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From hadron resonance gas to quark-gluon plasma by Mott dissociation of quark clusters

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We show that results for the thermodynamics of strongly interacting matter obtained by state of the art Monte-Carlo simulations of lattice QCD can be adequately described within a generalized Beth-Uhlenbeck type approach, where the hadron resonance gas (HRG) phase appears as a statistical ensemble of multi-quark clusters. The underlying chiral quark dynamics is coupled to a background gluon field using the Polyakov gauge. The transition to the quark-gluon plasma (QGP) phase appears as a Mott dissociation of the quark clusters described by medium-dependent hadron phase shifts that encode the dissociation of bound states in the continuum of scattering states as triggered by the chiral symmetry restoration transition. An important ingredient are Polyakov-loop generalized distribution functions of multi-quark clusters which are derived here for the first time [1].
This new approach gives a quantitative understanding for the observation of ultrarelativistic heavy-ion collision experiments that the abundances of hadrons produced in these collisions are well described by a statistical model within a sudden chemical freeze-out at a well-defined hadronization temperature despite the fact that the melting of the chiral condensate proceeds as a smooth crossover.
We report for the first time the remarkable finding that the ratio of generalized baryon number susceptibilities $R^B_{42}(T) = \chi^B_4(T)/\chi^B_2(T)$, which interpolates between the value $R^B_{42}(T \simeq 140~\mathrm{MeV}) = 1$ for a pure HRG and $R^B_{42}(T > 250~\mathrm{MeV}) \sim 2/(3\pi^2)$ for the QGP shall not be mistaken for a measure of the fraction of hadrons in the system. Its deviation from unity below the chiral restoration temperature can actually quantify the degree of overlap of quark wave functions which leads to the quark Pauli blocking effect in the HRG resulting in repulsive residual interactions which we model by a temperature dependent excluded baryon volume, in accordance with lattice QCD.

[1] D. Blaschke, M. Cierniak, O. Ivanytskyi and G. Röpke, Eur. Phys. J. A 60 (2024)
[2] D. Blaschke, O. Ivanytskyi and G. Röpke, in preparation

session

H. Equation of State and Neutron Stars

Primary author: BLASCHKE, David (University of Wroclaw)

Co-authors: IVANYTSKYI, Oleksii (University of Wroclaw); RÖPKE, Gerd (University of Rostock)

Presenter: BLASCHKE, David (University of Wroclaw)

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