Dileptons and Photons from Coarse–Grained Microscopic Dynamics and Hydrodynamics Compared to Experimental Data

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We compute the radiation of dileptons and photons using relativistic hydrodynamics and a coarse–grained version of the microscopic event generator UrQMD, both of which provide a good description of the hadron spectra. The currently most accurate dilepton and photon emission rates from perturbative QCD and from experimentally-based hadronic calculations are used. Comparisons are made to data on central Pb-Pb and Pb-Au collisions taken at the CERN SPS at a beam energy of 158 A GeV. Both hydrodynamics and UrQMD provide very good descriptions of the photon transverse momentum spectrum measured between 1 and 4 GeV, but very slightly underestimate the low mass spectrum of $e^+e^-$ pairs, even with greatly broadened $\rho$ and $\omega$ vector mesons.

1. Introduction

We focus on central Pb-Pb and Pb-Au collisions at 158 GeV per nucleon at the CERN SPS. A coarse–graining of 100 UrQMD simulation events was performed. This gives flow fields of temperature, baryon chemical potential, and fluid velocity that can be compared to the flow fields of relativistic hydrodynamics. The initial conditions and final freezeout temperature in the hydrodynamic calculations were previously adjusted to represent the rapidity and transverse momentum distributions of hadrons so there are no new parameters introduced here. The coarse–grained version of UrQMD does require a freezeout temperature; a value of 125±10 MeV reproduces not only the rapidity distribution very well (shown) but also the transverse momentum distributions of negative hadrons and the net proton number (not shown). We then compare to the measured photon spectrum by summing both the hard perturbative QCD photons together with the thermal emission. We also compare to the $e^+e^-$ spectrum as measured at the highest multiplicities. The background cocktail is the same as used by the experiment itself. The thermal rates are those computed by Eletsky, Belkacem, Ellis and Kapusta [2] based on kinetic theory and hadronic data. These rates are nearly identical to those computed by Rapp and Wambach [3]; both of them show a significant shift in spectral weight from the rho-meson region to lower masses. The results are shown in the following ten figures. Further details may be found in ref. [1].

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Figure 1. The temperature as a function of local time at the origin in the UrQMD model and the hydrodynamic model.

Figure 2. Temperature contours in local time and cylindrical radius in the central transverse plane for the UrQMD model and the hydrodynamic model.

Figure 3. Contours of equal radial flow velocity as a function of local time and cylindrical radius in the central transverse plane for the UrQMD model and the hydrodynamic model.

Figure 4. The rapidity distribution of negatively charged hadrons. Upper panel: UrQMD for various freeze-out temperatures; lower panel: hydrodynamic model; data: NA49 collaboration [4].
Figure 5. Photon spectrum from Pb-Pb collisions at 158 A GeV by the WA98 collaboration [5] compared to a perturbative QCD calculation.

Figure 6. Comparison of the WA98 photon spectrum [5] to the predictions of the UrQMD model and the hydrodynamic model at several freeze-out temperatures. The baryon densities are fixed at 1/10 and 1 times the equilibrium density of cold nuclear matter.

Figure 7. Thermal dilepton emission rates computed by Gale and Lichard [6], Rapp et al. [3] and Eletsky et al. [2] at various temperatures. The baryon densities are fixed at 1/10 and 1 times the equilibrium density of cold nuclear matter.

Figure 8. Comparison of the dilepton data for Pb-Au collisions at 158 A GeV ('95 data Ref. [7], '96 data Ref. [8]) with the contribution from the decay of hadrons after freezeout.
Figure 9. Comparison of the dilepton data [7,8] with predictions of the UrQMD model and the hydrodynamic model at several freeze-out temperatures.

Figure 10. Comparison of the dilepton data [8] with binned predictions of the UrQMD model and the hydrodynamic model at two freeze-out temperatures.

2. Conclusions

The space-time evolution of coarse-grained UrQMD is very similar to that of hydrodynamics. Both represent the hadronic data quite well. The thermal photon and dilepton rates are relatively well understood. The theoretical predictions for both photons and dileptons agree rather well with data for central heavy ion collisions at 158 GeV per nucleon, although there may be a slight underestimate of dileptons in the mass range from 500 to 700 MeV. We should celebrate the success of both theory and experiment!

REFERENCES