



Impacts of the LHC Drell-Yan data in the CTEQ-TEA global analysis

Keping Xie

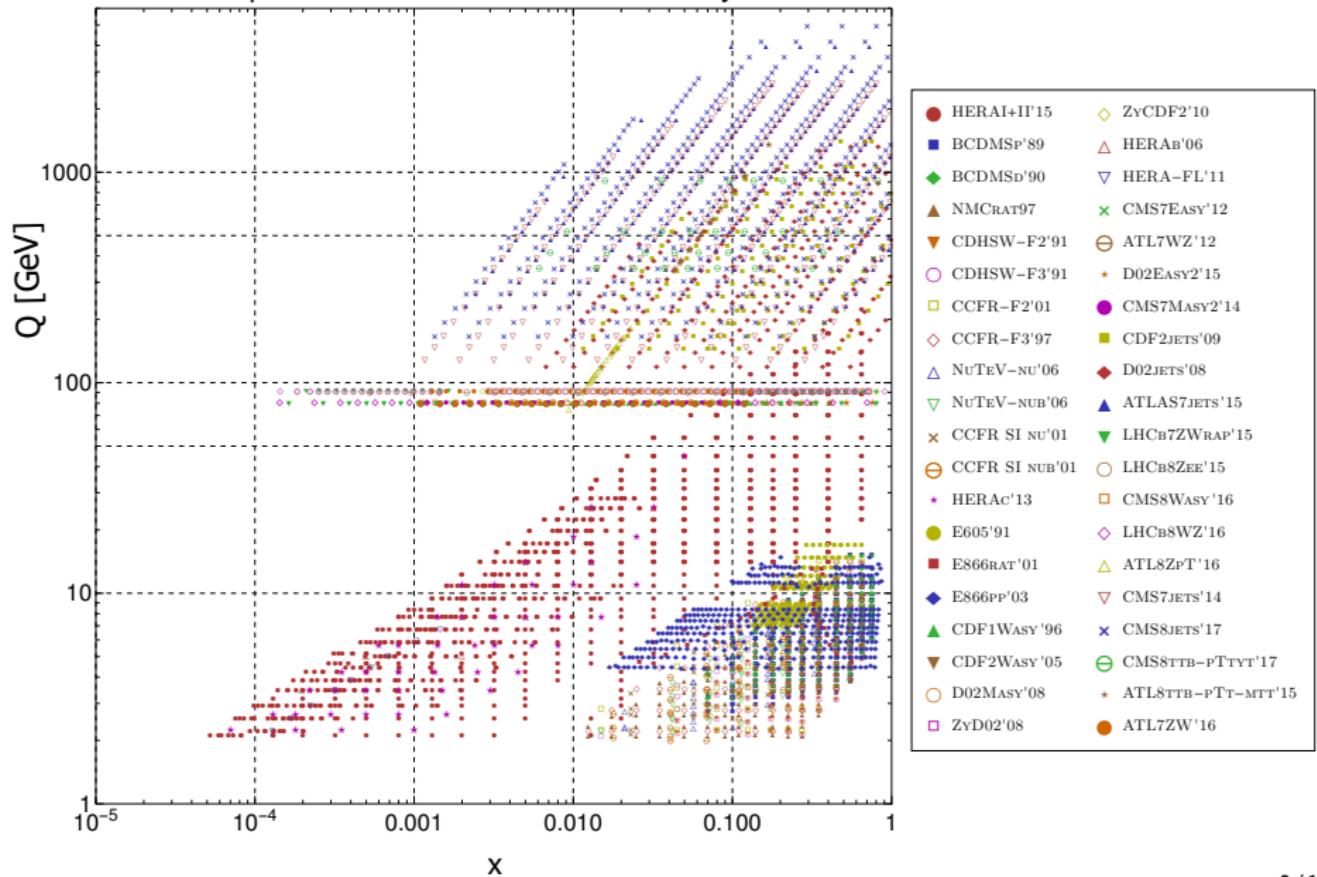
PITT PACC, University of Pittsburgh

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In collaboration with
A Ablat, S. Dulat, I. Sitiwaldi (XJU), T.-J. Hou, C.-P. Yuan (MSU)

Global data included in the CT18 global analysis

Experimental data in CT18 PDF analysis



CT18 family: CT18(A/X/Z)

Dealing with small- x effect in DIS.

- NNPDF/xFitter: BFKL to resum the small- x log's [1710.05935, 1802.00064]
- CT: x -dependent scale, motivated by saturation effect [Golec-Biernat & Wusthoff, PRD1998]

$$\mu_{\text{DIS},x}^2 = a_1(Q^2 + a_2/x^{a_3})$$

Dealing with ATLAS 7 TeV W, Z (ATL7WZ) precision data

- CT18/CT18X do not include ATL7WZ data
- CT18A/CT18Z include ATL7WZ.

Ensemble [1912.10053]	DIS factorization scale	ATL7WZ data included ?	CDHSW $F_2^{p,d}$ data included?	Pole mass [GeV] charm
CT18	Q^2	No	Yes	1.3
CT18A	Q^2	Yes	Yes	1.3
CT18X	$a_1(Q^2 + a_2/x^{a_3})$	No	Yes	1.3
CT18Z	$a_1(Q^2 + a_2/x^{a_3})$	Yes	No	1.4

Drell-Yan data in CT18(A/X/Z)

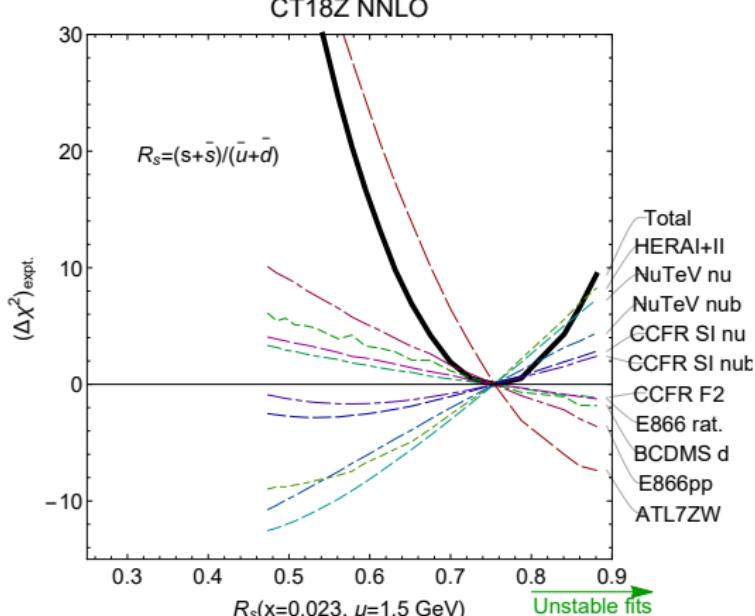
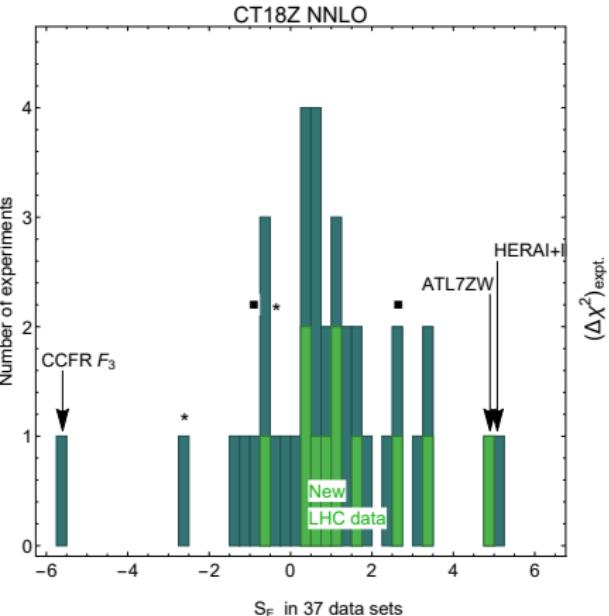
ID	Obs.	Expt.	fast table	NLO code	K-factors	$\mu_{R,F}$
201	$\sqrt{\tau}, y$	E605				
203	σ_{pd}/σ_{pp}	E866		CTEQ	FEWZ	$M_{\ell\ell}$
204	Q, x_F	E866				
225	$A(e)$	CDF1Z				$M_{\ell\ell}$
227	$A(e)$	CDF2W		CTEQ	ResBos	
234	$A(\mu)$	DØ2W				M_W
281	$A(e)$	DØ2W				
260	$y_{\ell\ell}$	DØ2		CTEQ	VRAP	$M_{\ell\ell}$
261	$y_{\ell\ell}$	CDF2				
266	$A(\mu)$	CMS7W				M_W
267	$A(e)$	CMS7W		CTEQ	ResBos	
268	$y_{\ell\ell}, \eta_\ell$	ATL7ZW ₍₂₀₁₂₎				$M_{\ell\ell,W}$
245	$y_{\mu\mu}, \eta_\mu$	LHCb7ZW				
246	y_{ee}	LHCb8Z				
250	$y_{\mu\mu}, \eta_\mu$	LHCb8ZW	APPLgrid	MCFM/aMCfast	MCFM/FEWZ	$M_{\ell\ell,W}$
249	$A(\mu)$	CMS8W				
253	$p_T^{\ell\ell}$	ATL8Z	APPLgrid	MCFM	NNLOJet	$M_T^{\ell\ell}$
248 [†]	$y_{\ell\ell}, \eta_\ell$	ATL7ZW ₍₂₀₁₆₎	APPLgrid	MCFM/aMCfast	MCFM/FEWZ	$M_{\ell\ell,W}$

[†]248 ATL7WZ precision data are included in CT18A/Z.

Fitting quality in CT18(Z)

ID	Expt.	N_{pt}	χ^2	χ^2/N_{pt}	S_E
CT14HERA2 data					
201	E605DY	119	103.4(102.4)	0.9(0.9)	-1.0(-1.1)
203	E866 $\sigma_{pd}/(2\sigma_{pp})$	15	16.1(17.9)	1.1(1.2)	0.3(0.6)
204	E866 $Q^3 d^2 \sigma_{pp}/(dQ dx_F)$	184	244(240)	1.3(1.3)	2.9(2.7)
225	CDF1Z $A(e)$	11	9.0(9.3)	0.8(0.8)	-0.3(-0.2)
227	CDF2W $A(e)$	11	13.5(13.4)	1.2(1.2)	0.6(0.6)
234	DØ2W $A(\mu)$	9	9.1(9.0)	1.0(1.0)	0.2(0.1)
260	DØ2Z $y_{\ell\ell}$	28	16.9(18.7)	0.6(0.7)	-1.7(-1.3)
261	CDF2Z $y_{\ell\ell}$	29	48.7(61.1)	1.7(2.1)	2.2(3.3)
266	CMS7W $A(\mu)$	11	7.9(12.2)	0.7(1.1)	-0.6(0.4)
267	CSM7W $A(e)$	11	4.6(5.5)	0.4(0.5)	-1.6(-1.3)
268	ATL7WZ ₍₂₀₁₂₎	41	44.4(50.6)	1.1(1.2)	0.4(1.1)
281	DØ2W $A(e)$	13	22.8(20.5)	1.8(1.6)	1.7(1.4)
New LHC data					
245	LHCb7WZ(μ)	33	53.8(39.9)	1.6(1.2)	2.2(0.9)
246	LHCb8Z(e)	17	17.7(18.0)	1.0(1.1)	0.2(0.3)
248	ATL7WZ ₍₂₀₁₆₎	34	287.3(88.7)	8.4(2.6)	13.7(4.8)
249	CMS8W $A(\mu)$	11	11.4(12.1)	1.0(1.1)	0.2(0.4)
250	LHCb8WZ(μ)	34	73.7(59.4)	2.1(1.7)	3.7(2.6)
253	ATL8ZpT	27	30.2(28.3)	1.1(1.0)	0.5(0.3)

Effective Gaussian variable $S_E = \sqrt{2\chi^2} - \sqrt{2N_{\text{pt}} - 1}$



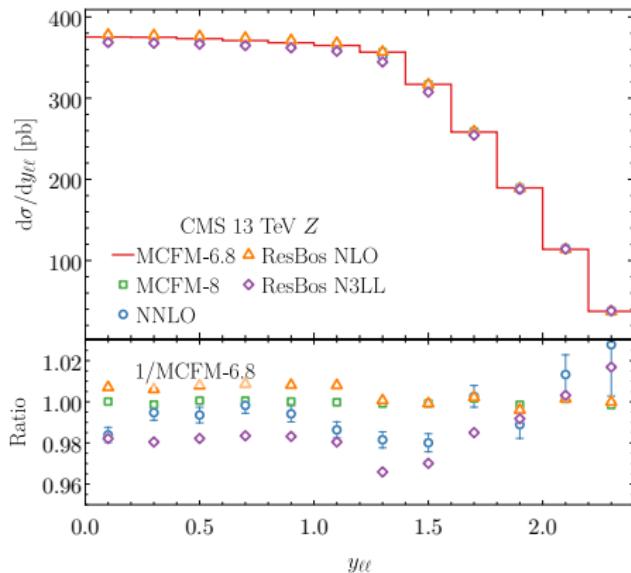
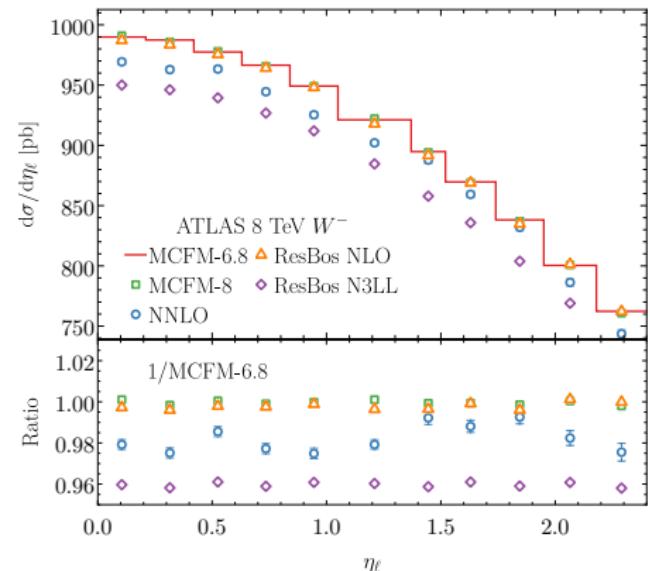
- ATL7ZW can not be fitted well, due to the tension with other data, mostly NuTeV and HERAI+II data.
- ATL7ZW prefer large strangeness.

New Drell-Yan data in consideration

Boson	\sqrt{s}	Lumi	Observable	Ref.
ATLAS				
W, Z	2.76	4.0 pb^{-1}	$\sigma^{\text{fid,tot}}$	1907.03567
W, Z	13	81.0 pb^{-1}	σ^{fid}	1603.09222
W, Z	5.02	25.0 pb^{-1}	$(\eta_\ell, y_{\ell\ell})$	1810.08424
Z	8	20.2 fb^{-1}	$(m_{\ell\ell}, y_{\ell\ell})$	1710.05167
$W \rightarrow \mu\nu$	8	20.2 fb^{-1}	η_μ	1904.05631
Z	13	36.1 fb^{-1}	$p_T^{\ell\ell}$	1912.02844
CMS				
Z	13	2.8 fb^{-1}	$m_{\ell\ell}$	1812.10529
Z	13	35.9 fb^{-1}	(y, p_T, ϕ^*)	1909.04133
W	13	35.9 fb^{-1}	$\sigma^{\text{fid}}, y_W, (\eta_\ell, p_T^\ell)$	2008.04174
LHCb				
$W \rightarrow e\nu$	8	2.0 fb^{-1}	η_e	1608.01484
Z	13	294 pb^{-1}	$\sigma^{\text{fid}}, (y, p_T, \phi^*)$	1607.06495
$Z \rightarrow \mu\mu$	13	5.1 fb^{-1}	$\sigma^{\text{fid}}, (y, p_T, \phi^*)$	2112.07458

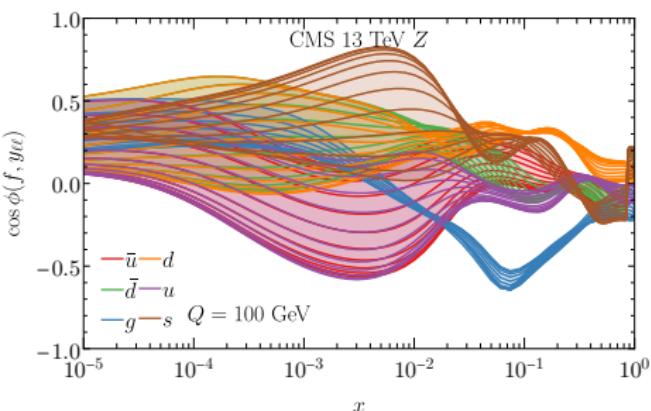
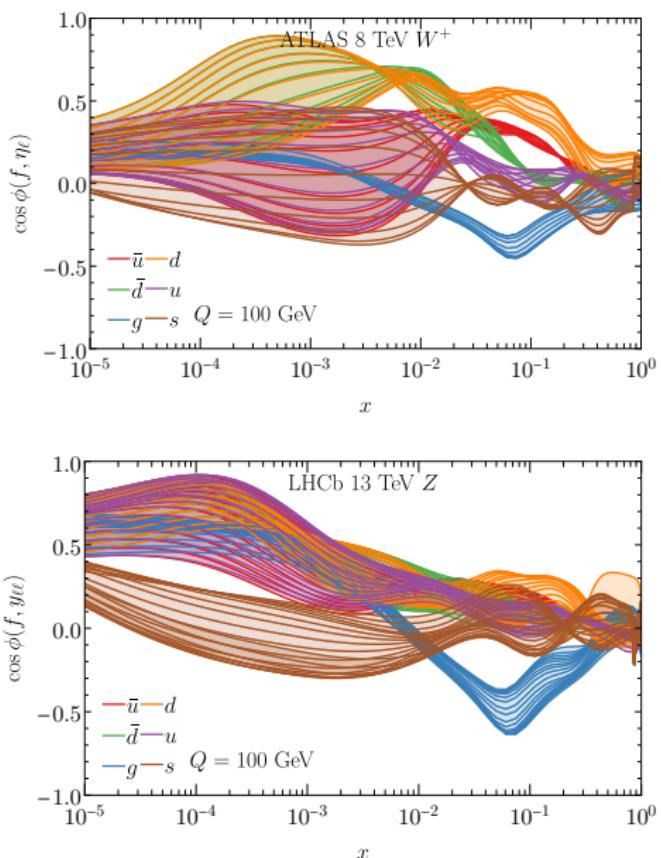
We mainly focus on ATL8WZ, CMS13Z, and LHCb13Z in this talk.

Theoretical calculations



- We have checked that the NLO fixed order calculation agrees well between MCFM and ResBos.
- ResBos (N3LL+NNLO resummation) gives an overall shift as a result of the fiducial effect.
- NNLO fixed-order calculations suffer a little from the Monte-Carlo uncertainty.

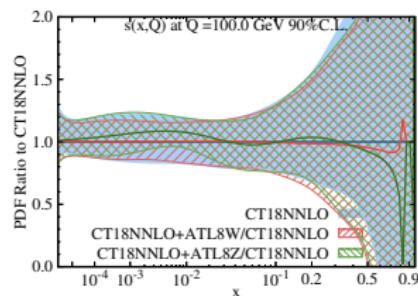
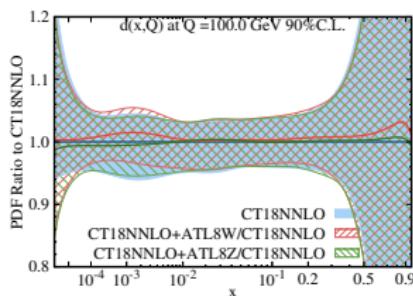
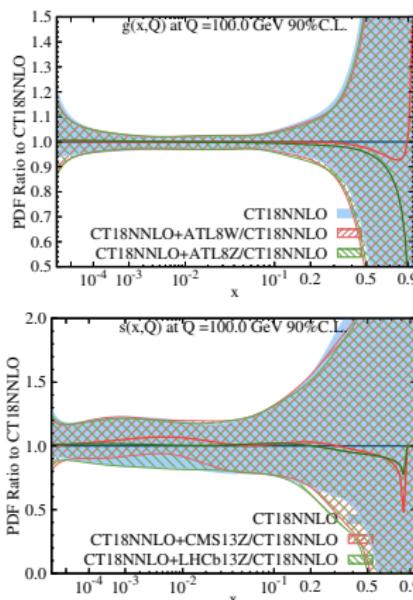
The correlation between data and PDFs



- Large correlations to d -quark and sea PDFs in the range $10^{-4} \lesssim x \lesssim 10^{-2}$.
- LHCb forward data probe much smaller x .
- Z data are sensitive to strangeness PDF.

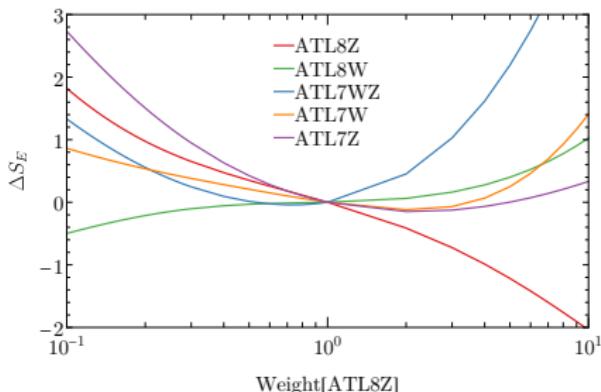
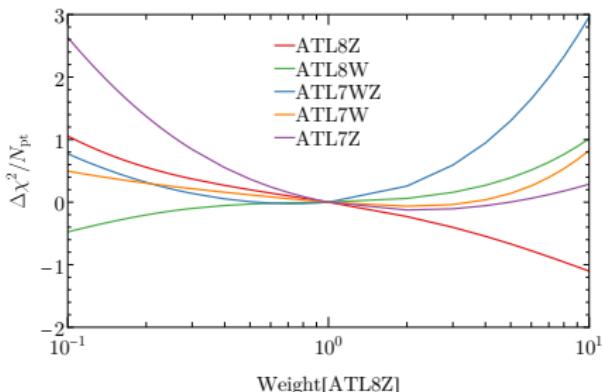
The impact on the CT18 fit (ePump)_(Error PDF updating method package)

Data	N_{pt}	χ^2/N_{pt}	Updated χ^2/N_{pt}	S_E
ATL8W	22	8.84	4.52	7.54
ATL8Z	48	12.3	7.58	17.2
CMS13Z	12	9.23	2.76	3.34
LHCb13Z	18	4.46	3.07	3.67



- The Z data give strong pull of gluon and strange PDFs.
- W data has some impact on the u and d quark PDFs.
- χ^2 's of ATLAS 8 TeV data are big, reflecting tensions.
- Need more flexible parameterizations, which is under investigation.

Consistency between ATLAS 7 and 8 TeV data



- ATLAS 8 TeV $W(Z)$ data are consistent with 7 TeV $W(Z)$ data
- ATLAS 8 TeV Z is in tension with W data.

Summary and prospects

- Drell-Yan data play an essential role in the global fitting.
- In CT18 global analysis, we cannot fit ATLAS 7 TeV WZ data well, due to tensions with other data sets, especially HERA I+II and NuTeV.
- ATLAS 8 TeV $W(Z)$ data are consistent with 7 TeV $W(Z)$ data.
- ATL8W data are in tension with ATL8Z data.
- LHC Z data give strong pull of strangeness.
- Need explore more flexible parameterizations (under investigation).