MSTW PDFs

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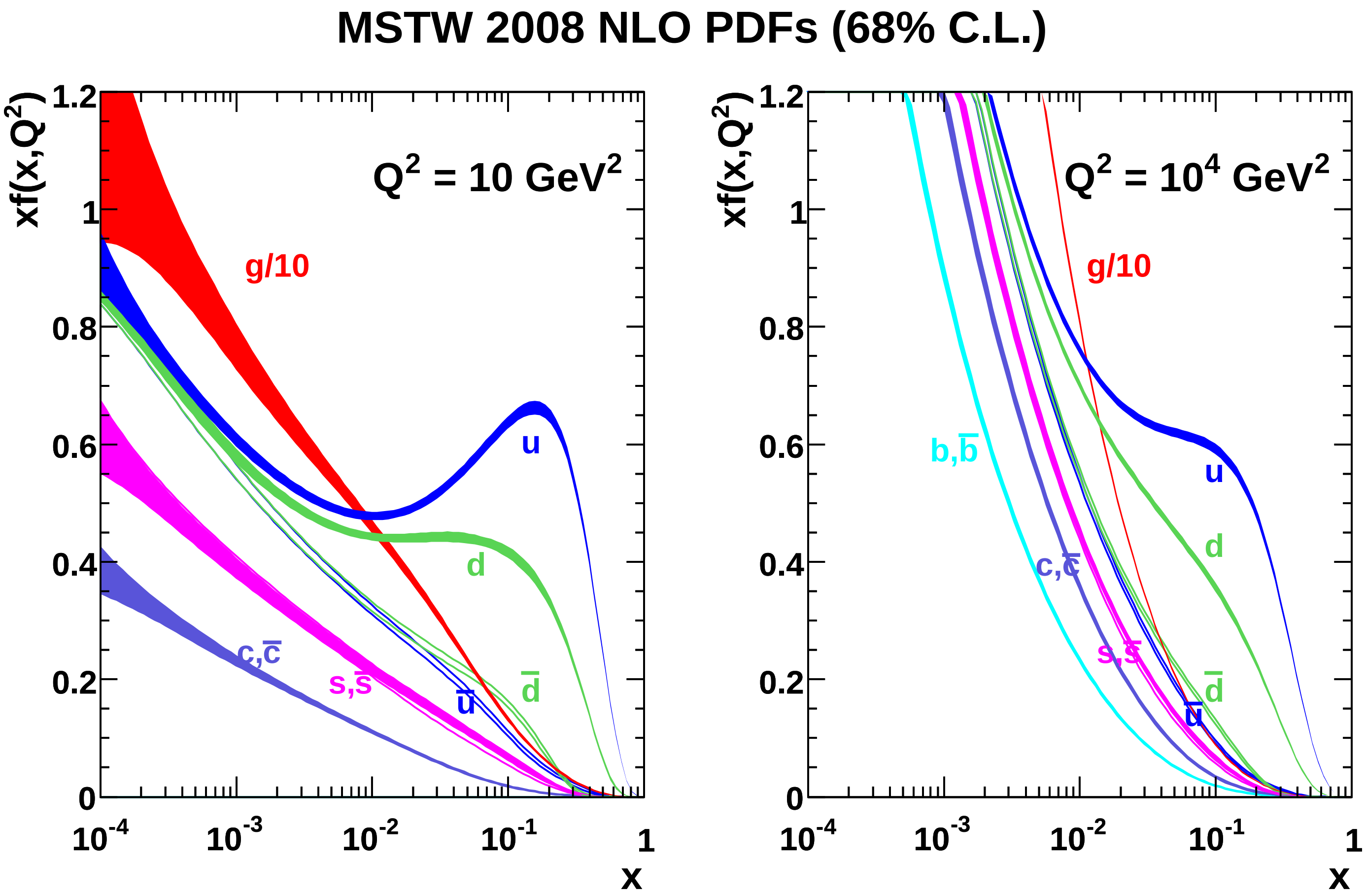


An illustration of the MSTW PDFs at NLO.

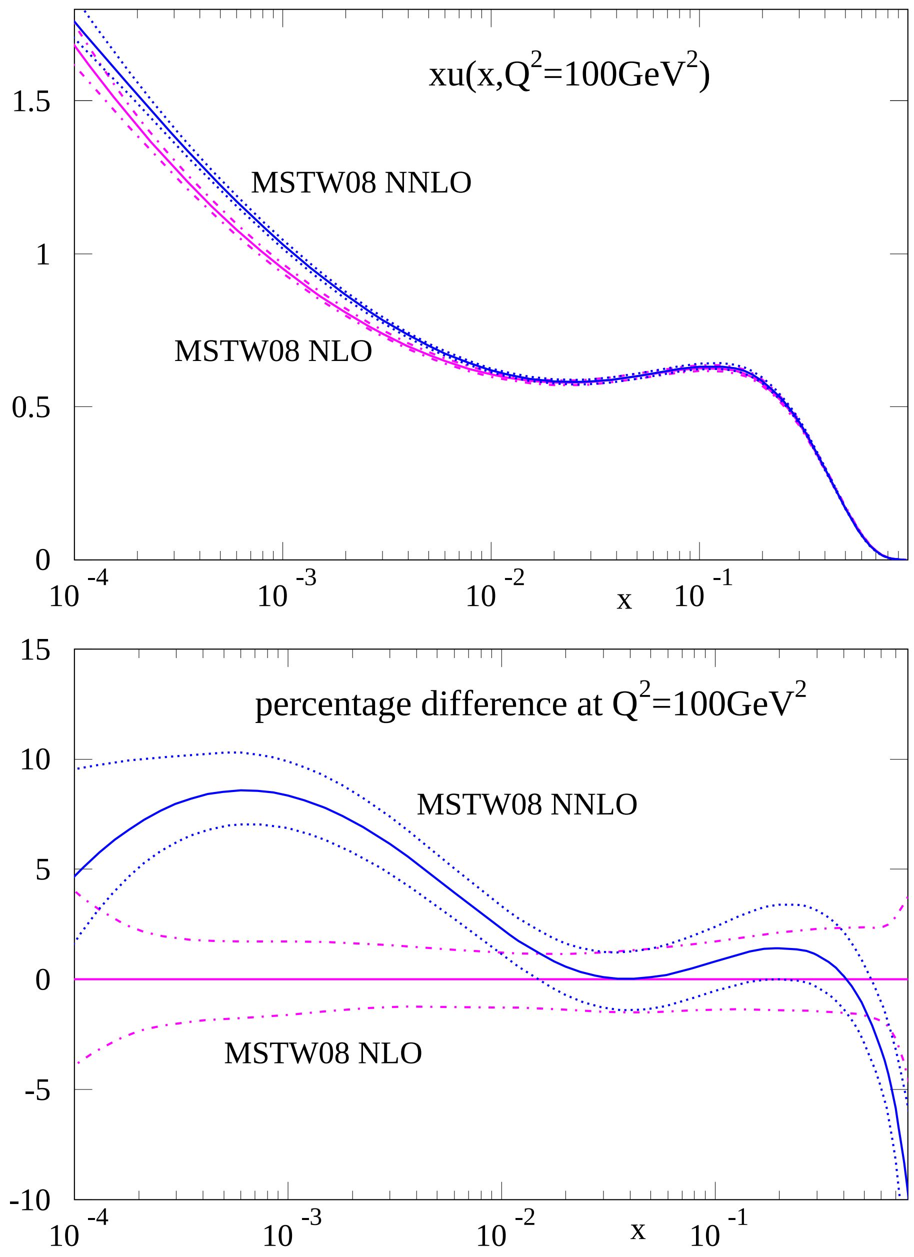
Variety of PDFs

MSTW make available PDFs in a very wide variety of forms.

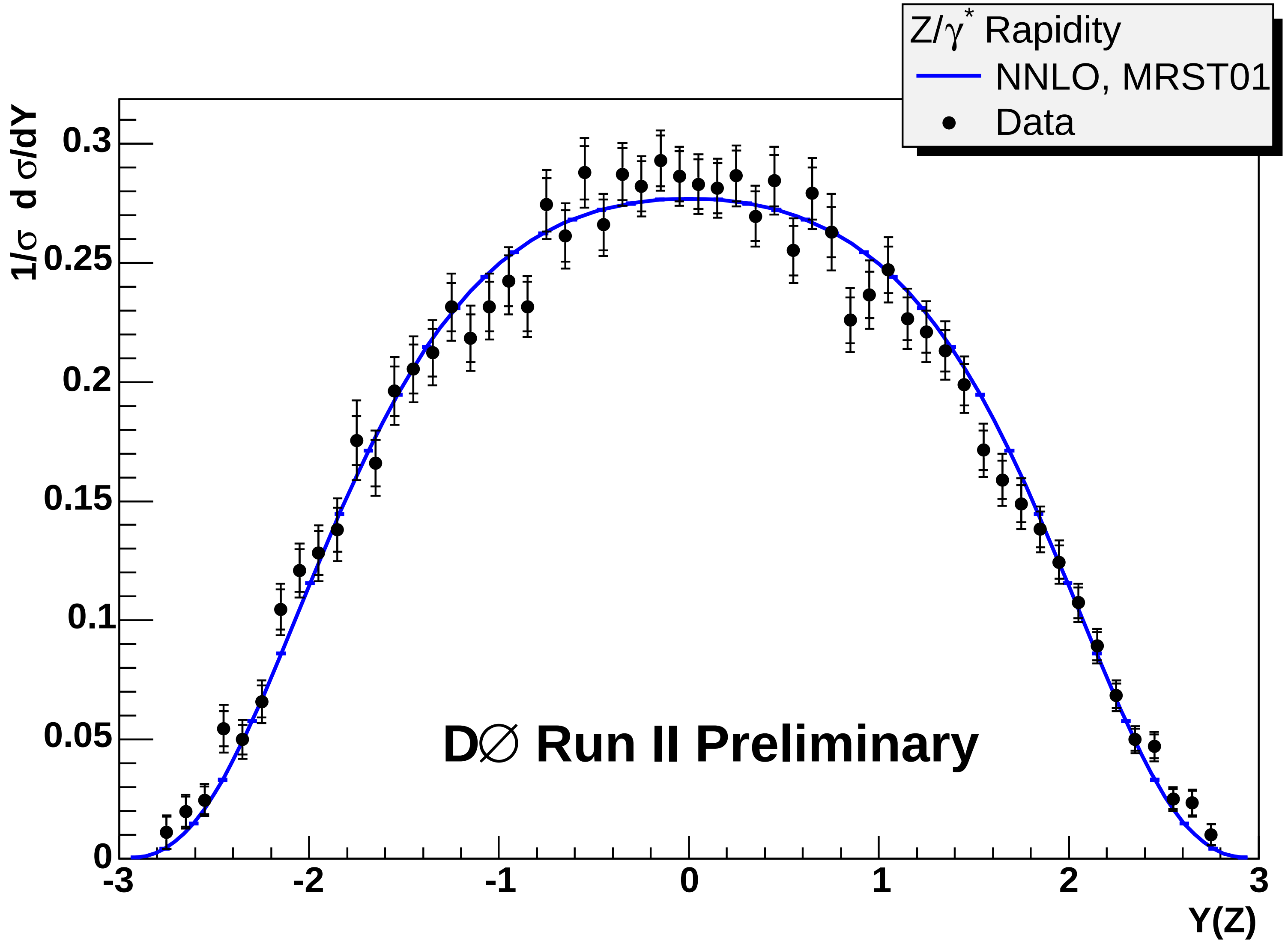
- At , LO, NLO and NNLO, with some minor approximations at NNLO (see later).
- Available for variable, up to 5, quark flavours using a GM-VFNS at all orders. Also for a maximum 4 and 3 flavours.
- Available for best-fit α_S along with variations of $\pm 0.5\sigma$ and $\pm 1\sigma$ (and $\pm 0.5\ 90\% CL$ and $\pm 90\% CL$). Also from $\alpha_S(M_Z^2) = 0.110 - 0.130$ in steps of 0.001.
- Available for variety of choices of m_c (1.05 – 1.75 GeV in steps of 0.05 GeV) and m_b (4.00 – 5.50 GeV in steps of 0.25 GeV), the former for fixed and varying $\alpha_S(M_z^2)$.
- Older MRST versions of modified LO* and LO** PDFs and of PDFs including QED evolution. Relatively stable with time so not too different from MSTW2008. Will both be updated.

Sometimes vital to use NNLO PDFs if calculating at NNLO.

Systematic difference between PDF defined at NLO and at NNLO.



Historically excellent predictive power – comparison of MRST prediction for Z rapidity distribution with preliminary data.



Data fit - need all types in order to obtain full constraints.

- Lepton-proton collider HERA – (DIS) → small-x quarks, and gluons from evolution. Also, jets → moderate-x gluon and α_S (not at NNLO, large NLO K-factor).
- Fixed target neutral current DIS – higher x – leptons (BCDMS, NMC, E665, SLAC) → up quark (proton) or down quark (deuterium).
- Fixed target charged current DIS – neutrinos (CHORUS, NuTeV) (cut above $x = 0.5$ on latter) → valence or singlet combinations.
- Di-muon production in neutrino DIS – (CCFR, NuTeV) strange quarks and neutrino-antineutrino comparison → asymmetry .
- Drell-Yan production of dileptons – quark-antiquark annihilation (E866 pp experiment) – high-x sea quarks. Deuterium target (E866) – $\bar{u}/\bar{d}$ asymmetry.
- High-p_T jets at colliders (Tevatron - Run II) – high-x gluon distribution.
- W and Z production at colliders (Tevatron -Run II) (low luminosity Run II for W(lepton) asymmetry) – different quark contributions to DIS.

Fit data for scales above $2\mathrm{GeV}^2$. Varying Q^2 cut only leads to slow improvement in fit/change in PDFs (higher orders).

Fit most DIS data for $W^2 > 15\mathrm{GeV}^2$. Raise from earlier MRST fits due to hints of dependence on higher twist just below $15\mathrm{GeV}^2$.

Fit $F_3(x, Q^2)$ only for $W^2 > 25\mathrm{GeV}^2$. Renormalon prediction for larger higher twist due to lack of sum rule protection. Data consistent with this.

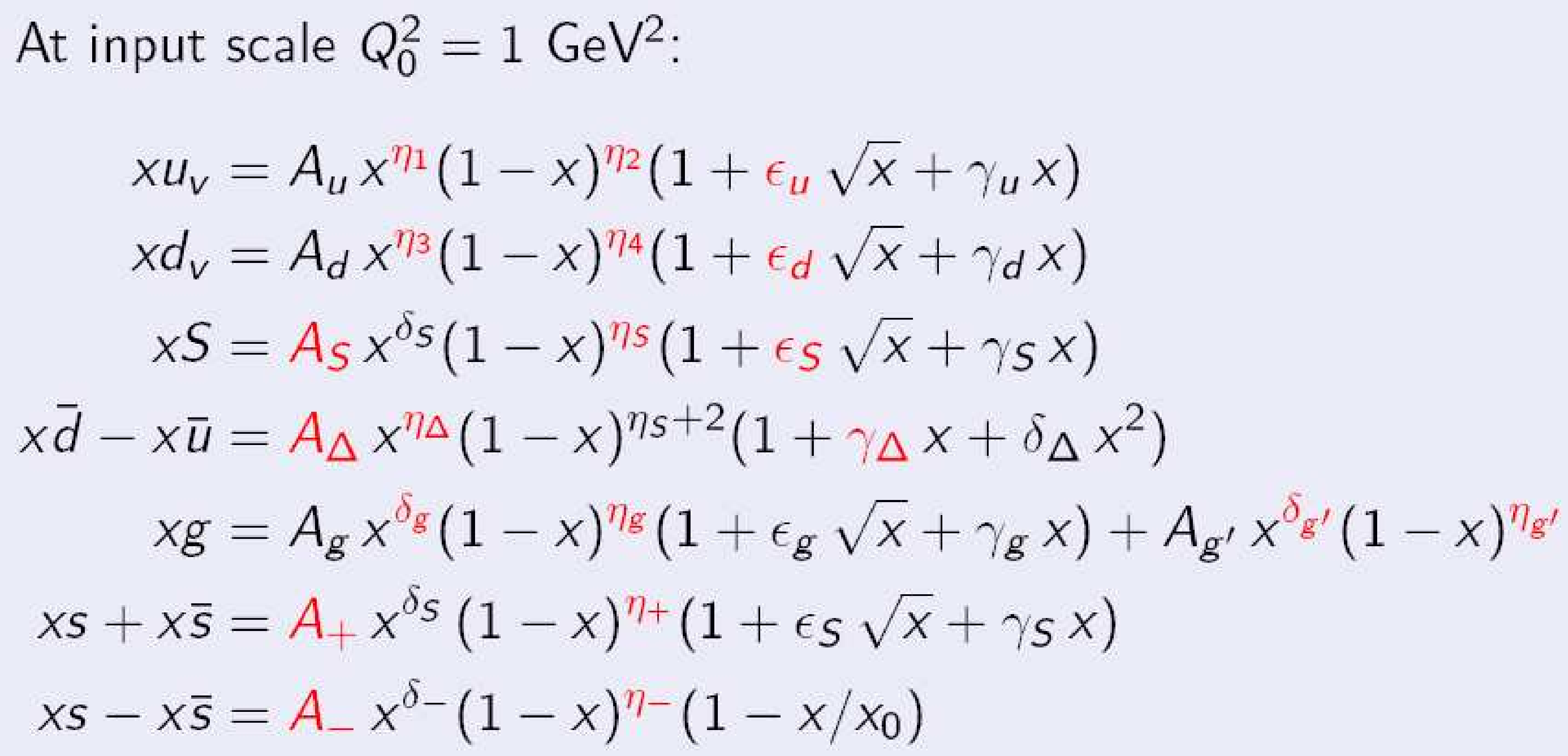
At NNLO use threshold (Kidonakis and Owens) approx. for Tevatron jets. Not large correction. NLO K-factor not large, and smooth. Quite similar to jet energy scale correlated uncertainty. Omit HERA jets at NNLO, but prediction using NLO cross section excellent.

Don't yet include combined HERA cross-section data. Have checked effects of this. In some cases predictions change by a little over 1σ, in many cases less. Slightly smaller change at NNLO.

Major problems with high-luminosity D0 lepton asymmetry in some binnings. Same for other groups.

Parameterisation

Parameterisation used in MSTW fits. Only those 20 in red appear in eigenvectors.



At input scale $Q_0^2 = 1\ \text{GeV}^2$:

$$xu_v = A_u\, x^{\eta_1}(1-x)^{\eta_2}(1+\epsilon_u\sqrt{x}+\gamma_u x)$$

$$xd_v = A_d\, x^{\eta_3}(1-x)^{\eta_4}(1+\epsilon_d\sqrt{x}+\gamma_d x)$$

$$xS = A_S\, x^{\delta_S}(1-x)^{\eta_S}(1+\epsilon_S\sqrt{x}+\gamma_S x)$$

$$x\bar{d} - x\bar{u} = A_\Delta\, x^{\eta_\Delta}(1-x)^{\eta_S+2}(1+\gamma_\Delta x+\delta_\Delta x^2)$$

$$xg = A_g\, x^{\delta_g}(1-x)^{\eta_g}(1+\epsilon_g\sqrt{x}+\gamma_g x) + A_{g'}\, x^{\delta_{g'}}(1-x)^{\eta_{g'}}$$

$$xs + x\bar{s} = A_+\, x^{\delta_S}(1-x)^{\eta_+}(1+\epsilon_S\sqrt{x}+\gamma_S x)$$

$$xs - x\bar{s} = A_-\, x^{\delta_-}(1-x)^{\eta_-}(1-x/x_0)$$

Of others only A_v, A_d, A_g and x_0 fixed by sum rules and $\delta_{s\_}$ fixed due to total correlation. 28 varied in best fit.

Similar or more than other groups (other than NNPDF).

Use Hessian approach, i.e. calculate best fit by minimising χ^2, expand about minimum to find parameter uncertainties, and as some other groups normalise and diagonalise to obtain orthonormal eigenvectors in parameter space.

(Currently summing in quadrature uncertainties for DIS data. Shown to have very little effect in MRST2001 study, first HERA-LHC benchmark (back-up) and NNPDF-Donati study (back-up). Use full correlations for vital sets, such as Tevatron jets.)

High quartic penalty for normalisations to prevent slight tendency to float down (details in back-up). Improved by higher order or relaxation of momentum sum rule.

Find that conventional $\Delta\chi^2 = 1$ gives unfeasibly low uncertainty. Possibly due to some inconsistency between data sets, failure of imperfect theory to fit all data simultaneously (well-recognised statistical problem) and limited parameterisation. Not seen much evidence of last from increasing parameters (see back-up). Main potential at very high x.

Use dynamical tolerance based on confidence levels for different sets (explained in (PDF4LHC talk - Watt DIS08).

- Define 90% C.L. region for each data set n (with N_n data points) as

$$\boxed{\chi_n^2 < \left(\frac{\chi_{n,0}^2}{\xi_{50}}\right)\xi_{90}}$$

- ξ_{90} is the 90th percentile of the χ^2-distribution with N_n d.o.f., i.e.

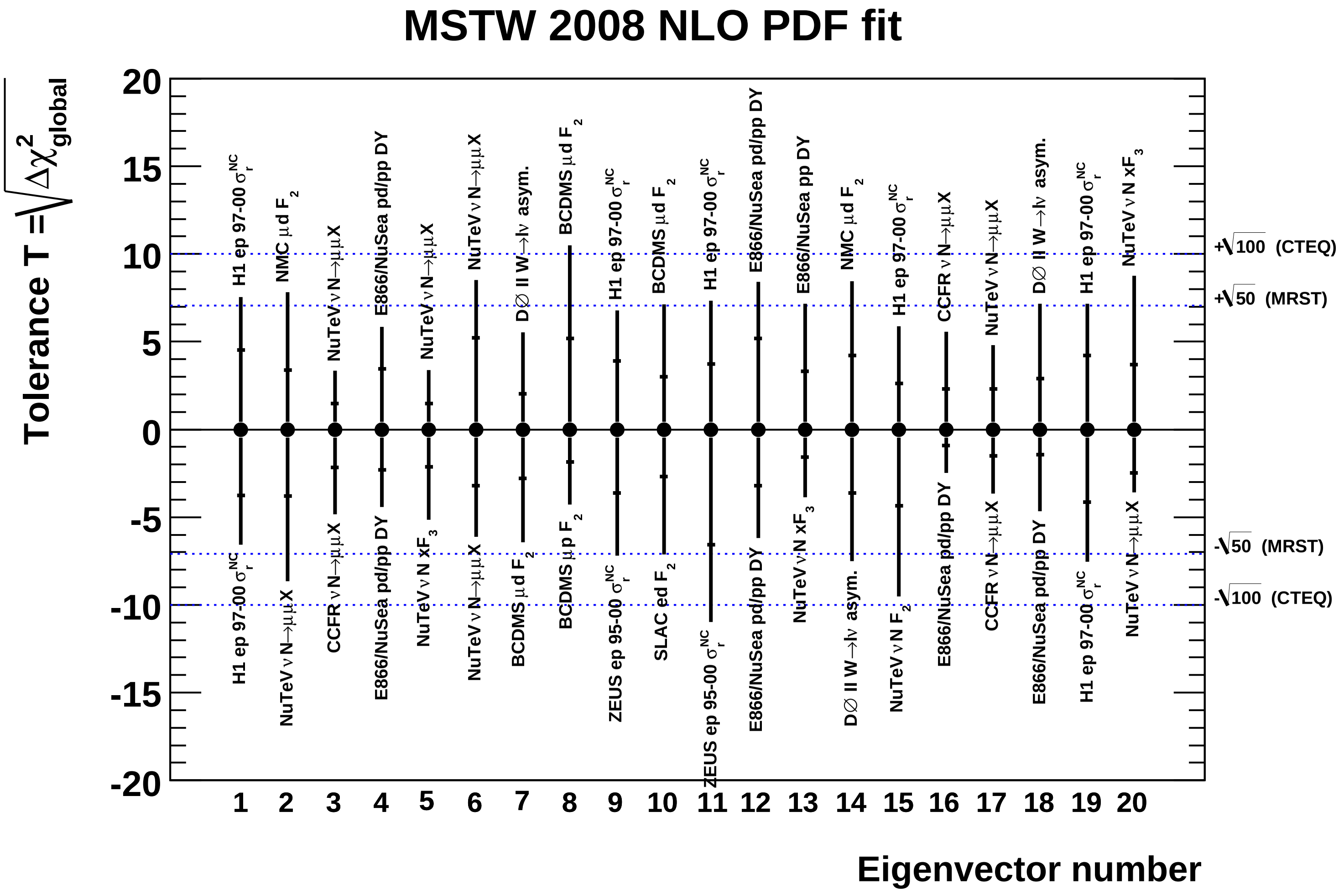
$$\int_0^{\xi_{90}} \mathrm{d}\chi^2\, f(\chi^2; N_n) = 0.90,$$

where the probability density function is

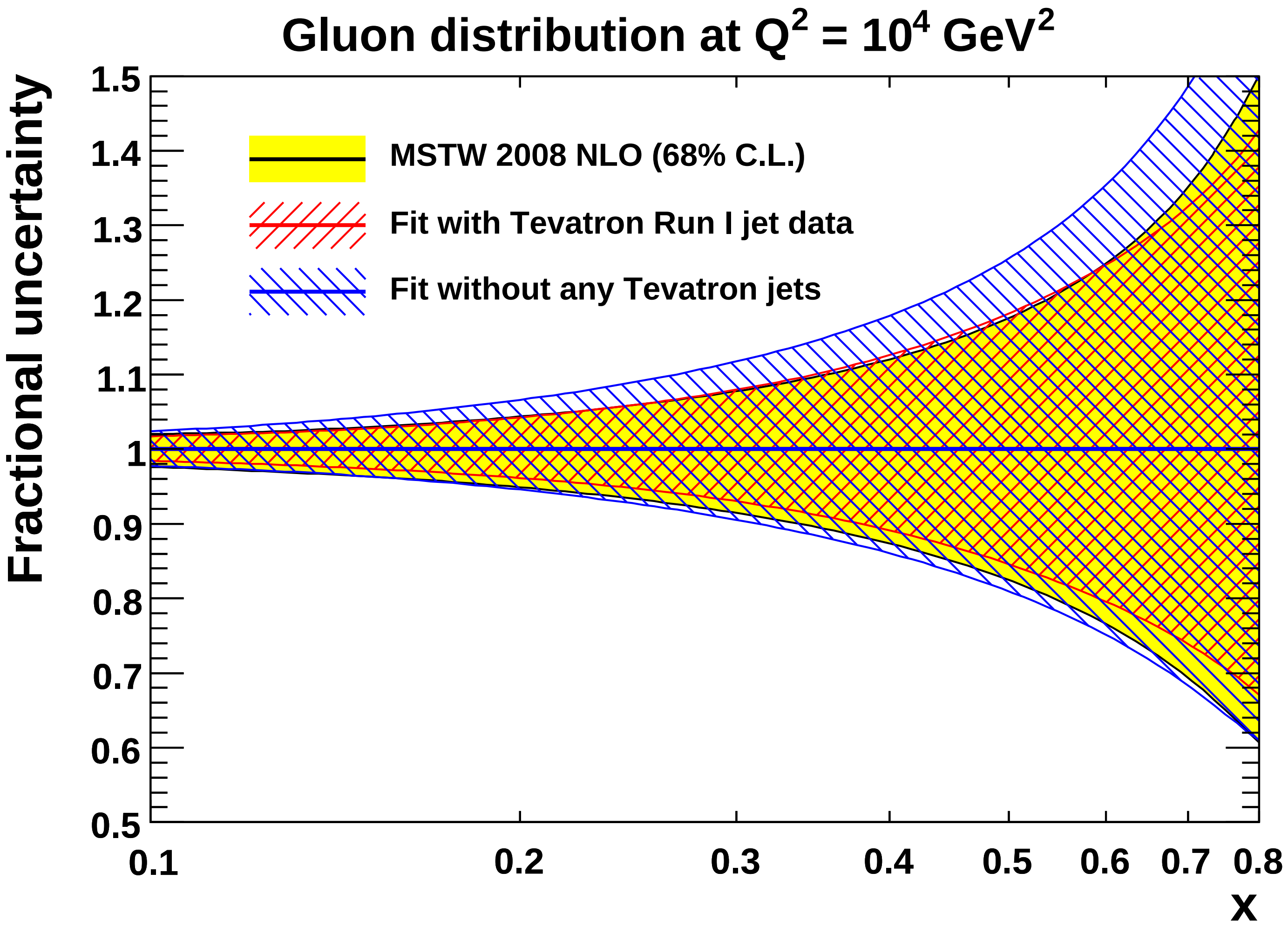
$$f(z; N) = \frac{z^{N/2-1}\,\mathrm{e}^{-z/2}}{2^{N/2}\,\Gamma(N/2)}.$$

- $\xi_{50} \simeq N_n$ is the most probable value of the χ^2-distribution.
- $\chi_{n,0}^2$ for data set n is evaluated at the **global** minimum.
- **Rescale** by a factor $\chi_{n,0}^2/\xi_{50}$ since this often deviates from 1.
- Similarly for the 68% C.L. region.

Approach repeated for all 20 eigenvectors to determine uncertainty on each. On average $\Delta\chi^2 = 40$ for 90% and $\Delta\chi^2 = 15$ for $1-\sigma$, but large variations, and asymmetries - numbers in back-up.



Even though one data set constrains each eigenvector limit, doesn't mean others do not contribute.



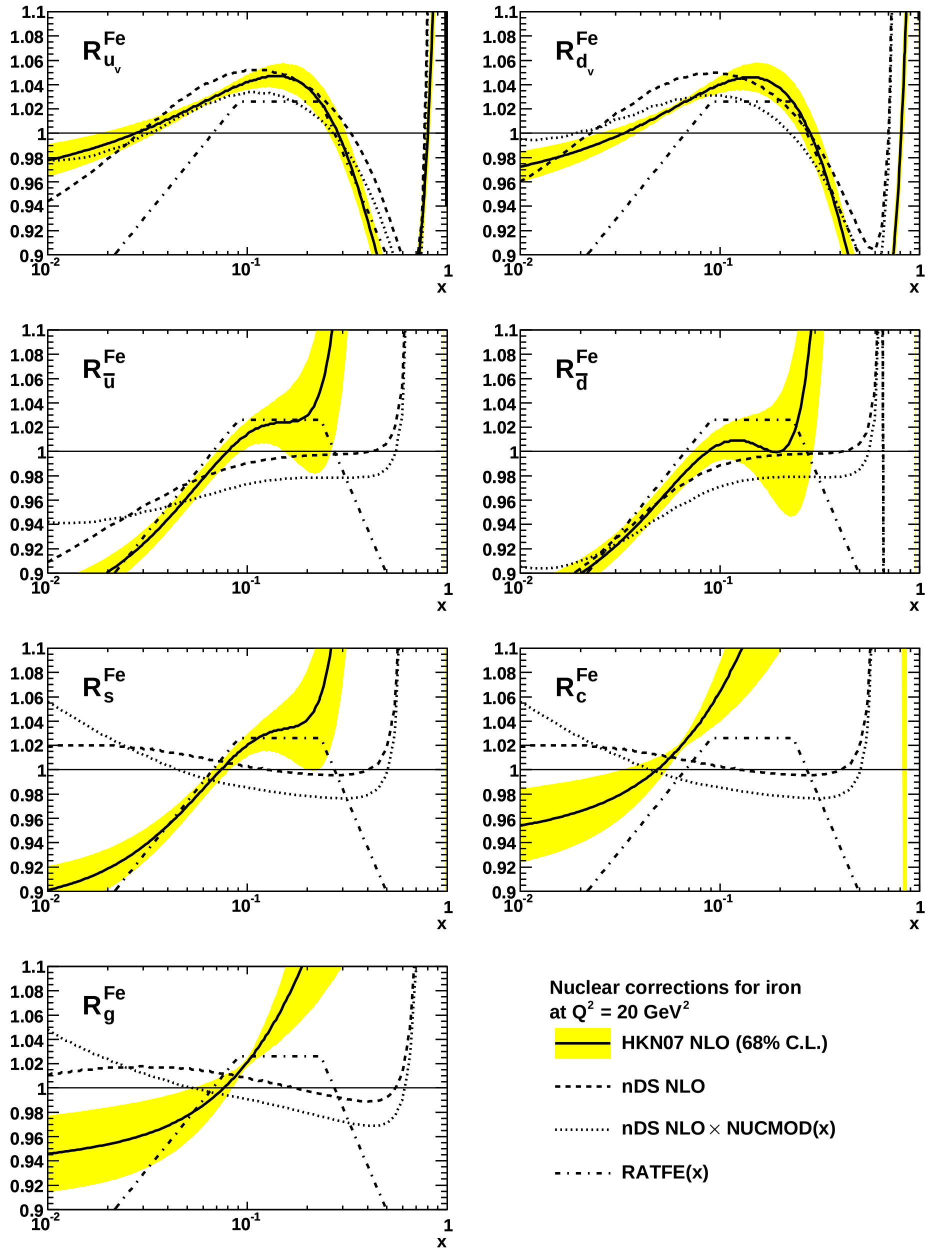
Nuclear Corrections.

Use De Florian and Sassot nuclear corrections obtained from NLO PDFs.

However, weight by three parameter function allowing normalisation and shape to vary without penalty. As can be seen, leads to changes of a couple of percent. Allowed to vary while finding uncertainty on PDFs.

Hence, PDFs not overly constrained by assumed nuclear corrections.

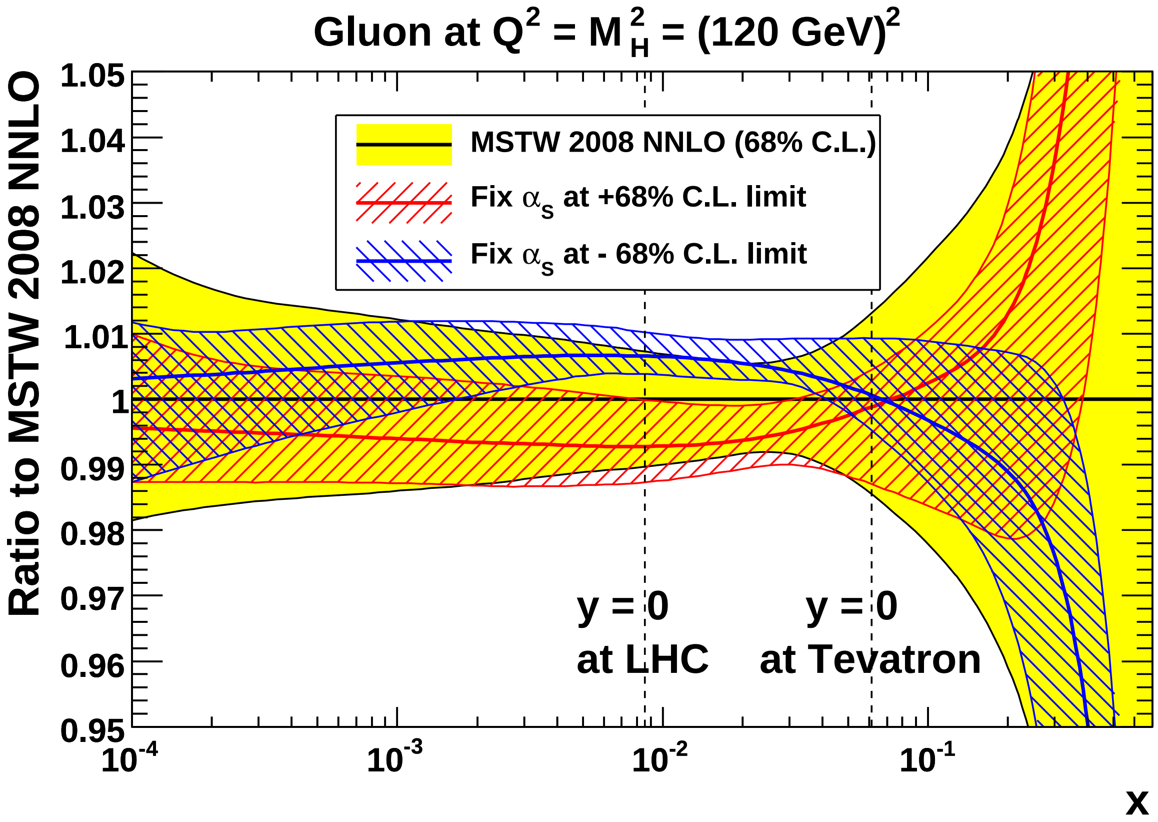
For deuterium currently use just a small shadowing correction at small x. Maximum 2% effect. Have expanded this in context of Tevatron lepton asymmetry. Potential to improve in future.



PDF correlation with α_S.

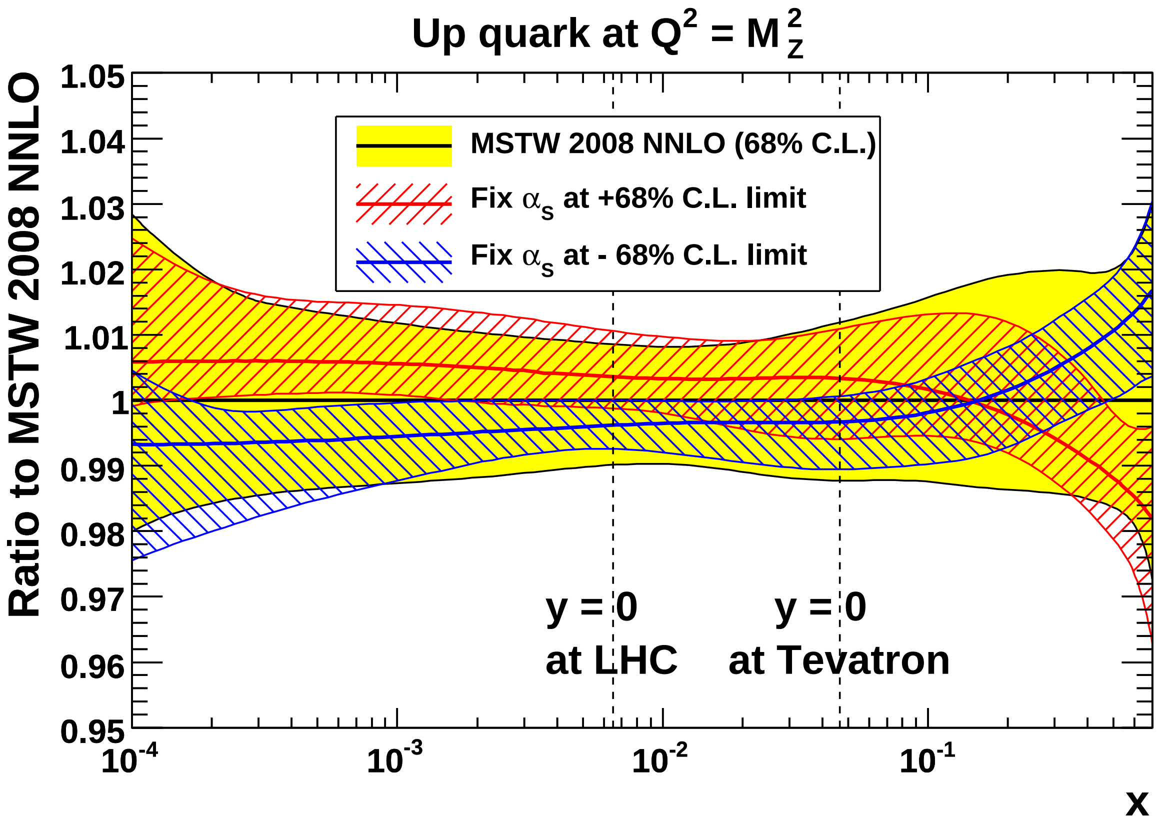
Examine PDF changes and uncertainties at different $\alpha_S(M_Z^2)$. Latter usually only for one fixed $\alpha_S(M_Z^2)$. Can be determined from fit, e.g. $\alpha_S(M_Z^2) = 0.1202^{+0.0012}_{-0.0015}$ at NLO and $\alpha_S(M_Z^2) = 0.1171^{+0.0014}_{-0.0014}$ at NNLO from MSTW.

PDF uncertainties reduced since quality of fit already worse than best fit.



Expected gluon–$\alpha_S(M_Z^2)$ small–x anti-correlation → high-x correlation from sum rule.

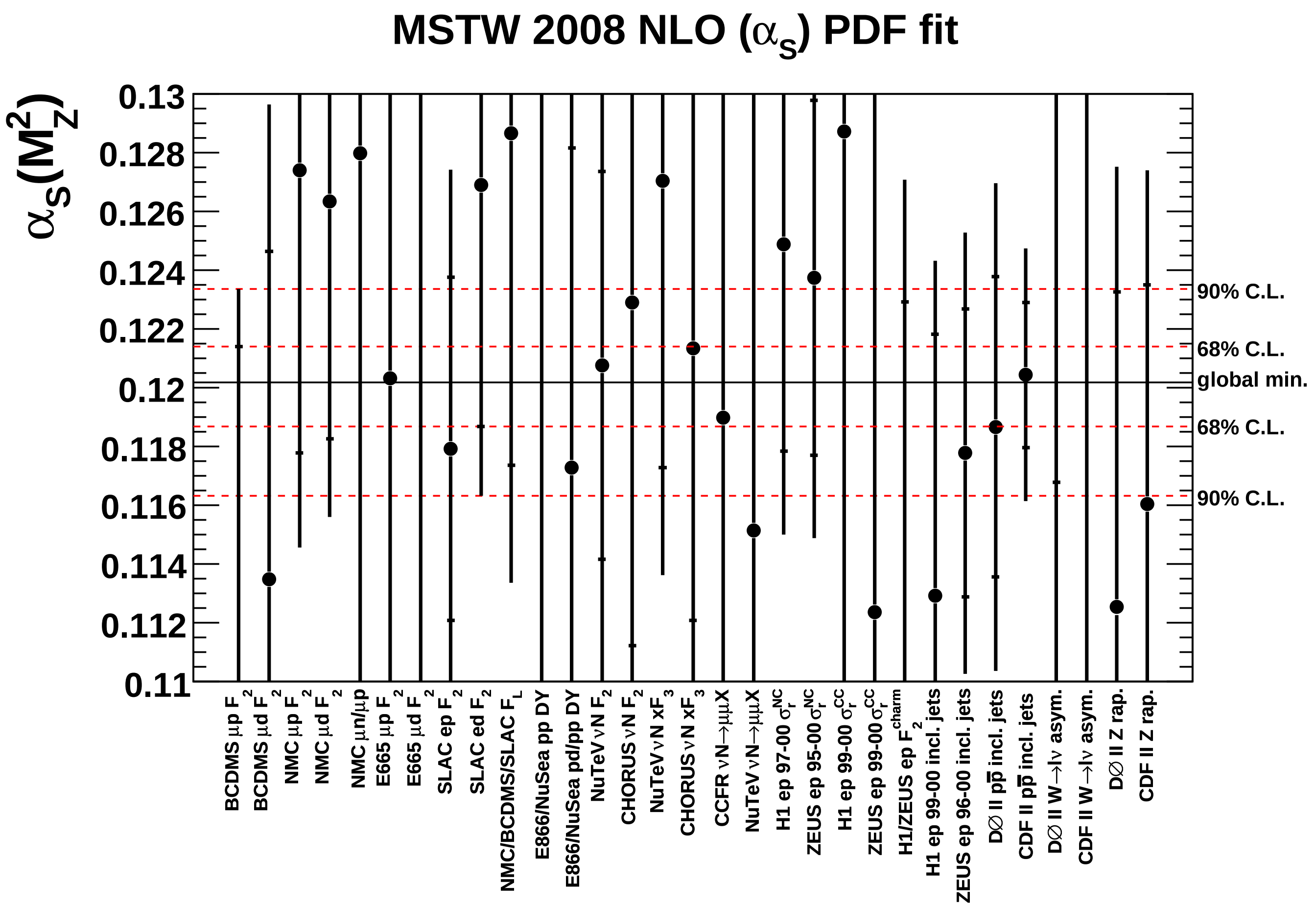
Gluon feeds into evolution of quarks, but change in $\alpha_S(M_Z^2)$ just outweighs gluon change, i.e. larger $\alpha_S(M_Z^2) \rightarrow$ slightly more evolution.



Strong anti-correlation at high-x due to evolution and positive coefficient functions.

Quarks roughly opposite to gluons.

Variation in fit of each data set with α_S



Some sets constrain α_S quite accurately alone (within context of the global fit), but a lot of constraint comes from very different values in both extremes preferred by some sets. Leads to competitive constraint on α_S, though addition of external constraints on this parameter into fit is an option to consider.

Heavy Flavours

MSTW (and all versions of MRST) use a GM-VFNS.

Changed in 2006. Previous version fine at NLO, only max. of 2% change in PDFs. As was clearly pointed out (in Appendix of two papers) was preliminary at NNLO until this point.

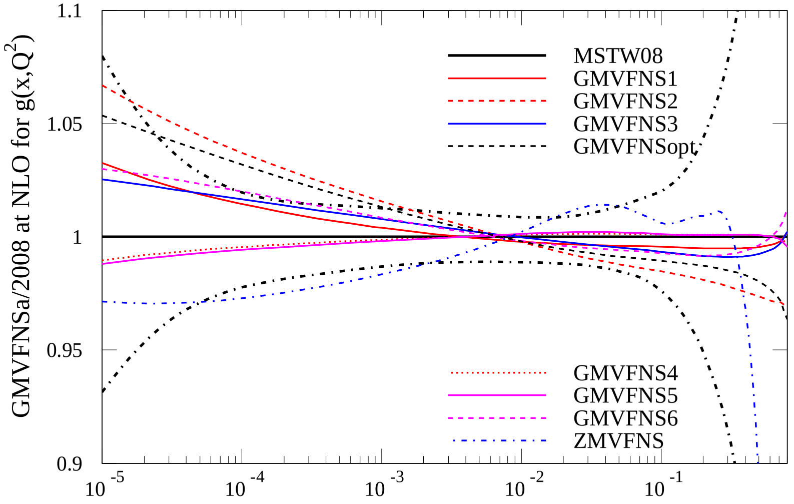
Now similar in a number of ways to SACOT(χ), but differs in ordering and in prefactor, and explicitly extended to NNLO.

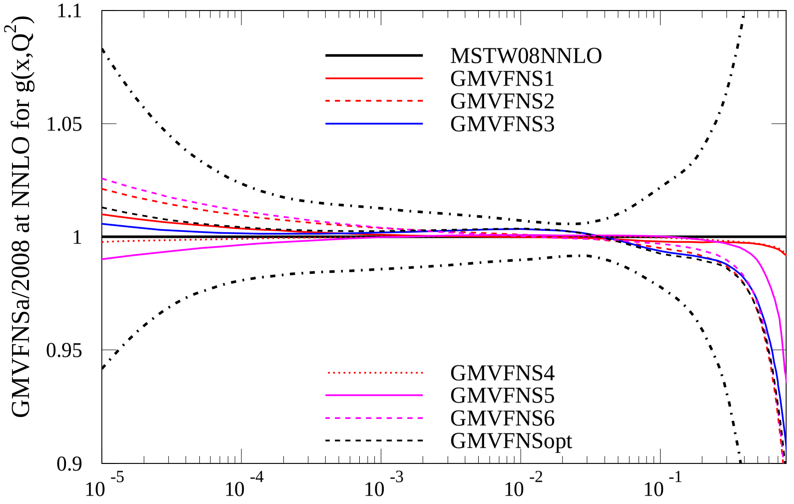
At NLO significant variation in results (similar to size of uncertainties) depending on detail of scheme. Default scheme not the smoothest, so "optimal" now devised. Fit slightly better than default.

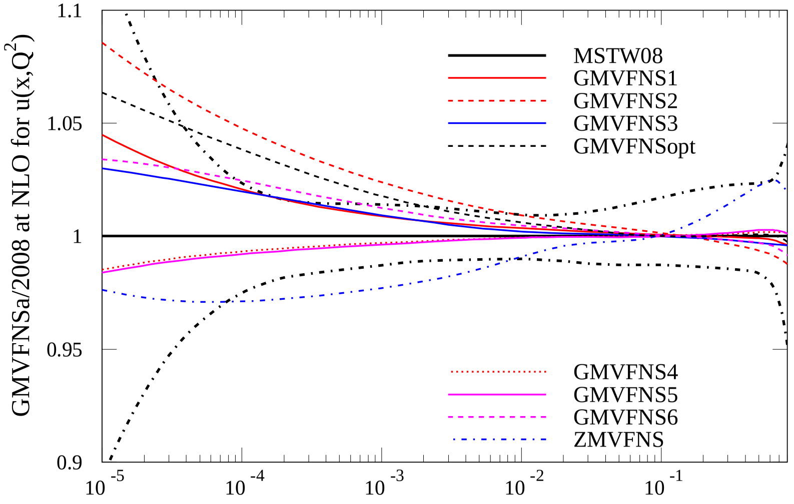
At NNLO in general much less scheme dependence. Uncertainty due to modelling FFNS $\mathcal{O}(\alpha_S^3)$ term at very low Q^2 using small-x and threshold terms. Effect similar to uncertainty at $x < 0.001$. This variation in scheme definition dies away for $Q^2 \gg m_h^2$ as GM-VFNS turns into the NNLO zero-mass limit expression.

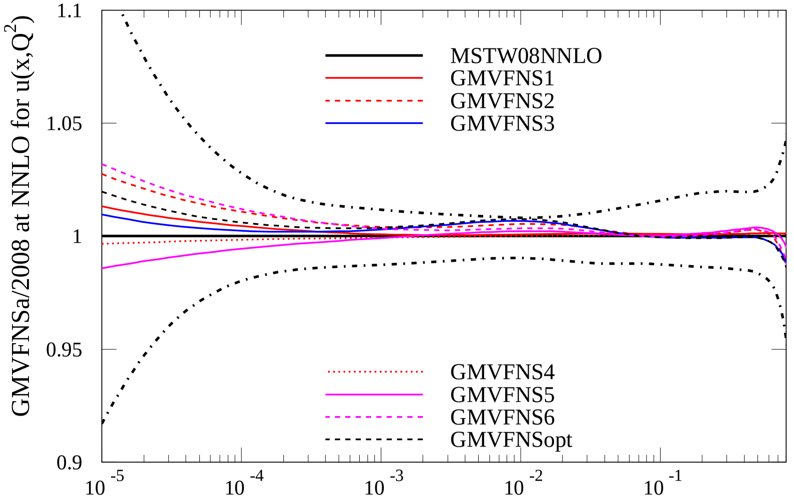
No approximation or assumption at all in NNLO definition for $Q^2 \gg m_h^2$.

Variations in partons extracted from global fit due to different choices of GM-VFNS at NLO (left) and NNLO (right). Variations in predictions in back-up.



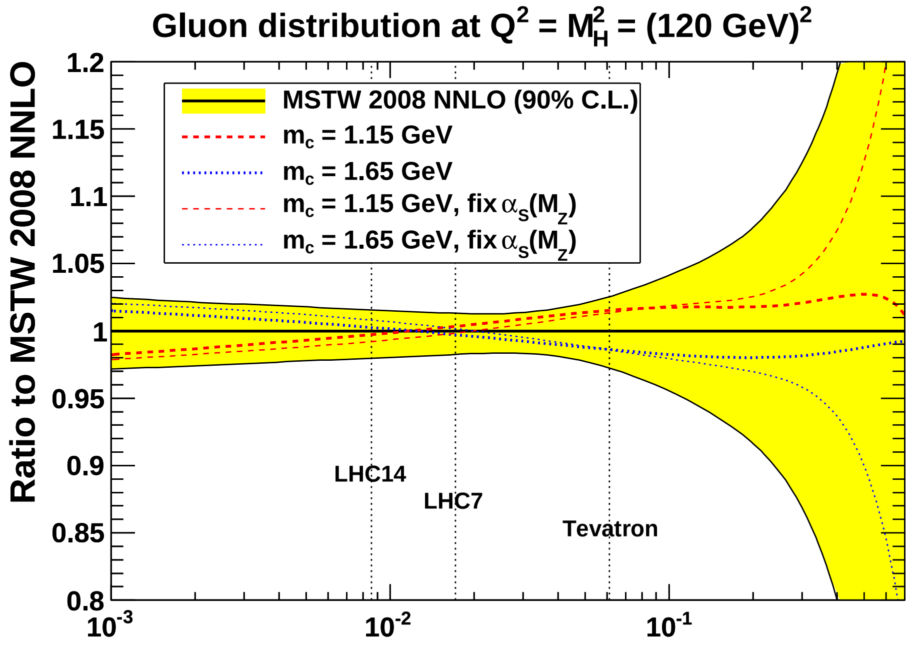


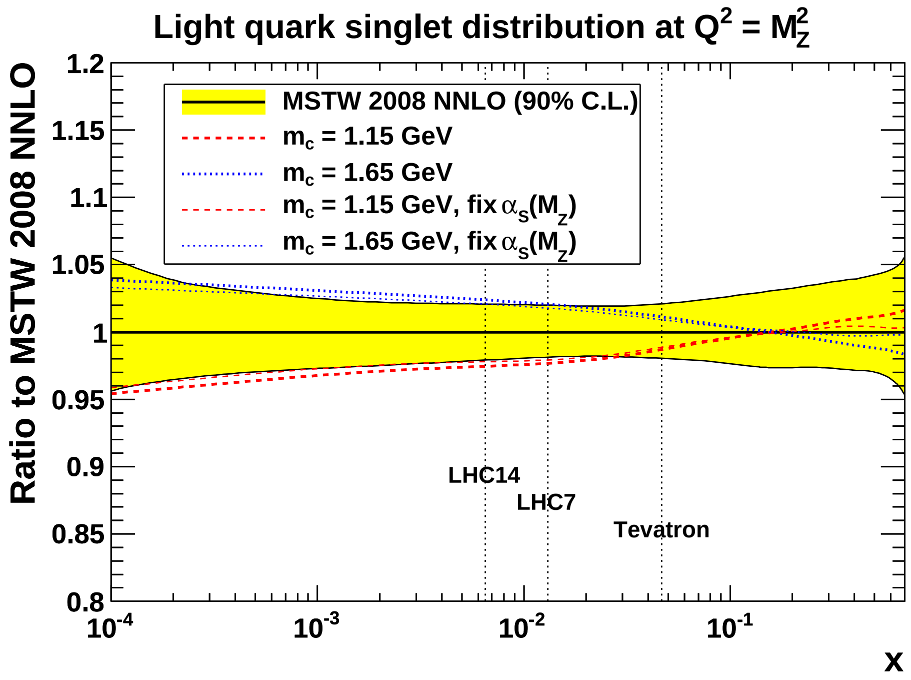




Changes in PDFs with changing heavy quark masses.

Ratio of partons when m_c is varied either with or without varying α_S





Summary

MSTW make available PDFs in a wider range of useful variations than any other group, particularly when including some MRST sets awaiting update. Have worked extremely well in the past with good time stability.

MSTW fit to arguably to widest range of data of any group (only one including HERA jets). No gaps in type of data fit to potentially cause deviations in PDFs.

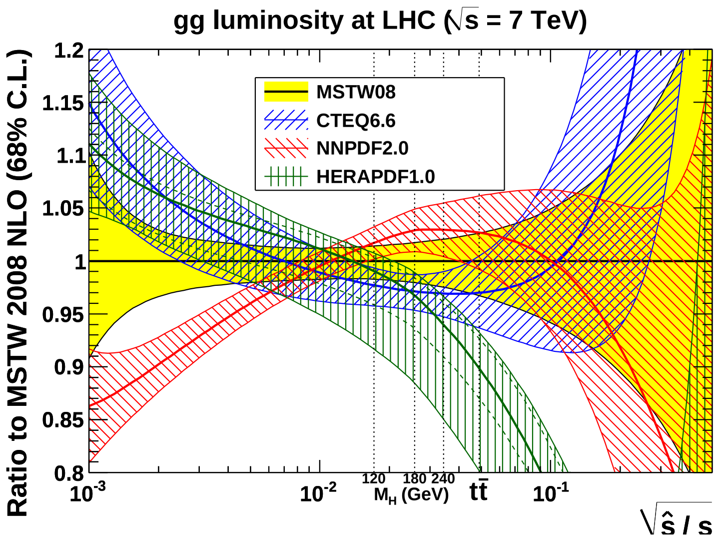
Would like to see all PDFs compared in a quantitative fashion to data not fit. Plots can be misleading, particularly for jets where smooth correlated uncertainties dominate (also, e.g. plots of MSTW2008 and MRST2004 NLO predictions for CDF Z-rapidity look extremely similar, but fit quality quite different).

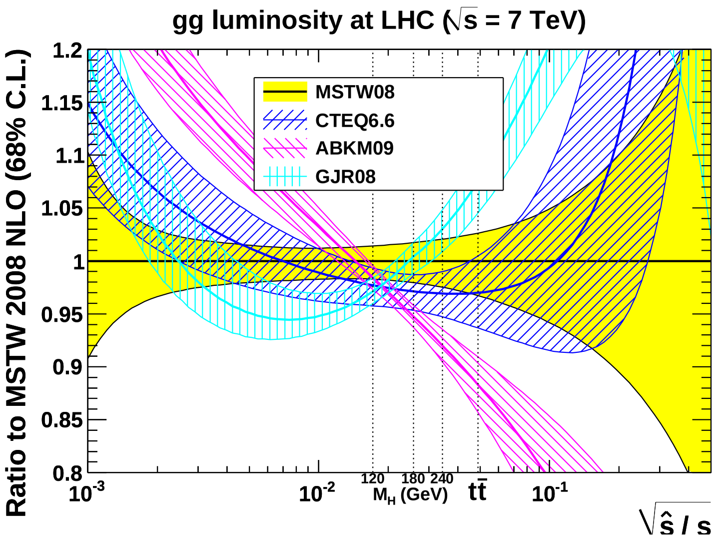
Parameterisation has increased flexibility in the regions where it was clearly seen to be overconstrained (small-x gluon, down quark, strange quark now fit directly).

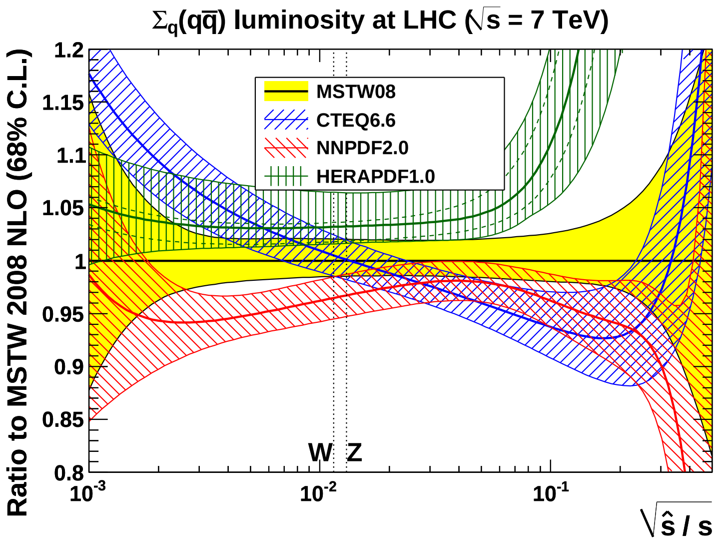
Uses a GM-VFNS which is correct low-Q^2 and asymptotic Q^2 limit at each order, and where variations in choices (or assumptions) has been explicitly checked.

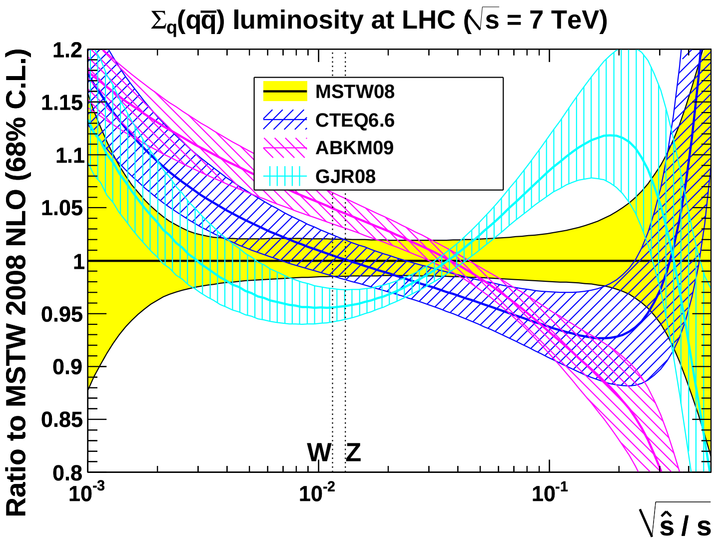
MSTW2008 is, by definition, not completely up-to-date with data. However, note that recent CT10 is nearer to MSTW08 for nearly all PDFs than CTEQ6.6, and prelim. NNPDF2.1 appears to be closer than NNPDF2.0 (mainly at small x).

Predictions by various groups - parton luminosities – NLO. Plots by G. Watt.

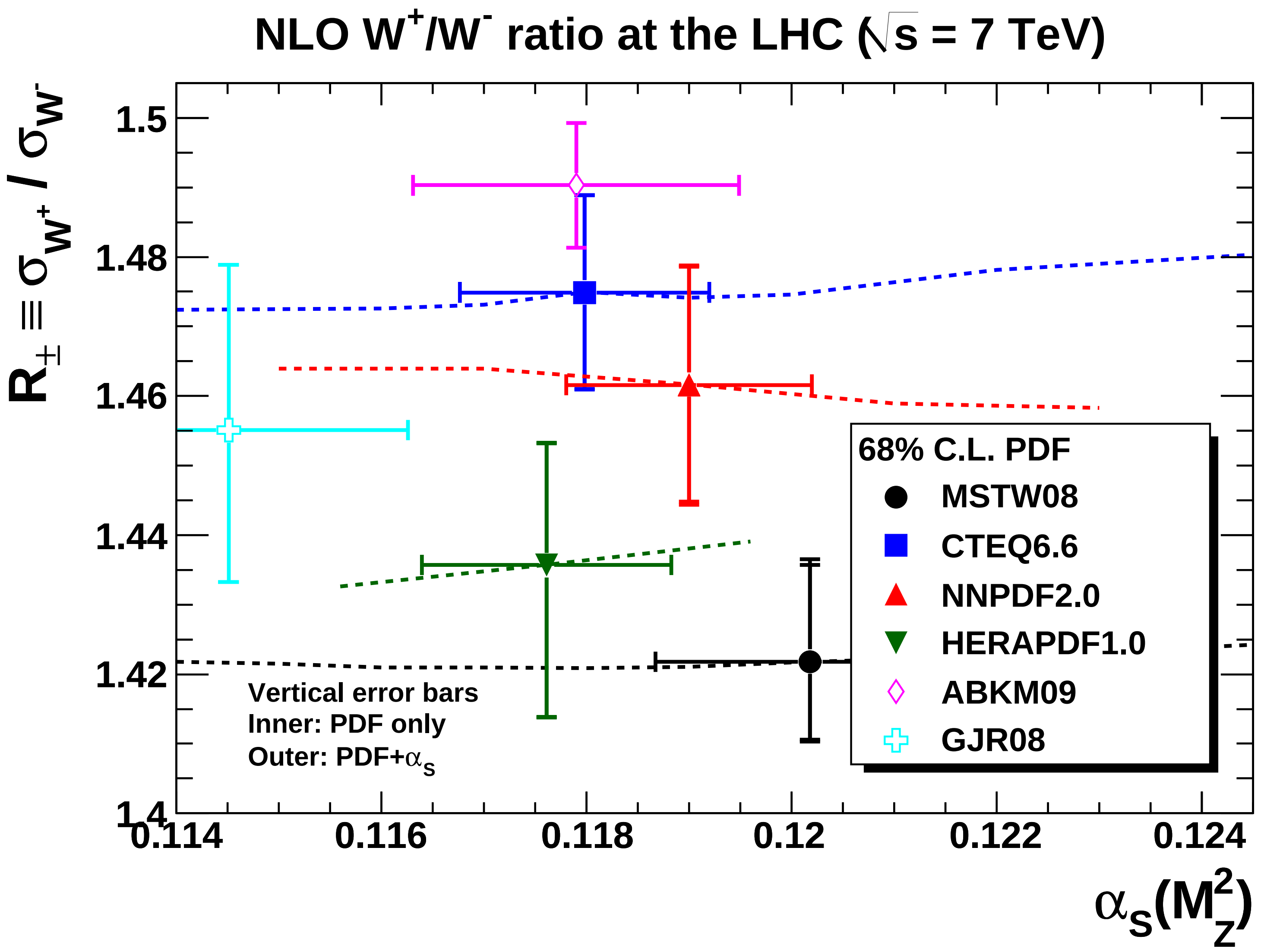








MSTW including all data, full GM-VFNS and sufficiently flexible parameterisation seems to lead to it never being the outlying PDF. (Outlying might not be wrong but surely requires explanation).



One exception, the W^+/W^- ratio (plot by G. Watt). Could be related to deterium corrections. In this case, as others, LHC data will soon provide the answer.

Back-up Slides

```
# iEigen x68plusMin x68minusMax
1 4.53655 -3.76623 (ZEUS ep 95-00 #sigma_{r}^{NC}, H1 ep 97-00 #sigma_{r}^{NC})
2 3.38422 -3.79217 (NMC #mud F_{2}, NuTeV #nuN#rightarrow#mu#muX)
3 1.46292 -2.17007 (NuTeV #nuN#rightarrow#mu#muX, CCFR #nuN#rightarrow#mu#muX)
4 3.45159 -2.31949 (NMC #mun/#mup, E866/NuSea pd/pp DY)
5 1.49487 -2.12523 (NuTeV #nuN#rightarrow#mu#muX, NuTeV #nuN xF_{3})
6 5.2242 -3.21227 (H1 ep 97-00 #sigma_{r}^{NC}, NuTeV #nuN#rightarrow#mu#muX)
7 2.03521 -2.78497 (D#oslash II W#rightarrowl#nu asym., BCDMS #mud F_{2})
8 5.20184 -1.84172 (NuTeV #nuN F_{2}, BCDMS #mup F_{2})
9 3.89046 -3.63201 (H1 ep 97-00 #sigma_{r}^{NC}, ZEUS ep 95-00 #sigma_{r}^{NC})
10 2.99034 -2.67972 (D#oslash II W#rightarrowl#nu asym., SLAC ed F_{2})
11 3.74202 -6.58278 (H1 ep 97-00 #sigma_{r}^{NC}, ZEUS ep 95-00 #sigma_{r}^{NC})
12 5.18993 -3.20527 (SLAC ep F_{2}, BCDMS #mup F_{2})
13 3.32487 -1.57418 (E866/NuSea pp DY, NuTeV #nuN xF_{3})
14 4.21973 -3.62346 (NMC #mud F_{2}, D#oslash II W#rightarrowl#nu asym.)
15 2.63335 -4.3632 (H1 ep 97-00 #sigma_{r}^{NC}, NuTeV #nuN F_{2})
16 2.32169 -0.925389 (CCFR #nuN#rightarrow#mu#muX, E866/NuSea pd/pp DY)
17 2.31104 -1.51795 (NuTeV #nuN#rightarrow#mu#muX, CCFR #nuN#rightarrow#mu#muX)
18 2.88709 -1.42061 (D#oslash II W#rightarrowl#nu asym., E866/NuSea pd/pp DY)
19 4.20991 -4.1461 (H1 ep 97-00 #sigma_{r}^{NC}, CDF II p#bar{p} incl. jets )
20 3.70876 -2.47281 (NuTeV #nuN#rightarrow#mu#muX, NuTeV #nuN#rightarrow#mu#muX)
```

Majority of eigenvectors correspond to $\sqrt{\Delta\chi^2} \sim 2 - 3$.

Treatment of errors.

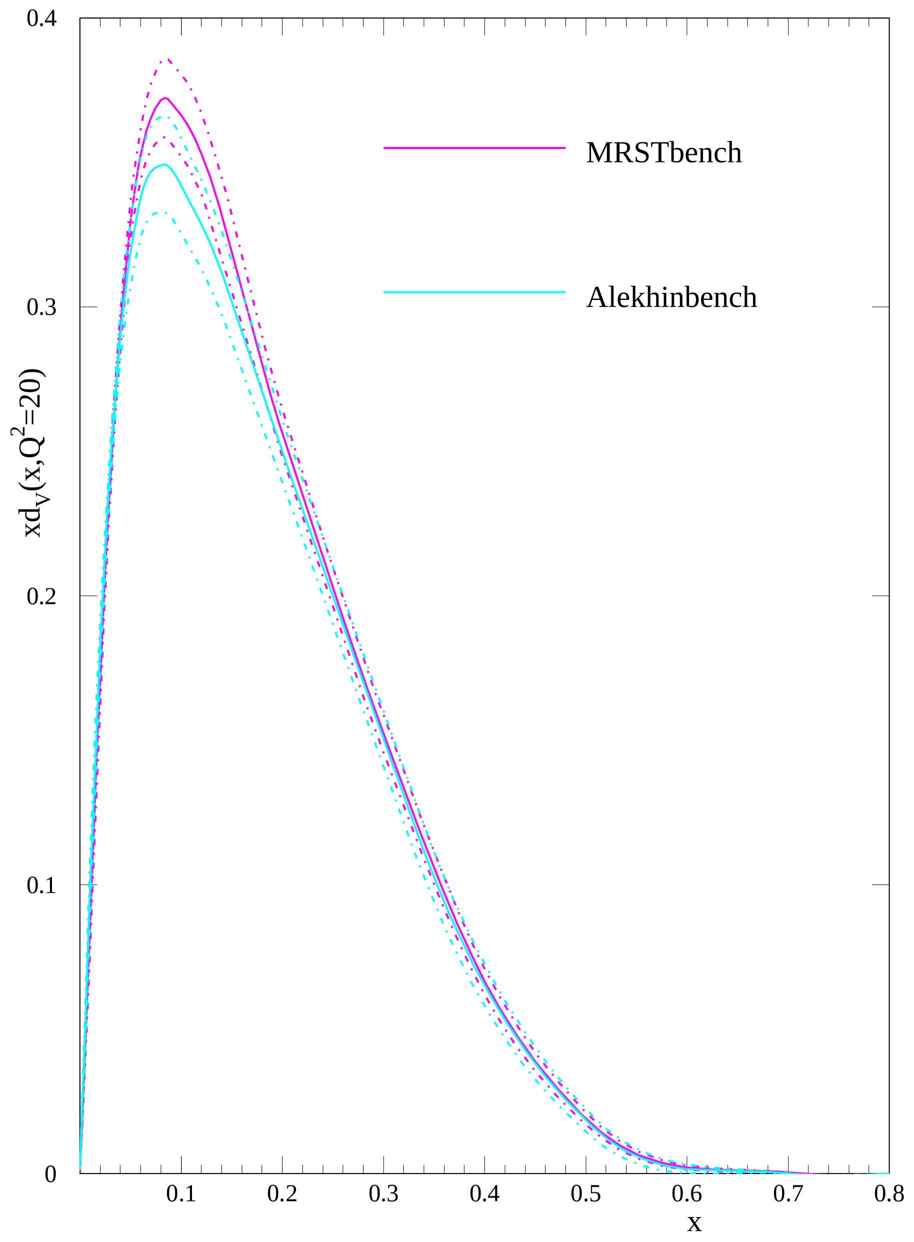
Exercise for $HERA-LHC$ meeting. Fit proton and deuteron structure function data from H1, ZEUS, NMC and BCDMS, for $Q^2 > 9\mathrm{GeV}^2$ using $ZM-VFNS$ and same form of parton inputs at same $Q_0^2 = 1\mathrm{GeV}^2$.

Very conservative fit.

Compare rigorous treatment of all systematic errors (Alekhin) with simple quadratures approach (MRST), both with $\Delta\chi^2 = 1$.

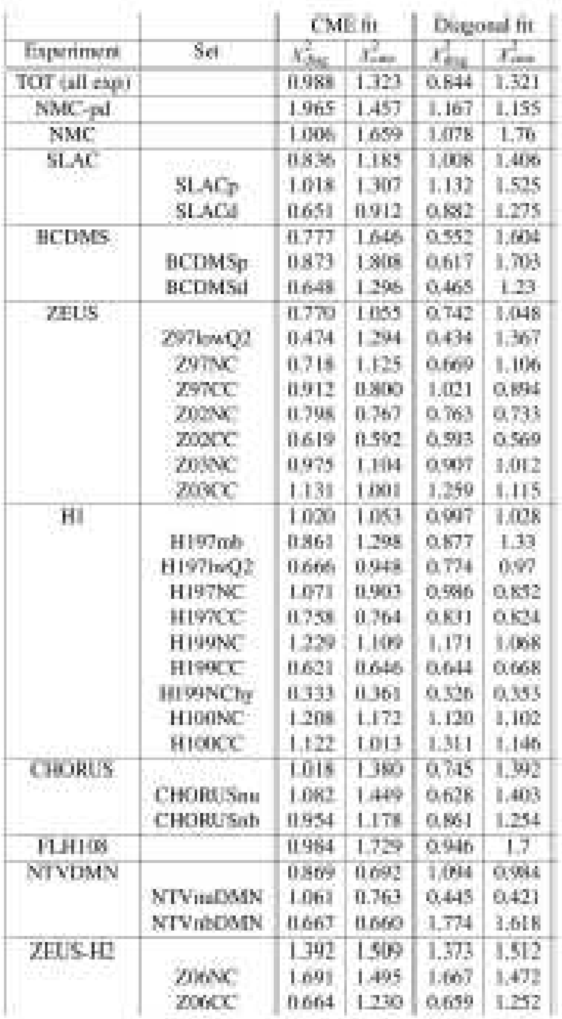
→ some difference in central values (other possible reasons) and similar errors.

Very consistent. (One of worst cases shown.)



THE IMPACT OF CORRELATED UNCERTAINTIES

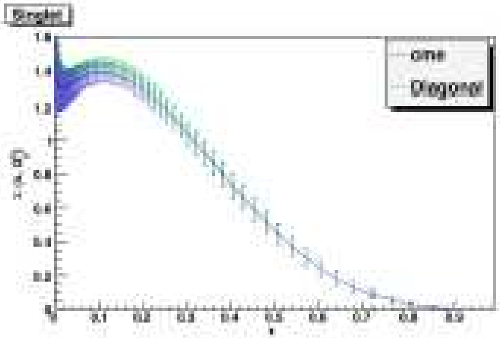
REPEAT THE FIT NEGLECTING ALL CORRELATIONS (A.Donati)



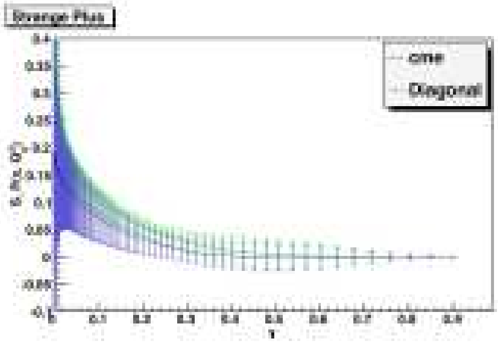
Experiment	Set	CME fit		Diagonal fit	
		$\chi^2_{\rm diag}$	$\chi^2_{\rm cov}$	$\chi^2_{\rm diag}$	$\chi^2_{\rm cov}$
TOT (all exp)		0.988	1.323	0.844	1.321
NMC-pd		1.965	1.457	1.167	1.155
NMC		1.006	1.659	1.078	1.76
SLAC		0.836	1.185	1.008	1.406
	SLACp	1.018	1.307	1.132	1.525
	SLACd	0.651	0.912	0.882	1.275
BCDMS		0.777	1.646	0.552	1.604
	BCDMSp	0.873	1.808	0.617	1.703
	BCDMSd	0.648	1.296	0.465	1.23
ZEUS		0.770	1.055	0.742	1.048
	Z97lowQ2	0.474	1.294	0.434	1.367
	Z97NC	0.718	1.125	0.669	1.106
	Z97CC	0.912	0.800	1.021	0.894
	Z02NC	0.798	0.767	0.763	0.733
	Z02CC	0.619	0.592	0.593	0.569
	Z03NC	0.975	1.104	0.907	1.012
	Z03CC	1.131	1.001	1.259	1.115
H1		1.020	1.053	0.997	1.028
	H197mb	0.861	1.298	0.877	1.33
	H197lowQ2	0.666	0.948	0.774	0.97
	H197NC	1.071	0.903	0.986	0.852
	H197CC	0.758	0.764	0.831	0.824
	H199NC	1.229	1.109	1.171	1.068
	H199CC	0.621	0.646	0.644	0.668
	H199NChy	0.333	0.361	0.326	0.353
	H100NC	1.208	1.172	1.120	1.102
	H100CC	1.122	1.013	1.311	1.146
CHORUS		1.018	1.380	0.745	1.392
	CHORUSnu	1.082	1.449	0.628	1.403
	CHORUSnb	0.954	1.178	0.861	1.254
FLH108		0.984	1.729	0.946	1.7
NTVDMN		0.869	0.692	1.094	0.984
	NTVnuDMN	1.061	0.763	0.445	0.421
	NTVnbDMN	0.667	0.660	1.774	1.618
ZEUS-H2		1.392	1.509	1.373	1.512
	Z06NC	1.691	1.495	1.667	1.472
	Z06CC	0.664	1.230	0.659	1.252

- DIAGONAL χ^2 OF DIAGONAL FIT MUCH LOWER, CORREL. χ^2 OF TWO FITS UNCHANGED
- DIAGONAL FIT REWEIGHTS EXPERIMENTS
  $\Rightarrow$ EXPTS WITH LARGER SYST. (FIXED TARGET) GET SMALLER WEIGHT
- VALENCE & STRANGE PDFS AFFECTED AT THE $\frac{1}{4}\sigma$ LEVEL

SINGLET



STRANGE



Normalisation Uncertainties

Previously the normalization of each data set was determined by the best fit – and then fixed.

Now implement procedure of allowing normalisations of all sets to vary in best fit and scan over eigenvectors, with penalty term for each set

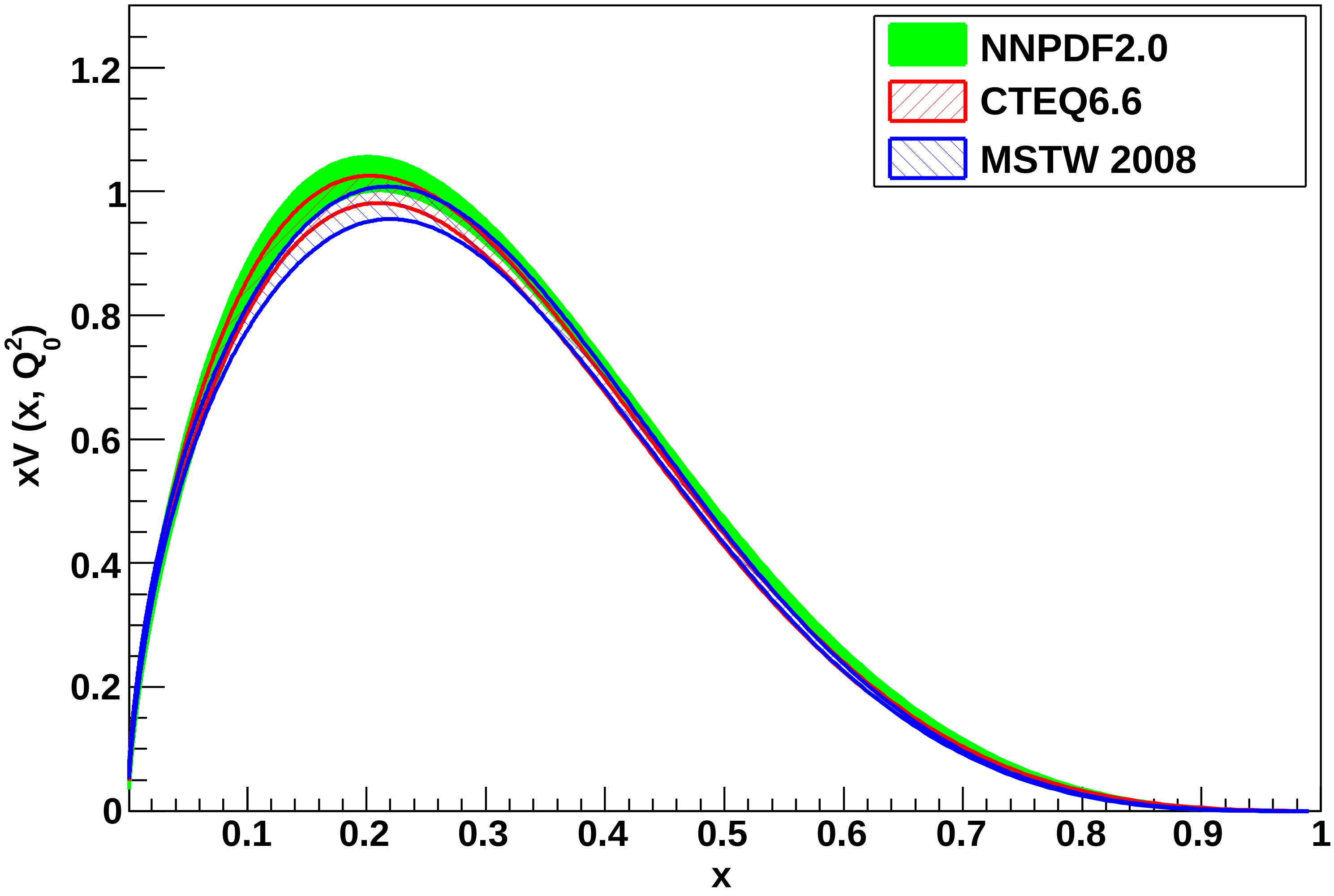
$$\chi^2_{\mathcal{N}} = \left(\frac{1-\mathcal{N}}{\sigma\mathcal{N}}\right)^4$$

Quartic penalty avoids very large deviations. Still shift down at LO (fit failure) and slightly at NLO.

Rescale errors with normalization to avoid bias (D'Agostini).

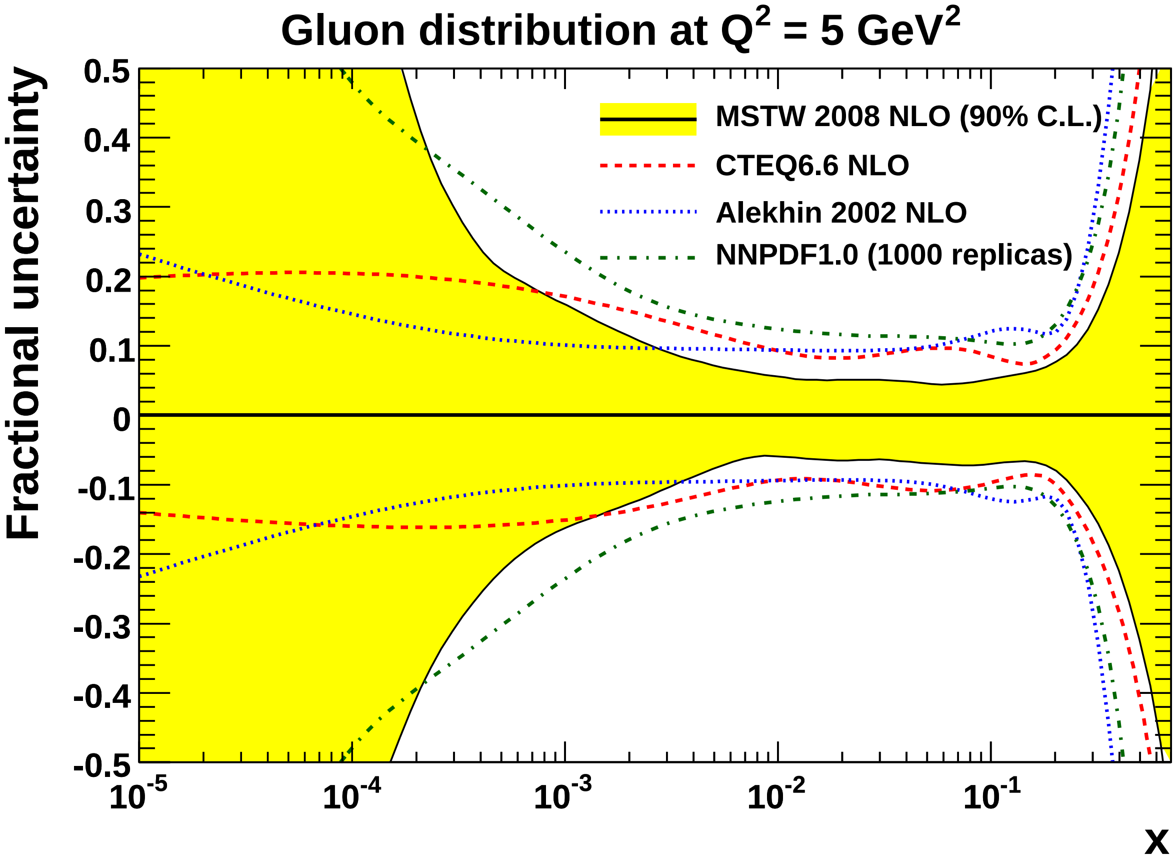
Data set	σ_n^N	LO	NLO	NNLO
BCDMS μp F_2 [32]	3%	0.9667	0.9644	0.9678
BCDMS μd F_2 [102]	3%	0.9667	0.9644	0.9678
NMC μp F_2 [33]	2%	1.0083	0.9982	0.9999
NMC μd F_2 [33]	2%	1.0083	0.9982	0.9999
NMC $\mu n/\mu p$ [103]	—	1	1	1
E665 μp F_2 [104]	1.85%	1.0146	1.0052	1.0024
E665 μd F_2 [104]	1.85%	1.0146	1.0052	1.0024
SLAC ep F_2 [105, 106]	1.9%	1.0227	1.0125	1.0078
SLAC ed F_2 [105, 106]	1.9%	1.0227	1.0125	1.0078
NMC/BCDMS/SLAC F_L [32–34]	—	1	1	1
E866/NuSea pp DY [107]	6.5%	1.0629	1.0086	1.0868
E866/NuSea pd/pp DY [108]	—	1	1	1
NuTeV νN F_2 [37]	2.1%	0.9987	0.9997	0.9992
CHORUS νN F_2 [38]	2.1%	0.9987	0.9997	0.9992
NuTeV νN xF_3 [37]	2.1%	0.9987	0.9997	0.9992
CHORUS νN xF_3 [38]	2.1%	0.9987	0.9997	0.9992
CCFR $\nu N \to \mu\mu X$ [39]	2.1%	0.9987	0.9997	0.9992
NuTeV $\nu N \to \mu\mu X$ [39]	2.1%	0.9987	0.9997	0.9992
H1 MB 99 e^+p NC [31]	1.3%	0.9861	1.0098	1.0090
H1 MB 97 e^+p NC [109]	1.5%	0.9863	0.9921	0.9953
H1 low Q^2 96–97 e^+p NC [109]	1.7%	1.0029	1.0095	1.0172
H1 high Q^2 98–99 e^-p NC [110]	1.8%	0.9782	0.9851	0.9860
H1 high Q^2 99–00 e^+p NC [35]	1.5%	0.9762	0.9834	0.9842
ZEUS SVX 95 e^+p NC [111]	1.5%	0.9944	0.9948	1.0004
ZEUS 96–97 e^+p NC [112]	2%	0.9735	0.9811	0.9871
ZEUS 98–99 e^-p NC [113]	1.8%	0.9771	0.9855	0.9862
ZEUS 99–00 e^+p NC [114]	2.5%	0.9656	0.9761	0.9762
H1 99–00 e^+p CC [35]	1.5%	0.9762	0.9834	0.9842
ZEUS 99–00 e^+p CC [36]	2.5%	0.9656	0.9761	0.9762
H1/ZEUS ep $F_2^{\rm charm}$ [41–47]	—	1	1	1
H1 99–00 e^+p incl. jets [59]	1.5%	0.9762	0.9834	—
ZEUS 96–97 e^+p incl. jets [57]	2%	0.9735	0.9811	—
ZEUS 98–00 $e^{\pm}p$ incl. jets [58]	2.5%	0.9656	0.9761	—
DØ II $p\bar{p}$ incl. jets [56]	6.1%	0.9353	1.0596	1.0759
CDF II $p\bar{p}$ incl. jets [54]	5.8%	0.8779	0.9646	0.9900
CDF II $W \to \ell\nu$ asym. [48]	—	1	1	1
DØ II $W \to \ell\nu$ asym. [49]	—	1	1	1
DØ II Z rap. [53]	—	1	1	1
CDF II Z rap. [52]	5.8%	0.8779	0.9646	0.9900

Specific Parameterisation Examples



Uncertainties on valence quarks not notably different in shape to other groups at all.
No obvious parameterisation limitation

Gluon Parameterisation - small x – different parameterisations lead to very different uncertainty for small x gluon.



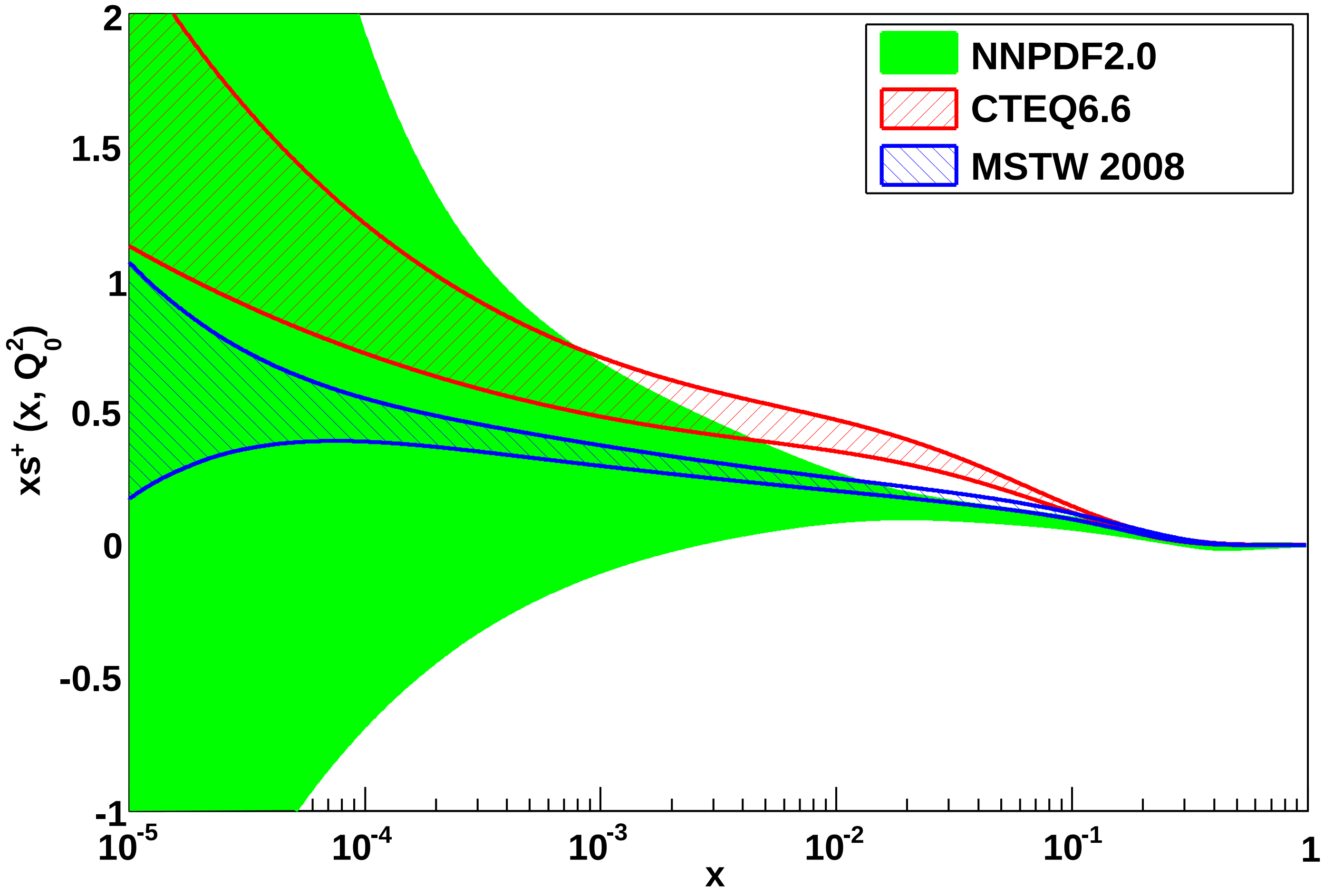
Most assume single power x^{λ} at input → limited uncertainty. If input at low Q^2 λ positive and small-x input gluon *fine-tuned* to ~ 0. Artificially small uncertainty.

If $g(x) \propto x^{\lambda \pm \Delta\lambda}$ then $\Delta g(x) = \Delta\lambda \ln(1/x) * g(x)$.

MRST/MSTW and NNPDF more flexible (can be negative) → rapid expansion of uncertainty where data runs out.

Strange Quarks

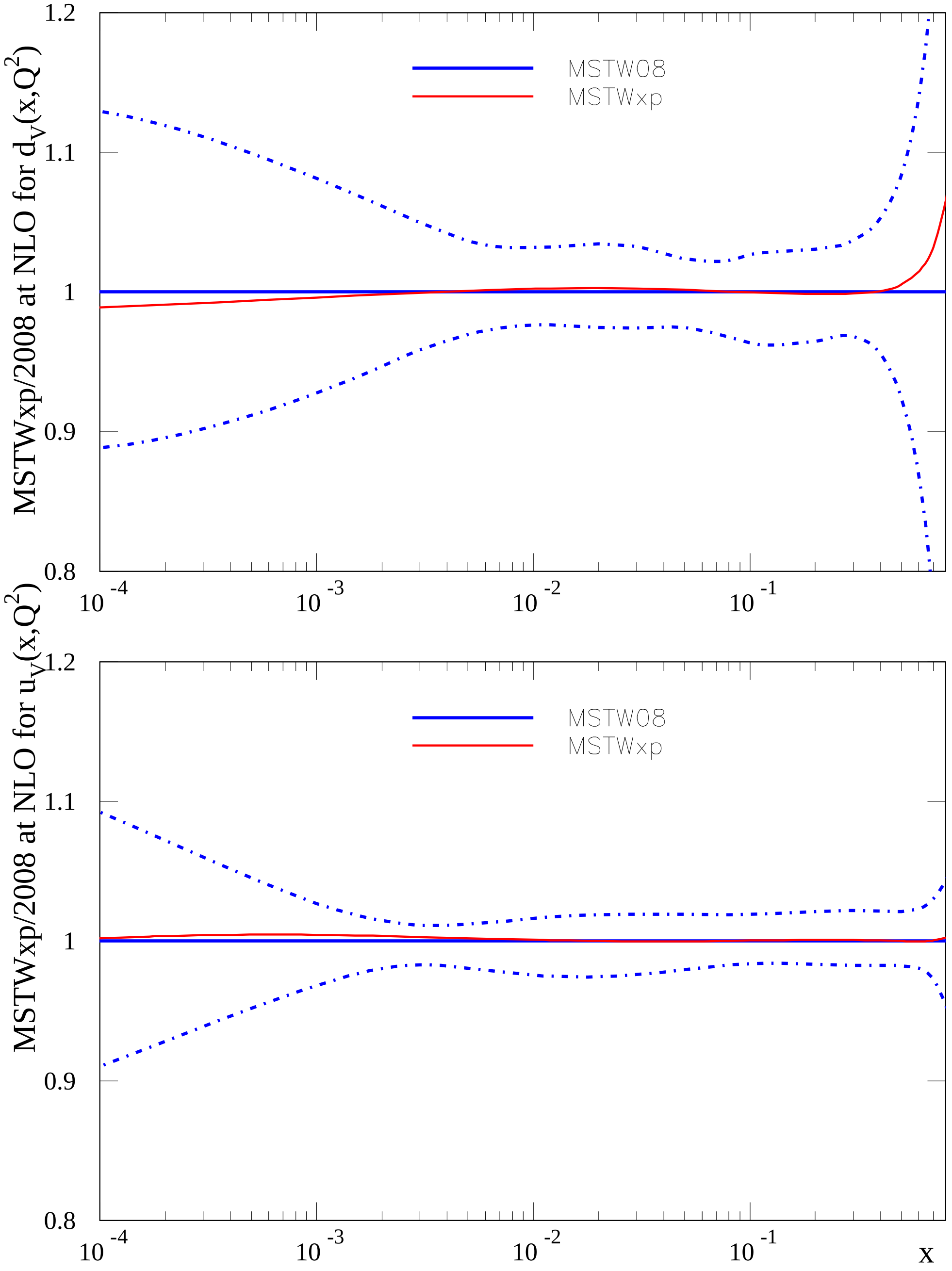
MSTW assumes shape of strange given by theory assumption that suppression of form of massive quarks. For charm and bottom shape below $x = 0.01$ rapidly becomes very similar to light quarks.



Tried adding x^2 terms to polynomial in two valence parameterisations.

Fit quality improved by 2 units.

Change in partons negligible.



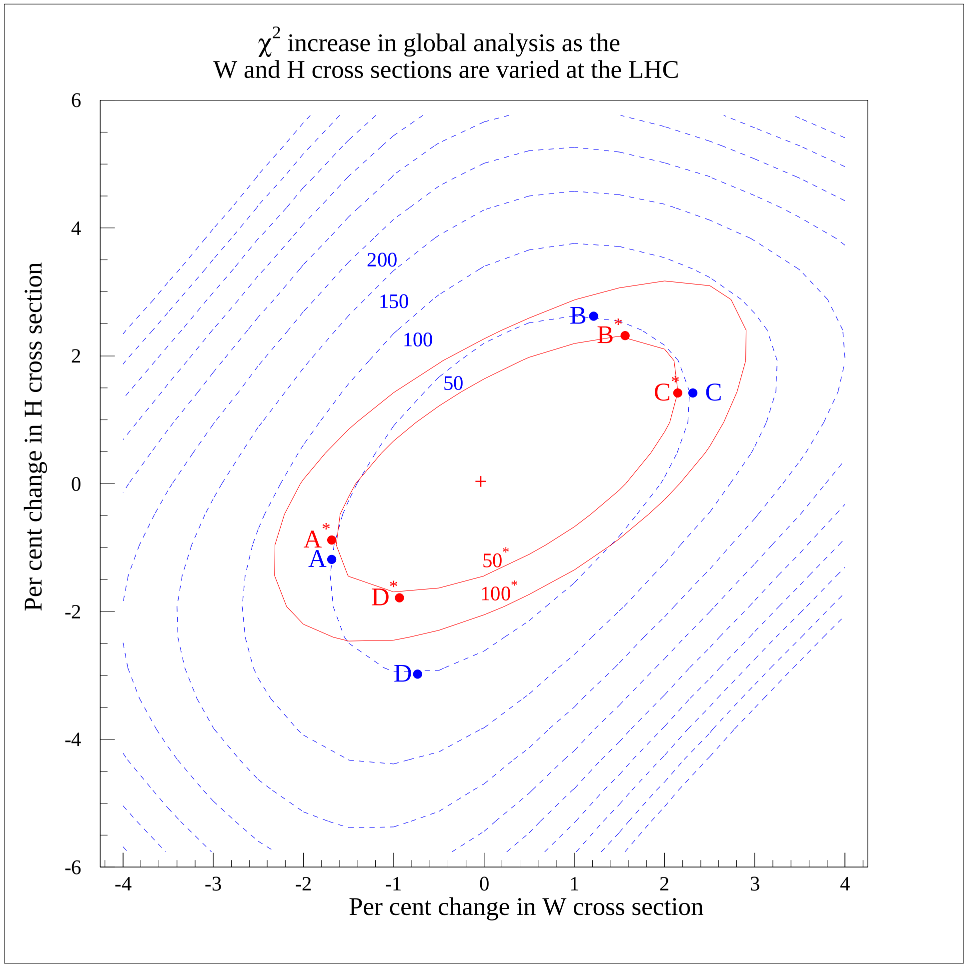
Lagrange multiplier method for W and $120\mathrm{GeV}$ Higgs at the LHC.

Uncertainty using Hessian approach about 10% smaller.

Also looked at uncertainties on moments of u–d using Hessian and Lagrange multiplier approaches. Very similar and latter could be slightly smaller.

In all cases introduction of extra parameters in the Lagrange multiplier method led to at most a moderate increase in uncertainty.

If this was clearly more than 10% the limitations in parameters were addressed and the problem solved.



The values of the predicted cross-sections at NLO for Z and a 120 GeV Higgs boson at the Tevatron and the LHC (latter for 14 TeV) as GM-VFNS altered.

PDF set	Tev		LHC	(14 TeV)
	σ_Z (nb)	σ_H(pb)	σ_Z (nb)	σ_H(pb)
MSTW08	7.207	0.7462	59.25	40.69
GMvar1	$+0.3\%$	-0.5%	$+1.1\%$	$+0.2\%$
GMvar2	$+0.7\%$	-1.1%	$+3.0\%$	$+1.5\%$
GMvar3	$+0.1\%$	-0.3%	$+1.1\%$	$+0.8\%$
GMvar4	$+0.0\%$	-0.1%	-0.4%	-0.2%
GMvar5	-0.1%	-0.1%	-0.5%	-0.3%
GMvar6	$+0.3\%$	-0.4%	$+1.6\%$	$+0.8\%$
GMvaropt	$+0.3\%$	-1.5%	$+2.0\%$	$+0.4\%$
ZM-VFNS	-0.7%	-1.2%	-3.0%	-3.1%
GMvarcc	$+0.0\%$	-0.1%	$+0.0\%$	-0.1%

Little more than 1% variation at Tevatron in σ_Z.

Up to $+3\%$ and -0.5% variation in σ_Z at the LHC. About half as much in σ_H due to higher average x sampled.

Most variation in ZM-VFNS.

The values of the predicted cross-sections at NNLO.

PDF set	Tev		LHC	(14 TeV)
	σ_Z (nb)	σ_H(pb)	σ_Z (nb)	σ_H(pb)
MSTW08	7.448	0.9550	60.93	50.51
GMvar1	$+0.1\%$	-0.5%	$+0.1\%$	-0.2%
GMvar2	$+0.3\%$	-0.8%	$+0.5\%$	$+0.1\%$
GMvar3	$+0.4\%$	-0.1%	$+0.5\%$	$+0.7\%$
GMvar4	$+0.0\%$	-0.2%	$+0.1\%$	-0.1%
GMvar5	$+0.1\%$	-0.3%	-0.2%	-0.2%
GMvar6	$+0.1\%$	-0.9%	$+0.3\%$	-0.2%
GMvaropt	$+0.4\%$	-0.2%	$+0.6\%$	$+0.8\%$
GMvarmod	-0.2%	-0.4%	-1.4%	-1.0%
GMvarmod′	$+0.0\%$	-0.7%	$+0.0\%$	$+0.1\%$

Maximum variations of order 1% at LHC. High-x gluon leads to 1% on σ_H at Tevatron.

Much improved stability compared to NLO.