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Jet correlations — opportunities and pitfalls

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Abstract

The simplest observables used to probe the interaction of hard partons with a QCD medium in ultra-relativistic heavy-ion collisions measure disappearance, such as the nuclear modification factor R_{AA}. The information content of such observables is however limited. More differential information is obtained from triggered correlation observables where a trigger condition ensures that a hard event has taken place and the correlation of other objects in the event with the trigger contains information about the nature of parton-medium interaction. By construction, triggered correlation observables are conditional probabilities, i.e. they measure events biased by the trigger condition. The presence of this bias makes the interpretation of observables non-intuitive, but at the same time represents an opportunity to design future measurements to selectively probe particular physics. In this work, an overview over the four types of biases occurring in triggered hard correlation observables is given, followed by a study of current jet correlation phenomenology in the light of the preceding discussion.

Keywords: Jet quenching

1. Jet correlations in theory and experiment

The idea underlying the use of hard probes in the context of ultrarelativistic heavy-ion (A–A) collisions is to gain information on both macroscopic (i.e. geometry and evolution) and microscopic (i.e. relevant degrees of freedom) of the droplet of QCD matter produced in such collisions. This is expected to work since the uncertainty relation can be used to argue that the

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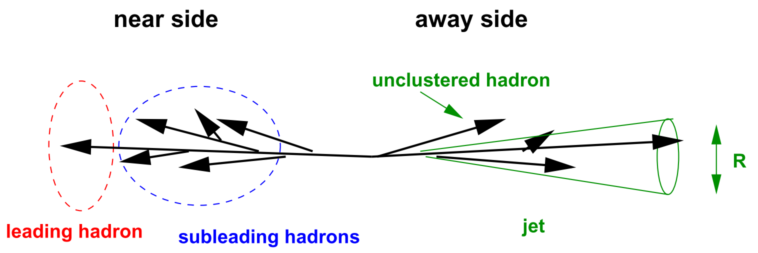

Fig. 1. Sketch of various ways of observing a hard back-to-back event experimentally

hard process itself will take place without influence by the surrounding medium, leaving the interaction with the medium as a final state effect modifying a perturbatively calculable process. In other words, the attenuation pattern of hard partons propagating through the medium can be used to do tomography since the initial production rate of these partons is under control. The simplest class of measurements focuses on disappearance, such as the nuclear modification factor R_{AA} for single hadrons or reconstructed jets. These reveal that the interaction with the medium suppresses high P_T hadrons and jets [1–3], but not much about the underlying mechanism. In order to probe the physics more differentially, other observables offer themselves, cf. Fig. 1.

The basic topology of a hard event consists of two highly virtual partons, approximately back to back, which evolve first in terms of a parton shower while passing through the medium before they hadronize. However, this process needs to be detected and studied on the background of hadrons coming from the medium itself. For this purpose, typically a trigger condition is evaluated to make sure that the transverse momentum P_T scale of the process is above some threshold. The trigger condition can refer to a single hadron (typically the leading hadron of the shower) or a clustering algorithm [4] can be used to combine part of the collimated spray of hadrons into jets. Given a valid trigger, other hadrons in the event can now be correlated and analyzed, both on the trigger (near) side and on the away side, which defines the range of experimentally available correlations (h–h, jet–h, h–jet, ...). Note that also analyses of properties of jets such as the CMS jet shape analysis [5] are technically a triggered correlation analysis and hence a conditional probability — first a jet in the given energy range is found, then given the trigger the near side hadron distribution is evaluated. It is thus important to understand the bias imposed by the respective trigger condition before interpreting any results.

This is in particular crucial in view of the fact that theoretical computations are often done forward in time, i.e. they start with a parton with a defined energy, propagate it through a specified medium and obtain a medium-modified hadron shower which can be clustered into a jet. In contrast, the experimental procedure clusters a final state to a defined energy and one has to conclude backwards in time what the original parton properties might have been. The existence of biases implies that there is no meaningful comparison between the two procedures, the only way to compare theory with experiment is to compute for all possible initial states and simulate how the experimental procedure selects out a particular subgroup of the resulting final states. As Fig. 2 shows, this is not an academic issue — results with and without bias are qualitatively and quantitatively different. In short, a 100 GeV parton (or any fixed energy parton) is not a meaningful representative of an experimentally identified 100 GeV jet.

2. Types of biases

Following the classification in [6], one can distinguish four main types of biases: