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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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ЕФИ-151(75)

A.S.ALEXANIAN, T.L.ASATIANI, M.I.DAYON,
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SELF-TRIGGERING DETECTORS FOR RECOIL NUCLEI

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Hybrid α-detectors consisting of wide gap spark chambers and signal α detectors are described. The investigations have been carried out with γ-beams of Yerevan Electron Synchrotron. The possibility of using such detectors in the experiments on particle photoproduction on gas helium with the determination of the interaction point, emission angle of the recoil nucleus and its energy by means of range measurement has been shown. It has been shown that self - triggering wide gap spark chamber allows to detect and measure the range of the recoil nuclei α-particles with energies $E_{\alpha} \simeq (1 - 2)$ MeV which correspond to momentum transfers $\sim (10^{-2} - 10^{-3})$ $(GeV/c)^2$.

Yerevan Physics Institute

Yerevan, 1975

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САМОУПРАВЛЯЕМЫЕ ДЕТЕКТОРЫ ЯДЕР ОТДАЧИ

Описаны гибридные α-детекторы, состоящие из широкозазорной искровой камеры и сигнального α-детектора. Исследования проводились на пучке γ-квантов Ереванского электронного ускорителя. Показана возможность их использования в экспериментах по фоторождению частиц на ядрах газообразного гелия для определения точки взаимодействия: угла вылета ядра отдачи, а также его энергии по пробегу. Показано, что самоуправляемая широкозазорная искровая камера позволяет детектировать и измерять пробеги ядер отдачи α-частиц с энергией $E_\alpha \gtrsim (1 \div 2)$ Мэв, что соответствует квадрату переданного импульса $\sim (10^{-2} \div 10^{-3})$ (Гэв/с^2).

Ереванский физический институт
Ереван 1975

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1. Introduction

In this work we describe self-triggering wide gap spark chambers (WGC) designed to detect and observe recoil nuclei and other products of the interaction of photons (or charged particles) with target which is the working gas of the chamber. We have investigated chambers with helium filling since the use of helium as target is of interest for many physical problems, in particular, for the study of photoproduction on the helium nuclei, $\gamma + He^4 \to He^4 +$ [1,2].

The triggering of WGC by the recoil nuclei with ranges $\geq$(1.0 - 2) cm was realized by combining them with particle counters (signal detectors) placed in the working volume of WGC.

Luminofor layess (Section 2) and multiwire proportional counters MPC (section 3) have been used as signal detectors. The both chamber variants have been calibrated by α and β - sources and tested in a $(10^8 - 10^9)$ eqv. γ-quanta.sec^{-1} intensive photon beam passing immediately through the working gas of WGC. Photos of the tracks of recoil nuclei and photoreaction products arising in the chamber gas have been obtained. When MPC were used as signal detector one could observe short range particle trajectories which begin and end in the chamber gas. In this case one could measure also the particle range besides the emission angle.

2. Self-Triggering WGC with a Luminofor Layer

The construction of WGC is shown in Fig.1. One of the chamber electrodes is made of wires. A $\sim$ 50μ thick ZnS(Ag) luminofor layer is placed behind the wire electrode. The distance between the γ-beam and luminofor is $\sim$3cm. The photon beam passes through thin mylar windows of thickness of $\sim 10\mu$. The chamber electrodes have round shape edges in order to reduce the electric field in the vicinity of mylar windows and to prevent the electric discharges along the chamber walls. The chamber were pumped up to 10^{-2} Torr and filled with mixture of He(99.9%) and Freon-12 (0.1%) at atmospheric pressure.

Recoil nuclei (α-particles) or other strongly ionizing particles arising in the gas along the photon beam and reaching the luminofor give scintillation light recorded by the photomultiplier. The photomultiplier pulse is used to form a high voltage pulse for WGC. The triggering of WGC is realized by a 60 kv pulse from a high voltage pulse generator (MG). The pulse rise time is $\sim$15nsec, the chamber memory time $\sim 4\mu$ sec. A diffuse gas luminescence along the beam is observed in the chamber in the absence of strongly ionizing particles; this luminescence is reduced by adding Freon-12(0.1%) to helium[3]).

In the presence of recoil nuclei (α - particles) or other multicharged particles produced in the volume through which the photon beam passes a discharge takes place along the particle path and clear sparks going along the trajectory from the track beginning up to the chamber wire electrode are observed in the chamber. Meanwhile a diffuse discharge is developed from the track beginning to the opposite electrode.

It is worthwhile to note that the radiation from the spark discharge initiates a long luminescence of the luminofor during 10 sec, however the amplitude characteristics of the photomultiplier is restored soon after this period.

No noticable change of the photomultiplier characteristics has been observed after 10^4 triggerings. The shielding of the luminofor with thin aluminium layer (0.1 - 0.3μ) completely protects the photomultiplier from the spark lights.

In the beginning the chamber characteristics were studied with the help of a radioactive source Pu^{239}($\sim 10^2$ α-particles.sec^{-1}) placed in the lower part of the chamber. The background loading were imitated by the electrons from Y^{90}+Se^{90} ($\sim 10^5$ β -particles.sec^{-1}).

In Fig.2 the pulse height distributions of α -particles of various E are given. The pulse height distribution from the source obtained by a CsI(Tl) crystal is shown in Fig. 2 (curve I). For an appropriate amplitude discrimination level in the region of photomultiplier noise one may obtain $\sim$95% detection effectiveness for α -particles with energy $\gtrsim$ 1MeV.

The chamber has been exposed to a photon beam with a maximal energy E_{max} = 4.7 GeV and intensity up to $\sim 10^9$eqv.γ quanta sec^{-1} at a frequency 50 hertz and spil time $\sim$ 2.0 m sec. The beam cross section was equal to 6 mm in horizontal and 4.0 mm in vertical directions. At a distance between the beam and luminofor equal to 3 cm the photomultiplier loading was $\sim 2.10^3 sec^{-1}$ after corresponding pulse discrimination. This loading conditioned by the strongly ionizing particles, the photoreaction products on helium nuclei, as well as by the background electrons and positrons accompanying the γ-beam has appeared to be comparatively low. Therefore including the photomultiplier pulse into the general logics of the arrangement triggering one may avoid completely from the false background triggerings.

The spark allows to determine the spatial emission angle of the particles with a high accuracy. The place of the pro - duction of a single track can be determined with the help of spark beginning which is not always sufficiently clear due to the diffuse continuation. The brightness of the track diffuse part may be weakened by an appropriate choice of the high voltage pulse parameters and aperture of the camera lens. The trajectory production point is localized within the limits of the vertical dimension of the γ-beam (in our case with a mean square error $\sim \pm 1.3$mm). By this chamber one can detect also few particles produced simultaneously in the interaction point ("stars"). It is evidient that in the case of "stars" the interaction point is determined with a higher accuracy. When the arrangement is tuned no track of relativistic electrons and positrons accompanying γ-beam is detected in WGC and only strongly ionizing particles going under angles of $\leq 30^{\circ} - 40^{\circ}$ with respect to the electric field direction are seen quite well.

3. Wide Gap Spark Chamber (WGC) Triggered by a Multiwire Proportional Counter

The replacement of the luminofor by multiwire proportional counter (MPC) with a high transparency ($\sim 90\%$) to the passing particles allows to determine also the energy of the recoil nuclei in the spark chamber by measuring their range.

The possibility of obtaining triggering pulses from MPC with He^4 gas and admixture of CO_2 and water vapour has been shown in the work[4]. Fig. 3 shows the construction of the device. The distance between the signal wires is equal to [illegible] while the distance between the cathode ones is $\sim$ 1mm. Two spark chamber sections allow to observe the passage of the particles from a Pu^{239} source through the lower chamber and its stoppage in the upper chamber (see Fig.4). The α-particle energy is determined by the particle total range in the chamber gas.

The operation of MPC in the gas volume of the spark chamber allows to use it to obtain additional information on the recoil nuclei.

Drift chambers with 2 cm distance between the signal wires in gas mixtures He^4+(0.5 - 5%) CH_4; He^4(0.5 - 10%)CO_2: He^4+(0.1 - 2%) Freon-12 have been also used as signal counters for triggering WGC. Pulse height distribution of α-particles and electrons have been obtained[5,6]. Besides, one may use the drift chamber to determine the particle coordinates with a high spatial resolution $\lesssim$ 0.2mm[7].

For a gas amplification $\sim$ 200 the MPC possesses good energy resolution[8] together with the good rejection factor in the identification of the strongly ionizing particles[9].

The energy loss of α-particles with energy $\simeq$ 5 MeV in the sensitive gap of MPC (1.5cm) is $\Delta E \approx$ 0.3 MeV, the precision of the determination of ΔE is $\sim$ 25% which together with the knowledge of the particle range in the spark chamber allows to identify nuclei with various charges (Z = 1, 2, 3...)

4. Investigation of the WGC Triggered by MPC in Intensive Photon Beam

In order to determine the possibilities of the given method of detection of recoil nuclei and other products of photoreactions on the gas helium nuclei the detector has been exposed[9]) to the intensive photon beams of Yerevan Electron Synchrotron (Fig.5). The filling gas mixture He^4+2%CH_4 serve simultaneously as physical target.

The strongly ionizing particles, the products of photoreactions on helium, have been detected by MPC and the pulses from MPC have triggered the spark chamber in which the tracks of these particles were observed. The distance between the spark chamber electrodes was equal to 9 cm while the chamber area is equal to 20 x 26 cm^2. The MPC had an area 150 x 50 mm^2 and a distance between the cathode and anode planes equal to 7 mm.

Constructively MPC is made in such a manner that the γ - beam can pass in parallel to the electrode not only outside the sensitive MPC volume but, in particular, inside MPC too. A P_u^{239} (E_α = 5.2 MeV) α -source was placed in the lower part of the detector. It served for the MPC calibration and WGC tuning while working with the photon beam the source was shielded. The photos from WGC were taken in two mutually perpendicular projections by a RFK-5 camera.

a) The Study of the Multiwire Proportional Chamber

In Fig. 6 the pulse height spectra from MPC obtained at various irradiation conditions are presented.

I. In the control measurements MPC has been irradiated in a direction perpendicular to the electrode by collimated α - particle sources (curve 2) and by electrons of energy E_e =0.5 and 2.1 MeV(curve 1). These curves show the pulse height distribution from MPC in γ-quanta beam and the peak position for the α-source (the absciss shows the number of the analyser channel). The curves have been obtained for the same exposition time at source intensities 10^2 and 10^5 particles.sec^{-1}, respectively.

2. The curve 4 has been obtained from MPC exposed to a γ-quanta beam with an intensivity $\sim 2.10^8$ eqv. γ. quanta sec^{-1}. The beam passed in parallel to the MPC wire planes along its largest direction (15cm) at (4 - 5)mm distance from the lower cathode plane. In this case MPC detects recoil nuclei and other strongly ionizing particles, the products of photoreactions on helium and CH_4. Besides, a high level background loading of MPC is present due to electrons and positrons accom - panying the γ -beam.

3. To estimate the contribution of electron-positron background into the total loading of MPC the chamber has been exposed to the same γ -beam with a $\sim$ 0.13 radiation. length thick aluminium convertor placed before the chamber entrance window in which $\sim 2.10^7$ electrons and positrons per second were produced. The results are shown on the curve 3.

From the comparison of the curves 3 and 4 one may conclude that the significant increase of the electron-positron flux in the second case has changed the pulse height distribution only in the region of relatively small amplitudes (channel numbers 40 - 50) while the number of events with large amplitude (channel numbers > 50) has remained almost unchanged and therefore they are conditioned mainly by the strongly ionising particles, the products of photoreactions in the chamber gas.

It is seen that even at very high background loading of MPC by relativistic particles one can detect only strongly ionising particles using an appropriate amplitude discrimination. For the measurement conditions a threshold has been found which corresponds to particle energy loss in MPC equal to 0.1 MeV, while the energy loss of α-particles passing through the chamber perpendicularly to the electrodes is 0.3MeV.

4. For the above given registration threshold the dependence of the MPC loading on the photon beam intensity has been measured (Fig.7) which has an approximately linear form. It is seen that the MPC loading appeared to be comparatively not high in such conditions in spite of high photon beam intensity. For instance, at 2.10^8 eqv.γquanta.sec^{-1} the MPC counting rate equal to (40÷50) sec^{-1}.

5. The Results of the Measurements

The spark chamber was traggered by the pulses from MPC. After each tri gering the WGC was blocked for 6 sec. The tuning of the WGC has been realized in such a manner that provided good visible α-particle tracks stopping in the chamber with clearly visible track ends (for the range measurement). In such conditions no track of particles with minimal ionization visible on the film has been recorded.

In the operation conditions the chamber has been expo - sed to a photon beam ($I_\gamma = 2.10^8$ eqv. γ-quanta.sec^{-1}) and triggered by MPC pulses with the above mentioned registra - tion pulse threshold. The MPC counting rate was $\sim 40\ sec^{-1}$. 5000 stereophotos have been obtained at 3.5 GeV maximal beam energy. In the average tracks of strongly ionizing particles have been found on each picture of $6 \div 7$ pictures (all the remained pictures were blank), all the particles being produced in the photon beam path through helium. There were events of two or three particles coming out from one point. About 30% of the tracks had an end point in the sensitive volume of the chamber so that one can measure their range. Typical photos are shown in Fig.8.

In spite of the high loading of the chamber volume by background electrons and positrons accompanying γ-beam, the relativistic particle background was completely absent at chamber memory time $\sim 50\ \mu$ sec. The polar and azimuthal particle emission angles with respect to the photon beam, the particle ranges in the cases of stoppage in the chamber gas) as well as the width of the track have been determined using the stereophotos.

In Fig. 9 the histogram of the particle ranges in the working volume of the chamber is given taking into account the invisible initial part of the trajectories in the chamber. Fig.10 shows the polar angle distribution. The azimuthal angle distribution is isotropic

In the assumption of isotopic angular distribution of the particles one may explain about 90% of the blank pictures by the spark chamber registration noneffectiveness of the particles going under large angles $> 30^{\circ}$ with respect to the electric field direction. Blank pictures are obtained also in that cases when the particle range ends in the MPC working volume and/or when MPC is loaded by background relativistic particles (electrons and positrons). One of the way to increase the WGC effectiveness is the increase of isotropy replacing the WGC by cylindrical spark chamber.

6. Conclusions

The self-triggering wide gap spark chamber may be used in a series of experiment for detection and observation of recoil nuclei and products of disintegration by intensive photon beams. The chamber working gas may serve as physical target. The application of this method is also possible for the charged particle beams, however, the permissible beam intensity must be elucidated experimentally.

It is shown that the self-triggering helium WGC allows to detect and measure the range of recoil nuclei, particles (for instance in the reaction $\gamma + He^4 \rightarrow He^4 + \pi^{\circ}$) with energies $\geq (1 - 2)$ MeV which corresponds to the square of momentum transfer $\sim (10^{-2} \div 10^{-3})$ $(GeV/c)^2$.

In conclusion the authors express their deep gratitude to A.Ts.Amatuni and A.I.Alikhanian for support and constant interest to the work, and the Yerevan Synchrotron personal for providing the photon beams.

Figure Captions

Fig. 1 The lay-out of the spark α-detector. 1-luminofor; 2-glass on which the luminofor is deposited; 3-light-pipe; 4-photomultiplier; 5-wires; 6-beam entrance window; 7- α-particle source; 8-electrodes (round shaped)

Fig. 2. Pulse height distribution from α-particles.

1 - E_α =5.1 MeV, CsI(Tl),

2 - E_α =3 MeV, ZnS(Ag);

3 - E_α = 1 MeV, ZnS(Ag);

Fig. 3. The spark chamber construction.

1 - multiwire proportional counter; 2 - spark gaps; 3 - α-particle source; 4 - high-voltage pulse generator; 5 - α particle track.

Fig. 4. Tracks of α-particles with various ranges.

Fig. 5. The scheme of the α-particle detector.

1.-wide gap spark chamber (WGC); 2-multiwire proportional counter(MPC); 3-10μ thick mylar windows; 4- α-particle source (Pu^{239}).

Fig. 6. Pulse height distribution of α-particles and electrons.

1. electrons with energies E_e = 2.1 and 0.5 MeV;
2. α-particles, E_α = 5.2 MeV.
3. Spectrum from MPC exposed to a γ-quanta beam (There is aluminium convertor before MPC).
4.- Spectrum from MPC exposed to a γ-quanta beam.

Fig. 7. The dependence of the MPC counting rate on the photon-beam intensity.

Fig. 8. Typical photos of a strongly ionizing particle.

Fig. 9. The distribution of the range of particles stopping in the spark chamber.

Fig. 10. Polar angle distribution of particle emission.

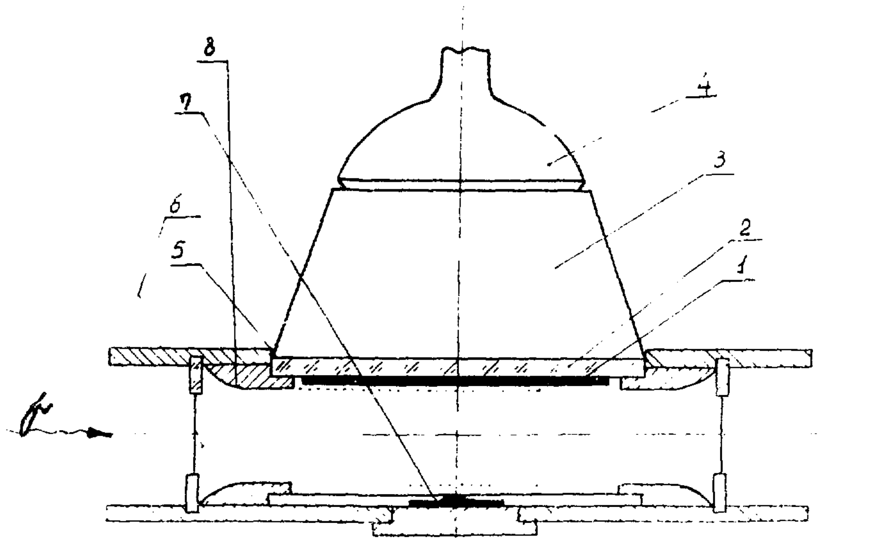

Fig.1

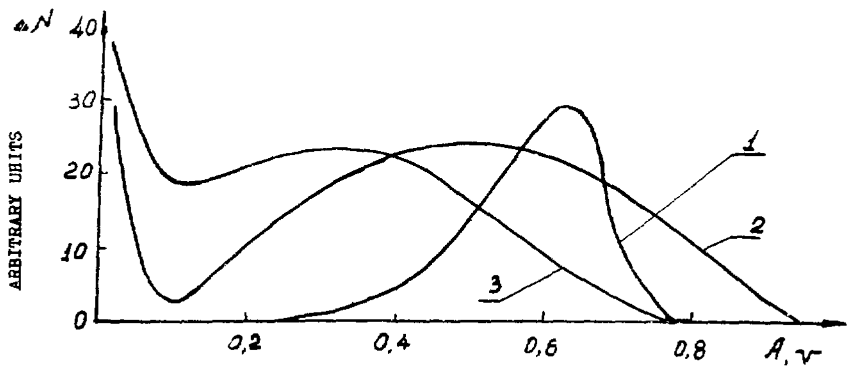

Fig.2

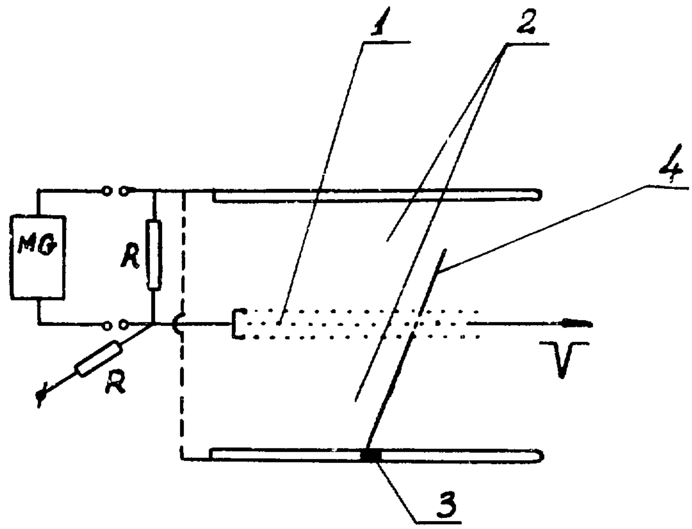

Fig.3

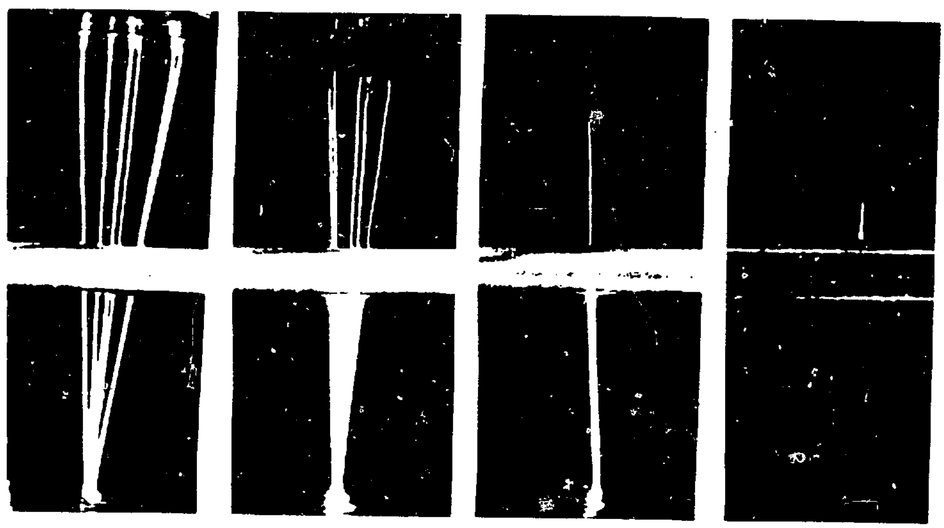

Fig.4

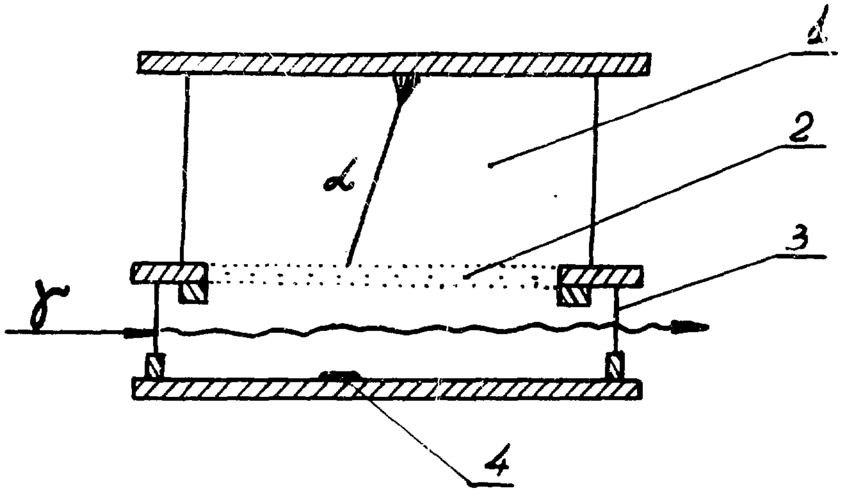

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Fig.5

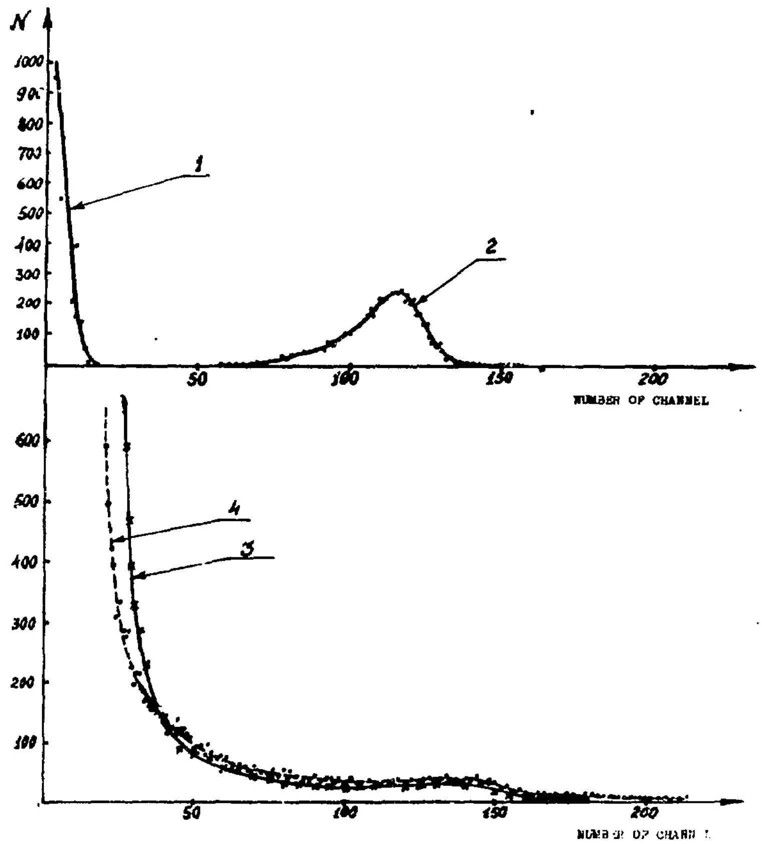

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Fig.6

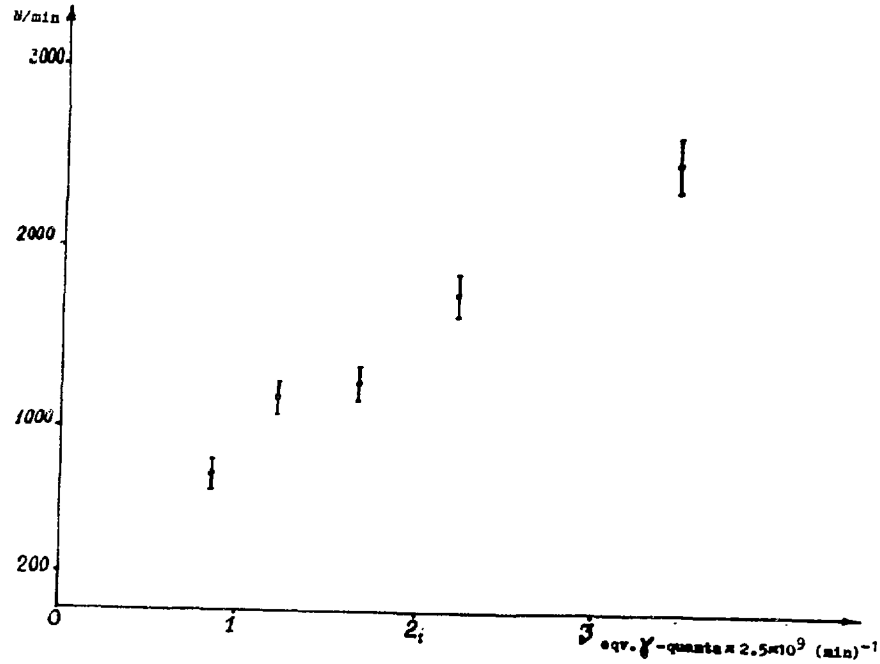

Fig.7

Fig.8

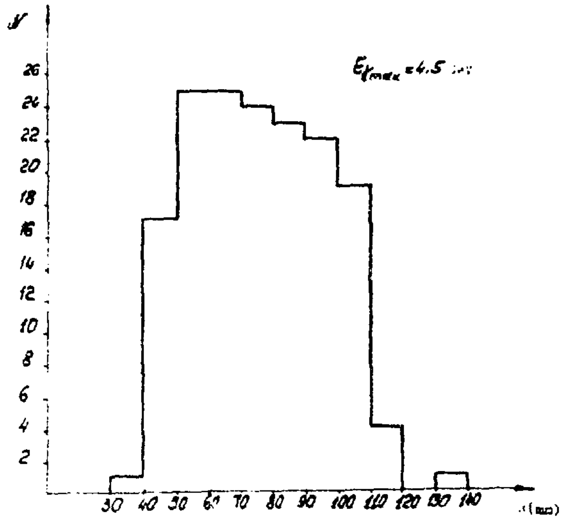
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Fig.9

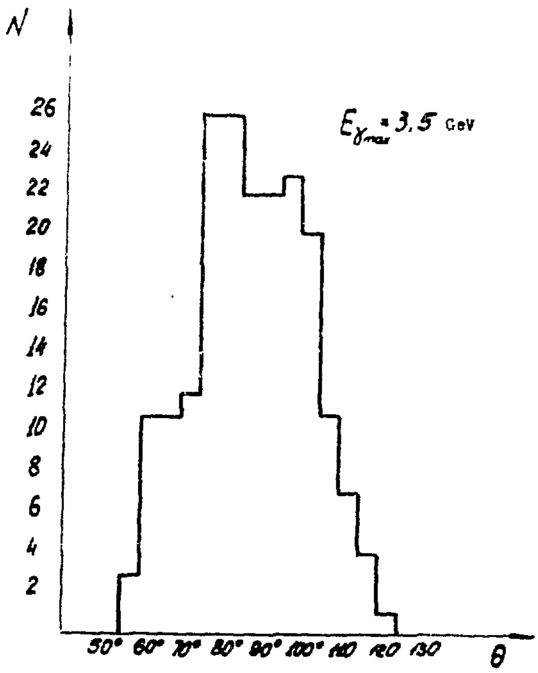
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Fig.10

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