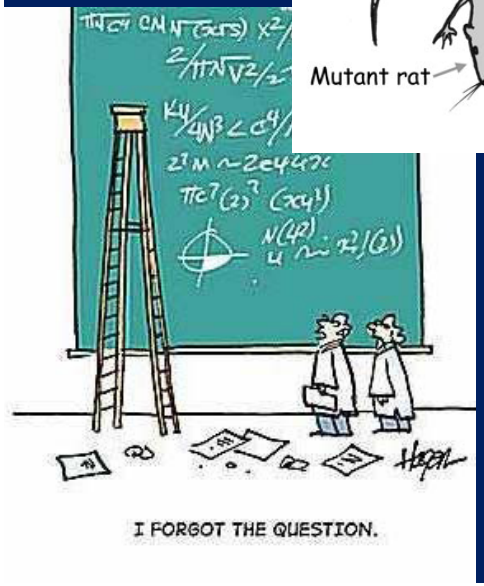
Therapeutic Medical Physics

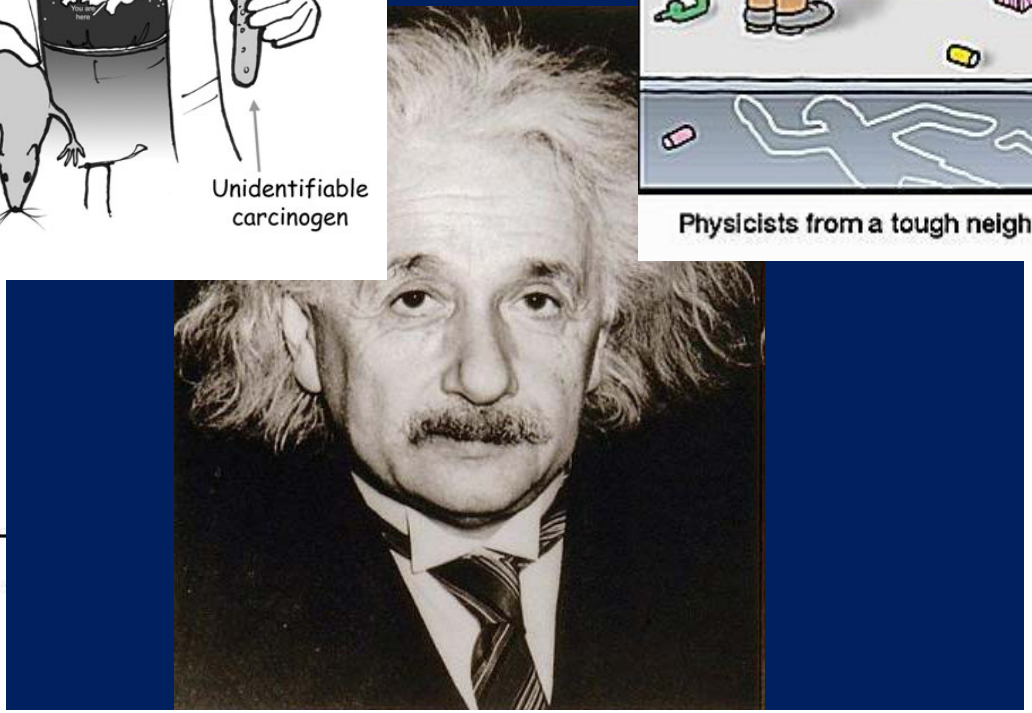
Stephen J. Amadon Jr., Ph.D., DABR

Outline

1. Why physicists are needed in medicine
2. Branches of medical physics
3. Physics in Radiation Oncology
4. Treatment types and Treatment Planning
    1. 3D conformal
    2. IMRT (Intensity Modulated Radiation Therapy)
    3. Brachytherapy
        1. LDR
        2. HDR
        3. Xoft – Electronic Brachytherapy

Worlds view of a physicist…



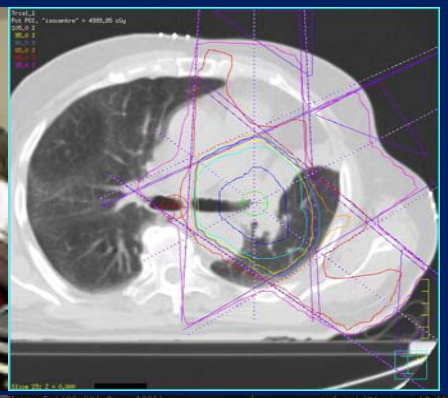


Physicist in Medicine

- Safety and Accuracy
- Education
- Radiation Protection + Shielding
- New technologies
- New methodologies

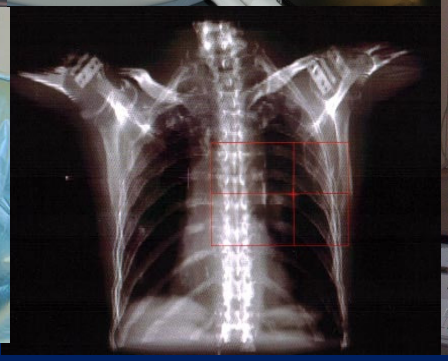
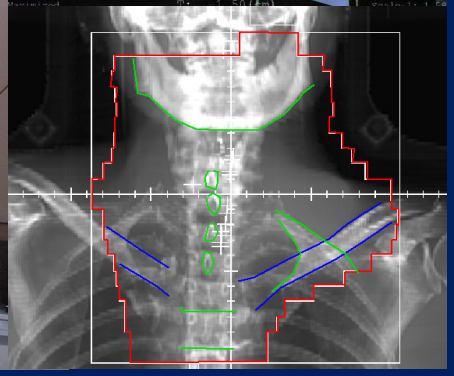
Radiotherapy

Radiotherapy is the treatment of disease (usually cancer) using very high doses of X-ray or particle radiation.

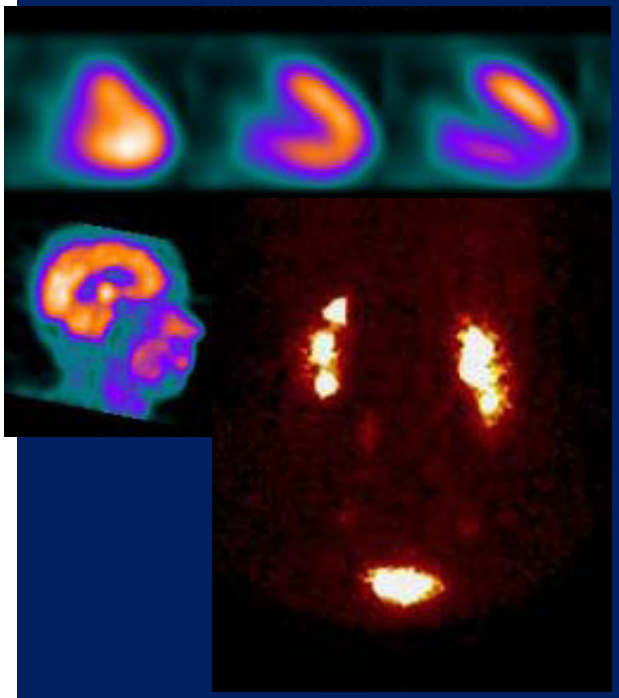







Nuclear Medicine

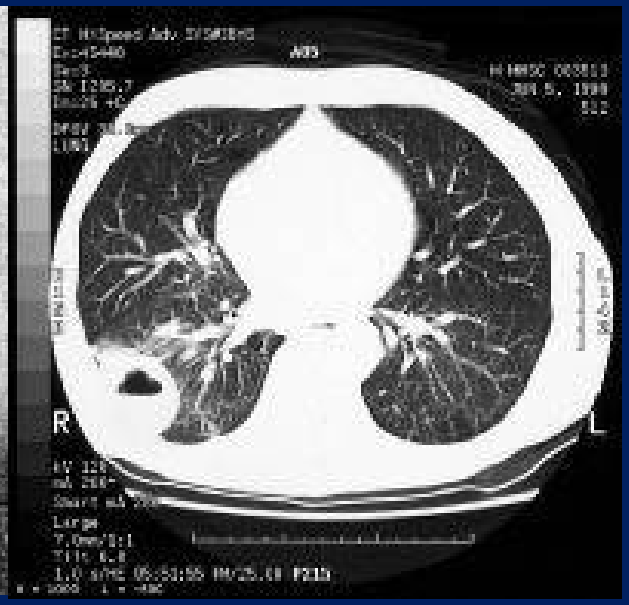


In Nuclear Medicine, radioactive materials are used to obtain images of tissue function. Large radiation doses are also used to treat disease.

Medical physicists are involved in:

- image processing
- assessing the performance and safety of imaging equipment
- working out radiation doses

Diagnostic Radiology (X-ray and CT)



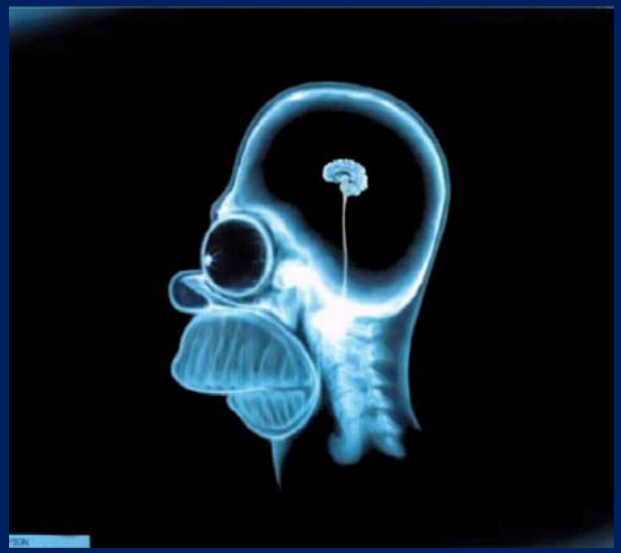
X-ray and CT images are made using X-ray radiation.

Medical physicists are involved in:

• assessing the performance of imaging equipment

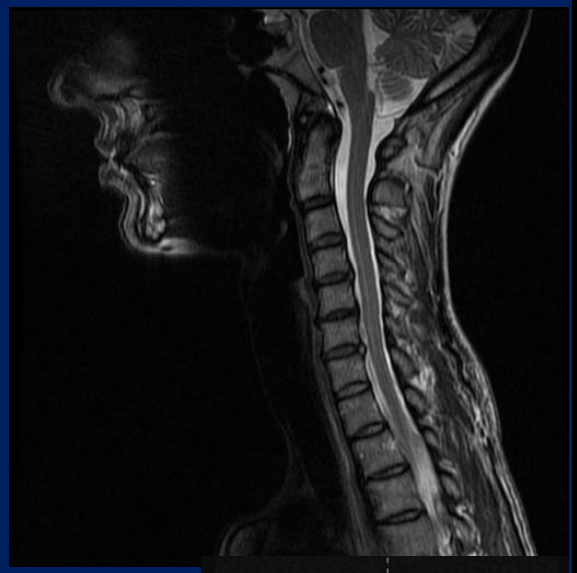
• working out X-ray radiation doses to patients and staff from scans

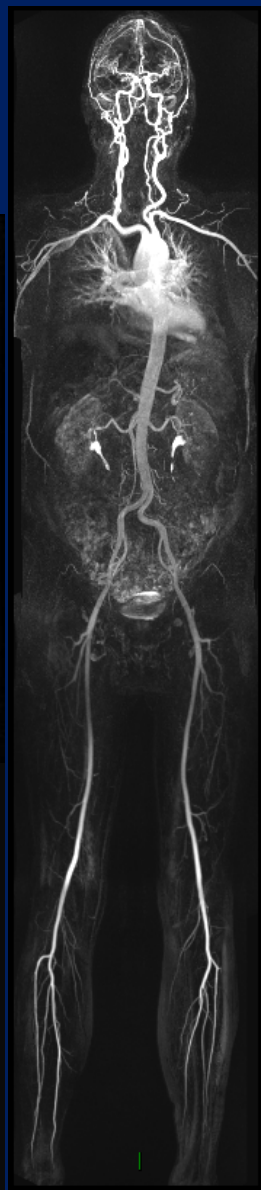
•improving image quality and safety



Magnetic Resonance Imaging (MRI)

MRI uses a big strong magnet to image the water in the body (good soft tissue contrast)



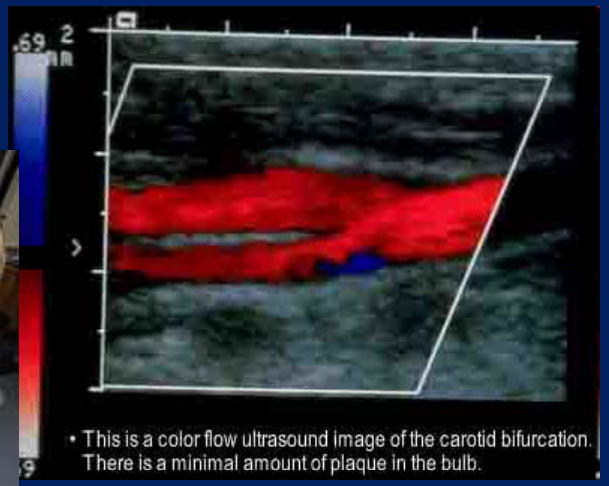


Medical physicists are involved in:

- all aspects of safety training- including checking patient implants
- carrying out quality assurance on equipment
- Analyzing patient data for reporting

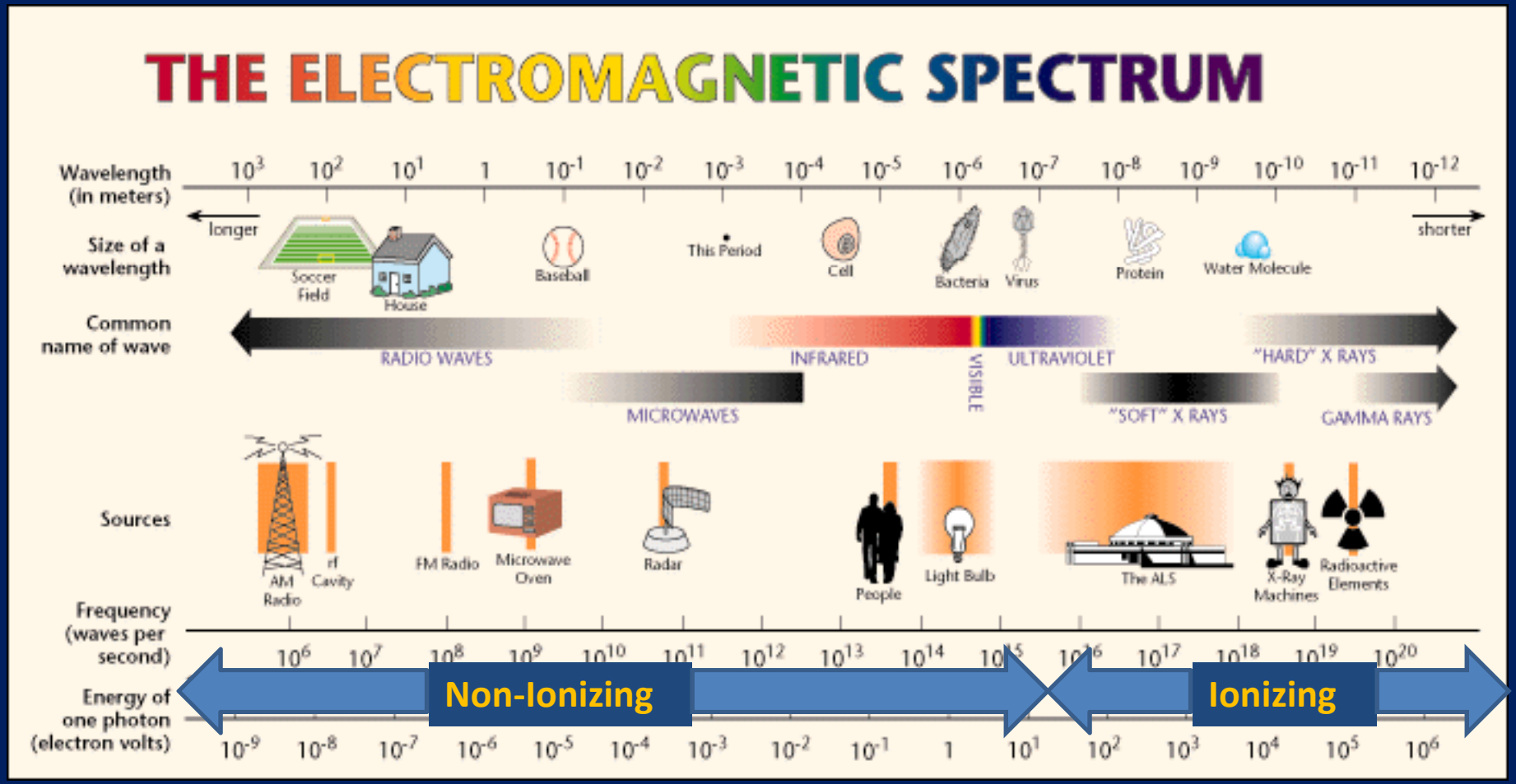
Other Areas of Medical Physics

- Ultrasound
- Radiation Protection
- Physiological Measurement
- Biomedical Engineering



Physics of Radiation Oncology

Ionizing Interactions can remove atomic orbital electrons
Particulate: electron, positron, proton, neutron, alpha



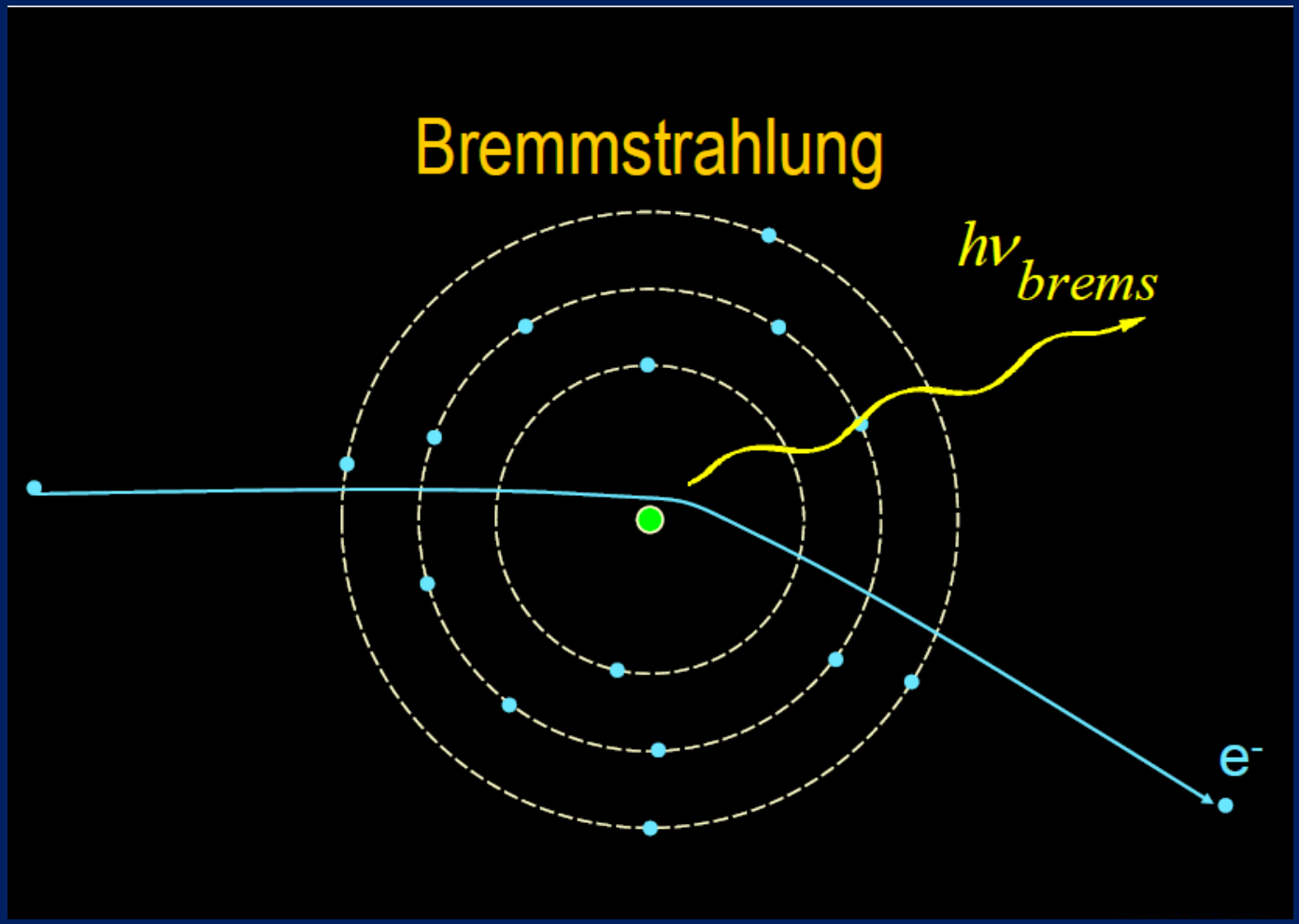
$c = \nu \lambda$ $E = h\nu$ $E = hc/\lambda$

X-Rays Interaction with Matter

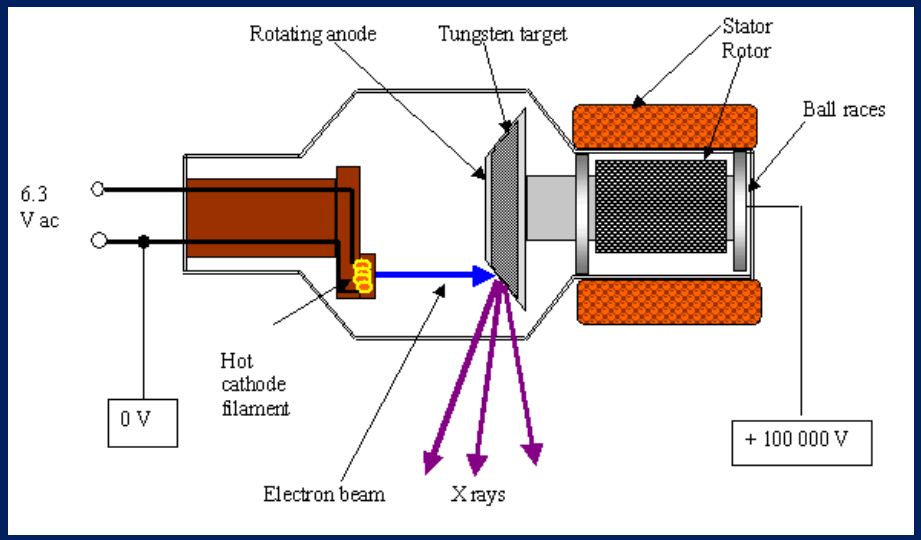
- Directly ionization
  - Electrons, Protons, positrons, heavy charged particles
- Indirectly ionization
  - Photons and neutrons
  - Interact via Coherent, Photoelectric, Compton, and pair production

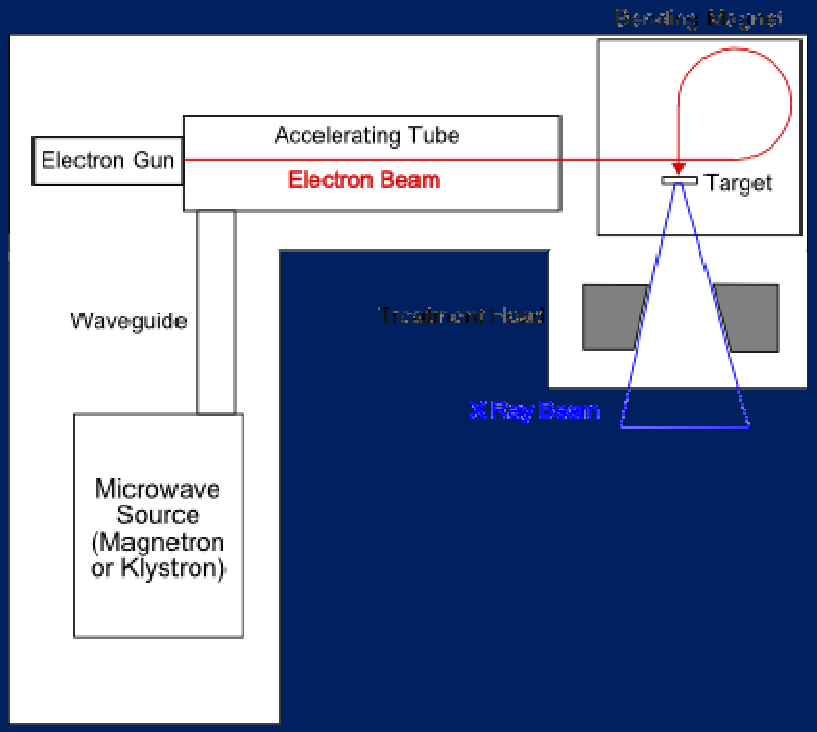
X-Ray Production

Electron Beam hits high density material. Typically Tungsten



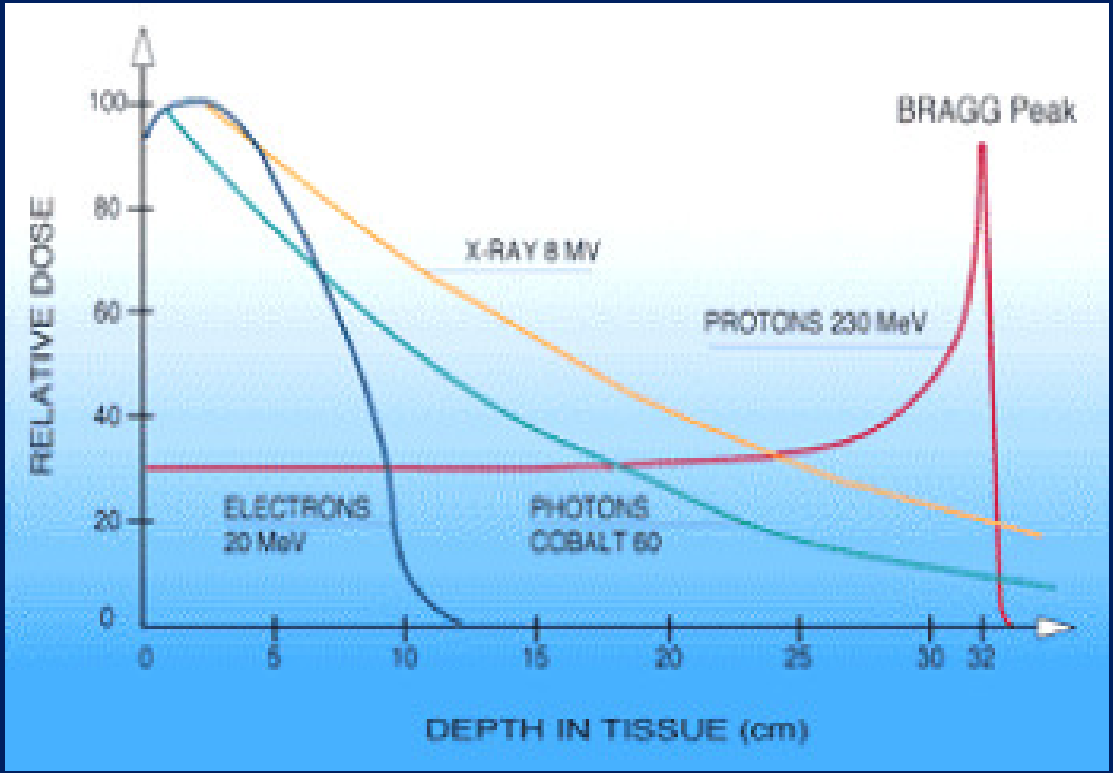
X-Ray Production





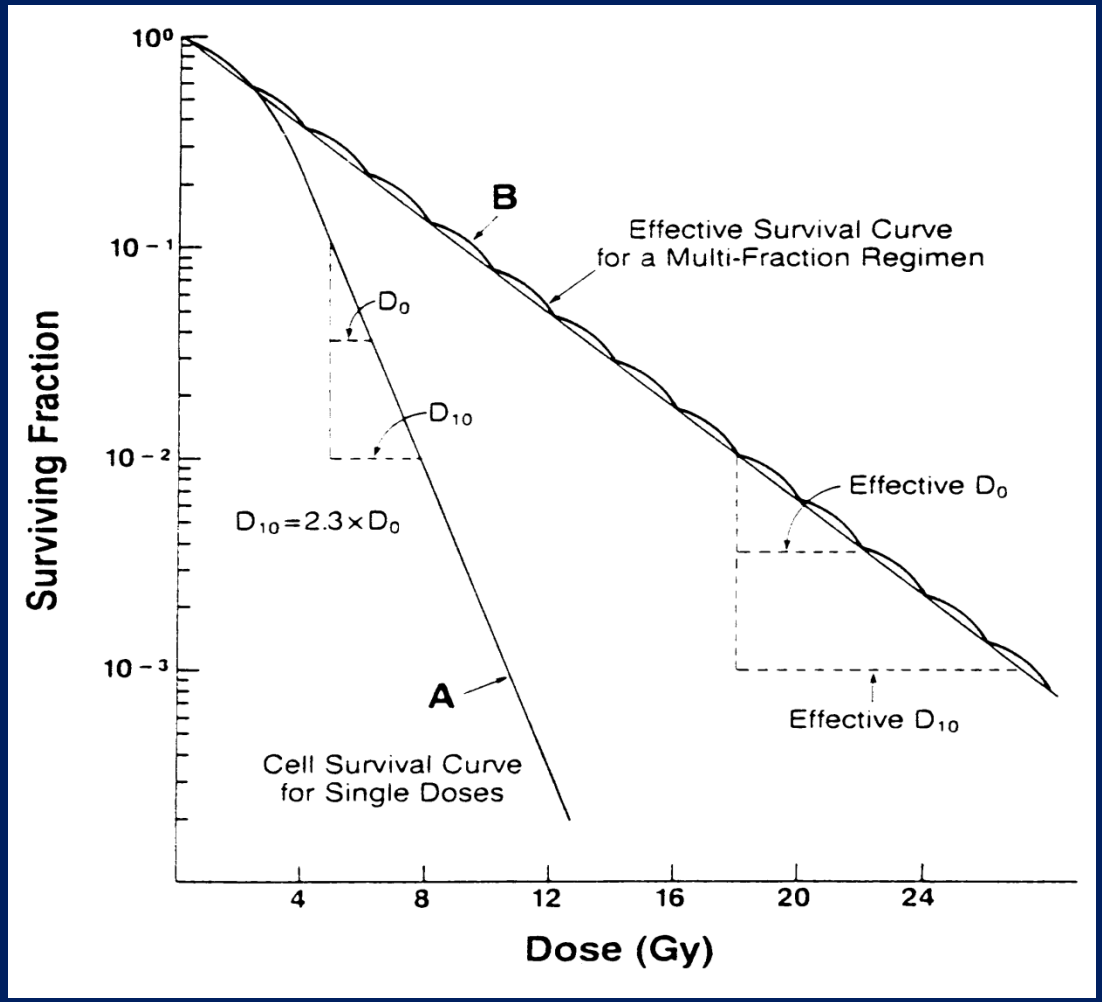
Depth Dose Curves

Dose = dE/dm



Why X-rays for Cancer Treatment

- Radiobiology
  - Damage DNA
- $SF = e^{-(\alpha D+\beta D2)}$
- $BED = nD\ (1 + (D/(\alpha/\beta)))$

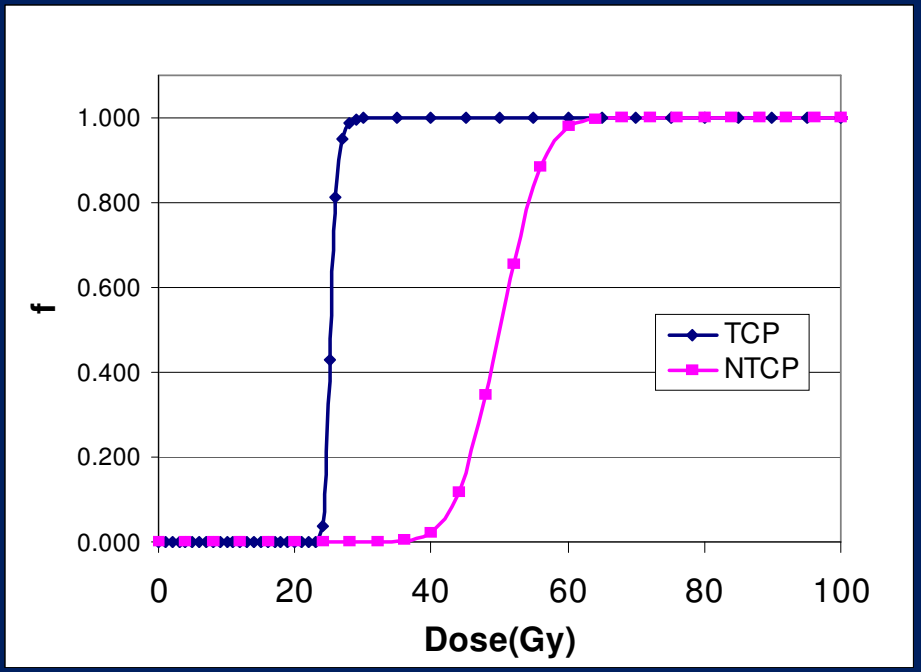


Biological Modeling

$$TCP_{pop} = \frac{1}{\sigma_\alpha \sqrt{2\pi}} \int_0^\infty e^{-(\alpha-\alpha_0)^2/2\sigma_\alpha^2} * \prod_{i=1}^{N} \exp[-\rho_i V_i \exp(-\alpha D_i - \beta D_i^2)] d\alpha$$

$$NTCP = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{-x^2/2} dx$$

$$OF_{Bio} = 1 - \left[TCP \prod_{i}^{\#ofOars} (1 - NTCP_i)^{wt} \right]$$



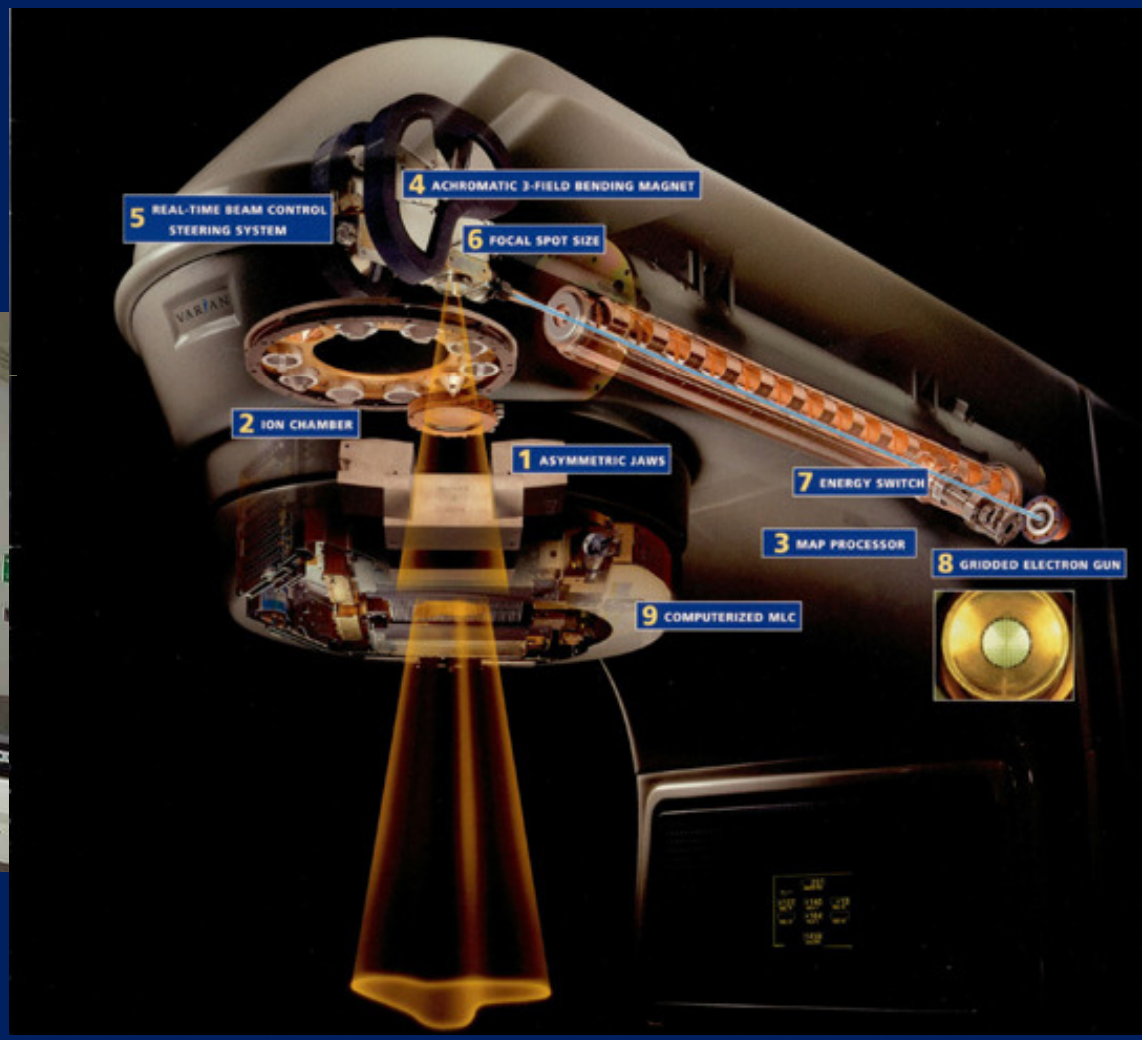
Medical physicists are involved in:

- CT System used for Planning
- Planning treatments
- Setting up and verifying Planning Systems
- Setting up and verifying Second Checks
- Maintaining treatment machines
- Calibrating treatment machines
- Developing new types of treatment
- Making sure radiation is used safely
- Checking the dose given by treatment machines is correct
- Review of Chart/Plan/Treatment

External Beam Therapy

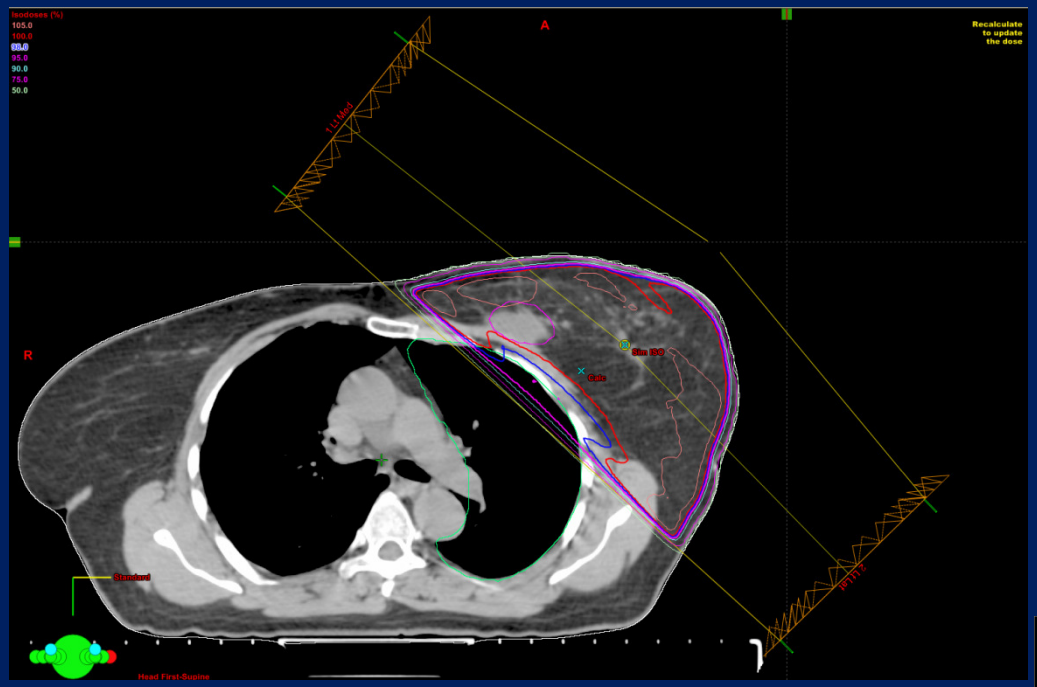
- 3D - Photons and Electrons
- IMRT
- Rapid Arc

Varian 21ex Treatment Machine



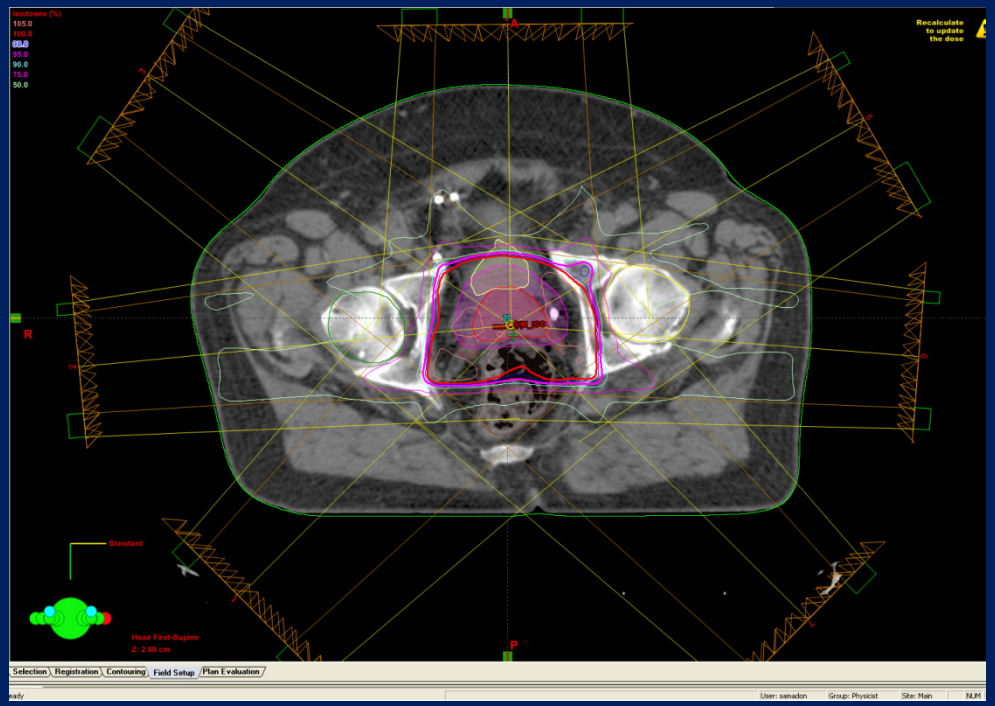
MLC

Breast Treatment



Daily imaging
- EPID
- Checking chest Wall
- Checking Flash

Prostate IMRT

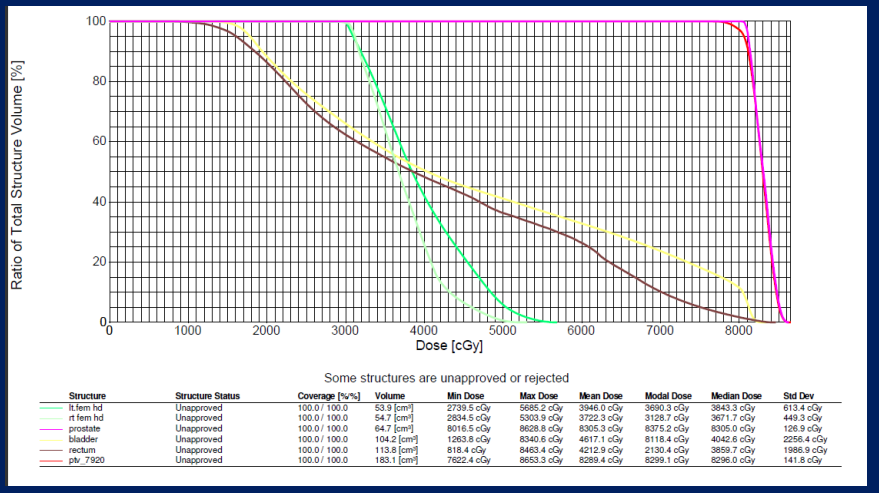


Dose Distribution

Daily Localization (imaging)

- Ultrasound
- Gold Seeds using EPID
- Calypso
- Cone beam CT or MVCT

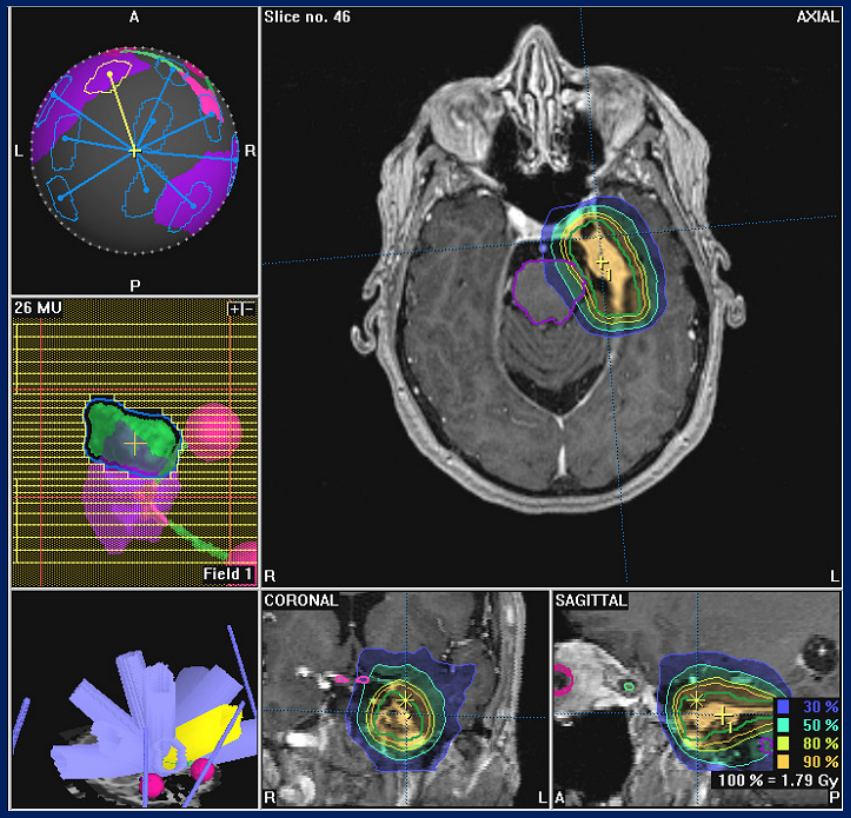
DVH



Structure	Structure Status	Coverage [%/%]	Volume	Min Dose	Max Dose	Mean Dose	Modal Dose	Median Dose	Std Dev
lt fem hd	Unapproved	100.0 / 100.0	53.9 [cm³]	2739.5 cGy	5685.2 cGy	3946.0 cGy	3690.3 cGy	3843.3 cGy	613.4 cGy
rt fem hd	Unapproved	100.0 / 100.0	54.7 [cm³]	2834.5 cGy	5303.9 cGy	3722.3 cGy	3128.7 cGy	3671.7 cGy	449.3 cGy
prostate	Unapproved	100.0 / 100.0	64.7 [cm³]	8016.5 cGy	8628.8 cGy	8305.3 cGy	8375.2 cGy	8305.0 cGy	126.9 cGy
bladder	Unapproved	100.0 / 100.0	104.2 [cm³]	1263.8 cGy	8340.6 cGy	4617.1 cGy	8118.4 cGy	4042.6 cGy	2256.4 cGy
rectum	Unapproved	100.0 / 100.0	113.8 [cm³]	818.4 cGy	8463.4 cGy	4212.9 cGy	2130.4 cGy	3859.7 cGy	1986.9 cGy
ptv_7920	Unapproved	100.0 / 100.0	183.1 [cm³]	7622.4 cGy	8653.3 cGy	8289.4 cGy	8299.1 cGy	8296.0 cGy	141.8 cGy

Tomotherapy

Stereotactic Radio Surgery

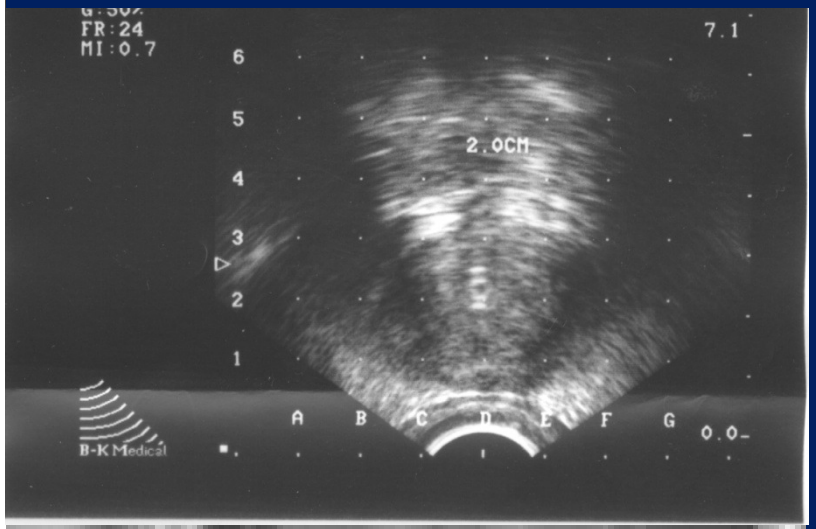


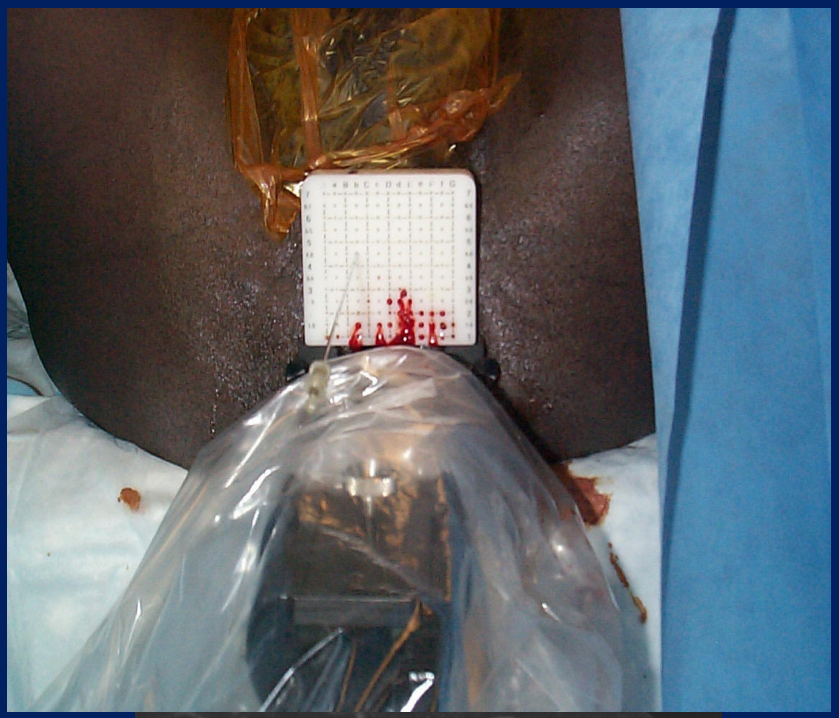
Cyberknife Treatment

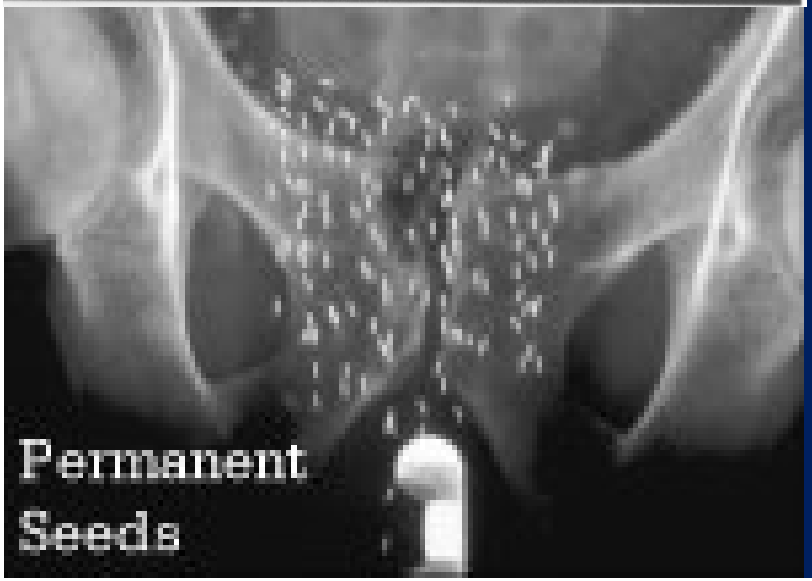
BrachyTherapy

- LDR (Low Dose Rate)
  - Prostate Seed Implants
- HDR (High dose Rate)
  - Partial Breast
  - Vaginal Cylinder
  - Tandem and Ovoid
  - Prostate

LDR: Prostate Seed Implant – Iodine 125



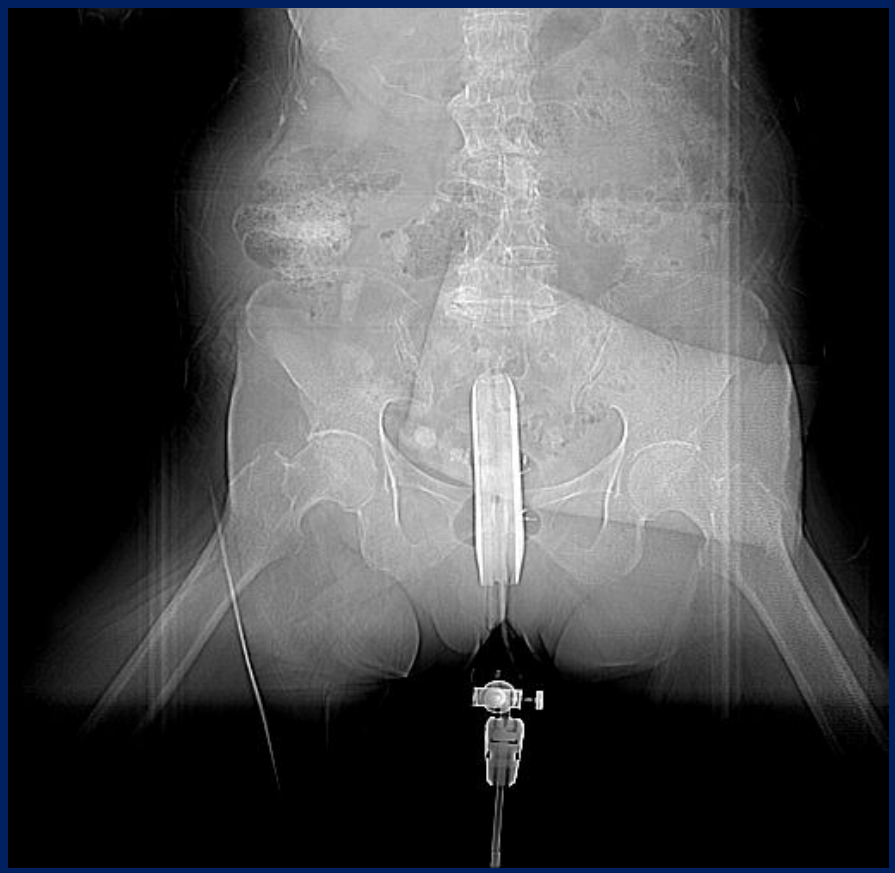


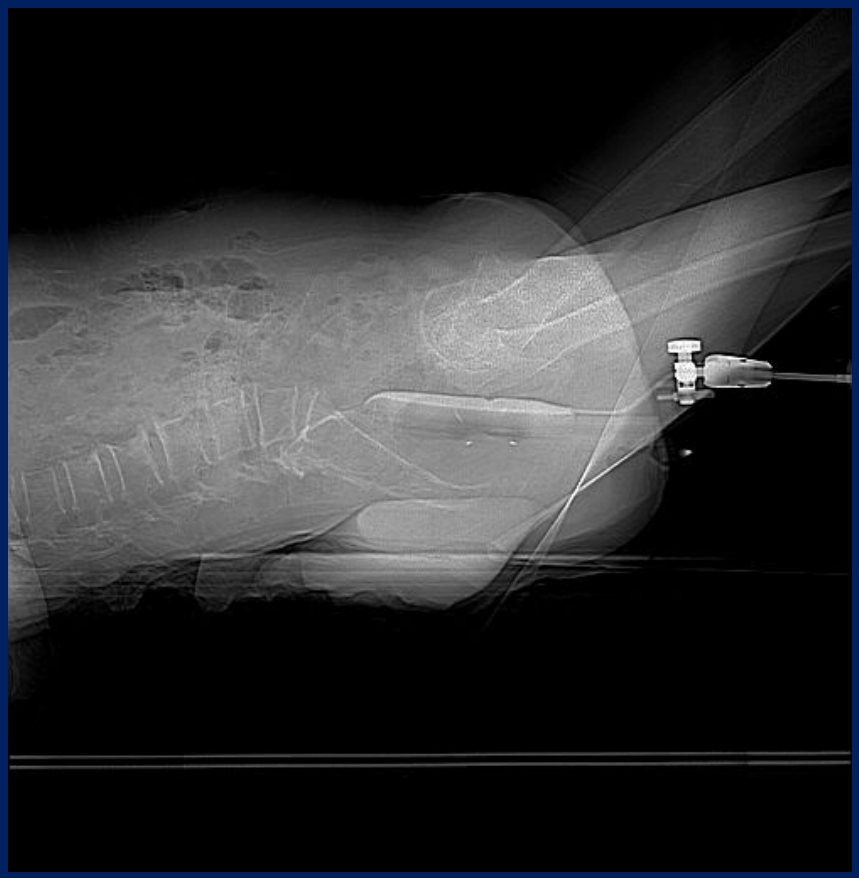


HDR

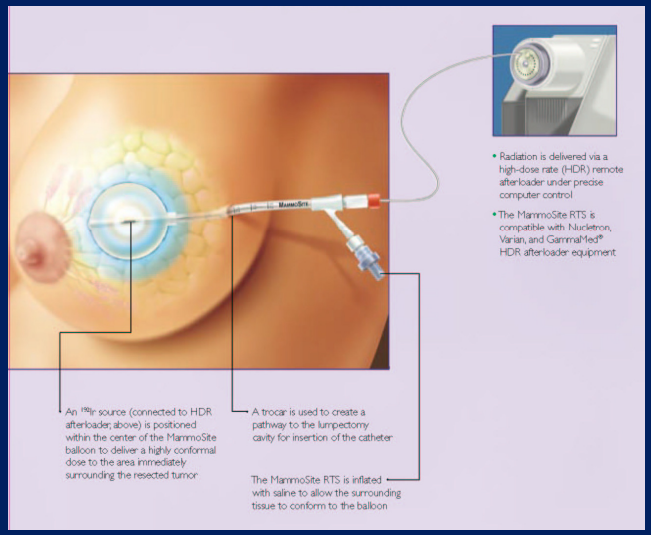
- 10 curie iridium 192 sealed source
- 12 Gy per hour dose rate (1200 cgy/hr)
- 2 ft. Concrete vault walls
- Extensive QA and safety procedures

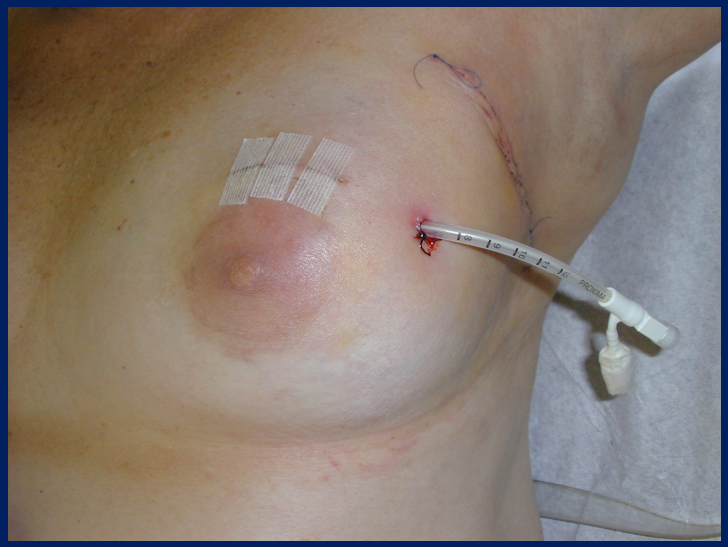
Vaginal Cylinder

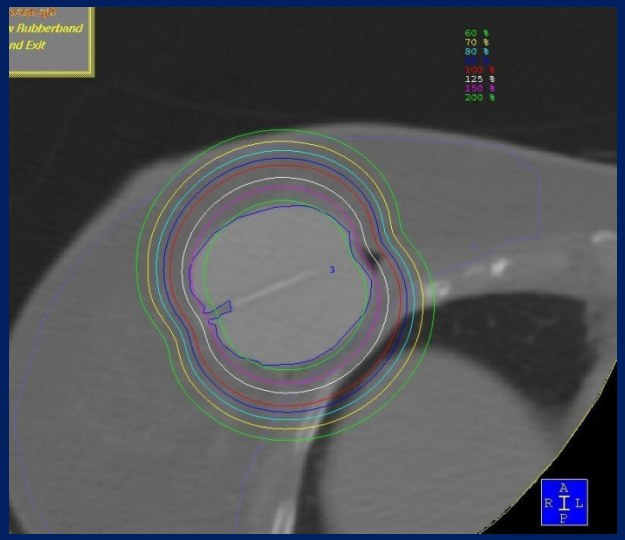




Advanced Partial Breast Treatment







Xoft

- No radioisotope regulatory, handling and safety issues
- Lower shielding requirements brings HDR treatment "out of the bunker"
- Unique capabilities will permit dose sculpting
- Medical personnel can remain in treatment room

Controller

Balloon Applicators

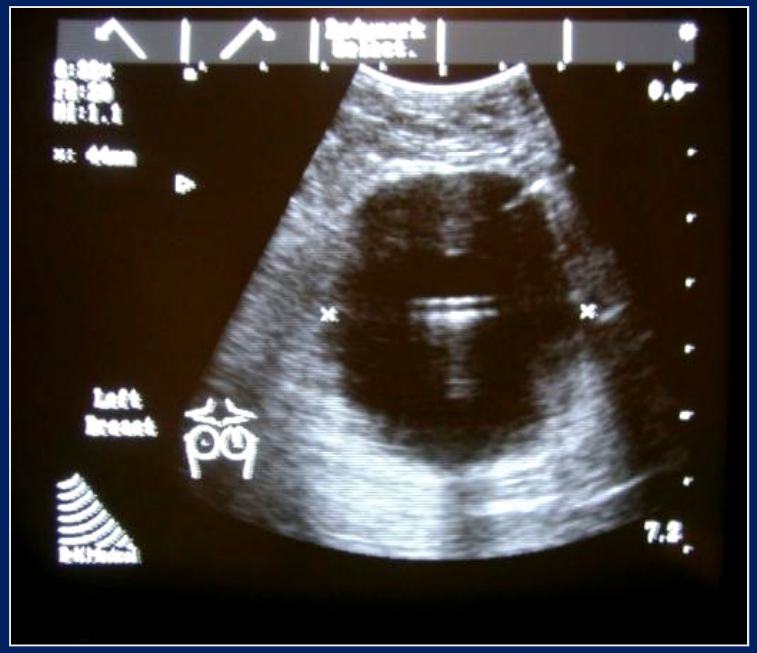
Vaginal Applicators

Xoft - Balloons

Good visualization of balloons under CT and Fluoro, and ultrasound.

NO CONTRAST NEEDED

Standardized contrast concentration in balloon wall material minimizes radiation attenuation

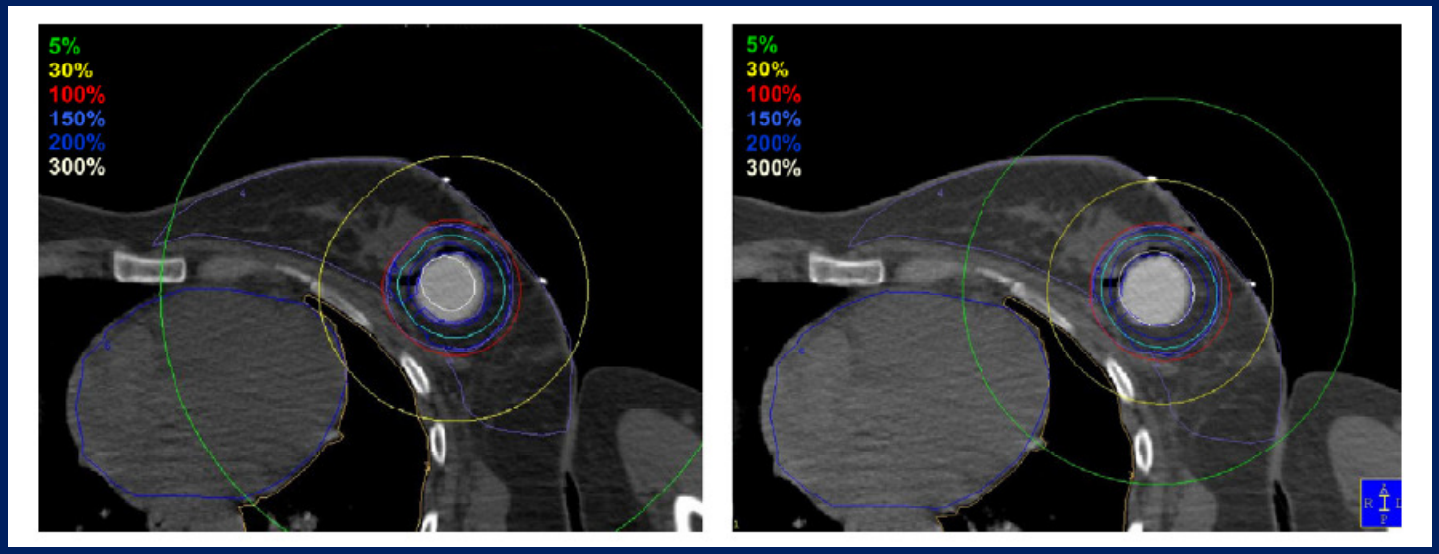


Xoft Comparison

^{192}Ir HDR

Xoft 50kV

APBI



Cylinder