Doctoral thesis abstract
Exploration of Baryon Number Factorial Cumulants in the Context of the Quantum Chromodynamics Phase Diagram

Michał Barej

12.09.2023

The strongly interacting matter phase diagram is not yet well explored. In particular, the search for the expected phase transition and critical point between the hadronic gas (protons, neutrons, etc.) and the quark-gluon plasma (deconfined quarks and gluons) is one of the greatest challenges in nuclear and high-energy physics nowadays. Theoretical studies predict that the fluctuations in the baryon number, electric charge, and strangeness are sensitive to such a transition and critical point. These fluctuations are quantified by the cumulants, factorial cumulants, and factorial moments which are measured experimentally at the major particle collider facilities. The cumulants naturally appear in statistical mechanics and lattice numerical calculations. On the other hand, factorial cumulants are useful when investigating multiparticle correlations. The recent results of the STAR and HADES collaborations might be interpreted as a signature of the critical phenomena. However, greater statistics as well as a careful study of various effects such as baryon number conservation or volume fluctuations are needed.

In this thesis, the cumulants and factorial cumulants originating from various effects are calculated analytically. First of all, the mixed proton-antiproton factorial cumulants from global baryon number conservation are obtained. They include more information than often studied net-proton cumulants. What is more, they might be helpful in distinguishing between the effects of the baryon annihilation with local baryon number conservation law and another scenario assuming global baryon number conservation only. Then, in this dissertation, the baryon number cumulants and factorial cumulants in the subsystem are obtained assuming the global baryon number conservation and short-range correlations. The fact that they are expressed by the cumulants without baryon number conservation can enable correcting the experimental data or numerical results for this effect. In the next step, a method of calculating corrections to the cumulants from baryon number conservation and short-range correlations is developed. It is especially important for small systems. In the last part, the cumulants and factorial cumulants due to fluctuations in the width of the proton rapidity density distribution are derived. They are expected to be caused, e.g., by the event-by-event fluctuations in the energy deposition of stopped protons resulting in longitudinal fluctuations of the fireball density. This effect is found to be potentially important when studying proton or baryon number cumulants.