

Inhomogeneous phases in effective models

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Chiral-density wave in the extended Linear Sigma Model (eLSM)

The eLSM is invariant under chiral and dilatation transformations and includes (pseudo)scalar and (axial-)vector [1]. The nucleons N and their chiral partners N^* are introduced as parity doublets in the mirror assignment, thus leading to a chirally invariant mass contribution [2]:

$$m_0 (\bar{\psi}_2 \gamma_5 \psi_1 - \bar{\psi}_1 \gamma_5 \psi_2) .$$

In order to preserve dilatation invariance the parameter m_0 is expressed in terms of the condensate of the tetraquark state χ . The model allows to reproduce vacuum phenomenology [1] and nuclear matter ground-state properties [3].

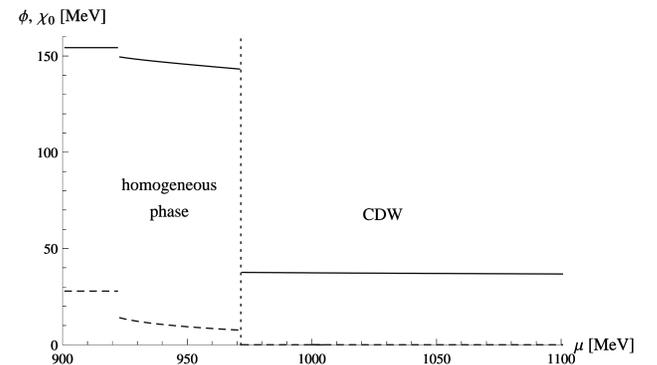


Figure 1: Chiral condensate ϕ and tetraquark condensate χ_0 as a function of μ . At $\mu = 923$ MeV the transition to nuclear matter takes place, at $\mu = 970$ MeV the onset of the CDW.

Chiral-density wave (CDW)

The requirement that the chiral condensate is a constant in space is too restrictive. Our Ansatz is the CDW:

$$\langle \sigma(z) \rangle = \phi \cos(2fz) , \quad \langle \pi_3(z) \rangle = \phi \sin(2fz) .$$

The CDW dominates the high-density regime (Fig. 1 and Fig. 2). At low energy the formation of a homogeneous nuclear matter ground state is possible if the parameter m_0 is large enough ($m_0 > 500$ MeV) [4].

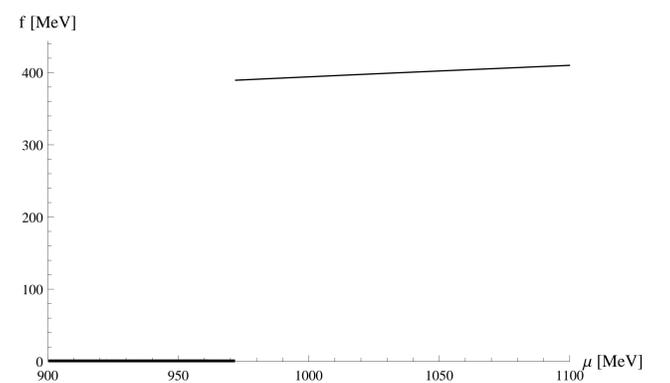


Figure 2: Wave vector f as a function of μ .

Finite-mode approach – towards arbitrary inhomogeneous condensation

Nambu–Jona-Lasinio models in a box

In the finite-mode approach [5, 6] the effective action

$$S = \int d^4x_E [gm^{*2} - \log(\det Q^\dagger Q)] , \quad \text{with } Q = \not{\partial} + \gamma_0 \mu + m^* ,$$

is calculated numerically. This allows to study inhomogeneous phases in a general framework. It is possible to have multiple inhomogeneous fields at the same time. Also, three-dimensional modulations can be implemented.

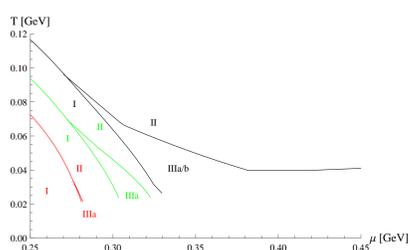


Figure 3: NJL model in a box.

In Fig. 3 the constituent quark masses are $m^* = 250, 300, 350$ MeV (red, green and black) [6, 7].

- homogeneous condensation (I)
- restored chiral symmetry (II)
- inhomogeneous regime (III)

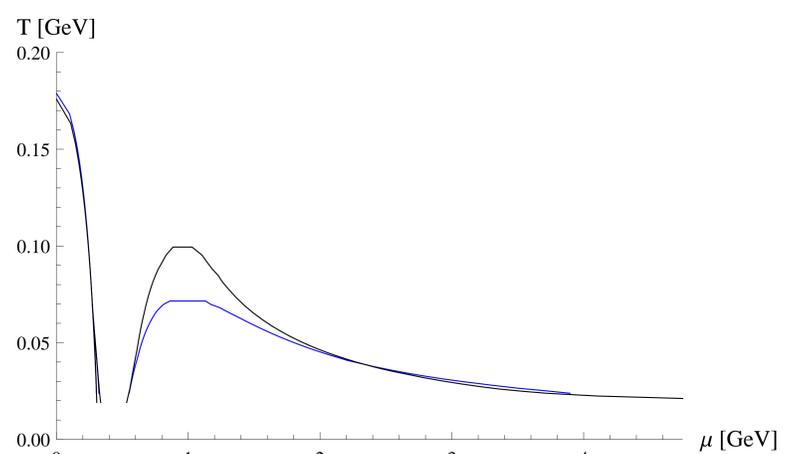


Figure 4: Constituent quark mass of $m^* = 300$ MeV. Blue line: 2 regulating masses, black line: 3 regulating masses.

Below $\mu = 0.5$ GeV the phase diagram shows only a minor dependence on the number of regulators. The inhomogeneous continent [6, 8] is finite but the precise shape depends on the number of regulators.

References

- [1] D. Parganlija, P. Kovacs, G. Wolf, F. Giacosa and D. H. Rischke, Phys. Rev. D 87, 014011 (2013) [arXiv:1208.0585 [hep-ph]].
- [2] C. E. Detar and T. Kunihiro, Phys. Rev. D 39, 2805 (1989).
- [3] S. Gallas, F. Giacosa and G. Pagliara, Nucl. Phys. A 872, 13 (2011) [arXiv:1105.5003 [hep-ph]].
- [4] A. Heinz, F. Giacosa and D. H. Rischke, arXiv:1312.3244 [nucl-th].
- [5] M. Wagner, Phys. Rev. D 76, 076002 (2007) [arXiv:0704.3023 [hep-lat]].
- [6] A. Heinz, F. Giacosa M. Wagner and D. H. Rischke, in preparation.
- [7] D. Nickel, Phys. Rev. D 80, 074025 (2009) [arXiv:0906.5295 [hep-ph]].
- [8] S. Carignano and M. Buballa, Acta Phys. Polon. Supp. 5, 641 (2012) [arXiv:1111.4400 [hep-ph]].