Geiger-Müller

- 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

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

- **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

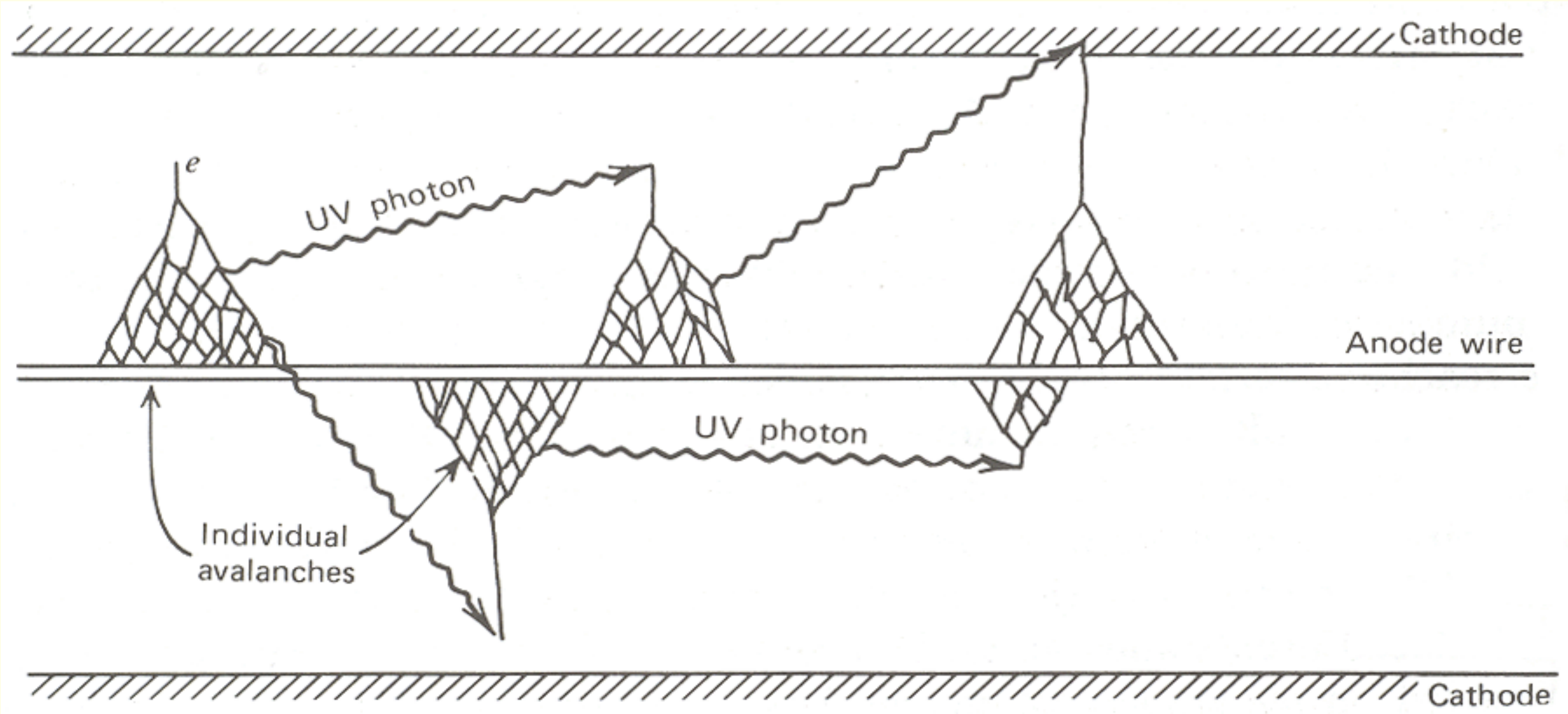
- **aside from lack of energy information, major disadvantages of G-M counters is their unusually large dead time**
- **greatly exceeds that of any other commonly used radiation detector**
- **detectors therefore limited to relatively low counting rates**

Geiger-Müller

- 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

Geiger-Müller – Geiger Discharge



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_o') 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 - ($n_o^{/}$) < 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 ($n_o^{/}$) is also much larger - $n_o^{/} \geq 1$**

- **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
- 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**

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

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

- 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

- 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**

- **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 Ouput

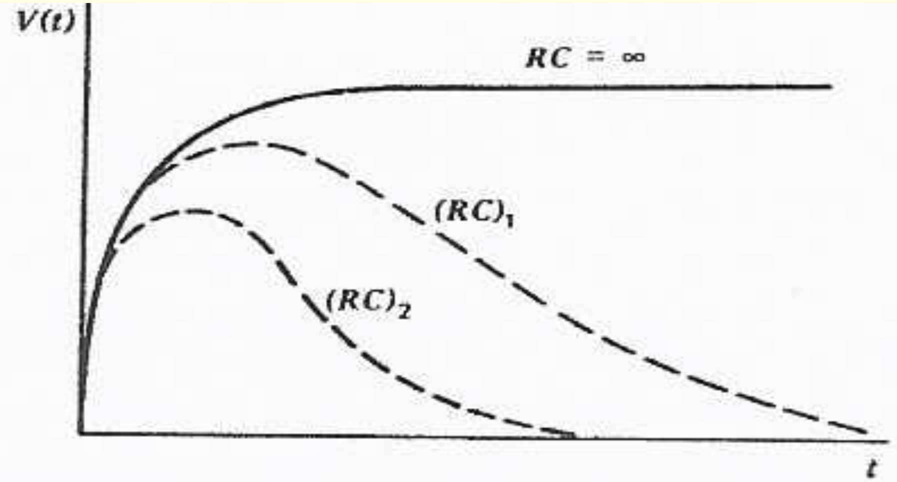


Figure 7.3 Shape of the G-M tube output pulse for different assumed time stants RC of the counting circuit. Here $(RC)_2 < (RC)_1 <$ infinite time constan signal voltage $V(t)$ is assumed to be measured as indicated in Fig. 7.2, giving a itive polarity. More conventionally, the pulse is measured with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

Geiger-Müller – Time Behavior

- 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 μsec which largely eliminate the slow-rising portion of the pulse and leave only the fast leading edge

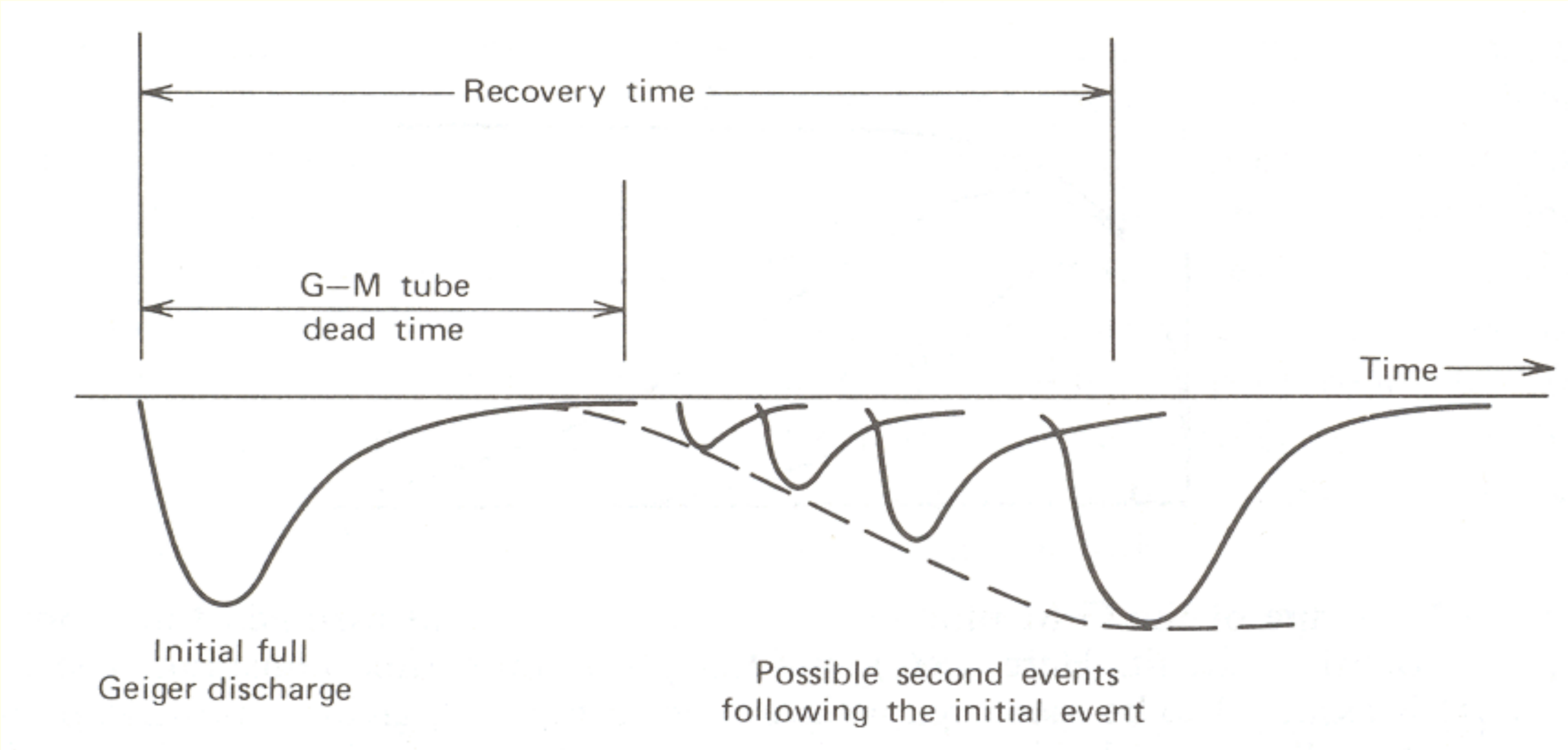
Geiger-Müller – Time Behavior

- 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
- in most Geiger tubes, this time is of the order of 50 –100 μsec

Geiger-Müller – Time Behavior



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

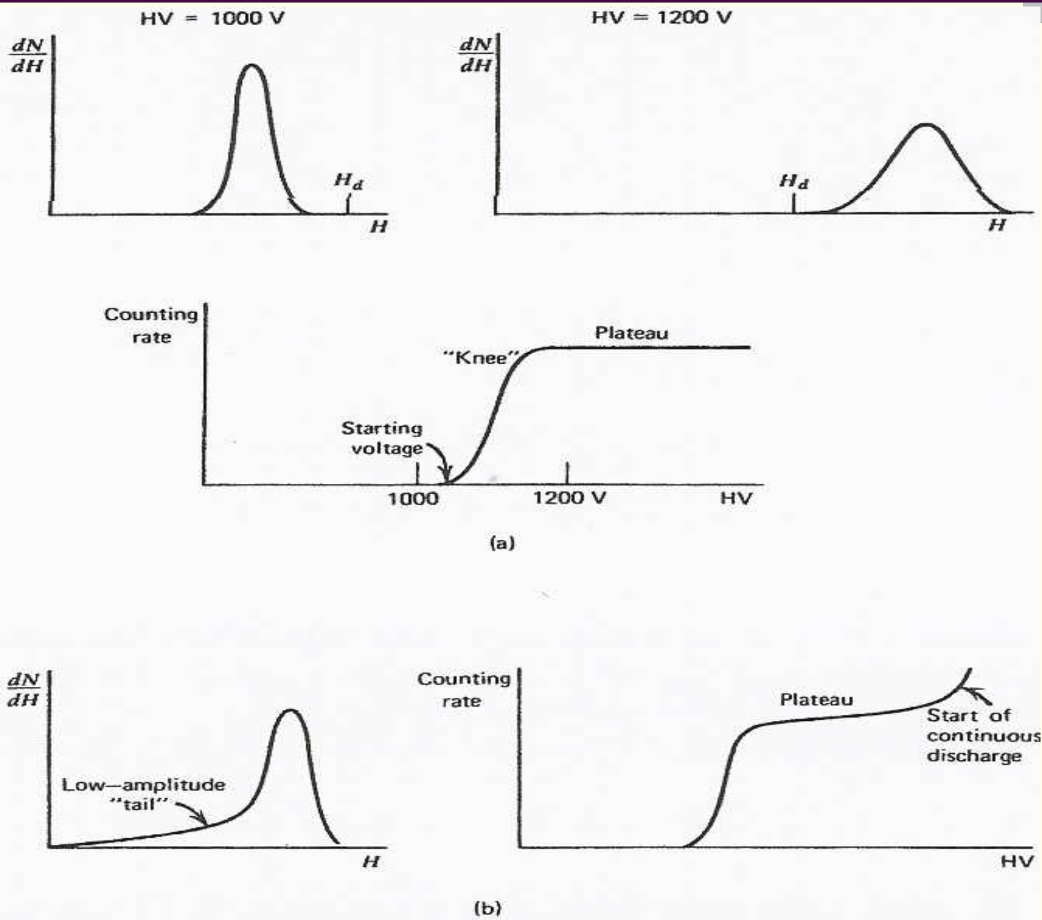


Figure 7.5 (*a*) The establishment of the counting plateau for a G-M tube. As the high voltage is varied in this example from 1000–1200 V, the output pulses change from falling below the counter threshold H_d to a situation in which all pulses are larger than H_d. (*b*) The low-amplitude tail on the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

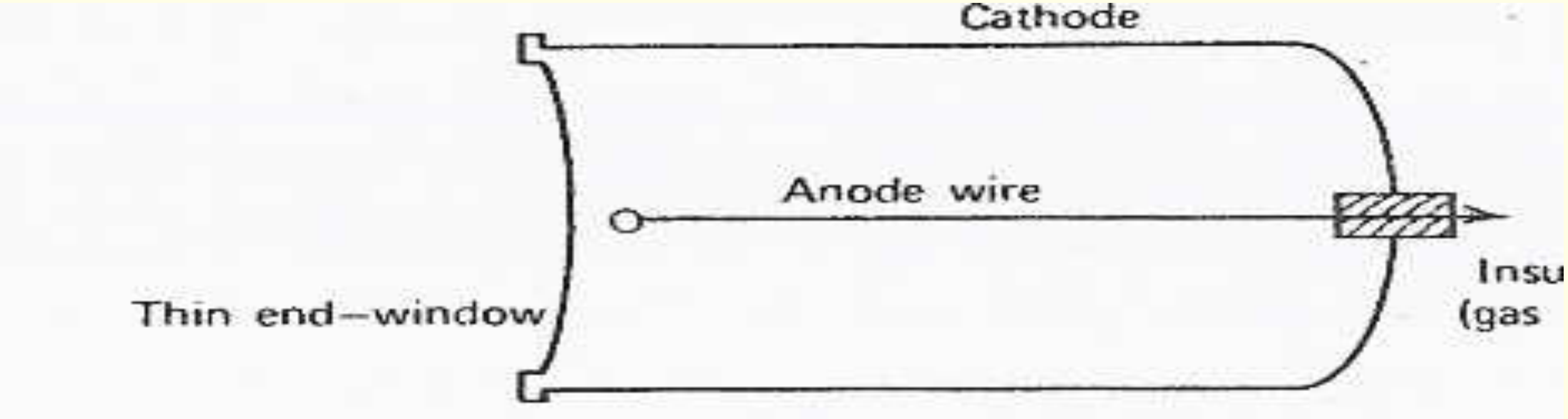


Figure 7.6 A cross section of a typical end-window Geig

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

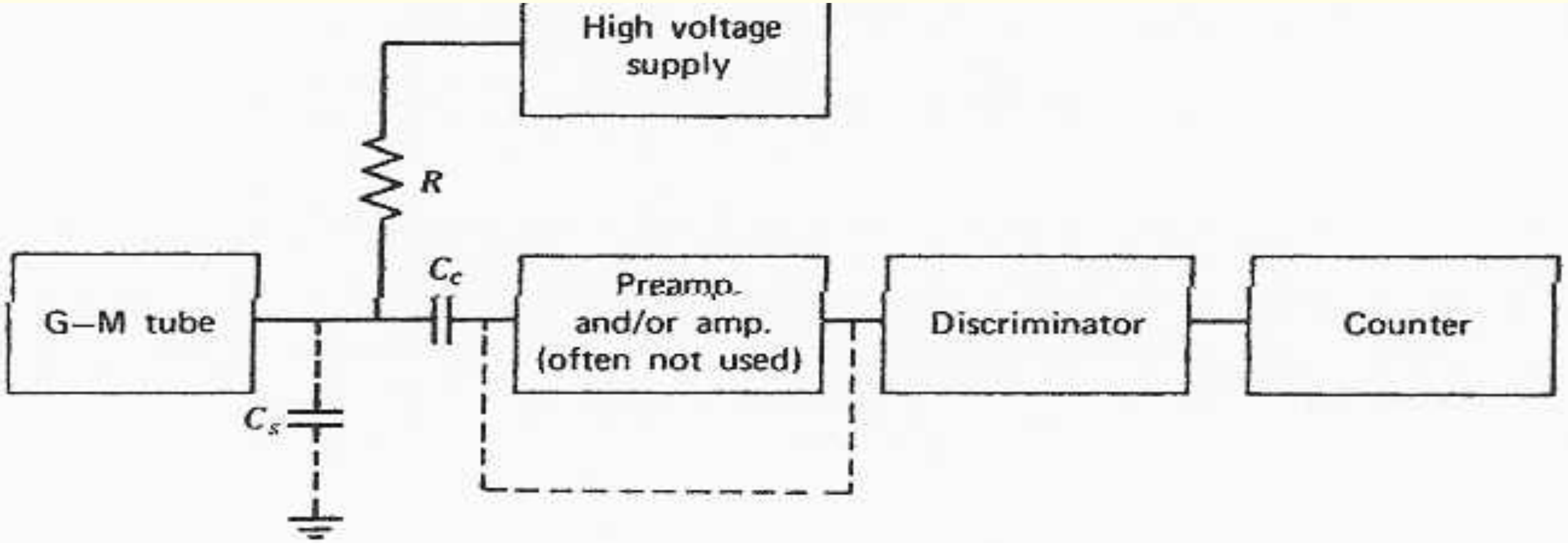


Figure 7.7 Block diagram of the counting electronics normally associated with a G-M tube.

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**

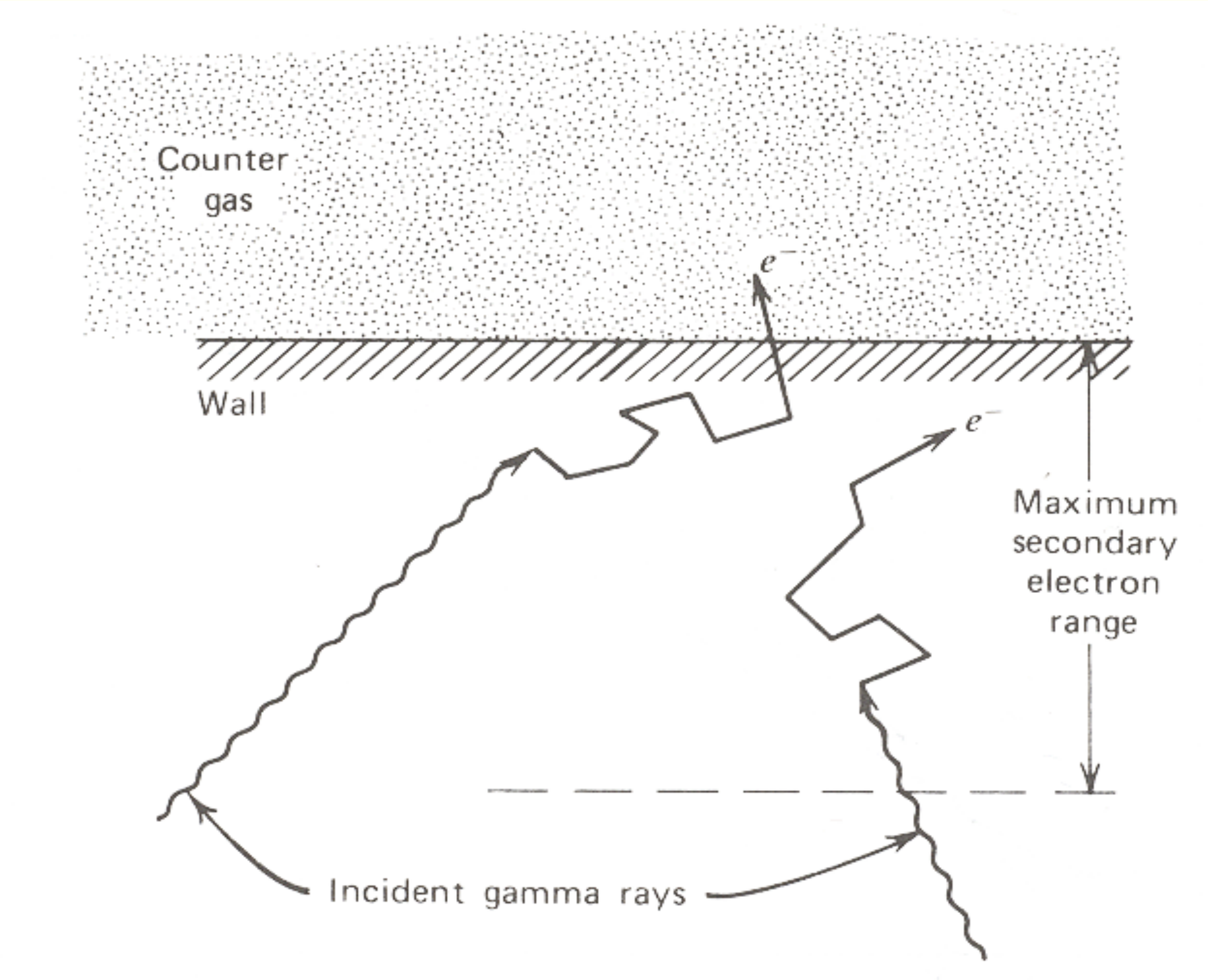
Geiger-Müller – Counting Efficiency

- 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 o the wall near the gas may contribute secondary electrons

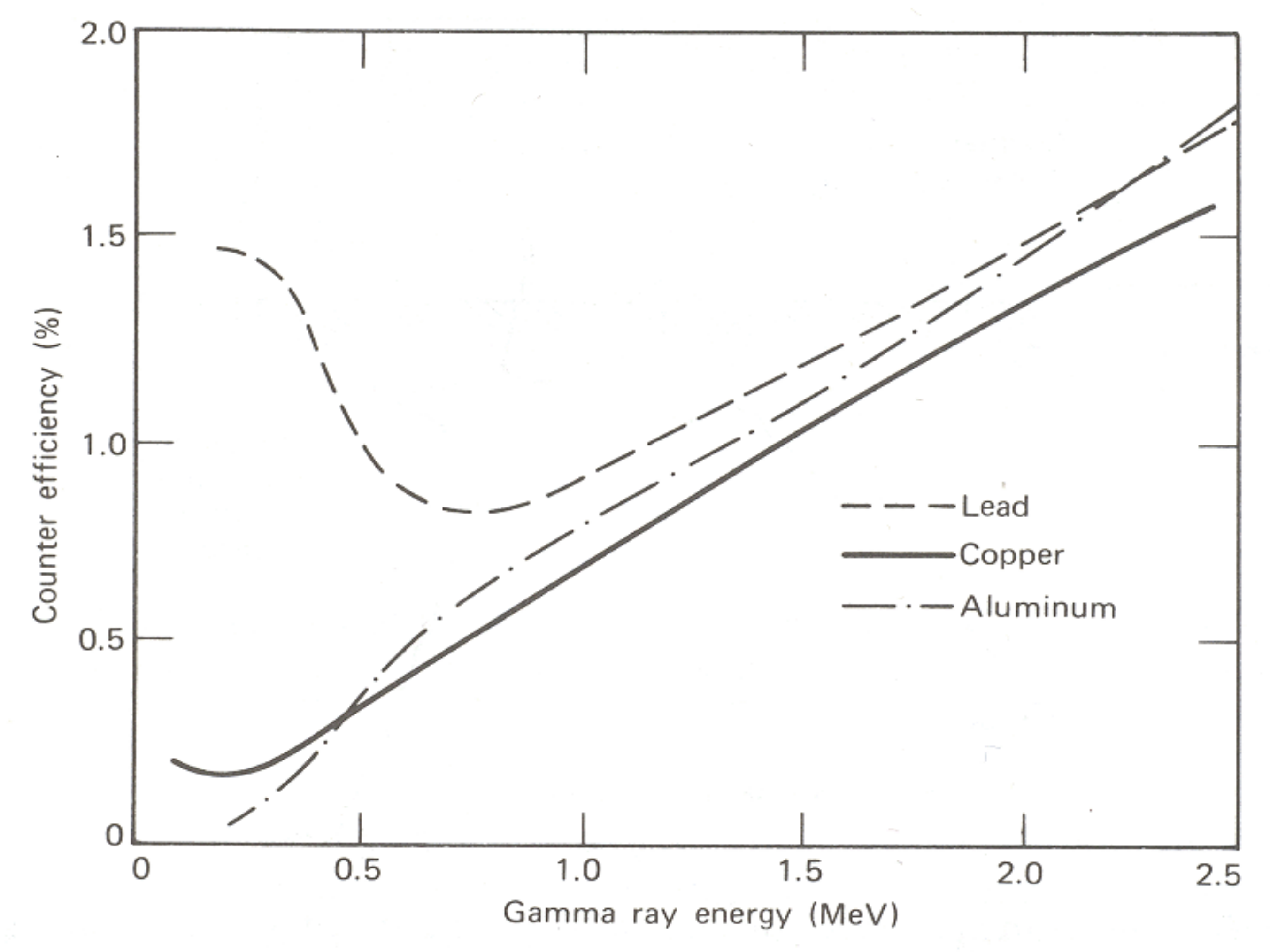
Geiger-Müller – Counting Efficiency

- 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

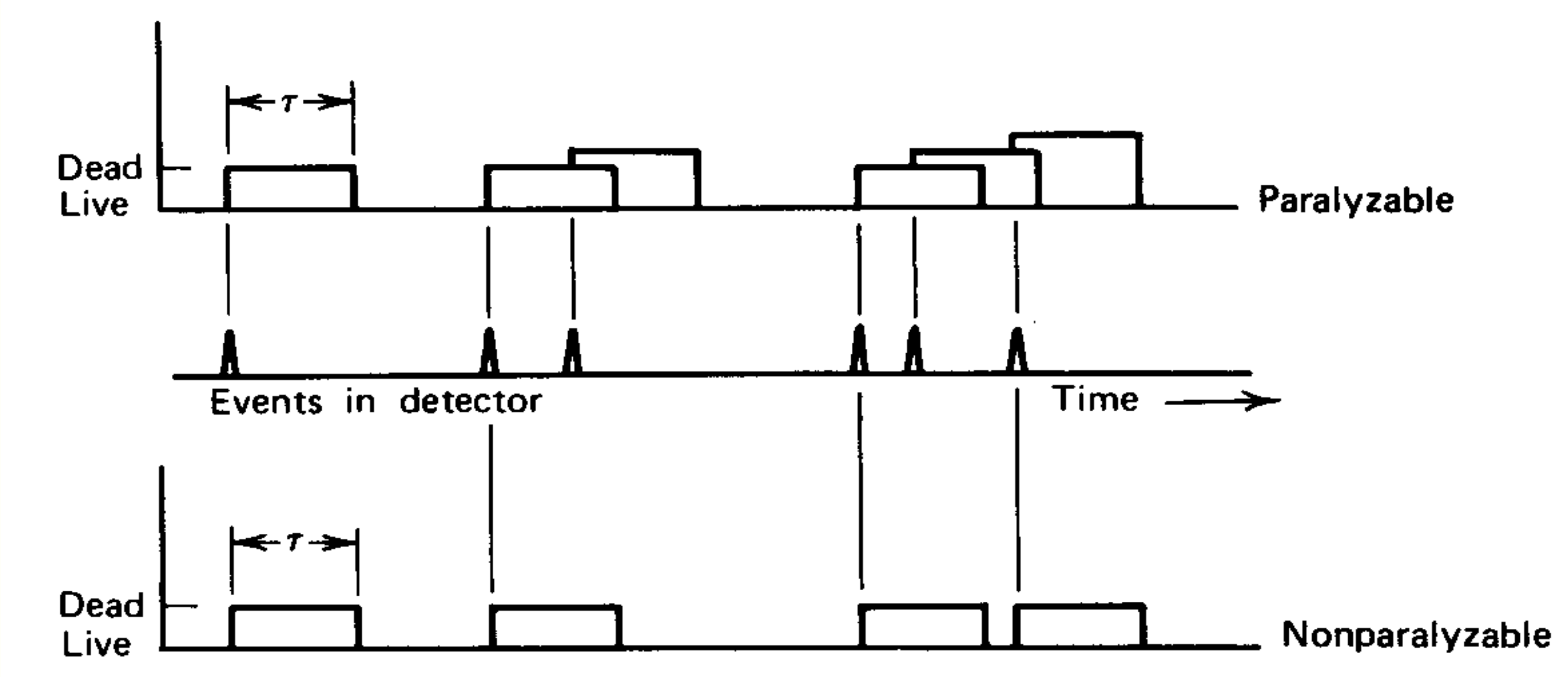
Geiger-Müller – Counting Efficiency



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 linearity 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