`ePump`: a fast tool to update/analyze PDFs

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ePump
(error PDF updating method package)

A set of global-fit PDFs
e.g. CT14HERA2

+

New data
(pseudo data)

update → ePump

A new set of PDFs

Who needs it ?

- Experimentalists: explore effects of new data
- Phenomenologists: inspect impacts of pseudodata

Why ePump?

- Precision era: High-Luminosity LHC
- Theory Uncertainties: scale uncertainty + PDF uncertainty

ATLAS: Eur. Phys. J. C 79 (2019) 128

	$\sigma^{\rm fid}_{W^+}$ [pb]	$\sigma^{\rm fid}_{W^-}$ [pb]	$\sigma^{\rm fid}_{Z}$ [pb]
PDF (CT14)	2203^{+62}_{-64}	1379^{+34}_{-42}	356^{+8}_{-10}
α_S	± 17	$^{+13}_{-11}$	$^{+3}_{-2}$
μ_R, μ_F scales	$^{+18}_{-11}$	$^{+11}_{-8}$	± 1
Data	2266 ± 53	1401 ± 33	374.5 ± 8.6

PDF uncertainties dominate the theory uncertainties !

How can we reduce the PDF uncertainties?

- Global fit usually takes days to perform analysis.
- ePump arises as a convenient tool to analyze PDFs approximately.
- ePump only takes **1 sec** to run.

ePump: simple approximation

- χ^2: quadratic
- Observables X: linear approximation

$$\Delta\chi^2(\mathbf{z})_{\rm new} = T^2 \sum_{i=1}^{N} z_i^2 + \sum_{\alpha,\beta=1}^{N_X} (X_\alpha(\mathbf{z}) - X_\alpha^E) C_{\alpha\beta}^{-1} (X_\beta(\mathbf{z}) - X_\beta^E)$$

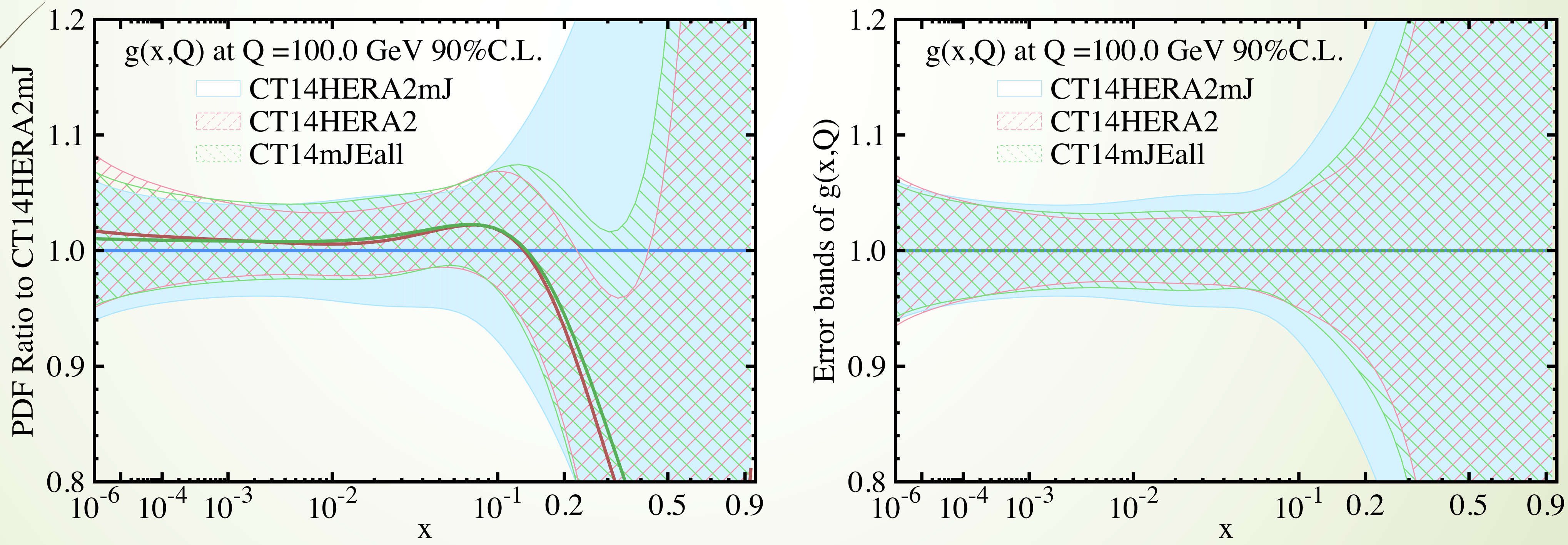
$\Delta\chi^2$ for the original data: quadratic approximation

χ^2 for the new data set: Take linear expansion for $X(z)$.

ePump calculates the new minimum and updates the PDFs and observables X_α.

Simple approximation works well

- CT14HERA2mJ: 2882 data points
- Jets: 405 data points
- CT14mJEall: CT14HERA2mJ +all jets ➔ reproduce CT14HERA2



Update observables

ePump can update **observables** at the same time of updating PDFs

- Update $\sigma(gg \rightarrow h)$ at the LHC
- Jet data reduce the $\sigma(gg \rightarrow h)$ uncertainty by ~ 20%.

Add jet data

For $\sigma(gg \rightarrow h)$ at 13 TeV at LHC

without jet data

CT14HERA2mJ

42.1 ± 2.0 pb

ePump → 42.7 ± 1.5 pb

global fit → 42.5 ± 1.2 pb

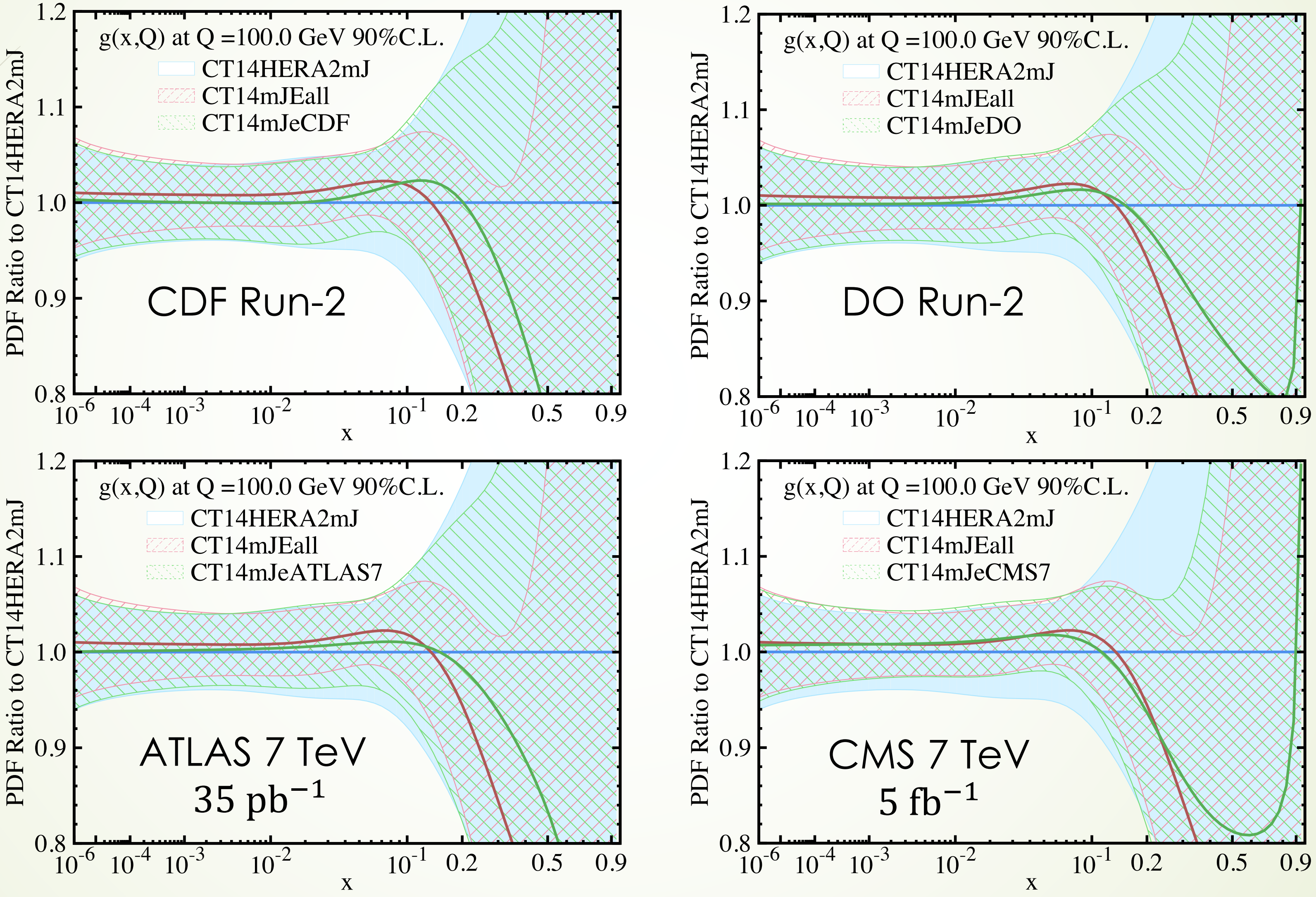
Impacts of 4 jet data sets in CT14HERA2

CDF: arXiv:0807.2204

DO: arXiv:0802.2400

ATLAS: arXiv:1112.6297

CMS: arXiv:1212.6660



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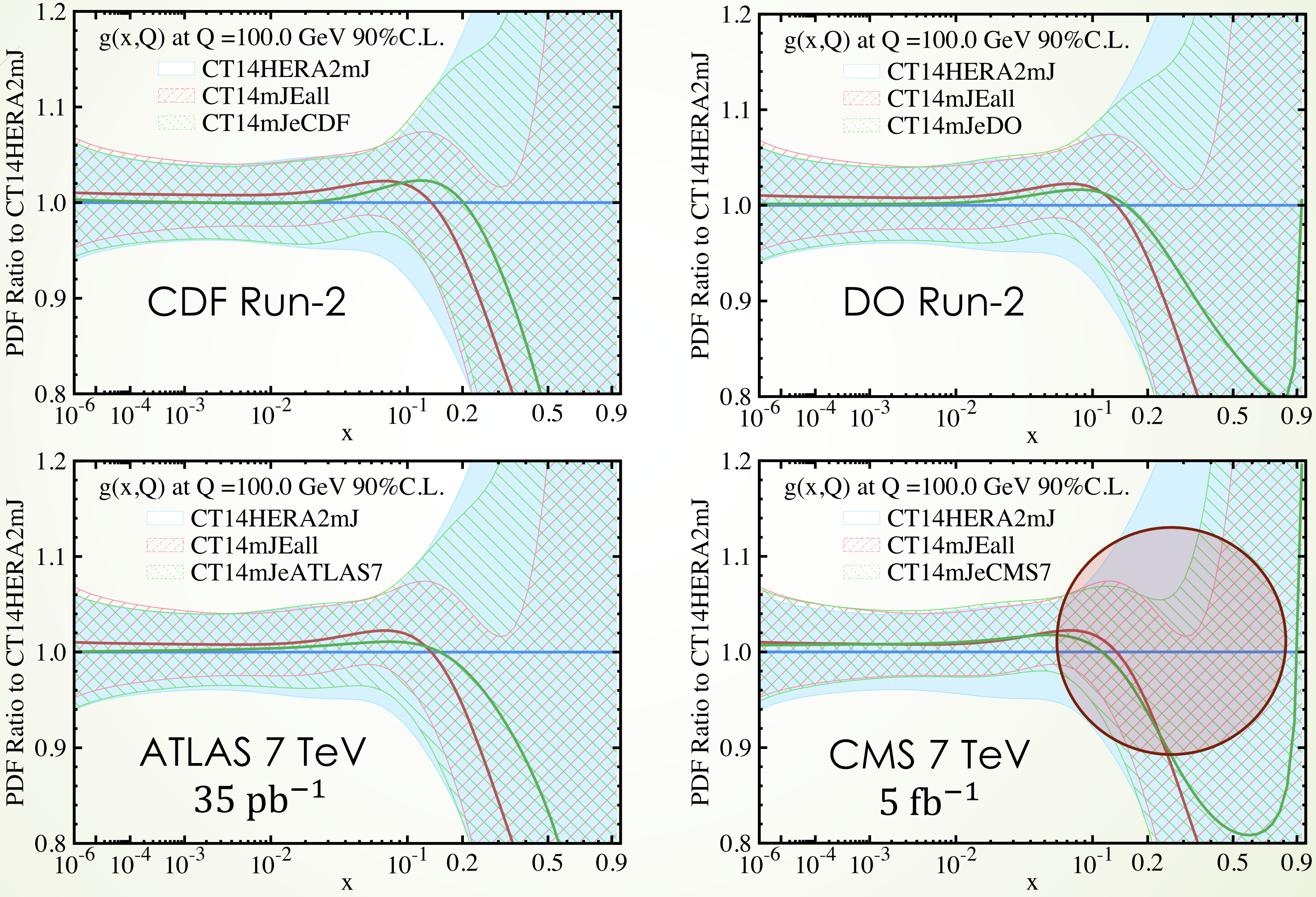


- **CMS jets data** has the **dominant** effect on constraining gluon PDF, reduces error band the most.

Impact of $t\bar{t}$ data

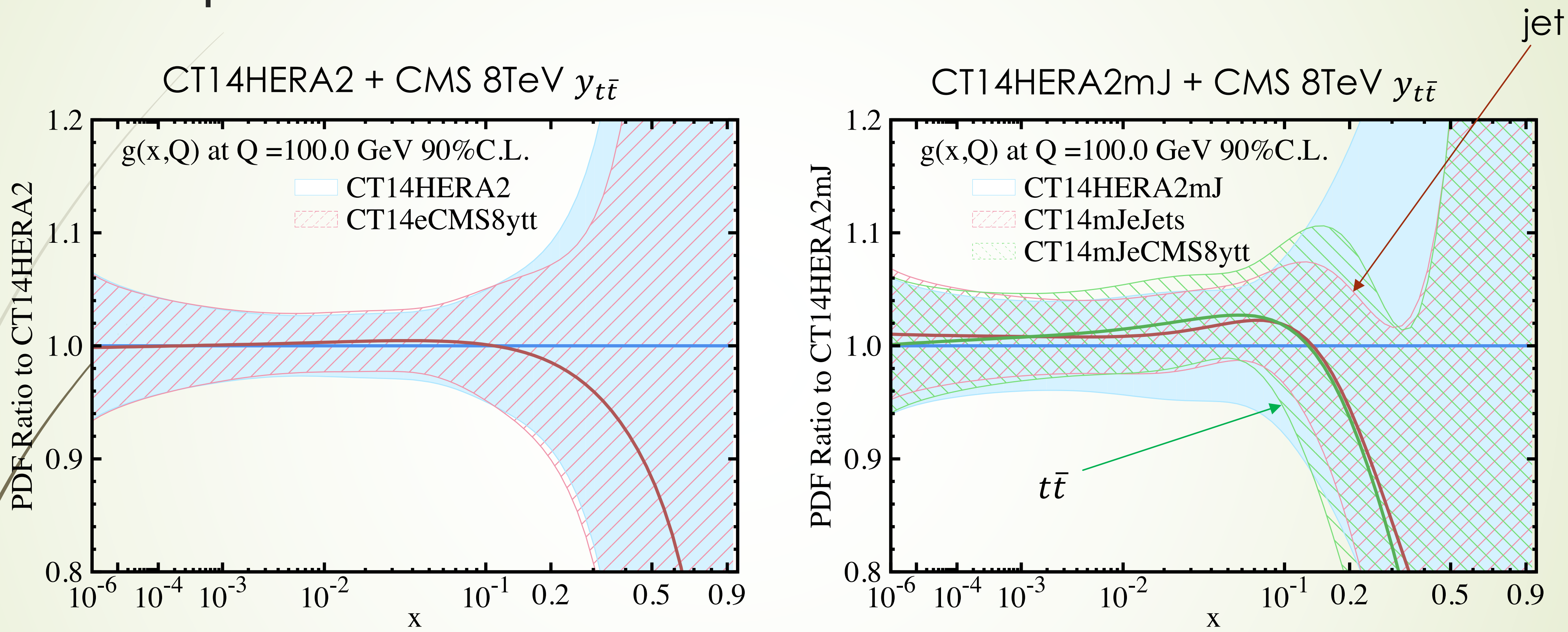
- Jet data are exclusively sensitive to gluon PDF
- $t\bar{t}$ data at LHC also depends on gluon PDF a lot

What impacts does $t\bar{t}$ data have on gluon PDF ?

How does $t\bar{t}$ compare to jet data ?

Impacts of new $t\bar{t}$ data

CMS 8TeV 19.7 fb^{-1}
arXiv:1505.04480



- $t\bar{t}$ only has small effects on CT14HERA2 PDFs.
- Compared to jets, $t\bar{t}$ changes the central PDF in a similar way, but not reduces the error band as much.

Improvement of $\sigma(gg \to h)$ by $t\bar{t}$ data

ePump

For $\sigma(gg \to h)$ at 13 TeV at LHC

without jet data

CT14HERA2mJ

42.1 ± 2.0 pb

Jets → 42.7 ± 1.5 pb

CMS 8TeV $t\bar{t}$ → 42.97 ± 1.70 pb

$t\bar{t}$ gives larger gluon PDF **central value**

$t\bar{t}$ gives larger gluon PDF **uncertainty**

What if $t\bar{t}$ had the same # data points ?

Compared to jet data

- $t\bar{t}$ data has similar impacts on gluon PDF central values
- But has less power of reducing gluon PDF errors

Reason: $t\bar{t}$ has much **fewer** production events than jets.

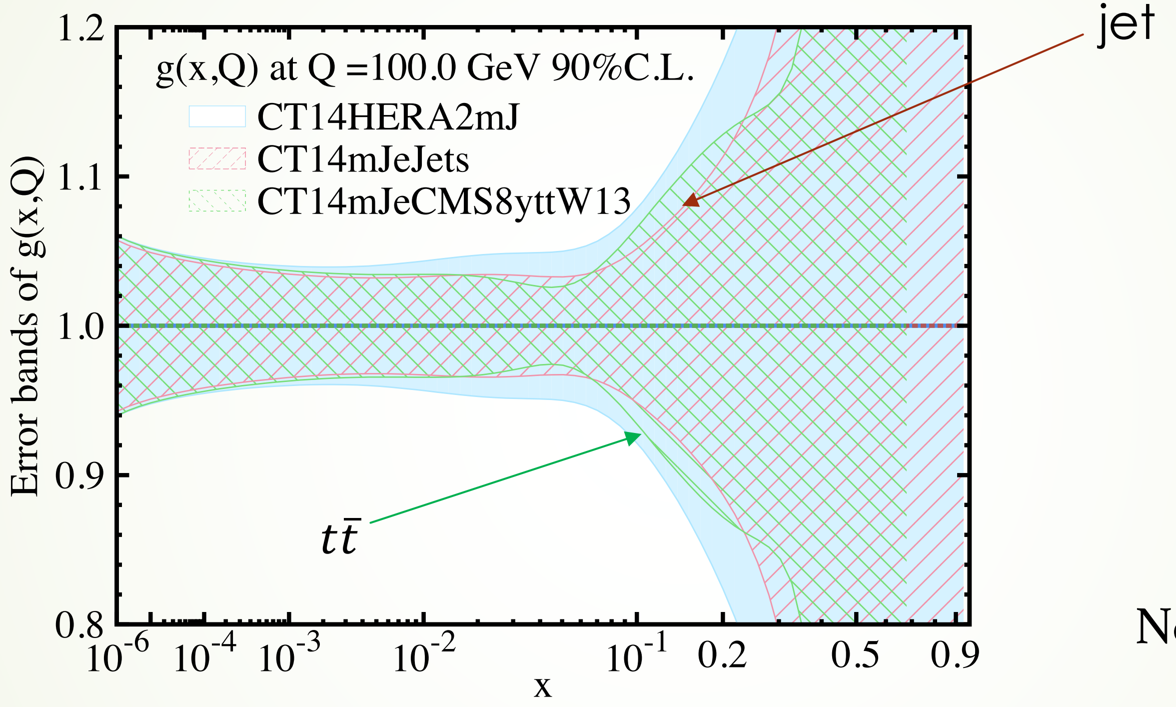
Roughly,

More data points ⟷ Increase WEIGHT

$$\text{Weight of } t\bar{t} = \frac{\#\ \text{CMS7}\ jet\ \text{data points}}{\#\ \text{CMS8}\ \ y_{tt}\ \text{data points}} = \frac{133}{10} \approx 13$$

Suppose higher integrated luminosity

Weight of $y_{t\bar{t}}$ =13.



- Given higher luminosity, $t\bar{t}$ has the potential to **constrain gluon PDF** as much as jets.
- $t\bar{t}$ is **NOT** sensitive to the same x region as jets. It's constraining **large x region** more than jets.

Not the same information as jets !

For $\sigma(gg \to h)$ at 13 TeV at LHC

without jet data

CT14HERA2mJ

42.1 $\pm$ 2.0 pb

Jets → 42.7 $\pm$ 1.5 pb

CMS 8TeV $t\bar{t}$ weight = 13 → 43.50 $\pm$ 1.48 pb

Conclusion and Prospects

- NOTE: `ePump` is not meant to replace global fit.
- But it's a convenient tool to QUICKLY analyze the effects of new/old data, and also pseudo-data!
- In the stage of high-luminosity LHC, `ePump` will certainly play an important role in studying PDFs.