Exploring the specific shear viscosity (η/s) of quark-gluon plasma using the high $p_\perp$ observables

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Introduction

Quark gluon plasma (QGP) is a thermalized color deconfined QCD matter created at extreme conditions such as very high temperature and/or density in ultra relativistic heavy-ion collisions. Successful production of this novel state of matter in Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) allowed systematic testing of different models of QGP evolution with experimental data. The formation of QGP has been confirmed at the LHC and RHIC experiments by comparison of low momentum ($p_\perp$) measurements with relativistic hydrodynamic predictions, and, by comparison of high $p_\perp$ data with pQCD predictions. While high $p_\perp$ physics had a decisive role in the QGP discovery, it was rarely used for understanding the bulk properties. On the other hand, with a proper description of high $p_\perp$ parton-medium interactions, high $p_\perp$ probes become also powerful tomography tools, since they are sensitive to global QGP features, such as different temperature profiles or initial conditions. Further, the low $p_\perp$ observables do not put strict constraints to all the parameters of the models used to describe the evolution of QGP, leaving some properties of QGP badly constrained. Therefore, high $p_\perp$ observables can be used to improve the constraints to the parameters, complementing the low $p_\perp$ ones. In this work, we perform analysis to determine if the high $p_\perp$ observables can distinguish the specific shear viscosity (η/s) of the system. We use '$\mathrm{T_RENTo}$' (Reduced Thickness Event-by-event Nuclear Topology) framework to generate event-by-event initial profiles, evolve the fluid with $(2+1)$-dimensional viscous hydrodynamics code 'VISH2+1'. The EoS is based on the lattice results by the HotQCD collaboration [1] at high temperature and hadron resonance gas equation of state at low temperature. The particlization is performed using Cooper-Frye prescription, and finally, we use 'UrQMD' (Ultra-relativistic Quantum Molecular Dynamics) hadronic afterburner to produce the low $p_\perp$ observables. To achieve the goal of utilizing high $p_\perp$ theory and data for inferring the bulk properties of QGP, a reliable high $p_\perp$ parton energy loss model is necessary. With this goal in mind, a dynamical energy loss formalism has been developed. This formalism is based on finite size, finite temperature field theory and takes into account that QGP constituents are dynamical particles. Both collisional and radiative energy losses are calculated in the same theoretical framework. Finally, this formalism is integrated in a numerical framework 'DREENA' (Dynamical Radiative and Elastic ENergy loss Approach) [2]. This has been used to compute the high $p_\perp$ observables.

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Acknowledgments

This work is supported by the European research council (ERC) 2016 Consolidation grant, ERC-2016-COG: 725741: QGP TOMOGRAPHY.

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