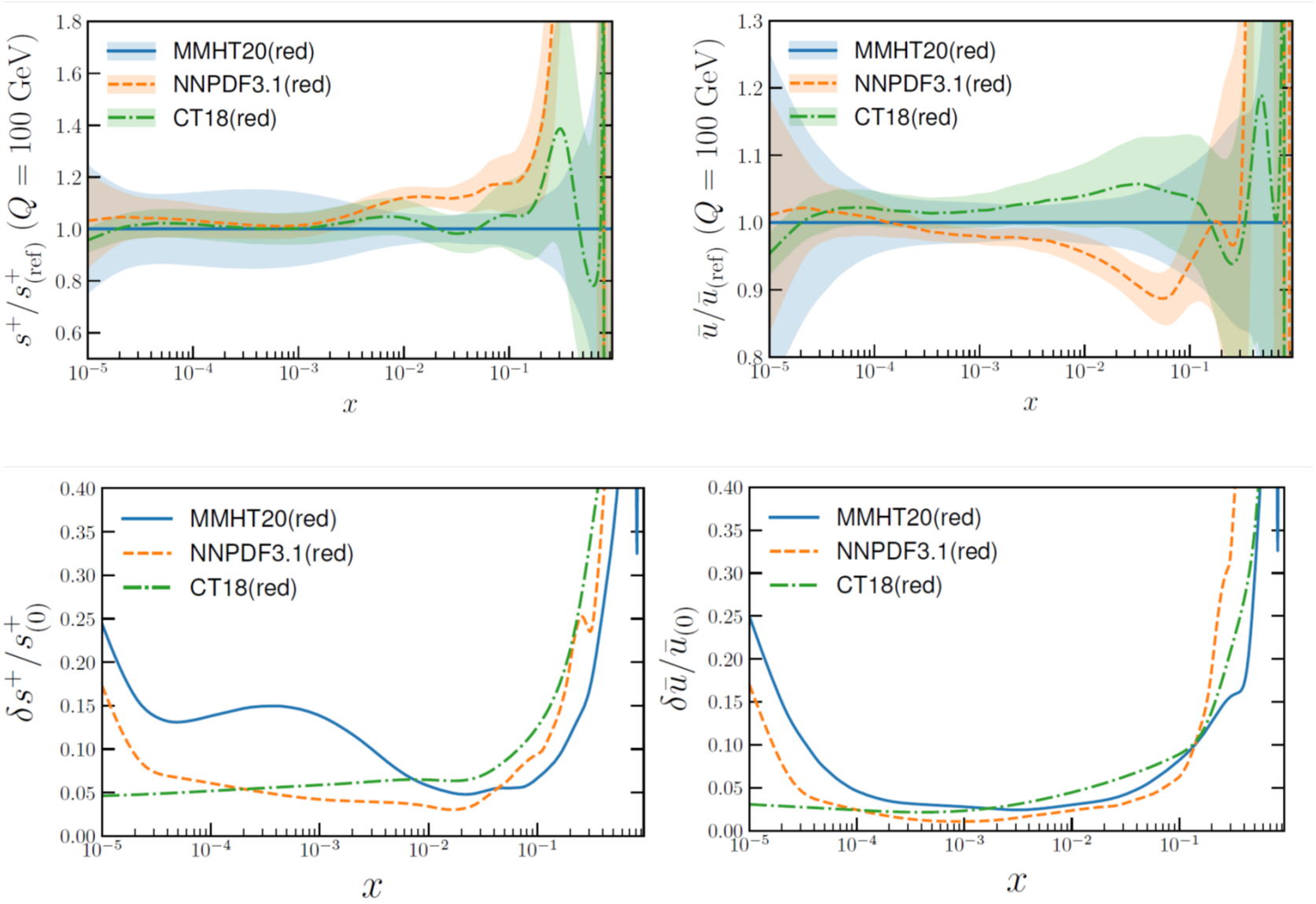
- $s - \bar{s} = 0$
- Perturbative charm only.
- Positive definite quark distributions (lack of constraints allow negative fluctuations).
- Common values of
- No deuteron or nuclear corrections.
- Fixed branching ratio for charm hadrons $\rightarrow$ muons.
- NNLO corrections for dimuon data.

Note this is for simplicity and these are not fully the defaults of any group, or indeed, always recommended practice in a global fit.

PDF comparison in reduced fits

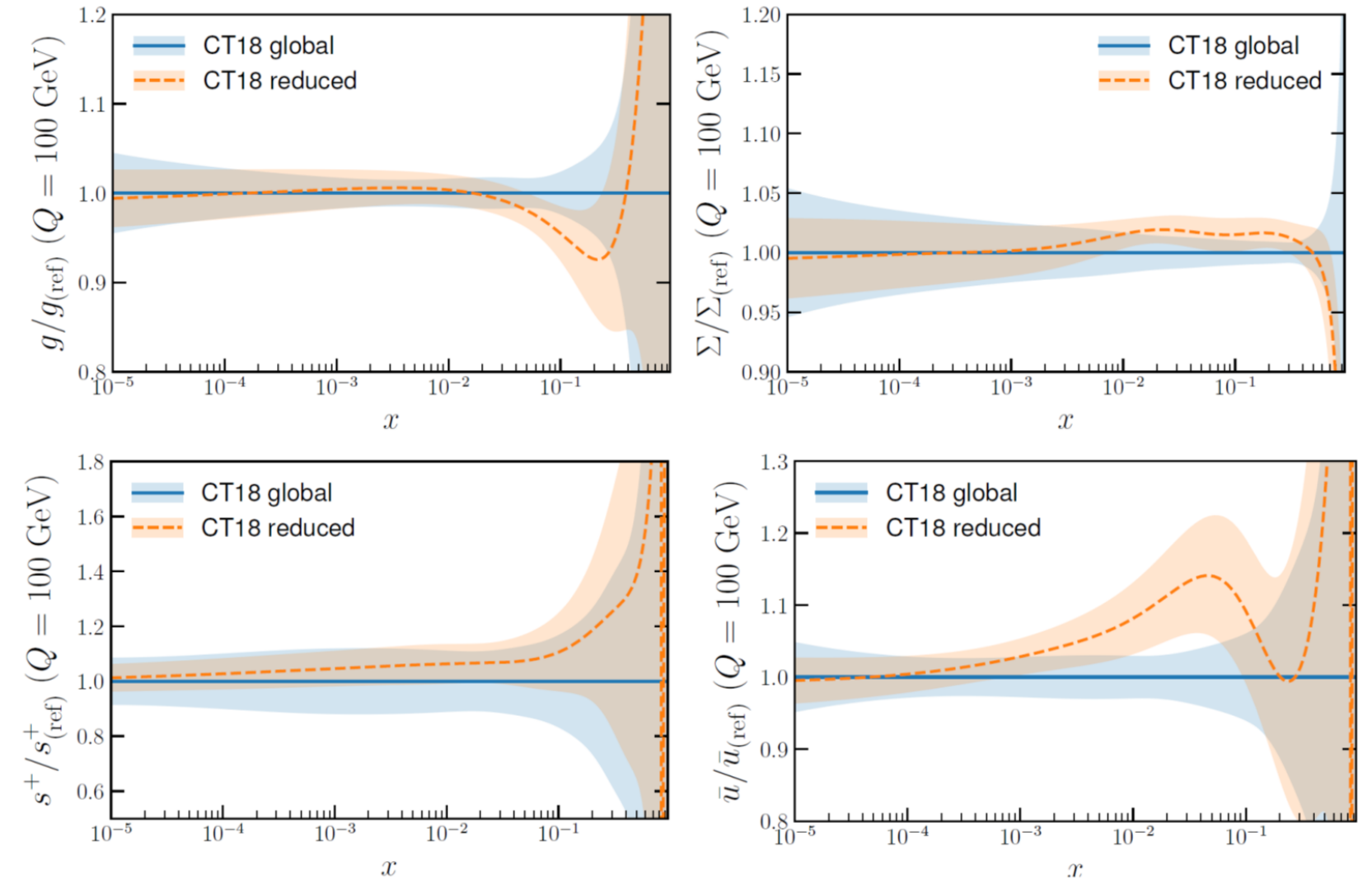


Plots from J. Rojo.



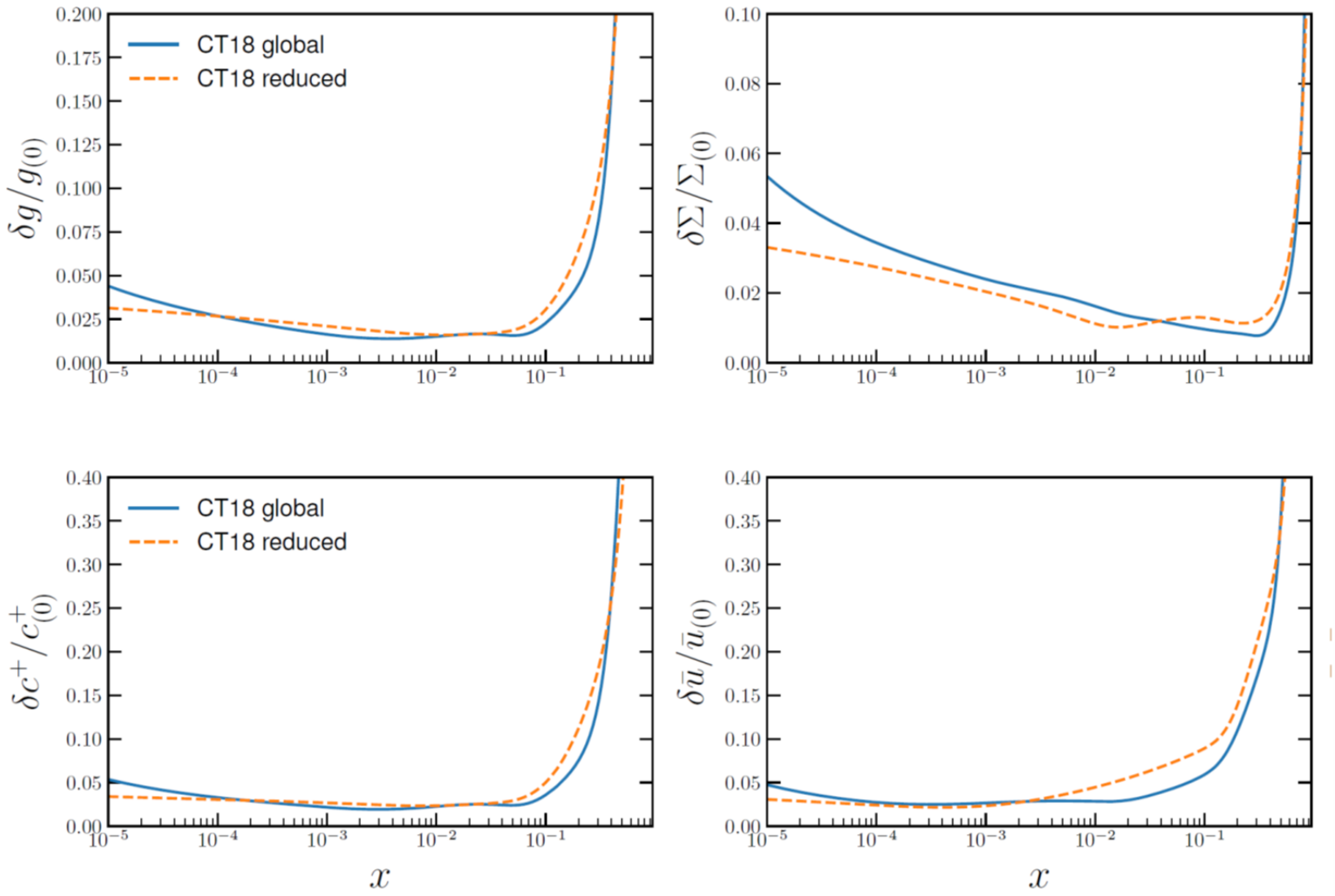
Plots from J. Rojo.

CT18 changes



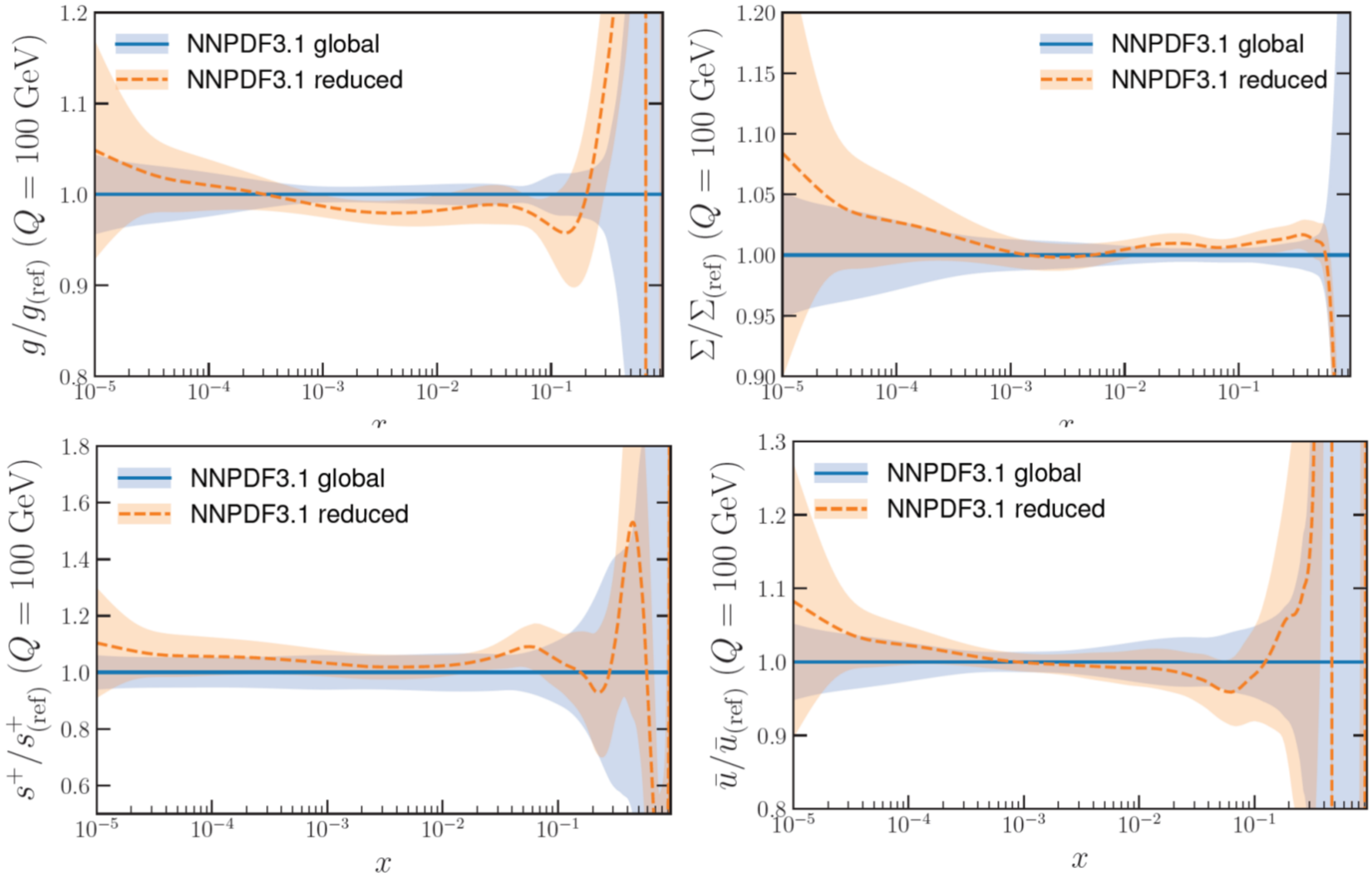
Plots from J. Rojo.

Uncertainies



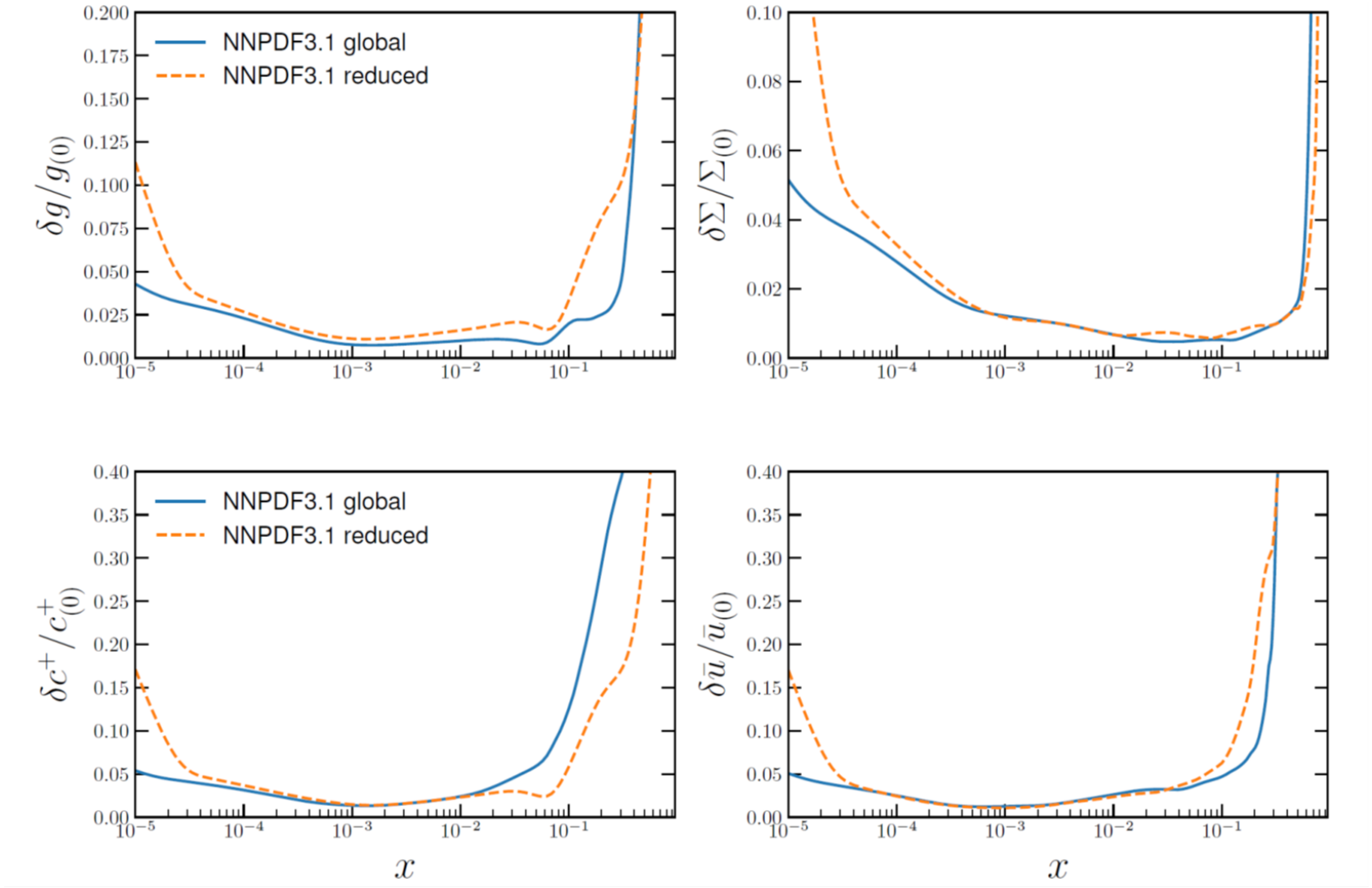
Plots from J. Rojo.

NNPDF3.1 changes



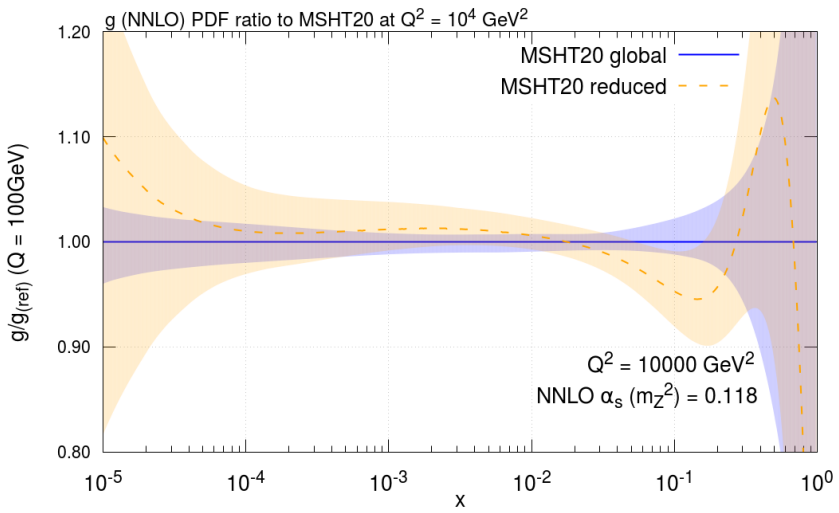
Plots from J. Rojo.

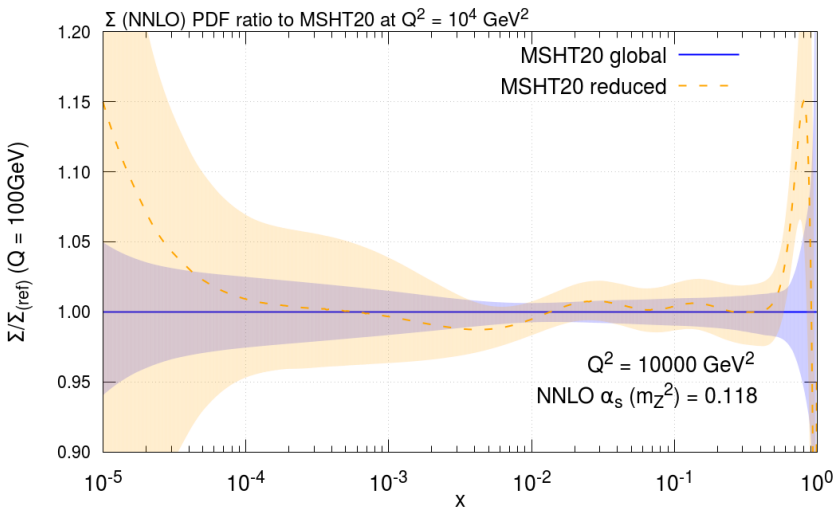
Uncertainties

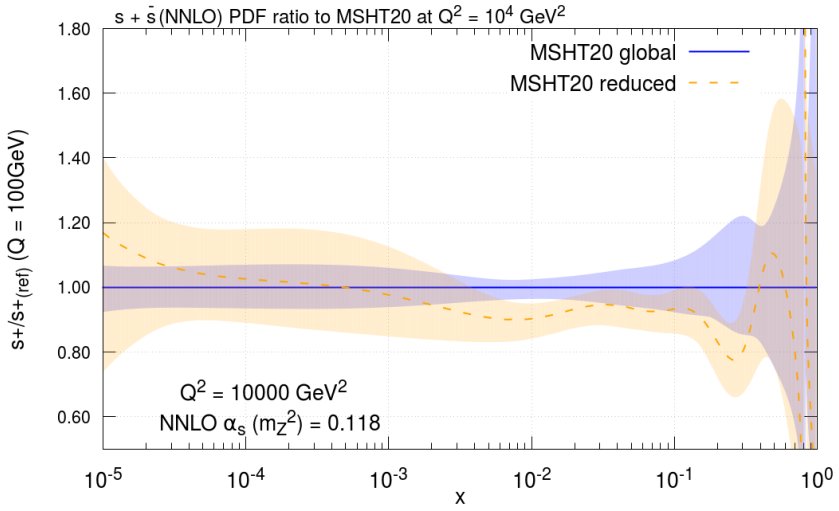


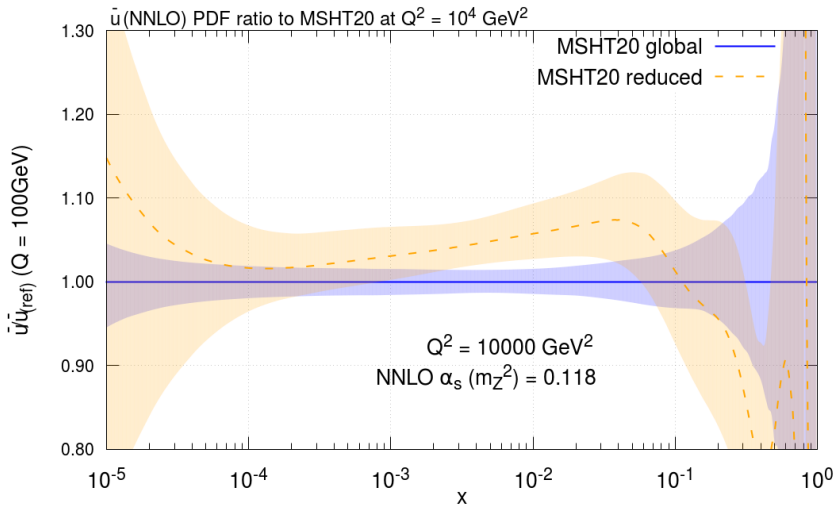
Plots from J. Rojo.

MSHT2020 changes

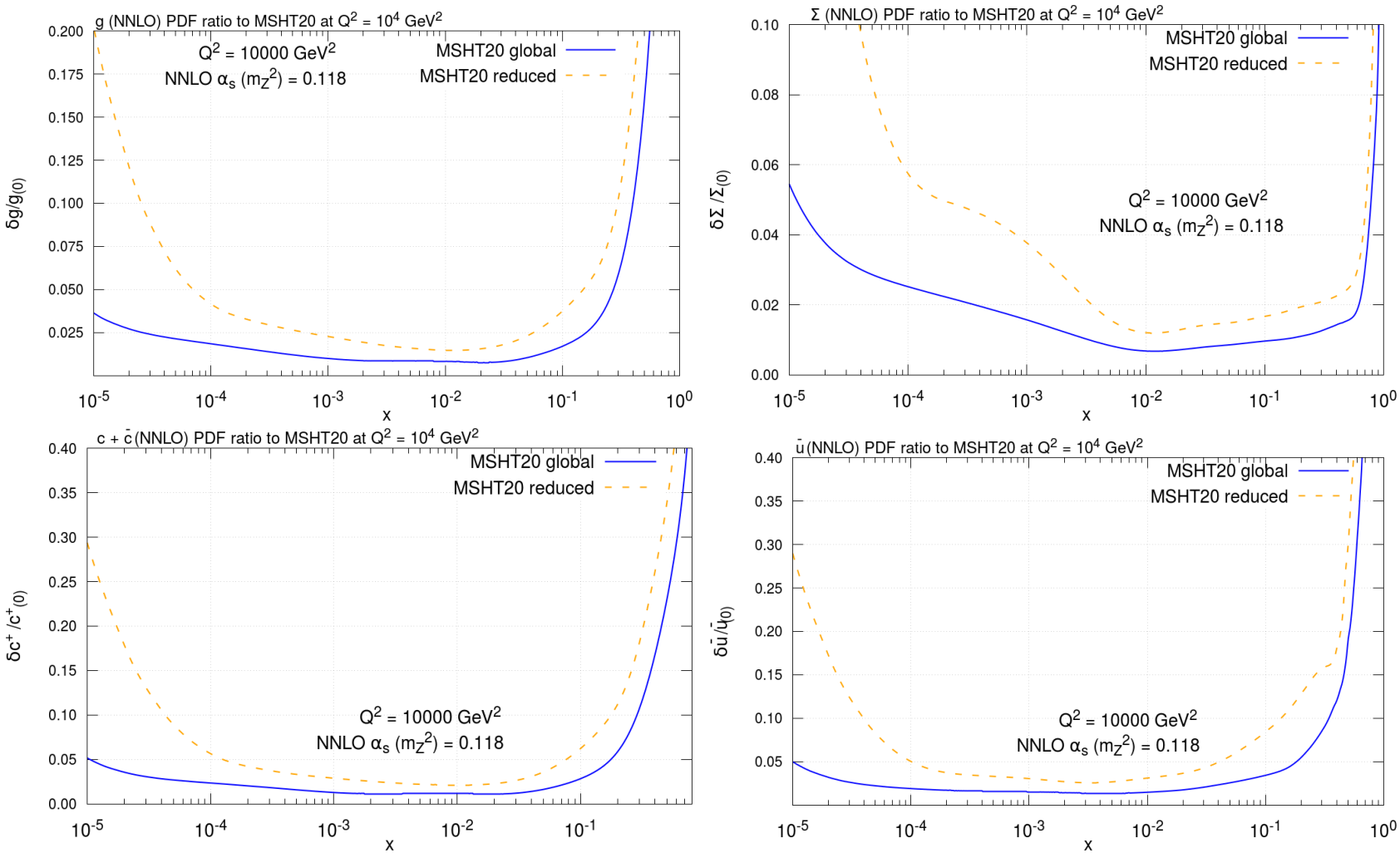






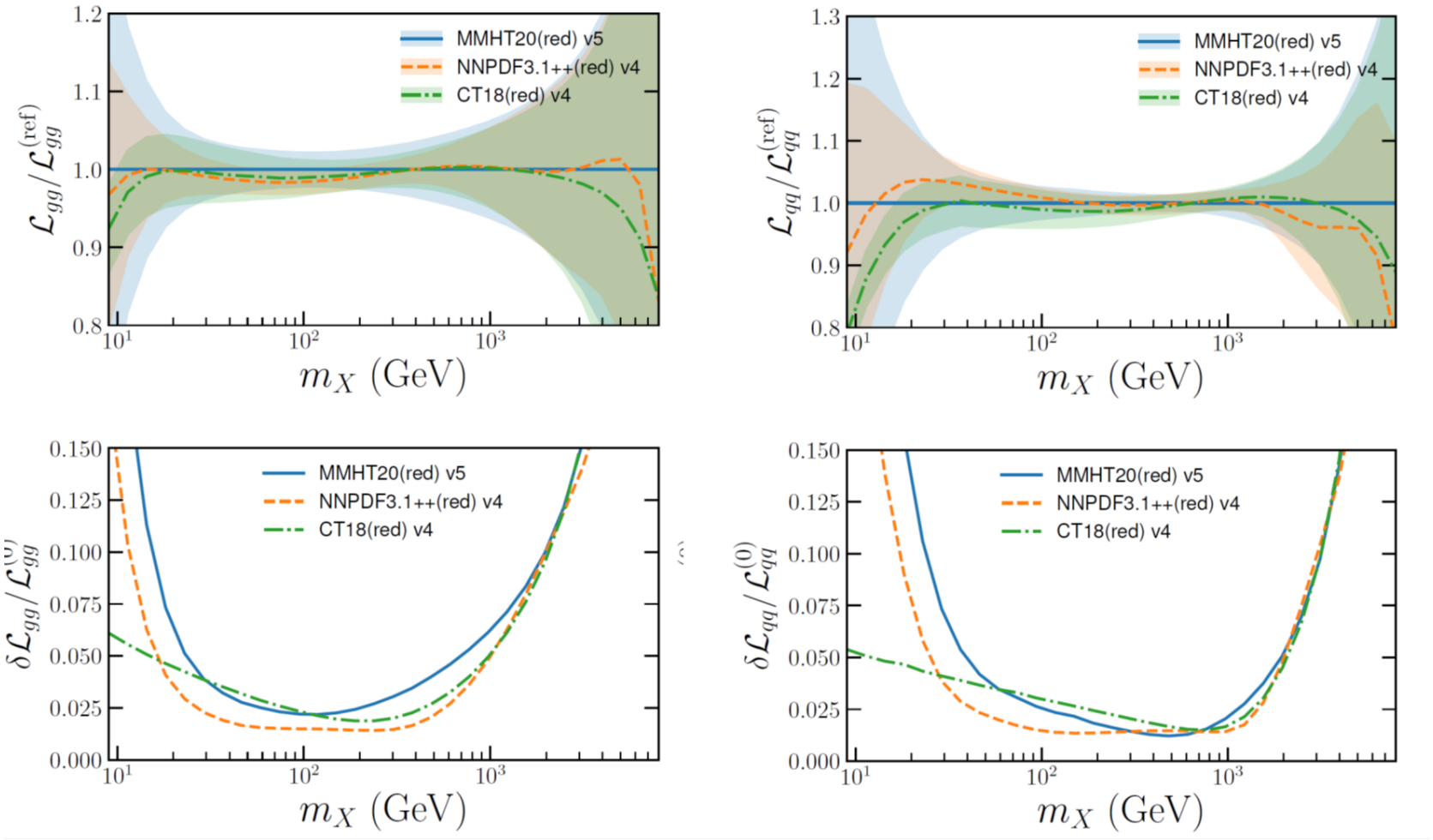


Uncertainties



Noticable that only MSHT2020 see very definite overall increase in uncertainties when using reduced set.

PDF luminosity comparison

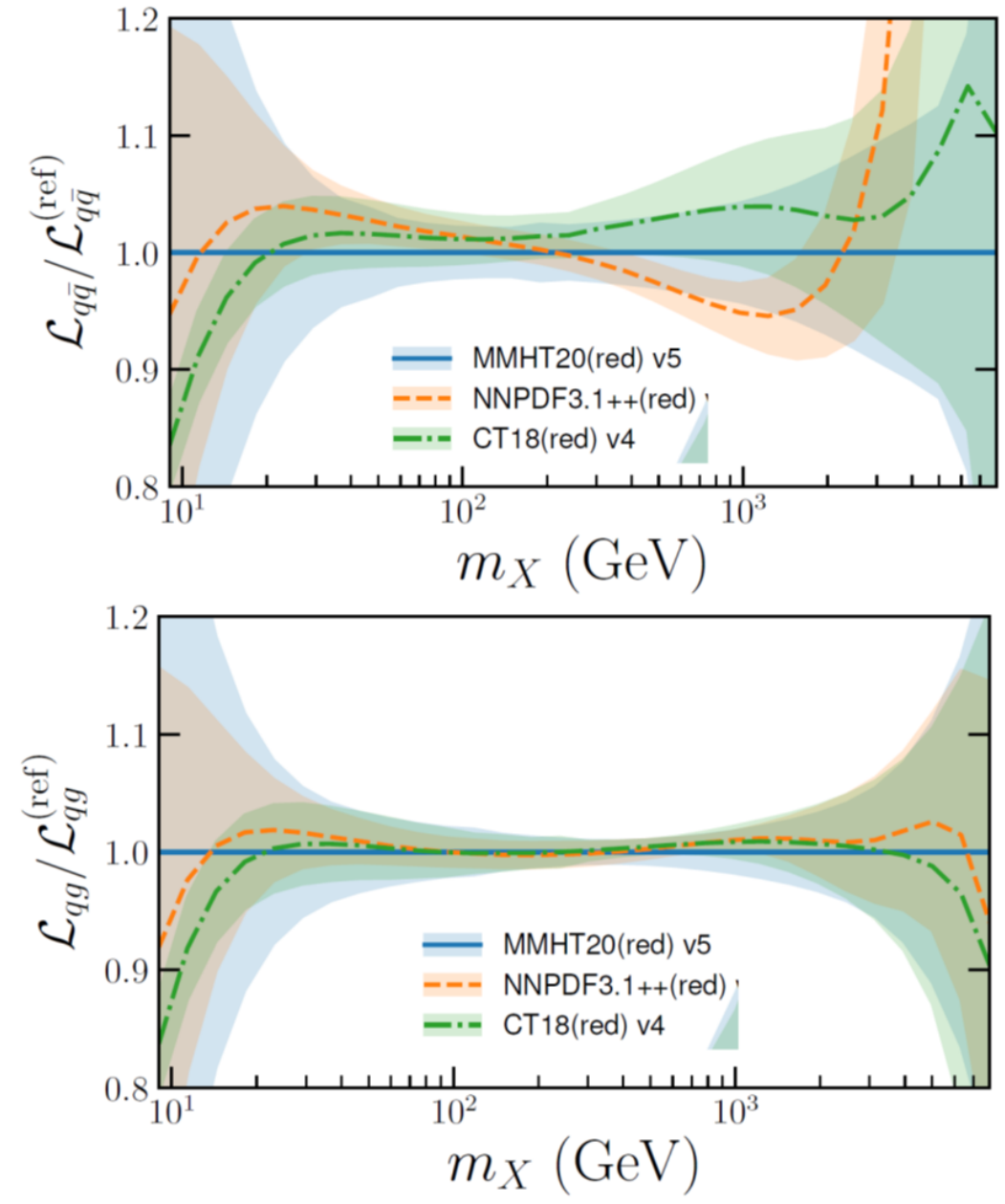


Good agreement in “main” luminosities. Plots from J. Rojo.

Not so good in those that depend on antiquarks.

Again differences seen when flavour or quark-antiquark separtion vital.

Plots from J. Rojo.



Theory comparisons

Also compare quality of fit obtained to “identical” data by each group.

comparison using the **resulting PDFs from the benchmark fits** from each group

ID	Expt.	N_{pt}	χ^2 (CT)	χ^2 (MSHT)	χ^2 (NNPDF)
101	BCDMS F_2^p	$329/163^{\dagger\dagger}/325^{\dagger}$	348.96	163.86	393.06
102	BCDMS F_2^d	$246/151^{\dagger\dagger}/244^{\dagger}$	260.50	133.68	265.35
104	NMC F_2^d/F_2^p	$118/117^{\dagger}$	111.54	109.87	103.38
124+125	NuTeV $\nu\mu\mu + \bar{\nu}\mu\mu$	38+33	62.03	48.46	92.53
160	HERAI+II	1120	1378.87	1344.87	1358.04
203	E866 $\sigma_{pd}/(2\sigma_{pp})$	15	21.35	12.52	5.49
245+250	LHCb 7TeV& 8TeV W,Z	29+30	64.65	70.17	82.57
246	LHCb 8TeV $Z \to ee$	17	23.42	24.91	26.24
248	ATLAS 7TeV W,Z(2016)	34	65.65	66.28	75.54
260	D0 Z rapidity	28	17.51	16.28	17.39
267	CMS 7TeV eletron A_{ch}	11	6.93	17.63	8.22
269	ATLAS 7TeV W,Z(2011)	30	31.35	28.04	29.07
545	CMS 8TeV incl. jet	$185/174^{\dagger\dagger}$	185.40	241.93	232.55
Total	N_{pt}	—	2263	1991	2256
Total	χ^2	—	2584	2278.51	2689.42

Table from T. Hobbs.

Do the same when using the same PDFs (PDF4LHC15) as input.

comparison using **PDF4LHC15 as input PDF** for the calculations of each group

ID	Expt.	N_{pt}	χ^2 (CT)	χ^2 (MSHT)	χ^2 (NNPDF)
101	BCDMS F_2^p	$329/163^{\dagger\dagger}/325^{\dagger}$	442.07	195.90	479.67
102	BCDMS F_2^d	$246/151^{\dagger\dagger}/244^{\dagger}$	239.36	191.57	298.47
104	NMC F_2^d/F_2^p	$118/117^{\dagger}$	109.11	110.31	108.22
124+125	NuTeV $\nu\mu\mu + \bar{\nu}\mu\mu$	38+33	60.76	35.94	34.04
160	HERAI+II	1120	1421.59	1394.38	1782.61
203	E866 $\sigma_{pd}/(2\sigma_{pp})$	15	6.68	8.15	7.70
245+250	LHCb 7TeV& 8TeV W,Z	29+30	103.04	79.21	154.97
246	LHCb 8TeV $Z \to ee$	17	22.93	28.10	45.63
248	ATLAS 7TeV W,Z(2016)	34	228.16	253.80	241.70
260	D0 Z rapidity	28	17.10	16.12	16.78
267	CMS 7TeV eletron A_{ch}	11	33.18	5.54	7.99
269	ATLAS 7TeV W,Z(2011)	30	35.92	36.91	40.73
545	CMS 8TeV incl. jet	$185/174^{\dagger\dagger}$	282.23	329.00	326.81
Total	N_{pt}	—	2263	1991	2256
Total	χ^2	—	3002.13	2684.92	3545.34

Table from T. Hobbs.

In order to investigate differences will look in detail at theoretical predictions from each group with same input PDFs.

Some differences expected from e.g. choice of heavy flavour scheme.

Benchmarking with Toy data sets for purposes of Correlations

Suggested a shorter subset of data which should provide reasonable constraints.

- HERA I + II inclusive cross sections from DIS.
- E866 fixed target Drell-Yan pd/pp data.
- CDF Z rapidity distribution.
- ATLAS W, Z 7 TeV rapidity distributions.
- D0 1.96 TeV W asymmetry.
- CMS 7 TeV inclusive jet data.

Significant, but not complete overlap with base set considered above.

Have been generated in xFitter input format.

- To check corelations between different datasets we generated toys for all datasets together.
- List of datasets:

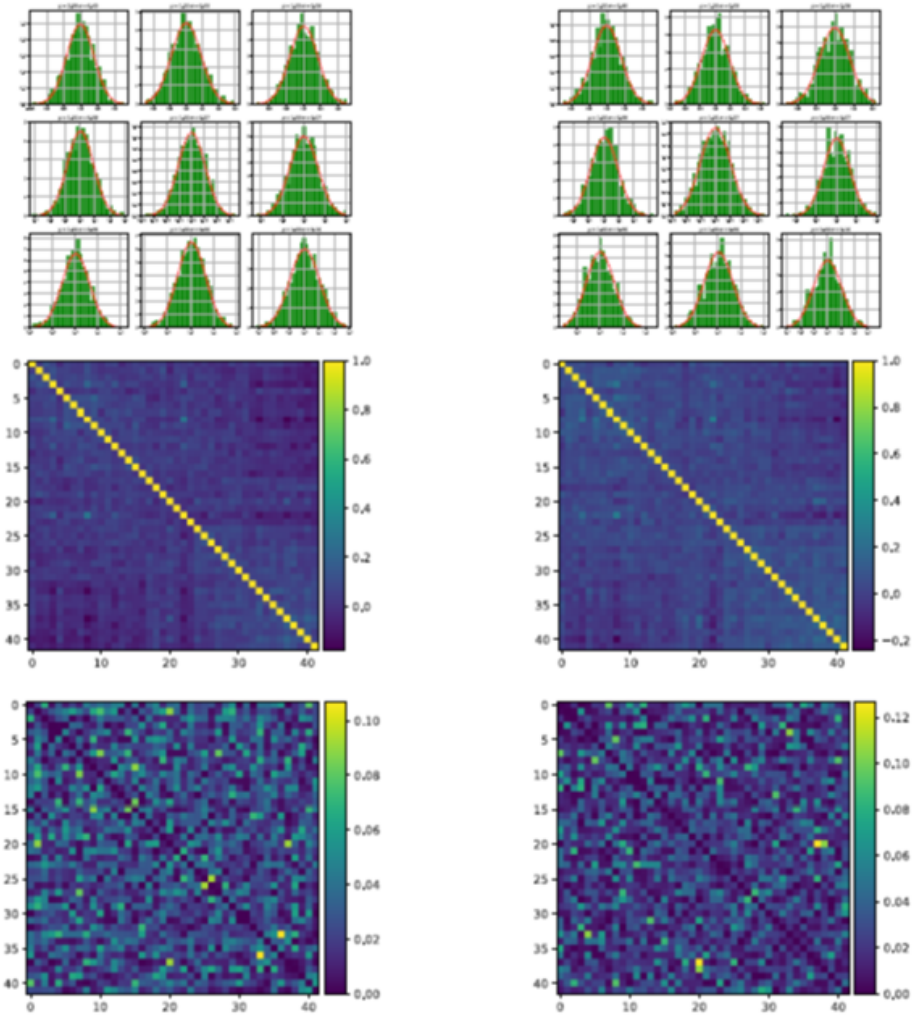
Experiment	DataSet Name
ATLAS	W-,W+, Z peak CC, Z peak CF, Z high mass CF, Z high mass CC, Z low mass
CMS	inclusive jets
HERA1+2	CCem, CCep, NCem, NCep 460, NCep 575, NCep 820, NCep 920
Tevatron	Tab11 (instead of E866), CDF Z Boson Rapidity, D0 Wel pt25

- For each dataset Valiantsin generated 999 toys.

“checked that the covariance matrices computed from the systematic uncertainties reported in the paper are well reproduced if they are recomputed from the toys”

Example for the HERA inclusive data.

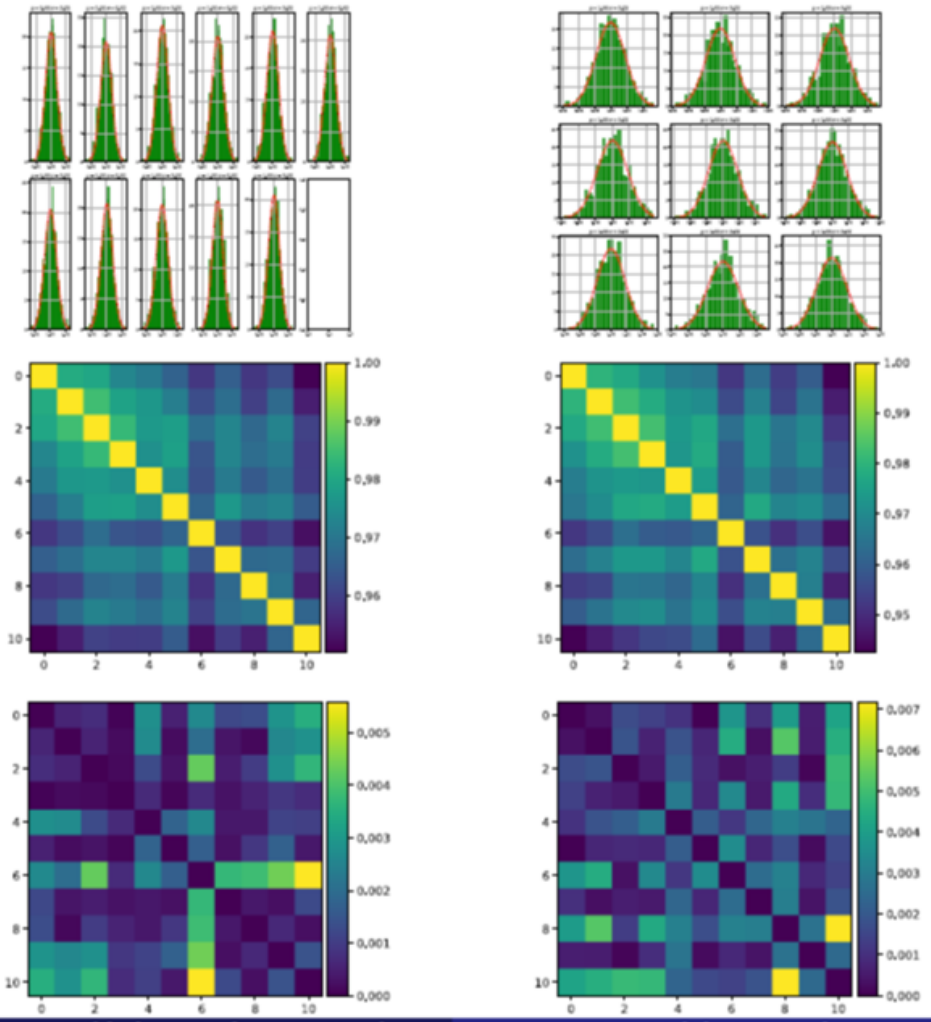
HERA CCem



- Left plots – separate generated toys, right – together;
- Top plots – Gaussian with mean 1.00;
- Mid plots – There are some bins with negative coeff in right plot;
- Bot plots – Abs difference corr matrices from xfitter and toys matrix – As a result of negative bins – larger difference;

Example for the ATLAS W data.

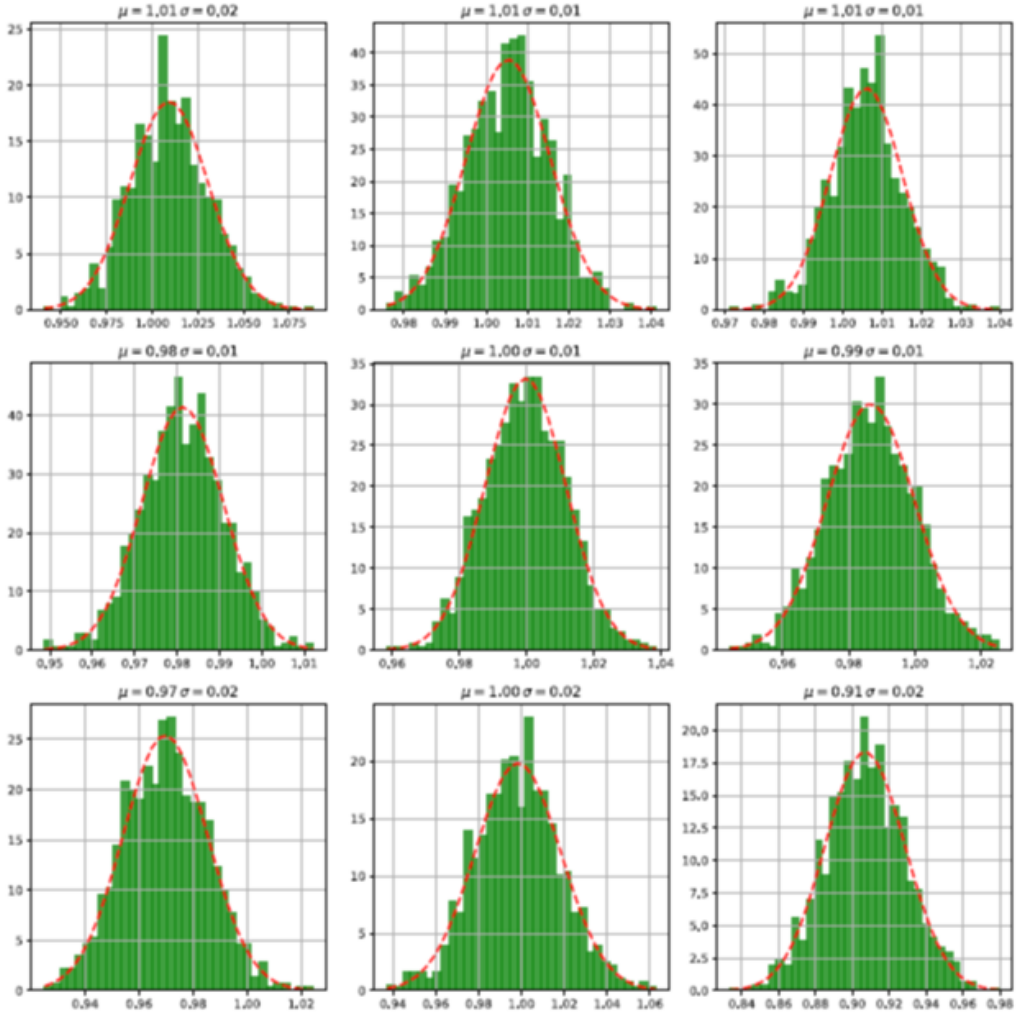
ATLAS W+



- Left plots – separate generated toys, right – together;
- Top plots – $\frac{\sigma_{toys}}{\sigma_{Orig}}$ – Gaussian with mean 1.00;
- Mid plots – Correlation toys matrices – left and right looks very similar;
- Bot plots – Abs difference corr matrices from xfitter and toys matrix – difference $<$ 0.04;
- Other ATLAS datasets on git.

Example for the E866 Drell Yanratio data.

Tevatron Tab11 bins



- Bin number 9 (bot right) have mean = 0.91.
- It is not a statistical problem.

Slight differences to data sets within PDF4LHC exercise.

Discover some data sets treated a little differently by different groups, e.g. different versions of data (CDF rapidity, CMS jets).

Not necessarily a problem - PDF4LHC study initially concentrating on data common to all groups – not necessarily limited selection giving best constraints. However, overlap clearly not perfect.