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ANALOGUE WIRE SPARK CHAMBER SYSTEM FOR MEASUREMENTS OF PARTICLE MOMENTA AND ANGLES

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I. Introduction

Wire spark chambers in which information is obtained with the aid of ferrite cores /1/ have recently drawn more and more attention. Being constructed in a usual way, these chambers allow to obtain spark coordinates in a form suitable for a direct transmission to a computer to be analysed. It is shown in /2/, that it is possible to get information with these chambers in another way. The idea is that if a number of ferrite cores is threaded by a common signal wire and the cores are flipped, on this wire appears a voltage pulse whose amplitude would be proportional to the number of the cores being flipped. This permits to receive the spark chamber data in an analogue manner. The analogue method of processing the data makes it possible to reduce, on the one hand, the volume of the output information and, on the other, to analyse, in some cases, spark chamber data for a comparatively short time (tenths of a microsecond). The results of this analysis can be used to trigger some other more complicated chambers, for instance, streamer chambers.

Below we shall be concerned with some problems pertaining to using wire spark chambers with an analogue method of taking information. A device for measuring particle momenta and angle of deflection will be described, and the results of tests of this device at the Joint Institute for Nuclear Research synchrophasotron beam will be presented.

2. Principle of Operation

Fig. 1 shows a schematic of a wire spark chamber with a ferrite core matrix.

A trigger pulse is applied to one of the electrodes of the spark chamber. The other electrode consists of parallel wires connected with each other by a common wire (write wire) which passes through all the ferrite cores and is grounded at one side. Besides, two more wires pass through all the ferrite cores...

A current necessary to reset the cores into the normal state is passed through one of these wires (control wire). The other is used as a signal wire.

When the spark discharge occurs through a section of the write wire the current will go to the grounded end. This current will flip all the cores located in this section into another state. At a moment when the cores are "flipping" on the signal wire will appear a voltage pulse whose amplitude is proportional to the number of the cores flipped.

This diagram is a simplified one and cannot work as such. This is mainly because some of the cores can be flipped by the displacement current when the spark chamber capacitance is being charged by the trigger pulse. The undesirable effect is also due to parasite capacities between the matrix wires owing to which some parasite signals may take place on the output wire if the front of the high voltage pulse is short. Besides, when the write current has a short front the cores neighbouring to the needed ones can be flipped also. One could avoid an undesirable effect of the displacement current if a somewhat unusual operation regime is applied. In Fig. 2 the voltages and currents corresponding to this regime are shown. Fig. 2a illustrates the shape of the trigger pulse applied to the chamber. At 0-t the voltage changes rapidly, after t_1 - smoothly. At t_1 a narrow current pulse is applied to the control wire. It sets all the cores into the normal position. The shape of this pulse is shown in Fig. 2b. The processes of charging and discharging the chamber capacitance have been finished by that time and all the cores have been set into the normal state, and along the write wire goes only the spark current. This current caused by a smooth part of the high voltage pulse after the moment t_2 makes only necessary cores flip once more. Fig. 2c shows the shape of the voltage on the signal wire of the matrix. In such an operational regime the amplitude of the second negative pulse is proportional to the number of the cores being flipped. If in a certain moment (at the moment t_3) one more pulse (read-out pulse) is applied to the control wire, all the cores will be set into the normal state while on the signal wire there will appear a pulse of positive polarity whose amplitude is also proportional to the number of the cores flipped. When working with the read-out pulse the spark coordinate can be measured both by the amplitude of the second negative pulse at the moment of recording and by the amplitude of the positive pulse at the moment of read-out pulse applying (t_3).

In the first case information about the spark coordinate can be obtained shortly (tenths of a microsecond) after the chamber was triggered. By operating in such a regime the information from the wire chambers can be used for triggering more complicated systems, e.g., a streamer chamber like it was mentioned in /2/. In the second case the accuracy of measuring the spark coordinates is somewhat higher because in this regime there is no effect of spark resistance on the output pulse amplitude which may occur because the histeresis characteristics of the ferrite cores are not rectangular.

3. Ferrite Matrices

In ref. /2/, various designs for ferrite matrices were discussed with the aid of which it could be possible to measure the spark, the number of sparks etc. Our chambers were designed for operating with only one spark and can be used to measure coordinates and angles. A spark coordinate can be measured by means of a circuit shown in Fig. 1.

Fig. 3 shows a circuit for angle measurements. Two identical wire spark chambers are located in parallel to each other at a distance t . All the wires of external electrodes are connected between each other. To one of them a high voltage pulse of positive polarity is applied and to the other - a pulse of negative polarity. When the spark chambers are triggered the current will go from the electrode to which the positive pulse is applied, through the spark in the chamber SC-1, through the write wire, and through the spark in the chamber SC-2 to the electrode to which the negative pulse is applied. This current makes the cores in the interval between the spark in the chamber SC-1 and the spark in the chamber SC-2 flip.

Evidently, the circuit shown in Fig. 3 is suitable for measuring angles of only one polarity. The angles of both polarities can be measured by means of a circuit shown in Fig. 4. The principle of operation of this matrix can be easily understood from the figure. Half of the cores is responsible for measuring positive angles, the other half - for measuring negative ones.

4. Spark Chambers

Fig. 5 shows a photograph of a wire spark chamber. The chamber has two wire electrodes (the wire is 0.1 mm berillium bronze). The spacing between the wires is 1.2 mm. The working area of the electrodes is 410x420 mm^2. The electrodes are separated by a glass frame 7 mm thick. The chambers are isolated from the external volume by means of Mylar of about 100 microns thick. The chambers are glued with epoxy. There are two inputs for filling with working gas. As such, a neon-helium mixture (75% of neon and 25% of helium) was used at a pressure of 1 atm.

The spark chambers can be used either separately (for coordinate measurements) or by pairs (for angle measurements). For angle measurements two spark chambers are fixed on the metal bottom. The spacing between the internal electrodes is about 1 m. In the middle of the bottom a ferrite matrix similar to those shown in Figs. 3 and 4 is located.

5. A Device for Particle Momentum Measurements

Fig. 6 shows a schematic of the device for measuring the particle momentum. It consists of four spark chambers and of an analyzing magnet. The device is designed for recording one-track events when the particles to be measured have a small angular spread in the vertical plane. In this case the value of the particle momentum can be found from the expression $p = \frac{K}{\alpha_H}$.

p is the magnitude of the particle momentum,

α_H is the angle of particle deflection in the horizontal plane in the magnetic field,

K is a coefficient determined by the magnet parameters.

Thus, in order to determine the particle momentum it is necessary to measure the quantity $\alpha_H = \alpha_2 - \alpha_1$. The angles are measured with pairs of spark chambers SC-1, SC-2 and SC-3, SC-4. The diagram of connection of each pair is similar to that shown in Fig. 3[x/].

To make the manufacturing of the matrices simpler the wires of the internal electrodes of the chambers were connected with each other by pairs. Thus, one ferrite core corresponds to 2.4 mm. The signal wire from each pair of chambers are connected to the ground so that the first pair gives always the positive signal and the second pair - the negative one. These signals are added in the summator and the resulting signal is applied to a 256-channel amplitude-time converter.

[x/] In the experiment on large-angle π^- meson-proton scattering for which this device is meant the angles of entering into the magnetic field have a small spread. Therefore, it is possible to have the angles of only one polarity by placing the pairs of the chambers at an angle greater than this angular spread.

Its output pulses are counted with a decade scaler.

6. Tests

The tests have been performed on a π^- meson beam of 4 GeV/c momentum. The average number of particles was about 10^5 mesons per second.

The spark chambers were triggered from a three 10 x 10 cm^2 scintillation counter telescope.

The spark chambers had an efficiency plateau in the range of operating voltages from 4 to 5.5 kV, the efficiency on the plateau was more than 99%. The memory time of the chambers without clearing field was 30 μ sec. The efficiency of the chambers did not decrease down to the clearing field voltage of 100 v. This field corresponds to the memory time of the chambers less than 1 μ sec. The delay of the high voltage pulse with respect to the time of the particle passage was about 0.4 μ sec.

A schematic of the experimental arrangement for measuring the characteristics of the pulse spectrometer is shown in Fig. 7. The angle of the first pair of chambers with respect to the second one simulated the particle deflection in the magnetic field.

In Fig. 8 are given the histograms of the measured values of the second differences of coordinates $\Delta_2 x = (x_4 - x_3) - (x_2 - x_1)$ which is proportional to the deflection angle (α_H). The histograms were taken with different amplitudes of the trigger pulse applied to the chambers with different clearing fields.

As is seen from the figures when the trigger pulse amplitude in the chambers changes from 4.25 kV up to 5.5 kV the root-mean-square error in determining $\Delta_2 x$ remains constant and is about 2 mm what corresponds to the error of the coordinate in one chamber about 1 mm.

The spectrometer efficiency was estimated as a ratio of the histogram area within the three-fold root-mean-square error around $\overline{\Delta_2 x}$ to the area of the whole histogram.

In Fig. 8 the values of efficiencies are shown for the corresponding values of the trigger pulse amplitude and the clearing field of the chamber.

The average inefficiency of the spectrometer is about 15% and is due, in the main, to a "simultaneous" passage of two and more particles through the chamber array.

For the π^- -meson momentum $p = 4$ GeV/c the deflection angle is about 8° for the magnet available. Thus, for the bases chosen which are 100 cm long the accuracy of measuring particle momentum is $\frac{\Delta p}{p} \approx \pm 1.5\%$.

Fig. 9 shows the results of measurements of the dependence of the first difference of coordinates $\overline{\Delta_1 x} = \overline{(x_2 - x_1)}$ on the angle of rotation of the chamber with respect to the beam. It is seen that the dependence is linear with a good accuracy.

There were also carried out angle measurements of the beam by means of two chambers with coordinate matrices. The distance between the chambers was 2.6 m.

In Fig. 10 the histogram obtained is plotted. This histogram is essentially the angular spread of the beam subtended by our counters.

7. Conclusion

Analogue wire spark chambers are a convenient recording tool which are extremely effective.

The system for measuring particle momenta and angles which consists of four spark chambers operates reliably in a wide range of supply voltages. Similar devices can be used in different physical experiments, e.g. in elastic scattering, search for resonances by using the method of the missing mass spectrum etc.

At present the available device is being modified.

Matrices with a digitization of 1 mm have been made, work is being carried out to decrease the dead time of the chambers, experiments are being done with thinner spark gaps.

The estimates show that using a device of such a type it is possible to study small-angle elastic scattering up to energies of several dozens of GeV.

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R e f e r e n c e s

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2. C. Ray, S. Parker, B. Sherwood and D. Schwartz. "Decision-Making Spark Chamber", EFINS 64-37.

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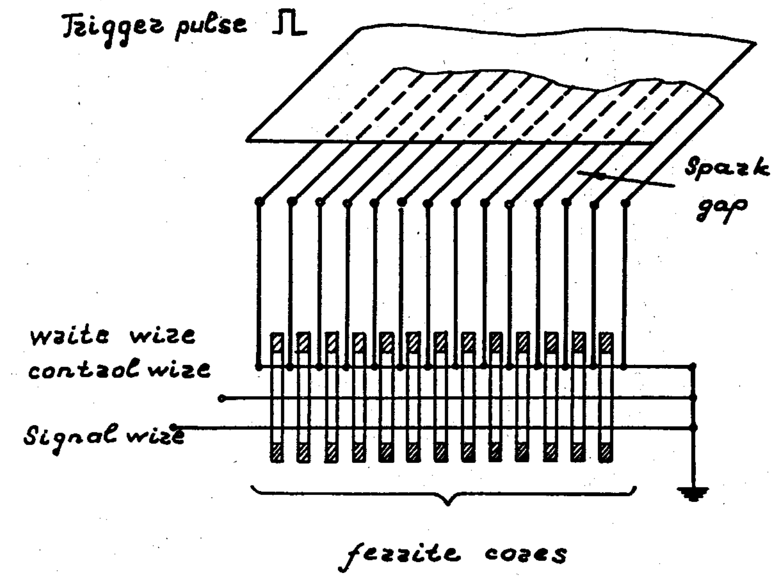
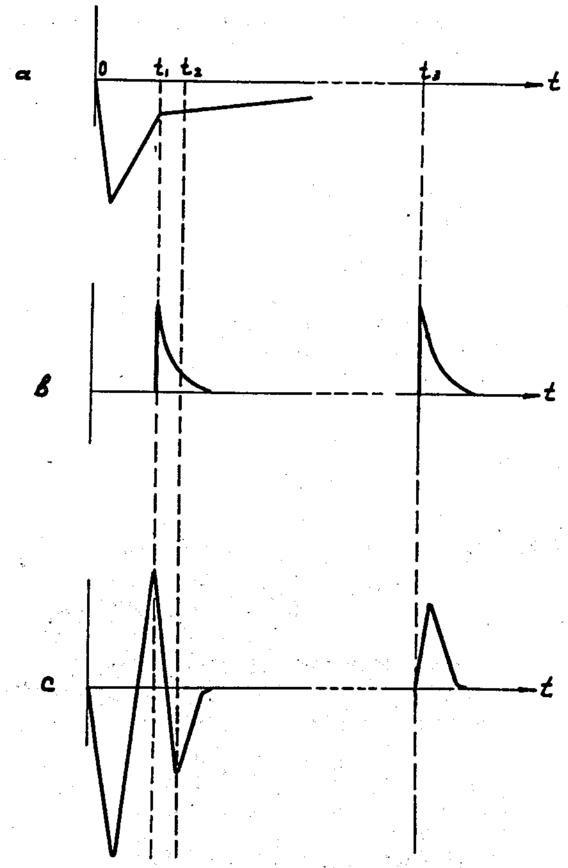
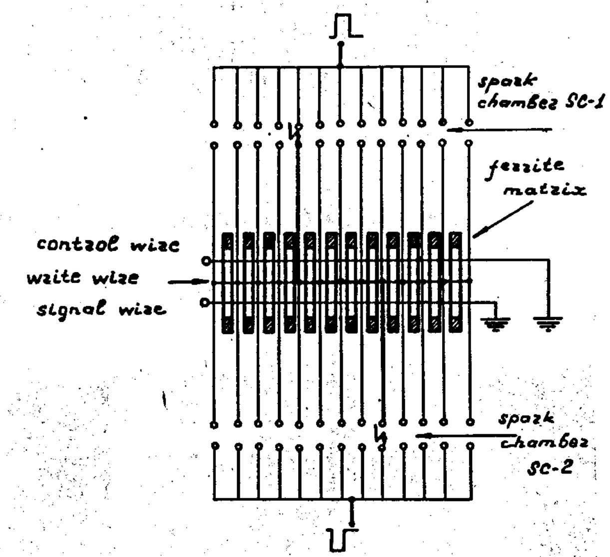


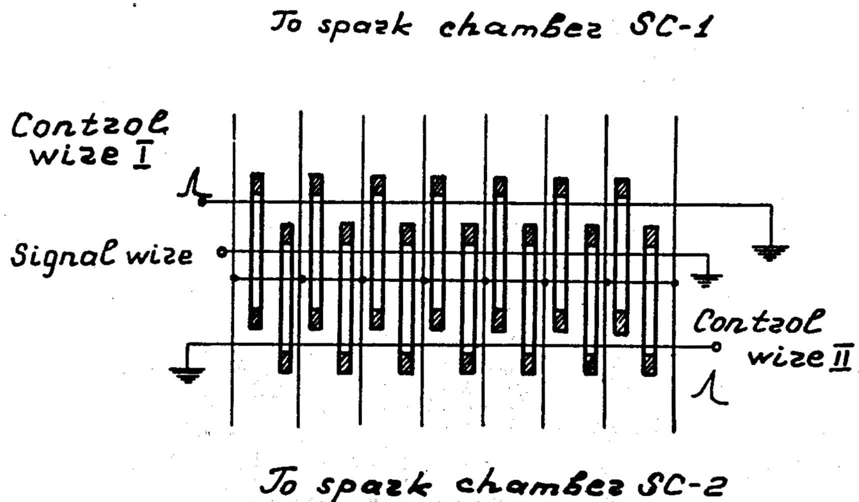
F i g. 1. A schematic of the wire spark chamber with a ferrite core matrix.



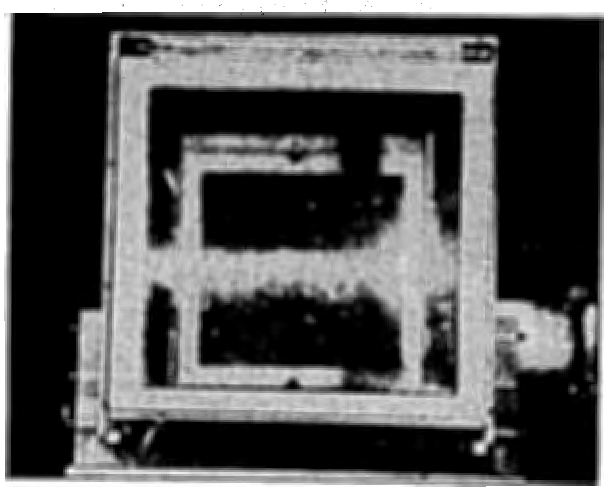
F i g. 2. Pulse shape of the voltage applied to the chamber and to the ferrite matrix wires
a) Voltage at the chamber,
b) Voltage at the control wire,
c) Voltage at the signal wire.



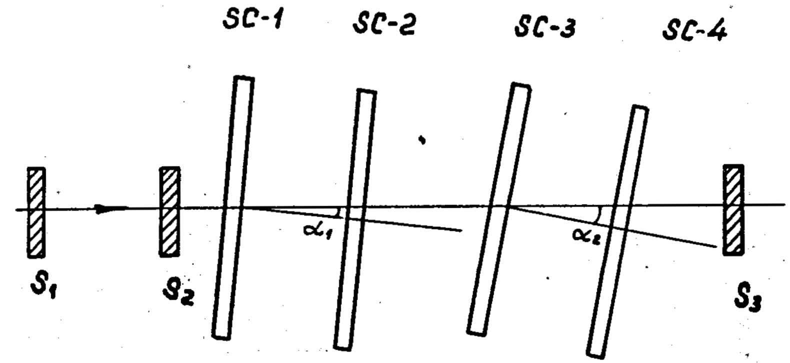
F i g. 3. A schematic of two wire spark chambers and of the ferrite core matrix designed for measuring the projection of the angle between the particle trajectory and the normal to the spark chambers.



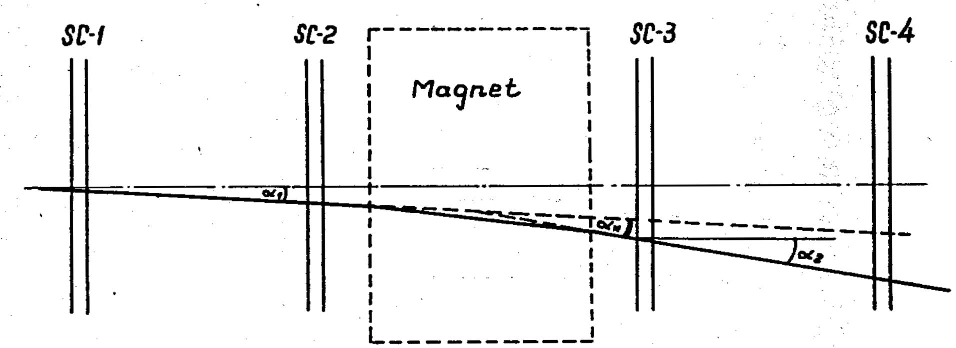
F i g. 4. A schematic of the ferrite matrix designed for measuring both positive and negative angles.



F i g. 5. Wire spark chamber.



F i g. 6. A schematic of the device for measuring particle momentum. SC-1, SC-2, SC-3, SC-4 are wire spark chambers.



F i g. 7. A schematic of the experimental arrangement for measuring characteristics of the pulse spectrometer. S_1, S_2, S_3 are the counters used for chamber triggering. The signal from the chamber is proportional to the angle difference $\alpha = \alpha_2 - \alpha_1$.

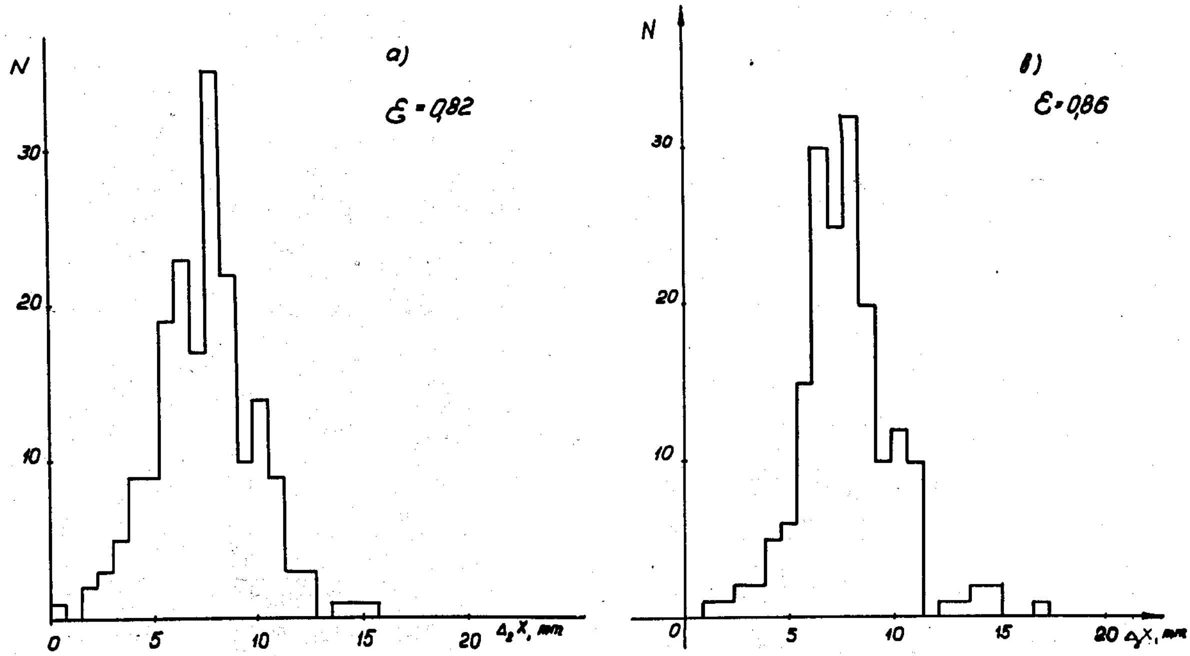


Fig. 8. Histograms of the measured values of the second differences of the coordinates $\Delta_2 x$. The abscissa axis is the second coordinate difference in mm, the ordinate axis is the number of events:
a) Voltage at the chambers 4.25 kV, the clearing field-40 V.
b) Voltage at the chambers 4.5 kV, the clearing field -60 V.

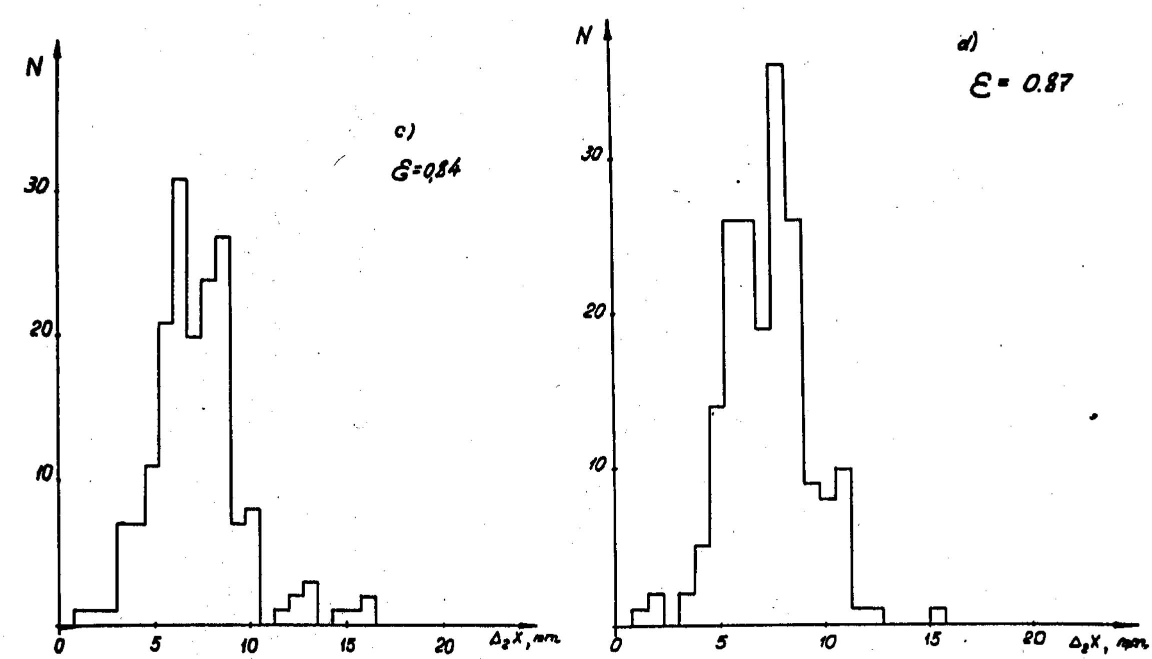
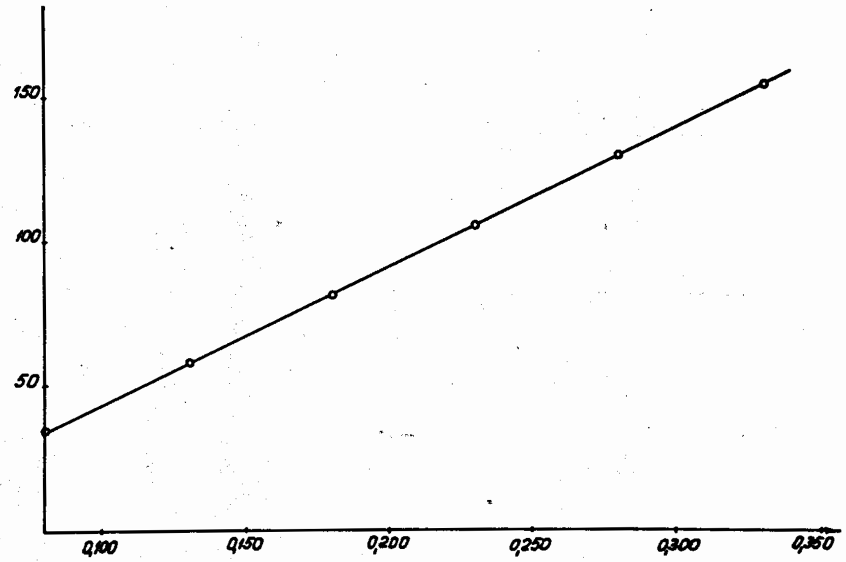
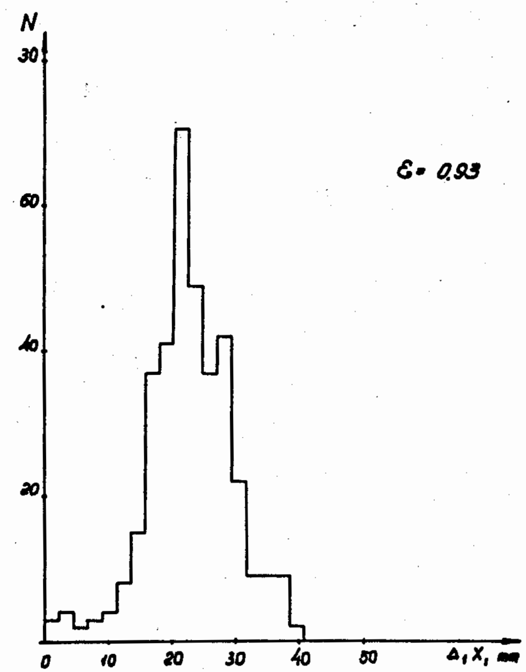


Fig. 8. Histograms of the measured values of the second differences of the coordinates $\Delta_2 x$. The abscissa axis is the second coordinate difference in mm, the ordinate axis is the number of events:
c) Voltage at the chambers 5.0 kV, the clearing field-70 V.
d) Voltage at the chambers 5.5 kV, the clearing field-70 V.



F i g. 9. Linearity of the scheme for angle measurements. (Fig. 3). The abscissa axis is the tangent of the rotation angle of a pair of chambers, the ordinate axis is the amplitude of the output signal in relative units.



F i g. 10. A histogram of distributions of counts of the first difference $\Delta_1 x$ taken with coordinate matrices. The voltage at the chambers - 4.7 kV, the clearing field - 60 kV. The base between the chambers is 2.60 m. The abscissa axis is the difference $\Delta_1 x$ in mm, the ordinate axis is the number of events.