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Degrees of freedom in various charm subsectors from Lattice QCD

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We establish that the charmed hadrons start dissociating at the chiral crossover temperature, $\mathrm{T_{pc}}$, leading to the appearance of charm degrees freedom carrying fractional baryon number. Our method is based on analyzing the second and fourth-order cumulants of charm (C) fluctuations, and their correlations with baryon number (B), electric charge (Q) and strangeness (S) fluctuations. First-time calculation of the QC correlations on the high statistics ($\mathrm{N_\tau} = 8$) datasets of the HotQCD Collaboration enables us to disentangle the contributions from different electrically-charged charm subsectors at and close to $\mathrm{T_{pc}}$. In particular, we see an enhancement over the PDG expectation in the fractional contribution of the $|\mathrm{Q}| = 2$ charm subsector to the total charm partial pressure for $\mathrm{T} < \mathrm{T_{pc}}$; this enhancement is in agreement with the Quark Model extended Hadron Resonance Gas (QM-HRG) model calculations. Furthermore, the agreement of QM-HRG calculations with the projections onto charmed baryonic and mesonic correlations in different charm subsectors indicates the existence of not-yet-discovered charmed hadrons in all charm subsectors below $\mathrm{T_{pc}}$.

For $\mathrm{T_{pc}} < \mathrm{T} < 240$ MeV, our data are well-described by a non-interacting gas of charmed quasi-particles composed of meson, baryon and quark-like excitations. We find no evidence for the existence of charmed diquarks above $\mathrm{T_{pc}}$. In addition to this, we find a clear agreement between three independent observables which correspond to the partial pressures of i) $\mathrm{B} = 1/3$, ii) $\mathrm{Q} = 2/3$, and iii) $\mathrm{B} = 1/3$ and $\mathrm{Q} = 2/3$ charm subsectors; this further supports the presence of charm-quark-like excitations in QGP. Moreover, similar to $\mathrm{T} < \mathrm{T_{pc}}$ regime, we conclude that for $\mathrm{T} > \mathrm{T_{pc}}$, the $|\mathrm{Q}| = 2$ charm subsector is solely composed of baryon-like states. For 240 MeV $< \mathrm{T} \leq 340$ MeV, our results approach the free charm-quark gas limit.

Topical area

QCD at Non-zero Temperature

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