Electric conductivity in hot QCD matter and dilepton spectra in heavy-ion collisions

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Thermal dilepton emission from the fireballs formed in heavy-ion collisions is the only known observable that provides direct access to an in-medium spectral function in QCD matter. Of particular interest is the regime of low invariant masses where the medium modifications of the vector-meson spectral functions, in particular that of the ρ-meson, can be studied. Experimental measurements and their theoretical interpretations over a wide range of collision energies have led to the conclusion that the ρ-meson undergoes a strong collisional broadening in the hadronic medium that ultimately leads to its melting in the quark-gluon plasma (QGP) [1-4]. More recently, the attention has shifted to the very-low mass region. This is motivated by the fact that the low-energy limit of the electromagnetic (EM) spectral functions (at vanishing 3-momentum) encodes a fundamental transport parameter of the medium, namely the electric conductivity, which characterizes the transport of electrically charged particles in the interacting medium, i.e., hadrons in hadronic matter and quarks in the QGP.

In the present work [5] we have investigated the conductivity following from the EM spectral functions [4] that lead to a successful phenomenology of dilepton data in heavy-ion collisions. In hot hadronic matter, vector-meson spectral functions are computed from hadronic many-body theory [3]. Using exact off-shell calculations of the loop diagrams at finite temperature, we have been able to conduct reliable calculations at very low masses, see Fig. 1. In particular, we have found that the main effect in producing a small conductivity (indicative of a strongly coupled medium, i.e., a large width of the peak around zero-energy) arises from interactions with the lightest charge carriers in the system, i.e., pions [6], rather than rescattering off the much heavier baryons. We also utilized a perturbatively inspired QGP rate that has been constructed to reproduce lattice-QCD data for Euclidean correlators and extrapolated to finite 3-momentum compatible with photon production rates [7].

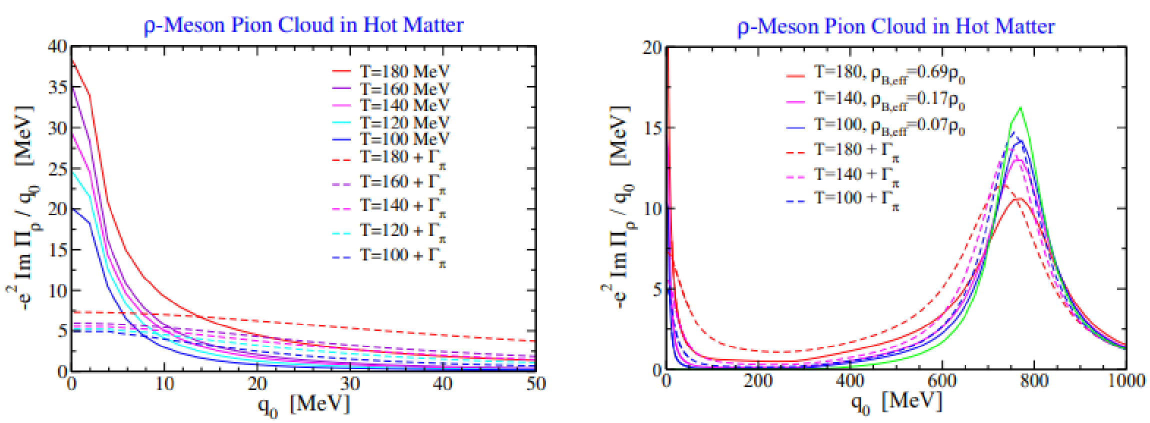

Fig. 1. EM spectral function in hot hadronic matter in the isovector channel. The right panel shows medium modifications of the ρ-meson spectral functions due to dressing of its pion cloud, while the left panel zooms into the low-energy region (both plots are for near vanishing there-momentum, q=1 MeV). The solid lines are the baseline results for pion interactions with baryons while the dashed lines additionally include scattering off thermal pions.

The improved dilepton rates have been convoluted over a schematic thermal fireball evolution to compute dilepton spectra in central Pb-Pb(5.02TeV) collisions at the LHC, see Fig. 2. It has been found that the main signature of a reduced conductivity is an enhancement of the very-low-mass dilepton yield, due to the broadening of the low-energy conductivity peak. This sensitivity can be further increased by applying experimental cuts on the electron pair momentum, albeit at the price of a reduced yield, which might be experimentally challenging. It also turns out that the ρ-meson peak region, for invariant masses above M≈0.4GeV, is not significantly affected by variations in the conductivity, since the broadening of the ρ-meson resonance peak is chiefly driven by interactions with baryons (which in turn play a small role at very low mass).

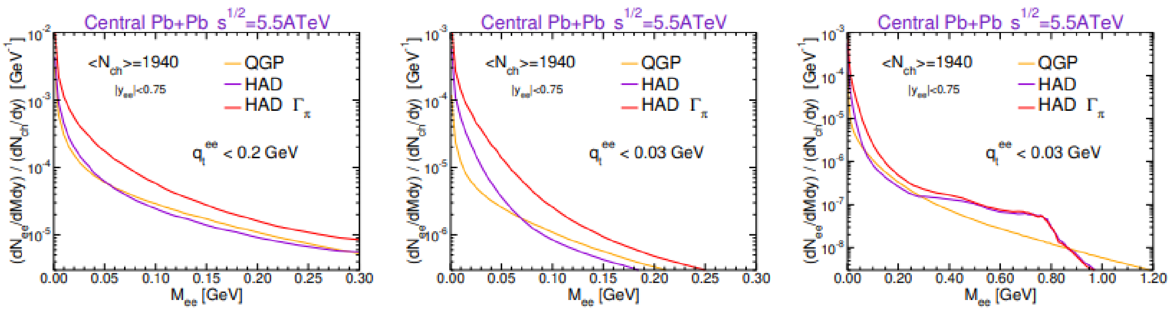

Fig. 2. Left and middle panel: Integrated thermal dilepton yield from both QGP (orange line) and hadronic matter (red or purple lines) in the very-low-mass region, when applying cuts on the lepton pair momentum of qtee < 0.2 GeV (left) and qtee < 0.03 GeV (right); note the reduction in the total yield for the smaller cut, and the enhancement of the yield when including pion interactions (red vs. purple lines). Right panel: Low-mass region up to M = 1.2 GeV, illustrating the insensitivity of the ρ-meson broadening to the conductivity.

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