Role of gluons in dilepton production from the quark-gluon plasma

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One possible signature for the quark-gluon plasma produced in heavy ion collisions at the Relativistic Heavy Ion Collider (RHIC) is the thermal dileptons it produces. Many studies have been carried out to calculate the expected dilepton yield from the quark-gluon plasma. In earlier works, contributions from the leading-order (LO) $q\bar{q}$ annihilation process [1] and processes up to $\mathcal{O}(\alpha_s)$ [2] have been evaluated by assuming that the quark-gluon plasma is in both thermal and chemical equilibrium. Although thermal equilibrium can be reached in the partonic matter created in heavy ion collisions at RHIC energies, chemical equilibrium is, however, unlikely to be established [3] as the partonic matter is expected to be dominated by gluons [4]. To take into account these effects, we have recently studied dilepton production from gluon-induced processes [6], i.e., the Compton processes ($gq \to q\gamma^*$ and $g\bar{q} \to \bar{q}\gamma^*$) and the process with two initial-state gluons ($gg \to q\bar{q}\gamma^*$).

In Fig. 1, we show the thermal dilepton rate from a quark-gluon plasma in full thermal and chemical equilibrium at $T = 570$ MeV. It is seen that for dileptons with mass above 2 GeV the LO $q\bar{q}$ annihilation process gives the dominant contribution while Compton processes give a small contribution, and that from the two-gluon process is even smaller.

The situation is, however, very different if partons are not in chemical equilibrium.

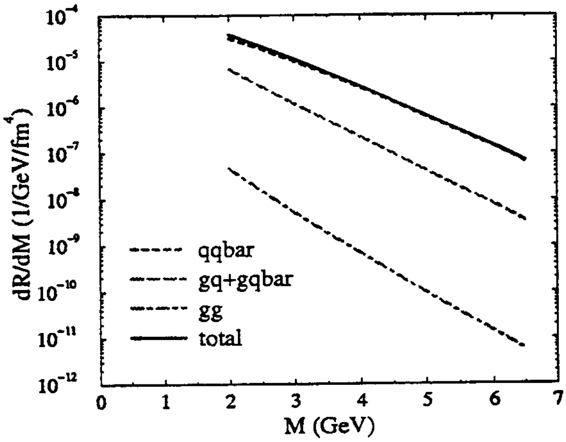

Figure 1: Thermal dilepton rate from a quark-gluon plasma in full thermal and chemical equilibrium at a temperature $T = 570$ MeV.

As an example, we show in Fig. 2 the thermal dileptons rate for $T = 570$ MeV and the gluon and quark fugacities $\lambda_g = 0.060$ and $\lambda_q = 0.0072$, which are the initial parton distributions used in Ref. [5] to describe the time evolution of the partonic matter based on kinetic equations that include the $2 \leftrightarrow 3$ gluonic process. In this case, Compton processes produce more thermal dileptons than the LO $q\bar{q}$ annihilation, and even the two-gluon fusion process gives a comparable contribution to lower-mass dileptons. As a result, the total thermal dilepton yield is significantly enhanced by gluonic processes.

We have also estimated the thermal dilepton yield in central Au+Au collisions at RHIC by integrating the thermal dilepton rate over the space-time four volume that is determined from the following schematic considerations. We assume that the parton fugacities increase linearly with proper time as

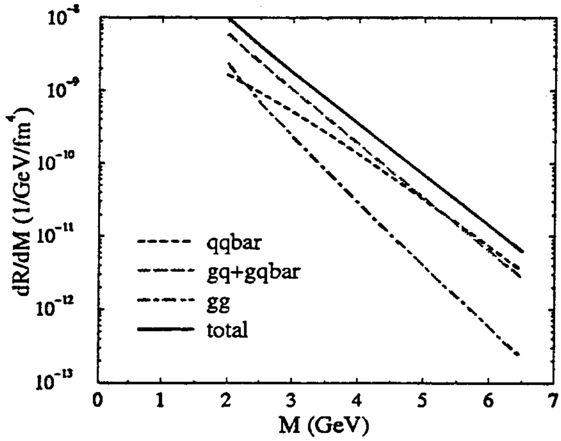

Figure 2: Thermal dilepton rate from a gluon-dominated, under-saturated quark-gluon plasma at $T = 570$ MeV, $\lambda_g = 0.060$ and $\lambda_q = 0.0072$.

indicated by the results of Ref. [5]. The time dependence of temperature is taken to be $T = T_0(\tau_0/\tau)^{1/2}$, which follows from the constant rapidity density of transverse energy as shown approximately in the parton cascade model [7]. Expansion of the partonic matter is assumed to follow the Bjorken scaling [9].

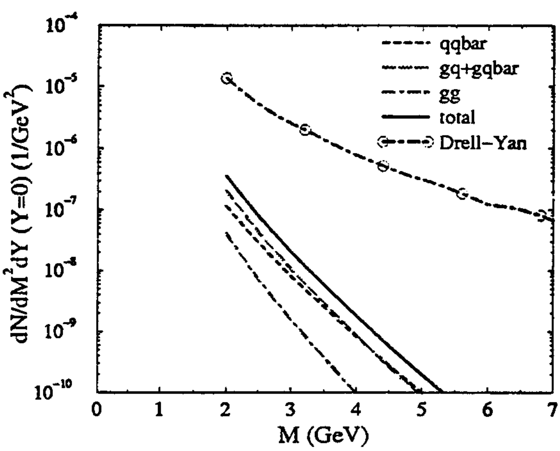

Figure 3: Thermal dilepton yield from central Au+Au collisions at RHIC with the initial conditions of $T_0 = 570$ MeV, $\lambda_{g,0} = 0.060$, $\lambda_{q,0} = 0.0072$.

The resulting dilepton yield is shown in Fig. 3. Also shown is the expected Drell-Yan yield from primary hard collisions with a K-factor of 1.7 to take into account higher-order contributions. One sees that more dilepton are produced from Compton processes than from the LO $q\bar{q}$ annihilation process and that the two-gluon fusion is least important. Despite the enhancement due to gluonic processes, the total thermal dilepton yield is still a factor of 30 or more, depending on the dilepton mass, below the Drell-Yan yield. Even if one assumes that quarks and antiquarks are initially in relative chemical equilibrium with gluons, which would lead to more than an order of magnitude increase in the dilepton yield from the LO $q\bar{q}$ annihilation process, the total thermal dilepton yield from the quark-gluon plasma is still about a factor of 5 or more below the Drell-Yan yield. It thus seems quite difficult to observe the thermal dileptons from the produced quark-gluon plasma in heavy ion collisions at RHIC.

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