Imprinting Quantum Fluctuations on Hydrodynamic Initial Conditions

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Abstract

Starting from the two-point covariance function derived in [1], we have developed a toy model to investigate the effect of gluonic fluctuations on the transverse energy profile predicted by Color-Glass Condensate initial conditions. We find that the effect of these fluctuations on the eccentricity harmonics ϵ_n varies strongly with the correlation length and consequently the value of the fixed saturation momentum Q_s used in the Müller-Schäfer calculation. Using approximate values for the minimum and maximum saturation momenta probed at RHIC in central Au-Au collisions, we estimate the increase in the eccentricity coefficients resulting from gluonic fluctuations is of order $10 - 20\%$ at RHIC in central collisions.

1. Introduction

Hybrid models, which couple viscous hydrodynamics to a Boltzmann cascade, have been highly successfully in describing collective flow properties of the quark-gluon plasma (QGP) and subsequent hadron resonance gas produced in relativistic heavy-ion collisions. The success of these simulations has generated accute interest in the hydrodynamic transport properties of the produced medium, specifically the QGP shear viscosity to entropy ratio η/s. Phenomenological extractions of η/s typically exploit the one-to-one mapping $\epsilon_n \leftrightarrow v_n$ between the initial state eccentricity harmonics ϵ_n characterized by,

$$\epsilon_n e^{in\Phi_n} = -\frac{\int r\,dr\,d\phi\,r^2\,e^{in\phi}\rho(r,\phi)}{\int r\,dr\,d\phi\,e^{in\phi}\,\rho(r,\phi)} \tag{1}$$

and the final state azimuthal flow harmonics v_n characterized by,

$$v_n e^{in\Psi_n} = \frac{\int p_T\,dp_T\,d\phi_p\,e^{in\phi_p}\frac{dN_{ch}}{d\eta p_T dp_T d\phi_p}}{\int p_T\,dp_T\,d\phi_p\frac{dN_{ch}}{d\eta p_T dp_T d\phi_p}} \tag{2}$$

Uncertainties in the models used to compute the initial state eccentricity coefficients ϵ_n are currently the largest source of error in phenomenological extractions of η/s, and stricter constraints on η/s require more more realistic descriptions of the initial state geometry.

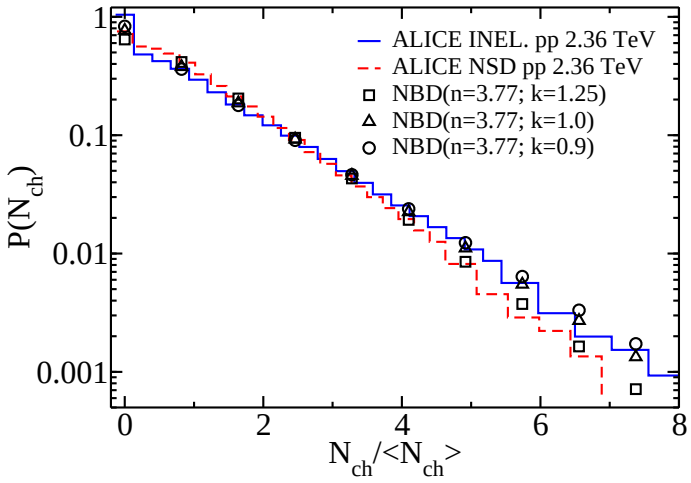
2. Event-by-event fluctuations

The importance of event-by-event fluctuations in the distribution of participant nucleons was first pointed out by Miller and Snellings.These fluctuations correctly explained the existence of odd flow harmonics v_{2n+1} and the

non-vanishing anisotropic flow detected in central Cu-Cu and Au-Au collisions $v_n|_{b=0} > 0$.

Consideration of the complete set of flow harmonics $\{v_2, ..., v_n\}$ is important to accurately extract the QGP shear viscosity, as for fixed η/s the flow harmonics v_n are uniquely determined from the eccentricity harmonics ϵ_n characterizing the initial state. Thus it is a necessary condition that hybrid simulations using a certain initial state model recreate not just, for example, the elliptic flow v_2, but also the the relative scaling of the anisotropic flow harmonics.

3. From nucleonic to sub-nucleonic fluctuations



4. Generating a toy model for transverse gluonic field fluctuations using the Müller-Schäfer Covariance

5. Results and Conclusions