scale setting for single jet and dijet inclusive cross sections

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Les Houches Workshop, Physics at the TeV colliders
June 8, 2017

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MAX-PLANCK-GESELLSCHAFT

Single jet inclusive cross section

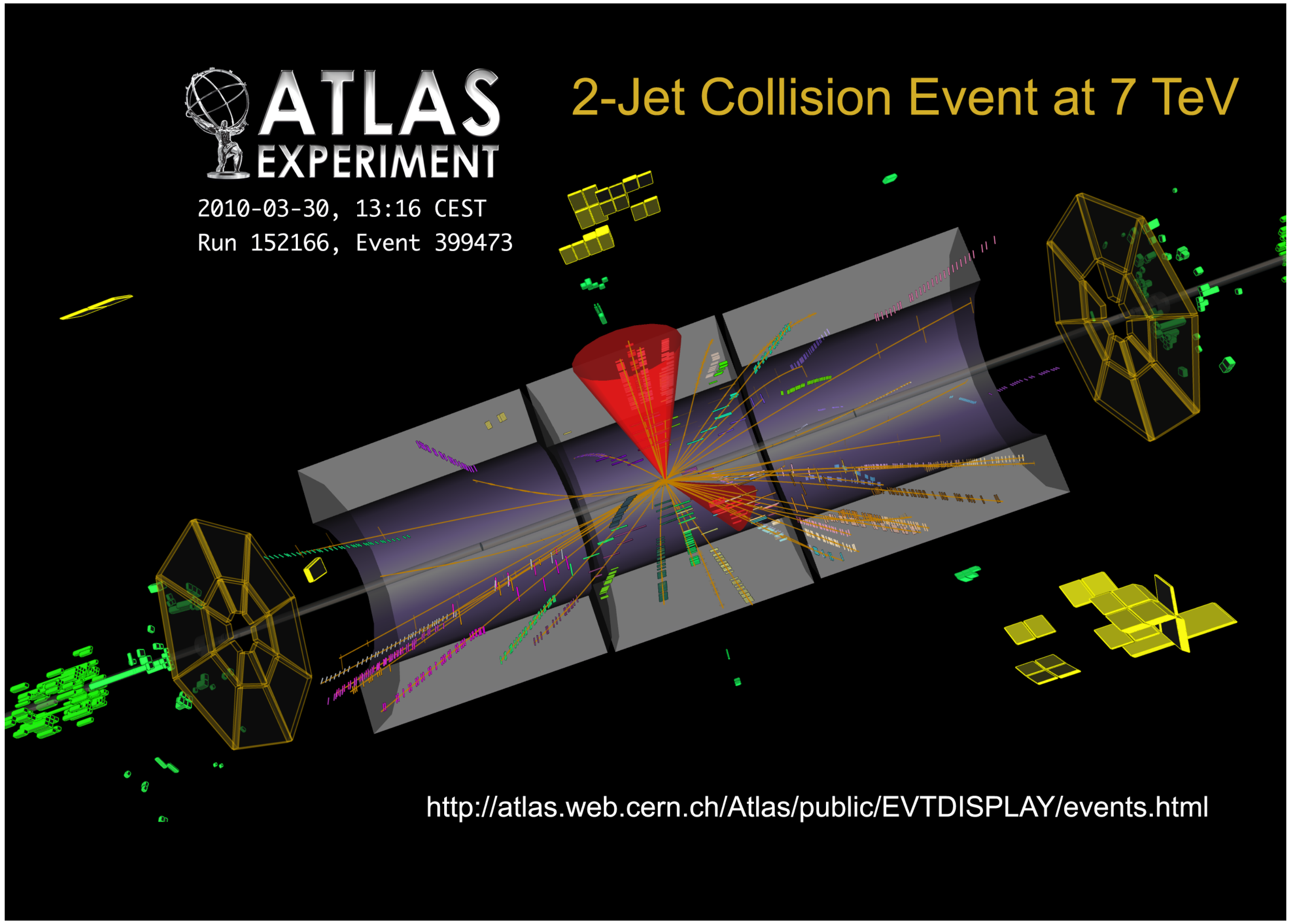
ATLAS jets

Theory setup

- NNPDF3.0_nnlo
- anti-k_T jet algorithm
- p_{Tmin} > 100 GeV ; $|y|$ <3.0
- $\mu_R = \mu_F = \{p_{T1}, p_T\}$
- vary scales by factors of 2 and 1/2

Comparison to data

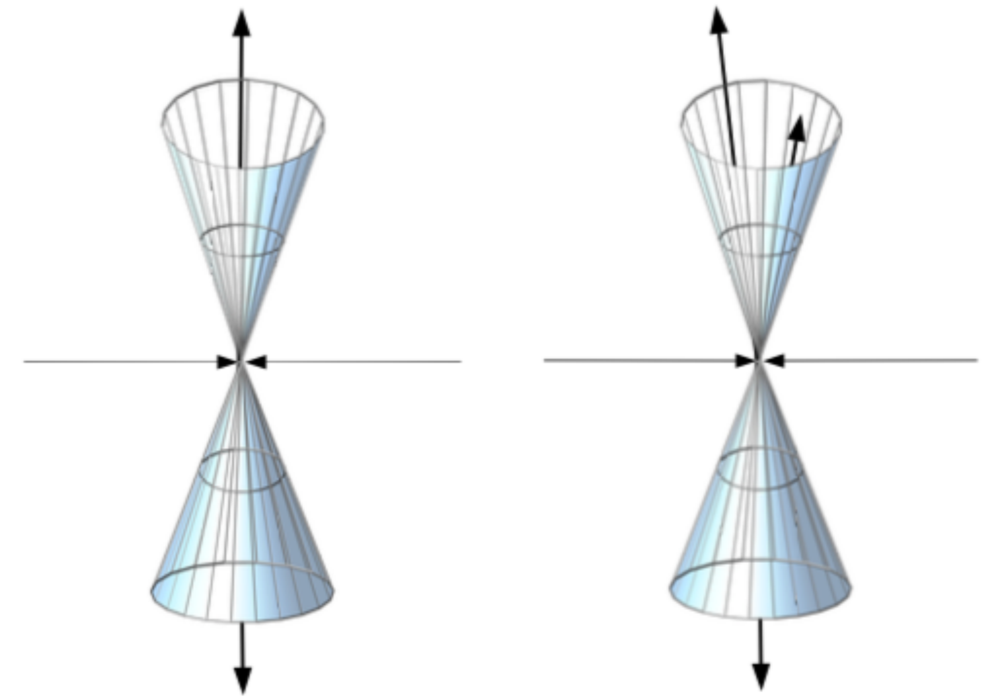
- ATLAS 7 TeV 4.5 fb^{-1}
- R=0.4



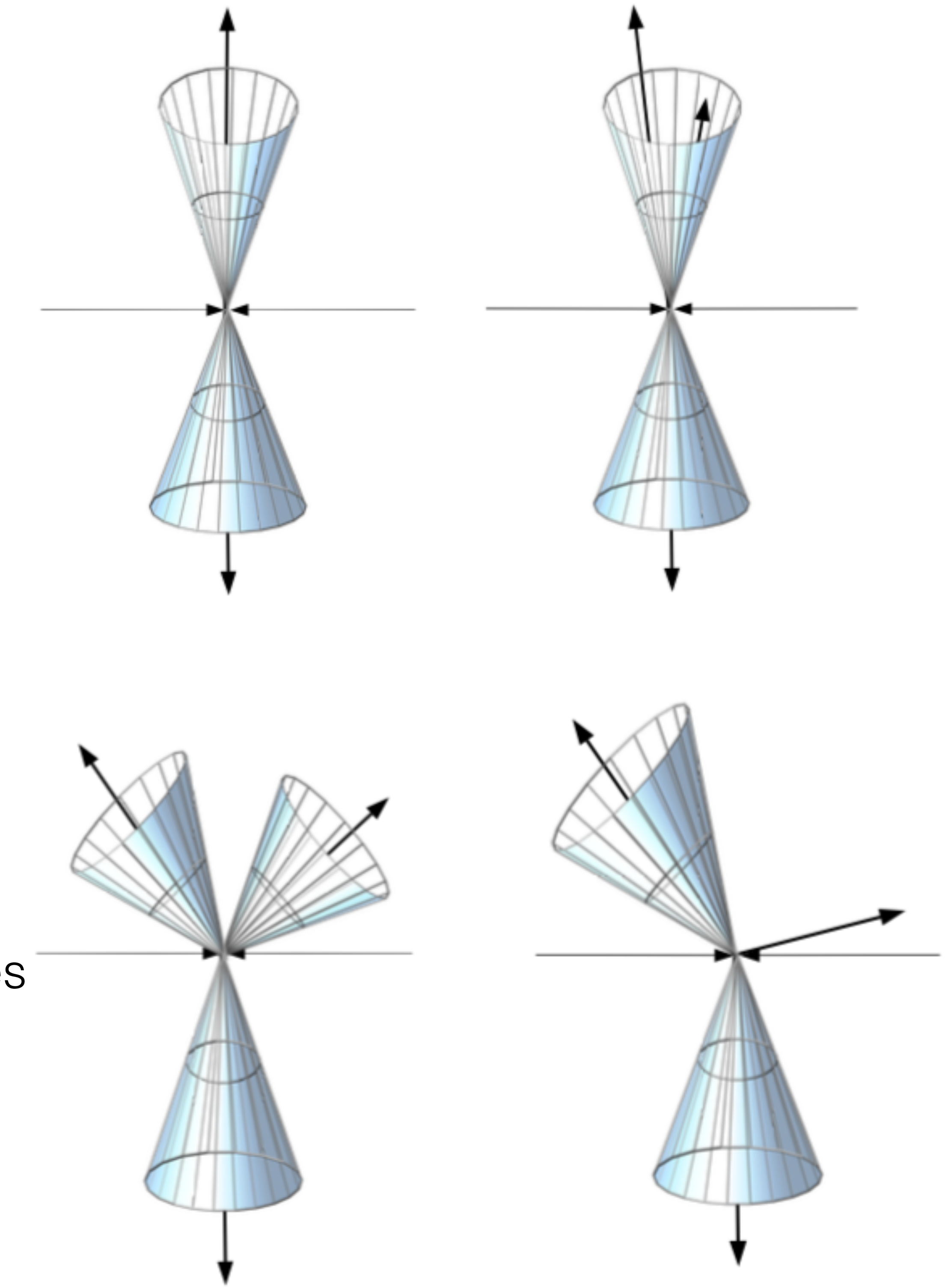
Single jet inclusive scale choice

two widely used scale choices:

- $\mu_R = \mu_F = \{p_{T1}, p_T\}$
  - leading jet p_T in the event p_{T1}
  - individual jet p_T
- high p_T jets are back to back $\Rightarrow$ $p_T \longrightarrow p_{T1}$



Single jet inclusive scale choice



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- $\mu_R = \mu_F = \{p_{T1}, p_T\}$
  - leading jet p_T in the event p_{T1}
  - individual jet p_T
- high p_T jets are back to back ⇒ p_T —> p_{T1}
- $p_T != p_{T1}$ for:
  - 3jet events
  - 3rd jet outside fiducial jet cuts

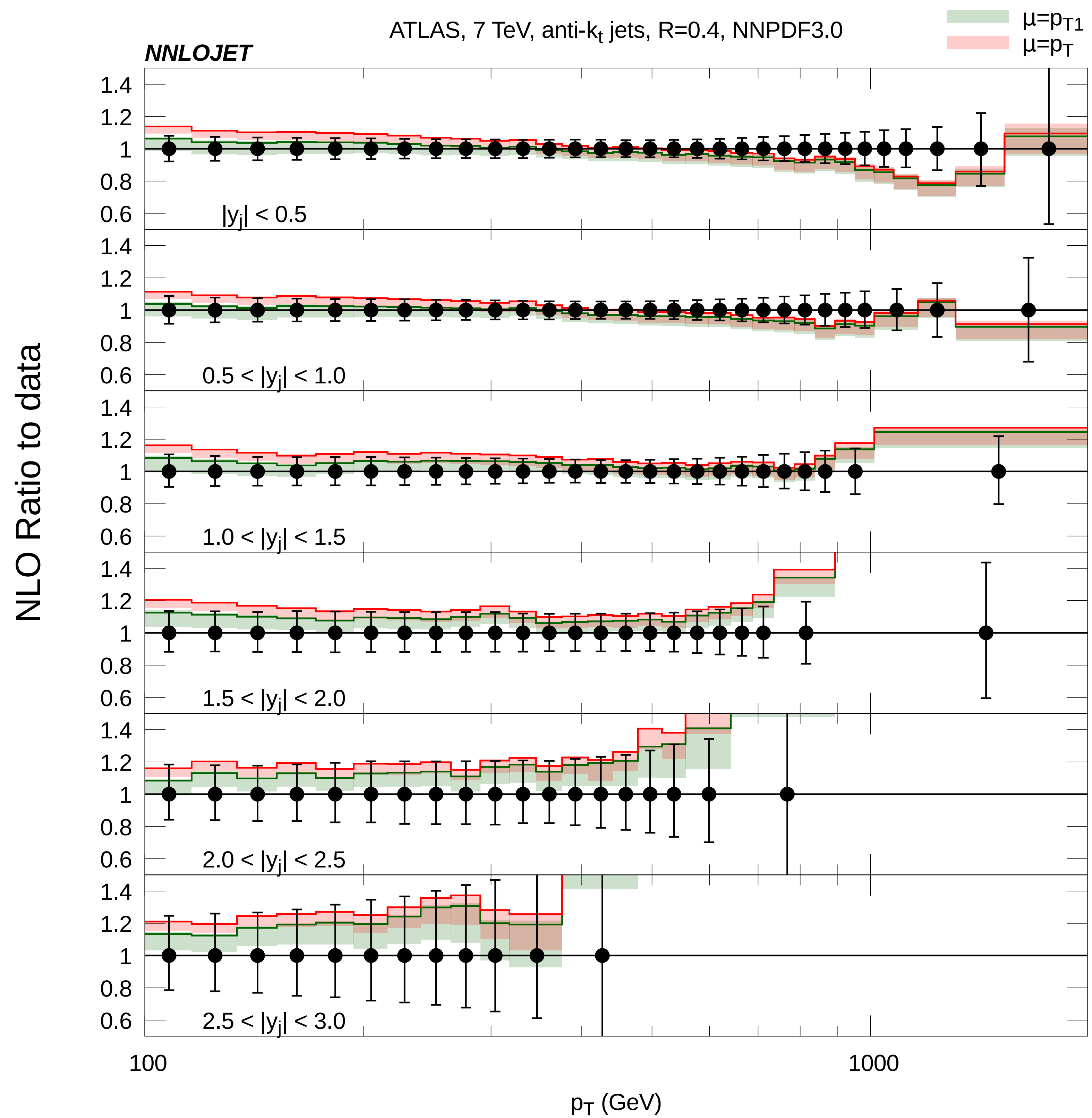
  ⇒ with p_T choice the real emission event with different R gives rise to a different scale ⇒ larger R ⇒ harder scale ⇒ p_T —> p_{T1} ; value of the scale depends on R
- at NLO the p_{T1} scale choice generates the same hard scale for the event independent of the value of R
- at NNLO for the first time p_{T1} scale depends on the value of R

Ratio to NLO

- asymmetric scale band variation
- underestimated at small pT due to turn over of the NLO coefficient
- 20% uncertainty for central high pT jets rising to 40% for forward jets

Comparison to data

- non perturbative effects < 2% effect [JHEP 1509, 141 (2015)]
- data favours the pT1 scale choice at NLO

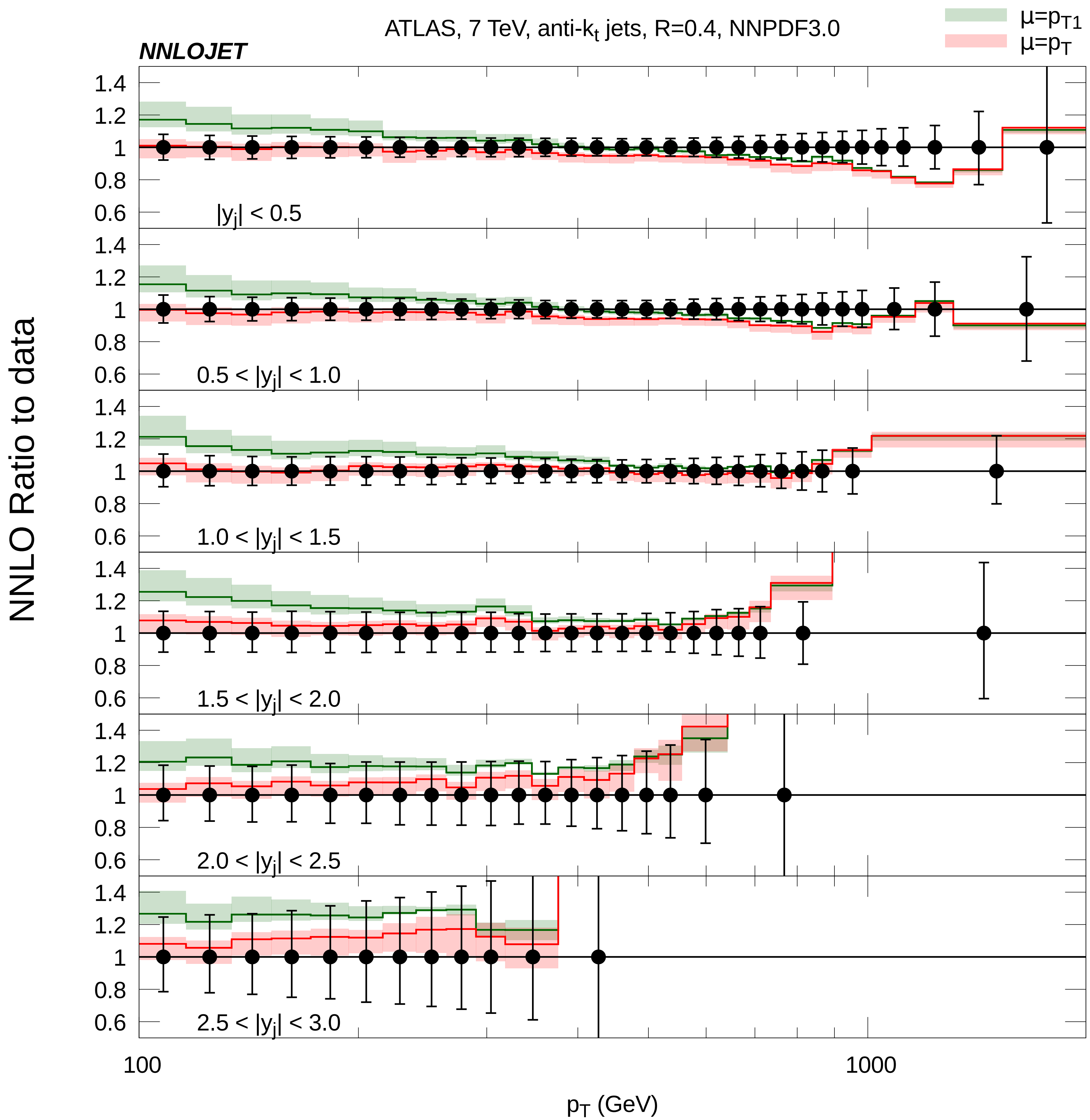


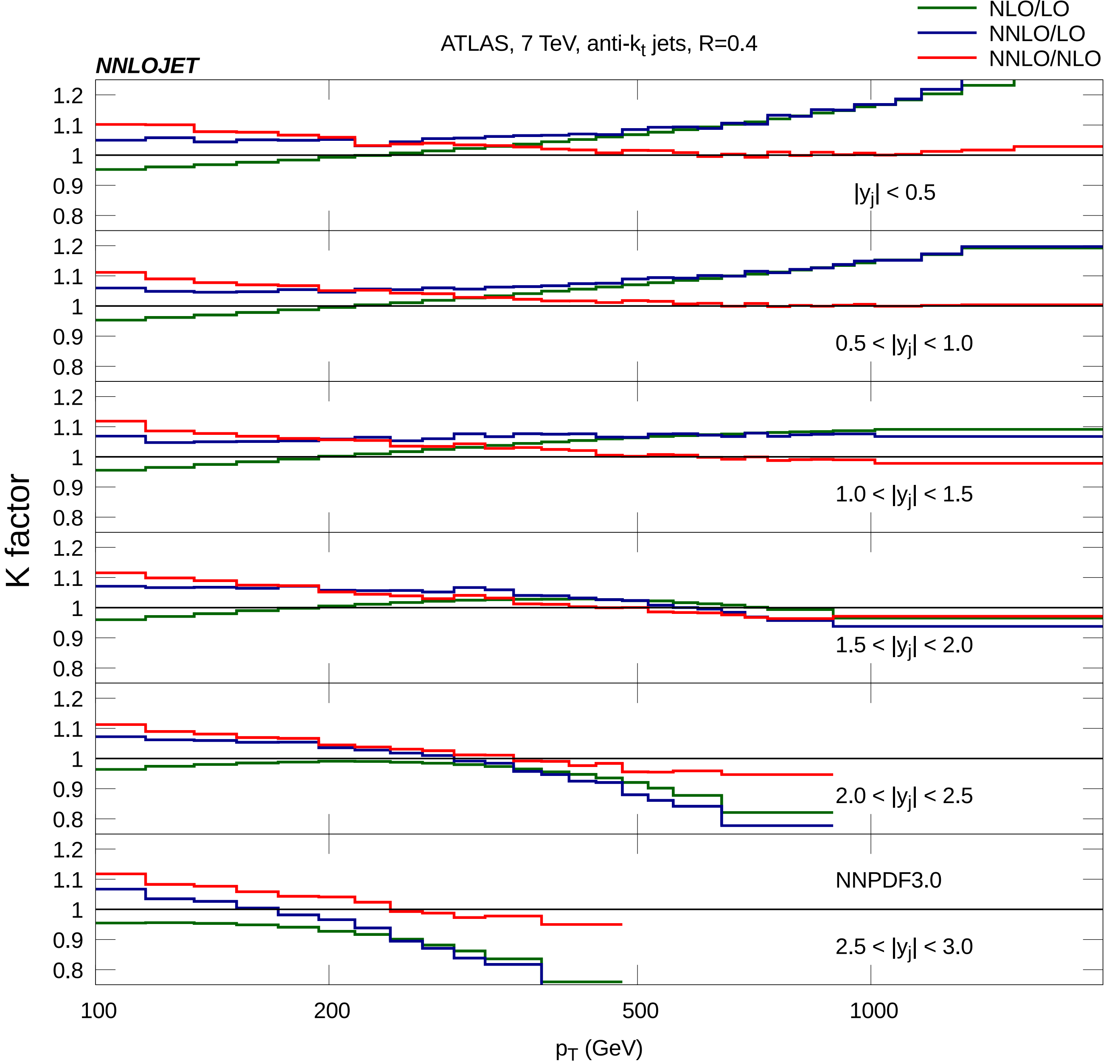
Ratio to NNLO

- symmetric scale band variation
- pT1!=pT effects enlarged at NNLO
- 10% scale uncertainty at low pT and percent level scale uncertainty at high pT

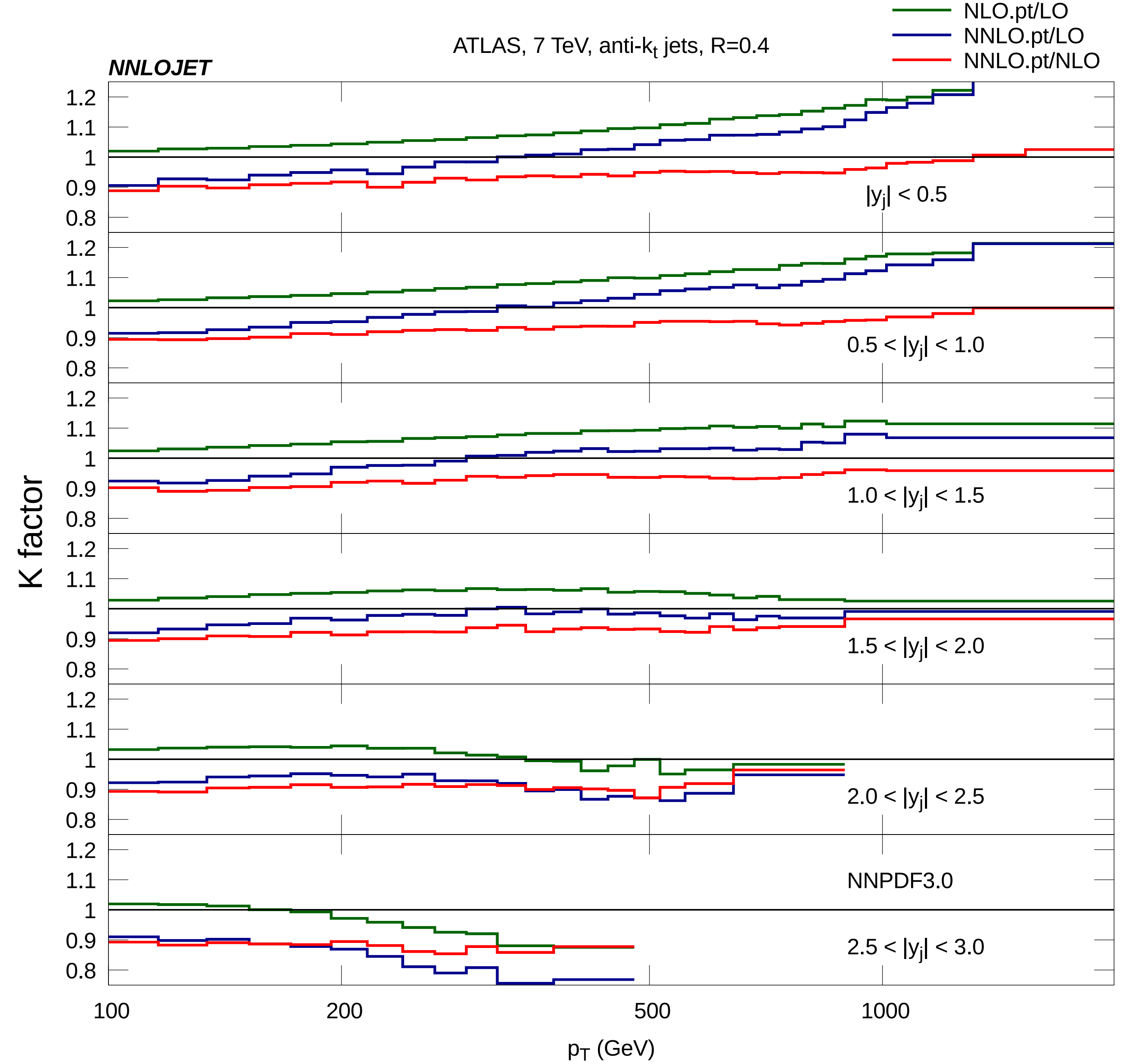
Comparison to data

- data favours the pT scale choice at NNLO





$$\mu_R = \mu_F = p_{T1}$$



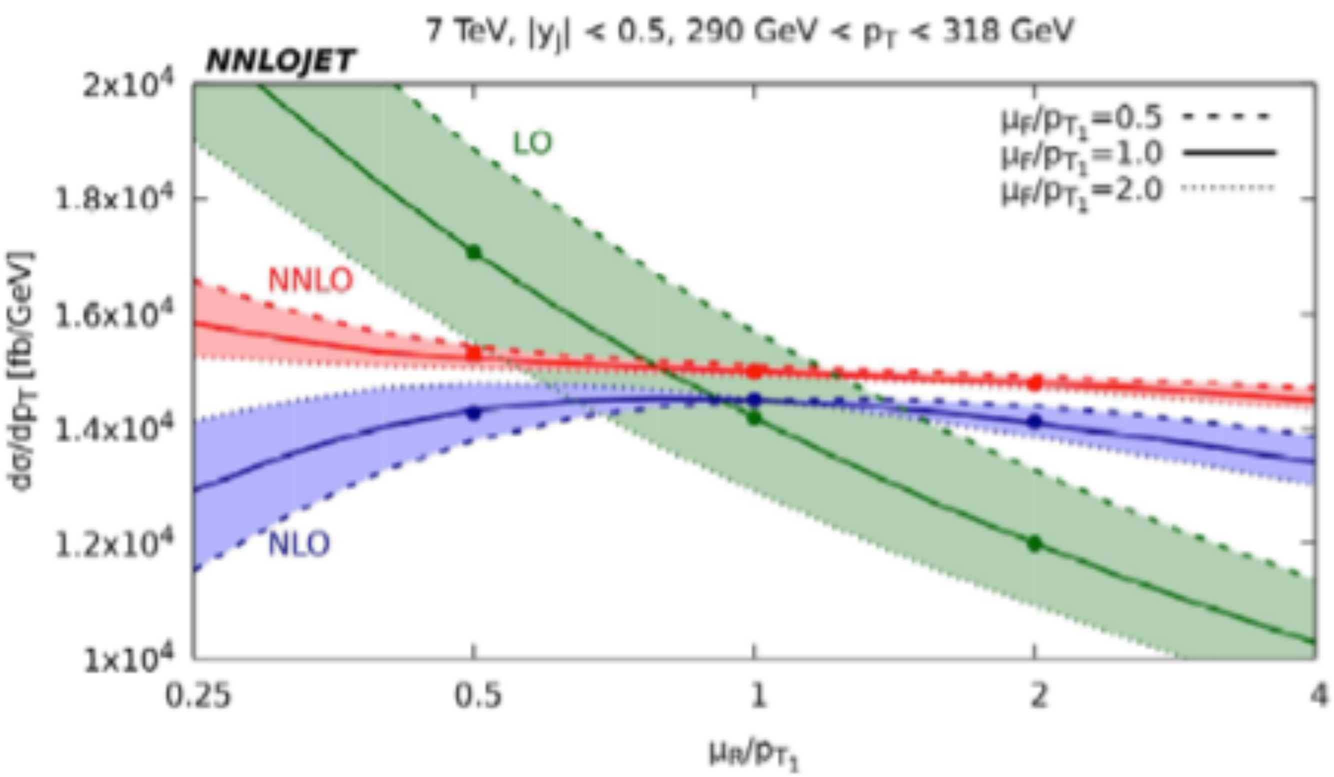
$$\mu_R = \mu_F = p_T$$

- NNLO effects around +10% at low pT and small at high pT
- Shape of NNLO/NLO k-factor is getting steeper going to the forward rapidity slices

- NNLO effects around -10% at low pT and small at high pT
- Shape of NNLO/NLO k-factor is getting flatter going to the forward rapidity slices

- Scale choice has a potential interplay with consistent fit of jet data in PDF's for all rapidity slices
- two commonly used scale choices show no evident instability in the respective perturbative expansion

Scale variation



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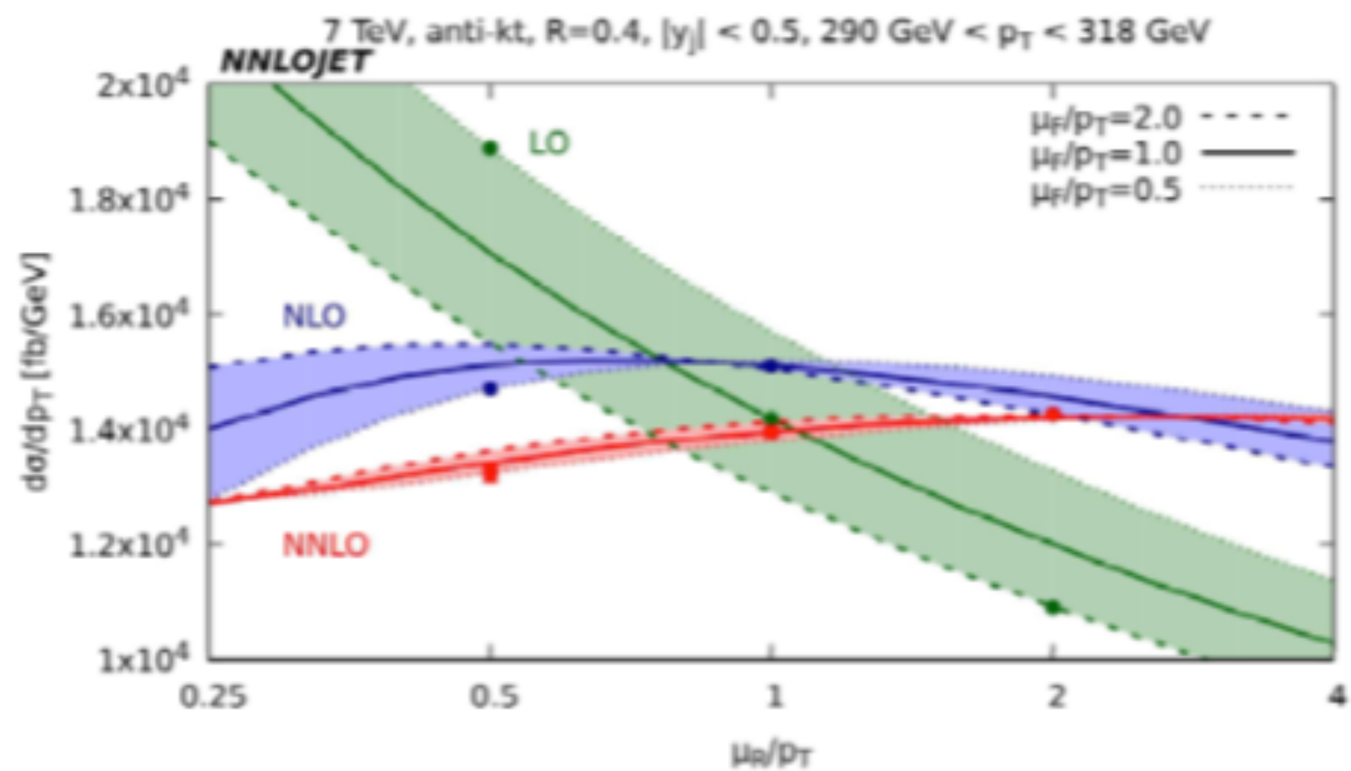


$$\mu_R = \mu_F = p_T$$

- Different behaviour in the NNLO scale variation
- Scale uncertainty much smaller than the difference between the two scale choices
- Difference in the prediction with either scale choice is beyond the scale variation uncertainty
- Lack of a theoretically well motivated preference motivates further study of this issue

K-factor plot

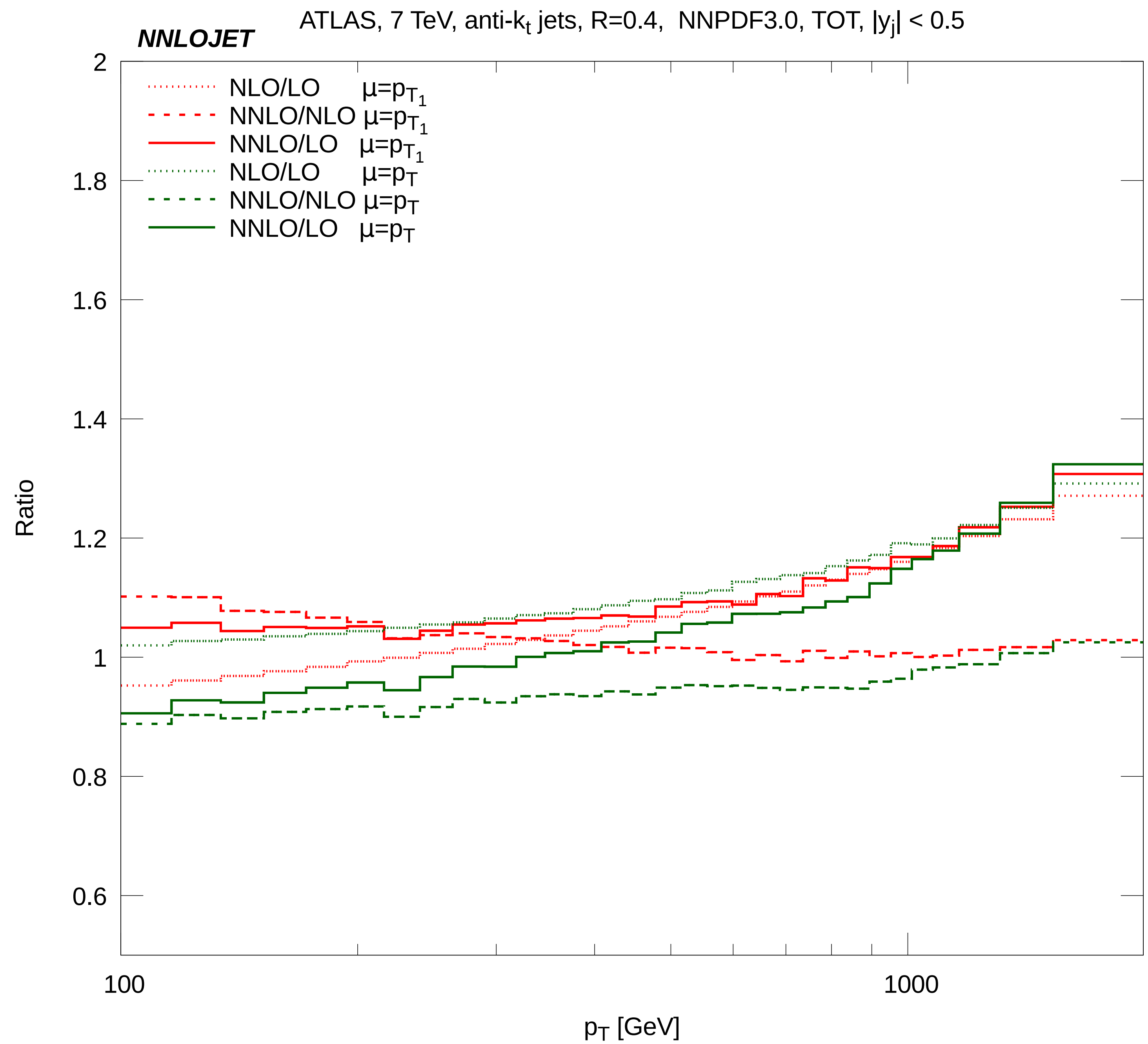
- pT1!=pT effects enlarged at NNLO at low pT
  - decrease for larger R values

Sensible criteria for scale choice for single jet inclusive production

- perturbative stability
- data driven scale choice

Future steps

- compare with CMS jet data; change R value ; change $\sqrt{s}$



- Obtain consistent description of jet data at NNLO for all jet data sets at low and high pT in the central and forward regions for multiple R values

K-factor plot

- pT1!=pT effects enlarged at NNLO at low pT
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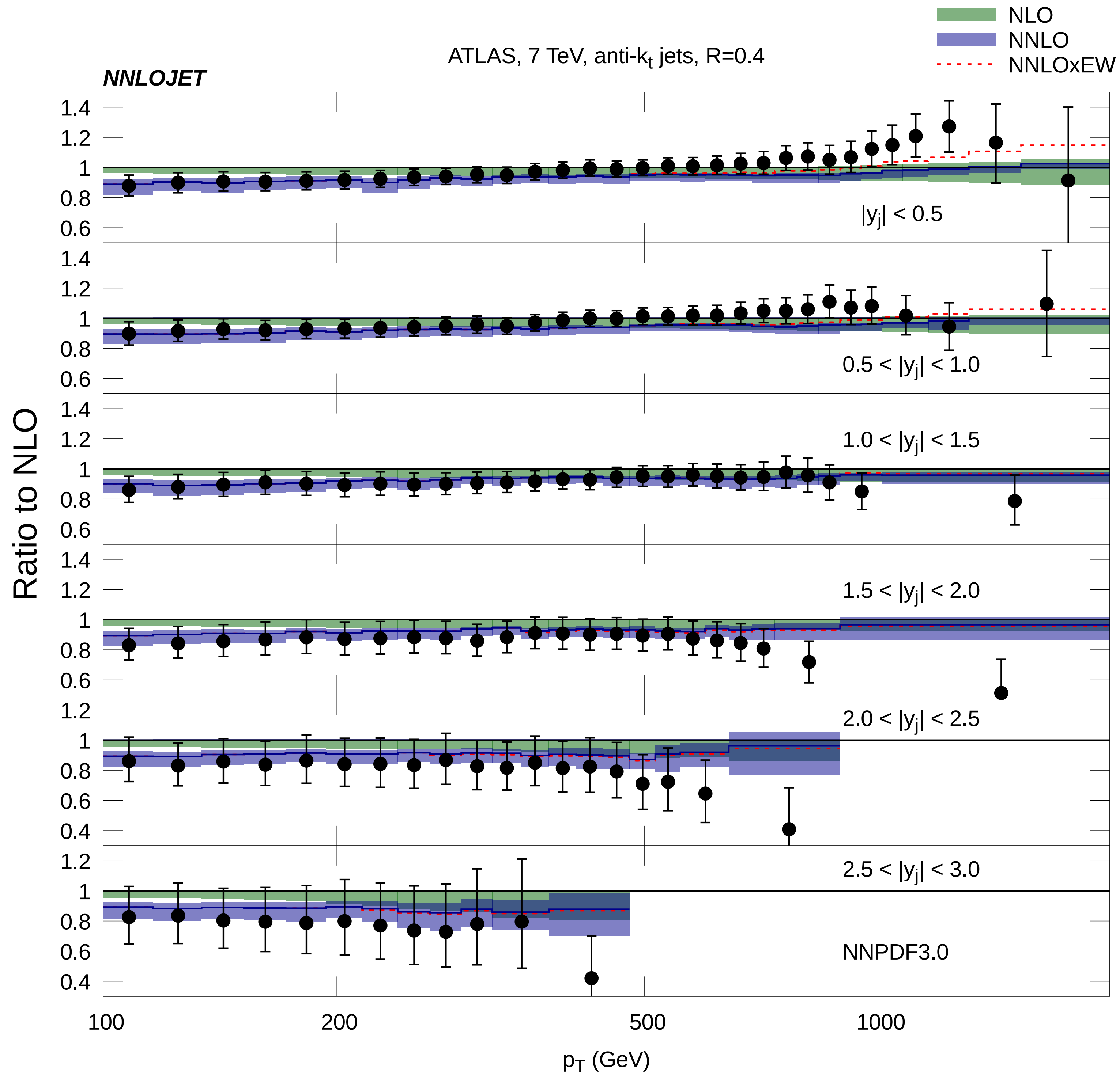


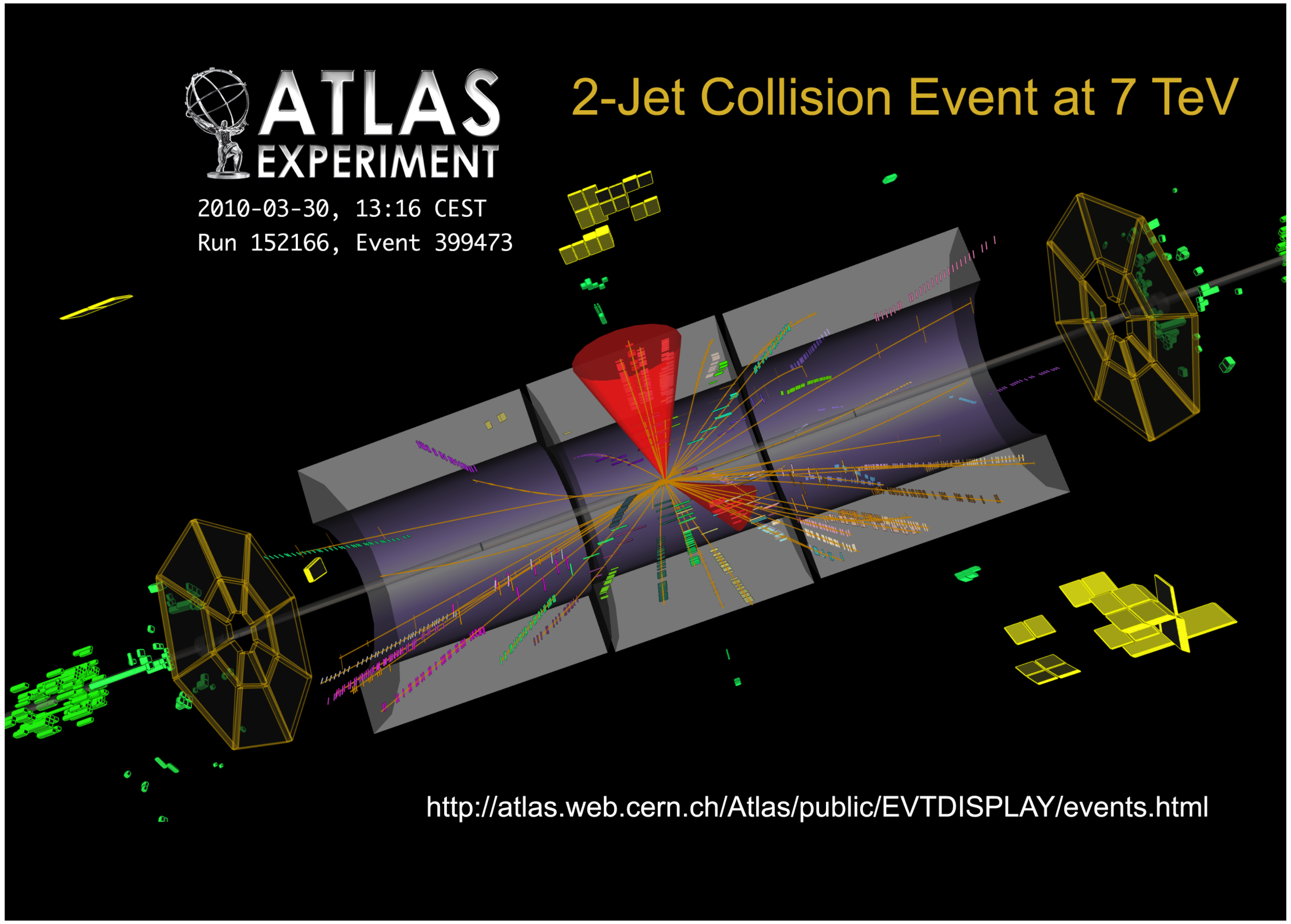
- For ATLAS 7 TeV R=0.4 data NNLO QCD + NLO EW prediction with PT scale choice gives the best description of the jet data

Dijet inclusive cross section

ATLAS jets

Theory setup

- MMHT2014 nnlo
- anti-k_T jet algorithm
- p_{T1}>100 GeV; p_{T2}>50 GeV;
- $|y_{j1}|$, $|y_{j2}|$ < 3.0
- $\mu_R=\mu_F=\{m_{jj}, <p_T>\}$
- vary scales by factors of 2 and 1/2

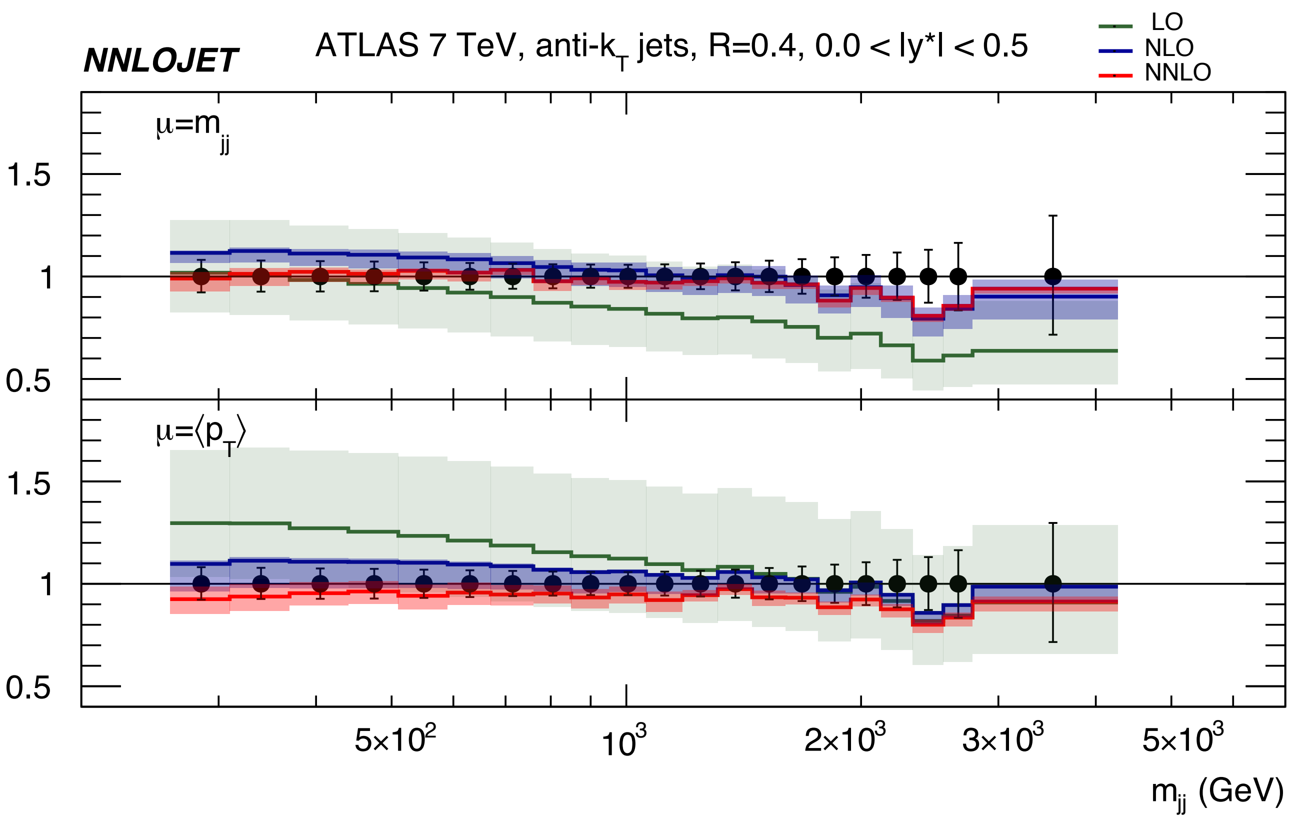


Comparison to data

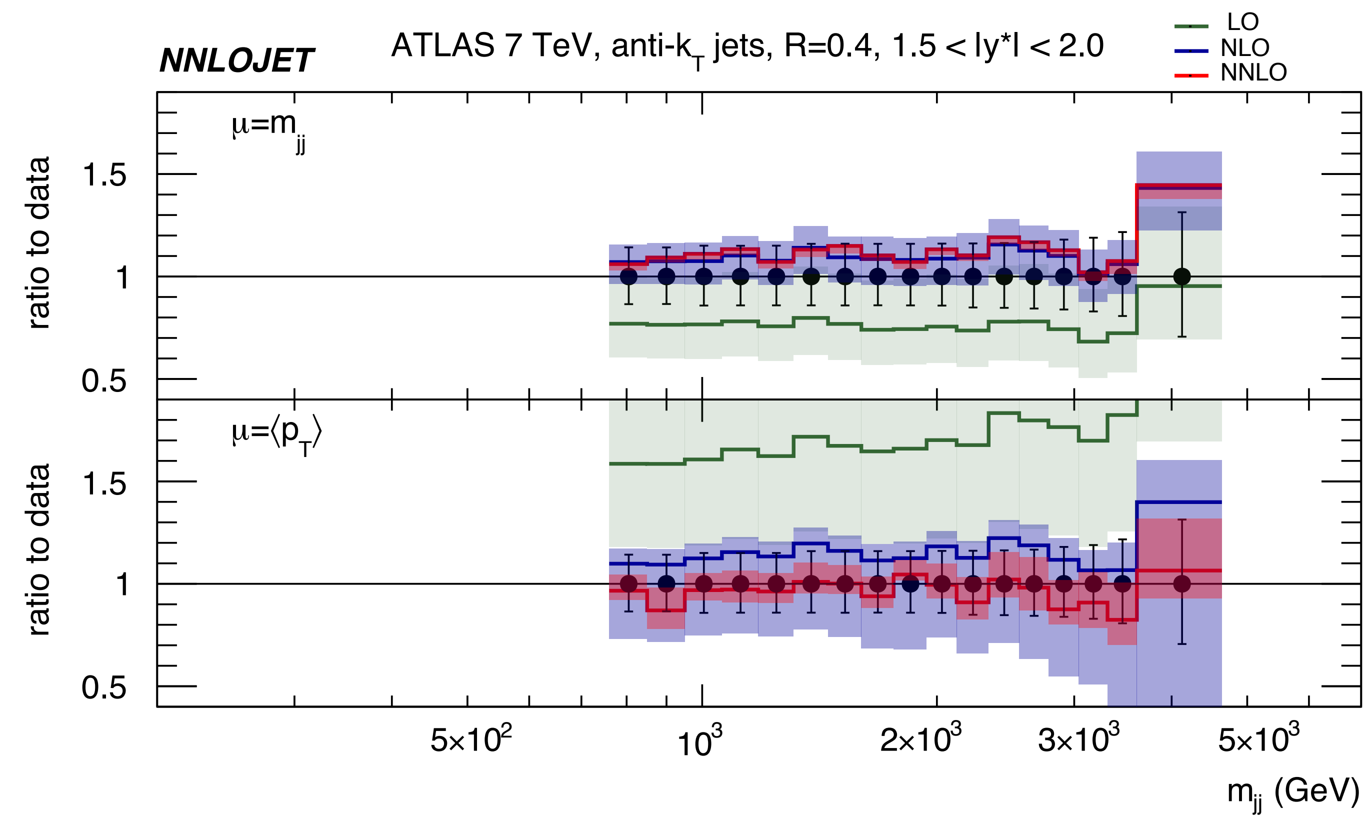
- ATLAS 7 TeV 4.5 fb^{-1}
- R=0.4

$$m_{jj}^2 = (p_{j1} + p_{j2})^2$$

$$y^* = \frac{1}{2}(y_{j1} - y_{j2})$$

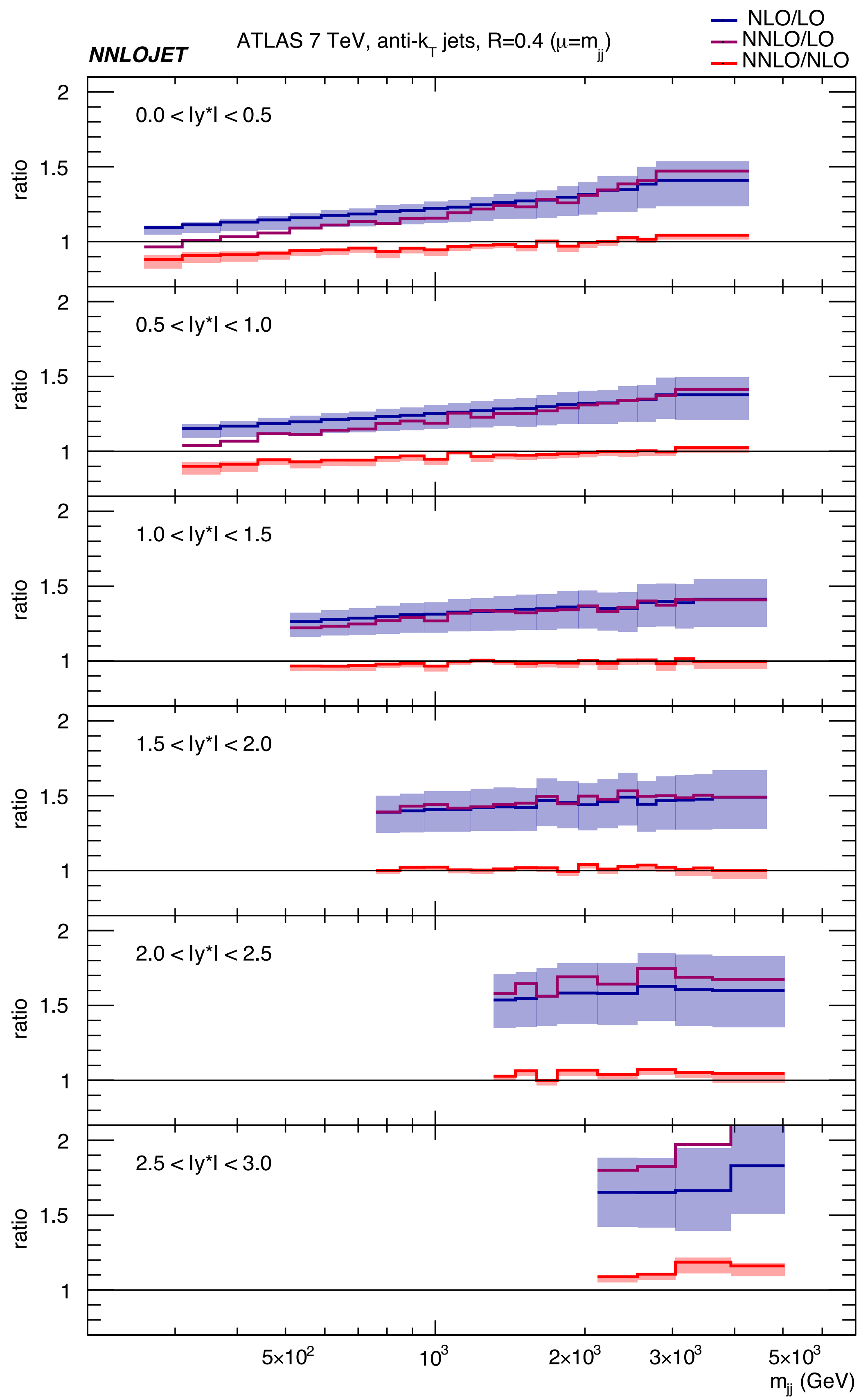


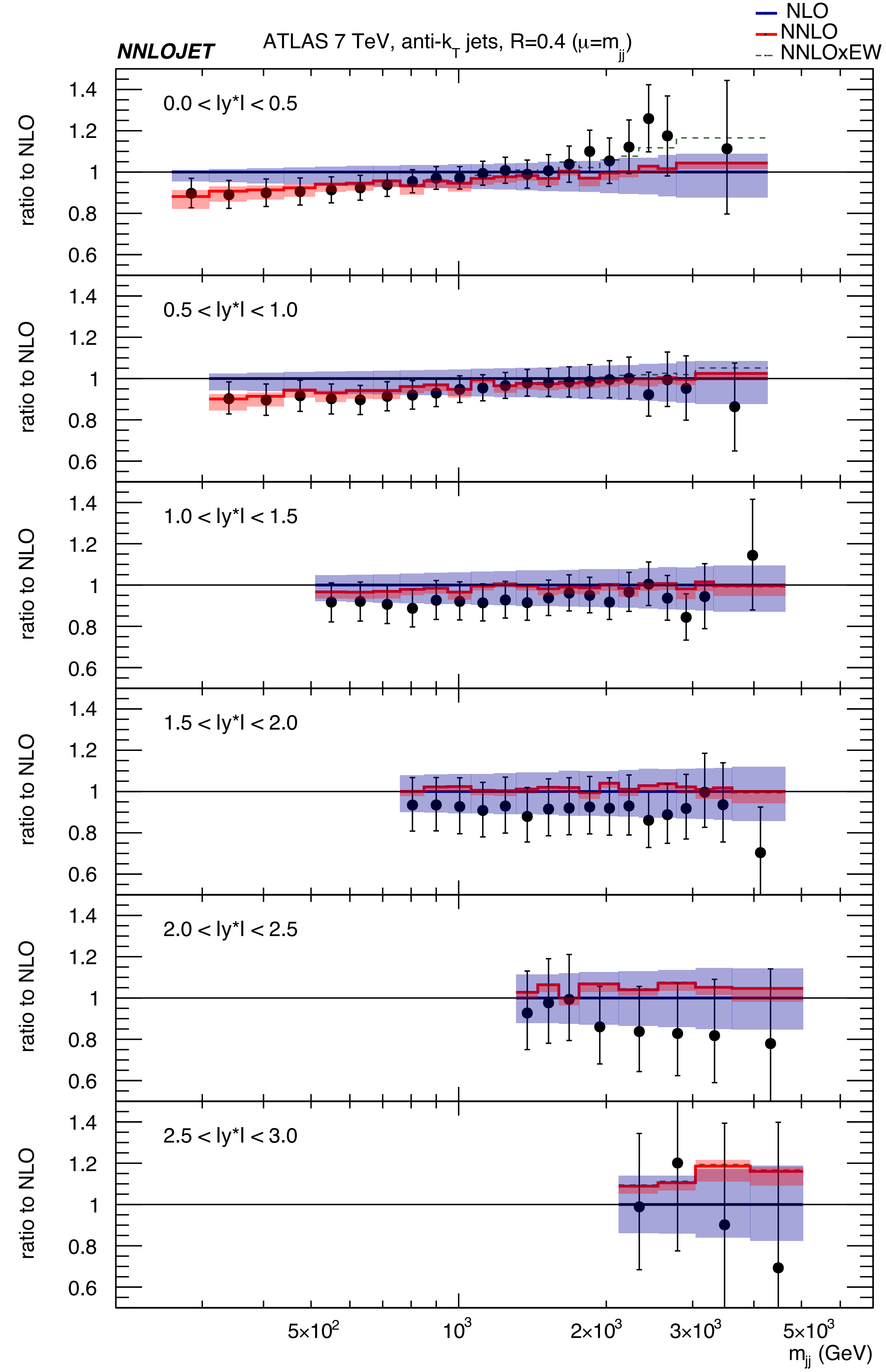
$0.0 < |y^*| < 0.5$



$1.5 < |y^*| < 2.0$

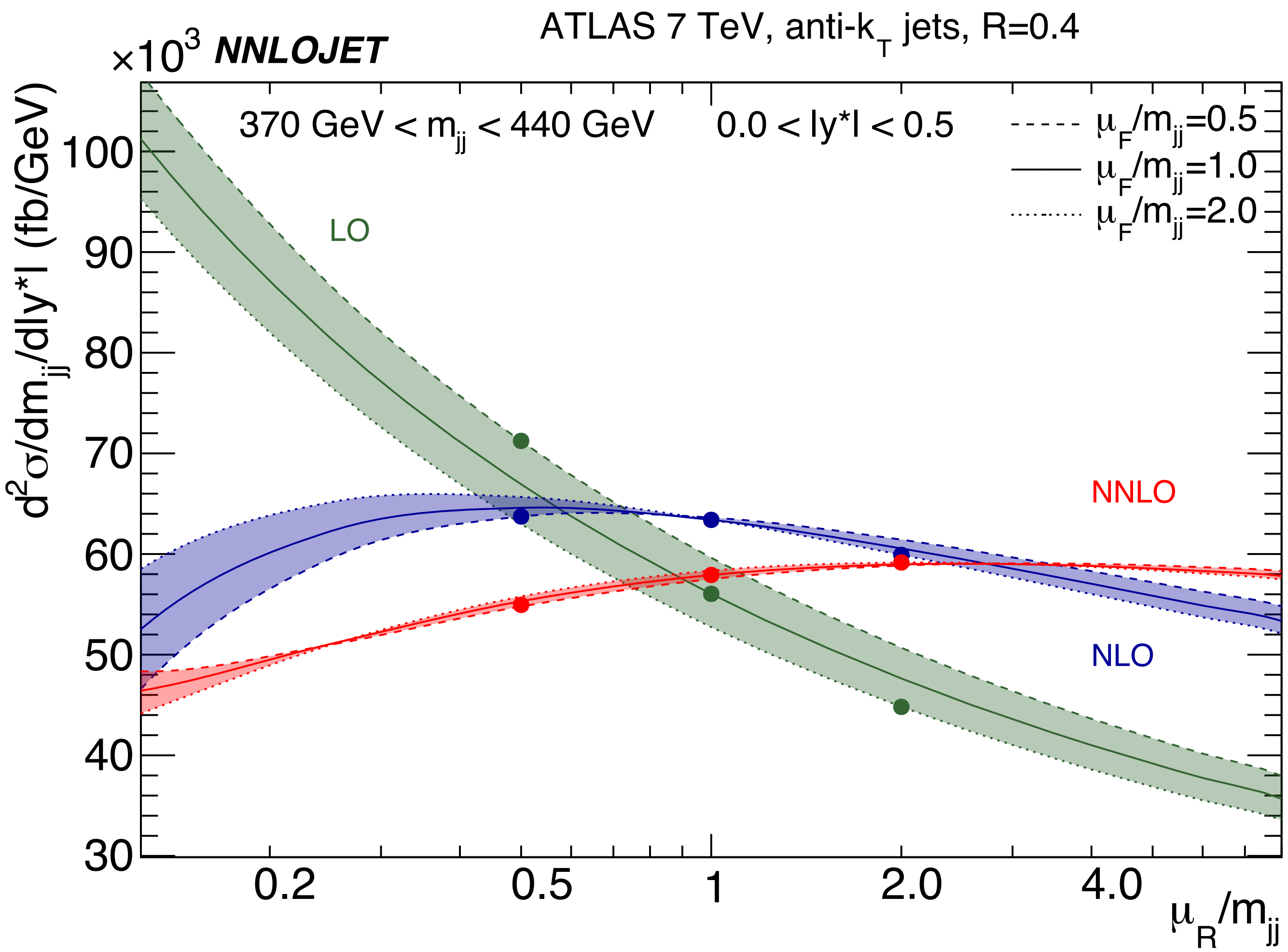
- Largely overlapping scale bands at small y* with either scale choice
- At large y* we observe with μ=<P_T> large negative NLO corrections, non-overlapping scale bands and residual NLO,NNLO scale uncertainty of ~100%,~20%
- Good theoretical motivation to use μ=m_{jj} as central scale choice





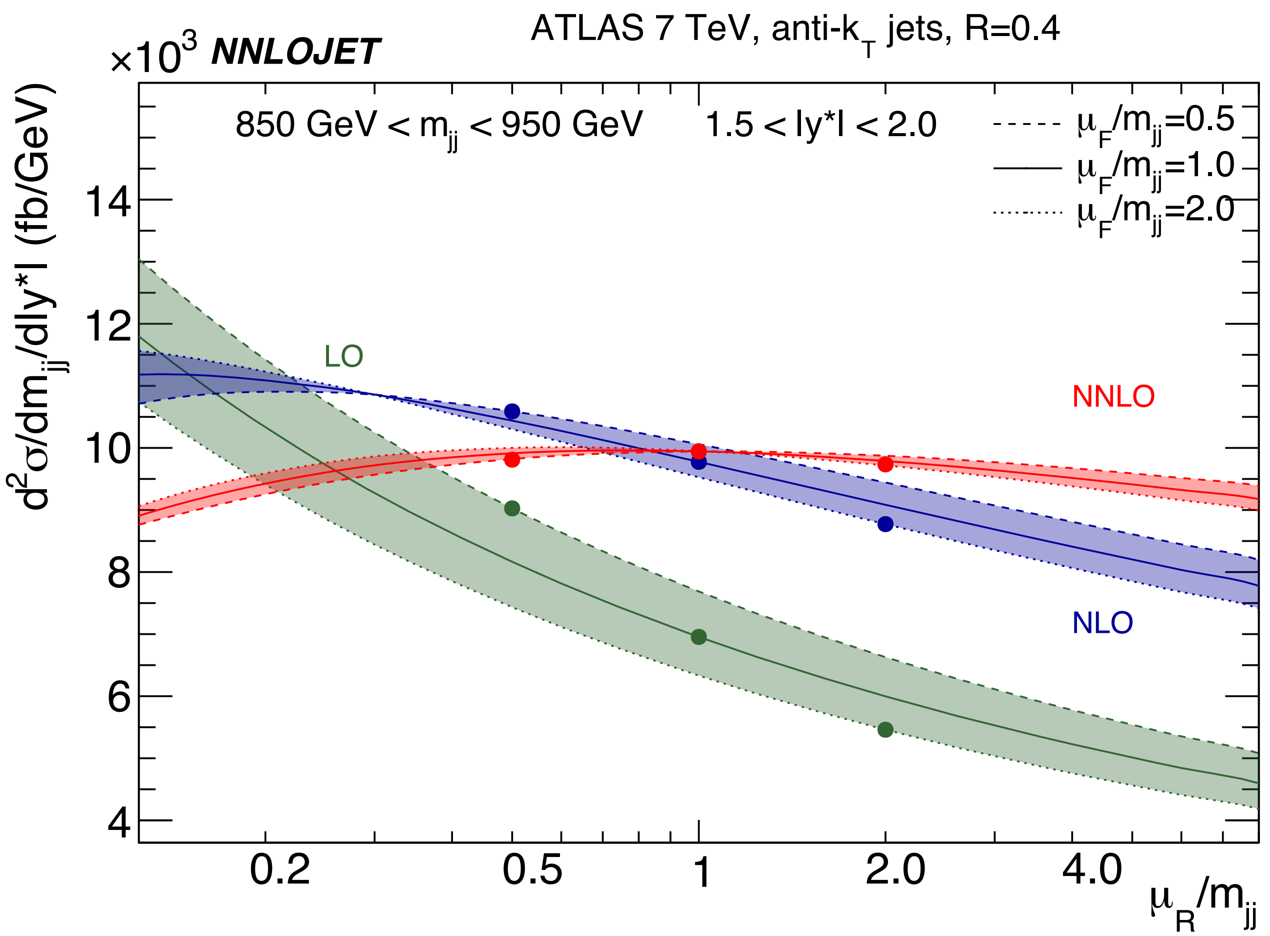
- Excellent convergence of the perturbative expansion; NNLO/NLO < 10% and flat
- Improved description of the dijet data at NNLO

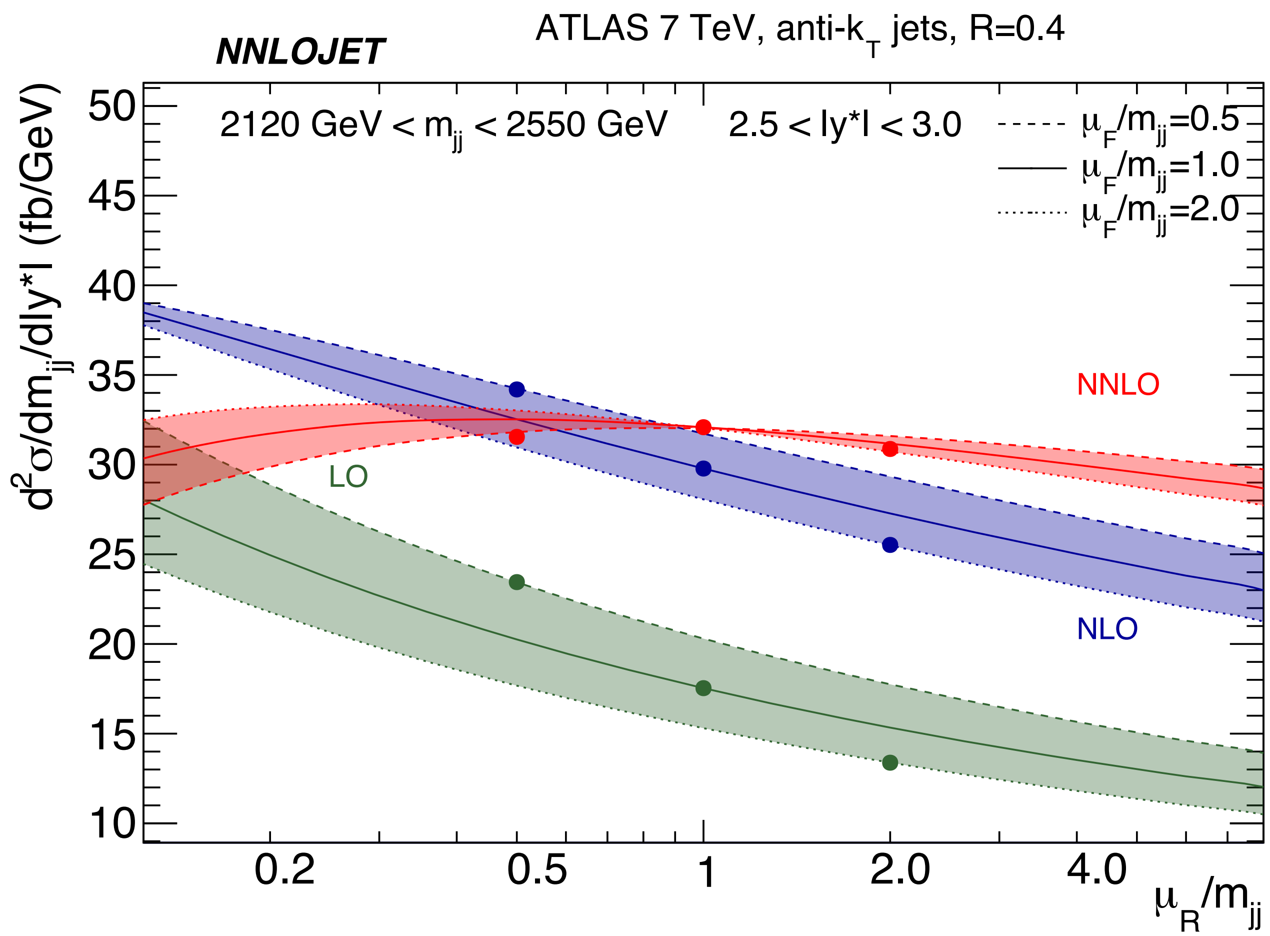
Scale variation



- at low m_{jj} and $|y^*|$ NNLO band of similar size as the NLO band
- central scale choice μ=m_{jj} lies close to extremum of the NLO curve
- variation in μ_R, μ_F accidentally minimised
- NLO band underestimates the missing higher order uncertainty

Scale variation





- More reliable NLO scale variation and overlapping NLO and NNLO scale bands
- Significant reduction in scale dependence of the prediction at NNLO
- Residual scale uncertainty <5% smaller than experimental uncertainty on the observable

Conclusions

Single jet inclusive cross section

- two commonly used scale choices (p_T,p_{T1}) show no evident instability in the respective perturbative expansion or significant differences in the residual scale dependence

- central value of the cross section at low pT is significantly different at NNLO (outside the NNLO scale band variation) between the two scale choices, difference increased with respect to NLO

- at large p_T scale choices converge to the same result as expected

Dijet inclusive invariant mass cross section

- central value of the NNLO cross section using p_{T_AVG} or m_{jj} is similar

- p_{T_AVG} scale choice shows non-overlapping LO and NLO scale bands, slower convergence of the perturbative expansion and fairly large residual scale variation at large |y*| the opposite of the m_{jj} scale choice

- Good theoretical motivation to use μ=m_{jj} as central scale choice