Modern equipment in classical radiotherapy based on linacs

Slawomir Wronka, CAS 11.10.2006

Contents

- **Epidemiological data**
- **Machines used for „classical” radiotherapy**
- **High-art. techniques**

Poland

- Cancer is the second main mortal disease in Poland (20%)
- 110 000 cases / year
- ~ 50-60% requires radiotherapy treatment

  → 60 000 patients yearly

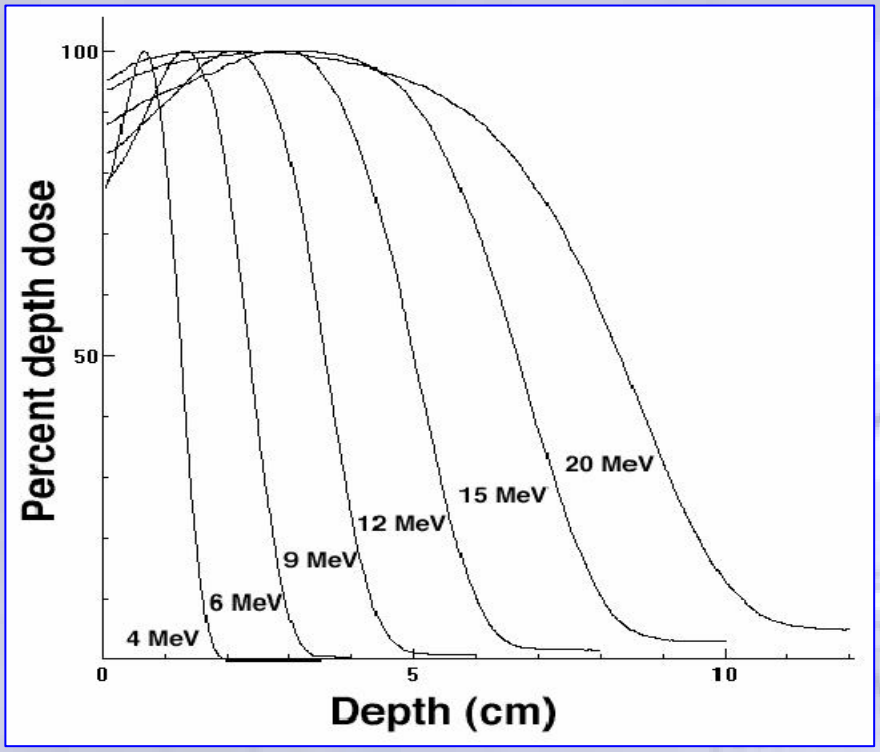
World

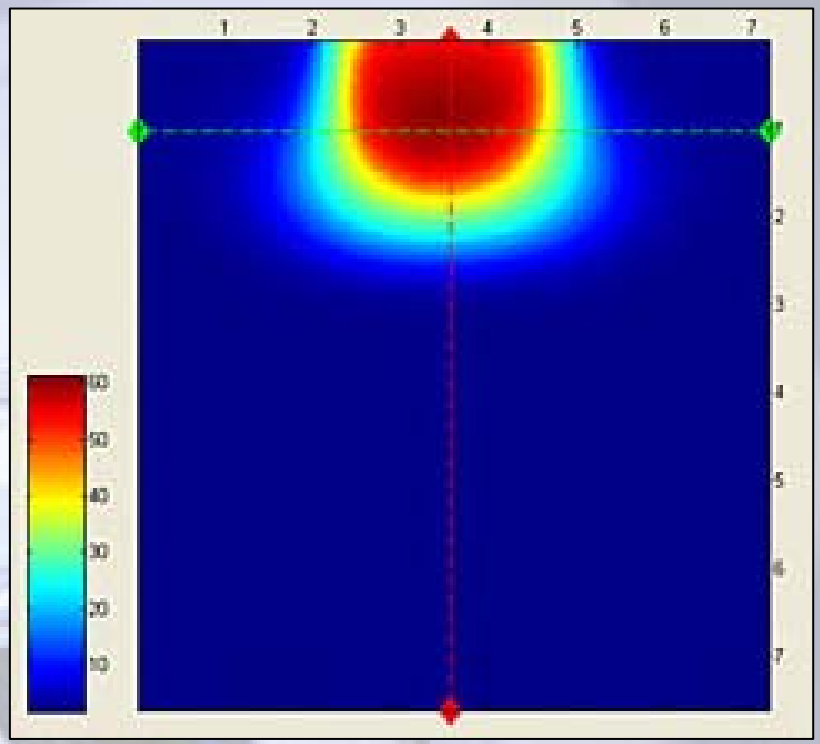
> 200,000 patients treated daily

> 7500 radiotherapy accelerators

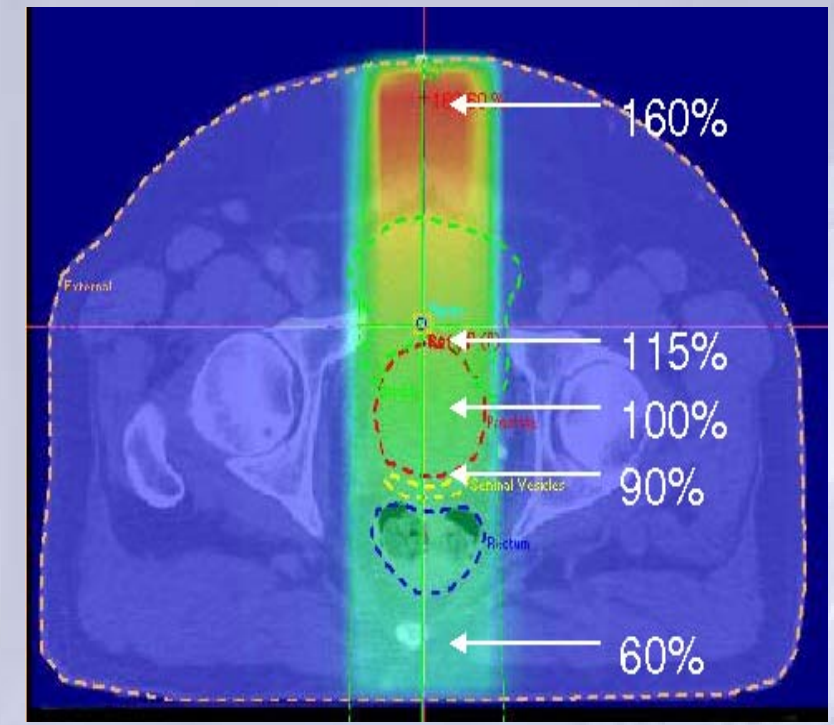
Typical beams

Electrons

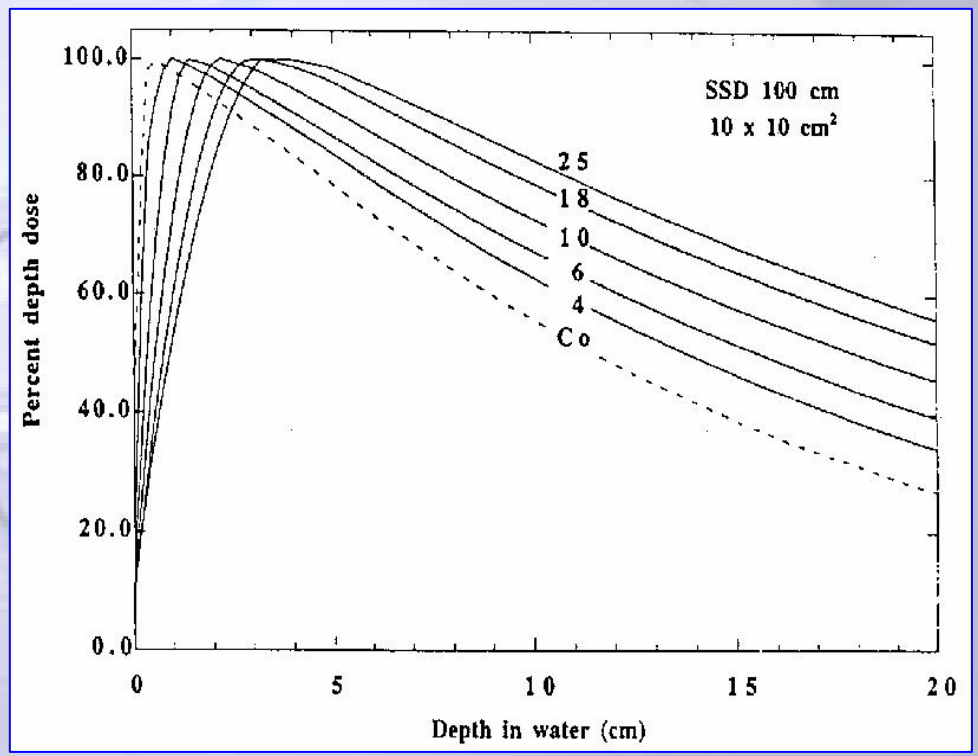




Typical beams



Photons

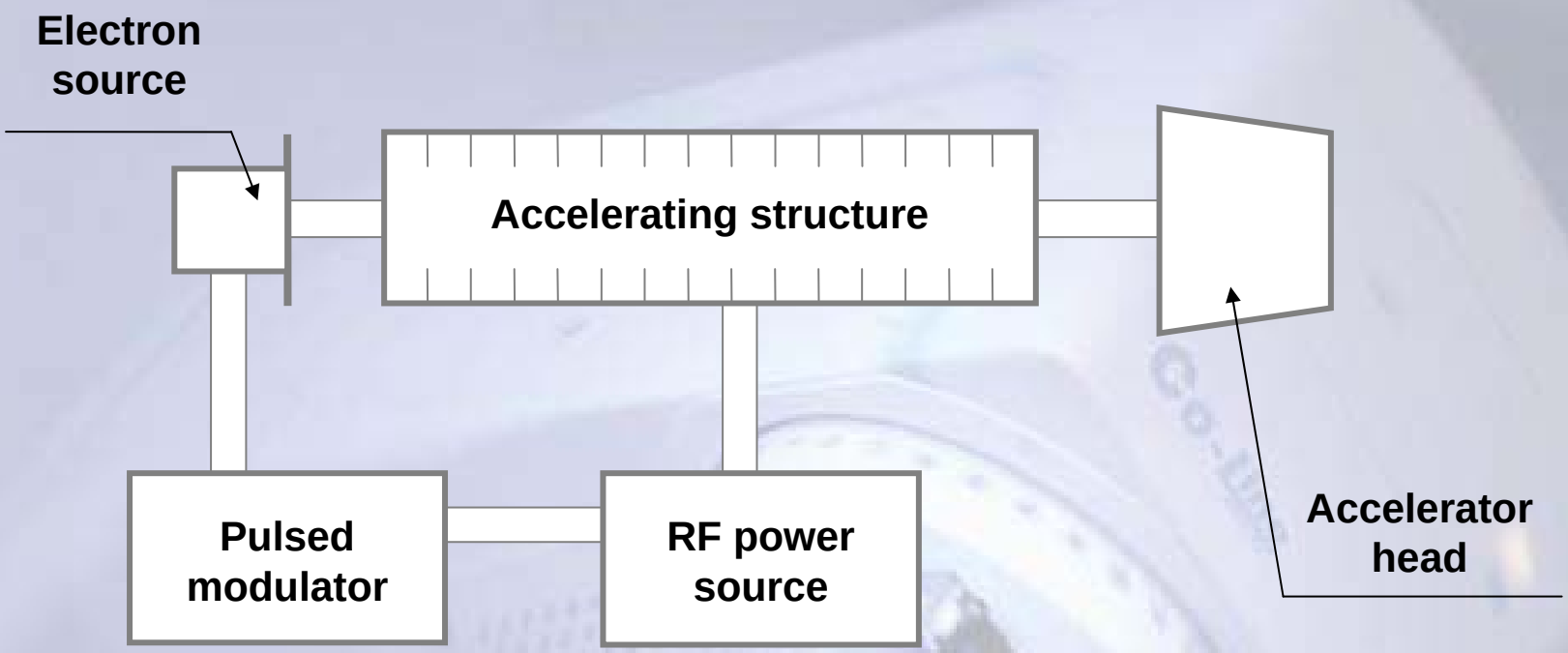


Typical beams

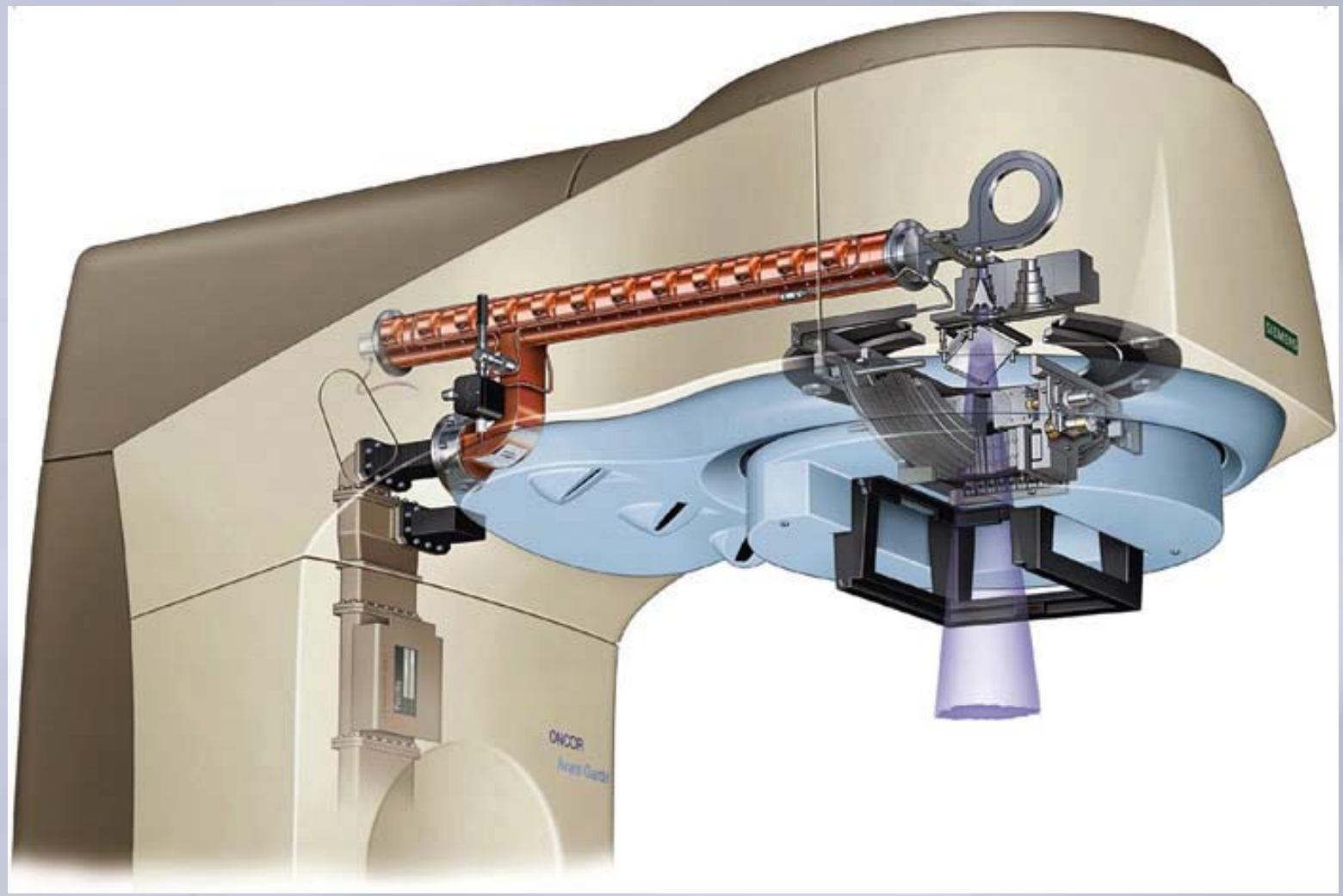
- At present, in radiotherapy, the upper energy range of 15 to 20 MeV is considered optimal. The lower limit in photon therapy is determined by clinical requirements of the treatment of head and neck tumors for which the energies of 4 to 6 MeV are optimal*.

* W.Maciszewszki, W. Scharf „PARTICLE ACCELERATORS FOR RADIOTHERAPY. PRESENT STATUS AND FUTURE. ”

Linear accelerator



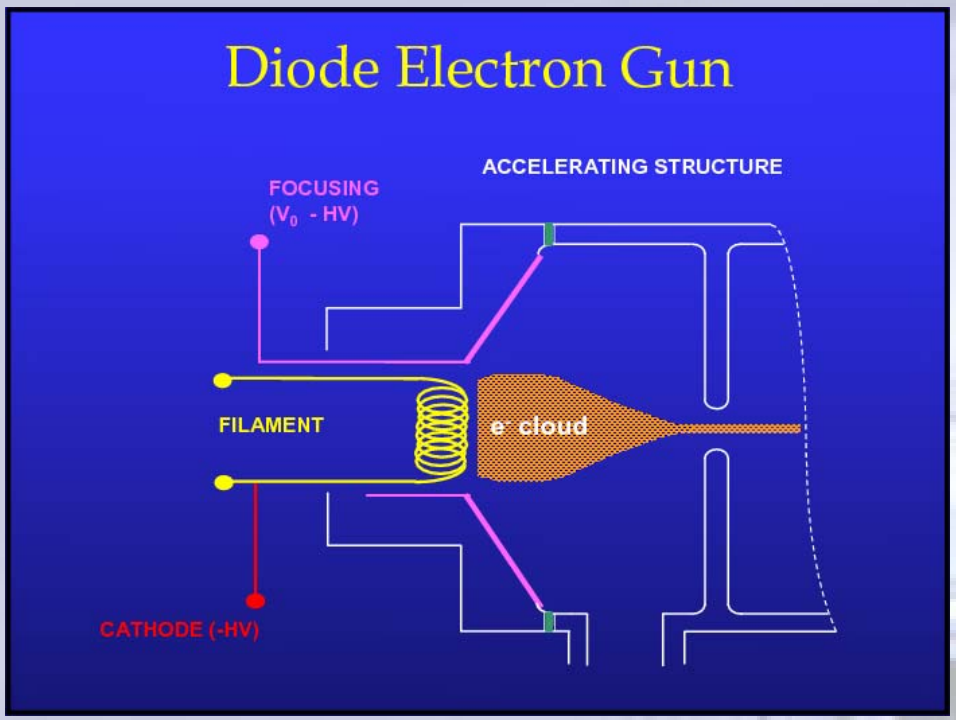
Medical linac

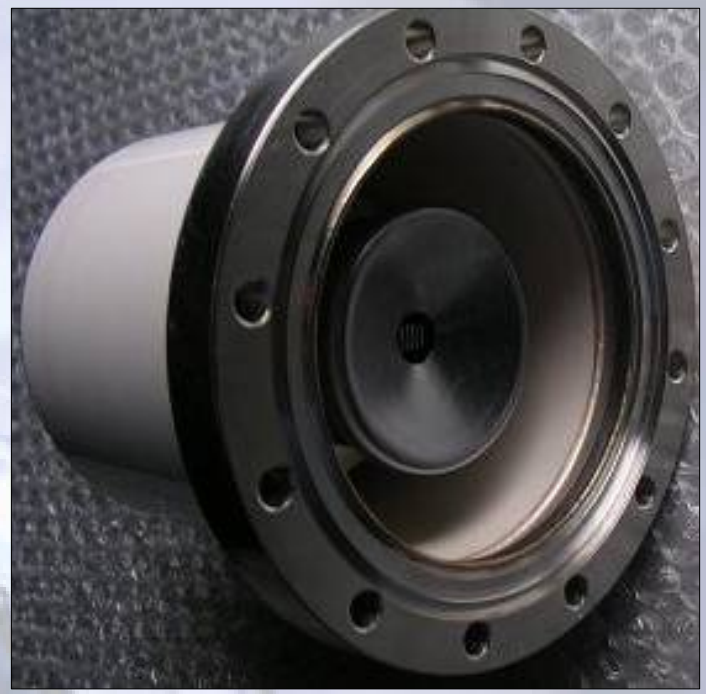


Electron source

- Electrons are thermionically emitted from the heated cathode and accelerated toward the anode through which they enter the accelerating structure.

Electron source

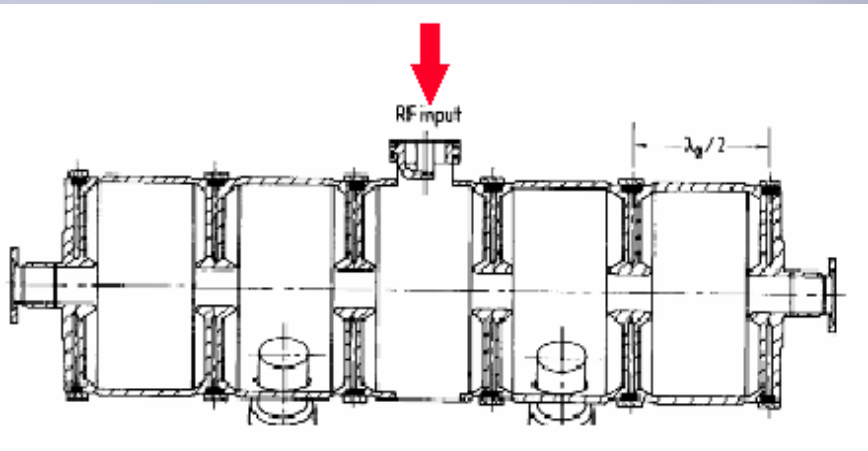


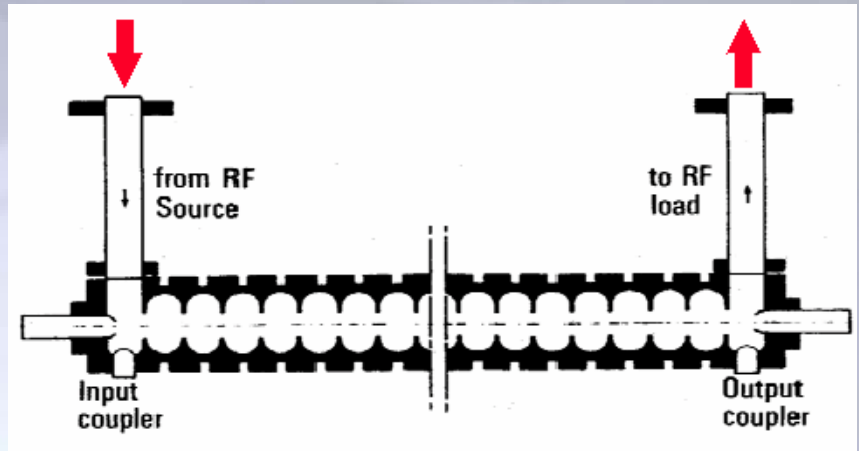


Accelerating structure

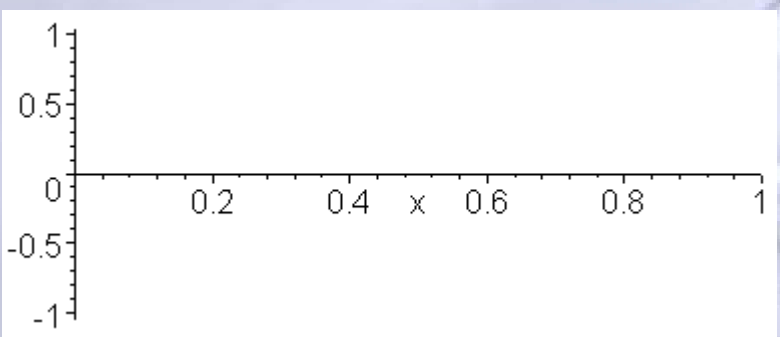
- The electrons are accelerated in the accelerating structure by radiofrequency (RF) fields which are produced by the RF power generators.
- The microwave frequency used for electrons acceleration is about 3 GHz.

Accelerating structure

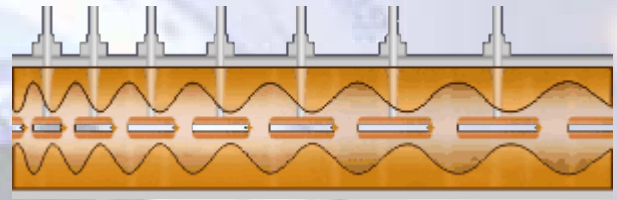




Standing wave

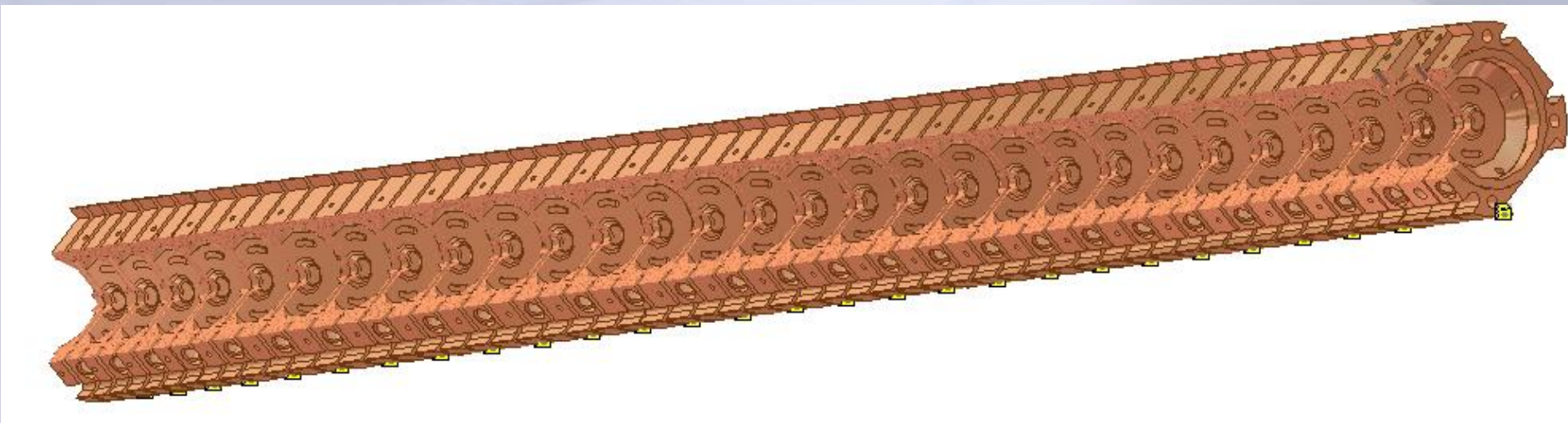


Traveling wave

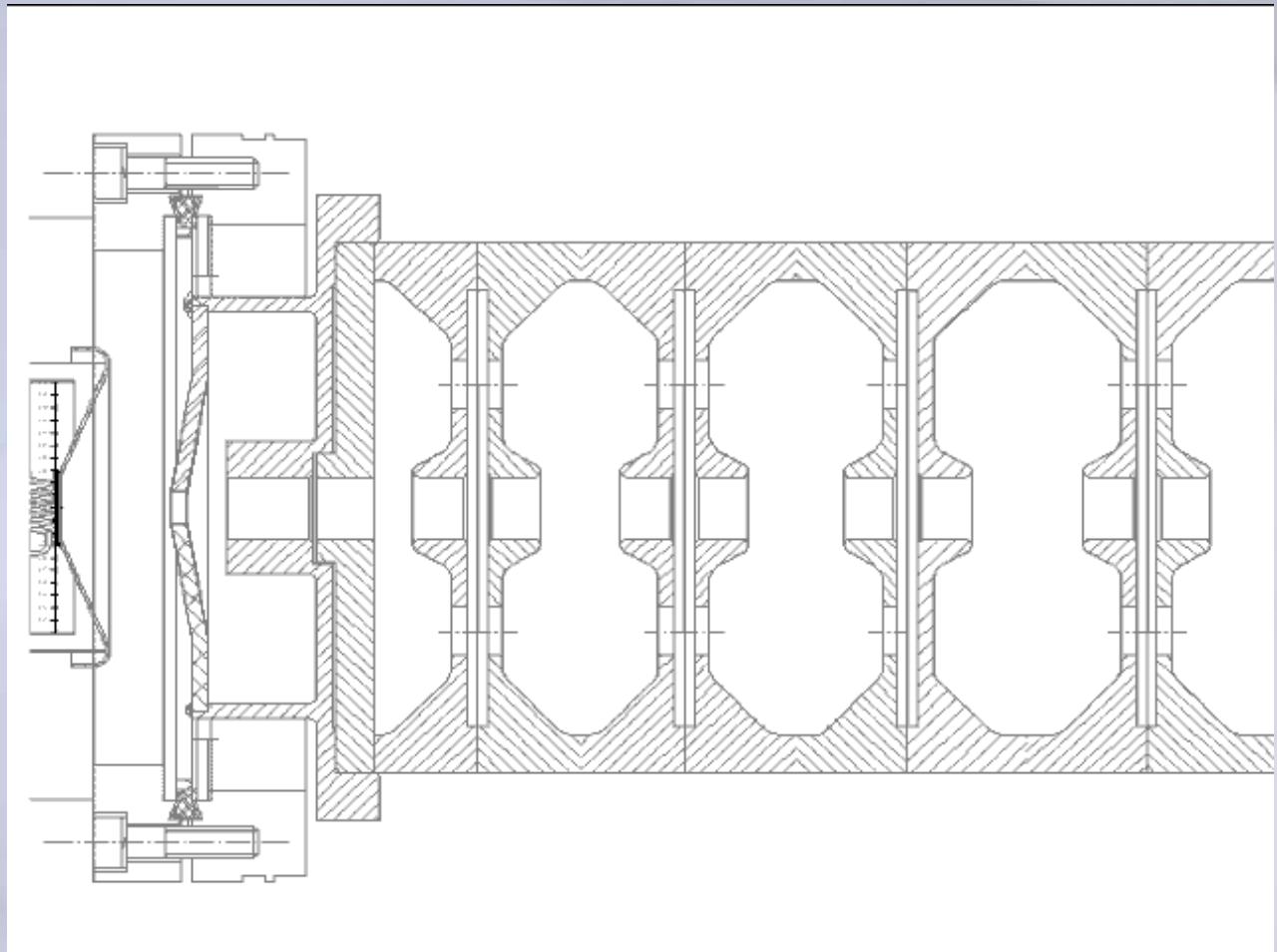


Accelerating structure

Accelerating structure



Accelerating structure



RF power generation system

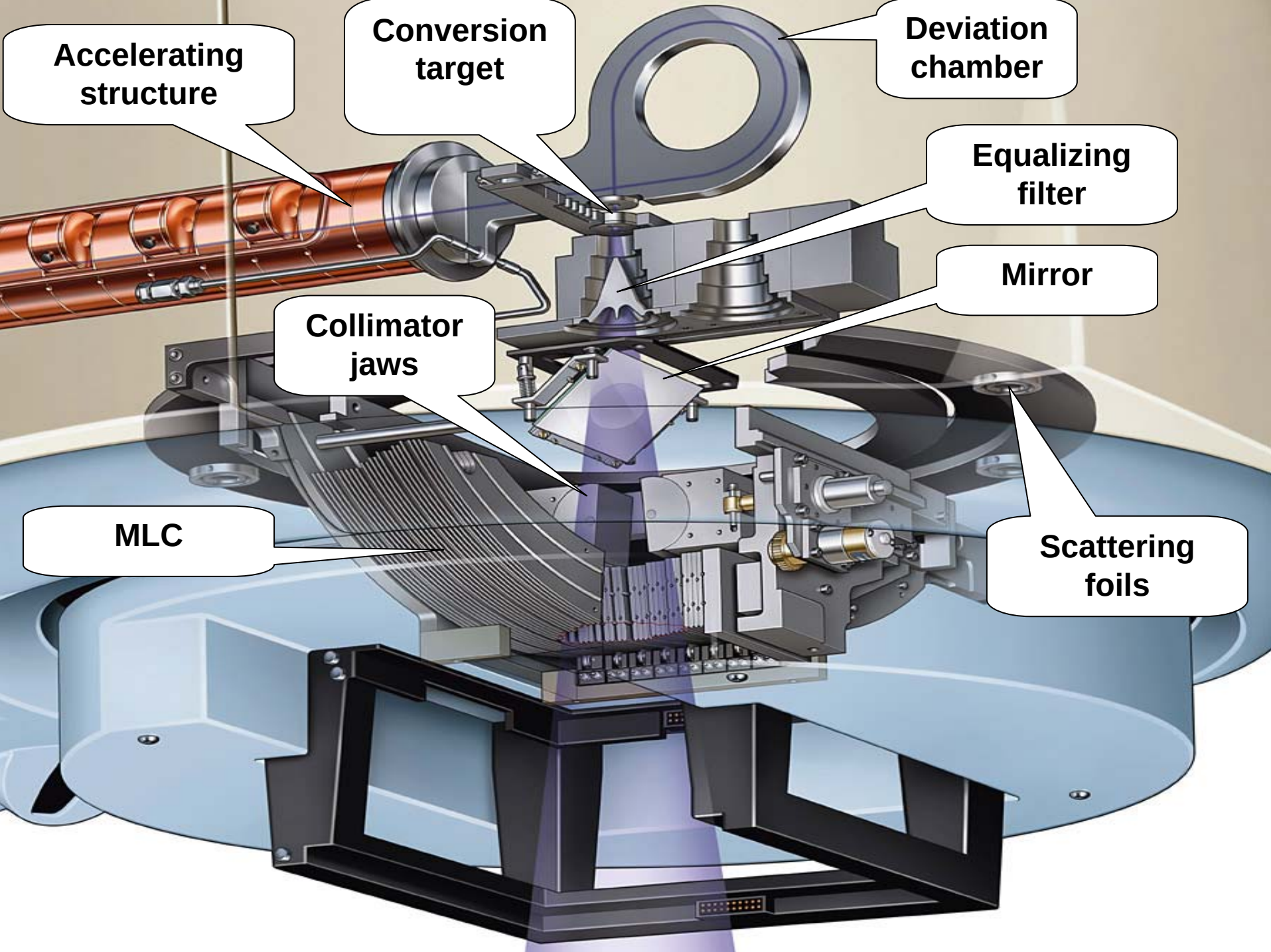
- The microwave radiation, used in the accelerating structure to accelerate electrons to the desired kinetic energy, is produced by the RF power generation system which consists of two components:
  - RF power source
  - Pulsed modulator

RF power source

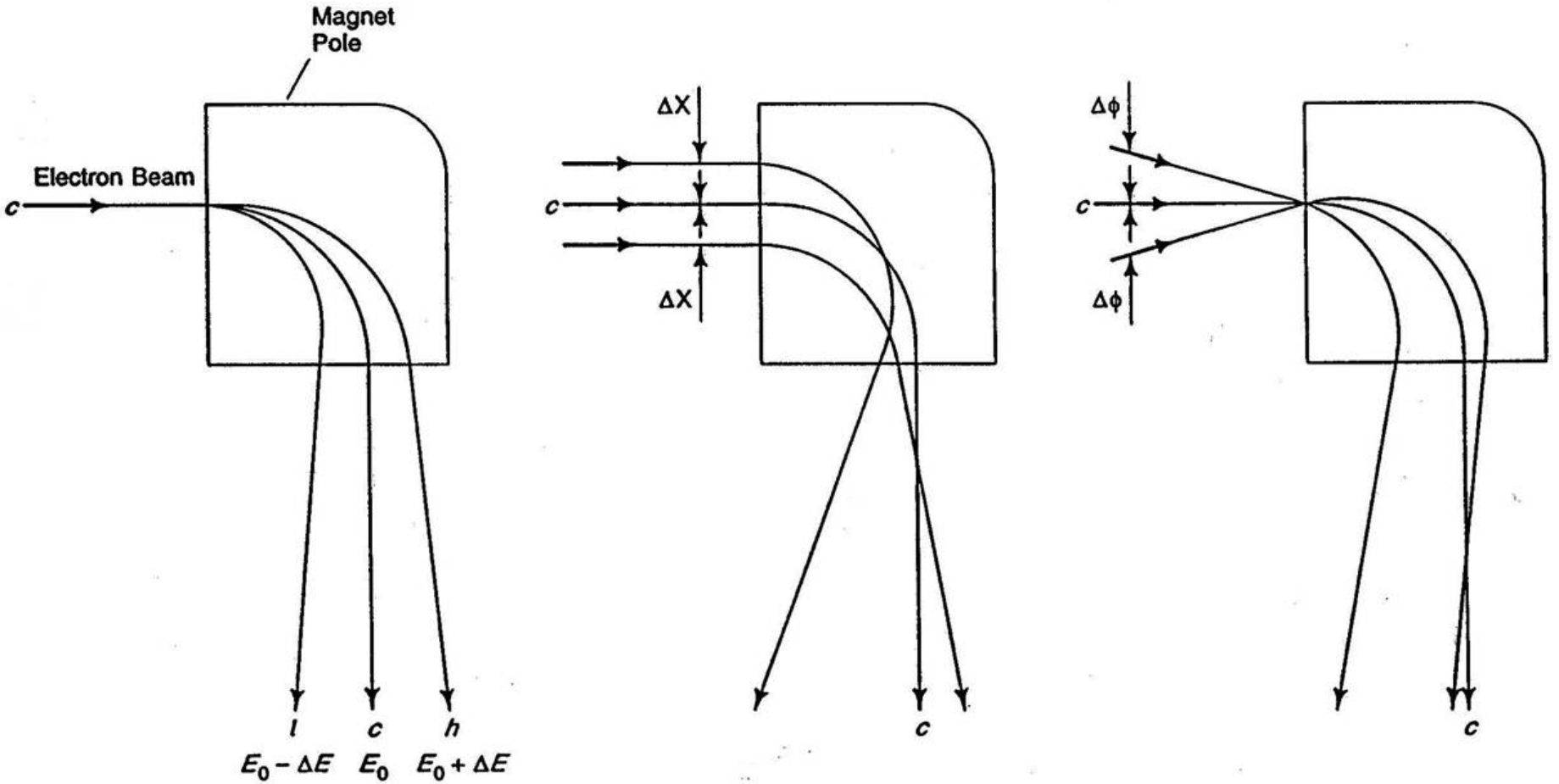
- The RF power source is either magnetron or klystron. Both are devices using electron acceleration and deceleration in vacuum for production of the high power RF fields. Both types use a thermionic emission of electrons from a heated cathode and accelerate the electrons toward an anode in a pulse electrostatic field.

Pulsed modulator

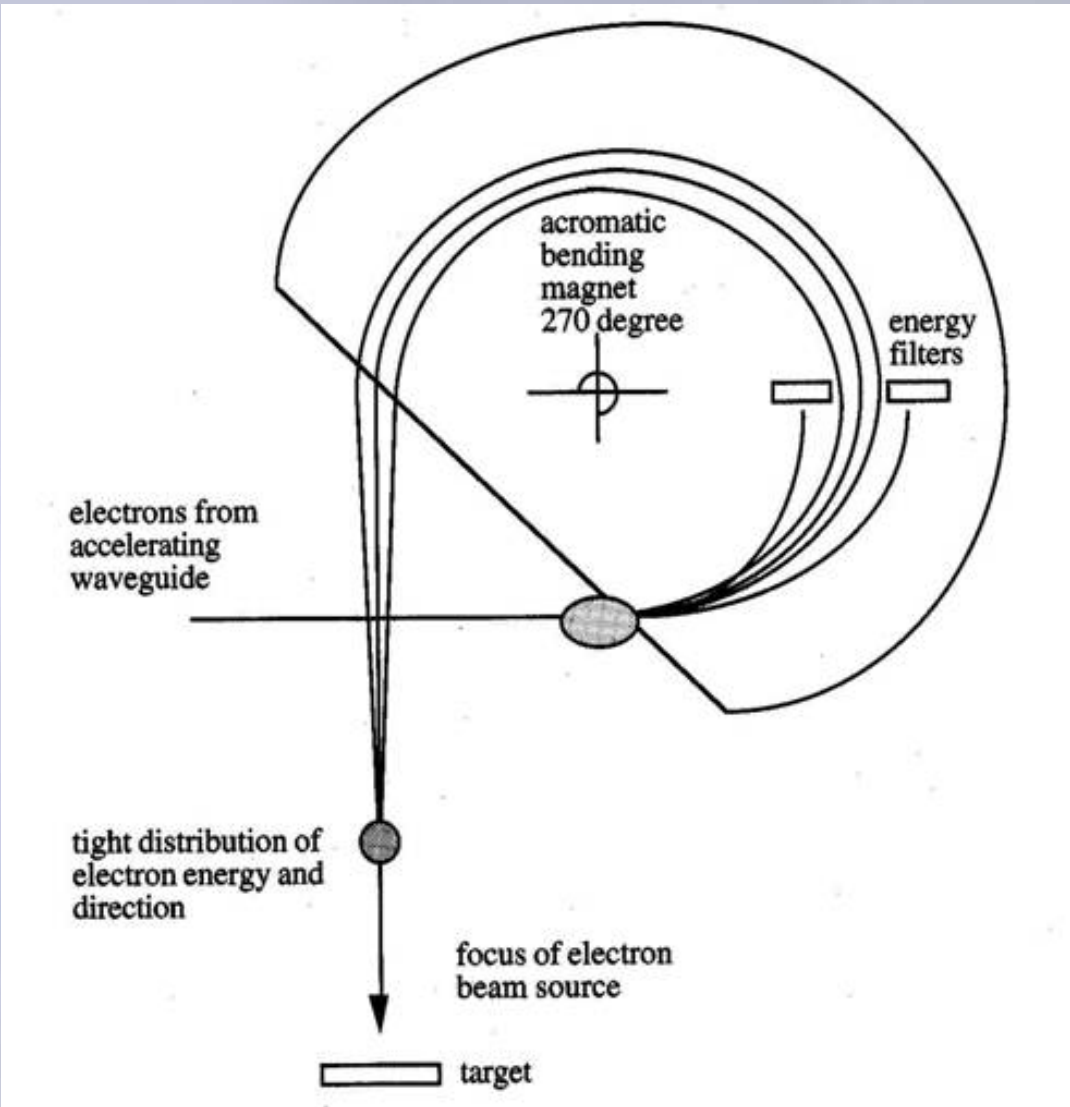
- The high voltage (~100kV), high current (~100A) and short duration pulses (~1μs) required by the RF power source (magnetron or klystron) and the injection system (electron gun) are produced by the pulsed modulator.


Accelerating structure
Conversion target
Deviation chamber
Equalizing filter
Mirror
Collimator jaws
MLC
Scattering foils

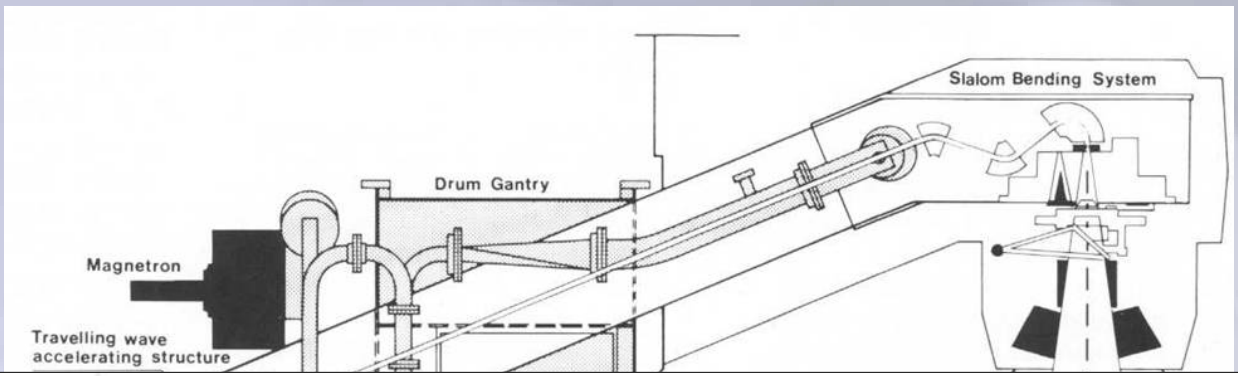
90° Magnet

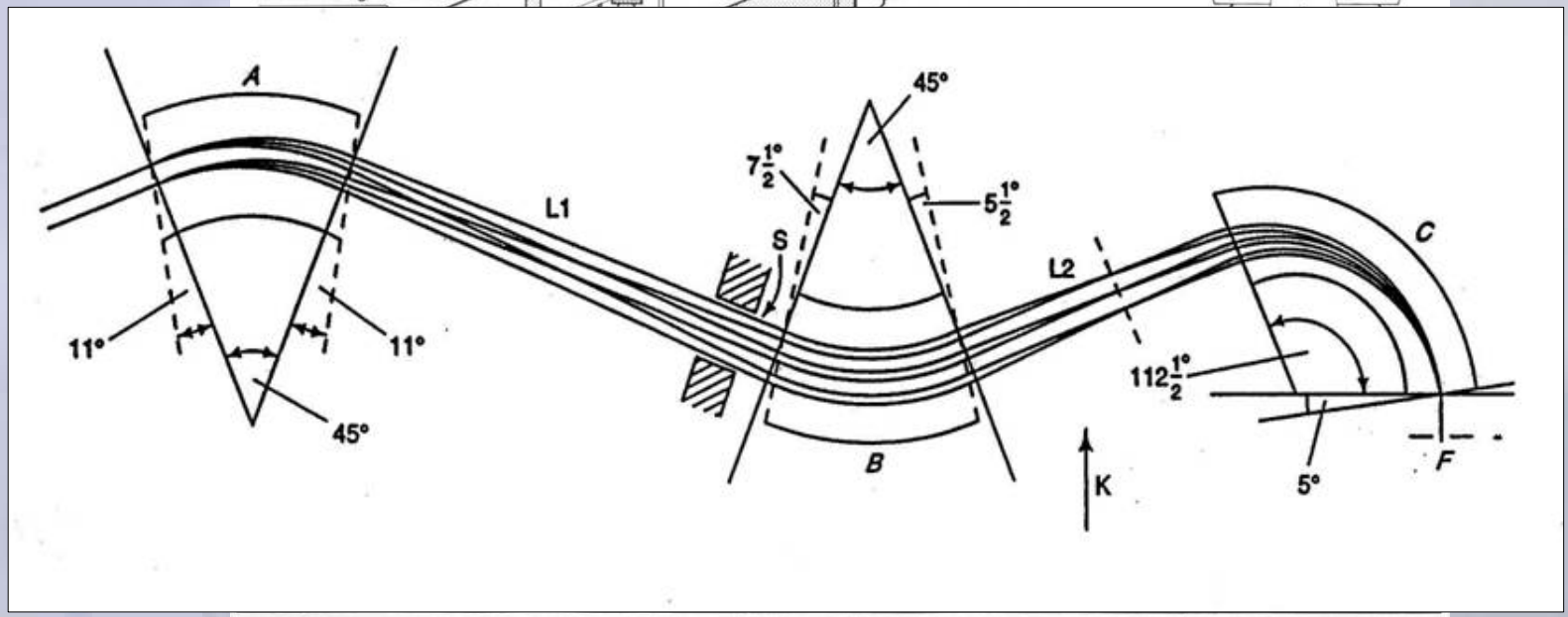

Magnet
Pole
Electron Beam
c
l
c
h
$E_0 - \Delta E$
E_0
$E_0 + \Delta E$
ΔX
ΔX
c
c
Δϕ
Δϕ
c
c

270° Magnet

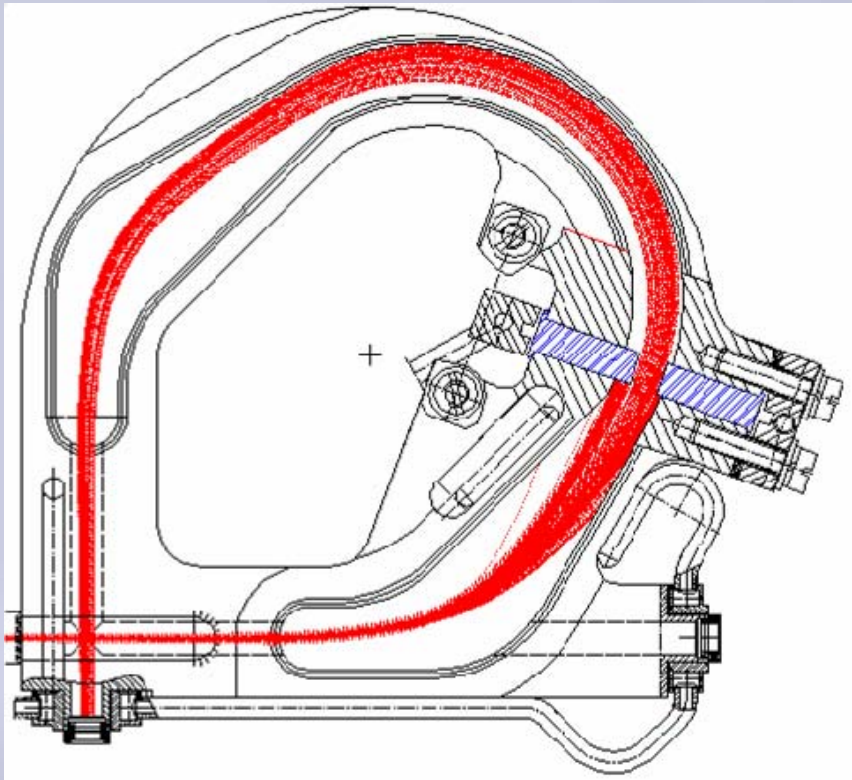

acromatic
bending
magnet
270 degree
energy
filters
electrons from
accelerating
waveguide
tight distribution of
electron energy and
direction
focus of electron
beam source
target

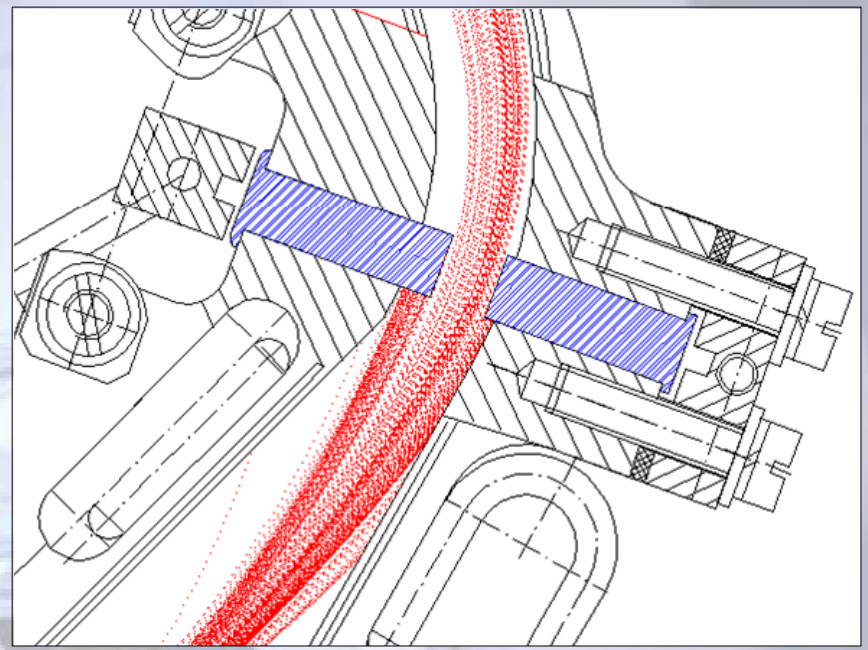
„Slalom”


Slalom Bending System
Drum Gantry
Magnetron
Travelling wave
accelerating structure


A
11°
11°
45°
L1
45°
7½°
5½°
S
B
K
L2
C
112½°
5°
F

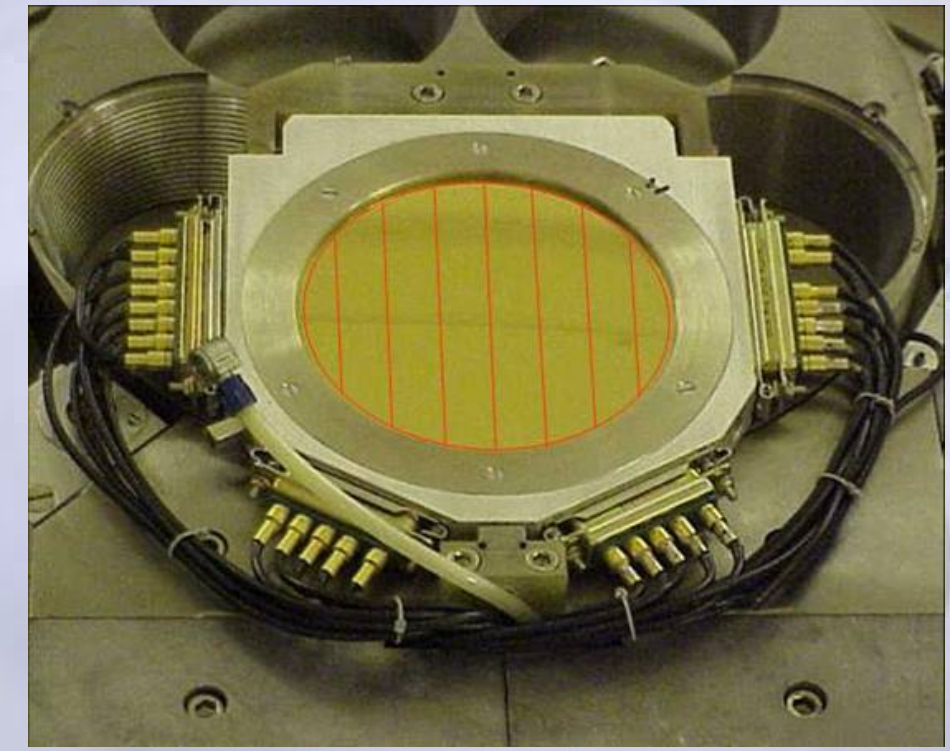
Energy spectrum filter



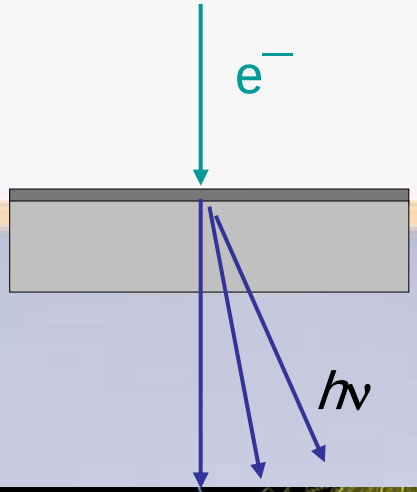


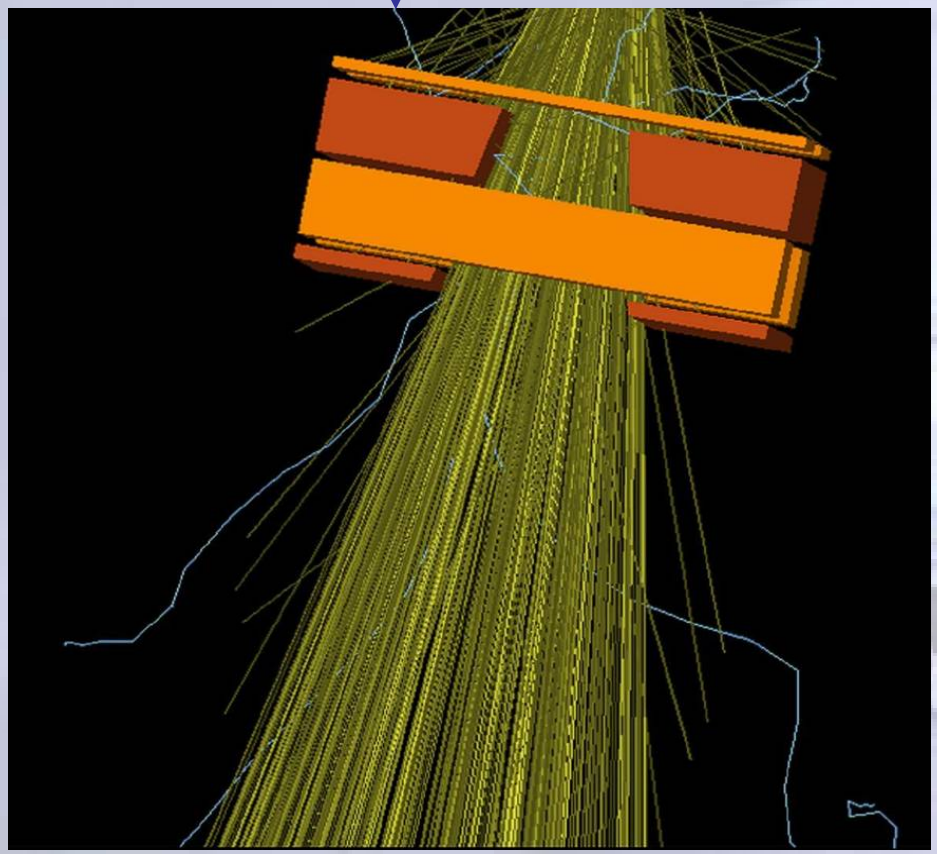
Dose monitoring

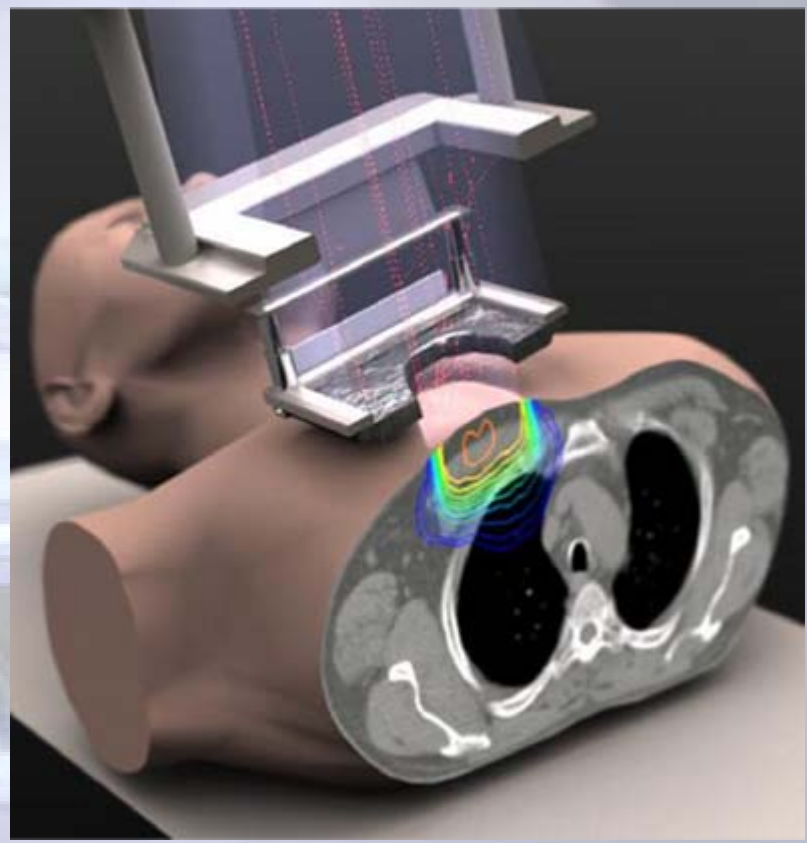
- The dose is monitored typically by two ionization chambers.



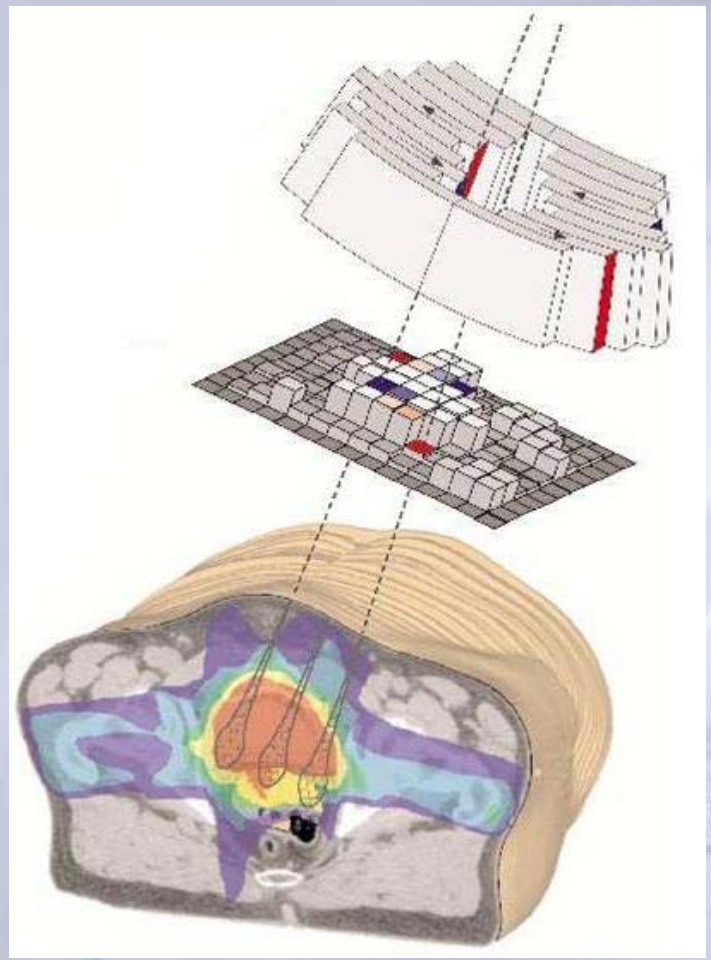
e^-/γ beam

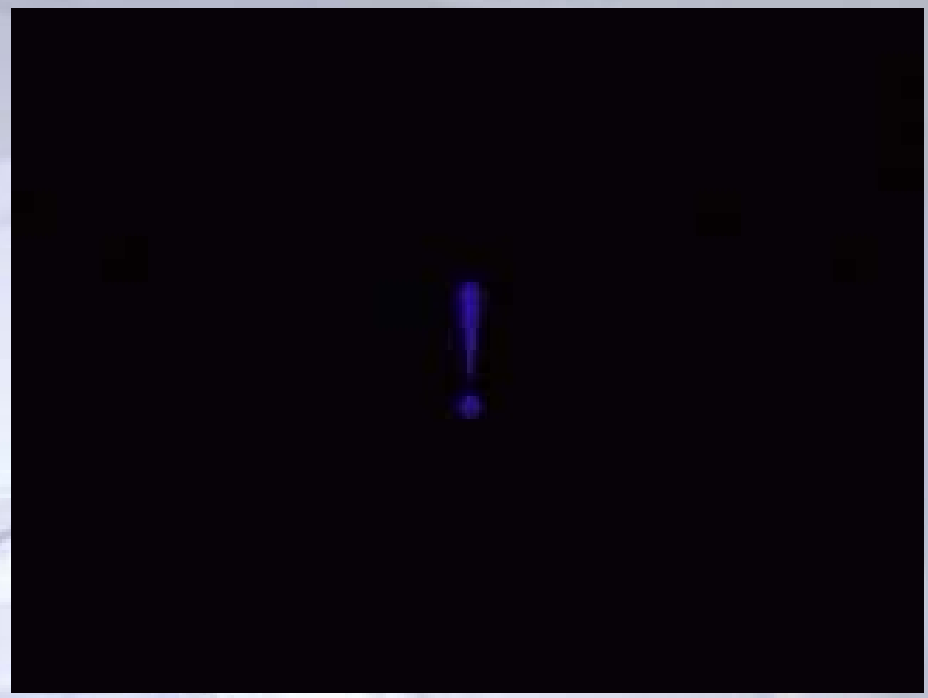




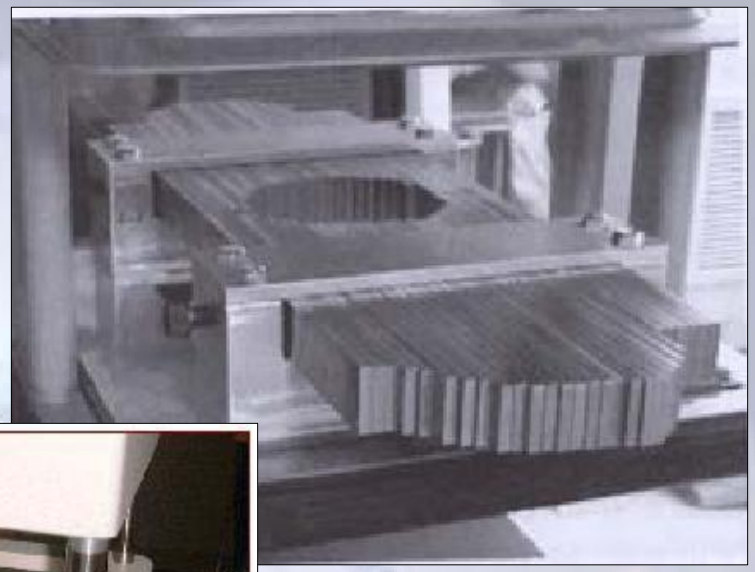


Multileaf collimator

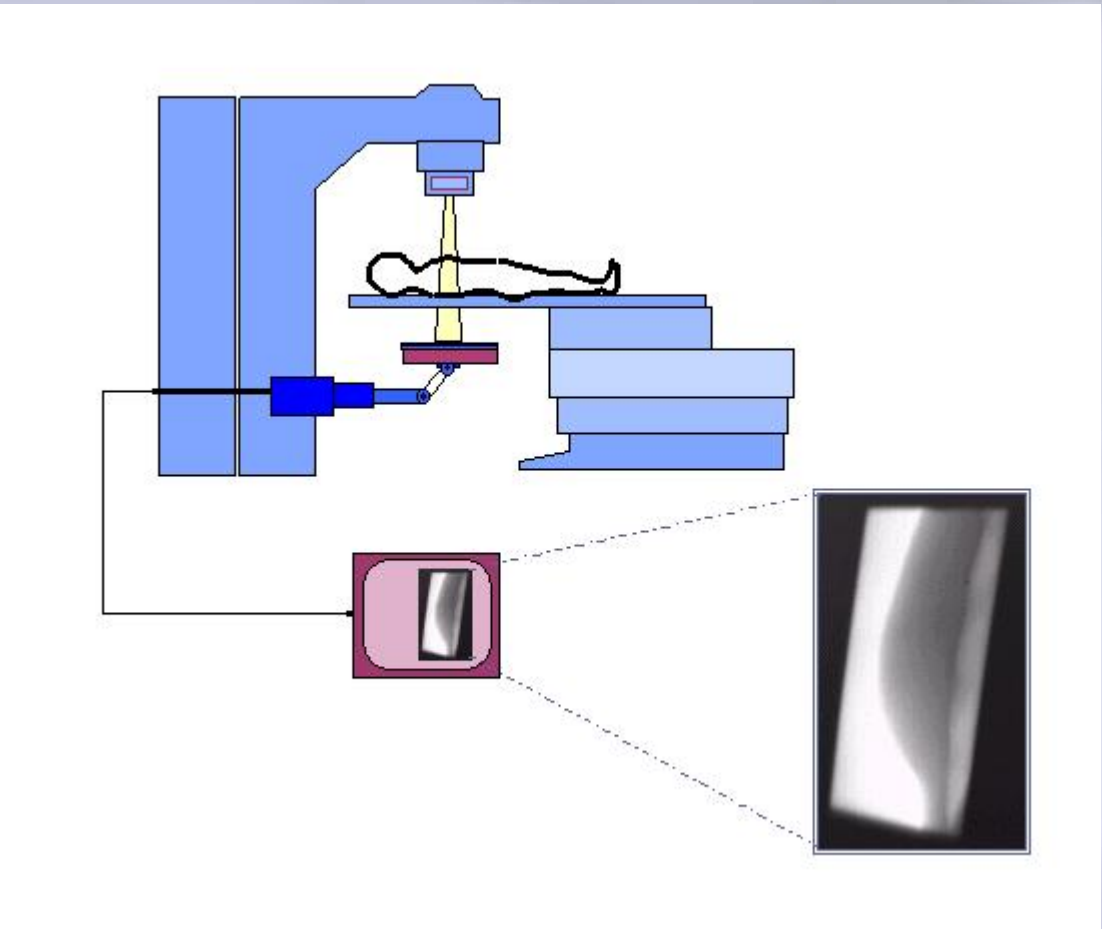




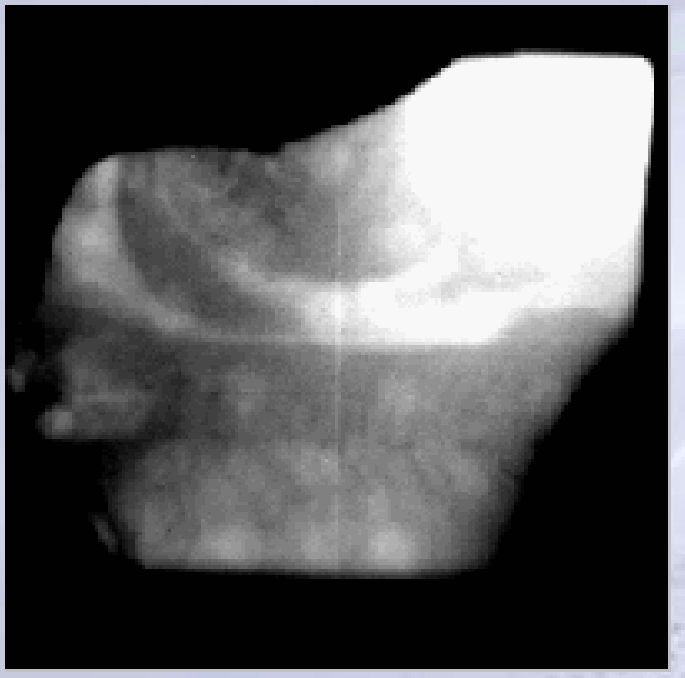
Electron MLC ?

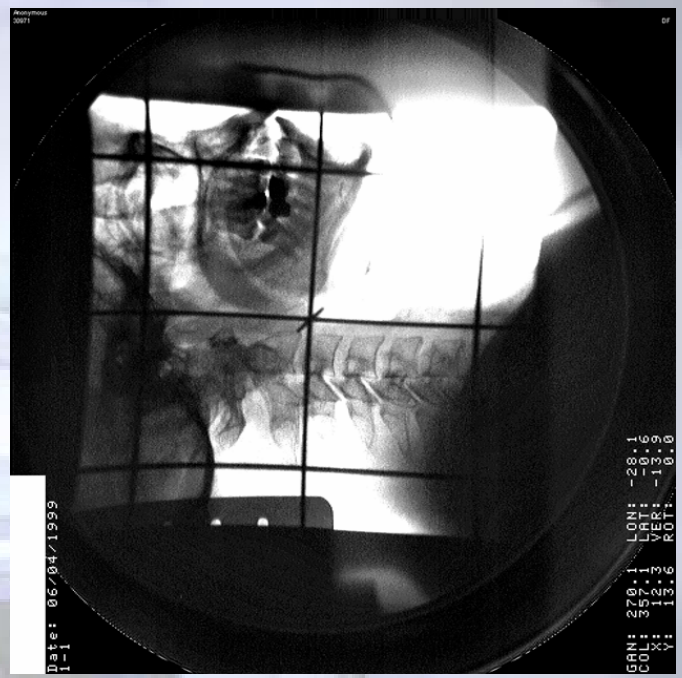


Portal imaging

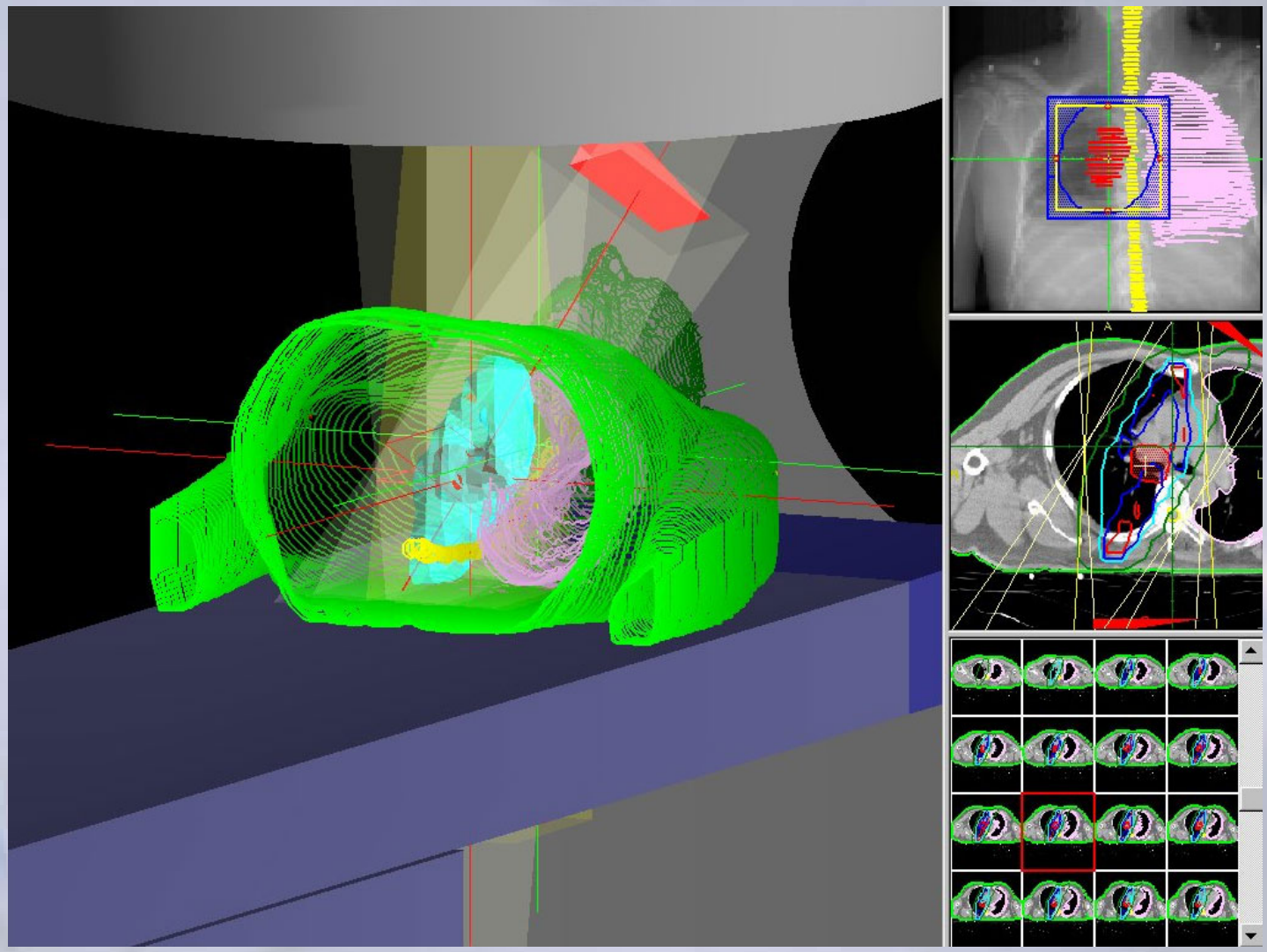


Portal imaging

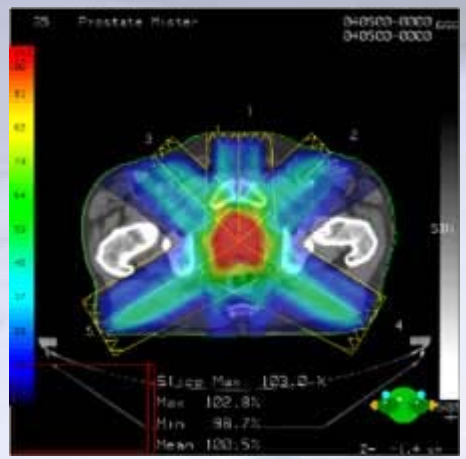


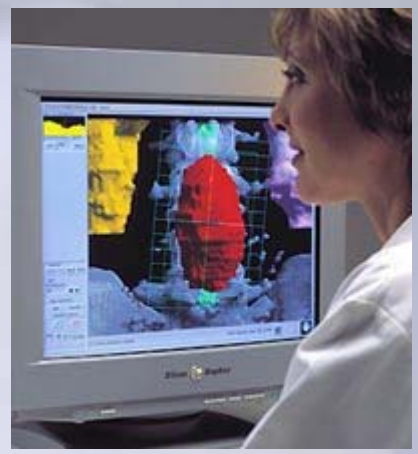


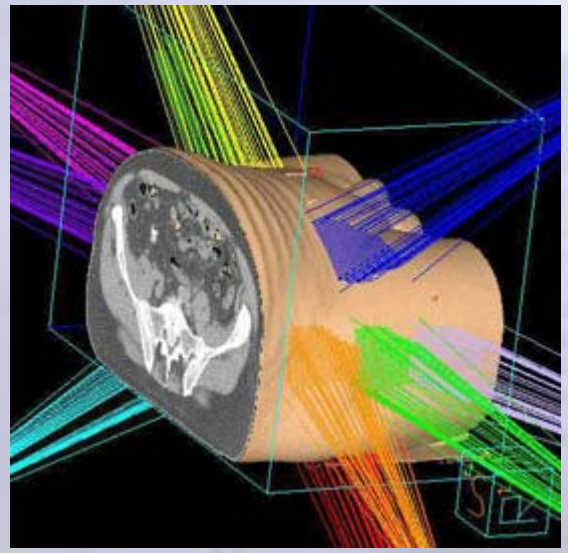
Treatment planning

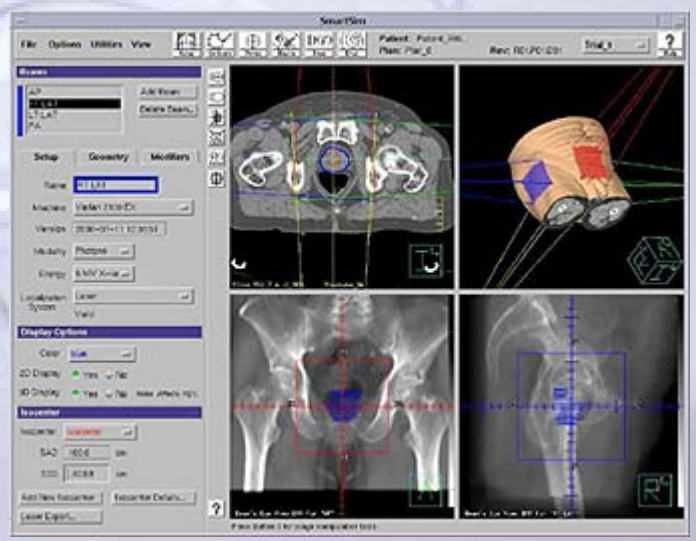


Treatment planning



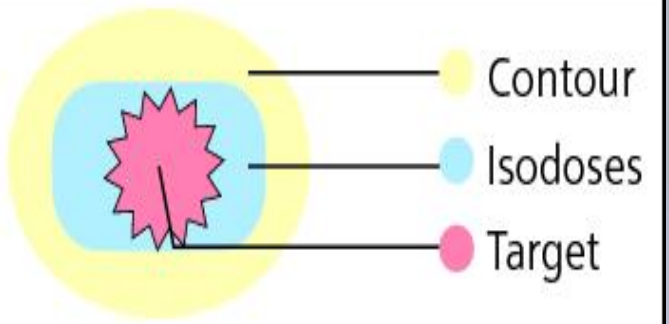


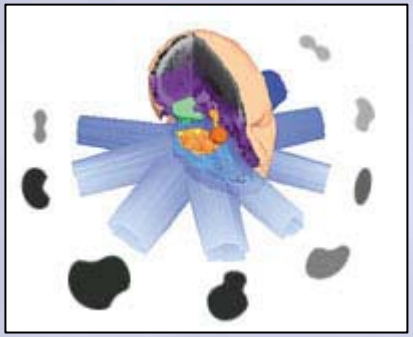




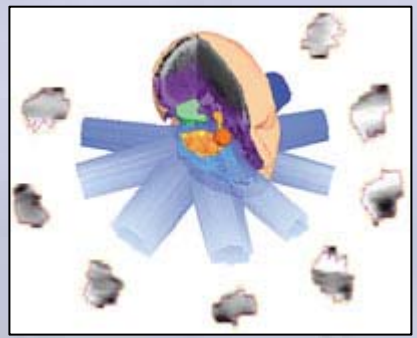
Treatment techniques

Conventional Radiation Therapy (external)



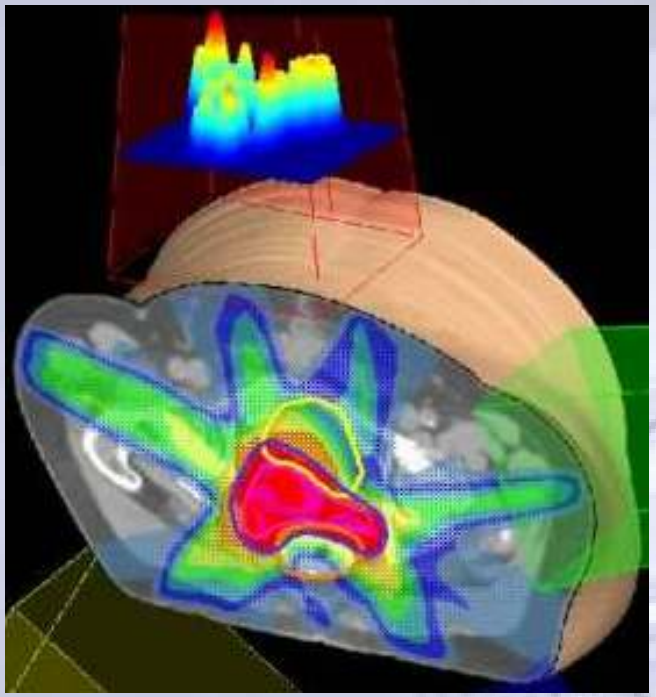


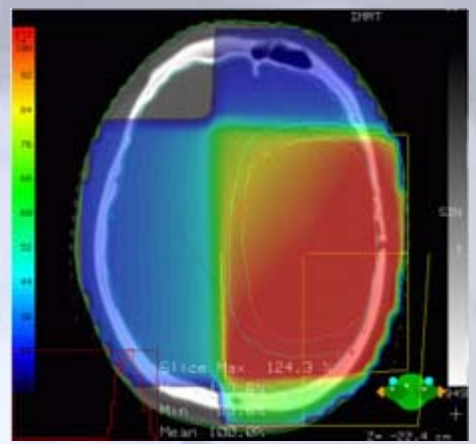
Conformal Radiation Therapy (external)

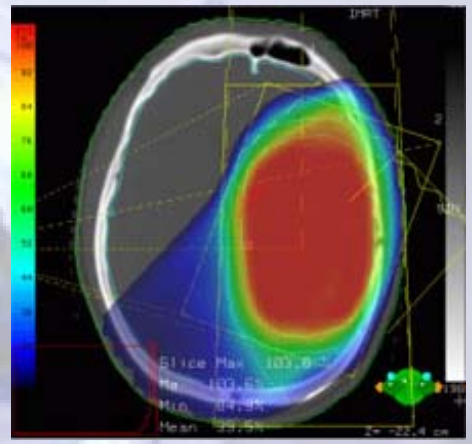


Intensity Modulated Radiation

Intensity Modulated RT (IMRT)





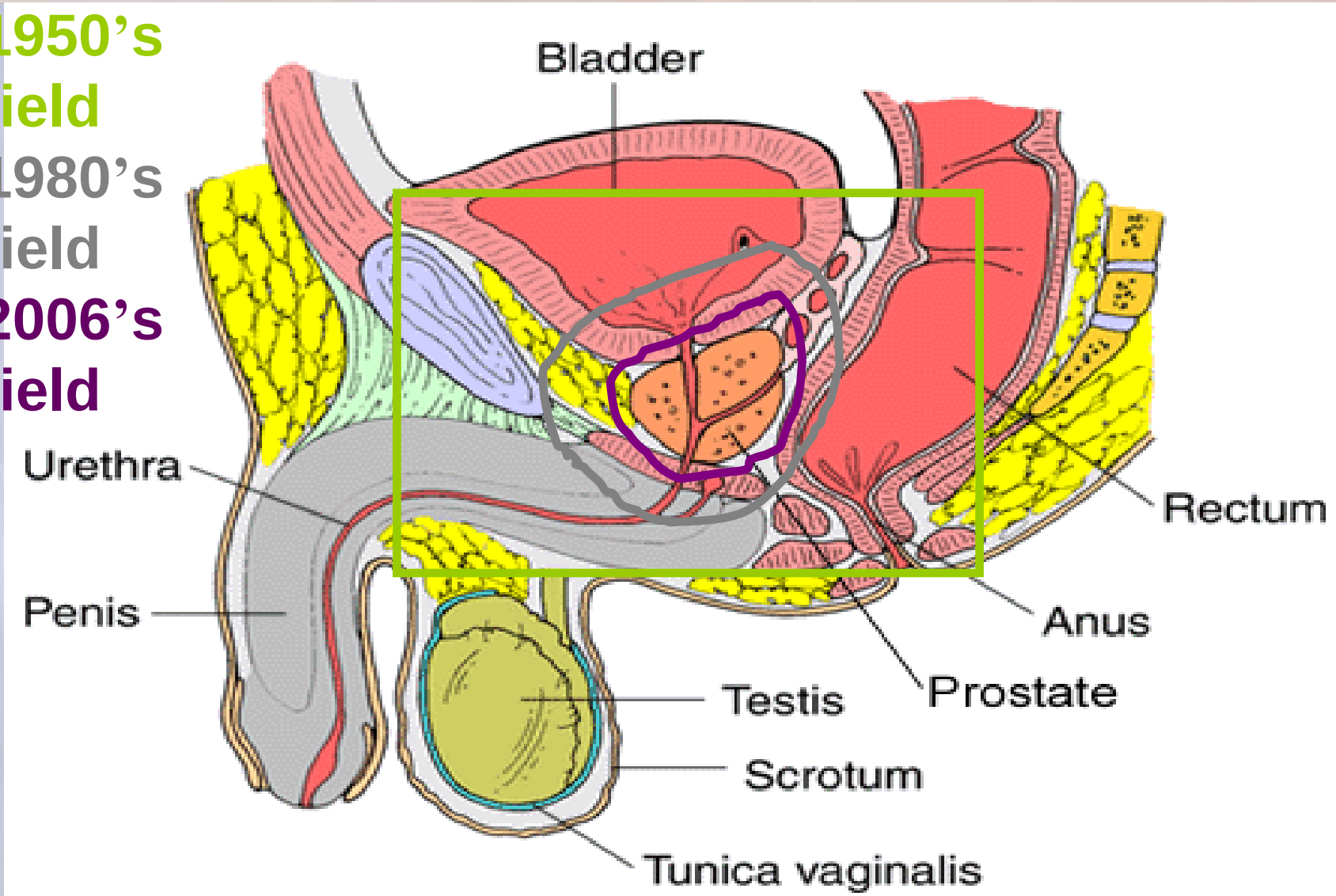


Improvement in Radiotherapy

1950's field

1980's field

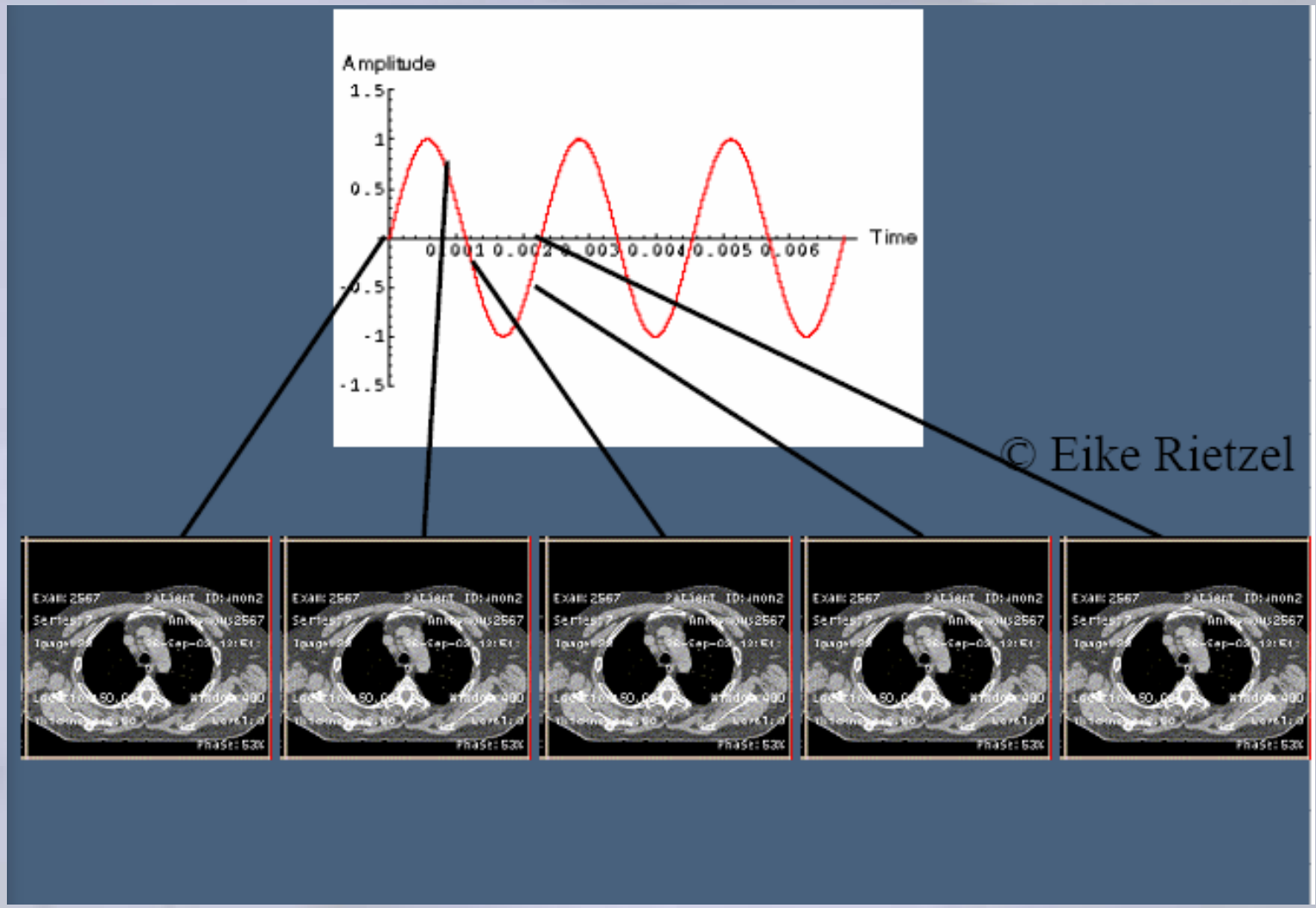
2006's field



Improvement in Radiotherapy

- 1950's – more people were harmed than benefited
- 1980's – approximately 70% of the people benefited and 10% were harmed
- 2006 – approximately 90% of the people are benefiting with 1-2% side effects.

Breathing motion control



Available systems

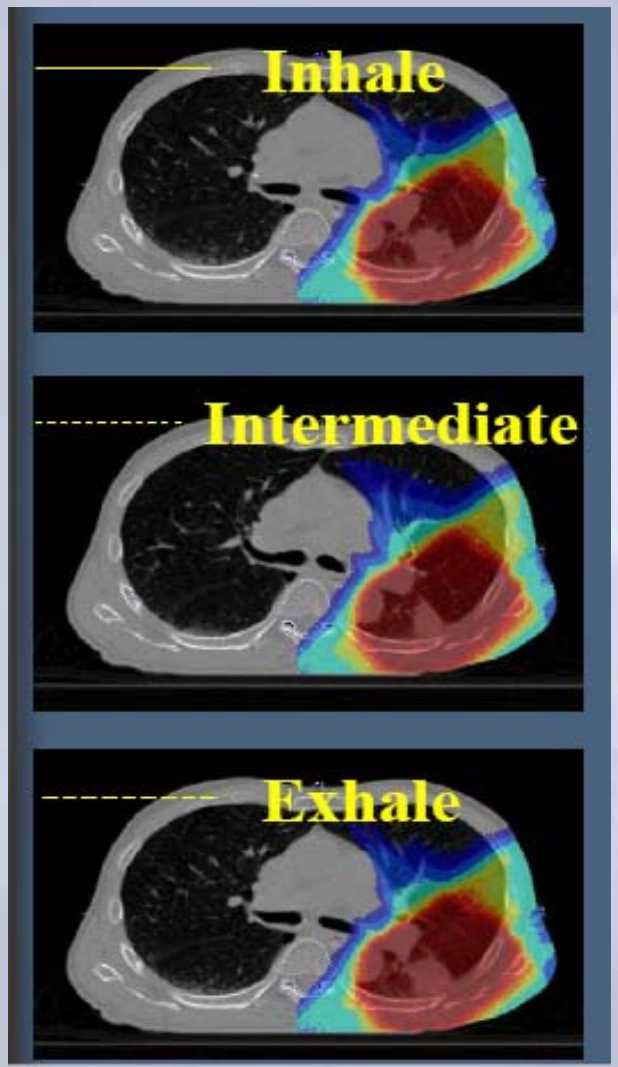
- Patient cooperation

And/Or

- Automatic beam gating

OR

DynamicAdaptiveRT



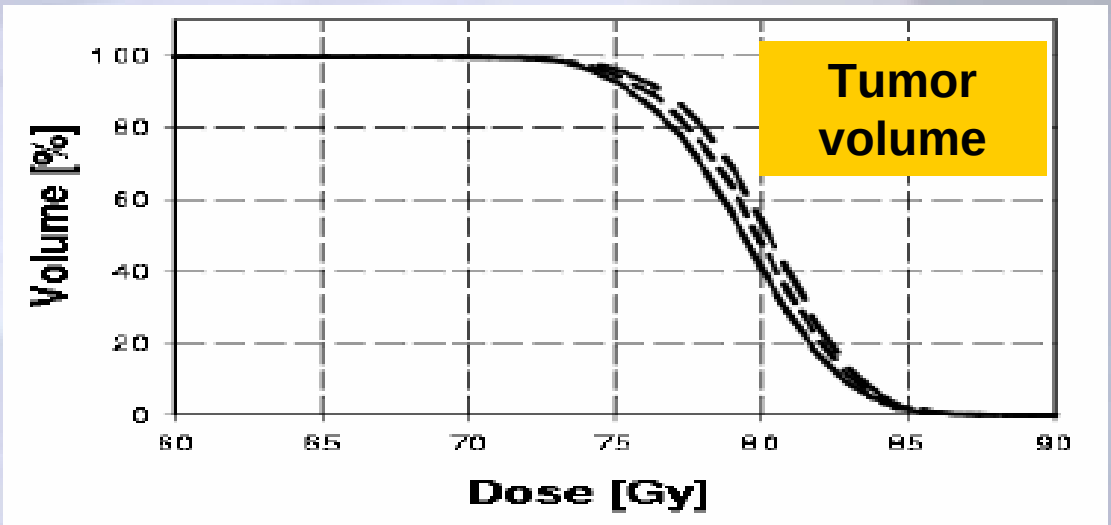
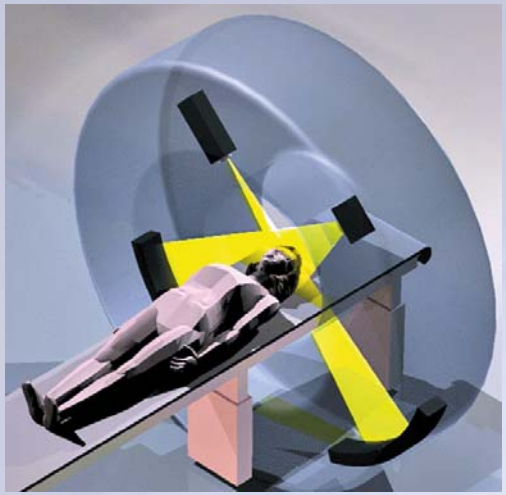
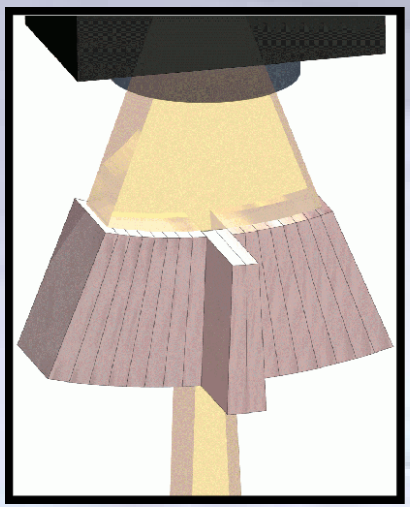
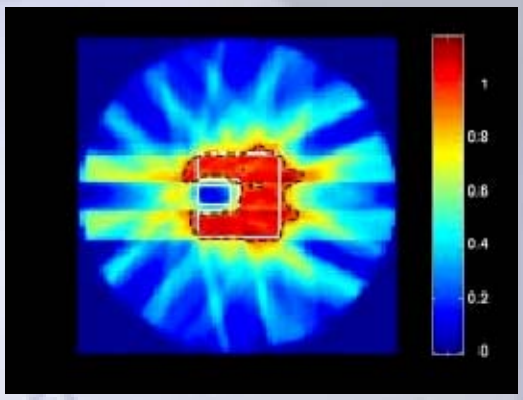


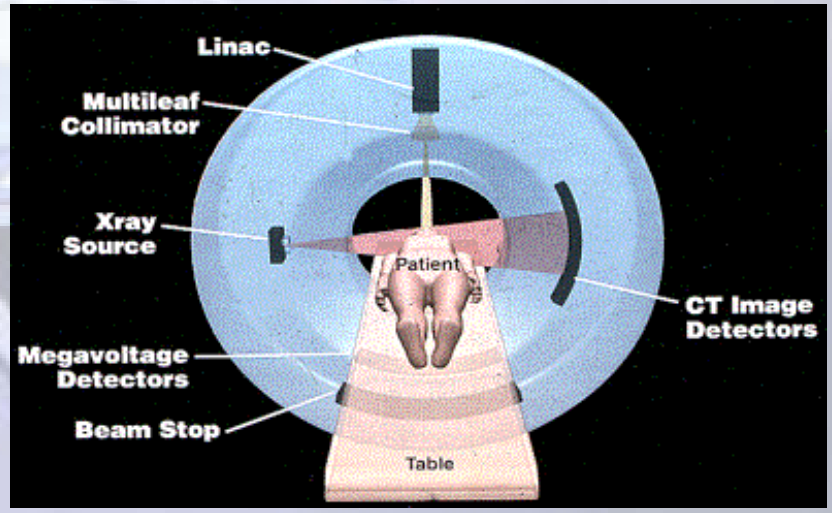
Image Guided RT (IGRT)

Tomotherapy

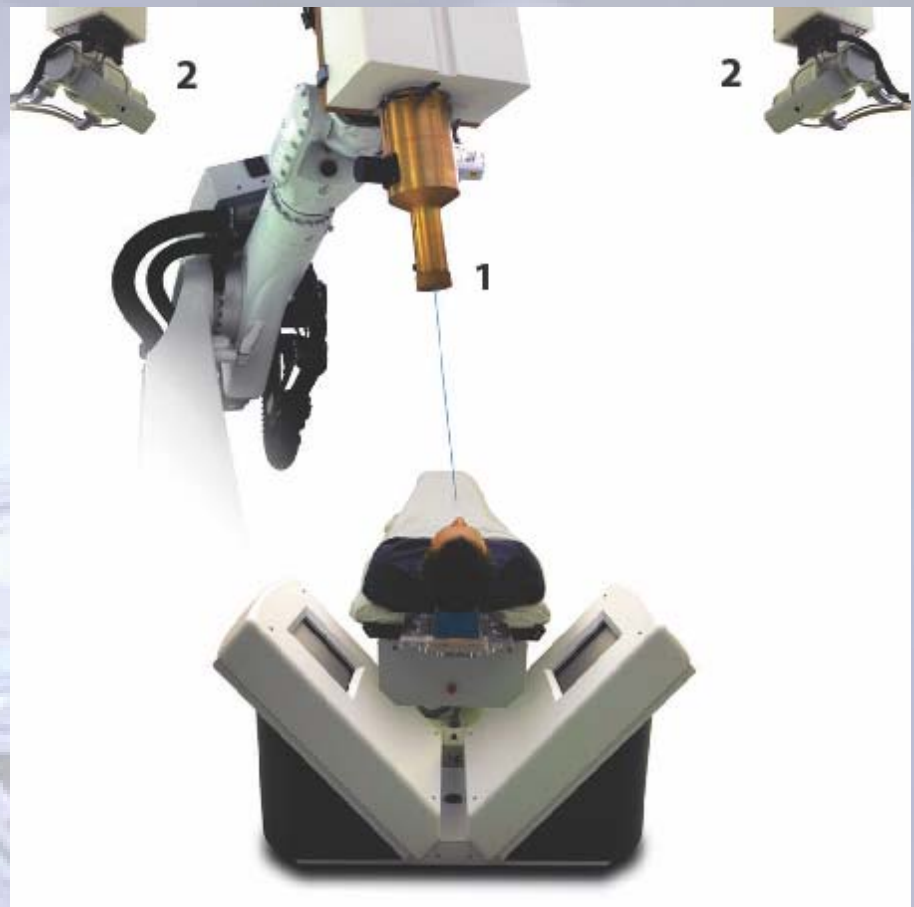




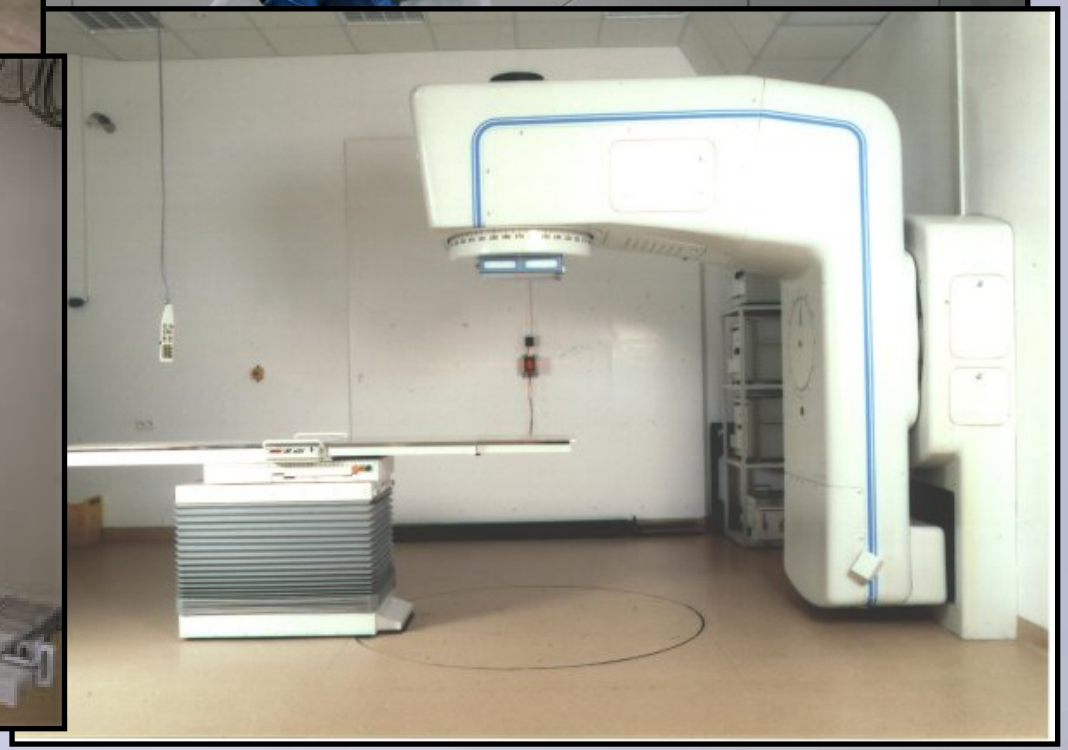




Robotic Arm (Cyber Knife)




Precise



Conclusions

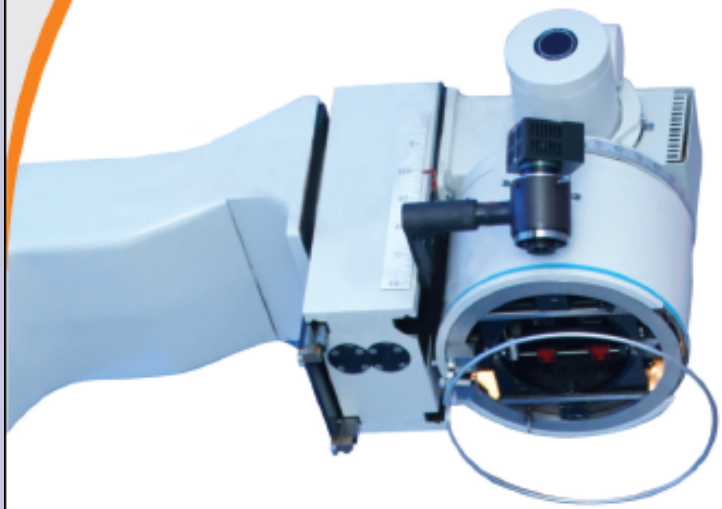
„About one person of three is confronted in his life with cancer and out of five dies from this disease. In a society with health-care services comparable to the United States, Japan or Western Europe, the average person has a one in eight chance of being treated on a linear accelerator in his or her lifetime...”

Let’s fight together!

HIGH TECHNOLOGY CENTER

X-Ray Simulator Simax

Equipped with a new generation tube and imaging system with integrated CCD camera, Simax X-ray simulator, thanks to rigid design and to cooperation with the Polkam 16 therapeutic table, provides excellent positioning and perfect imaging - necessary in modern radiotherapy.



Simulator uses radiographic and fluoroscopic imaging to verify treatment fields, and to prepare final simulations with necessary setup corrections.

HIGH TECHNOLOGY CENTER

DEPARTMENT OF NUCLEAR EQUIPMENT
THE ANDRZEJ SOLTAN INSTITUTE FOR NUCLEAR STUDIES
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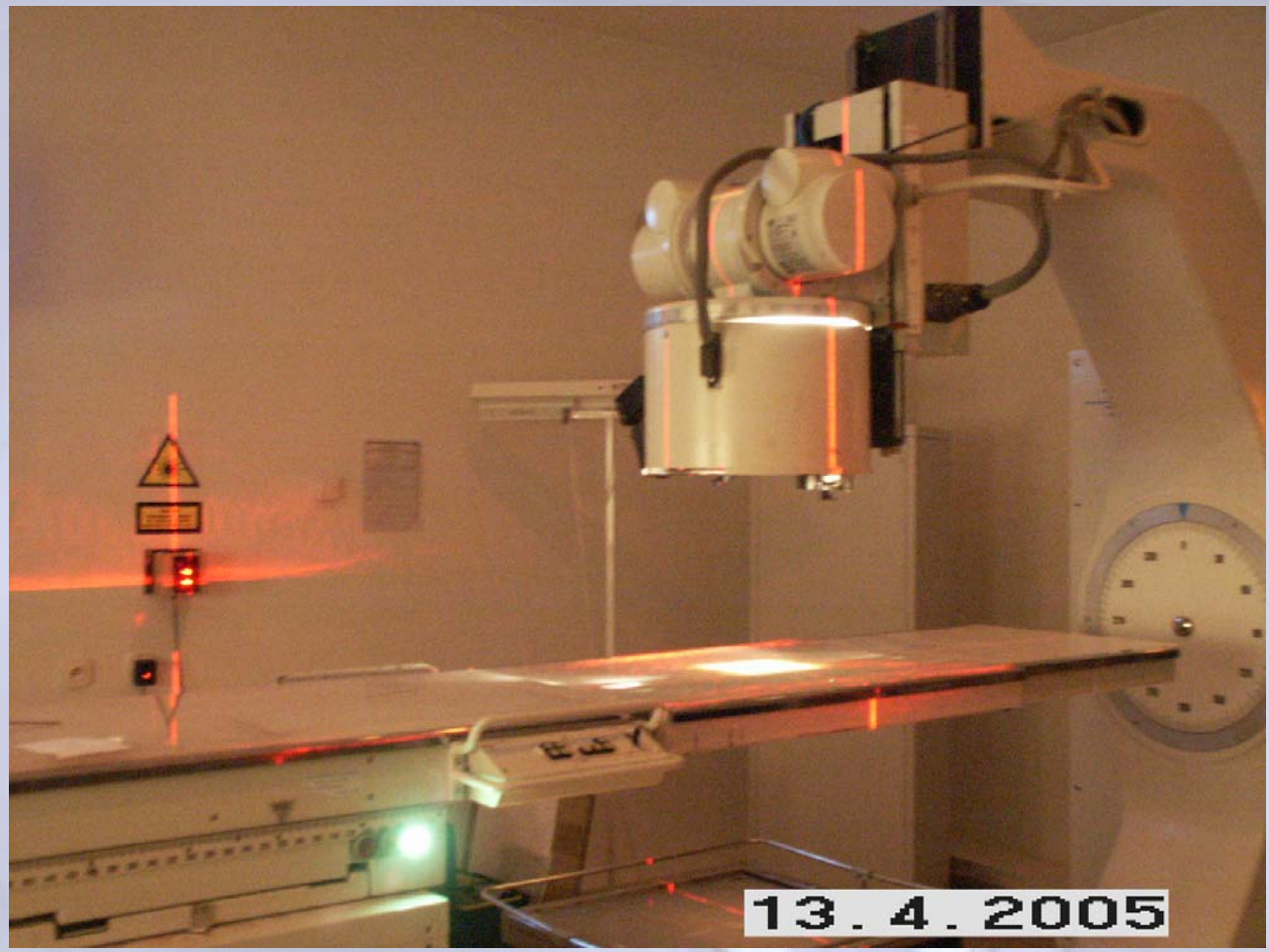
X-ray simulator



TAL IMAGING DEVICE (OPTIONAL)

ssed on amorphous silicon matrix

atrix size	41 cm x 41 cm
esolution	1024 x 1024
xel pitch	400 µm
DC converter	16 bits
integraqtion time	from 66.45 ms

- User-friendly software for advanced image processing
- DICOM RT standard

FACILITY REQUIREMENTS

Powersupply
- Imput voltage 360-440 VAC, 50 or 60 Hz,
- line to line 3-phase, 4 wire plus ground, 15 kW/data, resistance <3
- Cooling water
- One pass (domest... ...system or closed loop ... (option)
- Ventilation
- At least 6 air exchanges per hour
- Room temperature 22-25°C and humidity ≤70%

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