Ferromagnetism of Nuclear Matter in the Relativistic Approach

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We study the spin-polarization mechanism in the highly dense nuclear matter with the relativistic Hatree Fock (RHF) approach. In the RHF framework the total energy density ϵ_T is separated into two parts: the spin-independent part ϵ_{SID} and the spin-dependent part ϵ_{SD} as $\epsilon_T = \epsilon_{SID} + \epsilon_{SD}$. The spin-independent part ϵ_{SID} involves the kinetic energy and the interaction energyes in the scalar and vector channels. On the other hand the spin-dependent part ϵ_{SD} can be written, under the zero-range approximation for the nucleon-nucleon interaction, as

$$\epsilon_{SD} = \frac{1}{2M^2}\rho_B^2\{\tilde{C}_A < \sigma_z/A >^2 + \tilde{C}_T < \beta\sigma_z/A >^2\}. \tag{1}$$

where the first and second terms of the right hand side show the axial-vector and tensor channels. The couplings $\tilde{C}_A$ and $\tilde{C}_T$ are obtained by the Fiertz transformation from original interactions: for example $\tilde{C}_A/M^2 = g_\sigma^2/4m_\sigma^2 - g_\omega^2/2m_\omega^2$ and $\tilde{C}_T/M^2 = g_\sigma^2/4m_\sigma^2$ in the σ-ω model ,

We calculate the total energy as a function of the polarizablity with the parameter-set PM1 [1], allowing the deformation of the Fermi sphere. The spin-symmetry energy defined as

$$\varepsilon_{sp-sym} = \frac{\partial^2 E_T/A}{\partial < \sigma_z/A >^2}|_{<\sigma_z/A>=0}. \tag{2}$$

When ε_{sp-sym} becomes negative, there occurs spontaneous magnetization of nuclear matter. We examine the stability of the spin-saturated matter by varying $\tilde{C}_A$ and $\tilde{C}_T$.

In Fig. 1 we show the density-dependence of the spin-symmetry energies (ε_{sp-sym}) with PM1 ($BE = 16$MeV, $M^*/M = 0.7$, $K = 200$MeV at $\rho_0 = 0.17\text{fm}^{-3}$). Here we use three kinds of the parameter-sets: $\tilde{C}_A = 0$ (long-dashed line), $\tilde{C}_A = -50$ (dashed line) and $\tilde{C}_A = -100$ (solid line), where $\tilde{C}_T$ is given by the condition $\varepsilon_{sp-sym} = 25$(MeV) at normal density (ρ_0).

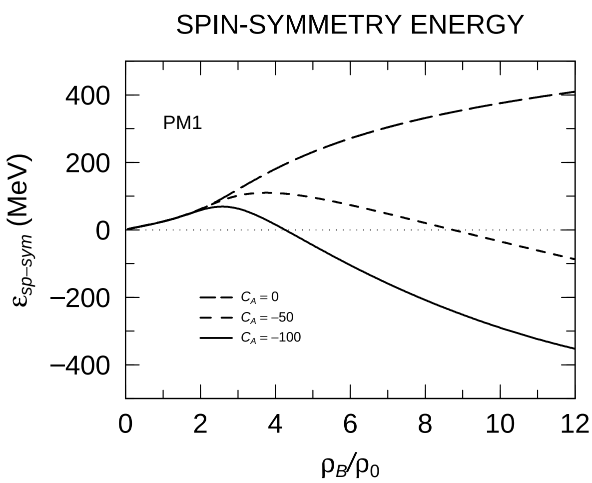

Fig. 1: Density-dependence of the spin-symmetry energies (ε_{sp-sym}) with PM1.

While the spin-symmetry energy monotoneously increases in the case of $\tilde{C}_A = 0$ (SD1), the spin-symmetry energy decreases and becomes minus above a critical density ρ_c in the case of a negative $\tilde{C}_A$ (SD2 and SD3). In this calculation we choose a spin-vector of each nucleon to maximize $< \sigma_z/A >$, and take into account the deformation of Fermi distribution, where the rotational symmetry is broken and $< \sigma_z/A >$ converges to a finite value in infinite density limit whereas $< \beta\sigma_z/A > \to 0$ there.

[1] H. Fujii, T. Maruyama, T. Muto and T. Tatsumi, Nucl. Phys. **A597**, 645 (1996).