Jet Cross Sections and Precision

Talk based on arXiv:1903.12563

work with:

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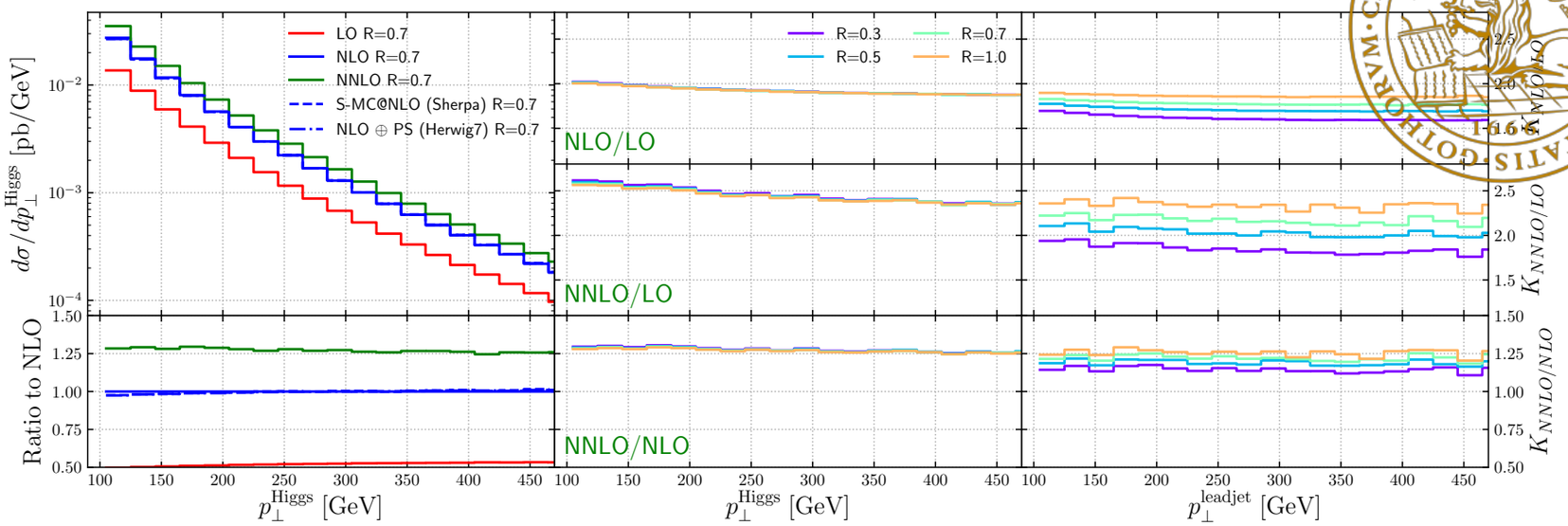
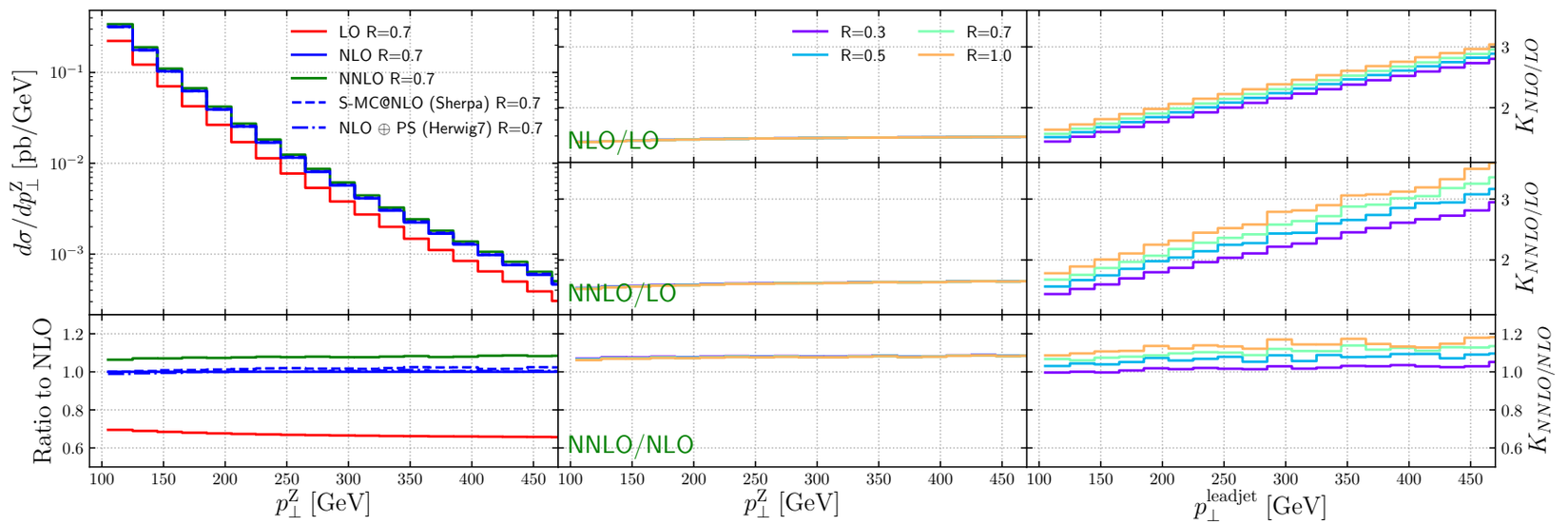
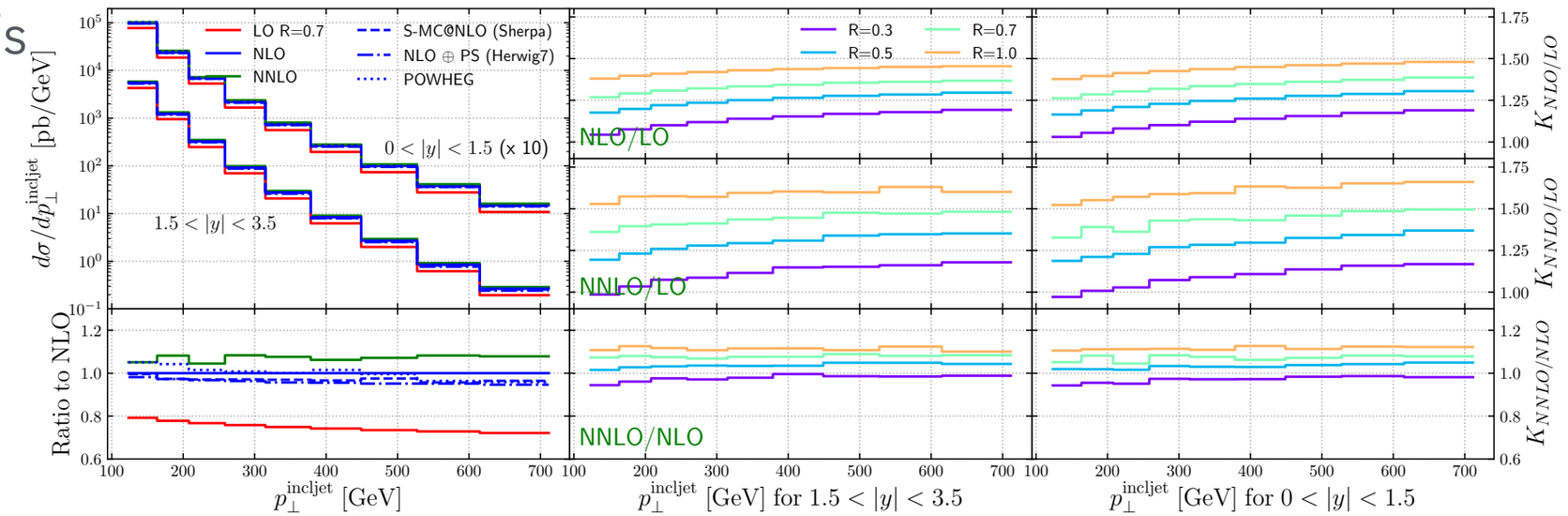
- Motivation
- Setup
- Boson pT (FO vs. MC)
- Jet pT (FO vs. MC)
- R-dep. and Uncertainties
- Non-pert. corrections

Motivation

- Compare MCEG to fixed order calculations up to NNLO.
- Compare MCEG on equal footings (synchronized setup)
- Scales for FO and PS.
- Test more Radii
- More reliable scale uncertainties for Dijet or incl Jet data comparisons be used to constrain PDFs

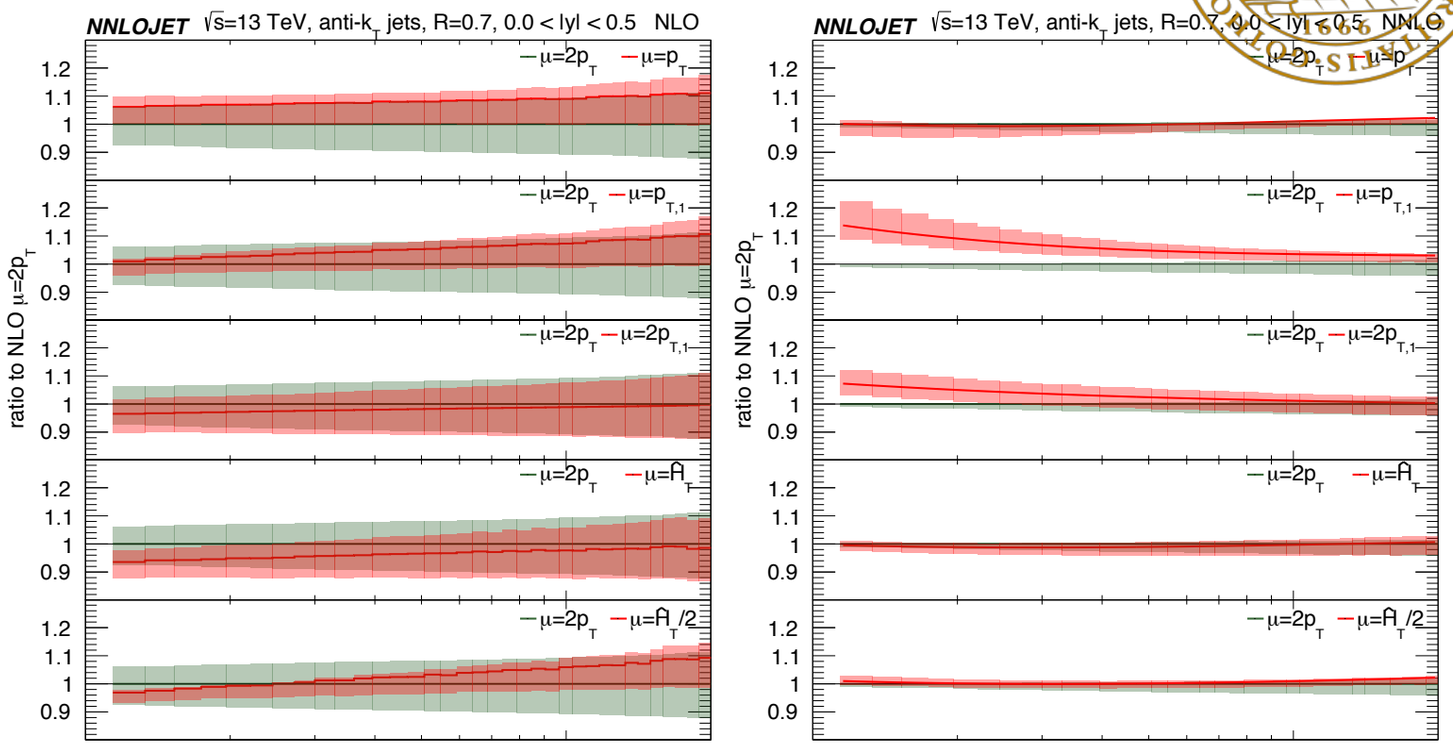


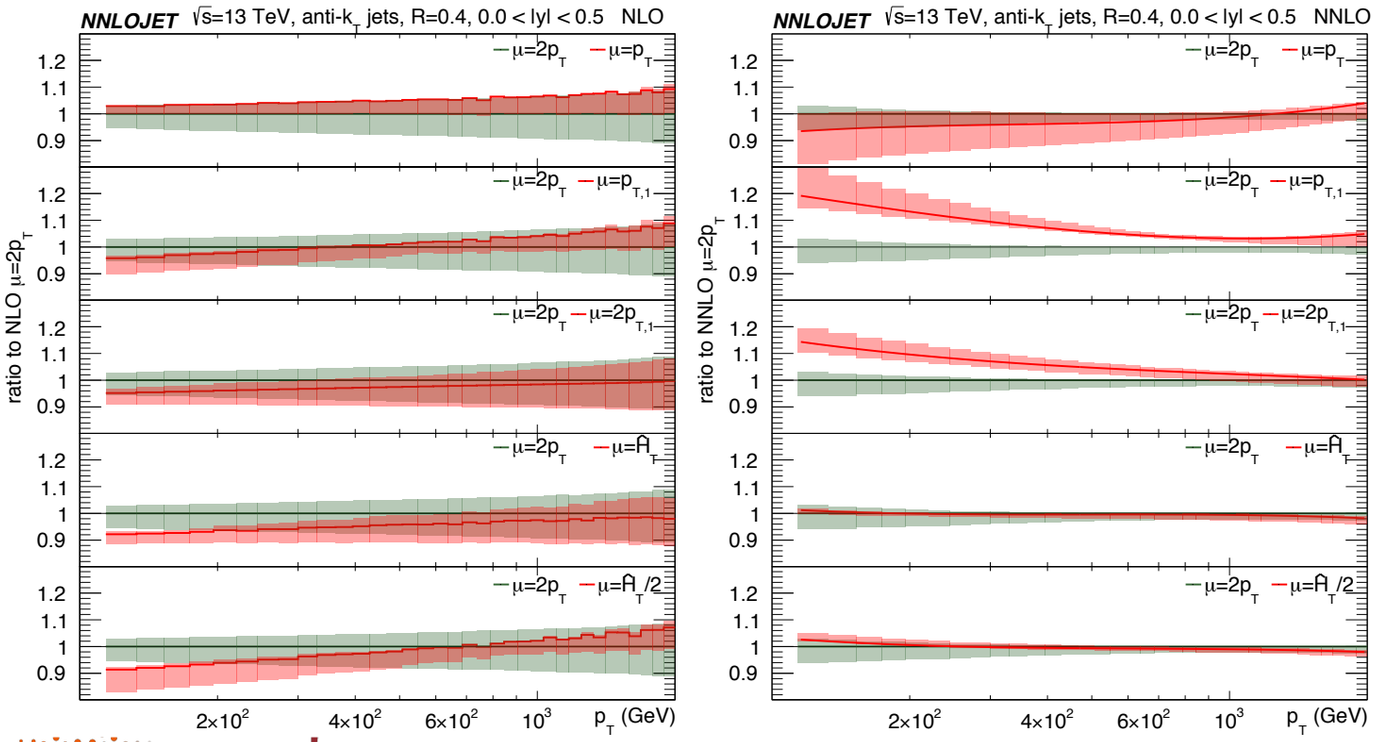




Example of Jet radii in FO (DiJets)

- Not from this study.
- Various scale choices tested
- Jet- vs. event based
- Set of rules to determine quality of scale choice.
- E.g.
  perturbative convergence





Plots from: JHEP 1810 (2018) 155

Currie, Gehrmann-De Ridder, Gehrmann, Glover, Huss, Pires

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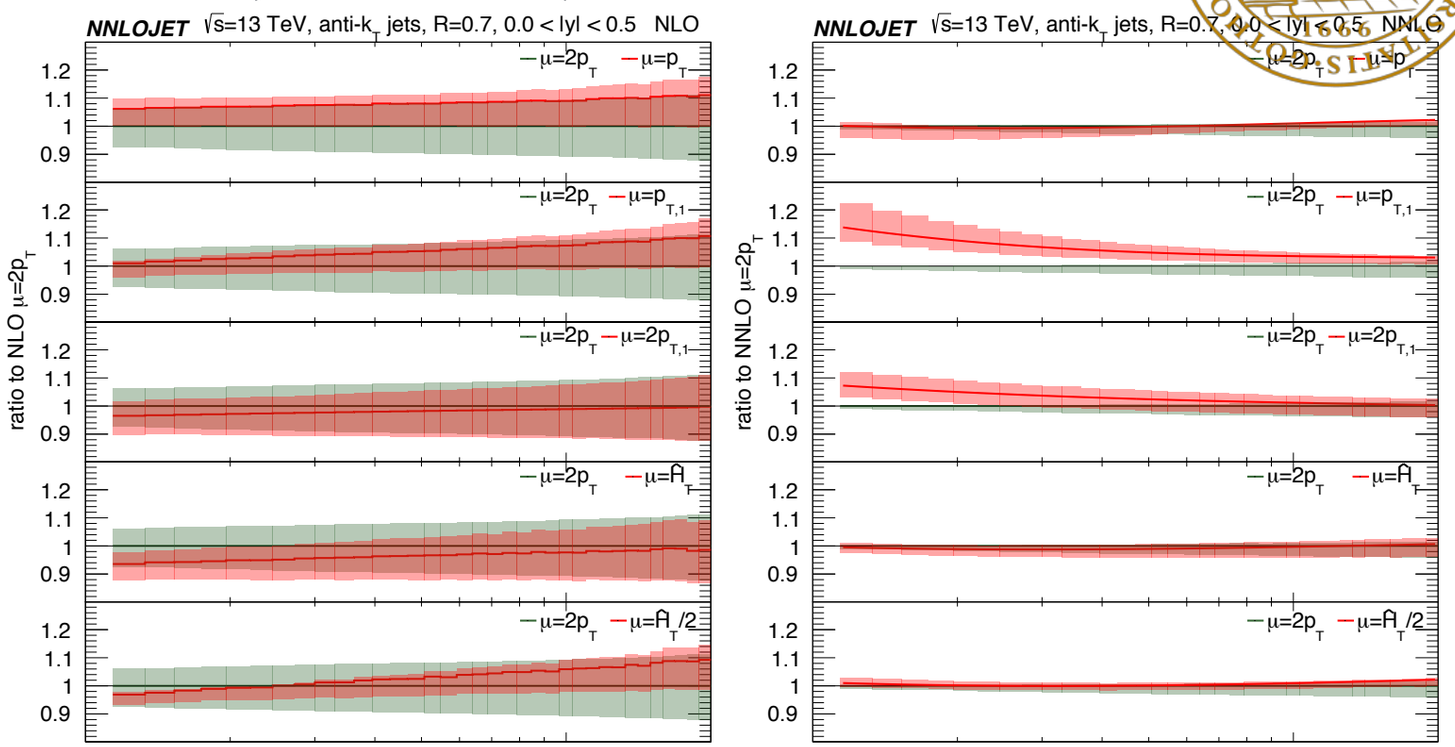

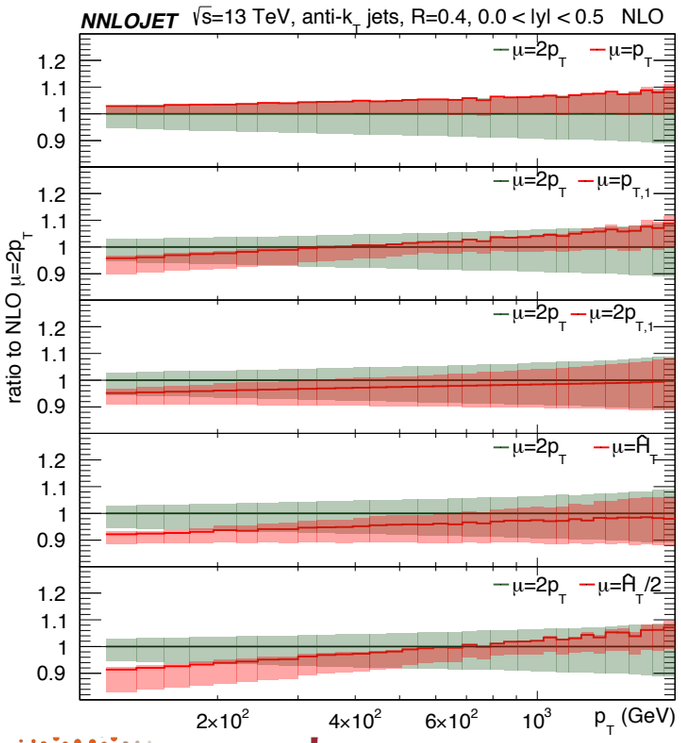

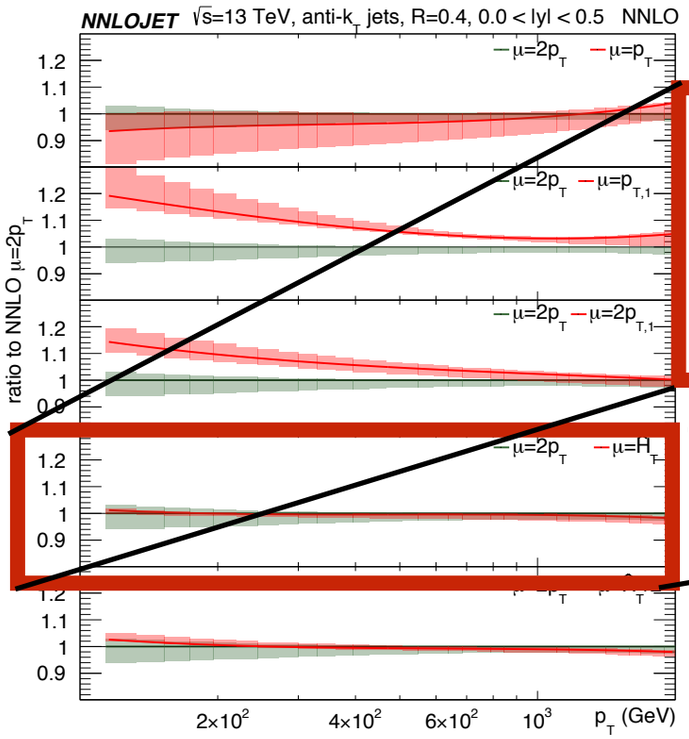

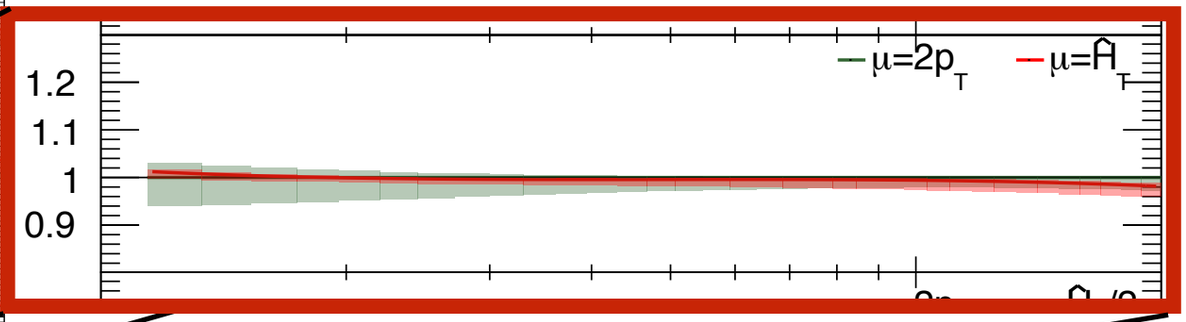

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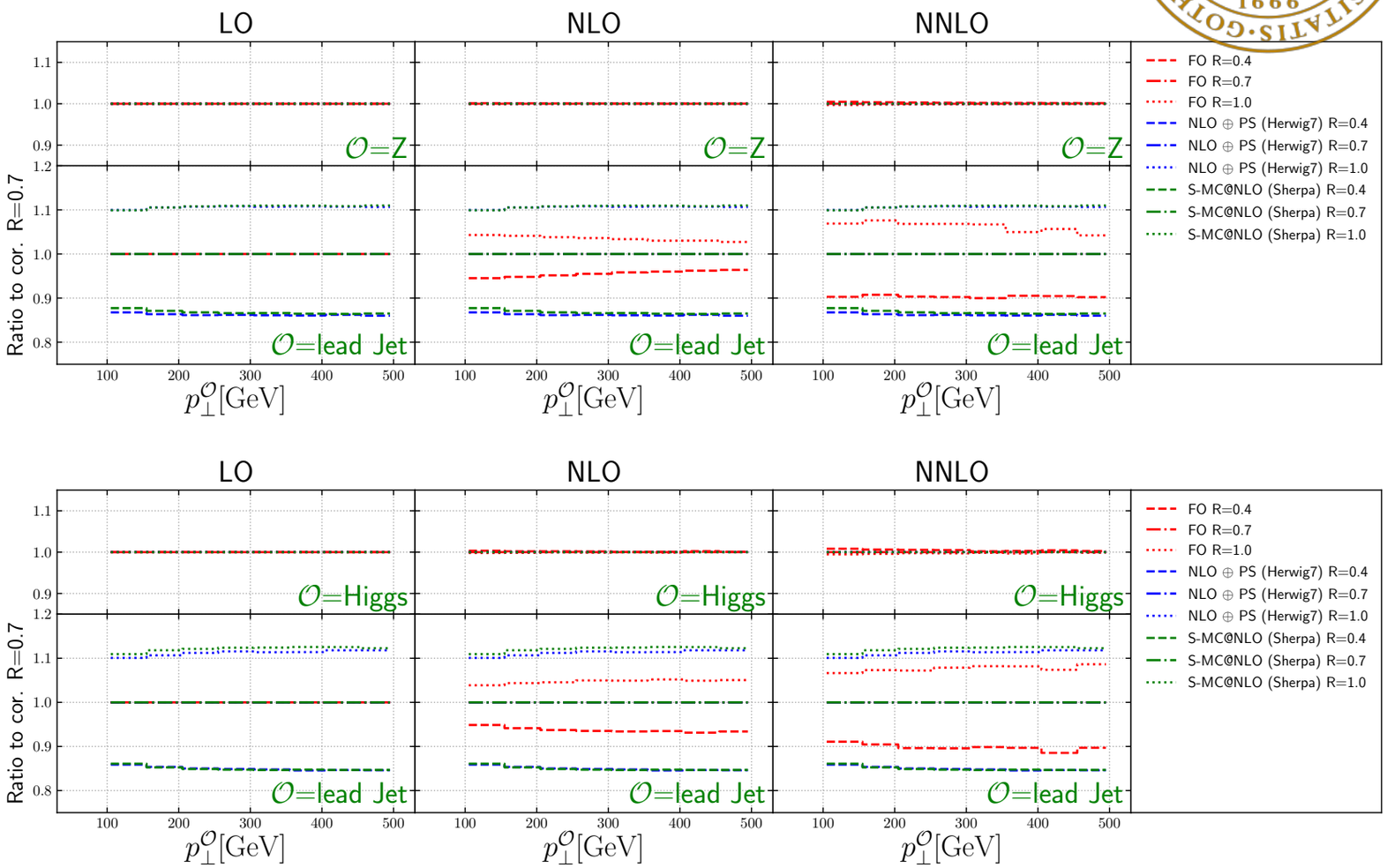
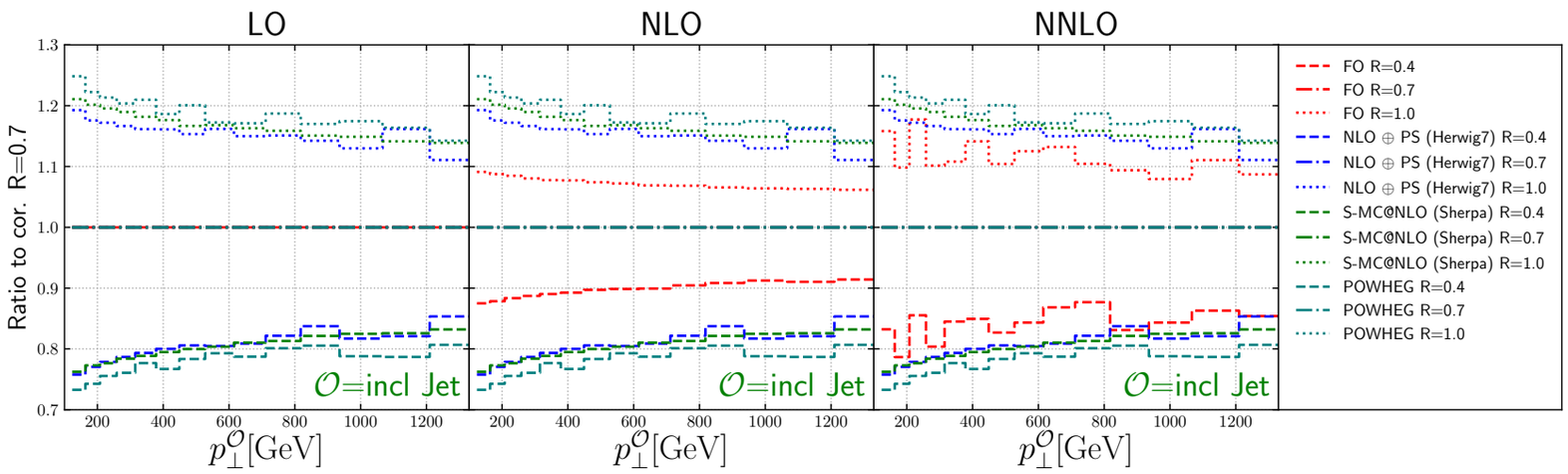
Setup

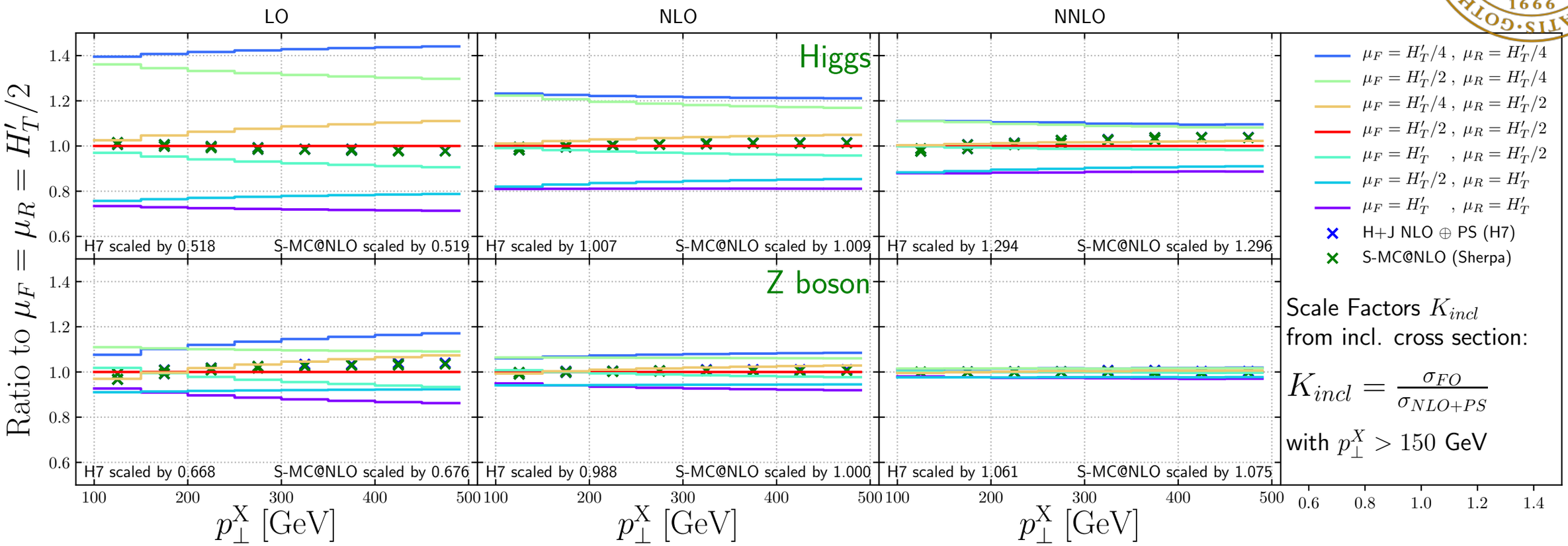
- Processes: Z+J/Higgs+J/DiJets
- Synchronized setup amongst generators (Herwig/Sherpa/Powheg) and the NNLO calculation from NNLOJET
- Scale choice:
  Hard Process: HT'/(2) (incl. mass)
  Shower Starting: HT/2 (no mass)
  +other jet-based scales for FO.
- Merged simulations would put scale choice in starting conditions for unordered histories.
- Here NLO matching is sufficient.





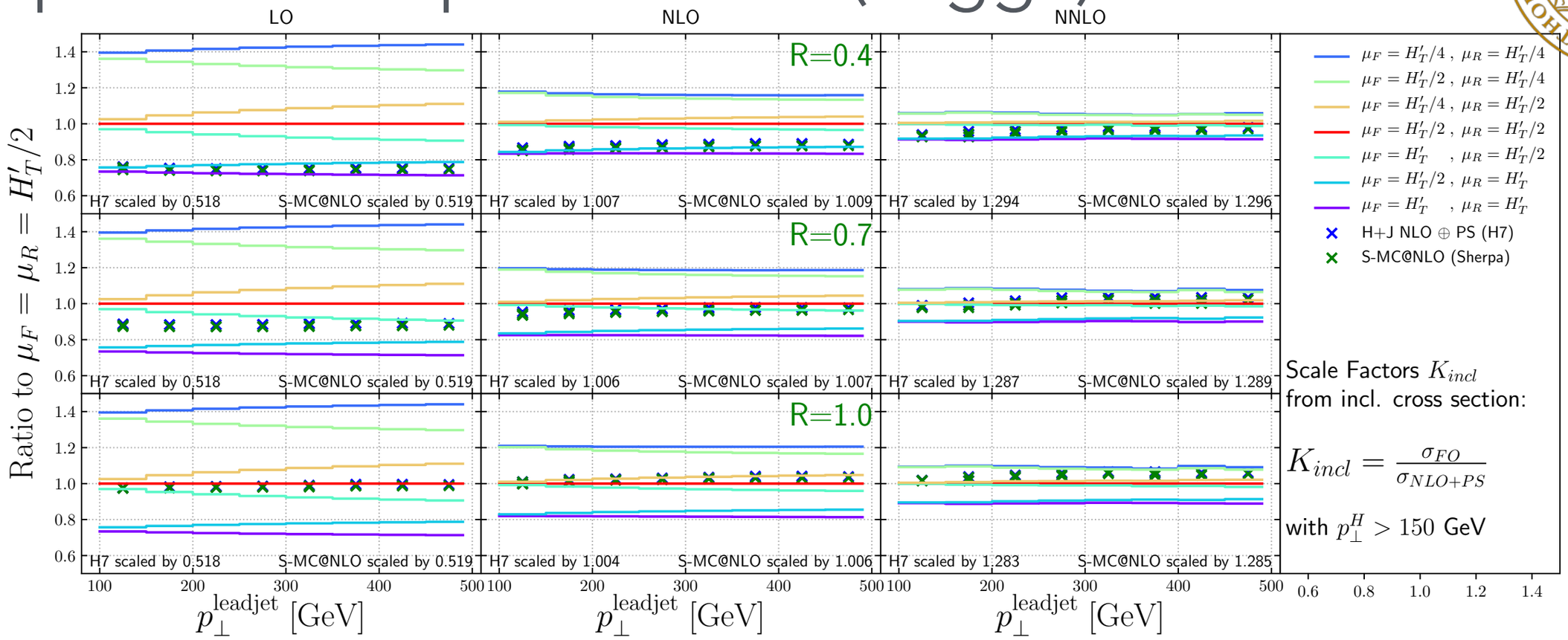
Plots:
Normalized to corresponding R=0.7
Good agreement between MCEG + FO approaches MC

Boson pT and comp. to MCEG



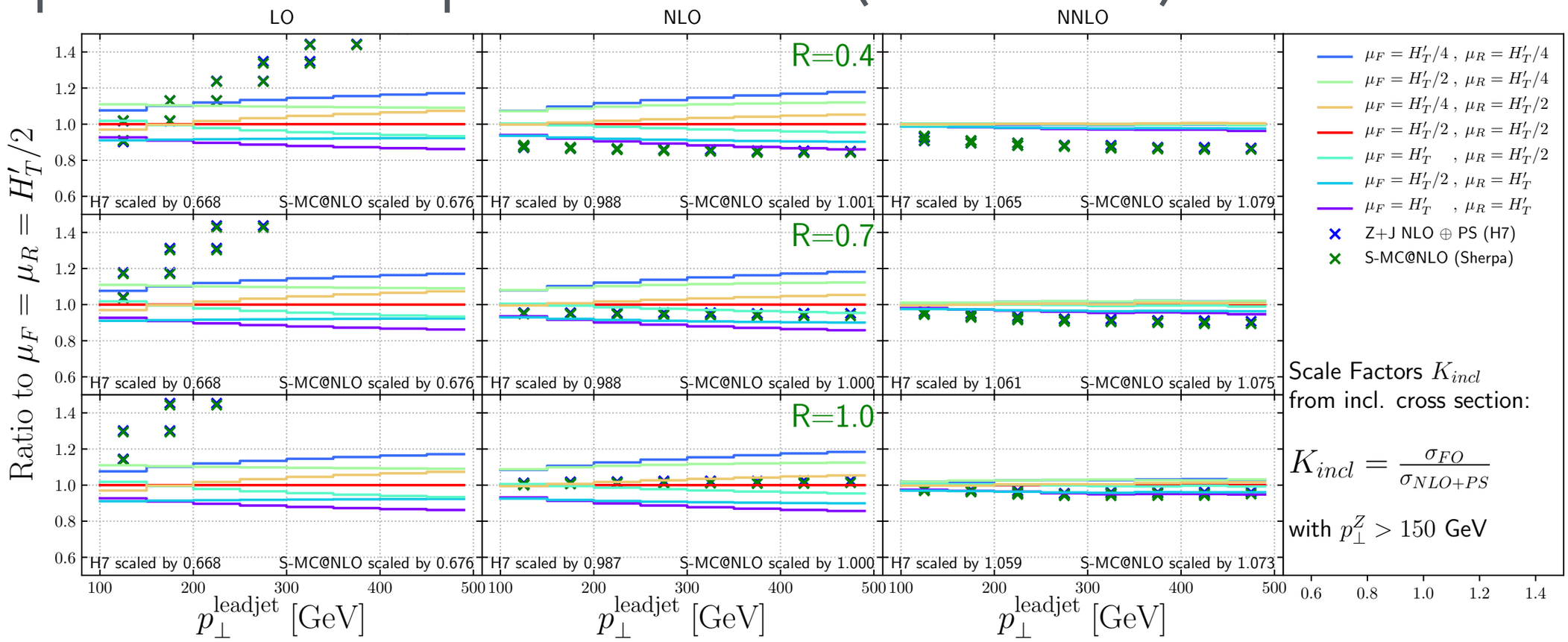
- If we require the transverse momentum of boson to be larger than the mass, we find good agreement between FO and scaled NLO+PS (for pT-distribution of boson)
- Scale factor from cross section with high pT bosons (>150 GeV).
- For purely matched simulation the shower starting scale here without mass of boson.
- This ambiguity could be „removed“ by using merged simulations (then part of merging algorithm: treatment of unordered histories)

Jet pT and comp. to MCEG (Higgs)



- Take same rescaling from boson pT and apply to leading jet.
- Flat ratio between MC and FO but on the edge of uncertainty band for small R.
- Better agreement when going to higher orders.

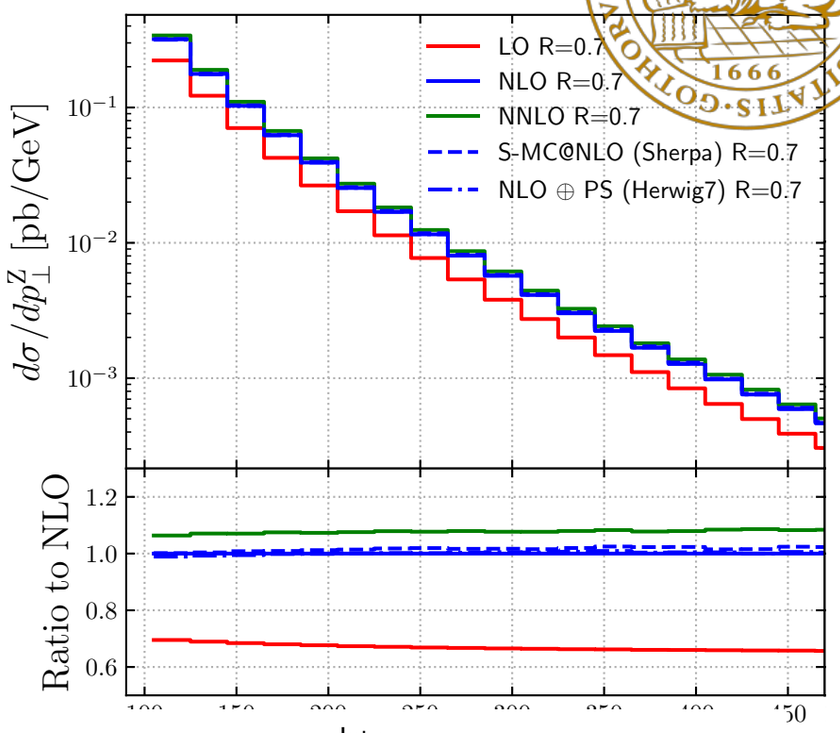
Jet pT and comp. to MCEG (Z-boson)

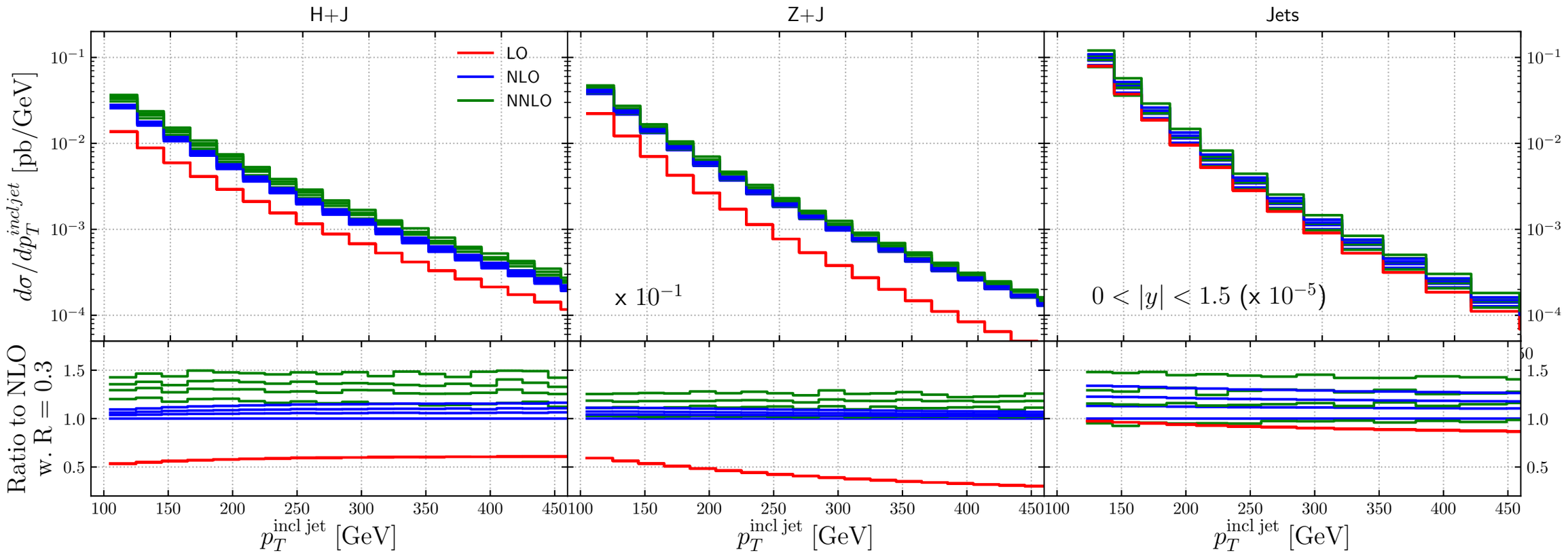


- Take same rescaling from boson pT and apply to leading jet.
- Z+J more affected by back-to-back JJ (+Z) -> LO ratio to MCEG worse.
- Flat ratio between MC and FO (starting from NLO), also outside of uncertainty band for small R.
- NNLO scale uncertainties very small. Very small for R=0.4.

Use H/Z+J to get insight to DiJet

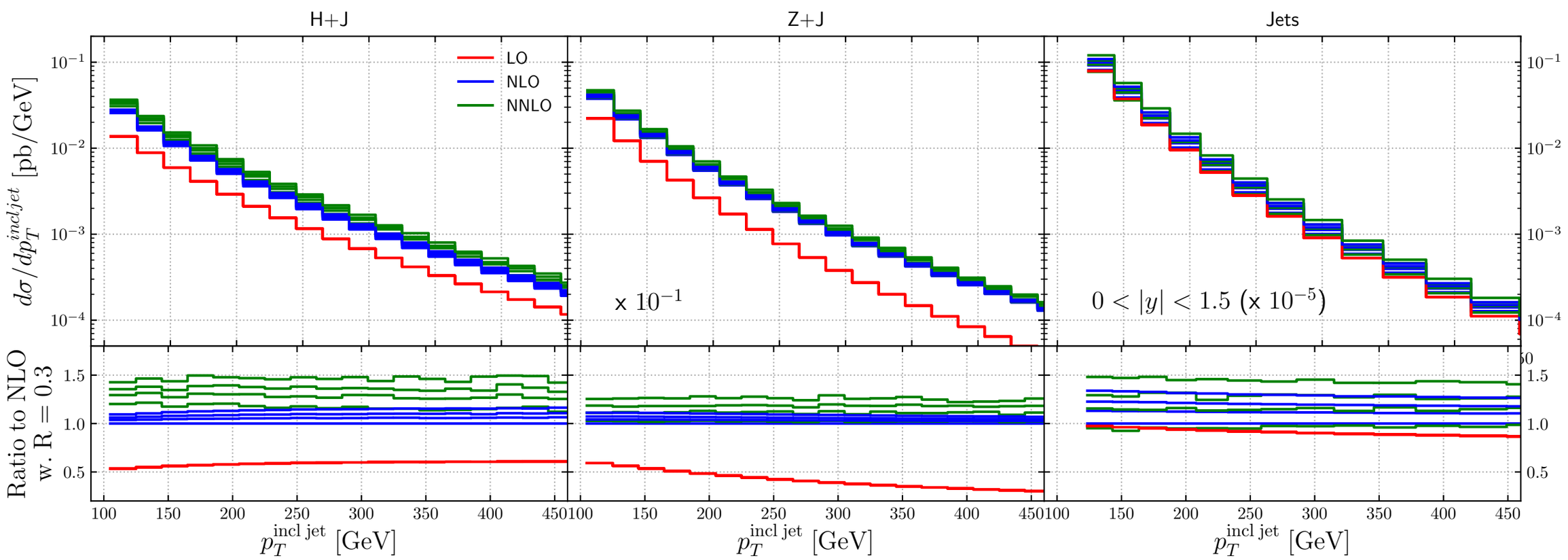
- H/Z +J well behaved distribution for pT of boson.
- Cross section of jet depends on radius
- More severe for increased order (more emissions)
- Also can influence scale choice if scale depends on jet definition
  (We saw up to 3 % for HT definitions at NNLO.)



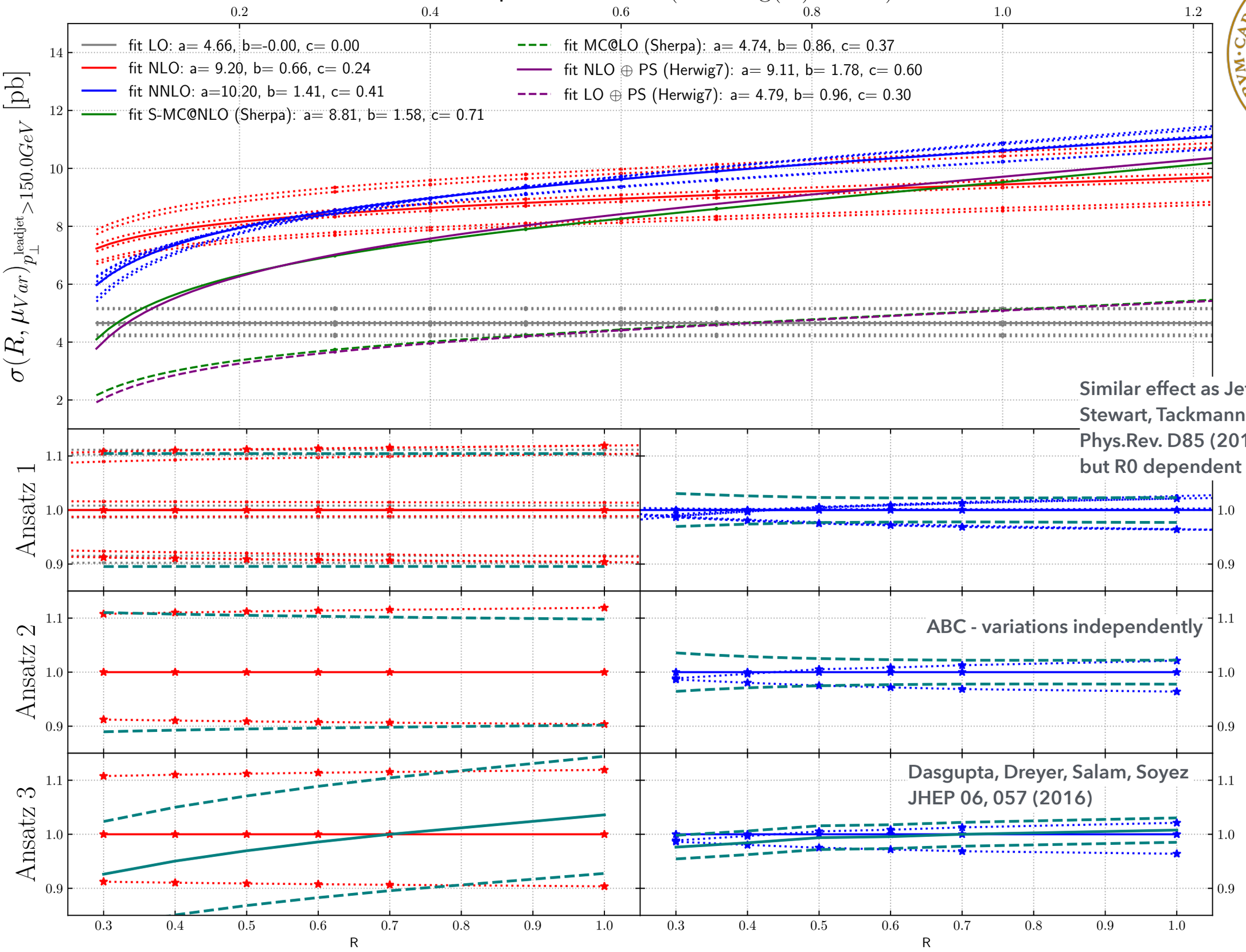


R-dependence and Uncertainties

- Processes with Jet(s) at Born level need regulator (e.g. cut on pt of Jet(s) and/ or colorless object).
- This renders the cross section exclusive at higher orders.
  The real emission can emit outside the jet cone.
- Logarithms of jet opening angle R are induced.



Z+J, R-dependence fit to $(a + b\log(R) + cR^2)$

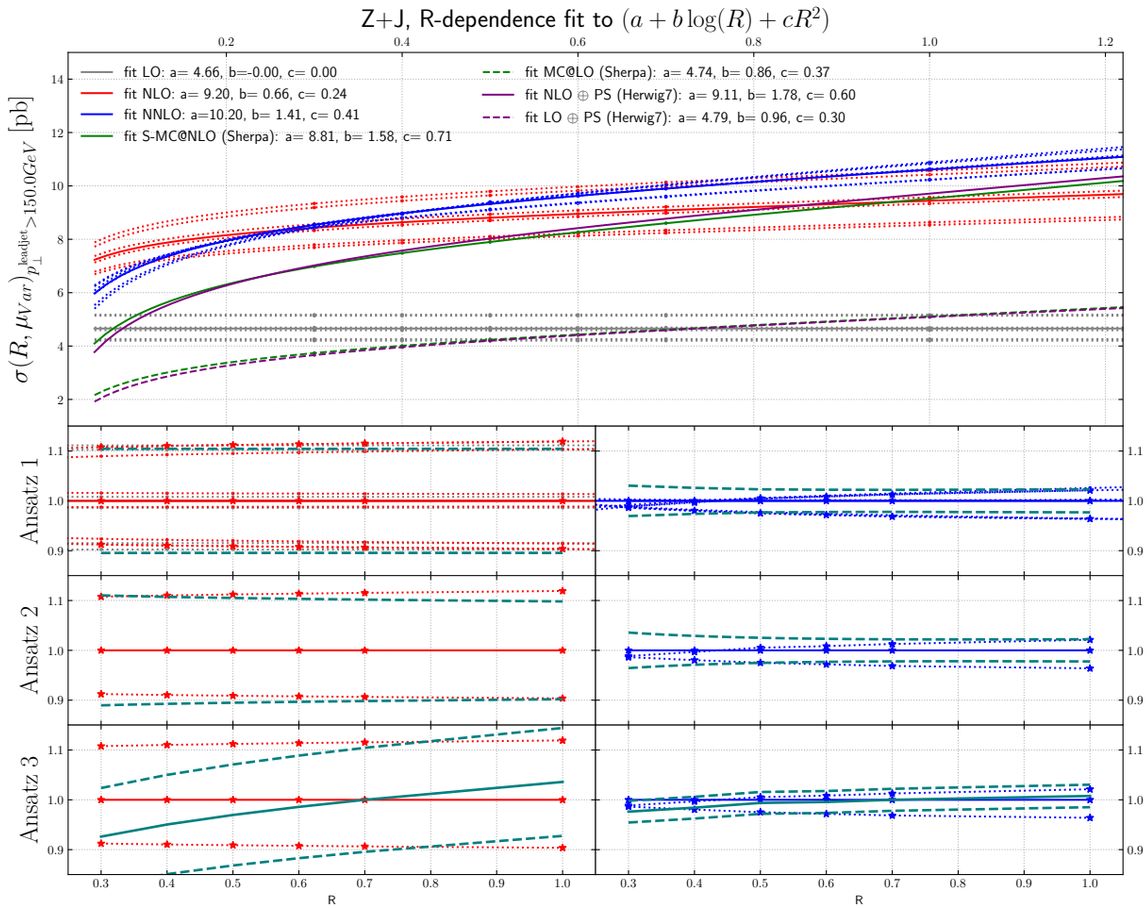


R-dependence and Uncertainties

- Better agreement of shape of NNLO and MCEG.
- Uncertainty band shrinks towards low radii. Similar to vetoed cross section.
- Functional form can be fitted to*:

$$\sigma(R) = a + b\log(R) + cR^2$$

- Various possibilities to estimate uncertainties more reliable.
- Still dependent on R_0



- Ansatz1:

$$\sigma(R) = \sigma(R_0)\frac{\sigma(R)}{\sigma(R_0)}$$

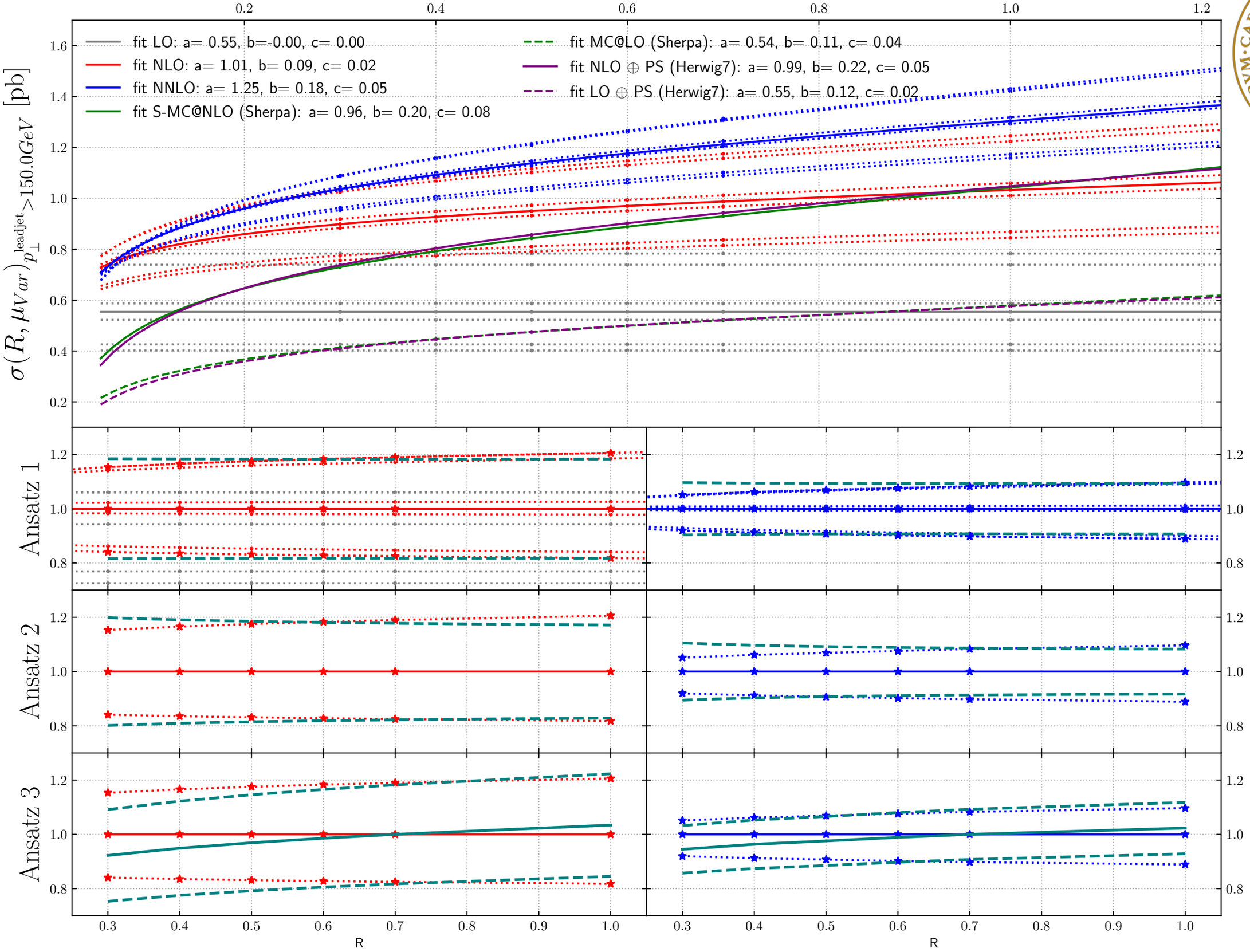
- Ansatz2:

$$\sigma(R, \mu) = a(\mu) + b(\mu)\log(R/R_0) + c(\mu)R^2$$

- Ansatz3:

$$\sigma(R) = \sigma(R_0)\frac{\sigma(R)}{\sigma(R_0)} \approx \sigma(R_0)\cdot\left(1 + \alpha_S\,\partial_{\alpha_S}\frac{\sigma(R)}{\sigma(R_0)}\Big|_{\alpha_S=0} + \alpha_S^2\,\partial^2_{\alpha_S}\frac{\sigma(R)}{\sigma(R_0)}\Big|_{\alpha_S=0}\right)$$

*Ellis, Kunszt, Soper
Phys.Rev.Lett. 69 (1992) 3615-3618


Higgs+J, R-dependence fit to $(a + b\log(R) + cR^2)$
fit LO: a= 0.55, b=-0.00, c= 0.00
fit NLO: a= 1.01, b= 0.09, c= 0.02
fit NNLO: a= 1.25, b= 0.18, c= 0.05
fit S-MC@NLO (Sherpa): a= 0.96, b= 0.20, c= 0.08
fit MC@LO (Sherpa): a= 0.54, b= 0.11, c= 0.04
fit NLO ⊕ PS (Herwig7): a= 0.99, b= 0.22, c= 0.05
fit LO ⊕ PS (Herwig7): a= 0.55, b= 0.12, c= 0.02
$\sigma(R, \mu_{Var})_{p_\perp}^{\text{leadjet}}>150.0GeV$ [pb]
Ansatz 1
Ansatz 2
Ansatz 3
R

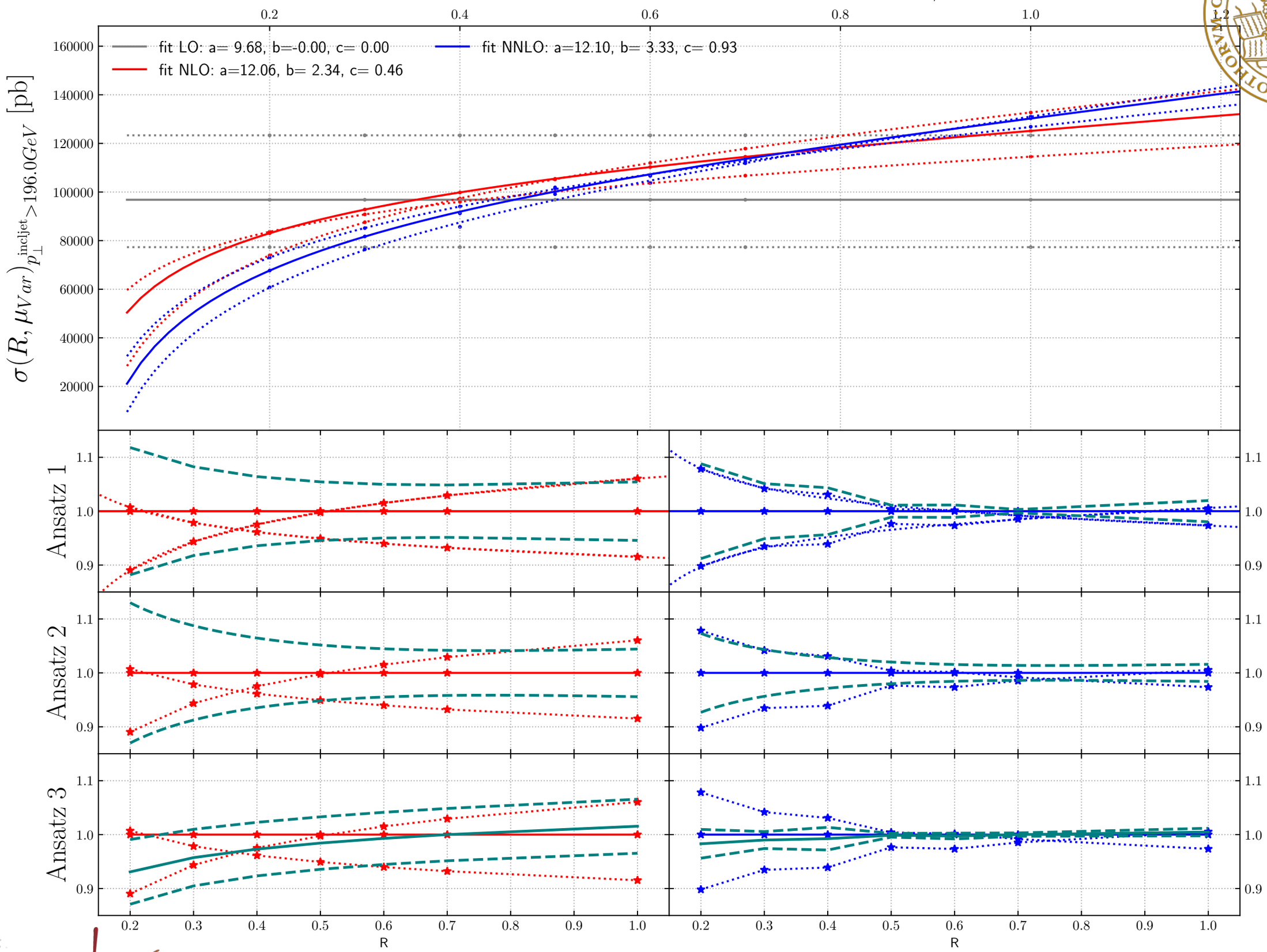
DiJets, R-dependence fit to $10^4 \cdot (a + b\log(R) + cR^2)$, $\mu_{R/F} = H_T$

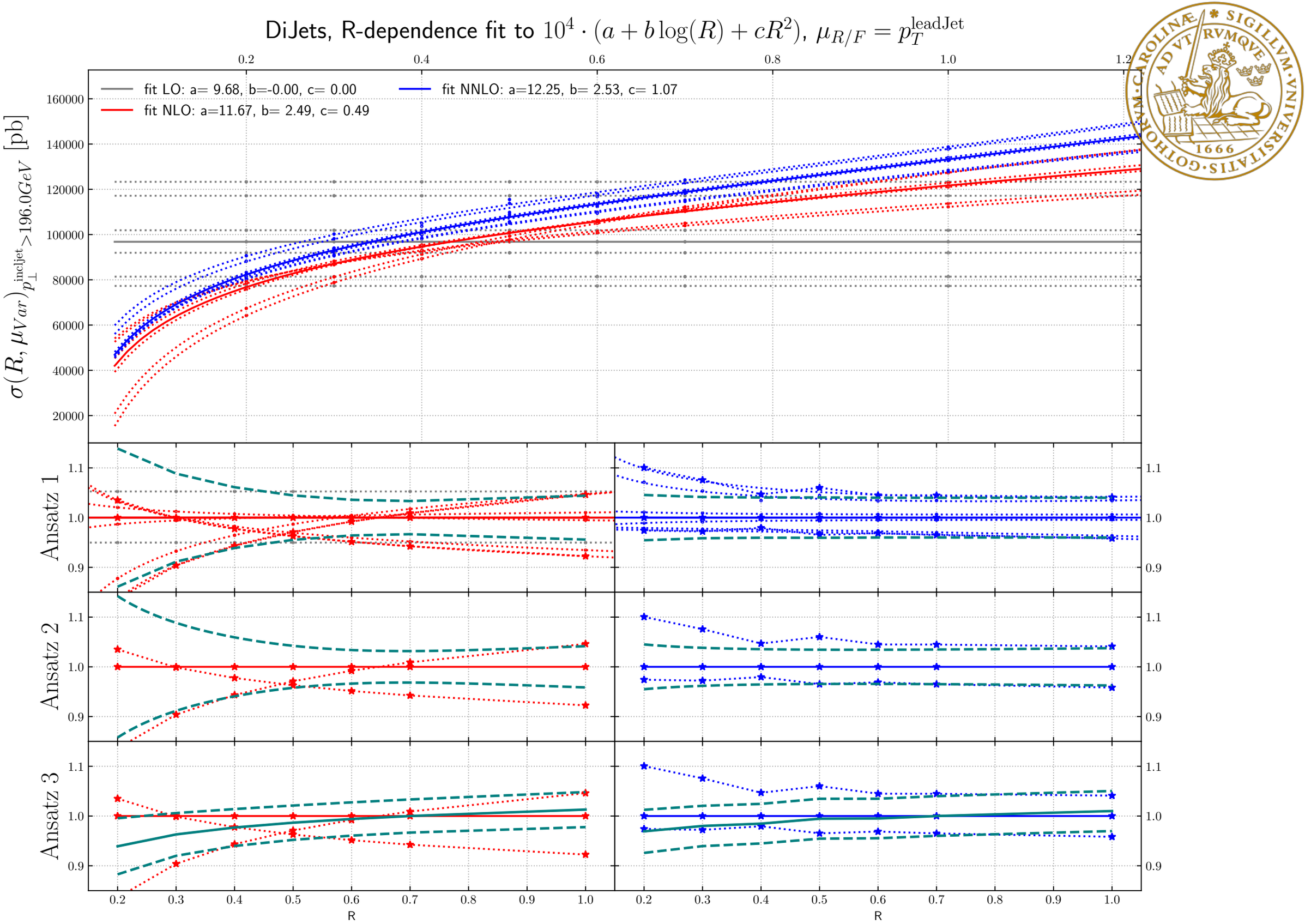
fit LO: a= 7.73, b=-0.00, c= 0.00
fit NLO: a=10.62, b= 1.82, c= 0.36
fit NNLO: a=11.20, b= 2.59, c= 1.04
fit S-MC@NLO (Sherpa): a= 9.82, b= 2.64, c= 1.82
fit MC@LO (Sherpa): a= 7.35, b= 1.97, c= 1.34
fit NLO ⊕ PS (Herwig7): a=10.34, b= 2.96, c= 1.17
fit LO ⊕ PS (Herwig7): a= 7.69, b= 2.24, c= 0.84
fit POWHEG: a=10.17, b= 2.90, c= 2.19

$\sigma(R, \mu_{Var})_{p_\perp^{\text{incljet}} > 196.0 GeV}$ [pb]

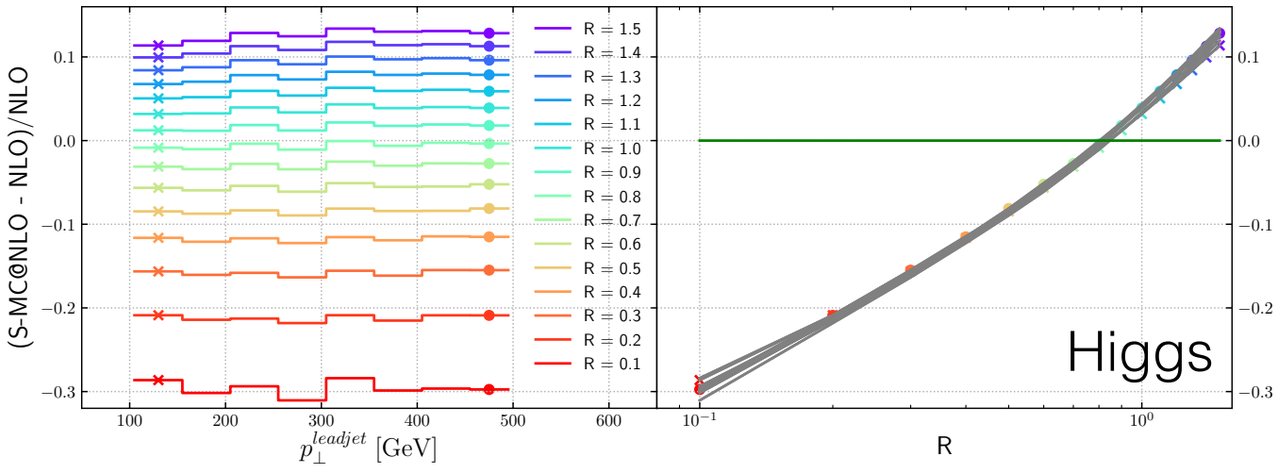
Ansatz 1
Ansatz 2
Ansatz 3

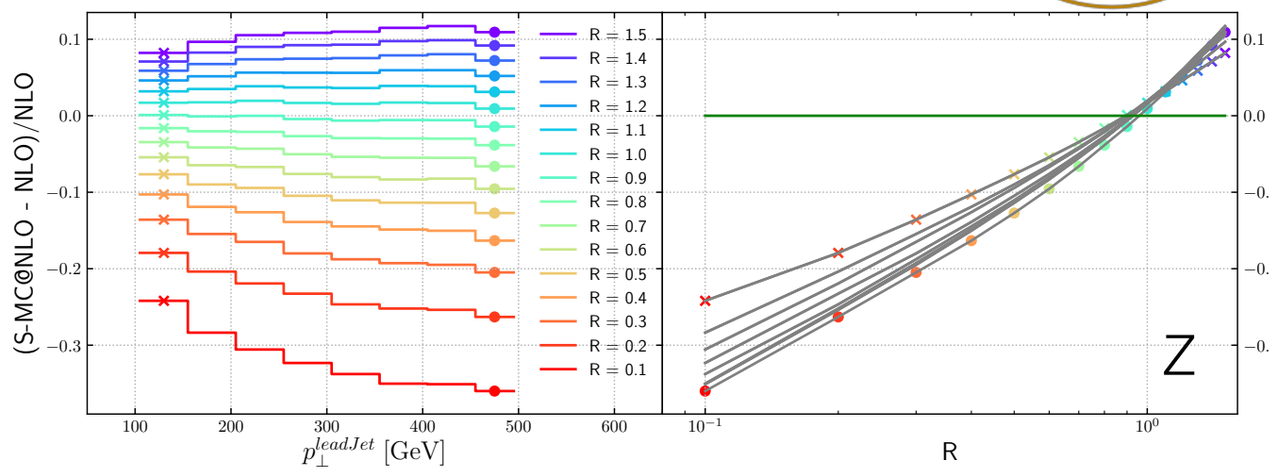
R

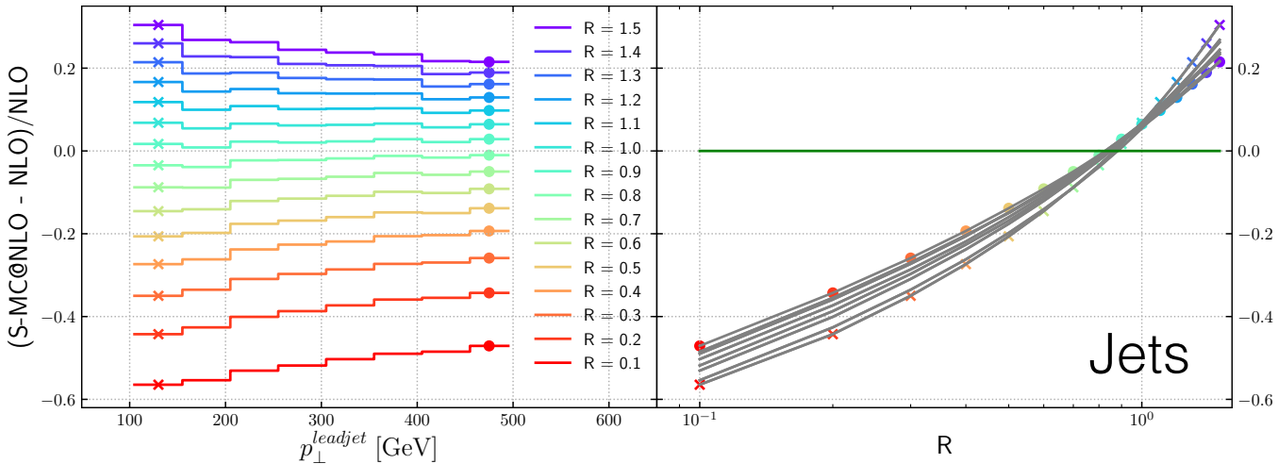

DiJets, R-dependence fit to $10^4 \cdot (a + b\log(R) + cR^2)$, $\mu_{R/F} = p_T^{Jet}$
fit LO: a= 9.68, b=-0.00, c= 0.00
fit NLO: a=12.06, b= 2.34, c= 0.46
fit NNLO: a=12.10, b= 3.33, c= 0.93
$\sigma(R, \mu_{Var})_{p_\perp^{\mathrm{incljet}}>196.0GeV}$ [pb]
Ansatz 1
Ansatz 2
Ansatz 3
R
R

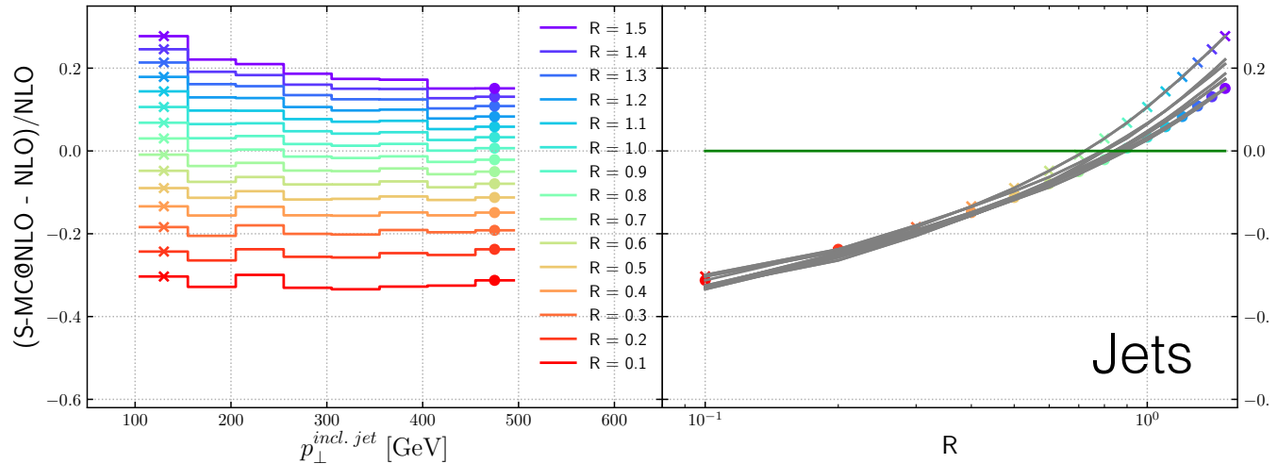

DiJets, R-dependence fit to $10^4 \cdot (a + b\log(R) + cR^2)$, $\mu_{R/F} = p_T^{\mathrm{leadJet}}$
fit LO: a= 9.68, b=-0.00, c= 0.00
fit NLO: a=11.67, b= 2.49, c= 0.49
fit NNLO: a=12.25, b= 2.53, c= 1.07
$\sigma(R, \mu_{Var})_{p_\perp^{\mathrm{incljet}}>196.0GeV}$ [pb]
Ansatz 1
Ansatz 2
Ansatz 3
R

R-dependence differential in pT







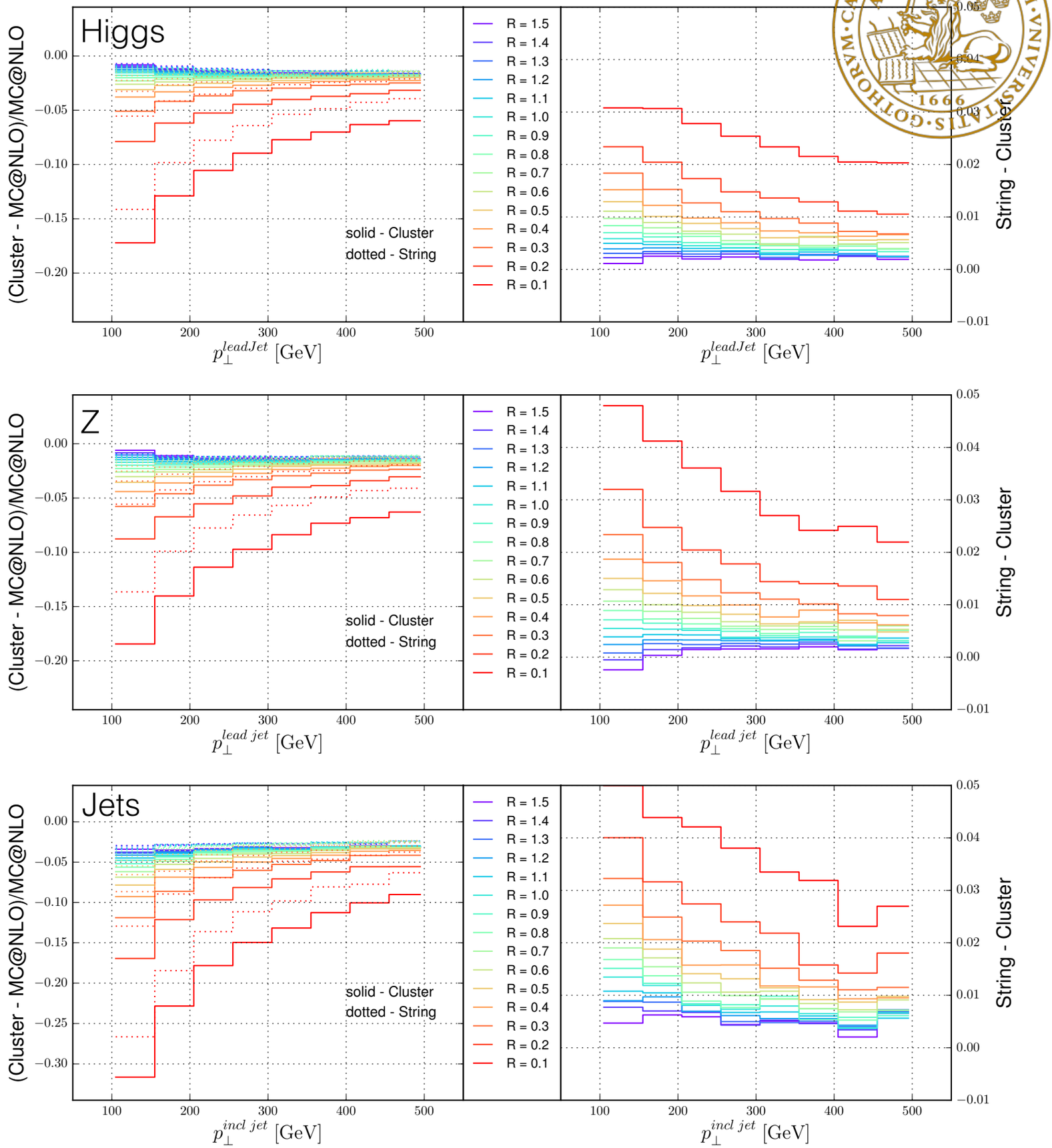


Interesting pT-independence of R dependence in Higgs production.
Not entirely clear why… Incoming quarks also play a role for Higgs.

Further investigation needed.

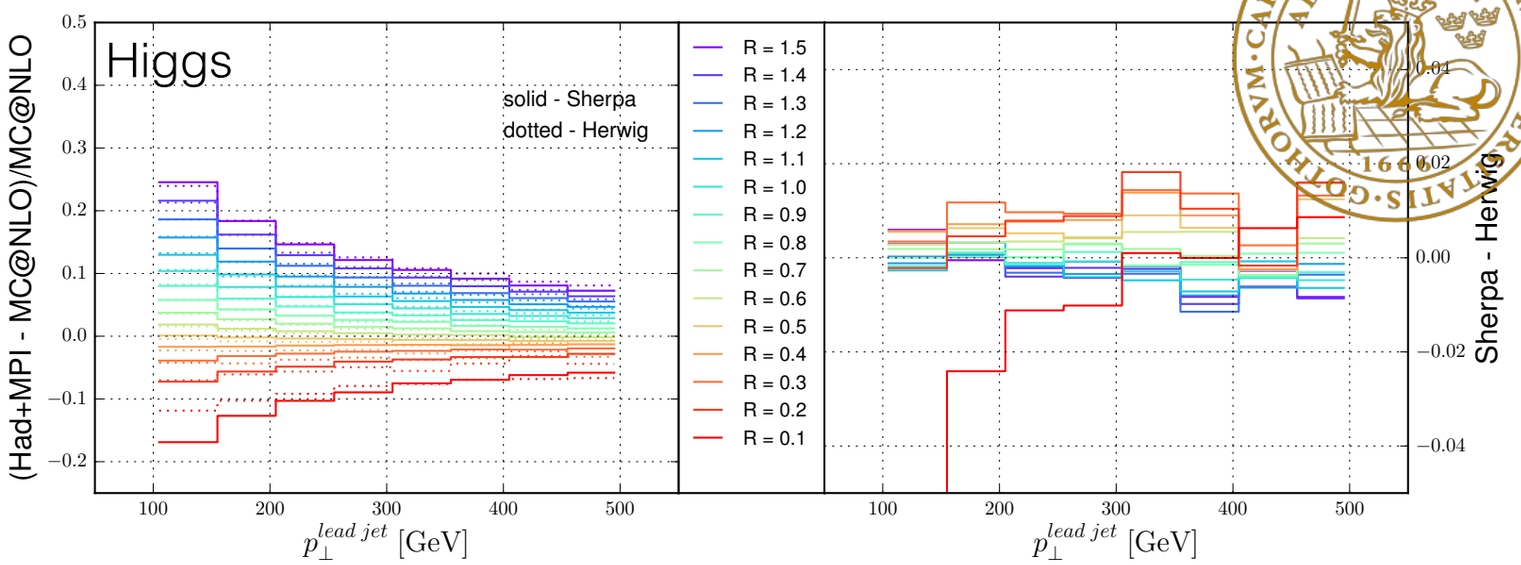
NP corrections

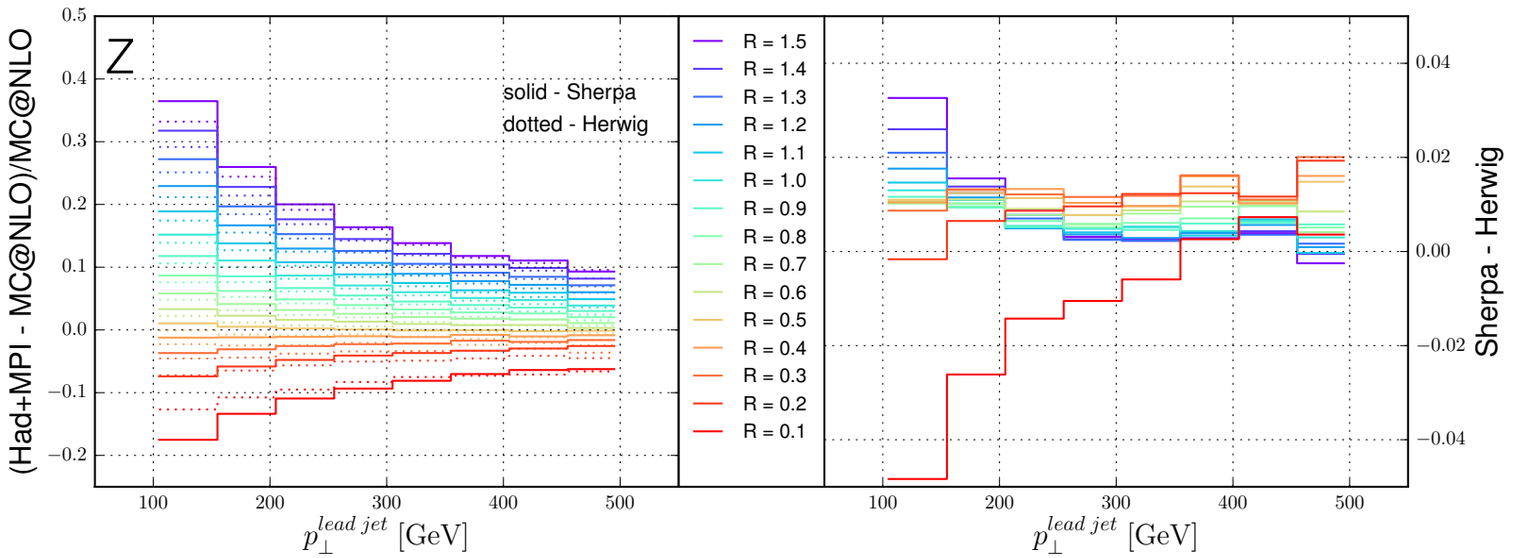
- Known out-of-cone radiation when Hadronisation is switched on.
- Most important for Jets.
- Clusters and strings give similar picture
- Uncertainty from comparing strings to cluster model smaller than correction.

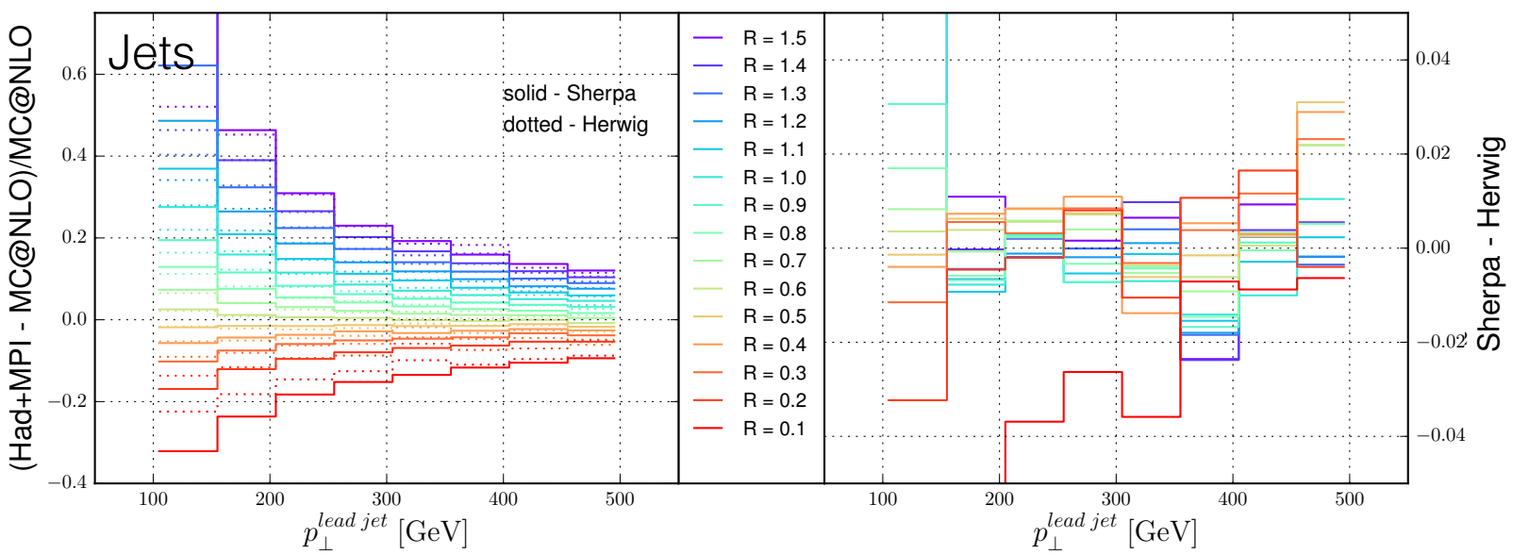


NP corrections

- Jets gain energy from MPI.
- Good agreement between NP corrections used in Herwig and Sherpa.
- Best agreement to parton level at R=0.5-0.6
- Correction from PL to full simulation about 10% for low pT decreasing for higher pTs.
- Similar behavior for all processes but different in size.







Conclusion

- We compared NNLO to NLO+PS (matched only). With focus on jets.
- LO->NLO opens back-to-back configurations. NLO->NNLO more stable.
- Comparison possible for event based scales.
- NLO+PS with inclusive K-factor for Z-boson pT (with the choices made) in good agreement with NNLO.
- We compared two (three) independent matching schemes and found good agreement. (Once parameters and scales have been aligned.)
- NP corrections are sizable but under control.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Thank you!


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Backup: SM/HEFT