At the accelerators RHIC at the Brookhaven National Laboratory and at the LHC at CERN, heavy ions with the highest available energies are collided. In the collisions a fireball of dense matter is formed, the quark-gluon plasma. The matter is so dense and strongly interacting, that it behaves as a liquid, and the fireball expands. The dynamics makes it possible to extract the properties of the fluid. The expansion is modeled using relativistic viscous hydrodynamics. Experimental and theoretical studies show that the quark-gluon plasma is a fluid with very low viscosity.

The initial fireball is formed in very first phase of the collision via nonperturbative quantum chromodynamic processes. The density distribution cannot be directly observed experimentally. However, the appearance of the collective flow makes it possible to study the initial distribution, as the collective flow can be extracted from the final particle spectra. A precise analysis of the spectra and correlations will be used to recover the initial profile and its fluctuations. An analogy can be drawn to studies of matter distribution in the early Universe using microwave background radiation. Results of model calculations will be compared to experimental data and the distribution in three dimensions will be reconstructed.

The presence of significant collective flow means, that particles emitted from a fluid element have similar velocities. The study of correlations of pair of particles with similar momenta restricts the size of the emission region of the pair. The emission of identical bosons is subject to Bose-Einstein correlations and the size of the emission region can be extracted. In the project we will use this method to find the size of the emission region in small colliding systems, p-Pb, d-Au, and He-Au. Predictions for pion-pion and kaon-kaon correlations can be used to verify the hypothesis of collectivity in small colliding systems.

The process of hadron formation at the end of the reaction is very poorly known. Its quantitative description within nonperturbative quantum chromodynamics is impossible. We propose to measure one of the important characteristics of hadronization. The correlation range for charge conservation. If a particle having an electric charge, barion number, or strangeness is formed, another particle with the corresponding anti-charge must appear. In a system with strong collective flow, the pair of charged and anti-charged particles has strongly collimated momenta. This collimation is stronger if the correlation range for charge conservation is small or if the flow is strong. Studying twoparticle correlations in systems of different sizes and with different amount of collective flow, the range, over which is charge is conserved, will be estimated.