THERMAL PHOTONS PRODUCTION IN PROTON-PROTON COLLISIONS AT HIGH ENERGIES

PART II. DETERMINATION OF DOMINANT PROCESS OF PRODUCTION OF THERMAL PHOTONS

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Thermal photons produced in following processes: $\pi^+\pi^- \to \gamma\rho^0$, $\pi^\pm\rho^0 \to \gamma\pi^\pm$, $\rho^0 \to \gamma\pi^+\pi^-$, $\pi^+\pi^- \to \gamma\eta$, $\pi^\pm\eta \to \gamma\pi^\pm$, $\pi^+\pi^- \to \gamma\gamma$ has been investigated. The dependencies of differential cross-sections of processes of production thermal photons on energy of colliding mesons ($\sqrt{s}$), transverse momentum (p_T) and on cosine of scattering angle of photons has been determined without and taking into account formfactor of meson and has been comparised. Dominant process has been determined. Energetic spectrums of thermal photons produced in these processes has been determined. A comparison of differential cross sections of thermal photon production processes and prompt photon production of processes of Compton scattering of quark-gluon and annihilation of a quark-antiquark pair has been carried out.

Keywords: proton-proton collision, mesons, thermal photons, Feynman diagram, differential cross-section.
PACS: 13.75.Lb; 13.30.Eg; 13.20.Cz; 13.25.Cq

I. INTRODUCTION

At present meson photoproduction has become a major tool for studying the properties of strong interaction in a mode where this fundamental force cannot be considered through perturbation theory methods. This almost completely replaced meson-induced reactions, such as the elastic scattering of the pion that previously dominated the area.

The number of photons introduced by the decay scale of the meson with the total number of charged particles formed in the collision, while the number of photons produced by the quark and gluon reactions could be expected to scale with the square of the number of charged particles [1,2]. Another method is that the number of photons introduced by the quark-gluon plasma is obtained by integrating the rate R (the number of reactions per unit time per unit volume that the photon produces) in the space-time history of the collision. Roughly speaking, the output is the speed x volume x time. More photons come out of the final state of the meson [3,4].

However, decay reactions are used in the case of heavier nuclei, the study of the average properties of hadrons and the effects of FSI, for example, the study of scaling the behavior of reaction sections depending on the number of nuclear masses.

We considered thermal photons productions in these processes: $\pi^+\pi^- \to \gamma\rho^0$, $\pi^\pm\rho^0 \to \gamma\pi^\pm$, $\rho^0 \to \gamma\pi^+\pi^-$, $\pi^+\pi^- \to \gamma\eta$, $\pi^\pm\eta \to \gamma\pi^\pm$, and $\pi^+\pi^- \to \gamma\gamma$. The dependencies of differential cross-section of processes on energy of colliding meson, transverse momentum of p_T and cosine of scattering angle of photons has been determined. The differential sections of the processes calculated without and taking into account the meson formfactor were compared.

Matrix elements, Manfelstam invariants and accounting of formfactor of mesons of considered priocesses was been given in previously in [5].

Purpose of the presented article is to determine influence of formfactor of mesons to differential cross-section of production of photons, to determine of doninant process of poroduction of thermal photons in mesons reactions. Energetic spectrums of thermal photons produced in these processes has been determined. A comparison of differential cross sections of thermal photon production processes and prompt photon production of processes of Compton scattering and annihilation of a quark-antiquark pair has been carried out [6].

II. DETERMINATION OF DOMINANT PROCESS OF
III. PRODUCTION OF THERMAL PHOTONS

a. comparison differential cross-sections of processes

Comparison of differential cross-sections of processes, calculated without and taking into account formfactor of mesons was carried out using the following formulas:

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$$R_{if}(\sqrt{s}) = \frac{d\sigma_i(\sqrt{s})}{d\sigma_{if}(\sqrt{s})}, \quad R_{if}(p_T) = \frac{d\sigma_i(p_T)}{d\sigma_{if}(p_T)},$$

$$R_{if}(Cos(\theta)) = \frac{d\sigma_i(Cos(\theta))}{d\sigma_{if}(Cos(\theta))}$$

where i, j =1,2,3….6 process number of production of thermal photons: 1. $\pi^+\pi^- \to \gamma\rho^0$, 2. $\pi^\pm\rho^0 \to \gamma\pi^\pm$, 3. $\rho^0 \leftarrow \gamma + \pi^+ + \pi^-$, 4. $\pi^+\pi^- \to \gamma\eta$, 5. $\pi^\pm\eta \to \gamma\pi^\pm$, 6. $\pi^+\pi^- \to \gamma\gamma$, $\frac{d\sigma_i(\sqrt{s})}{dt}$, $\frac{d\sigma_i(p_T)}{dt}$ and $\frac{d\sigma_i(Cos(\theta))}{dt}$ the differential cross-section of processes on dependence $\sqrt{s}$, p_T, $Cos(\theta)$, correspondingly, calculateed without taking into account formfactor of mesons, $\frac{d\sigma_{if}(\sqrt{s})}{dt}$, $\frac{d\sigma_{if}(p_T)}{dt}$ and $\frac{d\sigma_{if}(Cos(\theta))}{dt}$ differential cross-sections of processes on dependence $\sqrt{s}$, p_T, $Cos(\theta)$, correspondingly calculated taking into account formfactor of mesons.

Determination of dominant process of producation of thermal photons was been carried out by formulas:

$$R_{ij}(\sqrt{s}) = \frac{d\sigma_i(\sqrt{s})}{d\sigma_j(\sqrt{s})}, \quad R_{ij}(p_T) = \frac{d\sigma_i(p_T)}{d\sigma_j(p_T)},$$

$$R_{ij}(Cos(\theta)) = \frac{d\sigma_i(Cos(\theta))}{d\sigma_j(Cos(\theta))}$$

I. NUMERICAL RESULTS AND THEIR DISCUSSION

a. Comparison of differential cross-sections of processes, calculated without and taking into account formfactor of mesons

1. process $\pi^+\pi^- \to \gamma\rho^0$

Fig.1(a,b,c) represent the ratio of the dependencies of differential cross-sections of the $\pi^+\pi^- \to \gamma\rho^0$ processes on the energy of colliding mesons, on trnansverese momentum, and on the cosine of the scattering angle of photon, calculated without and taking into account the formfactor of the mesons.

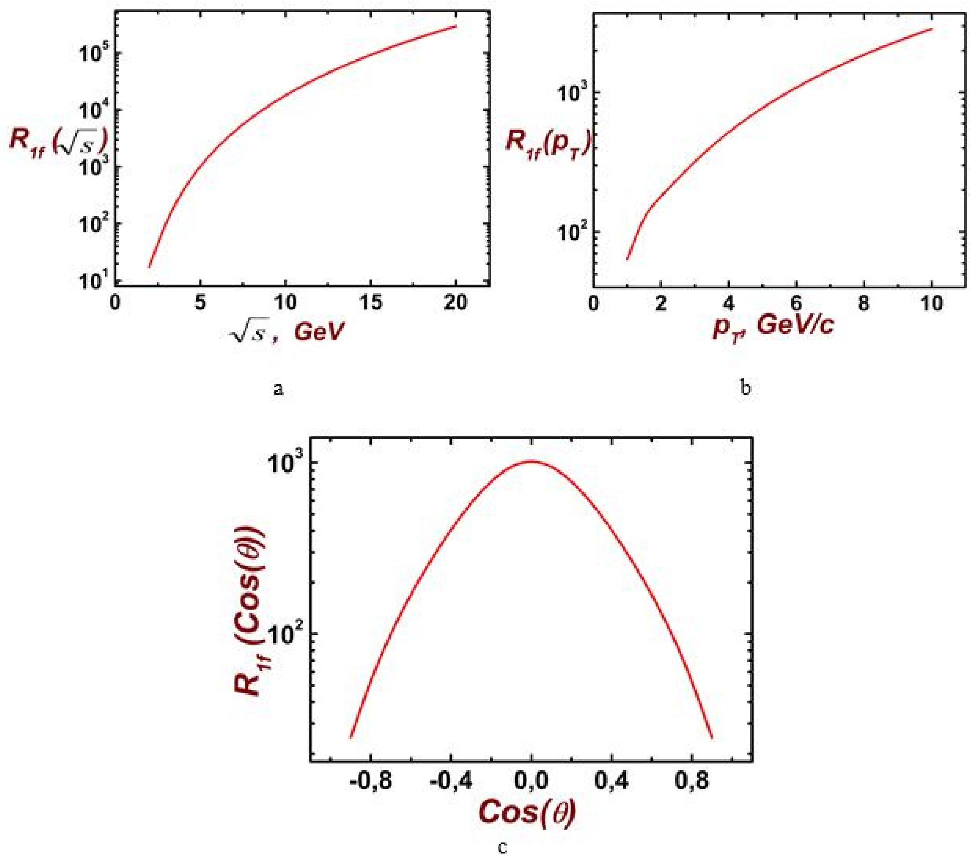

Fig. 1. (a,b,c) the rate of the dependencies of differential cross-sections of the $\pi^+\pi^- \to \gamma\rho^0$ processes on the energy of colliding mesons (*a*), on the transverse momentum p_T (*b*), and on the cosine of scattering angle of photons (*c*), calculated without and taking into account the formfactor of the meson.

As can be seen from fig.1(*a*,*b*) the ratio of dependencies of differential cross-sections on energy of colliding meson, on momentum p_T calculated without and taking into account the formfactor of meson is significant at large energy values of colliding mesons and transverse momentum. As ratio of $R_{1f}>1$ in all values of energy $\sqrt{s}$ and transverse momentum p_T means

$$\frac{d\sigma_1(\pi^+\pi^- \to \gamma\rho^0)}{dt} > \frac{d\sigma_{1f}(\pi^+\pi^- \to \gamma\rho^0)}{dt}.$$

Ratio of dependencies of differential cross-sections of meson of process $\pi^+\pi^- \to \gamma\rho^0$ on cosine of scattering angle of photons calculated without and taking into account formfactor of mesons has symmetrical form relative to *Cos(θ)=0*. It has a maximum at *Cos(θ)=0* and with an increase in the absolute value of the cosine of the angle of scattering of photons decreases (fig.1(*c*)). Taking into account the formfactor of mesons in the dependence of the differential cross-section on the cosine of the scattering angle has a large effect at small values of the cosine of the angle and a small effect at the *Cos(θ)*= ±1.

2. process $\pi^\pm\rho^0 \to \gamma\pi^\pm$

In the fig.2 (a,b,c) is presented rate of dependencies of differential cross-sections of $\pi^\pm\rho^0 \to \gamma\pi^\pm$ on energy, on transverse momentum and on cosine of scattering angle of photon, calculated without and talking into account formfactor of mesons.

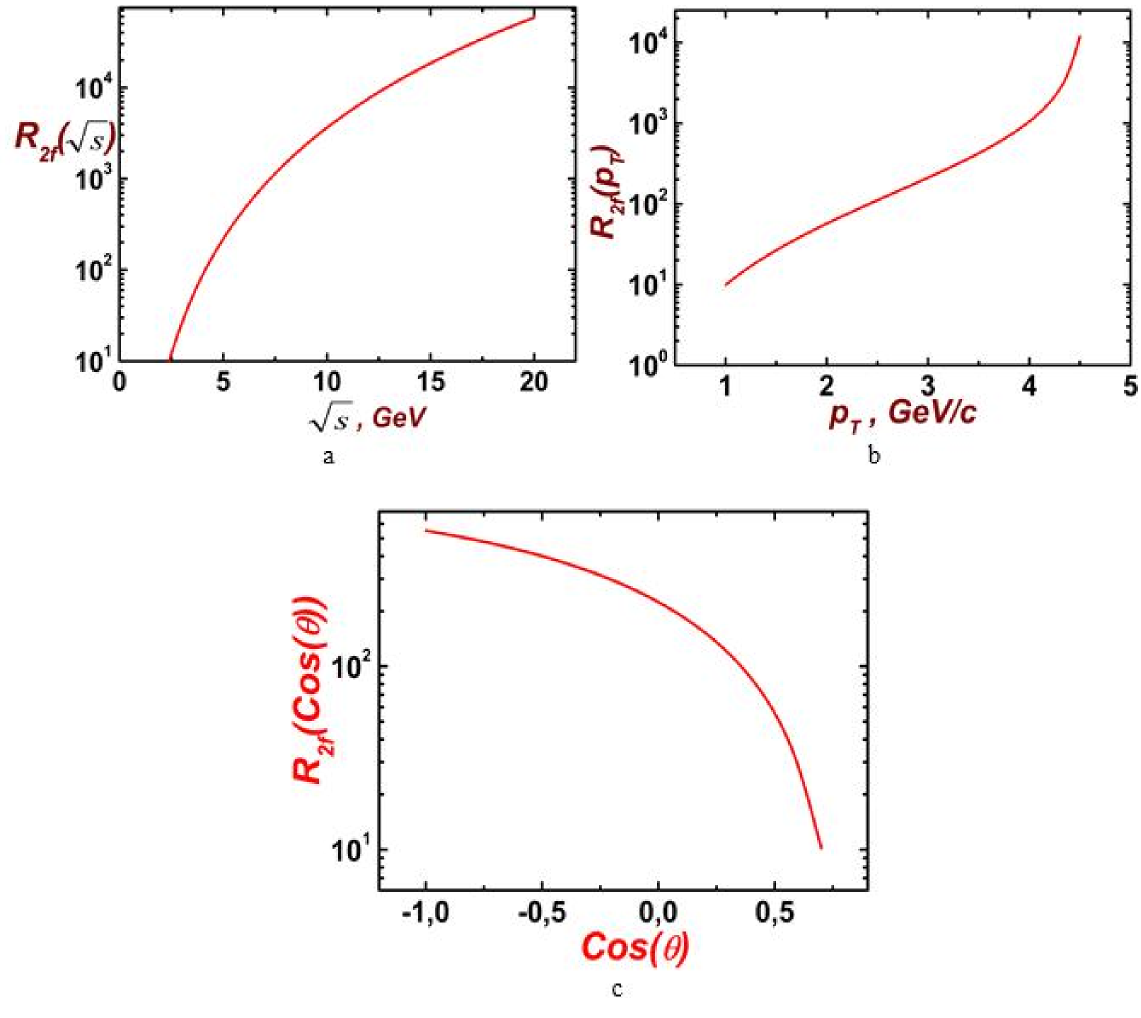

Fig.2. (a,b,c) The ratio of dependencies of differential cross-sections of process $\pi^\pm\rho^0 \to \gamma\pi^\pm$ on energy colliding mesons (*a*), on transverese momentum (*b*), on cosine of scattering angle of photons (*c*), calculated without and talking into account formfactor of mesons.

Ratio of dependencies of differential cross-section on energy of colliding mesons and on transverse momentum decrease with increasing of energy of colliding mesons and transverese momentum. Ratio of dependencies of differential cross-section on cosine of scattering angle of photon decrease with increasing cosine of scattering angle.

As ratio of $R_{1f}>1$ in all values of energy $\sqrt{s}$ and transverse momentum p_T means

$$\frac{d\sigma_1(\pi^{\pm}\rho^0 \to \gamma\pi^{\pm})}{dt} > \frac{d\sigma_{1f}(\pi^{\pm}\rho^0 \to \gamma\pi^{\pm})}{dt}.$$

Thus, taking into account the meson formfactor reduces the differential cross-section of process.

3. process $\rho^0 \to \gamma\pi^+\pi^-$

Fig.3 (*a*,*b*,*c*) represent the dependence of rate of the differential cross-section of $\rho^0 \to \gamma\pi^+\pi^-$ process on energy of colliding mesons $\sqrt{s}$, on the transverse momentum p_T and on the cosine of the scattering angle of photons, calculated without and taking into account the formfactor of mesons.

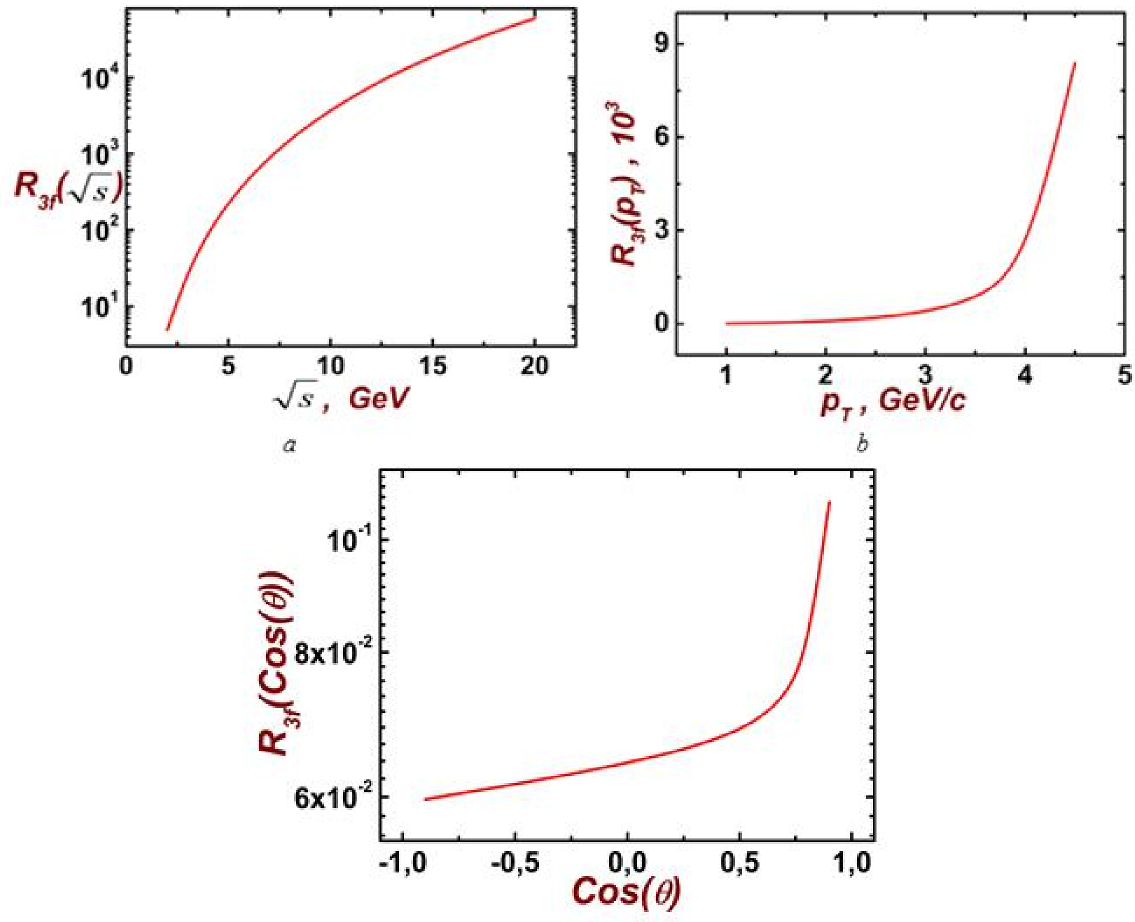

Fig.3. (*a*,*b*,*c*) the dependence of rate of the differential cross-section of $\rho^0 \to \gamma\pi^+\pi^-$ process on the energy of collidimg mesons $\sqrt{s}$ (*a*), on the transverse momentum p_T (*b*) and on the cosine of the angle of the scattering photon (*c*), calculated taking into account the formfactor of mesons.

3. Determination of dominant process

1. Comparison of processes $\pi^+\pi^- \to \gamma\rho^0$, $\pi^{\pm}\rho^0 \to \gamma\pi^{\pm}$ and $\pi^+\pi^- \to \gamma\gamma$

1.1 Comparison of processes $\pi^+\pi^- \to \gamma\rho^0$, $\pi^{\pm}\rho^0 \to \gamma\pi^{\pm}$

Fig.4(*a*,*b*,*c*) represent the ratio of dependencies differential cross-section of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^\pm\rho^0 \to \gamma\pi^\pm$ on energy colliding mesons $\sqrt{s}$, transverse momentum p_T and cosine of scattering angle of photons.

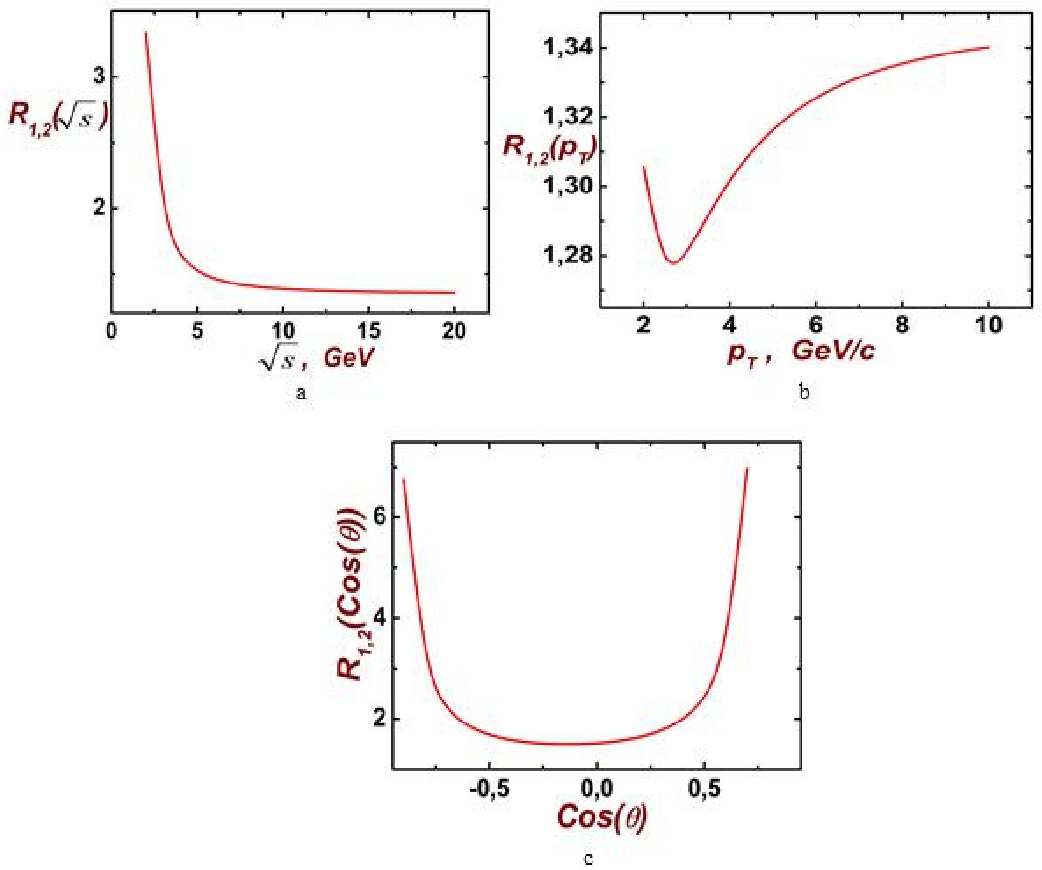

Fig.4. (a,b,c) the dependence ratio of differential cross-sections of the $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^\pm\rho^0 \to \gamma\pi^\pm$ processes calculated without and taking into account the formfactor of mesons on the energy of colliding mesons (a), on the transverse momentum of photons (b) and on the cosine of the scattering angle of photons (c).

As see from fig.4 (*a*) ratio of dependencies of differential cross-section of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^\pm\rho^0 \to \gamma\pi^\pm$ on energy of colliding mesons is significant at low energies of colliding mesons. Also rate of dependencies of differential cross-sections of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^\pm\rho^0 \to \gamma\pi^\pm$ on energy of colliding mesons large 1 for all values of energy and consequently

$$\frac{d\sigma(\pi^+\pi^- \to \gamma\rho^0)}{dt} > \frac{d\sigma(\pi^\pm\rho^0 \to \gamma\pi^\pm)}{dt}$$

1.2 Comparison of processes $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$

Fig.5 (*a*,*b*,*c*) represent the ratio of dependencies differential cross-section of processes $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$ on energy colliding mesons, transverse momentum p_T and cosine of the scattering angle of photons.

As see from fig.5(*a*) ratio of dependencies of differential cross-section of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$ on energy of colliding mesons is significant at low values energies of colliding mesons. Moreover, ratio of dependencies of differential cross-sections of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$ on energy of colliding mesons for all values of energy large 1 and consequently

$$\frac{d\sigma(\pi^+\pi^- \to \gamma\rho^0)}{dt} > \frac{d\sigma(\pi^+\pi^- \to \gamma\gamma)}{dt}.$$

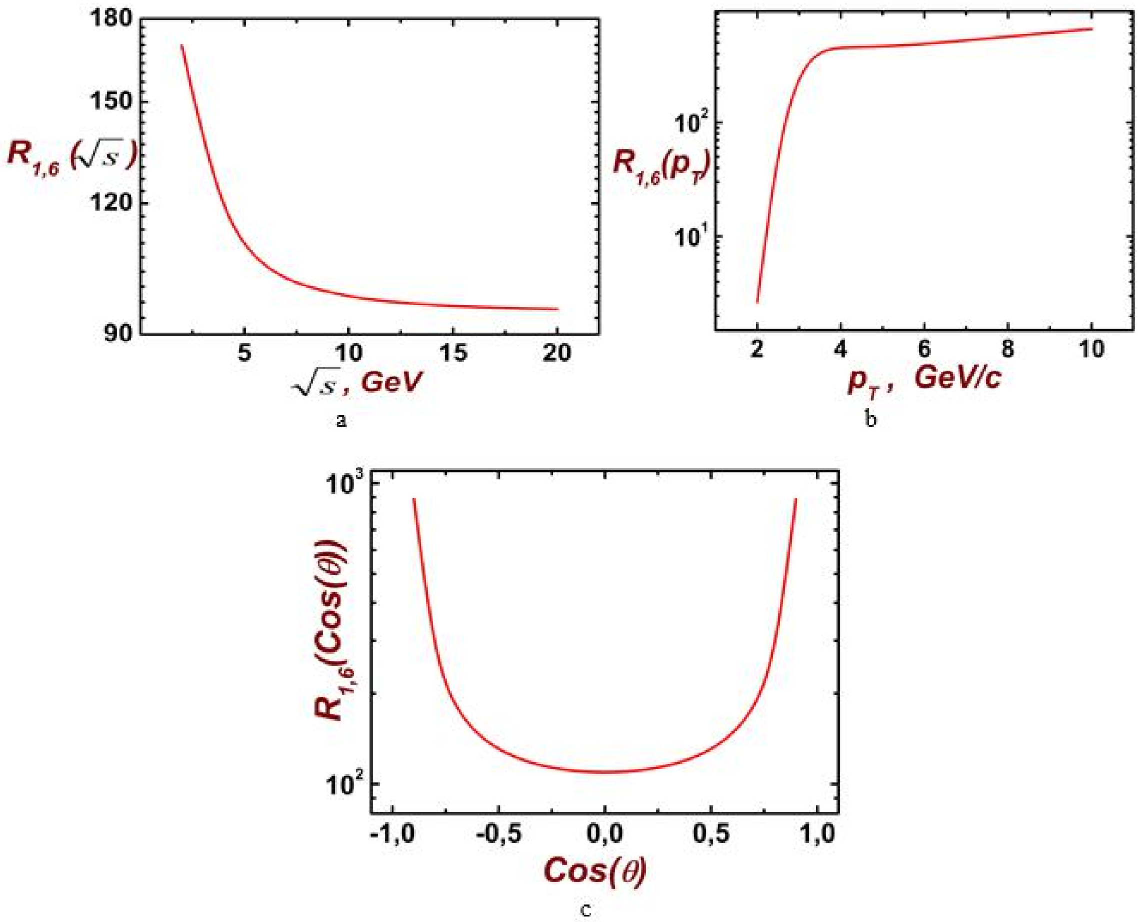

Fig. 5. (a,b,c) the dependence of the rate of differential cross-sections of the processes $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$ on the energy of colliding mesons (*a*), on transverse momentum p_T (b) and on cosine of the scattering angle of photons (*c*).

As see from fig.5 (b) ratio of dependencies of differential cross-section of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$ on p_T is significant at big values of energies of colliding mesons. Also rate of dependencies of differential cross-sections of $\pi^+\pi^- \to \gamma\rho^0$ and $\pi^+\pi^- \to \gamma\gamma$ on p_T large 1 for all values of p_T and consequently

$$\frac{d\sigma(\pi^+\pi^- \to \gamma\rho^0)}{dt} > \frac{d\sigma(\pi^+\pi^- \to \gamma\gamma)}{dt}.$$

In the fig.6 shown the dependencies of ratio of differential cross-section of process $\pi^+\pi^- \to \gamma\rho^0$, $\pi^\pm\rho^0 \to \gamma\pi^\pm$ and $\pi^+\pi^- \to \gamma\gamma$ to their sum.

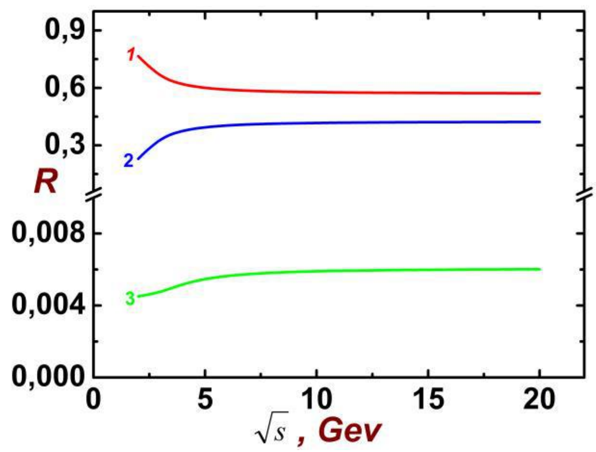

Fig. 6. Dependencies of ratio of differential cross-section of process $\pi^+\pi^- \to \gamma\rho^0$, $\pi^\pm\rho^0 \to \gamma\pi^\pm$ and $\pi^+\pi^- \to \gamma\gamma$ to their sum on energy of colliding mesons $\sqrt{s}$, correspondingle curve 1,2, and 3.

As seen from fig.6 contribution of process $\pi^+\pi^- \to \gamma\rho^0$ to total differential cross-section of production of tehermal photons is significant. Influence of contributions of all processes is significant at small value of energy of colliding mesons. Thus, the following ratio is satisfied:

$$\frac{d\sigma(\pi^+\pi^- \to \gamma\rho^0)}{dt} > \frac{d\sigma(\pi^\pm\rho^0 \to \gamma\pi^\pm)}{dt} > \frac{d\sigma(\pi^+\pi^- \to \gamma\gamma)}{dt}$$

1.3 Comparison of processes $\pi^+\pi^- \to \gamma\eta$, $\pi^\pm\eta \to \gamma\pi^\pm$

Fig.7 (*a*,*b*,*c*) represent the ratio of dependencies of differential cross-section of processes $\pi^+\pi^- \to \gamma\eta$ and $\pi^\pm\eta \to \gamma\pi^\pm$ on energy colliding mesons $\sqrt{s}$, transverse momentum p_T and cosine of scattering angle of photons.

As see from fig.7 (*a*,*b*,*c*) at all dependencies of differential cross-section on energy of colliding mesons, transverse momentum p_T and cosine scattering angle of photons

$$\frac{d\sigma(\pi^+\pi^- \to \gamma\eta)}{dt} > \frac{d\sigma(\pi^\pm\eta \to \gamma\pi^\pm)}{dt}.$$

As see from fig.7 (*c*) ratio of dependencies of differential cross-sections of processes $\pi^+\pi^- \to \gamma\eta$ and $\pi^\pm\eta \to \gamma\pi^\pm$ on cosine of scattering angle photon is large 1 and constant. It does not depend on the cosine of scattering angle of photons.

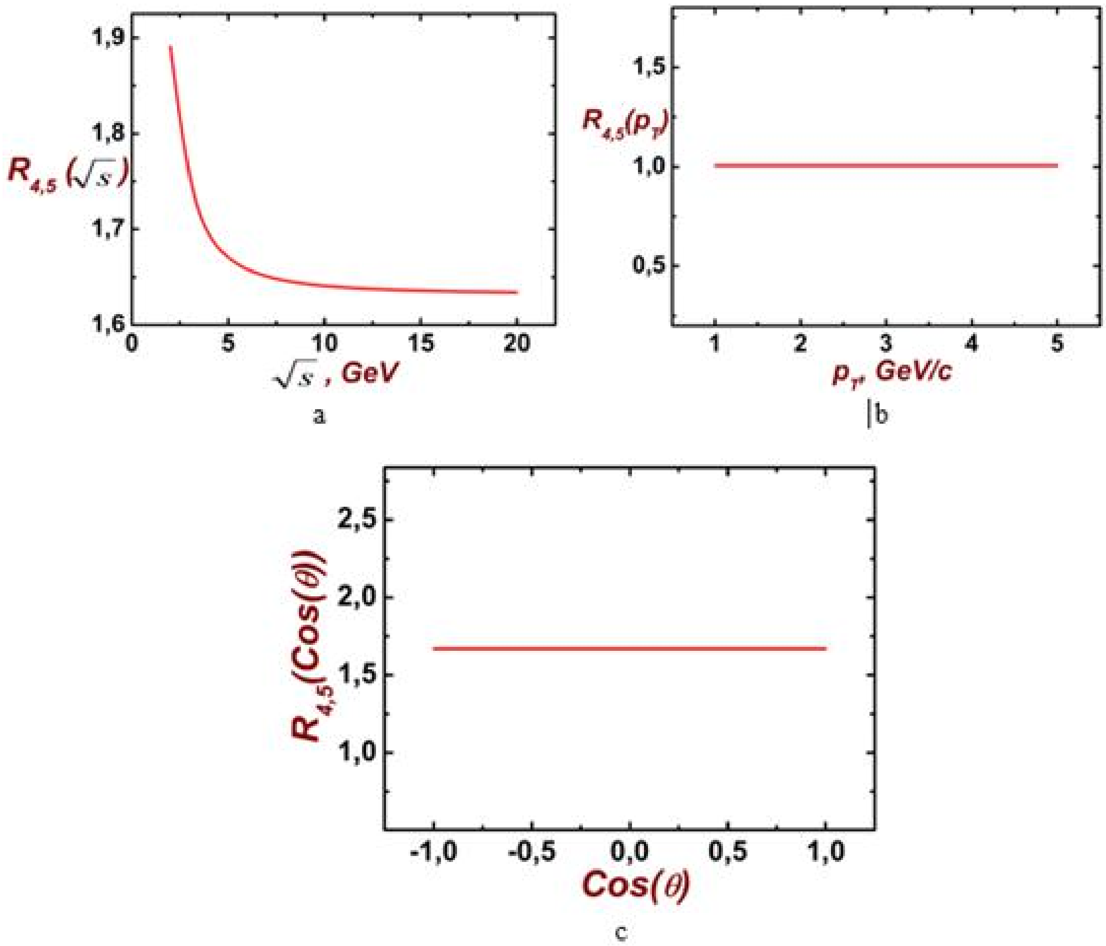

Fig.7. (a,b,c) the dependencies of the ratio of the differential cross-sections of the processes $\pi^+\pi^- \to \gamma\eta$ and $\pi^\pm\eta \to \gamma\pi^\pm$ on the energy of colliding mesons $\sqrt{s}$ (*a*), on transverse momentum p_T (*b*) and on cosine of the scattering angle of photons (*c*).

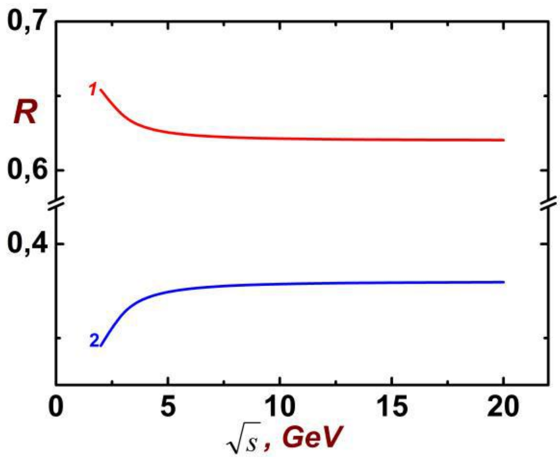

Fig.8. The dependencies of ratio of differential cross-section of process $\pi^+\pi^- \to \gamma\eta$ and $\pi^\pm\eta \to \gamma\pi^\pm$ to their sum on energy of colliding mesons, correspondingle curve 1 and 2.

In the fig.8 shown the dependencies of ratio of differential cross-section of process $\pi^+\pi^- \to \gamma\eta$ and $\pi^\pm\eta \to \gamma\pi^\pm$ to their sum.

As seen from fig.8 contribution of process $\pi^+\pi^- \to \gamma\eta$ to total differential cross-section production of tehermal photons is significant. Influence of contributions of all processes is significant at small value of energy of colliding mesons. Thus, the following ratio is satisfied:

$$\frac{d\sigma(\pi^+\pi^- \to \gamma\eta)}{dt} > \frac{d\sigma(\pi^\pm\eta \to \gamma\pi^\pm)}{dt}$$

c. Energy spectrum of produced thermal photons in processes

On fig.9 schematically has been shown thermal photon production processes with participoation of mesons: $\pi^+\pi^- \to \gamma\rho^0$, $\pi^\pm\rho^0 \to \gamma\pi^\pm$, $\pi^+\pi^- \to \gamma\eta$, $\pi^\pm\eta \to \gamma\pi^\pm$, $\pi^+\pi^- \to \gamma\gamma$.

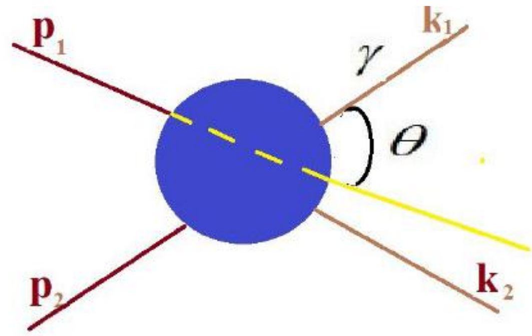

Fig. 9. Scheme of thermal photon production in processes $\pi^+\pi^- \to \gamma\rho^0, \pi^\pm\rho^0 \to \gamma\pi^\pm$, $\pi^+\pi^- \to \gamma\eta, \pi^\pm\eta \to \gamma\pi^\pm$, $\pi^+\pi^- \to \gamma\gamma$.

It has been introduced the following designations: $c' \equiv \cos\theta = \cos(k_1 \wedge p_1)$.

We write the law of conservation of momentum:

$$\vec{p_1} + \vec{p_2} = \vec{k_1} + \vec{k_2}, \qquad \vec{k_2} = \vec{p_1} + \vec{p_2} - \vec{k_1}$$

and the law of energy conservation:

$$E_1 + E_2 - E_{k_1} - E_{k_2} = 0$$

The law of conservation of energy in 4-dimensional coordinates will be:

$$p_1^0 + p_2^0 - \sqrt{\vec{k_1}^2} - \sqrt{\left(\vec{p_2} + \vec{p_1} - \vec{k_1}\right)^2 + m_{k_2}^2} = 0$$

Last equation has been squared to determine the momentum of a thermal photons

$$p_1^0 + p_2^0 - k_1 - \sqrt{p_1^2 + k_1^2 - 2|p_1|k_1 c + m_{k_2}^2} = 0$$

Let's take $x=k_1$ and square the previous expression

$$m_{p_1}^2 + m_{p_2}^2 - 2(p_2^0 + p_1^0)\sqrt{x^2} = -2\left|\vec{p_1}\right| xc$$

$$m_{p_1}^2 + m_{p_2}^2 + 2\left|\vec{p_1}\right| xc = 2(p_2^0 + p_1^0)\sqrt{x^2}$$

Let's square the previous expression again

$$\left(m_{p_1}^2 + m_{p_2}^2\right)^2 + 4\left|\vec{p_1}\right| xc\left(m_{p_1}^2 + m_{p_2}^2\right) + 4\left|\vec{p_1}\right|^2 x^2 c^2 = 4\left(p_2^0 + p_1^0\right)^2 x^2$$

$$\left(4\left|\vec{p_1}\right|^2 c^2 - 4\left(p_2^0 + p_1^0\right)^2\right)x^2 + 4\left|\vec{p_1}\right| c\left(m_{p_1}^2 + m_{p_2}^2\right)x + \left(m_{p_1}^2 + m_{p_2}^2\right)^2 = 0$$

We get a quadratic equation with respect to the momentum of the produced thermal photons *x*, with coefficients:

$$a = 4\left|\overrightarrow{p_1}\right|^2 c^2 - 4\left(p_2^0 + p_1^0\right)^2, \qquad b = 4\left|\overrightarrow{p_1}\right| c\left(m_{p_1}^2 + m_{p_2}^2\right), \qquad c = \left(m_{p_1}^2 + m_{p_2}^2\right)^2$$

Considering the following expressions

$$p_1^0 = E_1^2 = \overrightarrow{p_1}^2 + m_{p_1}^2;\; p_2^0 = E_2^1 = \overrightarrow{p_2}^2 + m_{p_2}^2 = m_{p_2}^2;$$

$$\left|\overrightarrow{p_1}\right|^2 = E_1^2 - m_{p_1}^2;$$

The solution to this quadratic equation will be as follows:

$$x_{1,2} = \frac{-4c\left(m_{p_1}^2 + m_{p_2}^2\right)\sqrt{E_1^2 - m_p^2} \pm \sqrt{16c^2\left(E_1^2 - m_{p_1}^2\right)\left(m_{p_1}^2 + m_{p_2}^2\right)^2 - 4\left(4c^2\left(E_1^2 - m_{p_1}^2\right) - 4c^2\left(E_1^2 + m_{p_1}^2\right)^2\right)\left(m_{p_1}^2 + m_{p_2}^2\right)^2}}{2\left(4c^2\left(E_1^2 - m_{p_1}^2\right)4c^2\left(E_1^2 + m_{p_1}^2\right)^2\right)}$$

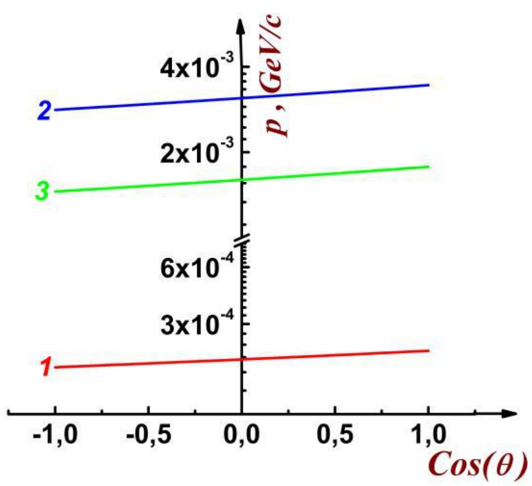

Fig. 10. The dependence of momentum of produced thermal photons in processes $\pi^+\pi^- \to \gamma\rho^0$, $\pi^+\pi^- \to \gamma\eta$, $\pi^+\pi^- \to \gamma\gamma$ (curve 1), $\pi^\pm\rho^0 \to \gamma\pi^\pm$ (curve 2), $\pi^\pm\eta \to \gamma\pi^\pm$ (curve 3) on cosine of scattering angle of photons.

We will consider those solutions of the equation that are not complex, i.e. the discriminant of the equation is greater than zero and is equal to zero, in this case the solution x_2 satisfies this condition. Data to estimate the dependence of energy of produced of thermal photons on the energy of colliding protons were taken E_1=10 *GeV*, $\overrightarrow{p_2} = 0$. For processes $\pi^+\pi^- \to \gamma\rho^0, \pi^+\pi^- \to \gamma\eta,$ $\pi^+\pi^- \to \gamma\gamma$ m_{p_1}, m_{p_2} - mass of π- mesons, for processes $\pi^\pm\rho^0 \to \gamma\pi^\pm$, $\pi^\pm\eta \to \gamma\pi^\pm$, m_{p_1} - mass of π- meson, m_{p_2} - mass of ρ^0 or η mesons. In the fig.10 the dependence of momentum on cosine of scattering angle of thermal photons is presented.

As seen from fig.10 the dependence of momentum on cosine of scattering angle of photons is linear. Energy of produced photons also have linear dependence on cosine of scattering angle of photons. Energy of produced photons change in the interval of [0.177, 3.446] *MeV*, which corresponds to the temperature interval of [2.952, 3.995] 10^9 *K*.

CONCLUSIONS

The consideration of the formfactor of mesons in the calculations of the differential cross section of the processes of production of thermal photons showed that it reduces the differential cross section of the processes. Influence of formfactor of mesons to differential cross section of process decreases with increasing energy of colliding mesons. There is a significant influence of the form factor of meson on the differential cross section at small values of the energy of the colliding particles and the transverse momentum.

Thus, it has been shown that for processes $\pi^+\pi^- \to \gamma\rho^0$, $\pi^\pm\rho^0 \to \gamma\pi^\pm$ and $\pi^+\pi^- \to \gamma\gamma$ the following ratio is satisfied

$$\frac{d\sigma\left(\pi^+\pi^- \to \gamma\rho^0\right)}{dt} > \frac{d\sigma\left(\pi^\pm\rho^0 \to \gamma\pi^\pm\right)}{dt} > \frac{d\sigma\left(\pi^+\pi^- \to \gamma\gamma\right)}{dt}$$

Thus, it has been shown that for processes $\pi^+\pi^- \to \gamma\eta$, $\pi^\pm\eta \to \gamma\pi^\pm$ the following ratio is satisfied

$$\frac{d\sigma\left(\pi^+\pi^- \to \gamma\rho^0\right)}{dt} > \frac{d\sigma\left(\pi^\pm\rho^0 \to \gamma\pi^\pm\right)}{dt}$$

Energetic spectrum of produced photons indicate to temperature quark gluon plasma, formed at meson-meson collision. Transverse momentum of photons linear depends on cosine of scattering angle of photons. It is more likely to detect photons with a large transverse momentum at large values of the cosine of the scattering angle.

A comparison of differential cross sections of thermal photon production processes and prompt photon production of processes of Compton scattering and annihilation of a quark-antiquark pair [6] showed that they are of the same order. Thermal photons contribute significantly to the spectrum of photons at $P_T < 3$ GeV

All mathematical calculations were performed in Mathmatica 10 and FeynCalc. Feynman diagrams are constructed using JaxoDraw 2. The graphs are constructed using the Origin 9 program and edited using the Adobe Photoshop 8.

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Received: 16.01.2023