Parton Distributions and Tevatron Jets

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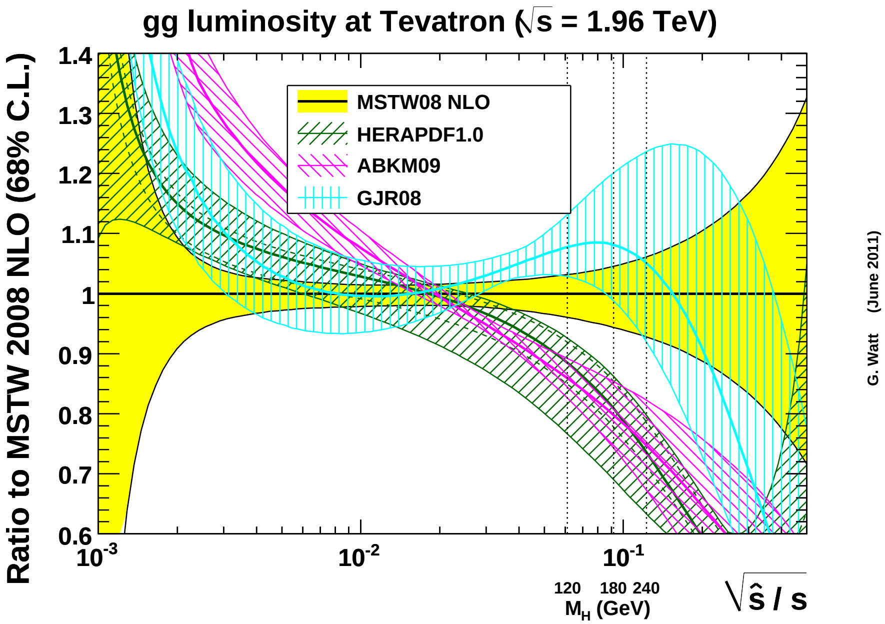
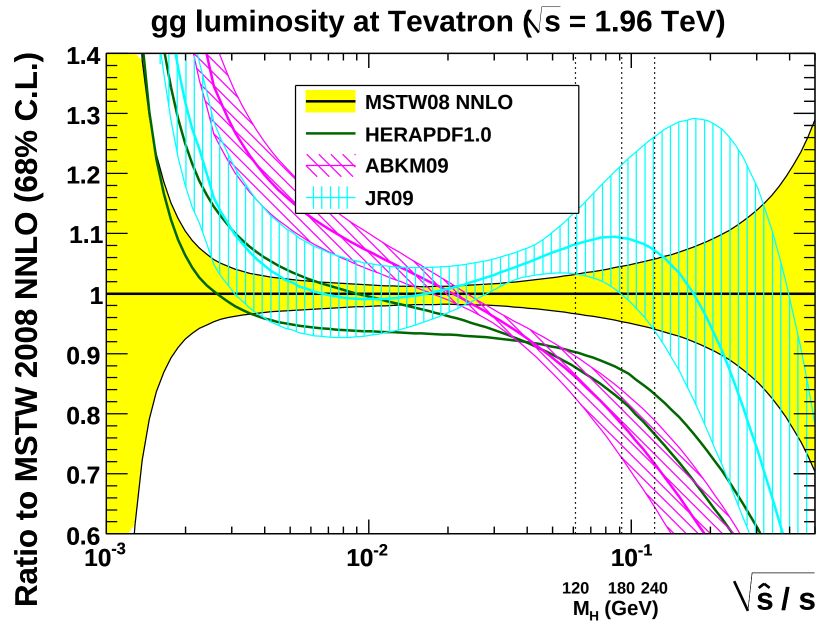
Work with Graeme Watt – `arXiv:1106.5789 [hep-ph]`

Plots (Watt) show the gluon luminosities at the Tevatron NLO and NNLO

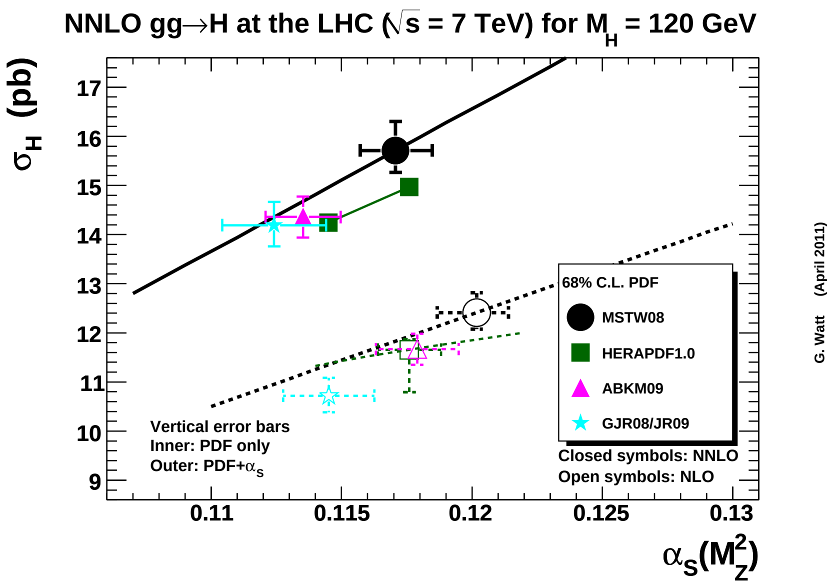


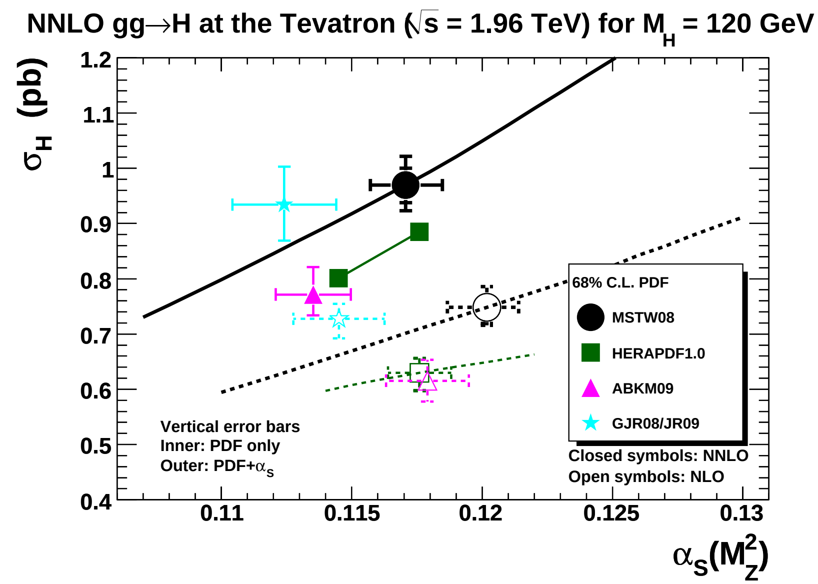


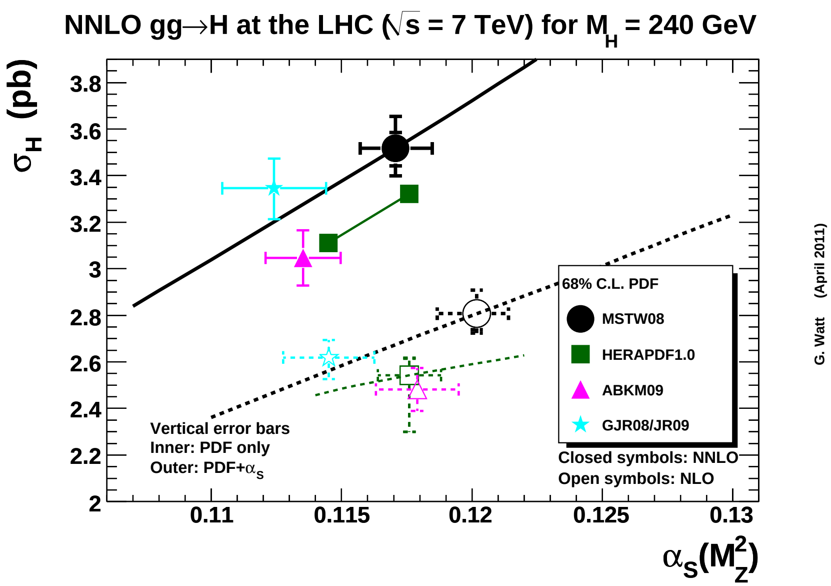
Similar to the LHC, but deviations with high-x PDF origin persist to lower $\hat{s}$.

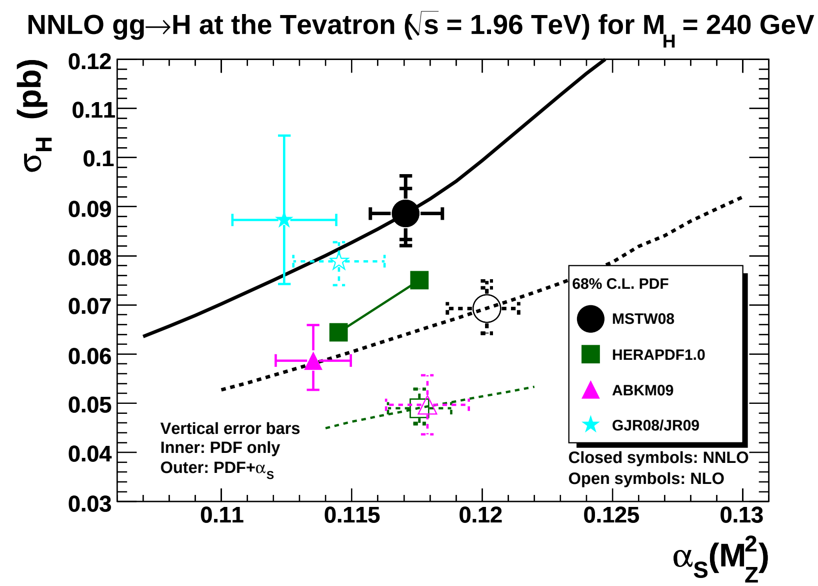
Differences in $\alpha_S(M_Z^2)$ generally increase effect of discrepancy.

Higgs production via gluon fusion at the Tevatron and LHC at NLO and NNLO.









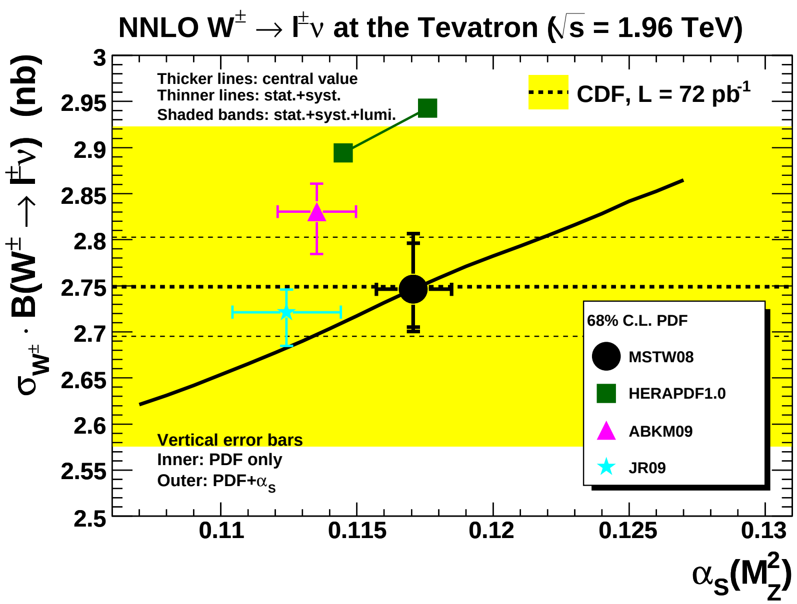
Larger deviation at the Tevatron. NNLO pattern very similar to NLO.

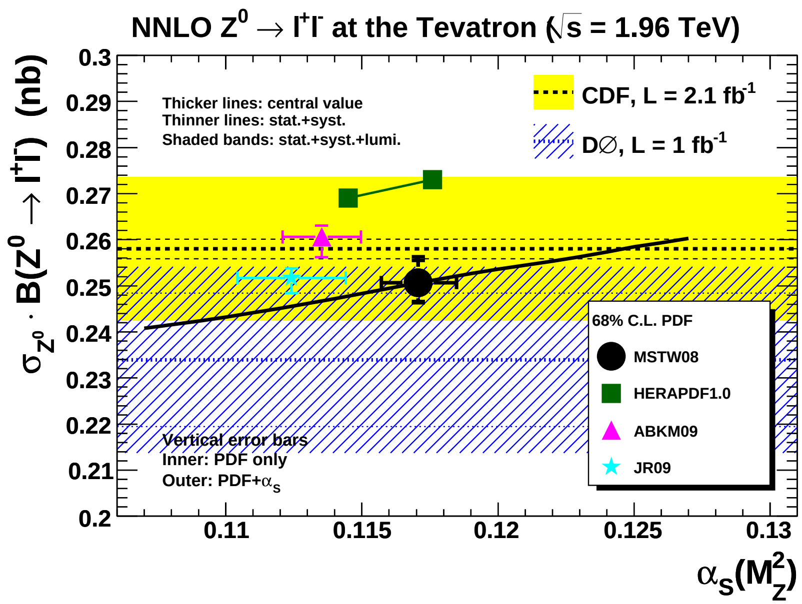
High-x gluon, at least to some extent, constrained by comparison to Tevatron jet data.

However, important point, CDF Z-rapidity data, or cross sections, sets Tevatron normalisation in a fit.

Only allows a few percent variation in normalisation.

Different PDF predictions for W and Z cross sections at the Tevatron compared to data.



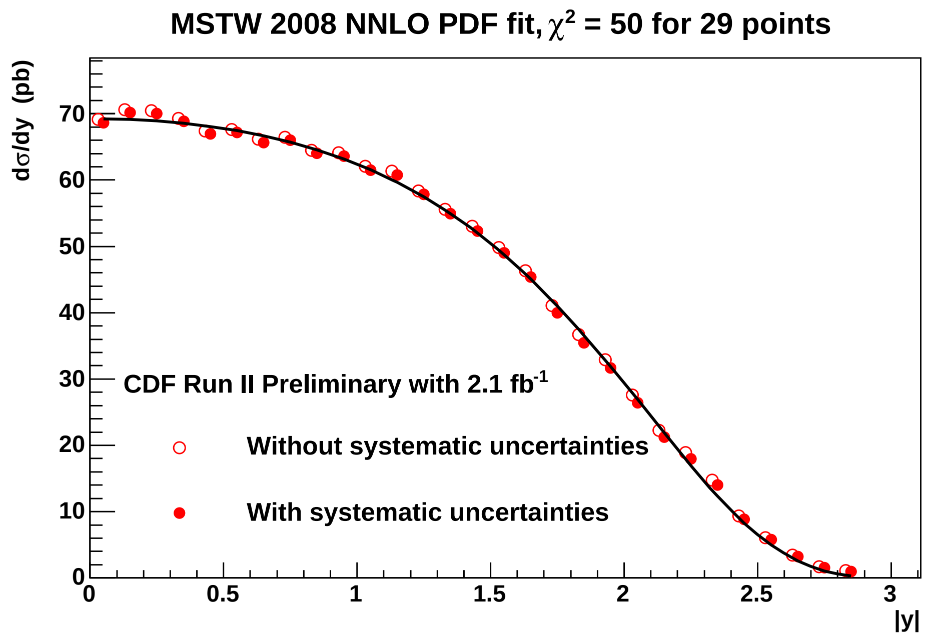


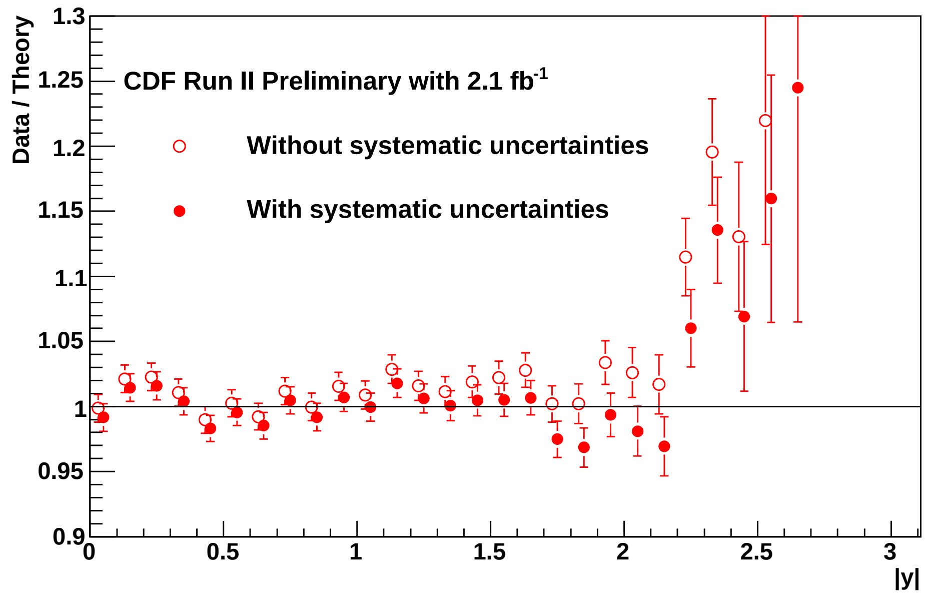
Everyone ok or a bit high. Normalisation no room to move down.

In practice use CDF Z-rapidity data sets Tevatron which determines normalisation in a fit.

Only allows a few percent variation in normalisation.

Z/γ^* rapidity distribution from CDF





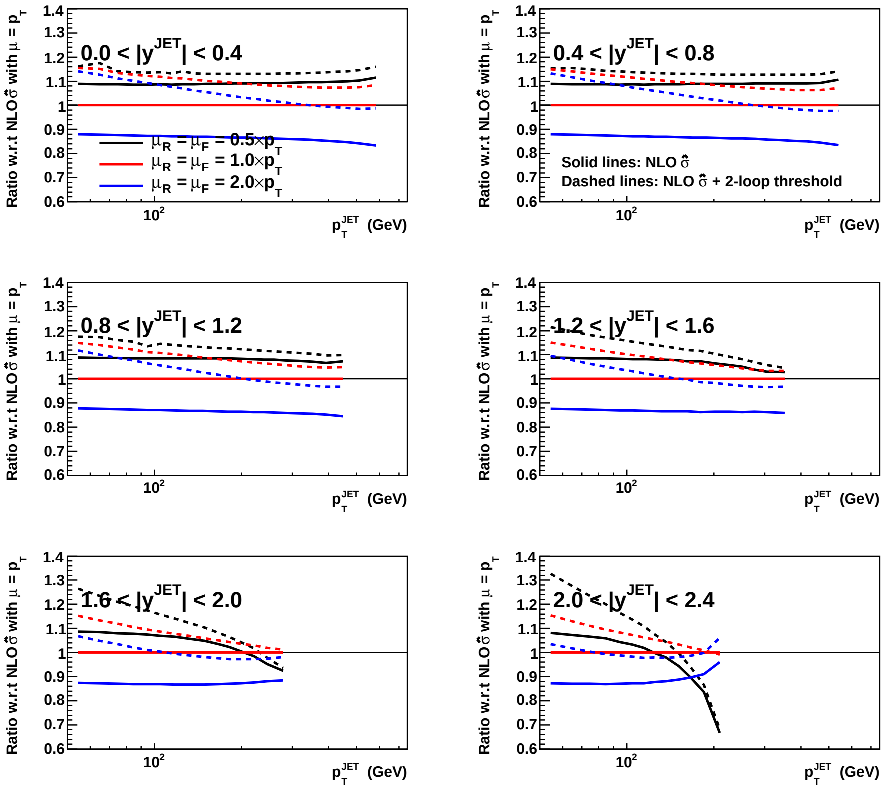
NNLO jet cross sections only approximate.

NNLO uses threshold (Kidonakis and Owens) approx. for Tevatron jets, as in FastNLO. (see also de Florian and Vogelsang).

NNLO approximation aids stability – always worst at high-p_T i.e. high-x. Includes large $\ln(p_T/\mu)$ terms predicted by renormalisation group.

Variation with scales a bit more extreme for dijets than for inclusive jets.

DØ Run II inclusive jet data (cone, R = 0.7)
(Ratio w.r.t. NLO $\hat{\sigma}$ with $\mu = p_T$ using MSTW08 NNLO PDFs)



DØ Run II dijet data (cone, R = 0.7)
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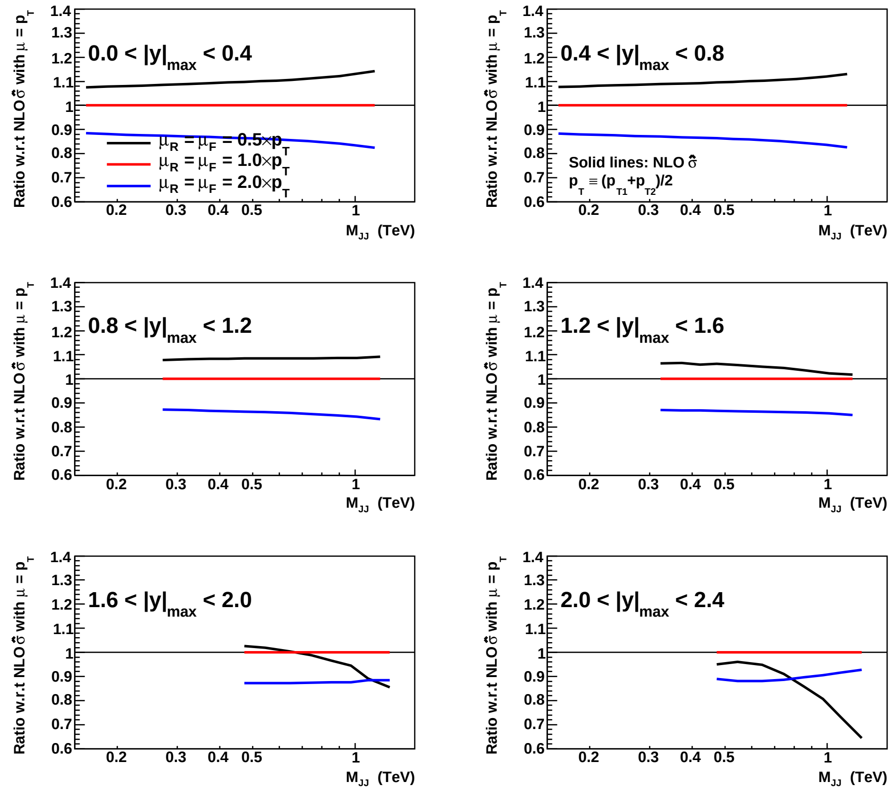


Shape of corrections as function of p_T at NLO and also at approx. NNLO in inclusive case. Problem at highest p_T and rapidity even for inclusive jets.

NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	**0.75** (0.30)	**0.68** (0.28)	0.91 (0.84)
CTEQ6.6	1.25 (0.14)	1.66 (0.20)	2.38 (0.84)
CT10	1.03 (0.13)	1.20 (0.19)	1.81 (0.84)
NNPDF2.1	**0.74** (0.29)	**0.82** (0.25)	1.23 (0.69)
HERAPDF1.0	2.43 (0.39)	3.26 (0.66)	4.03 (1.67)
HERAPDF1.5	2.26 (0.40)	3.05 (0.66)	3.80 (1.66)
ABKM09	1.62 (0.52)	2.21 (0.85)	3.26 (2.10)
GJR08	1.36 (0.23)	0.94 (0.13)	**0.79** (0.36)

NNLO PDF (with NLO+2-loop $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.39 (0.42)	**0.69** (0.44)	0.97 (0.48)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.64 (0.36)	2.15 (0.36)	2.20 (0.46)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.24 (0.35)	1.17 (0.32)	1.23 (0.31)
ABKM09	2.55 (0.82)	2.76 (0.89)	3.41 (1.17)
JR09	**0.75** (0.37)	1.26 (0.41)	2.21 (0.49)

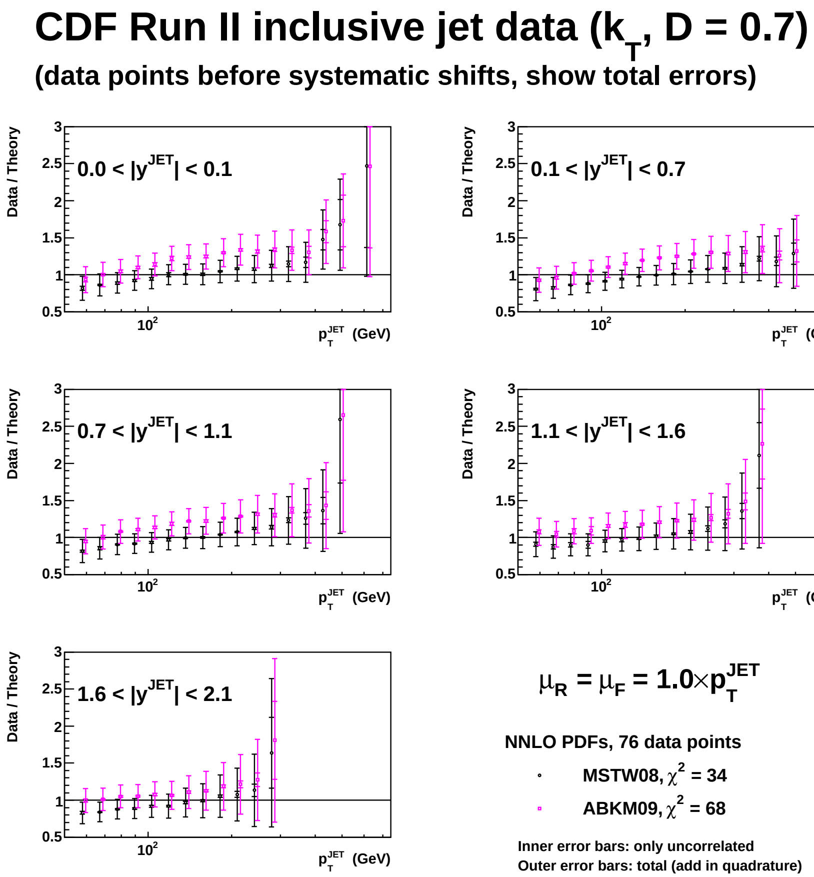
Table 1: Values of $\chi^2/N_{\rm pts.}$ for the CDF Run II inclusive jet data using the k_T jet algorithm with $N_{\rm pts.} = 76$ and $N_{\rm corr.} = 17$, for different PDF sets and different scale choices At most a 1-σ shift in normalisation is allowed.

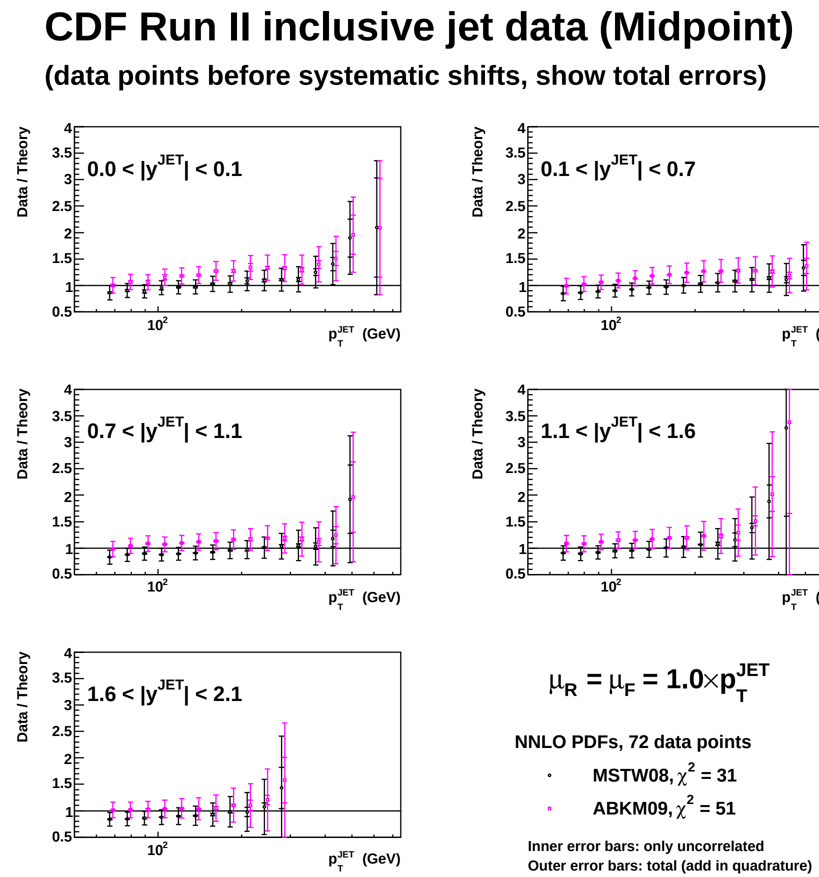
NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	0.75 (+0.32)	0.68 (−0.88)	0.63 (−*2.69*)
CTEQ6.6	1.03 (−*2.47*)	1.04 (−**3.49**)	0.99 (−**4.75**)
CT10	0.99 (−*1.64*)	0.92 (−*2.69*)	0.86 (−**4.10**)
NNPDF2.1	0.74 (−0.33)	0.79 (−*1.60*)	0.80 (−**3.12**)
HERAPDF1.0	1.52 (−**4.07**)	1.57 (−**5.21**)	1.43 (−**6.22**)
HERAPDF1.5	1.48 (−**3.85**)	1.52 (−**5.00**)	1.39 (−**6.03**)
ABKM09	1.03 (−**3.49**)	1.01 (−**4.53**)	1.05 (−**5.80**)
GJR08	1.14 (+*2.47*)	0.93 (+*1.25*)	0.79 (−0.50)

NNLO PDF (with NLO+2-loop $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.39 (+0.35)	0.69 (−0.45)	0.97 (−*1.30*)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.37 (−*2.65*)	1.48 (−**3.64**)	1.29 (−**4.12**)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.24 (−0.48)	1.13 (−*1.60*)	1.09 (−*2.23*)
ABKM09	1.53 (−**4.27**)	1.23 (−**5.05**)	1.44 (−**5.65**)
JR09	0.75 (+0.13)	1.26 (−0.61)	2.20 (−*1.22*)

Table 2: Values of $\chi^2/N_{\text{pts.}}$ for the CDF Run II inclusive jet data using the k_T jet algorithm No restriction is imposed on the shift in normalisation and the optimal value of "$-r_{\text{lumi.}}$" is shown in brackets.

Comparison of the raw comparison to CDF inclusive jet data using the k_T and cone algorithms.





Data/theory the same shape for both. Good compatibility. Verified by fits.

NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.45 (0.89)	**1.08** (0.20)	**1.05** (1.22)
CTEQ6.6	1.62 (1.15)	1.56 (0.59)	1.61 (1.35)
CT10	1.39 (0.88)	1.26 (0.37)	1.32 (1.29)
NNPDF2.1	1.41 (0.87)	1.29 (0.20)	1.22 (0.96)
HERAPDF1.0	1.73 (0.27)	1.84 (0.74)	1.83 (2.79)
HERAPDF1.5	1.78 (0.29)	1.87 (0.75)	1.84 (2.81)
ABKM09	1.39 (0.35)	1.43 (1.07)	1.63 (3.66)
GJR08	1.90 (1.46)	1.34 (0.45)	**1.03** (0.51)

NNLO PDF (with NLO+2-loop $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.95 (0.90)	1.23 (0.44)	**1.08** (0.35)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.11 (0.37)	1.68 (0.35)	1.41 (0.63)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.28 (0.95)	1.50 (0.40)	**1.17** (0.21)
ABKM09	1.68 (0.79)	1.55 (1.21)	1.63 (2.04)
JR09	1.84 (0.47)	1.61 (0.36)	1.58 (0.50)

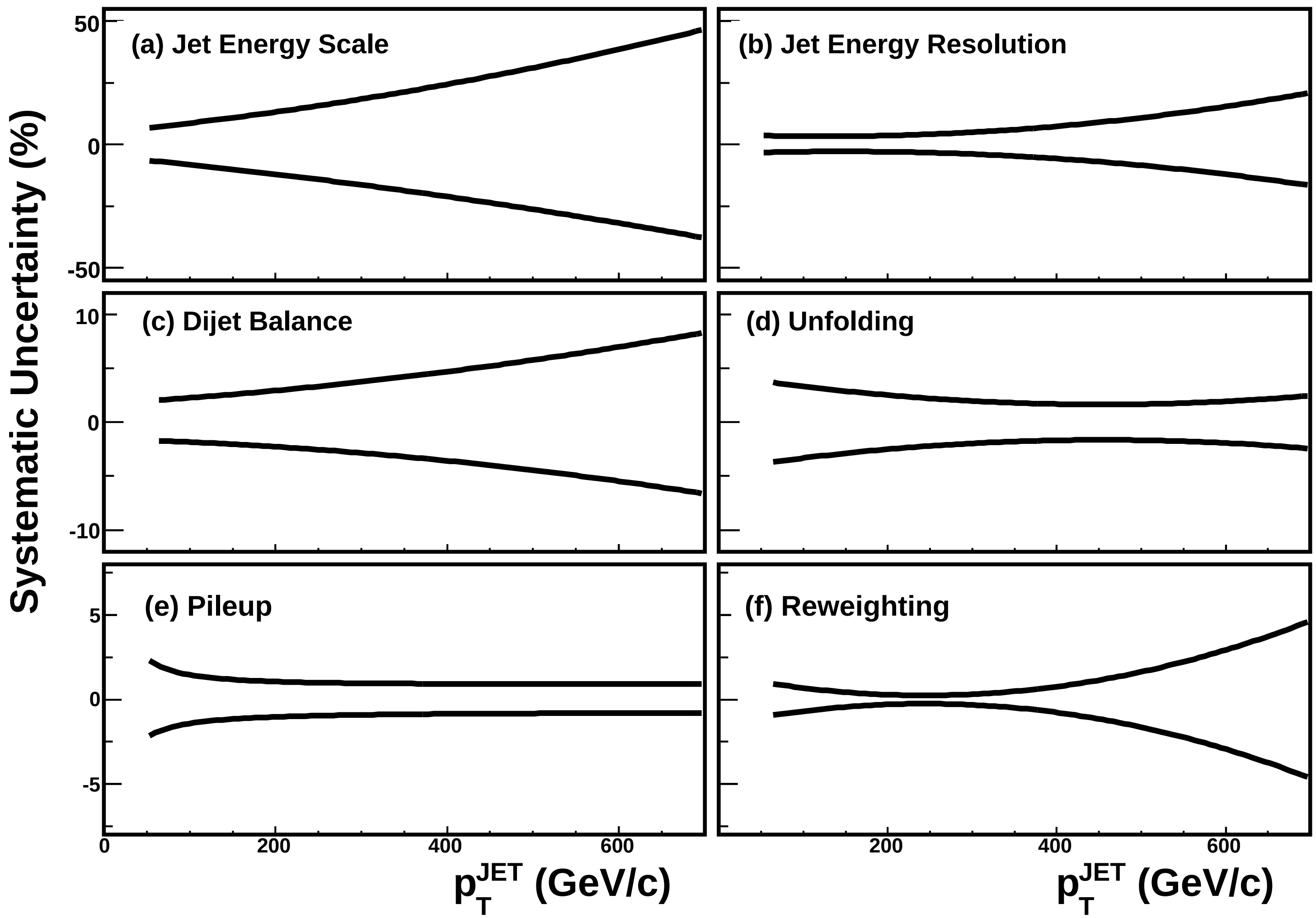
Table 3: Values of $\chi^2/N_{\rm pts.}$ for the DØ Run II inclusive jet data using a cone jet algorithm with $N_{\rm pts.} = 110$ and $N_{\rm corr.} = 23$, for different PDF sets and different scale choices. At most a 1-σ shift in normalisation is allowed.

NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.40 (+*1.05*)	1.08 (−0.55)	0.85 (−*2.25*)
CTEQ6.6	1.52 (−*1.61*)	1.25 (−*2.88*)	1.01 (−**4.02**)
CT10	1.39 (−0.66)	1.11 (−*2.02*)	0.90 (−**3.35**)
NNPDF2.1	1.41 (+0.37)	1.23 (−*1.22*)	0.95 (−*2.67*)
HERAPDF1.0	1.55 (−*2.16*)	1.38 (−**3.51**)	1.07 (−**4.52**)
HERAPDF1.5	1.63 (−*1.98*)	1.45 (−**3.35**)	1.12 (−**4.40**)
ABKM09	1.25 (−*1.90*)	1.04 (−**3.20**)	0.89 (−**4.44**)
GJR08	1.72 (+*2.14*)	1.34 (+0.53)	0.98 (−*1.05*)

NNLO PDF (with NLO+2+loop $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.87 (+*1.34*)	1.23 (+0.09)	1.08 (−0.87)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.11 (−0.82)	1.52 (−*2.03*)	1.14 (−*2.61*)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.28 (+0.94)	1.50 (−0.49)	1.11 (−*1.23*)
ABKM09	1.48 (−*2.33*)	1.13 (−**3.35**)	1.02 (−**4.03**)
JR09	1.84 (+0.63)	1.61 (−0.60)	1.50 (−*1.35*)

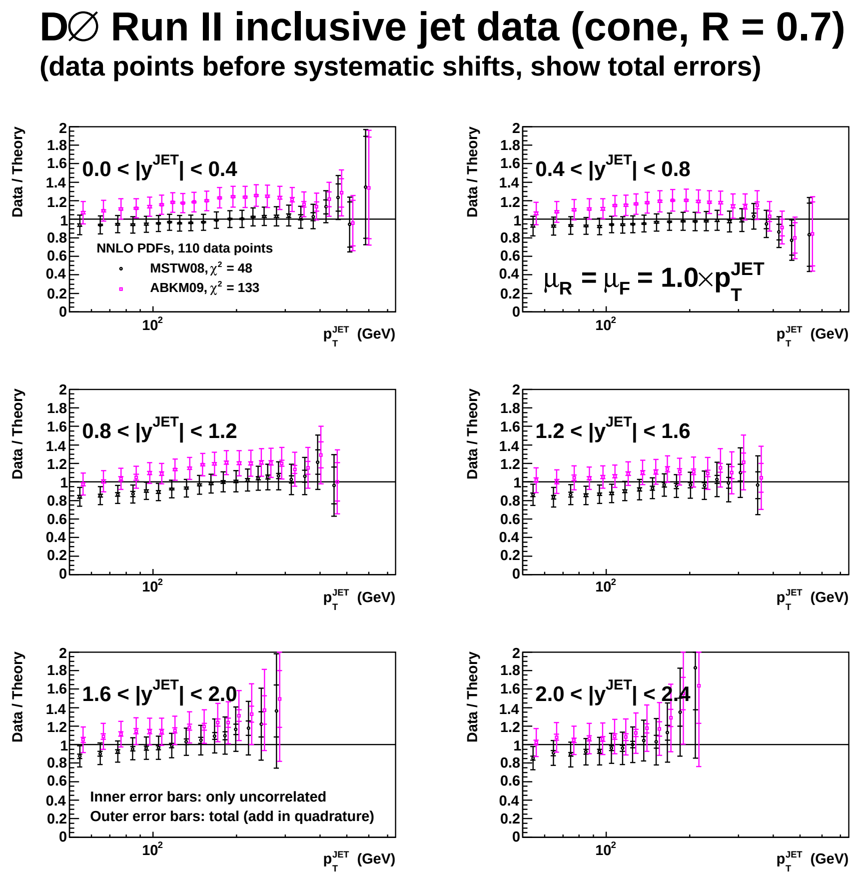
Table 4: Values of $\chi^2/N_{\rm pts.}$ for the DØ Run II inclusive jet data using a cone jet algorithm with $N_{\rm pts.} = 110$ and $N_{\rm corr.} = 23$, for different PDF sets and different scale choices. No restriction is imposed on the shift in normalisation and the optimal value of "$-r_{\rm lumi.}$" is shown in brackets.

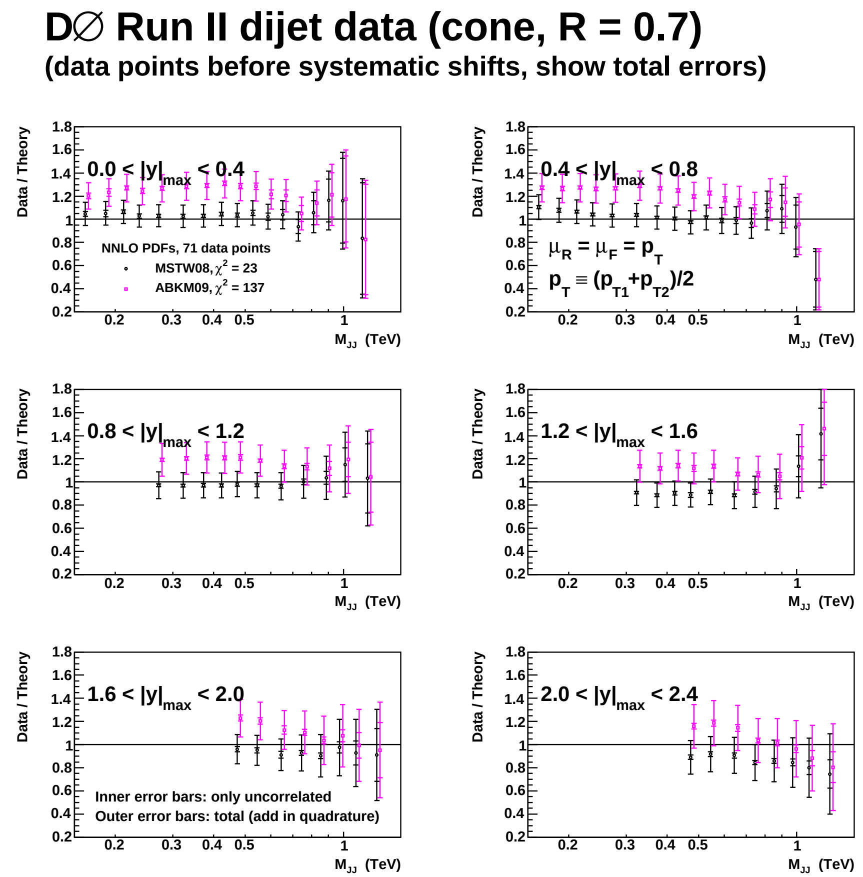
Systematic uncertainty plots for D0. Similar for CDF. Also vary with rapidity



No other systematic looks like normalisation, though some are bigger.

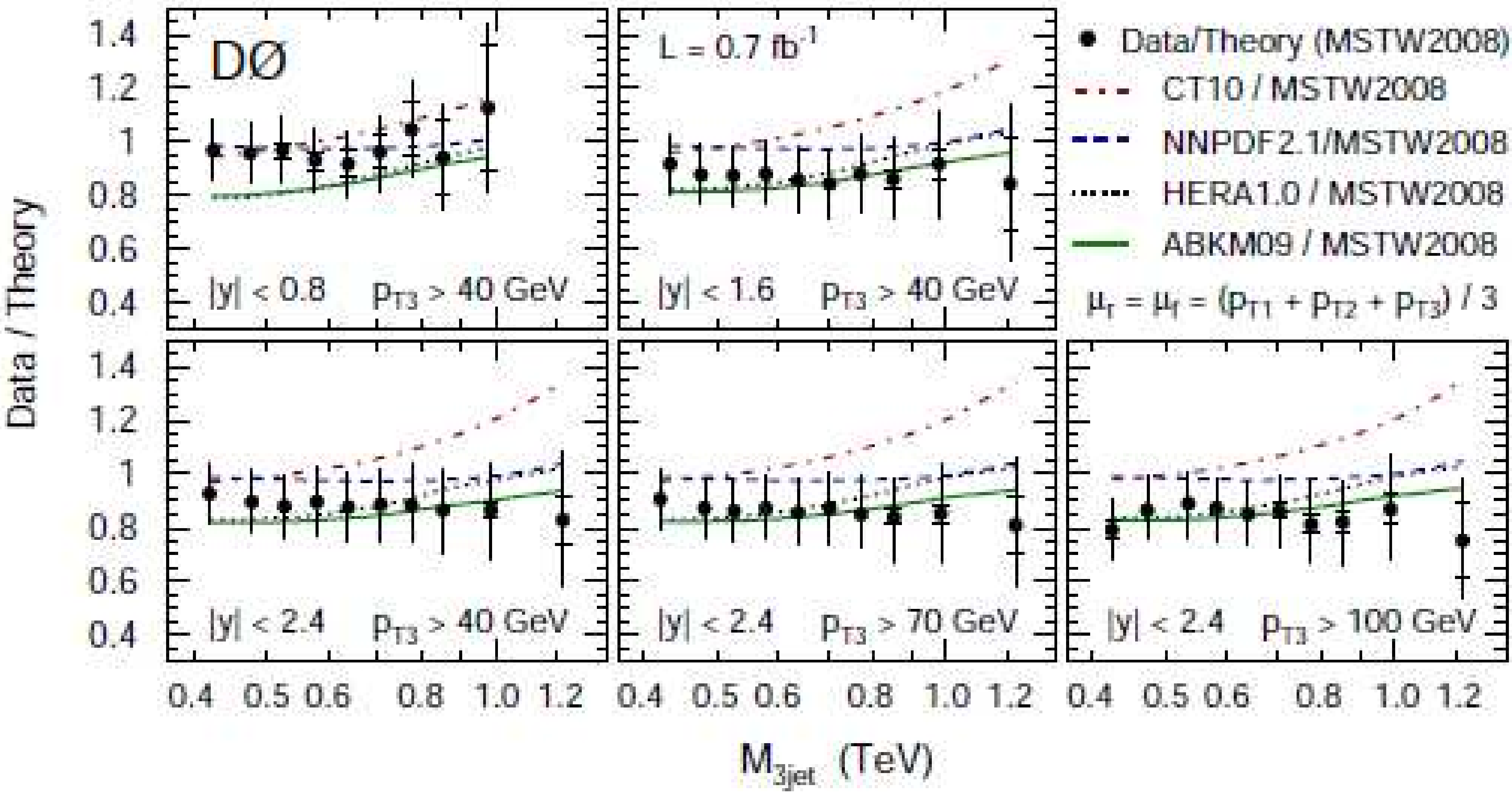
Comparison of the raw comparison to D0 inclusive jet data using the cone algorithms and D0 dijet data.





Not such good compatibility as for the two CDF sets.

Three-jet cross-sections



Recent results from D0 (`arXiv 1104.1986`) on three jets cross sections.

All the same work already done.

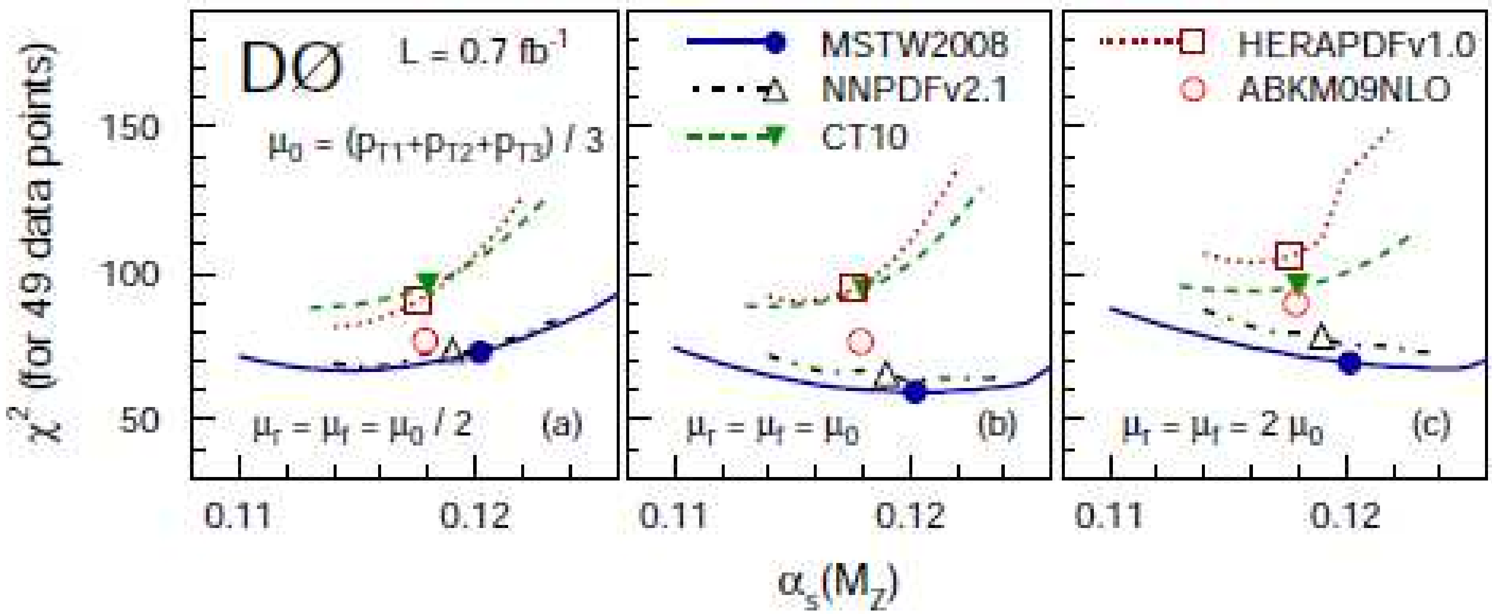


TABLE II: χ^2 values between data and theory for different PDF parametrizations in the order of decreasing χ^2, for all 49 data points.

PDF set	Default $\alpha_s(M_Z)$	χ^2 at $\mu_r = \mu_f = \mu_0$ for default $\alpha_s(M_Z)$	$\chi^2_{\rm minimum}$
HERAPDFv1.0	0.1176	95.1	81.7
CT10	0.1180	94.5	88.2
ABKM09NLO	0.1179	76.5	76.5
NNPDFv2.1	0.1190	65.9	63.3
MSTW2008NLO	0.1202	59.5	59.5

Broadly similar results.

Conclusions

Higgs production at the Tevatron (and to a slightly lesser extent at the LHC) is sensitive to gluons in principle constrained by Tevatron jet data.

Differences between PDFs much greater than uncertainties.

Full constraint from jet data achieved by simultaneously constraining normalisation from comparison to W and Z cross sections.

Doesn't allow drift to low normalisations which can be preferred by some PDF comparisons – fairly good fit can have very high normalisation penalty, always from downwards movement.

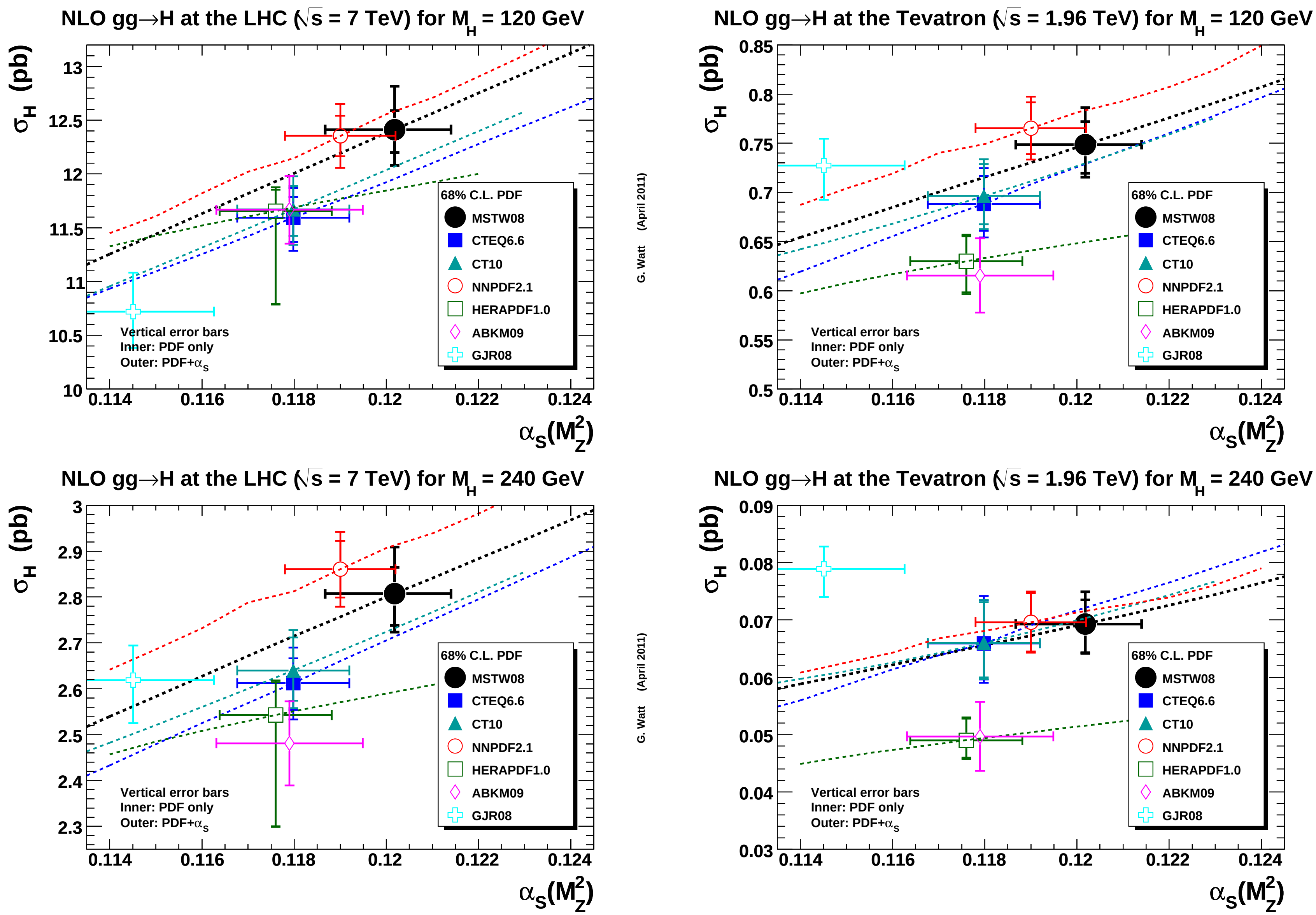
Considerations at NNLO require approx. cross section.However

– except at highest p_T and rapidity perturbative series appears quite convergent, corrections no large.

– patterns at NNLO extremely similar to NLO where no approximations made.

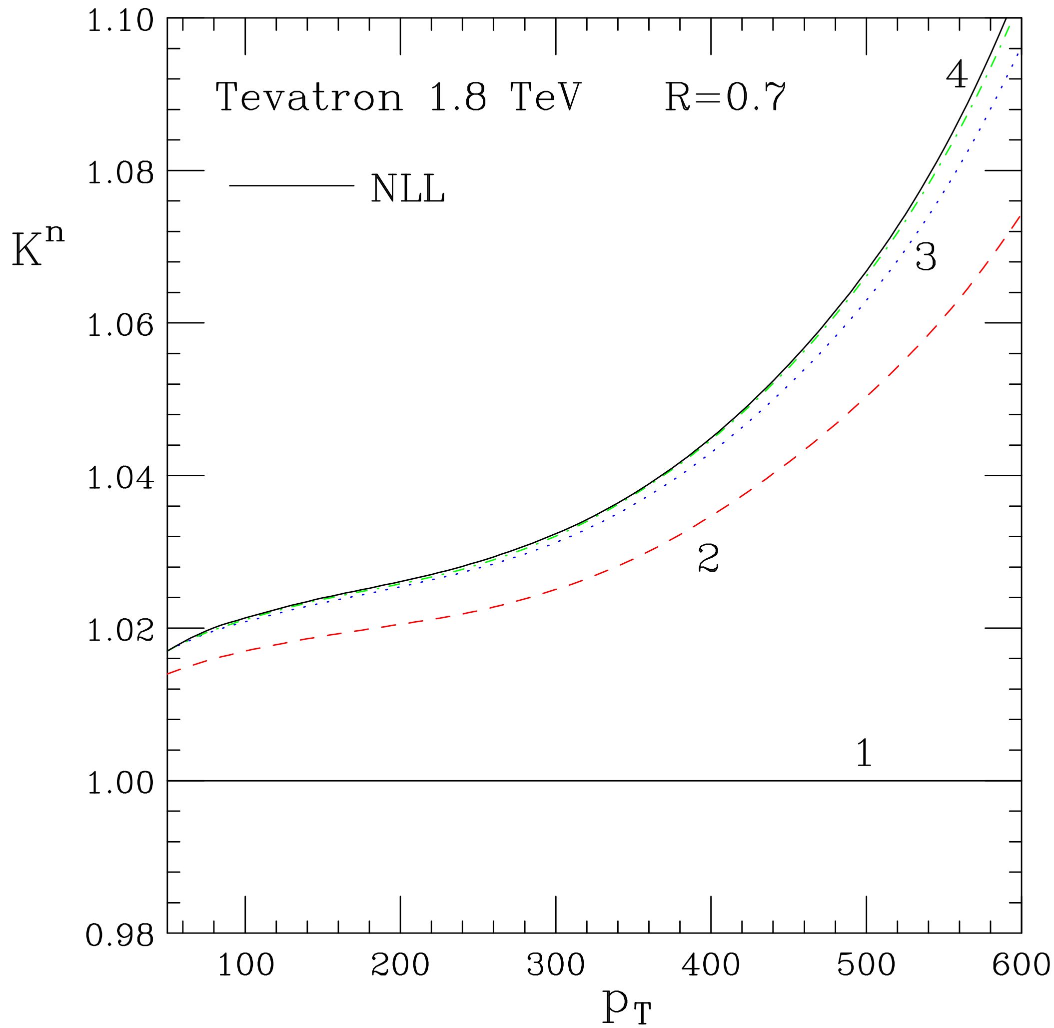
Personal opinion – smallest high-x gluons disfavoured (though not too large either).

Higgs production via gluon fusion at the Tevatron and LHC at NLO.



Larger deviation at the Tevatron.

de Florian and Vogelsang result for inclusive jet K-factor for $d\sigma/dp_T$ at order α_S^{2+n} compared to NLO.



NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.52 (0.61)	**1.40** (0.27)	**1.16** (0.73)
CTEQ6.6	1.93 (0.41)	1.98 (0.21)	1.78 (0.78)
CT10	1.75 (0.38)	1.69 (0.19)	1.50 (0.76)
NNPDF2.1	1.69 (0.60)	1.56 (0.25)	1.44 (0.60)
HERAPDF1.0	2.61 (0.23)	2.73 (0.49)	2.53 (1.58)
HERAPDF1.5	2.48 (0.24)	2.60 (0.49)	2.44 (1.57)
ABKM09	1.56 (0.26)	1.68 (0.65)	1.69 (2.01)
GJR08	2.11 (0.71)	1.75 (0.24)	1.52 (0.31)

NNLO PDF (with NLO+2-loop $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.67 (0.62)	**1.39** (0.43)	1.62 (0.37)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.20 (0.25)	2.06 (0.27)	2.19 (0.40)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.08 (0.55)	1.76 (0.33)	1.99 (0.23)
ABKM09	1.70 (0.50)	1.94 (0.71)	2.26 (1.12)
JR09	1.57 (0.41)	2.05 (0.36)	2.82 (0.39)

Table 5: Values of $\chi^2/N_{\rm pts.}$ for the CDF Run II inclusive jet data using the cone-based Midpoint jet algorithm with $N_{\rm pts.} = 72$ and $N_{\rm corr.} = 25$, for different PDF sets and different scale choices. At most a 1-σ shift in normalisation is allowed.

NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.52 (+*1.05*)	1.40 (−0.31)	1.15 (−*1.74*)
CTEQ6.6	1.93 (−*1.46*)	1.90 (−*2.50*)	1.58 (−**3.41**)
CT10	1.75 (−0.63)	1.67 (−*1.76*)	1.39 (−*2.82*)
NNPDF2.1	1.69 (+0.30)	1.56 (−*1.01*)	1.40 (−*2.20*)
HERAPDF1.0	2.49 (−*2.84*)	2.45 (−**3.86**)	2.11 (−**4.54**)
HERAPDF1.5	2.39 (−*2.68*)	2.36 (−**3.72**)	2.05 (−**4.42**)
ABKM09	1.52 (−*2.05*)	1.53 (−**3.10**)	1.38 (−**4.04**)
GJR08	2.02 (+*2.60*)	1.75 (+*1.18*)	1.52 (−0.26)

NNLO PDF (with NLO+2-loop $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.66 (+*1.54*)	1.39 (+0.06)	1.62 (−1.00)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.20 (−*1.15*)	1.99 (−*2.45*)	2.04 (−**3.06**)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.08 (+0.63)	1.76 (−0.97)	1.96 (−*1.78*)
ABKM09	1.63 (−*2.42*)	1.73 (−**3.50**)	1.93 (−**4.15**)
JR09	1.57 (+0.87)	2.05 (−0.55)	2.81 (−*1.44*)

Table 6: Values of $\chi^2/N_{\mathrm{pts.}}$ for the CDF Run II inclusive jet data using the cone-based Midpoint jet algorithm with $N_{\mathrm{pts.}} = 72$ and $N_{\mathrm{corr.}} = 25$, for different PDF sets and different scale choices. No restriction is imposed on the shift in normalisation and the optimal value of "$-r_{\mathrm{lumi.}}$" is shown in brackets.

NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	3.15 (1.63)	2.25 (0.70)	1.56 (0.70)
CTEQ6.6	5.41 (2.22)	4.85 (1.79)	3.36 (1.52)
CT10	4.74 (1.87)	4.06 (1.32)	2.70 (1.21)
NNPDF2.1	2.67 (1.56)	1.93 (0.66)	1.47 (0.55)
HERAPDF1.0	2.05 (0.38)	2.21 (0.77)	2.11 (2.28)
HERAPDF1.5	1.90 (0.34)	2.00 (0.67)	1.88 (2.16)
ABKM09	1.49 (0.33)	1.41 (0.80)	1.34 (2.78)
GJR08	10.7 (3.92)	7.91 (2.36)	5.30 (0.66)

NNLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	2.38 (0.63)	1.80 (0.33)	1.31 (1.24)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.61 (0.48)	2.55 (0.89)	2.40 (2.40)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.72 (0.83)	2.31 (0.50)	1.96 (1.08)
ABKM09	1.36 (0.98)	1.49 (1.93)	1.57 (4.53)
JR09	3.29 (0.42)	2.55 (0.24)	1.88 (1.26)

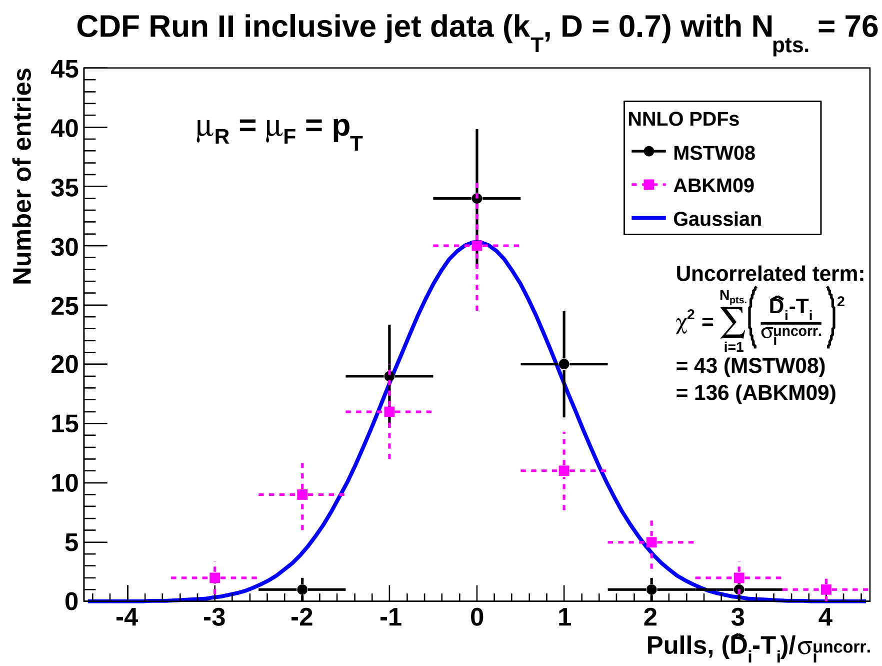
Table 7: Values of $\chi^2/N_{\rm pts.}$ for the DØ dijet data using a cone jet algorithm with $N_{\rm pts.} = 71$ and $N_{\rm corr.} = 70$, for different NLO PDF sets and different scale choices. Only NLO partonic cross sections are used with the NNLO PDFs, since the 2-loop threshold corrections a re only available for the inclusive jet cross section. At most a 1-σ shift in normalisation is allowed.

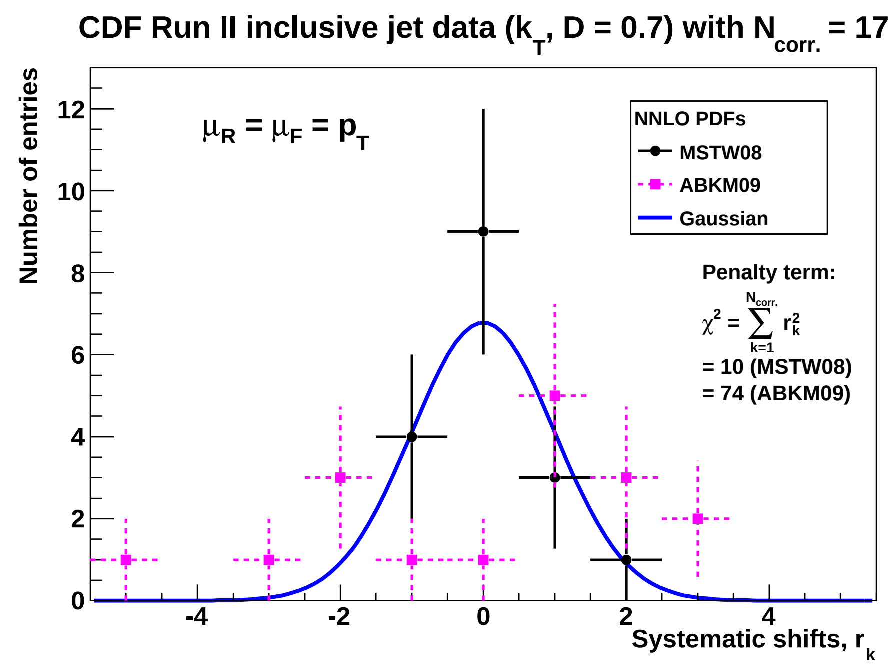
NLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	3.03 (+*2.82*)	2.25 (+*1.11*)	1.56 (−0.61)
CTEQ6.6	5.41 (+0.62)	4.85 (−0.92)	3.31 (−*2.14*)
CT10	4.74 (+*1.33*)	4.06 (−0.24)	2.68 (−*1.62*)
NNPDF2.1	2.59 (+*2.41*)	1.93 (+0.79)	1.47 (−0.75)
HERAPDF1.0	2.05 (−0.66)	2.17 (−*2.06*)	1.94 (−**3.11**)
HERAPDF1.5	1.90 (−0.46)	1.97 (−*1.85*)	1.73 (−*2.93*)
ABKM09	1.49 (−0.17)	1.39 (−*1.58*)	1.21 (−*2.83*)
GJR08	10.2 (+**4.48**)	7.79 (+*2.78*)	5.30 (+*1.07*)

NNLO PDF (with NLO $\hat{\sigma}$)	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	2.34 (+*1.96*)	1.80 (+0.42)	1.31 (−*1.12*)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1145$	2.61 (−0.09)	2.55 (−*1.44*)	2.31 (−*2.51*)
HERAPDF1.0, $\alpha_S(M_Z^2) = 0.1176$	2.71 (+*1.53*)	2.31 (−0.04)	1.95 (−*1.37*)
ABKM09	1.35 (−*1.36*)	1.40 (−*2.56*)	1.31 (−**3.60**)
JR09	3.27 (+*1.75*)	2.55 (+0.33)	1.88 (−*1.08*)

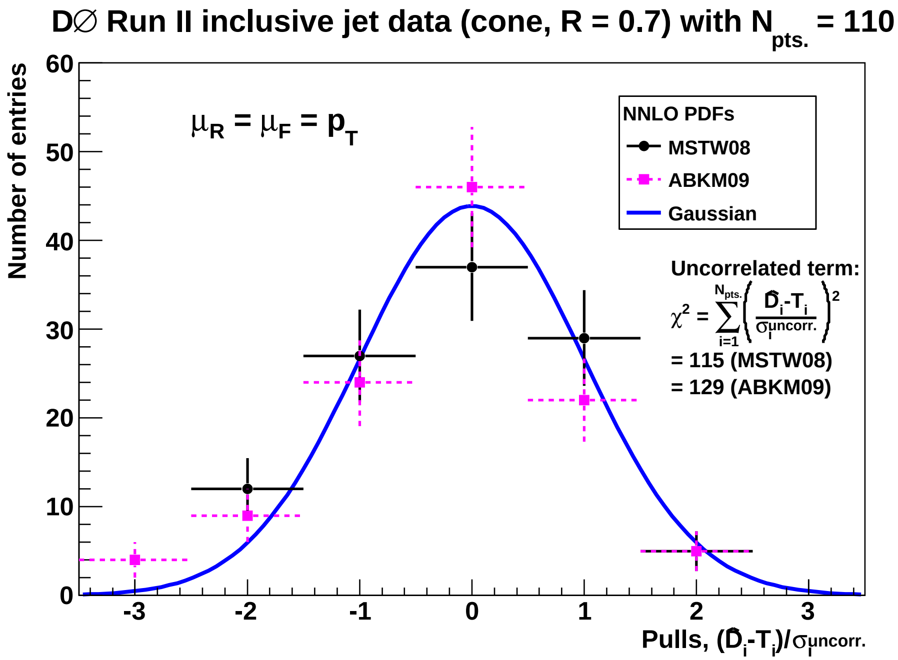
Table 8: Values of $\chi^2/N_{\mathrm{pts.}}$ for the DØ dijet data using a cone jet algorithm with $N_{\mathrm{pts.}} = 71$ and $N_{\mathrm{corr.}} = 70$, for different NLO PDF sets and different scale choices. Only NLO partonic cross sections are used with the NNLO PDFs, since the 2-loop threshold corrections are only available for the inclusive jet cross section. No restriction is imposed on the shift in normalisation and the optimal value of "$-r_{\mathrm{lumi.}}$" is shown in brackets.

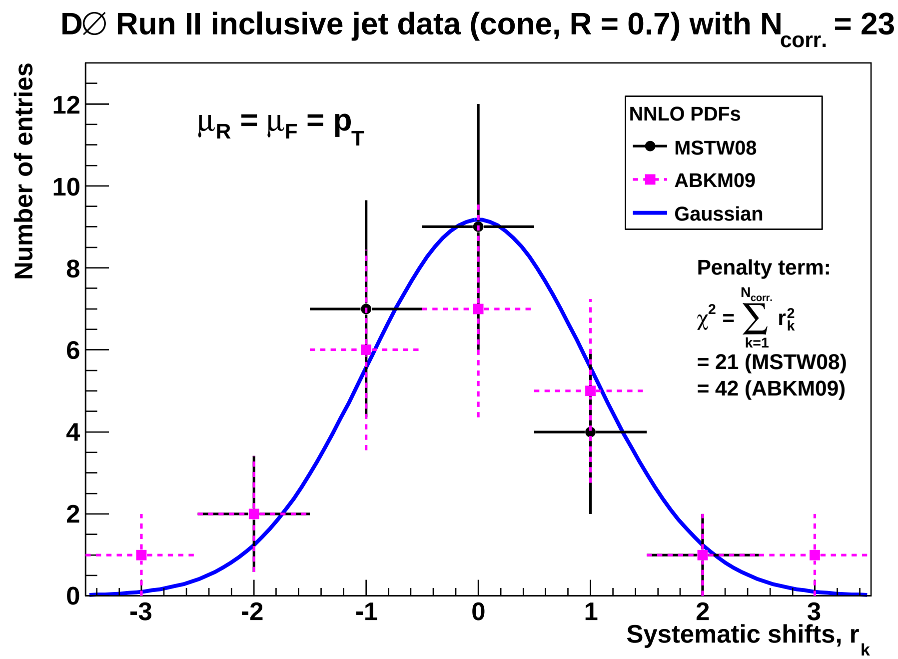
Pulls and systematic shifts in the fits to the CDF inclusive jet data using the k_T algorithm.





Pulls and systematic shifts in the fits to the D0 inclusive jet data using the cone algorithm.





ABKM below data, and to a lesser extent still generally low after fit.