# Legendre expansion of longitudinal two-particle correlations

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One of the most remarkable findings regarding high-energy heavy ion colliders is the fluidity of the quark-gluon plasma (QGP), which is supported by the fact that the anisotropy of azimuthal momentum distribution, characterized by the Fourier coefficients $v_n$, is large compared with that of the geometrical shape of the produced medium. Thus far, numerous efforts have been made to understand the transverse dynamics of the QGP by introducing event-by-event fluctuations as well as off-equilibrium corrections.

However, the longitudinal dynamics has not been throughly investigated. The isotropization mechanism in a heavy-ion system is not fully understood, and no direct experimental evidence for the fluidity of the QCD medium in the longitudinal direction has been found yet.

In this study, we extend the (3+1)-dimensional viscous hydrodynamic model MUSIC[1)] to finite baryon density and introduce more realistic setups to study the forward rapidity dynamics. For longitudinally and transversely fluctuating initial conditions, the Monte-Carlo Glauber model is extended to three dimensions by introducing a variation of the Lexus model,[2)] where the modification of the rapidity distribution of the valence quarks after each sub-collision is taken into account to calculate the net baryon distribution. The modification is controlled by the kernel

$$Q(y - y_P, y_P - y_T, y - y_P) = \lambda \frac{\cosh(y - y_P)}{\sinh(y_P - y_T)} + (1-\lambda)\delta(y - y_P), \quad (1)$$

where $y$ is the rapidity and the subscripts $T$ and $P$ denote target and projectile, respectively. $\lambda$ is a parameter to be determined experimentally. The entropy distribution is obtained by depositing entropy between the last sub-collision pairs. The finite-density equation of state is constructed by interpolating those of hadron resonance gas and lattice QCD, where the latter is obtained in the Taylor expansion method, at a connecting temperature near the crossover. Relaxation-type equations derived from the kinetic theory are employed as the viscous hydrodynamic equations.

We probe the longitudinal properties of the QGP in hydrodynamics by decomposing the two-particle rapidity correlation into Legendre polynomials, which have recently been measured at the ATLAS Collaboration at the CERN Large Hadron Collider,[3)]

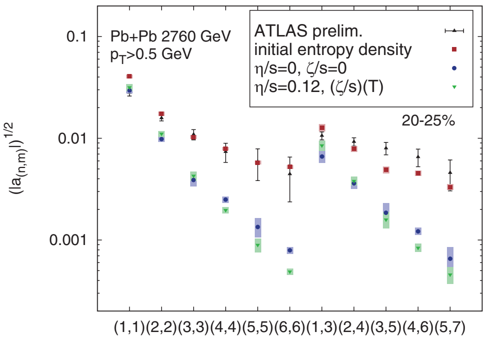


Fig. 1. (Color online) Calculations of $\sqrt{|a_{n,m}|}$ compared with experimental data.

$$a_{n,m} = \int C_N(\eta_1, \eta_2) \times \frac{T_n(\eta_1)T_m(\eta_2) + T_n(\eta_2)T_m(\eta_1)}{2} \frac{d\eta_1}{Y}\frac{d\eta_2}{Y}, \quad (2)$$

where $T_n(\eta_p) = \sqrt{n+1/2}P_n(\eta_p/Y)$ is the scaled Legendre polynomial and $C_N$ is the two-particle correlation defined as

$$C_N(\eta_1, \eta_2) = \frac{C(\eta_1, \eta_2)}{C_p(\eta_1)C_p(\eta_2)}, \quad (3)$$

$$C_p(\eta_1/2) = \frac{1}{2Y}\int_{-Y}^{Y} C(\eta_1, \eta_2) d\eta_{2/1}, \quad (4)$$

to remove the effects of residual centrality dependence. Note that a good analogy can be made between this quantity and the transverse flow harmonics $v_n$.

Figure 1 shows $\sqrt{|a_{n,m}|}$ before and after the hydrodynamic evolution of Pb-Pb collisions at 2.76 TeV for 20-25% centrality. As shown, the hydrodynamic result is close to the LHC data at $n = 1$ but has stronger $n$ dependence. The hydrodynamic evolution tends to smear out short range correlations more efficiently. Viscous effects are small. The Legendre coefficients of the initial entropy distribution appear to agree with the data, but the estimations at different centralities indicate that this is a coincidence. This disagreement may be due to the lack of post-hydrodynamic treatments. Our recent calculations suggest that they agree with experimental data when short range correlations from resonance decays are considered.[4)]

References
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