ABM news and benchmarks

S.Alekhin (*IHEP Protvino & DESY-Zeuthen)*

- LHC Drell-Yan data in the ABM fit
- Impact of the ttbar production data on the PDFs and α_s
- Theoretical errors in the VFN and FFN schemes

sa, Blümlein, Moch hep-ph/1303.1073

sa, Blümlein, Moch hep-ph/1302.1516

PDF4LHC meeting, CERN, 17 Mar 2013

The ABM12 fit ingredients

DATA:

- DIS NC inclusive
- DIS charm production (determination of $m_c(m_c)$)
- DIS μμ CC production
- fixed-target DY
- LHC DY
- t-quark production c.s.

QCD:

- NNLO evolution
- NNLO massless DIS and DY coefficient functions
- 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

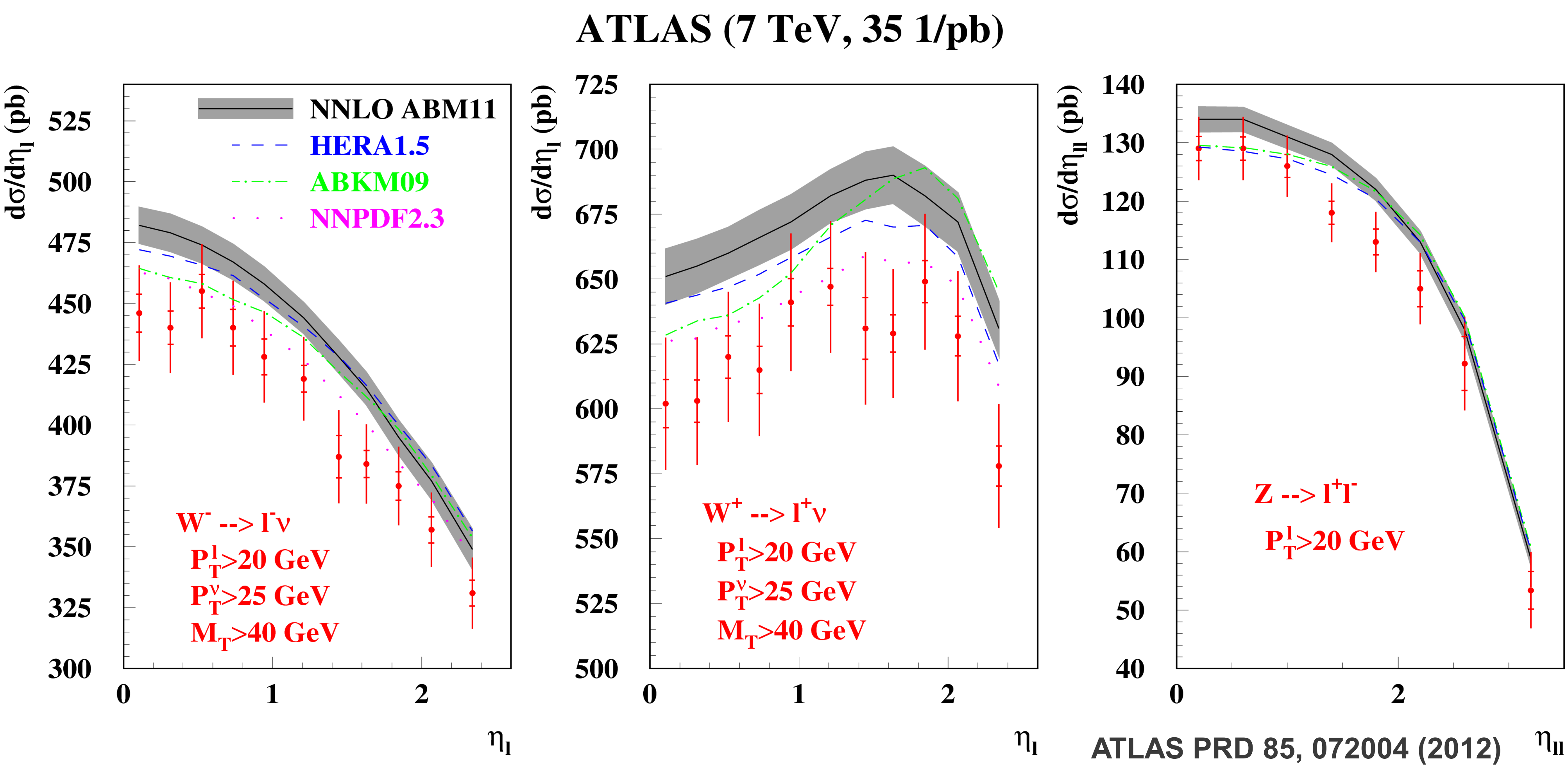
Power corrections in DIS:

- 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)

NNLO Drell-Yan codes



ATLAS PRD 85, 072004 (2012)

- DYNNLO 1.3 provides better numerical stability for the W-production in central region ~ 200h

  Catani, Cieri, Ferrera, de Florian, Grazzini PRL 103, 082001 (2009)

- FEWZ 3.1 more convenient/stable for estimation of the PDF uncertainties ~ 2d x 24 processors

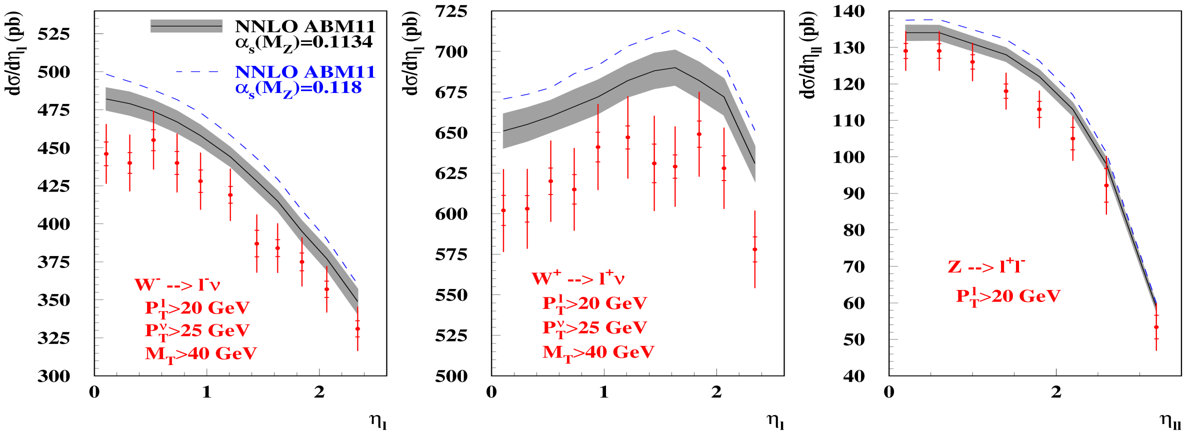
  Li, Petriello PRD 86, 094034 (2012)

→ *central values are computed with DYNNLO and the PDF errors are obtained with FEWZ*

Benchmark of ABM11with LHC Drell-Yan data

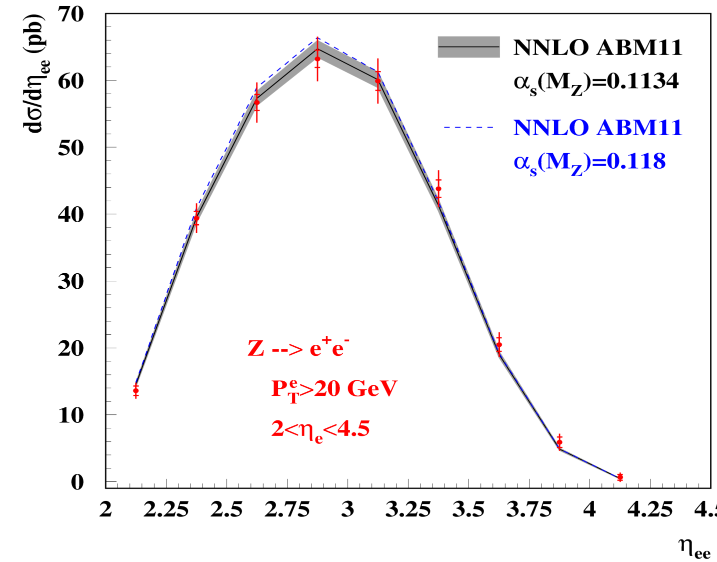
sa, Blümlein, Moch hep-ph/1302.1516

ATLAS (7 TeV, 35 1/pb)



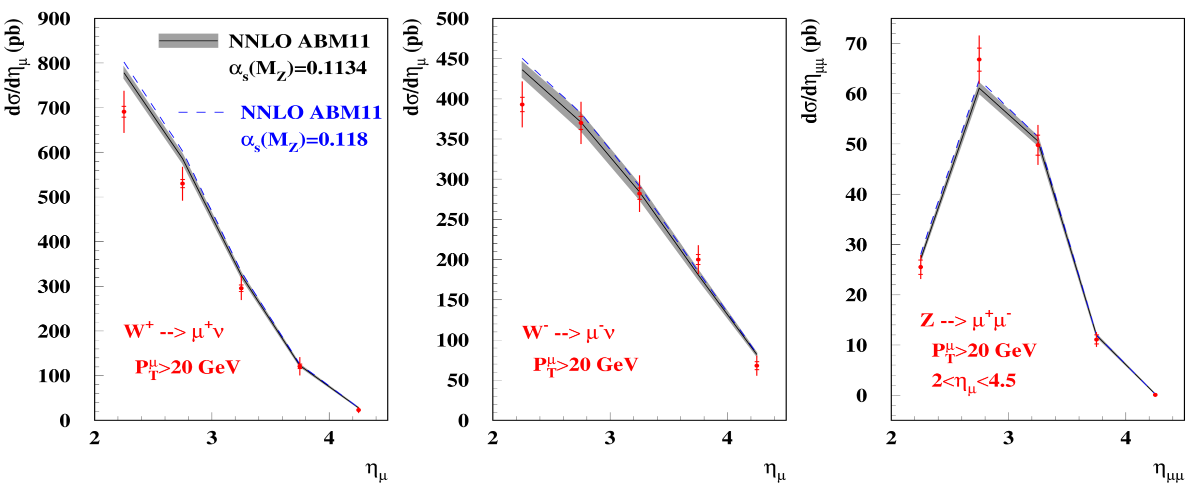
ATLAS PRD 85, 072004 (2012)

LHCb (7 TeV, 940 1/pb)



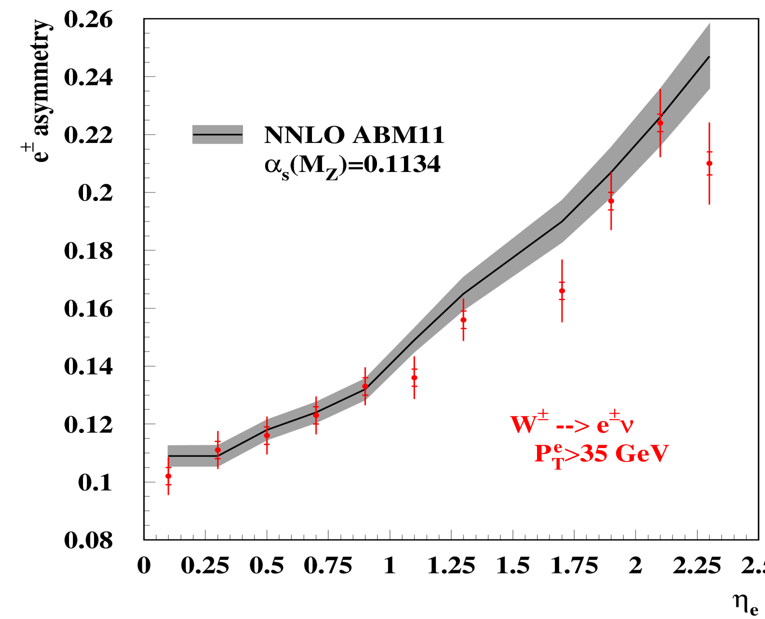
LHCb JHEP 1302, 106 (2013)

LHCb (7 TeV, 37 1/pb)



LHCb JHEP 1206, 058 (2012)

CMS (7 TeV, 840 1/pb)



CMS PRL 109, 111806 (2010)

- Good overall agreement
- Some tension between data in places:
  - ATLAS data go above recent LHCb e+e- data

NNLO DY corrections in the fit

The (N)NLO calculations are quite time-consuming → fast tools are employed (FASTNLO, Applegrid,.....)

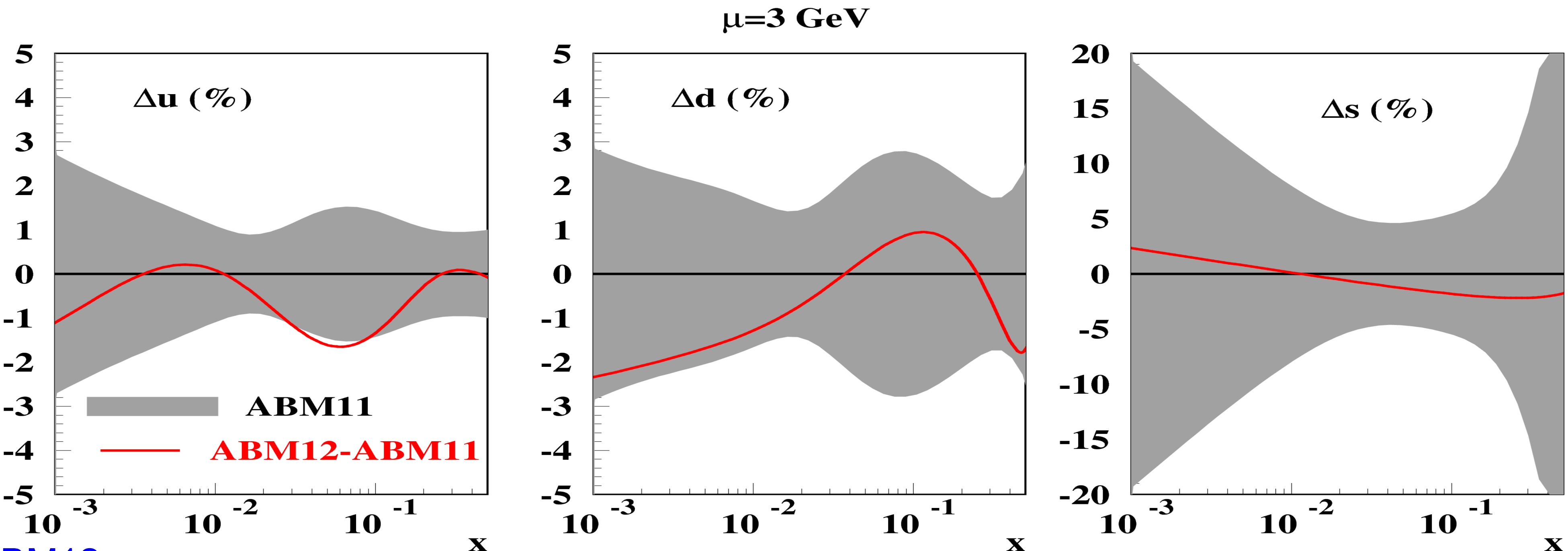
- the corrections for certain basis of PDFs are stored in the grid
- the fitted PDFs are expanded over the basis
- the NNLO c.s. in the PDF fit is calculated as a combination of expansion coefficients with the pre-prepared grids

The general PDF basis is not necessary since the PDFs are already constrained by the data, which do not require involved computations → *use as a PDF basis the eigenvalue PDF sets obtained in the earlier version of the fit*

$\mathbf{P_0} \pm \Delta\mathbf{P}_0$ – vector of PDF parameters with errors obtained in the earlier fit
E – error matrix
P – current value of the PDF parameters in the fit

- store the DY NNLO c.s. for all PDF sets defined by the eigenvectors of **E**
- the variation of the fitted PDF parameters ($\mathbf{P} - \mathbf{P}_0$) is transformed into this eigenvector basis
- the NNLO c.s. in the PDF fit is calculated as a combination of transformed ($\mathbf{P} - \mathbf{P}_0$) with the stored eigenvector values

Impact of the LHC DY data on the PDFs



ABM12:

- -- LHC DY data
- -- HERA charm production data
- – inclusive HERA data at Q^2>1000 GeV^2

Moderate change of quarks due to LHC DY data; strange sea is stable

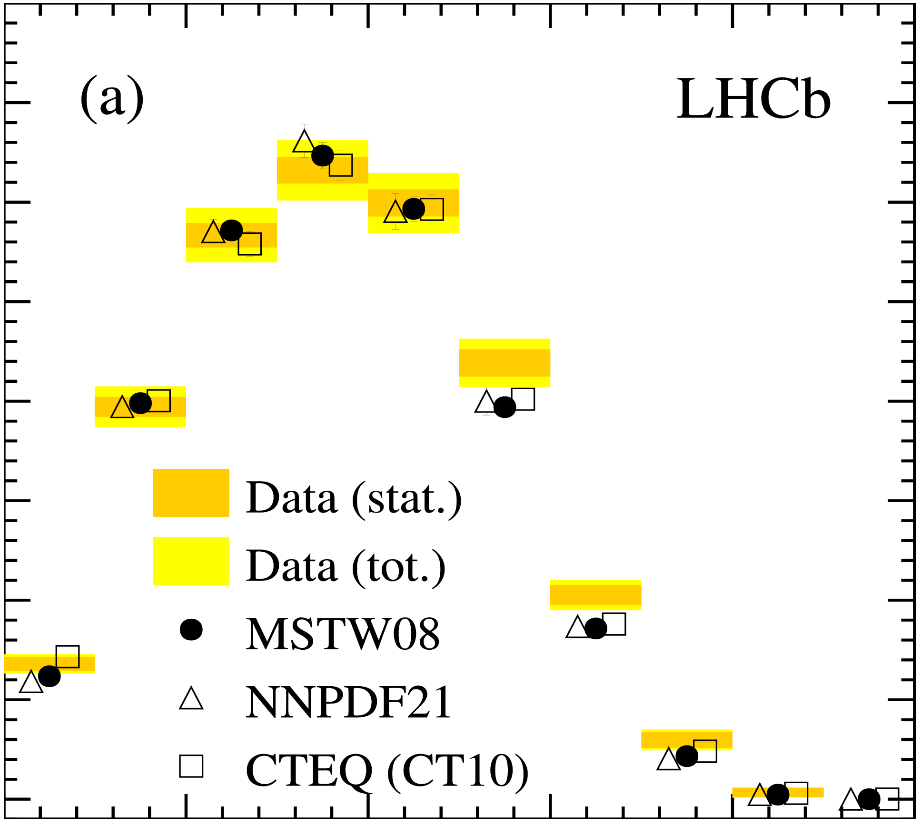
Experiment	ATLAS	CMS	LHCb	LHCb
Final states	$W^+ \to l^+\nu$ $W^- \to l^-\nu$ $Z \to l^+l^-$	$W^+ \to e^+\nu$ $W^- \to e^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$Z \to e^+e^-$
Luminosity (1/pb)	35	840	37	940
NDP	30	11	10	9
$\chi^2(ABM11)$	35.7(7.7)	10.6(4.7)	13.1(4.5)	11.3(4.2)
$\chi^2(ABM12)$	31.4	10.6	14.8	11.2

The benchmarking of ABM11 in 1211.5142 is wrong: the values of χ^2 are bigger than ours by factor of 1.5-2

- – NLO MCFM with K-factors
- – no PDF errors
- – shifted α_s

We recommend to use in comparisons the ABM11 predictions attached to hep-ph/1302.1516

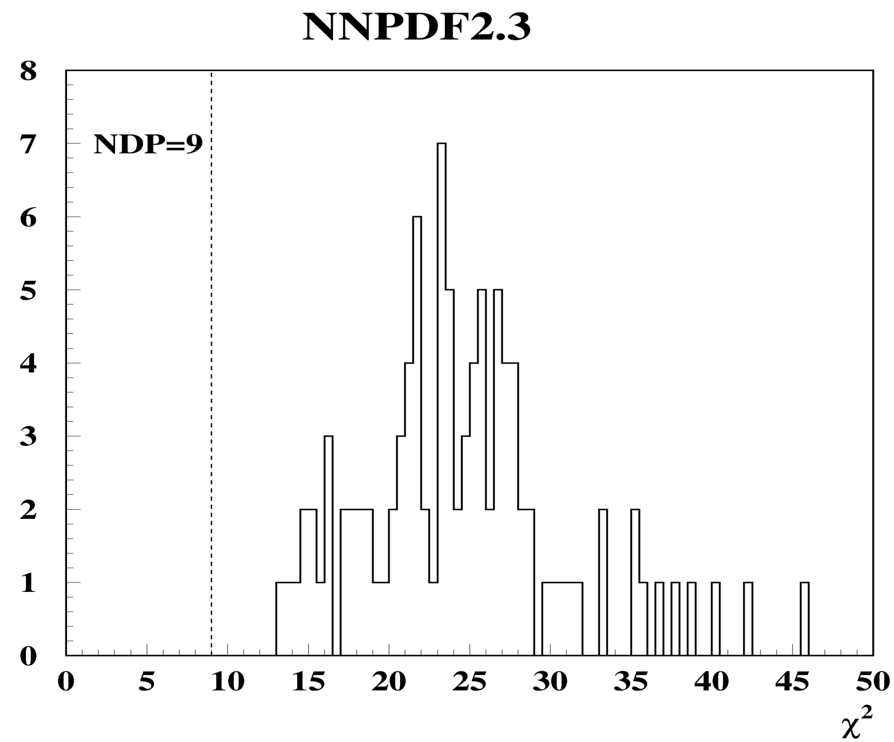
PDF benchmarking with LHC data (update)



LHCb JHEP 1302, 106 (2013)

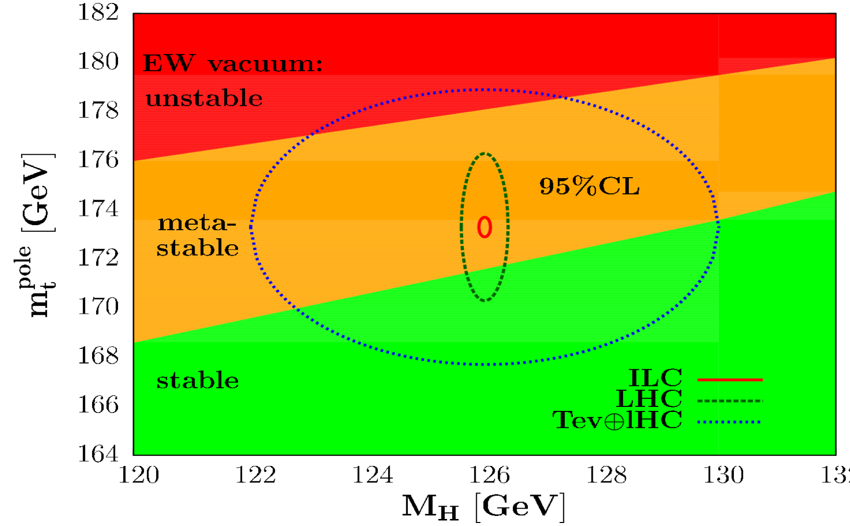
Value of χ^2 for 9 points:

- MSTW08: 27.6
- NNPDF23: 24.6 (average)
- CT10: 9.8
- ABM11: 11.3



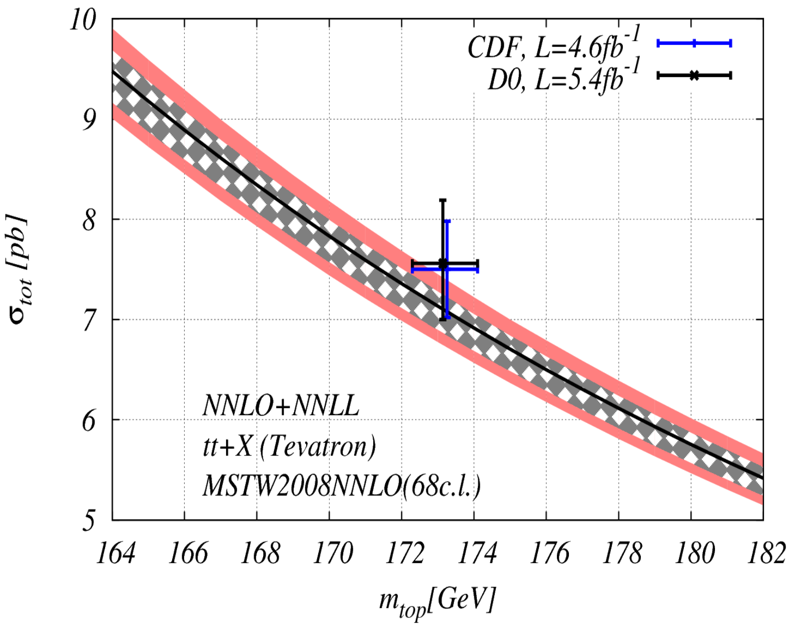
t-quark mass

- m_t(MC)=173.3±1 GeV (Tevatron/LHC)
- m_t(pole)≈ m_t(MC) - 1 GeV
- $m_t(m_t)$≈ m_t(pole) - 9 GeV



Vacuum stability condition requires m_t(pole)~171 GeV

sa, Djouadi, Moch PLB 716, 214 (2012)



CDF&D0	ABM11	JR09	MSTW08	NN21
$m_t^{\overline{MS}}(m_t)$	$162.0^{+2.3}_{-2.3}{}^{+0.7}_{-0.6}$	$163.5^{+2.2}_{-2.2}{}^{+0.6}_{-0.2}$	$163.2^{+2.2}_{-2.2}{}^{+0.7}_{-0.8}$	$164.4^{+2.2}_{-2.2}{}^{+0.8}_{-0.2}$
m_t^{pole}	$171.7^{+2.4}_{-2.4}{}^{+0.7}_{-0.6}$	$173.3^{+2.3}_{-2.3}{}^{+0.7}_{-0.2}$	$173.4^{+2.3}_{-2.3}{}^{+0.8}_{-0.8}$	$174.9^{+2.3}_{-2.3}{}^{+0.8}_{-0.3}$
(m_t^{pole})	$(169.9^{+2.4}_{-2.4}{}^{+1.2}_{-1.6})$	$(171.4^{+2.3}_{-2.3}{}^{+1.2}_{-1.1})$	$(171.3^{+2.3}_{-2.3}{}^{+1.4}_{-1.8})$	$(172.7^{+2.3}_{-2.3}{}^{+1.4}_{-1.2})$

Bärnreuther, Czakon, Mitov hep-ph/1204.5201

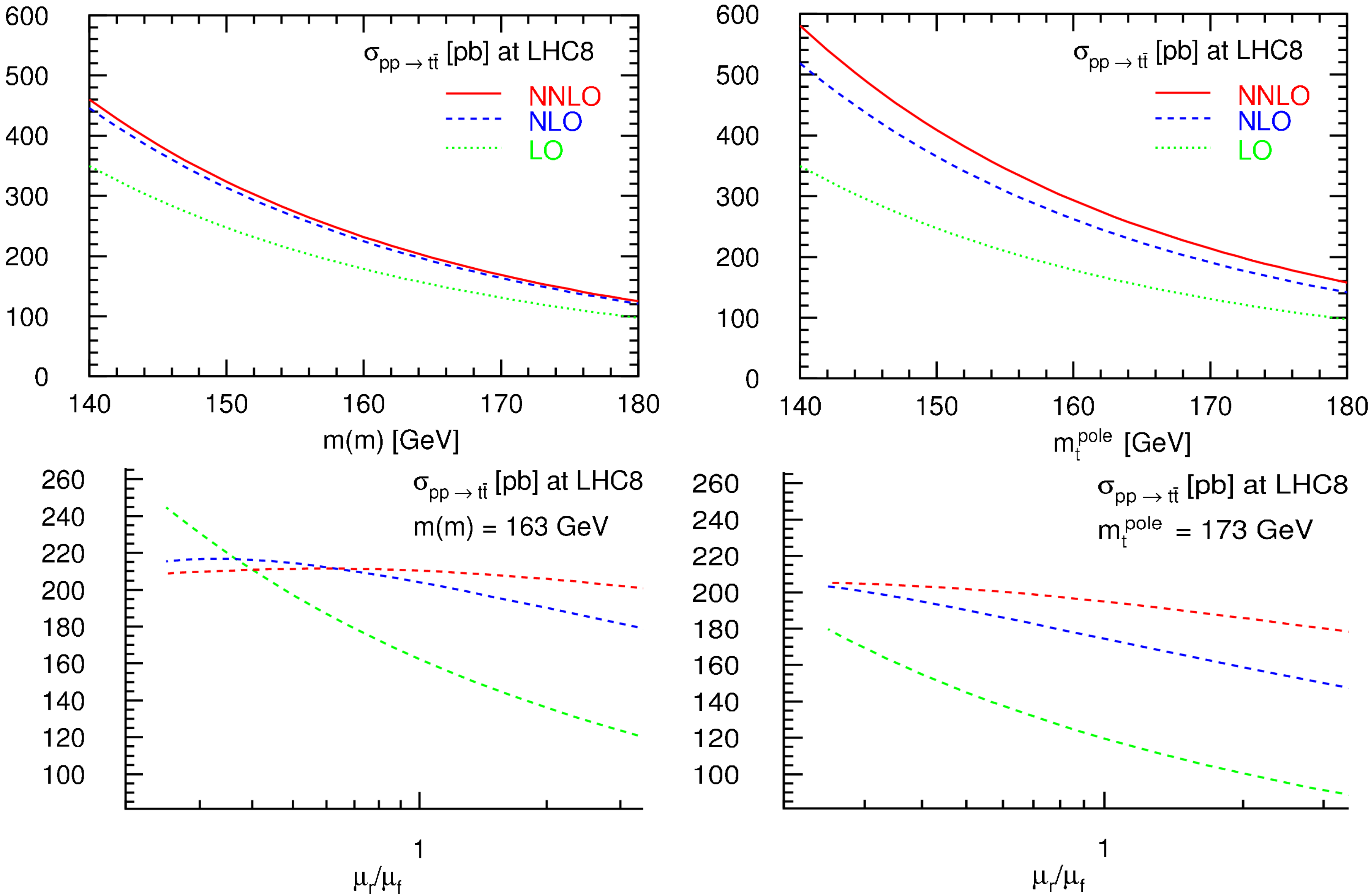
From the Tevatron c.s. m_t(pole)~171 GeV

ATLAS&CMS	ABM11	JR09	MSTW08	NN21
$m_t^{\overline{MS}}(m_t)$	$159.0^{+2.1}_{-2.0}{}^{+0.7}_{-1.4}$	$165.3^{+2.3}_{-2.2}{}^{+0.6}_{-1.2}$	$166.0^{+2.3}_{-2.2}{}^{+0.7}_{-1.5}$	$166.7^{+2.3}_{-2.2}{}^{+0.8}_{-1.3}$
m_t^{pole}	$168.6^{+2.3}_{-2.2}{}^{+0.7}_{-1.5}$	$175.1^{+2.4}_{-2.3}{}^{+0.6}_{-1.3}$	$176.4^{+2.4}_{-2.3}{}^{+0.8}_{-1.6}$	$177.4^{+2.4}_{-2.3}{}^{+0.8}_{-1.4}$
(m_t^{pole})	$(166.1^{+2.2}_{-2.1}{}^{+1.7}_{-2.3})$	$(172.6^{+2.4}_{-2.3}{}^{+1.6}_{-2.1})$	$(173.5^{+2.4}_{-2.3}{}^{+1.8}_{-2.5})$	$(174.5^{+2.4}_{-2.3}{}^{+2.0}_{-2.3})$

Stronger correlation between m_t, PDFs and α_s at LHC

Pole- and running-mass definitions

Running mass Pole mass



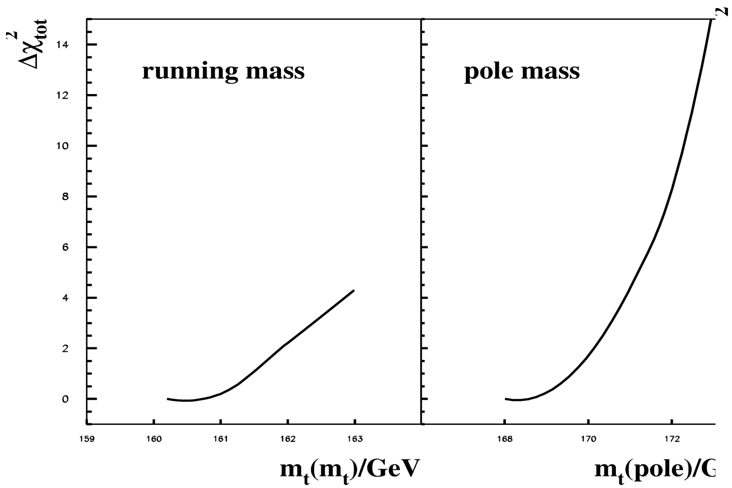
HATTOR (NNLO terms are checked with TOP++)

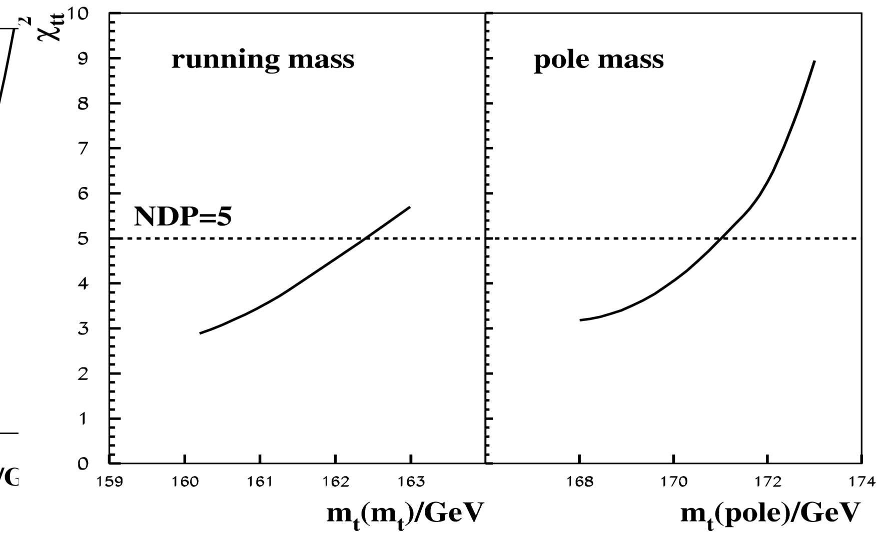
Langenfeld, Moch, Uwer PRD 80, 054009 (2009)

Czakon, Fiedler, Mitov hep-ph/1303.6254

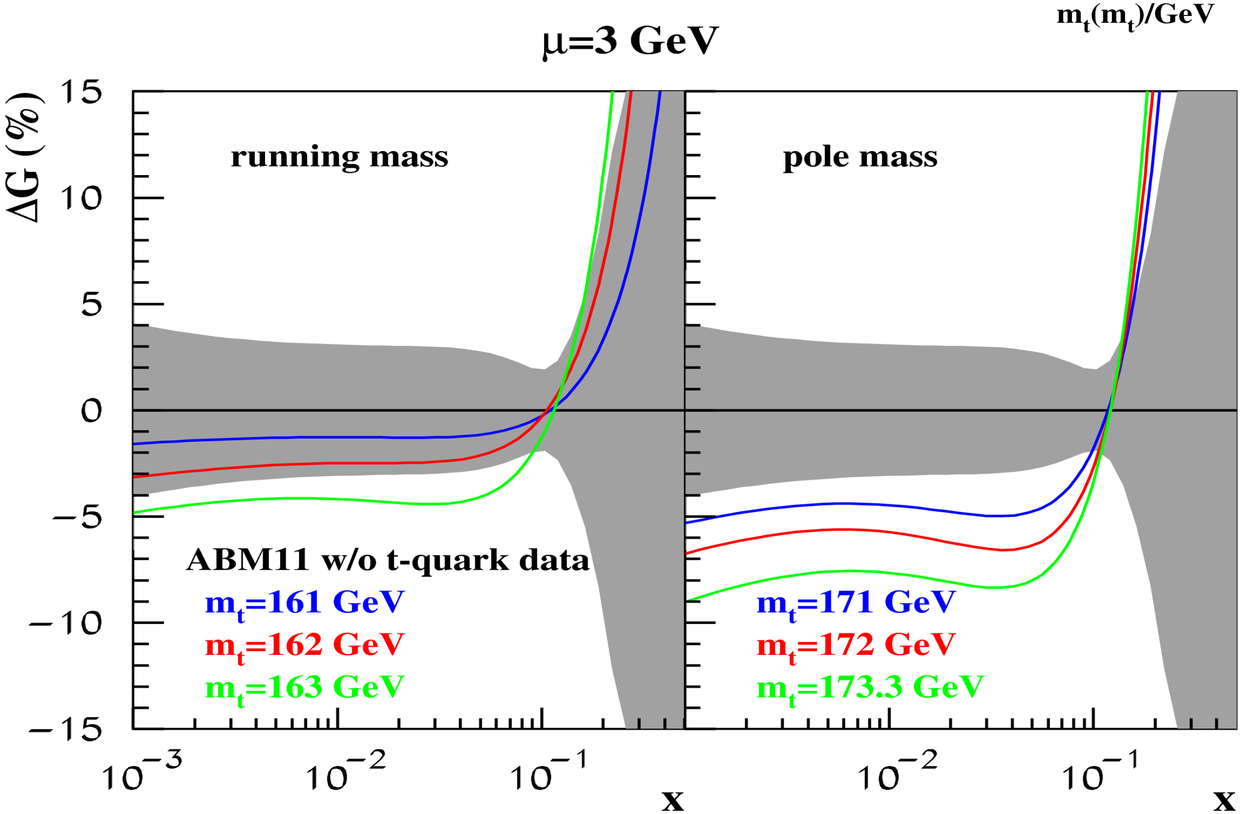
Running mass definition provides nice perturbative stability

Impact of the t-quark data on PDFs and α_s





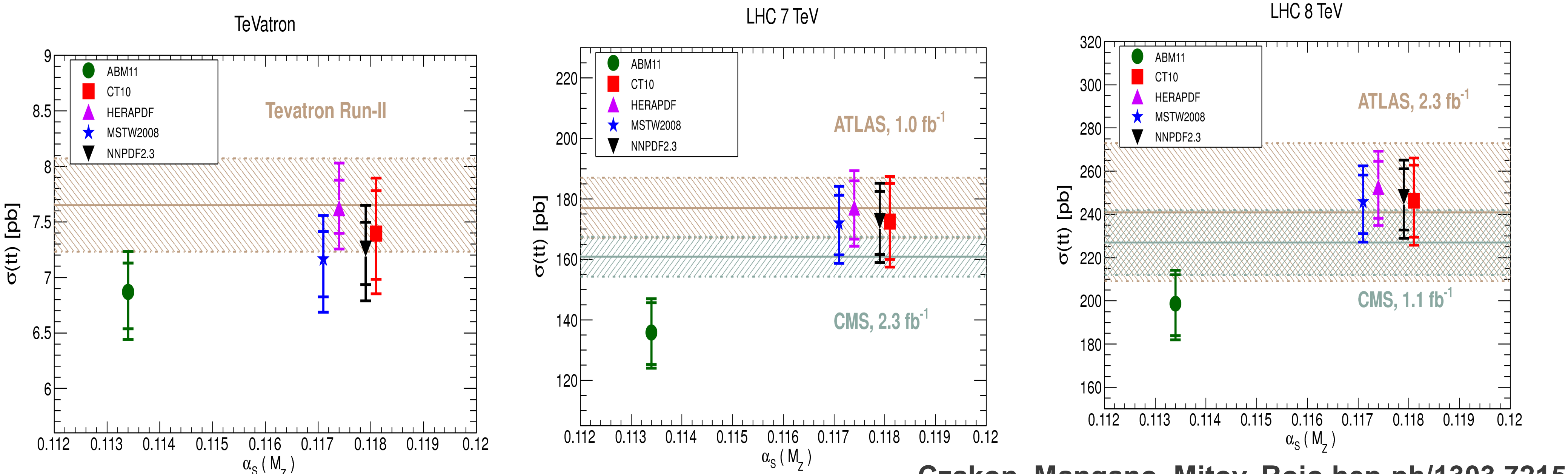
CMS-PAS-TOP-12-003
CMS-PAS-TOP-12-006
ATLAS-CONF-2012-149
CMS JHEP 122, 067 (2012)
ATLAS-CONF-2012-024
D0 Note 6363



- Steeper χ^2 profile for the pole-mass definition → bigger impact of the t-quark data
- For the running-mass definition the change in PDFs is within uncertainties

$\alpha_s(M_z)$ 0.1138 – 0.1149 0.1155 – 0.1162

Benchmarking of ABM11 PDFs with t-quark data



Czakon, Mangano, Mitov, Rojo hep-ph/1303.7215

The value of χ^2 is 40 for the ABM11 PDFs?? – computed without account of the PDF uncertainties and with m_t(pole)=m_t(MC)=173.3 GeV

ABM11 χ^2 with account of the PDF uncertainties (NDP=5)

+ m_t(pole)=172 / 171 GeV	17.4 / 12.5
or $m_t(m_t)$=163 / 162 GeV	10.6 / 7.0

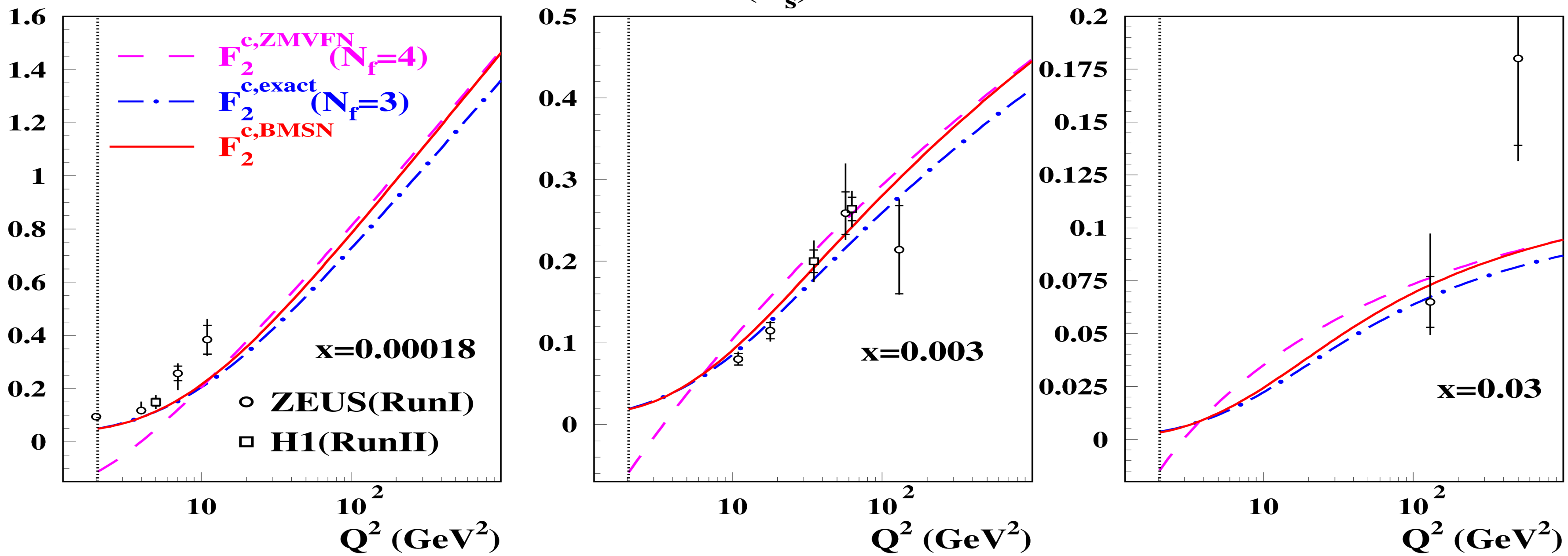
- *The error correlations are missing*
- *The LHC c.m.s. energy unc. may have impact on χ^2: 1% beam energy unc. → 3% c.s. unc.*

BMSN prescription

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)

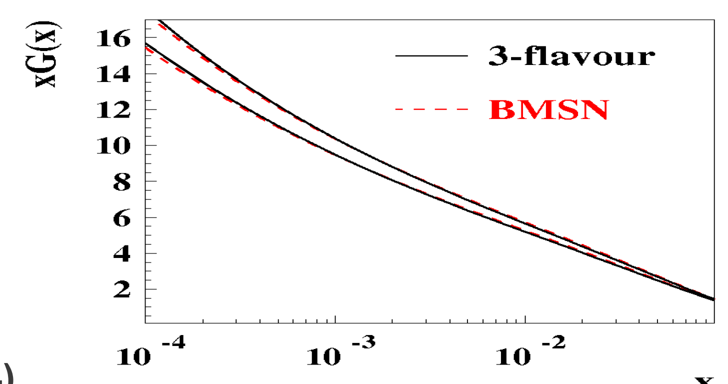


sa, Blümlein, Klein, Moch PRD 81, 014032 (2010)

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

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)



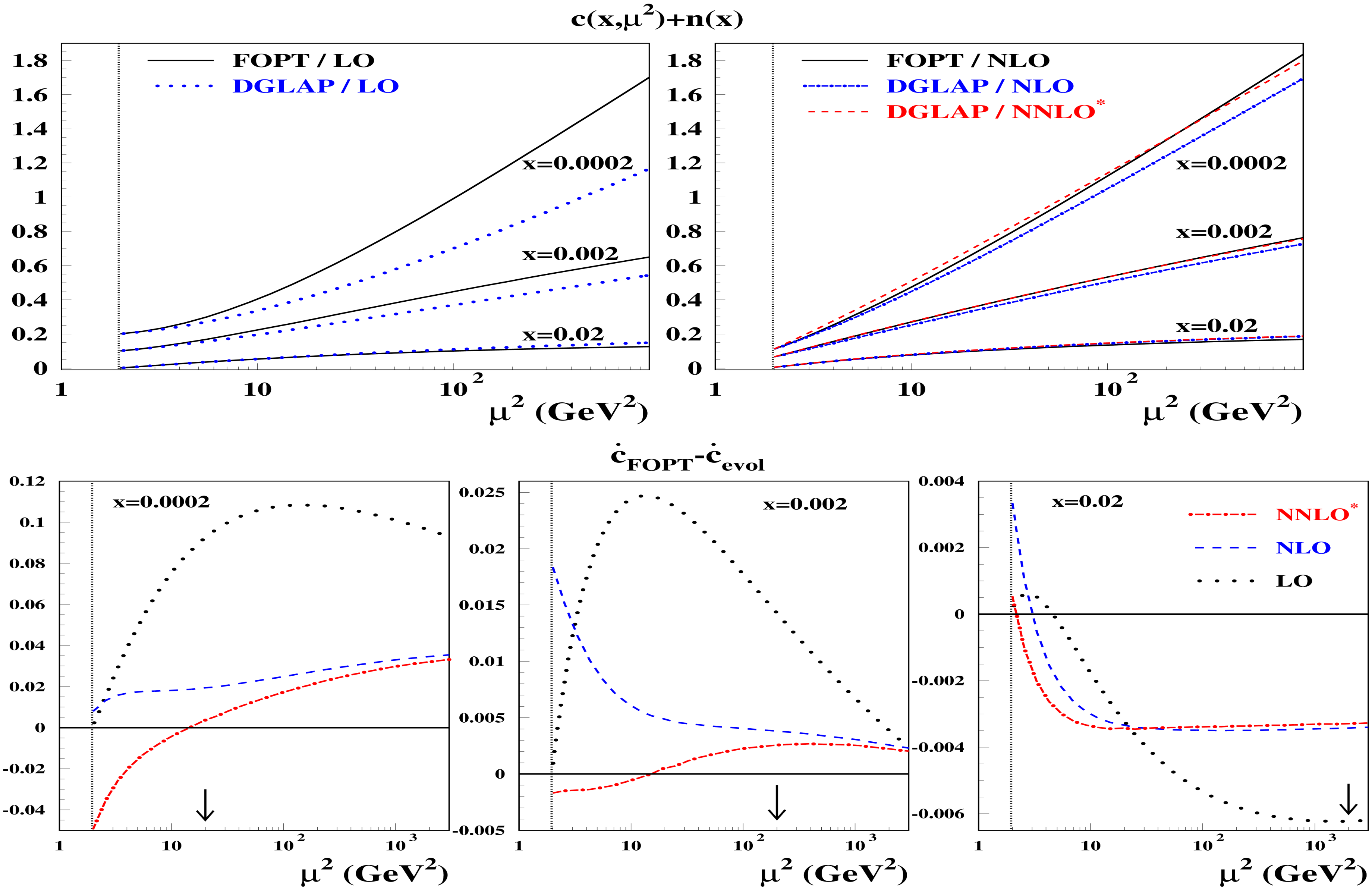
The big-log resummation is important NNPDF

The value of $\alpha_s(M_z)$ is reduced in FFN MSTW

$\alpha_s(M_z)=0.1135\pm0.0014$ FFN

$\alpha_s(M_z)=0.1129\pm0.0014$ BMSN

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

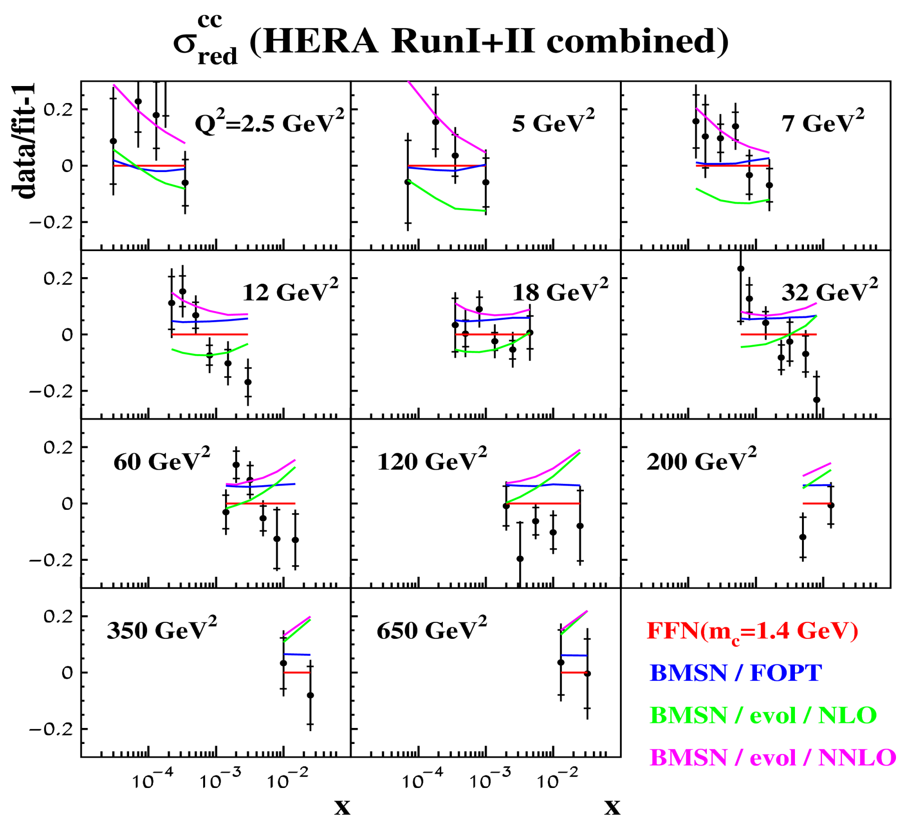
Blümlein, Riemersma, Botje, Pascaud, Zomer, van Neerven, Vogt hep-ph/9609400

BMSN with the evolved PDFs

- Combined HERA charm production data

H1/ZEUS PLB 718, 550 (2012)

- PDFs from variant of ABM11 fit with m_c=1.4 GeV (pole mass definition), option A of NNLO W.coef.



- Two variants of 4-flavor PDF evolution

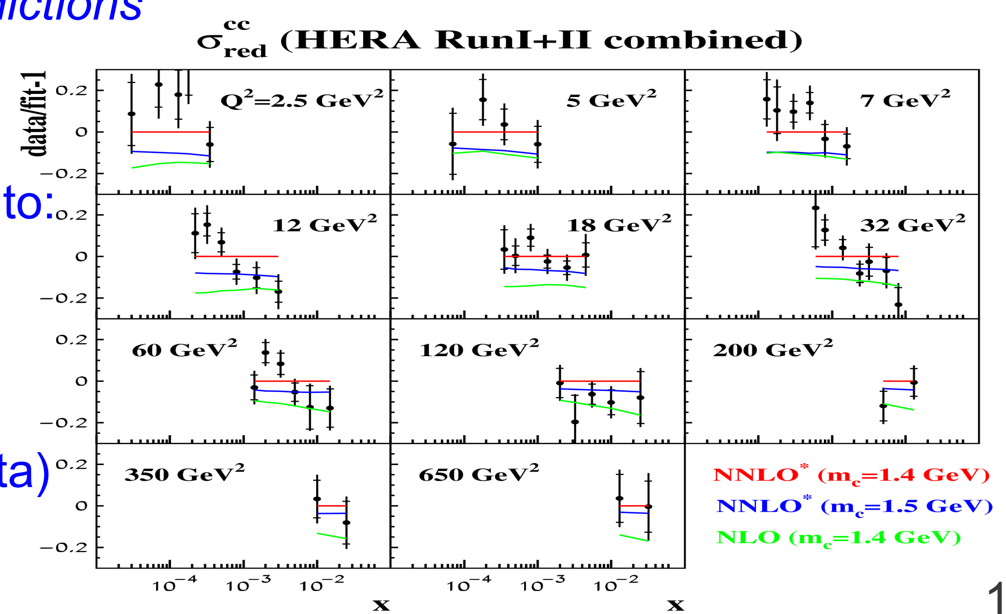
  NNLO (consistent with the light PDF evolution, inconsistent with the NLO matching) **

  NLO (inconsistent with the light PDF evolution, consistent with the NLO matching)

  ** commonly used in the VFN fits

- Substantial difference between NLO and NNLO versions
- 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 → should be considered as a theoretical uncertainty in the VFN predictions



For the FFN scheme basic uncertainties are due to:

- incomplete NNLO terms in the massive Wilson coefficients
- the c-quark mass variation (marginal if fitted to the data and/or constrained from e+e- data)

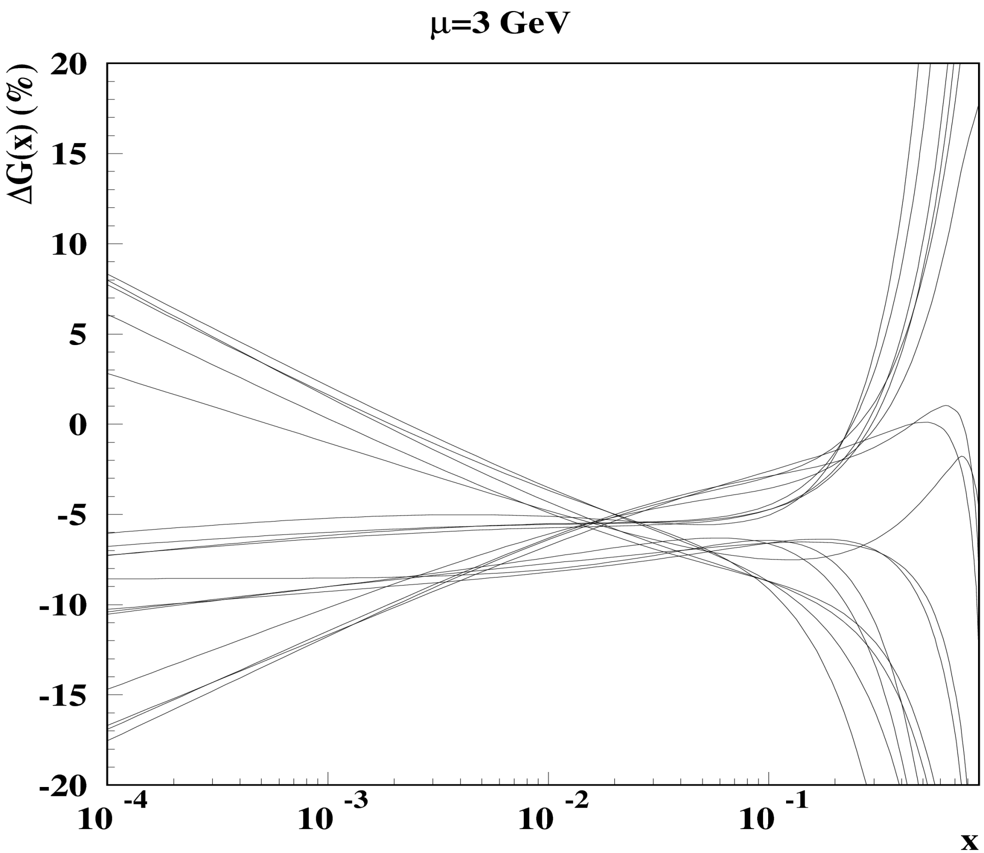
Uncertainties due to m_c and matching point μ_0

NLO

μ_0 (GeV) / m_c (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*

μ_0 (GeV) / m_c (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

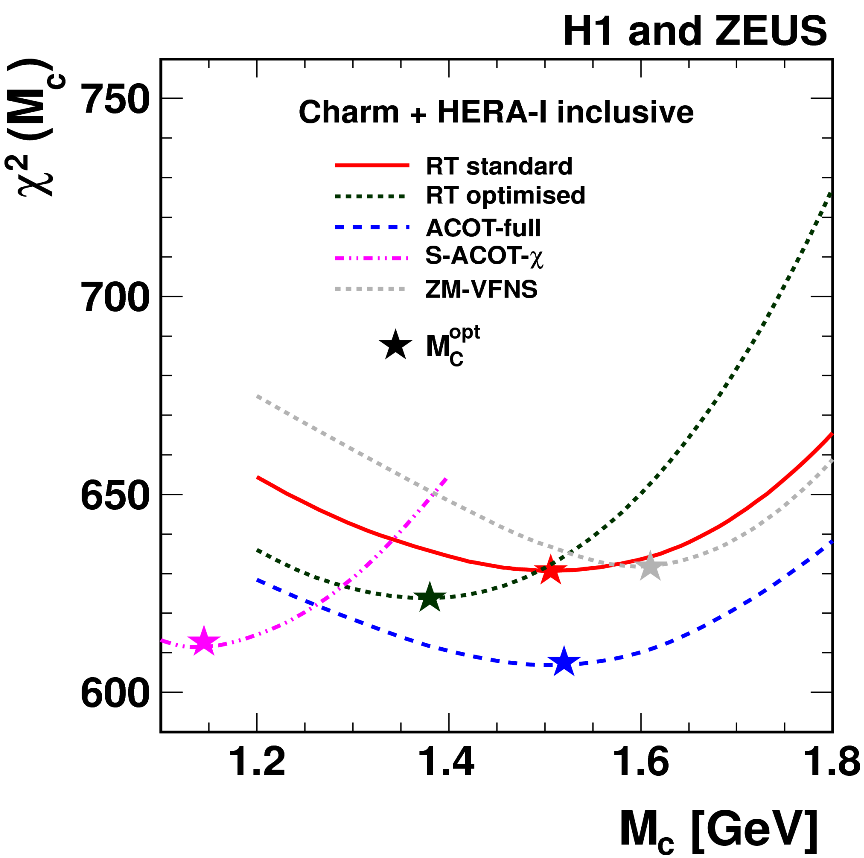
The GMVFN uncertainties due to PDF evolution are comparable to the total uncertainty in α_s

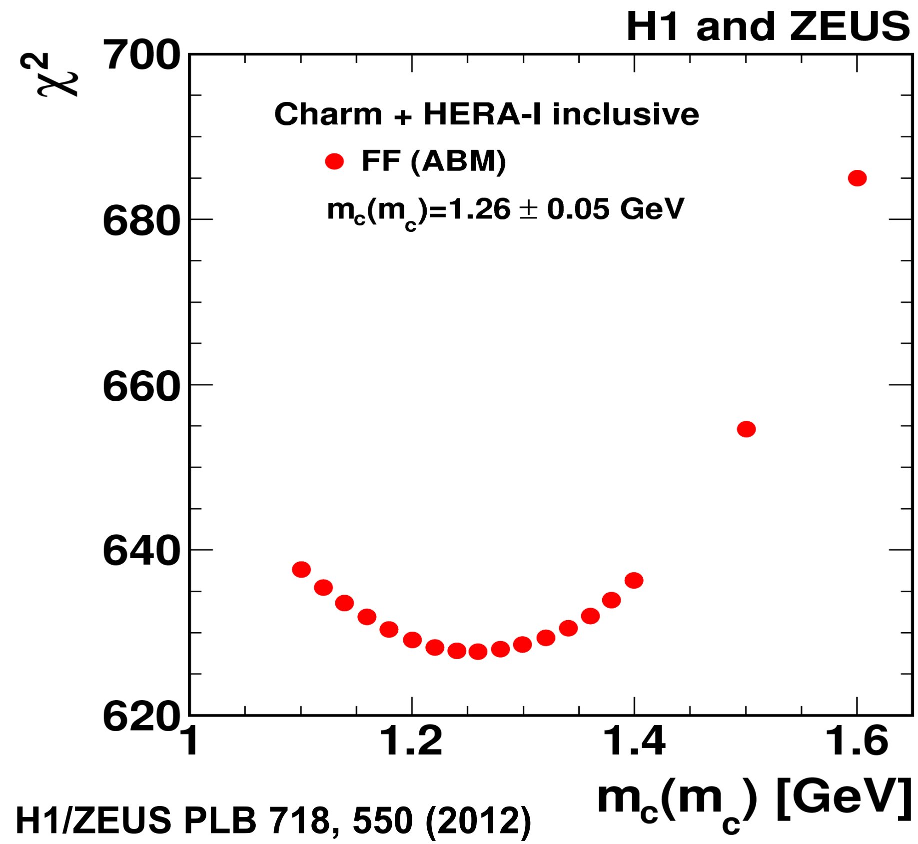
"We conclude that the FFN fit is actually based on a less precise theory, in that it does not include full resummation of the contribution of heavy quarks to perturbative PDF evolution, and thus provides a less accurate description of the data." **NNPDF 13013.1189**

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

Gao, Guzzi, Nadolsky hep-ph/1304.3494

Statistical check of the FFNS and VFNS





H1/ZEUS PLB 718, 550 (2012)

- *In the NNPDF fit the FFNS value of χ^2 for the FFNS is bigger than VFNS one by 77/592 for the HERA-I inclusive data (combined HERA charm data are not considered)*

- No significant difference in the description quality between VFNS and FFNS is observed in the HERAPDF analysis
- In the variants of ABM fit with different versions of BMSN the value of χ^2 is worse by some 20/608 for the HERA-I inclusive data
- A detailed benchmarking is difficult since the NNPDF code is not publicly available

Summary

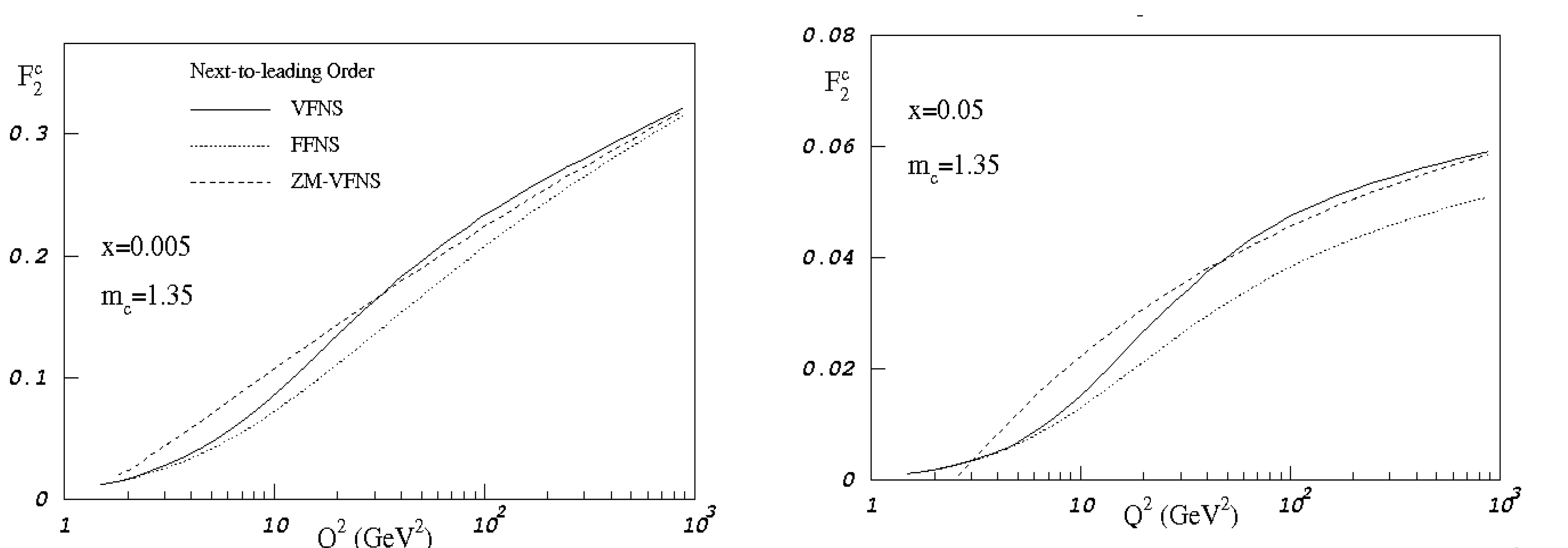
- The LHC DY data are smoothly accommodated into the ABM11 fit
  - exact NNLO corrections, no K-factors
  - the value of χ^2/NDP=68/70
  - some decrease(increase) of u(d)-quarks at x~0.1 / μ=3 GeV; marginal change in the strange quarks
- The t-quark data are checked in the ABM11 fit
  - the running-mass definition provides better description of data as compared to the pole mass case
  - the value of χ^2/NDP~5/5 is obtained for the Tevatron&LHC data with $m_t(m_t)$=162-163 GeV (equivalent to m_t(pole)=171-172)
  - the change in gluons due to t-quark data is about 1σ
  - the value of $\alpha_s(M_z)$ = 0.1138 – 0.1149 depending on $m_t(m_t)$
- The value of α_s obtained in the VFN version of the ABM11 fit (BMSN with PDF evolution) is lower with the FFN one with an additional theoretical uncertainty of 0.0010

Extras

ZMVFN and GMVFN schemes

ZMVFN (zero-mass variable-flavor-number) scheme

- The PDFs, including the the heavy-quark one are convoluted with the massless coefficient functions
- The corrections up to N^{3}LO are available
- The big logs $\sim ln^n(Q/m_c)$ can be in a natural way resummed in the massless QCD evolution
- Irrelevant outside the asymptotic region $Q >> m_h$



Thorne, Roberts PLB 421, 303 (1998)

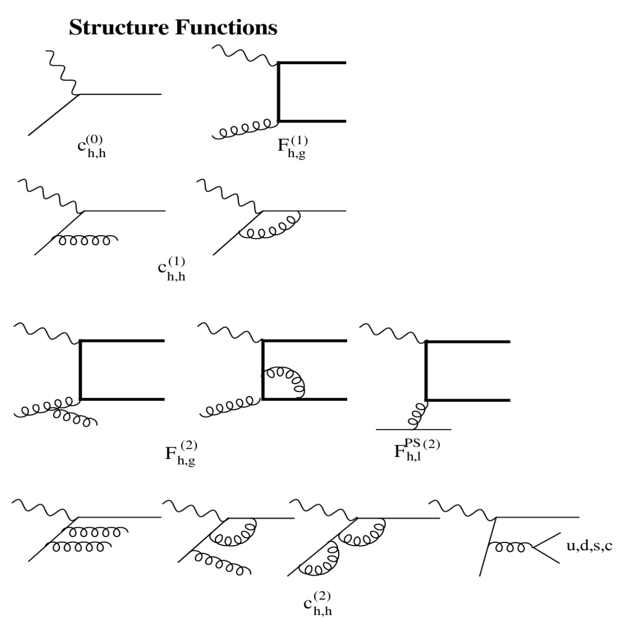
GMVFN (general-mass variable-flavor-number) scheme

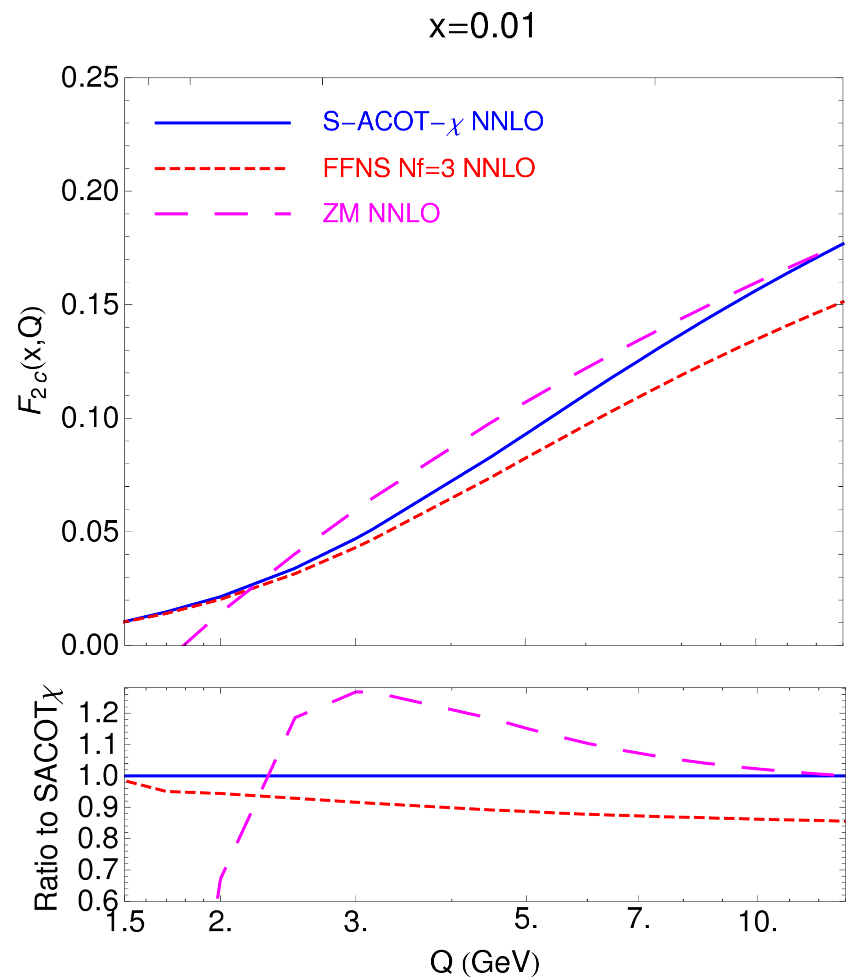
- Provides matching with the FFNS in the limit of $Q \rightarrow m_h$
- Modeling at small Q cannot be based on the solid footing; many prescriptions available that causes theoretical uncertainty

ACOT prescription

Guzzi, Nadolsky, Lai, Yuan PRD 86, 053005 (2012)

The prescription is based on the subtractions, similarly to the BMSN one





Extrapolation to $Q = m_h$ is based on the assumption for the coefficient function of heavy-quark initiated processes

$$C^{(k)}_{h,h}\left(\frac{x}{\xi}, \frac{Q}{\mu}, \frac{m_h}{Q}\right) = c^{(k)}_{h,h}\left(\frac{\chi}{\xi}, \frac{Q}{\mu}, m_h = 0\right)$$

$$\chi = x\left(1 + \frac{(\sum_{f_s} m_h)^2}{Q^2}\right)$$

$$x = \frac{\zeta}{1 + \zeta^{\lambda} \cdot (4m_c^2)/Q^2},$$

- The “slow-rescaling” is consistent with the QCD factorization
- A variety of rescaling forms gives different prescription: SACOT, ACOT-χ, …..
- Matching with FFNS $Q = m_h$ is not very smooth

Thorne's prescription

Thorne hep-ph/1201.6180

Based on the ACOT *(different from the Thorne-Roberts prescription)*

Thorne, Roberts PLB 421, 303 (1998)

$$C_{2,h\bar{h}}^{\mathrm{GMVF},(0)}(Q^2/m_h^2, z) \longrightarrow (1+b(m_h^2/Q^2)^c)\delta(z-x_{\max})$$

$$\xi = x/x_{\max} \longrightarrow x\left(1+\left(x(1+4m_h^2/Q^2)\right)^d 4m_h^2/Q^2\right)$$

Additional parameters b and c improved matching with FFNS and the NNLO term stemming from the threshold resummation added

$$A(Q^2/m_h^2)(1 - z/x_{\max})^{\tilde{a}}(\ln(1/z) - \tilde{b})/z,$$

- With the variety of parameters smooth matching is achieved
- Does the MSbar scheme persist?
- With a smooth matching to FFNS provided at $Q = m_h$ the Thorne's prescription in NNLO does not differ very much from FFNS elsewhere