The most general goal of the project are experimental studies of strong interactions under extreme energy density conditions. This is an important and interesting topic, because strong interactions are the source of more the 98% of the mass of matter visible in the universe. The strong force holds together the basic constituents of nuclear matter, quarks, to form nucleons: protons and neutrons. The nucleons are building blocks of the atomic nucleus, which account for almost all visible mass in the universe. Quarks are bound by an exchange of gluons. The fundamental goal of nuclear science is to understand their dynamics and how nucleons emerge from strong interactions between quarks and gluons.

Relativistic heavy ion collisions provide a unique opportunity for studying the strong force. The forces binding quarks together can be screened at sufficiently high energy density, which leads to a transition from ordinary nuclear matter to a new state, which properties are determined by quark and gluon degrees of freedom. Such "soup" of quarks and gluons is called Quark-Gluon Plasma (QGP) and experimental data suggest that it is created in relativistic heavy ion collisions at Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory and at the LHC at CERN.

One can use an approach analogous to tomography for studying the QGP properties: An external, penetrating probe, whose properties are under experimental and theoretical control, is shot through the medium; we can then infer properties of the analyzed system from modification of the probe. Heavy quarks, charm and bottom, are such probes, which are external to QGP. Because of their large mass ($m_{charm} \approx 1.3$ GeV/c^2, $m_{bottom} \approx 4.2$ GeV/c^2), they are produced very early in the collision, in the initial interactions with large momentum transfer, before the QGP phase.

A fast charm or beauty quark traversing QGP will lose its energy due to interaction with the medium. The properties of the medium are extracted by comparing energy loss dE/dx observed in the data with models, where dE/dx is related to transport properties of the nuclear medium, for instance diffusion coefficients.

Studies of the energy loss of heavy quarks confirm that charm quarks lose significant amount of energy in the QGP phase. However, there is no consensus regarding details of their in-medium interactions – there are a few theoretical calculations with different assumptions that reproduce the experimental data reasonably well. Thus, new observables are necessary to distinguish between models and provide new insights into charm and beauty quark behavior in the QGP.

One of the remaining puzzles hindering usability of heavy quarks as QGP probes is lack of knowledge about details of their interactions with a quark and gluon matter. There are two main mechanisms considered in the literature: radiative energy loss dE/dx_{rad} due to gluon radiation, and a collisional energy loss dE/dx_{coll} due to binary interactions with other objects in the QGP. A major difficulty in modeling heavy quark energy loss is that relative contributions of dE/dx_{coll} and dE/dx_{rad} are unknown and need to be constrained based on experimental data.

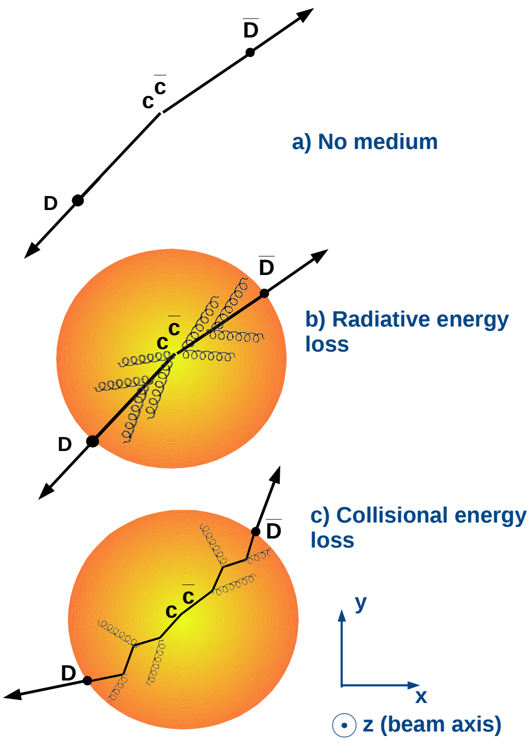

Fig. 1: Illustration of impact of charm quarks interactions with the quark-gluon plasma on the angular correlations of mesons containing charm quarks.

Model studies indicate that measurement of correlation in the azimuthal angle (angle in a plane perpendicular to the beam axis) of mesons containing charm quarks (D mesons) have a large discriminating power between dE/dx_{coll} and dE/dx_{rad}. If radiative energy loss dominates, the original directions of charm and anti-charm quarks will be preserved to a large degree, thus there will be significant back-to-back correlation of D and $\overline{D}$ mesons (see Fig. 1). In the case of collisional energy loss, directions will be smeared because of multiply collisions in the QGP, thus D - $\overline{D}$ correlations will be diluted.

In this project, we will measure correlations of particles containing heavy quarks in heavy ion collisions in the STAR experiment at RHIC. Such data can shed new light on heavy quark in-medium interactions, and in turn on the properties of a nuclear matter with quark and gluon degrees of freedom.