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When investigating a gas-discharge chamber the Japanese physicists Fukui and Miymoto[1] observed an interesting phenomenon: a discharge appeared along an ionizing particle track in the cases when the direction of the particle movement and the direction of the electrical field made the angle not larger than 30°. It should be noted that despite a great number of the earlier performed studies of a discharge in gas even theoretical considerations did not take into account the possibility of the formation of a streamer channel inclined to the direction of the external electrical field. A simple explanation of this phenomenon has been given in a subsequent paper of the same authors[2] who have taken into account the reciprocal influence of the space charge of neighbouring cascades the development of which precedes the formation of a streamer discharge. There is no quantitative theory describing the influence of various factors on the appearence of a discharge inclined to the field as yet and optimum conditions for the appearence of such a discharge are under investigation. These investigations are first of all of practical interest since their results may be applied to the construction of reliably operating discharge chambers having higher space resolution as compared to ordinary spark chambers . Thus, for instance, the appearence of a discharge inclined to the field along a particle track is very important for multi-layer chambers used for the determination of proton polarization by the asymmetry of their angular scattering in the electrode material of the chamber.

The discharge chamber used in experiment[1] had one construction peculiarity: the conducting layers of the electrodes were separated from the gas volume of the chamber by a layer of dielectric. In further investigations[3,4], performed at the Laboratory of Nuclear Problems of the Joint Institute for Nuclear Research, chambers with external electrodes were also employed. Then in paper[5] the authors have shown the possibility of obtaining a discharge inclined to the field in the chamber with electrodes without dielectric layers.

In the present paper the conditions of obtaining a discharge inclined to the field along an ionizing particle track in the chamber with electrodes of aluminium foil without dielectric layers between the electrodes and the working volume of the chamber have been investigated. These investigations have been carried out for the sake of obtaining information necessary for the construction of a large multi-layer discharge chamber to measure the polarization of recoil protons in the reaction of elastic π-meson scattering on hydrogen.

The Construction of the Chamber and the Pulse Supply System

The spark chamber consisted of two gas gaps between three electrodes of aluminium foil 7μ thick. The electrodes were of rectangular form. The dimensions of the electrodes are shown in Fig. 1. In order to remove a discharge caused by the edge effect two opposite edges of each electrode were rounded owing to the stretching of the foil on plexiglas frames with aluminium pipes on two sides . The curvature radius of the electrodes was determined by the curvature of the pipe and was 5 mm. The other two edges of each electrode (without curvature) were located at a distance from the discharge intervals of the chamber. The fastening of the electrode plates permitted to change the distance between the electrodes smoothly. The electrode system was placed into an aluminium box with two windows for observing and photographing the discharge. The vacuum condensations of the window plexiglas joints with the box walls were made of rubber.

The Geiger counters (counter of MC–7 type), fed to the coincidence circuit, selected particles which passed through the chamber in a certain range of angles to the direction of the electrical field between the electrodes of the chamber. A pulse from the coincidence system triggered a thyratron ТГ30,1/1,3 (see the circuit in Fig. 1). A positive pulse of this thyratron with an amplitude of 850 V was used to fire a high voltage hydrogen thyratron of ТГИ1-325/16 type. The capacity $C = 0.04 \mu F$ was discharged by the current of a high voltage thyratron. A negative pulse of triangular form with $0.3 \mu sec$ duration at the bottom and with the rise time about 10^{-8} sec appeared on the inductance L. The pulse amplitude was determined by the value of voltage on the anode of the high voltage thyratron.

In order to increase the steepness a high voltage pulse was supplied to a middle electrode through a hydrogen discharge switch of РБ-2 type. If a high voltage pulse was absent, a discharge switch broke the circuit between the inductance L with small ohm resistance and a batary forming the constant electrical field to remove electrons and ions from the working volume of the chamber.

The present system of pulse supply provided the appearence of high voltage between the electrodes of ıe chamber with a minimum delay of $0.4 \mu sec$ after the particle had passed the chamber. In the control system there was a possibility to change the delay time of a high voltage pulse from 0.4 to 2.0 μ sec.

Results of Measurements

When the chamber was filled with neon with 0.5% argon contamination up to 1.5 atm pressure, the distance between the electrodes being 17 mm, a discharge observed visually in the chamber appeared with an amplitude of a 7.5 kV high voltage pulse. With increasing the voltage on the thyratron anode the intensity of the spark channel luminescence increased sharply. A spark discharge gave rise to a point damage of the aluminium foil on the electrodes. In order to reduce current in a discharge the extreme electrodes of the chamber were earthed with the help of separate resistances of 15 ohm. These resistances were necessary also to avoid the reciprocal influence of discharges in separate gaps of the chamber.

If an ionizing particle passed the chamber, a spark discharge occurred only at the place of particle passing right up to 18 kV. However, with the absence of a particle passing the chamber a spark discharge occurred between the middle electrode and the box wall beginning from 15 kV. The point burning through of the electrodes did not give rise to the appearence of false discharges.

The main advantage of the spark chamber without dielectric layers underlies the fact that there is a possibility of reducing the resolution time owing to the formation of the constant electrical field clearing the chamber volume of electrons. The effectiveness of the registration of cosmic particles passing the chamber was measured with the amplitude of a 10 kV pulse supply with various delays of a high voltage pulse and with various voltages of the clearing field. The obtained curves of the time resolution for a separate gap of the chamber are given in Fig. 2.

The observed decrease of the effectiveness with the increase of the pulse with the presence of the clearing field proves the fact that a discharge in the chamber arises only due to electrons produced by a cosmic particle.

The investigation of the formation of discharge channels inclined to the field was performed with various amplitudes of a supply pulse and with various fillings of the chamber. It was cleared out that the limit angle for the formation of a spark channel along the chain of electrons produced by an ionizing particle, rises with the increase of the amplitude of a high voltage pulse. With overvoltage less than 1 kV a spark discharge arises only along the direction of the external electric field.

With the addition of alcohol to neon there was observed a sharp decrease of the limit angle for the formation of an inclined streamer. When the chamber was filled with argon up to the pressure of 1.1 atm there was obtained no satisfactory results, apparently, in connection with restriction to the increase of overvoltage in the chamber. (A discharge in the chamber, filled with pure argon, began at 16 kV. The maximum possible voltage, obtained in the described system of pulse supply, was 18 kV).

The largest limit angle for the production of an inclined streamer channel, was observed when the chamber was filled with pure neon and also with neon with 0.5% argon contamination, the discharger PБ–2 being used (see Fig. 1). With a probability of about 100% a discharge arose along the particle track with comparatively small distortions of electrodes for the inclination angles of 35°. Fig. 3 gives the picture of a discharge taken through a blue lightfilter CC–12 and with a diaphragme of 22 units. The chamber was filled with pure neon up to 1.5 atm pressure. The distance between the electrodes was 2.3 cm. [redacted]. A high voltage pulse was fed to a discharger PБ–2 with a 0.4 μ sec delay and the pulse amplitude was 14 kV. There was no clearing field. The blue lightfilter permitted to separate the central part of the spark channel. For the sake of comparison a discharge from a particle, passed at an angle of 35°, photographed without a lightfilter is given in Fig. 4.

When a particle was traversing the chamber at an angle larger than 30° in an inclined spark channel there appeared the distortions of electrodes. A relative value of these distortions increases quickly with the angle of the track inclination and becomes considerable for angles of 40°–50°.

In this region of angles along with the twisted inclined spark discharges of the electrodes there appear also the discharges coming strictly in the direction of the electrical field. The probability of arising of such straightened discharges for an angle of 45^{o} does not exceed 10% and for an angle of 50^{o} it is already about 90%.

It should be noted that in the chamber of Fukui and Miyamoto/2/ a stable inclined discharge was observed from particles passing the chamber at an angle of 15^{o}. In the angle region of $15-30^{o}$ a discharge along the particle track arose unstably with the large distortions and streamers of the spark channel.

Thus, the results obtained in the present paper do not confirm the assumption made earlier/3/ that the presence of dielectric layers between a gas gap and the conducting layers of electrodes promotes the formation of a discharge channel inclined to the field along the chain of electrons produced by an ionizing particle. The appearence of an inclined discharge in a larger angle region should be explained by the fact that in our experiment we have made use of higher gas pressure and quicker increase of high voltage between the electrodes of the chamber.

Earlier it was noted/1-5/ that in order to obtain a discharge inclined to the field of a sufficiently quick rise of the electrical field between the electrodes of the chamber was necessary. In paper/5/ it has been shown that as the rise time of high voltage on the spark counter increases, there takes place an increase of the distortions of the discharge channel of the negative electrode . With some sufficiently large pulse rise time a discharge becomes possible only along the electric field. On the basis of these observations the authors have come to the conclusion that the distortions in the inclined discharge channel and also the transition with the increase of voltage rise time to the discharge along the field takes place due to the bias of the chain of 'initial' electrons under the influence of the increasing electrical field.

In our measurements due to the use of two spark counters with a common electrode there was a possibility of direct measuring the value of the discharge channel bias under the influence of the increasing electrical field. For the case presented in Fig. 3 this bias is only 1 mm*. Only the distortions of discharge channels of the negative electrode might be explained by the observed bias of the initial electrodes. The greatest distortions are those of positive electrodes. These distortions cannot apparently be connected with the drift of initial electrons in the direction of positive electrodes.

Thus except the distortions in the inclined discharge channel caused by the replacement of the chain of 'initial' electrons under the influence of the increasing electrical field, the positive electrode has dis-

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* The bias of the discharge channels in various gaps of the chamber is removed by switching on of the clearing field about 100 V the corresponding polarity.

tortions of other origin the rise of which with the increase of the angle of the track inclination leads to the restriction by the angle of the appearence of inclined spark channel along an ionizing particle track. With the increase of the distance between the electrodes a relative fraction of these distortions in the spark chamber will increase. This should lead in its turn to the decrease of the probability of appearence of the straightened discharges for large inclination angles.

Fig. 5 gives a picture of a discharge in the large spark chamber containing 8 separate gaps. The construction of the electrode system is analogous to that described above. The working area of the electrodes is 25 x 50 cm^2; the distance between the electrodes is 2.3 cm. The chamber is filled with neon up to the pressure of 1.4 atm . For the formation of inclined discharges in this chamber which has the capacity of the electrode system about 500 pF a considerably greater overvolume is necessary than for a small spark chamber when the same system of pulse supply is used.

The discharge given in Fig. 5 has an inclination angle of 40°. The amplitude of pulse supply was 16 kV.

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References

1. S. Fukui, S. Miyamoto. Nuovo Cim. XI, 113 (1959).
2. S. Fukui, S. Miyamoto. Physical Institute Nagoy University, Japan, Preprint (1959).
3. A.A. Tyapkin. Reprinted from Proceedings of the Intern. Conf. on High Energy Instrumentaion, Berkeley (1960).
4. А.М. Говоров, В.И. Никаноров, Г.П. Петер, А.Ф. Писарев, Х. Позе, Препринт Д-715, ОИЯИ, 1961 г.
5. А.А. Борисов, Б.А. Долгошеин, Б.И. Лучков, А.В. Решетин, В.И. Умаков. ПТЭ № 1 /1962/.

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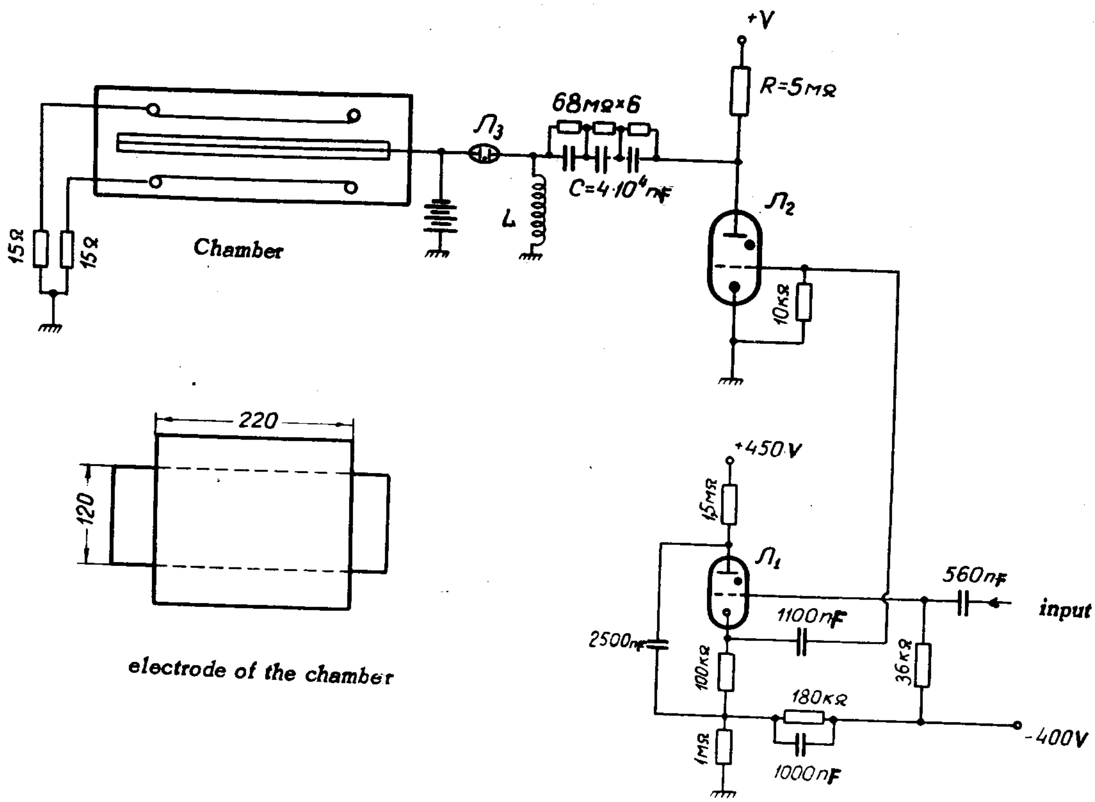

Fig. 1. Principal diagram

$Л_1$-ТГ3 $^{01}/_{1,3}$; $Л_2$-ТГИ1 $^{325}/_{16}$; $Л_3$-РБ-2.

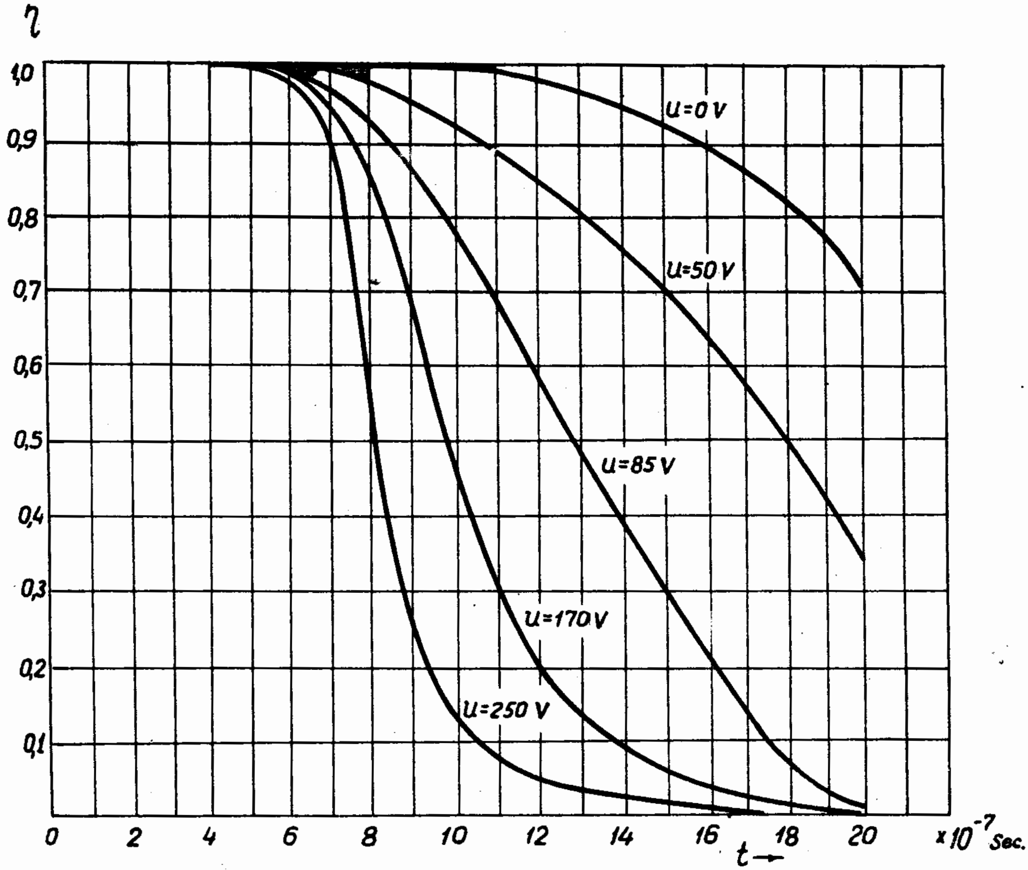

Fig. 2. Efficiency of a single gap as a function of delay in application of the high-voltage pulse. η - efficiency, t- the delay, u - the clearing field.

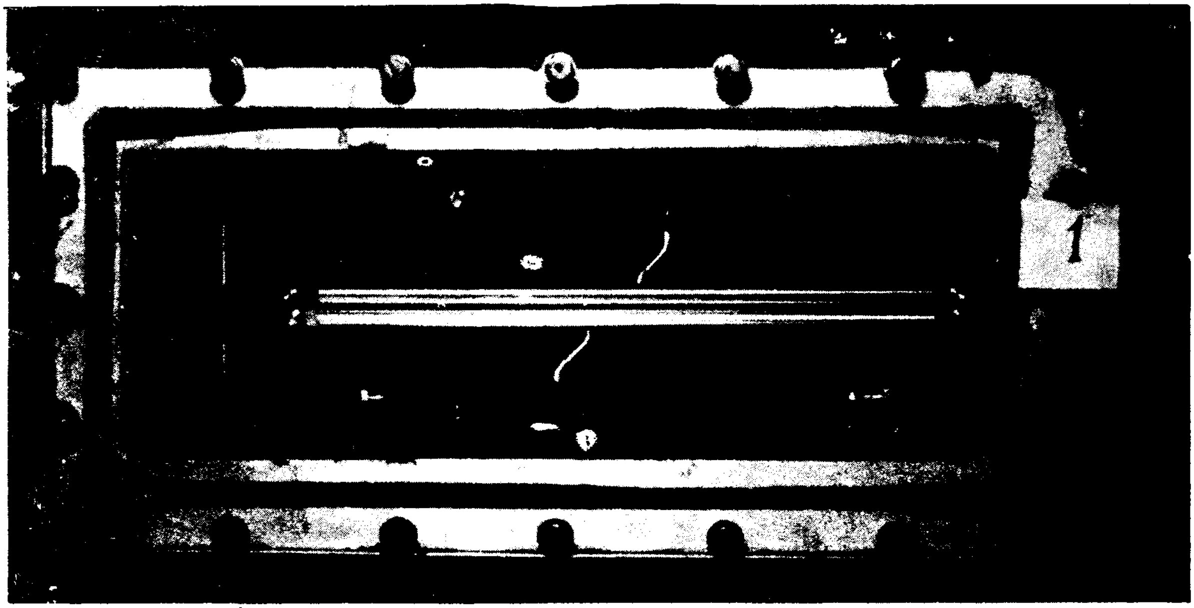

Fig. 3.

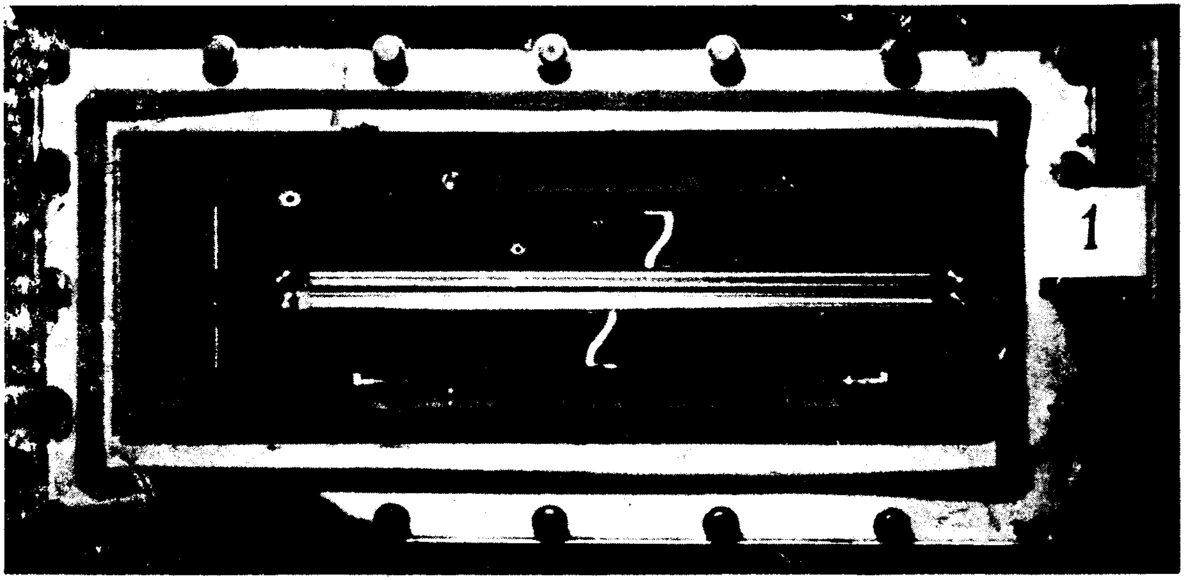

Fig. 4.

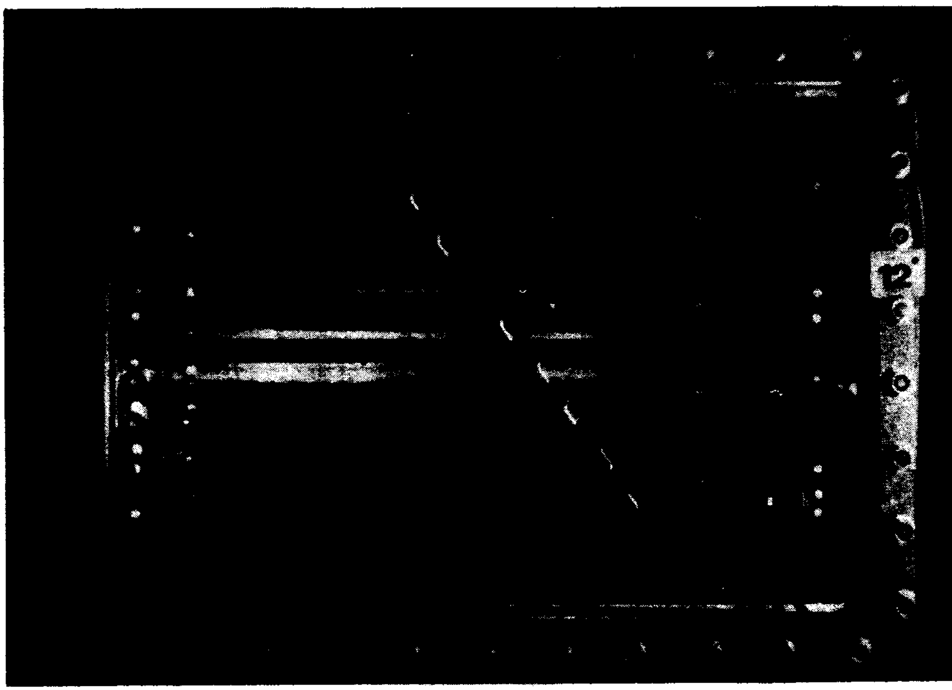

Fig. 5.