Low density equation of state of symmetric and assymetric nuclear matter within an extended relativistic mean field model

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Introduction

The properties of the compact stars are mainly determined by the equation of state (EOS) of nuclear dense matter, which is charge neutral matter in β equilibrium [1]. Any given EOS of baryonic matter determines uniquely the mass-radius relationship of a compact star and, in particular, the maximum mass a compact star can achieve before collapsing into a black hole [2].

In the present work we have used the extended relativistic mean field model [3–6] and its various parametrizations to study the low density behaviour of the EOS for symmetric and assymetric hot and cold nuclear matter. We have employed BSR1, BSR7 parameter set correspond to the value of ω-meson self-coupling $\zeta = 0.00$ and BSR15, BSR21 parameter set correspond to the value of ω meson self-coupling $\zeta = 0.06$, and for each parametrization set the value of neutron skin thickness(Δr) of ^{208}Pb is 0.16 and 0.28 fm respectively [3, 7].

The Lagrangian density for the extended relativistic mean field (ERMF) model can be written as [3]

$$\mathcal{L} = \mathcal{L}_{\mathcal{BM}} + \mathcal{L}_\sigma + \mathcal{L}_\omega + \mathcal{L}_\rho + \mathcal{L}_{\sigma\omega\rho}. \quad (1)$$

The Lagrangian terms and the Euler-Lagrangian equations for ground state expectation values of the meson fields are same as in [3, 8]. At finite temperatures the baryon vector density ρ_B, scalar density ρ_{sB} and charge density ρ_p are,

$$\rho_B = \frac{\gamma}{(2\pi)^3}\int_0^{k_B} d^3k(n_i - \overline{n_i}) \quad (2)$$

$$\rho_{sB} = \frac{\gamma}{(2\pi)^3}\int_0^{k_B} d^3k \frac{M_B^*}{\sqrt{k^2 + M_B^{*2}}}(n_i + \overline{n_i}) \quad (3)$$

$$\rho_p = \left\langle \overline{\Psi}_B \gamma^0 \frac{1+\tau_{3B}}{2}\Psi_B \right\rangle (n_i + \overline{n_i}). \quad (4)$$

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

$$n_i = \frac{1}{e^{\beta(\epsilon_i^* - \mu^*)} + 1} \qquad \overline{n_i} = \frac{1}{e^{\beta(\epsilon_i^* + \mu^*)} + 1} \quad (5)$$

where $\epsilon_i^* = \sqrt{k^2 + M_B^{*2}}$ and $\mu^* = \mu - g_{\omega N}\omega$. The asymmetric parameter used in the artical is defined as

$$\delta = (\frac{\rho_n - \rho_p}{\rho_n + \rho_p}) \quad (6)$$

where ρ_n and ρ_p are the neutron and proton densities respectively..

Result and discussions

In Fig. 1 we present the variation of the equation of state of symmetric nuclear matter as a function of nuclear matter density at various temperatures for the BSR1, BSR7, BSR15, and BSR21 parametrization, in the

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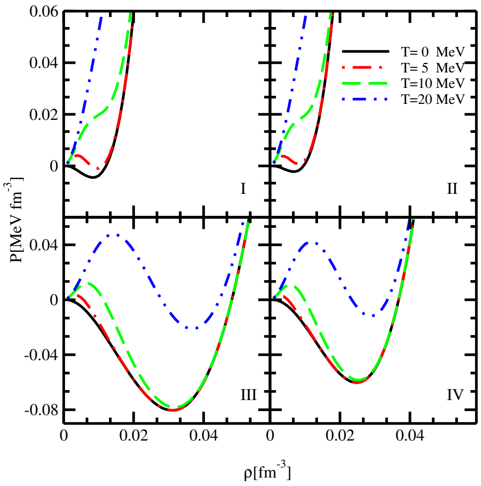

FIG. 1: (Color online) The pressure for symmetric nuclear matter for the BSR1, BSR7, BSR15, and BSR21 parametrizations is plotted as a function of density at temperatures of 0, 5, 10, and 20 MeV.

very low density region. The pressure varies with temperatures at small values of densities and has negligible effect at higher densities. The variation in pressure for a given density depends mostly on the choice of parametrizations and temperature. The pressure become negative for BSR7 and BSR21 parametrizations with Δr = 0.28fm, in the low density regime ($\rho \leq 0.04 fm^{-3}$). In Fig. 2 the pressure of asymmetric nuclear matter is plotted as a function of density in the low density region for various values of the asymmetry parameter δ. The solid line represents T = 0 MeV and the dashed line represent T = 20 MeV. The black line, red line, green line, and blue line represent the BSR1, BSR7, BSR15, and BSR21 parametrization respectively. On increasing the ζ parameter the EOS becomes stiff, whereas for a given ζ parameter on increasing the neutron skin thickness the EOS becomes soft. For all the parametrizations on increasing the temperature the EOS becomes stiff. Further EOS also becomes stiff with the increase in the asymmetry parameter δ and trend continues till it becomes pure neutron matter.

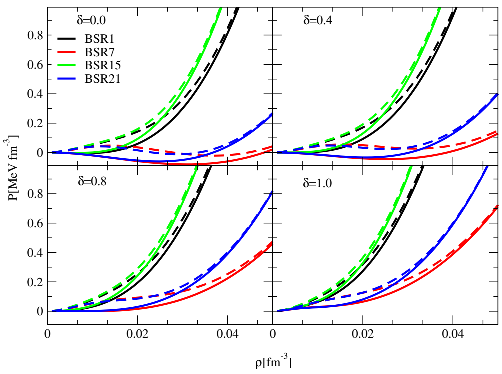

FIG. 2: (Color online) The pressure of asymmetric nuclear matter plotted as a function of density in low density regions for various values of the asymmetry parameter δ. The solid line represents T = 0 MeV and the dashed line represents T = 20 MeV. The black line, red line, green line, and blue line represent the BSR1, BSR7, BSR15, and BSR21 parametrizations respectively.

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