

Geiger-Müller

Fatta

La radiazione crea ionizzazione che si moltiplica in modo esagerato e satura. La tensione è elevata, quindi non ho bisogno di elettronica impegnativa, per questo sono portatili. È facile utilizzare il geiger connettendo l'impulso ad un altoparlante per produrre rumore.

- **GM is a gas-filled tube that has a very high voltage applied to it**
- **when radiation comes in contact with the outer glass tube or the gas inside it creates a reading on the instrument reader**
- **if the GM is outfitted with a speaker you can hear an audible and familiar “click” noise**



Abbiamo una regione limitata in cui si produce una valanga che eccita e ionizza il gas moltiplicando.
Spesso ho eccitazioni che producono fotoni ultravioletti che generano cascate secondarie in diversi punti.
Per questo motivo non ho una valanga ben posizionata nel punto di interazione della particella ionizzante.

Geiger-Müller

- at a critical value of the electric field, each avalanche can create, on the average, at least one more avalanche and a self-propagating chain reaction results
- one avalanche can itself trigger a second avalanche at a different position within the tube
- typical pulse from Geiger tube represents large amount of collected charge

Geiger-Müller

Le valanghe si autosostengono e la carica prodotta è fuori controllo, posso avere 10^{10} come fatt. di molt.
~~Ho segnali grandi nei volt, ma perdo memoria della ionizzazione iniziale.~~

- 10^9 - 10^{10} ion pairs being formed in the discharge
- output pulse amplitude is also large (typically of the order of volts)
- because tubes are relatively inexpensive, it's a best choice when a simple and economical counting system is needed

Geiger-Müller

Tempi morti grandi, utilizzati per flussi bassi di p. ionizzanti.

- aside from lack of energy information, major disadvantages of G-M counters is their unusually large dead time
- greatly exceeds that of any other commonly used radiation detector
- detectors therefore limited to relatively low counting rates

Devo utilizzare correzioni di tempo morto al rate osservato

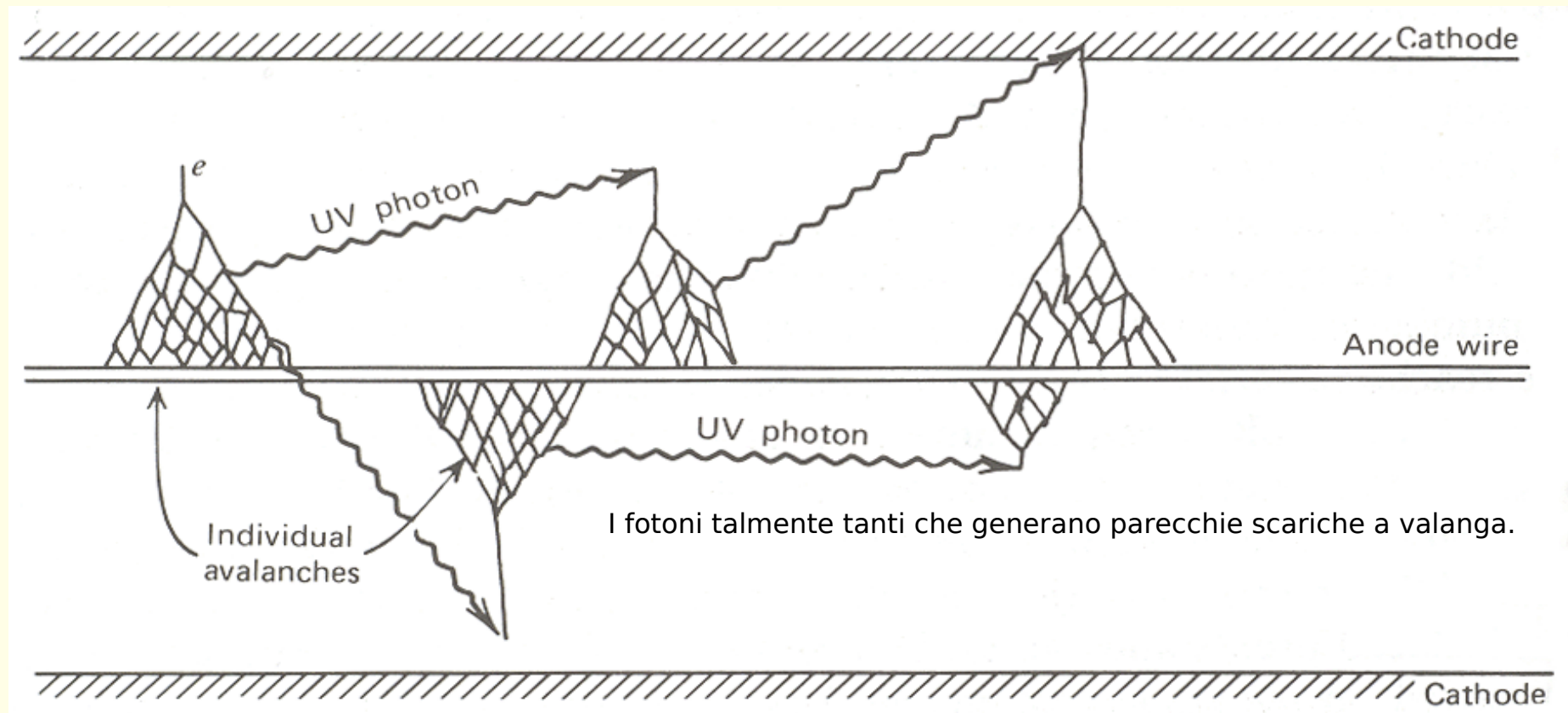
Geiger-Müller

Altrimenti registro rate falsi bassi.

- a dead time correction must be applied to situations in which the counting rate would otherwise be regarded as moderate
- some types of Geiger tube also have a limited lifetime and will begin to fail after a fixed number of total pulses have been recorded

La quantità di carica elevata porta al deterioramento del gas e del geiger, facendo perdere in efficienza. Le scariche distruggono le molecole del gas che poi si depositano sul catodo e anodo influenzando il campo elett. disturbando il funzionamento.

Geiger-Müller – Geiger Discharge



I fotoni talmente tanti che generano parecchie scariche a valanga.

Le valanghe si autosostengono e la carica prodotta è fuori controllo, posso avere 10^{10} come fatt. di molt. Ho segnali grandi nei volt, ma perdo memoria della ionizzazione iniziale.

Geiger-Müller – Geiger Discharge

- in a typical avalanche created by a single original electron, many excited gas molecules are formed by electron collisions in addition to the secondary ions
- these excited gas molecules return to their ground state through the emission of photons whose wavelength may be in the visible or ultraviolet region

Geiger-Müller – Geiger Discharge

- if gas multiplication factor M is relatively low ($10^2 - 10^4$) – number of excited molecules formed in a typical avalanche (n_0') is not very large
- most gases are relatively transparent in the visible and UV wavelength regions – probability p of photoelectric absorption of any given photon is also relatively low

Geiger-Müller – Geiger Discharge

- under these conditions - $(n_0') < 1$ and situation is “subcritical” in that relatively few avalanches are formed
- in a Geiger discharge – multiplication represented by a single avalanche is much higher ($10^6 - 10^8$) and therefore (n_0') is also much larger - $n_0' \geq 1$
- an ever increasing number of avalanches may potentially be created throughout the tube

Geiger-Müller – Geiger Discharge

- **time required for the spread of these avalanches is relatively short**

Il tempo di propagazione dei fotoni è breve, dunque tutto il geiger viene interessato dalla scarica in microsec.-

Non ho informazioni spaziali

- **time required to produce all the ion pairs and excited molecules in a given avalanche is a small fraction of a microsecond**

- **in Geiger discharge – rapid propagation of the chain reaction leads to many avalanches**

Geiger-Müller – Fill Gases

- gases used in a Geiger tube must meet some of the same requirement as proportional counters
- trace amounts of gases which form negative ions (such as oxygen) must be avoided in either case
- noble gases are widely used for the principal component of the fill gas in G-M tubes, with helium and argon the most popular choices

Si usano soprattutto gas nobili, ma anche aria.

Geiger-Müller – Quenching

- problem of multiple pulsing is potentially severe in Geiger tubes
- with Geiger tube – increased number of positive ions reaching the cathode greatly enhances the free electron emission probability
- secondary discharge, even though caused by only a single electron, builds to an amplitude equal to that of the primary discharge
- special precautions must be taken in Geiger counters to prevent possibility of excessive multiple pulsing

E' necessario spegnere le valanghe con quencher e tensione in modo impulsato, ovvero azzerarla dopo un certo tempo per fermare la moltiplicazione.

Geiger-Müller – Quenching

- **external quenching** consists of some method for reducing the high voltage applied to the tube, for a fixed time after each pulse, to a value that is too low to support further gas multiplication

RC indica il tempo di raccolta

- one method of external quenching is simply to choose **R** to be a large enough value (typically 10^8 ohms) so that time constant of the charge collection circuit is of the order of a millisecond

Geiger-Müller – Quenching

Saltato.

- more common to prevent possibility of multiple pulsing through internal quenching – accomplished by adding a second component called the quench gas to the primary fill gas
- chosen to have a lower ionization potential and a more complex molecular structure than the primary gas component and is present with a typical concentration of 5 –10%
- many organic molecules possess the proper characteristics to serve as a quench gas
- ethyl alcohol and ethyl formate are widely used in many commercial G-M tubes

Geiger-Müller – Time Behavior

- **Pulse Profile**

Saltato.

- in a Geiger discharge the pulse corresponds to the cumulative effect of many avalanches that have been formed along the entire length of the anode wire
- time required for secondary electrons to reach the multiplying region to trigger these multiple avalanches will be variable

Geiger-Müller – Pulse Output

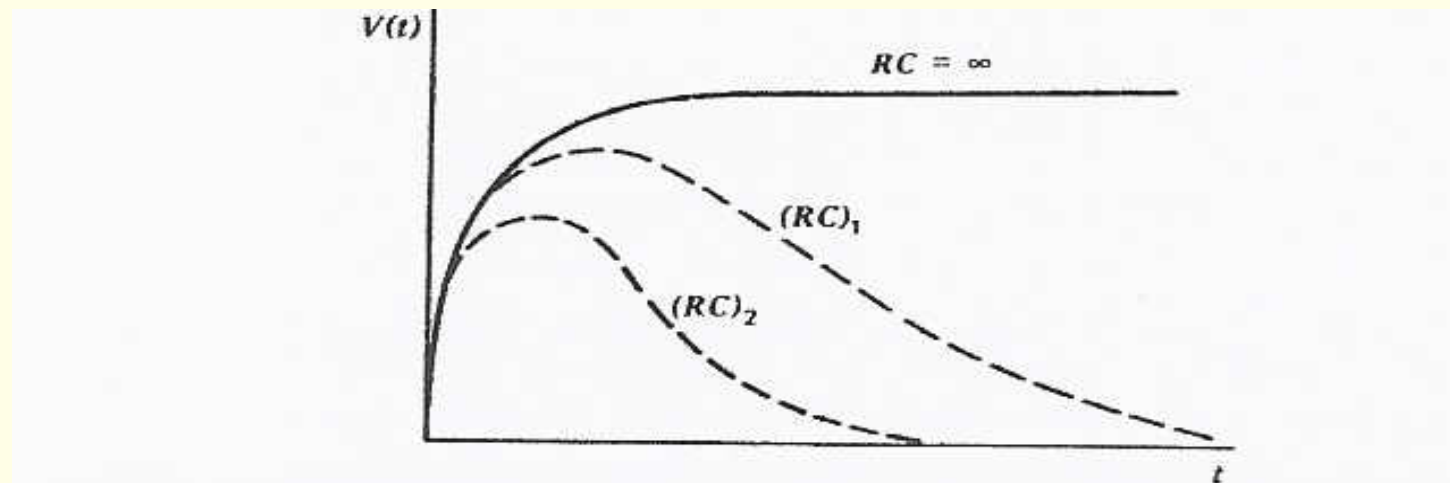


Figure 7.3 Shape of the G-M tube output pulse for different assumed time constants RC of the counting circuit. Here $(RC)_2 < (RC)_1 < \text{infinite time constant}$. The signal voltage $V(t)$ is assumed to be measured as indicated in Fig. 7.2, giving a positive polarity. More conventionally, the pulse is measured with respect to ground within the amplifier, leading to inverted shape or negative polarity.

Geiger-Müller – Time Behavior

Tempo salita più lento per via delle valanghe lontane, ma comunque salite veloci rispetto agli spegnimenti

- initial pulse rise will be somewhat slower than that for a single avalanche
- net effect is that the output pulse from a G-M tube still exhibits a fast rise on the order of a microsecond or less, followed by a much slower rise due to the slow drift of the ions
- from considerations of maximum counting rate, time constants are often chosen that are much less than $100\ \mu\text{sec}$ which largely eliminate the slow-rising portion of the pulse and leave only the fast leading edge

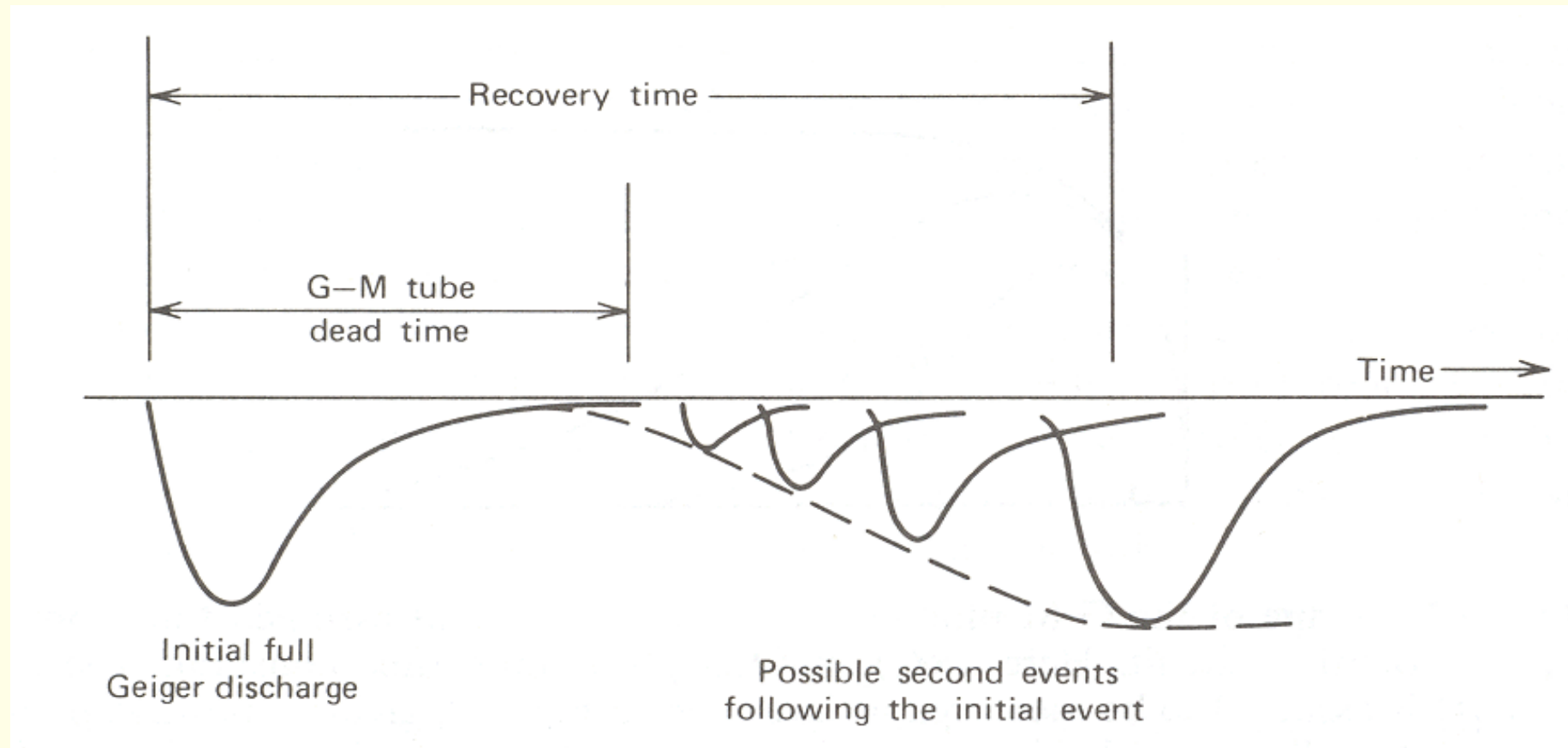
Geiger-Müller – Time Behavior

- **Dead Time**
- building of the positive ion space charge that terminates the Geiger discharge also ensures that a considerable amount of time must pass before a second Geiger discharge can be generated in the tube
- immediately following the Geiger discharge, electric field has been reduced below the critical point by the positive space charge
- if another ionizing event occurs under these conditions – a second pulse will not be observed because gases multiplication is prevented

Geiger-Müller – Time Behavior

- during this time the tube is therefore “dead”
 - **dead time** of the Geiger tube is defined as period between initial pulse and time at which a second Geiger discharge, regardless of size, can be developed
- dt 50-100 musec
- in most Geiger tubes, this time is of the order of 50 –100 μ sec

Geiger-Müller – Time Behavior



Posso avere effetti secondari che generano ulteriori scariche, quindi lo tengo spento per il recovery time per evitare altri impulsi che si autosostengono

Geiger-Müller – Time Behavior

- some finite pulse amplitude must be achieved before the second pulse is recorded
- elapsed time required to develop a second discharge that exceed this amplitude is sometimes called the resolving time of the system
- **recovery time** is time interval required for the tube to return to its original state and become capable of producing a second pulse of full amplitude

Geiger-Müller – Counting Plateau

- operating point is normally chosen by recording a plateau curve from the system under conditions in a radiation source generates events at a constant rate within the tube
- distributions are shown for 2 hypothetical values of applied voltage in the sketch
- minimum voltage at which pulses are first registered counting system is often called starting voltage
- transition between the rapid rise of the curve and plateau is its knee
- if voltage raised is sufficiently high, plateau abruptly because of the onset of continuous discharge mechanisms within the tube

Geiger-Müller – Counting Plateau

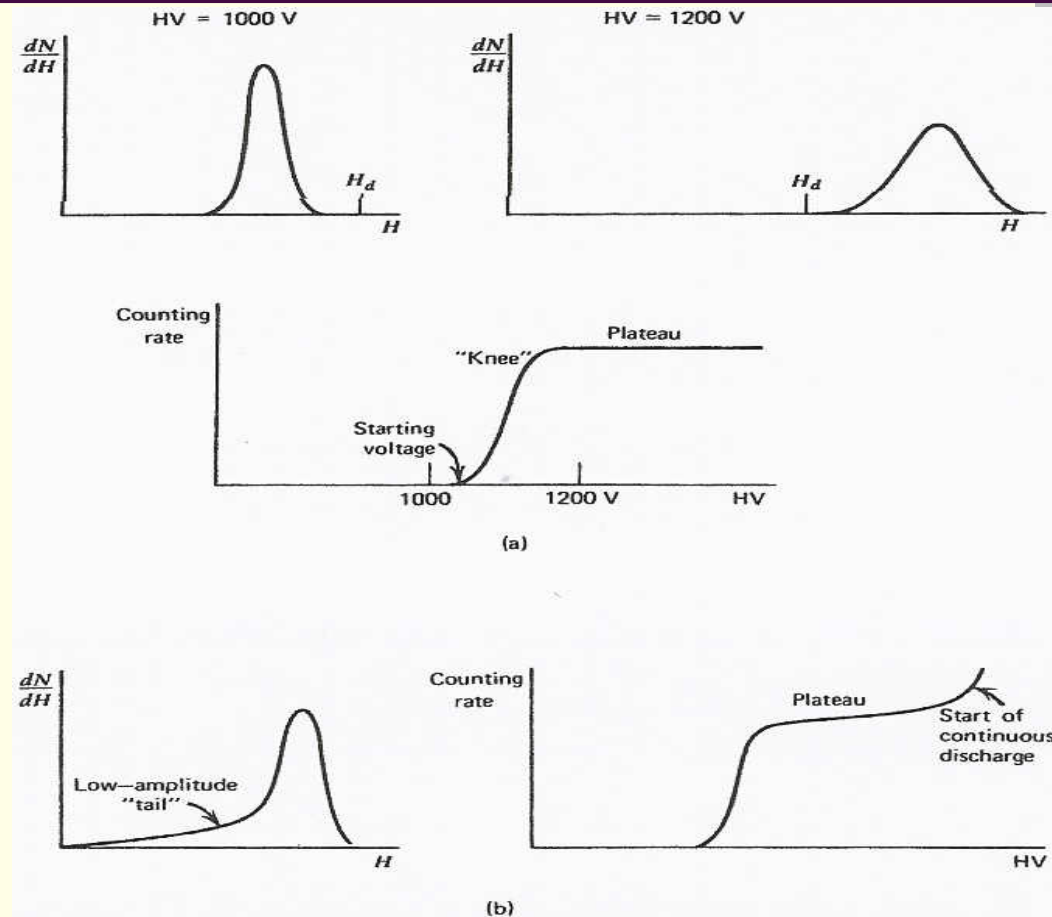


Figure 7.5 (a) The establishment of the counting plateau for a G-M tube. As the high voltage is varied in this example from 1000–1200 V, the output pulses change from falling below the counter threshold H_d to a situation in which all pulses are larger than H_d . (b) The low-amplitude tail on the pulse height spectrum at the left causes a finite slope of the plateau in the counting curve.

Geiger-Müller – Design Features

- typical design is the end-window type
- anode wire is supported at one end only and is located along the axis of a cylindrical cathode made of metal or glass with a metallized inner coating
- radiation enters the tube through the entrance window, which may be made of mica or other material that can maintain its strength in thin sections
- most Geiger tubes are operated below atmospheric pressure – window may have to support a substantial differential pressure

Geiger-Müller – End Window

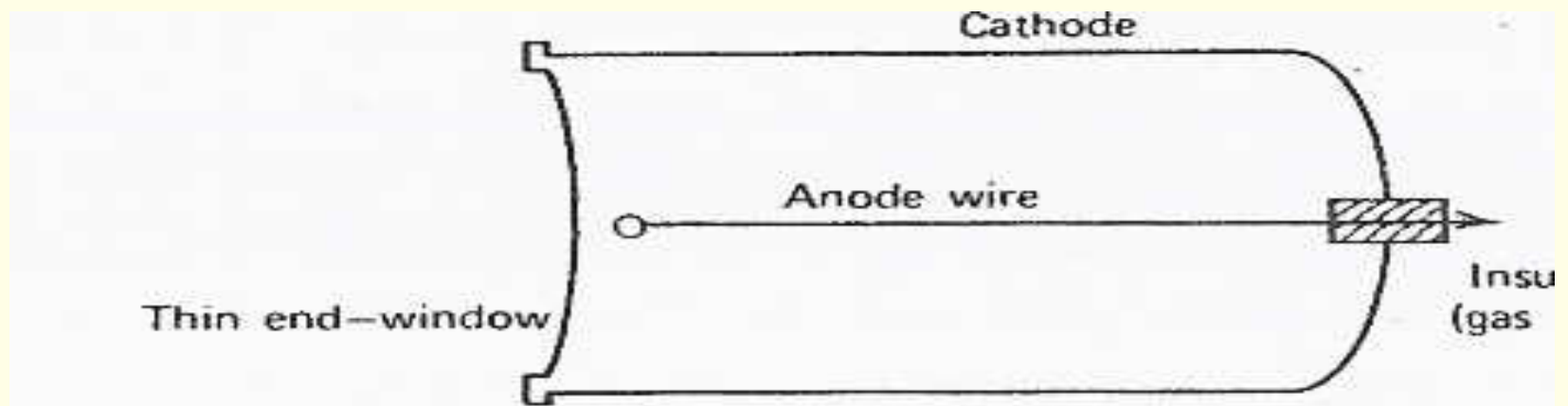


Figure 7.6 A cross section of a typical end-window Geig

Geiger-Müller – Design Features

- window should be as thin as possible when counting short-range particles, such as alphas
- for applications involving very soft radiations such as low-energy heavy charged particles or soft beta particles, it may be preferable to introduce the source directly into the counting volume

Geiger-Müller – Design Features

- continuous flow Geiger counters, which are similar in design to gas flow proportional counters are often used for this purpose
- because no preamplifier is normally required, a counting system involving Geiger tubes can be simple
- thicker window can be used for counting beta particles but some will be backscattered from the window without penetrating if the window thickness is a significant fraction of the electron range

Geiger-Müller – Block Diagram

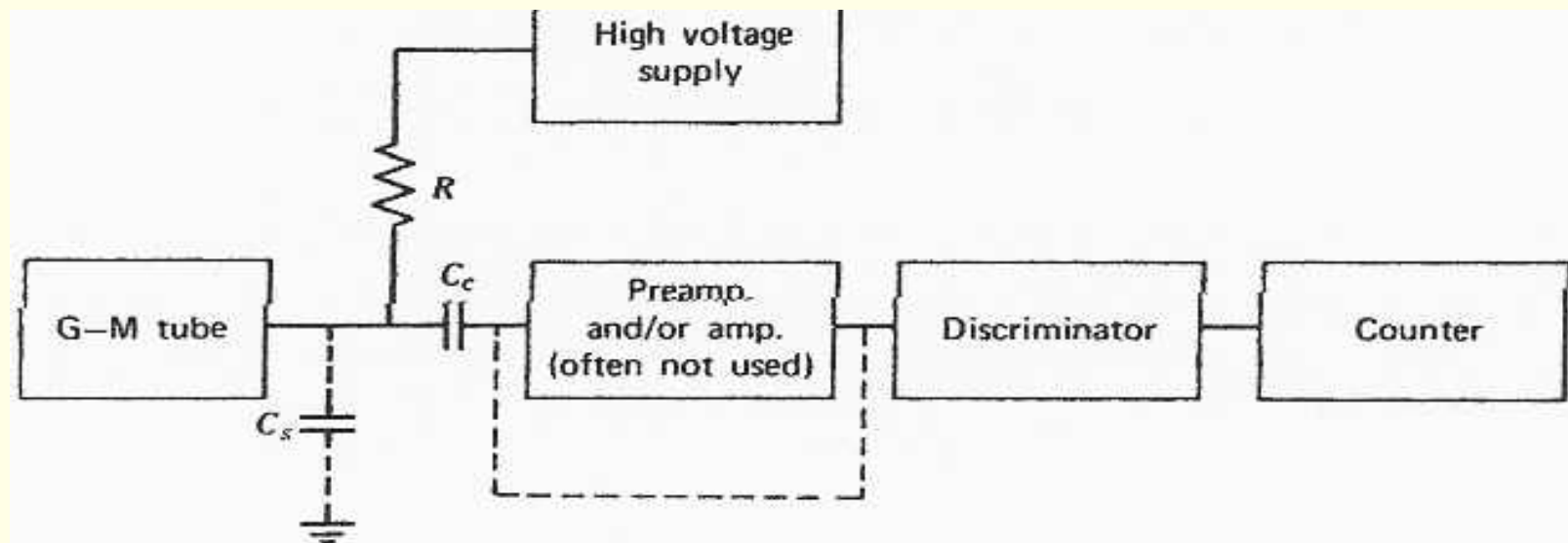


Figure 7.7 Block diagram of the counting electronics normally associated with a G-M tube.

Geiger-Müller – Counting Efficiency

- **Neutron**
- several Geiger tubes are seldom used to count neutrons
- for thermal neutrons, the conventional Geiger gases have low capture cross sections
- gases with a high capture cross section (such as BF_3) can be substituted

Geiger-Müller – Counting Efficiency

- then detector is much more sensibly operated in the proportional region than in the Geiger region
- fast neutrons can produce recoil nuclei in a Geiger gas which generate ion pairs and a subsequent discharge
- gas-filled fast neutron detectors are normally operated as proportional counters rather than as Geiger tubes to take advantage of the spectroscopic information provided

Geiger-Müller – Counting Efficiency

- **Gamma Rays**

- in a gases-filled counter, response to gamma rays of normal energy comes about by way of gamma-ray interactions in the solid wall of the counter
- if interaction takes place close enough to the inner wall surface so that the secondary electron created in the interaction can reach the gas and create ions – a pulse will result

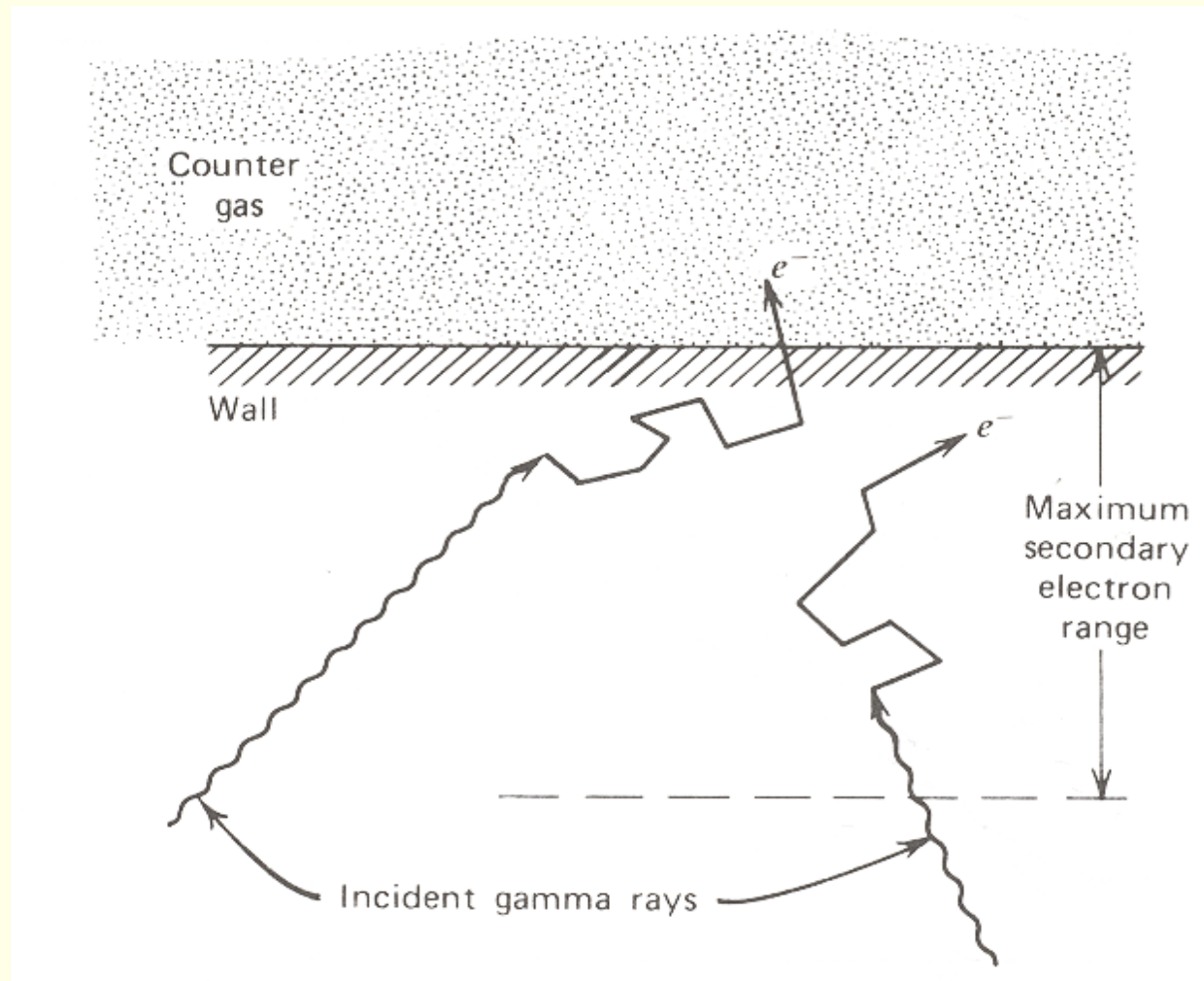
Geiger-Müller – Counting Efficiency

- since only a single ion pair is required, secondary electron need only barely emerge from the wall near the end of its track in order to generate a pulse from a Geiger tube
- efficiency for counting gamma rays therefore depends on:
 - probability that incident gamma ray interacts in the wall and produces a secondary electron
 - probability that secondary electron reaches the fill gas before the end of its track
- only innermost layer of the wall near the gas may contribute secondary electrons

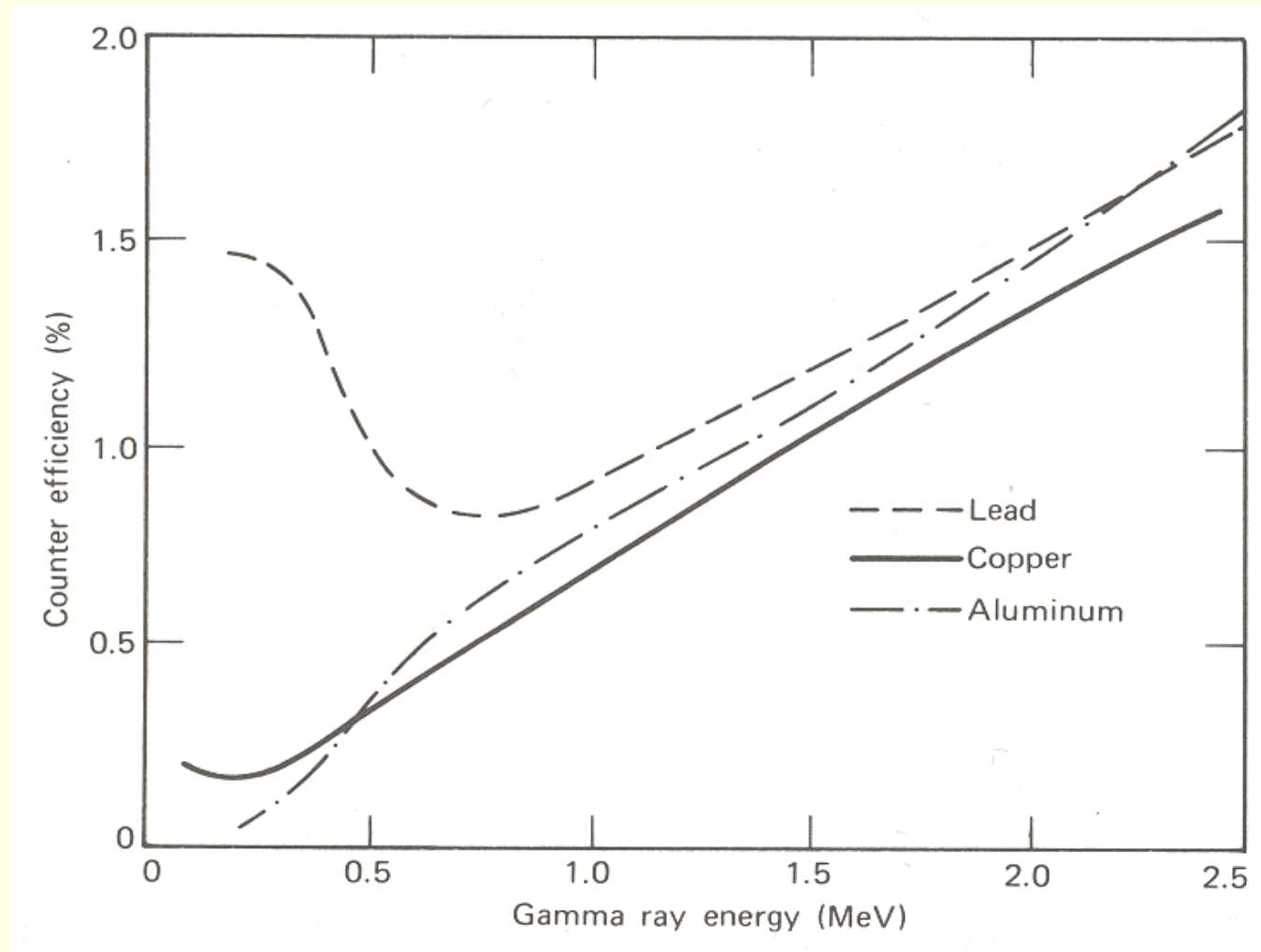
Geiger-Müller – Counting Efficiency

- probability of gamma-ray interaction increases with atomic number of the wall
- gamma-ray efficiency of Geiger tubes is highest for those tubes constructed with a cathode wall on high-Z material
- G-M tubes with bismuth ($Z = 83$) cathodes have been widely used in the past
- probability of interaction within the sensitive layer remains small even for high-Z materials
- typical gamma-ray counting efficiencies are seldom higher than several percent

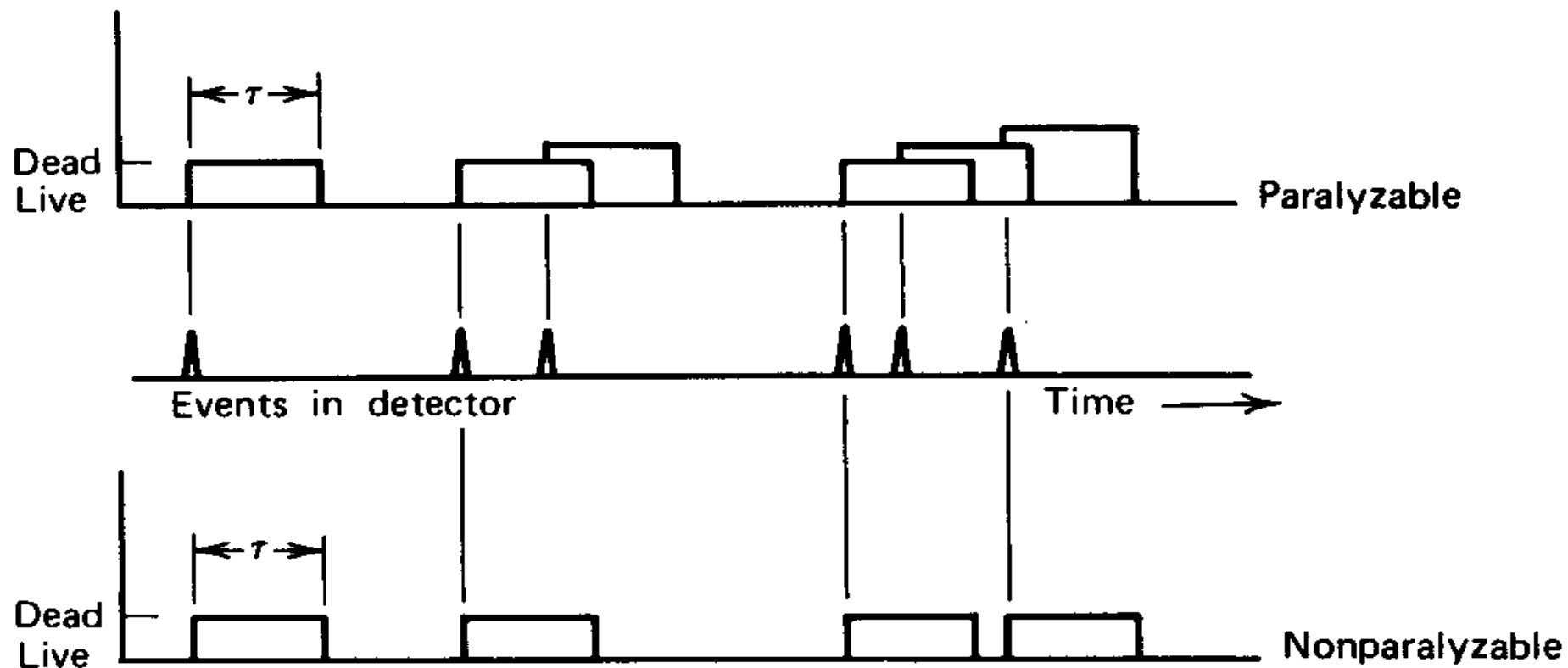
Geiger-Müller – Counting Efficiency



Geiger-Müller – Counting Efficiency



Geiger-Müller – Time to First Count



Geiger-Müller – Survey Meters

- common type of survey meter used in gamma-ray monitoring consists of a portable Geiger tube, high-voltage supply and pulse counting rate meter
- count rate meter – calibrated in terms of exposure rate units – readings can be in error by a factor of 2 or 3 or more
- count rate from a Geiger tube bears no fundamental relation to the gamma-ray exposure rate

Geiger-Müller – Survey Meters

- for a given gamma-ray energy, count rate obviously scales linearly with the intensity
- applications are likely to involve gamma rays of many different and variable energies
- variation of the counter efficiency with energy must be considered

Geiger-Müller – Survey Meters

- plots of this type are given for different cathode materials
- ideally one would like an efficiency versus energy curve that exactly matches a plot of exposure per gamma ray photon versus energy
- ratio of 2 curves at any given energy is a measure of correction factor that should be applied to the survey meter reading
- a plot of this correction factor versus gamma-ray energy for 2 commercial survey meters is shown

Geiger-Müller – Survey Meters

