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Publication Date
1960-09-29

UCRL -9405

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Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

Submitted to Nuclear Instruments

UCRL-9405
Limited distribution

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Berkeley, California

Contract No. W-7405-eng-48

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Abstract

A 15-channel scintillation counter has been constructed for use in magnetic spectrometers with extended focal line. It utilizes 15 organic scintillators placed along the focal line. The scintillators are optically coupled in binary code to four photomultiplier tubes. The output pulses from these tubes are electronically converted into standard current pulses (weighted 1, 2, 4, 8) in a common resistor. The resulting voltage pulse is proportional to the position of the scintillator giving the light pulse, and can be displayed on a "kicksorter." The results of an experimental test of the multichannel electron detector are described. Further improvements are expected with use of a fifth multiplier tube in coincidence with the above-mentioned tubes.

MULTICHANNEL DETECTOR FOR USE IN PARTICLE SPECTROMETERS*

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Introduction

Most magnetic spectrometers of the flat type have a focal line along which particles of various momenta are focused with good resolution. The length of the focal line depends on the type of spectrometer. Thus in magnetic spectrographs using photographic-plate detection, the ratio of maximum and minimum momenta focused can be as high as 5. In the various types of double-focusing spectrometers, the momentum range is less, typically of the order of 10% of the average momentum.

It is clear that the time required for taking data with a spectrometer is reduced considerably if information from several counters placed along the focal line can be taken in one run. Also there are advantages in recording as much as possible of a spectrum in one run, particularly when operating in conjunction with an accelerator or when recording particle spectra from rapidly decaying activities.

When placing several counters along a focal line, one encounters problems of space, and the external circuitry gets complicated as soon as more than a few counters are used. This is especially true for the application of scintillation detectors, in which even the smallest phototubes in connection with their light guides are large in comparison with the space available in most spectrometers.

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* This work was done under the auspices of the U.S. Atomic Energy Commission.

† On leave from the Institute for Theoretical Physics, University of Copenhagen, Copenhagen, Denmark.

This paper describes a 15-channel scintillation detector in which some of the problems mentioned above are solved by coding the light output of each scintillator into a binary system. The detector was constructed for use in a beta spectrometer of the wedge type,[1,2] but also should be useful for other spectrometers with a focal line or in angular-distribution equipment. The system of binary coding is of course applicable also to arrays of other types of detectors.[3]

The Spectrometer

The single-gap wedge spectormeter was of the type introduced by Koefoed-Hansen, Lindhard, and Nielsen.[1,2,†] It has a source-to-detector distance of 32 cm which experimentally yields a dispersion D of about 75 cm measured along the focal line. (The dispersion D is defined by the equation $\Delta p/p = \Delta s/D$, where Δp is a small change in the momentum p and Δs the corresponding movement of the image along the focal line.) The scintillator width of 4 mm thus corresponds to a momentum resolution of about 0.5%. This is somewhat large compared with the resolution of the spectrometer, which is about 1% under typical operating conditions. However, it was felt that the width of the individual scintillators could be reduced by baffles if necessary.

The inclination of the focal line with respect to the wedge axis was found to be about 38 deg. For convenience in construction, the scintillators were kept in air separated from the spectrometer vacuum by a 1-mg/cm^2 aluminized Mylar foil. Figure 1 shows the general arrangement of the counter when place in position on the spectrometer.

The Detectors

Organic scintillators were used; plastic in one unit, anthracene in another.

[†] We are grateful to Dr. O. B. Nielsen for drawings of and information about a similar spectrometer built by him.

The plastic has the advantage of being easy to machine to accurate dimensions, but the light output is smaller than for anthracene. As detection of low-energy electrons was essential for the experiments planned, anthracene was finally preferred. The size of the individual scintillators was 12 by 4 mm, with a thickness of 3 mm, corresponding to the range of about 800-kev electrons. Crystals thinner than the range of the electrons gave an undesirable output-pulse spectrum.

Each scintillator was glued onto a light coupler of Lucite (Fig. 2) with Epon Resin No. 820.

The Code

Fifteen of the light couplers were placed side by side, separated by 0.02-mm aluminum foils. The curved bottom surface of the coupler assembly was aluminized by evaporation in a binary pattern as shown in Fig. 3. This partly aluminized surface was then joined with Epon resin to an assembly consisting of four Lucite light pipes (Fig. 4) numbered 1, 2, 4, and 8. The binary pattern was carefully aligned with respect to the light guides so that scintillator No. 1 gives light to light guide No. 1; scintillator No. 2 to light guide No. 2; scintillator No. 3 to light guides Nos. 1 and 2; and so on up to scintillator No. 15, which is open to all light guides. Each of the four light guides is optically coupled to an RCA 6655A photomultiplier tube. The tubes were specially selected for low noise.

Digital-to-Analog Conversion

A block diagram of the digital-to-analog converter is shown in Fig. 5. The signal from each photomultiplier tube is amplified by a transistor amplifier having a gain of about 500. A simple discriminator cuts away low-energy pulses and noise. A standard one-shot multivibrator trigger circuit standardizes the pulses of the signals. The trigger-circuit signal cuts off the constant current flowing through a common collector resistor. The currents from the constant-current sources add algebraically in the common resistor. The constant-current source and common-collector-resistor scheme is shown in Fig. 6. The constant-current sources are adjusted to currents in the ratio 1: 2: 4: 8, for example 1, 2, 4, and 8 ma. The voltage pulse developed across the common resistor is proportional to the sum of the weighted currents, thus the voltage pulse is proportional to the position of the scintillator giving the light pulse.

An emitter-follower is used for a low-output-impedance driver. The signal is further amplified by a vacuum-tube linear amplifier with an output compatible with our vacuum-tube pulse-height analyzer (Penco PA-4).

Experimental Test

The first unit was built with plastic scintillators. It proved the feasibility of the system but also revealed a number of difficulties. As expected, the worst problem was to obtain equal sensitivity in all counters. It was found that the simplest way to check the sensitivity of each channel was to focus the flat maximum of a continuous beta spectrum on the counter by means of the spectrometer. Under these circumstances, the number of electrons per channel does not vary appreciably within the interval of about 8% momentum covered by the counter array, although there was a slight variation in counting rate from one end of the array to the other, probably reflecting a variation in the transmission of the spectrometer. That the variation was not due to the counter itself was proved by turning the counter assembly 180 deg.

Checked in this way, the sensitivity of the channels varied by up to 15% from the average. This result was obtained after some adjustment of the bias and high voltage on the phototubes. The nonuniformity in the counting rate was worst at low electron energies. Below an electron energy of about 200 kev it was difficult to obtain data with weak sources because of an increase of the general noise level. The noise was most prominent in Channels 1, 2, 4, and 8, which required a pulse in only one photomultiplier. Also there was a tendency for these channels to have a somewhat larger efficiency than the rest. This is probably related to the fact that owing to the complicated system of light collection, the pulse-height distribution from a single scintillator has a tail that extends down to zero pulse height with appreciable intensity. The bias on the phototubes therefore causes a certain loss of counts, e.g., 10%. The channels requiring only a single multiplier pulse then have 90% efficiency, those requiring two pulses have 81% efficiency, and so on. This effect was most pronounced for lower electron energies, and was almost absent above 500 kev.

The second unit, equipped with anthracene crystals, showed in general the same effects, but to a much smaller extent. With careful adjustment of the high voltage and the bias on each tube, the individual channels did not vary more than ±5% at an electron energy of 300 kev. Also this unit could work down to an electron energy of about 100 kev without serious noise problems. Firgure 7 shows the Cs^{137} K and L peaks recorded in a single run on this counter.

Further Improvements

We expect to be able to cure most of the difficulties encountered with the two units discussed above in a new unit presently under construction. In this device a fifth light guide and photomultiplier are introduced (referred to in the following as the coincidence multiplier). The light guide is placed between light guides 2 and 4 in Fig. 3, and is open to all 15 scintillators. 1 The signals from the coincidence multiplier are used to gate the combined signal obtained from the other multipliers. In this way several advantages are obtained:

(a) Tube noise is essentially eliminated by the coincidence requirement.

(b) Pulses produced by scintillations in the Lucite light guides are eliminated. Pulses of this origin may be partly responsible for a large increase in counting rate in Channels, 1, 2, 4, and 8 observed when the detector is used in a heavy background of fast neutrons.

(c) In practice only one bias has to be adjusted, namely that on the coincidence multiplier. The biases on the other tubes can be set somewhat lower, with correspondingly smaller losses. As the coincidence channel treats all the pulses in very much the same manner, it is to be hoped that the counting rate will show only small variations from channel to channel.

(d) The detector is very well suited for operation in a fast coincidence setup, e.g., for detection of the beta spectrum in coincidence with alpha particles or gamma rays. A fast coincidence signal is easily derived from the coincidence tube.

Acknowledgments

It is a pleasure to acknowledge several helpful discussion with Dr. Richard M. Diamond and Dr. John O. Rasmussen.

One of us (B. E.) wishes to acknowledge a Fulbright travel agent.

Footnotes and References

1. O. Koefoed-Hansen, J. Lindhard, and O. B. Nielsen; Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. 25, (1950) No. 16.
2. O. B. Nielsen and O. Koefoed-Hansen, Kgl. Danske Videnskab. Selskab Mat.-Fys. Medd. 29, (1955) No. 6.
3. Binary coding of scintillation detectors has also been used in a particle hodoscope: L. W. Alvarez, Rev. Sci. Instr. 31, 76 (1960).

Figure Legends

Fig. 1. Wedge-gap β spectrometer with multichannel counter.

Fig. 2. Scintillator and light coupler.

Fig. 3. Binary coding pattern on curved surface of the assembly of 15 light couplers with scintillators.

Fig. 4. Complete assembly of the multichannel counter.

Fig. 5. Block diagram of digital-to-analog converter.

Fig. 6. Constant-current control circuits for adjusting weighted currents in common collector resistor. The currents turned off in each circuit add algebraically in in the common collector resistor.

Fig. 7. K- and L-conversion lines from the 662-kev transition in Cs^{137} recorded in a single run on the multichannel counter.

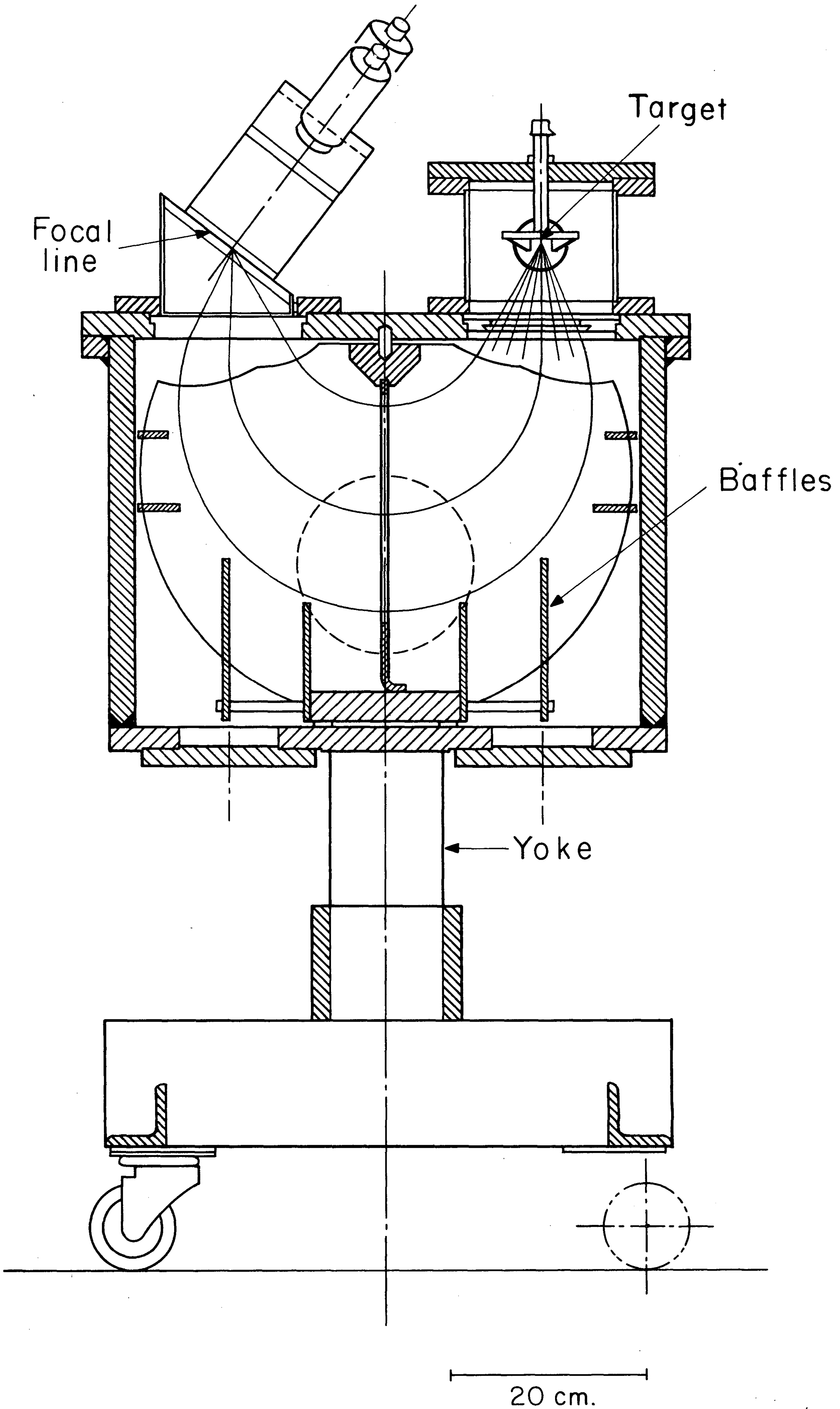


Fig 1
58353-2

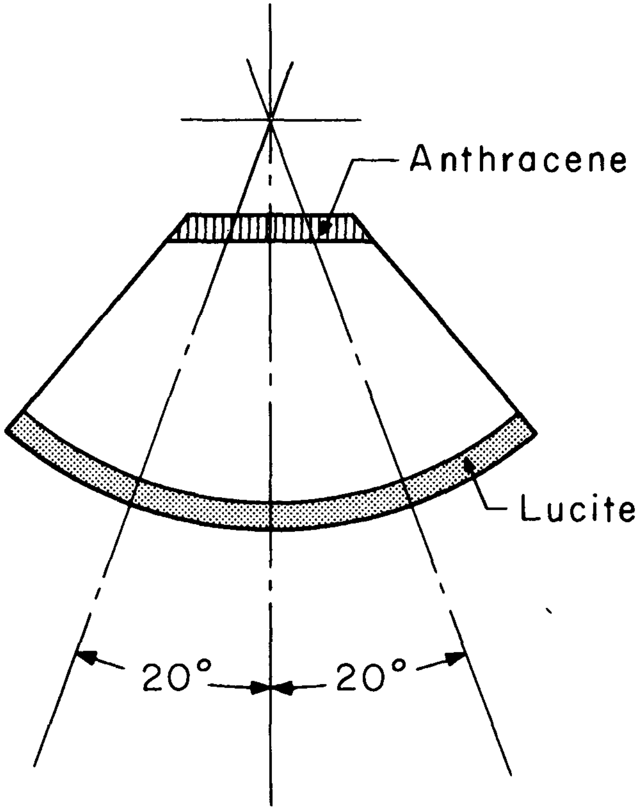


Fig 2
58354-1

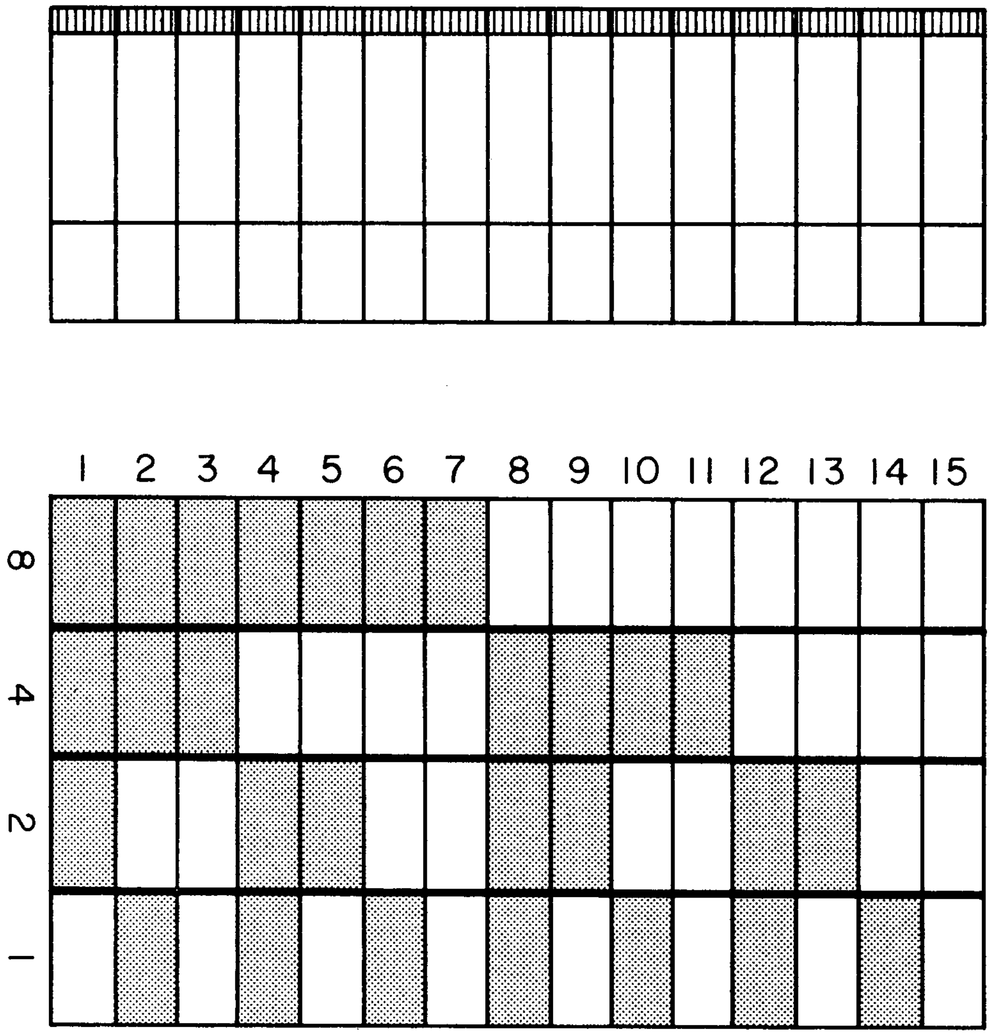
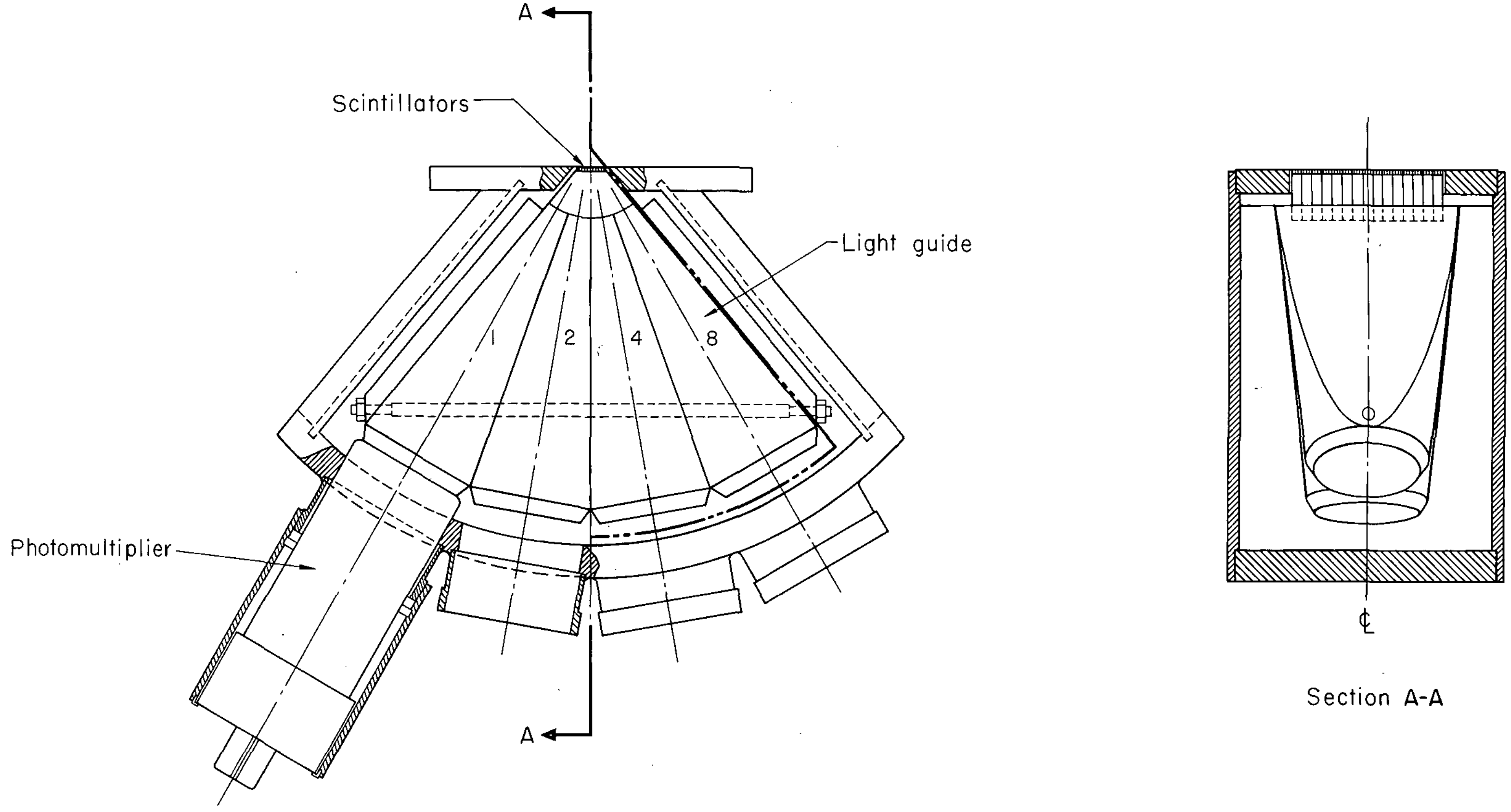


FIG 3
58355-1



Section A-A

F I G 4

MuB-483

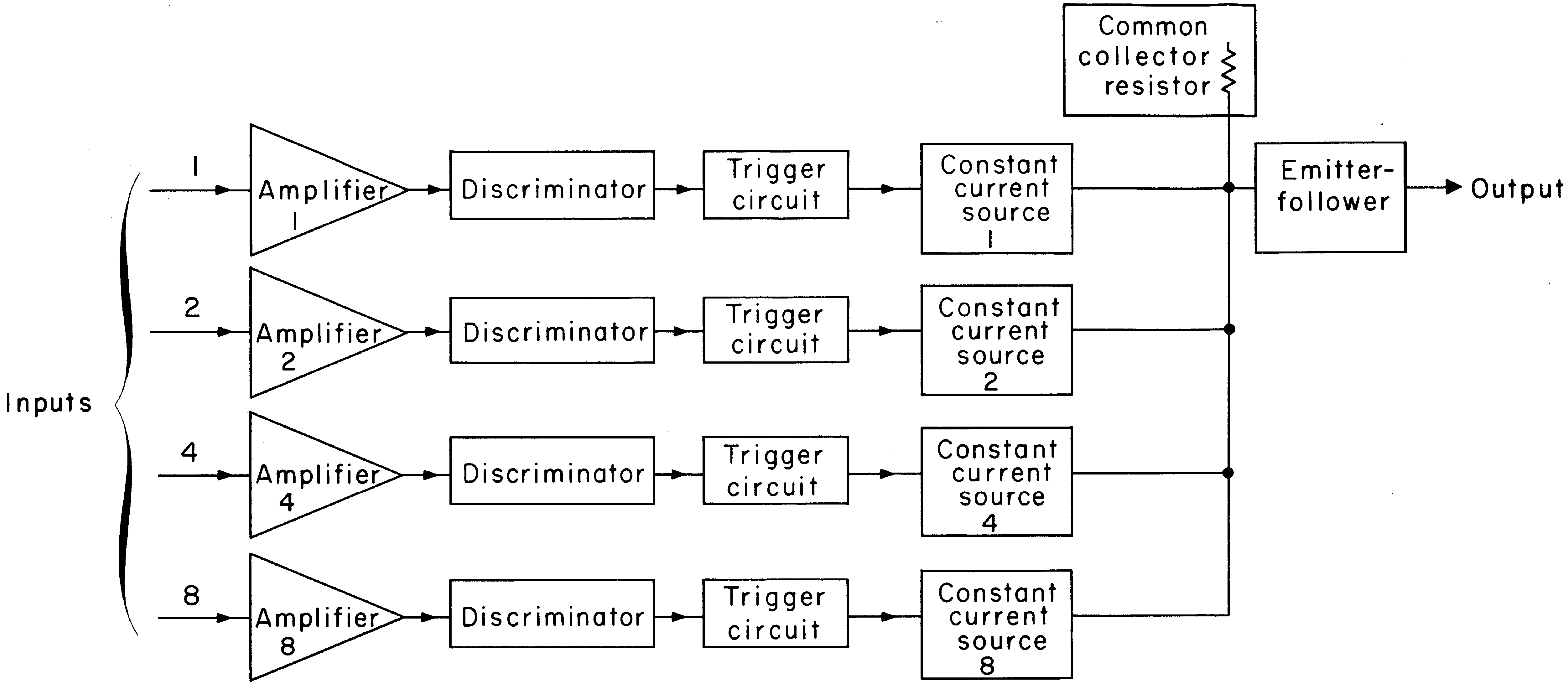

Common collector resistor
1
2
4
8
Inputs
Amplifier 1
Amplifier 2
Amplifier 4
Amplifier 8
Discriminator
Discriminator
Discriminator
Discriminator
Trigger circuit
Trigger circuit
Trigger circuit
Trigger circuit
Constant current source 1
Constant current source 2
Constant current source 4
Constant current source 8
Emitter-follower
Output

Fig. 5

58357-2

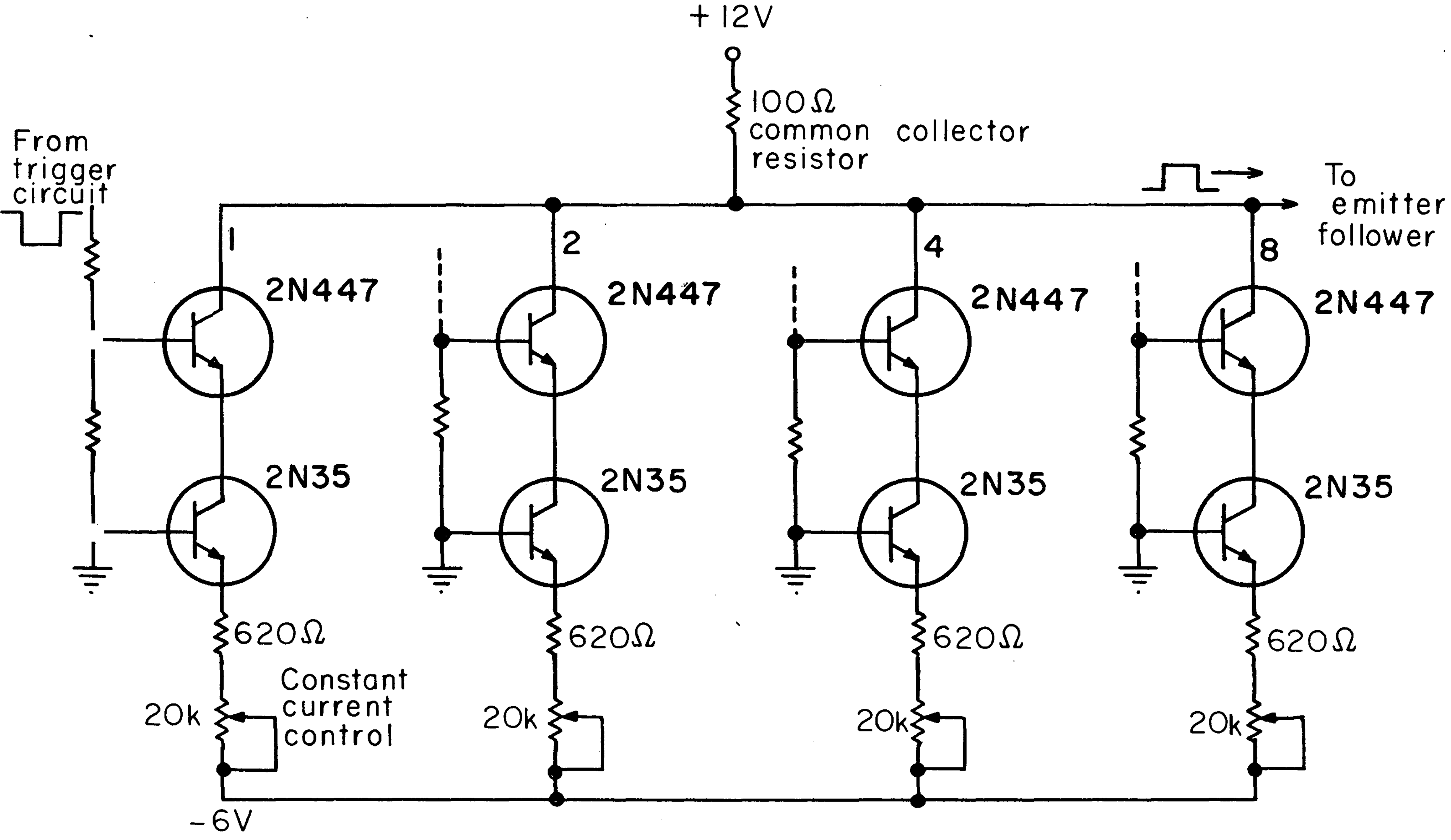
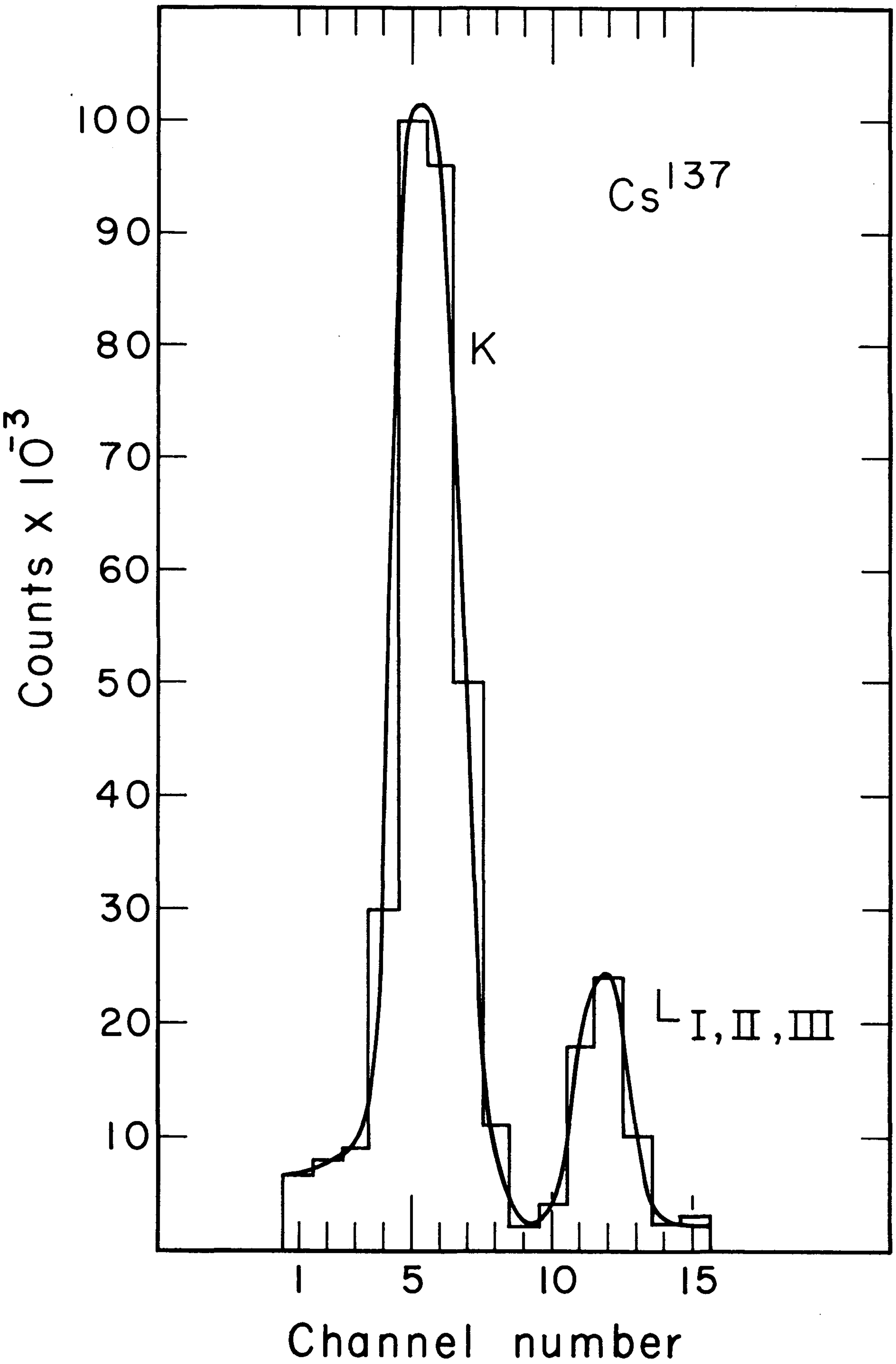

+12V
100Ω
common collector resistor
From trigger circuit
To emitter follower
1
2
4
8
2N447
2N447
2N447
2N447
2N35
2N35
2N35
2N35
620Ω
620Ω
620Ω
620Ω
20k
20k
20k
20k
Constant current control
-6V

FIG. 6
58358-1



Cs^{137}
K
L$_{I, II, III}$
Counts x 10^{-3}
100
90
80
70
60
50
40
30
20
10
1
5
10
15
Channel number

FIG 7

58359-2