Event and jet shapes

Daniel Reichelt

Institute for Particle Physics Phenomenology, Durham University

This talk...

- ...event shapes: thrust & soft-drop grooming
  - compare to preliminary H1 data:
  - thrust [H1 / Hessler (Master Thesis) '21]
  - groomed thrust [H1 / Klest (Talk at DIS '22)]
- ... use in (SHERPA) MC tuning
- ... analytic calculations (in SHERPA's CAESAR plugin)

Event/Jet shapes: Intro and motivation

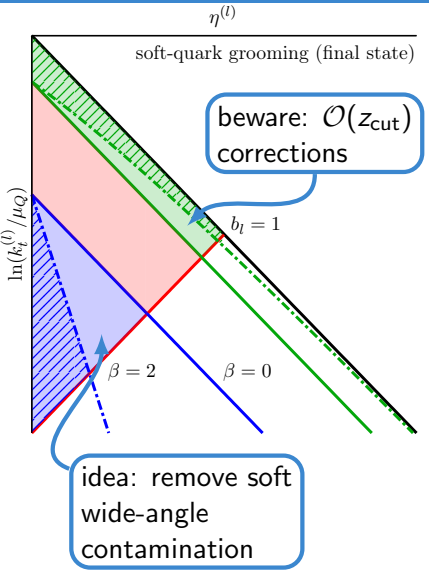
- standard tools to explore QCD
- $e^+e^- \to$ jets:
  - MC tuning
  - precision measurement of α_s
- LHC: jet shapes
  - substructure studies
  - q/g discrimination, tagging
- DIS
  - non-global logs (avoid or calculate)
  - α_s measurements
  - here: Thrust/1-jettiness + soft drop grooming
    $\Rightarrow$ resummation + MC tuning

Example: Thrust/1-jettiness

- "traditional" definition in Breit frame: $\tau = 1 - \sum_{H_C} 2p_z/Q$
- equivalent to 1-jettiness $\Rightarrow$ no non-global logs
- calculational very similar to e^+e^- thrust, jet mass etc. $\to$ many results reusable

Soft-Drop: Intro

[Larkoski, Marzani, Soyez, Thaler '14]



soft drop method: [Larkoski, Marzani, Soyez, Thaler '14]

- decluster jet with C/A
- check $\frac{\min(E_i,E_j)}{E_i+E_j} < z_{\text{cut}} \left(1 - \cos\theta_{ij}\right)^{\beta}$
- remove soft branches

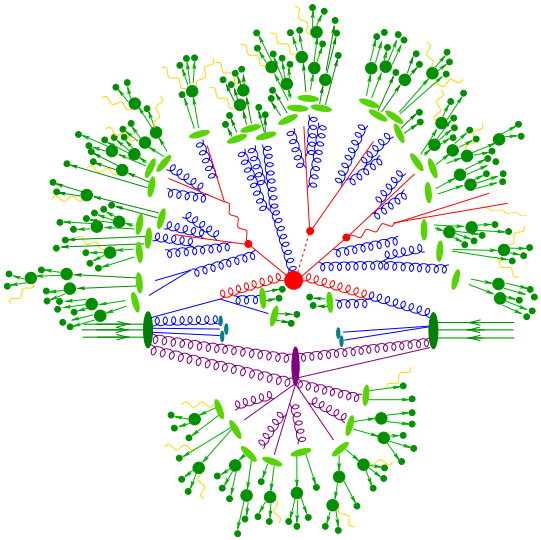
grooming in DIS [Makris '21]

- based on "Centauro" measure [Arratia, Makris, Neill, Ringer, Sato '20]
- preliminary data available from [H1 (Talk at DIS '22)]

- developed for UE/MPI suppression
- also helpful for hadronisation correction, already explored in e^+e^- [Baron, Marzani, Theeuwes '18] [Marzani, DR, Schumann, Soyez, Theeuwes '19]

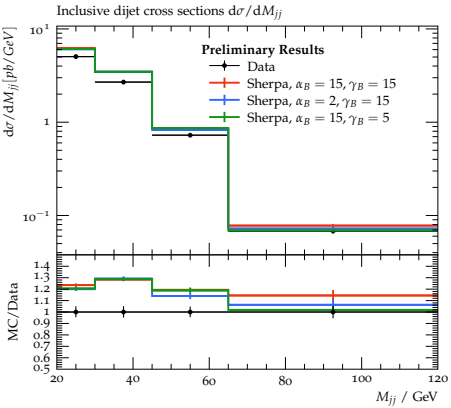
Motivation: use in tuning

- context: tuning of SHERPA's hadronisation model for SHERPA 3
- (rough) outline:
  - fragmentation in Cluster hadronisation, tuned to e^+e^- (mostly LEP1) data [Chahal, Krauss '22] + ongoing
  - remaining: clusters containing beam remnants $\Rightarrow$ fix w/ DIS data
    (+ sensitivity in min-bias at LHC)
    + further limits on FS
  - fix underlying event etc. at hadron-hadron colliders

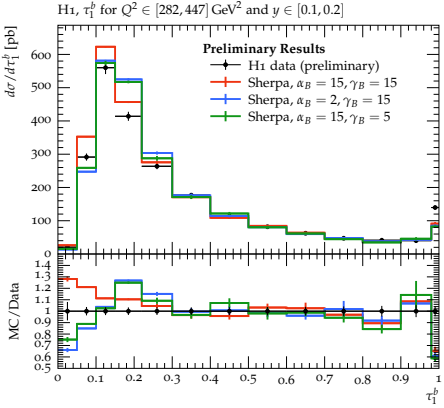


Motivation: use in tuning

- variation of example set tuning parameters
- note, sensitivity study at the moment, no final tune yet



data from [ZEUS in Eur.Phys.J.C70:965-982,2010]



preliminary data from [H1 / Hessler '21]

Analytic calculation: CAESAR framework in SHERPA

Basic soft gluon resummation

- CAESAR formalism [Banfi, Salam, Zanderighi '04]
- implemented in SHERPA

  [Gerwick, Höche, Marzani, Schumann '15]

  [Baberuxki, Preuss, DR, Schumann '19]
- extended for jet observables...
  - modified wide angle behaviour

    [Dasgupta, Khelifa-Kerfa, Marzani, Spannowski '12]

    [Caletti, Fedkevych, Marzani, DR, Schumann '21]
  - non-global logs [Dasgupta, Salam, '01]
- ...and soft drop grooming
  - modifies soft wide angle region
  - CAESAR-style formulas available

    [Baron, DR, Schumann, Schwanemann, Theeuwes '20]

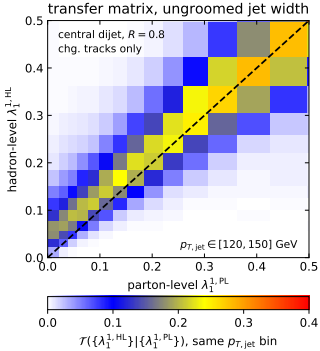
CAESAR in a nutshell:

- master formula for NLL resummation:
  $\Sigma(v) \sim \int d\mathcal{B}\; e^{-R(v)} \mathcal{S}(v) \mathcal{F}(v) \Theta_{\text{hard}}$
- $\mathcal{R}$ ... single collinear emission
- $\mathcal{S}$ ... soft emissions
- $\mathcal{F}$ ... multiple emissions
- Θ... hard cuts

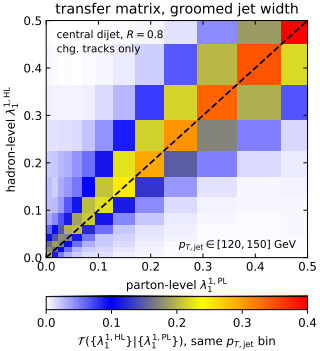
Analytic calculations: non-perturbative corrections

[JHEP 03 (2022) 131]

- simple MC based: ratio HL/PL $\times \frac{d\sigma}{d\tau}$
  - unphysical behaviour near PS boundaries
  - limited physics picture
- proposed solution:
  - transfer matrices $\mathcal{T}(\mathrm{HL}|\mathrm{PL}) \otimes \frac{d\sigma}{d\tau}$
- not discussed here:
  - completely analytic models



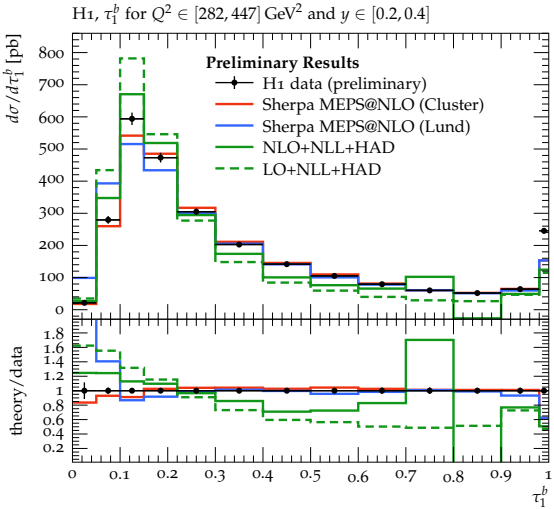
plain jet shape

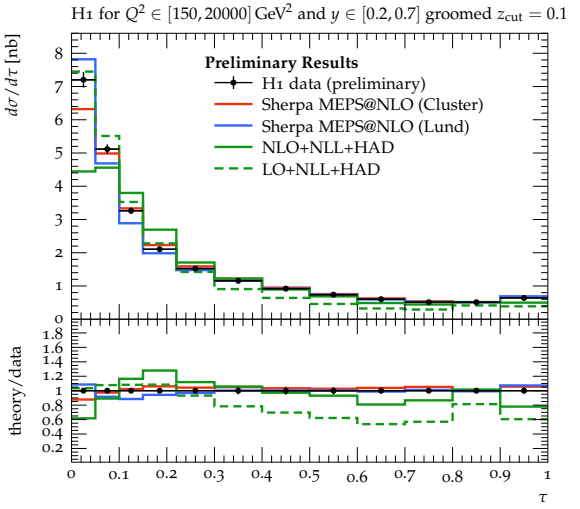


groomed jet shape

from [DR, Caletti, Fedkevych, Marzani, Schumann, Soyez '22]

Analytic calculation: Thrust/1-jettiness





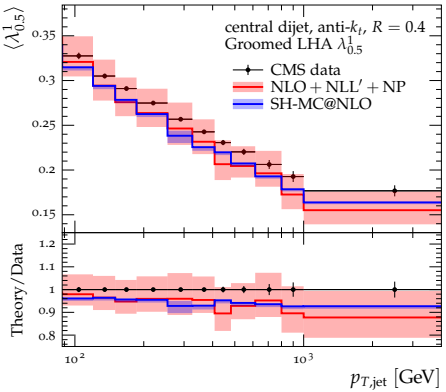
Summary

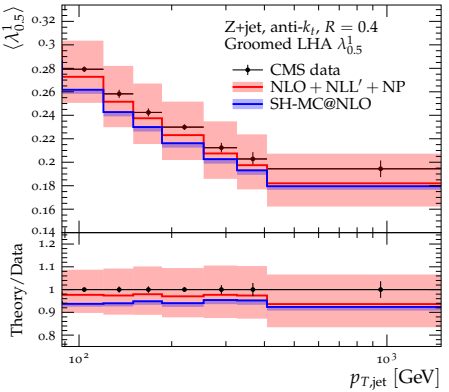
- event shapes as tools for QCD studies at all kinds of colliders
- concrete example: thrust/1-jettiness
- soft drop grooming $\rightarrow$ developed at LHC, applicable also to DIS
- use in MC tuning
- comparison to analytic calculations in SHERPA + CAESAR plugin

Backup

Analytic calculation: Example LHC

[JHEP 07 (2021) 076] [JHEP 03 (2022) 131]
data from [JHEP 01 (2022) 188]





- note on notation: LO $\equiv$ first non-trivial order for substructure observable
  (i.e. $O(\alpha_s^2)$ for Z+jet, $O(\alpha_s^3)$ for dijets)
  NLO$\equiv$ one more order in α_s