

Recording the Characteristics of a Geiger-Müller (end-window) Counter Tube

Objects of the experiment

- Recording the frequency of discharge pulses of a Geiger-Müller counter tube as a function of the counter tube potential for a constant radiation source.
- Determination of the Geiger threshold and the operating range.

Principles

Until today the Geiger-Müller counter tube, developed in 1928 by *H. W. Geiger* and his partner *W. Müller* is an indispensable means for detecting radioactivity. It even registers radiation with minute ionizing power. It consists of a tube with a thin wire isolated and suspended in its axis and filled with inert gas at a pressure of about 100 mbar. The radiation enters from the front side via a thin mica layer. Between the wall as cathode and the wire as anode a potential of several hundred volts works via a high-ohmic resistor. The voltage is selected to avoid self-discharge.

Incident radioactivity ionizes gas atoms in the counter tube. The liberated electrons move at high velocity towards the wire, the positive ions drift at relatively low velocity towards the wall. In the vicinity of the wire the electrons are strongly accelerated and through collisions produce new charge carriers or excite gas atoms to emit photons, which in turn can form additional charge carriers through photo-ionization. The charge carriers produce a current impulse, which ends when all ions have reached the cathode. At the outer resistor a short voltage drop occurs, which is applied to a counter via a coupling condenser.

If the counter tube potential is low, the charge avalanches are limited locally. As the counter tube potential rises they start to spread until they finally are distributed over the entire counter tube. All ionized particles, no matter what kind and of what energy, cause an identical voltage impulse. The counting rate for a constant radioactive source becomes independent of the counter tube potential. A counter tube working in this range is called the Geiger-Müller counter tube. If the counter tube voltage is raised, a self-actuated gas discharge occurs, which easily can destroy the entire counter tube.

A quenching process must prevent secondary electrons from being dissolved from the surface of the cathode, which could restart the discharging process. In self-quenching counter tubes a quenching gas (e.g. halogen) is mixed with the inert gas. It largely absorbs photons on their way to the cathode and thus prevents electrons from being triggered photonically. Furthermore the inert gas ions transmit their charge through collisions to molecules of the extinguishing gas ions. Thus only ions of the extinguishing gas reach the cathode. Due to their low ionizing power these are not able to activate secondary electrons there. The discharge process is extinguished.

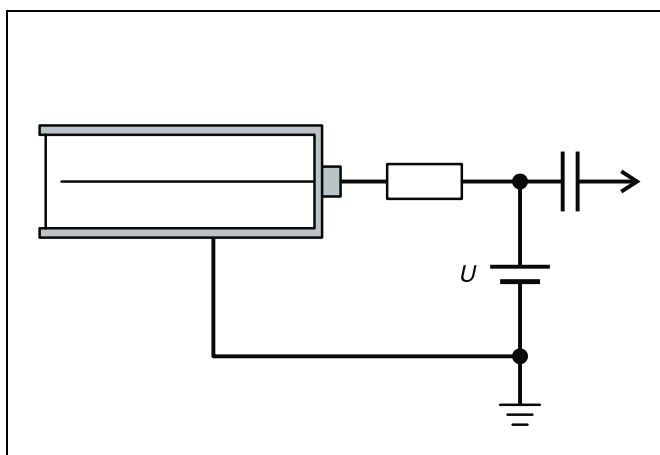


Fig. 1 Assembly diagram of a Geiger-Müller counter tube

Apparatus

1 End-window counter for α -, β -, γ - and X-rays	559 01
1 Ra-226 preparation	559 430
1 Digital counter	575 48
1 Insulated stand rod, 25 cm	590 13
1 Large clip plug	591 21
1 Connection rod	532 16
2 Saddle bases	300 11

Setup

Note:

The window of the end-window counter (12–15 μm mica) easily can be damaged mechanically. If the window is damaged the end-window counter tube is rendered unusable:

Do not touch the mica window; store end-window counter only with protective cover in place. Remove protective cover for making measurements only. Carefully remove and replace protective cover without twisting and without covering the air hole.

If the operating voltage is too high, the end-window counter will be damaged by self-activated gas discharge:

Do not permanently exceed the maximum operating voltage of 600 V.

The set-up for the experiment is shown in Fig. 2.

- Mount large clip plug on connection rod.
- Fasten the end-window counter with the brackets, connect to inlet A of the digital counter and carefully remove protective cover.
- Fasten Ra-226 preparation with 4-mm plug at suitable height on the insulated stand rod. Carefully guide preparation to a distance of about 1 mm from the end-window counter.

Safety notes

When radioactive preparations are handled, country specific regulations must be observed, in Germany e.g. the Radiation Protection Regulation (StrlSchV). The radioactive substances used in the experiment are permitted according to "StrlSchV" for school instruction. The following safety regulations must be observed however, since ionizing radiation is produced:

- Protect preparation from unauthorized use.
- Check preparation for damage prior to use.
- Store preparation in safety container for *shielding*.
- To guarantee *minimum time of exposure* and *minimum activity* remove preparation from the safety container for performing the experiment only.
- To ensure *maximum distance*, hold preparation at the upper lip of the metal container only.

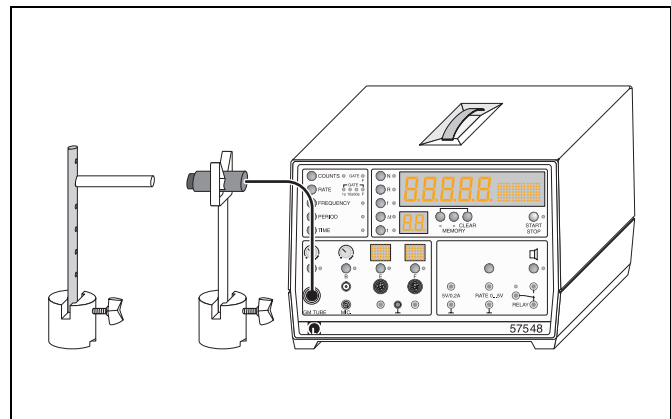


Fig. 2 Recording the characteristics of a Geiger-Müller counter tube

Carrying out the experiment

- Switch on the digital counter or, if available, push button A.
- Switch on loudspeaker, once press button Rate (gate time: 1 sec) and press button Start Stop.
- To reduce the potential of the counter tube, turn the potentiometer A to the left until the acoustic signal disappears and the display shows zero; read the voltage of the counter tube in the measuring display and record as Geiger threshold U_0 .

- Reduce the counter tube voltage by another about 100 V and again press the button Rate in order to raise the gate time to 10 sec.
- Start the counting rate measurement with button Start Stop; after the gate time has passed, read the counting rate R , and record together with the counter tube voltage U .
- Push button Start Stop to stop counting rate measurement, raise counter tube voltage by 40 V and restart counting rate measurement.
- To record additional measurements raise counter tube voltage to a total of 640 V (choose small increments in the range of the Geiger threshold U_0).
- Widen distances between preparation and counter tube to 10 mm or 20 mm and record additional series of measurements.

Measuring example

Working voltage: $U_0 = 356 \text{ V}$

Tab. 1: Counting rate R as a function of the counter tube voltage U at three different distances d between preparation and counter tube

	$d = 1 \text{ mm}$	$d = 10 \text{ mm}$	$d = 20 \text{ mm}$
$\frac{U}{\text{V}}$	$\frac{R}{\text{s}^{-1}}$	$\frac{R}{\text{s}^{-1}}$	$\frac{R}{\text{s}^{-1}}$
240	0.0	0.0	0.0
280	0.0	0.0	0.0
320	0.0	0.0	0.0
352	0.0	0.0	0.0
356	0.2	0.8	0.4
360	526.2	307.6	101.1
364	1012.4	627.0	149.1
368	1090.7	690.3	146.2
372	1156.7	691.6	145.0
380	1132.6	725.9	148.9
400	1220.4	727.7	145.4
440	1210.4	732.2	156.6
480	1223.1	743.2	152.6
520	1224.6	744.9	150.9
560	1205.1	737.3	153.0
600	1191.8	740.6	152.5
640	1219.4	747.8	154.9

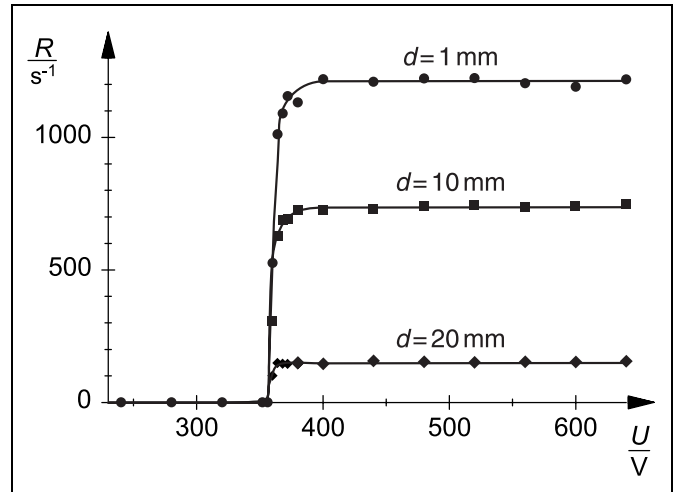


Fig. 3 Characteristics of the counter tube (counting rate R as a function of the counter tube voltage U) at three different distances d between preparation and counter tube

Evaluation and results

The Geiger threshold is approx. 356 V. Between 380 V and 640 V the counter tube works as a Geiger-Müller counter tube. The characteristics of the counter tube show a plateau.

The counting rate on that plateau depends for instance on the distance between preparation and counter tube, i.e. on the activity at the location of the counter tube.