Spectral Function of Quarks in Quark Matter

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We have investigated the spectral function of light quarks in infinite quark matter using a simple, albeit self-consistent model [1]. Relations between the spectral function and the collisional self-energies in the Born approximation were used to calculate the spectral function in an iterative process beyond the quasiparticle approximation. The quark interactions were described by the SU(2) Nambu–Jona-Lasinio (NJL) model [2]. It has the same symmetries as QCD and describes an effective quark-quark interaction with a constant coupling strength. Mean field effects have been neglected in the calculations.

This study has been motivated by similar calculations for nucleons in nuclear matter [3]. It was found there that the results are in good agreement with calculations from many-body theory. In particular the model was very successful in describing the influence of short-range correlations on the properties on nuclear matter using a simple pointlike nucleon interaction with constant scattering amplitude.

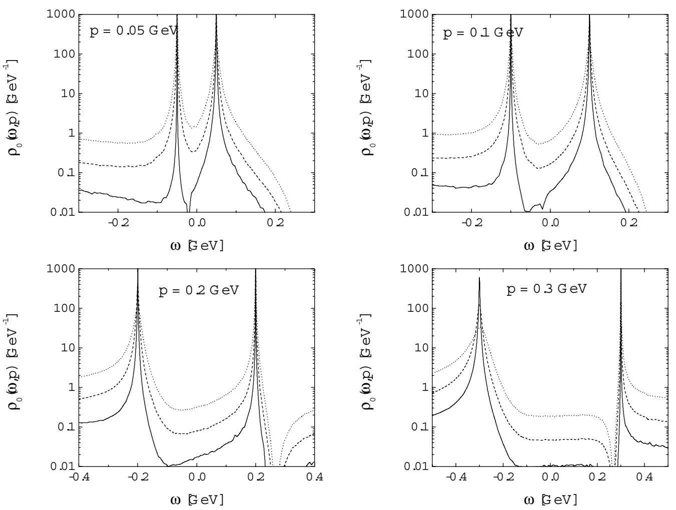

Figure 1: The spectral function of quarks at different momenta. The solid line corresponds to the usual NJL coupling strength, the dashed line is the result at a coupling twice as large and the dotted line has been obtained with a coupling four times larger than the usual value.

Our calculations were performed at zero temperature and in the chirally restored phase. We chose the quark matter such that it is comparable to regular nuclear matter, $\rho_{\rm qm} = 3 \cdot \rho_{\rm nm} = 3 \cdot 0.17\,{\rm fm}^{-3}$. This yields a Fermi energy of $\omega_F = 0.268\,{\rm GeV}$. The (three-momentum) cutoff Λ and the coupling constant G of the NJL model were chosen so that the model gives the known values [2] for the quark condensate and the pion coupling constant f_π in vacuum. In addition we did calculations with two times and four times larger coupling strengths to investigate the influence on the spectral function.

Fig. 1 shows our results for the spectral function at several momenta and coupling strengths. Physically the most interesting area lies in the energy range $0 < p_0 < \omega_F$ since that is the location of the populated quark states. All states above the Fermi energy as well as the anti-quark states at negative p_0 are unoccupied (no holes in the Dirac sea). The structure of the spectral function is dominated by the on-shell peaks of the quarks and anti-quarks at $p_0 = |\vec{p}|$ and $p_0 = -|\vec{p}|$. As one would expect the peaks get broader when the coupling is increased. Strength is distributed away from the peaks to the off-shell regions, the width of the peaks increases from $0.1 - 1\,{\rm MeV}$ at the lowest to $10\,{\rm MeV}$ at the largest value for the coupling constant.

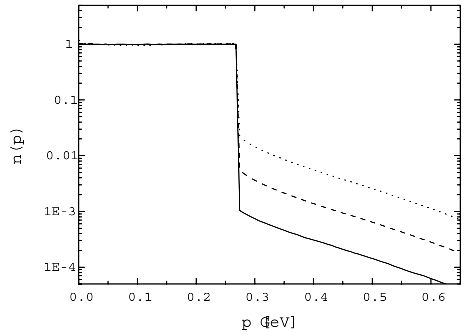

Figure 2: Quark momentum distribution in quark matter at different coupling strengths (see Fig. 1 for details).

The momentum distribution of nucleons in nuclear matter shows a depletion of occupation probabilites by about 10% [3]. The resulting high energy tail is taken as a universal sign of short-range correlations. In Fig. 2 we show the momentum distribution of the quarks that we have found for the different coupling strengths. As expected for an infinite system a sharp step at the Fermi momentum appears. At the lowest coupling a depletion of only 0.1% is found. For the coupling twice as large the short-range correlations increase but still the depletion effect is below 1%. Only for the largest couplings we find a high momentum tail of a few percent, comparable to the case of nucleons.

The results indicate that the influence of short-range correlations is small compared to nuclear matter. This finding, however, might be an artefact of the present model, the NJL model with vacuum parameters in the Born approximation. Since we know now that the model is technically feasible we plan to go beyond the simple model presented here. It is our plan to use more sophisticated interaction models for future calculations.

References

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[3] J. Lehr, M. Effenberger, H. Lenske, S. Leupold, U. Mosel, Phys. Lett. B 483 (2000) 324; J. Lehr, H. Lenske, S. Leupold, U. Mosel, nucl-th/0108008.