Event Shapes and Jet substructure at lepton colliders

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This talk ...

- three parts, common theme: event shapes and substructure techniques
- resummation of multi-jet rates [Baberuxki, Preuss, DR, Schumann '19]
- fitting α_s with groomed event shapes [Marzani, DR, Schumann, Soyez, Theeuwes '19]
- WIP: higgs couplings from event shapes

event shapes

- traditional QCD observables
- used in tuning, α_s measurements, ...
- resummation to high accuracy available

jet substructure techniques

- extensively measured at LHC
- provide tools for jet tagging, non-perturbative suppression

multi-jet rates

Jet rates

[Baberuxki, Preuss, DR, Schumann '19]

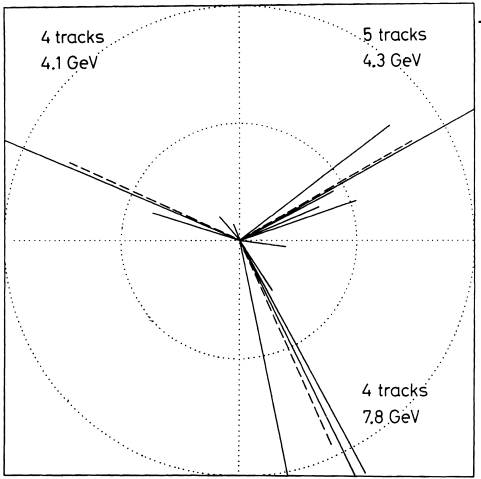


Fig.20g Another 3-jet event projected into the event plane.

- jet resolution scales, i.e. how close do we have to look to resolve 4th jet?
- Durham cluster algorithm:

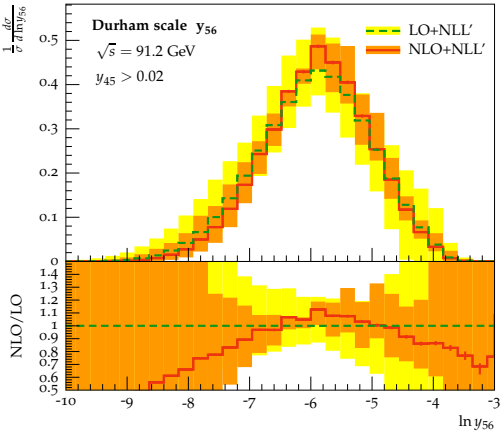
$$y_{ij} = \frac{2\min(E_i^2, E_j^2)}{Q^2}(1 - \cos\theta_{ij})$$

- y_{23} known at high accuracy, e.g. NNLO+NNLL [Banfi, McAslan, Monni, Zanderighi 2016]
- goal here: at least NLO+NLL′ accuracy for higher multiplicities y_{34}, y_{45}, y_{56}

Jet rates

[Baberuxki, Preuss, DR, Schumann '19]

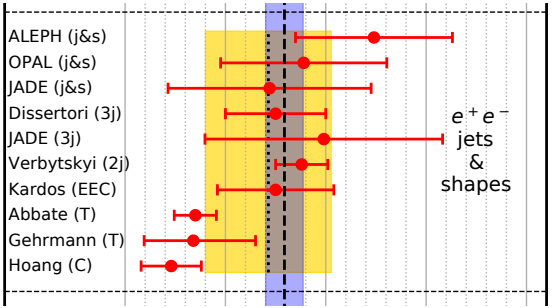
- make use of resummation plugin to Sherpa
  [Gerwick, Höche, Marzani, Schumann 2015]
- resummation around hard $(n-1$ parton) configurations $\Rightarrow$ require $y_{n-1,n} > 0.02$
  $\rightarrow$ different from the usual (experimental) definition
- test for colour structures beyond 2-particle dipole



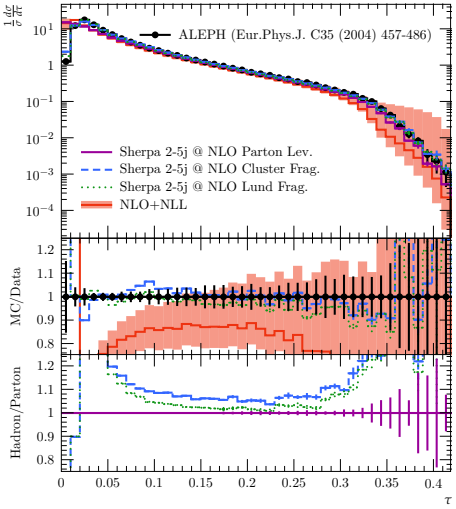
α_s from soft drop groomed event shapes

Thrust and α_s

[Marzani, DR, Schumann, Soyez, Theeuwes '19]



from [PDG '19]



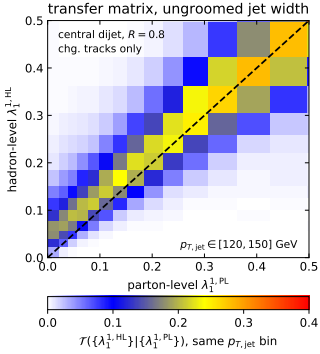
soft drop method: [Larkoski, Marzani, Soyez, Thaler '14]

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

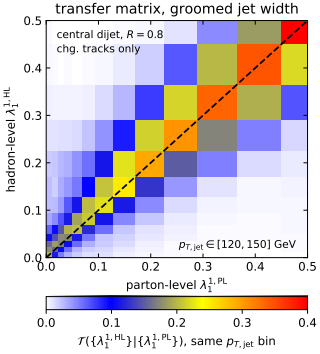
Soft-Drop: Hadronisation corrections

[Baberuxki, Preuss, DR, Schumann '19]

- soft drop constructed for UE suppression
- but also theoretical advantages like absence of non-global logs
- shown to reduce hadronisation correction in event shapes [Baron, Marzani, Theeuwes '18]
- idea: groom hadronic events → calculate thrust → input to α_s fit



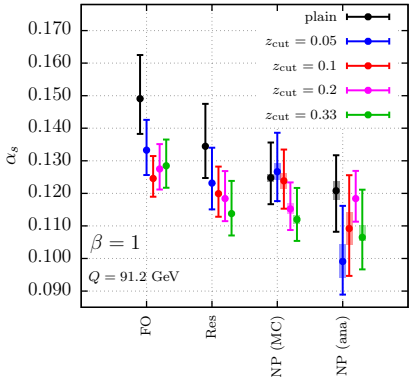
plain jet shape

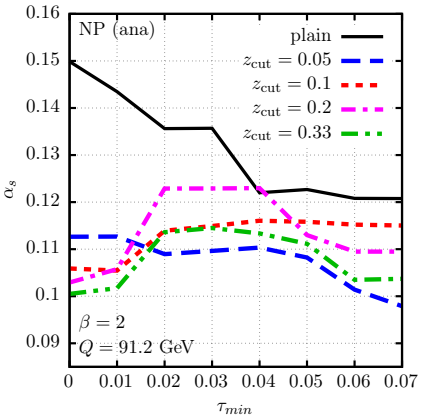


groomed jet shape

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

Fit results





Fits to MC data (SHERPA MEPS@NLO w/ up to 5 jets)

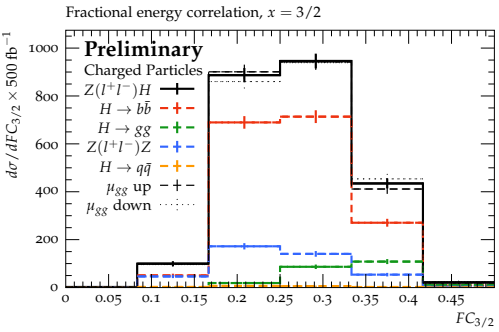
Competitive fits will need higher order understanding of grooming (NLL → NN(N)LL + $z_{\rm cut}$ corrections)

higgs couplings from event shapes

Outlook: higgs couplings

[work in progress by Knobbe, Krauss, DR, Schumann]

- consider $e^+e^- \to ZH$, $H \to$ QCD
- measure event shape v in CM of H
- total $\frac{d\sigma}{dv} = \sum \mu_i \frac{d\sigma_i}{dv}$, $i = H \to gg, H \to q_j\bar{q}_j$
- can we limit μ_i?
- based on stats (no systematics) $Z \to l^+l^-$ w/ 5ab^{-1} 240 GeV $\to \delta\mu_{gg} \sim 10\%$
- not immediately competitive, but complementary to tag + count
- ultimately limit $c\bar{c}$ / light $q\bar{q}$
- need to carefully consider hadronisation uncertainties



Summary

- event shapes / substructure as precision tools
- tests of fundamental theory components
  - colour structure
  - strong coupling constant α_s
  - decay ratios of hadronic decays

Backup