(Groomed) event shape observables in ep at H1

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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

Thrust in ee over wider range

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

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

\[ 2x \vec{P} + \vec{q} = 0 \]

\[
P = \left( \frac{Q}{2}, 0, 0, -\frac{Q}{2} \right)
\]

Current hemisphere \( \eta < 0 \)

Remnant hemisphere \( \eta > 0 \)

\[
q^\mu + xP^\mu
\]

Struck quark

Proton

\[
P = \left( \frac{Q}{2x}, 0, 0, \frac{Q}{2x} \right)
\]

\[
q = (0; 0, 0, -Q)
\]
Trust in DIS

- At HERA measured by both H1 & ZEUS

Calculated in Breit frame from particles in Current hemisphere

\[ T_C = \frac{\max_{\vec{n}_T} \left( \sum_h |\vec{p}_h \cdot \vec{n}_T| \right)}{\sum_h |\vec{p}_h|} \tau_C = 1 - T_C \]

H1 Data

- $<Q> = 15$ GeV (× 20$^6$)
- $<Q> = 18$ GeV (× 20$^5$)
- $<Q> = 24$ GeV (× 20$^4$)
- $<Q> = 37$ GeV (× 20$^3$)
- $<Q> = 58$ GeV (× 20$^2$)
- $<Q> = 81$ GeV (× 20$^1$)
- $<Q> = 116$ GeV (× 20$^0$)

NLO($\alpha_s^2$)+NLL+PC (fitted)
NLO($\alpha_s^2$)+NLL+PC (extrapolated)
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 $\tau_{zE}$ [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 $\tau_{zE} = \tau_{c}^{H1} = 1 - T_{\gamma}^{ZEUS}$ and $\tau_{tE} = \tau_{c}^{H1} = 1 - T_{T}^{ZEUS}$ [32, 35]. It would be interesting to reanalyze the data to measure the global observables $\tau_{1,2,3}^{a,b,c}$ we predict in this paper at NNLL order.

\[ \tau_Q = 1 - \frac{2}{Q} \sum_{i \in \mathcal{H}_C} (-P_{z,i}^{\text{Breit}}) \quad \text{Equivalence} \quad \tau_1^b = \frac{2}{Q^2} \sum_{i \in X} \min \{ xP \cdot p_i, (q + xP) \cdot p_i \} \]
Experimental setup

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

$$Q^2 = -q^2$$
$$y = \frac{Pq}{pk}$$

$P$: incoming proton 4-vector
$k$: incoming electron 4-vector
$q = k-k'$: 4-momentum transfer
Momenta distribution in Breit frame

- Particle-flow algorithm combines momentum information from tracks and clusters

\[ \tau_Q = 1 - \frac{2}{Q} \sum_{i \in H_c} (-P_{z,i}^{\text{Breit}}) \]

0.2 < y < 0.7
\[ Q^2 > 150 \text{ GeV}^2 \]

Current hemisphere
Results of 1-jettiness

- Pythia with DIRE showering gives the best description

$$0.2 < y < 0.7$$
$$Q^2 > 150 \text{ GeV}^2$$

$$\tau_1^b = \tau_Q = 1 - \frac{2}{Q} \sum_{i \in H_c} (-P_{z,i}^\text{Breit})$$

$$\sigma = \frac{N_{\text{data}} - N_{\text{Bkg}}}{\mathcal{L} \cdot \Delta_{\tau}} \cdot c_{\text{unfold}} \cdot c_{\text{QED}}$$

Vanilla Pythia 8.3
Results of 1-jettiness

- Fixed order calculations at NNLO from NNLOJET

\[ 0.2 < y < 0.7 \]
\[ Q^2 > 150 \text{ GeV}^2 \]

Calculation including analytical resummation not available yet
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

Breit frame
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.

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

\[ \tilde{\eta}_i = \frac{p_i^+}{p_i^-} \]

\[ z_i = \frac{p \cdot p_i}{P \cdot q} \]

Usage of the clustering history applying Grooming condition:

\[ \frac{\min(z_i, z_j)}{z_i + z_j} > z_{\text{cut}} \]

Similar to Soft Drop.
Standard & Groomed 1-jettiness

- The groomed spectrum is better described by the generators
- Pythia+DIRE has consistently the best performance

\[ 0.2 < y < 0.7 \]
\[ Q^2 > 150 \text{ GeV}^2 \]

H1prelim-22-033
Groomed event mass

- Good performance of legacy DIS generators
- Pythia+DIRE outperforms classical Pythia’s shower
- Sherpa with Lund fragmentation gives slightly better description than AHADIC cluster model

\[ 0.2 < y < 0.7 \]
\[ Q^2 > 150 \text{ GeV}^2 \]
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

• Measured data ready to be used in MC tunes as well as in analytical calculations