Finite pion width effects on di–lepton spectra^G

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The experiments by the CERES and DLS collaborations show significant enhancements of the di-lepton production rates in the invariant mass region between 300 to 600 MeV in heavy ion collisions compared to proton-proton collisions. This enhancement could arise from in-medium modification of hadrons.

In this contribution we study the in-medium properties of ρ–mesons within a schematic Vector Meson Dominance approach [1]. Special attention is drawn to the influence of a finite damping width of pions caused by collisional broadening in the medium. While in the physical world the main contributions to the in-medium π–width is due to the NN^{-1}– and ΔN^{-1}–channels [2] we simulate this width with a four-pion contact interaction. We also have included the a_1-meson, i.e. the chiral partner of the ρ–meson, in our model [3]. Thus our model system consists of the following mesons: pions, ρ- and a_1-mesons.

In order to achieve a truncated self-consistent scheme, which is at the same time conserving, satisfies detailed balance and is thermodynamically consistent, we use Baym's Φ–derivable approximation [4] based on a resummation of the partition sum [5]. Truncation on the two-point level provides us with coupled Dyson equations for the three particles with two-point self energies, describing the gain and loss terms for the different channels.

The resulting self consistent set is solved numerically treating all particles with their self consistently determined width in all self energy loops. The four pion contact interaction is tuned to provide two limiting example cases with a moderate damping width of $\Gamma_\pi = 50$ MeV and a strong damping case with $\Gamma_\pi = 125$ MeV. The figures below show the pion spectral function (left) and the dilepton rate (right), the latter resulting from the in-medium ρ-meson within our schematic model. In order to get rid of the problems with gauge invariance, we omitted the temporal parts of the vector–meson polarization tensors and also took only the imaginary parts into account which need no renormalization.

In the vacuum the pion spectrum has a pole at its physical mass, corresponding to a real stable particle, while a decay threshold opens for invariant masses beyond $3m_\pi$. In the self-consistent calculations the pion obtains spectral strength along the entire p_0-axis due to interactions with particles contained in the heat bath. There is even strength below the light cone, i.e. for energies below 150 MeV in the plot shown.

Such broad pion structures lead to significant spectral strength of the ρ-meson for invariant masses below 500 MeV with a corresponding enhancement of the di-lepton rates there compared to the rates simply determined from the vacuum spectral function of the ρ-meson. For the $\Gamma_\pi = 50$ MeV case we have split the total di-lepton rate into different physical subprocesses (right figure). Both the π-π-annihilation and the π-π-scattering parts attain significant strength in the low mass region. The latter account for the emission due to the self consistently calculated bremsstrahlung, which includes the in-medium pion form factor due to the modified ρ-meson and the Landau-Pomeranchuk suppression at very low masses [6]. In all calculations contributions from the a_1 Dalitz decay are seen to be unimportant. Note that the calculations ignored mass shifts so far. The latter can be included using renormalized dispersion relations. Furthermore work is in progress to restore gauge invariance by soluving Bethe-Salpeter type equations for the appropriate vertex corrections along the lines given in [6]. The experience gained in such equilibrium calculations also advances attempts to appropriately include finite width effects into transport theory [7, 8].

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