ABMP16 PDFs

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(in collaboration with J.Blümlein, S.Moch, and R.Plačakytė)

- HERA I+II data: $\alpha_s(M_Z)$, m_c, and m_b
- Drell-Yan data from the LHC and Tevatron: Isospin asymmetry and d/u at large x
- t-quark data: m_t and gluon distribution
- Charm production data from NOMAD and CHORUS: strange sea

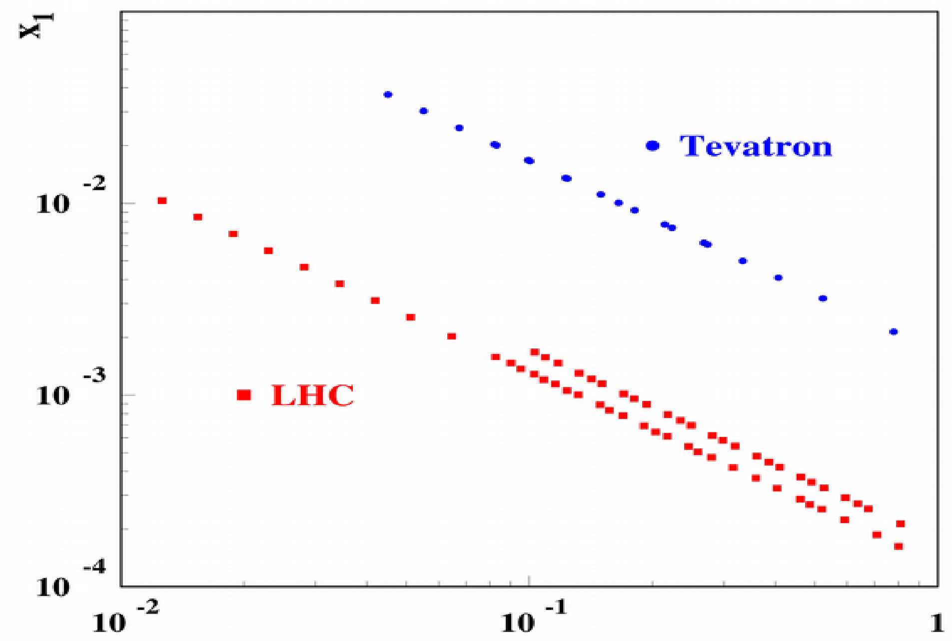
sa, Blümlein, Caminada, Lipka, Lohwasser,
Moch, Petti, Plačakytė hep-ph/1404.6469

sa, Blümlein, Moch, Plačakytė, hep-ph/1508.07923

sa, Blümlein, Moch, Plačakytė, hep-ph/1609.03327

PDF4LHC meeting , CERN, 13 *Sep 2016*

Collider W&Z data used in the fit



In the forward region $x_2 >> x_1$

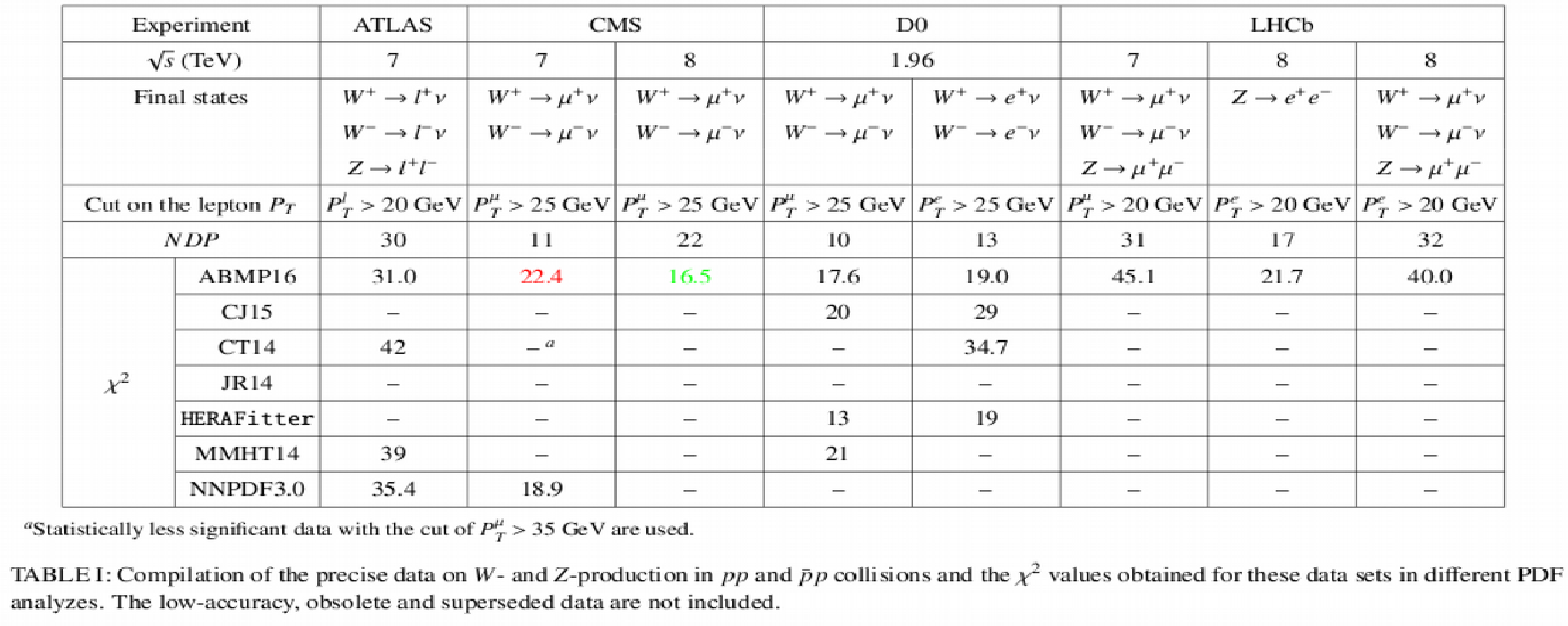
$\sigma(W^+) \sim u(x_2)\ \mathrm{dbar}\ (x_1)$

$\sigma(W^-) \sim d(x_2)\ \mathrm{ubar}(x_1)$

$\sigma(Z) \sim Q_U^2 u(x_2)\ \mathrm{ubar}\ (x_1) + Q_D^2 d(x_2)\ \mathrm{dbar}(x_1)$

$\sigma(\mathrm{DIS}) \sim q_u^2 u(x_2) + q_d^2 d(x_2)$

Forward W&Z production probes small/large x and is complementary to the DIS → constraint on the quark iso-spin asymmetry



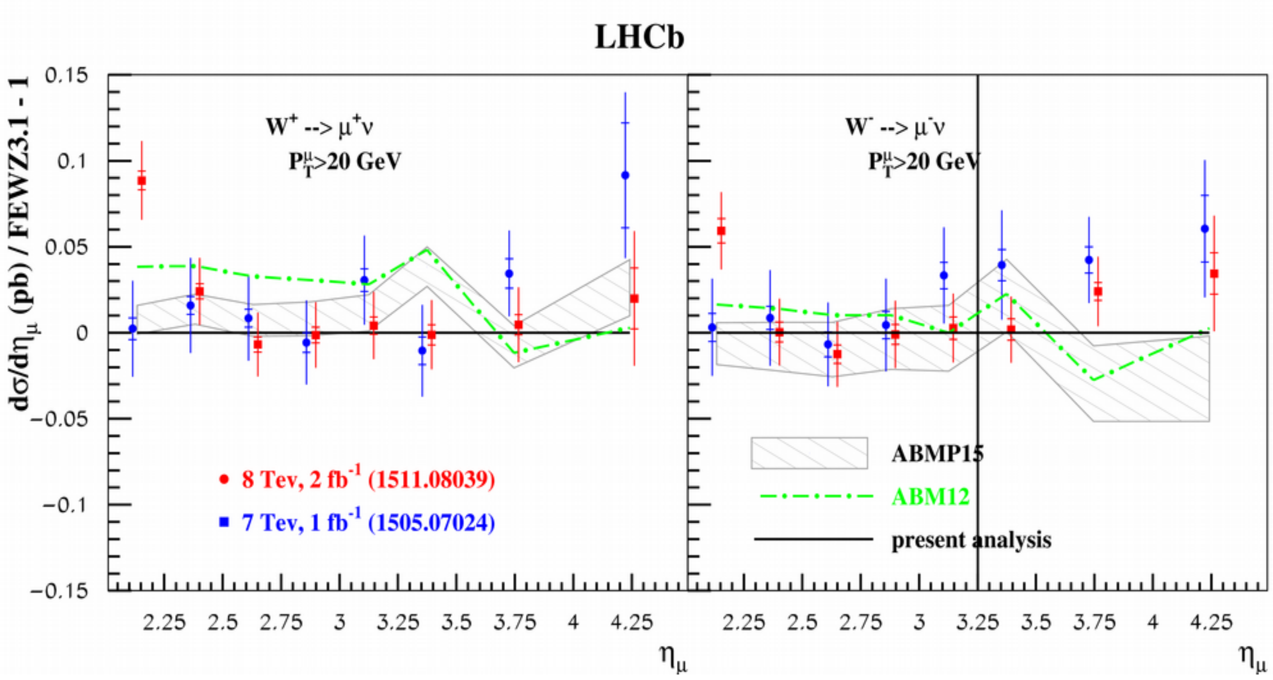
Experiment		ATLAS	CMS		D0		LHCb		
$\sqrt{s}$ (TeV)		7	7	8	1.96		7	8	8
Final states		$W^+ \to l^+\nu$ $W^- \to l^-\nu$ $Z \to l^+l^-$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to e^+\nu$ $W^- \to e^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ $Z \to \mu^+\mu^-$	$Z \to e^+e^-$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ $Z \to \mu^+\mu^-$
Cut on the lepton P_T		$P_T^l > 20$ GeV	$P_T^\mu > 25$ GeV	$P_T^\mu > 25$ GeV	$P_T^\mu > 25$ GeV	$P_T^e > 25$ GeV	$P_T^\mu > 20$ GeV	$P_T^e > 20$ GeV	$P_T^e > 20$ GeV
NDP		30	11	22	10	13	31	17	32
χ^2	ABMP16	31.0	22.4	16.5	17.6	19.0	45.1	21.7	40.0
	CJ15	–	–	–	20	29	–	–	–
	CT14	42	–^{a}	–	–	34.7	–	–	–
	JR14	–	–	–	–	–	–	–	–
	HERAFitter	–	–	–	13	19	–	–	–
	MMHT14	39	–	–	21	–	–	–	–
	NNPDF3.0	35.4	18.9	–	–	–	–	–	–

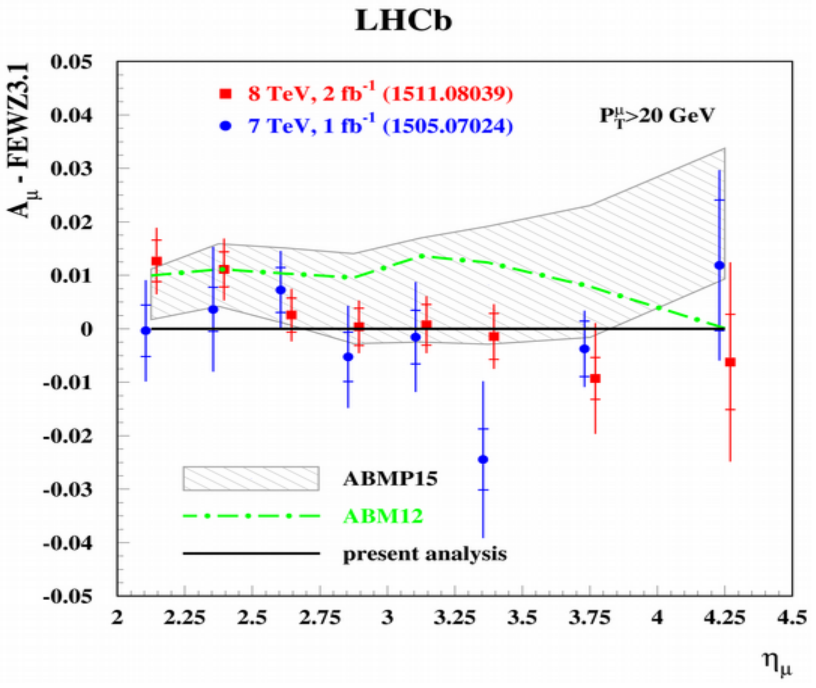
[a] Statistically less significant data with the cut of $P_T^\mu > 35$ GeV are used.

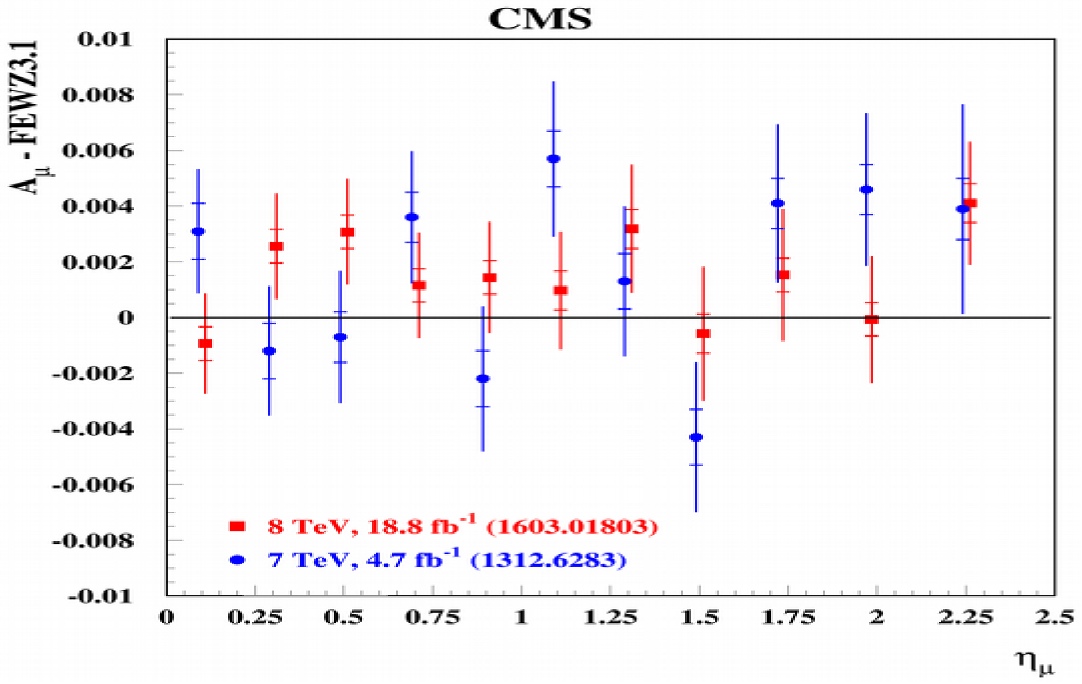
TABLE I: Compilation of the precise data on W- and Z-production in pp and $\bar{p}p$ collisions and the χ^2 values obtained for these data sets in different PDF analyzes. The low-accuracy, obsolete and superseded data are not included.

Obsolete/superseded/low-accuracy Tevatron and LHC data are not used

Most recent DY inputs







Filtering of the LHCb data has been performed:

– a bump at 7 Tev and Y=3.275
(not confirmed by the LHCb data at 8 TeV)

– and excess at 8 TeV and Y=2.125
(not confirmed by the CMS data at 8 TeV)

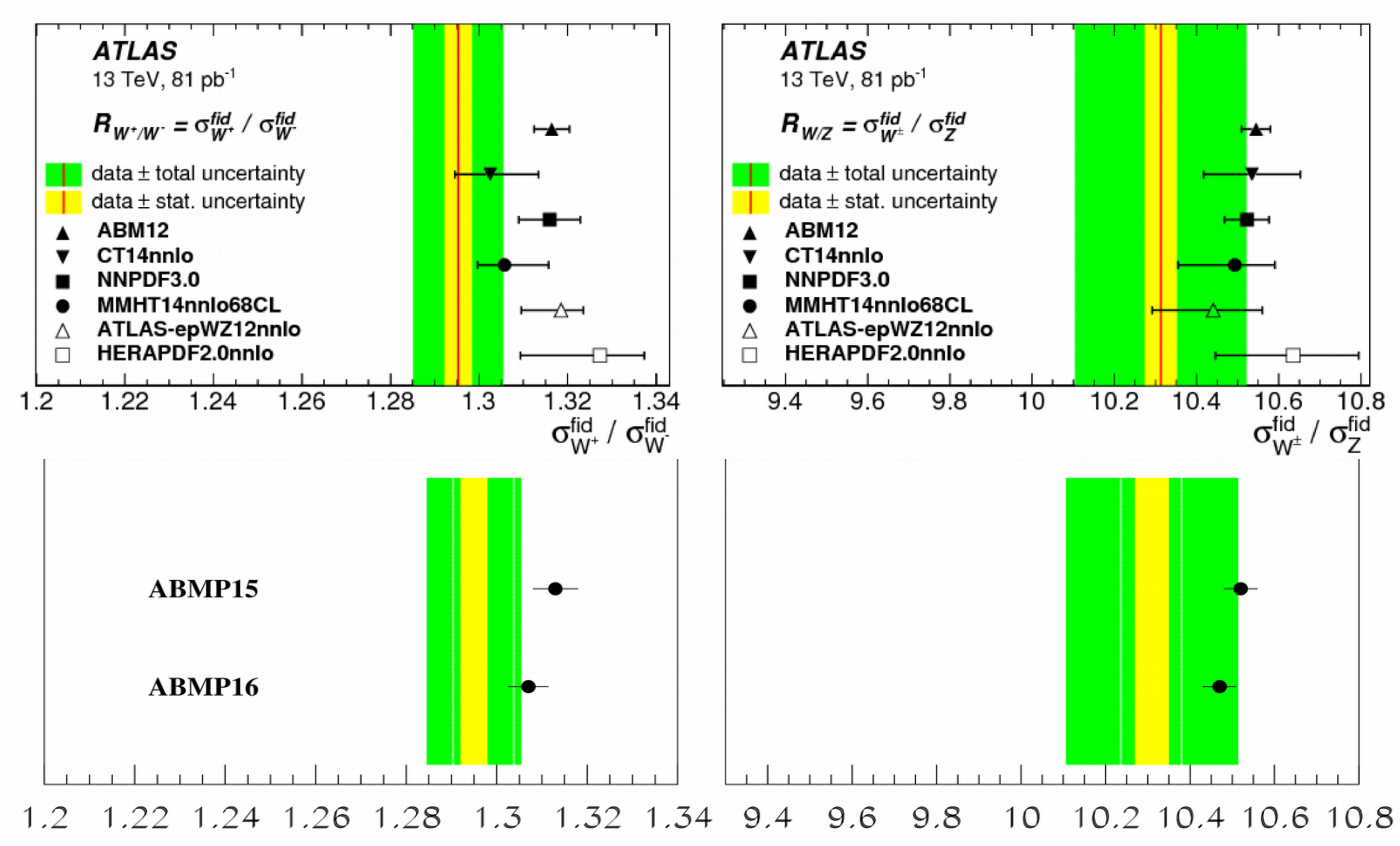
The CMS data at 8 TeV are much smoother than the ones at 7 TeV:

χ^2=17/22 versus 22/11

cf. earlier data in sa, Blümlein, Moch, Plačakytė, hep-ph/1508.07923

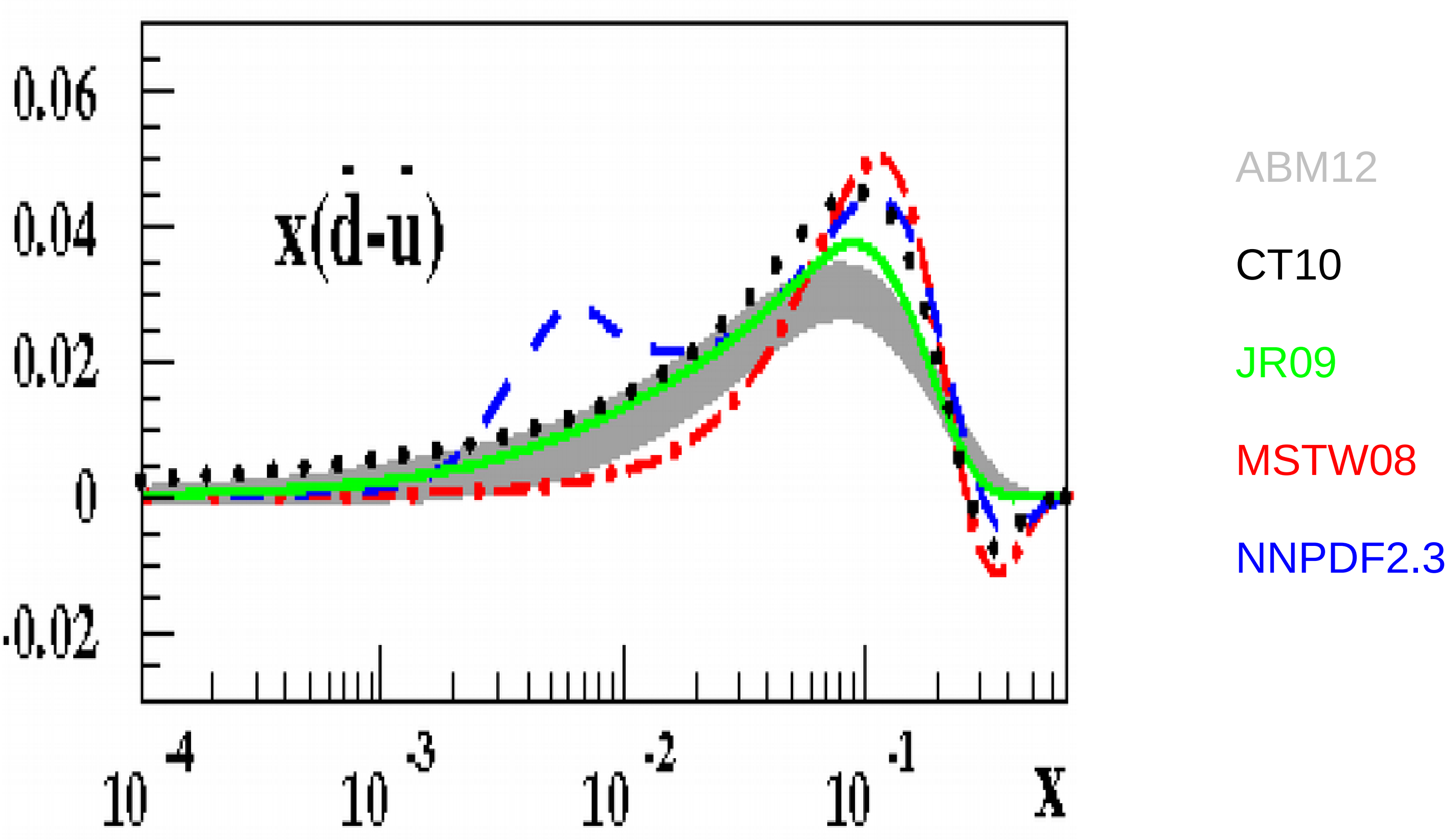
ATLAS W&Z at 13 TeV

ATLAS, hep-ex/1603.09222



Data are well accommodated into the fit χ^2/NDP=9/6

Sea quark iso-spin asymmetry



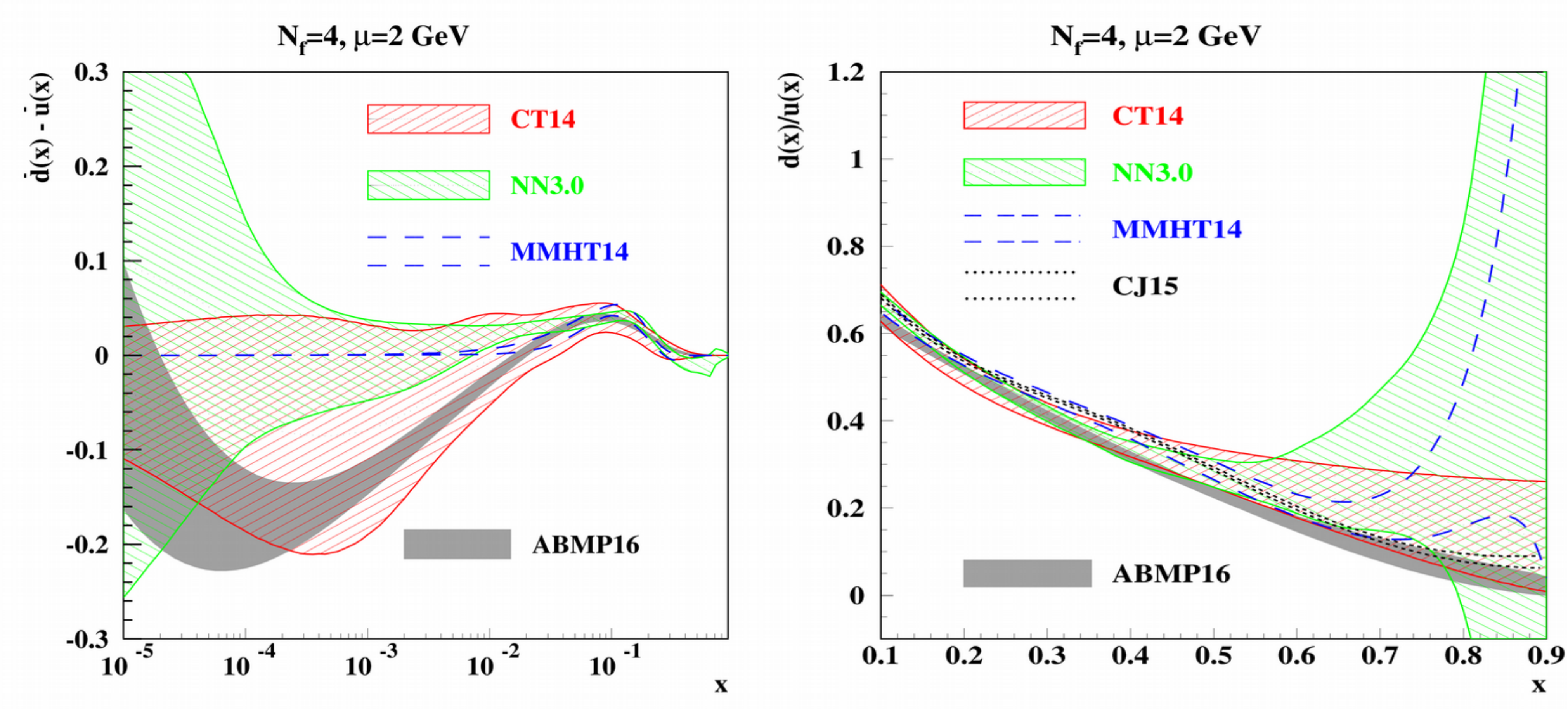
sa, Blümlein, Moch PRD 89, 054028 (2014)

- At x~0.1 the sea quark iso-spin asymmetry is controlled by the fixed-target DY data (E-866), weak constraint from the DIS (NMC)

- At x<0.01 Regge-like constraint like $x^{(a-1)}$, with a close to the meson trajectory intercept; the “unbiased” NNPDF fit follows the same trend

Onset of the Regge asymptotics is out of control

Impact of the forward Drell-Yan data

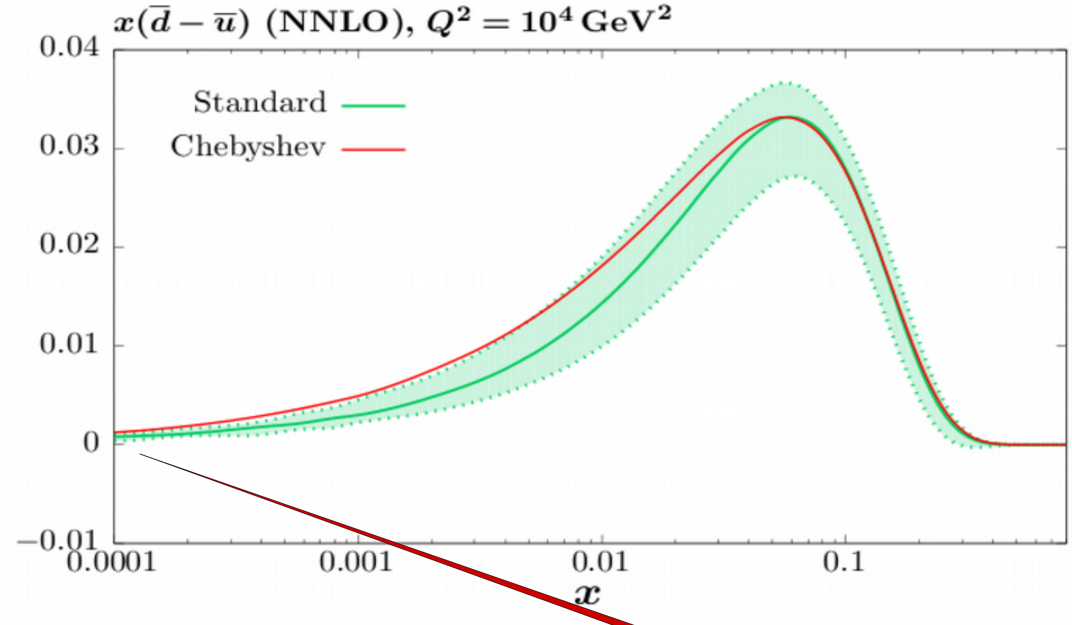


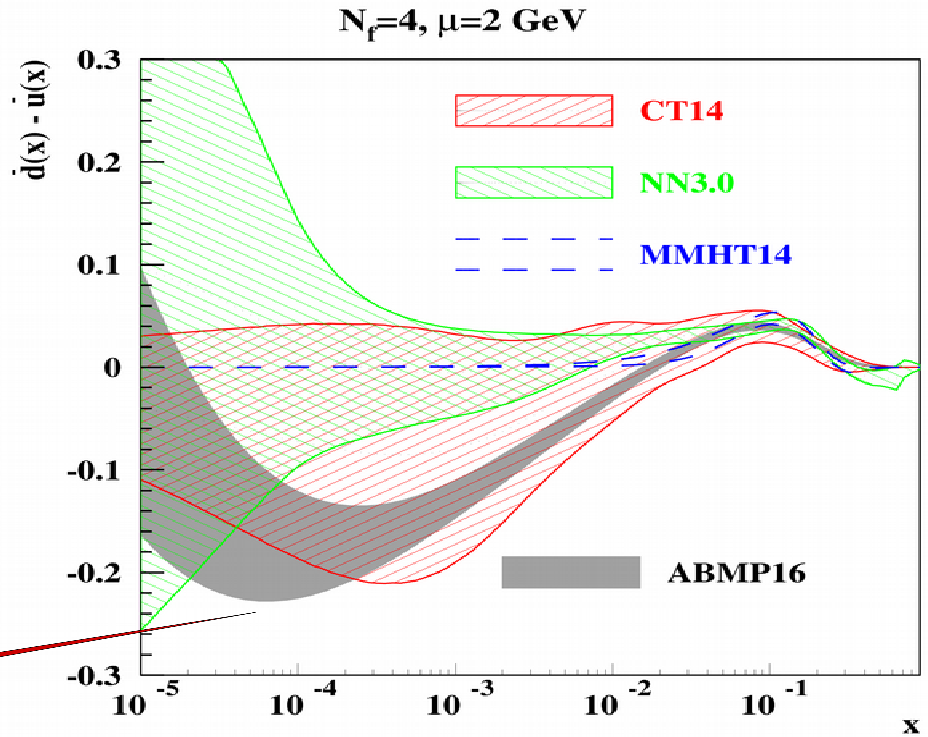
- Relaxed form of the sea iso-spin asymmetry I(x) at small x; Regge-like behaviour is recovered only at x~10^{-6}; at large x it is still defined by the phase-space constraint

- Good constraint on the d/u ratio w/o deuteron data → independent extraction of the deuteron corrections **Accardi, Brady, Melnitchouk, Owens, Sato hep-ph/1602.03154;**

- Big spread between different PDF sets, up to factor of 30 at large x → PDF4LHC averaging is misleading

$$(\bar d - \bar u)(x,Q_0^2) = A(1-x)^{\eta_{sea}+2}x^{\delta}\left(1+\sum_{i=1}^{4} a_i T_i(1-2x^{\frac{1}{2}})\right),$$





Thorne, this conference

	no. points	NLO χ^2_{pred}	NLO χ^2_{new}	NNLO χ^2_{pred}	NNLO χ^2_{new}
$\sigma_{t\bar t}$ Tevatron +CMS+ATLAS	18	19.6	20.5	14.7	15.5
LHCb 7 TeV $W+Z$	33	50.1	45.4	37.1	36.7
LHCb 8 TeV $W+Z$	34	77.0	58.9	76.1	67.2
LHCb 8TeV e	17	37.4	33.4	30.0	27.8
CMS 8 TeV W	22	32.6	18.6	57.6	29.4
CMS 7 TeV $W+c$	10	8.5	10.0	8.7	8.0
D0 e asymmetry	13	22.2	21.5	27.3	22.9
total	3738/3405	4375.9	4336.1	3768.0	3739.3

$$xu_s(x,\mu_0^2) = \bar u_s(x,\mu_0^2) = A_{us}(1-x)^{b_{us}}x^{a_{us}P_{us}(x)},$$

$$xd_s(x,\mu_0^2) = \bar d_s(x,\mu_0^2) = A_{ds}(1-x)^{b_{ds}}x^{a_{ds}P_{ds}(x)},$$

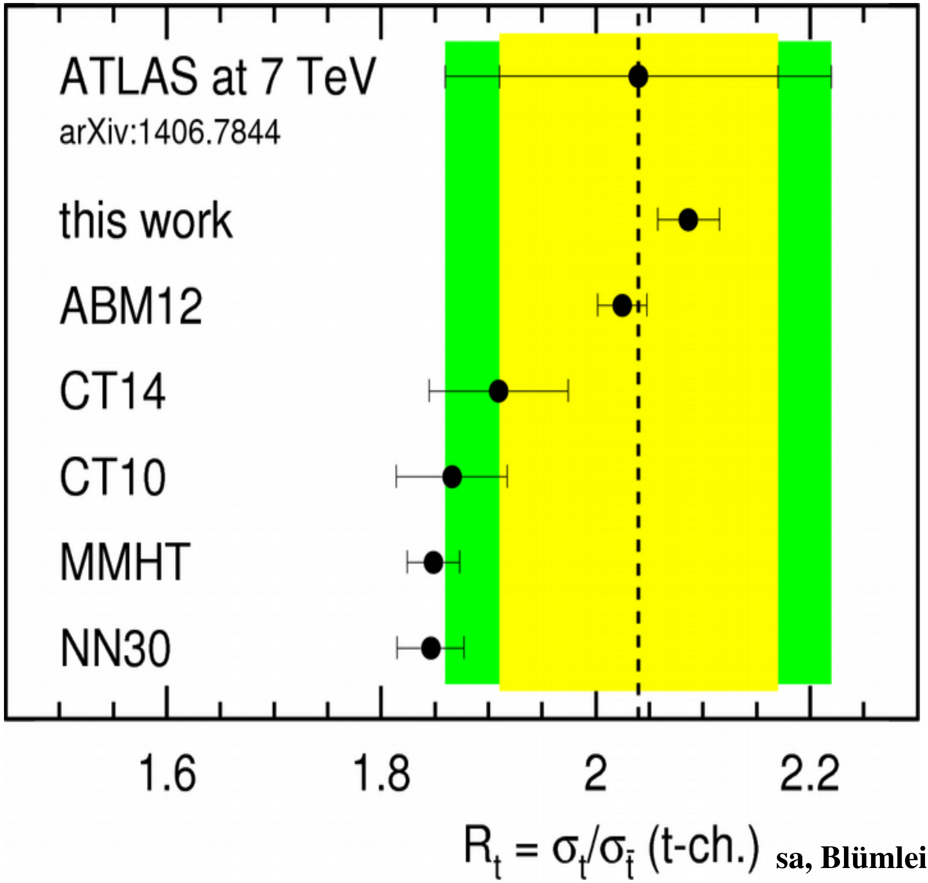
dbar≠ubar at small x
(the same applies for CT14)

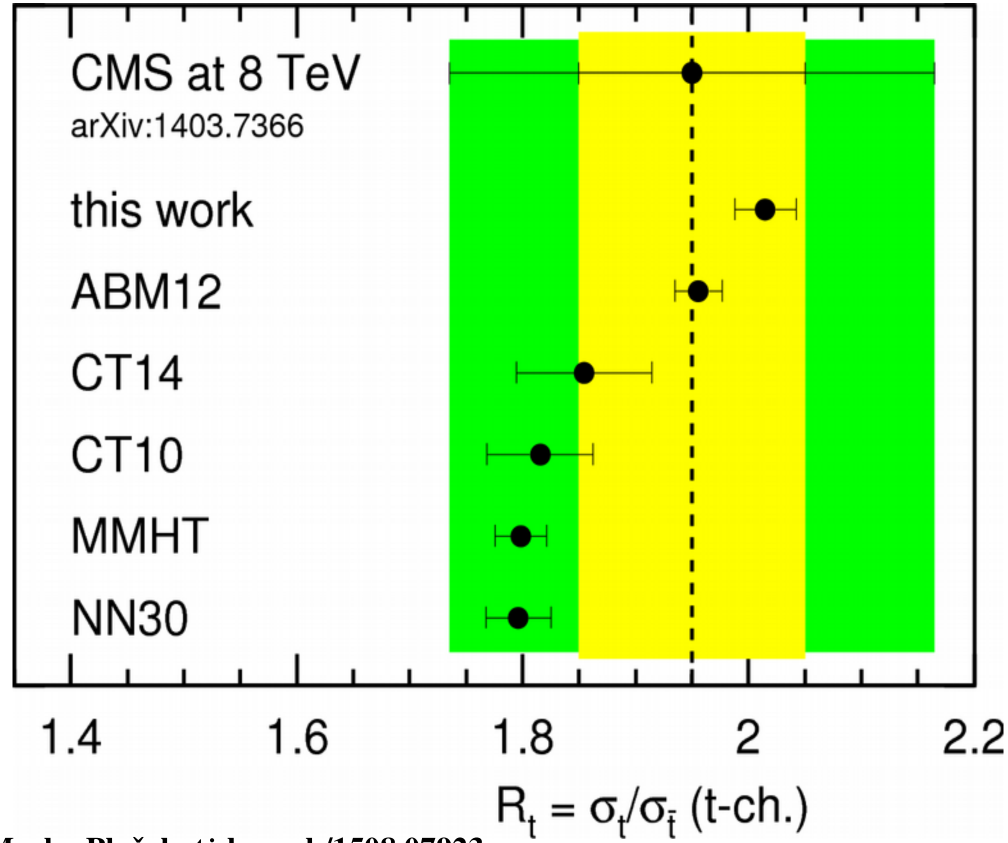
The sum of χ^2/NDP for the DY data by LHCB, CMS, and D0 from the table:

184/119 (MMHT16)

171/119 (ABMP16, no filtering), account of
other DY data increases the difference

Implication for(of) the single-top production





sa, Blümlein, Moch, Plačakytė hep-ph/1508.07923

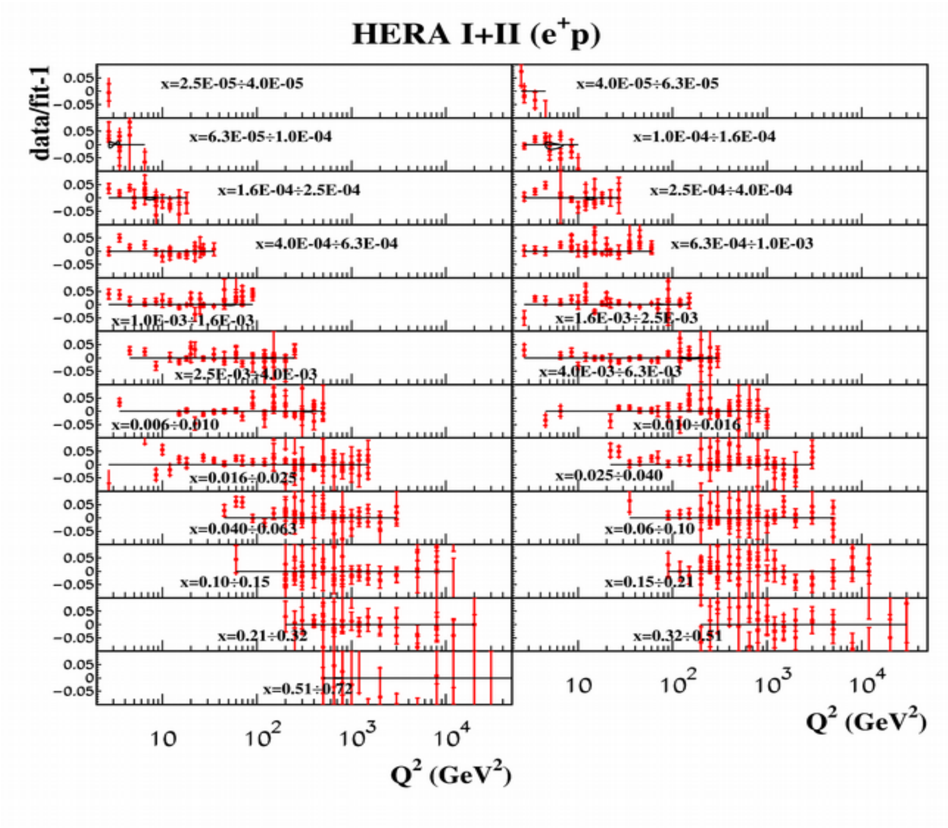
- ATLAS and CMS data on the ratio t/tbar are in a good agreement

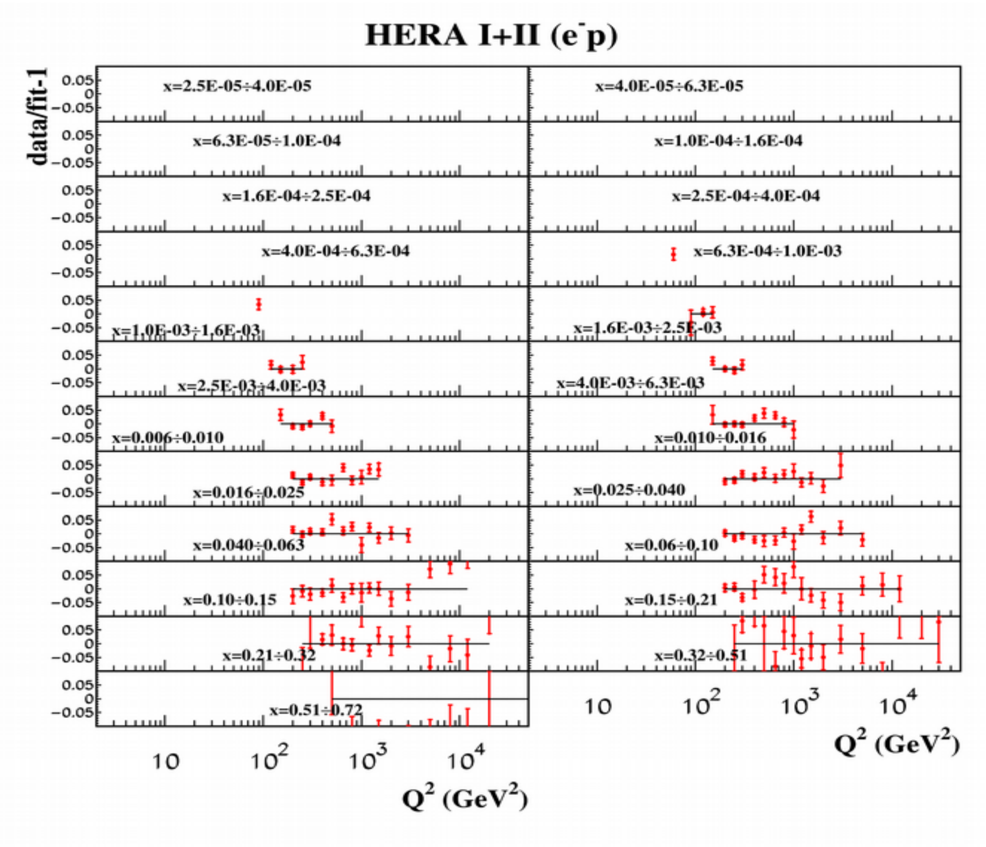
- The predictions driven by the froward DY data are in a good agreement with the single-top data (N.B.: ABM12 is based on the deuteron data → consistent deuteron correction was used) **talks by Petti at DIS2016**

Single-top production discriminate available PDF sets and can serve as a standard candle process

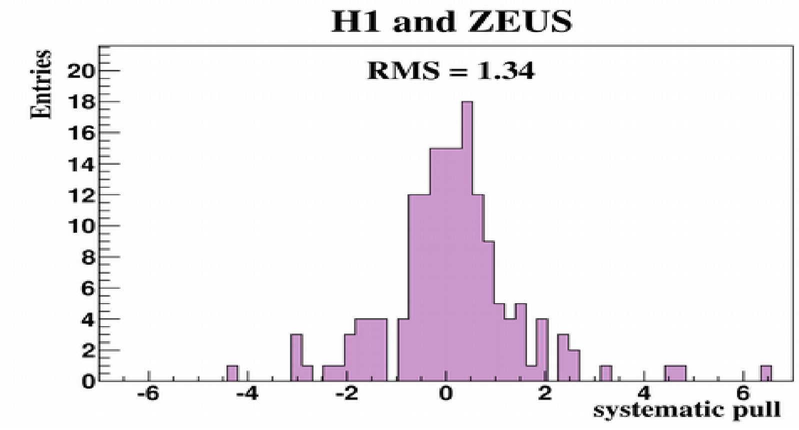
Inclusive HERA I+II data

H1 and ZEUS hep-ex/1506.06042





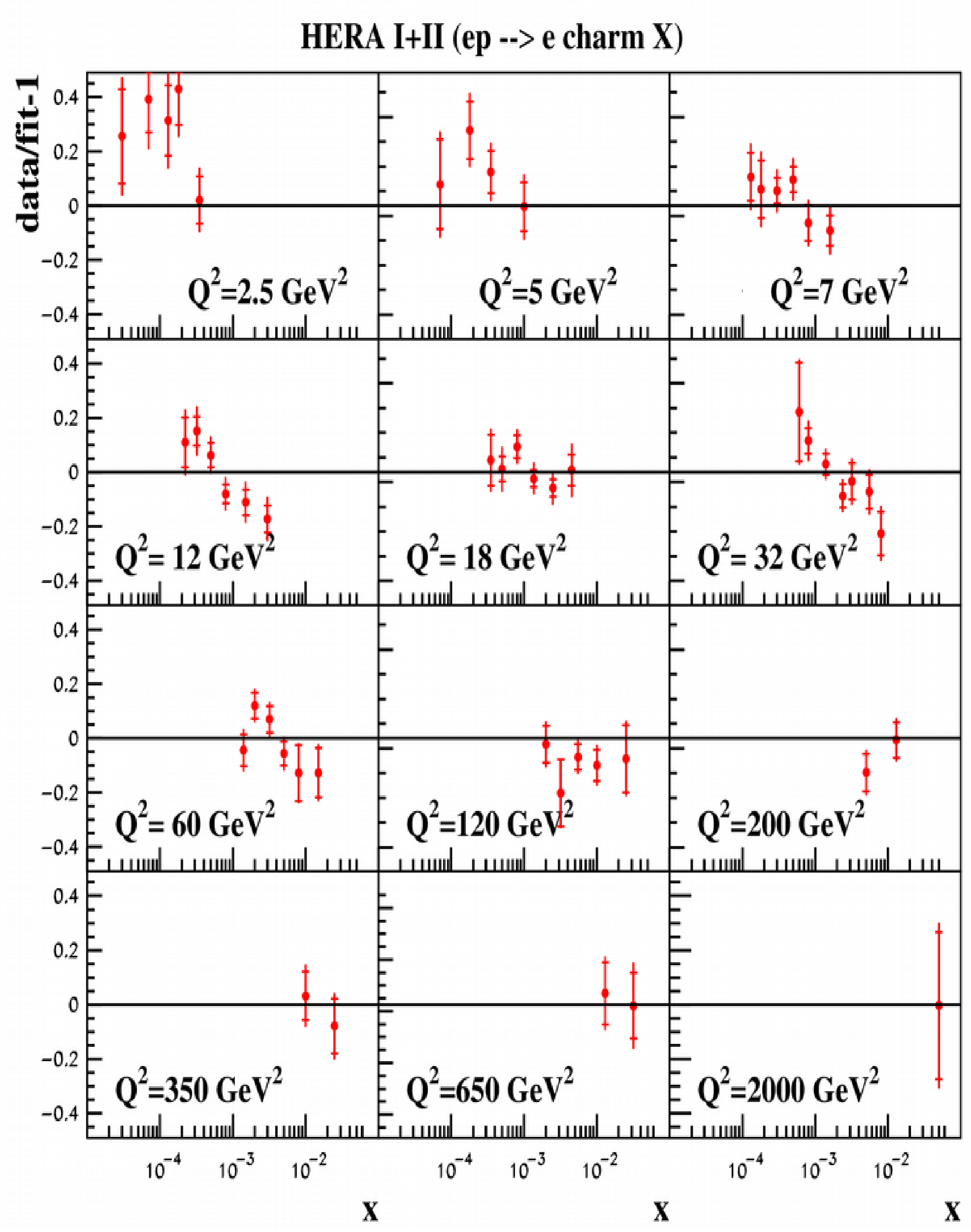
Q^2(HERA)	χ^2/NDP(HERA)
>2.5 GeV^2	1509/1168=1.29
>5 GeV^2	1354/1092=1.24
>10 GeV^2	1228/1007=1.22



The value of χ^2/NDP is bigger than 1, however still comparable to the pull distribution width

HERA charm data and $m_c(m_c)$

H1/ZEUS ZPC 73, 2311 (2013)



$m_c(m_c)$=1.246±0.023 (h.o.) GeV NNLO

Kiyo, Mishima, Sumino hep-ph/1510.07072

- Approximate NNLO massive Wilson coefficients (combination of the threshold corrections, high-energy limit, and the NNLO massive OMEs)

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

  Update with the pure singlet massive OMEs

  Ablinger et al. NPB 890. 48 (2014)

  → improved theoretical uncertainties

- Running-mass definition of m_c

  X^2/NDP=66/52

$m_c(m_c)$=1.252±0.018(exp.) GeV	ABMP16
$m_c(m_c)$=1.24±0.03(exp.) GeV	ABM12

- RT optimal

  X^2/NDP=82/52 NNLO

  m_c(pole)=1.25 GeV **MMHT14 EPJC 75, 204 (2015)**

- F0NLL

  X^2/NDP=60/47 NNLO

  m_c(pole)=1.275 GeV **NNPDF3.0 JHEP 1504, 040 (2015)**

- S-ACOT-χ

  X^2/NDP=59/47 NNLO

  m_c(pole)=1.3 GeV **CT14 hep-ph 1506.07443**

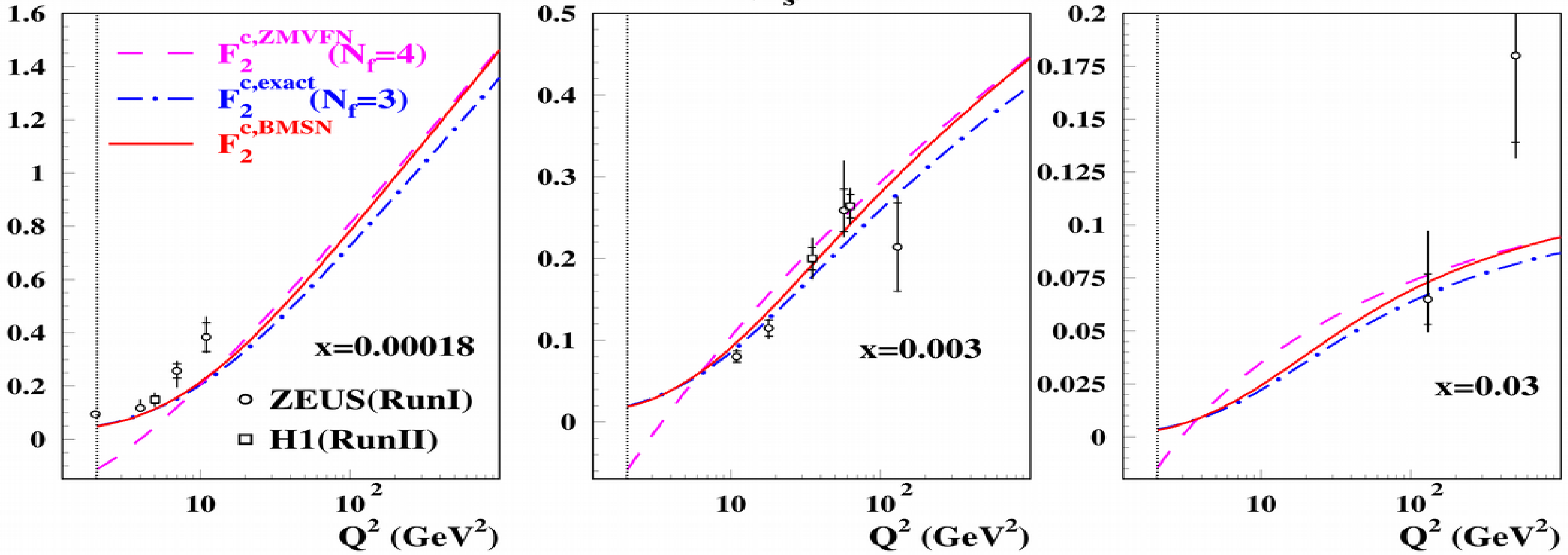
Accardi, et al. hep-ph/1603.08906

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)

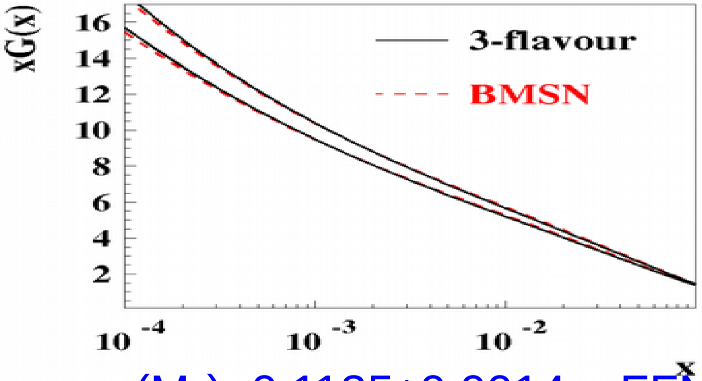
- Very smooth matching with the FFNS at $Q \to m_h$
- Renormgroup invariance is conserved; the PDFs in MSbar scheme

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**

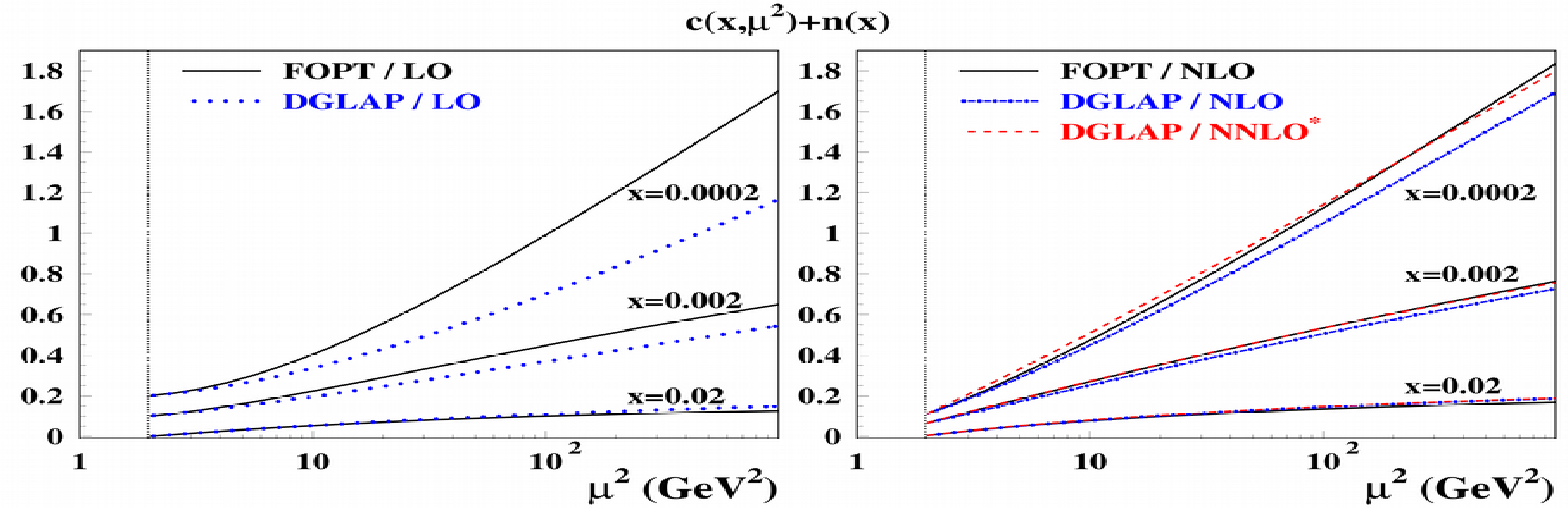
The value of $\alpha_s(M_z)$ is reduced in FFN **MSTW**

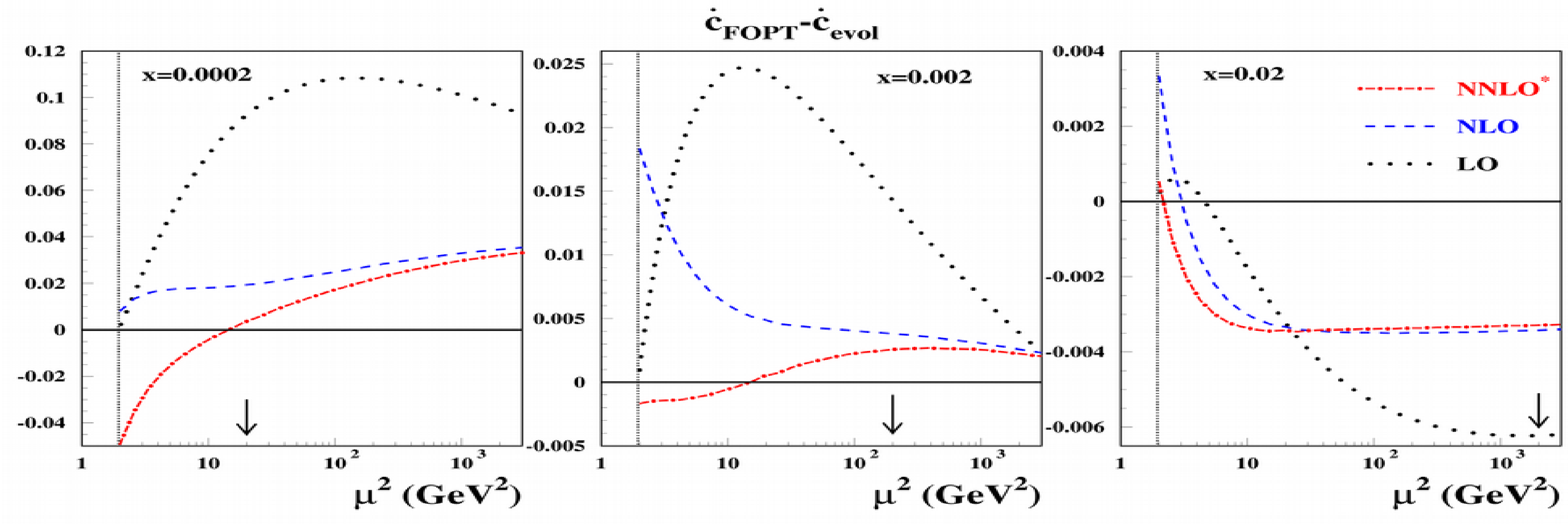


$\alpha_s(M_z)=0.1135\pm0.0014$ FFN

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

Comparison of the FOPT and evolved c-quark PDFs





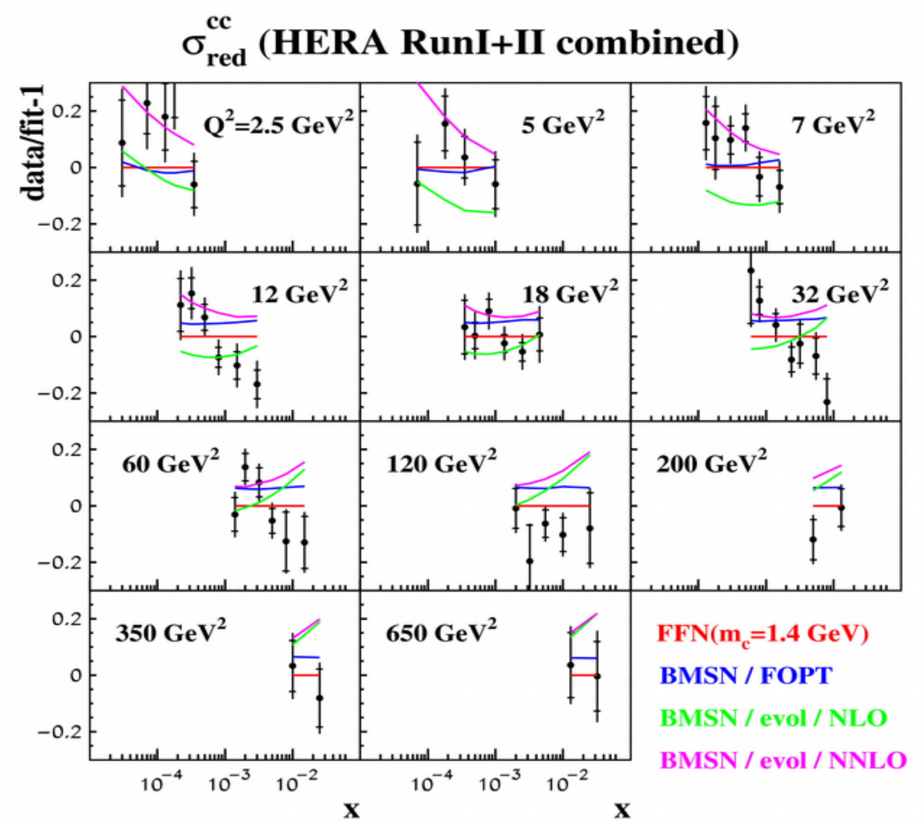
The difference between FOPT and evolved PDFs is localized at small scales: uncertainties due to missing high-orders rather than impact of the big-log resummation

sa, Blümlein, Moch hep-ph/1307.7258)

BMSN with the evolved PDFs

H1/ZEUS PLB 718, 550 (2012)

- Combined HERA charm production data
- 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

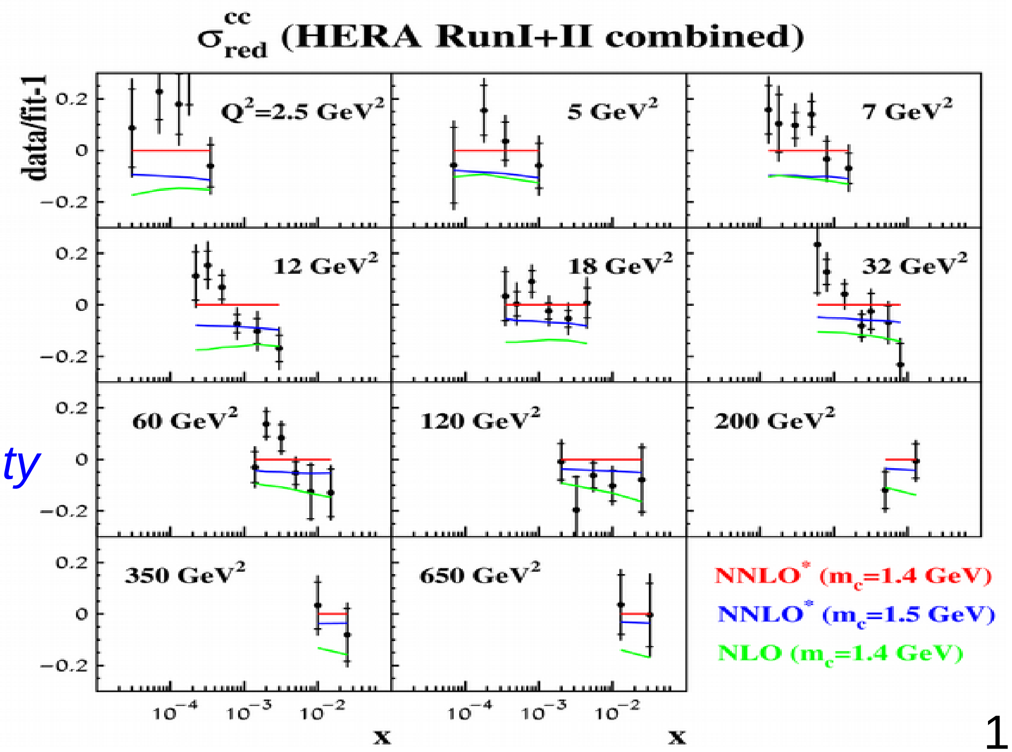
  NNLO (consistent with the light PDF evolution, inconsistent with the NLO matching) **

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

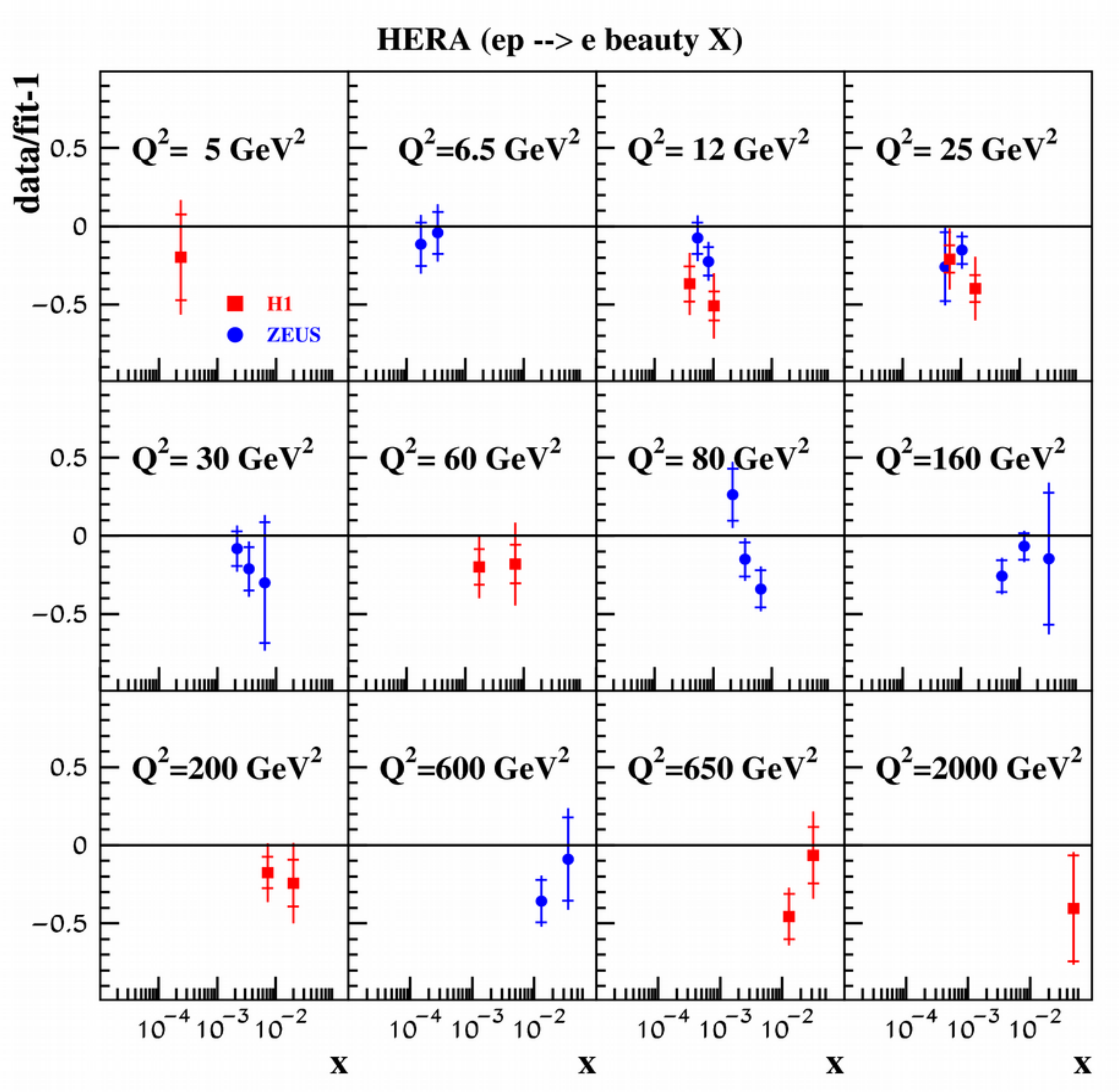
  ** commonly used in the VFN fits

- 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



HERA bottom data and $m_b(m_b)$



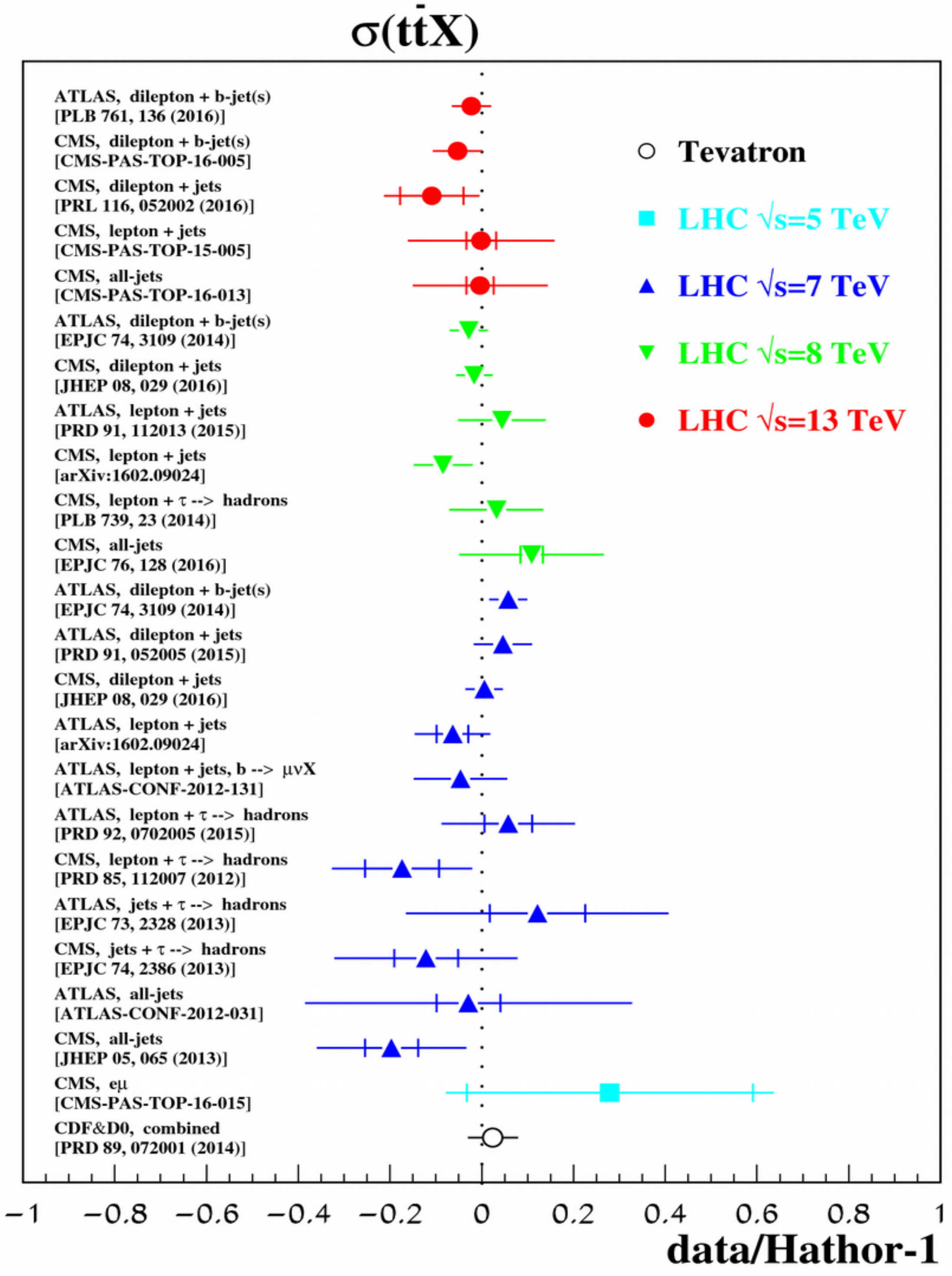
ZEUS JHEP 1409, 127 (2014)

χ^2/NDP=16/17

H1 EPJC 65, 89 (2010)

χ^2/NDP=5/12

$m_b(m_b)$=3.83±0.12(exp.) GeV


σ(tt̄X)
ATLAS, dilepton + b-jet(s)
[PLB 761, 136 (2016)]
CMS, dilepton + b-jet(s)
[CMS-PAS-TOP-16-005]
CMS, dilepton + jets
[PRL 116, 052002 (2016)]
CMS, lepton + jets
[CMS-PAS-TOP-15-005]
CMS, all-jets
[CMS-PAS-TOP-16-013]
ATLAS, dilepton + b-jet(s)
[EPJC 74, 3109 (2014)]
CMS, dilepton + jets
[JHEP 08, 029 (2016)]
ATLAS, lepton + jets
[PRD 91, 112013 (2015)]
CMS, lepton + jets
[arXiv:1602.09024]
CMS, lepton + τ --> hadrons
[PLB 739, 23 (2014)]
CMS, all-jets
[EPJC 76, 128 (2016)]
ATLAS, dilepton + b-jet(s)
[EPJC 74, 3109 (2014)]
ATLAS, dilepton + jets
[PRD 91, 052005 (2015)]
CMS, dilepton + jets
[JHEP 08, 029 (2016)]
ATLAS, lepton + jets
[arXiv:1602.09024]
ATLAS, lepton + jets, b --> μνX
[ATLAS-CONF-2012-131]
ATLAS, lepton + τ --> hadrons
[PRD 92, 0702005 (2015)]
CMS, lepton + τ --> hadrons
[PRD 85, 112007 (2012)]
ATLAS, jets + τ --> hadrons
[EPJC 73, 2328 (2013)]
CMS, jets + τ --> hadrons
[EPJC 74, 2386 (2013)]
ATLAS, all-jets
[ATLAS-CONF-2012-031]
CMS, all-jets
[JHEP 05, 065 (2013)]
CMS, eμ
[CMS-PAS-TOP-16-015]
CDF&D0, combined
[PRD 89, 072001 (2014)]
○ Tevatron
■ LHC √s=5 TeV
▲ LHC √s=7 TeV
▼ LHC √s=8 TeV
● LHC √s=13 TeV
−1
−0.8
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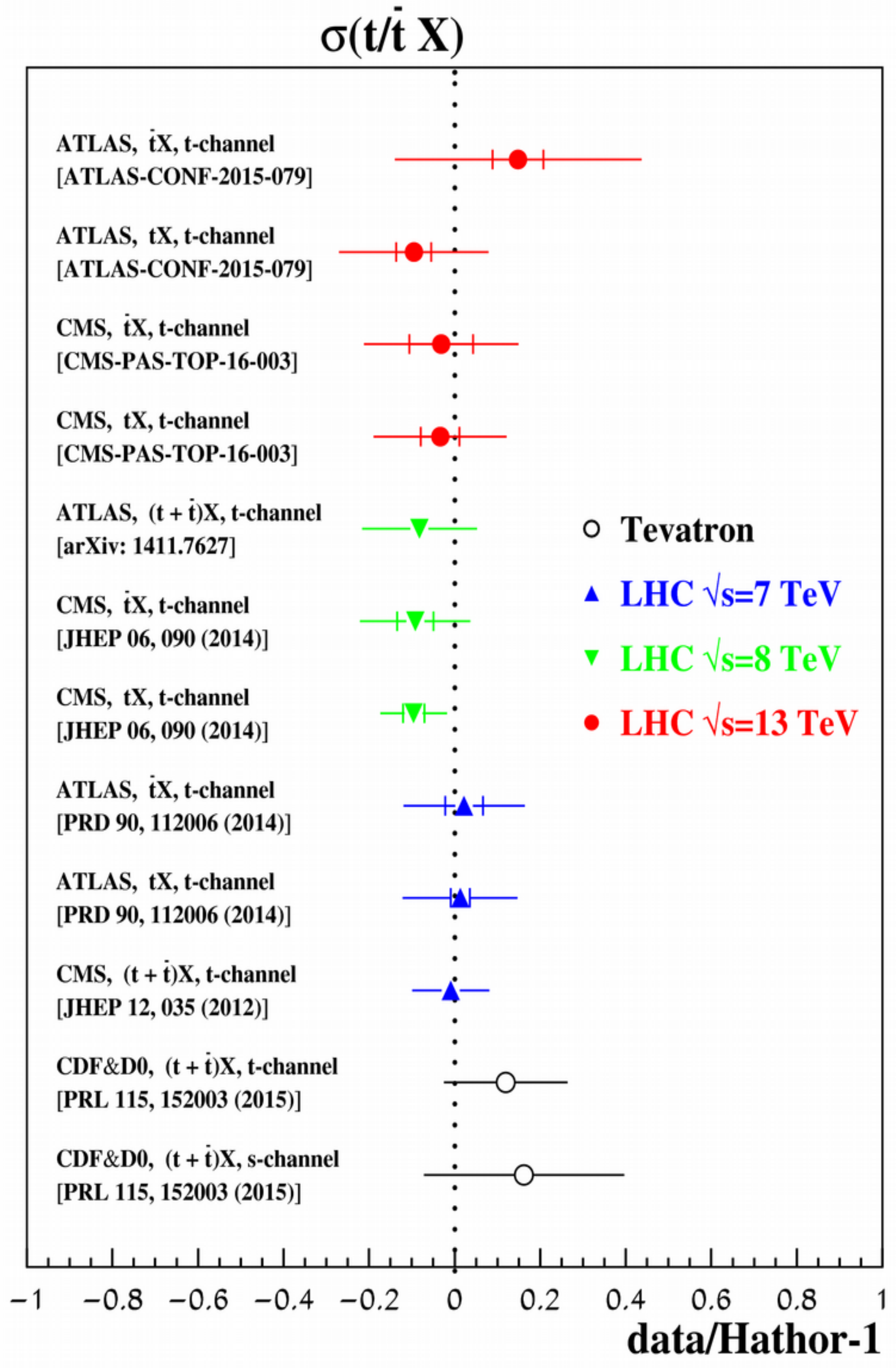
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
data/Hathor-1


σ(t/t̄ X)
ATLAS, t̄X, t-channel
[ATLAS-CONF-2015-079]
ATLAS, tX, t-channel
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CMS, t̄X, t-channel
[CMS-PAS-TOP-16-003]
CMS, tX, t-channel
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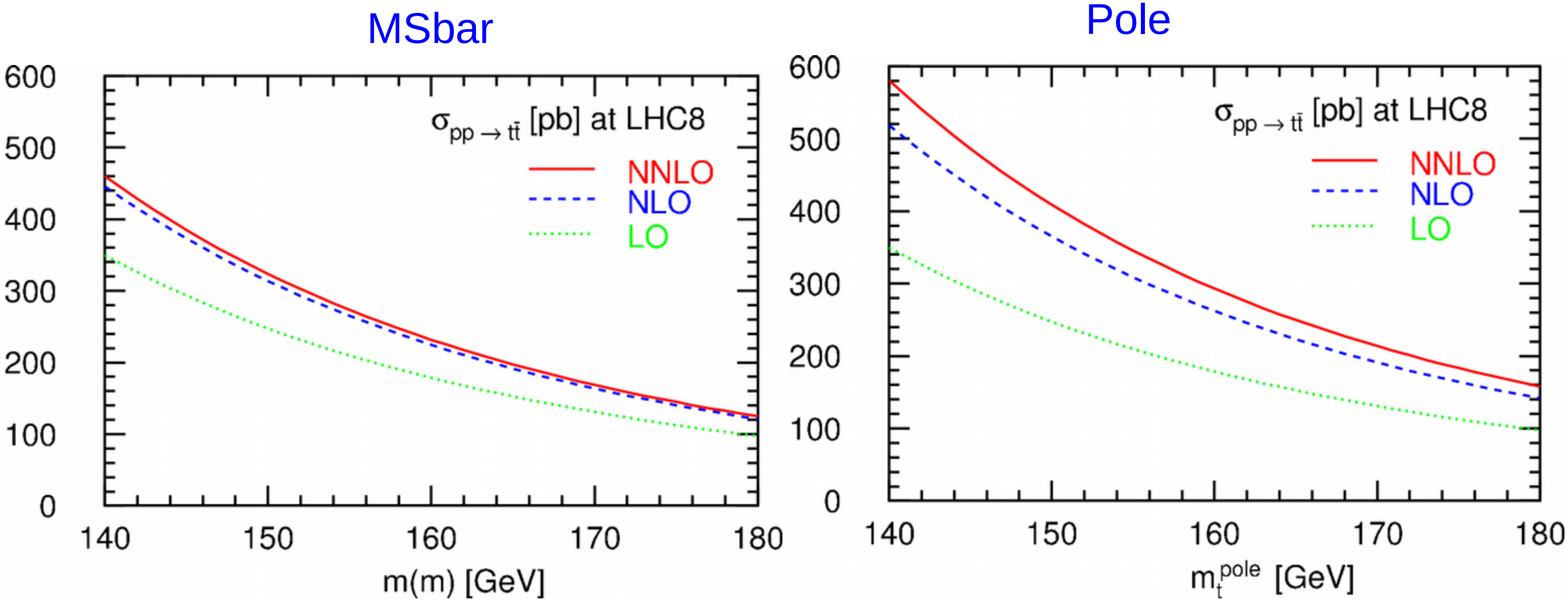
ATLAS, (t + t̄)X, t-channel
[arXiv: 1411.7627]
CMS, t̄X, t-channel
[JHEP 06, 090 (2014)]
CMS, tX, t-channel
[JHEP 06, 090 (2014)]
ATLAS, t̄X, t-channel
[PRD 90, 112006 (2014)]
ATLAS, tX, t-channel
[PRD 90, 112006 (2014)]
CMS, (t + t̄)X, t-channel
[JHEP 12, 035 (2012)]
CDF&D0, (t + t̄)X, t-channel
[PRL 115, 152003 (2015)]
CDF&D0, (t + t̄)X, s-channel
[PRL 115, 152003 (2015)]
○ Tevatron
▲ LHC √s=7 TeV
▼ LHC √s=8 TeV
● LHC √s=13 TeV
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
data/Hathor-1

ttbar production with pole and Msbar mass

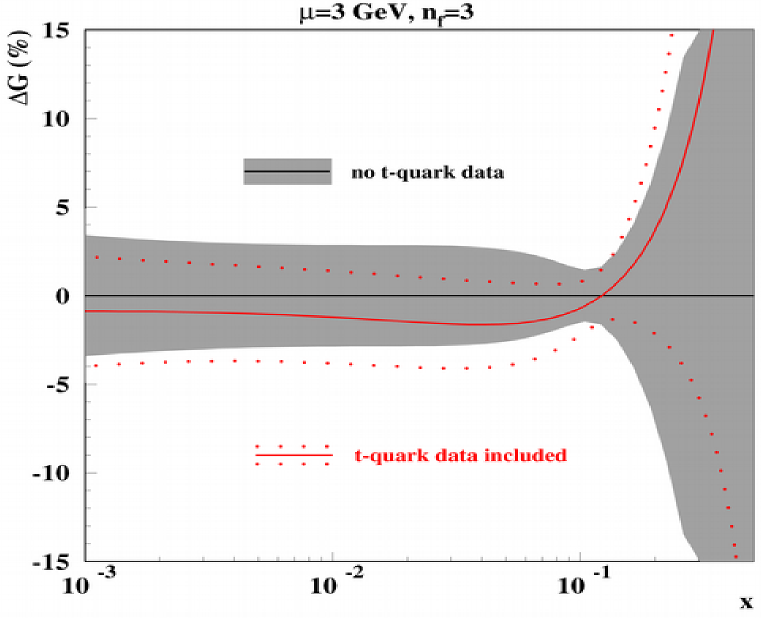


HATHOR (NNLO terms are checked with TOP++)

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

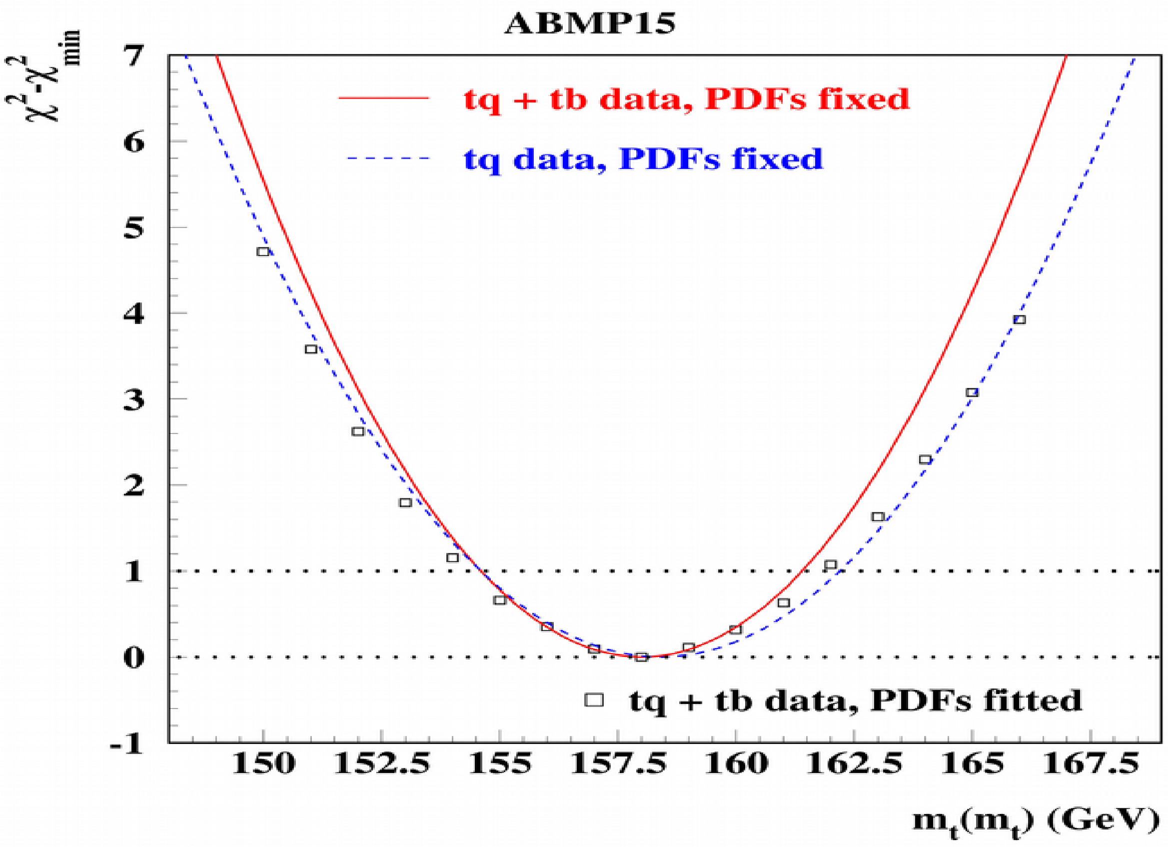
Running mass definition provides nice perturbative stability

Czakon, Fiedler, Mitov hep-ph/1303.6254



- $m_t(m_t)$=160.9±1.1(exp.) GeV NNLO
- $\alpha_s(M_Z)$=0.1145(9) → 0.1147(8) NNLO
- moderate change in the large-x gluon distribution

t-quark mass from the single-top production



- Electroweak production → reduced impact of α_s and the PDF umcertainties
- HATHOR framework

  t-channel: NNLO

  Brucherseifer, Caola, Melnikov PLB 736, 58 (2014)

  s-channel: NNLO threshold. resum.

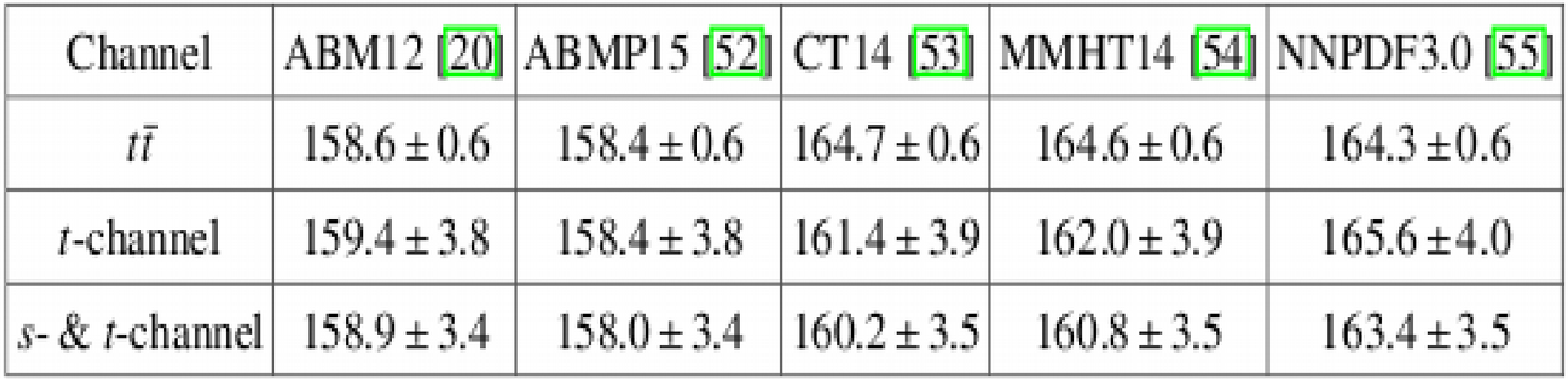
- Different PDFs prefer value of

  $m_t(m_t)$ ~160± 3.5 GeV

NNPDF goes higher by 3 GeV.

- The CT14 and MMHT14 go higher by 3 GeV with the ttbar channel

PDFs fixed



Channel	ABM12 [20]	ABMP15 [52]	CT14 [53]	MMHT14 [54]	NNPDF3.0 [55]
$t\bar{t}$	158.6 ± 0.6	158.4 ± 0.6	164.7 ± 0.6	164.6 ± 0.6	164.3 ± 0.6
t-channel	159.4 ± 3.8	158.4 ± 3.8	161.4 ± 3.9	162.0 ± 3.9	165.6 ± 4.0
s- & t-channel	158.9 ± 3.4	158.0 ± 3.4	160.2 ± 3.5	160.8 ± 3.5	163.4 ± 3.5

sa, Moch, Thier hep-ph/1608.05212

Summary

The improvements summarized in the new PDF set:

- deuteron data are replaced by the Drell-Yan ones from the LHC and Tevatron → reduced theoretical uncertainties in PDFs, in particular in d/u at large x
- the small-x iso-spin sea asymmetry is relaxed and turns negative at $x\sim10^{-3}$; an onset of the Regge asymptotics still may occur at $x<10^{-5}$
- improved strange sea determination, particularly at large x
- moderate increase in the large-x gluon distribution due to impact of the ttbar data
- HERA I+II data included → improved determination of $m_c(m_c)$;

$m_c(m_c)=1.252\pm0.018$ GeV
$m_b(m_b)=3.83\pm0.12$ GeV
$m_t(m_t)=160.9\pm1.1$ GeV

$\alpha_s(M_Z)=0.1145(9)$	DIS
$\alpha_s(M_Z)=0.1147(8)$	DIS+ttbar

EXTRAS

The fit ingredients

DATA:

- DIS NC/CC inclusive (HERA I+II added, no deuteron data included)
- DIS NC charm production (HERA)
- DIS CC charm production (HERA, NOMAD, CHORUS, NuTeV/CCFR)
- fixed-target DY
- LHC DY distributions (ATLAS, CMS, LHCb)
- t-quark data from the LHC and Tevatron

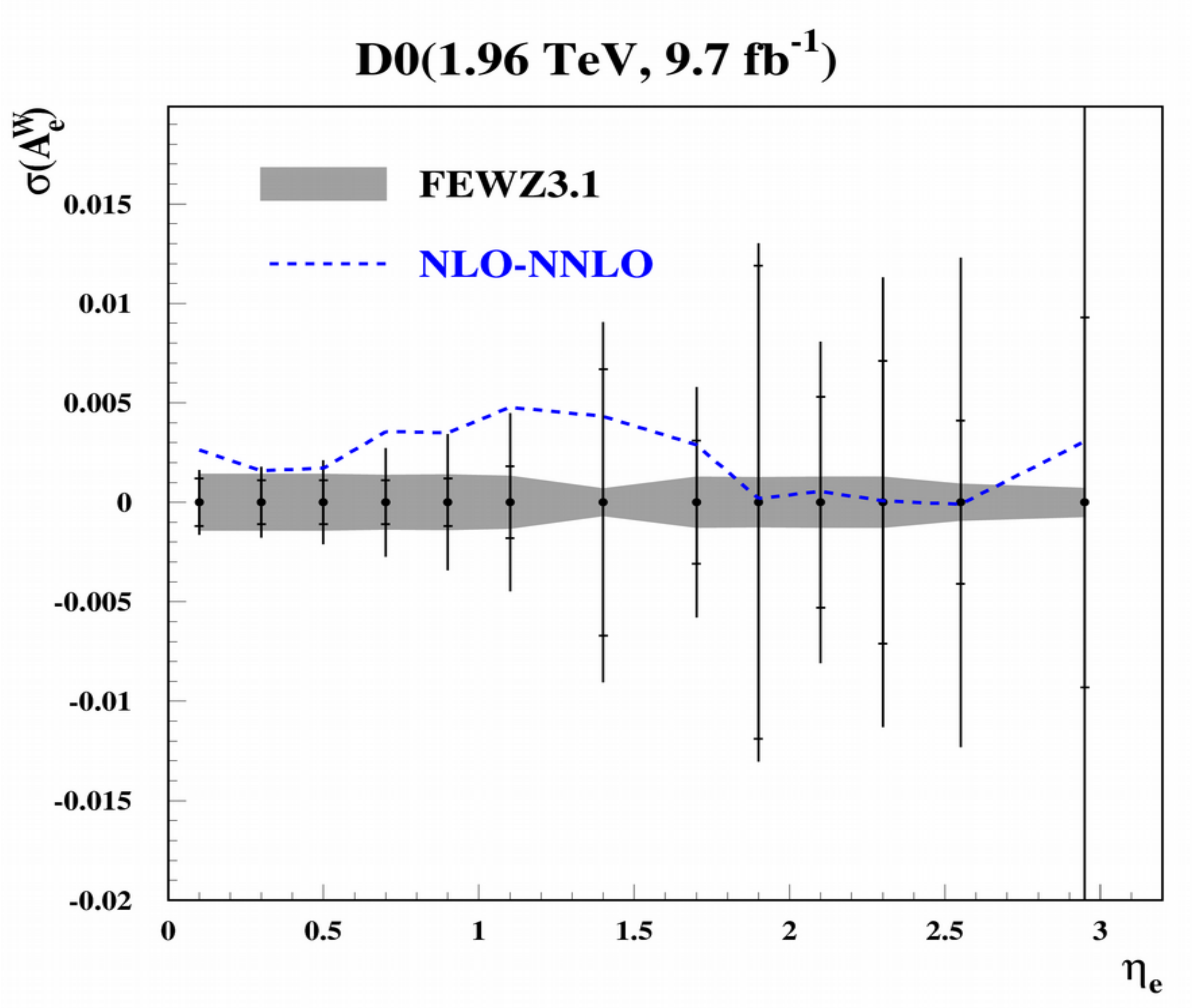
QCD:

- NNLO evolution
- NNLO massless DIS and DY coefficient functions
- NLO+ massive DIS coefficient functions (**FFN scheme**)
  - – NLO + NNLO threshold corrections for NC
  - – NNLO CC at Q>> m_c
  - – running mass
- NNLO exclusive DY (FEWZ 3.1)
- NNLO inclusive ttbar production (pole / running mass)
- Relaxed form of (dbar-ubar) at small x

Power corrections in DIS:

- target mass effects
- dynamical twist-4 terms

Computation accuracy



- Accuracy of O(1 ppm) is required to meet uncertainties in the experimental data → O(10^4 h) of running FEWZ 3.1 in NNLO

- An interpolation grid a la FASTNLO is used

NNLO DY corrections in the fit

The existing NNLO codes (DYNNLO, FEWZ) are quite time-consuming → fast tools are employed (FASTNLO, Applgrid,.....)

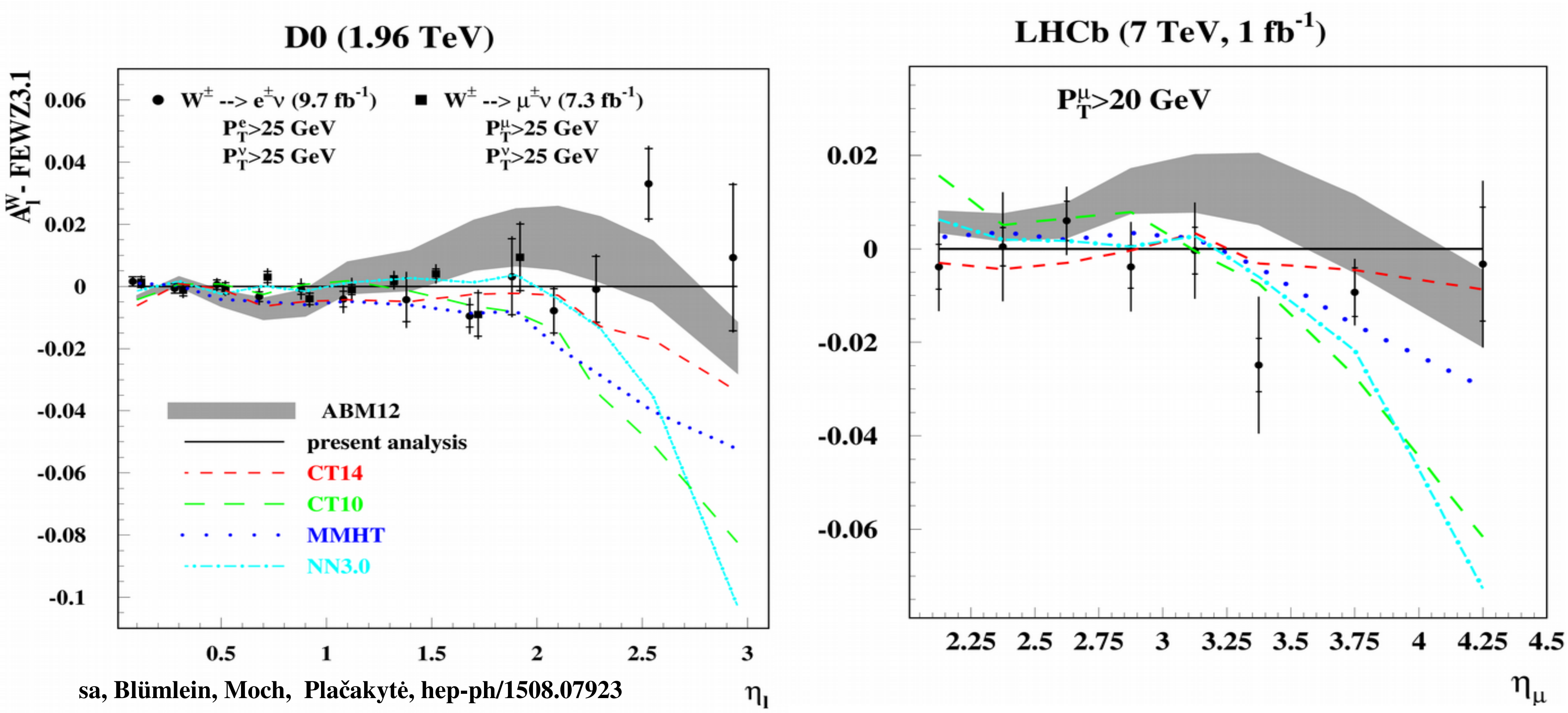
- the corrections for certain basis of PDFs are stored in the grid
- the fitted PDFs are expanded over the basis
- the NNLO c.s. in the PDF fit is calculated as a combination of expansion coefficients with the pre-prepared grids

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
$\mathbf{E}$ – error matrix
$\mathbf{P}$ – 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

DY at large rapidity

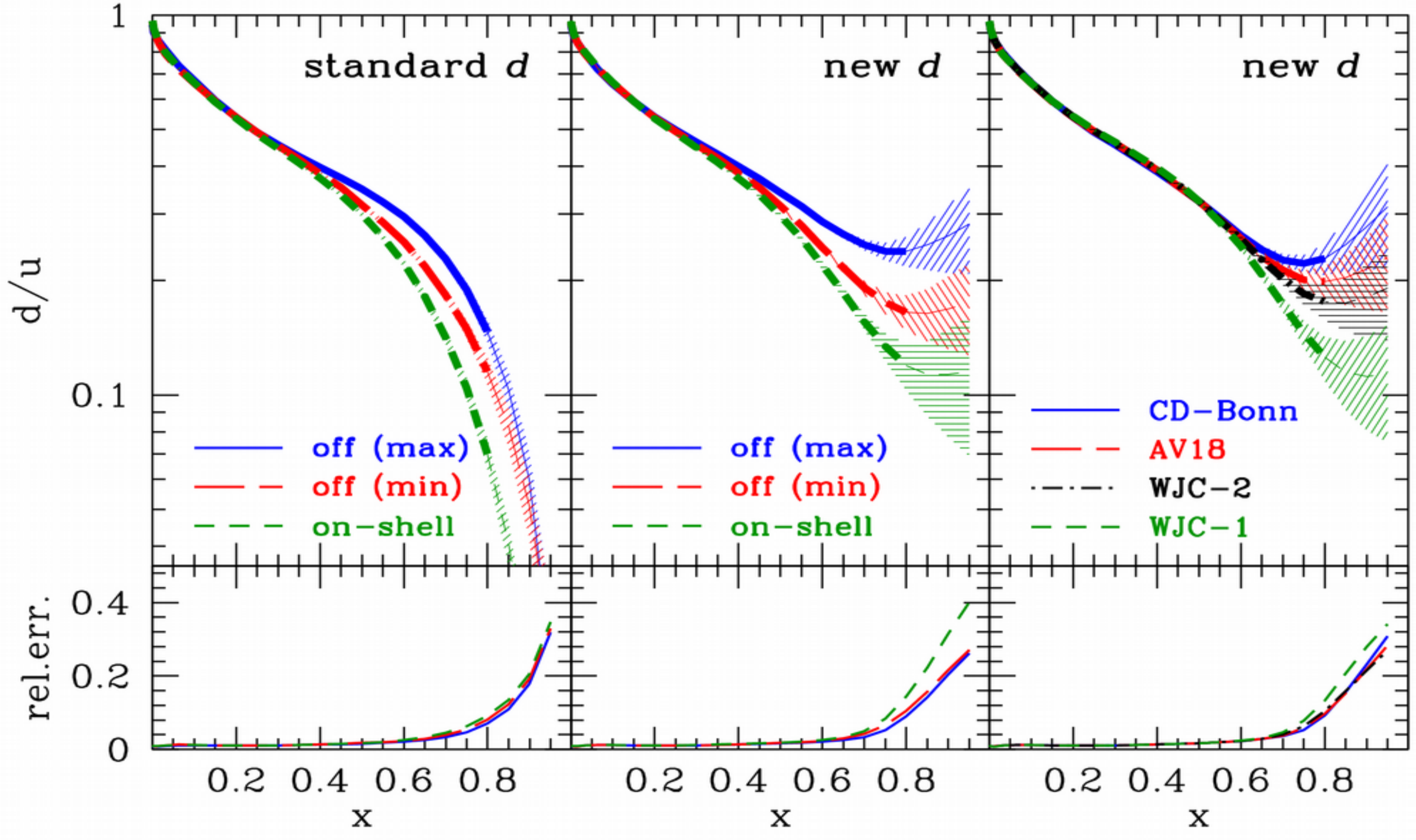


sa, Blümlein, Moch, Plačakytė, hep-ph/1508.07923

- The data can be evidently used for consolidation of the PDFs, however, unification of the theoretical accuracy is also needed

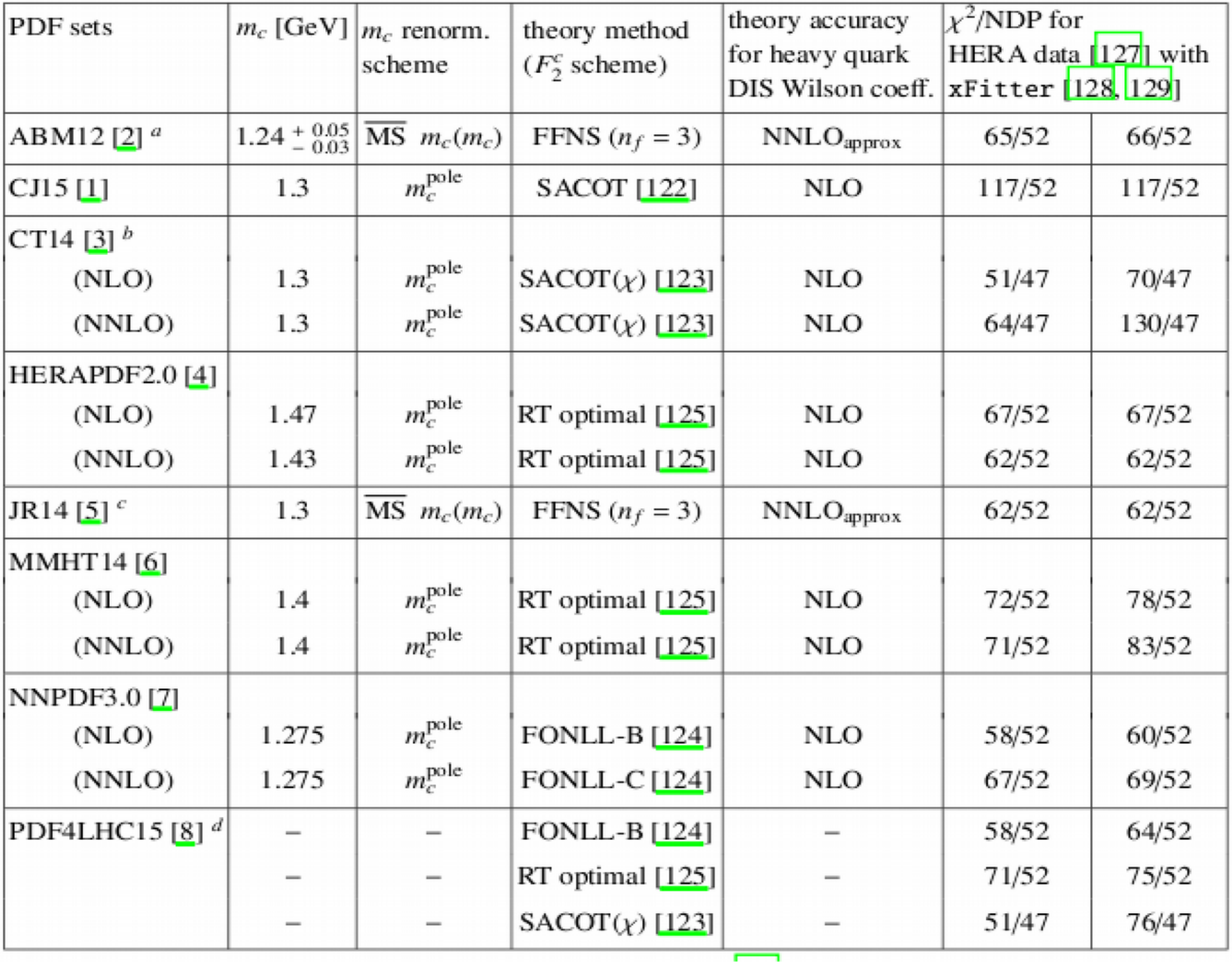
ABM	CT	MMHT	NNPDF
Interpolation of accurate NNLO grid (a la FASTNLO)	NNLL (ResBos)	NLO + NNLO K-factor	NLO + NNLO C-factors (y-dependent K-factors)

d/u ratio at large x



Accarti et al. PRD 84, 014008 (2011)

d/u ratio extracted from the DIS data is quite sensitive to the details of modeling nuclear effects in deuterium

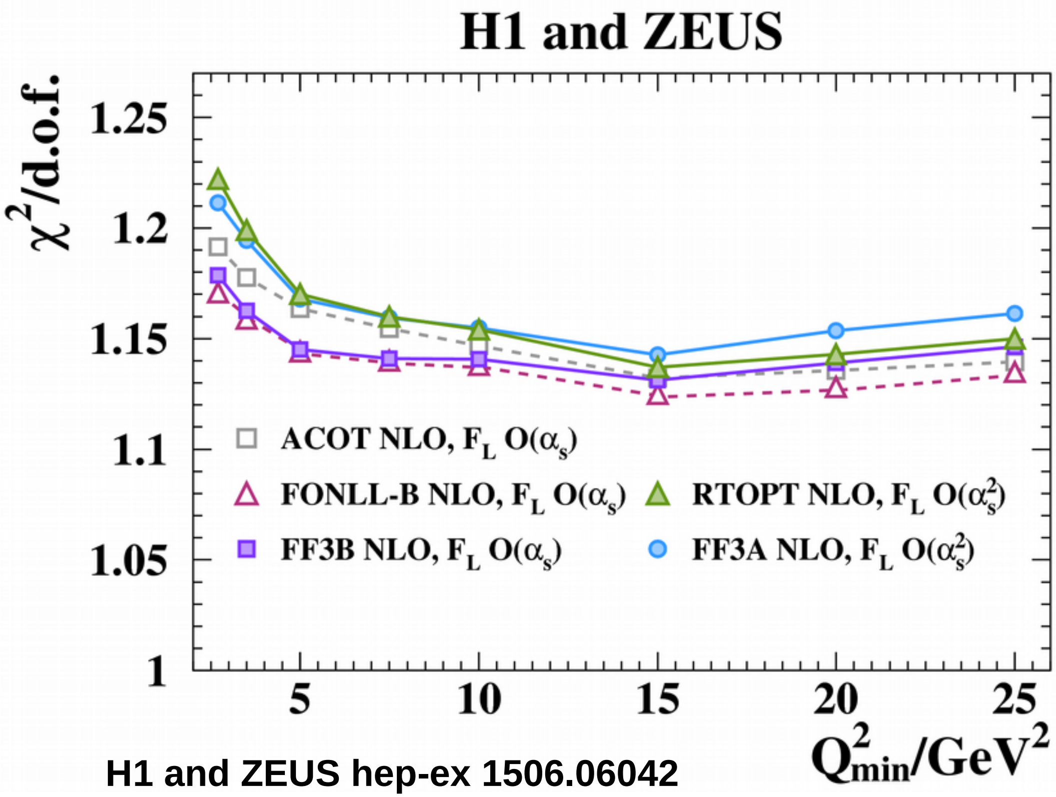


PDF sets	m_c [GeV]	m_c renorm. scheme	theory method (F_2^c scheme)	theory accuracy for heavy quark DIS Wilson coeff.	χ^2/NDP for HERA data [127] with `xFitter` [128, 129]	
ABM12 [2] [a]	$1.24^{+0.05}_{-0.03}$	$\overline{\text{MS}}$ $m_c(m_c)$	FFNS ($n_f = 3$)	$\text{NNLO}_{\text{approx}}$	65/52	66/52
CJ15 [1]	1.3	m_c^{pole}	SACOT [122]	NLO	117/52	117/52
CT14 [3] [b]						
(NLO)	1.3	m_c^{pole}	SACOT(χ) [123]	NLO	51/47	70/47
(NNLO)	1.3	m_c^{pole}	SACOT(χ) [123]	NLO	64/47	130/47
HERAPDF2.0 [4]						
(NLO)	1.47	m_c^{pole}	RT optimal [125]	NLO	67/52	67/52
(NNLO)	1.43	m_c^{pole}	RT optimal [125]	NLO	62/52	62/52
JR14 [5] [c]	1.3	$\overline{\text{MS}}$ $m_c(m_c)$	FFNS ($n_f = 3$)	$\text{NNLO}_{\text{approx}}$	62/52	62/52
MMHT14 [6]						
(NLO)	1.4	m_c^{pole}	RT optimal [125]	NLO	72/52	78/52
(NNLO)	1.4	m_c^{pole}	RT optimal [125]	NLO	71/52	83/52
NNPDF3.0 [7]						
(NLO)	1.275	m_c^{pole}	FONLL-B [124]	NLO	58/52	60/52
(NNLO)	1.275	m_c^{pole}	FONLL-C [124]	NLO	67/52	69/52
PDF4LHC15 [8] [d]	–	–	FONLL-B [124]	–	58/52	64/52
	–	–	RT optimal [125]	–	71/52	75/52
	–	–	SACOT(χ) [123]	–	51/47	76/47

Accardi, et al. hep-ph/1603.08906

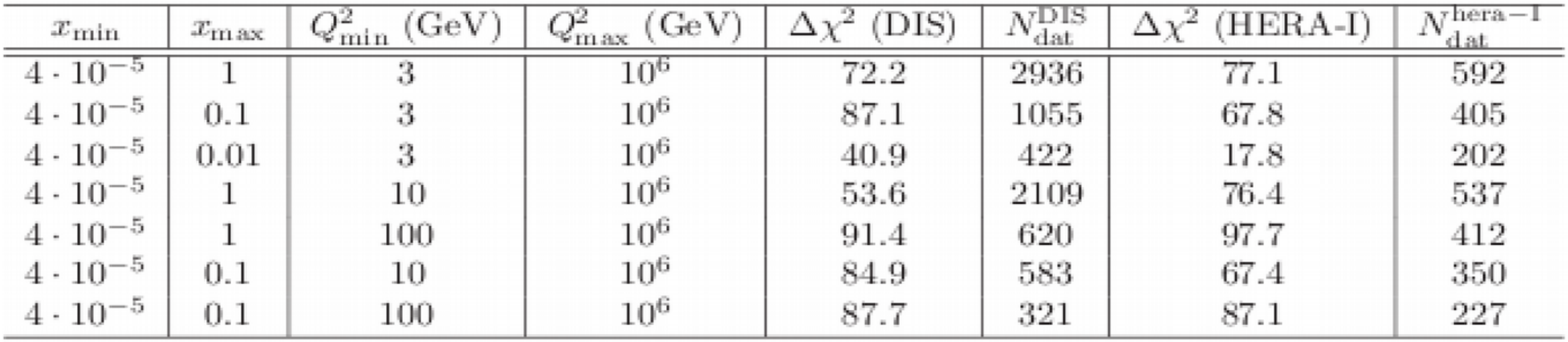
No advantage of the GMVFN schemes: the VFN χ^2 values are systematically bigger than the FFN ones

Factorization scheme benchmarking



H1 and ZEUS hep-ex 1506.06042

- Data allow to discriminate factorization schemes
- FFN scheme works very well in case of correct setting (running mass definition and correct value of m_c) → no traces of big logs due to resummation

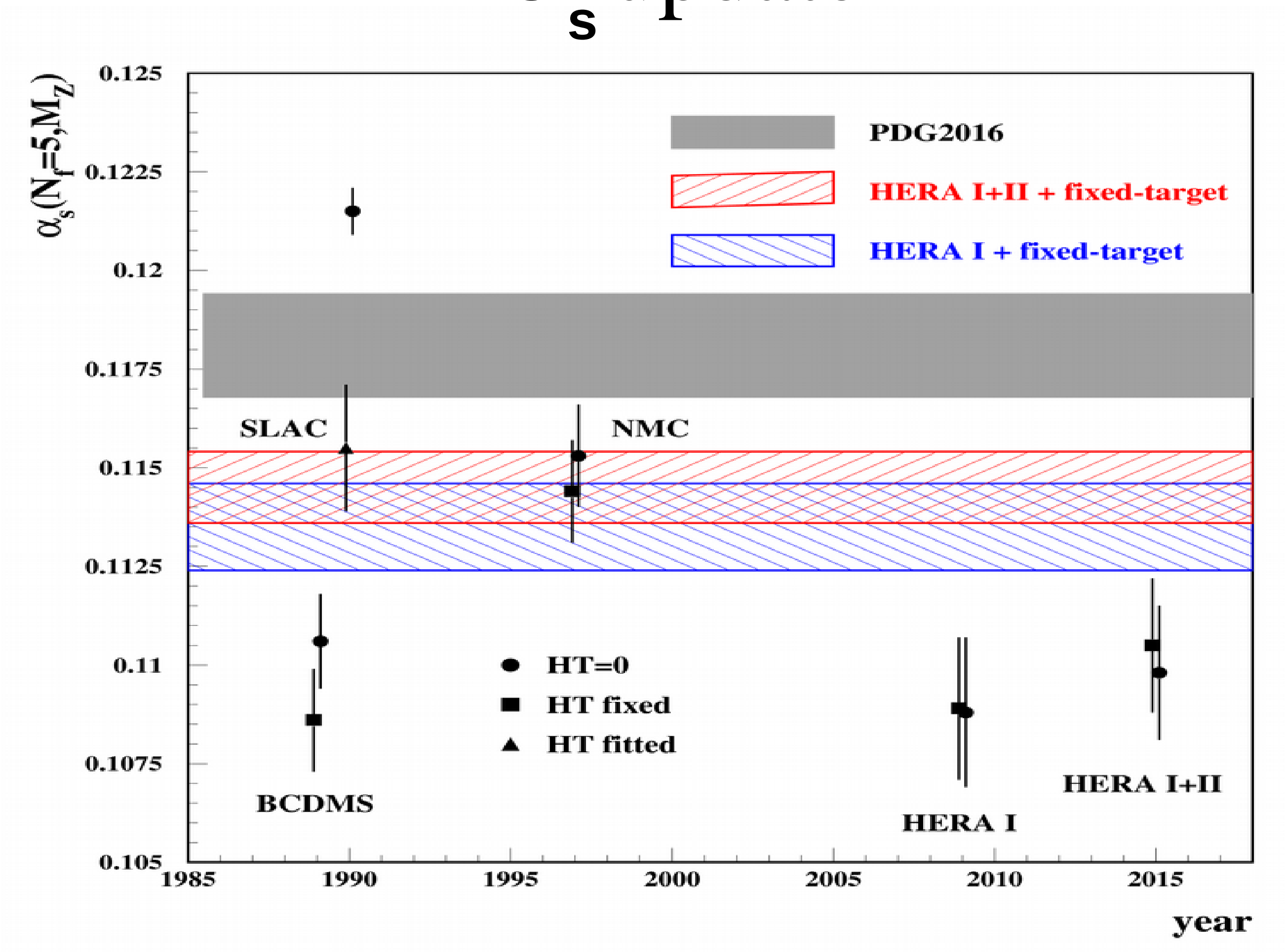


$x_{\min}$	$x_{\max}$	$Q^2_{\min}$ (GeV)	$Q^2_{\max}$ (GeV)	$\Delta\chi^2$ (DIS)	$N_{\rm dat}^{\rm DIS}$	$\Delta\chi^2$ (HERA-I)	$N_{\rm dat}^{\rm hera-I}$
$4 \cdot 10^{-5}$	1	3	10^6	72.2	2936	77.1	592
$4 \cdot 10^{-5}$	0.1	3	10^6	87.1	1055	67.8	405
$4 \cdot 10^{-5}$	0.01	3	10^6	40.9	422	17.8	202
$4 \cdot 10^{-5}$	1	10	10^6	53.6	2109	76.4	537
$4 \cdot 10^{-5}$	1	100	10^6	91.4	620	97.7	412
$4 \cdot 10^{-5}$	0.1	10	10^6	84.9	583	67.4	350
$4 \cdot 10^{-5}$	0.1	100	10^6	87.7	321	87.1	227

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 PLB 723, 330 (2013)

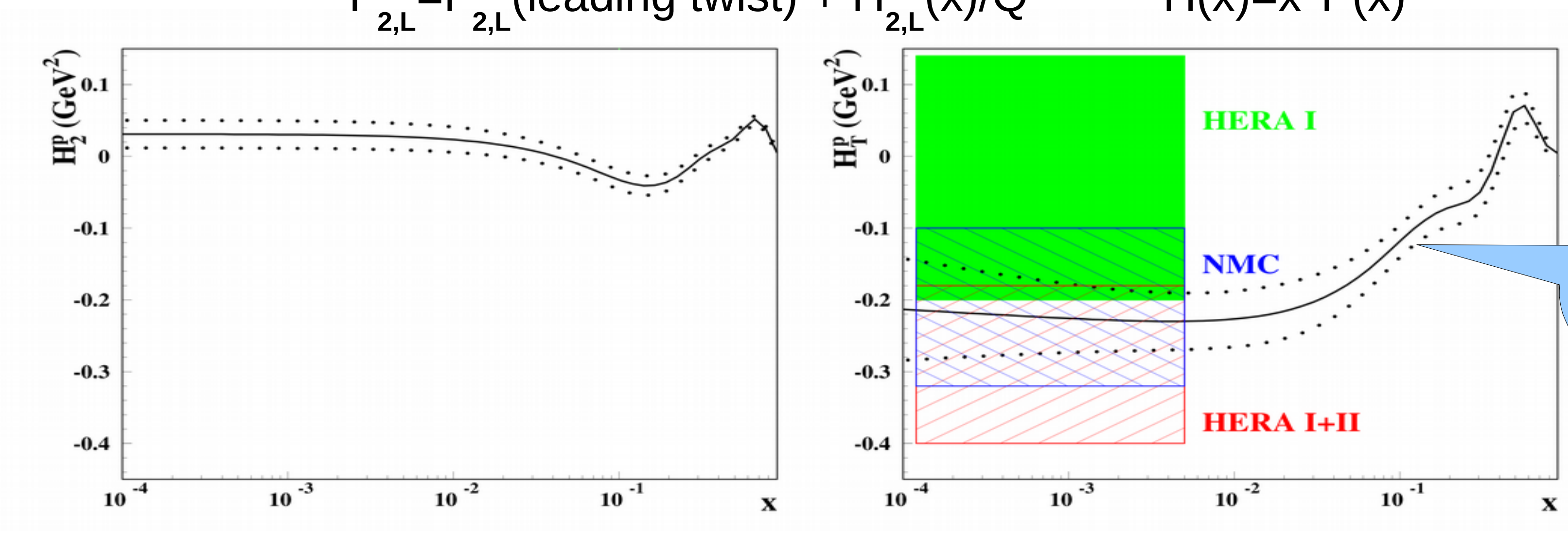
α_s update



- Combination of the DY data (disentangle PDFs) and the DIS ones (constrain α_s)
- Run-II data pull α_s up by 0.001
- the value of α_s is still lower than the PDG one: pulled up by the SLAC and NMC data; pulled down by the BCDMS and HERA ones
- only SLAC determination overlap with the PDG band provided the high-twist terms are taken into account

High twists at small x

$F_{2,L}=F_{2,L}(\text{leading twist}) + H_{2,L}(x)/Q^2$ $H(x)=x^hP(x)$

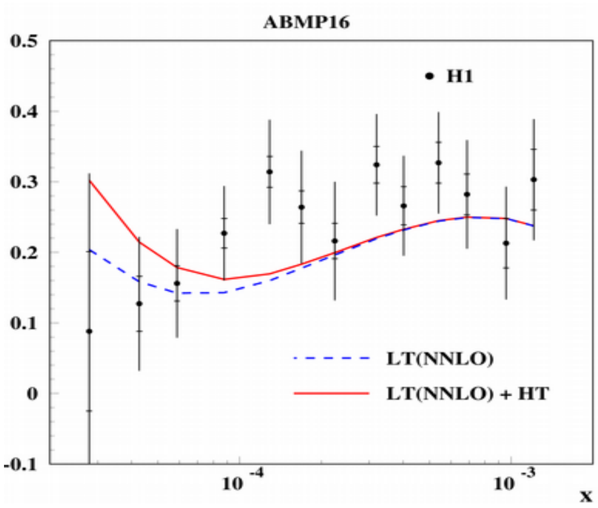


Controlled by SLAC and NMC data

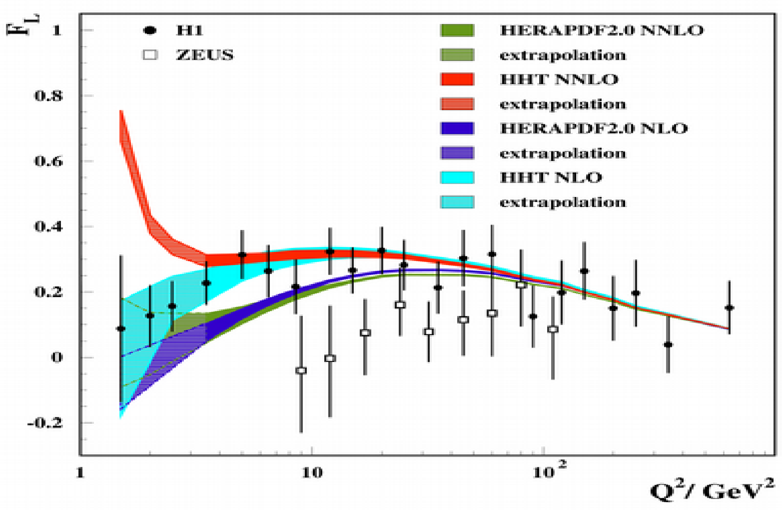
sa, Blümlein, Moch PRD 86, 054009 (2012)

- $H_T(x)$ continues a trend observed at larger x; $H_2(x)$ is comparable to 0 at small x
- $h_T=0.05\pm0.07$ → slow vanishing at x → 0
- $\Delta\chi^2 \sim -40$

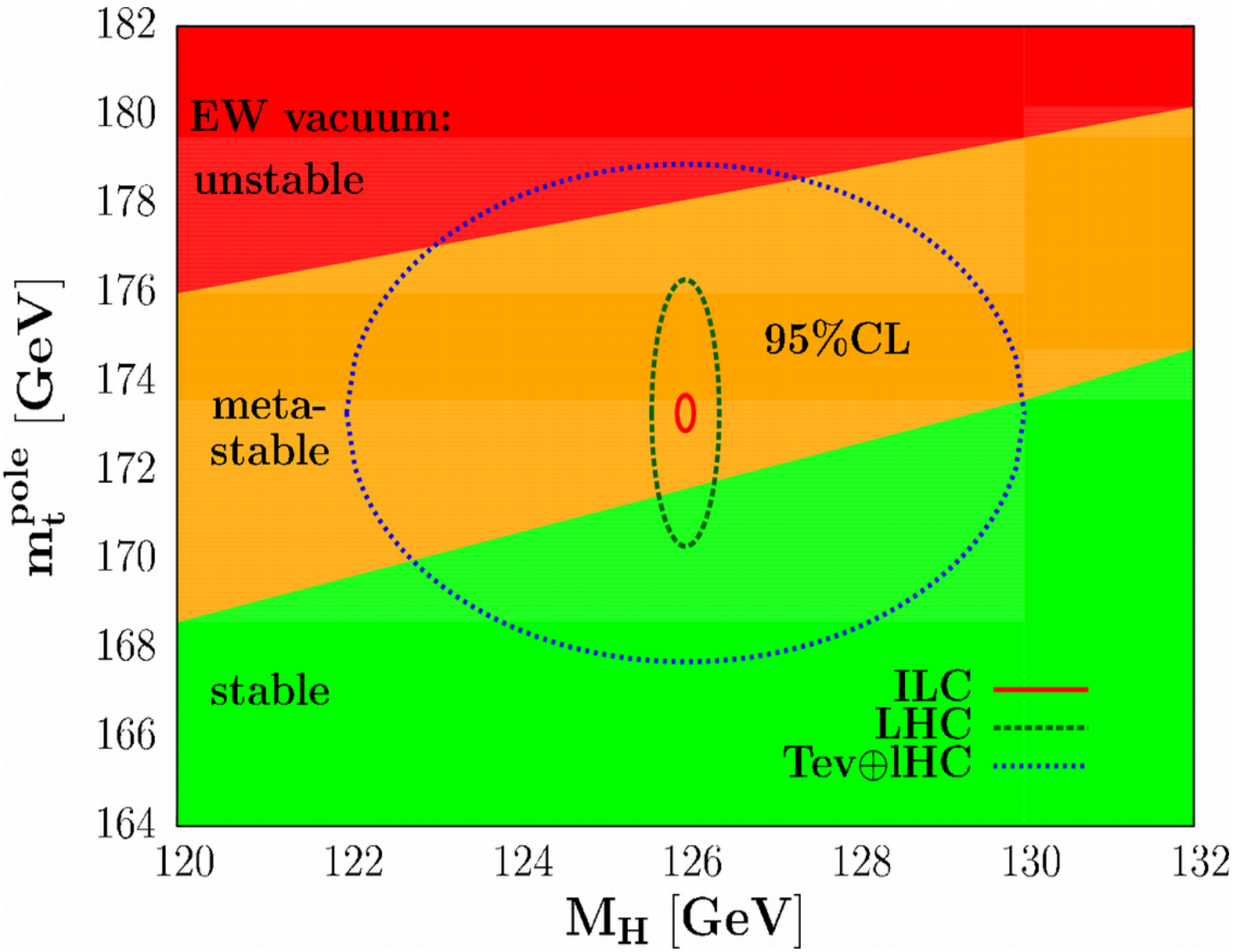
Harland-Lang, Martin, Motylinski, Thorne hep-ph/1601.03413



No dramatic increase of F_L at small x



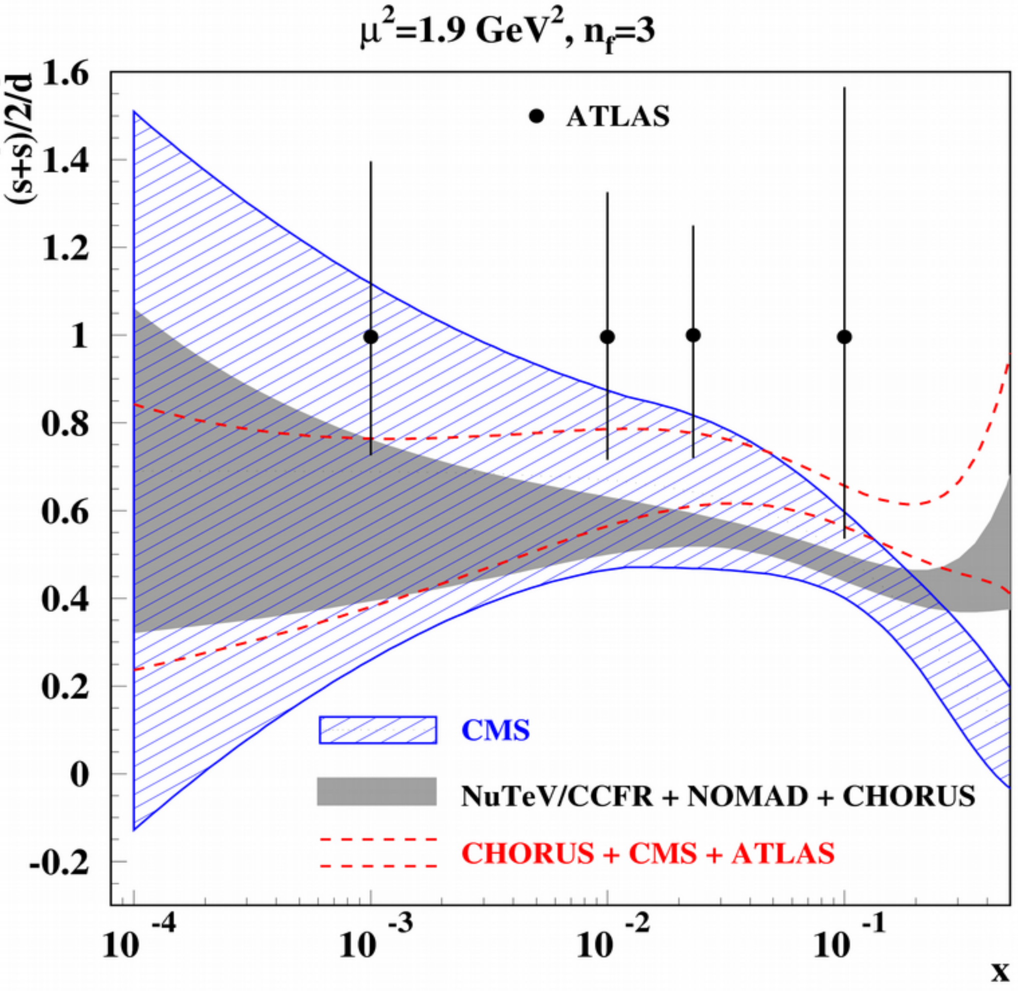
Abt, et al. hep-ex/1604.02299

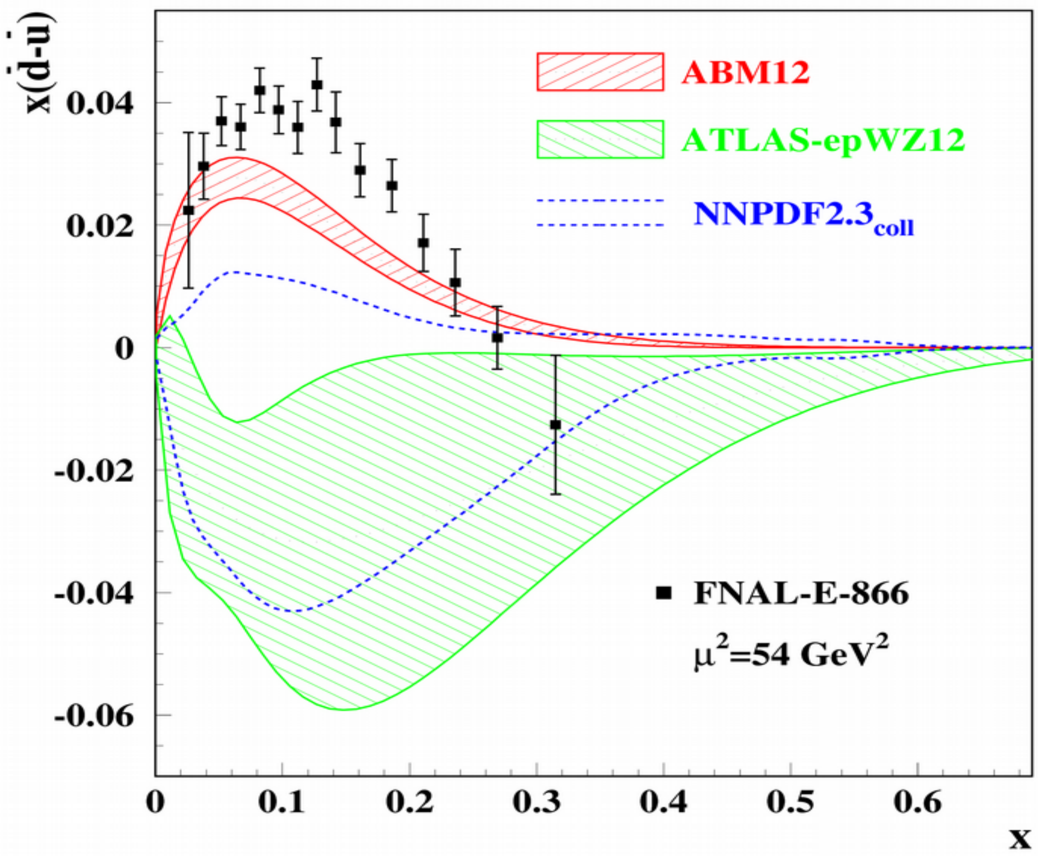


sa, Djouadi, Moch PLB 716, 214 (2012)

Vacuum stability is quite sensitive to the t-quark mass

Strange sea determinations





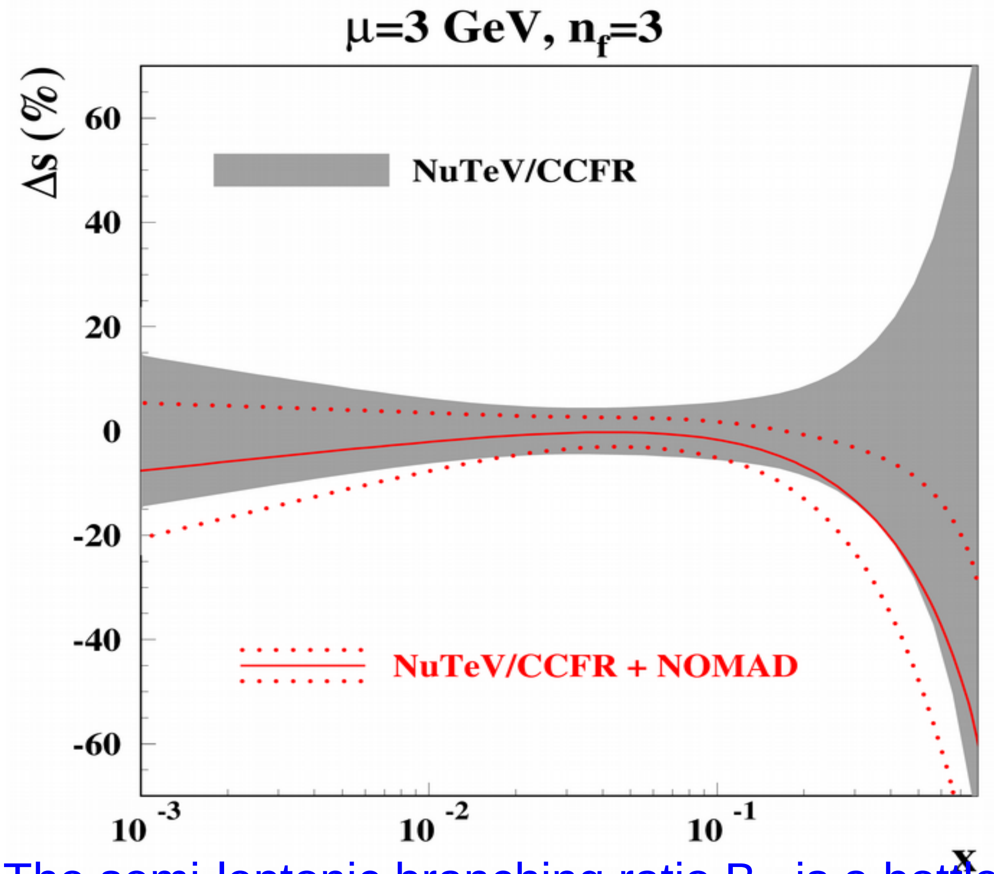
sa, Blümlein, Caminada, Lipka, Lohwasser,
Moch, Petti, Plačakytė hep-ph/1404.6469

- Nominal ABM update (NuTeV/CCFR+NOMAD+CHORUS) demonstrate good agreement with the CMS results
- The ATLAS strange-sea in enhanced, however it is correlated with the d-quark sea suppression → *disagreement with the FNAL-E-866 data*
- Upper margin of the ABM analysis (CHORUS+CMS+ATLAS) is still lower than ATLAS

	X²/NDP
ATLAS W/Z(incl.)	35/30
NOMAD (2μ)	52/48
CHORUS (charm)	10/6

Integral strangeness suppression factor κ_s(20 GeV²)=0.654(30)

NOMAD charm data in the ABM fit



The data on ratio 2μ/incl. CC ratio with the 2μ statistics of 15000 events (much bigger than in earlier CCFR and NuTeV samples).

NOMAD NPB 876, 339 (2013)

Systematics, nuclear corrections, etc. cancel in the ratio

- pull down strange quarks at x>0.1 with a sizable uncertainty reduction
- $m_c(m_c)$=1.23±0.03(exp.) GeV is comparable to the ABM12 value

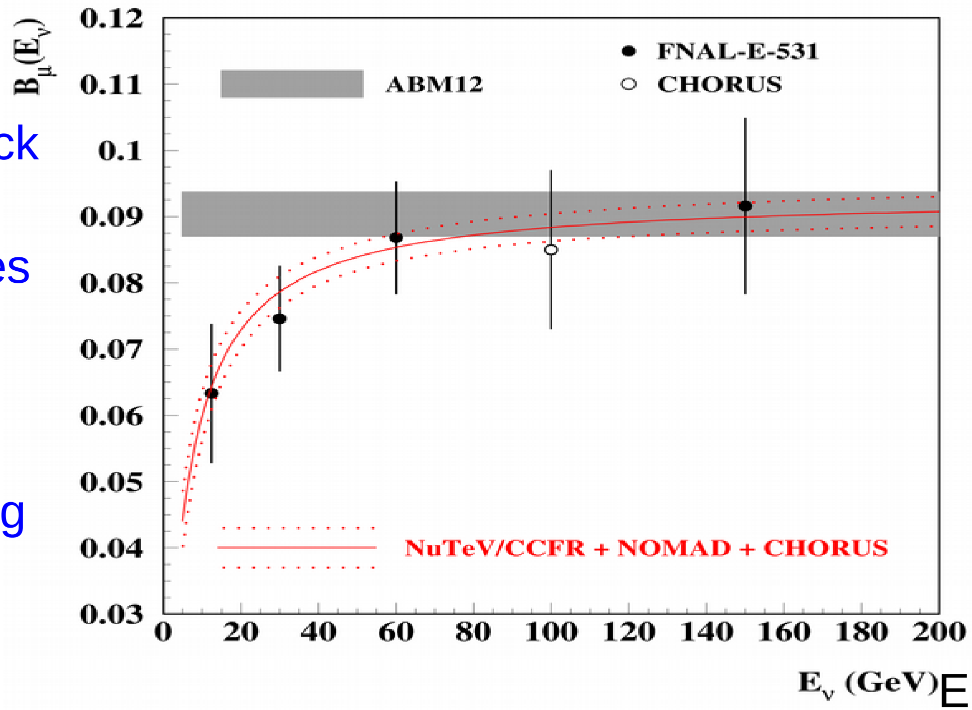
The semi-leptonic branching ratio B_μ is a bottleneck

- weighted average of the charmed-hadron rates

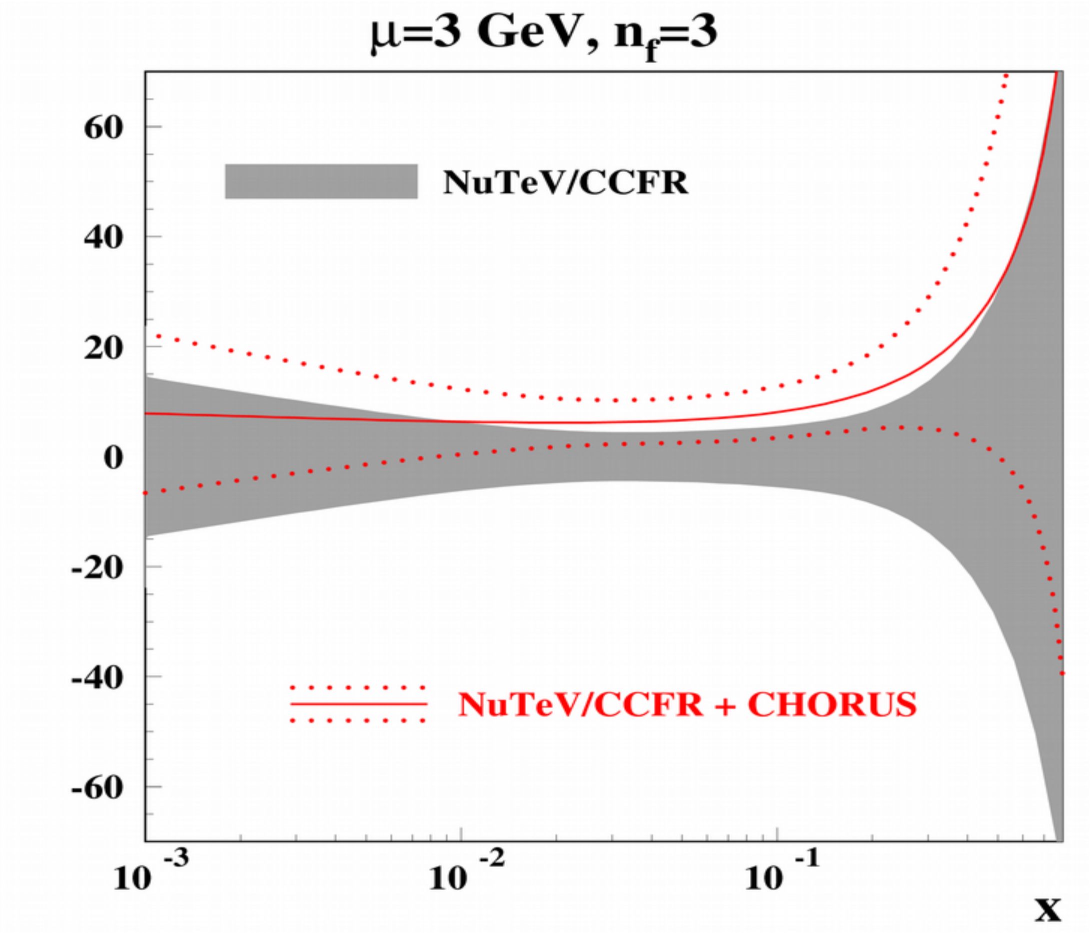
$$B_\mu(E_\nu)=\sum_h r^h(E_\nu)B^h_\mu = a/(1+b/E_\nu)$$

- fitted simultaneously with the PDFs, etc. using the constraint from the emulsion data

sa, Blümlein, Caminadac, Lipka, Lohwasser, Moch, Petti, Placakyte hep-ph/1404.6469



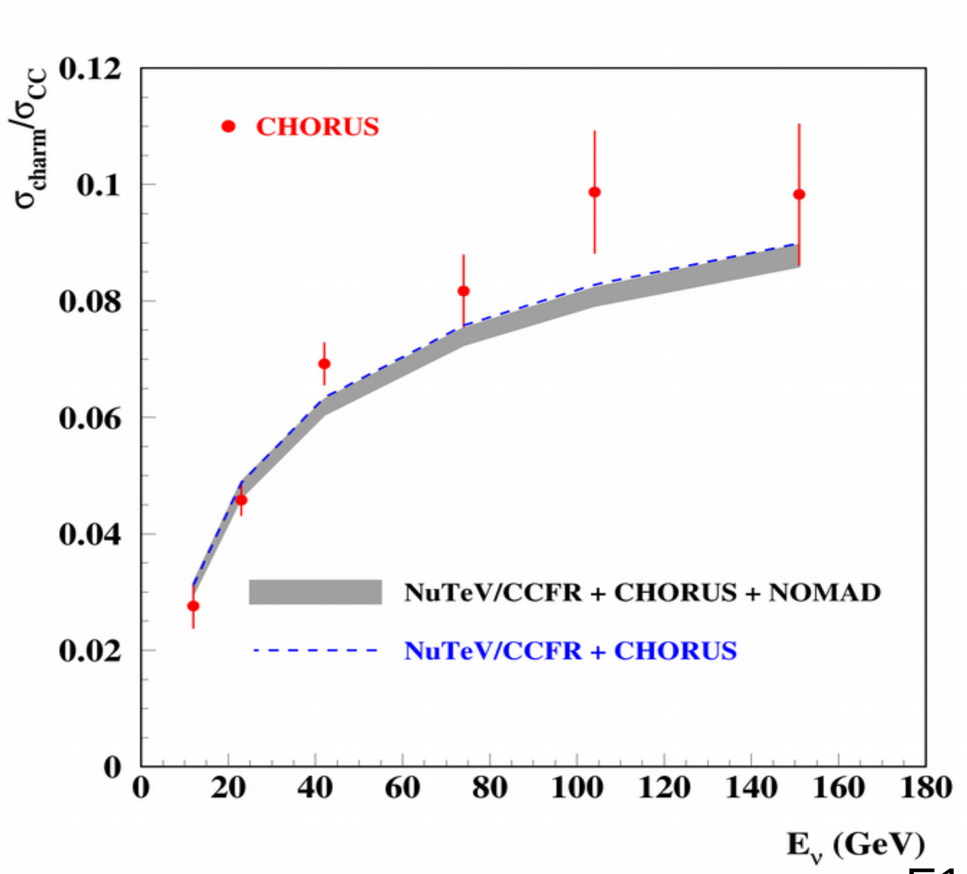
CHORUS charm data in the ABM fit



Emulsion data on charm/CC ratio with the charmed hadron vertex measured

CHORUS NJP 13, 093002 (2011)

- full phase space measurements
- no sensitivity to B_μ
- low statistics (2013 events)

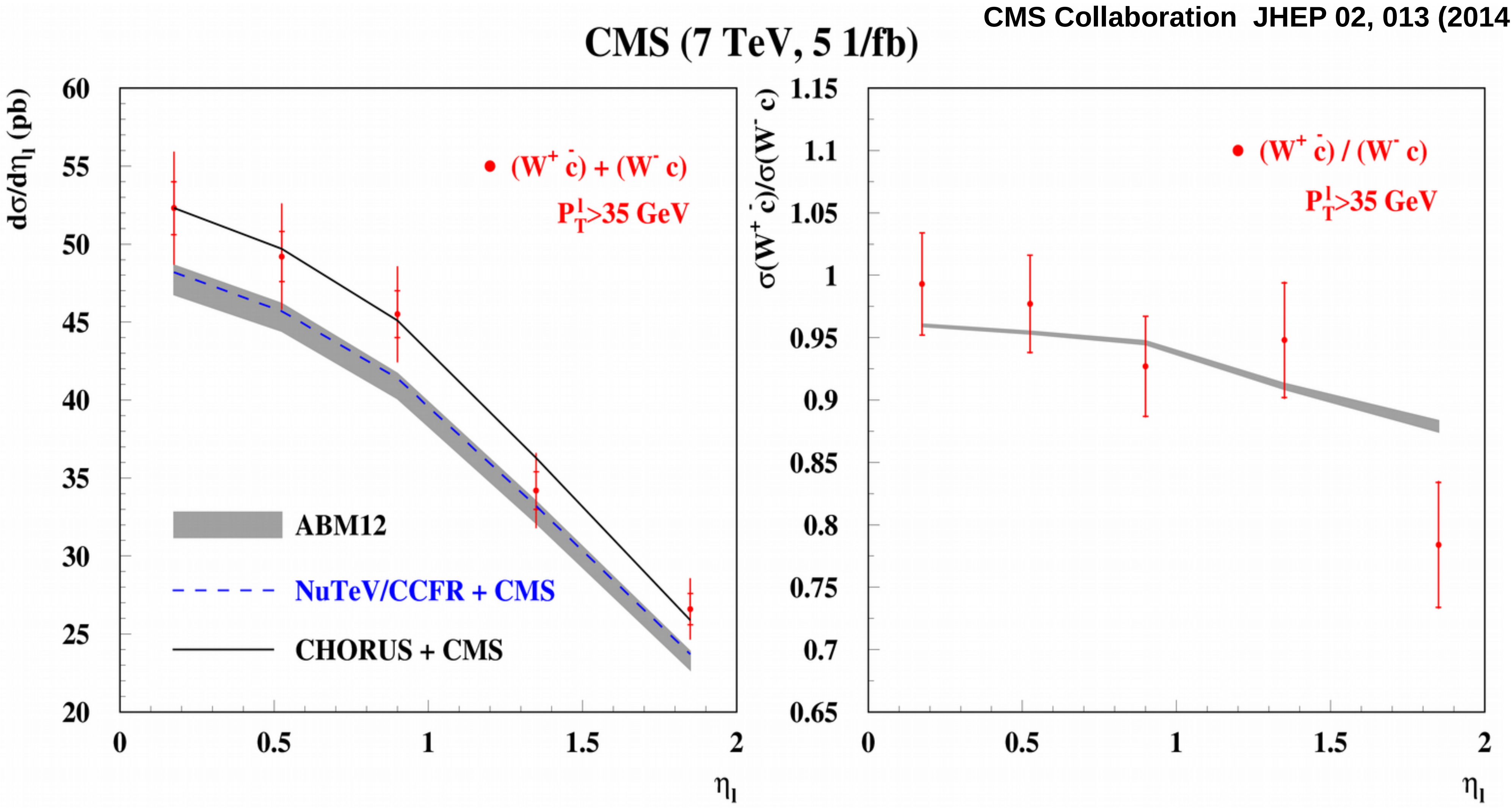


CHORUS data pull strangeness up, however the statistical significance of the effect is poor

sa, Blümlein, Caminadac, Lipka, Lohwasser, Moch, Petti, Placakyte hep-ph/1404.6469

CMS W+charm data in the ABM fit

CMS Collaboration JHEP 02, 013 (2014)



- CMS data go above the NuTeV/CCFR by 1σ; little impact on the strange sea
- The charge asymmetry is in a good agreement with the charge-symmetric strange sea
- Good agreement with the CHORUS data

ATLAS W+charm data in the ABM fit

ATLAS Collaboration arXiv:1402.6263