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Calculation and Analysis Of The Photon Rate Produce From Anti-Up Quark –Gluon Interaction Using The QCD Theory

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Abstract :

In this paper, we investigate theoretically the photon produces in nuclear interactions using the quantum chromodynamic QCD theory of the quark-gluon interaction . The QCD theory is implemented to derive a set of rate equations describing the interaction of quarks and gluons at a chemical potential $\mu_q = 500\ MeV$ .We focused on the photon rate calculated for anti-up-gluon interaction of the $\bar{u}g \rightarrow \bar{d}\ \gamma$ interaction at the energy of the system from (180 to 360) MeV and critical temperature 132.386, , 178.72 and 198.579 MeV with a range of photon energy from 1 GeV to 10 GeV with assuming of fugacity parameters of quark and gluon should be equal to λ_g=0.08, $\lambda_{\bar{q}}$=0.02 for gluon and quars are crude approximation. We examine the significant influence of strong coupling, critical temperature, and photons energy on the produced photon emission from the interaction the $\bar{u}g \rightarrow \bar{d}\ \gamma$ system . We show that photons emission rate increased with decreased strong coupling of quark-gluon due to the decreased energy of system from (360 to 180) MeV.

Here we present the spectrum of photons using photon energy intake account $1GeV \leq E \leq 10GeV$ with four critical temperatures . Regarding possible QCD features are quantitatively achieved for a unique flavour number n_f = 2 + 1 of the photon spectrum. The interesting point of the photon rate is minimum at the photon energy E=10 GeV which reflects the poor coupling between quark and gluon for the $\bar{u}g \rightarrow \bar{d}\ \gamma$ interaction.

Key words: Photon Rate , Anti-Up -Gluon , The QCD Theory .

حساب وتحليل إنتاج معدل الفوتون
من تفاعل مضاد كوارك فوقي-جلون باستخدام نظرية QCD

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الخلاصة:

في هذا البحث ، نتحرى تحقيقا نظريًا عن إنتاج الفوتون في التفاعلات النووية باستخدام نظرية الكم الديناميكي الكمومية QCD لتفاعل كوارك – جلون. تم تنفيذ نظرية QCD لاشتقاق مجموعة من معادلات المعدل التي تصف تفاعل كوارك – جلون عند جهد كيميائي $\mu_q = 500\ MeV$ ركزنا على معدل الفوتون المحسوب للتفاعل مضاد كوارك فوقي – جلون للتفاعل $\bar{u}g \rightarrow \bar{d}\ \gamma$ عند طاقة النظام من (180 إلى360) مليون إلكترون فولت ودرجة الحرارة الحرجة (132.386و 158.863و 178.72 و 198.579) مليون إلكترون فولت مع نطاق من طاقة الفوتون من 1GeV إلى 10 GeV مع افتراض معلمات انفلات كوارك – جلون يجب أن تكون مساوية لـ λ_g=0.08, $\lambda_{\bar{q}}$=0.02 ل كوارك – جلون هي تقريب مقبول. قمنا بفحص التأثير الهام للاقتران القوي ودرجة الحرارة الحرجة وطاقة الفوتونات على انبعاث الفوتون الناتج من تفاعل نظام $\bar{u}g \rightarrow \bar{d}\ \gamma$. لقد ظهر أن معدل انبعاث الفوتونات زاد مع انخفاض الاقتران القوي لكوارك – جلون بسبب انخفاض طاقة النظام من (360إلى180) مليون إلكترون فولت. نقدم هنا طيف الفوتونات باستخدام طاقة الفوتون $1GeV \leq E \leq 10GeV$ مع مراعاة أخذ أربع درجات حرارة حرجة. فيما يتعلق بخصائص QCD الممكنة يتم تحقيقها كميًا لرقم نكهة فريد 3 = n_f من طيف الفوتون. النقطة المثيرة للاهتمام لمعدل الفوتون هي الحد الأدنى عند طاقة الفوتون E = 10 GeV والتي تعكس الاقتران الضعيف بين الكوارك وغلون للتفاعل $\bar{u}g \rightarrow \bar{d}\ \gamma$.

الكلمات المفتاحية: معدل الفوتون ، مضاد كوارك فوقي-جلون ، نظرية QCD .

Introduction

High-energy physics introduced the basic theory to understand elementary particles and interactions depending on the standard model theory[1]. The fundamental constituents of the nucleons are elementary particles called quarks and gluons. Both gluons and quarks play an essential role in producing the mass of nucleons[2].The quark-gluon played a fundamental role in the development of the quantum chromodynamics theory of strong interaction[3] . Moreover, the quark-gluon used to study of behavior of nucleons created at relativistic heavy-ion collision depending on experimental from CERN and RHIC at BNL4]]. The standard model is the mathematical framework to describe elementary particles and the interactions of electromagnetism, weak, and strong interactions .However ,standard model had tremendous success to understand new state of matter of QCD theory and quark-gluon interaction5].]. The quarks model introduces a good picture to develop and describe the characteristic of hadrons. However, the color hypothesis introduced by Greenberg to describe the quarks has three colors degrees of freedom[6]. According to the color hypothesis, the quarks have two behavior confinement and asymptotic phenomena, quark bounds into the color media in hadrons by a variety of configurations[7]. A photon is emitted due to various mechanisms; thermal photons, prompt photons, and jet-medium photons . Photon emitters through the interaction of quark and gluon in QGP phase and hadron phase due to jet, and due to decay of resonances into real photons[8]. Moreover, the high temperature is never an extreme feature of the creation of quark-gluon interaction in heavy ion collisions.[9]

The photons are produced from quark-gluon interaction by different processes; decay photons from hadron decays and direct photons . Moreover ,the direct photons are divided to prompt photons emitted at hard partonic scatterings and jet fragmentations and thermal photons emitted from the quark-gluon medium[10]. In the present work, we calculate and analysis the photon rate at $\bar{u}g \rightarrow \bar{d}\,\gamma$ system interaction take into account the critical temperature ,coupling of quark-gluon ,energy of system ,fugacity of quark and gluon and integral constant I_T and I_L .

Theory

The rate of hard photon was produced through quark-gluon interaction with energy E and momentum P gives via QCD theory by [11].

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

Where $f_B(E)$ is the Bosonic distribution function and $\mathrm{Im}\prod_{qg}^{H}(E,P)$ is imaginary part of retarded self-energy polarization at finite temperature and gives by[12].

$$\mathrm{Im}\prod_{qg}^{H}(E,P) = (-1)\frac{NC_a}{\pi^4} g_E{}^2 g_H{}^2 \frac{T}{E^2} \left|\mathrm{I}_{T,L}\right| \int_0^\infty \left(f_q(P) - f_q(E-P)\right)(P^2 + (E-P)^2)\, dP \ldots\ldots\ldots\ldots\ldots(2)$$

Where N is net number of flavor for system , C_a is the Casimir operator, g_E and g_H are the quantum electrodynamics and quantum chromo dynamic coupling respectively , $f_q(P)$ is the Fermi distribution of quark, $\mathrm{I}_{T,L} = \mathrm{I}_T - \mathrm{I}_L$ is the self-integral of system relative to dimensionless constant I_T and I_L [13].. The Eq.(3-6) together Eq.(3-3) and for all electric charge $\sum e_q^2$ for quarks leads to

$$\mathrm{Im}\prod_{qg}^{H}(E,P) = (-1)\frac{N_c C_a}{\pi^4} g_E{}^2 g_H{}^2 \frac{T}{E^2} \left|\mathrm{I}_T - \mathrm{I}_L\right| \sum e_q^2 \int_0^\infty \left(f_q(P) - f_q(E-P)\right)(P^2 + (E-P)^2)\, dP \ldots\ldots\ldots\ldots\ldots(3)$$

The Juttner distribution function $f_q(P)$ and $f_q(p-E)$ as function of fugacity coefficient λ_q for quarks and writs [14]

$$f_q(P) = \frac{\lambda_q}{e^{\frac{(p+\mu_q)}{T}} + \lambda_q} \ldots\ldots\ldots\ldots\ldots .(4)$$

$$f_q(p-E) = \frac{\lambda_q}{e^{\frac{(E-p-\mu_q)}{T}} + \lambda_q} \ldots\ldots\ldots\ldots(5)$$

where μ_q is chemical potential coefficient . Obviously, the chemical potential with fugacity of quarks and gluons $\lambda_{q,g} = e^{\frac{\mu_{q,g}}{T}}$ is [15]. Substituting both Eq.(4) and Eq.(5) in Eq.(3) and expand $(P^2 + (E-P)^2) = P^2 + E^2 - 2EP + P^2 = 2P^2 + E^2 - 2EP$ to results .

$$\mathrm{Im}\prod_{qg}^{H}(E,P) = (-1)\frac{N_c C_a}{\pi^4} g_E{}^2 g_H{}^2 \frac{T}{E^2} \left|\mathrm{I}_T - \mathrm{I}_L\right| \sum e_q^2 \left[\int_0^\infty \frac{(2P^2+E^2-2EP)}{\left(\frac{e^{\frac{(p+\mu_q)}{T}}}{\lambda_q}+1\right)} dP - \int_0^\infty \frac{(2P^2+E^2-2EP)}{\left(\frac{e^{\frac{(E-p-\mu_q)}{T}}}{\lambda_q}+1\right)} dP\right] \ldots\ldots\ldots\ldots\ldots(6)$$

We assume that

$$A_1 = \int_0^\infty \frac{(2P^2+E^2-2EP)}{\left(\frac{e^{\frac{(p+\mu_q)}{T}}}{\lambda_q}+1\right)} dP = \int_0^\infty \left[\frac{e^{\frac{-(p+\mu_q)}{T}}}{\lambda_q{}^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{\lambda_q{}^{-2}} + \frac{e^{\frac{-3(p+\mu_q)}{T}}}{\lambda_q{}^{-3}} - \frac{e^{\frac{-4(p+\mu_q)}{T}}}{\lambda_q{}^{-4}} - \cdots .. \frac{e^{\frac{-n(p+\mu_q)}{T}}}{\lambda_q{}^{-n}}\right](2P^2 - 2EP + E^2)dP \ldots\ldots\ldots\ldots\ldots(7)$$

$$A_2 = \int_0^\infty \frac{(2P^2+E^2-2EP)}{(\frac{e^{\frac{(E-p-\mu_q)}{T}}}{\lambda_q}+1)} dP = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{\lambda_q^{-2}} + \frac{e^{e^{\frac{-3(E-p-\mu_q)}{T}}}}{\lambda_q^{-3}} - \frac{e^{\frac{-4(E-p-\mu_q)}{T}}}{\lambda_q^{-4}} \dots\dots\dots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{\lambda_q^{-n}}](2P^2-2EP+E^2)dP \dots\dots\dots(8)$$

To solve both integrals Eq.(7) and Eq.(8) ,we can simply to write both integral in six term;

$$J_1 = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{\lambda_q^{-2}} + \dots - \dots \dots \frac{e^{\frac{-n(p+\mu_q)}{T}}}{\lambda_q^{-n}}](2P^2)dP \dots\dots\dots(9)$$

The second integral is

$$J_2 = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{\lambda_q^{-2}} + \dots - \dots \dots \frac{e^{\frac{-n(p+\mu_q)}{T}}}{\lambda_q^{-n}}](2PE)dP \dots\dots\dots(10)$$

The third integral is

$$J_3 = \int_0^\infty [\frac{e^{\frac{-(p+\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(p+\mu_q)}{T}}}{\lambda_q^{-2}} + \dots - \dots \dots \frac{e^{\frac{-n(p+\mu_q)}{T}}}{\lambda_q^{-n}}](E^2)dP \dots\dots\dots(11)$$

The fourth terms is

$$J_4 = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{\lambda_q^{-2}} + - \dots \dots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{\lambda_q^{-n}}](2P^2)dP \dots\dots(12)$$

The five integral term

$$J_5 = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{\lambda_q^{-2}} + \dots - \dots \dots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{\lambda_q^{-n}}](2PE)dP \dots(13)$$

The final integral term is

$$J_6 = \int_0^\infty [\frac{e^{\frac{-(E-p-\mu_q)}{T}}}{\lambda_q^{-1}} - \frac{e^{\frac{-2(E-p-\mu_q)}{T}}}{\lambda_q^{-2}} + \dots - \dots \dots \frac{e^{\frac{-n(E-p-\mu_q)}{T}}}{\lambda_q^{-n}}](E^2)dP \dots(14)$$

The solutions of six term are given by .

$$J_1 = 2T^3\left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2^3} + \cdots - \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n\mu_q}{T}}\right]\Gamma(3) \ldots\ldots\ldots (15)$$

Second term in term J_2 is.

$$J_2 = 2ET^2\Gamma(2)\left[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1^2} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2^2} + \cdots - \cdots \frac{\lambda_q{}^n e^{\frac{-n\mu_q}{T}}}{n^2}\right] \ldots\ldots\ldots\ldots (16)$$

Third term integral in J_3

$$J_3 = E^2T[\frac{\lambda_q{}^1 e^{\frac{-\mu_q}{T}}}{1} - \frac{\lambda_q{}^2 e^{\frac{-2\mu_q}{T}}}{2} + \cdots - \cdots \frac{\lambda_q{}^{ne^{\frac{-n\mu_q}{T}}}}{n})\Gamma(1) \ldots\ldots (17)$$

On the other hand, the fourth term is .

$$J_4 == 2T^3\Gamma(3)[\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^3} + \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n(E-\mu_q)}{T}}] \ldots\ldots\ldots\ldots (18)$$

The five integral term is.

$$J_5 = 2ET^2\Gamma(2)[\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^2} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^2} .. - \frac{\lambda_q{}^5 e^{\frac{-5(E-\mu_q)}{T}}}{5^2} + \cdots \frac{\lambda_q{}^n}{n^2} e^{\frac{-n(E-\mu_q)}{T}}] \ldots\ldots\ldots\ldots (19)$$

The six term integral is gives .

$$J_6 = E^2T\Gamma(1)(\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2} .. + \frac{\lambda_q{}^5 e^{\frac{-5(E-\mu_q)}{T}}}{5} \ldots + \frac{\lambda_q{}^n}{n} e^{\frac{-n(E-\mu_q)}{T}}) \ldots\ldots\ldots\ldots (20)$$

Inserting the results of J_1 , J_2 , and J_3 in Eq.(7) to give A_1 .

$$A_1 = \int_0^\infty \frac{\lambda_q(2P^2+E^2-2EP)}{e^{\frac{(p+\mu_q)}{T}}+\lambda_q} dP =$$

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

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

On the other hand ,we insert the J_4 , J_5 , and J_6 in Eq.(8) to result integral term A_2 .

$$A_2 = \int_0^\infty \frac{\lambda_q(2P^2+E^2-2EP)}{e^{\frac{(E-p-\mu_q)}{T}}+\lambda_q}dP = 2T^3\Gamma(3)\left[\frac{\lambda_q{}^1 e^{\frac{-(E-\mu_q)}{T}}}{1^3} - \frac{\lambda_q{}^2 e^{\frac{-2(E-\mu_q)}{T}}}{2^3} + \cdots + \cdots \frac{\lambda_q{}^n}{n^3} e^{\frac{-n(E-\mu_q)}{T}}\right]$$

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

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

We assume $J = A_1 + A_2$,then with using Eq.(21) and Eq.(22)

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

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

$$E^2T\left[\frac{\lambda_q{}^1}{1}\left(e^{\frac{-\mu_q}{T}} + e^{\frac{-(E-\mu_q)}{T}}\right) - \frac{\lambda_q{}^2}{2}\left(e^{\frac{-2\mu_q}{T}} + e^{\frac{-2(E-\mu_q)}{T}}\right) \ldots\ldots \frac{\lambda_q{}^n}{n}\left(e^{\frac{-n\mu_q}{T}} + e^{\frac{-n(E-\mu_q)}{T}}\right)\right)\Gamma(1) \ldots\ldots\ldots(23)$$

Inserting Eq.(23) in Eq.(6) to give

$$\mathrm{Im}\prod_{qg}^{H}(E,P) = (-1)\frac{N_C C_a}{\pi^4} g_E{}^2 g_H{}^2 \frac{T}{E^2} \left|\mathrm{I_T} - \mathrm{I_L}\right| \sum e_q^2 \times 2T^3\left[\frac{\lambda_q{}^1}{1^3}\left(e^{\frac{-\mu_q}{T}} + e^{\frac{-(E-\mu_q)}{T}}\right) - \frac{\lambda_q{}^2}{2^3}\left(e^{\frac{-2\mu_q}{T}} + e^{\frac{-2(E-\mu_q)}{T}}\right) +\right.$$

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

$$E^2T\left[\frac{\lambda_q{}^1}{1}\left(e^{\frac{-\mu_q}{T}} + e^{\frac{-(E-\mu_q)}{T}}\right) - \frac{\lambda_q{}^2}{2}\left(e^{\frac{-2\mu_q}{T}} + e^{\frac{-2(E-\mu_q)}{T}}\right) + \cdots \frac{\lambda_q{}^n}{n}\left(e^{\frac{-n\mu_q}{T}} + e^{\frac{-n(E-\mu_q)}{T}}\right)\right)\Gamma(1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(24)$$

We assume that

$$\gamma(E,T,\lambda_q,\mu_q) = \left[2T^3\Gamma(3)\left(\frac{\lambda_q{}^1}{1^3} - \frac{\lambda_q{}^2}{2^3} + \frac{\lambda_q{}^3}{3^3} - \frac{\lambda_q{}^4}{4^3} + \frac{\lambda_q{}^5}{5^3} - \cdots \frac{\lambda_q{}^n}{n^3}\right) + 2ET^2\Gamma(2)\left(\frac{\lambda_q{}^1}{1^2} - \frac{\lambda_q{}^2}{2^2} + \frac{\lambda_q{}^3}{3^2} -\right.\right.$$

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

$$\left(e^{\frac{-2\mu_q}{T}} + e^{\frac{-2(E-\mu_q)}{T}}\right) + \left(e^{\frac{-3\mu_q}{T}} + e^{\frac{-3(E-\mu_q)}{T}}\right) + \left(e^{\frac{-4\mu_q}{T}} + e^{\frac{-4(E-\mu_q)}{T}}\right) + \left(e^{\frac{-5\mu_q}{T}} + e^{\frac{-5(E-\mu_q)}{T}}\right) \ldots +$$

$$\left.\left(e^{\frac{-n\mu_q}{T}} + e^{\frac{-n(E-\mu_q)}{T}}\right)\right) \ldots\ldots\ldots\ldots (25)$$

The Eq.(25) together Eq.(24) gives

$$\mathrm{Im}\prod_{qg}^{H}(E,P) = (-1)\frac{N_c C_a}{\pi^4} {g_E}^2 {g_H}^2 \frac{T}{E^2} \, |\mathrm{I_T} - \mathrm{I_L}| \, \sum e_q^2 \, \gamma\left(E,T,\lambda_q,\mu_q\right) \ldots\ldots\ldots (26)$$

Inserting the Casimiro operator $C_a = \frac{(N_c^2-1)}{2N_c} = \frac{4}{3}$ relative to color number $N_c = 3$ [16] and the effective strength coupling parameter for QCD theory is $\alpha_{QCD}(\mu^2) = \frac{{g_H}^2}{4\pi}$ [17] and quantum electrodynamics QED coupling constant is $\alpha_{\mathrm{QED}} = \frac{{g_E}^2}{4\pi}$ [18] in Eq.(26) to become

$$\mathrm{Im}\prod_{qg}^{H}(E,P) = (-1)4\frac{N}{\pi^2}\frac{16}{3}\alpha_{\mathrm{QED}}\alpha_{QCD}(\mu^2)\sum e_q^2 \, |\mathrm{I_T} - \mathrm{I_L}| \, \frac{T}{E^2}\gamma\left(E,T,\lambda_q,\mu_q\right) \ldots . (27)$$

Inserting Eq.(27) in Eq.(1) to results .

$$\mathrm{R}_{qg}^{H}(E,P) = \frac{8N}{3\pi^5}\alpha_{\mathrm{QED}}\alpha_{QCD}(\mu^2)\sum e_q^2 \, |\mathrm{I_T} - \mathrm{I_L}| \, \frac{T}{E^2}\mathrm{F}_B(\mathrm{E}) \, \frac{T}{E^2}\gamma\left(E,T,\lambda_q,\mu_q\right) \ldots . (28)$$

The Bosonic function distribution for gluon $\mathrm{f}_B(\mathrm{E}) = \frac{\lambda_g}{e^{\frac{E}{T}} - \lambda_g}$ [19],then Eq.(28) become.

$$\mathrm{R}_{qg}^{H}(E,P) = \left(\frac{8N}{3\pi^5}\right)\frac{\lambda_g}{e^{E/T} - \lambda_g}\alpha_{\mathrm{QED}}\alpha_{QCD}(\mu^2)\frac{T}{E^2} \, |\mathrm{I_T} - \mathrm{I_L}| \, \sum e_q^2 \, \gamma\left(E,T,\lambda_q,\mu_q\right) \ldots . (29)$$

the strong coupling constant is [20].

$$\alpha_{QCD}(\mu^2) = \frac{6\pi}{(33 - 2\,N_F)\,ln\frac{8T}{T_c}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

Where N_F is flavor number of quarks T , is temperature of system and T_C is critical temperature for the quark - gluon interaction , it gives by [21].

$$T_c = \left(\frac{90B}{\pi^2 d_{gq}}\right)^{\frac{1}{4}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

where B is the bag coefficient and d_{gq} is degeneracy factors for gluons and quarksand given by expression [22].

$$d_{gq} = d_g + \frac{7}{8}\left(d_q + d_{\bar{q}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (32)$$

where d_g is the number of gluons degrees of freedom as function of the gluons spin state and gluons color states n_c and d_g is the number of quarks degrees of freedom.as function of the number of quark colour n_c , spin n_s and flavour degrees of freedom n_f .Inserting together Eq.(32) in Eq.(31) to results as

$$T_c = \left(\frac{90B}{\pi^2[(n_s \times n_c) + \frac{7}{4}(n_c \times n_s \times n_f)]}\right)^{\frac{1}{4}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (33)$$

Results

An essential estimations in the critical temperature are predicted near the phase transition scale which is called the hadronic phase .The first step to evaluate of photon rate is calculated the critical temperature $T_c\ MeV$ due to the bag coefficient B in Eq.(33) .The degeneracy factor d_{gq} for gluon , $\bar{u}$ and $\bar{d}$ quarks is the main important factors to calculate the critical temperature associated with bag constant B .For anti -up and anti-down interaction ,the degeneracy d_{gq} in Eq.(30) as function to spin state n_s = 2 and n_c = 8 for gluons and function to n_s = 2, n_c = 3 and n_f = 3 for anti-up and anti-down quarks in system with taken the Bag constant from table (1) and inserting in Eq.(33), results are tabulated in table (1)

Table (1): Result of critical temperature uses the Bag mode of the quark -gluon system for $\bar{u}g \rightarrow \bar{d}\ \gamma$ System.

Bag constant $B^{1/4} MeV$[21]	$T_c\ MeV$
200	132.386
240	158.863
270	178.721
300	198.579

To calculate the coupling strength between quarks in Eq.(30), we substitute the critical temperature from table (1) with take account the energy of $\bar{u}g \rightarrow \bar{d}\ \gamma$ system in range T=180 to 360 MeV by inceased by 30 Mev with n_f = 3. The results of coupling show in table(2) .

Table(2) . The coupling strength of $\bar{u}g \rightarrow \bar{d}\ \gamma$ system at different critical temperature with variety temperature of system .

T_c	α_{QCD}						
	T= 180MeV	T= 210MeV	T= 240MeV	T= 270MeV	T= 300MeV	T= 330MeV	T= 360MeV
132.386	0.2925	0.2748	0.2610	0.2500	0.2409	0.2333	0.2267
158.863	0.3167	0.2960	0.2801	0.2675	0.2571	0.2484	0.2409
178.721	0.3346	0.3116	0.2940	0.2801	0.2688	0.2593	0.2512
198.579	0.3524	0.3269	0.3077	0.2925	0.2801	0.2698	0.2610

A complementary scenario for calculation the photon rate seems to completed when estimate the electric charge and flavour number of system , where one should be calculated the electric charge of quarks in system but no electric charge for gluon Therefore, summation methods $\sum e_q^2$ have been used to estimate the electric charge for system , which has already been to apply on anti-up and anti-down quarks to extractions of net charge $\sum e_q^2$=5/9 of $\bar{u}g \rightarrow \bar{d}\ \gamma$ system where charge of up quark is +2/3 and anti-down is -1/3 ,while the net favor is $n_f = 3$ for $\bar{u}g \rightarrow \bar{d}\ \gamma$ interaction system . From Eq.(29) follows Eq.(31), the photon emission rate produces from the anti-up -gluon interaction has been calculated with inserts the critical temperature from table(1), coupling α_{QCD} μ^2 from table (2), the self-integral constant I_L= 4.26 and I_T= 4.45 [12] with using α_{QCD} = 1/137 and n_f = 3 and take the photon energy from experimental result *E= 1,2,3,4,5,6,7,8,9 and 10GeV* [23]. Specifically ,we consider here the fugacity λ_q=0.02 for quark and λ_g =0.08 for gluon [24] and taken the chemical potential μ_q*=500MeV* [25]. Results are given in tables (3) ,(4),(5) ,(6) and figures (1),(2),(3) and (4).

Table (3): Results of photon rate produces at T_C= 132.386*MeV* , I_L= 4.26 and I_T= 4.45 , with λ_g=0.08, λ_q=0.02 and flavor number n_f = 3 for $\bar{u}g \rightarrow \bar{d}\ \gamma$ system .

$E_\gamma\ GeV$	$R^H_{qg}(E,P)\ \frac{1}{GeV^2 fm^4}$						
	T=180MeV	T=210MeV	T=240MeV	T=270MeV	T=300MeV	T=330MeV	T=360MeV
	α_{QCD} = 0.2925	α_{QCD} = 0.2748	α_{QCD} = 0.2610	α_{QCD} = 0.2500	α_{QCD} = 0.2409	α_{QCD} = 0.2333	α_{QCD} = 0.2267
1	1.0668E−11	4.9694E−11	1.6734E−10	4.5207E−10	1.0433E−09	2.1419E−09	4.0192E−09
2	1.6839E−14	1.6806E−13	9.9632E−13	4.1593E−12	1.3545E−11	3.6736E−11	8.6690E−11
3	6.0692E−17	1.3184E−15	1.3927E−14	9.0649E−14	4.1925E−13	1.5092E−12	4.4944E−12
4	2.2712E−19	1.0847E−17	2.0655E−16	2.1228E−15	1.4128E−14	6.8399E−14	2.6038E−13
5	8.6130E−22	9.0658E−20	3.1200E−18	5.0767E−17	4.8761E−16	3.1848E−15	1.5550E−14
6	3.2877E−24	7.6359E−22	4.7548E−20	1.2264E−18	1.7021E−17	1.5017E−16	9.4168E−16
7	1.2596E−26	6.4595E−24	7.2827E−22	2.9797E−20	5.9793E−19	7.1312E−18	5.7469E−17
8	4.8370E−29	5.4791E−26	1.1189E−23	7.2647E−22	2.1088E−20	3.4011E−19	3.5240E−18
9	1.8603E−31	4.6558E−28	1.7227E−25	1.7753E−23	7.4567E−22	1.6268E−20	2.1677E−19
10	7.1619E−34	3.9611E−30	2.6559E−27	4.3456E−25	2.6414E−23	7.7968E−22	1.3364E−20

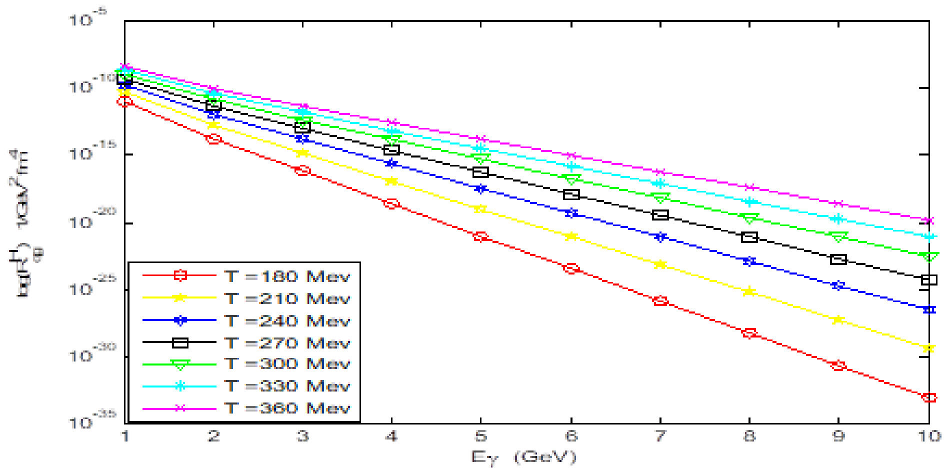

Figure (1): The rate of photon as a function to gamma energy produced at T_c=132.386.

Table (4) : Results of photon rate produces at T_c= 158.863 *MeV* , I_L = -4.26 and I_T = 4.45 , with λ_g =0.08, λ_q =0.02 and flavor number n_f = 3 for $\bar{u}g \rightarrow \bar{d}\ \gamma$ system .

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} = 0.3167	α_{QCD} = 0.2960	α_{QCD} = 0.2801	α_{QCD} = 0.2675	α_{QCD} = 0.2571	α_{QCD} = 0.2484	α_{QCD} = 0.2409
1	1.1550E-11	5.3536E-11	1.7959E-10	4.8365E-10	1.1134E-09	2.2809E-09	4.2721E-09
2	1.8232E-14	1.8105E-13	1.0692E-12	4.4498E-12	1.4455E-11	3.9119E-11	9.2145E-11
3	6.5712E-17	1.4203E-15	1.4946E-14	9.6981E-14	4.4740E-13	1.6071E-12	4.7772E-12
4	2.4590E-19	1.1685E-17	2.2166E-16	2.2711E-15	1.5077E-14	7.2836E-14	2.7677E-13
5	9.3254E-22	9.7666E-20	3.3482E-18	5.4314E-17	5.2035E-16	3.3915E-15	1.6529E-14
6	3.5596E-24	8.2261E-22	5.1027E-20	1.3121E-18	1.8164E-17	1.5992E-16	1.0009E-15
7	1.3638E-26	6.9589E-24	7.8155E-22	3.1878E-20	6.3808E-19	7.5938E-18	6.1085E-17
8	5.2371E-29	5.9027E-26	1.2008E-23	7.7722E-22	2.2504E-20	3.6218E-19	3.7457E-18
9	2.0141E-31	5.0157E-28	1.8487E-25	1.8994E-23	7.9574E-22	1.7323E-20	2.3041E-19
10	7.7543E-34	4.2673E-30	2.8502E-27	4.6491E-25	2.8188E-23	8.3026E-22	1.4205E-20

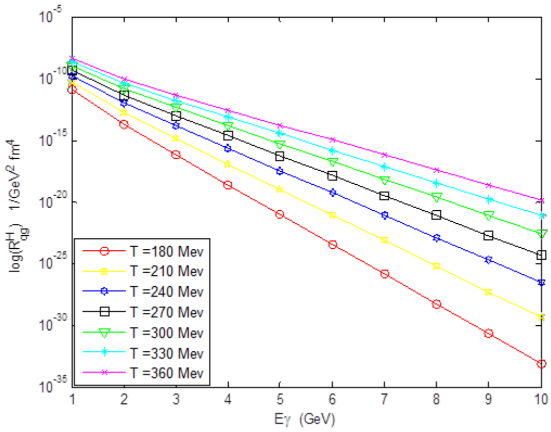

Figure (2): The rate of photon as a function to gamma energy produced at T_C= 158. 863 *MeV*.

Table (5) : Results of photon rate produces at T_C= 178.721 *MeV* , I_L = - 4.26 and I_T = 4.45 , with λ_g =0.08, λ_q =0.02 and flavor number n_f = 3 for $\bar{u}g \rightarrow \bar{d}\,\gamma$ system .

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} = 0.3346	α_{QCD} = 0.3116	α_{QCD} = 0.2940	α_{QCD} = 0.2801	α_{QCD} = 0.2688	α_{QCD} = 0.2593	α_{QCD} = 0.2512
1	1.2202E-11	5.6350E-11	1.8850E-10	5.0651E-10	1.1639E-09	2.3806E-09	4.4531E-09
2	1.9261E-14	1.9057E-13	1.1223E-12	4.6601E-12	1.5110E-11	4.0830E-11	9.6050E-11
3	6.9421E-17	1.4949E-15	1.5687E-14	1.0157E-13	4.6769E-13	1.6774E-12	4.9796E-12
4	2.5978E-19	1.2300E-17	2.3266E-16	2.3785E-15	1.5760E-14	7.6022E-14	2.8849E-13
5	9.8517E-22	1.0280E-19	3.5143E-18	5.6881E-17	5.4395E-16	3.5398E-15	1.7229E-14
6	3.7606E-24	8.6586E-22	5.3558E-20	1.3741E-18	1.8987E-17	1.6691E-16	1.0433E-15
7	1.4408E-26	7.3246E-24	8.2032E-22	3.3385E-20	6.6702E-19	7.9260E-18	6.3673E-17
8	5.5327E-29	6.2129E-26	1.2604E-23	8.1396E-22	2.3524E-20	3.7802E-19	3.9044E-18
9	2.1278E-31	5.2794E-28	1.9404E-25	1.9891E-23	8.3182E-22	1.8081E-20	2.4018E-19
10	8.1920E-34	4.4916E-30	2.9916E-27	4.8689E-25	2.9466E-23	8.6657E-22	1.4807E-20

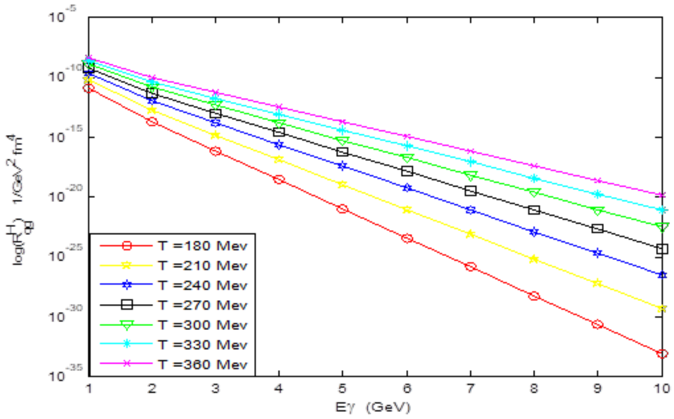

Figure (3): The rate of photon as a function to gamma energy produced at T_C = 178.721 *MeV* .

Table (6) : Results of photon rate produces at T_C = 198.579 *MeV* , I_L = - 4.26 and I_T = 4.45 , with λ_g =0.08, λ_q=0.02 and flavor number n_f = 3 for $\bar{u}g \rightarrow \bar{d}\,\gamma$ system .

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
	$\alpha_{QCD}=$ 0.3524	$\alpha_{QCD}=$ 0.3269	$\alpha_{QCD}=$ 0.3077	$\alpha_{QCD}=$ 0.2925	$\alpha_{QCD}=$ 0.2801	$\alpha_{QCD}=$ 0.2698	$\alpha_{QCD}=$ 0.2610
1	1.2851E-11	5.9130E-11	1.9725E-10	5.2887E-10	1.2131E-09	2.4776E-09	4.6286E-09
2	2.0286E-14	1.9997E-13	1.1744E-12	4.8659E-12	1.5749E-11	4.2493E-11	9.9834E-11
3	7.3113E-17	1.5687E-15	1.6416E-14	1.0605E-13	4.8746E-13	1.7457E-12	5.1758E-12
4	2.7360E-19	1.2906E-17	2.4346E-16	2.4835E-15	1.6427E-14	7.9117E-14	2.9986E-13
5	1.0376E-21	1.0787E-19	3.6775E-18	5.9392E-17	5.6694E-16	3.6839E-15	1.7908E-14
6	3.9606E-24	9.0858E-22	5.6045E-20	1.4348E-18	1.9790E-17	1.7371E-16	1.0845E-15
7	1.5174E-26	7.6860E-24	8.5841E-22	3.4859E-20	6.9522E-19	8.2488E-18	6.6181E-17
8	5.8270E-29	6.5195E-26	1.3189E-23	8.4989E-22	2.4519E-20	3.9341E-19	4.0583E-18
9	2.2410E-31	5.5398E-28	2.0305E-25	2.0770E-23	8.6699E-22	1.8817E-20	2.4964E-19
10	8.6277E-34	4.7132E-30	3.1305E-27	5.0838E-25	3.0712E-23	9.0186E-22	1.5390E-20

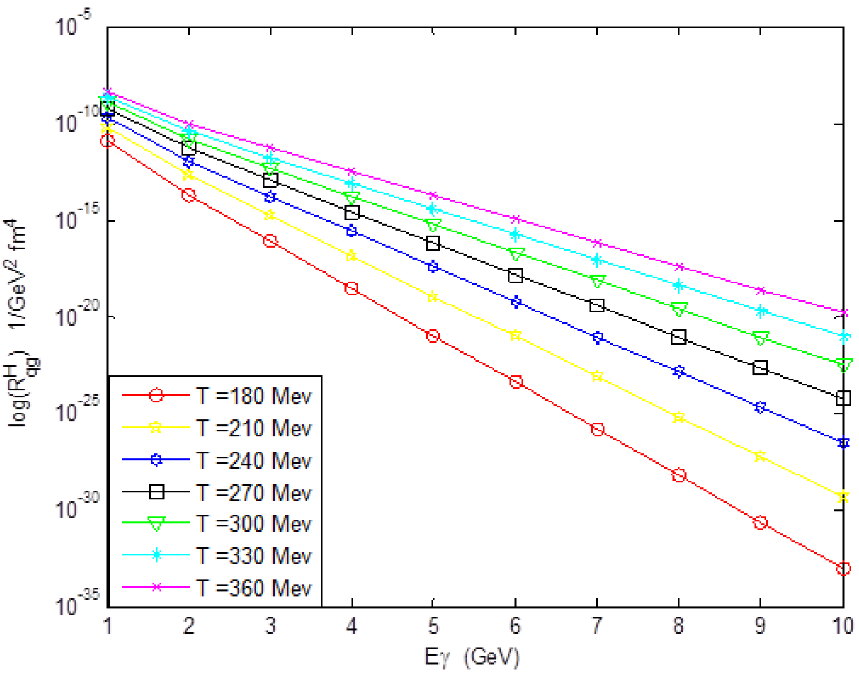

Figure (4): The rate of photon as a function to gamma energy produced at $T_C = 198.\ MeV$

Discussion

As has already to see the influence of the coupling ,energy of system ,photon energy and parameters of QCD theory on the photon rate from the expression in Eq.(29), we can find the results of this parameters are satisfied this .The strong coupling and photon energy are the main effect on the photon rate while the fugacity of quark and gluon ,quark charge are the much richer that alters the yields only slightly .In fact , the rate is related to the flavour number ,energy of system and critical temperature as consequence as dependent on the strong coupling. The critical temperature is underlying influence by flavour number and Bag constant .Table (1) shows the critical temperature increased with increased the bag constant ,it reach maximum 198.579 at bag constant 300MeV while reach minimum 132.386 at bag constant 200MeV This indicated that density of quark-gluon matter in the $\bar{u}g \rightarrow \bar{d}\ \gamma$ system increases leads to increase the bag constant, this agrees with experimental results of CERN SPS on the formation of a quark-gluon [26]. To discussion the influence of critical temperature on the photons rate ,we can perform the calculation with different critical temperature.However , one of the main motivations to calculate because the critical temperature is main factor influence on the photon rate through influence on strong coupling .We can be found less difference in photons rate for the two different critical temperatures and strength coupling .For the high critical temperature, a large strong coupling value is obtained than for the low critical temperature that indicating less coupling with agree with results in table (2). Thus, the strong coupling results in a table (2) decrease with the increase of the energy of the system in the range (180 -360)MeV, which has a significant effect on the photon rate. The strong coupling decreases with the increased thermal energy of system from 180 MeV to 360MeV in $\bar{u}g \rightarrow \bar{d}\ \gamma$ system .

The approach of strong coupling in Eq.(30) is also applied in the $\bar{u}g \rightarrow \bar{d}\ \gamma$ system, where thermal energy of $\bar{u}g \rightarrow \bar{d}\ \gamma$ system spectra are taken from 180 MeV to 360MeV . We examined the strong coupling in collisions of quarks at the of $\bar{u}g \rightarrow \bar{d}\ \gamma$ system under the assumption of a three flavoured quark-gluon state of matter (N_f = 3) and a range critical temperature of 132.386 MeV to 198.579 MeV. However, it can be seen from table (2) that the strong coupling was increased with increased the critical temperature and increased temperature of the system from 180 MeV to 360MeV.

Tables 3),(4),(5)and (6) are plotted in Figures (1) (2),(3) and (4) show the photon rate calculation for $\bar{u}g \rightarrow \bar{d}\ \gamma$ interaction at initial temperatures 180MeV to final temperature 360MeV and critical temperature in range 132.386 MeV to 198.579 MeV that were obtained for the assumptions three-flavored of $\bar{u}g \rightarrow \bar{d}\ \gamma$ system. The photon rate spectra computed under the theoretical model modifications in the quark-gluon interaction due to assuming a three-flavored number of photons produces in unit $\frac{1}{GeV^2 fm^4}$ for anti-up gluon -anti-down photon interaction using a variety of critical temperature and strong coupling α_{QCD}= 0.292 , 0.2748, 0.261 , 0.250 , 0.240 , 0.233 and 0.226 in range of energy of system from 180MeV to 360 MeV .The photon rate in tables (3),(4),(5) and (6) are maximum 4.0192E − 09 $\frac{1}{GeV^2 fm^4}$ for T_C= 132.386 MeV with α_{QCD}= 0.2267, 4.2721 E - 09 $\frac{1}{GeV^2 fm^4}$ for T_C= 158.863 MeV with 0.2409, 4.4531 E - 09 $\frac{1}{GeV^2 fm^4}$ for T_C= 178.72 MeV with 0.2512 and 4.6286 E - 09 $\frac{1}{GeV^2 fm^4}$ for T_C= 198.57 MeV with α_{QCD}=0.2610 at E = 1 GeV and T=360 MeV while the photon rate in tables (3),(4),(5) and (6) are minimum 7.1619 E - 34 $\frac{1}{GeV^2 fm^4}$ for T_C= 132.386 MeV with α_{QCD}= 0.2925, 7.7543 E - 34 $\frac{1}{GeV^2 fm^4}$ for T_C= 158.863.386 MeV with α_{QCD}=0.3167, 8.1920 E - 34 $\frac{1}{GeV^2 fm^4}$ for T_C= 178.72 MeV with α_{QCD} = 0.3346 and 8.6277 E - 34 $\frac{1}{GeV^2 fm^4}$ for T_C= 198.52 MeV with α_{QCD}=α_{QCD}=0.3524 at E=10 GeV and T=180 MeV .

Figures 1,2,3 and 4 indicate the photon rate spectra from the $\bar{u}g \rightarrow \bar{d}\ \gamma$ interaction .The photon rate yields from the quark-gluon state of $\bar{u}g \rightarrow \bar{d}\ \gamma$ are decreased with increased the photons energy E(GeV) at critical temperatures from 132.386 to 198.579 MeV and variety temperatures of system with three flavors number. There are increased with decreased the photons energy E(GeV) at different critical temperatures with varying temperatures of system with flavor number n_f = 3 .The photon yields rates from $\bar{u}g \rightarrow \bar{d}\ \gamma$ interaction is increased with increased energy of the system and decreased the strong coupling with an increased critical temperature However, the photon in the table (6) and Figure 4 including the rate of the upper value at the critical temperature T_c =198.579 MeV comparing with the lower rate at the critical temperature T_c =132.386 MeV . As we can be seen, the rate of photon emission produces are reach the maximum from $\bar{u}g \rightarrow \bar{d}\,\gamma$ interaction at the photons energy $E \leq 2GeV$ in tables (3) , (4) ,(5) and (6) and four figures(1), (2) , (3) and (4) (5) comparing the minimum at $E \geq 2GeV$ at E=10 GeV. In fact, a complementary theoretical picture of photons produce show that increase to the high and to influence by increasing the energy of the system and decrease the strong coupling between quark and gluon at any critical temperature in tables (3), (4),(5) and (6) for the $\bar{u}g \rightarrow \bar{d}\,\gamma$ system with n_f = 3 .

Conclusion

A systematic study of the photon rate spectra from $\bar{u}g \rightarrow \bar{d}\,\gamma$ heavy ion reactions at chemical potential $\mu_q = 500\,MeV$ MeV has been presented with emphasis on the influence of the strong coupling and critical temperature of quark flavors on photons spectrum . The photon rate spectra critical temperature and strong coupling were computed from the equation of photon rate within the well-understood and simple model for anti-up quark interacting with gluon at ultra-relativistic heavy ion collisions produce anti-down with photons gamma in the transparent energy. The model of photon rate which is based on the QCD theory describes the interaction in three flavour numbers. With implemented equation of photon rate, we conclude that a significant effect on the strong coupling and critical temperature contribution to the study of the photon rate behavior of the quark-gluon interaction. Strong coupling and the critical temperature are an ingredient in the emission of every photon spectrum calculation. That's a discussion of the main feature of QCD influence on the rate of the anti-up -gluon interaction at energy of system in range 180-360 MeV . Regarding possible QCD features such that; strong coupling, critical temperature, the energy of the system and photon energy for the photon produced have been quantitatively achieved for a unique feature n_f = 2 + 1 of the photon spectrum. The interesting result in the case of flavor is the rate of the minimum photon, especially in energy E=10 GeV. It reflects the weak relation between quarks and gluons which is already .We conclude that photon rate would produce in high energy is a best tool to investigate nucleons structure .

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