Thermal Dileptons at LHC

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Abstract. We predict dilepton invariant-mass spectra for central 5.5 ATeV Pb-Pb collisions at LHC. Hadronic emission in the low-mass region is calculated using in-medium spectral functions of light vector mesons within hadronic many-body theory. In the intermediate-mass region thermal radiation from the Quark-Gluon Plasma, evaluated perturbatively with hard-thermal loop corrections, takes over. An important source over the entire mass range are decays of correlated open-charm hadrons, rendering the nuclear modification of charm and bottom spectra a critical ingredient.

Due to their penetrating nature, electromagnetic probes (dileptons and photons) are an invaluable tool to investigate direct radiation from the hot/dense matter created in heavy-ion collisions. At low invariant mass, $M \leq 1$ GeV, the main source of dileptons is the decay of the light vector mesons, ρ, ω and ϕ, giving unique access to their in-medium spectral properties, most prominently for the short-lived ρ meson. If the chiral properties of the ρ-meson can be understood theoretically, dilepton spectra can serve as a signal for the restoration of chiral symmetry at high temperatures and densities.

We employ medium-modified vector-meson spectral functions in hot/dense matter following from hadronic many-body theory, phenomenologically constrained by vacuum $\pi\pi$ scattering, decay branching ratios for baryonic and mesonic resonances, photo-absorption cross sections on nucleons and nuclei, etc. [1]. The resulting spectral functions, especially for the ρ meson, exhibit large broadening with little mass shift, with baryonic interactions as the prevalent agent, especially in the mass region below the resonance peaks. Note that CP invariance of strong interactions implies equal interactions with baryons and antibaryons. Thus, even in a net-baryon free environment, the ρ resonance essentially "melts" around the expected phase transition temperature, $T_c \simeq 180$ MeV. Other sources of thermal dileptons taken into account are (i) four-pion type annihilation in the hadronic phase (augmented by chiral vector-axialvector mixing) [2], which takes over the resonance contributions at intermediate mass, and (ii) radiation from the Quark-Gluon Plasma (QGP), computed within hard-thermal loop improved perturbation theory for in-medium q-$\bar{q}$ annihilation.

Thermal dilepton spectra are computed by evolving pertinent emission rates over the time evolution of the medium in central 5.5 ATeV Pb-Pb collisions. To this end, we employ a cylindrical homogeneous thermal fireball with isentropic expansion and a total entropy fixed by the number of charged particles, which we estimate from a
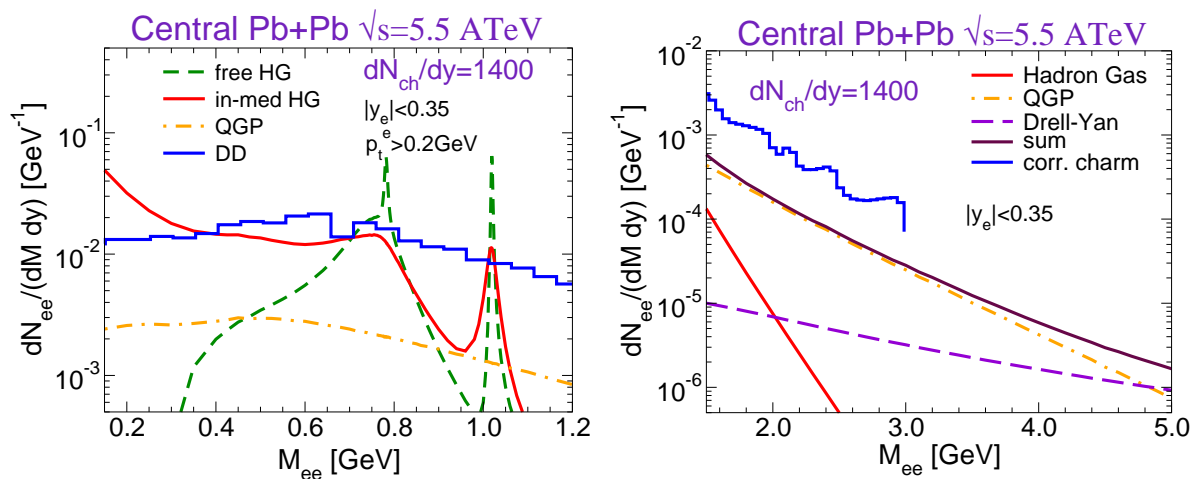
Figure 1. (Color online) Predictions for dilepton spectra in central 5.5 ATeV Pb-Pb collisions at LHC in the low- (left panel) and intermediate-mass region (right panel).

phenomenological extrapolation to be $dN_{ch}/dy \simeq 1400$. We use an ideal-gas equation of state (EoS) with massless gluons and $N_f = 2.5$ quark flavors for the QGP, and a resonance gas for the hadronic EoS with chemical freezeout at $(\mu_B^c, T_c) = (2, 180)$ MeV (finite meson and anti-/baryon chemical potentials are implemented to conserve the particle ratios until thermal freezeout at $T_{fo} \simeq 100$ MeV, with a mass-action law for short-lived resonances). We start the evolution in the QGP phase at initial time $\tau_0 = 0.17$ fm/c, translating into $T_0 \simeq 560$ MeV. The volume expansion parameters are taken to resemble hydrodynamic simulations. A standard mixed-phase construction connects QGP and hadronic phase at T_c, and the total fireball lifetime is $\tau_{fb} \simeq 18$ fm/c.

As for non-thermal sources, we include primordial Drell-Yan annihilation and decays of correlated charm pairs. The latter are estimated by scaling the spectrum at RHIC with a charm-cross section anticipated at LHC, which implies somewhat softer charm spectra than expected for primordial N-N collisions (and thus softer invariant-mass spectra). We neglect contributions from jet-plasma interactions.

Our predictions are summarized in Fig. 1. At low mass thermal dileptons are dominated by hadronic radiation, with large modifications due to in-medium vector-meson spectral functions. The QGP contribution takes over at around $M \gtrsim 1.1$ GeV. The yield from correlated open-charm decays is comparable to hadronic emission already at low mass, and dominant at intermediate mass. However, this result will have to be scrutinized by including the nuclear modification of heavy-quark spectra in the QGP (as well as analogous contributions from correlated bottom decays). Also, larger values of dN_{ch}/dy would help to outshine correlated open-charm decays, at least at low mass.

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[2] H. van Hees and R. Rapp, Phys. Rev. Lett. **97**, 102301 (2006)

[3] H. van Hees and R. Rapp, Proceedings of the 22nd Winter Workshop on Nuclear Dynamics, EP Systema, Budapest, Hungary 2006, 91-98, arXiv:hep-ph/0604269.