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Medium Recoils and background subtraction in JEWEL

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Abstract

Jewel is a fully dynamical event generator for jet evolution in a dense QCD medium, which has been validated for multiple jet and jet-like observables. Jet constituents (partons) undergo collisions with thermal partons from the medium, leading to both elastic and radiative energy loss. The recoiling medium scattering centers carry away energy and momentum from the jet. Keeping track of these recoils is essential for the description of intra-jet observables. Since the thermal component of the recoils is part of the soft background activity, comparison with data on jet observables requires the implementation of a background subtraction procedure. We will show two independent procedures through which background subtraction can be performed and discuss the impact of the medium recoil on jet shape observables and jet-background correlations. Keeping track of the medium recoil significantly improves the Jewel description of jet shape measurements.

Keywords: Heavy Ion Monte Carlo generators, Background subtraction, Jet Structure, Jet Mass

1. Introduction

High energetic partons propagating through the quark gluon plasma (QGP) lose energy through elastic, inelastic and radiative processes. One way of studying the complex nature of energy loss is by analyzing the structure of reconstructed jets. Recent measurements of jet substructure in heavy ion collisions highlight several key features of the medium induced modifications. One of the measurements that generated significant discussions in the community is the sub-jet groomed momentum fraction from CMS [1]. Due to the sensitivity of these measurements to medium-jet interactions, they have the potential of differentiate between different theory/MC calculations. In this report, we look at the recent developments to the Jewel [2] heavy ion generator and how a careful treatment of the background and its subtraction, along with a estimation of the systematic uncertainties involved, leads to a better comparison with data and the physics that can be extracted from the results.

2. Medium recoils and background subtraction

Jewel performs the final state medium modified jet evolution on dijet events generated by Pythia6 [3]. The implementation of energy loss in Jewel is through microscopic interactions, both elastic and inelastic with a thermal distribution of scattering centers along with a MC version of the LPM effect [2, 4]. The partons that scatter upon interaction with these scattering centers are known as the recoiled partons. The recoils are a consequence of the medium interaction and once created, they do not undergo further interactions with other scattering centers. Hence one can run Jewel with two modes that correspond to keeping the record of the recoil partons leading to the final state or remove them before hadronization. For jet observables that only depend on

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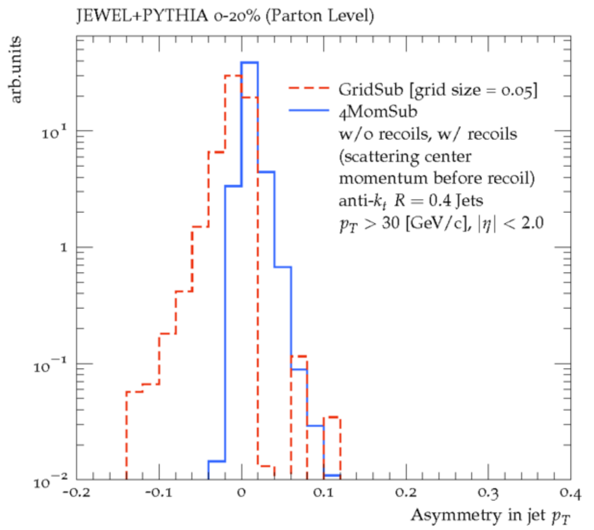

Figure 1: Asymmetry in parton level jet p_T with removal of the recoils compared to background subtraction techniques. The GridSub, in dotted lines is more broader as opposed to the 4MomSub technique shown in solid lines.

overall jet quantities such as transverse momenta (p_T) or the jet axis, it is sufficient to run JEWEL without storing the information of the recoil partons. On the other hand, for observables that depend on the structure of the jet such as the jet mass or profile etc. it is imperative that the recoil information is stored. Here a mismatch arises when comparing observables estimated using JEWEL with recoils to data. This mismatch is a consequence of the systematic removal of the fluctuating heavy ion underlying event in data, whilst in JEWEL the recoil partons still carry with them the thermal component of the scattering centers. It is precisely the momenta of the scattering center before interaction that needs to be subtracted and JEWEL is now capable of storing that information as comments in the HepMC file. In order to remove this background component to the jets in JEWEL, two background subtraction techniques are introduced.

- 4MomSub: Neutral particles with very small momenta that are pointing back to the scattering centers are added to the final state particle list. These dummy particles get clustered to the jet but do not affect the jet itself. Then the dummy particles are matched to the scattering centers in position. The sum of the four-momenta of the matched scattering centers constitute the background of the jet and they are vectorially subtracted from the jet's four momenta.

- GridSub: Similar to the previous method, we have two collections of objects comprising the final state particles (without the dummy particles in this case) and the scattering centers. A finite resolution grid is superimposed on the event and inside each cell, the four momenta of the scattering centers are subtracted from the final state particles that fall inside the grid. Then the jets are clustered using a single four momentum from each cell as input. If a cell turns out to have only scattering centers or if the total p_T of the scattering centers exceeds that of the final state particles, that cell's four momenta is set to zero and it does not participate in the jet clustering.

These background subtraction methods were systematically studied for any biases or smearing they might have on the jet collection and the observable at interest [5]. The routines are implemented in the RIVET [6] analysis framework and jets are reconstructed using the FastJet [7] toolkit with criteria similar to experimental measurements.

3. Systematic studies

As a first validation of the background subtraction, two sets of jets from the same events were compared. At the parton level, JEWEL w/ recoils and background subtraction when compared to JEWEL w/o recoils should yield similar jets if the background subtraction procedure is efficient. The asymmetry in the jet p_T for both the background subtraction procedures is shown in Fig: 1 for mid rapidity jets with $p_T > 30$ [GeV/c]. The red dashed lines represents the GridSub method which is seen to be under-subtraction precisely due to the fact that it doesn't take into account the cells that only contained the scattering centers, along with the smearing imparted to jet due to the finite resolution. The grid size is optimally chosen to be 0.05 in η, ϕ and the systematics are estimated by varying that by a factor of two. The 4MomSub method is shown in the blue solid lines and its not a delta function at zero because the jet area can still increase due to the presence of additional objects in the jet cone. The deviations from zero becomes significantly less likely when the jet p_T is increased. Similar to the detector resolution, GridSub method smears the jet's momenta and the axis, both of which are presented on the top and bottom of Fig: 2. For high p_T jets, the smearing decreases as expected. Due to the nature of the scattering centers being before hadronization, the subtraction procedure is only accurate for full jets. An accurate subtraction for charged jet (and or individual