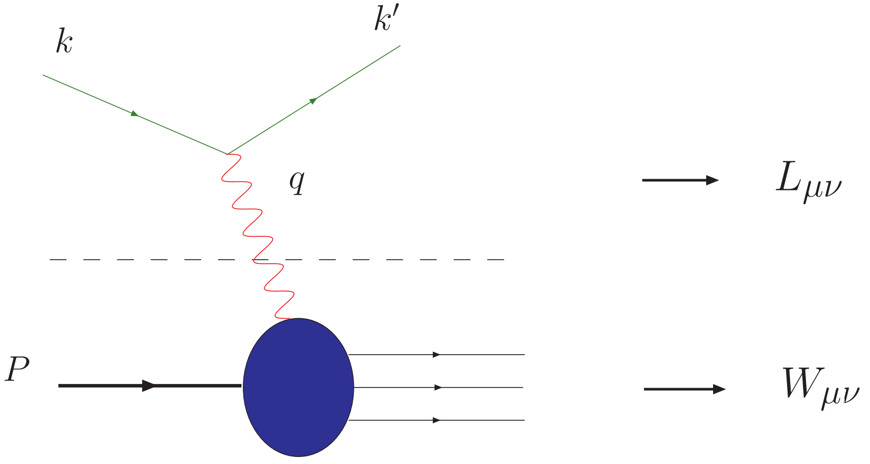
α_s from Deep-Inelastic Scattering: DESY Analysis

Johannes Blümlein
DESY

- NNLO Valence Analysis
- NNLO Valence + Singlet Analyses
- Λ_{QCD} and $\alpha_s(M_Z^2)$
- Consequences for Tevatron and LHC

In collaboration with:
J.B., H. Böttcher, A. Guffanti Nucl.Phys. B774 (2007) 182, hep-ph/0607200.
J.B., H. Böttcher Phys.Lett. B662 (2008) 336, arXiv:0802.0408; Nucl.Phys. B841 (2010) 205, arXiv:1005.3113.
S. Alekhin, J.B., S. Klein, S. Moch, Phys.Rev. D81 (2010) 014032 arXiv:0908.2766
S. Alekhin, J.B., S. Moch, PoS DIS2010 (2010) 021, arXiv:1007.3657; arXiv:1101.5261.
S. Alekhin, J.B., P. Jimenez-Delgado, S. Moch, E. Reya, Phys. Lett. B697 (2011) 127, arXiv:1011.6259.

Deep Inelatsic Scattering



$$Q^2 := -q^2, \quad x := \frac{Q^2}{2pq}$$ Bjorken–x

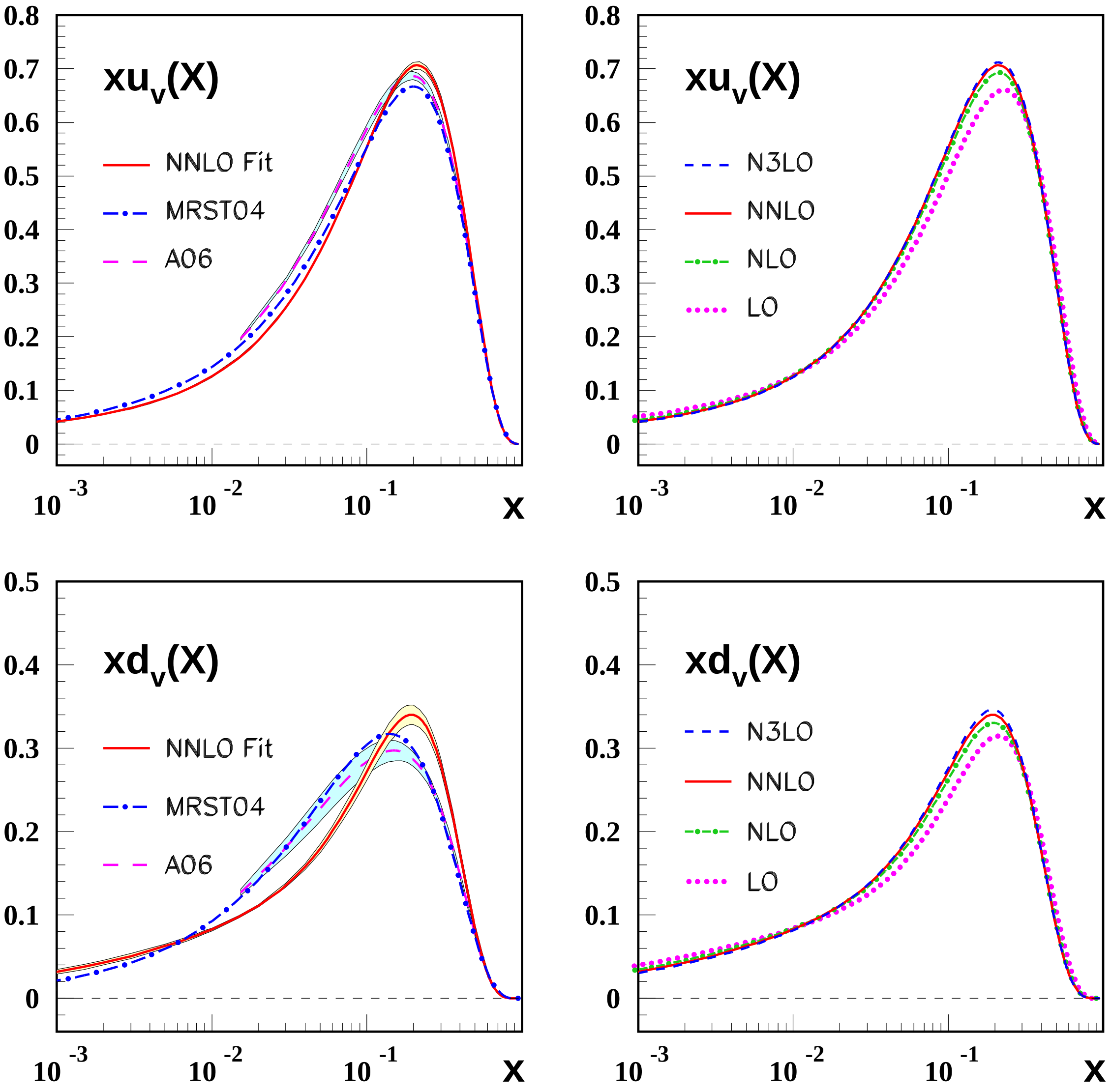
$$\nu := \frac{Pq}{M} ,$$

$$\frac{d\sigma}{dQ^2\ dx} \sim W_{\mu\nu} L^{\mu\nu}$$

$$\begin{aligned} W_{\mu\nu}(q,P,s) &= \frac{1}{4\pi}\int d^4\xi \exp(iq\xi)\langle P, s[J_\mu^{em}(\xi), J_\nu^{em}(0)]P, s\rangle \\ &= \frac{1}{2x}\left(g_{\mu\nu} - \frac{q_\mu q_\nu}{q^2}\right) F_L(x,Q^2) \\ &\quad + \frac{2x}{Q^2}\left(P_\mu P_\nu + \frac{q_\mu P_\nu + q_\nu P_\mu}{2x} - \frac{Q^2}{4x^2} g_{\mu\nu}\right) F_2(x,Q^2) \end{aligned}$$

Structure Functions: $F_{2,L}$ contain light and heavy quark contributions

1. World Data Analysis: Valence Distributions



World data:
NS-analysis

$W^2 > 12.5$ GeV^2, $Q^2 > 4$ GeV^2

N^{3}LO :

$$\alpha_s(M_Z^2) = 0.1141^{+0.0020}_{-0.0022}$$

J.B., H. Böttcher, A. Guffanti Nucl.Phys. B774 (2007) 182, hep-ph/0607200.

Why an $O(\alpha_s^4)$ analysis can be performed?

assume an $\pm 100\%$ error on the Pade approximant $\longrightarrow$ ± 2 MeV in Λ_{QCD}

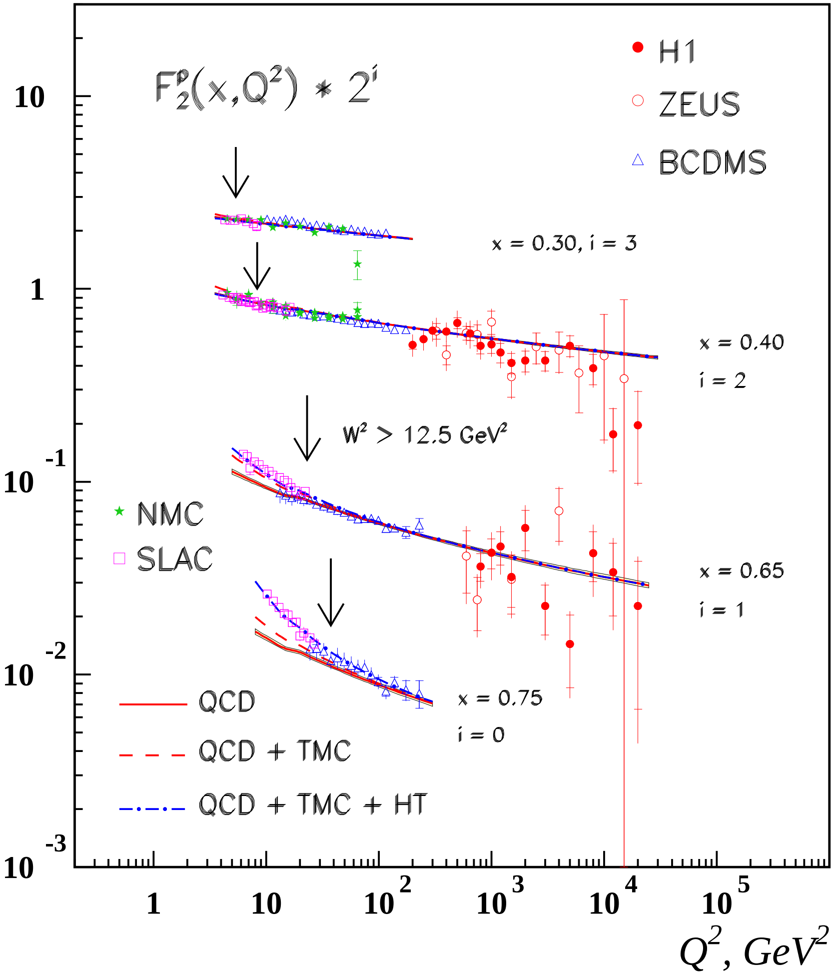
$$\gamma_n^{approx:3} = \frac{{\gamma_n^{(2)}}^2}{\gamma_n^{(1)}}$$

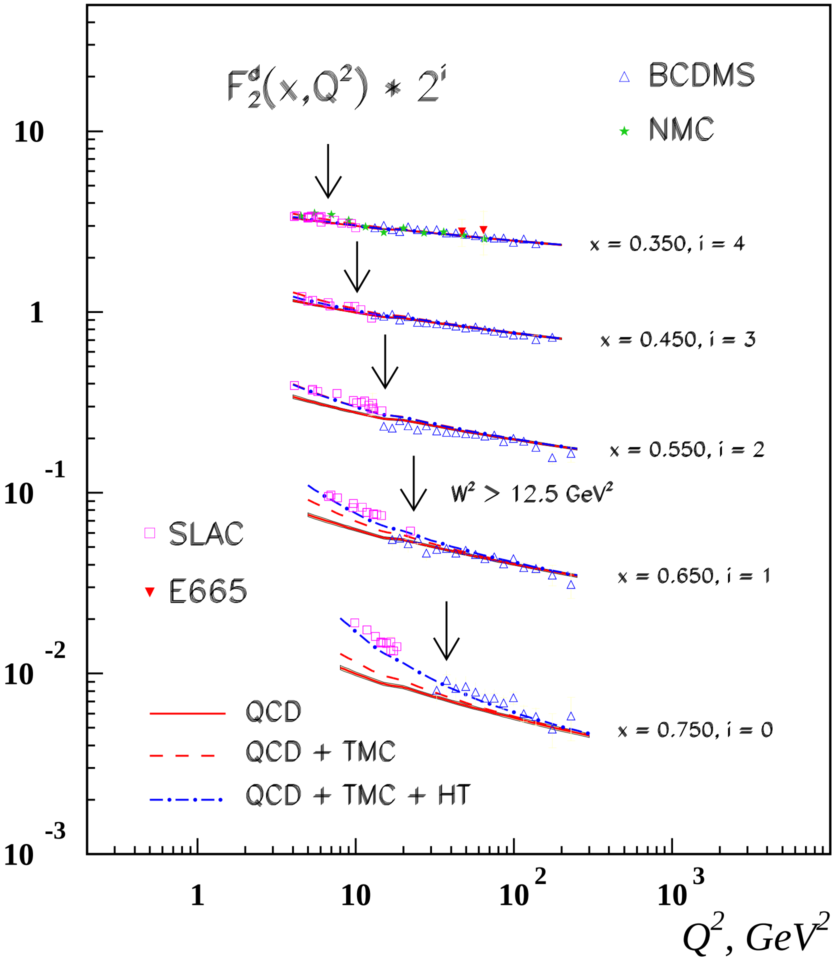
Baikov & Chetyrkin, April 2006:

$$\begin{aligned}\gamma_2^{3;NS} &= \frac{32}{9} a_s + \frac{9440}{243} a_s^2 + \left[\frac{3936832}{6561} - \frac{10240}{81}\zeta_3\right] a_s^3 \\ &+ \left[\frac{1680283336}{1777147} - \frac{24873952}{6561}\zeta_3 + \frac{5120}{3}\zeta_4 - \frac{56969}{243}\zeta_5\right] a_s^4\end{aligned}$$

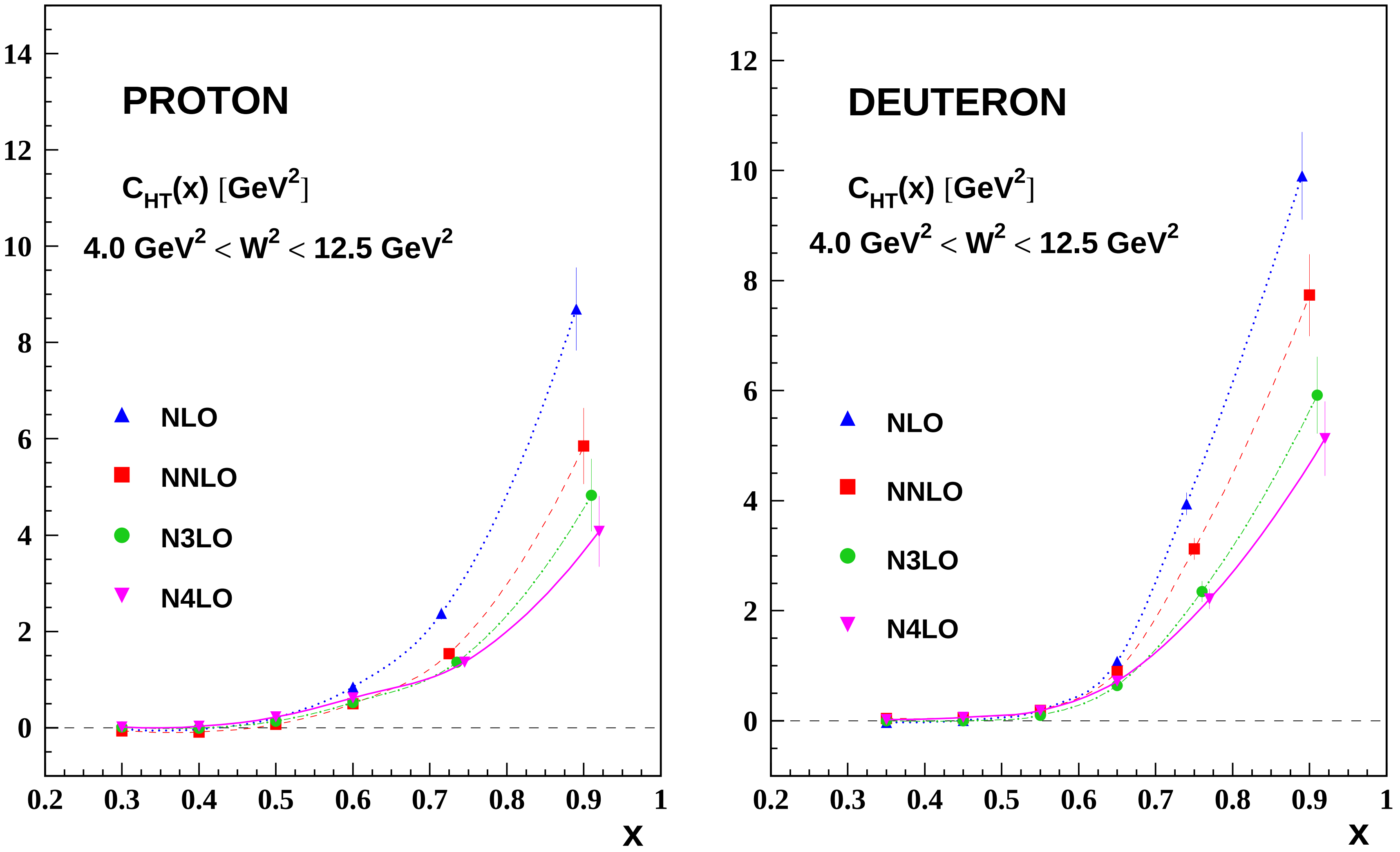
The results agree better than 20%.

Valence Distributions





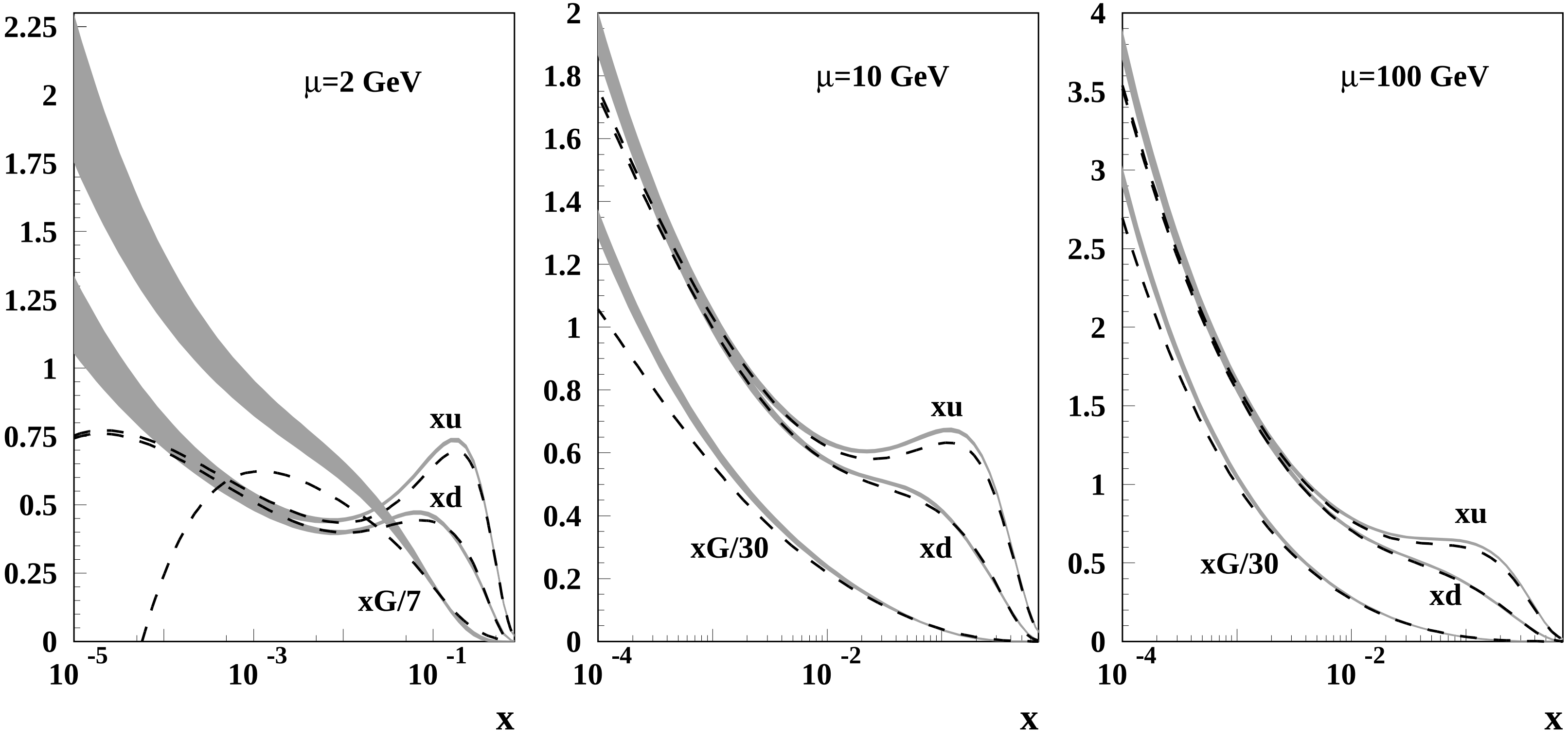
Valence Distributions: higher twist



- agreement between p and d analysis, J.B., H. Böttcher Phys.Lett. B662 (2008) 336
- LGT determination of interest

2. Flavor distributions: light quarks (NNLO)

Current Fitting Community (NNLO): 🇩🇪 🇩🇪 🇬🇧, H1 & ZEUS
+ Many NLO analyses worldwide: CTEQ, NNPDF, ...

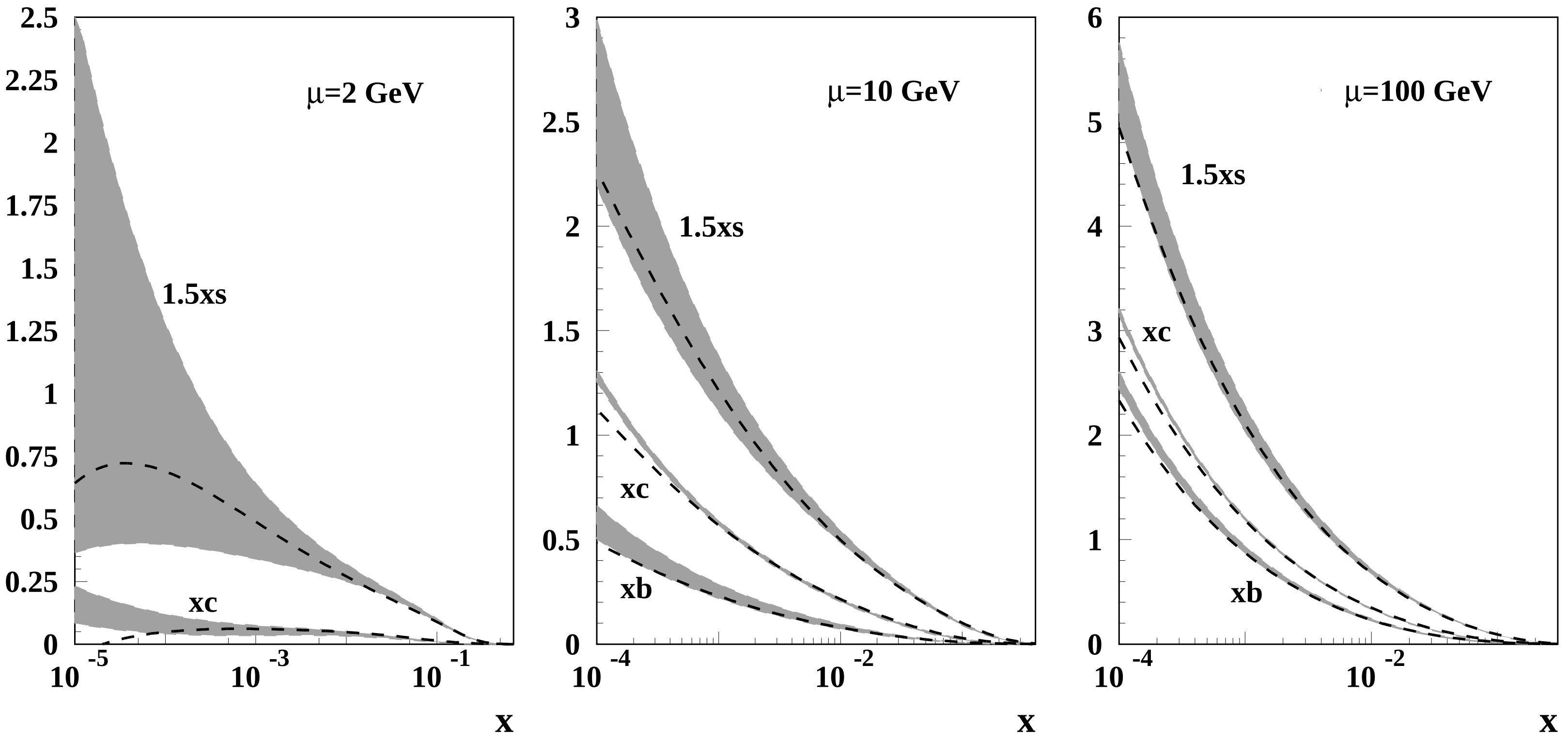


S. Alekhin, J.B., S. Klein, S. Moch, Phys.Rev. D81 (2010) 014032 arXiv:0908.2766

Correct treatment of HQ very essential: FFNS, BSMN-schemes.

full lines: ABKM error band; dashed lines: MSTW08

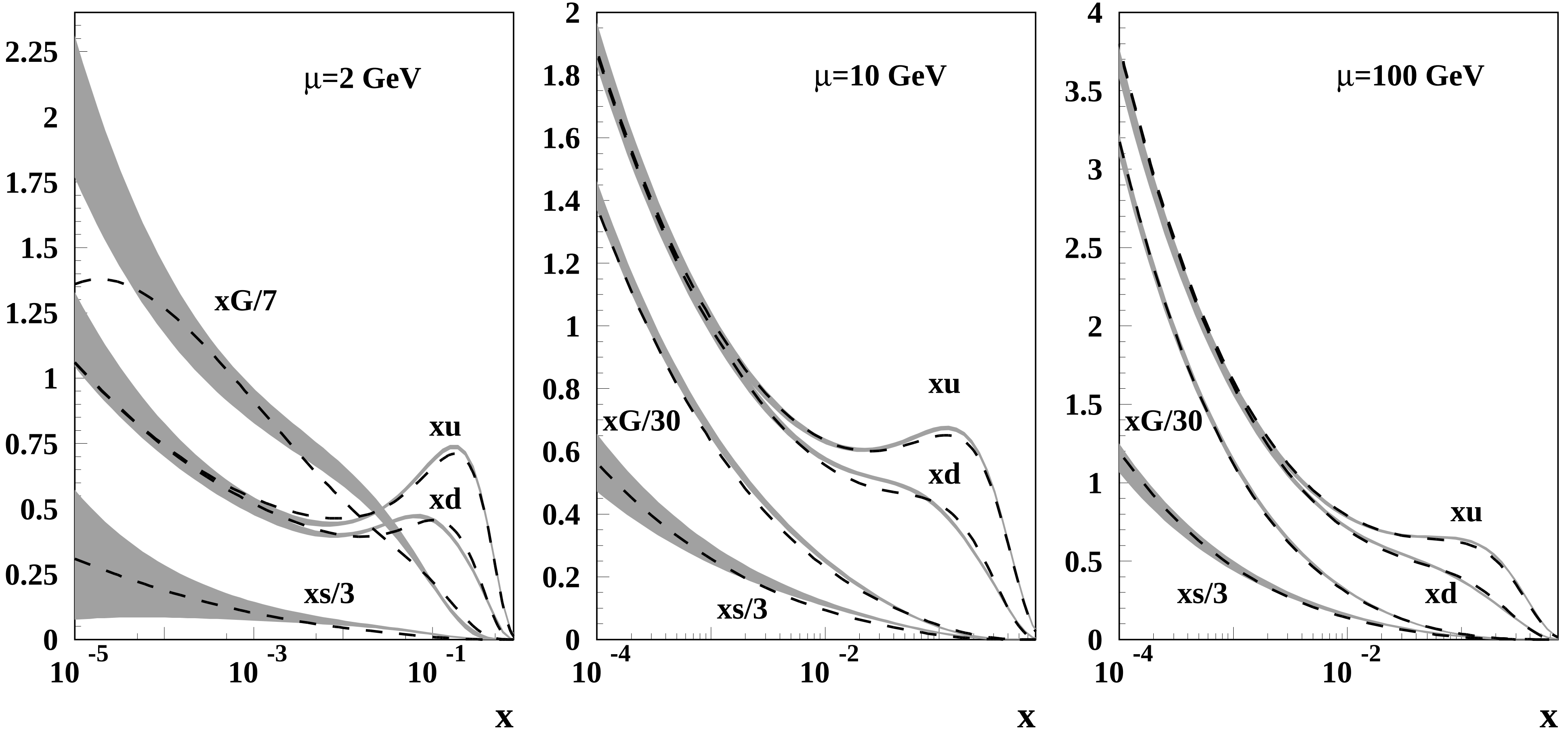
Heavy quarks and gluon (NNLO)



S. Alekhin, J.B., S. Klein, S. Moch, Phys.Rev. D81 (2010) 014032 arXiv:0908.2766

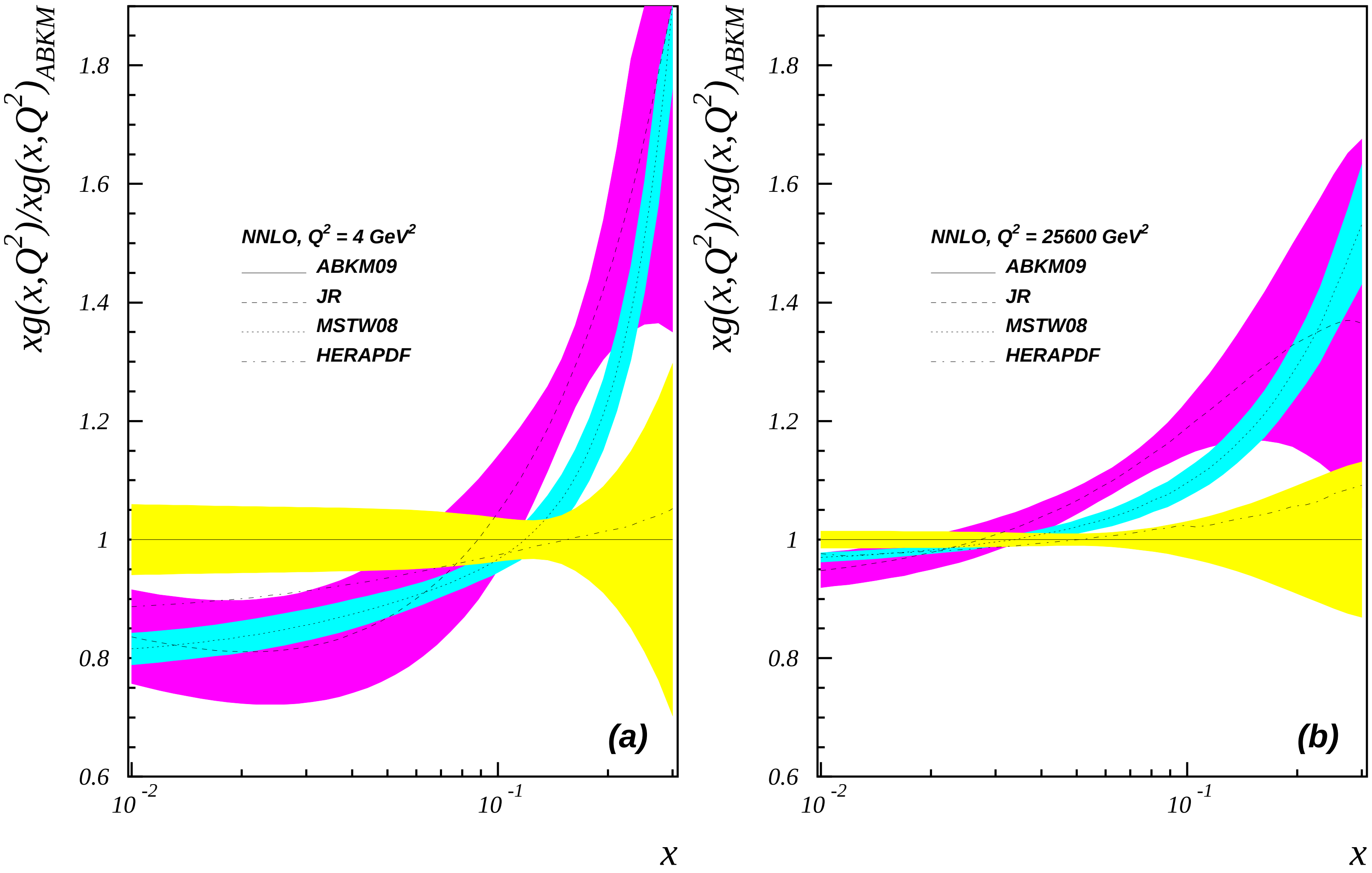
full lines: ABKM error band; dashed lines: MSTW08

FFNS, $N_f = 3$



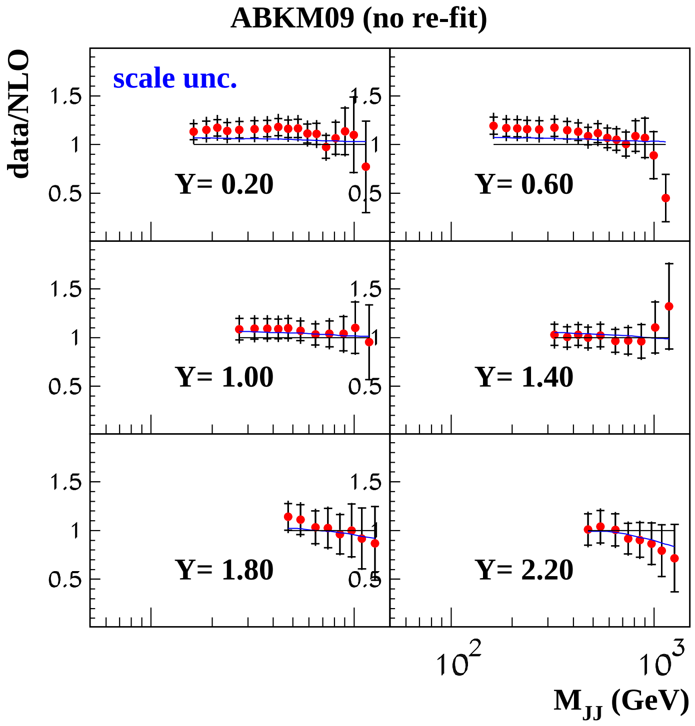
comparison: ABKM (2009) vs. Jimenez-Delgado/ Reya (2008)

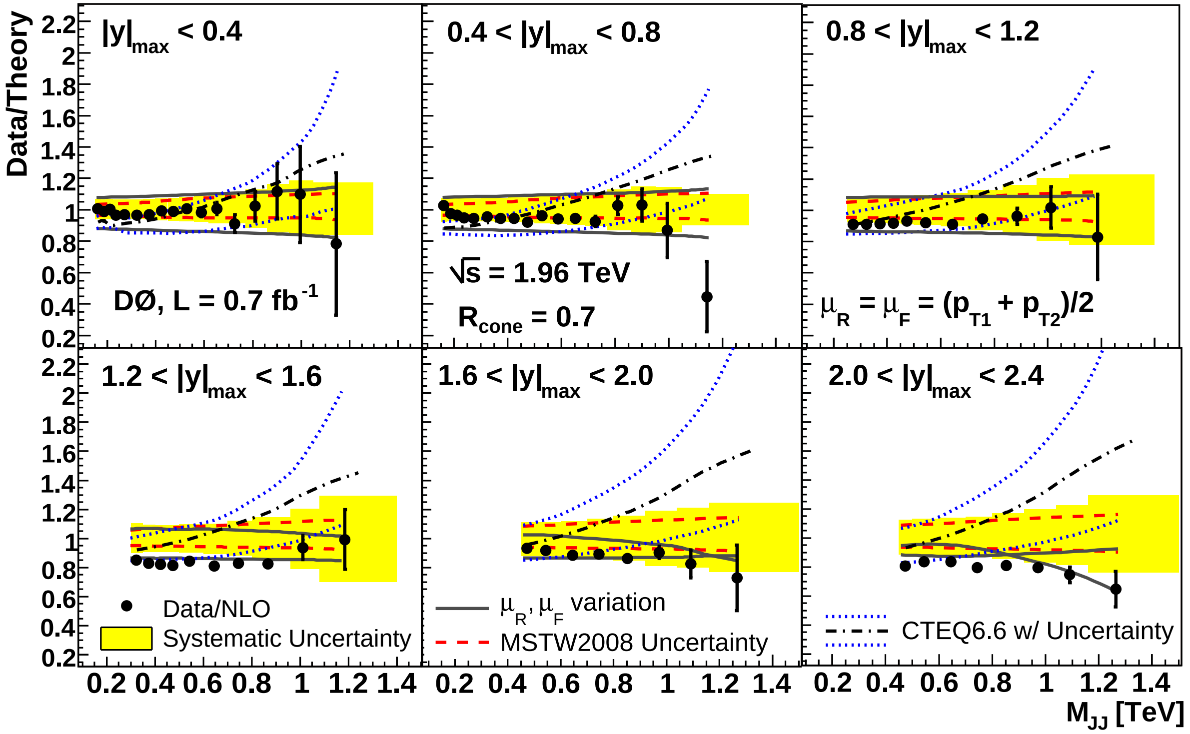
Gluon distribution in the Higgs region



S. Alekhin, J.B., P. Jimenez-Delgado, S. Moch, E. Reya, Phys. Lett. B697 (2011) 127

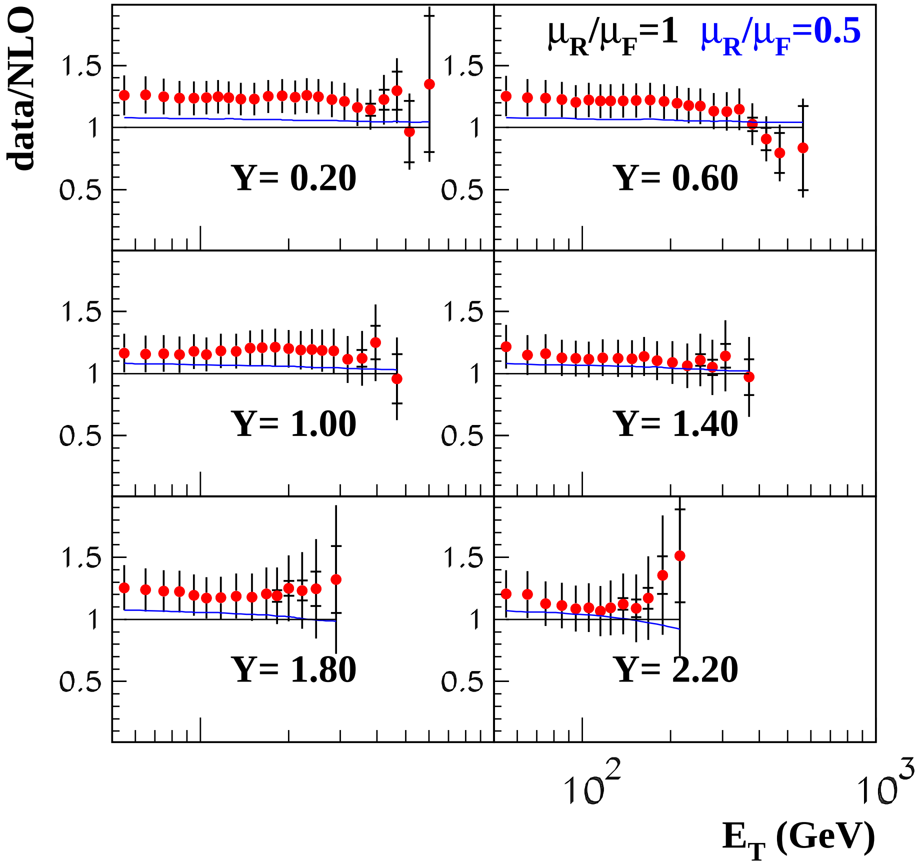
D0 run II dijet data



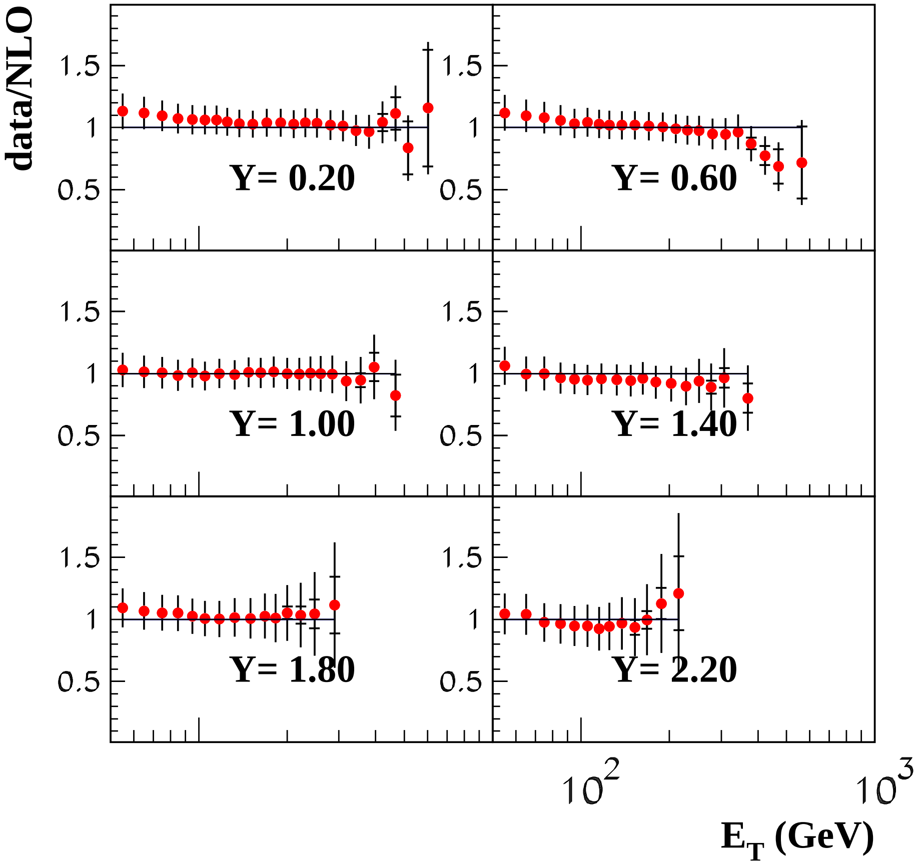


ABM (2011). Note that cross section is known to NLO only !

D0 run II djet data



before the fit



after the fit

ABM (2011) $\chi^2 = 104/110$

3. Λ_{QCD} and $\alpha_s(M_Z^2)$

older values: $\lesssim 2007$

NLO	$\alpha_s(M_Z^2)$	expt	theory	Ref.
CTEQ6	0.1165	±0.0065		[1]
MRST03	0.1165	±0.0020	±0.0030	[2]
A02	0.1171	±0.0015	±0.0033	[3]
ZEUS	0.1166	±0.0049		[4]
H1	0.1150	±0.0017	±0.0050	[5]
BCDMS	0.110	±0.006		[6]
GRS	0.112			[10]
BBG	0.1148	±0.0019		[9]
BB (pol)	0.113	±0.004	$^{+0.009}_{-0.006}$	[7]

NNLO	$\alpha_s(M_Z^2)$	expt	theory	Ref.
MRST03	0.1153	±0.0020	±0.0030	[2]
A02	0.1143	±0.0014	±0.0009	[3]
SY01(ep)	0.1166	±0.0013		[8]
SY01(νN)	0.1153	±0.0063		[8]
GRS	0.111			[10]
A06	0.1128	±0.0015		[11]
BBG	0.1134	$+0.0019/-0.0021$		[9]

N^{3}LO	$\alpha_s(M_Z^2)$	expt	theory	Ref.
BBG	0.1141	$+0.0020/-0.0022$		[9]

NLO at least: scale errors of ± 0.0050

NNLO systematic shifts down

N^{3}LO slight upward shift

- BBG: $N_f = 4$: non-singlet data-analysis at $O(\alpha_s^4)$: $\Lambda = 234 \pm 26$ MeV

Earlier lattice results :

- Alpha Collab: $N_f = 2$ Lattice; non-pert. renormalization $\Lambda = 245 \pm 16 \pm 16$ MeV
- QCDSF Collab: $N_f = 2$ Lattice, pert. reno. $\Lambda = 261 \pm 17 \pm 26$ MeV

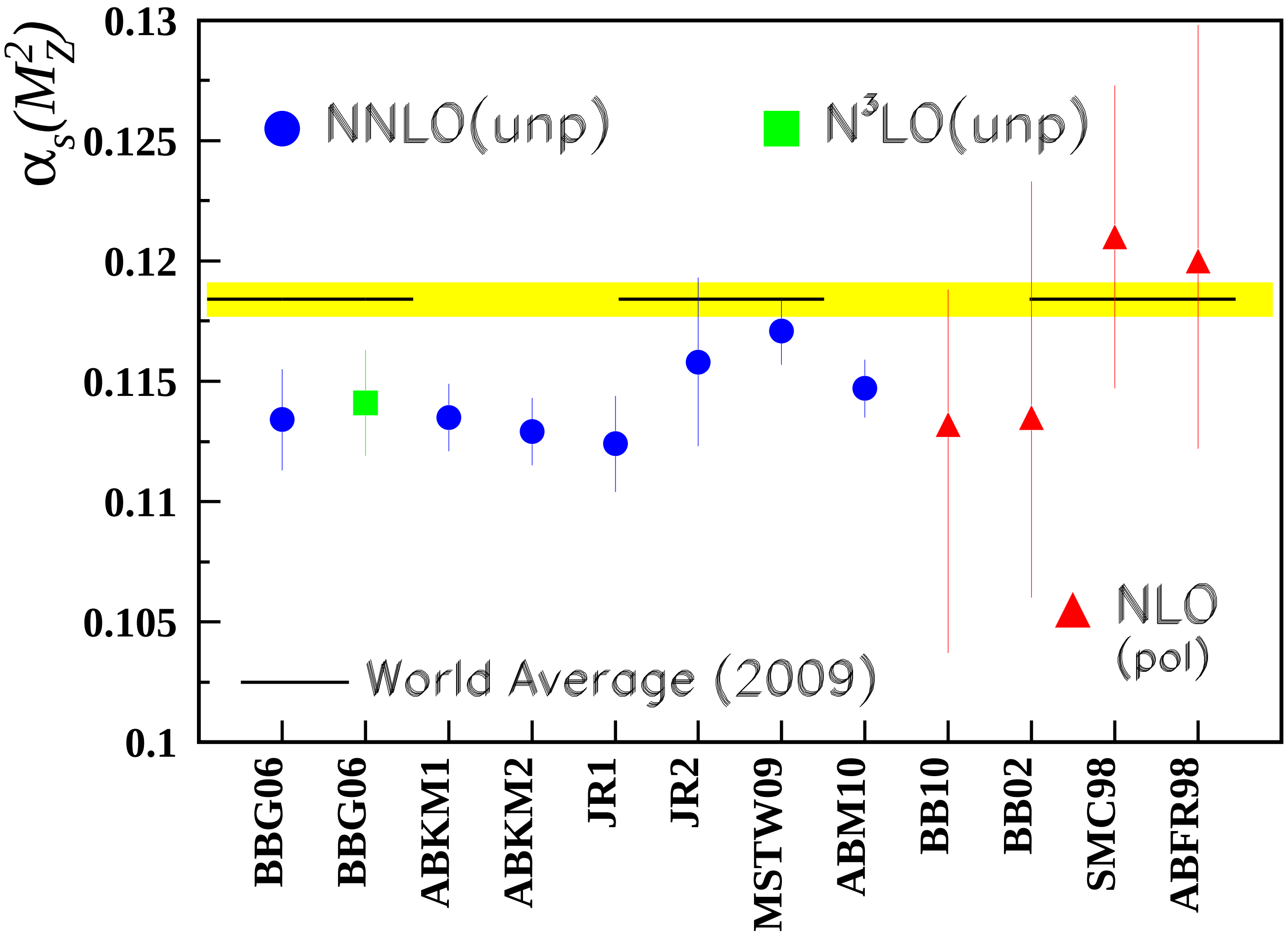
$\alpha_s(M_Z^2)$

S. Alekhin, J.B., S. Klein, S. Moch, Phys. Rev. D81 (2010) 014032

$$\delta\alpha_s(M_Z^2)/\alpha_s(M_Z^2) \approx 1\%$$

	$\alpha_s(\mathrm{M_Z^2})$	
BBG (2006)	$0.1134 \begin{array}{l} +0.0019 \\ -0.0021 \end{array}$	valence analysis, NNLO
ABKM	0.1135 ± 0.0014	HQ: FFS $N_f = 3$
ABKM	0.1129 ± 0.0014	HQ: BSMN-approach
JR (2008)	0.1124 ± 0.0020	dynamical approach
MSTW (2008)	0.1171 ± 0.0014	
HERAPDF (2010)	0.1145	(combined H1/ZEUS data, prelimiary)
ABM (2010)	0.1147 ± 0.0012	(FFN, combined H1/ZEUS data in)
A.Hoang et al.	$0.1135 \pm 0.0011 \pm 0.0006$	e^+e^- thrust
BBG (2006)	$0.1141 \begin{array}{l} +0.0020 \\ -0.0022 \end{array}$	valence analysis, N^{3}LO
WA (2009)	0.1184 ± 0.0007	

$\alpha_s(M_Z^2)$



J.B., H. Böttcher Nucl.Phys. B841 (2010) 205, arXiv:1005.3113.

Why is MSTW's $\alpha_s(M_Z^2)$ so high ?

$\alpha_s(M_Z^2)$	with σ_{NMC}	with F_2^{NMC}	difference
NLO	0.1179(16)	0.1195(17)	$+0.0026 \simeq 1\sigma$
NNLO	0.1135(14)	0.1170(15)	$+0.0035 \simeq 2.3\sigma$
NNLO +F_LO(α_s^3)	0.1122(14)	0.1171(14)	$+0.0050 \simeq 3.6\sigma$

S. Alekhin, J.B., S. Moch, arXiv:1101.5261.

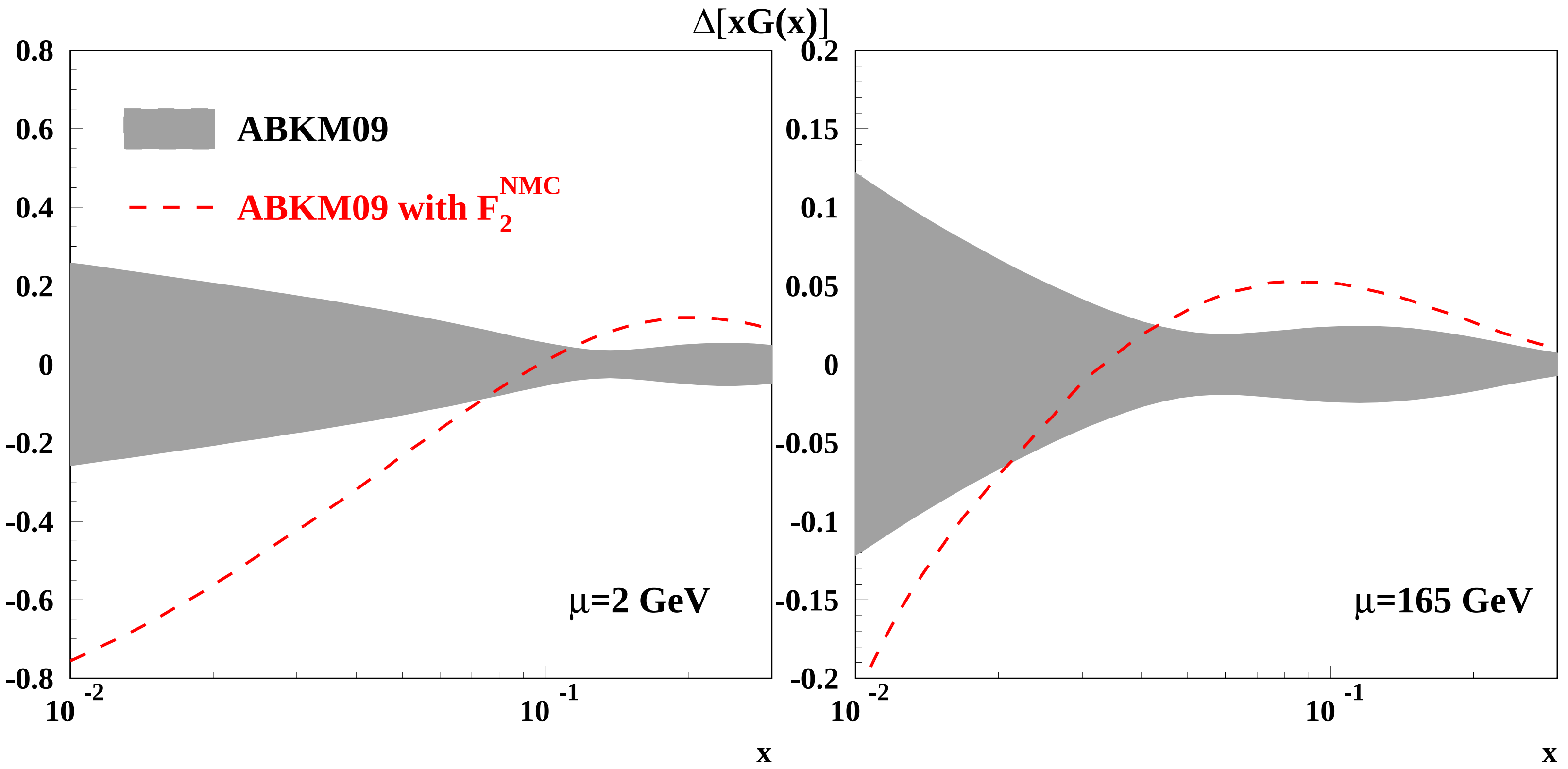
$\Longrightarrow$ also fixed target data shall be analyzed using σ.

$\Longrightarrow$ This applies to NMC in particular.

- Wrong treatment of $F_L(x,Q^2)$ in NMC F_2 extraction.

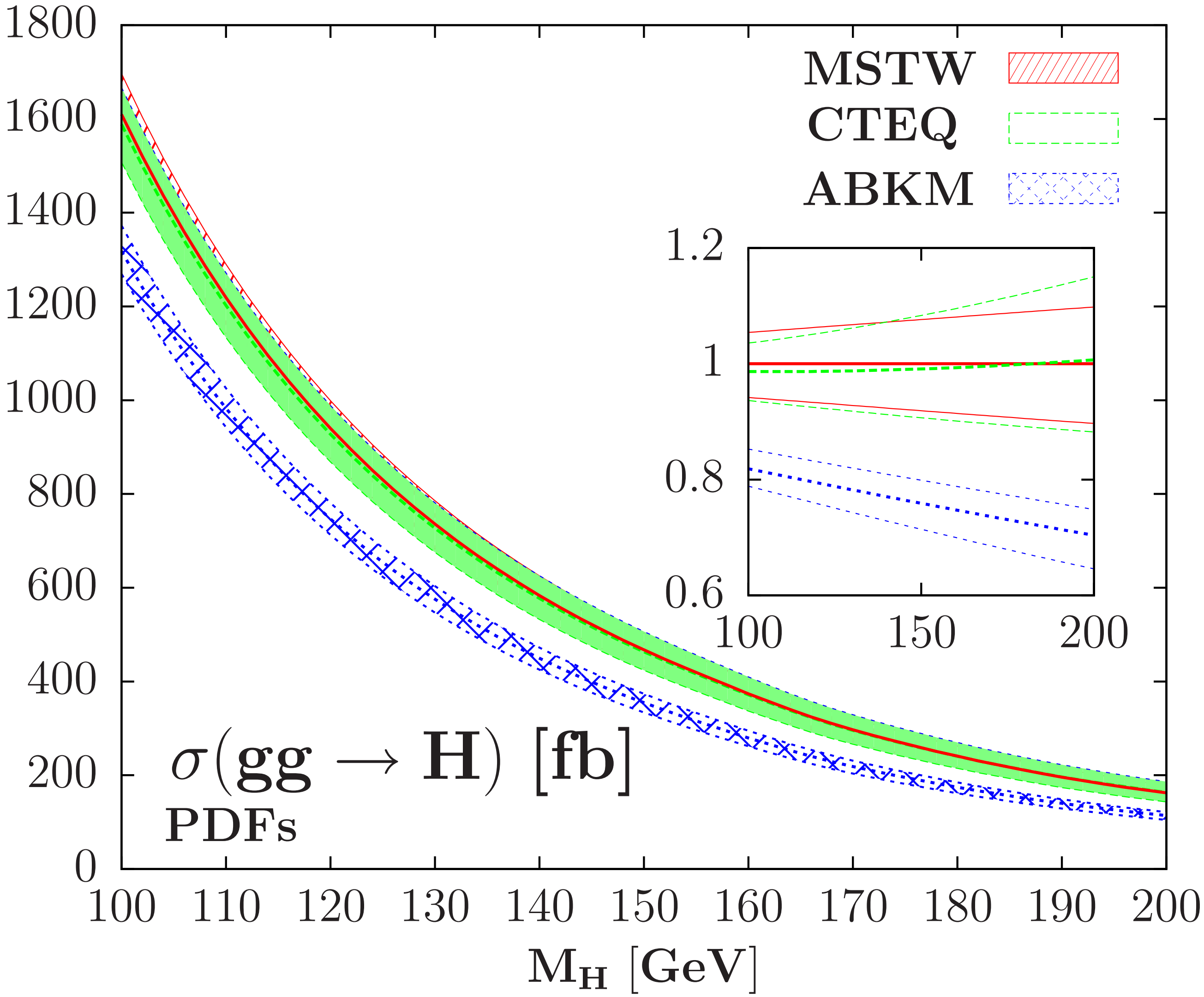
$\Longrightarrow$ also necessary for BCDMS, see BBG (2006).

Effect on the Gluon density



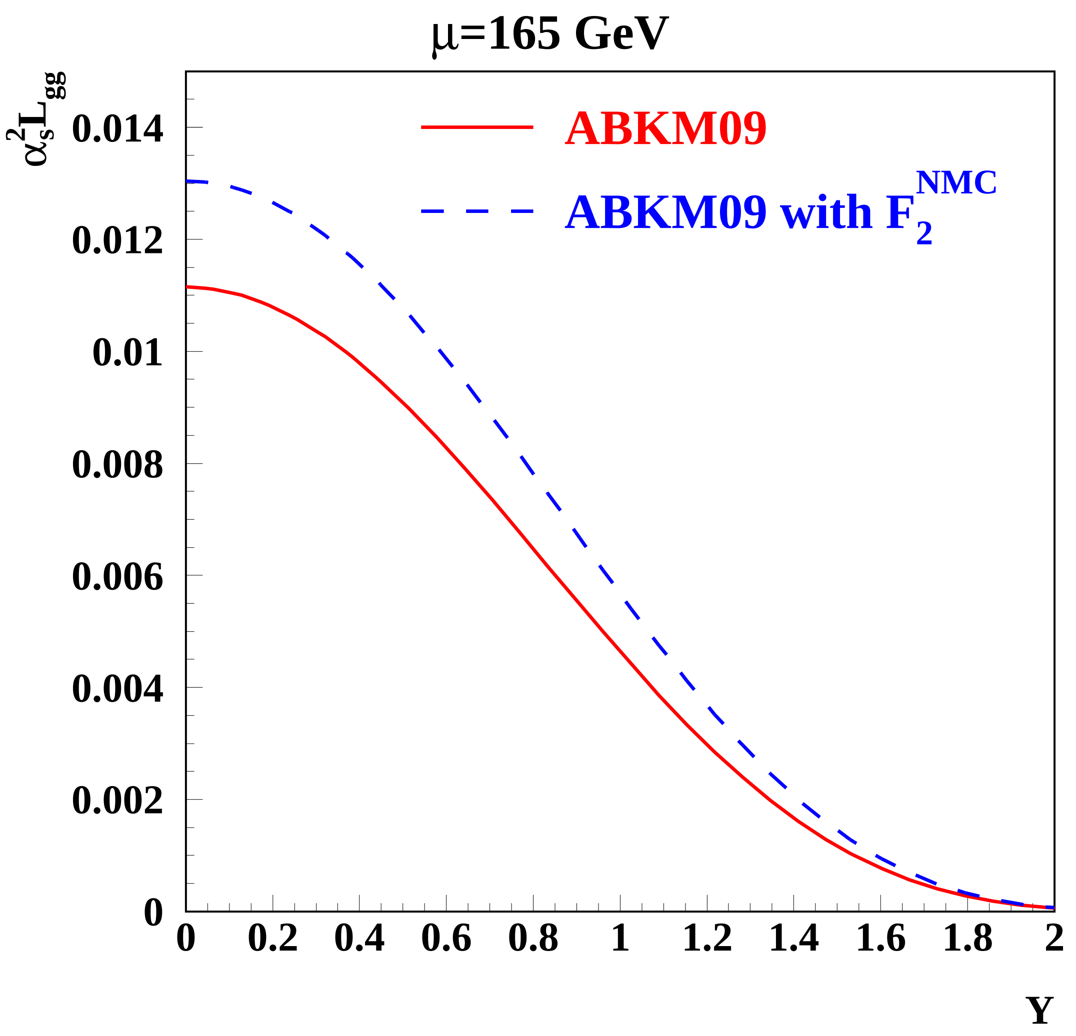
wrong treatment ($F_2^{\rm NMC}$): larger gluon at $x \simeq 0.1$

4. Consequences for Hadron Colliders



J. Baglio and A. Djouadi 2010.

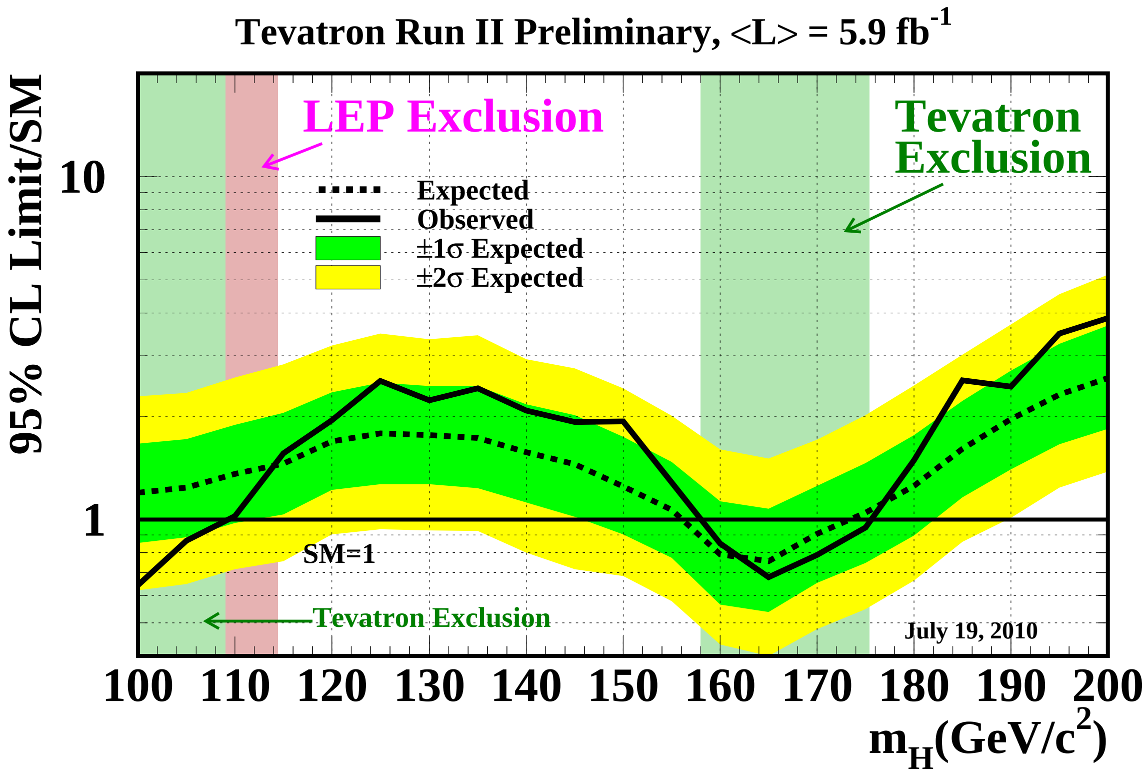
Gluon Luminosity



S. Alekhin, J.B., S. Moch, arXiv:1101.5261.

$\Longrightarrow$ The correct NMC analysis leads to lower values for $\alpha_s^2 g \otimes g$.

$gg \to H^0$



- Tevatron Higgs search group, Summer 2010.
- exclusion is based on MSTW08 NNLO only.

$\Longrightarrow$ systematic error of -39 % @ $M_H \sim 160$ GeV.

$\Longrightarrow$ halfs the exclusion region.

5. Conclusions

- The N^{3}LO DIS analysis yields : $\alpha_s(M_Z^2) = 0.1141 \pm 0.0021$
- Correct NNLO anlyses require the fit of $d^2\sigma/dxdQ^2$ and the correct decription of $F_L, F_2^{c\bar{c}}$.
- NNLO $\alpha_s(M_Z^2)$ values in the range $0.1122 - 0.1147 \pm 0.0014$ are obtained.
- The various systematic shifts are understood;
  presently not possible to resolve $\delta\alpha_s < 0.0008$.
- The difference to the MSTW08 value can be explained.
- NLO analyses yield systematic higher $\alpha_s(M_Z^2)$ values than NNLO analyses;
  averaging of these values is not possible.
- Direct relevance for the Higgs search at Tevatron and LHC and likewise for the other standard candle processes $(W/Z, t\bar{t})$.
- The present excluded range for the Higgs mass at Tevatron appears to be to large.