1. Introduction

Recently the dilepton spectra from the CERES collaboration \cite{1}, which indicate a mass shift of $\rho$ and $\omega$ mesons, have been interpreted as a signature for the formation of a new state of matter, the Quark Gluon Plasma. Within this picture, the medium modifications are a consequence of the restauration of chiral symmetry. For example, in the Brown-Rho scaling scenario \cite{2} the mass of the vector mesons scales with the chiral condensate which is supposed to drop at finite density and temperature. However, in a dense and hot medium a variety of conventional many-body phenomena with considerable impact on the in-medium properties of the vector mesons may occur \cite{3,4}. In this contribution we present a calculation of these effects at finite density and at $T = 0$. In particular, we concentrate on the effects played by the excitation of baryon resonances, which in turn are modified themselves in the nuclear environment. The interplay between resonances and vector mesons is accounted for in a selfconsistent approach.

2. The Model for VN Scattering

In the following we will focus on the calculation of the in-medium spectral function $A$ of both $\rho$ and $\omega$ meson. The spectral function is defined as the imaginary part of the propagator and can be directly interpreted as the mass distribution of a particle. Whereas in the vacuum the spectral functions are controlled by the well-known pionic decays of the vector mesons, new decay channels open up in the nuclear medium due to the possibility of scattering with surrounding nucleons. This is formally expressed in the low-density approximation, which relates the in-medium selfenergy to the vacuum forward scattering amplitude $M_{VN}$ on the nucleon. Experimental constraints on these amplitudes exist only through an analysis of vector meson production. In the case of the $\rho$ meson, a further complication arises from its large decay width, which makes the experimental identification difficult. Therefore, in principle $M_{VN}$ has to follow from a coupled-channel analysis of $\pi N$ (and $\gamma N$) scattering. This is a formidable task and one might wonder if
the gross information on $\mathcal{M}_{VN}$ can not be obtained from a more elementary model. The results of such an analysis from Manley et al. [10] indicate that resonances dominate $\pi N$ scattering. We therefore approximate $\mathcal{M}_{VN}$ within a resonance model for both $\rho$ and $\omega$ meson. Experimental information then enters directly through the coupling constant $f_{RN\rho}$ at the resonance vertex.

Let us point out the implications of resonance scattering on the spectral function. Through the excitation of a resonance the vector meson can convert into a resonance-hole state in the same manner as is well known from the pion Delta-hole model. The in-medium spectral function therefore contains additional peaks corresponding to these new states. From basic kinematical considerations it follows that their position moves down to lower invariant masses with increasing momentum $p$ of the vector meson relative to nuclear matter, thus producing a momentum dependent spectral function. Note also, that in nuclear matter transversely and longitudinally polarized vector mesons are modified differently for $p \neq 0$.

3. Results for the $\rho$ Meson

We turn now to the results for the $\rho$ meson. We consider all resonances which have been assigned a coupling to this channel in the analysis of Manley et al [10]. As it turns out, by far the strongest coupling constants are obtained for some subthreshold resonances with masses $m_R < m_N + m_\rho \approx 1.7$ GeV [6,7]. The $N \rho$ decay of these resonances is phase-space suppressed and can only proceed via the low-mass tail of the $\rho$ spectrum. Clearly, to accomodate the extracted decay widths, large coupling constants are mandatory. For the same reason we find the contribution from high lying resonances in general to be negligible.

This means for the spectral function that a substantial amount of strength is relocated to lower invariant masses, as is shown in figure 1. At low momenta both the transverse and the longitudinal spectral function are dominated from the $N^*(1520)$ resonance which has a $N \rho$ decay width of about 25 MeV and, therefore, a large coupling constant $f_{RN\rho}$.

![Figure 1](image-url)

Figure 1. Left: Longitudinal spectral function of the $\rho$ in nuclear matter as a function of its invariant mass $m$ and $p$. Right: same for the transverse spectral function.
At higher momenta, transverse and longitudinal $\rho$ mesons behave differently: in the longitudinal channel the free spectral function is nearly recovered, whereas the transverse channel exhibits a strong broadening.

4. Baryon Resonances in Nuclear Matter

As explained in the last section, the coupling of $\rho$ mesons to resonance-hole states leads to a substantial shift of spectral strength down to lower invariant masses. We also pointed out that the vacuum decay of the subthreshold resonances is phase space suppressed. One might therefore expect a large feedback effect of a lighter $\rho$ meson on the in-medium properties of baryon resonances [6]. We calculate this response in a self-consistent fashion by calculating the $N\rho$ decay width of the resonances with the in-medium spectral function of the $\rho$. In a different language, this amounts to a calculation of the collisional broadening of the resonance through the exchange of a medium modified $\rho$ meson. On top of the collisional broadening we also include, of course, Pauli-blocking for all decay channels. As shown in figure 2 for the $N^*(1520)$, the in-medium decay width is strongly enhanced, at the pole mass we find $\Gamma_{N\rho} \approx 100$ MeV for a $N^*(1520)$ at rest. At larger momenta the decay width increases as the effects from Pauli blocking get less important. This broadening leads to a reduction of the influence of the resonances on the $\rho$ spectral function.

Figure 2. Left: In-medium decay width of the $N^*(1520)$ at density $\rho = \rho_0$ and $p = 0$. Right: Effect of the selfconsistent calculation on the spectral function of the $\rho$ ($p = 0$).

5. Results for the $\omega$ Meson

A coupling of baryon resonances to the $N\omega$ channel has so far not been experimentally established. However, the previous discussion of the in-medium $\rho$ meson suggests that resonances have a strong impact on the in-medium $\omega$ meson as well. In order to obtain an estimate for the coupling constants $f_{RN\omega}$, we perform a VMD analysis of the electromagnetic (EM) decay vertex of the resonances, using the helicity amplitudes of Arndt [11]. By decomposing the EM coupling into an isoscalar and an isovector part both $f_{RN\rho}$ and $f_{RN\omega}$ can be accessed. In the isovector channel we compare the VMD results with our fits to the hadronic $N\rho$ width and find reasonable agreement. For the $\omega$ the VMD analysis predicts a sizeable coupling of the $N^*(1535)$, $N^*(1650)$ and $N^*(1520)$ resonances. Within
in a resonance model we confirmed that the obtained couplings are compatible with experimental data on $\pi(\gamma) N \to \omega N$. However, the couplings constants are smaller than in the case of the $\rho$. This leads to less pronounced resonance peaks in the spectral function, see figure 3. We find that the in-medium width of the $\omega$ is about 40 MeV and that its mass goes slightly up by about 20 MeV.

6. Summary & Outlook

We have presented a calculation of the spectral function of $\rho$ and $\omega$ mesons at finite density and $T = 0$ within a resonance model. We also considered the feedback effect on the baryon resonances caused by the change in the spectral distribution of the $\rho$. However, here only the collisional broadening of the resonance, but not the corresponding mass shift was calculated. We are currently working on a more complete calculation of these effects.

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