1 - 16 Angle Dependent Gap State in Asymmetric Nuclear Matter

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The fermion pairing between different spices with mismatched Fermi surfaces, which was discussed many years ago, promote new interest in both theoretical and experimental studies in recent years. In the asymmetric nuclear matter contexts, the mismatched Fermi surfaces can be realized both in the neutron-proton paring system where the asymmetry is small. In this system, the FFLO[1,2] state and DFS (deformed Fermi surfaces)[3] state are studied in Refs. [4,5]. In the FFLO state, the shift of the two Fermi spheres with respect to each other, which results in the Cooper pair moving with a finite momentum, enhances the overlap between neutron and proton Fermi surfaces. Thus the overlap regions provide the kinematical phase space for pairing phenomena to occur. And in the DFS state, the deformation of the Fermi surfaces may increase the phase-space overlap between the neutron and proton Fermi surfaces. Both in these two kinds of possible superfluid states the quasiparticle excitation spectra are no longer isotropic since the anisotropic overlapping configuration could increase the pairing energy. On the other hand, the usually adopted angle-averaging procedure in the previous calculations[4,5], which has been proved to be a quite good approximation in symmetry nuclear matter[6], considers the gap as isotropic gap by ignoring the angle dependence. As the true ground state connects with the anisotropic overlapping configuration, the angle-averaging procedure may be an insufficient approximation in isospin asymmetric nuclear matter.

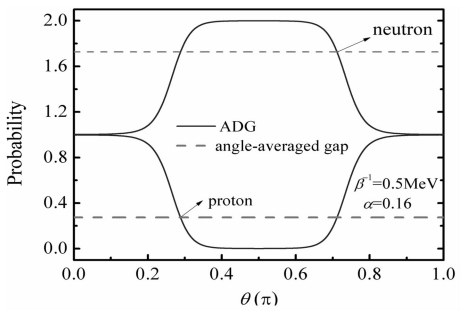

Fig. 1 The higher and lower curves are related to the neutron and proton occupation probabilities.

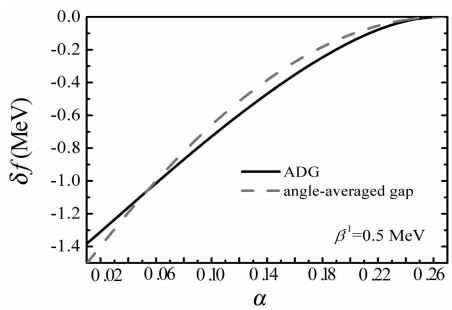

Fig. 2 The differences of the free energy between the superconducting and normal states.

In views of the reasons above, we propose an axi-symmetric angle dependent gap (ADG) state with broken rotational symmetry in isospin asymmetric nuclear matter. In this state, the deformation of neutron and proton Fermi spheres can increase the pairing probabilities along the direction of the symmetry breaking near the average Fermi surface. We find the state possesses of lower free energy and larger gap than the angle-averaged gap state for large isospin asymmetry. These properties are mainly caused by the coupling of different m_j components of the gap. Furthermore, we find the transition from the ADG state to normal state is of second order and the state vanish at the critical isospin asymmetry α_c where the angle-averaged gap vanishes.

The neutron and proton occupation probabilities at the average Fermi surface for the ADG state and angle-averaged gap state with the temperature $\beta^{-1}=0.5$ MeV and asymmetry $\alpha=0.16$ are exhibited in Fig. 1. It obviously that in the ADG state, the overlap between neutrons and protons is enhanced in the regime $\theta\subset(0,\pi/5)\bigcup(4\pi/5,\pi)$. The essential quantity to describe the thermodynamics of the system is free energy. We calculate the differences between the superconducting and normal states for the ADG state and angle-averaged gap state and show in Fig. 2.

References

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