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May 3, 1965

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I. INTRODUCTION

The CERN conference of March 1964 on the same subjects dealt mostly with the various techniques which were then in partially completed development. At that time very few experiments had been performed with the sonic chambers and none with Vidicons. The last year has demonstrated amply the success of these techniques; many experiments have been completed using sonic chambers and at least one with Vidicons.

The basic features of the sonic chambers are such that their use is optimal for applications which can be satisfied by using carefully built chambers with few gaps and with the expectation of recording one track only per chamber with a high efficiency. Since the velocity of sound in neon is 435 meters/sec, the dead time in a 1-meter chamber would be at least 3 millisec, excluding read out time. A characteristic use--as proposed by many research groups[1]--is in conjunction with magnetic spectrometers where sonic chambers at the input and output sides of the spectrometer serve to determine the momentum of charged particles with a high accuracy. Figure 1 shows the layout of a double spectrometer used by a Harwell group at the Rutherford Laboratory to detect and measure the momenta of the two pions in the $K_2^o \to 2\pi$ decay process.[2]

The Vidicon system described at the CERN meeting has been used successfully in a polarization experiment at Berkeley.[3] Figure 2 shows the experimental arrangement. A 360 MeV π^- beam incident on a hydrogen target: elastic scatters are tagged by a matrix of coincidences between the recoil protons and the scattered pions. The polarization analyzer is a set of carbon blocks graded in thickness and placed between two six-gap thin aluminum wall chambers. The input chamber determines the direction of the recoil proton incident on the carbon analyzers; the second chamber determines the direction of scatter of the protons from the carbon blocks. The digitizing scanning of the chambers by the Vidicon was done in a direction parallel to the chamber gaps.

The results were satisfactory. Spark positions were located to an accuracy of 1 part in 1000 in both views. The usefulness of the system can be seen from the following numbers. In the experiment 400,000 events were recorded on tape in digitized form by the Vidicon. Of these, 22,000 showed appreciable scatters and finally about 5000 had all the correct kinematic conditions to be included in the polarization analysis. The computer required an average of 30 milliseconds per event to reconstruct tracks from the spark coordinates stored on the tape and to select the particle trajectories which satisfied the kinematical conditions of the experiment. Thus, a total of three hours of 7094 computer time was used in the track reconstruction with a few hours more for the computation of polarization results.

This ability to select readily the required few events rapidly and automatically from the overall gross number recorded in experiments of these kinds is one of the most useful attributes common to all of the film-less spark chamber digitizing techniques.

II. IMPROVEMENTS IN TECHNIQUES

The many groups involved have evidently been so busy reaping the results of their successful techniques that they have not been able to spend much time in developing them further.

Nevertheless some changes have been made of which I will mention briefly the following. As regards sonic chambers, since one of the main limitations was the capacity to handle only one spark easily, various methods have been proposed to get around this difficulty by using more than a minimum number of microphones.

A different approach has been proposed by Kirsten;[4] the principle of the method is illustrated in Fig. 3. He uses the fact that the shock waves produced by a spark have a characteristic "N" shape with sharp leading and trailing edges. By differentiating the leading edge, a pulse of width T_s is obtained, where T_s is a property of the particular microphones used in a given chamber. Using this fact he developed a shape discriminating circuit which operates as follows. Three "windows" are set up in the amplitude time plane. Windows A and C are at the same amplitude level but separated by the time interval T_s. Window B is set at a time midway between A and C but has its lower level V_T volts above A and C. The common-mode level $V_{c.m.}$ is automatically set by the circuit so as to follow signal excursions. The microphone characteristic time T_s is typically 1 to 2 μsec. The analogue circuit marks the instant at which the output signal threads these three windows. The performance of the circuit indicated that two or more sparks could reasonably be distinguished from the chamber noise and reflections.

We have continued further developments of Vidicon systems at Berkeley. A second camera has been built and a third is under construction. In these cameras we have increased the data handling capacity and are using better Vidicon tubes (RCA 8507, 8573, in place of the 7263A originally used). Two Vidicon cameras are presently set up in the Bevatron in an experiment currently underway by Crowe, Maung, Haddock and collaborators to look at various decay modes of K^+ mesons. Sweep speeds have been increased so that each scanning sweep takes 30 μsec and the number of scalers is now four so that a maximum of four tracks can be digitized in each scanning sweep. Figure 4 shows a layout of three brass plate spark chambers looking at π^0 decays in this experiment. The total number of gap views scanned is 84 and the frame time is 15 milliseconds. Together with two erase frame times, the dead time is about 45 milliseconds.

III. MODIFICATION OF ACCOUSTIC TECHNIQUE: MAGNETOSTRICTIVE READOUT

This technique is a combination of a wire chamber with an ultra sonic readout and has many of the advantages of both. It works on the principle which has been used in the past by the computer industry to store and measure time intervals in a ferromagnetic wire. The method is illustrated in Fig. 5.

The wire, AB, is a nickel strip which is magnetized to a suitable bias level in the neighborhood of the knee of the B-H curve. A current pulse through the send coil, S, produces a local deformation of the ribbon which in the case of nickel is a longitudinal contraction. This deformation travels along the nickel ribbon with the velocity of sound in nickel which is ≈ 5000 meters/sec and produces a pulse of characteristic shape as seen at the receive coil, R. When used on the spark chambers the input pulse is made to correspond to the spark location--either by having the wires of the chamber made of ferromagnetic materials and having the spark strike them directly--as done by Gianelli[5] or by placing the nickel ribbon in close proximity to the chamber wires and coupling magnetically to them.[6]

Figure 6 shows the layout of the wire grids schematically. Both the high voltage and ground planes have copper conducting straps soldered on one side which convey the spark current from the discharge condenser on the high voltage plane to ground on the ground plane. The magnetostrictive nickel ribbons are mounted on aluminum holders and insulated from the chamber wires by 0.003-in. Mylar tape. The X and Y coordinates of the spark are determined by the time of arrival of the magnetostrictive pulses in nickel ribbons on the high voltage plane and ground plane respectively.

The width of the output pulse and hence the two spark resolution is a function of the duration of the spark current pulse, the dispersion in the nickel strip and the length of the receive coil. Using a nickel strip 0.002 x .012-in. in cross section and spark currents of duration less than 50 nanoseconds, the limiting factor is the length of the receive coil. Figure 7 shows an output pulse obtained with a receive coil of 200 turns, 0.020-in. long and 0.060-in. in diameter; the two spark resolution is thus less than 2 mm.

The number of sparks that can be handled simultaneously is limited only by the two spark resolution, the division of the discharge current through the various sparks and the capacity of the readout electronics.

The multi spark ambiguities in readout are easily handled by having some planes of wires oriented at 45 deg relative to the X and Y planes.

We have used wire planes made of 0.006-in. aluminum wire strung over plastic frames and wire planes made by photoetching lines on copper-plated plastic similar to that used for printed electronics circuitry. The copper platings are available on plastic as thin as 0.001-in. Mylar and hence provide a very convenient technique for making cylindrical or other non planar chambers.

IV. FUTURE APPLICATIONS

Since all of these techniques have the common objective of providing direct digitized readouts for spark chambers into buffer storages or directly into computers, the question arises as to the criteria by which any experimental group can decide on which method to use. The need for decisions of this nature in order to avoid duplication of effort is important since the readout electronics associated with the computer interface is usually rather specialized and costly.

While there is obviously no unique answer to this question, I would like to suggest the following considerations. The Vidicon technique is the only one of those discussed here that is capable of direct digitization of track coordinates in wide gap chambers. When these are operated in the spark mode--as for momentum measurements in magnetic fields where their potential high accuracy will be useful--the light output is more than sufficient for the sensitivity of the best commercially available Vidicon tubes. When these chambers are operated in the three dimensional streamer mode--which has many intriguing potential applications--the light output is low and insufficient for the sensitivity of present Vidicons. A possible solution to this is the use of image intensifiers in front of the Vidicon face plate with light gains of the order of 10^3 - 10^5 which are obtainable from commercial multi-stage intensifiers.[7] A further solution is the use of Vidicons with rectifying contact photoconducting layers which are under development currently by Phillips and have appreciably higher sensitivities.[8]

For narrow gap multiplate chambers I believe that the magnetostriction accoustic readout of wire chambers will supersede the use of sonic chambers. As mentioned previously, the advantages of these is the simplicity of construction by the photo etch methods for planar and non planar configurations, the shorter dead times for the readout and the capacity to handle multi spark events are over-riding advantages. Their use in multiplate chambers with lead plates--for γ ray dection--or with carbon plates for the polarization analysis of nucleons are potential needs in which they will be used at Berkeley.

In conclusion, I would like to say that while the direct use of computers in high energy physics was well underway, the development of these direct digitizing methods for spark chambers has accelerated this and removed what would otherwise be a tedious interlude between the start and end of an experiment.

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FIGURE CAPTIONS

Figure 1. Layout of the double spectrometer used in the Rutherford Laboratory $K_2^o \rightarrow 2\pi$ experiment. A, B, C, D, E, F, G, H are sonic chambers capable of detecting spark locations to an accuracy of ± 0.3 mm.

Figure 2. Layout of experimental arrangement in π-p elastic polarization experiment using Vidicon scanning.

Figure 3. Principle of "N" shape sonic spark detection.

(a) Response of microphone to spark showing spark leading edge.

(b) The three windows set by the detector electronics. The dashed line represents a signal that passes through the three windows.

Figure 4. Layout of brass plate γ detecting chambers in Berkeley K decay experiment showing 84 plates scanned by Vidicon.

Figure 5. Schematic representation of magnetostriction line pulses

(a) Pulse shape for trapezoidal pulse input from a send coil.

(b) Pulse shape from spark chamber wire input and output from small coil.

Figure 6. Method of coupling magnetostrictive delay line to wire chamber. A readout nickel slit is placed on the high voltage plane and on the ground plane with wires crossing at 90 deg.

Figure 7. Output pulse from test chamber using nickel ribbon 0.002-in. x 0.015-in. and a pickup coil 0.020-in. long.

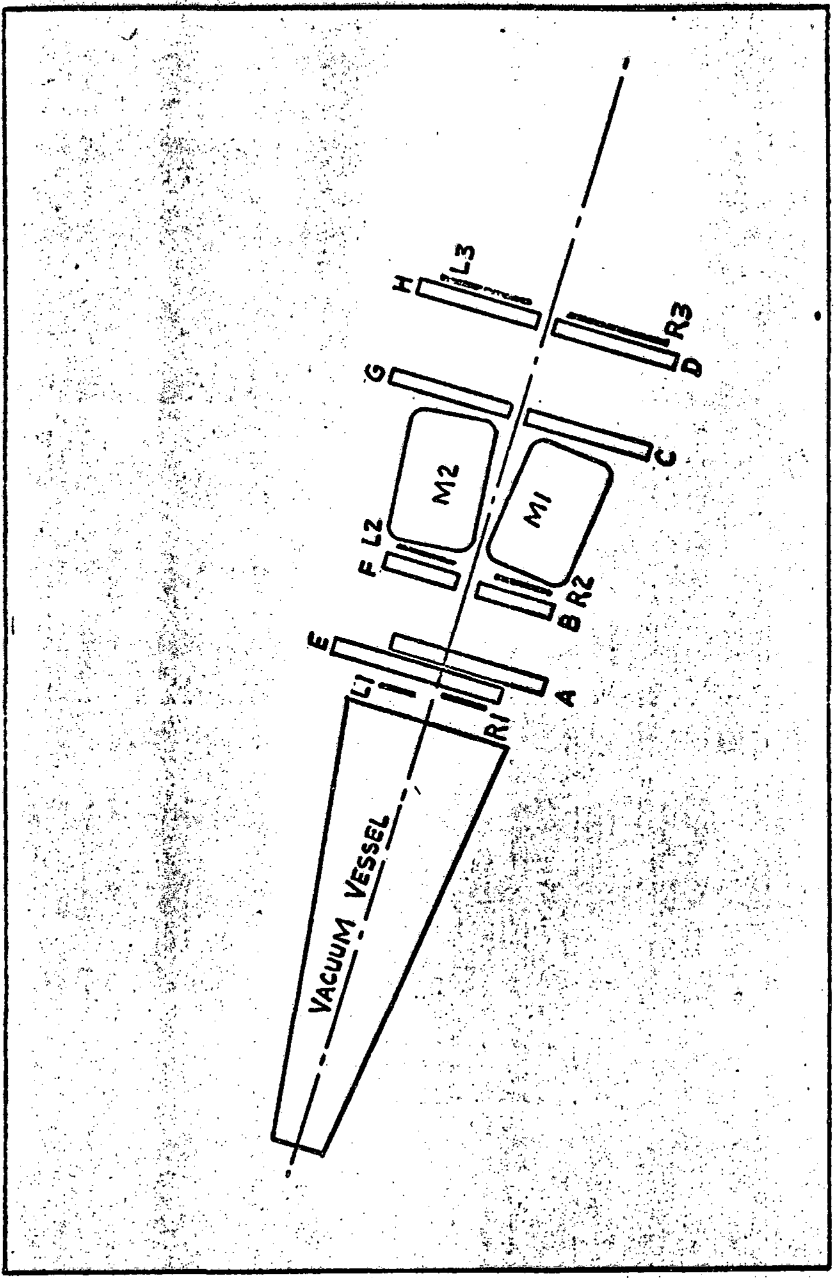

FIG. 1

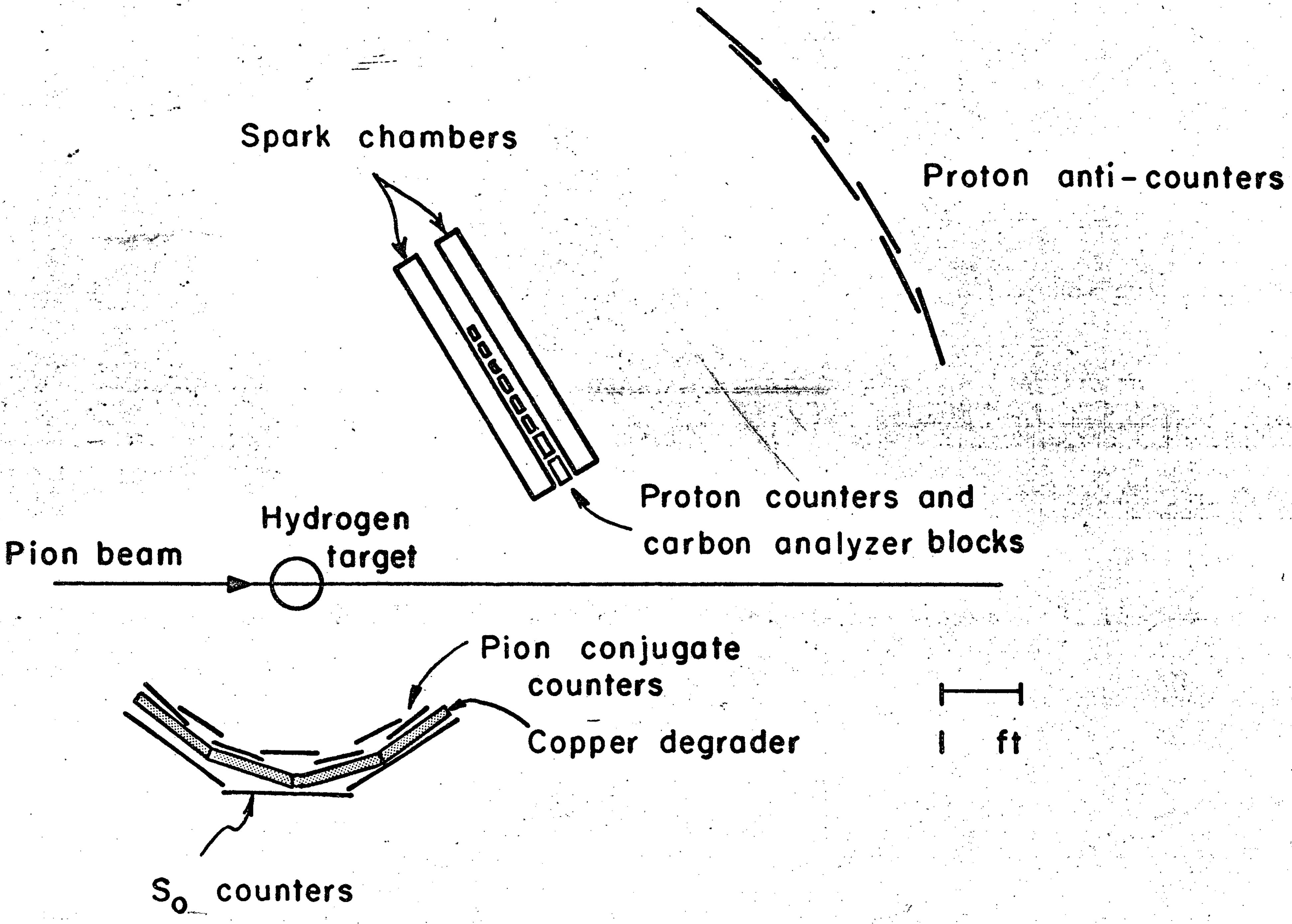
Spark chambers
Proton anti-counters
Proton counters and carbon analyzer blocks
Hydrogen target
Pion beam
Pion conjugate counters
Copper degrader
1 ft
S_o counters

FIG. 2

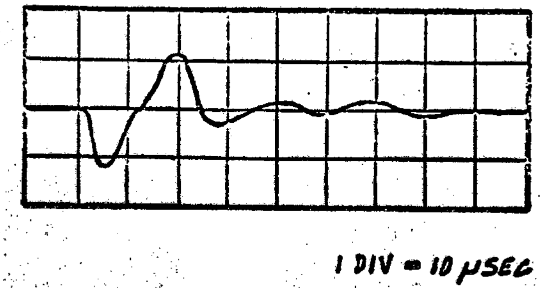
1 DIV = 10 μSEC

FIG. 3a

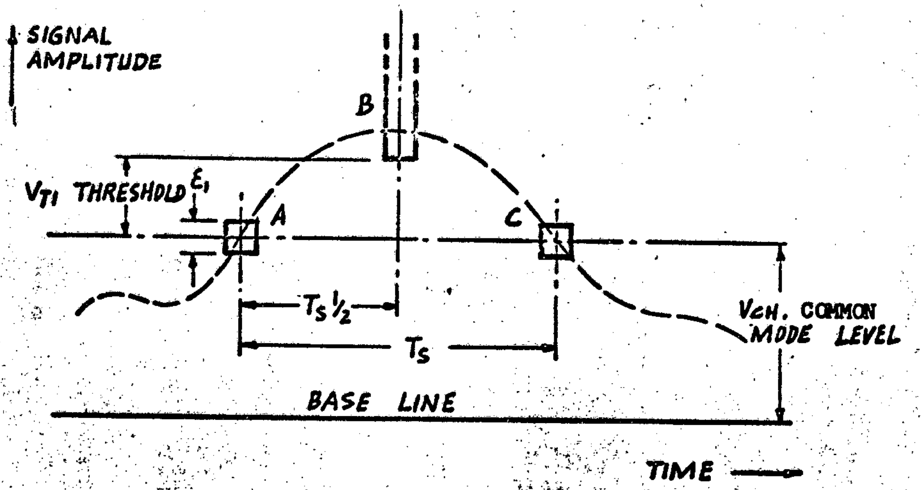
SIGNAL AMPLITUDE
B
V_T1 THRESHOLD
ε_1
A
C
T_S ½
T_S
V_CH, COMMON MODE LEVEL
BASE LINE
TIME

FIG. 3b

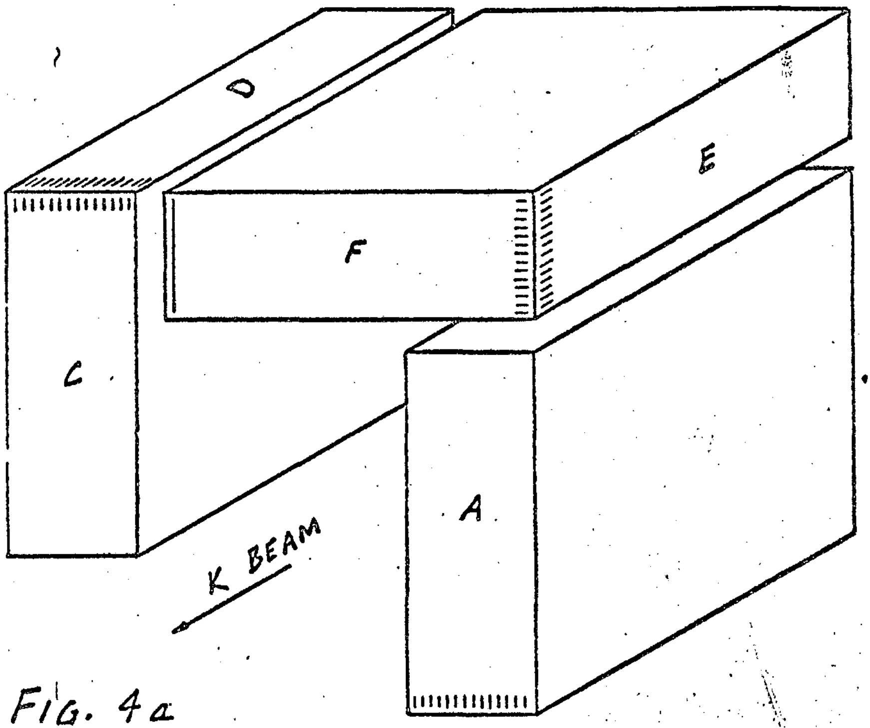
D
E
F
C
A
K BEAM

FIG. 4a

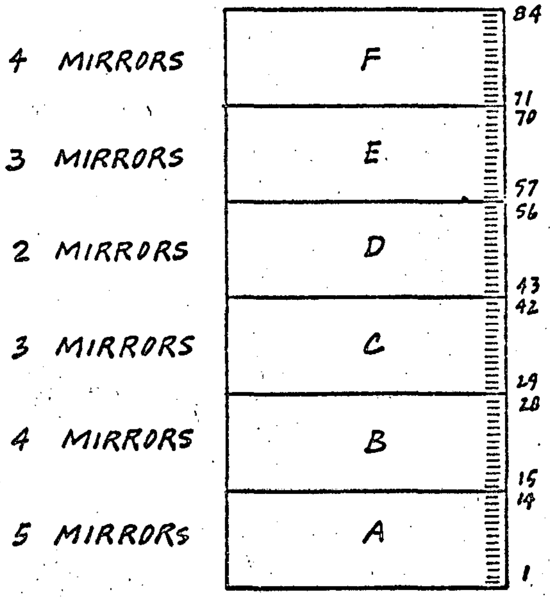
4 MIRRORS
F
84
71
70
3 MIRRORS
E
57
56
2 MIRRORS
D
43
42
3 MIRRORS
C
29
28
4 MIRRORS
B
15
14
5 MIRRORS
A
1

FIG. 4b

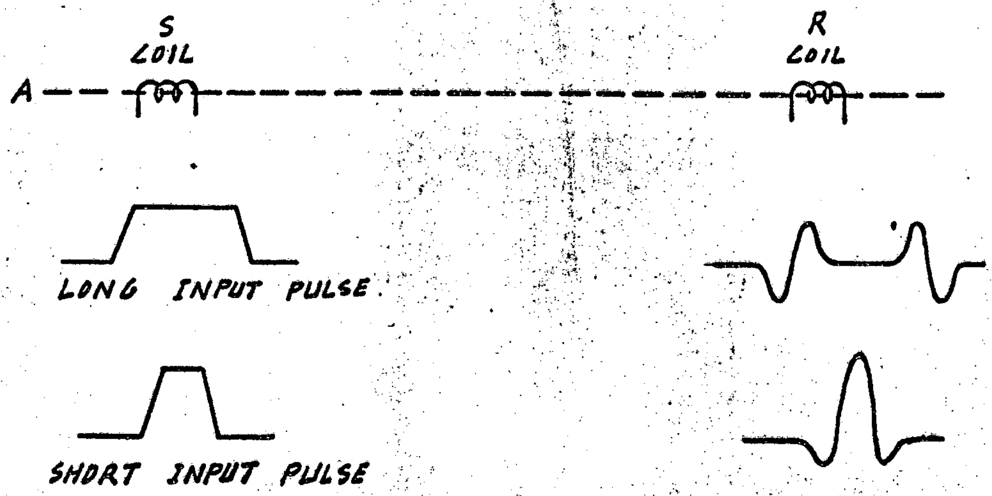
S
COIL
R
COIL
A
LONG INPUT PULSE
SHORT INPUT PULSE

FIG. 5a

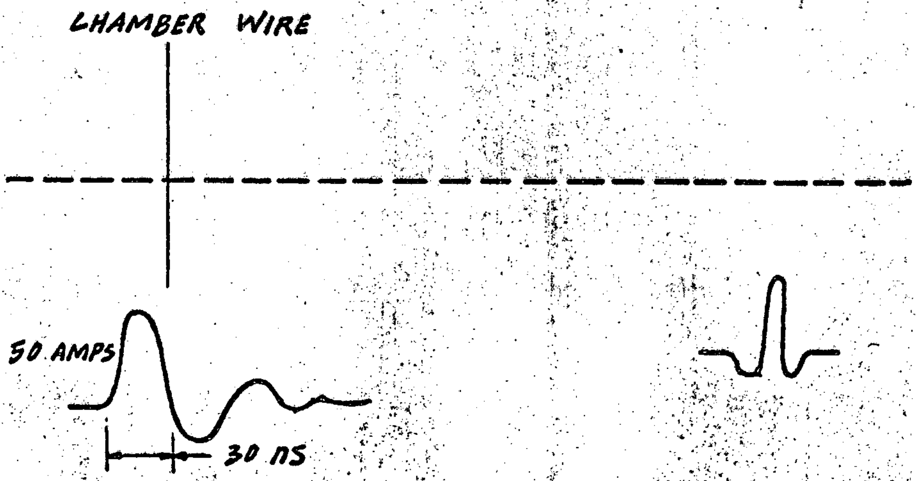
CHAMBER WIRE
50 AMPS
30 ns

FIG. 5b

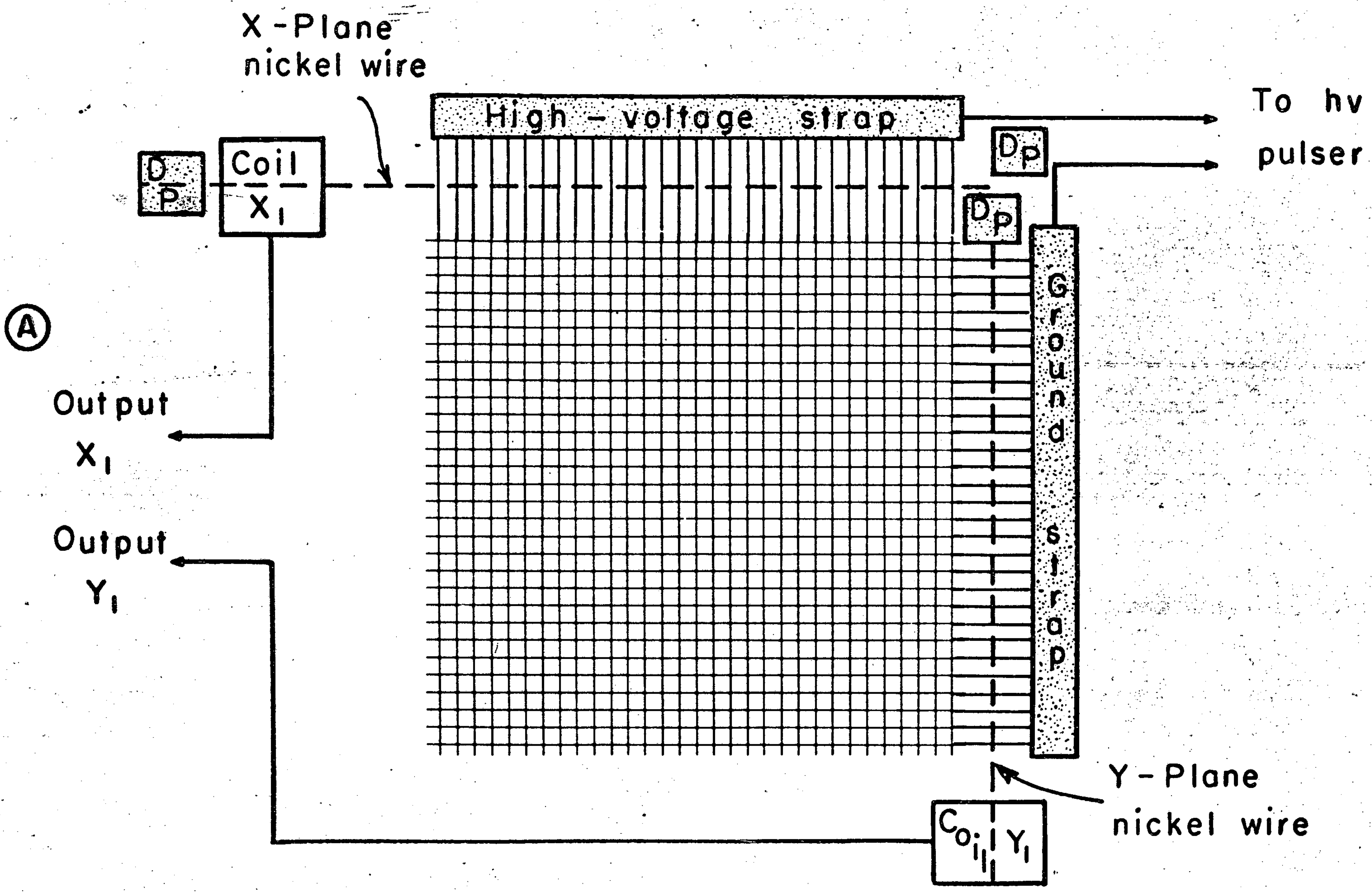
X-Plane
nickel wire
High-voltage strap
To hv
pulser
D
P
Coil
X1
Dp
Dp
Ⓐ
Ground strap
Output
X1
Output
Y1
Y-Plane
nickel wire
Coil
Y1

FIG. 6

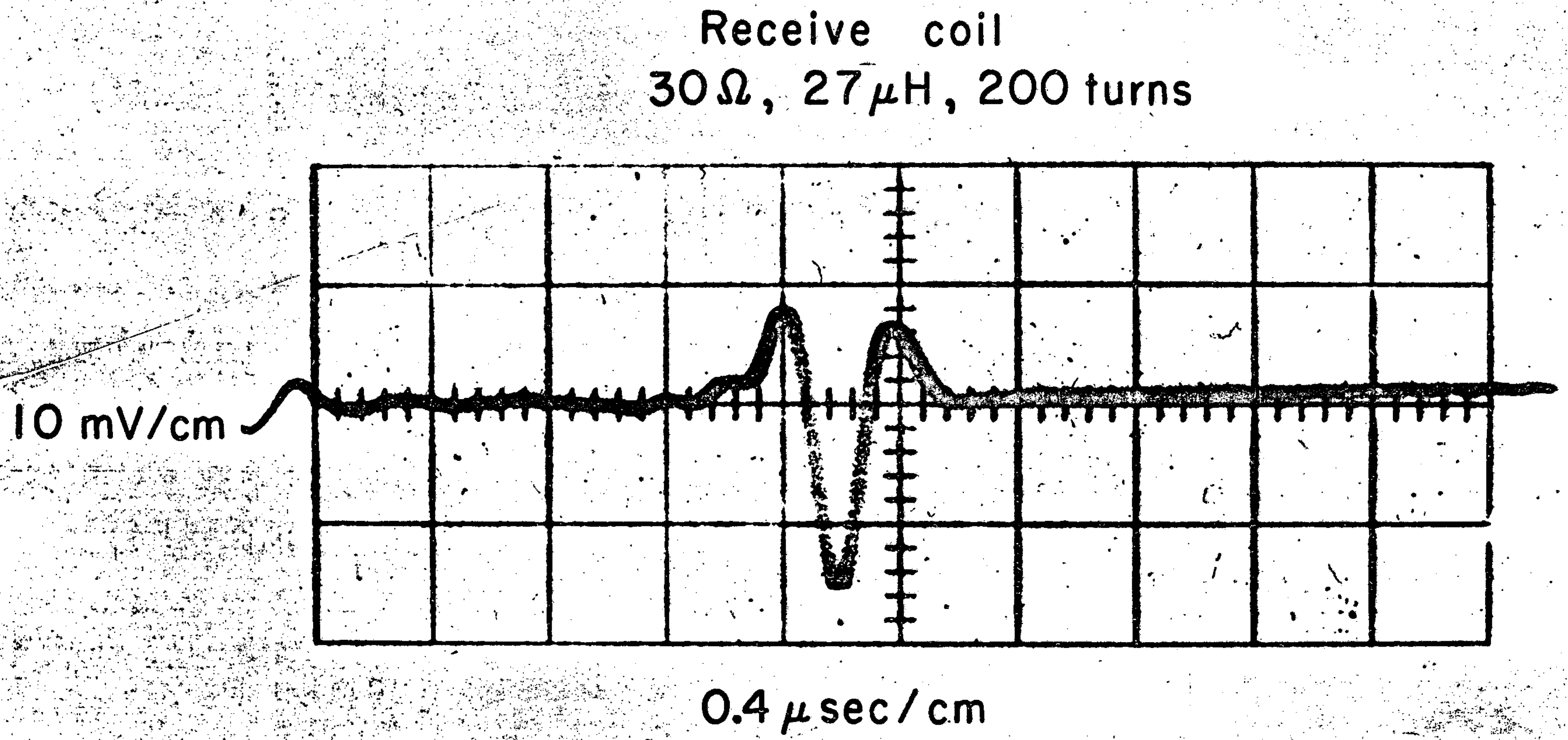

Fig. 7