J/ψ suppression in ultrarelativistic nuclear collisions

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Suppression of J/ψ production in ultrarelativistic heavy ion collisions is one of the most promising signals for the formation of a quark-gluon plasma in the collisions [1]. Since the quark-gluon plasma has a finite size, exits for a finite time, and may not be in equilibrium, it is important to study how J/ψ suppression is affected by these effects. To purse such a study, we have used a recently developed multiphase transport (AMPT) model [2], that uses an initial parton distribution from minijets (via the HIJING [3] event generator) and includes both subsequent partonic (via the ZPC parton cascade [4]) and hadronic (via the ART model [5]) scatterings. The transition from partons to hadrons is based on the Lund string fragmentation model [6].

Since the J/ψ production probability is small in heavy ion collisions, it is treated perturbatively in the AMPT model [7], i.e., a J/ψ is produced using the PYTHIA routine whenever the energy of an inelastic nucleon-nucleon collision is above the J/ψ production threshold. The produced J/ψ thus carries a probability that is given by the ratio of its production cross section from the nucleon-nucleon interaction to the nucleon-nucleon inelastic cross section at the same energy. Furthermore, a J/ψ is taken to have a formation time of 0.5 fm/c. To include the effect of plasma screening, a critical radius is introduced within which the plasma density is higher than the critical density of about 5 fm^{-3}, estimated from the critical Debye screening mass. A pair of $c\bar{c}$ then cannot form a J/ψ if their separation is smaller than the critical radius after the formation time. In the quark-gluon plasma, a J/ψ may also be destroyed by collisions with gluons with a cross section of about 3 mb [8]. Furthermore, J/ψ's can be absorbed in the hadronic matter following the phase transition of the partonic matter. The cross section is usually taken to be 6 mb for absorption by baryons and 3 mb for absorption by mesons [7].

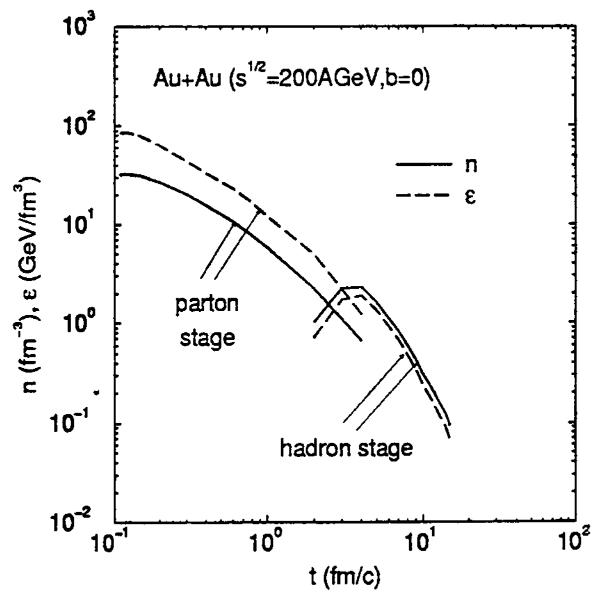

Figure 1: Time evolution of central particle and energy densities in central (b=0) Au+Au collisions at RHIC.

In Fig. 1, we show the time evolution of central particle and energy densities at central rapidity in central Au+Au collisions at $\sqrt{s}$ = 200 GeV. It deviates from the ideal Bjorken boost invariant scenario [9], which would leads to a linear curve on the log-log plot. The critical radius for J/ψ dissociation extracted from the model is about 6 fm at beginning of the parton cascade and vanishes after about 1.2 fm/c.

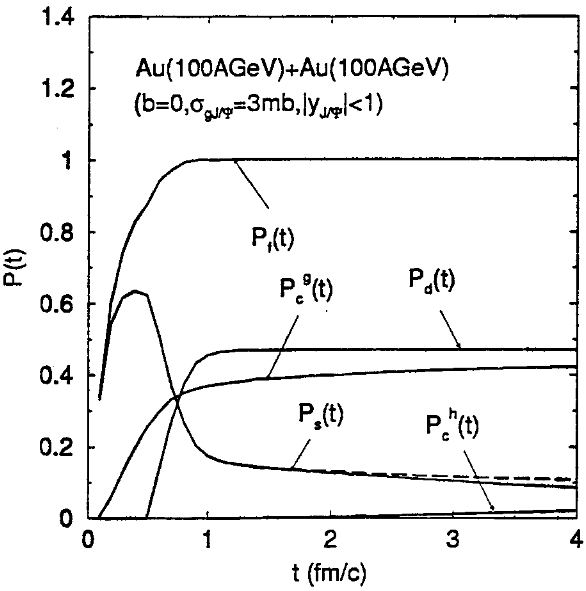

Figure 2: Time evolution of J/ψ formation probability P_f, J/ψ dissociation probability P_d due to plasma screening, J/ψ absorption probability P_c^g by gluons, J/ψ absorption probability P_c^h by hadrons, and J/ψ survival probability P_s (solid curve includes both gluon and hadron absorption while long-dashed curve includes only gluon absorption).

Fig. 2 shows the time evolution of the J/ψ formation probability P_f, J/ψ dissociation probability P_d due to plasma screening, J/ψ absorption probability P_c^g by gluons, J/ψ absorption probability P_c^h by hadrons, and J/ψ survival probability $P_s(t)$. The results are for J/ψ's produced in the central rapidity interval of $|y_{J/\psi}| < 1$. It is seen that the J/ψ formation probability increases quickly with time and by 0.5 fm/c about 90% of the J/ψ's are formed. Absorption by gluons starts very early in the process and stops at about 0.5 fm/c when dissociation due to plasma screening begins. The latter stops at about 1 fm/c. Both dissociation due to plasma screening and absorption by gluon collisions give comparable contributions to J/ψ suppression, leading to about 90% suppression, while absorption by hadrons contributes only about a few percent. The final J/ψ survivability is about 5%.

We have also studied J/ψ suppression in S+S collisions at RHIC energies. Although the initial density is above the critical density, J/ψ dissociation due to plasma screening is, however, negligible as a result of the short lifetime of the plasma. As a result, J/ψ has an appreciable survival probability (about 40%) after absorption by gluons and hadrons.

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