Quark isospin asymmetry at small and large x

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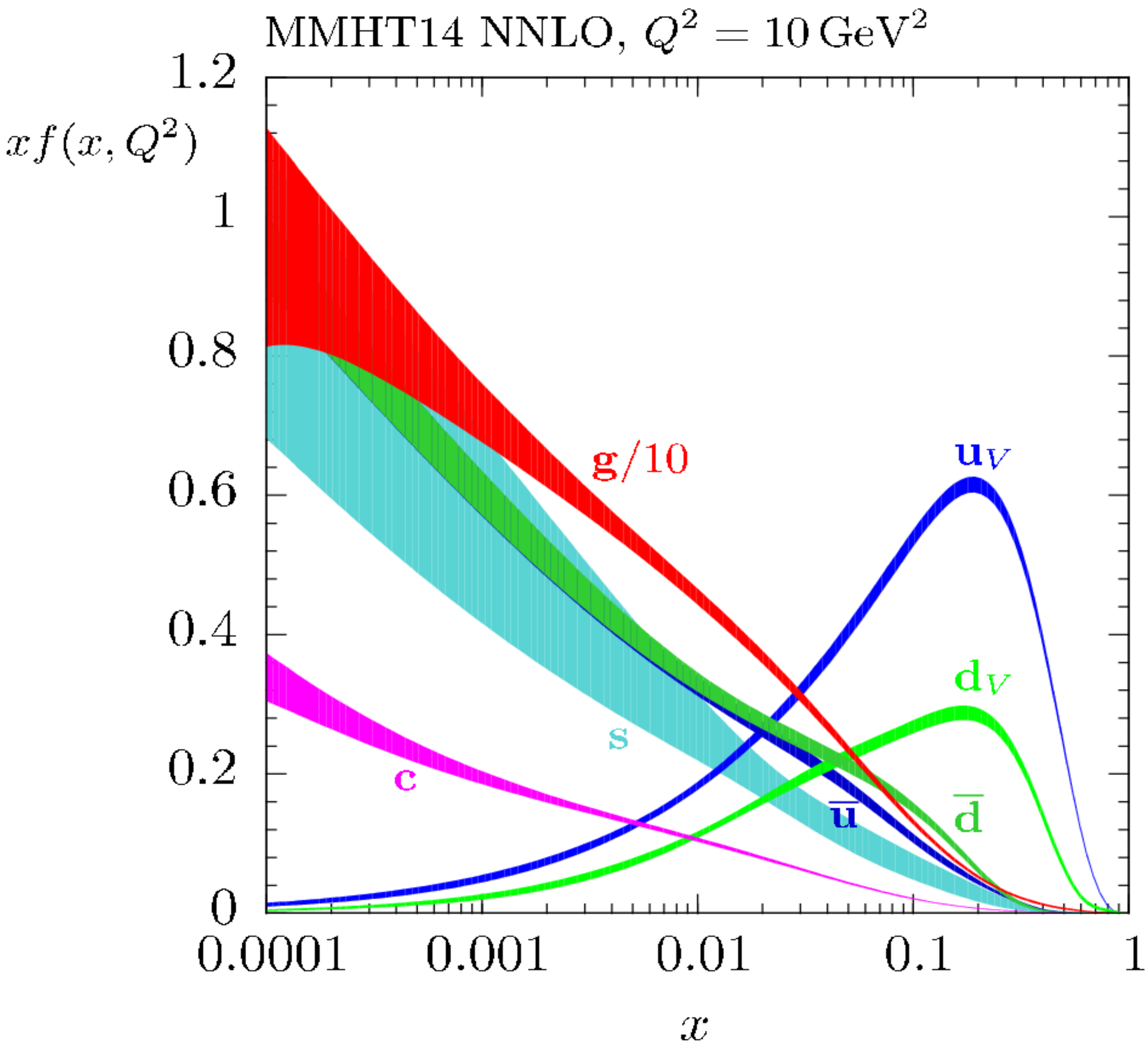
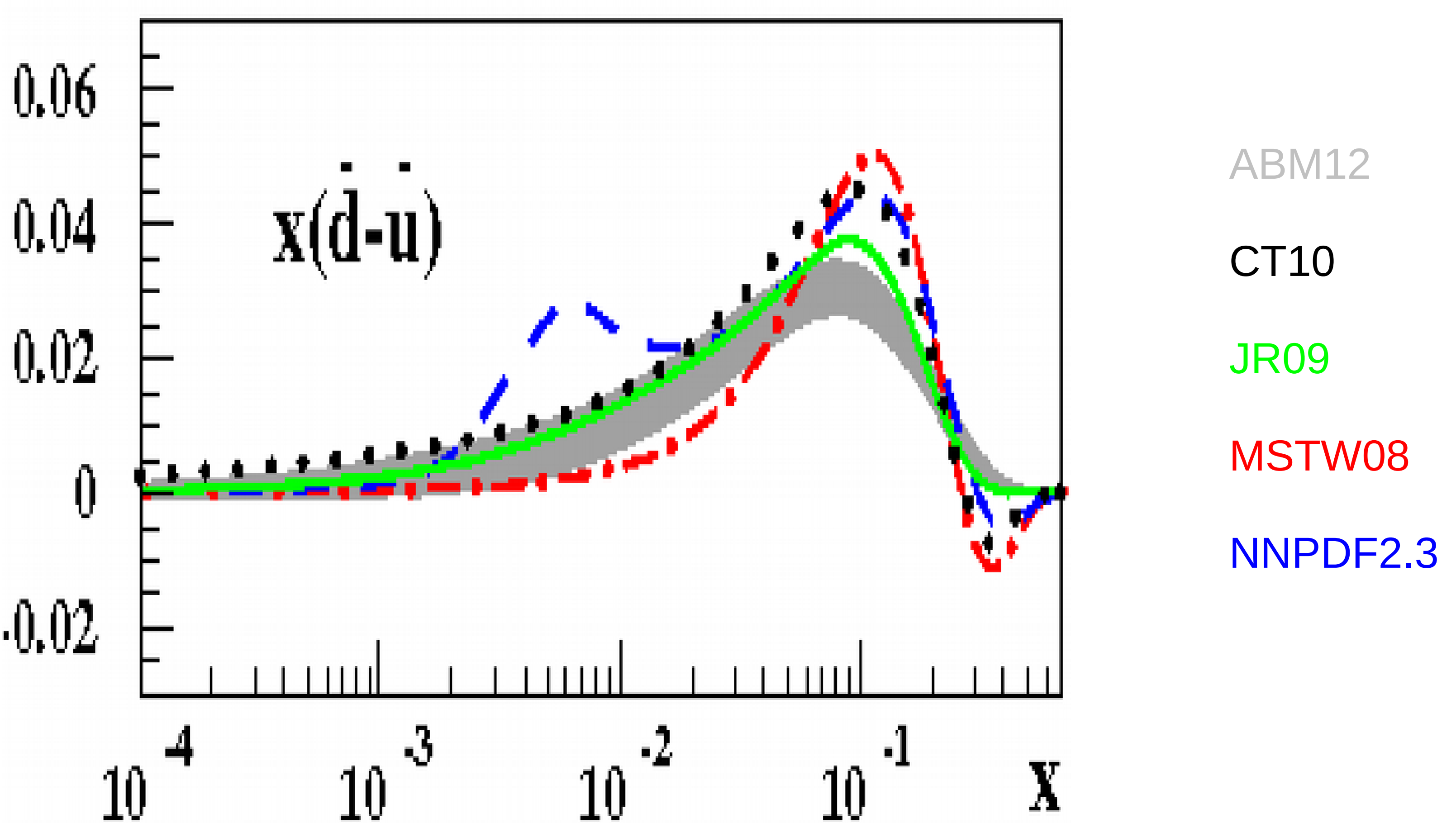
sa, Blümlein, Moch, Plačakytė hep-ph/1508.07923

Physics at the LHC and beyond, DESY, 1 Oct 2015



Accuracy of O(1%) is in general achieved for medium x

Sea quark iso-spin asymmetry



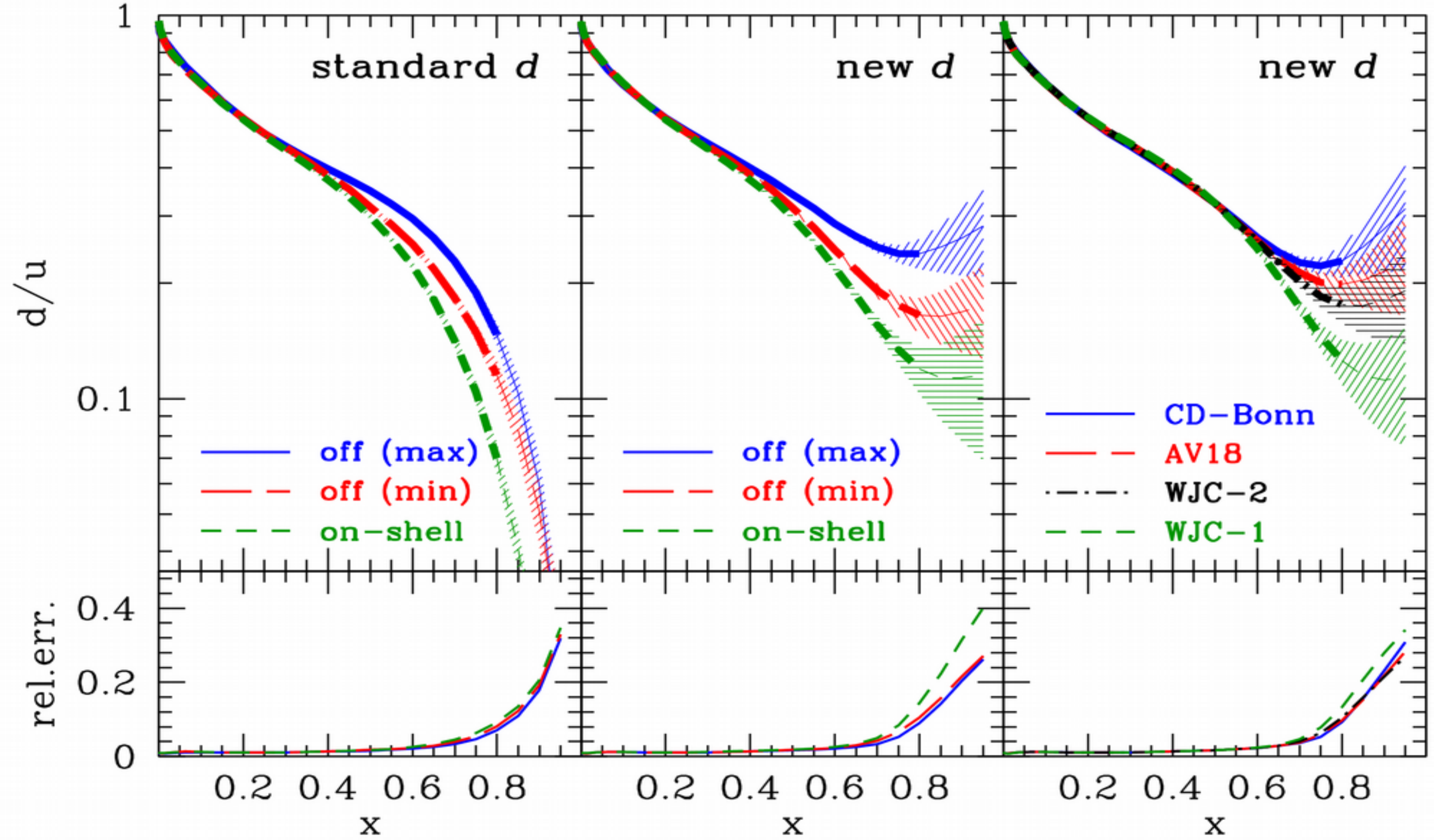
sa, Blümlein, Moch PRD 89, 054028 (2014)

- 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

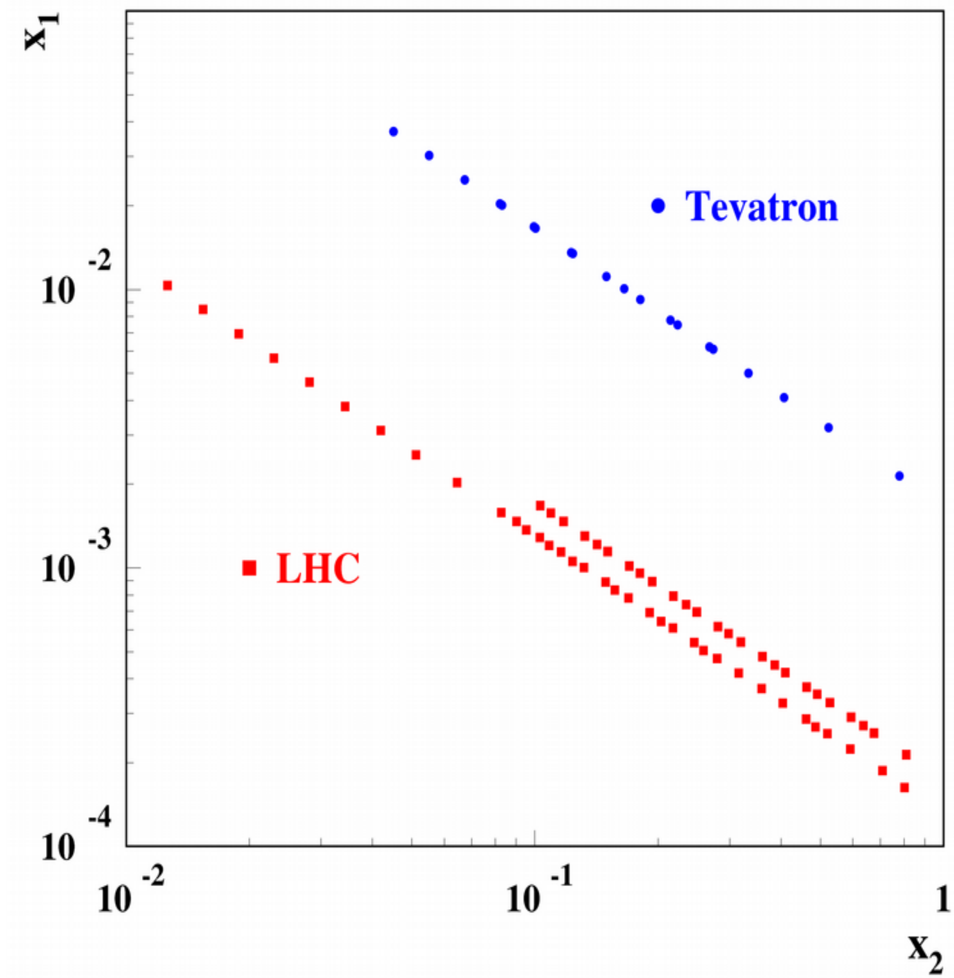
d/u ratio at large x



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

LO kinematics of the recent W&Z data



In the forward region $x_2 >> x_1$

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

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

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

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

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	1.96		7	8
Final states	$W^+ \to l^+\nu$ $W^- \to l^-\nu$ $Z \to l^+l^-$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to e^+\nu$ $W^- \to e^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ $Z \to \mu^+\mu^-$	$Z \to e^+e^-$
Reference	[23]	[1]	[3]	[4]	[18]	[19]
Cut on the lepton P_T	$P_T^l > 20$ 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
Luminosity (1/fb)	0.035	4.7	7.3	9.7	1.	2.
NDP	30	11	10	13	31	17

The fit ingredients

DATA:

- DIS NC inclusive (no deuteron data included)
- DIS CC inclusive
- DIS charm production
- DIS μμ CC production (NOMAD)
- DIS charmed-hadron CC production (CHORUS)
- fixed-target DY
- LHC DY distributions (ATLAS, CMS, LHCb)

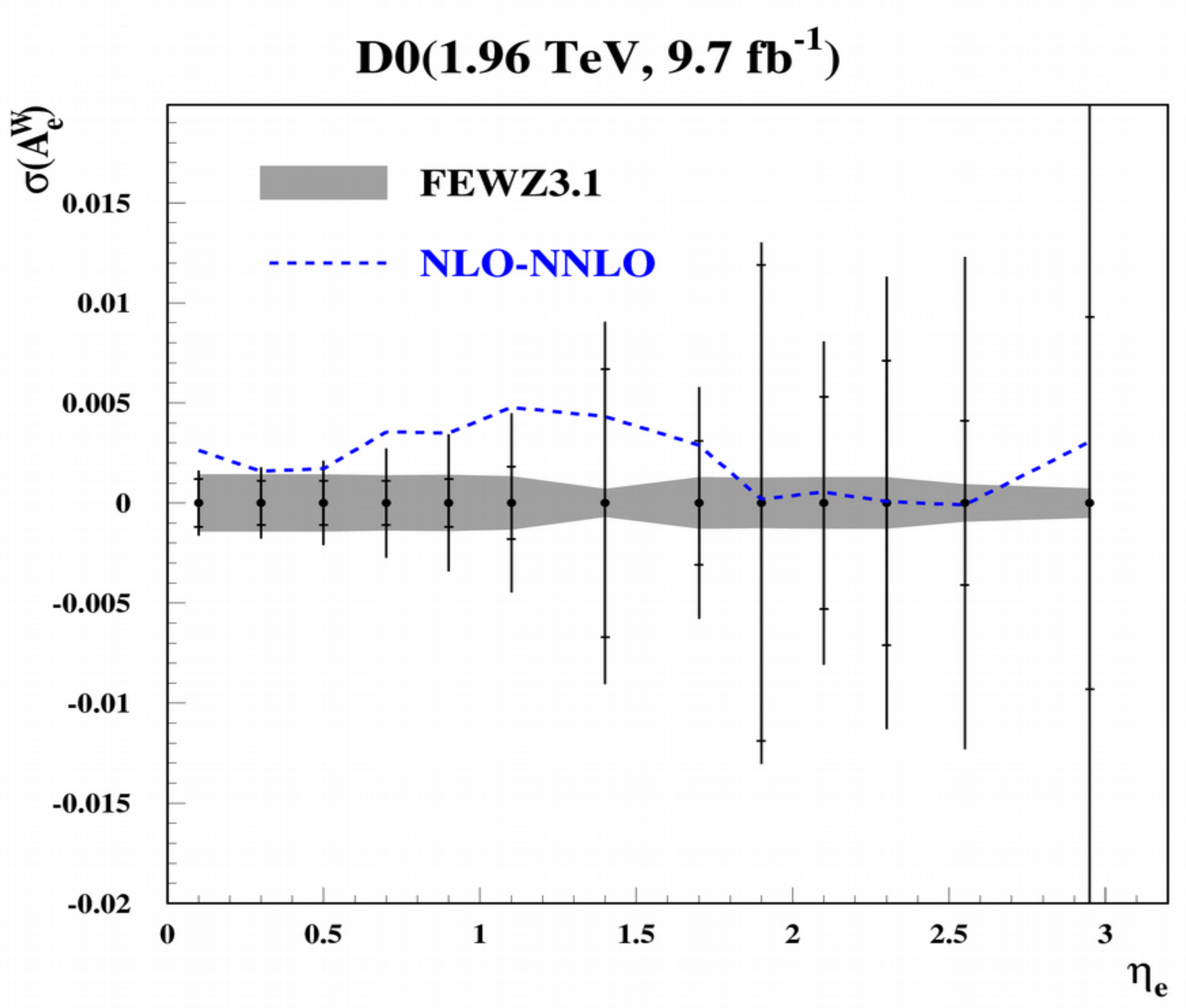
QCD:

- 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:

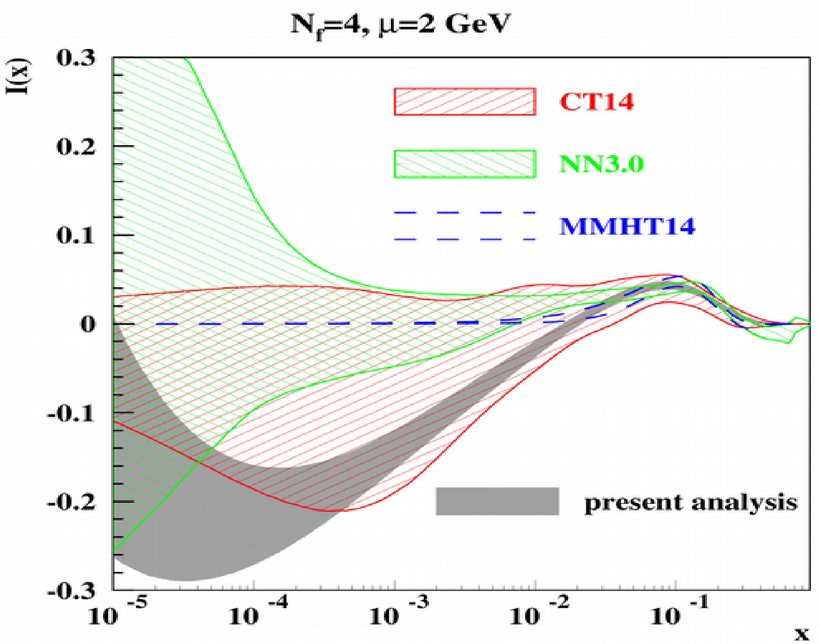
- target mass effects
- dynamical twist-4 terms

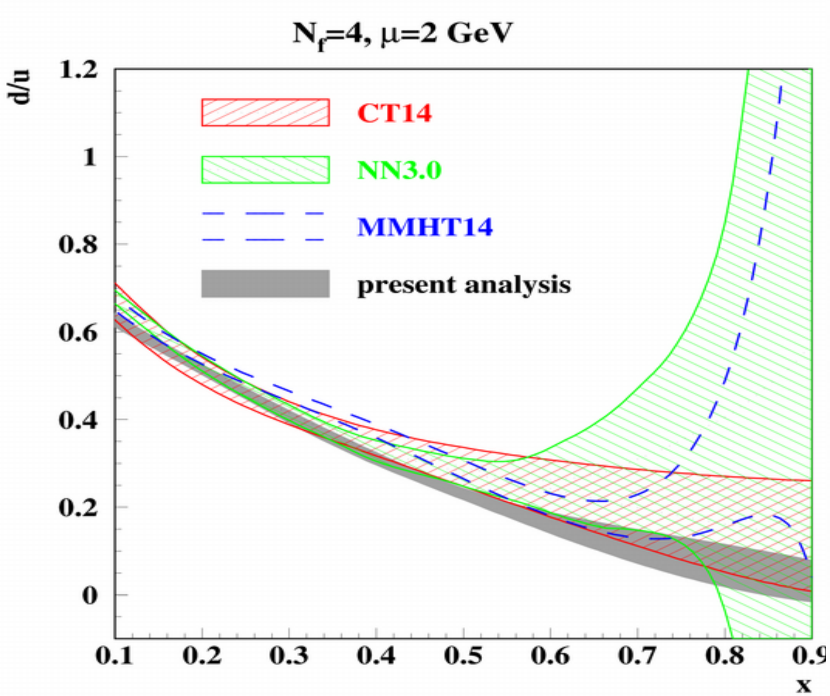
Computation accuracy



- 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 (cf. Extras)

ABM fit with recent Drell-Yan data





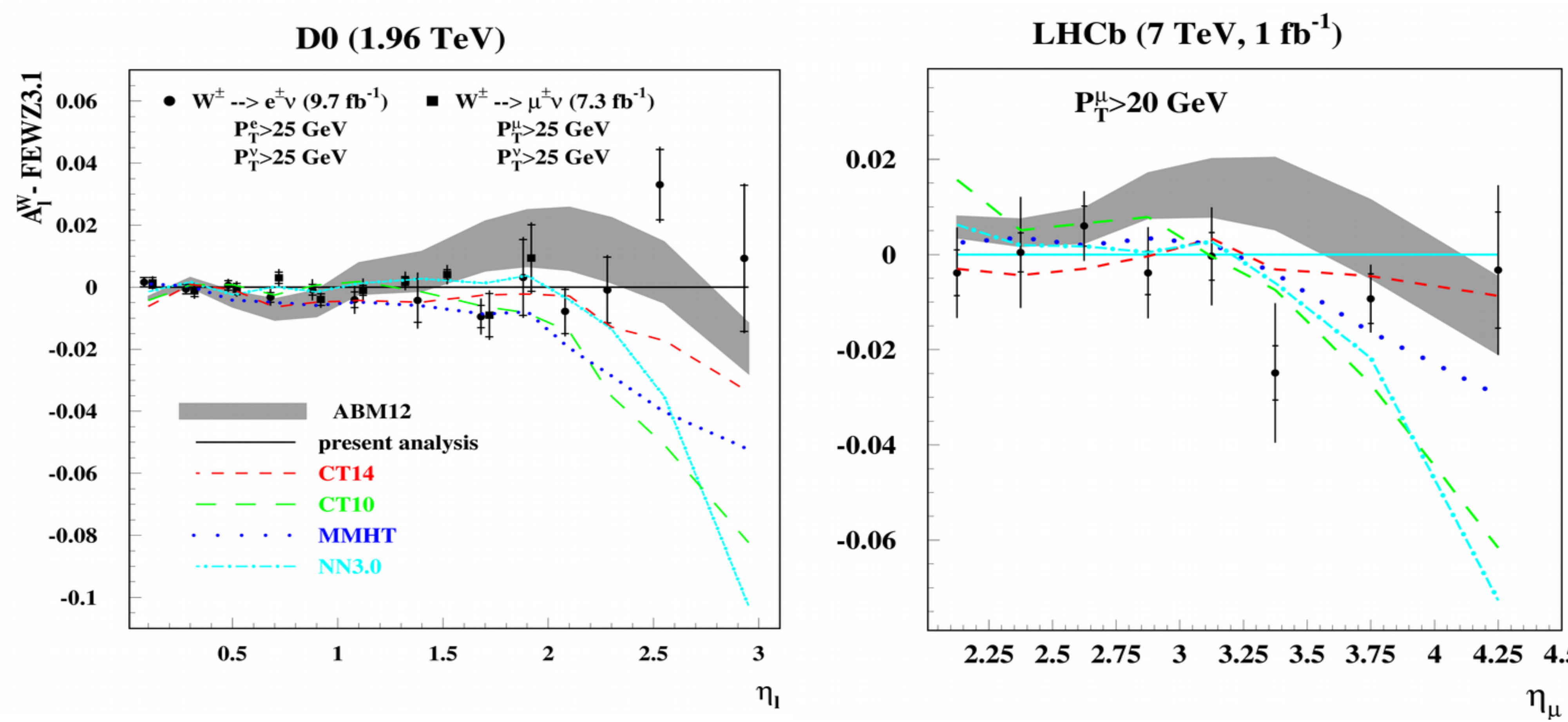
- Relaxed form of the sea iso-spin asymmetry at small x; Regge-like behaviour is reproduced only at $x \sim 10^{-6}$; at large x it is still defined by the phase-space constraint

- Good constraint on the d/u ratio w/o deuteron data; big spread between different PDF sets: up to factor of 30 at large x → PDF4LHC recommendations are misleading in this part

Experiment		ATLAS	CMS	D0		LHCb	
$\sqrt{s}$ (TeV)		7	7	1.96		7	8
Final states		$W^+ \to l^+\nu$ $W^- \to l^-\nu$ $Z \to l^+l^-$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to e^+\nu$ $W^- \to e^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ $Z \to \mu^+\mu^-$	$Z \to e^+e^-$
Reference		[23]	[1]	[3]	[4]	[18]	[19]
NDP		30	11	10	13	31	17
χ^2	this work	29.8	22.5	16.9	18.0	44.1	18.2
	this work[a]	32.3	19.5(13.5[b])	13.5	9.5	34.7	19.1
	ABM12 [8]	34.5	–	–	–	–	–
	CT14 [10]	42	–[c]	–	34.7	–	–
	HERAFitter [13]	–	–	13	19	–	–
	MMHT14 [11]	39	–	21	–	–	–
	NN3.0 [12]	35.4	18.9	–	–	–	–

[a]The variants with all collider DY and $W^\pm$-boson data excluded except the one given.
[b]The value obtained assuming systematic uncertainties to be uncorrelated.
[c]Statistically less significant data with the cut of $P_T^\mu > 35$ GeV are used.

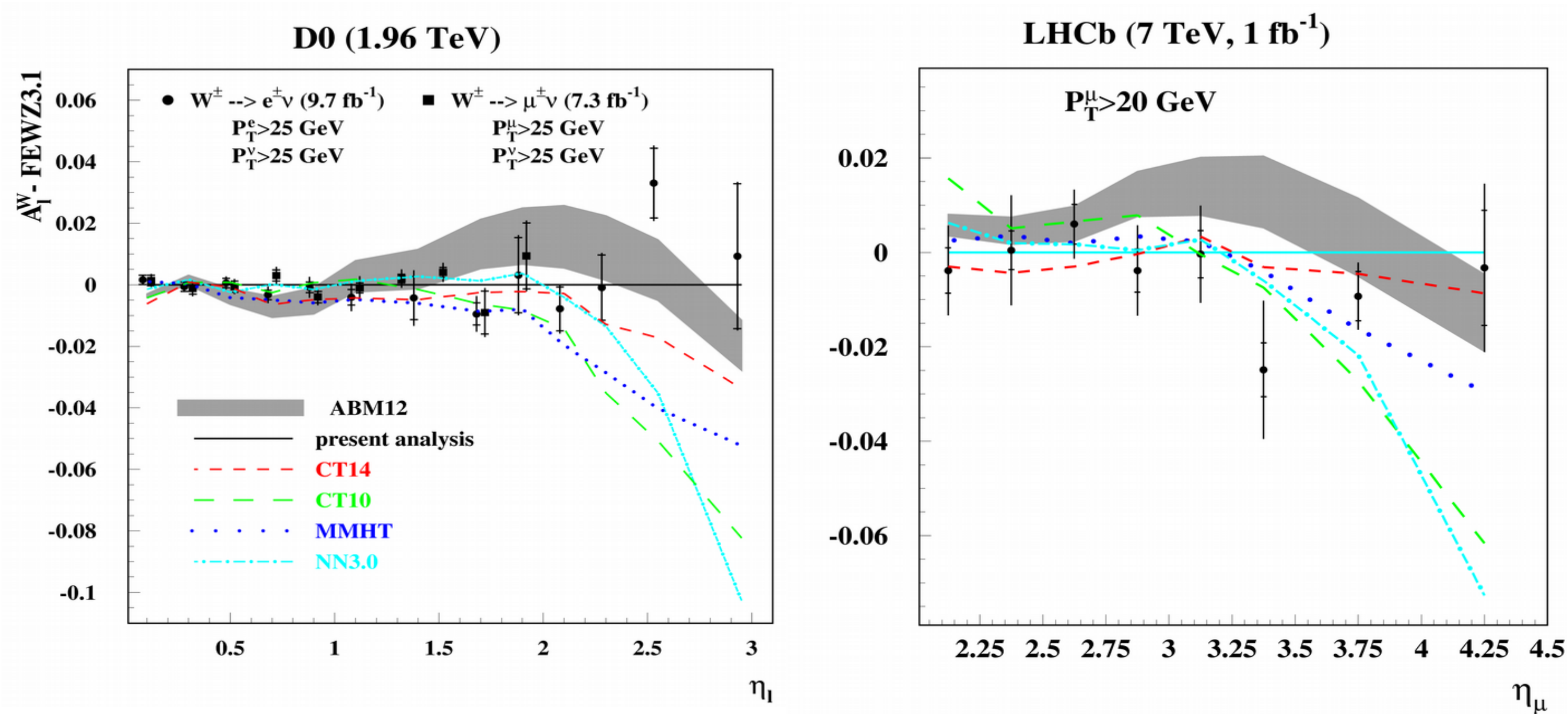
DY at large rapidity



- 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)

DY at large rapidity



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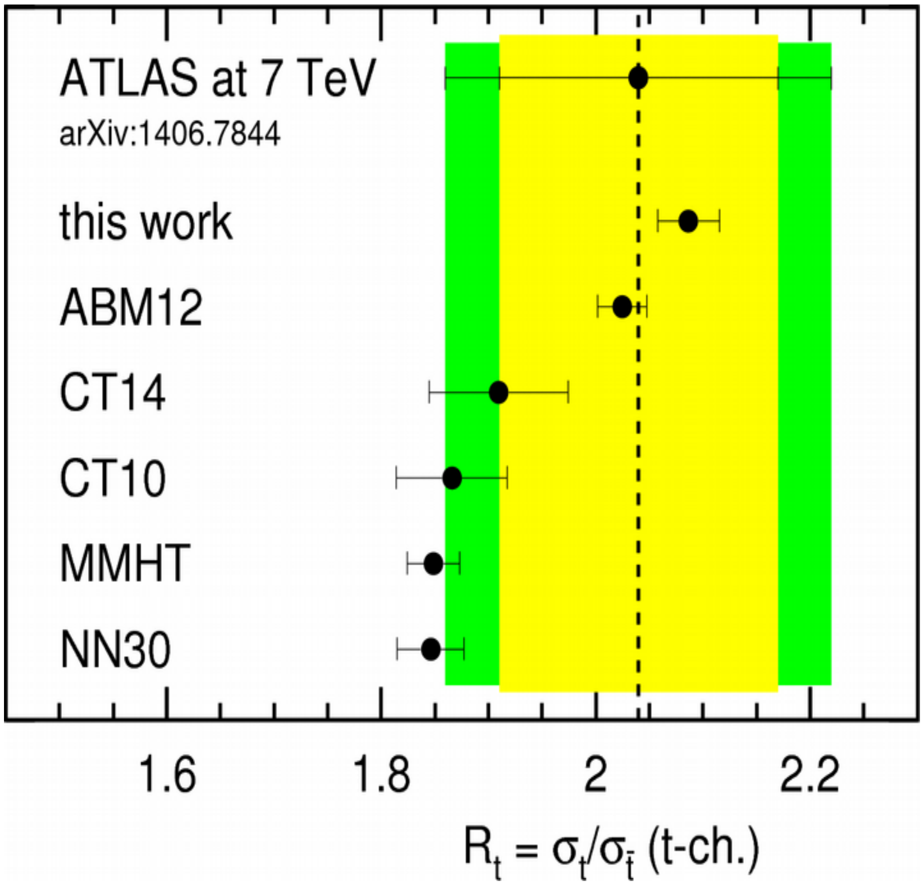
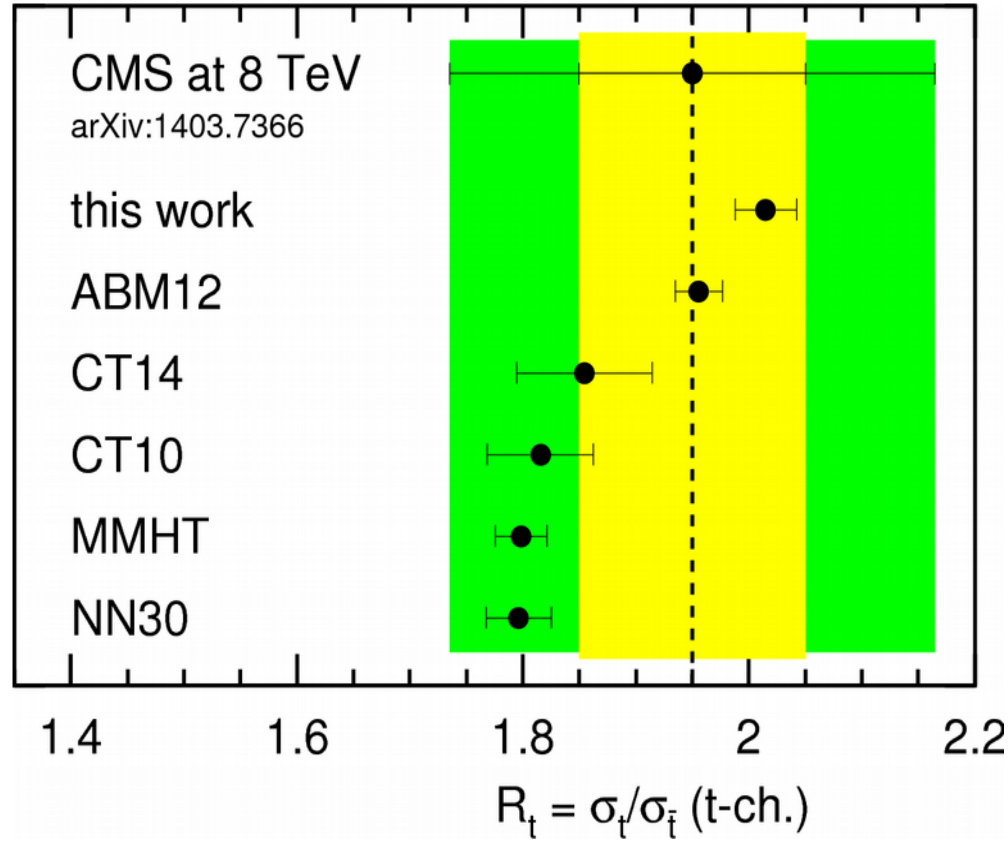
Implication for the single-top production





- 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

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

Summary

Recent TEVATRON and LHC data provide valuable constraint on the small- and large x quark iso-spin asymmetry

– the sea asymmetry is negative at $x \sim 10^{-3}$; an onset of the Regge asymptotics still may occur at $x < 10^{-5}$

– large-x asymmetry can be determined with a good accuracy w/o using the DIS data on deuterium target $\rightarrow$ reduced theoretical uncertainties in PDFs

– nice agreement with the LHC single-top production data; standard candle for the d/u ratio

EXTRAS

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