LPCC

LHC Physics Centre at CERN

Top quark production at the LHC as a gluon luminometer

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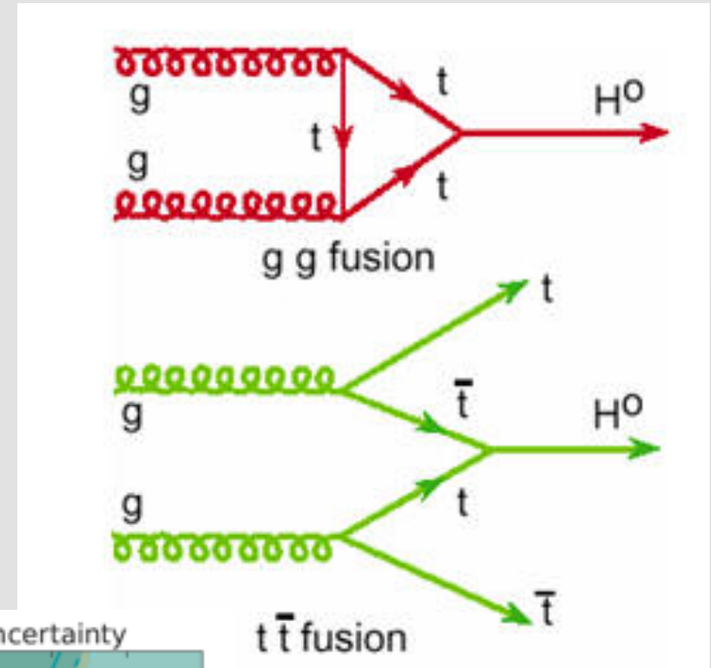
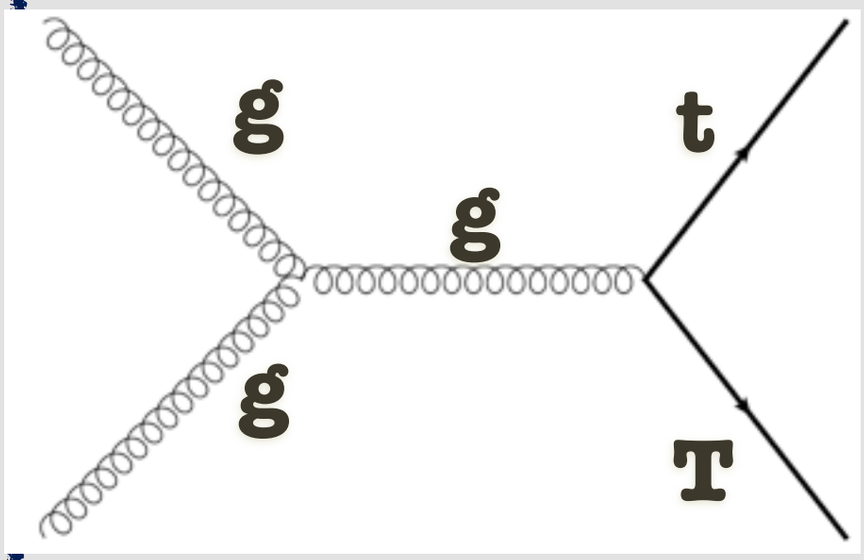
Top quarks as gluon luminometers

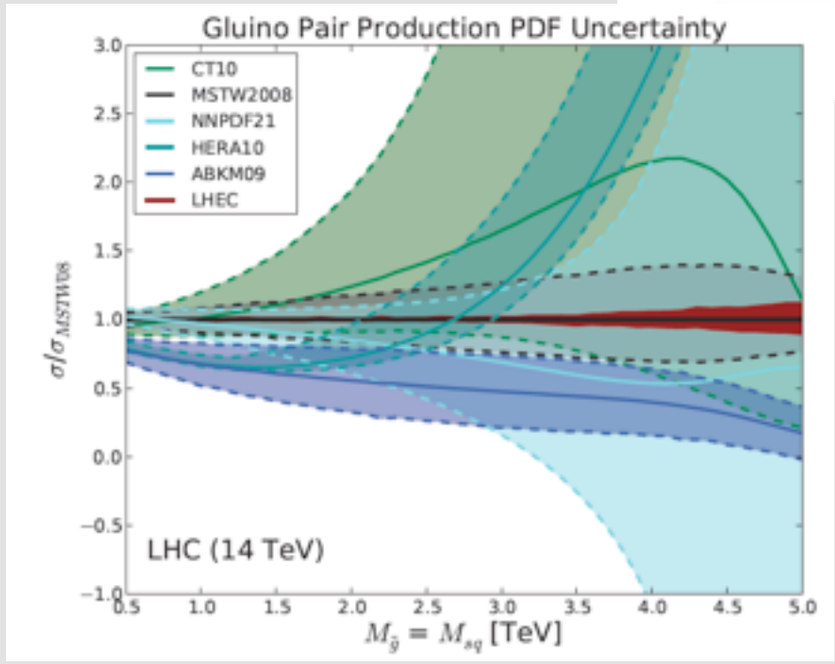
- The knowledge of **the gluon PDF is essential for LHC phenomenology**, in particular for **Higgs characterization**, but also in **many BSM models** (gluinos, KK gravitons,....)

- Top quark pair production is **directly sensitive to the gluon luminosity**, thus provides a potential new observable to constrain gluons in **global PDF analysis**

gluon driven Higgs production







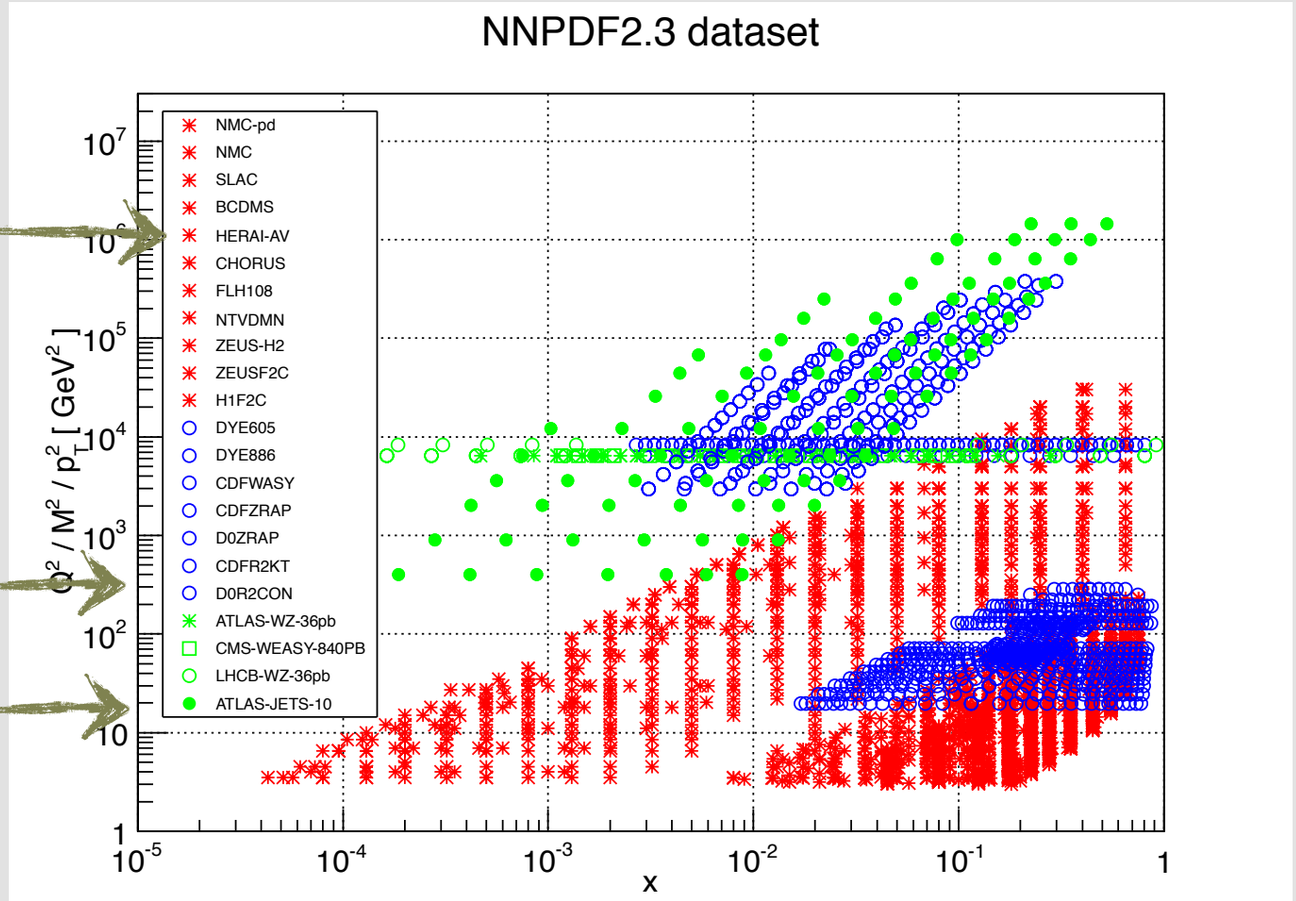
PDF error in heavy gluino xsec

Why tops for the gluon?

- Modern PDF analysis constrain the gluon **directly** from the **inclusive jet** cross section, and **indirectly** via **scaling violations** of deep-inelastic data. Also photons have been explored (arxiv:1202.1762).

- However jet and photon data, though very valuable, are affected by several **experimental** (JES, hadronization) and **theoretical** (missing NNLO corrections) issues

- Given the relevance of the gluon PDF at the LHC, a **complementary direct measurement** of it is of utmost importance



- Top quark pair production is a potential alternative: **NNLO calculation** soon available, l**arge statistics**, systematic errors getting smaller .....

- Top quark production **probes the gluon at medium and large-x**, very similar to the jet kinematics

- At the LHC, the cross section is **gg** dominated in all relevant kin regions

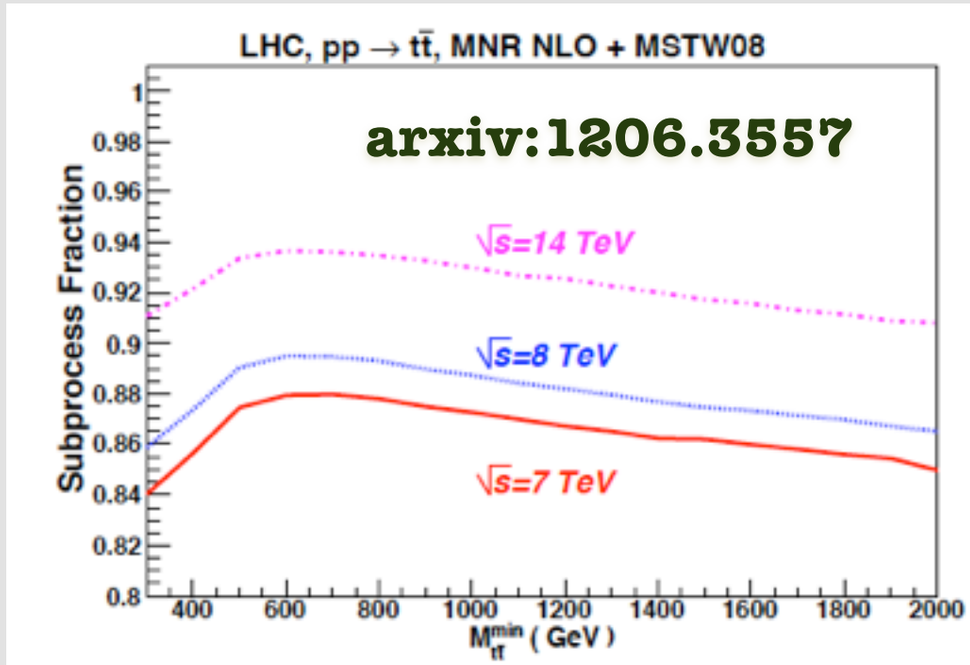
- **NNLO** will also be available for **differential distributions** in medium term

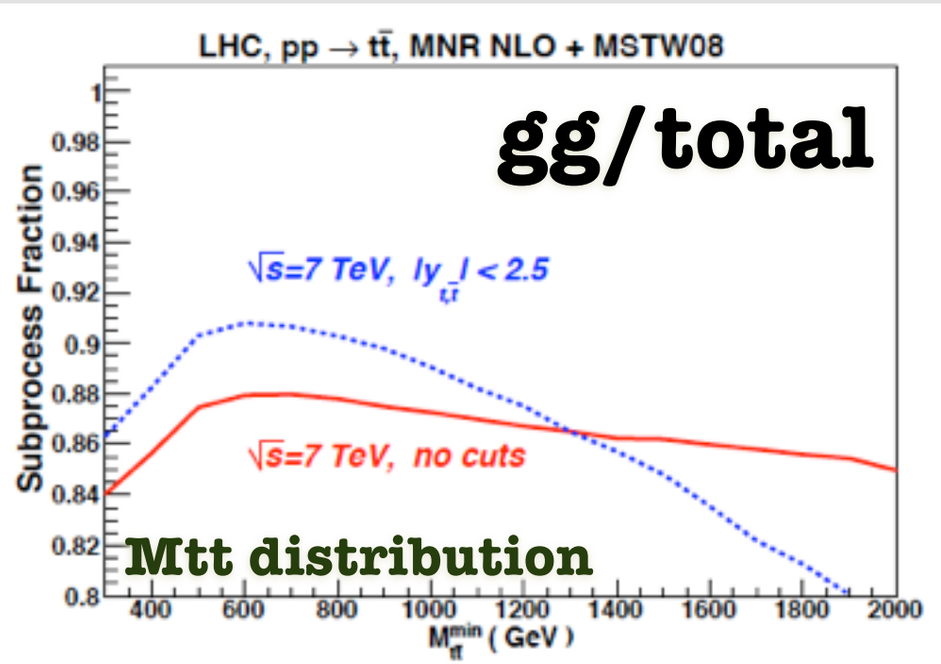
- **Fast NLO codes** for ttbar production already available: **MCFM+APPLgrid**

Top quarks as gluon luminometers

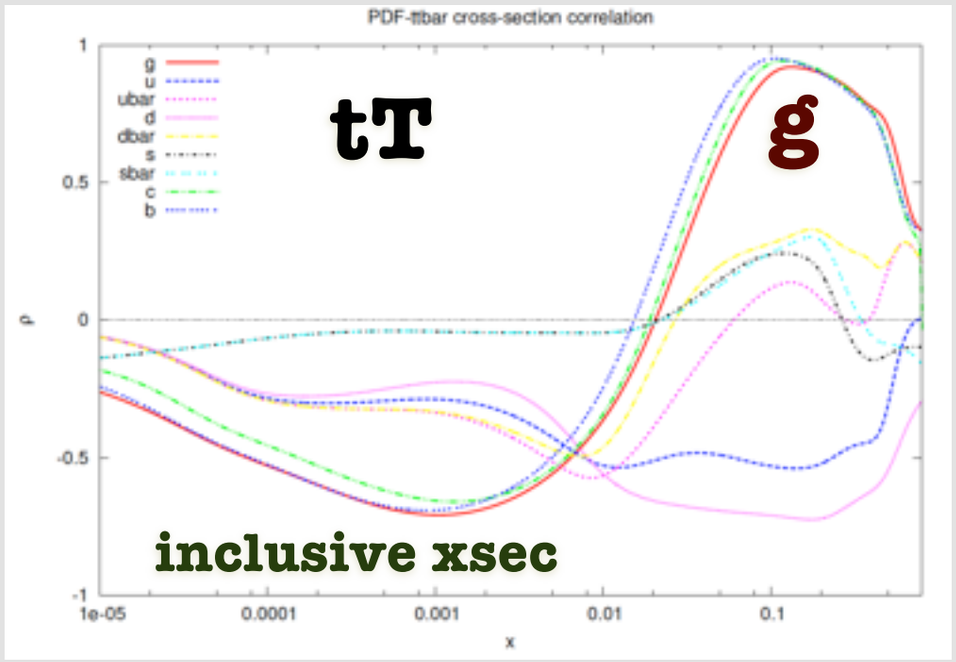
- At the **LHC**, top quark pair production is ***gg* dominated**, probing gluons at **medium and large x**. Both for the **inclusive cross-section** and for **differential distributions**

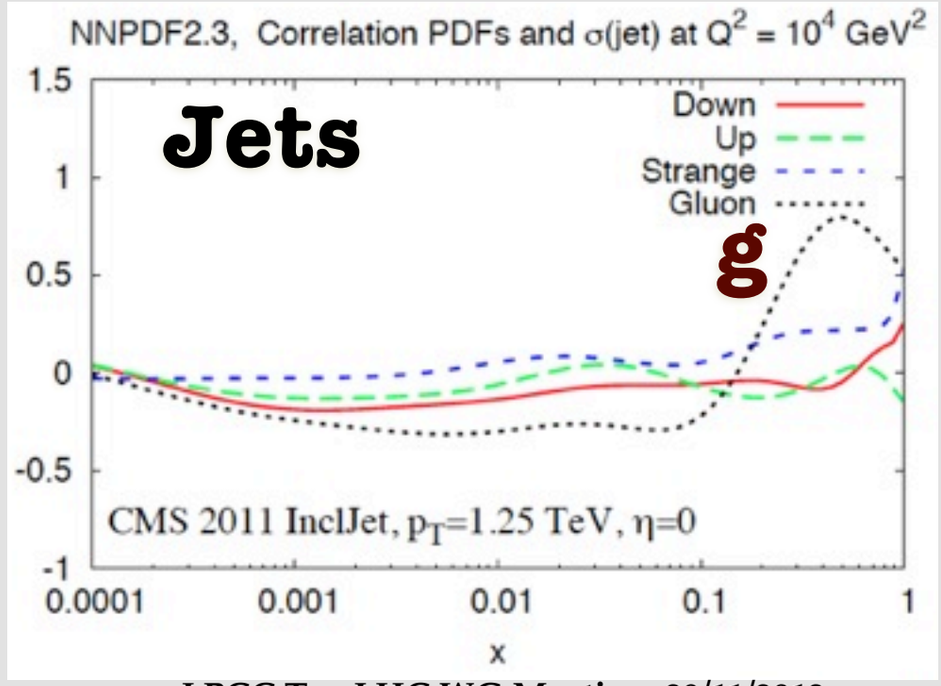
- Maximum sensitivity for ***x* around 0.1**: similar to jet production





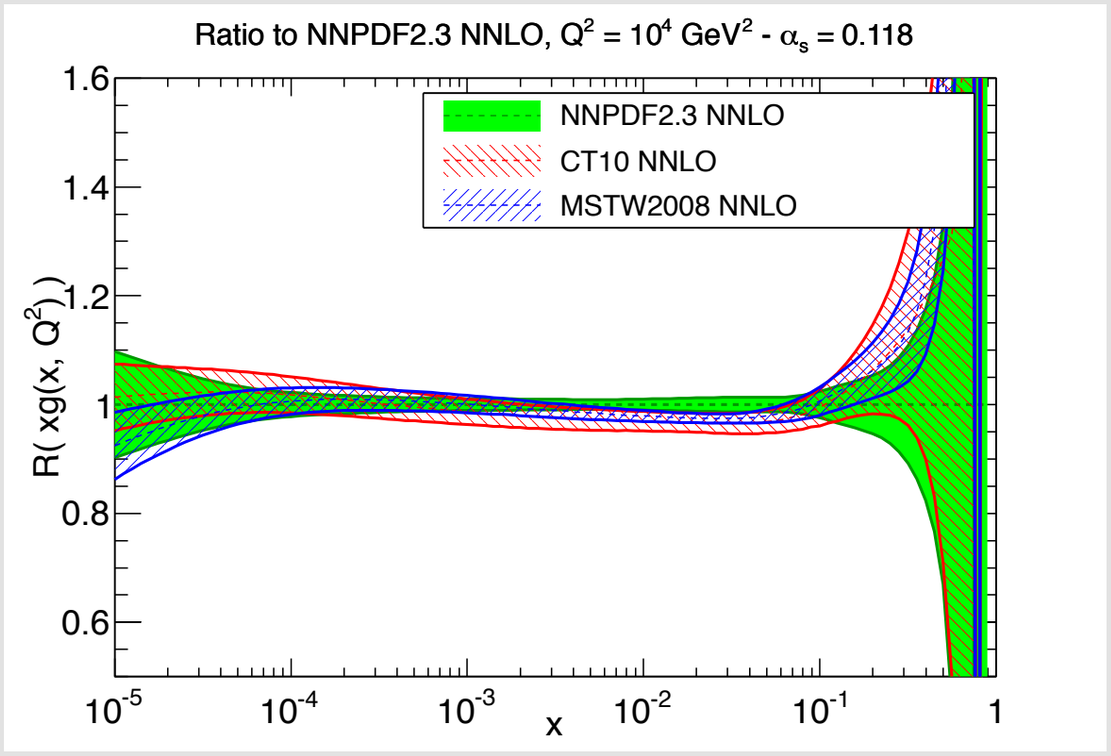
PDF - xsec Correlations

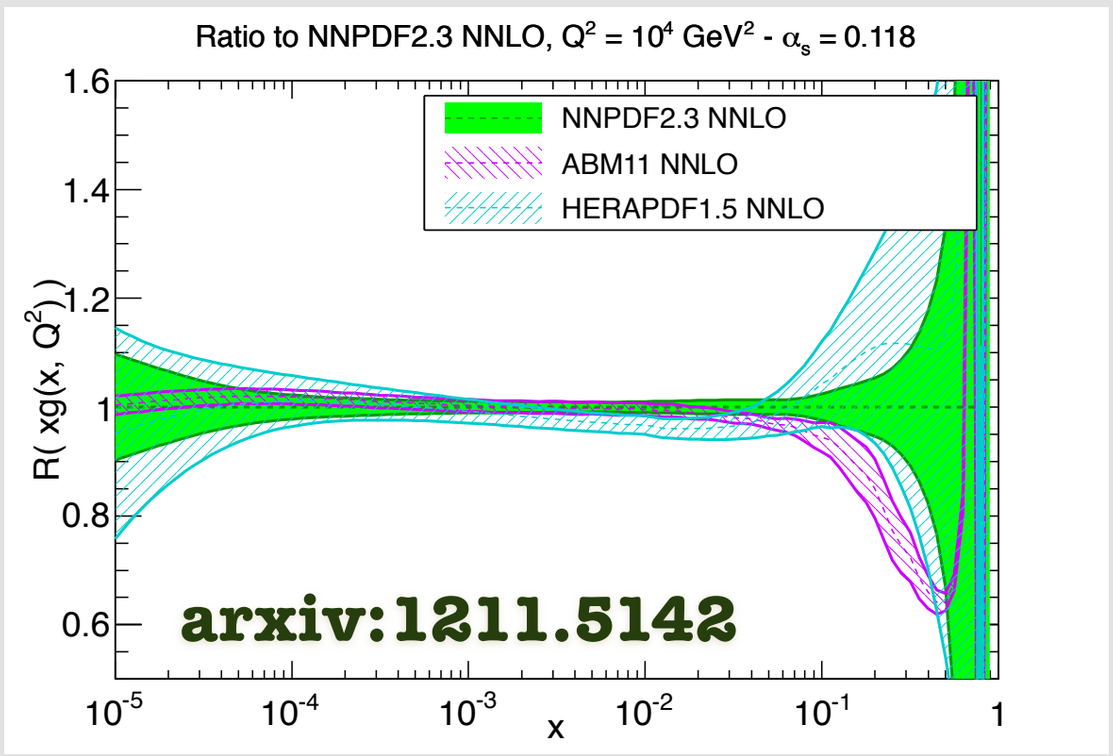


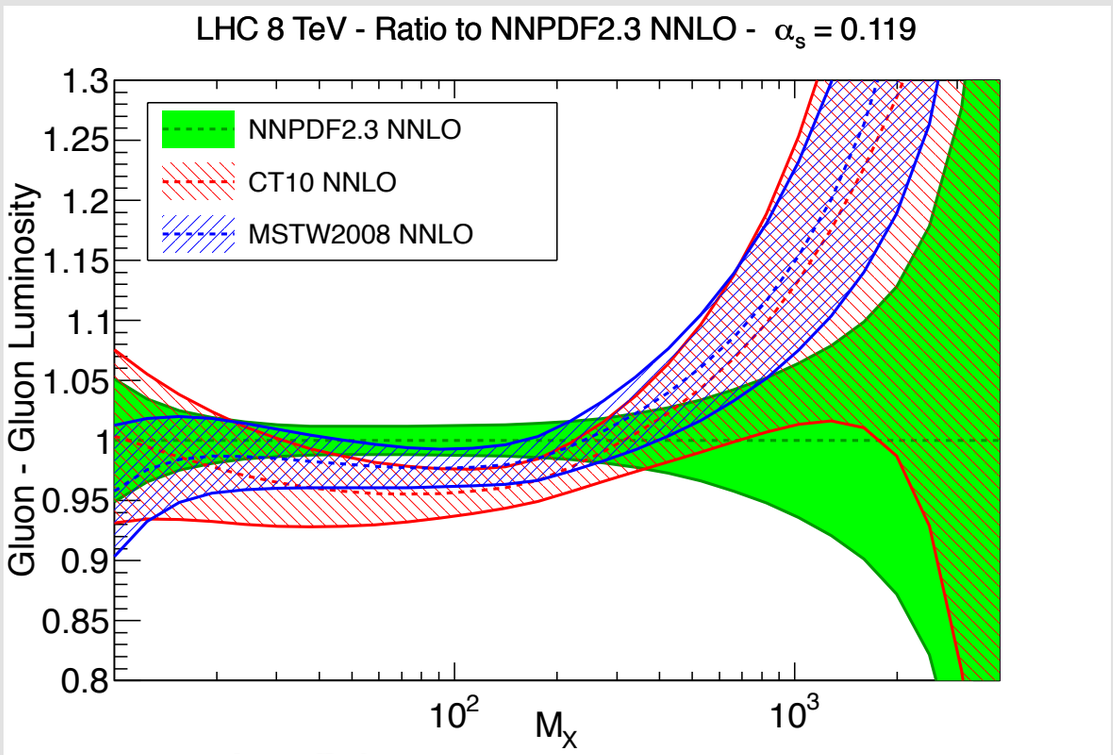


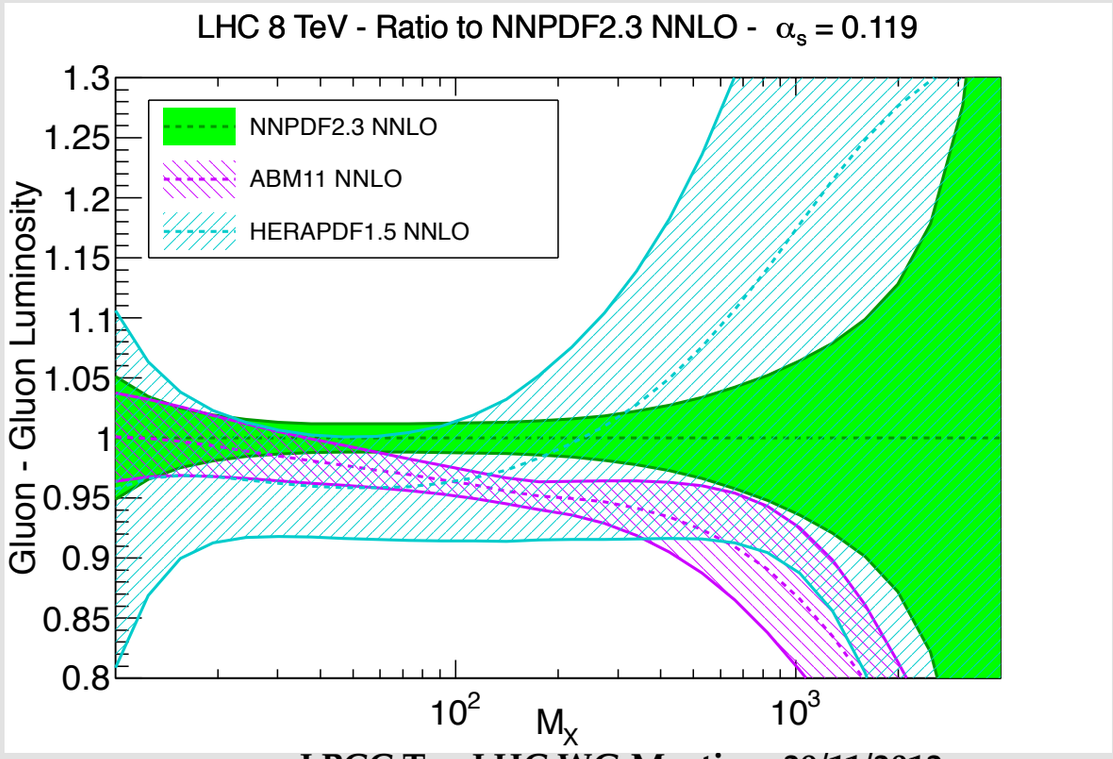
Gluon PDF

- Different PDF sets yield **different gluon PDFs**, sometimes differing more than nominal PDF uncertainties: need **LHC data** to discriminate between them



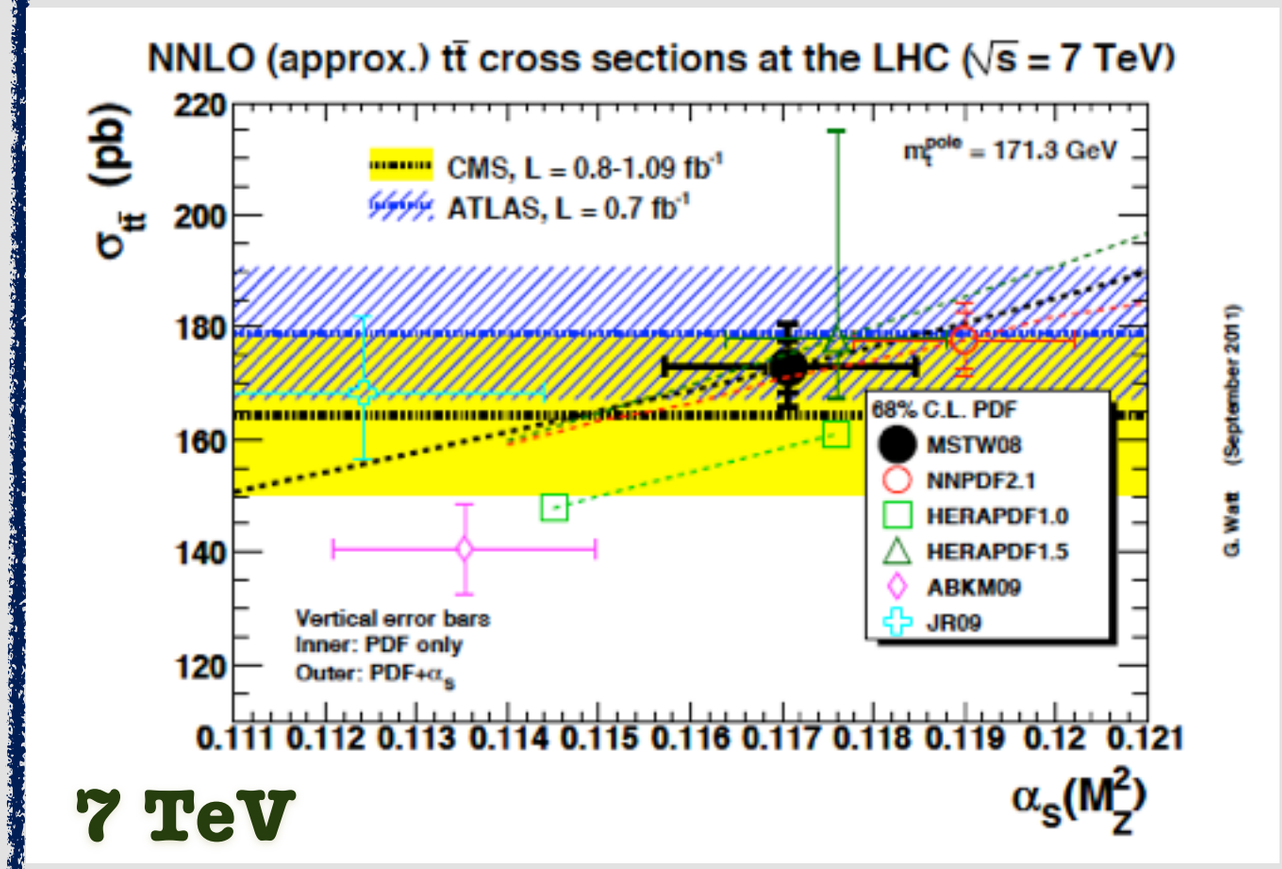




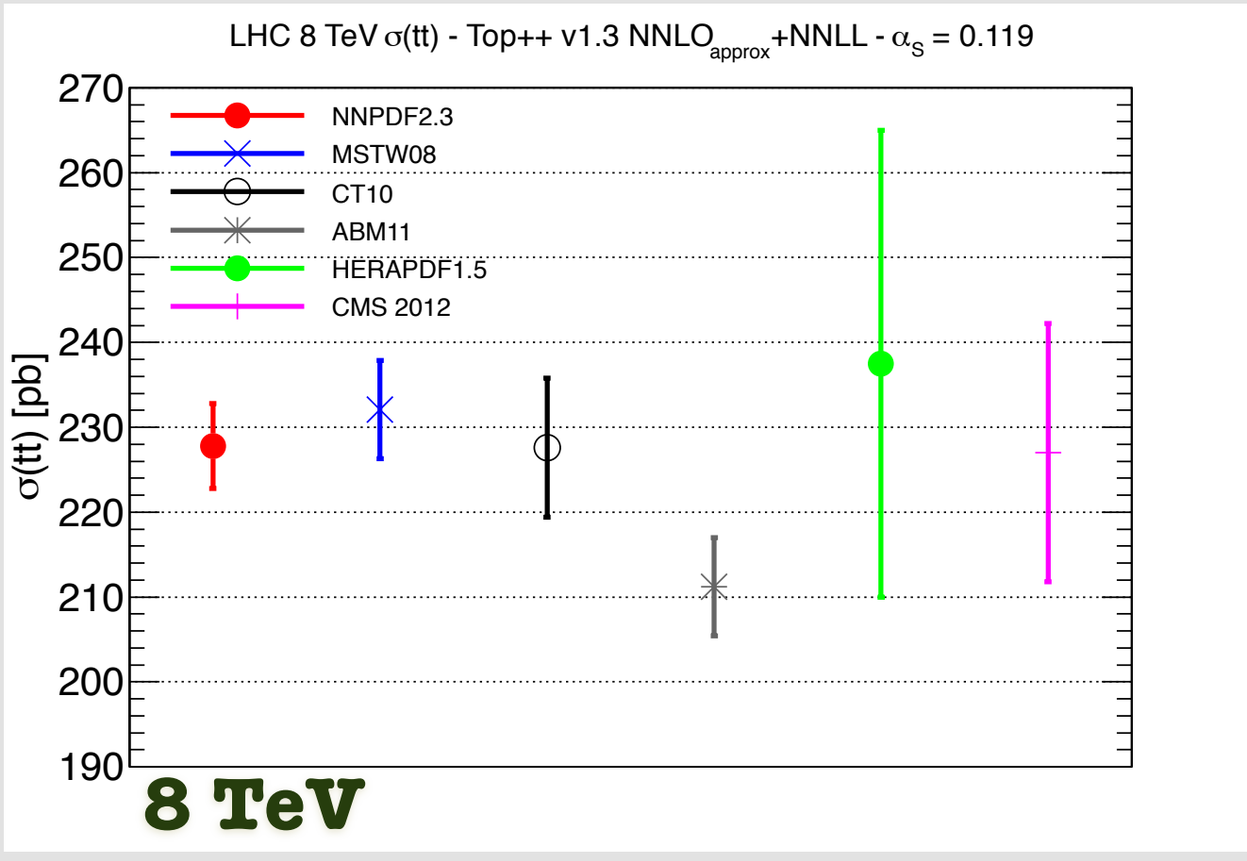


LHC data - Inclusive rates

- Results from ATLAS and CMS for **total inclusive cross sections** are available at 7 and 8 TeV
- Data is already **favoring/disfavoring some PDF sets** - but the real discrimination power requires differential measurements
- The **PDF uncertainty** could become the **dominant systematic error** once the full NNLO becomes available
- ABM11 with their default α_S**=0.1134** in poor agreement with top data (softer gluon)



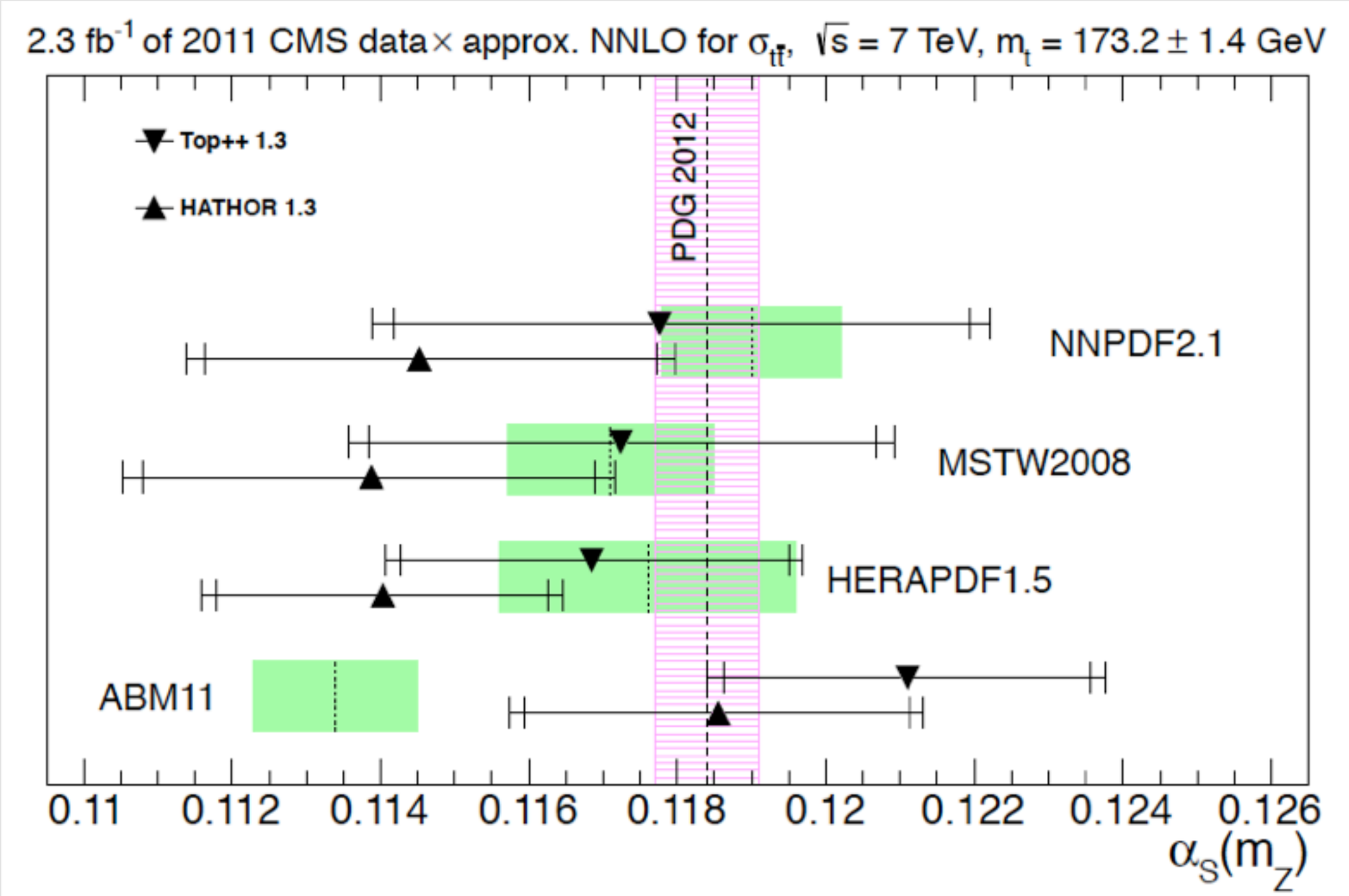
arxiv:1201.1295



arxiv:1211.5142

$\alpha_S(M_Z)$ from top data

LHC top data **disfavor small values** of α_S. Sensitivity justifies **direct extraction from cross section** (CMS-TOP-12-022). Systematic theory errors improved as compared to jets (smaller scale uncertainties)



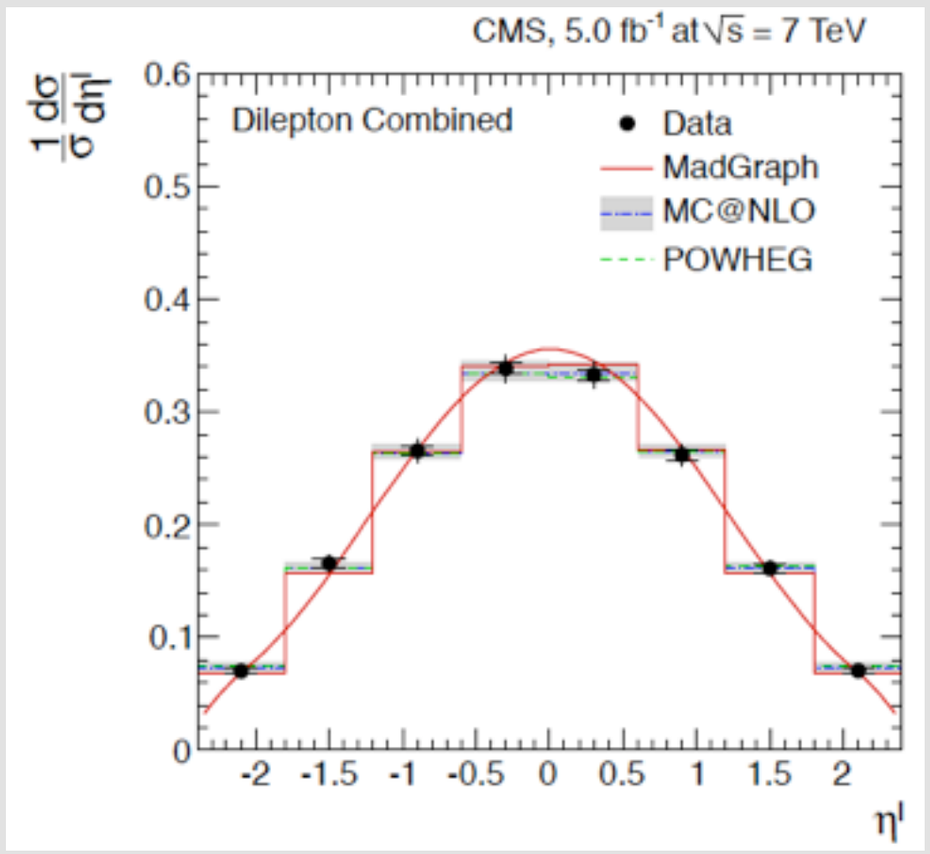
Differential Top Distributions

- On top of inclusive top cross sections, ATLAS and CMS have also measured **differential distributions** of top quarks and their decay products

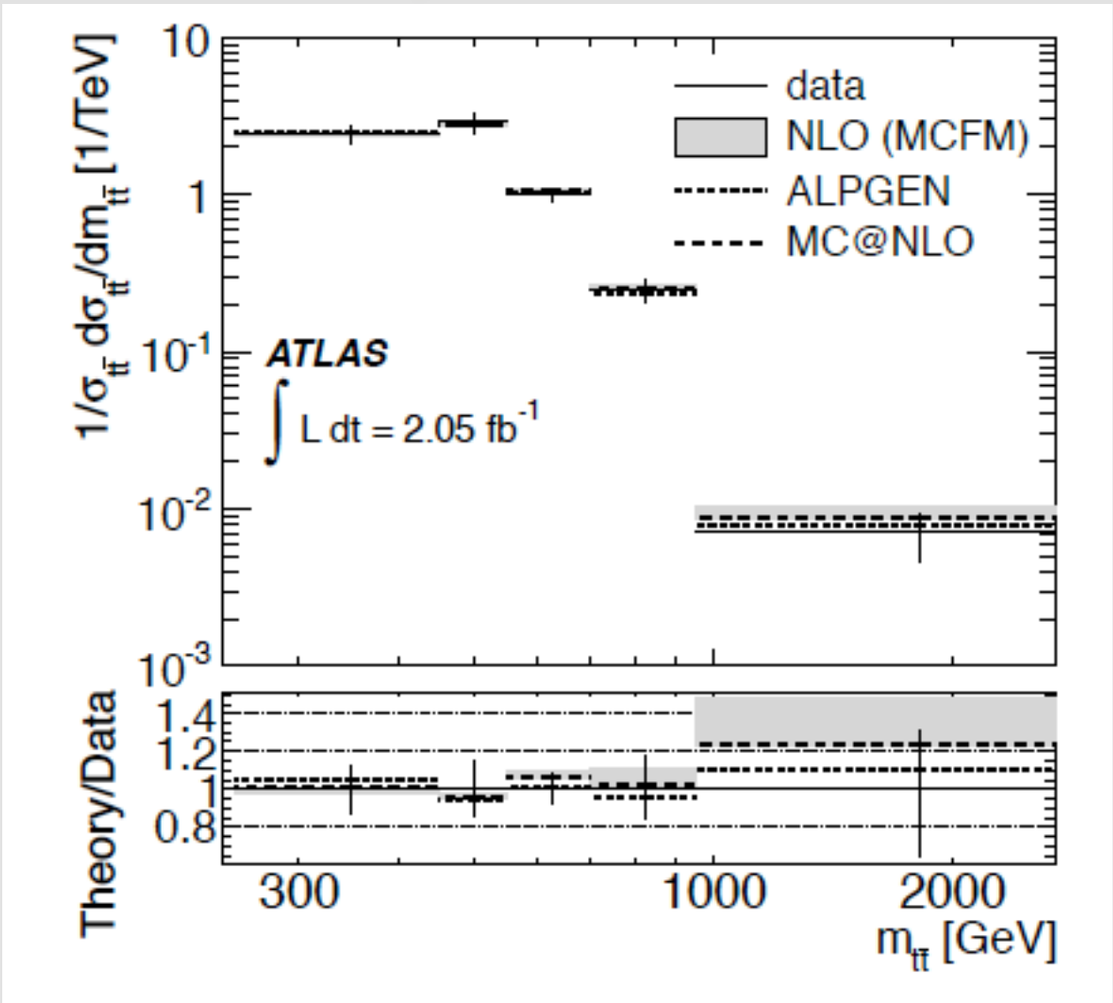
- For PDF analysis, only differential distributions with the **full experimental covariance matrix** can be used for gluon constrains. Provided in the 7 TeV ATLAS and CMS papers!

- **Lepton/jet level distributions** preferred over **reconstructed top distributions:** much cleaner experimentally, and no loss of accuracy from the theory point of view

CMS, arxiv:1211.2220



ATLAS, arxiv:1207.5644



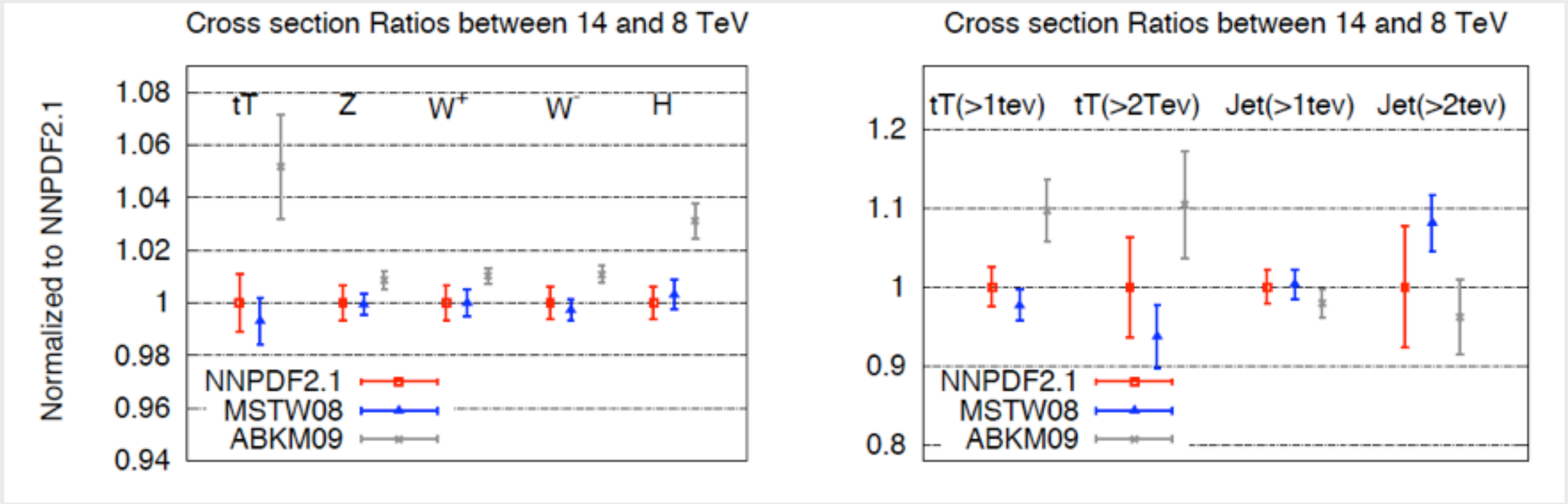
Cross section Ratios between 7, 8 and 14 TeV

- The **staged increase of the LHC beam energy** provides a new class of interesting observables: **cross section ratios** for different beam energies

$$R_{E_2/E_1}(X) \equiv \frac{\sigma(X,E_2)}{\sigma(X,E_1)} \qquad R_{E_2/E_1}(X,Y) \equiv \frac{\sigma(X,E_2)/\sigma(Y,E_2)}{\sigma(X,E_1)/\sigma(Y,E_1)}$$

- These ratios can be computed with **very high precision** due to the large degree of **correlation of theoretical uncertainties** at different energies. **Experimentally** these ratios can also be measured accurately since many systematics **cancel partially in the ratios**

- These ratios allow **stringent precision tests of the SM**, like **PDF discrimination. Ratios of Top quark production** (both inclusive and large Mtt distributions) specially useful.



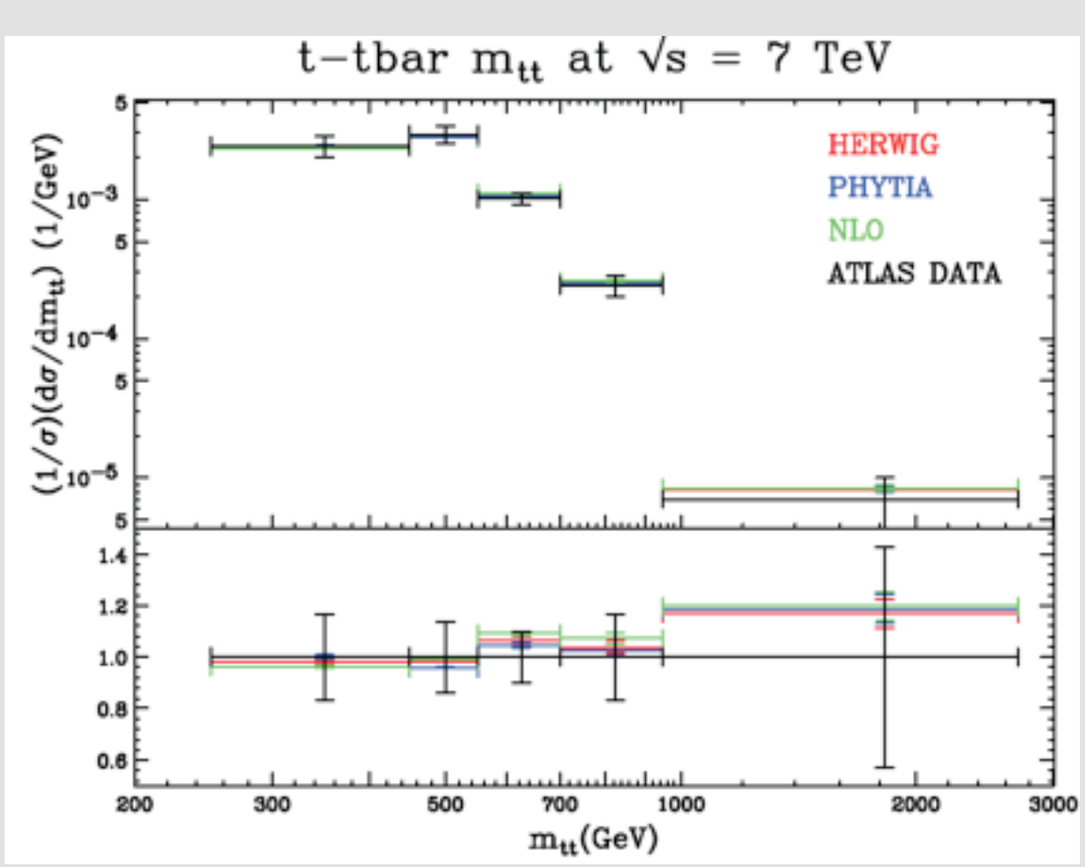
M. Mangano, J. Rojo, arXiv:1206.3557

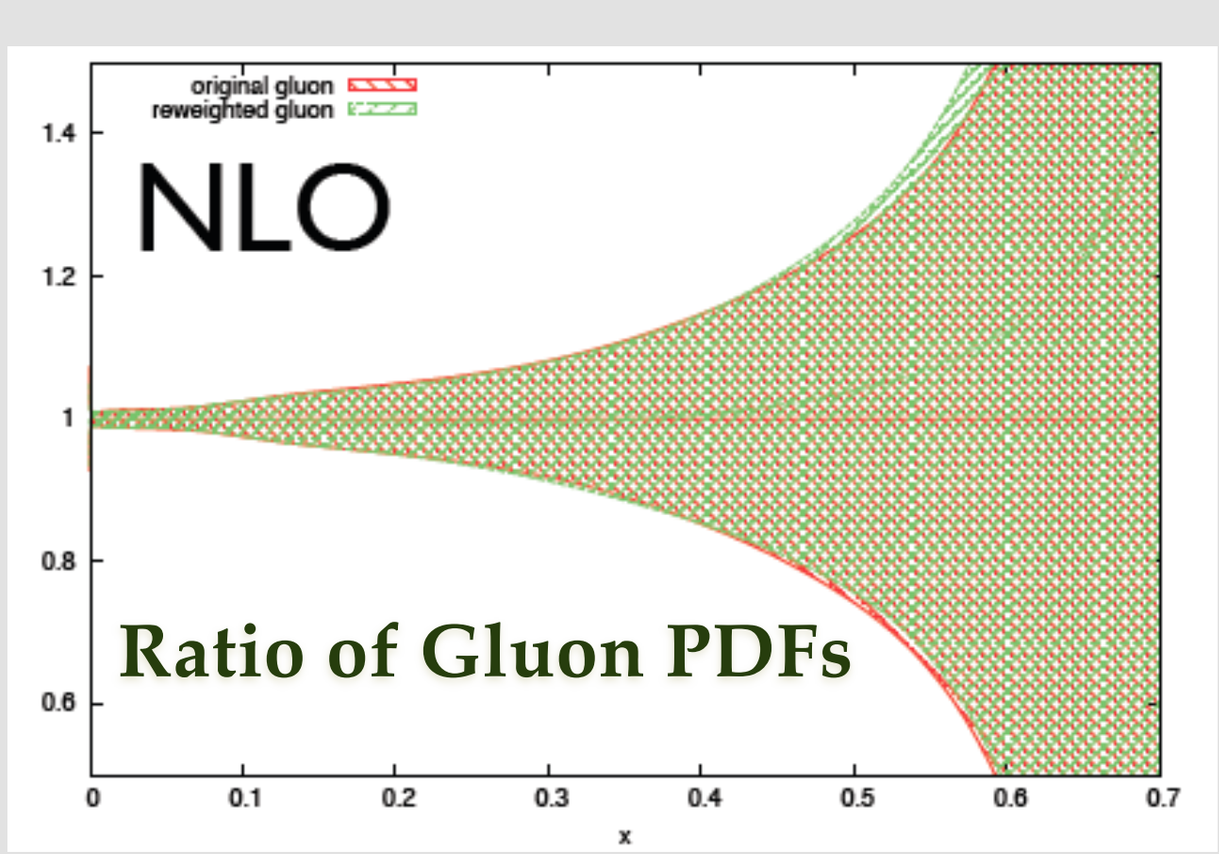
PDFs with Top data

- A first study of the potential of top data for PDF fits has been performed using **aMCatNLO** to generate **ttbar events**, both at **NLO** and **NLO+PS** (for Herwig and Pythia), and feed them into the **NNPDF analysis**

- We have used the **ATLAS differential distributions** (1207.5644) which provide the full covariance matrix

- Current data does not seem to be accurate enough to reduce the gluon PDF uncertainties, but **future, more precise data**, should provide more stringent constraints

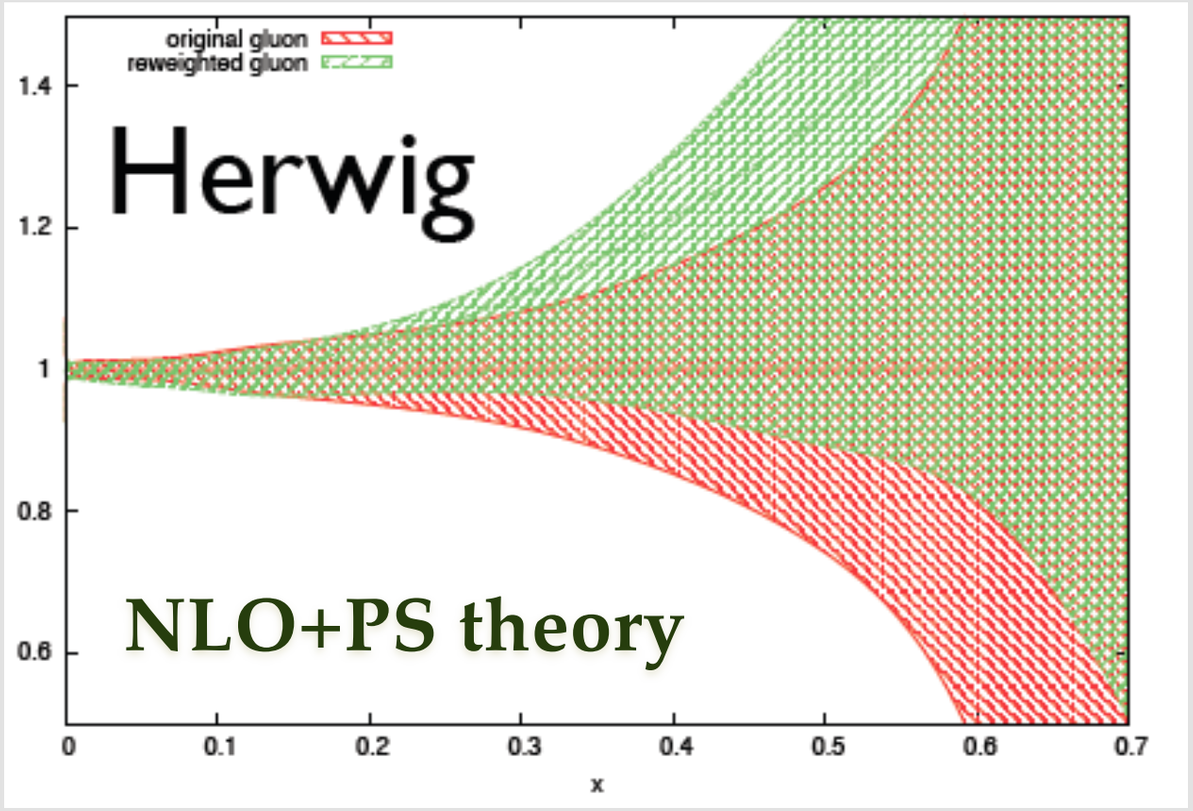


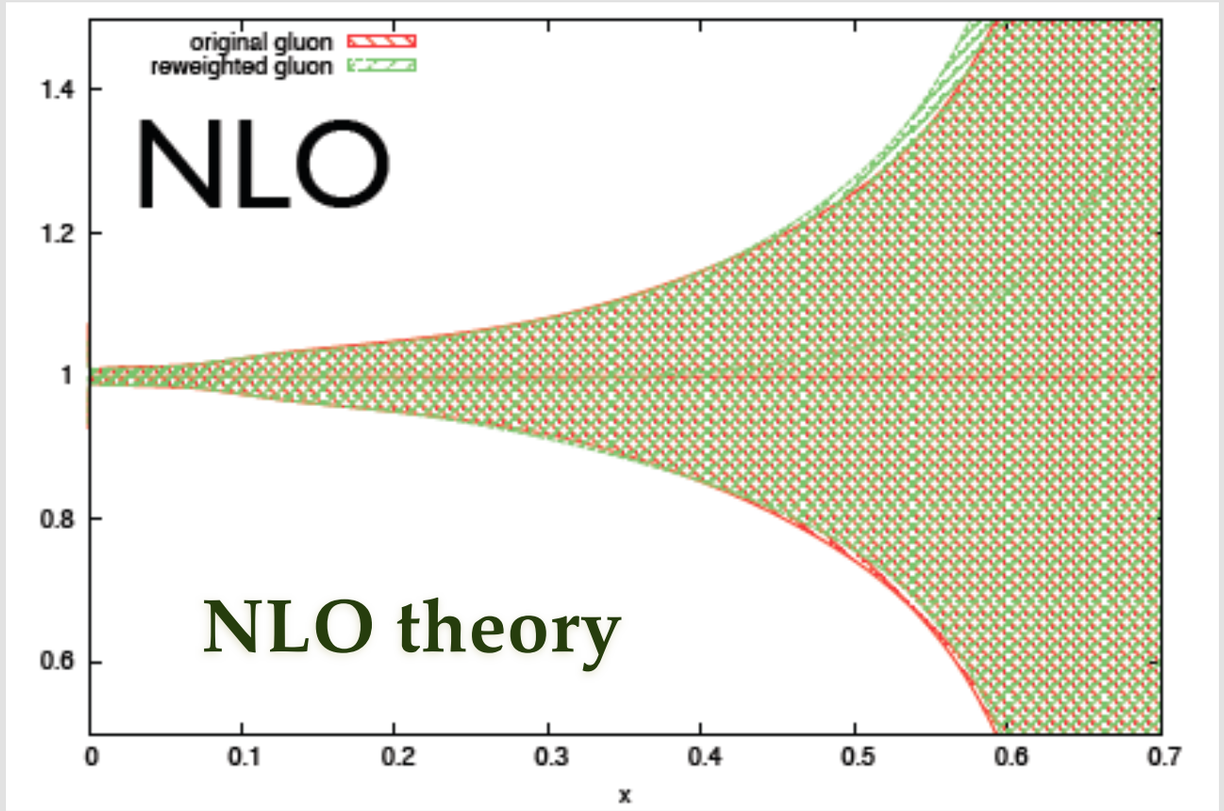


V. Bertone, S. Frixione, M. Mangano, J. Rojo, Preliminary

PDFs with Top data

- We also compare the differences extracting the gluon PDFs from top data when we use **NLO** theory and **NLO+PS** theory
- Preliminary results (both with Pythia and Herwig) seem to suggest that **NLO+PS** might prefer a **somewhat harder gluon at large-x** than **NLO**
- What are the best PDFs to be used in the context of **NLO+PS** event generators? Under investigation .....

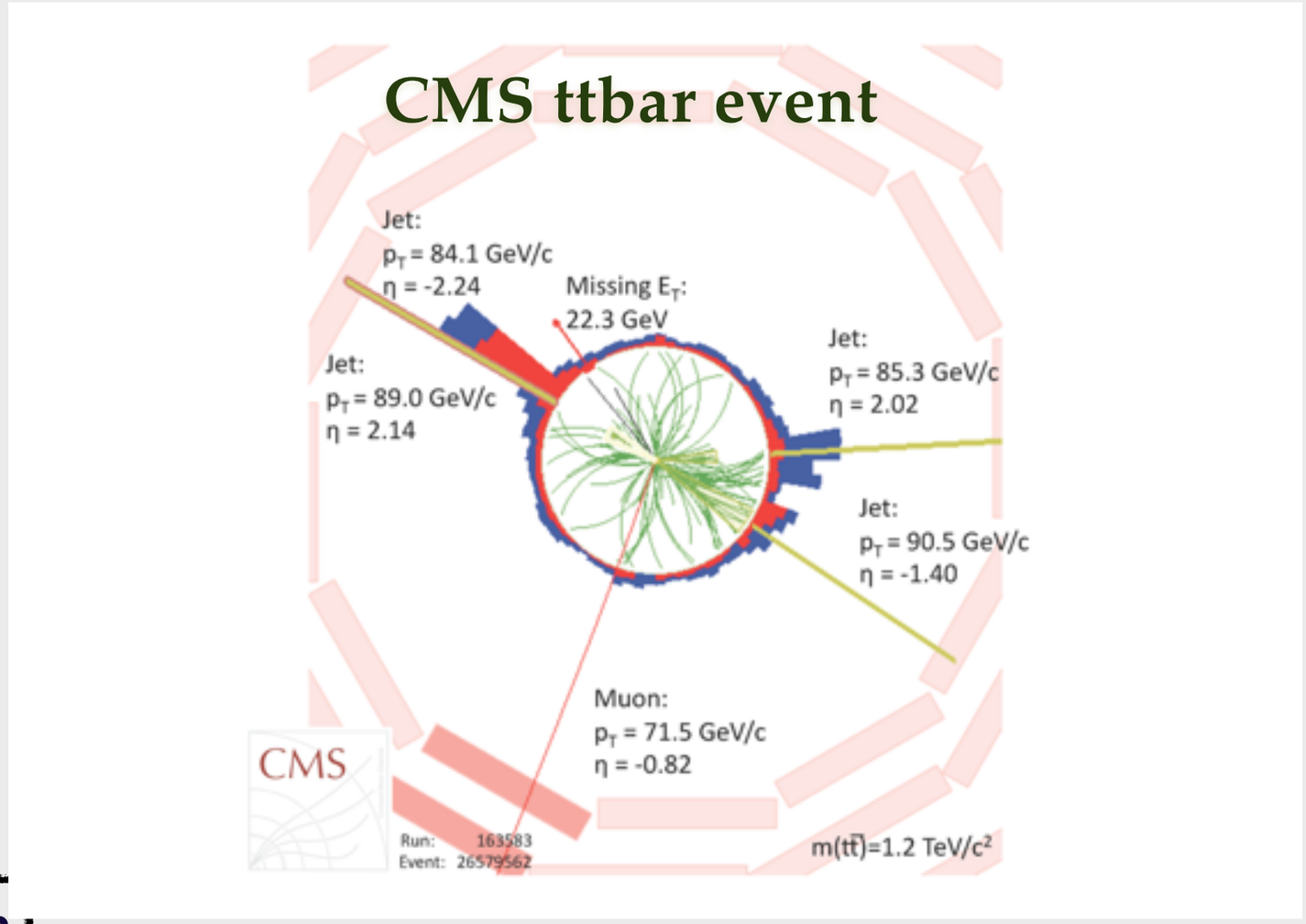




V. Bertone, S. Frixione, M. Mangano, J. Rojo, Preliminary

Summary and outlook

- The knowledge of the **gluon PDF** is essential for **LHC phenomenology**
- Top quark pair production provides a **possible cleaner alternative to jet data** as a **gluon luminometer** at the LHC
- **Inclusive top data** is already discriminating between PDF sets
- We have all the tools available to include **differential top distributions in PDF fits**



- **Precision measurements of top quark distributions** could provide unique information for **Higgs and BSM physics** at the LHC