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The effect of jet-induced medium excitation on Λ/k_s^0 in jet in Pb-Pb collisions

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Abstract

We use CoLBT-hydro model for simultaneous event-by-event simulations of jet propagation and hydrodynamics evolution of the bulk medium including jet-induced medium excitation. The final reconstructed jet in heavy-ion collision include not only hadrons from medium response for the deposited energy and momentum of hard partons, but also hadrons from the fragmentation and recombination process of in-medium hard partons. We carry out the study with CoLBT-hydro of medium modification of the Λ/k_s^0 in jet in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. We qualitatively describe the enhancement of the Λ/k_s^0 ratio in jet in the intermediate p_T region due to the contribution from jet-induced medium flow.

Keywords: jet-induced medium excitation, baryon-to-meson ratio, CoLBT-hydro model

1. Introduction

Jets are reconstructed from a collimated cluster of hadrons within a given cone-size in experimental measurement. In heavy-ion collisions, the final jet is not only modified by parton energy loss of leading partons but also is influenced by the redistribution of the lost energy and momentum from jet partons in the medium through induced gluon, rescattering and jet-induced medium excitation, maybe in the form of recoil particles or induced additional flow. It is therefore important to include the effect of recoil partons and their further propagation in the form of jet-induced medium response as well as the propagation of radiated gluons in the study of jet suppression and medium modification. Many recent research suggests that the effect of medium response on jet-related observables can't be neglected, and important especially in the description of jet-hadron based substructure observables, such as jet shape, jet fragmentation function, jet-hadron correlation and dijet missing p_T[1, 2].

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In addition, an increased baryon-to-meson production ratio at intermediate p_T in heavy-ion collisions when compared to pp collisions, has been observed at RHIC and the LHC. This effect is usually explained as a consequence of of a strong radial flow during the medium evolution, or by the coalescence of constituent quarks during QGP hadronization. One might expect a larger baryon-to-meson ratio at intermediate p_T in the modified jet in heavy ion collision due to the contribution of hadrons at low and intermediate p_T from jet-induced flow or the coalescence of quenched partons. So baryon-to-meson ratio in jet has potential to be a good observables to study the effect of medium responcs inside jet.

The paper is organized as follows. First, we will give a brief introduction of the framework and main features of the CoLBT-hydro model. Then on the basis of the model, we carry out the study of the Λ/k_s^0 ratio in jet in heavy-ion collisions, and shows the effect of jet-induced medium excitation on it compared to the corresponding p-p results.

2. CoLBT-hydro model

The CoLBT-hydro model [2] is typical jet transport model plus hydrodynamical model,in which Linear Boltzmann Transport(LBT) model [3] for jet propagation is coupled to (3+1)D relativistic hydrodynamics[4, 5] for bulk medium evolution in real time. It combines the pQCD approach for the propagation of energetic jet shower partons with the hydrodynamic evolution of the strongly coupled QGP medium, including j.i.m.e.. The main feature of the model is the ability to describe jet-medium interaction concurrently with considering the effect of the updated medium on the further propagation of hard partons. The whole frame of the CoLBT-hydro model is carried out at the Milne coordinates (τ, x, y, η_s) where $\tau = \sqrt{t^2 - z^2}$ and $\eta_s = \frac{1}{2}\ln(\frac{t+z}{t-z})$ are the proper time and the space-time rapidity.

At any given time τ, energetic partons including jet shower partons and thermal recoil partons are judged whether to take part in the processes of collision and gluon-radiation on the basis of the bulk medium information, such as temperature T and flow velocity u distribution provided by 3+1D hydrodynamic model. To preserve energy-momentum conservation in each scattering, "negative" partons are introduced with inverse energy and momentum of initial thermal partons, which are sampled out according to the local thermal distribution. These negative partons($p \cdot u < 0$), the final thermal partons and radiated gluons with the energy in local rest frame below the threshold value ($p \cdot u < p^0_{cut}$), as part of the lost energy and momentum from the initial hard partons, are deposited into the medium. The deposition process into the medium can be expressed by

$$\partial_\mu T^{\mu\nu} = J^\nu, \tag{1}$$

the source term J^ν, which specifies how much lost energy and momentum are deposited into medium, can be expressed by

$$J^\nu = \sum_i \frac{\theta(p^0_{cut} - p_i \cdot u)p_i^\nu/\Delta\tau}{\tau(2\pi)^{3/2}\sigma_r^2\sigma_{\eta_s}} \exp[-\frac{(\vec{x}_\perp - \vec{x}_{\perp i})^2}{2\sigma_r^2} - \frac{(\eta_s - \eta_{si})^2}{2\sigma_{\eta_s}^2}], \tag{2}$$

with a Gaussian smearing in Milne coordinates. Both of the Gaussian half width σ_r and σ_{η_s} have a value of 0.2. The tunable parameter p^0_{cut} is generally taken 2.0 GeV/c unless specifically stated. Here we make an assumption of instantaneous local thermalization of deposited energy and momentum and neglect the causality problem caused by it. Then the updated bulk medium information at the time $\tau+\Delta\tau$ can be obtained by solving the hydrodynamic equations with source terms numerically,while hard partons still simulated in LBT model propagate along the classical trajectory until the time $\tau+\Delta\tau$. We iterate this process until the end of hydrodynamic evolution, when the maximum value of the local temperature in the system drops below $T_{fo} = 137$ MeV.

3. Λ/k_s^0 ratio in jet

We use Pythia8 [6] to calculate Λ/k_s^0 ratio in inclusive jets with cone-size R=0.2 as a function of associated hadrons p_T for p-p collision at $\sqrt{s_{NN}}$=2.76 TeV, and also check the dependence of Λ/k_s^0 ratio on collision energy($\sqrt{s_{NN}}$=7, 13 TeV) and jet cone-size (R=0.2, 0.4). Shown in Fig.1, the Λ/k_s^0 ratio from

Pythia8 shows less denpendence on the collision energy and jet cone-size, compared with the measurement from ALICE in which the Λ/k_s^0 ratio increases with the collision energy and jet cone-size. But the Pythia8 results can describe well the trend of the Λ/k_s^0 ratio in the whole hadron p_T region, which reaches the maximum value around hadron p_T ≈4.5 GeV/c.

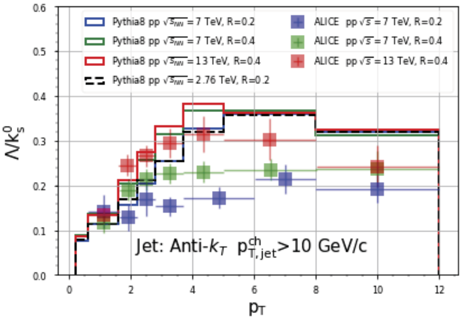

Fig. 1. The Λ/k_s^0 ratio in inclusive jets with different jet cone-size (R=0.2,0.4) as a function of associated hadrons p_T for p-p collision at different collision energy ($\sqrt{s_{NN}}$=2.76, 7 and 13 TeV)

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Then we use Pythia8 to generate initial jet shower partons for inclusive-jet events for Pb-Pb collisions. The produced position of the initial jet is sampled according to the spatial distribution of binary hard processes from the same AMPT event [7] that provides the initial energy density distribution for the bulk medium evolution. We assign a formation time $\tau_0 \approx 2k_0/k_T^2$ for each of the initially produced jet shower partons before which the partons is assumed to free-stream without interaction with medium partons. To obtain the final hadron spectrum in Pb-Pb collisions, we employ the parton recombination model [8] developed within the JET Collaboration for the hadronization processes of hard partons throughout the medium in the simulation of LBT model, and Cooper-Frye formula [9] to get soft hadrons from the bulk medium. All final-state particles with the transverse momentum $p_T > 150$ MeV/c and the pseudo-rapidity $|\eta| < 0.9$ are used for the jet reconstruction with the anti-k_T algorithm.

Due to the model limitation, we just try to give a qualitative description for Λ/k_s^0 ratio in jets in Pb-Pb collisions. Because jet-induced medium flow, which can be considered as a kind of collective behavior, is in the simulation of hydrodynamic model. And it is still strongly affected by the strong background radial flow. We make a assumption that the Λ/k_s^0 ratio in jet from jet-induced medium flow is the same with that in background medium. On the other side, we make another assumption that the Λ/k_s^0 ratio in hadrons from jet fragmentation processes in Pb-Pb collisions is the same with Λ/k_s^0 in jet in p-p collisions. Shown in Fig.2 is the Λ/k_s^0 ratio in jets in p-p and Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, compared with ALICE measurement. One can see that the Λ/k_s^0 ratio in jet is enhanced in the intermediate p_T region (1< p_T <3.5 GeV/c) due to the contribution from jet-induce medium flow, in which the Λ/k_s^0 is much larger than that from the jet fragmentation processes. But our results can't describe the ALICE data quantitatively. That may be caused by two reasons: One is that the Λ/k_s^0 ratio in jet as p-p reference is larger than experimental data at intermediate p_T region. The other is due to the assumption that the Λ/k_s^0 ratio in jet from jet fragmentation is the same with that in p-p collision. It is not valid for small and intermediate p_T region. The hadronization mechanism for hadrons in this region is dominated by coalescence instead of fragmentation processes. It will results in further enhancement of the Λ/k_s^0 ratio in the small and intermediate p_T region.

4. Summary

We use CoLBT-hydro model to calculate the Λ/k_s^0 ratio in jet in p-p and Pb-Pb collisions with two assumptions, due to model constrains. Our result qualitatively describes the experimental phenomena of the

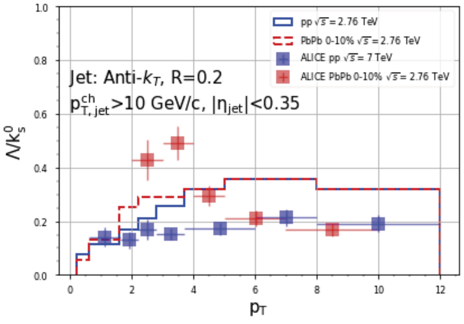

Fig. 2. The Λ/k_s^0 ratio in jet as a function of hadron p_T in p-p and Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV. Jets are reconstructed with jet cone-size R=0.2, p_T >10 GeV/c and pseudo-rapidity $|\eta_{jet}|$ <0.35.

enhancement of the Λ/k_s^0 ratio in jet in the intermediate p_T region due to the contribution from jet-induced medium flow. The enhancement of the Λ/k_s^0 ratio in jet in Pb-Pb collisions may causes by two factors: the larger baryon-to-meson ratio in jet-induced medium flow and the suppressed baryon-to-meson ratio from jet fragmentation in Pb-Pb collisions due to the modification of the fraction of quark jets to gluon jets.So it means that Λ/k_s^0 with other baryon-to meson ratio in jet have potential to be a observable to study the medium response. It can also provide a way to constrain the cut-off parameters which distinguish the soft and hard partons in the simulation.

5. Acknoledgement

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