TYBSc [Semester-6] Physics

US06CPHY23 Nuclear Physics

UNIT- 4 Part 2 Lecture 3

Radiation Detectors

Radiation Detectors

- Gas filled detectors ✓
- Ionization chamber ✓
- Geiger-Mueller counter ✓
- Cloud chamber ✓
- **Bubble chamber**
- **Spark chamber**

Radiation Detectors

- Applications of detectors:

  - Presence or absence of radiations
  - Nature of radiation
  - Energy and momentum measurements
  - Spatial coordinates of the particle trajectories

Radiation Detectors

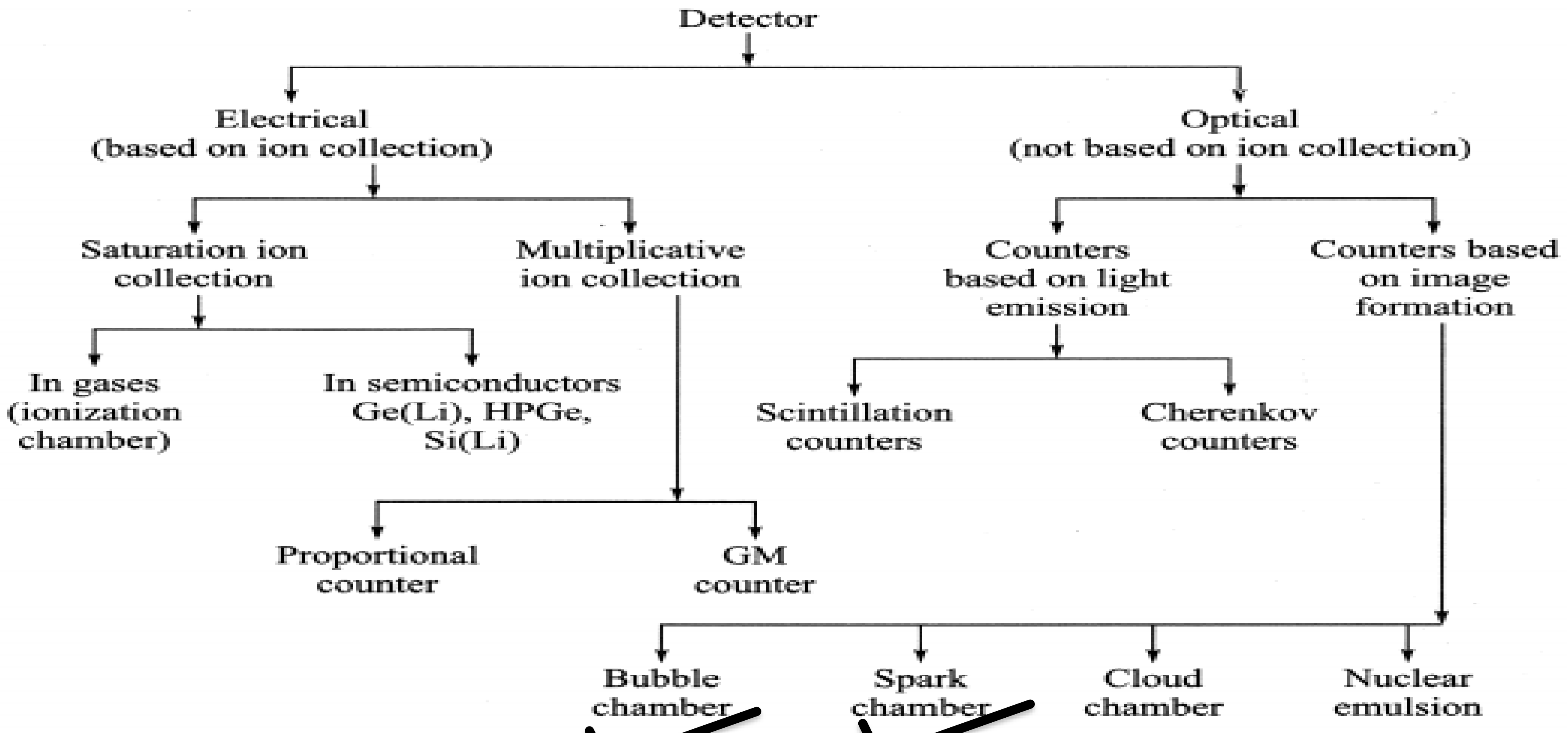


Figure 7.1 Classification of detectors according to signals produced.

7.5 GEIGER-MÜLLER (GM) COUNTERS

7.5.4 Main Uses

- It can detect even very small activities (due to large multiplication factor), these are extensively used for detecting ***X-rays***, ***β-particles***, ***α-particles***, etc.
- For ***γ -ray detection***, we require ***bigger size*** GM tubes.
- They are one of the cheapest kinds of nuclear radiation detectors.

7.5 GEIGER-MÜLLER (GM) COUNTERS

7.5.5 Main Drawback

- The major drawback of GM counters is that they cannot be used to measure the energy of radiations.

7.8 CLOUD CHAMBER

- It provides visual trajectory of a charged particle like electron, proton, α-particles, etc.
- Cloud chamber also known as ***Wilson Chamber*** was built by CTR Wilson in 1911.

7.8 CLOUD CHAMBER

7.8.1 Principle

- It is based on the principle that when dust-free air saturated with vapours of a liquid (like water, alcohol, ether, etc.) is allowed to expand adiabatically, supersaturation occurs.

7.8 CLOUD CHAMBER

7.8.1 Principle

- If at this stage an ionizing particle enters the chamber and creates ion-pairs, tiny droplets of liquid condense on these ions and form a visible track along the path of the ionizing radiation.
- These visible tracks can be photographed.

7.8 CLOUD CHAMBER

7.8.1 Principle

- In some cases, cloud chamber is subjected to a strong magnetic or electric field.
- Such a field causes the charged particles to travel in curved path. The curvature of the curved path gives information about the mass and charged of the ionization particle.

7.8 CLOUD CHAMBER

7.8.3 Working

- Air saturated with given liquid is taken in the space between the movable piston P and glass plate G.
- The pressure inside the chamber is kept high.

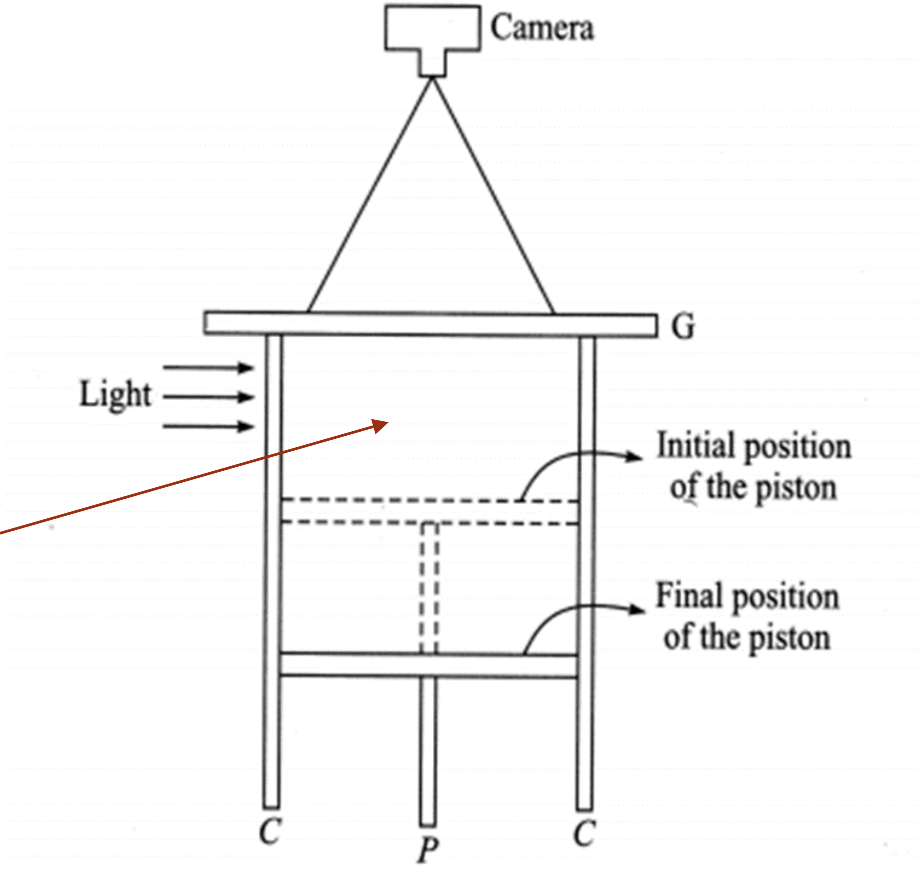


Figure 7.18 A simplified diagram of cloud chamber.

7.8 CLOUD CHAMBER

7.8.3 Working

- The pressure in the chamber is lowered by moving the piston down suddenly due to which the temperature of the saturated liquid falls and vapours become super saturated.

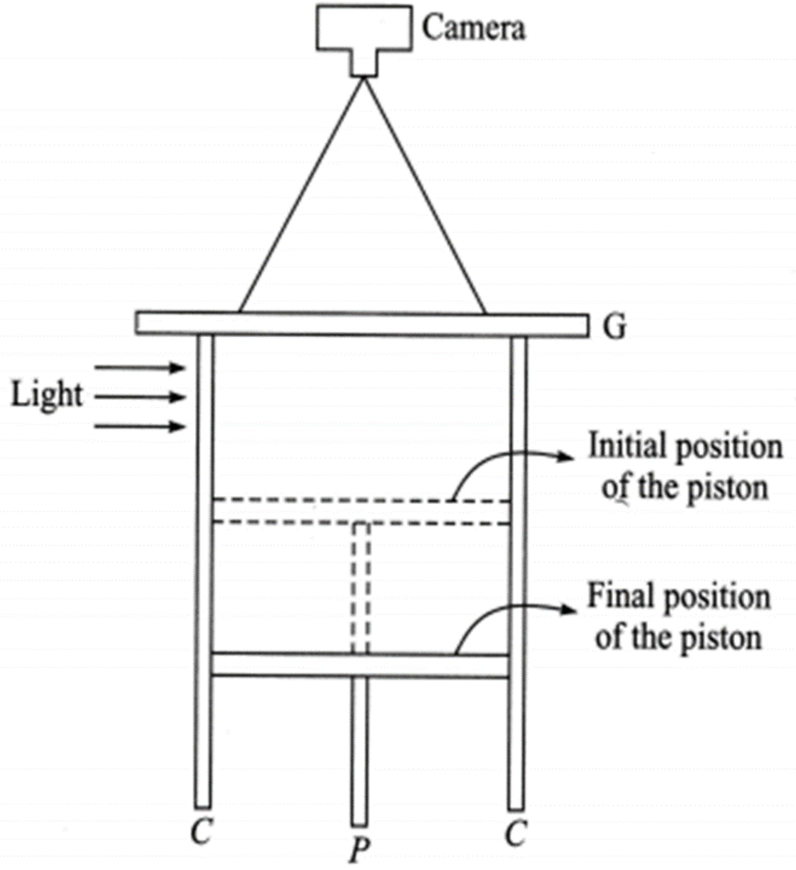


Figure 7.18 A simplified diagram of cloud chamber.

7.8 CLOUD CHAMBER

7.8.3 Working

- If at this moment, a charged particle passes through the chamber, it will produce ion-pairs.
- The supersaturated vapours condense on the ions and a trail of droplets along the path of the charged particle is seen.
- These tracks are known as ***cloud tracks***.

7.8 CLOUD CHAMBER

7.8.3 Working

- These tracks have distinctive shapes.
- for example,
- an **α-particle track** is broad and straight.
- an electron's trajectory is thinner and shows a zig-zag trajectory.

7.8 CLOUD CHAMBER

7.8.3 Working

- If the chamber is illuminated with light, a camera can take a photograph of the track, which appears as a white line on a dark background.
- When a vertical magnetic field is applied, positively and negatively charged particles curve in opposite directions.

7.8 CLOUD CHAMBER

7.8.4 Advantages (1)

When subjected to electric or magnetic field, cloud chamber is used to find charge on the ionizing particles and their momentum.

7.8.4 Advantages (2)

With cloud chamber, the range of high energy particles can easily be determined.

7.8 CLOUD CHAMBER

7.8.4 Advantages (3)

By seeing the broadness of a cloud track, we can immediately get an idea whether the track is due to heavy particle (like α-particle) or light particle (like electron).

7.8 CLOUD CHAMBER

7.8.5 Limitations (1)

If the energy of the ionizing particle is high, it may not completely stop in the cloud chamber and may come out of the chamber. So, we will not get full information about the particle.

7.8 CLOUD CHAMBER

7.8.5 Limitations (2)

The recovery time of the cloud chamber is relatively very long 10-60 seconds after the expansion, so it may miss many ionizing particles.

7.9 BUBBLE CHAMBER

7.9 BUBBLE CHAMBER

- The basic drawback of cloud chamber is that because of the low density of the gas, it is not possible to observe high energy particles.

- In 1952, D.A. Glaser at the University of Michigan, conceived the idea of using superheated liquid to display the tracks of ionizing particles, just as a cloud chamber utilizes a supersaturated vapour.

7.9 BUBBLE CHAMBER

- The instrument based on this concept is known as a ***Bubble Chamber***, because the tracks in bubble chamber consist of a series of closely spaced bubbles, whereas in a cloud chamber there are tiny droplets of the liquid.

7.9 BUBBLE CHAMBER

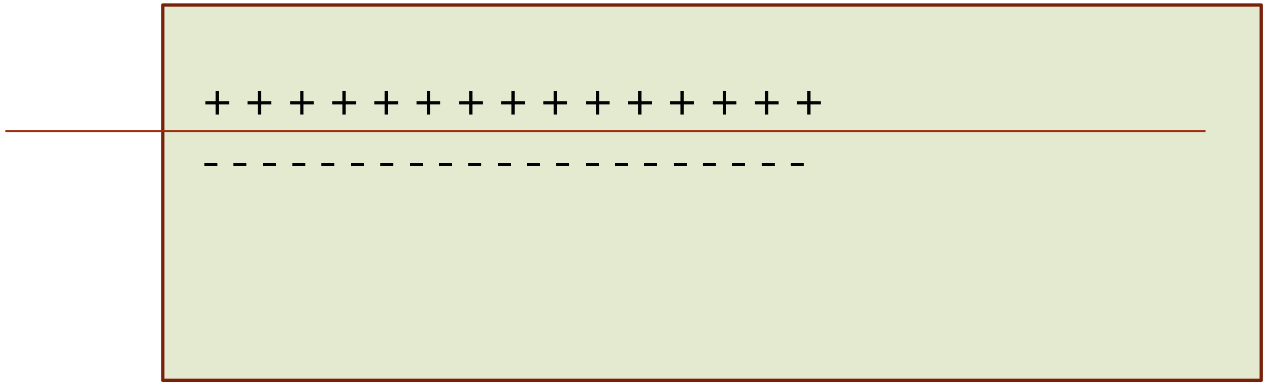
7.9.1 Principle

- It is based on the principle that under high pressure it is possible to heat a liquid without bubble formation well above its normal boiling point.
- If suddenly pressure is released, the liquid remains in a superheated state for some time.

7.9 BUBBLE CHAMBER

7.9.1 Principle

- If such a superheated liquid is exposed to ionizing particles, the ionizing particles produce ion-pairs and these ions act as condensation centres for the formation of vapour bubbles along the path of the particle.



7.9 BUBBLE CHAMBER

7.9.2 Construction

- The schematic diagram of the bubble chamber is shown in Figure 7.19.

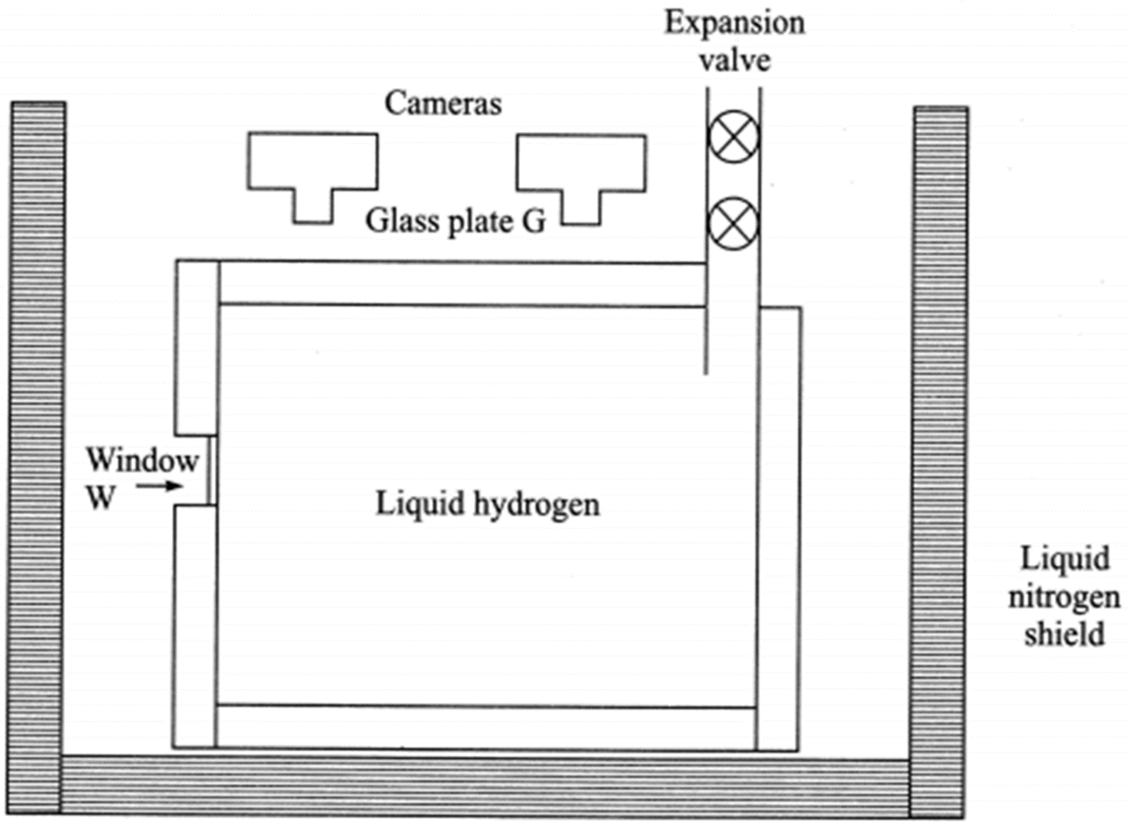


Figure 7.19 A schematic diagram of bubble chamber.

7.9 BUBBLE CHAMBER

7.9.2 Construction

- The main body of the chamber is made up of stainless steel with thick glass ports at the top for a viewing camera.

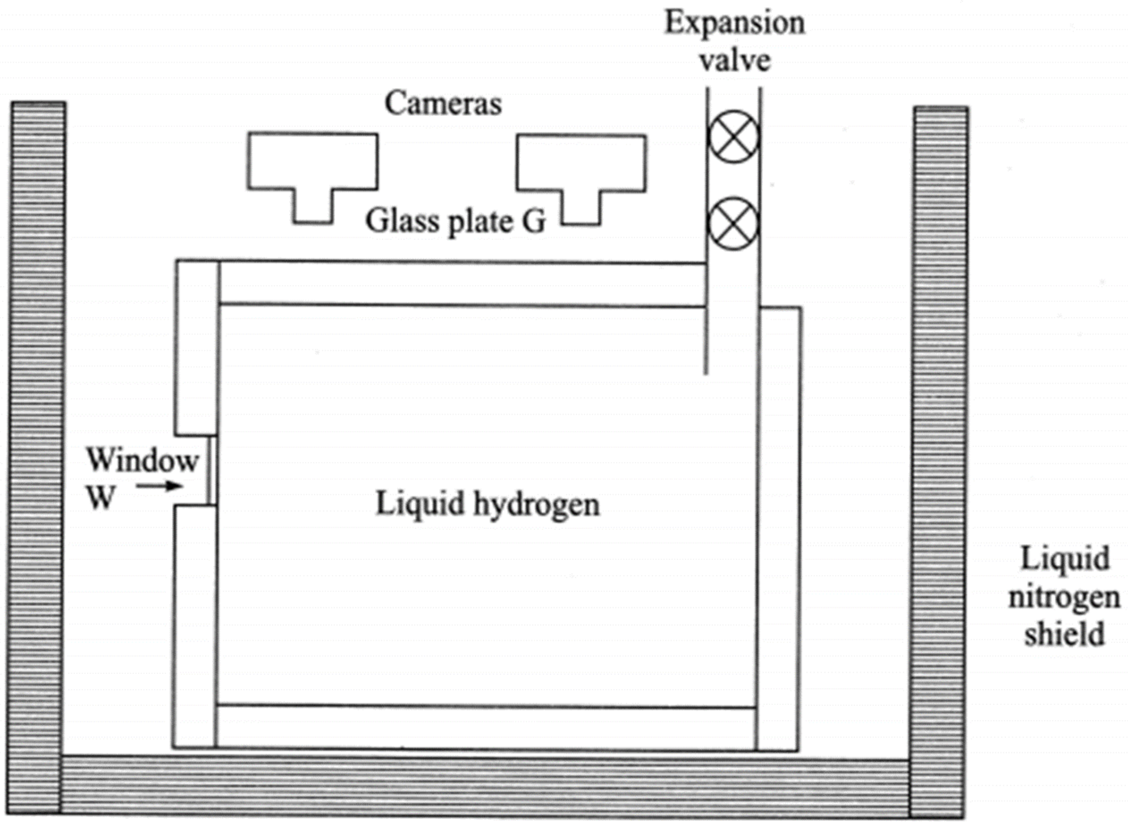


Figure 7.19 A schematic diagram of bubble chamber.

7.9 BUBBLE CHAMBER

7.9.2 Construction

- A box of thick-walled glass is filled with liquid hydrogen and is connected to the expansion pressure system.

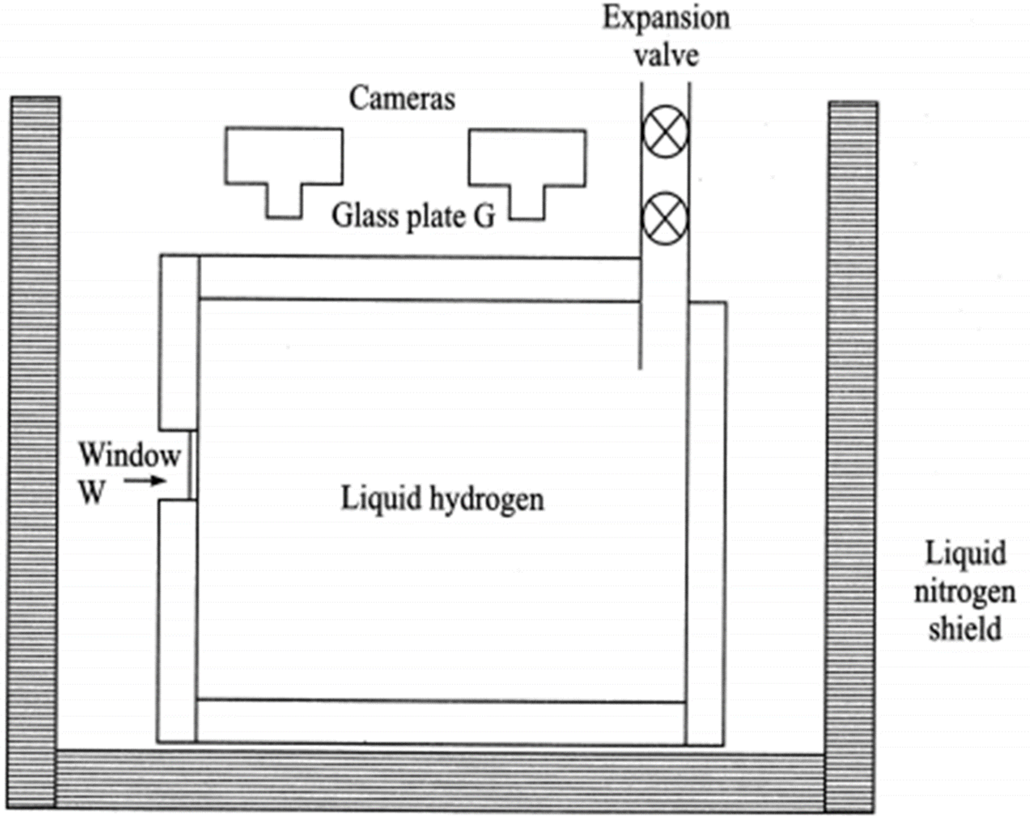


Figure 7.19 A schematic diagram of bubble chamber.

7.9 BUBBLE CHAMBER

7.9.2 Construction

- In order to maintain the chamber at constant temperature, it is surrounded by liquid nitrogen.

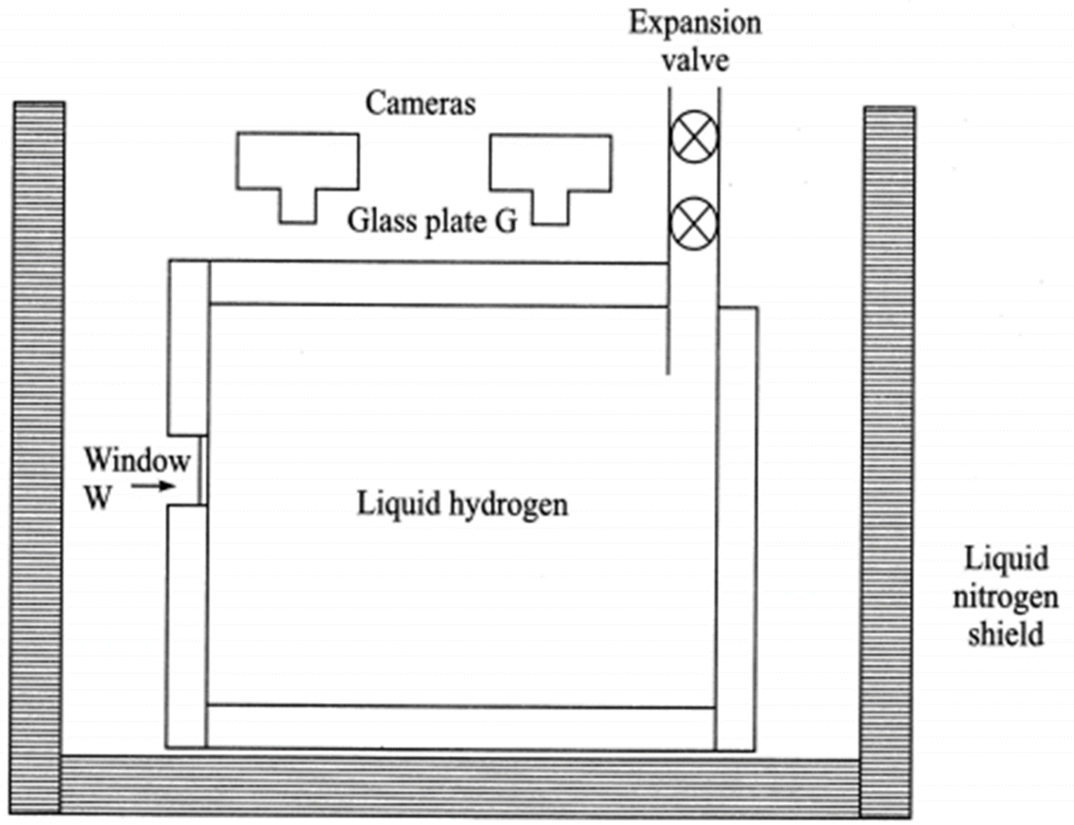


Figure 7.19 A schematic diagram of bubble chamber.

7.9 BUBBLE CHAMBER

7.9.2 Construction

- High energy particles are allowed to enter the chamber from a side window W

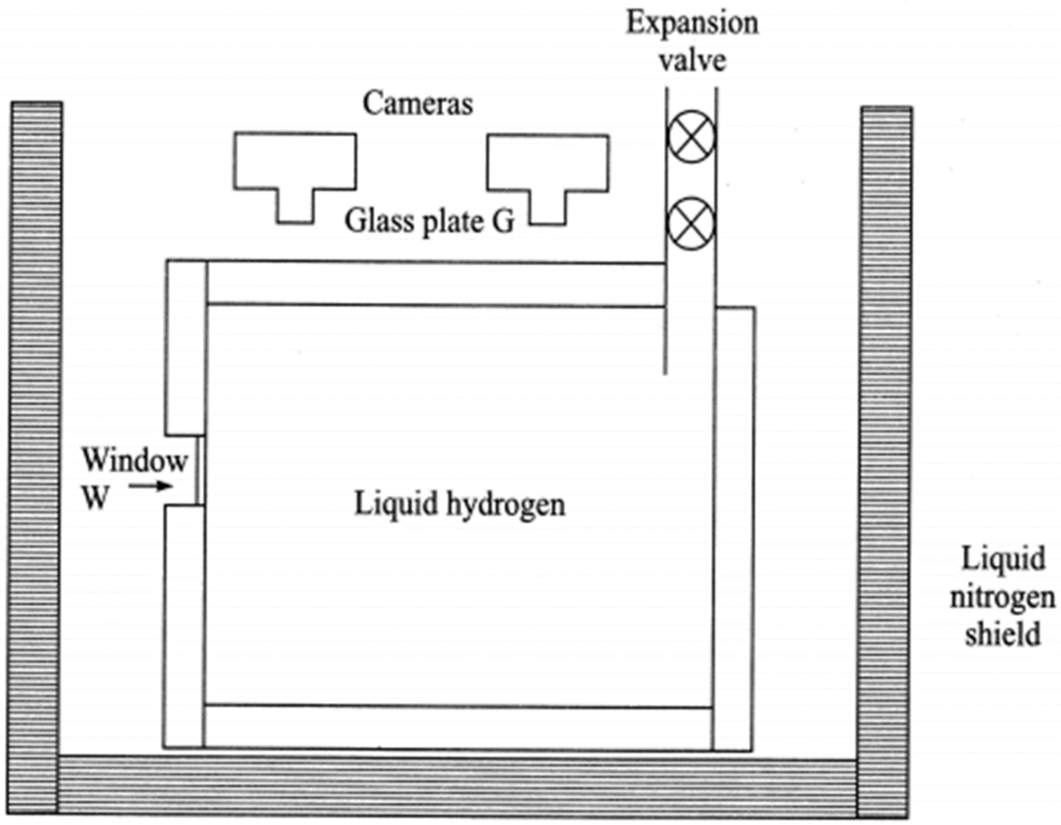


Figure 7.19 A schematic diagram of bubble chamber.

7.9 BUBBLE CHAMBER

7.9.3 Working

- Initially, the liquid hydrogen is kept under high pressure, but when a charged particle is passing through it, the pressure is released so that the liquid is in superheated state.

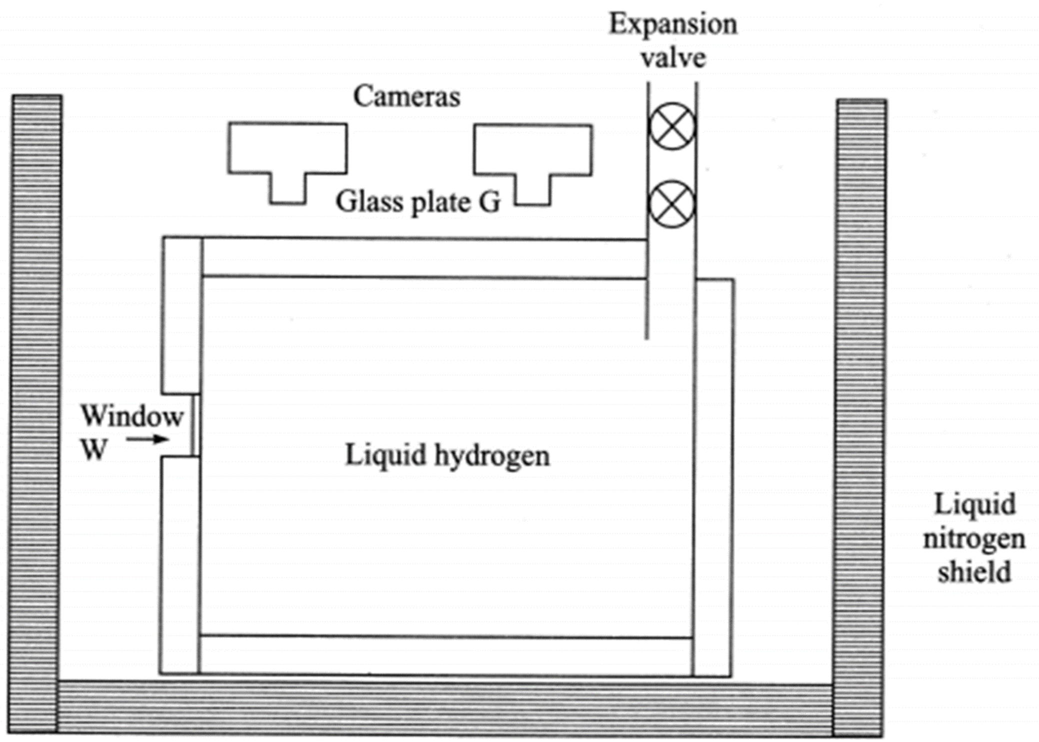
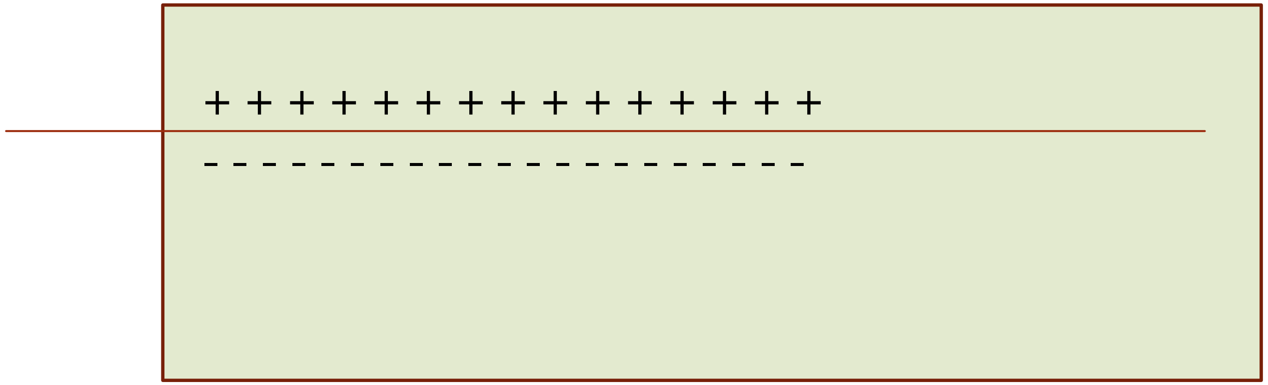


Figure 7.19 A schematic diagram of bubble chamber.

7.9 BUBBLE CHAMBER

7.9.3 Working

- The liquid vapours get condensed in the form of bubbles on the ions formed by ionizing particle and photographs of the tracks formed are obtained by the cameras.



7.9 BUBBLE CHAMBER

7.9.3 Working

- Generally, bubble chamber is subjected to a strong magnetic field in order to distinguish the sign of the charge on the ionizing particles and to measure their momenta from the radius of curvature of the bubble tracks.

- $B\,q\,v = m\,v^2/r \Rightarrow B\,q\,r = m\,v$

7.9 BUBBLE CHAMBER

7.9.3 Working

- The **most commonly used liquid** in bubble chamber is **liquid hydrogen.**

- It may be used other liquids such as deuterium, helium, xenon, propane, pentane, etc. in some cases.

7.9 BUBBLE CHAMBER

7.9.4 Advantages (1)

Due to high density of the liquid, even high energy cosmic rays can also be recorded in bubble chamber.

7.9 BUBBLE CHAMBER

7.9.4 Advantages (2)

The bubble chamber is sensitive to both high- and low-ionizing particles.

7.9 BUBBLE CHAMBER

7.9.4 Advantages (3)

As bubbles grow rapidly, the tracks formed in bubble chamber are clean and undistorted.

7.9 BUBBLE CHAMBER

7.9.5 Limitations (1)

The time during which bubble chamber is sensitive is only few milliseconds, the entry of ionizing particles and photographing the tracks formed must take place during this short time.

7.9.5 Limitations (2)

Bubble chambers are the costliest detectors.

7.10 SPARK CHAMBER

7.10 SPARK CHAMBER

It is also an image-forming detector. The details of a spark chamber are as under.

Ref: ep.ph.bham.ac.uk

7.10 SPARK CHAMBER

7.10.1 Principle

- A high voltage is maintained between two parallel plate electrodes in a gas.
- However, the electric field between the plates is not strong enough to permit the passage of spark.

7.10 SPARK CHAMBER

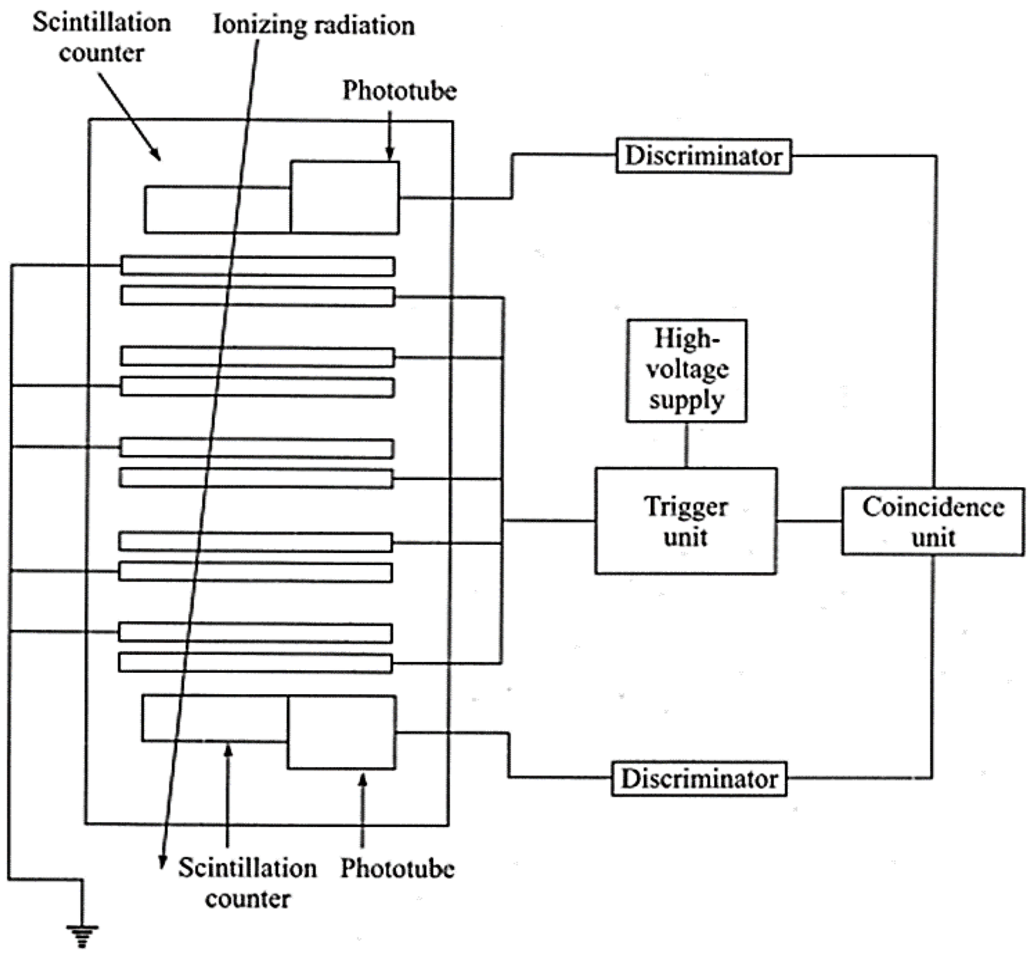
7.10.1 Principle

- Now, if an ionizing particle enters the gas, it ionizes the gas atoms creating ion-pairs along its trajectory.
- This provides a low-resistance path and due to high voltage across the electrodes a spark takes place along the trajectory followed by the ionizing particle

7.10 SPARK CHAMBER

7.10.2 Construction

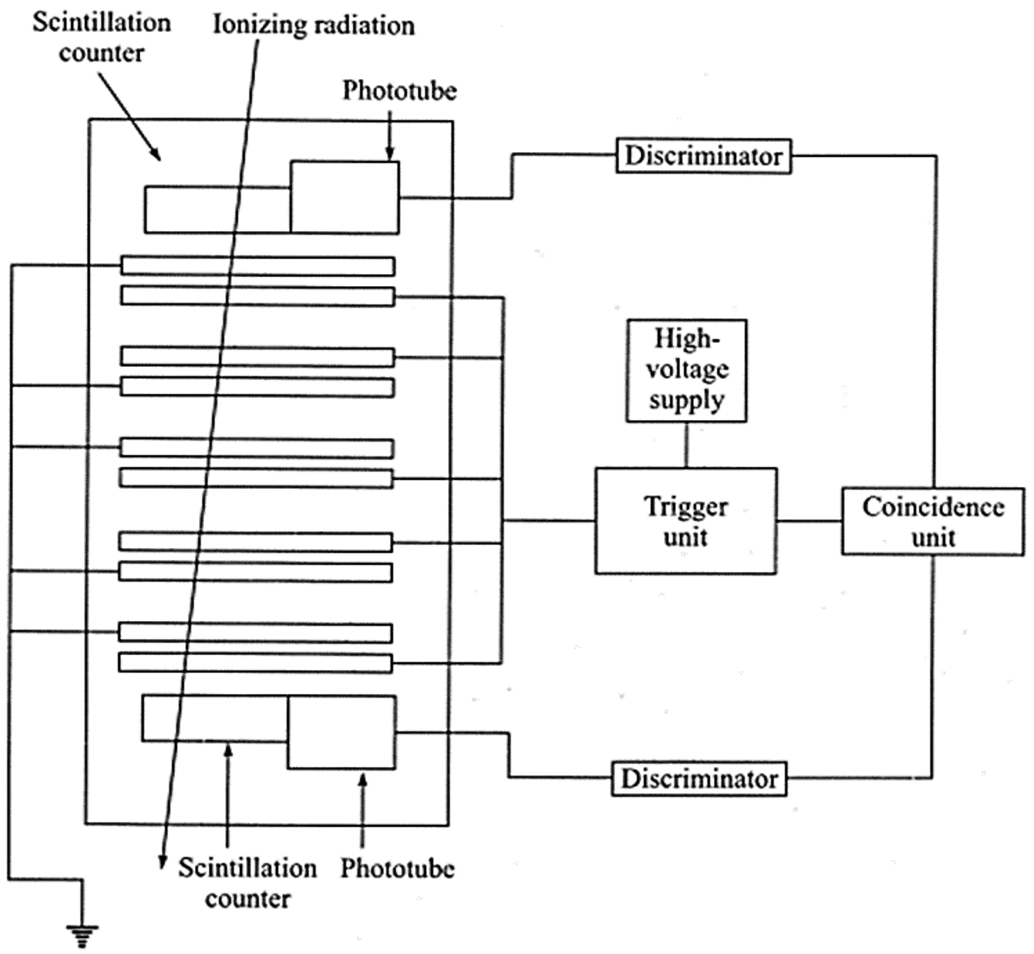
- Spark chamber consists of parallel plates of conducting material like aluminium, etc. spaced from about 0.2 cm to 3 cm apart.



7.10 SPARK CHAMBER

7.10.2 Construction

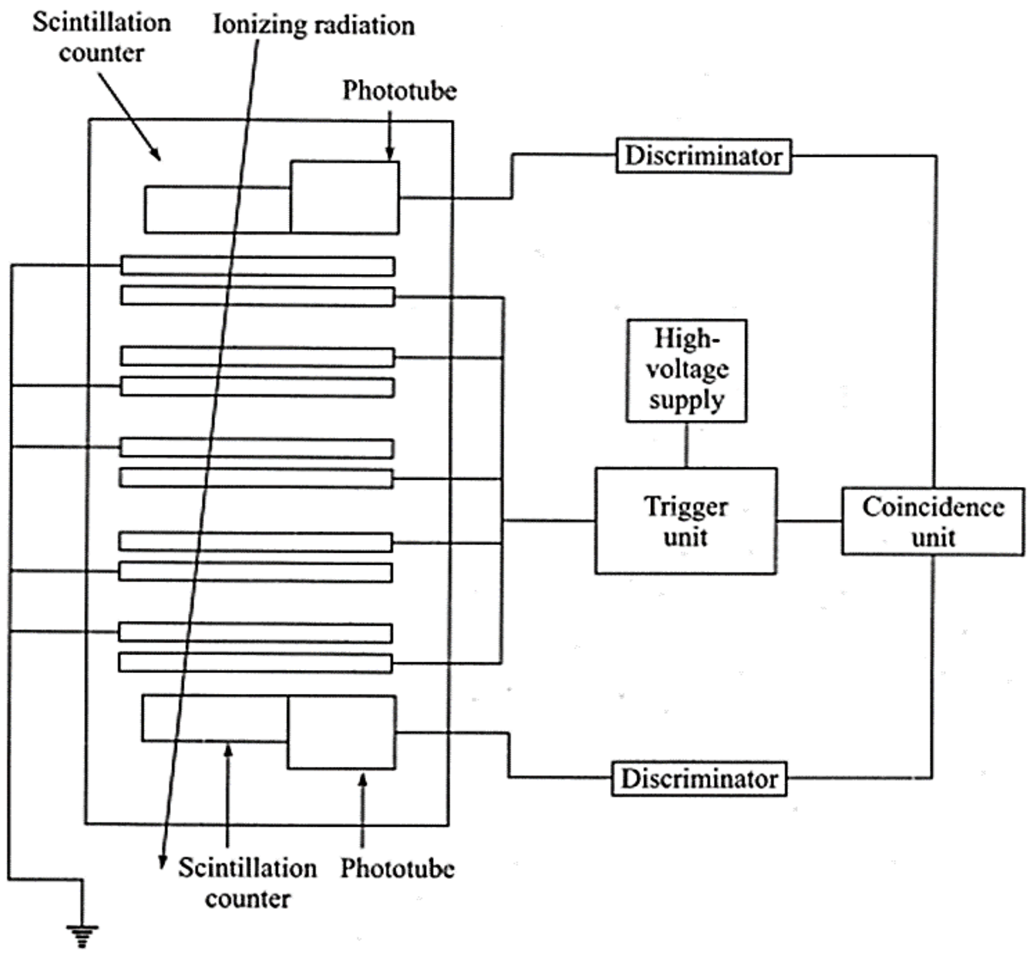
- The number of plates may range from a few to a hundred or more depending upon the nature and purpose of the experiment.



7.10 SPARK CHAMBER

7.10.2 Construction

- The size of plates can be as large as several square feet in area.



7.10 SPARK CHAMBER

7.10.2 Construction

- Alternate plates are connected to a high voltage direct pulse generator so that electric field of the order of 10,000 to 15, 000 volts/cm can be applied between adjacent pair of plates.
- The spark chamber is generally filled with neon or argon or a mixture of 90% neon and 10% helium.

7.10 SPARK CHAMBER

It is also an image-forming detector. The details of a spark chamber are as under.

Ref: ep.ph.bham.ac.uk

7.10 SPARK CHAMBER

7.10.3 Working

- When a high energy particle enters the spark chamber, the scintillation detector outside the chamber sends a pulse to the high-voltage pulse generator, which in turn sends a high-voltage pulse to the spark chamber plates.

7.10 SPARK CHAMBER

7.10.3 Working

- When a high energy charged particle passes through the chamber, it produces large number of ion-pairs along its path.

7.10 SPARK CHAMBER

7.10.3 Working

- A visible spark jumps along the path of the ionizing particle between two plates. Camera records the visible track of the particle.

7.10 SPARK CHAMBER

7.10.4 Advantages

1. It is capable of fast operations.

2. It provides good definition of direction of the ionizing particles.

3. It is relatively cheaper compared to bubble and cloud chambers.

7.10 SPARK CHAMBER

7.10.5 Limitation

Spark scatter 15 to 20 thousandths of an inch, and the path uncertainty increases as the path of the particle becomes parallel to the plates.

Thanks