THEORETICAL PARTICLE PHYSICS

AN EQUATION OF STATE FOR ASYMMETRIC NUCLEAR MATTER AT FINITE TEMPERATURE AND DENSITY IN EXTENDED VERSIONS OF QHD[1]

H. Baier, N. Fröhlich, C. Matulla and W. Bentz[2]

Our recently obtained equation of state (EOS) for symmetric nuclear matter [1] is generalized to the asymmetric case. Relativistic exchange and correlation contributions are included next to leading order in an appropriately defined generalization of the 1/N-approximation (N = 2 in the SU2-symmetric model). To obtain a reasonable symmetry energy we include the ρ-meson in addition to the nucleon, the σ and the ω. This is necessary for a decent application of our EOS to supernova explosions. Furthermore, to apply our results to realistic calculations of neutron star matter, leptons must be included since they contribute significantly to pressure in large parts of the star and are of course necessary to implement β-equilibrium in the usual way. As for the nucleonic and mesonic part of the problem, all the necessary formalism has been developed. Furthermore, a huge computer program has been produced to deduce all the thermodynamic observables. For the time being, ρ-meson and Δ-resonances are included using mean field and simple statistical methods only. As usual we will now include leptons in a crude way as a gas of free relativistic particles.

The following methods were applied:

1. As in our earlier work, we use relativistic renormalizable field-theoretical models to describe hadronic matter. We attempt to go beyond simple perturbation theory and mean-field methods. The 1/N-expansion used by us (see Ref. [1] and the papers cited therein) was shown to be a convenient starting point extendable to the non-chiral (generalized) σ-ω-model in the asymmetric case.

2. It has been argued [2,3,4] that one should start from linear chiral symmetric QHD in order to have a more sophisticated description of hot and dense matter. Possibly one could then circumvent some intricate fine-tuning of certain parameters when calculating the basic thermodynamic observables of nuclear matter by going over to nonlinear realizations of chiral symmetry. Therefore, one uses nonlinear field transformations (e.g. of Weinberg type) to deduce the nonlinear chiral Lagrangian. To preserve renormalizability, the mass of the σ-meson is assumed to be finite. As is well known, one can in this way obtain Lagrangians which in vacuum produce automatically all relevant low-energy pion theorems. It was argued [4] that the transformed linear Lagrangian plus the transformed counterterm Lagrangian should give automatically the complete renormal-

---

[1] Work supported by Fonds zur Förderung der wissenschaftlichen Forschung in Österreich (project number P10274-PHY).

[2] Department of Physics, Faculty of Science, University of Tokyo, Japan.

ized nonlinear Lagrangian. This has been checked in low order perturbation theory. However, since we are interested in the 1/N-expansion and not in a simple perturbation theory in bulk matter, we tried to implement the renormalization procedure explicitly in this much more complicated case. Our goal is the deduction of the renormalized effective action including terms in next to leading order in a 1/N-like expansion. Let's stress that all the methods usually applied to attack these problems in vacuum become a lot more complicated when used in hadronic matter. Even if one accepts the results of Bonneau [5] it is in no way trivial to implement his procedure (which he checked for the nonlinear realization of the chiral O(N+1) to one-loop order) to our more complicated model. At present, a paper dealing with the last-mentioned problems is in preparation. Furthermore, first results on our asymmetric equation of state recently presented in Stuttgart [6] will be submitted for publication in Nucl. Phys. **B**.

[1] G. Hejc, W. Bentz and H. Baier, Nucl. Phys. **A582**, 401 (1995).
[2] W. Bentz *et al.*, Annals of Phys. **188**, 1 (1988).
[3] W. Bentz, A. Arima and H. Baier, Nucl. Phys. **A541**, 333 (1992).
[4] B.D. Serot, Rep. Progr. Phys. **55**, 1855 (1992).
[5] G. Bonneau, Nucl. Phys. **B221**, 178 (1983).
[6] H. Baier, N. Fröhlich, W. Bentz and P. Pohl, Frühjahrstagung des Fachverbandes Physik der Hadronen und Kerne, Stuttgart, Germany, 25 - 29 March 1996, Verhandlungen der Deutschen Physikalischen Gesellschaft 5/96, 898.