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Abstract for general public of the project

Initial dynamics of relativistic hadronic collisions with subeikonal corrections

Strong interaction, described by Quantum Chromodynamics (QCD), is responsible for building the femtoworld - the structure of nucleons and atomic nuclei. Its strength, around 137 times bigger than next in the hierarchy electromagnetic interaction, renders it the most difficult to be accessed experimentally. In the physical jargon one frequently uses the phrase *extreme conditions* to refer to the conditions under which the matter must be placed to reveal features resulting from the strong interaction. These conditions can be achieved experimentally by accelerating beams of atomic nuclei in opposite directions to nearly the speed of light to collide them with each other. The temperature of a created system may exceed even 5 trillion degrees, which allows for liberation of the elementary ingredients of nucleons, quarks and gluons, from their interiors, producing the *quark-gluon plasma*. The plasma is a short-lived and very dynamical system, it equilibrates rapidly and then decays again into colour-neutral particles, which are registered by detectors. The registered momenta, motion paths, electric charges along with theoretical predictions enable one to reproduce the evolution of the strongly interacting matter and determine its characteristics.

The advanced experimental program dedicated to collisions of hadronic systems at the *Large Hadron Collider* (LHC) in Geneva and at *Relativistic Hadron Ion Collider* (RHIC) in Brookhaven, and also electrons on hadrons at the *Hadron-Electron Ring Accelerator* (HERA) in Hamburg has allowed for determination of the most important properties of hadrons and the dynamics of the quark-gluon plasma. At the same time, it has also delineated new directions of research, which will be undertaken at currently constructed the *Electron-Ion Collider* (EIC) in Brookhaven. These concern mostly explanation of the proton spin puzzle, its 3-dimensional structure and verification of the saturation phenomenon of gluons inside hadrons and nuclei.

The saturation phenomenon features the nuclear system at high energy density, or high gluonic density, when the splitting processes of so-called soft gluons are balanced by their recombination. The quark-gluon plasma is created in heavy-ion collisions just in the regime of the saturation. Inasmuch as the evolution of the plasma, when the near-equilibrium state is reached, is quite well understood, most uncertainties in the interpretation of experimental data are contributed by not precise enough theoretical models describing the *initial phase of the collision*. The initial phase of the collision can be ascribed both to the description of a nucleus before the collision and to the strongly anisotropic dynamics of the system (mostly gluonic) shortly after the collision. Since the energy density and velocity flow profiles and diverse fluctuations and correlations in this phase determine later behaviour of the system, it shall be expected that too-far-reaching approximations in theoretical descriptions of the initial stage cannot lead to the ultimate and reliable extraction of the plasma properties.

The main purpose of this project is to extend the MV model (McLerran-Venugopalan model), describing a highly-energetic heavy nucleus, by the dynamical effects emerging within its small, but finite width and to explore their consequences, using the methods of QCD. The foregoing formulations have treated a nucleus as infinitely thin due to the Lorentz contraction at high energies or implemented the finite extension of the nucleus, but microscopic dynamical effects along the direction of propagation have been mostly neglected. Such an approximation is well justified for collision energies achievable at the LHC. At RHIC and the planned EIC the collision energies are lower and the dynamics of microscopic fields along the longitudinal width of a nucleus should not be ignored. Among other properties, the dynamics within the width of a nucleus determines the helicity of particles, which in light of investigation of spin-sensitive observables, can have a conceptual meaning. At later stages of the project, two important applications of the results of the extended MV model will be studied. In particular, a newly-derived correlator of gluonic fields will be used to find subeikonal corrections in a few scattering processes, as well as it will allow for a more precise description of the dynamics of initial phase of a heavy ion collision, with a focus on exploring the effects that have not been included to date.