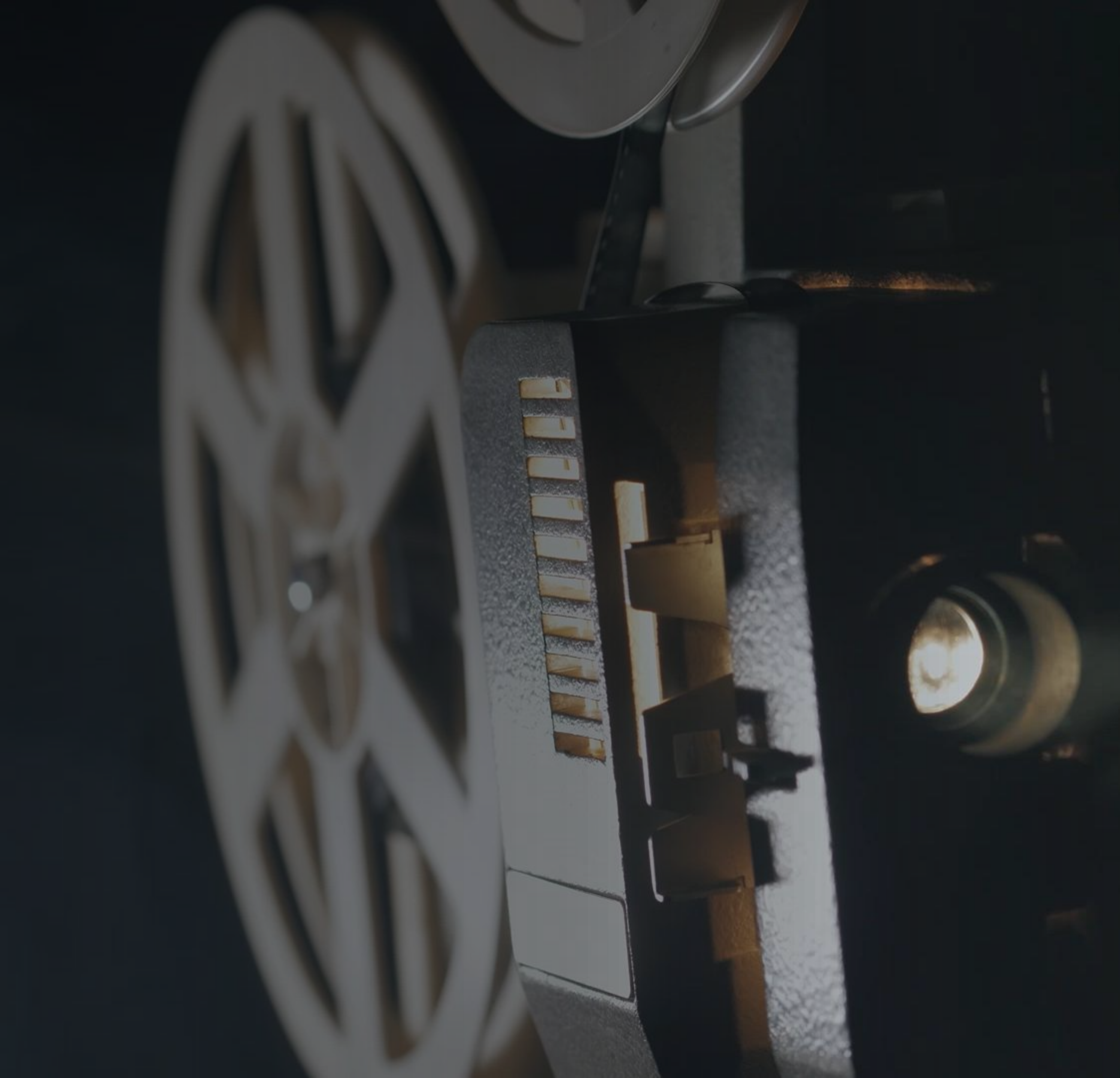

Detection of Radiation I

RT4220 – Lecture #10

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WSU

10/21/2025

Purpose of Radiation Detectors

- We cannot sense radiation with our bodies, full-stop
- We need to protect people and quantify ways to reduce dose
- We need to make sure we are giving a safe dose during imaging and therapy

Principle of Radiation Detection

Relevant modes of radiation interaction:

- Excitation (Scintillators)
- **Ionization (Gas-Filled)**

It all comes back to ionization → DNA damage

So we should measure ionizations! But we cannot stick a probe inside our bodies

We must either extrapolate or translate ionizations in air to human tissue

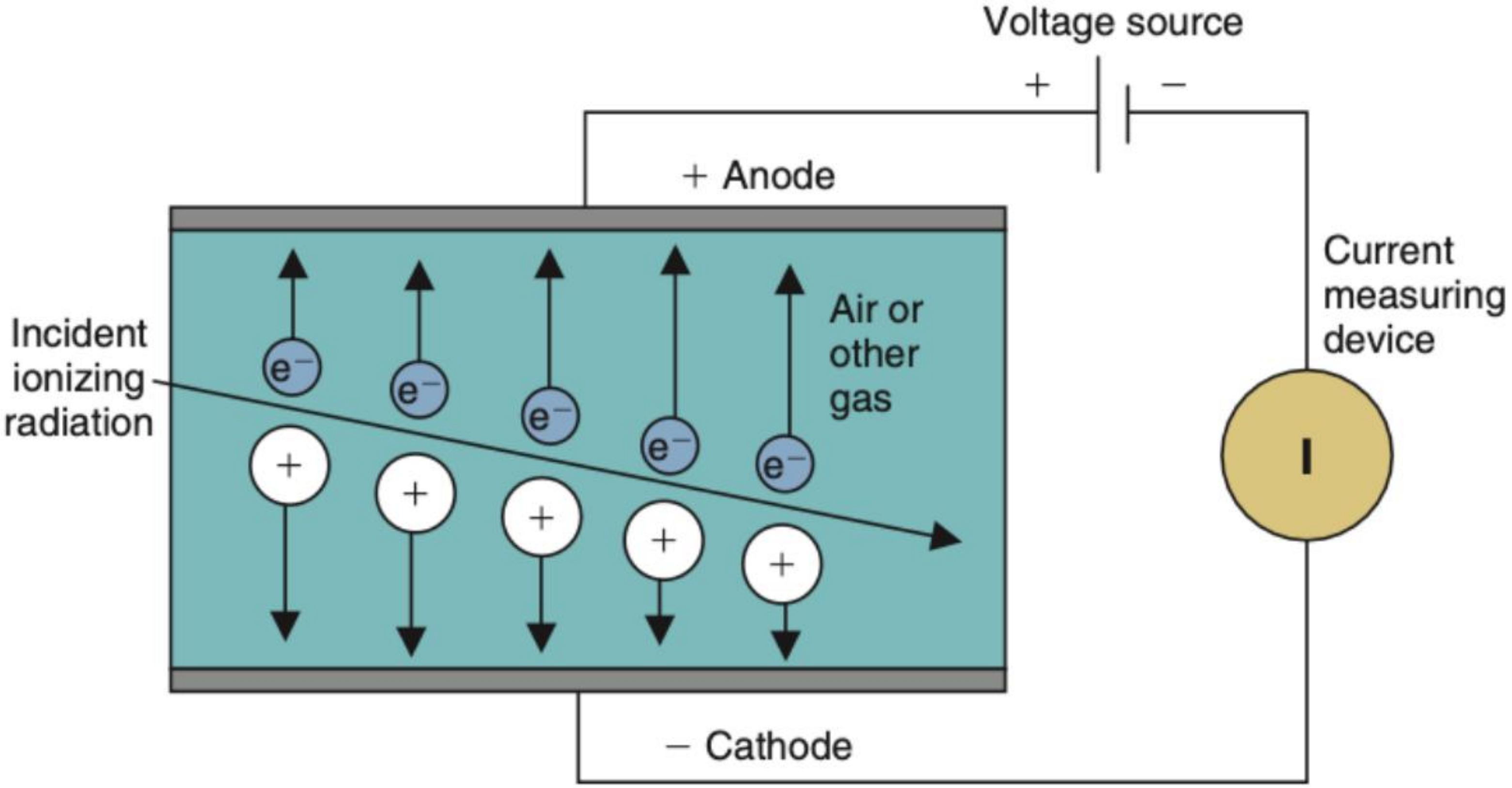
Types of Radiation Detectors

- There are so many:
  - **Gaseous Detectors**
    - Dose Calibrators, Ion Chambers, GM Counters, Proportional Counters…
  - **Semi-conductor Detectors**
    - Ge, Si, Diodes
  - **Film**
    - Radiographic
    - Radiochromic
  - **Scintillation Detectors**
    - NaI, CsI, BGO, TLDs, OSLDs
  - And many more on the way

Gaseous Detectors

Firefighters? Ok sure

Gaseous Detector Operation



Ionization of Gas

- The **average** energy required to ionize an atom of ‘normal, dry, atmospheric gas’ is:

$$\left(\frac{\overline{\mathrm{W}}}{\mathrm{e}}\right) = 33.97\ \frac{\mathrm{eV}}{\mathrm{ion\ pair}}$$

- If there is a voltage applied to the gas, then the ion pairs will be ripped apart
- Small Voltage → ions have enough time to recombine with other ions
- High Voltage → ions can gain enough energy to ionize the air by themselves!
- Some detectors are pressurized, others are open
  - Open-air chambers must correct for pV = nRT stuff

The Gas Amplification Curve

Gaseous detectors count either **ionizations events** (cps), or **energy deposited** (dose).

Six regions of operation depending on desired measurement:

I. Not useful

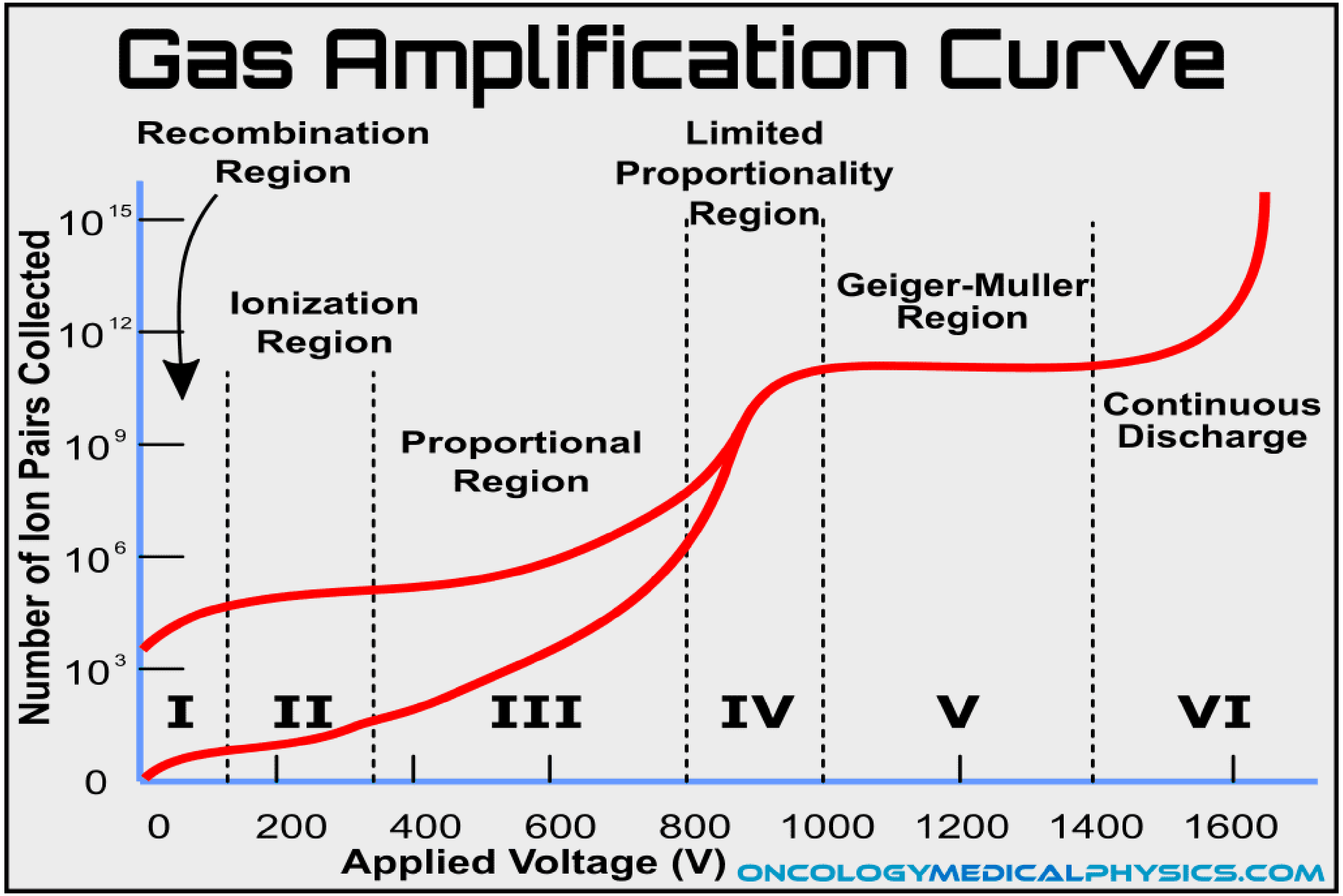
II. Ionization Chambers

III. Proportional Counters

IV. Not useful

V. GM Counters

VI. Not Useful



I. Recombination Region

Low voltage (~ 0-100 V)

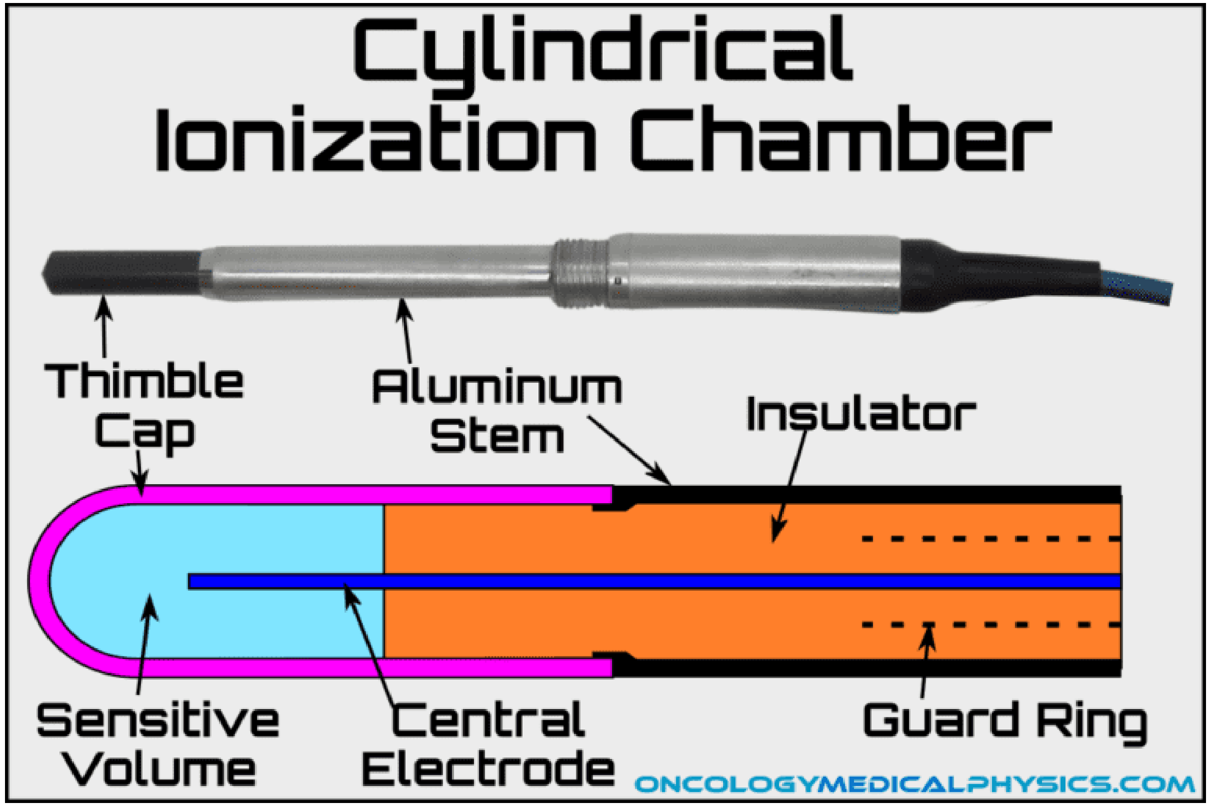
Ion pairs are **not pulled apart and collected fast enough** → recombination

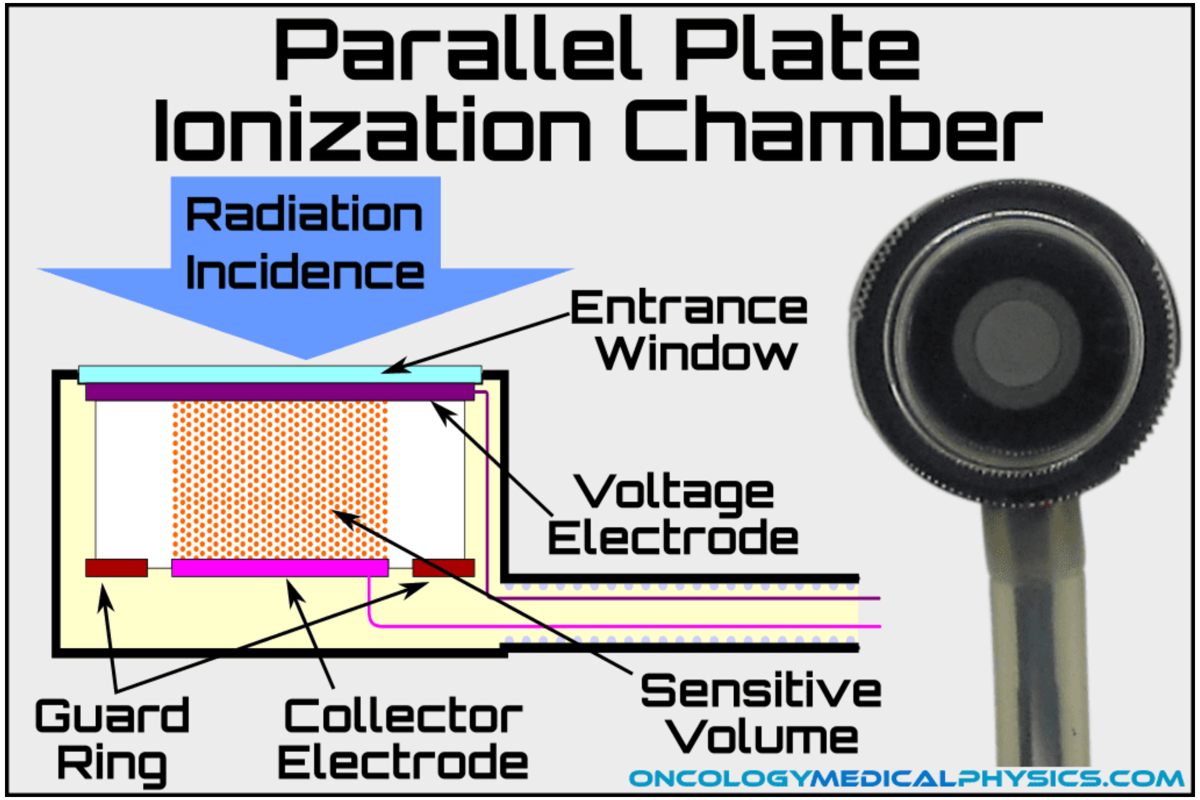
Lower than expected and unreliable ion pair counts → **not used**

II. Ionization Region

- Voltage is high enough for us to collect ~all of the ion pairs (~ 50-300 V)
- Used for **clinical ionization chambers** as the signal is directly proportional to ionizations (flat/straight line)
- Most relevant ion chambers are: **Farmer** (Cylindrical, Photons) and **Markus** (Plane-Parallel, Electrons)
- They tell us accurately ***how much dose*** a point and material is receiving

Ionization Chambers





III. Proportional Region

- Higher voltage than ionization region (~ 300-800 V)
- Charge collected is proportional to **energy and type of radiation**
- Gives rise to the proportional counter, it can tell us *what* type of radiation is out there

IV. Limited Proportionality Region

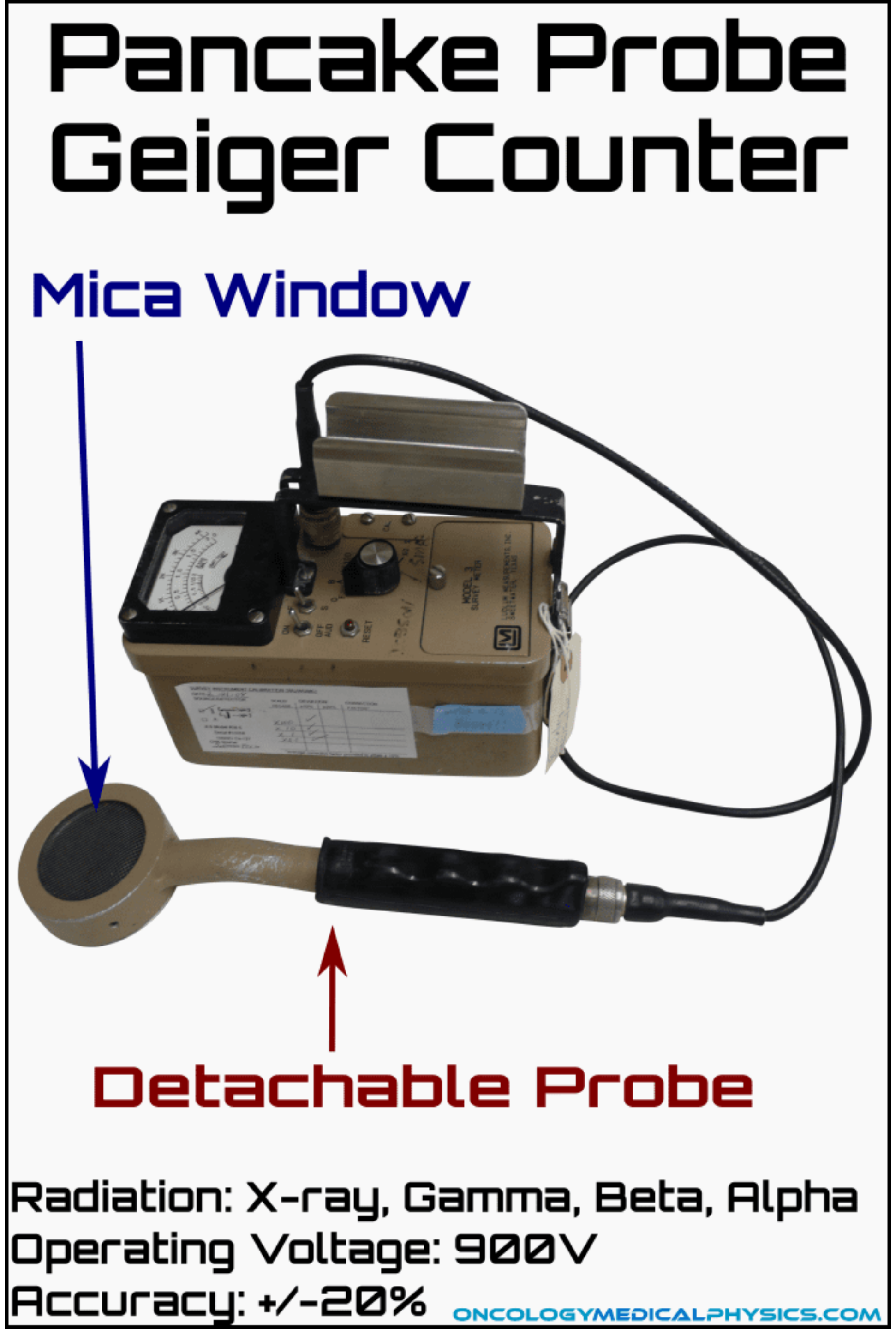
High voltage (~ 800-1000 V)

"Response to collected energy diminishes while response to applied voltage increases."

Not used

V. Geiger-Müller Region

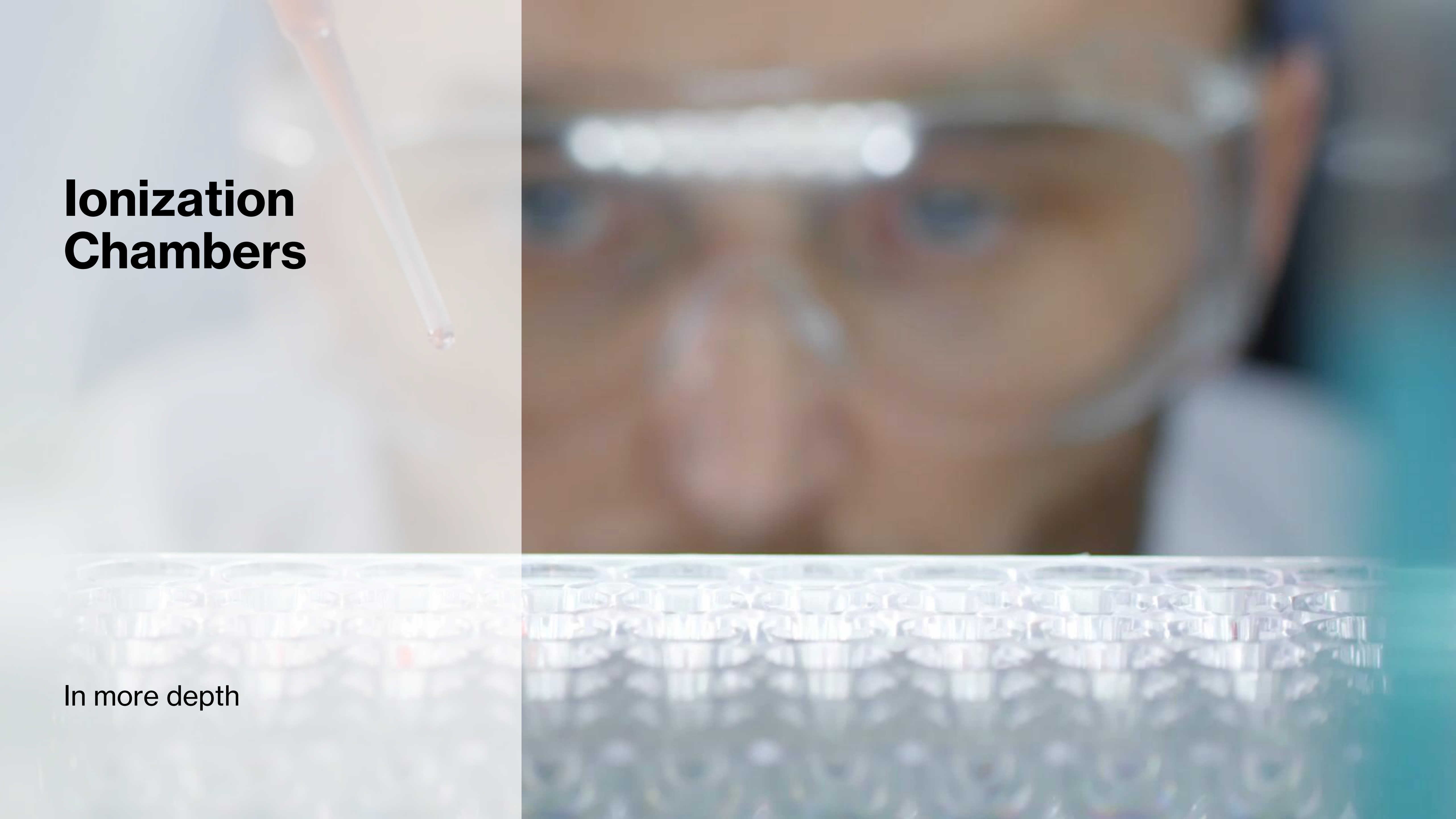
- Highest useful voltage (~ 1000-1400 V)
- One ionization event is **accelerated**, creating an **avalanche** of further ionization events
- **Extremely sensitive**, but can only tell us **how many events**, nothing to do with dose
- Has to be **quenched** so that the cycle breaks and it can record a new event



VI. Continuous Discharge

The voltage is so high that the potential arcs through the gas, breaking stuff

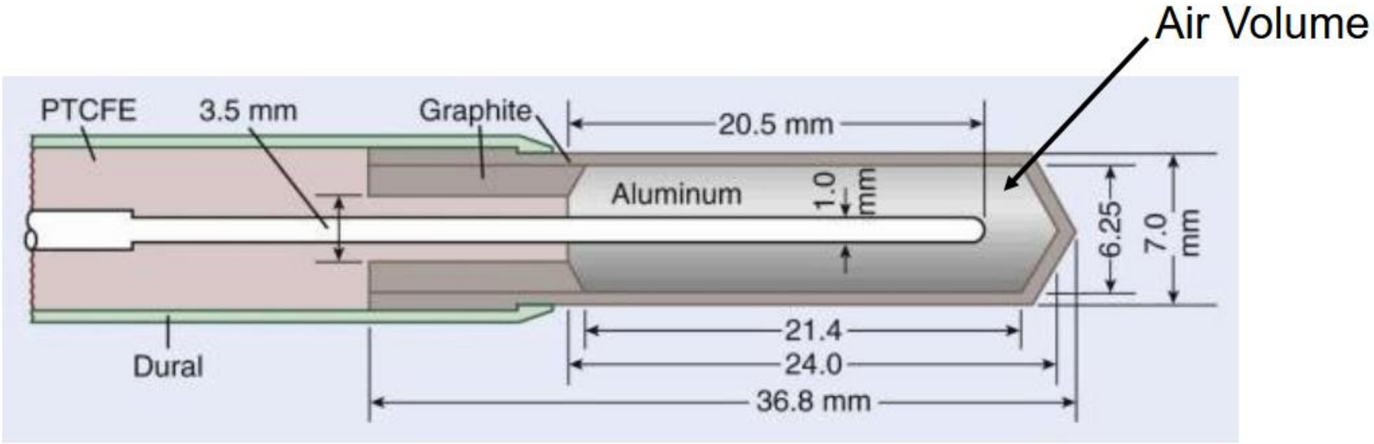
We do not want this to happen



Ionization Chambers

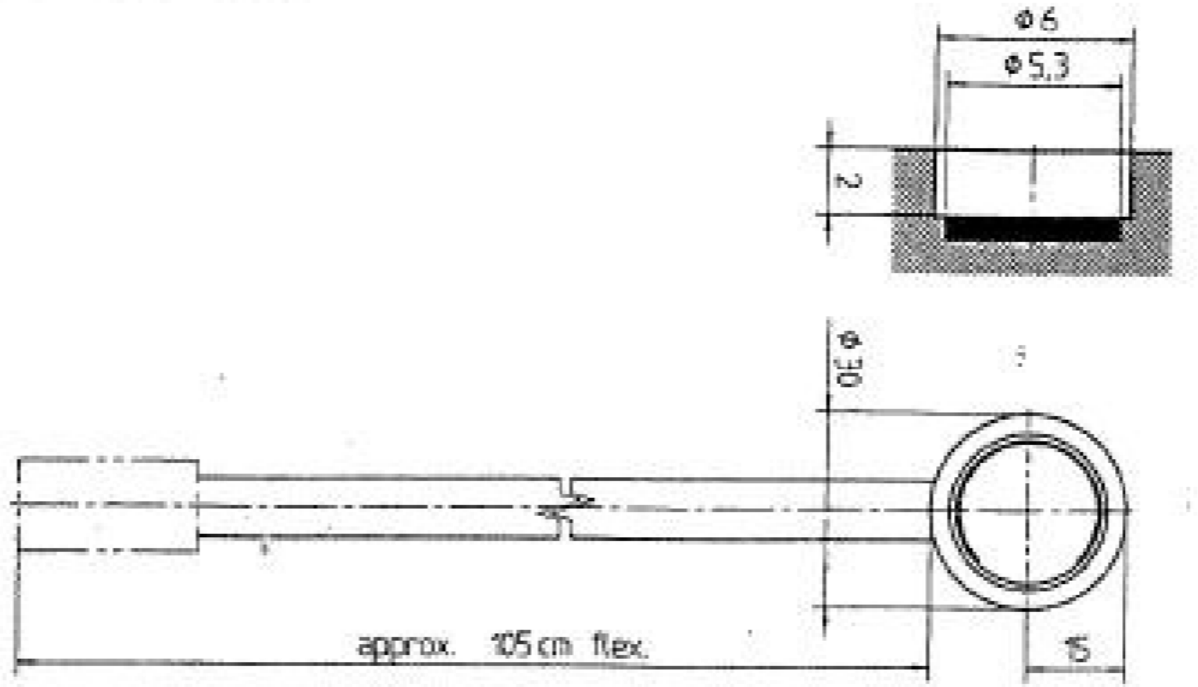
In more depth

Cylindrical Chambers (Farmer)



- Sometimes called a thimble chamber
- Farmer is the most common design
- 150 (QA) and (typical operation) operation modes
- Unsealed volume**300 V** (**correct for air pressure and temperature**)
- Standard chamber for **absolute dosimetry** of a **LINAC's output measurements**
- **Fully guarded chamber,** uses a **triaxial cable** (like coaxial, but cooler! And expensive, do not walk on them please)
- Sensitive volume of 0.6 cc
- Central electrode is made of graphite or aluminum

Plane-Parallel Chambers (Markus)



- Markus is the most common design
- Have a **flat-top**, direction dependent
- Much **smaller sensitive volume** (0.055 cc)
- Extremely thin entrance window is more suitable for **electron measurements**

Ionization Chamber Survey Meter

- Used to monitor radiation levels for radiation protection purposes
- Gives more information than a GM survey meter (it gives dose!)
- Battery operated and portable

Dose Calibrator

- NOT THE SAME THING AS A WELL COUNTER, DO NOT HEAR THEIR LIES
- Used in **nuclear medicine departments** to accurately **assay patient doses**
- **Sealed** chamber eliminates pv=nRT faff
- Converts exposure to **activity** automatically
- It is an IONIZATION CHAMBER in the SHAPE OF A WELL


CAPINTEC, INC.
CRC-55t, 3.08
Dose Decay
Sep 23 2013 14:48
F18
Ga67
In111
Tc99m
I123
I131
Xe133
Tl201
5.80uCi
Tc99m
Technetium 6.01 hr
Cal #: 080
Ch: 1, R
Print
Setup
CRC-55tR

Proportional Counters

In more depth!

Proportional Counter Design

- CHERRY wants you to know that proportional counters are NOT just ion chambers at a high voltage
- Purpose of the high voltage is to allow **some acceleration ionizations**
  - Different from GM, which would continue forever without quenching! The amplification factor is lower, self-quenching
- Construction of the prop. Counter facilitates and encourages amplification
  - Uniformity
  - Filled with noble gas which allows electrons to move easier (Argon/Xenon)

Proportional Counter Use

Can both detect **and** count individual radiation events

Size of current pulse depends on energy deposited → energy sensitive

Can distinguish between different energy events, allowing for:

- Analyzing the X-ray spectrum of an X-ray tube
- Investigating a mixed-radiation environment
- Research applications involving alpha particles

Geiger-Muller Counters

In more depth!!!!

GM Counter Design

- The **sealed** chamber is typically filled with argon and a quench gas like chlorine
- The quench gas soaks up excess electrons, otherwise, it would become **paralyzed**
- GM counters can only detect **one event at a time**
- If events overlap, they might only be counted as one event
- **Dead time** is how long two events need between each other to be distinguishable

Paralyzable Systems

- Counting systems have two categories:
  - Non-Paralyzable: If an event occurs during the deadtime of a preceding event the second event is **simply ignored**
  - Paralyzable: an event introduces a deadtime even without counting
- GM Counters **are** paralyzable!
- Classic Chernobyl scene