Precise ATLAS and CMS DY data in the ABM fit

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DY data in ABMP16 fit

TABLE II. The list of DIS and DY data used in the current analysis with the collider data listed first. The top-quark production data are detailed in Tables III and IV.

Experiment	Beam (E_b) or center-of-mass energy ($\sqrt{s}$)	$\mathcal{L}$ (1/fb)	Process	Kinematic cuts used in the present analysis (cf. orginal references for notations)	Ref.
			DIS		
HERA I + II	$\sqrt{s} = 0.225 \div 0.32$ TeV	0.5	$e^\pm p \to e^\pm X$	$2.5 \le Q^2 \le 50000$ GeV^2, $2.5 \times 10^{-5} \le x \le 0.65$	[4]
			$e^\pm p \to \overset{(-)}{\nu} X$	$200 \le Q^2 \le 50000$ GeV^2, $1.3 \times 10^{-2} \le x \le 0.40$	
BCDMS	$E_b = 100 \div 280$ GeV		$\mu^+ p \to \mu^+ X$	$7 < Q^2 < 230$ GeV^2, $0.07 \le x \le 0.75$	[61]
NMC	$E_b = 90 \div 280$ GeV		$\mu^+ p \to \mu^+ X$	$2.5 \le Q^2 < 65$ GeV^2, $0.009 \le x < 0.5$	[60]
SLAC-49a	$E_b = 7 \div 20$ GeV		$e^- p \to e^- X$	$2.5 \le Q^2 < 8$ GeV^2, $0.1 < x < 0.8$, $W \ge 1.8$ GeV	[54]
					[62]
SLAC-49b	$E_b = 4.5 \div 18$ GeV		$e^- p \to e^- X$	$2.5 \le Q^2 < 20$ GeV^2, $0.1 < x < 0.9$, $W \ge 1.8$ GeV	[54] [62]
SLAC-87	$E_b = 8.7 \div 20$ GeV		$e^- p \to e^- X$	$2.5 \le Q^2 < 20$ GeV^2, $0.3 < x < 0.9$, $W \ge 1.8$ GeV	[54] [62]
SLAC-89b	$E_b = 6.5 \div 19.5$ GeV		$e^- p \to e^- X$	$2.5 \le Q^2 \le 19$ GeV^2, $0.17 < x < 0.9$, $W \ge 1.8$ GeV	[56] [62]
			DIS heavy-quark production		
HERA I + II	$\sqrt{s} = 0.32$ TeV		$e^\pm p \to e^\pm c X$	$2.5 \le Q^2 \le 2000$ GeV^2, $2.5 \times 10^{-5} \le x \le 0.05$	[63]
H1	$\sqrt{s} = 0.32$ TeV	0.189	$e^\pm p \to e^\pm b X$	$5 \le Q^2 \le 2000$ GeV^2, $2 \times 10^{-4} \le x \le 0.05$	[15]
ZEUS	$\sqrt{s} = 0.32$ TeV	0.354	$e^\pm p \to e^\pm b X$	$6.5 \le Q^2 \le 600$ GeV^2, $1.5 \times 10^{-4} \le x \le 0.035$	[16]
CCFR	$87 \lesssim E_b \lesssim 333$ GeV		$\overset{(-)}{\nu} N \to \mu^\pm c X$	$1 \le Q^2 < 170$ GeV^2, $0.015 \le x \le 0.33$	[64]
CHORUS	$\langle E_b \rangle \approx 27$ GeV		$\nu N \to \mu^+ c X$		[18]
NOMAD	$6 \le E_b \le 300$ GeV		$\nu N \to \mu^+ c X$	$1 \le Q^2 < 20$ GeV^2, $0.02 \lesssim x \le 0.75$	[17]
NuTeV	$79 \lesssim E_b \lesssim 245$ GeV		$\overset{(-)}{\nu} N \to \mu^\pm c X$	$1 \le Q^2 < 120$ GeV^2, $0.015 \le x \le 0.33$	[64]
			DY		
ATLAS	$\sqrt{s} = 7$ TeV	0.035	$pp \to W^\pm X \to l^\pm \nu X$	$p_T^l > 20$ GeV, $p_T^\nu > 25$ GeV, $m_T > 40$ GeV	[67]
			$pp \to Z X \to l^+ l^- X$	$p_T^l > 20$ GeV, $66 < m_{ll} < 116$ GeV	
	$\sqrt{s} = 13$ TeV	0.081	$pp \to W^\pm X \to l^\pm \nu X$	$p_T^\nu > 25$ GeV, $m_T > 50$ GeV	[26]
			$pp \to Z X \to l^+ l^- X$	$p_T^l > 25$ GeV, $66 < m_{ll} < 116$ GeV	
CMS	$\sqrt{s} = 7$ TeV	4.7	$pp \to W^\pm X \to \mu^\pm \nu X$	$p_T^\mu > 25$ GeV	[24]
	$\sqrt{s} = 8$ TeV	18.8	$pp \to W^\pm X \to \mu^\pm \nu X$	$p_T^\mu > 25$ GeV	[25]
DØ	$\sqrt{s} = 1.96$ TeV	7.3	$\bar{p} p \to W^\pm X \to \mu^\pm \nu X$	$p_T^\mu > 25$ GeV, $E_T > 25$ GeV	[23]
		9.7	$\bar{p} p \to W^\pm X \to e^\pm \nu X$	$p_T^e > 25$ GeV, $E_T > 25$ GeV	[22]
LHCb	$\sqrt{s} = 7$ TeV	1	$pp \to W^\pm X \to \mu^\pm \nu X$	$p_T^\mu > 20$ GeV	[19]
			$pp \to Z X \to \mu^+ \mu^- X$	$p_T^\mu > 20$ GeV, $60 < m_{\mu\mu} < 120$ GeV	
	$\sqrt{s} = 8$ TeV	2	$pp \to Z X \to e^+ e^- X$	$p_T^e > 20$ GeV, $60 < m_{ee} < 120$ GeV	[21]
		2.9	$pp \to W^\pm X \to \mu^\pm \nu X$	$p_T^\mu > 20$ GeV	[20]
			$pp \to Z X \to \mu^+ \mu^- X$	$p_T^\mu > 20$ GeV, $60 < m_{\mu\mu} < 120$ GeV	
FNAL-605	$E_b = 800$ GeV		$p\, Cu \to \mu^+ \mu^- X$	$7 \le M_{\mu\mu} \le 18$ GeV	[68]
FNAL-866	$E_b = 800$ GeV		$pp \to \mu^+ \mu^- X$	$4.6 \le M_{\mu\mu} \le 12.9$ GeV	[69]
			$pD \to \mu^+ \mu^- X$		

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Impact of ATLAS data on strangeness

|	$\kappa_s(\mu^2=20\ \text{GeV}^2)$
HERA+ATLAS	0.81(18)
HERA+ATLAS+E866	0.72(8)
ABMP16(incl. NOMAD)	0.66(3)

κ_s is integral strange sea suppression factor:

$$\kappa_s(\mu^2) = \frac{\int\limits_0^1 x[s(x,\mu^2)+\bar{s}(x,\mu^2)]dx}{\int\limits_0^1 x[\bar{u}(x,\mu^2)+\bar{d}(x,\mu^2)]dx},$$

sa, Blümlein, Moch PLB 777, 134 (2018)
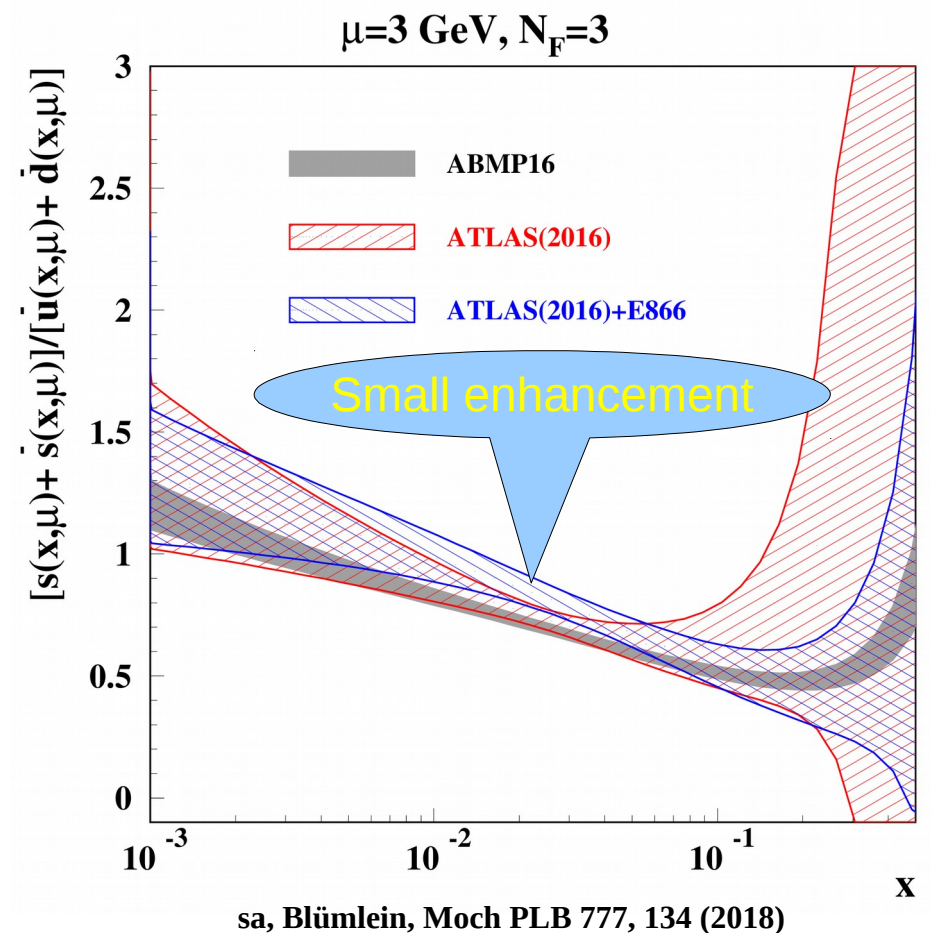
- The strangeness is in a broad agreement with the one extracted from the dimuon data

- The E866 data are consistent with the ATLAS(2016) central data: χ^2/NDP=48/39 and 40/34, respectively.

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NNLO tools' benchmaring
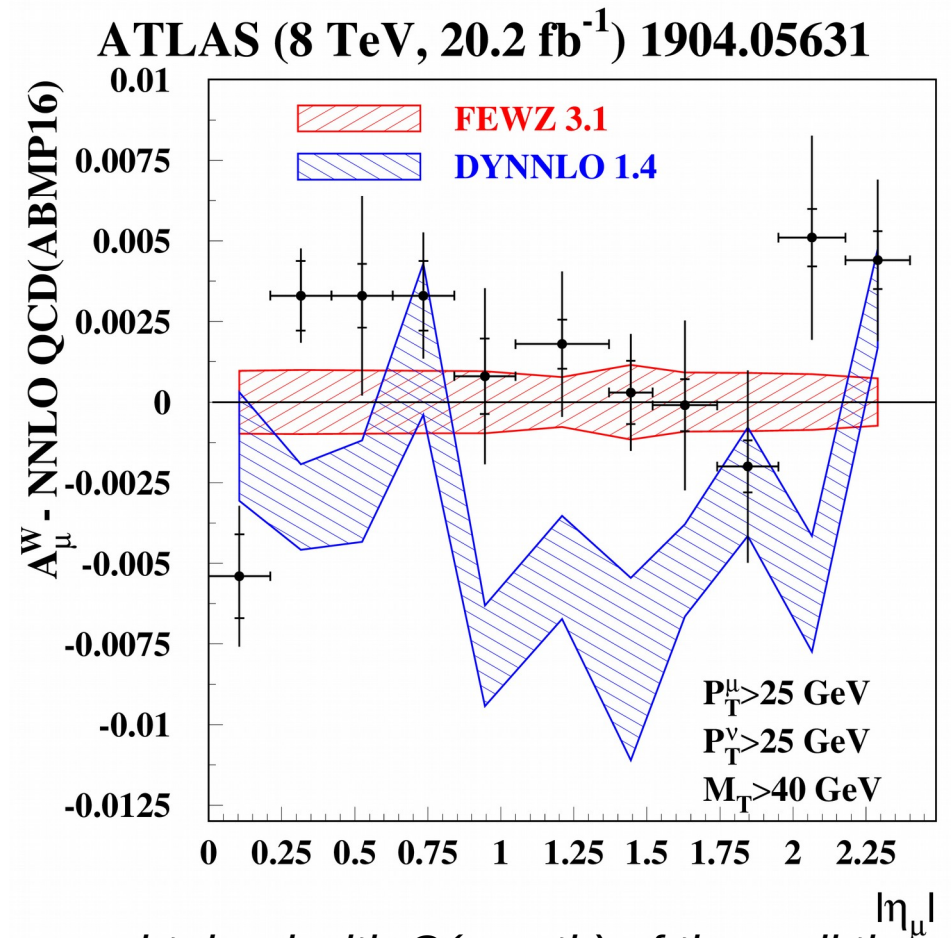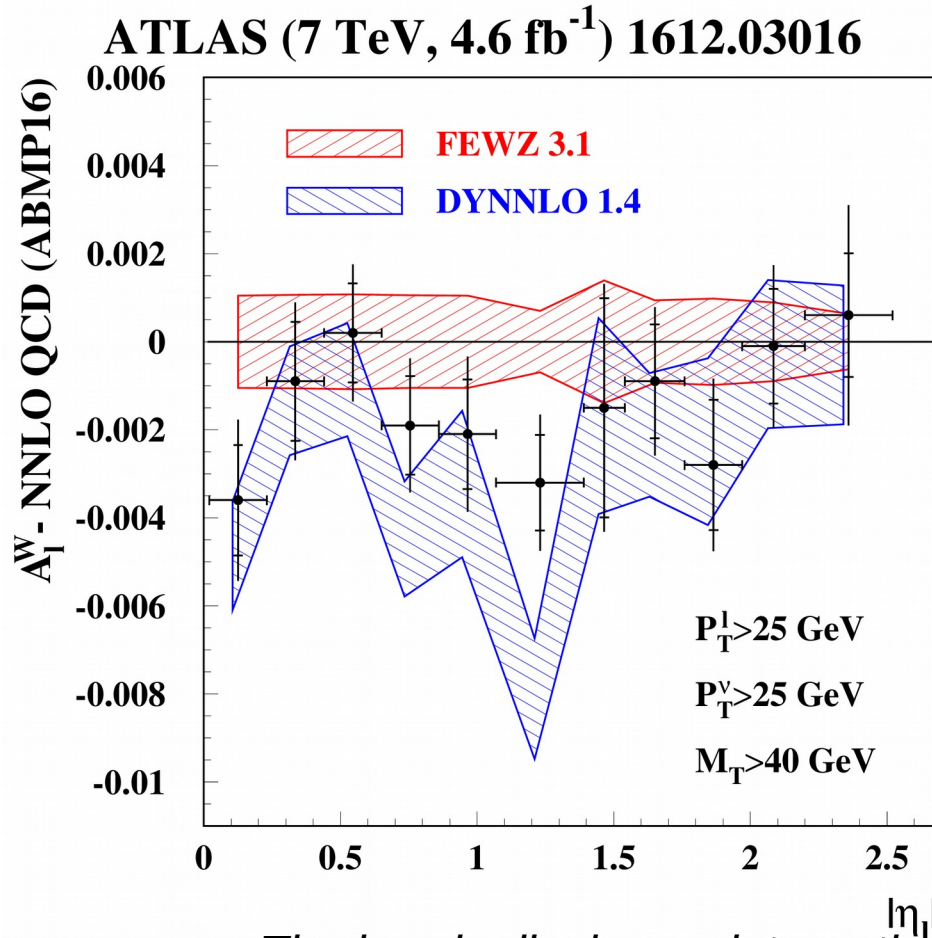
The bands display an integration accuracy obtained with O(month) of the wall time

- The FEWZ predictions somewhat overshoot the data at 7 TeV, while the DYNNLO ones go lower and are in better agreement with the measurements

- At 8 TeV the tendency is different: The FEWZ predictions somewhat undershoot the data and the DYNNLO ones go essentially lower

- FEWZ predictions demonstrate better overall agreement with the data therefore this tool is routinely used in the fit
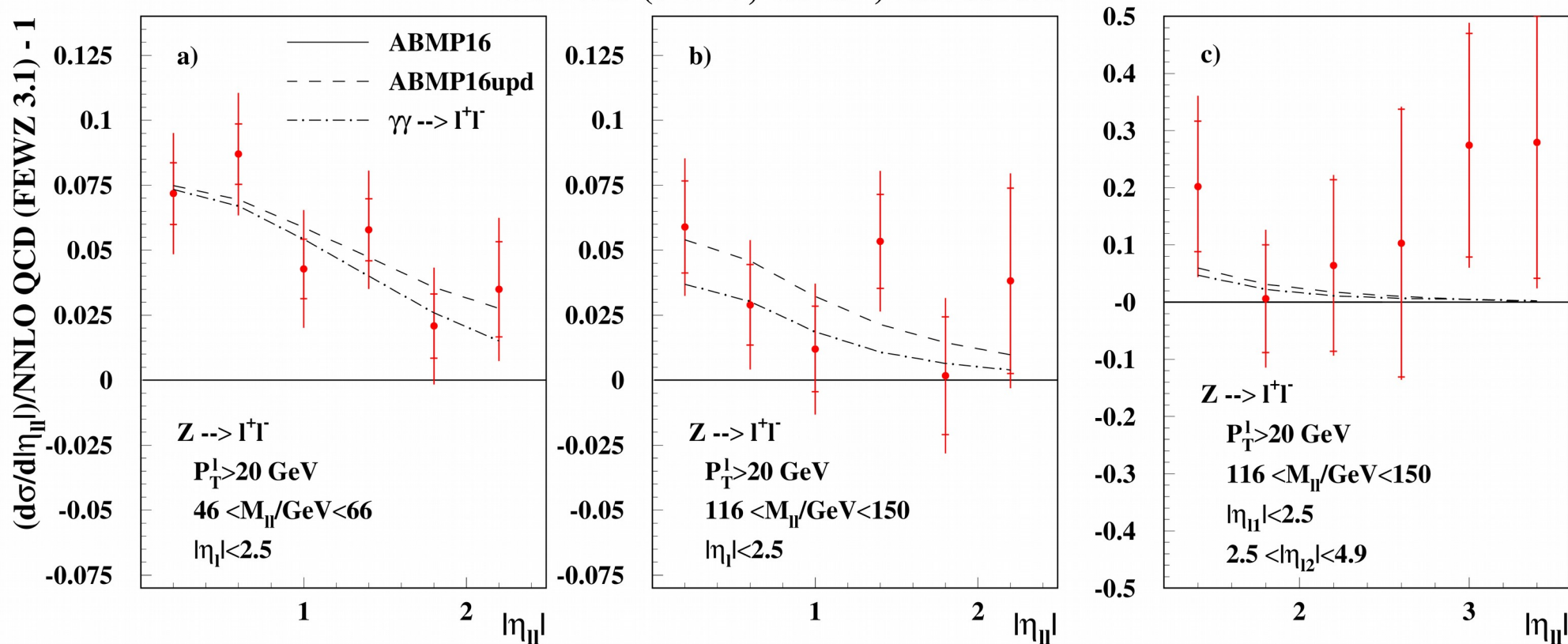
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W and Z 7-TeV ATLAS data in ABM fit

ATLAS (7 TeV, 4.6 fb^{-1}) 1612.03016
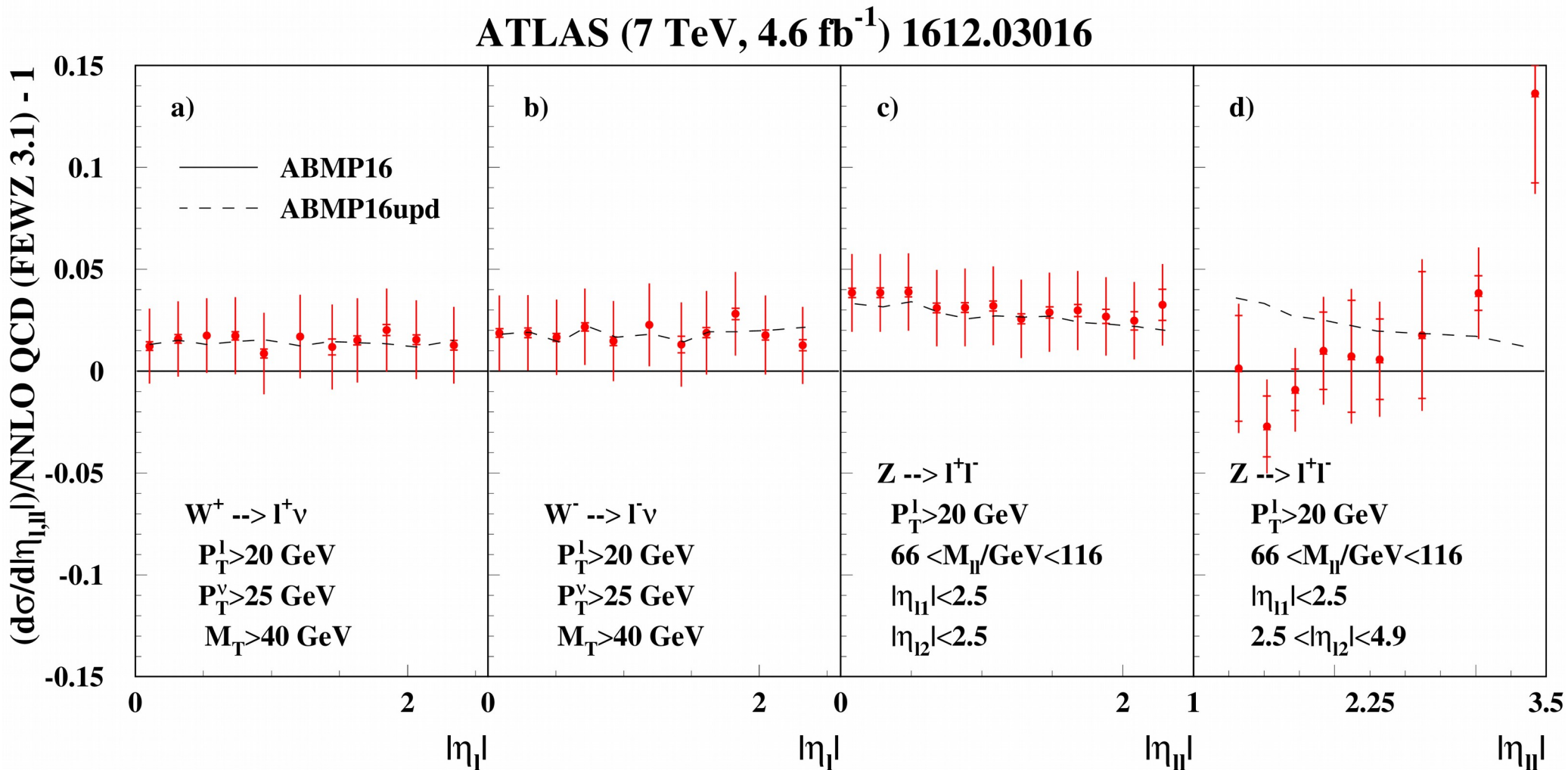
Data are well accommodated in general; forward Z-boson data have particular trend, however, χ^2 is also not bad due to large errors
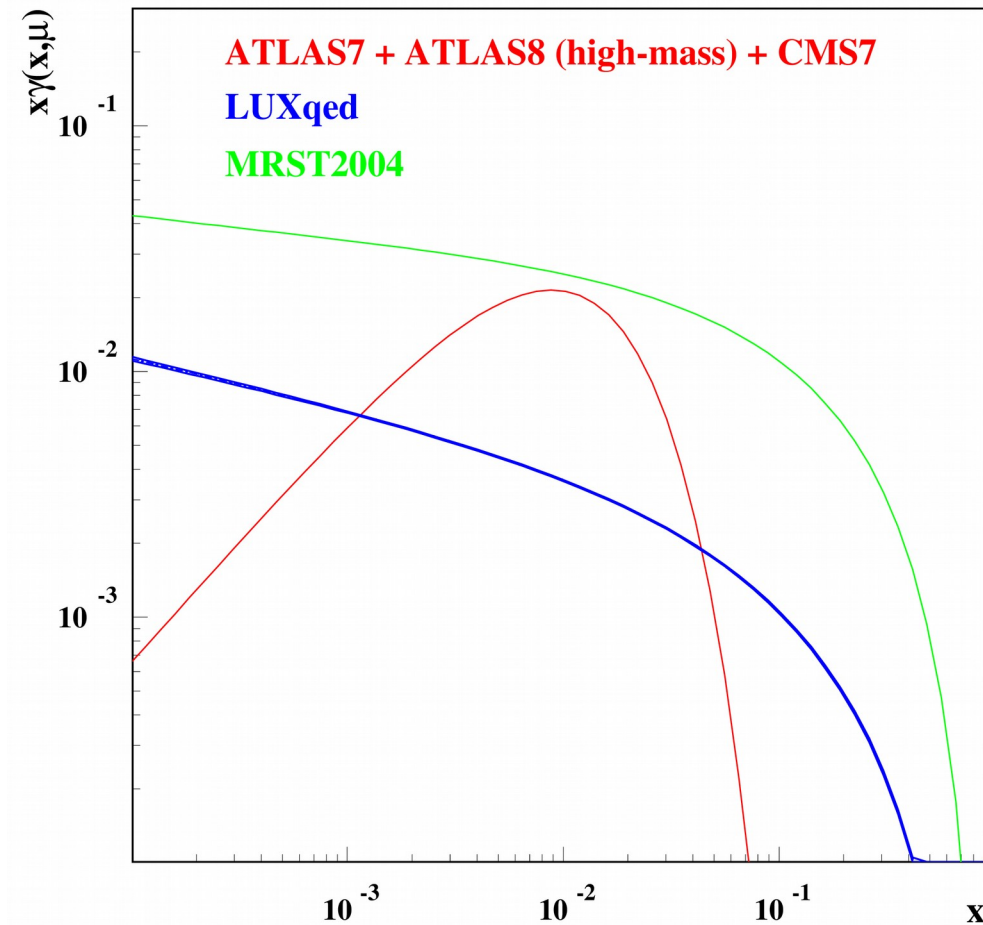
Non-resonant DY 7-TeV ATLAS data in ABM fit

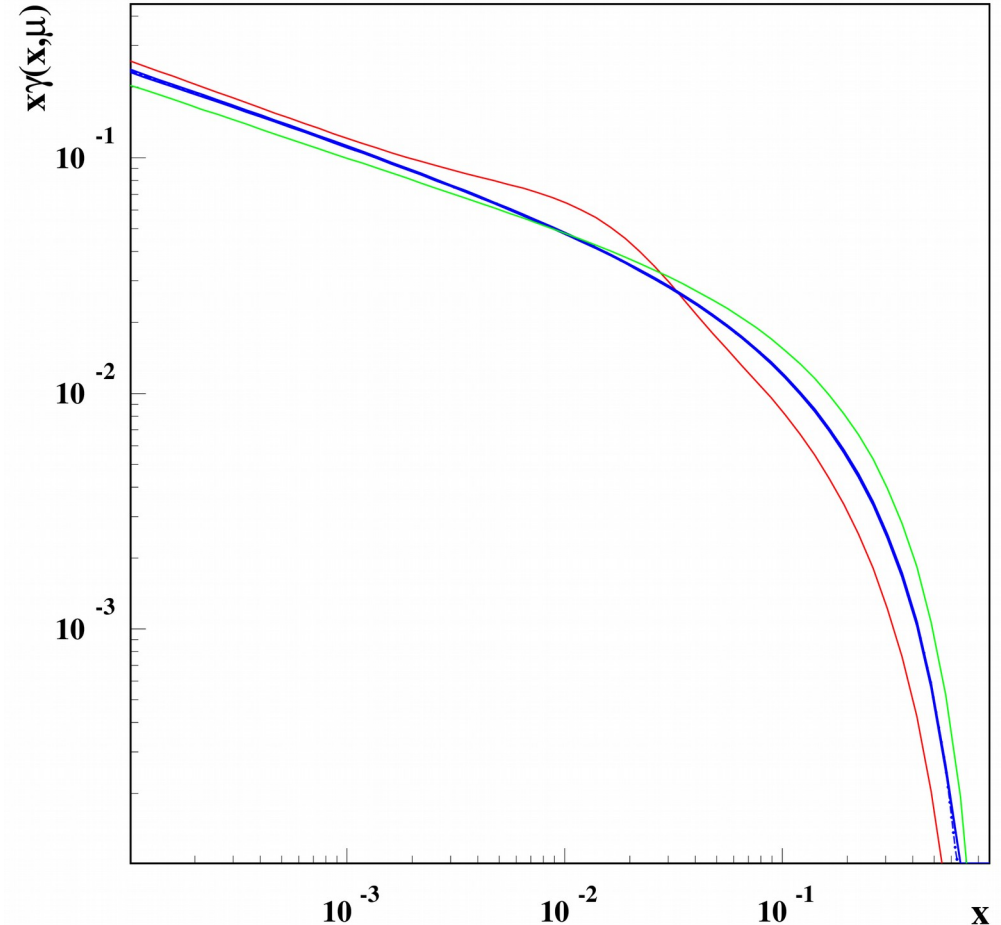
ATLAS (7 TeV, 4.6 fb^{-1}) 1612.03016

- The data can be well accommodated into the fit, the total χ^2/NDP for W, Z and Zγ* data is 68/61

- Account of the photon-photon contribution (in LO) improves agreement → photon distribution can be extracted from the data

Photon PDF fitted to the DY data

μ=3 GeV

ATLAS7 + ATLAS8 (high-mass) + CMS7
LUXqed
MRST2004

μ=100 GeV

Data set	X^2/NDP
ATLAS7 - 1612.03016	68/61
ATLAS8 (high-mass) – 1606.01736	192/132
CMS7 – 1310.7291	59/48

Quite different evolution input for the
available photon distributions. Reduces
at large scales, however still sensitive
to the quark distributions
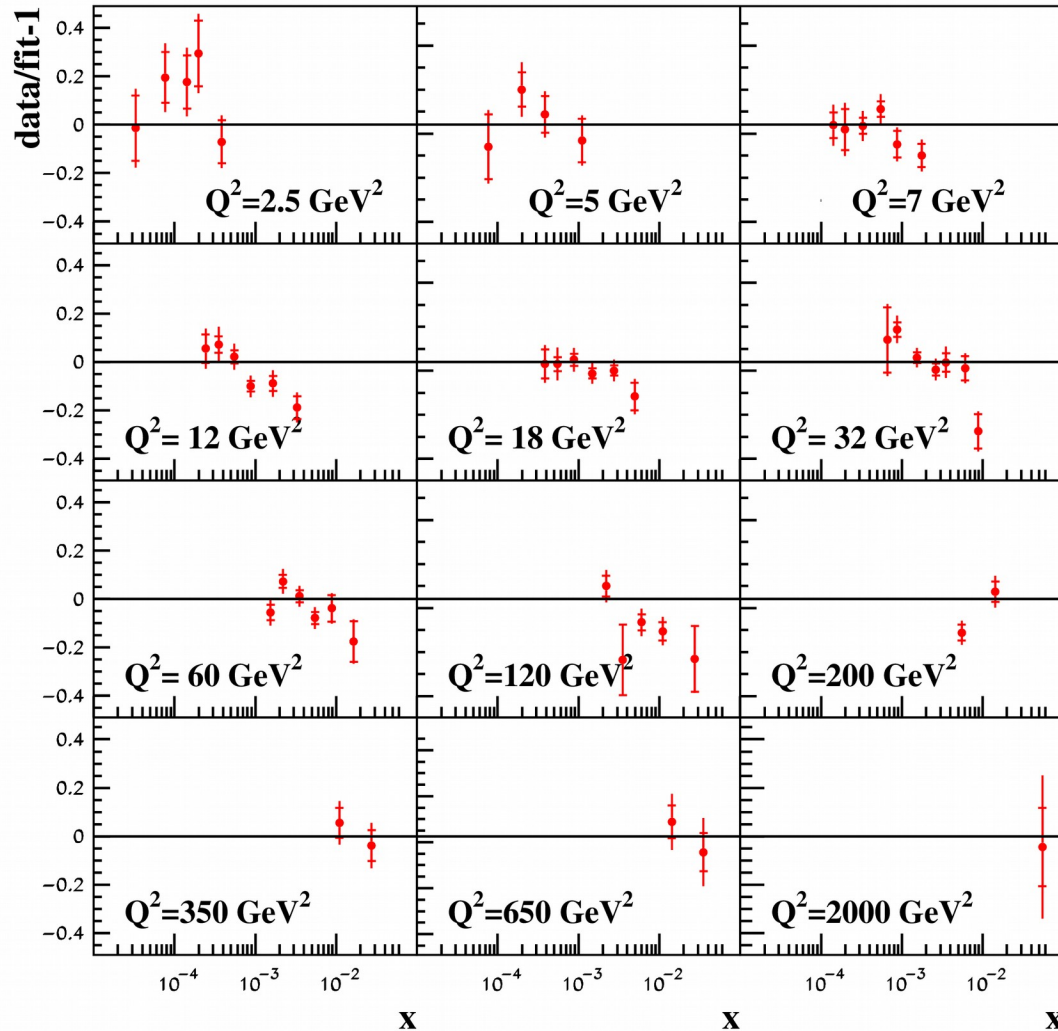(cf. PDF4LHC issue in LUXqed)

Manohar, Nason, Salam, Zanderighi hep-ph/1708.01256

The (quasi)-elastic contribution is not considered – conceptual difference with LUXqed

HERA charm data and m_c

Theory: FFN scheme, running mass definition

$m_c(m_c)=1.250\pm0.019$(exp.) GeV

ABMP16upd

$m_c(m_c)=1.252\pm0.018$(exp.) GeV

ABMP16

m_c(pole)~1.9 GeV (NNLO)

$m_c(m_c)=1.246\pm0.023$ (h.o.) GeV NNLO

$m_c(m_c)=1.279\pm0.008$ GeV

Good consistency with the earlier results and other determinations → further confirmation of the FFN scheme relevance for the HERA kinematics

HERA I+II (ep --> e charm X)

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Gluon and strange PDF updated
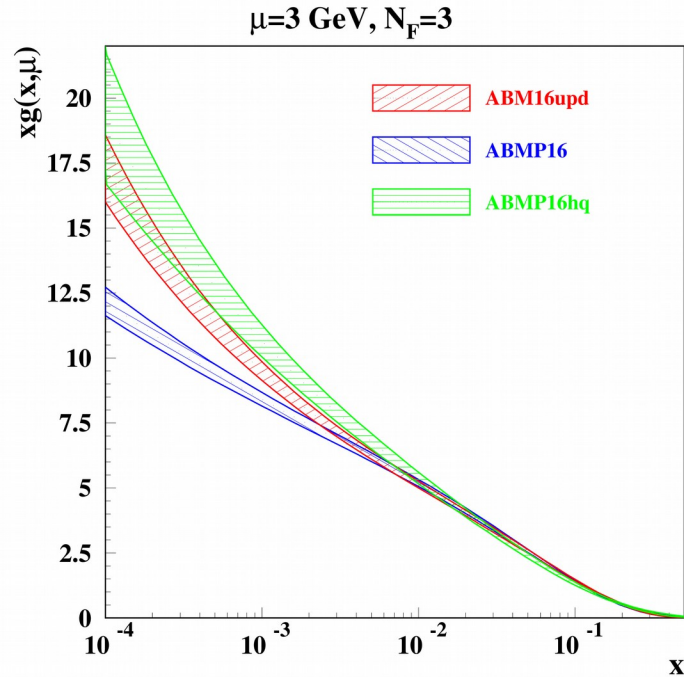
- Gluon goes higher, mainly due to more stringent cut on Q^2 (impact of the power corrections, resummations, etc. is reduced)

- Updated charm/beauty data are consistent with such an enhancement
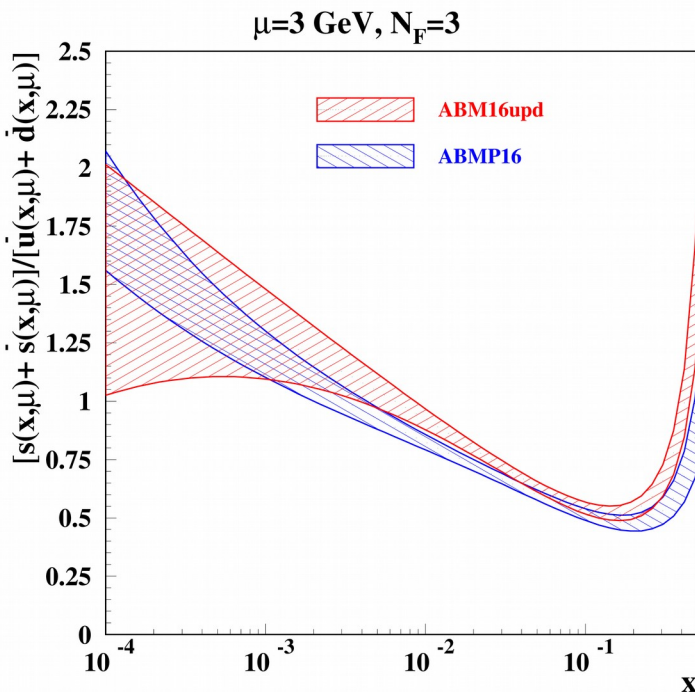
- Strange sea suppressoin factor goes lower at small x, consistent with 1 within errors

- At moderate x the strange sea is still suppressed, although integral suppression factor $\kappa_s(20 \text{ GeV}^2)=0.71(3)$, a little larger than 0.66(3) for ABMP16 fit

DY: impact of the recent data

ATLAS (5 TeV, 25 pb⁻¹) 1810.08242
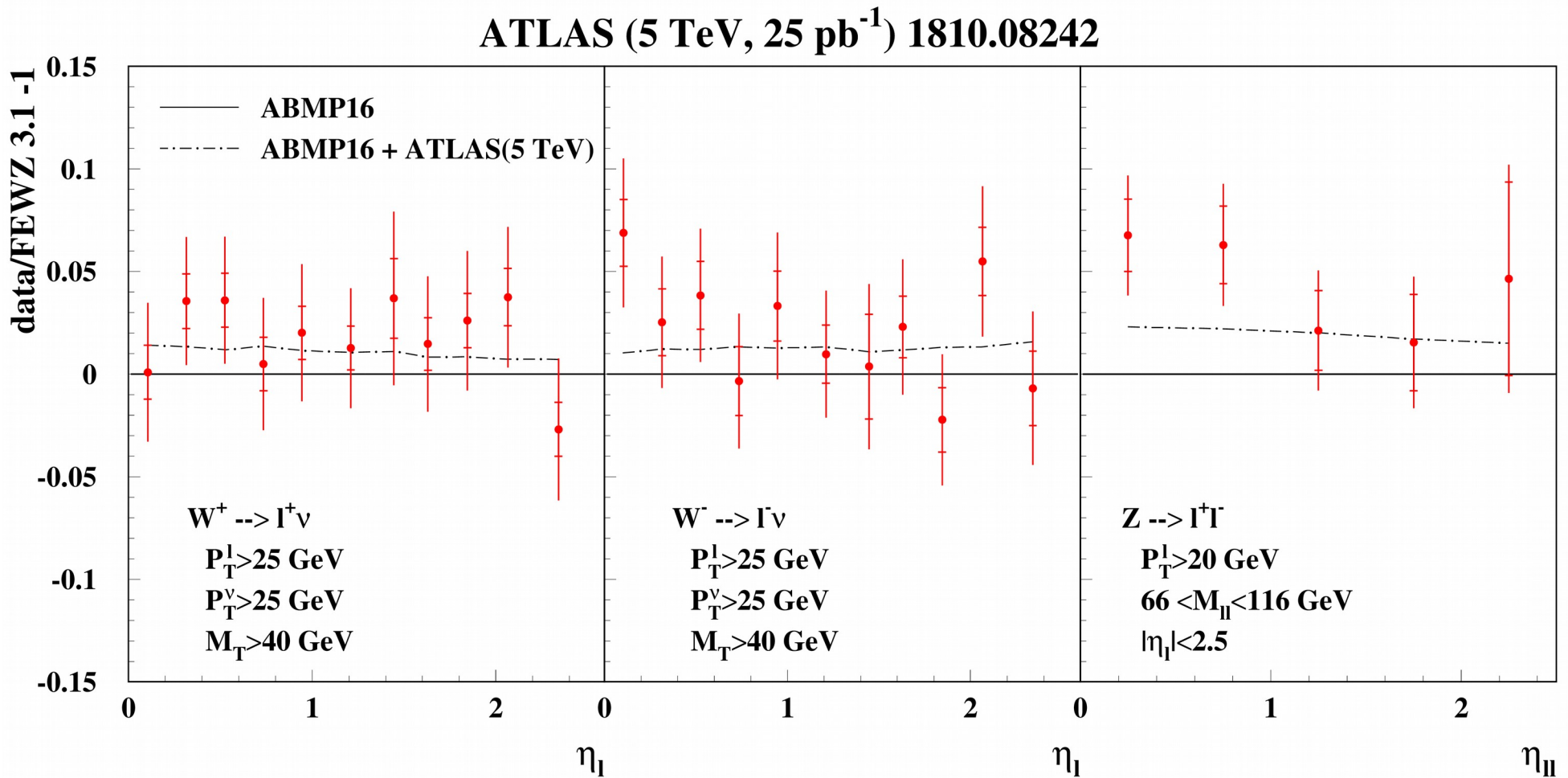
PRELIMINARY: Uncertainty correlations are not taken into account (still unpublished); smaller impact on fit is expected when they are included

ATLAS (8 TeV, 20.2 fb^{-1}) 1904.05631

ABMP16

$W^+ \to \mu^+ \nu$

$P_T^\mu > 25$ GeV

$P_T^\nu > 25$ GeV

$M_T > 40$ GeV

$W^- \to \mu^- \nu$

$P_T^\mu > 25$ GeV

$P_T^\nu > 25$ GeV

$M_T > 40$ GeV

data/FEWZ 3.1 -1

η_μ

η_μ
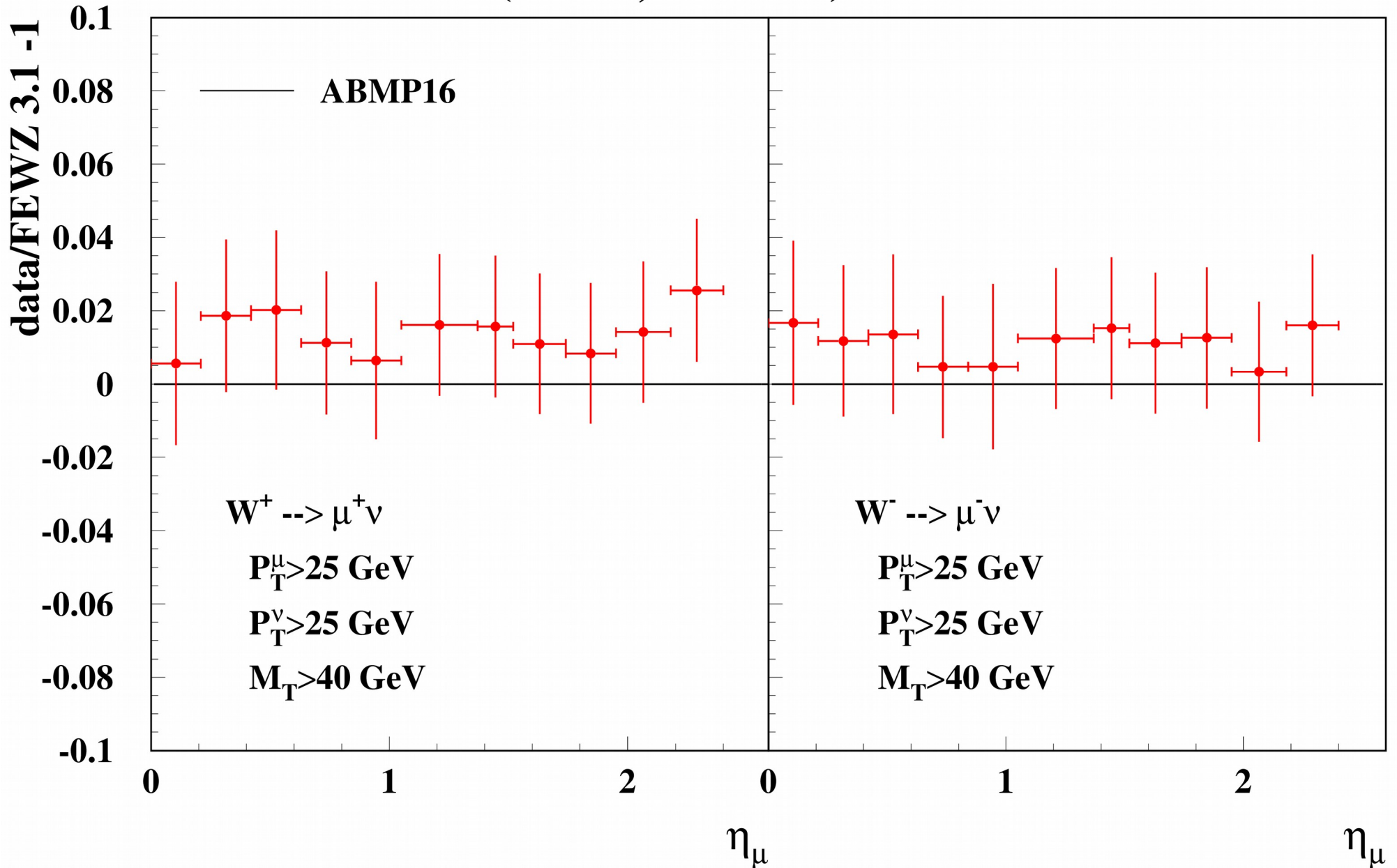
Uncertainty correlations are still unpublished

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Summary and outlook

- First non-resonant ATLAS and CMS DY data have been included into ABM fit

  – QED evolution is implemented

  – smooth accommodation of the ATLAS7 (W,Z/γ*), ATLAS8(γ*) (high mass), CMS7(Z/γ*) with account of the photon-photon contribution (NLO EW still has to be included)

  – first results on the photon distribution fitted to the DY data obtained

- More Z/γ* data are being processed:

ATLAS at 8 TeV	1710.05167
ATLAS at 7 TeV	1305.4192 (high mass)
	1404.1212 (low mass)
CMS at 8 TeV	1412.1115

  – better constraint on photon distribution is expected

- W and Z Atlas at 5 and 8 TeV can be quickly included into the fit, when the correlation matrices are provided

EXTRAS

Z ⇒ l⁺l⁻

fiducial

total

ABMP16

ATLAS 7 TeV
$p_T^e > 20$ GeV, $|\eta_e| < 2.47$
PR D85, 072004 (2012)
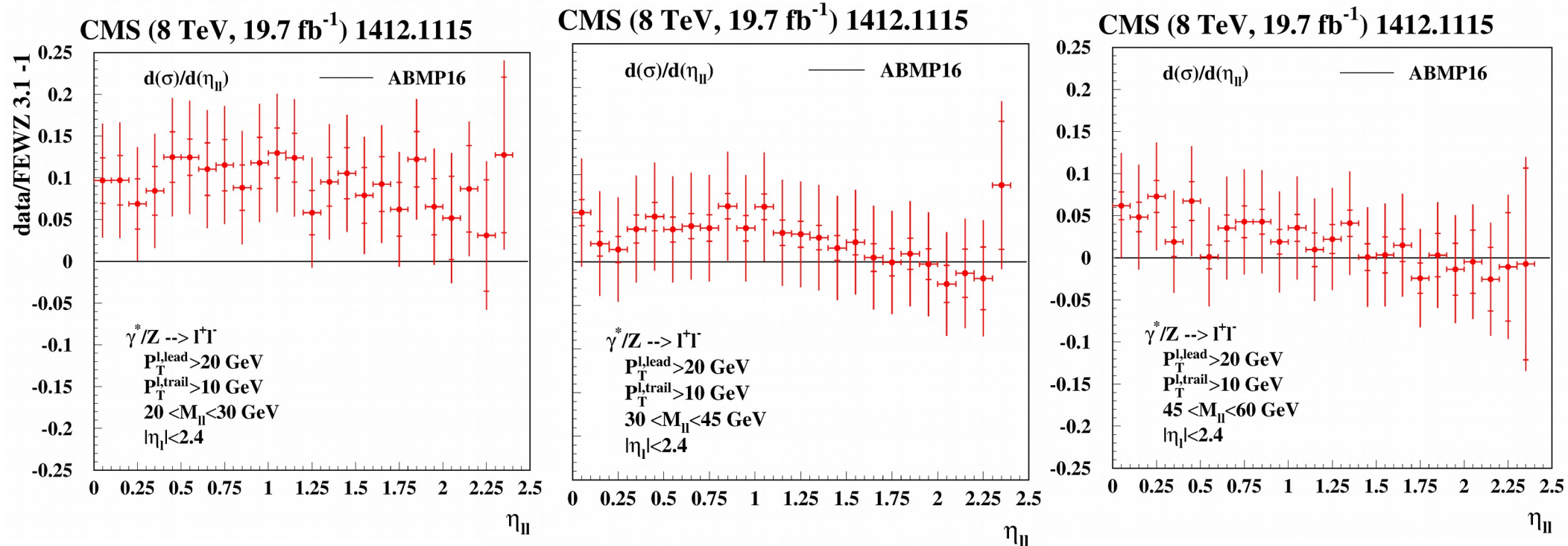
ATLAS 7 TeV
$p_T^\mu > 20$ GeV, $|\eta_\mu| < 2.4$
PR D85, 072004 (2012)

ATLAS 7 TeV
$p_T^e > 20$ GeV, $|\eta_e| < 2.47$
EPJ C77, 367 (2017)

ATLAS 7 TeV
$p_T^\mu > 20$ GeV, $|\eta_\mu| < 2.4$
EPJ C77, 367 (2017)

CMS 7 TeV
$p_T^{e,lead} > 20$ GeV, $p_T^{e,trail} > 10$ GeV
$|\eta_e| < 1.44$, $1.57 < |\eta_e| < 2.5$
JHEP 1312, 030 (2013)

CMS 7 TeV
$p_T^{\mu,lead} > 14$ GeV, $p_T^{\mu,trail} > 9$ GeV
$|\eta_\mu| < 2.4$, $|\eta_Z| < 2.4$
JHEP 1312, 030 (2013)

CMS 8 TeV
e+μ, no cuts
EPJ C75, 147 (2015)

ATLAS 13 TeV
$p_T^e > 25$ GeV, $|\eta_e| < 2.47$
PL B759, 601 (2016)

ATLAS 13 TeV
$p_T^\mu > 25$ GeV, $|\eta_\mu| < 2.4$
PL B759, 601 (2016)

-0.2   -0.15   -0.1   -0.05   -0.0   0.05   0.1

σ_Z / FEWZ3.1 -1

14
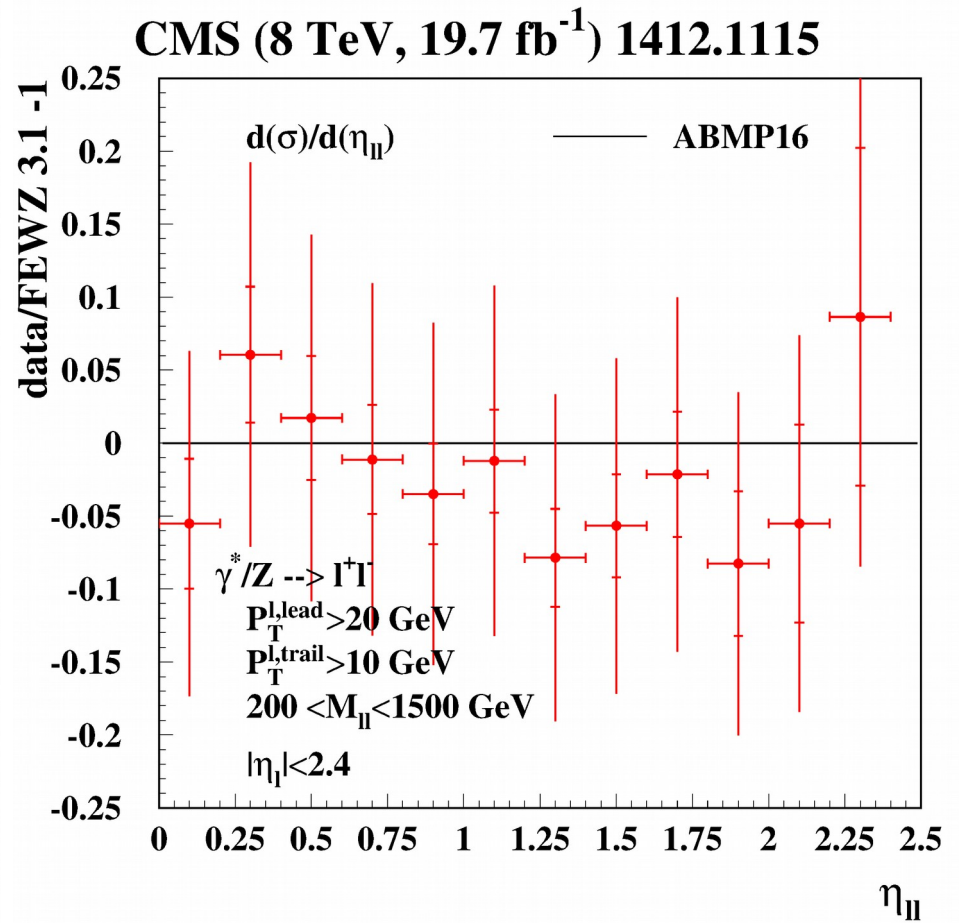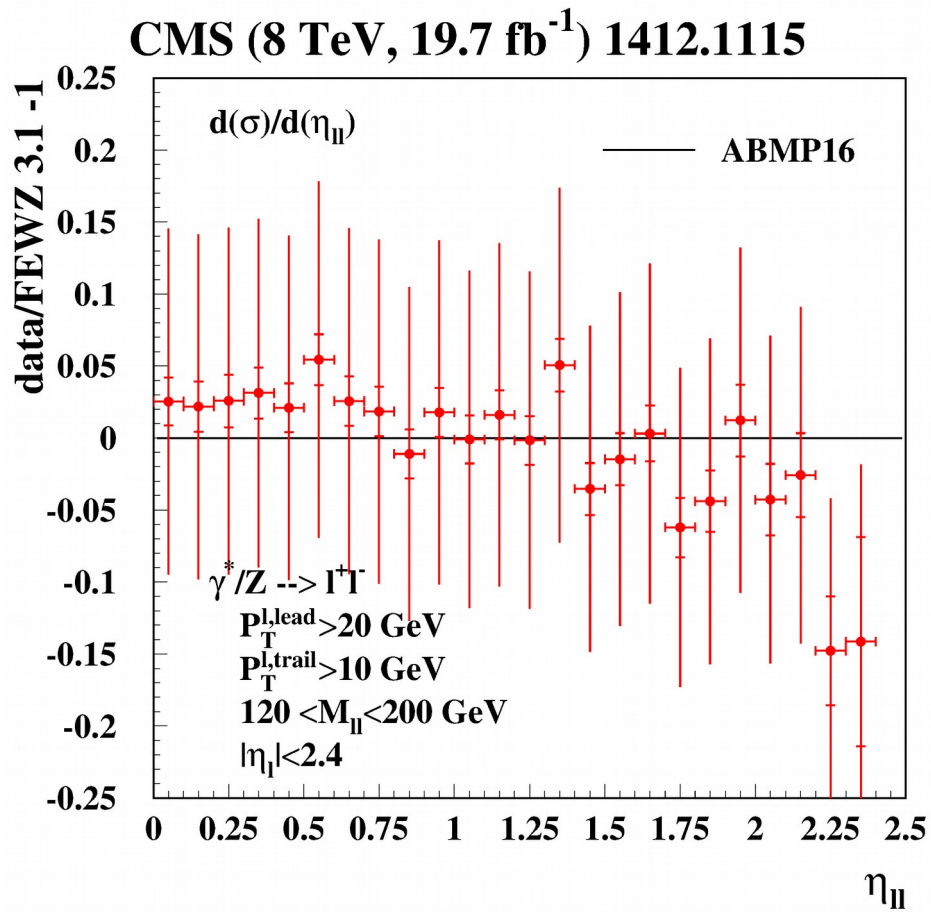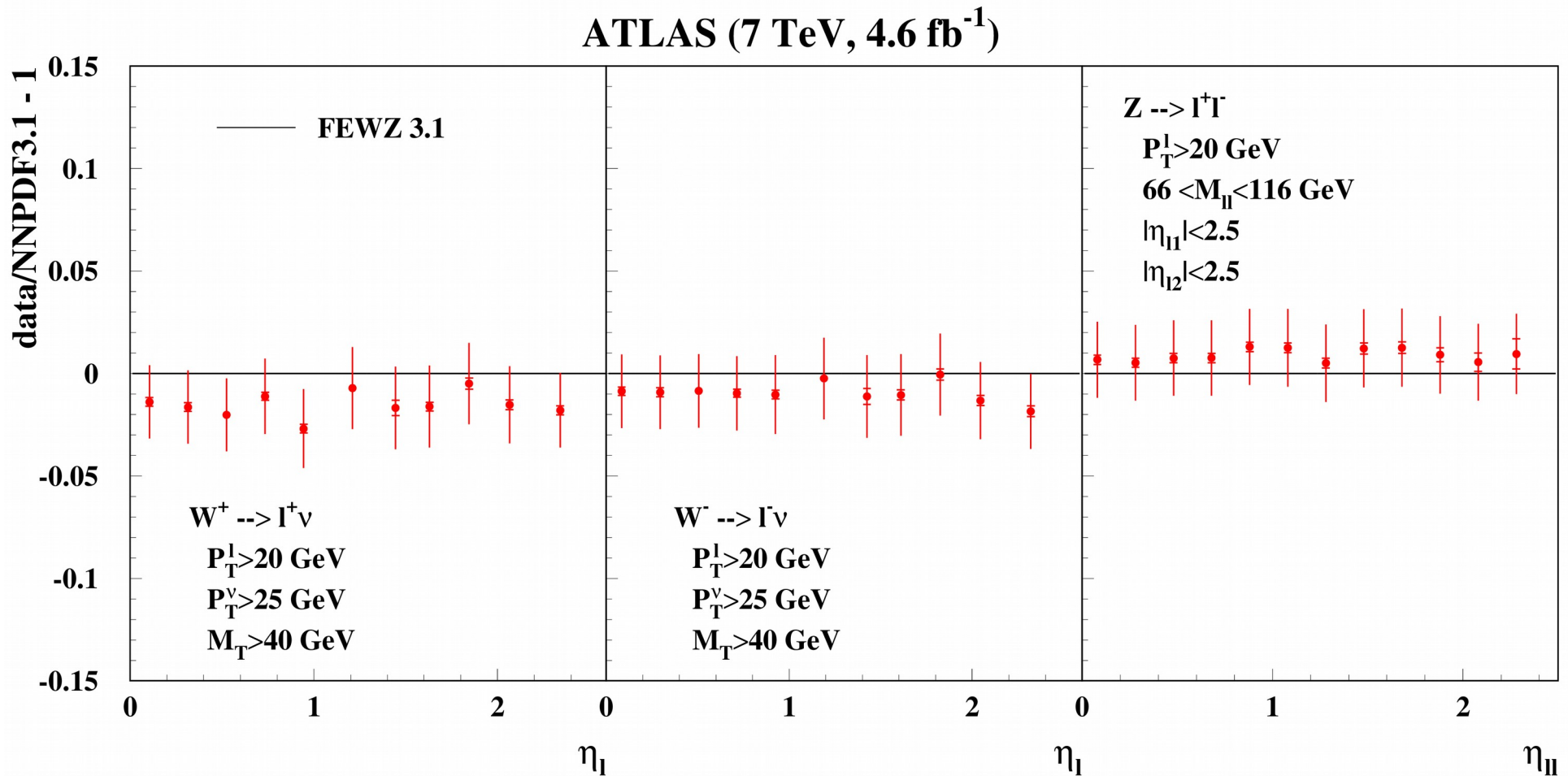
DY: towards double differential distributions

- Reasonable agreement with the previous fit predictions

- Complimentary constraint on PDFs → improved quark disentangling

- Other CMS and ATLAS data in progress; the bottleneck is NNLO computations with the fiducial-volume cuts

CMS (8 TeV, 19.7 fb^{-1}) 1412.1115

d(σ)/d(η_{ll})

ABMP16

γ^*/Z --> l$^+$l$^-$

P$_T^{l,lead}$>20 GeV

P$_T^{l,trail}$>10 GeV

120 <M$_{ll}$<200 GeV

|η_l|<2.4

data/FEWZ 3.1 -1

η_{ll}

CMS (8 TeV, 19.7 fb^{-1}) 1412.1115

d(σ)/d(η_{ll})

ABMP16

γ^*/Z --> l$^+$l$^-$

P$_T^{l,lead}$>20 GeV

P$_T^{l,trail}$>10 GeV

200 <M$_{ll}$<1500 GeV

|η_l|<2.4

data/FEWZ 3.1 -1

η_{ll}

Closure test of the NNPDF3.1 fit

ATLAS (7 TeV, 4.6 fb^{-1})

- Different trend for W and Z data ⇒ χ^2/NDP= 400/34; problems with the flavor disentangling

- Suppressed (fitted) charm distribution requires corresponding enhancement of strangeness sur to constraint from W data

Thorne QCD@LHC2018

HERA (ep --> e bottom X)