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Analysis and Investigation of Hard Photons Produce from Annihilation Processes in Quark Gluon Interaction at One Loop

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Abstract: In this research, we study and investigation the hard photons are production from annihilation processes at one loop level in high energy physics. Quantum chromodynamics postulate was taking to analysis the photonic produce depending on the simple model. Many physical parameters must estimation to evaluation photonic produce rate such that effective quantum coupling strength, fugacity, quantum color number effective transition momentum, photonic energies, total charge quark system, Euler factor, critical temperature and system temperature. The fugacity equilibration of Quark-Gluons system with finite temperature at one-loop based on Juttner distribution. For Quark Gluon system in one loop the photonic rate production in annihilation processes is found to be fugacity dependent the photonic rate is strongly depends on the quark effective quantum coupling strength, we find that the photonic rate increasing obviously due to increasing the effective quantum coupling strength and vice versa.

Key words: Hard photons, annihilation processes, Quark Gluon interaction, photonic, transition, strength

INTRODUCTION

According to finite quantum many body system, the atom of matter nucleus was constituents of two particles protons and neutron and all nucleus properties could be study and investigation depending on this. Recently years, the more scientists at many places in world had been research in elementary particles to search and study the constituents of proton and neutron matter and all their interactions (Braibant *et al*., 2012). The elementary particle is the fundamental and smallest pieces of material in all universes. In past, the philosophers research and thought about the matter origin in universe and they are providing good idea of the matter composed in atom. The advance of science and technology lead us much more development of matter information. They prove experimentally that the elementary particle was regarding as never breakable constituent or never consists to small any particle (Horaguchi, 2006). Until to final 1963's, the physicists were trying to and an acceptable a pattern providing better idea to understanding the confused of the large number subatomic particles. Gell-Mann and Zweig in 1964 are introducing independently the quarks model to understand the hadronic matter building (Hetland, 2005). At this time, the scientist is known that protons and neutrons are building by fundamental basic particles named quarks in hadrons. The hadron is subdivided to baryons groups that contain of three quarks and mesons groups contain pairs of quark-antiquark particles. In both cases the quarks or antiquarks in two baryons groups and mesons groups are condfined due to gluons (Bull, 2005). The best theory to describe the interaction at Quarks and Gluons is called Quantum Chromodynamics field theory. Generally, it's assumed that fundamental particles defined due to localized quantum fields. In specially, the physical terms were consensus to defined the local fields using quantum field theory and Quantum Chromodynamics theory QCD, the QCD is more theory to discussion the strong nuclear interactions depending on quarks behavior (Palaha, 2013). Evolution of nuclear strongly interacting at Quark-Gluon matter is the main aim of the ultra-relativistic heavy-ion collisions research. The quarks transform from confined to a deconned state refers to short life of the exists matter (Singh and Kumar, 2013). Under the field theory, we can find six quarks in three generation such that up, down, charm, strange, bottom and top. The spin for quarks is 1/2 while the gluon is mediate the quarks interactions have 1 spin. The Quarks and Gluons are called fermions and bosons, respectively (Chisholm, 2014).

MATERIALS AND METHODS

Theory: According to quantum chromodynamics theory the quarks dynamics behavior can be classified to asymptotic freedom and confinement. The study of hard

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photons at annihilation processes for Quark Gluon interaction depending on the estimation of the current photons rate .the current rate of photons is given by Le Bellac (1996):

$$\in \frac{dn_{\gamma}}{d^4 x d^3 P} = - \frac{\alpha_{em}}{(2\pi)^3} F^B(\in, T) \operatorname{Im} \prod\nolimits^{J}_{MN}(\in, \lambda_{q,\, q'}T) \quad (1)$$

Where:

a_{em} = The statical strength coupling

F^B = The Boson distribution function

$\operatorname{Im} \coprod^{T}_{MN} (\in, \lambda_q, q, T)$ = The propagation photon self-energy

Then Boson distribution function can be written as:

$$F^B(\in, T) = (e^{E_\gamma}/^{T}\text{-}1)^{-1} \quad (2)$$

However, propagation self-energy can be represented due to spectral function as (Braaten *et al*., 1990):

$$\begin{aligned} &\operatorname{IM}\prod\nolimits^{T}_{MN}(\in, \lambda_{q,\, q'}, T) = \frac{10\pi}{3} q^2 \sum q^2_{QCD} (e^{E_\gamma}/^{T}\text{-}1)\times \\ &\int \frac{d^3\kappa}{(2\pi)^3} \int_{-\infty}^{\infty} d\omega \int_{-\infty}^{\infty} d\omega^{\sim} \delta(\in \text{-}\omega\text{-}\omega^{\sim}) \\ &[F_{(q)}(\omega).F_{(q')}(\omega^{\sim})]\operatorname{Tr}[\wp^{\mu}(\kappa, \text{-}p) \\ &\rho^*(\omega, \kappa) p(\omega\text{-}\in, \bar{\kappa}\text{-}\bar{p}) \wp^{\vartheta}(\text{-}\bar{\kappa}, \text{-}\kappa, p) \end{aligned} \quad (3)$$

where, $F_{(q)}$ (w) and $F_{(q')}(w^{\sim})$ are the Jouttner distribution functions and may be written as by Long *et al*. (2005):

$$F_{(q)} = \frac{\lambda_q}{e^{\frac{E_1}{T}}+1} \text{ and } F_{(q')} = \frac{\lambda_{q'}}{e^{\frac{E_2}{T}}\text{-}1} \quad (4)$$

Then, we can be written the Eq. 3 using Eq. 4 to became:

$$\begin{aligned} &\operatorname{IM}\prod\nolimits^{T}_{MN}(\in, \lambda_{q,q'}T) = \frac{10\pi}{3} q^2 \sum q^2_{QCD} (e^{E_\gamma/T}\text{-}1)\times \\ &\int \frac{d^3\kappa}{(2\pi)^3} \int_{-\infty}^{\infty} \frac{d\omega}{2\pi} \int_{-\infty}^{\infty} \frac{d\omega^{\sim}}{2\pi} \delta(\in \text{-}\omega\text{-}\omega^{\sim}) \frac{F_{(q)}.F_{(q')}]}{\omega+\omega^{\sim} ip} \\ &\operatorname{Tr}[\wp^{\mu}(\kappa, \bar{\kappa}, \text{-}p) D^*(\omega, \bar{\kappa}) D(\omega\text{-}\in, \bar{\kappa}\text{-}\bar{p}) \wp^{\mu}(\text{-}\bar{\kappa}\text{-}\kappa, p)] \end{aligned} \quad (5)$$

However, the Eq. 5 can be simplified using higher mathematical physics to results (Hidaka *et al*., 2015):

$$\begin{aligned} &\operatorname{IM}\prod\nolimits^{J}_{MN}(\in, \lambda_{q,\, q'}T) = 4\pi \frac{10\pi}{3} q^2 \sum q^2 QCD(e^{E\gamma/T}\text{-}1)\times \\ &\int \frac{d^3\kappa}{(2\pi)^3} \int_{-\infty}^{\infty} \frac{d\omega}{2\pi} \int_{-\infty}^{\infty} \frac{d\omega^{\sim}}{2\pi} [F_{(q)}.F_{(q')}]\times \frac{1}{2\kappa} \\ &\delta(\cos\theta\text{-}\frac{\omega}{\kappa})[D^*_{+}(\omega, \bar{\kappa})(\text{-}1+\frac{\omega}{\kappa}) + D^*_{-}(\omega, \bar{\kappa})(\text{-}1\text{-}\frac{\omega}{\kappa}) \end{aligned} \quad (6)$$

However, we must use the suitable condition for large photon energy $E_q+E_{q'} = E_\gamma$ and $E_\gamma >> T$. In this limit it is a good approximation to replace:

$$F_{(q)}.F_{(q')} \rightarrow \frac{\lambda q}{e^{\frac{Eq}{T}}+1} . \frac{\lambda q}{e^{\frac{Eq'}{T}}\text{-}1} \approx \lambda_q \lambda_{q'} e^{\frac{Eq}{T}\frac{Eq'}{eT}} \approx \lambda_q \lambda_{q'} e^{\text{-}\frac{E\gamma}{T}} \quad (7)$$

Then, Eq. 6 simply using Eq. 7 to:

$$\begin{aligned} &\operatorname{IM}\prod\nolimits^{T}_{MN}(\in, \lambda_{q,\, q'}T) = 4\pi \frac{5\pi}{12\pi^2} q^2 \sum q^2_{QCD} (e^{E_\gamma/T}\text{-}1)\times \\ &[\lambda_q \lambda_{q'} e^{\text{-}\frac{E\gamma}{T}} \{\int \kappa d\kappa\times \_\sigma+(\kappa)(\text{-}1+\frac{\omega}{\kappa}) + \wp\text{-}(k)(\text{-}1\text{-}\frac{\omega}{\kappa}) + \\ &\int \kappa d\kappa \beta\text{-}(\omega, \kappa)\times \theta(\kappa^2\text{-}\omega^2) \end{aligned} \quad (8)$$

Since, the final term in integral Eq. 8 show the correction factor and can be solved by assume $\theta = 2/\pi\ Q_o (\sinh\eta)\text{-}Q(\sinh\eta)/1\text{-}\tanh\eta$ and $y_c = 2/\pi\ k^2_c/ m^2_q$ and we solve to Eq. 14 and results:

$$\mathbb{C}_{cor} = \int \kappa d\kappa \beta_{\pm}(\omega, \kappa)\times\theta(\kappa_2\text{-}\omega_2) \cong m^2_q(\text{-}1\text{-}C_E) \quad (9)$$

where, CE = 0577216 (Long *et al*., 2005). On the other hand, we can using equality formula to results (Le Bellac, 1996):

$$\begin{aligned} &\int[\sigma+(\kappa)(\text{-}1+\frac{\omega}{k}) + \sigma\text{-}(\kappa)(\text{-}1\text{-}\frac{\omega}{k})\kappa d\kappa = \\ &2m^2_q \int_{\kappa}^{\mu} \frac{\omega+(\kappa)\text{-}\omega\text{-}(\kappa)}{m^2_q} d\kappa = \operatorname{Ln}\frac{\mu^2}{\kappa^2} \end{aligned} \quad (10)$$

Inserting the Eq. 10 and Eq. 9 in Eq. 8 to:

$$\begin{aligned} &\operatorname{Im}\coprod\nolimits^{J}_{MN}(\in, \lambda_{q,\, q'}, T) = \text{-}4\pi \frac{5}{12\pi^2} e^2 (e^{E_\gamma/T}\text{-}1)\times \\ &[\lambda_q \lambda_{q'} e^{\text{-}\frac{E\gamma}{T}}]\times m^2_q [\operatorname{Ln}\frac{m^2_q}{k^2}\text{-}1\text{-}C_E \end{aligned} \quad (11)$$

Substituting Eq. 11 in Eq. 1 to gate current photons rate equation:

$$\varsigma_{ANN}(\alpha_{ASC},E_{\gamma},T)=\frac{1}{8\pi^{4}}\times\frac{5}{3}q^{2}\sum e_{QCD}^{2}\times [\lambda_{q}\lambda_{q}e\text{-}\frac{E\gamma}{T}]\times m\frac{2}{q}[Ln\frac{m_{q}^{2}}{k^{2}}\text{-}1\text{-}C_{E} \tag{12}$$

where, $\alpha = q^2/4\pi$ and $m^2{}_q = g^2C_FT^2/4$ and (Grebovic *et al*., 2012) and the activation nuclear strong constant $\alpha_{ASC} = g^2/4\pi$ (Arnold *et al*., 2001) for limit of k~gT and $\mu \sim \sqrt{2ET}$ the Eq. 12 becomes:

$$\lambda_{ANN}(\alpha_{ASC},E_{\gamma},T)=\frac{30\alpha_{em}\alpha_{ASC}}{27\pi^{2}} \sum q_{QCD}^{2}T^{2}\lambda_{q}\lambda_{q'}e^{-\frac{E\gamma}{T}}[Ln\frac{2E}{g^{2}T}\text{-}1\text{-}C_{E}] \tag{13}$$

The activity of strong coupling constant α_{ASC} for Quarks Gluon interaction giving (Algealy and Muhssen, 2015):

$$\alpha_{ASC}=\frac{6\pi}{(33\text{-}2n_{f})\ln(\frac{P_{EM}}{T_{c}})} \tag{14}$$

Where:

P_{em} = The momentum transition

T_c = Ccritical phase temperature and n_f is the quantum flavor number

RESULTS AND DISCUSSION

The current photons rate were obtained due to solving the rate in Eq.13 and 14 numerically using MATLAB program method using values of the fugacity $\lambda_q = 0.02$ (Long *et al*., 2005) and inserting the values of 4 GeV$\leq$E$\gamma$$\leq$8 GeV, 1.200 GeV$\leq$P$_{Em}$$\leq$, 2 GeV that's taking from experimental results (Singh, 2014) T_c is taken 155 and 185 MeV at hadronic phase. The active strong coupling constant is the much more important factor controlling on the photonic rate and dependent on active momentum. It can estimation according to Eq. 14 with evaluation the quantum flavor number using the $\Sigma N_f = 4+4+0+0 = 8$ for $c\bar{c}\rightarrow\gamma g$ system and evaluation the momentum P_{em} = 8T wher temperature of system are taken from 150-50 MeV with critical temperature T_c = 155 and 185 MeV, respectively. The results are tabulated in Table 1. Next ,we can evaluation the current of photons rate theoretically using Eq. 13 by taking two critical temperature =155 and 185 MeV with using fugacity parameter λ_q = 0.02 and photonic energy E_γ = 4, 4.5, 5.6, 6.7, 7.5 and 8 GeV evaluation the total charge of system $\Sigma_f e_f^2 = (2/3)^2+(-2/3)^2 = 0.888$ and taking the active of strong coupling constant from Table 1,the results are summarized in Table 2 and 3, respectively.

For the result in Table 2 and 3, we can show the current of photonic from Quark-Quark interaction at annihilation processes through the different photonic energy at range temperature 150$\leq$T$\leq$250 MeV with the activation of strong nuclear coupling contant that estimation from Eq. 14 for charm anti charm interaction and also in the quark quantum flavor number. Due to thermal energy that a suitable choice for the hadronic phase for annihilation process, the our evaluation was performed for charm quark have flavor quantum number is n_f = 4. In both Table 2 and 3 the total photonic ratesare increasing at increasing temperature from 150 MeV until to 250 MeV with the variation of the photonic energy E that increasing from 4-8 GeV for the process of $c\bar{c}\rightarrow\gamma g$ annihilation. According to results in Table 2 and 3, we can show the results of photonic rate are smaller when the photons energy closer to high energy Eγ = 8 GeV ,it turns out that the photons at this energy less probable compare that have low energy similar Eγ = 4 GeV. The calculation of current photons rate were performed at annihilation process when charm quark have flavor quantum number. the current rate of photons at quark anti-quark interaction was founded to varying from 4.4916×10^{-21} -1.7207×10^{-16} at Eγ = 4 GeV to from 2.8749×10^{-32}-8.8782×10^{-23} at Eγ = 8 GeV at T_c = 155 MeV and from 3.9929×10^{-21}-1.1635×10^{-16} at Eγ = 4 GeV to from 2.9047×10^{-32}-8.7669×10^{-23} at Eγ = 8 GeV at T_c for the fugacity λ_q = 0.02. On the other hand, the results in the relevant range of photons from annihilation process give the significant contribution at high photonic energy and results of photonic rate show increment at higher energy. In general the calculation results give a good agreement with other theoretical results (Singh and Kumar, 2013). The increase of photonic rate due to decreasing of active strong coupling are effected highly due to the temperature of system, and the active strong coupling be larger nearing the lower photonic rate and small thermal energy and the active strong coupling decreasing lead to increases the photonic rate and its considered to be existing at hot system . In both Table 2 and 3, we show the photonic spectrums at annihilation process are same ratio different for all range thermal temperatures with the active strong coupling value. This indicate that the activation of the coupling constant was dependent on temperature and the active of strong coupling becomes smaller when the temperature increases in system and its quark system approaches to deconfined. The active strong coupling is predicted and its function of active momentum of system from data results of photonic rate, we can show the rate is low sensitive to higher temperature, that's view when we look to photonic rate results at temperature large 200 MeV at any energy of photons.

Table 1: Result of active of strong coupling for $C\overline{C}\rightarrow\gamma g$, annihilation with critical temperatures T_c= 155 and 185 MeV

The momentum transition P_{em} GeV	α_{ASC} (P_{EM}) at T_c = 155 MeV	α_{ASC} (P_{EM}) at T_c = 185 MeV
1.200	0.5417	-0.5930
1.400	0.5038	0.5478
1.600	0.4749	0.5139
1.800	0.4521	0.4873
2.000	0.4335	0.4657

Table 2: Data results of current photonic rate for $C\overline{C}\rightarrow\gamma g$ system at annihilation processes in critical temperature T_c = 155 MeV

	$\Im$ANN (α_{ASC}, Eγ, T) 1/GeV^2 fm^4				
Variables	T = 150 MeV	T = 175 MeV	T = 200 MeV	T = 225 MeV	T = 250 MeV
	P_{EM}1.200 GeV	P_{EM}1.400 GeV	P_{EM}1.600 GeV	P_{EM}1.800 GeV	P_{EM}2.000 GeV
	a_{ASC}0.5417	a_{ASC} 0.5038	a_{ASC}0.4749	a_{ASC} 0.4521	a_{ASC}0.4335
4	4.4916×10^{-21}	2.131×10^{-19}	$3.7174\times10\text{-}^{18}$	$3.2617\times10_{.17}$	1.7207×10^{-16}
4.5	1.9945×10^{-22}	1.5845×10^{-20}	$4.156\times10\text{-}^{19}$	$5.1564\times10_{.18}$	3.7473×10^{-17}
5	8.3664×10^{-24}	1.0952×10^{-21}	4.2228×10^{-20}	7.16×10^{-19}	6.7888×10^{-18}
5.5	$3.3465\times10\text{-}^{27}$	$7.2528\times10\text{-}^{23}$	$4.0688\times10\text{-}^{21}$	9.3004×10^{-20}	1.129×10^{-18}
6	1.3402×10^{-26}	4.67×10-24	3.7913×10^{-22}	1.1603×10^{-20}	1.7876×10^{-19}
6.5	5.2128×10^{-28}	$5.4892\times10\text{-}^{26}$	3.4530×10^{-23}	1.4094×10^{-21}	2.7428×10^{-20}
7	2.0022×10^{-29}	$1.8354\times10\text{-}^{26}$	3.0934×10^{-24}	1.6798×10^{-22}	4.1168×10^{-21}
7.5	7.6161×10^{-31}	$1.1299\times10\text{-}^{27}$	2.7372×10^{-25}	1.9743×10^{-23}	6.0825×10^{-22}
8	$2.8749\times10\text{-}^{32}$	$6.8968\times10\text{-}^{29}$	$2.3989\times10\text{-}^{26}$	2.2955×10^{-24}	8.8782×10^{-23}

Table 3: Data results of current photonic rate for $C\overline{C}\rightarrow\gamma g$ system at annihilation processes in critical temperature T_c = 185 MeV

	$\Im$ANN (α_{ASC}, Eγ, T) 1/GeV^2 fm^4				
Egev	T = 150 Mev	T = 175 Mev	T = 200 Mev	T = 225 Mev	T = 250 Mev
	P_{EM}1.200 Gev	P_{EM}1.400 Gev	P_{EM}1.600 Gev	P_{EM}1.800 Gev	P_{EM}2.000 Gev
4	$a_{ASC}3.9929\times10^{-21}$	$a_{ASC}1.8318\times10^{-19}$	$a_{ASC}3.0466\times10^{-18}$	$a_{ASC}2.4888\times10^{-17}$	$a_{ASC}1.1635\times10^{-16}$
4.5	1.8536×10^{-22}	1.444×10^{-20}	3.6964×10^{-19}	4.4448×10^{-18}	3.0986×10^{-17}
5	7.9824×10^{-24}	1.0308×10^{-21}	3.9122×10^{-20}	6.5116×10^{-19}	6.0384×10^{-18}
5.5	3.2897×10^{-25}	6.9672×10^{-23}	3.8632×10^{-21}	8.7176×10^{-20}	1.0430×10^{-18}
6	1.3175×10^{-26}	4.55×10^{-24}	3.6596×10^{-22}	1.1090×10^{-20}	1.6907×10^{-19}
6.5	5.1724×10^{-28}	2.9032×10^{-25}	3.3728×10^{-23}	1.3656×10^{-21}	2.6355×10^{-20}
7	2.0012×10^{-29}	1.8215×10^{-26}	3.049×10^{-24}	1.6443×10^{-22}	4.002×10^{-21}
7.5	7.6577×10^{-31}	1.1286×10^{-27}	2.7170×10^{-25}	1.9478×10^{-23}	5.9648×10^{-22}
8	2.9047×10^{-32}	6.9247×10^{-29}	2.3947×10^{-26}	2.2789×10^{-24}	8.7669×10^{-23}

CONCLUSION

We presented an updated evaluation the photonic rate through the quark anti-quark interaction at annihilation processes. The evaluation is performed for charm-anti charm interaction quarks for flavor quantum number N_f. The rate data are founded to varying approximation to by 10^6 time. It means that increase of active strong coupling leading to decreases the photonic rate. It's find the relation of photonic rate with active strong coupling is opposite proportional of temperature. In case of temperature, the rate is increasing with respect to the decreases of the active coupling while the rate increases with increases to temperature which indicates that the rate as functions to temperature. On the other hand the rate of photons effected by the critical temperature and rate decreases by increasing the critical temperature. The photonic rates are to be increased due to decreasing the photonic energy and it's a function of critical temperature and strength coupling. The increasing in photonic rate is highly elected due to thermal energy (temperature of system).

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