Nucleon Properties and Nuclear Equation of State

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We investigate the role of excluded volume corrections in nuclear medium and the corresponding nucleon properties: the nucleon radius and nucleon mass. We argue that even small departures above equilibrium density with the independent of pressure, constant nucleon mass $M(\varrho)$, require an energy transfer from the repulsive mean field to the quarks forming the nucleon bags in nuclear natter. The presented energy transfer ensures the decreasing nucleon radius $R(\varrho)$ in compress matter and shifts the deconfinement phase transition to the higher nuclear density (ϱ). Different courses of the nuclear equation of state, which depend on nucleon volumes, are considered in the Relativistic Mean Field approach (RMF).

We found, that the scenario with the energy transfer and constant mass $M(\varrho)$ [arXiv:1406.3832, IJMPE in print] is more realistic then the scenario without energy transfer and constant $R(\varrho)$, which predicts an unobserved crossover transition for $\varrho \simeq 0.4$ fm^{-3} [arXiv:1501.06945, JPG 42, 045109 (2015)]. In particular, the energy transfer equal to the nucleon volume energy provides the good values of the compressibility $K_q^{-1} \sim (250 - 350)$ MeV and the symmetry energy $E_s = 31$ MeV for $R_0 \sim 0.7$ fm, in the basic version of the RMF. The additional energy transfer near the saturation density reduces the value of the slope of the symmetry energy from $L \simeq 108$ MeV to $L \simeq 61$ MeV. Thus, the presented model comprising the finite nucleon volumes is the alternative to the widely exploit RMF models for point like nucleons with the rich virtual meson structure and additional parameters in nonlinear terms of the scalar interaction together with the density dependent couplings to exchanged mesons. For higher density and reasonable nuclear radii, the presented volume corrections convert the unrealistic, very stiff equation of state of the scalar-vector model into equation which follows realistic Dirac-Brueckner-Hartree-Fock calculations.

In that way, we show how the experimental constrains like nuclear compressibility, symmetry energy and its slope are sensitive to the nucleon properties like the nucleon radius and mass, which are tuned above the equilibrium density by the energy transfer mediated by the repulsive interaction between nucleons. It will be interesting to include this mechanism in other calculations (e.q. ab-initio) of equation of state for a dense nuclear matter and finite nuclei.