Thermal Photons and Dileptons from Lattice QCD

Because of infrared problems in finite temperature QCD which occur at momentum scales g^2T ($g^2 = 4\pi\alpha_s(T)$ is the QCD coupling) the perturbative calculation of thermal photon and dilepton rates becomes unreliable at low energies [1]. Parametrically one would expect this to happen for energies $\omega \sim \mathcal{O}(g^2T)$. However, since the QCD coupling constant itself is $\mathcal{O}(1)$ in the temperature range of interest to heavy ion physics (a few times T_c), infrared problems show up already at energies of the order of the temperature. Thus a non-perturbative calculation is necessary.

Recently it has been suggested that a lattice calculation of the imaginary time vector current correlators can provide information about thermal dilepton rate [2]. In principle one can extract from the imaginary time correlator the relevant vector spectral function which is proportional to the thermal photon and dilepton rates. This can be done using the Maximum Entropy Method [3]. In practice, however, the extraction of the spectral function from finite temperature correlators is quite difficult. Nevertheless, already the imaginary time correlator on its own can provide stringent constraints on the spectral function [2]. In Fig. 1 the vector correlator from lattice calculations normalized by the corresponding free correlator is shown for temperatures $1.5T_c$ and $3T_c$ (T_c being the transition temperature). All these calculations were performed within the quenched approximation. As one can see from the figure the correlator deviates from the free field limit only by about 10%. This already rules out the strong enhancement of the vector spectral functions predicted in HTL perturbation theory [4]. In fact, the vector correlator is divergent in HTL perturbation theory as the corresponding spectral function is diverges in the limit $\omega \to 0$.

The spectral functions reconstructed from the vector correlator as well as the corresponding thermal dileptons rates are shown in Fig. 2. The most striking feature of the spectral function shown in Fig. 2 is the fact of its suppression at low energies which translates into the suppression of low mass thermal dileptons as shown in Fig. 2. The dilepton

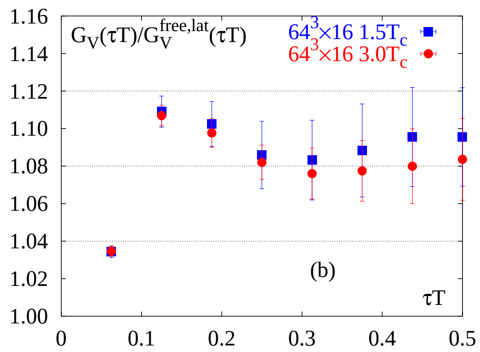

Figure 1: Thermal vector current correlation functions, G_V, divided by the free correlator calculated on the lattice, $G_V^{free,lat}$, versus Euclidean time τ.

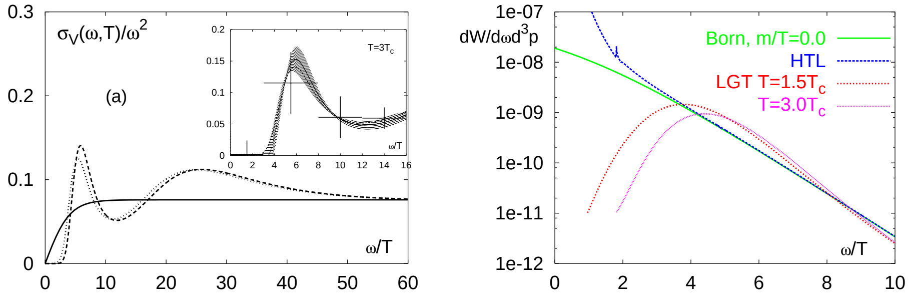

Figure 2: Reconstructed vector spectral function σ_V in units of ω^2 at zero momentum (a) and the resulting zero momentum differential dilepton rate (b) at $T/T_c = 1.5$ (doted line) and 3 (dashed line). The solid lines give the free spectral function (a) and the resulting Born rate (b). The insertion in (a) shows the error band on the spectral function at $3T_c$ obtained from a jackknife analysis and errors on the average value of $\sigma_V(\omega, T)/\omega^2$ in four energy bins (see text). Also shown in (b) is the leading order HTL result for the thermal dilepton rate from [4].

rate obtained in HTL perturbation theory, diverges at small ω. Another interesting feature of the spectral function obtained in lattice calculations is the bump around $\omega = (5-6)T$. Further detailed studies with improved fermion discretization schemes, which do have a better controlled ultra-violet behavior, are needed to confirm this structure.

The results shown in Figs. 1,2 refer to the case of zero spatial momentum $\vec{p} = 0$. Similar results have been obtained also for finite momenta [5]. In particular, in accordance with the $\vec{p} = 0$ results, it was found that $\sigma_V(\omega, p = \omega) \simeq 0$. This implies that thermal photon rate will be small. Vector spectral functions above the transition temperature have been also been calculated in Ref. [6]. It was also found in this study that the vector spectral functions is suppressed at small energies and that the existence of a peak at $\omega = (5-6)T$ has been confirmed.

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