# PARTICLE DETECTORS

**Class:** M. Sc. Physics, Semester IV

**Subject:** Nuclear and Particle Physics

**Unit:** III

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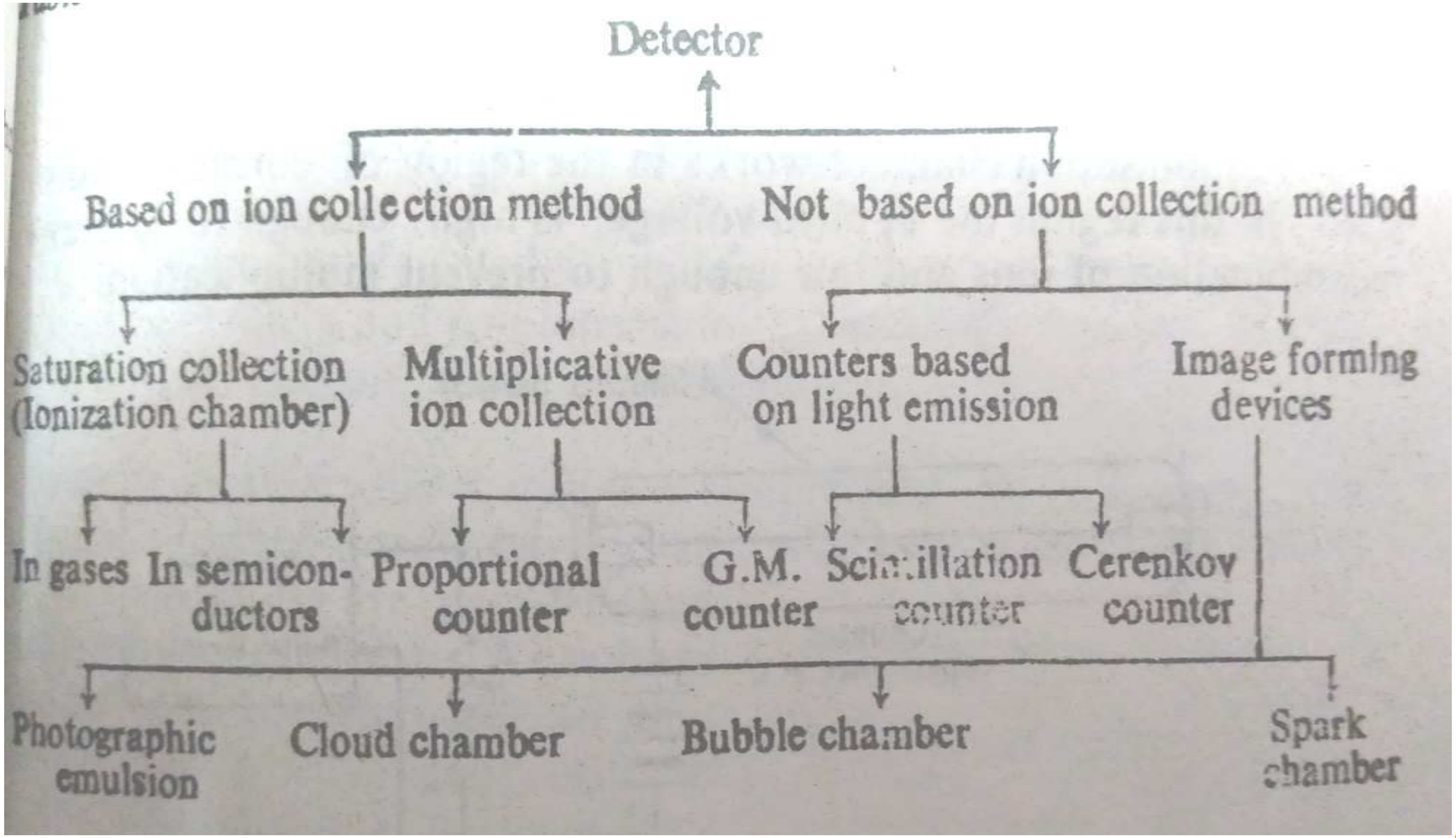
A particle detector, also known as a radiation detector, is a device used to detect, track, and/or identify ionizing particles, such as those produced by nuclear decay, cosmic radiation, or reactions in a particle accelerator. Detectors can measure the particle energy and other attributes to energy such as momentum, spin, charge or particle type, in addition to merely registering the presence of the particle.

Image credit: https://en.m.wikipedia.org/wiki/Particle_detector#/

# A PERFECT DETECTOR MIGHT HAVE THE FOLLOWING CHARACTERISTICS

- 100 percent detection efficiency
- high-speed counting and timing ability
- good energy resolution
- linearity of response
- application to virtually to all types of particles and radiations
- large dynamic range
- virtually no limit to the highest energy detectable
- reasonably large solid angles of acceptance
- discrimination between types of particles
- directional information
- low background, and
- picturization of the event.

# TYPES OF PARTICLE DETECTORS



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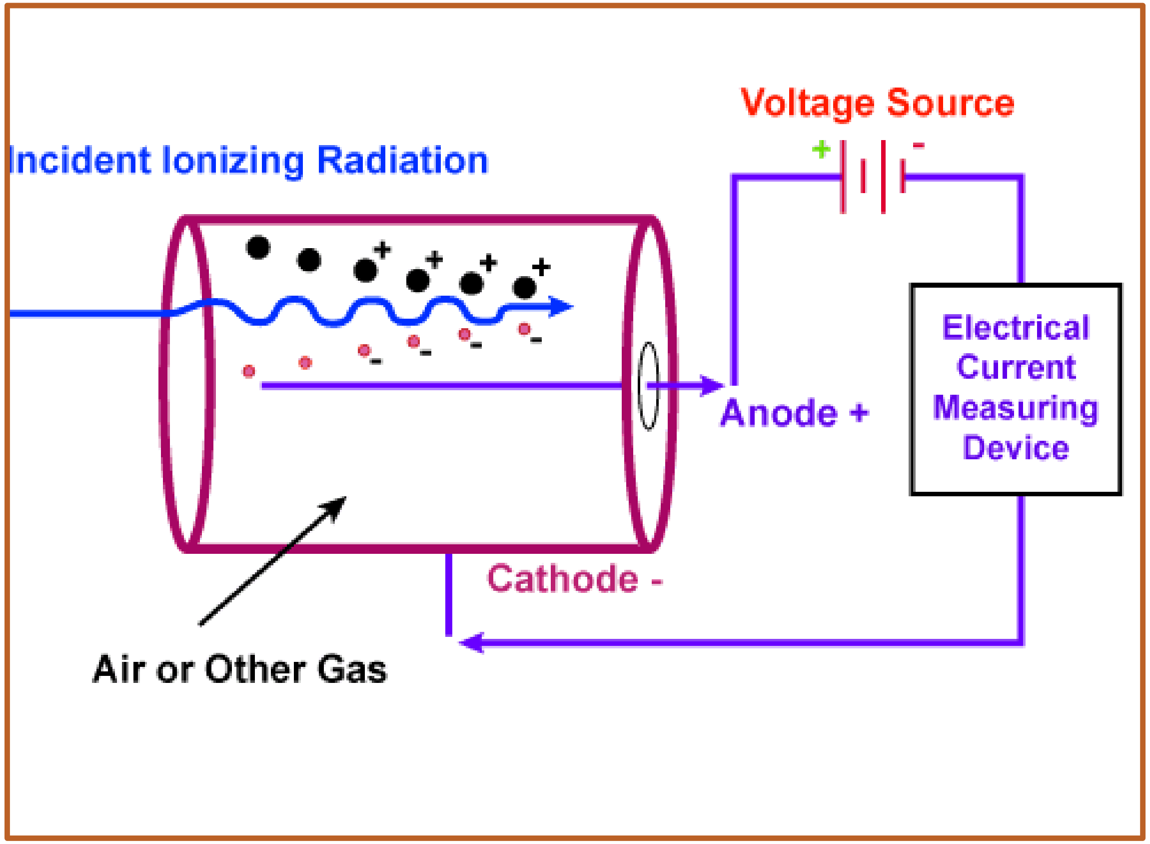
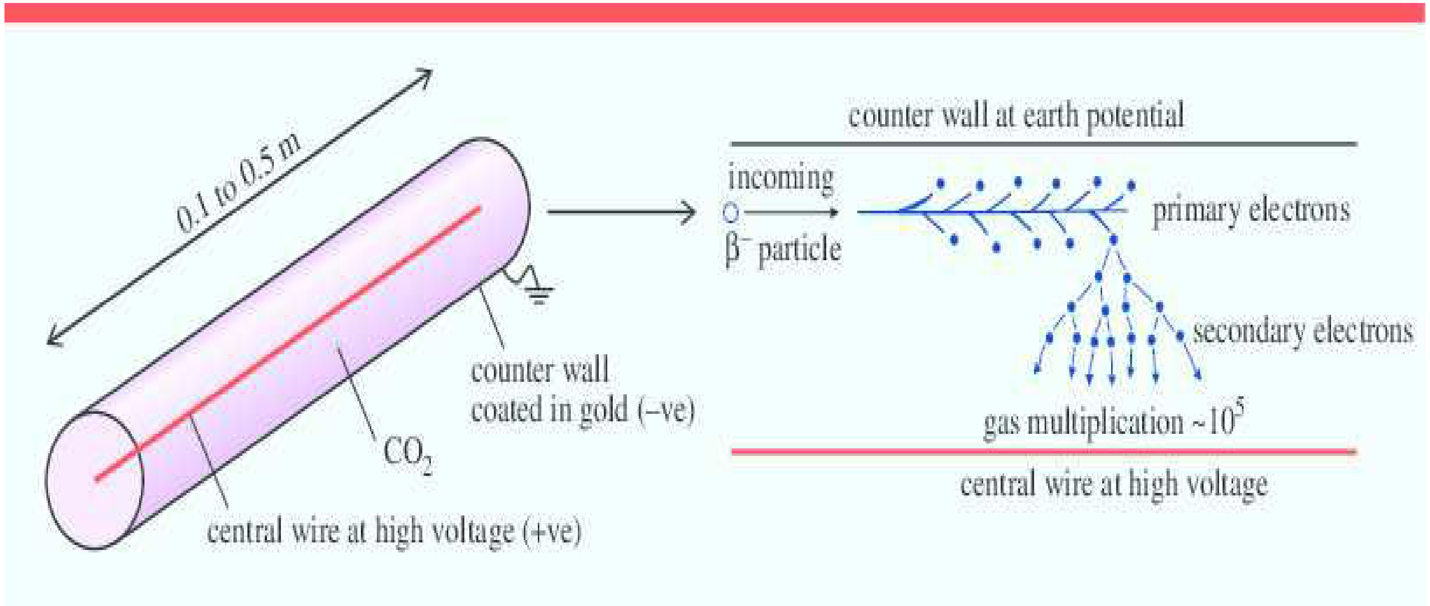
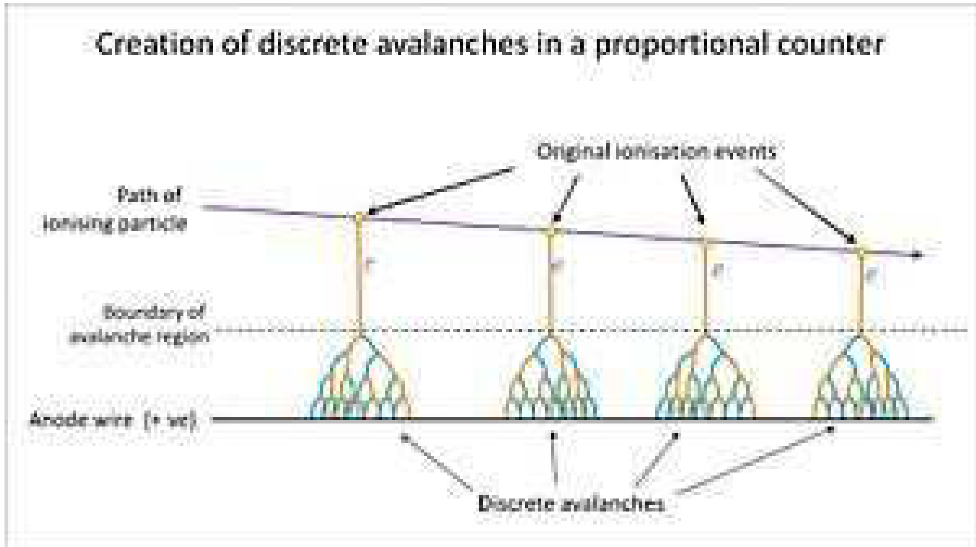
# Ionization chamber



# PROPORTIONAL COUNTER

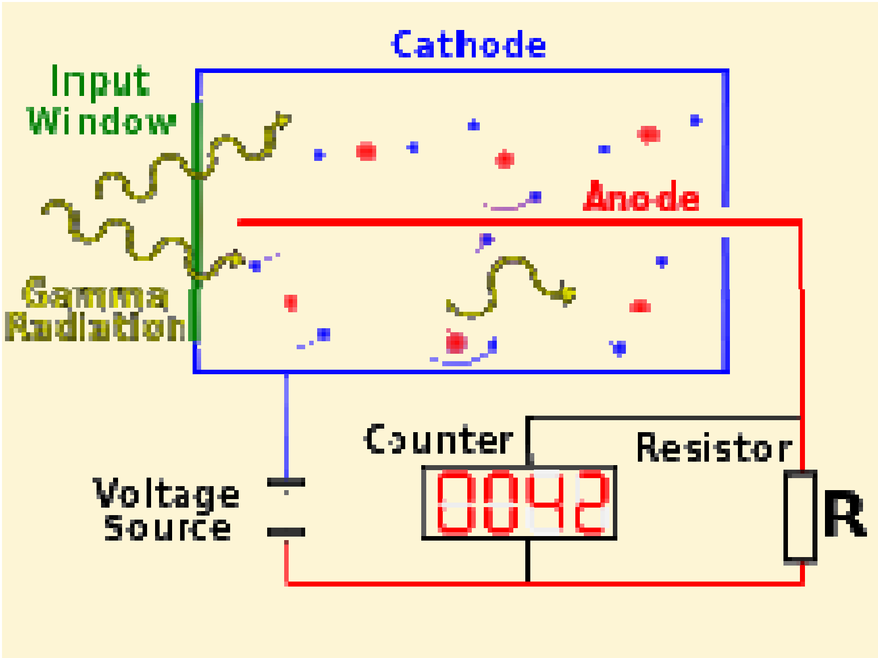
- When a particle of low ionization power passes through ionization chamber, the pulse produced will be too small to be detected.
- When the applied voltage is increased in the chamber, it start working in proportional region
- Gas filled detector based on the ion collection method
- Contains cylindrical metallic tube filled with argon + methane gas in 9:1 ratio at atmospheric pressure
- Central tungsten wire acts as Anode
- Metallic cylinder acts as cathode
- A pulse amplifier is connected in ckt.


0.1 to 0.5 m
counter wall
coated in gold (–ve)
$CO_2$
central wire at high voltage (+ve)
counter wall at earth potential
incoming
$\beta^-$ particle
primary electrons
secondary electrons
gas multiplication ~$10^5$
central wire at high voltage


Creation of discrete avalanches in a proportional counter
Original ionisation events
Path of
ionising particle
Boundary of
avalanche region
Anode wire (+ ve)
Discrete avalanches

## GEIGER-MULLER COUNTER

- G-M tube 1cm to 100 cm long and up to 10cm in diameter
- Metallic cylinder fixed inside the tube
- Central wire usually of Tungsten with thickness about 300 μm
- Metal tube is well insulated from central wire
- Tube is filled with 90% Argon and 10% alcohol at pressure about 10cm of Hg
- Applied voltage is about 1000V
- External circuit contain a high leak resistance R



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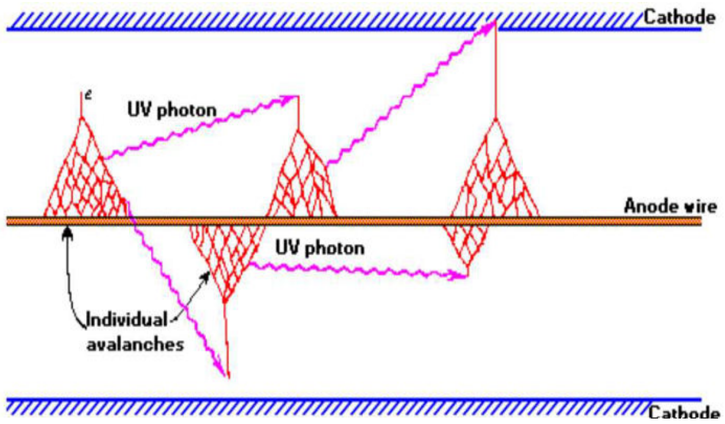
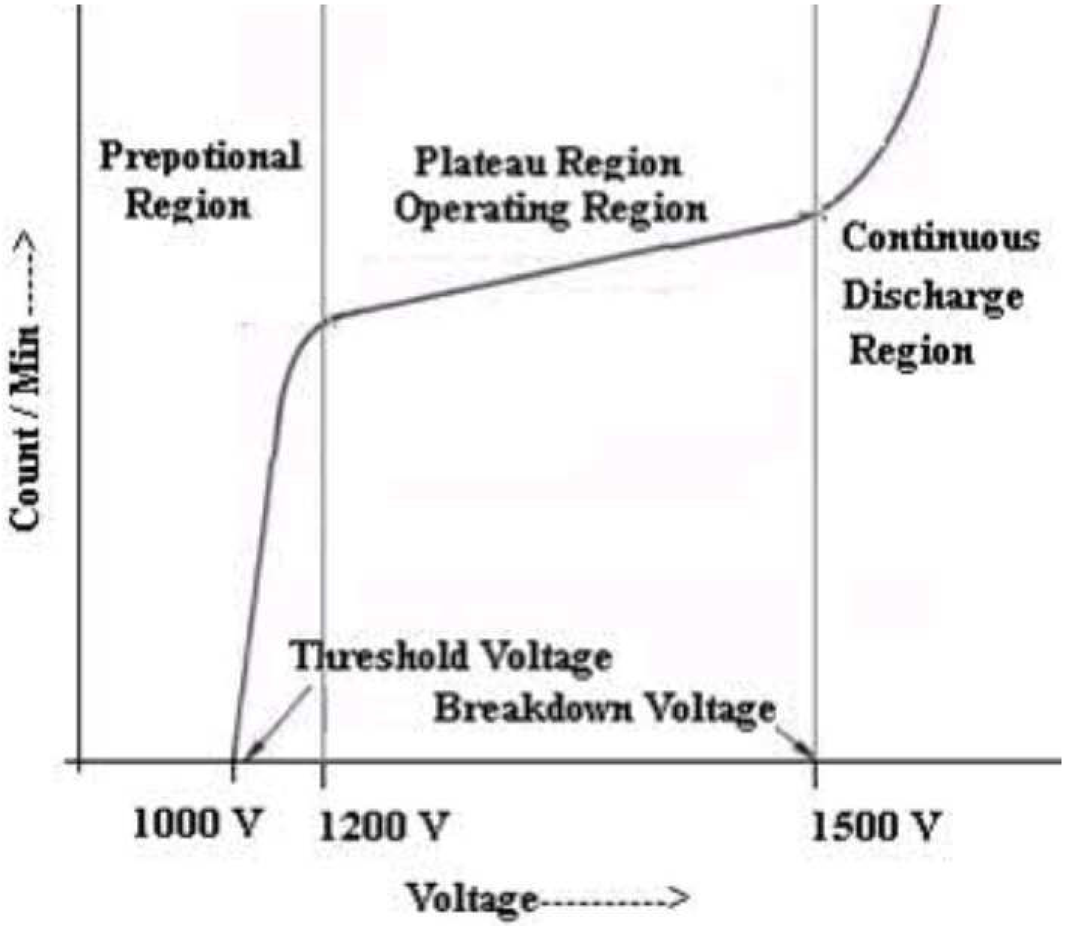
# G-M COUNTER : WORKING

- Incident radiation create electron –ion pair
- Electrons drift towards positive electrode and ion towards negative electrode
- If electrons have sufficient energy, it produce additional ionization by collision with molecules of gas
- Electrons raise some atoms to excited state followed by UV radiation
- These radiations produce a new avalanche.
- Thus avalanche spread over the length of anode wire




- As compared with electrons , ions move slowly , and form a sheath around anode
- Which decreases the electric field below $V_G$ and no further pulse will be detected. Conuter become inoperative.

# G-M COUNTER : CHARACTERISTICS



# G-M COUNTER : TERMINOLOGIES

- Quenching: The process to suppress the continuous avalanche in order to allow G-M counter to detect fresh event .
- Dead time: The time during which counter becomes inoperative due to presence of ion sheath around anode wire( about 200µ sec).
- Recovery time: After dead time , counter start recoding pulse of small
- Resolving time: Dead time + recovery time .It is equal to the time taken by ions to reach cathode.
- Paralysis time: High counting rate is generally reduced by reducing the high potential supply to counter for a definite time

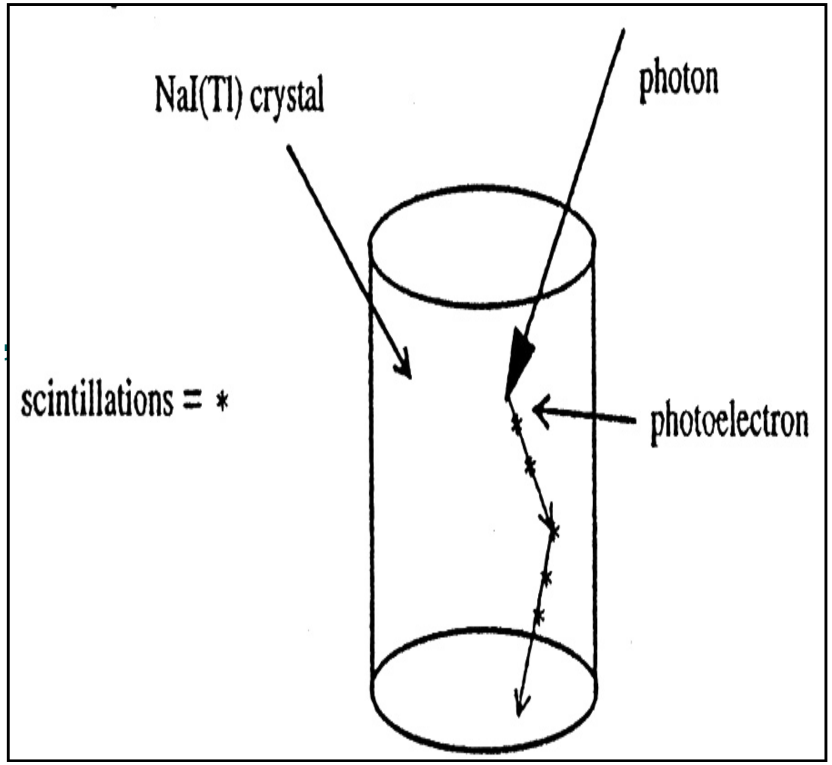
# Gas detectors

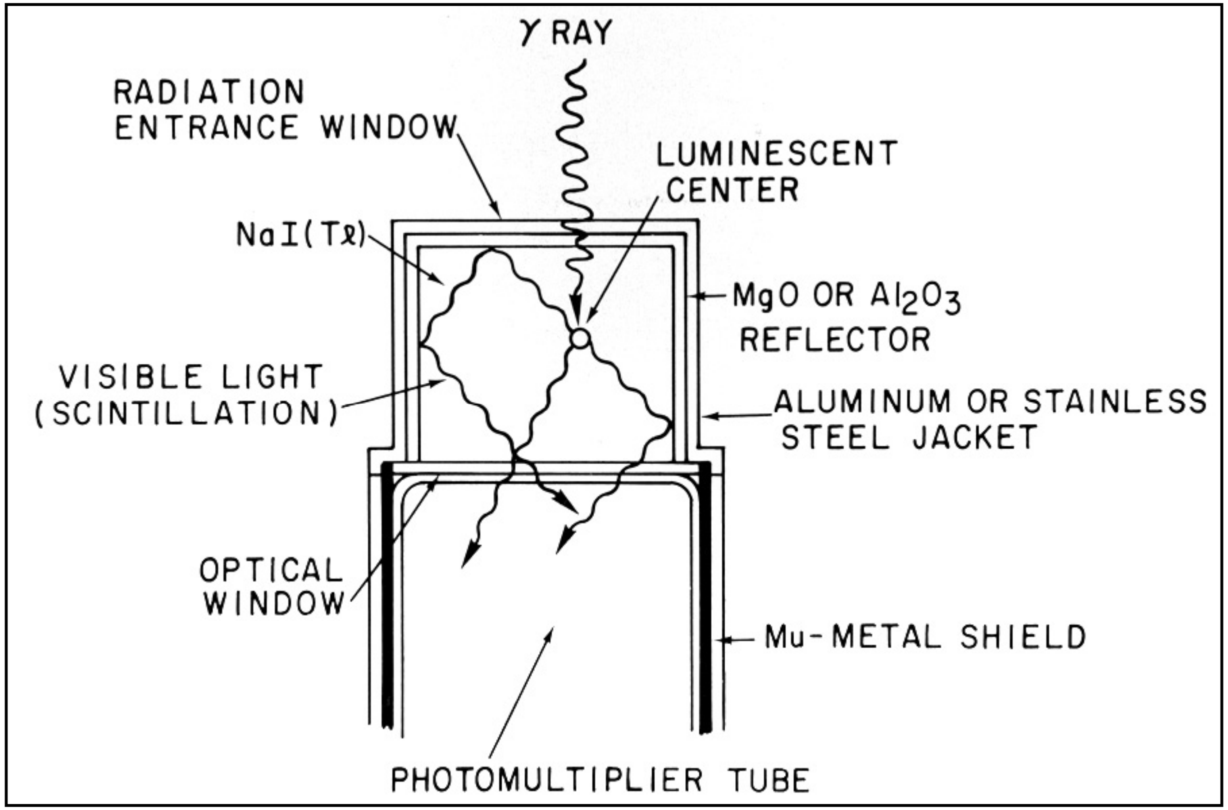
- Ionization chamber has relatively low sensitivity, good for high radiation fields, has energy info.
- Proportional counter as neutron detector with $BF_3$ as filling gas (slow neutrons undergo n-alpha reaction). Has energy info.
- GM has large dead time (~100 micro-sec), saturation in high radiation field, very sensitive, no energy info.

# Scintillation detector

Mainly contain following parts

- Phosphors (NaI(Tl), CsF, BGO, LSO)
- Photomultiplier Tube (PMT)
  - dynodes, counting chain, spectra
- Liquid Scintillation Counting ("wipes")

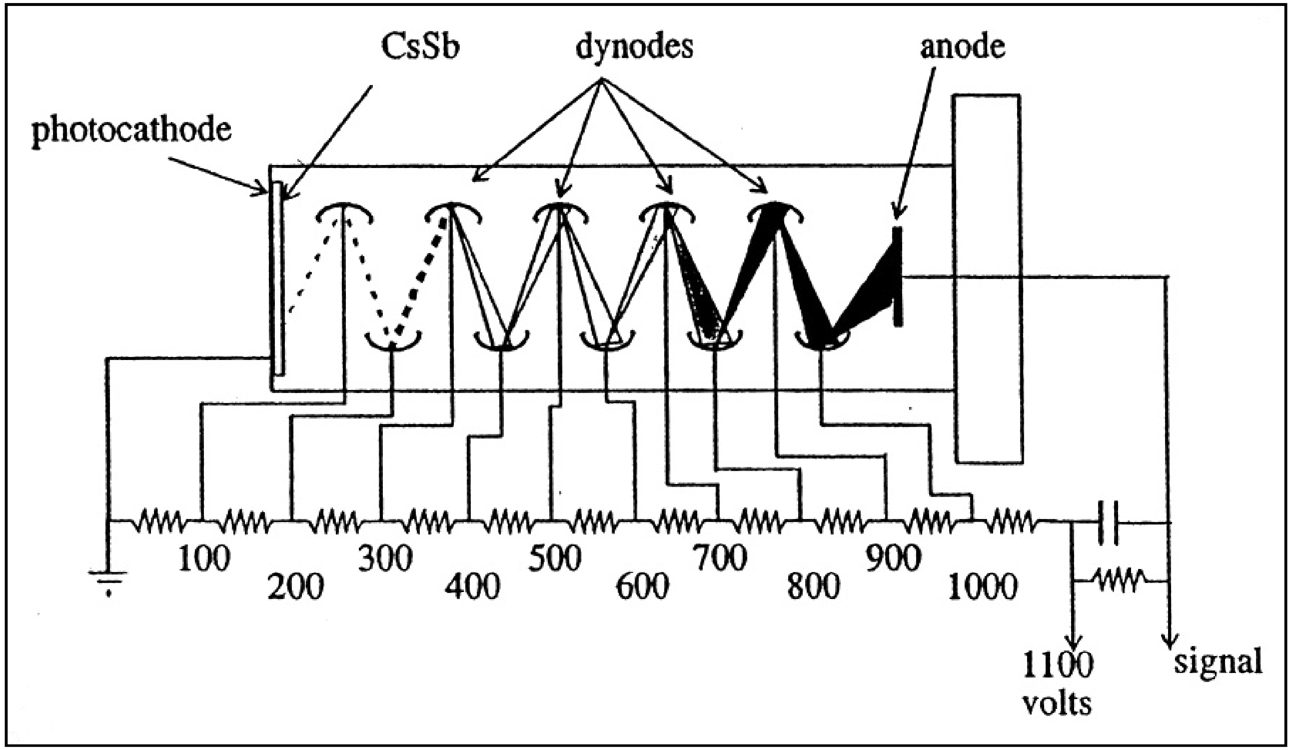


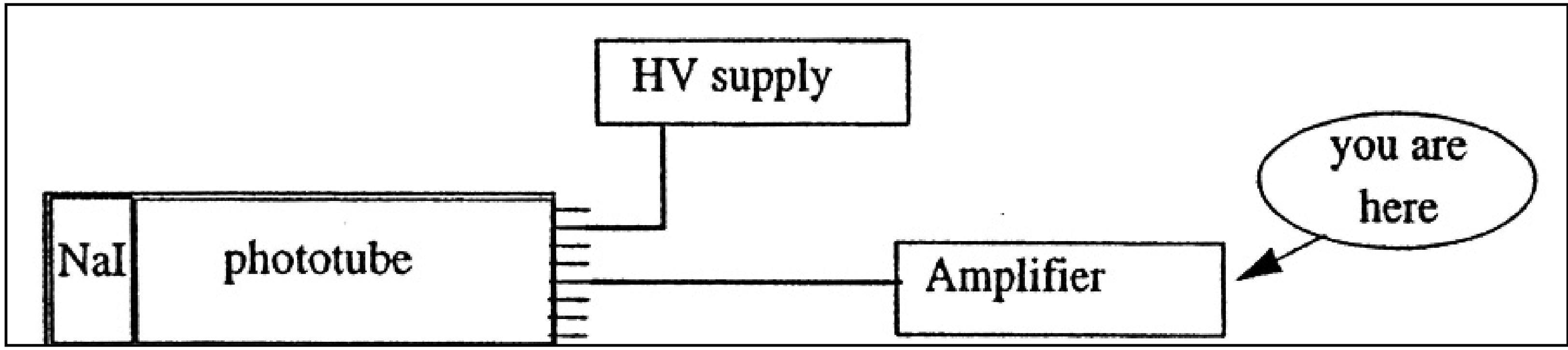

γ RAY
RADIATION
ENTRANCE WINDOW
LUMINESCENT
CENTER
NaI(Tℓ)
MgO OR Al2O3
REFLECTOR
VISIBLE LIGHT
(SCINTILLATION)
ALUMINUM OR STAINLESS
STEEL JACKET
OPTICAL
WINDOW
Mu-METAL SHIELD
PHOTOMULTIPLIER TUBE

# SCINTILLATOR CHARACTERISTICS

- Phosphors (NaI(Tl), CsF, BGO, LSO)
  Photoelectric interaction ~ $Z^4$
- NaI(Tl): reference, decay const. ~ 1μs
- CsF : faster than NaI(Tl), TOF PET
- BGO : slower but more efficient, PET
- LSO : very fast (~1ns), high res. PET

# PMT STRUCTURE



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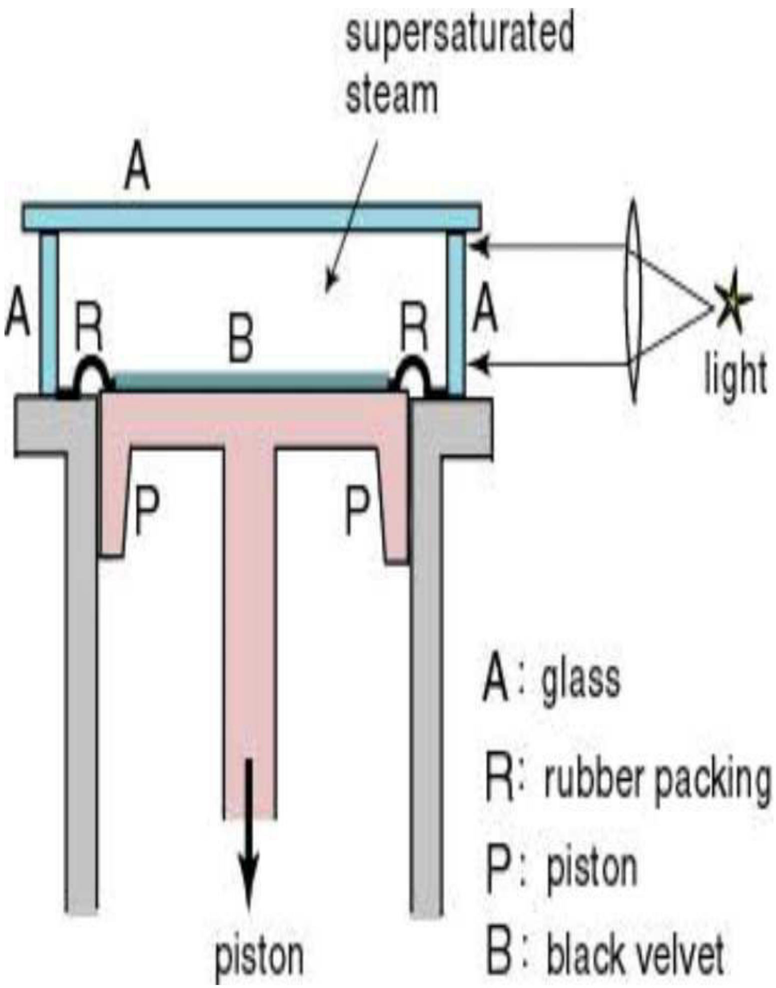
# WILSON CLOUD CHAMBER DETECTOR




- It consist of a cylindrical chamber with walls and roofs glass and contains dust free air saturated with water vapor.
- P is movable piston connected to an evacuated container through a tube containing valve.
- Piston moves and gas get expanded adiabatically .
- Temperature of system decreases and cause super-saturation of liquid, result into the formation of cloud of water droplets
- Ions produces by external radiations act as the sites for condensation of water droplets.
- Cloud track will be photographed by camera.



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