

Critical structures in strong interactions

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One of the important issues of contemporary physics is the understanding of strong interactions and in particular the study of the properties of strongly interacting matter in equilibrium. It is commonly expected that the matter at very high densities may exist in a state of quasi-free quarks and gluons, the quark-gluon plasma (QGP). Does a QGP exist in nature? What does the transition from a low-density state of strongly interacting matter, in which quarks and gluons are confined in hadrons, to QGP look like? Is it similar to the transition from liquid water to water vapour: the first order transition line ending by the second order critical point and followed by the cross over? How does the transition between a non-equilibrium system created in inelastic proton-proton interactions and the equilibrium one in central heavy ion collisions look like?

The objective of the project is to address these questions by study of of high energy nuclear collisions within the international scientific collaboration, NA61/SHINE. The collaboration performs measurements using the NA61/SHINE detector located the Super Proton Synchrotron (SPS) in the European Organization for Nuclear Research (CERN), Geneva. NA61/SHINE was initiated and is led by the PI of this project.

The project consists of two parts:

- (i) **Critical structures and protons.** Within this part of the project a dedicated analysis of proton production in high energy nuclear collisions will be conducted. The world unique data recorded by NA61/SHINE at different collision energies and for different colliding nuclei will be analyzed.
- (ii) **Critical structures and charm.** This part of the project will be devoted to an upgrade of the NA61/SHINE detector. It is planned to significantly contribute to this upgrade by developing and constructing a new data acquisition system. The new system will be able to accommodate the increased - by a factor of about 10 - speed at which collisions are recorded with the upgraded detector. The high speed is needed to measure rarely produced heavy charm hadrons.

The first part of the project may lead to the discovery of the critical point of strongly interacting matter and evidence for a minimum volume of the colliding nuclear matter needed to create a system in equilibrium. The second part has may lead to future discoveries based on the systematic measurements of charm hadron production in heavy ion collisions. Pioneering measurements provided by NA61/SHINE at the CERN SPS will be continued in the future in emerging new experimental facilities, FAIR in Germany, J-PARC-HI in Japan and NICA in Russia. In particular, a new evidence for a minimal collision energy needed to create quark-gluon plasma is expected.

Independently of discoveries, the project will provide unique systematic experimental results on proton production and it will open new perspectives for unique measurements of charm hadron production in nuclear collisions at the CERN SPS.

The project will be located in Jan Kochanowski University in Kielce. The project assumes participation of experts from several NA61/SHINE groups in Poland.