PROCEEDINGS OF SCIENCE

Imaging the Wake of a Jet with Energy Correlators

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In heavy ion collisions, jets are formed during the initial hard scattering event and move through the quark-gluon plasma (QGP) as it evolves. The evolution of the medium manifests itself on the jet via various jet-medium interactions, modifying its substructure as compared to vacuum QCD. Recently, the energy correlator observable has been shown to be a powerful method to decode correlations in pp collisions through measurements in ALICE, CMS and STAR. Additionally, recent studies have shown the sensitivity of this observable to medium modification due to the QGP. In this work [1], we perform the first study of the three-point energy correlator for medium modified jets, to show how it can be used to map out the shape of medium induced modifications. We illustrate this for the specific case of the Hybrid Model, where we show how higher-point correlation functions can image the wake of a jet.

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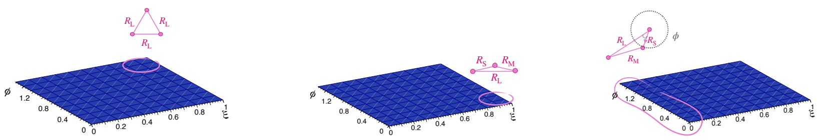
1. Introduction

Jets produced during the initial hard scattering of a heavy ion collision traverse the QGP as it evolves from a strongly coupled plasma to free streaming hadrons. Jets and their substructure are modified due to interaction with the medium [2]. In these proceedings, we discuss how a novel jet substructure observable, the N-point Energy Correlator, can be used to probe jet-medium interactions.

2. Projected Correlators and Full, Shape-Dependent, Energy Correlators

N-point Energy correlators (ENCs) are a class of ensemble-averaged, infrared, and collinear (IRC) safe observables, which measure correlations in the asymptotic energy flux. Recent measurements show that in vacuum, projected correlators exhibit a clear scaling behavior separating pQCD and npQCD effects [3–6].

While the projected correlators are sensitive to the scale of the correlation, R_L, we can probe information about the shape of energy flow by studying higher point correlators, the first non-trivial of which is the three-point correlator, EEEC. These correlators were first studied for hadronic collisions in [7].



(a) Equilateral **(b)** Flattened **(c)** Squeezed

Figure 1: Configurations of triangles of interest for the EEEC in the $\xi - \phi$ plane.

The EEEC is constructed by taking triplets in the jet and ordering them via their longest (R_L), middle (R_M), and shortest (R_S) side. Once these sides are identified, we can classify the shapes of interest intro three categories, as shown in figure 1 via the coordinate system defined in (1).

$$\xi \equiv \frac{R_\mathrm{S}}{R_\mathrm{M}}, \qquad \phi \equiv \arcsin\sqrt{1 - \frac{(R_\mathrm{L} - R_\mathrm{M})^2}{R_\mathrm{S}^2}}. \tag{1}$$

We use the Hybrid Model to investigate the sensitivity of the correlator to medium effects. In the Hybrid Model, the parton showers interact with and lose energy and momentum to the QGP produced in the heavy-ion collision. The energy and momentum gained by the droplet take the form of hydrodynamical wake in the QGP, after freezeout, becomes soft hadrons [8].

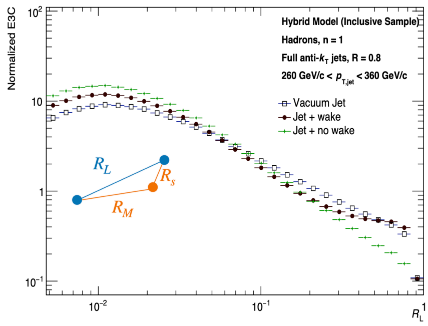
3. Mapping the medium response with projected and full energy correlators

We reconstruct inclusive and γ-tagged hadron-level anti-k_T jets of $R = 0.8$ (cuts detailed in [1]). We study three scenarios: (i) vacuum, (ii) medium with wake (jet includes hadrons from parton shower and hadrons from the wake) and (iii) medium without wake. [1]

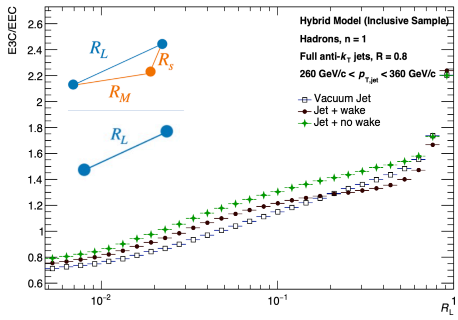
[1]This is an unphysical scenario – turning the wake off violates momentum and energy conservation. However, looking at observables in this sample is particularly illustrative and informative, as the comparison with observables in

3.1 Mapping the scale of medium response with ENC

As mentioned above, the projected correlators preserve the scale of the correlation by identifying the scale at which medium effects become manifest (as shown in Fig.3(a) of [1] for the EEC). Here we extend this to the E3C and the E3C/EEC ratio as shown in 2.



(a) E3C



(b) E3C/EEC ratio

Figure 2: Projected correlators showing large angle deviation from vacuum behavior.

We see that the EEC and the E3C show a large angle enhancement for the case where the wake is turned on.[2] The E3C/EEC ratio shows a distinct break from vacuum scaling. While in the case of vacuum, this represents the anomalous dimensions of the energy flow operators, it is much less clear how to interpret this in the case of a medium. This offers an exciting avenue for future theoretical and experimental pursuits.

3.2 Mapping the Wake with EEEC

Once the scale of the medium effects is identified by the ENC, we use this scale to study the shape of the correlators. In Fig.3, we see that compared to vacuum, wake effects populate the equilateral region ($\xi \approx 1, \phi \approx \pi/2$). To ensure that these effects are due to the medium response, we study different contributions to this ratio, shown in Fig.13 in [1]. As one can see clearly it is the jet-wake-wake and wake-wake-wake correlations that populate this regime. We also study the R_L dependence of medium effects. In Fig.4, we show the EEEC for three different R_L slices for γ-tagged jets. One can see that at larger R_L, wake effects are enhanced – similar to what is observed in the projected correlators.

Additionally, we see that these effects are more prominent for γ-tagged jets, as can be seen by the magnitude of the wake effects in Fig.4c as compared to Fig.3.

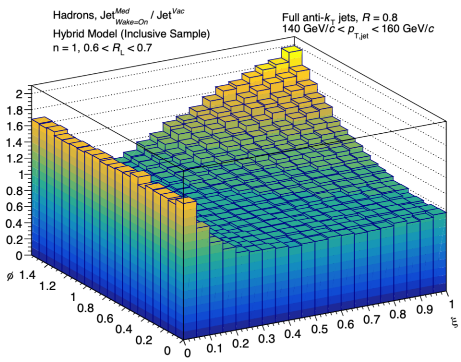
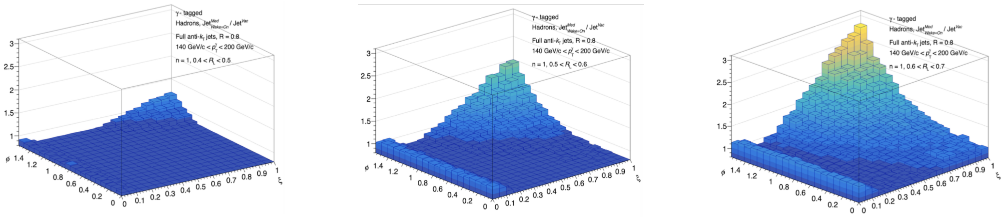


Figure 3: Ratio of EEEC in medium to vacuum for $140 < p_T^{jet} < 200$ GeV$/c$). The peak in the equilateral regime is due to the presence of the jet-wake correlations.

the "medium with wake" sample isolates the impact of the wake on any chosen observable.

[2]This large angle enhancement for the EEC has been predicted by various models and analytical calculations, as well as recent results [9].

This clearly depicts a mitigation of jet selection bias. This is attributed to the absence of a negative-



(a) $0.4 < R_L < 0.5$ **(b)** $0.5 < R_L < 0.6$ **(c)** $0.6 < R_L < 0.7$

Figure 4: R_L scan for γ-tagged jets ($140 < p_T^{\gamma} < 200$ GeV/c), $p_{T,min}^{jet} > 40$ GeV/c. One can see that wake effects increase as we go to larger R_L

wake on the away side of the photon. Energy correlators are proving to be a powerful probe of jet substructure in vacuum and its modification in the QGP. We have shown that both projected and full energy correlators are sensitive to jet-medium interactions. We have also shown how higher-point correlators show a unique signature of the wake. This first investigation will benefit from future explorations in other models which implement different jet-medium interactions.

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