



# Radiation Detection



United States  
Environmental Protection  
Agency

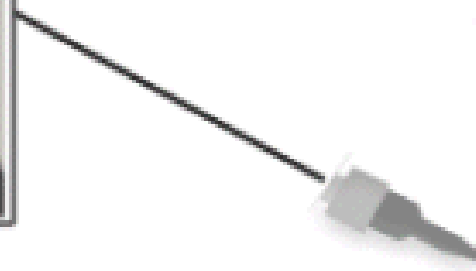
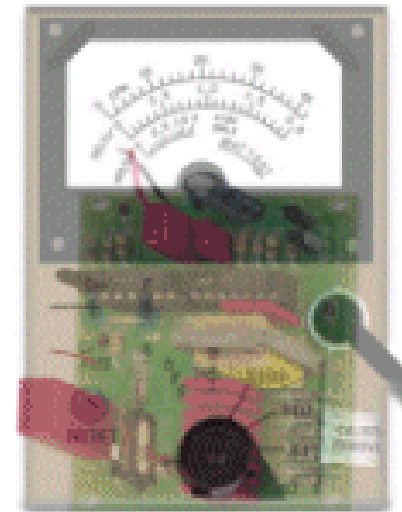
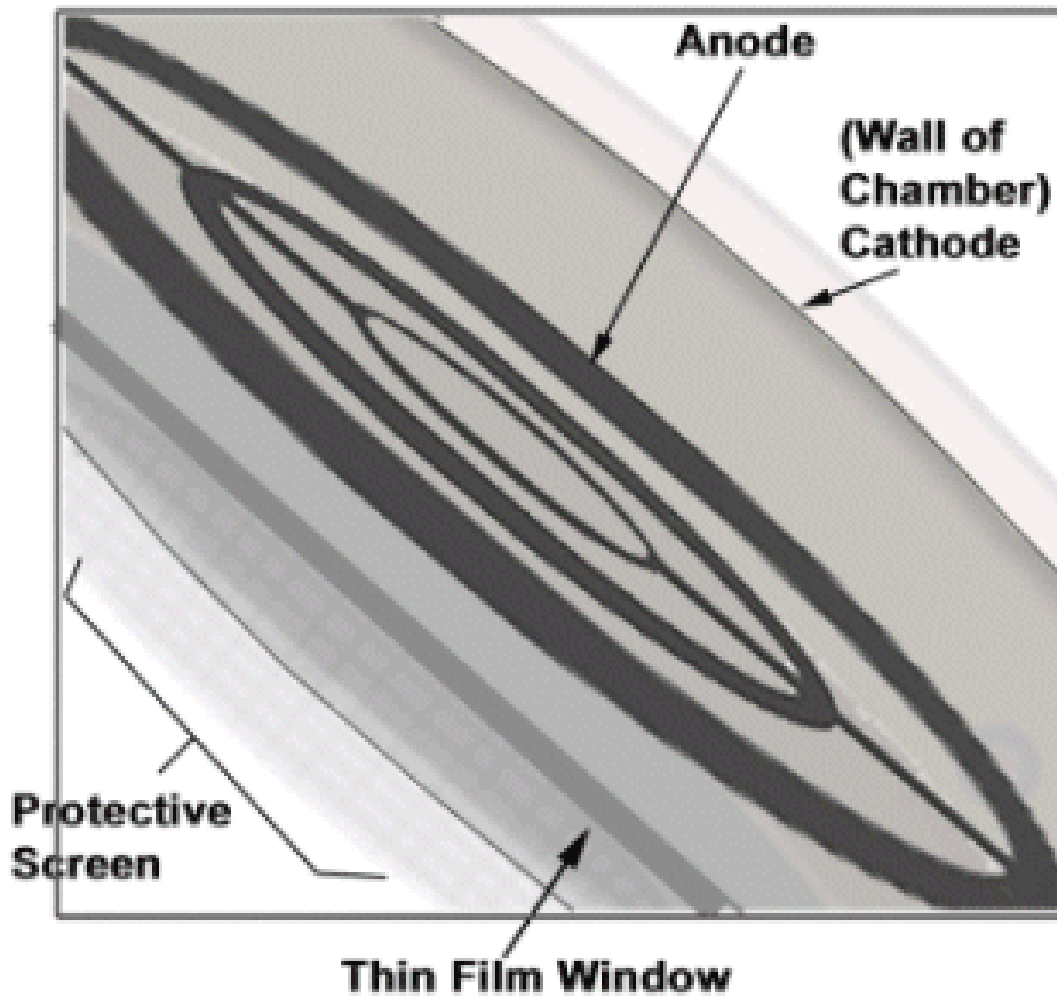
15<sup>th</sup> Annual OSC Readiness Training Program

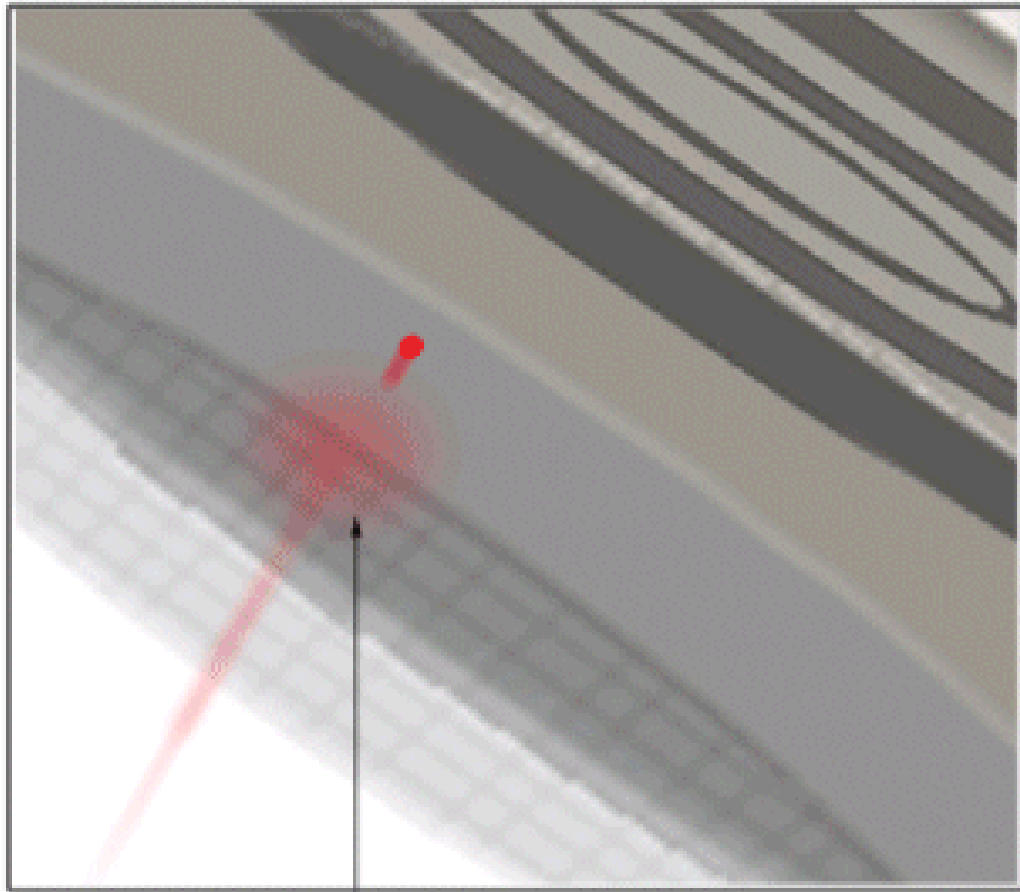
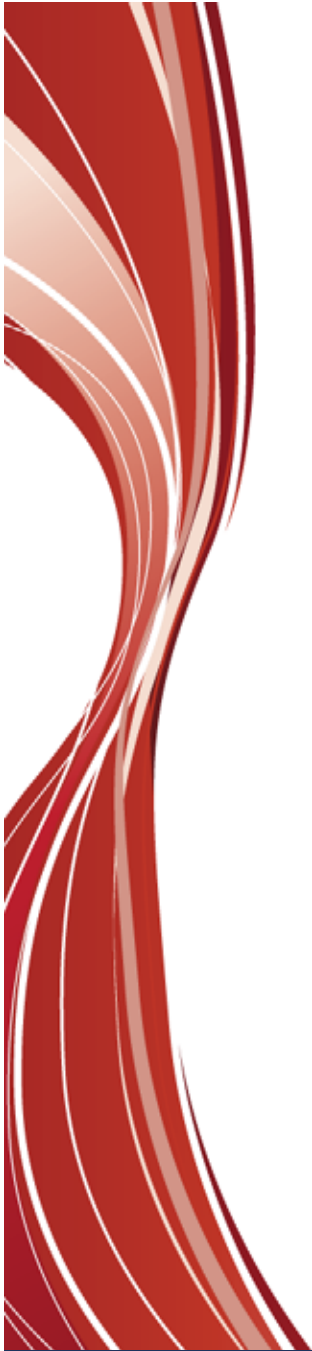
◆ [www.oscreadiness.org](http://www.oscreadiness.org) ◆

# GM Detectors

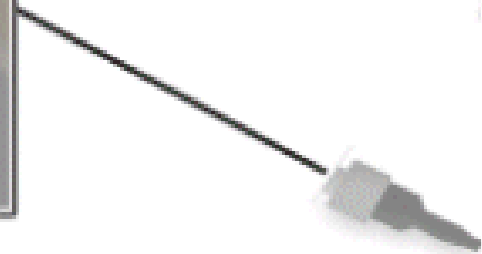
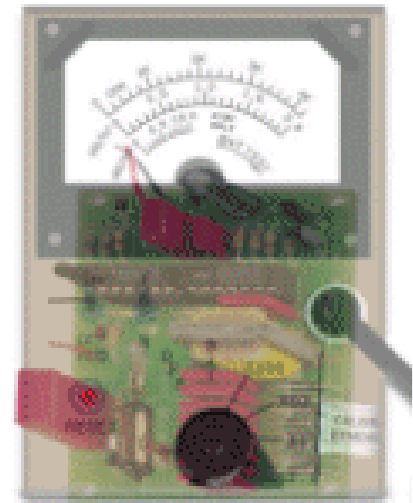


# A closer look

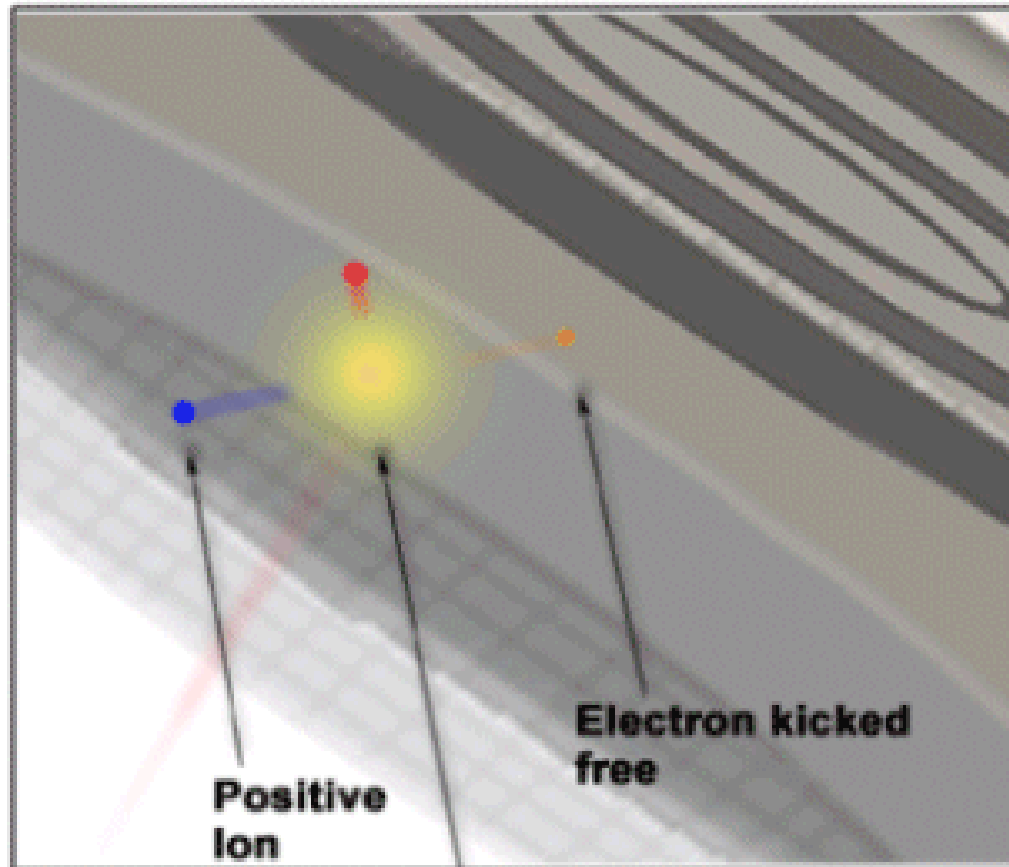




**Beta passes  
through probe window**



# Ionization

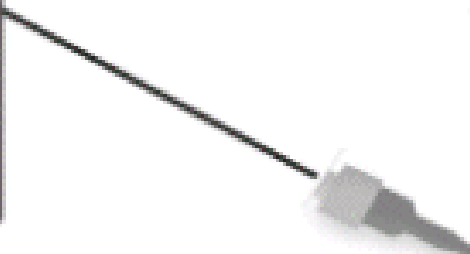
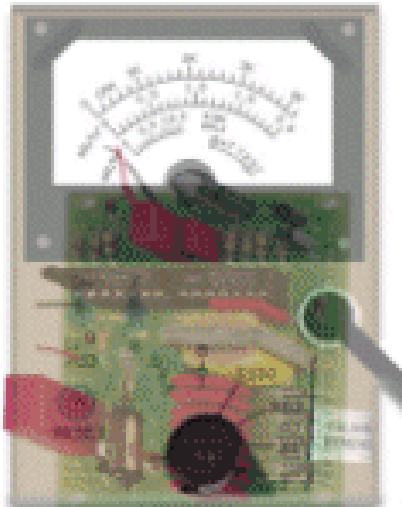
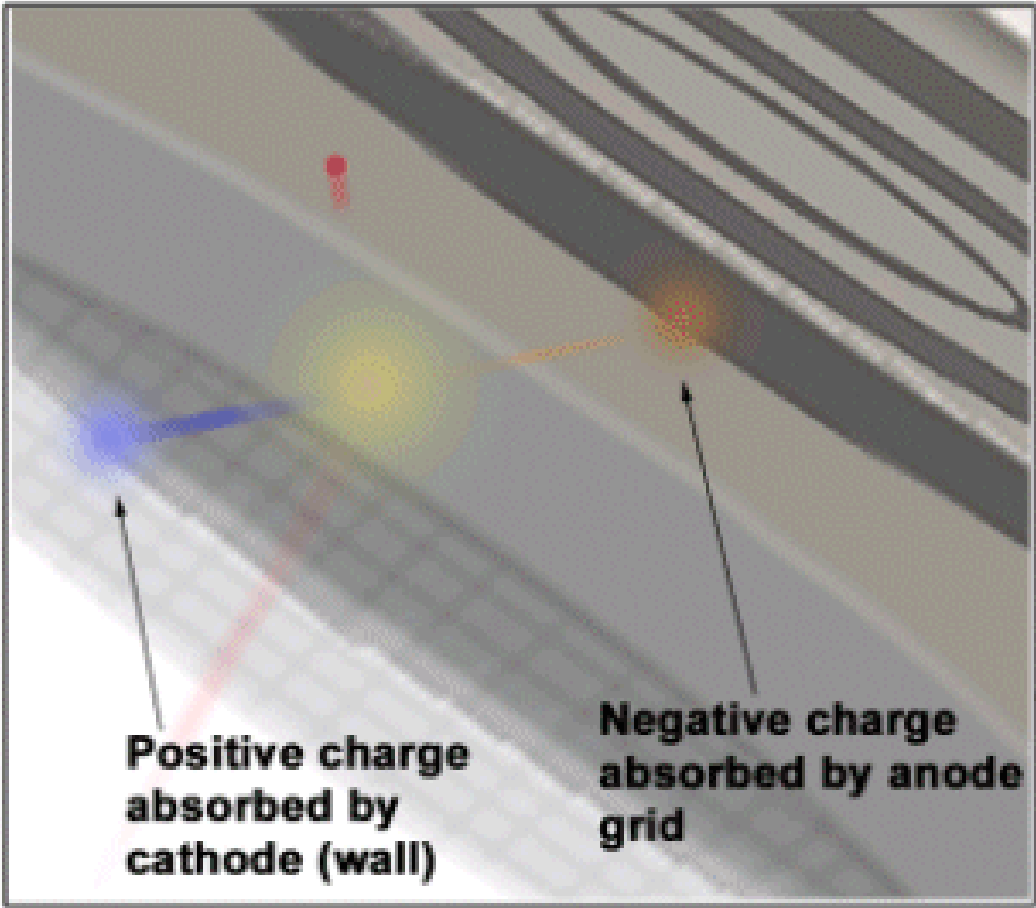


Positive Ion

Electron kicked free

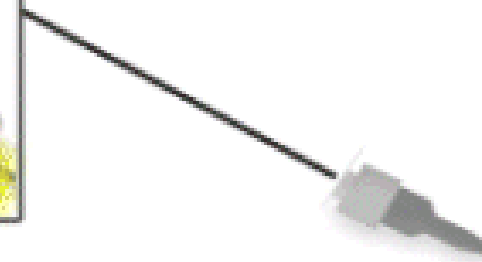
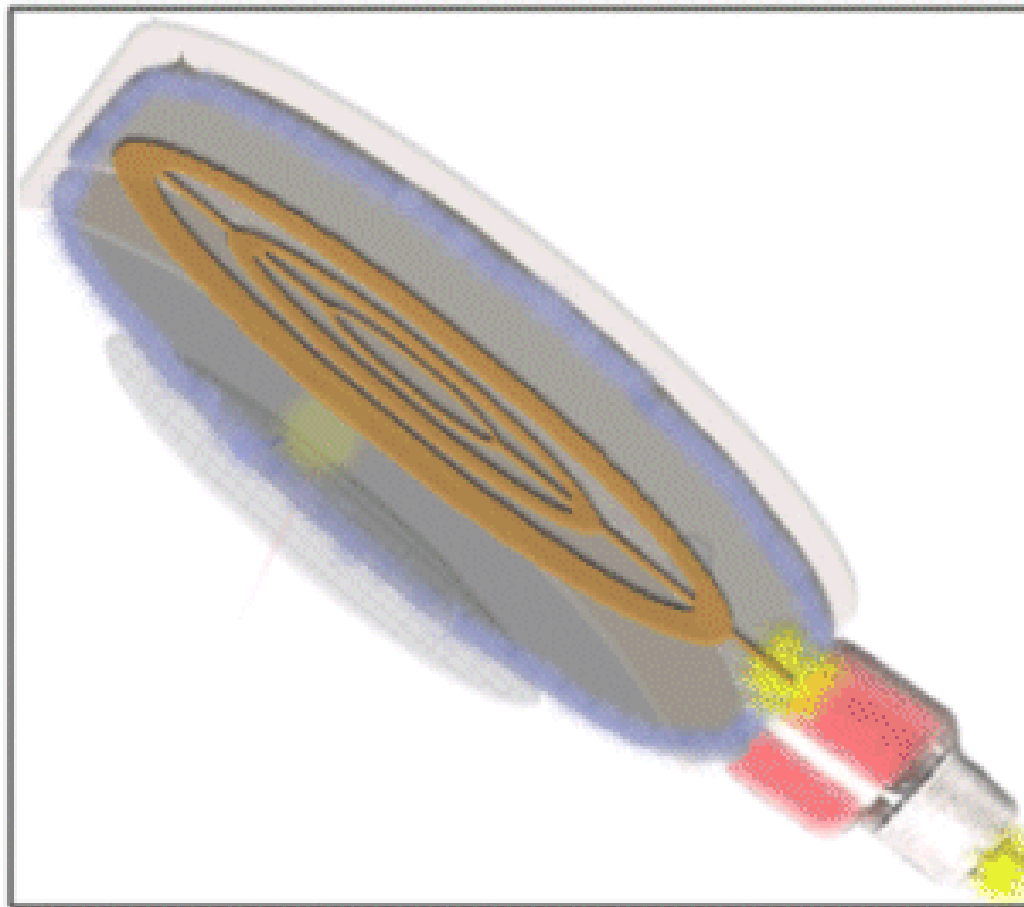
Beta collides with gas atom and ionization occurs.



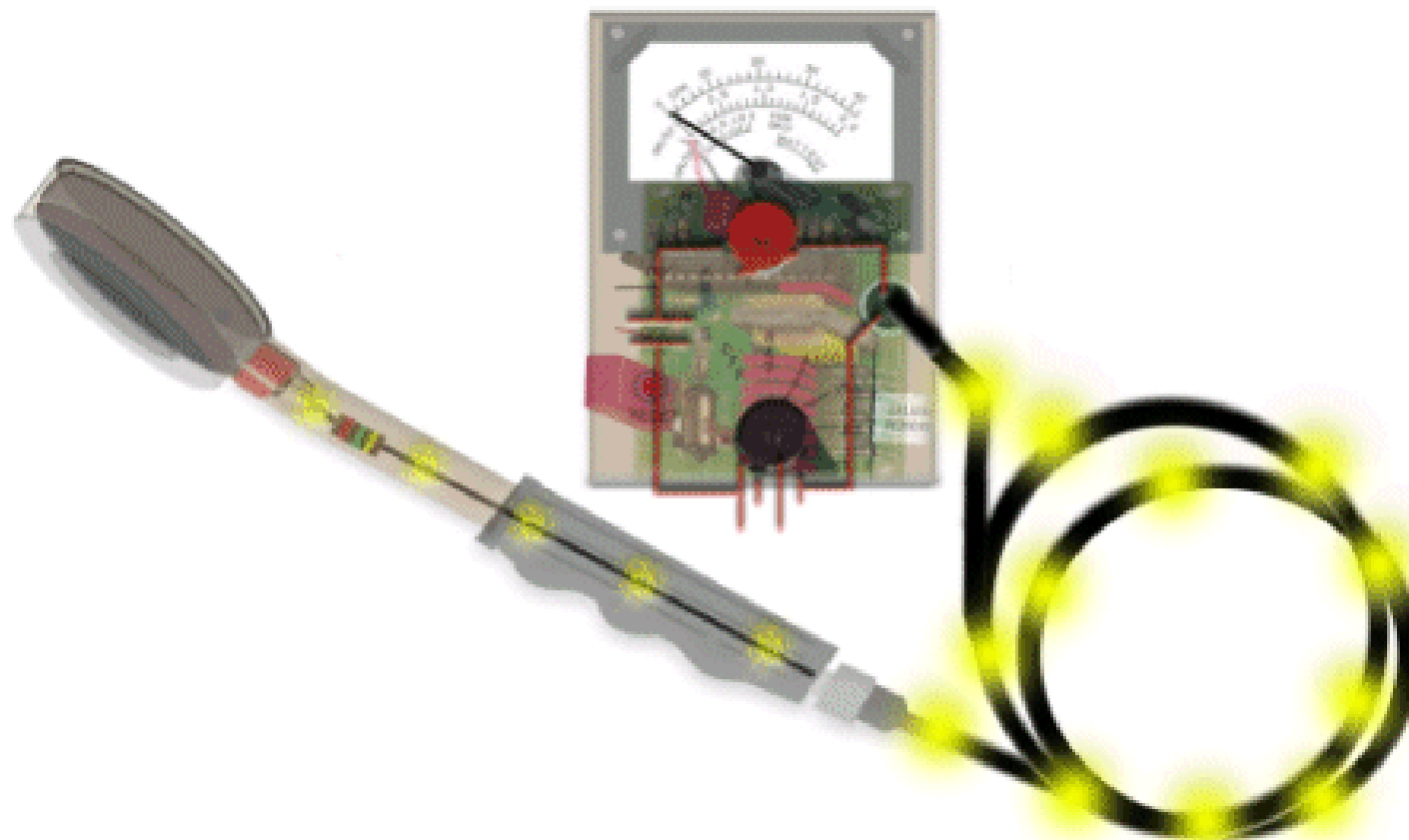




# The ionization creates an electric current in the circuit



**The electric current is processed in the scaler and sorts out the radiation interaction pulses**





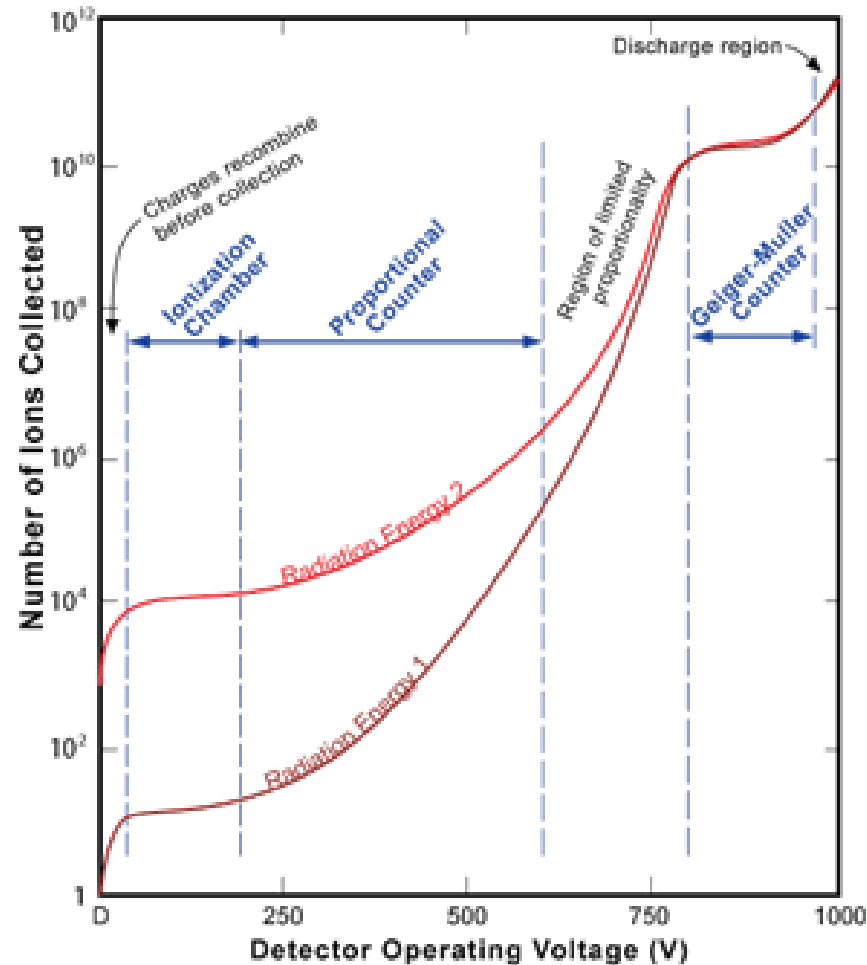


# Instruments Detect Effects of Ionization

## ◆ Types

- Gas Filled (Ion chambers, G-M detectors)
- Scintillation (NaI, Plastic, ZnS)
- Solid State (semiconductor, GeLi, CdTe, TLD)
- Liquid Scintillation

# Number of Ion Pairs Collected in a gas-filled chamber as a function of voltage across electrodes





# Ion Chamber Region

- ◆ Higher voltage, 200 – 300 volts
  - All electrons collected on anode
- ◆ Current depends on radiation
  - Saturation current
- ◆ Amplification of 1
- ◆ Amount of ionization is a function of:
  - Type of radiation
  - Energy
  - Density of gas



## Ion Chambers

- ◆ Measures the transfer of energy (via ionization) through the air
- ◆ Works well for X and g rays
- ◆ Use to measure “exposure”, Roentgen
- ◆ Amplification factor = 1
- ◆ Typically has slow response time
- ◆ Usually does not have audio



# Proportional Region

- ◆ Primary ions produce more ions
  - Cascade or avalanche
- ◆ Pulse size is proportional to primary ions
- ◆ Amplification factor – 10,000
  - Amplification related to voltage
- ◆ Can distinguish different types of radiation
  - Alpha gives the largest signal

# Gas-Proportional Counter

- ◆ Best for  $\alpha$  and  $\beta$  ( $\gamma$ )
- ◆ Amplification Factor 100 – 10,000
- ◆ Fast Response
- ◆ Thin or no window
- ◆ Needs a gas such as P-10
- ◆ Signal is proportional to energy



# Geiger – Mueller Region

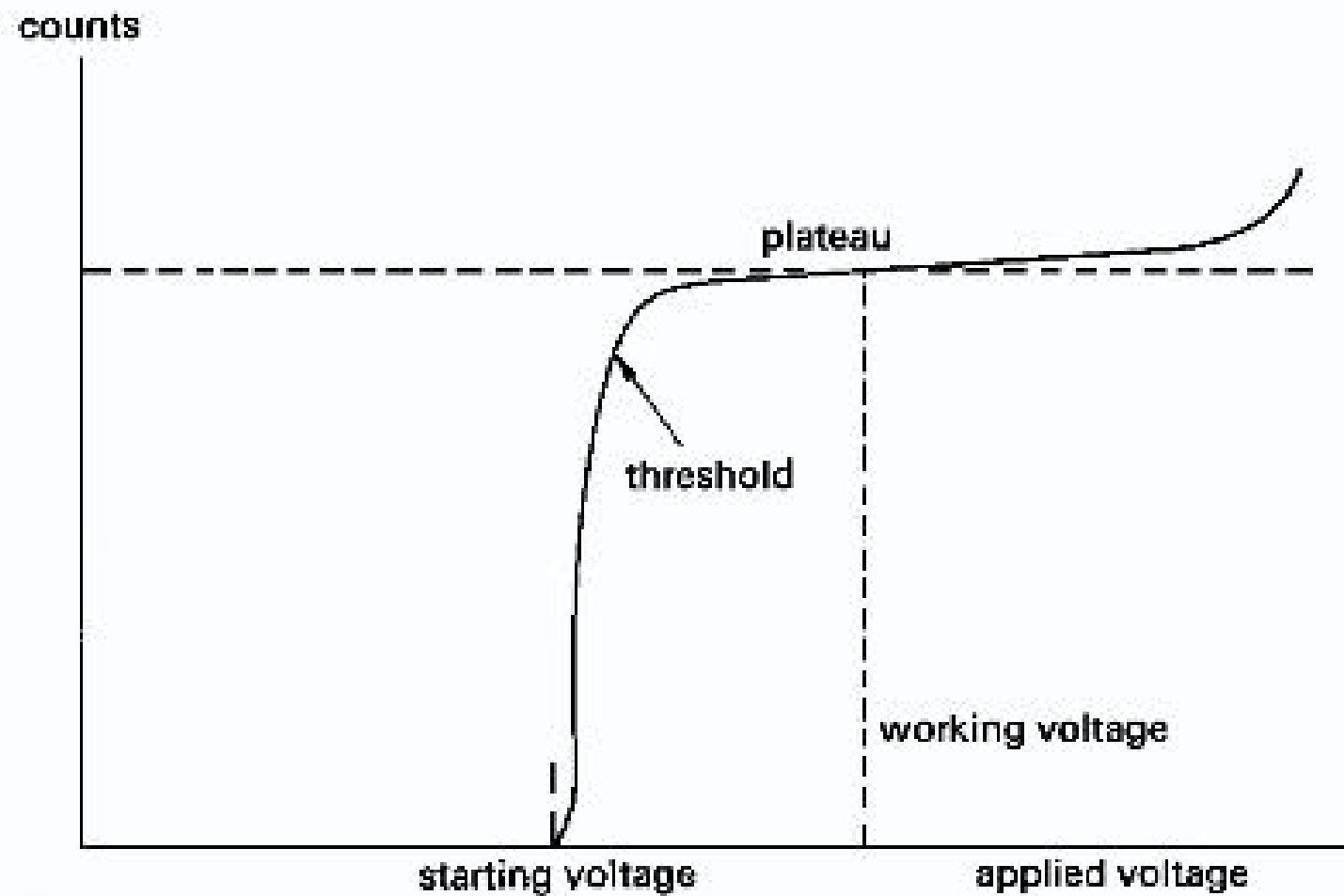
- ◆ All pulse sizes are equal
  - Complete avalanche for each ionization
  - Cannot distinguish types of radiation
- ◆ Need for quenching to prevent continuous discharge
  - Halogen gases, Cl



# Geiger – Mueller Detector

- ◆ Voltage 800 – 1000 volts, avg. 900 volts
- ◆ Gases, organic – propane
- ◆ Very fast response
- ◆ Thick window, blocks low energies and some  $\alpha$
- ◆ Signal is not related to energy
- ◆ Event counter
- ◆ High sensitivity, avalanche
  - Amplification factor, 1 million – 100 million
- ◆ May become saturated giving zero response on dial

# The GM Plateau

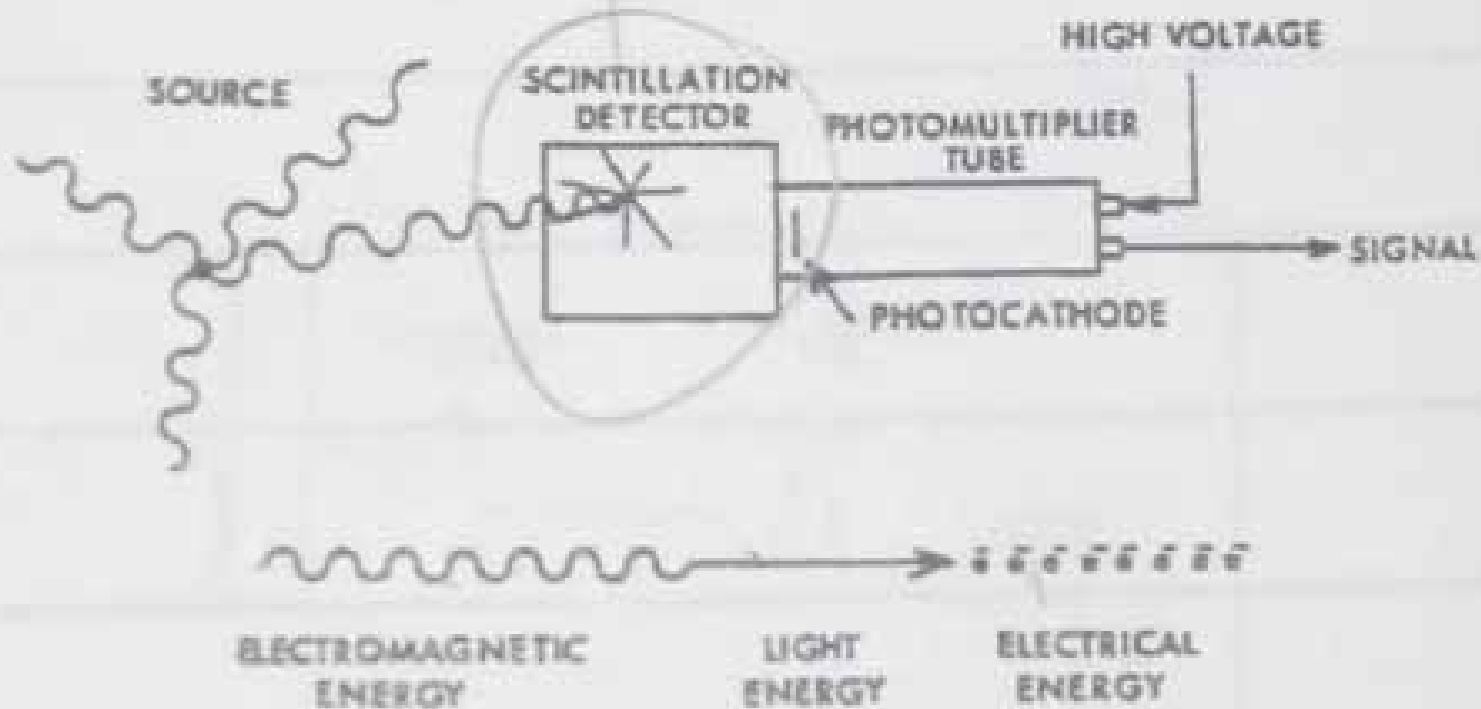




# Scintillation Detectors

- ◆ Based on luminescent properties of material
- ◆ Radiation energy absorbed in material
  - Raises molecular atoms to excited state
  - Decay to ground state
- ◆ Emission of light photons results
  - Light pulse proportional to energy
- ◆ Light detected by photocathode
  - Conversion to electrons
- ◆ Signal increased in photomultiplier

# Scintillation Detector





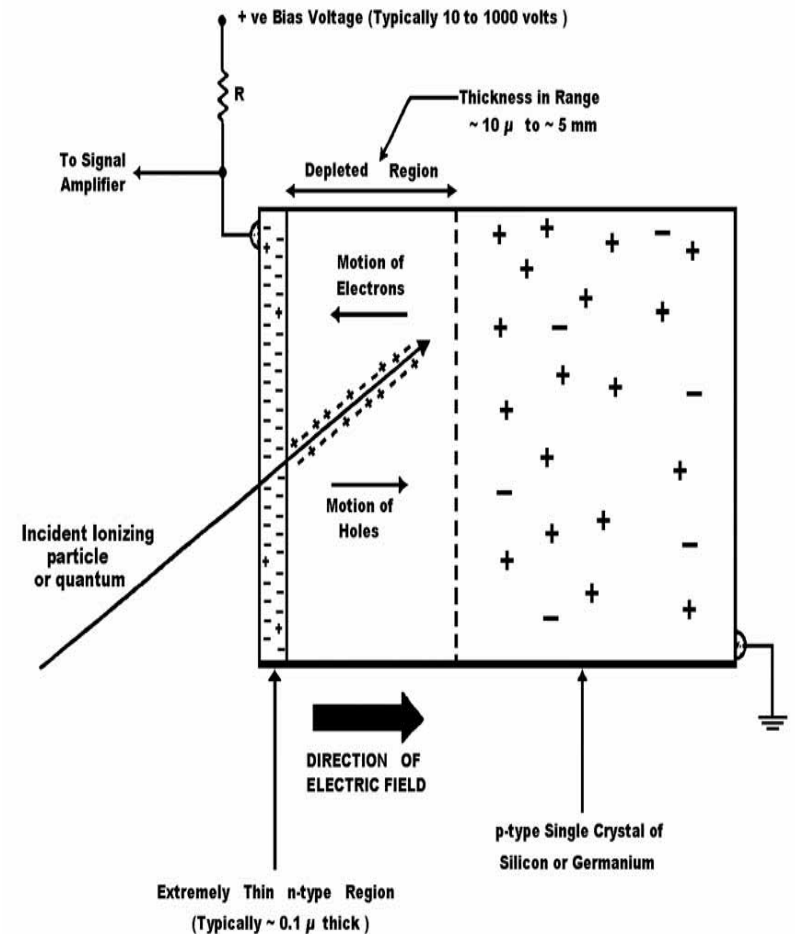
# Nal Gamma Detector

- ◆ High Z number – good gamma absorption
- ◆ Large crystals and good light output
- ◆ Features of Gamma Spectrum:
  - Photopeaks, from photoelectric effect
  - Compton edge, from Compton scattering
  - Compton plateau
  - Backscatter peak, from walls of shield
  - Single and double escape peaks
  - Coincidence sum peaks



# Semiconductors

- ◆ Solid ion chambers
  - Based on band structure of crystals
  - Unfilled conduction band
- ◆ Electrons move across band gap to filled band
  - Insulator has a 5 eV band gap
  - Semiconductor requires  $< 2$  eV to bridge gap





# Typical Response Instrumentation

- ◆ Ludlum 19 and 192 microR meters (gamma only)
- ◆ Ludlum 2241-2 with 44-9 pancake and 43-90 alpha probes (gamma, beta, alpha)
- ◆ Berkley SAM 935 Gamma Spectroscopy system
- ◆ Eberline RO20 Ion chamber (mid range gamma, beta)
- ◆ Ludlum Model 15 with Neutron detector and 44-7 probe (low range gamma, beta and alpha)
- ◆ RADeCo Model H-810AC HighVolume PAS
- ◆ Ludlum Model 3030 Alpha/Beta Counter
- ◆ Siemens Electronic Personnel Dosimeter (EPD)

## Ludlum Model 19 and 192

- ◆ Gamma and x-ray only
- ◆ NaI detector
- ◆ Can measure down to background
- ◆ Limited range (0 to 5 mr/hr)
- ◆ Automatically Adjusting Alarm Setting (Model 192)



# Ludlum 2241 and associated probes

- ◆ Excellent contamination survey instrument
- ◆ Can measure  $\alpha$ ,  $\beta$ ,  $\gamma$  and x-ray depending on probe
- ◆ Auto ranging
- ◆ Built in scaler
- ◆ 2 independent detector set-ups



## 44-9 Pancake Probe

- ◆ Alpha, beta, gamma
- ◆ 15.5 cm<sup>2</sup>
- ◆ Contamination
  
- ◆ 180-2 holder (optional)
  - Swipes
  - Air filters (?)



## Model 44-7 End Window Probe

- ◆ Model 44-7 end window G-M that can be used with several different instruments including survey meters, scalars, ratemeters, and alarm ratemeters
- ◆ Alpha beta gamma survey and sample counting





## 43-90 Probe

- ◆ Alpha scintillation
- ◆ 100 cm<sup>2</sup>
- ◆ Alpha contamination
- ◆ Fragile faceplate
- ◆ Fragile PM tube
  
- ◆ May respond to high gamma or neutron



## 44-10 Probe

- ◆ Gamma probe
- ◆ 2" x 2" NaI(Tl)
- ◆ Low activity level gamma
- ◆ Energy range ~60-3000 keV
- ◆ Very sensitive detector



# Berkeley Nucleonics SAM 935

- ◆ Nuclide identification
- ◆ Dose rate (rem/Sv) calculation, total dose
- ◆ Spectrum analysis
- ◆ Can store and download spectra
- ◆ External NaI probe for gamma, internal He-3 neutron detector (optional)



# ThermoEberline RO20

## ◆ Ion Chamber Survey Meter with Beta Shield

- Measures Gamma, X-ray or Beta exposure rate
- Will measure radiation at strengths that can cause personal injury in a short time
- Five linear ranges: 0-5, 0-50, 0-500 mR/hr; 0-5, 0-50 R/h
- Air filled ionization chamber vented to atmosphere
- Temperature Compensated Measurements



# Ludlum Model 15

## ◆ Neutron Counter

- Fast and thermal neutron, alpha, beta-gamma survey
- End Window G-M Detector for Alpha Beta and Gamma
- BF<sup>3</sup> Proportional Detector with Moderator for Neutron
- 4 Ranges
- Total Counting Range from 0 - 500,000 cpm



# RADeCO H-810

- ◆ LCD displays
  - elapsed sample time
  - flow rate
  - total volume
- ◆ Flow rate up to 10 cfm
- ◆ Collects sample on filter which can be counted in the Ludlum 3030



# Ludlum 3030

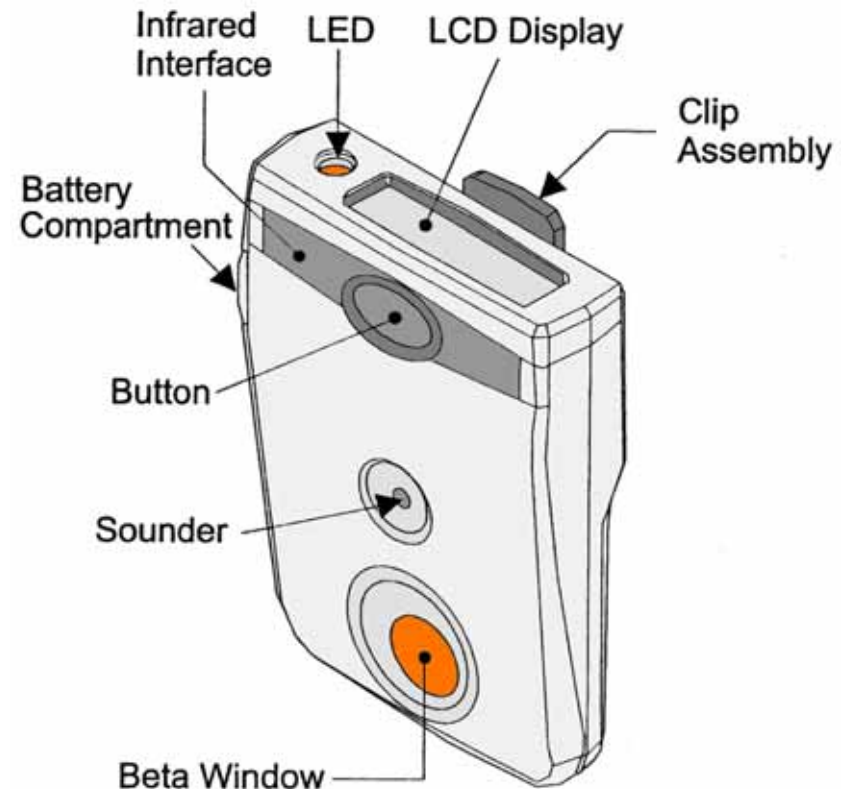
- ◆ Simultaneous Alpha and Beta sample counting
- ◆ Swipes, air filters
- ◆ Samples  $\leq 47$  mm (not 2")
- ◆ 8-hr battery operation
- ◆ PC controller software





# Siemens EPD

- ◆ Real-time response to gamma, x-ray and beta radiation
- ◆ Used to indicate EPA turn-back limits
- ◆ Used along with TLD
- ◆ Gamma response:
  - 15 keV to 10 MeV
- ◆ Beta response:
  - 250 keV to 1.5 MeV





# Radiation Response Kits

- ◆ Instrument
  - Detector assignments
- ◆ Probes
- ◆ Cables
- ◆ Check source
- ◆ Spare parts (cables, mylar windows)
- ◆ Calibration certificates
- ◆ Manuals
- ◆ Shipping forms



# Questions?