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ANALYZING POWER OF THE HIGH ENERGY PHOTON POLARIMETERS BASED ON PROCESSES PAIR AND TRIPLET PHOTOPRODUCTION

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In the work it is considered influence of experimental factors on analyzing power processes of e^+e^--pairs photoproduction in the field of nuclei and atomic electrons (triplet photoproduction), which can be used for measurement the linearly polarizations of photon beams in the energy range 30-3000 MeV. Modeling has shown that analyzing power of both processes does not practically depend on initial photon energy in the interval under study and can reach Λ~0.11 when there is no applied any selection of the events. The analyzing power of the processes can be increased up to Λ~0.2 at the e+e⁻-pairs selection with close energies of electron and positron, or in the case of triplet photoproduction, if the recoil electron selection near the border of kinematically permitted region is used.
KEY WORDS: analyzing power, photon polarimeter, linear polarization, photoproduction e^+e^--pair, triplet photoproduction, recoil electrons, δ-electrons, symmetric pairs.

АНАЛІЗУЮЧА СПРОМОЖНІСТЬ ПОЛЯРИМЕТРА ФОТОНІВ ВИСОКИХ ЕНЕРГІЙ НА ОСНОВІ ПРОЦЕСІВ ФОТОНАРОДЖЕННЯ ПАР ТА ТРИПЛЕТІВ

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В роботі розглядається вплив експериментальних факторів на аналізуючу спроможність процесів фотонародження e^+e^--пар на ядрі та атомних електронах (фотонародження триплетів), які можуть бути використані для вимірювання лінійної поляризації фотонних пучків в області енергій 30-3000МеВ. Моделювання показало, що аналізуюча спроможність обох процесів практично не залежить від енергії початкового фотона в досліджуваному проміжку енергій і може досягати значення Λ~0,11 для поляриметра, в якому не проводиться селекція подій. Величина аналізуючої спроможності процесів може бути збільшена до величини Λ~0,2 при відборі подій народження e^+e^--пар з близькими енергіями електрона та позитрона, або у випадку з фотонародженням триплетів, при відборі електронів віддачі поблизу границі кінематичної області.
КЛЮЧОВІ СЛОВА: аналічуюча спроможність, фотонний поляриметр, лінійна поляризація, фото народження e^+e^--пар, фото народження триплетів, електрони віддачі, δ-електрони, симетричні пари.

АНАЛИЗИРУЮЩАЯ СПОСОБНОСТЬ ПОЛЯРИМЕТРА ФОТОНОВ ВЫСОКИХ ЭНЕРГИЙ НА ОСНОВЕ ПРОЦЕССОВ ФОТОРОЖДЕНИЯ ПАР И ТРИПЛЕТОВ

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В работе рассматривается влияние экспериментальных факторов на анализирующую способность процессов фоторождения e^+e^--пар на ядре и атомных электронах (фоторождение триплетов), которые могут быть использованы для измерения линейной поляризации фотонного пучка в области энергий 30-3000МэВ. Моделирование показало, что анализирующая способность обоих процессов практически не зависит от энергии начального фотона в исследуемом диапазоне и может достигать значения Λ~0,11 для поляриметра, в котором не производится селекции событий. Величина анализирующей способности процессов может быть увеличена до значения Λ~0,2 при отборе событий рождения e^+e^--пар с близкими энергиями электрона и позитрона или, в случае фоторождения триплетов, при отборе электронов отдачи вблизи границы кинематически разрешенной области.
КЛЮЧЕВЫЕ СЛОВА: анализирующая способность, фотонный поляриметр, линейная поляризация, фоторождение e^+e^--пар, фоторождение триплетов, электроны отдачи, δ-электроны, симметричные пары.

Polarization experiments play an important role in researches of nucleon and nuclear structure. Therefore linearly polarized photon beams have been produced and applied for photonuclear investigations practically at all electron accelerators. And at present they are successfully used in all leading center, such as, MAMI, ELSA and JLAB.

The main problem in polarized photon experiments is an accurate determination of the photon polarization. Overall tendency of increasing experimental data accuracy brings to requirement of increasing the photon polarization measurement precision. There are various approaches to the high energy photon beam linear polarization determination, see, e.g. [1], but more preferable and reliable way is its direct measurement with a photon polarimeter based on the QED processes, such as e^+e^- pairs photoproduction in a nuclear field or in a field of atomic electrons (the triplet photoproduction). That results from these processes properties: (i) sufficiently high azimuthal dependence of the cross section on direction of the photon polarization (the analyzing power); (ii) weak dependence of the analyzing power on photon energy; (iii) possibility to calculate the analyzing power with high precision; (iv) large cross section and convenient signature for their identification.

However, there are some effects which have influence on the analyzing power and can sufficiently reduce it. They are, firstly, experimental conditions and technique of the polarization measurement and, secondly, background processes initiated in a matter of the polarimeter target both by the initial photons and by the particles produced in the primary QED processes.

Influence of the background processes have been studied in detail in the previous papers [2,3] for plastic (C_6H_6), Al, Si targets and photon energies in the range 50-3000 MeV. It was found that background processes are especially important when the triplet photoproduction is used for polarization measurement. Among them the main is the δ-electrons (δ-rays) production due to electron knocking-out by the fast charged particles produced due to primary QED processes in the matter of the polarimeter target. This background is comparable with the recoil electron yield from the triplet photoproduction, thus it may have a big influence on the analyzing power of the triplet polarimeter.

It should be noted that reactions of the δ-electron and the triplet photoproduction have the similar kinematics, so it is practically impossible to remove the δ-electron contribution with help of any trigger conditions. Thus, for the δ-electron background suppression in the triplet polarimeter one can use some differences in the angular and energy distributions of the processes, for example, to restrict the angular interval of the recoil electron registration by the range ~10-45^0 and apply the differential thresholds of the recoil electrons registration in dependence on their angle emission. At these conditions it is possible to reduce the δ-electron contribution up to ~15-20%.

In this article the following step has been made for study of the e^+e^- pairs and the triplet photoproduction processes using for photon polarization measurement. The goal of the work was studied in more detail these processes analyzing power, its dependence on background and other experimental factors such as multiple scattering and selection of the events of the e^+e^- pairs production. The investigations have been carried out by mathematical simulation method with using computer code developed for simulation of the processes which take place in the polarimeter target when the high energy polarized photon beam passes through the target. The code is based on the GEANT-3 package [4] which was supplemented by some subroutines for calculation azimuthal differential distributions of the final particles produced by the polarized photons at the Compton scattering, pair and triplet photoproduction. For the triplet photoproduction description the BASE/SPRING code [5] was applied. Some details of the simulation were presented in [2, 3, 6].

SOME FEATURES OF THE PAIRS PROCESSES

Pair photoproduction in the field of nuclei

Proposition to use process of the e^-e^+ pair production in the field of nuclei, $\gamma+Z\rightarrow Z+e^++e^-$, for linear photon polarization measurement was put forward in 1950's [7, 8]. Detail calculations of the process characteristics were produced in [9]. It has been shown that the plane of emitted e^-e^+ pair's particles correlates with direction of the photon polarization in such a way that the pairs are preferably emitted in the plane of photon polarization and the azimuthal distribution can be presented as

$$d\sigma/d\varphi=\sigma_0^{pair}[1+P\Lambda\cos(2\varphi)]. \qquad (1)$$

$\sigma_0^{pair}=\sigma^{pair}(Z, E_\gamma)$ is the cross section of the pair photoproduction with unpolarized photons, P is the photon polarization, Λ is the analyzing power (or asymmetry) when P=1, φ is the azimuthal angle counted from the photon polarization direction. The main experimental restriction of this process using for polarization measurements is small angle between the pair's components, which decreases with increasing photon energy to the level when it becomes practically impossible to determine the needed azimuthal distribution. Therefore, the method can be effectively used, as a rule, at energies up to a few GeV the detected particle or particles.

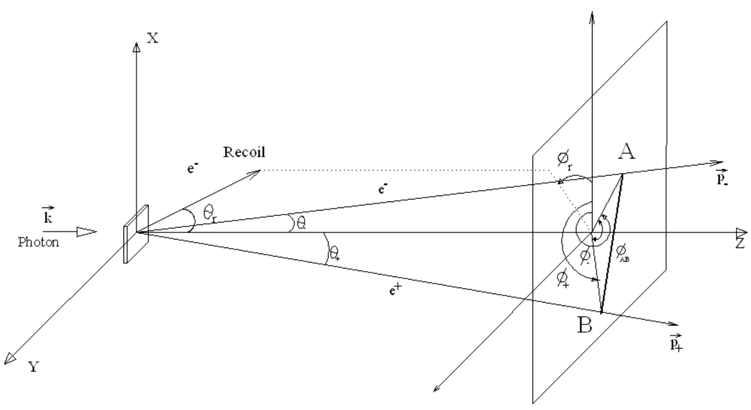

Fig. 1. The kinematics of the pair photoproduction. "Recoil" denotes a recoil nucleus for the pair production on the nuclei and recoil electron for the triplet photoproduction.

At first the azimuthal distribution of one pair particle was measured. The problem of small angles was resolved by using magnetic spectrometer to separate electrons and positrons but at the price of a decreasing the analyzing power. New scheme was proposed by Wojtsekhowski [10]. It was suggested to measure azimuthal distribution of the vectors ***AB***, which connect the positron and electron crossing points of the "detector plane", Fig.1, that can be made with coordinate detectors (silicon micro-strip or pixel detectors). In this case the angle $\varphi=\varphi_{AB}$ in (1) [10]. This is most easily measurable parameter of the process, depending on the photon polarization. In according to estimation [10] the asymmetry of the vectors ***AB*** azimuthal distribution is Λ~0.14 and can be increased up to Λ~0.2-0.3 at selection of nearly symmetric pairs.

The method was successfully tested experimentally on the polarized photon beam, produced at interaction of high energy electron beam with laser radiation [11]. The measurements were carried out in the photon energy interval E_γ~1.5-2.3 GeV, in which the photon beam polarization was P~0.9-0.98. It was obtained close to expected values (taking into consideration the experimental factors) of the analyzing power Λ~0.1 (without events selection) and Λ~0.18 at the selection of nearly symmetrical pairs.

In the article we will study only this azimuthal distribution for the pair photoproduction process and will call it the asymmetry (analyzing power) of the process.

Triplet photoproduction

It was Boldyshev and Peresunko, who firstly in the early seventies proposed to use the triplet photoproduction process, $\gamma+e^-\rightarrow e^-+e^++e^-$, for photon linear polarization measurement [12,13]. Since then the method was steadily developed and improved up to now [14]. This process is attractive to be used for the linear photon polarization measurement because, firstly, it is pure electrodynamical process, thus its characteristics can be calculated with high accuracy. Secondly, the recoil electrons are emitted under large polar angles (up to 80^0) and sufficient part of them has energy up to some MeV that is enough for their reliable registration.

In the lowest order of perturbation theory the process is described by 8 Feynman diagrams. The differential on azimuthal angle φ (φ_r in Fig. 1) cross section of the recoil electron yield has the form analogous (1) but the recoil electrons are preferably emitted in the plane orthogonal to the photon polarization direction,

$$d\sigma/d\varphi=\sigma_0^{tr}[1-P\Lambda\cos(2\varphi)]. \quad (2)$$

$\sigma_0^{tr}=\sigma^{tr}(E_\gamma,q)_0$ is the cross section of the triplet photoproduction with unpolarized photons, q is the momentum of the recoil electron. At photon energy E_γ>10 MeV influence of the electron identity effect may be neglected [12-14] and process with accuracy better then 2% can be described by two Feynman diagrams. The theoretical calculations have shown that analyzing power Λ are slowly decreased from Λ=0.27 at E_γ~10 MeV up to Λ=0.17 at E_γ~500 MeV and at asymptotically high photon energy its value is Λ≈0.14. It also can be increased up to Λ~0.2-0.3 by imposing various rules of the events selection, e.g, when the events with nearly equal electron and positron energy are selected. So, the analyzing power of the process is high enough and that is very important, both analyzing power and kinematical characteristics of the recoil electrons weakly depend on the photon energy in very wide energy range, that allows to use this method for linearly photon polarization measurements in a wide energy range (up to some hundreds GeV) without any changing in the polarimeter scheme.

From the process kinematics one can obtain that recoil electrons are emitted in the permitted physical region, $q_-(\theta)\le q\le q_+(\theta)$ limited by the borders

$$q_\pm(\theta)=m\frac{(s-m^2)(s+m^2-\Delta^2)\cos\theta\pm(s+m^2)\sqrt{D_1}}{4sm^2+(s-m^2)^2\sin^2\theta}, \quad (3)$$

where

$$D_1=(s+m^2-\Delta^2)^2-(4sm^2+(s-m^2)^2\sin^2\theta);\quad s=m(2\omega+m),\quad \Delta=\sqrt{(p_++p_-)^2}\rightarrow 2m. \quad (4)$$

In this expressions Δ is the invariant mass of the pair and equality $\Delta=2m$ determines the borders. One can see that the recoil electrons are preferably emitted near the borders, Fig. 2 and the triplet photoproduction cross section strongly depends on the recoil electron momentum *q*. At that, the recoil electrons with low energies are mainly emitted under large angles and large part of them do not exit from the target. Thus, for plastic target ~0.3…0.5 mm thickness the electrons, produced with q<0.5 MeV/c, are practically stopped in the target [3] and in the experiment it can be reliably measured only recoil electrons which are produced with the momentum which exceeds q_0≈0.5 MeV/c. The calculations have shown that introduction of the threshold on registration of the recoil electron momentum q_0 in reasonable limits (q_0=0.05-1.25 MeV/c) leads to insignificant reduction asymmetry but to decreasing the process cross section [14].

At the physical region border the analyzing power is Λ=1, Fig. 2, but it quickly reduces in the middle of physical region, so the analyzing power averaged over angles θ and momentum q decreases down to Λ~0.14. Therefore, selection of the recoil electrons near the border of the physical region is of large interest for the increasing of the analyzing power.

The photon polarimeters on the base of the triplet photoproduction process were created in Japan [15] and by the GWU group [16]. Their principle schemes are practically identical (it is shown in Fig. 3) and assume measurement of the azimuthal asymmetry of the recoil electrons distribution averaged on intervals of polar Δθ and azimuthal Δφ angles but there are some differences in the these intervals value. The telescope parameters are presented in Table 1.

Linearly polarized photons come to polyethylene target. Before the target a veto counter was placed. The azimuthal angular distribution of the recoil electrons were measured by 8 (Japan polarimeter) or 4 (GWU polarimeter) telescopes placed under polar angle (~25-30^0) to the photon beam. Each telescope covers some polar and azimuthal angular width and consisted of ΔE and E counters for measurement of the ionization losses and total energy of the particles. The e^+ and e^- of the pairs are detected by the pair telescope. At the particles detection the events with pulses height corresponding to twice of the minimum particles ionization value were selected.

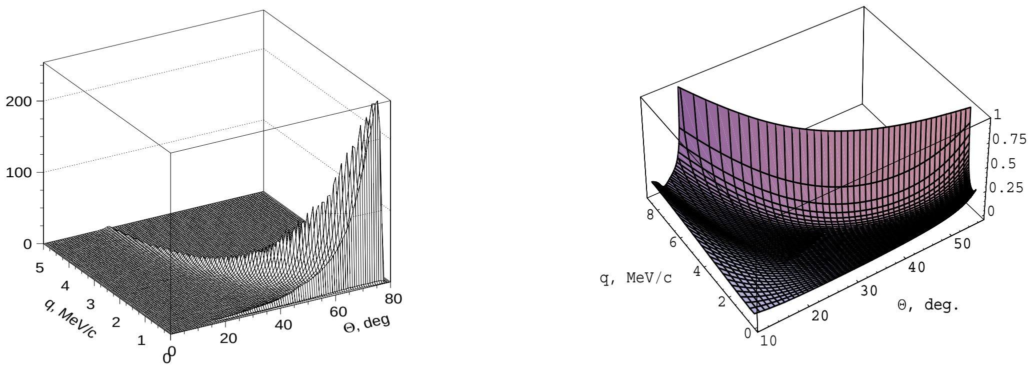

Fig. 2. Two-dimensional distributions of the recoil electrons (left) and asymmetry (right) for the triplet photoproduction. Photon energy is E_γ=50 MeB, target is plastic 0.5 mm thick.

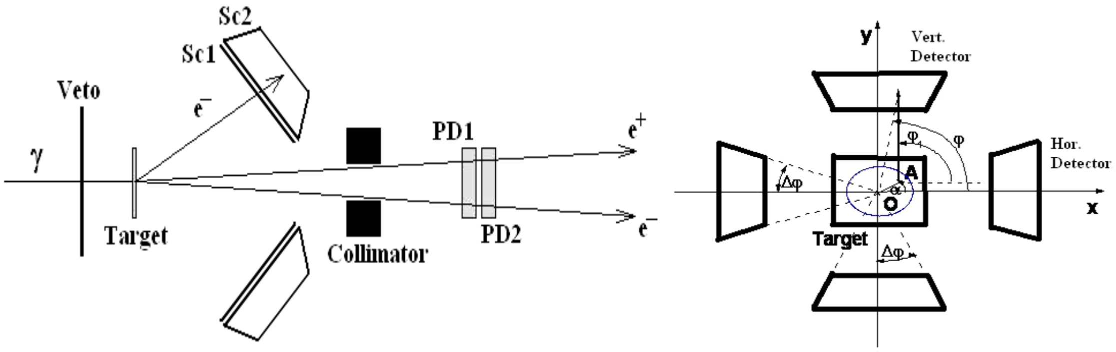

Fig. 3. Principle scheme of the triplet polarimeter. Side view (left) and view along the beam (right)

Table 1. Main parameters of the Japan and GWU polarimeter.

	JAPAN	GWU
Target polyethylene thickness, mm	1.2	2
Recoil detectors (number)	8	4
ΔE counter thickness, mm	1	3
E counter, mm	50	
Pair detectors		
First, mm	3	3
Second, mm	6	6
Θ	25^0-35^0	8.5^0-40^0
Δφ	±11.50	±22.50
Tagger range, MeV	240-620	220-330
Photon rate, γ/sec	3×10^5	10^6
Trigger rate, Hz	1.5	<100
Λ	0.08±0.02	0.03
Photon energy range, MeV	360±20	220-330

These polarimeters were tested on the tagged polarized photon beams of the coherent bremsstrahlung (Japan group) and at the backscattered laser photons of the LEGS facility (GWU). The analyzing power for Japan polarimeter measured for the energy ω=360 MeV was Λ=0.06±0.018 and 0.088±0.026 for selection the pairs with the opening angles less 3.5^0 and less 0.7^0, respectively. The measured asymmetry for GWU polarimeter was found to be very low, Λ~0.03, that is as twice as smaller than the Japan measurements and much less than the theoretical value Λ~0.14. It was supposed that this reduction of the analyzing power might be due to background from the δ-rays production and bigger angular acceptance of the GWU polarimeter.

ANALYZING POWER OF THE PHOTON POLARIMETERS BASED ON PAIR AND TRIPLET PHOTOPRODUCTION PROCESSES

Scheme of the simulation

Investigations of the analyzing power were performed by mathematical simulation method [2, 3]. The scheme of the simulation is shown in Fig. 4. A point-like polarized photon beam arrives along Z axis and falls on the polarimeter target. The interaction points along Z axis are determined in a random way. If the interaction has happened, the type of process is determined and kinematical characteristics of the reaction products are calculated. Then the way of every particle is tracked from the point of origin up to the target exit and all kinematical parameters and type of the particles flying off in forward direction are fixed on the "detector plane" which was placed at 1.5 cm distance from the target. In such a way large body of the simulation events of the photon interaction with polarimeter target has been accumulated for initial photon energies in the range 10-3000 MeV, the various target thicknesses and materials. Some details of the simulation were presented in [2, 3].

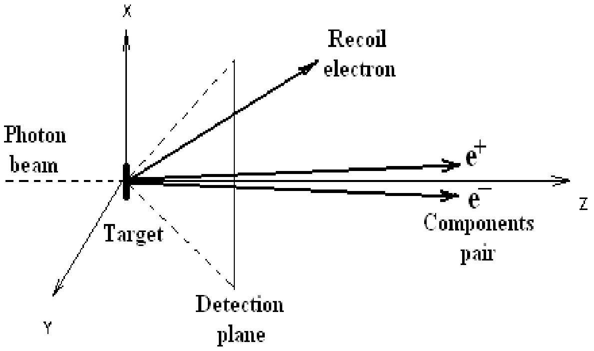

Fig. 4. The scheme of the simulation

The accumulated data base allows one to study all necessary distributions of the particles produced in the target by polarized photons and obtain the azimuthal distributions of the measurable characteristics for each processes: the azimuthal distributions of the vectors **AB** that connects the points of "detector plane" intersections by electron and positron of the pair for pair production, and azimuthal distributions of the recoil electrons for the triplet photoproduction process. At that, such distributions were obtained both in the points of the reactions (this coincides with the theoretical distributions) and on the "detector plane" where the multiple scattering and background give their contribution. As an example, the azimuthal distribution of the vectors **AB** without using any events selection is shown in Fig.5. The value of the azimuthal distribution asymmetry was determined from fitting the obtained distributions by the theoretical formula for azimuthal cross section (1), where the analyzing power Λ was one of the parameters that were fitted.

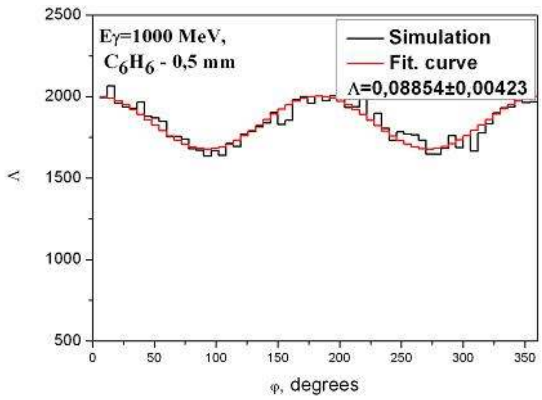

Fig. 5. Azimuthal distribution of the vectors **AB** that connects the points of detector plane intersections by electron and positron of the pair. Target is plastic 0.5 mm thickness, photon energy is E_γ=1000 MeV.

Influence of the multiple scattering

Multiple scattering has large influence on the analyzing power of the pair photoproduction processes. At that, we have in mind first of all the multiple scattering in the matter of the polarimeter target because it is in principle unremovable and could be only decreased by selection of the target parameters.

In Fig. 6 it is shown the analyzing power values for processes of the pair and triplet photoproduction in the point of particles production and on the "detector plane" for plastic target 0.5 mm thickness. In the point of particles production where multiple scattering has not any influence the analyzing power of both processes is Λ~0.14 that agrees with the theoretical prediction. Due to multiple scattering of the reaction products the analyzing power reduces up to Λ~0.09 for both processes that is in ~1.6 times less, than the theoretical value, and it practically does not depend on photon energy in the range under study. For the triplet photoproduction reaction the analyzing power decreases more drastically, up to Λ~< 0.06 for the plastic target of the 0.5 mm thickness, due to the δ-electron background contribution.

In more detail influence of the multiple scattering on the reaction analyzing power is shown in Fig.7, where it is presented dependence of the analyzing power value for both reactions as a function of target thickness in the radiation length units X_0 for photons with energy E_γ=1 GeV. Its value smoothly increases with the target thickness decreasing and reaches Λ~0.11 for the target thickness ~<0.00025X_0. The calculated dependence for E_γ=2 GeV from [10] is in a good agreement with the simulation data and confirms as mentioned above weak dependence of the analyzing power on the photon energy in this energy range.

The similar dependences are obtained for the triplet photoproduction. The azimuthal asymmetry dependence of the

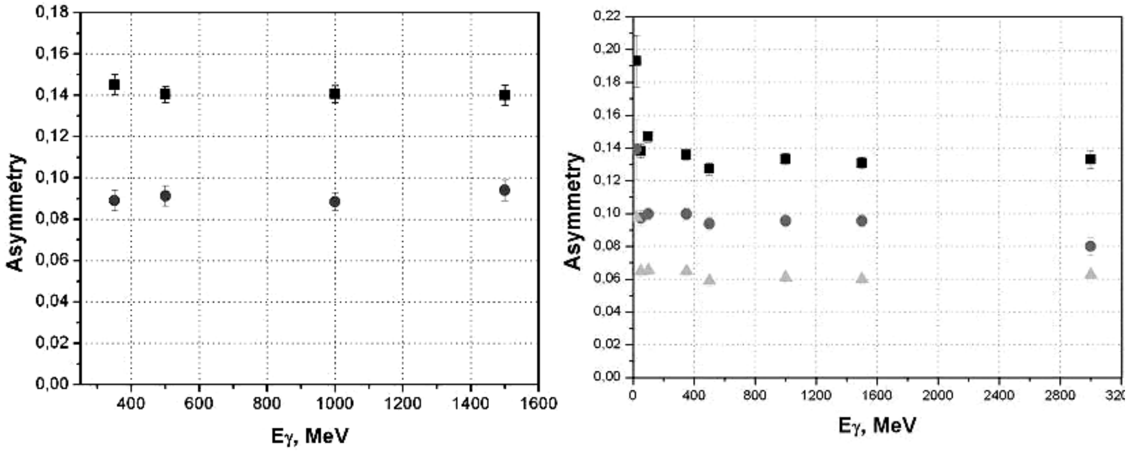

Fig. 6. The azimuthal asymmetry (analyzing power) of the pair production vectors **AB** (left) and recoil electrons (right) as a function of photon energy. Black squares - in the target, grey circles on the detector plane, triangles - on the detector plane when the δ-electrons are taken into account. Target is the plastic with thickness 0.5 mm.

recoil electrons as a function of the target thickness if we do not take into account the δ-electron background is practically the same as for the pair production. But the δ-electron background considerably increases with the target thickness [2, 3] and additionally reduces the analyzing power of the process. So, the triplet photoproduction process is very critical to polarimeter target parameters.

In the figure there are also presented the experimental results obtained by the Japan and GWU groups. They are as a whole keep within the simulated thickness dependence. One can see, for GWU polarimeter very low analyzing power is a result of using the thick (2 mm) target and large acceptance on polar angle ($8\text{-}40^0$). As it was shown [2, 3], at polar angles less than 10^0 there could be large background contribution from the pair production and Compton scattering.

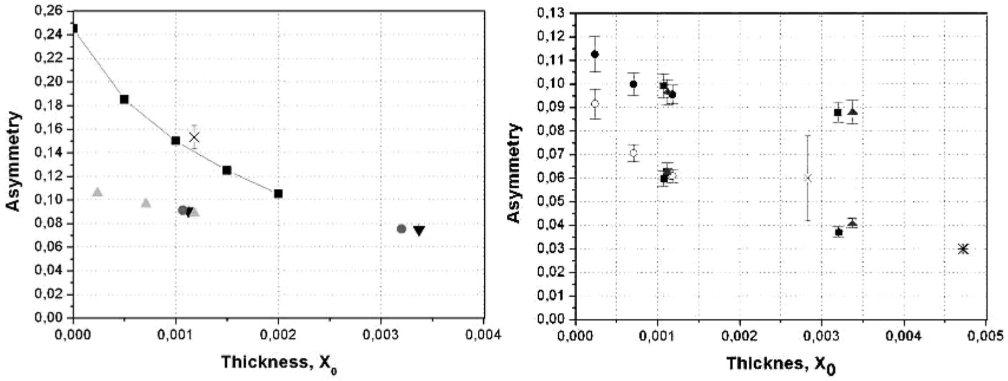

Fig. 7. The asymmetry of the pair photoproduction (left) and the recoil electrons (right) on the "detector plane" for E_γ=1 GeV as function of the target thickness measured in units of radiation length X_0. Left: light grey triangles - C_6H_6 (0.1, 0.3 and 0.5 mm); black triangles - Al (0.1 and 0.3 mm); grey circles - Si (0.1 and 0.3 mm), cross – symmetrical pairs for C_6H_6 0.5 mm. Curve is the results from [10] for E_γ=2 GeV. Right: empty and full points are the simulation results with and without the δ-electron taking into account, respectively. Circles - C_6H_6 (0.1, 0.3 and 0.5 mm); triangles - Al (0.1 and 0.3 mm); squares – Si (0.1 and 0.3 mm); cross – data of the Japan group [15]; star- data of the GWU group [16].

The Japan group results have large error and somewhat larger analyzing power due to selection pair events in the angle less 3.5^0 and the collimation of the e^+e^- pairs increases the analyzing power of the process. So, one can see that the triplet process is very critical to the polarmimeter target parameters. One cannot obtain the analyzing power bigger than Λ~0.05-0.06 with the plastic target of 1 mm thickness without special selection the reaction events. In order to reach higher analyzing power value in this case the thinner (0.1-0.3 mm) target is needed.

Selection of the symmetric pairs

Analyzing power of both reactions can be substantially increased if the pairs with approximately equal energies of electron and positron of the pairs are selected. Theoretical estimations show [10] that such selection can increase the analyzing power of the pair production from Λ~0.14 to ~0.25 for E_γ=1 GeV, Fig.7. Similar behavior is observed for other photon energies. The dependence of the analyzing power from the part of positron energy for pair photoproduction is presented in Fig.8.

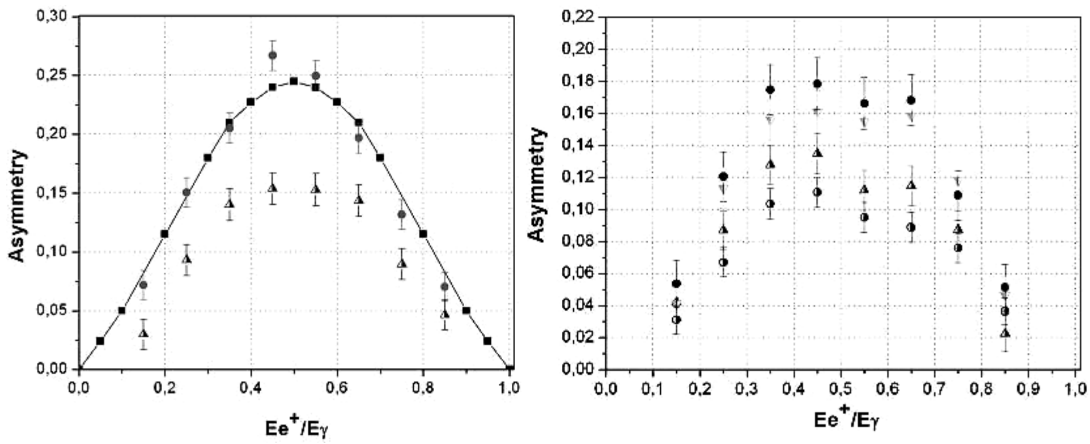

Fig. 8. The asymmetry of the pair photoproduction (left) and the recoil electrons (right) as a function of positron energy for photon energy E_γ=1 GeV. Left: in the target (grey circles) and on the detector plane (triangle) target 0.5 mm C_6H_6. Curve is the results from [10] for E_γ=2 GeV. Right: on the "detector plane". Full points (without) and empty (with) δ-electrons. Target - C_6H_6 0.3 mm (circles) and 0.5 mm (triangles).

One can see that the symmetrical pairs selection considerably increase the analyzing power, especially for thin targets, where its value increases about twice. Simulation result is in agreement with the calculation [10], taking into account the difference in the photon energies. But for the real targets due to multiple scattering the increasing will be less, down to Λ~0.15 for the plastic target (C_6H_6) 0.5 mm thick and down to Λ~0.2 for the target 0.1 mm thick.

For the triplet photoproduction process the selection of symmetrical pairs also increases asymmetry of the recoil electron distribution, but in real case only up to Λ~0.12 if the multiple scattering and δ-electrons background are taken into account, Fig. 8.

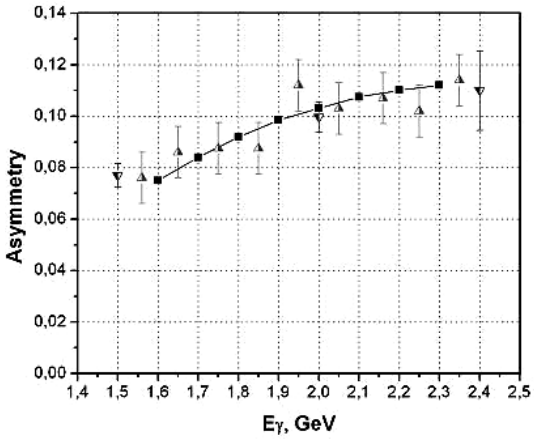

Fig. 9. Data on pair photoproduction asymmetry measurements [11] without (left) and with (right) selection of the pairs with condition $0.8<E_+/E_-<1.2$. The curves show the dependence of the photon beam polarization as a function of the photon energy. Target is the carbon 0.1 mm thickness. Grey triangles are the simulation results

For verification of the simulation code and procedure some calculations of the analyzing power were performed for the pair photoproduction at conditions of experiment [11]. The simulation results are in reasonable agreement with the experimental asymmetry measurements, Fig. 9.

Selection of the recoil electrons near the boundary of the physical range

Another way to increase the analyzing power of the triplet photoproduction reaction is the selection of recoil electrons in the range near the upper boundary of the physical range (3) Fig. 2. In more detail the recoil electron distributions were considered in the previous work [3] for a wide interval of photon energies, E_γ=50-3000 MeV. The typical two-dimensional distribution is shown in Fig. 10 for photon energy E_γ=100 MeV, but it practically does not depend on photon energy.

As was shown [3], the optimal angular interval (coming from the δ-electrons background contribution) of the recoil electron selection is θ~20-40^0. So, the calculations of the analyzing power for the triplet photoporoduction process were performed with the recoil electrons selection in two regions limited by the angular range of the electron emission 20^0-40^0 and two lines, Fig. 11:

(i)- curves 2 (theoretical border + 1 MeV) and 3 (theoretical border ×0.7);

(ii)- curves 2 (theoretical border + 1 MeV) and 4 (theoretical border ×0.5).

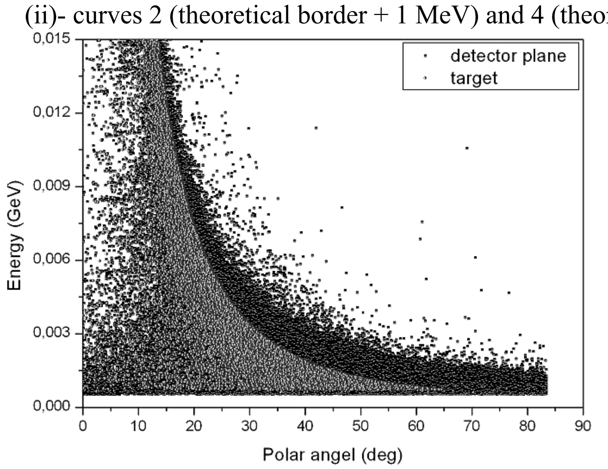

Fig. 10. Two-dimensional (energy-angle) distribution of the recoil electrons. Light points correspond to distribution in the points of births, dark – on the "detector plane". Target is a plastic with thickness 0.5 mm, $q>q_0$=0.5 MeV/c. Photon energy is 100 MeV

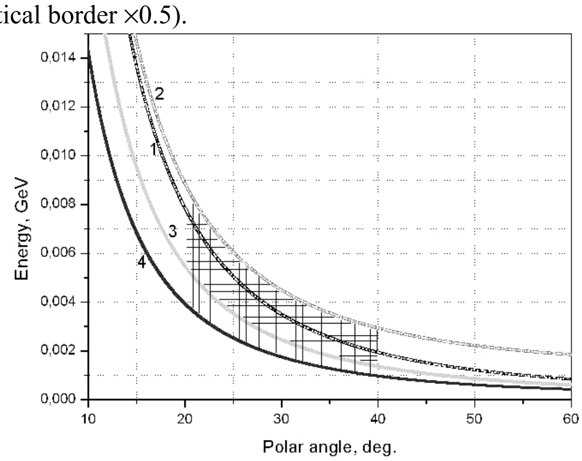

Fig. 11. The selection ranges of recoil electrons. (1)- theoretical border; (2)- theoretical border +1 MeV; (3)- theoretical border ×0.7; (4)- theoretical border ×0.5

Results are presented in Fig. 12 for recoil electrons selection in the region (i). Such events selection increases analyzing power from Λ~0.06 to Λ~0.1 practically without decreasing statistics.

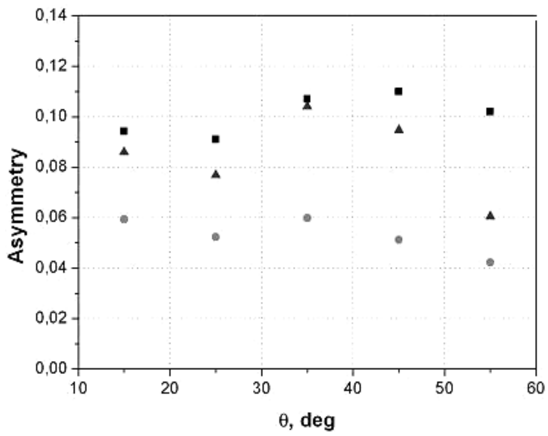

Fig. 12. Asymmetry averaged on the targets C_6H_6 (thickness 0.1, 0.3, 0.5 mm), Al (0.1, 0.3 mm), Si (0.1, 0.3 mm). Photon energy is E_γ=1000 MeV: squares-on the "detector plane" without δ-electron background; circles- with δ-electron background; triangles- with δ-electron background and selection electrons in the range (i).

At the additional selection of the e^+e^--pairs with close energies of electron and positron the analyzing power can be additionally increased. Aggregate results of the recoil electron selection influence on the analyzing power value are given in Table 2 for photon energy 1000 MeV.

Table 2. Analyzing power of the triplet photoproduction for various conditions of the events selection. Photon energy is 1000 MeV. Interval of polar angles selection $15^0<\theta<40^0$

C_6H_6 0.5mm	In the target	On the "detector plane"	On the "detector plane" with δ-electrons
Without selection	0.119±0.006	0.095±0.006	0.065±0.006
Symmetrical pairs	0.193±0.012	0.154±0.011	0.101±0.009
In the range (ii)	0.120±0.006	0.115±0.007	0.091±0.006
In the range (i)	0.123±0.006	0.120±0.008	0.092±0.007
In the range (ii) + symmetrical pairs	0.196±0.012	0.186±0.014	0.145±0.012
In the range (i) + symmetrical pairs	0.195±0.012	0.189±0.015	0.146±0.013

In Tables 3-5 the estimations are presented of the photon polarization measurement accuracy and needed beam time for processes of e^+e^--pair and triplet photoproduction. Estimation were done for photon beam energy E_γ=1000 MeV and intensity $N_\gamma=10^6\gamma$/s for some target materials, thickness and events selection conditions.

Table 3. Accuracy and needed beam time for polarization measurement by e^+e^--pair production process without any events selection

Targets	T, mm	Λ±ΔΛ	ΔΛ/Λ	Nγ	T, hours
CH	0.1	0.106±0.002	0.018	5×10^9	1.4
CH	0.5	0.089±0.001	0.008	5×10^9	1.4
Al	0.1	0.090±0.001	0.008	5×10^9	1.4
Si	0.1	0.091±0.001	0.008	5×10^9	1.7

Table 5.Accuracy and needed beam time for polarization measurement by the triplet photoproduction process without any selections

Targets	T, mm	Λ±ΔΛ	ΔΛ/Λ	Nγ	T, hours
CH	0.1	0.092±0.006	0.068	5×10^9	1.4
CH	0.3	0.071±0.004	0.053	5×10^9	1.4
CH	0.5	0.061±0.003	0.045	5×10^9	1.4
Al	0.1	0.063±0.004	0.056	5×10^9	1.4
Si	0.1	0.060±0.003	0.056	5×10^9	1.7

Table 4.With selection of electron and positron energies $0.8<E_+/E_-<1.2$.

Targets	T, mm	Λ±ΔΛ	ΔΛ/Λ	Nγ	T, hours
CH	0.5	0.173±0.014	0.014	5×10^9	1.4

The calculations have shown, that at the photon beam intensity 10^6 γ/s it is possible to measure polarization of the beam (at P=100%) for 2 hours with accuracy ~1%, using process of the e^+e^--pairs production and with accuracy ~5%, using process of the triplet photoproduction.

CONCLUSIONS

Summarizing, it should be noted, that both processes – the e^+e^--pair and triplet production can be used for photon polarization measurement but for achievement sufficient analyzing power the thin target (e.g., ~0.1mm plastic) should be used. For the both processes, the analyzing power practically does not depend on photon energy in interval under study, 30-3000 MeV.

For the pair production the analyzing power Λ≈0.11 can be obtained without any events selection.

Analyzing power for the triplet photproduction process in traditional scheme of the triplet polarimeter (without selection and measurement average recoil electron yield) will not exceed Λ~0.05-0.06 for real target thickness. The optimal target thickness is not bigger than 0.3 mm for plastic C_6H_6 target.

For increasing the analyzing power the event selection is needed. The selection of the e^+e^--pairs with the close energies of electron and positron will allow one to reach the analyzing power $\Lambda\approx0.2$ for the pair and $\Lambda\approx0.12$ for the triplet photoproduction. For the triplet process one can get some additional analyzing power increasing if two simultaneous selections use: the e^+e^--pairs with close energies of electron and positron and selection of the recoil electrons near the border of the physical region.

The beam time needed for polarization measurements with accuracy ~1% at the photon beam intensity $10^6\gamma$/s can be ~ 2 hours (at P=100%) for the pair polarimeter and ~5% for the triplet photoproduction.

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