Slides for Dose and Dosimetry

22.01 – Intro to Radiation

November 18th, 2015

Dose Quality Factors

From Turner, J. E. *Atoms, Radiation, and Radiation Protection*.

Table 12.1 Dependence of Quality Factor Q on LET of Radiation as Formerly Recommended by ICRP, NCRP, and ICRU

LET (keV μm^{-1} in Water)	Q
3.5 or less	1
3.5–7.0	1–2
7.0–23	2–5
23–53	5–10
53–175	10–20
Gamma rays, X rays, electrons, positrons of any LET	1

Table 12.2 Dependence of Quality Factor Q on LET as Currently Recommended by ICRP, NCRP, and ICRU

LET, L (keV μm^{-1} in Water)	Q
<10	1
10–100	$0.32L-2.2$
>100	$300/\sqrt{L}$

Table 12.3 Principal Elements in Soft Tissue of Unit Density

Element	Atoms cm^{-3}
H	5.98×10^{22}
O	2.45×10^{22}
C	9.03×10^{21}
N	1.29×10^{21}

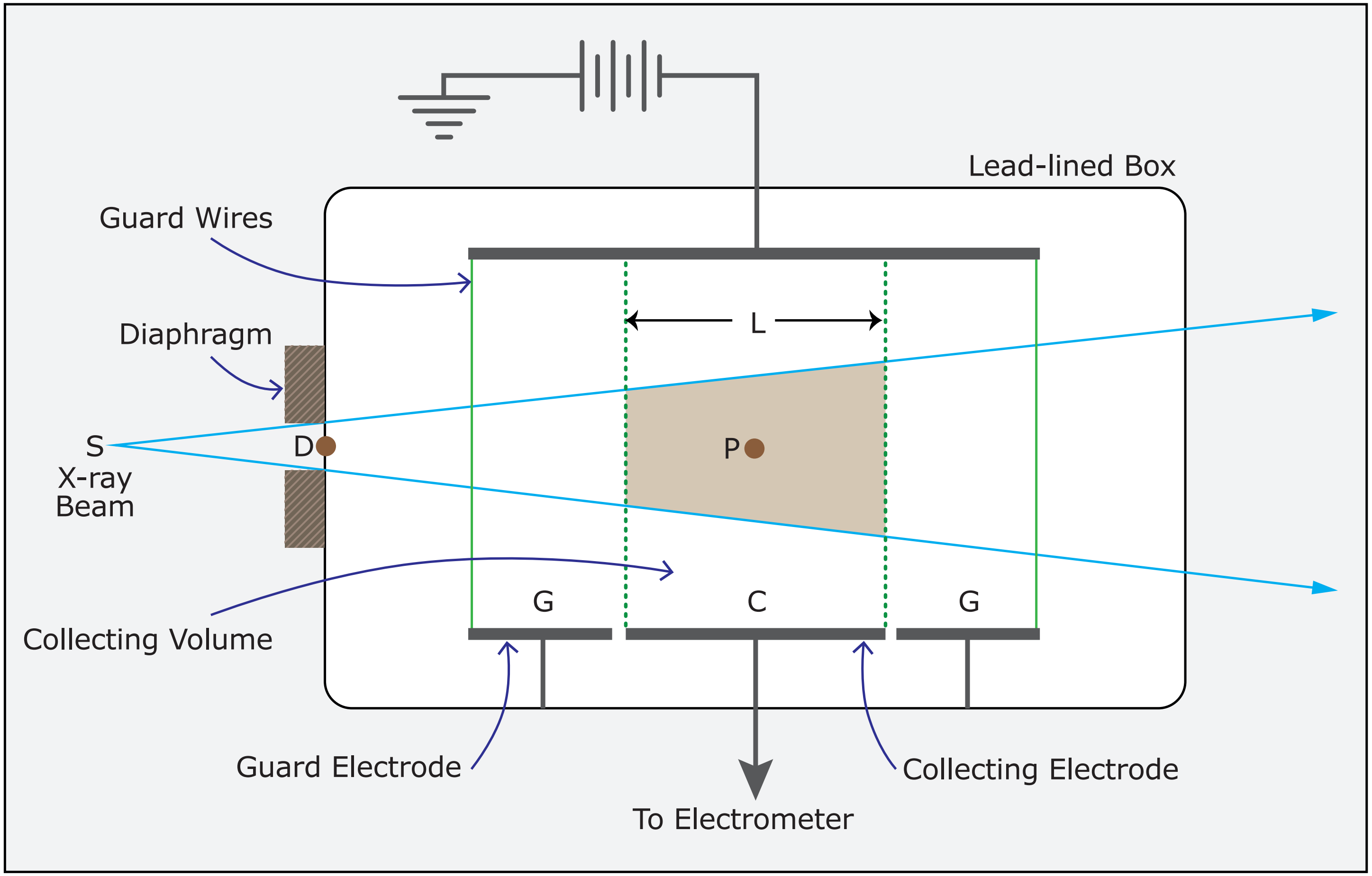
Other Quality Factors

From Yip, Sidney. *Nuclear Radiation Interactions.*.

Table 9.1. Values of the quality factor for different radiations. Source: ICRP [1991]; NCRP [1993].

Radiation	QF
X, γ, $\beta^{\pm}$, (all energies)	1
Neutrons < 10 keV	5
10–100 keV	10
0.1–2 MeV	20
2– 20 MeV	10
> 20 MeV	5
Protons (> 2 MeV) [ICRP]	5
Protons (> 2 MeV) [NCRP]	2
Alpha particles	20

Free Air Ionization Chamber



Air-Wall Chambers

Air-wall pocket ionization chamber.
The plastic wall and air have similar responses to photons.

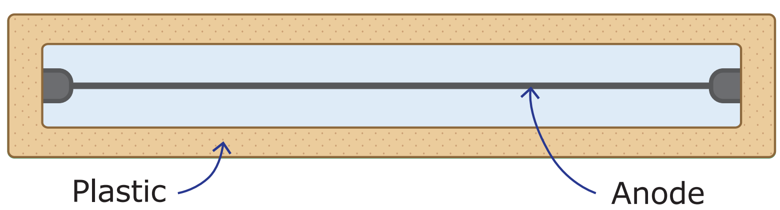
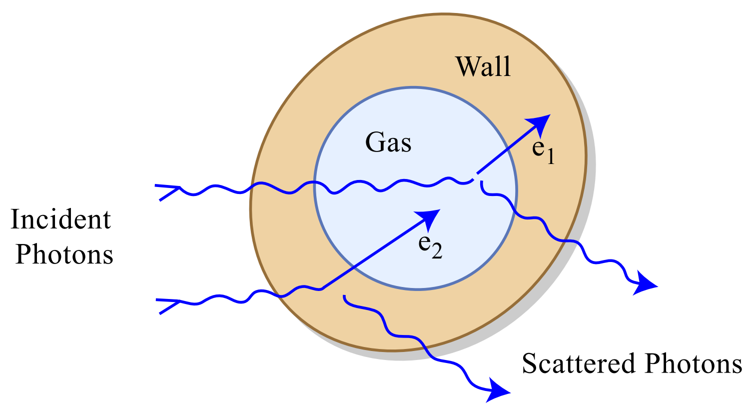


Image by MIT OpenCourseWare.



Gas in Cavity Enclosed by Wall to Illustrate Bragg-Gray Principle

Figure by MIT OCW.

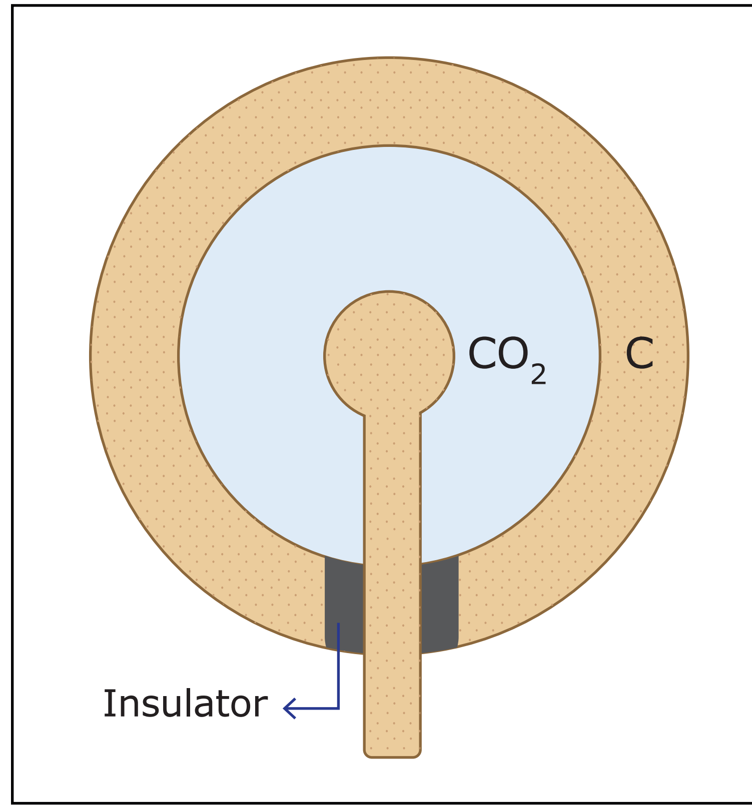


Image by MIT OpenCourseWare.

Air Wall Chambers – Civil Defense

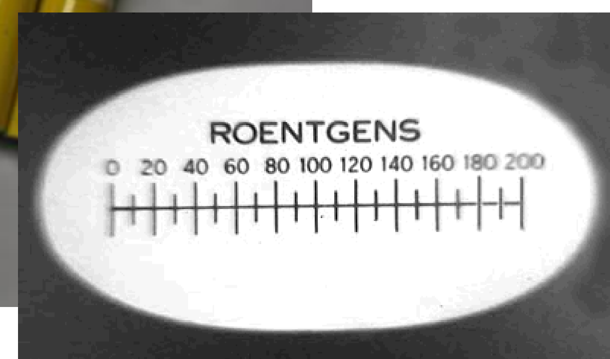
Image removed due to copyright restrictions.
Schematic diagram of a pocket ion dosimeter.
Figure 8.23 in Yip, Sidney. *Nuclear Radiation Interactions*.

For more information, see
https://www.orau.org/ptp/collection/dosimeters/pocketchamdos.htm

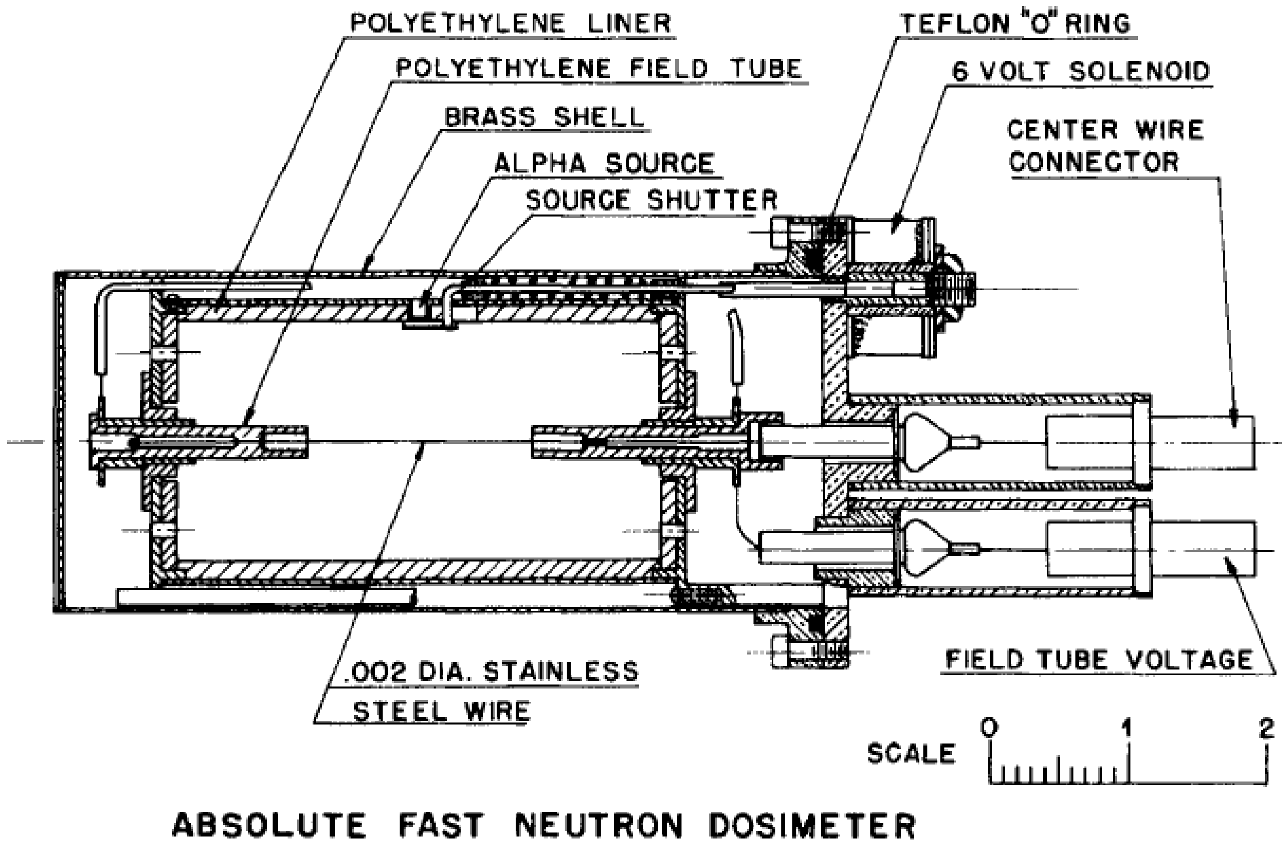
Air Wall Chambers – Civil Defense

https://www.orau.org/ptp/collection/civildefense/cdv742.htm

http://forums.ubi.com/showthread.php/474129-Creepy-cold-war-souvenir-Forums

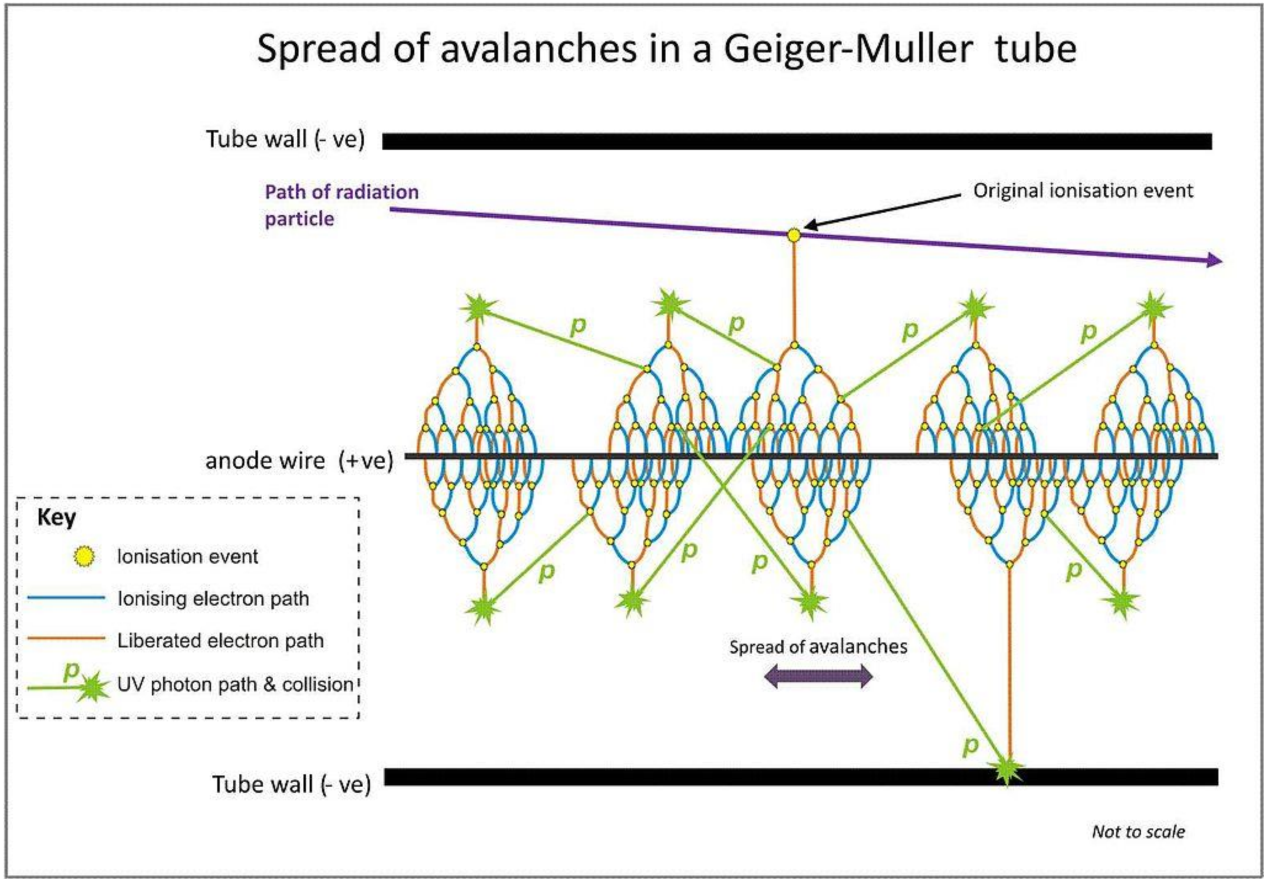


Fast Neutron Detector (Tissue Equiv.)



Ionization (Geiger) Chamber

https://commons.wikimedia.org/wiki/File:Spread_of_avalanches_in_G-M_tube.jpg



Gas Detector Cutaway

Image removed due to copyright restrictions.
Schematic diagram of coaxial gas detector, commonly used for Geiger-Müller tubes.
Figure 8.2 in Yip, Sidney. *Nuclear Radiation Interactions*.

Gaining/Losing Energy Resolution

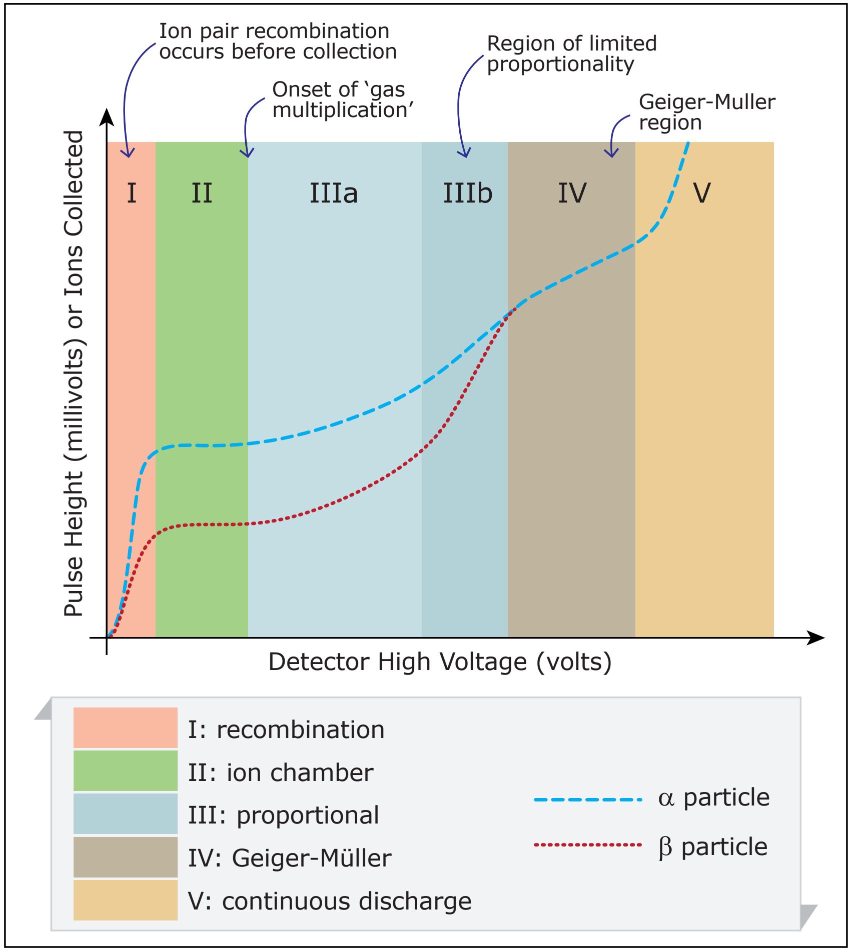


Image by MIT OpenCourseWare.

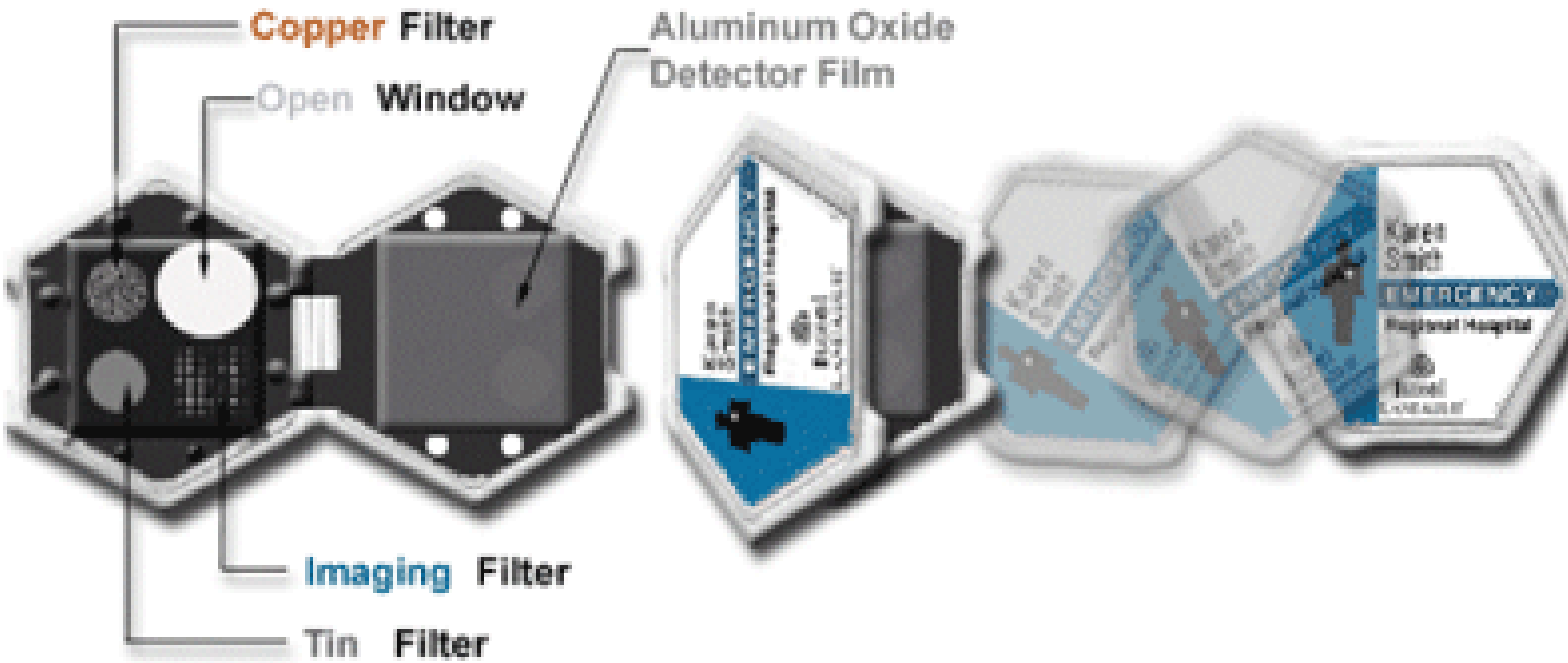
Image removed due to copyright restrictions.
Explanation of quench gas effect.
Figure 8.7 in Yip, Sidney. *Nuclear Radiation Interactions*.

Combined Gamma/Neutron Detector

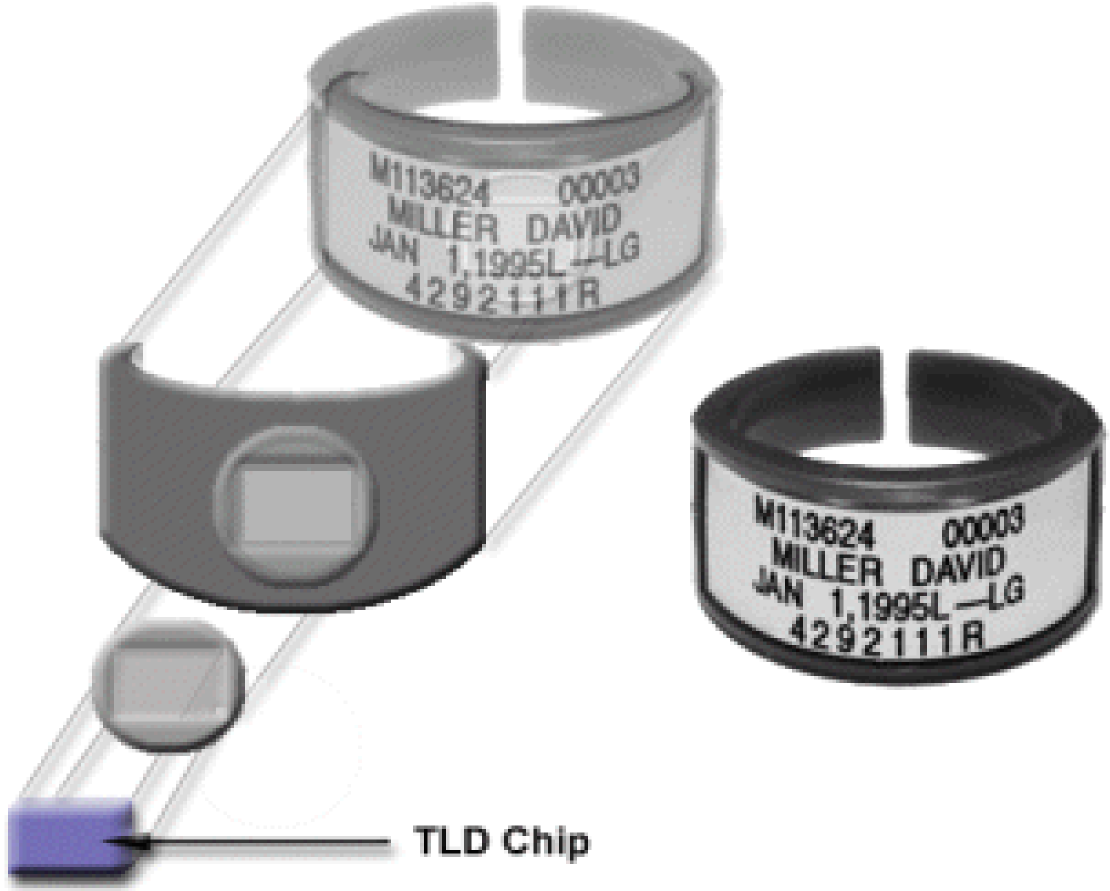
Image removed due to copyright restrictions.
Cross-section diagram of compensated ion chamber.
Figure 8.3 in Yip, Sidney. *Nuclear Radiation Interactions*.

Occupational Dosimetry – TLDs

https://www.ehs.harvard.edu/programs/radiation-dosimetry

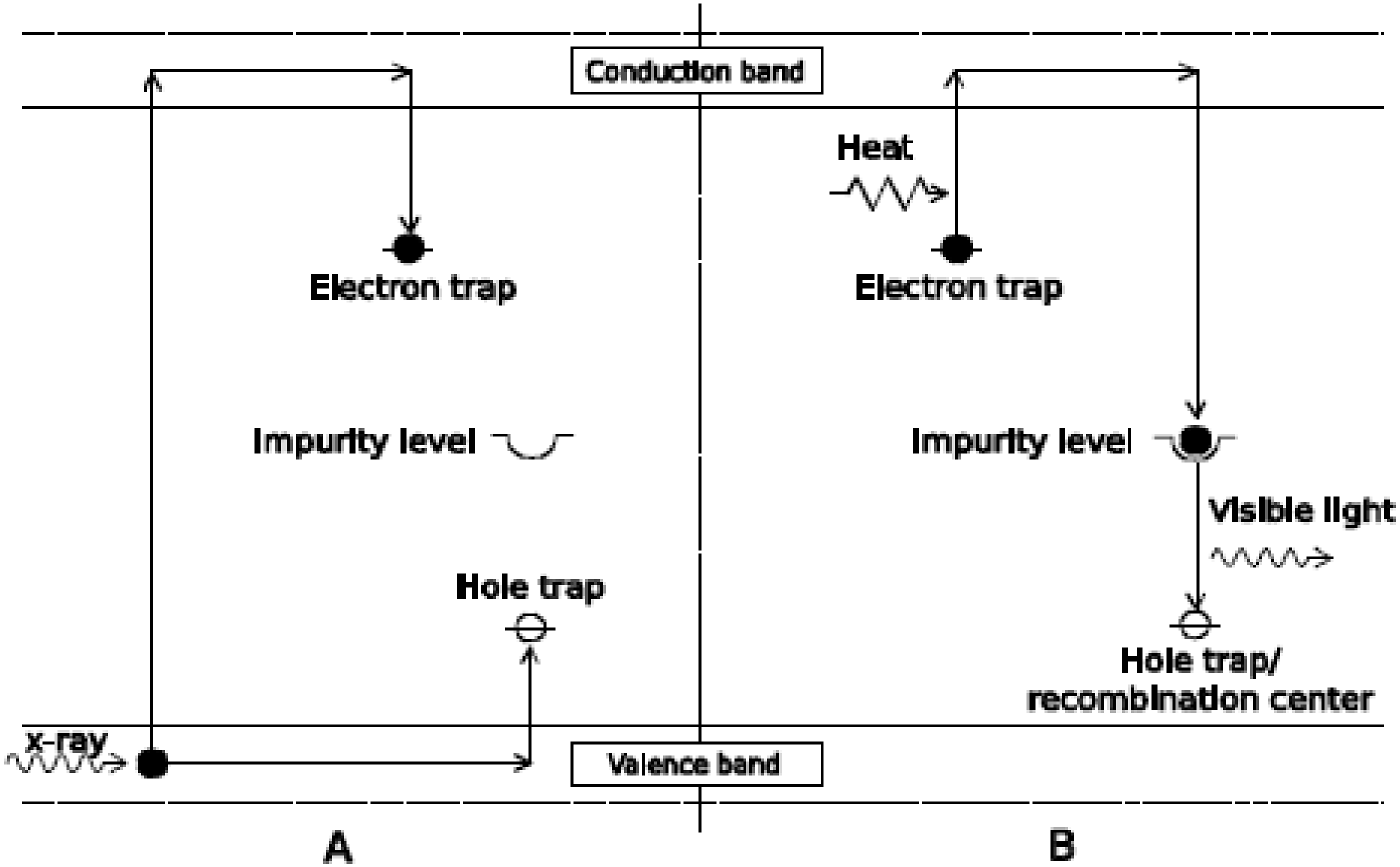


Occupational Dosimetry – TLDs



Reading a TLD

L. A. DeWerd, L. Bartol, S. Davis. "Thermoluminescence Dosimetry." *Presentation, AAPM Summer School 2009*, June 24, 2009. Accessed online at www.aapm.org/meetings/09SS/documents/24DeWerd-TLDs.pdf *on 2015-01-16*

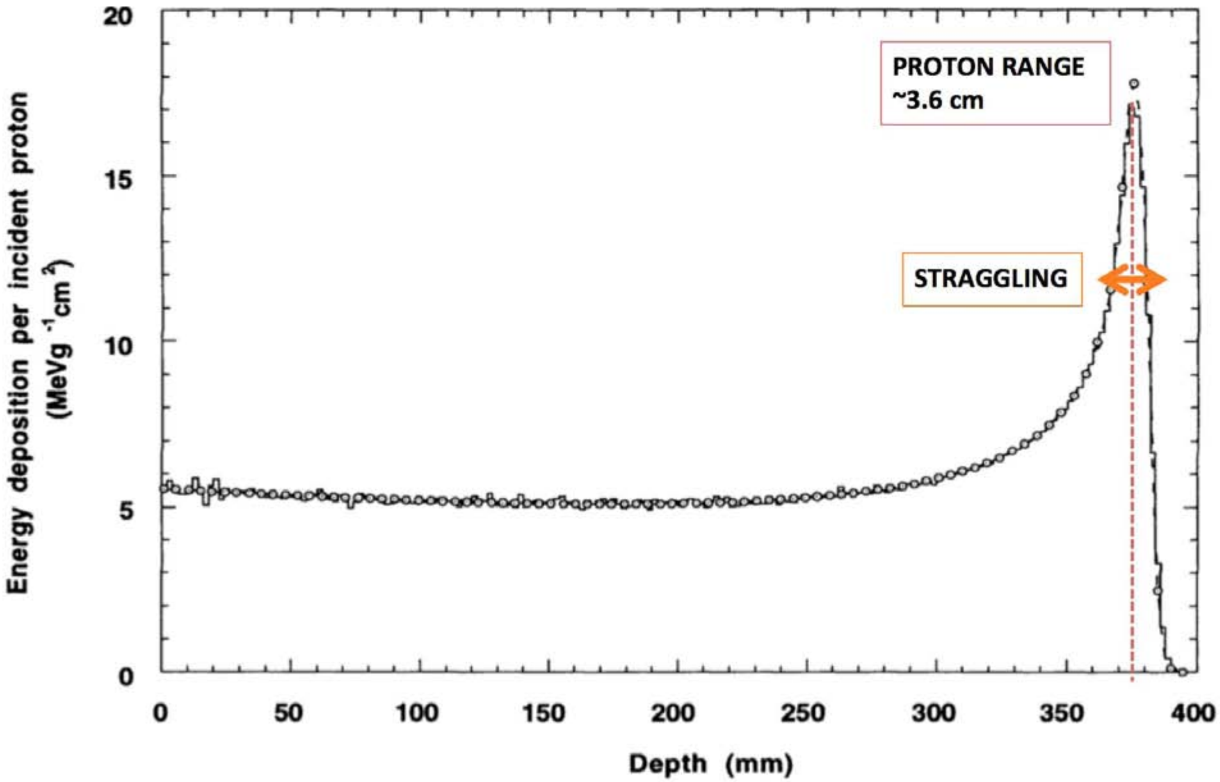


Courtesy of Larry DeWerd. Used with permission.

Medical Procedures & Dosimetry

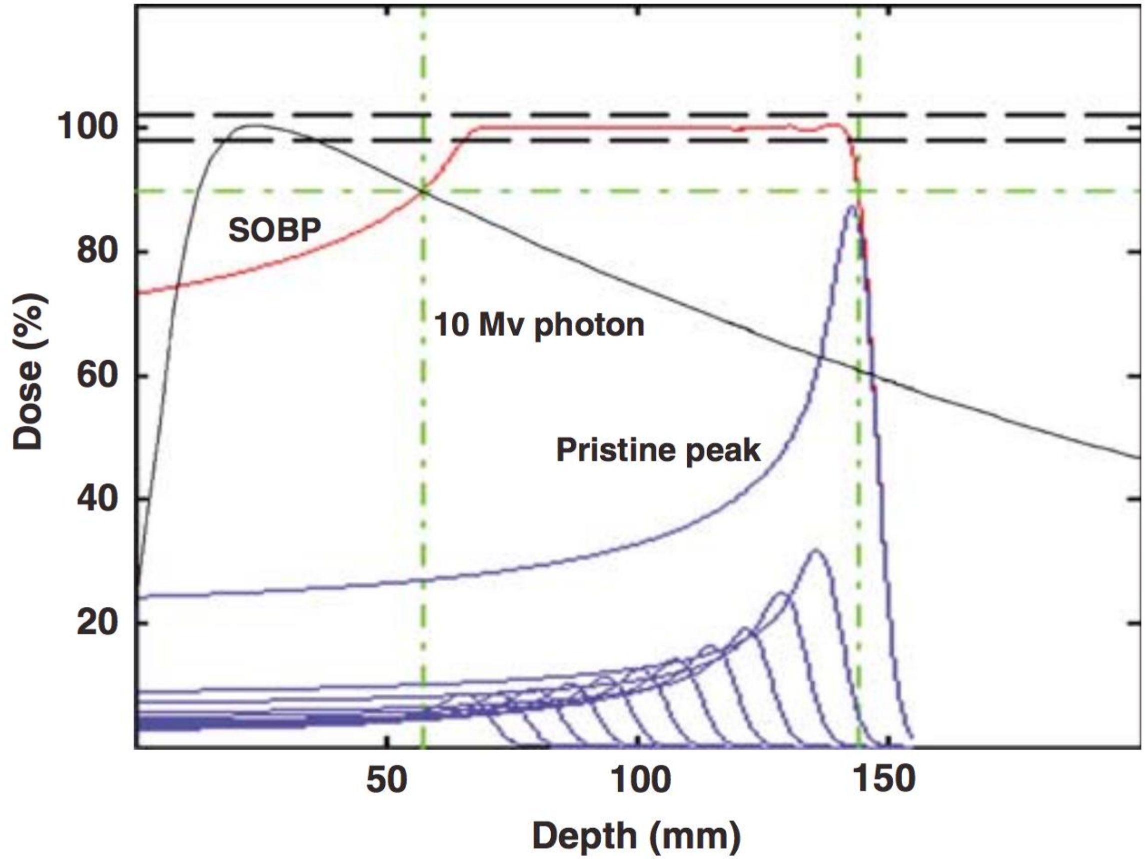
J. Medin and A. Pedro. "Monte Carlo calculated stopping-power ratios, water/air, for clinical proton dosimetry (50-250 MeV)." *Phys. Med. Bio.*, 42(1):89-105 (1997).

Goal: Destroy tumors, minimize collateral damage to tissue



IMRT – Intensity Modulated RT

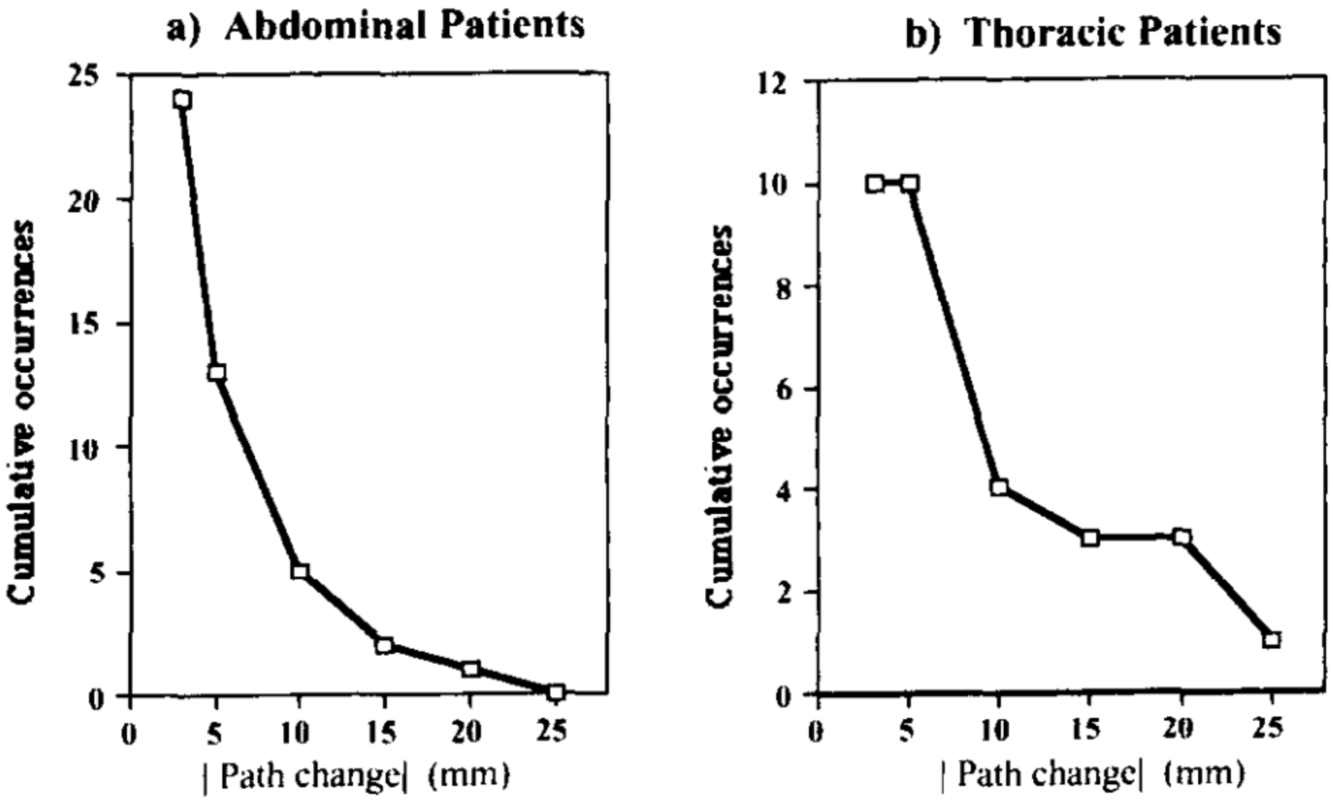
W. P. Levin et al. "Proton beam therapy." *British J. Cancer*, 93(8):849-854 (2005).



Problem: Normal Movement

J. M. Balter et al. "Uncertainties in CT-based radiation therapy treatment planning associated with patient breathing." *Intl. J. Rad. Oncology Bio. Phys.* 36(1):167 (1996).

Humans tend to breathe, swallow, digest… moving their organs



The Ideal IMRT Dosimeter

- The dosimeter can determine absolute dose
- The dosimeter can provide three-dimensional data
- The dosimeter’s response isn’t orientation-dependent
- The dosimeter is well-calibrated, and the interpretation of its readout is rigorously supported by data
- The dosimeter’s ability to measure absolute dose is insensitive to dose rate and energy of the radiation
- The dosimeter is non-toxic
- The dosimeter’s cost to build and maintain is reasonable

Existing Dosimetry Methods

- Monte Carlo calculations
- Conventional port films
- Electronic portal imaging devices (EPID)
- Gel dosimetry
- Electron spin resonance spectroscopy
- Thermoluminescent dosimetry
- Silicon diodes
- Scintillation fibers
- Prompt gamma monitoring
- PET scans
- MOSFET dosimeters

Electronic Portal Imagers (EPID)

http://www.dallasdentalspa.com/digital-radiography.php

Tissue Equivalent Gels

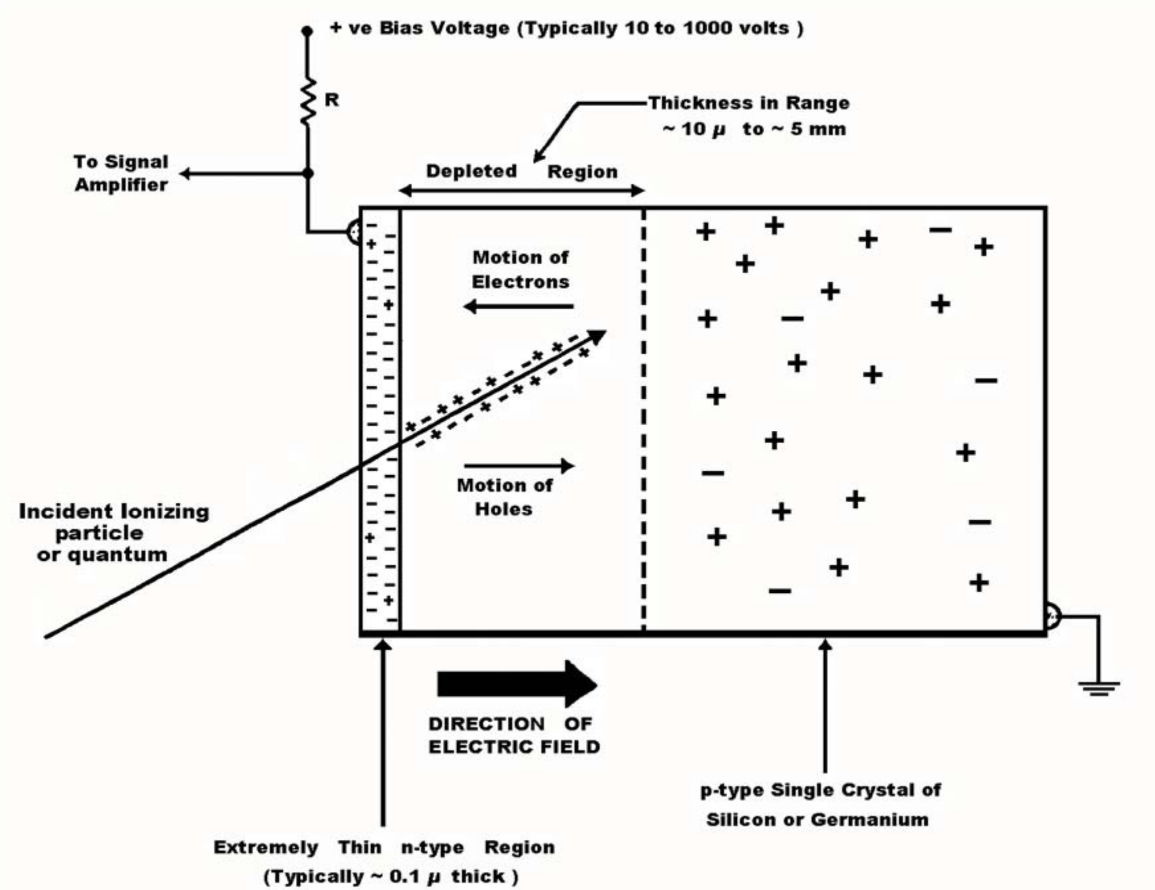
L. J. Schreiner, T. Olding. "Gel Dosimetry." *Presentation, 2009 AAPM Summer School*, Colorado College, CO, USA, June 21-25, 2009.

Courtesy of Yves De Deene. Used with permission.

Courtesy of Andrew Jirasek. Used with permission.

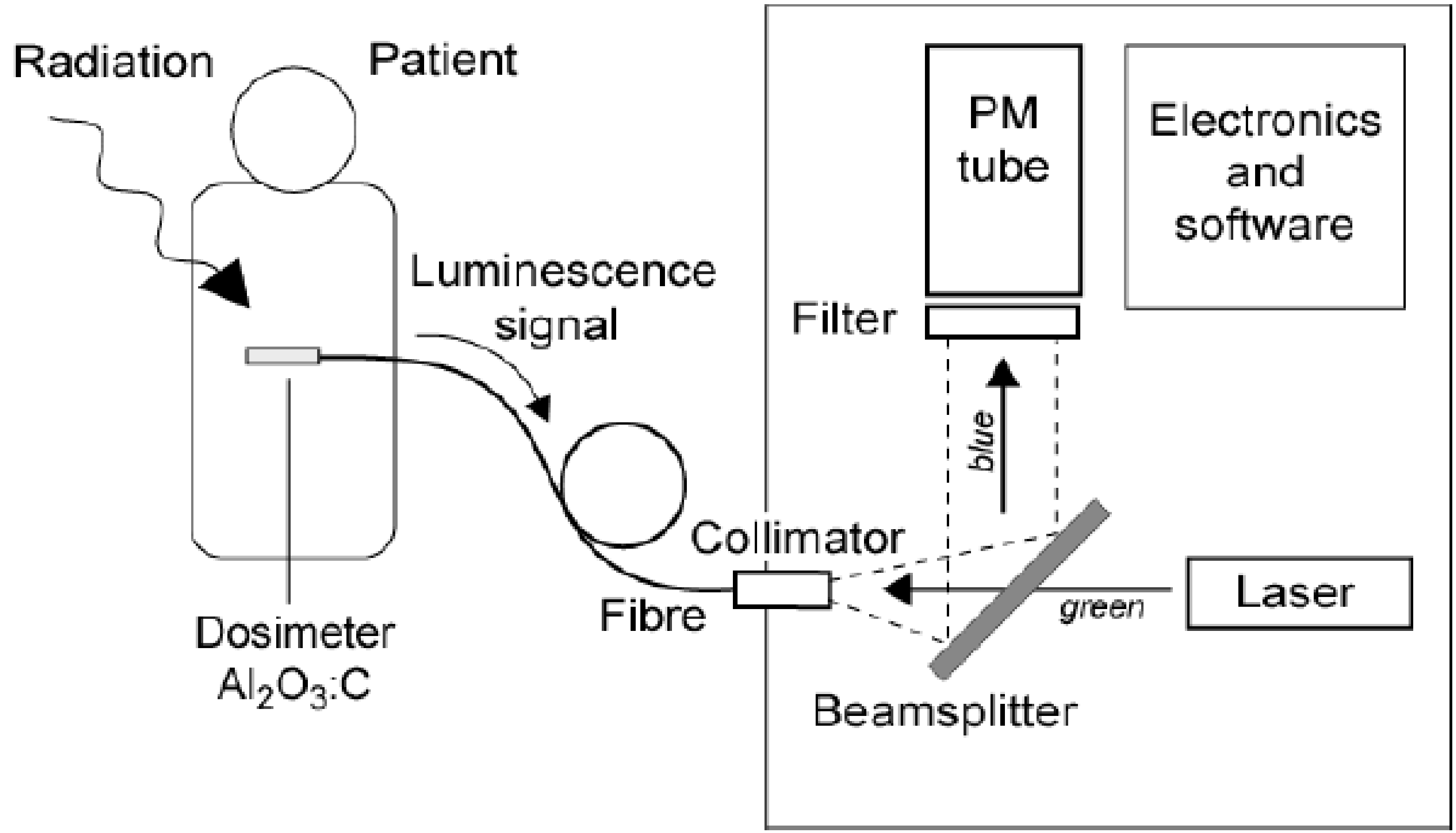
Silicon Diodes (Band Gap Change)

TAMU, Nuclear Safeguards Education Portal, "Basic Radiation Detection." http://nsspi.tamu.edu/nssep/courses/basic-radiation-detection/semiconductor-detectors/introduction/introduction.



Optically Stimulated Luminescence

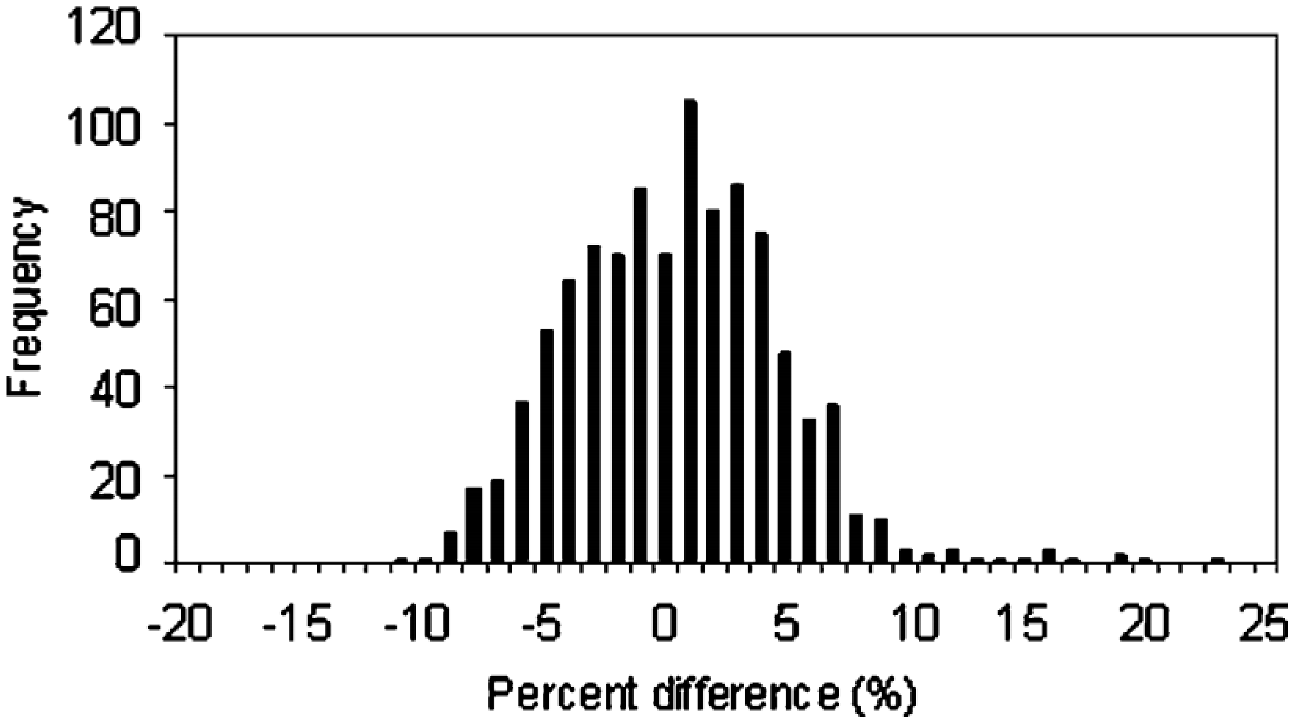
M. C. Aznar et al. "Real-time optical-fibre luminescence dosimetry for radiotherapy: physical characteristics and applications in photon beams." *Phys. Med. Bio.*, 49(9):1655 (2004).



Implanted MOSFETs

G. P. Beyer et al. "An Implantable MOSFET Dosimeter for the Measurement of Radiation Dose in Tissue During Cancer Therapy." *IEEE Sensors* 8 no. 1 (2008). doi:10.1109/JSEN.2007.912542

Significant differences were found to exist between prescribed and delivered cancer therapy treatments!



Problems

- Don’t know the real dose to the tumor
- Don’t know the dose to surrounding tissue
- Can’t control the proton accelerator in real time
- Don’t know the dose rate vs. time
- In-situ methods haven’t worked well
- Ex-situ methods don’t tell you real-time information

Our Idea…

… I will present it once our provisional patent is filed!!!