MSTW Parton Distributions and α_S

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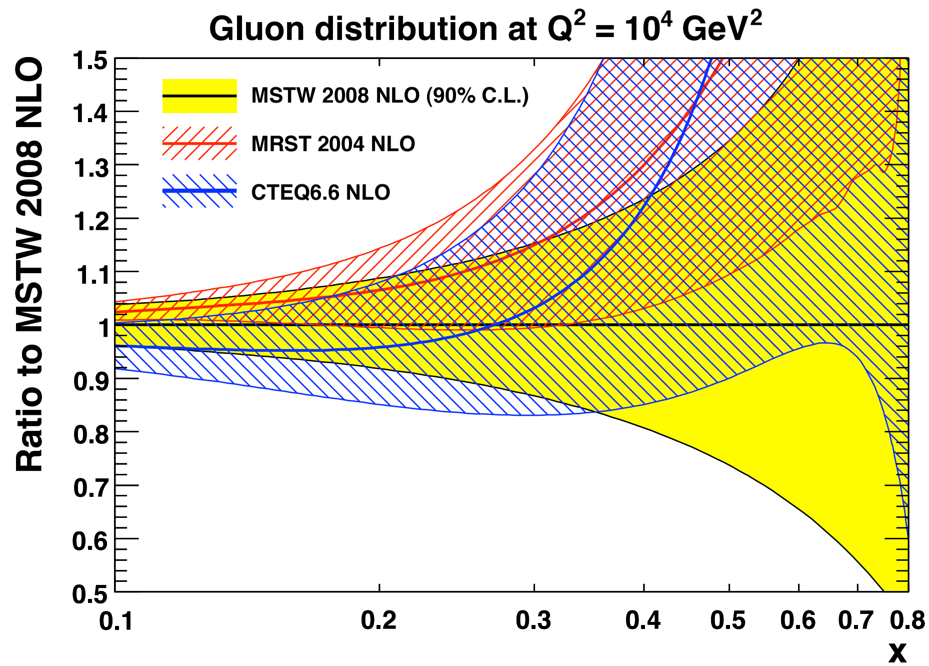
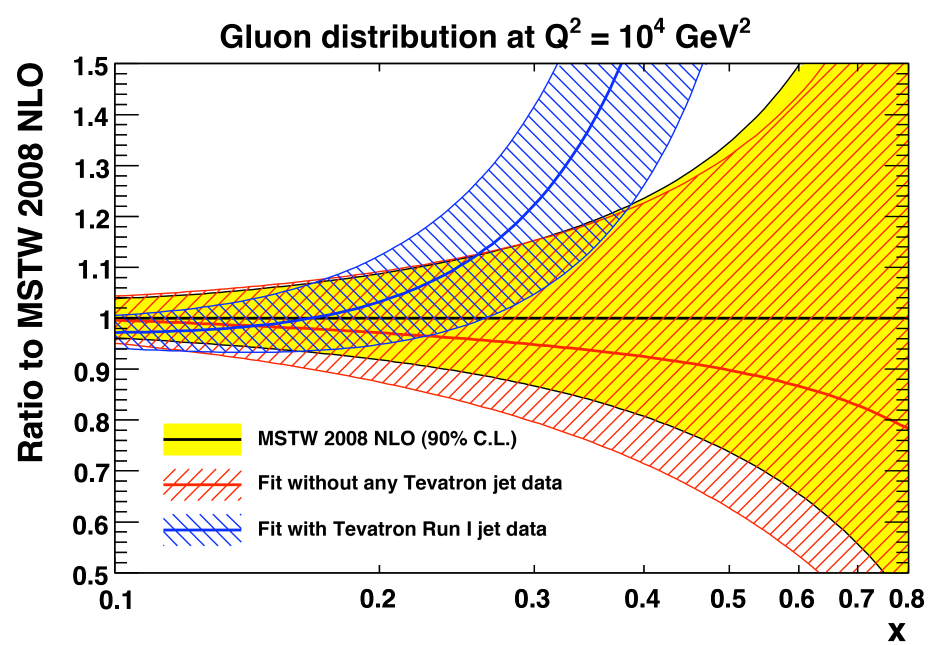
Begin by considering the gluon. Affects many LHC predictions.

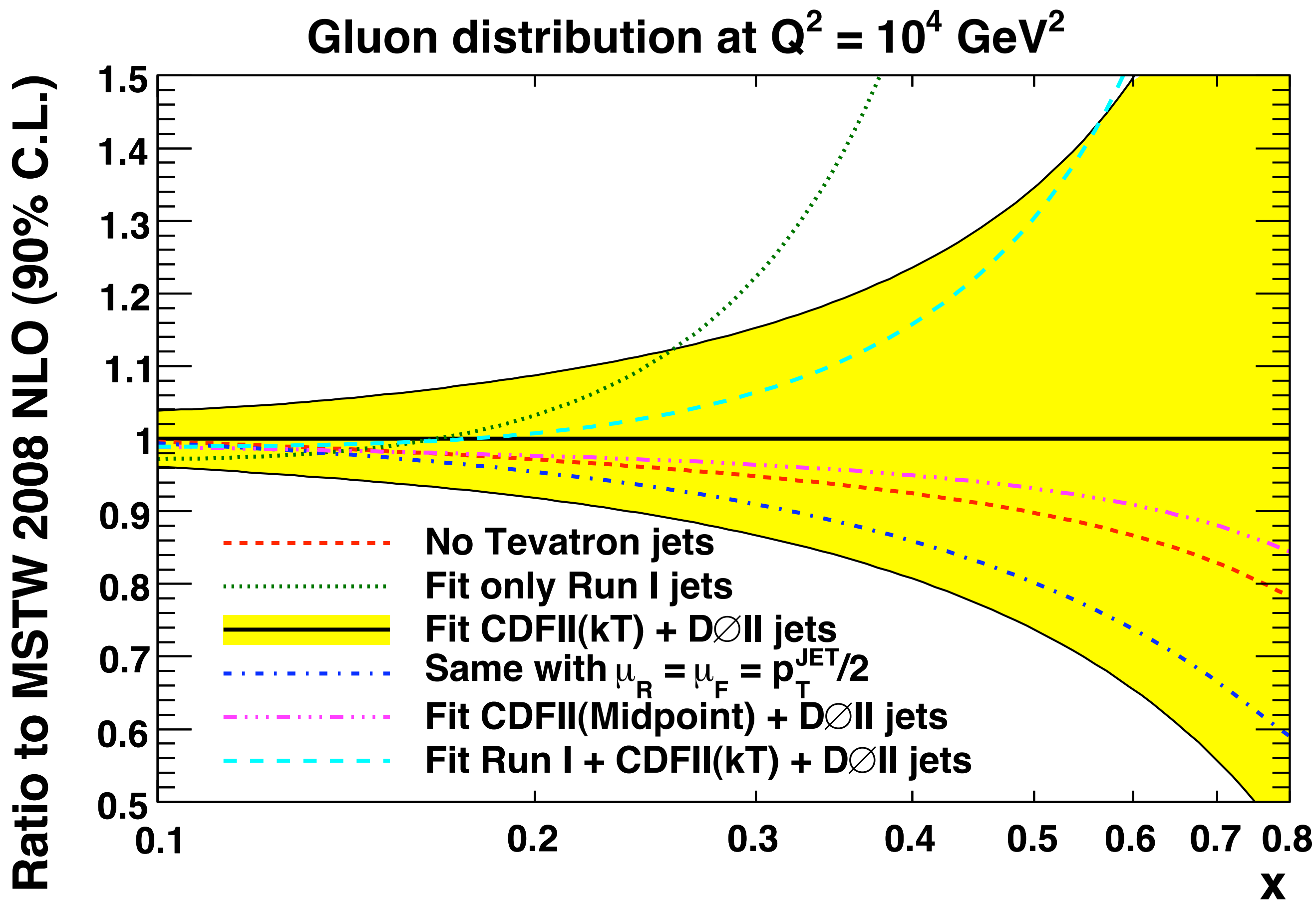
Inclusion of Run II Tevatron jet data instead of Run I softens gluon at high x significantly.





Unlike CT09G do not find good consistency between fits to Run I and Run II.

Little change in conclusions if CDFII k_T-algorithm or (corrected) midpoint algorithm data used.



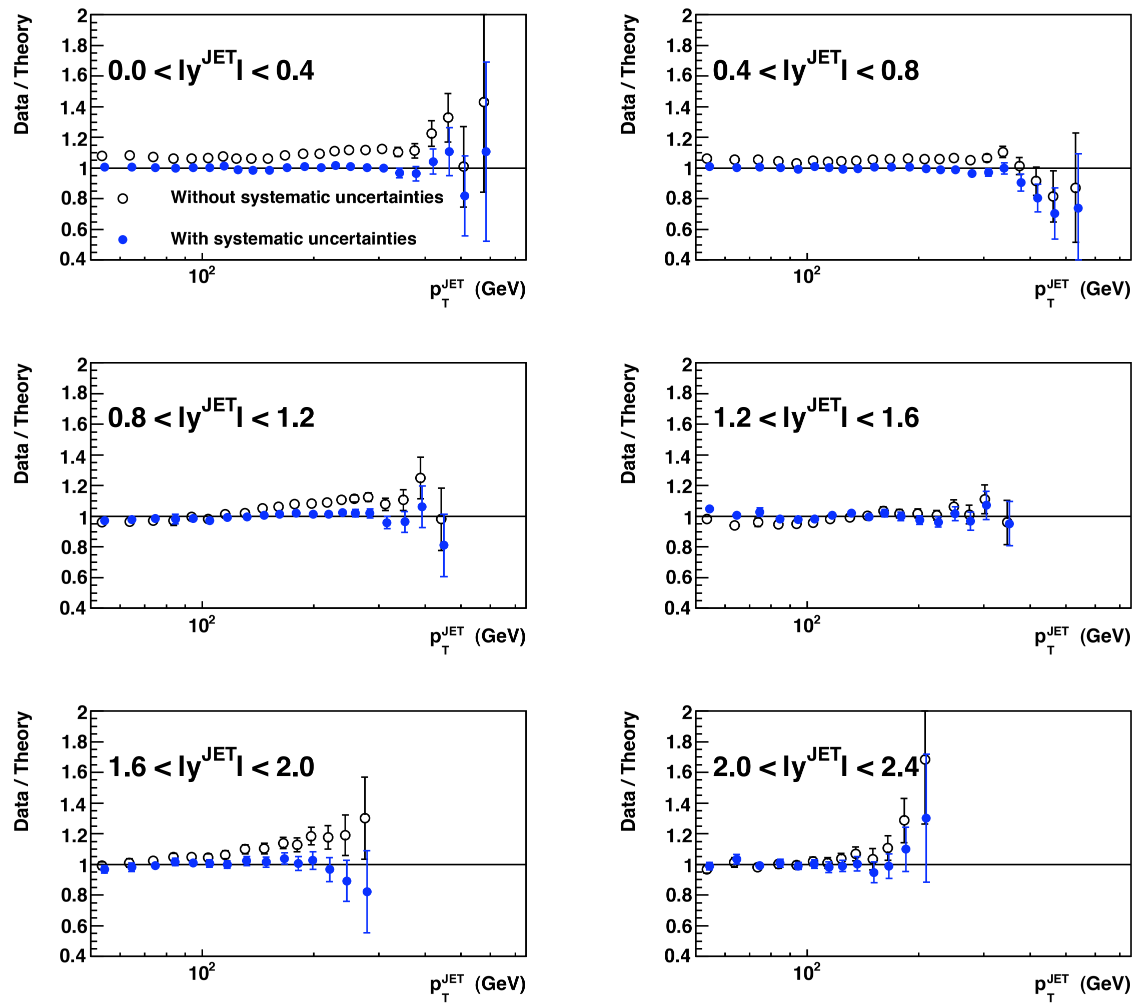
Note different gluons correspond to α_S variation of ~ 0.002.

Fit to D0 Run II data excellent.

No large shifts of data relative to theory required.

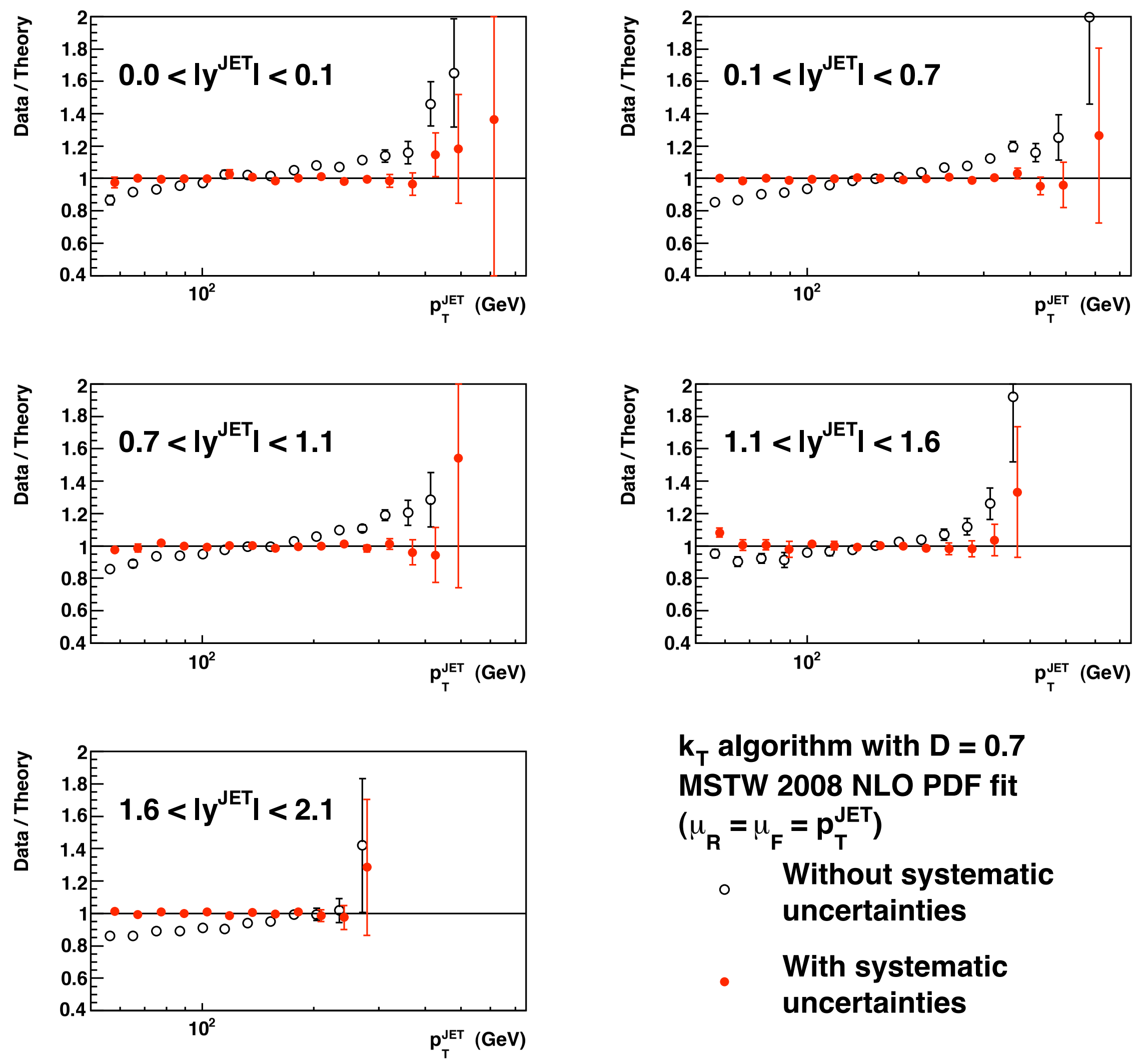
DØ Run II inclusive jet data (cone, R = 0.7)

MSTW 2008 NLO PDF fit ($\mu_R = \mu_F = p_T^{JET}$), $\chi^2 = 114$ for 110 pts.



Fit to CDF Run II data similarly good.

CDF Run II inclusive jet data, $\chi^2 = 56$ for 76 pts.



Quality of fit to various combinations of jet data by MSTW.

CDFI [179] (33 pts.)	DØI [176] (90 pts.)	CDFII [54] (76 pts.)	DØII [56] (110 pts.)	$\Delta\chi^2_{\text{non-jet}}$ (2513 pts.)	$\alpha_S(M_Z^2)$
53	119	64	117	0	0.1197
51	**48**	132	180	9	0.1214
56	110	**56**	**114**	2	0.1202
53	**85**	**68**	**117**	1	0.1204

Quality of fit to various combinations of jet data by CTEQ.

CDF_I (33 pts)		$D0_I$ (90 pts)		CDF_{II} (72 pts)		$D0_{II}$ (110 pts)		$\Delta\chi^2$
Wt	χ^2	Wt	χ^2	Wt	χ^2	Wt	χ^2	non-jet
0	55.4	0	115.3	0	99.5	0	134.0	0.0
1	52.6	1	47.0	0	105.6	0	138.3	11.8
0	56.6	0	82.2	1	85.6	1	124.1	6.2
1	52.1	1	59.4	1	88.5	1	121.5	9.6

Quality of fit to combinations of jet data by CTEQ with restricted gluon parameterization – far worse. Therefore not obvious source of discrepency.

CDF_I (33 pts)		$D0_I$ (90 pts)		CDF_{II} (72 pts)		$D0_{II}$ (110 pts)		$\Delta\chi^2$
Wt	χ^2	Wt	χ^2	Wt	χ^2	Wt	χ^2	non-jet
0	55.8	0	145.9	0	120.6	0	155.2	2.0
1	53.2	1	124.0	0	118.2	0	148.6	7.7
0	58.6	0	121.3	1	98.1	1	137.8	16.8
1	54.5	1	108.8	1	95.5	1	134.2	25.8

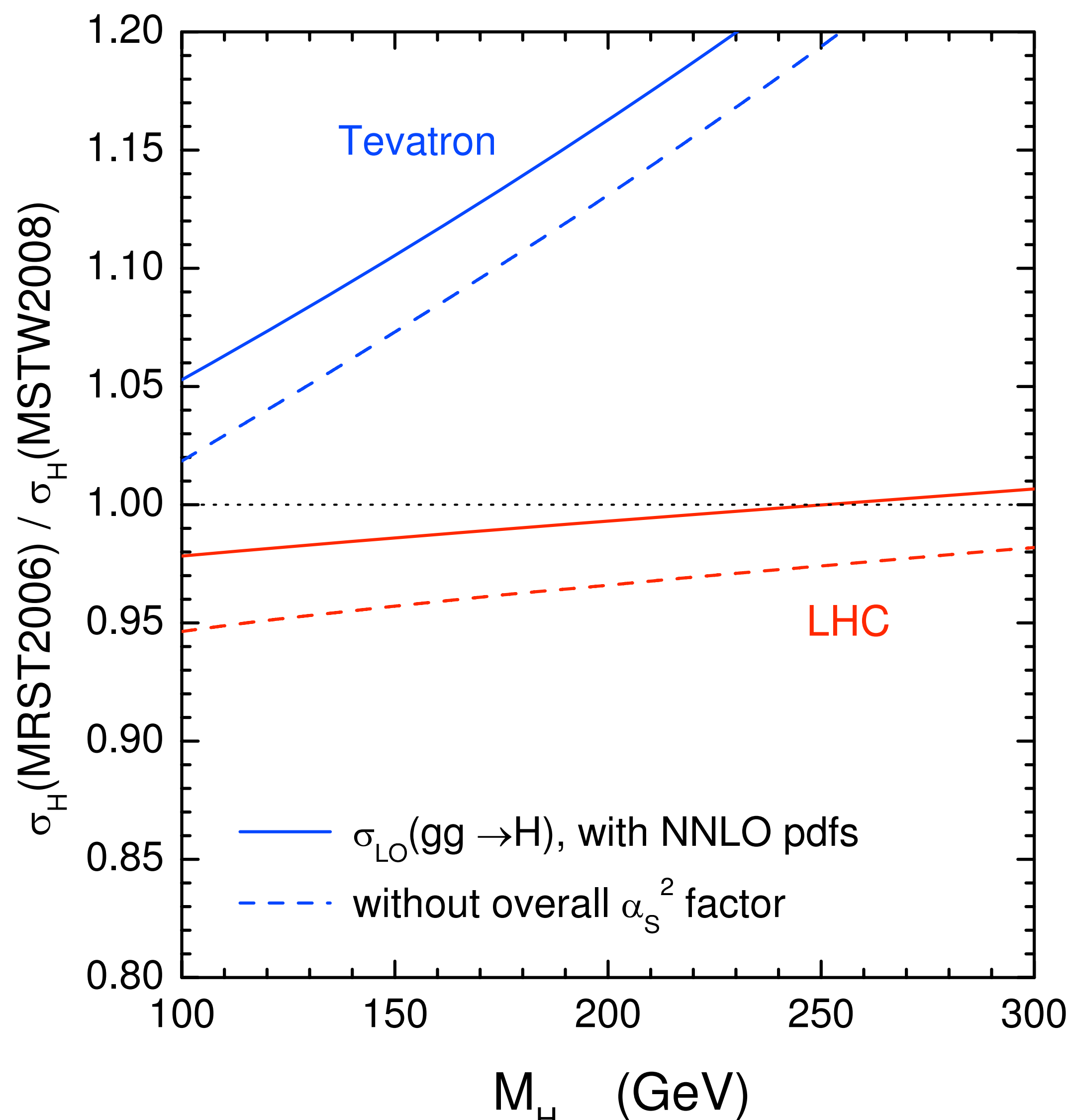
Higgs predictions

Also consider implications for new physics from updated PDFs.

In MSTW2008 larger small-x gluon, smaller high-x gluon.

$\rightarrow$ decrease in Higgs rate at Tevatron, slight increase at LHC (de Florian *et al*, Anastasiou *et al*).

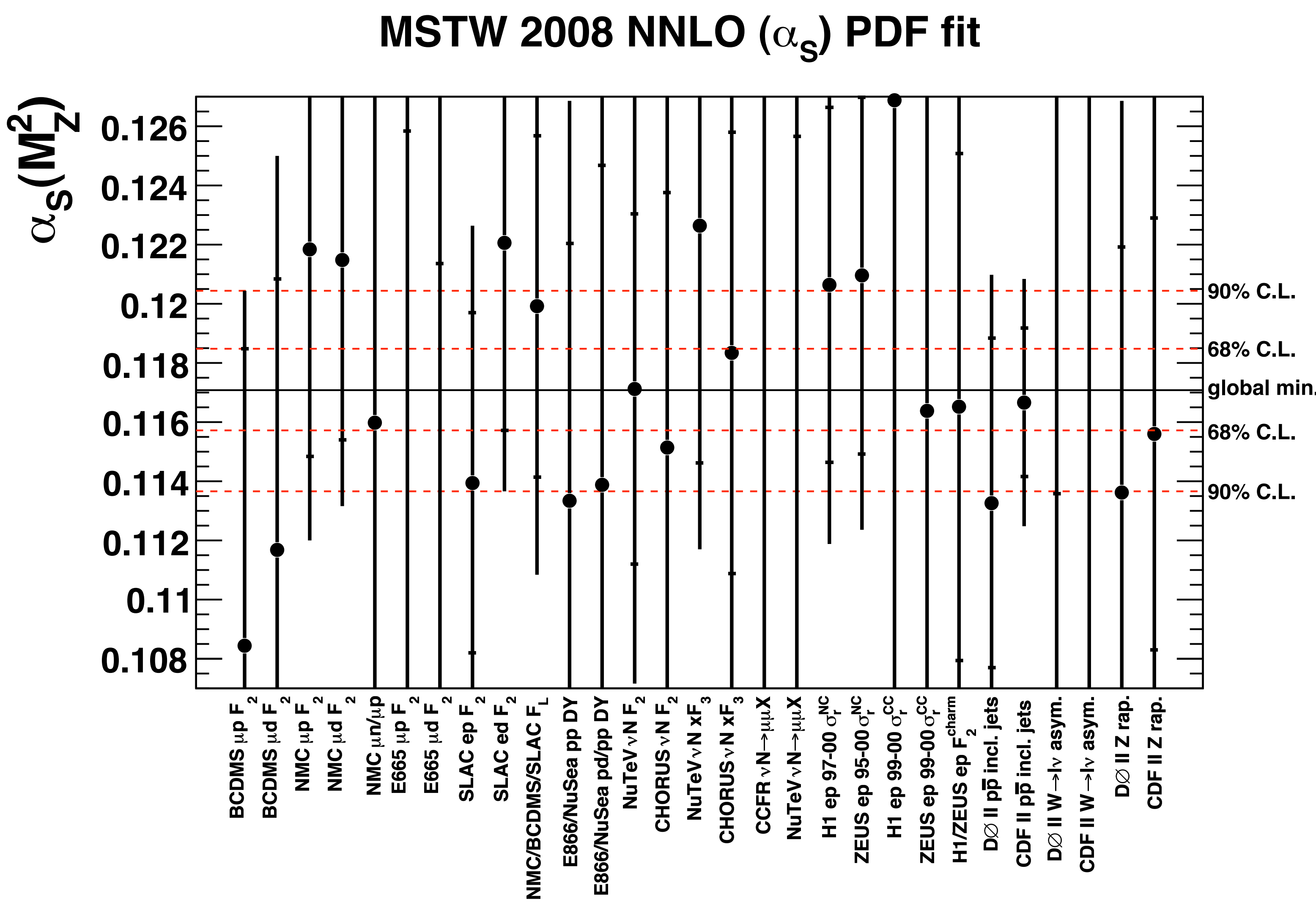
But largely affected by change in central value of coupling – down 2% – anticorrelated with small-x gluon. Increases Tevatron effect, limits LHC effect.



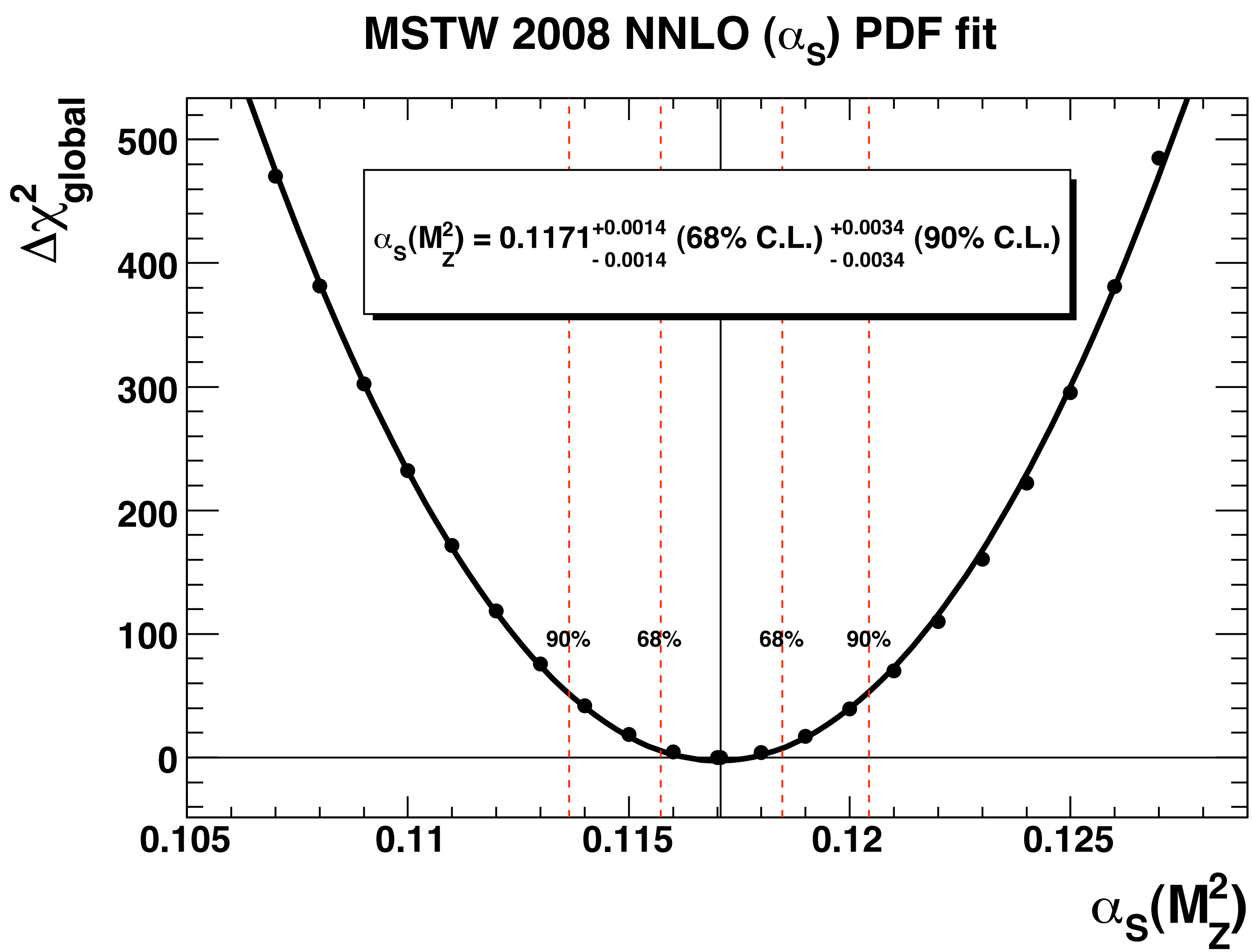
Shows importance of correlations of PDFs and $\alpha_S(M_Z^2)$. Not usually considered.

Uncertainties on PDFS and $\alpha_S(M_Z^2)$.

Determine uncertainties by scanning over fit quality to different data sets, as with eigenvectors.



Leads to competitive looking uncertainties.



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

High-x $F_L(x,Q^2)$ data recieve 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.

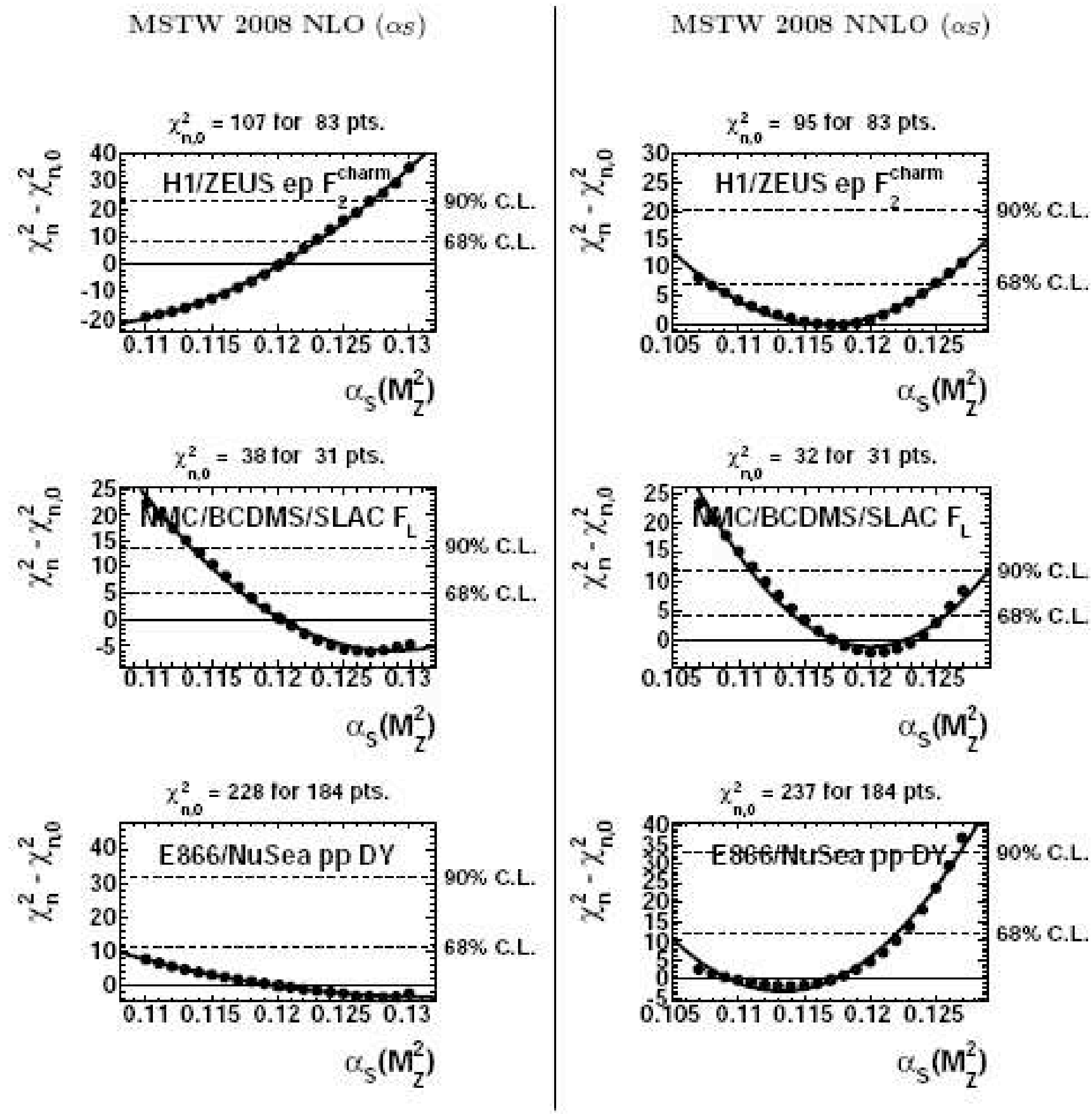
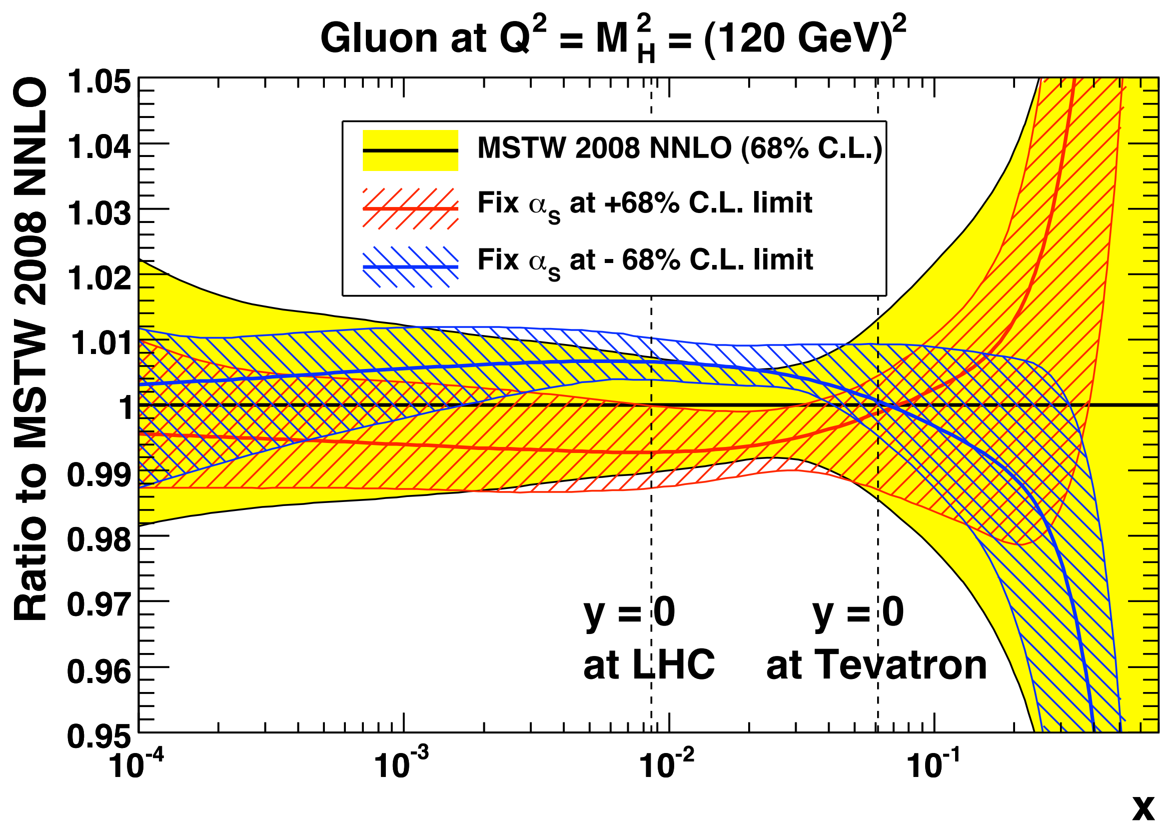


Figure 5: Comparison of selected χ^2_n profiles in the NLO (left) and NNLO (right) fits.

Can also look at PDF changes and uncertainties at different $\alpha_S(M_Z^2)$ values using same technique as before.

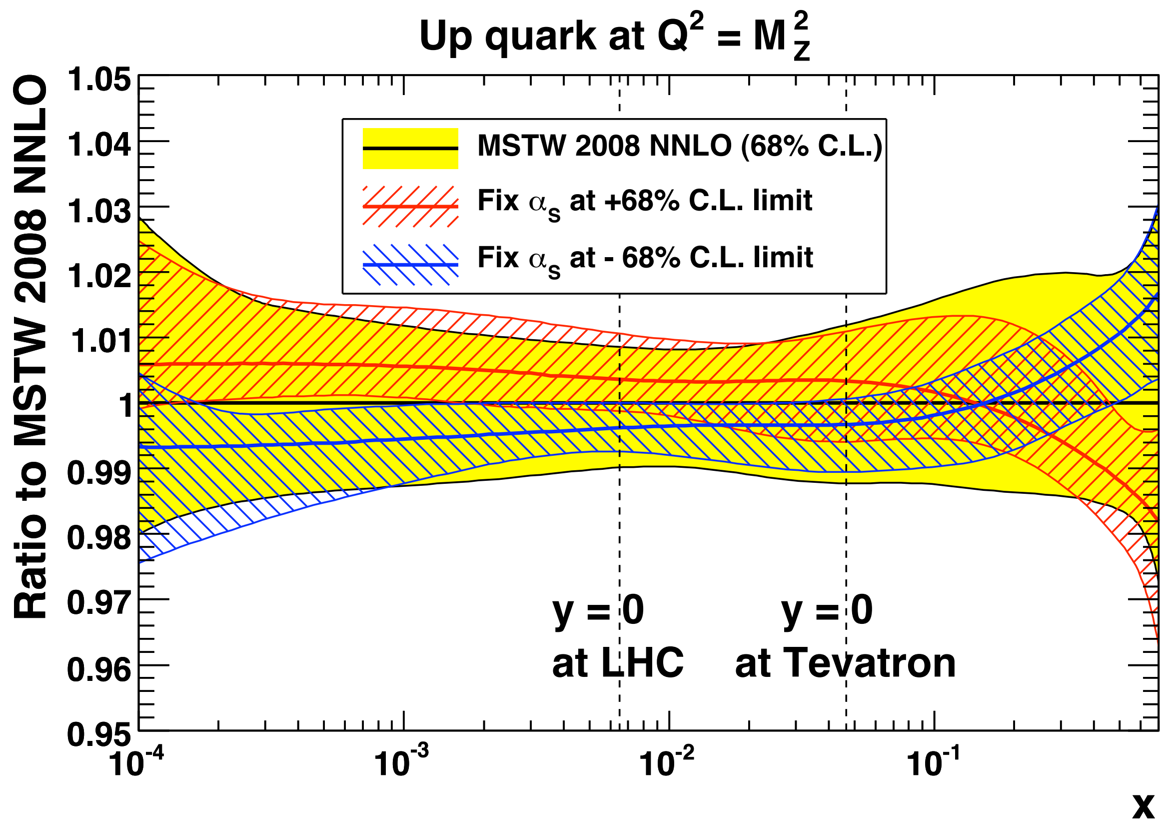
PDF uncertainties reduced since quality of fit already worse than best fit.



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

Variation of gluon largely within central uncertainty band.

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.

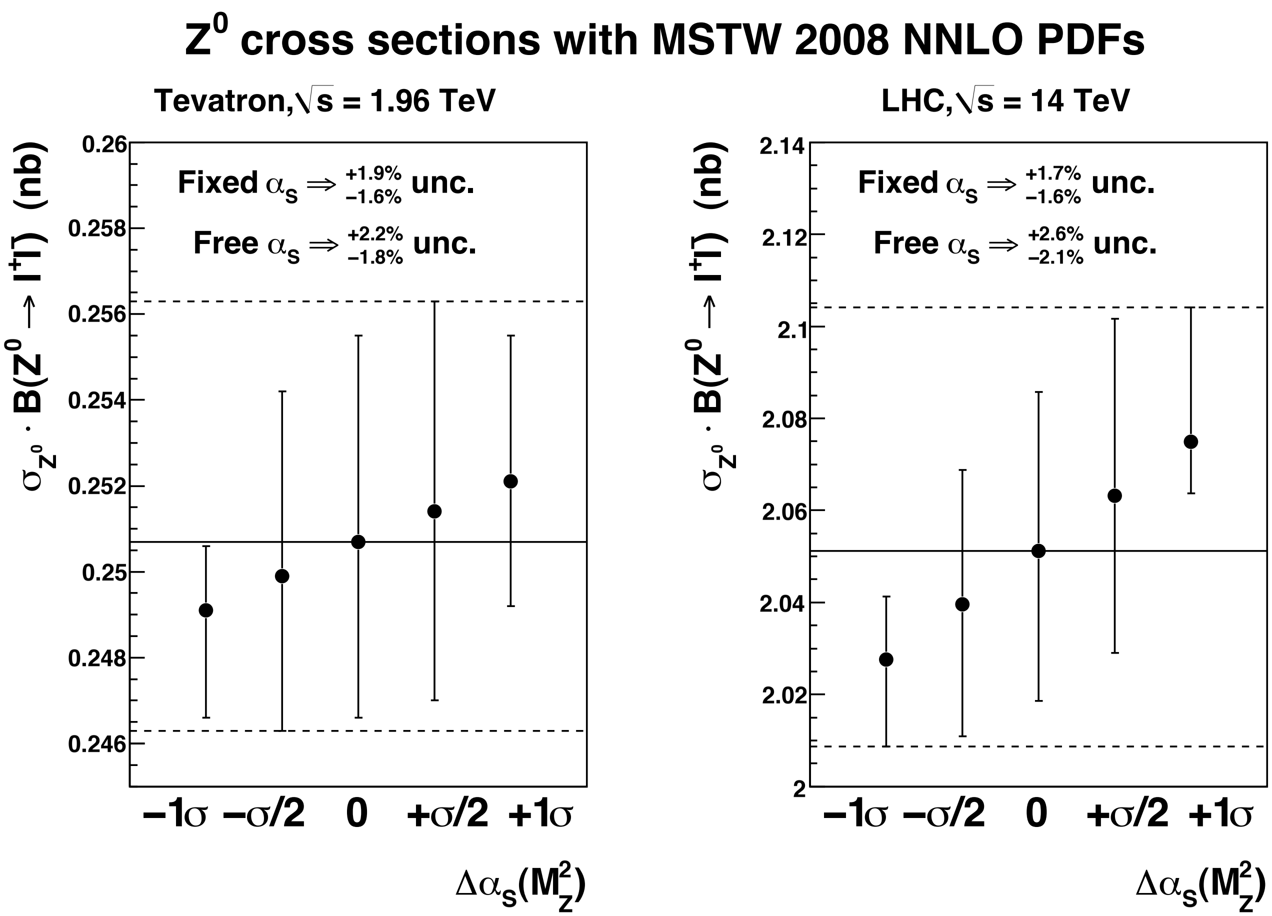


Strong anticorrelation at high-x due to evolution and positive coefficient functions.

Again, changes within, or close to within, initial uncertainties.

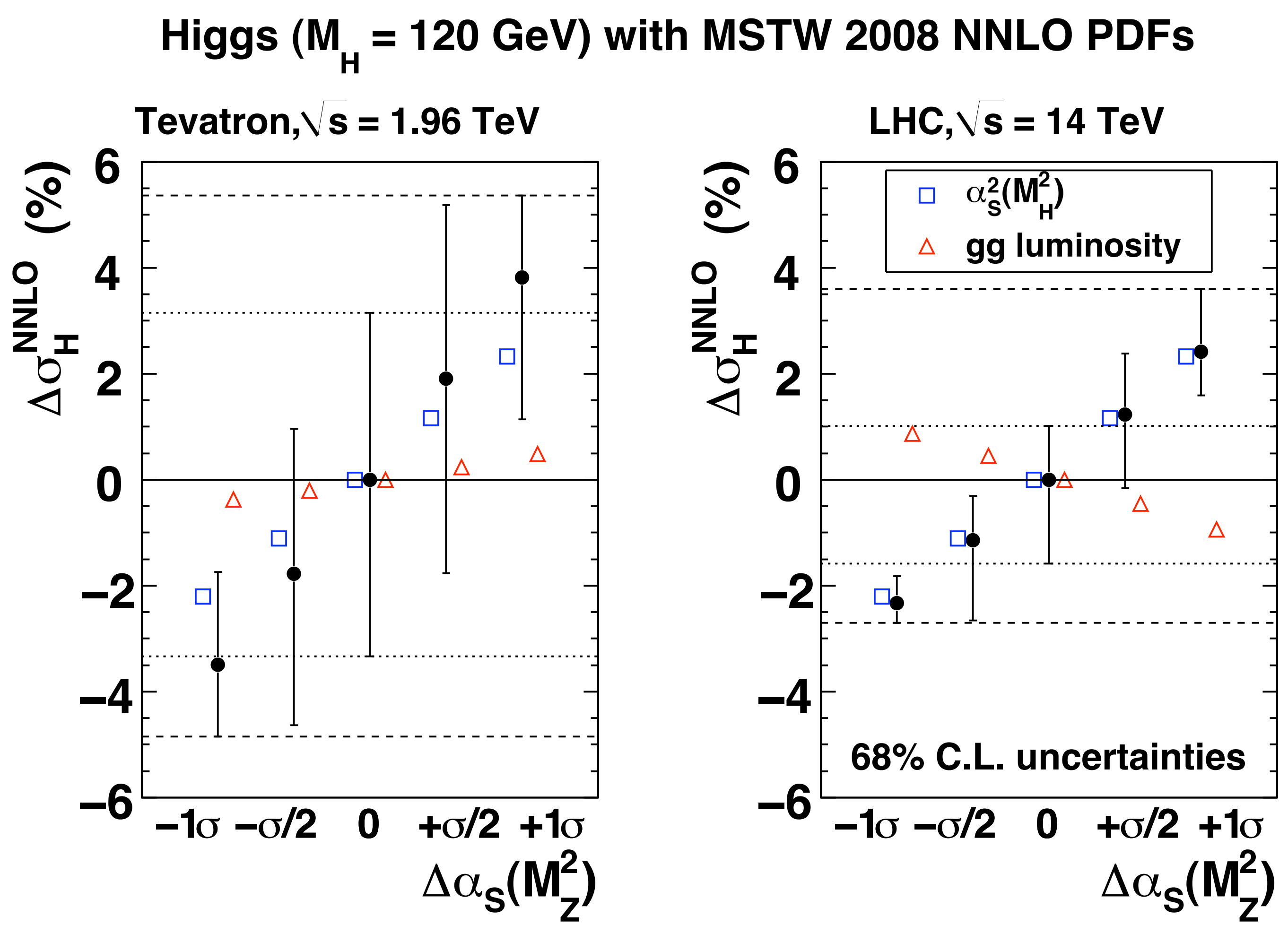
Additional uncertainty from $\alpha_S(M_Z^2)$ variation for quantities depends on how PDFs and coupling are correlated.

NNLO predictions for Z production for allowed $\alpha_S(M_Z^2)$ values and their uncertainties.



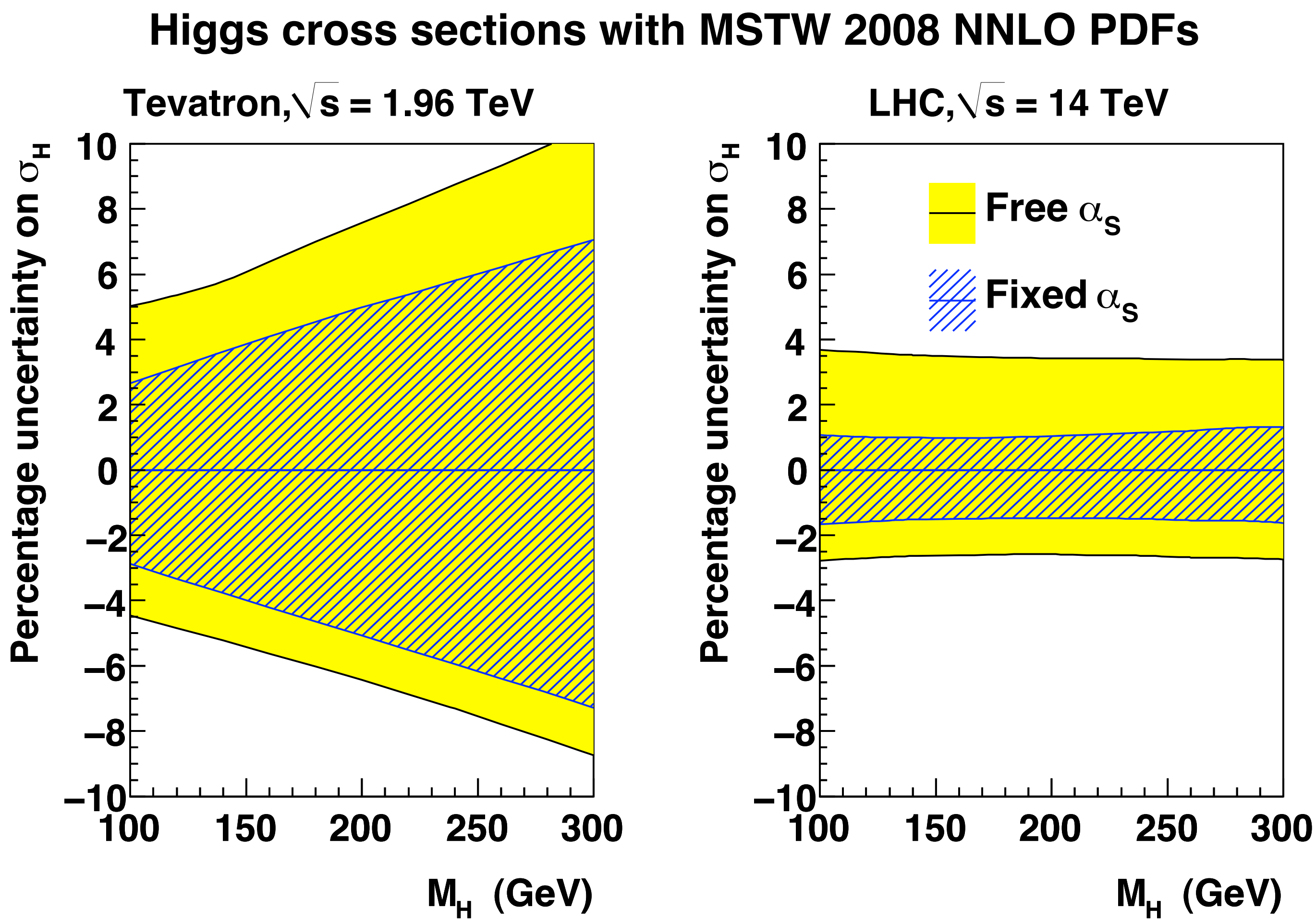
Total uncertainty envelope of set of uncertainties. Increases by up to 50% at LHC. Largely due to effect of PDFs.

NNLO predictions for Higgs ($120\mathrm{GeV}$) production for different allowed $\alpha_S(M_Z^2)$ values and their uncertainties.



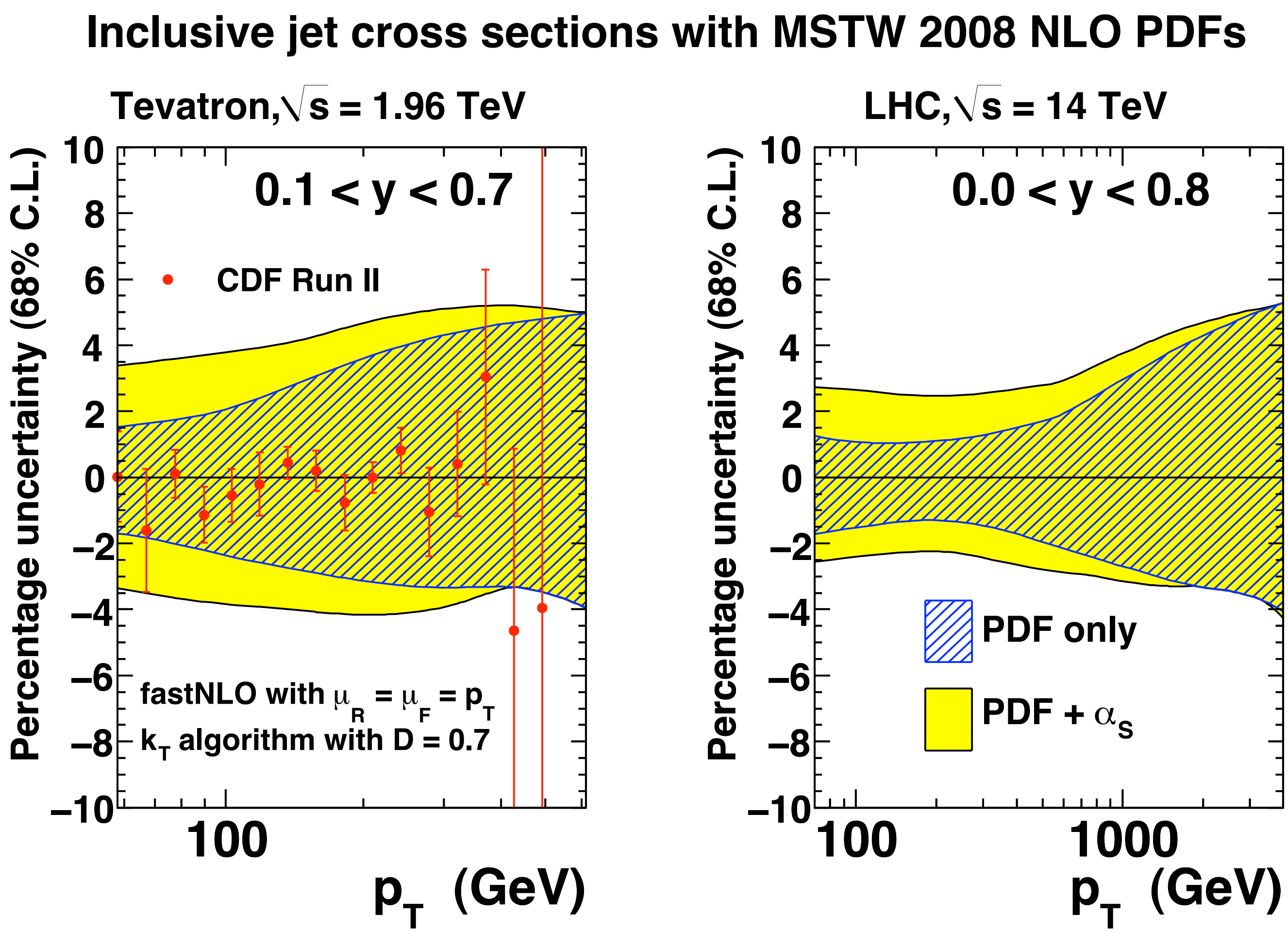
Increases by a factor of $2-3$ (up more than down) at LHC. Direct $\alpha_S(M_Z^2)$ dependence mitigated somewhat by anti-correlated small-x gluon (asymmetry feature of *minor* problems in fit to HERA data). At Tevatron intrinsic gluon uncertainty dominates.

Can extend study to a range of Higgs masses. See same features, i.e. intrinsic PDF uncertainty most important at Tevatron and increases with mass (high-x gluon). Roughly constant at LHC with coupling effect large.



Consistently more PDF-α_S anti-correlation in downwards direction.

Can also investigate uncertainties for inclusive jets at Tevatron and at LHC.



At lower p_T gluons dominate and α_S correlated. At higher p_T quarks become more important and high-x quarks anticorrelated to α_S so no additional α_S uncertainty.

Conclusions

HERA and Tevatron jets now fit using fastNLO. New run II CDF and D0 jet data included. Smaller high-x gluon, larger small-x gluon – impacts on Higgs predictions.

No not find very good agreement between fits including run I and run II Tevatron jet data, 90% uncertainty bands do not overlap at highest x.

Change in best fit values of $\alpha_S(M_Z^2)$. At NLO 0.120 compared to 0.121 in unofficial MRST06 set. At NNLO 0.117 compared to 0.119 in MRST06 set.

Find uncertainty on coupling itself due to experimental errors $\alpha_S(M_Z^2) = 0.1202^{+0.0012}_{-0.0015}$ at NLO and $\alpha_S(M_Z^2) = 0.1171^{+0.0014}_{-0.0014}$ at NNLO.

PDF uncertainty approach now being applied with additional $\alpha_S(M_Z^2)$ variation. As $\alpha_S(M_Z^2)$ moves away from best-fit value PDF uncertainty band shrinks.

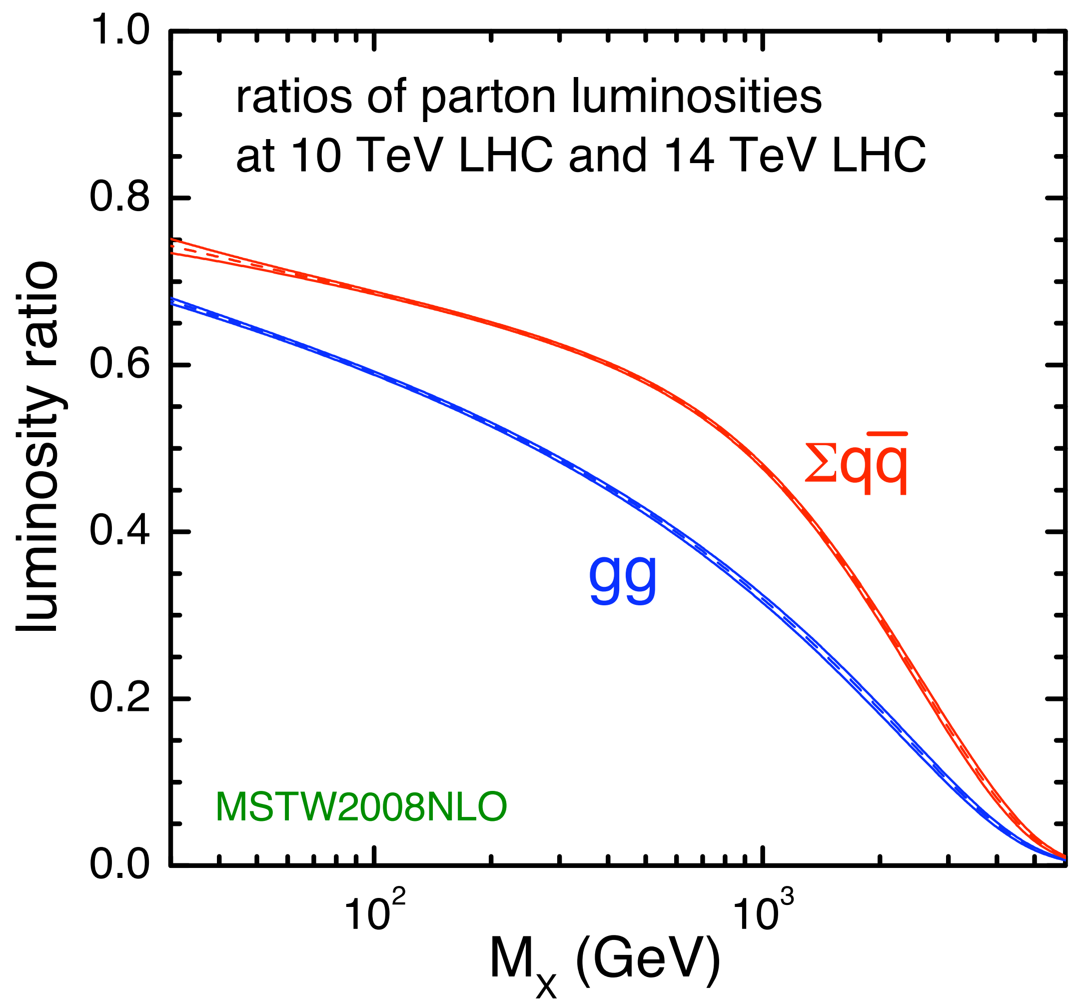
Some PDFs highly correlated, or anti-correlated with $\alpha_S(M_Z^2)$.

Full study of correlated PDF and α_S uncertainty leads to uncertainties at LHC often about 1.5, and up to $3-4$ times bigger. Correlations vitally important.

Initial Running

Of course, will be starting the LHC running at 10 TeV rather than the full 14 TeV.

Roughly $60 - 70\%$ the full cross-sections for most standard model (including light Higgs) processes.

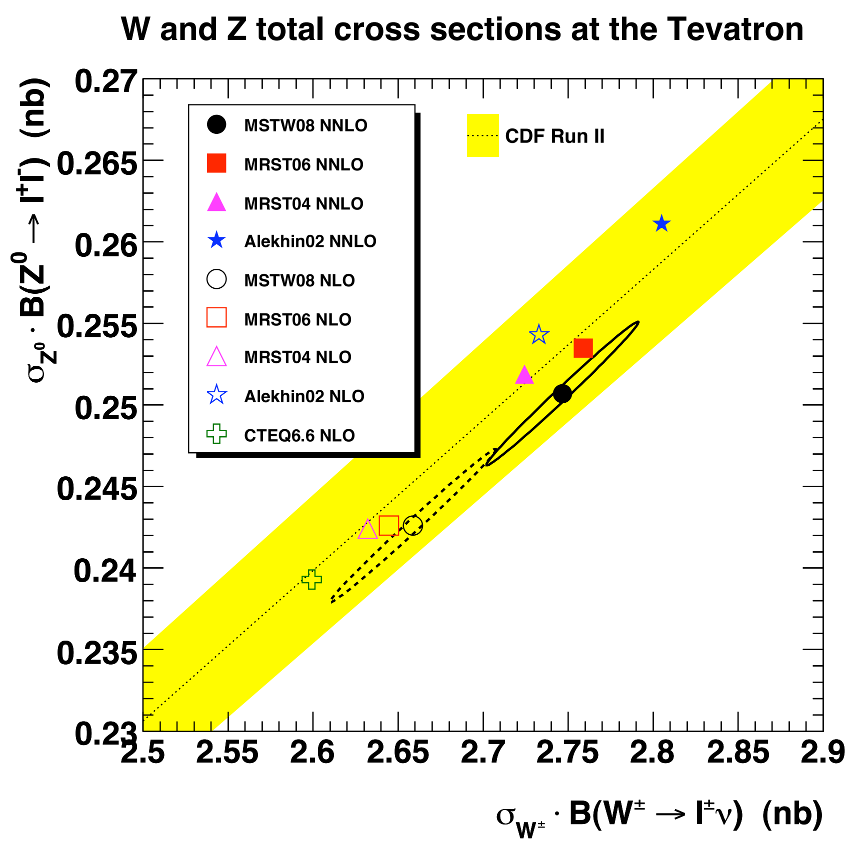


Predictions – Cross-sections

Predictions for W and Z cross-sections for Tevatron with common fixed order QCD and vector boson width effects, and common branching ratios.

Fairly significant change from NLO to NNLO mainly due to hard cross-section correction.

Other than this reasonable agreement in predictions.

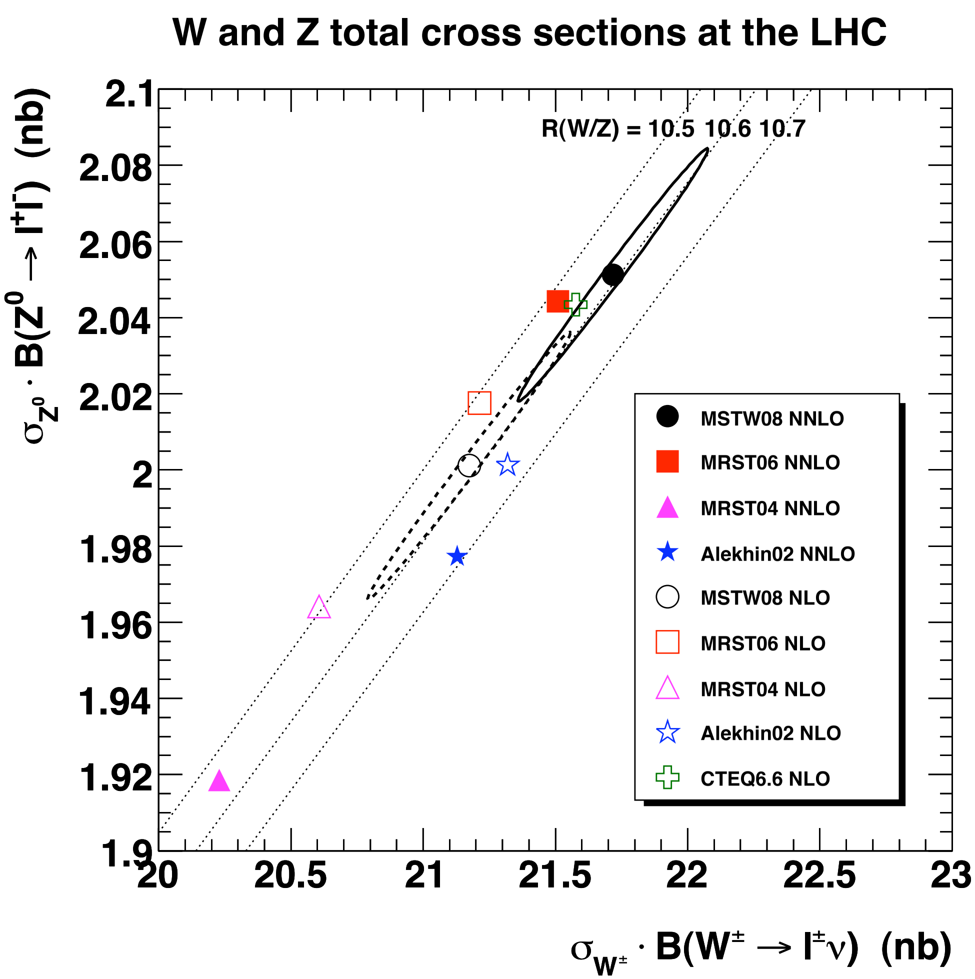


Predictions for W and Z cross-sections for Tevatron with common fixed order QCD and vector boson width effects, and common branching ratios.

Increases from MRST2006 compared to MRST2004 due to changes due to improved (NLO) or completed (NNLO) heavy flavour prescription.

Virtually no change from MRST2006 → MRST2008. Ratio changes due to change in strange distribution.

Reasonable agreement at NLO with CTEQ6.6, but systematic difference mirrors shape of gluon/quarks.

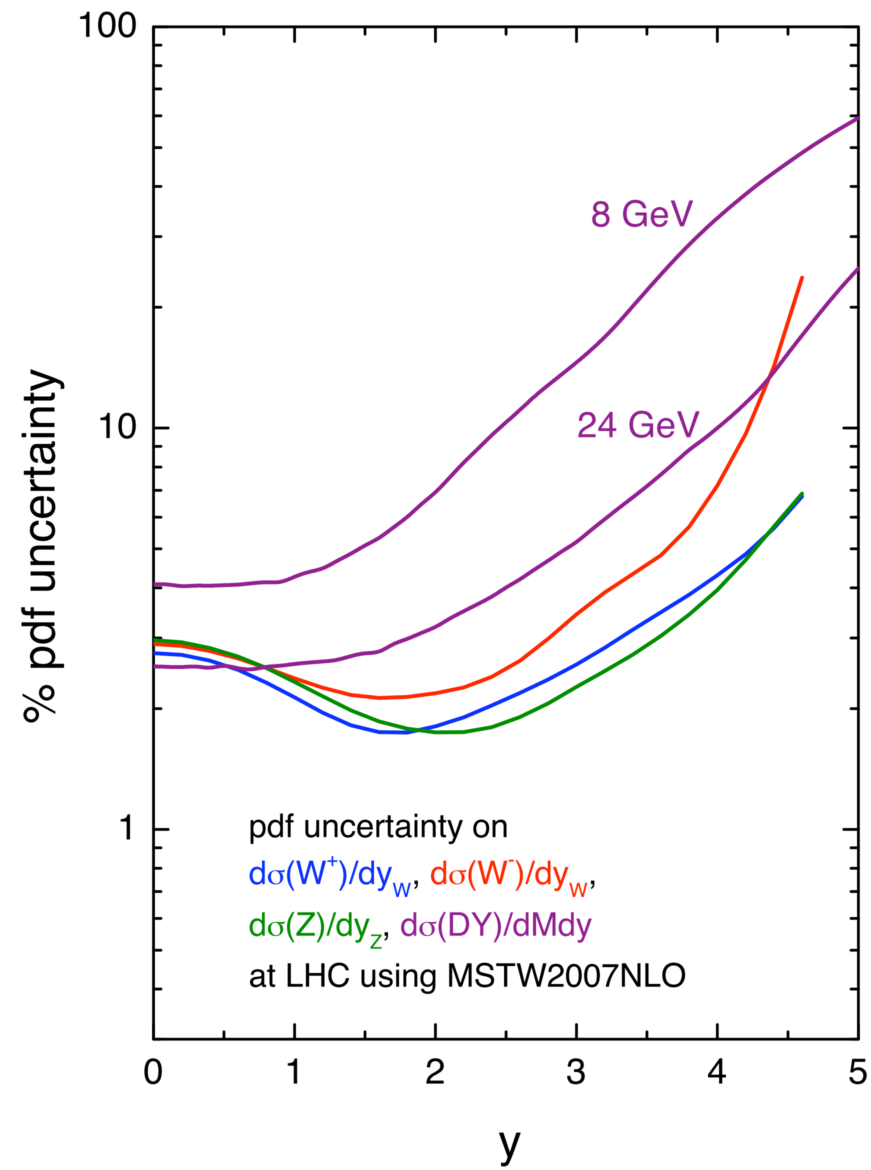


Uncertainty – more details

Uncertainty on $\sigma(Z)$ and $\sigma(W^+)$ grows at high rapidity.

Uncertainty on $\sigma(W^-)$ grows more quickly at very high y – depends on less well-known down quark.

Uncertainty on $\sigma(\gamma^\star)$ is greatest as y increases. Depends on partons at very small x.



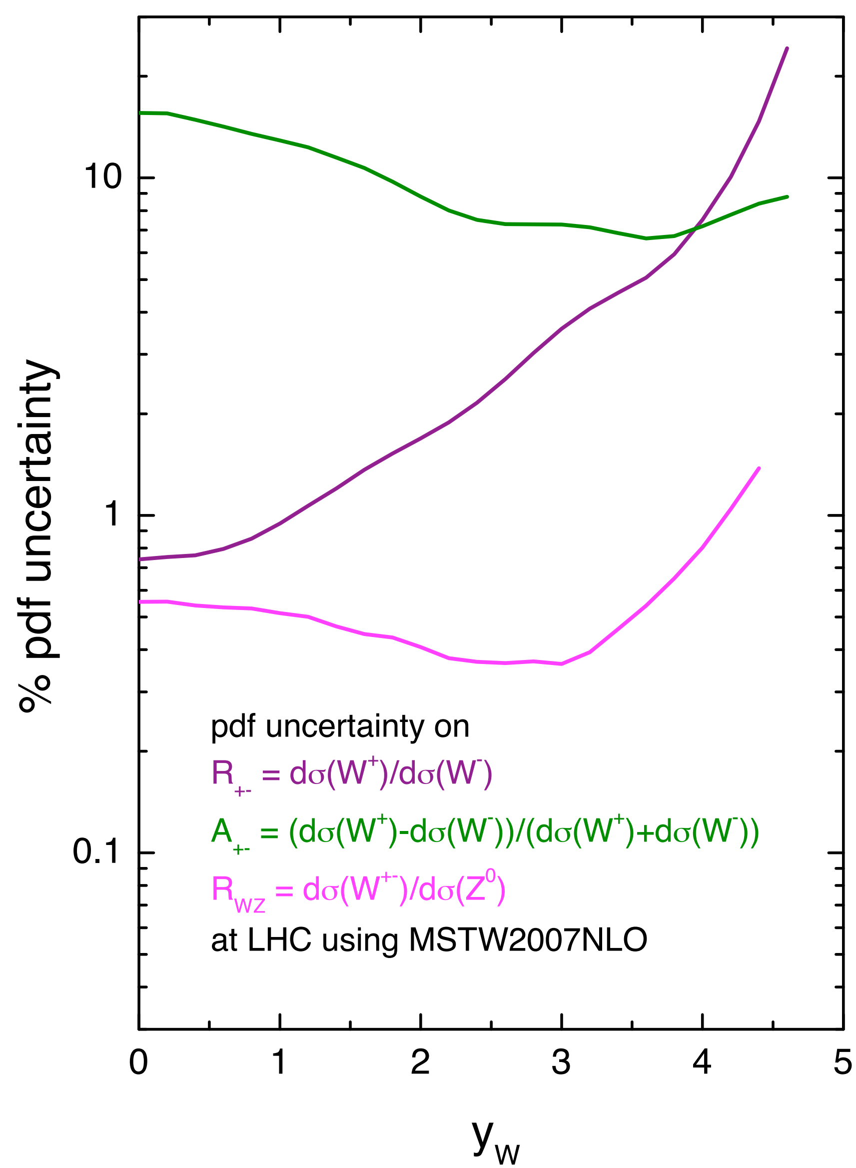
More information from ratios including $\sigma(Z)$, $\sigma(W^-)$ and $\sigma(W^+)$.

Cleaner experimentally.

Uncertainty on A_W large even just from experimental sources.

But $y = 0$ is $x_1 = x_2 = 0.006$ – range of extrapolation of valence quarks. Differences in different PDF extractions.

One of most useful inputs to PDFS with very little data.



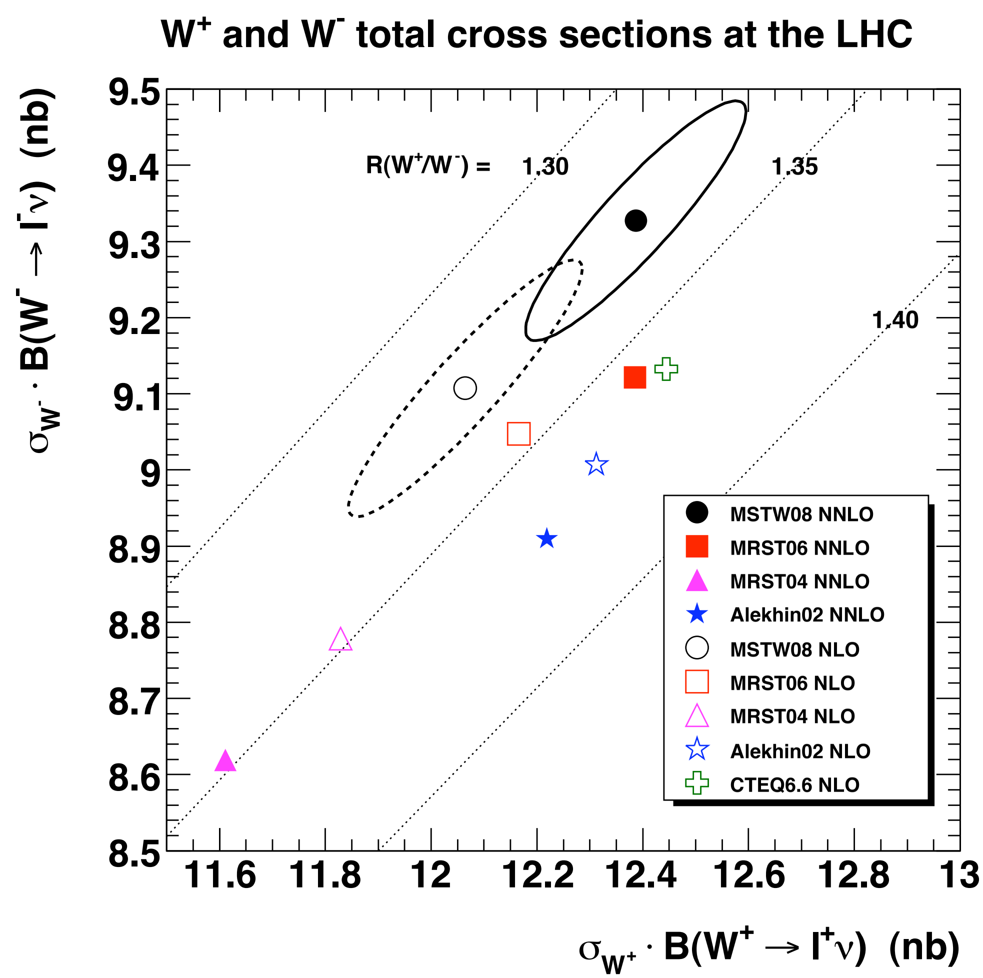
Extremely small uncertainty on ratios W/Z and W^+/W^-.

Predictions for W+ and W- cross-sections for LHC with common fixed order QCD and vector boson width effects, and common branching ratios.

Quoted uncertainty for ratio very small, i.e. $\approx 0.8\%$.

Significantly more difference in this from other PDFs, including MRST.

Again very interesting for early data.



Perturbative Stability at the LHC

Now have QCD calculations at LO, NLO and NNLO in the coupling constant α_S for Z, W and $\gamma^\star$ production Anastasiou, Dixon, Melnikov, Petriello).

Good stability in predictions for e.g. Z and $\gamma^\star$ cross-sections for very high virtuality.

Becomes worse at lower scales where α_S larger and large $\ln(s/M^2)$ terms appear in expansion (equivalent to $\ln(1/x)$) and large threshold $\ln(1-x)$ terms.