

Popular scientific summary of the project:

Studies of the Strong Interactions and Exploration of the Phase Diagram of QCD Matter Using Correlation Femtoscopia at the STAR Experiment at RHIC

The scientific aim of the project is to perform the studies of the strong interaction between hadrons created during at heavy-ion collisions at highest RHIC energies and in an unexplored so far range of collision energy of the order of several or several tens of GeV using the femtoscopy method by the team from the Faculty of Physics, Warsaw University of Technology in close collaboration in the frame of the STAR experiment at RHIC.

The results of nearly three decades of studying the relativistic heavy-ion collisions, and in particular the decade associated with the use of the largest collectors: LHC at CERN and RHIC at BNL, led to the creation of a new state of matter in which the so-called quark degrees of freedom, or the smallest, yet indivisible components of matter. However, the results obtained concerned the conditions for high temperature and low baryon density values, when the proportions of baryons and anti-baryons are almost identical. Using smaller collision energies of elementary particles and heavy ions, it is possible to explore the properties of matter with lower temperature and higher baryon density values.

The general physics goal would be to study the strong interactions between hadrons and to explore the QCD phase diagram in so far unexplored region relevant for one of the hottest recently topic related to phase transition between Hadron Gas (HG) and Quark-Gluon Plasma (QGP) by the analysis of particle correlations at highest RHIC energies, and in the frame of Beam Energy Scan (BES) program – Phase II and Fixed Target mode. We will investigate the unexplored region of the mixed-phase of hadronic matter in close collaboration in the STAR experiment frame.

These studies will describe parameters of strong interactions between nucleon and hyperons that are predicted to exist inside neutron stars. They will fill a missing gap between measurements obtained for collision energies of the order of a few MeV (e.g., GANIL) and researches for collision energies of the order of several hundreds of GeV (RHIC) or even TeV (LHC). Understanding the QCD phase diagram is one of the most important goals of relativistic heavy-ion physics. Several methods are proposed to study first-order phase transition between the hadron gas and quark-gluon plasma; here, we focus on particle correlations, our original contribution, and subject to this project. By measuring particle correlations in the region of small relative velocities, the space-time information can be extracted. This method, called correlation femtoscopy, is widely used in the studies of heavy-ion collisions. Femtoscopy is related to the femto scale ($m = 1 \text{ fm}$), which any other experimental technique can not access.

The effects expected here are an essential element of our knowledge about the structure and properties of matter. If the results show unexpected phenomena, it will open new research directions in nuclear reactions' physics. The results of this research also have a direct reference to understanding the first moments of the universe's evolution and understanding the interiors of the neutron stars.