Hadrons and Quarks in an Effective Chiral Model

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SU(3)-flavor σ–ω model, using non-linear realization of chiral symmetry [1,2,3]. Mean field Lagrangian

$$\mathcal{L} = \mathcal{L}_{\text{kin}} + \mathcal{L}_{\text{int}} + \mathcal{L}_{\text{meson}} \quad (1)$$

includes a kinetic term, interactions between quarks and baryons of species i with scalar/vector meson fields

$$\mathcal{L}_{\text{int}} = \mathcal{L}_{\text{BS}} + \mathcal{L}_{\text{BV}} = -\sum_i \bar{\psi}_i \left[\gamma_0 \left(g_{i\omega}\omega^0 + g_{i\phi}\phi^0\right) + m_i^*\right]\psi_i, \quad (2)$$

and mesonic part, which includes mass terms, all meson self-interactions, and explicit chiral symmetry breaking.

Effective masses: $m_i^* = g_{i\sigma}\sigma + g_{i\zeta}\zeta + \delta m_i$,

Effective potential: $\mu_i^* = \mu_i - g_{i\omega}\omega - g_{i\phi}\phi$.

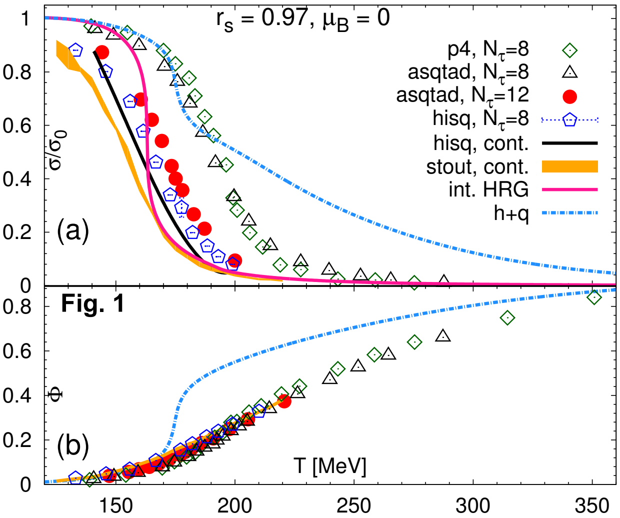
Vector coupling strength of baryon resonances scaled via parameter r_v.
Similar to PNJL, here, quarks couple to a Polyakov loop potential Φ. Hadron suppression at high T and μ by an excluded volume mechanism.
Model includes: three lightest quarks; scalar, pseudoscalar, and vector mesons; baryonic octet, and all hadronic resonances up to $m = 2.6$ GeV.

Chiral transition: [Fig. 1(a)]

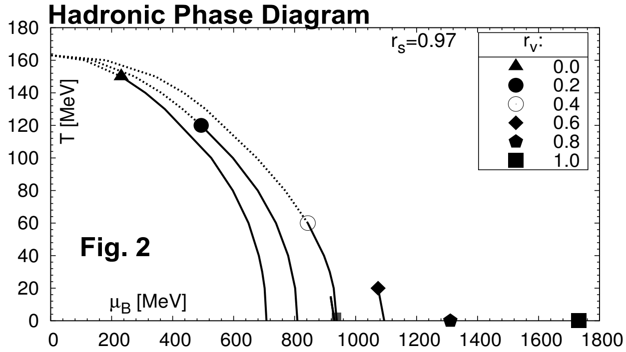
hadrons only: $T_c = 165$ MeV,

quarks & hadrons: $T_c = 175$ MeV (slow decrease of σ at larger T).

Fig. 2 shows impact of resonance couplings on phase diagram of purely hadronic model. No first oder phase transition for $r_v \geq 0.6$.



Hadronic Phase Diagram

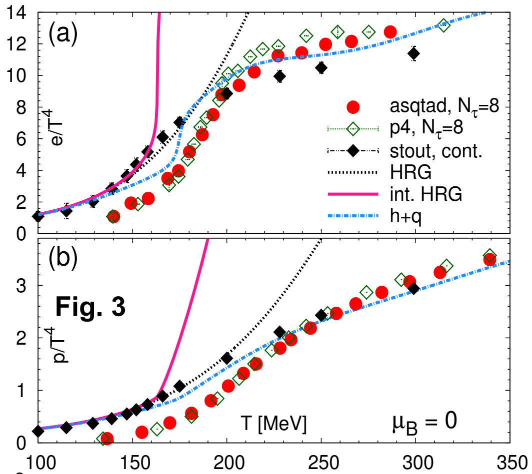


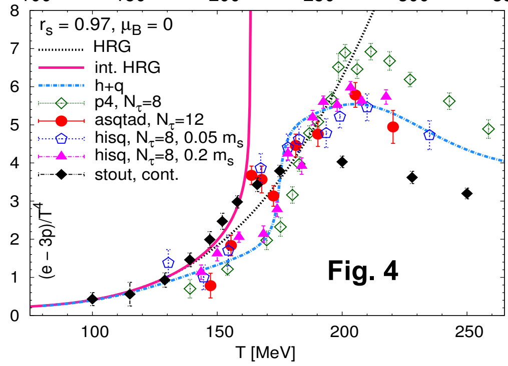
Thermodynamics

Thermodynamic quantities (Fig. 3,4) derived from grand canonical potential

$$\frac{\Omega}{V} = -\mathcal{L}_{\text{int}} - \mathcal{L}_{\text{meson}} + \frac{\Omega_{\text{th}}}{V} - U_{\text{Pol}}, \quad (3)$$

with thermal contribution from quarks, baryons, mesons $\Omega_{\text{th}} = \Omega_{q\bar{q}} + \Omega_{B\bar{B}} + \Omega_{M}$.





Susceptibilities

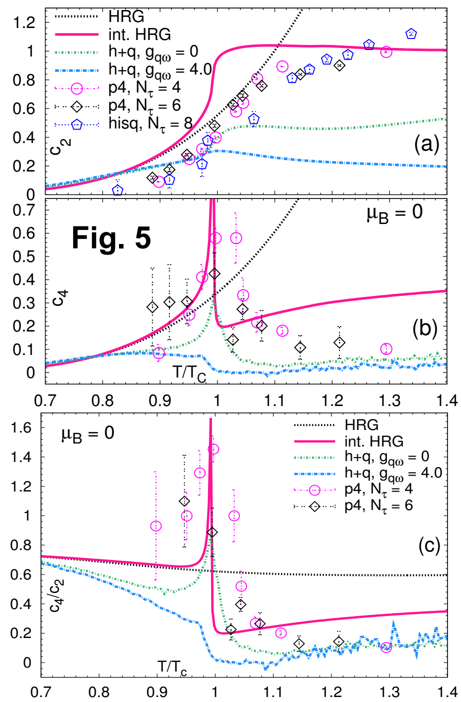
Fluctuations of conserved charges at T_C reflected in susceptibility coefficients c_n. Taylor expanding the pressure $p = -\Omega/V$ with respect to μ/T

$$\frac{p(T,\mu_B)}{T^4} = \sum_{n=0}^{\infty} c_n(T) \left(\frac{\mu_B}{T}\right)^n$$

leads to susceptibility coefficients (Fig.6)

$$c_n(T) = \frac{1}{n!} \frac{\partial^n \left(p(T,\mu_B)/T^4\right)}{\partial \left(\mu_B/T\right)^n}\bigg|_{\mu_B=0}.$$

Susceptibilities very sensitive to the vector coupling strength of resonances and quarks. Only baryon couplings $r_v \approx 1$ give results in the range of lattice data. These values for r_v rule out a first order phase transition and a CEP in our model.



References:
[1] P. Papazoglou et al., PRC57, 2576 (1998),
[2] P. Papazoglou et al., PRC59, 411 (1999),
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[4] C. Ratti et al., Eur.Phys.J. C49, 213 (2007).

Summary

- SU(3)-flavour σ–ω model with quarks & hadrons up to $m = 2.6$ GeV,
- pure hadronic model: good agreement up to T_c with lattice data (stout action) for $r_v \approx 1$,
- Susceptibilities sensitive to vector couplings of quarks & resonances,
- reasonable vector couplings rule out 1^{st} order phase transition and CEP.