Single particle potential in asymmetric nuclear matter

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Introduction

Equation of state (EOS) of asymmetric nuclear matter at finite temperature and at high densities is one of the relevant issues in theory of neutron star calculation where nucleon-nucleon interaction plays a major role for this and single particle potential has its own place. In our earlier works[1, 2] we have studied the single particle potentials for proton U_p and neutron U_N at various values of temperatures and it was of great success. Now our interest goes to observe how the single particle potential for proton U_P and neutron U_N varies at various values of densities and proton fractions.

Formalism

In our calculation, two body density dependent effective Sussex interaction[3] is used. As the original Sussex interaction does not produce correct saturation property in nuclear matter, Tripathy et al.[3] introduced a simple density dependent term whose parameters are fixed empirically by fitting the binding energies and densities of nuclear matter and ^{16}O. Single particle potential U_τ(k) is calculated using the formula

$$U_\tau(k_1) = \frac{1}{2\pi^2}\int_0^\infty dk_2[n_+(k_2)g_{++}(E_S,k_1,k_2) + n_-(k_2)g_{-+}(E_S,k_1,k_2)]$$

Where n_τ(k) Fermi distribution function,
τ (+ for protons and - for neutrons).
$g_{\tau\tau} \rightarrow$ are the interaction matrices.
$E_S \rightarrow$ starting energy for two particles.

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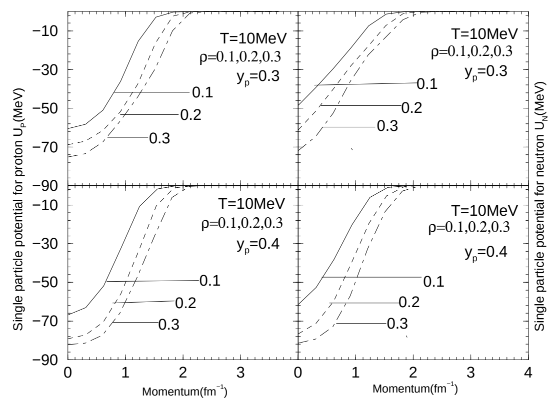

FIG. 1: Single particle potential for proton U_P and neutron U_N verse momenta at proton fractions y_p=0.3 and 0.4 for nuclear matter densities ρ=0.1, 0.2 and 0.3.

In this formalism, asymmetry parameter is defined as $\gamma = \frac{n_+}{n_-}$ and proton fraction is defined as $y_p = \frac{n_+}{n}$.
Where $n_+ \rightarrow$ no density of proton and
$n_- \rightarrow$ number density of neutron and $n = n_+ + n_-$ is the nuclear matter density. This integration is performed upto infinity and the potential accounts properly the scattering into intermediate states and self consistency is satisfied. Effect of temperature is taken into account through Fermi distribution function.

Results and Discussion

The calculations for single particle potentials are performed at a given temperature T=10 MeV and at nuclear matter densities ρ=0.1, 0.2 and 0.3 for proton fractions y_p=0.3 and 0.4.

Our results are plotted at various values of momenta in Fig.1. It is found that at a given temperature T = 10 MeV and proton fraction y_p = 0.3, on increasing nuclear matter density ρ, from 0.1 to 0.3 fm^{-3} the depth of the single particle potential increases at low momentum, agrees well with calculation made by Lejeune et al.[4]. We also observe that single particle potential for proton U_P is more attractive than that of neutron U_N. By enhancing the proton fraction from $y_p = 0.3$ to 0.4 the depth of these potentials for both proton and neutron increases. As the fraction of proton increases, the isospin t=0 part of the nuclear force is enhanced resulting in increase of depth of single particle potentials. Similar things also happen as the density increases. Towards higher momentum single particle potential decrease with momentum, agrees well with the calculation made by Lejeune et al.[4] and Sammarruca et al.[5].

References

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