Title

THE APPLICATION OF PULSE-SHAPE DISCRIMINATION TO SEPARATING PHOTOTUBE NOISE PULSES FROM SCINTILLATION PULSES

Authors

Landis, D.
Goulding, F.S.

Publication Date

1964-09-01

UCRL-11301

University of California

Ernest O. Lawrence Radiation Laboratory

THE APPLICATION OF PULSE-SHAPE DISCRIMINATION TO SEPARATING PHOTOTUBE NOISE PULSES FROM SCINTILLATION PULSES

Berkeley, California

To be published in Nuclear Instruments
and Methods

UCRL-11301

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

THE APPLICATION OF PULSE-SHAPE DISCRIMINATION TO SEPARATING PHOTOTUBE NOISE PULSES FROM SCINTILLATION PULSES

D. Landis and F. S. Goulding

September 1, 1964

THE APPLICATION OF PULSE-SHAPE DISCRIMINATION TO SEPARATING PHOTOTUBE NOISE PULSES FROM SCINTILLATION PULSES

D. Landis and F. S. Goulding

Lawrence Radiation Laboratory
University of California
Berkeley, California

September 1, 1964

ABSTRACT

A description is given of a pulse-shape discrimination technique to reduce phototube noise counts when measuring low-energy X-rays. This technique uses a conventional fast-slow base-line crossing coincidence system to discriminate between the phototube noise, which consists predominately of fast rising pulses, and the signal from the scintillator which may be much slower.

Experimental results are given for two types of phototubes using NaI (Tl) scintillators. Under ideal conditions the noise count above the equivalent of 2 keV can be reduced to a few a minute.

THE APPLICATION OF PULSE-SHAPE DISCRIMINATION TO SEPARATING PHOTOTUBE NOISE PULSES FROM SCINTILLATION PULSES

D. Landis and F. S. Goulding

Lawrence Radiation Laboratory
University of California
Berkeley, California

September 1, 1964

INTRODUCTION

The use of pulse-shape discrimination for the removal of the majority of phototube noise pulses from scintillation signals is of value when measuring low-energy X-rays.(1) The usefulness of the technique was demonstrated in an experiment where, before using the pulse-shape discrimination system, considerable effort was spent to reduce noise counts to a very low level below 5 keV. In the earlier efforts noise counts were reduced by using light pipes between the scintillator and two cooled phototubes operated in coincidence. The pulse-shape discrimination technique produced better results with much less overall expense.

The pulse-shape discrimination technique uses a base-line cross-over coincidence system to discriminate between the slow-rising scintillation signals and the fast-rising noise pulses produced at the phototube anode due to single electrons emitted by the cathode.(2) The slower rise-time of the scintillation signal, which is double delay-line shaped, causes the cross-over point to be delayed compared with that of the faster rising noise pulses. A pulse developed at the cross-over time is put in coincidence with a pulse that is almost independent of the rise-time of the incoming signal. The delay in the coincidence circuit input is adjusted so that only the delayed cross-over pulses (i.e., those produced by the slow-rising pulses) produce an output from the coincidence circuit. These output pulses are used to open a linear gate that controls the signals from the phototube. The gate output signal consists of scintillation pulses, and noise signals produced in the phototube itself are rejected.

DESCRIPTION OF SYSTEM

A block diagram of the pulse-shape discrimination system is shown in Fig. 1. The circuits inside the dotted box are added to a conventional linear-amplifier and coincidence system (11X1981 P-1)[3] to permit pulse-shape discrimination. The output signal of the phototube preamplifier consists of scintillation pulses and noise pulses. The scintillation pulses have a rise-time with a time constant equal to the scintillators fluorescence decay time (about 250 ns) and the noise pulses have a rise-time equal to the characteristic rise-time of the preamplifier (about 100 ns). These signals are shaped with an 800 ns delay-line circuit in the linear amplifier. The output of the linear amplifier is then split and applied to two further delay-line shapers. Delay-line #2 shapes the amplifier pulses producing 800 ns wide biphase pulses. Biphase shaper #1 amplifies this signal and applies it to the delay amplifier and to base-line cross-over circuit #1. The output of the base-line cross-over circuit is delayed in the variable delay circuit and applied to one input of the fast coincidence circuit. Delay-line shaper #4, a 400 ns delay-line, also reshapes the pulses from the linear amplifier. The resulting double delay-line shaped pulses consist of a positive 400 ns wide pulse followed by a negative 400 ns wide pulse delayed 400 ns. These pulses are amplified by biphase shaper #2 and applied to base-line cross-over circuit #2. The threshold of this cross-over circuit is adjusted so that an output pulse is produced when the input pulse crosses a threshold set a few millivolts negative. The timing of the output pulses from the cross-over circuit is nearly independent of the rise-time of the pulses from the amplifier (this is almost equivalent to triggering a few millivolts above the base-line on the leading edge of the amplifier pulses). Pulses from base-line cross-over circuit #2 are delayed about 300 ns and fed to the other input of the fast coincidence unit. The delay in the variable delay circuit and the resolving time of the coincidence circuit are adjusted to put the two cross-over pulses from scintillation signals in coincidence and those from noise out of coincidence. The coincidence pulses open the linear gate allowing the scintillation pulses to pass through the gate and on to the pulse output-shaper and to a multichannel analyzer.

EXPERIMENTAL RESULTS

Measurements were made using several types of phototubes and X-ray energies. Results are shown in Figs. 2 to 5 for 2.6 and 5.8 keV X-ray energies using the Philips XP1010 and RCA 6199 phototubes. The results using the XP1010 are shown to illustrate the ability of the system to reject phototube noise using a tube exhibiting very low noise and the results on the 6199 illustrate the behavior with a more noisy tube.

Fig. 2 shows four different spectra using a typical XP1010 phototube. These include the noise from the phototube with and without pulse-shape discrimination, with no X-ray source present and with the addition of an Fe^{55} X-ray source (5.8 keV) with and without pulse-shape discrimination. The total noise count above a 1 keV threshold with pulse-shape discrimination is about 10 per minute, and it is about 2 per minute above 2 keV.

Fig. 3 is similar to Fig. 2 except that the X-ray source is A^{37} (2.6 keV). This source consists of about 0.5 mc of A^{37} in a 1 cc container with a 2 mil Be window, operating about an inch from the scintillator.

Figs. 4 and 5 are similar to Figs. 2 and 3, but the phototube is changed to a 6199. The pulse-shape discriminator system reduces the noise from this phototube by a factor of about 50 allowing both the Fe^{55} (Fig. 4) and A^{37} (Fig. 5) peaks to be well separated from the phototube noise. The A^{37} X-ray source (Fig. 5) was operated somewhat closer to the scintillator than in Fig. 3.

CONCLUSION

The pulse-shape discrimination system can reduce noise counts from a phototube and this can be useful when measuring low-energy X-rays with a scintillator exhibiting a long fluorescence decay time such as NaI (Tl). Work on calcium iodide [(4)] shows that it has a higher light output and slower decay than NaI (Tl). The pulse-shape discrimination system described here should give even better results with a scintillator having these properties.

REFERENCES

1. Private communications with L. F. Hansen and J. J. Wesolouski, Lawrence Radiation Laboratory, Livermore, California

2. F. S. Goulding and T. K. Alexander, "An amplitude insensitive system that distinguishes pulses of different shapes", Nuc. Inst. & Methods #13, 240-246 (1961).

3. F. S. Goulding and D. Landis, "Linear Amplifier, Gating and Timing System", Monterey Conference on Instrumentation Techniques in Nuclear Pulse Analysis, National Academy of Sciences - National Research Council Publication 1184.

4. R. Hofstadter, E. W. O'Dell and C. T. Schmidt, "CaI_2 and CaI_2 (Eu) Scintillation Crystals", IEEE Trans. on Nuc. Science Vol. NS-11 June, 1964, No. 3 - Proceedings of the Ninth Scintillation and Semiconductor Counter Symposium, Washington, D. C. Feb. 26-28, 1964.

FIGURE CAPTIONS

Fig. 1 - Block diagram of the Pulse-Shape Discrimination System.

Fig. 2 - Noise and Fe^{55} X-ray spectra with and without pulse-shape discrimination, counting 5 minutes for each spectrum.
Phototube: Philips XP1010 #10973, H.V. 1 kV.
Scintillator: NaI (Tl) Harshaw - 4HDIM.

Fig. 3 - Noise and A^{37} X-ray spectra with and without pulse-shape discrimination, counting 5 minutes for each spectrum.
Phototube: Philips XP1010 #10973, H.V. 1 kV.
Scintillator: NaI (Tl) Harshaw - 4HDIM.

Fig. 4 - Noise and Fe^{55} X-ray spectra with and without pulse-shape discrimination, counting 5 minutes for each spectrum.
Phototube: RCA 6199 #B.I. 55, H.V. 850 V.
Scintillator: NaI (Tl) Harshaw - 4HDIM.

Fig. 5 - Noise and A^{37} X-ray spectra with and without pulse-shape discrimination, counting for 5 minutes for each spectrum.
Phototube: RCA 6199 #B.I.55, H.V. 850 V.
Scintillator: NaI (Tl) Harshaw - 4HDIM.

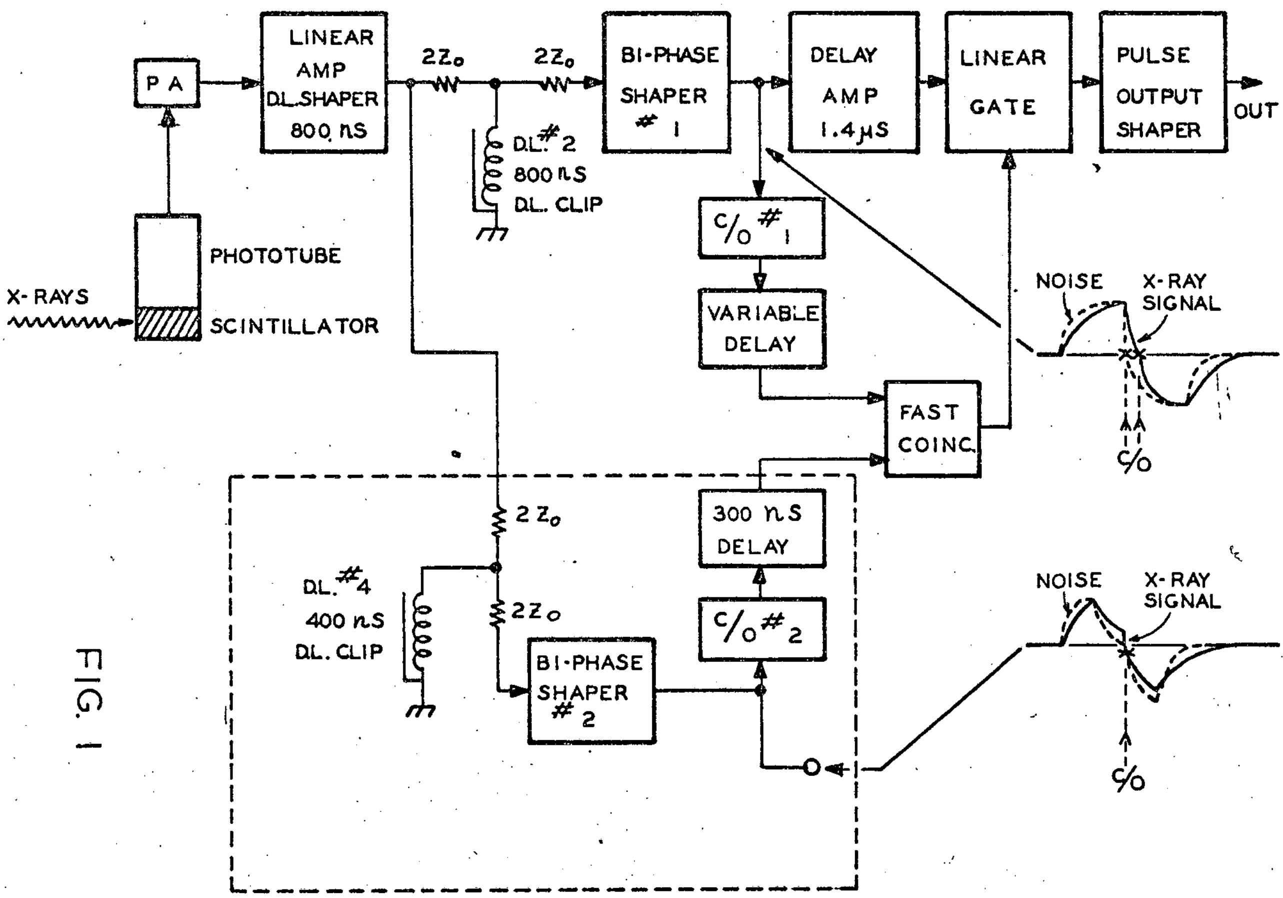

PA
LINEAR AMP DL SHAPER 800 nS
2Z₀
2Z₀
BI-PHASE SHAPER # 1
DELAY AMP 1.4 μS
LINEAR GATE
PULSE OUTPUT SHAPER
OUT
DL. # 2 800 nS DL. CLIP
C/O # 1
VARIABLE DELAY
FAST COINC.
PHOTOTUBE
X-RAYS
SCINTILLATOR
NOISE
X-RAY SIGNAL
C/O
2 Z₀
2 Z₀
DL. # 4 400 nS DL. CLIP
BI-PHASE SHAPER # 2
300 nS DELAY
C/O # 2
NOISE
X-RAY SIGNAL
C/O
FIG. 1
MUB-4070

Fig. 1

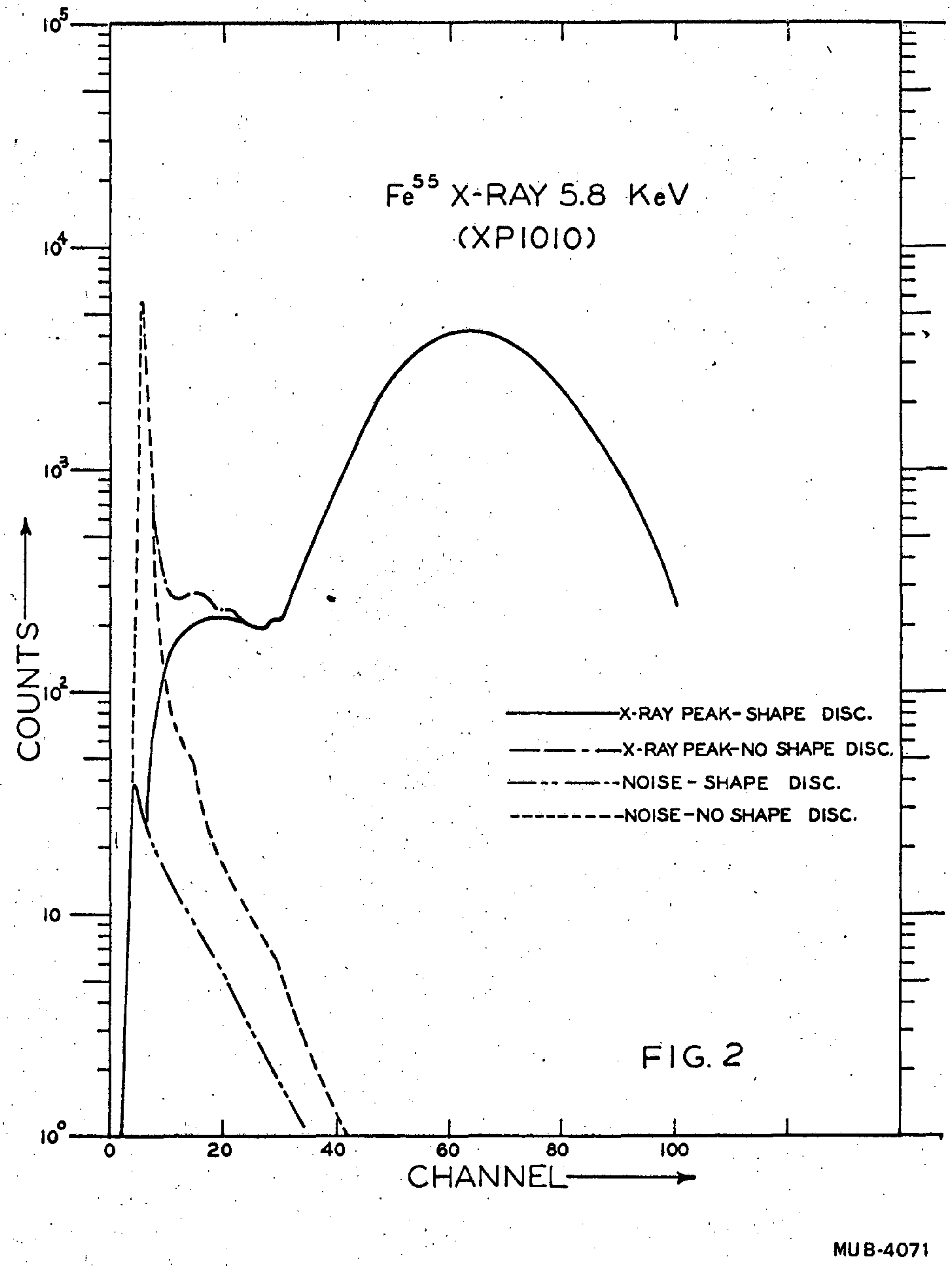
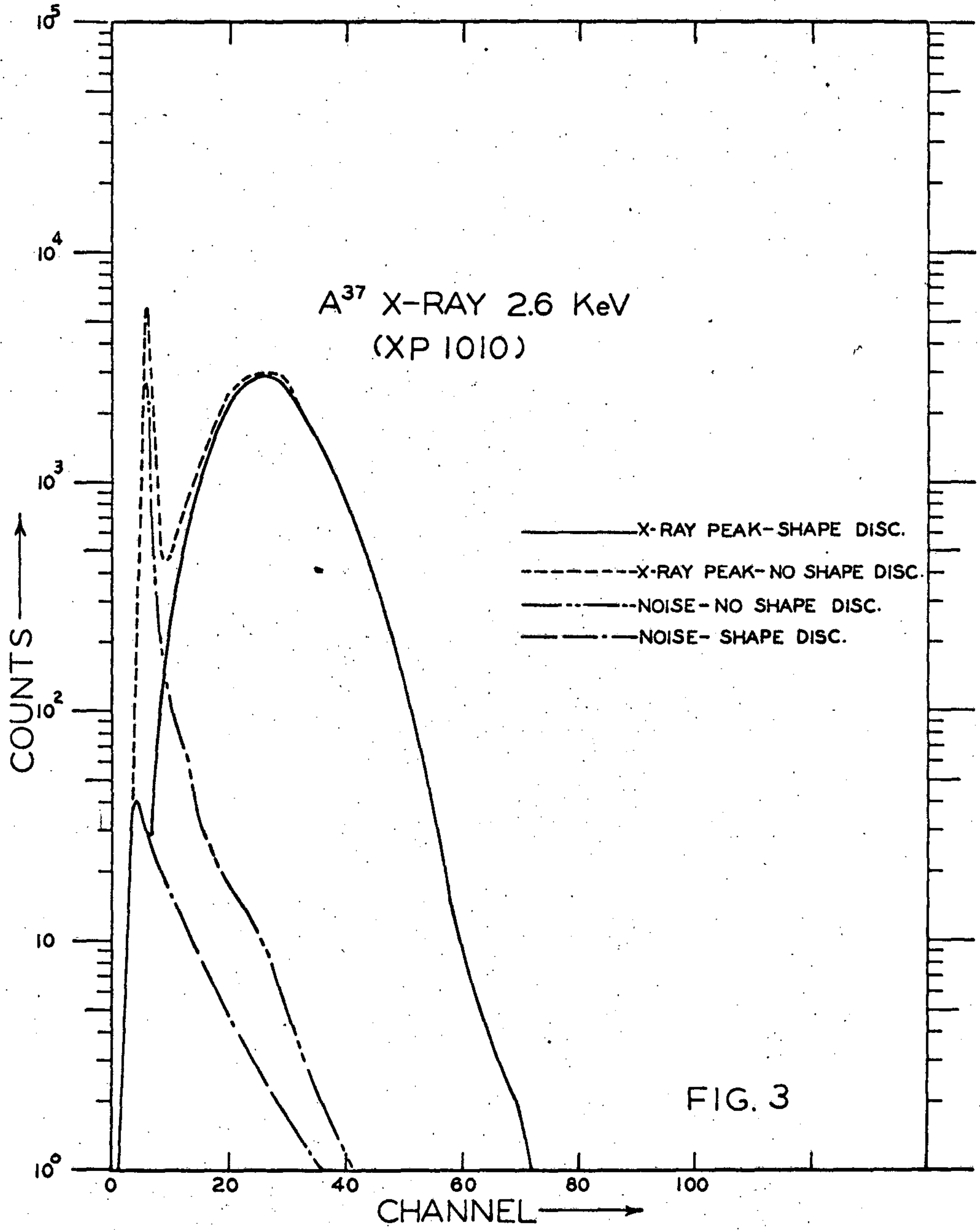

Fe55 X-RAY 5.8 KeV
(XP1010)
COUNTS
CHANNEL
X-RAY PEAK-SHAPE DISC.
X-RAY PEAK-NO SHAPE DISC.
NOISE - SHAPE DISC.
NOISE-NO SHAPE DISC.
FIG. 2
0
20
40
60
80
100
10
MUB-4071

Fig. 2



MUB-4072

Fig. 3

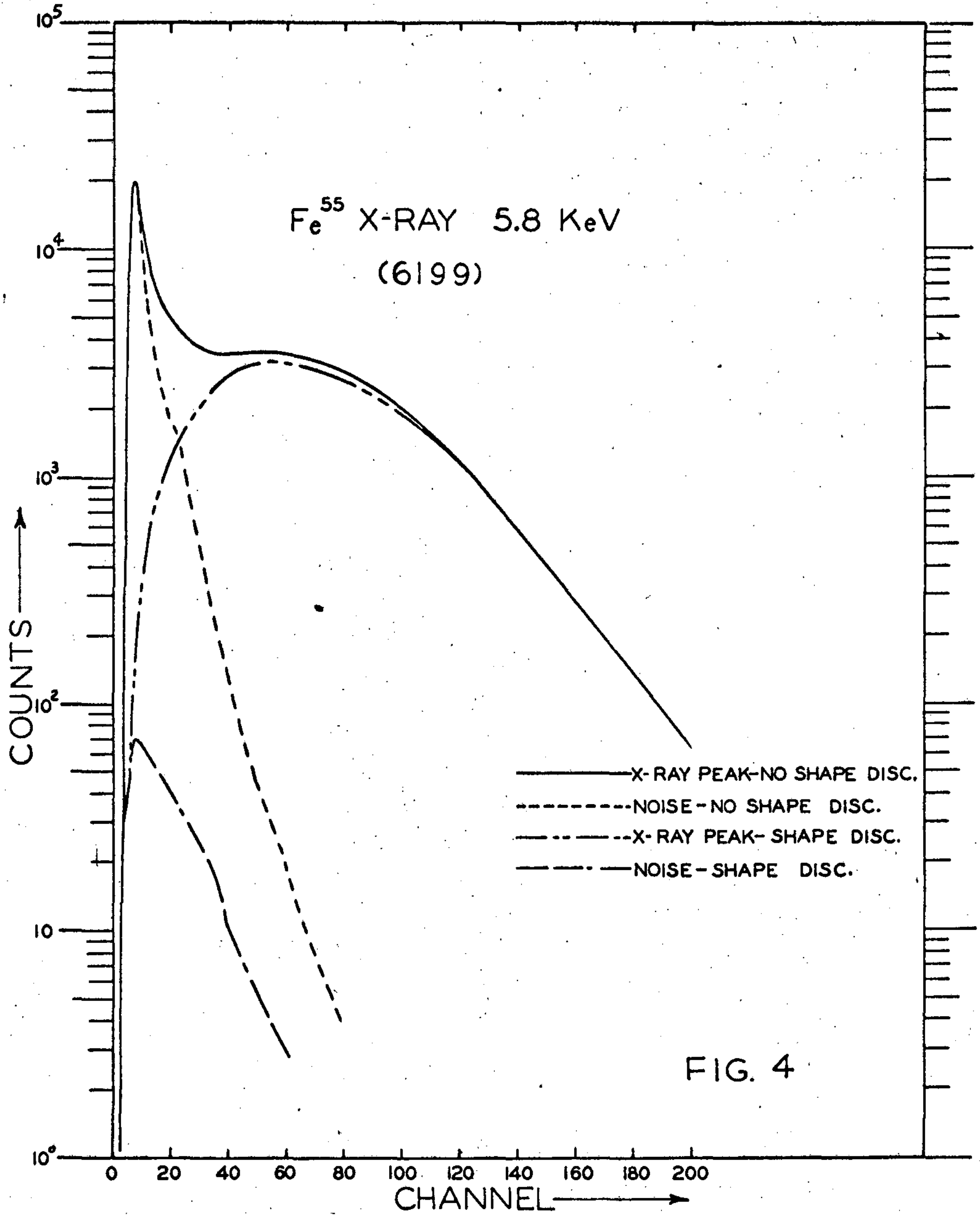
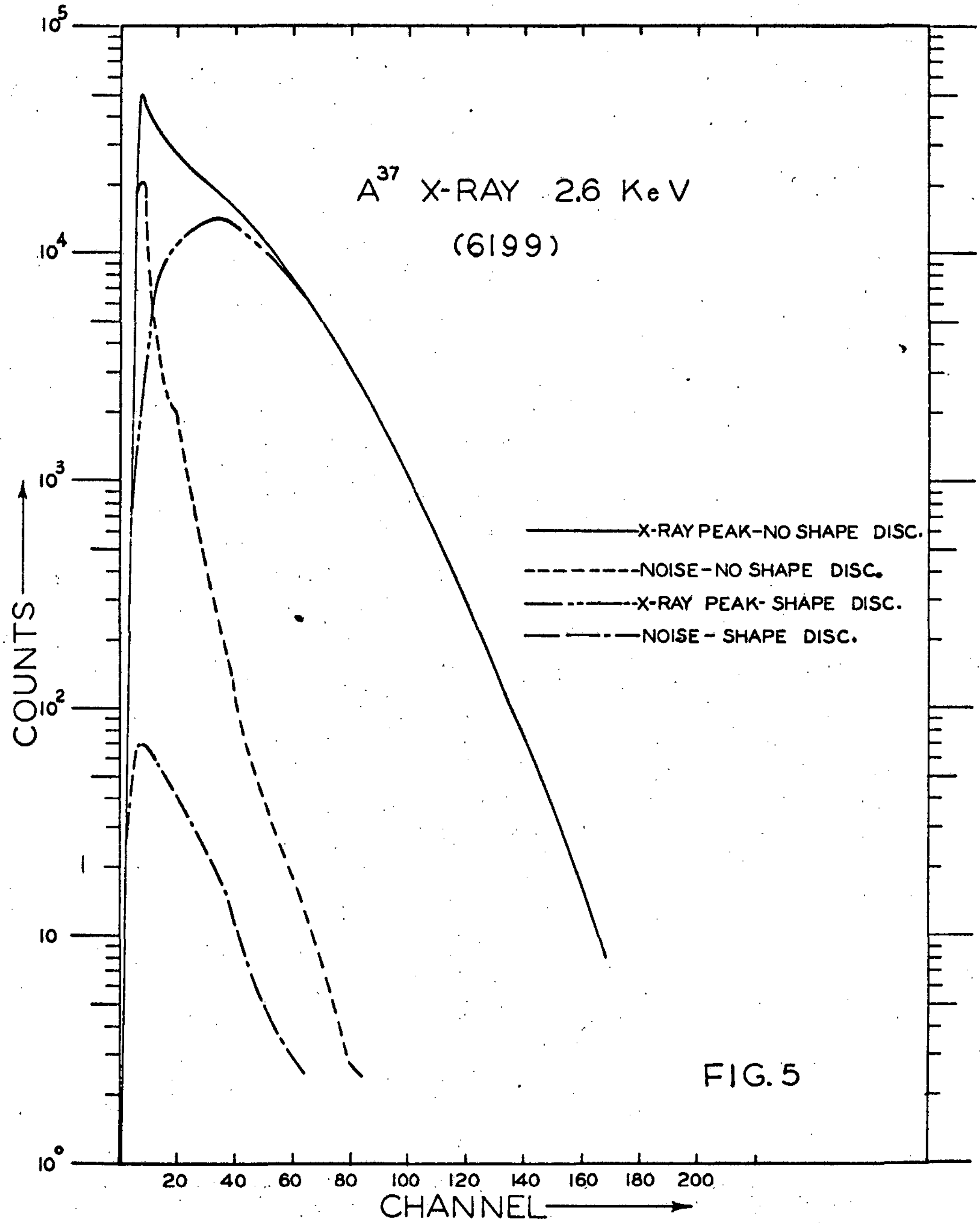


FIG. 4

MUB-4073

Fig. 4



MUB-4074

Fig. 5