Leading jets and energy loss at the EIC

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Why jets?

Jets can act as “image” recorders for the evolution of the event.

Momentum fluctuations at large angles will not be changed at small angles.

Angular-Ordering: Angles form an irreversible “time” for dynamics.
What is a leading Jet?

Inclusive Leading $e^+e^-$ half hemisphere

Threshold resummation

Pick the largest $z$

- $\sigma^{-1}d\sigma/dz$
- $R = 0.05$
- $R = 0.10$
- $R = 0.20$
- $R = 0.40$
- $R = 0.80$

Leading

$z_3$

$z_1$

$z_2$

$Q$
QCD evolution for inclusive and leading jets

**Inclusive jets**

\[
\mu \frac{d}{d\mu} J_i = \frac{\alpha_s}{2\pi} \sum_j P_{ji} \otimes J_i
\]

Can be solved analytically

**Leading jets**

\[
\mu \frac{d}{d\mu} J_i(z, \hat{p}_T R, \mu) = \frac{1}{2} \sum_{j,k} \int dz' dz_j dz_k \frac{\alpha_s(\mu)}{\pi} P_{i \rightarrow jk}(z') \mathcal{J}_j(z_j, \hat{p}_T R, \mu) \mathcal{J}_k(z_k, \hat{p}_T R, \mu)
\]

\[
\times \delta(z - \max \{z' z_j, (1 - z') z_k\})
\]

Requites MC approach

"Angular time"

see also 1411.5182, 1912.06673
Connection of **leading jets with broken objects**

Derrida, Flyvbjerg 1987

Probability distribution of the largest fragment
Existing measurements

Why leading jets at EIC?

Leading jets are much closer proxy for “struck quarks”

Arratia, Makris, Neill, Ringer, NS
Why leading jets at EIC?

\[ z_1 = \frac{p_{T1}}{Q} \]

\[ z_{\text{loss}} = 1 - z_1 \]

Provides a clean definition for energy loss.
Why leading jets at EIC?

Leading jets are probability distributions

\[ \int_{0}^{1} dz_1 P(z_1) = 1 \]

\[ \int_{0}^{1} dz_1 z_1 P(z_1) = \langle z_1 \rangle \]

Allows to define consistently statistical measures

We can use more statistics, shannon, KL etc
Example: energy loss

\[ z_1 = \frac{pT_1}{Q} \]

\[ z_{\text{loss}} = 1 - z_1 \]

**e+e- half hemisphere**

\[ \left\langle k_T \right\rangle_{z_{\text{loss}}} \]

- Red: Gluon \( Q = 91.2 \text{ GeV} \)
- Red: Quark \( Q = 91.2 \text{ GeV} \)
- Blue: Gluon \( Q = 500 \text{ GeV} \)
- Blue: Quark \( Q = 500 \text{ GeV} \)

\( \ln (1/R) \)
Example: energy loss

Quark gluon fractions are approximately constant across angular time.
Example: **KL divergence**

There is an optimal “angular time” for quark/gluon discrimination.

$$D_{KL}(P \parallel Q) = \sum_{x \in X} P(x) \log \left( \frac{P(x)}{Q(x)} \right)$$
Summary & outlook

- Theory framework for **leading jets** with higher order corrections (threshold corrections)
- New venues to study hadronization of quarks and gluons
- Extension to leading hadrons are now possible