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Brilliance of coherent peaks for type-B photoproduction of
electron-positron pairs in a crystal

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Abstract

The shape and magnitude of coherent peaks are studied for the type-B coherent photoproduction of electron-positron pairs in a crystal. It is shown that under detection of pairs with restricted emission angles the coherent peaks become more brilliant, with larger height and lower width. The influence of channeling effect on the position of coherent maxima is estimated.

1 INTRODUCTION

The type-A coherent creation of e^+e^- pairs by the high energy photons in a crystals has been predicted [1-2] and experimentally observed for the total pair yield [3]. The type-A coherent processes in a crystal arrive when the angle between the photon momentum and the crystal axis is quite large. During the last years the interest in the coherent pair photoproduction in the crystals is connected with the coherent process of type B, when the photon momentum is parallel to the crystal axis. In this case the coherent maxima arise at a sufficiently lower photon energies as compared with the type-A coherent photoproduction.

The type-B coherent pair photoproduction in a crystal has been predicted in [4-5] and experimentally observed in [6-7]. The observed enhancement of the yield due to coherence effect was about 10 – 20%, both for detection of all emitted pairs [6] and for detection of only symmetrical pairs [7]. The goal of this paper is to show how the detection of the created particles with given kinematical characteristics increases sufficiently (in terms of orders of magnitude) the relation between the coherent peak and the incoherent background.

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2 THEORY

The cross-section of e^+e^- pair creation in a crystal can be expressed as usual [1-5] by the sum of coherent $d\sigma_{coh}$ and incoherent $d\sigma_{incoh}$ parts :

$$d\sigma = d\sigma_{coh} + d\sigma_{incoh}. \quad (1)$$

For type-B process (the photon momentum $\vec{k}$ is parallel to the crystal axis OZ)

$$\begin{aligned} \frac{d\sigma_{coh}}{d\Omega_+ d\Omega_- d\epsilon_+} &= \frac{d\sigma_1}{d\Omega_+ d\Omega_- d\epsilon_+} \exp(-q^2 \bar{u}^2) |S(q_{||})|^2 \left| \sum_{n=0}^{N-1} \exp(iq_{||}nd) \right|^2, \\ \frac{d\sigma_{incoh}}{d\Omega_+ d\Omega_- d\epsilon_+} &= \frac{d\sigma_1}{d\Omega_+ d\Omega_- d\epsilon_+} N[1 - \exp(-q^2 \bar{u}^2)]. \end{aligned} \quad (2)$$

Here, $\hbar = c = 1$ units are used, $d\sigma_1/d\Omega_+ d\Omega_- d\epsilon_+$ - is the pair photoproduction cross-section on a separate atom of a crystal, $\exp(-q^2 \bar{u}^2)$ - is the Debye-Waller factor taking into account the thermal vibrations of the crystal atoms,

$$\vec{q} = \vec{k} - \vec{p}^+ - \vec{p}^- = \vec{q}_{||} + \vec{q}_{\perp},$$

- is the momentum transfered with $\vec{q}_{\perp}$ - being perpendicular to $\vec{k}$, and $\vec{q}_{||}$ - being parallel to $\vec{k}$, $S(\vec{q}_{||})$ - is the structure factor of the crystal axis and N - is the number of atoms in an axis, with d - being the crystal lattice constant, and

$$I(q_{||}) = \left| \sum_{n=0}^{N-1} \exp(iq_{||}nd) \right|^2 = \frac{\sin^2(Nq_{||}d/2)}{\sin^2(q_{||}d/2)}, \quad (3)$$

- is the interference multiplier. As it follows from Eqs.(2-3), the coherent contribution to the cross-section has the sharp maxima (coherent peaks) at

$$q_{||} = \omega - p_{||}^+ - p_{||}^- = g_n, \quad n = 1, 2, 3, \dots, \quad (4)$$

where $\omega = k$ - is the photon energy, $p_{||}^{\pm}$ - is the projection of electron (positron) momentum on the crystal axis, $g_n = g_0 n$ ($g_0 = 2\pi/d$) - is the reciprocal lattice vector. In the relativistic limit ($\omega \gg m$) the emission angles of electron and positron are small: $\Theta_{\pm} \sim m/\omega \ll 1$, and the relation (4) takes the form :

$$\omega - p^+(1 - \Theta_+^2/2) - p^-(1 - \Theta_-^2/2) = g_n, \quad n = 1, 2, 3, \dots \quad (5)$$

As it follows from (5), if $d\sigma_1/d\Omega_+ d\Omega_- d\epsilon_+ \neq 0$, then for every fixed momenta of the electron and the positron one can choose those values of ω , Θ_+ , Θ_- (or choosing fixed $p^+ \Theta_+$ and changing ω and $p^- \Theta_-$ ect.,) when the interference multiplier equals N^2 and the cross-section has a sharp peak.

Figure 1a shows the dependence of the differential cross section

$$\frac{d\sigma}{d\Theta_- d\Theta_+ d\epsilon_+},$$

on the emission angles of electron and positron (Θ_+ , Θ_-), integrated over the angle φ between the momenta $\vec{p}^+$ and $\vec{p}^-$ in the plane perpendicular to the photon momentum, for the case when the photon beam is parallel to the crystal axis consisting of N atoms (symmetrical pairs, $x = \omega/\varepsilon_+ = 0.5$ and $< 100 >$ Si crystal) in the vicinity of the coherent peak with $n = 1$ ($\omega = 240$ MeV). Figure 1b shows the same cross-section in an amorphous target of equal thickness. Comparing Figures 1a and 1b we conclude that the differential cross-section in a crystal has the sharp coherent peak in the vicinity of the "resonant" photon energy.

Note, that the equality of the cross-sections to zero in Figures 1a-1b at $\gamma_+\Theta_+ = \gamma_-\Theta_-$ (with accuracy of the order of m^2/ω^2) is the consequence of the integration over φ . The cross-section of the positronium atom photoproduction, both in a crystal and in an amorphous target, is defined by the corresponding cross-section of pair photoproduction when the conditions $\gamma_+\Theta_+ = \gamma_-\Theta_-$ and $\varphi = 0$ are satisfied and is not equal to zero, as one can see considering Figures 1a-1b.

The partial case of (5) considered in [8-9], is the coherent photoproduction of positronium atoms. For this process, the cross-section has the sharp peaks at the photon energies defined by [8-9]:

$$\omega_n = (4m^2 + g_n^2)/2g_n, n = 1, 2, 3, \dots,$$

which follows from (4-5) assuming $\vec{p}^+ = \vec{p}^-$.

Fig.2 shows the relation

$$R = \frac{d\sigma_{coh} + d\sigma_{incoh}}{Nd\sigma_1},$$

of the differential cross-section of coherent photoproduction of positronium atom on the crystal string consisting of N atoms, to the differential cross-section on N atoms in an amorphous target, calculated taking into account the energy spread of the initial photon beam $\Delta\omega/\omega = 10^{-2}$ [8-9]. Comparing the enhancement due to the coherence effect under measurements of the total pair yield [6,7], one can see the increase of the relative enhancement of the coherent peak from 10^{-1} up to $10 - 10^2$.

It is obvious that the measurement of any differential cross-section under the condition (5) can lead to an observation of the sharp coherent peaks. In a real experiment, due to angular and energy resolutions of a detecting system, one can only approach to the exact condition (5) and the sharp maxima will be "washed away". One of the simplest ways to measure the pair yield with given kinematical characteristics, could be the detection of pairs with the fixed value of $x = \varepsilon_+/\omega$, emitted at angles less than the chosen Θ_m (some kind of the collimation or momentum correlation).

The pair yield with fixed energies of electron ε_- and positron ε_+ , and the emission angles $\Theta_{\pm} \leq \Theta_m$ one can calculate by substitution of the differential cross-section from [10] in Eq.(2) and integration over permitted emission angles. In order to perform the integration, we use the representation of an interference multiplier $I(q_{||})$ as a sum of a δ -functions, assuming $N \gg 1$:

$$I(q_{||}) = \frac{\sin^2(\frac{1}{2}Nq_{||}d)}{\sin^2(\frac{1}{2}q_{||}d)} = g_0 N \sum_{n=-\infty}^{n=\infty} \delta(q_{||} - g_0 n).$$

Taking into account (4) and

$$p^{(\pm)} = (\varepsilon_{\pm}^2 - m^2)^{1/2} \simeq \varepsilon_{\pm}(1 - 1/2\gamma_{\pm}^2),$$

we rewrite further $\delta(q_{||} - g_0 n)$ in the form :

$$\delta(q_{||} - g_0 n) = \delta\left[\frac{\varepsilon_+}{2\gamma_+^2}(\xi_+^2 + 1) + \frac{\varepsilon_-}{2\gamma_-^2}(\xi_-^2 - 1) - ng_0\right] =$$

$$\frac{2\gamma_+^2}{\varepsilon_+} \delta\left\{\xi_+^2 - \left[\frac{2\gamma_+^2 ng_0}{\varepsilon_+} - \zeta(\xi_-^2 - 1)\right]\right\},$$

where $\zeta = \gamma_+/\gamma_-$, $\xi_{\pm} = \gamma_{\pm}\Theta_{\pm}$, $\gamma_{\pm} = \varepsilon_{\pm}/m$. Now the integration over ξ_+ is trivial due to δ - functions and we immediately obtain :

$$\frac{d\sigma_{coh}}{dx} = \sigma_0 \gamma_+ \frac{\lambda}{d} \times$$

$$\int_{-\varphi_0}^{\varphi_0} d\varphi \int_{(\Delta\gamma_-)^2}^{((\Delta+\Theta_m)\gamma_-)^2} d\xi_-^2 \sum_{n=n_1}^{n_2} \frac{\Xi(\xi_-, \xi_n, \varphi) E(\xi_-, \xi_n, \varphi)}{Q^2(\xi_-, \xi_+, \varphi) + (\lambda/R)^2} |S(q_{||})|^2 . \quad (6)$$

Here, Δ - is the angle between the crystal axis and the axis of solid angle over which the integration is performed; Θ_m , φ_0 - define the integration region.

We restored here usual units ($\lambda = \hbar/mc$, $r_0 = e^2/mc^2$, $\alpha = e^2/\hbar c$) , took into account the atomic screening in the form $V(r) = (Ze/r) \times \exp(-r/R)$ and introduced the following notations :

$$\sigma_0 = 8x(1-x)Z^2\alpha r_0^2 N ,$$

$$\Xi(\xi_-, \xi_+, \varphi) = -\frac{\xi_n^2}{(1+\xi_n^2)^2} - \frac{\xi_-^2}{(1+\xi_-^2)^2} + \frac{1}{2x(1-x)} \times \frac{\xi_n^2 + \xi_-^2}{(1+\xi_n^2)(1+\xi_-^2)}$$

$$+ \left(\frac{x}{1-x} + \frac{1-x}{x}\right) \times \frac{\xi_n \xi_- \cos \varphi}{(1+\xi_n^2)(1+\xi_-^2)} ,$$

$$Q^2(\xi_-, \xi_n, \varphi) = g^2(\xi_-, \xi_n,)/m^2 c^2 =$$

$$\xi_n^2 + \xi_-^2 + 2\xi_n \xi_- \cos \varphi + \left(\frac{mc^2}{2\hbar\omega}\right)^2 \times \left[\frac{1+\xi_n^2}{x} + \frac{1+\xi_n^2}{1-x}\right]^2 ,$$

$$E(\xi_-, \xi_n, \varphi) = \exp[-Q^2(\xi_-, \xi_n, \varphi)\bar{u}^2/\lambda^2] ,$$

$$\xi_n = \frac{4\pi\gamma_+\lambda}{d}n - 1 - \zeta(1 + \xi_-^2),$$

where n_1, n_2 define the reciprocal lattice vectors which give rise to the cross-section for the given photon energy and permitted region of the emission angles for electron and positron. For our kinematics,

$$n_1 = \frac{d}{4\pi\gamma_+\lambda}[\gamma_+\Delta^2 + 1 + \zeta(1 + \xi_-^2)],$$

$$n_2 = \frac{d}{4\pi\gamma_+\lambda}[\gamma_+(\Delta + \Theta_m)^2 + 1 + \zeta(1 + \xi_-^2)].$$

The incoherent part (the same notations used) has the form:

$$\frac{d\sigma_{incoh}}{dx} = \frac{\sigma_0}{\pi} \times \int_{-\varphi_0}^{\varphi_0} d\varphi \int_{(\Delta\gamma_-)^2}^{((\Delta+\Theta_m)\gamma_-)^2} d\xi_-^2 \int_{(\Delta\gamma_+)^2}^{((\Delta+\Theta_m)\gamma_+)^2} d\xi_+^2 \frac{\Xi(\xi_-, \xi_+, \varphi)(1 - E(\xi_-, \xi_n, \varphi))}{Q^2(\xi_-, \xi_+, \varphi) + (\lambda/R)^2}. \quad (7)$$

The angle φ - in(6-7) is the angle between electron and positron momenta in the plane perpendicular to the photon momentum. For small enough angles Δ and Θ_m ($\Delta > \Theta_m$ - when the axis of emission cone does not coincide with the crystal axis) :

$$\varphi_0 = \arctan(\tan \Theta_m / \sin \Delta) \sim \arctan(\Theta_m / \Delta) \sim \Theta_m / \Delta$$

For those angles φ the pair photoproduction cross-section is small [10] and therefore the most interesting case for an experiment is the case $\Delta = 0$, i.e. the axis of emission cone of e^+e^- coincides with the crystal axis. In this geometry, the integration over φ in (6-7) is performed from 0 up to 2π .

Since the function

$$F(\varphi) = \frac{1}{Q^2(\xi_-, \xi_+, \varphi) + (\lambda/R)^2},$$

has a very sharp maximum at $\varphi \simeq \pi$:

$$F(\varphi) \sim \begin{cases} \gamma^4 \gg 1; & \gamma \gg (R/\lambda) \\ (R/\lambda)^4 \gg 1; & \gamma \ll (R/\lambda) \\ (\gamma^2 + (R/\lambda)^2)^{-2} \gg 1; & \gamma \sim (R/\lambda) \end{cases}$$

(for photon energy of order of hundreds of MeV $F(\pi) \sim 10^8 - 10^9$), and

$$F(0) \sim F(2\pi) \sim 1; \quad \xi_{\pm} \sim 1,$$

and the remaining multipliers in (5-6) are slowly changing functions , we keep only $F(\varphi)$ under the integral sign and take the remaining factors at $\varphi = \pi$. After the integration we found :

$$\frac{d\sigma_{coh}}{dx} = \sigma_0 \gamma_+ \frac{\lambda}{d} \times \int_0^{(\Theta_m \gamma_-)^2} d\xi_-^2 \sum_{n=n_1}^{n_2} \Xi(\xi_-, \xi_n, \pi) E(\xi_-, \xi_n, \pi) \Phi(\xi_-, \xi_n) |S(q_{||})|^2 , \quad (8)$$

$$\frac{d\sigma_{incoh}}{dx} = \frac{\sigma_0}{\pi} \times \int_0^{(\Theta_m \gamma_-)^2} d\xi_-^2 \int_0^{(\Theta_m \gamma_+)^2} d\xi_+^2 \Xi(\xi_-, \xi_+, \pi) (1 - E(\xi_-, \xi_n, \pi)) \Phi(\xi_-, \xi_n) , \quad (9)$$

where

$$\Phi(\xi_-, \xi_n) = \frac{2\pi/a^2}{(1 - b^2/a^2)^{3/2}} ,$$

$$a(\xi_-, \xi_n) = \xi_n^2 + \xi_-^2 + \left(\frac{mc^2}{2\hbar\omega}\right)^2 \times \left[\frac{1 + \xi_n^2}{x} + \frac{1 + \xi_-^2}{(1 - x)}\right]^2 + (\lambda/R)^2 ,$$

$$b(\xi_-, \xi_n) = 2\xi_n \xi_- .$$

The remaining integration is performed numerically.

3 NUMERICAL RESULTS

Let us consider first the photoproduction of equal-energy pairs (symmetrical pairs, $\varepsilon_- = \varepsilon_+ = \hbar\omega/2$; $x = \varepsilon_+/\hbar\omega = 0.5$) with closely the same directions of momenta and the geometry $\Delta = 0$.

For those pairs, instead of (5) we can write :

$$\hbar\omega - \frac{cp}{2}(\Theta_+^2 + \Theta_-^2) = g_n, \quad n = 1, 2, 3, \dots, \quad (10)$$

at $p^+ = p^- = p$.

Fig.3 shows the results of the calculations of the yield of those pairs with closely the same momenta, in dependence on the photon energy and in the vicinity of the first coherent peak ($n = 1, < 100 >$ Si at the photon energy $\omega = 240$ MeV) , for two values of $\Theta_{m1} = 10^{-2}$, $\Theta_{m2} = 10^{-3}$.

Fig.3a shows only the coherent part of cross-section and Fig.3b shows the sum of the coherent and incoherent parts. As follows from Fig.3a, the coherent peak for Θ_{m2} becomes more brilliant, the maximal value of the peak is of the same order as for Θ_{m1} and the width becomes sufficiently less. The total pair yield for this

kinematics decreases approximately by orders of magnitude, Fig.3b (mainly due to the suppression of the incoherent part of the cross-section), which one can compensate in an experiment by increase of the bremsstrahlung beam intensity entering the crystal.

Fig.4 demonstrates the results of the calculation of the yield of asymmetrical pairs ($x = 0.7$) for the same kinematics as above for symmetrical pairs. The main difference with symmetrical pairs is that the position of coherent peak is shifted to the region of higher energy photons. The height and the width of coherent peak for the photoproduction of asymmetrical pairs (for given kinematics $\Delta = 0$) is larger.

Therefore, one can investigate the coherent type-B photoproduction of e^+e^- pairs under conditions, when the coherent peak is more brilliant and the incoherent background is suppressed, in an experiment with restricted emission angles of e^+e^- in the final state ("narrow" pair).

4 CHANNELING OF CREATED PARTICLES AND POSITION OF COHERENT PEAK

Similar to the distortion of the shape of the coherent maxima in the type-B coherent bremsstrahlung of the relativistic electrons in a crystal, due to an influence of the interaction of electron with a continuous axial potential [12] one can expect the same effect for the cross-symmetrical process, which is the type-B coherent creation of e^+e^- pairs in a crystal (coherent pair creation in a channeled states).

Let us estimate the typical photon energy region in the vicinity of the coherent peak, where the channeling of pair particles can manifest itself. Let the photon momentum $\vec{k}$ be parallel to the crystallographic axis. The energy and longitudinal momentum conservations can be written as:

$$\omega = \sqrt{(p_{\parallel}^+)^2 + m^2} + \sqrt{(p_{\parallel}^-)^2 + m^2} + \varepsilon_{\perp}^+ + \varepsilon_{\perp}^-, \quad (11)$$

$$\vec{k} = \vec{p}_{\parallel}^+ + \vec{p}_{\parallel}^- + \vec{g}_n, \quad |\vec{k}| = \omega, \quad (12)$$

where g_n is defined in Sec.2 and $\varepsilon_{\perp}^+, \varepsilon_{\perp}^-$ are so called transverse energies of the positron and the electron in a continuous potential of a crystallographic axis. These energies and the corresponding wave functions are the eigenvalues and the eigen wave functions of the corresponding quantum equation describing channeling of the electron (positron) in a crystal (see, for the relativistic particles channeling e.g. the review [13]).

Let us further introduce new definition for the symmetrical pairs : $p_{\parallel}^- = p_{\parallel}^+ = p$. Using this definition and substituting p from (12) into (11) we obtain after a simple algebra:

$$\omega_n^* = \frac{4m^2 + g_n^2}{g_n} \frac{1}{(1 - \Delta_{\perp}/g_n)}, \quad (13)$$

where $\Delta_{\perp} = \varepsilon_{\perp}^+ + \varepsilon_{\perp}^-$ characterizes the channeling of the created particles of pair. The case $\Delta_{\perp} = 0$ corresponds to the coherent pair creation without taking into account the interaction of e^+e^- with the continuous axial potential and leads to the formula

$$\omega_n^* = \omega_n = (4m^2 + g_n^2)/2g_n, n = 1, 2, 3...$$

for the positions of the coherent maxima exactly as in the standard (without channeling) theory [1-5], see also Section 2.

As it follows from (13), the interactions of e^+e^- with a continuous axial potential lead to the "spread" of the threshold for appearance of the coherent maximum. In order to estimate the "uncertainty" of position of the coherent peak it is enough to substitute $\Delta_{\perp} = \pm V_0$, where V_0 - is the characteristic value of the depth of axial potential well. In particular, in Sec.3 we calculated the position of coherent peak ($n = 1$) for type-B pair photoproduction in $< 100 > Si$ at ($\omega_1 = 240 MeV$). For this case $g_1 = 2\pi/d \sim 2.3 MeV$, $V_0 \sim 140 eV$, i.e. $\Delta_{\perp}/g_1 \sim 0.08$, which leads to the uncertainty of the peak position $\Delta\omega_1 \sim \pm 15 MeV$ near the one obtained using standard theory value $\omega_1 = 240 MeV$.

Thus, for the coherent type-B pair photoproduction we can expect the change of the shape of the coherent peak in the region of about $30 MeV$ near $\omega_1 = 240 MeV$, due to the interaction of the pair particles with an axial continuous potential. Our formula (13) estimates only the photon energy region where the channeling of created particles can change the shape of coherent peaks. In order to describe the shape of the coherent peak quantitatively, one has to leave the standard theory of coherent pair creation [1-5] and to carry out the calculation of a matrix elements using not plane waves but wave functions of particles which are solutions of the corresponding wave equations with a continuous axial potential. As one can suppose, the greater the $\Delta_{\perp}$ value is, the less will be the matrix element since it depends strongly on the overlapping of electron and positron wave functions in a classically forbidden (for each of the particles) region, which strongly depends on a transverse energies of created particles.

The effect of the "spread" of the position of coherent peak depends on the crystal temperature T due to a dependence of V_0 on T . We found from formula (13) an additional temperature shift of the position of the coherent peak caused by the temperature decrease from T_1 to T_2 :

$$\omega_n^*(T_2) - \omega_n^*(T_1) = \omega_n \frac{[V_0(T_2) - V_0(T_1)]/2\pi d}{[1 - V_0(T_1)/2\pi d][1 - V_0(T_2)/2\pi d]}. \quad (14)$$

For example, the typical amplitude of a change of $V_0(T)$ for the case of $< 100 > Si$ is: $V_0(300K) = 140 eV$, $V_0(0K) \sim 175 eV$, i.e. the maximal additional uncertainty of the position of coherent peak can be about $\sim 10 MeV$ and therefore the total "uncertainty" at $T = 0K$ can reach the value $\sim 40 MeV$ near the photon energy about $\omega = 240 MeV$, defined using the standard coherent theory.

The estimation of the channeling effect on the coherent creation of asymmetrical pairs can be done in a similar way as by obtaining of the formula (13) but the algebra

is more complicated.

Since the height of coherent maxima is proportional to the Debye-Waller factor $\exp(-q^2\bar{u}^2)$ (see, Eq.2), which increases with the temperature decrease, there appear two effects: the first one is the increase of the height of the coherent peak and the second one is the increase of the width of this peak.

Thus, the channeling of created particles can change the brilliance of coherent peaks as compared with our numerical results, Fig.3-5. The experimental investigation of type-B coherent pair photoproduction in a channeled states (including temperature effect) could be very interesting, but requires more fine experimental resolution as used before [7].

5 CONCLUSION

In conclusion, we point out that :

1. The simple estimation shows that the channeling of created pair particles can lead to the uncertainty of the position of coherent peak and probably to the splitting of coherent peak which is the combined effect of quantum electrodynamics analogous to the splitting of the peak in the coherent bremsstrahlung of type B [12]. Therefore, the special kinematics described above (when the coherent peak is more brilliant and the incoherent background is suppressed) is favourable for the experimental investigations of the structure of coherent peaks and for the search of combined effects. An interesting observation is that the magnitude of the combined effect depends on the crystal temperature according Eq.(14).

2. The experimental studies of the influence of correlations between electron and positron momenta in the final states can be considered as the first stage of the sequential transition to an experiment which is the observation of the coherent photoproduction of positronium atoms in a crystal [8,9] and the search for the Sakharov effect [11].

3. The increase of the relative height of the coherent peak and the suppression of the incoherent background under the special kinematics can be considered as a possible method to prepare a positron (electron) beam with a small angular and energy spread. The advantages of the crystal target in comparison with an amorphous target are: i) the photoproduction cross-section in a crystal has narrow maxima at definite photon energies and emission angles; ii) the yield of positrons at some given values of Θ_m and ϵ_+ is greater in terms of orders of magnitude in comparison to the yield of an amorphous target, see Fig.5. The production of intense positron beams using the channeling radiation from the crystal target plus a conversion of this radiation into pairs in an amorphous target has been discussed recently in [14-15].

4. The possibility discussed above of the increase of brilliance of coherent peaks can be applied not only for the type-B photoproduction of e^+e^- pairs but for an arbitrary direction of the photon momentum with respect to the crystal axis (the type-A process). In this case all three components of momentum transferred to the crystal are quantized and our relation (4) is replaced by three equations which connect

the incident photon energy with energies and momenta of the created electron and positron. In this case the typical photon energies at which the coherent peaks appear are much greater than for the type-B process considered here .

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FIGURE CAPTION

- Fig.1a** The dependence of the differential cross-section of type-B pair photoproduction on $\gamma_+ \Theta_+$ and $\gamma_- \Theta_-$ (the sum of coherent and incoherent parts), in the vicinity of the coherent peak $n = 1$, $\omega = 240$ MeV. The target is a $Si < 100 >$ crystal, and the other parameters are: $N = 10$, $T = 273K$, $\gamma_+ = \gamma_- = \omega/2m$.
- Fig.1b** The dependence of the differential cross-section of pair photoproduction on $\gamma_+ \Theta_+$ and $\gamma_- \Theta_-$ in an amorphous target, at the same photon energy $\omega = 240$ MeV, $\gamma_+ = \gamma_- = \omega/2m$.
- Fig.2** The relation of the differential cross-sections of photoproduction of positronium atom (bounded e^+e^- pair) on the crystal axis consisting of N atoms ($Si < 100 >$, $N = 10^3$, $T = 273K$) to the same cross-section on N atoms in an amorphous target. The energy spread of incident photon beam $\Delta\omega/\omega = 10^{-2}$ is taken into account.
- Fig.3** The yield of symmetrical e^+e^- pairs under photons interaction with $< 100 > Si$ axis ($T = 273K$, $L = 0.35\mu m$), for two maximal emission angles $\Theta_{m1} = 10^{-2}$ (dashed line) and $\Theta_{m2} = 10^{-3}$ (solid line):
- a) only coherent part of the cross-section
 - b) the sum of coherent and incoherent parts of cross-section
- Fig.4** The same as in Fig.2 but for asymmetrical pairs ($x = 0.7$)
- Fig.5** The yield of symmetrical e^+e^- pairs under interaction of photons with $< 100 > Si$ axis ($T = 273K$, $L = 0.35\mu m$), and with amorphous target of the same thickness, into the emission cone $\Theta_m \leq 10^{-3}$.

fig.1a

fig.1b

fig.2

fig.3a

fig.3b

fig.4a

fig.4b

Si $\langle 100 \rangle$ $x = 0.5$

fig.5