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Calculation of the Photons Emission Rate by Interaction of Charm Quark with Gluon

Ola Z Ridha[1*] and Ahmed M Shweikh[2]
[1,2]Department of Physics, College of Education for Pure Science (Ibn-Al-Haitham), University of Baghdad, Baghdad,Iraq.
*Corresponding Author.

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Abstract
In this paper, a theoretical model has been presented to calculate the rate of photon emission. The photonic yield has been calculated for the interaction of heavy charm quarks with gluon from Bremsstrahlung processes. The rate of photon emission was evaluated for the interaction of the charm quarks with the gluons for $cg \to d\gamma$ system based on quantum chromodynamics theory. The calculation is due to essential parameters, including the quantum flavor number N_f =6 the chromodynamics constant, thermal energy in range 185MeV $\leq$ T $\leq$305MeV, and critical temperature T_C=0.1311479288GeV, 0.1748639051 GeV, 0.2040078893GeV. It was considered the energy of photons in the range 1GeV $\leq$ E $\leq$ 3.5GeV. Furthermore, the values of the fugacity of quark λ_Q=0.068 and gluon λ_G=1. We found that the photonic yield at T_C= 0.2040078893GeV was greater than the photonic yield at T_C=0.1311479288 and 0.1748639051 GeV. The rate of photon emission increases with increases in both the critical temperature and thermal energy and decreases with chromodynamic constant, and it decreases with increases in the energy of photons.
Keywords: Charm-gluon interaction, photon emission, chromodynamics, bremsstrahlung.

1. Introduction

The picture of the basic components of matter and the interactions between them that has emerged in recent years is very amazing [1]. All matter appears to consist of quarks and leptons, which are assumed to be point-like (no structure), spin 1/2 particles [2]. Quarks are hypothetical particles hypothesized by the two scientists George Zweig and Gell-Mann [3]. The six flavors of quarks are divided into three generations (up, down), (strange, charm), and(top, bottom) [4]. Each particle that consists of a quark is known as a hadron, which is classified into mesons and baryons [5]. Baryon is made of three quarks, and Meson is made of quarks and antiquarks [6]. Quarks have many intrinsic properties, like mass, spin, charge, symmetry, etc. All these properties are called quantum numbers and must be conserved [7]. They are subject to electromagnetic interactions as they carry the electric charge [8]. Furthermore, they have a second type of charge, which is the color charge (red, blue, or green), which makes them also subject to strong interactions by gluon exchanging [9,10].

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Charm (C) is a quark flavor that was invented to explain the big narrowness of the huge resonances (ψ) during observation of the meson J/ψ resonance produced by electron and antielectron annihilation [11]. The theory that depicts strong interactions is quantum chromodynamics theory [12]. Photons are produced in heavy ion collisions by establishing the quark-gluon matter system and exploring the state of matter in decoupled quarks and gluons. The two phenomena that predict the behavior of quarks at high temperatures and high densities are confinement and deconfinement [13] and [14]. In the Large Hadron Collider, there are many processes for photon production, such as Compton scattering, bremsstrahlung, and annihilation processes [15,16]. In the present paper, the photonic yield rate for the $cg \rightarrow d\gamma$ system is calculated and discussed for bremsstrahlung processes.

2. Materials and Methods

The photon emission rate from the interaction of quark and gluon is given [17].

$$R^{H}_{qg}(E,P) = -\frac{F_G(E)}{(2\pi)^3}\, \mathrm{Im}\prod{}^{f}_{i}(E,P) \tag{1}$$

Where $F_G(E)$ is the distribution function of gluons, $\mathrm{Im}\prod^{f}_{i}(E,P)$ is the propagation of self-energy for photon emission, which is given in [18].

$$\mathrm{Im}\prod{}^{f}_{i}(E,P) = \left(\frac{N}{\pi^4} C_{ca}\right) g_E^2\, g_C^2\, \frac{T}{E_\gamma^2} \int_0^\infty |I_{tl}|\, [F_a(P) - F_q(E+P)][P^2 + (P+E)^2]dp \tag{2}$$

C_{ca} is Casmir factor given by[19].

$$C_{ca} = \frac{N_c^2 - 1}{2N_c} \tag{3}$$

Where N_c is the quarks number $N_c = 3$, then $C_{ca} = 4/3$, and N is the degeneracy factor $N \approx 3$, with introducing the total electric charge of the quarks $\sum_q (\frac{e_q}{e})^2$ into the system, Equation (2) is reduced to:

$$\mathrm{Im}\prod{}^{f}_{i}(E,P) = \left(\frac{4}{\pi^4}\right) g_E^2\, g_C^2\, \frac{T}{E_\gamma^2} \sum_q \left(\frac{e_q}{e}\right)^2 \int_0^\infty |I_{tl}|\ [F_a(P) - F_q(E+P)][P^2 + P^2 + 2EP + E^2]\, dp \tag{4}$$

Integration of self-energy [20]

$$|I_{tl}| = |I_t - I_l| \tag{5}$$

Where I_t and I_l are dimensionless constants, and by inserting Equation (5) into Equation (4), it is reduced to:

$$\mathrm{Im}\prod{}^{f}_{i}(E,P) = \left(\frac{4}{\pi^4}\right) g_E^2\, g_C^2\, \frac{T}{E_\gamma^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_l| \int_0^\infty [F_a(P) - F_q(E+P)]\ [2P^2 + 2PE + E^2]\, dp. \tag{6}$$

The juttner distribution function for quarks is [21]

$$F_a(P) = \frac{\lambda_Q}{e^{\frac{P}{T}} + \lambda_Q} \tag{7}$$

And

$$F_q(E+P) = \frac{\lambda_Q}{e^{\frac{(P+E)}{T}} + \lambda_Q} \tag{8}$$

Where λ_Q is the fugacity function of quark, and by inserting Equations (7) and (8) in Equation (6), it is reduced to:

$$\mathrm{Im}\prod{}^{f}_{i}(E,P) = \left(\frac{4}{\pi^4}\right) g_E^2\, g_C^2\, \frac{T}{E_\gamma^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_l| \int_0^\infty \frac{\lambda_Q(2P^2 + 2PE + E^2)}{e^{\frac{P}{T}} + \lambda_Q} dP - \int_0^\infty \frac{\lambda_Q(2P^2 + 2PE + E^2)}{e^{\frac{(P+E)}{T}} + \lambda_Q} dP \tag{9}$$

The solution to the integral term is:

$$\int_0^{\infty} \frac{\lambda_Q(2P^2+2PE+E^2)}{e^{\frac{P}{T}}+\lambda_Q}dP - \int_0^{\infty} \frac{\lambda_Q(2P^2+2PE+E^2)}{e^{\frac{(P+E)}{T}}+\lambda_Q}dP = \lambda_Q T(1-e^{-\frac{E_\gamma}{T}})[2T^2\Gamma(3)+2ET\,\Gamma(2)+E^2\Gamma(1)] \quad (10)$$

Inserting equation (10) into equation (9), it is reduced to

$$Im\prod{}_i^f(E,P) = (\frac{4}{\pi^4})\, g_E^2 g_C^2 \frac{T}{E_\gamma^2} \sum_q (\frac{e_q}{e})^2 |I_t - I_l| \; [\lambda_Q\, T(1-e^{-\frac{E_\gamma}{T}})\,(2T^2\Gamma(3)+2ET\,\Gamma(2)+E^2\Gamma(1))] \quad (11)$$

The strength of electrodynamics is [22]

$$g_E^2 = 4\pi\alpha_E \quad (12)$$

The quantum chromodynamics coupling is [23]

$$g_C^2 = 4\pi\alpha_C \quad (13)$$

Inserting the Equations (12) and (13) in Equation (11), Equation (11) is reduced to:

$$Im\prod{}_i^f(E,P) = \left(\frac{64}{\pi^2}\right)\alpha_E\alpha_C \frac{T^2}{E_\gamma^2} \sum_q (\frac{e_q}{e})^2 |I_t - I_l|\, [\lambda_Q\,(1-e^{-\frac{E_\gamma}{T}})(2T^2\Gamma(3)+2ET\,\Gamma(2)+E^2\Gamma(1))] \quad (14)$$

Substituting Equation (14) in Equation (1), it is reduced to:

$$R_{qg}^H(E,P) = -\frac{F_G(E)}{(2\pi)^3}\left(\frac{64}{\pi^2}\right)\alpha_E\alpha_C \frac{T^2}{E_\gamma^2} \sum_q (\frac{e_q}{e})^2 |I_t - I_l| [\lambda_Q\,(1-e^{-\frac{E_\gamma}{T}})(2T^2\Gamma(3)+2ET\,\Gamma(2)+E^2\Gamma(1))] \quad (15)$$

The distribution of gluons $F_G(E)$ for $E_\gamma \gg T$ is [24].

$$F_G(E) = \frac{\lambda_G}{e^{\frac{E_\gamma}{T}}-\lambda_G} = \frac{1}{\frac{e^{E_\gamma/T}}{\lambda_G}-1} \approx \lambda_G e^{-\frac{E_\gamma}{T}} \quad (16)$$

Where λ_G is the fugacity of gluons and by inserting Equation (16) in Equation (15), Equation (15) reduced to:

$$R_{qg}^H(E,P) = \frac{8}{\pi^5}\alpha_E\alpha_C \frac{T^2}{E_\gamma^2} \sum_q (\frac{e_q}{e})^2 |I_t - I_l|\, \lambda_Q\lambda_G e^{-\frac{E_\gamma}{T}}(e^{-\frac{E_\gamma}{T}}-1)(2T^2\Gamma(3)+2ET\,\Gamma(2)+E^2\Gamma(1)) \quad (17)$$

For $E_\gamma \geq T$, then

$$e^{-\frac{E_\gamma}{T}} - 1 \approx e^{-\frac{E_\gamma}{T}} \quad (18)$$

Inserting Equation (18) in Equation (17), it is reduced to

$$R_{qg}^H(E,P) = \frac{8}{\pi^5}\alpha_E\alpha_C \frac{T^2}{E_\gamma^2} \sum_q (\frac{e_q}{e})^2 |I_t - I_l|\, \lambda_Q\lambda_G e^{-\frac{2E_\gamma}{T}}(2T^2\Gamma(3)+2ET\,\Gamma(2)+E^2\Gamma(1)) \quad (19)$$

The critical temperature is [25]

$$T_C = \left[\frac{90B}{\pi^2(N_S\times N_C)+\frac{7}{4}(n_c\times n_s\times n_f)}\right]^{1/4} \quad (20)$$

Where T_C is the critical temperature, $B^{1/4}$ is the Bag constant, N_S, N_C is the number of spin and gluon color, and n_c, n_s, n_f is the number of quark color, spin, and flavor number.

The coupling strength is given by [26]

$$\alpha_c = \frac{6\pi}{(33-2N_f)\ln\frac{8T}{T_C}} \quad (21)$$

Where T is the temperature of the system.

3. Results

The rate of photons emitted from the interaction of heavy charm quarks with gluons was studied and evaluated theoretically. We estimated the critical temperature according to the bag constant in Eq (20) with $B^{1/4}$= 225, 300, and 350MeV [27], and the degrees of freedom for gluon are N_S=2, N_C=8 and the degrees of freedom for quarks are n_c =3, $n_s = 2$, $n_f = 6$. The result of the critical temperature calculation can be shown in **Table 1**.

Table 1. Critical temperature calculation result for $cg \rightarrow d\gamma$ system

$B^{1/4}$(GeV)	Critical temperature T_c(GeV)
0.225	0.1311479288
0.300	0.1748639051
0.350	0.2040078893

The chromodynamics constant between charm quarks and gluon was calculated using Eq (21) with the critical temperature in **Table1**, and the system temperature in the limit (185-305MeV) and N_f=6.The result of strength coupling is listed in **Table 2**.

Table 2. Critical result of strength coupling for $cg \rightarrow d\gamma$ system.

T (GeV)	Chromodynamics constant α_C		
	T_c=0.1311479288	T_c=0.1748639051	T_c=0.2040078893
0.185	0.3703769235	0.4202651765	0.4529573937
0.205	0.3553259183	0.4009919782	0.4306486485
0.225	0.3426971623	0.3849816976	0.4122369774
0.245	0.3319059992	0.3714159636	0.3967211497
0.265	0.3225468018	0.359735121	0.3834229094
0.285	0.3143284738	0.3495424097	0.3718652301
0.305	0.307036152	0.3405480378	0.3617020613

The rate of photon emission was calculated by summation of the electric charge $\sum_q(\frac{e_q}{e})^2$ for $cg \rightarrow d\gamma$ system with e_c= +3/2e and e_d= -1/3e and the results was 5/9e. The flavor number N_f=6 for the system as it was calculated from the summation of $N_{f_i} = \sum_{i=1}^{6} N_{f_i}$ for charm and down quarks with inserting $\propto_E = 1/137$ and the self-integral constant I_t=4.45,I_l=-4.26 [28], supposing that the fugacity λ_Q=0.068, λ_G=1[29]. In addition to the system temperature in the range (185–305MeV), photon energy (1–3.5GeV) [30] and the values of chromodynamics constant are stated from **Table 2**. The emission rate of photons is calculated by substituting all the above values into Eq (19) and using MATLAB software. The photon emission rate result for the system $cg \rightarrow d\gamma$ is shown in **Table 3** to **Table 5** and **Figure 1** to **Figure 3**.

Table 3. Rate of emission photons $R^{H}_{qg}(E,P)$ at T_C= 0.1311479288GeV for $cg \rightarrow d\gamma$ system with N_f =6 and λ_Q =0.068, λ_g = 1

E_γ GeV	$R^{H}_{qg}(E,P)\,\frac{1}{GeV^2 fm^4}$						
	T=185 MeV	T=205 MeV	T=225MeV	T=245MeV	T=265MeV	T=285MeV	T=305MeV
	$\alpha_C = 0.3704$	$\alpha_C = 0.3553$	$\alpha_C = 0.3427$	$\alpha_C = 0.3319$	$\alpha_C = 0.3225$	$\alpha_C = 0.3143$	$\alpha_C = 0.3070$
1	2.4203E-11	8.5728E-11	2.4825E-10	6.1664E-10	1.3588E-09	2.7218E-09	5.0461E-09
1.25	1.4895E-12	6.8040E-12	2.4251E-11	7.1575E-11	1.8238E-10	4.1351E-10	8.5300E-10
1.5	9.4340E-14	5.5742E-13	2.4523E-12	8.6236E-12	2.5477E-11	6.5543E-11	1.5079E-10
1.75	6.0746E-15	4.6509E-14	2.5299E-13	1.0618E-12	3.6428E-12	1.0651E-11	2.7371E-11
2	3.9518E-16	3.9251E-15	2.6429E-14	1.3253E-13	5.2860E-13	1.7584E-12	5.0526E-12
2.25	2.5884E-17	3.3377E-16	2.7841E-15	1.6693E-14	7.7462E-14	2.9337E-13	9.4327E-13
2.5	1.7034E-18	2.8532E-17	2.9499E-16	2.1161E-15	1.1430E-14	4.9312E-14	1.7750E-13
2.75	1.1249E-19	2.4484E-18	3.1388E-17	2.6947E-16	1.6950E-15	8.3333E-15	3.3595E-14
3	7.4471E-21	2.1070E-19	3.3502E-18	3.4434E-17	2.5229E-16	1.4139E-15	6.3859E-15
3.25	4.9399E-22	1.8171E-20	3.5846E-19	4.4117E-18	3.7660E-17	2.4065E-16	1.2179E-15
3.5	3.2818E-23	1.5698E-21	3.8425E-20	5.6639E-19	5.6342E-18	4.1057E-17	2.3287E-16

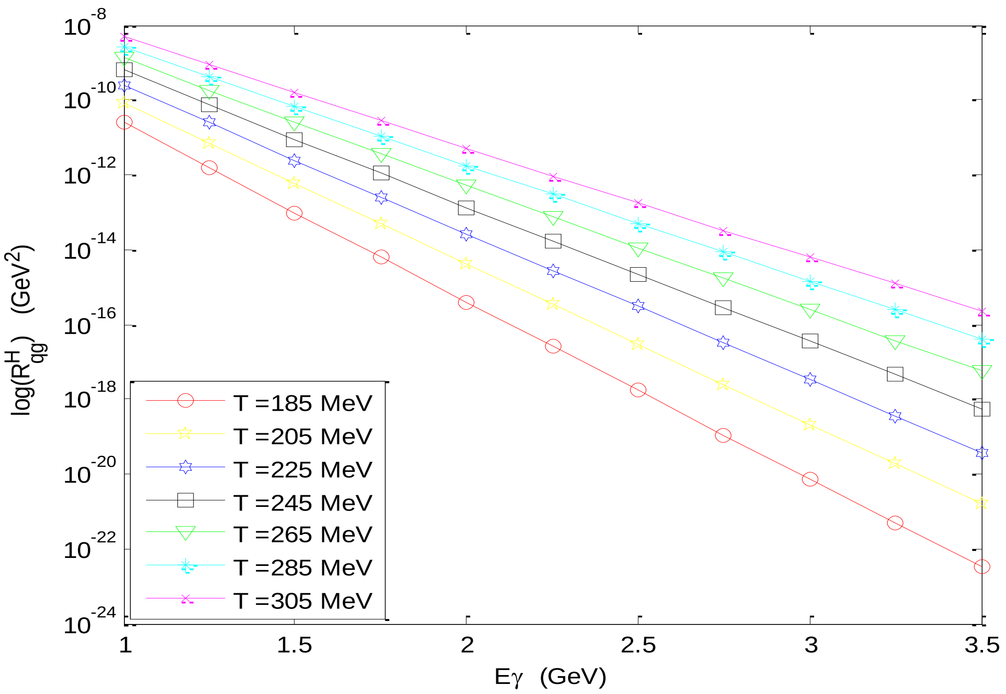

Figure 1. Rate of emission photons $R^{H}_{qg}(E,P)$ as function of E_γ at T_C= 0.1311479288GeV for $cg \rightarrow d\gamma$ system.

Table 4. Rate of emission photons $R^{H}_{qg}(E,P)$ at T_C= 0.1748639051GeV for $cg \rightarrow d\gamma$ system with N_f =6 and λ_Q =0.068, λ_g = 1.

E_γ GeV	$R^{H}_{qg}(E,P)\,\frac{1}{GeV^2 fm^4}$						
	T=185 MeV	T=205 MeV	T=225MeV	T=245MeV	T=265MeV	T=285MeV	T=305MeV
	$\alpha_C = 0.4203$	$\alpha_C = 0.4010$	$\alpha_C = 0.3850$	$\alpha_C = 0.3714$	$\alpha_C = 0.3597$	$\alpha_C = 0.3495$	$\alpha_C = 0.3405$
1	2.7463E-11	9.6746E-11	2.7889E-10	6.9005E-10	1.5155E-09	3.0267E-09	5.5969E-09
1.25	1.6901E-12	7.6784E-12	2.7243E-11	8.0095E-11	2.0341E-10	4.5983E-10	9.4610E-10
1.5	1.0705E-13	6.2906E-13	2.7549E-12	9.6502E-12	2.8414E-11	7.2886E-11	1.6725E-10
1.75	6.8928E-15	5.2486E-14	2.8421E-13	1.1882E-12	4.0628E-12	1.1844E-11	3.0359E-11
2	4.4841E-16	4.4295E-15	2.9690E-14	1.4831E-13	5.8954E-13	1.9554E-12	5.6041E-12
2.25	2.9370E-17	3.7666E-16	3.1276E-15	1.8681E-14	8.6393E-14	3.2624E-13	1.0462E-12
2.5	1.9329E-18	3.2199E-17	3.3139E-16	2.3680E-15	1.2748E-14	5.4836E-14	1.9688E-13
2.75	1.2764E-19	2.7631E-18	3.5261E-17	3.0155E-16	1.8904E-15	9.2669E-15	3.7262E-14
3	8.4502E-21	2.3778E-19	3.7636E-18	3.8533E-17	2.8138E-16	1.5723E-15	7.0829E-15
3.25	5.6053E-22	2.0507E-20	4.0269E-19	4.9369E-18	4.2002E-17	2.6761E-16	1.3508E-15
3.5	3.7238E-23	1.7716E-21	4.3166E-20	6.3381E-19	6.2838E-18	4.5657E-17	2.5829E-16

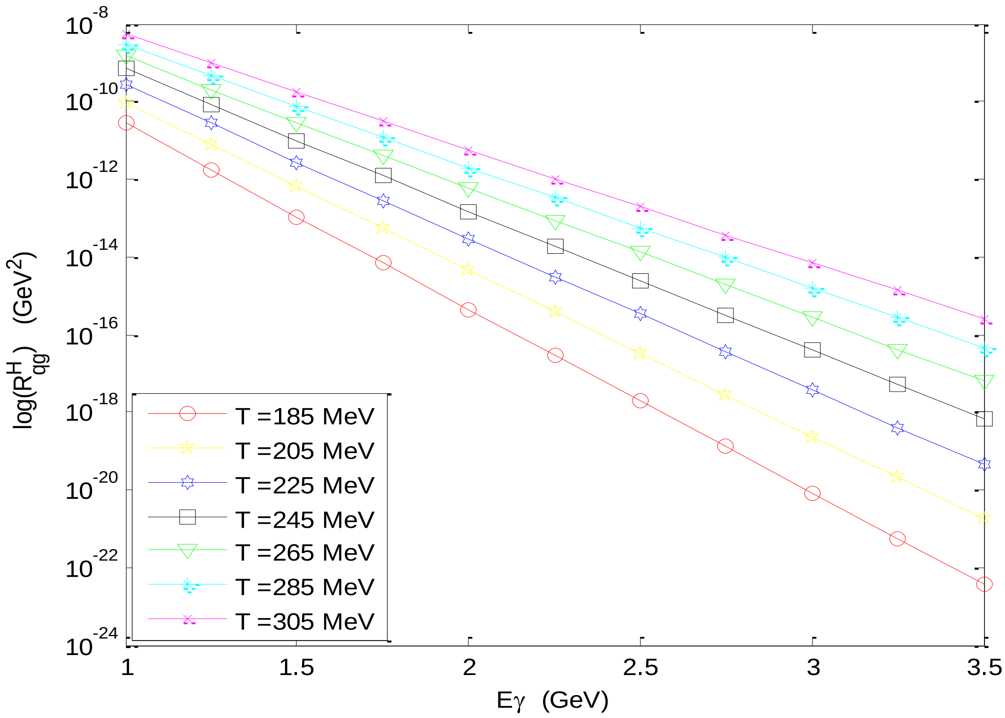

Figure 2. Rate of emission photons $R^{H}_{qg}(E,P)$ as function of $E_\gamma$at T_C=0.1748639051GeV for $cg \rightarrow d\gamma$ system.

Table 5. Rate of emission photons $R^{H}_{qg}(E,P)$ at T_c= 0.2040078893GeV for $cg \rightarrow d\gamma$ system with N_f =6 and λ_Q =0.068, λ_g = 1.

E_γ GeV	$R^{H}_{qg}(E,P)\frac{1}{GeV^2fm^4}$						
	T=185 MeV	T=205 MeV	T=225MeV	T=245MeV	T=265MeV	T=285MeV	T=305MeV
	$\alpha_c = 0.4530$	$\alpha_c = 0.4306$	$\alpha_c = 0.4122$	$\alpha_c = 0.3967$	$\alpha_c = 0.3834$	$\alpha_c = 0.3719$	$\alpha_c = 0.3617$
1	2.9600E-11	1.0390E-10	2.9863E-10	7.3706E-10	1.6153E-09	3.2200E-09	5.9445E-09
1.25	1.8216E-12	8.2463E-12	2.9172E-11	8.5552E-11	2.1681E-10	4.8920E-10	1.0049E-09
1.5	1.1537E-13	6.7559E-13	2.9499E-12	1.0308E-11	3.0285E-11	7.7540E-11	1.7764E-10
1.75	7.4290E-15	5.6368E-14	3.0433E-13	1.2691E-12	4.3303E-12	1.2601E-11	3.2245E-11
2	4.8329E-16	4.7571E-15	3.1792E-14	1.5841E-13	6.2836E-13	2.0802E-12	5.9522E-12
2.25	3.1655E-17	4.0452E-16	3.3490E-15	1.9953E-14	9.2082E-14	3.4707E-13	1.1112E-12
2.5	2.0832E-18	3.4580E-17	3.5485E-16	2.5293E-15	1.3587E-14	5.8338E-14	2.0911E-13
2.75	1.3757E-19	2.9674E-18	3.7757E-17	3.2210E-16	2.0149E-15	9.8587E-15	3.9577E-14
3	9.1075E-21	2.5536E-19	4.0301E-18	4.1159E-17	2.9991E-16	1.6728E-15	7.5229E-15
3.25	6.0413E-22	2.2023E-20	4.3119E-19	5.2732E-18	4.4768E-17	2.8470E-16	1.4347E-15
3.5	4.0135E-23	1.9026E-21	4.6222E-20	6.7700E-19	6.6975E-18	4.8572E-17	2.7433E-16

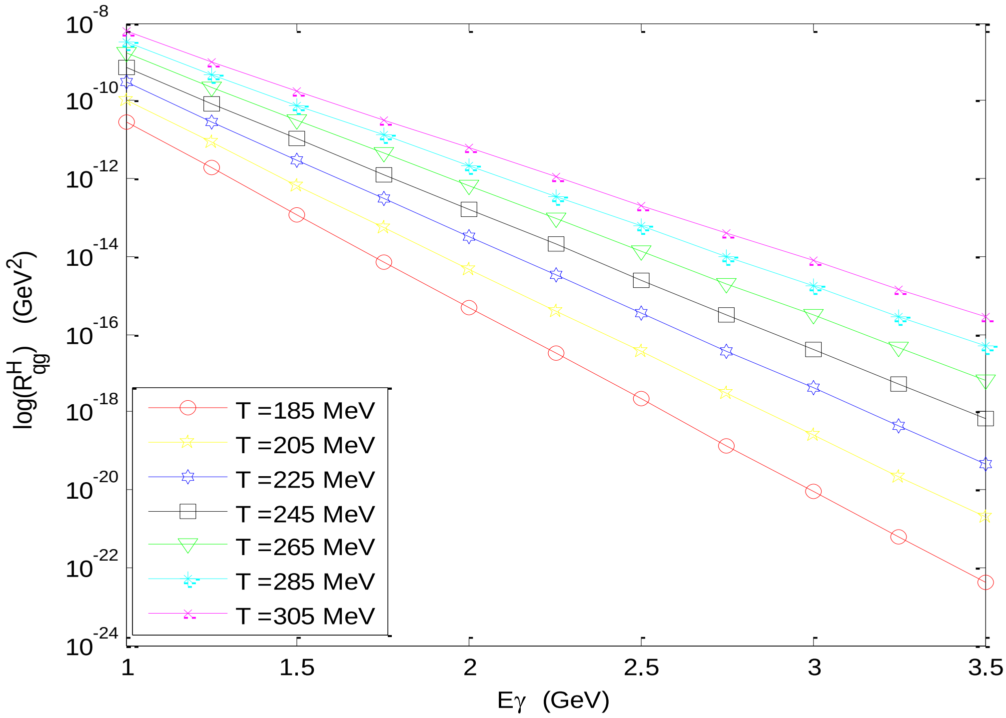

Figure 3. Rate of emission photons $R^{H}_{qg}(E,P)$ as function of $E_\gamma$at T_c=0.2040078893GeV for $cg \rightarrow d\gamma$ system.

4. Discussion

The rate of photon emission was calculated to understand the behavior of quarks. It is related to the energy of photons and chromodynamics constant which is affected by the critical temperature, thermal energy, and flavor number for $cg \rightarrow d\gamma$ system. The chromodynamics constant was calculated with the N_f=6 and different values of the critical temperature and thermal energy in Eq (21). It can be found that the chromodynamics constant decreases with increases of the thermal energy from 185MeV to 305MeV as we note from the results in **Table 2**, chromodynamics constant at T=185MeV isα_c=0.3703769235, 0.4202651765, 0.4529573937 for Tc=0.1311479288, 0.1748639051, 0.2040078893 GeV respectively. It decreases with the increase of the system temperature, where it reaches at T=305MeV to α_c=0.307036152, 0.3405480378, 0.3617020613. On the other side, the chromodynamics constant increases with the increase of the critical temperature as we can note for T=185MeV that α_c=0.3703769235 at T_C= 0.1311479288GeV and α_c= 0.4529573937at T_C= 0.2040078893GeV. The rate of photon emission $R_{qg}^{H}(E,P)$ was calculated using Eq (19) with the thermal energy in the range of (185MeV$\leq$ T $\leq$ 305MeV) and the energy of photons (1GeV$\leq$ E_γ $\leq$ 3.5GeV). The critical temperature was calculated using Eq (20). We can observe that the maximum value of photons rate at T= 305MeV and E_γ =1GeV where $R_{qg}^{H}(E,P)$=5.9445E-09$\frac{1}{GeV^2 fm^4}$at $\alpha_c =$ 0.3617 and T_C=0.2040078893 GeV. On the other hand the minimum value of photon emission rate at T= 185MeV and E_γ=3.5GeV where $R_{qg}^{H}(E,P)$ = 3.2818E-23$\frac{1}{GeV^2 fm^4}$ at α_c= 0.3704 and T_C=0.1311479288GeV. If a comparison can be made between the calculation values of **Table 3**, **Table 4**, and **Table 5**, one can find that the rate of photon emission for three tables is $R_{qg}^{H}(E,P)$ =2.4203E-11, 2.7463E-11, 2.9600E-11$\frac{1}{GeV^2 fm^4}$, respectively at T=185MeV and it increases with the increasing of the system temperature as it reaches to $R_{qg}^{H}(E,P)$ =5.0461E-09, 5.5969E-09, 5.9445E-09$\frac{1}{GeV^2 fm^4}$ at T=305MeV. In contrast, the above result of the photon emission rate shows that the photon is yield at T_C=0.1311479288GeV is less than the rate of photons yield at T_C= 0.2040078893GeV which mean the rate of photon emission increases with increasing the critical temperature. **Figure 1, Figure 2** and **Figure 3** demonstrate the relationship between the rate of photon emission $R_{qg}^{H}(E,P)$ and the energy of photons E_γ. We can note from figures that the photons rate decreases with the increasing of the energy of photons from 1GeV to 3.5GeV at various values of the critical temperatures and thermal energy, and the production of photons emitted at E_γ = 1GeV is faster compared to E_γ= 3.5GeV.

5. Conclusion

In conclusion, the emission rate of photons from the bremsstrahlung processes for a system $cg \rightarrow d\gamma$ system is calculated based on the quantum chromodynamics (QCD) theory using a flavor number, chromodynamics constant, critical temperature, system temperature, fugacity of quark and gluon and photon energy for the charm-gluon reaction. It was found that chromodynamics constant decreases with increases in system temperature from 185MeV to 305MeV and this affects the photon emission rate, which increases with decreases in chromodynamics constant as a result of deconfinement phenomena. On the other hand, the photon emission rate decreases with the increase in photon energy from 1GeV to 3.5GeV. The maximum value of photonic yield is obtained at the highest value of the critical temperature. Quantum chromodynamics is a good tool for calculating the photon rate of a quark-gluon interaction.

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Conflict of interest

The authors declare that they have no conflict of interest.

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References

1. Heilbron, J.L. The History Of Physics A Very Short Introduction. *Oxford University Press*. **2018**, *12*(*3*), 34-45.
2. Khana, M.P. Introduction to particle physics. *Book* 5^{th}*ed, PHI Learning Private Limited*. **2013**, *22*(*12*), 23-34.
3. Alattabi, H.D.; Shafik, S.S.; Kadhim, M.A. Secondary Emission Effect on Some Pre-Equilibrium Nuclear Reactions Spectra at Different Energies. *Iraqi Journal of Science Special Issue*. **2019**, *45*(*4*), 12-24. https://doi.org/10.1088/1742-6596%2F1178%2F1%2F012005.
4. Tarek, F. Introduction to history of elementary particles and their dynamics. *Oxford University Press*. **2019**, *23*(*2*), 45-56.
5. Das, A.; Ferbel, T. Introduction to Nuclear and Particle Physics. *University of Rochester*. **2005**, *23*(*12*), 45-67.
6. Shwiekh, A.M.; Hussein, S.M.; Al-Agealy, H.J.M.; Hassooni, M.A. Flow Production Rate of Hard Photons Probes of Quark- Anti Quark Annihilation Processes at Plasma Phase. *IOP Conf. Series: Materials Science and Engineering*. **2020,** *871*, 012089. https://doi.org/10.1088/1757-899X%2F871%2F1%2F012089.
7. Ahmed, E.M.; Al-Agealy, H.J.M.; Kadhim, N.F. Theoretical Calculation of Photon Emission from Quark-Antiquark Annihilation Using QCD Theory. *Ibn AL-Haitham Journal for Pure and Applied. Scieence*. **2022**, *35* (*4*), 46-65. https://doi.org/10.30526/35.4.2879.
8. Ridha, O.Z.; Shwiekh, A.M. Calculation of the Rate of Photons Emission from Charm-Gluon Interaction. *Journal of Kufa Physics*. **2023,** *15*(*1*), 66-76. http://dx.doi.org/10.31257/2018 /JKP/2023/v15.i01.11516.
9. Streeter, J.; Lull, D.J. God and the History of The Universe. *Wipf and Stock Puplishers*. **2016**. 233.
10. Al-Agealy, H.J.; Hussein, H.H.; Hussein, S.M. Theoretical estimation of Photons flow rate Production in quark-gluon interaction at high energies. *Journal of Physics: Conference Series. IOP Publishing*. **2018**, *1003*, 1, 012119. https://doi.org/10.1088/1742-6596%2F1003%2F1% 2F012119.
11. Mann, R. An Introduction to Particle Physics and The Standard Model. *Book 1st.CRC Press*. **2009**, *12*(*3*), 34-45. https://doi.org/10.1201/9781420083002.
12. Feynman, R.P. Photon-hadron Interactions (Frontiers in physics). *USA:W.A. Benjamin*. **1972**, 233. https://doi.org/10.1201/9780429493331.
13. Bali, G.S.; Schilling, K. Static Quark-Antiquark Potential: Scaling Behavior and Finite-Size Effects in SU(3) Lattice Gauge Theory. *Physical Review*. **1992**, *46*(*6*), 2636. https://doi.org /10.1103/PHYSREVD.46.2636.
14. Bengt, F.; Höhne, C.; Knoll, J.; Leupold, S.; Randrup, J.; Rapp, R.; Senger, P. *The CBM Physics Book: Compressed Baryonic Matter in Laboratory Experiments. Springer*. **2011**, *12*(*3*), 65-77.
15. Hauksson, S. Photon Emission in a N0n-Equilibrium Quark-Gluon Plasma. Msc thesis. *McGill University*. **2017**, *3*(*23*), 12-34. https://doi.org/10.1016/j.nuclphysa.2018.09.066.
16. Al-Agealy, H.J.; Ghadhban, R.Q.; Hassooni, M.A.; Theoretical Study of the Photons Production Kinetic In Hot Quark-Gluon Plasma Matter. *Ibn AL-Haitham Journal for Pure and Applied. Scieence*. **2020,** *33*(*4*), 45-56. https://doi.org/10.23851/mjs.v33i4.1193.
17. Hussein, S.M.; Al-Agealy, H.J.; Al-Rubaiee, A.A.; Theoretical Analysis of The Photon Production Rate in The Quark-Gluon Interaction According to The Quantum Chromodynamic QCD Theory. *Ibn AL-Haitham Jour. Pure Appl. Sci.* **2023**, *36*(*3*), 66-76. https://doi.org/10. 1088/1742-6596%2F1003%2F1%2F012119.
18. Aurenche, P.; Gelis, F.; Kobes, R.; Zaraket, H. Bremsstrahlung and Photon Production in Thermal QCD. *Physical Review D*. **1998**, *58*, 085003. https://doi.org/10.1103/PhysRevD.58.085003.

19. Peskin, M.E. Introduction To Quantum Field Theory. *Perseus Books Publishing L.L.C.* **1995,** 231. https://doi.org/10.1201/9780429503559.
20. Sastry, D.D.; Kumar, K.; Choudhury, R. K. Nuclear Physics. *Appl. Phys*. **2000**, *710*(*15*), 3-14. https://doi.org/10.1016/j.cmpb.2022.107156.
21. Long, J.L.; He, Z.J.; Ma, Y.G.; Liu, B. Hard Photon Production from a Chemically Equilibrating Quark-Gluon Plasma with Finite Baryon Density at One Loop and Two Loop. *Physical Review C*. **2005**, *72*, 64907.
22. Ahmed, E.M.; Al-Agealy, H.J.; Kadhim, N.F. Study of Photons Emission Rate of Quark-Antiquark at Higher Energy. *Al-Mustansiriyah Journal of Science.* **2022**, *33*(*4*), 2521-3520. https://doi.org/10.23851/mjs.v33i4.1193.
23. Noel, C.W.; Greenwood, D.A. An introduction to the standard model of particle physics. *Cambridge University Press*. **2007**, *23*(*4*), 56-67. https://doi.org/10.1017/9781009401685.
24. Biro, T.S. Parton Equilibration in Relativistic Heavy Ion Collisions. *Physical Review C*. **1993**, *48*, 1275. https://doi.org/10.1103/PhysRevC.48.1275.
25. Gross, D.J.; Wilczek, F. Ultraviolet Behavior of Non-Abelian Gauge Theories. *Physical Review Letters.* **1973**, *30(26)*, 1343. https://doi.org/10.1103/PHYSREVLETT.30.1343.
26. Al-Agealy, H.J.; Sahib, M.J. Theoretical Evaluations of Probability of Photons Yield Depending on Quantum Chromodynamics Theory. *Ibn AL-Haitham Journal for Pure and Applied. Scieence*. Special Issue **2017**, 179-186. http://dx.doi.org/10.30526/2017.IHSCICONF.1790.
27. Jacobs, P.; Wang, X.N. Matter in Extremis: ultrarelativistic nuclear collisions at RHIC. *Progress in Particle and Nuclear Physics*. **2005**, *54*(*2*), 443-534. https://doi.org/10.1016/j.ppnp.2004.09.001.
28. Younis, T.A.; Al-Agealy, H.J. Study and Investigation of Hard Photons Emission in Heavy Ion Collisions. *NeuroQuantology*. **2021**, *19*(*2*), 45-56. https://doi.org/10.14704/NQ.2021.19.2. NQ21018.
29. Bkmurd, R.I.; Al-Agealy, H.J.; Shwiekh, A.M. Study and Evaluation the Photonic Emission Rate at Quark Gluon plasma From Compton and Bremsstrahlung Process Solid State Technology. *Solid State Technology*. **2020**, *63*(*6*), 156569-16579.
30. Ahmed, E.M.; Al-Agealy, H.J.; Kadhim, N.F. Theoretical Study of Photons Spectra around High Energy of Quark-antiquark Using QCD Theory**.** *NeuroQuantology*. **2022**, *20*(*4*), 58-63. http://dx.doi.org/10.14704/nq.2022.20.4.NQ22095.