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Single inclusive jet production at the LHC

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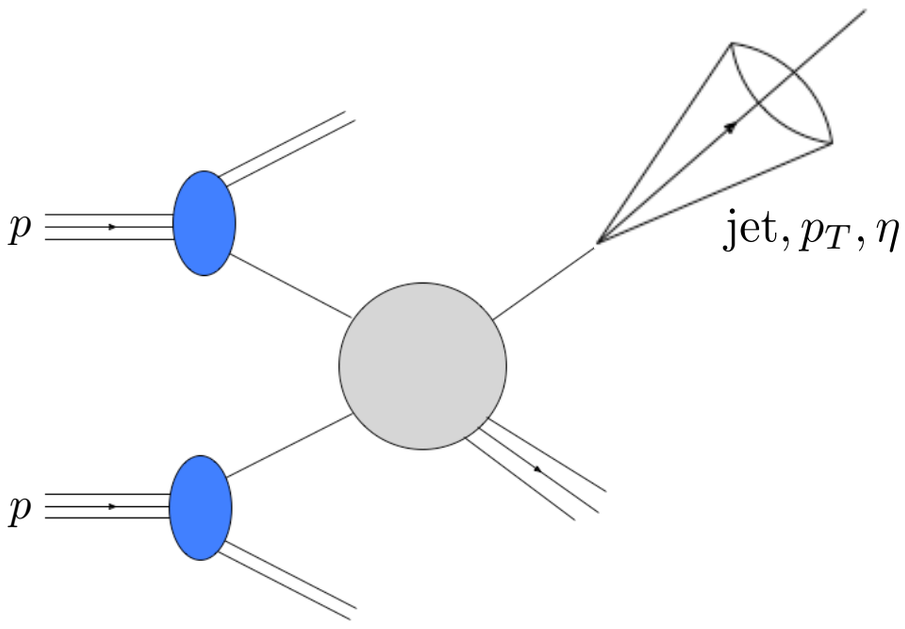
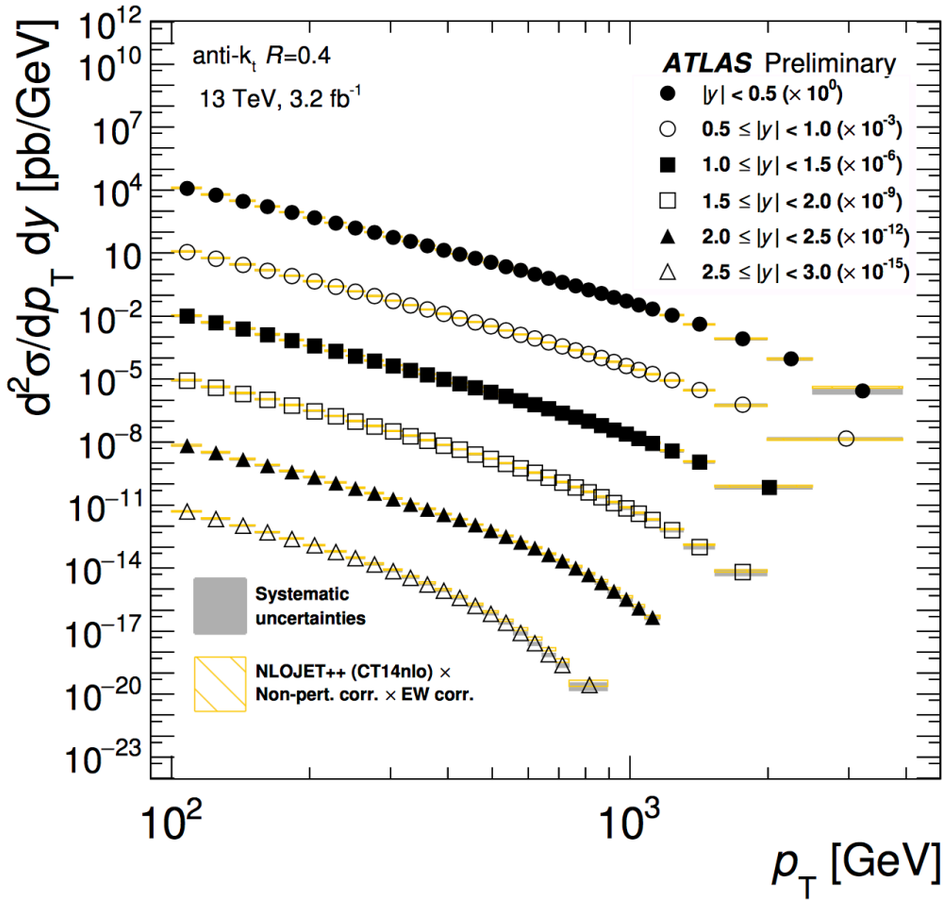
CLHCP 2017 @ Nanjing Univeristy

XL, Moch, Ringer, PRL 2017
XL, Moch, Ringer to appear

Jets @ the LHC

- Benchmark processes at the LHC
  - Inclusive jet, di-jet, V+jet(s) …
    - PDF fitting
    - alphas extraction
    - New physics searches





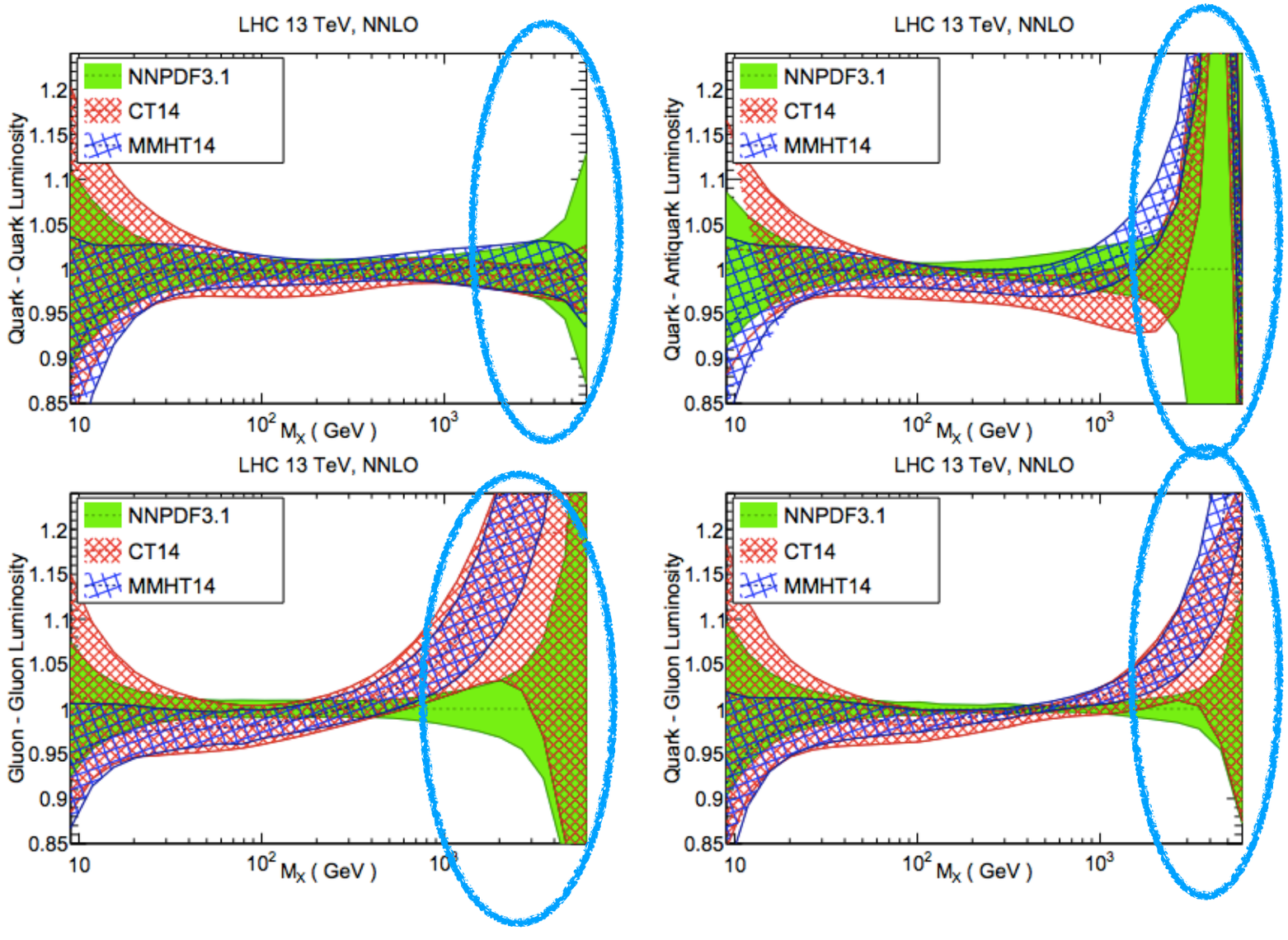
lots of data at the LHC to very large pT

Jets @ the LHC

- Benchmark processes at the LHC
  - Inclusive jet, di-jet, V+jet(s) …
    - PDF fitting
    - alphas extraction
    - New physics searches

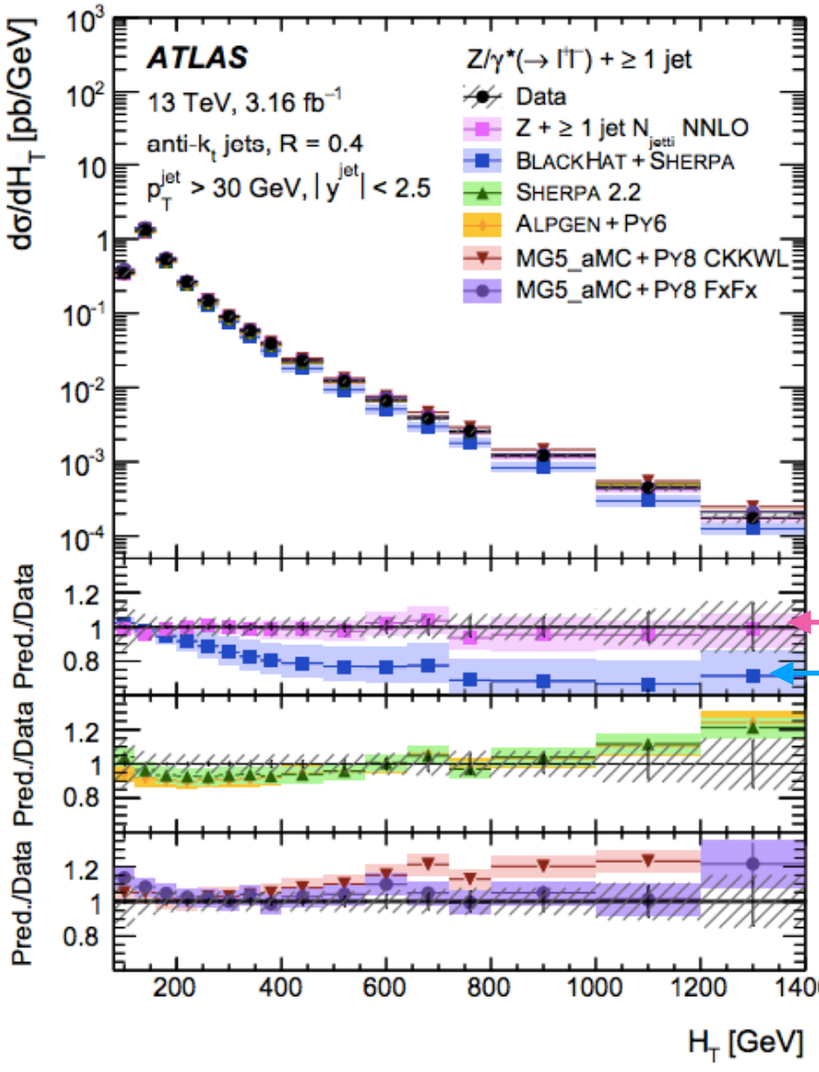
- Still large discrepancies and uncertainties for different PDF fittings in large x region.

- Can be constrained by near future inclusive jet pT analysis.



Jets @ the LHC

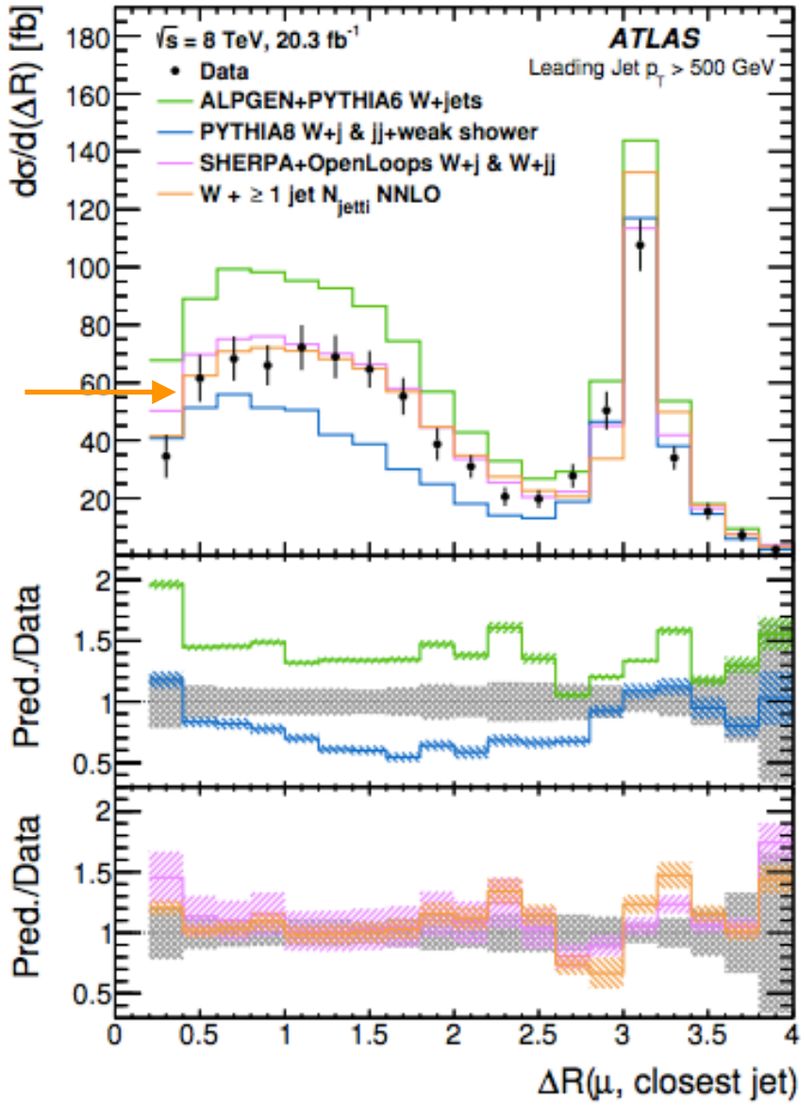
- Current Status of arts
  - Overall improved understanding at NNLO for V+jet and Higgs+jet



NNLO

NLO

Boughezal, Campbell, Focke, Giele, Keith, XL, Petriello, PRL 2016



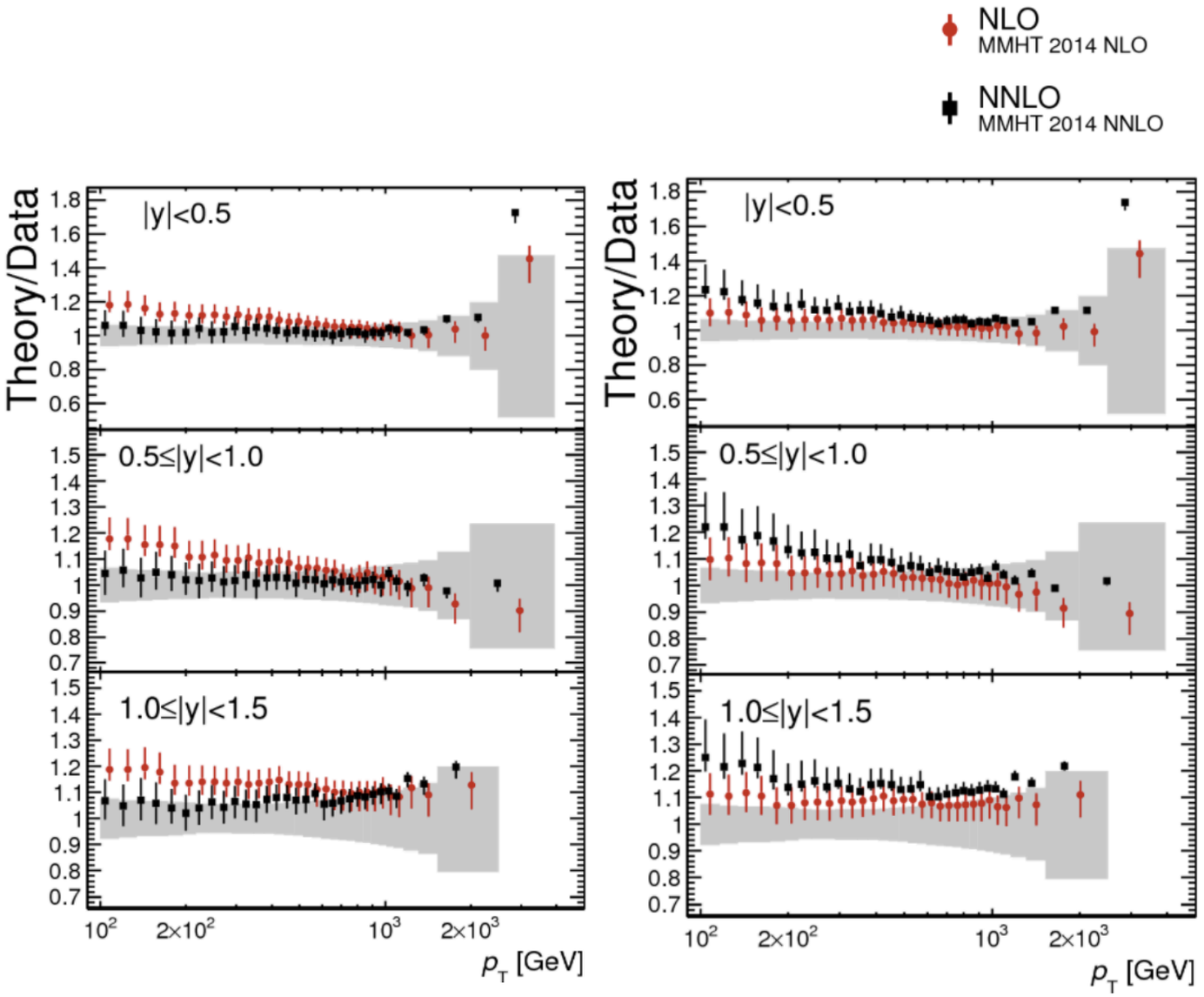
NNLO

Boughezal, Focke, XL, Petriello, PRL 2015

Inclusive jet production

- Current Status of arts
  - Subtle for inclusive jet @ NNLO with leading color approximation

- NNLO theory seems to describe the data with a specific scale choice, (still systematically higher than the data).
- Slightly different scale choices lead to different conclusions.



scale = individual jet pT

scale = leading jet pT

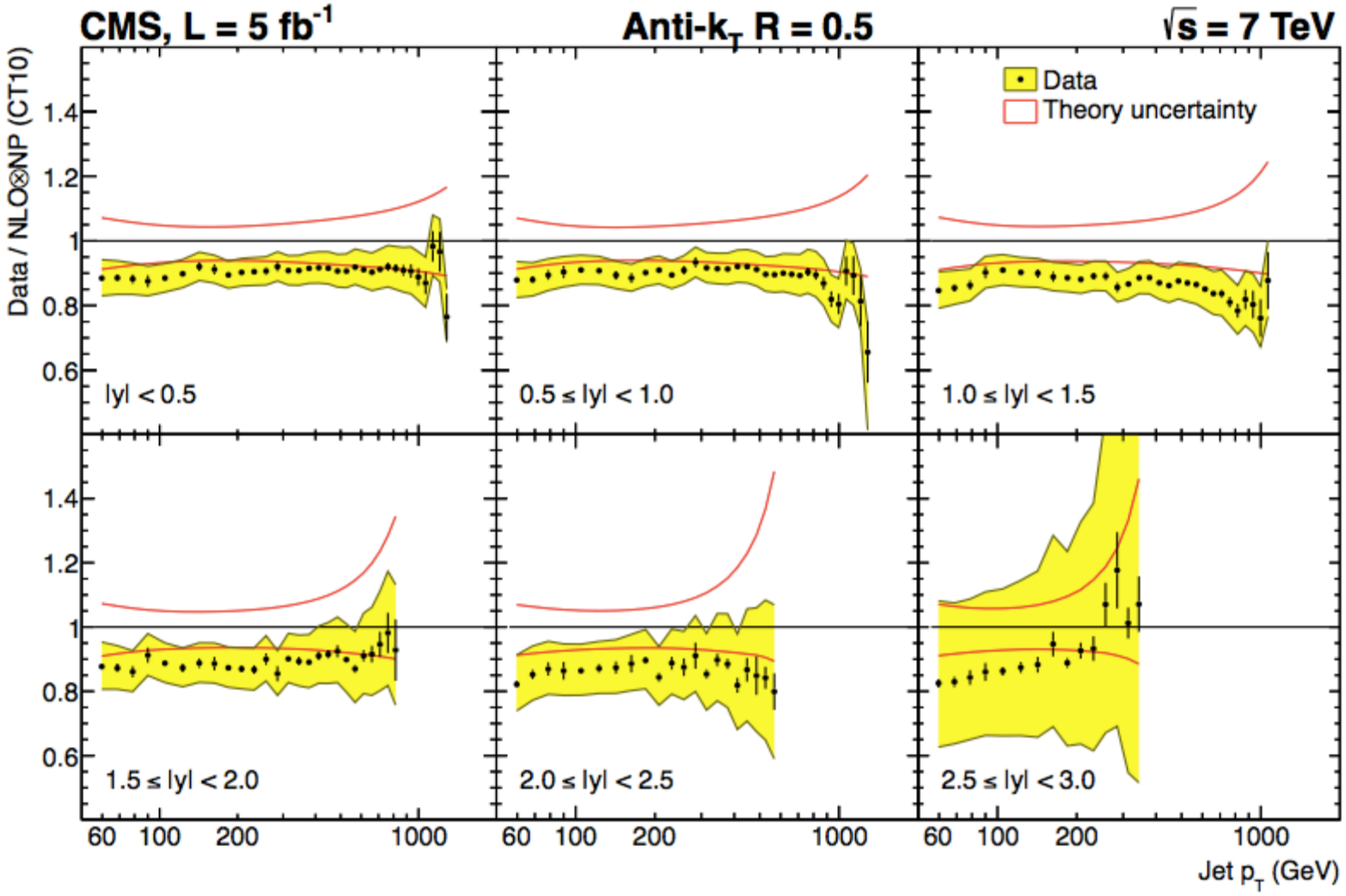
Currie, Glover, Pires, PRL 2017

Inclusive jet production

- Current Status of arts
  - NLO known for decades:

    NLOJET++, (M)EKS …

  - Theory is systematically higher than the data for all rap bins.
  - Also seen in other LHC inclusive jet analyses, with machine energy ranging from 2.76TeV to 13TeV



Inclusive jet production

- Current Status of arts
  - NLO known for decades:

    NLOJET++, (M)EKS …

" While no cuts were applied to all jet datasets included in NNPDF3.1, for the 2011 ATLAS 7 TeV dataset a good agreement between data and theory was obtained when fitting only the central rapidity bin, $|y_{jet}| < 0.5$. Concurrently, it was found that achieving a good description of the ATLAS 2011 7 TeV data set would be impossible, if all five rapidity bins were included simultaneously and if all cross-correlations among rapidity bins were taken into account accordingly."

Nocera and Ubiali, 1709.09690

Inclusive jet production

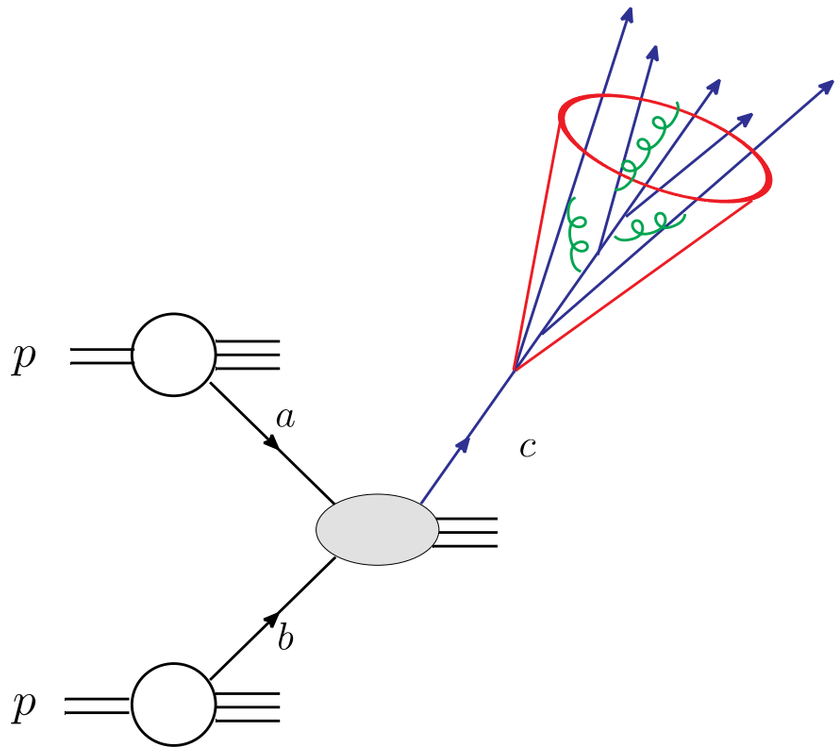
- Current Status of arts
  - persistent tension between NLO/NNLO theory and the LHC data

Large higher order corrections?

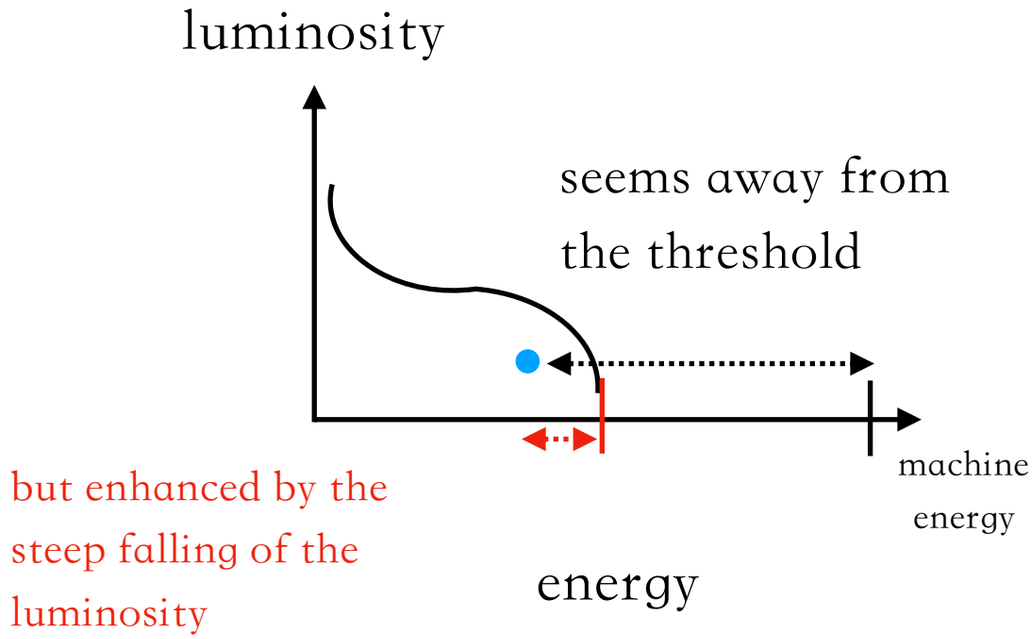
Possible sources: threshold + small radius

Inclusive jet production

- Possible large corrections
  - small R
  - threshold



$$\sum_{m=0,k=1} \alpha_s^n \left[\frac{\ln^{2n-m-k} z}{z} \right]_+ \ln^m R$$

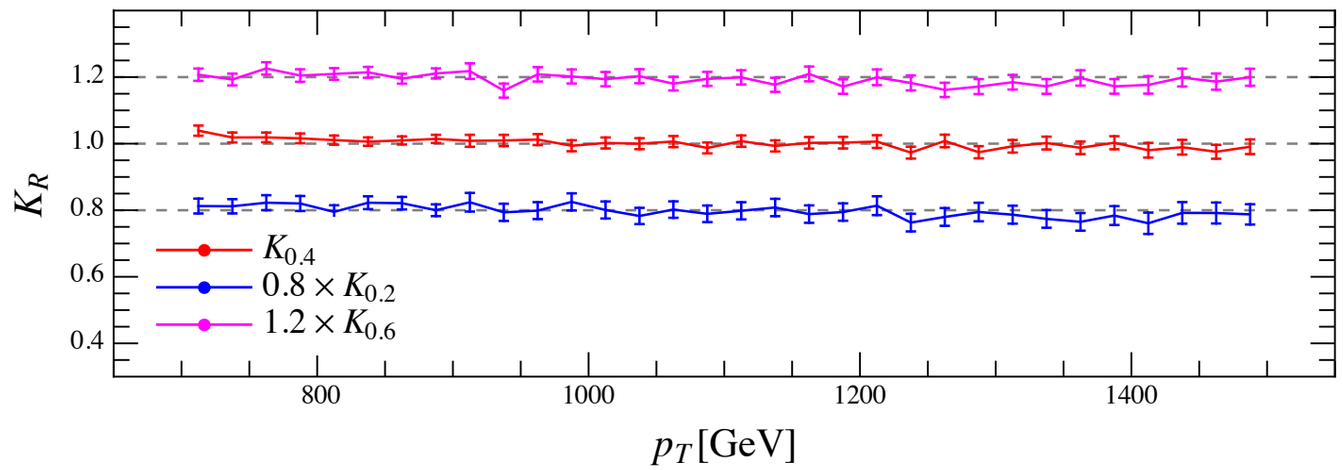


but enhanced by the steep falling of the luminosity

Inclusive jet production

- Possible large corrections
  - small R
  - threshold

NLO singular /NLO full



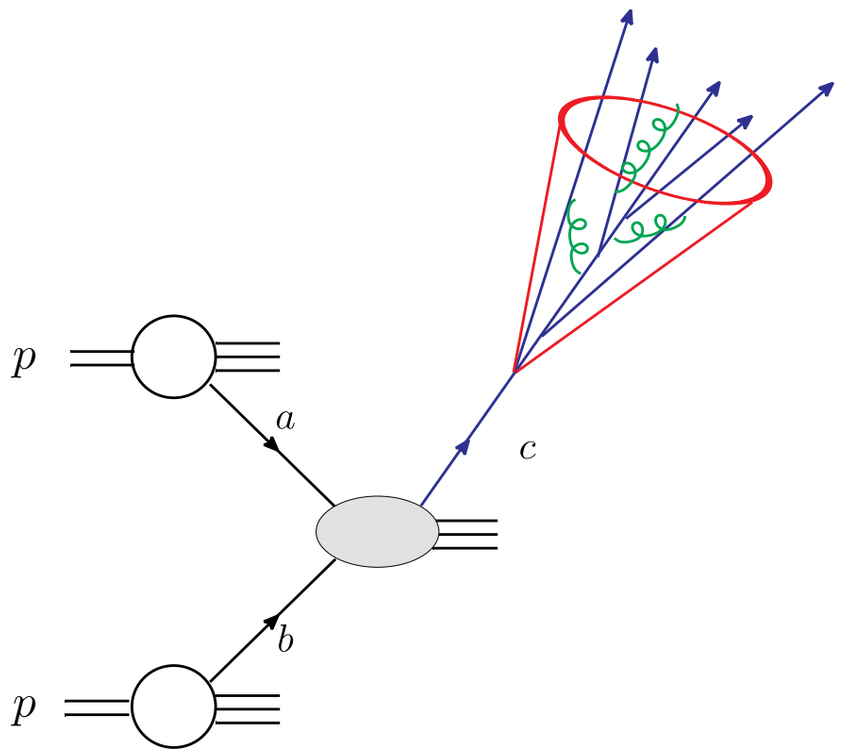
$$\sum_{m=0,k=1} \alpha_s^n \left[\frac{\ln^{2n-m-k} z}{z} \right]_+ \ln^m R$$

singular terms make up the dominant bulk of the NLO result.

Inclusive jet production

- Factorization and resummation

$$\sum_{m=0,k=1} \alpha_s^n \left[\frac{\ln^{2n-m-k} z}{z} \right]_+ \ln^m R$$



$$\ln R = \ln \frac{p_T R}{p_T} = \ln \frac{p_T R}{\mu} + \ln \frac{\mu}{p_T}$$

$$\frac{\mathrm{d}^2\hat{\sigma}_{i_1 i_2}}{\mathrm{d}v\,\mathrm{d}z} = s \int \mathrm{d}s_X\,\mathrm{d}s_c \mathrm{d}s_G\,\delta(zs - s_X - s_G - s_c)$$
$$\times \mathrm{Tr}\left[\mathbf{H}_{i_1 i_2}(v, p_T, \mu_h, \mu)\,\mathbf{S}_G(s_G, \mu_{sG}, \mu)\right] J_X(s_X, \mu_X, \mu)$$
$$\times \sum_m \mathrm{Tr}\left[J_m(p_T R, \mu_J, \mu) \otimes_\Omega S_{c,m}(s_c R, \mu_{sc}, \mu)\right]$$

derived within SCET + Becher, Neubert, Rothen, Shao, PRL 2016

Inclusive jet production

- Factorization and resummation

Fixed Order

Resummation

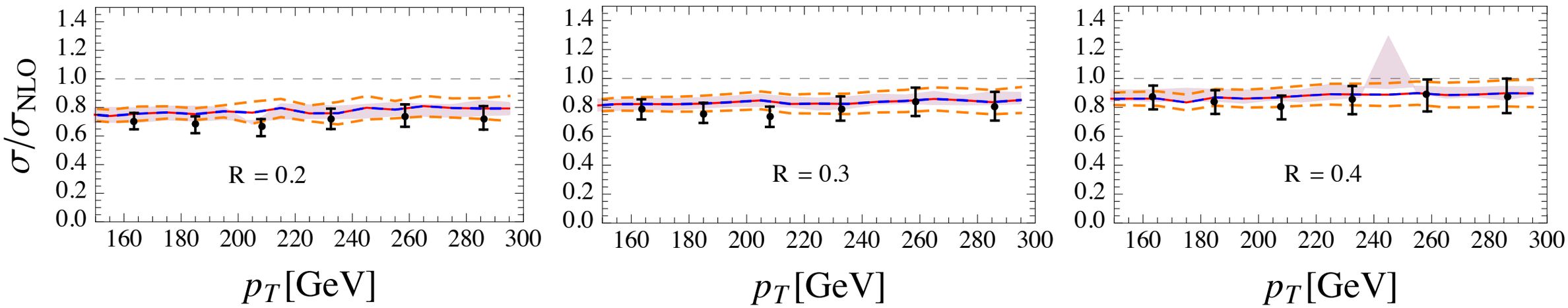
LO	1					
NLO	$\alpha_s L^2$	$\alpha_s L$	α_s			
NNLO	$\alpha_s^2 L^4$	$\alpha_s^2 L^3$	$\alpha_s^2 L^2$	$\alpha_s^2 L$	α_s^2	
...	...	...	...	...	...	
N^kLO	$\alpha_s^k L^{2k}$	$\alpha_s^k L^{2k-1}$	$\alpha_s^k L^{2k-2}$	$\alpha_s^k L^{2k-3}$	$\alpha_s^k L^{2k-4}$	...

LL NLL NNLL

Inclusive jet production

- Phenomenology
  - compare with 2.76 TeV LHC data

with NLO CT10 PDF sets
NP effects included



- NLO consistently higher than the data for all choices of R ’s.
- NLL + NLO agrees very well with the data

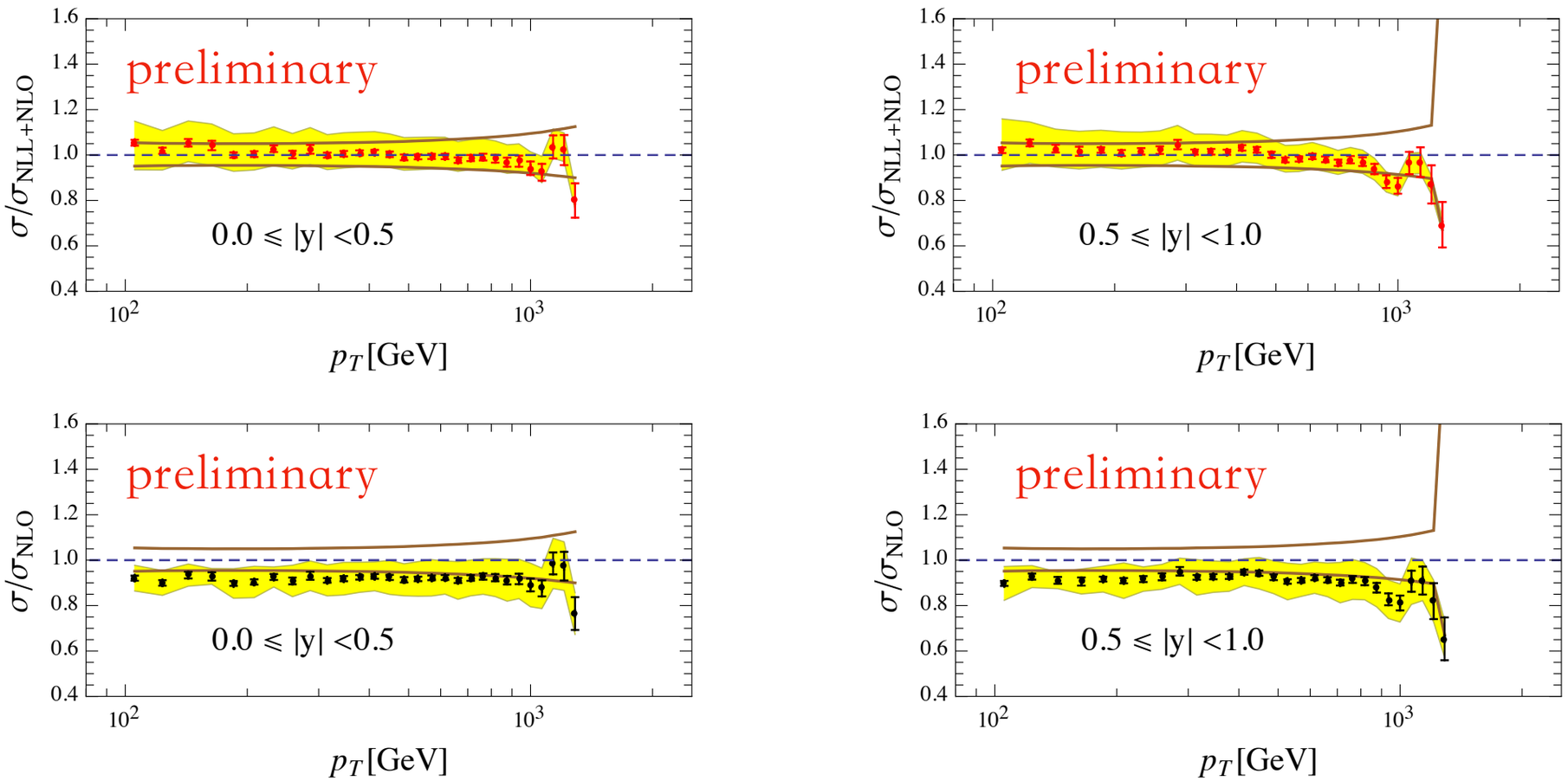
XL, Moch, Ringer, PRL 2017

NLO using MEKS, Gao, et. al. 2012

Inclusive jet production

- Phenomenology
  - compare with 7 TeV LHC data

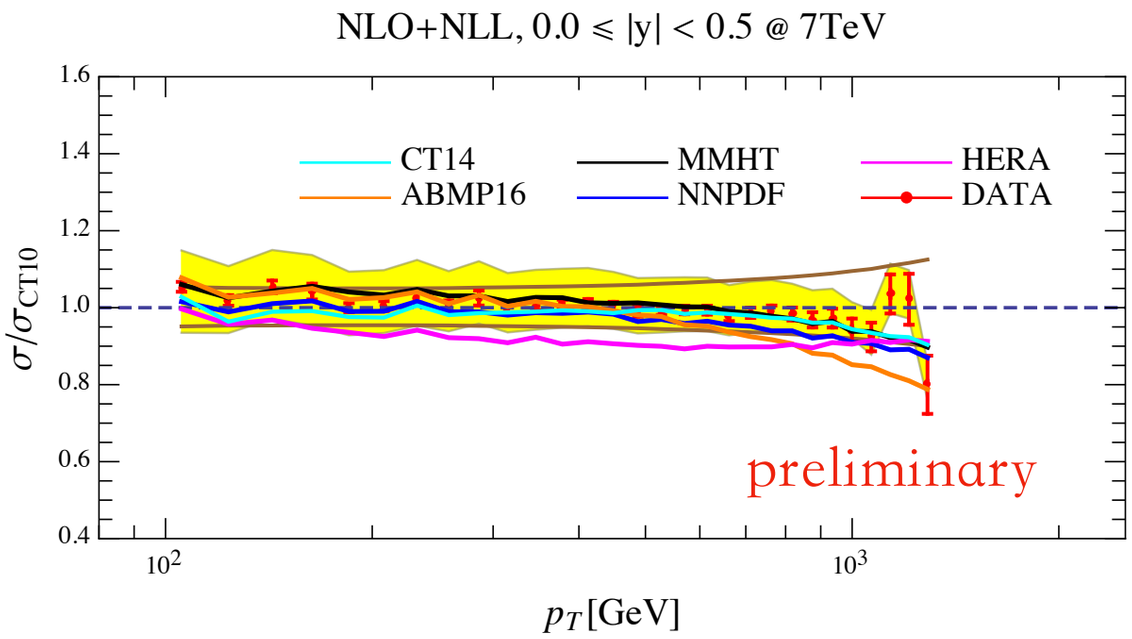
with NLO CT10 PDF sets
NP effects included

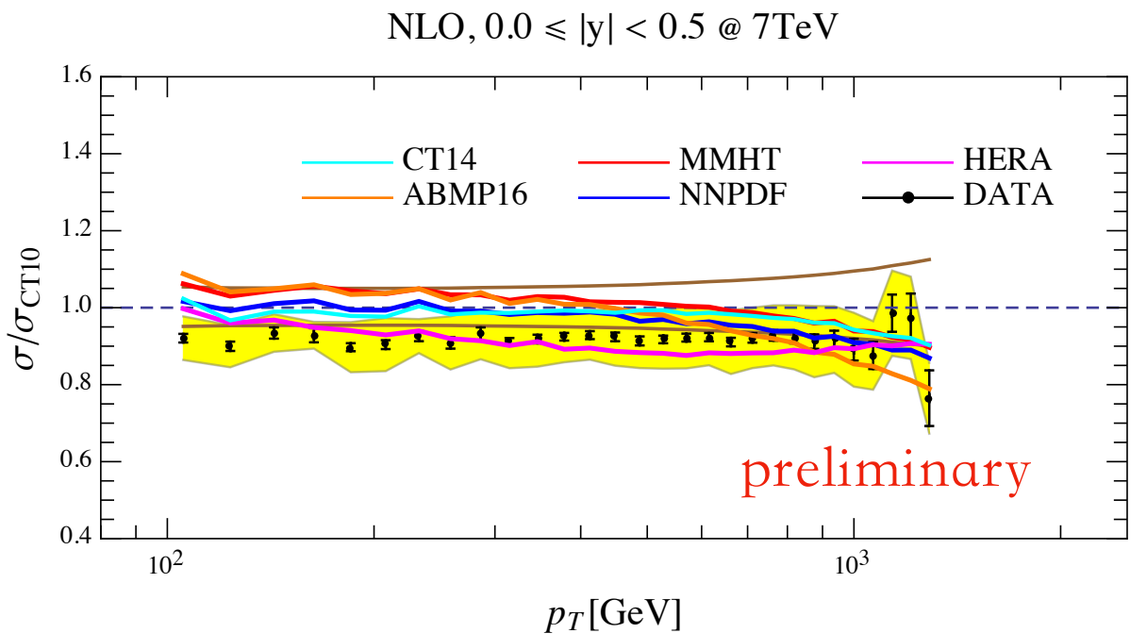


- NLO is higher than the data while NLL + NLO agrees well

Inclusive jet production

- Phenomenology
  - Impact of PDFs

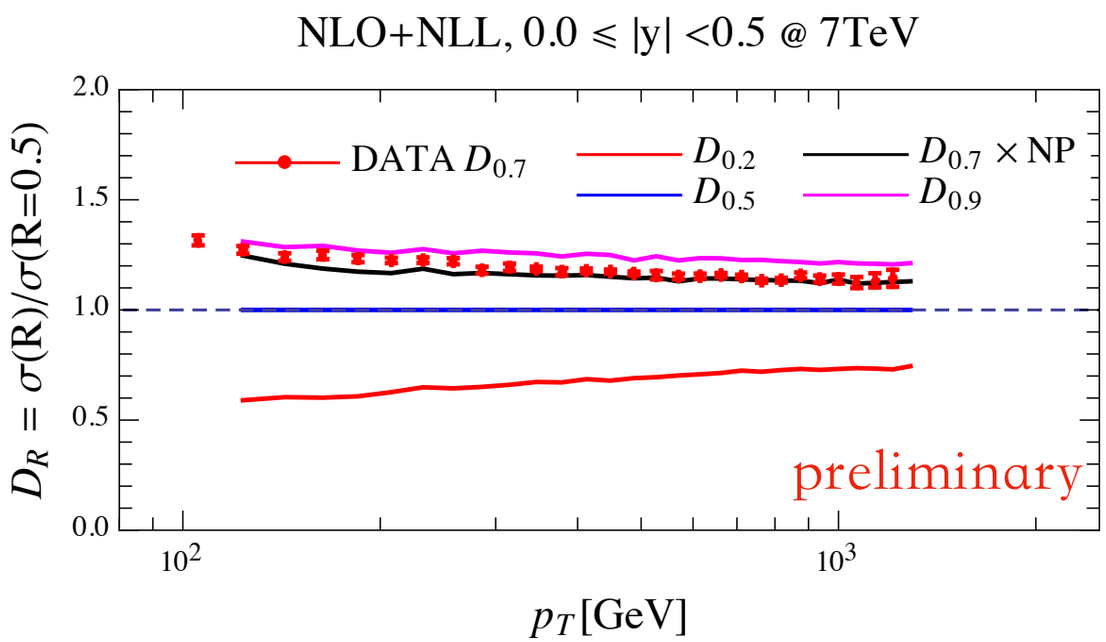


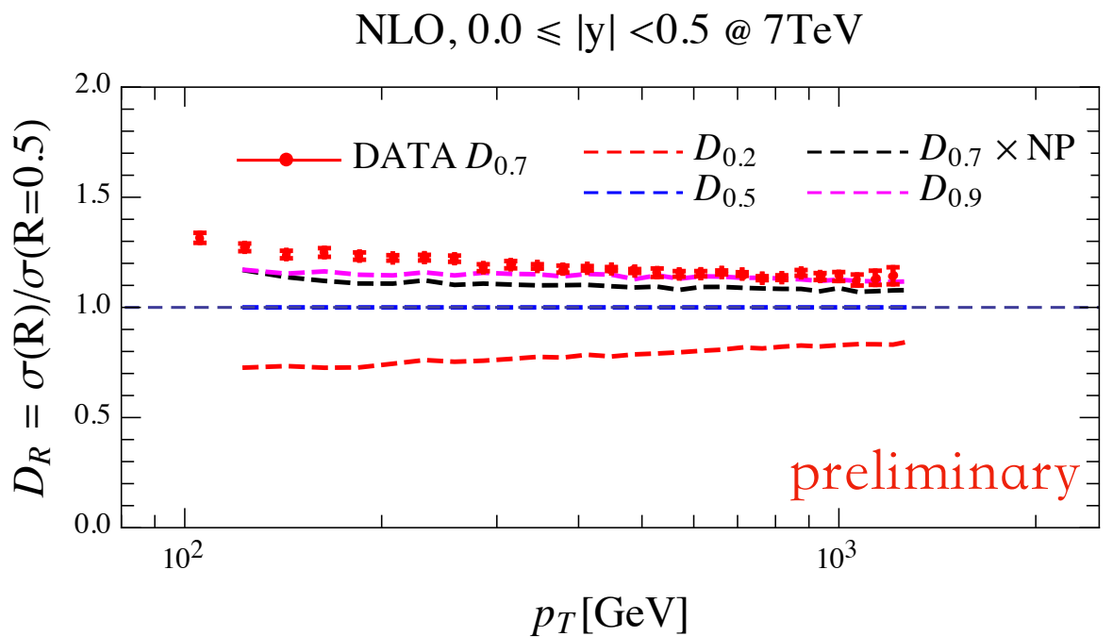


- Considering the impact of PDFs does not change the conclusion

Inclusive jet production

- Phenomenology
  - compare with 7 TeV LHC data





- Take the ratio to reduce the PDF impacts
- NLO does not describe the data while NLO + NLL does a much better job

Conclusions

- A framework allows to do threshold and small R joint resummation.

- Can go beyond the current accuracy to achieve NNLO + NNLL in the future.

- Tensions between the theory and the LHC data are dramatically relieved.

- Start to provide numbers for the CMS inclusive jet analysis.