ω spectral function in hot and dense matter

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It is well known that in-medium correlation functions of vector current of QCD, manifested in terms of the propagator of vector meson fields can be measured through the dilepton spectra in heavy ion collisions. A large volume of literature is dedicated to the study of vector mesons in the medium, the bulk of which concerns the ρ meson. Theoretical activities regarding the ω meson have been mostly performed in cold nuclear matter (see e.g. [1, 2] for a review). The most of the cases are done in the lowest order virial expansion and all the approaches differ widely in their methods resulting in a large variation in the results concerning the mass and width. Consequently both positive and negative shifts of the peak position have been proposed. On the experimental front the situation is far from settled [1] with different groups reporting a reduction in mass [3] and increase in width [4] in pA and γA collisions respectively. The upcoming experiments at the FAIR facility at GSI thus assumes great significance in resolving some of the issues.

In the framework of real-time thermal field theory we have evaluated the in-medium ω self-energy from baryon and meson loops [5] . We have analyzed in detail the discontinuities across the branch cuts of the self-energy function and obtained the imaginary part for each loop diagrams from the non-vanishing contributions in the cut regions. In addition to the unitary cut, present already in the vacuum amplitude, the thermal amplitude generates new, so-called Landau cut.

As baryonic contribution, we have included an extensive number of spin one-half and three-half 4−star resonances (B) listed by the PDG so that B stands for the $N^*(1440)$ $N^*(1520)$, $N^*(1535)$, $N^*(1650)$, $N^*(1720)$ resonances as well as the $N(940)$ itself. Using fully relativistic propagators and off-shell corrections for spin three-half fields, we have evaluated ω self-energy for each NB loops at finite temperature (T) and baryon density (ρ_B). The novelty of this full relativistic approach is that the baryons and anti-baryons naturally appear on an equal footing and the additional singularities which are not considered in the Lindhard function approach are automatically included. Baryons and anti-baryons have an important role to play in determining the spectral properties of ω mesons in the medium. This applies not only in baryon-dense situations (see the dash-dotted line of Fig. 1) likely to be encountered in the CBM experiment but also in almost baryon-free systems (see the dotted line of Fig. 1) such as produced at the RHIC and LHC. In the latter case baryons and anti-baryons in fact, contribute additively in the medium effects.

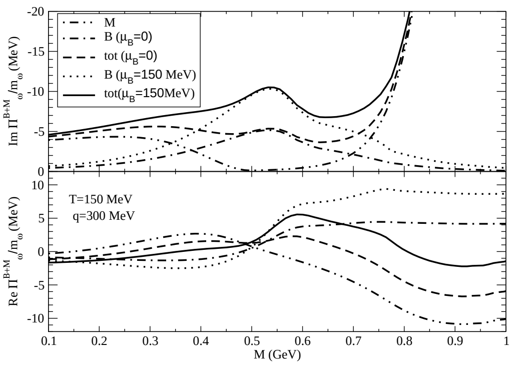

FIG. 1: Figure shows the total imaginary (upper panel) and real (lower panel) parts of ω self energy for meson and baryon loops.

Fig. 1 is shown the total contribution from the meson and baryon loops for two values of the baryon chemical potential (μ_B). A noticeable contribution is seen in the imaginary part below the nominal ω mass. In the lower panel

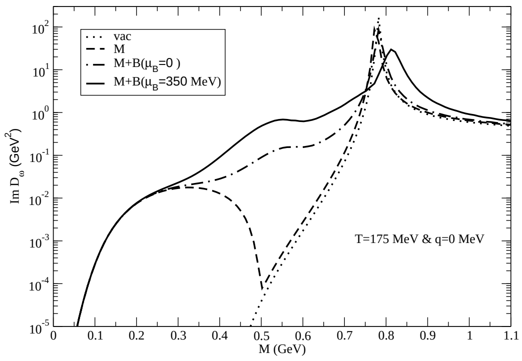

FIG. 2: The ω spectral function showing individual contributions due to mesonic and baryonic.

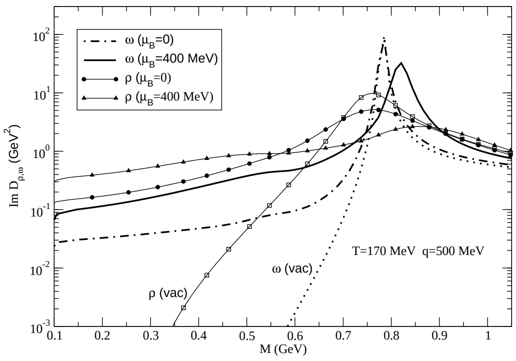

FIG. 3: The ω spectral function seen in comparison with the ρ.

is shown the real part where the meson and baryon loops provide a negative and positive contribution respectively at the ω pole which will be manifested in the spectral function. The mesonic contribution has been shown by dash-double-dooted line in Fig. (1) and it is constructed by the in-medium self-energy of $\rho\pi$ loop where ρ is folded by its vacuum spectral function [5].

In Fig. 2 we show the contributions of the different loops to the spectral function. To bring out the relative strengths at low invariant masses a logarithmic scale is employed in this figure. The dashed line represents $\rho\pi$ loop in which the Landau cut contribution falls off in the vicinity of $M = m_\rho - m_\pi$ and then increases as the unitary cut contribution builds up. The Landau cut contributions from the baryonic loops, shown by the solid and dash-dotted lines, however dominate in the region below the ω mass. In view of the fact that the ρ and ω peaks are close to each other it is worthwhile to compare their relative spectral strengths below their nominal masses. We have plotted (Fig. 3) the ω spectral function at two values of the chemical potential along with that of the ρ which has been recently calculated in Ref. [6]. The sharp peak of the ω is stands out against the smooth profile of the ρ. The characteristic 2π and 3π thresholds for the ρ and ω in the vacuum case are also visible. From the Fig. (3), the ω contribution is showing to be lower but of comparable magnitude. However, the fact that the latter is suppressed by a factor ~ 10 compared to the ρ in the dilepton emission rate makes a quantitative study of the ω difficult. Nevertheless, the contribution of the ω spectral strength is essential for a quantitative description of the dilepton data from heavy ion collisions [7]. In view of high quality data expected in future from heavy ion collisions at the FAIR facility at GSI we can conclude that an exhaustive evaluation of the spectral strength at finite temperature and baryon density is necessary for a quantitative analysis.

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