QCD phase transitions in Polyakov-chiral fluid dynamics*

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Introduction

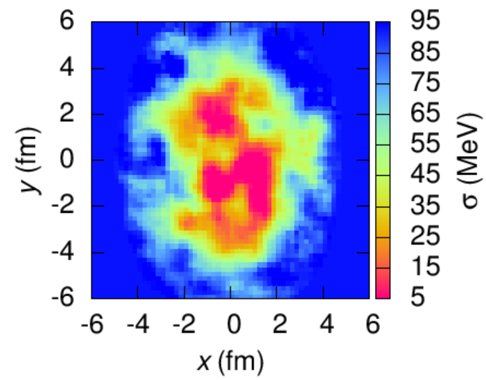
The possibility of a critical point (CP) in QCD is under intensive theoretical and experimental investigation. For thermalized systems, fluctuations of conserved quantities may serve as a probe for the CP. However, it is not yet clear if and how these signals can survive the impact of nonequilibrium effects, which may become dominant in heavy ion collisions. On the other hand, for the same reason, effects at a first-order (FO) phase transition are enhanced. Here phenomena like nucleation or spinodal decomposition may lead to characteristic signals like the formation of disoriented chiral condensates or non-monotonic hadron multiplicity fluctuations.

Polyakov-chiral fluid dynamics

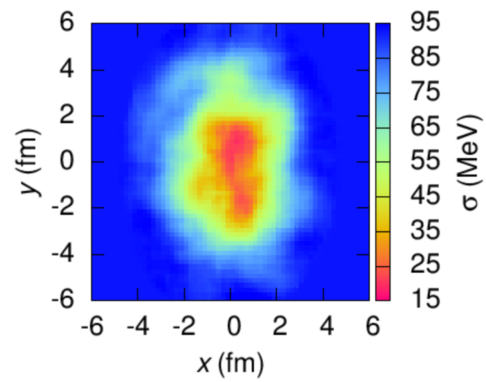
With the use of the Polyakov loop extended chiral fluid dynamics model (PχFD) we study these effects for a FO and a CP scenario at vanishing baryochemical potential. A heat bath of quarks and antiquarks provides the fluid dynamically expanding background on which the relevant order parameters are propagated. These are the sigma field for the chiral and the Polyakov loop for the deconfinement phase transition. For the latter one we deploy its explicit propagation via a relaxation equation including stochastic noise [1,2].

Main results

If we allow the system to thermalize we observe critical slowing down and an enhancement of soft modes at the CP compared with the FO scenario [2]. During the expansion of a hot plasma, supercooling and reheating significantly delay the relaxation process in the FO scenario [1,2]. Correlating the stochastic fluctuations over spatial areas of volume $(1/m_\sigma)^3$ gives us the possibility to study qualitative differences in the two transition processes. While through the CP it proceeds smooth and homogeneous, we observe coexisting domains of the high- and low-temperature phases near the FO transition temperature, cf. Fig. 1. We expect this behavior to create clusters of high baryon density in systems of finite chemical potential, an excellent probe for the QCD phase transition in upcoming experiments at FAIR.



(a)



(b)

Figure 1: (a) Sigma field for $z = 0$ at $t = 4$ fm at the FO phase transition. Domain formation creates coexisting bubbles of the chirally broken and restored phase. (b) Sigma field for $z = 0$ at $t = 3.2$ fm near the CP. Here the ellipsoidal shape is preserved. Figures from [2].

References

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