# Particle detection

## Topics covered

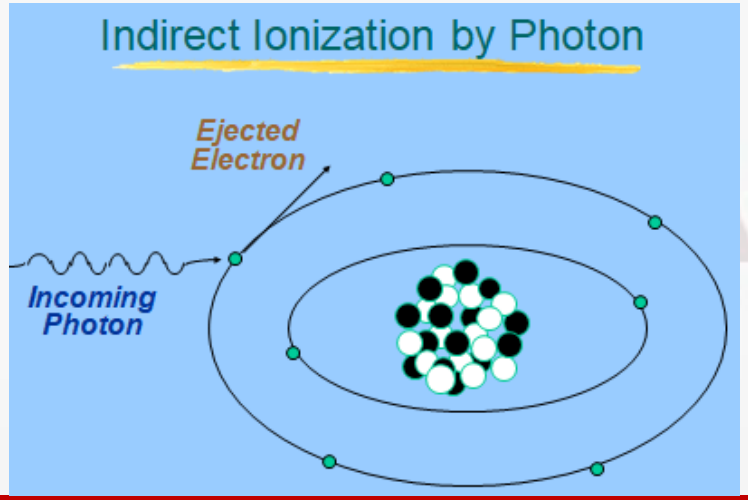
- Introduction
- Types of Radiations
- Basic principle of detector
- Classification of detector
- Construction of Gas filled detector
- Working of Gas filled detector
- References

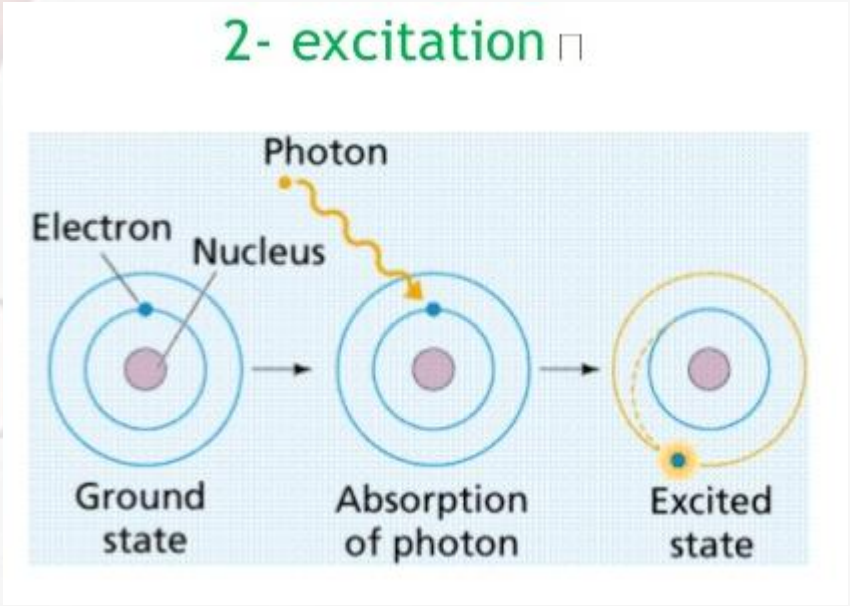
# Introduction

The instrument which is used to detect the nuclear particles or radiation are called Nuclear radiation detectors

These are based on the principle of

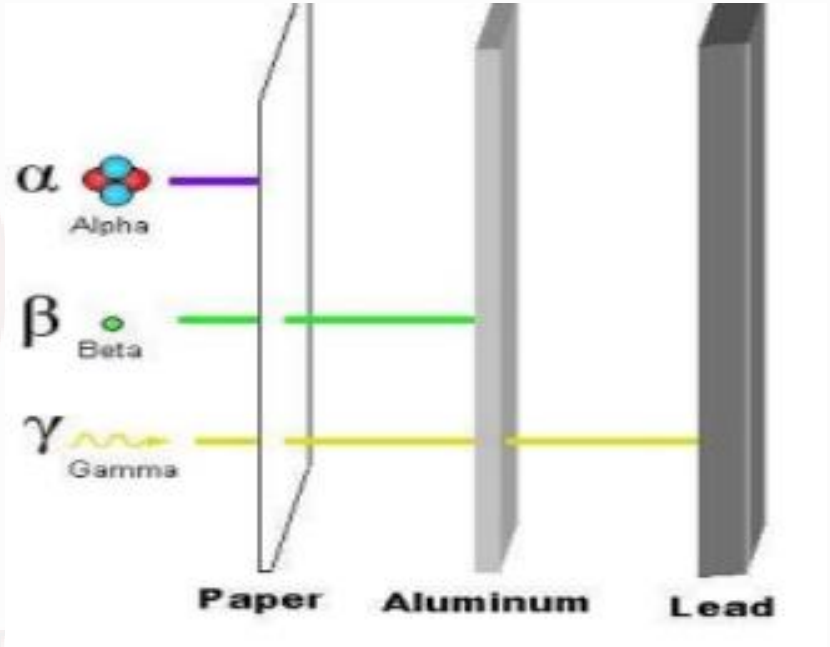
- Excitation of atoms of medium
- Ionization of atoms of medium in which the incident charged particles pass through.



# Types of Radiations

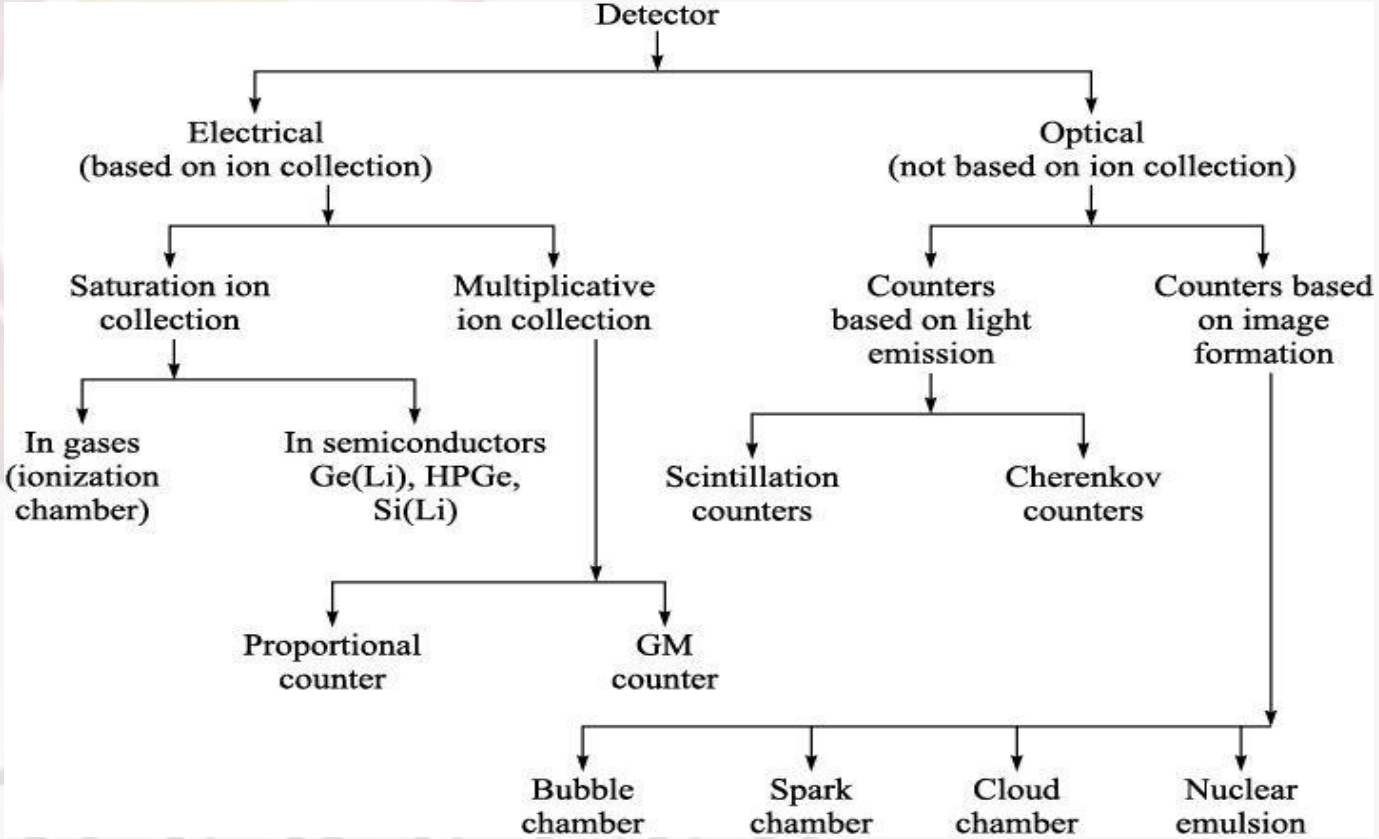
1) Charged particles
   - α- particles
   - Protons
   - Fast moving electrons
2) Uncharged particles
   - Neutrons
3) Electromagnetic radiations
   - γ- particles
   - X-rays



# Basic principle of detector

- All methods of detection are based on the interaction of the nuclear particles of radiations with the base material of the detector.
- When a charge particles moves through material of a detector it ionises or excites the atoms or molecules of the substance of the detector.
- Charged particles and γ- rays are capable of producing ions in the detectors directly
- Neutrons which are uncharged particles intermediate reactions have to be used for detection.

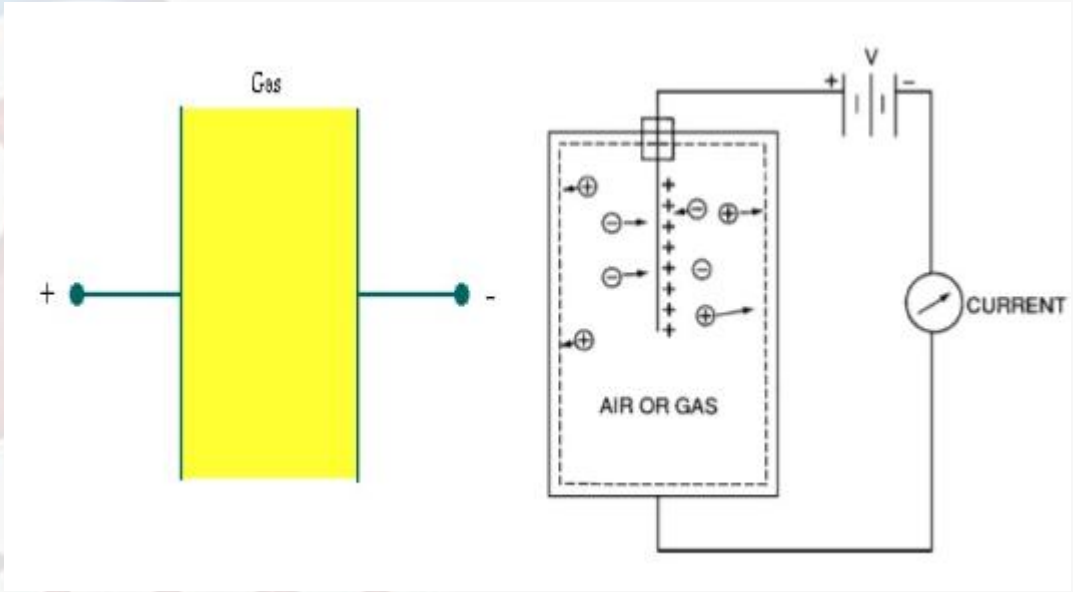
Classification of detectors according to signals produced



# Construction of Gas filled detector

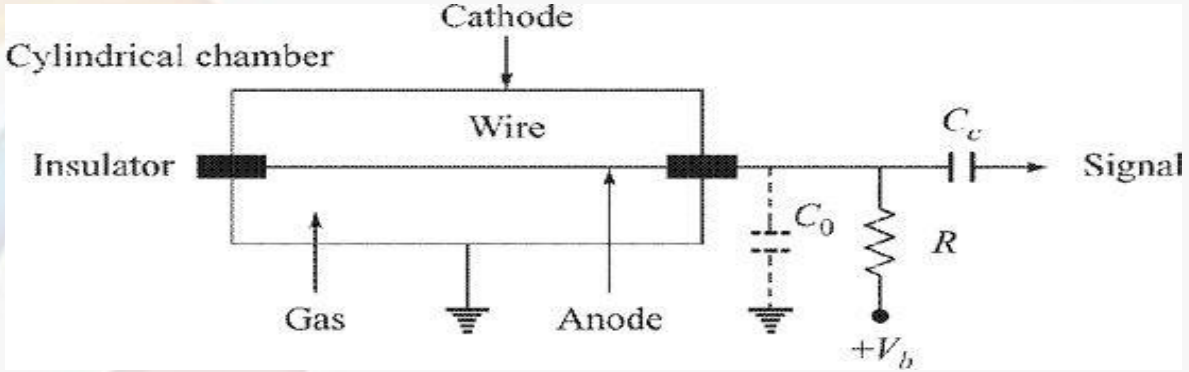
Gas-filled detectors are some of the oldest and most widely used detectors for nuclear radiations.

- It consists of a cylindrical gas-filled chamber.
- A thin wire is placed along its axis and is well insulated from the walls of the chamber. Through an external resistance $R$ a positive potential is applied to the central wire, which acts as anode.
- The cylindrical chamber is grounded and it acts as a cathode.
- Capacity of the electrodes and stray capacities of the connecting wires, etc. constitutes the total capacity $C_0$ as shown in Figure circuit.



# Working of Gas filled detector

•When a nuclear radiation (like electrons, $\alpha$-particles, etc.) enters the chamber, it ionizes the gas present in the chamber thus creating number of positive ions and electrons called *ion-pairs*.



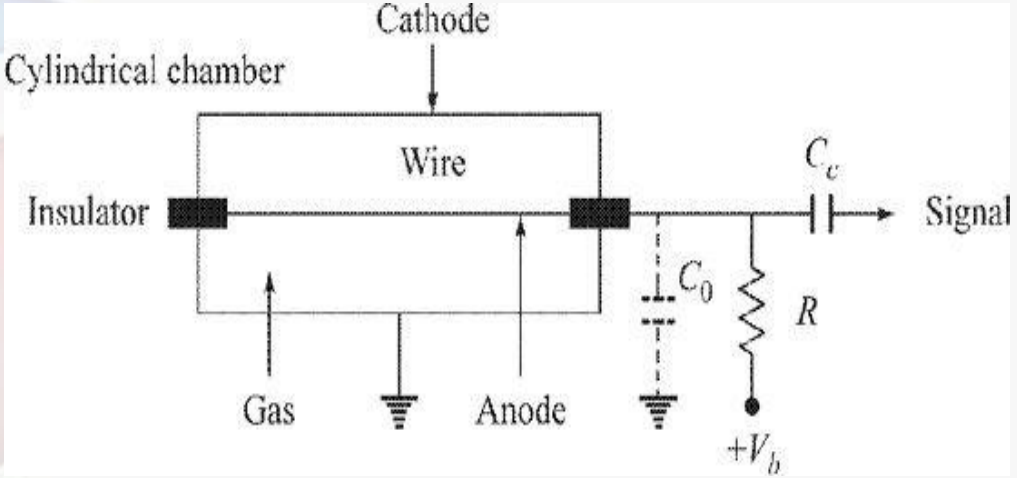

•If there is no electric field present, i.e. $V_b = 0$, the ion-pairs just created recombine forming neutral atoms/molecules.

• In the presence of the applied electric field ($V_b > 0$), the positive ions move along the radial electric lines of force i.e. towards the cathode or outer walls of the chamber. Similarly, electrons move towards the anode or central wire.

•Electrons being lighter than positive ions move at a much higher drift velocity (~$10^6$ cm/s).

## Working of Gas filled detector (contd.)

- The net effect of this is a charge $Q$ gets collected on the anode,
- This charges the capacitor $C_0$ to a potential of $Q/C_0$.
- The detector gives rise to a pulse, which is processed by external electronic circuit.




- In ionization an electron–ion pair is created. The electrons so liberated when they reach the anode give information that a radiation has entered the detector.
- In excitation no such pair is formed. The energy consumed in excitation is wasted, as during excitation no electron reaches the anode.

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# Working of Gas filled detector (contd.)

- The average energy lost by the incident particle in creating one ion-pair (defined as *W*-value) is always greater than the ionization energy of that gas.
- The *W*-value is a function of the gas present in the detector, type of radiation and its energy.
- Table shows ionization potential *Ip* and *W*-value for fast electrons and *α*-particles for some of the commonly used gases in the radiation detectors.

| Gas | $I_p$ (eV) | W (eV /ion-pair) | |
|---|---|---|---|
| | | Fast electrons | $\alpha$-particles |
| $H_2$ | 15.6 | 36.5 | 36.4 |
| He | 24.5 | 41.3 | 42.7 |
| $N_2$ | 15.5 | 34.8 | 36.4 |
| Ar | 15.7 | 26.4 | 26.3 |
| Air | – | 33.8 | 35.1 |
| $CH_4$ | 14.5 | 27.3 | 29.1 |

# Working of Gas filled detector

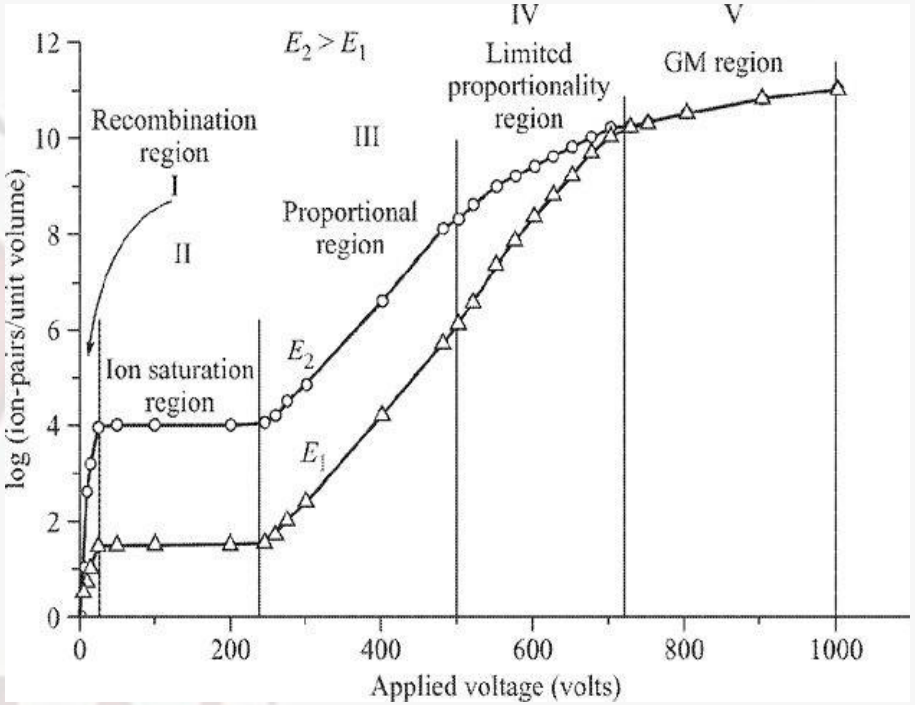
•The variation of the logarithm of the number of ion-pairs formed or pulse height, with applied voltage $V$ for a gas detector is sketched in Figure.

•Lower curve marked as $E_1$ is for less-energetic particles while the upper curve marked as $E_2$ is for higher energy particles entering the gas detector.

•In the diagram symbols (0 and V) are the measured values and line through the points is only a guide for the eye.

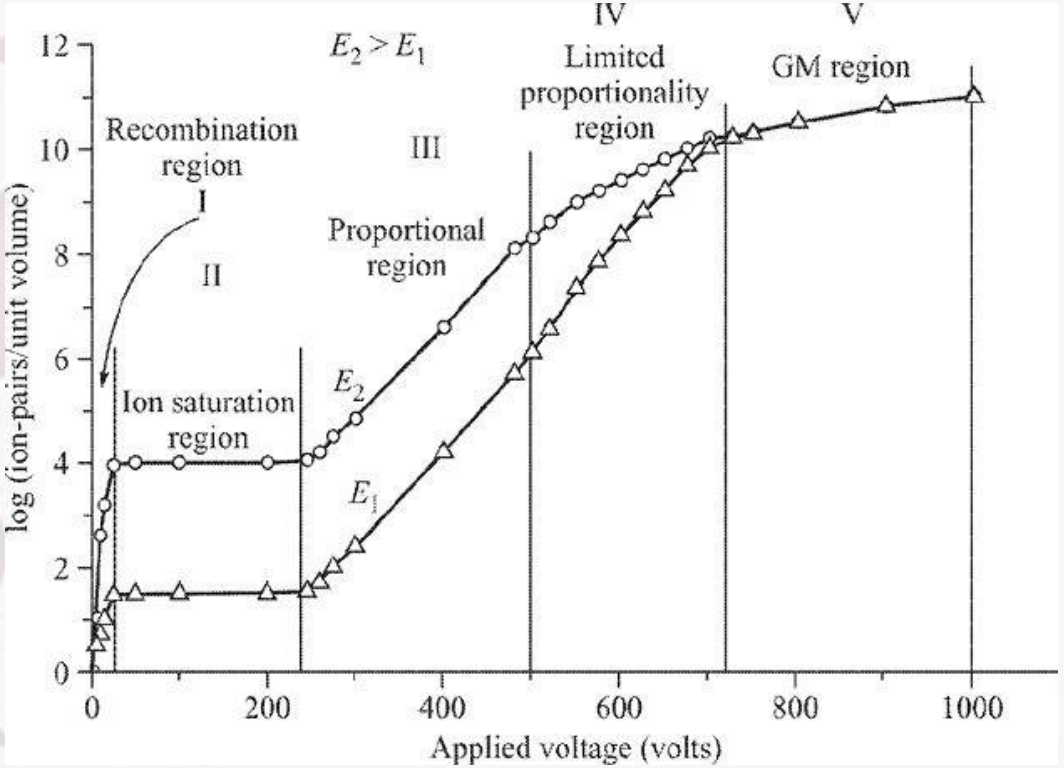
•Both these curves have been drawn when the pressure inside the chamber is about 0.5 torr (1 torr = 1 mm of Hg) and the spacing between anode and cathode is 5 mm.

•In this diagram there are five regions marked as I, II, III, IV and V.



# Working of Gas filled detector

In this diagram there are five regions marked as I, II, III, IV and V. Details of various regions are given below



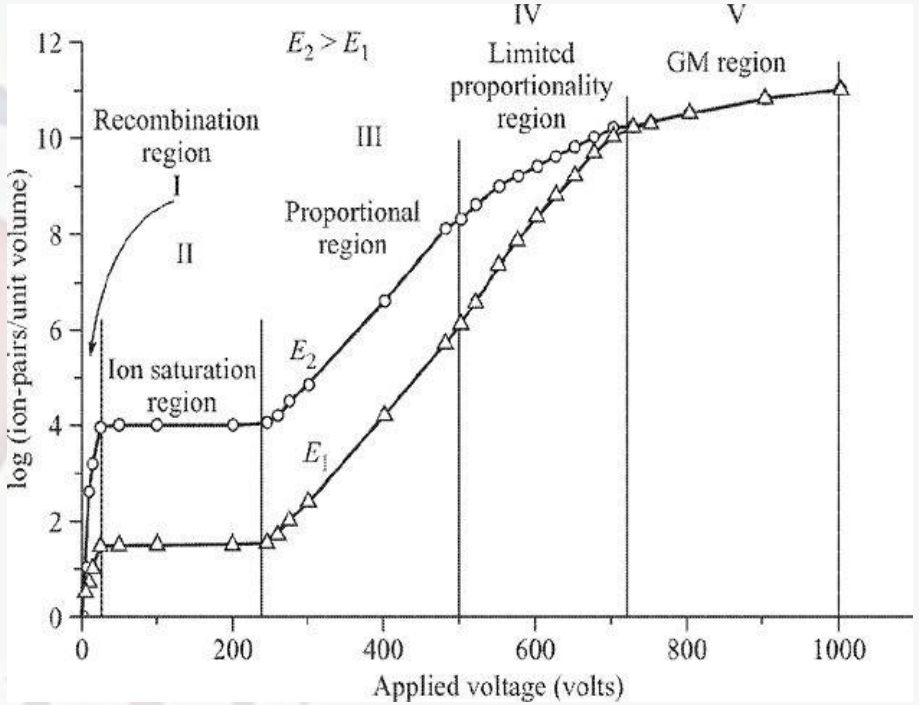

***Region* I (~0 V *to* ~30 V)**

- In this region, the applied voltage is not sufficient to overcome the recombination of ion-pairs formed (recombination region).
- As voltage is increased from 0 V to 30 V, more and more electrons start reaching the central anode
- Pulse height is increasing with applied voltage

# Working of Gas filled detector

***Region* II (~30 V *to* ~250 V)**

- In this region, the curves are almost flat which signifies the collection of all the ion-pairs formed initially.
- Depending upon the energy of incident radiation about $10^1$ to $10^4$ ion-pairs are formed in this region due to primary radiation
- All the ion pairs are collected by the respective electrodes resulting in flattening of the curve.




- This region is known as *ionization region* and detectors operating in this region are called *ionization chambers*.
- The output pulses produced are of low amplitude, of the order of few mV.

# Working of Gas filled detector

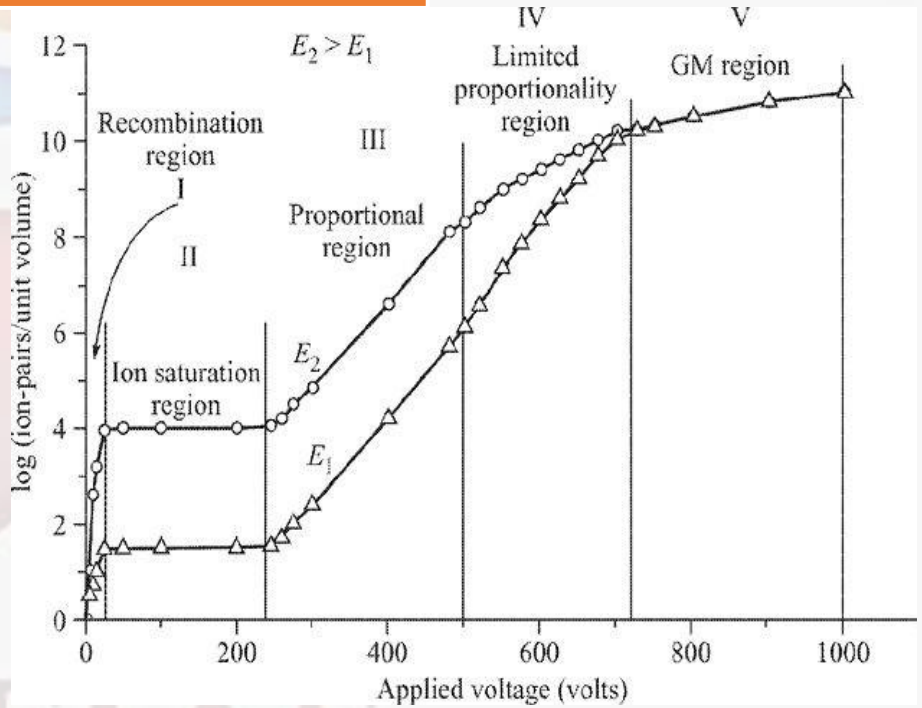
## *Region* III (~200 V *to* ~500 V)

• Production and collection of the ion-pairs increase rapidly with the applied voltage.

•This phenomenon is known as *gas multiplication.*

•So, as long as the curves remain approximately parallel, the charge collected is proportional to the amount of the charge produced in the initial event which in turn is proportional to the energy of the incident radiation.

•This region is known as *proportional region* and the detectors operating in this region are known as *proportional counters*.



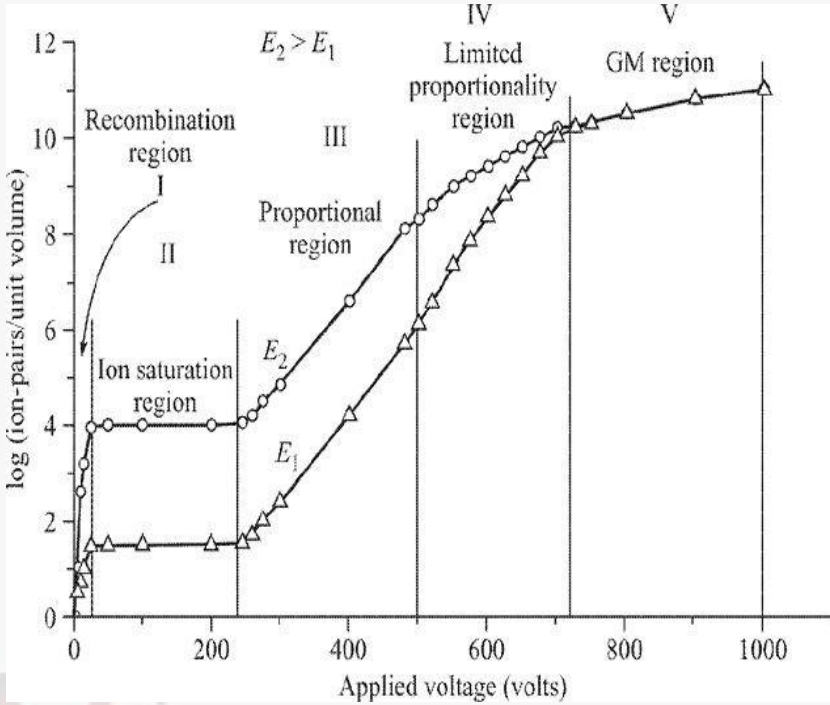
# Working of Gas filled detector

***Region* IV (~500 V *to* ~700 V)**

In this region, larger amount of ionization is produced, but with less discrimination between the ion-pairs due to two different energy radiations. This region is known as *region of limited proportionality* and generally no detector operates in this region.

***Region* V (~800 V *to* ~1000 V)**

In this voltage range, there is approximately flat region, also known as plateau and the number of ion-pairs formed per unit volume is ~109 to 1010. This number is independent of the amount of initial ionization. This region is known as Geiger–Müller region and detectors operating in this region are known as *Geiger–Müller counters* or simply *GM counters*.



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# Thank you