Popular scientific description of the project
Studying the Equation of State of strongly interacting matter in the STAR-BES program.

The modern heavy ions experiments like STAR at BNL or experiments at LHC at CERN allowed us to create and study the Quark-Gluon Plasma (QGP). It is a state of matter in which the quarks are semi-free particles- not bounded in the form of hadrons like in ordinary matter. Various experiments still explore the nature of QGP. However, these studies are related mainly to the highest energies corresponding to the matter at high temperatures and low baryon density. Colliding the heavy ions at lower energies allows for probing the matter with very high baryon density.

The conditions created during collisions of heavy ions at low energies are similar to those in the cores of neutron stars. The conditions at the collisions at high energies are more similar to those at the early stage of the evolution of the Universe. We expect different behavior of matter under different conditions, e.g., we should observe the change in the transformation from Quark-Gluon Plasma to hadronic matter. At high energies, there should be a smooth cross-over transformation from one type of matter into another, whereas for lower energies, we expect a first-order phase transition. Understanding the Equation of state at these energies is crucial to understand the evolution of the Universe and the neutron stars.

We propose to use a femtoscopic measurement to study the properties of strongly interacting matter like EoS. Femtoscopy is a technique that uses two-particle correlations to measure the size of the source that emits particles. This method allows us to measure the sources of particles; these sizes are comparable to the size of a proton. Femtoscopy is sensitive to the geometrical size of the source that emits particles and gives information about the dynamics of the collision process, like the duration of particle emissions.

We want to perform a femtoscopic analysis of data collected by the STAR experiment in the Beam Energy Scan program, where collisions at a broad range of energies were registered. In these analyses, we would like to perform a pioneering type of analysis - a three-dimensional correlation analysis of proton-proton correlations. This kind of analysis is much more complicated than one-dimensional femtoscopy used nowadays but gives us much more information. Our work will also use the models to study the impact of the EoS on femtoscopic measurements and will help to improve them.

The effect of our work will significantly improve our knowledge about the EoS of the strongly interacting matter. Understanding the nature of the EoS of such matter will help us better understand the early stage of the Universe's evolution and the nature of neutron stars. The methodology that we develop for our studies (three-dimensional femtoscopy of proton-proton) can be useful also for other studies - like those related to the interactions between hadrons.