

# MC Event Generators: Recent Developments

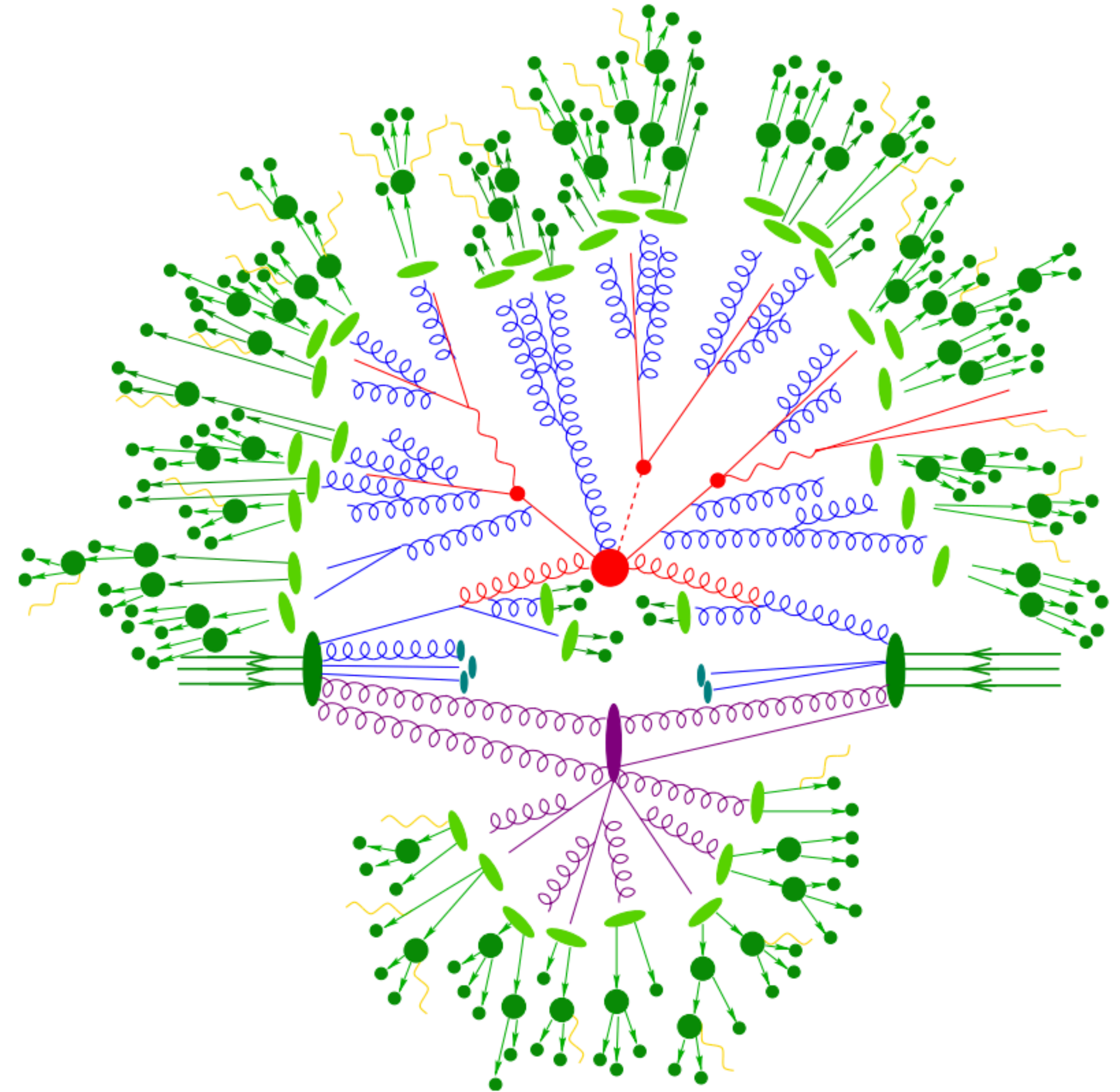
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Daide Napoletano, GDR 04/06/2021

# Introduction

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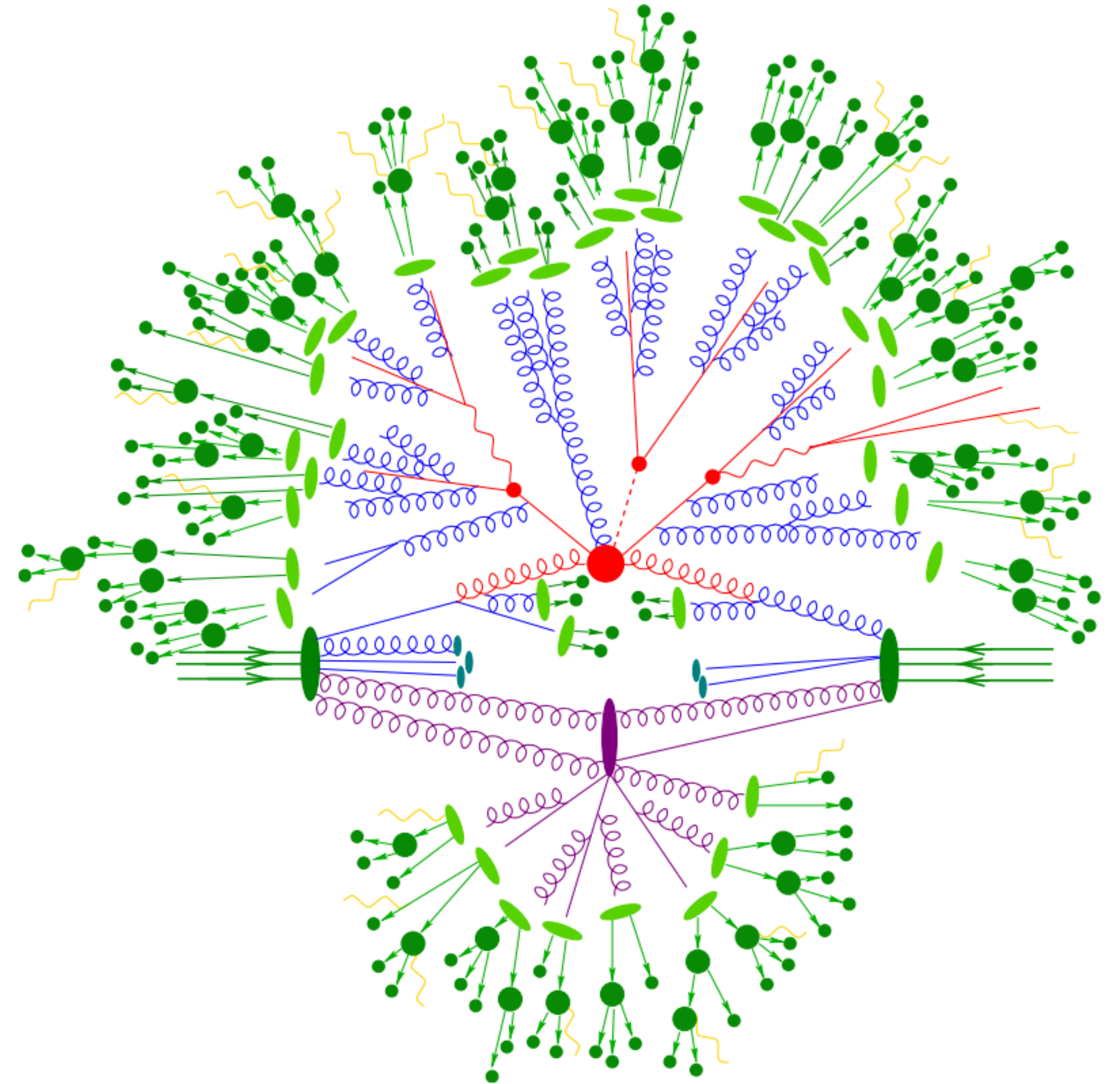
- **Hard Process**
- **Parton Shower**
- **Photons**
- **Multi-Parton Scattering**
- **Fragmentation**
- **Hadron Decay**



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**Order of active development!**

# Hard Process

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- **NNLO QCD is now close to be the new standard, yet many technical challenges...**

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## Subtraction

- **Antenna**
- **CoLoRFulNNLO**
- **qT / N-Jettiness**
- ...

## Matching to PS

- **U2NLOPS**
- **Geneva**
- **MINNLO-PS**
- ...

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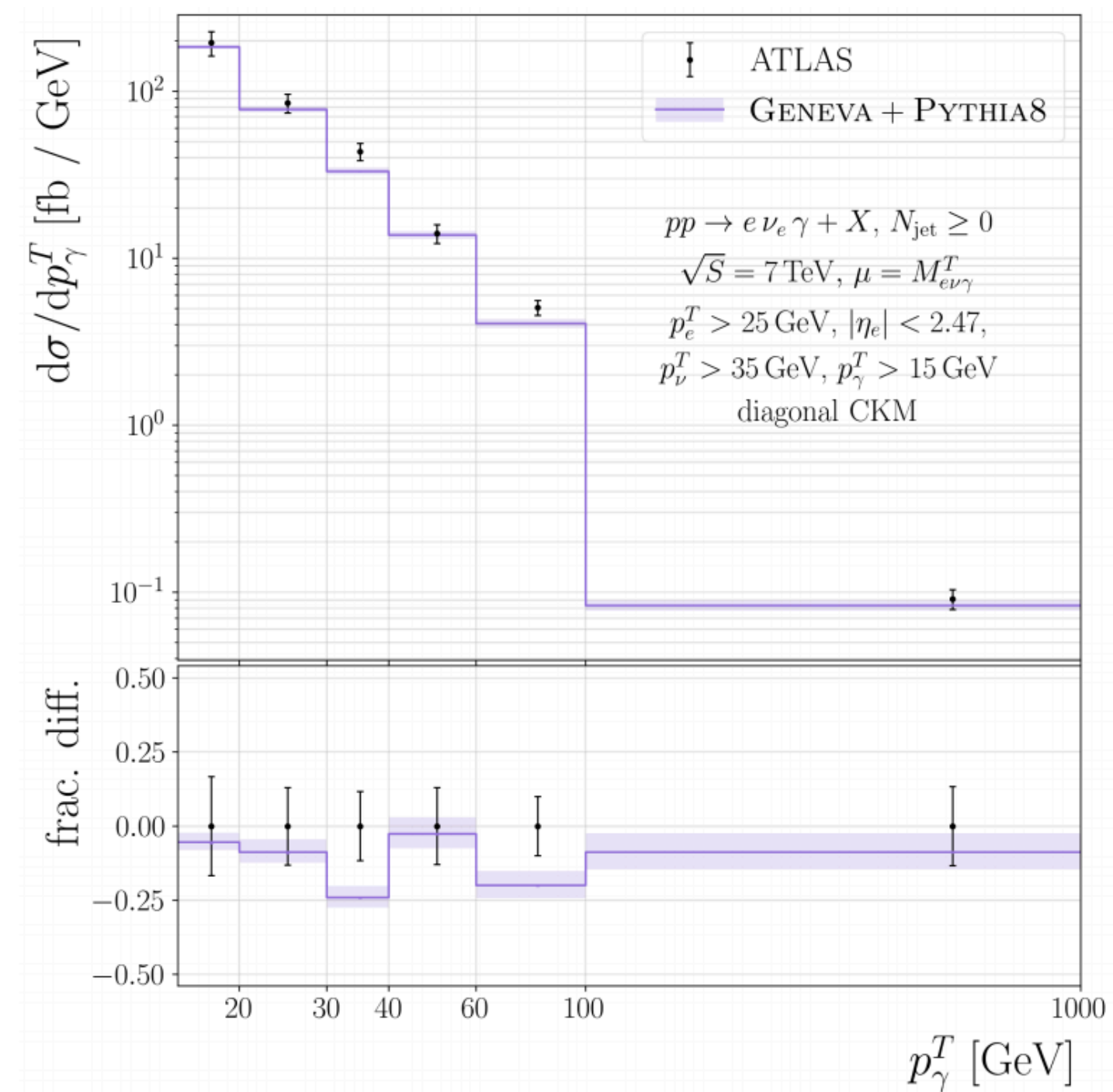
## Matching to PS

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- **...**

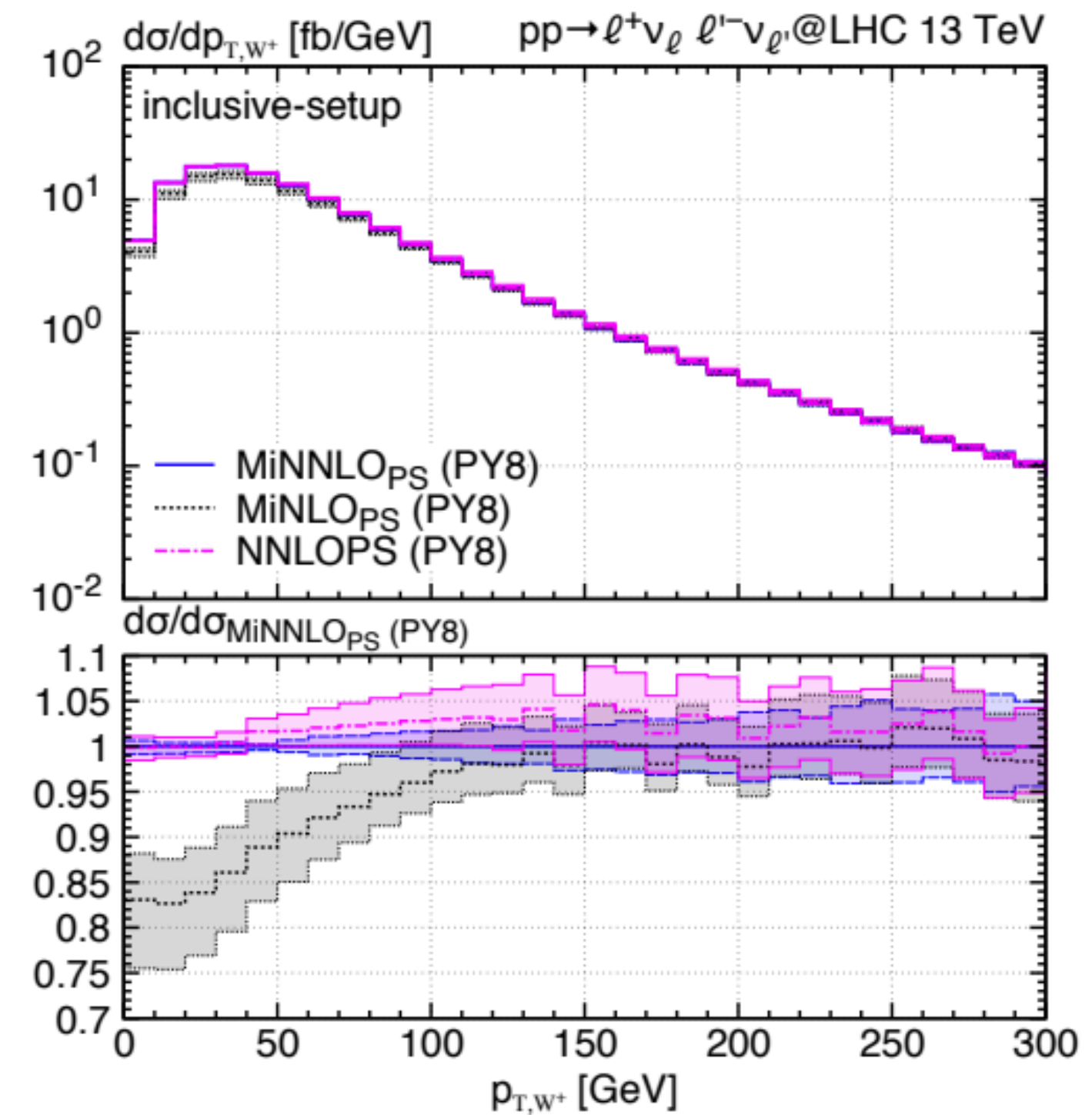
**... Almost exclusively for CS**

# Hard Process

- NNLO QCD is now close to be the new standard, yet many technical challenges...



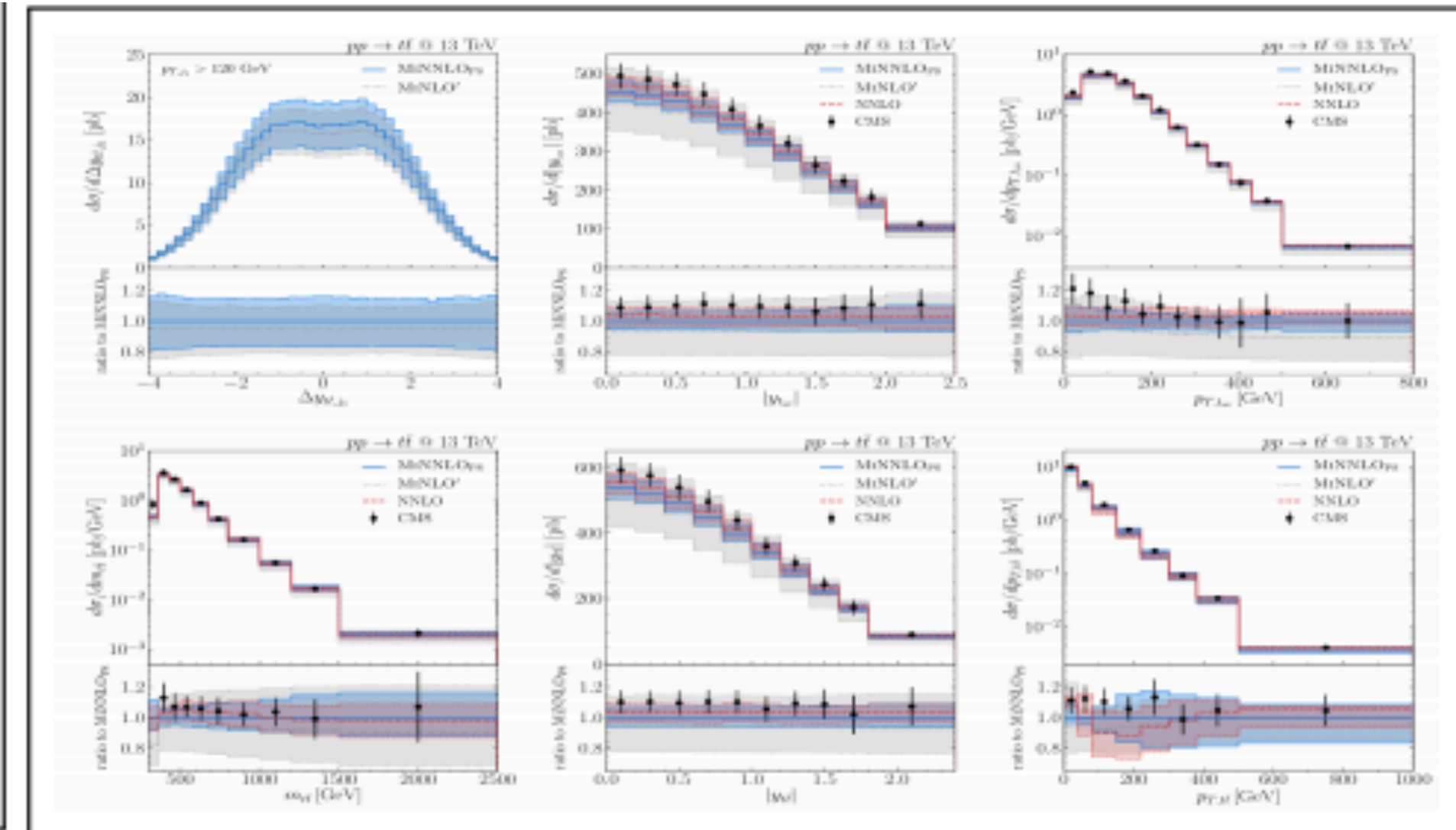
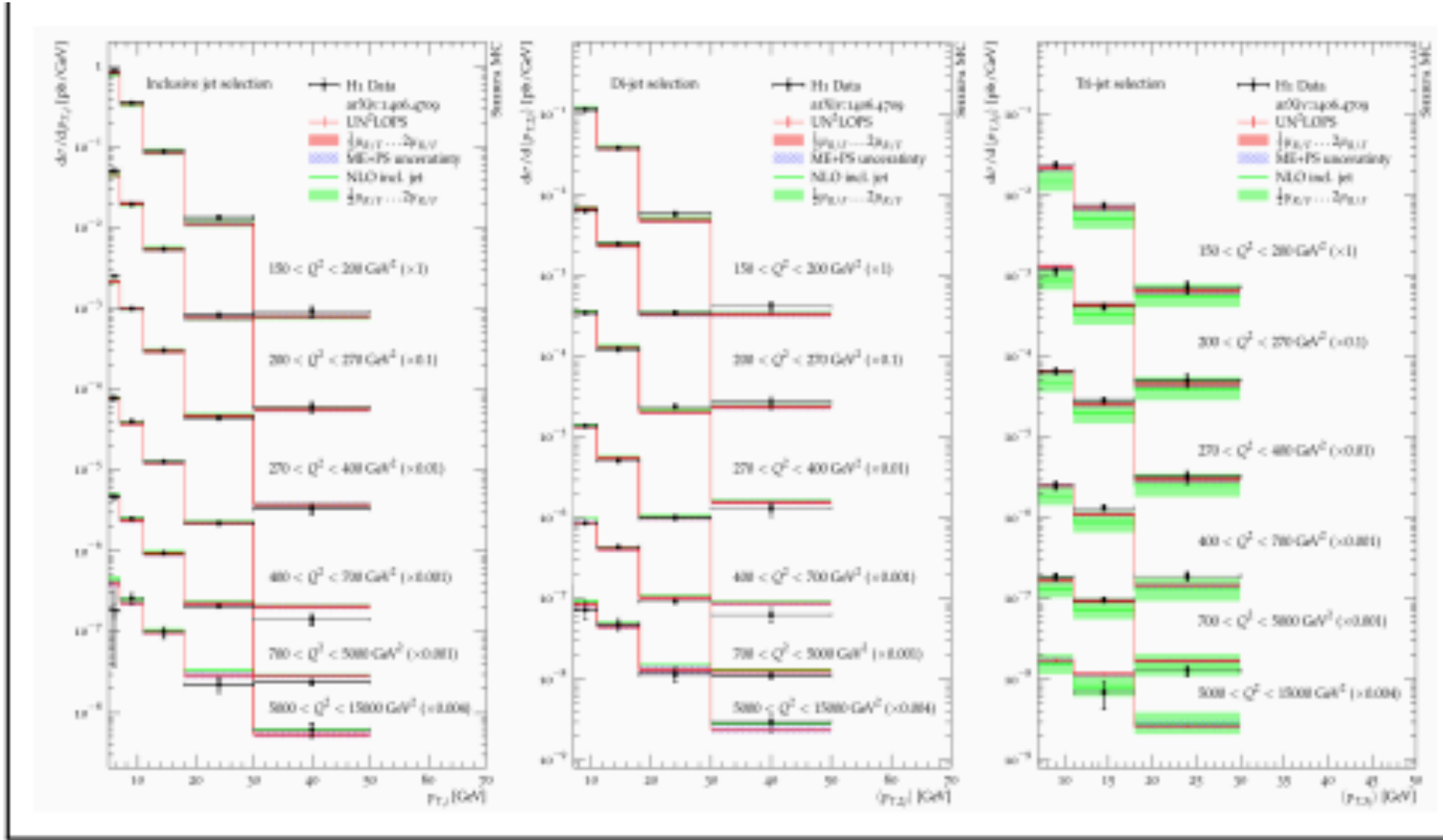
Wy, Cridge et al, 2105.13214



WW, Lombardi et al, 2103.12077

# Hard Process

- Higher order QCD, beyond color singlet

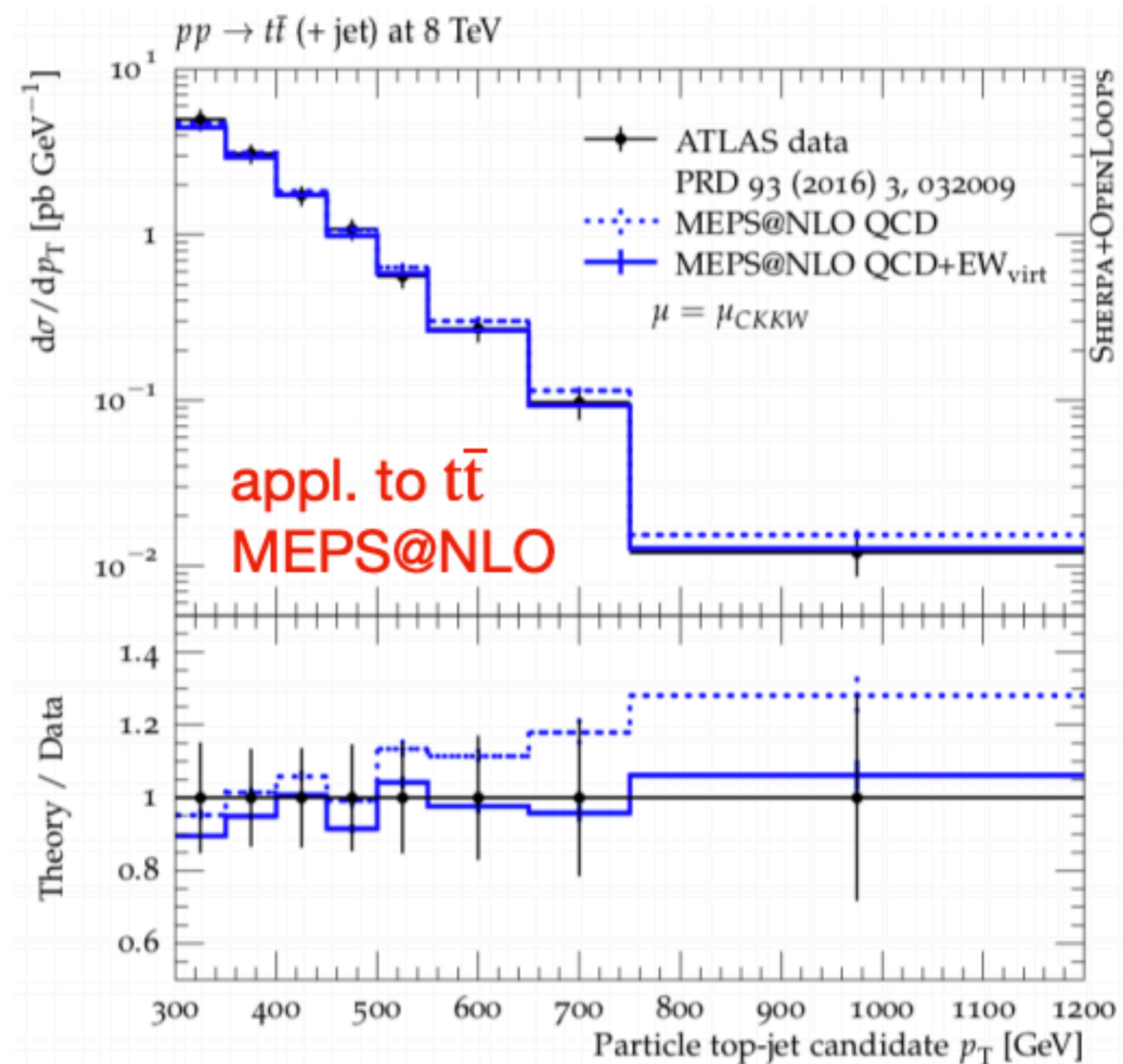


DIS NNLO+PS (arXiv:1809.04192):  $t\bar{t}$  NNLO+PS (arXiv:2012.14267):

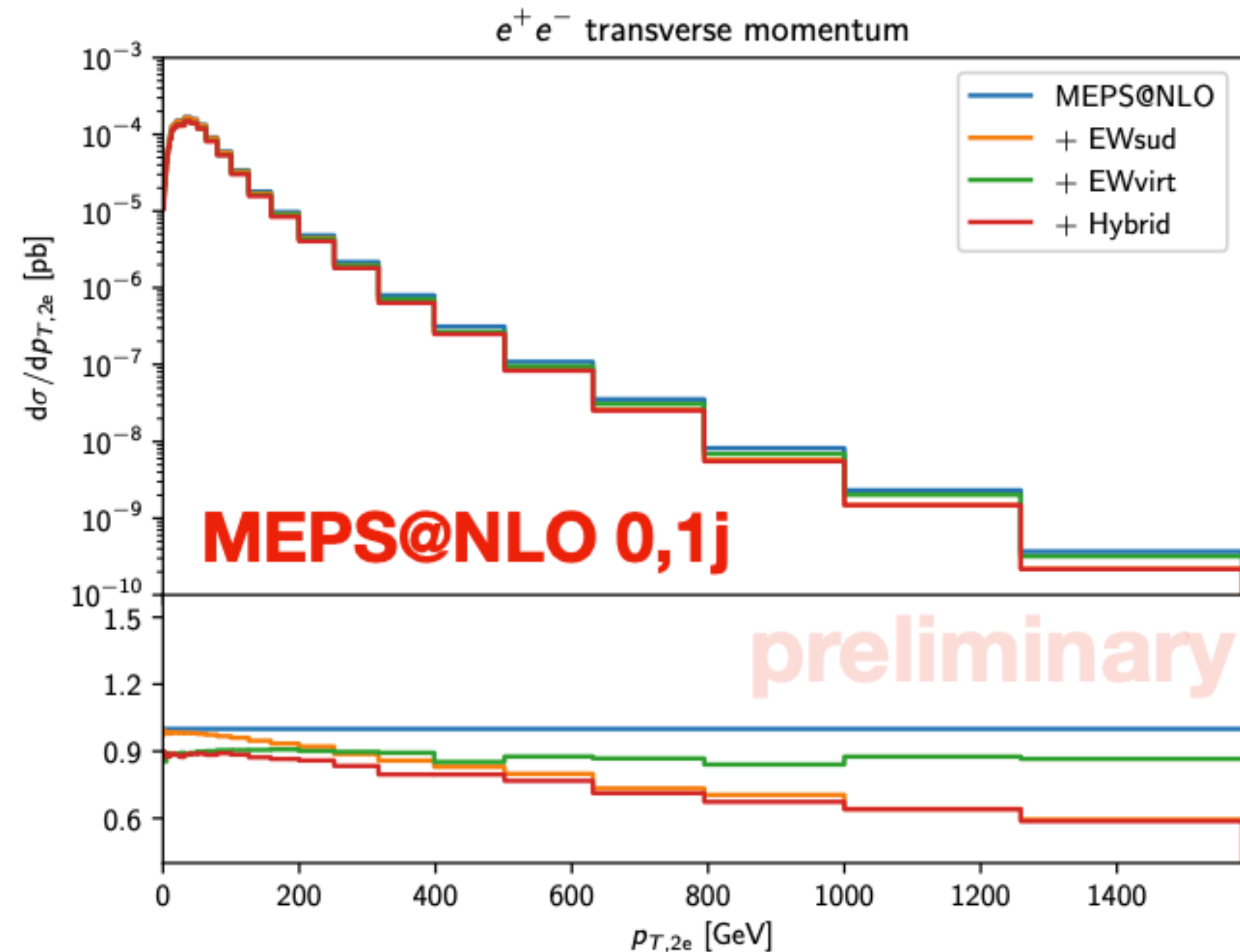


# Hard Process

- NLO EW Fully automated in Sherpa/Madgraph + process specific POWHEG
- With full QED + EW, no matching/merging technology yet... resort to approximations



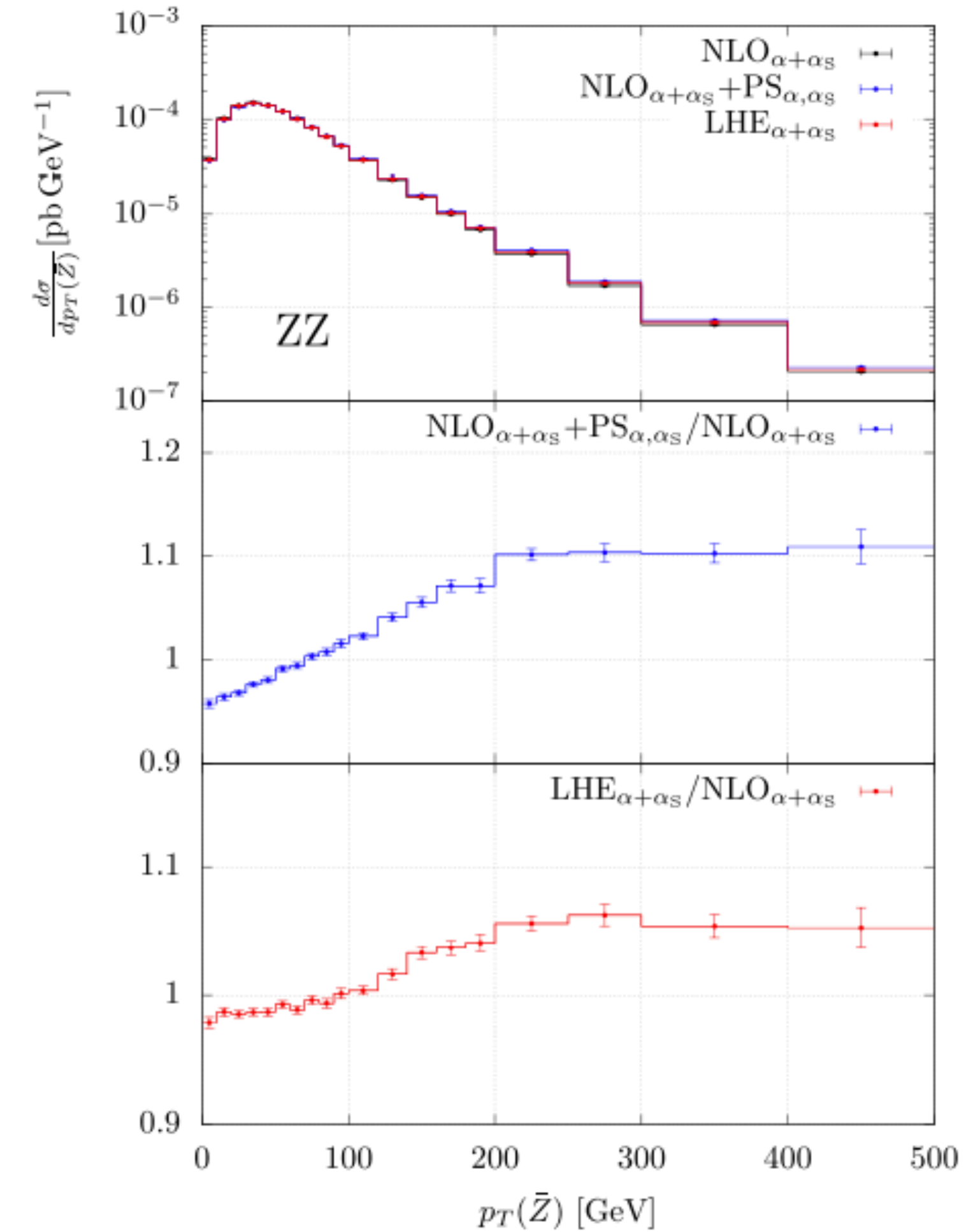
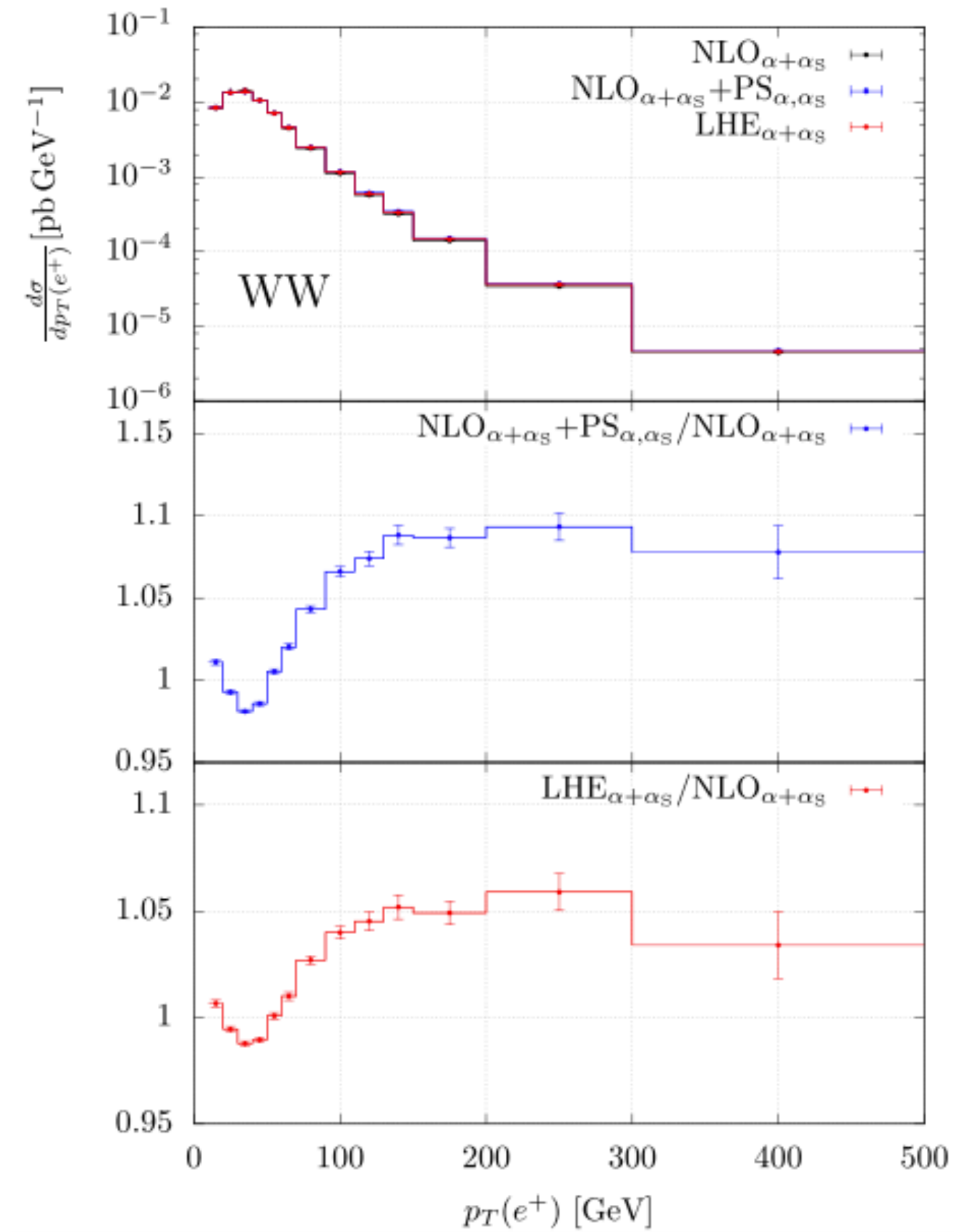
Gütschow et al, Eur.Phys.J. C78 (2018) 317



ZZ, based on Bothmann, DN, Eur.Phys.J.C 80 (2020) 11, 1024

# Hard Process

- First calculations of full NLO EW + QCD matched to QCD and QED Shower

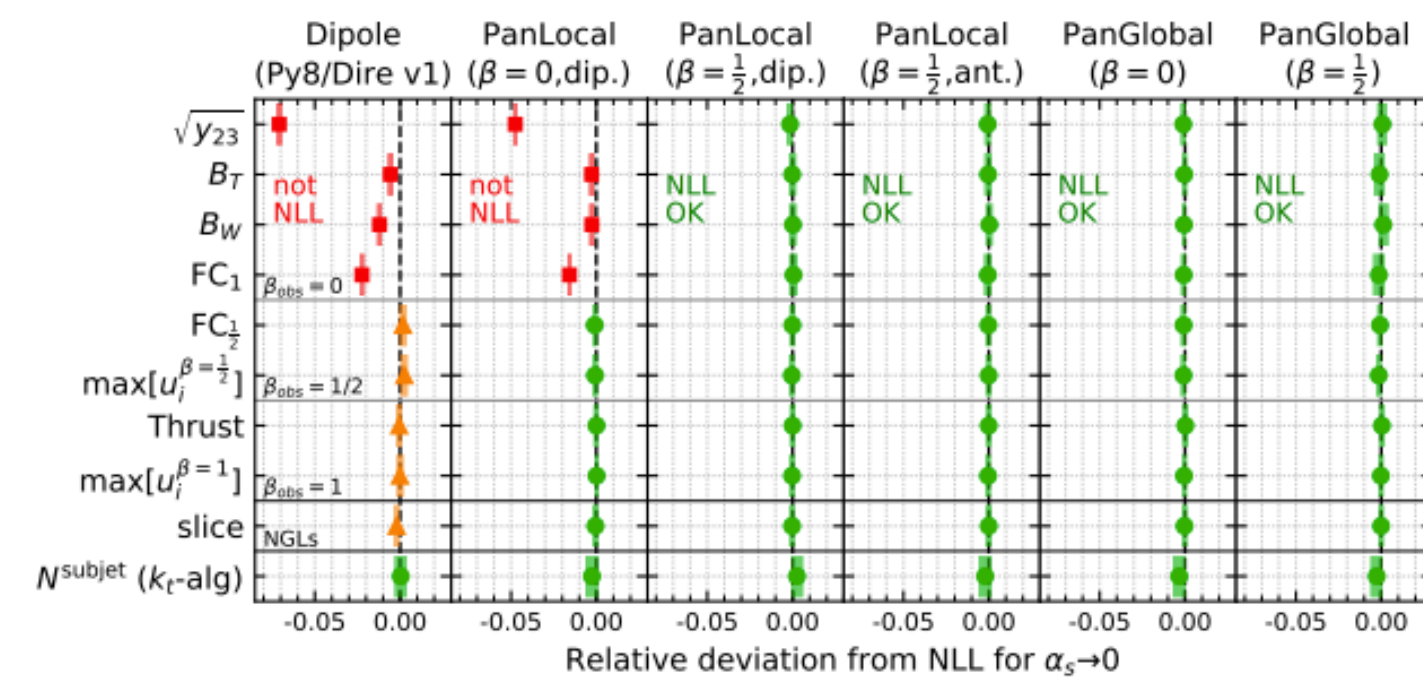


# Parton Shower

- NLL Showers

## PanScales

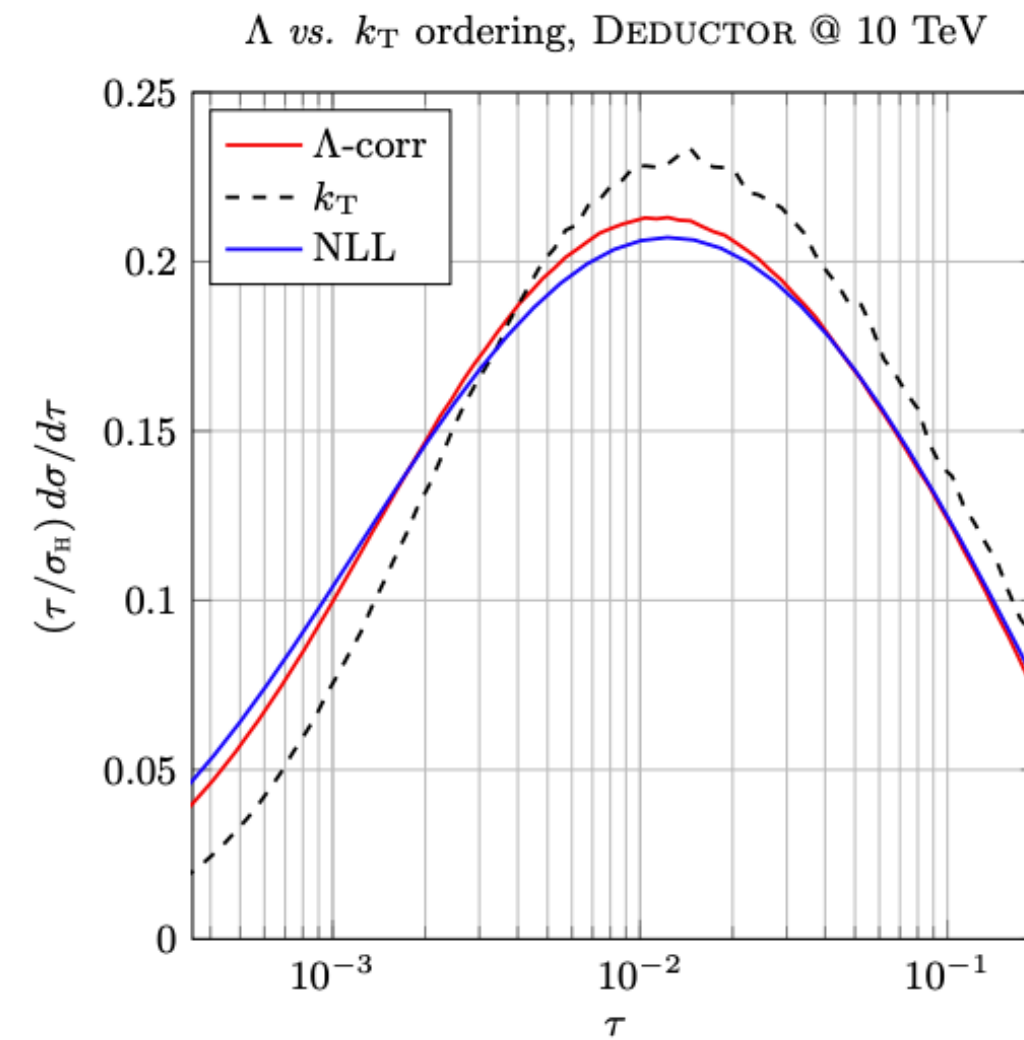
Dasgupta et al, 2002.11114



- Fixes usual dipole shower recoil issues with a suitable choice of evolution variable and recoil scheme

## Deductor

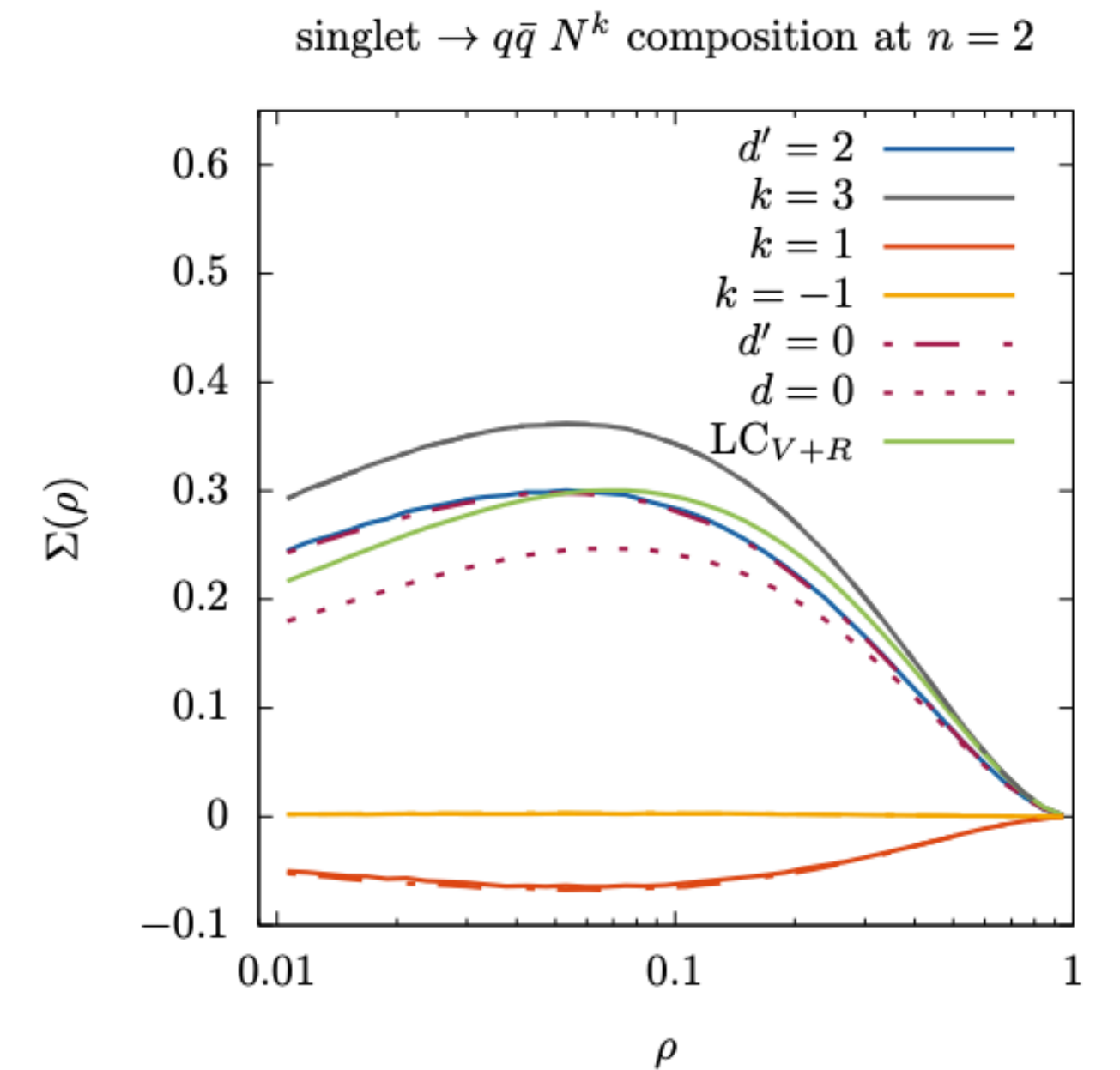
Nagy, Soper, 2011.04777



- Quantum Mechanics / Statistical space approach to evolution, extends beyond LC

## CVolver

Forshaw et al, 2003.06400



- Amplitude level evolution, matches full singular structure of amplitudes and extends beyond LC and spin

# Parton Shower

- NLO Showers, Dire

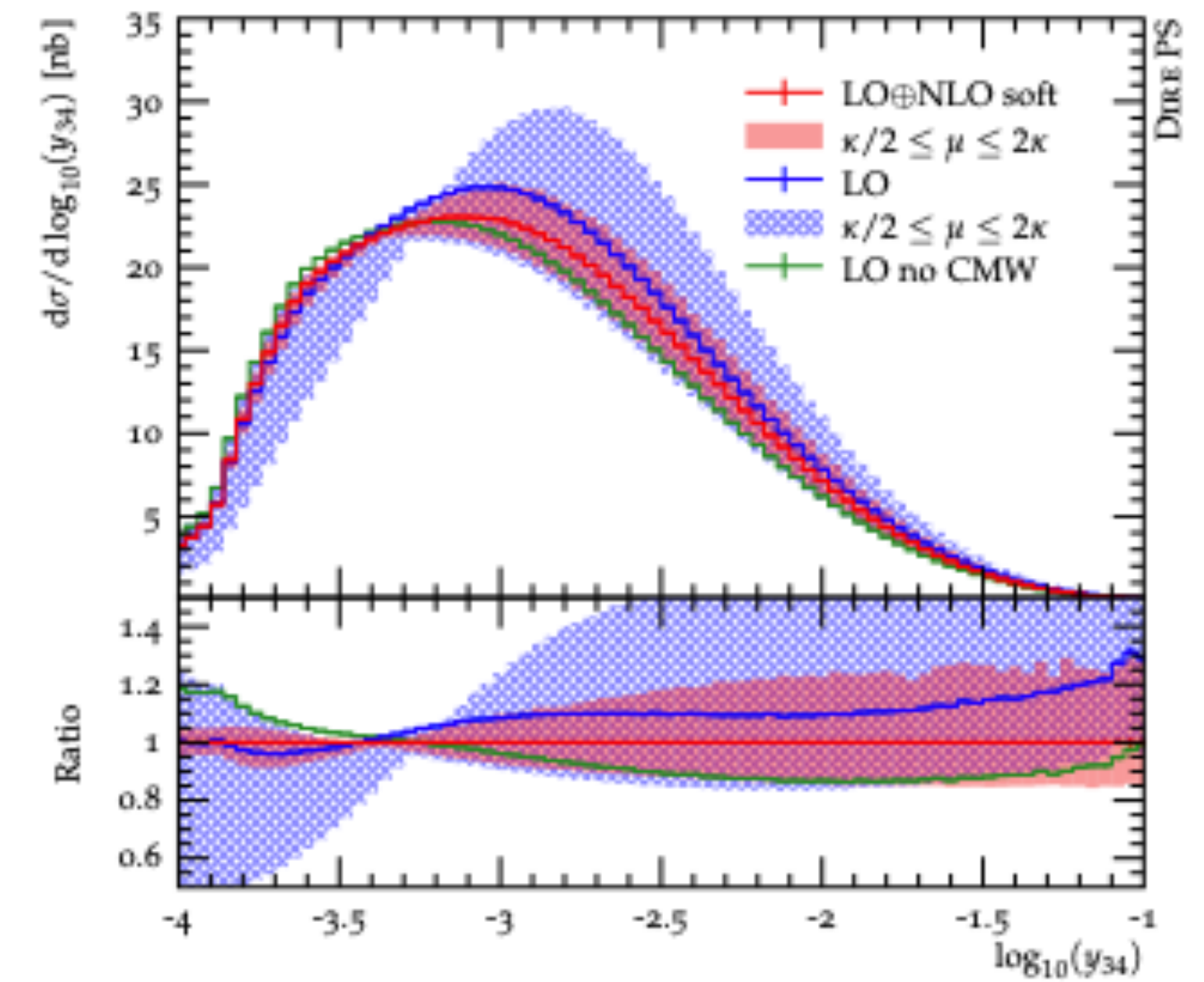
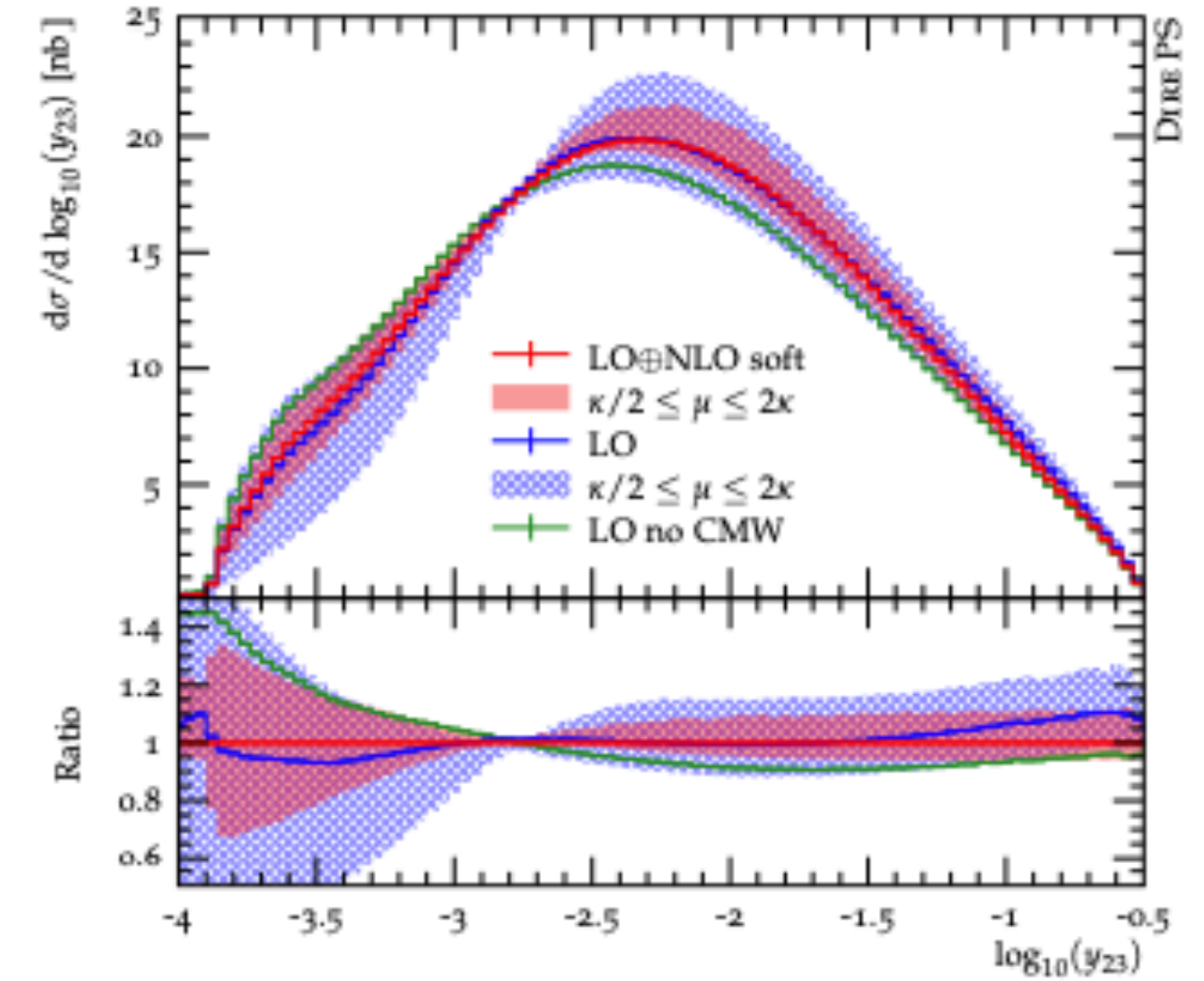
$$D_{ji}^{(0)}(z, \mu) = \delta_{ij} \delta(1-z) \quad \leftrightarrow \quad \text{[Diagram: Splitting of parton } i \text{ into } j \text{ and } 1 \text{]}$$

$$D_{ji}^{(1)}(z, \mu) = -\frac{1}{\epsilon} P_{ji}^{(0)}(z) \quad \leftrightarrow \quad \text{[Diagram: Splitting of parton } i \text{ into } j \text{ and } z \text{ with a gluon emission]}$$

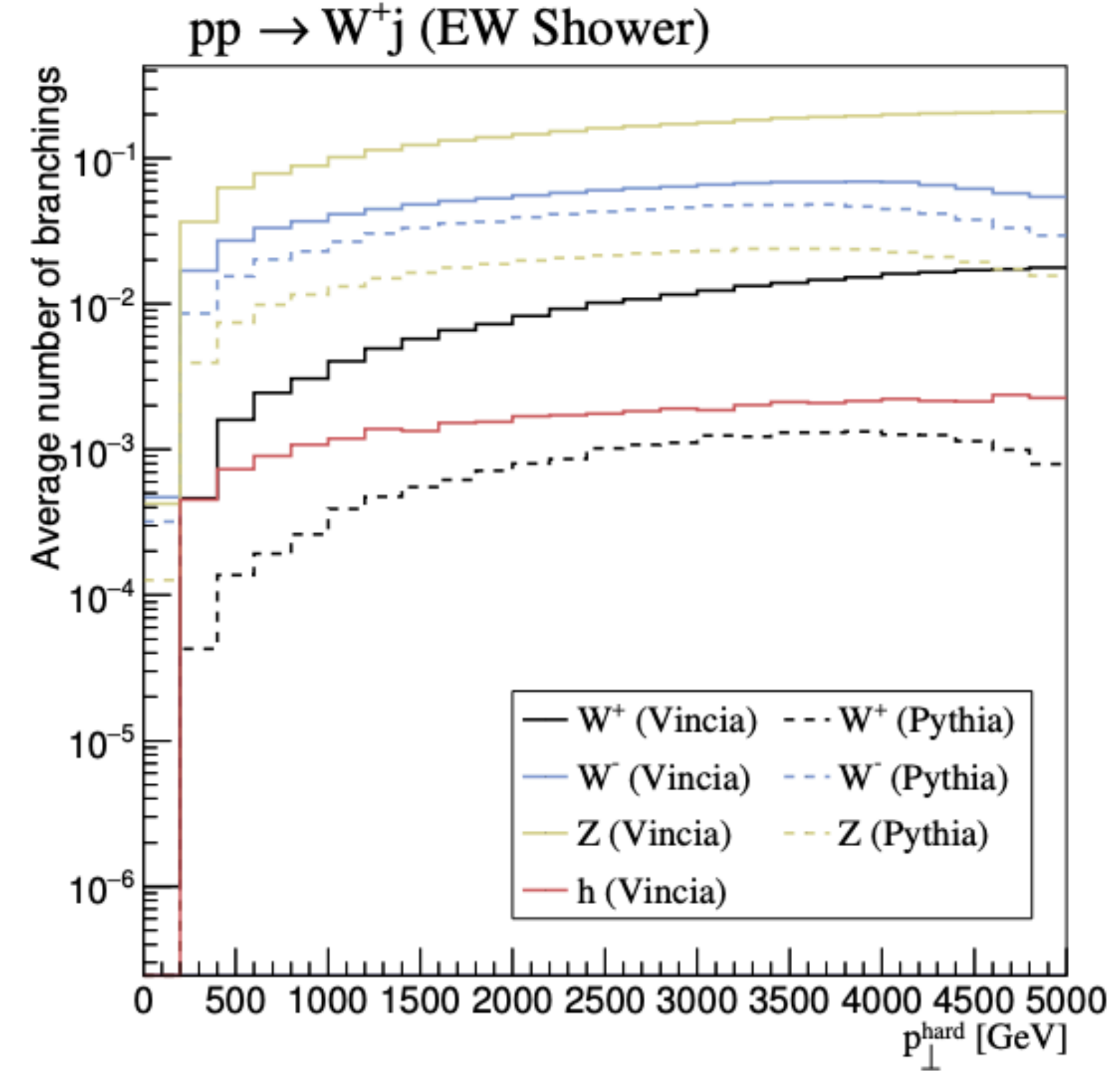
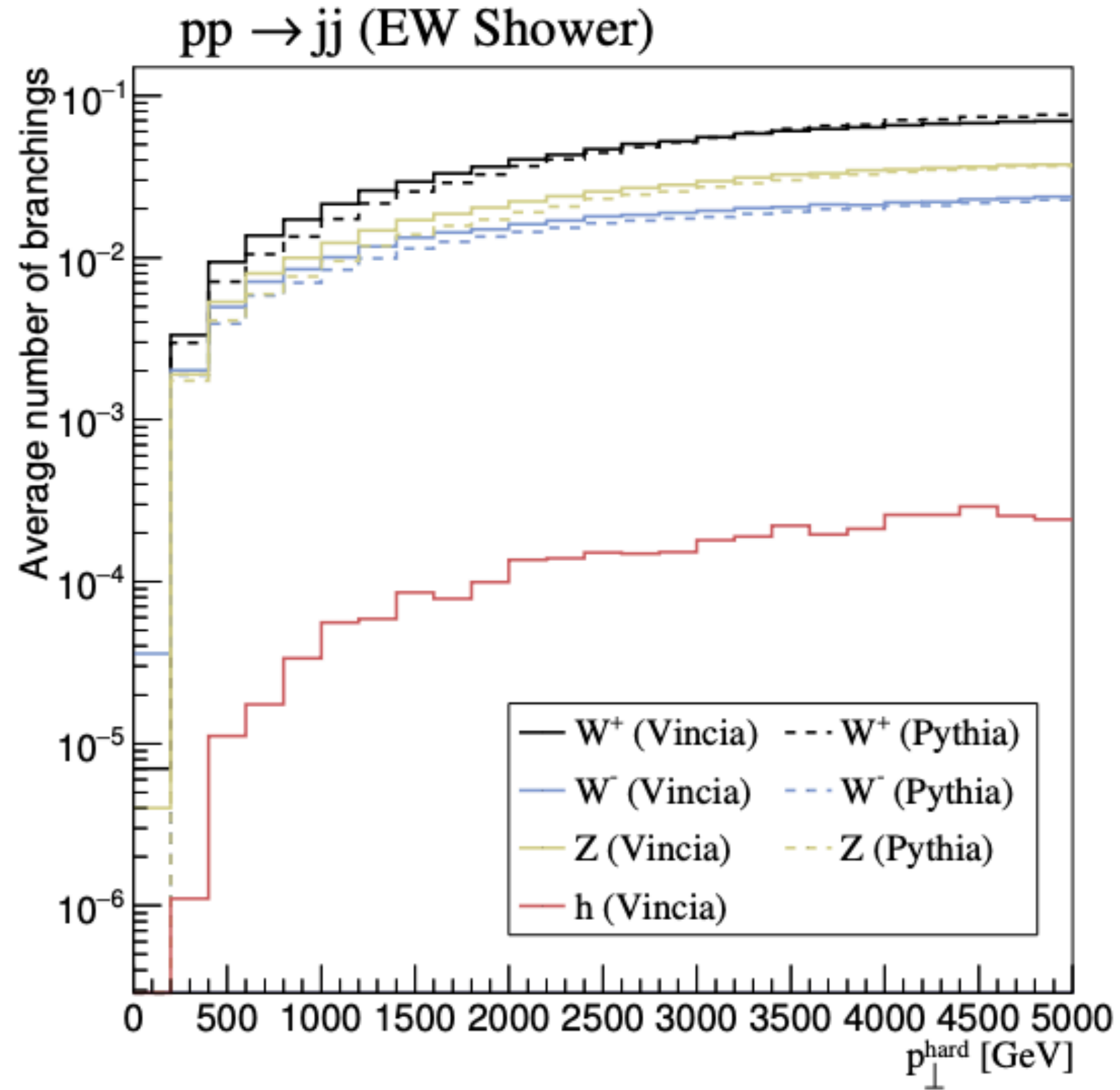
$$D_{ji}^{(2)}(z, \mu) = -\frac{1}{2\epsilon} P_{ji}^{(1)}(z) + \frac{\beta_0}{4\epsilon^2} P_{ji}^{(0)}(z) + \frac{1}{2\epsilon^2} \int_z^1 \frac{dx}{x} P_{jk}^{(0)}(x) P_{ki}^{(0)}(z/x)$$

$$\leftrightarrow \quad \text{[Diagram: Sum of two diagrams representing second-order corrections to the splitting function]}$$

Exponentiates a MC@NLO calculation



- EW Showers



- Spin-Helicity based antenna EW shower

# Parton Shower (unsaid)

- **Beyond LC**

Höche, Reichelt 2001.11492

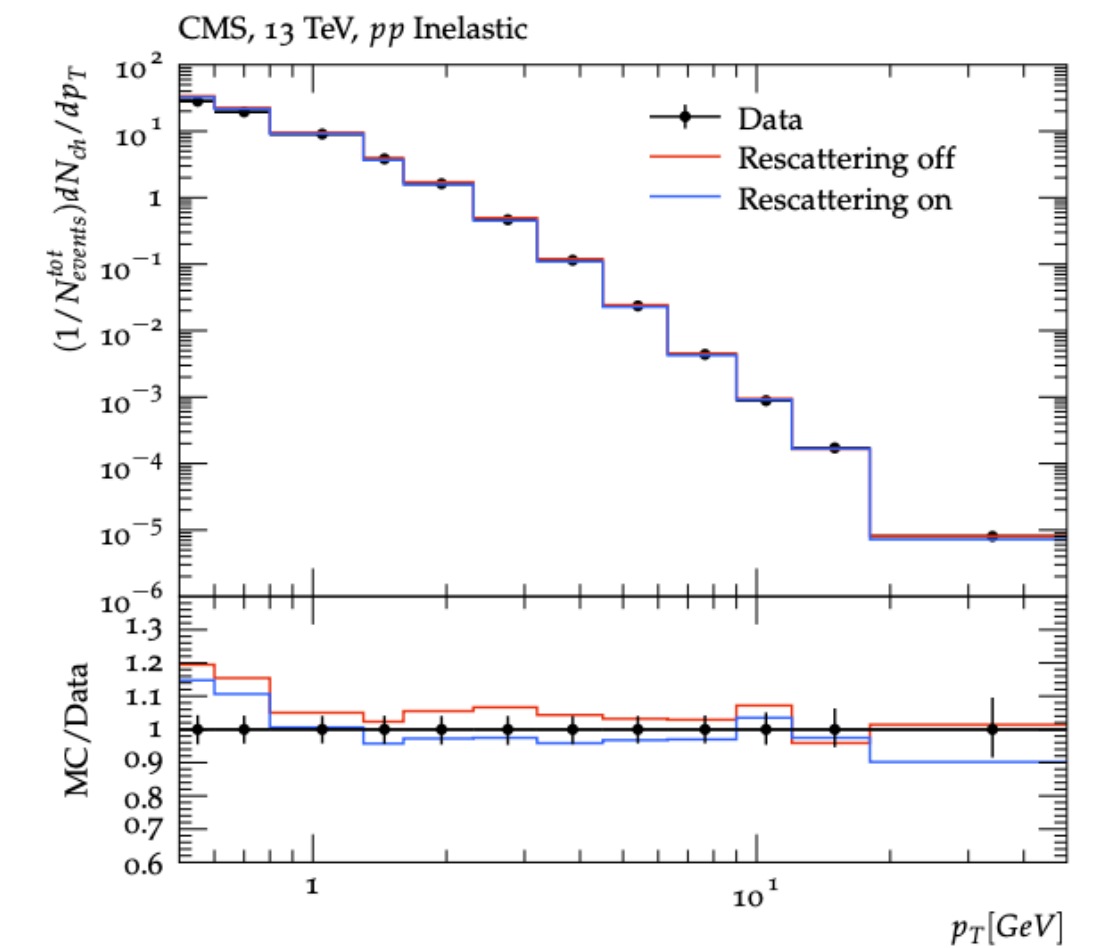
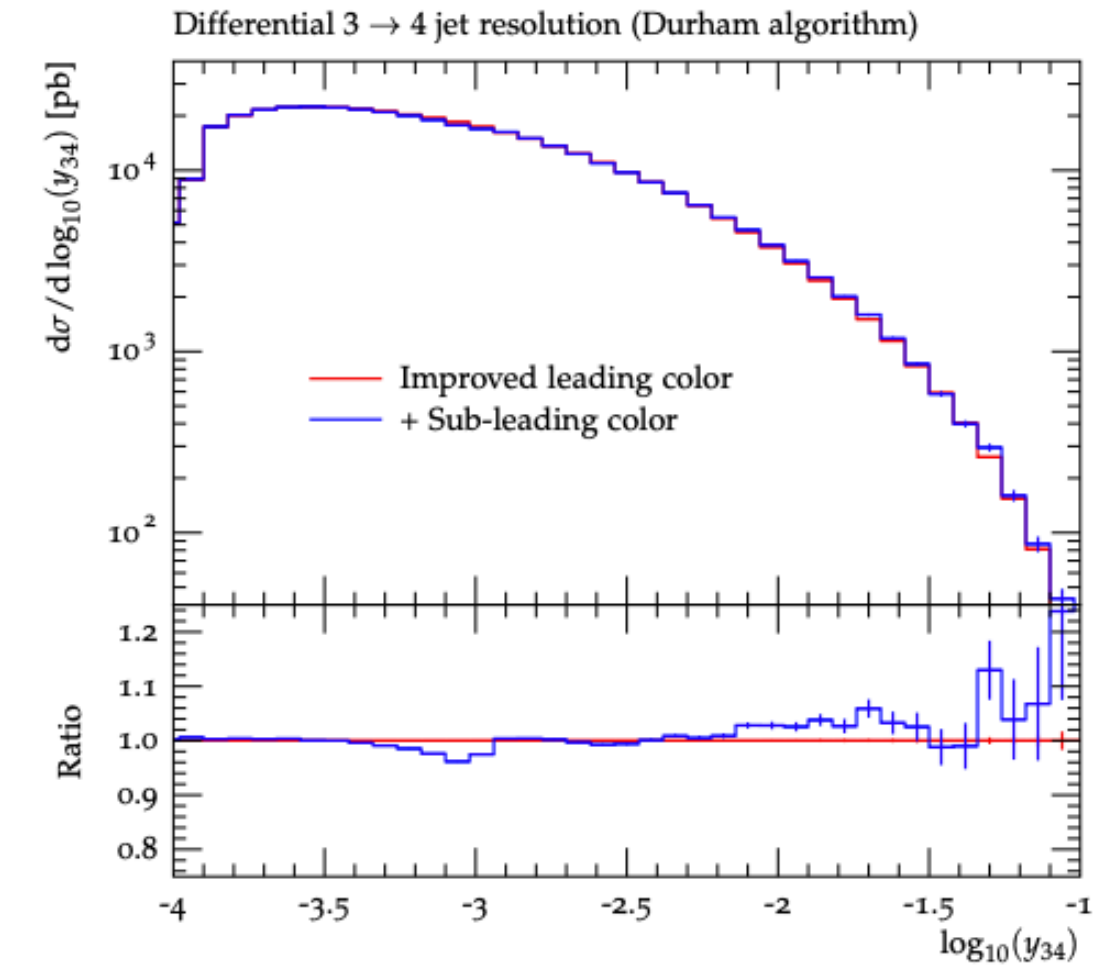
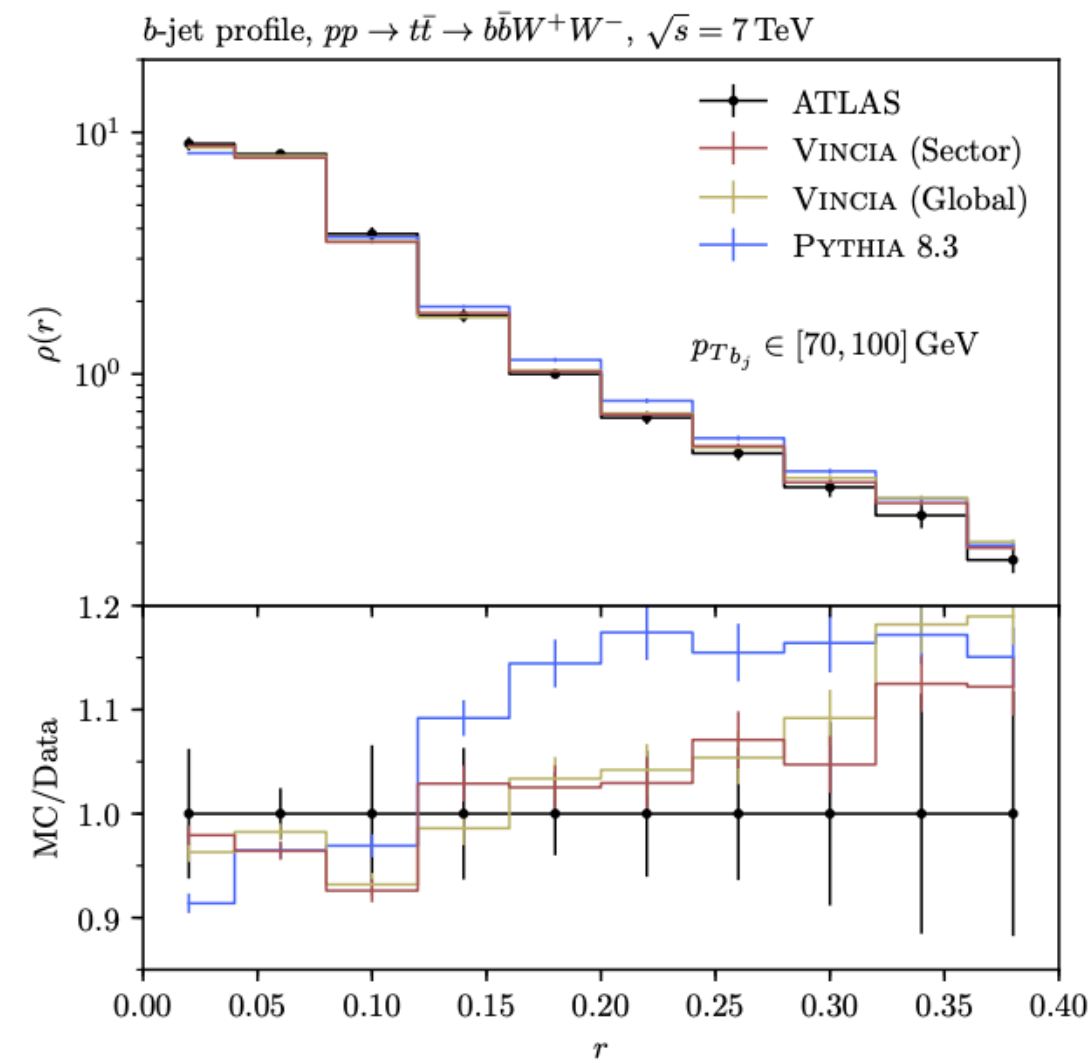
- **Sector showers**

Brooks et al, 2003.00702

- **Parton rescattering**

Sjöstrand, Uthm, 2005.05658

... and more...

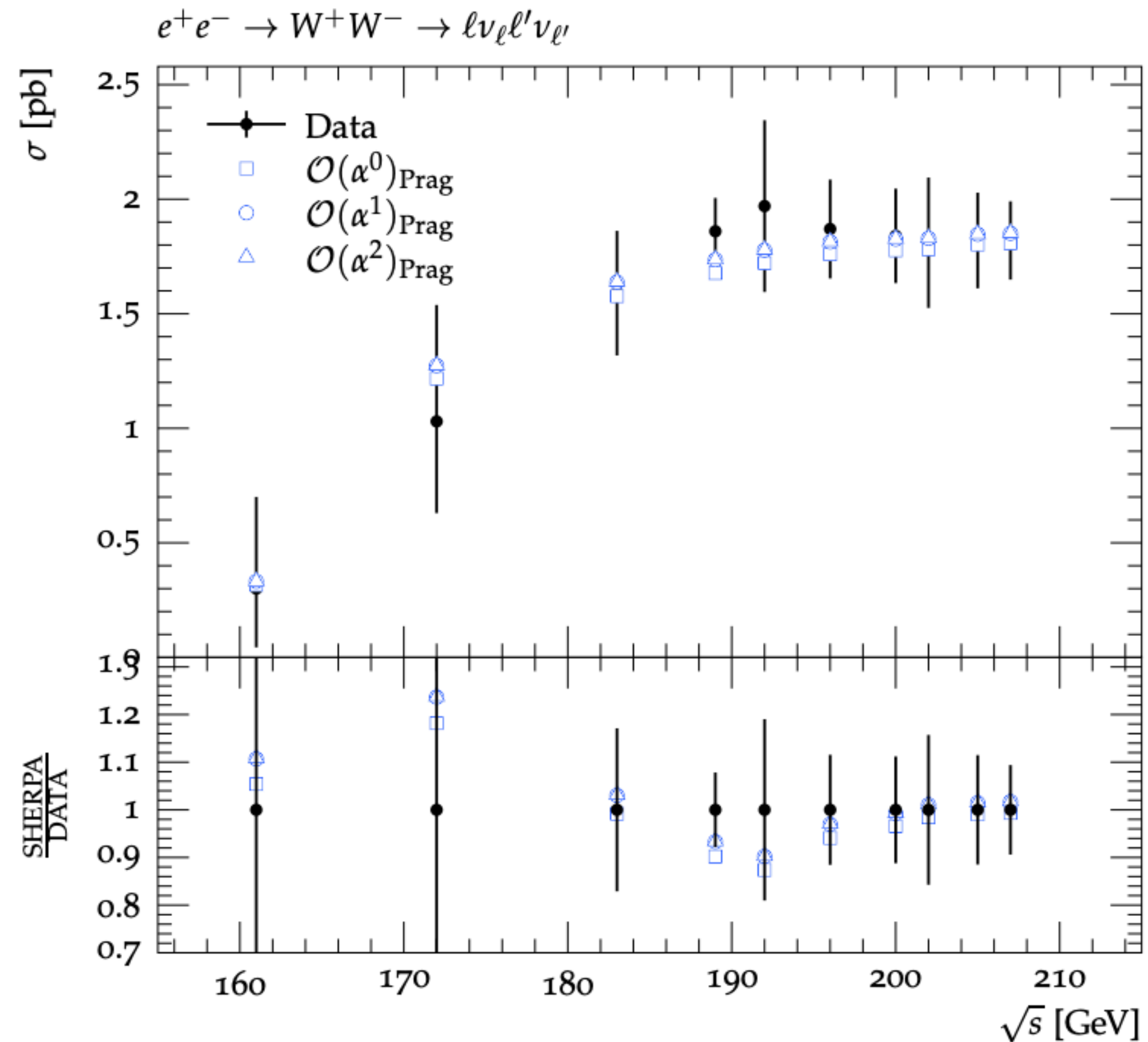


# Photons

- Important for lepton colliders (but also for hadron colliders!)

- Uses YFS formalism to resum large logs from photon emissions

Krauss, Price, TBP



# EW-Approximations

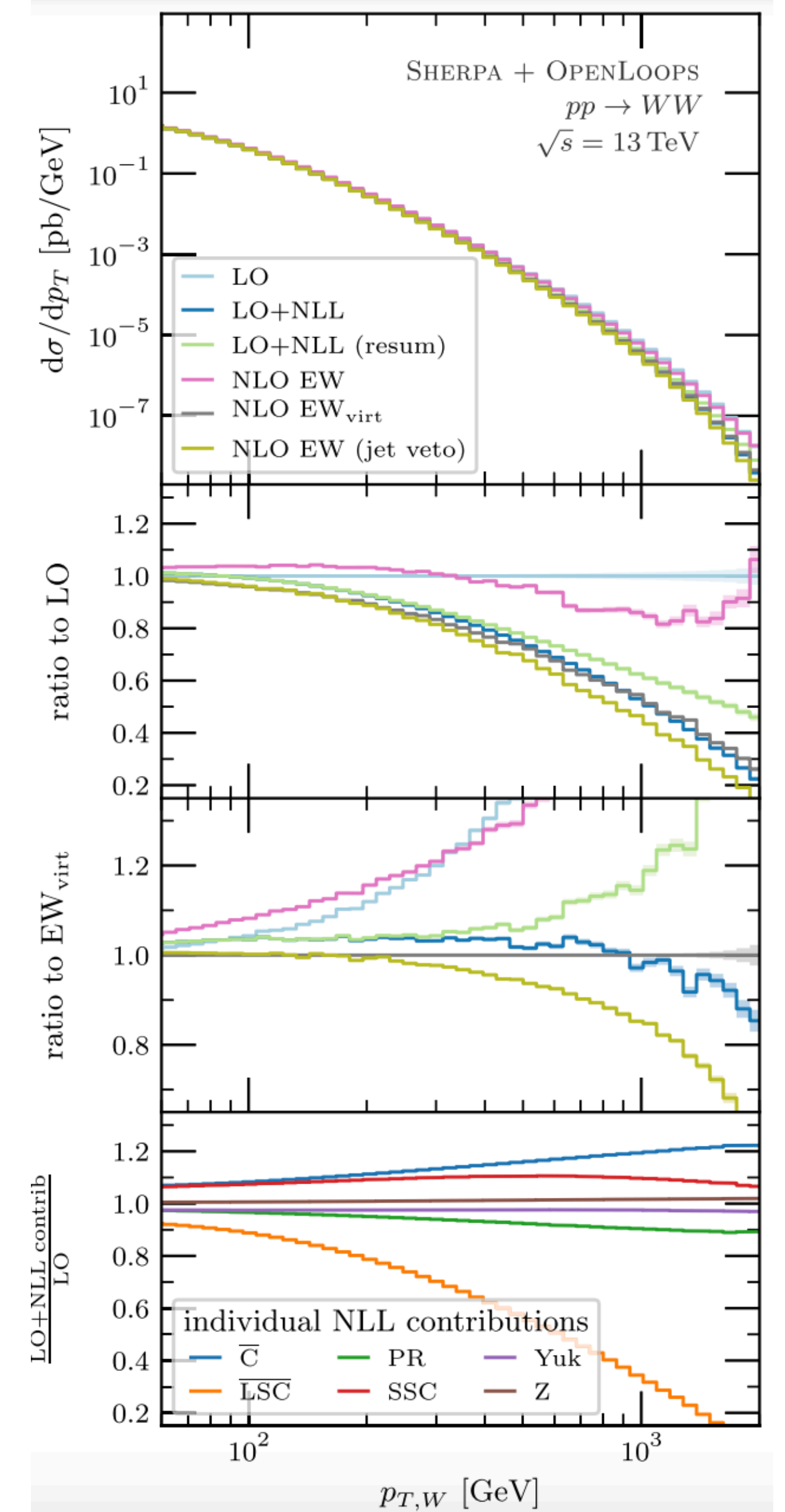
- **Large tail corrections (Sudakov Logs)**

Denner, Pozzorini *Eur.Phys.J.C* 18 (2001) 461-480

- **Calculation fully automated in Sherpa**

Bothmann, DN, *Eur.Phys.J.C* 80 (2020) 11, 1024

- **Valid both as approximation and as resummation!**





# Conclusions

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- **Active and continuous development in (almost) all aspects of MCEGs**
- **Didn't cover it all, but there are two main directions:**
  - 1) **Improvements for precision at the LHC**
  - 2) **Extension of current MCEGs to accommodate for future colliders**