Study of two-particle correlations in azimuthal angle and pseudorapidity in Beryllium-Beryllium collisions at the energies of the SPS accelerator

The Standard Model describes interactions of elementary particles - the smallest and indivisible parts of the matter in the Universe. These particles are six quarks (and six antiquarks), six leptons (and six antileptons) and force carriers: photon (electromagnetic interactions), gluons (strong interactions), W^+, W^- and Z^0 bosons (weak interactions) and recently confirmed Higgs boson, responsible for particle mass.

Normal nuclear matter (protons and neutrons) consists of quarks and gluons, which cannot be separated. However, at higher temperatures one can create a state of Quark-Gluon Plasma (QGP), where quarks and gluons are deconfined. Looking for QGP - very hot and dense state of matter, which probably existed a fraction of second after the Big Bang, is one of the main goals of the modern physics. These studies take place in some of the world-biggest research centers: e.g. at the European Organization for Nuclear Research (CERN, Geneva) and at Brookhaven National Laboratory (BNL, USA). The main problem for QGP studies is that it cannot be observed directly. Only the particles produced in the final state can be measured. One of the best-known ways of studying QGP is analyzing the collective flow. Long time ago QGP was called a “soup” and indeed, the latest Relativistic Heavy-Ion Collider (RHIC) and Large Hadron Collider (LHC) collective flow results suggest that QGP behaves like an almost perfect liquid.

The other way of searching for Quark-Gluon Plasma is exploring the phase diagram of strongly interacting matter. Such diagram, just like e.g. phase diagram of water, specifies all of its states and transitions between them. In case of strongly interacting matter its states are e.g. hadron gas and Quark-Gluon Plasma. If QGP exists then a border (phase transition) between it and hadron gas should exist also. When collided system is close to the boundary between phases, enlarged correlations and fluctuations are expected. Study of the phase transition is one of goals of the NA61/SHINE experiment. Its predecessor, NA49, studied the energy threshold for QGP creation at Pb+Pb collisions at middle Super Proton Synchrotron (SPS) energies.

In order to have reliable analysis results, we need to measure collisions of the systems where QGP is created and of the system where it is not. The latter are called reference measurements. We expect QGP in heavy-ion collisions at high energies and we do not expect QGP in e.g. proton-proton collisions. Thus, proton-proton collisions are our reference to the results from lead-lead collisions, where QGP appears (at least for higher SPS energies). It would be interesting to check whether QGP appears also in collisions of lighter and mid-heavy nuclei. The NA61/SHINE experiment at the SPS accelerator has the possibility to study particle production from such systems: p+p, Be+Be, Ar+Sc, Xe+La, and Pb+Pb. In these middle systems the signatures of changing phases may appear.

In my opinion, two-particle correlations in azimuthal angle and pseudorapidity are interesting study because they allow to distinguish and specify the effects such as the collective flow, resonance decays, quantum statistics effects, etc. The experiments at Large Hadron Collider (LHC) accelerator (ATLAS, ALICE, CMS) as well as at Relativistic Heavy-Ion Collider, RHIC (e.g. STAR) performed such analyses for lighter (p+p, p+Pb) and heavier systems (Au+Au, Pb+Pb).

The main objective of this project is to study two-particle azimuthal angle and pseudorapidity correlations in Beryllium-Beryllium collisions. It will allow for better understanding of physics in heavier (than p+p) systems than proton-proton (p+p datasets were analyzed in the NA61/SHINE experiment by the author of this grant application). Be+Be collisions is the first system in which the signatures of the phase change may appear. The results of the analysis will be complementary to the results of LHC and RHIC experiments.

The studies in this research topic are pure-cognitive. The goal of these studies is to contribute to the understanding of the Standard Model and verification of The Big Bang Theory.