JOURNAL OF KUFA−PHYSICS
journal.uokufa.edu.iq/index.php/jkp/index | ISSN: 2077−5830

Calculation of the Rate of Photons Emission from Charm-Gluon Interaction

*** Ola Z. Ridha** **Ahmed M. Shweikh**

Department of physics, College of Education for pure Science (Ibn-Al-Haitham),University of Baghdad, Baghdad, Iraq .

*Corresponding Author E-mail: ula.Reda2104m@ihcoedu.uobaghdad.edu.iq

ARTICLE INF

Article history:
Received: 14 MAR, 2023
Revised: 14 APR, 2023
Accepted: 26 APR, 2023
Available Online: 05 JUN, 2023

Keywords:

Photons emission
strength coupling
quark-gluon interaction
quantum chromodynamics theory

ABSTRACT

In this research, the rate of photons emission from quark-gluon interaction based on the quantum chromodynamics theory was calculated. The rate of photons emission was evaluated for $cg \rightarrow d\gamma$ system due to essential parameters, include the strength coupling constant, system temperature and critical temperature. The photons emission from charm interaction with gluon affected strongly with increasing or decreasing of the coupling strength. The effect of critical temperature on the rate of photons emission which is small at critical temperature T_c =0.160291913GeV when compared with the rate of photons emission at T_c=0.1894358972GeV was investigated. The effect of the energy of system in the limit of $1 \leq E_\gamma \leq 3.5$GeV on the photons emission rate was discussed and, we found that it decrease with increase of the photon energy. On the contrary, the rate of emission photon was increased with increasing of system temperature from 185 to 305MeV.

DOI: https://doi.org/10.31257/2018/JKP/2023/v15.i01.11516

حساب معدل انبعاث الفوتونات من تفاعل الساحر-الجلون

علا زياد رضا **احمد موسى اشويخ**

قسم الفيزياء ، كلية التربية للعلوم الصرفة (ابن الهيثم)، جامعة بغداد ،بغداد، العراق

الكلمات المفتاحية:

انبعاث الفوتونات
اقتران القوة
تفاعل كوارك-جلون
نظرية الديناميكية اللونية الكمية

الـــخُـــلاصـــة

في هذا البحث، نحسب معدل انبعاث الفوتونات من تفاعل كوارك-جلون اعتمادا على نظرية الديناميكية اللونية الكمية. معدل انبعاث الفوتونات قدر من نظام $cg \rightarrow d\gamma$بسبب معلمات اساسية ، تشمل ثابت اقتران القوة ، درجة حرارة النظام ، درجة الحرارة الحرجة . انبعاث الفوتونات من تفاعل الكوارك الساحر مع الجلون يتأثر بقوة مع زيادة او نقصان قوة الاقتران . تحققنا في تأثير درجة الحرارة الحرجة على معدل انبعاث الفوتونات والذي يكون صغير عند الدرجة الحرجة T_c =0.160291913GeV مقارنة مع معدل انبعاث الفوتونات

عند الدرجة الحرجة $T_c=0.1894358972GeV$. تم مناقشة تـأثير طاقـة النظـام علـى معدل انبعـاث الفوتونـات بمـدى ١≤ $E_\gamma \leq 3.5GeV$ ووجـد انهـا تتنـاقص مـع زيـادة طاقـة الفوتـون. وبالمقابـل فـأن معـدل انبعـاث الفوتـون يـزداد مـع زيـادة درجـة حـرارة النظـام مـن ١٨٥ الى ٣٠٥ MeV .

1. INTRODUCTION

Elementary particles physics is one of most important branches of physics [1]. Elementary particles are defined as the particles do not broken up into smaller pieces [2]. It is classified according to standard model into fermions and bosons [3]. The basic component of matter is the quark, which is a hypothetical particle hypothesized by the two scientists George Zweig and Gell-Mann [4]. There are six quarks increasing in mass, distributed over three generations, in addition to the antiquarks, all these quarks interacted with fundamental forces and the only one who interacted with the strong force through the exchange of gluons [5]. The color charge is property of quark and gluon and through which strong interactions take place. There are three kind of color charge red, blue, and green. The rule that allows quarks to combine to form hadrons is that they are color neutral. There are eight gluons which represent a pair of colors and anti-colors [6][7]. The theory that depicts the strong interactions is quantum chromodynamics theory (QCD) [8]. Charm (C) is a quark flavor was invented to explain the big narrowness of the huge resonances (ψ) during observation of meson J/ψ resonance produced by electron and antielectron annihilation [9]. Photon is a massless elementary particle in the form of electromagnetic radiation. Photons are produced in heavy ions 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 temperature and high density are confinement and deconfinement [10][11]. Direct photons can be produced in the quark-gluon plasma phase through interactions $q + q \rightarrow g + \gamma$ or $q + g \rightarrow q + \gamma$ while in the hadron gas phase, bremsstrahlung photons can be produced through the scattering of mesons or baryons[12], and they can also be produced in the quark-gluon plasma phase through the elastic scattering of a quark - quark or a quark - gluon But it is dominated by direct photon production interactions, and the condition for the emission of bremsstrahlung photons is the availability of a particle with an electric charge [13].

2. THEORY

The photons emission from quark-gluon interaction given by [14].

$$R^{H}_{qg}(E,P) = -\frac{1}{8\pi^3} F_G(E) \operatorname{Im}\prod{}^{f}_{i}(E,P) \cdots\cdots\cdots\cdots (1)$$

Where $F_G(E)$ is distribution function of gluons which is given by [15].

$$F_G(E) = \frac{1}{\frac{e^{E/T}}{\lambda_G}-1} \cdots\cdots\cdots\cdots (2)$$

Where λ_G is fugacity of gluons, the propagation of self-energy $\operatorname{Im}\prod{}^{f}_{i}$ (E,P) for photons emission from the interaction of quarks with gluons is [16]

$$\operatorname{Im}\prod{}^{f}_{i}(E,P) = \left(\frac{N}{\pi^4} C_{ca}\right) g_E^2 \; g_c^2 \; \frac{T}{E_\gamma^2} \int_0^\infty |I_{tl}| \, [F_a(P) - F_q(E+P)] \, [P^2 + (P+E)^2] \, dp \;\cdots (3)$$

Where N is degeneracy factor $N \approx 3$, C_{ca} is casimir factor which is given by[17]

$$C_{ca} = \frac{N_c^2-1}{2N_c} \cdots\cdots\cdots\cdots (4)$$

Where N_c is the number of quarks $N_c = 3$, inserting Eq(4) in Eq (3) and substitute the value of degeneracy facture and the number of quarks and simply reduced to

$$\mathrm{Im}\prod{}_{i}^{f}(E,P) = \frac{4}{\pi^4} g_E^2\ g_c^2\ \frac{T}{E_\gamma^2}\int_0^\infty |I_{tl}|\ [F_a(P) - F_q(E+P)]\ [P^2 + 2EP + E^2]\,dP \cdots (5)$$

The strength of electrodynamics is [18].

$$g_E^2 = 4\pi\alpha_E \cdots\cdots\cdots\cdots (6)$$

The quantum chromodynamics coupling is [19].

$$g_c^2 = 4\pi\alpha_c \cdots\cdots\cdots\cdots (7)$$

The integral self-energy is [20]

$$|I_{tl}| = |I_t\text{-}I_l| \cdots\cdots\cdots\cdots (8)$$

Where I_t and I_l are dimensionless constant, inserting the Eq(6),(7),(8) in Eq (5)and introduce the total electric charge for quarks in system$\sum_q(\frac{e_q}{e})^2$, Eq (5) is reduced to

$$\mathrm{Im}\prod{}_{i}^{f}(E,P) = \frac{64}{\pi^2}\ \alpha_E\alpha_c\ \frac{T}{E_\gamma^2}\ |I_t\text{-}I_l|\ \sum_q(\frac{e_q}{e})^2 \int_0^\infty [F_a(P) - F_q(E+P)]\,[P^2 + 2EP + E^2]dP \ldots(9)$$

The juttner distribution function for quarks is [21]

$$F_a(P) = \frac{\lambda_Q}{e^{P/T}+\lambda_Q} \cdots\cdots\cdots\cdots (10)$$

And

$$F_q(E+P) = \frac{\lambda_Q}{e^{(P+E)/T}+\lambda_Q} \cdots\cdots\cdots\cdots (11)$$

Where λ_Q is the fugacity function of quark, inserting Eq(10),(11) in Eq(9) which reduced it to

$$\mathrm{Im}\prod{}_{i}^{f}(E,P) = \frac{64}{\pi^2}\ \alpha_E\alpha_c\ \frac{T}{E_\gamma^2}|I_t - I_l|\sum_q(\frac{e_q}{e})^2 \int_0^\infty \frac{\lambda_Q(2P^2 + 2PE + E^2)}{e^{P/T}+\lambda_Q}dP - \int_0^\infty \frac{\lambda_Q(2P^2 + 2PE + E^2)}{e^{(P+E)/T}+\lambda_Q}dP \ldots(12)$$

The solve of the integral term is

$$\int_0^\infty \frac{\lambda_Q(2P^2 + 2PE + E^2)}{e^{P/T}+\lambda_Q}dP - \int_0^\infty \frac{\lambda_Q(2P^2 + 2PE + E^2)}{e^{(P+E)/T}+\lambda_Q}dP = \lambda_Q T - \lambda_Q T e^{-E/T}[2T^2\Gamma(3) + 2ET\,\Gamma(2) + E^2\Gamma(1)]\ldots(13)$$

Inserting Eq(13) in Eq(12) and simply reduced to

$$\mathrm{Im}\prod{}_{i}^{f}(E,P) = \frac{64}{\pi^2}\ \alpha_E\alpha_c\ \frac{T}{E_\gamma^2}|I_t - I_l|\sum_q(\frac{e_q}{e})^2 [\lambda_Q\ T(1\text{-}e^{-E/T})(\ 2T^2\Gamma(3) + 2ET\,\Gamma(2) + E^2\Gamma(1))]\ldots(14)$$

At E≫T, the distribution of gluons $F_G(E)$ in Eq(2) reduced to

$$F_G(E) = \lambda_G\ e^{-E/T} \ldots\ldots(15)$$

Inserting Eq (15) ,(14) in Eq (1) can be reduced to

$$R_{qg}^H(E,P) = -\frac{1}{8\pi^3}\ (\frac{64}{\pi^2})\ \alpha_E\alpha_c\ \frac{T^2}{E_\gamma^2}|I_t - I_l|\sum_q(\frac{e_q}{e})^2\ \lambda_Q\ \lambda_G e^{-E/T}(1\text{-}e^{-E/T})\ (\ 2T^2\Gamma(3) + 2ET\,\Gamma(2) + E^2\Gamma(1))\ldots(16)$$

And by multiplying Eq(16) by (-1) and simply reduced to

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

For E≫T, $e^{-E/T} - 1 = e^{-E/T}$…….(18)

Then Eq(18) together with Eq(17) reduced to

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

The strength coupling is given by [22].

$$\alpha_c = \frac{6\pi}{(33-2N_f)\ln\frac{8T}{T_C}} \cdots\cdots\cdots\cdots (20)$$

Where T is the temperature of system, T_C is the critical temperature and N_f is the flavor number. The critical temperature is given by [23].

$$T_C = \left[\frac{90B}{\pi^2(N_S \times N_C) + \frac{7}{4}(n_c \times n_s \times n_f)}\right]^{1/4} \cdots\cdots\cdots (21)$$

Where $B^{1/4}$ is the Bag constant.

3. RESULT AND DISCUSSION

The rate of photons produced in quark-gluon interaction at high energies created in relativistic heavy ions collisions (RHIC) was studied and evaluated theoretically. We estimated the critical temperature according to the Bag constant in Eq(21) with $B^{1/4}$=0.275, 0.325GeV 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 results of critical temperatures can be shown in Table.1

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

$B^{1/4}$(GeV)	T_c(GeV)
0.275	0.160291913
0.325	0.1894358972

The strength coupling between charm quarks with gluon was calculated using Eq(20) with T_c in Table1, and system temperature in limit(185-305MeV) and N_f=6. The result of strength coupling is listed in Table 2.

The rate of photons 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 results was 5/9e. The flavor number N_f=6 for the system, it was calculated from the summation of $N_{f_i} = \sum_{i=1}^{6} N_{f_i}$ for charm and down quarks and with inserting $\propto_E$ = 1/137 and the self-integral constant I_t=4.45,I_l=-4.26 [24] , supposing that the fugacity λ_Q=0.068, λ_G=1[25] in Eq(19) with taking the values of critical temperature from Table1, and the values of strength coupling from Table 2 with photon energy in rang (1-3.5GeV). The resulted data are given in Table (3),(4) with Figures(1),(2)

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

T (GeV)	Coupling strength α_c	
	T_c=0.160291913	T_c= 0.1894358972
0.185	0.4038139262	0.4366286532
0.205	0.3859880906	0.4158624709
0.225	0.3711313111	0.3986681721
0.245	0.3585081177	0.3841389437
0.265	0.3476131498	0.3716575784
0.285	0.3380866955	0.3607882578
0.305	0.329665114	0.3512137494

Table 3. Rate of emission photons $R^H_{qg}(E,P)$ at Tc=0.160291913GeV 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
	$\alpha_{QCD} = 0.4038$	$\alpha_{QCD} = 0.3860$	$\alpha_{QCD} = 0.3711$	$\alpha_{QCD} = 0.3585$	$\alpha_{QCD} = 0.3476$	$\alpha_{QCD} = 0.3381$	$\alpha_{QCD} = 0.3297$
1	2.6388E-11	9.3126E-11	2.6885E-10	6.6606E-10	1.4644E-09	2.9275E-09	5.4180E-09
1.25	1.6239E-12	7.3911E-12	2.6263E-11	7.7312E-11	1.9656E-10	4.4476E-10	9.1587E-10
1.5	1.0286E-13	6.0552E-13	2.6558E-12	9.3148E-12	2.7457E-11	7.0497E-11	1.6191E-10
1.75	6.6230E-15	5.0522E-14	2.7398E-13	1.1469E-12	3.9259E-12	1.1456E-11	2.9389E-11
2	4.3086E-16	4.2638E-15	2.8622E-14	1.4315E-13	5.6968E-13	1.8913E-12	5.4250E-12
2.25	2.8221E-17	3.6257E-16	3.0151E-15	1.8031E-14	8.3482E-14	3.1555E-13	1.0128E-12
2.5	1.8572E-18	3.0994E-17	3.1947E-16	2.2857E-15	1.2318E-14	5.3039E-14	1.9058E-13

2.75	1.2264E-19	2.6597E-18	3.3992E-17	2.9107E-16	1.8267E-15	8.9632E-15	3.6071E-14
3	8.1194E-21	2.2888E-19	3.6282E-18	3.7194E-17	2.7190E-16	1.5208E-15	6.8566E-15
3.25	5.3858E-22	1.9739E-20	3.8820E-19	4.7653E-18	4.0587E-17	2.5884E-16	1.3076E-15
3.5	3.5780E-23	1.7053E-21	4.1613E-20	6.1179E-19	6.0720E-18	4.4160E-17	2.5003E-16

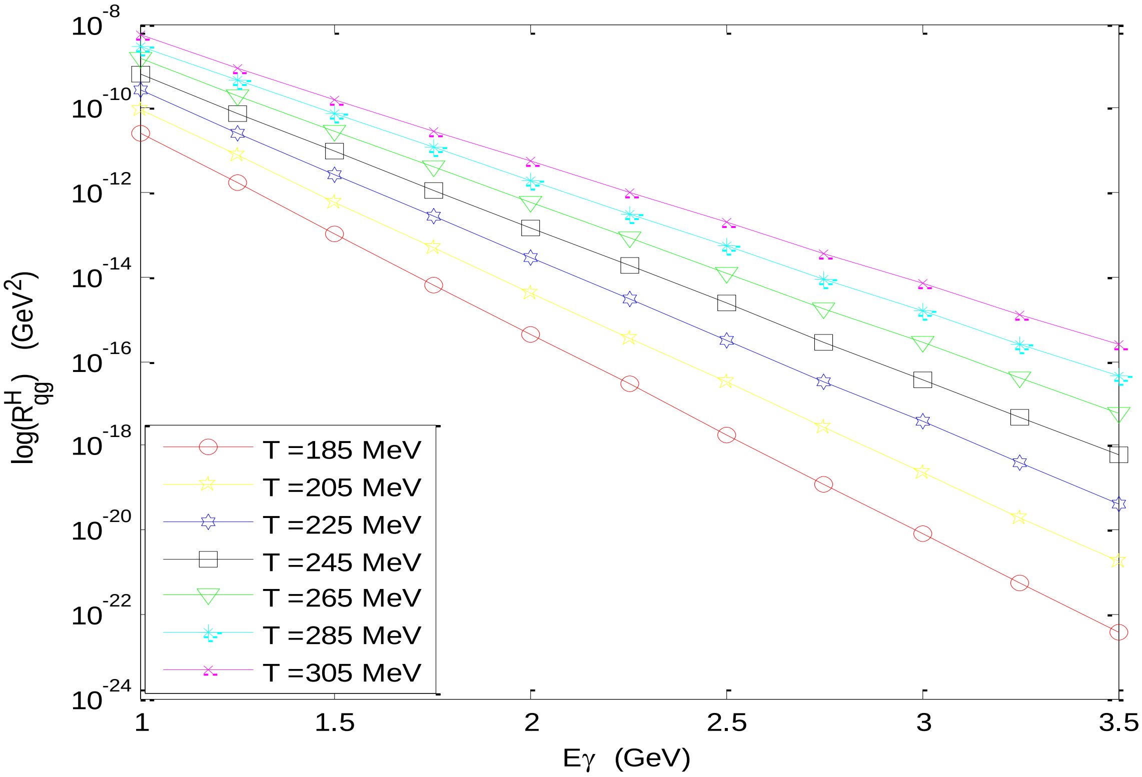

Figure 1. Rate of emission photons $R^{H}_{qg}(E,P)$ as function of E_{γ}at Tc= 0.160291913GeV for $cg \rightarrow d\gamma$ system.

Table 4. Rate of emission photons $R^{H}_{qg}(E,P)$ at Tc=0.1894358972GeV 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
	$\alpha_{QCD} = 0.4366$	$\alpha_{QCD} = 0.4159$	$\alpha_{QCD} = 0.3987$	$\alpha_{QCD} = 0.3841$	$\alpha_{QCD} = 0.3717$	$\alpha_{QCD} = 0.3608$	$\alpha_{QCD} = 0.3512$
1	2.8532E-11	1.0033E-10	2.8880E-10	7.1368E-10	1.5657E-09	3.1241E-09	5.7722E-09
1.25	1.7559E-12	7.9632E-12	2.8212E-11	8.2839E-11	2.1015E-10	4.7463E-10	9.7574E-10
1.5	1.1121E-13	6.5239E-13	2.8528E-12	9.9808E-12	2.9356E-11	7.5231E-11	1.7249E-10
1.75	7.1612E-15	5.4433E-14	2.9431E-13	1.2289E-12	4.1975E-12	1.2225E-11	3.1310E-11
2	4.6587E-16	4.5938E-15	3.0746E-14	1.5339E-13	6.0908E-13	2.0183E-12	5.7796E-12
2.25	3.0514E-17	3.9063E-16	3.2388E-15	1.9321E-14	8.9256E-14	3.3674E-13	1.0790E-12
2.5	2.0081E-18	3.3393E-17	3.4317E-16	2.4491E-15	1.3170E-14	5.6600E-14	2.0304E-13
2.75	1.3261E-19	2.8655E-18	3.6514E-17	3.1188E-16	1.9530E-15	9.5650E-15	3.8429E-14

3	8.7792E-21	2.4660E-19	3.8974E-18	3.9853E-17	2.9070E-16	1.6229E-15	7.3047E-15
3.25	5.8235E-22	2.1267E-20	4.1700E-19	5.1060E-18	4.3394E-17	2.7622E-16	1.3931E-15
3.5	3.8688E-23	1.8373E-21	4.4700E-20	6.5553E-19	6.4920E-18	4.7125E-17	2.6638E-16

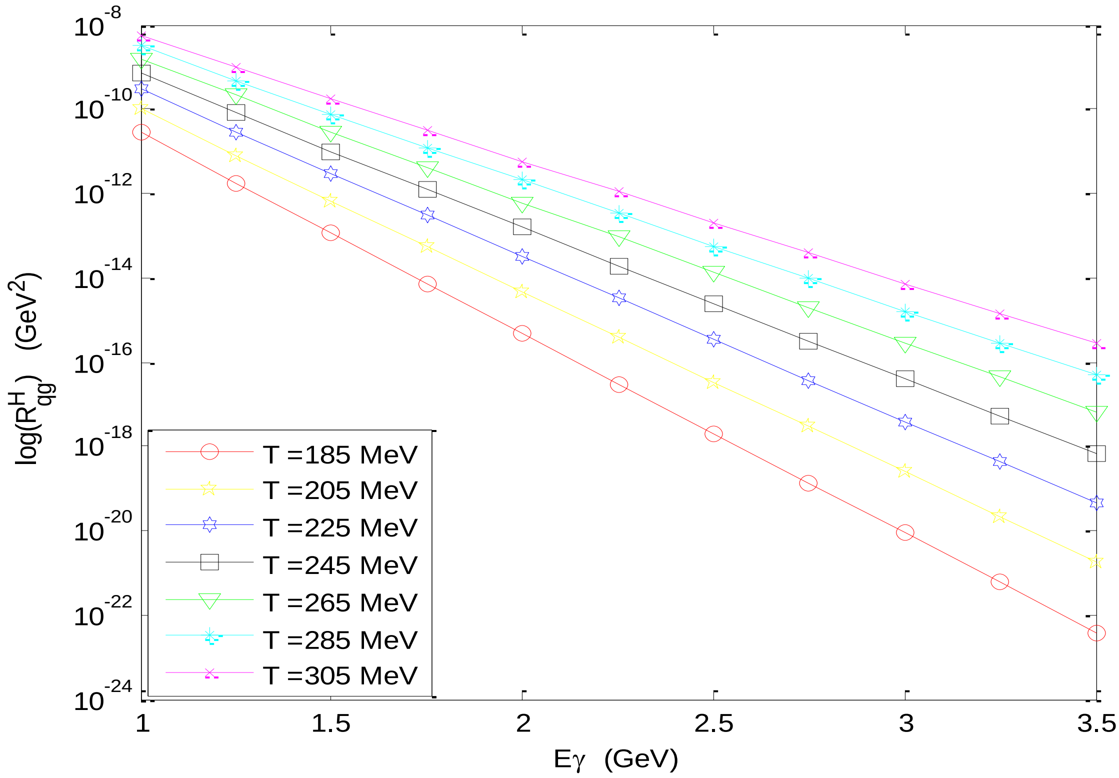

Figure 2. Rate of emission photons $R^H_{qg}(E,P)$ as function of $E_\gamma$at T_c= 0.1894358972GeV for $cg \to d\gamma$ system

The rate of photons emission was calculated and studied to understand the mechanism of quark system. The rate of photons emission $R^H_{qg}(E,P)$ in Eq (19) is related to energy of photons E_γ and coupling strength α_c which was affected by the critical temperature Tc, system temperature T and flavor number N_f of charm-gluon interaction. From **Table 2**, the coupling strength was calculated with the N_f=6 and various critical temperatures and the system temperatures in Eq (20). It can be found that the coupling strength decreases with increasing the system temperature from 185MeV to 305MeV. On the other side, the coupling strength of charm - gluon is function of critical temperature Tc and it can be observed increase coupling strength with increasing the critical temperature from 0.160291913GeV to 0.1894358972GeV. The rate of photons emission $R^H_{qg}(E,P)$ was calculated via Eq(19) with the system temperature in the limit of (185MeV$\leq$ T $\leq$ 305MeV) and the energy of photons (1GeV$\leq$ $E_\gamma \leq$ 3.5GeV) ,the critical temperature was calculated using Eq(21) where the result of $R^H_{qg}(E,P)$ can be seen in **Table 3** and **Table 4** with **Figure 1** and **Figure 2**. We can observe that the maximum value of photons rate at T= 305MeV and E_γ = 1GeV where $R^H_{qg}(E,P)$ = 5.4180E-09$\frac{1}{GeV^2 fm^4}$at α_c = 0.3297 and Tc=0.160291913GeV and $R^H_{qg}(E,P)$= 5.7722E-09$\frac{1}{GeV^2 fm^4}$at α_c=0.3512 and Tc= 0.1894358972GeV. On the other hand the minimum value of photons emission rate at T= 185MeV and E_γ=3.5GeV where $R^H_{qg}(E,P)$ = 3.5780E-23$\frac{1}{GeV^2 fm^4}$ at α_c= 0.4038 and Tc=0.1894358972GeV and $R^H_{qg}(E,P)$ = 3.8688E-23$\frac{1}{GeV^2 fm^4}$at α_c= 0.4366 and

Tc=0.1894358972GeV. If a comparison can be made between the calculation values of **Table 1** and **Table 2**, one can find that the rate of photons emission for two tables increase with the increasing of the system temperature from 185MeV to 305MeV and in contrast, the rate of photons emission of **Table 1** with Tc=0.160291913GeV is less than the rate of photons emission of **Table 2** with Tc= 0.1894358972GeV that mean the rate of photons emission increases with increasing the critical temperature. **Figure 1** and **Figure 2** demonstrate the relationship between the rate of photons emission $\mathrm{R}_{\mathrm{qg}}^{\mathrm{H}}(\mathrm{E},\mathrm{P})$ and the energy of photons E_{γ}. The decreasing of the photons rate with increasing of the energy of photons from 1GeV to 3.5GeV at various values of critical temperatures and the system temperatures and N_{f}=6and at E_{γ}=3.5GeV can be noticed.

4. CONCLUSION

In conclusion, the quantum chromodynamics theory can be considered to derive a hypothetical model to calculate the rate of emission of photons for $cg \rightarrow \mathrm{d}\gamma$ system with flavor number N_f=6. The rate of photon was calculated as a function of critical temperature, strength coupling, photon energy, thermal energy, electric charge and fugacity of quark and gluon using MATLAP program. It was found that the emitted photons that yield at high temperature of system (185-305MeV) for charm-gluon interaction is inversely proportional to the coupling strength and directly proportional to critical temperature and the system temperature for $cg \rightarrow \mathrm{d}\gamma$ system. In addition the emitted photons yield is related to the photon energy, where it decreases with increasing of the photon energy for two critical temperature.

5. REFERENCES

[1] J.L.Heilbron,"The History Of Physics A Very Short Introduction", Oxford University Press, 2018.

[2] A. Das, T. Ferbel,"Introduction to Nuclear and Particle Physics", University of Rochester, 2005.

[3] N. Timneanu," The Color of Gluon Interactions", PhD Thesis, Uppsala University, 2002.

[4] Fady Tarek,"Introduction to History of Elementary Particles and Their Dynamics ", Oxford University Press, 2019.

[5] Browning , Tyler Allen, "Direct Photon Anisotropy and The Time Evolution Of The Quark-Gluon Plasma", PhD thesis , University West Lafayette ,2016.

[6] Kevin Christoher Murphy," The Structure of Gluons in Point Form Quantum Chromodynamics", PhDthesis , university of lowa, 2009.

[7] D.J.Gross," The Discovery of Asymptotic Freedom and The Emergence of QCD", PNAS, Vol, 102,Nu, 26, 2005.

[8] Richard P. Feynman ,"Photon-hadron Interactions (Frontiers in physics)", USA:W.A. Benjamin,1972.

[9] C. Roychoudhuri, A.F. Kracklauer, and K.Creath, " The Nature of Light: What is A Photon? " CRC Press, 2017.

[10] Bali, G.S, and K.Schilling, "Static Quark-Antiquark Potential: Scaling Behavior and Finite-Size Effects in SU(3) Lattice Gauge Theory", Physical Review D 46,No, 6:2636, 1992.

[11] Friman, Bengt, Claudia Höhne, Jörn Knoll, Stefan Leupold, , Jorgen Randrup, Ralf Rapp, and Peter

Senger, eds, "The CBM Physics Book:Compressed Baryonic Matter in Laboratory Experimments" . Springer,2011.

[12] O.Linnyk, E.L.Bratkovskaya, and W.Cassing, Prog.Part. Nucl. Phys.87, 50 (2016), 1512.08126.

[13] H.Fujii, K.Itakura, K. Miyachi, and C.Nonaka (2022), 2204.03116.

[14] C.Gale and J.Kapusta,"Vector Dominance Model at Finite Temperature", Journal of Nuclear Physics B, Vol,357, Issue1, 1991.

[15] T.S.Biro,"Parton Equilibration in Relativistic Heavy Ion Collisions",Phys.Rev.C,Vol 48,Nu 1275, 1993.

[16] P. Aurenche, F. Gelis, R.Kobes and H.Zaraket,"Bremsstrahlung and Photon Production in Thermal QCD", Physics Review D, Vol,58,Nu,085003, 1998.

[17] M. E. Peskin ,Introduction To Quantum Field Theory Perseus Books Publishing L.L.C,1995.

[18] E. Mohammed Ahmed , H. J. M. Al-Agealy and N.Farhan , "Study of Photons Emission Rate of Quark-Antiquarkat Higher Energy" , Al-Mustansiriyah Journal of Science, 2521-3520 , 33, 4,2022.

[19] C. W. Noel and D. A . Greenwood , "An introduction to the standard model of particle physics ",Cambridge university press,2007.

[20] D. D Sastry S V S Mohanty A K Kumar K and Choudhury R K , Nuclear Physics, A 710 (3-4) 415,2000.

[21] J. L. Long ,Z. J. He , Y. G. Ma and B. Liu , Physical Review C 72 (6) 064907,2005.

[22] H. J. M. -agealy, R. Q. Ghadhban, and M. A. Hassooni, "Theoretical Study of the Photons Production Kinetic In Hot Quark-Gluon Plasma Matter," Ibn AL-Haitham J. Pure Appl. Sci., Vol,33, No 4 ,2020.

[23] Al-agealy, Hadi JM, Rawnaq Qays Ghadhban, and Mohsin A. Hassooni. "Theoretical Study of the Photons Production Kinetic In Hot Quark-Gluon Plasma Matter." Ibn AL-Haitham Journal For Pure and Applied Sciences 33.4 (2020): 34-41

[24] Viktor V. Begun, Mark I. Gorenstein and Oleg A. Mogilevsky"Equation of State for the Quark Gluon Plasma with the Negative Bag Constant"Ukrainian Journal of Physics, Vol. 55, No.9, 2010.

[25] Rana I. Bkmurd ,Hadi J. M. Al-Agealy and Ahmad M. Ashwiekh "Study and Evaluation the Photonic Emission Rate at Quark Gluon plasma From Comptonand Bremsstrahlung Process" Solid State TechnologyVol,63 Issue,6, 2020.