Resummed predictions for jet-resolution scales in multijet production in e^+e^- annihilation

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based on
Nick Baberuxki, Christian Preuss, DR, Steffen Schumann, *JHEP* 04 (2020) 112,
arXiv:1912.09396

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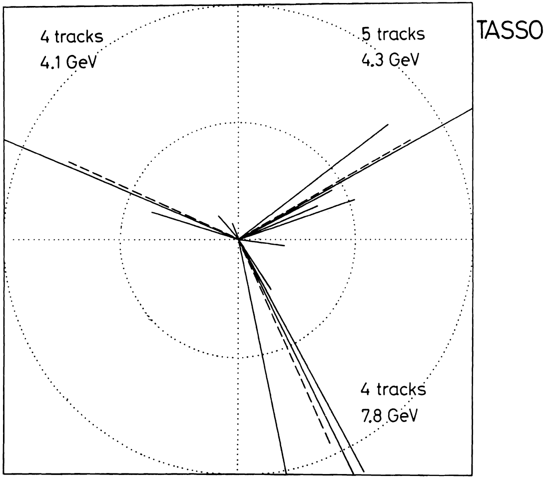


Fig.20g Another 3-jet event projected into the event plane.

[TASSO Collaboration 1997]

- 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}

- setup:
  - make use of resummation plugin to Sherpa [Gerwick, Höche, Marzani, Schumann 2015]
  - immediate access to technology for phase space integration, fixed order (virtuals via OpenLoops and Recola), etc.
  - general implementation, results shown here for LEP1 energy $Q = 91.2$ GeV
  - resummation around hard ($n-1$ parton) configurations $\Rightarrow$ require $y_{\mathrm{n}-1,n} > 0.02$
    $\rightarrow$ different from the usual (experimental) definition

- semi-analytic resummation in the Sherpa framework (based on the CAESAR [Banfi, Salam, Zanderighi 2004] formalism):
  - general formula for rIRC save observable:

$$\Sigma_{\mathrm{res}}^{\delta} = \int d\mathcal{B}_\delta \frac{d\sigma_\delta}{d\mathcal{B}_\delta} \exp\left[-\sum_{l\in\delta} R_l^{\mathcal{B}_\delta}\right] \mathcal{S}^{\mathcal{B}_\delta} \mathcal{F}^{\mathcal{B}_\delta} \mathcal{H}^{\delta}(\mathcal{B}_\delta)$$

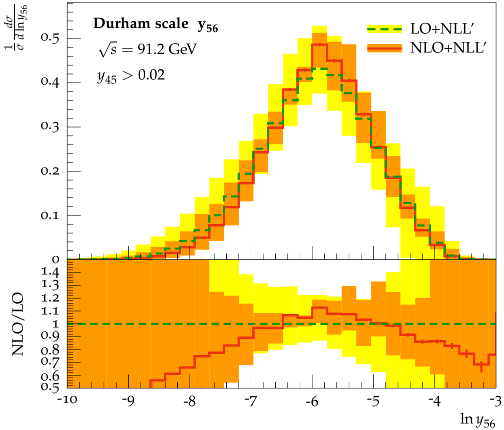
  - hard function $\mathcal{H}$ to regularise born phase space $\mathcal{B}$
    - ⋆ implements phase space cuts in Sherpa
  - collinear radiators R_l
    - ⋆ known in relatively general form
  - soft function $\mathcal{S} \rightarrow$ captures non-trivial colour correlations
    - ⋆ using matrix-element generator COMIX within Sherpa
  - multiple emission function $\mathcal{F}$
    - ⋆ numerical evaluation of limits with multiple precision arithmetic
  - achieving NLL′ accuracy: $\Sigma_{\mathrm{NLL}'} = \sum_\delta \left(1 + C^{(1),\delta}\right) \Sigma_{\mathrm{res}}^{\delta}$
    - ⋆ simple to extract since full information on flavour channels δ in fixed order calculation

- setup for matched calculation:
  - scale choice "CKKW-like":

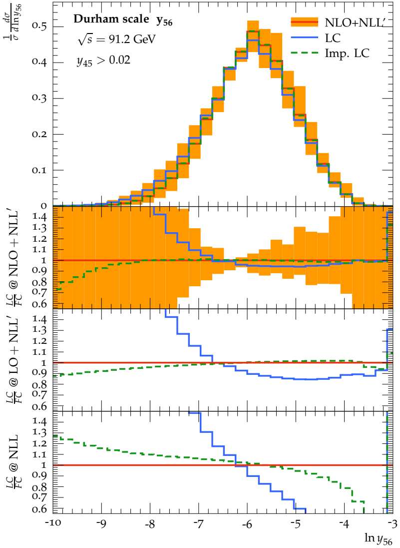
$$\alpha_S(\mu_R^2)^{(n-2)} = \alpha_S(y_{23}Q^2)\cdot\ldots\cdot\alpha_S(y_{n-1,n}Q^2)$$

  - assuming LO running

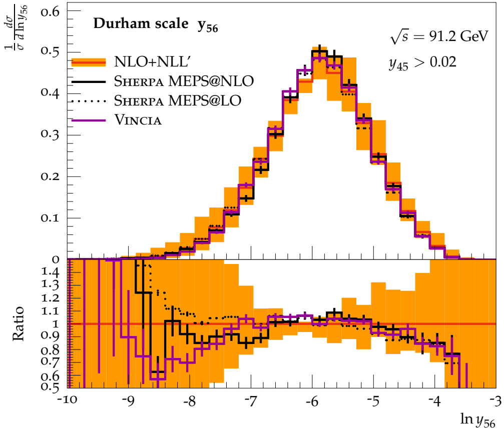
$$\mu_R^2 = \Lambda_{\mathrm{QCD}}^2 \exp\left[\frac{\prod_{i=3}^{n}(1-\lambda_i)^{1/(n-2)}}{\alpha_S\beta_0}\right]$$



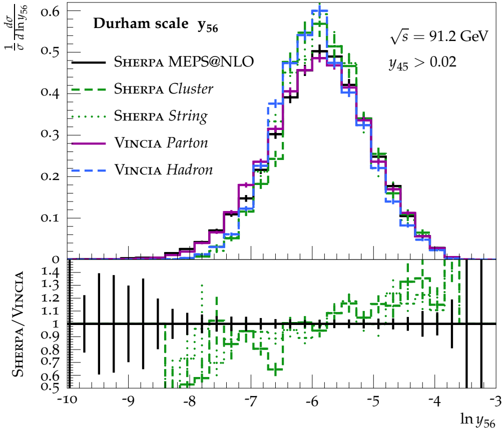
- assess effect of leading color approximation
- strict leading color $N_C \to \infty$
- "improved" leading color
  $\to$ only simplify $\mathcal{S}$,
  correct color factors in radiators, beta function, anomalous dimensions etc.



- Sherpa MEPS@LO w/ up to 5 jets
- Sherpa MEPS@NLO w/ up to 4 jets at NLO
- Vincia w/ 2+3 jets at NLO and up to 6 jet matrix element corrections



- hadronisation corrections from both MCs
- Cluster and String model w/ consistent underlying PS in Sherpa
- sizeable correction, also compared to differences to analytic calculation



- Summary
  - presented Durham jet resolution scales, at NLO+NLL′ accuracy for the first time for y_{34}, y_{45}, y_{56}
  - sizeable finite color corrections, however only mild corrections with respect to typical shower treatment of colour
  - use of generic event generator environment to easily include $C^{(1),\delta}$ coefficients for NLL′ accuracy
  - concrete results for CME 91.2 GeV, but could extend this to other collider energies
  - also applicable to other studies in this environment e.g. study on groomed event shapes [Marzani, DR, Schumann, Soyez, Theeuwes 2019]

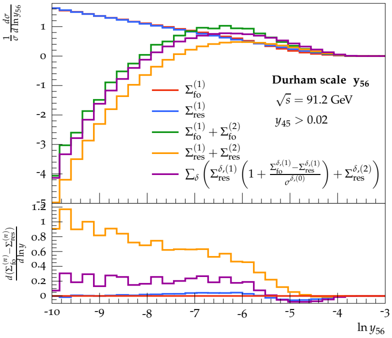
Backup

$C^{(1),\delta}$ coefficient and matching

- at NLL accuracy, enough to include [Banfi, Salam, Zanderighi 2010]

$$\frac{\alpha_s}{2\pi} C^{\delta,(1)} = \lim_{v\to 0} \frac{\Sigma_{\text{fo}}^{\delta,(1)} - \Sigma_{\text{res}}^{\delta,(1)}}{\sigma^{\delta,(0)}}$$

- define channels by IRC safe flavour algorithm (we use [Banfi, Salam, Zanderighi 2006])



- effectively included via matching scheme, i.e.

$$\Sigma_{\text{LogR}}^{\delta} = \Sigma_{\text{res}}^{\delta} \exp\left(\frac{\Sigma_{\text{fo}}^{\delta,(1)} - \Sigma_{\text{res}}^{\delta,(1)}}{\sigma^{\delta,(0)}}\right) \sim \left(1 + \frac{\alpha_s}{2\pi} C^{\delta,(1)}\right) \Sigma_{\text{res}}^{\delta} + \mathcal{O}(v)$$