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Synchrotron Contribution to Photon Emission from Quark-gluon Plasma

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Experimental study of photon spectra in the low and intermediate k_T region in AA collisions can provide vital information on the parameters of the produced quark-gluon plasma (QGP) [1]. It is widely believed that the observed in AA collisions at RHIC [2–4] and LHC [5] excess of the photon yield (above the photons from hadron decays and from the hard perturbative mechanism) at $k_T \lesssim 3{-}4\,\mathrm{GeV}$ is related to photon emission from the QGP. It is surprising that the thermal photons exhibit a significant azimuthal asymmetry v_2 ("elliptic flow") comparable to that for hadrons. It is difficult to reconcile with the expectation that the thermal photons should be mostly radiated from the hottest initial stage of the QGP where the flow effects should be small (it is usually called "the direct photon puzzle").

It was suggested by Tuchin [6] that the azimuthal anisotropy of the direct photons may be due to synchrotron mechanism of the photon emission in a strong transverse (to the reaction plane) magnetic field in the noncentral AA collisions. The synchrotron contribution obtained in [6] can explain a significant fraction of the photon yield in the central rapidity region at $k_T \sim 1{-}3\,\mathrm{GeV}$. However, the calculations performed in [6] are of a qualitative nature. In particular in [6] it was ignored the fact that multiple scattering of quarks, which they undergo in the thermal bath, will suppress the synchrotron emission (because of reduction of the coherence/formation length of the photon emission). In fact for the photon emission in the QGP with magnetic field one cannot distinguish between the synchrotron radiation and the bremsstrahlung due to multiple scattering. One can only define the difference between the photon emission rate from the QGP with and without magnetic field. On the other hand, in [6] there was not taken into account the contribution of the synchrotron annihilation $q\bar{q} \to \gamma$ which increases the the photon emission. It is known that for the QGP without magnetic field the annihilation contribution is more important than bremsstrahlung at the photon momenta $k_T \gg T$ [7].

In the present work we address the effect of the magnetic field on both the processes $q \to \gamma q$ and $q\bar{q} \to \gamma$. We develop a formalism which treats on an even footing the effect of multiple scattering and curvature of the quark trajectories in the collective magnetic field in the QGP. Our analysis is based on the light cone path integral formalism [8], which was previously successfully used [9] for very simple derivation of the well known photon emission rate from the higher order collinear processes $q \to \gamma q$ and $q\bar{q} \to \gamma$ obtained by Arnold, Moore and Yaffe [7] using methods from thermal field theory with Hard Thermal Loop resummation. It is known that the higher order diagrams corresponding to these processes contribute to leading order [10], and turn out to be as important as the leading order $2 \to 2$ processes $q(\bar{q})g \to \gamma q(\bar{q})$ and $q\bar{q} \to \gamma g$. Contrary to the collinear processes the $2 \to 2$ processes should not be affected by the presence of the magnetic field.

Our results differ drastically from that of [6]. We find that even for very optimistic magnitude of the magnetic field ($eB \sim m_\pi^2$) for RHIC and LHC conditions the effect of the magnetic field on the photon emission from the QGP is very small. For this reason the synchrotron mechanism cannot solve "the direct photon puzzle".

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