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Theoretical estimation of Photons flow rate Production in quark gluon interaction at high energies

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Abstract. photons emitted from higher energetic collisions in quark-gluon system have been theoretical studied depending on color quantum theory. A simple model for photons emission at quark-gluon system have been investigated. In this model, we use a quantum consideration which enhances to describing the quark system. The photons current rate are estimation for two system at different fugacity coefficient. We discussion the behavior of photons rate and quark gluon system properties in different photons energies with Boltzmann model. The photons rate depending on anisotropic coefficient: strong constant, photons energy, color number, fugacity parameter, thermal energy and critical energy of system are also discussed.

1-Introduction

High-energy physics had been established a basic theory for an elementary particles and interactions. Standard Model one of the most important model to establishment this. the physics of ultra-relativistic heavy-ion collision aimed to apply Standard Model theory on dynamically systems to study and understand the properties of nuclear matter [1]. Both Zweig and Gell-Mann independently had been introduced the quarks idea for building the matter in 1964. Quarks in proton or neutron were holding together due to strong nuclear force. Beside the quarks, the sciences introduce an idea that for any quarks corresponding antiquark have same properties except the charge was opposite for each other. Proton is composed of quarks and gluons. The spin values in proton is $(1/2)$, it's coming from quarks the spin [2]. Quarks and gluons have a color quantum number that's makes quarks confined in hadron [3]. The particles protons and neutrons that contain quarks are called hadrons. Hadrons could be divided to baryons and mesons. Baryons are building of three quarks for protons and neutrons or antiquarks for anti neutrons and anti protons. On the other hand, mesons are bounding from pairs quark-antiquark confined by gluons [4]. The interacting



matter is found to exist in the form of a super fluid state called The quark-gluon plasma is the super fluid state that produce from quark gluon matter interaction and it was investigation in the Relativistic Heavy Ion Collision (RHIC) or/and Large Hadron Collider (LHC) [5–6]. Nuclear strong interaction could be establishing by Quantum Chromodynamics (QCD). QCD was theory dependent on the distance between quarks [7]. Moreover, the report from lattice QCD calculation proves the existence of such matter (QGP) at very high temperature [8]. In recent years ago, The photons production studies at relativistic heavy ion collisions has available from CERN experimental and RHIC experiments at BNL [9]. However, the theoretical studies of quark Gluon interaction Was utilize with resummation technique [[10] to estimation the photon self energy to evaluate the photonic rate.

2. Theory

To study and evaluation the photonic rate at quark gluon interaction is obtained the approximation rule from real time calculation of hard photonic production rate in order adopted at quantum field theory [11]. The photonic rate of the Gama emitted from quarks system per unit time per unit volume is given by self-energy retarded appropriate [12].

$$E \frac{dN}{d^3p d^4x} = -\frac{\alpha}{(2\pi)^3} \text{Im} \Pi_{\mu\theta}^R \frac{1}{e^{E_\gamma/T} - 1} \quad (1)$$

The self-energy retarded propagators $\text{Im} \Pi_{\mu\theta}^R$ due to spectral representation can be given by [13].

$$\text{Im} \Pi_{\mu}^{R,\mu} = -\frac{10\pi}{3} e^2 \sum q_Q^2 \left(e^{\frac{E_\gamma}{T}} - 1 \right) \times \int \frac{d^3k}{(2\pi)^3} \int_{-\infty}^{\infty} dw \int_{-\infty}^{\infty} dw^\sim \delta(E_\gamma - w - w^\sim) [f_{FD(q)}(w) \cdot f_{BE(g)}(w^\sim)] \text{Tr}[\xi^\mu(k, \bar{k}, -p) \rho^*(w, \bar{k}) \rho(w - E_\gamma, \bar{k} - \bar{p}) \xi^\theta(-\bar{k}, -k, p)] \quad (2)$$

Where e^2 is the static strength, q_Q^2 is quark charge, E_γ is the photonic energy, T is the thermal energy of system, w frequency propagator of quark system, k is cut off parameter, $\xi^\mu(k, \bar{k}, -p)$ is propagator of system, $\rho(w - E_\gamma, \bar{k} - \bar{p})$ is the density distribution of system, $f_{FD(q)}$ and $f_{BE(g)}$ are the Jouttner distribution functions for quarks, anti-quarks and gluons and may be written as by[14].

$$f_{FD(q,\bar{q})} = \frac{\lambda_{(q,\bar{q})} e^{\pm \frac{\mu}{T}}}{e^{\frac{E_\gamma}{T}} + 1}, \text{ and } f_{BE(g)} = \frac{\lambda_g}{e^{\frac{E_\gamma}{T}} - 1} \quad (3)$$

where $\lambda_{(q,\bar{q})}$ is the fugacity of quark and anti quark, and λ_g is the fugacity of gluon By substituting the Eqs.(2) and(3) in Eq.(1) and treatment mathematically, the results is

$$\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E) = \frac{10\alpha\alpha_{str}}{9\pi^2} \lambda_Q \lambda_G \sum q_Q^2 T^2 e^{-\frac{E_\gamma}{T}} \left[\text{Ln}\left(\frac{2E_\gamma}{4\pi\alpha_{sc}T}\right) + \frac{1}{2} - C_{Euler} \right] \quad (4)$$

Where becomes. $C_{Euler} = 0.577$ is the Euler constant, α is electrodynamic strength approximated equally to $\alpha \approx \frac{1}{137}$, q_Q is the charge of quark and $\alpha_{str}(P_m)$ is the strength quantum coupling that's may be written as[15].

$$\alpha_{str}(P_m) = \frac{6\pi}{(33-2N_f) \ln\left(\frac{P_m}{T_c}\right)} \quad (5)$$

Where P_m is the transfer momentum of media, N_f is the flavor quantum number and T_c is the transition critical energy.

3. Result

In this paper we evaluated the photonic rate at Compton processes for quark gluon interaction depending on extended the expression using the fugacity correlation. The evaluation are performed for quarks system have quantum flavor number $N_f=2$ and 4 for $ug \rightarrow d\gamma$ and $Cg \rightarrow d\gamma$ sytems respectively. Strength quantum coupling, photonic energy, color quantum number, thermal energy media, flavor number and fugacity correlation parameter are active parameters controlling on the photonic flow rate in quarks interactions at Compton processes. The photonic rate as fulfillment to estimation the strength quantum coupling for $ug \rightarrow d\gamma$ and $Cg \rightarrow d\gamma$ systems using Eq.(5) and the results is shown in table (1).

Table1. Strength quantum coupling estimation for $ug \rightarrow d\gamma$ and $Cg \rightarrow d\gamma$ systems at $T_c = 160$, and 190 MeV

		$\alpha_{Str}(P_m)$									
		$P_m=1$ Gev		$P_m=2$ Gev		$P_m=3$ Gev		$P_m=4$ Gev		$P_m=5$ Gev	
		Critical energy temperature T_c MeV									
system	N_F	190	160	190	160	190	160	190	160	190	160
ug	2	0.335	0.367	0.247	0.264	0.214	0.227	0.195	0.206	0.183	0.192
$\rightarrow d\gamma$											
cg	4	0.389	0.426	0.286	0.306	0.248	0.263	0.226	0.239	0.212	0.223
$\rightarrow d\gamma$											

The rate was evolution of two system using calculated date of the strength quantum coupling $\alpha_{str}(P_m)$ that's shown in table (1) and matlab program with fugacity correlation parameter $\lambda_Q = 0.02$ and $\lambda_G = 0.09$ for quark and gluon [16]. Next parameter for the photonic rate is quark charge at both system. It is played more effective in photonic emission at system according to electromagnetic field effect. The quarks charge of system can be estimation using $\sum q_Q^2 = q_u^2 + q_d^2$ and $\sum q_Q^2 = q_c^2 + q_d^2$. However, the photonic rate is function of the fugacity parameter for quark and gluon that's was shown in Eq. (4). The photonic rate should be evaluation using Eq.(4) for both system by substituting the strength coupling α_{str} , photonic energy E_γ (GeV), thermal energy media T , fugacity parameter, quarks charge system $\sum q_Q^2$ and Euler constant C_{Euler} . A MATLAB soft ware program has been using to evaluation the photonic rate for $ug \rightarrow d\gamma$ and $Cg \rightarrow d\gamma$ systems using Eq.(4), the results are tabulated in tables (2),(3), (4) and (5) respectively.

Table 2. The evaluated result of photonic rate production $\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E)$ in $ug \rightarrow dy$ interaction at $T_C=160$ MeV.

E_γ GeV	$\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E) (GeV^2 fm^4)^{-1}$			
	Thermal energy of quarks system (T)MeV			
	150 MeV	200 MeV	250 MeV	300 MeV
	Strength quantum coupling $\alpha_{str}(P_m)$			
	0.25779	0.2764	0.30319	0.34648
1	8.4942×10^{-12}	2.682×10^{-10}	8.858×10^{-9}	1.972×10^{-9}
1.5	4.208×10^{-13}	3.207×10^{-11}	1.84×10^{-10}	6.066×10^{-10}
2	8.100×10^{-14}	3.218×10^{-12}	3.107×10^{-11}	1.460×10^{-10}
2.5	3.261×10^{-15}	3.014×10^{-13}	4.853×10^{-12}	3.218×10^{-11}
3	1.271×10^{-16}	2.724×10^{-14}	7.283×10^{-13}	6.789×10^{-12}

Table 3. The evaluated result of photonic rate production $\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E)$ in $ug \rightarrow dy$ interaction at $T_C=190$ MeV.

E_γ GeV	$\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E) (GeV^2 fm^4)^{-1}$			
	Thermal energy of quarks system (T)MeV			
	150 MeV	200 MeV	250 MeV	300 MeV
	Strength quantum coupling $\alpha_{str}(P_m)$			
	0.378790	0.327648	0.296587	0.2752668
1	3.820×10^{-11}	2.645×10^{-10}	8.620×10^{-10}	1.891×10^{-9}
1.5	1.943×10^{-12}	3.257×10^{-11}	1.854×10^{-10}	6.075×10^{-10}
2	8.399×10^{-14}	3.307×10^{-12}	3.171×10^{-11}	1.460×10^{-10}
2.5	3.402×10^{-15}	3.117×10^{-13}	4.987×10^{-12}	3.292×10^{-11}
3	1.332×10^{-16}	2.829×10^{-14}	7.518×10^{-13}	6.976×10^{-12}

Table 4. The evaluated result of photonic rate production $\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E)$ in $Cg \rightarrow d\gamma$ interaction at $T_c=160$ MeV.

$\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E) (GeV^2 fm^4)^{-1}$				
E_γ GeV	Thermal energy of quarks system (T) MeV			
	150 MeV	200 MeV	250 MeV	300 MeV
	Strength quantum coupling $\alpha_{str}(P_m)$			
	0.40674211	0.355924266	0.3244790019	0.3026332043
1	3.796×10^{-11}	2.580×10^{-10}	8.189×10^{-10}	1.739×10^{-9}
1.5	1.977×10^{-12}	3.298×10^{-11}	1.862×10^{-10}	6.036×10^{-10}
2	8.630×10^{-14}	3.394×10^{-12}	3.244×10^{-11}	1.508×10^{-10}
2.5	3.514×10^{-15}	3.224×10^{-13}	5.150×10^{-12}	3.390×10^{-11}
3	1.417×10^{-16}	2.940×10^{-14}	7.810×10^{-13}	7.236×10^{-12}

Table 5. The evaluated result of photonic rate production $\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E)$ in $Cg \rightarrow d\gamma$ interaction at $T_c=190$ MeV .

$\xi(\alpha_{esc}, \lambda_Q \lambda_G, T, E) (GeV^2 fm^4)^{-1}$				
E_γ GeV	Thermal energy of quarks system (T) MeV			
	150 MeV	200 MeV	250 MeV	300 MeV
	Strength quantum coupling $\alpha_{str}(P_m)$			
	0.44466763	0.38463064	0.3481683	0.32313931
1	3.730×10^{-11}	6.075×10^{-12}	7.755×10^{-10}	1.605×10^{-9}
1.5	2.012×10^{-12}	7.378×10^{-12}	1.858×10^{-10}	5.970×10^{-10}
2	8.893×10^{-14}	3.468×10^{-12}	3.291×10^{-11}	1.521×10^{-10}
2.5	3.652×10^{-15}	3.320×10^{-13}	5.269×10^{-12}	3.449×10^{-11}
3	1.441×10^{-16}	3.042×10^{-14}	8.032×10^{-13}	7.407×10^{-12}

4. Discussion

The photonic rate in quark-gluon interaction at Compton process have been studied and evaluation in term of a quantum chromodynamic theory. According to quantum chromodynamic postulate of field theory, the photons are emission by fluctuations of

propagation of both quarks and gluon system. In this research, we have calculation of photons produce from one-loop contributions. With a suitable quarks election in $u\bar{g} \rightarrow d\gamma$ and $Cg \rightarrow d\gamma$ reaction systems the flow rate at Compton scattering are performed to the quantum flavor number 2 and 4 respectively. The electromagnetic coupling constant $\alpha \approx 1/137$ is much smaller than the strength coupling α_{str} for strong interactions. In the results, the photonic producing during the quark gluon interaction at hadronic Phase as a result the to large free path compare to lifetime of the system fireball. In tables (2 to 5), we can show the net photonic rate emission at different thermal energies $T = 0.150, 0.200, 0.250$ and 0.300 GeV with the various photonic energy for Compton process. This indicates that results of flow rate of photons are highly effected due to thermal energy for the system, and it seems to be large near the hot temperature. This leads to the fact of strength coupling is dependent on thermal energy and critical temperature dependent and when increased in thermal energy T lead to smaller Strength quantum coupling and the system approaching to the deconfined behavior that's means the quarks and gluons are weakly interaction in system. It means that increasing of thermal energy system increasing in photonic rate that's means in case of finite thermal energy, the increasing thermal energy lead to increase the size of droplet which refers to good output photonic flow in respect of hadronic phase structure. In quark gluon interaction system the phase transition was opposite to thermal energy (temperature). This results at tables (2 to 5) in all the system interaction, the simple model for this reactions is very advantage to study the photonic rate production at Compton processes.

It is founded to be very large rate in high temperature $T = 300$ MeV for all system through the quarks interaction at Compton processes. Photon emission at Compton process is increased when the critical temperature is increased, and for both system the rate production in this process have been still a high at $T_c = 190$ GeV. In tables (2-5), we can show the photonic rate at different critical temperature $T = 160$ and 190 MeV through Compton process for quark quantum flavor number $n = 2$ and 4 , the photonic rates are showing to be increases with the thermal energy T of system. This increasing in photonic rate was effected due to thermal energy temperature as well as the fugacity parameters of the system. So the photonic rate calculation of simple model with different quantum flavor number 2 , and 4 has improvement the color quantum theory for the strong nuclear forces. Moreover, the results of photonic rate at tables (2-5) for two systems are suppressing by about a $1-5$ factor, it shows that photonic rate results are approximated values at hadronic phase dependent on physical features of photons. Overall the data results in all tables indicate that Photonic rate production a function of decreases the strength quantum coupling and transverse momentum P_m for system incorporating with quantum flavor for quark. Finally, we conclusion that the effect of calculation strength quantum coupling factor on photonic rate by discussion of the behavior of strong nuclear forces and the rate was decrease due to decreases the strength quantum coupling and vice versa.

5. Conclusion

In this research, we have been study and evaluation the photonic rate produce in Quark gluon interaction at hadronic phase. Its solving a set equation that preparing to evaluate the photonic rate based on the color quantum theory and using the Juttner function of distribution of the system, next we have obtained an expressions to evaluate the photonic production at Compton processes. We could be concluded that photonic rate calculation of quark gluon interaction as a function of strength quantum coupling. However, we have evaluated the photonic rate in a hadronic phase at deferent photonic energies. We find that the increase of the thermal energy will change the photonic rate caused by the increase thermal energy system, making the net photonic rate strongly increasing of the photonic energy to emission. From results, its shown that quark-gluon interaction at the Compton

scattering is the main feature of quantum chromodynamic theory and making to understanding the postulate of field theory, so the photonic yield is good sensor of quantum color hypothesis.

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