Geiger Replies: In the preceding paper, Asakawa [1] comments on my Letter [2] on the $M_\perp$ dependence of dilepton emission [3] calculated within the framework of the parton cascade model (PCM) [4]. He suggested that the $M_\perp$ scale breaking effects discussed in [2] may possibly be of unphysical origin, arising from the perturbative QCD infrared cutoffs (μ_0 and $p_{\perp \mathrm{cut}}$) inherent to the PCM. I would like to respond first with a number of general remarks, followed by some comments on the PCM approach in particular.

(1) It is a fact that QCD is *not* scale invariant, even for massless particles. The characteristic scale is set by the "glueball mass" associated with the gluon condensate, which can be interpreted phenomenologically, e.g., in terms of the string constant, the energy density residing in the gluon field, being determined to be of the order of $\kappa \simeq 1$ GeV/fm^2. Thus, in any perturbative QCD description that does not account for the rather little understood nonperturbative mechanisms, one must inevitably introduce some invariant mass cutoff around 1 GeV that separates the perturbative regime from the nonperturbative domain. However, this is not an arbitrary, unphysical parameter, but rather reflects the fact that there is a fundamental scale in the problem.

(2) In addition to the above natural QCD scale one is faced with further (external) scale breaking quantities when addressing nucleus-nucleus collisions that modify QCD processes in nuclear matter as compared to free space. (i) The nuclear radii R_A and the collision geometry define a finite size system that gives rise volume and surface effects. (ii) The nuclear density ρ_A together with the Lorentz contraction at high energies leads to an initial quark and gluon density already in the initial state. (iii) The time-dependent local temperature or density are manifest in medium dependent propagators (or formfactors) of the partons and control their mean free paths.

(3) In a description of high energy nuclear reactions on the basis of "scaling hydrodynamics" one assumes *a priori* an ideal fluid dynamical expansion of the matter produced in the central collision region. That is, one assumes local thermalization, a longitudinally boost invariant expansion, absence of radial flow, and no scales other than the temperature are involved in the dynamical evolution [5]. In other words, all of the above mentioned scale breaking quantities are completely ignored here—an approach which is certainly not illegitimate, but should not be taken as a measure of realistic description.

Responding to the specific points of Asakawa's Comment, I state the following:

(4) *Mass cutoff.*—The argument that by a time of about $1/\mu_0 = 0.2$ fm/c the partons have reached this invariant mass cutoff and propagate on as massive ($\approx$1 GeV) particles is definitely not correct, because this estimate is based on "free" cascading of virtual partons by successive bremsstrahlung, e.g., in jet evolution of e^+e^- annihilation. In a nuclear collision, that is in the dense matter environment of the central collision region, this gradual deexcitation of virtual particles toward mass shell is considerably delayed due to scatterings and fusions [6]. The more frequent these interactions with the environment are, the longer it takes for a parton to reach μ_0. In the PCM calculations for Au + Au at the BNL Relativistic Heavy Ion Collider, it takes about 1 fm/c until the majority of materialized virtual partons do not radiate anymore because they have reached μ_0. It is true, however, that in the PCM the parameter μ_0 and also the minimum allowed momentum transfer $p_{\perp \mathrm{cut}}$ in parton collisions are partly responsible for the $M_\perp$ scale breaking in the dilepton spectrum. This has been clearly stated in Ref. [2] on p. 3078. However, this scale breaking contribution is a physical effect and is intimately connected to the (medium dependent) Sudakov formfactors of the partons.

(5) *$q\bar{q}$ annihilation.*—As stated in Ref. [3] on p. 1922, the turnover at lower dilepton mass is due to the neglect of contributions from quark antiquark scatterings which are treated with the phenomenological scattering amplitude, if the momentum transfer of a parton collision is below $p_{\perp \mathrm{cut}}$. These low $p_\perp$ processes were not included in the calculation of the dilepton spectrum, because perturbative QCD does not tell us about the soft physics of these contributions, and they are therefore model dependent. In order not to spoil the results for the perturbative QCD yield of dileptons where the amplitudes are well known, a phenomenological description of soft production was avoided. On the other hand, Asakawa is ultimately correct in saying that the PCM predictions for dilepton masses less than about 3 GeV should not be taken seriously at this time. But this was stressed in the paper too.

In conclusion, I think that one has to be careful when comparing the PCM calculations with, e.g., the solutions of the Bjorken hydrodynamical model. The latter cannot account for the scale breaking effects discussed above, because it assumes *a priori* that those are absent.

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