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The origin of collectivity in small systems via heavy-flavour measurements at the ALICE LHC experiment

Summary

Quantum chromodynamics (QCD) is a gauge field theory that describes one of the fundamental interactions – the strong interaction. QCD has a dual nature: the strength of the coupling depends on the energy scale. At low energy scales we observe colour confinement, that is, quarks and gluons are confined into colour-neutral states. On the other hand, at high-energy-scale processes, strongly interacting particles exhibit asymptotic freedom. However, at high energy densities, which can be achieved in modern particle accelerators, a state of matter forms in which quarks and gluons can be found in an unconfined state – the quark-gluon plasma (QGP). This QGP is believed to have comprised the Universe during the first several microseconds after the Big Bang.

Heavy-flavour quarks, charm and beauty, are formed in the initial stages of high-energy hadronic collisions, before the formation of the QGP, and survive throughout the entire evolution of the system. This makes heavy-flavour probes a crucial tool for studying the properties of the QGP.

Recent measurements at particle colliders, such as the LHC and RHIC, have observed effects typically attributed to the presence of the QGP even in small collision systems with both high and low final-state multiplicities. In such systems, the QGP is not expected to form due to much lower energy densities. Theoretical works attempt to explain the observed similarities between small and large collision systems using vacuum QCD models such as mini-jet production or multiple-parton interactions (MPI). Heavy-flavour measurements can aid in testing these QCD models in proton–proton and proton–ion collisions.

In my thesis, I use heavy-flavour production from small to large systems, both in theory and in experiment, to understand the thermodynamical properties and the QGP-like effects in reactions. I investigate the production of heavy-flavour D and B mesons, as well as *c* and *b* quarks as a function of transverse-event activity in simulations, to study the influence of MPI on heavy-flavour particle production. Based on the results of these simulations, I carry out the data analysis of D^0-meson production in the ALICE experiment and compare the results with the simulations. Finally, I utilise a non-extensive thermodynamics model to investigate the timeline of heavy-flavour production and compare it with light flavours based on measurements of the ALICE and STAR experiments.