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Theoretical predictions of jet suppression: A systematic comparison with RHIC and LHC data

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Abstract

Accurate theoretical predictions of jet suppression are necessary for studying the properties of QCD matter created in ultra-relativistic heavy ion collisions. However, testing the prediction accuracy – and extracting useful qualitative knowledge – is often limited by constraining the predictions to only few experimental probes at a time, and by using free parameters. To address this issue, we here summarize comprehensive suppression predictions, which run across all available probes and different centrality regions at RHIC and LHC. These predictions are generated by the finite size dynamical QCD formalism that we previously developed, together with its recent extensions to finite magnetic mass and running coupling; this formalism is integrated into a numerical procedure that uses no free parameters in model testing, and we here briefly review the entire computational procedure. We demonstrate that a very good agreement with the experimental results is obtained across all particle species, for different centrality regions, and for both RHIC and LHC. We will also discuss improved qualitative understanding of the relevant experimental data, which follows from this comprehensive comparison.
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1. Introduction

Jet suppression [1] is considered to be excellent probe of QCD matter. Furthermore, suppression for a number of observables under different experimental conditions has been measured at both RHIC and LHC. Consequently, their systematic comparison with theoretical predictions allows both testing our understanding of QCD matter, and the underlying assumptions used in

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theoretical predictions. However, to generate reliable suppression predictions, one must have reliable calculations of jet energy loss, since the suppression is a consequence of the energy loss of energetic partons that move through the plasma [2–4]. Having this in mind, over the past several years we developed a dynamical energy loss formalism, which removes the widely used assumption of static scattering centers, and calculates parton radiative [5,6] and collisional [7] energy loss within the same theoretical framework. We further integrated this energy loss into numerical procedure for jet suppression calculations, which enables generating a wide set of suppression predictions for different experiments, observables and collision centralities. In this proceedings, we first provide a brief overview of the dynamical energy loss and numerical procedure used in our suppression calculations, and then summarize a comprehensive comparison of generated predictions with the available experimental data from both RHIC and LHC, in order to test how well our model describes the underlying medium created in these collisions. Note that only the main results are presented in this proceedings, while for more details please refer to [8–10].

2. Jet suppression predictions

The dynamical energy loss formalism that we developed, calculates the jet radiative and collisional energy loss in a finite size QCD medium of thermally distributed light quarks and gluons (for more details see [5–7]). To calculate the energy loss we used the hard thermal loop approach (see e.g. [11]), which allowed removing the assumption of static scattering centers [12]. We recently extended the formalism to the case of finite magnetic mass [13], and most recently we included running coupling [8]. To generate suppression predictions, we incorporated this formalism into a numerical procedure (for more details see [8,10]), which also includes light [14] and heavy flavor [15] production, path-length [16,17] and multi-gluon [18] fluctuations, fragmentation for light [19] and heavy flavor [20,21] and, in the case of heavy mesons, their decays to single electrons and J/ψ [15]. As a starting point in our calculations, for LHC we used effective temperature of 304 MeV [22] as extracted by ALICE, and for RHIC we used 221 MeV [23] as extracted by PHENIX. All other parameters correspond to standard literature values, and are provided in [8,10].

We next concentrate on RHIC and LHC data, and our goal is to generate a comprehensive set of joint predictions for all available light and heavy flavor suppression measurements. Within this, our goal is to test how our model works for different probes, experiments and centrality regions. Note that all predictions are generated by the same (above outlined) formalism, with the same numerical procedure, and with no free parameters used in model testing. Also, note that on each figure gray regions correspond to finite magnetic mass case [29,30] (i.e. $0.4 < \mu_M/\mu_E < 0.6$), where the lower boundary corresponds to $\mu_M/\mu_E = 0.4$ and the upper boundary corresponds to $\mu_M/\mu_E = 0.6$.

In Fig. 1,we show the predictions for central collisions at LHC, which are, as pointed above, generated for a diverse probes, for which LHC measurements are available. Specifically, we generate predictions and compare them with experimental data for charged hadrons, D mesons, non-photonic single electrons and non-prompt J/ψ. We see that we obtain an excellent agreement for charged hadrons and D mesons. We see that the single electron data are quite noisy, but we still obtain a very good agreement with the predictions. There is also a good agreement for non-prompt J/ψ, except for the last datapoint, which comes with large error bars.

In Fig. 2, we test how our model works for RHIC central-collision data, since it is known that the suppression data at RHIC lead to a well-known heavy flavor puzzle at RHIC; that is, the previous static energy loss models were not able to explain these data. However, from this figure,

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