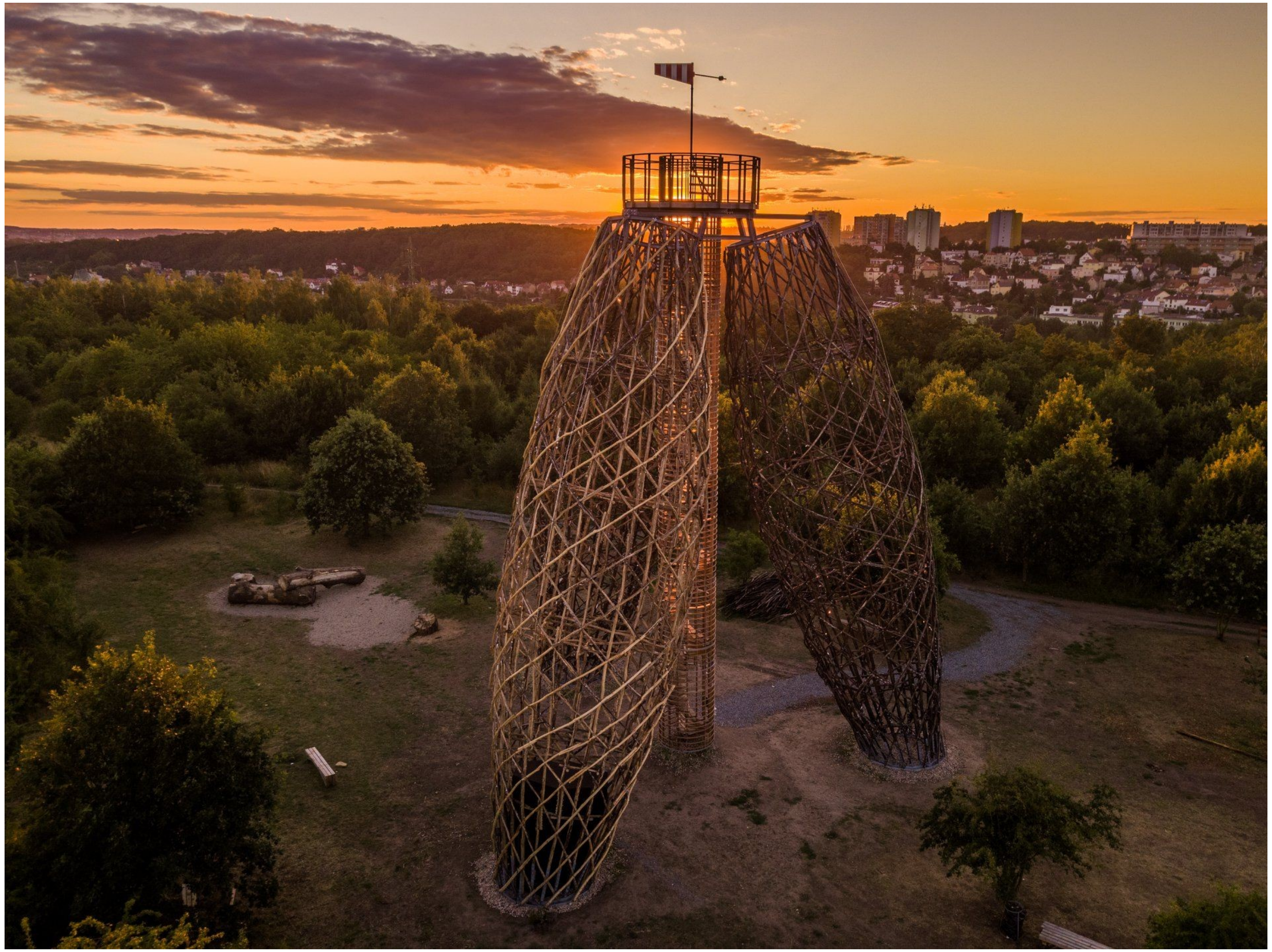
Groomed event shape observables in ep at H1

Radek Žlebčík
on behalf of the H1 Collaboration

July 18, 2023
ICHEP2024
Prague, Czechia

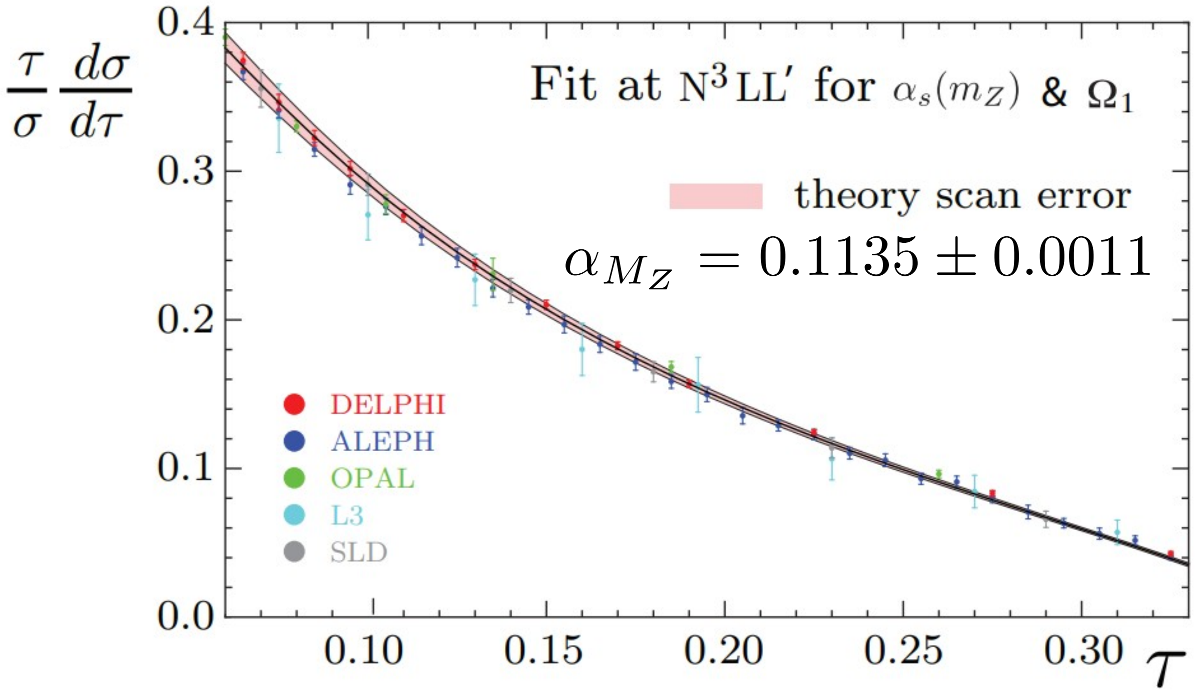


Doubravka observation tower, Prague 9

Importance of event shape observables

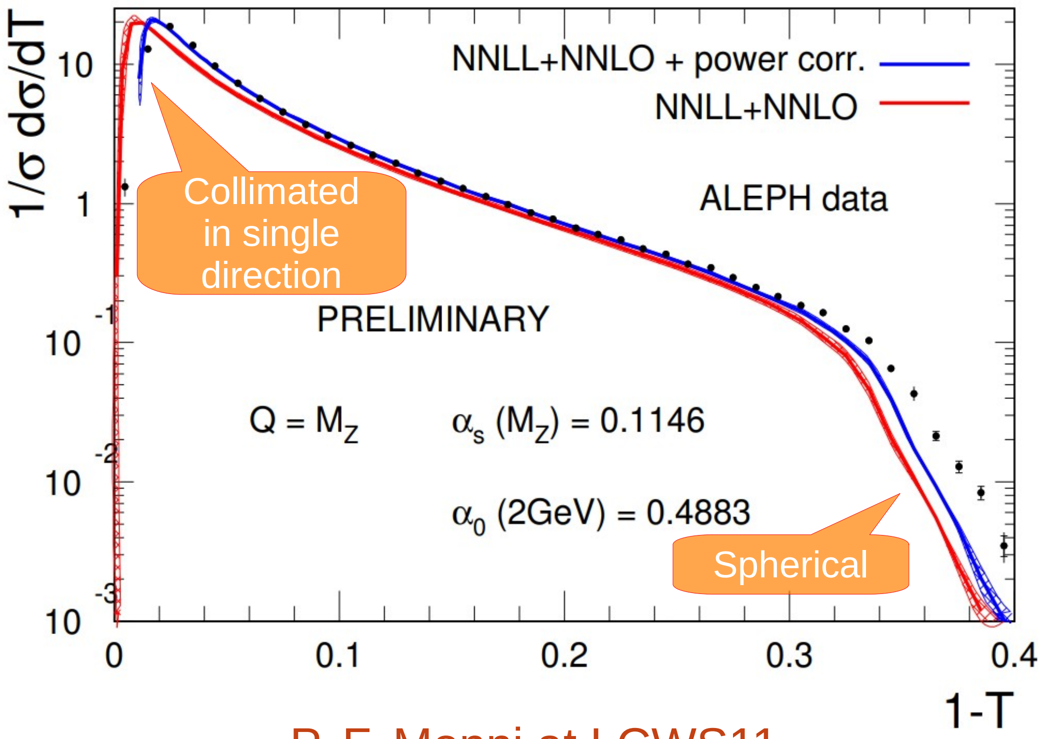
- Extensively studied in ee, pp and ep collisions
- Sensitive to both fixed order calculations and resummation effects

Thrust in ee used in $\alpha_S(M_Z)$ fit



Albbate et al, Phys.Rev.D 83 (2011) 074021

Thrust in ee over wider range



P. F. Monni at LCWS11

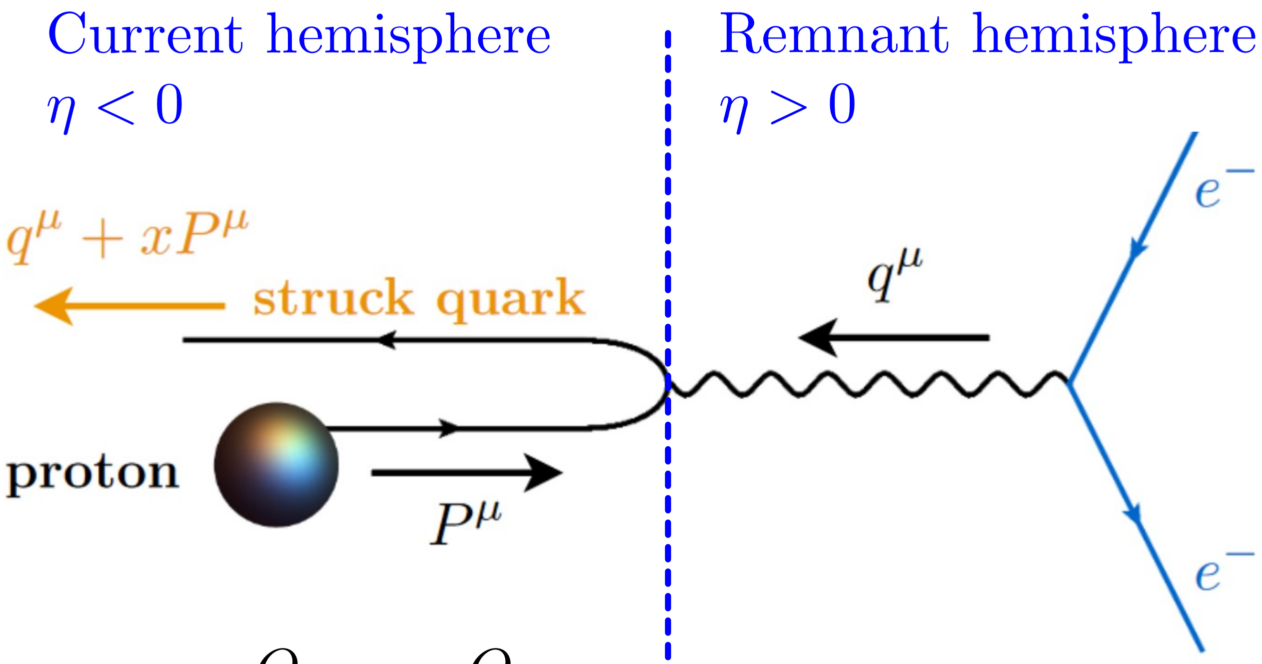
Breit frame in ep scattering

- Intermediate photon has only space component
- Struck quark goes to Current hemisphere
- Spectating partons into Remnant hemisphere

Breit frame condition

$$2x\vec{P} + \vec{q} = 0$$

$$P = (\frac{Q}{2}; 0, 0, -\frac{Q}{2})$$



$$P = (\frac{Q}{2x}; 0, 0, \frac{Q}{2x})$$

$$q = (0; 0, 0, -Q)$$

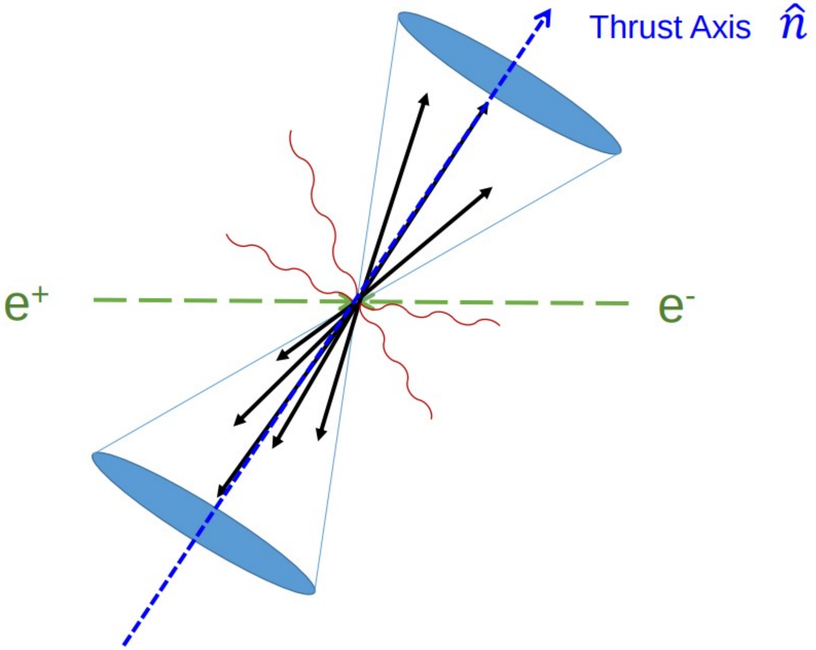
Trust in DIS

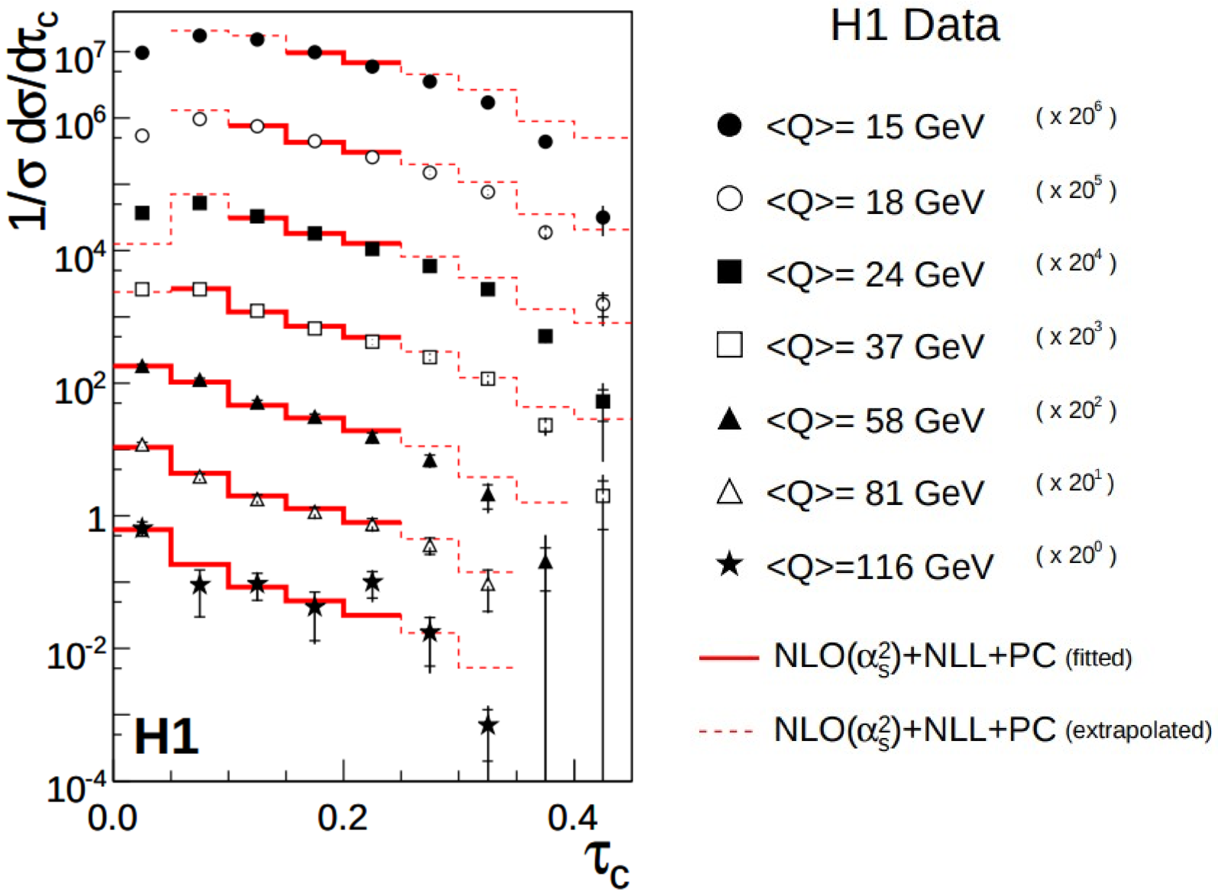
- At HERA measured by both H1 & ZEUS

Eur.Phys.J.C 46 (2006) 343

Calculated in Breit frame from particles in Current hemisphere

$$T_C = \max_{\vec{n}_T} \frac{\sum_h |\vec{p}_h \cdot \vec{n}_T|}{\sum_h |\vec{p}_h|} \qquad \tau_C = 1 - T_C$$





Trust in DIS – revisited

- Suggestion of better observable with only global logarithm in D. Kang et al, Phys.Rev.D 88 (2013) 054004

> Yet another variation is τ_{zE} [30, 48] which is like Eq. (47) with the same normalization, but with respect to the **z**-axis in the Breit frame. It is also not global [48]. H1 and ZEUS have measured $\tau_{zE} = \tau_c^{\rm H1} = 1 - T_\gamma^{\rm ZEUS}$ and $\tau_{tE} = \tau^{\rm H1} = 1 - T_T^{\rm ZEUS}$ [32, 35]. It would be interesting to reanalyze the data to measure the global observables $\tau_1^{a,b,c}$ we predict in this paper at NNLL order.

Thrust

$$\tau_Q = 1 - \frac{2}{Q} \sum_{i \in \mathcal{H}_\mathcal{C}} (-P_{z,i}^{\rm Breit})$$

Equivalence

1-jettiness

$$\tau_1^b = \frac{2}{Q^2} \sum_{i \in X} \min\{xP \cdot p_i, (q + xP) \cdot p_i\}$$

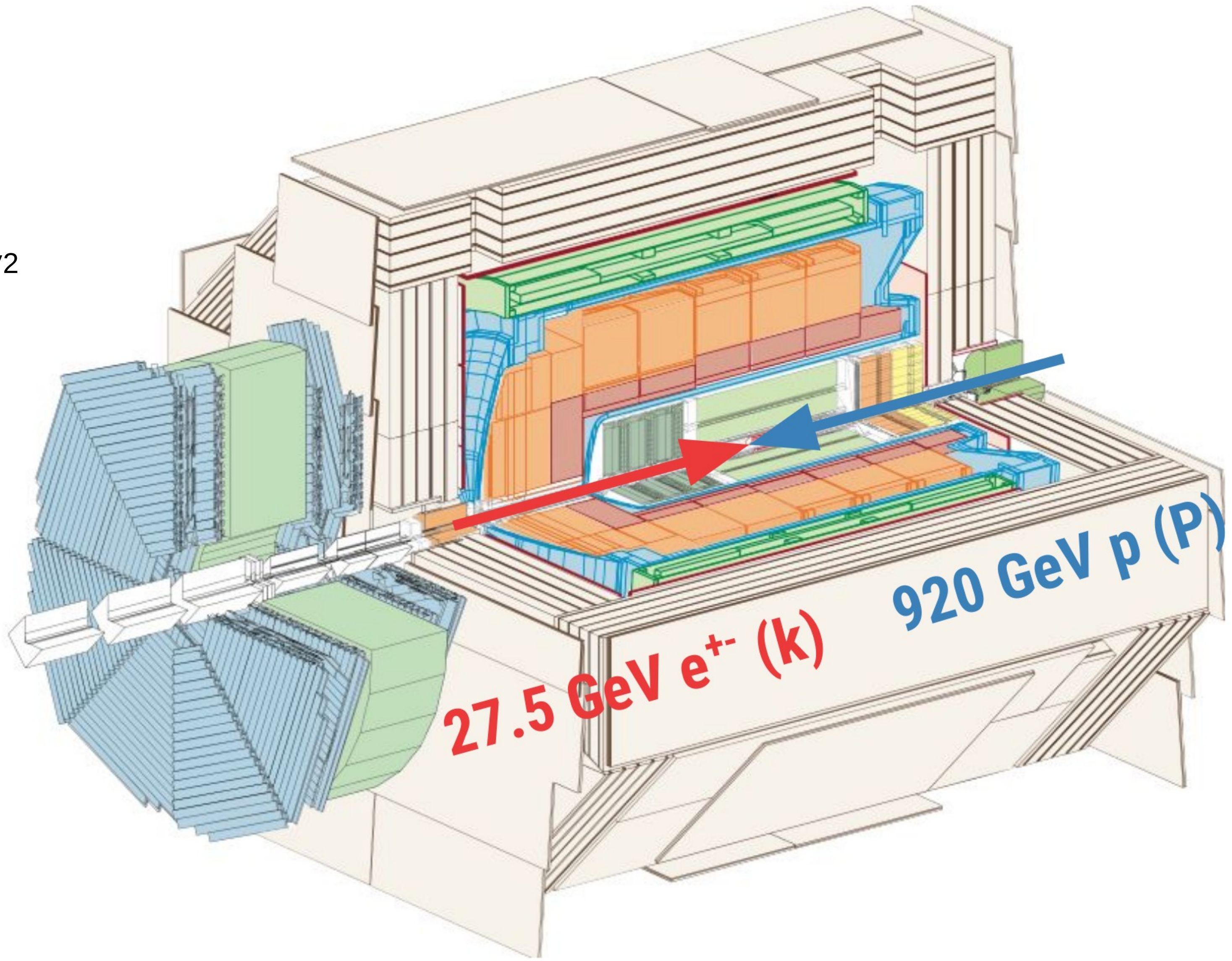
Experimental setup

- 352 pb^{-1} of data collected by H1 in 2003-2007 at $\sqrt{s}$ = 319 GeV
- Phase space definition
  $0.2 < y < 0.7$, $Q^2 > 150(200)\ GeV^2$

$$Q^2 = -q^2$$

$$y = Pq / pk$$

P: incoming proton 4-vector
k: incoming electron 4-vector
q=k-k' : 4-momentum transfer

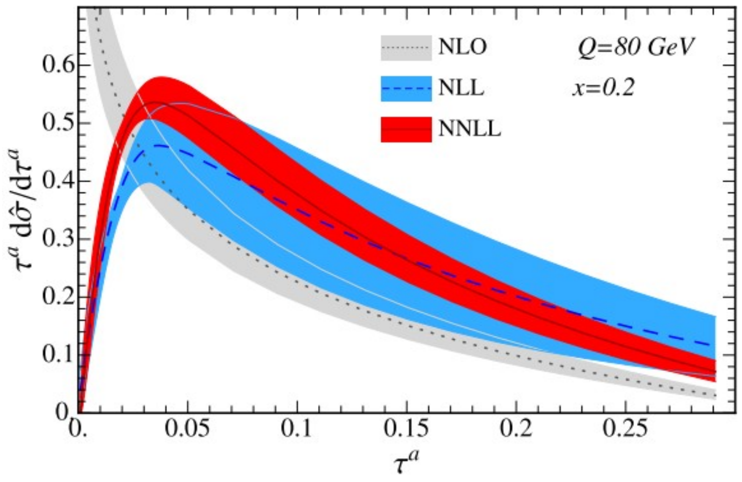


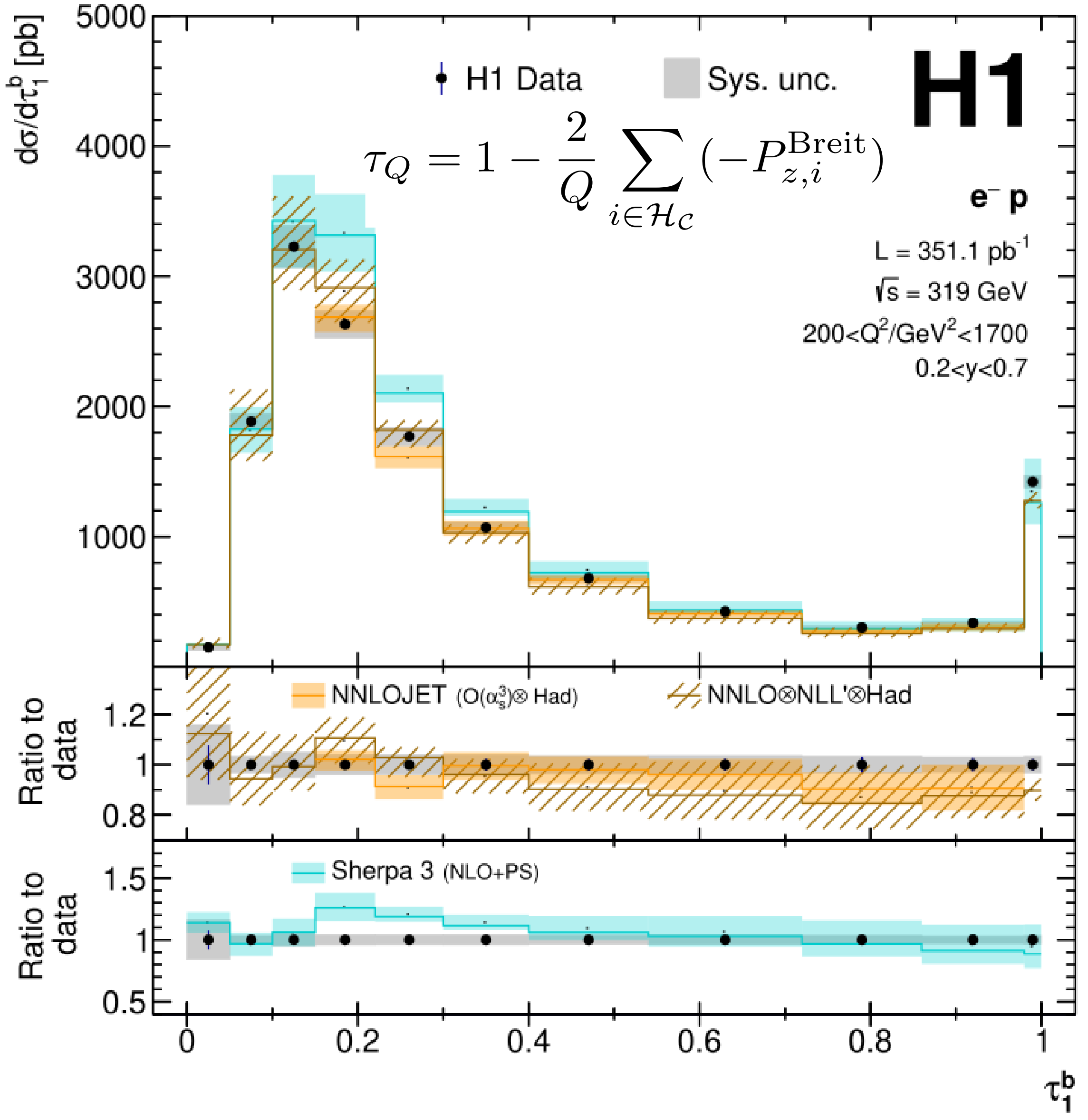
Momenta distribution in Breit frame

H1 DESY-24-035 (for EPJC)

- (N)NLOxNLL (Knobble at al.) and NNLOJET calculations agree with data within ~10% teor. unc. band
- From MC generators, Sherpa 3 (NLO+PS) has the best performance, for comparisons to Hergwig & Pythia see the full paper/next talk

D. Kang et al, Phys.Rev.D 88 (2013) 054004





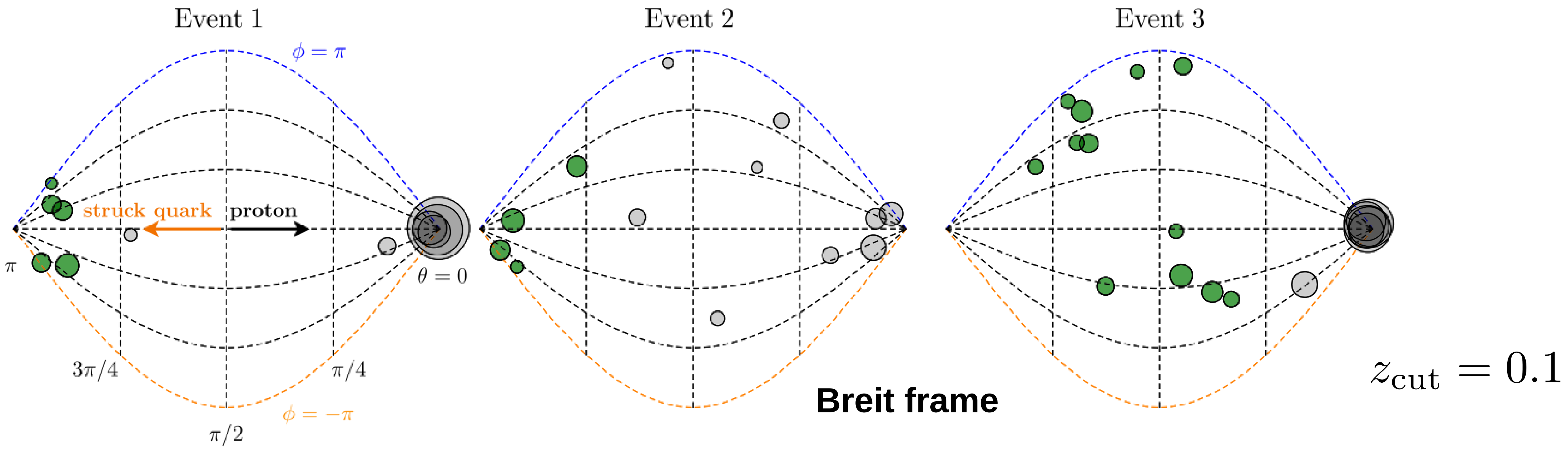
Groomed event shape observables in DIS

Jet Grooming at LHC

- Removing soft (non-perturbative) component of the jet
- See for example:
  Soft Drop JHEP 05 (2014) 146

In ep the Underlying Event is not an issue, why grooming Y. Markis, Phys.Rev.D 103 (2021) ?

1) Constructing observables free from nonglobal-logarithms
2) Mitigation of hadronization corrections
3) Phenomenological handle on soft radiation
4) Dial for nonperturbative contributions



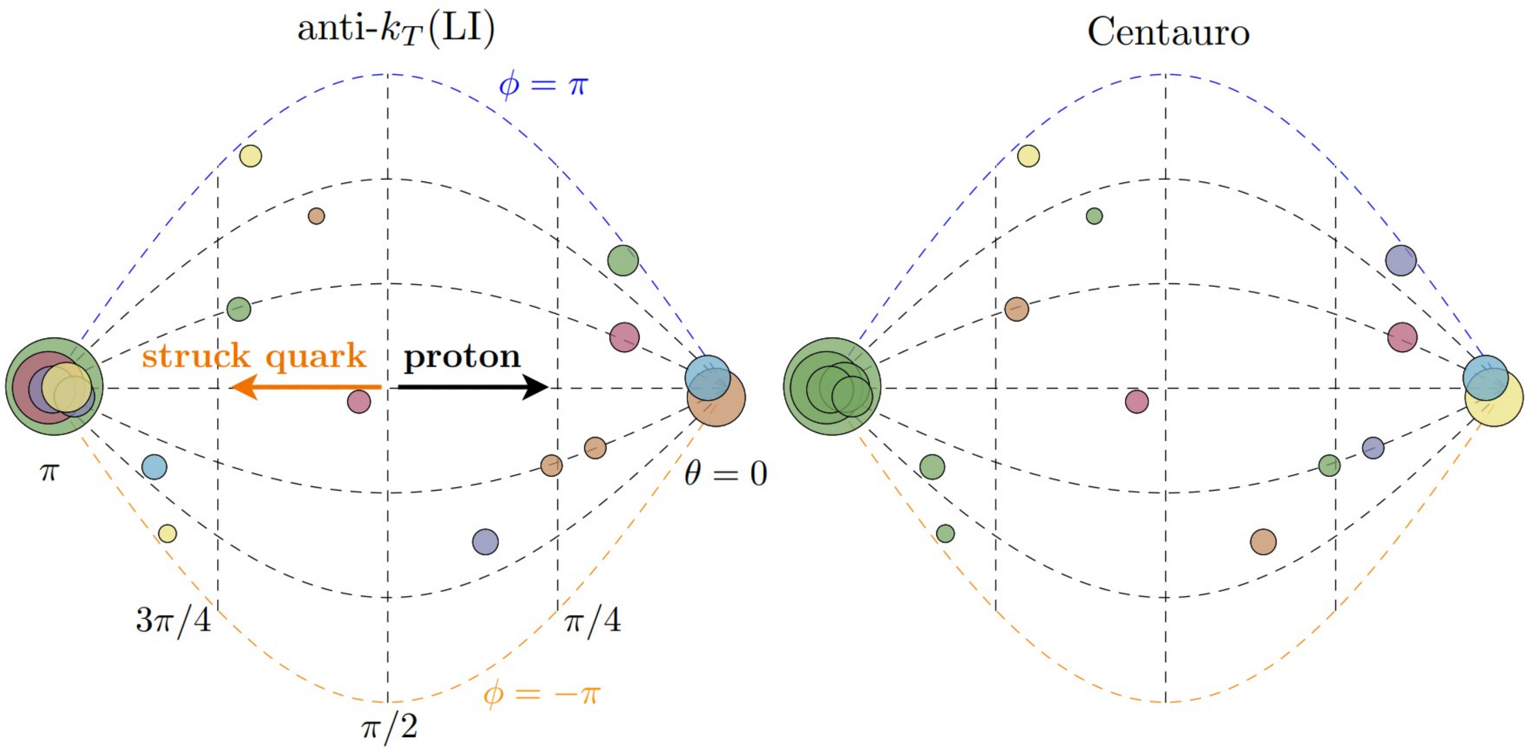
Centauro jet algorithm & Grooming

- Centauro jet algorithm uses asymmetric distance metric such that "Born" jet in the current hemisphere is clustered into single object
- Particles in remnant hemisphere are clustered into "soft" jets

$$d_{ij} = (\Delta\bar{\eta}_{ij})^2 + 2\bar{\eta}_i\bar{\eta}_j(1 - \cos\Delta\phi_{ij})$$

$$\bar{\eta}_i = \frac{p_i^\perp}{p_i^+}$$

$$z_i = \frac{P \cdot p_i}{P \cdot q}$$



Usage of the clustering history applying Grooming condition

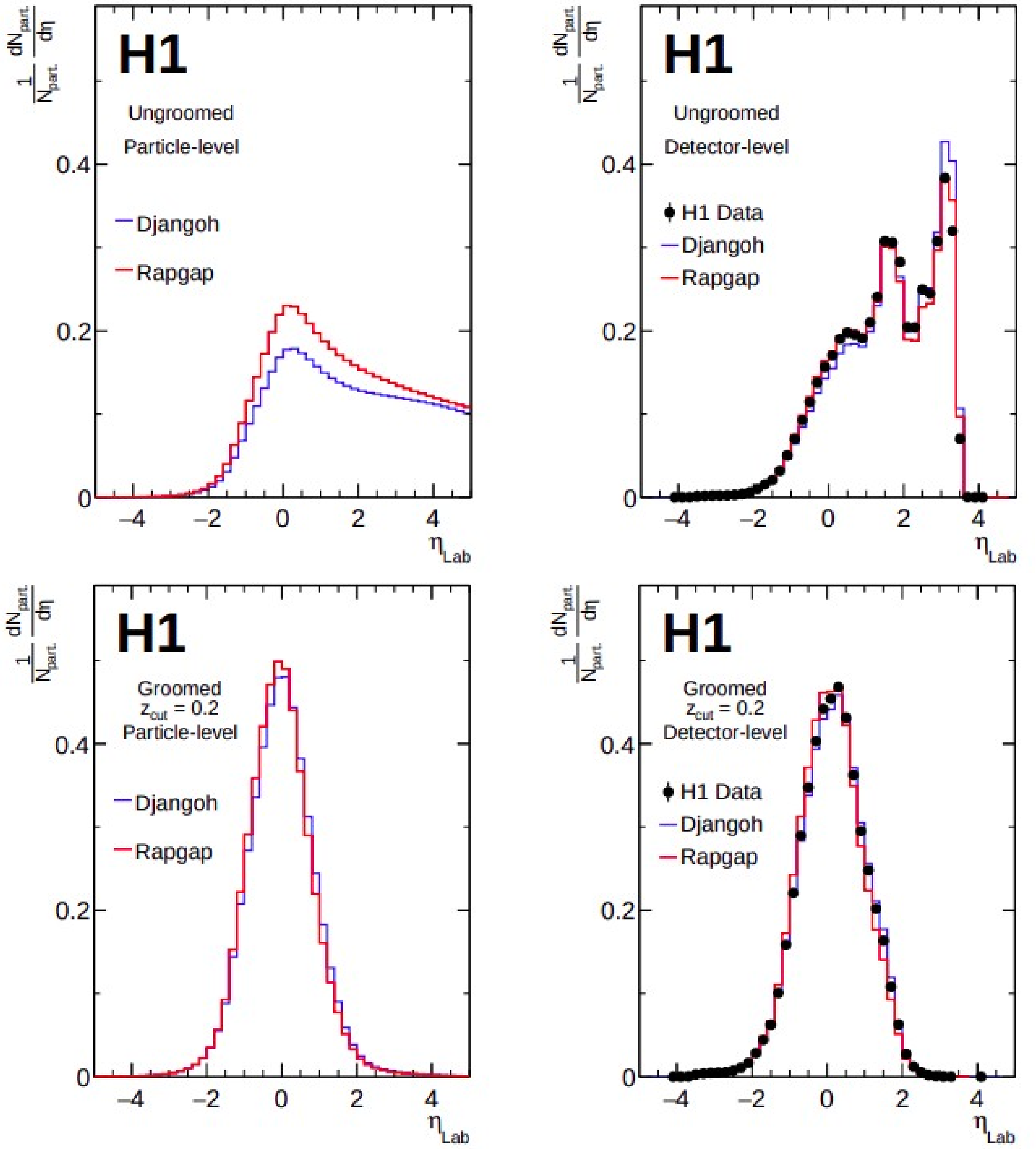
$$\frac{min(z_i, z_j)}{z_i + z_j} > z_{cut}$$

Similar to Soft Drop

Phys.Rev.D 104 (2021) 3, 034005

Impact of grooming

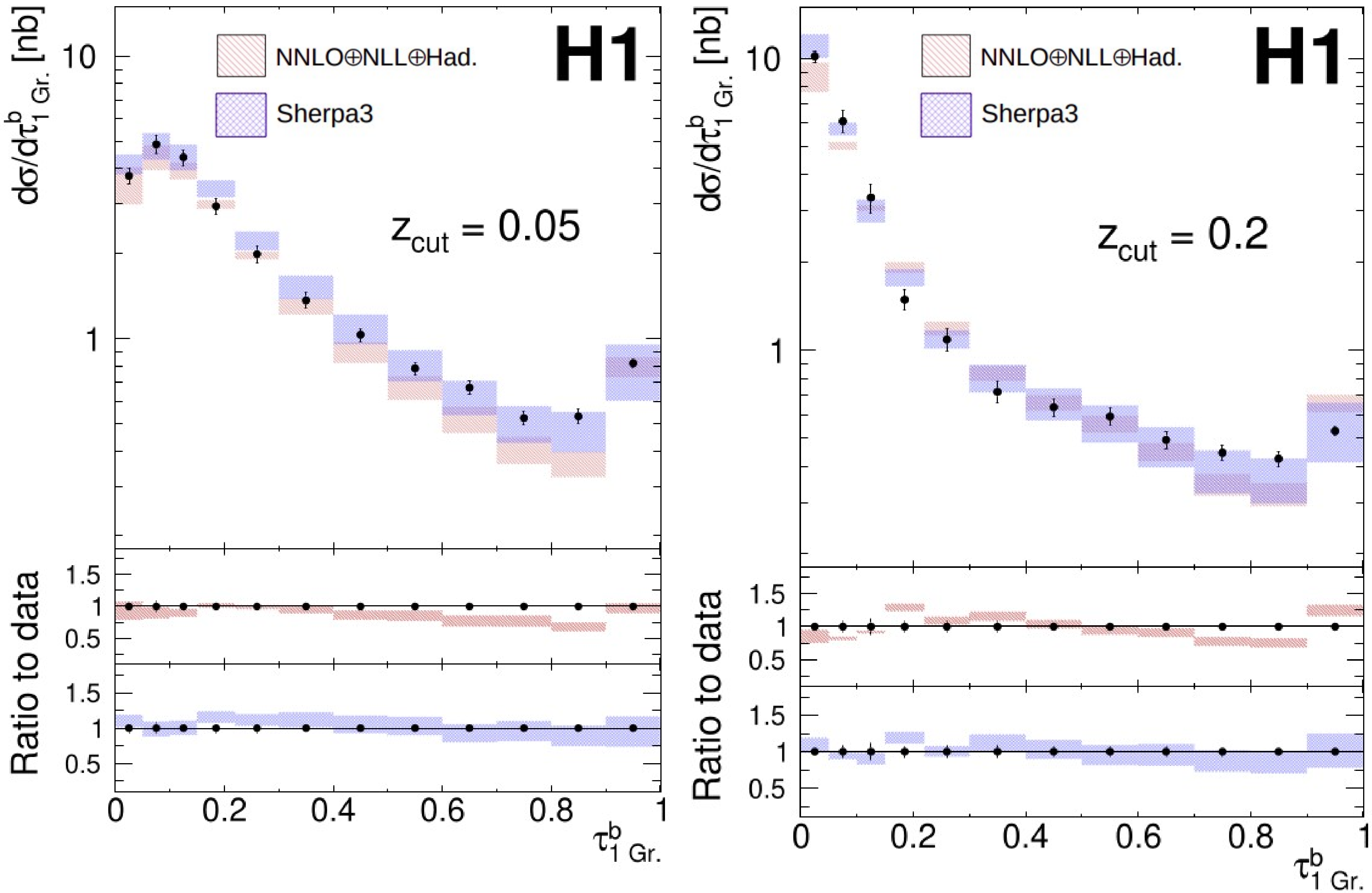
- There is better correspondence of particle rapidity between detector-level and particle-level when grooming is applied
  → reduction of the unfolding uncertainty
  → PS better matches with detector acc.
- Correction for the detector effects via unfolding based on Tikhonov regularization
- Main systematic uncertainties (~7%)
  → Unfolding (MC model + reg. strength)
  → Luminosity



Groomed 1-jettiness

H1 DESY-24-035 (acc. to EPJC)

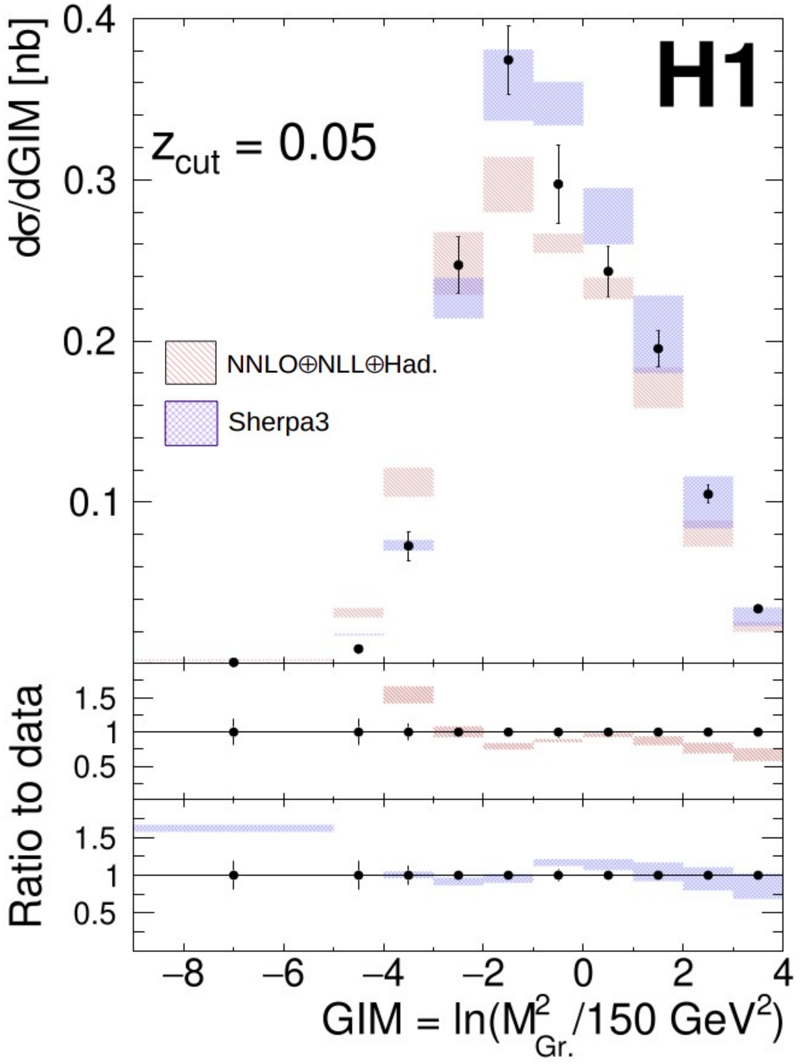
- The (N)NLO+NLL predictions have similar level of agreement as Sherpa 3 (NLO+PS)
- Differences at high τ can be related to missing higher order elements

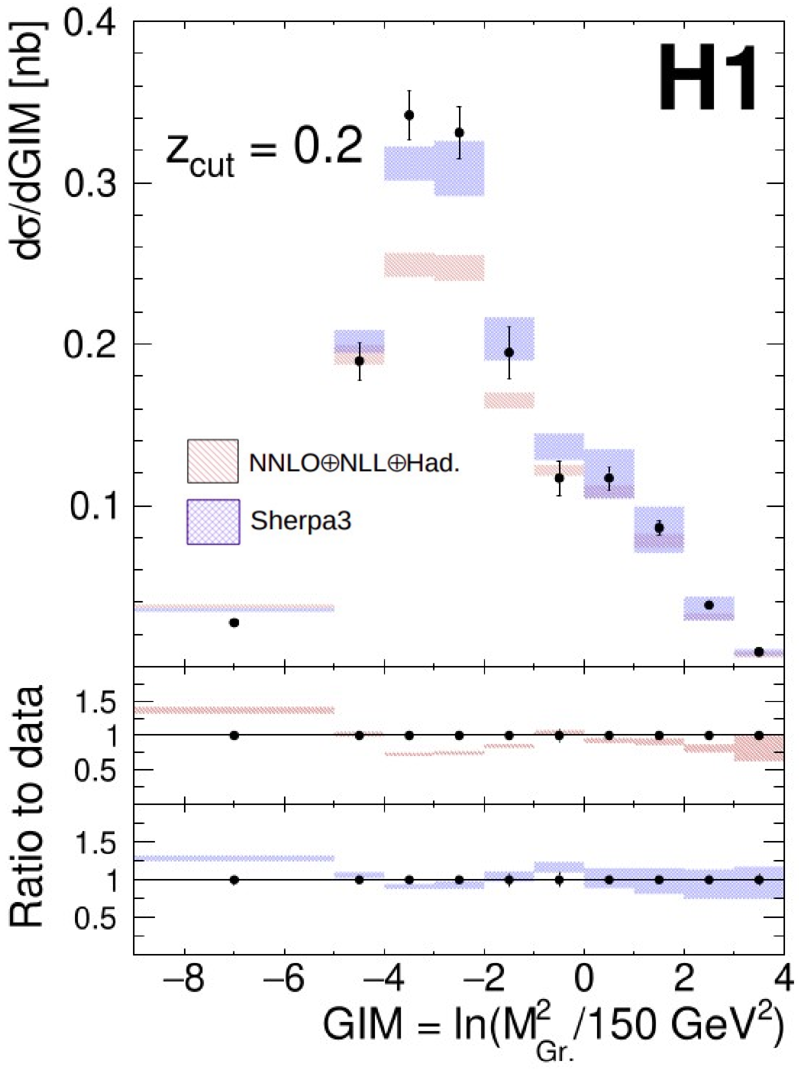


Groomed Invariant Mass

H1 DESY-24-035 (acc. to EPJC)

- The (N)NLO+NLL predictions have similar level of agreement as Sherpa 3 (NLO+PS)
- Small GIM: resummation region
  Higher GIM: Multi-jet region
- Stronger grooming improves description at low GIM

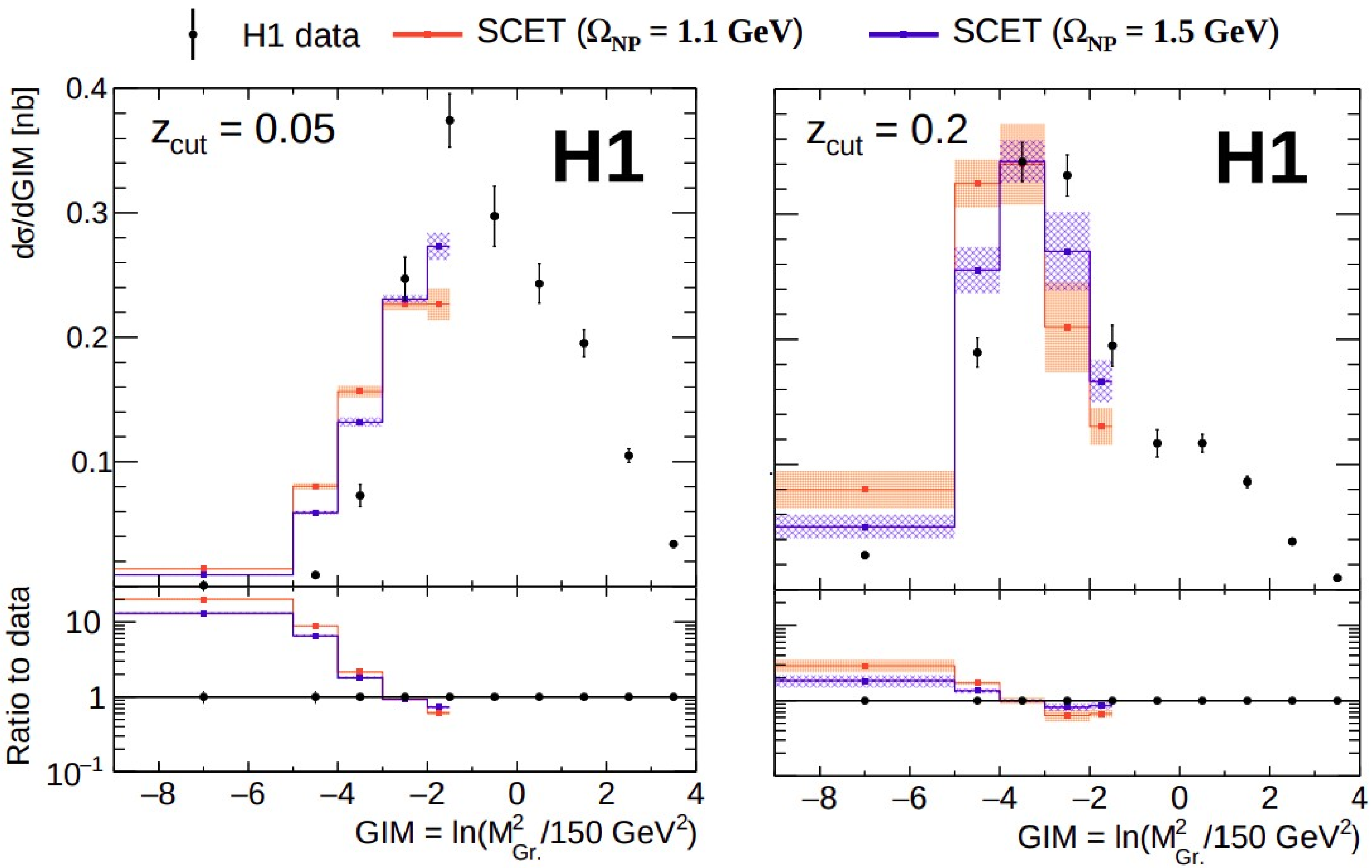




Groomed Invariant Mass - NNLL

H1 DESY-24-035 (acc. to EPJC)

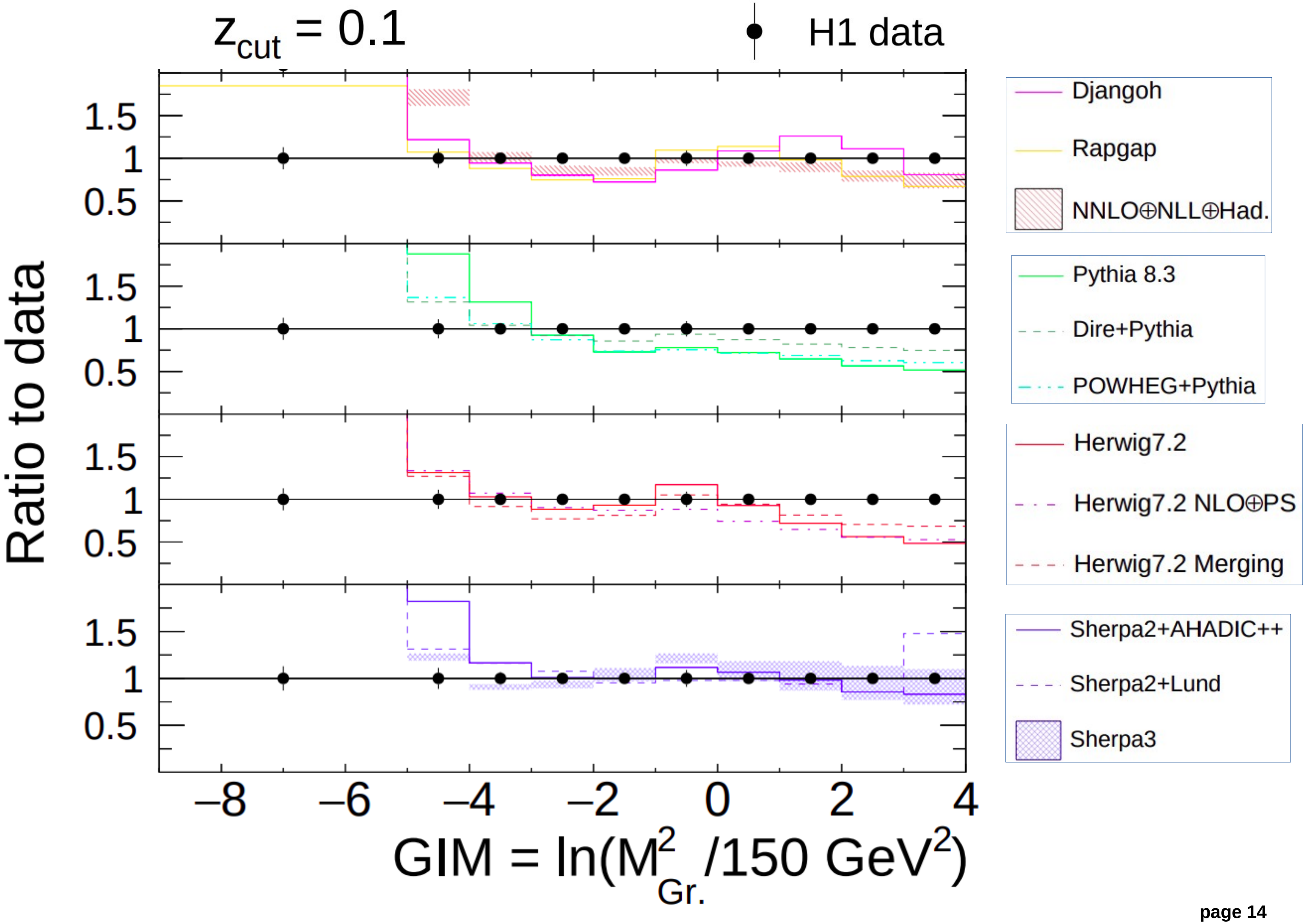
- SCET predictions at NNLL normalized to data
- Predictions depend on non perturbative shaper parameter Ω_{NP}
- Works better for stronger grooming, where GIM is lower



Comparison between MC generators

H1 DESY-24-035 (acc. to EPJC)

- Good performance of legacy DIS generators Django & Rapgap
- Pythia+DIRE outperforms classical Pythia's shower
- Sherpa 3 superior to Sherpa 2 with both Lund string & AHADIC cluster fragmentation



Conclusions

- The Thrust observable remeasured on HERA II data using definition free of non-global logs
  → equivalent to 1-jettiness observable
- In addition, grooming technique was applied which also reduced e.g. hadronization component
  → Groomed Invariant Mass is IR-safe
- Measured data well described by (N)NLO+NLL predictions & NNLO calculations
- ep event shapes are precious input into MC tunes (on the half way from ee to pp collisions)