Stages and Mechanisms in Nuclear Collisions

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July 9, 2019

1 Introduction

Small collision systems (pp, pA, ...) were historically used to study initial and final state effects in cold nuclear matter to establish a baseline for the interpretation of the heavy-ion (AA) results. Comparisons with this baseline established medium effects in AA collisions such as jet quenching, Quarkonium suppression and regeneration, strangeness enhancement, and collectivity, all of which together provide strong evidence for the production of a color de-confined medium, the Quark Gluon Plasma (QGP).

However, in recent years collective, fluid-like features strikingly similar to those observed in heavy-ion collisions – such as long-range correlations – as well as the increase of strange particle yields with charge particle multiplicity have been also observed in small collisions systems. The question arises whether QGP is also created in small systems or, conversely, whether for example coherent multi-parton scattering effects can explain the observations in all systems.

For example, theoretical modelling of the initial state within the CGC / saturation physics framework and the subsequent space-time evolution (using kinetic theory and event generators) has suggested alternative potential descriptions of collective phenomena in these systems which do not require the formation of a strongly coupled, de-confined plasma which evolves hydrodynamically. A wide variety of different approaches are available to model the stages of relativistic nuclear collisions, with each approach offering a unique way of understanding the microscopic properties of these systems.

There are several possible ways to compare and classify the different available models. For instance, one might consider:

1. Models that focus on initial state correlations vs. models that focus on a response to an initial geometry.

2. Models that assume the creation of some kind of deconfined plasma, and models that do not.

3. Models that generate collective behavior intrinsically vs. models that generate it dynamically.

There may be other respects in which the models can be distinguished and classified as well.

The goal of classifying the various approaches in this way is twofold: first, to enable us to compare the different models in a systematic way and second, to aid in identifying unique experimental measurements which help to discriminate between the different models.

From the experimental point of view it is important to note that collectivity and strangeness enhancement develop smoothly as functions of particle multiplicity and the limit of the smallest multiplicity at which these effects can be observed continues to decrease. This could provide the unique opportunity to perform model comparisons for relatively simple final states, for example, by using additional event classifiers such as event shapes.

The questions we seek to address are the following:

- What are the most important aspects with respect to which competing models can be classified?

- How are commonly used terms ("collectivity", "de-confinement", "hydrodynamization", etc.) relevant to defining and classifying the different approaches? How should these terms themselves be defined?

- Where are the "points of commonality" at which competing approaches can be directly compared with one another?

- What are the primary weaknesses and limitations of the different approaches? On what approximations or assumptions do the different approaches rely?

- Can the different approaches be combined, and if so, how? What could we gain from an approach which combines or 'interpolates' between two or more approaches?

- What are the most reliable, concrete experimental discriminators for distinguishing between the mechanisms underlying competing models?

- How well do different models reproduce global event observables such as multiplicity and event shapes?

- Which key observables could be measured more differentially and/or against novel event classifiers, in order to yield clearer insights into the microscopic properties of nuclear collisions?