

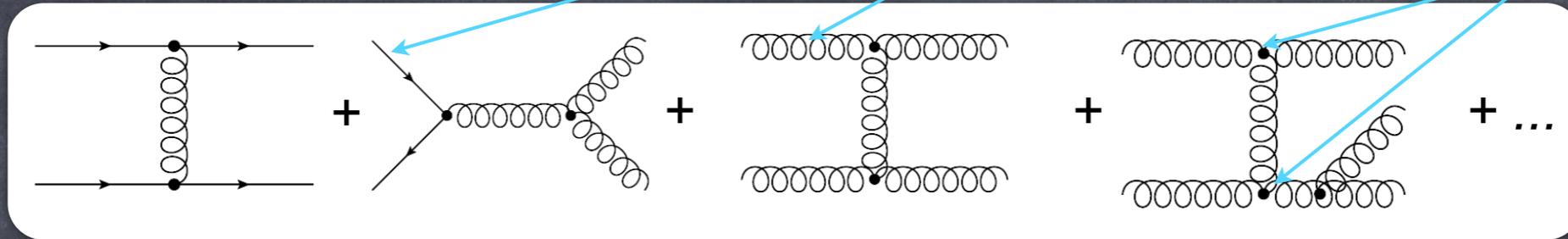
# Multi-differential jet cross sections from CMS

Engin Eren (DESY)  
on behalf of CMS Collaboration

*DIS 2017*  
*Birmingham*

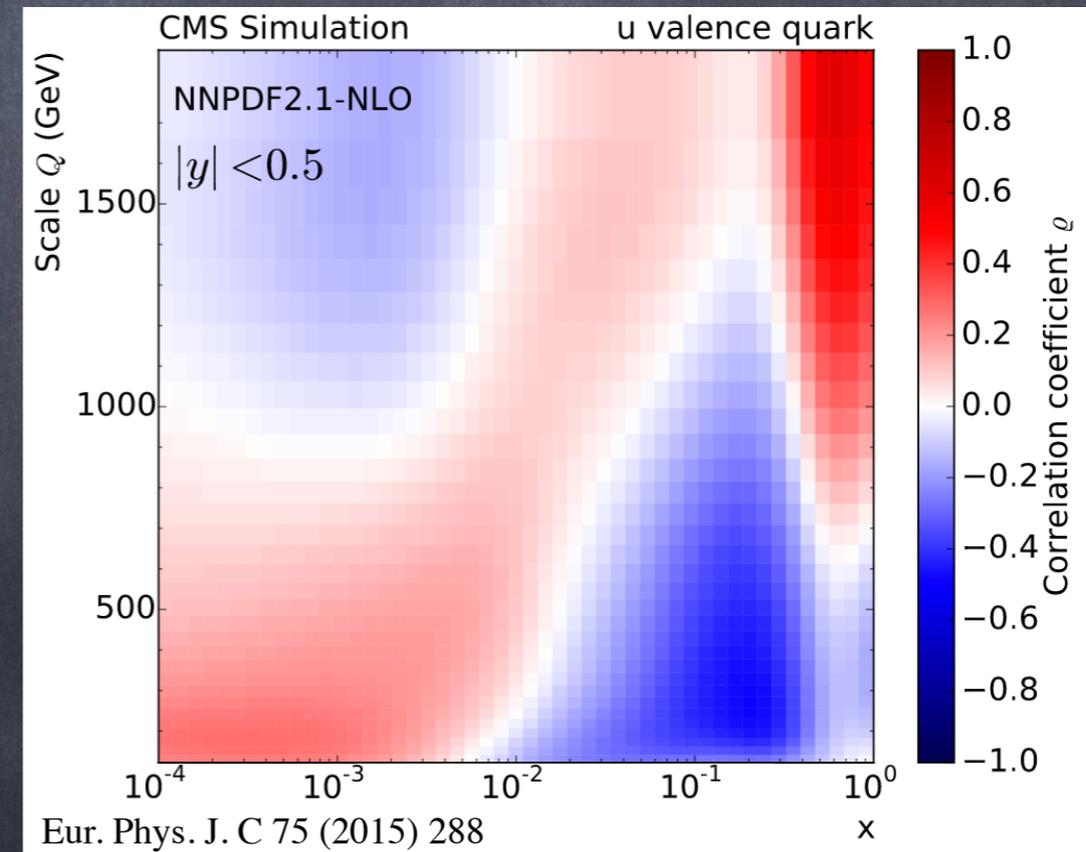
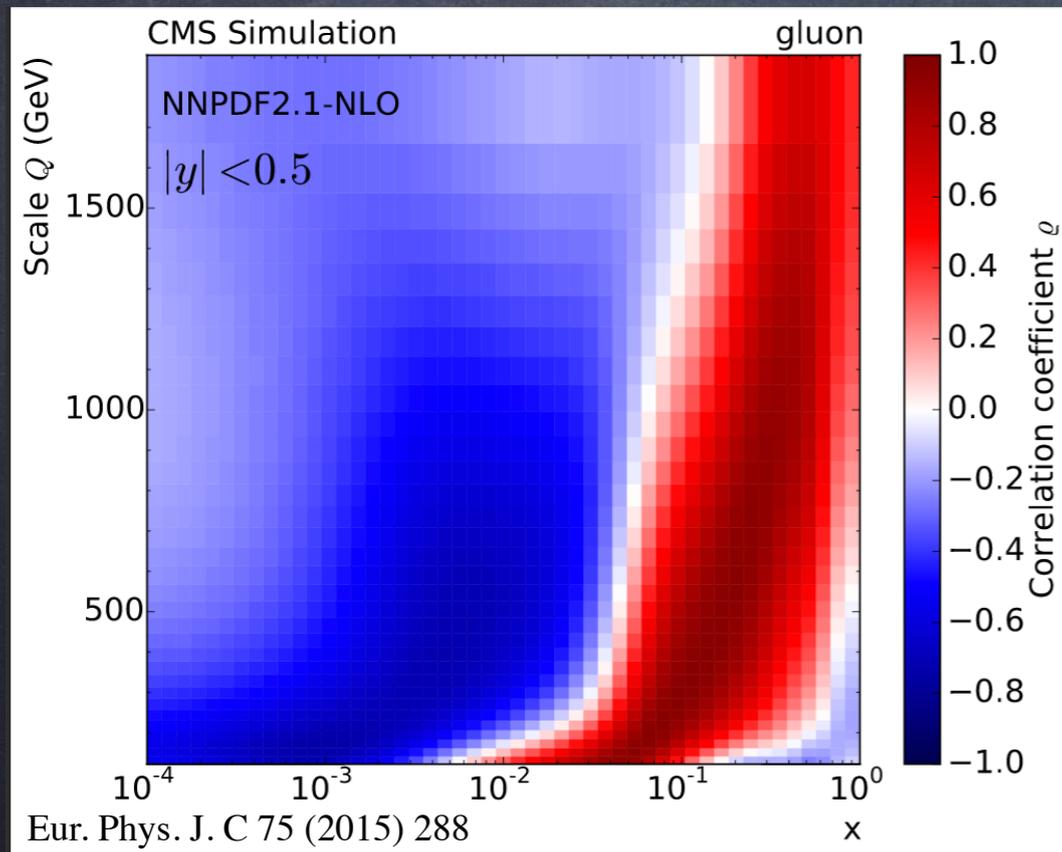
# Probing QCD with Jet Cross Sections

- Jet production sensitive to quark and gluon distributions, and to  $\alpha_s$



Strong correlation between inclusive jet cross section and gluon at high-middle  $x$

Strong correlation between inclusive jet cross section and quark at high  $x$

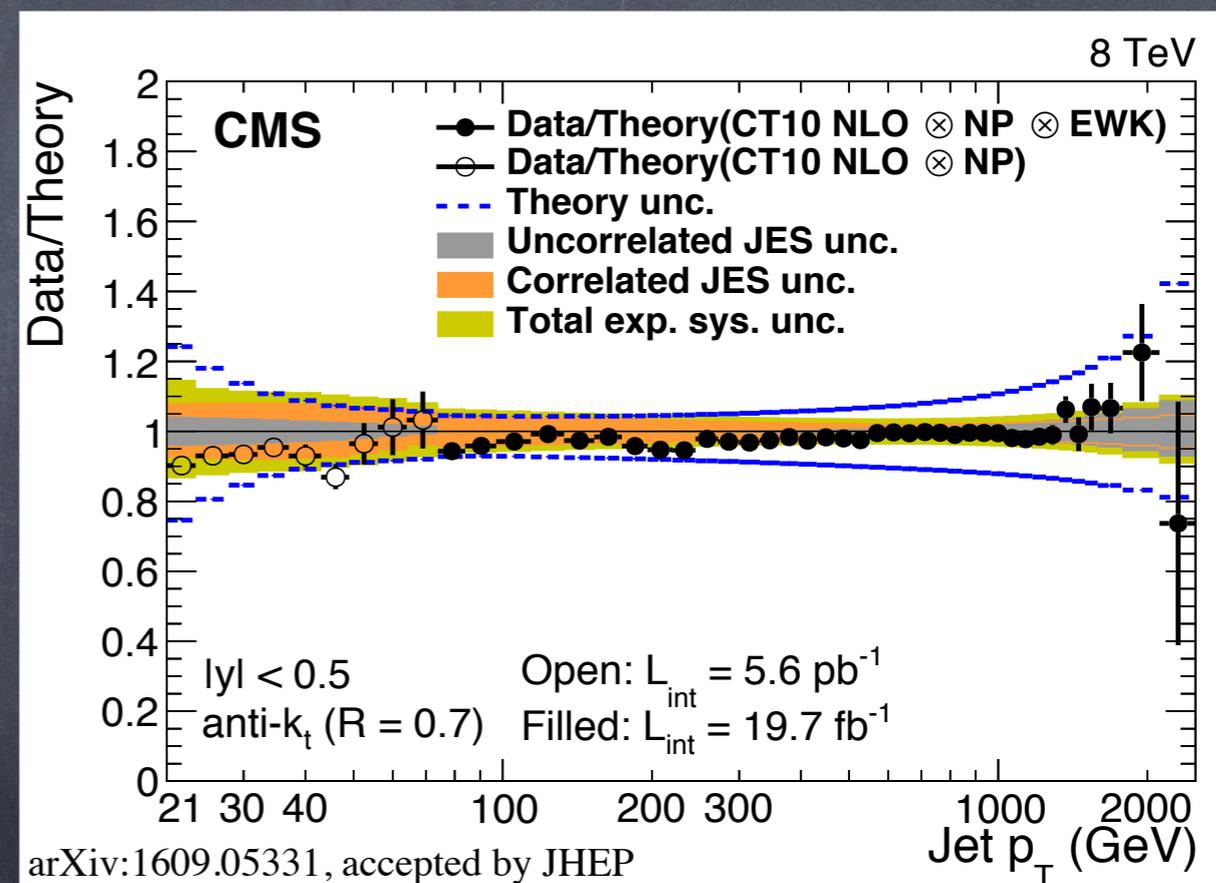
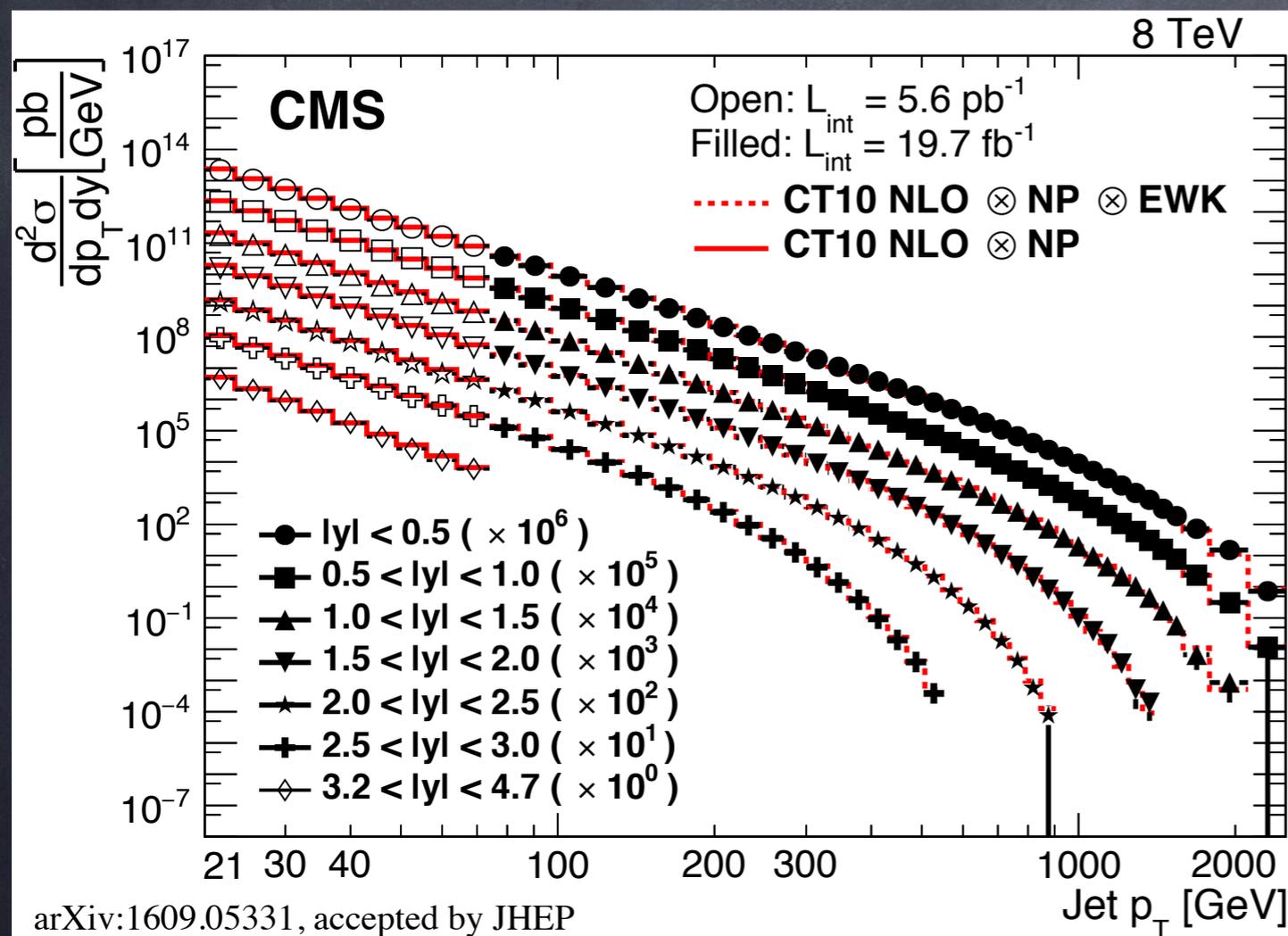


# Inclusive jet measurement @ 8 TeV

- Measurement @ 8 TeV,  $L = 19.7 \text{ fb}^{-1}$  and  $L = 5.6 \text{ pb}^{-1}$ , anti- $k_T$  with  $R=0.7$

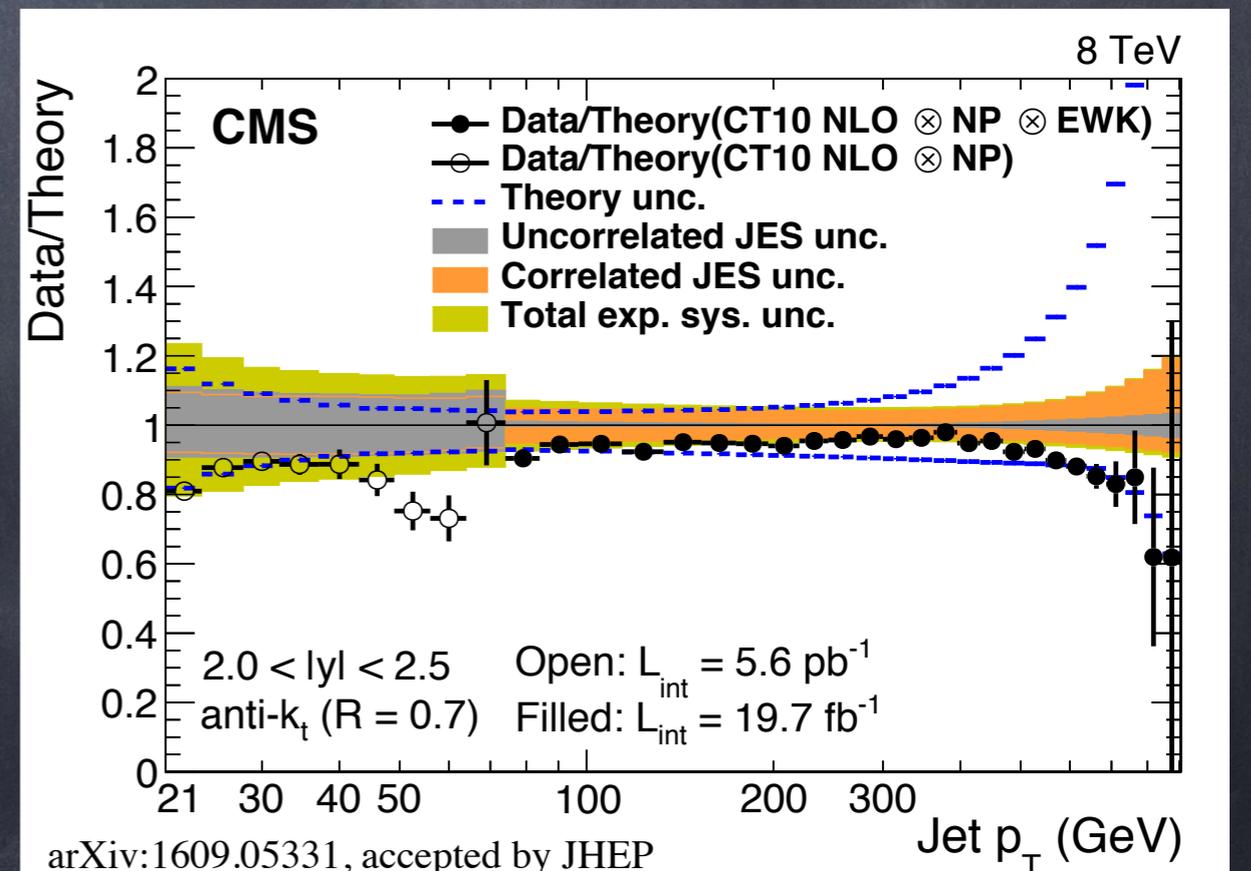
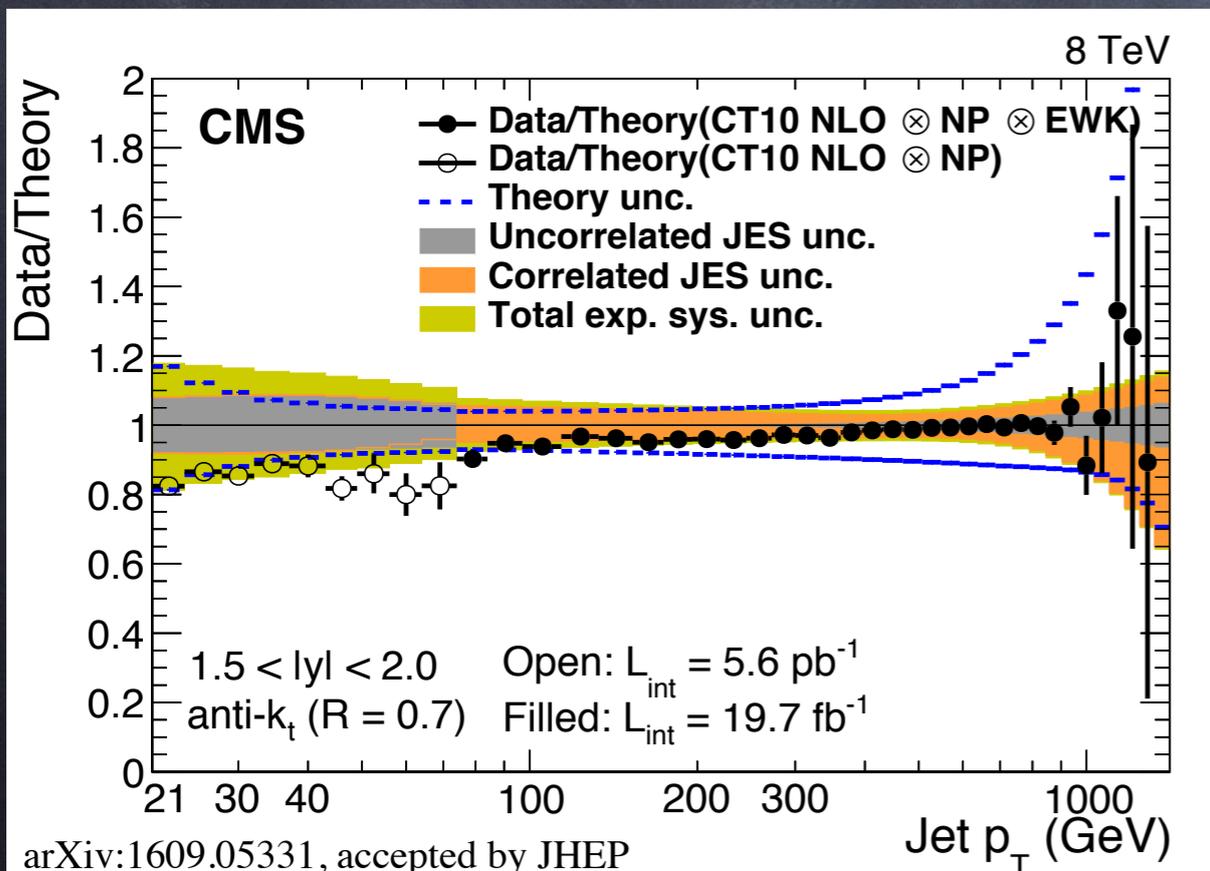
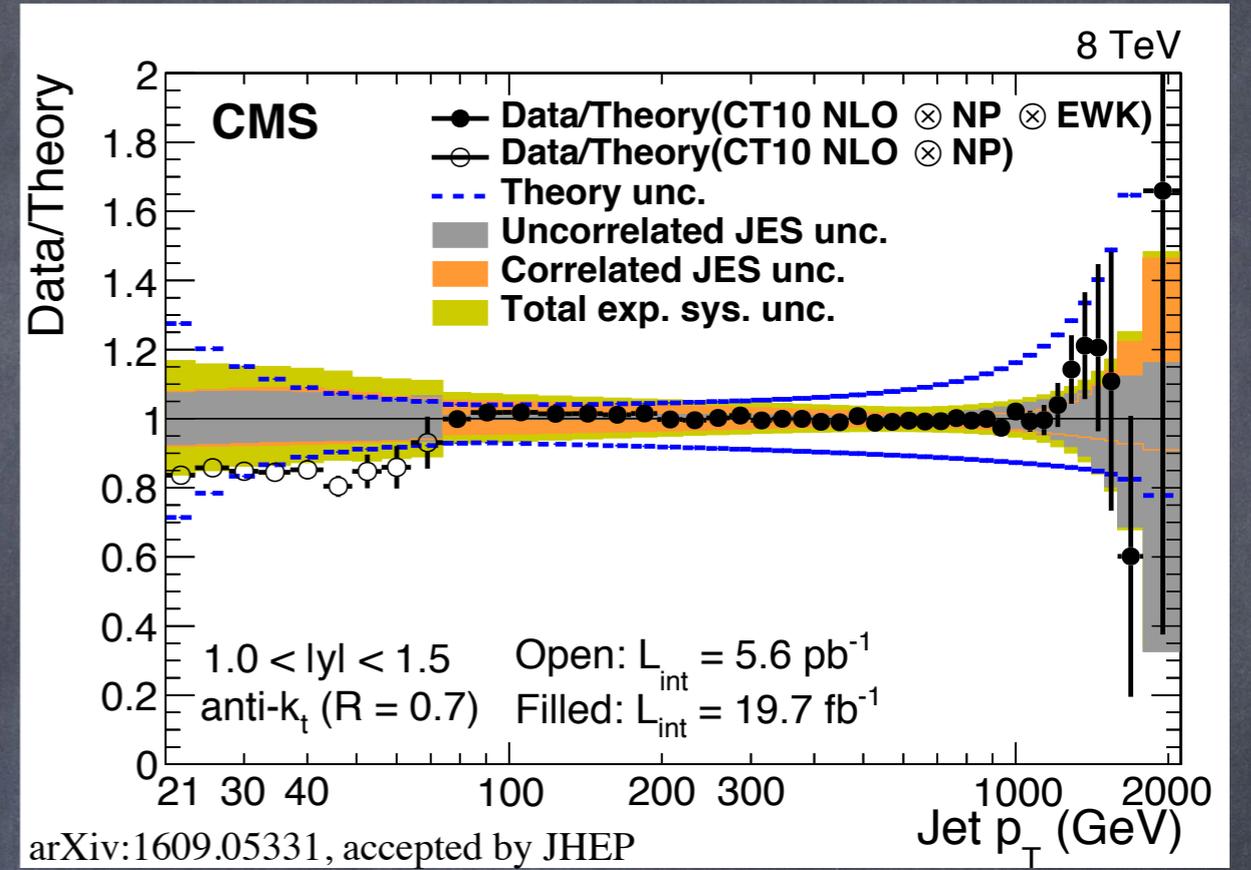
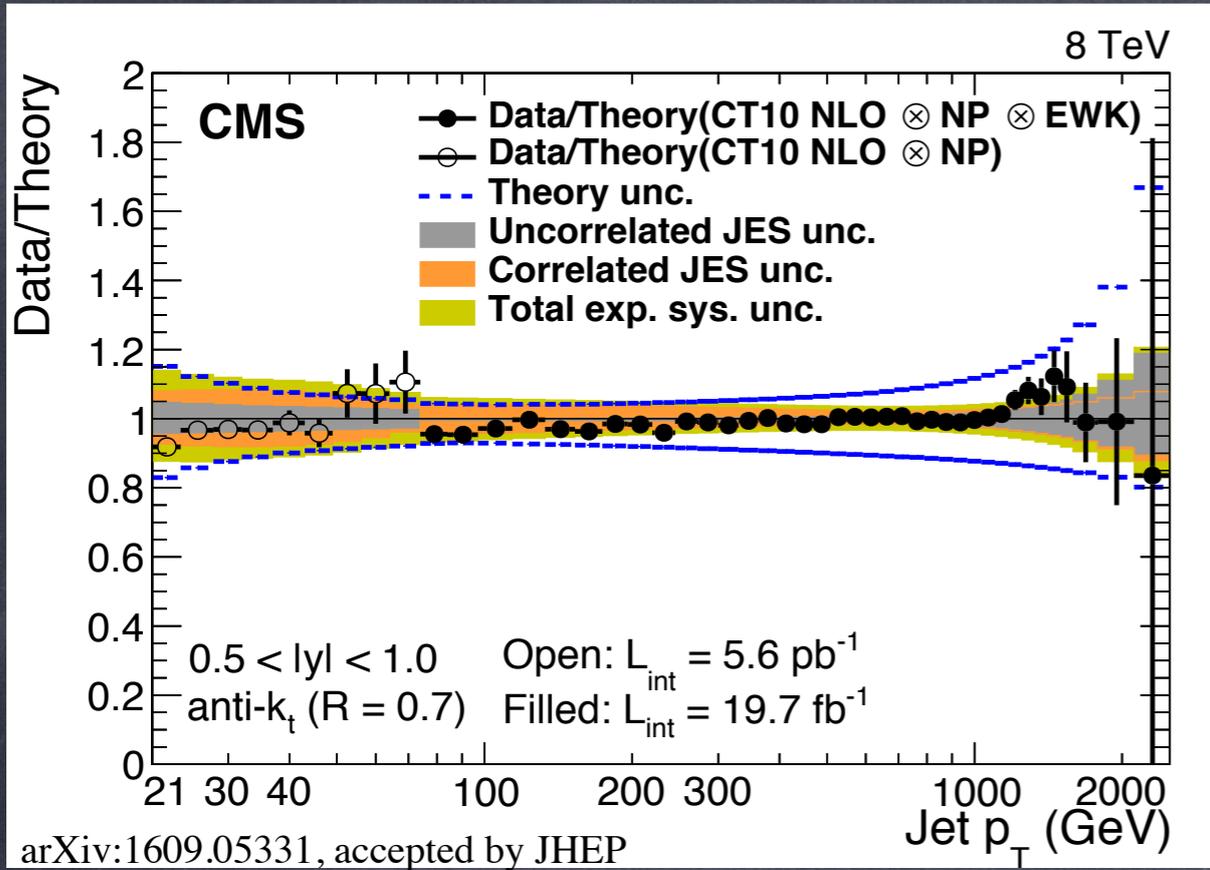
$$\frac{d^2\sigma}{dp_T dy} = \frac{1}{\epsilon L_{int}} \frac{N_j}{\Delta p_T \Delta y}$$

- $P_T$  spectrum in all  $y$  bins
- Theory :
  - NLOJET++ with CT10
  - Corrected for NP and EW

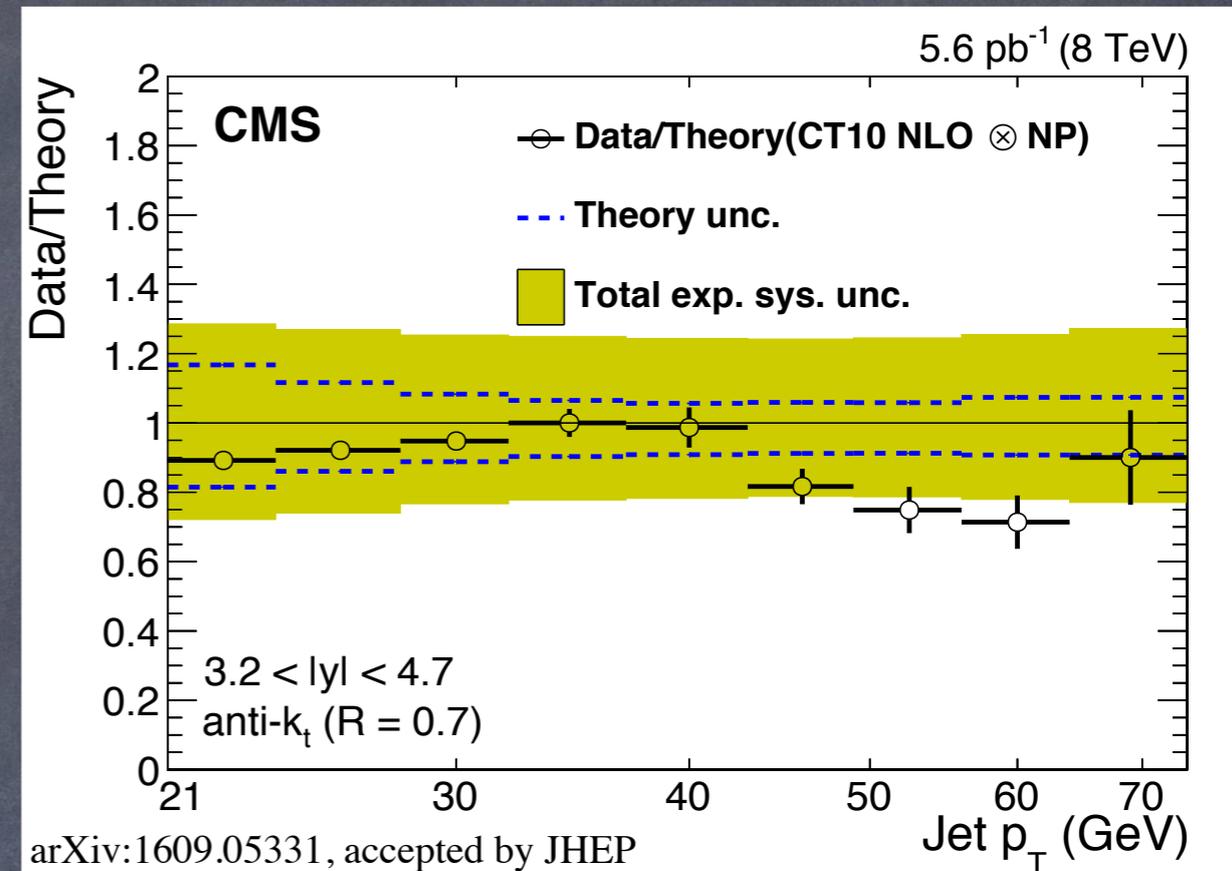
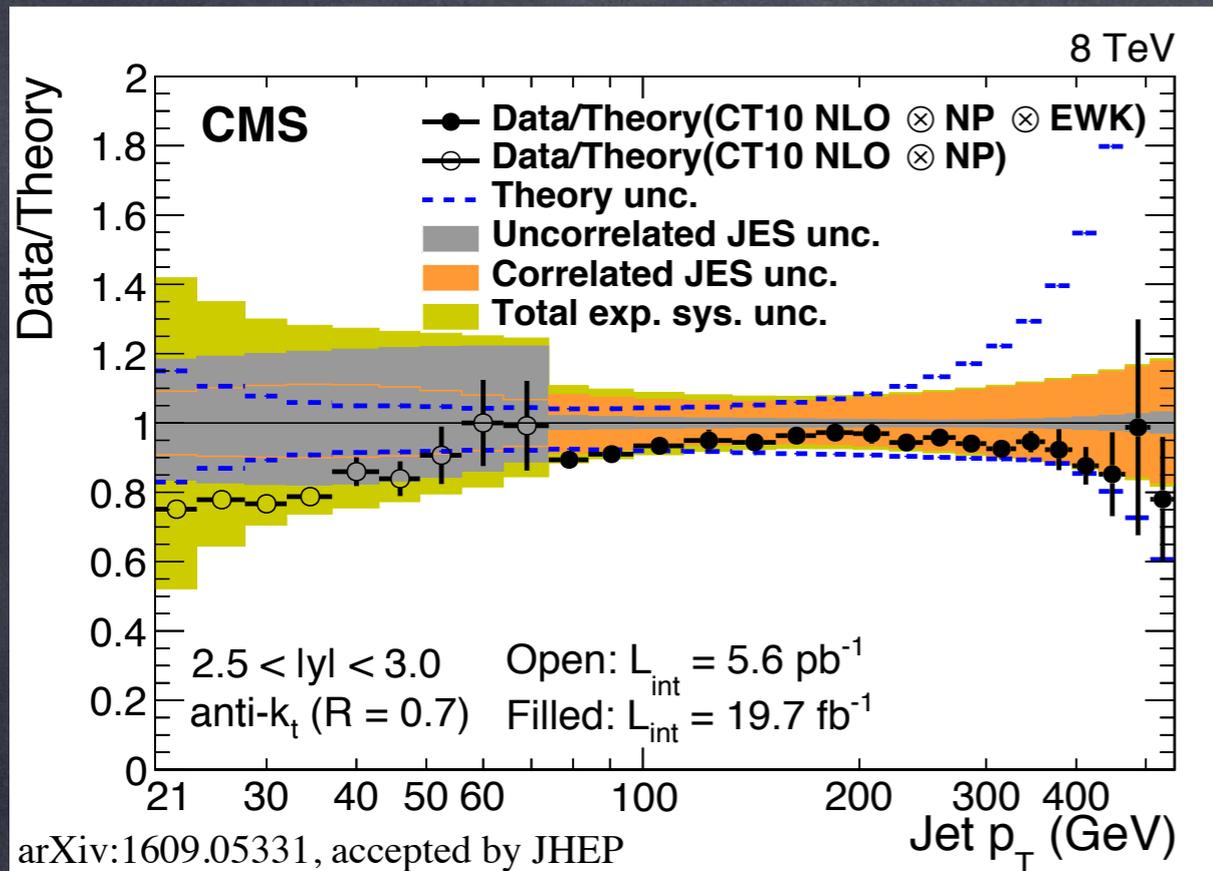


Transverse momenta range from 21 GeV to 2.5 TeV

# Inclusive jet measurement @ 8 TeV



# Inclusive jet measurement @ 8 TeV



## Dominant uncertainties:

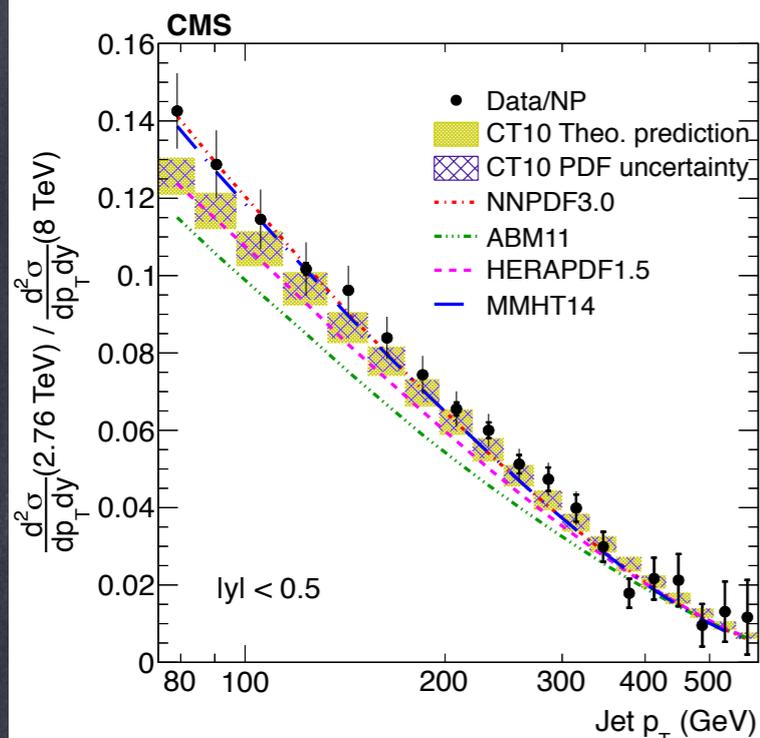
Data: Jet Energy Scale (1-4% central |y| ; 6-45% outer |y| )  
Luminosity 2.6%

Theory: Scale (5-10% central |y|, up to 40% outer |y|)  
PDF(10-50% central |y|, up to 100% outer |y|)

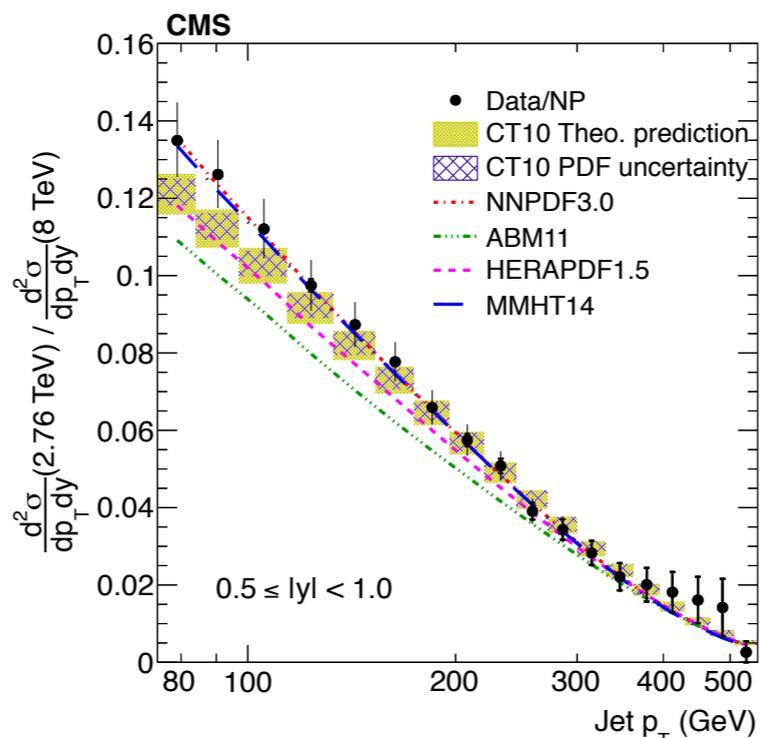
impact on PDFs &  $\alpha_s$  → See K.Lipka's talk

# Inclusive jets : Ratio of 2.76 / 8 TeV

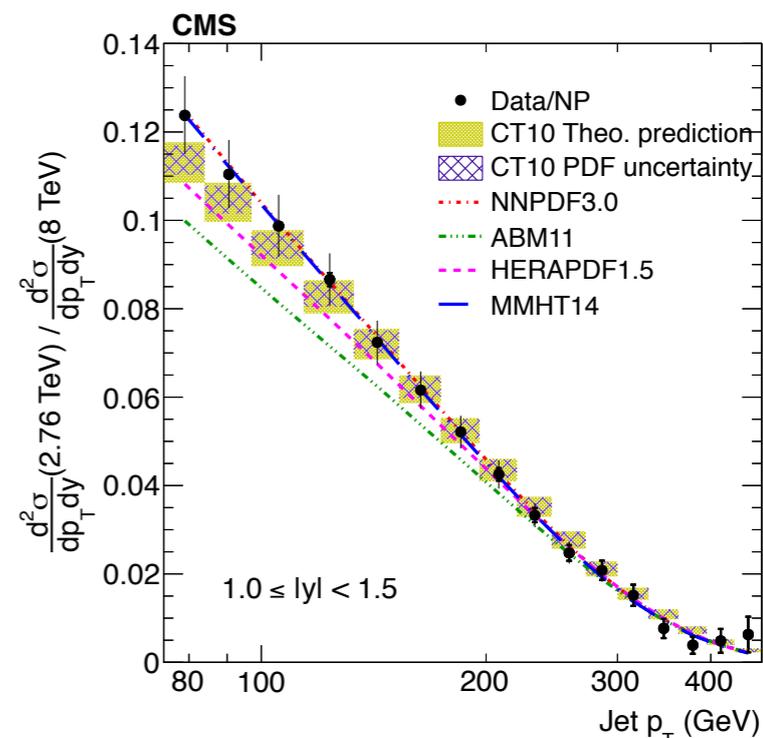
- Ratio of cross-sections at different energies may show a better sensitivity to PDFs.



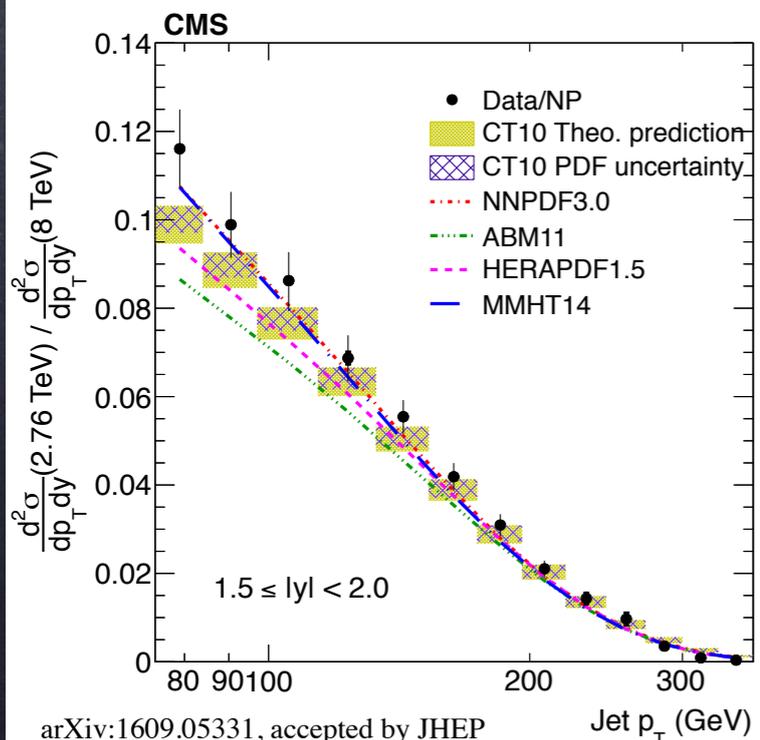
arXiv:1609.05331, accepted by JHEP



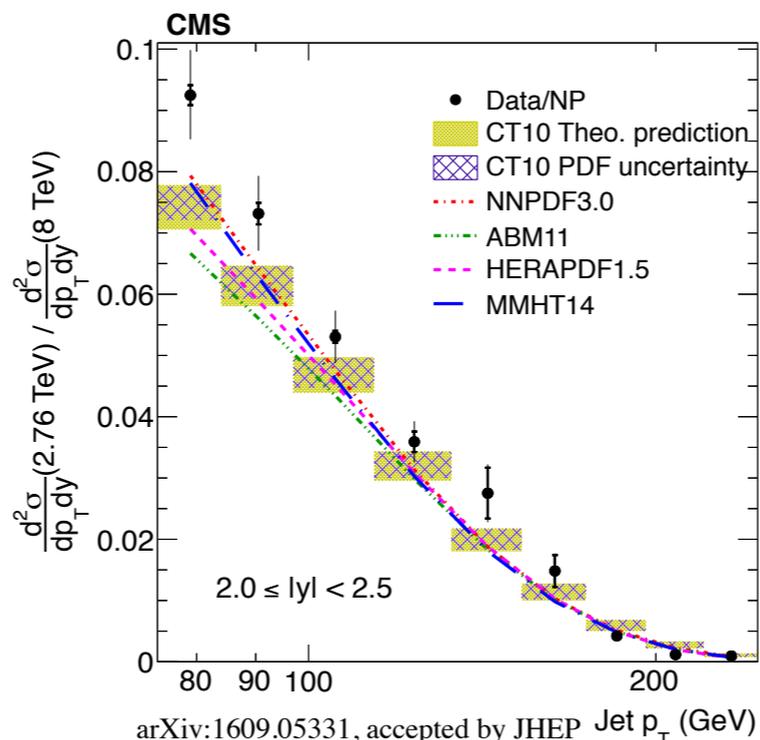
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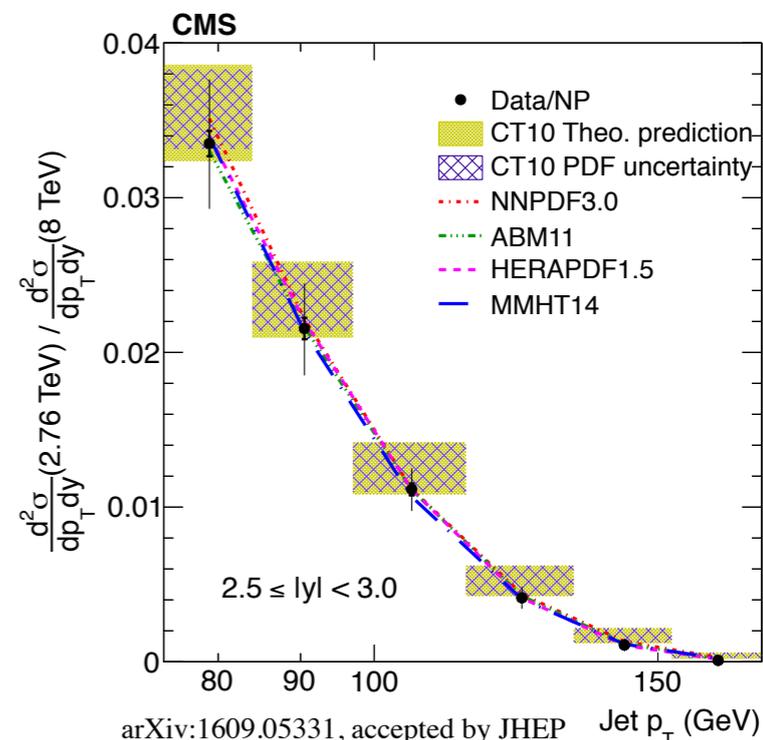
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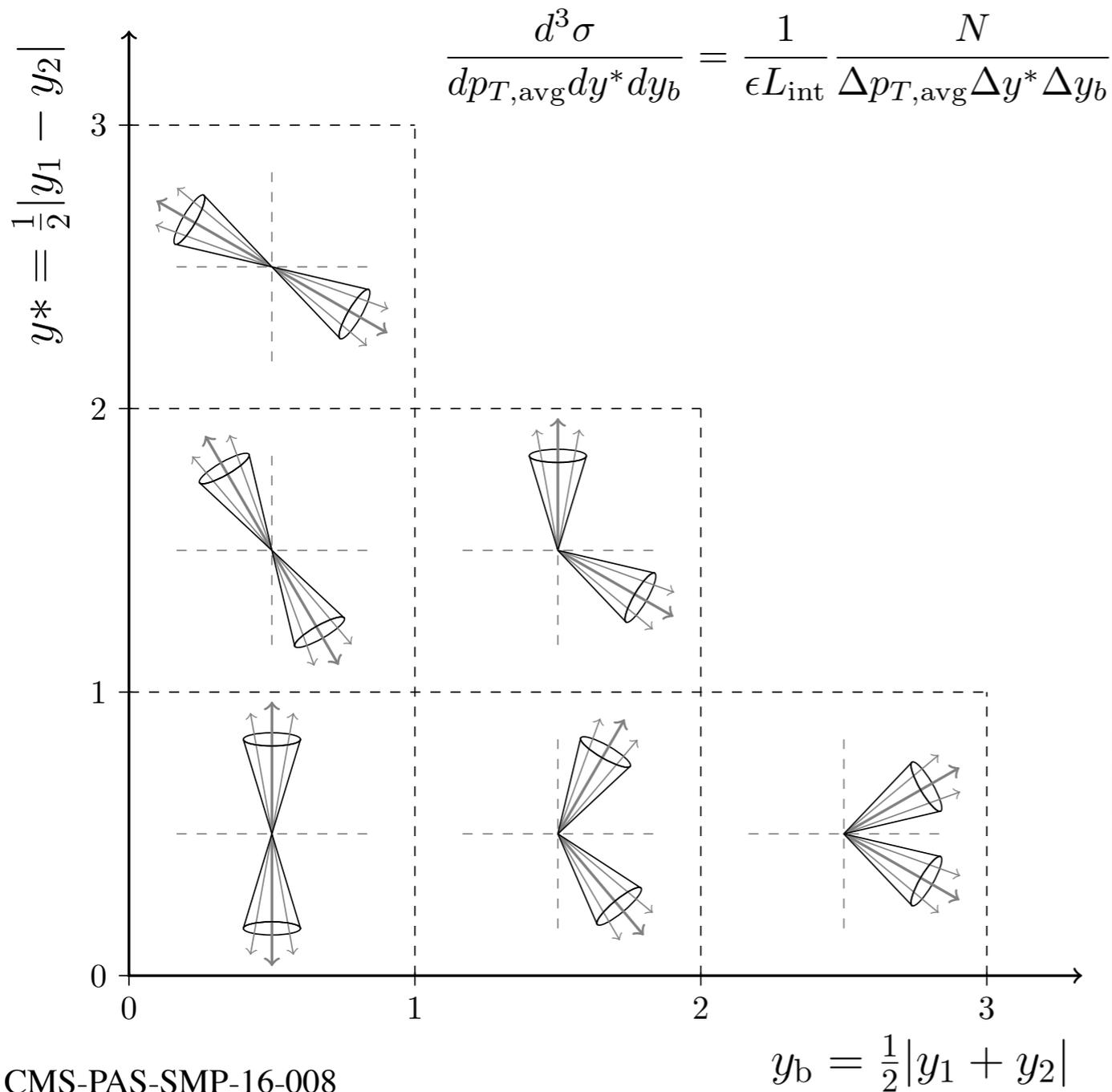


arXiv:1609.05331, accepted by JHEP

Ratios are mainly dominated by PDF uncertainty (theory)!

# Triple-Differential Dijet Measurement

- Measurement @ 8TeV,  $L = 19.7 \text{ fb}^{-1}$ , anti- $k_T$  with  $R=0.7$



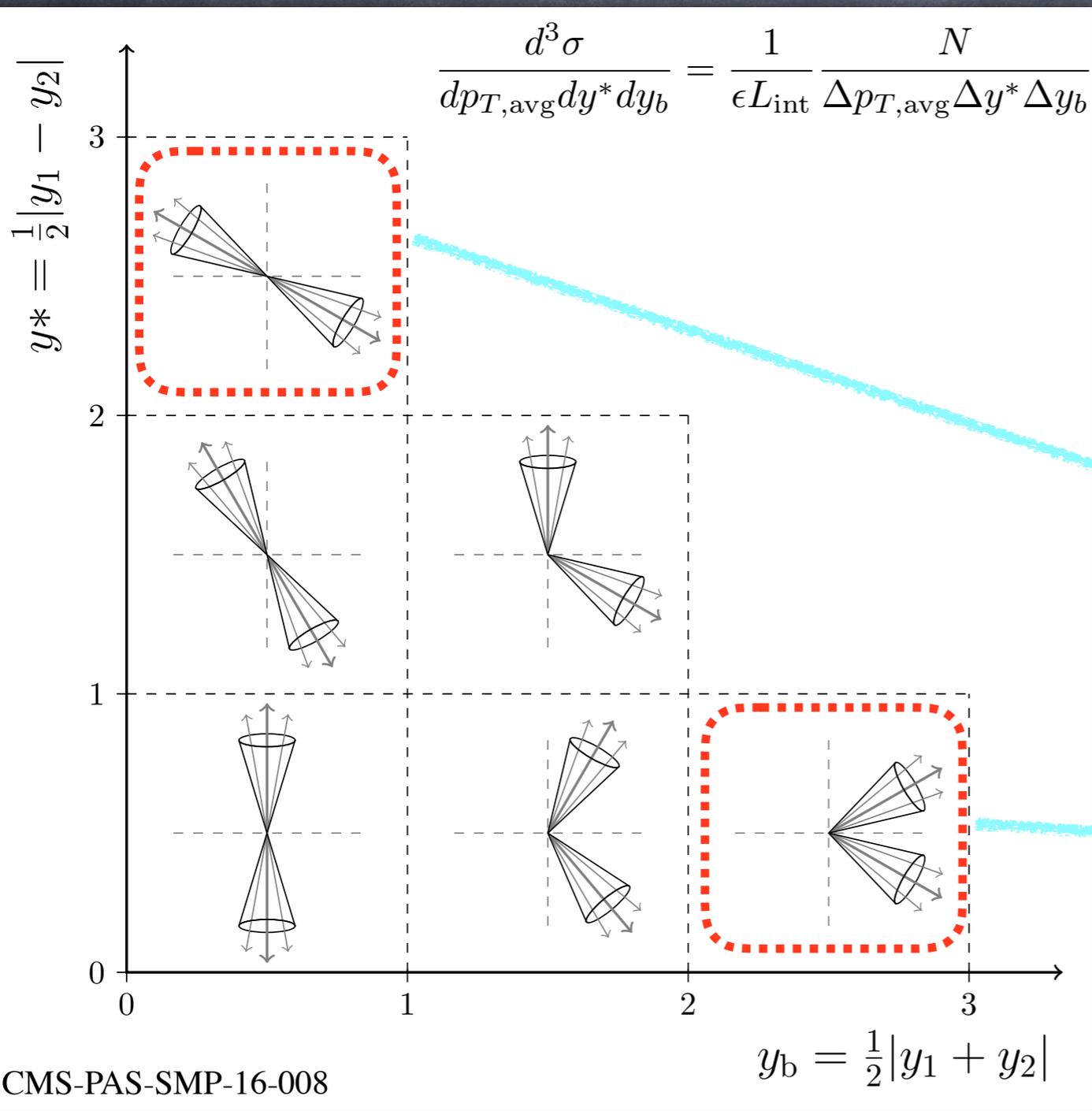
Event selection :

- Two leading jet with :
  - $|y_{1,2}| < 3.0$
  - $p_{T1,2} > 50 \text{ GeV}$
- $E_{T}^{\text{miss}} / \sum E_T < 0.3$

- $p_{T,\text{avg}} = (p_{T1} + p_{T2})/2$
- $y_b = \frac{1}{2} |y_1 + y_2|$
- $y^* = \frac{1}{2} |y_1 - y_2|$

# Triple-Differential Dijet Measurement

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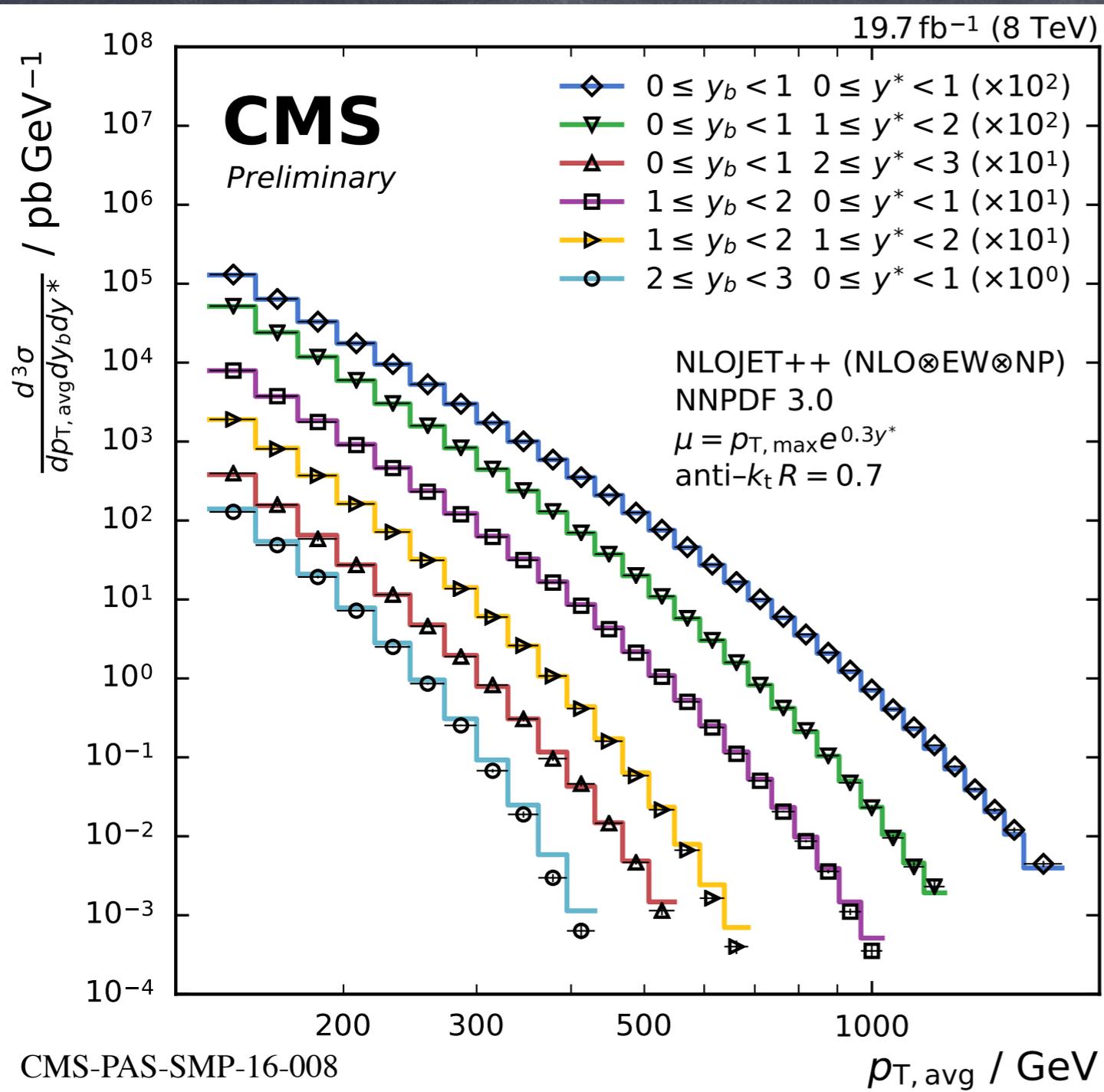


- $p_{T,\text{avg}} = (p_{T1} + p_{T2})/2$
- $y_b = \frac{1}{2}|y_1 + y_2|$
- $y^* = \frac{1}{2}|y_1 - y_2|$

Opposite side events  
 $x_1 \approx x_2$

Same side events (Dijet boost!)  
 $x_1 \gg x_2$

# Triple-Differential Dijet Measurement @ 8TeV



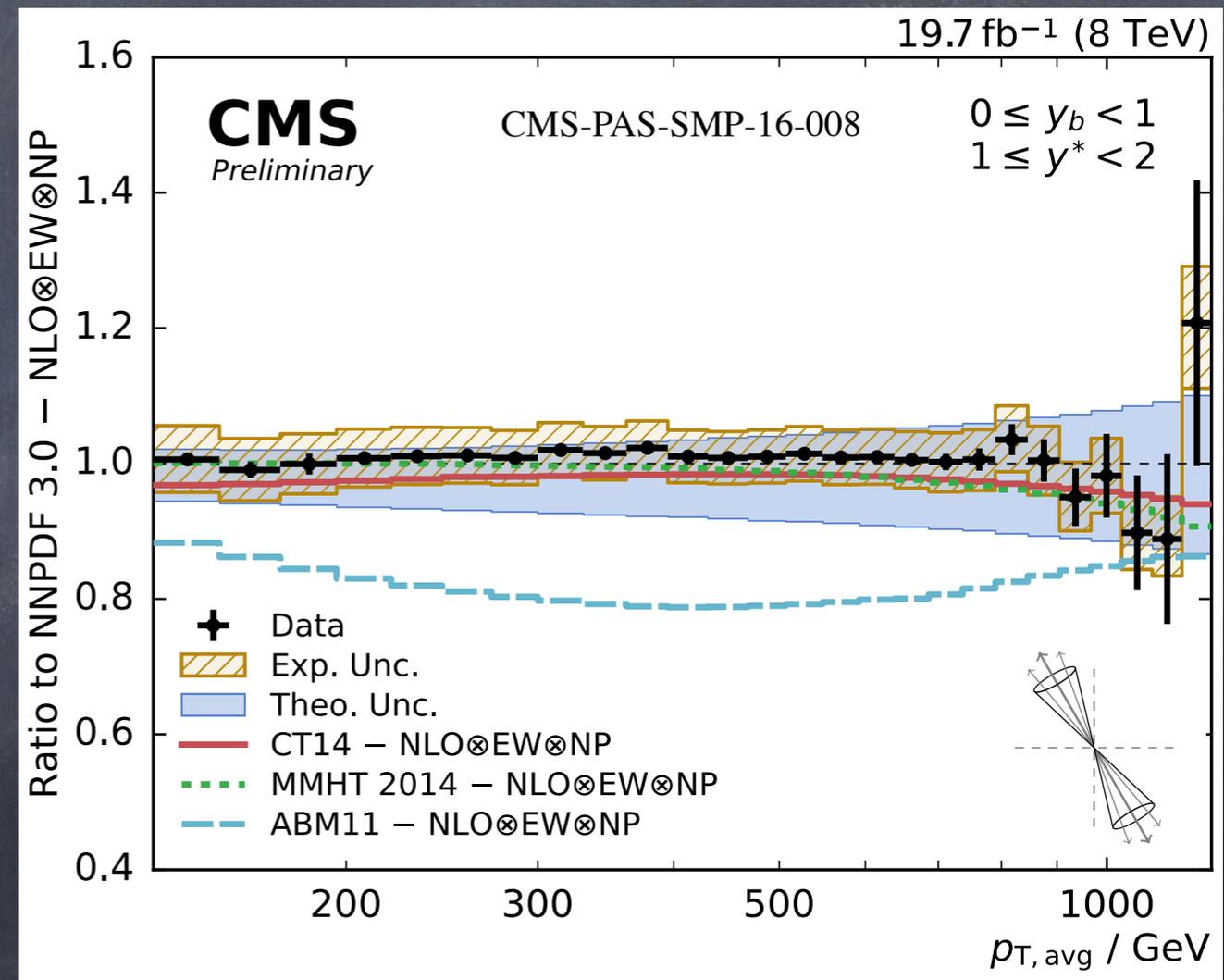
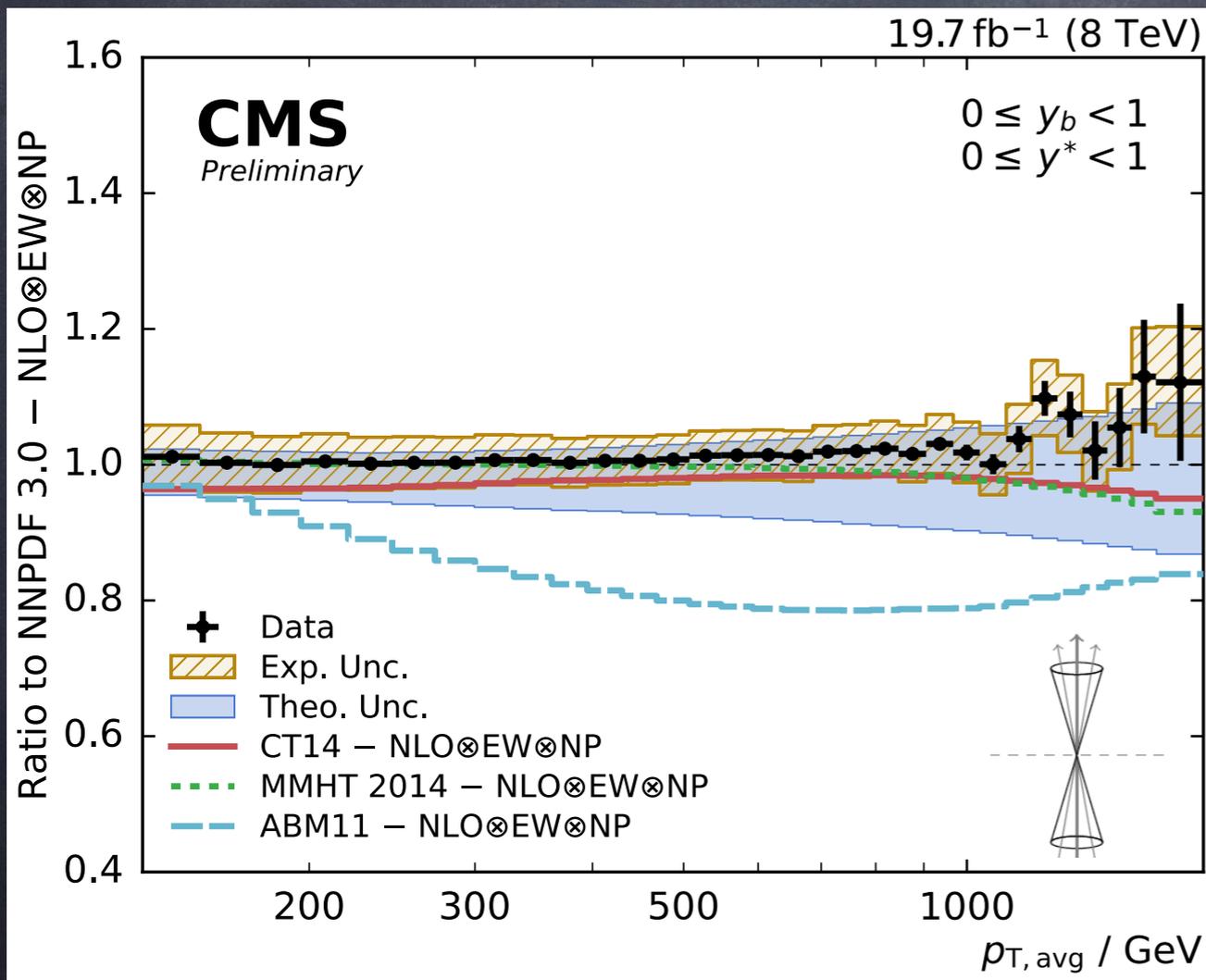
- $P_{T,avg}$  spectrum of all  $y_b / y^*$  bins
- Theory :
  - NLOJET++ with NNPDF3.0
  - Corrected for NP and EW

## Dominant systematics :

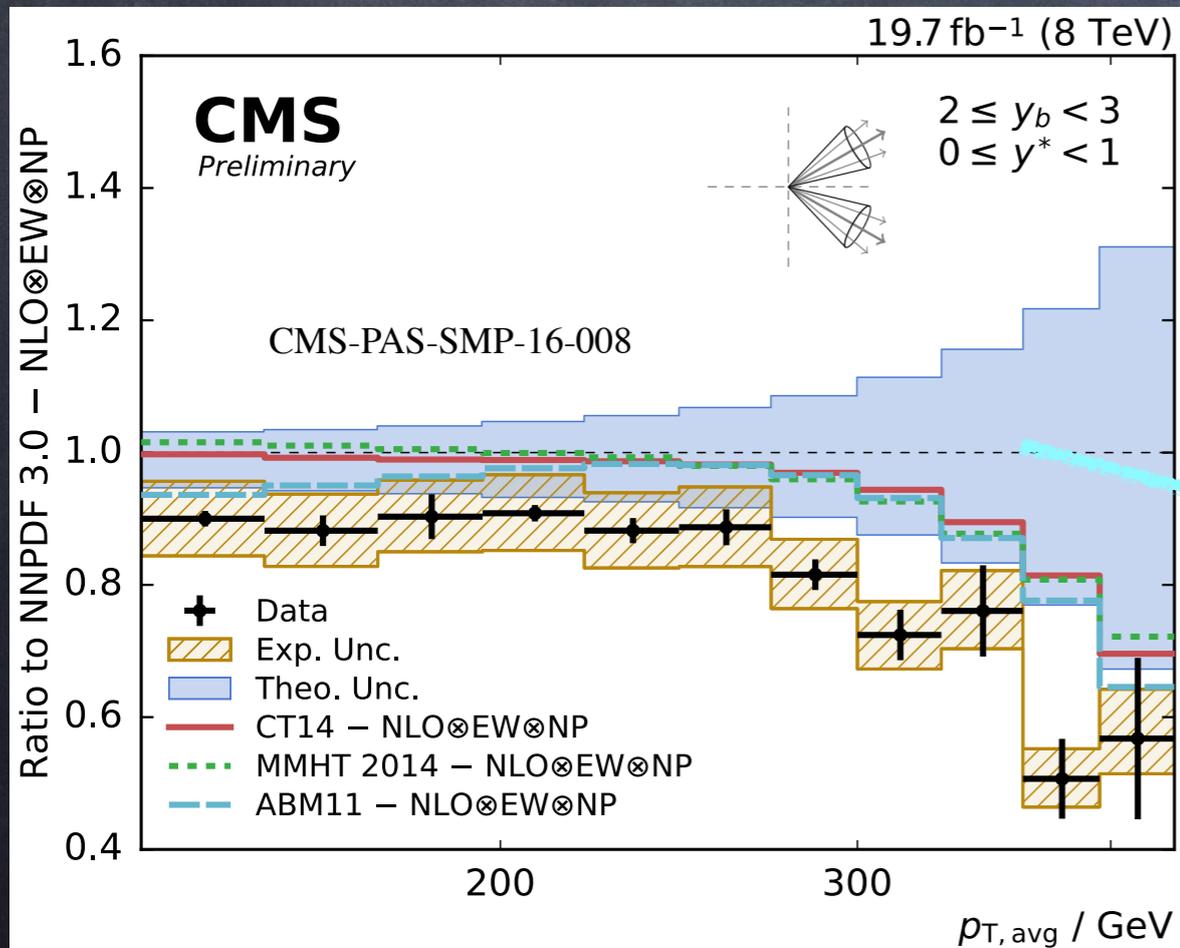
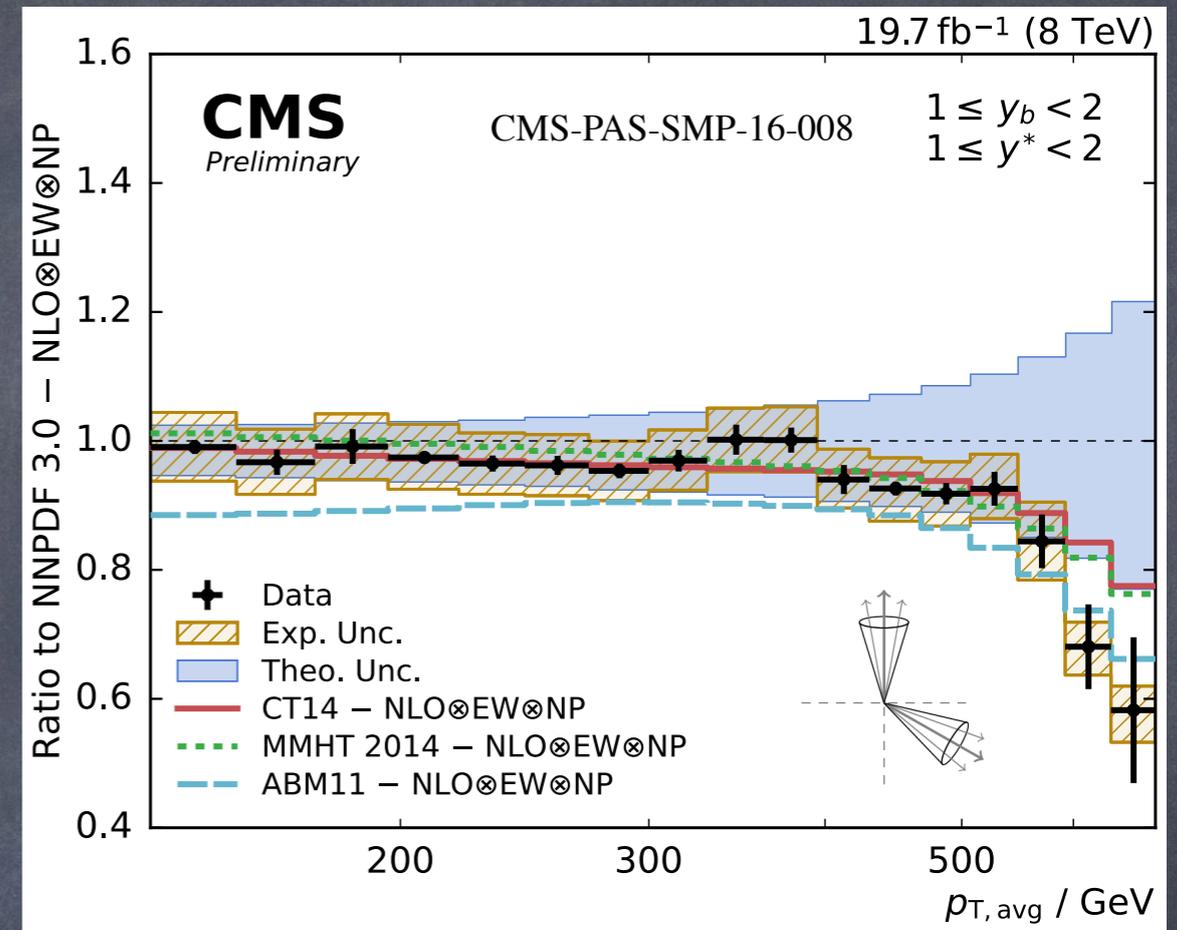
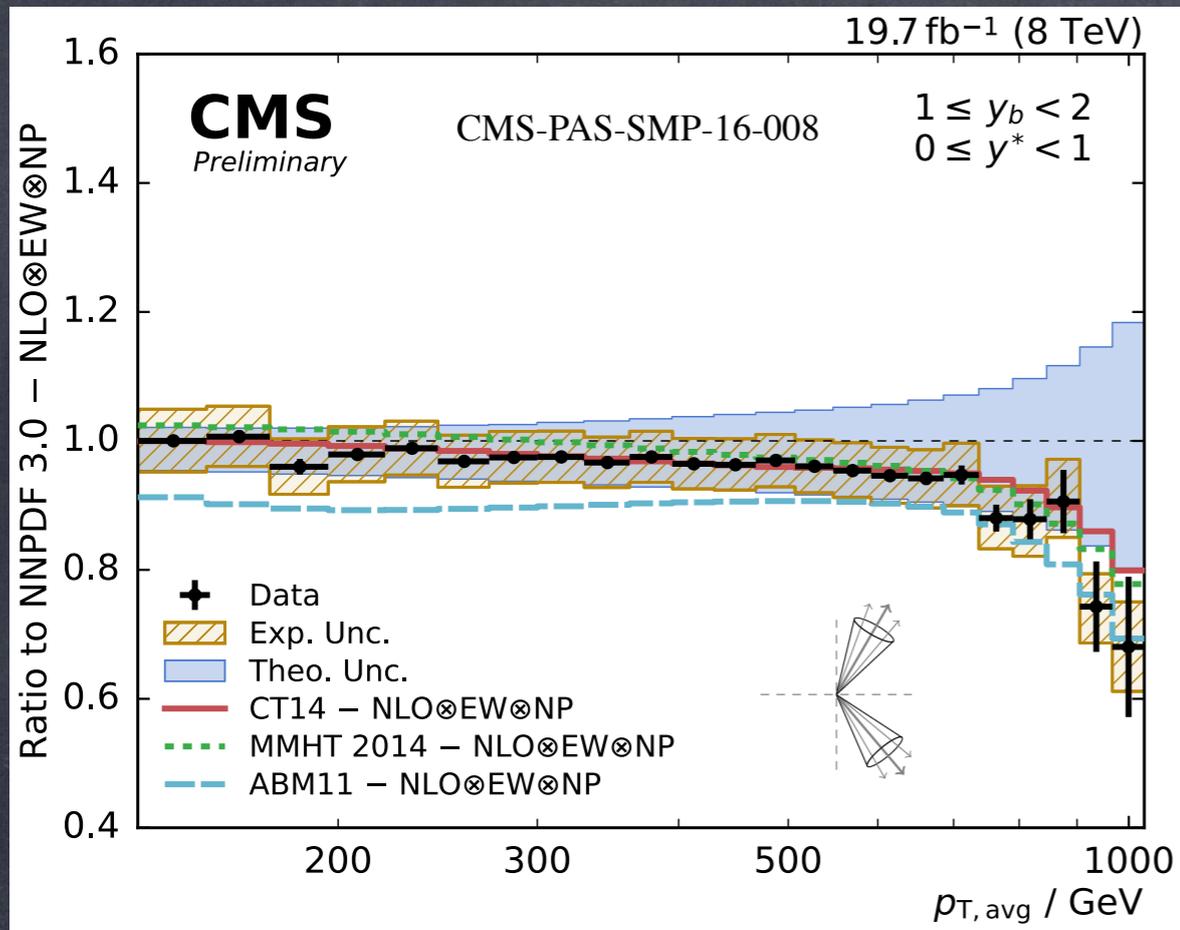
- Data:
  - ▶ JES : 5-10%
  - ▶ Statistical uncert. : 1-15%
  - ▶ Luminosity : 2.6%
- Theory :
  - ▶ PDF : 4-50%
  - ▶ Scale : 5-20%

# Triple-Differential Dijet Measurement @ 8TeV

- ▶ Ratio to NLO x NP - with NNPDF3.0
- ▶ Black dots : Data points with statistical uncertainty
- ▶ Yellow bands : Total systematic uncertainty
- ▶ Blueish bands : Total theory uncertainty (PDF, Scale and NP)



# Triple-Differential Dijet Measurement in Detail



Data are well described in most of the phase spaces but some difference in at high  $p_{T, \text{avg}}$  and  $y_b$ , which we need to understand!

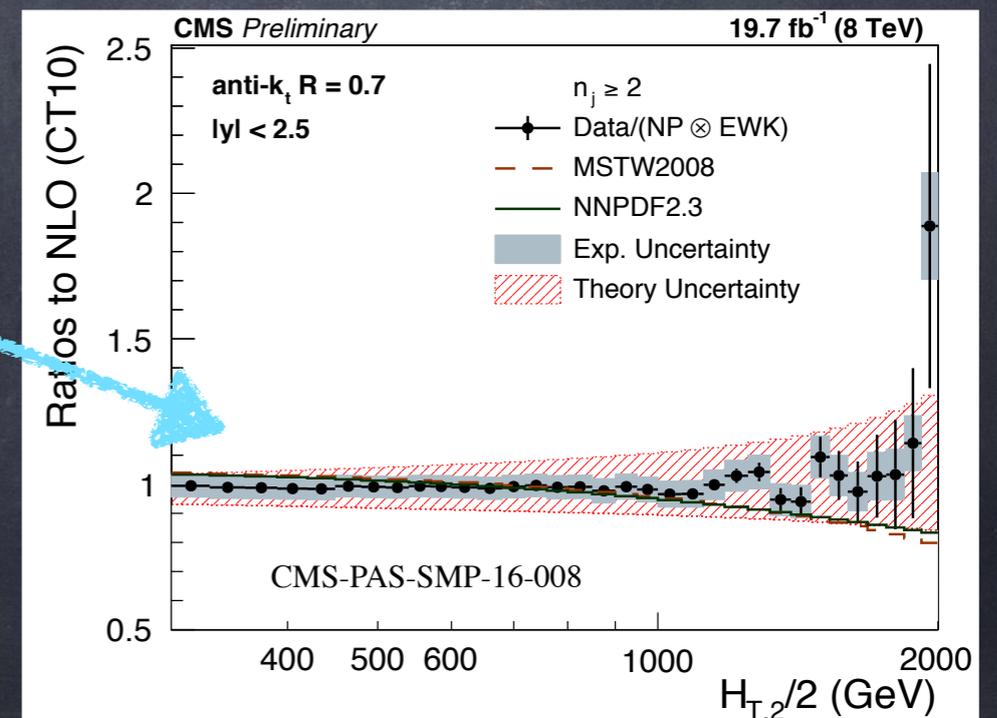
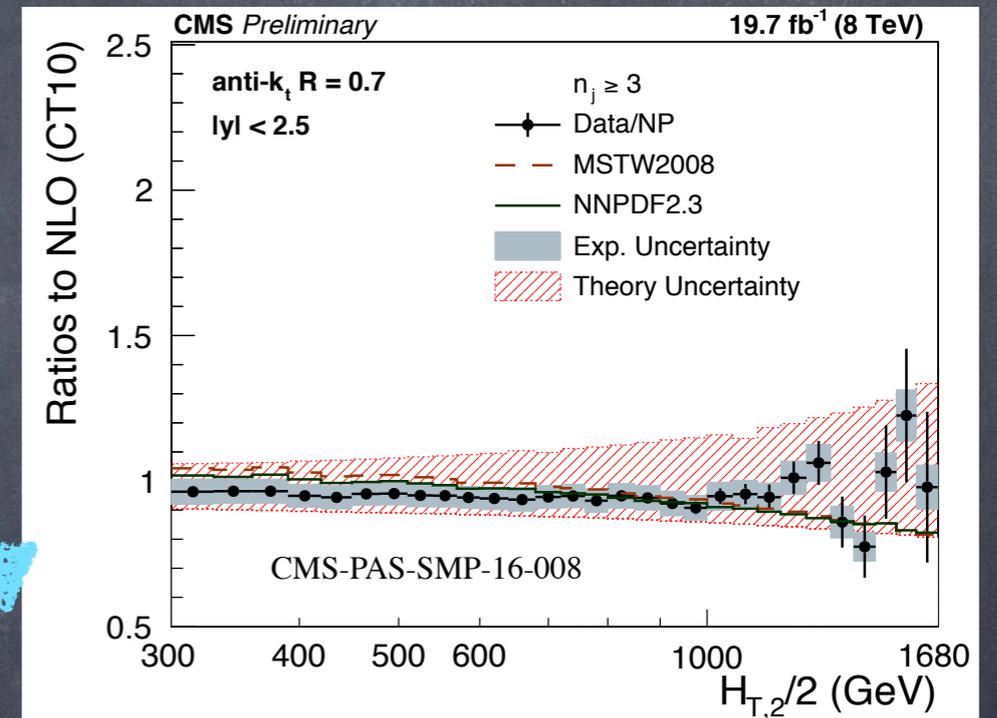
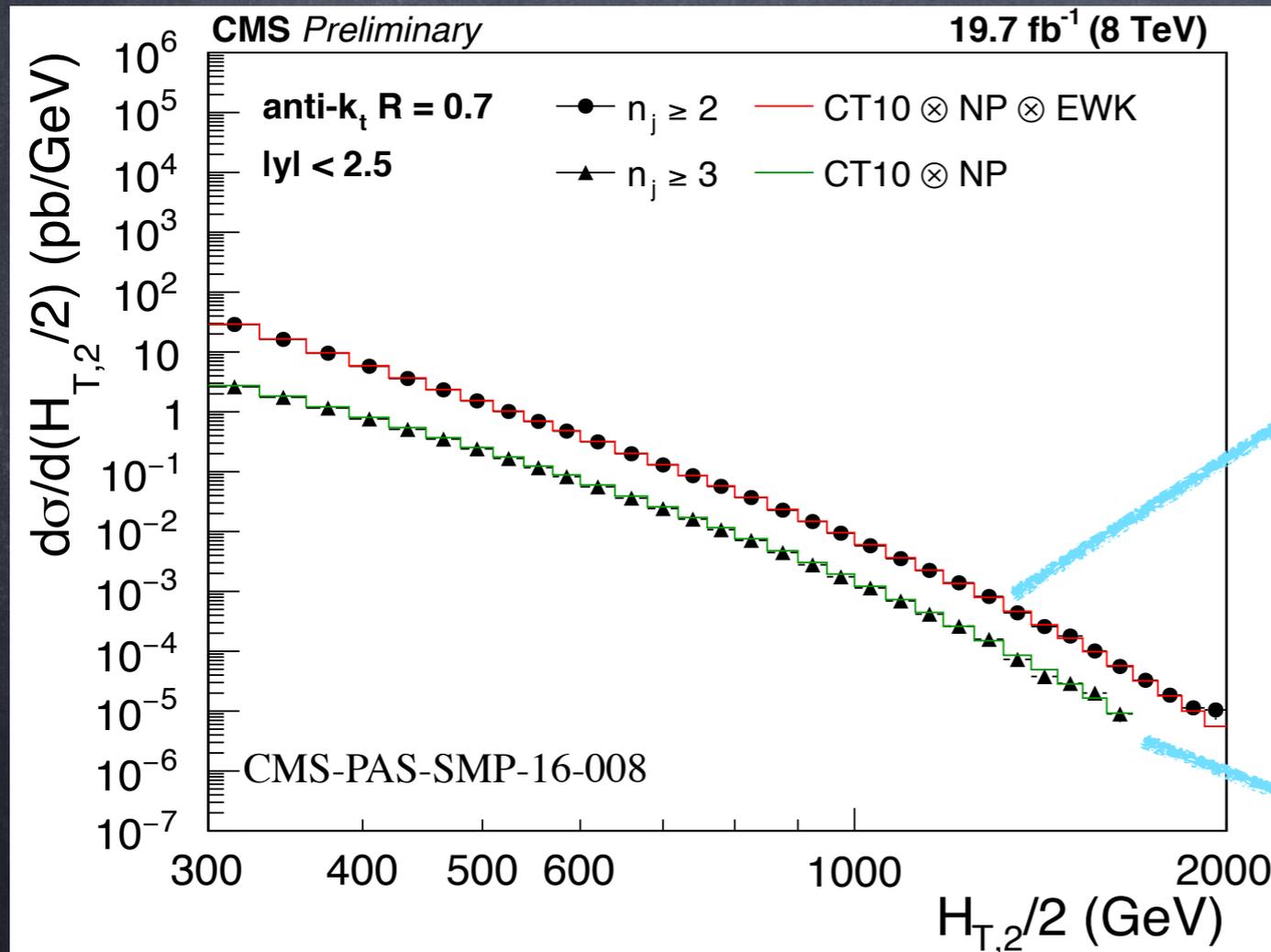
Poor knowledge of PDFs!!

impact on PDFs &  $\alpha_s$  → See K.Lipka's talk

# Inclusive multijet measurement @ 8 TeV

- Measurement @ 8TeV,  $L = 19.7 \text{ fb}^{-1}$ , anti- $k_T$  with  $R=0.7$
- Inclusive 2-jet and 3-jet event cross sections as a function of  $H_{T,2} / 2$

$$\frac{d\sigma}{d(H_{T,2}/2)} = \frac{1}{\epsilon L_{\text{int}}} \frac{N_{\text{event}}}{\Delta(H_{T,2}/2)} \quad H_{T,2}/2 = \frac{1}{2}(p_{T,1} + p_{T,2})$$



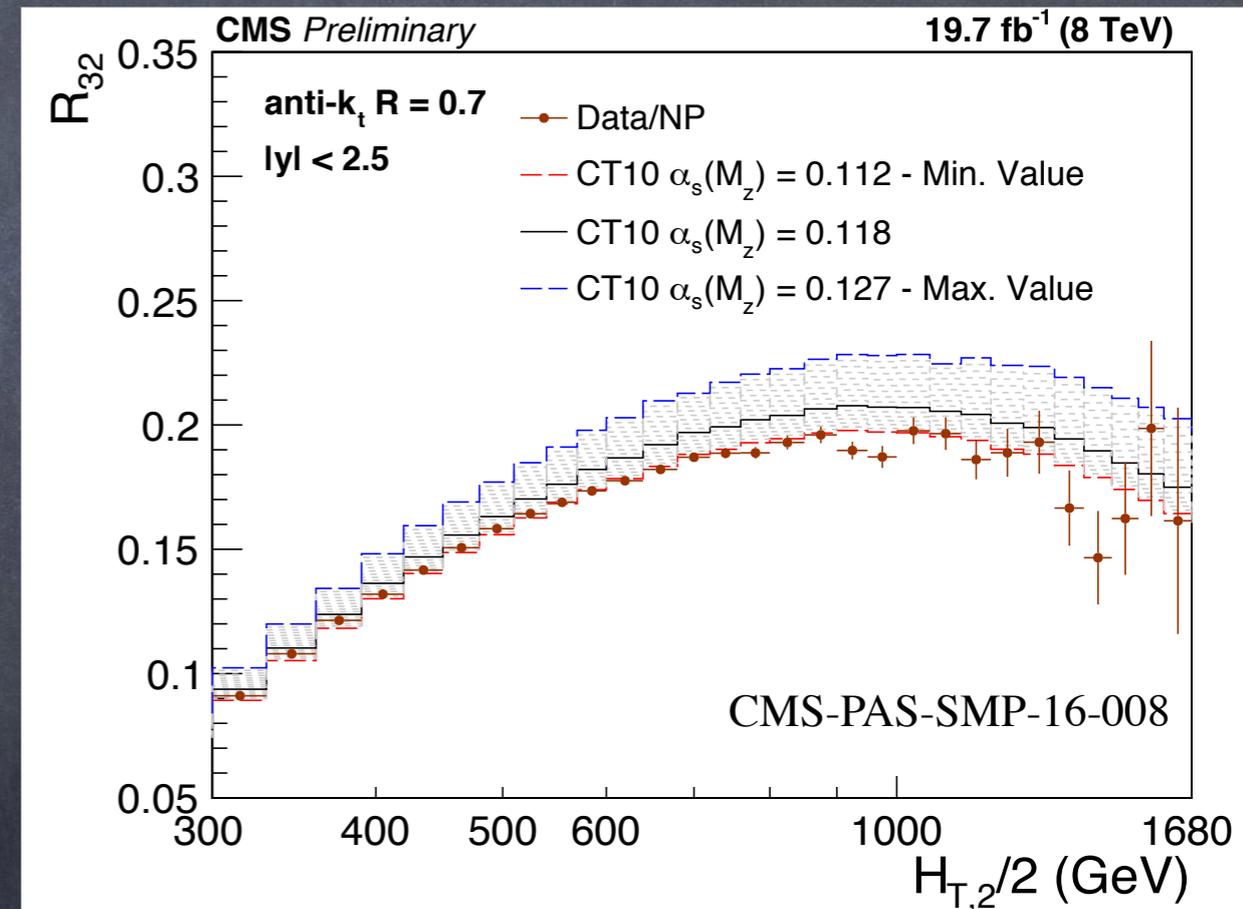
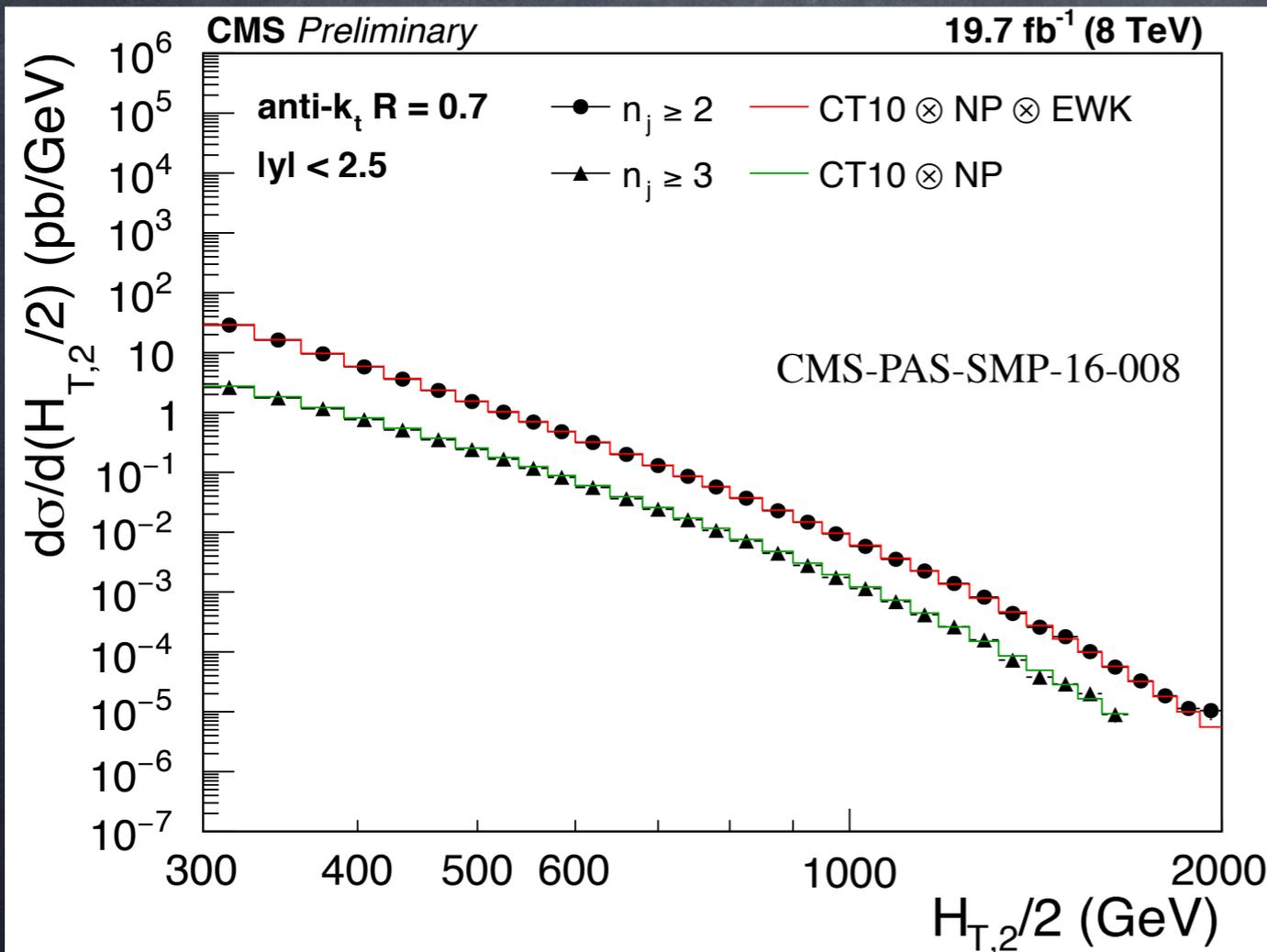
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$$\frac{d\sigma}{d(H_{T,2}/2)} = \frac{1}{\epsilon L_{\text{int}}} \frac{N_{\text{event}}}{\Delta(H_{T,2}/2)}$$

$$R_{mn} = \frac{\sigma_{m\text{-jet}}}{\sigma_{n\text{-jet}}} \sim \alpha_S^{m-n}; \quad m > n$$

some systematics cancels!

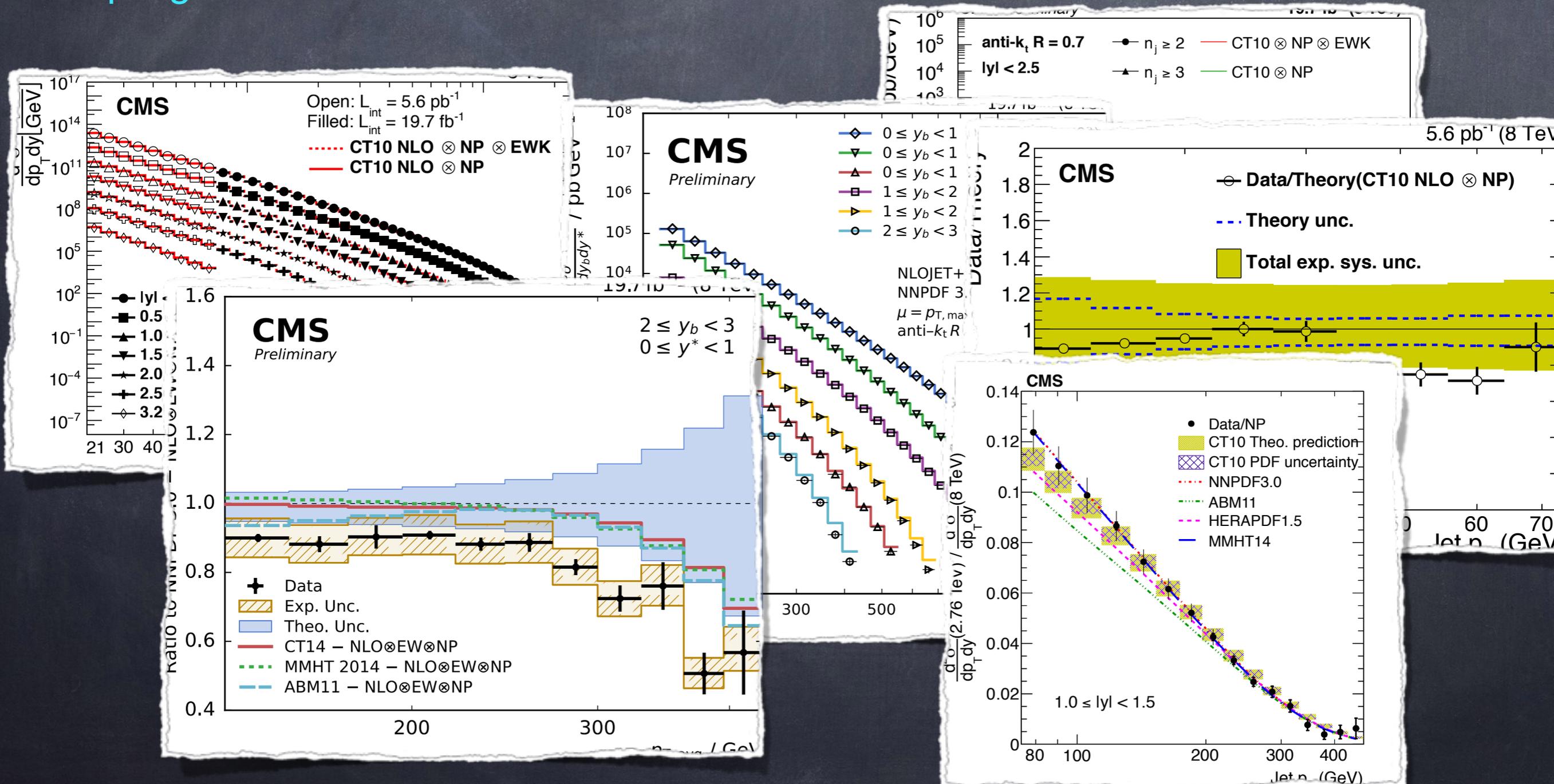


$R_{32}$  is sensitive to  $\alpha_S$

See K.Lipka's talk

# Summary

- ✓ Measurement of multi-differential jet cross-sections over a wide range in transverse momenta from inclusive jets to multi-jet final states is presented.
- ✓ These text-book measurements are sensitive to **proton structure** and **strong coupling  $\alpha_s$**



# Backup Slides