In-Medium Modifications of the Nucleon and Δ(1232) at RHIC

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From asymptotic freedom of QCD, at sufficiently high temperatures and densities of nuclear matter, one expects a (pseudo-)phase transition to a quark-gluon plasma (QGP). Lattice calculations show that this transition is closely related with the restoration of the approximate chiral symmetry in the light-quark sector of QCD. Since in the restored phase the spectral functions of chiral-partner hadrons become degenerate, one expects significant medium modifications which one hopes to observe in ultra-relativistic heavy-ion collisions [1].

In this work, we employ a hadronic model to describe interacting pions, nucleons, and baryon resonances to investigate their properties within a hot and dense medium, particularly for the Δ(1232) resonance, which recently became accessible to experiment through the measurement of πN-invariant mass spectra at RHIC [2].

The $\pi N \Delta$-coupling is taken as a p-wave interaction with a monopole form factor with a three-momentum cutoff of 290 MeV, which fits the πN-phase shift in the Δ(1232) channel [3].

To assess medium modifications, we dressed the Δ(1232) with self-energy contributions from scattering off thermal pions, including the baryon resonances N(1440), N(1520), N(1700), Δ(1600), Δ(1620), and Δ(1700). We furthermore included πN interactions as well as vertex corrections in the Δ-self-energy loop, employing standard Migdal parameters to account for short-range NN and $N\Delta$ correlations, to suppress an artificial threshold enhancement due to the in-medium pion-dispersion relation. The resulting model has been checked to approximately agree with photo-absorption data on nuclei.

As shown in Fig. 1, under RHIC conditions the peak position of the Δ–spectral function shifts to higher masses with increasing temperature and density, and the width increases as compared to the vacuum. The broadening is mainly caused by a Bose enhancement of the pion in the decay of the Δ and by resonant π–Δ interactions. For conditions resembling thermal freeze out (dashed line in Fig. 1), the peak position is located at about $M \cong 1.226$ GeV and the width has increased to $\Gamma \cong 177$ MeV to be compared to the vacuum values of $M \cong 1.219$ GeV and $\Gamma \cong 110$ MeV respectively, which is in qualitative agreement with preliminary data from the STAR collaboration [2].

We have also calculated the in-medium modifications of the nucleon with πN- and $\pi\Delta$-loops. As shown in Fig. 2, the nucleon-spectral function becomes substantially broadened.

The next step in evaluating in-medium modifications of the Δ resonance will be the inclusion of interactions with vector and axial-vector mesons, with particular emphasis on the nature of the chiral phase transition.

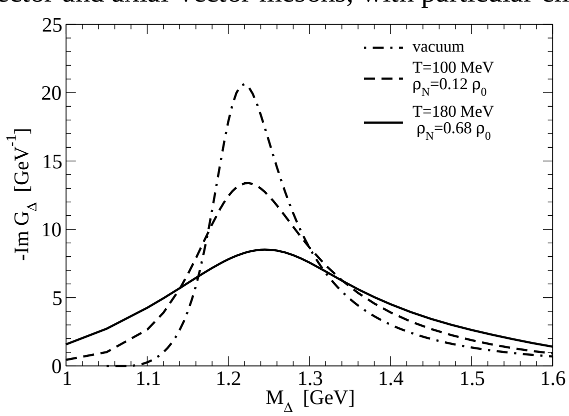

Fig. 1: The Δ–spectral function at finite temperature and density in comparison to the vacuum.

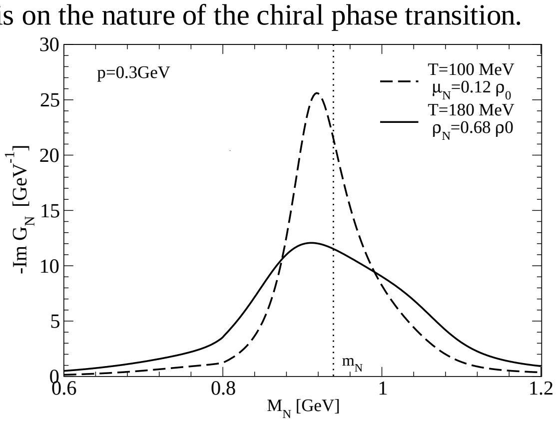

Fig. 2: The nucleon-spectral function at finite temperature and density.

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