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

Simple Scenario of Photons Emission from Anti Charm–Gluon Interaction using QCD Theory

***Saba Mustafa Hussein[1]** **Hadi J. M. Al-Agealy[2]** **Ahmad A. Al-Rubaiee[1]**

[1]*Department of Physics, College of science, Mustansiriyah University*
[2] *Department of Physics, College of Education for Pure Science Ibn-ALHaitham, University of Baghdad, Baghdad-Iraq .*

*Corresponding Author E-mail: sabamustafa@uomustansiriyah.edu.iq

ARTICLE INF

Article history:
Received: 15 FEB, 2023
Revised: 19 APR ,2023
Accepted: 27 APR, 2023
Available Online: 28 JUN, 2023

Keywords:

Photons Emission
Anti Charm
Gluon
QCD Theory

ABSTRACT

In this work, the chromodynamics (QCD) theory was used to investigate the photon rate which was produced in interactions of anti-charm with gluon. The simple quantum scenario theory was implemented to give the rate equation that describe the collision of quark and gluon at a chemical potential $\mu_q = 500\, MeV$ .The photon emission rate was evaluated from anti-charm-gluon interaction of the $\bar{c}$g $\rightarrow \bar{d}\ \gamma$ collision at the temperature of the system in the range of 180 - 360 MeV with different critical temperatures (e.g. 116.575 , 139.891, 157.377 and 174.863 MeV) with photons energy $(10 \geq E \geq 1)$ GeV under the assumption that fugacity of quark and gluon are λ_g=0.08 and $\lambda_{\bar{q}}$=0.02 respectively . The photons rate increases with decreasing the coupling of quark and gluon according to decrease in the temperature of the system from 360 MeV to 180 MeV. The photon emission spectrum was calculated and discussed using photon energy of 1GeVto 10GeV with different critical temperatures. In terms of QCD theory, quantitative accomplishment was made for a unique six flavour number n_f = 4 + 2 of photon emission. The photon rate reach minimum with photon energy E=10 GeV, it reflects the less coupling for the $\bar{c}$g $\rightarrow \bar{d}\ \gamma$ interaction.

DOI: http://doi.org/10.31257/2018/JKP/2023/v15.i01.11300

وصف تصوري بسيط للانبعاث الفوتونات من تفاعل ضديد الكوارك الساحر - جلون باستخدام نظرية الديناميكا اللونية الكمومية QCD

صبا مصطفى حسين[1] هادي جبار مجبيل[2] احمد عزيز الربيعي[1]

[1]قسم الفيزياء - كلية العلوم - الجامعة المستنصرية، بغداد ، العراق
[2]قسم الفيزياء ، كلية التربية للعلوم الصرفة ابن الهيثم ، جامعة بغداد ، بغداد ، العراق

الـــخُـــلاصـــة

الكلمات المفتاحية:

. في هذا العمل ، نستخدم نظرية QCD للتحقيق في معدل انبعاث الفوتون الناتج عن تفاعلات ضديد الكوارك الساحر مع الكلون. تم تطبيق وصف نظري تصوري كمي بسيط لإعطاء معادلة المعدل لوصف تفاعل الكوارك و الكلون عند جهد كيميائي $\mu_q = 500\ MeV$. تم تقييم معدل انبعاث الفوتون من خلال التفاعل المضاد للكلوونات لنظام التفاعل $\bar{c}g \to \bar{d}\ \gamma$ عند درجة حرارة النظام في النطاق $(180 - 360)\ MeV$ ميجا فولت مع درجات حرارة حرجة مختلفة 116.575، 139.891 ، 157.377 174.863 مليون إلكترون فولت مع طاقة الفوتونات $(10 \geq E \geq 1)\ GeV$ بافتراض سرعة هروب الكوارك والكلون $\lambda_g=0.08$ و $\lambda_{\bar{q}}=0.02$ على التوالي. تم مناقشة تأثير الاقتران ودرجة حرارة النظام وطاقة الفوتونات ودرجة الحرارة الحرجة على الفوتون الناتج من نظام $\bar{c}g \to \bar{d}$ γحيث يزداد معدل الفوتونات مع انخفاض اقتران الكوارك والكلون وفقًا لتقليل درجة حرارة النظام من 360ميجا فولت إلى 180ميجا فولت ، وقد حسب ونوقش طيف انبعاث الفوتونات باستخدام طاقة الفوتون من $1GeV$ جيجا إلكترون فولت إلى $10GeV$ جيجا إلكترون فولت وبدرجات حرارة حرجة مختلفة. فيما يتعلق بنظرية QCD الممكنة ، كان الإنجاز الكمي لعدد فريد من ستة نكهات $n_f = 4 + 2$ من انبعاث الفوتون ليصل معدل الفوتون إلى الحد الأدنى مع طاقة الفوتون $E = 10\ GeV$ ، وهو يعكس الاقتران الأقل للتفاعل $\bar{c}g \to \bar{d}\ \gamma$.

انبعاث الفوتونات
الكوارك الساحر
الكلون
نظرية QCD

1. INTRODUCTION

An elementary particle is one of the main important branches of physics. It considers describing the fundamental building blocks of materials from an unbreakable component of bit small particles [1]. In recent years, the quark-gluon interaction that occurred in the heavy-ion collisions (RHIC) and large hadron collider (LHC) experiments were introduced as a valuable probing for photon production [2]. Nevertheless, the quark-gluon produced in heavy-ion collisions introduces a good understanding of the behavior of nucleons in a hadron medium [3]. Gell-Mann and Zweig are introduced independently the quark model in 1964 for building nuclear matter. Quark is the basic building matter of protons and neutrons; they are held together according to the strong nuclear force [4]. However, the higher temperature is not been an extreme feature for the interaction of quark-gluon that's producing in the heavy ion collisions [5]. Different theories have been introduced to study the structure of matter and interaction of quark-gluon in a variety of scientific institutes across the world [6]. Most of the theoretical treatments of quark-gluon interaction try to describing the quantities relying on the loss energy of heavy quarks via different dynamics [7]. The charm hadrons are observable in heavy ion collision experiments and that is important to provide detailed knowledge about the strong coupling of quark gluon [8]. The photons are produced in various processes; decay photons come from hadron decays and direct photons. Moreover, the direct photons are divided to prompt photons and thermal photons are emitted from the quark-gluon medium [9]. The photons are produced through quark-gluon interaction and achieved in higher energy relativistic heavy-ion collisions to understand the equilibrium state of quark-gluon matter [10]. The standard model introduces a mathematical framework for describing the interactions of elementary particles; electromagnetism, weak, and strong interactions. Moreover, the standard model had succeeded in understanding new state of matter of quantum chromodynamics and quark-gluon interaction [11]. The main goal of this article is to theoretically calculate the photon emission rate form Interaction of anti-Charm quark with gluon using simple model based on quantum chromodynamic theory.

2. THEORY

The photon emission rate produces from hard interaction of quark-gluon **with** energy E and momentum P can be given by [12].

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

where $f_B(E)$ is the Bosonic distribution and $\mathrm{Im}\prod^{H}_{qg}(E,P)$ is imaginary part of retarded self-energy polarization and given as follows [13]:

$$\mathrm{Im}\prod^{H}_{qg}(E,P) = \frac{-NC_a}{\pi^4}\frac{T({g_E}^2{g_H}^2)|\ I_T - I_L|\sum e_q^2}{E^2}\int_0^\infty \Big(f_q(P) - f_q(E-P)\Big)(P^2+(E-P)^2)\,dP \quad (2)$$

where N and C_a are number of flavor and the Casimir operator, g_E and g_H are the quantum electrodynamics and quantum chromodunamic coupling, $f_q(P)$ is Fermi distribution of quark, I_T and I_L are the dimensionless constant of self-integral [14], and e_q^2 is square electric charge for quarks. The Juttner function $f_q(P)$ and $f_q(p-E)$ as function of fugacity of quarks λ_q is as below [15]:

$$f_q(P) = \frac{\lambda_q}{e^{\frac{(p+\mu_q)}{T}}+\lambda_q} \quad (3)$$

$$f_q(p-E) = \frac{\lambda_q}{e^{\frac{(E-p-\mu_q)}{T}}+\lambda_q} \quad (4)$$

where μ_q is chemical potential relative to fugacity of quarks and gluons by $\lambda_{q,g} = e^{\frac{\mu_{q,g}}{T}}$ [16]. Inserting Eq. (3) and Eq.(4) in Eq.(2) with expand $(P^2+(E-P)^2) = 2P^2+E^2-2EP$ to given .

$$\mathrm{Im}\Pi^{H}_{qg}(E,P) = \frac{-NC_a}{\pi^4}\frac{T({g_E}^2{g_H}^2)|\ I_T - I_L|}{E^2}\sum e_q^2\ \ [A_1 + A_2] \quad (5)$$

where A_1 and A_2 are integral parameters that's given by

$$A_1 = \int_0^\infty \frac{(2P^2+E^2-2EP)}{(\frac{e^{\frac{(p+\mu_q)}{T}}}{\lambda_q}+1)}dP = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{{\lambda_q}^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{{\lambda_q}^{-2}} \ldots \frac{e^{\frac{-n(p+\mu_q)}{T}}}{{\lambda_q}^{-n}}](2P^2-2EP+E^2)dP \quad (6)$$

$$A_2 = \int_0^\infty \frac{(2P^2+E^2-2EP)}{(\frac{e^{\frac{(E-p-\mu_q)}{T}}}{\lambda_q}+1)}dP = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{{\lambda_q}^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{{\lambda_q}^{-2}} + \cdots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{{\lambda_q}^{-n}}](2P^2-2EP+E^2)dP \quad (7)$$

We reform integrals Eq.(6) and Eq.(7) in six term;

$$J_1 = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{{\lambda_q}^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{{\lambda_q}^{-2}} +..-\cdots..\frac{e^{\frac{-n(p+\mu_q)}{T}}}{{\lambda_q}^{-n}}](2P^2)dP \quad (8)$$

The second integral is

$$J_2 = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{{\lambda_q}^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{{\lambda_q}^{-2}} + \cdots - \cdots..\frac{e^{\frac{-n(p+\mu_q)}{T}}}{{\lambda_q}^{-n}}](2PE)dP \quad (9)$$

The third integral is

$$J_3 = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{{\lambda_q}^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{{\lambda_q}^{-2}} + \cdots.-\cdots..\frac{e^{\frac{-n(p+\mu_q)}{T}}}{{\lambda_q}^{-n}}](E^2)dP \quad (10)$$

The fourth terms is

$$J_4 = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{{\lambda_q}^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{{\lambda_q}^{-2}} + -\cdots \ldots..\frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{{\lambda_q}^{-n}}](2P^2)dP \quad (11)$$

The five integral term

$$J_5 = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{\lambda_q^{-2}} + \cdots - \cdots \ldots\ldots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{\lambda_q^{-n}}](2PE)dP \quad (12)$$

The final integral term is

$$J_6 = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{\lambda_q^{-2}} + \cdots - \cdots \ldots\ldots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{\lambda_q^{-n}}](E^2)dP \quad (13)$$

The solutions of six term are given by .

$$J_1 = 2T^3 \left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2^3} + \cdots - \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n\mu_q}{T}}\right] \Gamma(3) \quad (14)$$

$$J_2 = 2ET^2\Gamma(2) \left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1^2} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2^2} + \cdots - \cdots \frac{\lambda_q{}^n e^{\frac{-n\mu_q}{T}}}{n^2}\right] \quad (15)$$

$$J_3 = E^2T[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2} + \cdots - \cdots \frac{\lambda_q{}^n e^{\frac{-n\mu_q}{T}}}{n})\Gamma(1) \quad (16)$$

$$J_4 = 2T^3\Gamma(3) [\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^3} + \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n(E-\mu_q)}{T}}] \quad (17)$$

$$\boldsymbol{J_5 = 2ET^2\Gamma(2) [\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^2} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^2} + \cdots \frac{\lambda_q{}^n}{n^2} e^{\frac{-n(E-\mu_q)}{T}}]} \quad (18)$$

$$J_6 = E^2T\Gamma(1)(\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2} \ldots + \frac{\lambda_q{}^n}{n} e^{\frac{-n(E-\mu_q)}{T}}) \quad (19)$$

Substituting J_1 , J_2 ,and J_3 in Eq.(6) to give A_1 .

$$A_1 = 2T^3 \left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2^3} - \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n\mu_q}{T}}\right]\Gamma(3) + 2ET^2\Gamma(2) \left[\left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1^2} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2^2} - \cdots \frac{\lambda_q{}^n}{n^2} e^{\frac{-n\mu_q}{T}}\right]\right] + E^2T\left[\left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2} - \cdots \frac{\lambda_q{}^n}{n} e^{\frac{-n\mu_q}{T}}\right]\right)\Gamma(1) \quad (20)$$

On the other hand, we insert the J_4 , J_5, and J_6 in Eq.(7) to result .

$$A_2 = 2T^3\Gamma(3) \left[\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^3} + \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n(E-\mu_q)}{T}}\right] + 2ET^2\Gamma(2) [\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^2} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^2} + \cdots \frac{\lambda_q{}^n}{n^2} e^{\frac{-n(E-\mu_q)}{T}}] + E^2T\Gamma(1)[\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2} + \cdots \frac{\lambda_q{}^n}{n} e^{\frac{-n(E-\mu_q)}{T}}](21)$$

We assume $J = A_1 + A_2$,then with using Eq. (20) and Eq.(21)

$$J = 2T^3 \left[\frac{\lambda_q{}^1}{1^3}\left(e^{\frac{-\mu_q}{T}} + e^{\frac{-(E-\mu_q)}{T}}\right) - \frac{\lambda_q{}^2}{2^3}\left(e^{\frac{-2\mu_q}{T}} + e^{\frac{-2(E-\mu_q)}{T}}\right) - \cdots \frac{\lambda_q{}^n}{n^3}(e^{\frac{-n\mu_q}{T}} + e^{\frac{-n(E-\mu_q)}{T}})\right]\Gamma(3) + 2ET^2\Gamma(2)\left[\frac{\lambda_q{}^1}{1^2}\left(e^{\frac{-\mu_q}{T}} + e^{\frac{-(E-\mu_q)}{T}}\right) - \frac{\lambda_q{}^2}{2^2}\left(e^{\frac{-2\mu_q}{T}} + e^{\frac{-2(E-\mu_q)}{T}}\right) + \cdots - \cdots \frac{\lambda_q{}^n}{n^2}(e^{\frac{-n\mu_q}{T}} + e^{\frac{-n(E-\mu_q)}{T}})\right] + E^2T\left[\frac{\lambda_q{}^1}{1}\left(e^{\frac{-\mu_q}{T}} + e^{\frac{-(E-\mu_q)}{T}}\right) -\right.$$

$\frac{{\lambda_q}^2}{2}\left(e^{\frac{-2\mu_q}{T}}+e^{\frac{-2(E-\mu_q)}{T}}\right)\ldots\ldots \frac{{\lambda_q}^n}{n}(e^{\frac{-n\mu_q}{T}}+ e^{\frac{-n(E-\mu_q)}{T}})\Big)\Gamma(1)$ (22)

We insert Eq. (22) in Eq. (5) to give

$$\mathrm{Im}\prod_{qg}^{H}(E,P)=\frac{-N_cC_a}{\pi^4}\frac{T({g_E}^2{g_H}^2)|\mathrm{I_T}-\mathrm{I_L}|\ \sum e_q^2}{E^2}\ 2T^3\left[\frac{{\lambda_q}^1}{1^3}\left(e^{\frac{-\mu_q}{T}}+e^{\frac{-(E-\mu_q)}{T}}\right)-\frac{{\lambda_q}^2}{2^3}\left(e^{\frac{-2\mu_q}{T}}+e^{\frac{-2(E-\mu_q)}{T}}\right)-\cdots\frac{{\lambda_q}^n}{n^3}(e^{\frac{-n\mu_q}{T}}+e^{\frac{-n(E-\mu_q)}{T}})\right]\Gamma(3)+2\mathrm{E}T^2\Gamma(2)\left[\frac{{\lambda_q}^1}{1^2}\left(e^{\frac{-\mu_q}{T}}+e^{\frac{-(E-\mu_q)}{T}}\right)-\frac{{\lambda_q}^2}{2^2}\left(e^{\frac{-2\mu_q}{T}}+e^{\frac{-2(E-\mu_q)}{T}}\right)-\cdots\frac{{\lambda_q}^n}{n^2}(e^{\frac{-n\mu_q}{T}}+e^{\frac{-n(E-\mu_q)}{T}})\right]+E^2T\left[\frac{{\lambda_q}^1}{1}\left(e^{\frac{-\mu_q}{T}}+e^{\frac{-(E-\mu_q)}{T}}\right)-\frac{{\lambda_q}^2}{2}\left(e^{\frac{-2\mu_q}{T}}+e^{\frac{-2(E-\mu_q)}{T}}\right)+\cdots\frac{{\lambda_q}^n}{n}(e^{\frac{-n\mu_q}{T}}+e^{\frac{-n(E-\mu_q)}{T}})\right)\Gamma(1) \quad (23)$$

let assume

$$\gamma(E,T,\lambda_q,\mu_q)=\Bigg[2T^3\Gamma(3)\left(\frac{{\lambda_q}^1}{1^3}-\frac{{\lambda_q}^2}{2^3}+\frac{{\lambda_q}^3}{3^3}-\frac{{\lambda_q}^4}{4^3}+\frac{{\lambda_q}^5}{5^3}-\cdots\frac{{\lambda_q}^n}{n^3}\right)+2\mathrm{E}T^2\Gamma(2)\left(\frac{{\lambda_q}^1}{1^2}-\frac{{\lambda_q}^2}{2^2}+\frac{{\lambda_q}^3}{3^2}-\frac{{\lambda_q}^4}{4^2}+\frac{{\lambda_q}^5}{5^2}-\cdots\frac{{\lambda_q}^n}{n^2}\right)+E^2T\Gamma(1)(\frac{{\lambda_q}^1}{1}-\frac{{\lambda_q}^2}{2}+\frac{{\lambda_q}^3}{3}-\frac{{\lambda_q}^4}{4}+\frac{{\lambda_q}^5}{5}-\cdots\frac{{\lambda_q}^n}{n})\Bigg]\Bigg[\Bigg(\left(e^{\frac{-\mu_q}{T}}+e^{\frac{-(E-\mu_q)}{T}}\right)+\left(e^{\frac{-2\mu_q}{T}}+e^{\frac{-2(E-\mu_q)}{T}}\right)+\left(e^{\frac{-3\mu_q}{T}}+e^{\frac{-3(E-\mu_q)}{T}}\right)+\left(e^{\frac{-4\mu_q}{T}}+e^{\frac{-4(E-\mu_q)}{T}}\right)+\left(e^{\frac{-5\mu_q}{T}}+e^{\frac{-5(E-\mu_q)}{T}}\right)\ldots+(e^{\frac{-n\mu_q}{T}}+e^{\frac{-n(E-\mu_q)}{T}})\Bigg)$$
(24)

Insert Casmir operator $C_a=\frac{(N_c^2-1)}{2N_c}=\frac{4}{3}$ for color number $N_c=3$ [17] and the strong coupling $\alpha_{QCD}(\mu^2)=\frac{{g_H}^2}{4\pi}$ [18] where quantum electrodynamics coupling $\alpha_{\mathrm{QED}}=\frac{{g_E}^2}{4\pi}$[19] and Eq.(24) in Eq.(23) to become

$$\mathrm{Im}\prod_{qg}^{H}(E,P)=(-1)4\frac{N}{\pi^2}\frac{16}{3}\alpha_{\mathrm{QED}}\alpha_{QCD}(\mu^2)\sum e_q^2\ |\mathrm{J_T}-\mathrm{J_L}|\ \frac{T}{E^2}\gamma(E,T,\lambda_q,\mu_q) \quad (25)$$

Inserting Eq. (25) in Eq.(1) with Bosonic distribution for gluon $\mathrm{f}_B(\mathrm{E})=\frac{\lambda_g}{e^{\frac{E}{T}}-\lambda_g}$ [20] gives.

$$\mathrm{R}_{qg}^{H}(E,P)=\left(\frac{8N}{3\pi^5}\right)\frac{\lambda_g}{e^{E/T}-\lambda_g}\alpha_{\mathrm{QED}}\alpha_{QCD}(\mu^2)\frac{T}{E^2}\ |\mathrm{I_T}-\mathrm{I_L}|\ \sum e_q^2\ \gamma(E,T,\lambda_q,\mu_q) \quad (26)$$

The strong coupling constant is [21].

$$\alpha_{QCD}(\mu^2)=\frac{6\pi}{(33-2\,N_F)\,ln\frac{8T}{T_c}} \quad (27)$$

Where N_F is flavor number, T is temperature of system and T_c is critical temperature of system, it can be given by [22].

$$T_c=(\frac{90B}{\pi^2 d_{gq}})^{\frac{1}{4}} \quad (28)$$

where B is the bag coefficient and degeneracy factors for gluons d_g and quarks $(d_q,d_{\bar{q}})$ is $d_{gq}=d_g+\frac{7}{8}\,(d_q+d_{\bar{q}})$ [23]. The d_g is number of gluons degrees of freedom as function of gluons spin n_s and color states n_c and d_q is number of quarks degrees of freedom.as function of color number n_c, spin n_s and flavour degrees n_f,the Eq. (28) become

$$T_c=(\frac{90B}{\pi^2[(n_s\times n_c)+\frac{7}{4}(n_c\times n_s\times n_f)]})^{\frac{1}{4}} \quad (29)$$

3. RESULTS

Firstly, the critical temperature to predict the photon emission rate was estimated

.The critical temperature $T_c(MeV)$ was evaluated according to the bag constant B in Eq.(29) using the degeneracy factor d_{gq} as function of spin state $n_s = 2$ and $n_c = 8$ for gluons and function to $n_s = 2$, $n_c = 3$ and $\boldsymbol{n_f = 6}$ for anti-charm and anti-down quarks in system with using the Bag constant from table (1) with insert in Eq.(29), the results are presented in Table (1) for $\bar{\boldsymbol{c}}$ quark, gluon to produce $\bar{d}$ quarks and emission .

TABLE 1. The calculated critical temperature due to the Bag mode of the $\bar{\boldsymbol{c}}$g $\rightarrow\bar{\boldsymbol{d}}$ γ system at $\boldsymbol{n_f = 6.}$

Bag constant $B^{1/4} MeV$[21]	T_c MeV
200	116.575
240	139.891
270	157.377
300	174.863

Next, we had evaluated the coupling between anti-charm quarks with gluon in Eq. (27), we were inserted the critical temperature from table (1) and take into account the temperature of $\bar{c}$g $\rightarrow\bar{d}$ γ system from T=180 to 360 MeV and increases by 30 Mev with $n_f = 6$. The results can be shown in Table (2).

TABLE 2. Results of the calculation of coupling for $\bar{c}$g $\rightarrow\bar{d}$ γ system at variety critical temperature of system with $n_f = 6$.

T_C	α_{QCD}						
	T=180MeV	T=210MeV	T=240MeV	T=270MeV	T=300MeV	T=330MeV	T=360MeV
116.575	0.3571	0.3364	0.3204	0.3075	0.2968	0.2877	0.2799
139.891	0.3850	0.3611	0.3427	0.3279	0.3158	0.3055	0.2968
157.377	0.4055	0.3791	0.3588	0.3427	0.3294	0.3183	0.3088
174.863	0.4257	0.3967	0.3746	0.3571	0.3427	0.3307	0.3204

A simple scenario to evaluate the photon rate need to compute the electric charge with flavour number of $\bar{c}$g $\rightarrow\bar{d}$ γ system ,where one can evaluate the electric charge of anti-charm and anti –down quarks in the system with no electric charge for gluon. However, the electric charge of $\bar{c}$g $\rightarrow\bar{d}$ γ system uses summation $\sum e_q{}^2$, which was already applied on anti-charm and anti-down quarks to extract of charge system, ,this results ii $^5/_9$ of $\bar{c}$g $\rightarrow\bar{d}$ γ system where charge of anti-charm quark is $-^2/_3$and anti-down is $-^1/_3$,and the favor of quarks system is $n_f = 6$ for $\bar{c}$g $\rightarrow\bar{d}$ γ collision system .The photon rate produces from the anti-charm –gluon collision was calculated using Eq.(26) with insertion of the critical temperature from Table(1) and coupling α_{QCD} from Table(2), the self-integrals constant $I_L = -4.26$ and $I_T = 4.45$ [23] and takes $\alpha_{QED} = 1/137$ and $N = 3$ with uses the photon energy $E = 1,2,3,4,5,6,7,8,9$ and $10GeV$ [24].Specifically ,we assume the fugacity λ_q=0.02 for quark , λ_g=0.08 for gluon [25] and take the chemical potential $\mu_q = 500\,MeV$ [26]. The Resulted data are given in Tables (3),(4),(5) ,(6) with figures (1),(2),(3) and (4).

TABLE 3. The data calculated for rate of photon at $T_c = 116.575\ MeV$, $I_T = 4.45$ and $I_L = -4.26$ with λ_g=0.06, $\lambda_{\bar{q}}$=0.02 $\bar{c}g \rightarrow \bar{d}\ \gamma$ system in $n_f = 6$

$E_\gamma\ GeV$	$R^H_{qg}(E,P)\frac{1}{GeV^2 fm^4}$						
	T=180MeV	T=210MeV	T=240MeV	T=270MeV	T=300MeV	T=330MeV	T=360MeV
	α_{QCD} =0.4161	α_{QCD} =0.3884	α_{QCD} =0.3672	α_{QCD} =0.3503	α_{QCD} =0.3365	α_{QCD} =0.3249	α_{QCD} =0.3149
1	9.7659E-12	4.5627E-11	1.5399E-10	4.1673E-10	9.6308E-10	1.9793E-09	3.7173E-09
2	1.5416E-14	1.5433E-13	9.1712E-13	3.8359E-12	1.2512E-11	3.3979E-11	8.0273E-11
3	5.5563E-17	1.2107E-15	1.2820E-14	8.3603E-14	3.8728E-13	1.3960E-12	4.1620E-12
4	2.0793E-19	9.9608E-18	1.9013E-16	1.9578E-15	1.3051E-14	6.3267E-14	2.4113E-13
5	7.8852E-22	8.3253E-20	2.8720E-18	4.6822E-17	4.5042E-16	2.9459E-15	1.4400E-14
6	3.0099E-24	7.0122E-22	4.3768E-20	1.1311E-18	1.5723E-17	1.3891E-16	8.7204E-16
7	1.1532E-26	5.9319E-24	6.7038E-22	2.7481E-20	5.5233E-19	6.5962E-18	5.3218E-17
8	4.4283E-29	5.0316E-26	1.0300E-23	6.7001E-22	1.9480E-20	3.1460E-19	3.2634E-18
9	1.7031E-31	4.2755E-28	1.5857E-25	1.6374E-23	6.8880E-22	1.5048E-20	2.0074E-19
10	6.5568E-34	3.6376E-30	2.4448E-27	4.0078E-25	2.4400E-23	7.2119E-22	1.2376E-20

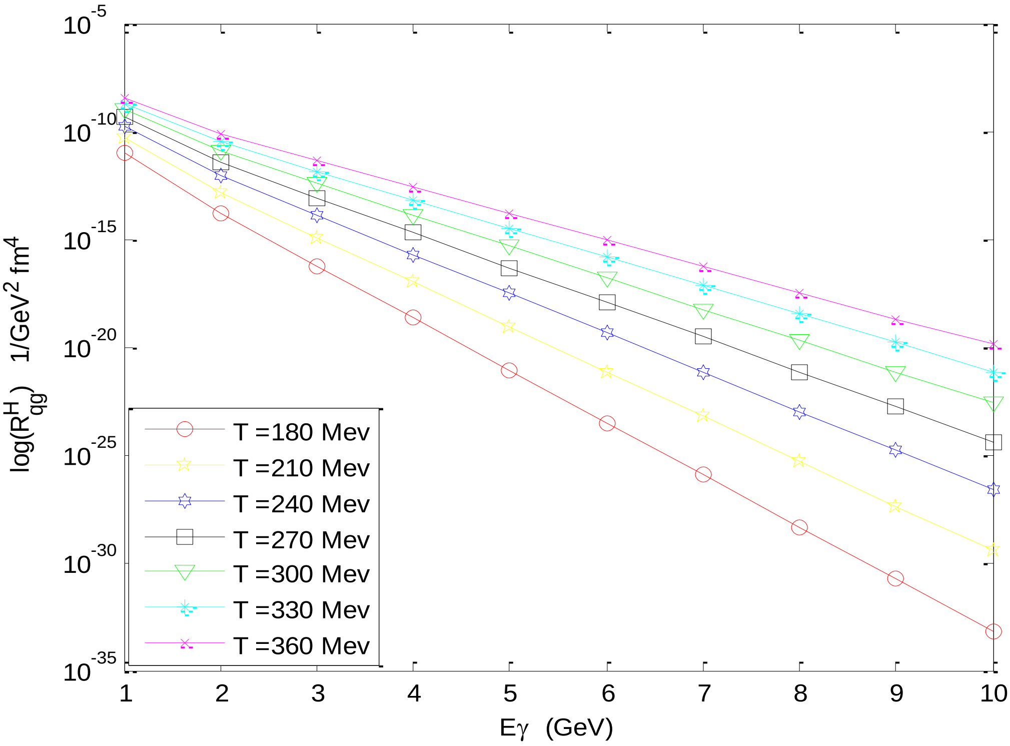

FIGURE 1. The photon rate at $\boldsymbol{T_c} = 116.575\ MeV$, λ_g=0.06 for gluon , $\lambda_{\bar{q}}$=0.02 and flavor number $\boldsymbol{n_f} = \mathbf{6}$ for $\bar{c}g \rightarrow \bar{d}\ \gamma$ system .

TABLE 4. Data calculated of rate of photon at $T_c = 139.891\ MeV$, $I_T = 4.45$ and $I_L = -4.26$ with λ_g=0.06, $\lambda_{\bar{q}}$=0.02 $\bar{c}g \rightarrow \bar{d}\ \gamma$ system in $n_f = 6$.

$E_\gamma\ GeV$	$R^H_{qg}(E,P)\frac{1}{GeV^2 fm^4}$

	T=180MeV	T=210MeV	T=240MeV	T=270MeV	T=300MeV	T=330MeV	T=360MeV
	α_{QCD} =0.3850	α_{QCD} =0.3611	α_{QCD} =0.3427	α_{QCD} =0.3279	α_{QCD} =0.3158	α_{QCD} =0.3055	α_{QCD} =0.2968
1	1.0530E-11	4.8974E-11	1.6471E-10	4.4449E-10	1.0249E-09	2.1021E-09	3.9414E-09
2	1.6622E-14	1.6565E-13	9.8096E-13	4.0915E-12	1.3314E-11	3.6087E-11	8.5112E-11
3	5.9908E-17	1.2995E-15	1.3712E-14	8.9172E-14	4.1212E-13	1.4826E-12	4.4128E-12
4	2.2419E-19	1.0691E-17	2.0337E-16	2.0883E-15	1.3888E-14	6.7194E-14	2.5566E-13
5	8.5018E-22	8.9360E-20	3.0719E-18	4.9940E-17	4.7931E-16	3.1288E-15	1.5268E-14
6	3.2453E-24	7.5265E-22	4.6815E-20	1.2064E-18	1.6731E-17	1.4753E-16	9.2461E-16
7	1.2434E-26	6.3670E-24	7.1704E-22	2.9311E-20	5.8776E-19	7.0056E-18	5.6426E-17
8	4.7746E-29	5.4006E-26	1.1017E-23	7.1464E-22	2.0729E-20	3.3412E-19	3.4601E-18
9	1.8363E-31	4.5891E-28	1.6961E-25	1.7464E-23	7.3299E-22	1.5982E-20	2.1284E-19
10	7.0695E-34	3.9044E-30	2.6150E-27	4.2748E-25	2.5965E-23	7.6595E-22	1.3122E-20

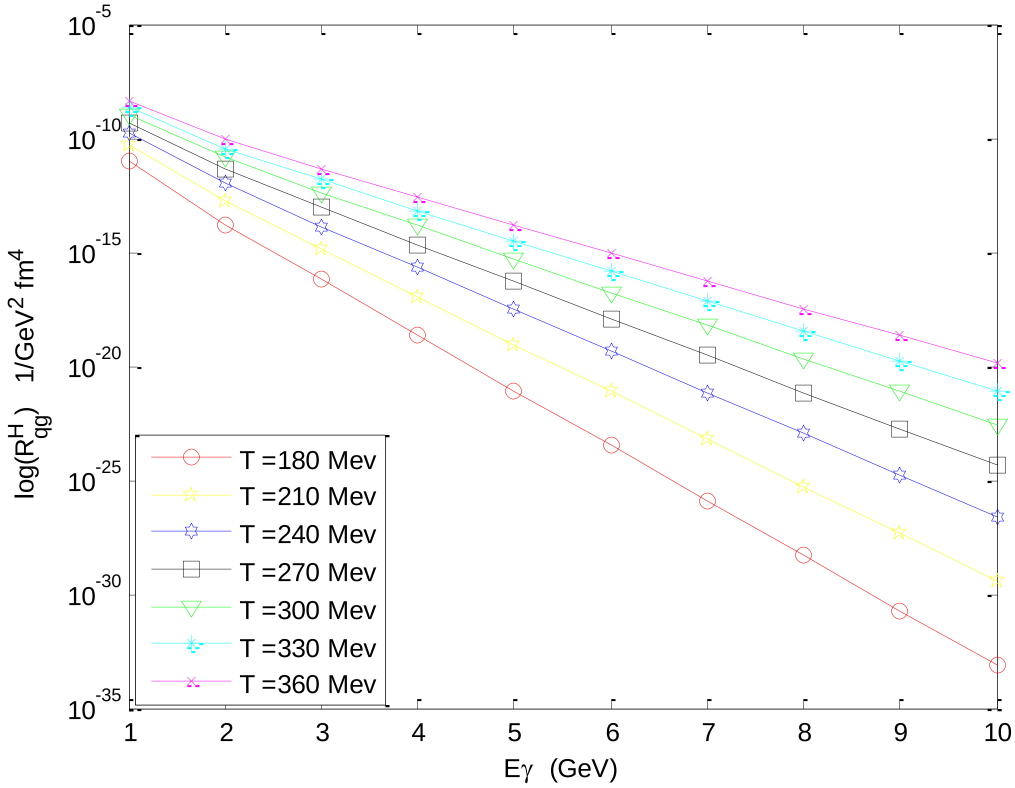

FIGURE 2. The photon rate at $T_c = 139.891 MeV$, λ_g=0.06 for gluon, $\lambda_{\bar{q}}$=0.02 and flavor number $n_f = 6$ for $\bar{c}g \rightarrow \bar{d}\,\gamma$ system.

TABLE 5. Data calculated for rate of photon at $T_c = 157.377\ MeV$, $I_T = 4.45$ and $I_L = -4.26$ with λ_g=0.06, $\lambda_{\bar{q}}$=0.02 $\bar{c}g \rightarrow \bar{d}\,\gamma$ system in $n_f = 6$.

E_γ GeV	$R^H_{qg}(E,P)\frac{1}{GeV^2 fm^4}$						
	T=180MeV	T=210MeV	T=240MeV	T=270MeV	T=300MeV	T=330MeV	T=360MeV
	α_{QCD} =0.4055	α_{QCD} =0.3791	α_{QCD} =0.3588	α_{QCD} =0.3427	α_{QCD} =0.3294	α_{QCD} =0.3183	α_{QCD} =0.3088
1	1.1090E-11	5.1410E-11	1.7247E-10	4.6448E-10	1.0692E-09	2.1900E-09	4.1011E-09

2	1.7506E-14	1.7389E-13	1.0271E-12	4.2755E-12	1.3890E-11	3.7595E-11	8.8560E-11
3	6.3096E-17	1.3641E-15	1.4358E-14	9.3182E-14	4.2993E-13	1.5445E-12	4.5916E-12
4	2.3611E-19	1.1223E-17	2.1294E-16	2.1822E-15	1.4488E-14	7.0000E-14	2.6602E-13
5	8.9541E-22	9.3804E-20	3.2165E-18	5.2186E-17	5.0004E-16	3.2594E-15	1.5887E-14
6	3.4179E-24	7.9009E-22	4.9019E-20	1.2607E-18	1.7455E-17	1.5369E-16	9.6207E-16
7	1.3095E-26	6.6837E-24	7.5081E-22	3.0629E-20	6.1317E-19	7.2982E-18	5.8713E-17
8	5.0286E-29	5.6693E-26	1.1535E-23	7.4678E-22	2.1625E-20	3.4808E-19	3.6003E-18
9	1.9340E-31	4.8174E-28	1.7760E-25	1.8250E-23	7.6467E-22	1.6649E-20	2.2147E-19
10	7.4456E-34	4.0986E-30	2.7381E-27	4.4670E-25	2.7088E-23	7.9794E-22	1.3653E-20

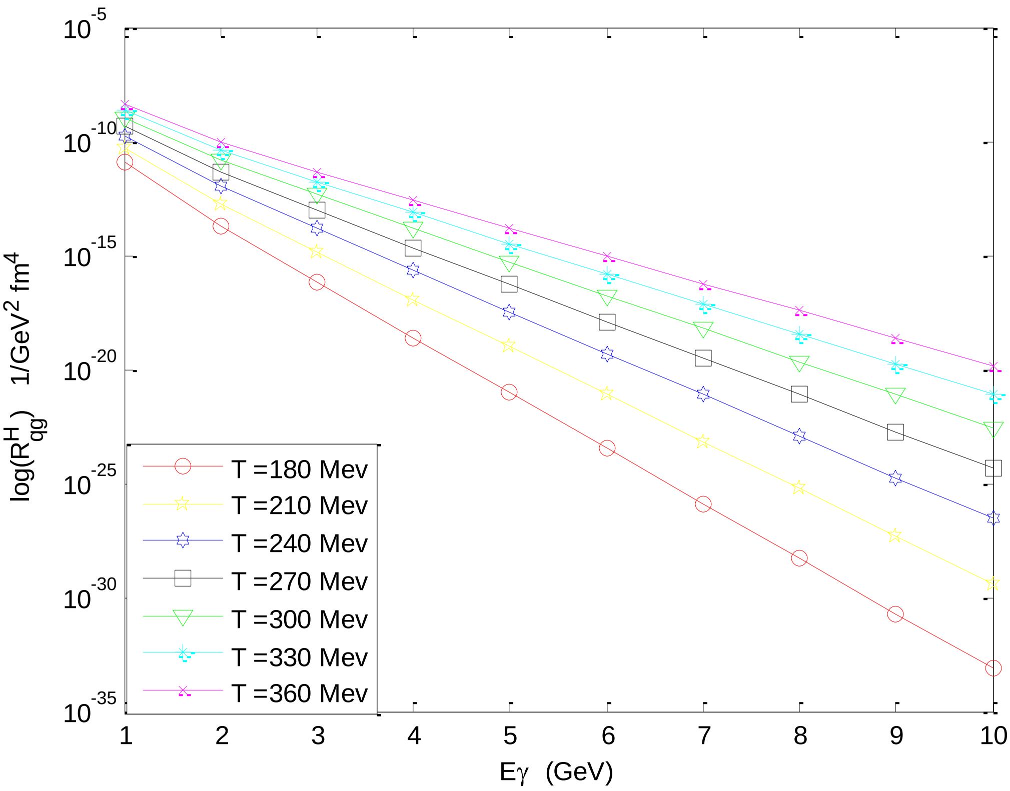

FIGURE 3. The photon rate at $T_c = 157.377 MeV$, λ_g=0.06 for gluon , $\lambda_{\bar{q}}$=0.02 and flavor number $n_f = 6$ for $\bar{c}$g →$\bar{d}$ γ system .

TABLE 6. Data calculated for rate of photon at $T_c = 174.863 MeV$, $I_T = 4.45$ and $I_L = -4.26$ with λ_g=0.06, $\lambda_{\bar{q}}$=0.02 $\bar{c}$g →$\bar{d}$ γ system in $n_f = 6$.

E_γ GeV	$R^H_{qg}(E,P)\frac{1}{GeV^2 fm^4}$						
	T=180MeV	T=210MeV	T=240MeV	T=270MeV	T=300MeV	T=330MeV	T=360MeV
	α_{QCD} =0.4257	α_{QCD} =0.3967	α_{QCD} =0.3746	α_{QCD} =0.3571	α_{QCD} =0.3427	α_{QCD} =0.3307	α_{QCD} =0.3204
1	1.1644E-11	5.3804E-11	1.8005E-10	4.8394E-10	1.1122E-09	2.2750E-09	4.2553E-09
2	1.8381E-14	1.8199E-13	1.0723E-12	4.4547E-12	1.4449E-11	3.9054E-11	9.1891E-11
3	6.6249E-17	1.4276E-15	1.4989E-14	9.7088E-14	4.4723E-13	1.6045E-12	4.7643E-12
4	2.4791E-19	1.1746E-17	2.2231E-16	2.2736E-15	1.5071E-14	7.2717E-14	2.7602E-13

5	9.4016E-22	9.8173E-20	3.3579E-18	5.4373E-17	5.2015E-16	3.3859E-15	1.6485E-14
6	3.5887E-24	8.2688E-22	5.1175E-20	1.3135E-18	1.8157E-17	1.5966E-16	9.9825E-16
7	1.3750E-26	6.9949E-24	7.8382E-22	3.1913E-20	6.3784E-19	7.5815E-18	6.0921E-17
8	5.2799E-29	5.9333E-26	1.2043E-23	7.7808E-22	2.2495E-20	3.6159E-19	3.7357E-18
9	2.0306E-31	5.0417E-28	1.8541E-25	1.9015E-23	7.9543E-22	1.7295E-20	2.2980E-19
10	7.8177E-34	4.2894E-30	2.8585E-27	4.6542E-25	2.8177E-23	8.2891E-22	1.4167E-20

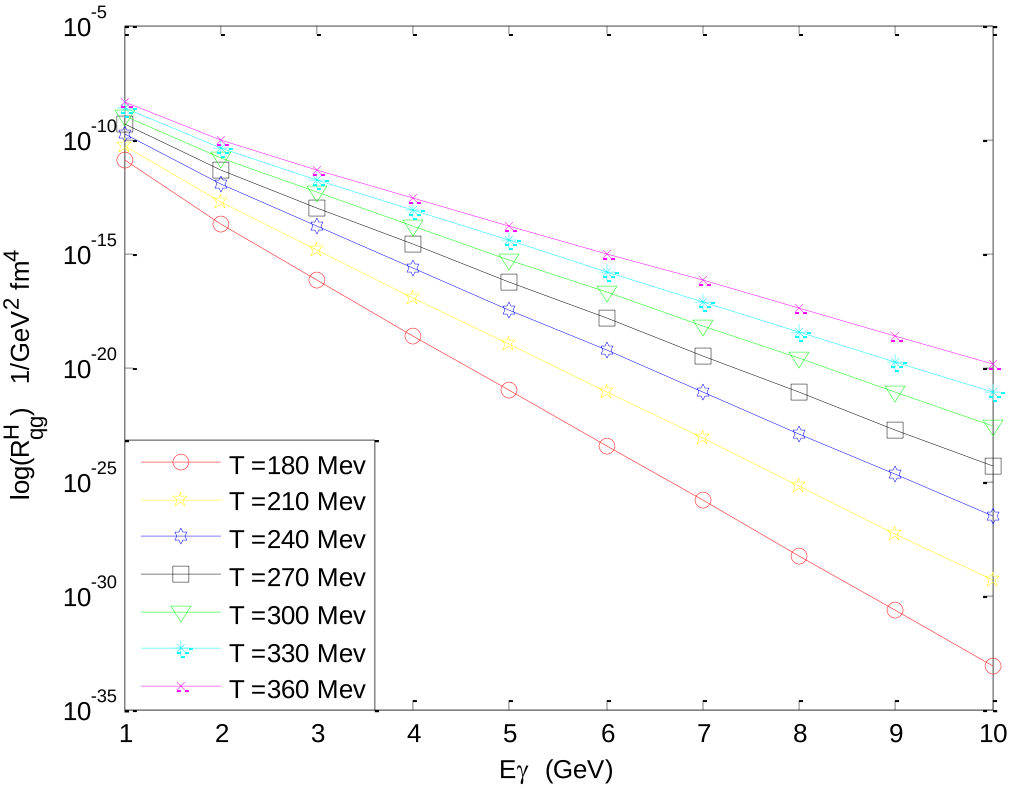

FIGURE 4. Photon rate at $T_c = 174.863\ MeV$,λ_g=0.06 for gluon , $\lambda_{\bar{q}}$=0.02 and flavor number $n_f = 6$ for $\bar{c}g \rightarrow \bar{d}\ \gamma$ system.

4. DISCUSSION

The photon rate theory in Eq.(26), is good tool to discuss the hard interaction between quark and gluon interaction depending on the QCD theory and strength coupling ,temperature of system , energy of photon , fugacity of quark and gluon , and critical temperature parameters. Coupling between quark and gluon is the main parameters that has impact on QCD parameters. It is influenced by the flavour number, temperature of system and critical temperature. In fact, the critical temperature has been implicitly affected by Bag constant and flavor number. However, we can see from Table (1) that the critical temperature increases with increasesing the bag constant, it becomes maximum at 174.863 with bag constant of 300MeV compared with minimum 116.575 with bag constant of 200MeV. The results indicate that density of quarks and gluons in the $\bar{c}g \rightarrow \bar{d}\ \gamma$ system at $n_f = 6$ increase and increase the bag constant, there are agreed with experimental data from CERN SPS [27]. We use variety of critical temperatures (i.e., 116.575, 139.891, 157.377 and 174.863 MeV) to study the effect on the photons rate, we can perform the calculation with different critical temperatures. In fact, the critical temperature is the main parameter that influence the strong coupling and photon rate. The photons rate in tables (3) to (6) are different for different critical temperatures and the coupling of quark and gluon. In fact, we can find a large coupling at the higher critical temperature and low photon rate. The Coupling of quark and gluon in Table (2) was decreased with the increase of the temperature of the system from 180 MeV to 360 MeV, which was a significant influence on the rate. The coupling was decreased with the increase temperature of system in the range of 180 MeV to 360MeV for $\bar{c}$g $\rightarrow \bar{d}$ γ system. The approach expression in Eq.(27) shows that coupling proportional with critical temperature and temperature of $\bar{c}$g $\rightarrow \bar{d}$ γ system . The coupling of quark-gluon collisions at $\bar{c}$g $\rightarrow \bar{d}$ γ system varied at different critical temperature. As seen as from Table (2), the coupling increases with increaseing the critical temperature and increases temperature from 180 MeV to 360MeV.Figures (1) (2),(3) and (4) and Tables 3),(4),(5)and (6) are shown the photon rate spectra in unit $\frac{1}{GeV^2 fm^4}$ for $\bar{c}$g $\rightarrow \bar{d}$ γ interaction compute using the theoretical using many critical temperature 116.575 , 139.891, 157.377 and 174.863 MeV and coupling α_{QCD} =0.4161, 0.3884, 0.3672, 0.3503, 0.3365, 0.3249 and 0.3149 in temperature of system from 180MeV to 360 MeV .In tables (3),(4),(5) and (6) ,the rate reaches to maximum $3.7173\text{E}-09\ \frac{1}{GeV^2 fm^4}$ for $T_c = 116.575\ MeV$ with α_{QCD} =0.3149, $3.9414\text{E}-09\frac{1}{GeV^2 fm^4}$, for $T_c = 139.891 MeV$ with 0.2968, $4.1011\text{E}-09\frac{1}{GeV^2 fm^4}$ for $T_c = 157.377 MeV$ with α_{QCD} =0.3088 and $4.2553\text{E}-09\ \frac{1}{GeV^2 fm^4}$ for $T_c = 174.863 MeV$ with α_{QCD} =0.3204 at T=360 MeV and $E = 1\ GeV$. On the other hand , the rate is reached minimum $6.5568\text{E}-34\ \frac{1}{GeV^2 fm^4}$ for $T_c = 116.575\ MeV$ with α_{QCD} =0.4161 , $7.0695\text{E}-34\ \frac{1}{GeV^2 fm^4}$, for $T_c = 139.891 MeV$ with $\alpha_{QCD} = 0.3850$, $7.4456\text{E}-34\frac{1}{GeV^2 fm^4}$ for $T_c = 157.377\ MeV$ with $\alpha_{QCD} = 0.4055$ and $7.8177\text{E}-34\frac{1}{GeV^2 fm^4}$ for $T_c = 174.863\ MeV$ with α_{QCD} =0.4257 $E = 10\ GeV$ and T=180 MeV in tables (3),(4),(5) and (6) respectively . In Figures (1) to (4), we can notice the rate of photon spectra in $\bar{c}$g $\rightarrow \bar{d}$ γ collision. The rate of photon yields from the in $\bar{c}$g $\rightarrow \bar{d}$ γ system decreases with increasing the energy of photons E(GeV) from 1 to 10 GeV at critical temperatures from $T_c = 116.575$ to 174.863 MeV with six flavors number and various temperatures of system. The rate of photon yields from interaction of quark –gluon in $\bar{c}$g $\rightarrow \bar{d}$ γ system increases with increasing energy of the system and decreases the coupling with an increasing critical temperature. It can be seen from Table (6) and Figure (4) that the rate of photon was with large value at the critical temperature of T_c=174.863 MeV when compared to the less rate at the T_c=116.575 MeV. However, the photon rate was reached to maximum from $\bar{c}$g $\rightarrow \bar{d}$ γ system at the energy of photons $E \leq 2GeV$ in Tables from (3) to (6) and Figures from (1) to (4) compares to minimum for $\geq 2GeV$. In general, the theoretical model of photons spectrum shows that rate increases to the high values and effects by increases the temperature of the system and decreases the coupling between anti charm quark and gluon to produces anti down with photons emission at any critical temperature in all Tables from (3) to (6) for the $\bar{c}$g $\rightarrow \bar{d}$ γ system with $n_f = 6$.

5. CONCLUSION

A systematic discussion of a hard collision of quark-gluon to produce photon spectra at chemical potential $\mu_q = 500\ MeV$ is presented with emphasis on the influences of the coupling, temperature of the system, photon energy and critical temperature of quark flavors on photons spectrum. The rate of photon emission at various critical temperatures and coupling of quark and gluon calculated according to the expression of photon emission using a simple model for collisions for anti-charm quark interaction with gluon to produce anti-down and photons in the energy region. The models of the emission of photon rate was based on the QCD model that describes the collision in six flavour numbers. According to the implemented expression of the photon rate equation, we can conclude that there is a significant influence on the coupling, temperature of the system, photon energy and critical temperature on the contribution of the rate of photon behavior of the $\bar{c}$g $\rightarrow \bar{d}$ γ interaction. The coupling photon energy, critical temperature and temperature of the system have been an ingredient in the production of the photon rate. We discussed the feature of the QCD effect on the photon rate of the anti-charm -gluon interaction at a temperature of the system in the range of 180-360 MeV.

With regard to possible QCD features; coupling, the temperature of the system, critical temperature and photon energy to produce the photon was quantitatively achieved for a unique flavor number of n_f = 4 + 2 of the photons spectrums. The interest of data in the case of flavour number n_f=6 was the minimum of photon rate at E=10 GeV especially. It indicates the weak proportional of quarks and gluons which was already expected. Finally, the rate of photon will be producing in higher energy, it is a good tool to work with nucleons structure.

6. REFERENCES

[1] Al-Agealy, Hadi JM, and Mudhafar J. Sahib. "Theoretical evaluations of probability of photons yield depending on quantum chromodynamics theory." Ibn AL-Haitham Journal for Pure and Applied Science (2018): 179-186.

[2] Ashwiekh, Ahmed M., Saba Mustafa Hussein, Hadi JM Al-Agealy, and Mohsin A. Hassooni. "Flow Production Rate of Hard Photons Probes of Quark–Anti Quark Annihilation Processes at Plasma Phase." In IOP Conference Series: Materials Science and Engineering, vol. 871, no. 1, p. 012089. IOP Publishing, 2020.

[3] Aarts, Gert, Chris Allton, Simon Hands, Benjamin Jäger, Chrisanthi Praki, and Jon-Ivar Skullerud. "Nucleons and parity doubling across the deconfinement transition." Physical Review D 92, no. 1 (2015): 014503.

[4] Al-Agealy, Hadi JM, Hyder Hamza Hussein, and Saba Mustafa Hussein. "Theoretical estimation of Photons flow rate Production in quark gluon interaction at high energies." In Journal of Physics: Conference Series, vol. 1003, no. 1, p. 012119. IOP Publishing, 2018.

[5] Wang, Xinyang, Igor A. Shovkovy, Lang Yu, and Mei Huang. "Ellipticity of photon emission from strongly magnetized hot QCD plasma." Physical Review D 102, no. 7 (2020): 076010.

[6] Bkmurd, Rana Issa, Hadi JM Al-Agealy, and Ahmed M. Ashwiekh. "Investigation and Study of Photonic Current Rate in Bremsstrahlung process." In Journal of Physics: Conference Series, vol. 1879, no. 3, p. 032094. IOP Publishing, 2021

[7] Cao, Shanshan, Guang-You Qin, and Steffen A. Bass. "Energy loss, hadronization, and hadronic interactions of heavy flavors in relativistic heavy-ion collisions." Physical Review C 92, no. 2 (2015): 024907.

[8] Mukherjee, Swagato, Peter Petreczky, and Sayantan Sharma. "Charm degrees of freedom in the quark gluon plasma." Physical Review D 93, no. 1 (2016): 014502.

[9] Sinyukov, Yuri, and Volodymyr Shapoval. "Direct Photon Production in High-Energy Heavy Ion Collisions within the Integrated Hydrokinetic Model." J 5, no. 1 (2022): 1-14.

[10] 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 Science 33, no. 4 (2020): 34-41.

[11] Yang, Yi, and Cheng-Wei Lin. "Search for axion (-like) particles in heavy-ion collisions." Journal of High Energy Physics 2022, no. 7 (2022): 1-12.

[12] Paquet, Jean-François, Chun Shen, Gabriel S. Denicol, Matthew Luzum, Björn Schenke, Sangyong Jeon, and Charles Gale. "Production of photons in relativistic heavy-ion collisions." Physical Review C 93, no. 4 (2016): 044906.

[13] Aurenche, Patrick, François Gelis, H. Zaraket, and R. Kobes. "Bremsstrahlung and photon production in thermal QCD." Physical Review D 58, no. 8 (1998): 085003.

[14] Dutta, D., S. V. S. Sastry, A. K. Mohanty, and K. Kumar. "Hard photon production from unsaturated quark–gluon plasma at two-loop level." Nuclear Physics A 710, no. 3-4 (2002): 415-438.

[15] Long, J. L., Z. J. He, Y. G. Ma, and B. Liu. "Hard photon production from a chemically equilibrating quark-gluon plasma with finite baryon density at one loop and two loop." Physical Review C 72, no. 6 (2005): 064907.

[16] Al Maadhede, Taif Saad, Hadi JM Al-Agealy, Bahjat B. Kadhim, and Hind Abdulmajeed Mahdi. "Theoretical Study of Hard Photonic Produce from Interaction of Quark-Gluon at Critical Temperature 190MeVand196MeV." NeuroQuantology 20, no. 4 (2022): 588-595.

[17] Peskin, Michael. An introduction to quantum field theory. CRC press, 2018.

[18] Cottingham, W. Noel, and Derek A. Greenwood. An introduction to the standard model of particle physics. Cambridge university press, 2007.

[19] Peskin, Michael E. "Beyond the standard model." arXiv preprint hep-ph/9705479 (1997).

[20] Biro, T. S., E. Van Doorn, B. Müller, M. H. Thoma, and X-N. Wang. "Parton equilibration in relativistic heavy ion collisions." Physical Review C 48, no. 3 (1993): 1275.

[21] Al-Agealy, Hadi JM, and Nada Farhan Kadhim. "Theoretical Calculation of Photon Emission from Quark-Antiquark Annihilation Using QCD Theory." Ibn AL-Haitham Journal for Pure and Applied Sciences 35, no. 4 (2022): 37-44.

[22] Ahmed, Elaf Mohammed, Hadi JM Al-Agealy, and Nada Farhan Kadhim. "Theoretical and Calculation the Photon Production from Quark-Antiquark Interaction." Journal of Education and Scientific Studies 5, no. 20 (2022).

[23] Begun, Viktor V., Mark I. Gorenstein, and Oleg A. Mogilevsky. "Equation of state for the quark gluon plasma with the negative bag constant." arXiv preprint arXiv:1001.3139 (2010).

[24] Kasmaei, Babak S., and Michael Strickland. "Photon production and elliptic flow from a momentum-

anisotropic quark-gluon plasma." Physical Review D 102, no. 1 (2020): 014037.

[25] Ahmed, Elaf Mohammed, Hadi JM Al-Agealy, and Nada Farhan Kadhim. "Theoretical Study of Photons Spectra around High Energy of Quark-antiquark UsingQCD Theory." NeuroQuantology 20, no. 4 (2022): 58.

[26] Peitzmann, Thomas, and Markus H. Thoma. "Direct photons from relativistic heavy-ion collisions." Physics Reports 364, no. 3 (2002): 175-246.

[27] Yazdizadeh, T., and G. H. Bordbar. "The effect of a density-dependent bag constant on the structure of a hot neutron star with a quark core." Astrophysics 56, no. 1 (2013): 121-129.