



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

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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  $cg \rightarrow d\gamma$  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  $185\text{MeV} \leq T \leq 305\text{MeV}$ , and critical temperature  $T_C = 0.1311479288\text{GeV}$ ,  $0.1748639051\text{ GeV}$ ,  $0.2040078893\text{GeV}$ . It was considered the energy of photons in the range  $1\text{GeV} \leq E \leq 3.5\text{GeV}$ . Furthermore, the values of the fugacity of quark  $\lambda_q = 0.068$  and gluon  $\lambda_g = 1$ . We found that the photonic yield at  $T_C = 0.2040078893\text{GeV}$  was greater than the photonic yield at  $T_C = 0.1311479288$  and  $0.1748639051\text{ GeV}$ . 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].



Charm (C) is a quark flavor that was invented to explain the big narrowness of the huge resonances ( $\psi$ ) during observation of the meson  $J/\psi$  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].

$$R_{qg}^H(E, P) = - \frac{F_G(E)}{(2\pi)^3} \text{Im} \prod_i^f(E, P) \quad (1)$$

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

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

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

$$C_{ca} = \frac{N_c^2 - 1}{2N_c} \quad (3)$$

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  $\sum_q \left(\frac{e_q}{e}\right)^2$  into the system, Equation (2) is reduced to:

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

Integration of self-energy [20]

$$|I_{tl}| = |I_t - I_l| \quad (5)$$

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

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

The juttner distribution function for quarks is [21]

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

And

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

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

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

The solution to the integral term is:

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

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

$$\text{Im}[\Pi_i^f(E,P)] = \left(\frac{4}{\pi^4}\right) g_E^2 g_C^2 \frac{T}{E_Y^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_1| [\lambda_Q T(1 - e^{-\frac{E_Y}{T}}) (2T^2\Gamma(3) + 2ET\Gamma(2) + E^2\Gamma(1))] \quad (11)$$

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:

$$\text{Im}[\Pi_i^f(E,P)] = \left(\frac{64}{\pi^2}\right) \alpha_E \alpha_C \frac{T^2}{E_Y^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_1| [\lambda_Q (1 - e^{-\frac{E_Y}{T}}) (2T^2\Gamma(3) + 2ET\Gamma(2) + E^2\Gamma(1))] \quad (14)$$

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

$$R_{qg}^H(E,P) = \frac{F_G(E)}{(2\pi)^3} \left(\frac{64}{\pi^2}\right) \alpha_E \alpha_C \frac{T^2}{E_Y^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_1| [\lambda_Q (1 - e^{-\frac{E_Y}{T}}) (2T^2\Gamma(3) + 2ET\Gamma(2) + E^2\Gamma(1))] \quad (15)$$

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

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

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

$$R_{qg}^H(E,P) = \frac{8}{\pi^5} \alpha_E \alpha_C \frac{T^2}{E_Y^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_1| \lambda_Q \lambda_G e^{-\frac{E_Y}{T}} (e^{-\frac{E_Y}{T}} - 1) (2T^2\Gamma(3) + 2ET\Gamma(2) + E^2\Gamma(1)) \quad (17)$$

For  $E_Y \geq T$ , then

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

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

$$R_{qg}^H(E,P) = \frac{8}{\pi^5} \alpha_E \alpha_C \frac{T^2}{E_Y^2} \sum_q \left(\frac{e_q}{e}\right)^2 |I_t - I_1| \lambda_Q \lambda_G e^{-\frac{2E_Y}{T}} (2T^2\Gamma(3) + 2ET\Gamma(2) + E^2\Gamma(1)) \quad (19)$$

The critical temperature is [25]

$$T_C = \left[ \frac{90B}{\pi^2(N_S \times N_C) + \frac{7}{4}(n_c \times n_s \times n_f)} \right]^{3/4} \quad (20)$$

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  $B^{1/4} = 225, 300, \text{ and } 350 \text{ MeV}$  [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

$B^{1/4}(\text{GeV})$	Critical temperature $T_c(\text{GeV})$
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 **Table 1**, and the system temperature in the limit (185-305MeV) and  $N_f = 6$ . The result of strength coupling is listed in **Table 2**.

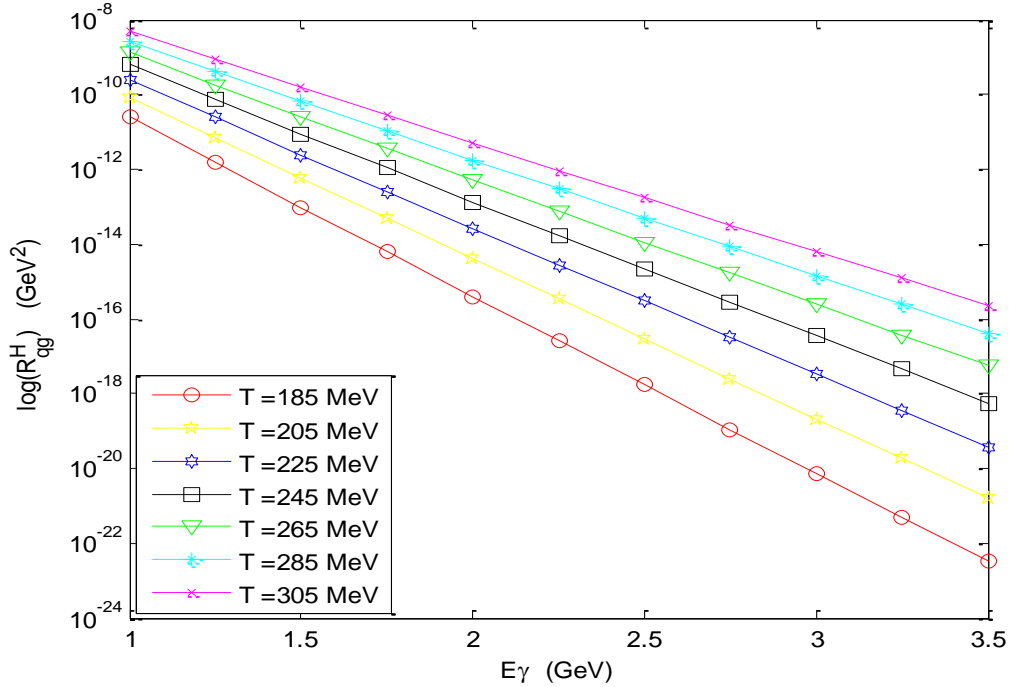
**Table 2.** Critical result of strength coupling for  $cg \rightarrow d\gamma$  system.

T (GeV)	Chromodynamics constant $\alpha_c$		
	$T_c = 0.1311479288$	$T_c = 0.1748639051$	$T_c = 0.2040078893$
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  $\alpha_E = 1/137$  and the self-integral constant  $I_t = 4.45, I_l = -4.26$  [28], supposing that the fugacity  $\lambda_Q = 0.068, \lambda_G = 1$  [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  $R_{qg}^H(E, P)$  at  $T_c = 0.1311479288 \text{ GeV}$  for  $cg \rightarrow d\gamma$  system with  $N_f = 6$  and  $\lambda_Q = 0.068$ ,  $\lambda_g = 1$

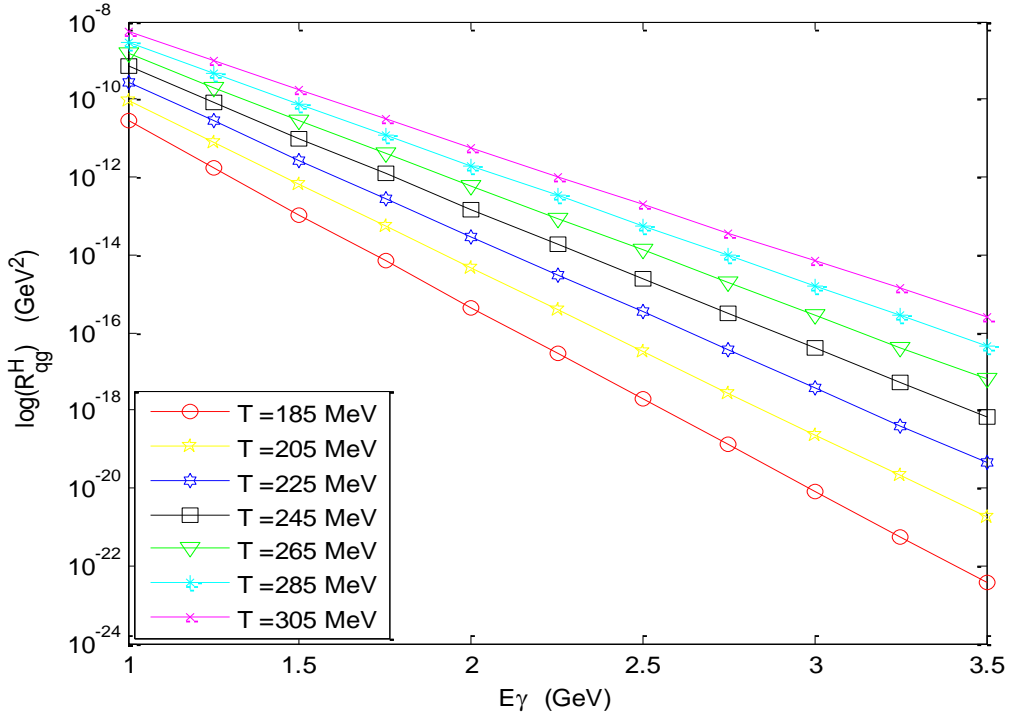
$E_\gamma$ GeV	$R_{qg}^H(E, P) \frac{1}{\text{GeV}^2 \text{fm}^4}$						
	T=185 MeV $\alpha_c = 0.3704$	T=205 MeV $\alpha_c = 0.3553$	T=225 MeV $\alpha_c = 0.3427$	T=245 MeV $\alpha_c = 0.3319$	T=265 MeV $\alpha_c = 0.3225$	T=285 MeV $\alpha_c = 0.3143$	T=305 MeV $\alpha_c = 0.3070$
1	2.4203E-11	8.5728E-11	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  $R_{qg}^H(E, P)$  as function of  $E_\gamma$  at  $T_c = 0.1311479288 \text{ GeV}$  for  $cg \rightarrow d\gamma$  system.

**Table 4.** Rate of emission photons  $R_{qg}^H(E, P)$  at  $T_c=0.1748639051\text{GeV}$  for  $cg \rightarrow d\gamma$  system with  $N_f=6$  and  $\lambda_Q=0.068, \lambda_g=1$ .

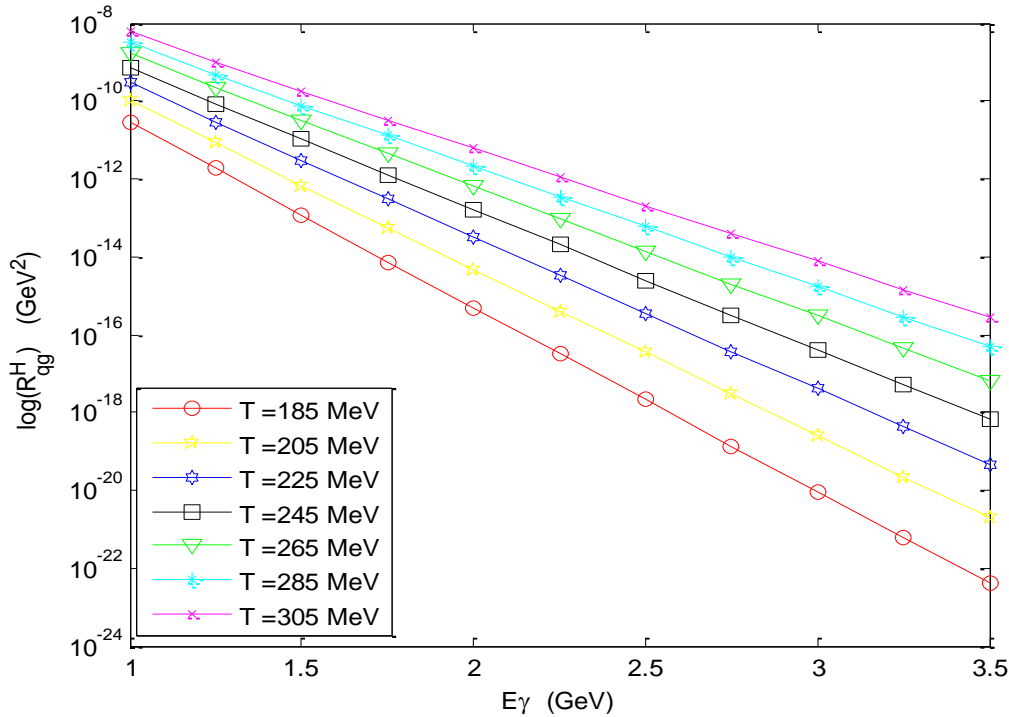
$E_\gamma$ GeV	$R_{qg}^H(E, P) \frac{1}{\text{GeV}^2 \text{fm}^4}$						
	T=185 MeV	T=205 MeV	T=225 MeV	T=245 MeV	T=265 MeV	T=285 MeV	T=305 MeV
	$\alpha_c = 0.4203$	$\alpha_c = 0.4010$	$\alpha_c = 0.3850$	$\alpha_c = 0.3714$	$\alpha_c = 0.3597$	$\alpha_c = 0.3495$	$\alpha_c = 0.3405$
1	2.7463E-11	9.6746E-11	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  $R_{qg}^H(E, P)$  as function of  $E_\gamma$  at  $T_c=0.1748639051\text{GeV}$  for  $cg \rightarrow d\gamma$  system.

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

$E_\gamma$ GeV	$R_{qg}^H(E, P) \frac{1}{\text{GeV}^2 \text{fm}^4}$						
	T=185 MeV	T=205 MeV	T=225 MeV	T=245 MeV	T=265 MeV	T=285 MeV	T=305 MeV
	$\alpha_c$ = 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  $R_{qg}^H(E, P)$  as function of  $E_\gamma$  at  $T_c = 0.2040078893 \text{ GeV}$  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 185 MeV to 305 MeV as we note from the results in **Table 2**, chromodynamics constant at  $T = 185 \text{ MeV}$  is  $\alpha_c = 0.3703769235, 0.4202651765, 0.4529573937$  for  $T_c = 0.1311479288, 0.1748639051, 0.2040078893 \text{ GeV}$  respectively. It decreases with the increase

of the system temperature, where it reaches at  $T=305\text{MeV}$  to  $\alpha_c=0.307036152, 0.3405480378, 0.3617020613$ . On the other side, the chromodynamics constant increases with the increase of the critical temperature as we can note for  $T=185\text{MeV}$  that  $\alpha_c=0.3703769235$  at  $T_c=0.1311479288\text{GeV}$  and  $\alpha_c=0.4529573937$  at  $T_c=0.2040078893\text{GeV}$ . The rate of photon emission  $R_{\text{qg}}^{\text{H}}(E, P)$  was calculated using Eq (19) with the thermal energy in the range of ( $185\text{MeV} \leq T \leq 305\text{MeV}$ ) and the energy of photons ( $1\text{GeV} \leq E_{\gamma} \leq 3.5\text{GeV}$ ). The critical temperature was calculated using Eq (20). We can observe that the maximum value of photons rate at  $T=305\text{MeV}$  and  $E_{\gamma}=1\text{GeV}$  where  $R_{\text{qg}}^{\text{H}}(E, P)=5.9445\text{E-}09 \frac{1}{\text{GeV}^2\text{fm}^4}$  at  $\alpha_c = 0.3617$  and  $T_c=0.2040078893 \text{ GeV}$ . On the other hand the minimum value of photon emission rate at  $T=185\text{MeV}$  and  $E_{\gamma}=3.5\text{GeV}$  where  $R_{\text{qg}}^{\text{H}}(E, P) = 3.2818\text{E-}23 \frac{1}{\text{GeV}^2\text{fm}^4}$  at  $\alpha_c = 0.3704$  and  $T_c=0.1311479288\text{GeV}$ . 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  $R_{\text{qg}}^{\text{H}}(E, P) = 2.4203\text{E-}11, 2.7463\text{E-}11, 2.9600\text{E-}11 \frac{1}{\text{GeV}^2\text{fm}^4}$ , respectively at  $T=185\text{MeV}$  and it increases with the increasing of the system temperature as it reaches to  $R_{\text{qg}}^{\text{H}}(E, P) = 5.0461\text{E-}09, 5.5969\text{E-}09, 5.9445\text{E-}09 \frac{1}{\text{GeV}^2\text{fm}^4}$  at  $T=305\text{MeV}$ . In contrast, the above result of the photon emission rate shows that the photon is yield at  $T_c=0.1311479288\text{GeV}$  is less than the rate of photons yield at  $T_c=0.2040078893\text{GeV}$  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  $R_{\text{qg}}^{\text{H}}(E, P)$  and the energy of photons  $E_{\gamma}$ . We can note from figures that the photons rate decreases with the increasing of the energy of photons from  $1\text{GeV}$  to  $3.5\text{GeV}$  at various values of the critical temperatures and thermal energy, and the production of photons emitted at  $E_{\gamma} = 1\text{GeV}$  is faster compared to  $E_{\gamma} = 3.5\text{GeV}$ .

## 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  $185\text{MeV}$  to  $305\text{MeV}$  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  $1\text{GeV}$  to  $3.5\text{GeV}$ . 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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