QUASIPARTICLES IN QCD THERMODYNAMICS AND DILEPTON RADIATION*

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A first-principles understanding of the equation of state (EOS) of hot QCD is of great interest in order to reliably identify and calculate experimental signatures of that elusive state in ultra-relativistic heavy-ion collisions. However, perturbative results show bad convergence, and current experiments only probe that non-perturbative temperature regime close to the critical temperature T_c where the underlying physics, the confinement and chiral symmetry breaking mechanism, is not sufficiently understood. Phenomenological models incorporating as much physics as is known are therefore necessary. Here, we propose a new quasiparticle model of the quark-gluon plasma (QGP) that incorporates a parametrization of confinement, supplemented by thermal masses compatible with lattice results. Details can be found in [1].

From asymptotic freedom, we expect that at very high temperatures the plasma consists of quasifree quarks and gluons. As long as the spectral function of the thermal excitations at lower temperatures resembles qualitatively this asymptotic form, a quasiparticle description of the QGP is expected to be applicable. Their dispersion relation reads

$$\omega_k^2 \simeq k^2 + m_*^2(T), \tag{1}$$

where $m_*(T)$ acts as an effective mass generated dynamically by the interaction of the partons with the heat bath background.

However, the picture of a simple massive gas is presumably not appropriate close to T_c because the driving force of the transition, the confinement process, is not taken into account. While the confinement mechanism as such is still not understood, it is not necessary to know it in detail since we consider a *statistical* system. All confinement does on a *large* scale is to cut down the number of thermally active partons as the temperature is lowered: since the confined particles have large masses, their contribution to thermodynamics is negligible. This effect can be included in a quasiparticle picture by modifying the distribution function f of the partons by a temperature-dependent *confinement factor* $C(T)$: $f(\omega_k) \to C(T) f(\omega_k)$. Since there are indications that the confinement mechanism is only weakly flavour-dependent, we assume that the function $C(T)$ acts in a universal way on quarks and gluons. Reassuringly, the pressure of the confinement model for $N_f = 2$ lies then well within a narrow lattice estimate for the continuum EOS in the chiral limit.

Based on the observation that the gluon Debye screening mass m_D evaluated on the lattice in pure gauge theory shows approximate critical behaviour, in accordance with a weakly first order phase transition and in contrast to perturbative results, we parametrize

$$m_*(T) \sim G_0 T \left(1 - \frac{T_c}{T}\right)^{\beta}. \tag{2}$$

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The explicit temperature dependence of the confinement factor $C(T)$ can be obtained as the ratio of the lattice entropy - that is a measure for the number of degrees of freedom - and the entropy calculated with a dropping input mass. $C(T)$ again shows near-critical behaviour: $C(T) \sim (1 - T_c/T)^{\gamma}$.

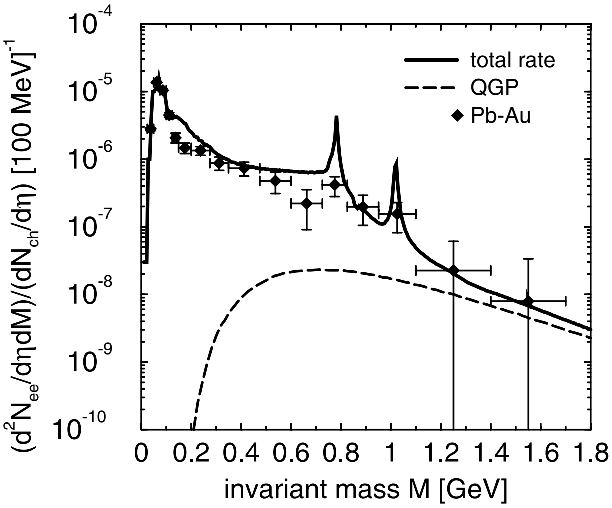
Comparing the EOS with lattice data, as a function of T, a good and economic parametrization is achieved. The so-called interaction measure, related to the trace of the energy-momentum tensor, $T^{\mu}_{\mu} = \epsilon - 3p$, is also nicely reproduced.

We apply the proposed model now to dilepton production in URHIC where it enters in two ways: the EOS serves as input for the construction of the fireball that is discussed at length in [2]. Second, the dilepton emissivity of a static hot spot,

$$\frac{d\mathcal{N}_{ee}}{d^4x d\omega d^3k} \sim \frac{\rho_V(\omega, k; T)}{\exp(\omega/T) - 1}, \tag{3}$$

is proportional to the vector spectral function ρ_V that is calculated from the photon self energy. By construction, the quasiparticle $q\bar{q}$-loop is the only contribution above T_c. In addition, the confinement mechanism reduces the probability of thermally exciting a quark by $C(T)$ and thus the total rate by $C(T)^2$. Below T_c, the hadronic photon self-energy is obtained using Vector Meson dominance in combination with chiral dynamics and medium effects.

To compare with experiment, the rate (3) has to be convoluted with the space-time fireball expansion [2]. The figure shows a comparison of our calculation with the dilepton rate from the CERES/NA45 experiment at 160 AGeV Pb-Au collisions, with the explicit QGP contribution plotted.



References

[1] R.A. Schneider, W. Weise, Phys. Rev. **C64** (2001) 055201.

[2] T. Renk, R.A. Schneider and W. Weise, hep-ph/0201048.