

Resummed single jet inclusive production at the LHC

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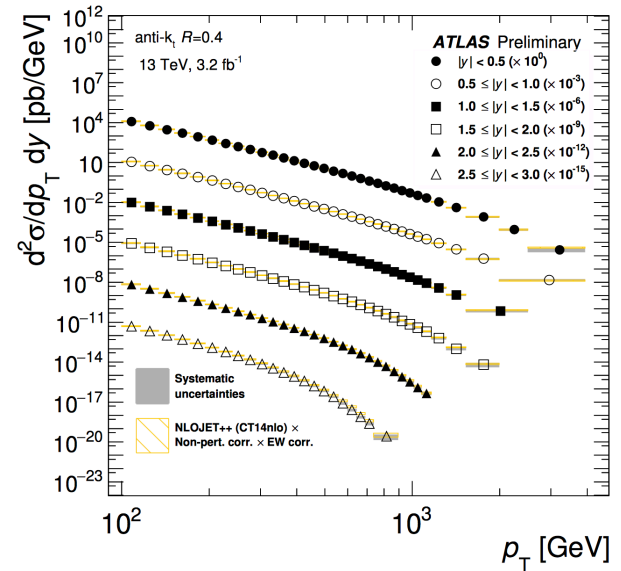
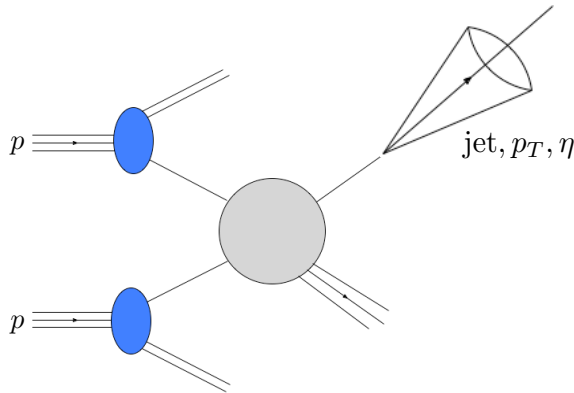
XL, Moch, Ringer, 17
XL, Moch, Ringer, 1801.07284

Outlines

- Motivation
 - Jets@LHC
 - Current theory status
- Threshold and small R joint resummation
- Phenomenology

Jets @ the LHC

- Benchmark processes at the LHC
 - Inclusive jet, ...
 - alphas extraction
 - PDF fitting
 - ...



lots of data at the LHC to very large p_T

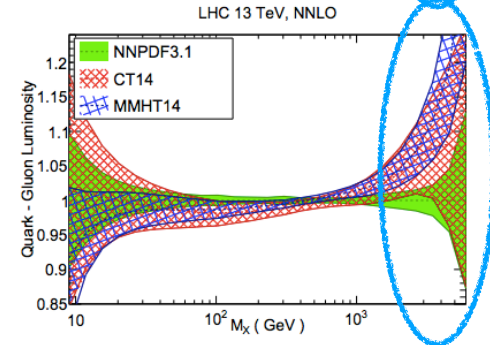
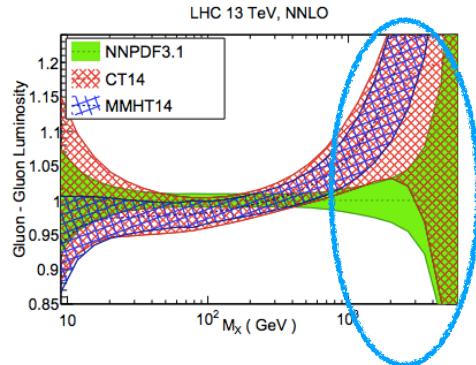
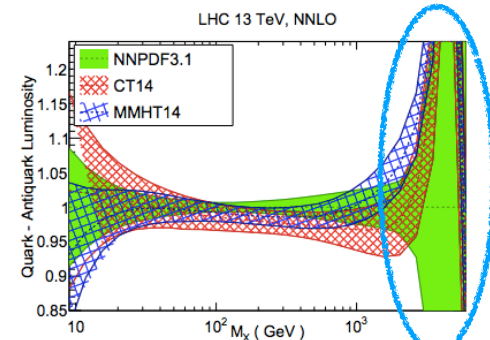
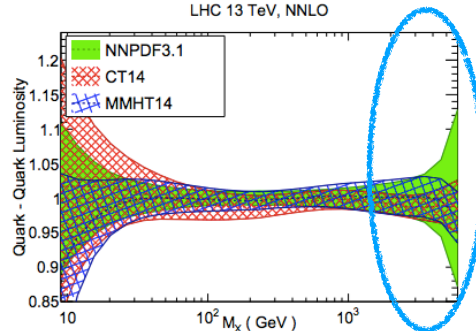
Jets @ the LHC

- Benchmark processes at the LHC

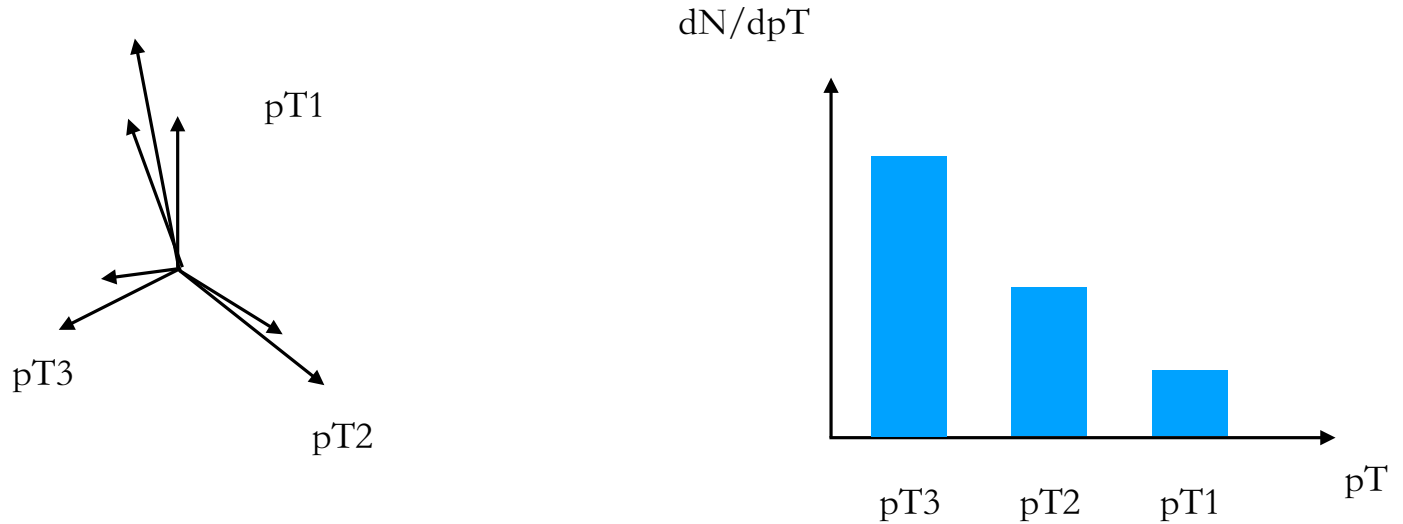
- Inclusive jet, ...
 - α_s extraction
 - PDF fitting
 - ...

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

- May be constrained by near future inclusive jet p_T analyses.



Inclusive jet production



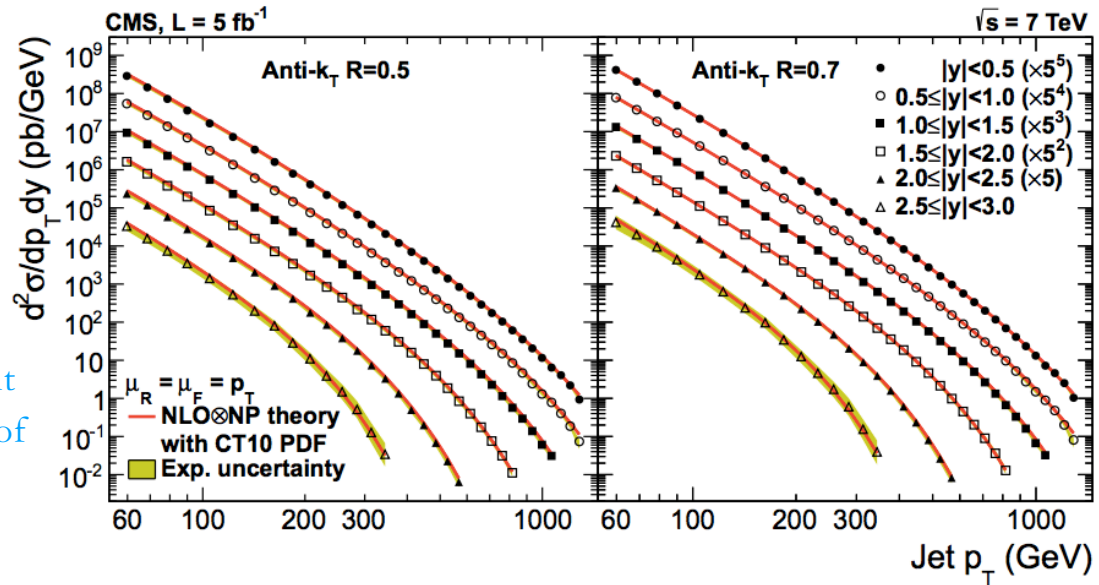
n-jets to n pT -bins

Inclusive jet production

- Current Status of arts
- NLO known for decades: NLOJET++ (Nagy, 02), (M)EKS (Ellis,

Kunszt, Soper, 92) ...

Impressive agreement
up to several orders of
magnitude

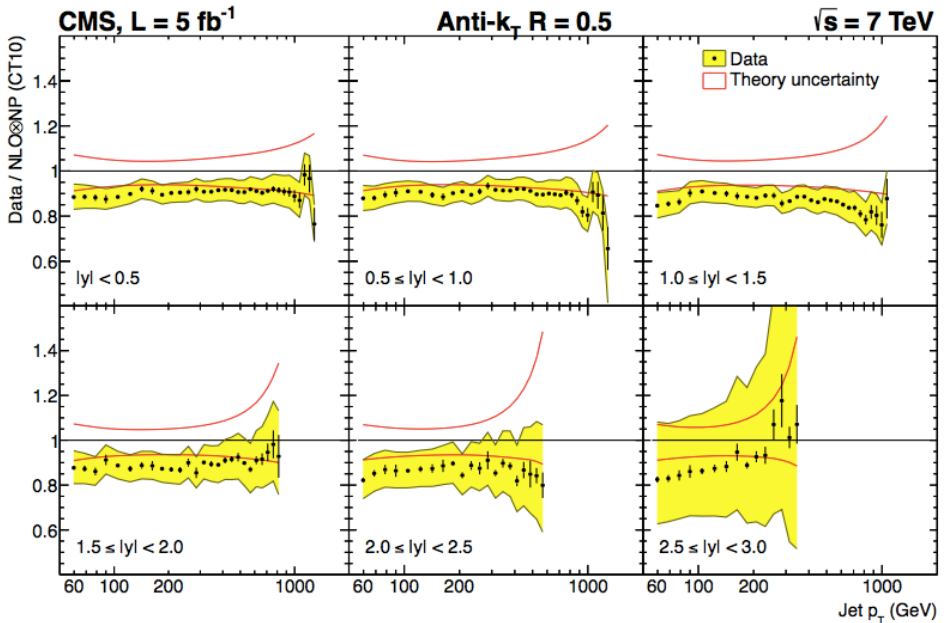


Inclusive jet production

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- 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

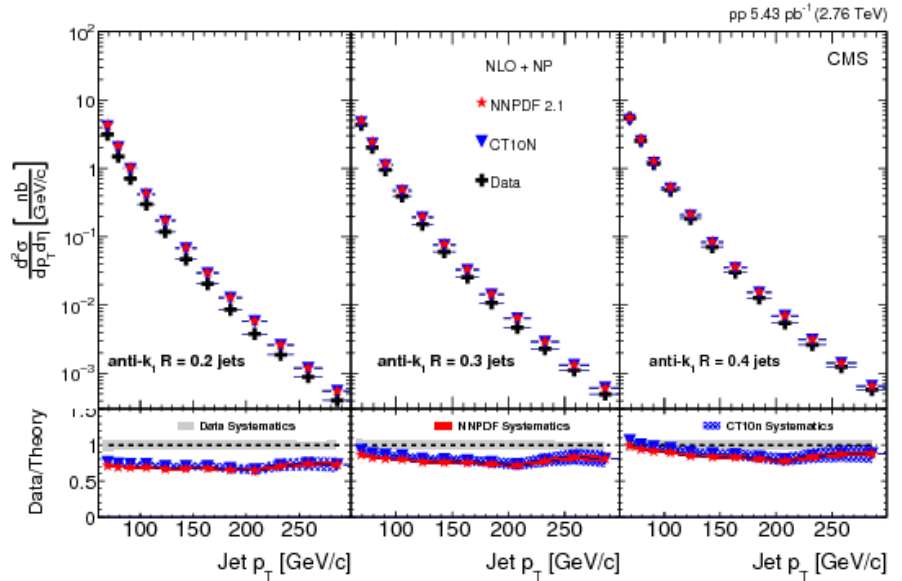


Inclusive jet production

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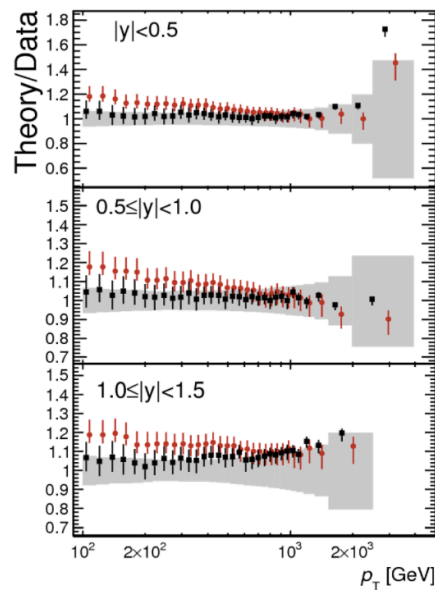
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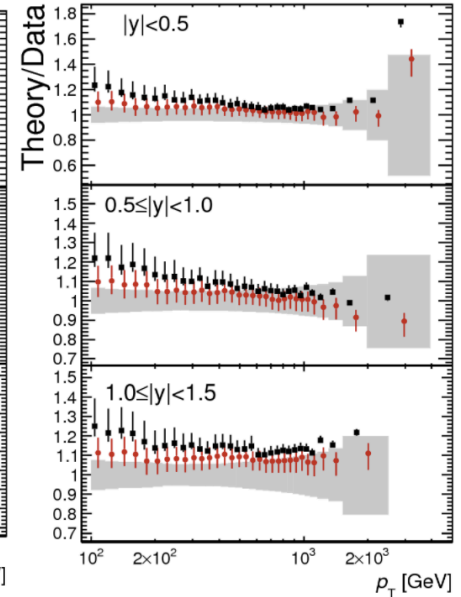
CMS, 1609.05383

Inclusive jet production

- Current Status of arts
 - 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

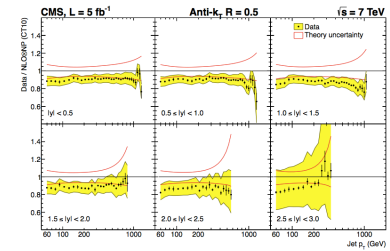


scale = leading jet pT

Currie, Glover, Pires, 17

Inclusive jet production

- Current Status of arts
 - NLO known for decades: NLOJET++ (Nagy, 02), (M)EKS (Ellis, Kunszt, Soper, 92) ...
 - NNLO with leading color approximation

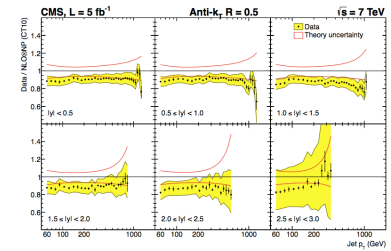


“ While no cuts were applied to all jet datasets included in NNPDF3.1, for the 2011 ATLAS 7 TeV dataset a good agreement between data and theory was obtained when fitting only the central rapidity bin, $|y_{\text{jet}}| < 0.5$. Concurrently, it was found that achieving a good description of the ATLAS 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
 - NLO known for decades: NLOJET++ (Nagy, 02), (M)EKS (Ellis, Kunszt, Soper, 92) ...
 - NNLO with leading color approximation



“ We find that some improvement is in general achieved when going to NNLO, with the exception of the p_T^{jet} and lower R choice, where there is a slight deterioration.”

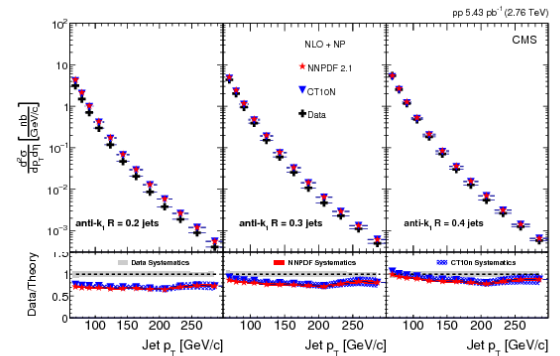
Harland-Lang, Martin, Thorne `17

Inclusive jet production

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

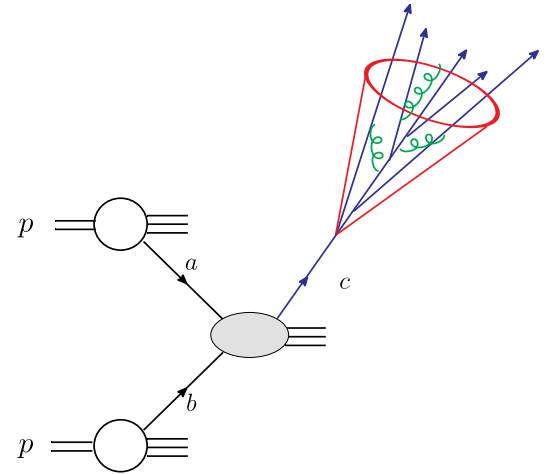
Large higher order corrections?

Possible sources: threshold + small radius



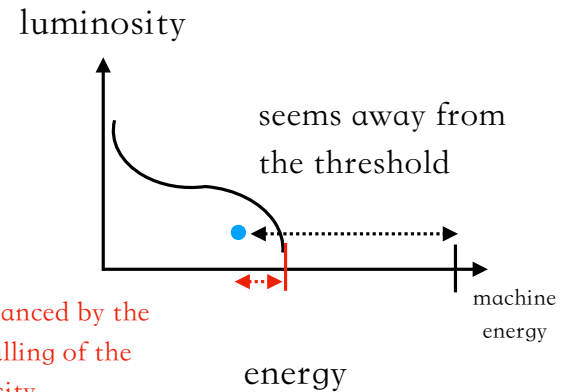
Inclusive jet production

- Possible large corrections
 - small R
 - threshold



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

z measures the invariant mass outside the signal jet, characterize the distance to the threshold

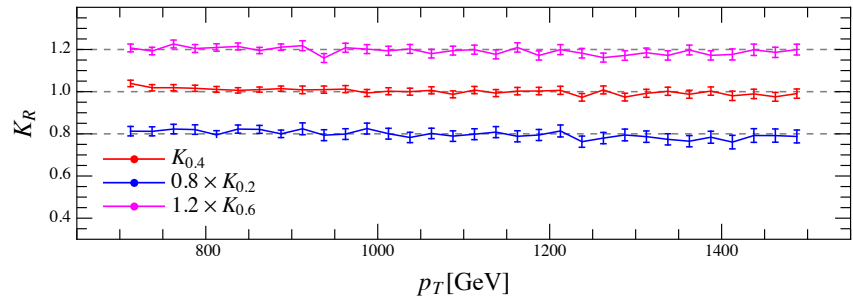


Inclusive jet production

- Possible large corrections

NLO singular /NLO full

- small R
- threshold

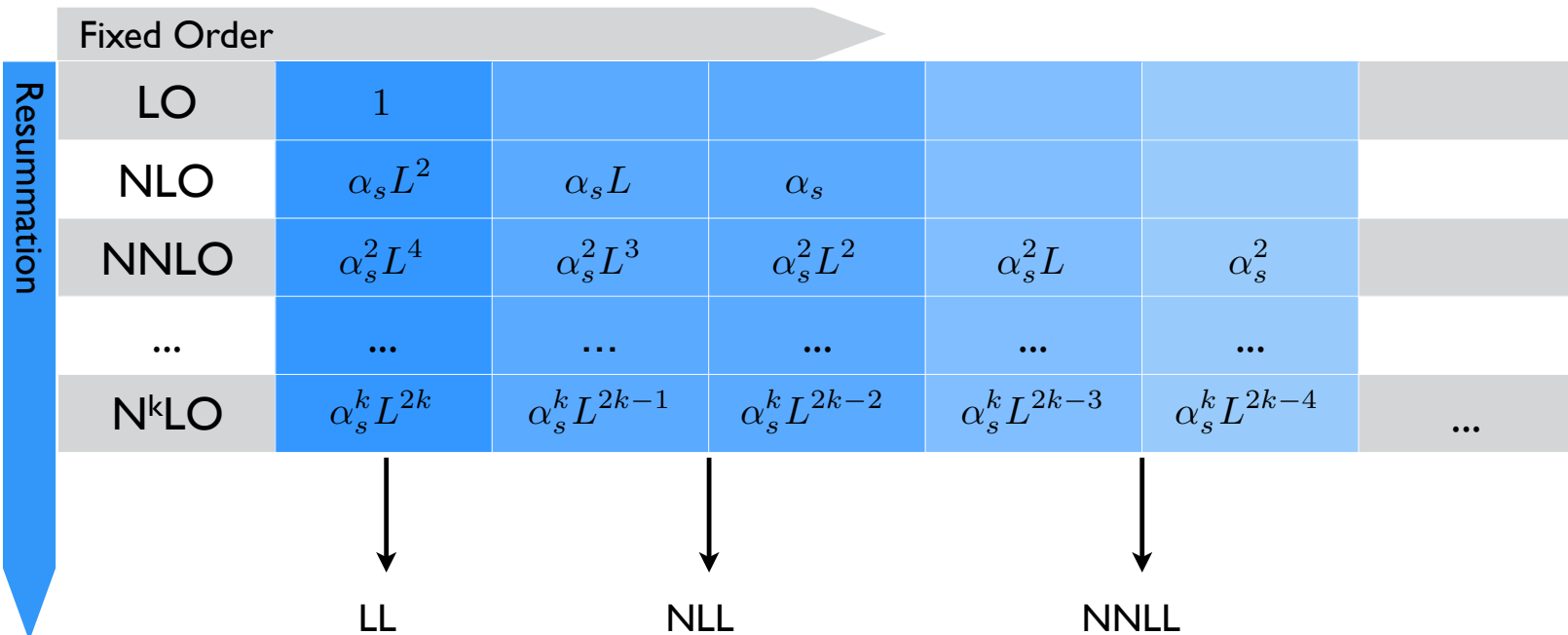


$$\sum_{m=0, k=1} \alpha_s^n \left[\frac{\ln^{2n-m-k} z}{z} \right]_+ \ln^m R$$

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

Inclusive jet production

- Factorization and resummation



Inclusive jet production

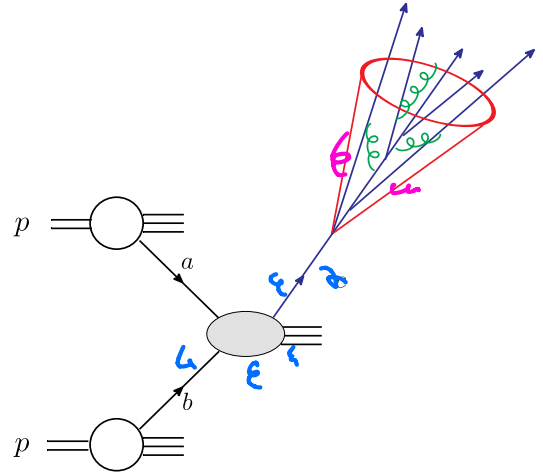
- Factorization and resummation

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

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



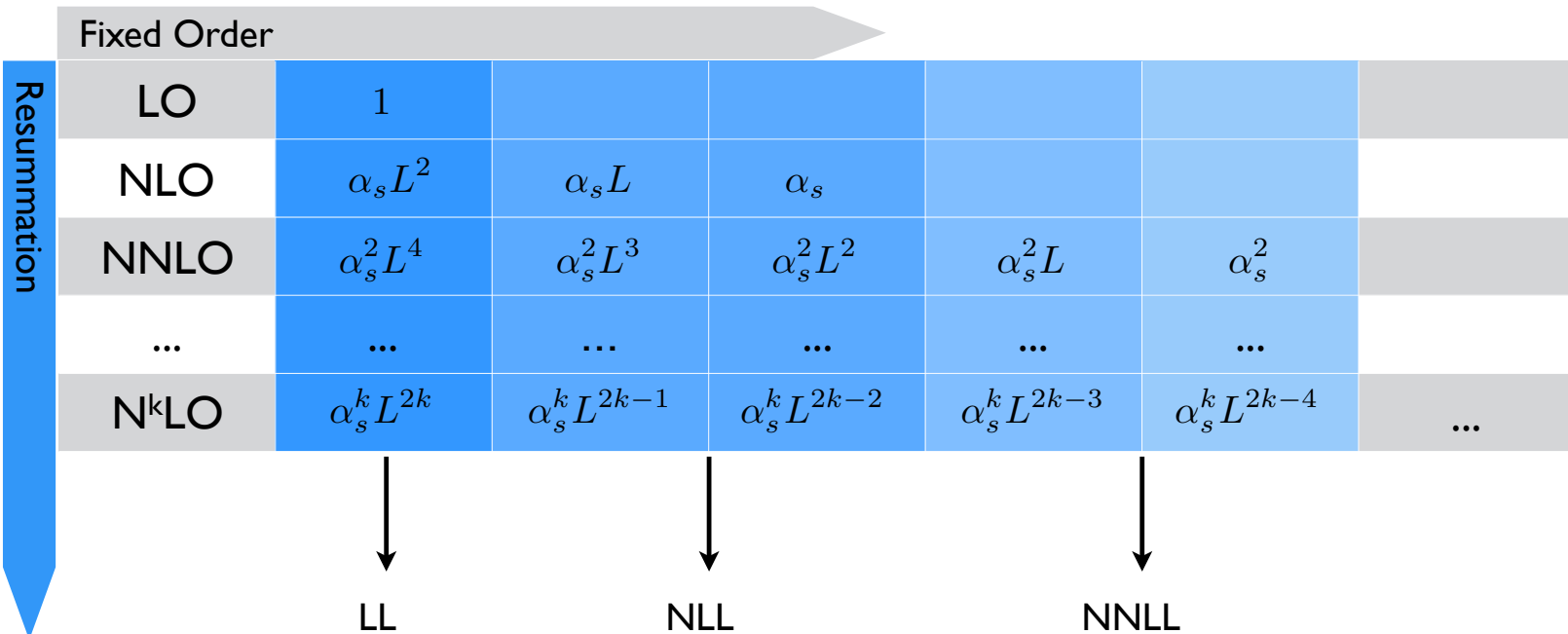
$$\begin{aligned} \frac{d^2 \hat{\sigma}_{i_1 i_2}}{dv dz} &= s \int ds_X ds_c ds_G \delta(zs - s_X - s_G - s_c) \\ &\times \text{Tr} [\mathbf{H}_{i_1 i_2}(v, p_T, \mu_h, \mu) \mathbf{S}_G(s_G, \mu_{sG}, \mu)] J_X(s_X, \mu_X, \mu) \\ &\times \sum_m \text{Tr} [J_m(p_T R, \mu_J, \mu) \otimes_{\Omega} S_{c,m}(s_c R, \mu_{sc}, \mu)] \end{aligned}$$



derived within SCET + Becher, Neubert, Rothen, Shao ...

Inclusive jet production

- Factorization and resummation

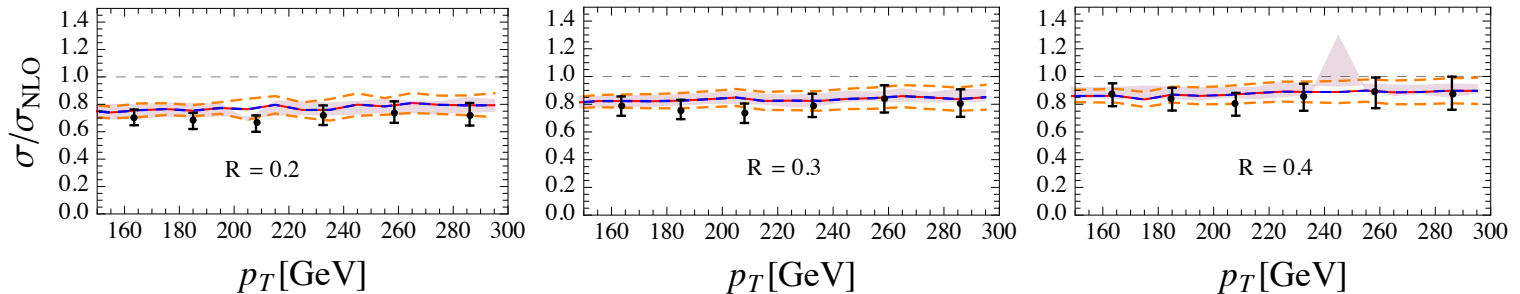


$$\sigma = \sigma_{\text{NLO}} - \sigma_{\text{sin.}} + \sigma_{\text{NLL}}$$

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 radii.
- NLL + NLO agrees very well with the data

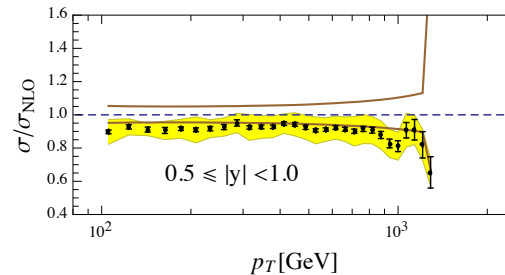
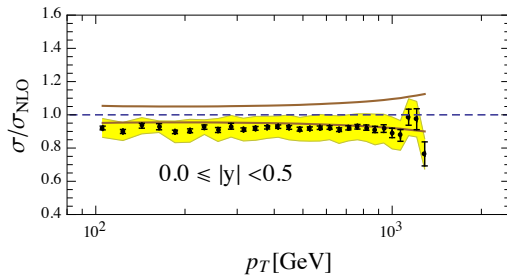
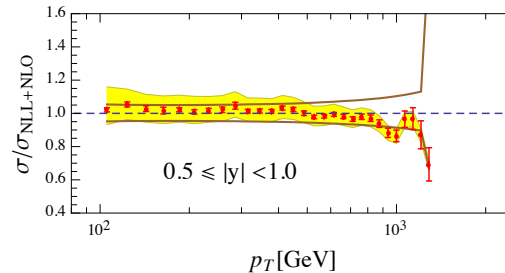
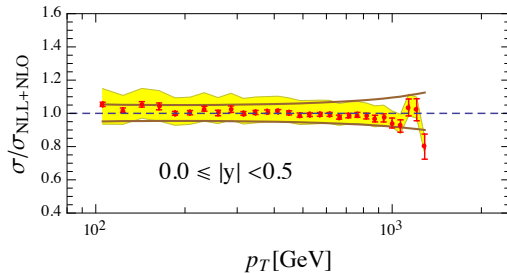
XL, Moch, Ringer, 2017

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

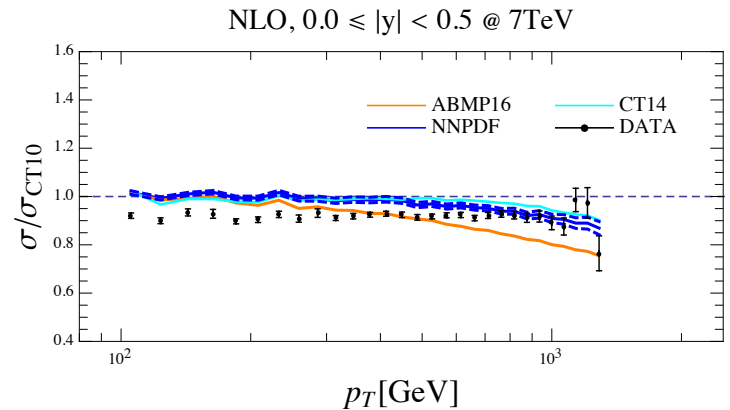
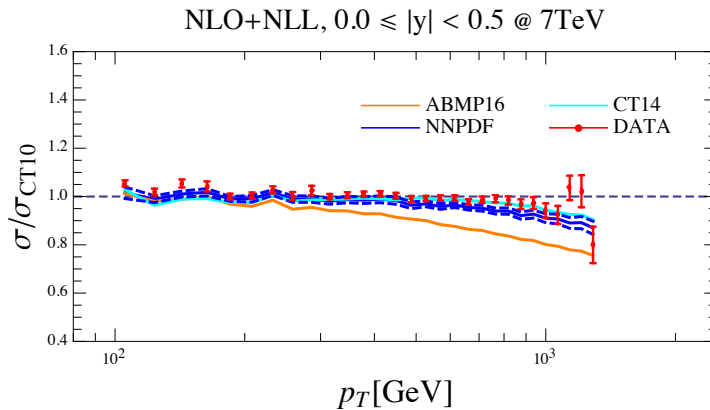


similar story
for higher
rapidity bins

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

Inclusive jet production

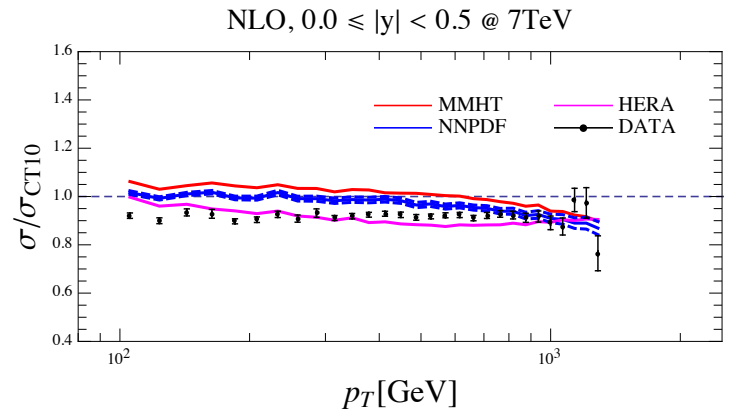
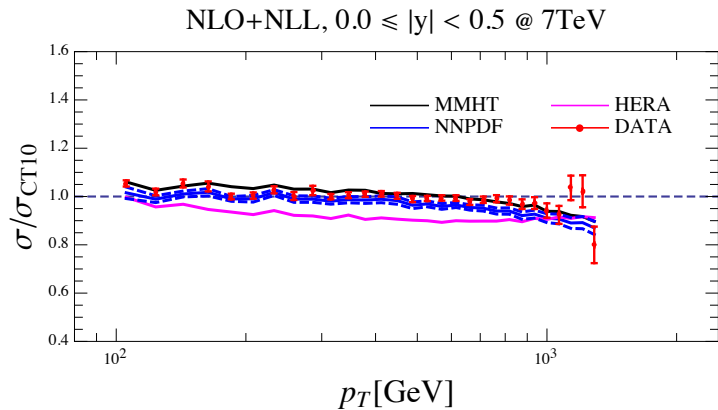
- Phenomenology
 - Impact of PDFs



- PDF uncertainty is small
- Considering the impact of PDFs does not change the conclusion: resummation improves the theory prediction quite a lot.

Inclusive jet production

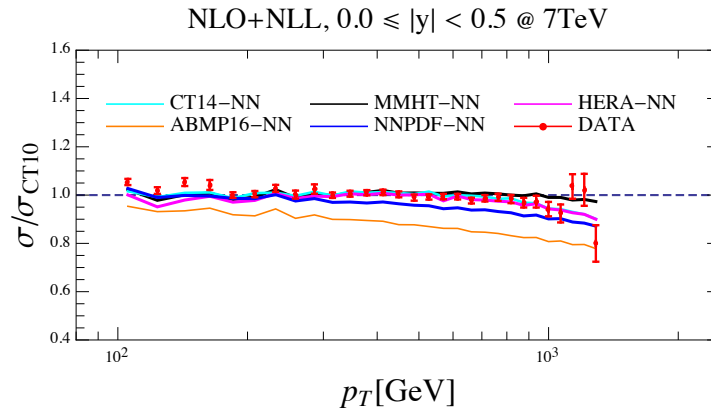
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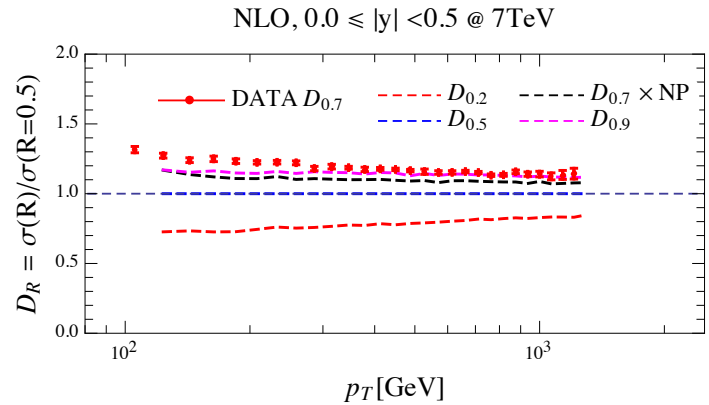
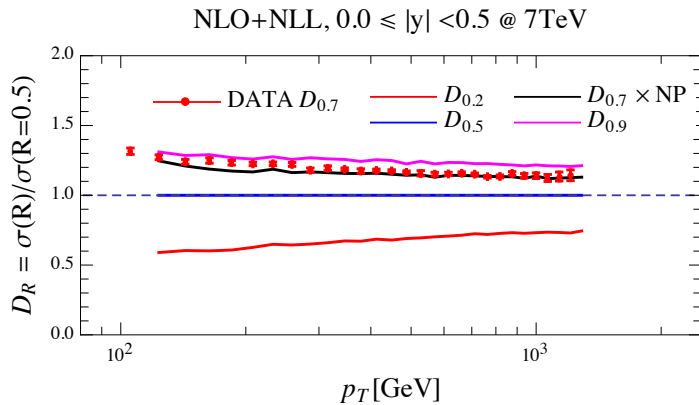
- Phenomenology
- Impact of PDFs



- NNLO extraction of PDF overall does good job in describe the data
- Still missing possible large NNLO correction like 2-loop constant terms.
- ABMP is lower due to the small coupling constant used, correctly captures the shape

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

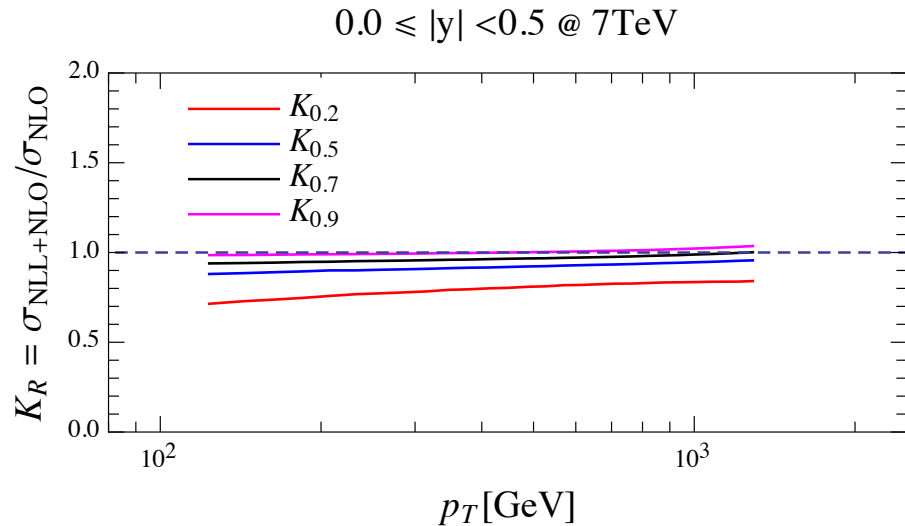
Conclusions

- 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.
- Would like to do further comparison with more LHC inclusive jet analyses.

Thanks

Backup

- Threshold enhancement v.s. log R suppression



XL, Moch, Ringer, 17-18
see also Nagy and Soper, 17