مجلة الدراسات التربوية والعلمية - كلية التربية - الجامعة العراقية
العدد العشرون - المجلد الخامس - علوم الفيزياء - كانون الأول 2022 م
doi.org/10.52866/esj.2021.05.20.07

Theoretical and Calculation The Photon Production From Quark-Antiquark Interaction

Elaf Mohammed Ahmed[1] , Hadi J.M. Al-Agealy[2] , Nada Farhan Kadhim[1]
[1] Mustansiriyah University / College College of Science, Department of Physics
2 University of Baghdad / College of Education for Pure Science Ibn-ALHaitham, Department of Physics
E-mail: elaafmuhamed@uomustansiriyah.edu.iq;
hadi.j.m@ihcoedu.uobaghdad.edu.iq and dr.nada@uomustansiriyah.edu.iq

Abstract :

In this paper, we present a theoretical calculation of photons rate from the annihilation of quark anti-quark interaction. A theoretical model for this process was provided using the quantum chromodynamic theory. In addition, we introduced and discussed the role of the QCD strength coupling, critical temperature, photons energy and thermal energy of the system, as well as the rate of the photons used to study the behavior of quarks theoretically .The photon rate was calculated for the interaction of charm (C) and anti-strange ($\bar{s}$) quarks in two critical temperatures T_c = 113 MeV and T_c = 147 MeV and the range of photon energy from 1.5GeV/c to 5GeV/c. we noticed the strong coupling, critical temperature, photon energy and thermal energy were to influence the rate dramatically, which can form photons' possible emission from the annihilation process.The increased photons rate with decreased QCD strength couple of quarks interaction due to increasing the critical temperature from 113 MeV to 147 MeV had been predicted.We also find a small difference in photon yield and QCD strength coupling with two critical temperatures 113 and 147 MeV.

Key words: Photon Production , Quark-Antiquark .

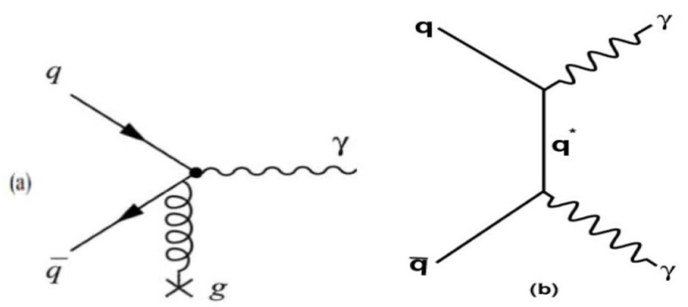
نظرية وحساب انتاج الفوتون
من تفاعل الكوارك والكوارك المضاد

الخلاصة :

في هذا البحث ، نقدم حسابًا نظريًا لمعدل الفوتونات من فناء تفاعل الكوارك مع مضاد الكوارك. تم تقديم نموذج نظري لهذه العملية باستخدام نظرية الكم الديناميكي اللوني. بالإضافة إلى ذلك ، قدمنا وناقشنا دور اقتران قوة QCD و درجة الحرارة الحرجة وطاقة الفوتونات والطاقة الحرارية للنظام ، بالإضافة إلى معدل الفوتونات المستخدمة لدراسة سلوك الكواركات نظريًا. تم حساب معدل الفوتون لتفاعل الكواركات الساحرة (c) ومضاد الغريب ($\bar{s}$) في درجتين حرجتين T_C = 113 MeV و T_C = 147 MeV ومدى طاقة الفوتون من 1.5 GeV / c إلى 5 GeV / c لقد لاحظنا أن الاقتران القوي ودرجة الحرارة الحرجة وطاقة الفوتون والطاقة الحرارية تؤثر على المعدل بشكل كبير ، والذي يمكن أن يشكل الانبعاث المحتمل للفوتونات من عملية الفناء. تم توقع زيادة معدل الفوتونات مع انخفاض قوة QCD بين تفاعل الكواركات بسبب زيادة درجة الحرارة الحرجة من 113 MeV إلى 147 MeV. نجد أيضًا اختلافًا بسيطًا في إنتاجية الفوتون وقوة اقتران QCD مع درجتي حرارة حرجتين 113 MeV و 147 MeV.

Introduction

The quarks and gluons are fundamental constituents of protons and neutrons and the building blocks of matter[1]. The quarks model has been introduced by Zweig and Gill Mann in 1964 as fundamental building blocks of hadrons[2]. The Standard Model was introduced to describe the particle physics interactions. It is built depending on quantum chromodynamics QCD and quantum electrodynamics QED for electroweak interactions. The discovery of the Higgs boson in CERN was the final part of completing the Standard Model [3]. Recently, the structure of the nucleons has been understood by focusing on the quarks and gluons. There are played an important role to produce the mass of the nucleon. They both have spin The quarks are fermions and carried 1/2 spin and gluon has spin 1 because gluons are Bosons [4]. The dynamic of quark and gluon interaction has been studied and understood depending on to QCD framework using different experimental at the BNL, RHIC and CERN LHC[5].One of the important explored extensively discoveries in the CERN Large Hadron Collider experiments is produced quark matter. The understanding of thermodynamic properties of quark-gluon implies understanding relativistic nuclear collisions[6].In general, the photons are produced from different stages and sources in heavy-ion collisions . There are influenced by different characteristics of the QCD materials [7-8]. In recently, many researchers introduced a variety of studies of photon emission according to hydrodynamic models of heavy-ion collisions. It has been developed by connecting experimental data to theoretical ideas [9].Photons are produced by different sources such that; thermal photons ,photons produced in the preequilibrium by hard interactions and prompt photons . Experimentally the photons were created from collisions and the photons produce at in heavy ion collisions with high momentum [10]. The state of quark and antiquark produce in collisions ,its widely interested in physics.it investigates for evidence of transition in nuclear matter, when quarks and gluons are confined in hadrons [11]. In Figure, Feynman diagrams of photon produce mechanisms from, quark-antiquark annihilation[12].



Figure(1) : Diagrams of photons emission from quark-anti-quark annihilation [12].

The quark - antiquark matter is annihilation to produce lepton. The annihilation of quark - antiquark are into two types; quark-antiquark annihilation by annihilation the color charges and quark-antiquark annihilation by annihilation the color and electric charges[13]. In addition, the photons are emitted throughout quark gluon plasma QGP in strong reaction and produces in heavy ions collision at the LHC in CERN and the RHIC in Brookhaven[14]. In this work ,we can focus on the calculation photons rate produce from interaction of quark and anti-quark interaction at two critical temperature with spectrum of photon energy .

Theory

The photons emission rate from quark anti quarks annihilation process is [15]

$$R_P = \frac{4N_s{}^2}{(2\pi)^6} F_q(p_\gamma) \iiint f_{\bar{q}}(p_{\bar{q}})[1 + f_g(p_{\bar{q}})\sigma_{q\bar{q}}(s) \frac{\sqrt{s(s-4m^2)}}{2E_{\bar{q}}} \frac{E_{\bar{q}}}{2E_\gamma} ds d\phi d E_{\bar{q}} \ldots\ldots.(1)$$

Where N_S is spin quantum number of quark s , $F_q(p_\gamma)$ and $f_g(p_{\bar{q}})$ are Juttner distribution functions for quark and gluon , $\sigma_{q\bar{q}}(s)$ is cross section, $E_{\bar{q}}$ and E_γ are quark and photons energy, ds, $d\phi$ and $dE_{\bar{q}}$ are element of momentum , solid angle and quarks energies .The total cross section of quark anti quarks relative to effective cross section $\sigma_a(s)$ and given by[16].

$$\sigma_{q\bar{q}}(s) = (\frac{e_q}{e})^2 \sigma_a(s) \ldots\ldots.(2)$$

Where e_q and e are the quarks and electronic charges .The Eq.(1) withEq.(2) become

$$R_P = \frac{4N_s{}^2}{(2\pi)^6} f_q(p_\gamma) \left(\frac{e_q}{e}\right)^2 \frac{1}{4E_\gamma} \int f_{\bar{q}}(p_{\bar{q}})[1 + f_g(p_{\bar{q}}) dE_{\bar{q}} \int \sigma_a(s)\sqrt{s(s-4m^2)} ds \int_0^{2\pi} d\phi \ldots.(3)$$

The Juttner distribution of quark as function of fugacity $\lambda_{\bar{q}}$ and energy $E_{\bar{q}}$ and given by [17].

$$f_{\bar{q}}(E_{\bar{q}}) = \lambda_{\bar{q}}(e^{\frac{E_{\bar{q}}}{T}} + 1)^{-1} \ldots\ldots\ldots\ldots\ldots.(4)$$

The distribution for gluon $f_B(E)$ using Bose-Einstein function is [18].

$$f_g(E_g) = \lambda_g(e^{E_g/T} - 1)^{-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

Inserting Eq.(4) and Eq.(5) in Eq.(3) and integralunder $E_{\bar{q}} \geq \frac{s}{4E_\gamma}$ to results [19].

$$R_P = \frac{4N_s{}^2}{(2\pi)^6} F_q(p_\gamma) \left(\frac{e_q}{e}\right)^2 \frac{1}{4E_\gamma} [\int_{\frac{s}{4E_\gamma}}^{\infty} \left[\lambda_{\bar{q}}(e^{\frac{E_{\bar{q}}}{T}} + 1)^{-1} + \lambda_{\bar{q}}\lambda_g(e^{\frac{E_{\bar{q}}}{T}} + 1)^{-1}(e^{E_g/T} - 1)^{-1}\right] dE_{\bar{q}}] \int \sigma_a(s)\sqrt{s(s-4m^2)}\, ds \int_0^{2\pi} d\phi \ldots.(6)$$

The first integral reduce at $E_{\bar{q}} \cong E_g$ to

$$\int_{\frac{s}{4E_\gamma}}^{\infty}\left[\lambda_{\bar{q}}(e^{\frac{E_{\bar{q}}}{T}}+1)^{-1}+\lambda_{\bar{q}}\lambda_g(e^{\frac{E_{\bar{q}}}{T}}+1)^{-1}(e^{E_g/T}-1)^{-1}\right]dE_{\bar{q}} =$$

$$T\lambda_{\bar{q}}[\sum_{n=1}^{\infty}\frac{(-1)^{n+1}\left(e^{\frac{-s}{4E_\gamma T}}\right)^n}{n}+\lambda_g\sum_{n=1}^{\infty}\frac{e^{\frac{-(2n+1)s}{4E_\gamma T}}}{2n+1}] \;....(7)$$

And third integral was given

$$\int_0^{2\pi} d\phi = 2\pi....(8)$$

Inserting Eq.(7) and Eq.(8) in Eq.(6) to given

$$R_P = \frac{4N_s{}^2}{(2\pi)^5}f_q(p_\gamma)\left(\frac{e_q}{e}\right)^2\int T\lambda_{\bar{q}}[\sum_{n=1}^{\infty}\frac{(-1)^{n+1}\left(e^{\frac{-s}{4E_\gamma T}}\right)^n}{n}+\lambda_g\sum_{n=1}^{\infty}\frac{e^{\frac{-(2n+1)s}{4E_\gamma T}}}{2n+1}]\sigma_a(s)\sqrt{s(s-4m^2)}\,ds....(9)$$

Also ,the $\sqrt{s(s-4m^2)}\,\sigma(s)$ can be simply to[20].

$$\sqrt{s(s-4m^2)}\,\sigma(s) = 4\pi\alpha_0\alpha_s m^2[\ln\left(\frac{s}{m^2}\right)-1] \;...........(10)$$

The rate in Eq.(9) togother Eq.(10) ands > 4 m 2 become

$$R_P = \frac{4N_s{}^2}{(2\pi)^5}f_q(p_\gamma)\left(\frac{e_q}{e}\right)^2 4\pi\alpha_0\alpha_s m^2 T\lambda_{\bar{q}}\int\left[\sum_{n=1}^{\infty}\frac{(-1)^{n+1}\left(e^{\frac{-s}{4E_\gamma T}}\right)^n}{n}+\lambda_g\sum_{n=1}^{\infty}\frac{e^{\frac{-(2n+1)s}{4E_\gamma T}}}{2n+1}\right]_a \ln[\left(\frac{s}{m^2}\right)-1]\,ds....(11)$$

Under assume $s = 4m^2$z we obtain that .

$$R_P = \frac{4N_s{}^2}{(2\pi)^5}f_q(p_\gamma)\left(\frac{e_q}{e}\right)^2 4\pi\alpha_0\alpha_s m^2 T\lambda_{\bar{q}}[\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n}\frac{(-E_\gamma T)}{nm^2}\int_{4m^2}^{\infty}\frac{-nm^2}{E_\gamma T}e^{\frac{-nm^2 z}{E_\gamma T}}\left[\ln\left(\frac{4m^2 z}{m^2}\right)-1\right]dz+\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{2n+1}\left(\frac{-E_\gamma T}{(2n+1)m^2}\right)\int_{4m^2}^{\infty}\frac{-(2n+1)m^2}{E_\gamma T}e^{\frac{-(2n+1)m^2 z}{E_\gamma T}}\left[\ln\left(\frac{4m^2 z}{m^2}\right)-1\right]dz]....(12)$$

The two integral in Eq.(12) solve when $m^2 \ll E_\gamma T$ and $(-x)^k = (-\frac{m^2}{E_\gamma T})^k$ [20] to

$$\int_1^{\infty}\frac{-E_\gamma T}{nm^2}e^{\frac{-nm^2 z}{E_\gamma T}}[\ln z+\ln 4-1]\,dz = C+\ln\left(\frac{m^2}{4E_\gamma T}\right)+\ln n+1 \;...........(13)$$

And

$$\int_1^{\infty} \frac{-E_\gamma T}{(2n+1)m^2} e^{\frac{-(2n+1)m^2 z}{E_\gamma T}} [\ln z + \ln 4 - 1]\, dz = [C + \ln\left(\frac{m^2}{4E_\gamma T}\right) + ln(2n+1) + 1] \;\ldots\ldots\ldots\ldots(14)$$

Iserting Eq.(13) and Eq.(14) in Eq.(12) to given

$$R_P = \frac{4{N_s}^2}{(2\pi)^5} \frac{f_q(p_\gamma)}{4E_\gamma} \left(\frac{e_q}{e}\right)^2 4\pi\alpha_0\alpha_s m^2 T [\lambda_{\bar{q}} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n} (\frac{E_\gamma T}{nm^2}) \left[\ln\left(\frac{4E_\gamma T}{m^2}\right) - C - lnn - 1\right] + \lambda_{\bar{q}}\lambda_g \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{2n+1} \frac{E_\gamma T}{(2n+1)m^2} [\ln\left(\frac{4E_\gamma T}{m^2}\right) - C - ln(2n+1) - 1] \ldots\ldots\ldots\ldots(15)$$

However ,the two sumation in Eq.(15)equal to [21].

$$\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{(2n+1)^2} = \left(1 - \frac{1}{2^2}\right)\zeta(2) \sim \frac{\pi^2}{6} \ldots\ldots\ldots\ldots(16)$$

And

$$\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} = \frac{\pi^2}{6} \ldots\ldots\ldots\ldots(17)$$

The Eq.(15) together Eq.(16) and Eq.(17) at $\lambda_g \sim 1$ reduced to

$$R_P = \frac{4{N_s}^2}{(2\pi)^5} f_q(p_\gamma) \left(\frac{e_q}{e}\right)^2 \pi\alpha_0\alpha_s T^2 \lambda_{\bar{q}} \left(\frac{\pi^2}{6}\right) \left[\ln\left(\frac{4E_\gamma T}{m^2}\right) - C - lnn - ln(2n+1) - 1\right] \ldots\ldots\ldots\ldots(18)$$

The Juttner function in Eq.(5) for $E_\gamma \gg T$ reduce to

$$f_g(E_g) = \lambda_g (e^{E_g/T} - 1)^{-1} \approx \lambda_q e^{\frac{-E_\gamma}{T}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(19)$$

Substituting Eq.(19) in Eq.(18) with $C_{q\bar{q}} = C + 1 + lnn + ln(2n+1)$ and $N_s = 2$ to we obtain.

$$R_P = \frac{\alpha_0\alpha_s}{3(2\pi)^2} \left(\frac{e_q}{e}\right)^2 T^2 \lambda_{\bar{q}}\lambda_q e^{\frac{-E_\gamma}{T}} [\left[\ln\left(\frac{4E_\gamma T}{m^2}\right) - C_{q\bar{q}}\right] \ldots\ldots\ldots\ldots(20)$$

Where α_0 is fine structure constant $\alpha_0 = \frac{e^2}{\hbar c} = (137)^{-1}$, α_s, is the QCD strength constant , $\lambda_{\bar{q}}$ and λ_q are the fugacity of quarks and anti quarks with mass $m = gT = \sqrt{4\pi\alpha_s}T$ [22],then Eq.(20) become

$$R_P = \frac{\alpha_0\alpha_s}{3(2\pi)^2} \left(\frac{e_q}{e}\right)^2 T^2 \lambda_{\bar{q}}\lambda_q e^{\frac{-E_\gamma}{T}} [\left[\ln\left(\frac{4E_\gamma}{4\pi\alpha_s T}\right) - C_{q\bar{q}}\right] \ldots\ldots\ldots\ldots(21)$$

The QCD strength coupling is given by [23].

$$\alpha_s = \frac{6\pi}{(33-2n_f)ln\frac{8T}{T_c}} \ldots\ldots\ldots\ldots(22)$$

Where critical temperature is [24].

$$T_c = \left(\frac{90B}{\pi^2 n_{gq}}\right)^{\frac{1}{4}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

Where B is the Bag constant and n_{gq} is the number of gluons and quarks degrees of freedom .It is given by [25].

$$n_{gq} = n_g + \frac{7}{8}\left(n_q + n_{\bar{q}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

Results

We consider two critical temperatures for the evaluation of photon rate that's produced from the annihilation of charm (c) anti-strange ($\bar{s}$) interaction using a simple model based quantum chromo dynamic theory QCD. The photons rate coefficient QCD strength coupling, critical temperature were evaluated theoretically , except the thermal energy and photons energy were taken from experimental data .The inelastic cross-section and the Juttner distribution of quarks were calculated at critical temperatures of 113 and 147 MeV respectively.Two critical temperaturesfor system were calculated using Eq.(23) taking the Bag constant $B^{1/4} = 200$ *and* 260 MeV [26] with taking the the spin and color states are $n_s=2$ and $n_c=8$ for gluon and $n_c=3$, $n_s=2$ *and* $n_f=7$ for quarks to obtained critical temperature results are $T_c=113$ *MeV* and $T_c=147$ *MeV* .The QCD strength coupling was calculated using Eq.(22) as a function of the favor number and critical temperature ,the flavor number is summation flavors in $\sum n_f = 7$ in $c\bar{s}\longrightarrow\gamma g$ system. One can insert the critical temperature $T_c = 113$ *MeV* and $T_c = 147$ *MeV* , thermal energy T=170,190,210,230,250 and 270 MeVand the flavor number $n_f=7$ in Eq.(22) to be results are listed in table (1) and table (2) of QCD strength couplingat $T_c = 113$ *MeV* and 147 *MeV* respectively.

Table(1). The QCD strength coupling at T_C =113 MeV for charmquark interaction with anti-strange $\bar{s}$.

T (MeV)	The QCD strength coupling α_s
170	0.39877
190	0.38170
210	0.36755
230	0.35556
250	0.34525
270	0.33624

Table(2). The QCD strength coupling at T_C =147 MeV for charmquark interaction with anti-strange $\bar{S}$.

T (MeV)	The QCD strength coupling α_s
170	0.44591
190	0.42468
210	0.40723
230	0.39257
250	0.38003
270	0.36915

Although the charge of system $\Sigma(\frac{e_q}{e})$ using summation of charge of charm quark $e_c = +{}^{2}/_{3}\, e$ interaction with charge anti-strange $e_{\bar{s}} = +{}^{1}/_{3}\, e$ to be equal ${}^{5}/_{9}$ relative to electric charge. Thephotons rate yields to interaction of the charm with anti-strange is calculated using Eq.(21) by insert-thephoton energy $E_\gamma = 1.5\ to\ 5GeV$ from experimental data [26], strength coupling from tables (1) and (2) , critical temperature 113 and 147 MeV and fugacity of charm and anti-strangebe taken as $\lambda_q = \lambda_{\bar{q}} = 0.06$ and annihilation parameter is $C_{q\bar{q}} = 1.415$ [27].The calculated results showin tables (3) and (4) for T_C=113 MeV.

Table (3): The photon rate produces T_C=147 MeV at for charmquark interaction with anti-strange $\bar{S}$ at $\lambda_q = \lambda_{\bar{q}}$ =0.06 .

E_γ GeV	$R_P(\frac{1}{GeV^2 fm^4})$					
	T= 170Mev	T= 190Mev	T= 210Mev	T= 230Mev	T= 250Mev	T= 270Mev
	$\alpha_s = 0.399$	$\alpha_s = 0.382$	$\alpha_s = 0.368$	$\alpha_s = 0.356$	$\alpha_s = 0.345$	$\alpha_s = 0.336$
1.5	1.123E-13	2.973E-13	6.432E-13	1.192E-12	1.948E-12	2.862E-12
2	9.108E-15	3.449E-14	1.015E-13	2.472E-13	5.204E-13	9.765E-13
2.5	6.111E-16	3.214E-15	1.239E-14	3.795E-14	9.737E-14	2.175E-13
3	3.788E-17	2.743E-16	1.374E-15	5.231E-15	1.616E-14	4.236E-14
3.5	2.251E-18	2.236E-17	1.448E-16	6.829E-16	2.528E-15	7.741E-15
4	1.303E-19	1.772E-18	1.482E-17	8.634E-17	3.820E-16	1.363E-15
4.5	7.415E-21	1.379E-19	1.486E-18	1.069E-17	5.647E-17	2.346E-16
5	4.168E-22	1.059E-20	1.470E-19	1.304E-18	8.220E-18	3.969E-17

Table (4): The photon rate produces
at T_C=147 MeV for charmquark interaction with anti-strange $\bar{s}$ at $\lambda_q = \lambda_{\bar{q}}$ =0.06 .

	$R_P(\frac{1}{GeV^2 fm^4})$					
	T= 170Mev	T= 190Mev	T= 210Mev	T= 230Mev	T= 250Mev	T= 270Mev
E_γ GeV	$\alpha_s = 0.446$	$\alpha_s = 0.425$	$\alpha_s = 0.407$	$\alpha_s = 0.393$	$\alpha_s = 0.380$	$\alpha_s = 0.369$
1.5	9.946E-14	2.555E-13	5.332E-13	9.431E-13	1.448E-12	1.944E-12
2	8.804E-15	3.297E-14	9.585E-14	2.304E-13	4.785E-13	8.841E-13
2.5	6.104E-16	3.186E-15	1.220E-14	3.708E-14	9.441E-14	2.092E-13
3	3.851E-17	2.772E-16	1.380E-15	5.227E-15	1.605E-14	4.187E-14
3.5	2.313E-18	2.286E-17	1.473E-16	6.916E-16	2.548E-15	7.772E-15
4	1.349E-19	1.826E-18	1.520E-17	8.822E-17	3.888E-16	1.382E-15
4.5	7.725E-21	1.429E-19	1.534E-18	1.099E-17	5.788E-17	2.396E-16
5	4.361E-22	1.103E-20	1.525E-19	1.348E-18	8.469E-18	4.077E-17

The photon rate produces as a function of the photons energy E_γ (GeV) and thermal energy T(MeV) for for charm C quark interaction with anti-strange $\bar{s}$ at $\lambda_q = \lambda_{\bar{q}}$=0.06 are shown in Figure (1) at T_C = 113 MeV and Figure (2) at T_C = 147 MeV .

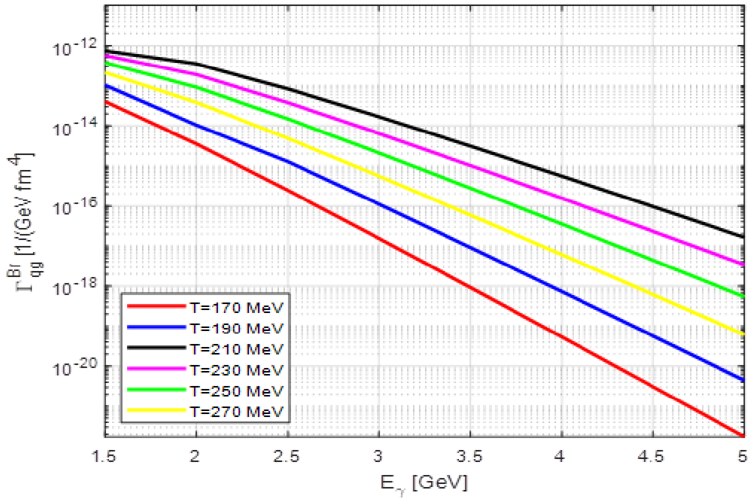


Figure (1): The photon rate R_P foror charm c quark interaction with anti-strange $\bar{s}$ at $T_c = 113\ MeV$ and $\lambda_q=\lambda_{\bar{q}}=0.06$

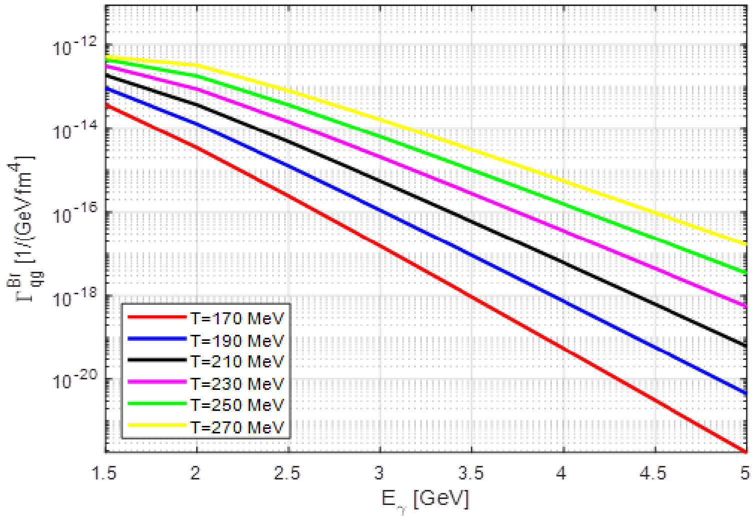


Figure (2): The photon rate R_P foror charm c quark interaction with anti-strange $\bar{s}$ at $T_c = 147\ MeV$ and $\lambda_q=\lambda_{\bar{q}}=0.06$

Discussion

The photons rate with the QCD strength coupling ,photons energy ,thermal energy and the relativeto charge ratio is presented in Eq. (21) .The QCD strength coupling is affected by the critical temperature , flavour number and temperature of system forannihilationreaction of charm quark and anti-strange quark.The QCD strength coupling in both tables (1) and (2) are increases between quark and gluon with the decrease of the thermal energy (170 MeV to 270 MeV) of system .However ,the QCD strength coupling in Eq.(22) as function of critical temperature, it increases due to increase T_c from T_c=$113\ MeV$ to T_c=147

MeV and vice versa . The photons rate as a function of the QCD strength coupling and critical temperature for interaction of charm and anti-strange quarks due to our theoretical model at photons energy from 1.5GeV to 5.0 GeV and thermal energy from T=170MeV to T=270 MeV 270was done in Figures (1) and (2) and both tables (3) and (4). The photon rate reach to maximumat $R_p = 2.862 \times 10^{-12} \frac{1}{GeV^2 fm^4}$ at $E_\gamma = 1.5GeV$ with T=270 MeV for critical temperature $T_C = 113\ MeV$ and QCD strength coupling α_s = 0.336 and become to minimum $R_p = 4.168 \times 10^{-22} \frac{1}{GeV^2 fm^4}$ at $E_\gamma = 5GeV$ with α_s = 0.399 for low thermal energy T=170 Mev with same critical temperature .On the other hand , the photon rate is maximum $R_p = 1.944 \times 10^{-12}$ at $E_\gamma = 1.5GeV$ for α_s = 0.369 and T=270MeV while reach to minimum $R_p = 4.361 \times 10^{-22}$ at $E_\gamma = 5GeV$ with α_s =0.446 and critical temperature $T_C = 147\ MeV$.

From figures 1 and 2,we can see that the photonrate increase with decrease the photons energywithboth critical temperature and vice versa. Furthermore ,thephotons rate wasdecreased with the decreased thermal energy and increased the QCD strength coupling for interaction charm quark with anti-strange quark in the system in both critical temperature .However , the rate of photonin table (4) and Figure 2was larger than rate in table(3) and figure (1) because the rate increases with increases the critical temperature 147MeV for table (4) compare with critical temperature 113MeV for table (3) **this because the critical temperature cooperation with temperature of system to increase the photon rate.** In general , we can see that photon rate was increased with increased the thermal energy of system T> 170 MeV and become large at thermal energy T = 270 MeV. In fact, we find the photon rate in tables (3) and (4) and figures (1) and (2) with different critical temperature are maximum at energy $E_\gamma \geq 1.5\ GeV \leq 2GeV$ .Finally, we showthe photons rate affected by QCD strength coupling, thermal energy ,photons energy and critical temperature to $T_C = 113\ MeV\ to\ 147\ MeV$ for interaction of quarks in system.

Conclusion

In conclusion, we study and calculate the photon emission rate from interaction of charm with anti-strangeat annihilation processdepending on QCD strength coupling, thermal energy ,photon energy and critical temperature. We have demonstrated in the QCD analysis that photon rate description depending on QCD strength coupling and thermal and critical temperature .It is increased with decreased the QCD strength coupling and increased critical temperature and thermal energy of system for charm -anti strange annihilation process in thermal energy of system in range $270\ MeV \geq T \geq 170\ MeV$ .Our results imply that the photons energy affected on photon rate ,It rather reach to maximum at $2GeV \geq E_\gamma$. We have explored the distribution of photon rate and QCD strength coupling relative to the critical and thermal temperature of the system has been a unique feature of the photon rate. In conclusion, photon production becomes more probable at decreases strength coupling and increased temperature 270 MeV and critical temperature 147 MeV and photon energy $E_\gamma \leq 2GeV$.

References

1-Haiyan Gao" Antimatter in the proton is more down than up" Nature ,Vol. 590, no. 25, PP(559-560), (2021).

2-Hadi J.M. Al-Agealy, and Sahib, M. J. . Theoretical Evaluations of Probability of Photons Yield Depending on Quantum Chromodynamics Theory. Ibn AL-Haitham Journal For Pure and Applied Sciences, IHSCICONF, PP(179-186), (2018).

3- Bass S. D., De Roeck A. and Kado M., "The Higgs boson - its implications and prospects for future discoveries" Nature Rev. Phys.Vol. 3, no.9, (PP608-624), (2021).

4Arbuzov,A.Bacchetta,M.Butenschoen ,F.G.Celiberto,U.D'Alesio,M.Deka,I. Denisenk,M.G.Echevarr,A.Efremov,N. Ya.Ivanov,A.Guskov,A.Karpishkov,Ya. Klopot,B.A.Kniehl,A.Kotzinian,S. Kumano,J.P.Lansberg,Keh-FeiLiu,O. Teryaev" On the physics potential to study the gluon content of proton and deuteron at NICA SPD" Progress in Particle and Nuclear Physics,Vol. 119, 103858, (2021).

5-Elaf Mohammed Ahmed, Hadi J.M. Al-Agealy, Nada Farhan Kadhim"Theoretical Study of Photons Spectra around HighEnergy of Quark-antiquark Using QCD Theory" Neuro-Quantology, Vol. 20, Issue 4, PP (58-63), (2022).

6- Akihiko Monnaia ,Bj¨ornSchenkeb, Chun Shen "QCD equation of state at finite densities for nuclear collisions"Nuclear Physics A 00 (2020), pp (1-4).

7-L. Oliva, M. Ruggieri, S. Plumari, F. Scardina, G. X. Peng, and V. Greco, " Photons from the early stages of relativistic heavy-ion collisions "Phys. Rev. C 96, 014914 (2017).

8-G. David,"Direct real photons in relativistic heavy ion collisions" Rep. Prog. Phys. 83, 046301 (2020).

9-A. Adare et al. (PHENIX Collaboration)," Beam Energy and Centrality Dependence of Direct-Photon Emission from Ultrarelativistic Heavy-Ion Collisions" Phys. Rev. Lett. 123, 022301 (2019).

10-Hadi J.M. Al-agealy ,RawnaqQaysGhadhban and Mohsin A. Hassooni " Theoretical Study of the Photons Production Kinetic In Hot Quark-Gluon Plasma Matter" Ibn Al-Haitham Jour. for Pure & Appl. Sci. 33 (4),PP (34-39), (2020).

11-Adare, Andrew ,Ogilvie, Craig ,Apadula, Nicole,Campbell, Sarah Hill, John Hotvedt, NelsLajoie, John Lebedev, Alexandre Ogilvie, CraigPatel, Milap Perry, Joshua Rinn, Timothy Rosati, MarziaRunchey, Jonathan Sen, Abhisek Shimomura, M. Timilsina, Arbin et al."Measurement of the relative yields of ψ(2S) to ψ(1S) mesons produced at forward and backward rapidity in p+p, p+Al, p+Au, and 3He+Au collisions at √sNN = 200 GeV "PHYSICAL REVIEW C 102, 014902 (2020)

12-C. Klein-Boesing, " Production of Neutral Pions and Direct Photons in Ultra-Relativistic Au+AuCollisions"ph.D. thesis, University of Muenster, (2005).

13-T. X. Zhang " Quark Annihilation and Lepton Formation versus Pair Production and Neutrino Oscillation: The Fourth Generation of Leptons " PROGRESS IN PHYSICS ,Vol. 2, no. 3, PP(20-26), (2011).

14-Xinyang Wang, Igor A. Shovkovy, Lang Yu, and Mei Huang "Ellipticity of photon emission from strongly magnetized hot QCD plasma" PHYSICAL REVIEW D 102, 076010 (2020).

15-Somorendro S. Singh"Free energy and direct photon emission at finite chemical potential"Journal of Physics: Conference Series 535, IOP Publishing, 012002, (2014).

16-Boris Z. Kopeliovich, Andreas Schäfer, and Alexander V.Tarasov"Bremsstrahlung of a quark propagating through a nucleus"Phys. Rev. C 59, 1609 - Published 1 March (1999).

17-Long J. L., He Z. J., Ma Y. G. and Liu B." Hard photon production from a chemically equilibrating quark-gluon plasma with finite baryon density at one loop and two loop" PHYSICAL REVIEW C 72, 064907 (2005),PP (064907-1- 064907-8).

18-David A. B. Miller"Quantum Mechanics for Scientists and Engineers "Book, Cambridge University Press, (2008).

19-R. Baier, M. Dirks, K. Redlich, D. Schiff" Thermal photon production rate from non-equilibrium quantum field theory"High Energy Physics - Phenomenology (hep-ph),Phys.Rev. D56 (1997) 2548-2554.

20-Cheuk-Yin Wong"Introduction to-High-Energy Heavy-Ion Collisions " Book,world scientific publishing co .pte . ltd ., (1994).

21-Abramowitz M. and Stegun I.A. "Handbook of Mathematical Tables " book,Dover Publication New York,(1965).

22- Hadi, J.M, Al-agealy1, Hadi Dawyich Al Attabi and Hassan Ali Al Badri"Theoretical Calculation of the Photons Rate for theQuark-Gluon System at Compton Scattering"International Journal of Science and Research IJSR,Volume 5 Issue 8, (PP 1770-1775), (2016).

23-Hadi J.M. Al-agealy,Hyder Hamza Hussein and Saba Mustafa Hussein "Theoretical estimation of Photons flow rate Production in quark gluon interaction at high energies" IOP Conf. Series: Journal of Physics: Conf. Series 1003,PP 012119, (2018).

24-Maher Sami Saleh"Theoretical characterization of the PhotonsEmission at Annihilation Quarks Interaction " Master Thesis, Physics, College of Education for Pure Science

25-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).

26-Maher Sami Saleh and Hadi J.M. Al-agealy "Analysis and investication of hard photons produce from annihilation process in Quarks Gluon interaction at one loop" journal of Engineering and Applied of Science, Ibn Al-Haitham / University of Baghdad, Vol.13 ,no.10 ,PP(3381-3385), (2018).

27-Poonam Jain, YogeshKumar"Photon Emission from Quark Gluon Plasmaat RHIC and LHC "Journal of Modern Physics, 5, PP(686-692), (2014).