Experimental and Theoretical Investigation of Relativistic Heavy Ion Collisions at RHIC with Focus on Non-Central Collisions

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Ultra-relativistic collisions, so called "Little Bangs" of gold nuclei are observed at the experiments of the Relativistic Heavy Ion Collider (RHIC) of the Brookhaven National Laboratory, New York. The aim of these experiments is to create and investigate new forms of matter that existed in Nature a few microseconds after the Big Bang, the creation of our Universe. An important (though mathematically never proven) property of the theory of the color degree of freedom of the quarks and gluons (Quantum Chromo Dynamics, QCD) is that they are bound into hadrons in a matter of normal temperature and pressure. In the early Universe, energy density was many orders of magnitude higher than that, thus deconfined phases of colored matter might have existed. Quark Gluon Plasma (QGP) was predicted to be such a possible phase. This type of matter is searched for at the RHIC experiments.

A consistent picture emerged after the first three years of running the in RHIC experiments: quarks indeed become deconfined, but also behave collectively, hence this hot matter acts like a liquid [1], not like an ideal gas theorists had anticipated when defining the term QGP. The situation is similar to as if prisoners (quarks and gluons confined in hadrons) have broken out of their cells at nearly the same time, but they find themselves on the crowded jail-yard coupled with all the other escapees. This strong coupling is exactly what happens in a liquid [2].

Based on elliptic flow measurements and the broad range success of analytic hydro models, we can make the definitive statement that in relativistic Au+Au collisions observed at RHIC we see a perfect fluid [3, 4]. Based on our estimates on the temperature [5] and energy density [6] we also conclude that the observed matter is in a deconfined state. We also see a possible signal of partial restoration of the chiral $U_A(1)$ symmetry via the mass reduction of η' bosons [7]. Future plan is to explore all properties of the Quark Matter, by analyzing more data and using higher luminosity. We are after the full map of the QCD phase diagram, and in order to explore it, we also have to go to higher energies and compare them to lower energy data. If the Quark Matter is the New World, then Columbus just realized he is not in India, but on a new continent.

References

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