

Geometry and multiplicity in high energy collisions of d-Au

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Abstract. In characterizing the strongly coupled QCD system produced in nuclear collisions an important uncertainty is the initial state, in particular the role of nuclear and subnuclear scale fluctuations in small systems. In this regard, the d-Au collision is a potentially unique probe since the deuterium nucleus contains only two nuclei, allowing potentially to separate nucleonic and sub-nucleonic dynamics from multiplicity cuts. We investigate this possibility via the PHOBOS Glauber Monte Carlo program. We calculate geometric quantities of the initial state of an ultra-relativistic collision between a deuterium and a gold nucleus, and systematically examine the relationship between geometry and experimental observables.

1. Introduction

Asymmetric collisions have a large fluctuation in the geometry of the initial conditions, thus providing a field of study where we can more accurately analyze their possible influences on the quantities observed with the number of charged particles produced. More specifically we have that in d-Au collisions we can separate classes of events with a nucleon of deuterium and two nucleons to study its probable influences in the observables.

2. The Glauber Monte Carlo Model

In Glauber's model the following assumptions are made: highly energetic ones are not deflected, in this way, they have a linear trajectory. The movement of the nucleons are independent of the nuclei. The total cross section is given in terms of the nucleon-nucleon cross section. The first step of the Glauber Monte Carlo Model is to prepare two nuclei randomly defining the position of the nucleons in each nucleus. The position of each nucleon in the transverse plane is determined by the probability density function as two parameters. The second step is to simulate the nuclear collision, where the impact parameter $\hat{\mathbf{b}}$ is randomly selected from the geometric distribution $\frac{d\sigma}{db} = 2\pi b$ [1]. It is assumed that two nucleons of different nuclei collided when the transverse distance is smaller than the “ball diameter” defined as $D = \sqrt{\sigma_{NN}/\pi}$ [2] where the σ_{NN} is the cross section.

3. Geometric Quantities

The geometric quantities are determined through many nucleon-nucleon collisions. Below we have the following geometric quantities produced in a collision of $\sqrt{s_{nn}} = 200$ GeV between deuterium and gold.



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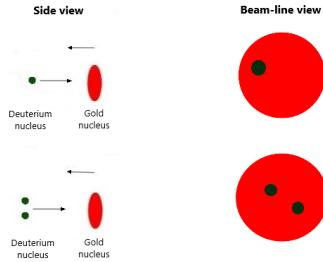


Figure 1. The figure above depicts the two types of events during the various collisions between d and Au.

The image above represents events with only one nucleon of deuterium as participant and with two nucleons of deuterium as participants. With this we can exemplify how through the d-Au collision we have two very different geometries.

Below is a graph that relates the N_{part} , is defined as the number of nucleons of different nuclei that have made at least one collision, to the distance between the nucleons of deuterium.

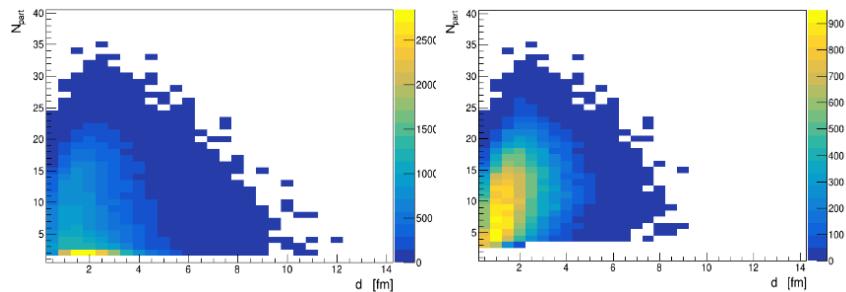


Figure 2. The figure on the right lists the number of participants with the distance between deuterium nucleons for all events and the second with the restriction that the two deuterium nucleons are always participants.

This relation to the components of the positions of the nucleus of deuterium with respect to the plane $x - y$ can best be understood from the figure below.

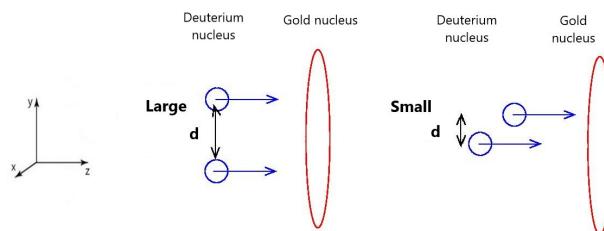


Figure 3. The figure above represents a schematic view of a d-Au collision and the possible arrangements of the deuterium nucleons.

In the figure 2, we see a clear correlation between the N_{part} and the distance between the nucleons, d , for events with two nucleons of deuterium as participants. This happens because

depending on the configuration of the nucleons we will have a greater or smaller number of participants.

We can also determine the eccentricity of the participant plane from the MC Glauber model and we can include fluctuations in the shape of nucleon known as Glauber-Gribov fluctuations.

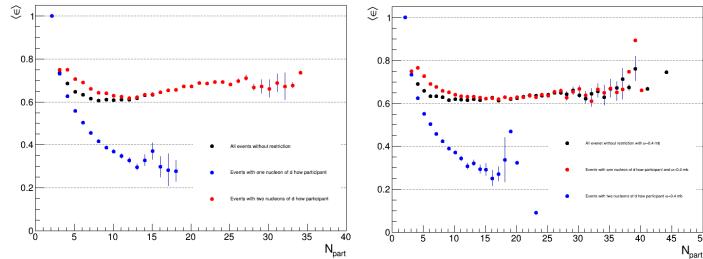


Figure 4. The graph above compares the eccentricities of the participant plane produced in a collision d-Au with one and two nucleons of deuterium as participant.

The graph above compares the eccentricities produced for a collision that has as participant only one nucleon of deuterium, represented by the blue plot, with events with two nucleons of deuterium as participants, represented by the red plot, and events without any restriction of number of deuterium nucleons as participants, represented by the black plot. The left plot was made using the MC Glauber model and the right plot using Glauber-Gribov fluctuations. From these graphs, we can see that classes of events with one nucleon of deuterium and two nucleons of deuterium have different eccentricities of the participant plane and, therefore, different geometric quantities. Thus we can study these classes separately and their influences in the observables, as for example the number charged particles.

4. Particle Production

We can use N_{coll} , that is defined as the number of binary nucleon-nucleon collisions, and N_{part} to determine the number of charged particles generated after interaction. These two values are incorporated into the model by the following $P(\mu, \kappa, n) \times N_{ancs}$ where $N_{ancs} = fN_{part} + (1 - f)N_{coll}$ refers to the number of ancestors, f is a parameter and $P(\mu, \kappa, n)$ is the negative binomial distribution with n being the number of collisions per ancestor, μ the mean multiplicity and k controlling the width of the distribution

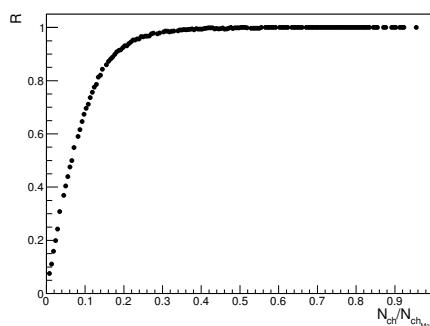


Figure 5. The histogram represents the fraction of events that generate charged particles and that have two nucleons of deuterium as participants.

We note that events with two nucleons of deuterium as participants are the ones that produce the largest amount of charged particles and, thus, events with only one nucleon deuterium produce a smaller amount of particles. The next step of this work is the comparison between simulations results and experimental data. We, for this, can utilize cuts of multiplicity using the zero degree calorimeter, where these measurements can be used to separate events with two nucleons of deuterium as participant.

5. Concluding Remarks

Collisions between deuterium and gold are important because we can separate classes of events with different geometries, for example, events with a nucleon of deuterium as participants and two nucleons of deuterium. In this way, we can verify theoretical models that depend on geometry.

6. References

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