Jet Clustering for DIS in the Breit Frame

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Breit Frame kinematics

$$n^\mu = (1, 0, 0, +1) \qquad \bar{n}^\mu = (1, 0, 0, -1)$$

Proton

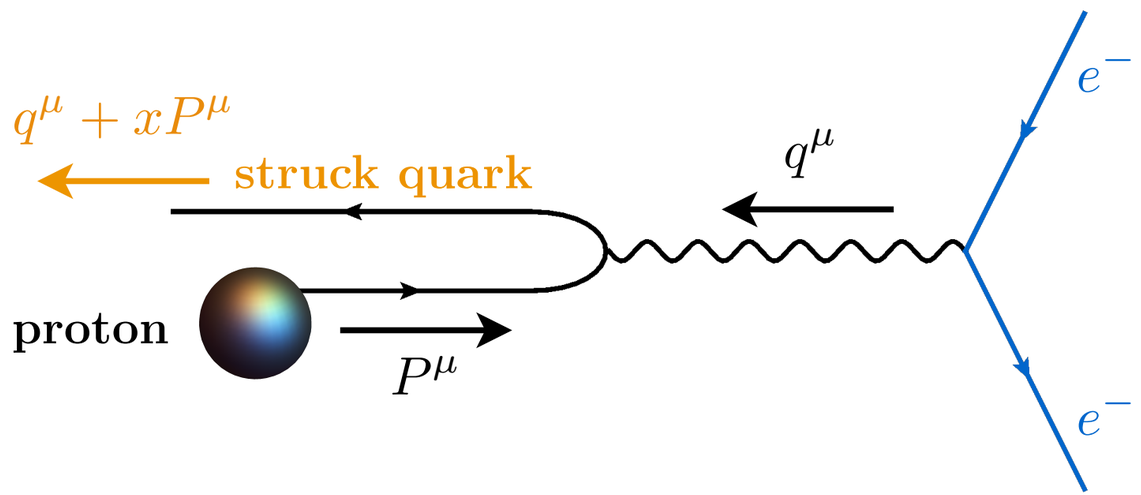
$$P^\mu = \frac{Q}{2x_B} n^\mu$$

Photon

$$q^\mu = \frac{Q}{2}(n^\mu - \bar{n}^\mu)$$

Struck quark

$$p^\mu = q^\mu + xP^\mu = \frac{Q}{2}\bar{n}^\mu$$



Hadronization of the struck quark will generate a jet close to the (anti-)beam axis. These configurations are the majority of the events and offer vast range of applications. The jets found away from beam remnant provide “clean” jets similar to those found in lepton-lepton colliders (but with dynamical Q).

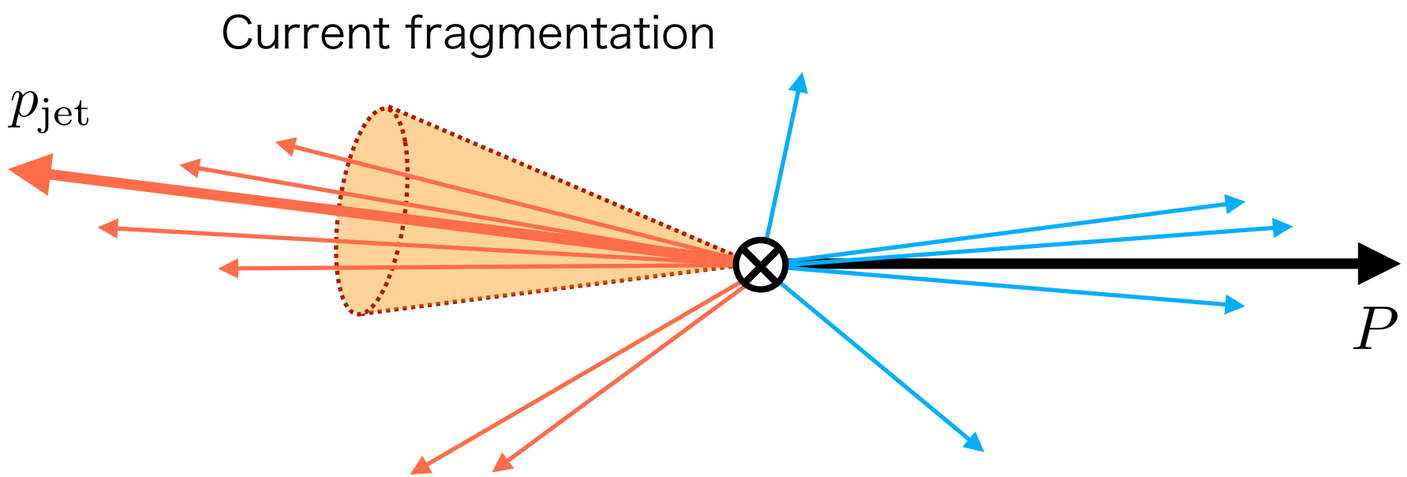
The backward jet

Jet observables
- Energy (fraction) distributions
- Hadron-in-jet
- Jet substructure (e.t.c. Angularities)

TMDs
- unpolarized TMDs
- Sivers (quark)
- Hadron-in-jet

The only frame for which TMDPDFs are universal to conventional TMDs.
(i.e., the soft function involves Wilson-lines in the back-to-back direction)

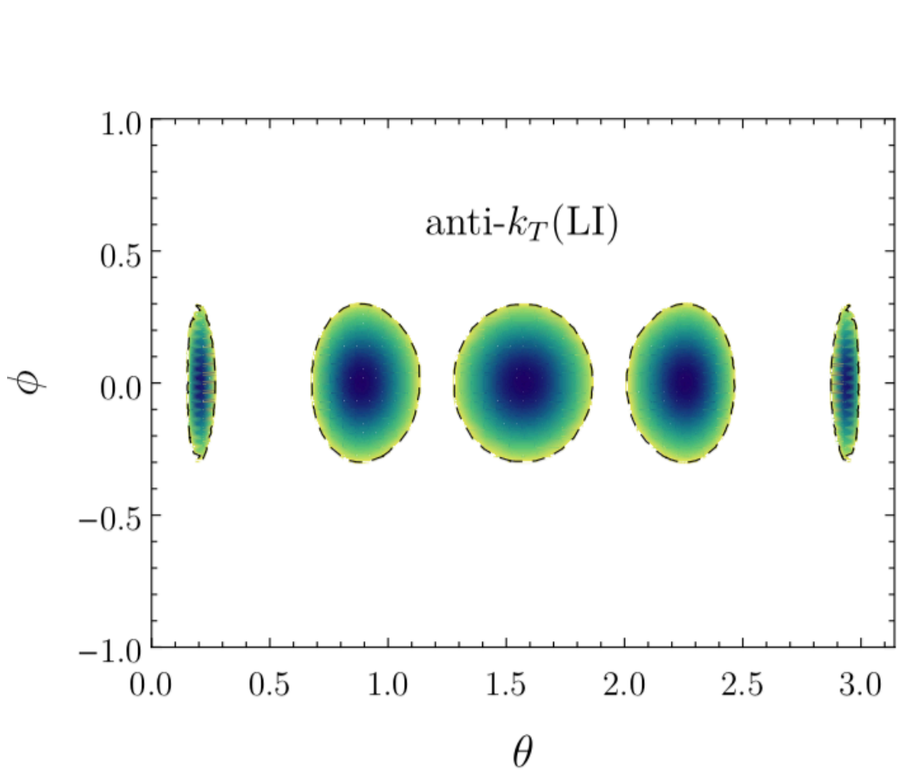
Event shapes (in BF)
- 1-jettiness
- Angularities
- Broadening

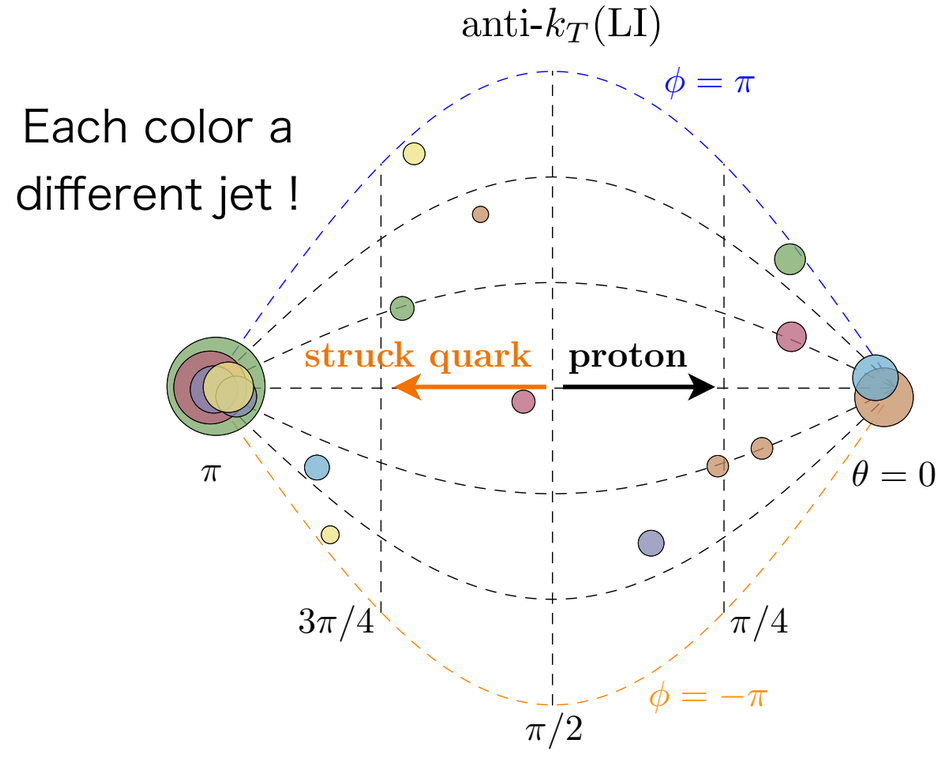


Longitudinally invariant algorithms

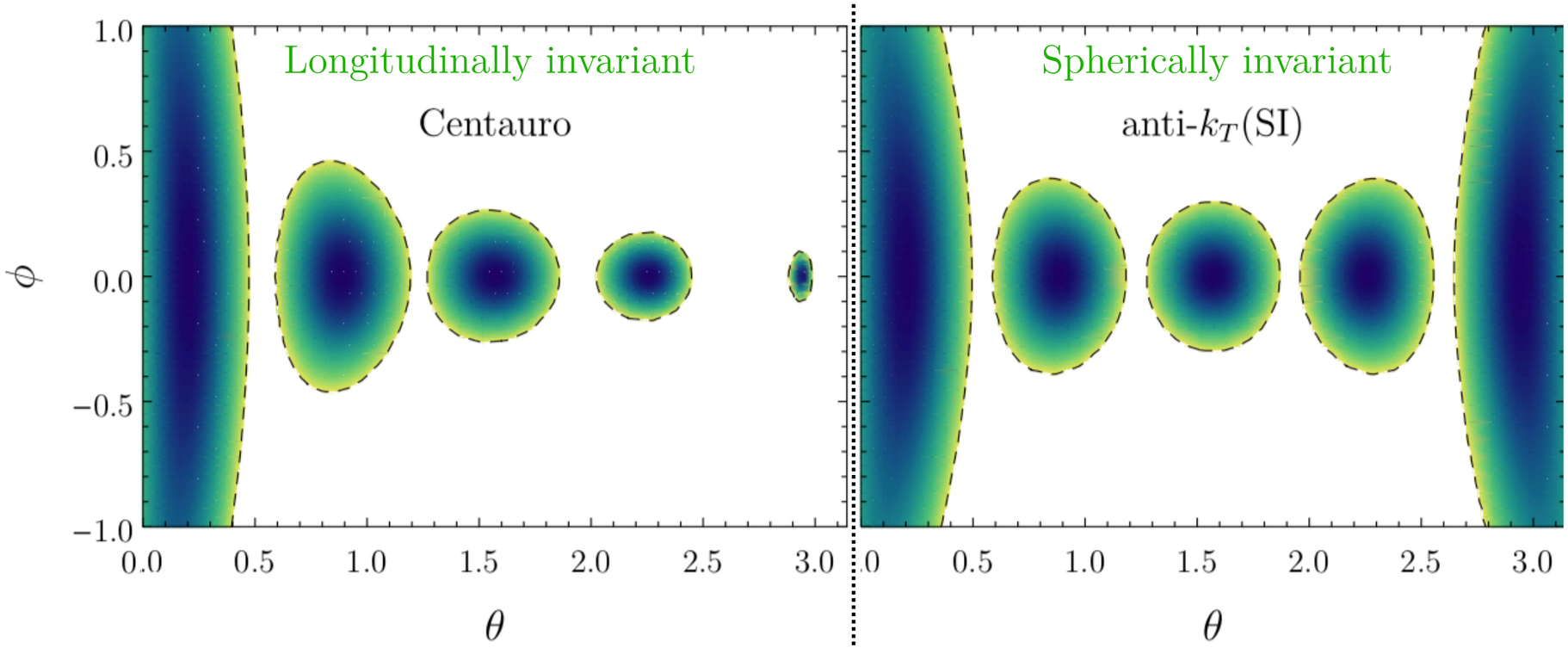
kT-type jet algorithms (and particularly anti-kT) dominate the
hadronic physics market. Are well known and well behaved algorithms in the LAB frame.

However, in Breit Frame since they cluster in the y -ϕ space,
they fail to capture hadrons in the very backward direction, where we are looking for one.





Alternatives



$$d_{ij} = \Big[(\Delta f_{ij})^2 + 2 f_i f_j (1 - \cos \Delta\phi_{ij})\Big]/R^2$$

$$d_{ij} = \min(E_i^{2p}, E_j^{2p}) \frac{1 - \cos\theta_{ij}}{1 - \cos R}$$

Asymmetric measure is necessary

$$f(x) = x + \mathcal{O}(x^2)$$

$$\bar{\eta}_i = -\frac{2Q}{\bar{n}\cdot q}\frac{p_i^\perp}{n\cdot p_i}$$

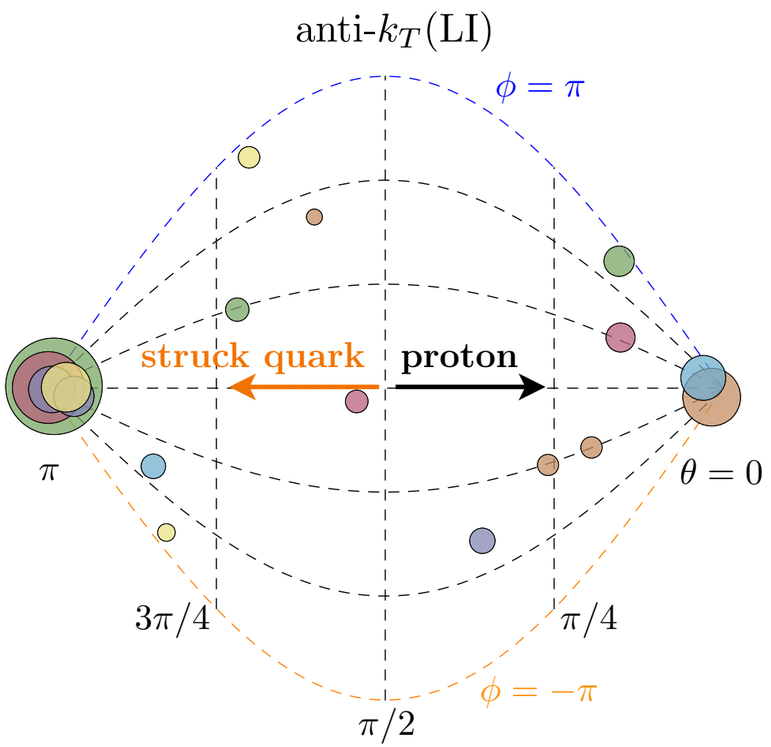
$$\bar{\eta}_i(\mathrm{BF}) = 2p_i^\perp/p_i^+$$

Here we use:

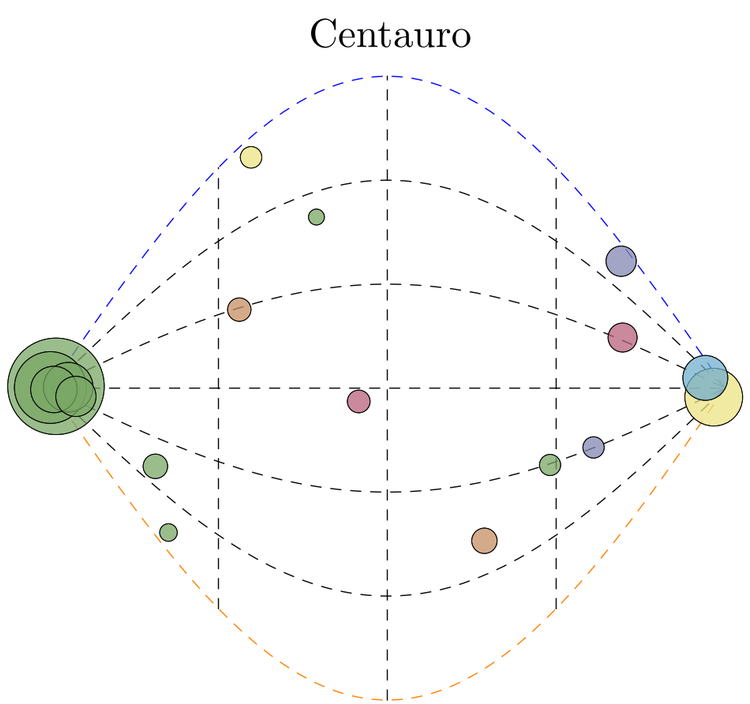
$$d_{iB} = E_i^{2p} \qquad p = -1$$

Similar algorithm for DIS by:
S. Catani, Y. L. Dokshitzer, and B. Webber, (1992)

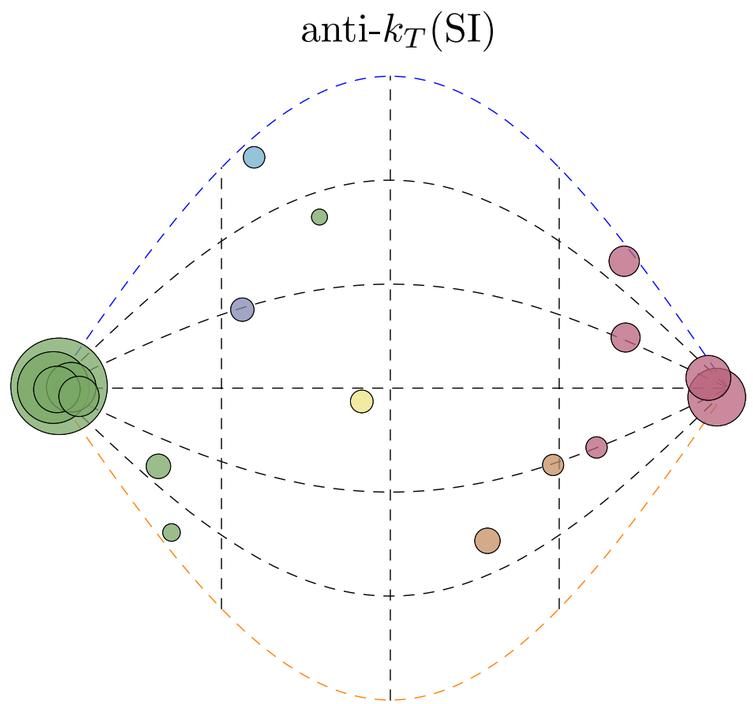
Alternatives



Longitudinally invariant
Symmetric

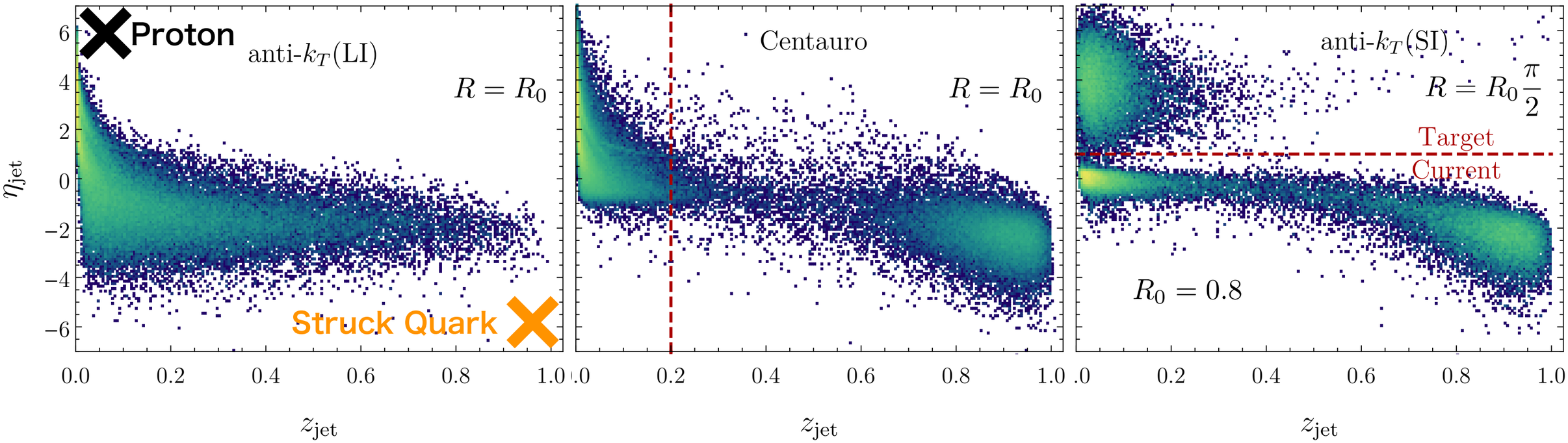


Longitudinally invariant
Asymmetric



Spherically invariant
Symmetric

First look



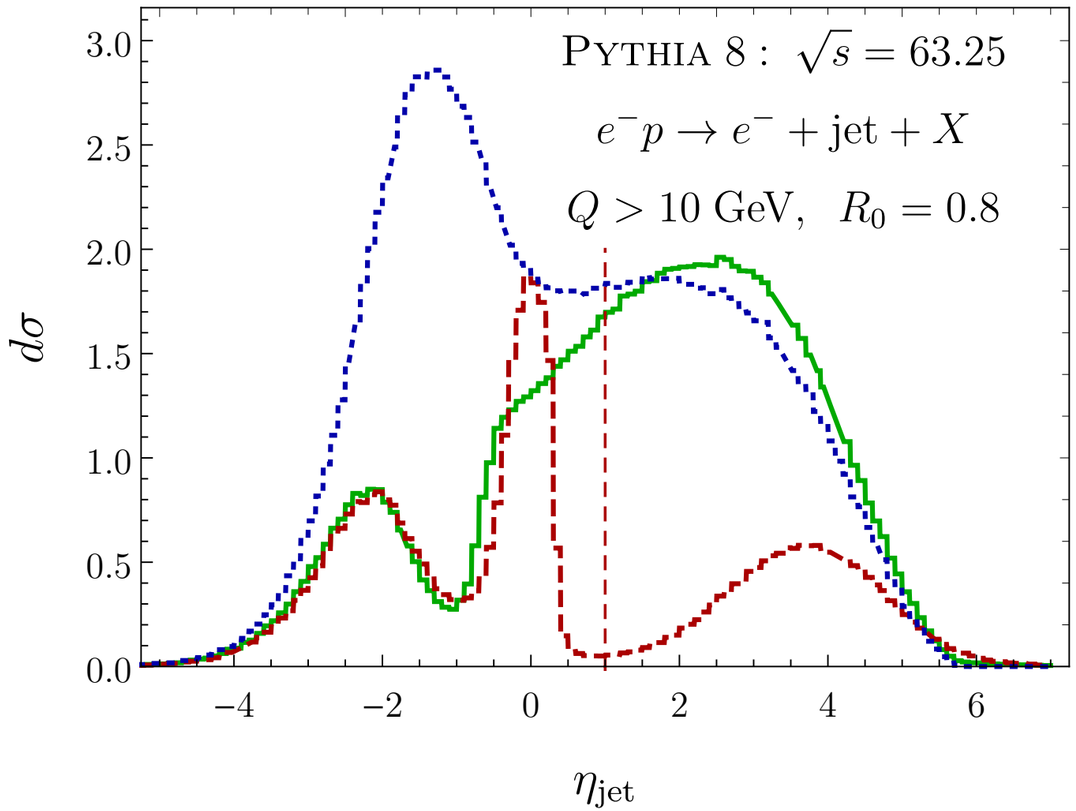
$$z_{\rm jet} = \frac{P \cdot p_{\rm jet}}{P \cdot q} \qquad z_{\rm jet}(\text{Breit frame}) = p^+/Q$$

$z_{\rm jet} > 0$ $\Rightarrow$ $z_{\rm jet} \leq 1$

$$z_{\rm jet} = \sum_{i \in \rm jet} z_i$$

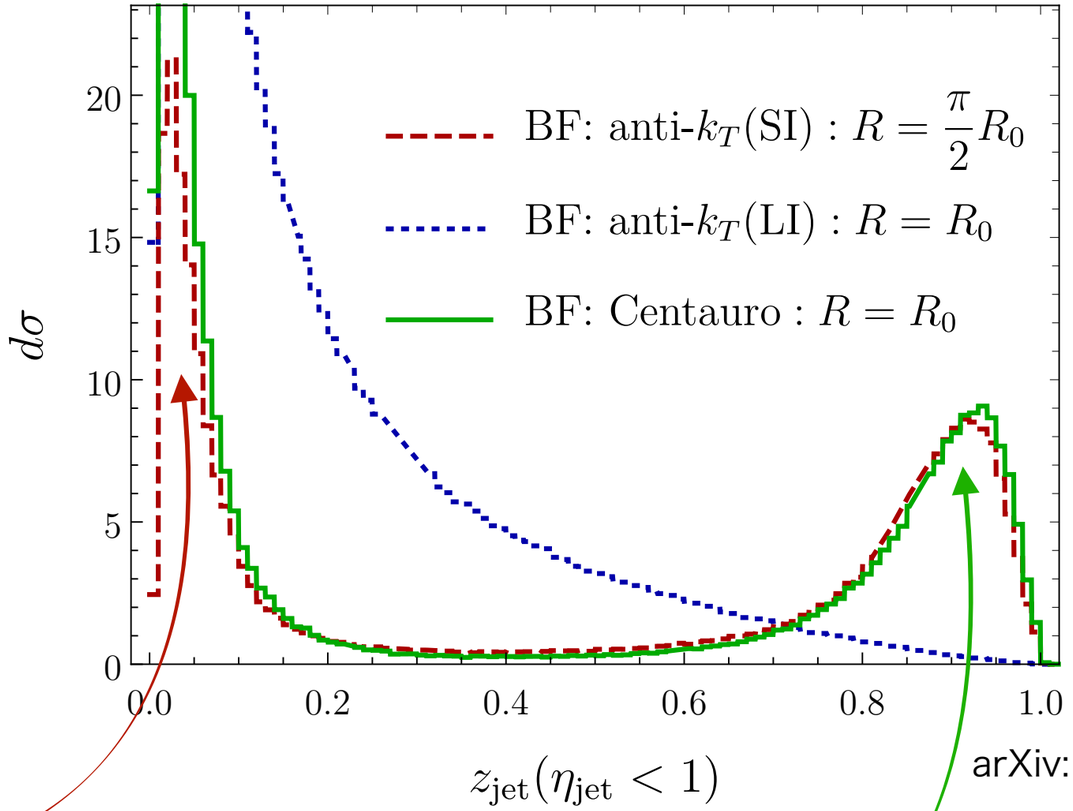
$$\sum_{\rm jet \in event} z_{\rm jet} \leq \sum_{i \in \rm event} z_i = 1$$

Pseudo-rapidity and Energy fraction



Rapidity cutoff to remove target fragmentation in SI allows for studies of the full z-spectrum. Other wise only possible in hadronic colliders

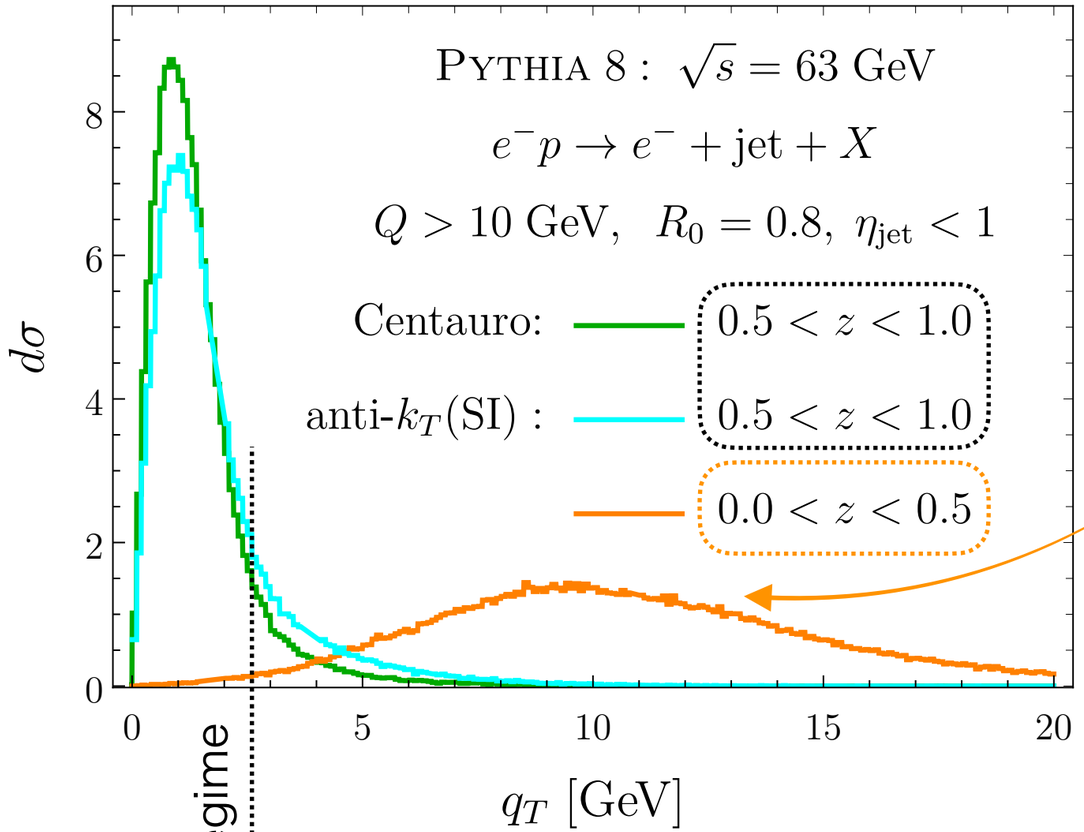
arXiv:2003.02275

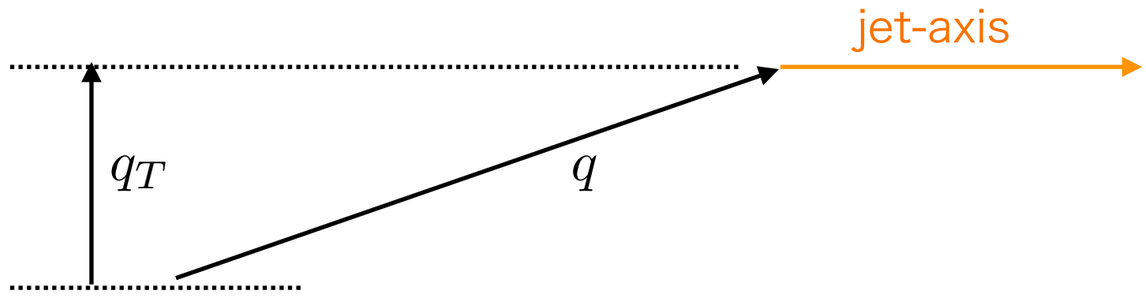


Endpoint distribution associated with the energetic jets requires threshold analysis. Hadronization effects for Centauro are universal to event-shape observables

arXiv:1701.05660

TMDs





New regime from current fragmentation at small transverse momentum that is not studied theoretically yet.

The z-cut at 0.5 it is arbitrary and can be relaxed within the region 0.2 - 0.6 inducing only minor effects.

arXiv:1807.07573
arXiv:1904.04259 arXiv:1907.05896

Implementation with Fastjet::contrib

by Miguel A.

The necessary files can be found here:

https://github.com/miguelignacio/CentauroJetAlgorithm

We plan to include this code in the standard fastjet-contrib release. To install it, you should copy this folder as "CentauroPlugin" in your fastjet contrib folder (https://fastjet.hepforge.org/contrib/) along with all the other plugings. Then do:

```
./configure --only=CentauroPlugin –fastjet-config=YOURPATH/fastjet-install/bin/fastjet-
config CXXFLAGS=-fPIC CFLAGS=-fPIC
make
make install
```

You can then run an example with:

```
./example < ../data/single-epDIS-event.dat
```

How to use in Pythia 8

```
#include “fastjet/contrib/CentauroPlugin.hh”
.
.
.

fastjet::contrib::CentauroPlugin * centauro_plugin = new fastjet::contrib::CentauroPlugin(0.8);

JetDefinition centauro(centauro_plugin);

ClusterSequence clustSeqCentauro(fjInputsBF, centauro);

inclusiveJetsCentauro = clustSeqCentauro.inclusive_jets(0);

JetsCentauro = sorted_by_E(inclusiveJetsCentauro);
```

jet Radius

minimum pT for jets

Outlook

(1) In progress - Energy spectrum: projections for the EIC and HERA

+

Theory predictions including
threshold resummation and
hadronization corrections

(2) Look the behavior of Centauro in di-jet configurations and consider simultaneous analysis for single and di-jet cross sections.

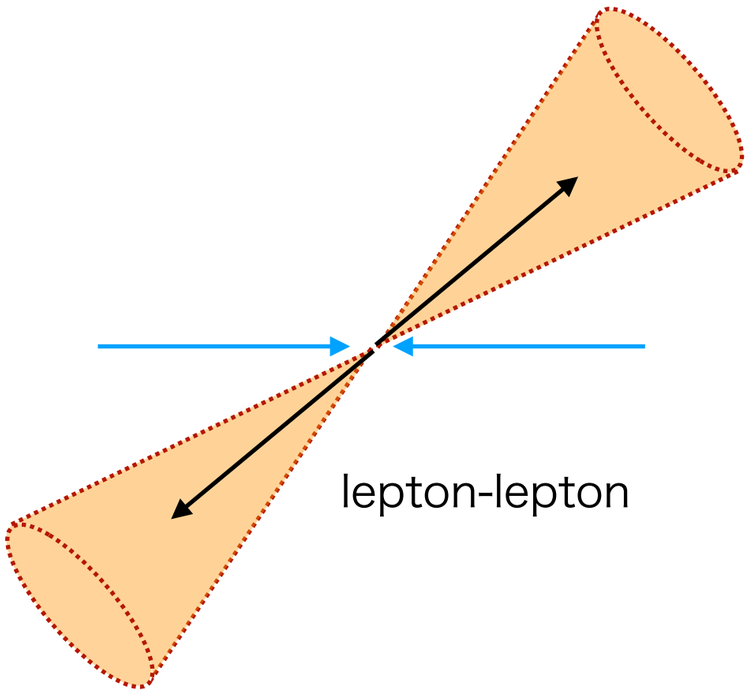
(3)Theory + pheno. study of the quark-Sivers function from jets in the Breit Frame

(4) Integration in the FastJet framework: effects of soft radiation in the threshold region (Grooming and/or use of soft-recoil free axis)

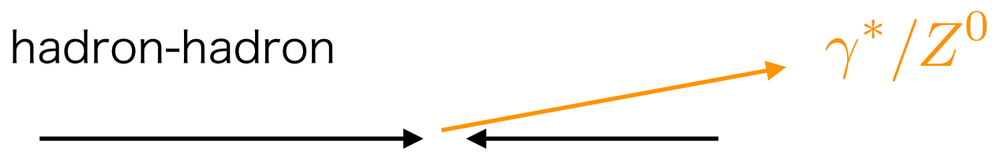
(5) Applications in event and jet shape observables

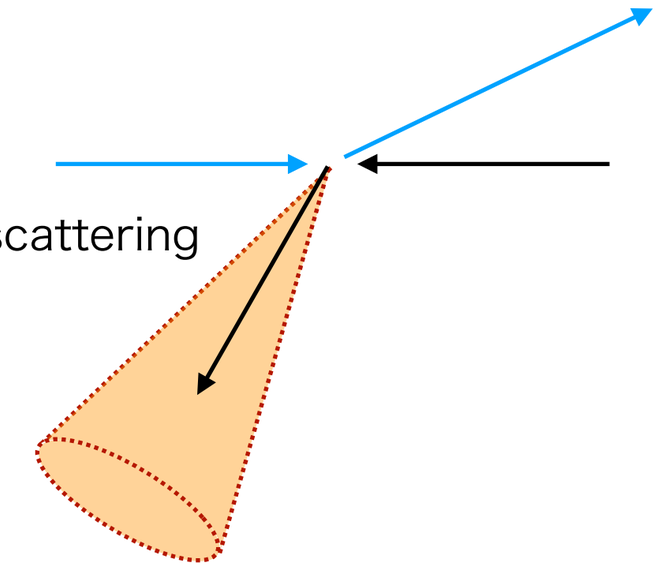
Thank you

Leading order processes in the LAB



lepton-lepton





Deep inelastic scattering