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Van der Waals interactions in hadron resonance gas: from nuclear matter to lattice QCD

An extension of the ideal non-interacting hadron resonance gas (HRG) model is constructed which includes the attractive and repulsive van der Waals (VDW) interactions between baryons. This VDW-HRG model yields the nuclear liquid-gas transition at low temperatures and high baryon densities. The VDW parameters a and b are fixed by the ground state properties of nuclear matter, and the temperature dependence of various thermodynamic observables at zero chemical potential are calculated within VDW-HRG model.

Compared to the ideal non-interacting HRG, the inclusion of VDW interactions between baryons leads to a qualitatively different behavior of 2nd and higher moments of fluctuations of conserved charges, in particular in the so-called crossover region $T \sim 140 - 190$ MeV. For many observables this behavior resembles closely the results obtained from lattice QCD simulations. Detailed comparisons suggest that strange baryons have weaker VDW interactions compared to non-strange ones. We also explore the effect of VDW interactions on the thermal fits to heavy-ion hadron yield data and find that existing agreement of ideal HRG is not spoiled in the VDW-HRG model. Finally, we find that VDW interactions have a substantial influence on the higher orders of fluctuations of conserved charges at finite chemical potential, in the regions where chemical freeze-out in heavy-ion collisions is expected to occur.

Our results imply that VDW interactions play a crucial role in thermodynamics of hadron gas. Thus, the commonly performed comparisons of the ideal HRG model with the lattice data may lead to misconceptions and misleading conclusions, and should therefore be treated with extreme care.

Preferred Track

Correlations and Fluctuations

Collaboration

Not applicable

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