AITANA ANNUAL MEETING

Interpretation of the top quark mass parameter in Monte Carlo samples at NNLL precision

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Top quark mass interpretation

- **Test the relation between the top quark MC mass parameter, m_t^{MC} and the MSR mass scheme used in calculations, $\Delta_{t,MC}$, given by:**

$$m_t^{MC} = m_t^{MSR} + \Delta_{t,MC}$$

- Can establish whether, and to which precision, the numerical value of the MC mass parameter can be identified with the renormalised mass.
  - If the result is incompatible, then the mass relation can be used to convert the top quark mass parameter in the MC that is measured in direct measurements to a field-theoretical mass scheme.
  - In any case, this study can shed light on subtle effects in Monte Carlo generators.

Goal of analysis

- **The interpretation of the top mass in an MC generator, in terms of a renormalised mass in the MSR scheme:**

$$\mathbf{m_t^{MC} = m_t^{MSR}(R = 3GeV) + \Delta_{t,MSR}}$$

- Previously, theory uncertainties at NLL were a large source of uncertainty. ***arXiv:1608.01318, arXiv:1708.02586, ATL-PHYS-PUB-2021-034***.

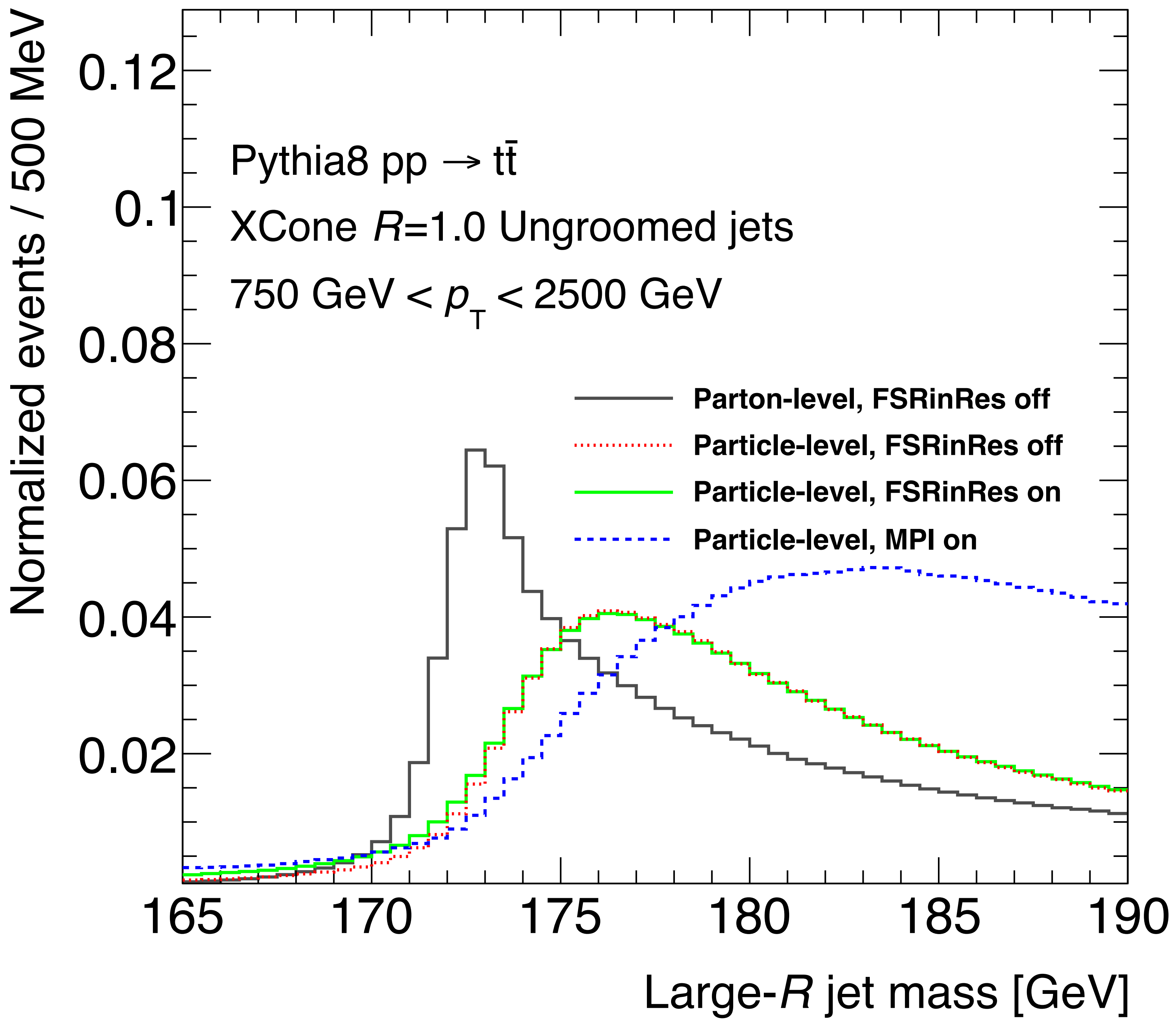
- Calibration performed with **new NNLL calculation** compared against **Pythia MC** predictions with NNPDF3.0 NLO PDF set and A14 set of tuned parameters.

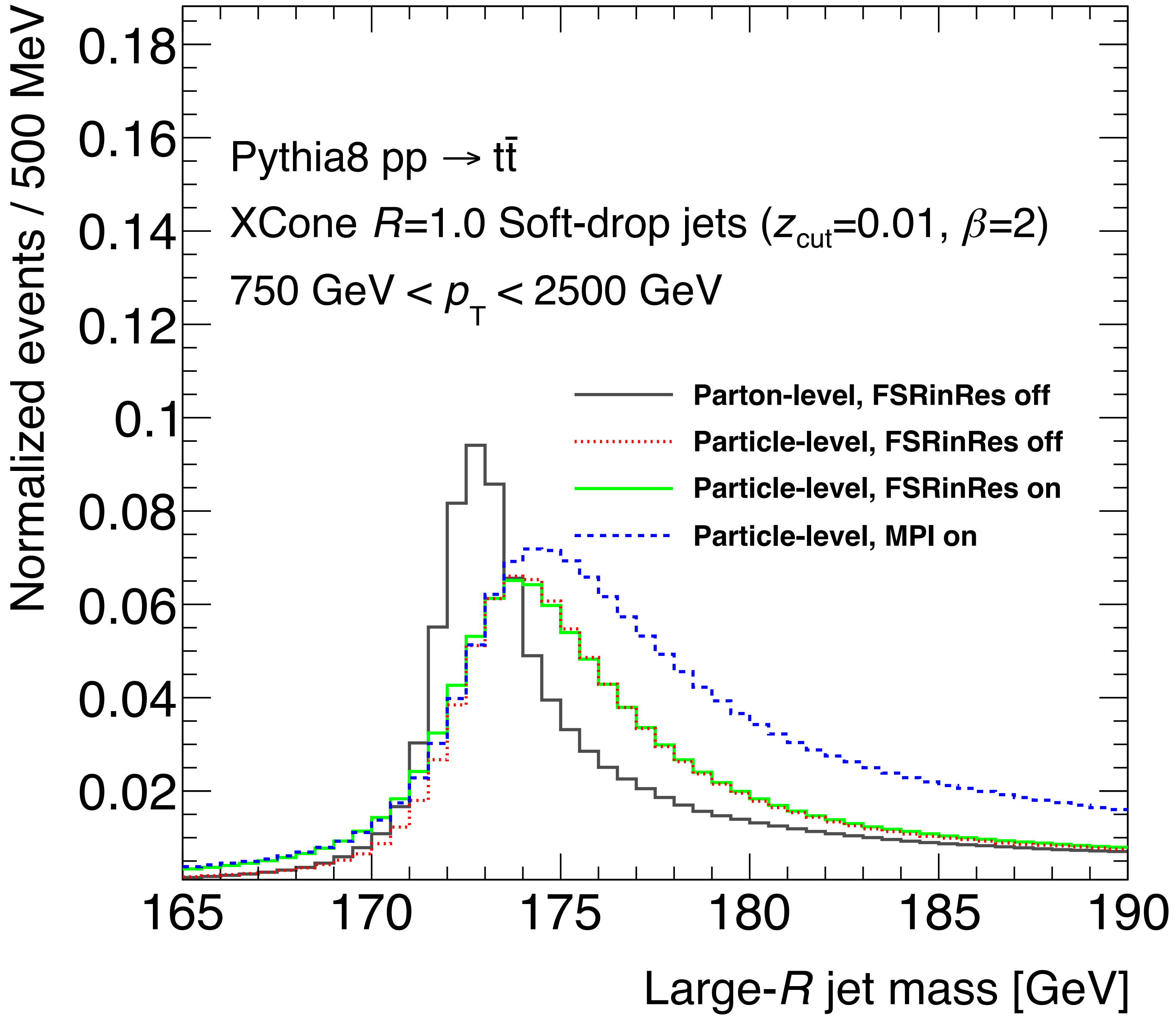
m_t^{MC} **is set to 172.5 GeV.**

Large-R Jet Mass

- Top mass determined by measuring large-R jet mass containing hadronic top.
  - Mass reconstructed using information from decay products of top quark within large-R jet.

- Light grooming applied to large-R jet mass
  - Reduces undesirable effects of soft radiation on the jet mass spectrum.
  - Considerably reduces UE impact. Shift of ~5 GeV down to ~1 GeV.





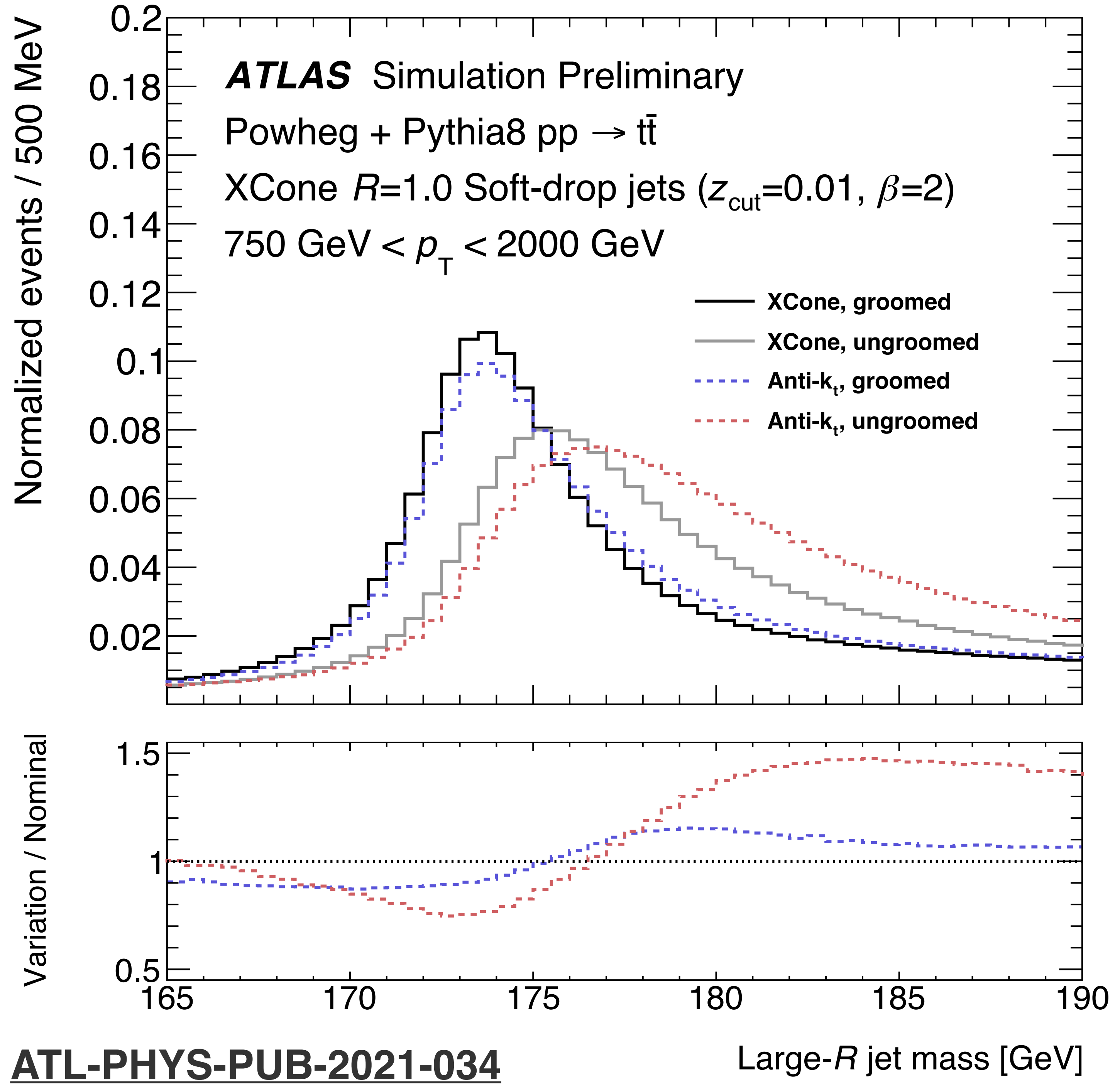
arXiv:1708.02586

Jet building

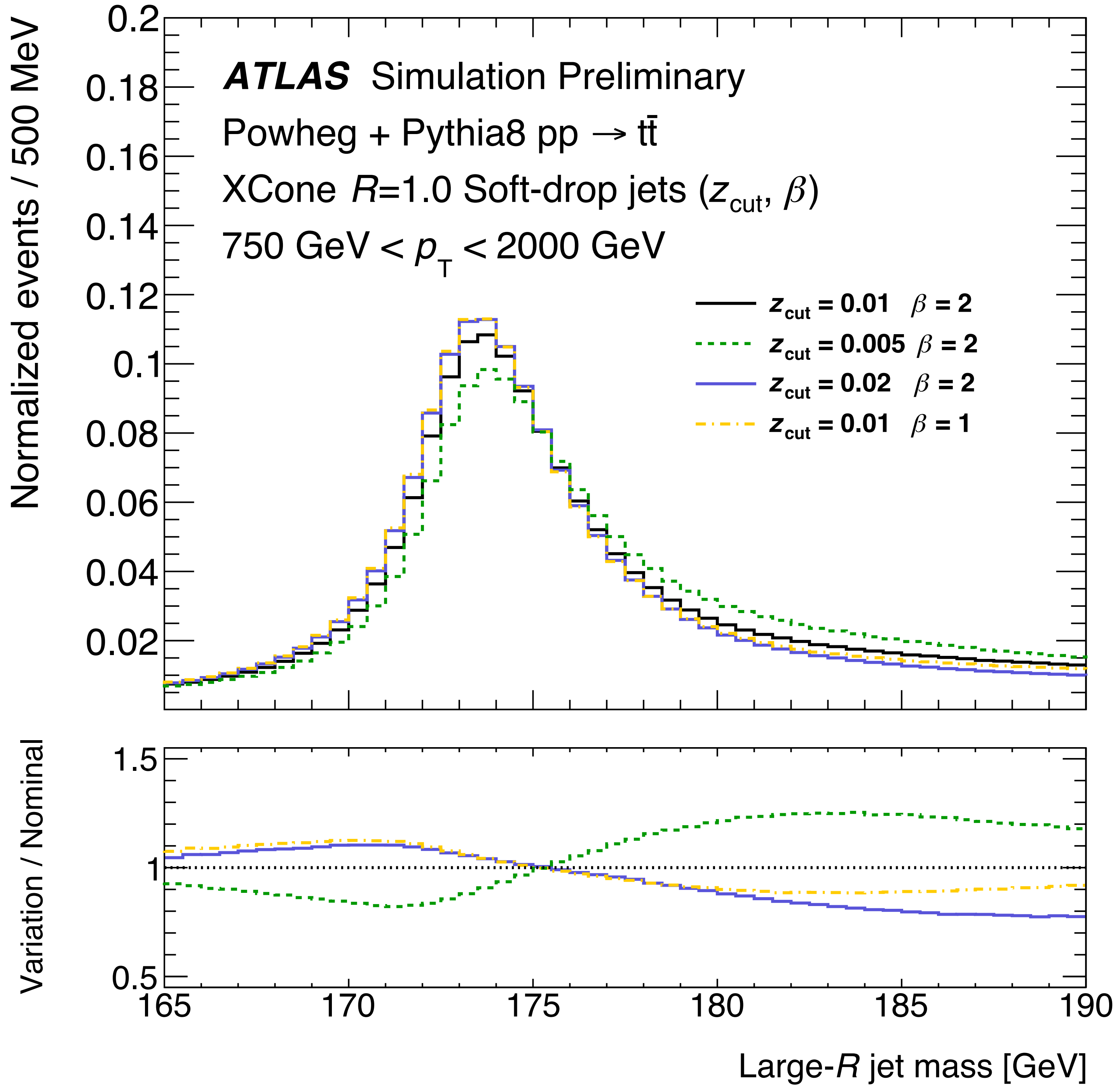
- Focus on particle-level hadronic top quark decay in $pp \rightarrow t\bar{t}$ processes.
- Boosted jet: Inclusive treatment of decay products.
  - **Four orthogonal jet p_T bins**:

$$p_T^{jet} \in \{750, 1000, 1500, 2000, 2500\} \text{GeV.}$$

- Jets built with:
  - **XCone** jet algorithm with **R = 1**.
  - Parton matching $\Delta R(jet, top) < 1$.
  - **Soft-drop light grooming** applied to remove soft-wide radiation (**$z_{cut} = 0.01$, $\beta = 2$**).

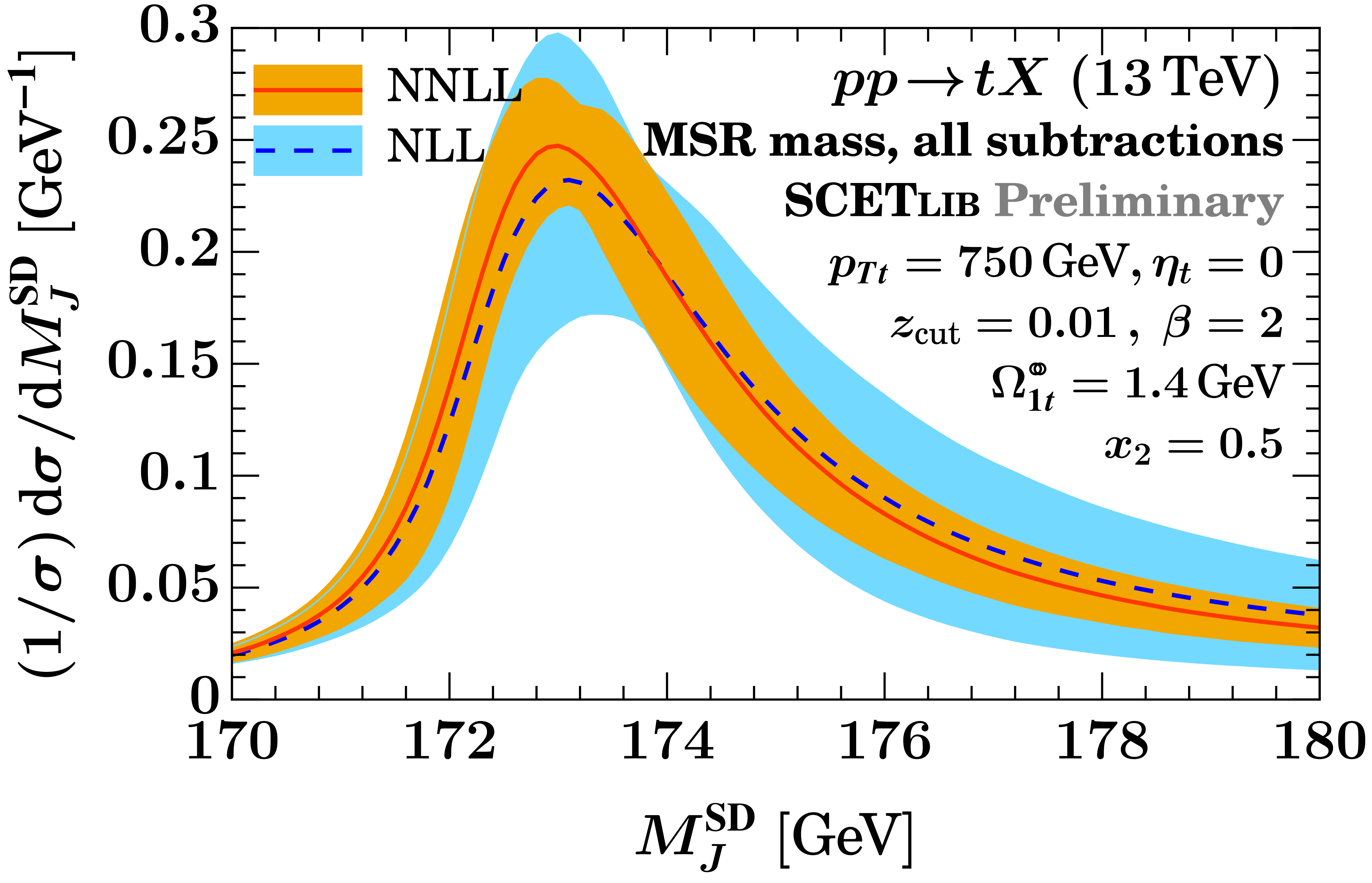


ATL-PHYS-PUB-2021-034



Theoretical Calculation

- Continuation of the top mass interpretation with NLL accuracy found at ATL-PHYS-PUB-2021-034.
- Model uses three parameters, $\mathbf{m_t^{MSR}}$, $\mathbf{\Omega_1^{had}}$, and $\mathbf{x_2}$ associated with **first-** and **second-moment non-perturbative corrections.**
- Using SCET-based theory with NNLL accuracy
  - Improved perturbative stability
  - Renormalon subtraction - Renders the first-moment non-perturbative correction renormalon free.



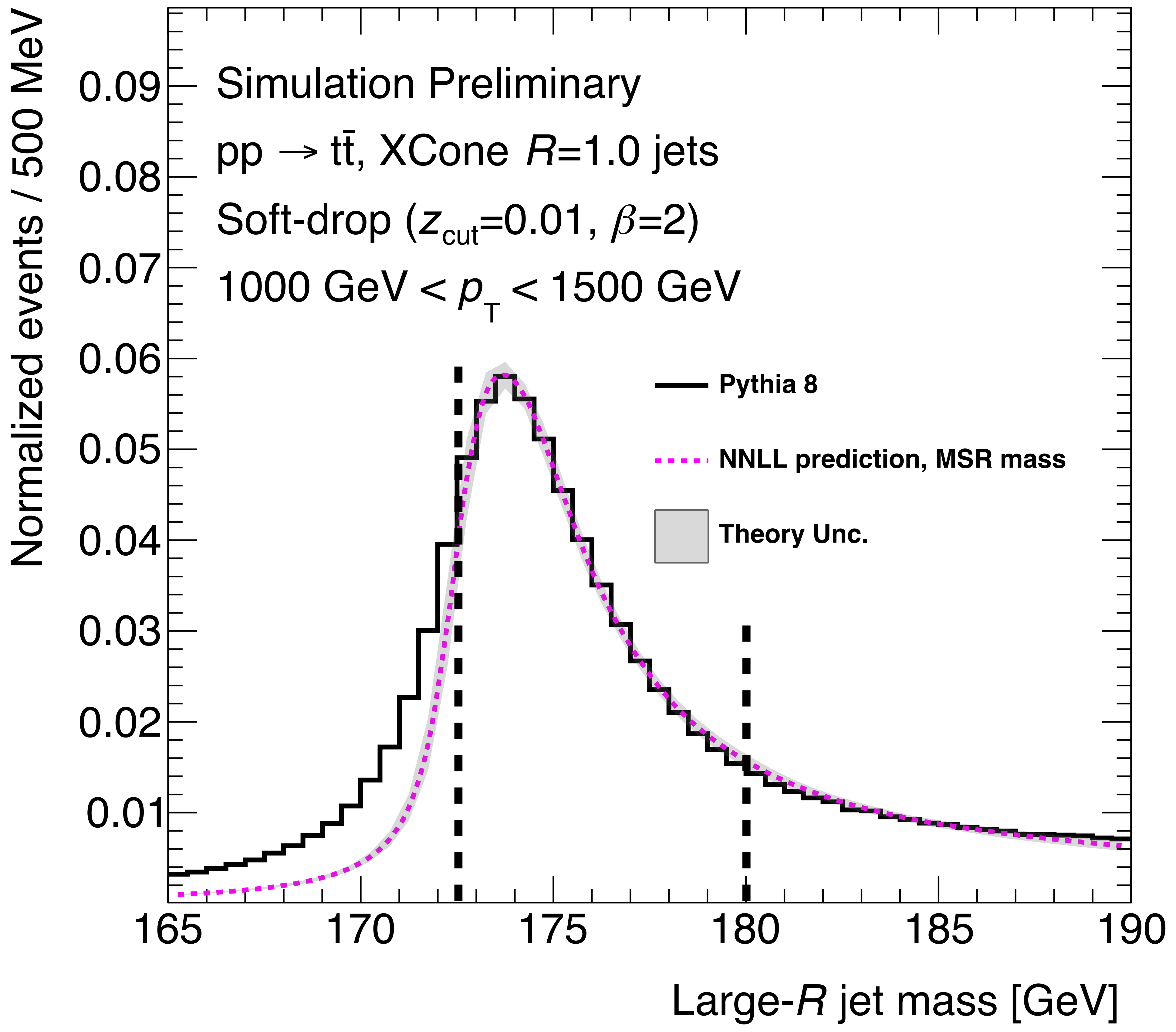
Mantry, Michel, Pathak, Stewart
Preliminary

Fitting Details

- Idea is to obtain **value of parameters in NNLL theory** calculation that **best describe MC prediction.**

- m_t, Ω_1^{had}, and x_2 varied:
    - χ^2 minimisation fit applied to the three parameters to find the global minimum.

- Fit range set to 172.5-180 GeV.
    - In grooming procedure, theory does not accurately describe the low-mass tail present in the generator prediction due to decay product FSR effects that are not included.
    - Restrict fit range to avoid the low jet-mass tail, that would bias the extracted top mass to lower values.



We take a **fit range study**, checking the top quark mass value at 172-180 GeV and 173-180 GeV as an uncertainty: ± 215 MeV.

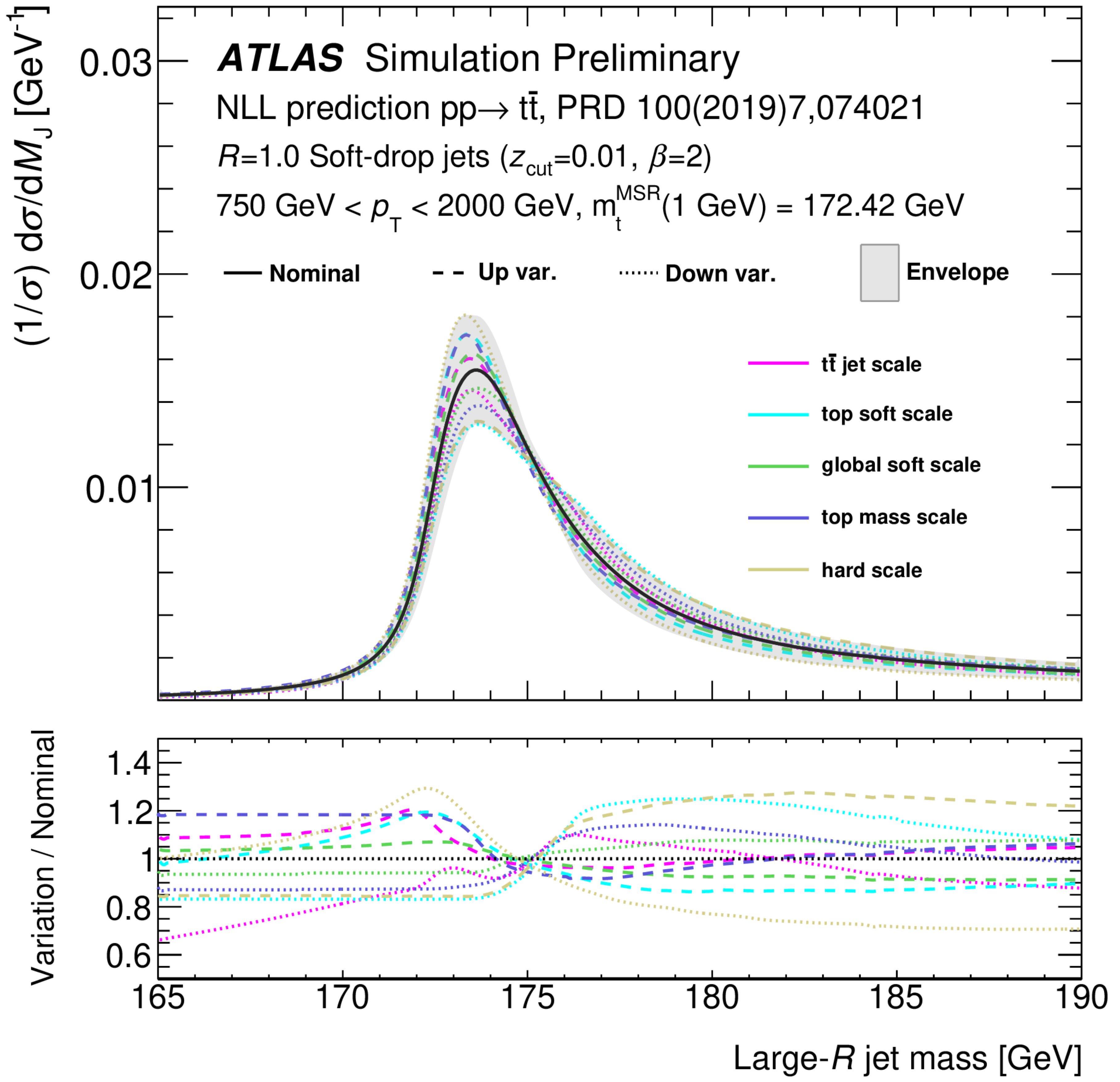
Theoretical Uncertainties

- Theoretical uncertainty determined by scale variations that provide a prescription for estimating perturbative uncertainties.

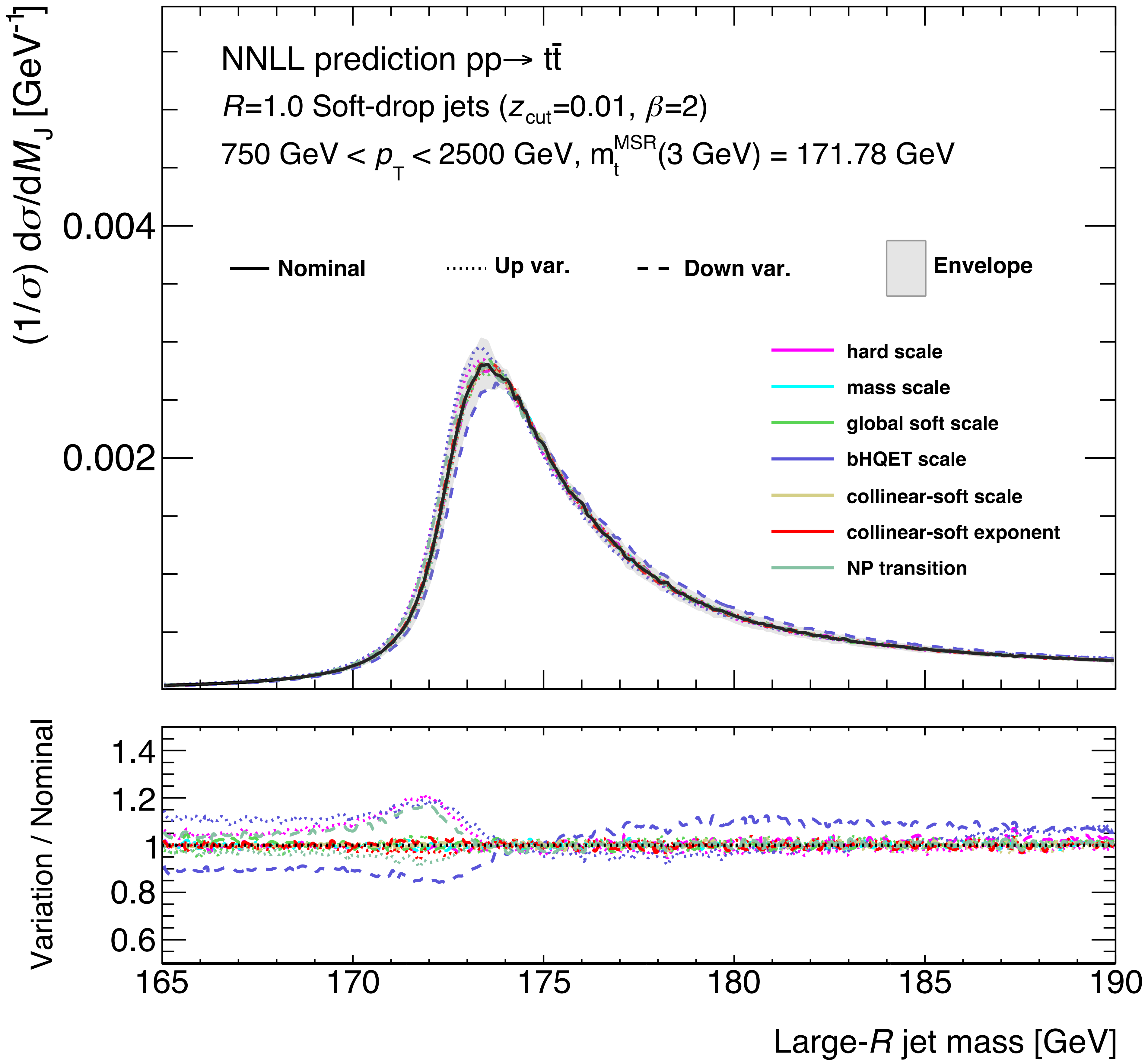
Measured to be +110 MeV and -200 MeV.

Big decrease from previous that was +230 MeV and - 310 MeV

Old



New

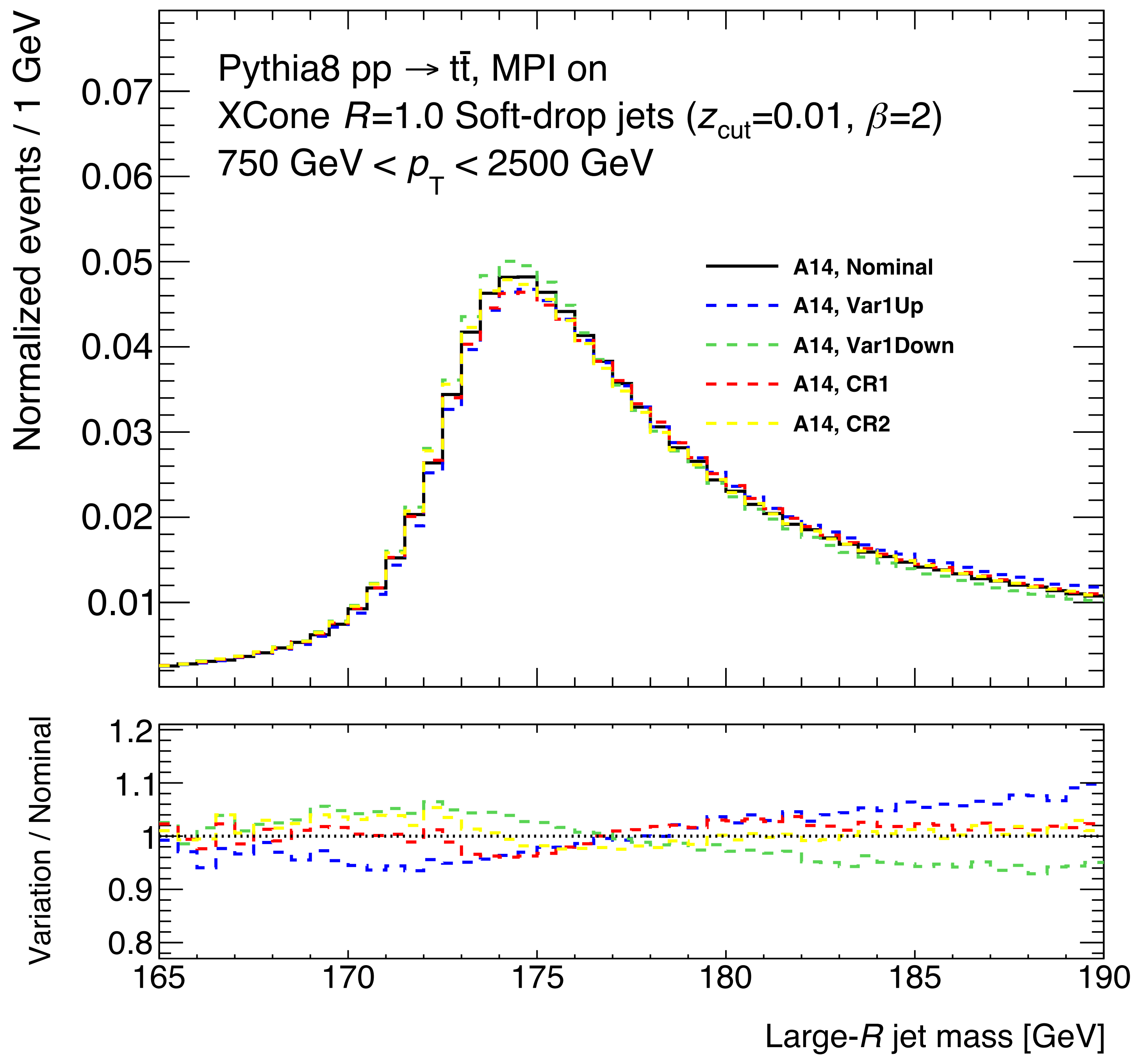


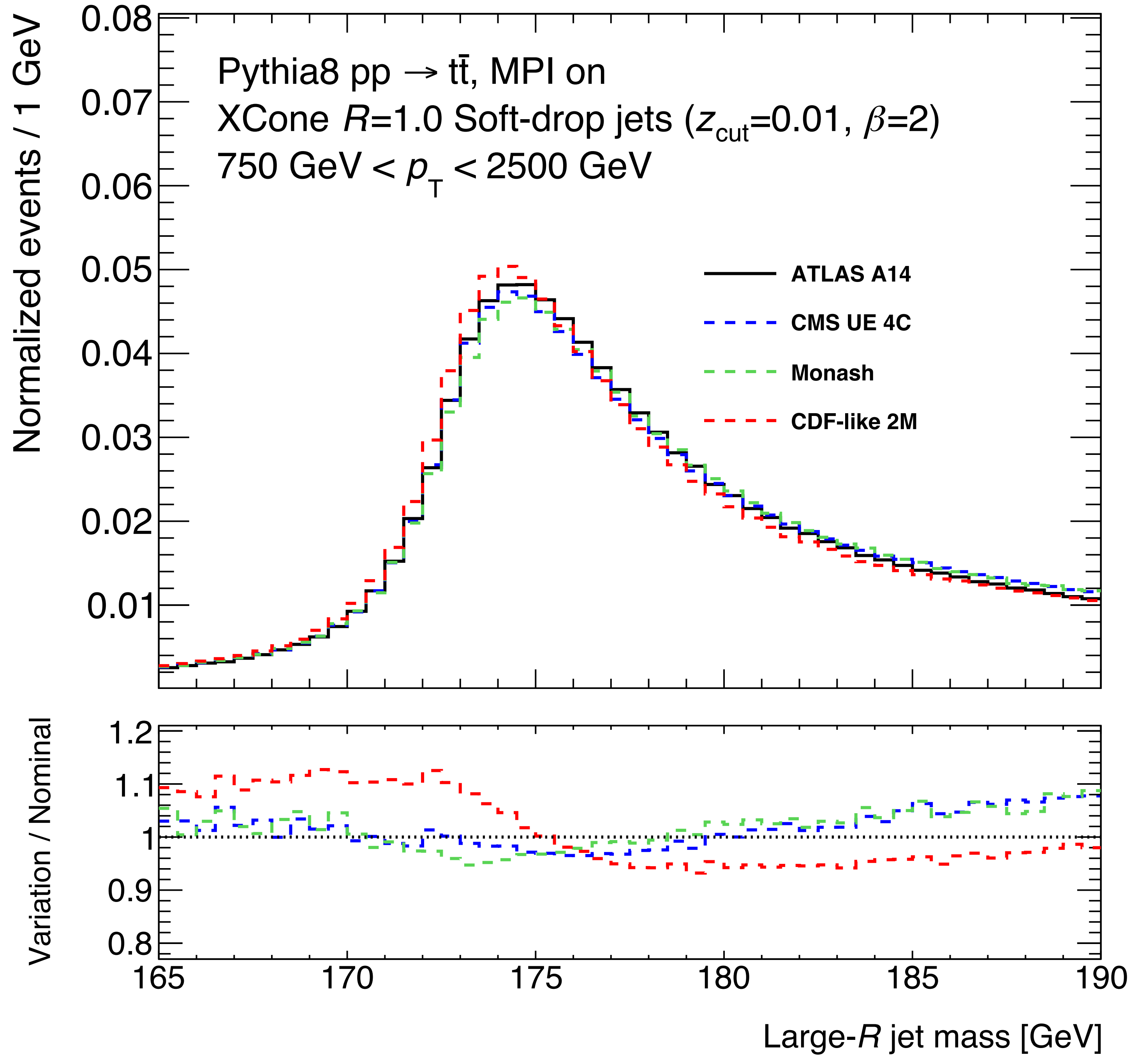
UE Uncertainties

- The **Underlying Event** (UE) encompasses **all additional activity** that occurs in conjunction **with hard scattered processes at low energy.**

- **Underlying event**
  - Comparing nominal MPI-on Pythia against A14 Var1 and CR eigentune variations (coverage of UE variations modelling uncertainties).
  - Extend to inclusion of MPI-on Pythia against different tunes based on other detectors to evaluate the effect.

Uncertainty of -122 MeV and +137 MeV.





Result

Mass relation of:

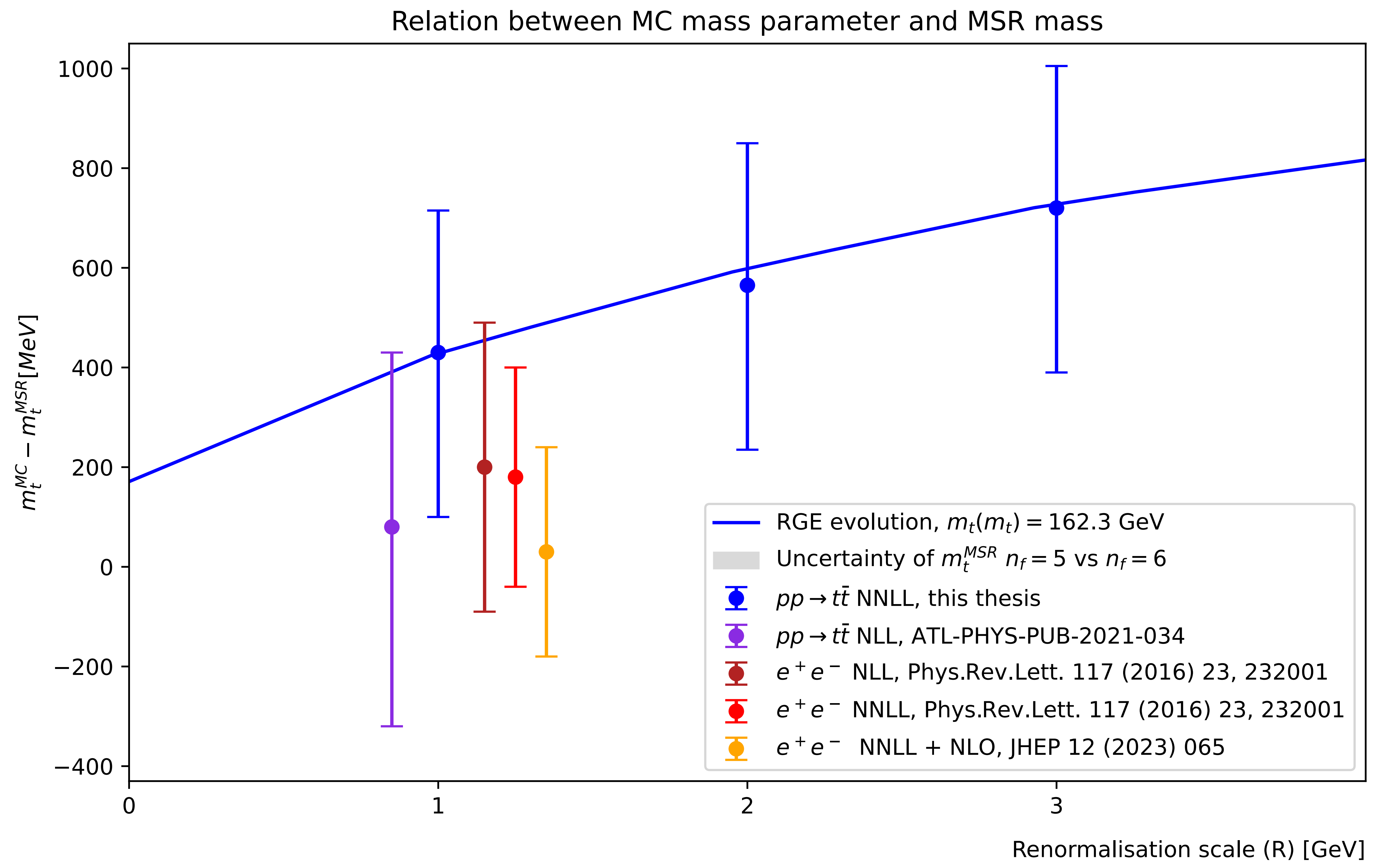
$$\Delta^{MSR} = m_t^{MC} - m_t^{MSR}(1\ \text{GeV}) = 430^{+285}_{-330}\ \text{MeV}$$

Uncertainty corresponding to the total uncertainty.

Mass relation of:

$$\Delta^{MSR} = m_t^{MC} - m_t^{MSR}(3\ \text{GeV}) = 720^{+285}_{-330}\ \text{MeV}$$

Uncertainty corresponding to the total uncertainty.



Conclusion

- **New SCET-based theoretical model yields NNLL predictions for $pp \to t\bar{t}$ with a decrease of theoretical uncertainties.**

- **Pythia MC top mass with MSR top mass at 1 GeV computed:**

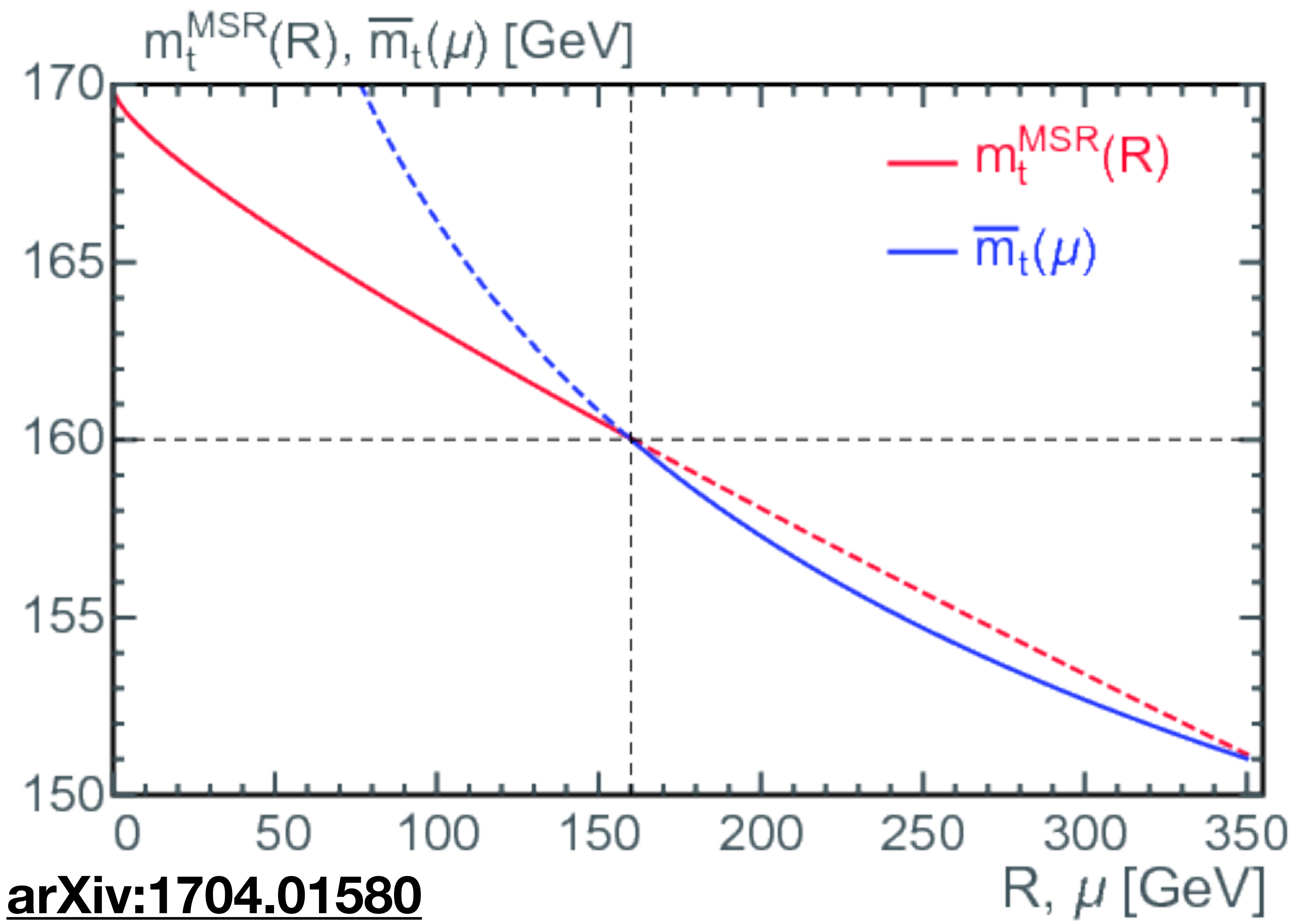
$$m_t^{MC} = m_t^{MSR}(1\ \text{GeV}) + 430^{+285}_{-330}\ \text{MeV}$$

- **Consistent results with previous result at NLL ($\Delta_{t,MSR} = 80^{+350}_{-400}$).**

$\overline{MS}$ and MSR scheme

arXiv:20004.12915

- Want different renormalisation schemes to obtain short-distance mass that numerically not too far from the pole mass.



arXiv:1704.01580

- $\overline{MS}$ **scheme:** $\bar{m}_t(\mu)$ is defined at fixed scale where $\mu \approx m_t$
  - **More stable than pole but mostly applicable to energy scale greater than the top mass.**

- **MSR scheme:** $m_t^{MSR}(R)$ is defined at evolving scale where typically R **<<** m_t
  - Better separates long and short distance effects.

MSR mass can be converted to any other mass (i.e. $\overline{MS}$) with negligible loss in precision.