MSTW PDFs
NNLO, Fits to Collider data, LO*

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Variety of PDFs

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

- At , LO, NLO and NNLO.
- Also a variety of extensions such as different α_S values, heavy quark masses, different flavour numbers.
- Older MRST versions of modified LO* and LO** PDFs and of PDFs including QED evolution.

Here will concentrate on NNLO (with discussion of necessary approximations), a NLO fit to only collider data and very briefly LO* PDFs.

Data fit

- Lepton-proton collider HERA – (DIS) $\longrightarrow$ small-x quarks, and gluons from evolution. Also, jets $\longrightarrow$ moderate-x gluon and α_S (not at NNLO).

- 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.

- Fixed target neutral current DIS – higher x – leptons (BCDMS, NMC, E665, SLAC) $\longrightarrow$ up quark (proton) or down quark (deuterium).

- Fixed target charged current DIS – neutrinos (CHORUS, NuTeV) (cut above $x = 0.5$ on latter) $\longrightarrow$ valence or singlet combinations.

- Di-muon production in neutrino DIS – (CCFR, NuTeV) strange quarks and neutrino-antineutrino comparison $\longrightarrow$ asymmetry .

- Drell-Yan production of dileptons – quark-antiquark annihilation (E866 pp experiment) – high-x sea quarks. Deuterium target (E866) – $\bar{u}/\bar{d}$ asymmetry.

Keep first three in collider only fits.

Fit data for scales above $Q^2_{\rm cut} = 2{\rm GeV}^2$. (most) DIS data for $W^2 > 15{\rm GeV}^2$. Will mention effect of cuts later.

Don't yet include combined HERA cross-section data in official sets. Have produced unofficial sets which include effects of this. In some cases predictions change by a little over 1σ, in many cases less. Smaller change at NNLO, and slightly smaller again with relaxation of (quartic) normalisation constraint.

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

NNLO PDFs – MRST/MSTW have produced NNLO PDFs since 2000.

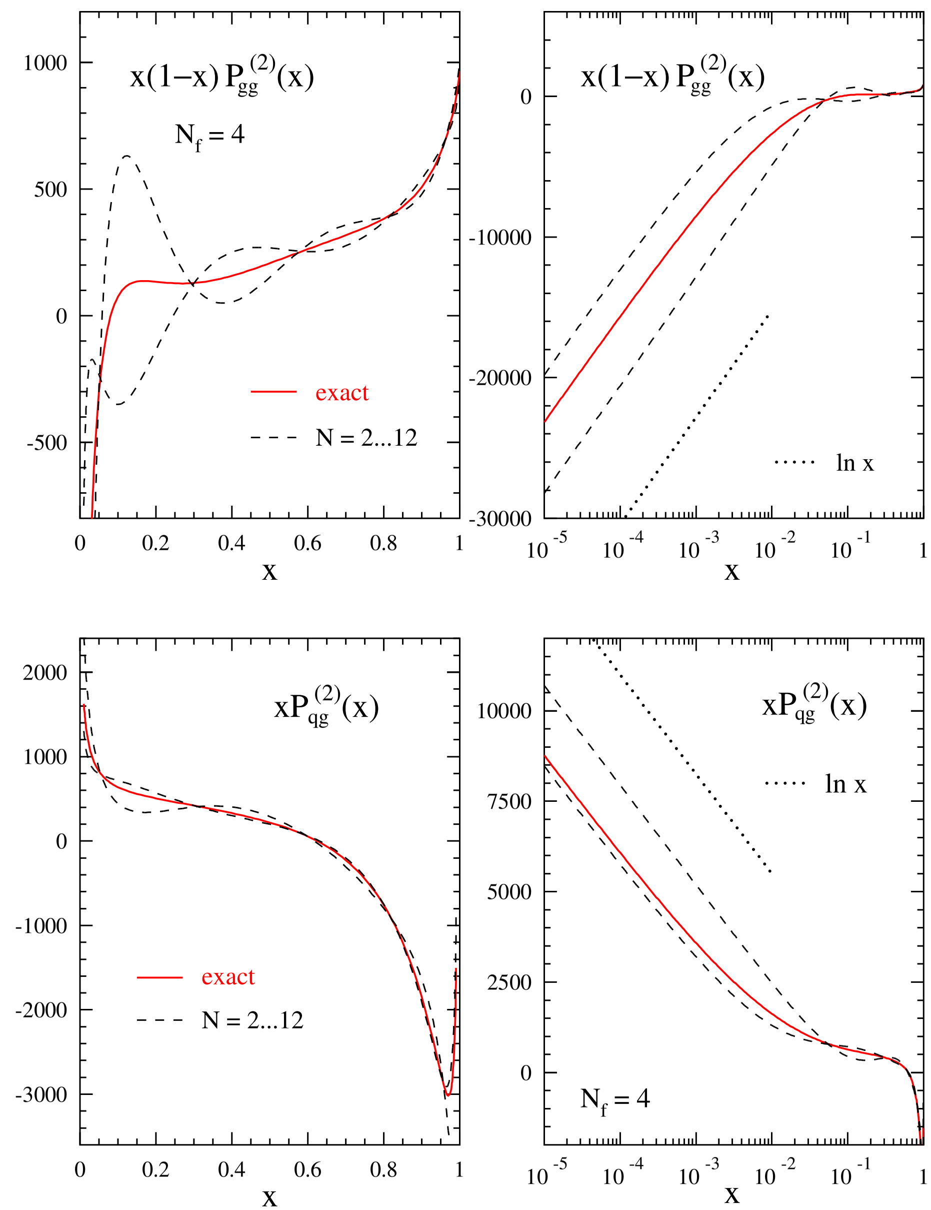
Massless coefficient functions for structure functions have always been exact (Zijlstra and W.L. van Neerven).

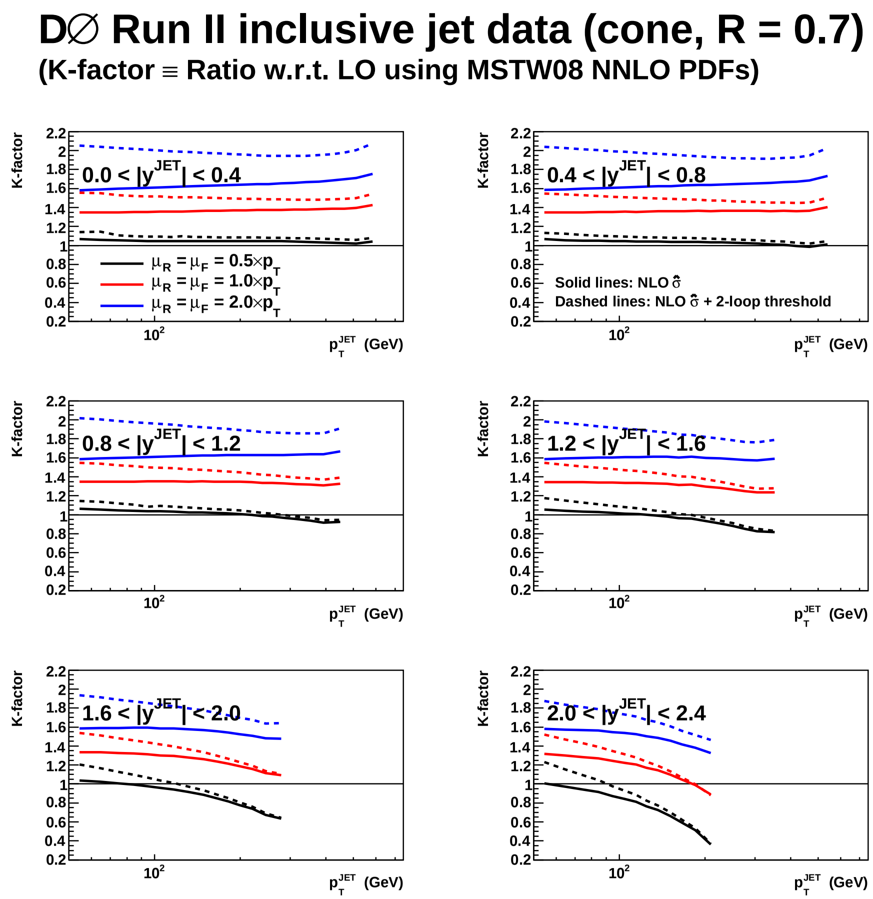
Originally used approx. (van Neerven and Vogt) to full splitting functions. Excellent approx to exact result (Moch *et.al*).

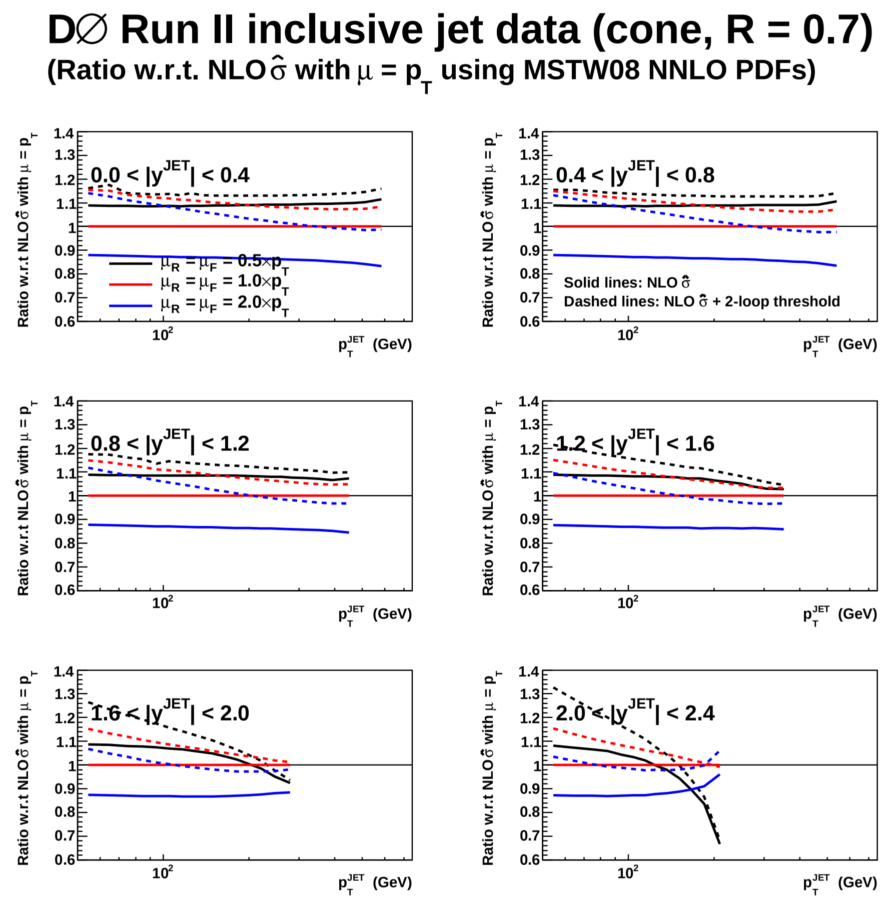
Always used GM-VFNS for heavy flavour (see later).

Exact at high Q^2, some approximation for $Q^2 \sim m_h^2$.

Exact (massless) coefficients for Drell-Yan, with α_S-factorised K-factors.



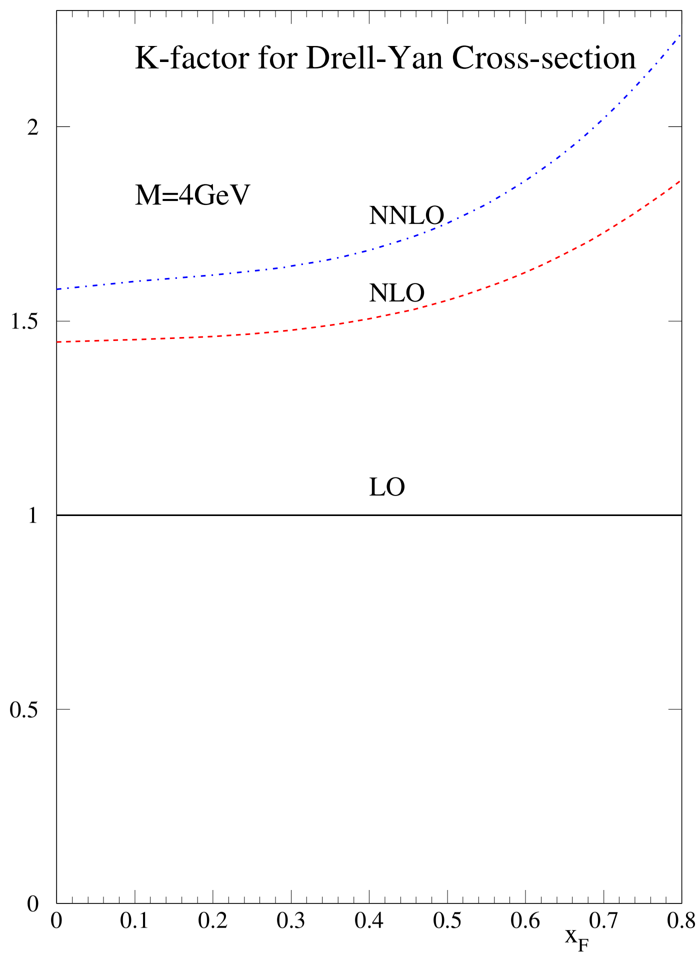


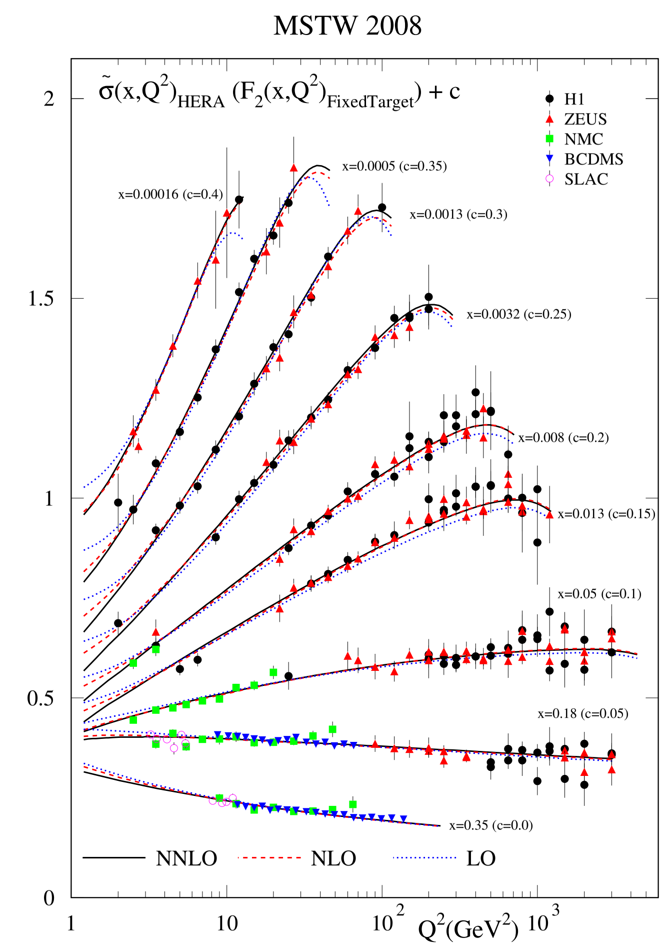


At NNLO use threshold (Kidonakis and Owens) approx. for Tevatron jets. Not large correction. NLO K-factor not large, and smooth.

NNLO approximation aids stability.

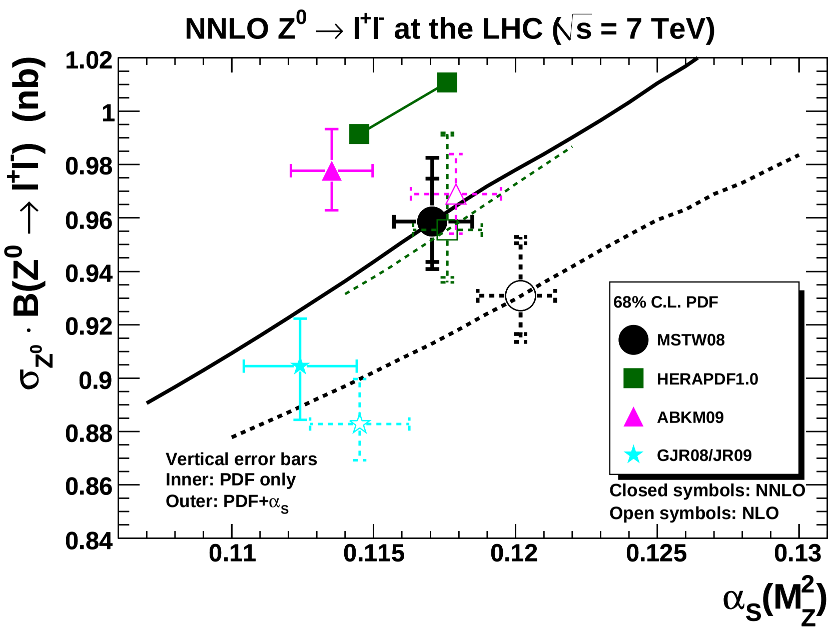
Omit HERA jets at NNLO. No NNLO approximation, and NNLO correction arguably a bit bigger and more shape-dependent than for Tevatron jets. Prediction using NLO cross section and NNLO PDFs excellent, however.

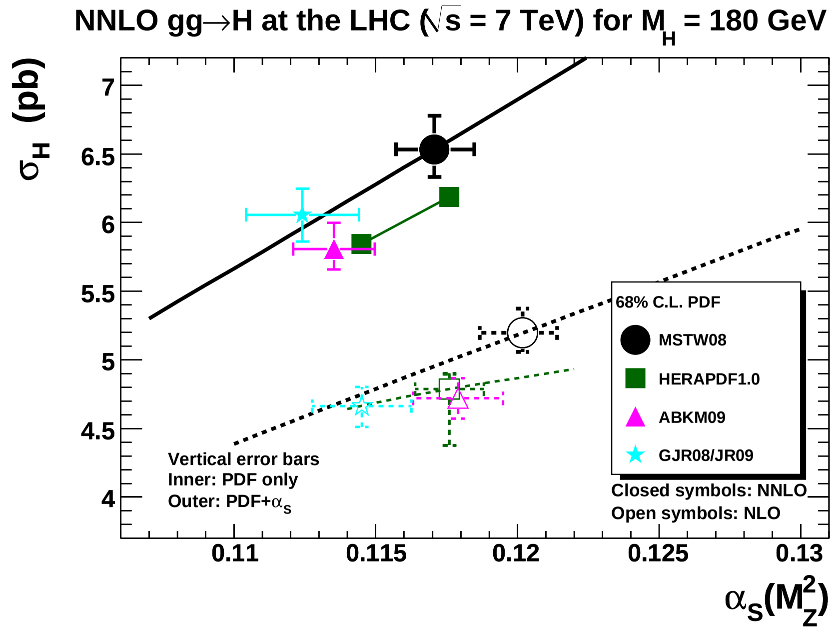




In general NNLO corrections either positive for cross sections, e.g. Drell Yan, or for evolution in structure functions.

Automatically leads to lower $\alpha_S(M_Z^2)$ at NNLO than at NLO, i.e. 0.1171 rather than 0.1202. Difference between two quite stable.





Stability better from NLO to NNLO if the value of $\alpha_S(M_Z^2)$ is appropriately modified as plots by Watt show.

The $\Delta\chi^2$ profiles for some data sets are stabilised by NNLO corrections.

High-x $F_L(x,Q^2)$ data receive large positive NNLO corrections, mimicked by large α_S at NLO.

HERA $F_2^{c\bar{c}}(x,Q^2)$ data prefer slope predicted at NNLO – difficult to achieve at NLO.

E866 Drell-Yan data more complicated. Prefer NLO normalisation but NNLO shape.

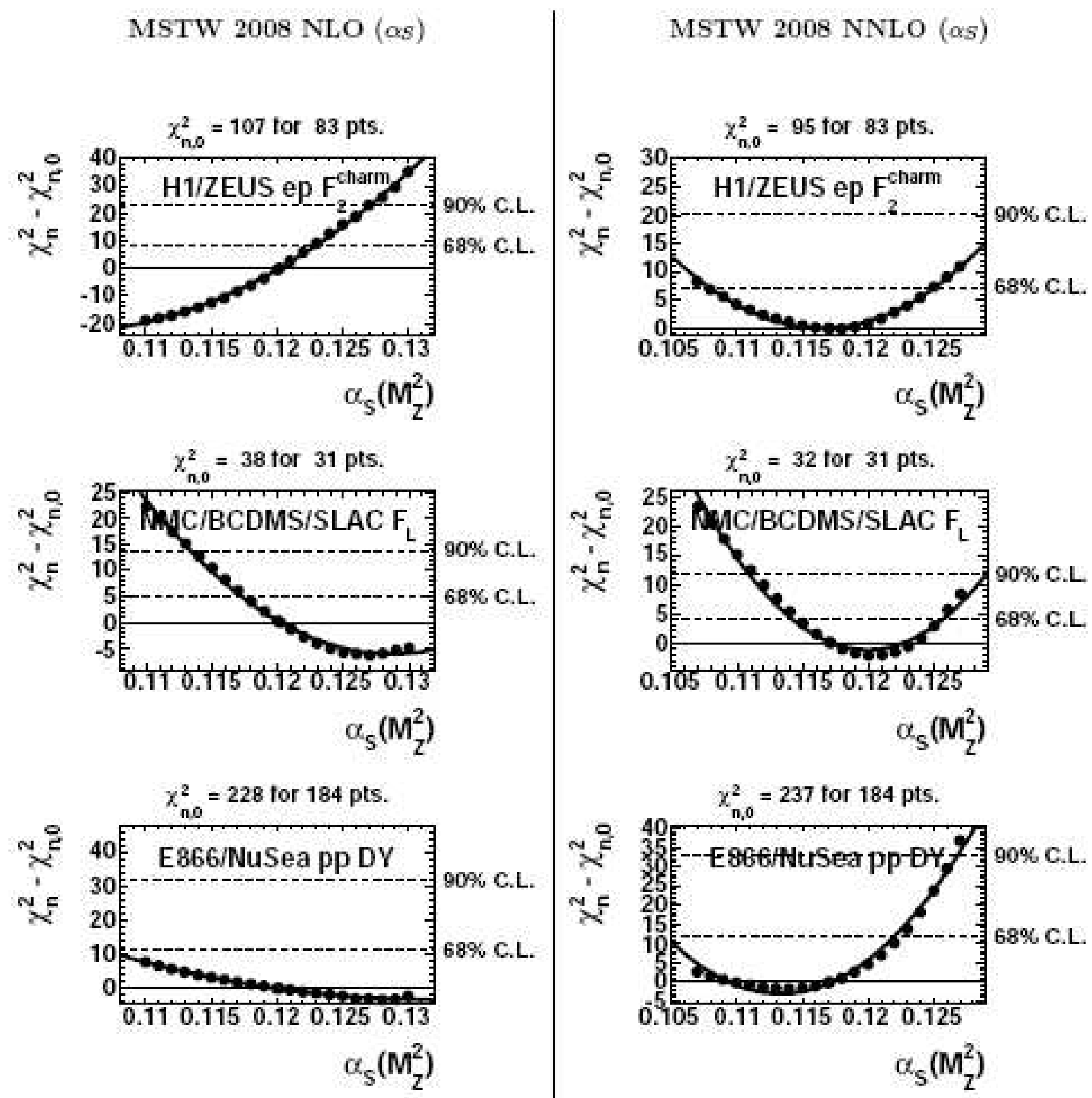
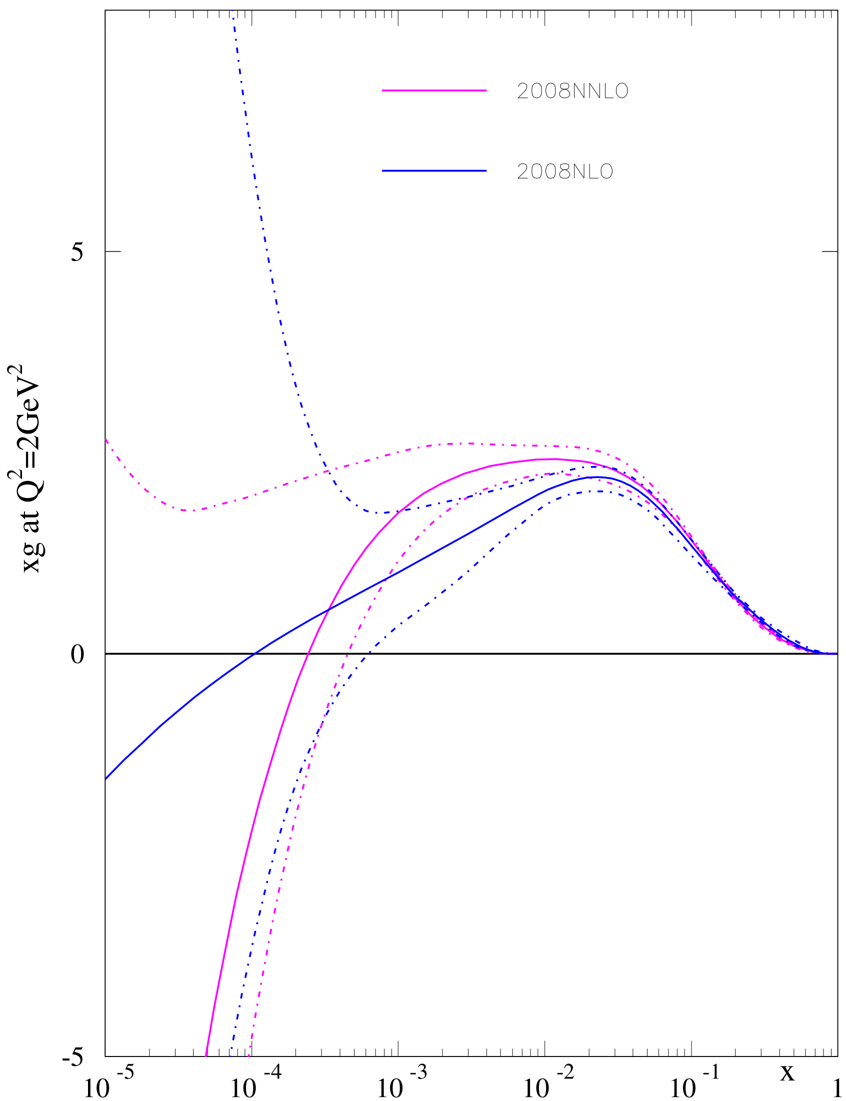
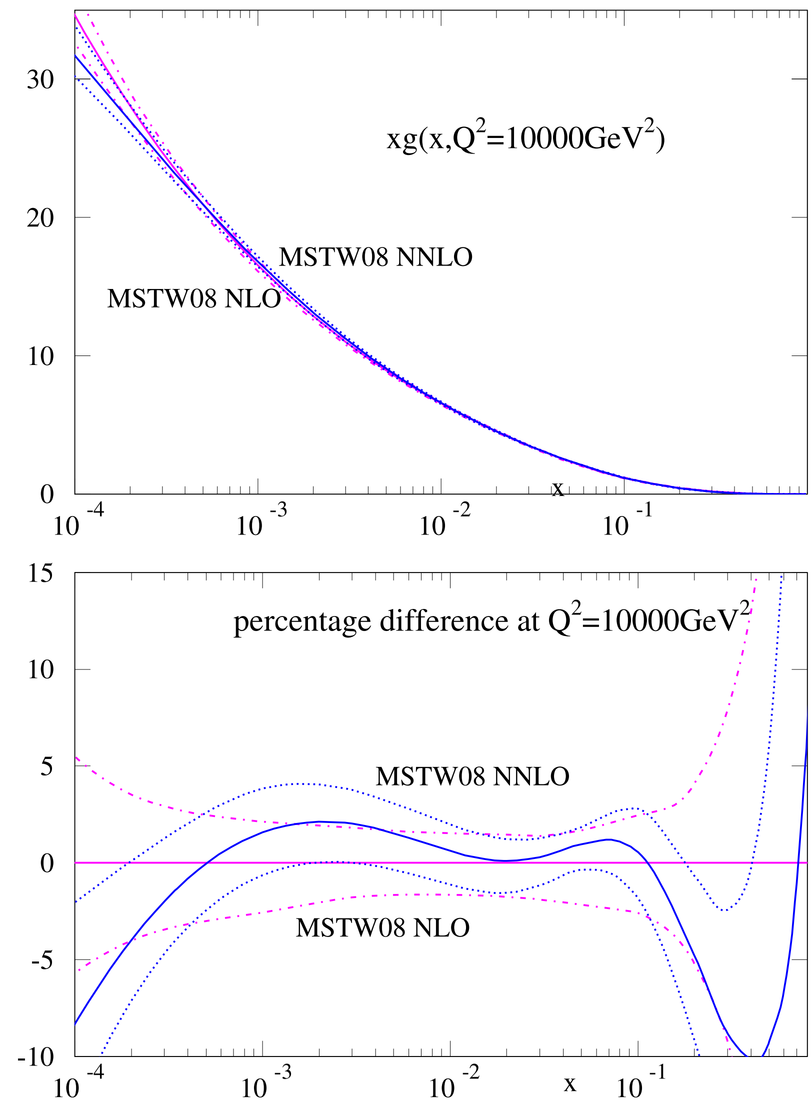


Figure 5: Comparison of selected χ^2_n profiles in the NLO (left) and NNLO (right) fits.





Gluons a little different at NLO and NNLO at low Q^2. Largely washed out by evolution, but only because of different α_S.

Shape of low x and low Q^2 gluon only achieved by having a very flexible parameterisation (7 free parameters) – normalisation of first term set by momentum sum rule.

$$xg(x, Q_0^2 = 1\ \mathrm{GeV}^2) = A_g\, x^{\delta_g}(1-x)^{\eta_g}\,(1+\epsilon_g\sqrt{x}+\gamma_g x) + A_{g'}\, x^{\delta_{g'}}(1-x)^{\eta'_g},$$

Introduced for first NNLO fit, but soon also used as standard at NLO.

Removing second term leads to $\Delta\chi^2 = 80, 63$ at NLO and NNLO respectively.

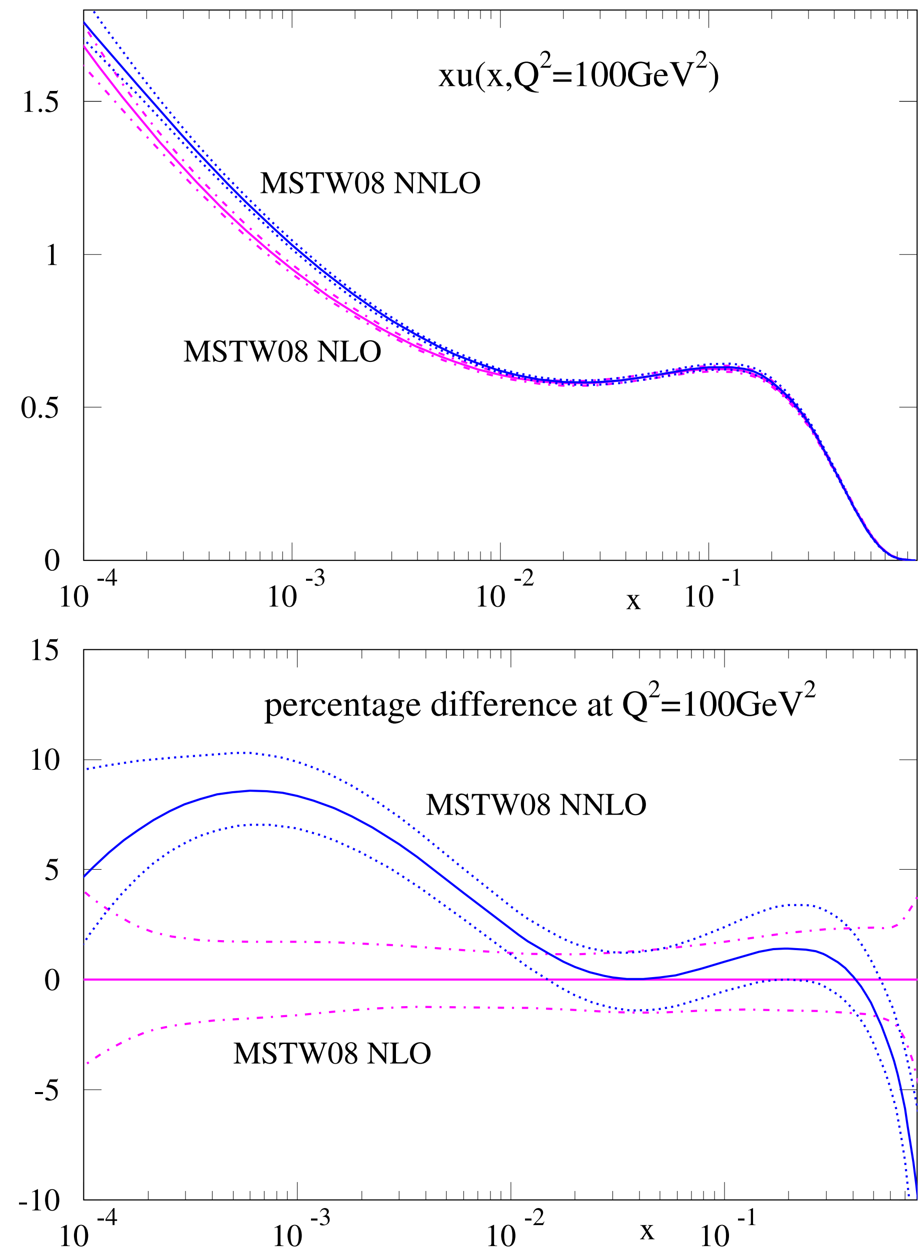
Also lowering of $\alpha_S(M_Z^2)$, e.g. at NNLO $\alpha_S(M_Z^2) = 0.1156$.

Note that removing second term and jet data from NNLO fit (and keeping high-x gluon positive) results in $\alpha_S(M_Z^2) = 0.1139$.

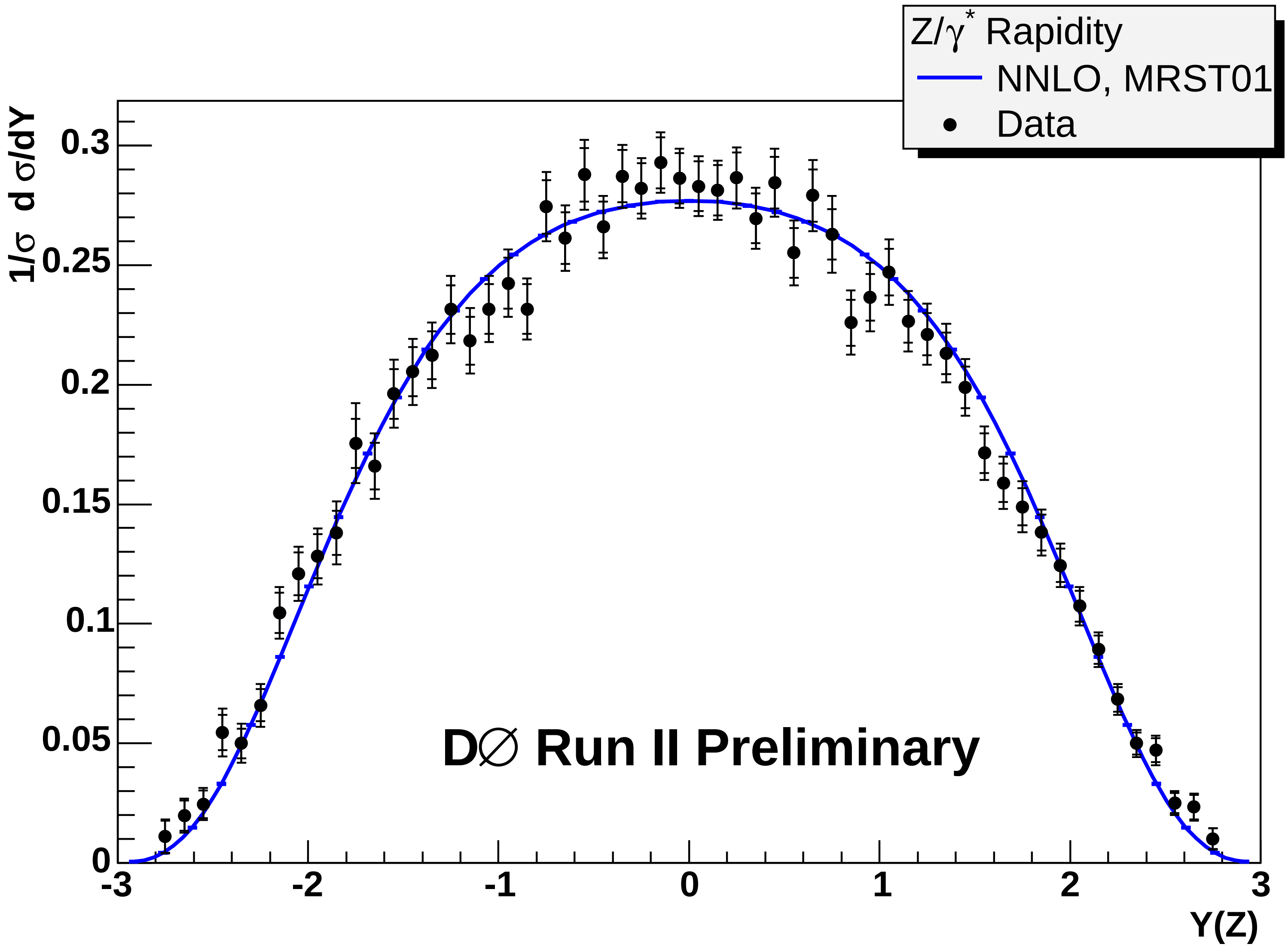
Sometimes vital to use NNLO PDFs if calculating at NNLO.

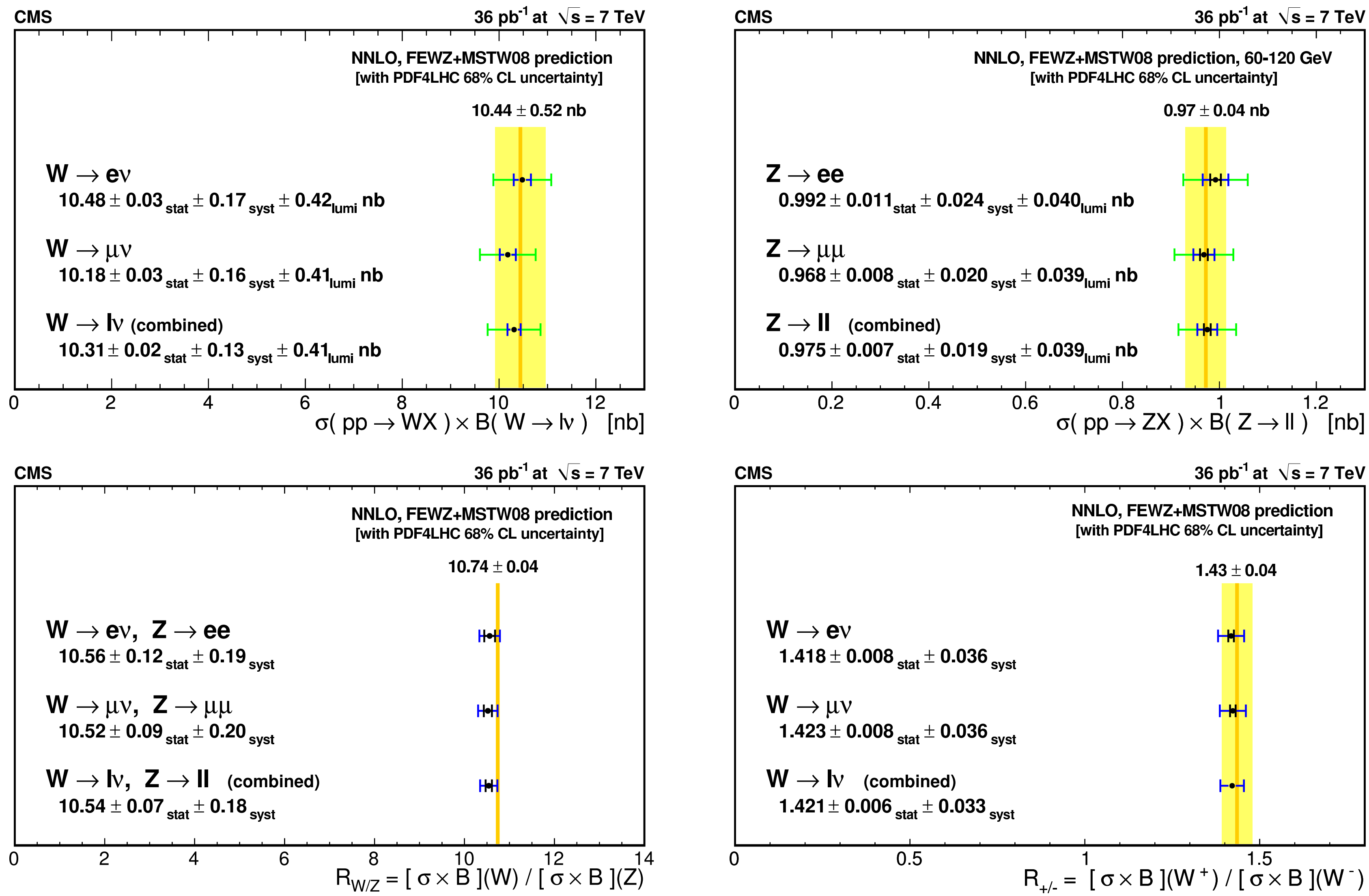
Systematic difference between PDF defined at NLO and at NNLO.

Due to large (negative) gluon coefficient function $C^2_{2,g}$ at not too small x.



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

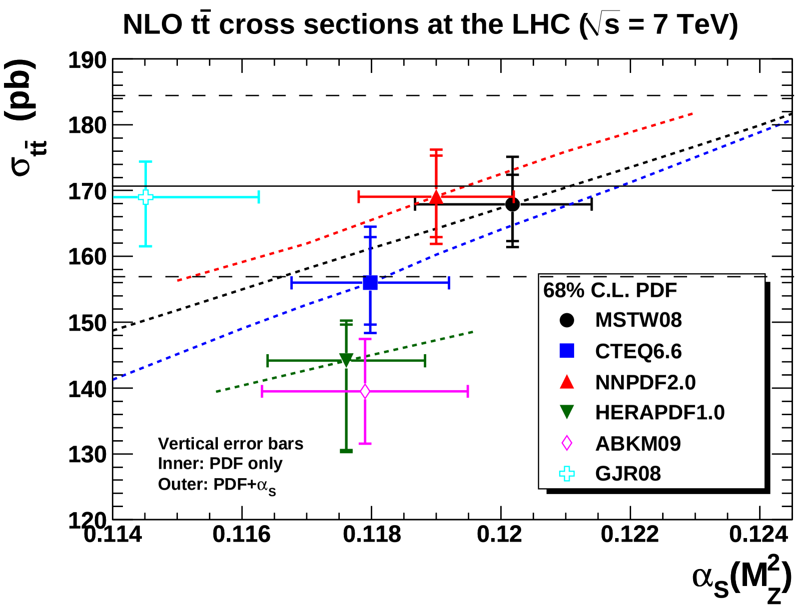


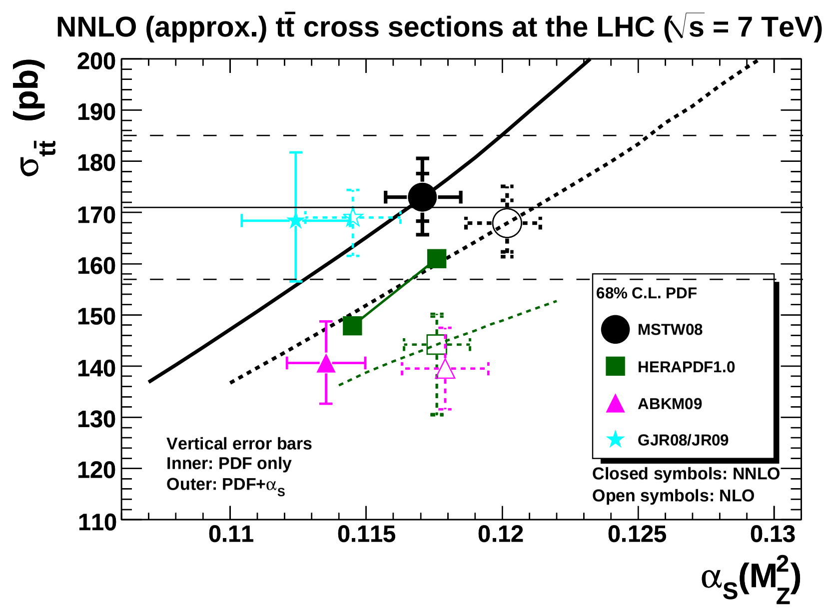


Also excellent predictions for CMS total cross sections and ratios. (Not quite so good for prelim. ATLAS, central values in both cases dependent on acceptance corrections).

Not best place for PDF4LHC recipe.

Very good also for $t\bar{t}$ cross sections.



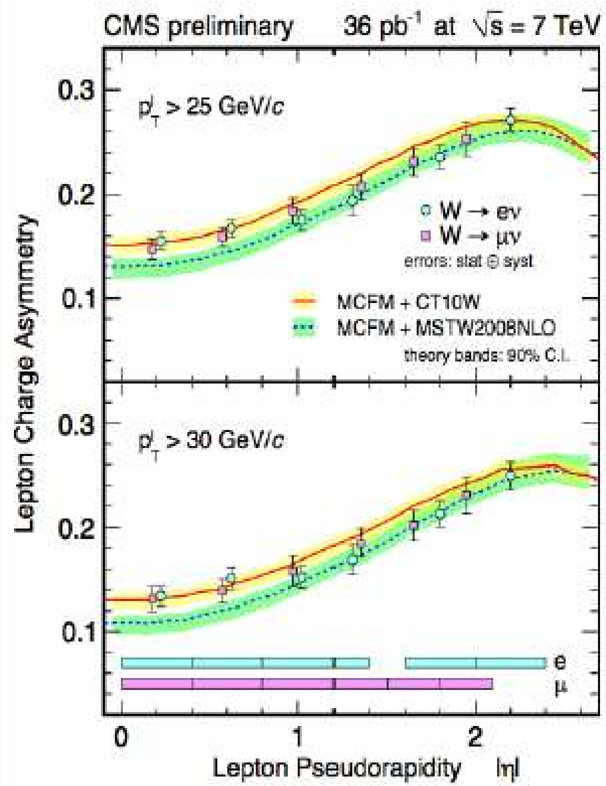


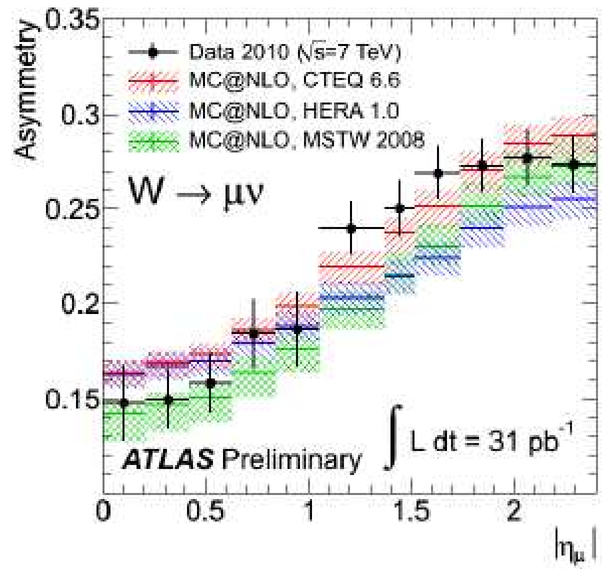
Plots by G. Watt – use $m_t = 171.3\mathrm{GeV}$. $\sim 10\mathrm{pb}$ lower if used $m_t = 173.3\mathrm{GeV}$.

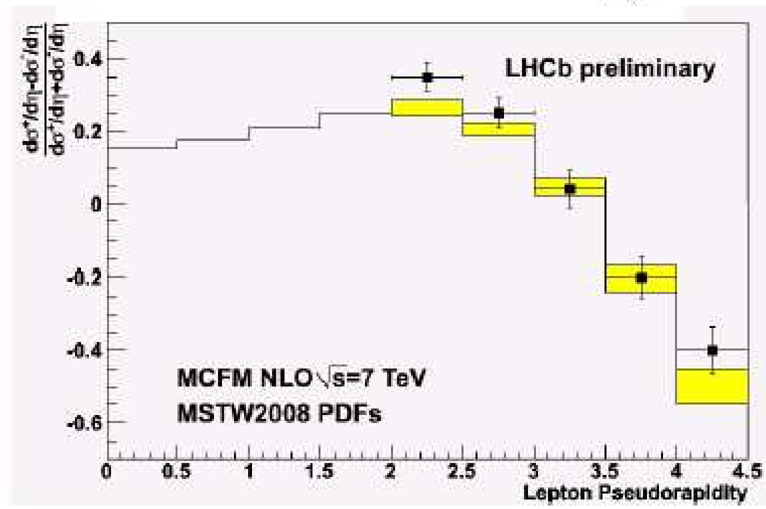
Approx NNLO using HATHOR - (Aliev *et al*), includes scale-dependent parts and large threshold corrections at NNLO. Hence some theoretical uncertainty, but NNLO corrections not large at LHC. See that lower NNLO α_S improves stability.

Top cross-section measurement potential discriminator of PDF sets, and correlated to Higgs predictions. ATLAS and CMS preliminary combined very naively $\sigma_{t\bar{t}} = 0.169 \pm 0.14\mathrm{pb}$.

Also not best place for PDF4LHC recipe.







Clearly not perfect for lepton asymmetry at the LHC (NNLO predictions only slightly different). Some tension between data and ATLAS electron data (and higher luminosity data) to come.

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 was preliminary at NNLO until this point.

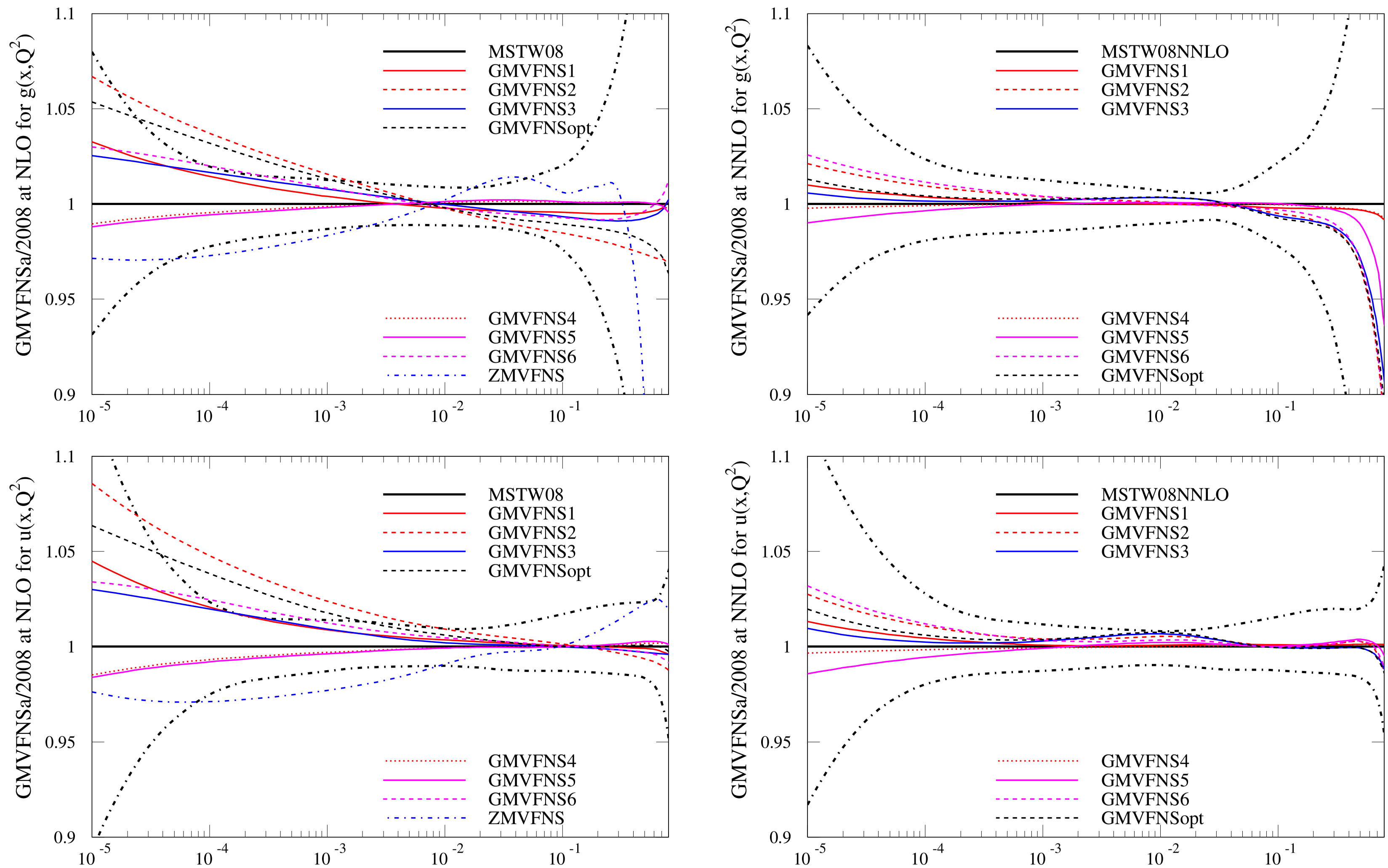
Now similar in a number of ways to SACOT(χ), but differs in ordering and in prefactor, and explicitly extended to NNLO for two PDF sets.

Defined by speed of turn on in structure function of heavy quark PDFs and compensating subtraction of high $Q^2/m_h^2 \rightarrow \infty$ (mainly large logs) from coefficient functions. In MSTW also recognise that there is one higher order in α_S below than above m_h^2, so keep this in. Choice in what to do above m_h^2. Default to freeze at m_h^2.

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.(Some uncertainty due to modelling FFNS $\mathcal{O}(\alpha_S^3)$ term at very low Q^2 using small-x and threshold terms.) 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 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 slides.)

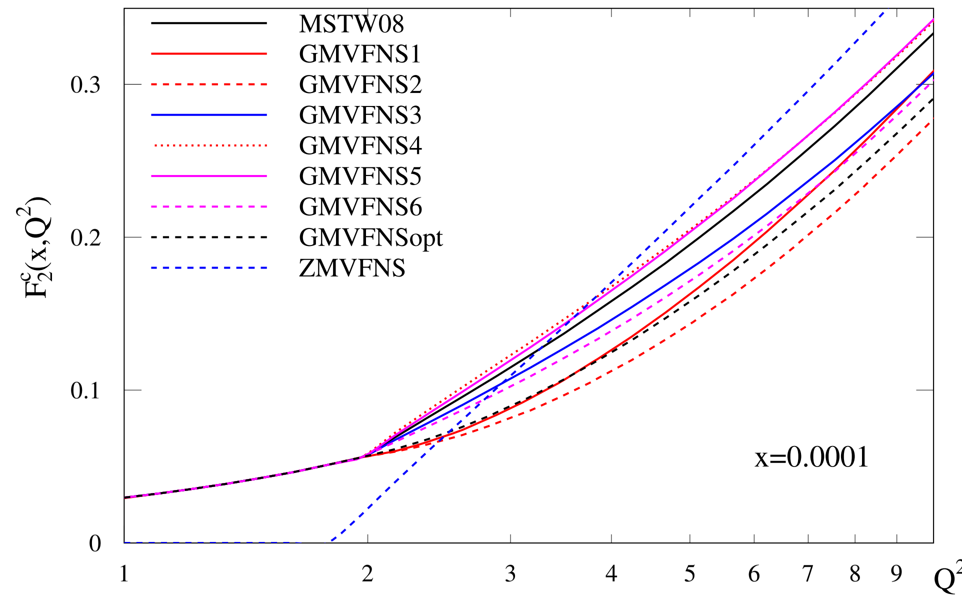


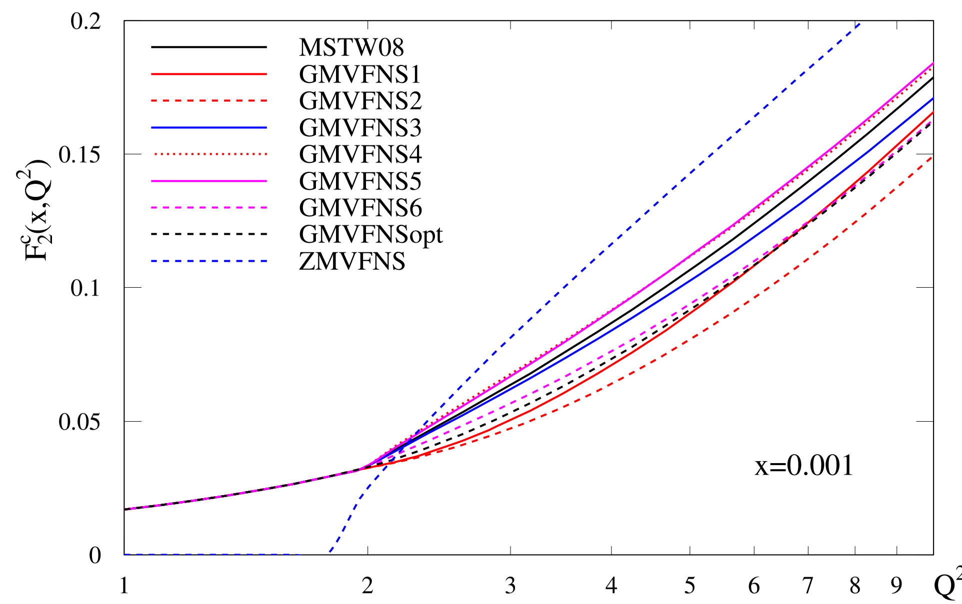
6 extreme variations tried, along with ZM-VFNS

At NLO extremes determined by same sort of deterioration in fit as required for eigenvector definitions (mainly for steepening), or *sensible* limits.

Variations in $F_2^c(x, Q^2)$ near the transition point at NLO due to different choices of GM-VFNS.

Optimal, turns heavy quark on more smoothly than default and allows higher order contribution to $F_2^h(x, Q^2)$ to fall like $F_2^{h,HO}(x, Q^2)(m_h^2/Q^2)$, whereas optimal freezes term at m_h^2.



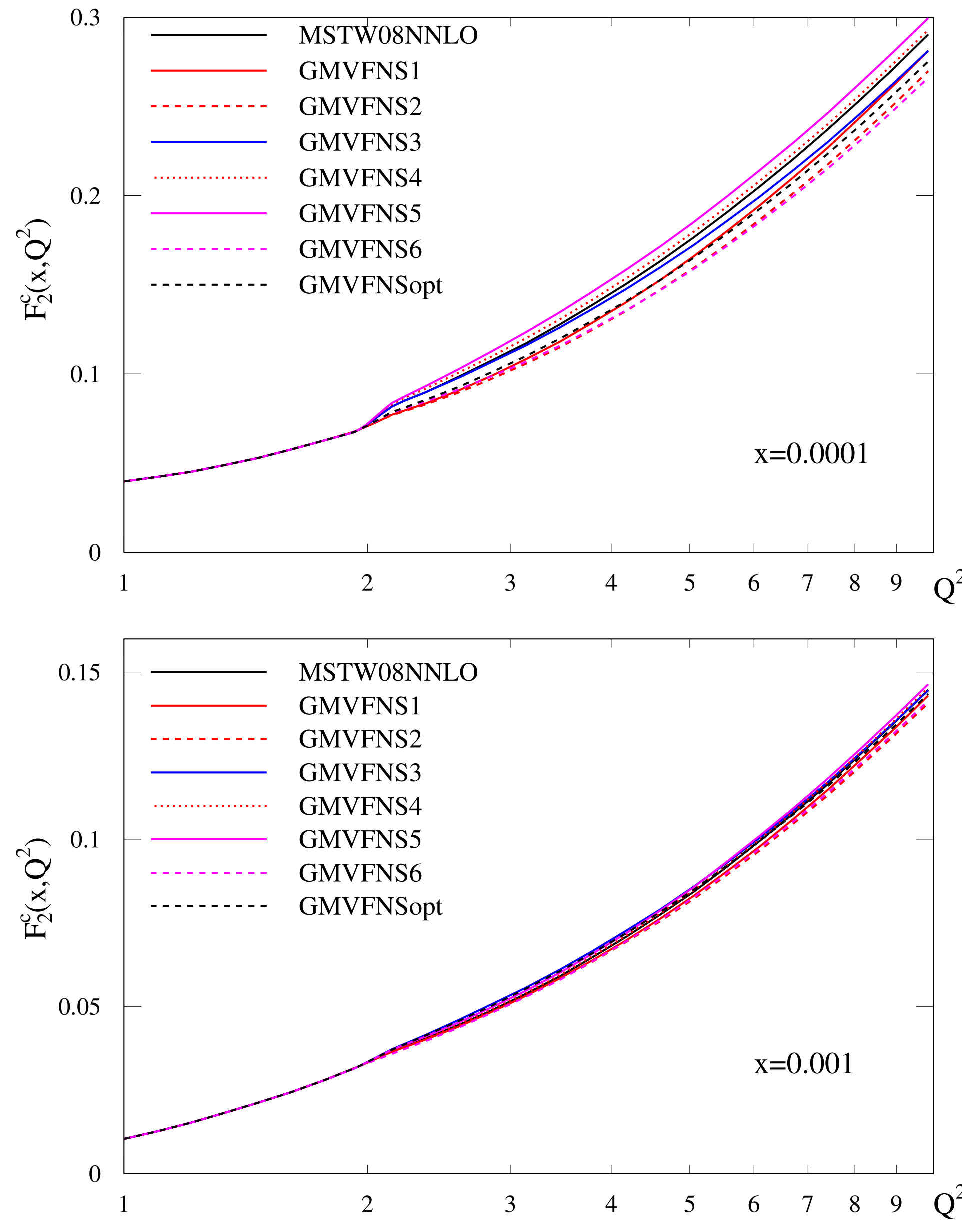


Variations in $F_2^c(x, Q^2)$ near the transition point due to different choices of GM-VFNS at NNLO.

Use limits on parameters determined at NLO. Changes in χ^2 very much smaller so not a useful method.

Very much reduced variation, almost zero variation until very small x.

Shows that NNLO evolution effects most important in this regime.



Previously noticed very slight change of slope at transition point.

Already using all variation at $Q^2 > m_h^2$

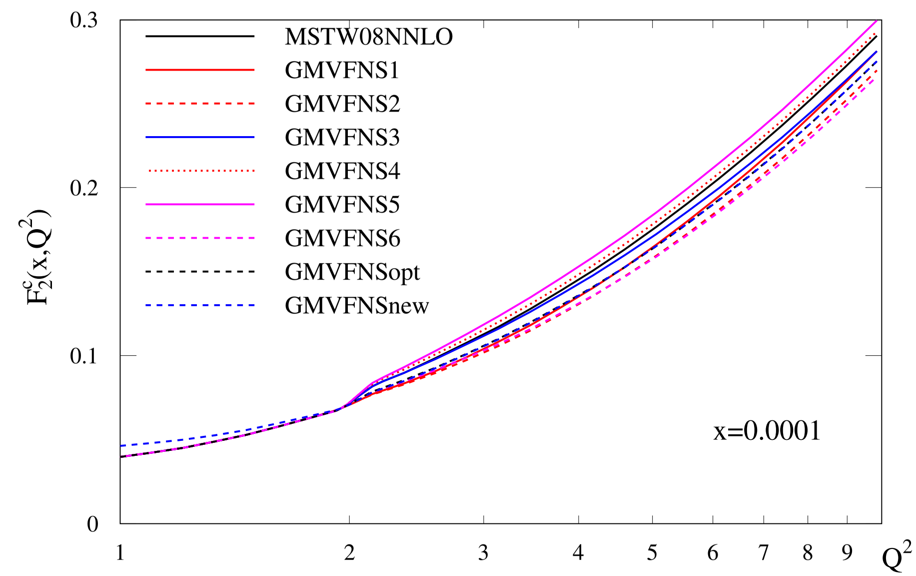
Smoothness improved at low Q^2 by slight change in model for $\mathcal{O}(\alpha_S^3)$ coefficient function.

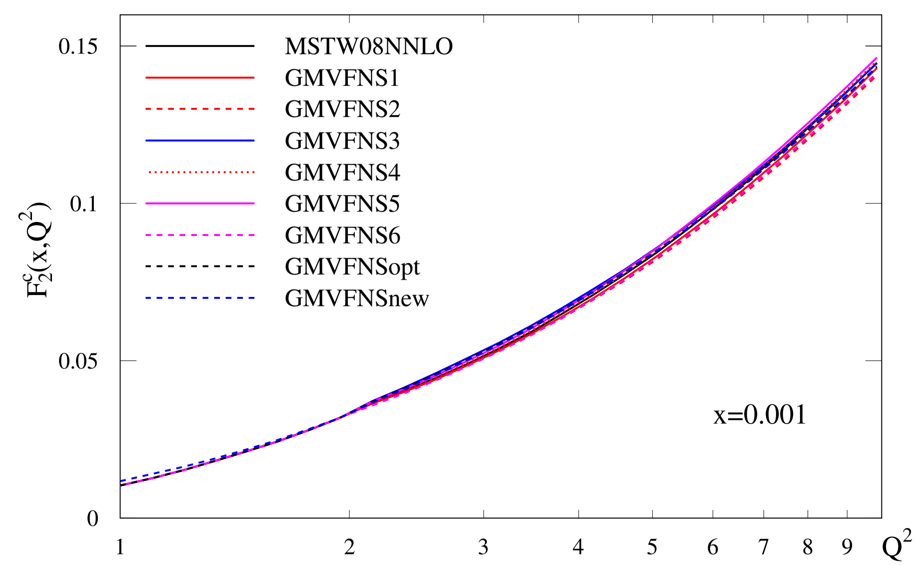
Threshold logs plus small-x term of form

$$(1-x)^{20} * A/x(\ln(1-x)-4)f(Q^2/m_h^2)$$

where A and $f(Q^2/m_h^2)$ known from small-x resummation (Catani *et al*).

-4 guess like approx NNLO splitting functions. Allow very slightly different Q^2-dependence in this term.



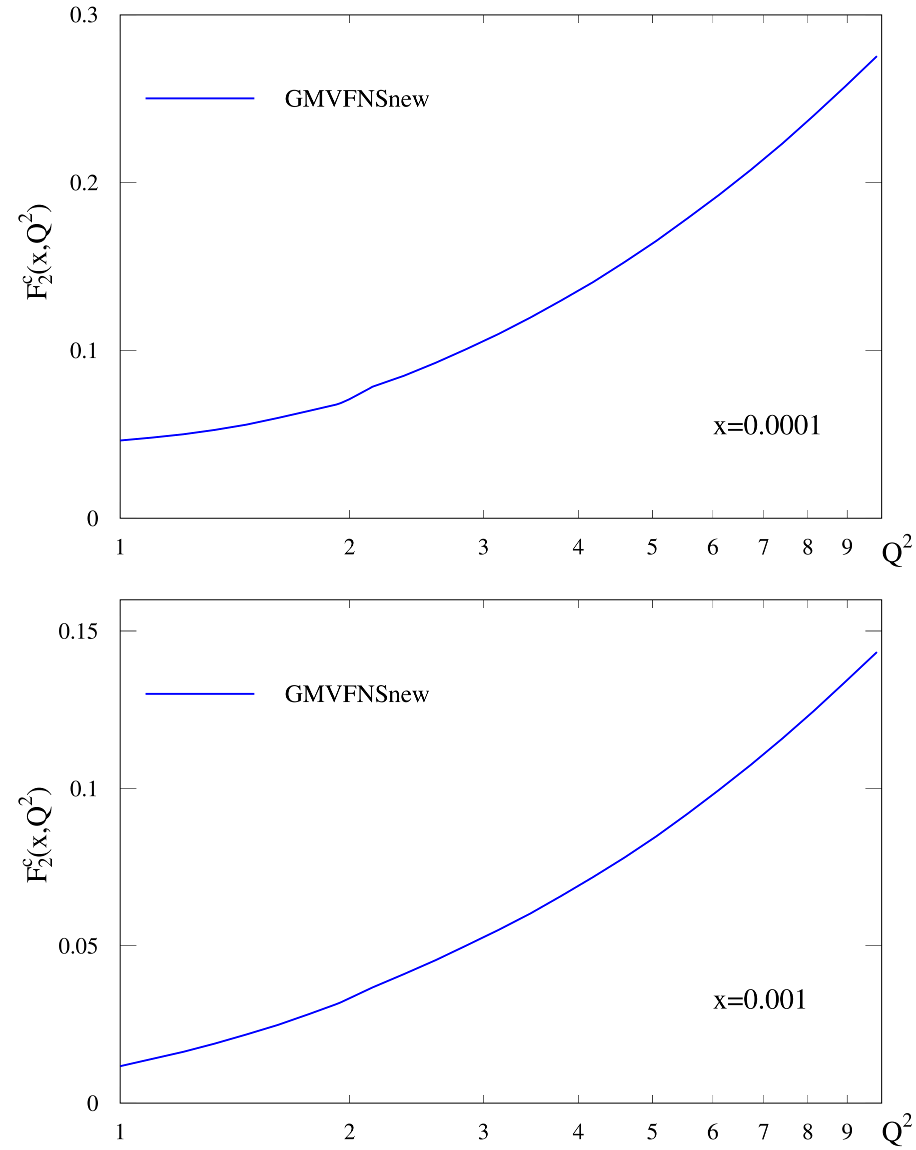


Shown as single curve in order to see more clearly.

Slight kink at very low x due to sensitivity to new $\ln(1/x)/x$ terms at NNLO.

Change leads to essentially no difference in PDFs or predictions.

Improved threshold calculations (Lo Presti *et al*), not available at time of MSTW2008. Will use in future. Rather similar effect to above. Extremely little change in fit, but slightly smoother $F_2^h(x, Q^2)$.



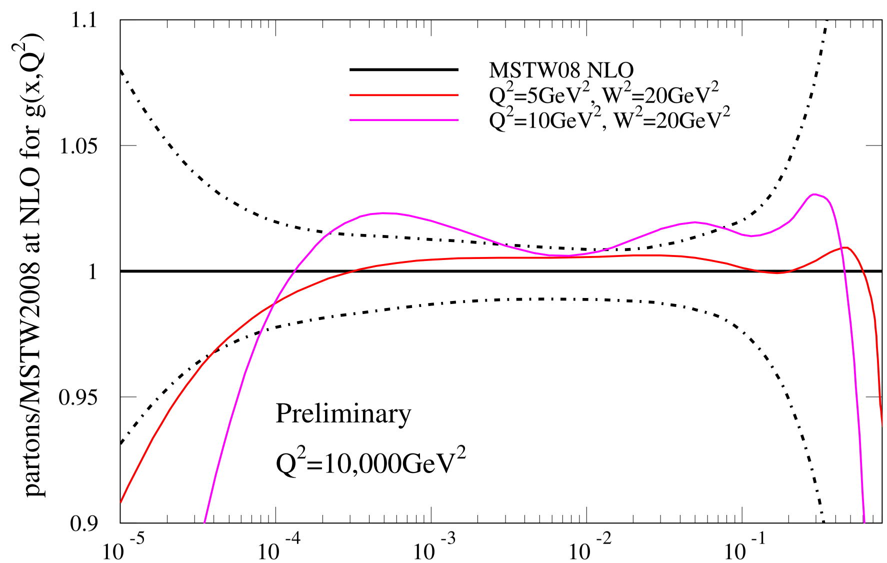
Investigation to stability under changes in cuts.

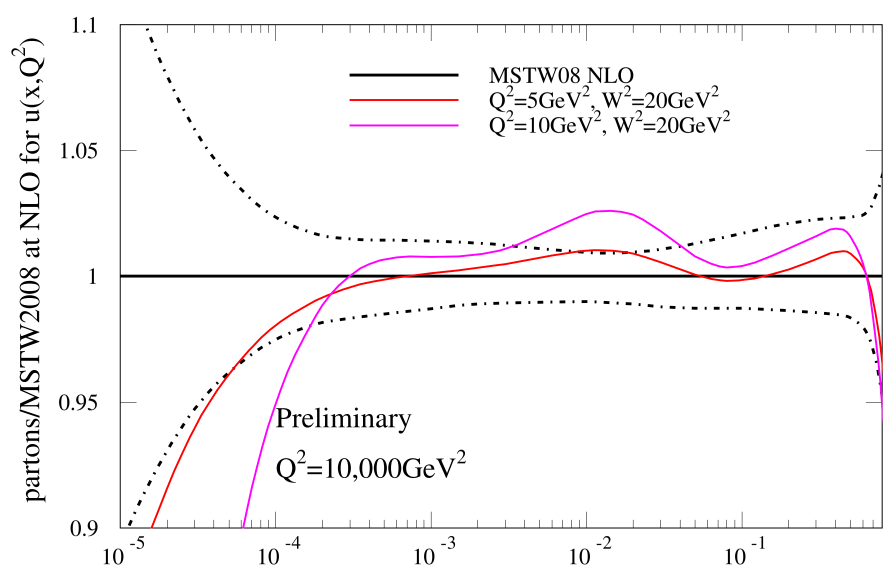
Raise $W^2_{\rm cut}$ to $20{\rm GeV}^2$, but no real changes.

Also raise $Q^2_{\rm cut}$ to $5{\rm GeV}^2$ and then $10{\rm GeV}^2$.

At NLO some movement just outside default error bands at general x.

Find $\alpha_S(M_Z^2) = 0.1202 \to 0.1193 \to 0.1175$, though for $Q^2 = 10{\rm GeV}^2$ cut error has roughly doubled to about 0.0025.

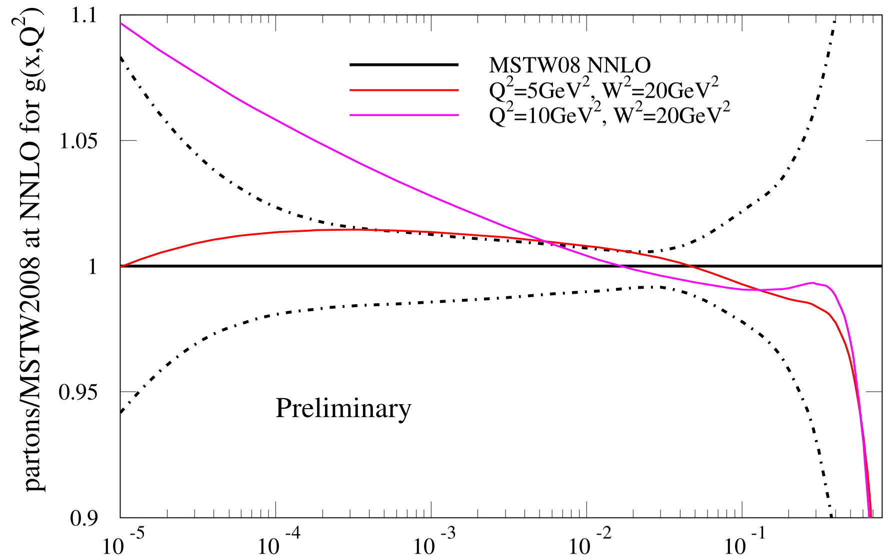


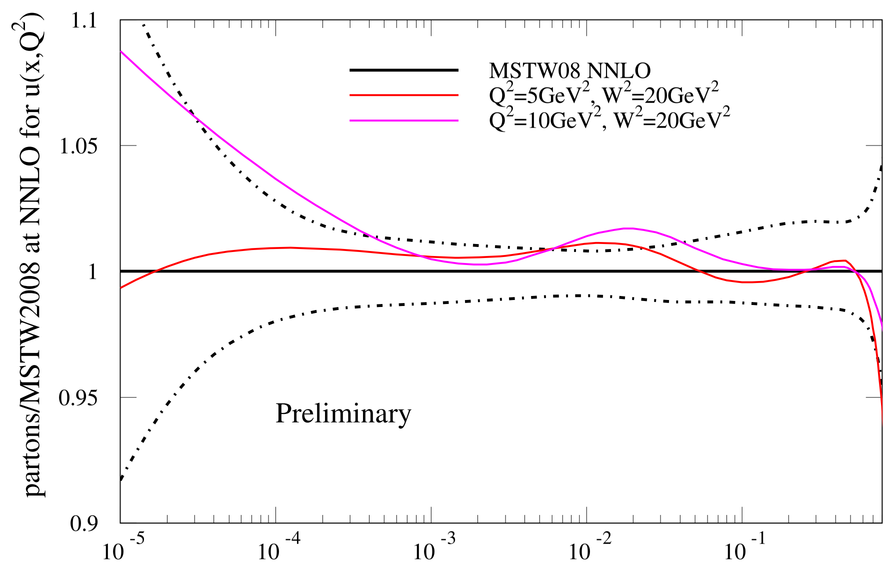


At NNLO most movement outside default error bands at low x, where constraint vanishes as Q^2 cut raises.

For $Q^2_{\rm cut} = 10{\rm GeV}^2$ no points below $x = 0.0001$, and little lever arm for evolution constraint for $x < 0.0005$.

Find $\alpha_S(M_Z^2) = 0.1171 \rightarrow 0.1171 \rightarrow 0.1164$, i.e. no change of significance. .





The % change in the cross sections after cuts ($M_H = 165\mathrm{GeV}$).

	NLO		NNLO	
	$Q^2 = 5\mathrm{GeV}^2$	$Q^2 = 10\mathrm{GeV}^2$	$Q^2 = 5\mathrm{GeV}^2$	$Q^2 = 10\mathrm{GeV}^2$
W Tev	0.0	–2.4	–0.7	–0.4
Z Tev	0.0	–0.8	–0.4	0.0
W LHC (7TeV)	–0.2	–0.1	–0.2	–0.2
Z LHC (7TeV)	–0.2	–0.3	–0.4	–0.5
W LHC (14TeV)	–0.6	–1.1	+0.3	+0.8
Z LHC (14TeV)	–0.6	–1.5	+0.2	+0.4
Higgs TeV	–1.1	–1.5	–1.2	–3.2
Higgs LHC (7TeV)	–0.8	–2.5	0.4	–1.8
Higgs LHC (14TeV)	–0.9	–1.9	1.0	–0.8

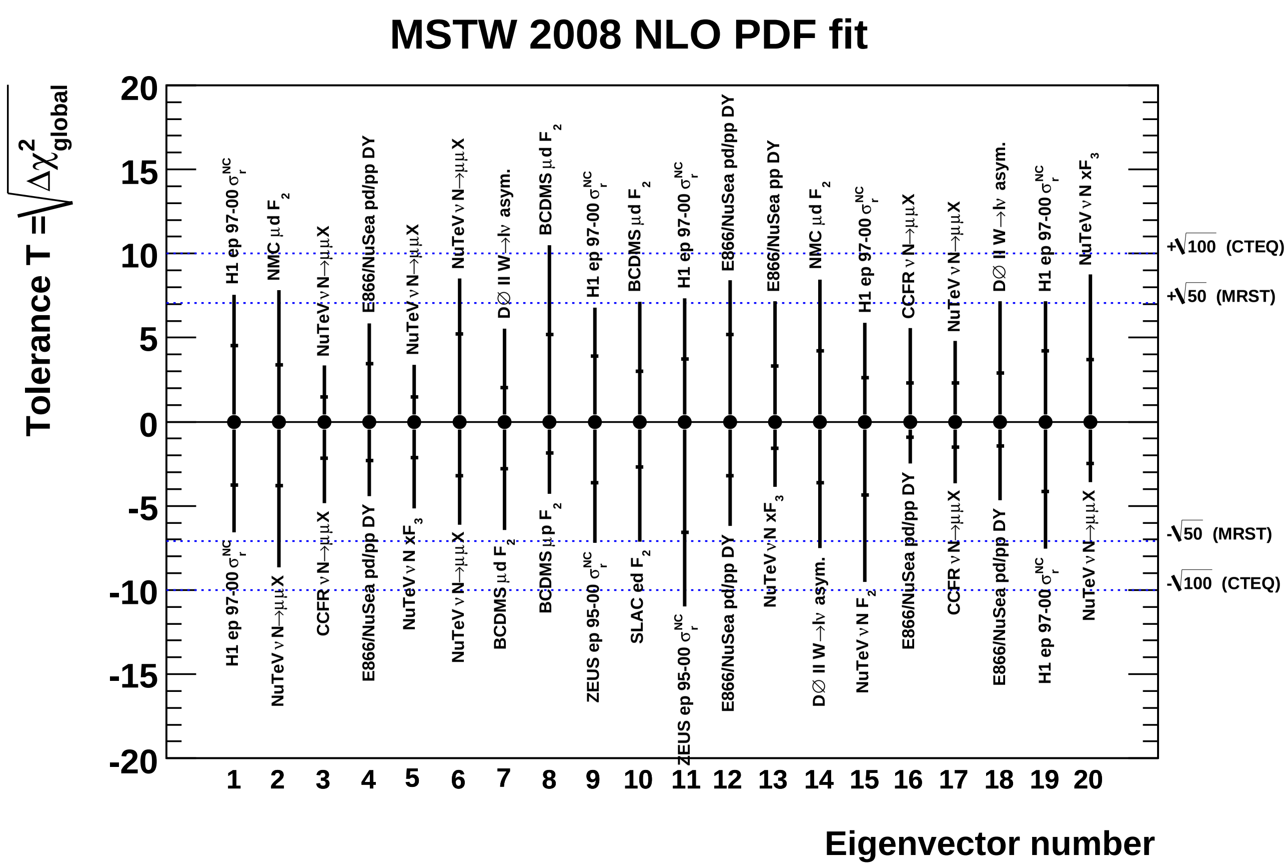
More variation at NLO than at NNLO, i.e. 7 changes of $> 1\%$ compared to 4.

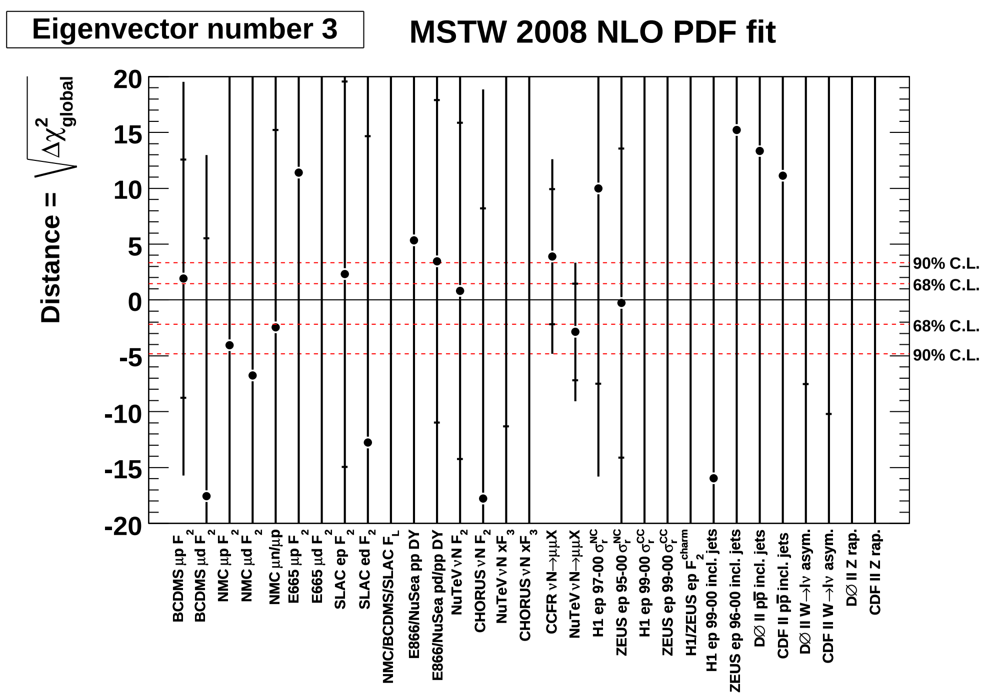
However, both small, and changes with change in Q^2 slow. Does not suggest significant higher twist or problem with default cuts.

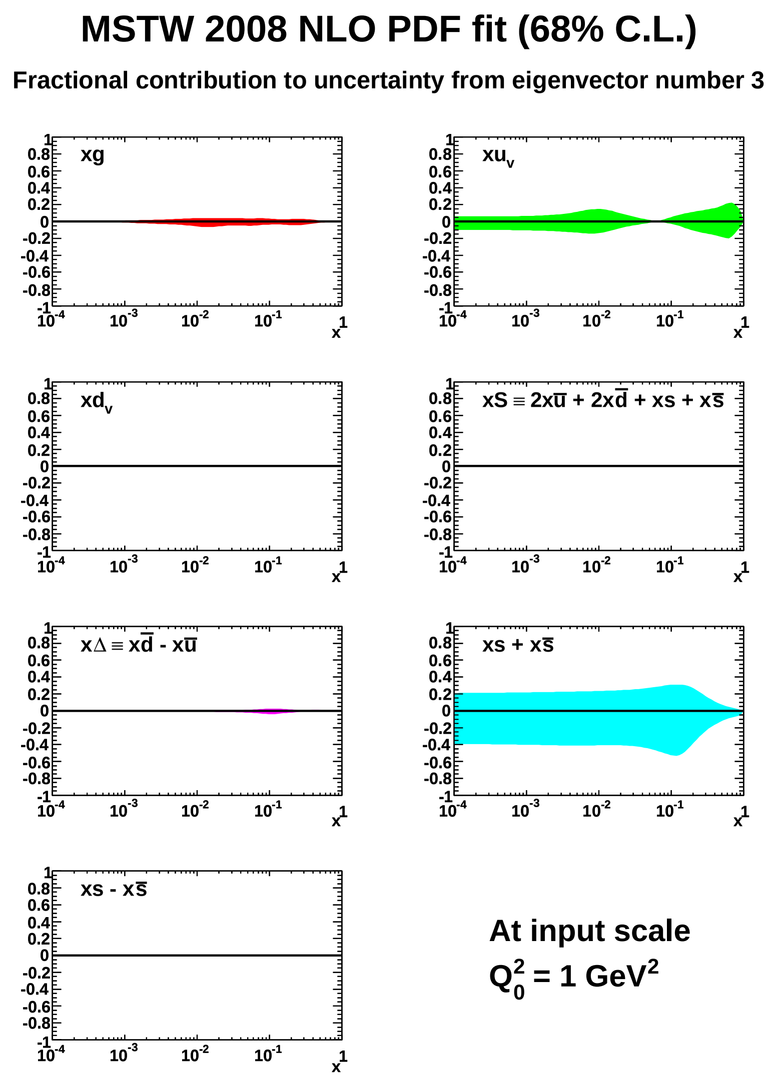
Fits to only Collider data

Agreed to investigate the consequences of fitting to data sets not including any fixed-target data.

in MSTW08 PDFs have 20 eigenvectors and have to to determine uncertainty on each. Constraining sets not always collider data. Now do not set any PDF “by hand” (except some small-x constraint on $s - \bar{s}$).

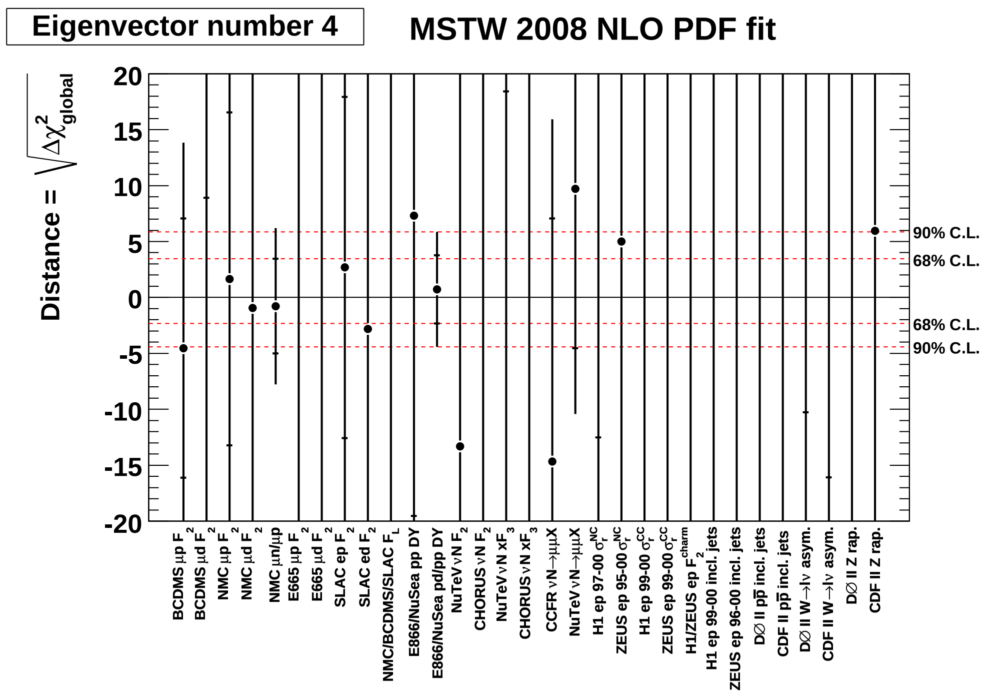


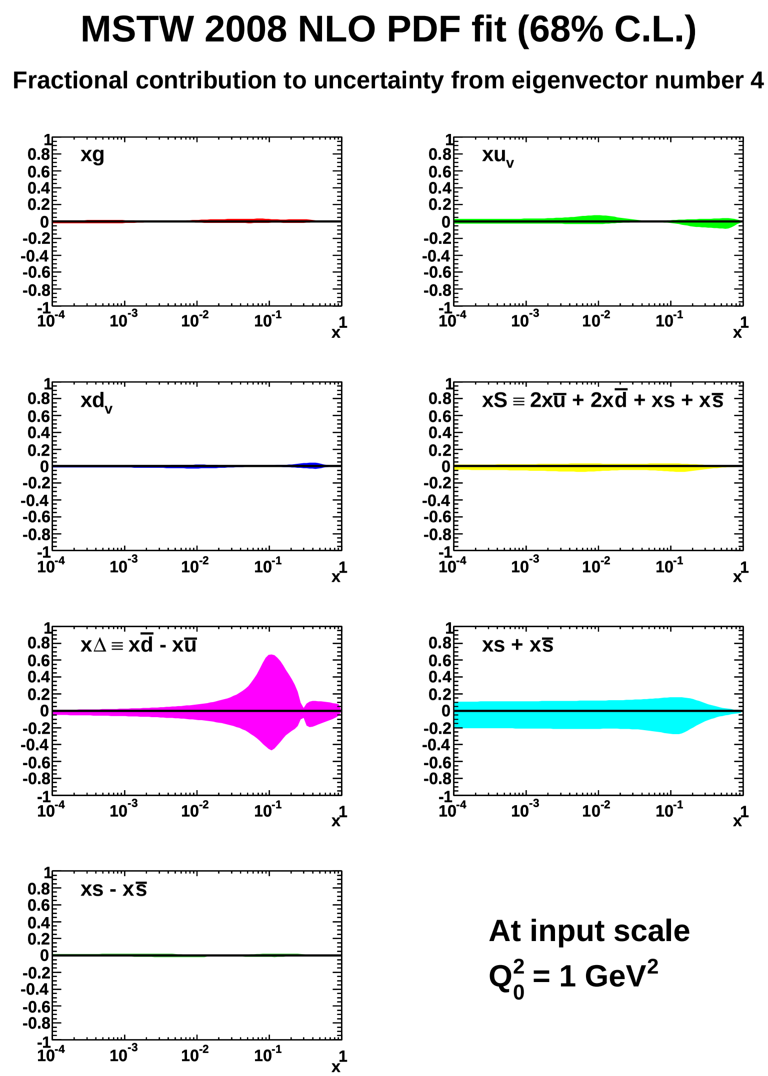




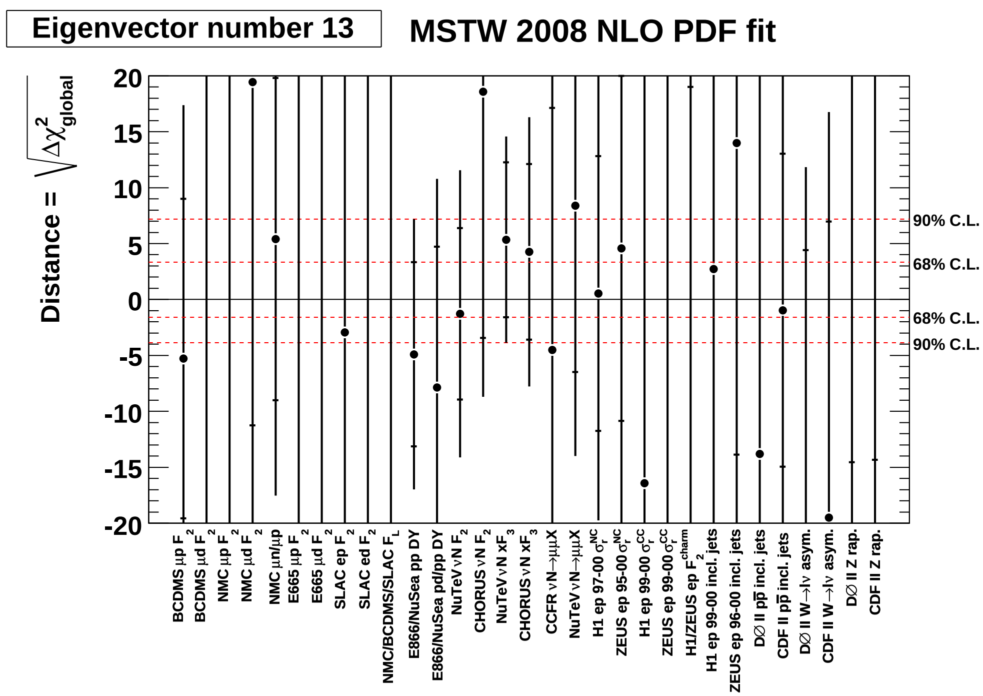
In MSTW08 fits see constraint on each eigenvector from different data sets.

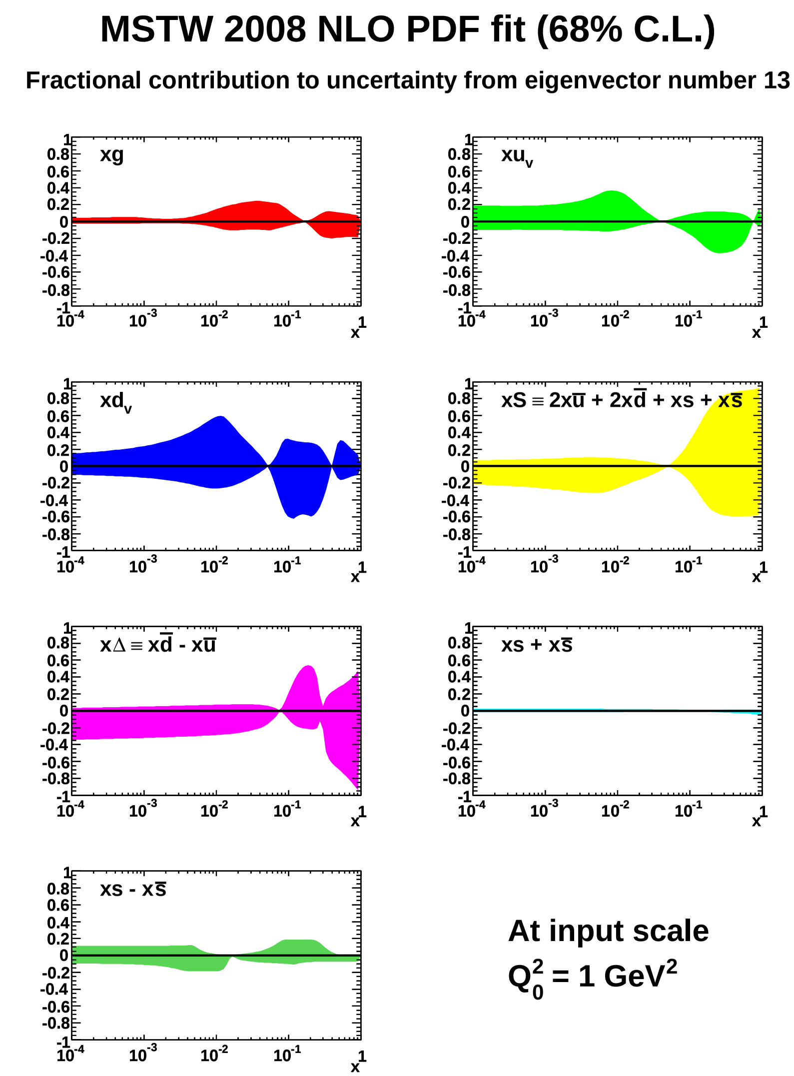
Eigenvector 3 has only a very weak, asymmetric constraint from collider data. Without dimuon data weak constraint on strange normalisation and push downwards.





Eigenvector 4 has almost no constraint from collider data. $\bar{d} - \bar{u}$ and again strange.





Eigenvector 13 has only a very weak, asymmetric constraint from collider data.

High-x sea and flavours weakly pulled from default by Tevatron asymmetry data.

Change in PDFs for fit to collider data only .

For default simply repeat MSTW2008 NLO fit with HERA structure function data updated to combined data.

Then try replacing default D0 low luminosity muon asymmetry data with higher luminosity electron data (in combined-p_T bin), which is the most constraining published asymmetry data (at present).

Fit quality to 1053 data points improves by $\Delta\chi^2 \sim -120$.

Improvement of 30 in lepton asymmetry data and 47 in HERA inclusive structure function data.

Small improvement in jet (Tevatron and HERA) data.

To avoid pathological behaviour have to fix some parameters. $s - \bar{s}$ fixed otherwise negative quarks, and $(1-x)$ power of strange also fixed to be same as averaged sea.

In eigenvectors also need one more fixed parameter in valence quarks to avoid redundancy of parameters. $\rightarrow 16$ rather than 20 eigenvectors.

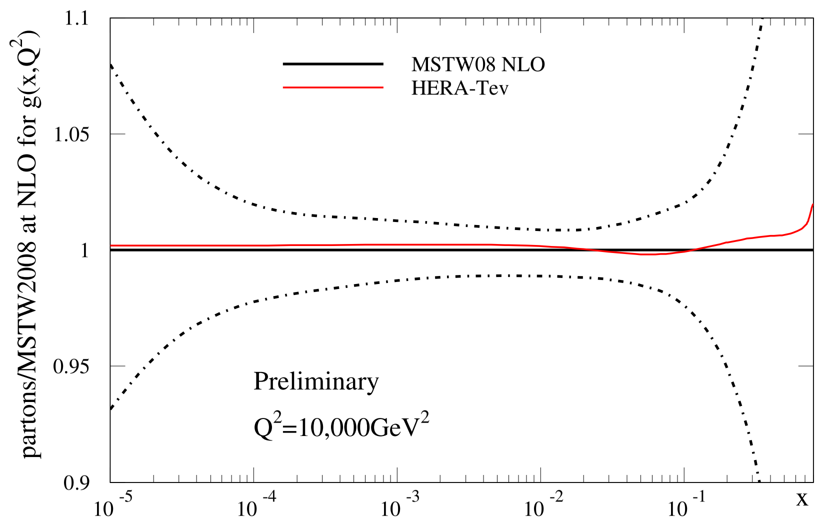
$\alpha_S(M_Z^2) = 0.1193$, but related to behaviour of strange sea. Uncertainty about 0.0025.

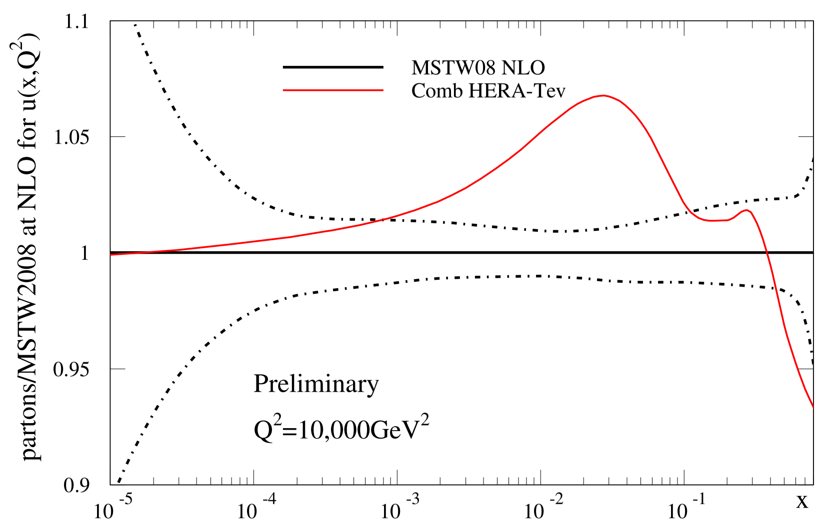
Almost no change in gluon distribution. All major constraints present.

Marginal improvement in jets and big improvement in HERA data due to quark changes.

Large increase in $u(x,Q^2)$ for $x \sim 0.02$ compensated by other quarks.

$(1-x)$ power of sea, usually constrained by Drell Yan and neutrino structure function data at least 5 times more uncertain (with constraint from HERA charged current data and lepton asymmetry).

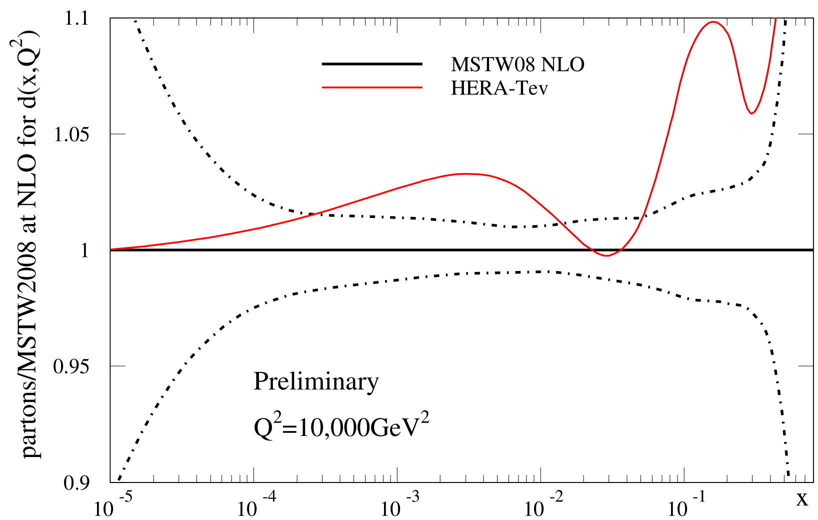


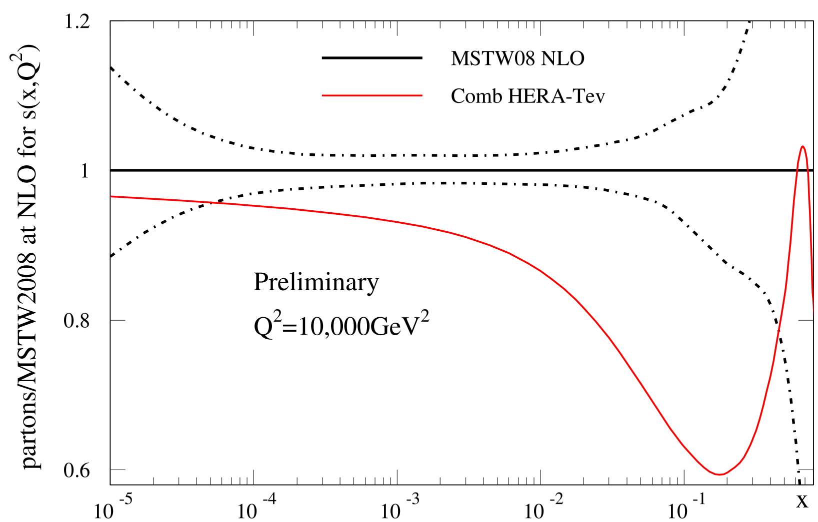


Not too much change in $d(x,Q^2)$ except near $x=0.2$.

However, $\int(\bar{d}(x,Q_0^2) - \bar{u}(x,Q_0^2))\,dx$ about 1.5 times bigger but with uncertainty similar to magnitude (normally $\sim 15\%$). Constrained by HERA $F_2(x,Q^2)$ (down) and CDF jets (up), rather that E866 DY ratio.

Input sea normalisation at $Q_0^2 = 1\mathrm{GeV}^2$ about zero. Can vary up to about 40% of input sea (constrained by HERA $F_2(x,Q^2)$) and if allowed down to -30%. Normally about 30% of input sea with $\sim 15\%$ uncertainty, constrained by dimuon data from NuTeV and CCFR.

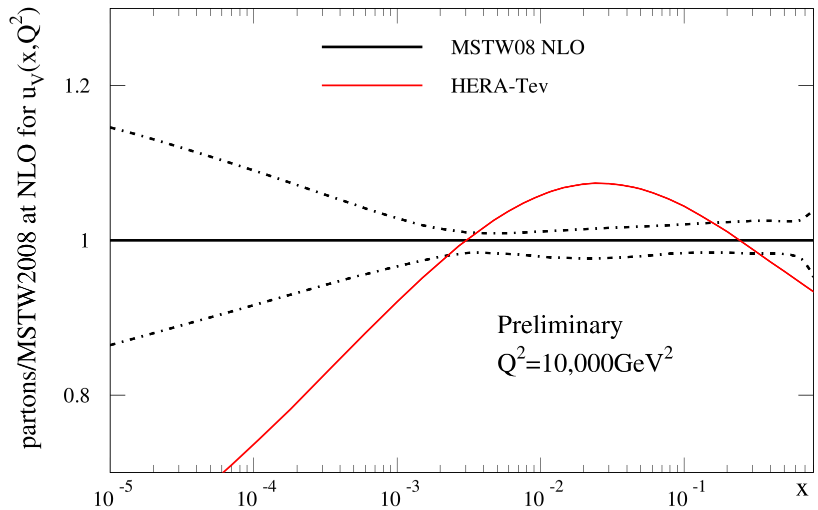


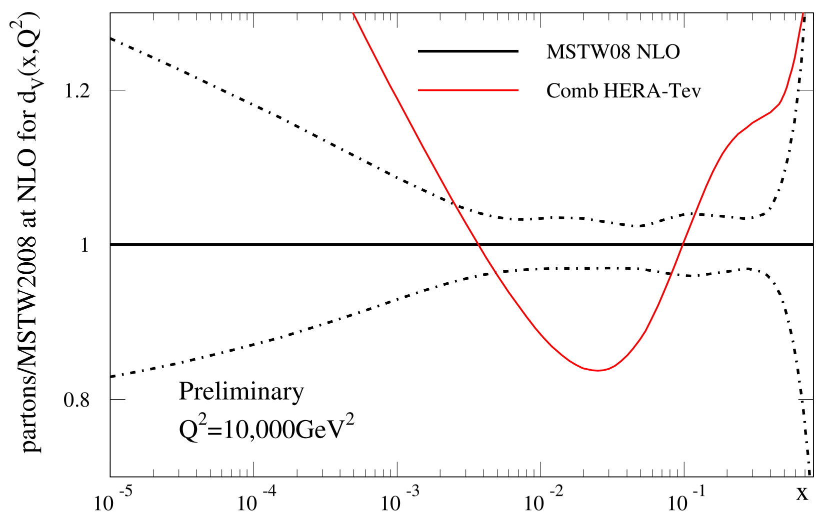


Both valence distributions much changed. Particularly at small x.

High-x $u_V(x,Q^2)$ about 3 times as uncertain. Constrained by HERA charged current data and lepton asymmetry – usually by most fixed target data. At low x similar, with sensitivity to Tevatron rapidity data.

$d_V(x,Q^2)$ at least twice as uncertain. Constrained by HERA charged current data, lepton asymmetry and to some extent Tevatron jet data at high x. Usually by deuterium data and to some extent lepton asymmetry.





When the D0 asymmetry data is swapped the initial prediction is not very good.

Before refit over $40/12$ (good fit for $20/12$, i.e. lots of scatter). Actually worse than predictions made by variety of fits to all data where some deuterium corrections has been fit/modelled.

However, consistent within large uncertainties, i.e. very little change in quality of fit to other data in refit (most in D0 jets).

Few percent change in PDFs, almost all in high-x ($x > 0.1$) $d_V(x, Q^2)$ (down) and sea quarks (up).

% change in cross sections for collider only fit ($M_H = 165\text{GeV}$).

	MSTW comb HERA	D0$_\mu$ $0.4 fb^{-1}$	D0$_{\text{el}}$ comb p_T
W Tev	+3.1	+5.0	+4.8
Z Tev	+3.0	+5.9	+5.5
W/Z Tev	+0.2	–0.9	–0.6
W^+/W^- Tev	+0.0	+0.1	+0.1
W LHC (7TeV)	+2.9	+2.7	+2.5
Z LHC (7TeV)	+2.7	+2.3	+1.9
W/Z LHC (7TeV)	+0.2	+0.5	+0.6
W^+/W^- LHC (7TeV)	+0.1	+1.3	+1.9
W LHC (14TeV)	+2.4	+1.5	+1.3
Z LHC (14TeV)	+2.5	+0.9	+0.9
W/Z LHC (14TeV)	–0.1	+0.6	+0.5
W^+/W^- LHC (14TeV)	–0.5	+1.3	+1.3
Higgs TeV	–1.4	–1.4	+0.2
Higgs LHC (7TeV)	+0.4	–1.6	–1.0
Higgs LHC (14TeV)	+1.0	–1.5	–1.1

Changes not that large. In total cross sections largely due to inclusion of combined HERA data, (smaller at NNLO or if normalisation constraint relaxed). Changes greater than uncertainties in ratios. Mainly in W/Z ratio due to change in strange quarks.

PDFs for LO Monte Carlo generators.

Often (sometimes) need to use generators which calculate only at LO in QCD.

LO matrix elements + LO PDFs often very inaccurate in normalisation and general shape.

Using NLO PDFS suggested – sometimes better, sometimes even worse (particularly small x, important for underlying event etc).

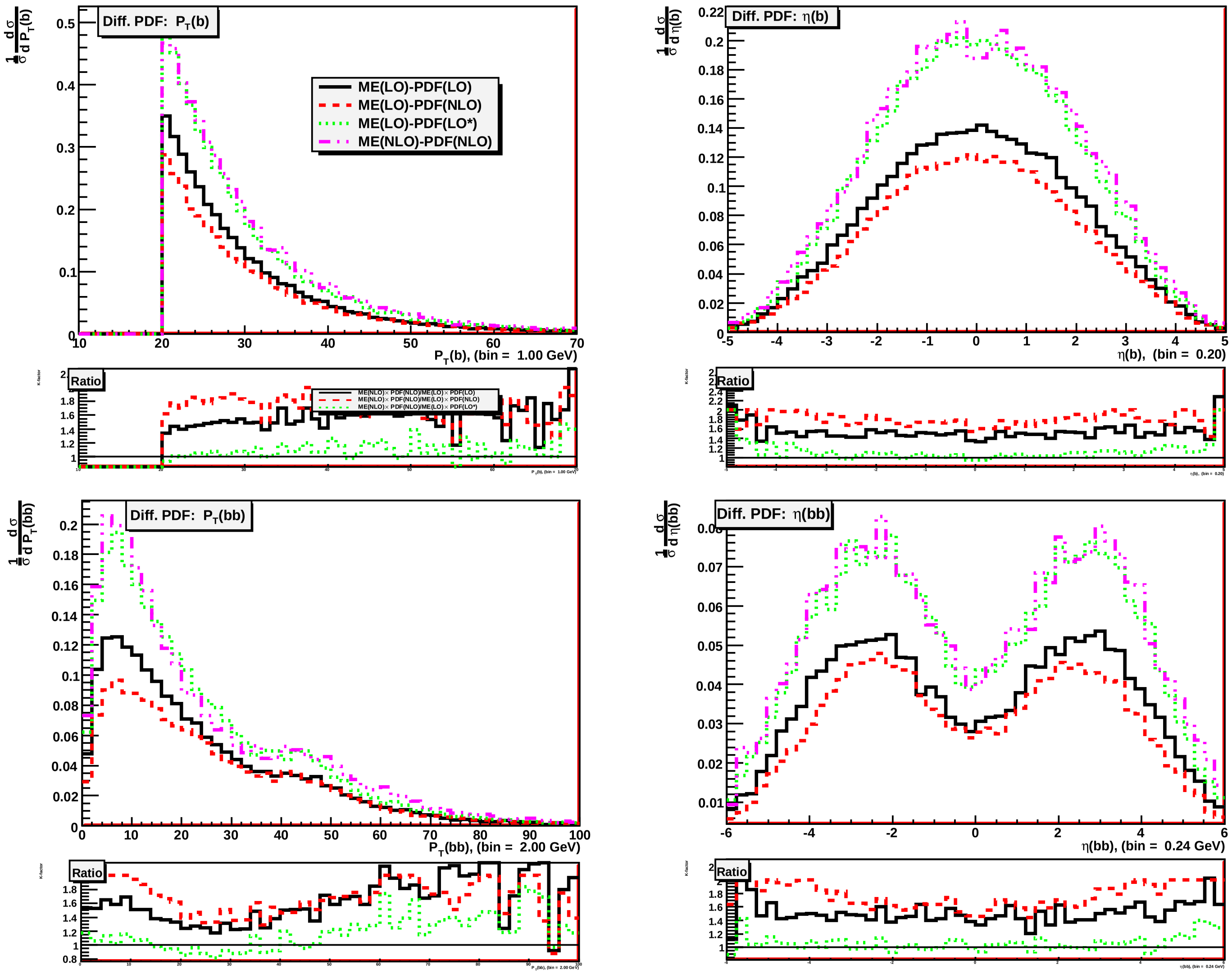
Leads to introduction of new type of LO* PDF.

NLO corrections to total cross-section usually positive $\rightarrow$ LO PDFs bigger by allowing momentum violation in global fits, using NLO α_S, fit LHC pseudo-data ......

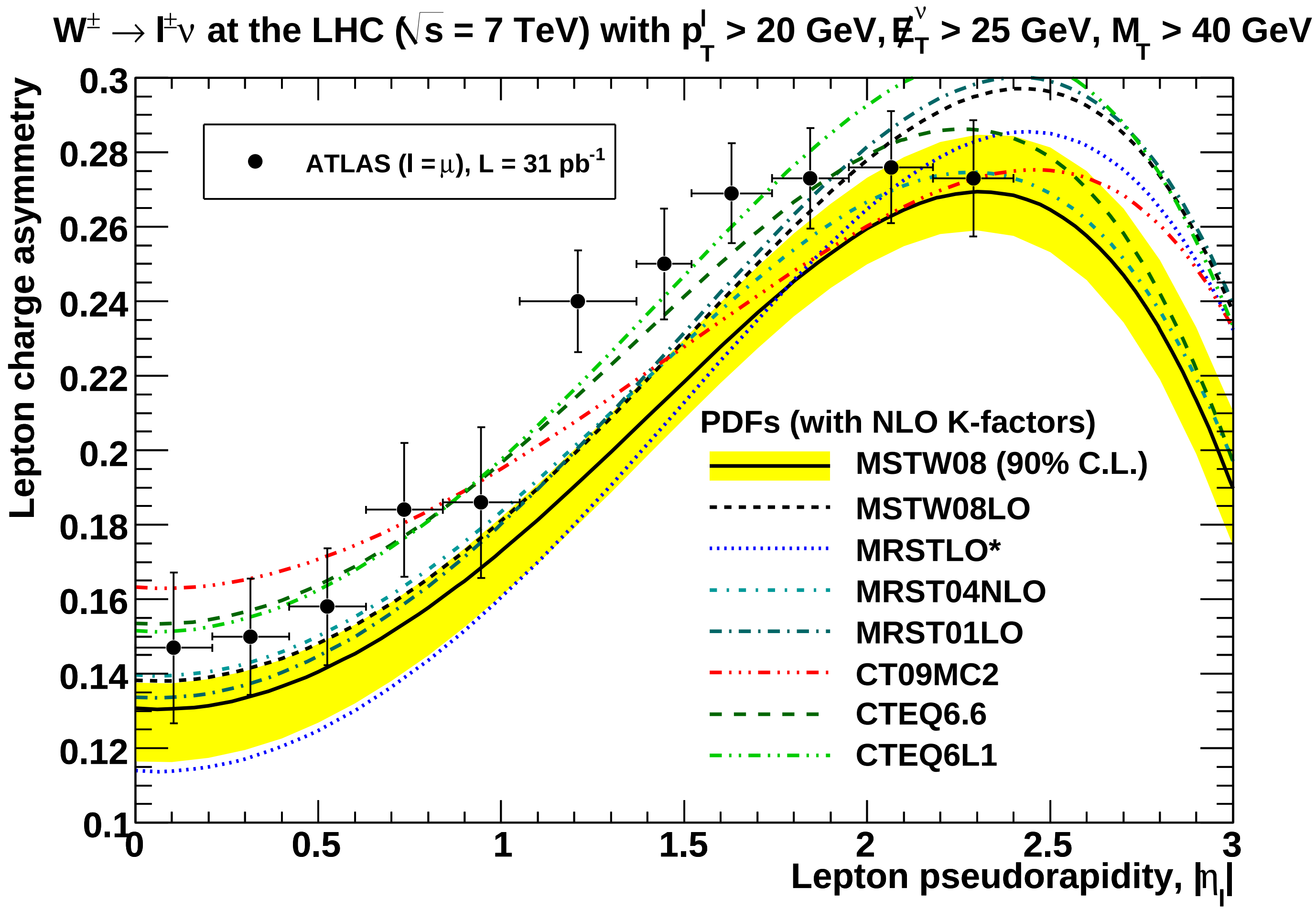
Can also make evolution more "Monte Carlo like", e.g. change of scale in coupling.

LO* PDFs from MRST.

Example, look at e.g. distributions for single b and $b\bar{b}$ pair (Shertsnev, RT).



Results using LO* partons clearly best in normalization. NLO worst and problems with shape at low scales (i.e. small x).



Need to be more careful with precision quantities relying on flavour decomposition (Watt), especially if NLO corrections are available. Consistent LO/LO* and NLO difference at high η_l.

Summary

MSTW/MRST have been providing NNLO PDFs for over 10 years. Have remained largely stable over this time. Have predicted quantities well.

Always requires lower $\alpha_S(M_Z^2)$ than NLO, and predictions more stable this way. Demonstrate little variation with change in kinematic cuts. Consistent with previous studies where higher twist not significant at NNLO.

Main change due to introduction of a fully consistent NNLO GM-VFNS over (acknowledged)approximation in 2006. Now 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 and are small at NNLO. Phenomenological minor updates in progress.

Include all types of data other than HERA jets. Only obvious significant reason for update is inclusion of new data.

Fits to only collider data require some constraints to stop extreme central behaviour and variation in some PDFs. Uncertainties much bigger, though changes small for gluon. Total cross-sections fairly stable to change in fit, particularly at the LHC, perhaps because dominated by evolution driven by gluon, but even ratios fairly similar to default. More change at Tevatron.

Personal opinion, better to include all data - if we want some constraint on strange normalisation it is from rather "unclean" nuclear target data (similar for $\bar{d} - \bar{u}$ and deuterium data) - but take proper account of full uncertainties rather than make assumptions.

LO* PDFs useful for gross features if using LO generators, but no replacement for full NLO if available.

Back-up Slides

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.

Fits at NNLO

Standard fit – global fit quality $\sim 2505/2387$. To HERA NC data $\sim 585/553$ ($Q^2 > 2\mathrm{GeV}^2$) and $\sim 535/524$ ($Q^2 > 3.5\mathrm{GeV}^2$). ~ 15 better than NLO for full data but similar for $Q^2 > 3.5\mathrm{GeV}^2$. Normalisation down slightly less than at NLO.

$\alpha_S(M_Z^2) = 0.1178$ – much less than $1-\sigma$ effect. Quarks generally bigger, sometimes outside $1-\sigma$ band, until very low x, then smaller. Gluon not changed much except some decrease at large x, and at lowest x.

Also fit fixing $\alpha_S(M_Z^2) = 0.1171$, i.e. MSTW2008 NNLO value. Both global and HERA NC data fit only $\sim 2-3$ higher. PDF change tiny.

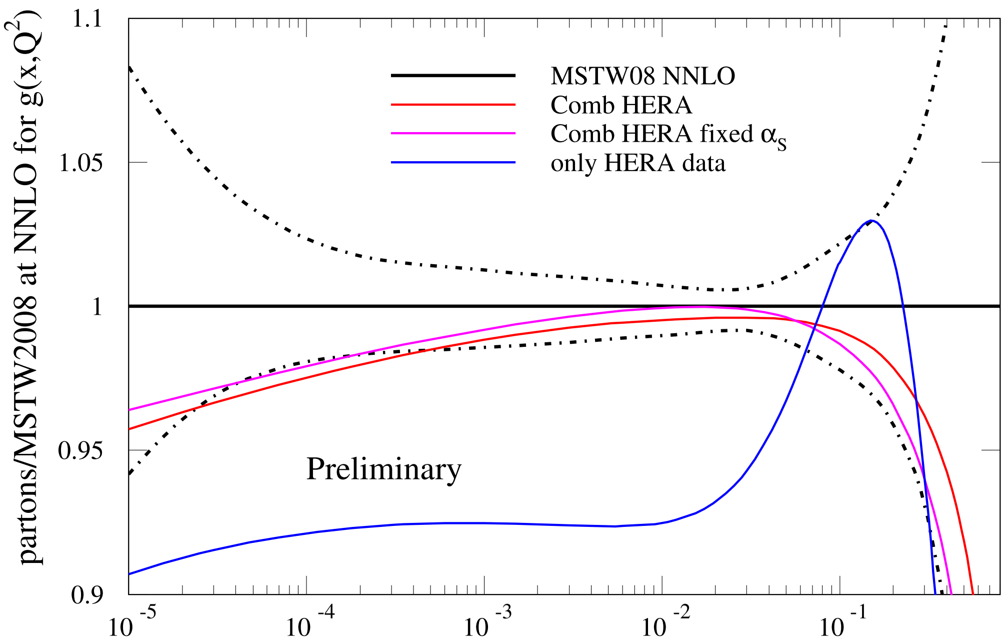
Fit only HERA NC and CC cross-section data. Obtain $\sim 495/553$ ($Q^2 > 2\mathrm{GeV}^2$) and $\sim 465/524$ ($Q^2 > 3.5\mathrm{GeV}^2$). Better than NLO for former, but worse for latter.

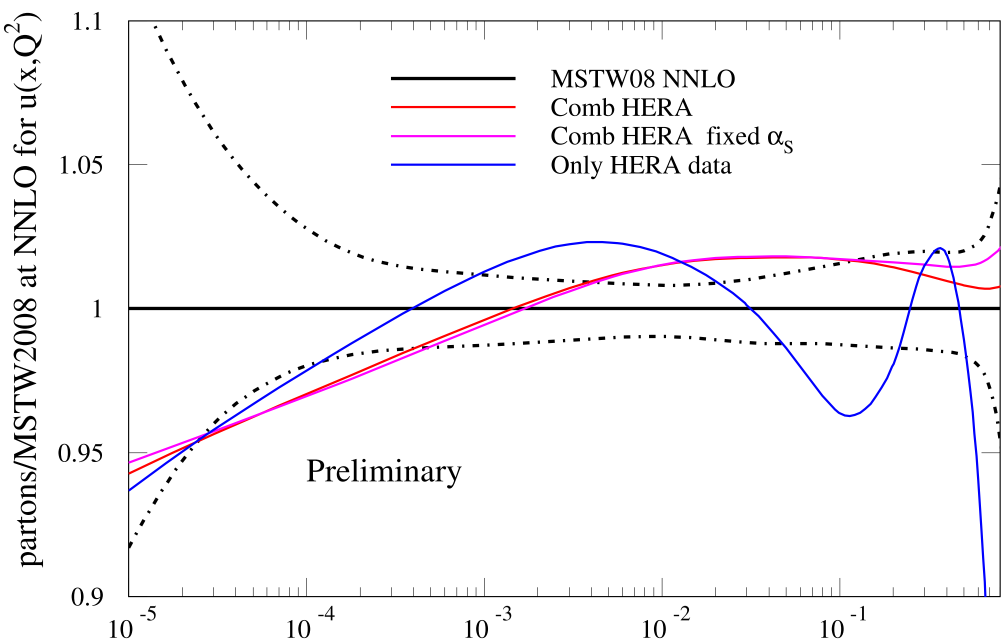
$\alpha_S(M_Z^2) = 0.127$, but sensitivity much lower than global fit. Gluon generally reduced, quark flavours change dramatically. Comparison to all non HERA data extremely poor.

Comparison of gluon and up quark from fits using combined HERA data to MSTW2008 NNLO versions with $1-\sigma$, uncertainty shown.

Significant effect in places. Very little dependence on whether α_S left free.

Most dramatic for quark at about $x = 0.01$, and PDFs at about $x \sim 0.0001$.





Impact on Cross Sections - NNLO.

The values of the predicted cross-sections at NNLO for Z and a 120 GeV Higgs boson at the Tevatron and the LHC (latter for 14 TeV centre of mass energy).

PDF set	$B_{l^+l^-} \cdot \sigma_Z$(nb)TeV	σ_H(pb)TeV	$B_{l^+l^-} \cdot \sigma_Z$(nb)LHC	σ_H(pb)LHC
MSTW08	0.2507	0.9549	2.051	50.51
Comb HERA	0.258	0.954	2.07	50.7
fixed $\alpha_S(M_Z^2)$	0.258	0.931	2.06	50.0

For new global fits $2-3\%$ effect on Z (and W) cross sections at Tevatron, but small change at LHC. Similar to $1-\sigma$ uncertainty in former case.

Maximum of 1% for Higgs, less when α_S changes. Small effect.

HERA-only fit much higher for Z and for Higgs due to very large coupling.

Low Q^2.

Previously performed fits with the known NNNLO large $\ln(1-x)$ terms included explicitly.

Also parameterize higher twist contributions by

$$F_i^{\mathrm{HT}}(x,Q^2) = F_i^{\mathrm{LT}}(x,Q^2)\left(1+\frac{D_i(x)}{Q^2}\right)$$

where i spans bins of x.

No evidence for any higher twist except at low W^2.

x	LO	NLO	NNLO	NNNLO
0–0.0005	−0.07	−0.02	−0.02	−0.03
0.0005–0.005	−0.03	−0.01	0.03	0.03
0.005–0.01	−0.13	−0.09	−0.04	−0.03
0.01–0.06	−0.09	−0.08	−0.04	−0.03
0.06–0.1	−0.02	0.02	0.03	0.04
0.1–0.2	−0.07	−0.03	−0.00	0.01
0.2–0.3	−0.11	−0.09	−0.04	0.00
0.3–0.4	−0.06	−0.13	−0.06	−0.01
0.4–0.5	0.22	0.01	0.07	0.11
0.5–0.6	0.85	0.40	0.41	0.39
0.6–0.7	2.6	1.7	1.6	1.4
0.7–0.8	7.3	5.5	5.1	4.4
0.8–0.9	20.2	16.7	16.1	13.4

Table 1: The values of the higher-twist coefficients D_i, in the chosen bins of x, extracted from the LO, NLO, NNLO and NNNLO (NNLO with the approximate NNNLO non-singlet quark coefficient function) global fits.