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Monte Carlo Glauber Modeling of Initial State Anisotropies in Ultrarelativistic Heavy-ion Collisions

In ultrarelativistic heavy-ion collisions performed at the Relativistic Heavy Ion Collider (RHIC) and Large Hadron Collider (LHC) significant azimuthal momentum distribution anisotropies have been measured (1). These anisotropies can be explained with relativistic hydrodynamics: the initially produced QCD-matter contains spatial anisotropies and during the hydrodynamical evolution these anisotropies are transferred to the momentum distributions of final state particles.

Simulations with viscous hydrodynamics have shown that the shear viscosity of the quark-gluon plasma produced in ultrarelativistic heavy-ion collisions can be estimated from the final state momentum anisotropies. Since the origin of these anisotropies is in the initial state, uncertainties related to the initial state must be charted before reliable estimates for the QCD-matter viscosity can be made. In this work (2) we consider two sources of uncertainties related to the Monte Carlo Glauber (MCG) model which is often used to initialize the hydrodynamical simulations (see *e.g.* (3)).

In the MCG modeling one needs to know the positions of the initial state nucleon configurations. An example of a MCG event is shown in Fig. 1. In most cases the nucleon positions inside the colliding nuclei are just sampled using the Woods-Saxon potential, neglecting nucleon-nucleon correlations (4). In (5, 6) a method for producing realistically correlated configurations was introduced and here we study the effects of such correlations on initial anisotropies.

In each simulated event, given the impact parameter of the $A+A$ collision, the nucleon-nucleon interactions must be modeled. In Ref. (2) we studied *black disk* and *profile function* models. In the black disk approach two nucleons collide always when their transverse separation $\boldsymbol{b}$ is small enough, while in the profile function ($\Gamma(\boldsymbol{b})$) approach we have a transverse separation dependent probability for the collision to happen.

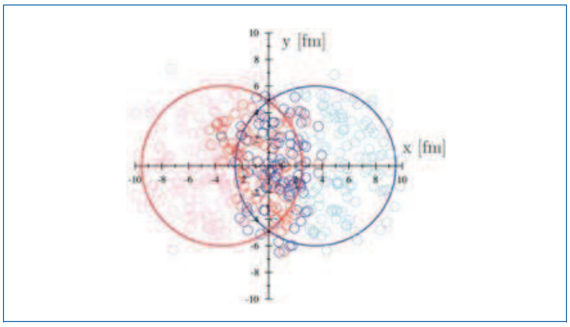

Fig. 1. – An example of one Monte Carlo Glauber event. Larger circles represent the colliding nuclei and smaller circles represent the nucleons.

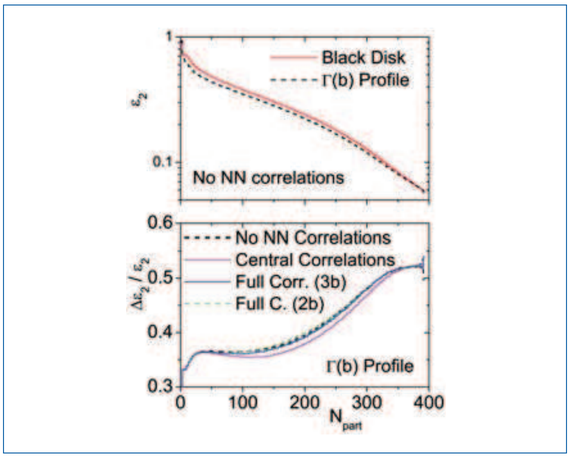

Fig. 2. – Eccentricity and its relative fluctuations as a function of the participant nucleons. In the upper panel the eccentricity is shown with different interaction models. In the lower panel its relative fluctuations are shown with different nucleon-nucleon correlation models.

After the nucleon-nucleon interactions have been determined, we can calculate the initial asymmetries from the positions of the nucleons which had experienced at least one collision. These are called wounded (or participant) nucleons. In this work we study three anisotropy measures ε_n with $n = 1, 2, 3$: dipole asymmetry, eccentricity and triangularity (2). We also consider the relative fluctuations of these anisotropies. All results shown in here are for Au+Au collisions at RHIC with an inelastic nucleon-nucleon cross section $\sigma_{NN} = 42$ mb.

First we considered the different interaction models, neglecting all nucleon-nucleon correlations for simplicity. We saw that for every ε_n with $n = 1, 2, 3$ the black disk interaction model leads to larger anisotropies. In central collisions the difference between different interaction models is small and it grows towards peripheral collisions as shown in Fig. 2. At largest the difference is order of 10%.

Next we studied the effects of the nucleon-nucleon correlations; in this case we use only the profile function interaction model. We studied four different cases here: no correlations, central correlations and two sets with different approximations of full correlations (see definition in (2)). We found that including only central correlations makes the anisotropies smaller (by at most 10-20%), while the full correlations return the results quite close back to the no correlations case. The effects of the correlations are largest in the most central collisions and the difference gets smaller in the more peripheral collisions.

As far as the fluctuations of the anisotropies are concerned, shown in Fig. 2, we found that while the full correlations reduce the effects produced by the central ones to a very small deviation from the uncorrelated case, different models of full correlations give an hint that three-body correlations may play a role. For a more detailed discussion of our results see Ref. (2).

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