Strange sea from collider data

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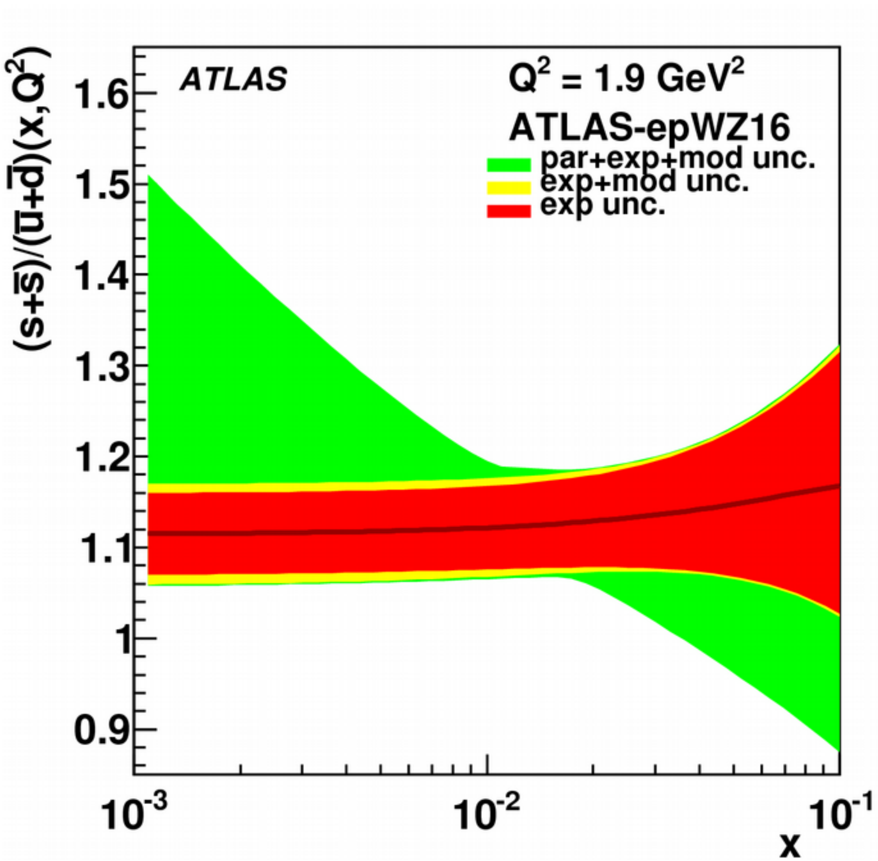
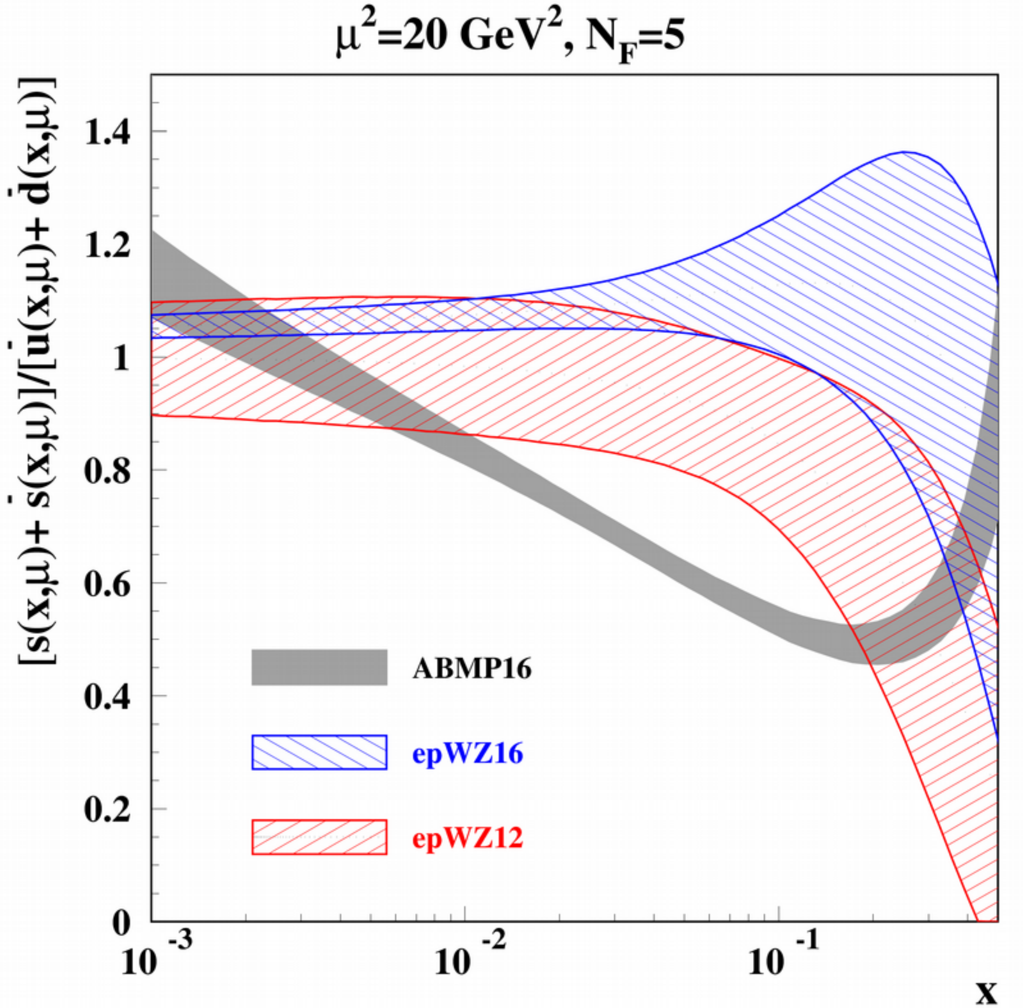
sa, Blümlein, Moch hep-ph/1708.01067

PDF4LHC meeting, CERN, *6 Sep 2017*

ATLAS strange enhancement



ATLAS arXiv:1612.03016



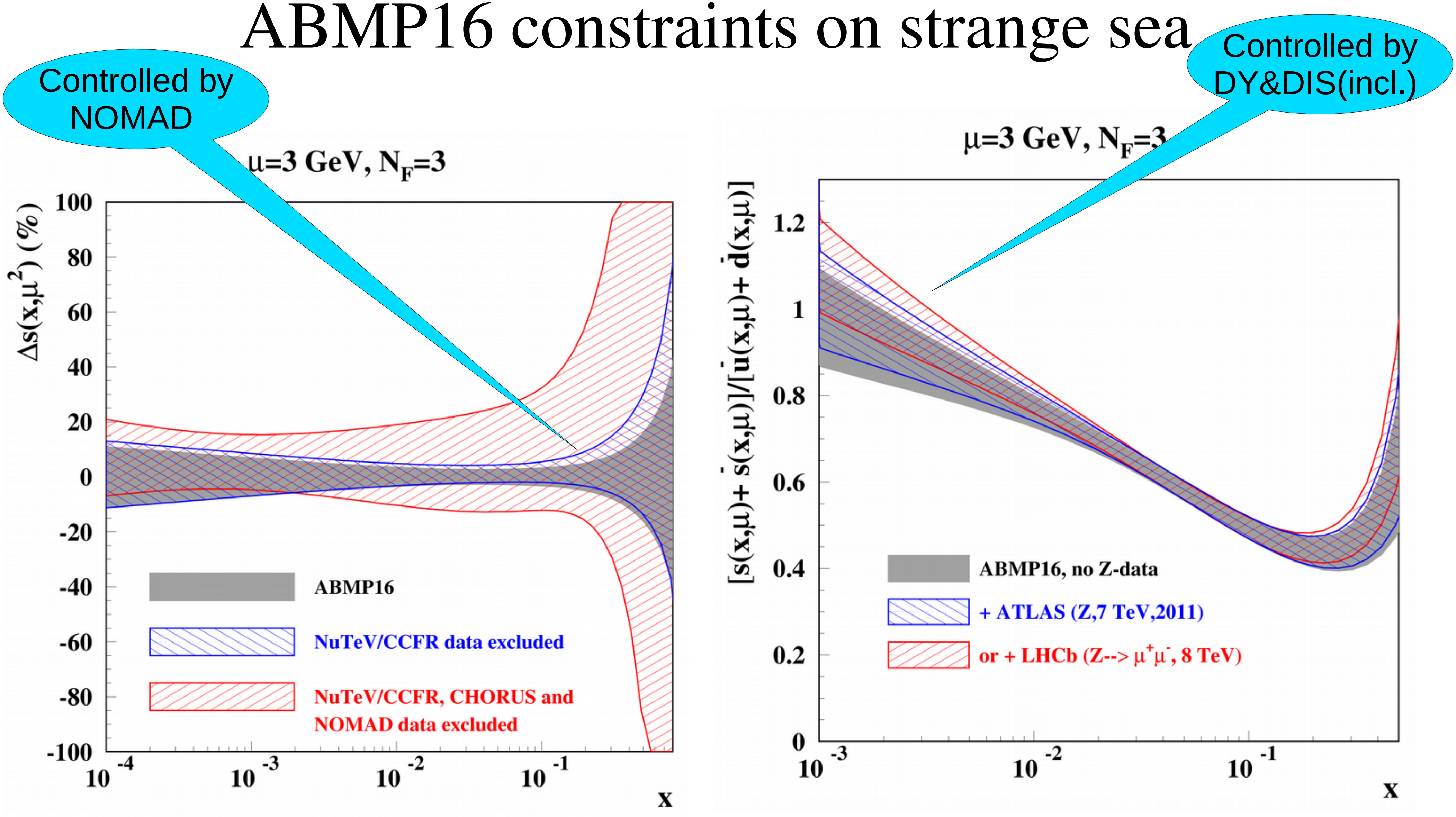
The epWZ16 strange-sea determined from analysis of the combined HERA-ATLAS data is enhanced as compared to other (earlier) determinations

Disentangling d- and s- contribution?

ABM strange sea determination is in particular based on the dimuon neutrino-nucleon DIS production (NuTeV/CCFR and NOMAD) that gives a strange sea suppression ~0.5 at x~0.2

Impact of the nuclear corrections?
Old data quality?
......

ABMP16 constraints on strange sea



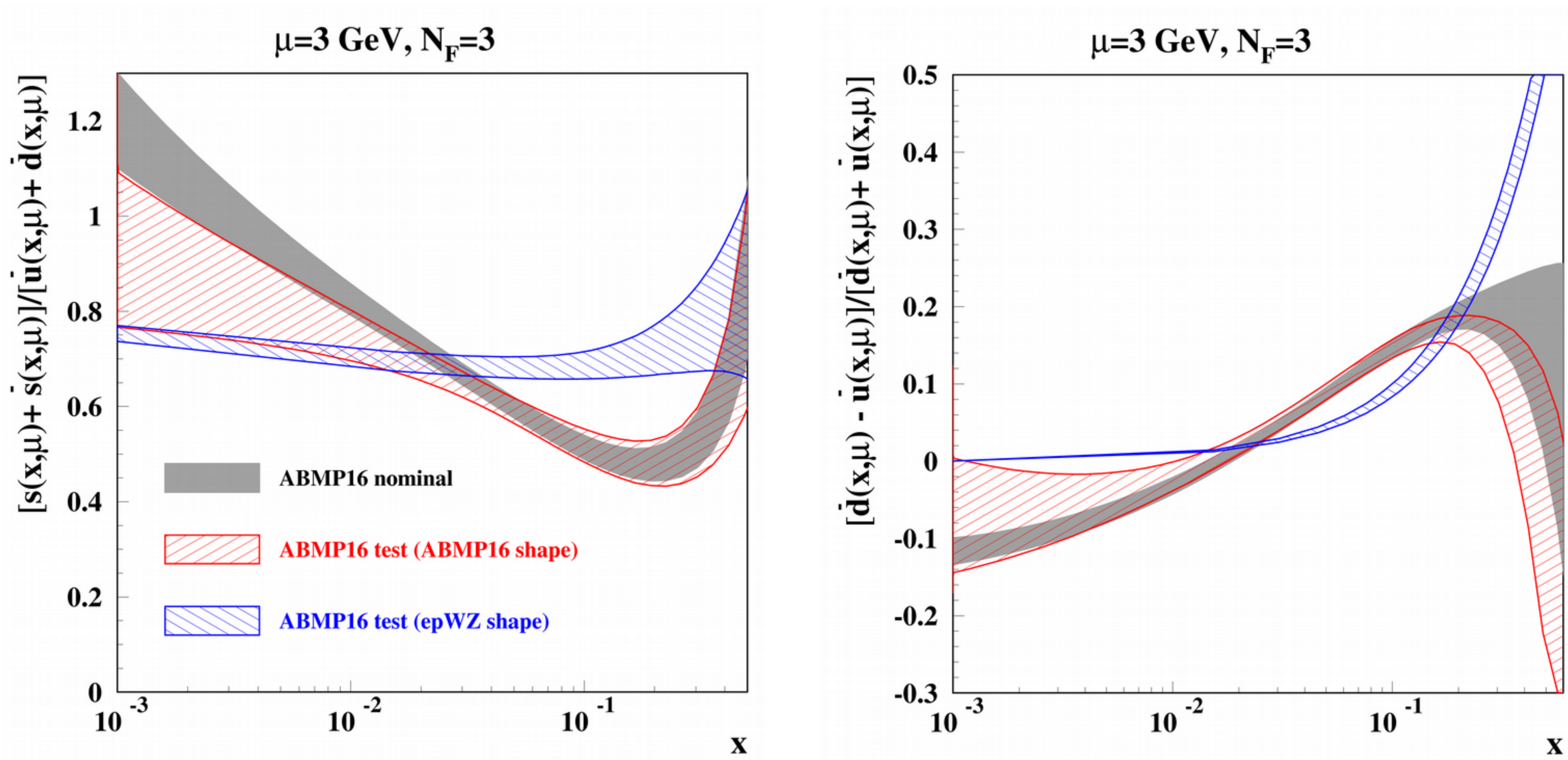
- Uncertainty of ~5% is achieved at x around 0.1
- NuTeV/CCFR data play no essential role → impact of the nuclear corrections is greatly reduced (NOMAD and CHORUS give the ratio CC/incl.)

Details of the epWZ and ABMP16 fits

	epWZ16	ABMP16
Data	HERA, ATLAS W&Z	HERA, LHC and Tevatron W&Z, fixed-target DIS and charm production, fixed-target DY, ….
PDF shape	$xu_v(x,\mu_0^2) = A_{u_v} x^{B_{uv}} (1-x)^{C_{uv}} (1+E_{u_v} x^2)$, $xd_v(x,\mu_0^2) = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}}$, $x\bar{u}(x,\mu_0^2) = A_{\bar{u}} x^{B_{\bar{u}}} (1-x)^{C_{\bar{u}}}$, $x\bar{d}(x,\mu_0^2) = A_{\bar{d}} x^{B_{\bar{d}}} (1-x)^{C_{\bar{d}}}$, $xg(x,\mu_0^2) = A_g x^{B_g} (1-x)^{C_g} - A'_g x^{B'_g} (1-x)^{C'_g}$, $x\bar{s}(x,\mu_0^2) = A_{\bar{s}} x^{B_{\bar{s}}} (1-x)^{C_{\bar{s}}}$, 15 free parameters	$xq_v(x,\mu_0^2) = \frac{2\delta_{qu}+\delta_{qd}}{N_q^v} (1-x)^{b_{qv}} x^{a_{qv} P_{qv}(x)}$, $xq_s(x,\mu_0^2) = A_{qs} (1-x)^{b_{qs}} x^{a_{qs} P_{qs}(x)}$, $xg(x,\mu_0^2) = A_g (1-x)^{b_g} x^{a_g P_g(x)}$, $P_p(x) = (1+\gamma_{-1,p} \ln x)\left(1+\gamma_{1,p} x + \gamma_{2,p} x^2 + \gamma_{3,p} x^3\right)$, 25 free parameters

ABMP16 PDFs are selected more flexible in order to accommodate more data as compared to the EpWZ16 fit, which was evolved form the HERA data analysis

Test fit (the PDF shape comparison)

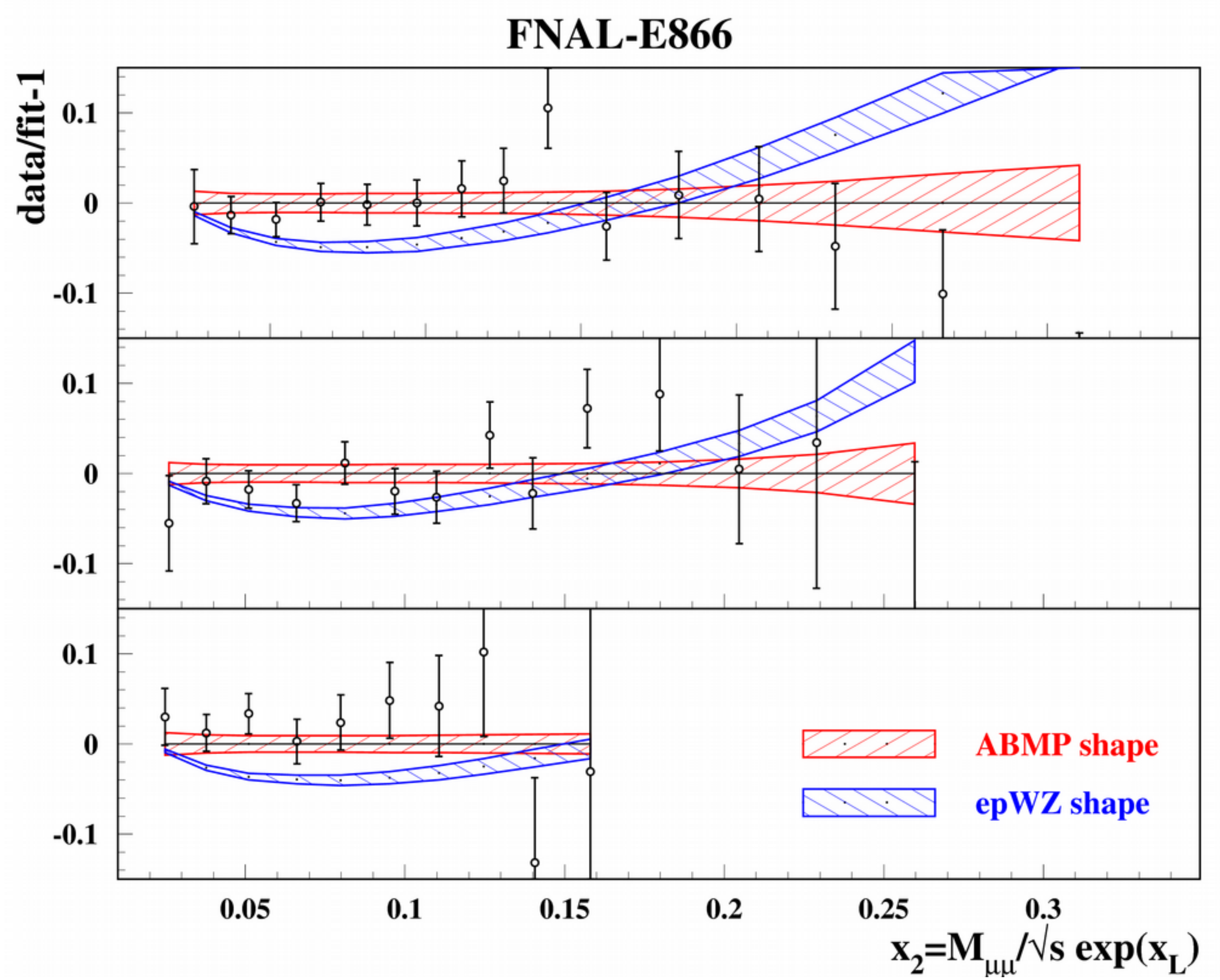


The data used in test fit: collider data discarded and replaced by the deuteron ones (fit is consistent with the nominal ABMP16 at x>0.01) **sa, Kulagin, Petti hep-ph/1704.00204**

The strange sea is enhanced for the epWZ shape despite the ATLAS data are not used. However, the dimuon data description is not deteriorated: χ^2=167 versus 161 for the ABMP shape ⇒ enhancement is achieved by the price of the d-quark sea suppression

sa, Blümlein, Caminada, Lipka, Lohwasser, Moch, Petti, Plačakytė PRD 91, 094002 (2015)

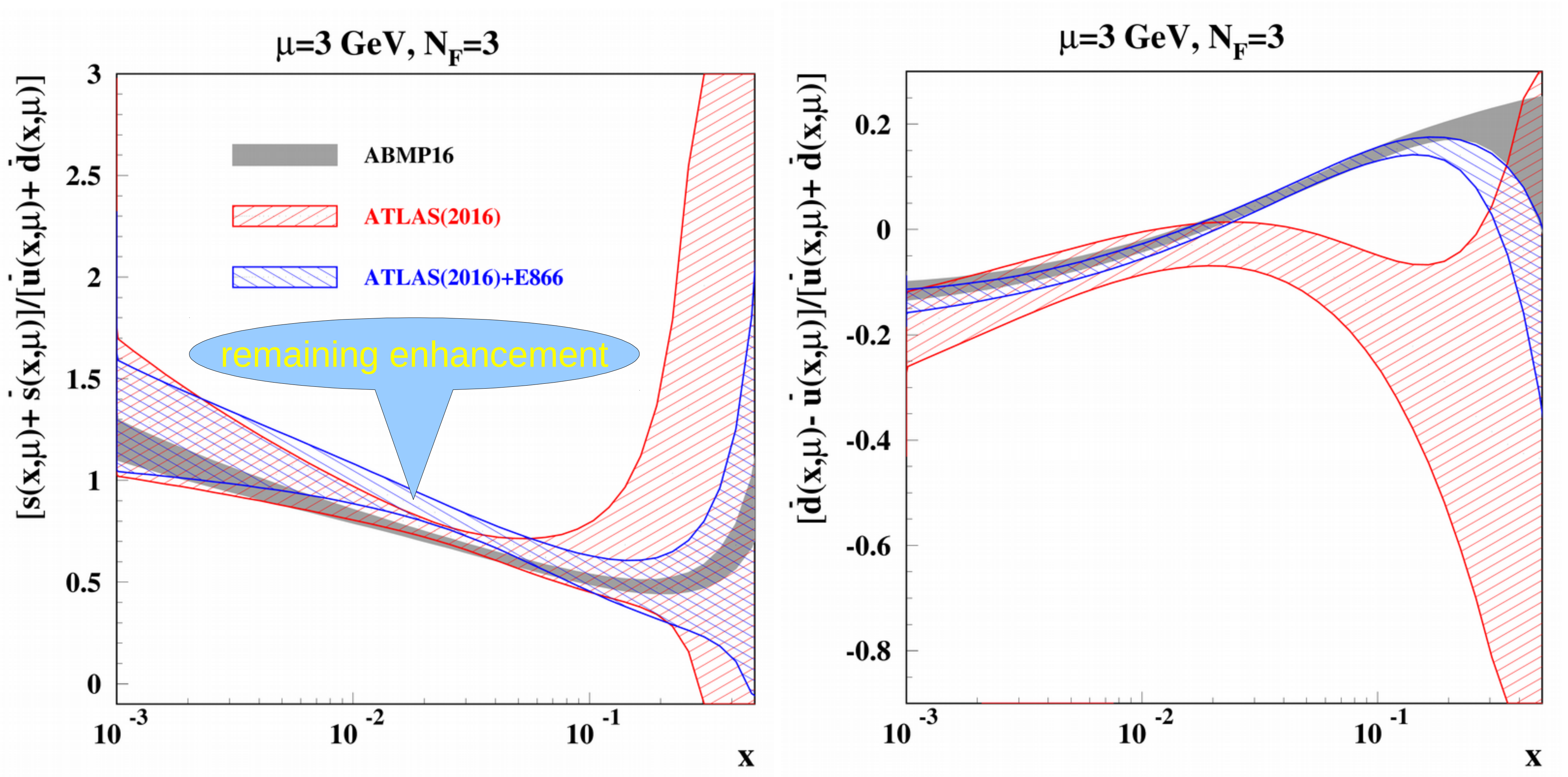
E866 data in the test fit



The E866 data on p/d DY cross sections are sensitive to the iso-spin sea asymmetry

The epWZ shape does not allow to accommodate E866 data: χ^2/NDP=96/39 versus 49/39 for the ABMP shape; the errors in epWZ predictions are suppressed at small x, evidently due to over-constrained PDF shape at small x

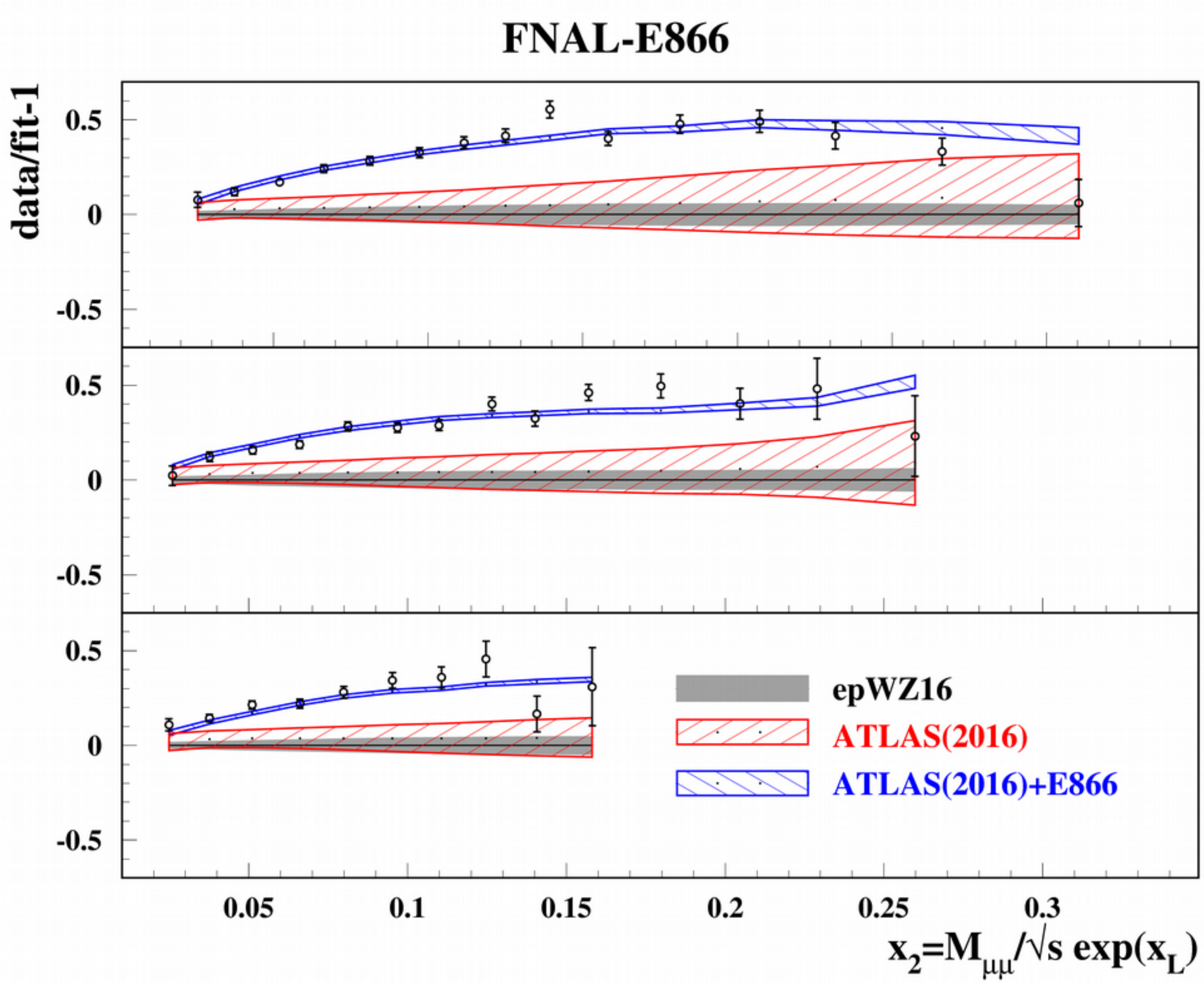
Strange and non-strange sea from ATLAS data



The data used in test fit: collider W&Z data except of ATLAS(2016) discarded to approach the data selection of epWZ16 fit

For the flexible PDF shape the strangeness is in a broad agreement with the ABMP16 results; the E866 data are consistent with the ATLAS(2016) set: χ^2/NDP=48/39 and 40/34, respectively.

Consistency of ATLAS and E866 data

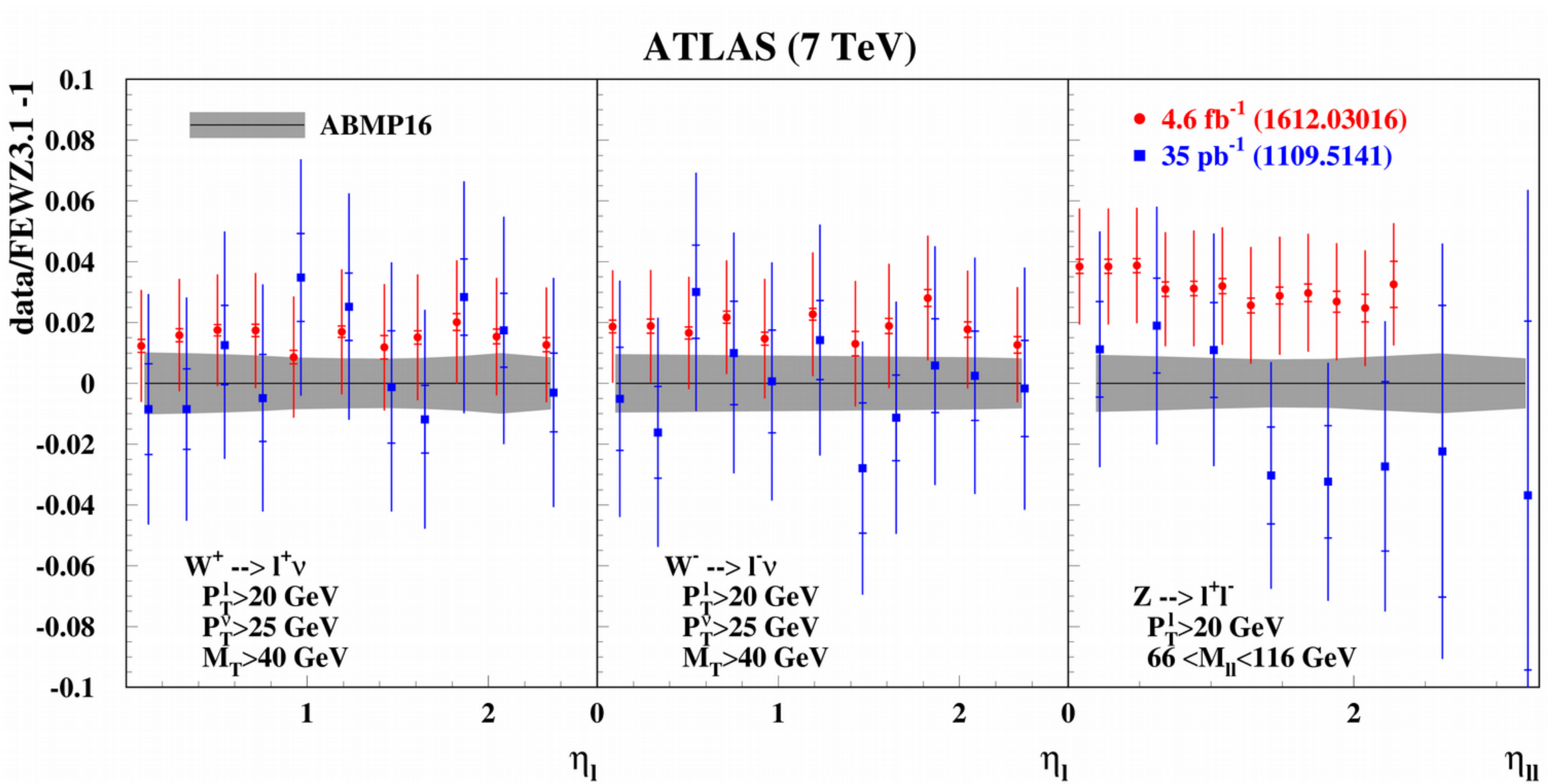


- The uncertainties in epWZ predictions are quite narrow and several σ off the E866 data ⇒ E866 cannot be accommodated into the fit

ATLAS, private communication

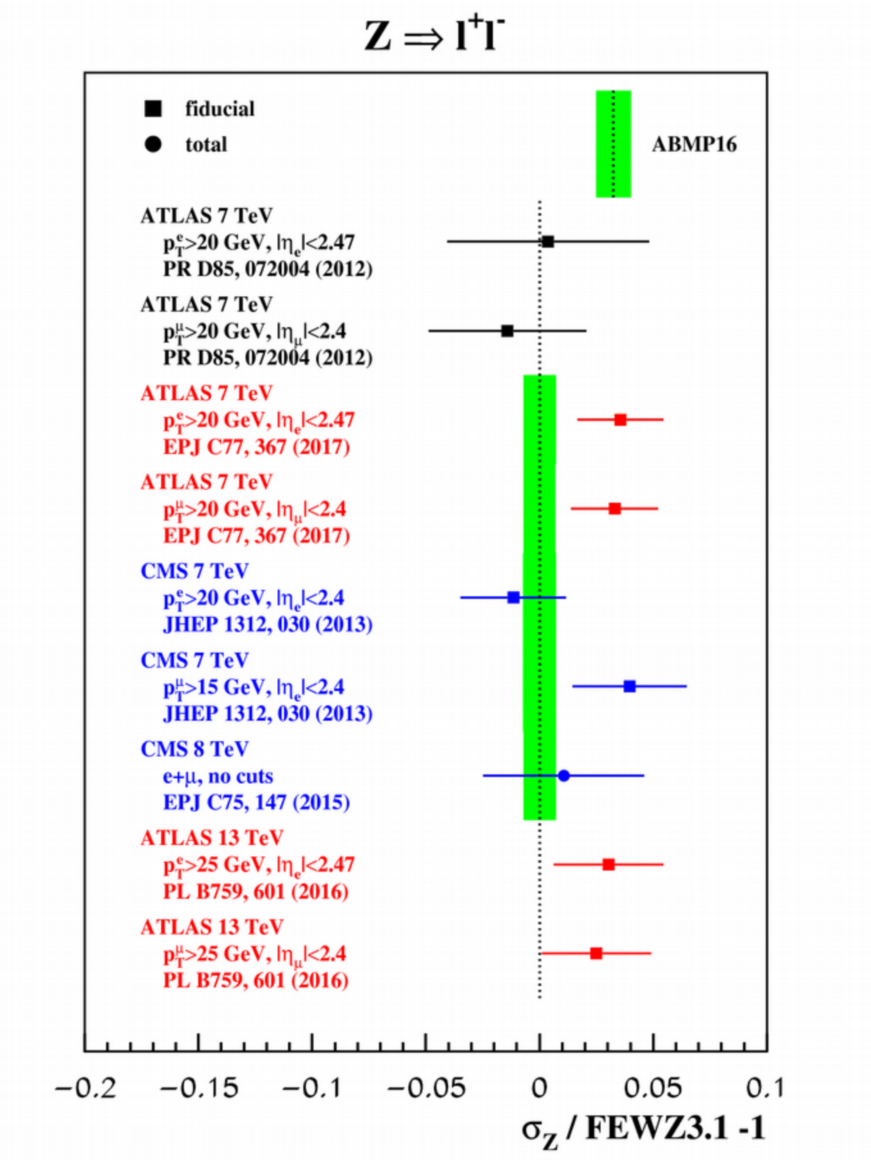
- The ABMP16 shape gives much wider error band ⇒ E866 data are well accommodated: χ^2/NDP=48/39 and 40/34 for the E866 and ATLAS, respectively

ATLAS data on the W&Z central production



The updated ATLAS data on $W^{\pm}$ production are in a good agreement with the earlier ATLAS sample; the data on Z production go higher, particularly at large rapidity ⇒ *impact on the strange sea at x~0.01*

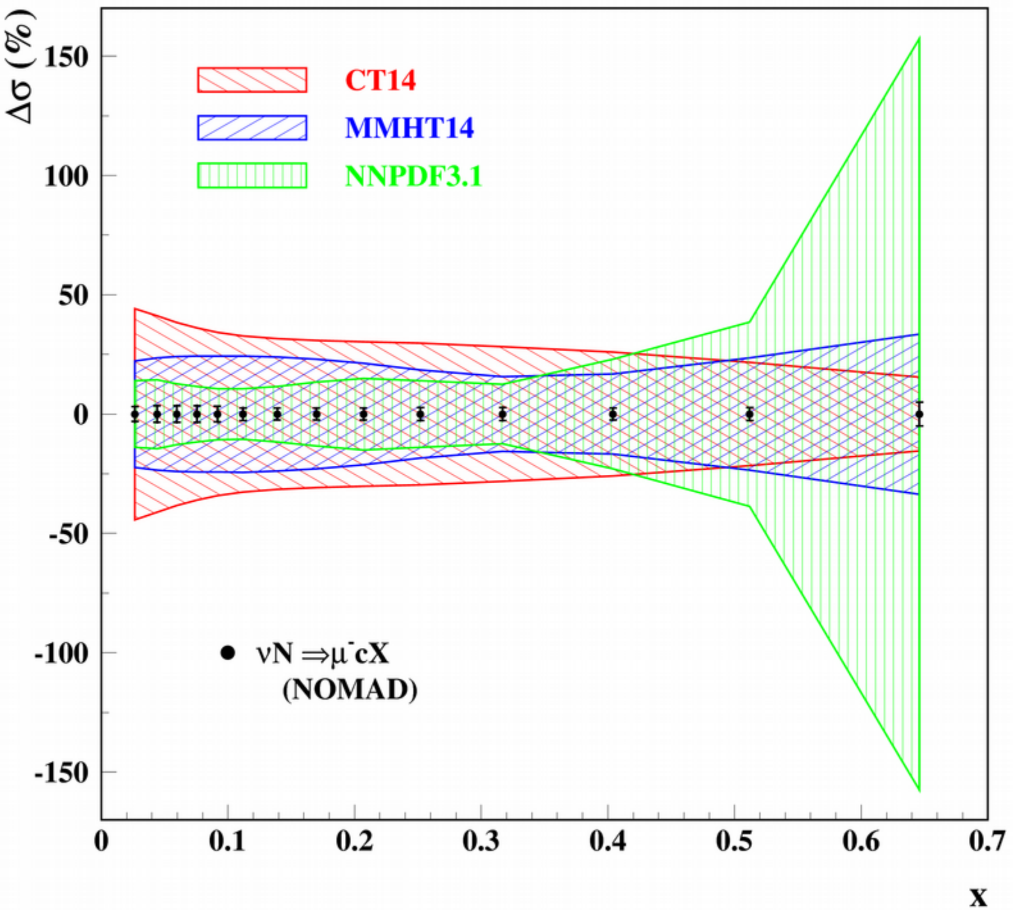
LHC data on central Z-boson production



The CMS data go somewhat lower than the ATLAS ones, however, significance of discrepansy is marginal and further clarification is necessary

Impact of NOMAD data

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

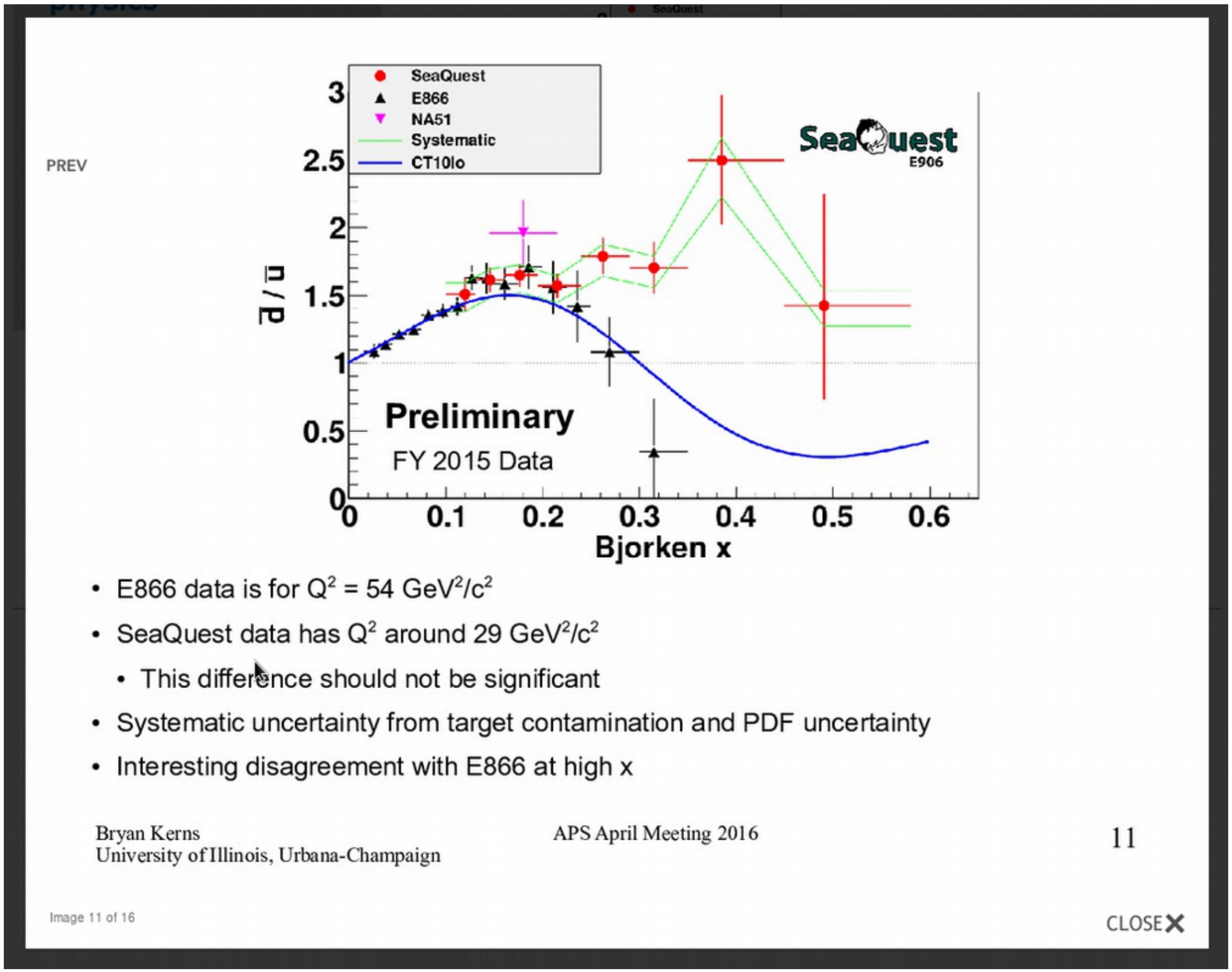


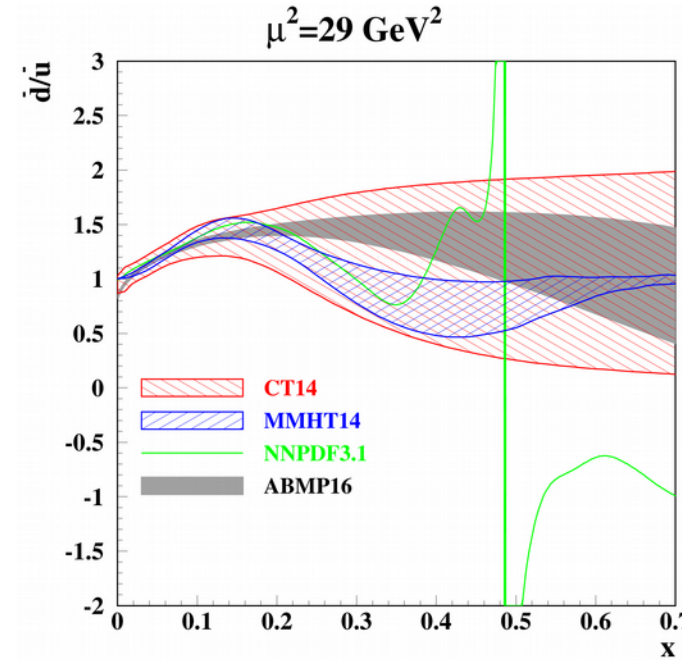
κ_s is integral strange sea suppression factor:

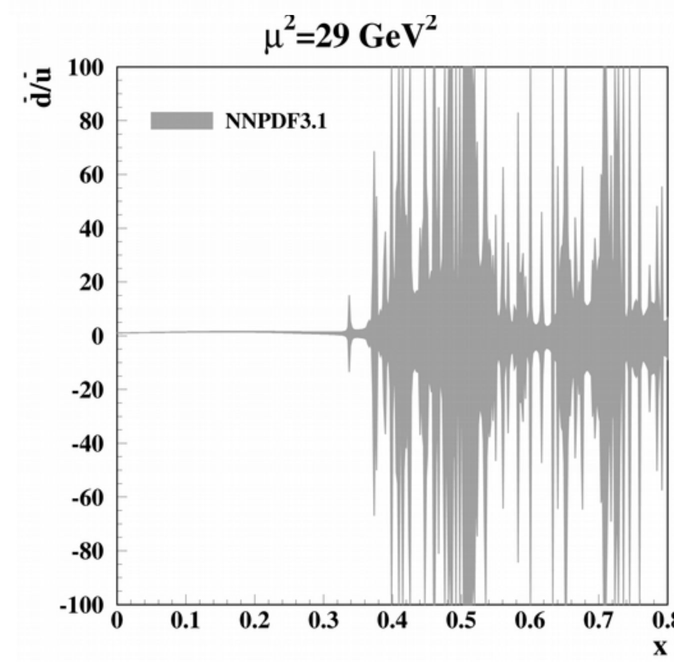
$$\kappa_s(\mu^2) = \frac{\int_0^1 x[s(x,\mu^2)+\bar{s}(x,\mu^2)]dx}{\int_0^1 x[\bar{u}(x,\mu^2)+\bar{d}(x,\mu^2)]dx},$$

- Evident room for the PDF improvement by adding NOMAD data to various PDF fits
- Big spread in the predictions ⇒ PDF4LHC averaging provides inefficient estimate

SeaQuest (FNAL-E906) prospects







- E906 confirms the E866 results at x ~0.1 and continues the positive trend in the sea iso-spin asymmetry at bigger x
- The existing PDF sets can be consolidated with the E906 data

Summary

- The epWZ16 PDF shape used in the ATLAS analysis of the strange sea is not flexible enough:
  - at small x it reproduces a tune used in the HERAPDF fit, which suppress (dbar-ubar) asymmetry
  - for the fit with ATLAS data included this leads to enhancement of strange sea
- In the fit with more flexible ABMP16 shape
  - the strange sea is poorly constrained by the ATLAS data due to bad disentangling quark species
  - the E866 data can be well accommodated into the fit; with these data included the strange sea determination is improved and the result is consistent with the dimuon data by NOMAD and NuTeV/CCFR, however, still much less accurate:
- Some strange sea enhancement at $x \sim 0.01$ is preferred by ATLAS data, to be checked with CMS

EXTRAS

Collider W&Z data used in the fit

Experiment		ATLAS		CMS		DØ		LHCb		
$\sqrt{s}$ (TeV)		7	13	7	8	1.96		7	8	
Final states		$W^+ \to l^+\nu$ $W^- \to l^-\nu$ $Z \to l^+l^-$	$W^+ \to l^+\nu$ $W^- \to l^-\nu$ $Z \to l^+l^-$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ (asym)	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ (asym)	$W^+ \to e^+\nu$ $W^- \to e^-\nu$ (asym)	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ $Z \to \mu^+\mu^-$	$Z \to e^+e^-$	$W^+ \to \mu^+\nu$ $W^- \to \mu^-\nu$ $Z \to \mu^+\mu^-$
Cut on the lepton P_T		$P_T^l > 20$ GeV	$P_T^e > 25$ 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	$P_T^\mu > 20$ GeV
Luminosity (1/fb)		0.035	0.081	4.7	18.8	7.3	9.7	1	2	2.9
Reference		[66]	[26]	[24]	[25]	[23]	[22]	[19]	[21]	[20]
NDP		30	6	11	22	10	13	31	17	32
χ^2	present analysis [a]	31.0	9.2	22.4	16.5	17.6	19.0	45.1	21.7	40.0
	CJ15 [6]	–	–	–	–	20	29	–	–	–
	CT14 [7]	42	–	– [b]	–	–	34.7	–	–	–
	JR14 [8]	–	–	–	–	–	–	–	–	–
	HERAFitter [197]	–	–	–	–	13	19	–	–	–
	MMHT14 [9]	39	–	–	–	21	–	–	–	–
	NNPDF3.0 [10]	35.4	–	18.9	–	–	–	–	–	–

[a] The ABM12 [1] analysis has used older data sets from CMS and LHCb.
[b] For the statistically less significant data with the cut of $P_T^\mu > 35$ GeV the value of $\chi^2 = 12.1$ was obtained.

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

Thorne, QCD@LHC2016

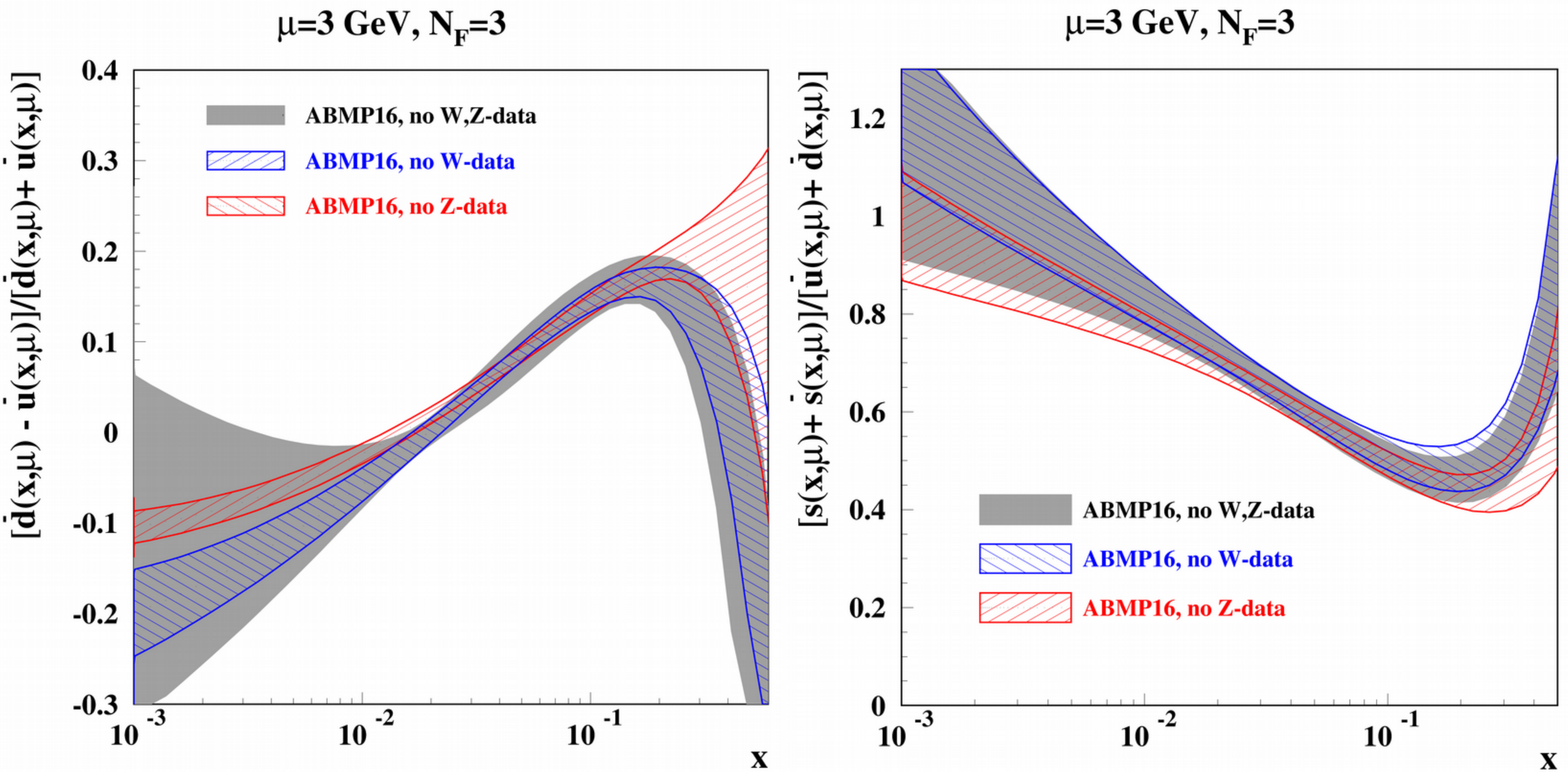
	no. points	NLO χ^2_{pred}	NLO χ^2_{new}	NNLO χ^2_{pred}	NNLO χ^2_{new}
$\sigma_{t\bar{t}}$ Tevatron +CMS+ATLAS	18	19.6	20.5	14.7	15.5
LHCb 7 TeV $W+Z$	33	50.1	45.4	37.1	36.7
LHCb 8 TeV $W+Z$	34	77.0	58.9	76.1	67.2
LHCb 8TeV e	17	37.4	33.4	30.0	27.8
CMS 8 TeV W	22	32.6	18.6	57.6	29.4
CMS 7 TeV $W+c$	10	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

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

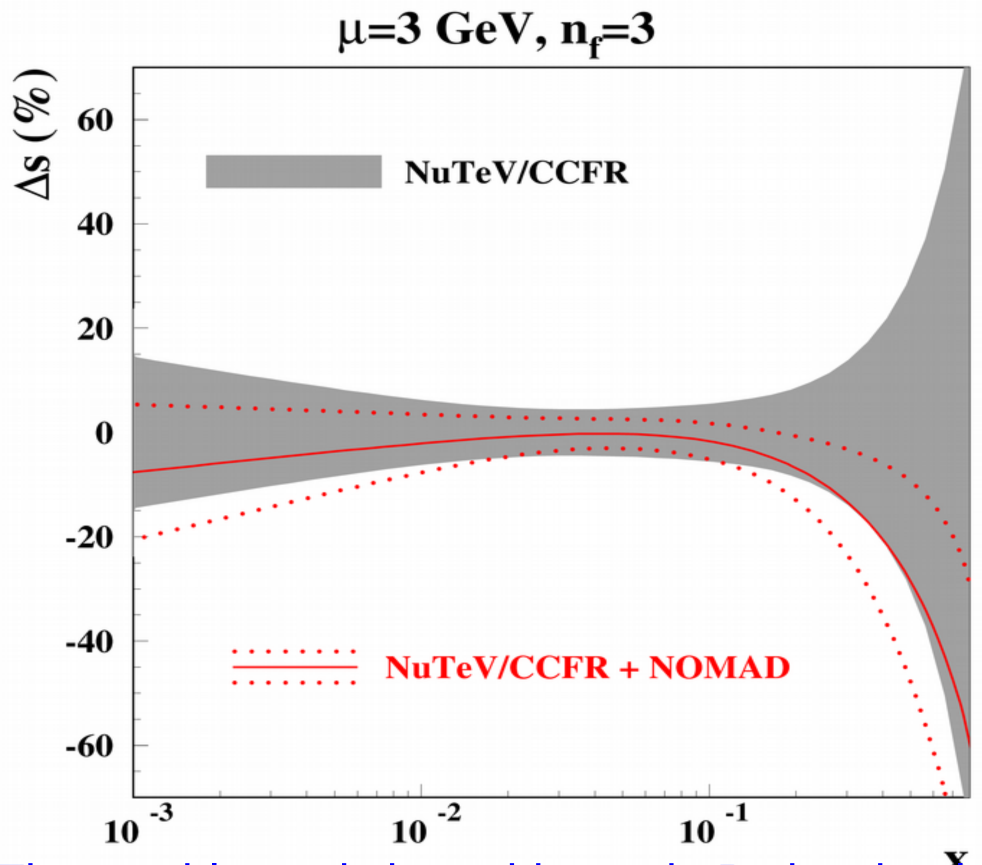
184/119 (MMHT16)
171/119 (ABMP16, no filtering)

account of other DY data increases the difference

Impact of the W-, Z-data



NOMAD charm data



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

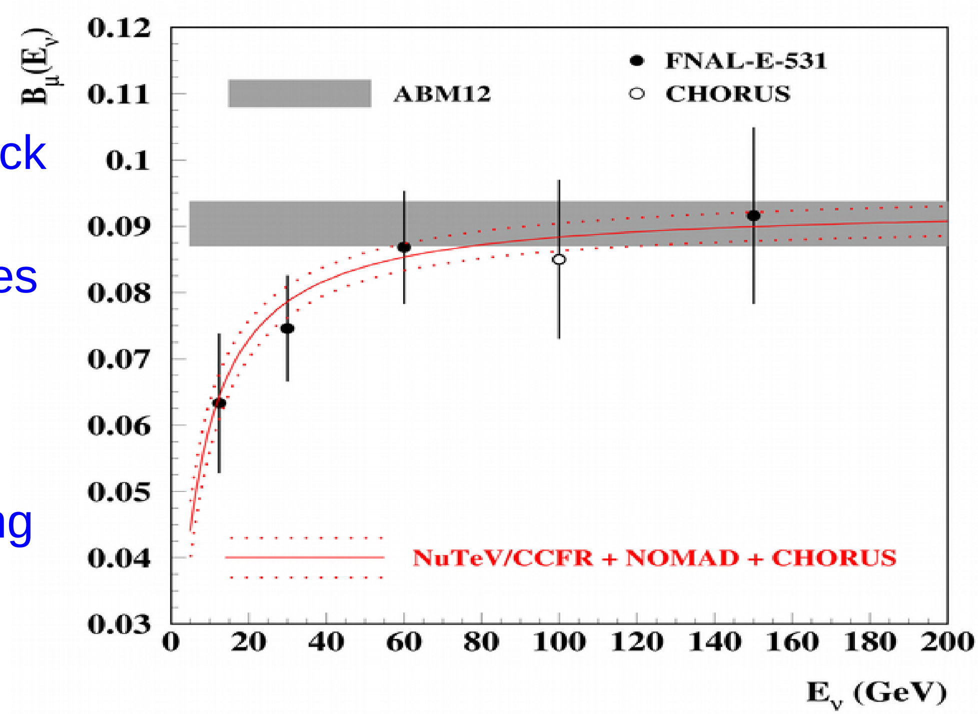
– $m_c(m_c)$=1.23±0.03(exp.) GeV is comparable to the ABM12 value

The semi-leptonic branching ratio B_μ is a bottleneck

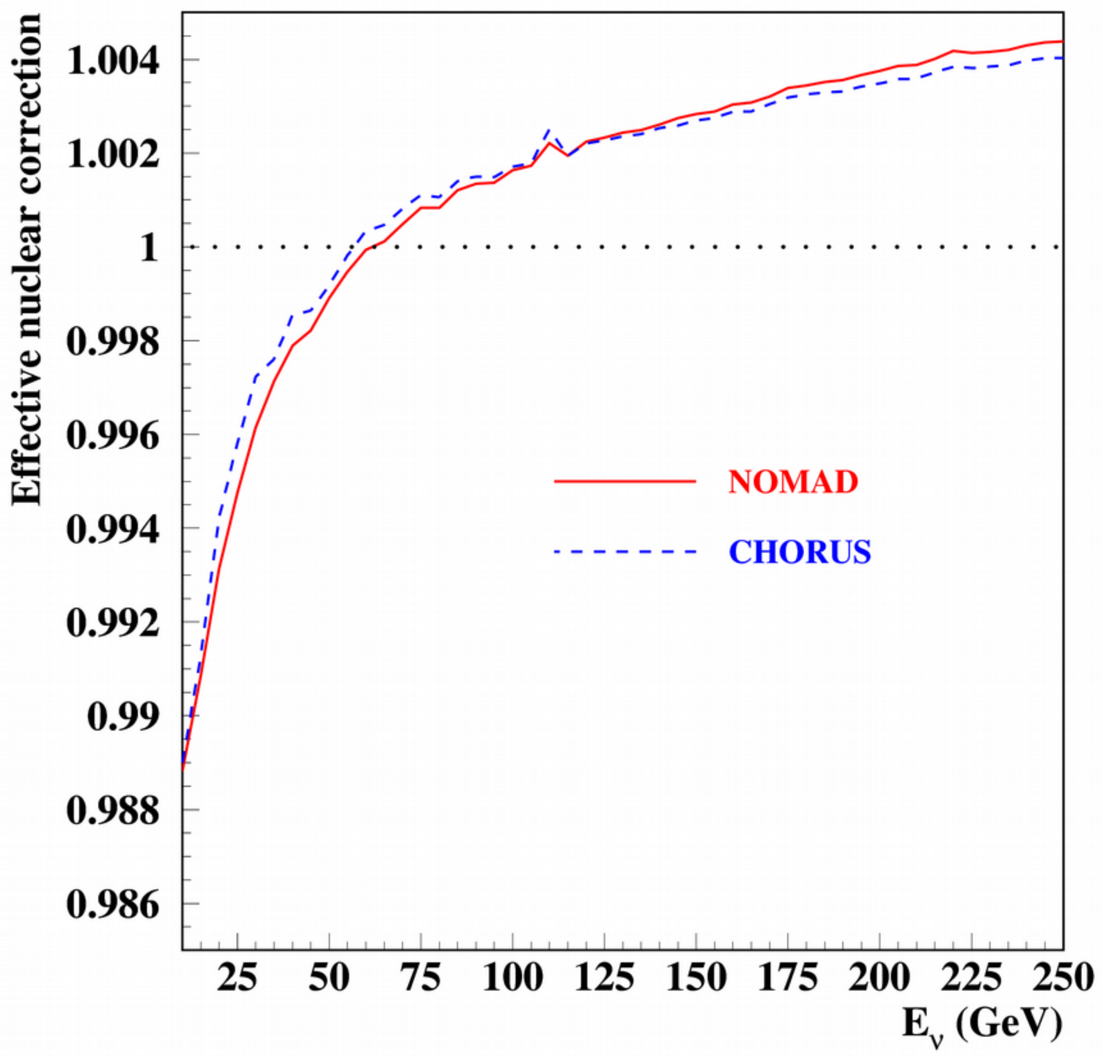
– weighted average of the charmed-hadron rates

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

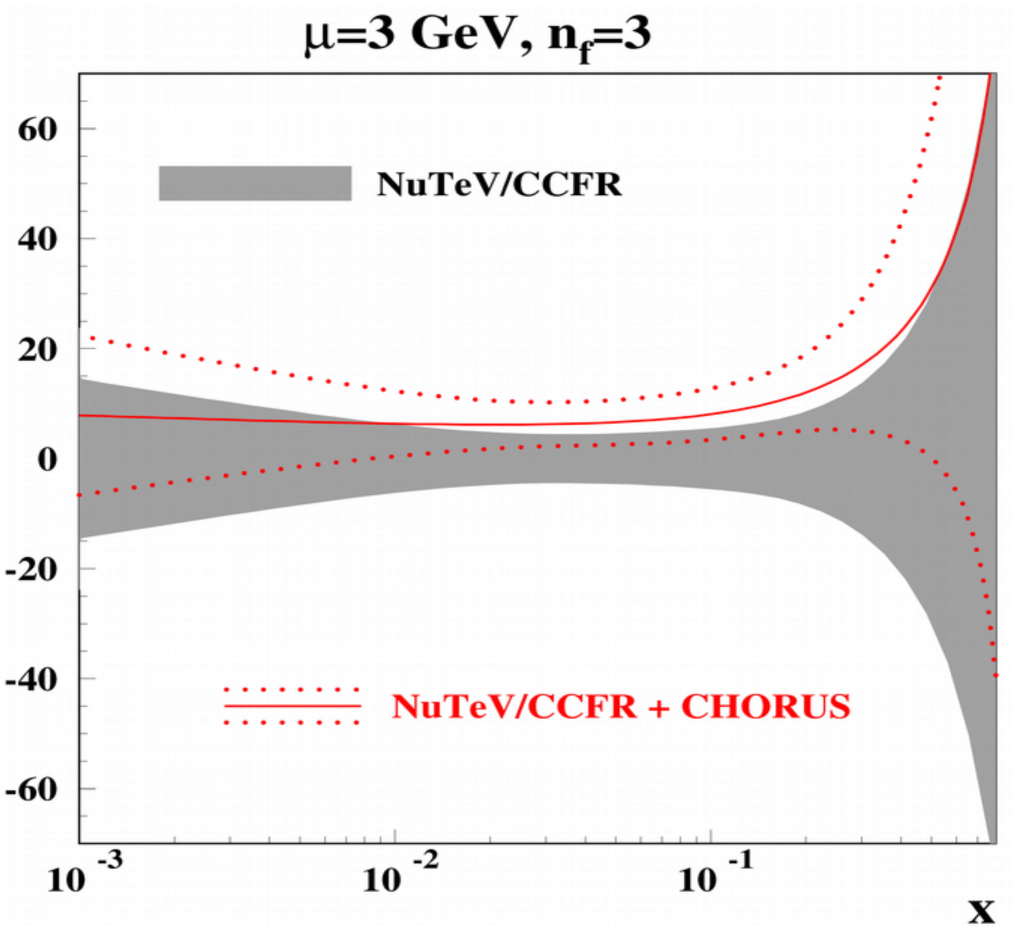
– fitted simultaneously with the PDFs, etc. using the constraint from the emulsion data



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


Effective nuclear correction
1.004
1.002
1
0.998
0.996
0.994
0.992
0.99
0.988
0.986
NOMAD
CHORUS
25
50
75
100
125
150
175
200
225
250
E_ν (GeV)

CHORUS charm data



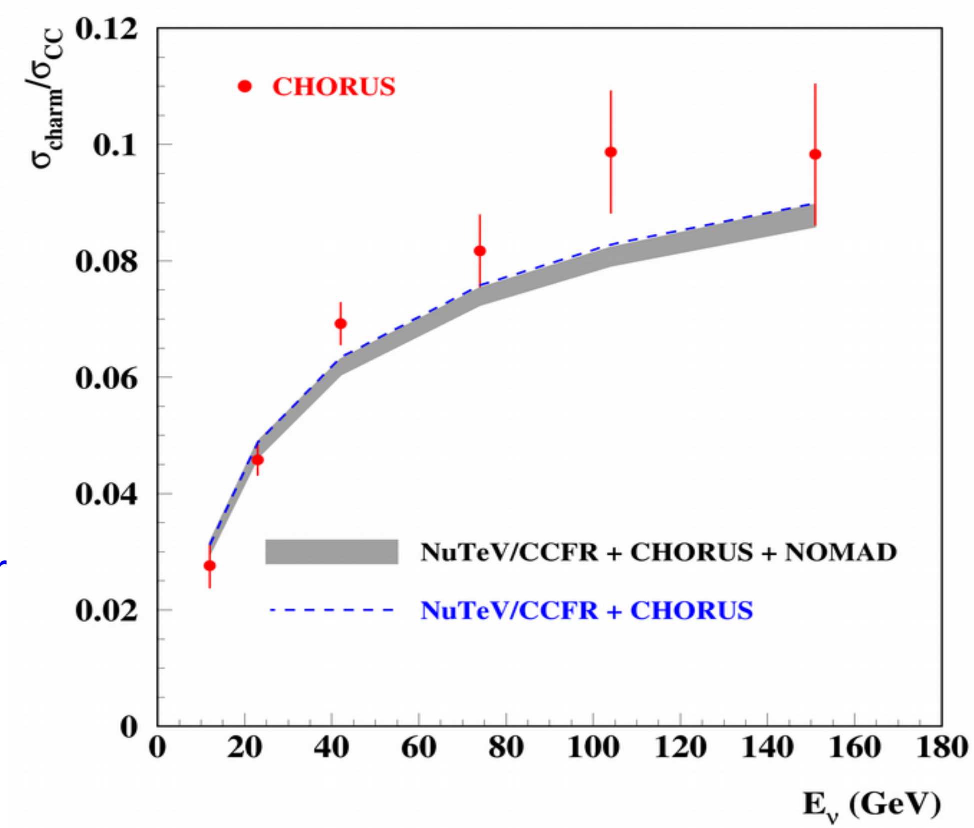
Emulsion data on charm/CC ratio with the charmed hadron vertex measured

CHORUS NJP 13, 093002 (2011)

– full phase space measurements

– no sensitivity to B_μ

– low statistics (2013 events)

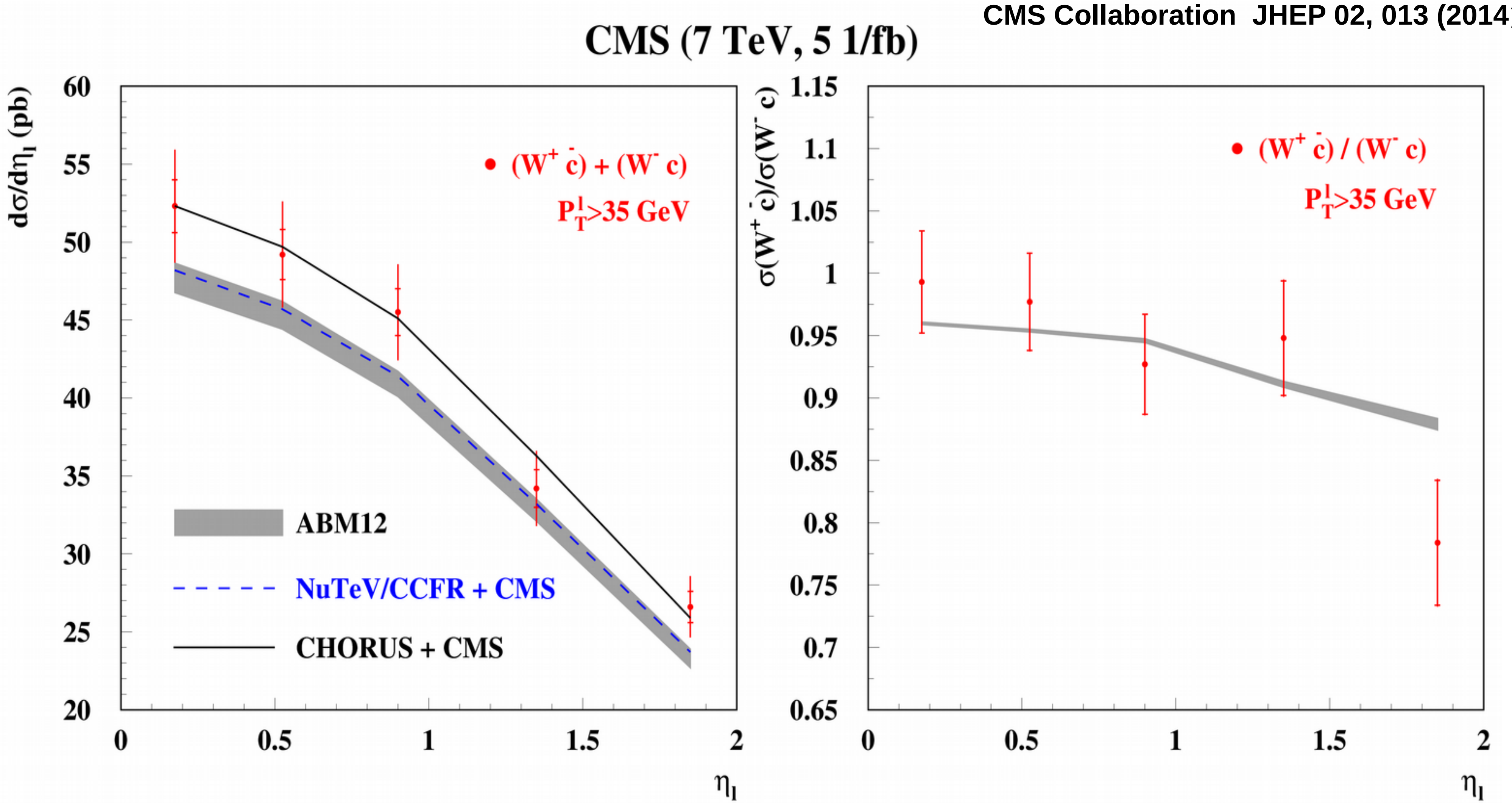


CHORUS data pull strangeness up, however the statistical significance of the effect is poor

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

CMS W+charm data

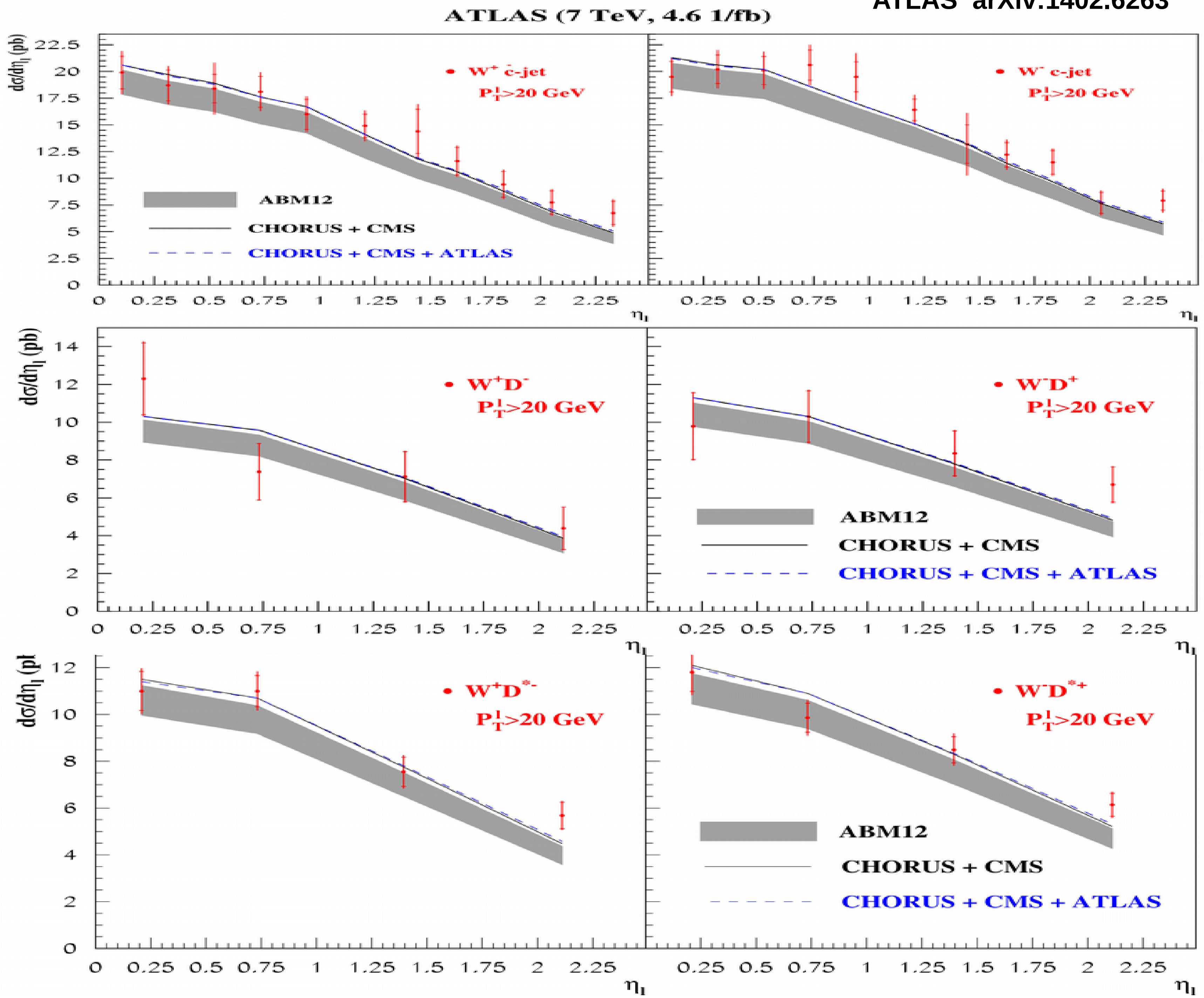
CMS Collaboration JHEP 02, 013 (2014)

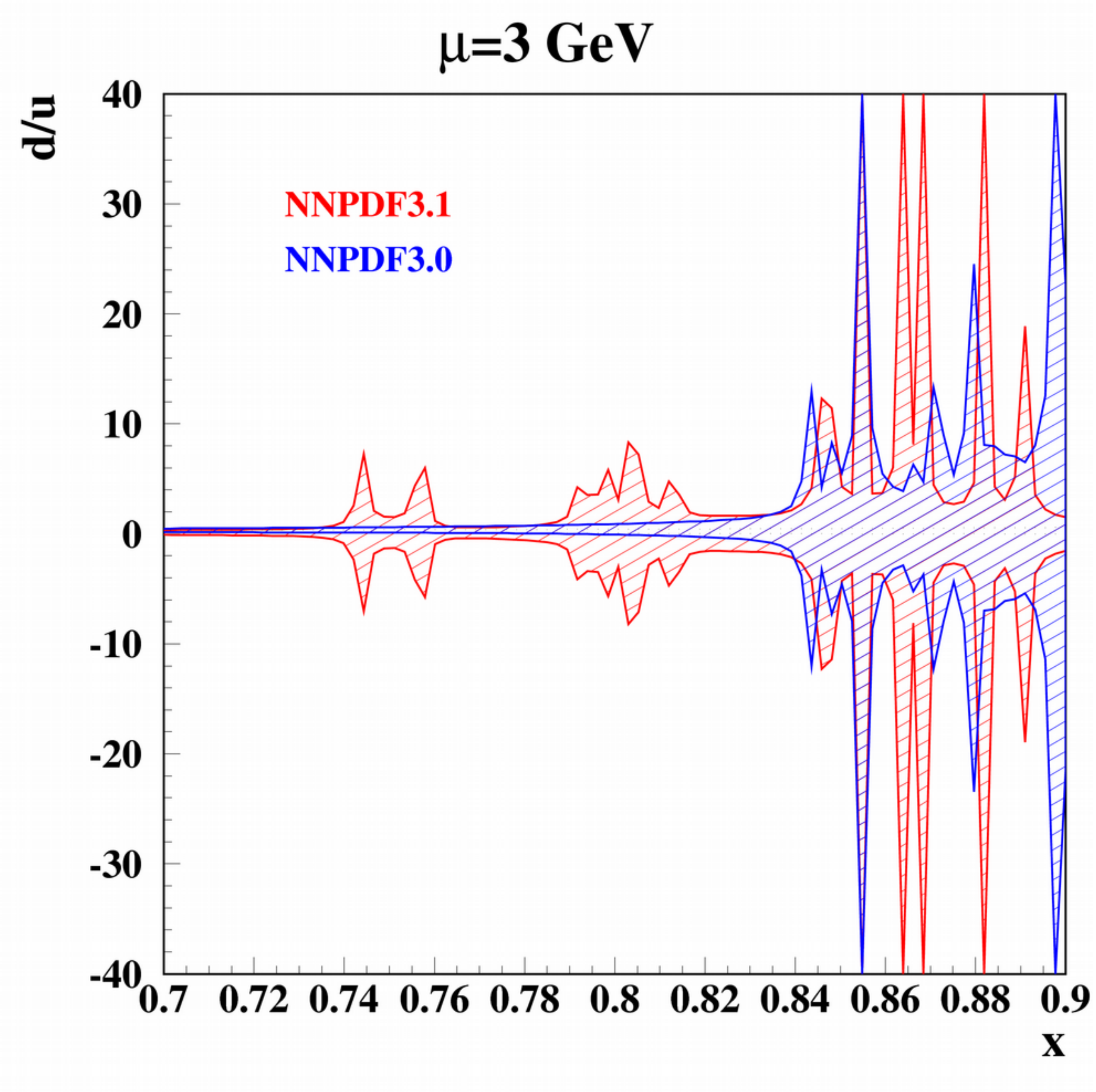


- CMS data go above the NuTeV/CCFR by 1σ; little impact on the strange sea
- The charge asymmetry is in a good agreement with the charge-symmetric strange sea
- Good agreement with the CHORUS data

ATLAS W+charm data

ATLAS arXiv:1402.6263





μ=3 GeV
d/u
NNPDF3.1
NNPDF3.0
40
30
20
10
0
-10
-20
-30
-40
0.7
0.72
0.74
0.76
0.78
0.8
0.82
0.84
0.86
0.88
0.9
x