The QCD phase diagram - does a phase transition exist or not?
- Studies of effective models of QCD indicate the existence of a phase transition and a critical endpoint at large baryochemical potential [1]
- Event-by-event fluctuations are sensitive to the correlation length and could serve as a signal for a possible critical end point [2]
- Growth of the correlation length is limited by nonequilibrium effects: finite system size, finite time, critical slowing down [3]
- Spontaneous instabilities at the first order phase transition might also lead to strong fluctuations if the system is out of equilibrium [4]

A dynamical model for the QCD phase transition in heavy ion collisions
- Couple chiral fields to hydrodynamically expanding fluid of quarks and antiquarks [5, 6]
- Include effects of dissipation and fluctuation that the fields encounter in the locally thermalized heat bath of quarks [7, 8]
- Ensure self-consistency and energy-momentum conservation [7]
- Include Polyakov loop dynamics on a phenomenological basis [9]

Chiral fluid dynamics with explicit propagation of the Polyakov loop
- We use the Polyakov-quark-meson model as the basis for our studies

\[ \mathcal{L} = \mathcal{L}_0 + \mathcal{L}_r + \mathcal{L}_\sigma \]

- For the sigma field this yields a Langevin equation with temperature dependent damping coefficient and stochastic noise term

\[ \dot{\phi}_\sigma = \phi_0 - \left( \frac{\phi_0}{\lambda_0} \right) \phi_\sigma + \sqrt{2 \eta \tau_0} \xi(t) \]

- The coupled dynamics of fields and fluid have been derived self-consistently within the 2PI approach [10]

Equilibration in a box
- Studies of the relaxation dynamics of the system after a temperature quench in a box [10]
- Results are not sensitive to the choice of the Polyakov loop damping coefficient \( \eta \)
- We observe a delay in the relaxation time near the phase transition as well as critical slowing down near the critical point (see red curves)

Evolution of volume and event averaged sigma field after several quenches in a first order transition scenario.
- During the transition process the intensity of sigma and Polyakov loop fluctuations is stronger in a first order than in a critical point scenario
- After the system is equilibrated we find an enhancement of soft modes at the critical point

Evolution of volume and event averaged sigma field after several quenches in a first order transition scenario.
- Evolution of density fluctuations at the phase transition, formation of domains

The expanding medium at finite densities
- With growing baryochemical potential, the trajectories bend away from the isentropes

Evolution of sigma fluctuations for different trajectories.
- Strong nonequilibrium fluctuations \( \langle \Delta \sigma \rangle = \sqrt{\langle (\sigma_0 - \langle \sigma \rangle)^2 \rangle} \), \( \langle \Delta T \rangle = \sqrt{\langle (T_0 - \langle T \rangle)^2 \rangle} \) at the first order phase transition hint at the formation of a supercooled phase

Evolution of Polyakov loop fluctuations for different trajectories.

Outlook
- Study event-by-event fluctuations of order parameters, baryon density, see Marlene Nahrngang's talk

References