Vector mesons within a conserving self-consistent approximation$^{\mathrm{G}}$

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The experimental results on di-lepton production in heavy ion collisions by the CERES and DLS collaborations has shown an enhancement of the di-lepton production rate in the invariant pair mass region between 300-600 MeV compared to the rate to be expected from proton-proton collisions. Since di-leptons are direct signals from the decay of vector mesons within the hot reaction zone this enhancement points towards in-medium modifications of vector-mesons in dense hadronic matter.

From the theoretical point of view a consistent description of such phenomena within effective quantum field theoretical models needs a treatment of particles which considers the finite spectral width. This concerns not only the widths of resonances but also the width due to collisions of the particles within the hot and dense medium. For such questions a perturbative approach is generally insufficient and a self-consistent treatment is at place.

There is a class of self-consistent approximations derived from a generating functional which leads to a closed set of conserving equations of motion for the mean fields and the Dyson resummed dressed propagators [1]. They posses exact conservation laws for the expectation values for conserved Noether-currents (including those from space-time symmetry, i.e., energy, momentum and angular momentum).

A detailed symmetry analysis nevertheless shows that on the level of higher order correlation functions such as propagators the Ward-Takahashi identities (WTI) of the underlying symmetries are not fulfilled [2]. In the case of vector or gauge fields this has serious consequences: The WTI are necessary to ensure the physicality of states. A violation of this symmetry causes the excitation of unphysical degrees of freedom and violates unitarity and causality within the dressed propagators and currents are no longer conserved at the correlator level.

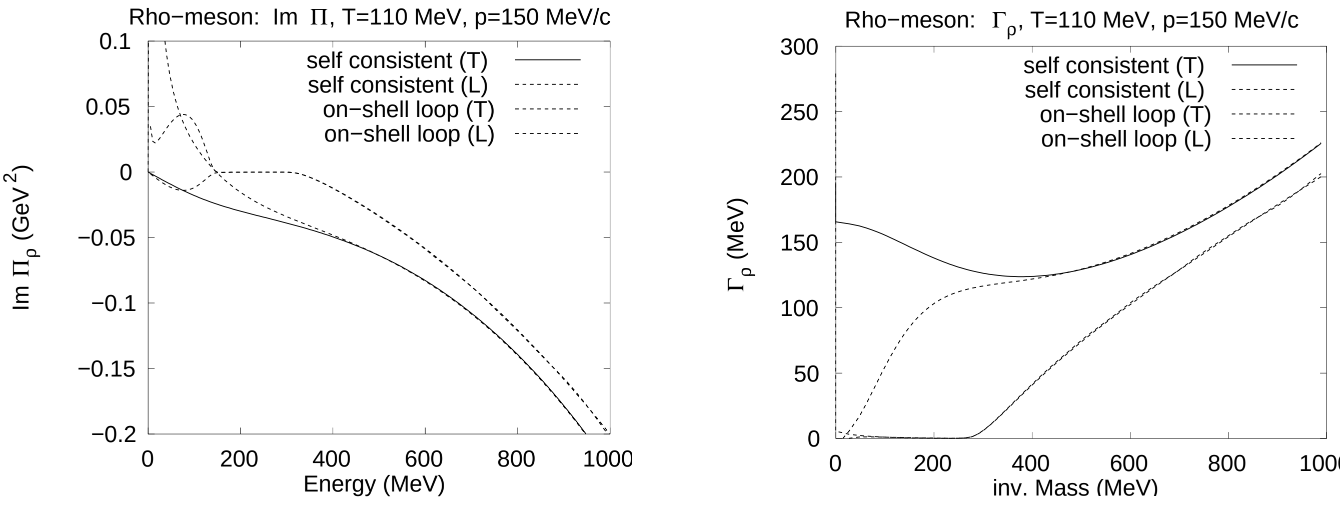
On the other hand corrections which restore current conservation on the correlator level have been studied within a diffusion equation approximation of the according kinetic equation (Fokker-Planck-equation) [3]. The study shows that the space components of the polarization tensor suffer only small corrections, if the scattering of a particle is isotropic on the average. The self consistent time component, however has a completely wrong behavior as it also exponentially decay in time within this approximation, while it should stay constant in time due to charge conservation.

In order to cure this defect we have invented a particular projection method. It discards the wrong time components of the polarization tensor and solely uses the space components. This way a 4-dimensionally transverse polarization tensor for the vector field can be constructed. The two independent components of the thermal polarization tensor, the longitudinal and transverse components, $\Pi_T(q)$ and $\Pi_L(q)$, can be obtained from

$$2\Pi_T + g_{ik}\Pi^{ik} = -\frac{q_i q_k}{\vec{q}^{\,2}}\Pi^{ik} = -\frac{(q^0)^2}{q^2}\Pi_L.$$

Here the indices (i,k) run over the spatial components from 1 to 3. We have numerically solved the coupled self-consistent equations of motion for this projected self-energies. For details see [2, 4].

The results show a significant enhancement of the spectral width in the low energy mass region and all thresholds, present in the perturbative quantities, are gone due to collision broadening of the self-consistently treated pions.



The transverse components of the imaginary part of the self-consistent ρ–meson self-energy (left) and the corresponding spectral width (right).

References

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