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Probing transverse momentum broadening via dihadron and hadron-jet angular decorrelations

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Abstract

In the recent paper [1], we carry out the numerical calculations for back-to-back dihadron and hadron-jet angular correlations within the Sudakov resummation framework. This framework allows us to compute transverse momentum broadening and away-side angular correlations in pp collisions for the first time and use it as the baseline to study the medium effects in AA collisions. It paves the way for the quantitative study of jet-medium interaction and the transport properties of QGP. This proceeding is mainly a brief summary of that paper.

Keywords:
jet quenching, angular correlation, Sudakov resummation, jet transport parameter

1. Introduction

In high energy heavy-ion collisions, there have been a lot of experimental evidences for the formation of the strongly coupled quark-gluon-plasma (sQGP). Jets, that are produced in the hard collisions, interact with the medium and get modified while they propagate through the sQGP. This is the well-known jet-quenching phenomenon which has provided an important tool to probe the transport properties of the hot QCD matter.

In jet quenching study, jet energy loss and transverse momentum broadening are two important effects that quantify the interaction between the jets and the medium. According to the BDMPS approach, these two effects are actually two faces of the same coin. Both are related to the so-called jet transport parameter $\hat{q}$, which can be interpreted as the transverse momentum square transferred between the jet and the medium per unit length. This makes $\hat{q}$ one of the most important parameters in the study of jet-medium interaction and in the description of the properties of QGP.

In [2], JET collaboration has extracted the $\hat{q}$ through single hadron suppression factor R_{AA} measured in the experiments at RHIC and the LHC. From the jet energy loss side, this is one of the most important theoretical development in the study of jet quenching. On the other hand, the back-to-back angular decorrelation due to the transverse momentum broadening induced by the medium serves as a new gateway to quantitatively study the jet-medium interactions. However, the theoretical study along this direction is still lacking. In this work, we present the first systematic study on this issue.

This proceeding is organized as following. In Sec. II, we discuss the Sudakov resummation framework to study the back-to-back angular correlations. In Sec. III, we present the numerical results for dihadron and hadron-jet angular correlations in pp and AA collisions. In Sec. IV, we present our summary.

2. Sudakov resummation

It is well known that for back-to-back dijet angular correlations, the perturbative expansion starts to oscillate at the region where $\Delta\phi$ is close to π, as shown in Fig. 1. The underlying reason for this oscillation is due to the alternating signs of large double logarithms arising from soft gluon radiations. To mitigate this oscillation and to describe the experimental data on angular correlations at $\Delta\phi$ around π region, we need to resum

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these large logarithms to all orders. This is the so-called Sudakov resummation framework. In the past decades, the Sudakov resummation has been widely used in the SIDIS and Drell-Yan processes. In hadronic collisions, it has also been derived for the Higgs or heavy boson production. For dijet production in pp collisions, the formalism was recently derived in [4, 5], since the situation is much more complicated.

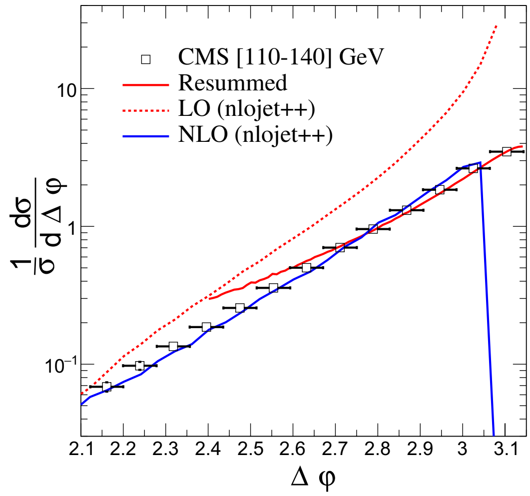

Figure 1: Normalized dijet angular correlation comparing with the CMS data [3]. Experimental configurations: $\sqrt{s}$ = 7 TeV; 110 < $p_{\perp 1}$ < 140 GeV; $p_{\perp 2}$ > 30 GeV; $|y|$ < 1.1; R = 0.5. The leading order and next-to-leading order results are calculated with the nlojet++ program [6, 7] in [8].

The formalism of the Sudakov resummation can be easily extended to dihadron and hadron-jet productions (angular correlations). The complete description of the formalism can be found in [1]. In this proceeding, we will mainly focus on the concepts and try to present the physical pictures.

The Sudakov resummation resums large double logarithms arising from $2 \to 2 + n$ process with n soft gluons, where n is an arbitrary number. It corresponds to the parton shower in many event generators, such as PYTHIA. The physical origin of Sudakov resummation for initial state radiation is similar to the inertia effect. For the incoming colored partons, the directions of their core momenta are changed due to the hard collision, while the gluon cloud may still move along the beam direction due to its inertia. Therefore the dressed partons which carry small energy and small transverse momentum are forced to radiate. The Sudakov factor for the final state radiation is similar to the initial state radiation for hadron production; for jet production, only the gluon radiation outside jet cone matters.

In AA collisions, in addition to the vacuum parton shower which can contribute to the angular decorrelation, there also exists the transverse momentum broadening effect induced by the medium. The transverse momentum broadening in the medium could arise from the tree level elastic scattering and medium induced gluon radiation. Since the vacuum parton shower and the medium induced gluon radiation come from different phase spaces [9], their effects on the transverse momentum broadening can be separated, i.e., there is no interference between these two effects.

Thereafter, we can write the effective Sudakov factor in AA collisions by combining the vacuum Sudakov factor in vacuum and the medium broadening factor in the coordinate space [9, 10]:

$$S_{AA}(Q, b_\perp) = S_{\text{vacuum}}(Q, b_\perp) + \frac{1}{4}\langle \hat{q}L\rangle b_\perp^2. \tag{1}$$

Here, $\langle \hat{q}L\rangle$ is the averaged (or typical) transverse momentum broadening square in the transverse plane induced by the medium.

By comparing with the experimental data, we can extract the value of $\langle \hat{q}L\rangle$. This value characterizes the jet-medium interaction in a model independent way. One can also take into account the collision geometry and the evaluation of the medium, to extract the value of $\hat{q}_0$ (which is the value of $\hat{q}$ at the initial temperature T_0). We would like to note here that this will introduce model dependence since different groups give different parameterizations of $\hat{q}$. Also, since the p_T broadening effect arises from both tree level elastic scattering and medium induced gluon radiation, the parameterization should be different with the tree level parameterizations which are usually used in various jet energy loss models.

3. Numerical results

Based on the above discussion, we can perform the numerical calculation in the Sudakov resummation framework for dihadron (Fig. 2) and hadron-jet (Fig. 3) angular correlations in both pp and AA collisions.

In the pp collisions, our results nicely describe the experimental data. This is for the first time that the baselines are established from the theoretical calculation and allows us to study the transverse momentum broadening effect in the AA collisions. Despite the large error bars for the experimental data, we can still see a clear tendency that the curves in the AA collisions are flatter comparing to those in the pp collisions.

We can also see from Fig. 3 that the low energy hadron-jet angular correlations from low energy RHIC collisions are more sensitive to the medium effect. This