Impact of LHC top-quark pair measurements to CTEQ-TEA PDF analysis

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- The top-quark pair production is a brand new observable available for global analysis in CT PDFs after CT14HERA2.
- Absolute and normalized 1D distributions of p_T, y_t, $m_{t\bar{t}}$ and $y_{t\bar{t}}$ from ATLAS and CMS, and 2D distributions from CMS are considered.
  Eur.Phys.J. C75 (2015) no.11, 542,
  Eur.Phys.J. C76 (2016) no.10, 538,
  Eur.Phys.J. C77 (2017) no.7, 459
- Theory prediction is done at NNLO QCD with $\mu_R, \mu_f = \frac{H_T}{4}, \frac{m_T}{4}$ by Czakon, Heymes and Mitov through fastNLO grids. 1704.08551, 1703.01630.
- We study the impact of top-quark pair production on PDFs in the framework of CT14HERA2 by using ePump.

Observable	Detector	Npts	χ^2/N
$\frac{1}{\sigma}\frac{d\sigma}{dp_T^t}$	ATLAS, CMS	8,8	0.39, 3.88
$\frac{1}{\sigma}\frac{d\sigma}{dy_t}$	ATLAS, CMS	5,10	2.70, 2.53
$\frac{1}{\sigma}\frac{d\sigma}{dm_{t\bar{t}}}$	ATLAS, CMS	7,7	0.25, 8.67
$\frac{1}{\sigma}\frac{d\sigma}{dy_{t\bar{t}}}$	ATLAS, CMS	5,10	2.46, 3.67
$\frac{d\sigma}{dp_T^t}$	ATLAS	8	0.34
$\frac{d\sigma}{dy_t}$	ATLAS	5	3.18
$\frac{d\sigma}{dm_{t\bar{t}}}$	ATLAS	7	0.45
$\frac{d\sigma}{dy_{t\bar{t}}}$	ATLAS	5	4.65
$d^2\sigma/dy_t dp_T^t$	CMS	16	1.23
$d^2\sigma/dm_{t\bar{t}} dp_T^{t\bar{t}}$	CMS	16	2.01
$d^2\sigma/dm_{t\bar{t}} d\Delta\eta_{t\bar{t}}$	CMS	12	1.70
$d^2\sigma/dm_{t\bar{t}} dy_t$	CMS	16	1.28
$d^2\sigma/dm_{t\bar{t}} dy_{t\bar{t}}$	CMS	16	1.27

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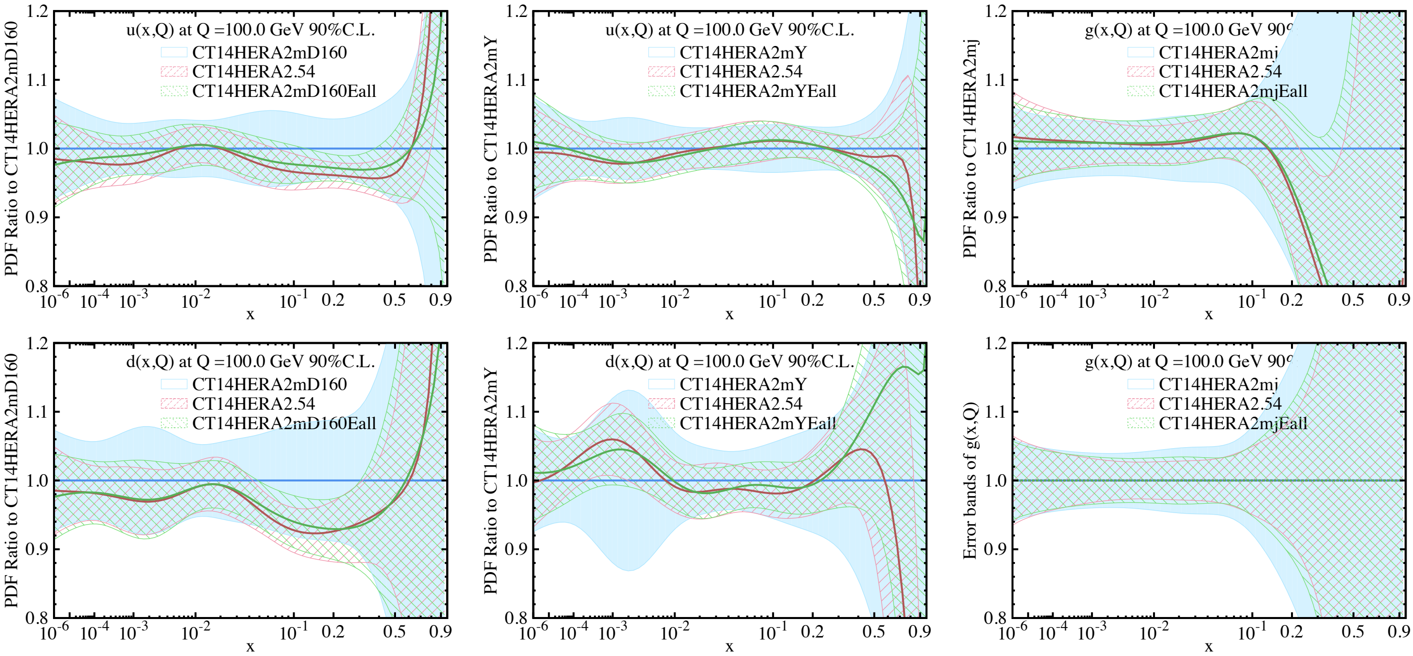
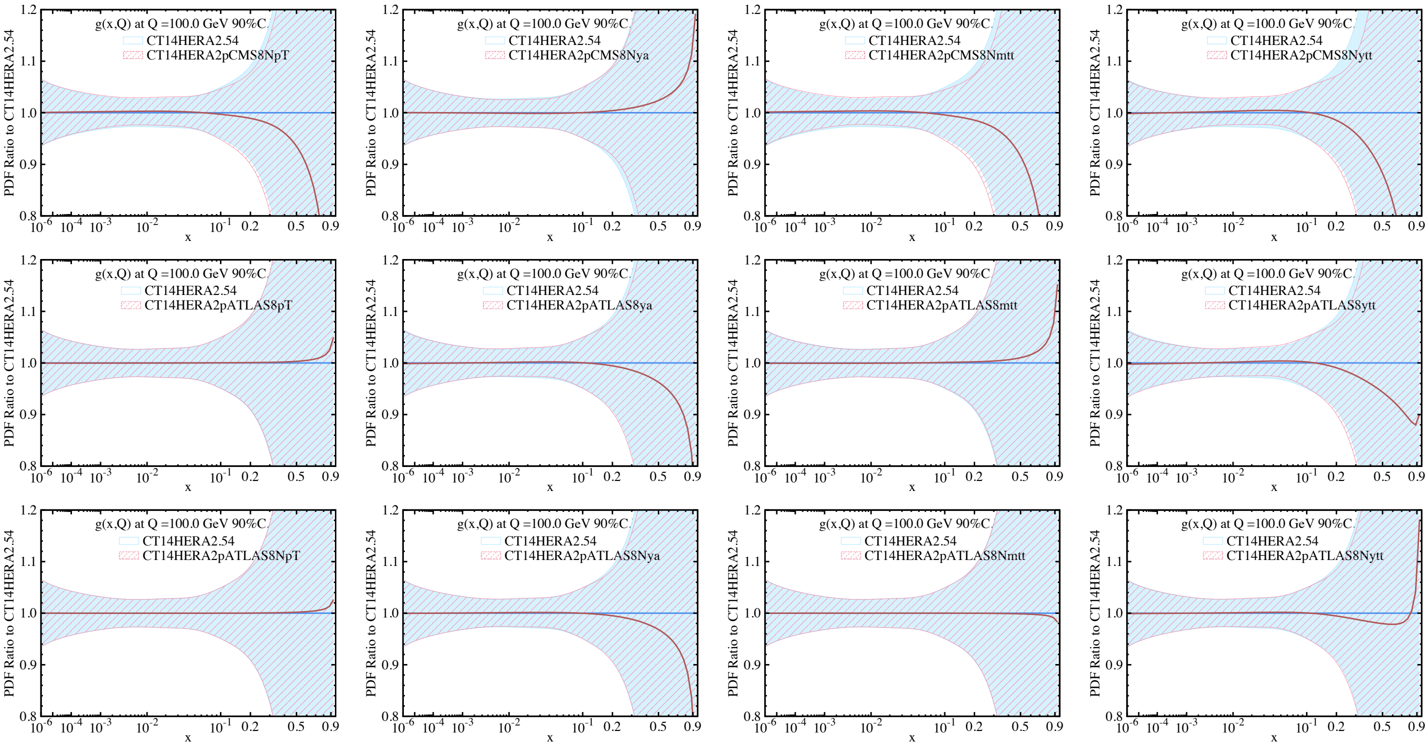
ePump: Error PDF Updating Method Package



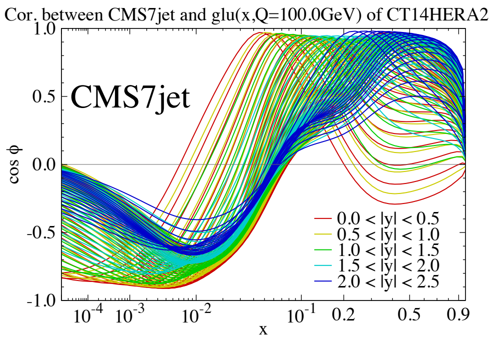
CT14HERA2mD160: CT14HERA2 without DIS, except HERA2 I+II combined data.
CT14HERA2mY : CT14HERA2 without Drell-Yan data.
CT14HERA2mj : CT14HERA2 without jet data.

- After adding back the DIS data, Drell-Yan data and jet data in CT14HERA2mD160, CT14HERA2mY and CT14HERA2mj, respectively, the ePump reproduces CT14HERA2 central predictions and error bands of PDFs in the well-constrained regions.

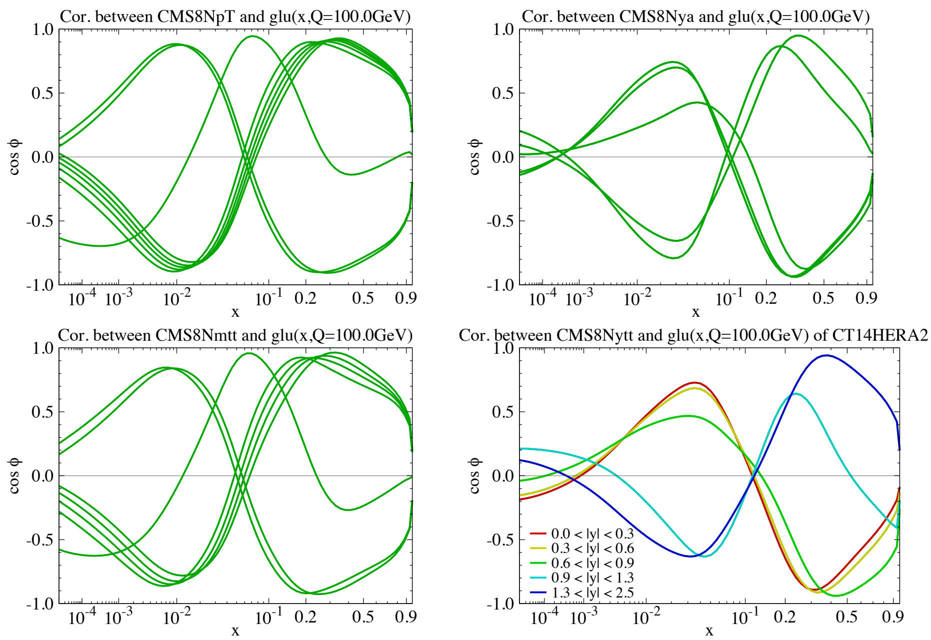
Impact of top-quark pair production on CT14HERA2



- No significant impact on the uncertainty of PDFs.
- Minor impact on gluon in large x region.

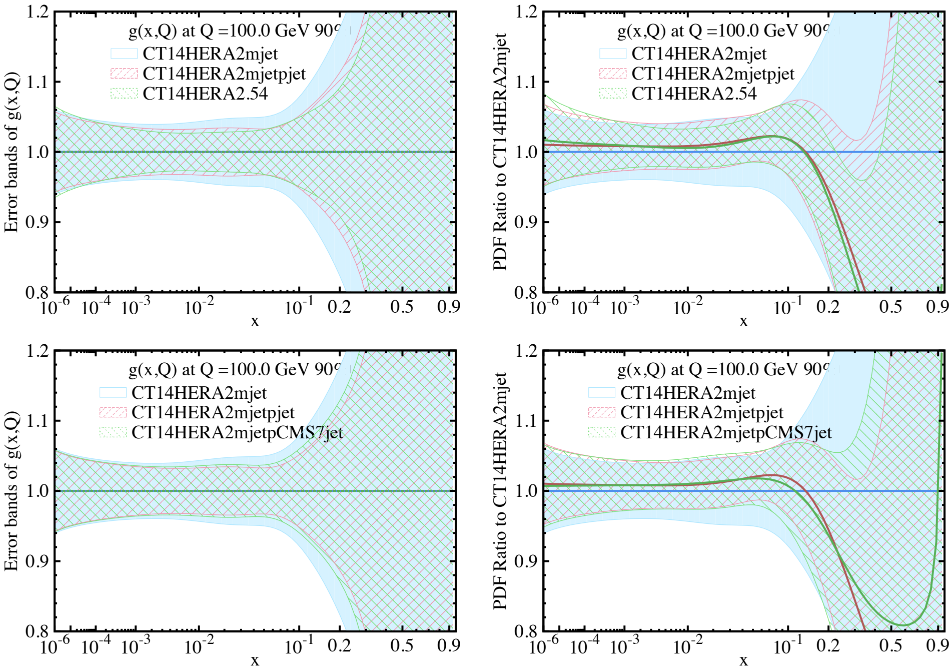


Norm. p_T Norm. y_t



Norm. $m_{t\bar{t}}$ Norm. $y_{t\bar{t}}$

- The $t\bar{t}$ data have high correlation with the gluon PDF in some x range.
- The most correlated region in gluon from top-pair production is already well-constrained by jet data.

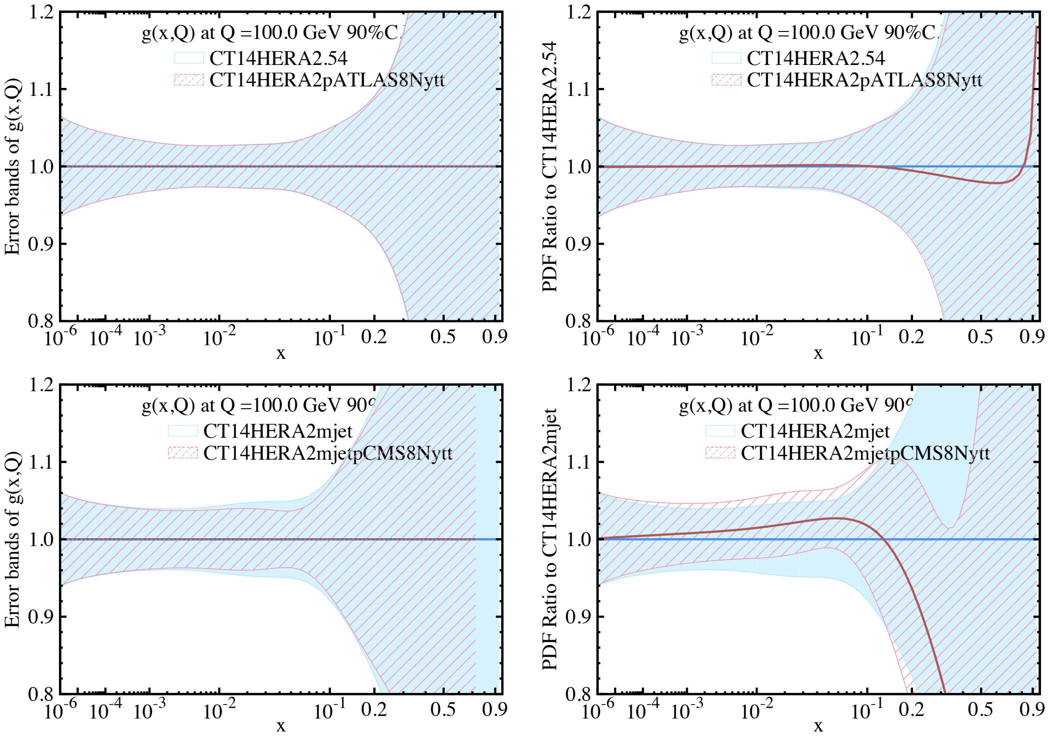


CT14HERA2mjetpjet : Starting from CT14HERA2mjet, including all jet data

CT14HERA2mjetpCMS7jet : Starting from CT14HERA2mjet, including CMS 7TeV jet data

CT14HERA2mjet : Eigenvector set as CT14HERA2 without jet data.

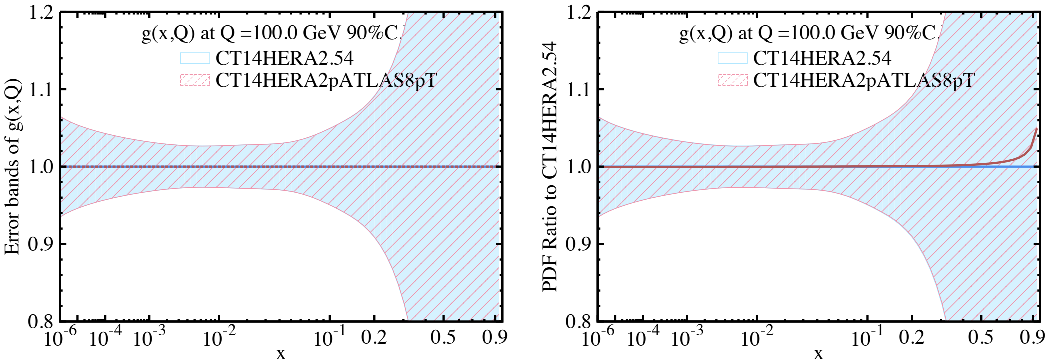
- The jet data constrain most of the well-constrained region of gluon.
- CMS 7 TeV inclusive jet data (1212.6660) dominate the contribution among jet data.



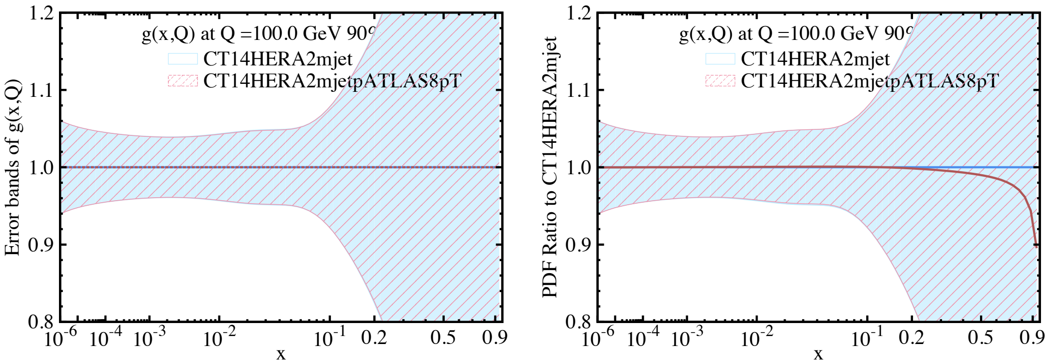
Impact from ATLAS 8TeV norm. y_{tt} $t\bar{t}$ data on CT14HERA2

Impact from ATLAS 8TeV norm. y_{tt} $t\bar{t}$ data on CT14HERA2mjet

- Without the jet data included in global analysis, $t\bar{t}$ data have rather obvious impact on both central predictions and error bands of PDFs.



Impact from ATLAS 8TeV abs. p_T $t\bar{t}$ data on CT14HERA2



Impact from ATLAS 8TeV abs. p_T $t\bar{t}$ data on CT14HERA2mjet

- However, for the normalized distribution, we don't see obvious impact on PDFs, even without jet data included in the global analysis.

Distribution	Detector	Npts	χ^2/N
inclusive jet	CDF	72	1.50
inclusive jet	D0	110	1.03
inclusive jet	ATLAS	90	0.57
inclusive jet	CMS	133	0.93
$\frac{1}{\sigma}\frac{d\sigma}{dp_T^t}$	ATLAS, CMS	8,8	0.39, 3.88
$\frac{1}{\sigma}\frac{d\sigma}{dy_t}$	ATLAS, CMS	5,10	2.70, 2.53
$\frac{1}{\sigma}\frac{d\sigma}{dm_{t\bar{t}}}$	ATLAS, CMS	7,7	0.25, 8.67
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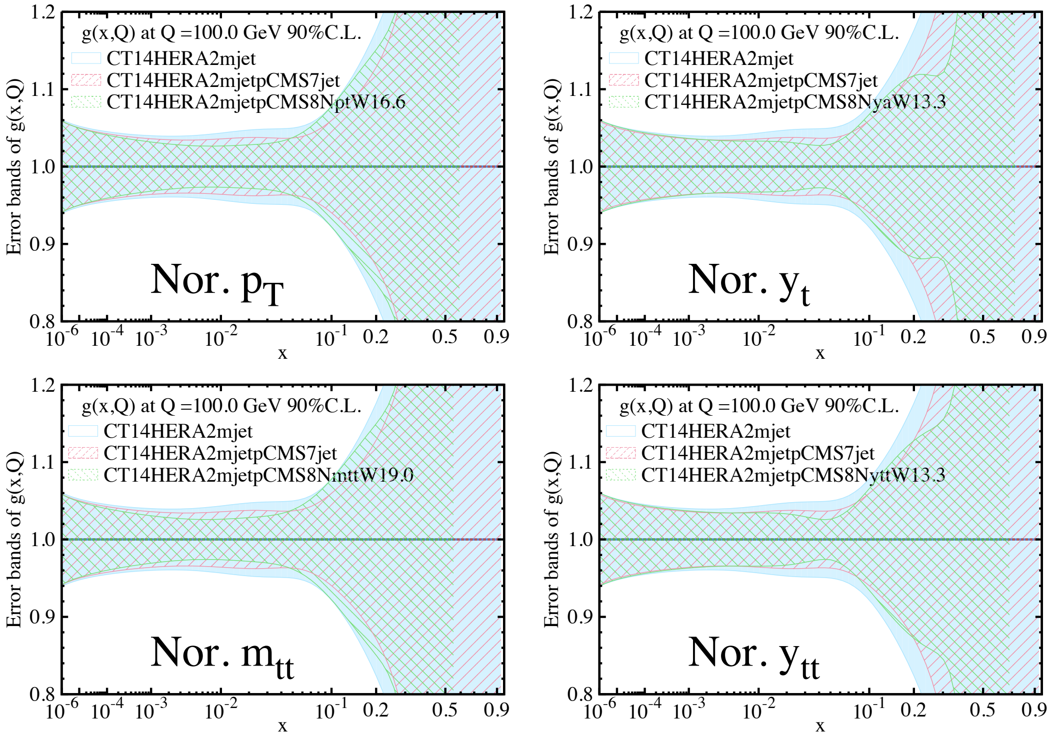
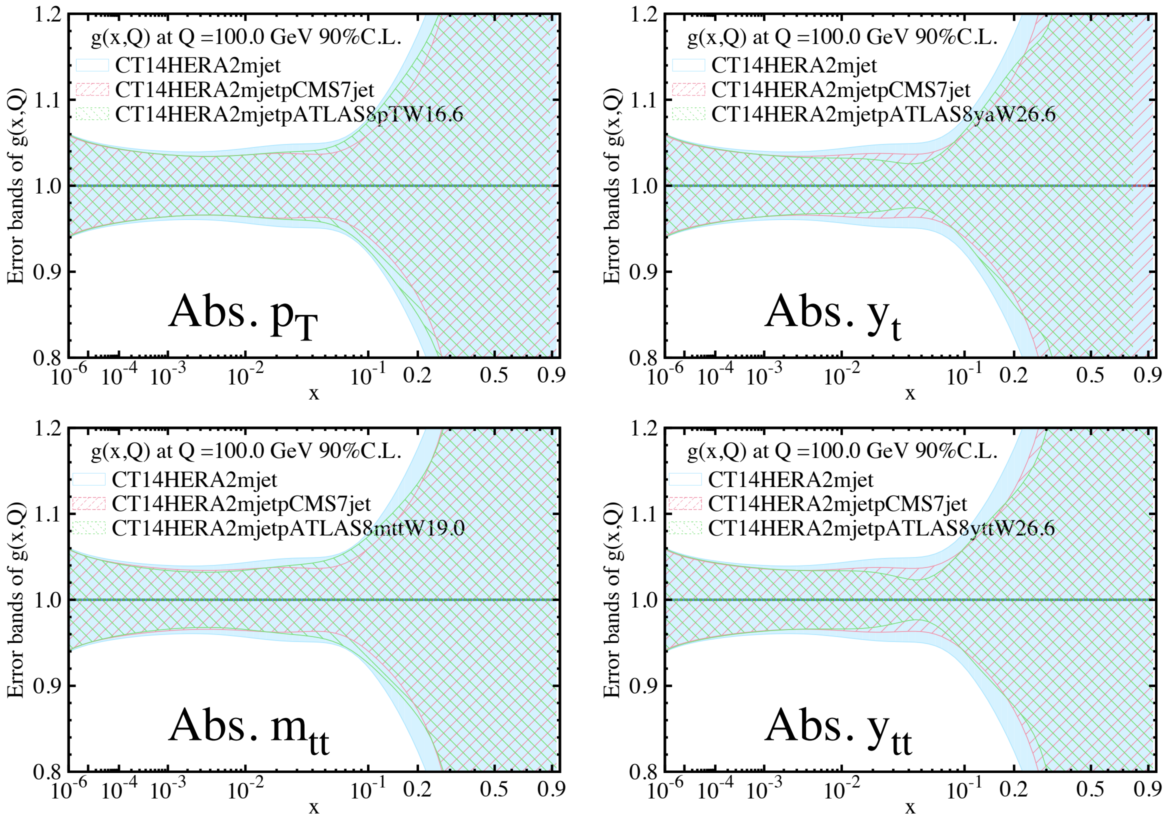
- The $t\bar{t}$ data have Npts of $O(10)$, which is smaller by a factor of 10 than jet data, which have Npts of $O(100)$ in the framework of CT14HERA2 which has 3287 Npts.

Impact of top-quark pair production on CT14HERA2mjet with hypothetical weight



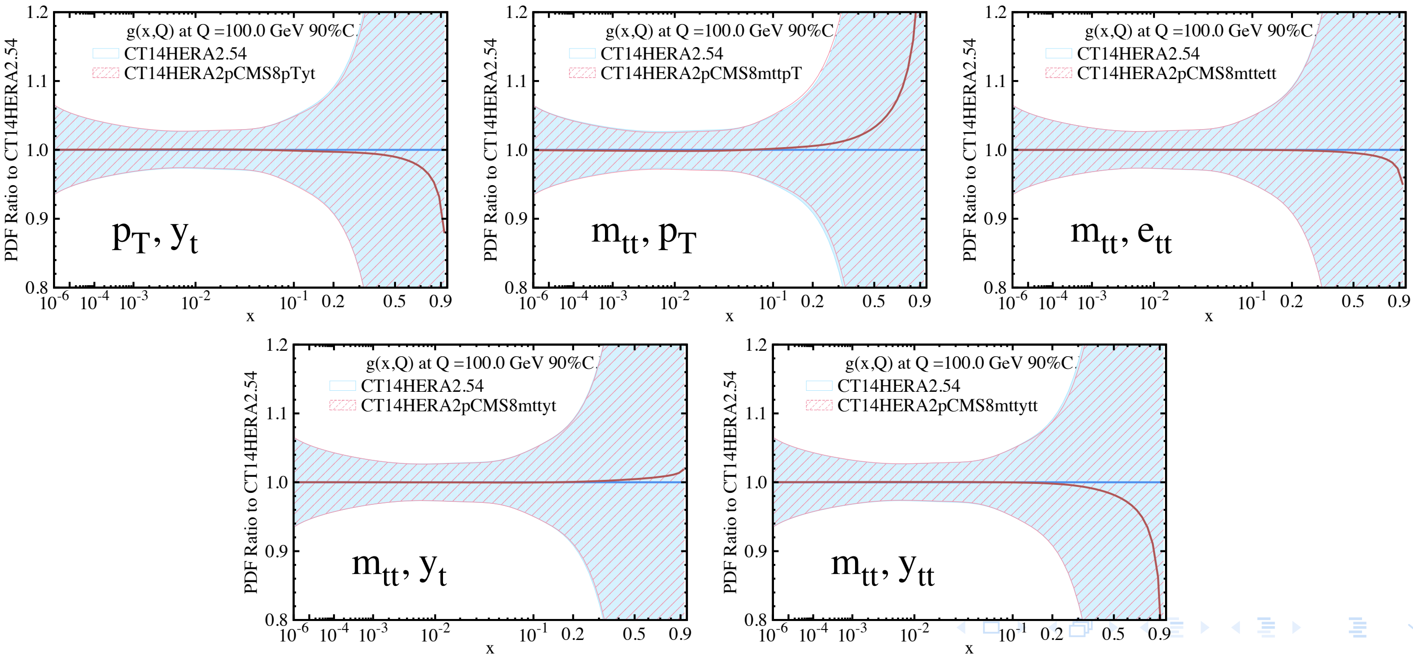
- We assume a higher weight for $t\bar{t}$ data.
- The weight is taken to be the ratio of Npts of CMS 7 jet(133) to Npts of $t\bar{t}$ data.
- A higher weight will come with HI-LHC. (A naive statistic scalling gives about a factor of 100.)
- Impact from weighted $t\bar{t}$ data on gluon PDF is as strong as jet data.

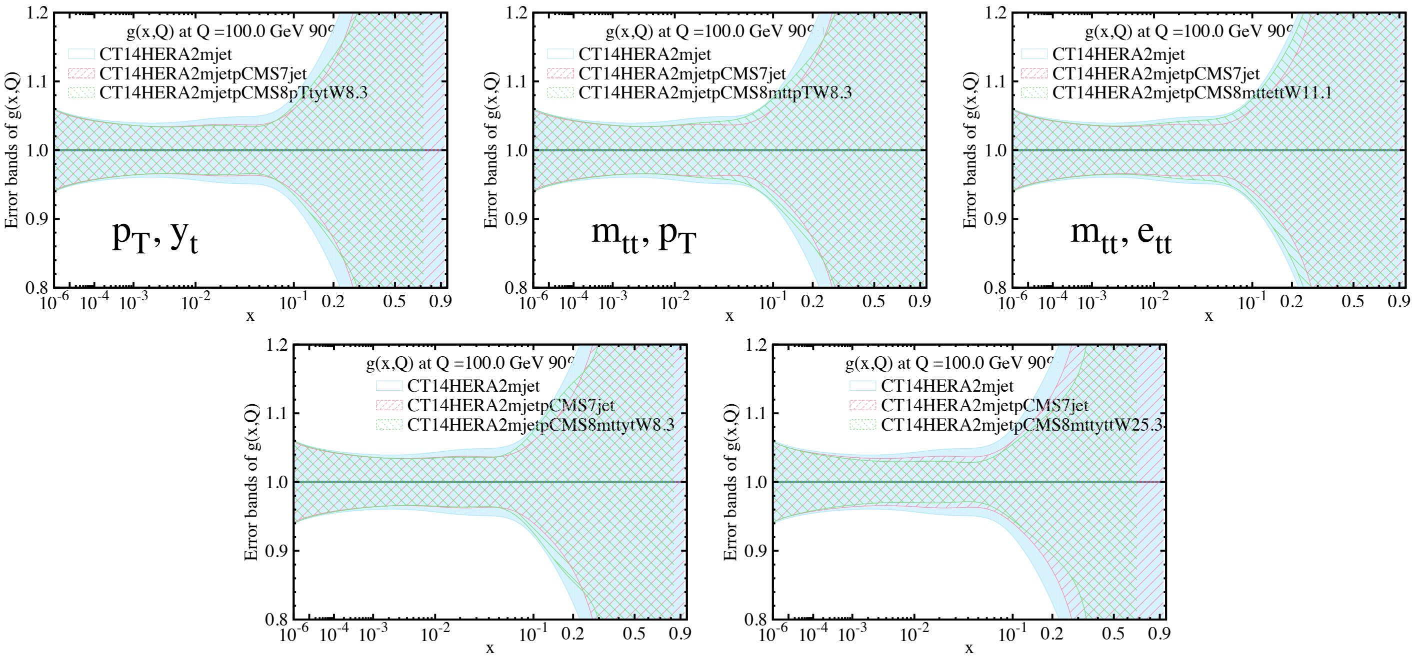


- Obvious impact is also found for the absolute distribution which have no significant impact with weight 1.

2D top-quark pair production

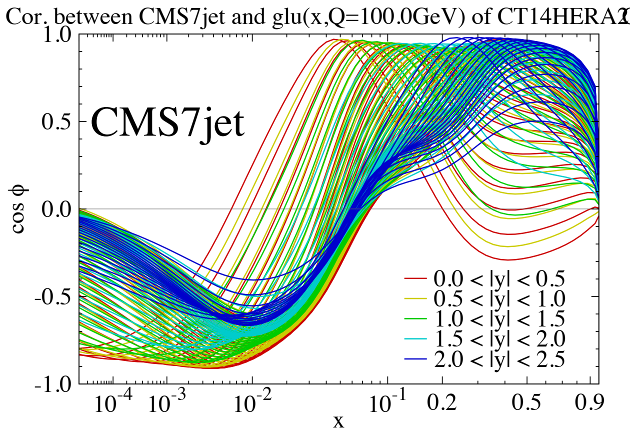
Distribution	Detector	Npts	χ^2/N
$d^2\sigma/dy_t dp_T^t$	CMS	16	1.23
$d^2\sigma/dm_{t\bar{t}} dp_T^{t\bar{t}}$	CMS	16	2.01
$d^2\sigma/dm_{t\bar{t}} d\Delta\eta_{t\bar{t}}$	CMS	12	1.70
$d^2\sigma/dm_{t\bar{t}} dy_t$	CMS	16	1.28
$d^2\sigma/dm_{t\bar{t}} dy_{t\bar{t}}$	CMS	16	1.27

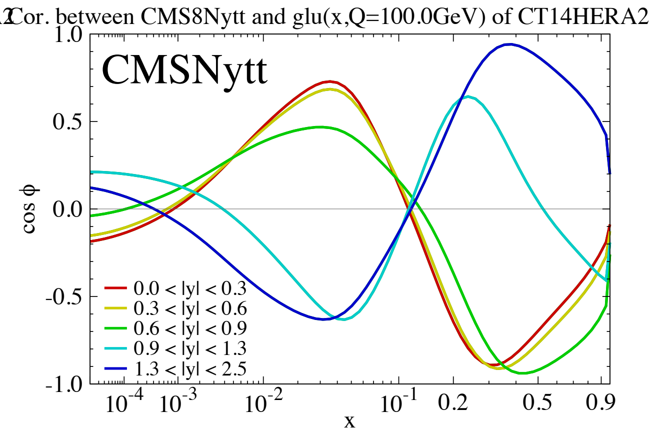


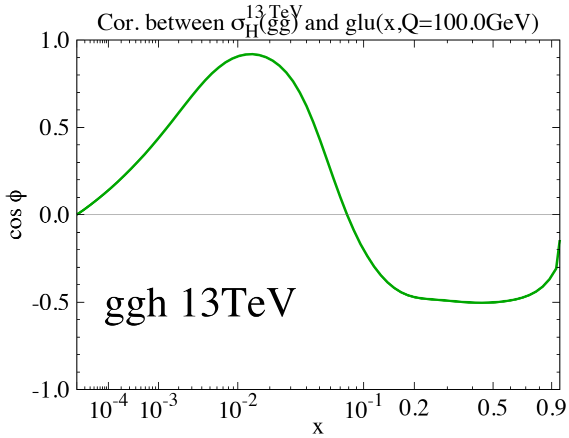


- The 2D $t\bar{t}$ data also provide similar constraints on gluon PDF after scaling by the hypothetical weight.
- Sensitivity per data point of $t\bar{t}$ data is similar to that of jet data.‘
- Total sensitivity of the data set also depends on the total number of data points. (See talk by Pavel Nadolsky at WG1+WG7.)

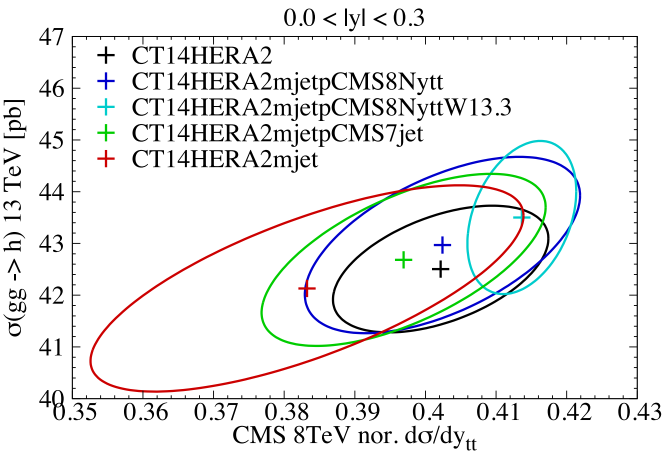
Higgs production through gluon fusion



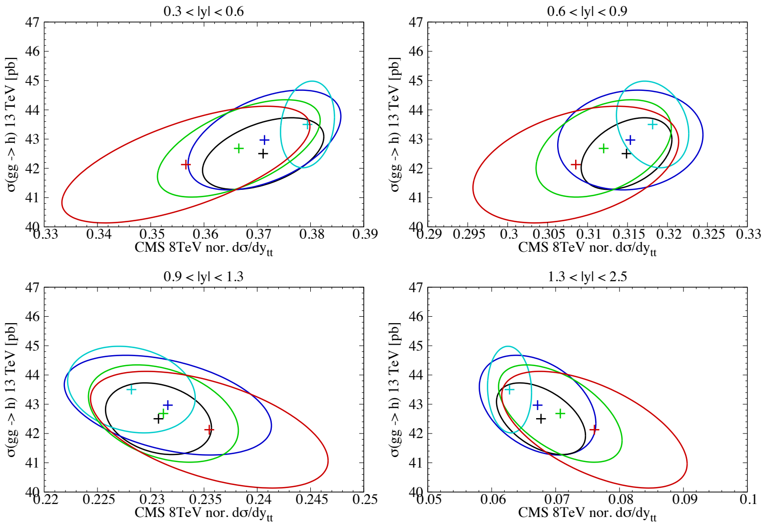




Update uncertainty for Higgs production with hypothetical weight on $t\bar{t}$ data



CT14HERA2, CT14HERA2mjet
CT14HERA2mjetpCMS8Nytt:
CT14HERA2mjet + CMS 8 norm. ytt
CT14HERA2mjetpCMS8NyttW13.3
CT14HERA2mjetpCMS7jet:
CT14HERA2mjet + CMS7jet



- The uncertainty of ggh production given by PDFs with weighted $t\bar{t}$ data is compatible with that of CT14HERA2.
  The central prediction of the weighted $t\bar{t}$ data is obtained by assuming the central measurement is the same as the unweighted case.

Summary

- All the top-quark pair production data has minor impact on CT14HERA2 gluon PDF when jet data have been included in global analysis. It is due to the number of data points for the $t\bar{t}$ data is much less than the jet data.
- By giving a hypothetical weight on the $t\bar{t}$ data as the ratio of number of data points between jet data and $t\bar{t}$ data, the $t\bar{t}$ data show good agreement with the impact from jet data with similar strength.
- Sensitivity per data point of $t\bar{t}$ data is similar to that of jet data.‘
- Total sensitivity of the data set also depends on the total number of data points.