Phenomenology of Jet Angularities at NLO+NLL' accuracy

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based on

[JHEP 07 (2021) 076], [EPJC 81 (2021), 884], [JHEP 03 (2022) 131]

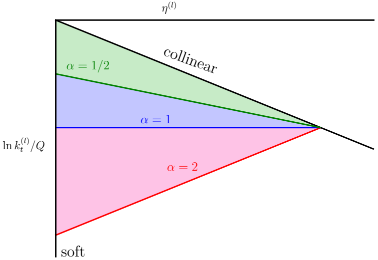
this talk...

- jet substructure observable: jet angularities
- setup: as recent CMS measurement [JHEP 01 (2022) 188]
- jets with and without soft drop grooming
- theoretical predictions: NLO+NLL' based on CAESAR plugin to SHERPA
- NP corrections using transfer matrix approach
- + MC@NLO (and MEPS@NLO) predictions from SHERPA
- application to quark-gluon discrimination
- outlook: first look at similar observables/techniques in DIS compared to H1 data

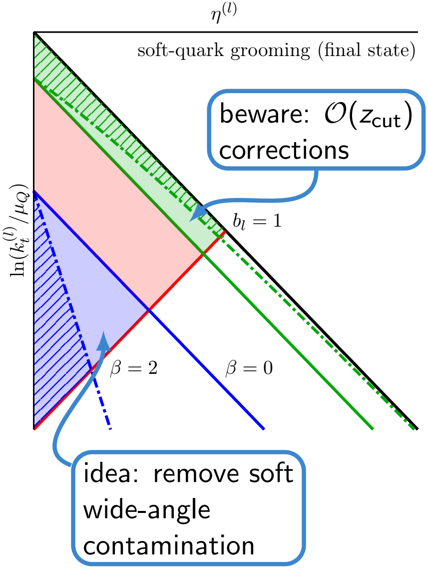
- jet angularity family of observables

$$\lambda_\alpha^\kappa = \sum_{i \in J} \left(\frac{p_{T,i}}{p_{T,J}} \right)^\kappa \left(\frac{\Delta R_i}{R} \right)^\alpha$$

- parameters κ (here $= 1$ for IR safety), and α to probe different phase space regions



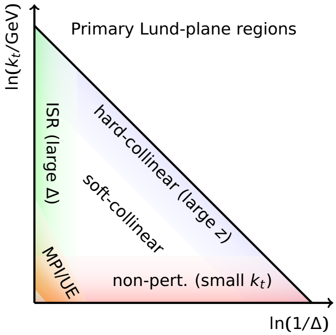
- measured on anti-k_t jets ($R = 0.4, 0.8$) for
  - leading jet in Z+jet
  - separately the more forward/backward of the two leading jets in dijets



method:

- ▷ decluster given jet with Cambridge/Aachen
  $\Rightarrow$ angular ordered splitting sequence
- ▷ go through sequence, remove softer branch if

$$\frac{\min(p_{T,i}, p_{T,j})}{p_{T,i}+p_{T,j}} < z_{\rm cut}\left(\frac{\Delta R}{R}\right)^{\beta}$$



framework for NLO + NLL$'$ +NP calculations

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

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

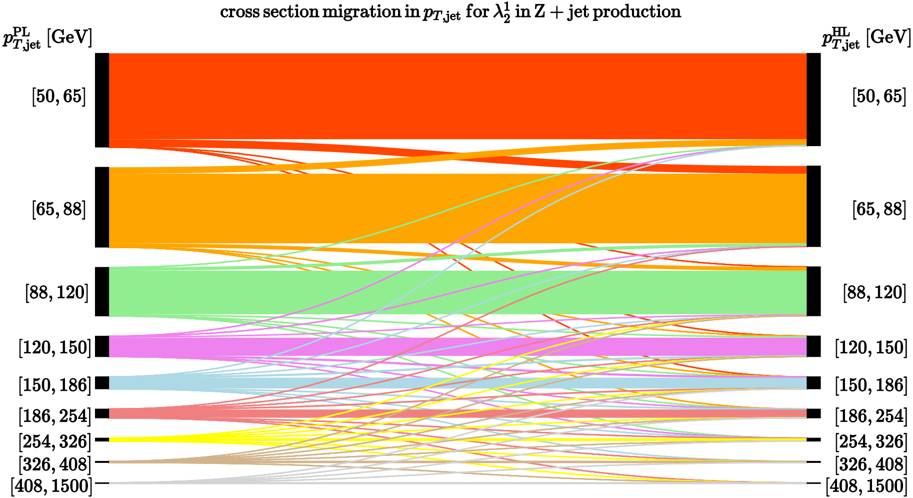
    [Baron, DR, Schumann, Schwanemann, Theeuwes '20]

non-perturbative effects

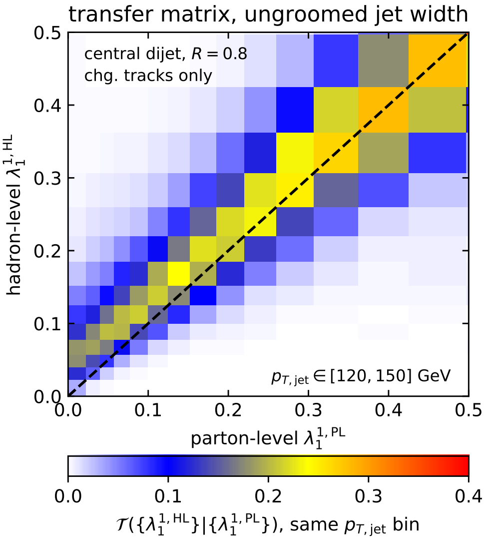
- Extract "transfer matrix" from MC
  - migration between p_T bins
  - shifts within observable

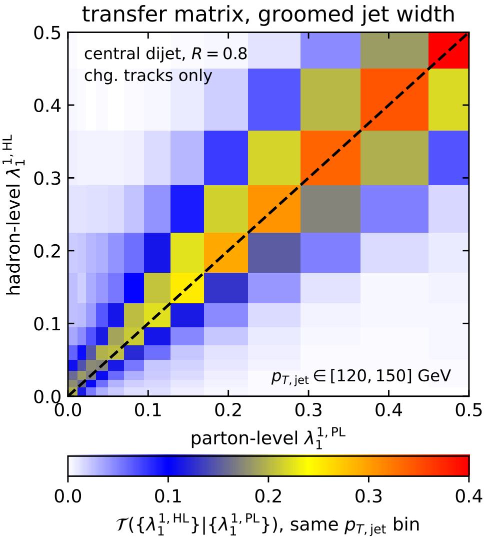
$$\frac{d^m\sigma^{\mathrm{HL}}}{dv_{h,1}\ldots dv_{h,m}} = \int d^m\vec{v}_p\;\mathcal{T}(\vec{v}_h|\vec{v}_p)\,\frac{d^m\sigma^{\mathrm{PL}}}{dv_{p,1}\ldots dv_{p,m}}\,.$$

migration between transverse momentum regions



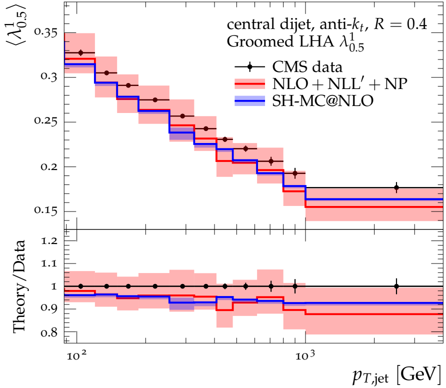
migration between observable bins

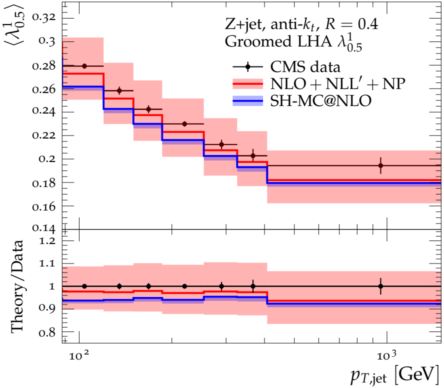




results: means of distributions

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

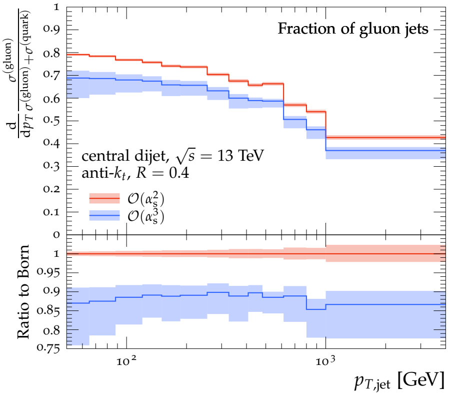


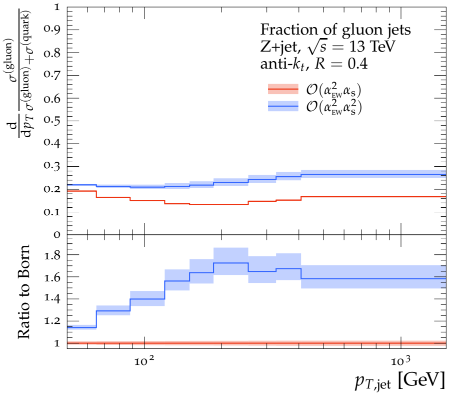


▷ note on notation: LO $\equiv$ first non-trivial order for substructure observable
(i.e. $O(\alpha_s^2)$ for Z+jet, $O(\alpha_s^3)$ for dijets)
NLO$\equiv$ one more order in α_s

proxies for q and g jets

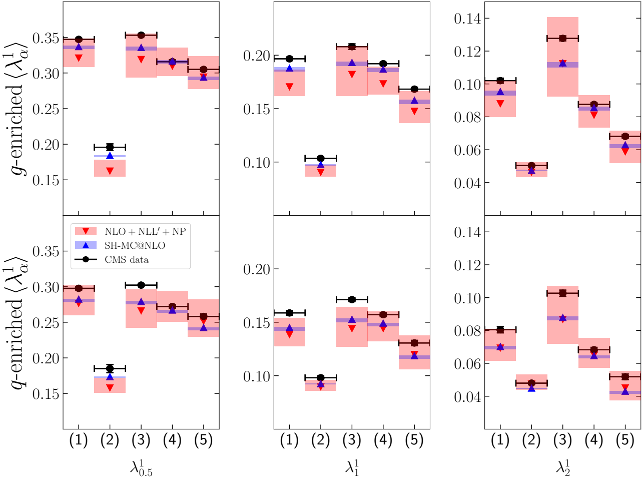
[JHEP 07 (2021) 076] [JHEP 03 (2022) 131]
data from [JHEP 01 (2022) 188]





- ▷ as expected, dijet ∼ gluon, Z+jet ∼ quark
- ▷ qualitatively similar result to [JHEP 01 (2022) 188] (w/ simpler working definition)

overview of mean in 5 different selections (as in [JHEP 01 (2022) 188])



- (1),(3),(4),(5): 120 GeV $< p_T <$ 150 GeV
  - quark $\sim$ Z+jet, gluon $\sim$ dijet
  - (1) $R = 0.4$, plain
  - (3) $R = 0.8$
  - (4) $R = 0.4$ charged
  - (5) $R = 0.4$ w/ grooming
- (2): 1000 GeV $< p_T <$ 4000 GeV
  - quark $\sim$ forward dijet, gluon $\sim$ central dijet
  - $R = 0.4$, plain

Long list of observables considered overall, including differential distributions, see [more results]

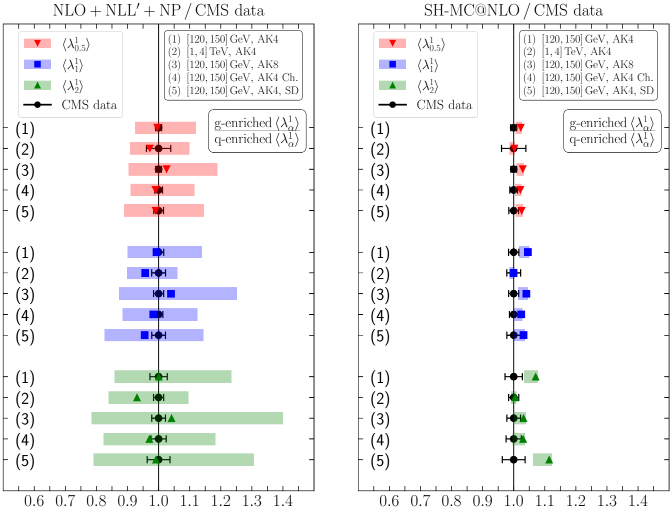
results: global view on data vs. theory

[JHEP 07 (2021) 076] [JHEP 03 (2022) 131]

data from [JHEP 01 (2022) 188]

ratios between quark and gluon enhanced samples (normalised to data)

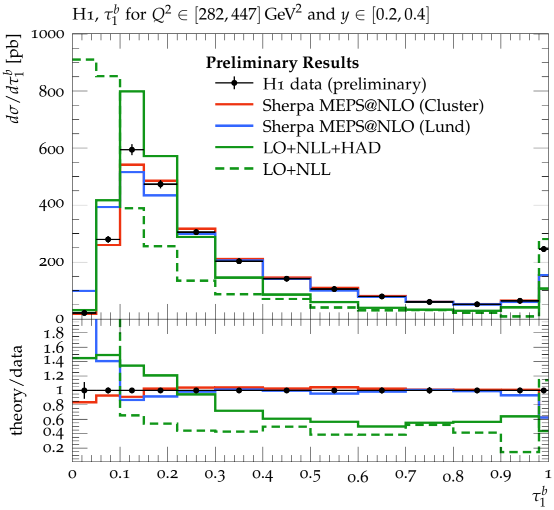
- ▷ same selections a before
- ▷ data well described by MC@NLO and NLO+NLL′+NP
  $\Rightarrow$ challenges traditional "quarks are better understood than gluons"

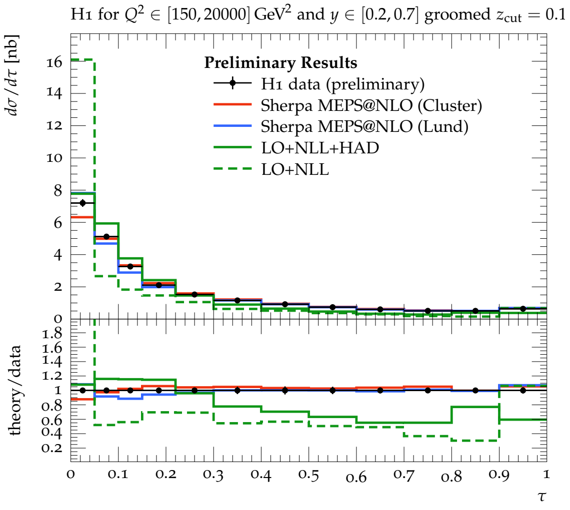


Outlook: towards DIS applications

- now look at similar observables in DIS
- at first "jet" $\rightarrow$ "hemisphere" (in Breit frame)
- hemisphere thrust/1-jettiness $\rightarrow$ same scaling as λ^1_2
  - preliminary data from [Hessler '21]
- grooming in DIS [Makris '21] based on Centauro measure [Arratia, Makris, Neill, Ringer, Sato '20]
  - preliminary data from [H1 (Talk at DIS '22)]
- validate same tools:
  - (N)LO+NLL' calculation + transfer matrices
  - Sherpa MEPS@NLO calculation
    $\rightarrow$ hadronisation via Cluster and Lund models

Outlook: towards DIS applications





Summary & Outlook

- Precise calculations for jet angularities
  - NLO+NLL'+NP with NP from transfer matrices
  - SHERPA MC@NLO simulations

  ⇒ reasonable description of data, good description of ratios of means
- First steps towards precision predictions for DIS in light of EIC
  - validation & tuning with H1 data
  - very good description of groomed (and ungroomed) thrust
  - first calculation in Sherpa CAESAR plugin + transfer matrix framework