Extracting space-time energy and charge correlations in relativistic nuclear collisions from experimental observables

Collisions of heavy atomic nuclei at speeds close to the speed of light allow, for a very short time, to produce temperatures of the order of 10^{12} kelvins. For comparison, the temperature at the center of our Sun is about 10^{7} kelvin. In collisions, atomic nuclei interact with each other, which leads to the deposit of very large energy in a very small volume, which consequently translates into enormous temperatures. A temperature of 10^{12} kelvin prevailed at the beginning of the Universe. For this reason, collisions of atomic nuclei at high energies are often called small bangs, in analogy to the Big Bang Theory. Theoretical calculations within quantum chromodynamics, currently the most fundamental physical theory, indicate that at such temperatures the matter we know is completely melted, and a new state of matter called quark-gluon plasma is created. Such experiments are carried out at the Brookhaven National Laboratory (BNL) in New York (e.g. gold nuclei) and the CERN laboratory on the LHC in Geneva (e.g. lead nuclei). The produced quark-gluon plasma cools quickly and turns into well-known particles (pions, protons, etc.), the number of which can reach up to several thousand. The difficulty of research on quark-gluon plasma is trying to study it by observing these particles. This is a difficult task that requires a lot of ingenuity. It turns out that quark-gluon plasma is created not only in the collisions of heavy ions. Experimental data suggest that a new state of matter is also created in proton-nucleus and proton-proton collisions. The project aims to better learn and understand the mechanism of formation and properties of quark-gluon plasma. For this purpose, we will study long-range correlations of the final particles, which carry information about the early stage of collisions of heavy atomic nuclei, and thus carry information about the quark-gluon plasma. One of the most interesting questions is the nature of the potential phase transition between the known hadronic matter and the quark-gluon plasma. A large part of the project is devoted to this issue. Research on quark-gluon plasma is fundamental research. Their goal is to answer the question of what properties the matter had in the first moments of the Universe's existence, and how particles and matter as we know it from everyday life are created.