Thermal photons and collective flow at RHIC

H. van Hees,[1] C. Gale,[2] and R. Rapp
[1]*Frankfurt Institute for Advanced Studies, Frankfurt, Germany,*
[2]*McGill University, Montreal, Canada*

Electromagnetic radiation (photons and dileptons) in heavy-ion collisions is emitted throughout the evolution of the hot and dense fireball created in these reactions. To extract quantitative information about the strongly interacting medium from electromagnetic observables, such as the in-medium vector spectral function or the (evolving) temperature of the matter, it is of prime importance to reliably understand the contributions from the different phases of the fireball. In this context, a recent first measurement of the elliptic flow of direct photons in Au-Au collisions at the Relativistic Heavy-Ion Collider has yielded a surprising result [1]: the data for the pertinent anisotropy coefficient, $v_2(p_T)$, are comparable to those of pions, even though the latter are only emitted at the end of the fireball evolution where the elliptic flow has fully built up. In particular, the v_2 from thermal photons emitted from the Quark-Gluon Plasma (QGP), when evaluated in standard hydrodynamic evolution models [2, 3], has been predicted to lead to much smaller values, reflecting the early fireball phases during which the momentum anisotropy is still rather small.

In the present work we have revisited this problem by (i) utilizing our earlier calculated photon emission rates from hadronic matter [4] which are significantly larger than those currently employed in hydrodynamic evolutions; (ii) constructing a thermal fireball expansion where the bulk elliptic flow (as observed through the final hadron spectra) is built up by the time the system reaches the QGP-hadron phase transition; in particular, the spectra and v_2 of multistrange hadrons (Φ, Ξ, Ω^-) are quantitatively constrained by the common assumption that their kinetic freezeout occurs close to the quark-hadron phase boundary. These two components lead to a significant increase of hadronic radiation and pertinent elliptic flow in the total photon spectra in 0-20% Au-Au collisions compared to previous calculations, cf. Fig. 1. In particular, the thermal hadronic component turns out to be the largest contribution in the p_T spectra out to momenta of 2-3GeV. The large elliptic flow carried by this component leads to a total v_2 of direct photons (including QGP radiation and primordial emission from binary NN collisions upon first impact of the colliding nuclei) which reaches into the lower part of the error bars of the experimental data. These calculations suggest that the dominant emission source of thermal photons in ultrarelativistic heavy-ion collisions is not from the early QGP phases but from the medium right around the transition regime. This conclusion is corroborated by the rather small slope parameter in the excess spectra (above the primordial component), which approximately reproduces the experimentally measured effective temperature of only about $T_{eff} \approx 220 \pm 20$ MeV [6] which is quite close to the (pseudo-) critical temperature of 170 MeV but well above typical initial temperatures of 350-400 MeV. Note also that the true medium temperature is smaller due to the spectral blue shift induced by the radially expanding medium (“Doppler effect”).

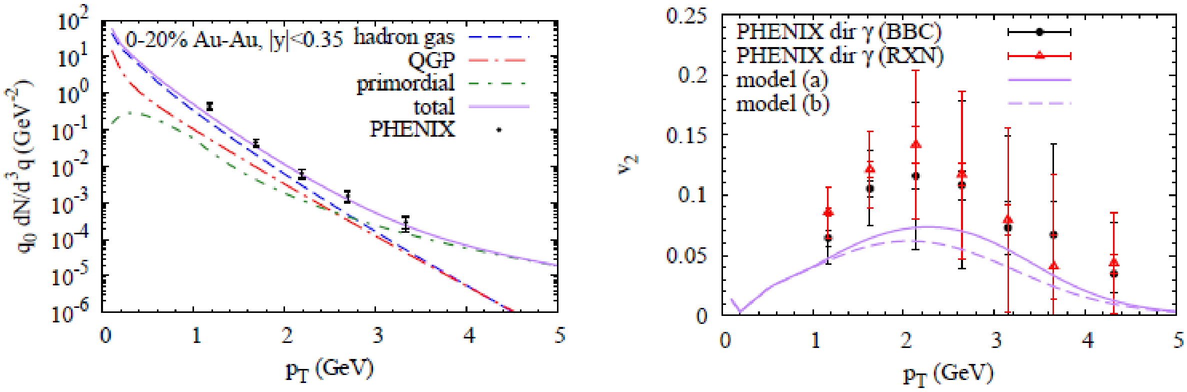

FIG. 1. Transverse-momentum spectra (left panel) and elliptic flow (right panel) of direct photons in 0-20% central Au-Au($\sqrt{s_{NN}}$=200GeV) collisions at RHIC. Our calculations of thermal radiation from QGP and hadronic phases are added to a primordial contribution from binary NN collisions estimated from the spectra in elementary pp collisions. The two curves in the right panel indicate the uncertainty of the primordial contribution in the total elliptic flow. The data are from the PHENIX collaboration [1,6].

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