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Influence of relativistic nucleon dynamics on the scalar quark condensate in nuclear matter

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The scalar quark condensate $\kappa(\rho) = \langle M|\sum_i \bar{q}_i q_i|M\rangle$ in nuclear matter can be presented as $\kappa(\rho) = \kappa(0) + \kappa_N\rho + S(\rho)$ with $\langle M|$ the ground state of the matter while q are the operators of the light quarks u and d. Here ρ is the density of the matters, $\kappa(0)$ is the vacuum value of the condensate. In the second term on the right hand side the matrix element κ_N is $\kappa_N = \langle N|\sum_i \bar{q}_i q_i|N\rangle$ with $\langle N|$ standing for the free nucleon at rest. This matrix element can be expressed in terms of the nucleon sigma term σ_N related to observables. The various experiments provide the values between 40 MeV and 65 MeV for σ_N. The first two terms in definition of $\kappa(\rho)$ compose the gas approximation.

The contribution $S(\rho)$ describes the change of $\kappa(\rho)$ caused by the nucleon interactions. It was demonstrated that $S(\rho)$ is due mostly to the pion cloud created by interacting nucleons (see [1] for references). In the latter calculations $S(\rho)$ was obtained employing the nonrelativistic approximation for nucleons of the matter (curve 1 in Fig.1). The latest results obtained in framework of chiral perturbation theory [2] are shown by the curve 2.

In the present report the matter is viewed as a relativistic system of nucleons. In the first step we neglect their interactions. We find that the quark condensate can be presented as $\kappa(\rho) = \kappa(0) + \kappa_N\rho F(\rho, m^*(\rho))$ with $F(\rho, m^*(\rho)) = 2/(\pi^2\rho)\int_0^{p_F} dp\, p^2\, m^*/\sqrt{m^{*2}+p^2}$. Here p_F is the Fermi momentum, m^* is the nucleon Dirac effective mass. Note that the same function $F(\rho, m^*(\rho))$ connects the vector and scalar densities in the Walecka model.

The effective mass m^* can be calculated in a hadron model. In the version of QCD sum rules presented in [3] the right hand side of the scalar channel equation contains the effective mass $m^*(\rho)$ while the left hand side contains the scalar condensate $\kappa(\rho, m^*(\rho))$. Thus we come to self-consistent equation for $m^*(\rho)$ which was solved in [3]. Here we employ these results for calculation of $\kappa(\rho)$ (curve 3 in Fig.1). One can see that inclusion of the relativistic dynamics of nucleons is as important as that of nucleon interactions.

References:

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