In one of the most interesting ideas it is postulated that the matter of the present Universe must have been in a state of the quark-gluon plasma (QGP). According to the Big Bang model, about 10 μsec. after the Big Bang, the whole Universe was filled with a hot and dense soup made of elementary particles including quarks and gluons, fundamental constituents of protons, neutrons and other hadronic particles. These particles, quarks and gluons, which are not observed as single particles, in the early moments of the Universe, were free to move on their own in the QGP phase.

With the present rapid advances in the high-energy physics, scientists can "recreate" the conditions of the early Universe in the laboratory producing QGP at a small scale. To this end, massive nuclei at the highest possible energies are brought into head-on collisions. Presently, ultra-relativistic nuclei of gold and lead atoms are collided at Relativistic Heavy Ion Collider (RHIC in operation since 2000) located at Brookhaven National Laboratory in the US and at the Large Hadron Collider (LHC in operation since 2010) at CERN in Switzerland. In these collisions protons and neutrons of the two nuclei form a "small droplet" of hot and dense matter in which quarks are not longer confined within particular nucleons but are free to move. The droplet instantly cools down, and the quarks and gluons from the QGP state recombine, forming thousands of hadronic matter particles (like pions, kaons, protons as well as their anti-particles) in which quarks and gluons again remain confined. The produced particles in the heavy-ion collisions are measured in large detectors, which operate at the LHC and RHIC accelerators. The experimental results clearly reveal the presence of the QGP phase and its unexpected properties. The results from RHIC experiments showed that the QGP behaves like a perfect fluid with very small viscosity. The unexpected properties of the QGP have been confirmed by LHC experiments. The much greater collision energies at the LHC allow new and more detailed characterization of the QGP.

One the most important measurements which reveals the fluid-like, collective nature of QGP is the measurement of azimuthal angles of produced particles in the final state which show large anisotropy. It is expected that the azimuthal anisotropy results from large pressure gradients in the hot, dense matter due to the initial spatial asymmetry of the colliding zone of the two nuclei, which typically has an elliptical shape. These pressure gradients transform the initial spatial asymmetry into momentum anisotropies of the final-state particle production. The results on the large azimuthal anisotropy were found in an agreement with one of the most successful models of heavy-ion collisions treating the QGP phase as an ideal fluid with a very low viscosity. Although other explanations are also considered, it is the fluid nature of QGP, which is commonly accepted

Within this project scientists from the Institute of Nuclear Physics PAS from Kraków will perform measurements of azimuthal anisotropy based the recent experimental heavy-ion data collected by the ATLAS experiment. ATLAS is a general-purpose detector, which obtained substantial samples of lead-lead (Pb+Pb) and proton-lead (p+Pb) collisions, which are used by investigators of the project for comprehensive study of the collective effects of heavy-ion interactions. The azimuthal anisotropy measurements provide long-wavelength characteristics of heavy ion collisions and are essential for understanding the dynamic evolution of dense matter, as well as its detail properties like viscosity. The experimental results and predictions from theoretical models may lead to a better understanding of the most important problems in quantum chromodynamics, the theory of strong interactions, e.g. understanding why quarks are confined in protons or neutrons.