CALCULATING METHODS OF THE POLARIZATION RADIATION CHARACTERISTICS

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Nowadays, research in the high energy physics is an important component of modern science. Advanced technologies and new knowledge can provide answers to fundamental questions about the properties of matter. But with the advent of new technologies and knowledge there is a need for new theoretical and data analysis tools. Therefore it is necessary to develop and explore different methods of processing experimental data. As well as the development of various methods calculating the characteristics of the studied systems. That is why the aim of this work is to study existing methods of calculating the characteristics of the polarization radiation (diffraction and transition radiation) and to compare the methods based on three approaches, the so-called, virtual photons method, polarization current method and the method of images [3].

The virtual photons method is based on the similarity of a moving charged particles field and electromagnetic pulse. That lets to establish communication between the effects produced in collisions of the relativistic charged particles with a certain system, and the corresponding effects caused by the interaction of radiation (virtual photons) with the same system [1, 4].

The radiation, arises when a particle with arbitrary speed goes through the material with randomly distributed in homogeneities, can be calculated due to using this method. Perturbing effect of the fields of the incident particle is replaced by an equivalent pulse of radiation that can be represented in the form of spectral decomposition for virtual photons. Method of virtual photons is applicable when the perturbation caused by the fields can be considered small, and due to the assumption of a small displacement of the scattering particle din process of collision.

The calculation formula for determining the spectral-angular density of radiation energy has the following form:

$$\frac{d^2W}{d\omega dQ} \sim |E_x|^2 + |E_y|^2, \text{ where}$$

1. For the case when the particle goes through the circular aperture:

$$E_x = \frac{ie}{2\pi^2 c}\frac{q}{q^2+a^2}J_0(qa)\cos\psi,\ E_y = \frac{ie}{2\pi^2 c}\frac{q}{q^2+a^2}J_0(qa)\sin\psi,\ q = k * \mathrm{Sin}Q,$$

E_x –longitudinal component of the electromagnetic radiation field,

E_y – transverse component of the electromagnetic radiation field,

k – radiation wave vector,

a – diameter of the aperture,

c – the speed of light,

J_0– Bessel function,

Q– polar angle in a spherical coordinate system,

ψ– azimuthal angle in a spherical coordinate system.

2. For the case when the particle goes through the slit

$$E_x = \frac{iek_x}{4\pi^2 cf}\left(\frac{e^{-a_1(f-ik_y)}}{f-ik_y}+\frac{e^{-a_2(f+ik_y)}}{f+ik_y}\right),\ E_y = \frac{e}{4\pi^2 c}\left(\frac{e^{-a_1(f-ik_y)}}{f-ik_y}-\frac{e^{-a_2(f+ik_y)}}{f+ik_y}\right),$$

k_x, k_y– wave vector components along the x axis and y axis,

a_1, a_2 – the distance from the point of entry of particle to the edges of the slit,

$$f = \sqrt{k_x{}^2+\alpha^2}.$$

Image method is applied according to the real motion of particles in matter. This requires calculation of the arbitrarily moving charged particle radiation field at presence of the matter interface. Image method is based on the possibility of representing a charged particle field in the form of fields' sets of the dipoles along the particle trajectory, the representation of these dipoles images and finding arbitrarily moving charged particle field, expressed directly by the law of its motion [5, 6].

The calculation formula for determining the spectral-angular density of radiation energy has the following form:

$$\frac{d^2W}{d\omega dQ} = cR^2\left|H_\omega\right|^2, \text{ where}$$

$$H_\omega = \frac{\omega}{c}k\Pi_\omega,$$

Π_ω – Hertz vector sum of the transverse and longitudinal polarization.

To calculate the spectral-angular density of the radiation energy is necessary to know six Hertz vectors that characterize the different components radiation of a particle dipole and its image. These expressions are quite complicated in form and not to take plenty of space they were not given in the report.

Polarization current method is based on the representation of the polarization radiation as the current field induced in the substance by the field of the moving charged particle. In the case of a perfectly conducting infinitely thin screen polarization in complete analogy with the diffraction of the "free" wave is manifested in the induced dipole moment, is considered distributed over the surface of the screen with some density [2].

For the case when the particle goes through the circular aperture:

The calculation formula for determining the spectral-angular density of radiation energy has the following form:

$$\frac{d^2W}{d\omega dQ} = \frac{e^2}{\pi^2 c}\frac{\beta^2 Sin^2Q}{(1-\beta^2Cos^2Q)}\left(\frac{a\omega}{v\gamma}\right)^2\left(J_0(kaSinQ)K_1\left(\frac{a\omega}{v\gamma}\right)+\frac{1}{\beta\gamma SinQ}J_1(kaSinQ)K_0\left(\frac{a\omega}{v\gamma}\right)\right)^2, \text{ where}$$

$$\beta = \frac{v}{c},$$

$$\gamma = \frac{1}{\sqrt{(1-\beta^2)}}.$$

k – radiation wave vector,

a – diameter of the aperture,

c – the speed of light,

ν –the speed of particle,

J_0 , J_1– Bessel function,

K_0, K_1– Macdonald function,

ω – frequency of radiation,

Q– polar angle in a spherical coordinate system.

Figures 1-4 are graphs of the spectral-angular density of radiation energy for different parameters for all three methods. All graphs are given along the ordinate axis in relative units.

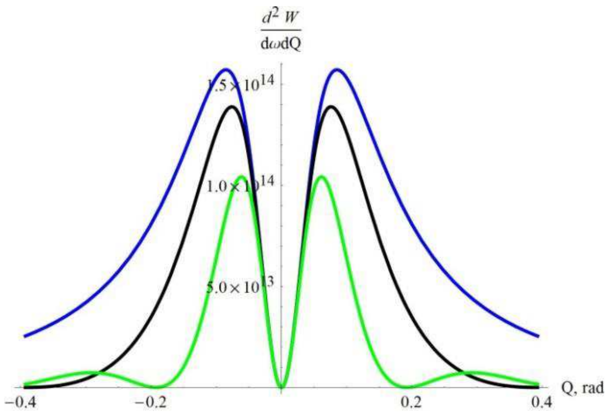

Fig 1. Spectral-angular density of diffraction radiation forvirtual photons method when particles go through a circular aperture on the viewing angle Q for different hole diameters (0.5mm (green lower line), 1 mm (black middle line), 5mm (blue upper line)) E=6 MeV, λ =5 mm, a =1 mm, ψ =1 rad.

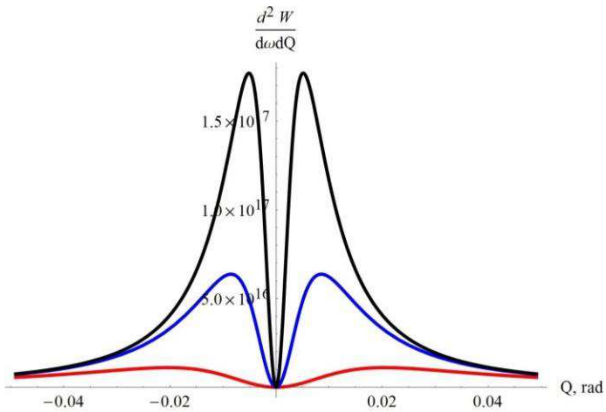

Fig 2. Spectral-angular density of diffraction radiation forvirtual photons method when particles go through a slit on the viewing angle Q for different energies of the incident particle (25MeV(red lower line), 60MeV (blue middle line), 100MeV(black upper line)) a_1 = 0,1 mm, a_2 = 0,9 mm, λ=10mm, ψ= π/2 rad.

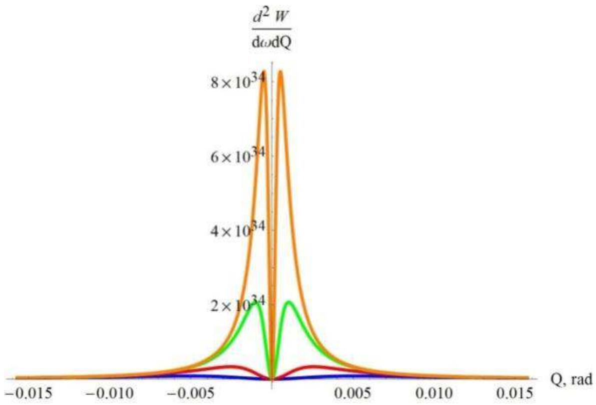

Fig 3. Spectral-angular density of the transition radiation forpolarization current method on a viewing angle Q for different energies of the incident particle (200 MeV (blue lower line), 500 MeV (green middle line), 1000 MeV (orange upper line)). λ = 5 mm, $\psi = \pi$ / 2 rad.

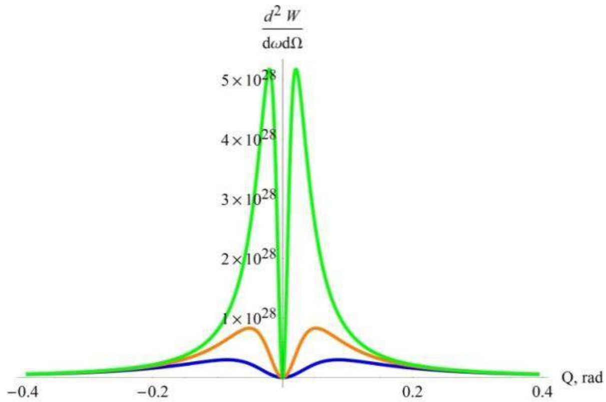

Fig 4. Spectral-angular density of the transition radiation for image method on a viewing angle Q for different energies of the incident particle (200 MeV (blue lower line), 500 MeV (orange middle line), 1000 MeV (green upper line)). λ = 1 mm.

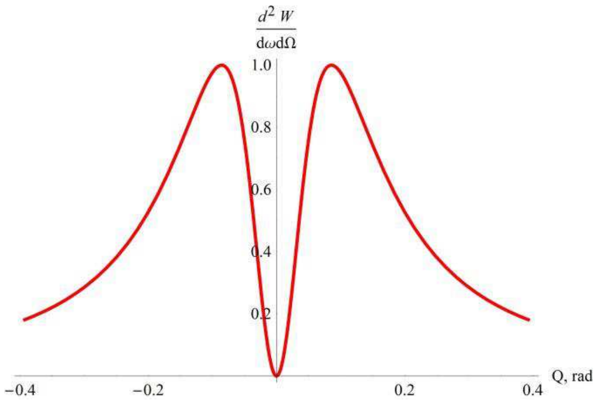

Fig 5. Normalized spectral-angular density of transition radiation for virtual photons method on a viewing angle Q

E=6 MeV, λ =5 mm, $\psi = \pi$ / 2 rad.

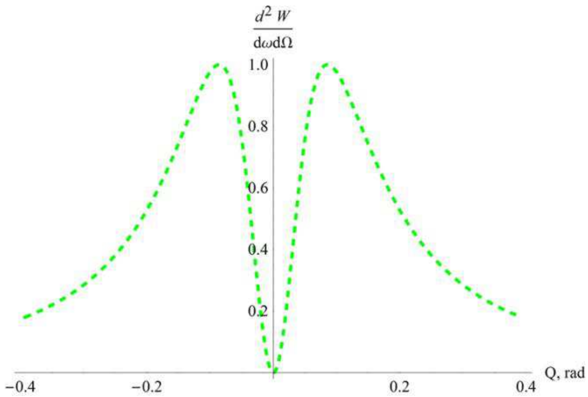

Fig 6. Normalized spectral-angular density of the transition radiation for image method on a viewing angle Q

λ = 1 mm, E=6 MeV.$\psi = \pi$ / 2 rad.

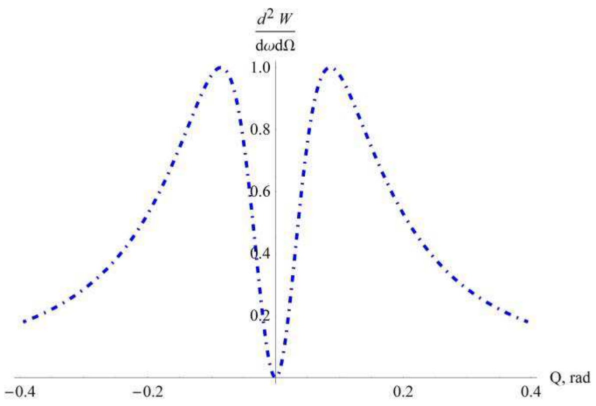

Fig 7. Normalized spectral-angular density of the transition radiation forpolarization current method on a viewing angle Q
λ = 5 mm, *E=6 MeV,* $\psi = \pi / 2$ rad.

From these graphs it is clear that the obtained dependences coincide with the known distribution of the spectral-angular density of radiation at the angles. Symmetrical peaks occur in the angles ~ $\frac{1}{\gamma} = 1 - \frac{v^2}{c^2}$.

The minimum at the center is due to the interference of the radiation from the edges of the target.

With the increase in the diameter of the circular aperture (Fig 1), the spectral energy density increases as the fraction of the radiation transmitted through the aperture. With increasing energy of the incident particle the spectral energy density is also increasing at a constant emission wavelength (Figure 2, 3, 4).

Spectral-angular density distribution of the transition radiation was calculated for the same system parameters for all three methods. As it's clear from the graphs all three methods have similar distribution that means any of them can be used for the calculation. The choice of method depends on the system for which each method has been developed and the parameters of the target and the incident particle (Figure 5, 6, 7).

During the work the following results were obtained:

1. for the virtual photons method two problems were considered: passage of a charged particle through a circular aperture and passage through the slit at different initial characteristics (particle energy, wavelength) and various parameters of slit and circular aperture (dimensions, entry of the particle)

2. for the method of images we calculated the intensity of the transition radiation produced by a charged particle through the boundary between matters, depending on the viewing angle and for different particle energies.

3.for the method of polarization currents we calculated the intensity of the transition radiation produced by a charged particle through the boundary between matters, depending on the viewing angle and for different particle energies.

4. three classic methods for the analysis of problems associated were studied and applied with the interaction of charged particles with different targets, that produces the polarization radiation.

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