Heavy Ion Physics: Bulk properties of the Quark-Gluon Plasma

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1 Introduction

One of the fundamental questions in the field of subatomic physics is what happens to matter at extreme densities and temperatures as may have existed in the first microseconds after the Big Bang and exist, perhaps, in the core of dense neutron stars. At these very high temperatures and densities hadronic matter is expected to undergo a phase transition to a new state of matter where quark and gluon degrees of freedom are not anymore confined inside the hadrons. This new state of matter is called the Quark-Gluon Plasma (QGP). The aim of heavy-ion physics is to collide nuclei at very high energies and thereby create such a state of matter in the laboratory.

The experimental program started in the 1990's with fixed target collisions made available at the AGS and SPS with energies up to 20 GeV per nucleon in the center of mass. It continued at the Relativistic Heavy Ion Collider in Brookhaven, USA with energies of up to 200 GeV per nucleon and recently at the Large Hadron Collider at CERN, Geneva, Switzerland where energies of 2.76 TeV were reached. Soon collisions of heavy-ions at the unprecedented energy of 5.5 TeV will be made available at the LHC.

In the lectures I will give a brief introduction to the physics of ultra-relativistic heavy-ion collisions and review some selected highlights of the current and future experimental program. I will start the lectures with predictions from Lattice QCD about the nature of the QCD phase transition. I will show how we experimentally characterize and group the different events and focus what we learn from so called soft probes about the properties of the QGP. The material covered in these lectures is published in, amongst others, [1, 2, 4, 5, 6, 7] to which I refer for more details.

References

[1] R. Stock, "Relativistic Nucleus-Nucleus Collisions and the QCD Matter Phase Diagram," arXiv:0807.1610 [nucl-ex].

[2] H. Satz, "The States of Matter in QCD," arXiv:0903.2778 [hep-ph].

[3] F. Karsch and E. Laermann. Thermodynamics and in-medium hadron properties from lattice QCD. In R.C. Hwa, editor, *Quark gluon plasma*, pages 1–59. 2003.

[4] P. Braun-Munzinger and J. Stachel, "Charmonium from Statistical Hadronization of Heavy Quarks – a Probe for Deconfinement in the Quark-Gluon Plasma," arXiv:0901.2500 [nucl-th].

[5] H. Oeschler, H. G. Ritter and N. Xu, arXiv:0908.1771 [nucl-ex].

[6] U. W. Heinz, "Early collective expansion: Relativistic hydrodynamics and the transport properties of QCD matter," arXiv:0901.4355 [nucl-th].

[7] S. A. Voloshin, A. M. Poskanzer and R. Snellings, "Collective phenomena in non-central nuclear collisions," arXiv:0809.2949 [nucl-ex].