Principal Component Analyses of Final States in Relativistic Nuclear Collisions using PYTHIA/Angantyr

Nicoline Krogh Hemme

Department of Astronomy and Theoretical Physics, Lund University

Bachelor thesis supervised by Leif Lönnblad and Christopher Plumberg

Popular Science Abstract

At the two particle accelerators located in New York and Switzerland, the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC), respectively, experiments are conducted in which atomic nuclei are collided at ultra-relativistic velocities. The aim of these experiments is to study nuclear matter under extreme conditions, i.e. extreme high temperatures and energy densities, similar to the conditions of our Universe shortly after its birth.

A particularly interesting result of these experiments is the observation of a collective, fluid-like motion known as *flow* [1][2][4]. The two colliding nuclei can each be thought of as a thin disk, and they can collide in such a way that the overlapping area forms an almond-like shape rather than a full circle. A consequence of this geometry is that the density gradients are larger along the short axis of the "almond" than the long axis. This means that particles emitted along the short axis are "pushed" with greater force than particles travelling along the almond's long axis, leading to more momentum being produced in the former direction than in the latter. This phenomenon can be observed using particle detectors and is known as anisotropic flow.

Flow is conventionally interpreted as the signature of a *quark-gluon plasma* (QGP), an extremely hot and dense state of matter, often envisioned as a "soup" of quarks and gluons, which are some of the most elementary particles we know of. According to the Big Bang Theory, our Universe existed in this state during the first few microseconds. It is therefore an exceptionally interesting state of matter to study. However, it still remains to be properly explored whether observables such as flow can be explained without a QGP.

Simulations of heavy-ion collisions provide a tool to probe the properties of the system by comparing the results to experimental data. The programs that simulate these events are known as event generators. The PYTHIA event generator [3], developed at Lund University, is based on a microscopic model of particle interactions and does not assume that the system reaches a state of QGP. This makes it a valuable tool for testing whether we have truly created a QGP in heavy-ion collisions.

In this project, a tool will be developed to provide a detailed flow-analysis of the final-state particles produced in PYTHIA simulations of relativistic nuclear collisions. The analysis will enable detailed comparisons of these simulations with corresponding experimental measurements. The purpose of this project is to expand the tool-box for future research to be done in this field.

References

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