CT update

J. Huston

MSU

for the CTEQ-TEA (Tung et al)
collaboration

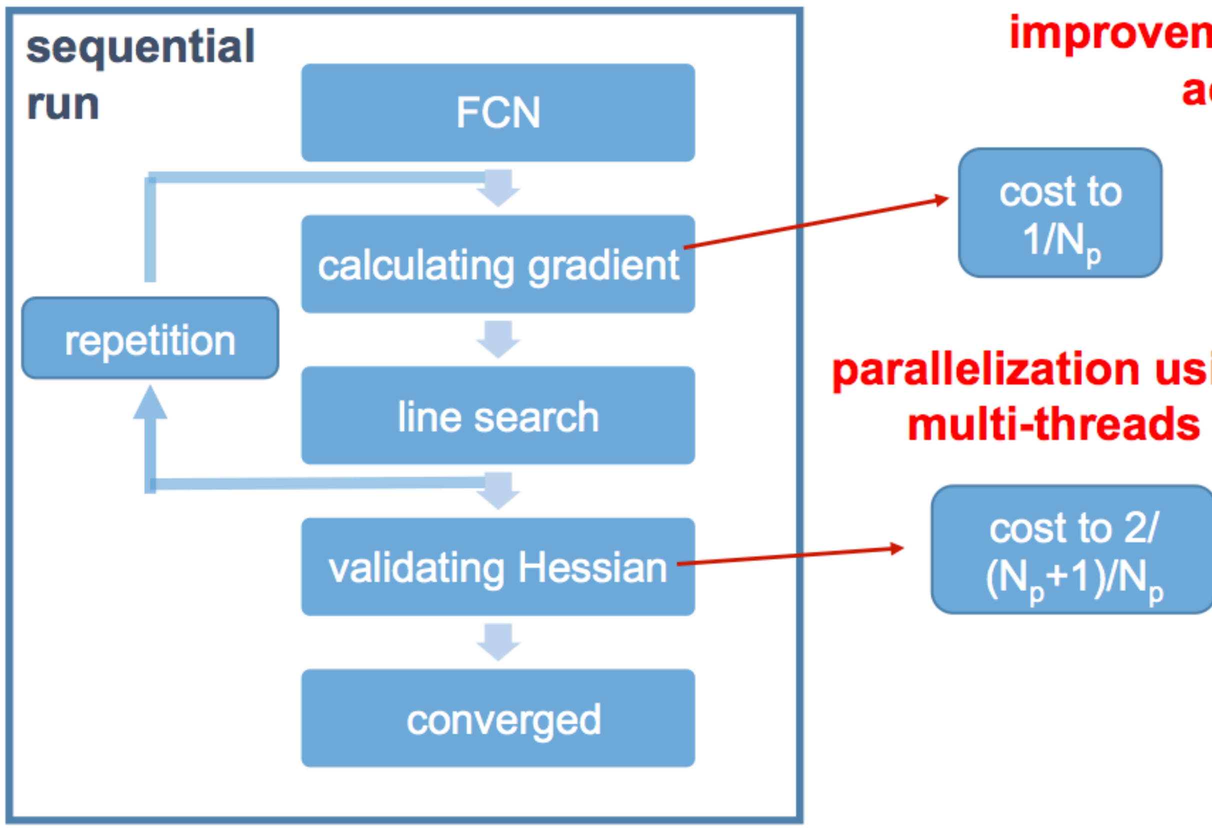
Data sets included in CT17

- Start with CT14-HERAII (HERAII combined data released after publication of CT14)
- Use as much relevant LHC data as possible using applgrid/ fastNLO interfaces to data sets, with NNLO/NLO K-factors, or fastNNLO tables in the case of top pair production
- Implement a parallelization of the global PDF fitting to allow for faster turn-around time
- PDFSense (see Pavel's talk this afternoon) to determine which data will have impact on global PDF fit
- ePump (see Carl Schmidt's talk this afternoon) on exploring the impact of data prior to global fit
  - high impact data directly included in the global PDF fit
  - low impact data included via ePump

Fitting code changes

upgrade to a parallelized version of the fitting code, through rearrangement of the minimization algorithm, rather than a redistribution of the data sets

MINUIT
variable matric method



after all a factor of 4~5 improvement on speed is achieved!

LHC data sets included in CT17

- LHCb Z (W) rapidity (muon rapidity) at 7 (applgrid); 8 TeV Z rapidity (applgrid)
- *LHCb heavy flavor (applgrid) (to be added)*
- ATLAS W/Z lepton(s) rapidity at 7 TeV (applgrid)
- ATLAS 8 TeV DY (applgrid)
- ATLAS 7 TeV Z pT (applgrid)
- ATLAS 8 Z p_T, as a function of mass (applgrid)
- CMS Z p_T,as a function of y, at 8 TeV (applgrid)
- CMS W lepton rapidity (asymmetry) at 8 TeV (applgrid);
- CMS W,Z p_T at 8 TeV (applgrid)
- CMS inclusive jet cross section at 7,8 TeV with R=0.7 (fastNLO)
- ATLAS inclusive jet cross section at 7 TeV with R=0.6 (applgrid)
- ATLAS and CMS 7,8 TeV tT differential distributions (fastNNLO)
  - *including double differential from CMS at 8 TeV (work in progress)*
- ATLAS low mass/high mass Drell-Yan at 7 TeV (applgrid)
- CMS low mass/high mass DY at 8 TeV (applgrid)

There is a lot of new data, but there is also a lot of old data already in the fit, that continues to have an impact, and will tend to dilute the impact of new data.

How sensitive is an experiment to a PDF? Can we know it **before** doing the global fit?

PDFsense predicts that the CMS data will have the largest impact

PDFSense estimates…

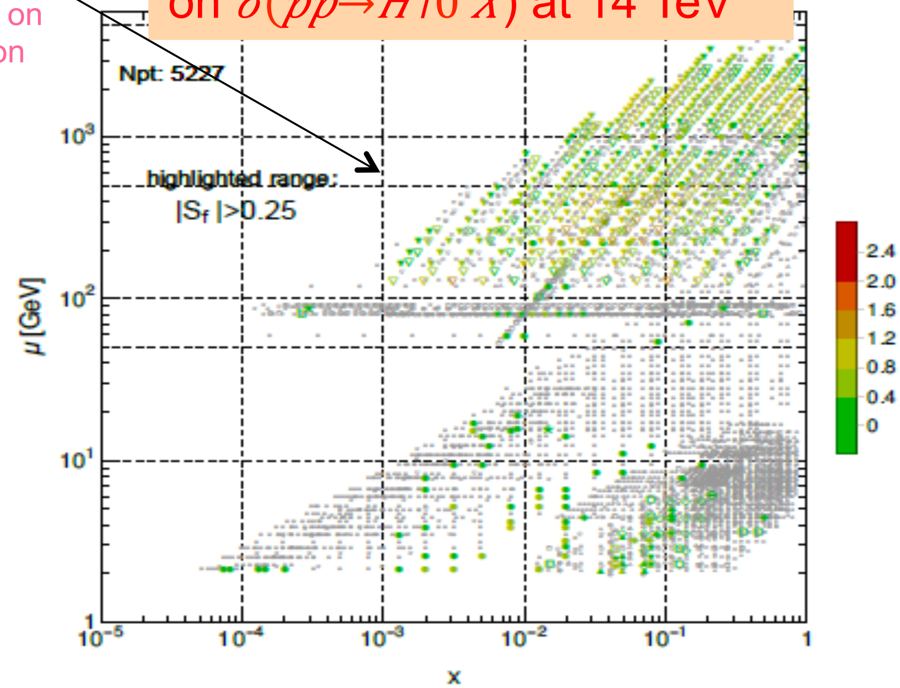
- ranking of strength of sensitivities of experimental data sets to PDF flavors without (re-)doing the full global fit
- impact on global fit requires both correlation and sensitivity

for example, HERAII, CMS jets provide information on gluon and on Higgs σ

No.	Exp. ID	N_{pt}	$\sum_f \lvert S_f\rvert$	$\sum_f \langle\lvert S_f\rvert\rangle/N_f$	$\lvert S_{\bar u}\rvert$	$\langle\lvert S_{\bar u}\rvert\rangle$	$\lvert S_{\bar d}\rvert$	$\langle\lvert S_{\bar d}\rvert\rangle$	$\lvert S_g\rvert$	$\langle\lvert S_g\rvert\rangle$	$\lvert S_u\rvert$	$\langle\lvert S_u\rvert\rangle$	$\lvert S_d\rvert$	$\langle\lvert S_d\rvert\rangle$	$\lvert S_s\rvert$	$\langle\lvert S_s\rvert\rangle$
					Rankings											
1	160	1120.	620.	0.0922	A	3	B		A	3	A	3	B		C	
2	**545**	288	397.	0.234	B	3	B	3	A	1	C		C	3	B	3
3	**542**	280	359.	0.217	B	3	B	3	A	1	C		C		B	3
4	201	238	225.	0.158	B	2	B	2			C	3				
5	111	86	218.	0.423	C	1	C	1		3	B	1	C	2		
6	204	368	206.	0.0942	B	3	C	3	C		C	3				
7	101	337	184.	0.0909	C				C		B	3	C			
8	104	123	169.	0.229			C	2			C	2	B	2		
9	102	250	141.	0.0938			C		C	3	C	3	C	3		
10	109	96	115.	0.199	C	2	C	2		3	C	2	C	3		
11	538	222	109.	0.0834					C	3						
12	110	69	89.3	0.216		3		3	C	2		3		2		3
13	**250**	84	82.9	0.165		3	C	3		3		3	C	2		
14	108	85	82.4	0.161		3		3		3		3	C	3		
15	**544**	236	79.8	0.0573					C	3						
16	268	82	79.3	0.161		3		3				3		3		3
17	**249**	66	78.3	0.198		3		2				3		2		3
18	**252**	94	68.5	0.121		3		3				3				3
19	203	30	66.6	0.37	C	1	C	1				3		2		
20	**245**	66	60.3	0.152		3		3		3		3		3		
21	124	38	58.9	0.258		3		3				3		3	C	1

…kinematical distributions of sensitivities to the PDFs in the $\{x,\mu\}$ plane

Sensitivity to the PDF error on $\sigma(pp\to H^0 X)$ at 14 TeV



2018-03-05

P. Nadolsky, xFitter workshop, Krakow

see for example http://metapdf.hepforge.org/PDFSense

ePump (error PDF updating package)

- ePump (Error PDF Updating Method Package) is a set of classes, functions, etc. for analyzing the impact of new data on the PDF predictions and uncertainties, in the Hessian method.
- It assumes quadratic dependence of the global χ^2 function on the parameters, and linear dependence of the observables on the parameters.
- It allows for the inclusion of a dynamical tolerance in each of the original Hessian eigenvector directions.
- Extensively cross-checked against actual global fitting

It contains two main executables

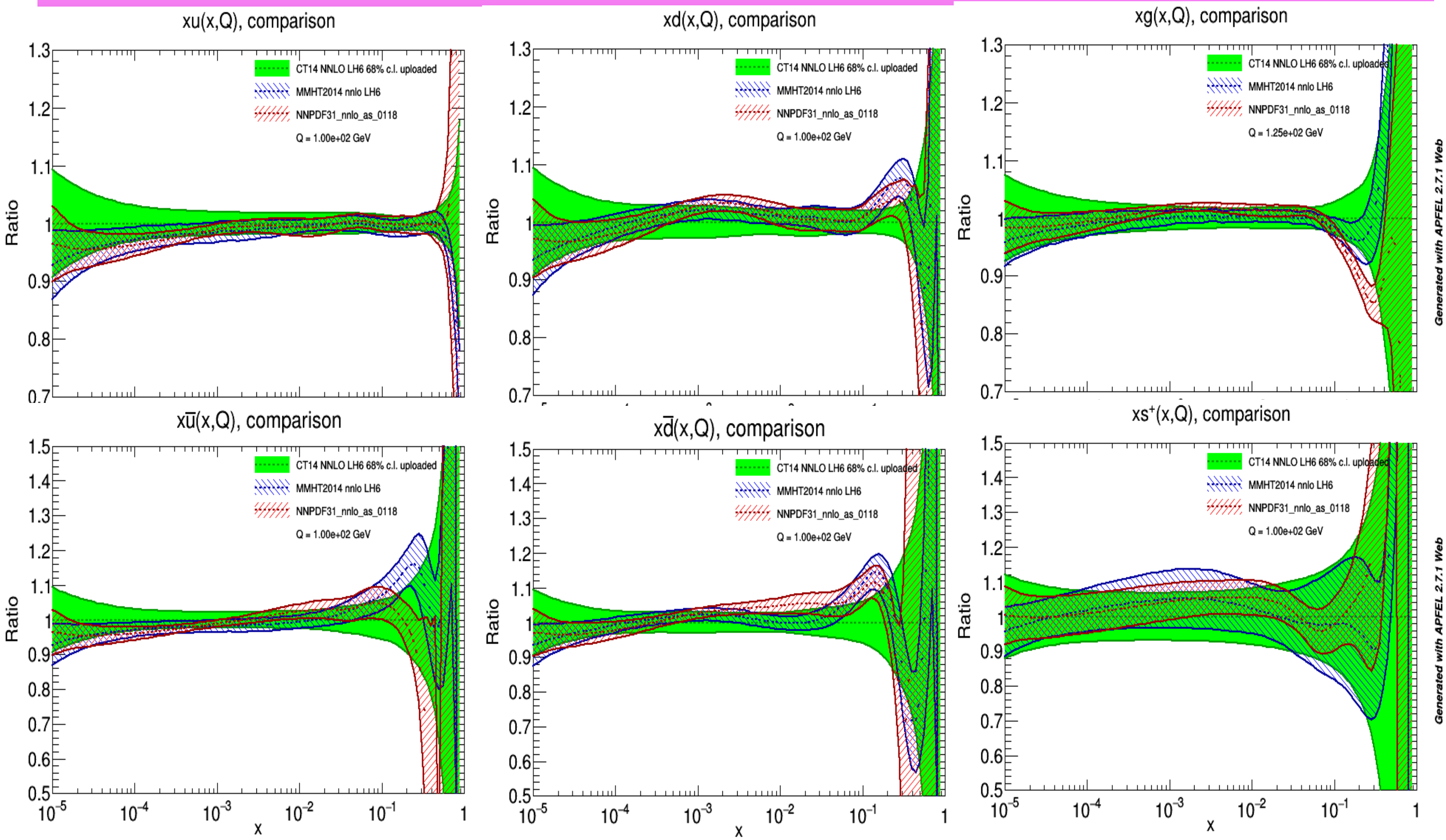
1) UpdatePDFs

- Given the original theory predictions for a set of observables, and the experimental data for some subset of the observables, it computes the updated predictions and uncertainties for all of the observables, incorporating the effects of the new data.
- If the original best-fit and Hessian error PDFs are supplied, it also computes updated best-fit and Hessian error PDFs that incorporate the effects of the new data.

2) OptimizePDFs

- Given the original best-fit and Hessian error PDFs, along with theory predictions for a set of observables, it computes a new set of Hessian error PDFs that are optimized for the particular set of observables.
- The new set of error PDFs produce equivalent results to the original set of error PDFs (at least in the linear/ quadratic approximations assumed in the Hessian method). However, each new Hessian eigenvector PDF has an associated eigenvalue that gives the sum of the relative contributions of that eigenvector direction to the variance of each of the observables in the given set. The eigenvalues can be used to choose a reduced set of Hessian error PDFs by discarding those that are irrelevant to the given set of observables.

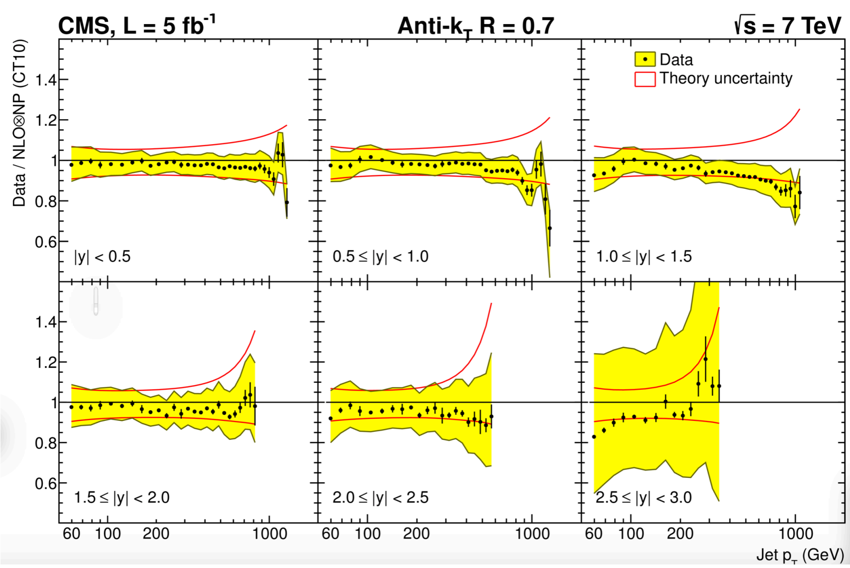
Existing comparisons of 3 PDFs

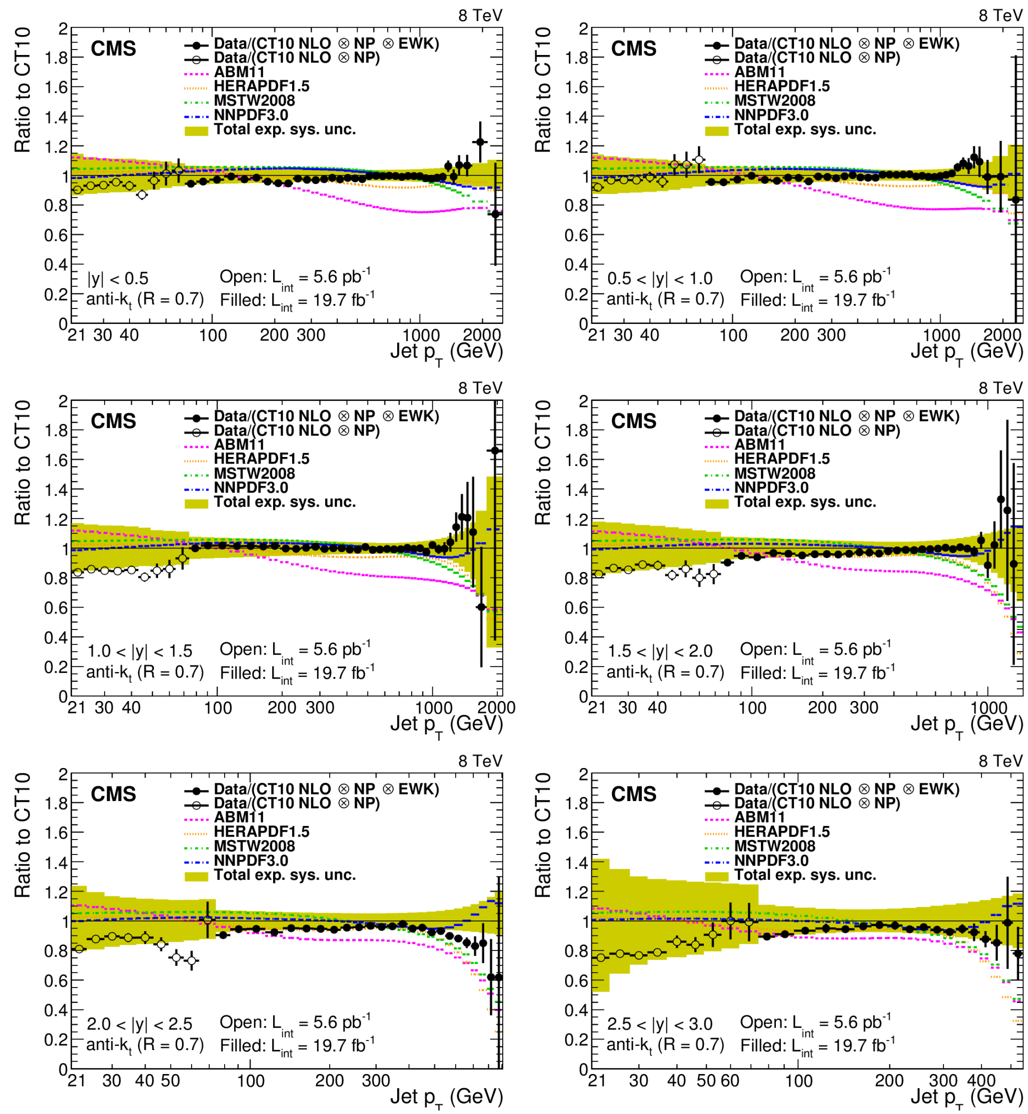


3 PDF groups are compatible; can new generation of PDFs improve precision?
Especially for gluon distribution in Higgs mass range.

CMS jet production

- From PDFSense, expect CMS jet data, both at 7 TeV and 8 TeV to have impact, in fact the highest impact, primarily on gluon distribution, but on other distributions such as strange as well
- They do

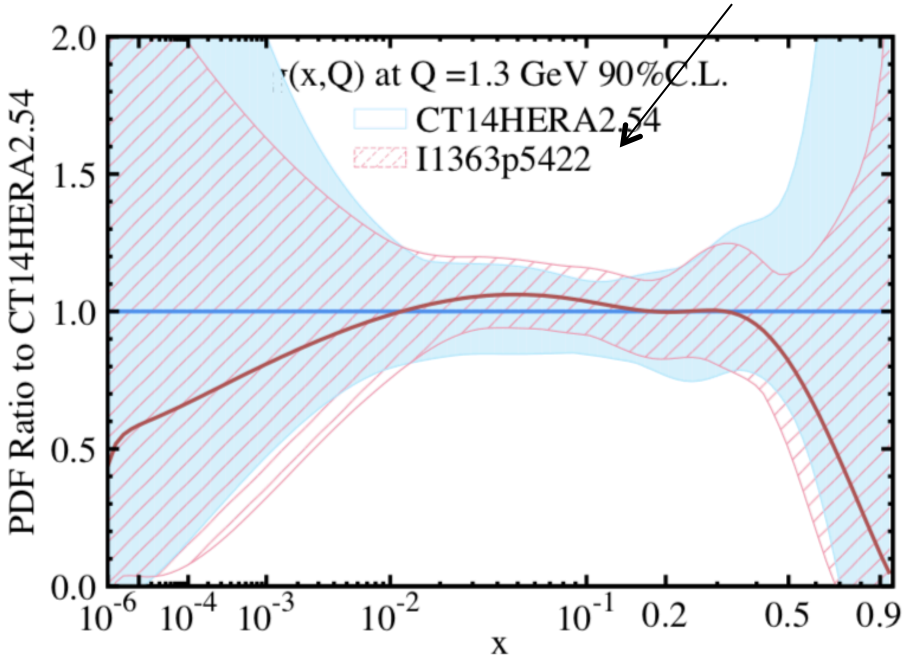


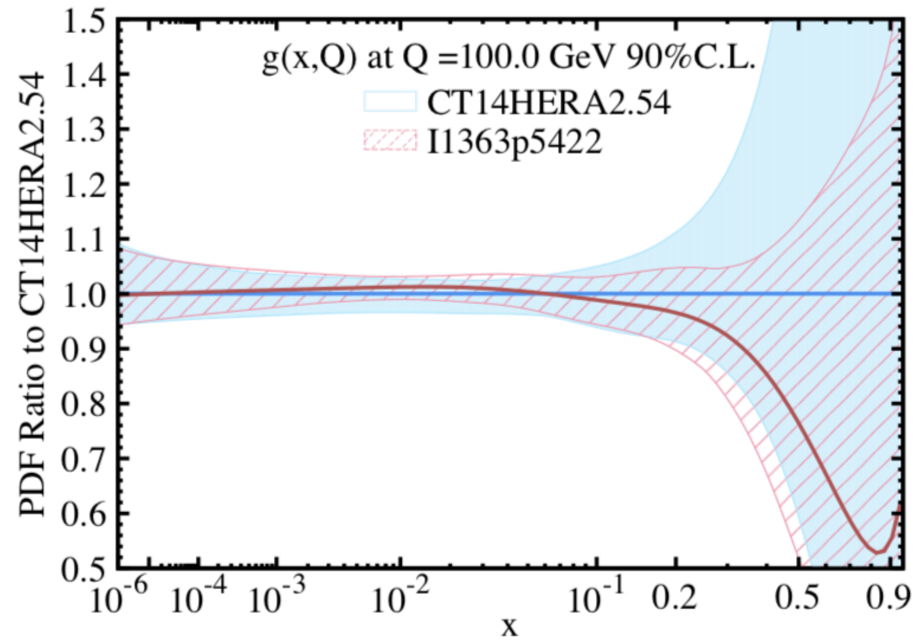


CMS 7 TeV jet data

- Some tension when using all rapidity bins
- Results below using first two y bins
- Still has good constraining power on gluon distribution

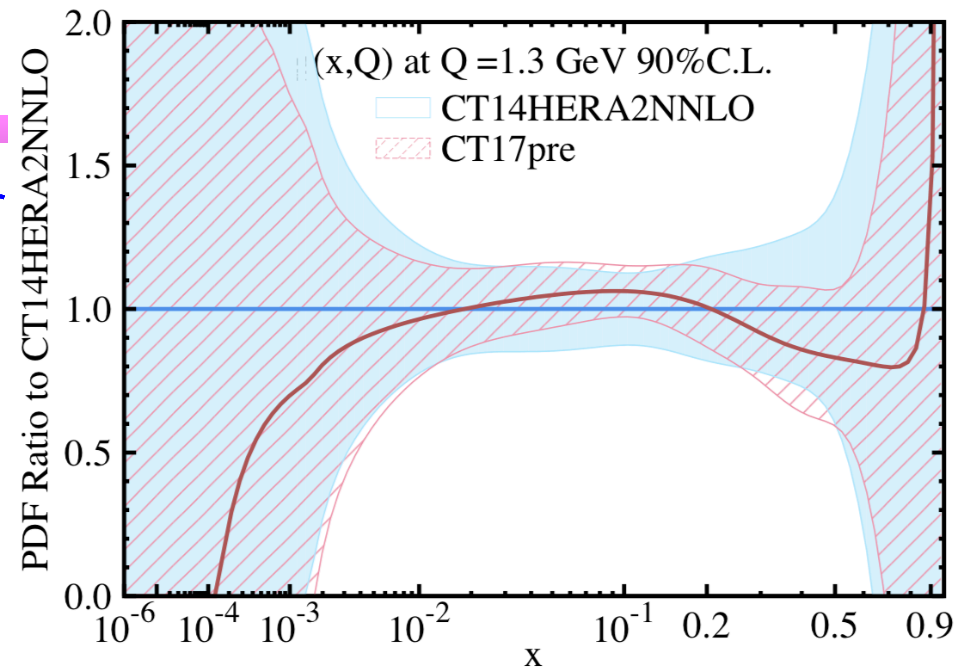
add first two y bins of CMS 7 TeV jet data

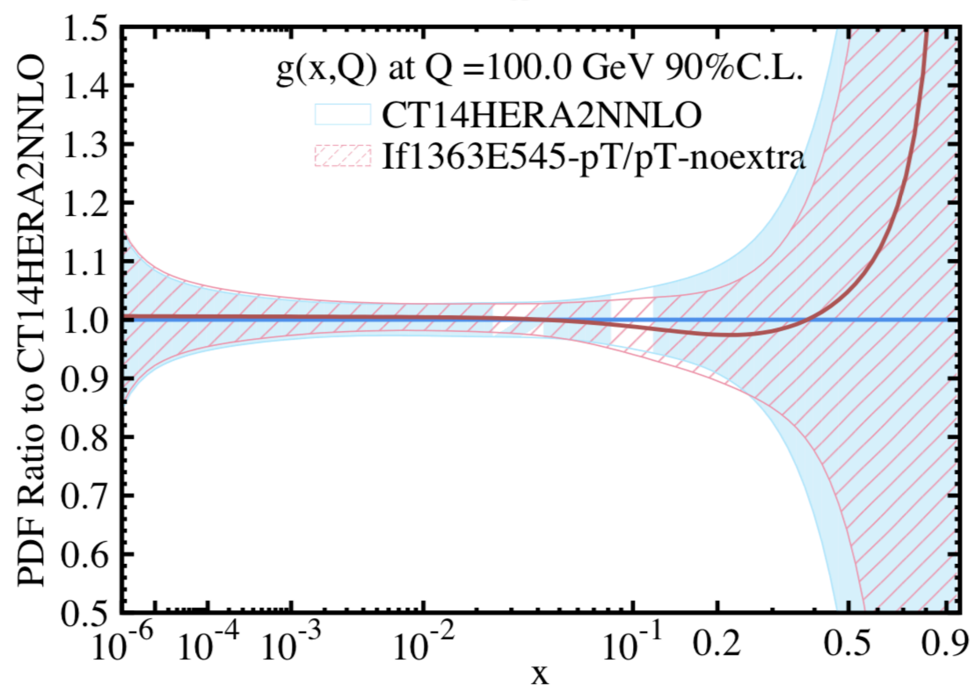




CMS 8 TeV jets

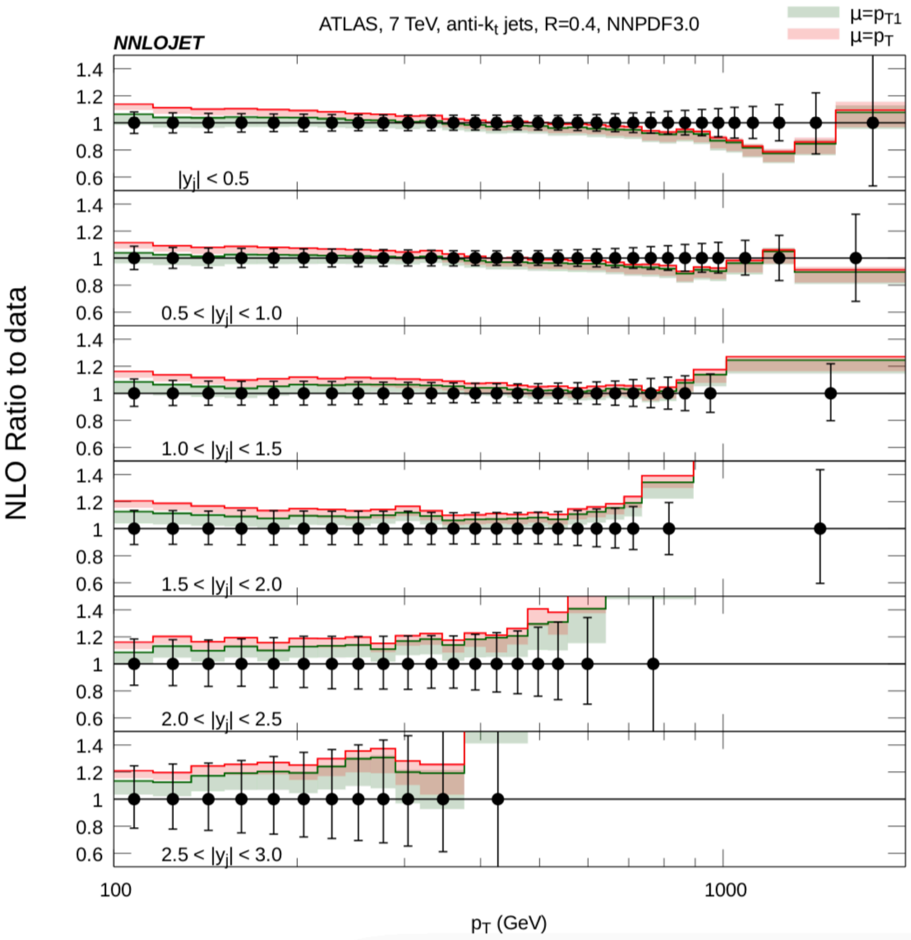
- For the moment, use K-factors for 7 TeV
  - little change from 7 TeV to 8 TeV (checked with ATLAS)
- CMS 8 TeV jet data prefers a harder gluon at high x
- Some reduction in gluon uncertainty for both moderate x and high x
- χ^2=168 (for 185 points) before fitting; 132 after fitting
- PDFSense predicted this would be highest impact data set, followed by 7 TeV CMS jet data





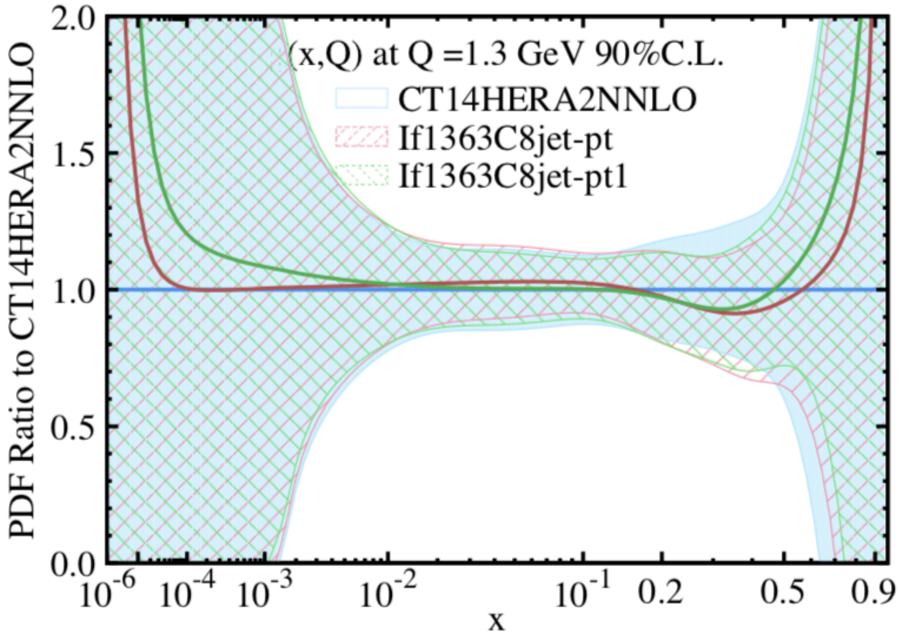
p_T vs p_{T1}

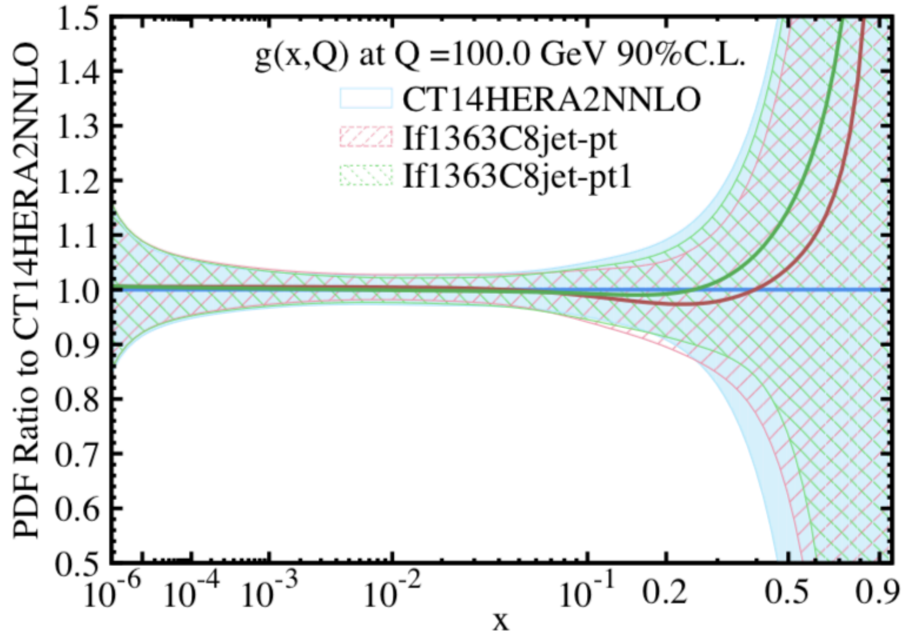
- Non-negligible difference between scale choice of p_T (inclusive jet p_T) and lead jet p_T (p_{T1}) for NNLO predictions
  - could potentially result in different gluon distribution
- Nominal (obvious to me) choice by PDF fitting groups is p_T



p_T vs p_{T1}

- In fact, fitted gluon is almost exactly the same in kinematic region where difference is important
- There is a resilience in the global fit due to other data present in this kinematic region (and evolution)

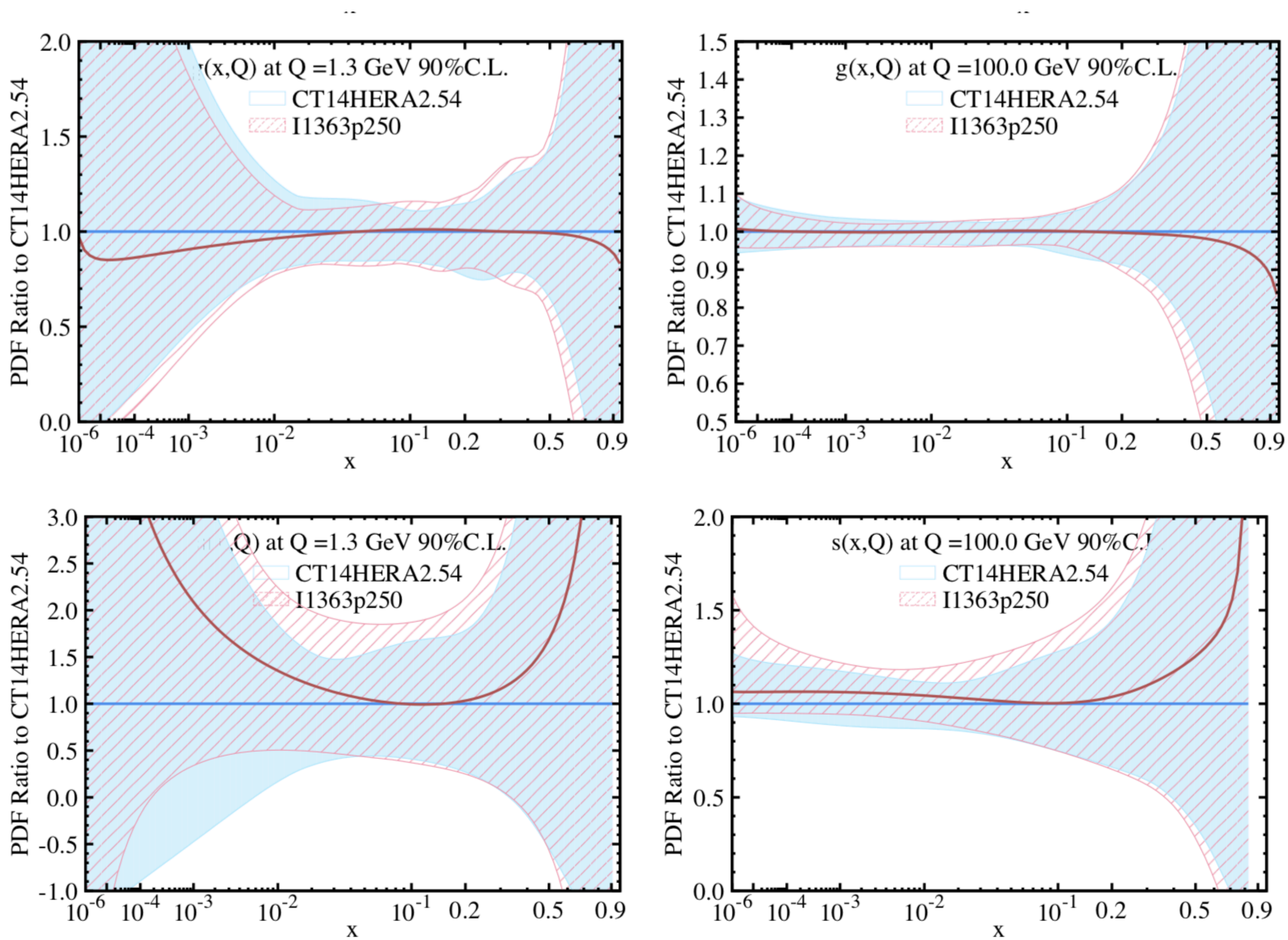




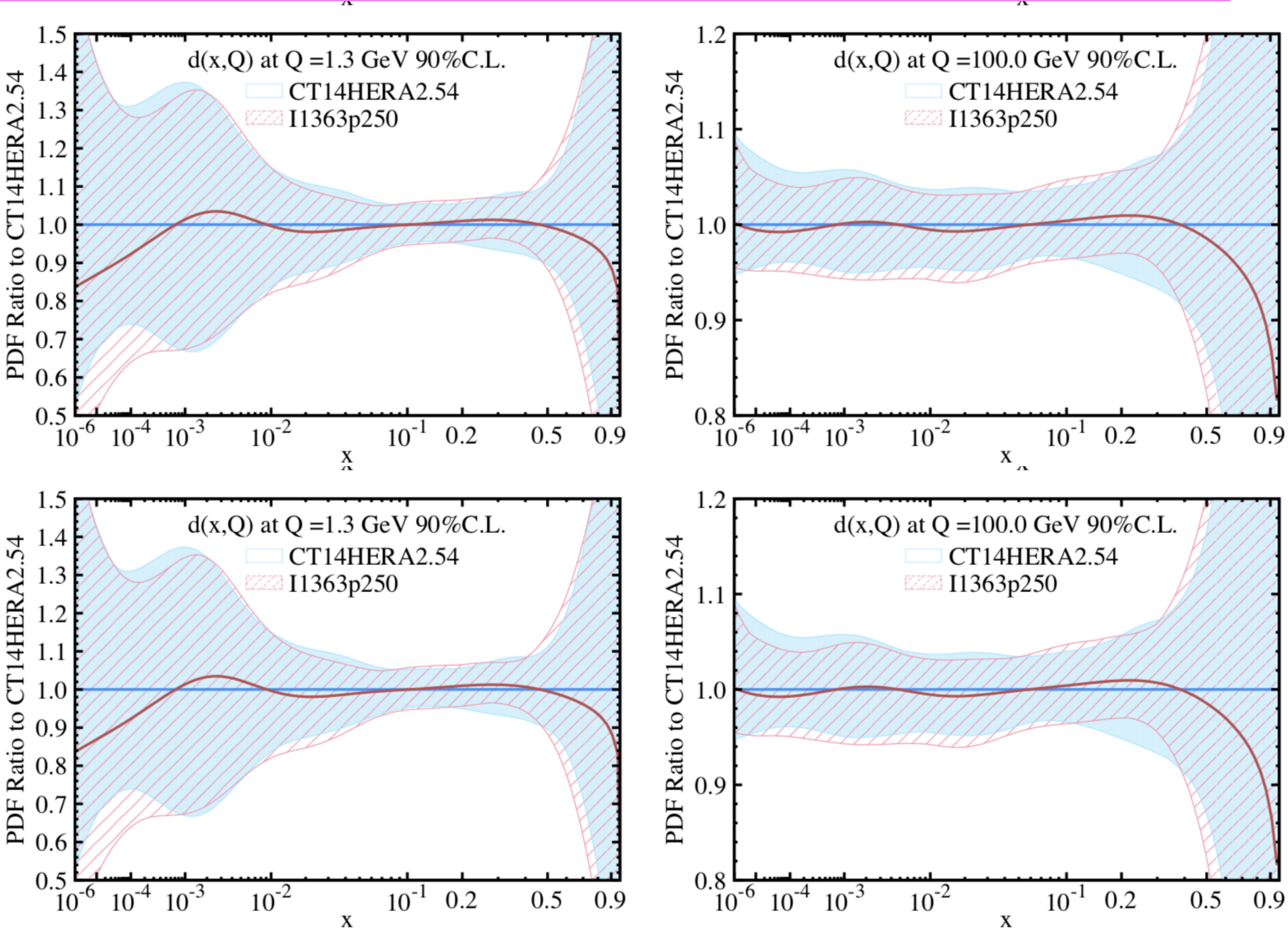
LHCb 8 TeV W/Z data

small impact on gluon distribution

increase in strangeness



LHCb W/Z data



d(x,Q) at Q =1.3 GeV 90%C.L.
CT14HERA2.54
I1363p250
PDF Ratio to CT14HERA2.54
x
d(x,Q) at Q =100.0 GeV 90%C.L.
CT14HERA2.54
I1363p250
PDF Ratio to CT14HERA2.54
x
d(x,Q) at Q =1.3 GeV 90%C.L.
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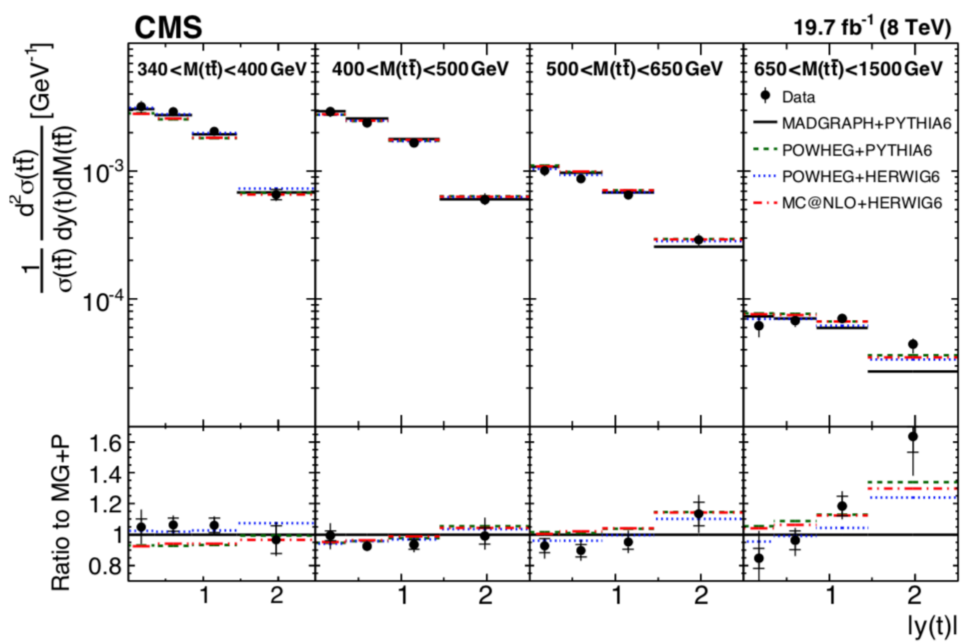
x
d(x,Q) at Q =100.0 GeV 90%C.L.
CT14HERA2.54
I1363p250
PDF Ratio to CT14HERA2.54
x

Top distributions

- There are several distributions measured by ATLAS and CMS that have information on the high x gluon
  - m_{tT}, y_{tT}, $p_T^{t,T}$ directly
  - $y_{t,T}$, p_T^{tT} indirectly
- Only one distribution should be used, unless a correlation model can be developed
  - which one?
  - do they give the same answer? if not, do we understand why?
  - how do the constraints/trends from each distribution compare?
  - similar to ATLAS jet data in different y bins
- Fits being carried out at NNLO using grids provided by Czakon, Heymes, Mitov
  - single differential constraints are not as large as those provided by CMS jets
- One way to solve the quandry is to use double-differential distributions, as for example from CMS 8 TeV
- Work in progress with Czakon, Heymes and Mitov

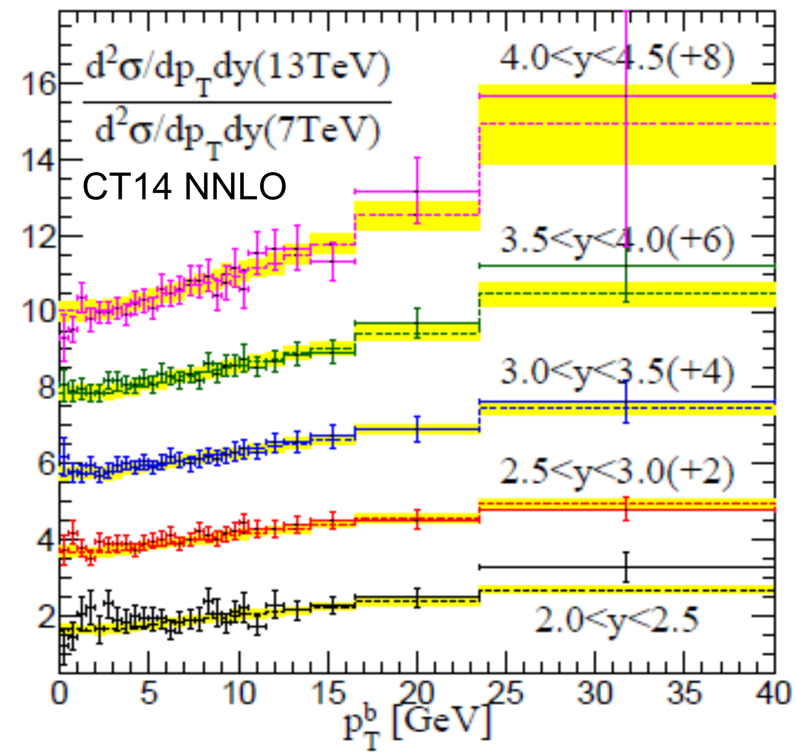


Gluon distribution using LHCb heavy flavor production

The S-ACOT-χ scheme allows a consistent implemention for LHCb data on pp->bX at y>2 in CT global fits, resulting in a reduction of theoretical uncertainty at small p_T

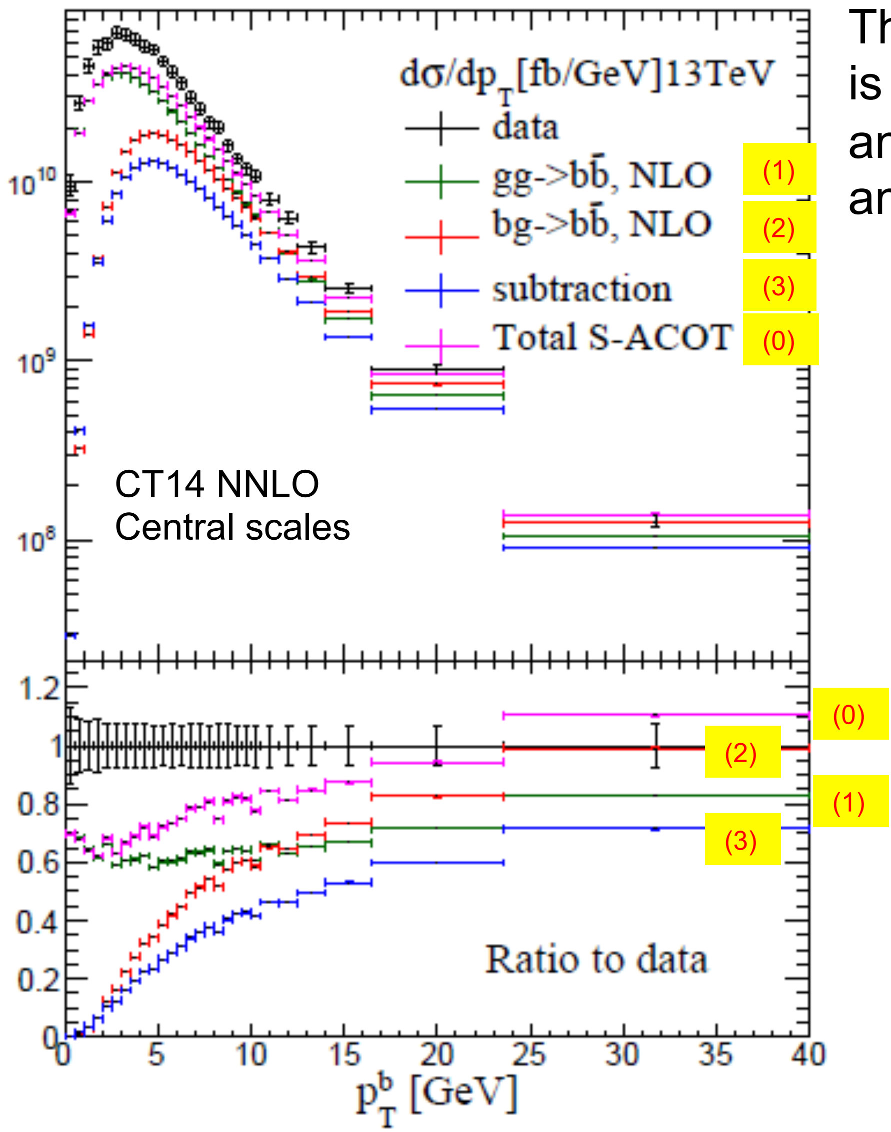
forthcoming publication: Campbell, Nadolsky, Xie, 1804.xxxxx

- Cross section ratios of 13 TeV to 7 TeV help to constrain gluon for x>1E-05
- Implemented using an applgrid interface generated by MCFM

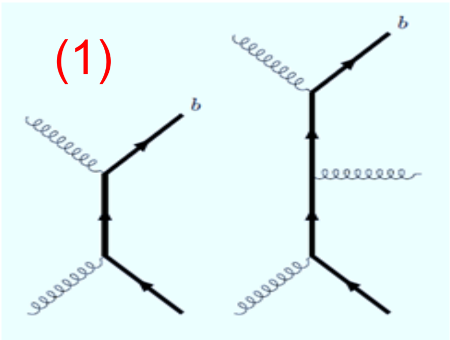


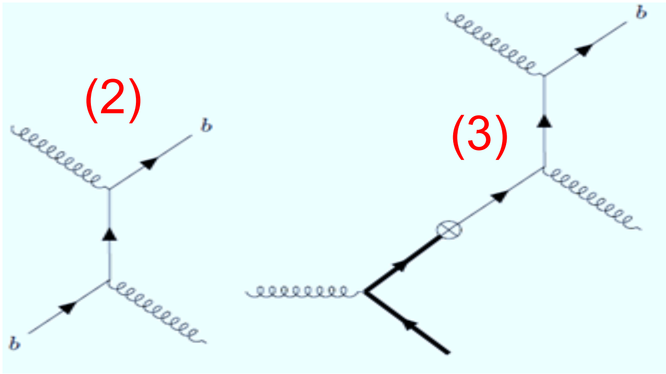
Good agreement of CT14 NNLO with ratio data

S-ACOT-χ vs. $pp \to bX$ at the LHCb



The S-ACOT-χ NLO prediction (magenta, ID=0) is given by gg channels (1) at $p_T \sim m_b/2$, and gets an increased cross section from bg channels (2) and subtractions (3) as $p_{Tb}^2 \gg m_b^2$



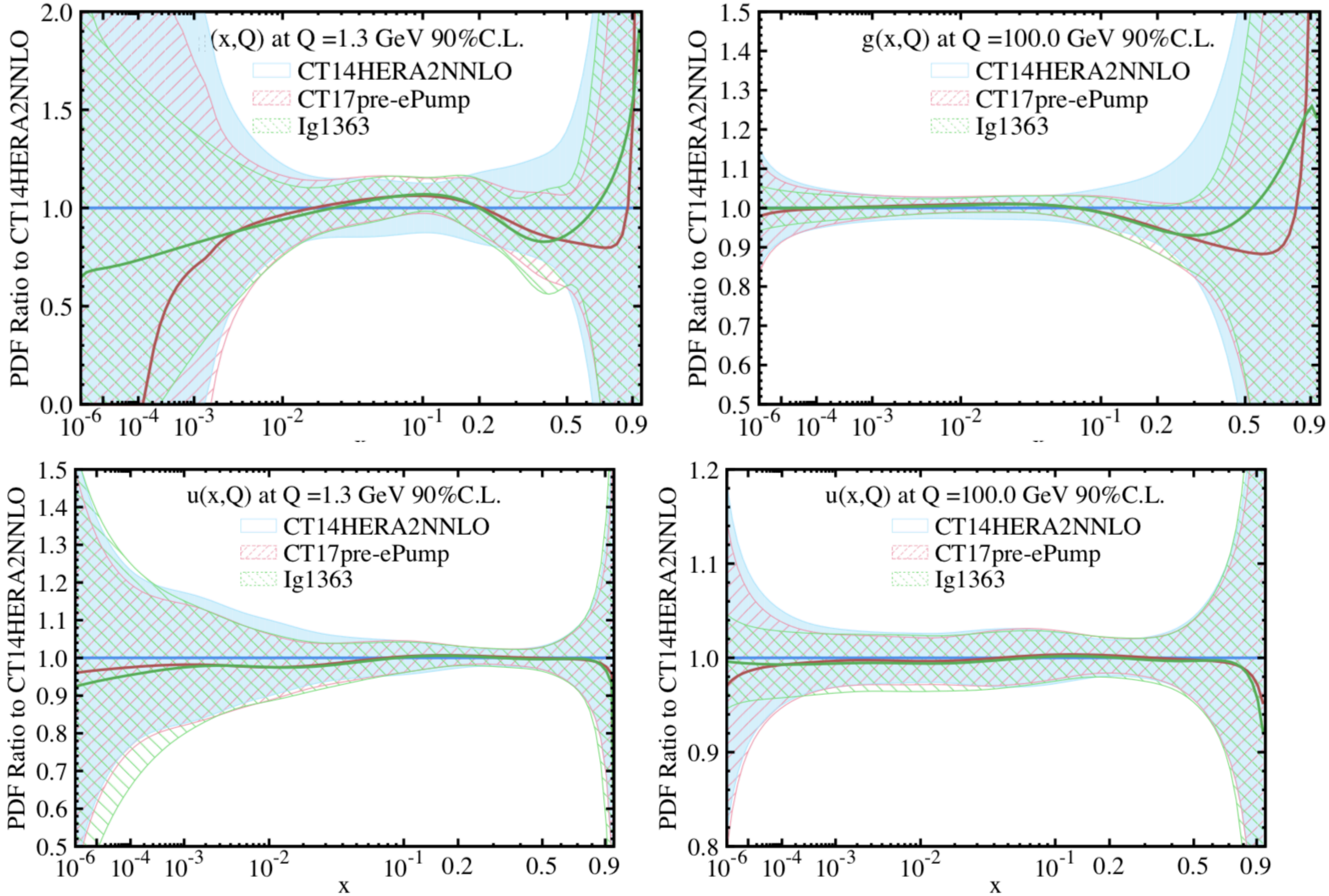


(0)=(1)+(2)-(3)

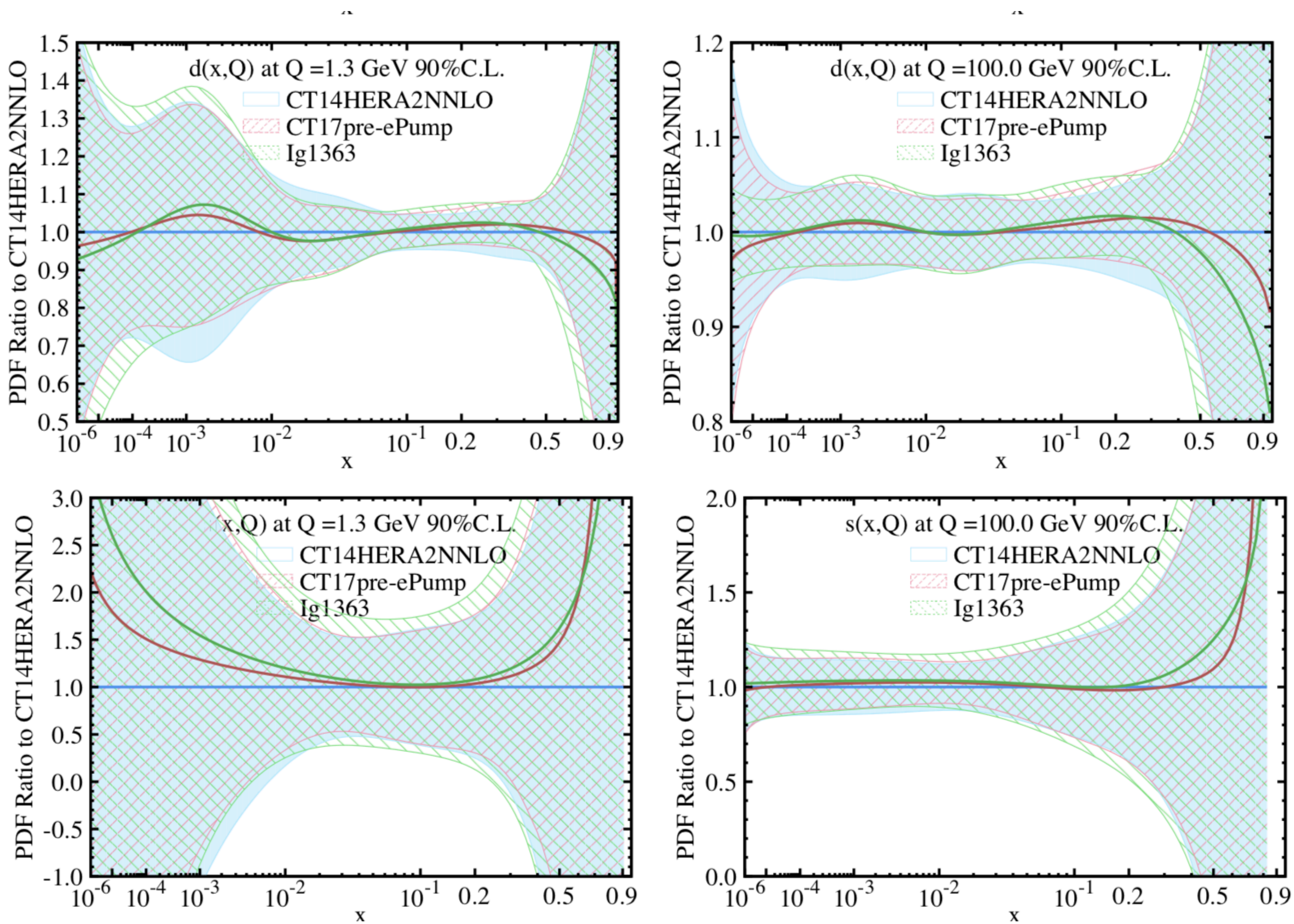
Preview of CT17

- Excellent agreement between ePump predictions and full global fit (termed n these plots as lg1363)

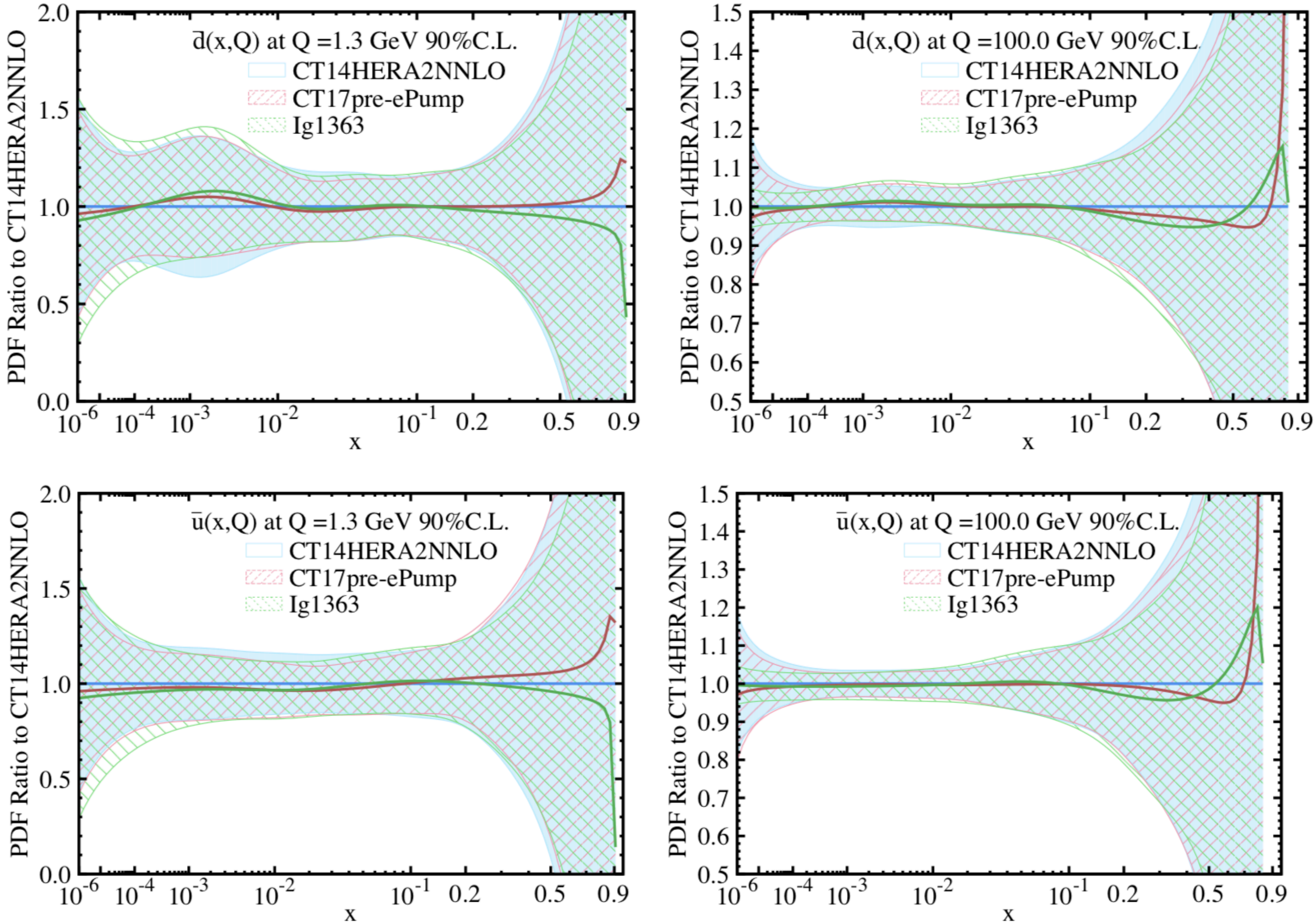
some improvement in gluon uncertainty in region sensitive to Higgs



Preview of CT17



Preview of CT17



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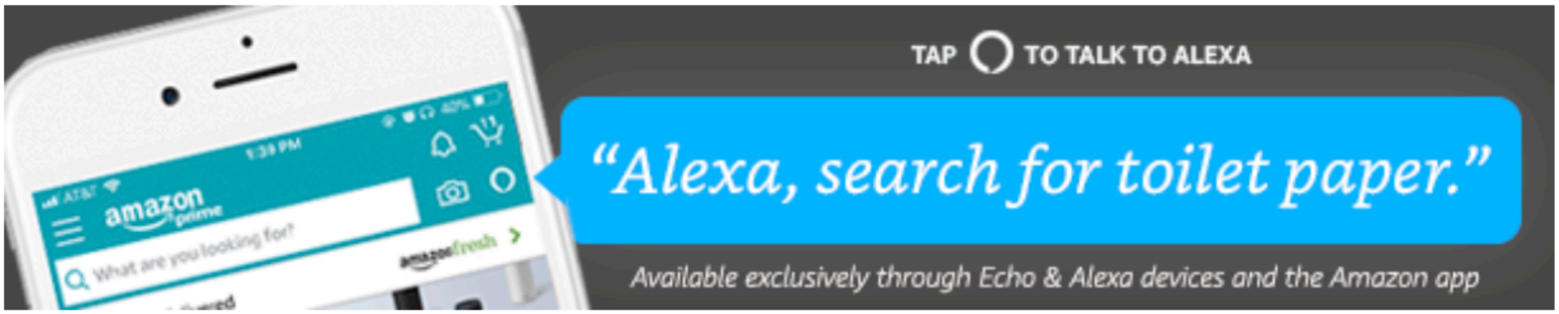

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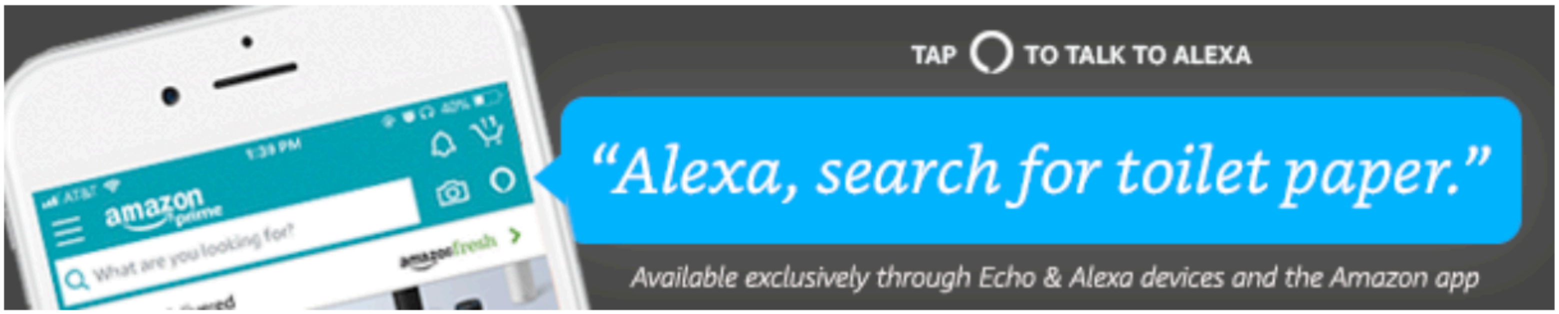

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Summary

- New LHC data has impact on PDFs/uncertainties
  - keep it coming
- More details/phenomenology regarding CT17 in talk at DIS2018 by T-J Hou
- ePump paper in progress
  - code to be made available at http://hep.pa.msu.edu/epump
  - website still under construction
- PDFSense code has been released, together with many comparisons
- CT17 PDFs will be used as a framework for new developments in the photon PDF

- After new updates on individual PDFs are complete, probably time to update PDF4LHC (3 years since last update)


LoopFest XVII
Michigan State University
July 16-20, 2018
http://web.pa.msu.edu/people/huston/LoopFest2018
Advisory committee: L. Dixon, F. Petriello, L. Reina, D. Wackeroth
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