α_s determination in the PDF fits

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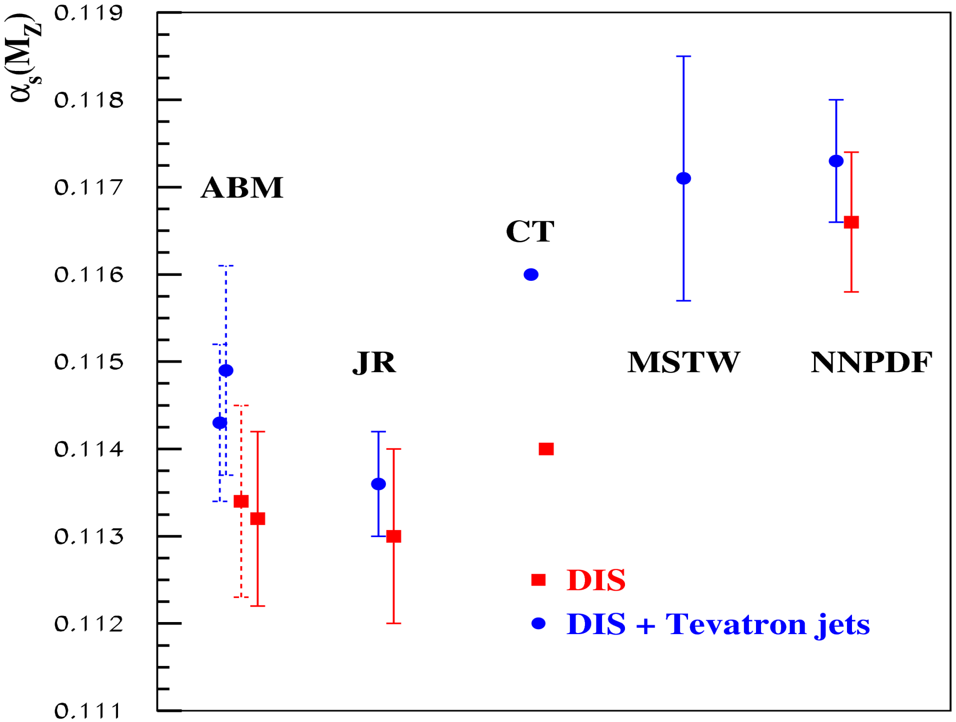
“*High precision fundamental constants at the TEV scale”, Mainz*, 11 Mar 2014

Summary of α_s from the global PDF fits



Constraints on α_s come from:

- scaling violation in the DIS
- c.s. of the gluon-initiated processes, primarily jets and to a certain extent, c-quark DIS production

A variety of data used in the global fits should Provide good disentangling of the PDFs

Pitfalls:

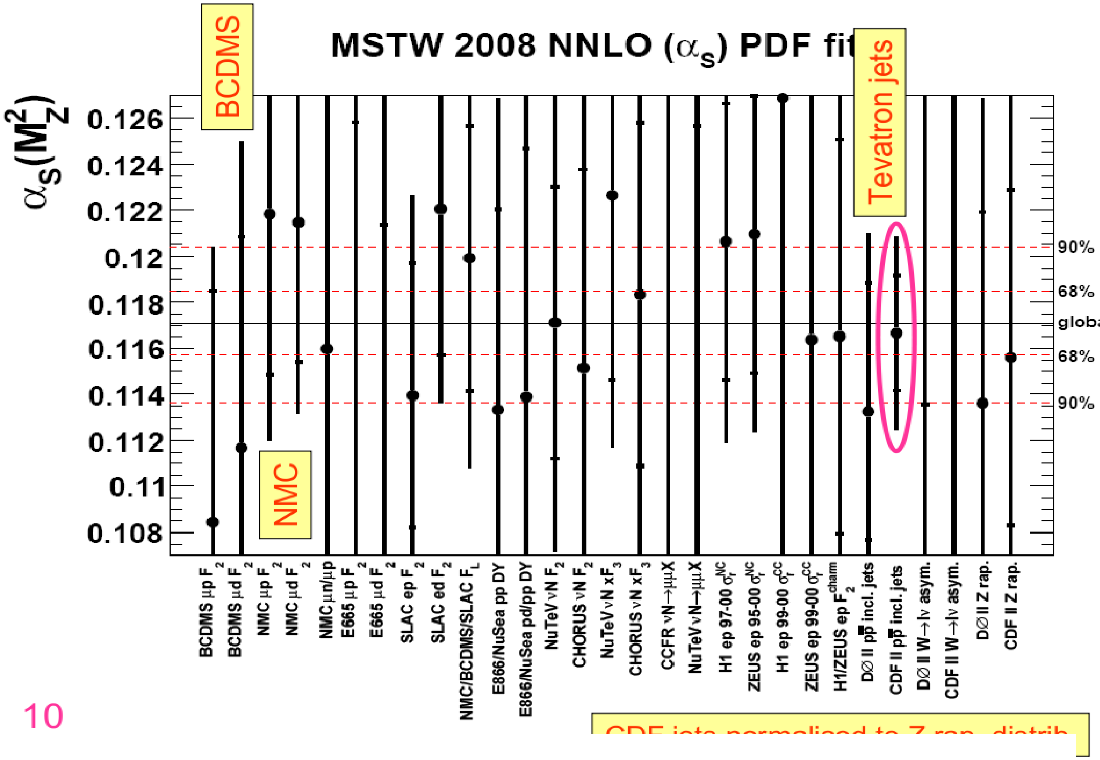
- power corrections in the DIS at small Q and/or W
- NNLO corrections for the jet productoin
- scheme choice for the c-quark DIS production

- The Tevatron jet data push α_s up by ~0.001
- The MSTW08 and NNPDF2.1 values are bigger than the ABM one in particular due to impact of hight-twist terms and/or error correlations

sa, Blümlein, Moch PRD 86, 054009 (2012)

- Recent CT 10 value is more close to ABM (no SLAC data used, stronger cut on Q^2, the error correlations are taken into account)

Theoretical issues in the jet data analysis



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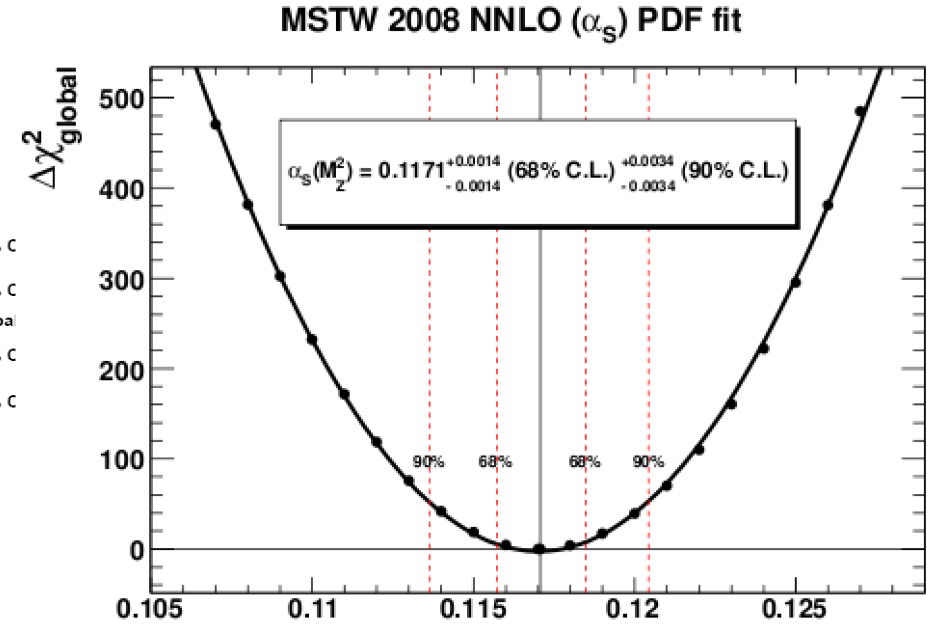
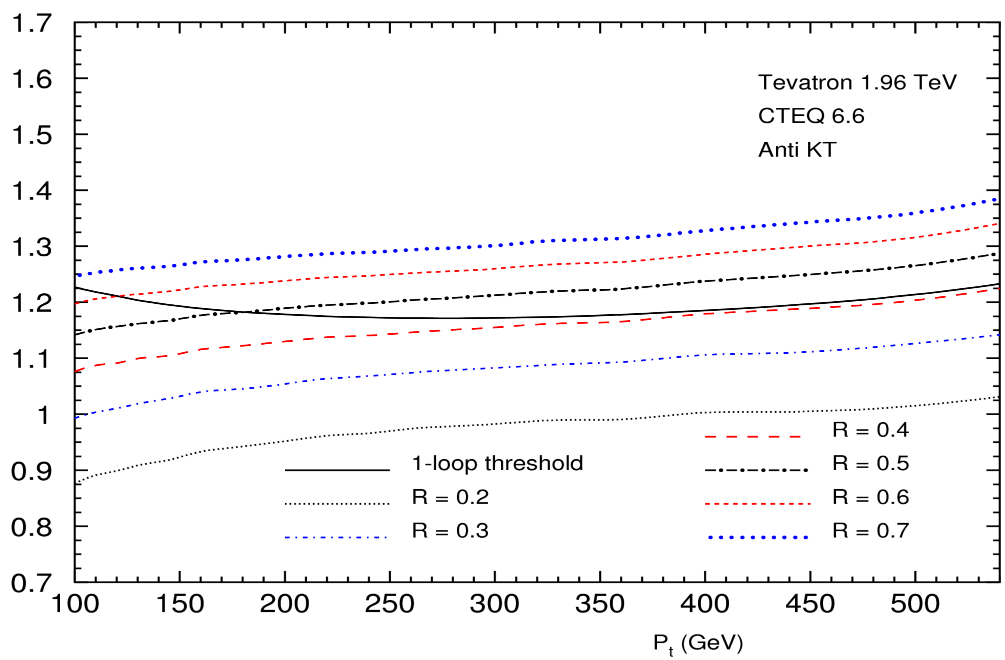


MSTW EPJC 64, 653 (2009)

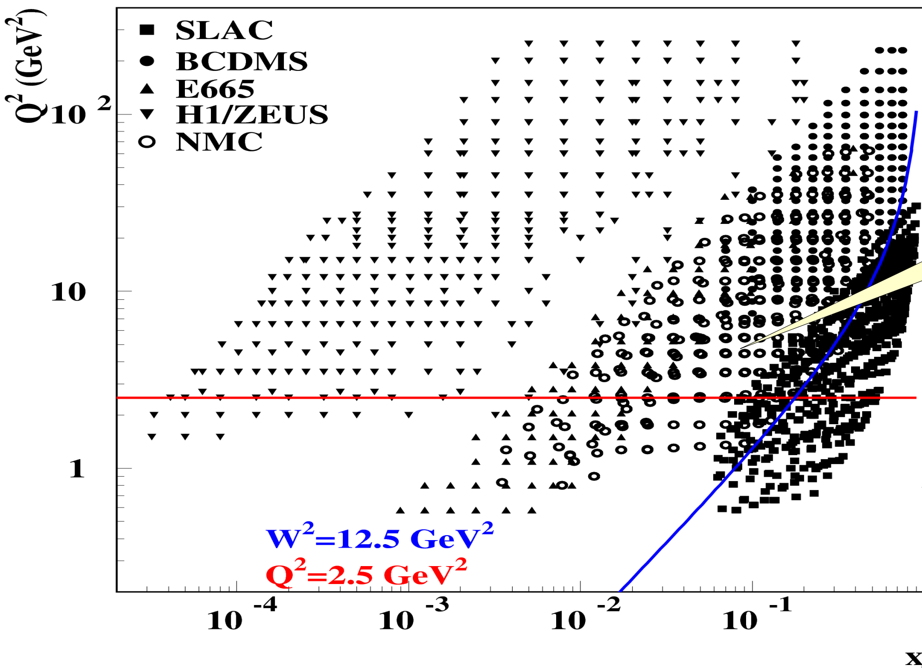


Kumar, Moch hep-ph/1309.5311

- Threshold corrections commonly used in the existing PDF fits are applicable at very large P_T only **Kumar, Moch hep-ph/1309.5311**
- Cone size dependence is essential
  de Florian, Hinderer, Mukherjee, Ringer, Vogelsang hep-ph/1310.7192
- Sizable NNLO corrections, 15-20% for the gluon channel
  Currie, Gehrmann-De Ridder, Glover, Pires JHEP 1401. 110 (2014)
- The MSTW update gives 0.1155 – 0.1171 depending on the jet data treatment

Watt, Motylinsky, Thorne hep-ph/1311.5703

High-twist terms in DIS

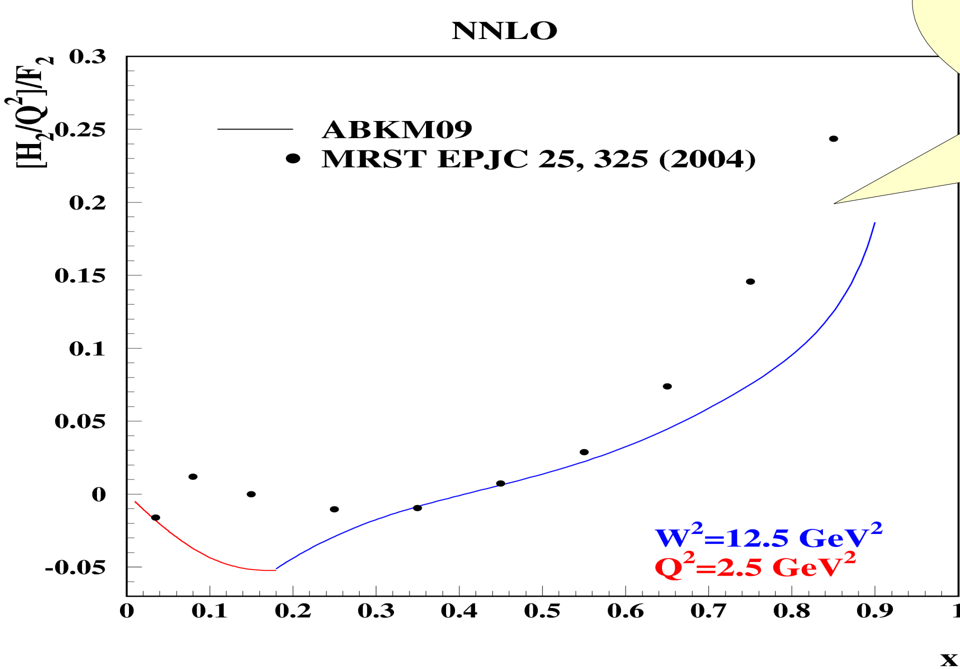


Is not removed with the “safe” cut on W

At small Q and /or W the high-twist (HT) terms give substantial contribution. One can try to get rid of them with a “safe” cut on W:

The selection of W_{cut} is unclear due to fluctuations

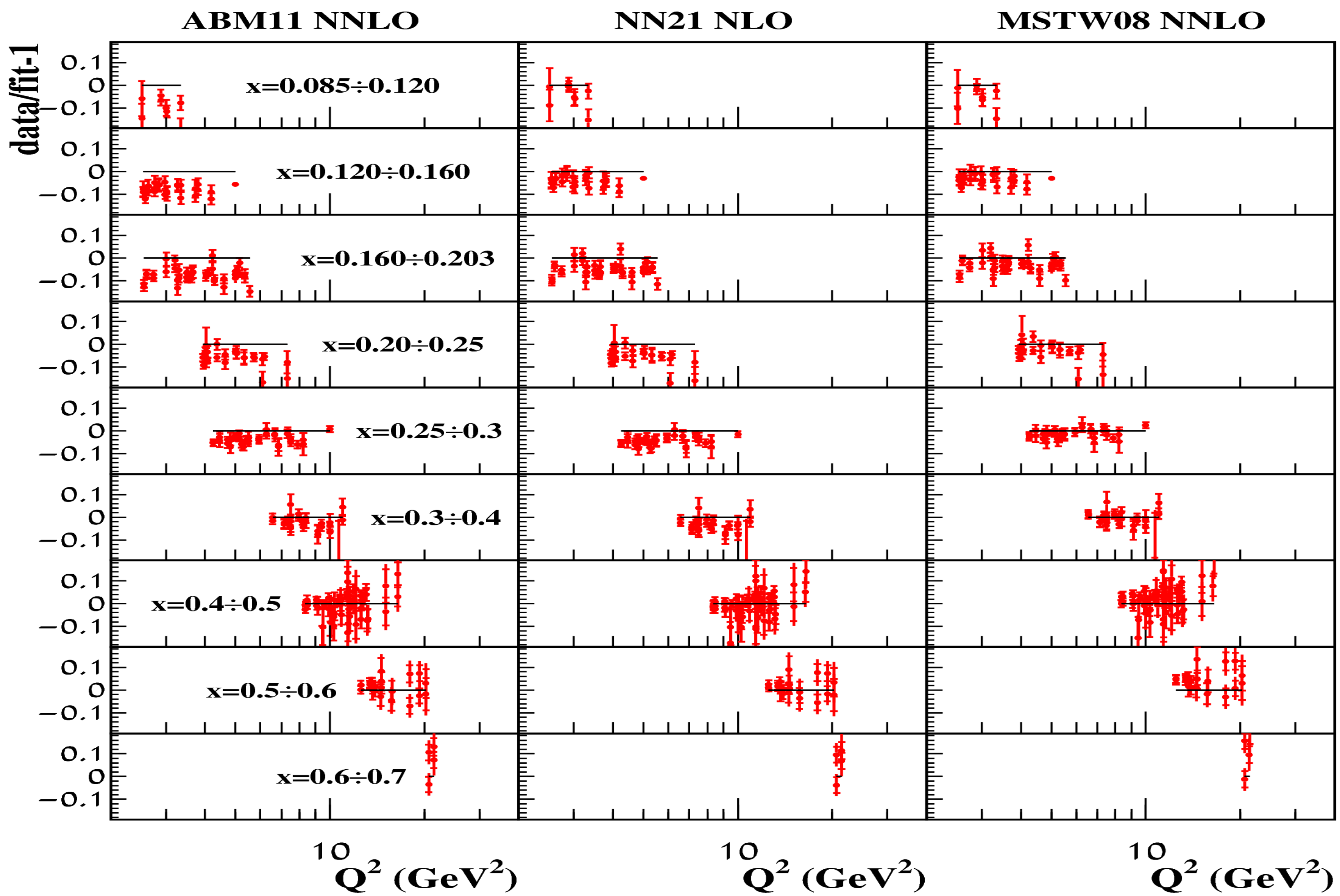
In the data → the HT terms are essential at the border of kinematics left after the cut



In the ABM fit the twist-4 terms are fitted simultaneosly with the leading-twist PDFs → consistent separation:

$$F_{2,T}=F_{2,T}(LT) + H_{2,T}(x)/Q^2$$

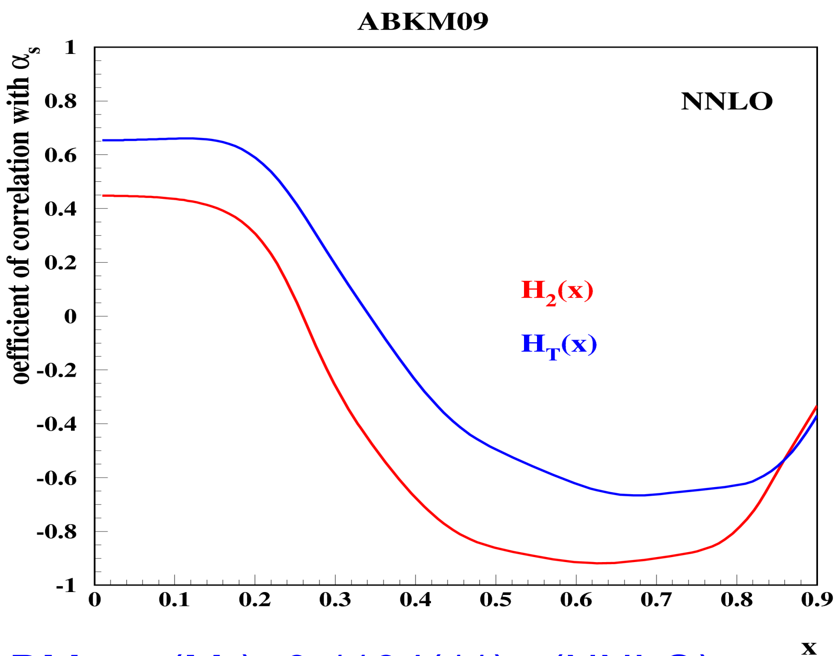
Comparison to SLAC data w.o. HT terms and W^2>12.5 GeV^2



- The high-twist terms are essential for the SLAC data even with the “safe” cut on W
- Significant contribution of the HT terms to structure function $R=\sigma_L/\sigma_T$; also essential for analysis of the NMC data

sa, Blümlein, Moch EPJC 71, 1723 (2011)

Correlation of α_s with twist-4 terms



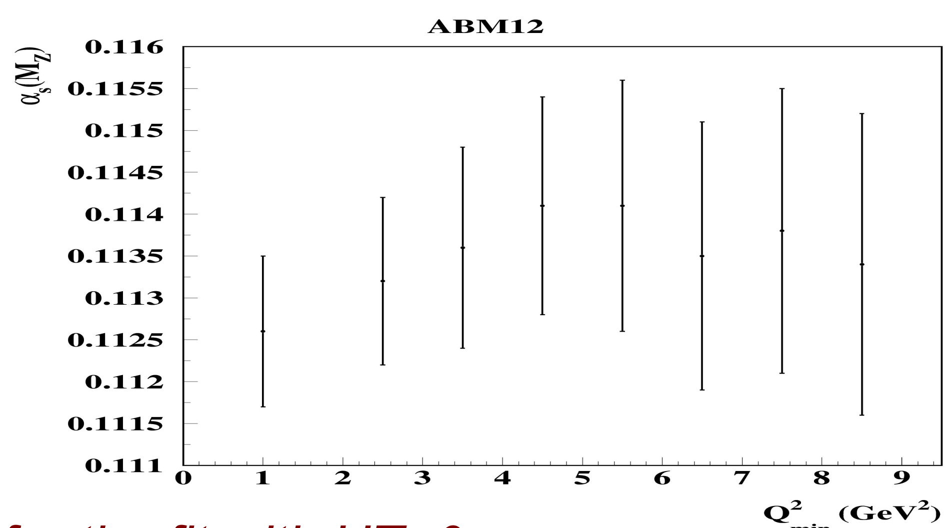
The value of α_s and twist-4 terms are strongly correlated

- With HT=0 the errors are reduced → no uncertainty due to HTs
- With account of the HT terms the value of α_s is stable with respect to the cuts
- With the HT terms fitted the fit is sensitive to the ansatz details

ABM: $\alpha_s(M_Z)=0.1134(11)$ (NNLO)
($W>1.8$ GeV, $Q^2> 2.5$ GeV^2, fitted twist-4 terms in $F_{2,T}$)

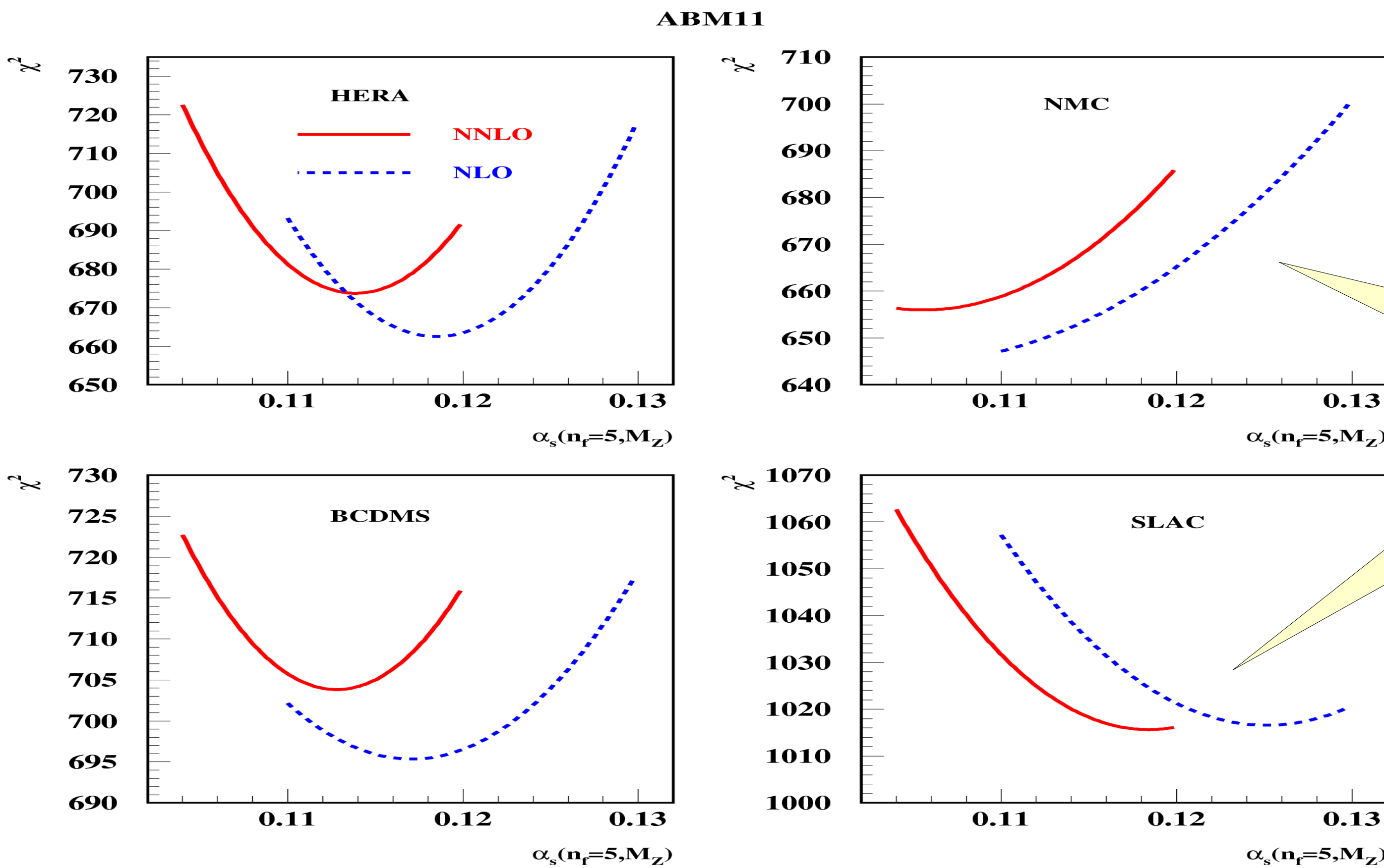
MRST: $\alpha_s(M_Z)=0.1153(20)$ (NNLO)
($W^2>15$ GeV^2, $Q^2> 10$ GeV^2)

	$W^2>12.5$ GeV^2 $Q^2>2.5$ GeV^2	$W^2>12.5$ GeV^2 $Q^2>10$ GeV^2
HT fixed	0.1125(7)	0.1125(10)
HT=0	0.1168(7)	0.1143(10)



Very stringent cut on Q at x~0.1 is necessary for the fit with HT=0

Another way to get rid of the HT terms



Sensitive to HT terms

sa, Blümlein, Moch
PRD D86, 054009 (2012)
EPJC 71, 1723 (2011)

The HERA and BCDMS data are insensitive to the HT contribution and are quite complementary in the α_s fit

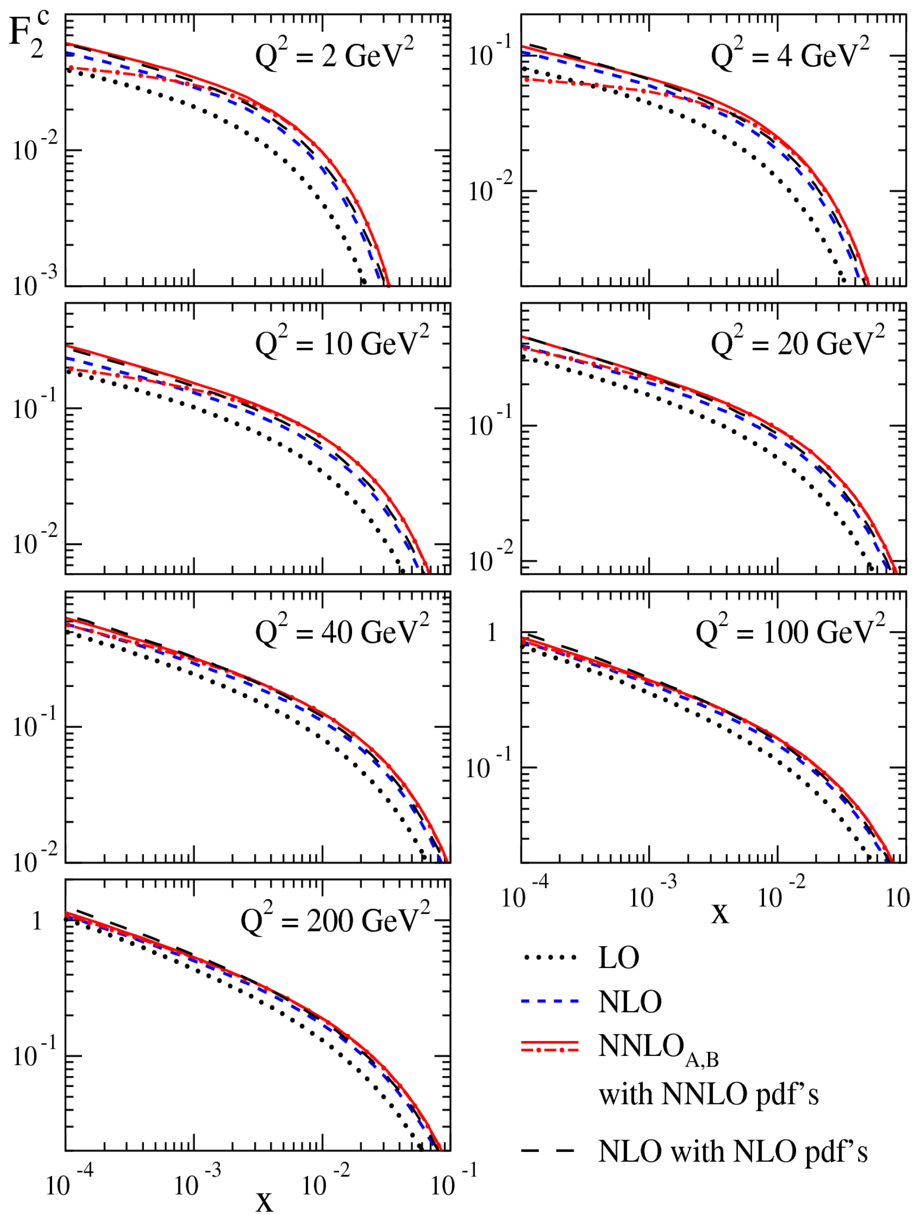
H1 Collaboration EPJC 21, 33 (2001)]

With the NMC and SLAC dropped $\alpha_s(M_z)=0.1133\pm0.0011$ (NNLO)

0.1184 ± 0.0011 (NLO)

The cross-check with MSTW, CTEQ and NNPDF is highly desirable

Massive NNLO coefficients: state of art



Kawamura, Lo Presti, Moch, Vogt NPB 864, 399 (2012)

- The NNLO log terms are known due to the recursive relations
- The constant NNLO term stem from:
  - the threshold resummation terms including the Coulomb one

    Lo Presti, Kawamura, Moch, Vogt [hep-ph 1008.0951]

  - high-energy asymptotics obtained with the small-x resummation technique

    Catani, Ciafaloni, Hautmann NPB 366, 135 (1991)

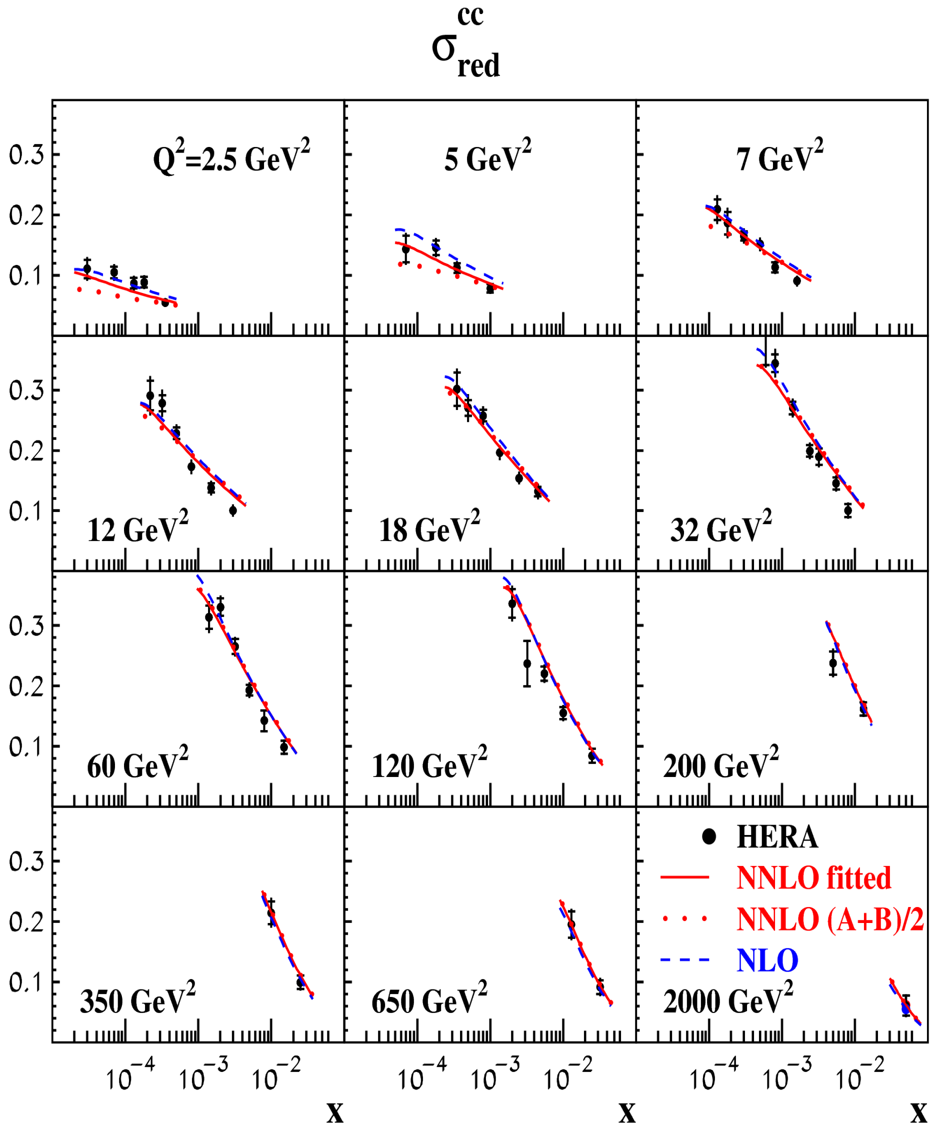
  - available NNLO Mellin moments for the massive OMEs

    Ablinger at al. NPB 844, 26 (2011)

    Bierenbaum, Blümlein, Klein NPB 829, 417 (2009
- The uncertainty in the NNLO coefficients is due to matching of the threshold corrections with the high-energy limit → two options for the coefficients are provided
- Further improvement should come from additional Mellin moments

  Blümlein at al. in progress

c-quark mass from the ABM fit



From the variant of ABM11 fit including the HERA charm data: **H1/ZEUS PLB 718, 550 (2012)**

$m_c(m_c)$=1.15±0.04(exp.) GeV NLO

$m_c(m_c)$=1.24±0.03(exp.),+0.-0.07(th) GeV NNLO

The constant term in the massive NNLO Wilson coefficients is modeled as a linear combination of the options A and B provided by KIPMV

The data prefer option A, the option B is clearly disfavored. The dominant uncertainty in $m_c(m_c)$ at NNLO is due to variation of the massive Wilson coefficients between options A and (A+B)/2

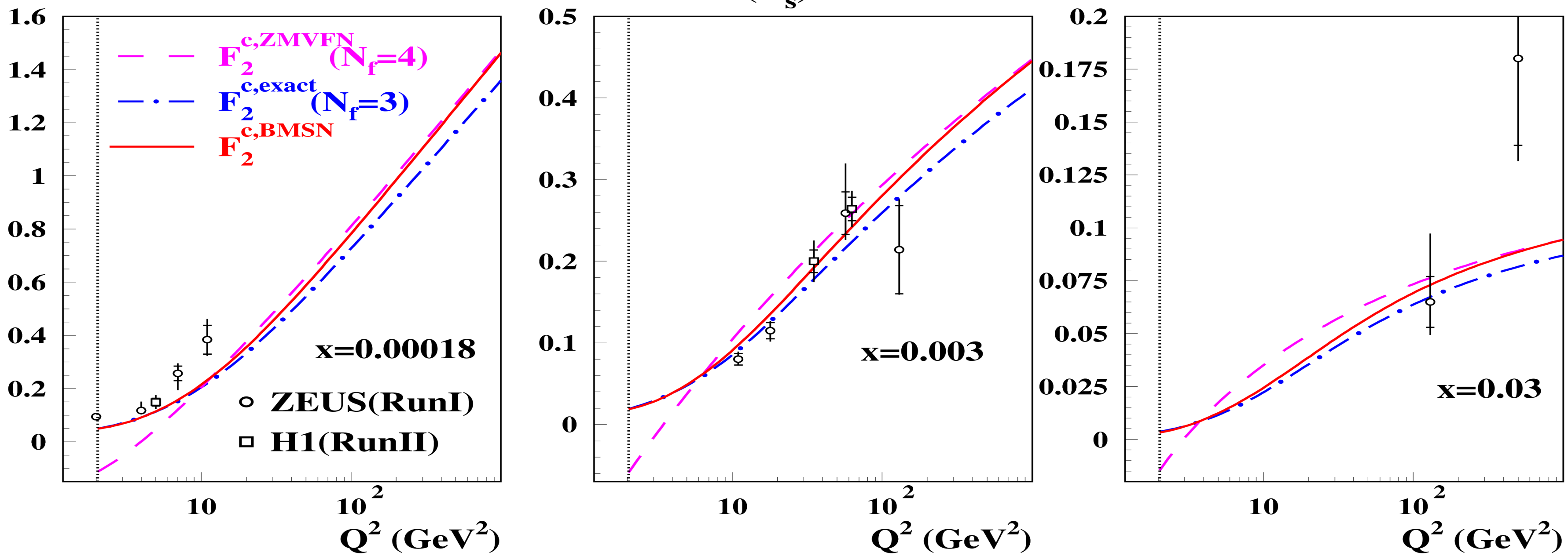
sa, Blümlein, Daum, Lipka, Moch PLB 720, 172 (2013)

BMSN prescription of GMVFNS

Buza, Matiounine, Smith, van Neerven EPJC 1, 301 (1998)

$$F_2^{h,\mathrm{BMSN}}(N_f+1,x,Q^2)=F_2^{h,\mathrm{exact}}(N_f,x,Q^2)+F_2^{h,\mathrm{ZMVFN}}(N_f+1,x,Q^2)-F_2^{h,\mathrm{asymp}}(N_f,x,Q^2)$$

$O(\alpha_s^2)$ Cacciari, Greco, Nason JHEP 9805, 007 (1998)



sa, Blümlein, Klein, Moch PRD 81, 014032 (2010)

- Very smooth matching with the FFNS at $Q \rightarrow m_h$
- Renormgroup invariance is conserved; the PDFs in MSbar scheme

$\alpha_s(M_z)$=0.1135±0.0014 FFN

$\alpha_s(M_z)$=0.1129±0.0014 BMSN

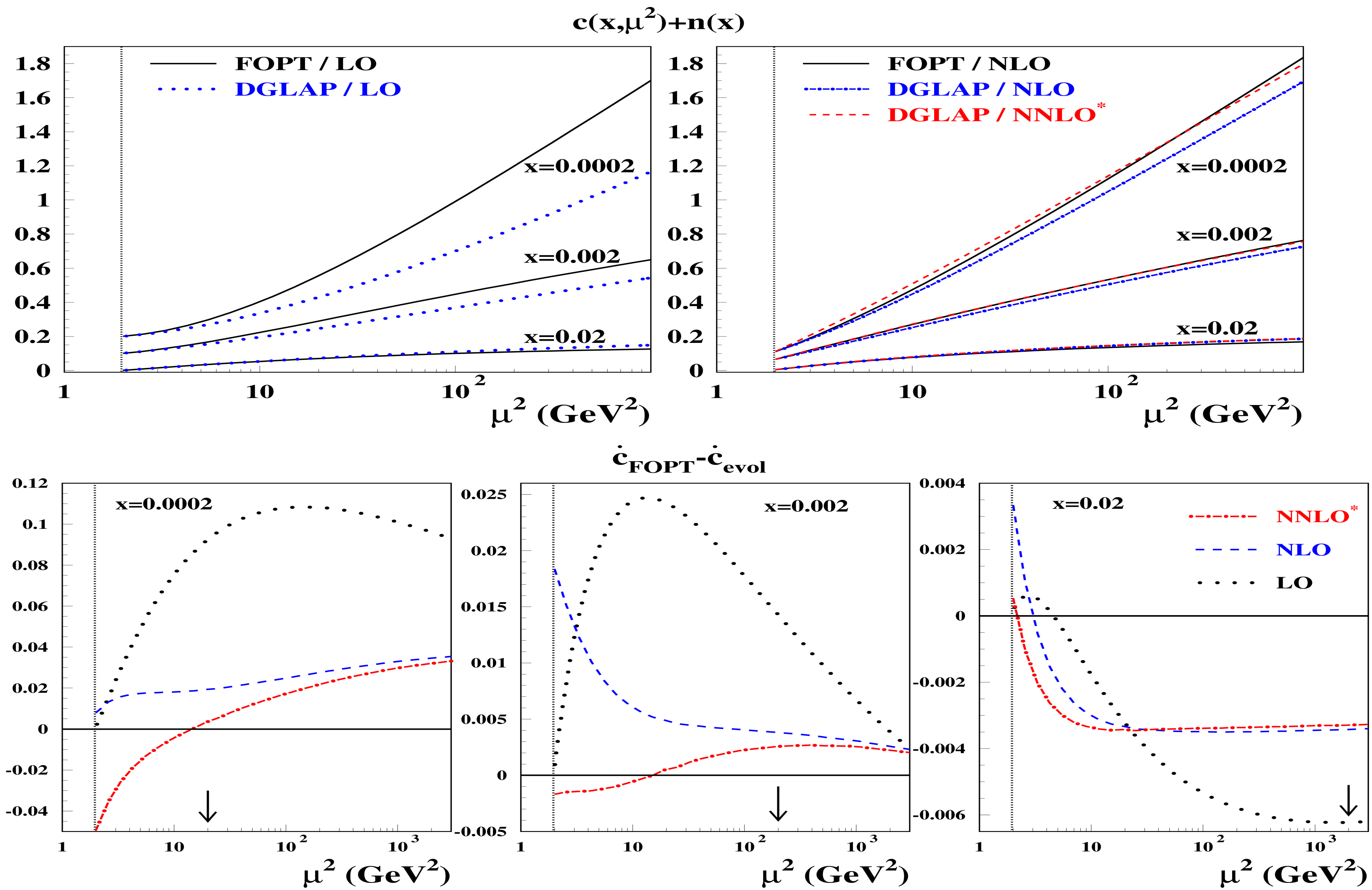
In the $O(\alpha_s^2)$ the FFNS and GMVFNS are comparable at large scales since the big logs appear in the high order corrections to the massive coefficient functions

Glück, Reya, Stratmann NPB 422, 37 (1994)

The big-log resummation is important NNPDF hep-ph/1303.1189

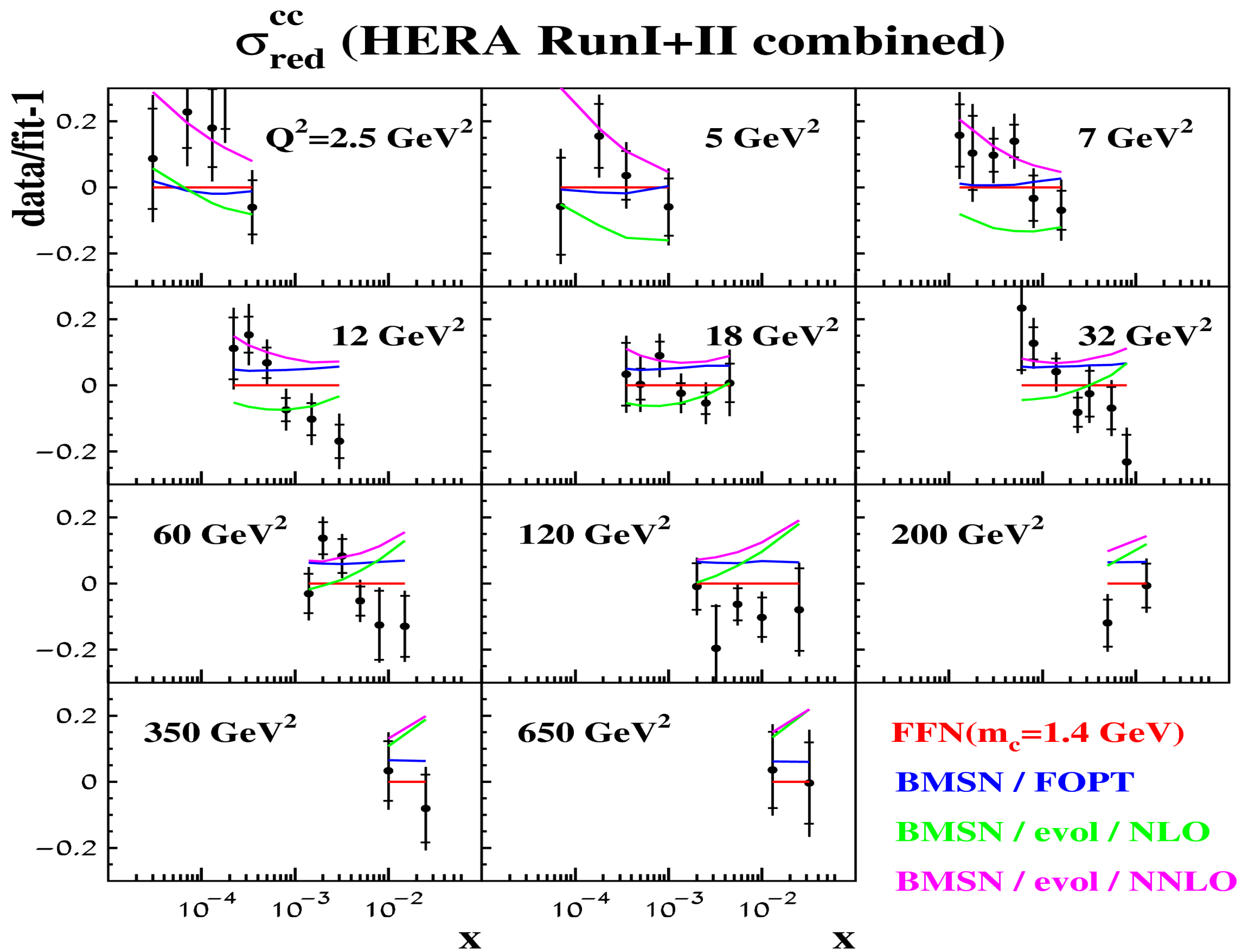
The value of $\alpha_s(M_z)$ is increased in VFN ?? MSTW hep-ph/1402.3526

Comparison of the FOPT and evolved c-quark PDFs



The difference between FOPT and evolved PDFs is localized at small scales: uncertainties due to missing high-orders rather than impact of the big-log resummation

BMSN with the evolved PDFs



- Two variants of 4-flavor PDF evolution
  NNLO (consistent with the light PDF evolution, inconsistent with the NLO matching)
  NLO (inconsistent with the light PDF evolution, consistent with the NLO matching)
- The evolved predictions demonstrate strong x-dependence and weak Q^2-dependence

The difference with FOPT appears rather due to inconsistent evolution than due to big-logs and should be considered as a theoretical uncertainty in the VFN predictions

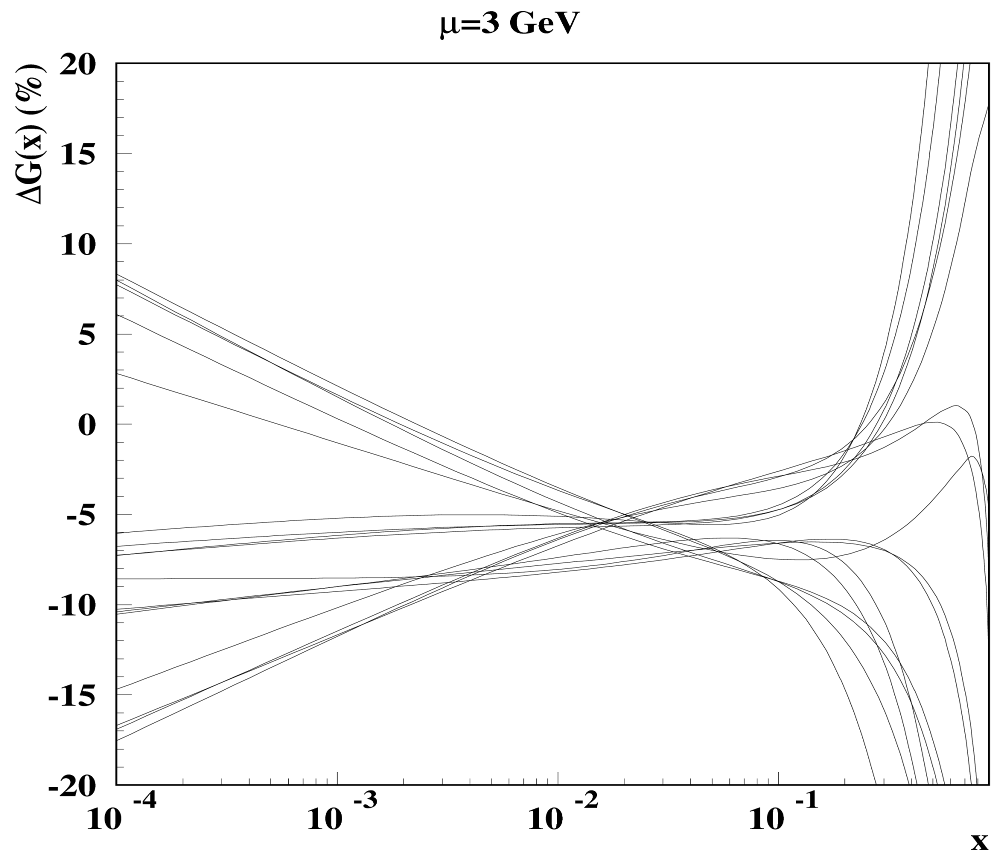
Uncertainties due to m_c and matching point

NLO

m_c (Gev) \ μ_0 (GeV)	1.2	1.3	1.4	1.5
1.2	−0.0006	−0.0007	−0.0007	−0.0010
1.5	+0.0009	+0.0009	+0.0010	+0.0009

NNLO*

m_c (Gev) \ μ_0 (GeV)	1.2	1.3	1.4	1.5
1.2	−0.0007	−0.0006	−0.0006	−0.0005
1.5	−0.0004	−0.0001	−0.0002	+0.0001



Change in $\alpha_s(M_Z)$ due to PDF evolution is -0.0015 ± 0.0010

The uncertainties due to PDF evolution are comparable to experimental ones

“We conclude that the FFN fit is actually based on a less precise theory, in that it does not include full resummation of the contribution of heavy quarks to perturbative PDF evolution, and thus provides a less accurate description of the data.”

NNPDF 13013.1189

- The NNPDF conclusion is wrong: the theoretical uncertainties have not been considered

Gao, Guzzi, Nadolsky hep-ph/1304.3494

- Value of α_s further reduces in the resummed VFN scheme

Further validation

Consistent selection of data for the PDF fit:

- take DIS c.s. instead of structure functions → correct estimate of the high-twist terms; consolidation of the α_s value

- the jet data should not be used in the NNLO PDF fits → theory uncertainty out of control

Theory improvements:

- the NNLO corrections to the jet production → additional constraint on α_s

- the NNLO massive Wilson coefficients for DIS → reduced uncertainty in m_c

Avoid using results based on the VFN scheme because of the additional theory uncertainties

Extras

The ABM fit ingredients

DATA:

- DIS NC inclusive (Q^2>1000 GeV^2)
- DIS charm production (determination of $m_c(m_c)$)
- DIS μμ CC production
- fixed-target DY
- LHC DY distributions
- t-quark production c.s.

QCD:

- NNLO evolution
- NNLO massless DIS and DY coefficient functions (Z- and Z-γ terms)
- NLO+ massive DIS coefficient functions (**FFN scheme**)
  - (NLO + NNLO threshold corrections, running mass)
- NNLO exclusive DY (DYNNLO 1.3 / FEWZ 3.1)
- NNLO inclusive ttbar production (pole / running mass)

Deuteron corrections in DIS:

- Fermi motion
- off-shell effects

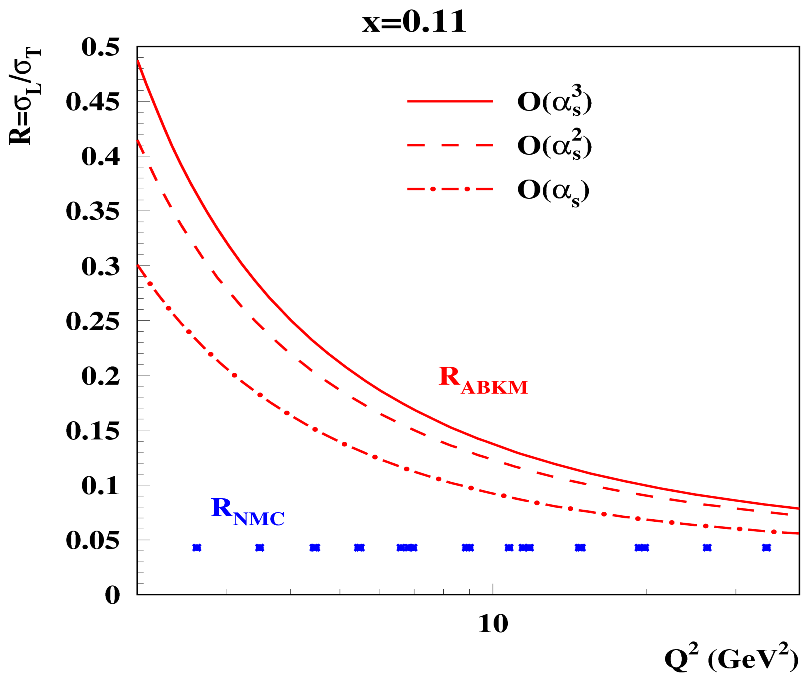
Power corrections in DIS:

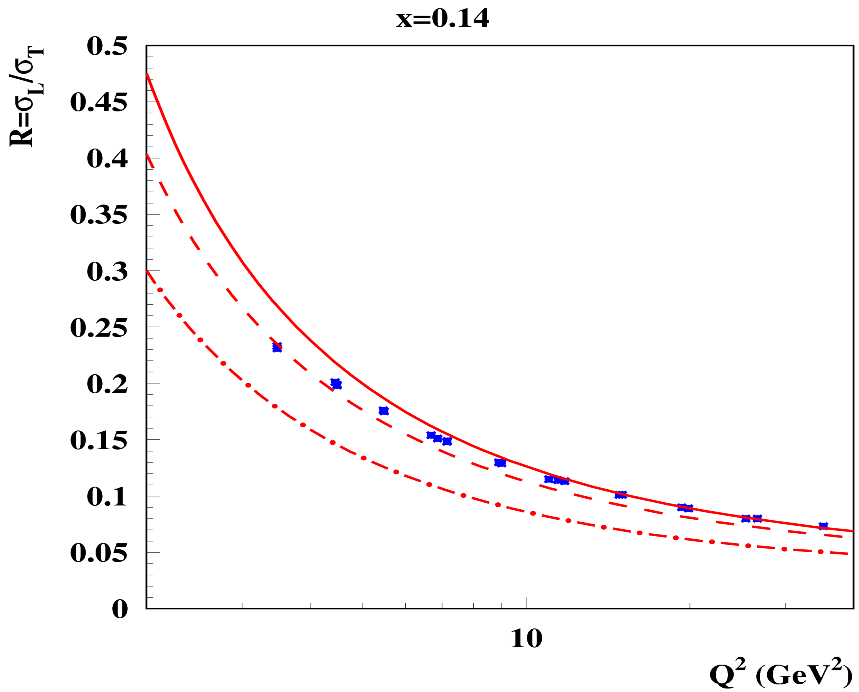
- target mass effects
- dynamical twist-4 terms

The jet data are still not included: The NNLO corrections may be as big as 15-20%

Gehrmann-De Ridder, Gehrmann, Glover, Pires JHEP 1302, 026 (2013)

Value of R and α_s from the NMC data



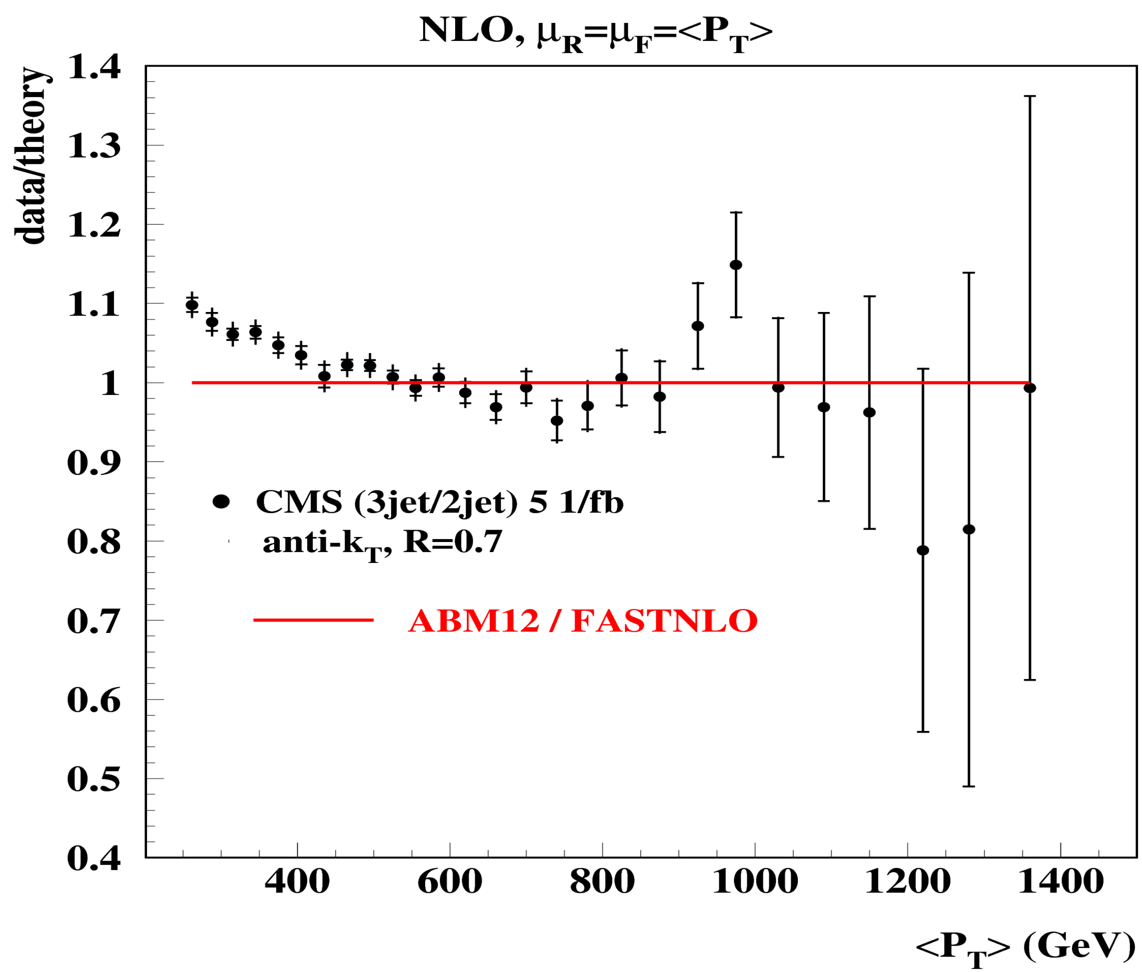


sa, Blümlein, Moch EPJC 71, 1723 (2011)

$\alpha_s(M_Z)$	$\alpha_s(M_Z)$ with $\sigma_{\rm NMC}$	$\alpha_s(M_Z)$ with $F_2^{\rm NMC}$	difference
NLO	0.1179(16)	0.1195(17)	$+0.0016 \simeq 1\sigma$
NNLO	**0.1135(14)**	0.1170(15)	$+0.0035 \simeq 2.3\sigma$
NNLO $+F_L$ at $O(\alpha_s{}^3)$	0.1122(14)	0.1171(14)	$+0.0050 \simeq 3.6\sigma$

- With a smooth model of R the value of α_s is smaller
- Effect rises from NLO to NNLO

CMS jets in ABM fit



CMS hep-ex/1304.7498

P_T(GeV) >	500	400	300	NLO ABM12
$\alpha_s(M_Z)$	0.1181(10)	0.1200(9)	0.1220(9)	0.1179(11)

The discrepancies are localized at small PT: NNLO corrections? scale choice?