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Percolation approach to initial stage effects in high energy collisions

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Abstract

Possible phase transition of strongly interacting matter from hadron to a quark–gluon plasma state have in the past received considerable interest. The clustering of color sources provides a framework of the partonic interactions in the initial stage of the collisions. The onset of deconfinement transition is identified by the spanning percolation cluster in 2D percolation. In this talk results are presented both for the multiplicity and the elliptic flow at RHIC and LHC energies. The thermodynamic quantities temperature, equation of state and transport coefficient are obtained in the framework of clustering of color sources. It is shown that the results are in excellent agreement with the recent lattice QCD calculations (LQCD).

Keywords: Relativistic heavy-ion collisions; Percolation; QGP; EOS

1. Introduction

One of the main goals of the study of relativistic heavy ion collisions is to study the deconfined matter, known as Quark–Gluon Plasma (QGP), which is expected to form at large densities. It has been suggested that the transition from hadronic to QGP state can be treated by percolation theory [1]. The formulation of percolation problem is concerned with elementary geometrical objects placed on a random d-dimensional lattice. Several objects can form a cluster of communication. At certain density of the objects a spanning cluster appears, which marks the percolation phase transition. This is defined by the dimensionless percolation density parameter ξ [2]. Percolation theory has been applied to several areas ranging from clustering in spin system to the

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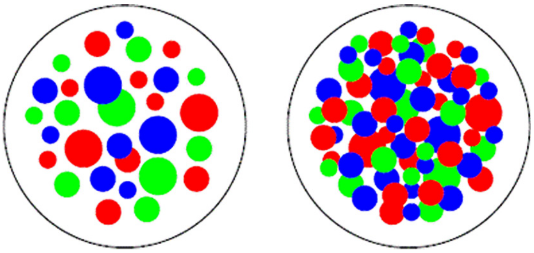

Fig. 1. Partonic cluster structure in the transverse collision plane at low (left) and high (right) parton density [3].

formation of galaxies. In nuclear collisions there is, indeed, as a function of parton density, a sudden onset of large scale color connection. There is a critical density at which the elemental objects form one large cluster, loosing their independent existence. Percolation would correspond to the onset of color deconfinement and it may be a prerequisite for subsequent formation of the QGP. Fig. 1 shows the parton distribution in the transverse plane of a overlapping region of low and high density partons.

All high energy soft multi-hadron interactions exhibit thermal patterns of abundances characterized by the same temperature, independent of the center of mass energy [4,5]. The hadron limiting temperatures were measured by statistical thermal analyses that fit the data with a minimum of parameters [4,5]. In heavy ion collisions it may be plausible that multiple parton interactions produce a thermalized system.

In this talk we present some of the results from the Color String Percolation Model (CSPM), e.g. for the multiplicity and elliptic flow in A+A collisions. Results are also presented for the temperature, equation of state and the transport coefficient.

2. Clustering of color sources

Multi-particle production at high energies can be described at an effective level in terms of color strings stretched between the projectile and target. Hadronizing these strings produce the observed hadrons. At low energies only valence quarks of nucleons form strings that then hadronize. The number of strings grows with the energy and with the number of nucleons of participating nuclei. Color strings may be viewed as small discs in the transverse space filled with the color field created by colliding partons. Particles are produced by the Schwinger mechanisms [6]. These strings act as color sources of emitted particles through the creation of $q\bar{q}$ pairs as they split. Subsequent hadronization produces the observed hadrons [7,8]. In the transverse space color strings due to the confinement looks like a disk of area πr_0^2 with $r_0 = 0.2$ fm. With growing energy and size of the colliding nuclei the number of strings grow and start to overlap to form clusters, very much similar to the disks in the 2D percolation theory [7,8]. At a certain critical density a macroscopic cluster appears that marks the percolation phase transition. This is termed as Color String Percolation Model (CSPM) [7,8]. The string density ξ is defined as $N_s S_1/S_n$ where N_s is the number of strings, S_1 the transverse area of a single string, $S_1 = \pi r_0^2$ and S_n the area of collision, which depends on the impact parameter. The interaction between strings occurs when they overlap and the general result, due to the SU(3) random summation of charges, is a reduction in the multiplicity and an increase in the string tension or an increase in the average transverse momentum squared, $\langle p_t^2 \rangle$. We assume that a cluster of n strings that occupies an area of S_n behaves as a single color source with a higher color field $\vec{Q}_n$ corresponding to the