Reg. No: 2016/22/M/ST2/00176; Principal Investigator: prof. dr hab. Marek Wiesław Kowalski

Investigation of fundamental properties of nuclear matter in the ALICE experiment at CERN LHC

Ordinary matter is made of atoms, each of which consists of a nucleus surrounded by a cloud of electrons. Nuclei are made of protons and neutrons, which in turn are made of quarks. As far as we know today, the quarks seem to be elementary constituents. Quarks are bound together into protons and neutrons by a force known as the strong interaction, mediated by the exchange of force-carrier particles called gluons. The strong interaction is also responsible for binding together the protons and neutrons inside the atomic nuclei. No quark has ever been observed in isolation: the quarks, as well as the gluons, seem to be bound permanently together and confined inside composite particles, such as protons and neutrons. This is known as confinement. The exact mechanism that causes it remains unknown.

The current theory of the strong interaction predicts that at very high temperatures and very high energy densities, quarks and gluons should no longer be confined inside composite particles. Instead they should exist freely in a new state of matter known as Quark-Gluon Plasma. Such a transition should occur when the temperature exceeds a critical value estimated to be around 2000 billion degrees, about 100 000 times hotter than the core of the Sun. Such temperatures have not existed in Nature since the birth of the Universe. We believe that for a few millionths of a second after the Big Bang the temperature was indeed above the critical value, and the entire Universe was in a Quark-Gluon Plasma state.

By inducing head-on collisions of heavy nuclei (such as nuclei of lead atoms) accelerated by the LHC to a speed close to the speed of light, we should be able to obtain – albeit over a tiny volume, only about the size of a nucleus, and for a fleetingly short instant, a drop of such primordial matter and observe it as it reverts to ordinary matter through expansion and cooling. This occurs when the QGP is cooled to 10^{12} K, barely 10^{-23} s. after the collision.

By studying such collisions at the LHC, ALICE should be able to explore deep into the physics of confinement, to probe the properties of the vacuum and the generation of mass in strong interactions, and to get a glimpse of how matter behaved immediately after the Big Bang.

Used to study the Quark-Gluon Plasma, weighing 10 000 tons and with a height of 16 m and a length of 26m, ALICE is a large and complex detector composed of 18 sub-detectors to track and identify the tens of thousands of particles produced in each heavy-ion collision. To record up to 8000 collisions per second, the ALICE detector is based of state-of-the-art technologies:

- high precision systems for detecting and tracking the particles;
- ultra miniaturized systems for processing electronic signals;
- a worldwide distribution of computing resources for data analysis (the Grid).

The ALICE Collaboration counts over 1500 scientists from more than 30 countries. Polish groups participate in ALICE from the very beginning, being one of its founders. The Collaboration gives the unique possibilities of usage the most advanced apparatus ever built for the nuclear and high energy physics. None of the existing National Laboratories, even in the richest countries of the world, is able to offer a possibility on similar scale.

Our Project, takes advantage of the excellent experimental performance of the detector, the detailed knowledge, the experience, the international recognition of the Research Team and our good contacts with the leading theorists in the field.

Results of the Project will be published in the most prestigious papers and will be presented at international conferences and seminars. The result of the realization of the Project will significantly enrich the theoretical and experimental knowledge on the fundamental properties of the state of matter created in such collisions.