Nuclear matter equation of state at finite temperature within Extended relativistic mean field model

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I. INTRODUCTION

To understand the behavior of nuclear matter at high density and finite temperature, is one of the challenging problem in Nuclear physics. A successful and widely used approach for nuclear matter is the mean field theory which includes nonrelativistic mean field theory with effective nucleon-nucleon interactions such as skyrme and the relativistic mean field theory(RMF) . The RMF theory is more fundamental as it starts from hadronic field theory with strongly interacting baryons and mesons as degree of freedom and describes very well the basic properties of nuclei near the valley of stability and also the properties of exotic nuclei with large neutron or proton. Nuclear matter at zero temperature has been studied extensively using a variety of theoretical methods whereas the problem at finite temperature has received little attention. The main objective of this work is to construct Nuclear matter EOSs at finite temperatures by using different perametrizations obtained by varing the neutron skin thickness Δr and ω-meson self coupling(ζ) [1]. The Lagrangian density for the extended ERMF model can be written as $\mathcal{L} = \mathcal{L}_{\mathcal{BM}} + \mathcal{L}_\sigma + \mathcal{L}_\omega + \mathcal{L}_\rho + \mathcal{L}_{\sigma\omega\rho}$ [1, 2]. The Lagrangian terms and the Euler-Lagrangian equations for ground state expectation values of the meson fields are same as in [1]. At finite temperatures the baryon vector density ρ_B, scalar density ρ_{sB} an d charge density ρ_p are, $\rho_B = \frac{\gamma}{(2\pi)^3}\int_0^{k_B} d^3k(n_i - \overline{n_i}), \rho_{sB} = \frac{\gamma}{(2\pi)^3}\int_0^{k_B} d^3k \frac{M_B^*}{\sqrt{k^2+M_B^{*2}}}(n_i + \overline{n_i}), \rho_p = \left\langle \overline{\Psi}_B \gamma^0 \frac{1+\tau_{3B}}{2}\Psi_B \right\rangle (n_i + \overline{n_i})$. Where, γ is the spin-isospin degeneracy. The $M_B^* = M_B - g_{\sigma B}\sigma - g_{\sigma^* B}\sigma^*$ is the baryon effective mass , k_B is its Fermi momentum and τ_{3B} denotes the isospin projections of baryon B. The thermal distribution function in these expression are defined by $n_i = \frac{1}{e^{\beta(\epsilon_i^* - \mu^*)}+1}, \overline{n_i} = \frac{1}{e^{\beta(\epsilon_i^* + \mu^*)}+1}$ where $\epsilon_i^* = \sqrt{k^2 + M_B^{*2}}$ and $\mu^* = \mu - g_{\omega N}\omega$.

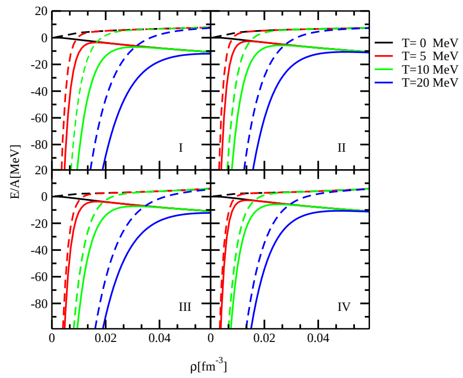

FIG. 1: The variation in energy per nucleon (E/N) for symmetric nuclear matter(solid lines) and for pure neutron matter(dashed lines) with ζ = 0.00&Δr= 0.16 (I), ζ = 0.06&Δr= 0.16(II), ζ = 0.00&Δr= 0.28(III), and ζ = 0.06&Δr= 0.28(IV) is plotted as a function of density at temperatures of 0,5,10, and 20 MeV

II. RESULT AND DISCUSSIONS

We explored the effect of density on energy per nucleon (E/A) for symmetric nuclear and pure neutron matter at finite temperatures in Fig.1 for the change in ζ and Δr. Energy per nucleon for symmetric nuclear matter decreases sharply as compared to the energy for pure neutron matter at very low densities. Also on increasing the ζ the decrease becomes moderate whereas on increasing Δr the symmetric nuclear matter remains unaffected but energy per nucleon for pure neutron matter decreases. The Fig.2 is plotted to

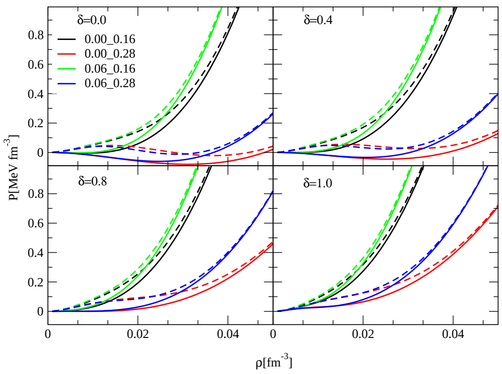

FIG. 2: The pressure at different density is plotted for various values of asymmetry parameter δ.The solid lines are for temperature of 0 MeV whereas the dashed line is for 20 MeV.The black line is for the 0.00_0.16 (parameterization having $\zeta = 0.00\Delta$r $= 0.16$), red line for 0.00_0.28, green line for 0.06_0.16 and the blue line for 0.06_0.28 parameterization.

show the effect on EOSs of different parameterization with change in asymmetry parameter $\delta(= \frac{\rho_n - \rho_p}{\rho_n + \rho_p})$. So it can be seen from the figure on increasing asymmetry parameter the EOSs become stiff and trend continues till it becomes pure neutron matter. On increasing ζ the EOSs becomes stiff which becomes further stiffer on increasing temperature whereas on increasing Δr the EOSs become soft. In Fig.3 we have shown the comparison of bulk properties of our parameterization with those existing in literature(TM1 and NL3 parameterization). We choose the intermediate parameter $0.03 - 0.22$ (parameterization having $\zeta = 0.03$ and Δr $= 0.22$). The symmetry energy (E_{sym}),incompressibility coefficient (K), Pressure (P) and energy per nucleon (E/N) for symmetric nuclear matter is plotted against density (ρ) at a temperature of 0 MeV and 30 MeV. It can be visualized from the figure that except incompressibility for NL3 parameterization all the parameter yield almost same values of bulk properties whereas equation of state varies a lot. Therefore the temperature effects the bulk properties and EOSs of symmetric and asymmetric nuclear matter significantly at densities lower than its saturation

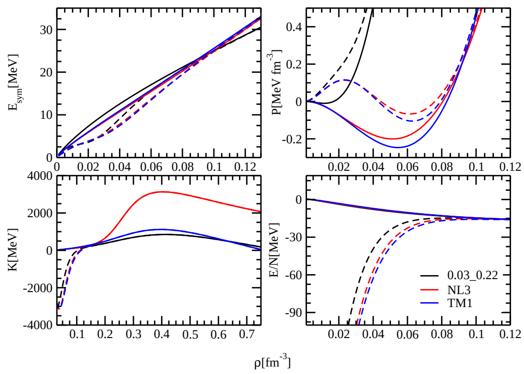

FIG. 3: The symmetry energy (E_{sym}),incompressibility coefficient (K), Pressure (P) and energy per nucleon (E/A) for symmetric nuclear matter is plotted against density (ρ) for the 0.03_0.22 (parameterization having $\zeta = 0.03$ and neutron skin thickness Δr $= 0.22$) as solid and dashed black line, NL3 parameterization as solid and dashed red line and for TM1 parameterization as solid and dashed blue line. The solid lines are at a temperature of 0 MeV whereas the dashed lines are for a temperature of 30 MeV.

density and is insignificant at higher densities.

References

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