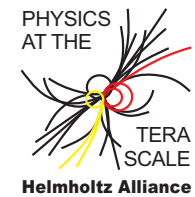# Analysis Center: the PDF Working Group

Johannes Blümlein

DESY

- Mission
- Cooperation between Theory & Experiment
- Schools & Workshops
- Some Results
- Work plans for the next time

Annual Meeting of the Helmholtz Alliance: Physics at the Tera-Scale, Hamburg, November 12th 2009

Mission

- provides training on all aspects concerning pdfs and inclusive hard scattering processes in ep and pp reactions

- supports the final analyses of HERA data w.r.t. to the extraction of pdfs

- coordinates comparisons of different pdf analyses to refine the understanding of pdfs and their errors, including $\alpha_s(M_Z^2)$

- provides further theoretical calculations needed to improve ongoing ep and pp analyses

- will provide a platform to analyze inclusive hard scattering data at the LHC (DY, $t\bar{t}$, Higgs-production) to refine the understanding of the pdfs

- will provide an open-source code for NNLO structure function and pp inclusive hard scattering process analyses to extract pdfs

Members & Cooperation

- <u>Coordination:</u> J. Blümlein, S.-O. Moch, DESY, Z , A. Glazov, DESY, HH

- Partners (that far):

NNPDF	A. Guffanti, U. Freiburg
Heavy Flavor, DIS	A. Geiser, K. Lipka, DESY, S. Klein, RWTH Aachen
pdf comparisons	E. Reya et al. TU Dortmund
4-loop analyses	K. Chetyrkin, J.H. Kühn, KIT
systematics studies	V. Radescu, U. Heidelberg
code development	H. Böttcher, DESY, S. Alekhin, DESY & IHEP

- External Partners:

hard processes comp.	P. Jimenez-Delgado, U. Zürich
code development	A. Vogt et al., TP, U. Liverpool

- all interested partners are invited to join the work.

Cooperation between Theory and Experiment

- finalize the HERA data: H1+ZEUS and extract the most precise results possible; inclusive DIS data, heavy flavor data

- recent and ongoing NNLO Heavy Flavor Calculations

- Code Comparisons for evolution codes and hard scattering cross sections at HERA and the LHC

- longer term: computation of the NNLO ep jet cross sections

- Mutual comparisons of global analyses started $\implies$ thoroughly understood pdfs for the LHC

- Started: development of Open Source Code for NNLO Evolution and hard processes in ep and pp: fast Mellin-space technology

Cooperation between Theory & Experiment

- $\Longrightarrow$ Theory tools need to be quickly transferred to experiment

- $\Longrightarrow$ Close contacts and collaboration T+E on analysis issues required

- $\Longrightarrow$ Incorporate newly calculated 3-loop heavy flavor corrections into data analysis of $F_2(x, Q^2)$

- $\Longrightarrow$ Apply newly calculated 3-loop heavy flavor corrections in ongoing data analyses of $F_2^{c\bar{c}}(x, Q^2)$ and $F_2^{b\bar{b}}(x, Q^2)$ at H1 and ZEUS

- $\Longrightarrow$ With the advent of LHC data : systematic study of light candle processes as Drell-Yan, W/Z-production ... to unravel the different sea quark distributions.

- Final Goal : High precision pdfs and value of $\alpha_s(M_Z^2)$ for LHC.
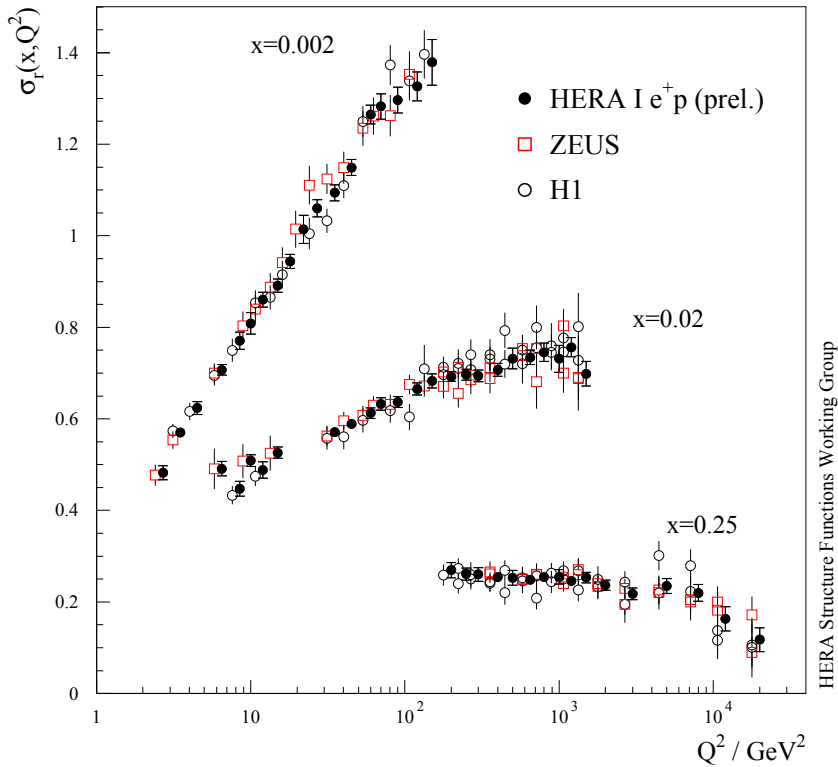
Schools & Workshops

- PDF-school, Nov. 2008 J.B., A. Glazov, S.O. Moch

- PDF-school, Oct. 2009 J.B., A. Glazov, S.O. Moch, T. Schoerner-Sadenius

- In preparation : PDF-school, Oct. 2010; working meeting pdf group + MC group Feiburg/Br. 2010

- Bi–annually since 1992 :
Loops and Legs in Quantum Field Theory;
next workshop: April 2010, J.B., S.O. Moch, T. Riemann
- a central meeting to discuss all new theoretical activities in
Terascale-physics

Development of Open Source Fitting Code

- 2 year project; so far: 1 yr funding for exp. scientist (S. Alekhin)
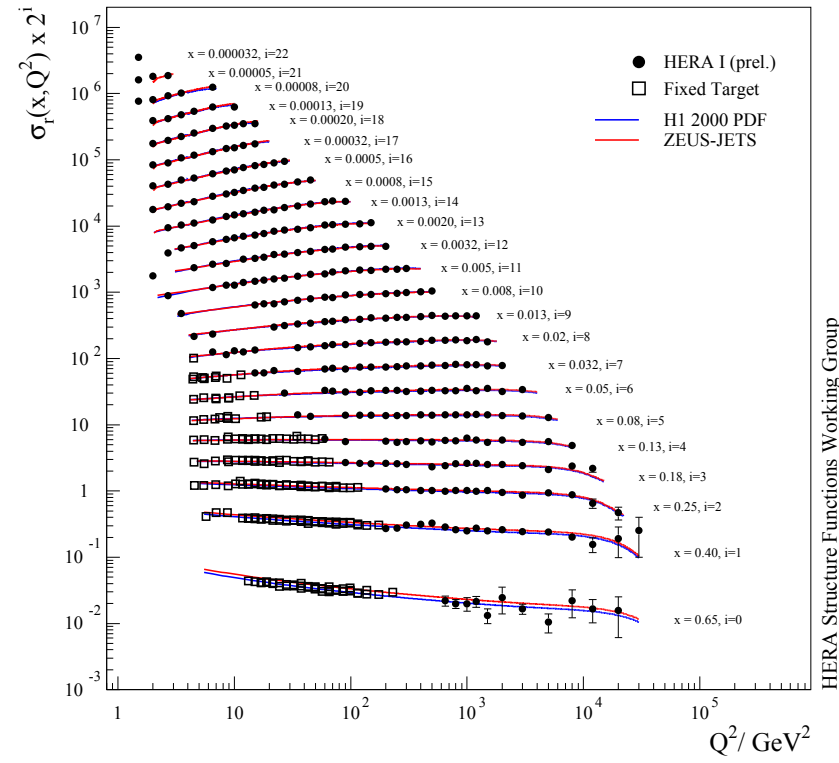
- other phenomenology groups joined

Combined Fits: H1 + ZEUS

HERA I e$^+$p Neutral Current Scattering - H1 and ZEUS

- HERA I e$^+$p (prel.)
- ZEUS
- H1

x=0.002

x=0.02

x=0.25

$\sigma_r(x,Q^2)$

Q^2 / GeV^2

HERA Structure Functions Working Group

DIS08   Joël Feltesse

HERA I e$^+$p Neutral Current Scattering - H1 and ZEUS

$\sigma_r(x,Q^2) \times 2^i$

- HERA I (prel.)
- Fixed Target
- H1 2000 PDF
- ZEUS-JETS

x = 0.000032, i=22
x = 0.00005, i=21
x = 0.00008, i=20
x = 0.00013, i=19
x = 0.00020, i=18
x = 0.00032, i=17
x = 0.0005, i=16
x = 0.0008, i=15
x = 0.0013, i=14
x = 0.0020, i=13
x = 0.0032, i=12
x = 0.005, i=11
x = 0.008, i=10
x = 0.013, i=9
x = 0.02, i=8
x = 0.032, i=7
x = 0.05, i=6
x = 0.08, i=5
x = 0.13, i=4
x = 0.18, i=3
x = 0.25, i=2
x = 0.40, i=1
x = 0.65, i=0

Q^2/ GeV^2
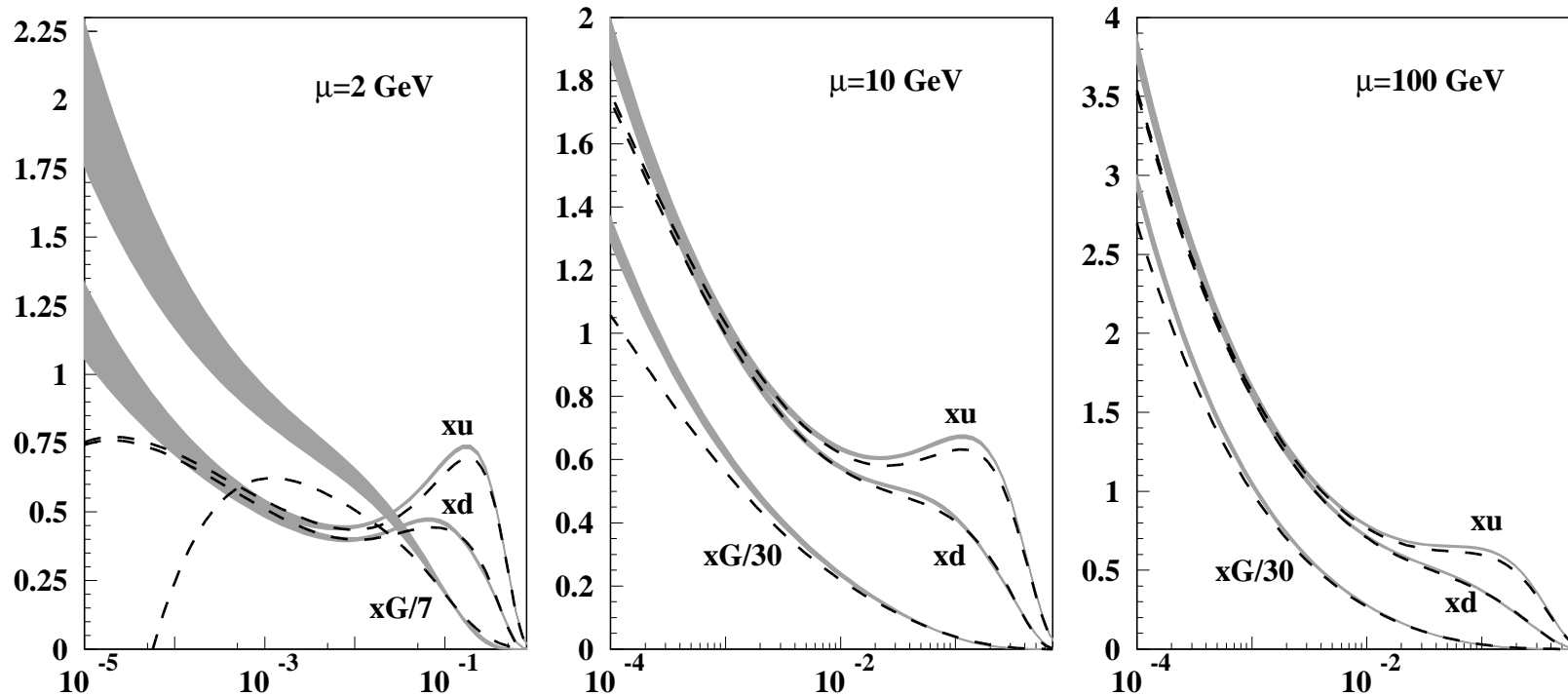
HERA Structure Functions Working Group

DIS08   Joël Feltesse

New ZEUS + H1 averaged $F_2(x, Q^2)$

Flavor distributions: light quarks (NNLO)

Current Fitting Community (NNLO): ABMK, JR, A, MSTW
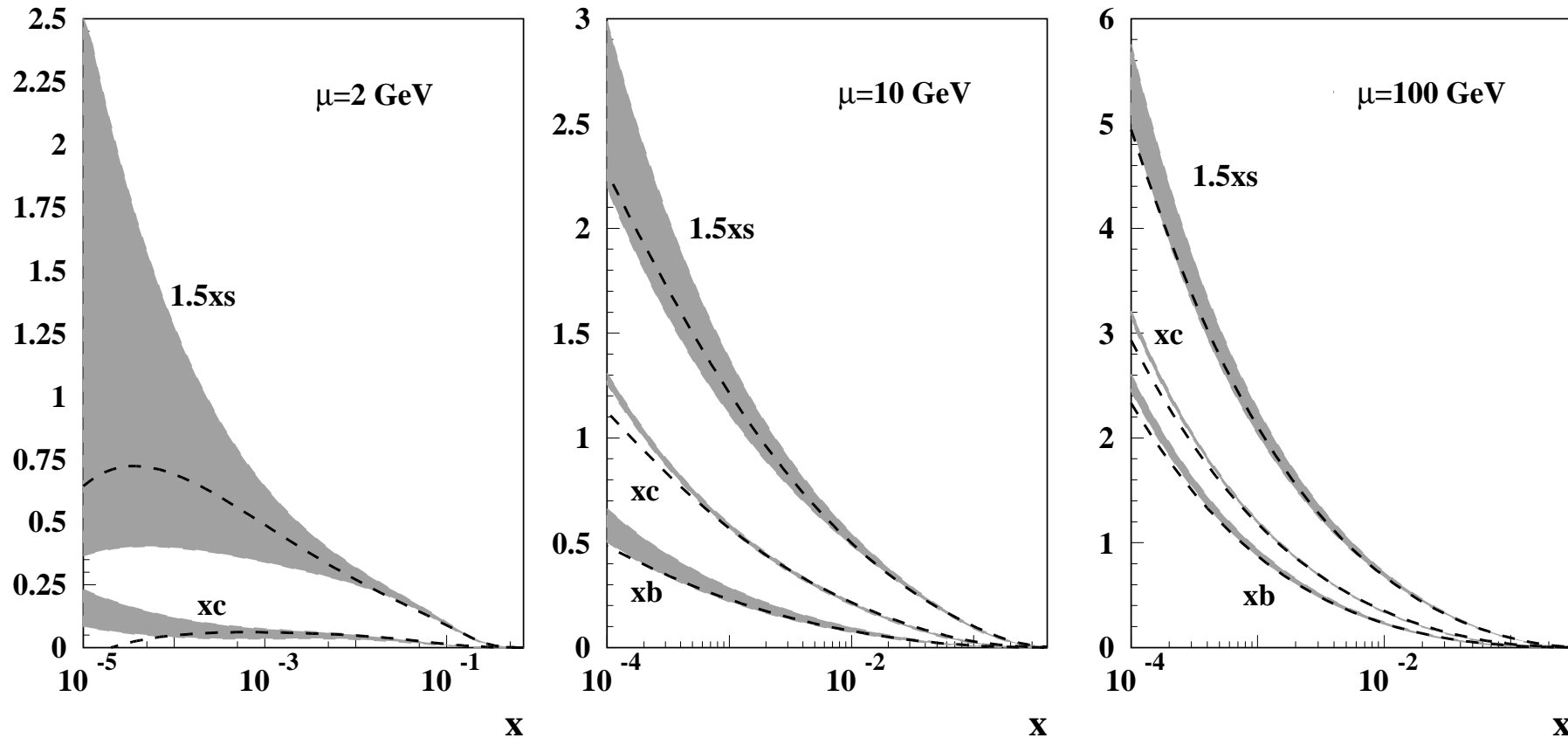
+ Many NLO analyses worldwide: CTEQ, NNPDF, H1, ZEUS, ...

S. Alekhin, J.B., S. Klein, S. Moch, DESY 09-102; Correct treatment of HQ very essential: FFNS, BSMN-schemes.; full lines: ABKM error band; dashed lines: MSTW08
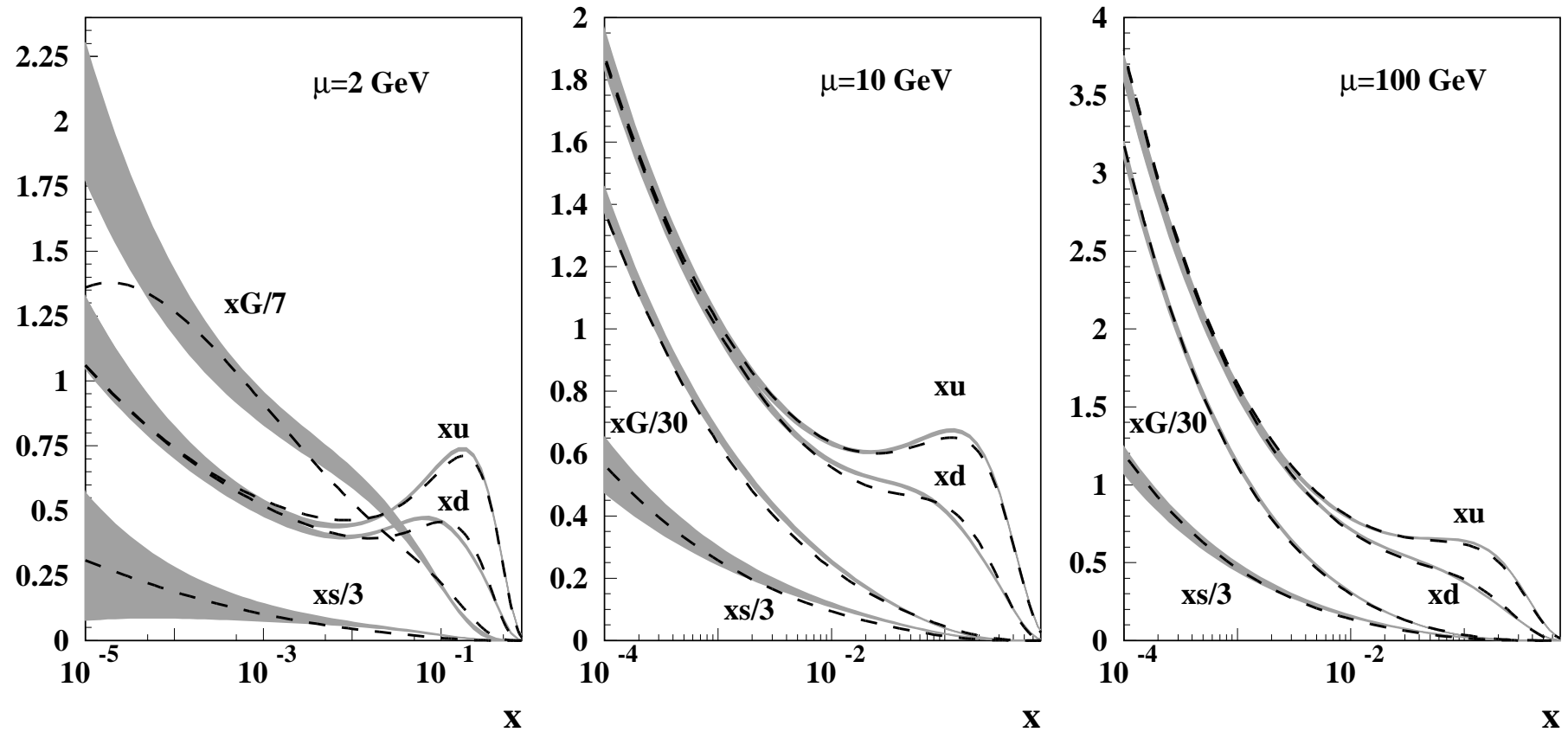
Heavy quarks and gluon (NNLO)
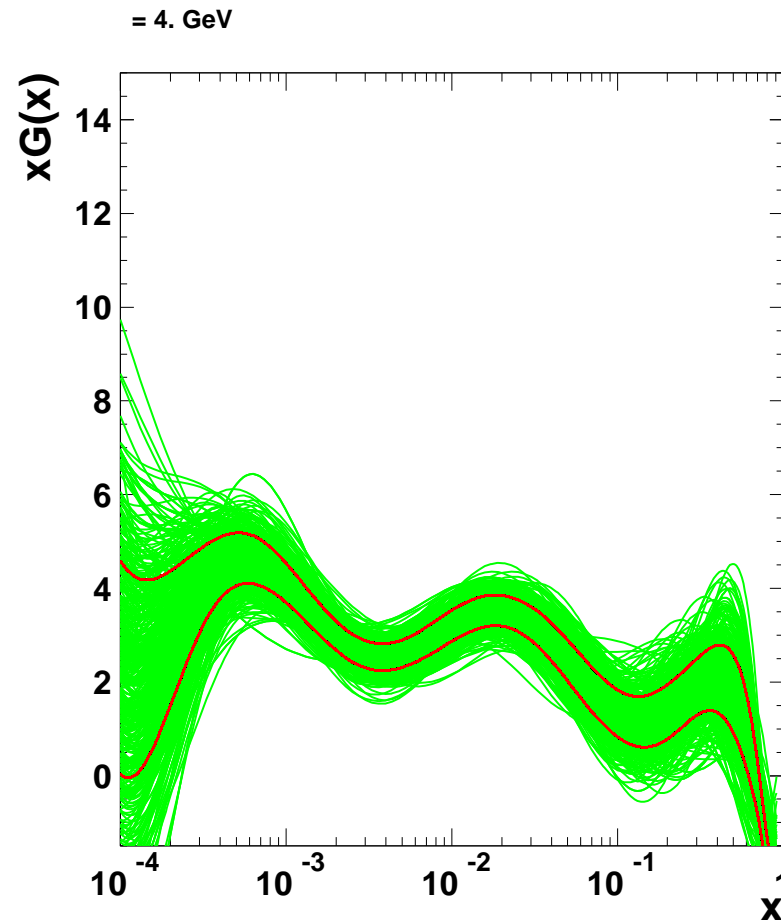

S. Alekhin, J.B., S. Klein, S. Moch, DESY 09-102

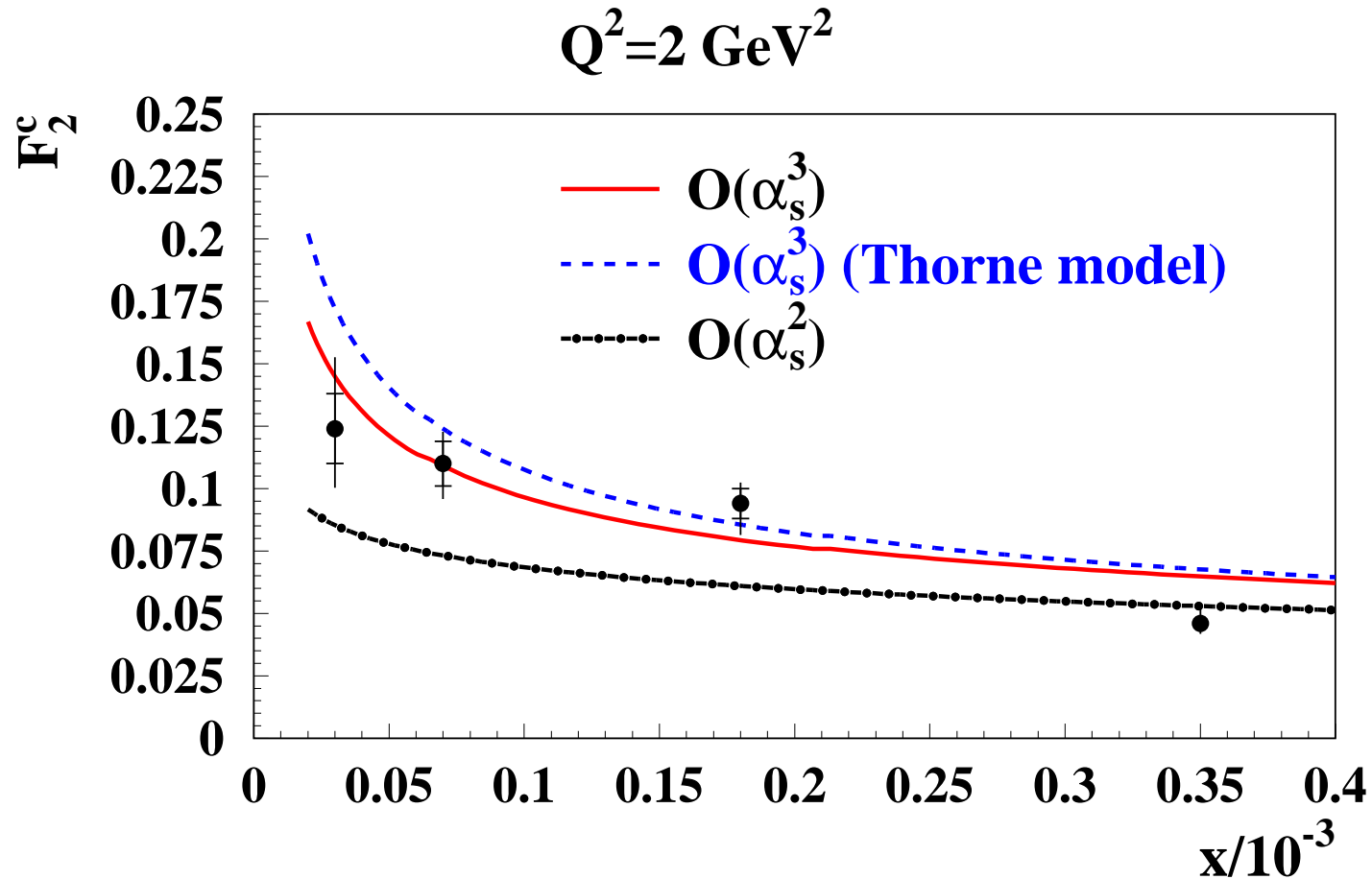full lines: ABKM error band; dashed lines: MSTW08

FFNS, $N_f = 3$

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

Study of shape uncertainty

= 4. GeV
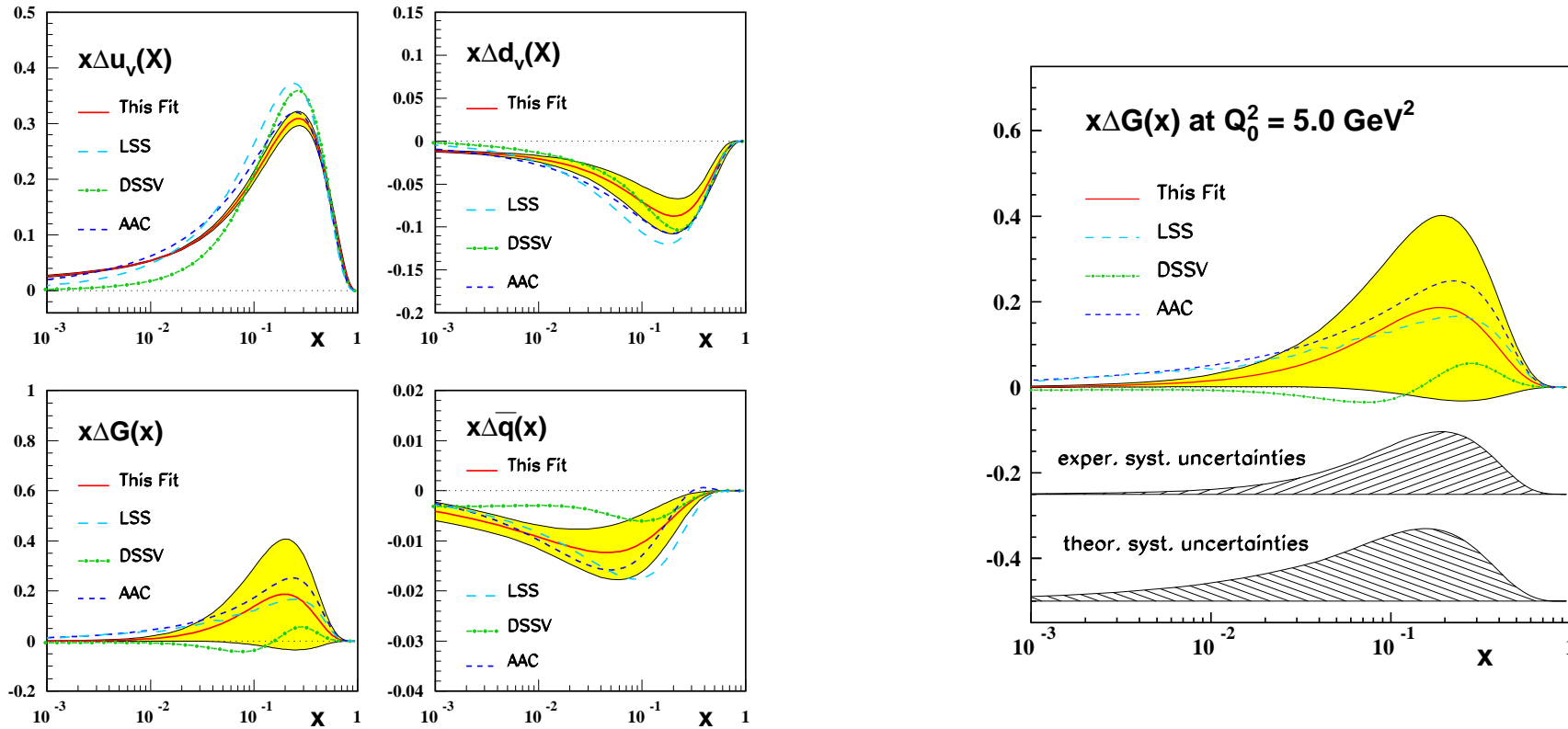

A. Glazov, S. Moch, V. Radescu ; using Chebyshev polynomials.;

Improved Threshold Resummation: DIS $c\bar{c}$

$Q^2 = 2\ \text{GeV}^2$

Legend:
- $O(\alpha_s^3)$ (red solid)
- $O(\alpha_s^3)$ (Thorne model) (blue dashed)
- $O(\alpha_s^2)$ (black dash-dotted)

Axes: F_2^c versus $x/10^{-3}$

S. Alekhin, S.-O. Moch (2008)
- implementation of large Q^2 NNLO effects upcoming; J.B., S. Klein
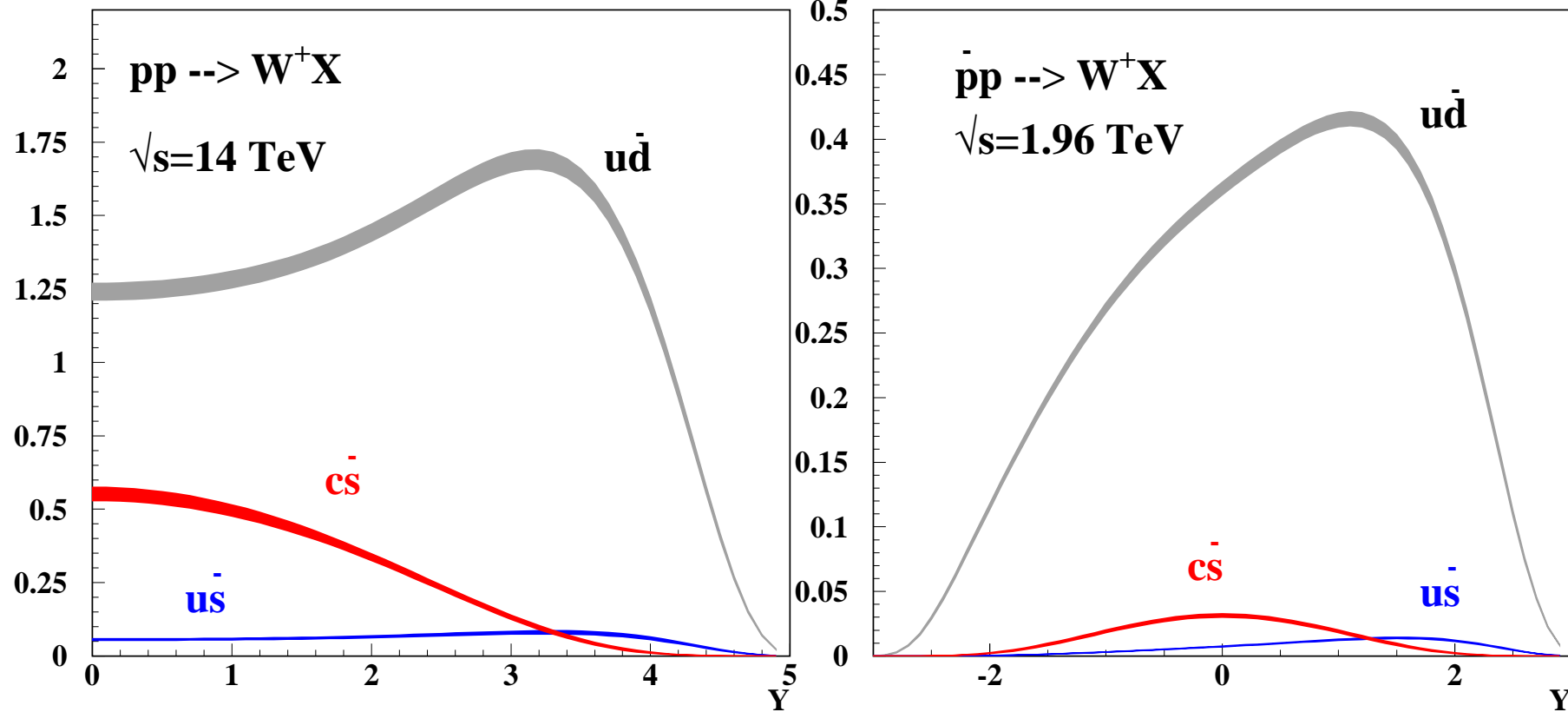
Polarized DIS

- polarized world data analysis J.B., H. Böttcher

- 3-loop analysis: anomalous dimensions + massless WC Moch, Vermaseren, Vogt, upcoming

- 3-loop analysis: HQ WC's J.B. et al., upcoming

Some Predictions for Tevatron and the LHC

Drell-Yan Process (NNLO)

ABKM (2009)

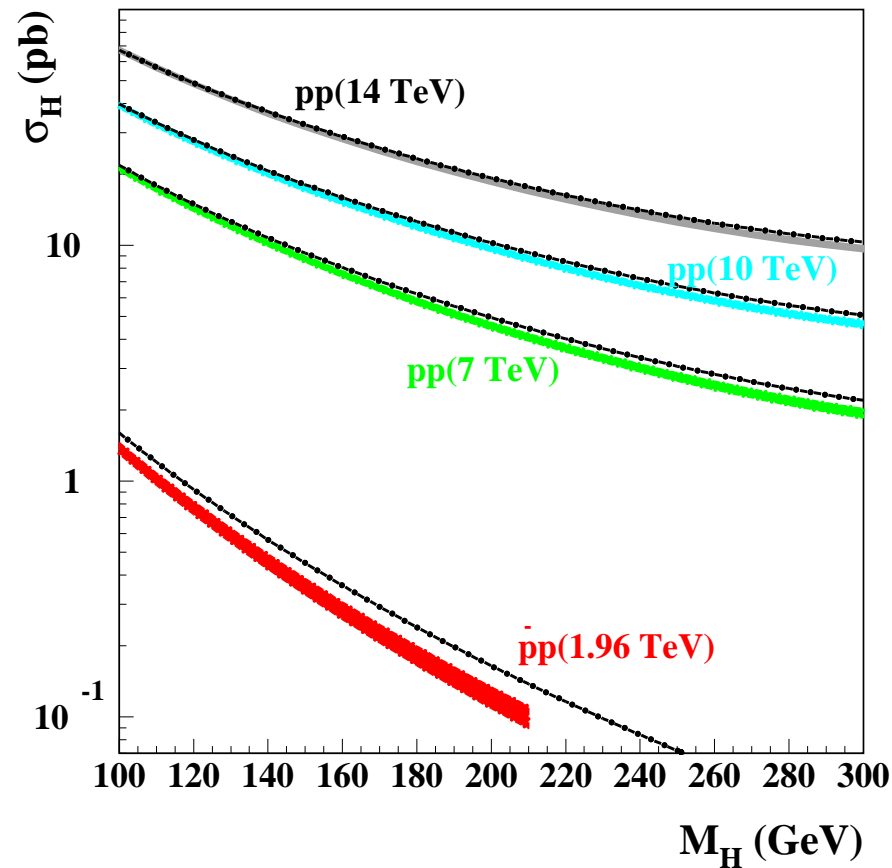# $t\bar{t}$ Cross Section in $pp(\overline{p})$ scattering at (NNLO)

$\sqrt{s}$ (TeV)	this paper	MSTW2008
1.96 $(\bar{p}p)$	6.91 ± 0.17	7.04
7 (pp)	131.3 ± 7.5	160.5
10 (pp)	343 ± 15	403
14 (pp)	780 ± 28	887

ABKM (2009) vs MSTW08

• Yet significant differences.

Higgs Cross Section in $pp(\bar{p})$ scattering at (NNLO)

bands: ABKM (2009); lines: MSTW08

• LHC has a great potential to limit the gluon distribution.

$$\alpha_s(M_Z^2)$$

$$\frac{\delta\alpha_s(M_Z^2)}{\alpha_s(M_Z^2)} \simeq 1.2\%$$

	$\alpha_s(\mathrm{M}_Z^2)$	
ABKM	0.1135 ± 0.0014	HQ: FFS $N_f = 3$
ABKM	0.1129 ± 0.0014	HQ: BSMN-approach
BBG (2006)	$0.1134\,^{+0.0019}_{-0.0021}$	valence analysis, NNLO
JR (2008)	0.1124 ± 0.0020	dynamical approach
MSTW (2008)	0.1171 ± 0.0014	
BBG (2006)	$0.1141\,^{+0.0020}_{-0.0022}$	valence analysis, N^{3}LO

$$\alpha_s(M_Z^2)$$

$$\frac{\delta\alpha_s(M_Z^2)}{\alpha_s(M_Z^2)} \simeq 1.2\%$$

	$\alpha_s(\mathrm{M}_Z^2)$	
ABKM	0.1135 ± 0.0014	HQ: FFS $N_f = 3$
A.Hoang et al.	0.1135 ± 0.0013	e^+e^- thrust
ABKM	0.1129 ± 0.0014	HQ: BSMN-approach
BBG (2006)	$0.1134\ {}^{+0.0019}_{-0.0021}$	valence analysis, NNLO
JR (2008)	0.1124 ± 0.0020	dynamical approach
MSTW (2008)	0.1171 ± 0.0014	
BBG (2006)	$0.1141\ {}^{+0.0020}_{-0.0022}$	valence analysis, N^{3}LO

$\Longrightarrow$ Stay tuned.

Work Plans for the Next Time

- NNLO analysis of the DIS world data including the combined H1+ZEUS data; special investigation of gluon-sensitive observables

- Provide controlled NLO Data sets for LHC process simulations including correct HQ effects

- Implementation of the NNLO Heavy Flavor Effects

- Detailed Code Comparisons between NNLO global fitters

- Development of the fast Open Source Evolution Code

- The PDF-WG invites all interested Experimental and Theory Teams to join in the vast work to be done at the different construction places.