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Interplay between hydrodynamics and jets

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Abstract

By combining the jet quenching Monte Carlo JEWEL with a realistic hydrodynamic model for the background we investigate the sensitivity of jet observables to details of the medium model and quantify the influence of the energy and momentum lost by jets on the background evolution. On the level of event averaged source terms the effects are small and are caused mainly by the momentum transfer.

Keywords: Jet quenching; Hydrodynamic evolution

1. Introduction

While properties of soft particles produced in heavy-ion collisions can be understood in a hydrodynamic framework, it is clear that hard particles cannot be in local thermal equilibrium. The interplay between the soft, strongly coupled and the hard, weakly coupled sector gives access to non-trivial QCD dynamics. Different techniques are used to describe these two regimes and there is currently no satisfactory approach allowing for a fully self-consistent description of the entire dynamics in a common framework. Instead, it is common practice to use perturbative techniques for hard probes and hydrodynamics for the soft bulk of the event. The drawback of this approach is that the separation between the soft and the hard regime is to some extent arbitrary and that it is difficult to fully account for the crosstalk between the two regimes. So far the modification of hard probes, particularly jets, due to interactions in the soft background and the resulting jet quenching phenomenology has received more attention than the modification of the bulk evolution. In a recent study [1] we combined the jet quenching Monte Carlo JEWEL

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with a Bjorken boost invariant and azimuthally symmetric viscous hydrodynamic evolution of the bulk to get a realistic estimate of the effect that the passage of jets can have on the soft event.

2. Combining hydrodynamics and jets

On the hydrodynamic side viscous corrections are taken into account in a second order formalism including shear viscosity and the corresponding relaxation time, which take their AdS/CFT values (bulk viscosity is neglected). The equation of state is a parametrisation of a lattice equation of state combined with a hadron resonance gas (s95p-PCE of [2]). The system is assumed to be boost-invariant along the beam axis and to have azimuthal symmetry (corresponding to the most central $b = 0$ collisions). The initial conditions are specified at $\tau = 0.6$ fm following [3], i.e. $T = 485$ MeV in the centre of the collision with a profile in the transverse plane given by a Glauber calculation, $u^r = 0$ and the Navier–Stokes values of the shear stress.

The QCD evolution of jets in the presence of re-scattering in a dense background is simulated with JEWEL [4]. The jet production points are distributed according to the density of binary nucleon–nucleon collisions extracted from a Glauber model [5]. The number of di-jets per event is Poisson distributed. The jet production matrix elements and initial state parton showers are generated with PYTHIA 6 [6] using the EPS09 nuclear pdf sets [7]. In the absence of a medium the final state jet evolution reduces to a standard virtuality ordered parton shower similar to the one in PYTHIA 6 (the main difference is the way the of-shell kinematics is constructed). In the presence of a background medium re-scattering can occur, that can be either elastic or inelastic, i.e. give rise to QCD bremsstrahlung. Re-scattering is described using leading order perturbative $2 \to 2$ scattering matrix elements with radiative corrections being generated by the parton shower. The space–time structure of the parton shower and the interplay between different sources of radiation as well as the destructive LPM-interference are dictated by the formation times of the emissions.

JEWEL has to be provided with information about the background, namely the local density and the momentum distribution of scattering centres. When running with the hydrodynamic medium it takes the local temperature and fluid velocity as input and constructs the parton density and momentum distribution from it assuming an ideal gas equation of state.

As JEWEL is a completely microscopic model it is straightforward to extract the energy–momentum transfer between the jets and the medium in the individual scattering processes,

$$J^\mu(x) = \sum_i \Delta p_i^\mu \delta^{(4)}(x - x_i). \quad (1)$$

This can interpreted as a source term in the hydrodynamic equations. It is convenient to decompose it into components parallel and orthogonal to the fluid velocity u,

$$J_S = u_\nu J^\nu \quad \text{and} \quad J_V^\mu = \Delta^\mu{}_\nu J^\nu, \quad (2)$$

where $\Delta^{\mu\nu} = u^\mu u^\nu + g^{\mu\nu}$. The source term varies from event to event. One possible solution is to solve the hydrodynamic equations event-by-event, which is, however, computationally expensive. We therefore chose to characterise the statistical properties of the source term in terms of n-point functions. Assuming the fluctuations to be Gaussian it is sufficient to specify the event averages

$$\bar{J}_S = \langle J_S(x) \rangle \quad \text{and} \quad \bar{J}_V^\mu = \langle J_V^\mu(x) \rangle \quad (3)$$

and the correlation functions