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A SPARK CHAMBER FISSION FRAGMENT DETECTOR

by

E. MIGNECO, J.P. THEOBALD and M. MERLA

1968

Joint Nuclear Research Center
Geel Establishment - Belgium

Central Bureau for Nuclear Measurements - CBNM

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SUMMARY

A study of the properties of a wire-to-plane spark chamber as fission fragment detector discriminating against less ionizing radiation is reported.

KEYWORDS

SPARK CHAMBERS
FISSION PRODUCTS
WIRES
PLATES
DETECTION
EFFICIENCY

A SPARK CHAMBER FISSION FRAGMENT DETECTOR

Introduction (*)

The properties of a wire-to-plate spark chamber as charged heavy particle detector have been studied already by several authors (1-9). C.D.Bowman (7) has demonstrated that the ratio of the efficiencies for fission fragment and α-particle detection can reach about 10^{12}, when the inter-electrode voltage and other detector parameters are properly adjusted. It is this discrimination quality which makes the spark chamber particularly useful for fission cross section measurements on isotopes with half-lives of less than 1000 years. For the envisaged application of the spark chamber in such experiments at an electron linear accelerator the detector should have a large sensitive area (in the order of 500 cm^2) and a small quantity of scattering material in the beam. Moreover, a high mechanical precision (1/100 mm) is necessary for counting and discrimination homogeneity and stability against spurious voltage breakdowns.
C.D.Bowman (7), (10), verified that the geometry wire-to-cavity admits an efficiency of about 30% in test chambers, while in large area detector only 5% could be reached due to the difficulties in the mechanical construction.
This facts have determined our choice of the plane-to-wire geometry for the construction of the detector.
In order to investigate the behaviour of such a wire-to-plane spark counter a test chamber has been constructed.
In what follows the results concerning the influence of the type of the filling gas (air, argon, nitrogen), of the gas pressure and the inter-electrode distance are reported.
The goal was to reach an optimum detection efficiency for fission fragments at a prefixed α-discrimination value and a longtime stability of the counter. The time delay of the spark and its time jitter were measured for optimalized working conditions of the test chamber.

(*) **Manuscript received on July 2, 1968.**

The test spark chamber

The test detector consists of a plane cathode of polished stainless steel of 10 cm x 10 cm and an anode of 22 tungsten wires with 0.15 mm diameter stressed and clamped on a rigid frame (fig. 1). The wire-to-wire distance is 4 mm, the inter-electrode gap can be varied between 0 and 4 mm. The precision of the electrode distance is $\pm$ 1/100 mm. For the test a fission fragment source of ^{252}Cf with an activity of 32 fragments per second and a ^{241}Am α-source with $1.2 \cdot 10^6$ α-particles/sec have been used. The source distance is 2 cm above the wire plane. The energy loss of the fragments in the gas is in the order of magnitude of the energy loss in the fissile layers used as samples for cross section measurements (for example 1-2 mg/cm^2 uranyl-acetate). The test detector is placed in a glass bell which is connected with a gas flow system. The pulses are taken from the wire electrode via an appropriate voltage devider. The plate electrode is connected with a negative high voltage supply.

Experimental results

For the following text we define the threshold voltage V_{th} as the voltage for which the counter records one count in 10 min with the uncollimated ^{241}Am source. The efficiency for fission fragments at V_{th} is called ϵ_{th}. The first filling gas used in the test chamber is air under atmospheric pressure. In figure 2 the characteristic curve of the counting rates as a function of the inter-electrode voltage is shown. The value of ϵ_{th} is about 8% and in agreement with the results of V.F.Gerasimov (11). The efficiency ϵ_{th} does not show a sensible variation, when the electrode gap varies between 1 and 2 mm. Smaller distances cause voltage breakdown while for larger gaps the efficiency decreases.

The influence of the humidity has been studied.
The counting rate in the plateau of the curve in figure 2 for α-particles increases with the vapour content of the air, while ϵ_{th} remains constant or decreases slightly.
It is important to note that in air the electrodes and the gas are quickly deteriorated probably by the formation of ozone and nitrogen oxides. This leads to instability of the counter, which makes air not suitable as filling gas for longtime measurements (12).

Argon does not have such an inconvenience. But the curve of the counting rate versus voltage rises very sharply and does not reach any plateau (see figure 3 as example). The counter works properly only in a small voltage range. The efficiency ϵ_{th} in the experimental conditions of figure 3 is about 12%. The influence of alcool vapour in the argon filling is similar to that of the water vapour in the air.
The gas, which is free from the difficulties found for air and argon is nitrogen.
For this gas the influence of the pressure on ϵ_{th} has been measured and is shown in figure 4. The most suitable working pressure lies between 200 and 300 Torr.
For 300 Torr the characteristic curve is shown in figure 5. There the efficiency ϵ_{th} is 17%. Variations of the inter-electrode distance between 1.5 and 2.5 mm and of the wire diameter between 0.10 and 0.20 mm do not influence sensibly the value of ϵ_{th}. Small air impurities tend to reduce the counting efficiency (figure 6).
The electrodes do not show significant deterioration after some millions of sparks and we can conclude that for a final detector nitrogen is a suitable filling gas. What concerns the other parameters a wire diameter of 0.15 mm and a wire-plane-distance of 2 mm are most suited.

The above results concerning the efficiency, discrimination and stability of the counter are valid for the radiation strength of our sources. For much stronger ones the final results can be different.

Measurement of the time delay jitter

The pulse delivered by a spark chamber has a rise time of a few nanoseconds (13) (7). However, for the application of the counter in high resolution time-of-flight measurements it is necessary that there are no strong fluctuations in the time delay between the passage of the ionizing particle and the appearance of a spark.
A measurement done by Marinescu et al. (14) with a wire-to-cavity chamber gives for the standard deviation of the time resolution function a value of 150 ns and the authors conclude that the counter is not suited for fast timing work in spite of the excellent rise time.
We have studied this matter and the results have not confirmed the conclusion of the paper of Marinescu et al.
The measurement determines the distribution of the time intervals between the detection of the prompt fission γ's by means of a NaI crystal mounted on a 58 AVP photomultiplier and the spark triggered by the passage of a fission fragment. In fig. 7 the geometry of the experiment and its associated electronics are shown.

With a filling of dry air at 250 Torr, an inter-electrode distance of 2 mm and a wire diameter of 0.15 mm, the standard deviation σ of the distribution curve is 13 ns. The contributions of the scintillation detector and of the electronics are about 3 ns. The standard deviation of the spark counter under consideration and under these operating conditions therefore is about 13 ns.

When the pressure is increased up to 400 Torr σ becomes higher than 70 ns and at 700 Torr σ > 100 ns.
Our results agree, then, with those of Marinescu (14) as his value of σ = 150 ns was taken at atmospheric pressure, but this value cannot be considered as the lower limit of the time jitter.

The measurements were repeated with nitrogen as filling gas at different pressures and voltages and with an inter-electrode gap of 2 mm and a wire diameter of 0.15 mm. The results are summarized in the following table: (see fig. 8)

P(Torr)	150		250	
Voltage(V)	1900	2000	2350	2450
σ(ns)	15	14	13	12

Also the influence of the distance source-wires D has been checked. At a pressure P = 250 Torr for D = 8 mm, σ was equal to 12 ns, for D = 30 mm, σ = 15.5 ns.

Large area multiple spark chamber design

On the basis of the results obtained with the test chamber a multiple spark counter was constructed consisting of 6 chambers each with a sensitive area of 20 cm x 20 cm.
The inter-electrode gap is 2 mm, the wire-to-wire distance 3 mm and the wire diameter 0.15 mm. The plane cathodes are spanned 50 μ thick nickel plated aluminium foils. The electrodes are isolated with glass spacers. In this construction a clamped sandwich of 6 chambers has a thickness of 2.6 cm. The assembly is placed in a vacuum tight aluminium

box connected with a gas flowing system controlling the stability of the pressure.
A mapping of the efficiency reproduces for this detector the results obtained with the test chamber.
The detector has worked satisfactorily in a time-of-flight spectrometer for the measurement of the ^{233}U fission cross section.

Acknowledgement

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Figure Captions

Fig. 1: Test spark chamber.

Fig. 2: Counting rates and corona current versus inter- electrode voltage filling gas: 760 Torr air + 9 Torr water vapour
wire diameter 0.15 mm.
interelectrode distance 1.8 mm.

Fig. 3: Counting rates versus interelectrode voltage, filling gas: 500 Torr argon + 10 Torr ethyl-alcool vapour
wire diameter 0.15 mm
interelectrode distance 2 mm.

Fig. 4: ϵ_{th} as a function of nitrogen pressure,
wire diameter 0.15 mm
interelectrode distance 2 mm.

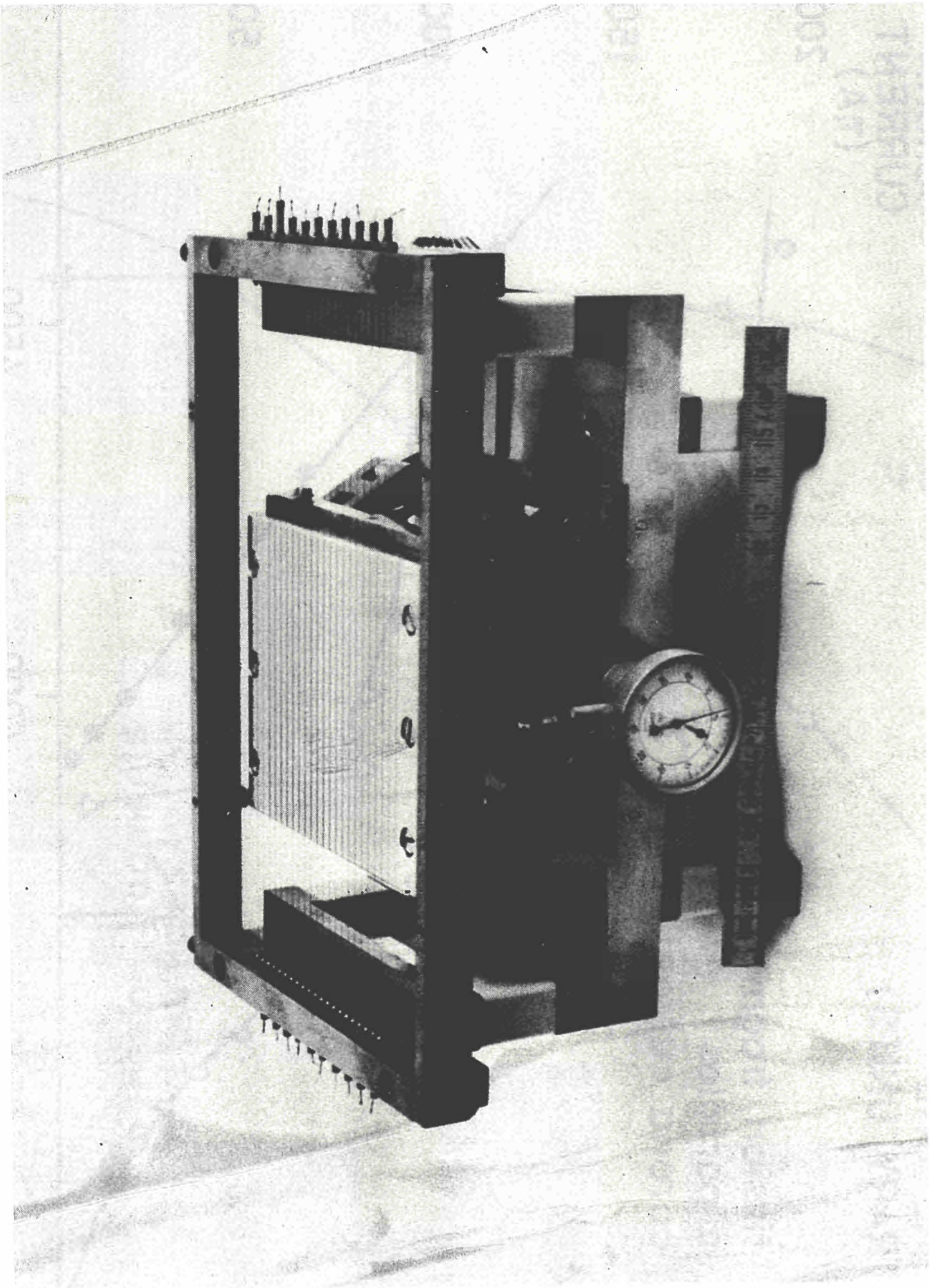
Fig. 5: Counting rates and corona current versus inter- electrode voltage, filling gas 300 Torr nitrogen
wire diameter 0.15 mm
interelectrode distance 2 mm.

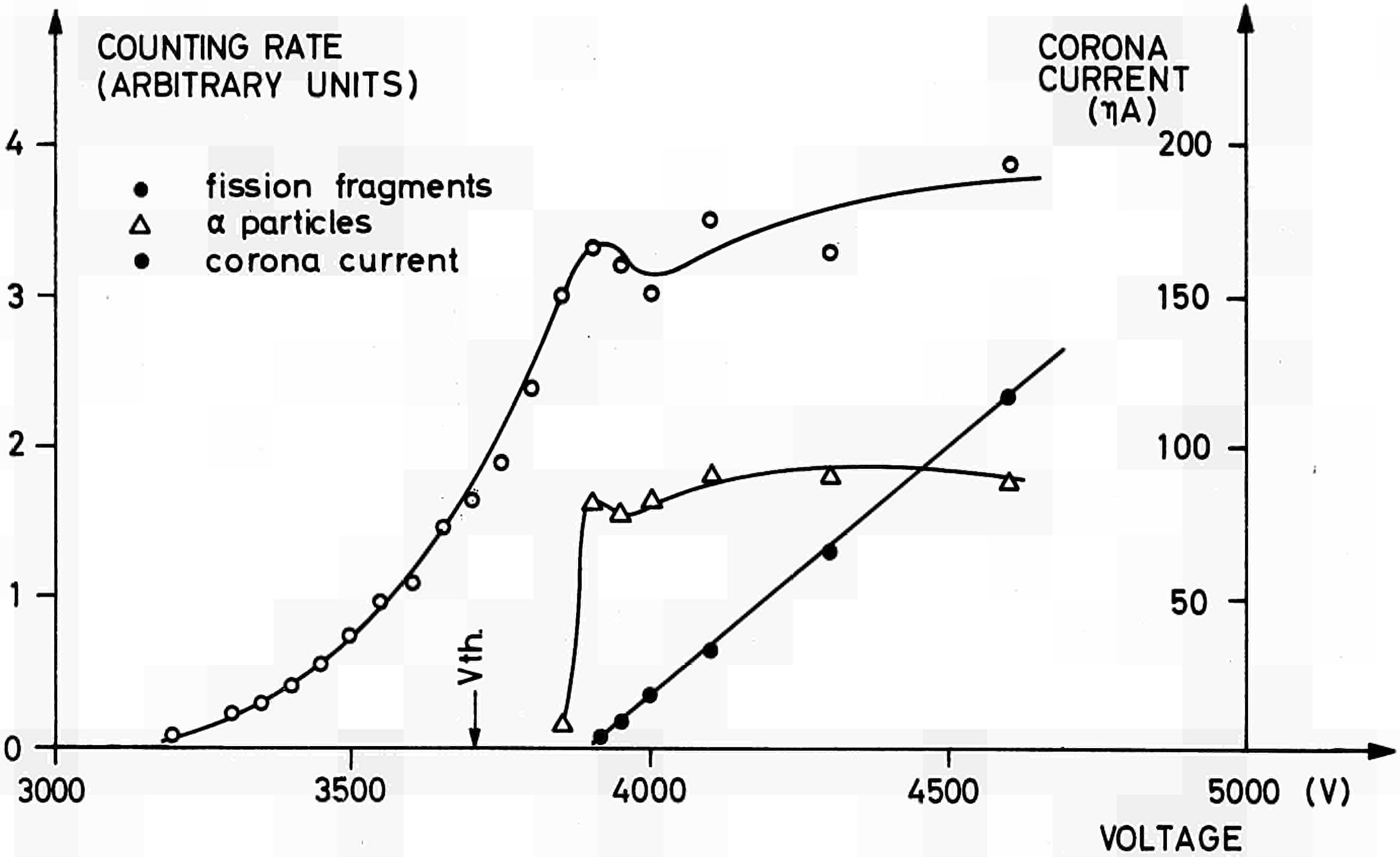
Fig. 6: Fragment counting rate versus interelectrode voltage,
Δ pur nitrogen 300 Torr
□ 300 Torr nitrogen + 0.25 Torr air.

Fig. 7: Experimental set-up of the time delay jitter measurement.

Fig. 8: Time resolution function of the spark chamber
filling gas: 250 Torr nitrogen
wire diameter: 0.15 mm
interelectrode distance: 2 mm
fragment source distance: 8 mm.

II




COUNTING RATE
(ARBITRARY UNITS)
CORONA
CURRENT
(ηA)
fission fragments
α particles
corona current
Vth.
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1
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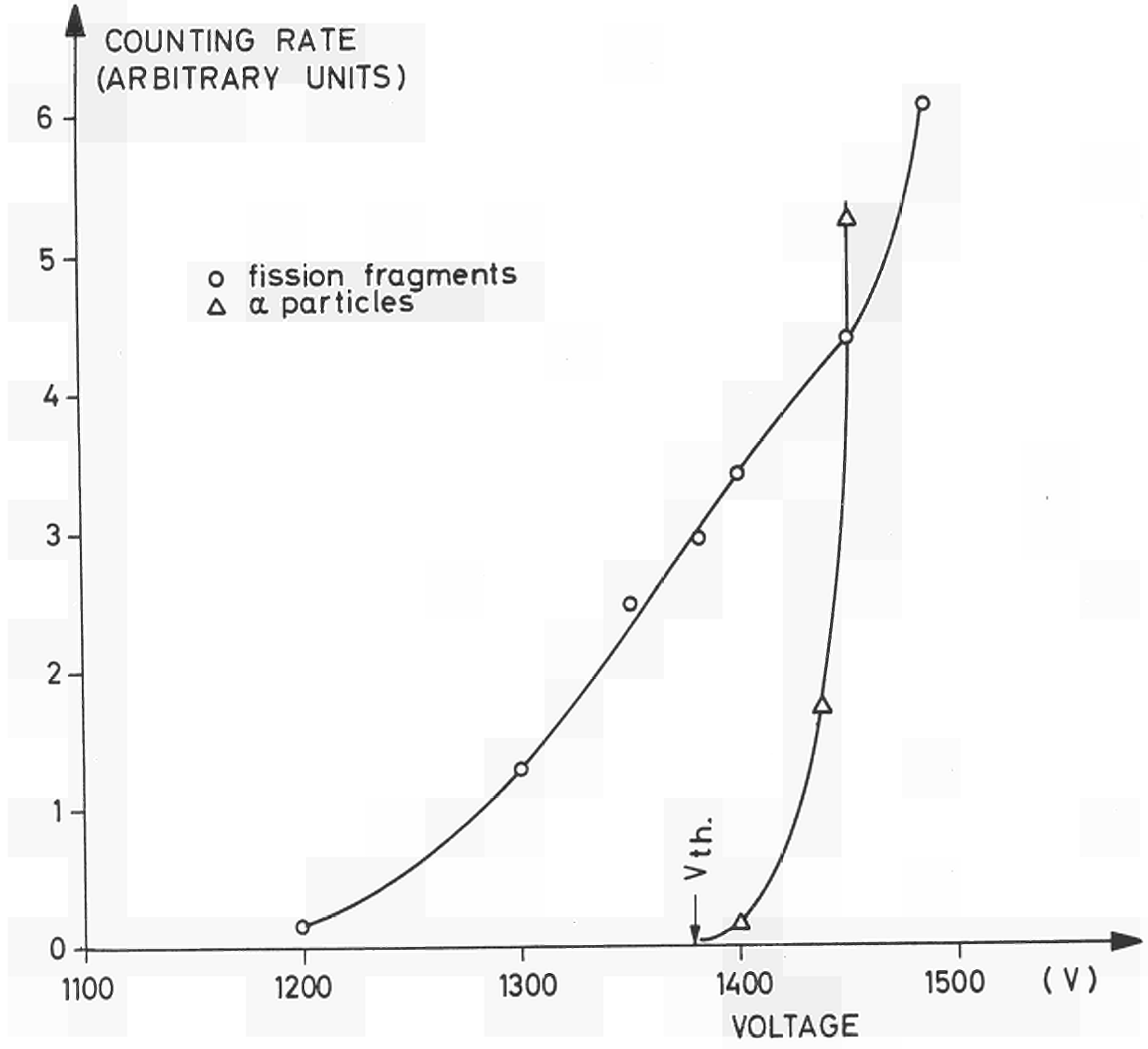
3
4
50
100
150
200
3000
3500
4000
4500
5000 (V)
VOLTAGE



COUNTING RATE
(ARBITRARY UNITS)
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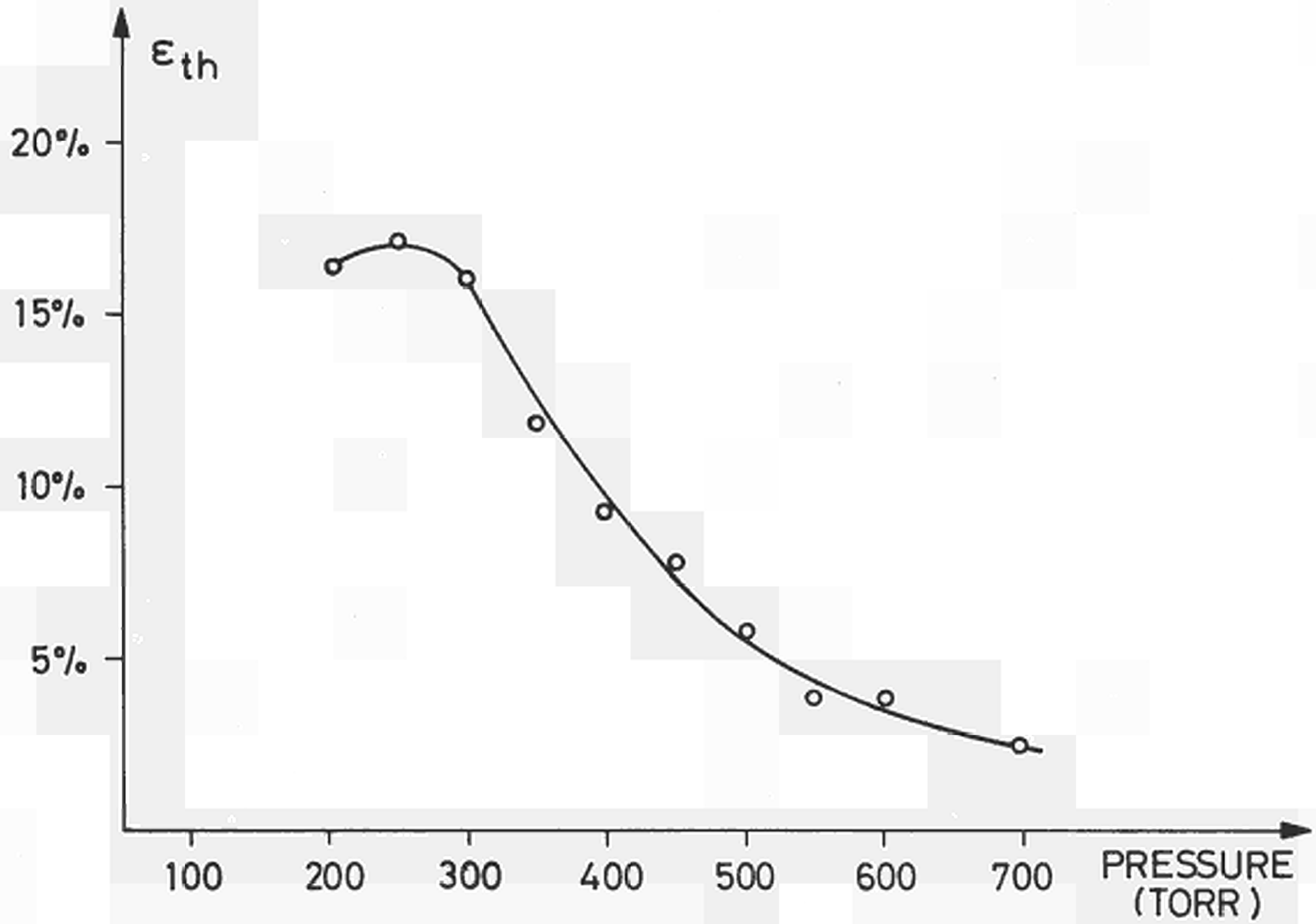
Δ α particles
Vth.
1100
1200
1300
1400
1500
(V)
VOLTAGE



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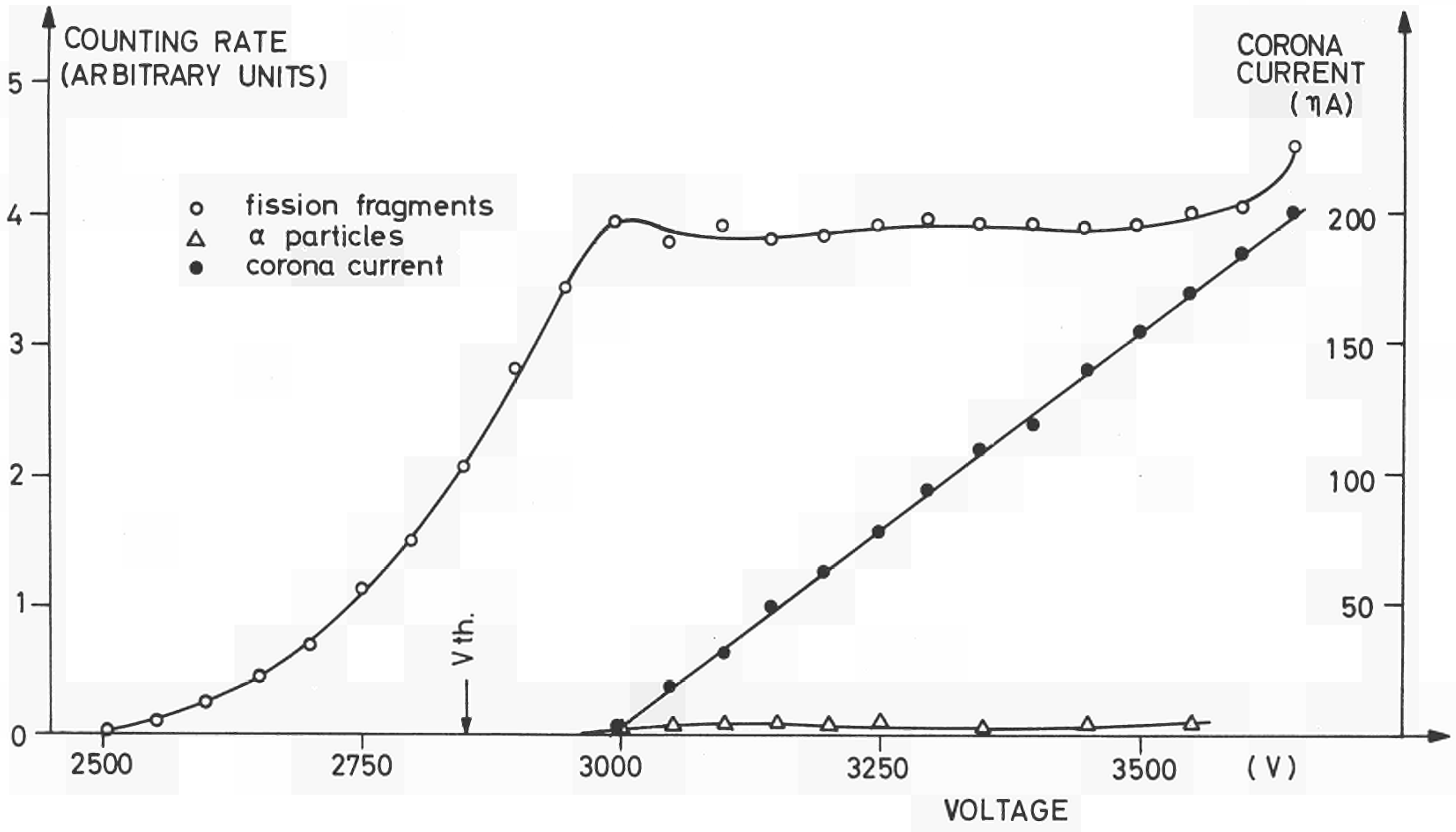
PRESSURE
(TORR)



COUNTING RATE
(ARBITRARY UNITS)
CORONA
CURRENT
(ηA)
fission fragments
α particles
corona current
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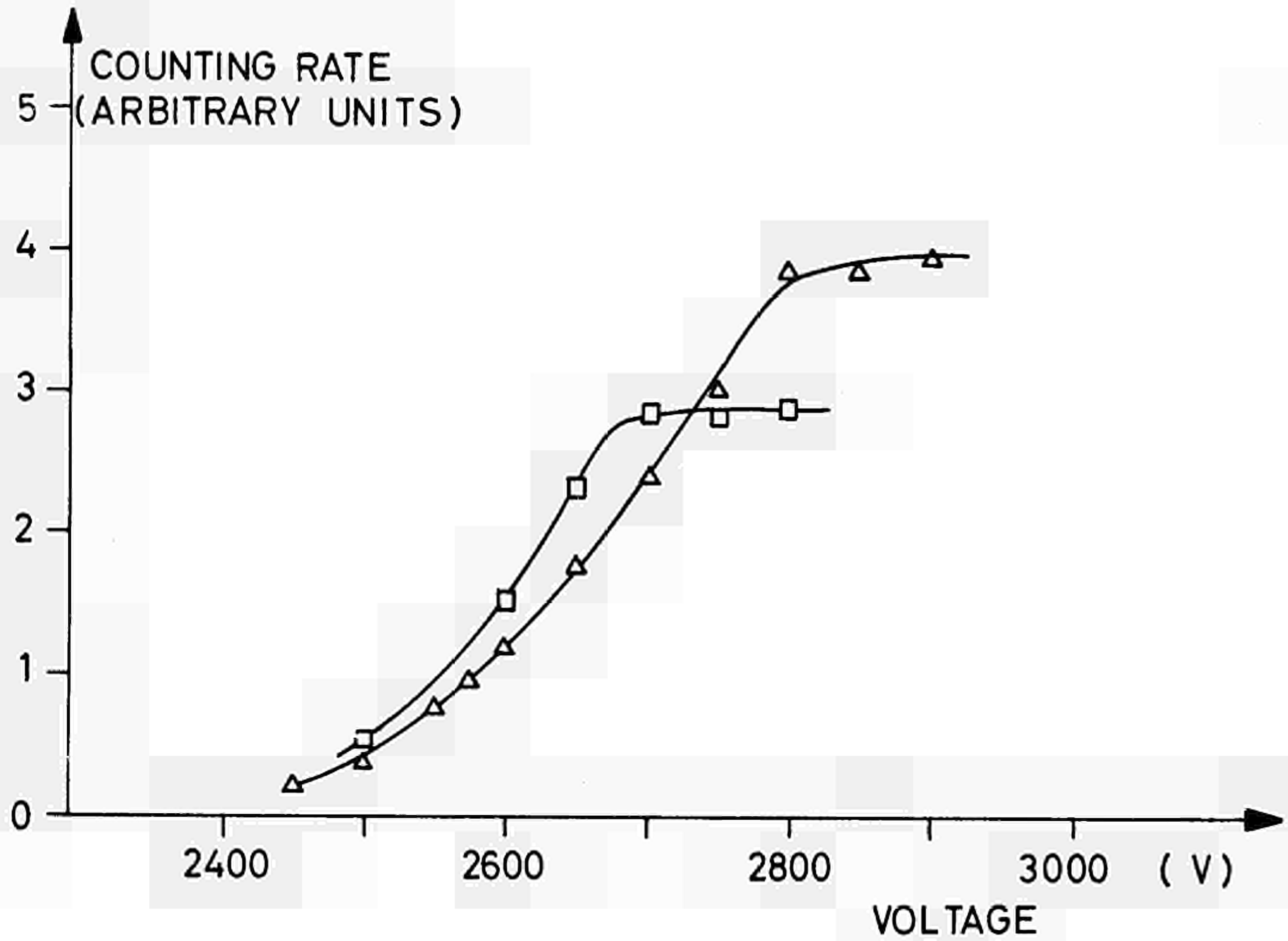
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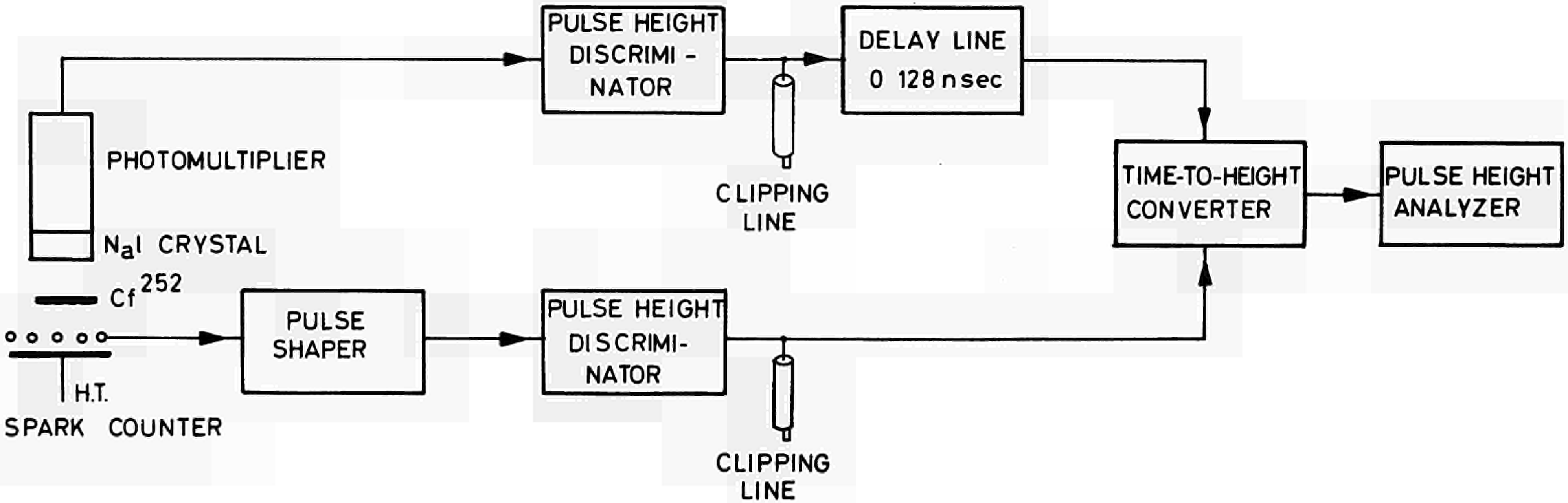
PULSE HEIGHT DISCRIMI - NATOR
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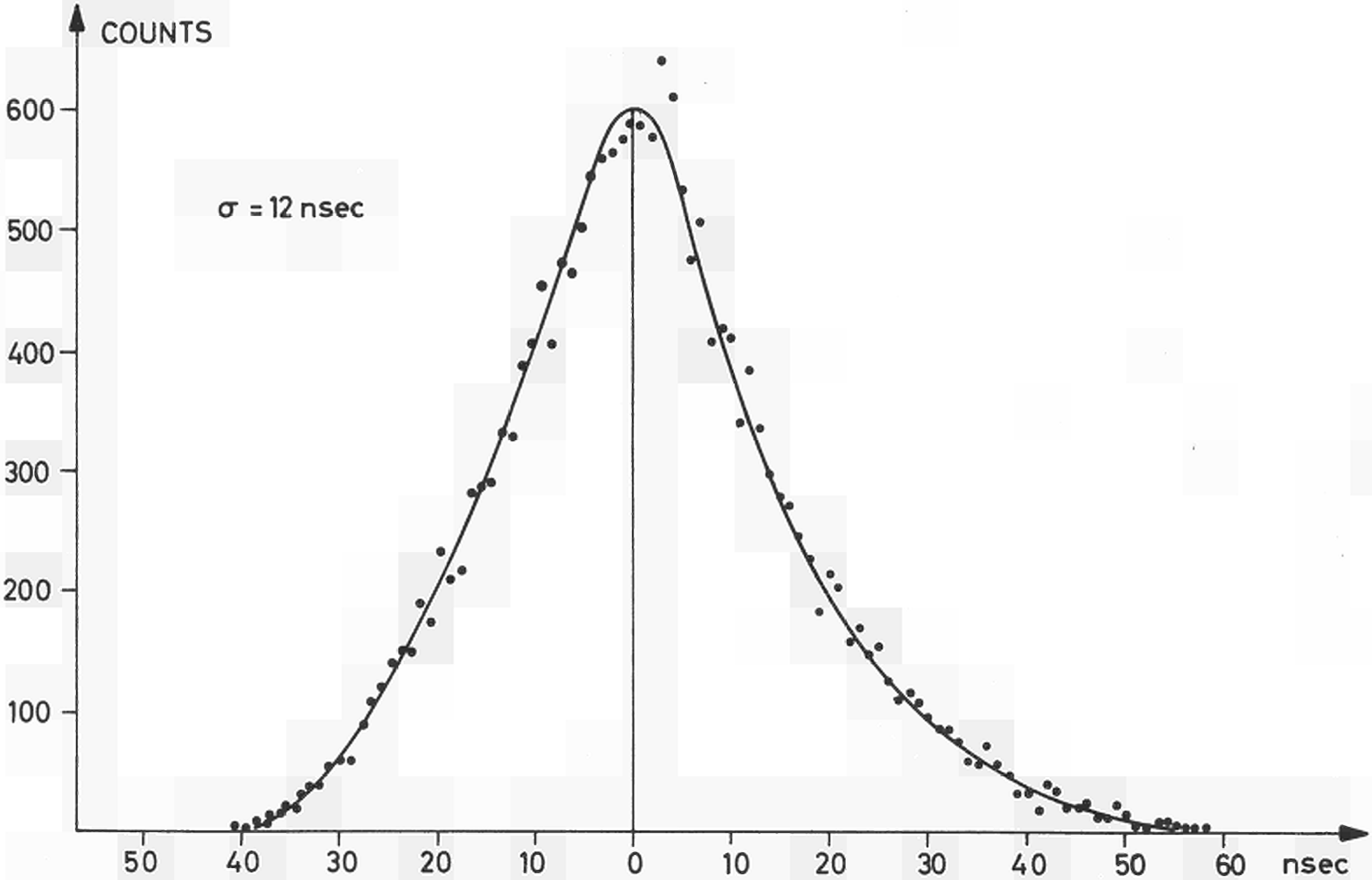
PHOTOMULTIPLIER
CLIPPING LINE
TIME-TO-HEIGHT CONVERTER
PULSE HEIGHT ANALYZER
NaI CRYSTAL
Cf 252
PULSE SHAPER
PULSE HEIGHT DISCRIMI- NATOR
H.T.
SPARK COUNTER
CLIPPING LINE


COUNTS
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500
400
300
200
100
σ = 12 nsec
50
40
30
20
10
0
10
20
30
40
50
60
nsec

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