Short-Range Correlations in Nuclear Matter

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The density and temperature dependence of short-range correlations in nuclear matter is of interest for various regions of nuclear physics. In heavy ion collisions like those planned at the Compressed Baryonic Matter (CBM) facility at GSI densities of several times nuclear matter saturation density ρ_0 are reached. Similar conditions are encountered when a neutron star is formed. In a supernova explosion temperatures of several tens of MeV and densities far beyond ρ_0 arise. We have extended [1] the approach to short-range correlations in symmetric nuclear matter presented initially in [2] to the more general cases of arbitrary temperatures and densities. Using a pointlike NN interaction and relations between correlation functions and collision integrals a simple but fully self-consistent model for the calculation of nucleon spectral functions was constructed. The density and temperature dependence of the mean-field self-energy was taken into account by incorporating a Skyrme-type energy density functional.

We have investigated the short-range correlations in nuclear matter at temperatures from 10 to 70 MeV and at densities $\rho = \rho_0 \cdots 3\rho_0$. ($\rho_0 = 0.16\,\mathrm{fm}^{-3}$). The averaged scattering amplitude of the effective NN interaction was adjusted to reproduce the results of Benhar et al. [3] at $T = 0$. A constant value was used independent of temperature and density. In addition we have introduced a form factor acting in the t-channel to suppress large energy and momentum transfers.

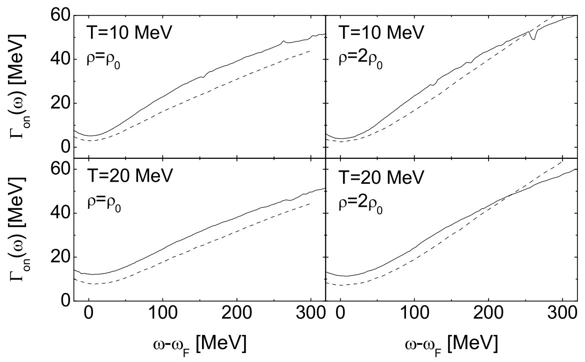

Figure 1: The on-shell width $\Gamma_{\mathrm{on}}(\omega)$ for two temperatures and densities. The dashed lines show the result of [4].

In Fig. 1 we show our results for the on-shell width Γ_{on} at several temperatures and densities. Also shown are the results of Alvarez-Ruso et al. [4] that are calculated using a similar, "semiphenomenological" model. In contrast to the situation at $T = 0$, Γ_{on} does not drop to zero at $\omega = \omega_F$. The states at the Fermi surface cease to be quasi-stable at finite temperatures. Compared to [4] our results are shifted to higher values by approximately 5 MeV. This might be explained by the different NN interactions that were used. The shape of the curves is in good agreement for $\omega - \omega_F < 150\,\mathrm{MeV}$. At higher energies the form factor that was used in our calculations affects the shape of Γ_{on}.

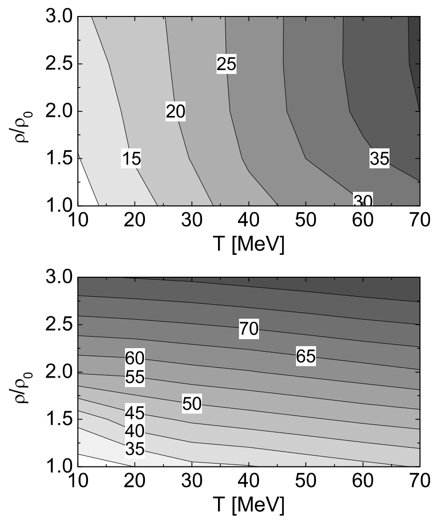

Figure 2: **(a)** The on-shell width $\langle\Gamma_{\mathrm{on}}\rangle$ in the (T,ρ)-plane (Γ in MeV). Γ_{on} was averaged over the occupied states for each T and ρ. **(b)** The same as in (a) but Pauli-blocking was switched of in the calculation.

The behavior of Γ_{on} over the full temperature and density range is shown in Fig. 2(a). For this plot Γ_{on} has been averaged over the occupied states for each T and ρ. It can be seen that $\langle\Gamma_{\mathrm{on}}\rangle$ rises almost linearly with the temperature. The density dependence has a different structure. At low densities (below $2\rho_0$) $\langle\Gamma_{\mathrm{on}}\rangle$ does increase with ρ, as naively expected. At higher ρ, however, the density dependence becomes very weak. Since we take $\langle\Gamma_{\mathrm{on}}\rangle$ as a measure for short-range correlations this means that the correlations saturate at densities above $2\rho_0$.

The explanation for the saturation is rather simple. Pauli-blocking suppresses nucleon collisions (the source of the correlations) with final states below the Fermi surface. Thus more final states are blocked at higher ρ. In Fig. 2(b) we show the result of a calculation in which Pauli-blocking was switched off. As expected, a linear dependence of $\langle\Gamma_{\mathrm{on}}\rangle$ on both, temperature and density, is found.

Our model is open for further improvements. We plan to use separate spectral functions for protons and neutrons and to introduce an isospin dependent coupling strength. Thus we will be able to investigate isospin asymmetric nuclear matter in the future.

References

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