Jet-dilepton conversion in spherical expanding quark-gluon plasma

Yong-Ping Fu and Qin Xi

Department of Physics, Lincang Teachers College, Lincang 677000, China

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We calculate the production of large mass dileptons from the jet-dilepton conversion in spherical expanding quark-gluon plasma at Relativistic Heavy Ion Collider (RHIC) and Large Hadron Collider (LHC) energies. The jet-dilepton conversion exceeds the thermal dilepton production and Drell-Yan process in the large mass region of 4.5 GeV $< M <$ 5.5 GeV and 7 GeV $< M <$ 9 GeV in central Pb+Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV and 5.5 TeV, respectively. We present the solution of 1+3 dimensional fluid hydrodynamics with spherical symmetry. We find that the transverse flow leads to a rapid cooling of the fire ball. The suppression due to transverse flow is also important at intermediate and large mass at LHC energies. The energy loss of jets in the hot and dense medium is also included.

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I. INTRODUCTION

One of the most important aim in the experiments of relativistic heavy-ion collisions is that of the study of a quark-gluon plasma (QGP). The electromagnetic radiation is considered to be a useful probe for the investigation of the evolution of the QGP due to their very long mean free path in the medium [1].

In relativistic heavy-ion collisions dileptons are produced from several sources. These include the dileptons from the Drell-Yan process of primary partons [2], thermal dileptons from the interactions of thermal partons in the QGP [3] and the hadron interactions in the hadronic phase [4, 5], and dileptons from the hadronic decays occurring after the freeze-out [6]. Energetic jets produced via the parton scattering in relativistic heavy-ion collisions also provide an excellent tool that enables tomographic study of the dense medium [7, 8]. In Refs. [9, 10] the authors indicated that the electromagnetic radiation from jets interacting with the QGP is a further source. The jet-dilepton conversion in the 1+1 dimensional (1+1 D) evolution of the plasma has been investigated [11, 12].

The exact solutions of the relativistic hydrodynamical equations can describe the collective properties of the strongly interacting matter. The Bjorken solution provides an estimate of the 1+1 D cylindrical expansion of the plasma [14]. The 1+3 dimensional (1+3 D) hydrodynamics have been calculated numerically which assumes cylindrical symmetry along the transverse direction and boost invariant along the longitudinal direction [15, 16]. After the initial proper time $\tau_i$ and initial temperature $T_i$, the system is regarded as thermalized. The system temperature $T$ is given as a function of proper time $\tau$ by the numerical calculation of the flow. The transverse flow effect of the dilepton production from the QGP, with cylindrical symmetry, are shown to be important in the region of low invariant mass [17]. In the present work, we derive the hubble-like solutions ($\tau T = \tau_i T_i$) of 1+3 D relativistic hydrodynamics which favors spherical symmetry, and investigate the initial condition of the temperature $T$ and proper time $\tau$ in the spherical evolution. We find the transverse flow effect is also apparent at intermediate and high invariant mass at LHC energies.

Jets crossing the hot and dense plasma will lose their energies. For high energy partons, the radiative energy loss is dominant over the elastic energy loss [19]. The jet energy loss through gluon bremsstrahlung in the medium has been elaborated by several models: Gyulassy-Wang (GW) [13, 20], Gyulassy-Levai-Vitev (GLV) [21, 22], Baier-Dokshitzer-Mueller-Peigne-Schiff (BDMPS) [23, 24], Guo-Wang (HT) [25, 26], Wang-Huang-Sarcevic (WHS) [27, 28], and Arnold-Moore-Yaffe (AMY) [29, 30]. In Ref. [11, 12] the authors use the AMY formalism to investigate the electromagnetic signature of jet-plasma interactions. The AMY formalism assumes that hard jets evolve in the 1+1 D medium according to the Fokker-Planck rate equations for their momentum distributions $dN^{jet}/dE$. Energy loss is described as a dependence of the parton momentum distribution on time. In this paper we use the WHS and BDMP frameworks to calculate the energy loss of the momentum distribution of jets passing through the QGP in the 1+3 D spherical symmetry.

This paper is organized as follows. In Sec. II we discuss the 1+3 D spherical evolution of the plasma. In Sec. III we calculate the jet production and jet energy loss. In Sec. IV we rigorously derive the production rate for the jet-dilepton conversion by using the relativistic kinetic theory. The Drell-Yan process is also presented in Sec. V. Finally, the numerical discussion and summary are presented in Sec. VI and VII.

II. 1+3 DIMENSION HYDRODYNAMICS

In this section we begin with the equation for conservation of energy-momentum

$$\partial_\mu T^{\mu\nu} = 0, \hspace{1cm} (1)$$

the energy-momentum tensor of an ideal fluid produced in relativistic heavy-ion collisions is given by

$$T^{\mu\nu} = (\varepsilon + P)u^\mu u^\nu - P g^{\mu\nu}, \hspace{1cm} (2)$$

where $\varepsilon$, $P$, and $u^\mu$ are the energy density, pressure, and four-velocity of the fluid, respectively.
where $\varepsilon$ is the energy density, $P$ is the pressure, and $u^\mu = \gamma(1, \mathbf{v})$ is the four-velocity of the collective flow, where $\gamma = 1/(1 - \mathbf{v}^2)^{1/2}$. The $u^\mu$ satisfies the constraint $u^2 = 1$. We denote the space-time coordinate by $x^\mu = (t, \mathbf{r})$ and the metric tensor by $g^{\mu\nu} = \text{diag}(1, -1, -1, -1)$. We have $(g^{\mu\nu})^2 = 1 + d$, $\delta_{ij} = d$, where Greek letters denote Lorentz indices, Latin letters denote three-vector indices, the notation $d$ stands for the dimensionality of the space. In 1+3 D ideal fluid, the fluid velocity vector $u^\mu$ is Lorentz invariant:

$$u^\mu = \frac{x^\mu}{\tau},$$  

(3)

the proper time is

$$\tau = (t^2 - r^2)^{1/2},$$  

(4)

where we denote $|\mathbf{r}|$ by $r$ and the space-time rapidity $\eta$ as

$$\eta = \frac{1}{2} \ln \frac{t + r}{t - r},$$  

(5)

where the $t$ and $r$ coordinates as functions of $\tau$ and $\eta$ are

$$t = \tau \cosh \eta,$$

(6)

$$r = \tau \sinh \eta.$$  

(7)

Under the condition of spherical expansion of the fireball, we have the space-time integration as

$$d^4x = r^2 \sin \theta dt dr d\theta d\phi = r^2 \sin \theta \tau d\tau d\eta d\phi d\varphi,$$  

(8)

where the Jacobian $dt dr$ is related to $\tau d\tau d\eta$.

Now the relativistic hydrodynamic equation of motion for a 1+3 D expansion with spherical symmetry read

$$\frac{\partial \varepsilon}{\partial \tau} + (\varepsilon + P) \frac{\partial u^\mu}{\partial x^\mu} = 0,$$  

(9)

where $\partial u^\mu/\partial x^\mu = (g^{\mu\nu} - 1)/\tau$. If the QGP has the longitudinal and transverse expansion, we derive the universal solution of the relativistic hydrodynamics equation as

$$\frac{\tau}{\tau_i} = \left( \frac{T_i}{T} \right)^{3/d},$$  

(10)

where $\tau_i$ and $T_i$ are the initial time and initial temperature of the equilibrium QGP, respectively. In the 1+1 D case, $d=1$, Eq. (10) is the well-known Bjorken solution.

In the 1+3 D condition, $d = 3$, we have the Hubble-like solution as

$$\frac{\tau}{\tau_i} = \frac{T_i}{T},$$  

(11)

this solution favors the spherical symmetry. The end of the QGP phase occur at proper time $\tau_c = \tau_i T_i/T_c$, where $T_c = 160$ MeV is the critical temperature of the phase transition. In the 1+1 D cylindrical expansion the QGP cooling time is $\tau_c = \tau_i (T_i/T_c)^3$. The transverse expansion leads to a more rapid cooling of the system.

At proper time $\tau$ and temperature $T$, the initial entropy $S_i$ is essentially constant and the system is regarded as thermalized. Since the initial entropy density is related to the initial temperature as

$$s_i = \frac{4\pi^2}{90} g_Q T_i^3,$$  

(12)

where the factor $g_Q = 42.25$ is the degrees of freedom for the plasma of $u$, $d$, $s$ quarks and gluons. Therefore the total entropy is

$$S_i(\eta) = \int s_i dV,$$  

(13)

the space volume is $dV = r^2 \tau d\eta \sin \theta d\theta d\phi$. Then we have that the initial entropy per unit rapidity is

$$\frac{dS_i}{d\eta} = 4\pi r_i^2 \tau_i s_i.$$  

(14)

The entropy density and particle multiplicity for the case of spherical expansion have the relation as

$$\frac{dS}{dy} = 3.7 \frac{dN}{dy},$$  

(15)

where $y$ is the true momentum rapidity. In the 1+3 D expanding QGP, the space-time rapidity $\eta = \frac{1}{2} [(t + r)/(t - r)]$ and the true momentum rapidity $y = \frac{1}{2} [E + \mathbf{p}]/[E - \mathbf{p}]$ are correlated. Then we have $dy = d\eta$ and $\eta = y + \tilde{y}$, where $\tilde{y}$ is an arbitrary constant. At mid-rapidity $y = 0$, $\eta = \tilde{y}$, we define $r(\eta, y = 0) = \tau$. Therefore the initial time and temperature for the 1+3 D spherical expansion are related by the following

$$T_i^3 \tau_i^4 = \frac{3.7 \times 90}{4\pi^2 g_Q} \frac{dN}{dy}.$$  

(16)

We use the initial temperature $T_i = 370$ MeV for $dN/dy = 1260$ at RHIC, $T_i = 636$ MeV for $dN/dy = 2400$ at LHC (Pb+Pb, $\sqrt{s_{NN}}=2.76$ TeV), and $T_i = 845$ MeV for $dN/dy = 5624$ at LHC (Pb+Pb, $\sqrt{s_{NN}}=5.5$ TeV) \cite{11, 12, 33, 54}. The numerical results of the initial conditions for $y=0$ are presented in Table I.

| TABLE I: Initial conditions of the hydrodynamical expansion. |
|----------------------------------|-----------------|-----------------|
| $T_i$(MeV) | $\tau_c$(fm/c) | $\tau_i$(fm/c) |
| RHIC     | 370            | 1.44            | 3.33            |
| LHC      | 636            | 1.038           | 4.13            |
|          | 845            | 1.037           | 5.49            |

Bjorken solution:

| RHIC | 0.26 | 3.22 |
| LHC  | 0.088 | 5.53 |
|      | 0.087 | 12.96 |
III. JET ENERGY LOSS

The BDMPS model determines the energy loss of jets crossing the hot and dense plasma by means of the spectrum of energy loss per unit distance $dE/dx$. Induced gluon bremsstrahlung, rather than elastic scattering of partons, is the dominant contribution of the jet energy loss \[22\]. If an energetic jet passes through a long distance in the QGP, and hadronize outside the system, the energy loss of the jet is large \[19, 23, 27, 28\]. However, in the case of the jet-dilepton (or jet-photon) conversion, jets travel only a short distance through the plasma before they convert into dileptons (or photons), and do not lose a significant amount of energy. The energy loss in the jet-photon conversion is found to be small, just about 20% at RHIC \[10\].

Because we discuss the jets produced at midrapidity, in this restriction a jet will only propagate in the transverse directions. The total distance a parton produced at $(r, \varphi)$ travels through the QGP is $\bar{L}_{1+3}(r, \varphi, \tau) = \sqrt{R_A^2 - r^2 \sin^2 \varphi} - r \cos \varphi$, where $R(\tau)$ is the radius of the expanding QGP. In the 1+1 D Bjorken evolution, neglecting the transverse expansion, the average value of $\bar{L}_{1+1} = \sqrt{R_A^2 - r^2 \sin^2 \varphi} - r \cos \varphi$ is $\langle \bar{L}_{1+1} \rangle \approx 0.9 R_A$, where $R_A = 1.2 A^{1/3}$ fm is the initial radius of the system \[11\] \[23\]. Considering the spherical expansion, we have $R(\tau) \geq R_A$ and $\langle \bar{L}_{1+1} \rangle \approx \langle \bar{L}_{1+1} \rangle$.

In the ultra-relativistic collisions, we assume the parton is massless and travels with the speed of light in the transverse direction, as suggested in Ref. \[11\]. Then the distance of the jets passing through the QGP before the jet-dilepton conversions is

$$L(\tau) = c(\tau - \tau_i),$$

the average value of the distance of jet-dilepton processes is

$$\langle L \rangle = \frac{1}{\Delta \tau} \int_{\tau_i}^{\tau_f} c(\tau - \tau_i) d\tau = \frac{1}{2} c \Delta \tau,$$

where $\Delta \tau = \tau_f - \tau_i$ is the lifetime of the QGP phase. In Table II we can see that the distance $\langle L \rangle$ of the jet-dilepton conversion process is smaller than the total distance $\langle \bar{L} \rangle$. The jets covers a short distance in the QGP before they convert into dileptons. Since the transverse expansion will reduce the lifetime of the QGP, the distance $\langle \bar{L}_{1+3} \rangle$ is smaller than the value of $\langle L \rangle_{1+1}$. In the high energy collisions, the energy loss can be written as

$$\frac{dE_a}{dx} = \frac{c_s c_m^2}{8 \lambda_g} L \ln \frac{L}{\lambda_g},$$

where $c_s = 4/3$ for quarks and 3 for gluon, $\mu^2 = 4 \pi a_s T^2$, $\mu$ is the Debye mass of the medium, $\lambda_g$ is the gluon mean free path. The quark mean free path is $\lambda_q = 9 \lambda_g / 4$, we use $\lambda_q = 2$ fm from Ref. \[24\] \[25\]. For large values of $N$, the energy loss is $\Delta E = N_a \frac{dE_a}{dx}$. The initial yield $dN_{jet} / d^2 p_\perp dy_{jet}$ for producing jets in the relativistic heavy-ion collisions ($A + B \rightarrow jets + X$) can be factorized in the perturbative QCD (pQCD) theory as \[35\]

$$\frac{dN_{jet}^0}{d^2 p_\perp dy_{jet}} = T_{AA} \sum_{a,b} \int_{x_{min}^a}^{1} dx_a G_{a/A}(x_a, Q^2) G_{b/B}(x_b, Q^2) K_{jet} d\sigma_{ab \rightarrow cd} \frac{x_a x_b}{x_a - x_1} \frac{dt}{dt_a},$$

where $T_{AA} = 9 A^2 / 8 \pi R_A^4$ is the nuclear thickness for central collisions \[4\] \[10\]. $x_a$ and $x_b$ are the momentum fraction of the parton. The momentum fractions with the rapidity are given by $x_a^{min} = x_1 / (1 - x_2)$ and $x_b = x_a x_2 / (x_a - x_1)$, where the variables are $x_1 = x_T e^{y_{jet} / 2}$, $x_2 = x_T e^{-y_{jet} / 2}$, $x_T = 2 p_{jet} / \sqrt{s_{NN}}$. $\sqrt{s_{NN}}$ is the center of mass energy of the colliding nucleons. The parton
the number of nucleons. The functions $q$ rate for the above annihilation process can be written as

$$\text{TeV and 5.5 TeV, the initial temperature is } T \rightarrow a/n (1+1D) \text{ is the pQCD correction factor to take into account the next-to-leading order of parton collisions at leading order, these processes are: } gq \rightarrow q'q', qq' \rightarrow qq', \bar{q}q' \rightarrow \bar{q}q', qq \rightarrow qg, \bar{q}q \rightarrow \bar{q}g, gg \rightarrow \bar{q}q \text{ [30]}. K_{\text{jet}} \text{ is the pQCD correction factor to take into account the expanding QGP without transverse flow (1+1D). The solid line shows thermal dileptons produced from spherical expanding QGP (1+1D).}

distribution for the nucleus is given by

$$G_{a/A}(x, Q^2) = R_A(x, Q^2)[Z f_{a/p}(x, Q^2) + (A - Z) f_{a/n}(x, Q^2)]/A,$$

where $R_A(x, Q^2)$ is the nuclear modification of the structure function [36], $Z$ is the number of protons, $A$ is the number of nucleons. The functions $f_{a/p}(x, Q^2)$ and $f_{a/n}(x, Q^2)$ are the parton distributions of the proton and neutron, respectively [37]. $\delta_{\text{ab}} \rightarrow \text{cd}/d\hat{u}$ is the cross section of parton collisions at leading order, these processes are: $q \bar{q} \rightarrow q' \bar{q}'$, $q q' \rightarrow q q'$, $\bar{q} \bar{q}' \rightarrow \bar{q} q'$, $q q' \rightarrow q g$, $q g' \rightarrow q q'$, $g g \rightarrow q q'$ [38]. $K_{\text{jet}}$ is the pQCD correction factor to take into account the expanding QGP without transverse flow (1+1D).

IV. JET-DILEPTON CONVERSION

The jets produced in initial parton collisions are defined by all partons with transverse momentum $p_{\perp} > 1 \text{ GeV}$ [11]. The dilepton production is sensitive to the choice of the cutoff $p_{\perp}^{\text{cut}}$. In order to avoid such sensitivity, the authors of Ref. [11, 12] have constrained a lower cutoff $p_{\perp}^{\text{cut}} \geq 4 \text{ GeV}$. We adopt this limit in the integration of Eq. (25).

$$\frac{dR_{\text{jet} \rightarrow \ell^+ \ell^-}}{dM^2} = \frac{\sigma(M) M^2}{2(2\pi)^4} \int dl |f_{\text{jet}}(l)| T e^{-\frac{M^2}{4T^2}},$$

The cross section of the $q \bar{q} \rightarrow \ell^+ \ell^-$ interaction is given by

$$\sigma(M) = 4\pi\alpha^2 N_c N_f^2 \sum_q e_q^2 / 3M^2,$$

where the parameters $N_c$ and $N_f$ are the color number and spin number, respectively. The relative velocity is $v_{12} = (p_1 + p_2)^2 / 2E_1 E_2$. In the relativistic collisions, $|p| \approx E$, the integration over $d^3p = |p|^2 d|p| d\Omega$ can be done with the relatively simple result [13]

$$\int d|p| f_{\text{jet}}(p) T e^{-\frac{M^2}{4T^2}} = \frac{\sigma(M) M^2}{2(2\pi)^4} \int d|p| f_{\text{jet}}(p) T e^{-\frac{M^2}{4T^2}},$$

The phase-space distribution function for a jet, assuming the constant transverse density of nucleus, is as follows [39]

$$f_{\text{jet}} = \frac{(2\pi)^3}{g_q V p_{\perp}^2 d^2 p_{\perp} d\eta_{\text{jet}}(\eta_{\text{jet}} = 0)},$$

where $g_q = 6$ is the spin and color degeneracy of the quarks (and antiquarks), $V = 4\pi r^3$ is the volume of the spherical expanding QGP.

If the phase-space distribution for the quark jets $f_{\text{jet}}(p)$ is replaced by the thermal distribution $f_{\text{th}}(p)$ in Eq. (25), one can obtain the rate for producing thermal
dileptons as \[ \frac{dR_{th}}{dM^2} = \frac{\sigma(M)M^3}{2(2\pi)^3}TK_1 \left( \frac{M}{T} \right), \] (27)
where the Bessel function is \( K_1(z) = \sqrt{\pi/(2z)}e^{-z}. \)

Because we are interested in jets produced at midrapidity (\( y_{jet}=0 \)), we only consider dileptons produced at midrapidity (\( y=0 \)). The yield as a function of invariant mass \( M \) and dilepton rapidity \( y \) is given by the 1+3 D space-time integration \( d^2x=r^2\tau d\tau dy \sin \theta d\theta d\phi \) as
\[
\frac{dN_{jet-l\rightarrow l-1}}{dM^2dy} = \int_{\tau_1}^{\tau_2} 4\pi\tau^3 d\tau \frac{dR_{jet-l\rightarrow l-1}}{dM^2dy}(y = 0). \tag{28}
\]

In the jet-dilepton conversion processes the jet only propagates in the pure QGP phase, therefore we limit the \( \tau \) integration as \([\tau_1, \tau_2]\).

V. DRELL-YAN PROCESS

In the central collisions of two equal-mass nuclei with mass number \( A \) the yield for producing Drell-Yan pairs with the invariant mass \( M \) and rapidity \( y \) can be obtained as \[ 2 \]
\[
\frac{dN_{DY}}{dM^2dy} = T_{AA}K_{DY} \frac{4\pi\alpha^2}{9M^4} \sum_q e_q^2 [x_q G_{q/A}(x_q, Q^2) x_b G_{\bar{q}/B}(x_b, Q^2) + (q \leftrightarrow \bar{q})], \tag{29}
\]
where the momentum fractions with rapidity \( y \) are \( x_q = M e^{y/\sqrt{S_{NN}}}, x_b = M e^{-y/\sqrt{S_{NN}}} \). A \( K_{DY} \) factor of 1.5 is used to account for the NLO corrections [13].

VI. RESULTS AND DISCUSSIONS

In Fig. 1 we plot the results of thermal dileptons produced from the QGP at RHIC and LHC energies. In the central Au+Au collisions at \( \sqrt{s_{NN}}=200 \) GeV we choose the initial temperature of the 1+3 D spherical expanding QGP \( T_i=370 \) MeV [11, 12]. Then we have the initial time \( \tau_i = \frac{1}{T_i^3} \sqrt{\frac{2\pi}{4\pi^2 g}} \frac{2\pi^2}{dN/dy} = 1.44 \) fm/c and the critical time \( \tau_c = \tau_i T_i/T_c = 3.33 \) fm/c corresponding to \( y=0 \). In the 1+1 D Bjorken expansion the initial time \( \tau_i = \frac{1}{T_i^3} \sqrt{\frac{2\pi}{4\pi^2 g}} \frac{2\pi^2}{dN/dy} = 0.26 \) fm/c and the critical time \( \tau_c = \tau_i (T_i/T_c) = 3.22 \) fm/c at RHIC. The life time of the QGP phase of the 1+3 D expansion (\( \Delta \tau_{1+3}=1.89 \) fm/c) is smaller than the one of the 1+1 D case (\( \Delta \tau_{1+1}=2.96 \) fm/c) at RHIC energy. At LHC we have \( \Delta \tau_{1+3}=3.092 \) fm/c, \( \Delta \tau_{1+1}=5.442 \) fm/c and \( \Delta \tau_{1+3}=4.453 \) fm/c, \( \Delta \tau_{1+1}=12.873 \) fm/c corresponding to \( T_i=636 \) MeV and \( T_i=845 \) MeV, respectively. The initial conditions at RHIC and LHC are calculated in Table I. We observe that transverse flow effect of the spherical expansion leads to a rapid cooling of the fire ball.

For comparison, the yields of the thermal dileptons and the jet-dilepton conversion from the 1+1 D cylindrical expanding and 1+3 D spherical expanding QGP are given in Fig. 11 and 12 respectively. We find that the transverse flow of the spherical expansion reduces the yields from low to high invariant mass and the reduction is largest at small \( M \), the transverse flow effect is still important at intermediate and large \( M \). In Fig. 11 the reduction of thermal dileptons is in the region of \( M < 2.5 \) GeV for \( T_i=370 \) MeV, \( M < 4.5 \) GeV for \( T_i=636 \) MeV and \( M < 6 \) GeV for \( T_i=845 \) MeV. The thermal production is suppressed by a factor~2 at \( M \sim 2 \) GeV for \( T_i=845 \) MeV.
In Fig. 2 the reduction of the jet-dilepton conversion is in the region of $M < 7$ GeV for $T_\text{i}=370$ MeV, $M < 13.5$ GeV for $T_\text{i}=636$ MeV and $M < 16$ GeV for $T_\text{i}=845$ MeV. We find a factor $\sim 2$ of suppression at $M \sim 4$ GeV for $T_\text{i}=845$ MeV.

Fig. 3, 4 and 5 present the results for thermal dileptons, direct dileptons from Drell-Yan process and dileptons from the interaction of jets with the spherical expanding QGP at RHIC and LHC energies, respectively. In Fig. 3 the contribution of the jet-dilepton conversion is not prominent at RHIC energy. However the jet-dilepton conversion is comparable to that of the thermal contribution and Drell-Yan process at LHC energies. The jet-dilepton conversion is a dominant source in the region of 4.5 GeV $< M < 5.5$ GeV and 7 GeV $< M < 9$ GeV in central Pb+Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV and 5.5 TeV, respectively (see Fig. 4 and 5). In Ref. [13] the contribution of the jet-dilepton conversion is prominent in the region for 4 GeV $< M < 10$ GeV at LHC ($\sqrt{s_{NN}}=5.5$ TeV) due to the absence of the transverse flow and the energy loss.

The energy loss effect on jet-dilepton conversion is presented in Fig. 6 at RHIC and LHC energies. The energy loss effect suppresses the jet-dilepton spectrum, the suppression decreases with increasing invariant mass $M$. For a given invariant mass $M$ and thermal parton energy $E_{th}$, the minimum energy of the jet is $E_{jet} = M^2/4E_{th}$ [13]. The energy loss rate $\Delta E/E_{jet} \propto M^{-2}$, this implies that jet-dilepton conversion with large $M$ favors small jet propagation length and small energy loss. The energy loss depends on the propagating length $L$ of the jet. In Table II we find that $\langle L \rangle_{\text{LHC}} > \langle L \rangle_{\text{RHIC}}$, the large value of $L$ corresponds to the increase of the energy loss rate. The suppression induced by the jet energy loss is much larger at LHC energies. At RHIC dileptons are reduced by about 23% for $M=1$ GeV, and 10% for $M=4$ GeV. These results agree with the numerical results from the AMY approach [12]. In central Pb+Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV the suppression is about 13% and 7% at $M=4.5$ GeV and 5.5 GeV, respectively. At LHC($\sqrt{s_{NN}}=5.5$ TeV) the suppression is about 6% at $M=7$ GeV and 2% at $M=9$ GeV.

The main background for the dilepton production in the intermediate and high invariant mass region is the decay of open charm and bottom mesons. The $cc(\bar{b}\bar{b})$ pairs are produced from the initial hard scattering of partons and can thereafter fragment into $D(B)$ and $\bar{D}(\bar{B})$ mesons. If the energy loss of heavy quarks crossing the hot medium is considered, the contribution of the decay of open charm and bottom mesons will be suppressed [11,12]. In Ref. [13] the authors study the Parton-Hadron-String Dynamics transport approach, and find that the contribution of the dileptons from the decays of $D\bar{D}$ and $B\bar{B}$ mesons is lower than the thermal dileptons in the intermediate and high invariant mass region at LHC. This provides the possibility to measure the jet-dilepton conversion from the QGP. Since there is no single model that could address reliably decays of open charm and bottom mesons, these backgrounds are not plotted in this article and the background of $J/\Psi$ vector meson decay is also not concerned.

**VII. SUMMARY**

We have calculated the large mass dilepton produced from the jet-dilepton conversion, QGP and Drell-Yan at RHIC and LHC energies. We presented the temperature evolution equation which favors the spherical symmetry
of fire ball. We have found that the transverse flow effect from the spherical expanding QGP leads to a smaller life time of the QGP phase, and suppresses the production of jet-dileptons and thermal dileptons from low to high invariant mass region. We have found an important window of the jet-dilepton conversion. The jet-dilepton conversion is a dominant source in high invariant mass regions at LHC, after the background of heavy quark decays is subtracted. The jet energy loss has been included by using the WHS and BDMPS frameworks. The energy loss is small at large mass $M$ due to the small propagating length of a jet.

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