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Spectrum of fermion coupled with massive vector boson at finite temperature in gauge invariant formalism

We investigate the massless fermion spectral function coupled with a massive vector boson (mass: m) in the whole region of temperature (T) [1]. The massive vector boson is described as a U(1) gauge boson so that we can analyze the extremely high-T region where T/m $\gg$ 0, in contrast to the Proca formalism [2]. We show that a novel peak appears in the fermion spectral function for T˜m in addition to the two peaks corresponding to the normal fermionic and anti-plasmino excitations obtained in the m=0 case [3].
We find that the novel peak seems to persist though with a small strength
even for T$\gg$m, where the other two peaks remains robust and are smoothly connected to those obtained in the HTL approximation.
Since our model has a U(1) gauge invariance, the poles of the fermion propagator must be gauge invariant. We have confirmed the gauge invariance of the poles for T$\ll$m and T˜m, while the gauge invariance of the poles are satisfied only for a restricted region of the gauge-fixing parameter for T$\gg$m. We explicitly obtained the adequate region of the gauge-fixing parameter for T$\gg$m. Our results shows that the unitary gauge, which corresponds to the large gauge-fixing parameter limit, is found to be inadequate for the calculation of the fermion propagator in the T$\gg$m region, although the unitary gauge is often adopted in the literature.
The relevant physical systems of our analysis include the quark-gluon plasma phase near the phase transition temperature (T_c) since vector-type collective excitation may exist there and its mass may become very small (T$\gg$m) just above T_c. The neutrino spectrum in the early universe is also relevant since the neutrino couples with the massive vector particles, W and Z boson. The present work tells us that the analysis of the neutrino spectral function in the unitary gauge or in the Proca formalism [4] can
suffer from a strong gauge dependence in the T$\gg$m region.

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