Impact of DY data on PDFs

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(in collaboration with J.Blümlein and S.Moch)

- Charge-lepton asymmetry
  - LHC

    CMS_{μ} – 7 TeV 4.7 1/fb (central) **hep-ex/1312.6283**

    $LHCb_{\mu}$ – 7 TeV 1/fb (forward) **Hep-ex/1408.4354**
  - Tevatron

    $D0_{\mu}$ – 1.96 TeV 7.3 1/fb (central) **hep-ex/1309.2591**

    D0e – 1.96 TeV 9.7 1/fb (incl. forward) **Hep-ex/1412.2862**
- W asymmetry

    D0 – 1.96 TeV 9.7 1/fb (incl. forward **Hep-ex/1312.2895**

PDF4LHC, CERN, 13 Apr 2015

NNLO DY corrections in the fit

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

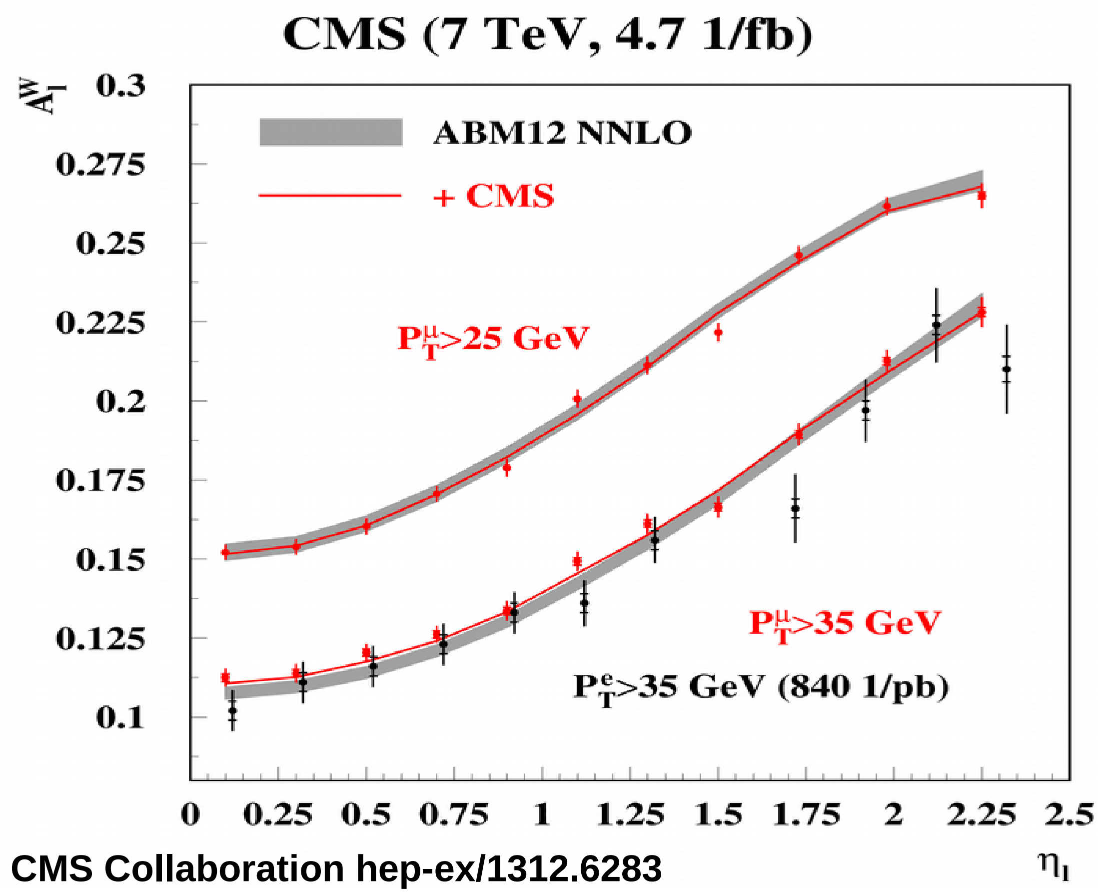
- the corrections for certain basis of PDFs are stored in the grid
- the fitted PDFs are expanded over the basis
- the NNLO c.s. in the PDF fit is calculated as a combination of expansion coefficients with the pre-prepared grids

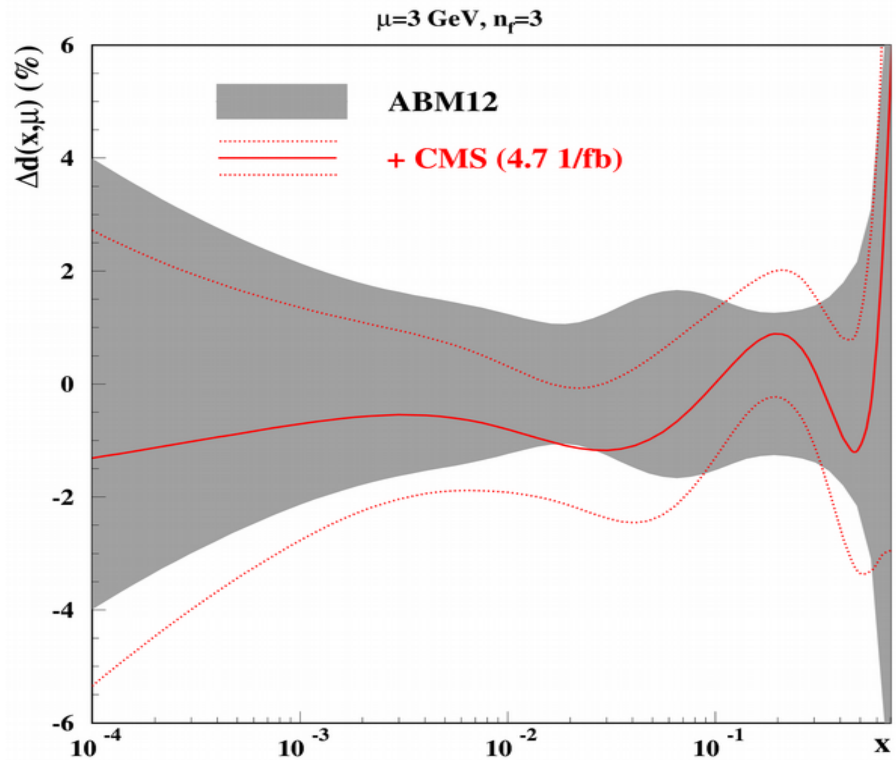
The general PDF basis is not necessary since the PDFs are already constrained by the data, which do not require involved computations → *use as a PDF basis the eigenvalue PDF sets obtained in the earlier version of the fit*

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

CMS DY data iteration





CMS Collaboration hep-ex/1312.6283

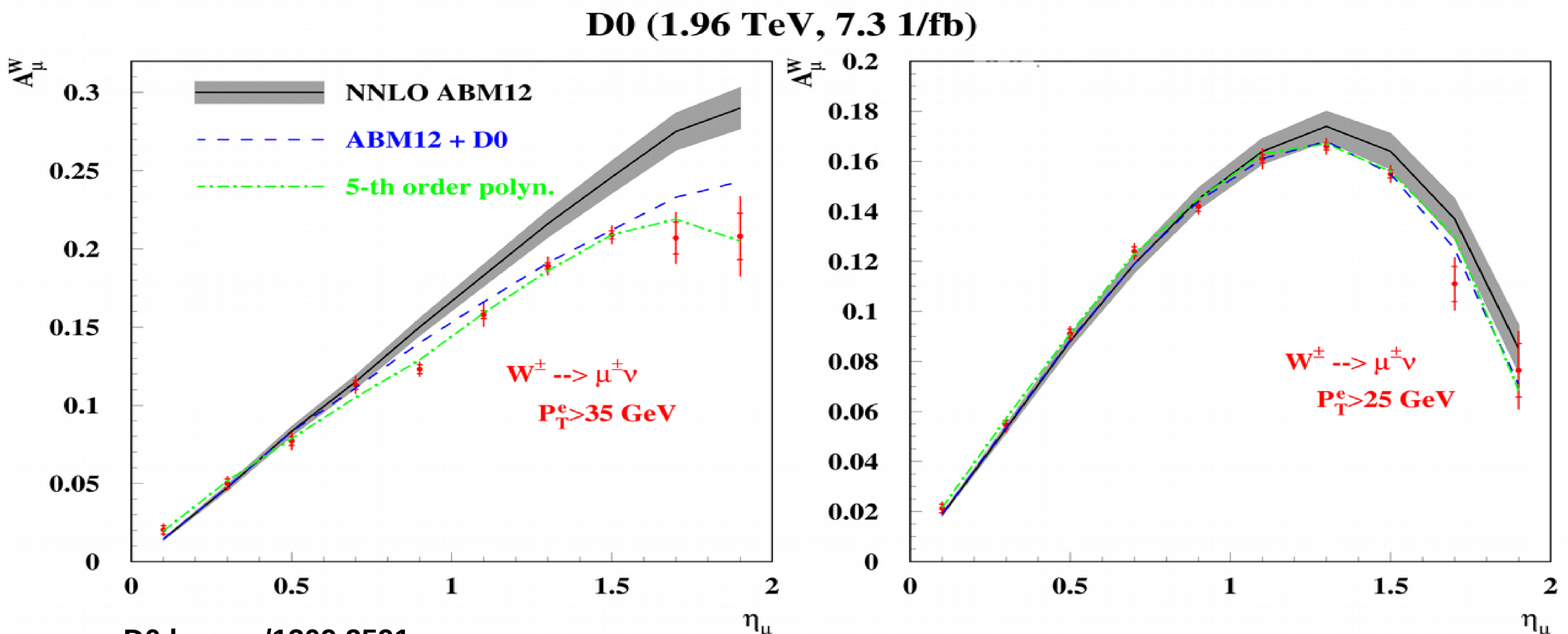
- Data converge to the ABM12 predictions in general, however at P_T>35 GeV and small η overshoot predictions and earlier data

- Improved accuracy of predictions is required(*7000h of DYNNLO 1.3 to get a smooth curve*!)

  – good agreement with the updated CMS data

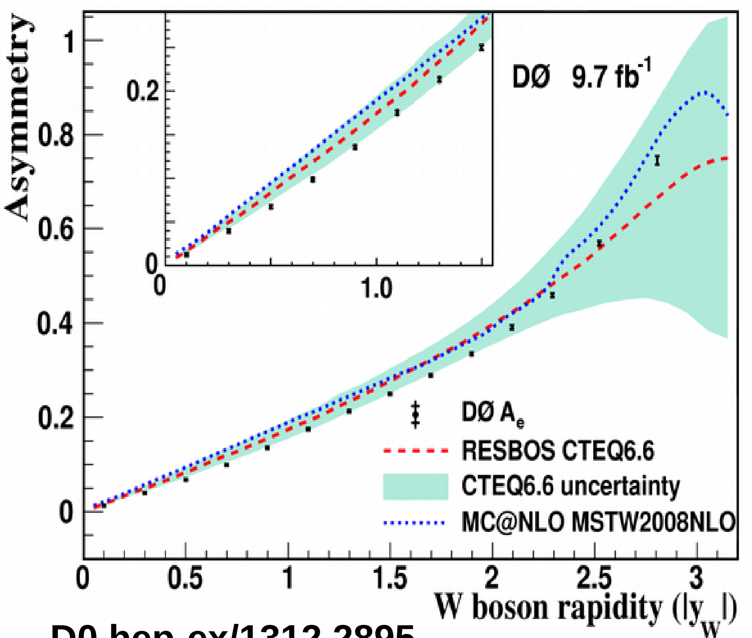
P_T	>25 GeV	>35 GeV	
X^2	16	11	for NDP=11

D0 muon asymmetry



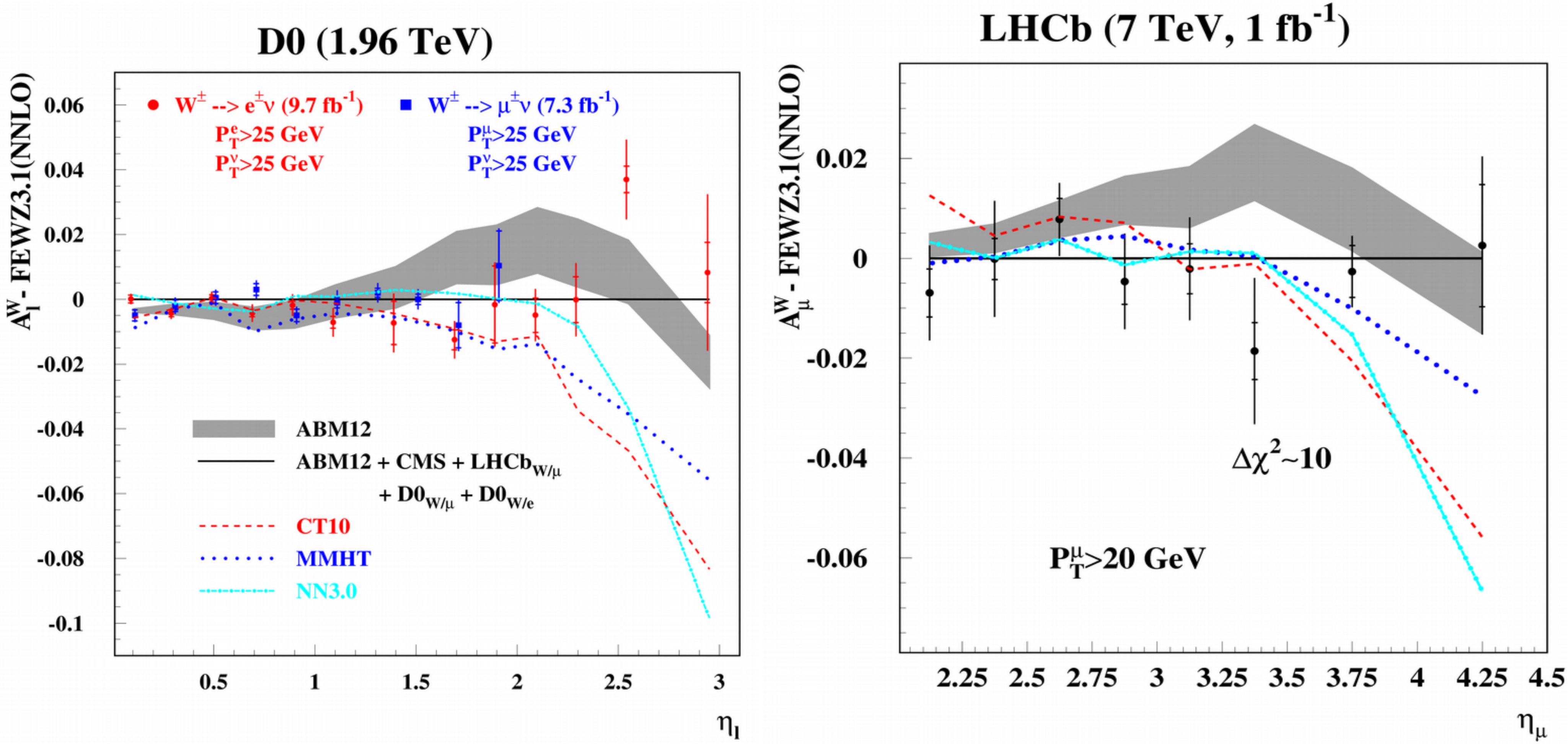
D0 hep-ex/1309.2591

- Poor agreement with the ABM12 predictions at P_T>35 GeV
- Poor description in the fit: χ^2=40/10 and 19/10 for P_T>35 and 25, respectively
- Polynomial fit gives χ^2=11/10, however displays a step structure at Y~1
- Smooth shape is observed in case of electron



D0 hep-ex/1312.2895

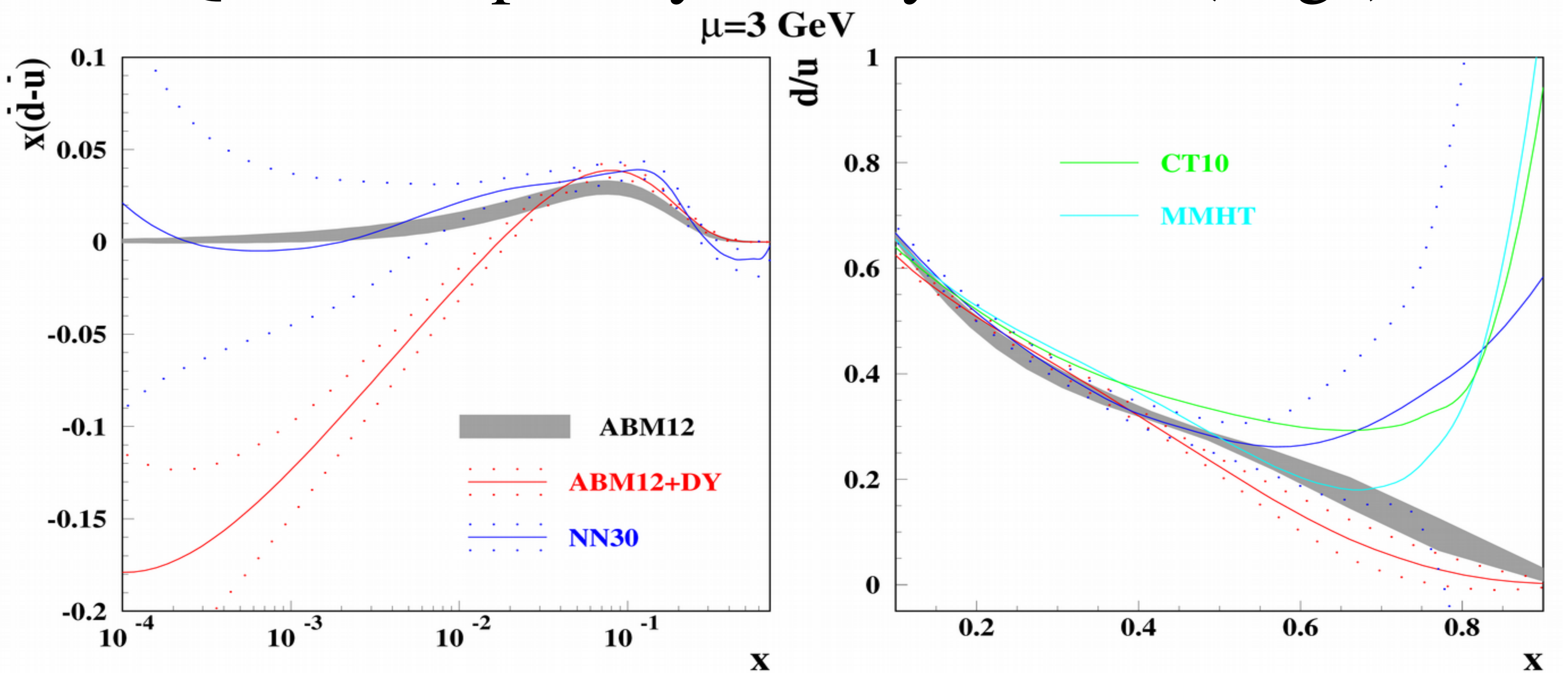
DY at large rapidity



Data are sensitive to valence quarks at large x and to *sea at small x*

- Good agreement with the ABM predictions/fit in general, although some data point fluctuate significantly
- Other recent PDFs undershoot the data at large rapidities.

Quark isospin asymmetry at small(large) x



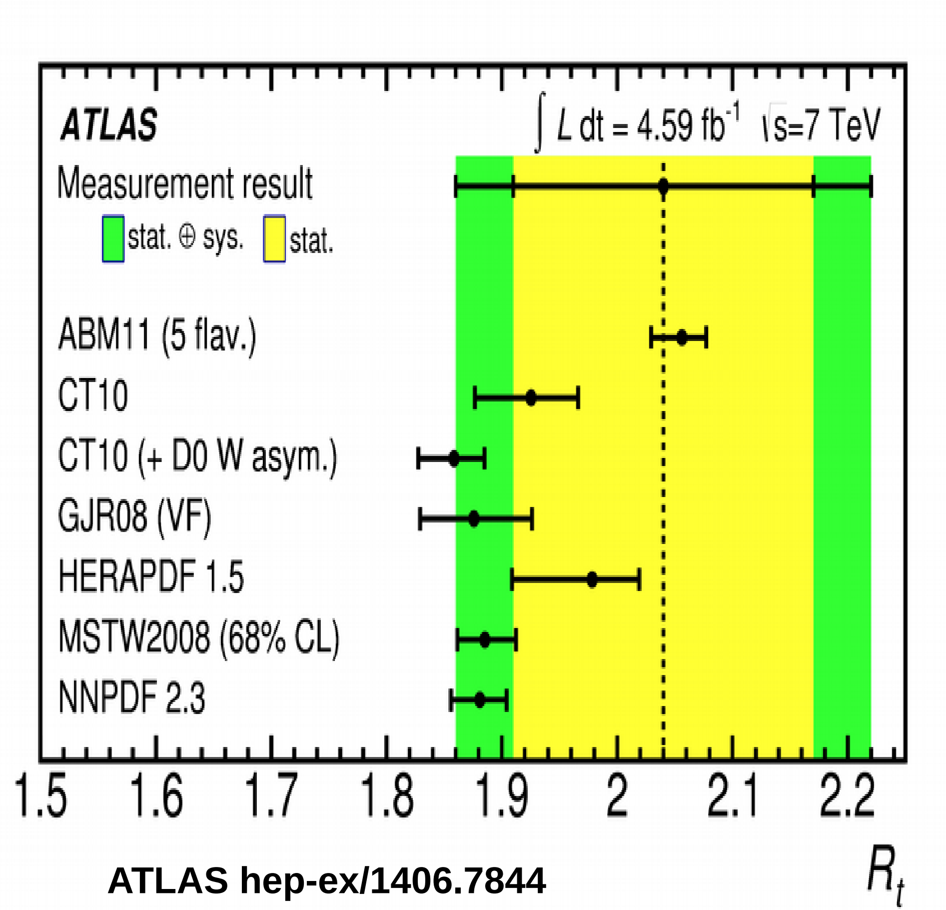
- Variant of ABM fit with CMS, LHCb, and D0 data included, however, DIS deuteron data dropped → no impact of the nuclear effects, the isospin effect are constrained by DY data

- Essential small-x sea asymmetry is observed; Regge asymptotics may recover only at very small x.

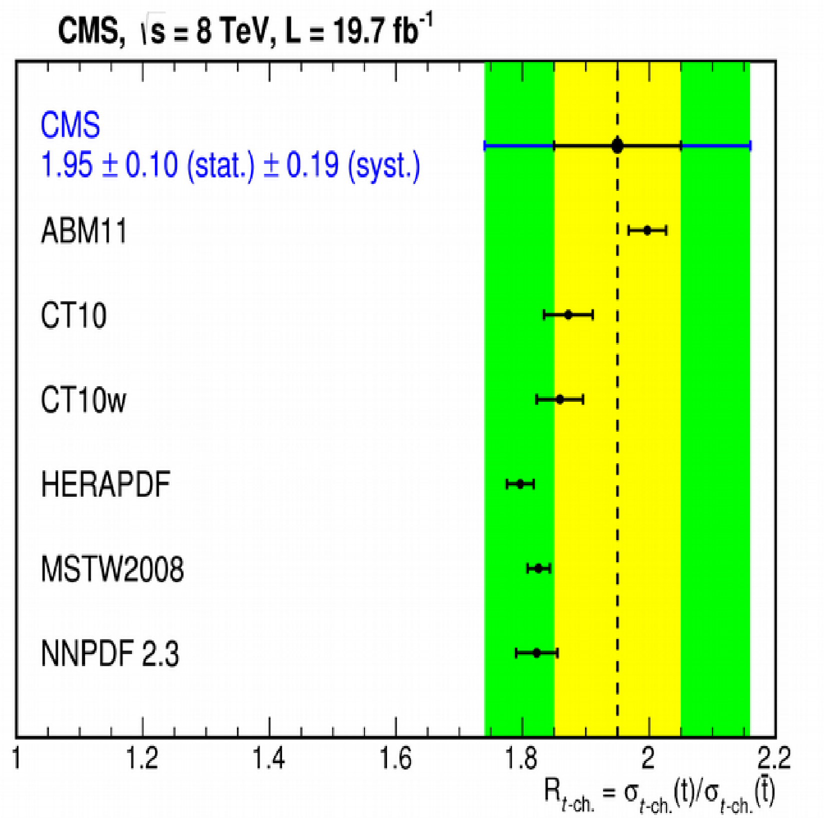
- Additional small/large x variation of the PDF shape do not improve the fit quality

- Strong enhancement in the large-x d-quarks lead to discrepancy with large- DY data: (impact of jet data or treatment of the large-x DIS data or ….)

t-channel single-top production



ATLAS hep-ex/1406.7844



CMS hep-ex/1403.7366

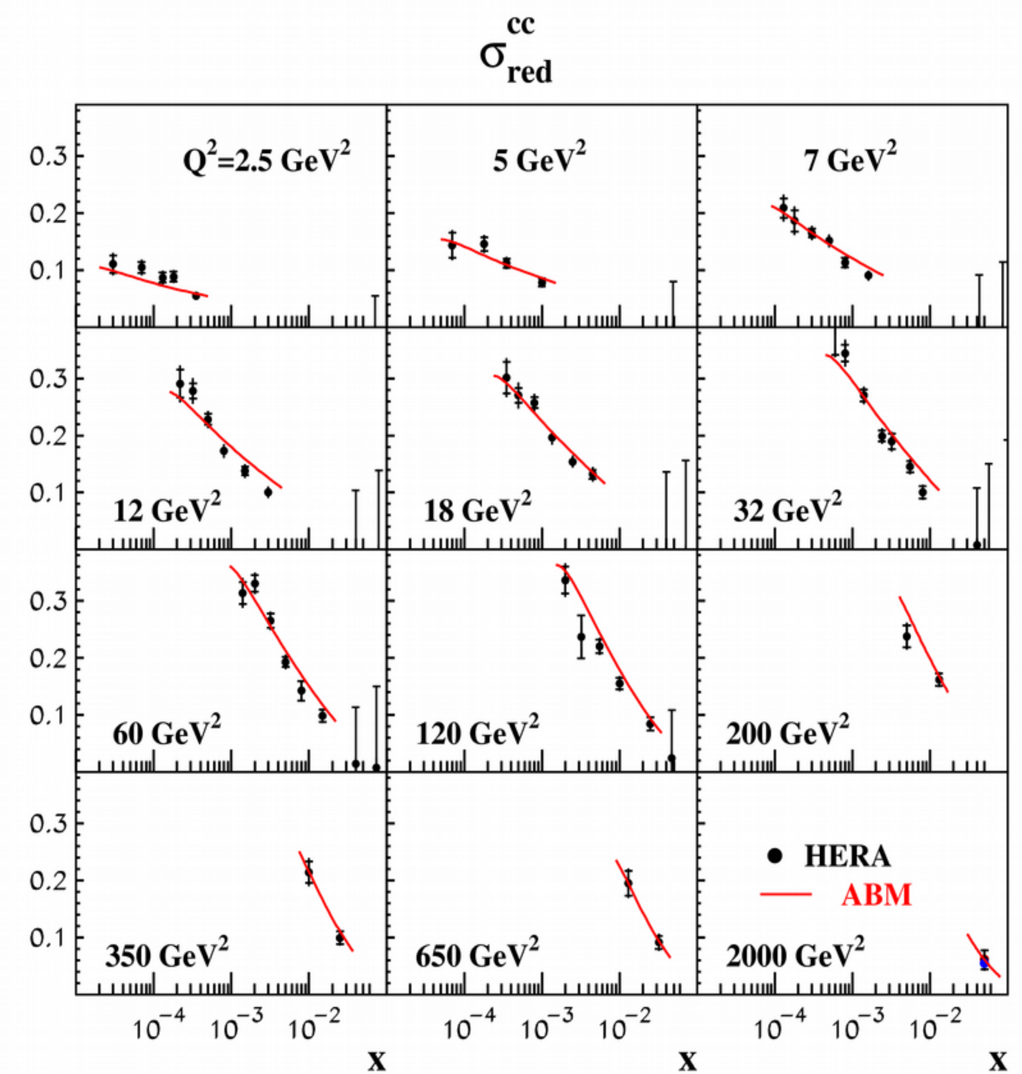
- The ratio of t/tbar rates is driven by u/d → suppressed for the "truly global PDFs"
- For ABM with LHC/Tevatron DY data included

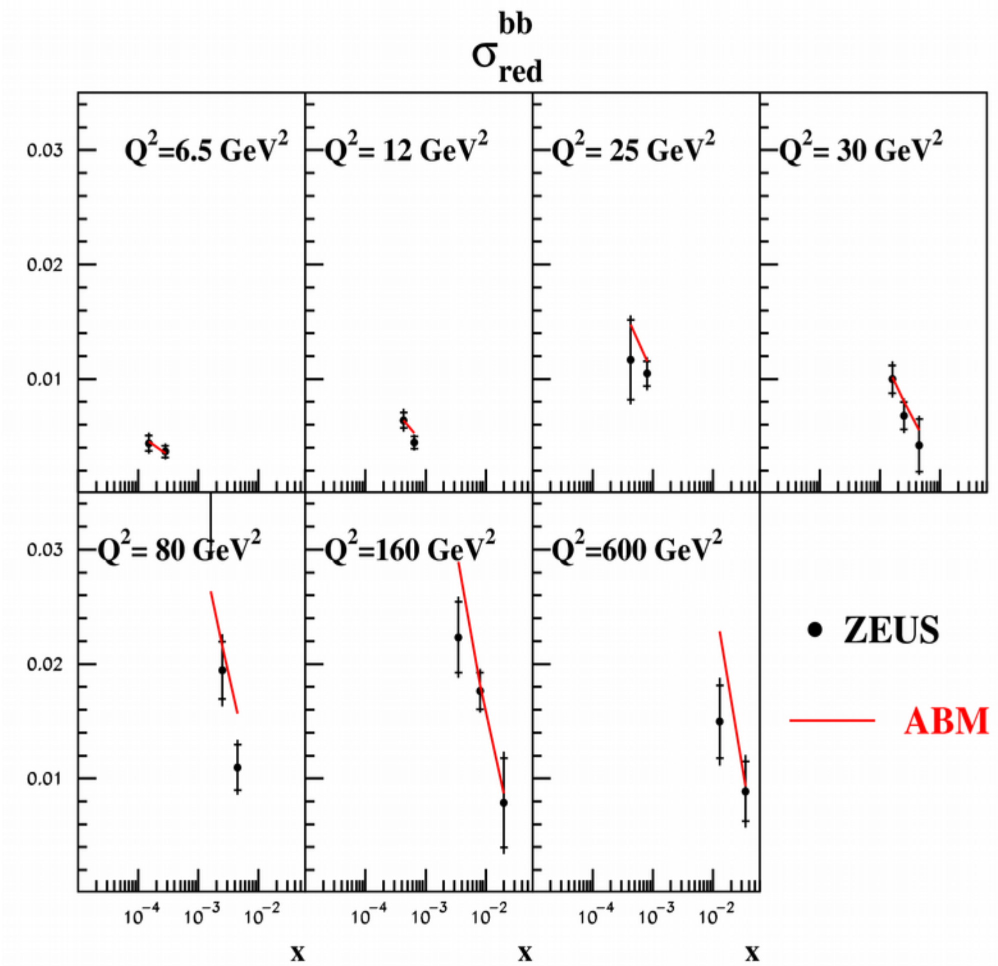
7 Tev	2.07
8 Tev	1.99

Hathor 2.1/NLO
hep-ph/1406.4403

NNLO corrections under control: **Brucherseifer, Caola, Melnikov hep-ph/1406.4403**

Heavy-quark masses





H1&ZEUS hep-ex/1211.1182 X^2/NDP=64 / 52

ZEUS hep-ex/1405.6915 X^2/NDP=15 / 17

$m_c(m_c)$=1.223±0.022(exp.) GeV

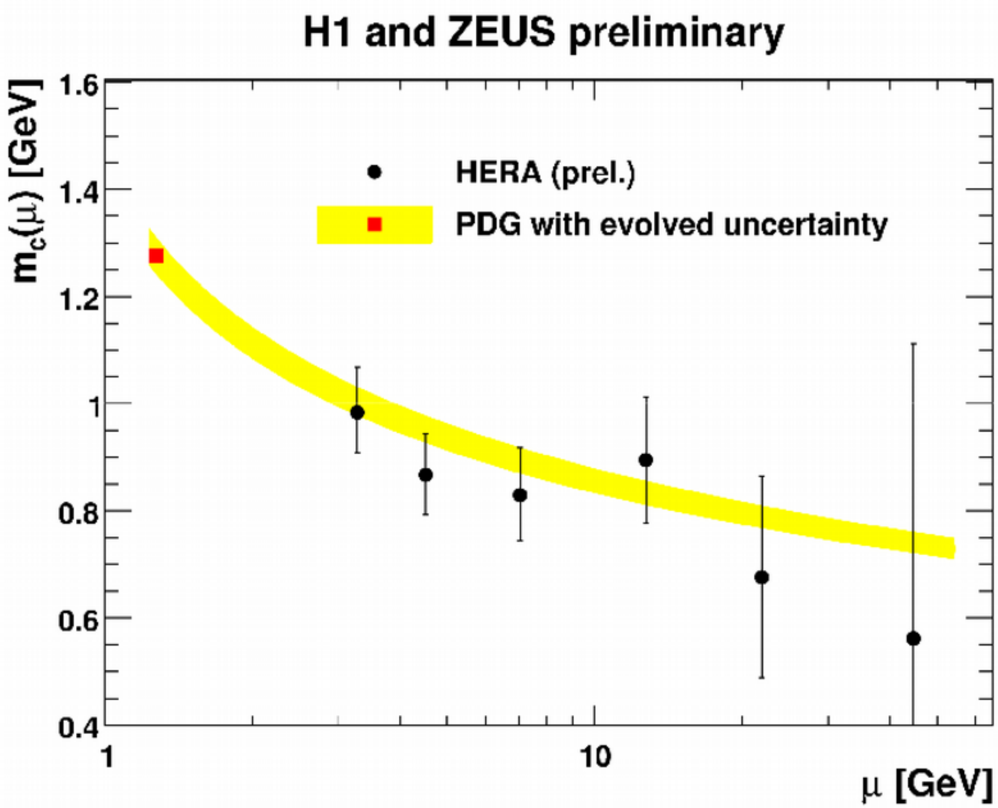
$m_b(m_b)$=3.98±0.15(exp.) GeV

Nice agreement with the e+e- determination

the running charm quark mass

H1-prelim-14-071, ZEUS-prel-14-006, + S. Moch

translate back to $m_c(\mu)$ using LO formula consistent with NLO $\overline{MS}$ QCD fit (OpenQCDrad, Alekhin et al.)



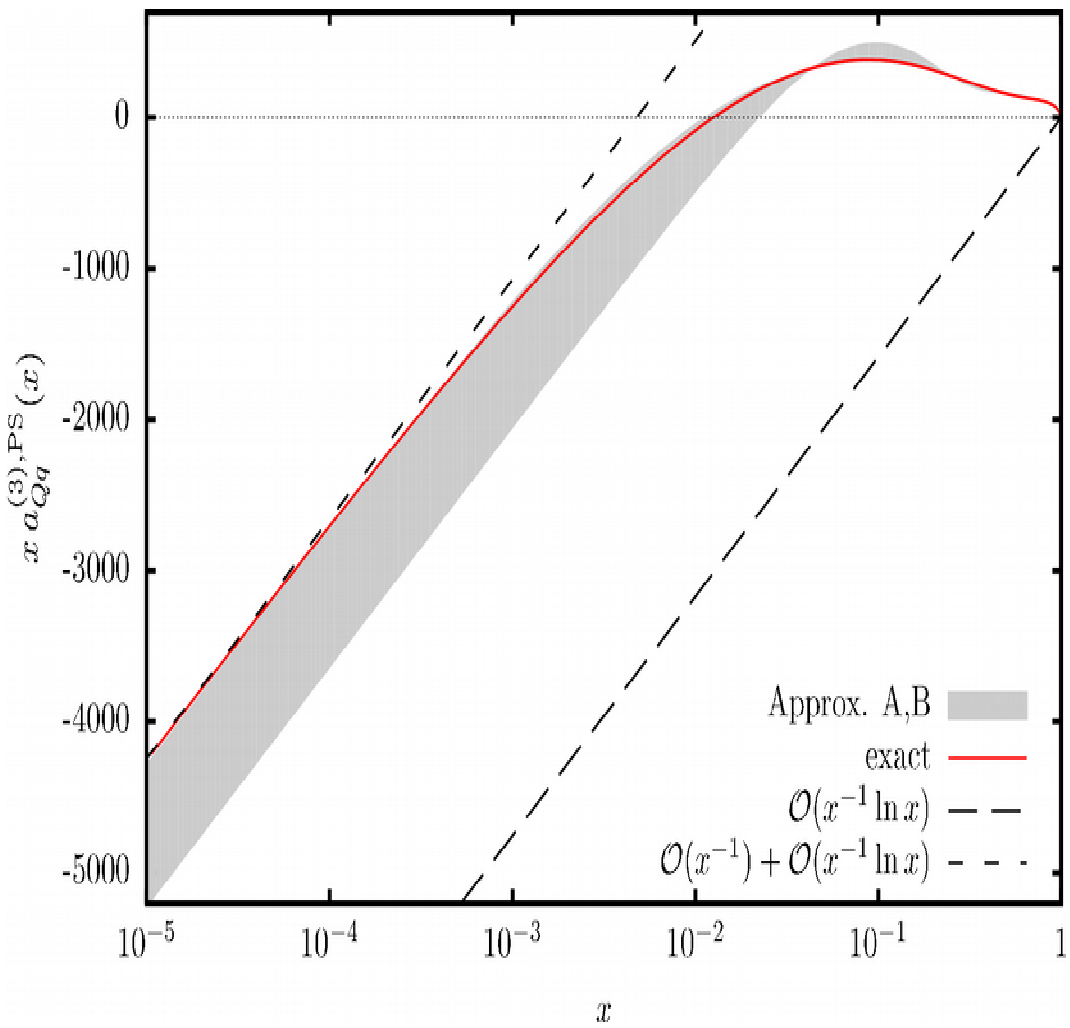
running mass concept in QCD is self-consistent !

26. 8. 14 A. Geiser, charm and beauty mass, QCDLHC 14 15

$m_b(m_b)$=4.07±0.14(exp.),+0.08-0.075(th) GeV NLO

ZEUS hep-ex/1405.6915

News in theory



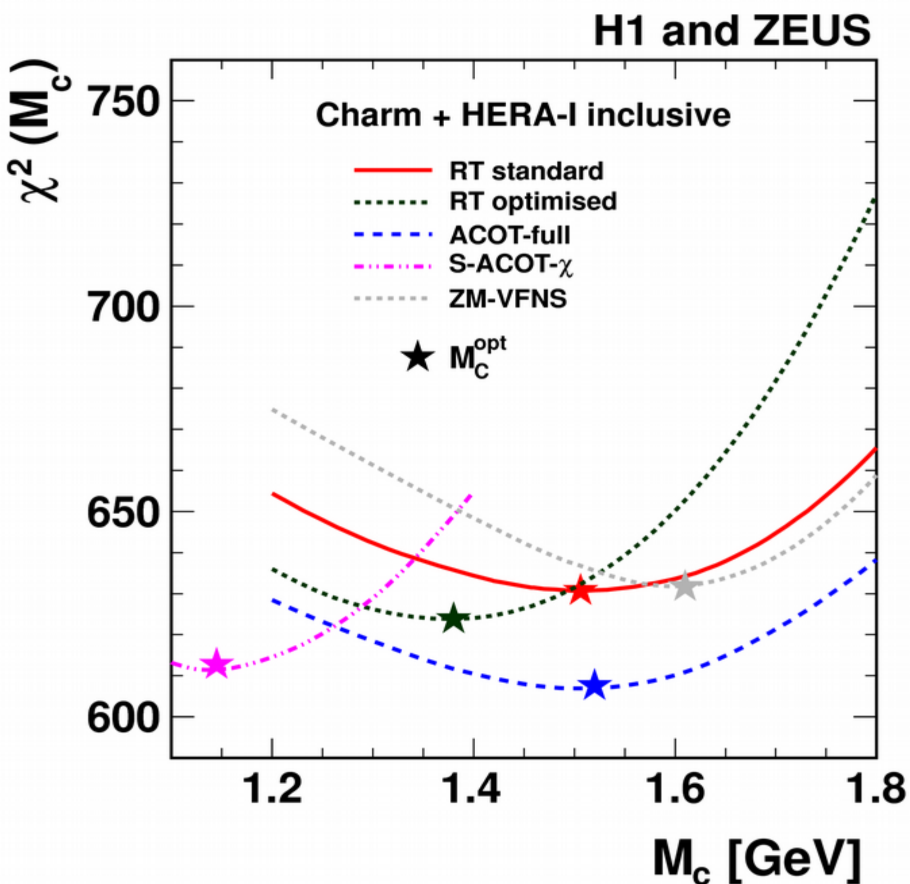
- Exact pure-singlet NNLO term in the massive OME is in agreement with the approximation in ABM fit

Ablinger et al. hep-ph/1409.1135

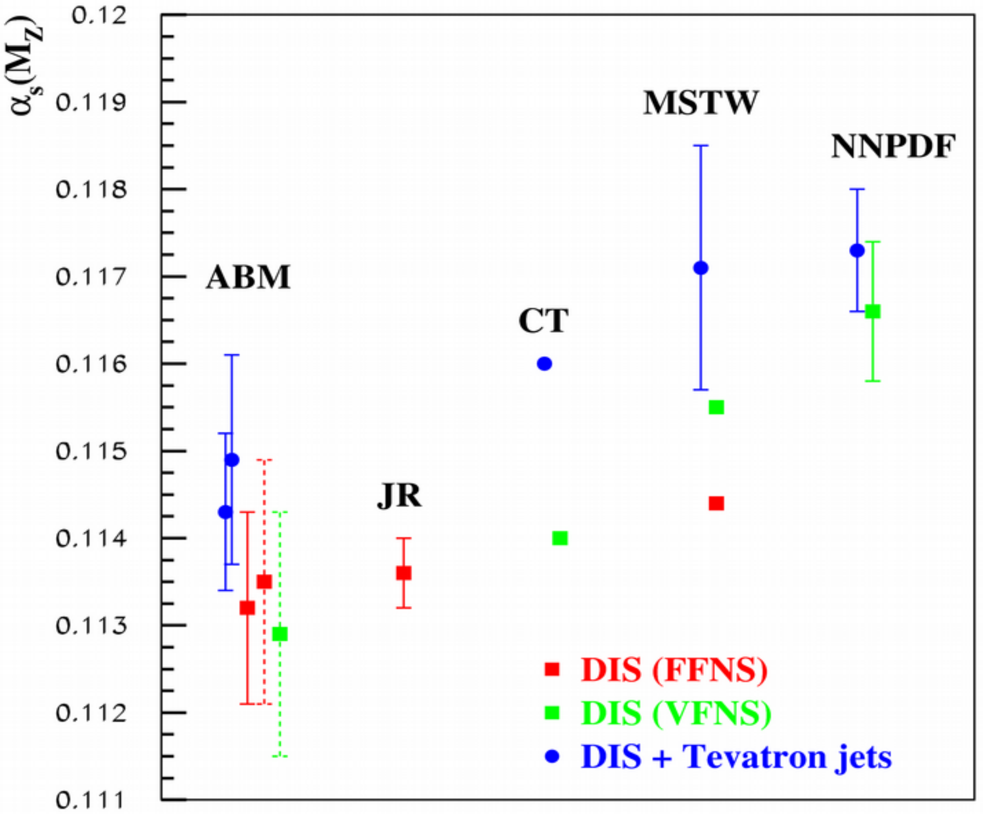
- The exact non-singlet NNLO term is also available

Ablinger et al. NPB 886, 733 (2014)

VFNS uncertainties in m_c and α_s

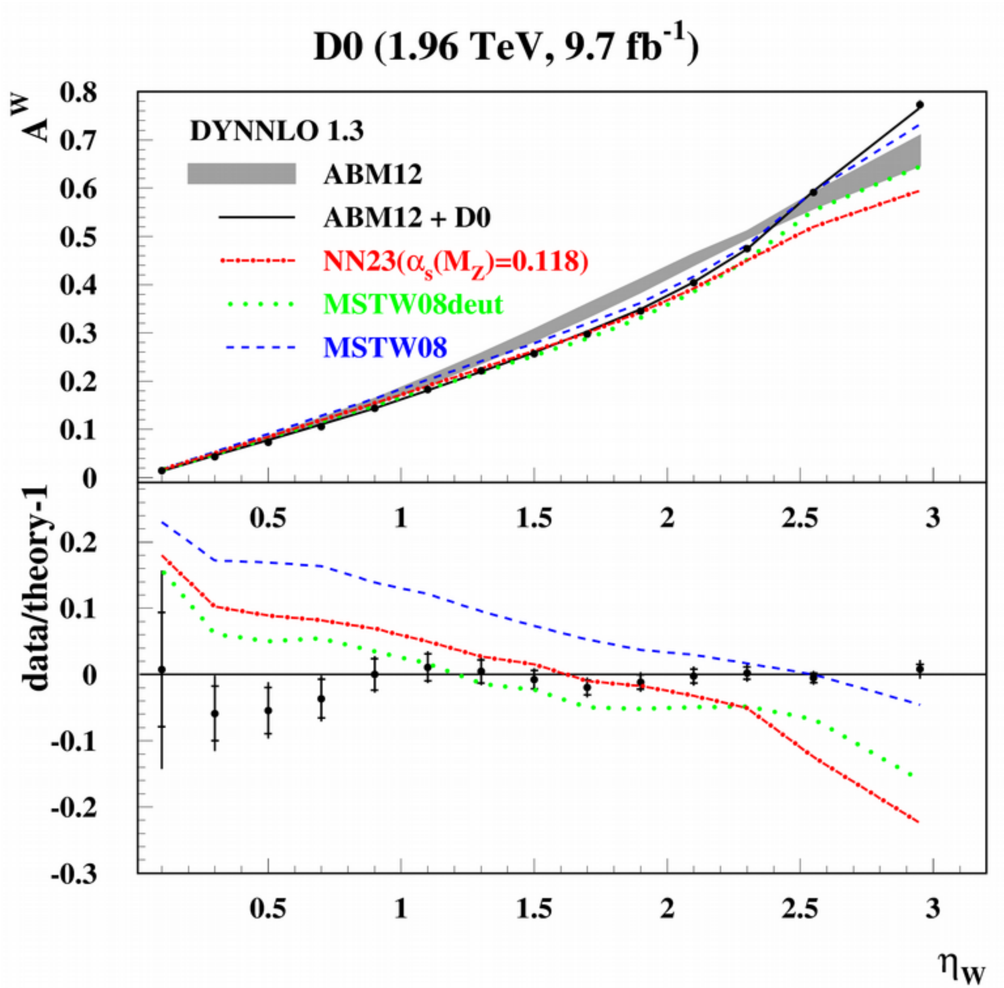


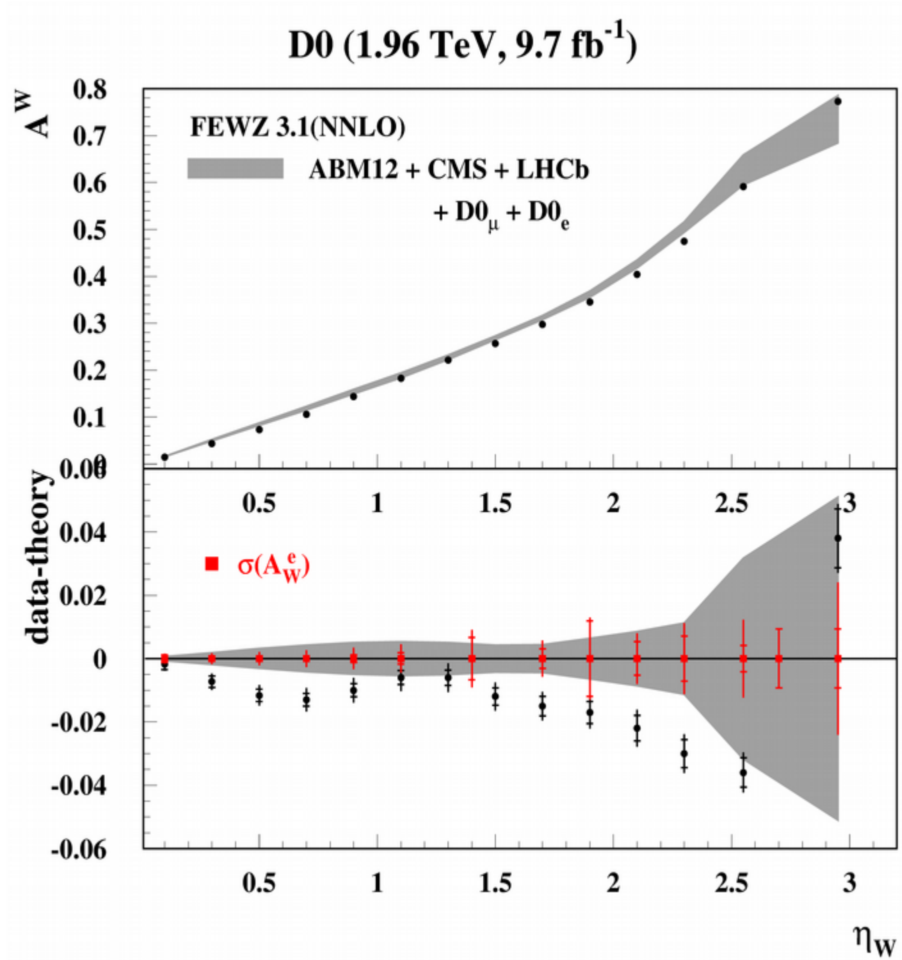
H1/ZEUS PLB 718, 550 (2012)



Wide spread obtained in different version of the GMVFN schemes → quantitative illustration of the GMVFNS uncertainties

Charge W asymmetry from D0





Used by HERAFITTER team to constraint quark distributions at large x

HERAFITTER hep-ph/1503.05425

The data can be accommodated into the ABM fit (X^2/NDP=6 / 14), however,

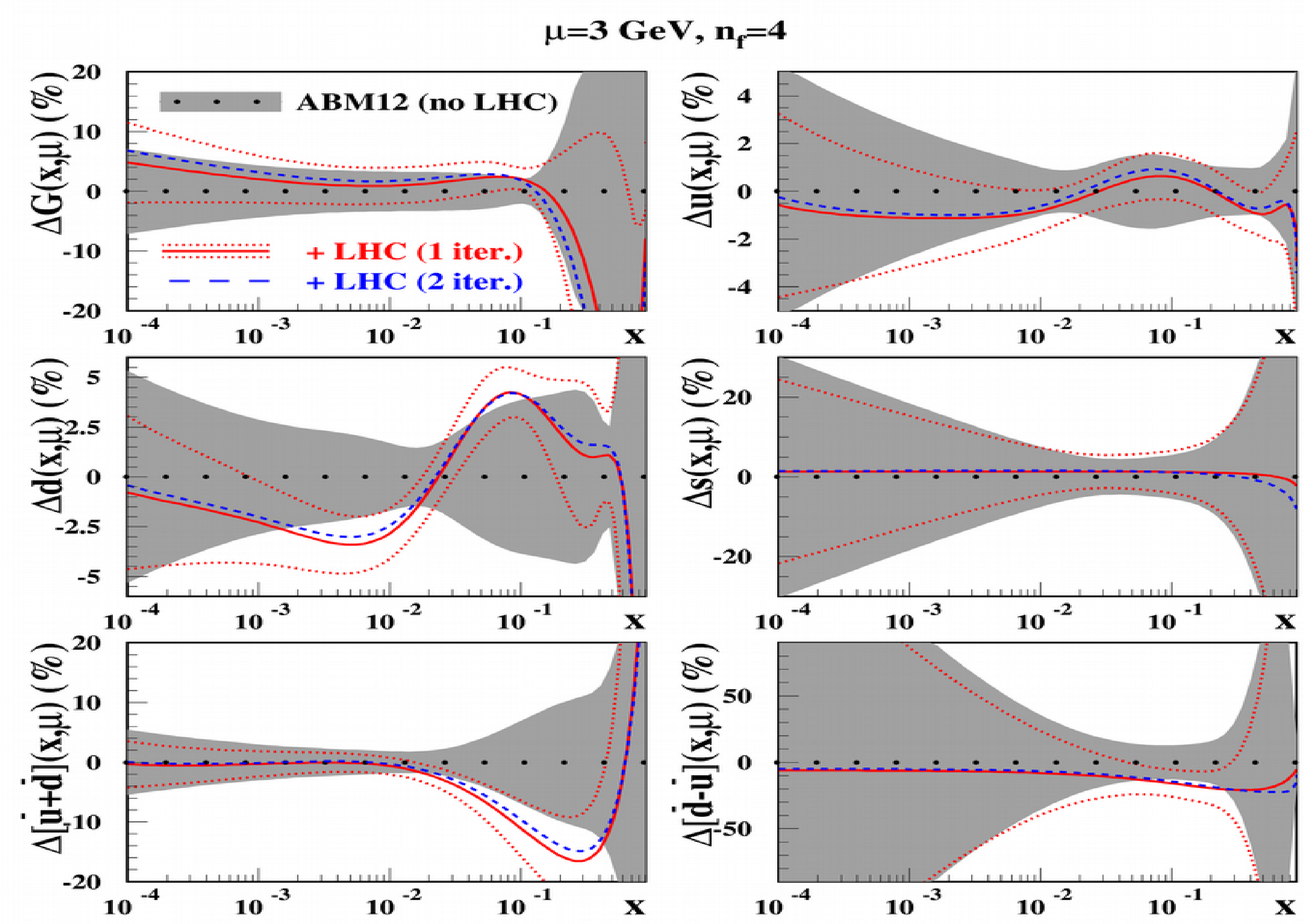
- *The data disagree with the predictions based on the charge-lepton data*
- *The errors in data seems to be too small in places*

Summary/outlook

- Recent high-statistical DY data are accommodated into the ABM fit
  - negative (dbar-ubar) asymmetry is observed at small x
  - the large-x du/ration stable → predictions for single-top production are confirmed
  - still too big fluctuations in the data are observed in places
- The value of $m_c(m_c)$=1.223±0.022(exp.) GeV is updated and
  $m_b(m_b)$=3.98±0.15(exp.) GeV obtained for the first time in ABM fit
  Both are in agreement with the e+e- data → one more check of the FFN/running mass scheme consistency
- Other PDFs undershoot the DY data at large rapidity and single-top rate ratio → further clarification is necessary (impact of the jet data? DIS at large x? ….?)

Extras

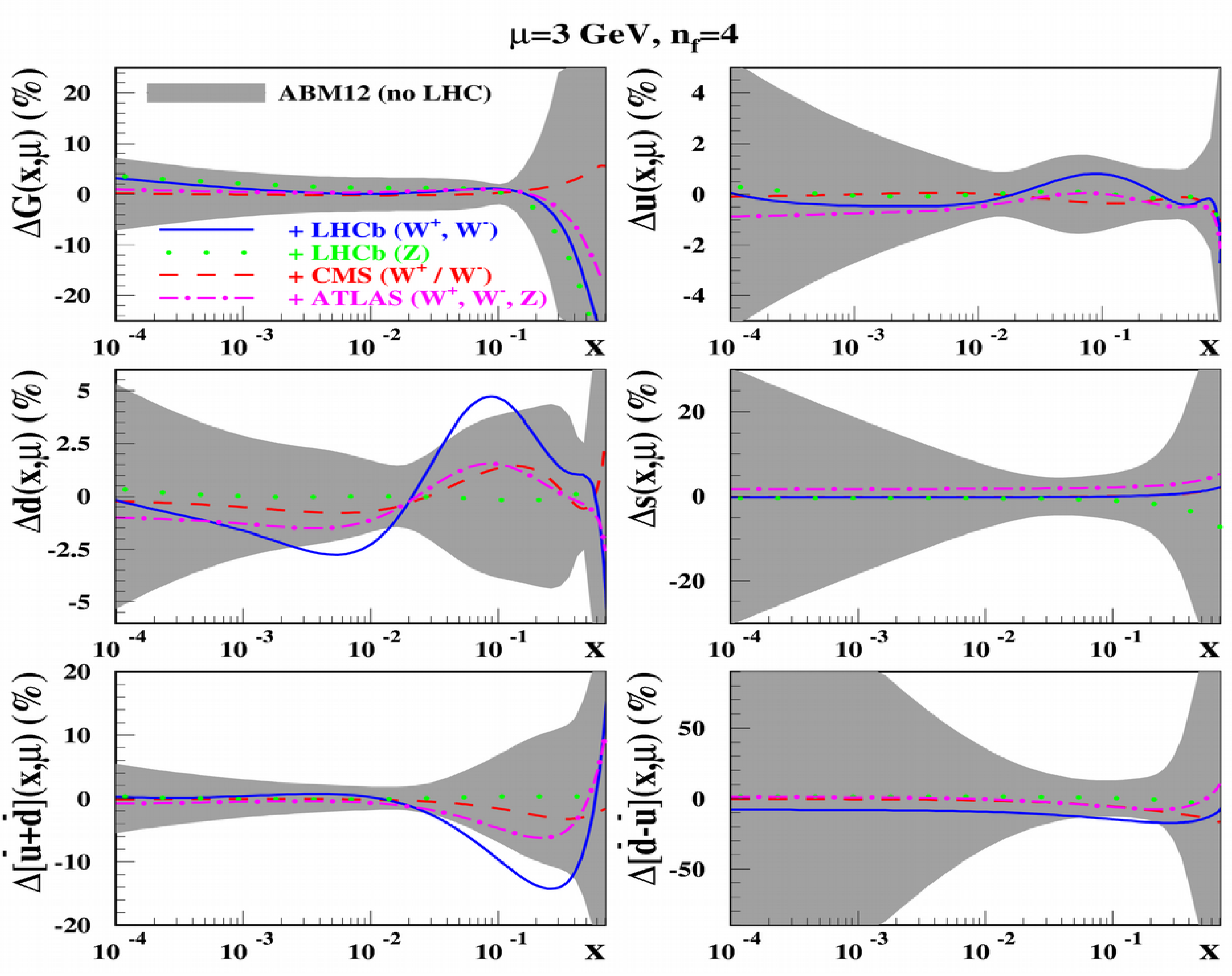
Impact of the LHC DY data on the PDFs



- d-quarks increase at x~0.1; *the errors get smaller*
- non-strange sea decrease at x~0.1
- strange sea stable → the enhancement observed by ATLAS is not reproduced

The algorithm used to include the LHC data is quite stable

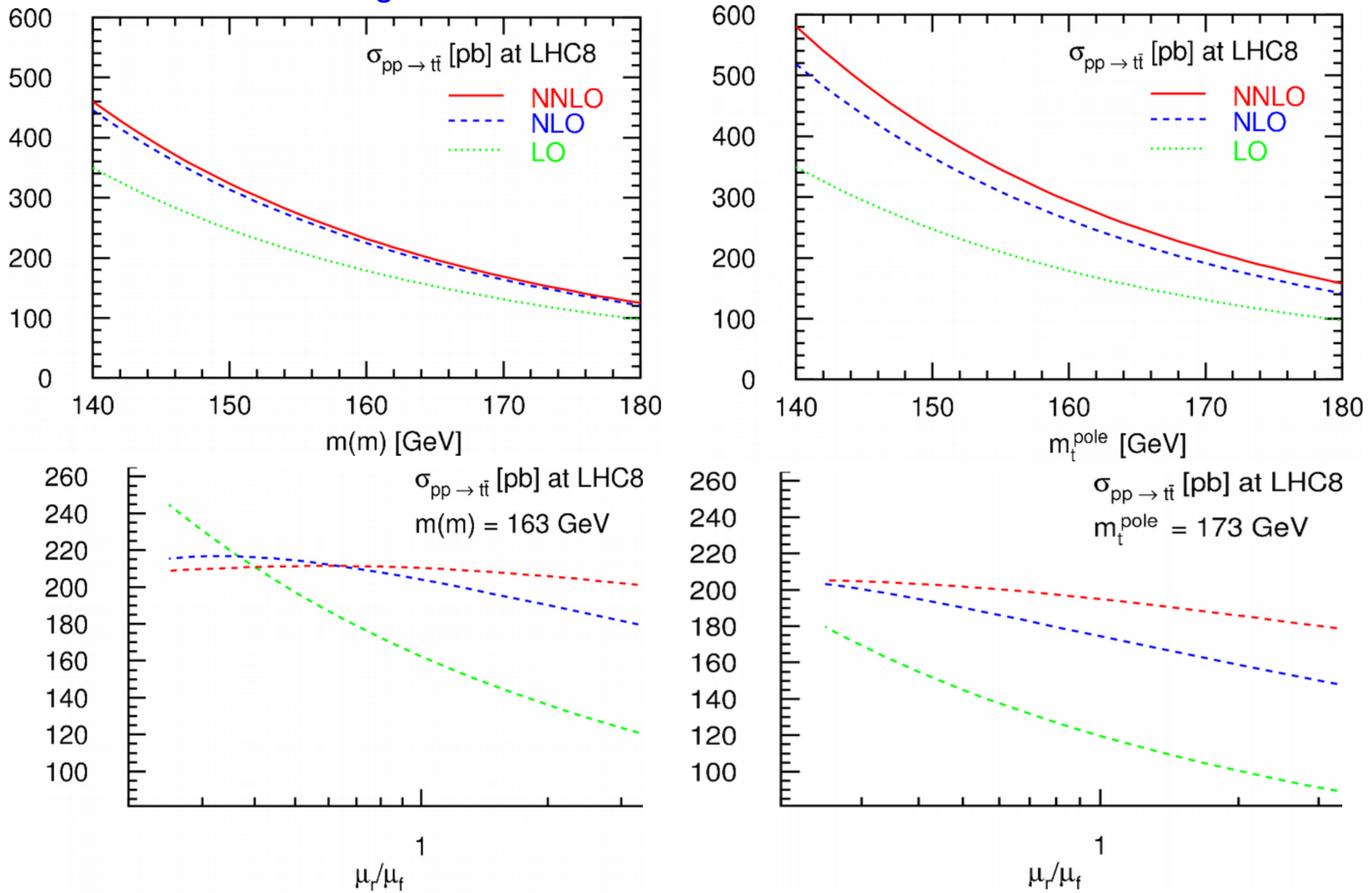
Impact of the separate LHC data sets



The biggest effect come from the LHCb data, i.e. from the large rapidity region

Pole- and running-mass definitions

Running mass — Pole mass



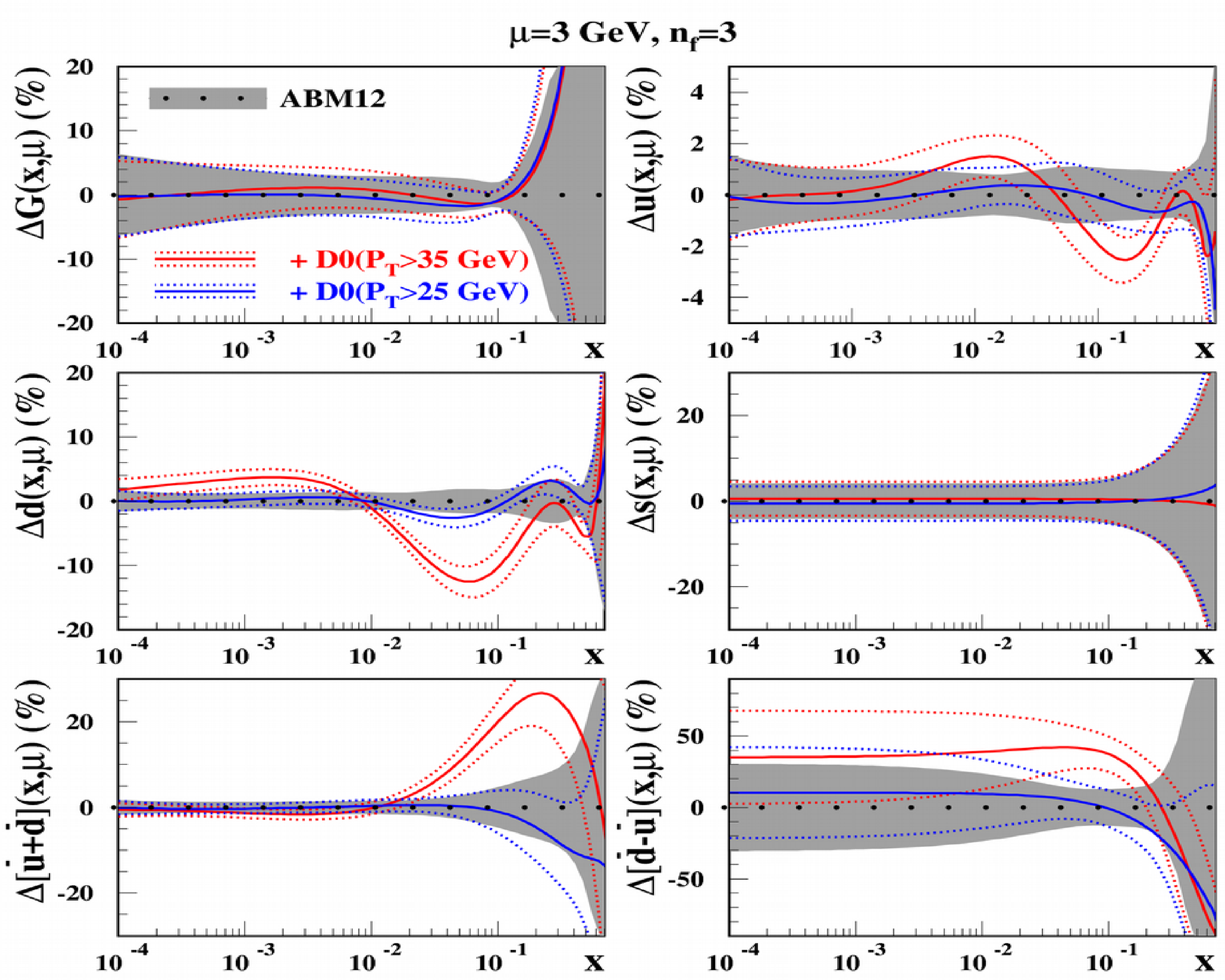
HATTOR (NNLO terms are checked with TOP++)

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

Czakon, Fiedler, Mitov hep-ph/1303.6254

Running mass definition provides nice perturbative stability

Impact of DY D0 data



Impact of the data on PDFs is quite sensitive to the the cut on P_T
→ clarification is necessary

The ABM fit ingredients

DATA:

- DIS NC inclusive
- DIS charm production
- DIS μμ CC production
- DIS charmed-hadron CC production
- fixed-target DY
- LHC DY distributions (CMS 4.7 1/fb, LHCb 1/fb)
- W+charm production (CMS and ATLAS data)

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 (DYNNLO 1.3 / FEWZ 3.1)
- NNLO inclusive ttbar production (pole / running mass)

Deuteron corrections in DIS:

- Fermi motion
- off-shell effects

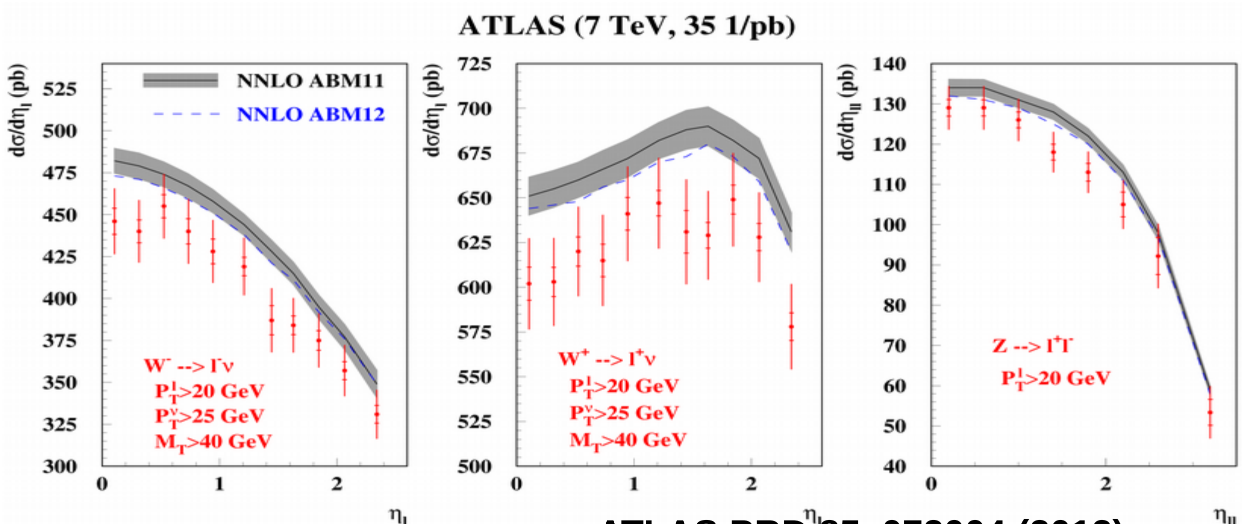
Power corrections in DIS:

- target mass effects
- dynamical twist-4 terms

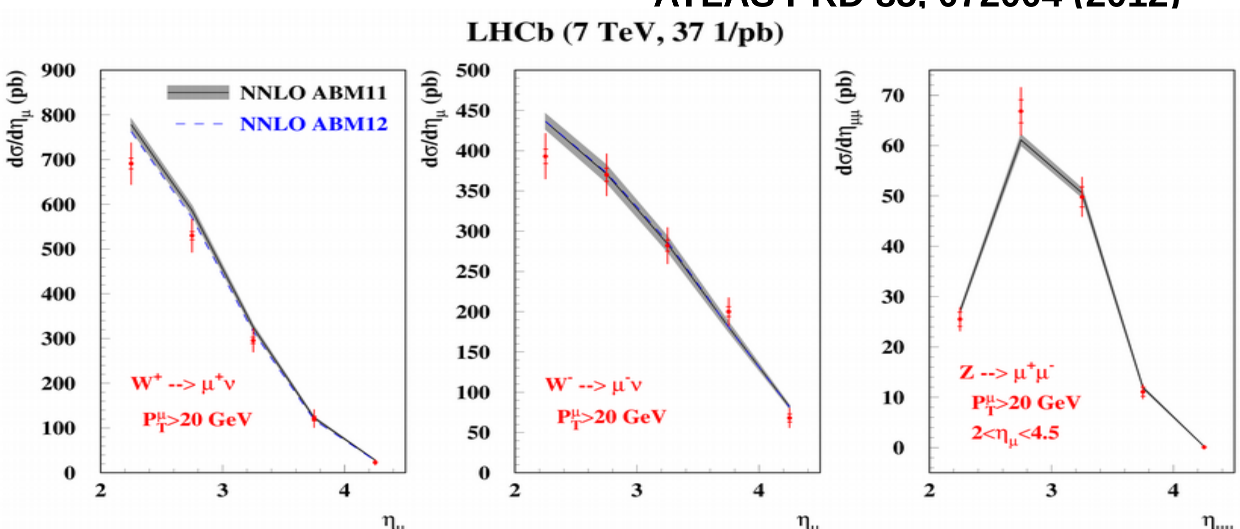
The jet data are still not included: The NNLO corrections may be as big as 15-20%

LHC Drell-Yan data included

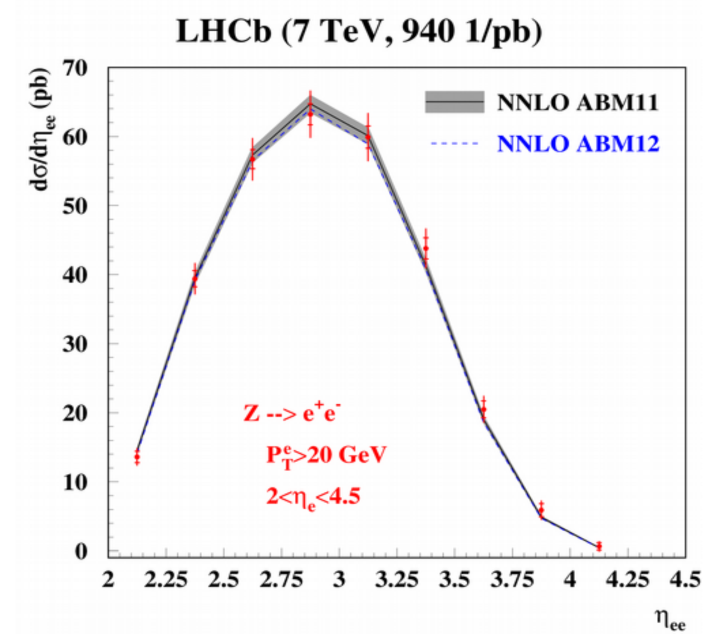
sa, Blümlein, Moch hep-ph/1302.1516



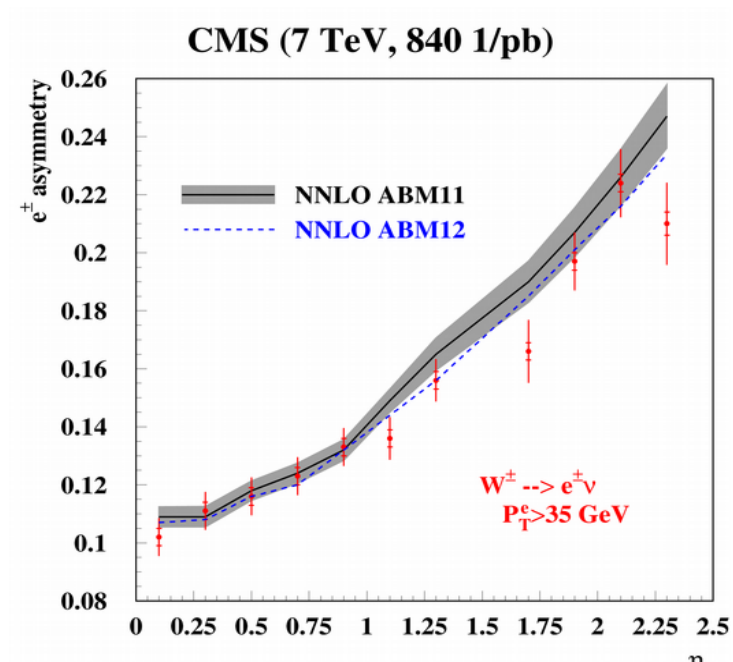
ATLAS PRD 85, 072004 (2012)



LHCb JHEP 1206, 058 (2012)



LHCb JHEP 1302, 106 (2013)



CMS PRL 109, 111806 (2010)

- Exact NNLO calcuations (DYNNLO&FEWZ)
- Good overall agreement

ATLAS	CMS	LHCb	
36/30	9/11	14/10	13/11