Thermal Effect on Pressure Genaration of Constituent Particles in Asymmetric Nuclear Matter

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Introduction

The knowledge of pressure generation in hot asymmetric nuclear matter by its constituent particles is the key factor in understanding the dynamical evolution of massive stars and the supernova explosion mechanism. In view of this statement, we have investigated the role of thermal effect in generation of pressure due to protons and neutrons at various values of nuclear matter density ρ=0.1, 0.2 and $0.3fm^{-3}$ for the proton fraction y_p=0.1 and 0.3.

Formalism

We have performed a non-relativistic microscopic calculation in frame work of Bruckner Goldstone expansion using density dependent effective two body Sussex interaction [1]. The starting point of our formalism is to calculate grand thermodynamic potential per unit volume as it can be expressed as a linked cluster expansion analogous to zero temperature Bruckner Goldstone expansion i.e.

$$\Omega = \Omega_0 + \Omega_1 + \Omega_2 + \cdots \qquad (1)$$

where Ω_0, Ω_1 and Ω_2 are the contributions to the thermodynamical potential due to unperturbed part, one body part and two body part of Hamiltonian. In our formalism chemical potential is calculated from number-density constraint and double self consistency is satisfied with respect to single particle potential and chemical potential. Taking into considerations upto two body part, the pressure is calculated using the formula

$$P = \frac{1}{\pi^2}\sum_\tau \int_o^\infty dk k^2 n_\tau(k)\left(\frac{1}{3}k\frac{d\epsilon_\tau}{dk} + \frac{1}{2}U_\tau(k)\right) \qquad (2)$$

where

$$\begin{aligned} \tau &\rightarrow stands\ for\ isospin \\ n_\tau(k) &\rightarrow Fermi\ distribution\ function \\ \epsilon_\tau &\rightarrow single\ particle\ energy \\ U_\tau(k) &\rightarrow single\ particle\ potential \end{aligned}$$

We have introduced proton fraction $y_p = \frac{n_p}{n}$ in our asymmetry nuclear matter calculation where $n_p \rightarrow$ proton density and $n \rightarrow$ nuclear matter density. Thermal effect is defined as the ratio of thermal energy to Fermi kinetic energy.

Results and Discussion

Our results are plotted in FIG. 1. We observe that for a given nuclear matter density, say for $\rho = 0.1\ fm^{-3}$ and proton fraction y_p = 0.1, the generation of pressure with thermal effect in case of proton is very less. On the contrary, in case of neutron, it is large. It is due to the difference in their respective probability of distribution resulted due to the difference in their corresponding thermal effect. In our earlier publications [2, 3] we have discussed that for a given value of nuclear matter density, temperature and proton fraction say y_p = 0.1, probability of distribution of proton is less due to its larger thermal effect and the probability of distribution of neutron is larger due to its smaller thermal effect. When proton fraction is enhanced from y_p = 0.1 to 0.2 and 0.3, its thermal effect is reduced and probability of distribution is enhanced which

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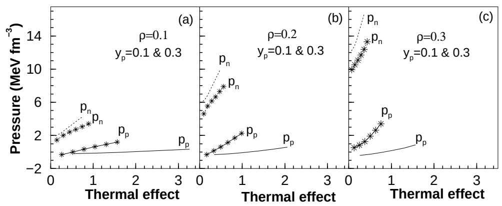

FIG. 1: Generation of pressure due to proton (solid curve), neutron (dotted curve) for proton fraction y_p=0.1 and respective curves with asterisks represent for y_p=0.3.

causes the enhancement of pressure generation in case of proton. on the otherhand, in case of neutron, its thermal effect increases resulting the decrease in probability of distribution which reduces pressure generation.

When nuclear matter density is increased from $\rho = 0.1\ fm^{-3}$ to 0.2 and 0.3 fm^{-3}, thermal effect of proton and neutron are reduced for both the proton fractions due to increase in their corresponding densities. As a result, probability of distribution of both the particles increase. It enhance the generation of pressure for both the particles. Thermal effect is one of the factors to understand the generation of pressure.

References

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