Fluctuating Glasma initial condition for heavy ion collisions.

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Introduction

We present a model of fluctuating initial conditions for heavy ion collision based on the *ab initio* color glass condensate (CGC) framework. Initial nuclear color charge distributions are obtained from the IP-Sat parameterization constrained by HERA data. The early time classical "Glasma" fields are computed by solving Classical Yang-Mills (CYM) equations. The model includes quantum fluctuations on length scales smaller than the nucleon size, given by the inverse nuclear saturation scale. Soft modes ($k_T < Q_s$) are treated in a more appropriate way than in other CGC models based on factorization schemes. The model naturally produces initial energy densities and gluon multiplicities whose fluctuations are described by convolution of negative binomial distributions. We present first computations of observable particle spectra and flow harmonics $v_n(p_T)$, obtained by matching the solution to the CYM equations to a relativistic viscous hydrodynamic model, and compare to results obtained using other models for the initial state. The resulting ratio of triangular to elliptic flow is compatible with experimental observations, as opposed to previous CGC based models (KLN).

IP-Glasma Model

The IP-Glasma model introduced in ref. [1] calculates event-by-event initial energy distribution for heavy ion collision at a time τ by solving CYM equations in 2+1 dimensions. Nucleon positions are sampled for two colliding nuclei from a Fermi distribution. A Gaussian color charge density with width $g^2\mu^2(x, \mathbf{b}_\perp)$, proportional to the nucleon saturation scale $Q^2_{s,(p)}(x, \mathbf{b}_\perp)$ as obtained from the IP-Sat model is added for each nucleon. The nuclear color charge distribution $g^2\mu^2_A(x, \mathbf{b}_\perp)$ is obtained by summing individual nucleon $g^2\mu^2$. The final Gaussian sampled color charge distribution $\rho^a(\mathbf{x}_\perp)$ gives rise to the color current $J^\nu = \delta^{\nu\pm}\rho_{A(B)}(x^\mp, \mathbf{x}_\perp)$ generated by nucleus A(B) moving along the $x^+(x^-)$ direction. The classical gluon fields inside the nuclei due to these color currents are obtained by solving the classical Yang-Mills equation $[D_\mu, F^{\mu\nu}] = J^\nu$. The components of Glasma fields after collision can be expressed in terms of individual gluon fields of the colliding nuclei. Energy densities and initial gluon multiplicities at time τ can be computed by CYM evolution of the components of the Glasma gluon fields. The event-by-event Glasma distribution can be matched to viscous relativistic hydrodynamic model.

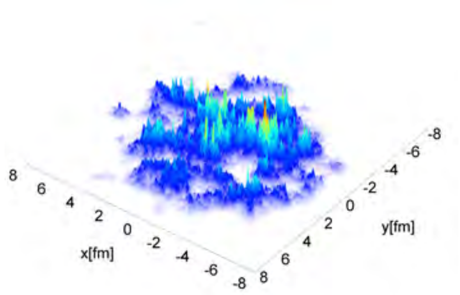

FIG. 1: Energy density (arbitrary units) in the transverse plane at $\tau = 0\,\text{fm}$.

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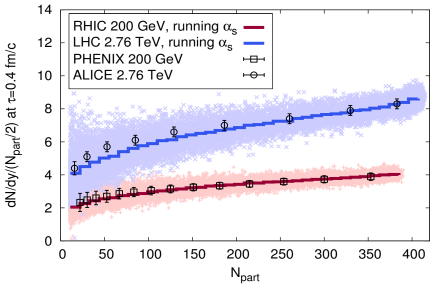

FIG. 2: The pale blue and red bands are a collection of the multiplicities for individual events, with the solid lines representing the average multiplicity.

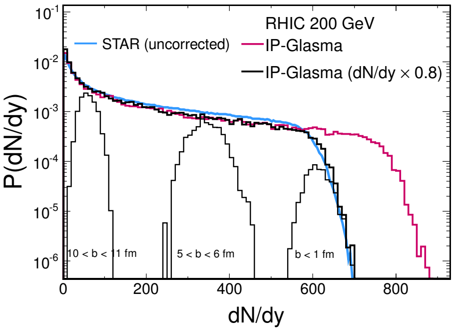

FIG. 3: Probability distribution of gluon multiplicities dN/dy at $\tau = 0.4\,\text{fm}/c$.

Results

Fig. 1 shows the energy density in the transverse plane after the collision, at time $\tau = 0\,\text{fm}$. The Gluon multiplicity per participants at $\tau = 0.4\,\text{fm}/c$ times 2/3 compared to experimental data for $\sqrt{s} = 200\,\text{GeV}$ Au+Au and $\sqrt{s} = 2.76\,\text{TeV}$ Pb+Pb collisions as a function of N_{part} is shown in fig. 2. The probability distribution of the total gluon multiplicity distribution can be obtained by weighting the probability of the event depending on the impact parameter of the collision according to an eikonal model. The resulting distribution as shown in fig. 3 is found to be a convolution of negative-binomial distribution as predicted by the original Glasma flux tube picture. The Glasma NBD distribution has been shown to provide good fit to multiplicity distributions for p + p and A + A data over RHIC and LHC energies[3]. In Fig. 4 we present results for anisotropic flow of thermal pions after evolution using MUSIC [4] with boost-invariant initial conditions and shear viscosity to entropy density ratio $\eta/s = 0.08$. Predictions from the present calculations are compared to MC-KLN and MC-Glauber models. Differences in $v_2(p_T)$ and $v_3(p_T)$ are as expected from the initial eccentricities of the different models.

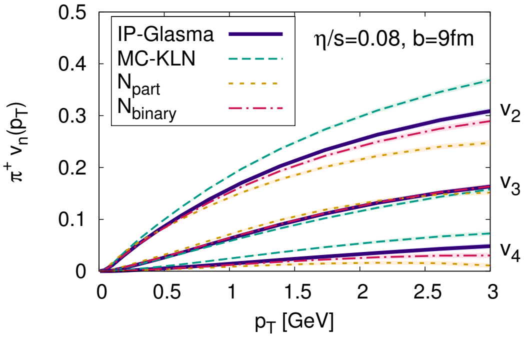

FIG. 4: Thermal π^+ anisotropic flow coefficients v_2, v_3, and v_4 as functions of p_T from our model compared to MC-KLN and MC-Glauber model.

Summary

We present a model for initial condition of heavy ion collisions that includes various sources of quantum fluctuations on an event-by-event basis. This model naturally produces fluctuations of initial energy densities and gluon multiplicities that are described by convolutions of negative binomial distributions and produces mean multiplicity and flow harmonics compatible with experimental data.

References

[1] B. Schenke, P. Tribedy, and R. Venugopalan, **Phys. Rev. Lett. 108, 252301** (2012)

[2] B. Schenke, P. Tribedy, and R. Venugopalan, **arXiv:1206.6805**, submitted to PRC.

[3] P. Tribedy and R. Venugopalan, **Nucl.Phys. A850** (2011), **Phys. Lett. B 710** (2012).

[4] B. Schenke, S. Jeon, and C. Gale, **Phys. Rev. Lett. 106, 042301** (2011).