Au+Al STAR Collisions at 5.75 GeV

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I. INTRODUCTION

The goal of ultra-relativistic heavy ion collisions is to verify and characterize a partonic state of matter. This Quark-Gluon Plasma (QGP) has been verified through two results. The first: suppression of the away-side jet peak in high centrality Au+Au collisions done at various center-of-mass energies. This phenomenon is indicative of the existence of a colored nuclear medium shortly after the initial collision and explained by hadrons produced at the beginning of the collision strongly interacting with the medium. The second: the scaling of kinetic energy and elliptic flow by constituent-quark number. When scaling as such, the distinction between hadrons is lost and all particles follow the same hydrodynamic model, indicative of the existence of free quarks rather than hadrons at this stage of the collision. With these two pieces of evidence, it is widely accepted that the QGP exists and focus has now shifted to uncovering the characteristics of this medium at various baryon chemical potentials (μ_B) and temperatures.

Presently, there is very little data to establish a new equation of state for this medium. As such, considerable effort has been put forth to complete a nuclear matter phase diagram (Figure 1). Researchers currently know two things: the location of nuclear matter at room temperature and the transition temperature. The diagram is largely a framework and illustrates the theoretical behavior, including the location of the critical point, kinetic freeze-out curve, and chemical freeze-out curve. The critical point is the initial theoretical location of the first-order phase transition (the point where the transition changes order), the kinetic freeze-out curve marks when both elastic collisions and momentum transfer cease, and the chemical freeze-out curve similarly indicates the conditions when thermal production of hadrons ceases.

In order to probe this new phase of matter with the highest efficiency an intelligent method of determining initial baryon chemical potentials and temperatures during the collisions was needed. This issue was resolved by a beam energy scan (BES). The BES is the best determination of which collisions energies will produce equilibrated systems with initial conditions near those desired. Unfortunately, these initial conditions cannot be directly measured during the collisions, and until more is known about the various curves in Figure 1 the diagram will remain incomplete.

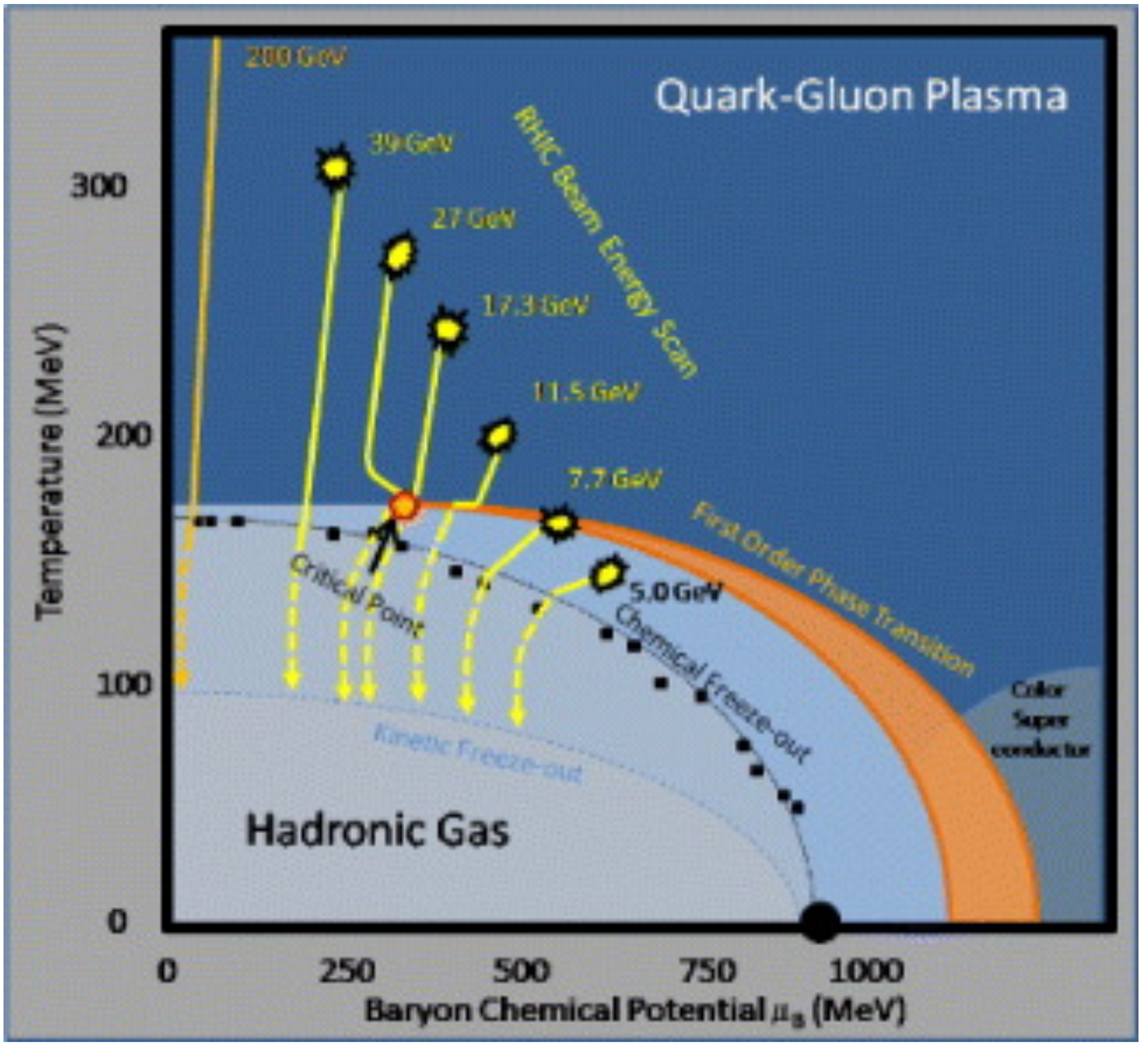

Figure 1

II. Motivation

As stated previously, until more is known about the initial conditions of the collisions, Figure 1 will largely remain a mystery. In order to determine the properties of the various pertinent curves in Figure 1, multiple collisions must be run at varying energies in addition to colliding different ions at their appropriate energies. Using a BES, the energies that are likely to yield QGP signatures can be determined. By studying the collisions performed at these energies, the bulk observables of the collision medium can be observed and signatures of the QGP uncovered.

With this goal in mind, the STAR collaboration performed a BES for Au+Au collisions with the hope of determining the critical point as well as further discovering the exact behavior of the kinetic and chemical freeze-out curves. Plans were made to run collisions over an energy range of 5.0 GeV per nucleon pair to 39 GeV per nucleon pair. However, it was found that the magnetic field in the rings of the collider could not be safely held at strengths low enough to produce collisions at energies below 5.5 GeV. This caused a very obvious problem, measurements below the energy the critical point supposed location could not be made. Fortunately, a clever solution was found almost accidentally.

III. The Solution

During the lowest energy runs possible in the collider, collisions between Au nuclei and the Al beam pipe were recorded whose extrapolated vertices lied within the main detector. In the past, considerable effort would have been put forth to exclude these “bad” collisions from the data, but in this circumstance these collisions can be used to extract useful information. Namely, by creating an unusual fixed-target collision, the center of mass energy of the collision was lowered below the 5.5 GeV threshold of the collider. This allowed data to be taken at the lowest energies proposed by the BES.

The unique challenges that these collisions presented arose from their conditions deviation from those normally measured by the detector. A large amount of work is required to accurately determine the energy and centrality of these beam+pipe collisions, as well as appropriate acceptance conditions and efficiency estimates. When these factors are known and accounted for, particle spectra can be extracted from the data and fit to the appropriate distribution functions. With this knowledge, these collisions can be used to determine the chemical freeze-out and kinetic freeze-out points at their specific energy.

IV. Future Research

Before this data is truly useful, spectra for pions, kaons, and protons must be found and μ_B must be determined to know where this data fits on the nuclear matter phase diagram. One major problem that may arise when these spectra are being created is a lack of matter produced in these collisions due to the small amount of atomic particles in Al. If there is not a large enough volume of matter produced during these collisions, the bulk properties will be incalculable and spectra for certain particles will be out of our grasp. In this case, a fixed target will need to be installed and the appropriate runs carried out before spectra can be extracted at energies below the critical point.