Mátyás Molnár: Emission shape evolution in the Monte-Carlo models of heavy-ion collisions

In high-energy heavy-ion collisions, measuring the source function is essential for understanding the space-time evolution of the hot and dense matter known as the quark-gluon plasma (QGP). This function can be studied through the analysis of the two-particle Bose-Einstein correlation function, which is directly linked to the phase-space density of the particle-emitting source. While a Gaussian shape has traditionally been assumed for the source function, experimental measurements indicate significant deviations, suggesting that it may instead follow a Lévy-stable distribution -- an assumption tested in several studies. Recent experiments provide strong evidence for Lévy-walk processes, characterized by heavy-tailed random walks, occurring in the QGP. However, a comprehensive theoretical interpretation of this phenomenon remains an open question. To better understand the freeze-out process and the spatial distribution of emitted particles, event generators play a crucial role. EPOS4, a sophisticated Monte Carlo-based model, simulates high-energy nuclear and particle collisions by incorporating the Parton-Based Gribov--Regge theory for the initial partonic interactions, followed by a hydrodynamic evolution phase accounting for collective medium effects, and concluding with hadronization, where particles are formed. This framework aligns with the nature of the QGP, which -- similarly to the early Universe -- undergoes rapid expansion and transitions back into nuclear matter, forming an expanding hadron gas where particles continue to interact until kinetic freeze-out, the stage at which their momenta stops changing. Thus, measuring and simulating spatial freeze-out distributions is crucial for understanding the dynamics and interactions within strongly interacting matter created in high-energy collisions. Additionally, the CRAB (Correlation After Burner) toolkit provides a powerful method for generating correlation functions from semi-classical transport models. By integrating CRAB with EPOS4 simulation data, both the simulated source function and the resulting correlation function can be analysed and fitted using a Lévy-stable distribution. This approach establishes a solid framework for interpreting experimental data and further exploring the fundamental properties of QGP and its freeze-out characteristics.