Deconfinement, Color Screening and Quarkonium Suppression

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The study of color deconfinement in strongly interacting matter leads to challenging problems of theoretical as well as of more phenomenological nature. How does the transition from hadronic matter to a quark-gluon plasma take place - is it a genuine phase transition or some less 'singular' cross-over, and what are the basic properties of the new deconfined medium? In the chiral limit ($m_q = 0$) and in the limit of pure gauge theory ($m_q = \infty$) we do have critical behavior in the classical sense, with well-defined order parameters and singularities in the partition function and hence in thermodynamic observables. Is there some way to really 'define' the transition in full QCD with light but not massless quarks? On the other hand, the aim of high energy nuclear collisions is to investigate the transition and the predicted new deconfined state of matter in the laboratory. What probes exist for these tasks? Is there an experimentally accessible deconfinement order parameter, and how can the temperature dependence of the hot deconfined medium be tested?

The role of the effective quark mass in QCD is similar to that of an ordering external field H in spin theories [1]. For $H = 0$, spin systems show at $T = T_c$ the familiar order-disorder transition, which disappears for $H \neq 0$. The critical behavior at $T = T_c$ can be described either in terms of singularities of thermal observables, or equivalently, as singular behavior of suitably defined geometric cluster variables. Such singular cluster percolation features persist, however, even for $H \neq 0$. It is thus of particular interest to see if the deconfinement transition can in some way be associated to the onset of percolation of clusters of deconfined medium. The answer to this question requires a systematic study of percolation in QCD. First steps had indicated that in the strong coupling limit Polyakov loop percolation indeed led to the correct deconfinement transition in pure Gauge theory [2]. In recent work it was shown that this conclusion can in fact be extended to $SU(2)$ gauge theory in general [3]. Studies of full QCD with dynamical quarks are under way. They could eventually check if the cross-over line between confined and deconfined matter in the $m_q - T$ plane coincides with the line of singular behavior defined through cluster percolation [1].

The behavior of a deconfined medium can be tested by studying the dissociation of quarkonium states through color screening [4]. A prerequisite for this is an understanding of the heavy quark potential in a hot medium, which can in principle be obtained through finite temperature lattice studies. Such studies, however, require extensive computational efforts which have become possible only recently; hence the past year has led to pioneering work in this field [5, 6]. The results of this work will certainly have an impact on the application of quarkonium dissociation as deconfinement probe in nuclear collisions.

The results of experimental studies of J/ψ production in nuclear collisions at the CERN-SPS have made this a particularly interesting as well as challenging probe [7]. While peripheral $Pb-Pb$ collisions lead only to the pre-resonance absorption, already seen in pA and light ion interactions, there appears at a certain centrality a rather sudden onset of an additional 'anomalous' suppression, and for very central collisions a second further drop of the production rate occurs (see Fig. 1). Such a pattern is in fact expected from sequential charmonium suppression, leading first to the dissociation of the χ_c state and of its J/ψ decay products, then to the dissociation of the directly produced J/ψ [8]. More detailed recent investigations have led to a behavior which is qualitatively in accord with data [9, 10]; in particular, however, the central second drop appears to be much stronger than predicted by an onset of direct J/ψ suppression. The possible effects of fluctuations must therefore be taken into account in more detail [9, 11]. Such work is under way.

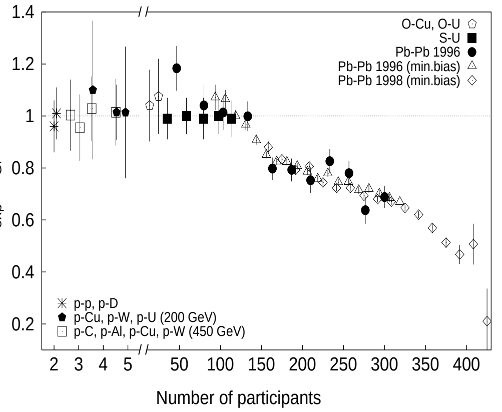

Figure 1: J/ψ production in different interactions

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