One of the most fundamental problems in modern physics is understanding of the structure and properties of nuclear matter. Our current knowledge about its features follows from the fundamental theory of strong interactions known as quantum chromodynamics (QCD). The latter states that protons and neutrons forming atomic nuclei are made of more elementary particles called quarks which are bound together by other particles called gluons. According to asymptotic freedom property of QCD at extremely high temperatures or densities quarks and gluons are liberated creating a new state of hot and dense strongly-interacting matter dubbed quark-gluon plasma. The properties of this new state of matter are of great interest to physicists as it is commonly believed that it existed in the early Universe, just after the Big Bang, as well as forms the cores of neutron stars. It turns out that similar physical conditions may be reproduced in laboratory by colliding head-on bare nuclei of heavy elements with the speeds near the speed of light in the accelerating facilities, such as RHIC (Relativistic Heavy-Ion Collider) at BNL and the LHC (Large Hadron Collider) at CERN. Enormous kinetic energy accumulated is this way is released in the collision zone and used for heating or compression of the nuclei, allowing for setting quarks and gluons free. Subsequent cooling and expansion of the created system into the surrounding vacuum results in their recombination back into hadrons (a family of particles to which protons and neutrons belong) which are then being observed in detectors. It turns out that in experiments at top RHIC and LHC colliding energies the nuclei pass through each other, leaving the collision area, rather than being compressed. The so called baryon charge carried by protons and neutrons is carried with them. Particles produced in such collision emerge purely at the expense of kinetic energy being released in the collision process. Theoretical studies show that this baryon-free matter behave as an almost perfect fluid with the lowest viscosity observed in Nature. Moreover, the latter result is in agreement with the sophisticated numerical solutions of QCD.

Our main interest in the project is the study of relativistic nuclear collisions at somewhat smaller speeds, though still exceeding 95% of the speed of light, which are subject of intense investigations at SPS (Super Proton Synchrotron) and RHIC, as well as are planned for the near future at NICA (Nuclotron-based Ion Collider Facility) and FAIR (Facility for Antiproton and Ion Research). In such processes a large baryon charge is being measured in the detectors suggesting that at low energies, unlike at RHIC and LHC, the nuclei undergo strong compression creating conditions similar to the ones in the core of neutron star. It turns out that QCD in this regime is not yet solvable making the nuclear collisions a unique tool for studying properties of the baryon-rich strongly-interacting matter. Our aim is to understand the dynamics of such processes using the statistical and hydrodynamic models.

Very recently an intriguing discovery was made by STAR at RHIC in the regime of low energy collisions concerning the global polarization of spin of Λ particles. It turns out that states of Λ particles measured in the processes, where the nuclei collide non-centrally, prefer to be emitted in certain states of an internal quantum number called spin, i.e., they are polarized. As it is clear that in such low energy non-central collision the created matter must rotate and classically spin of an object is interpreted as an internal angular momentum related to its rotation, the STAR results suggest that there must be a connection between macroscopic rotation of the matter formed in the collision zone and the spin state of its microscopic constituents. This phenomenon, although not yet completely understood, may be the first direct manifestation of quantum phenomena in heavy-ion physics. Inspired by these findings it is our goal to study mechanisms of spin-polarization and provide fluid-dynamics description of its evolution. The investigation of polarization represents an essential innovative element of the proposed project.