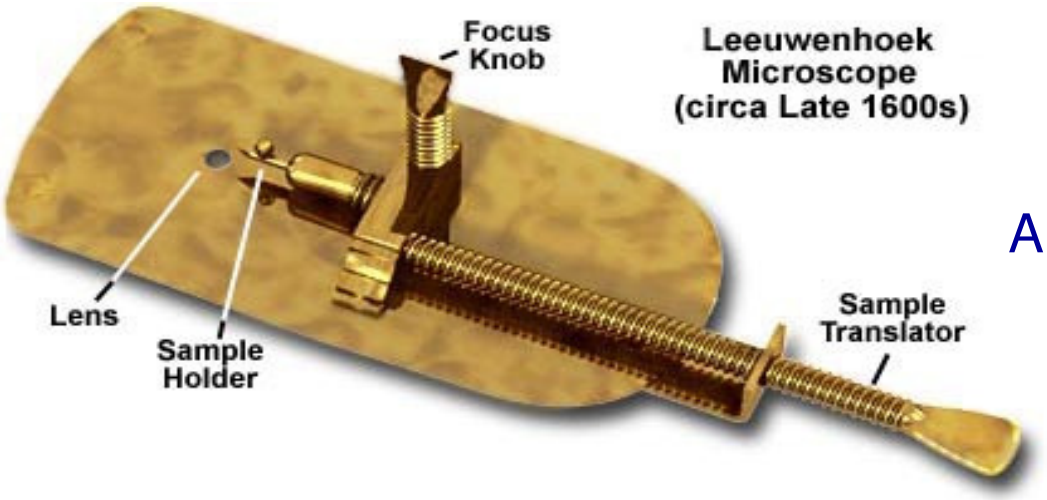
Radiotherapy: Equipment

Ben Mijnheer



Netherlands Cancer Institute /
Antoni van Leeuwenhoek Hospital
(NKI-AVL)

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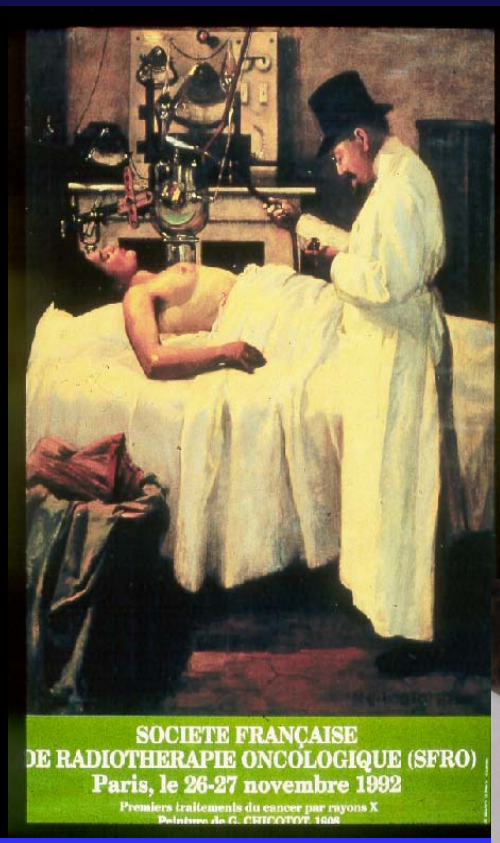
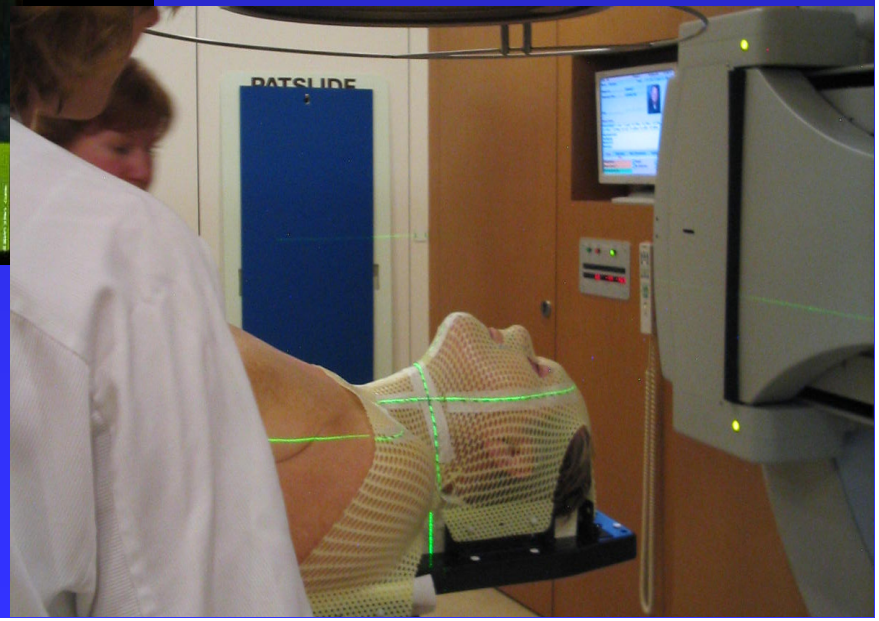
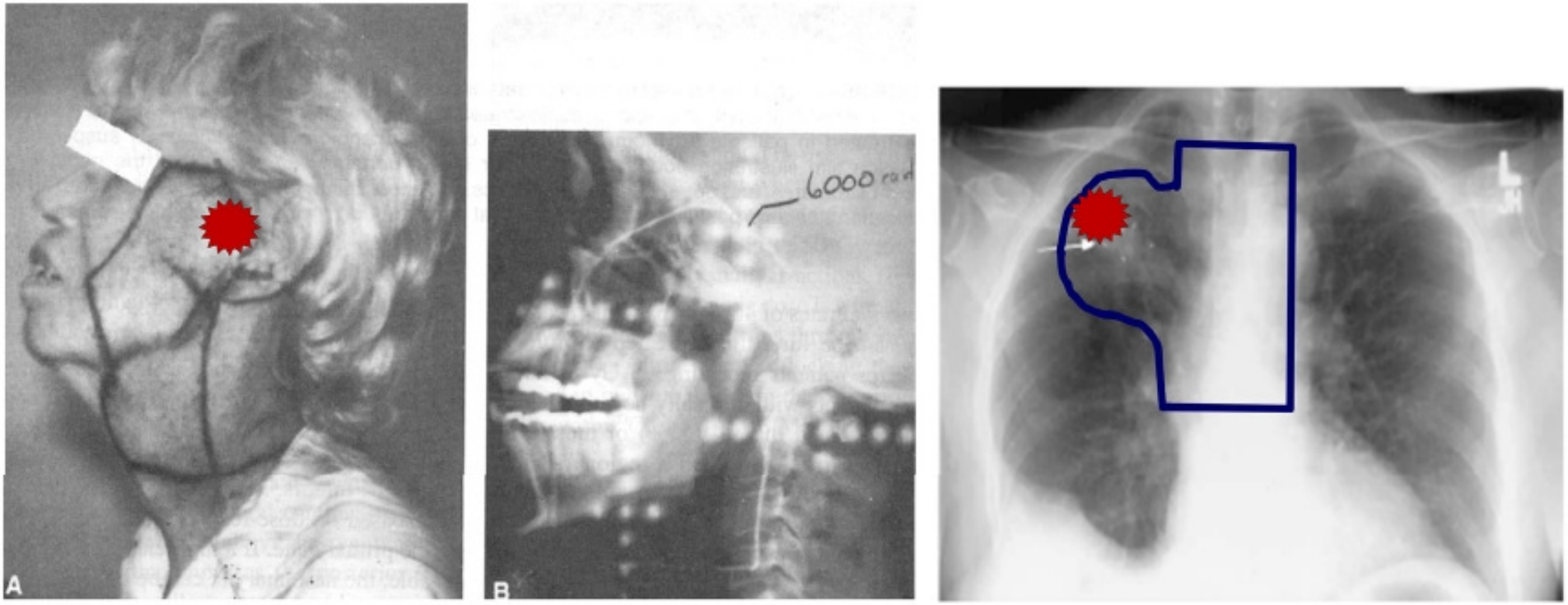




Conventional radiation therapy

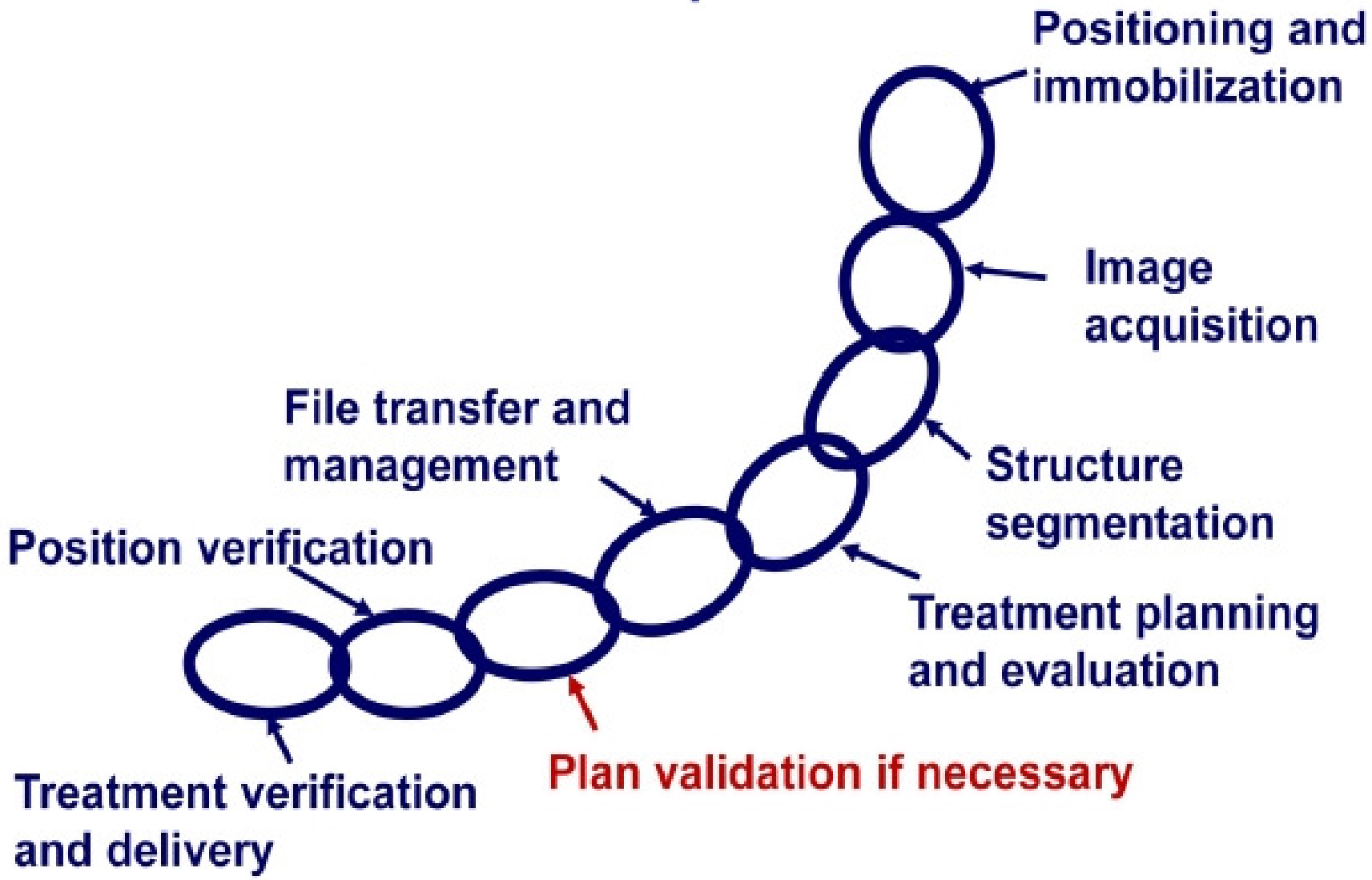


This slide shows images two patients, one with a T3 N2c nasopharyngeal CA and the other with a T1/2 N1/2 lung tumor. In the early days of radiotherapy, and even today in many developing countries, radiotherapy for such tumors is planned and delivered using field shapes defined from planar radiograph. Point dose calculations are performed at various points of interest. This has been identified as "conventional radiation therapy" in IAEA TECDOC 1588.

Outline

- 3-D conformal radiotherapy (3-D CRT)
- Intensity-modulated radiotherapy (IMRT)
- Image-guided radiotherapy (IGRT)

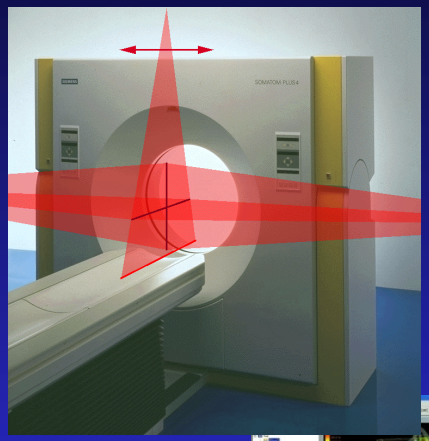
3D CRT process

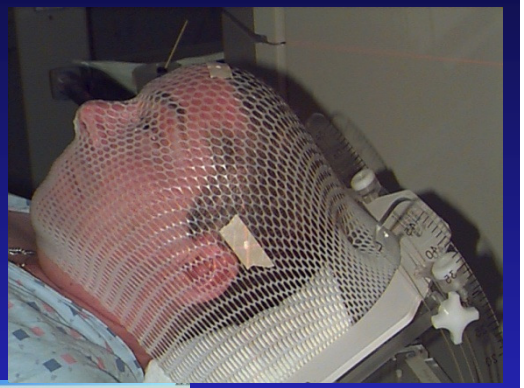


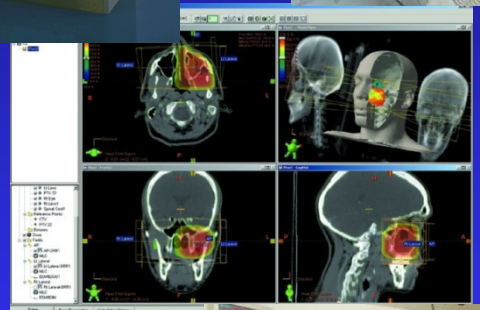
Adapted from an illustration presented by Webb, 1996

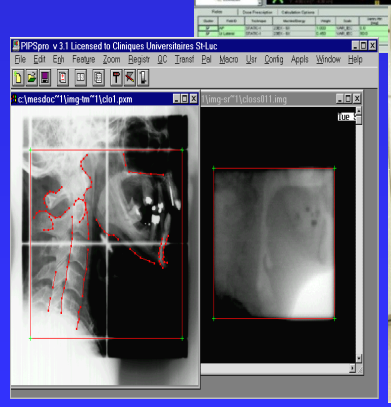
Guidance on equipment

- CT, CT Simulator
- Immobilization
- Treatment Planning Systems
- Accelerators with MLC and EPID
- Networking



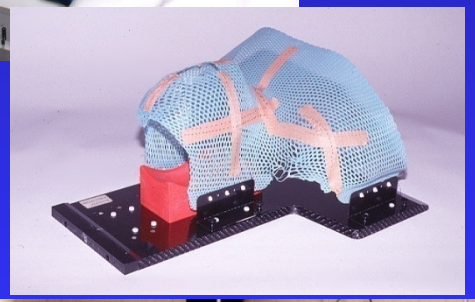






Positioning and immobilization

- Determine optimum treatment position
- Decision on immobilization method of the patient
- Study reproducibility of the immobilization system to determine realistic margin for planning
- Using radio-opaque markers to establish reference points on the patient or the immobilization device



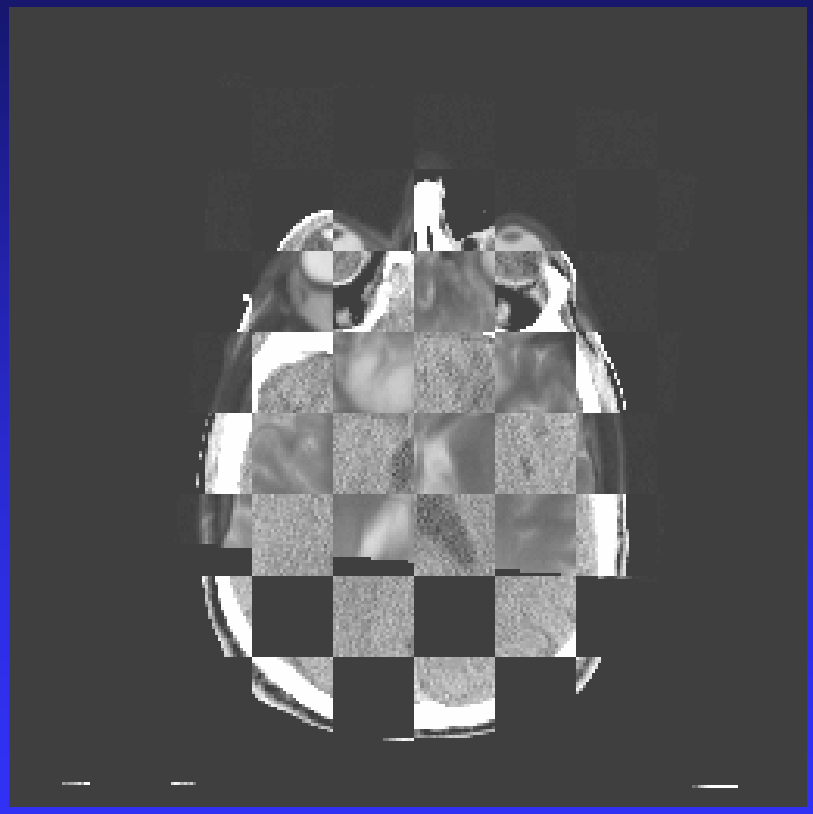
Imaging equipment used in oncology

Computed Tomography, CT

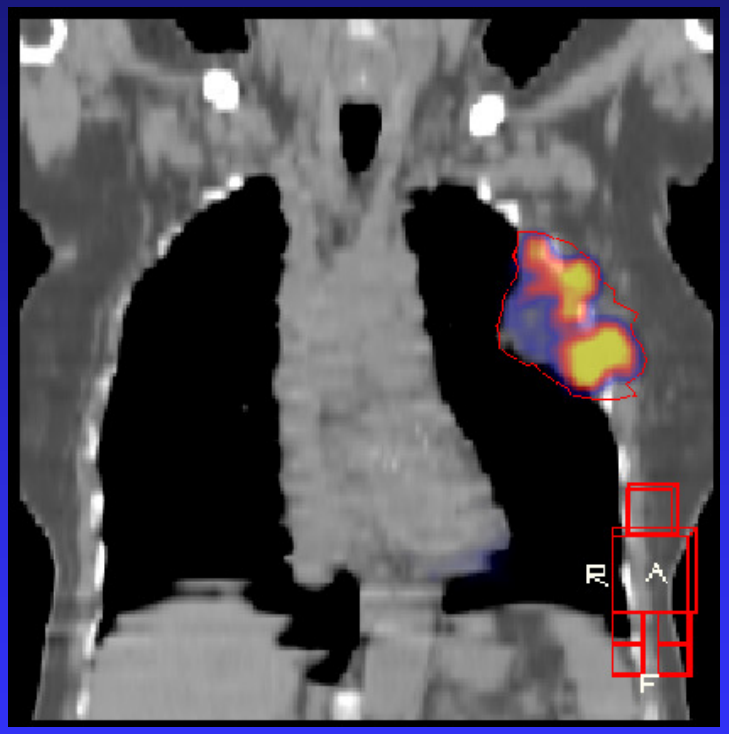
Magnetic Resonance Imaging, MRI

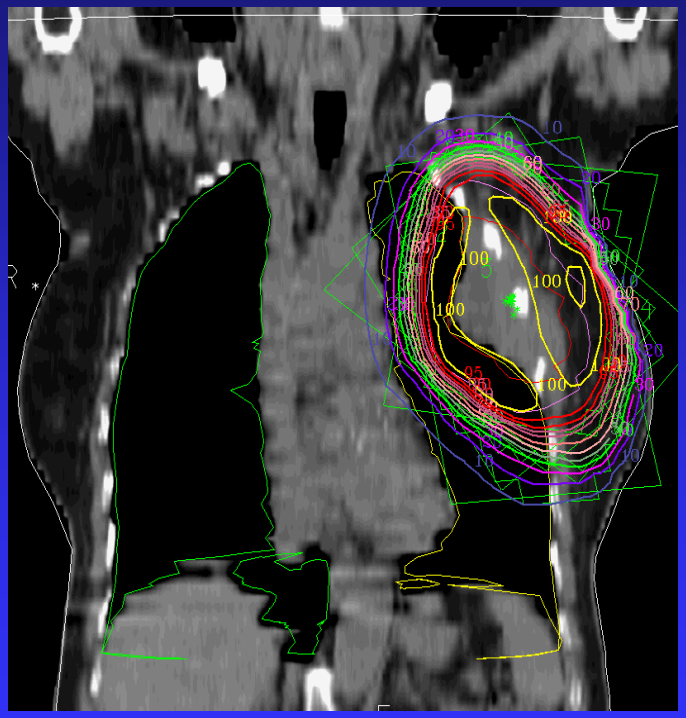
Positron Emission Tomography, PET

MRI - CT matching in the NKI-AVL

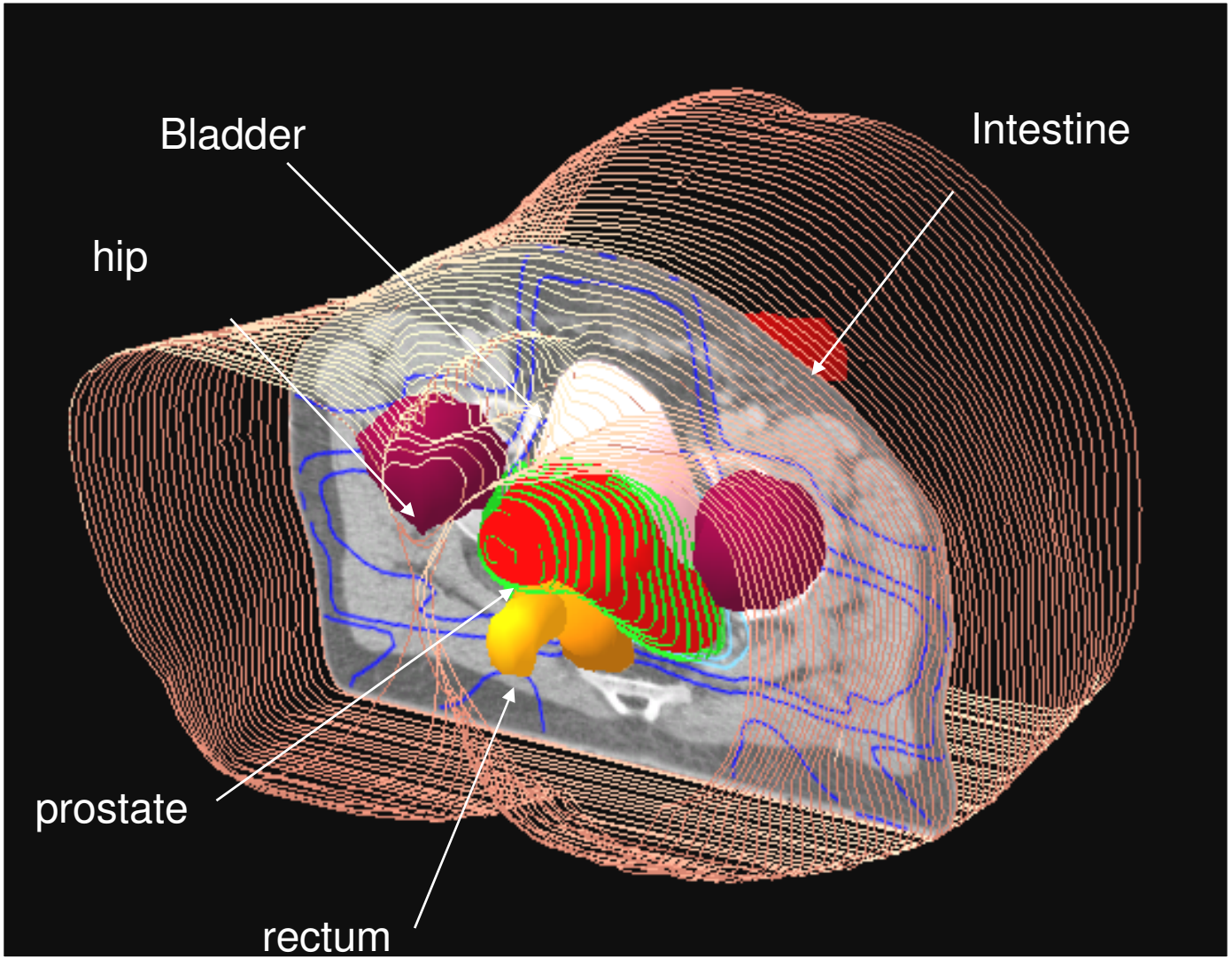


PET - CT matching in the NKI- AVL



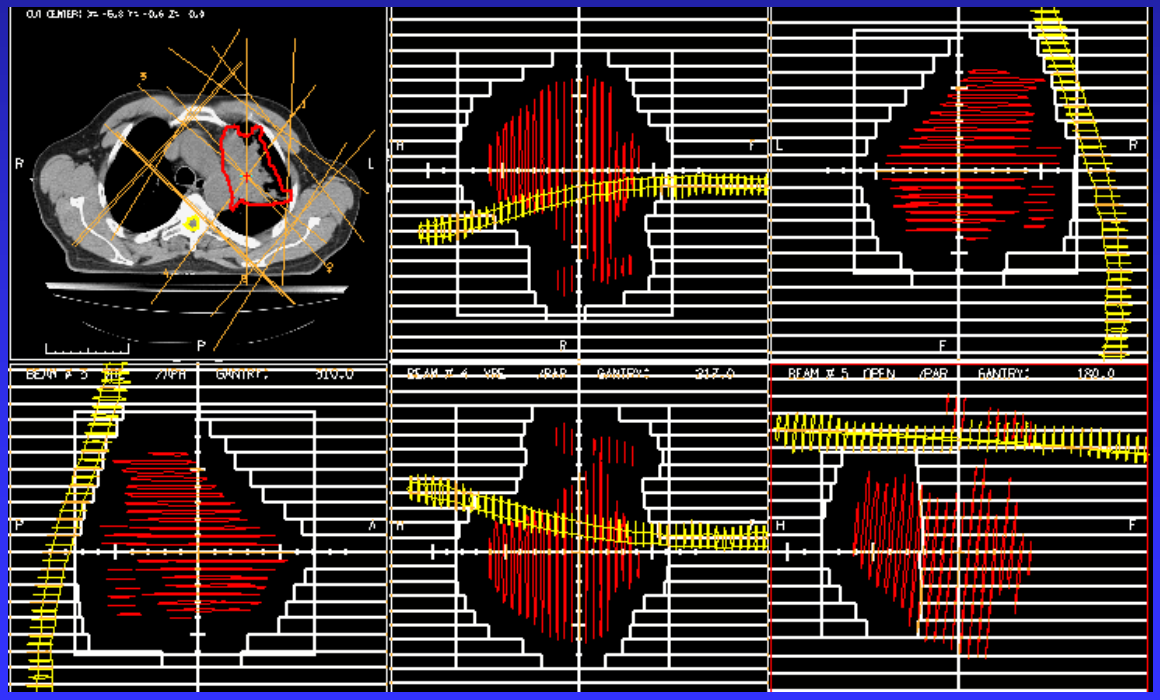


Structure segmentation and reconstruction: 3D structures



What is 3-D conformal radiotherapy ?

- Beam set-up:
  - complete freedom in beam set-up (gantry, collimator, table)
  - design of beams in relation with the patient's anatomy



What is 3-D conformal radiotherapy ?

- Dose calculation: 2-D versus 3-D dose calculation

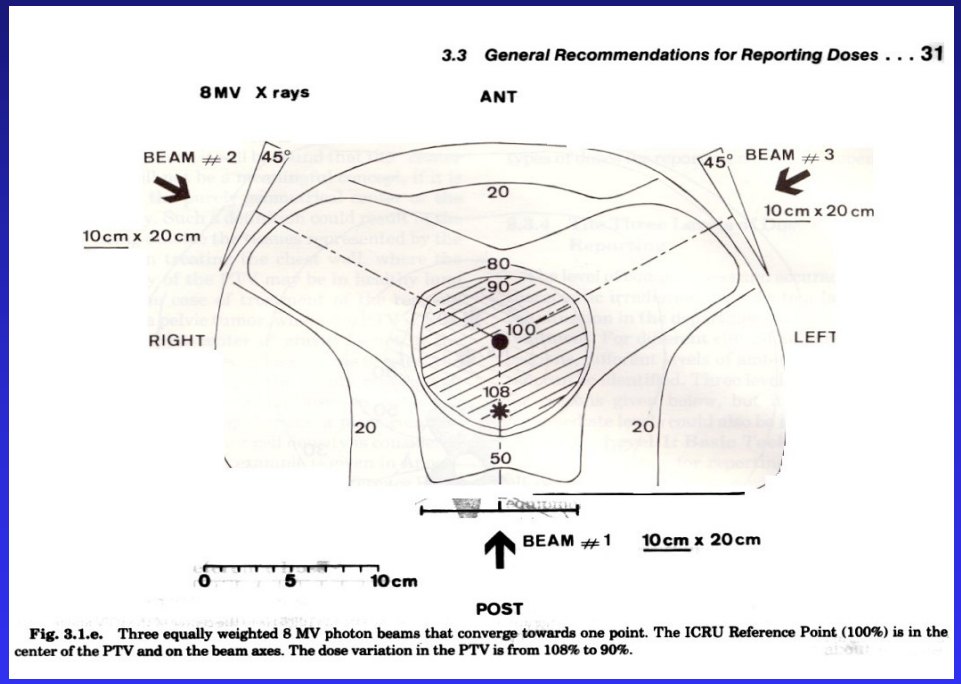
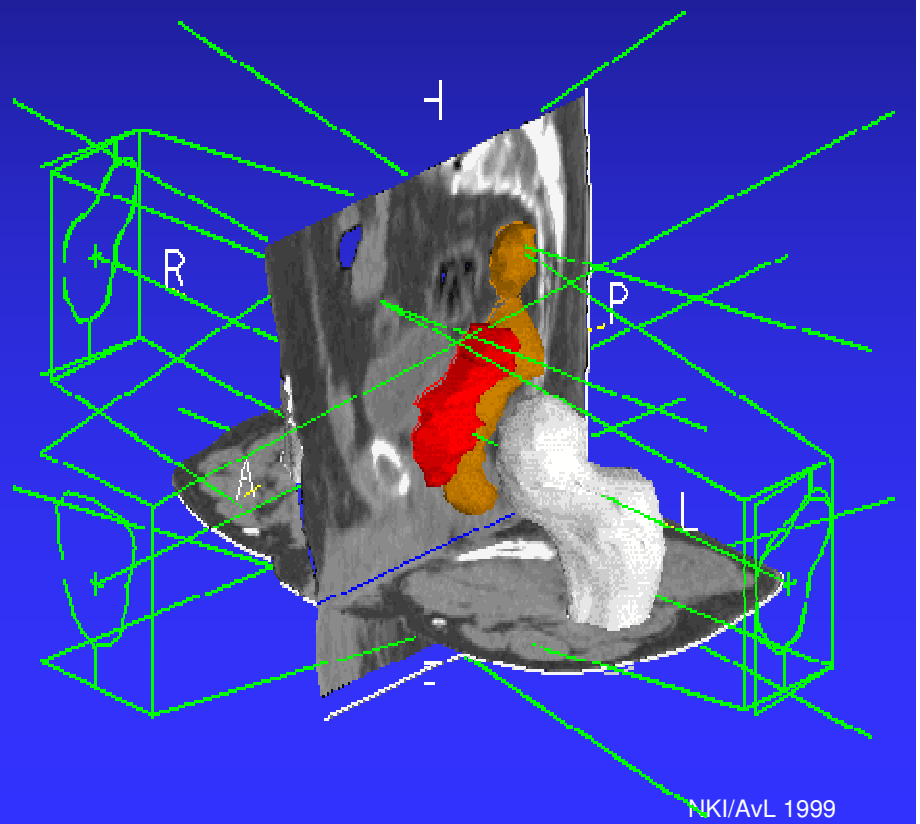


Fig. 3.1.e. Three equally weighted 8 MV photon beams that converge towards one point. The ICRU Reference Point (100%) is in the center of the PTV and on the beam axes. The dose variation in the PTV is from 108% to 90%.



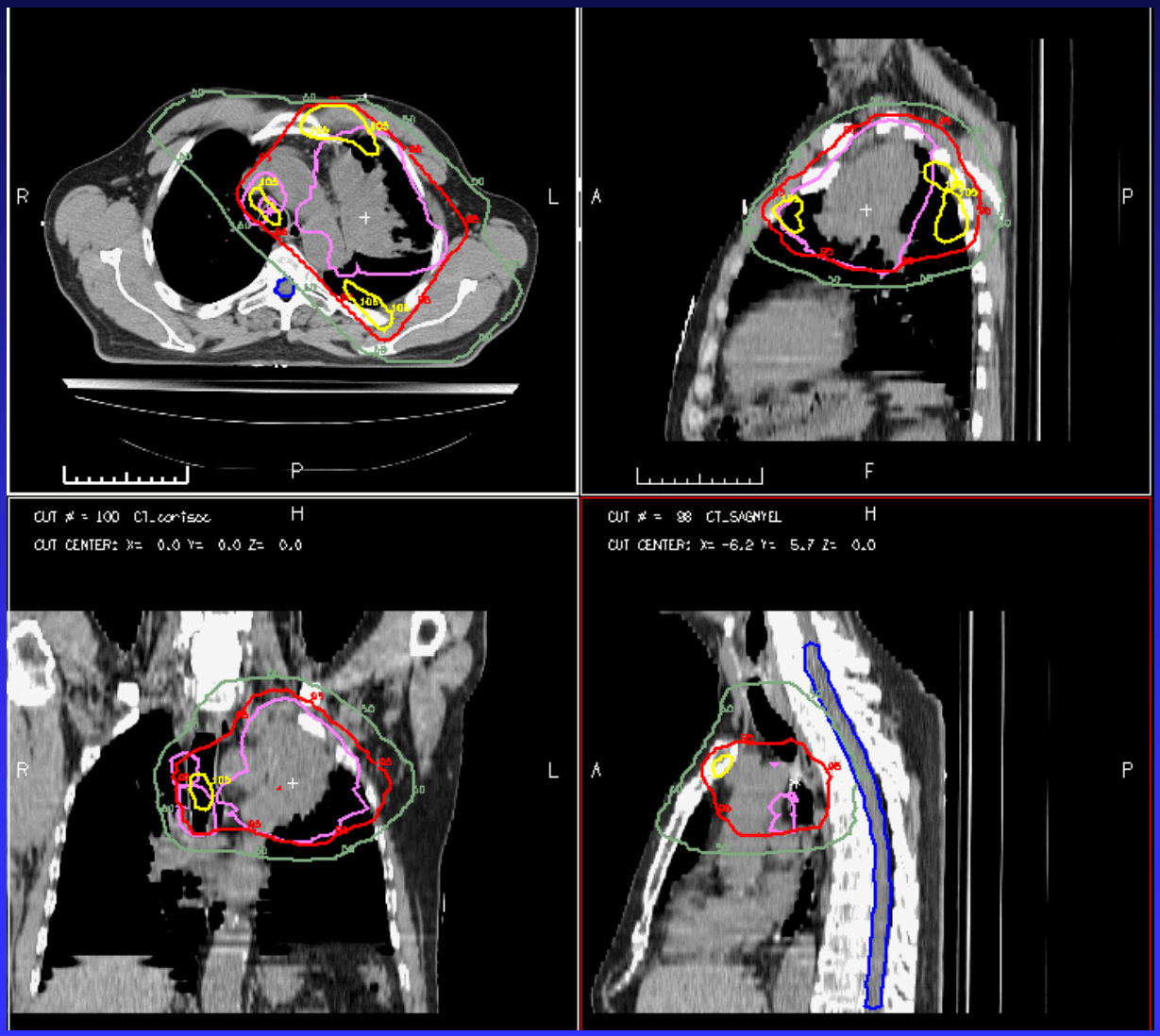
"2D – 3D revolution"

NKI/AvL 1999

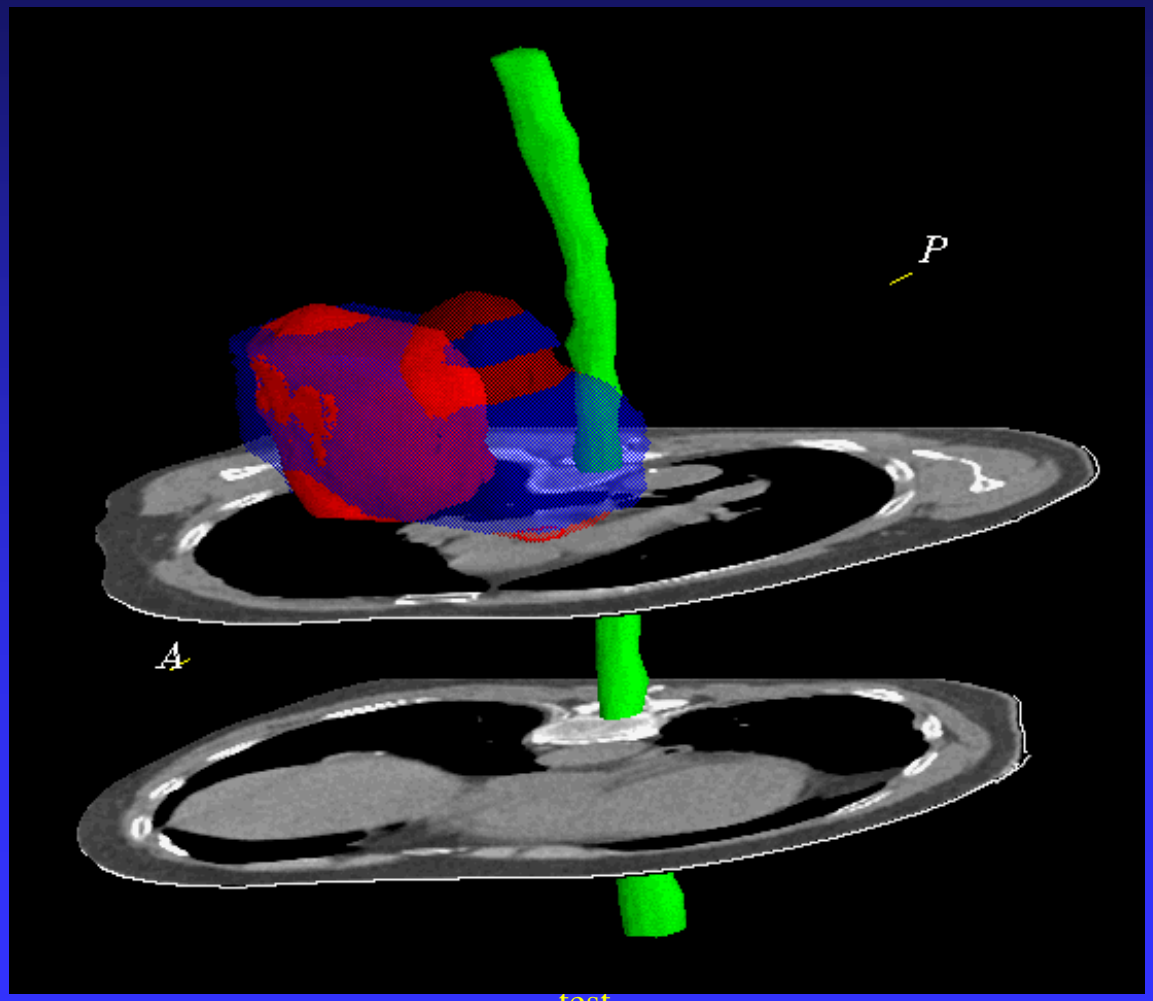
Treatment planning and evaluation:

- Approve final plan
- Determine monitor unit settings
- Verify monitor unit calculation manually or with secondary calculation software, if available

3-D dose distribution

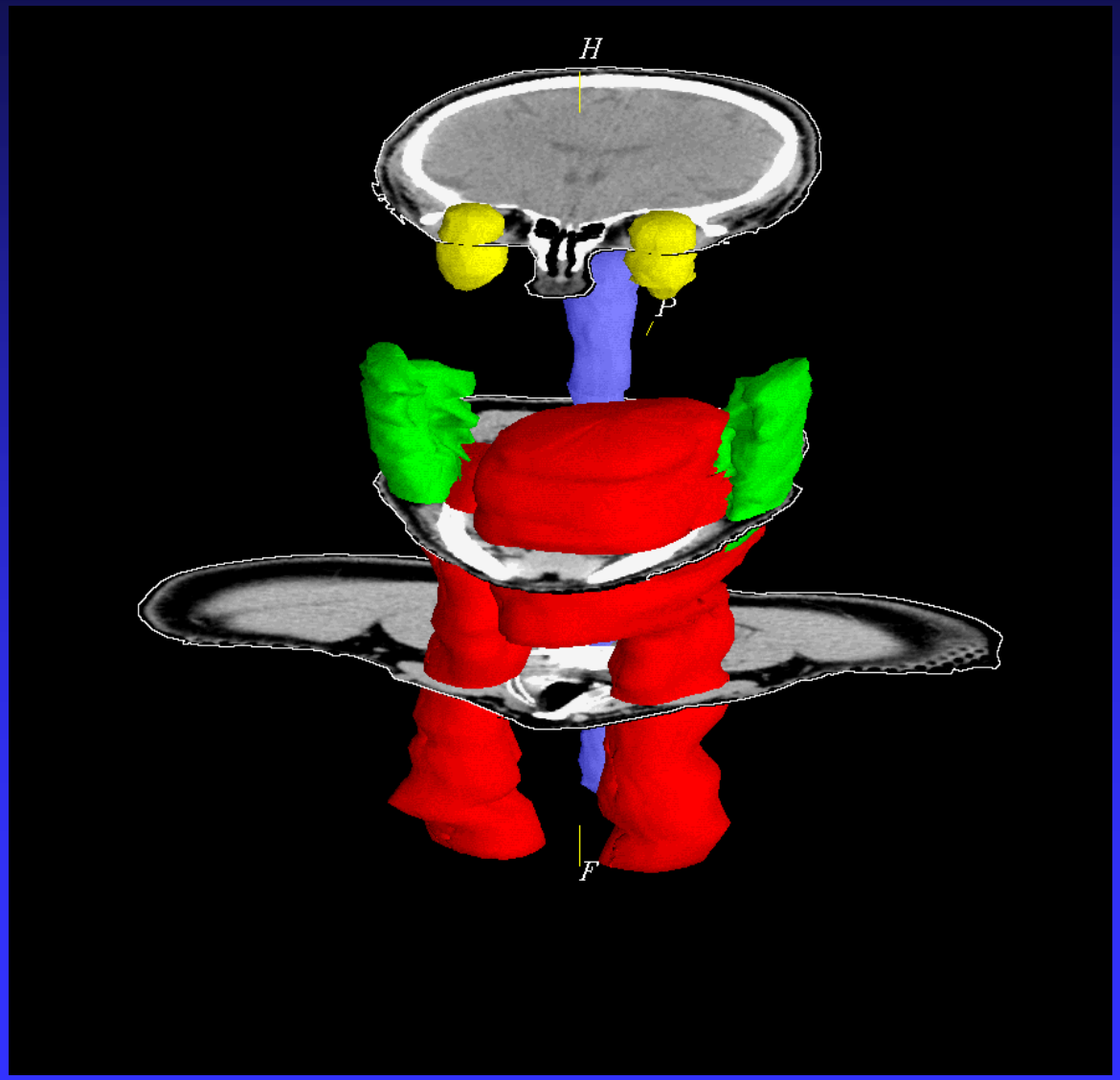


3-D dose display

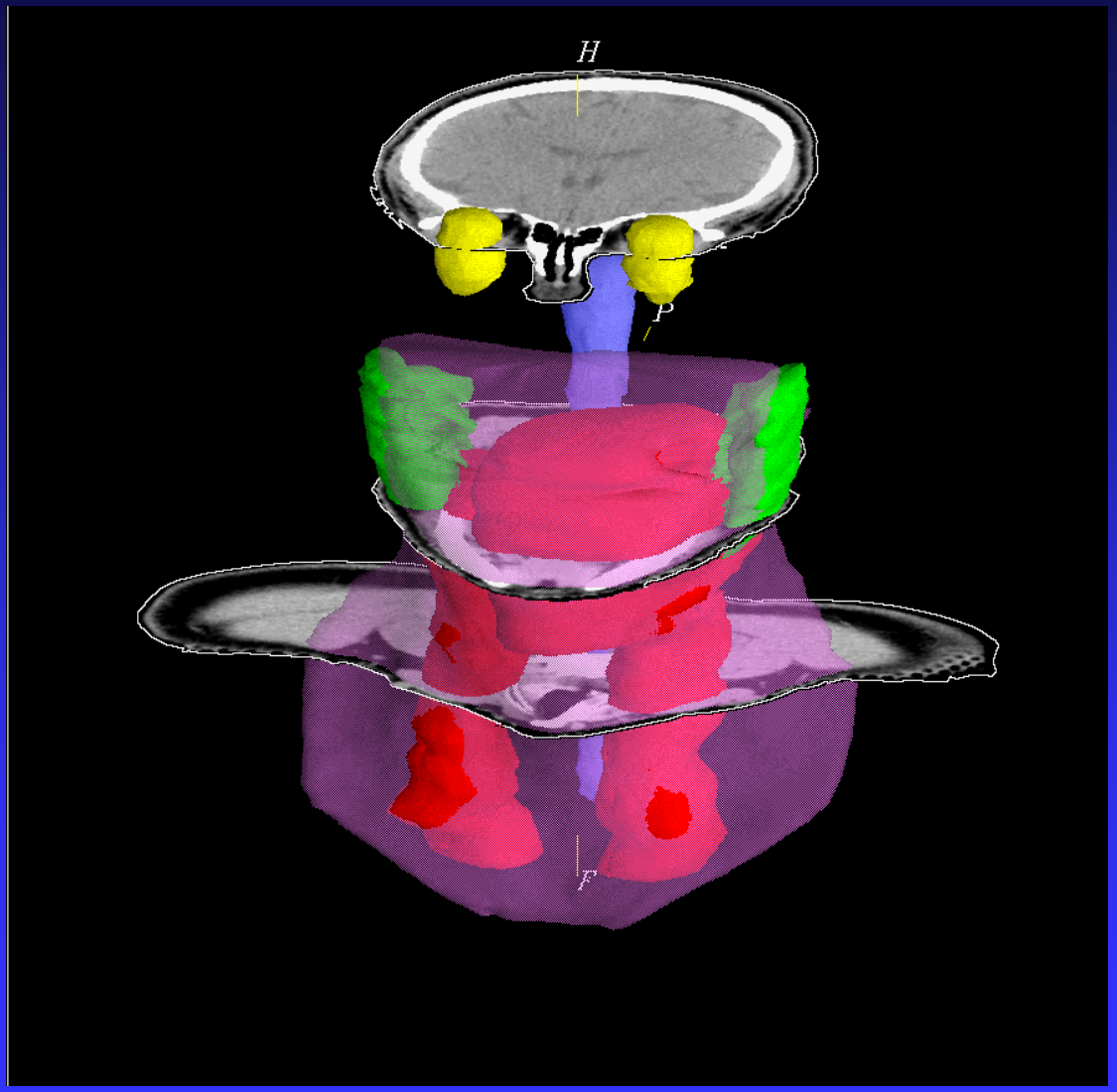


test

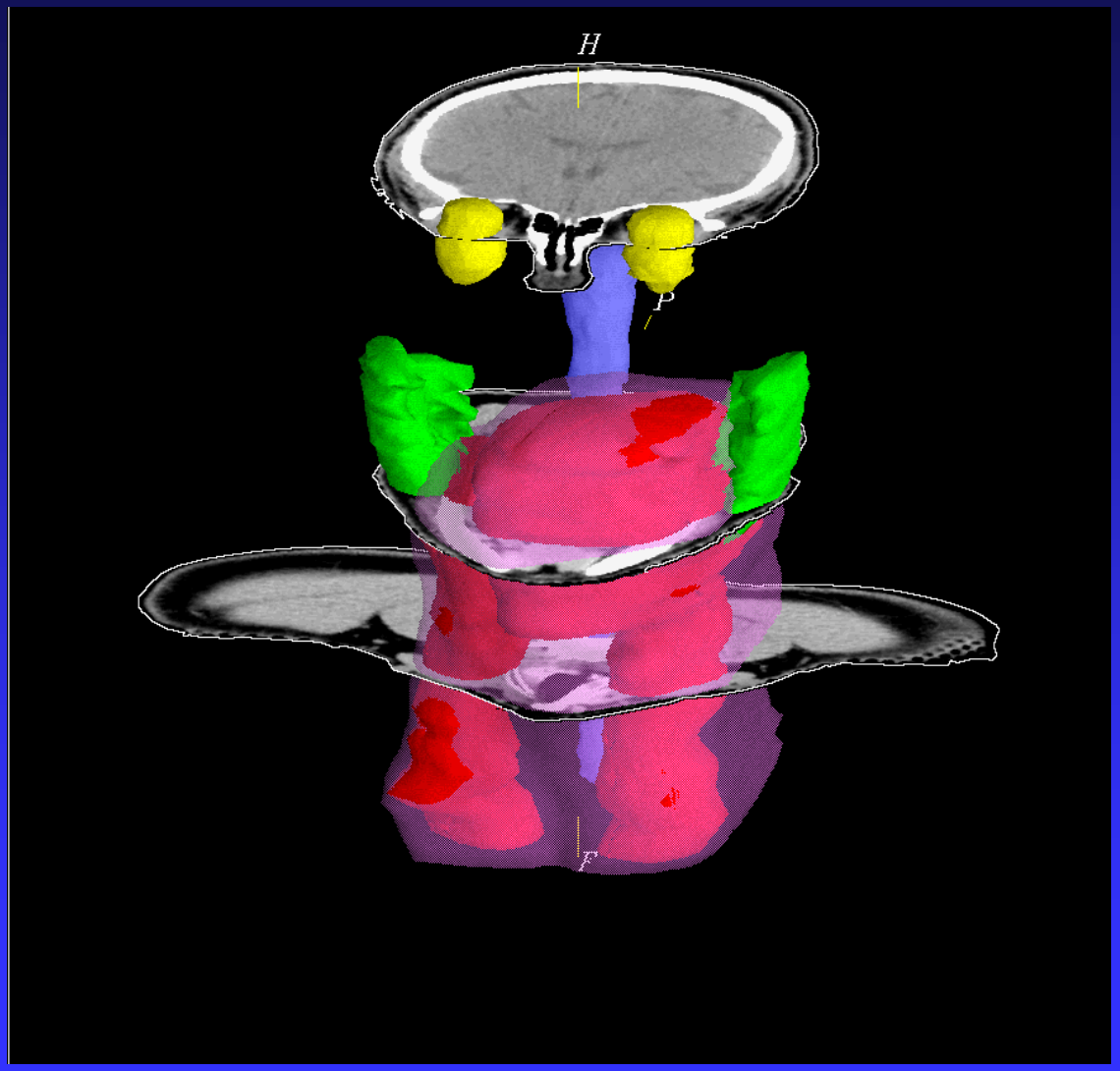
Comparison of treatment techniques: target volume and organs at risk



Comparison of treatment techniques: old technique



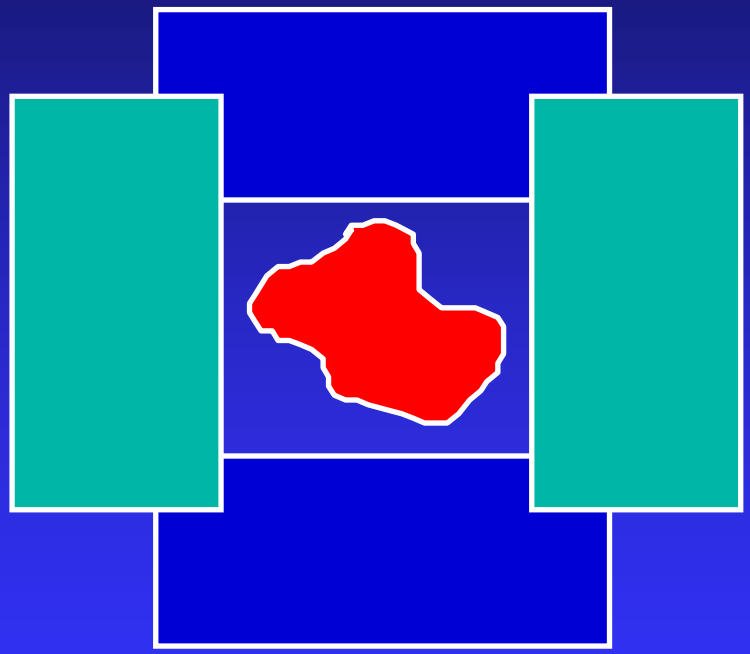
Comparison of treatment techniques: new technique



Outline

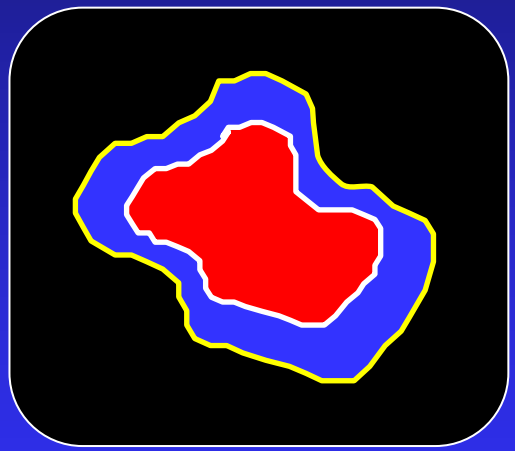
- 3-D conformal radiotherapy (3-D CRT)
- Intensity-modulated radiotherapy (IMRT)
- Image-guided radiotherapy (IGRT)

Collimation

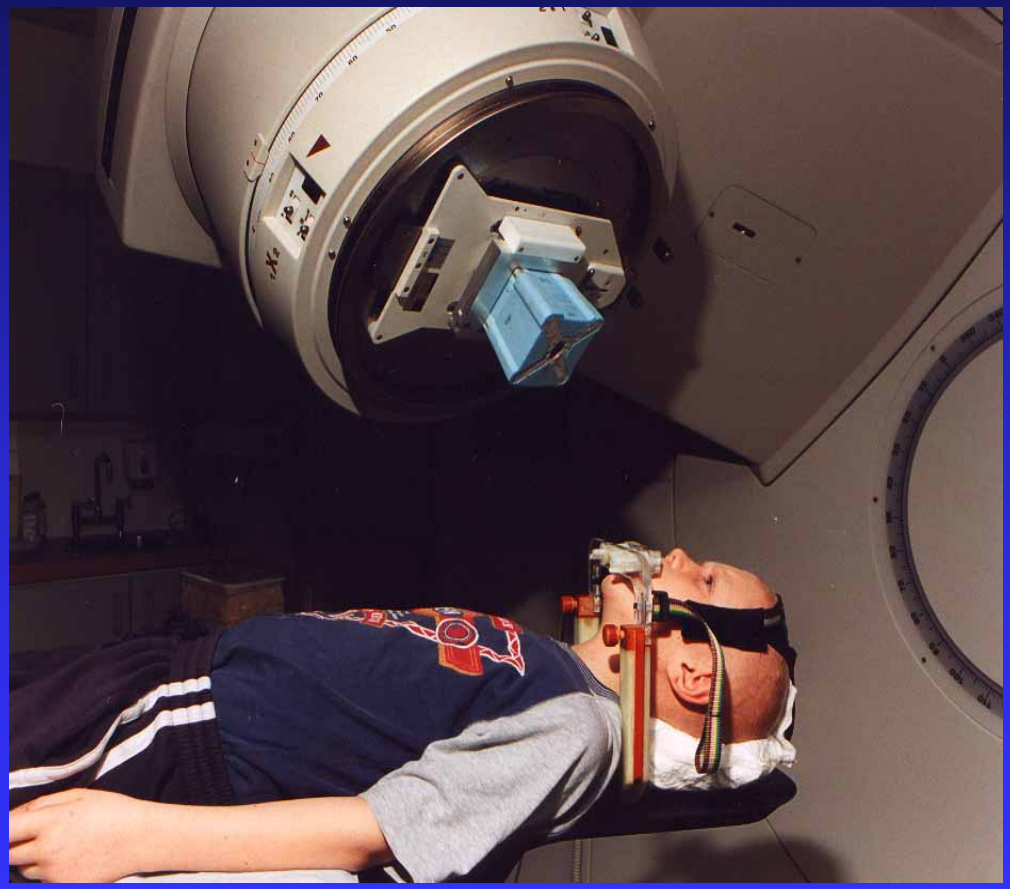


Collimation

Collimation

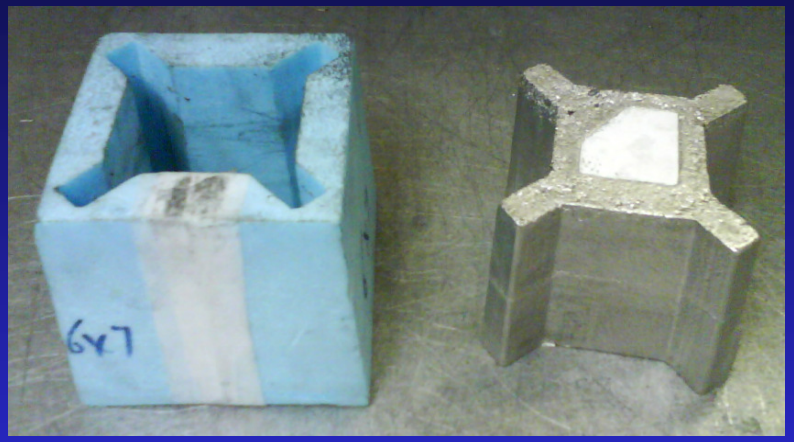


Collimation



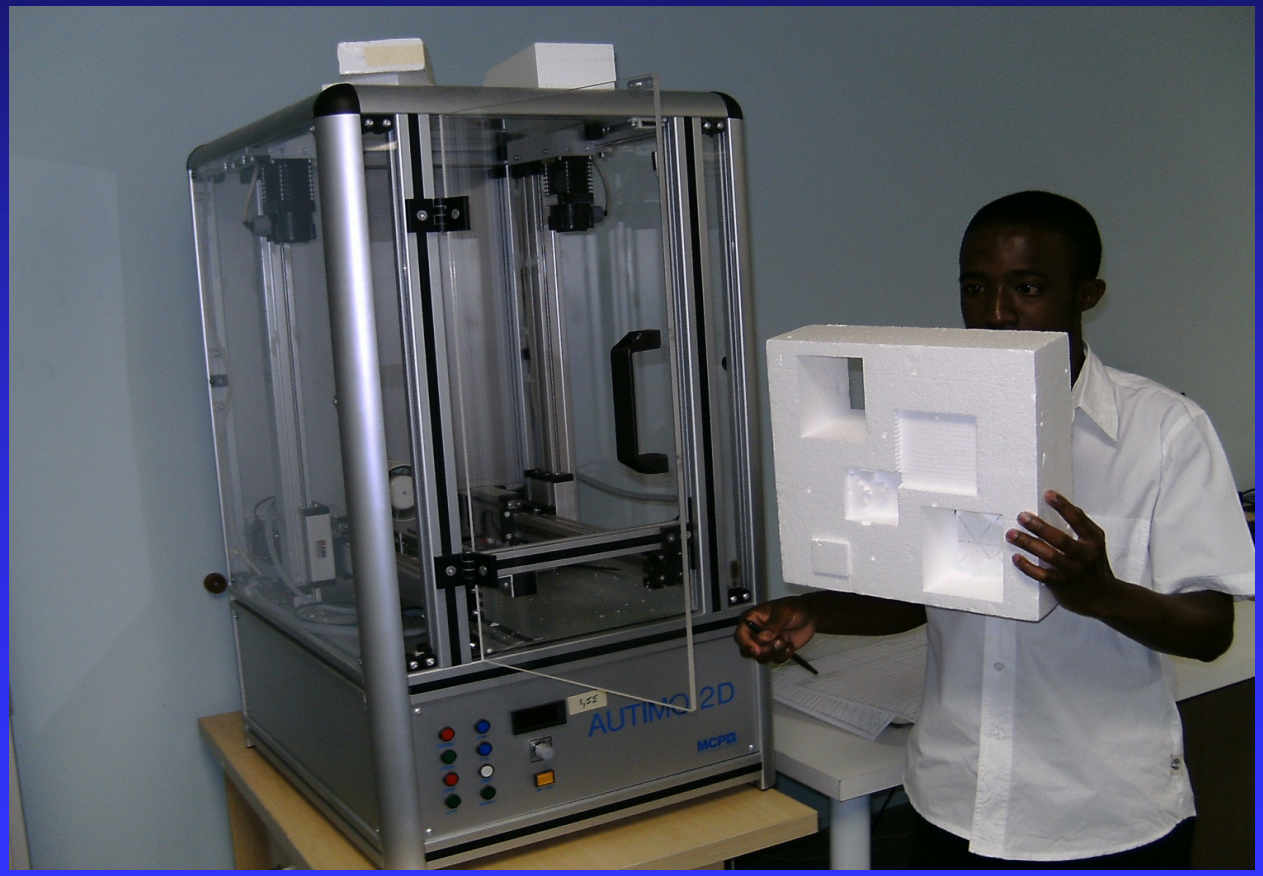
Delivery of 3-D CRT using beam blocks

Customised beam block mounted on conventional linac or cobalt unit without MLC

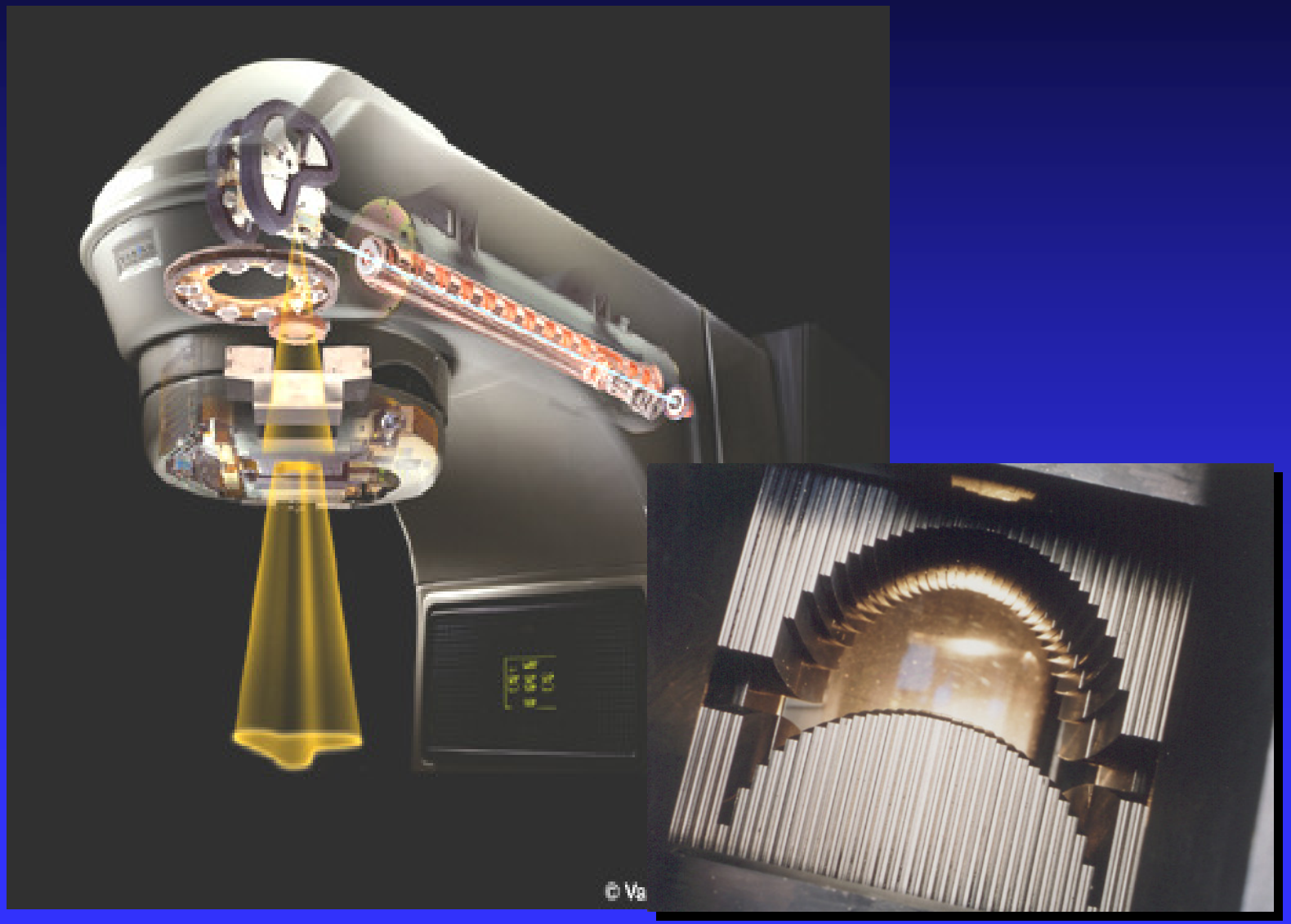


Customised beam block to collimate a conformal beam. A separate customised block is used for each conformal beam.

Automatic block cutting



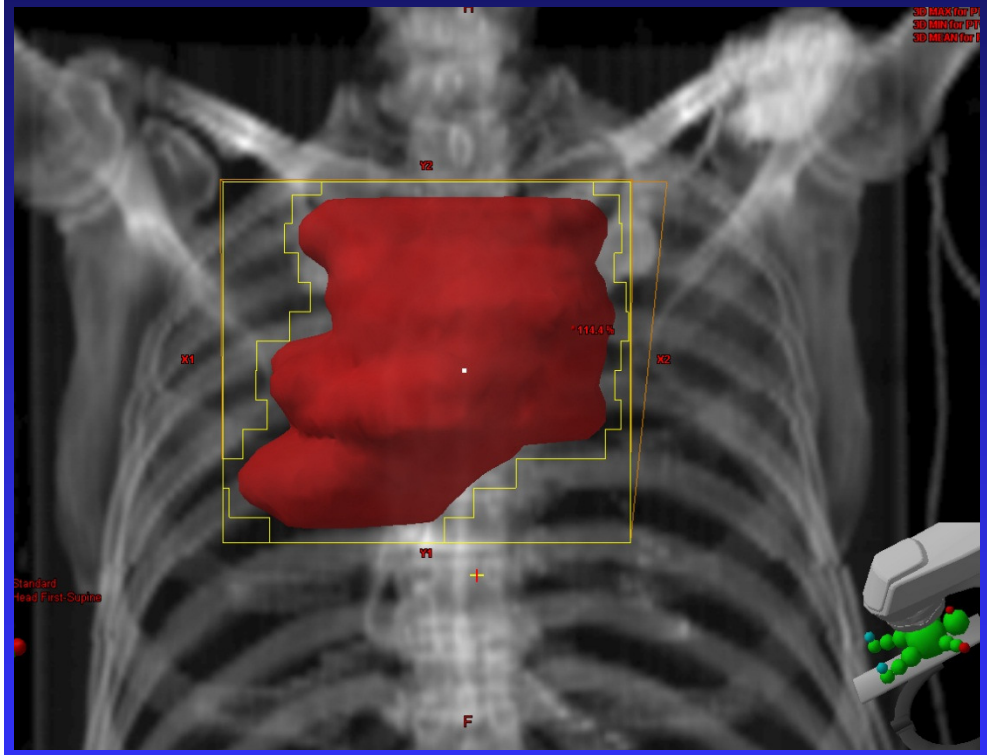
Treatment delivery: multileaf collimator



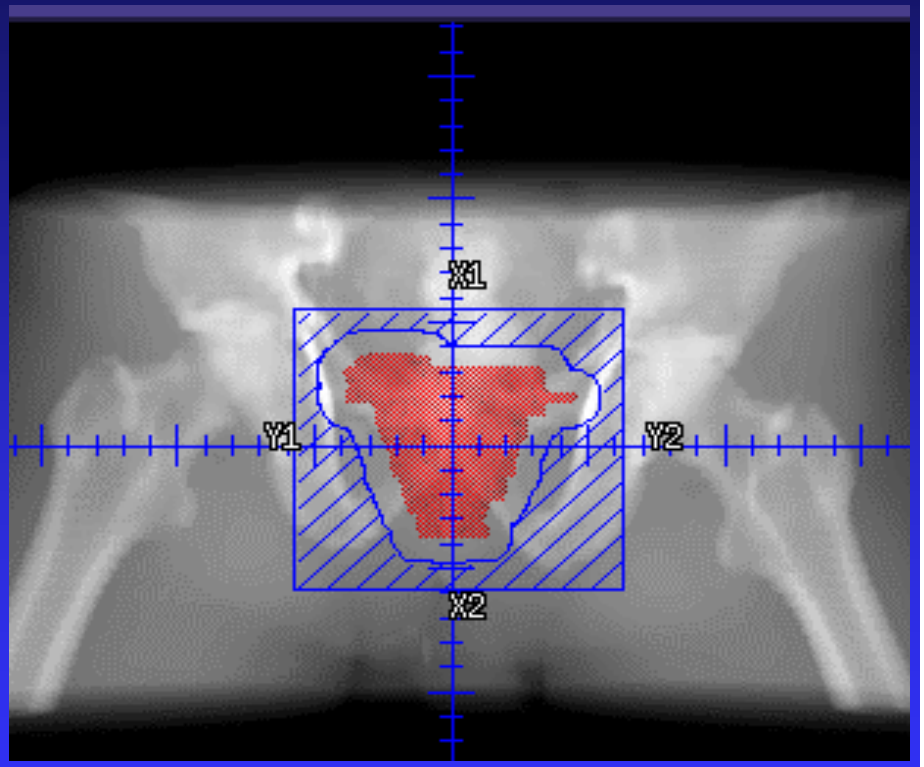
Collimation

multileaf collimator

Beams-eye-view (BEV) planning of treatment beam to conform the shape of the target with a margin



MLC collimated



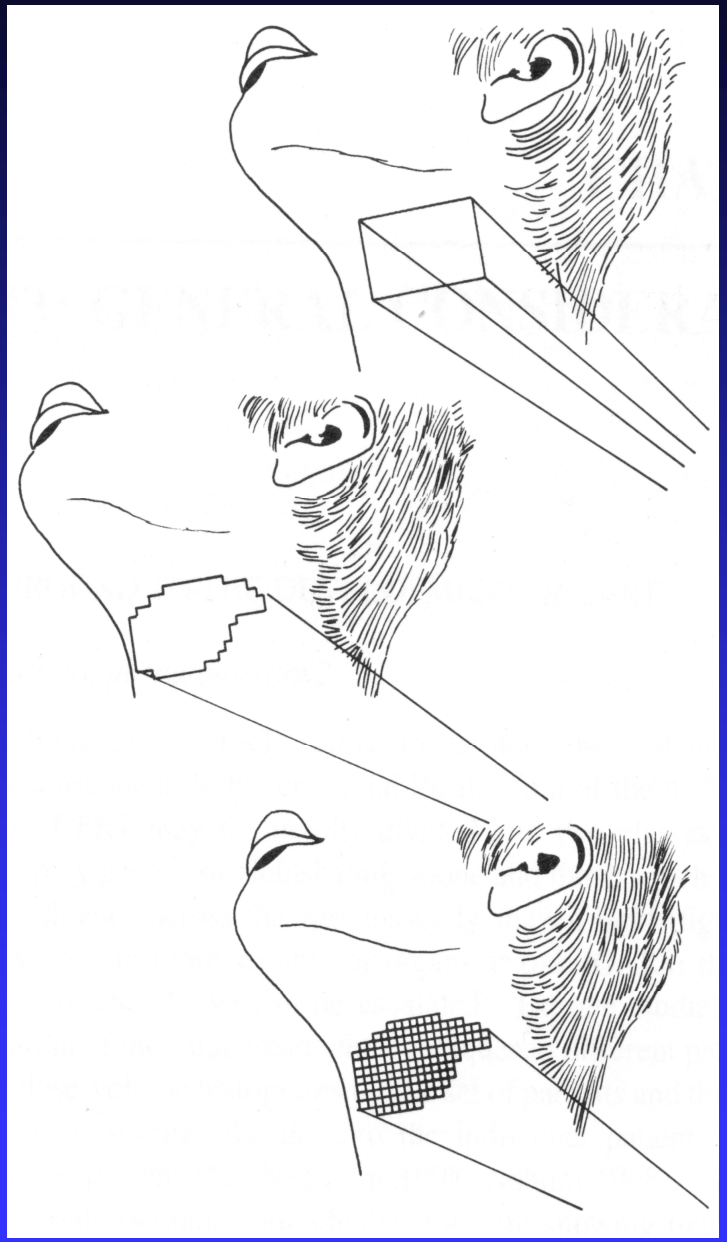
Lead block collimated

Key differences between:

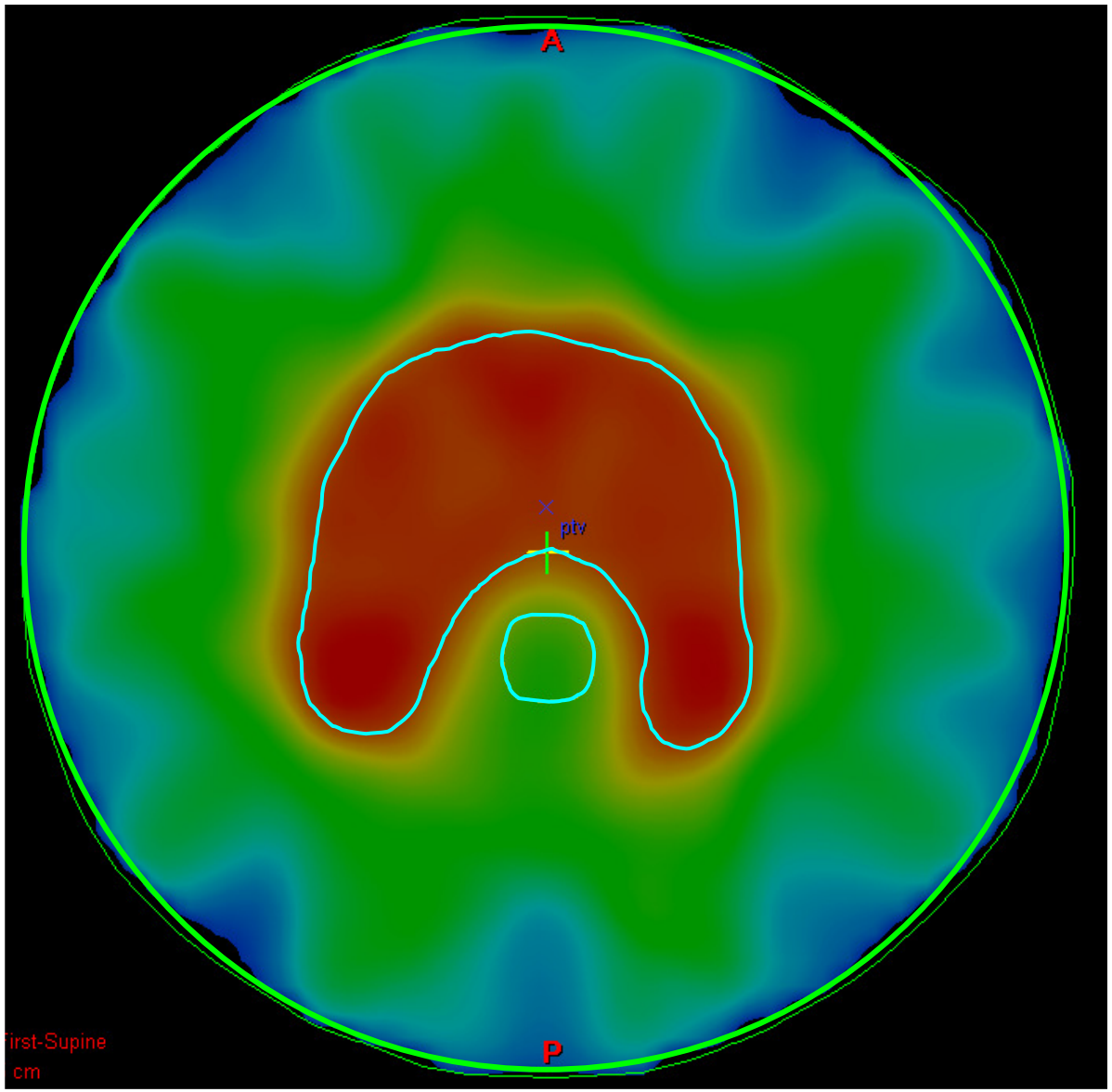
Conventional Radiation Therapy

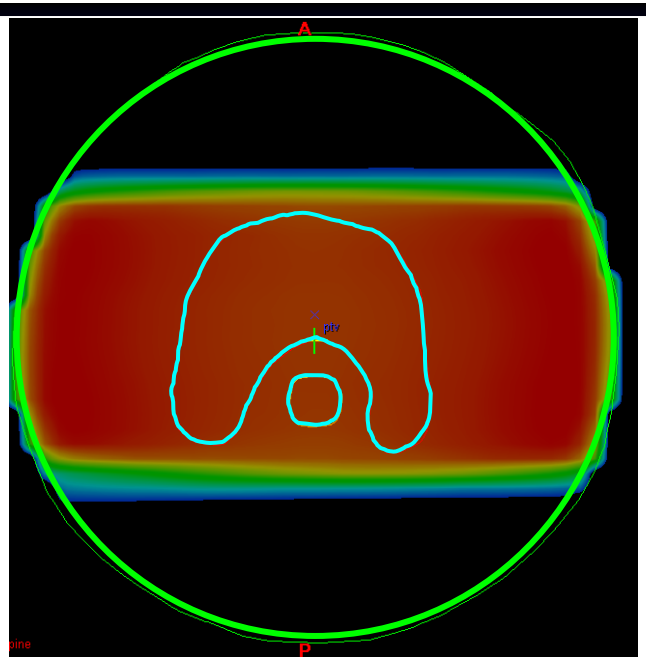
3-D Conformal Radiation Therapy (3D CRT)

Intensity-Modulated Radiation Therapy (IMRT)



(From: Steve Webb, Intensity- Modulated Radiation Therapy, IoP publishing, 2001)


A
ptv
P
irst-Supine
cm


A
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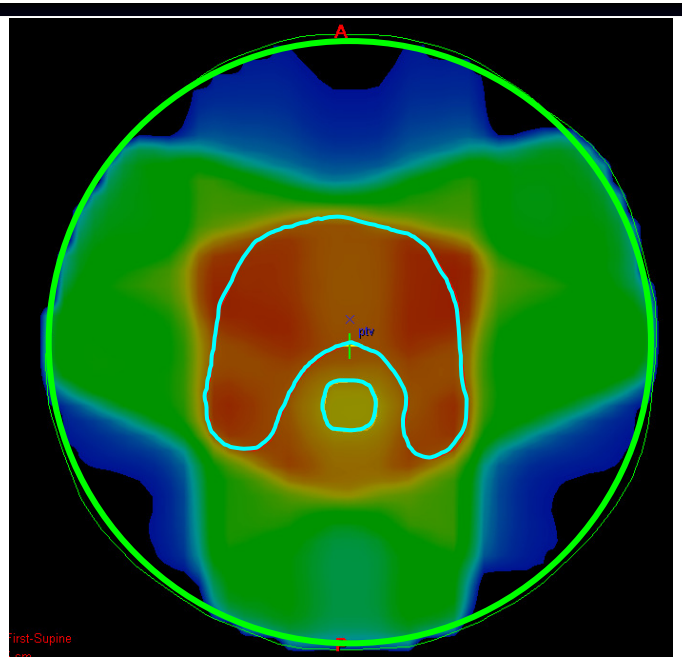
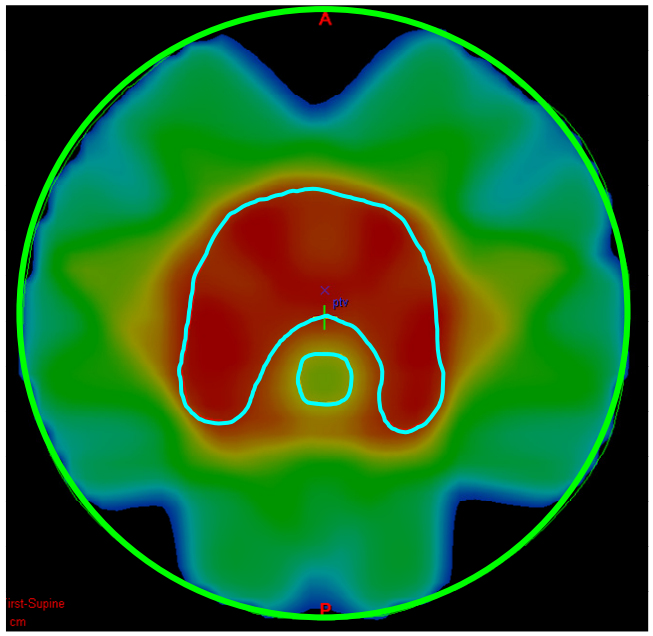

A
ptv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ptv
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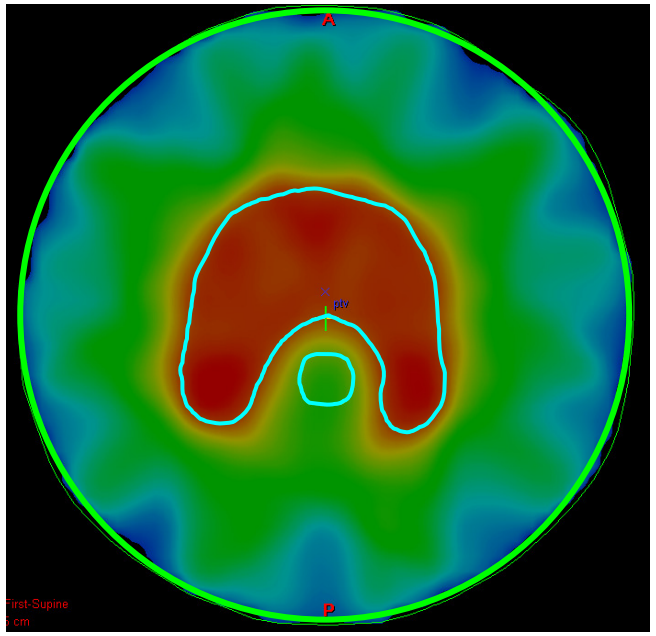
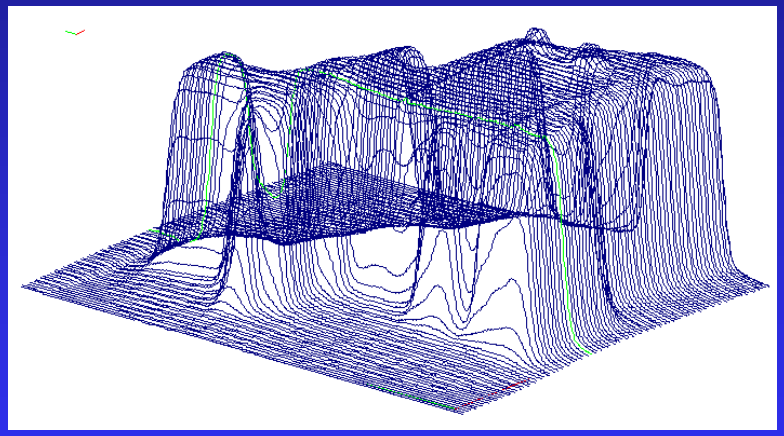
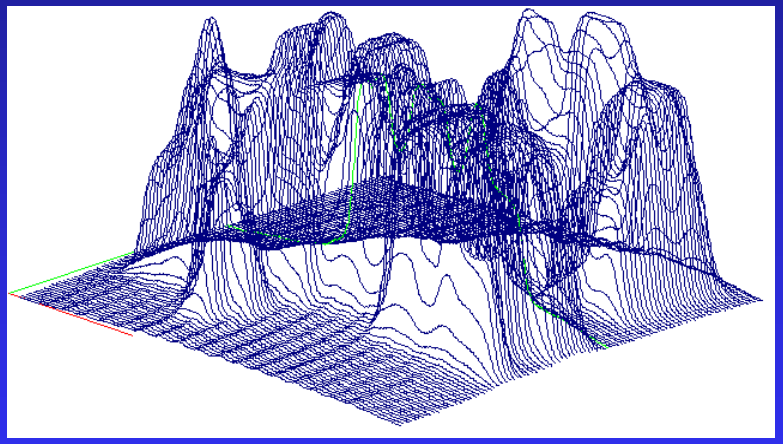

A
ptv
P

3-D Conformal versus Intensity-Modulated Radiotherapy

3-D conformal radiotherapy without intensity modulation

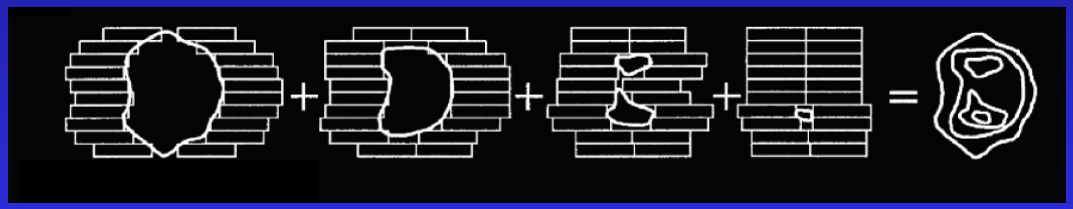


Intensity-modulated radiotherapy

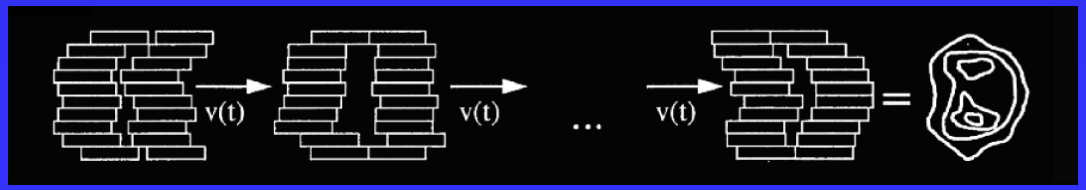


Production of IMRT Beams Using MLC-equipped Linear Accelerators

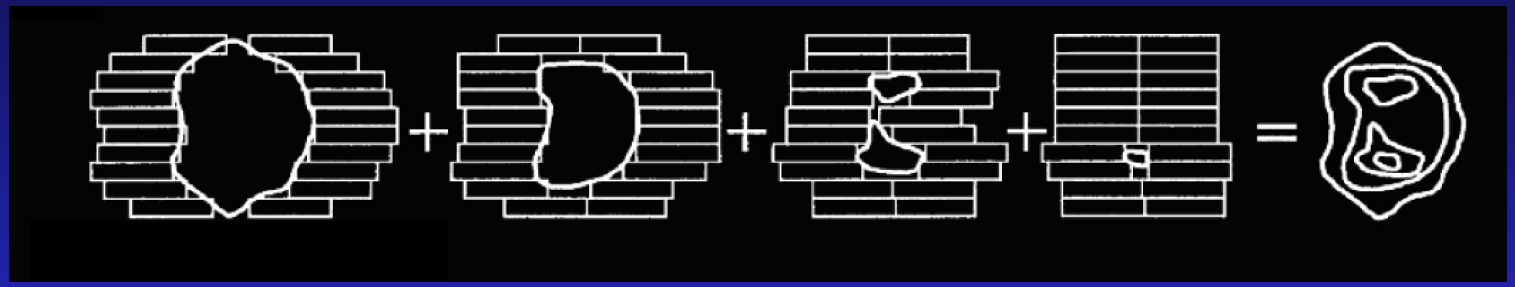
Static approach with several static intensity-modulated fields at a specific gantry angle



Dynamic approach with intensity-modulation during irradiation at a specific gantry angle

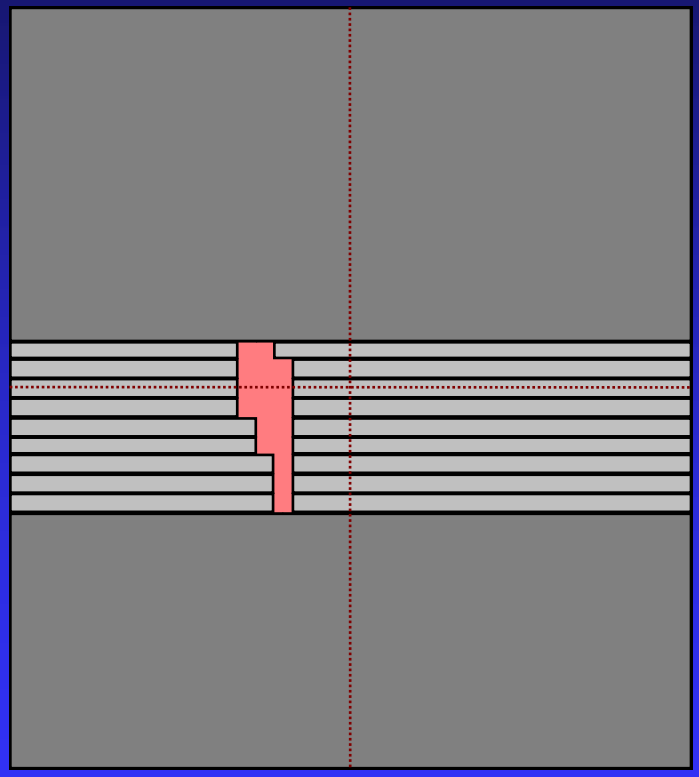


Static MLC

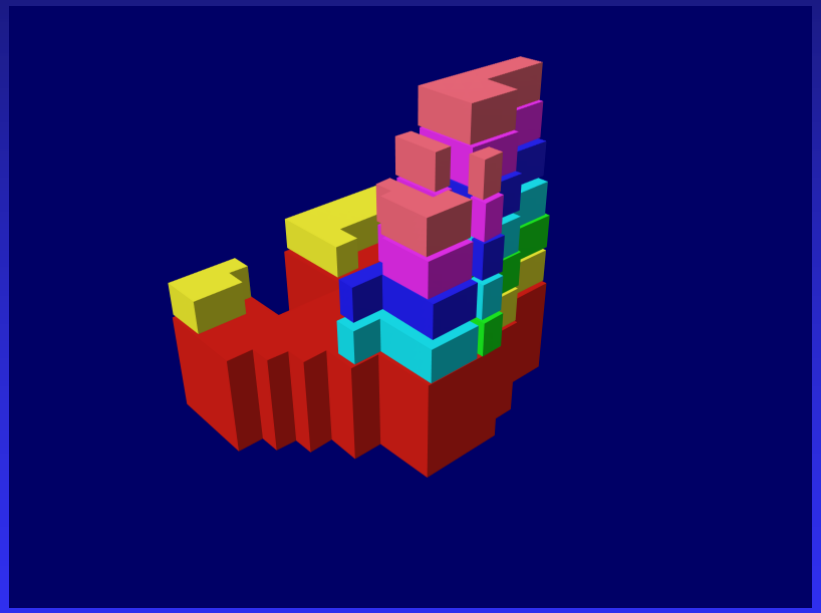


- This is often known as the ‘step-and-shoot’ method
- A sequence of sub-fields is treated one after the other to create the overall fluence. Each sub-field is defined by a different MLC setting
- The injector is switched off between each field and there is no radiation during leaf movement
- Each sub-field can be recorded and verified separately

Static MLC

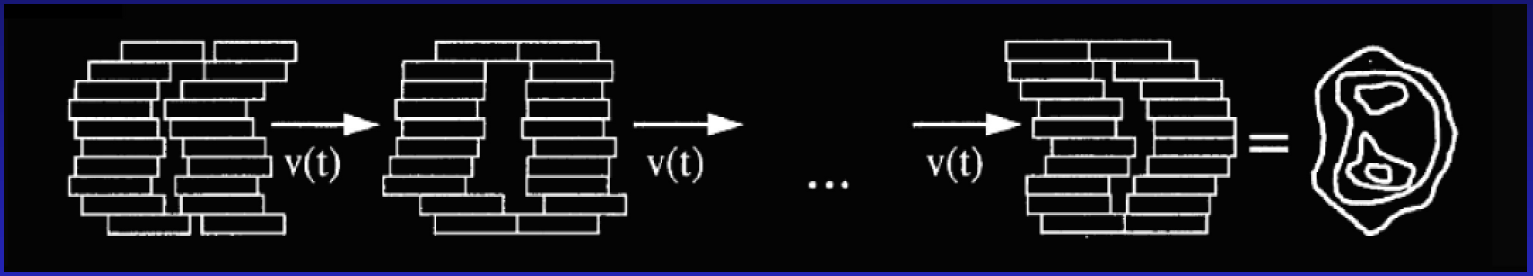


MLC shape

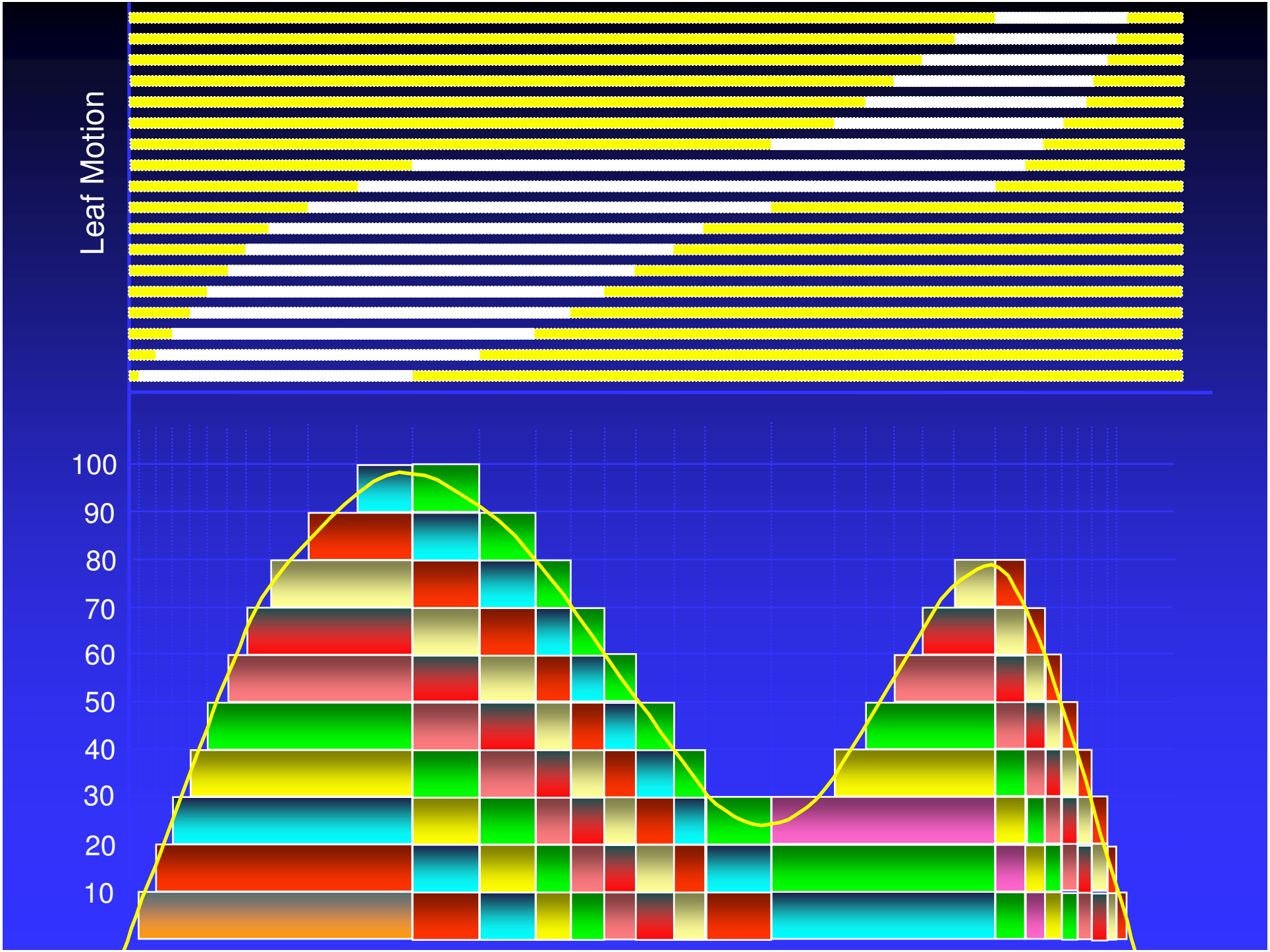


Fluence

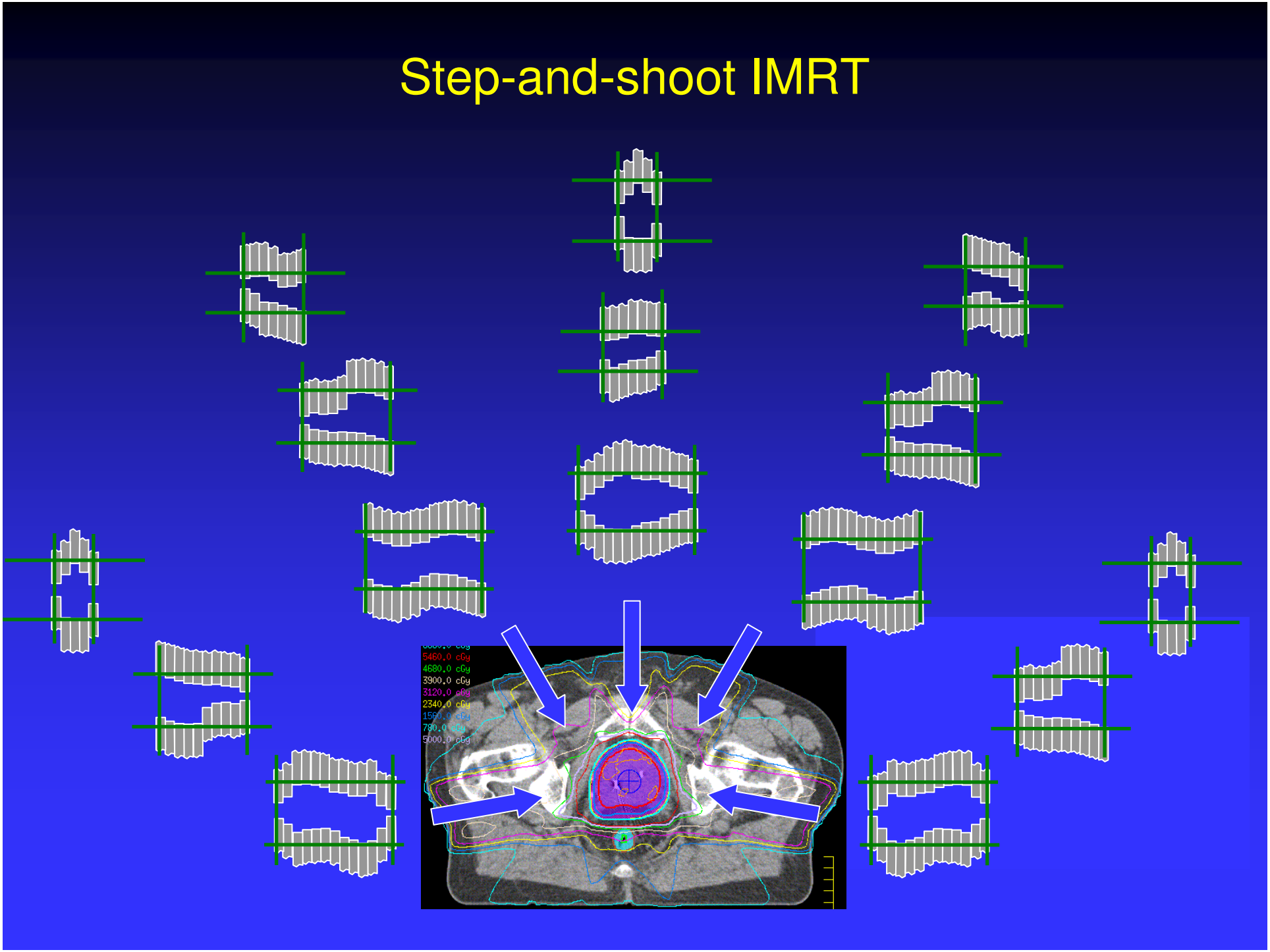
Dynamic MLC



- This technique uses either a ‘closing’ or ‘sliding’ window depending on how each MLC leaf-pair traverses the field
- In this case, the biggest difference from a static MLC delivery is that radiation is delivered during leaf movement
- This method has the same challenges as soft wedging in the event of a beam interruption and/or termination

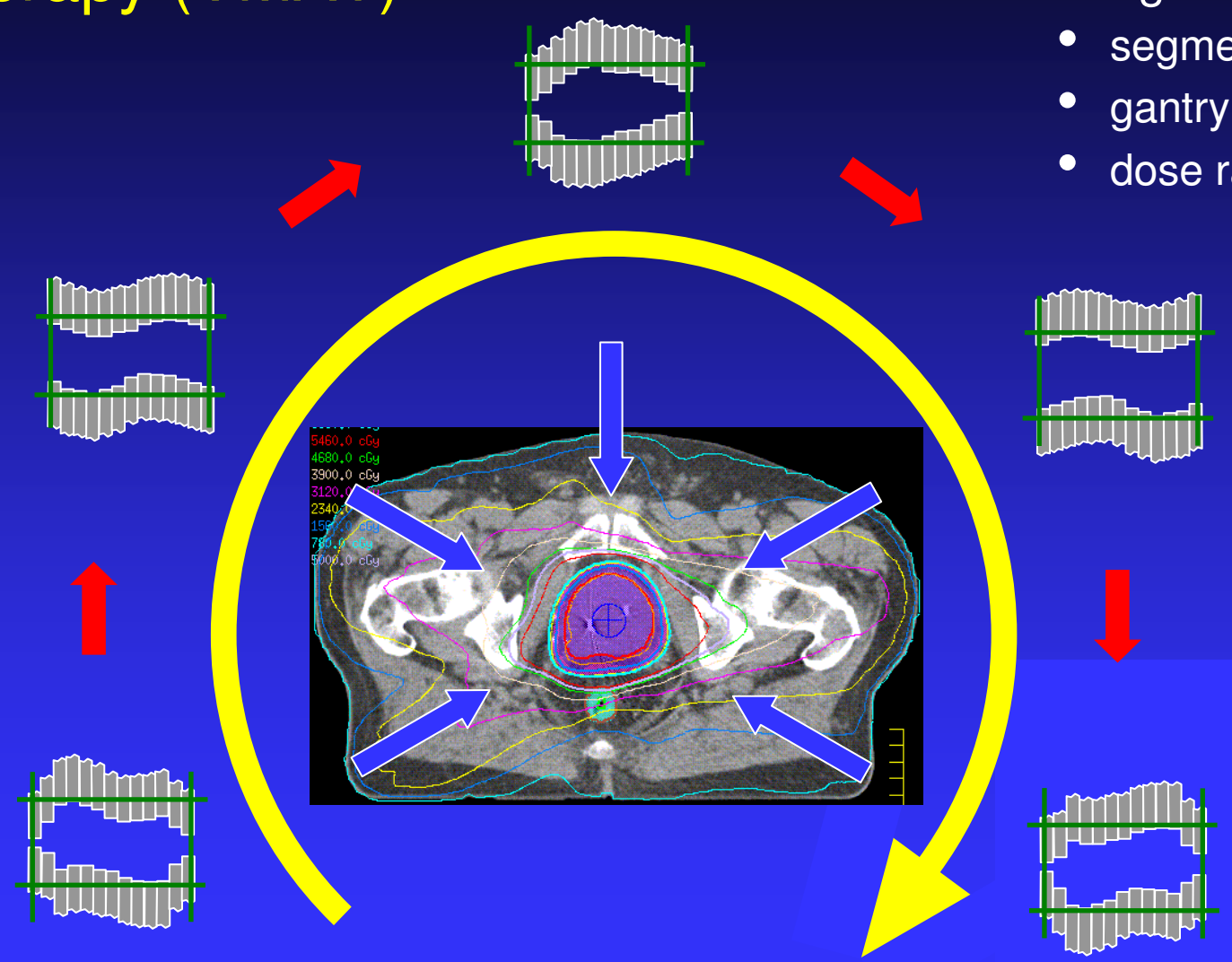

Leaf Motion
100
90
80
70
60
50
40
30
20
10

Step-and-shoot IMRT



Volumetric-Modulated Arc Therapy (VMAT)

- During gantry rotation changes in:
  - segment shape
  - gantry speed
  - dose rate

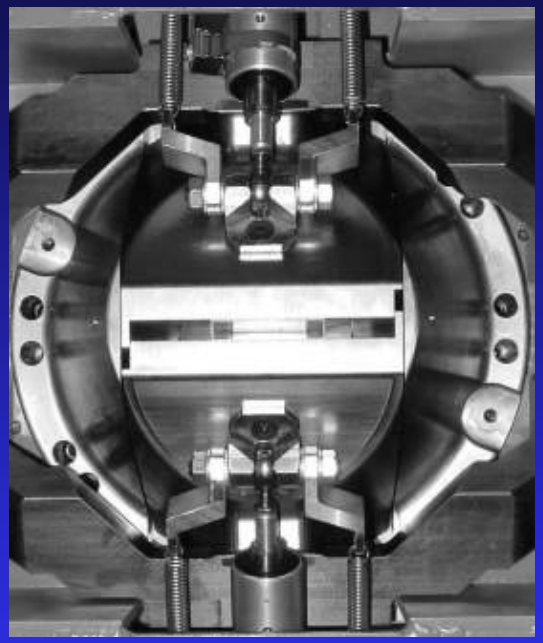


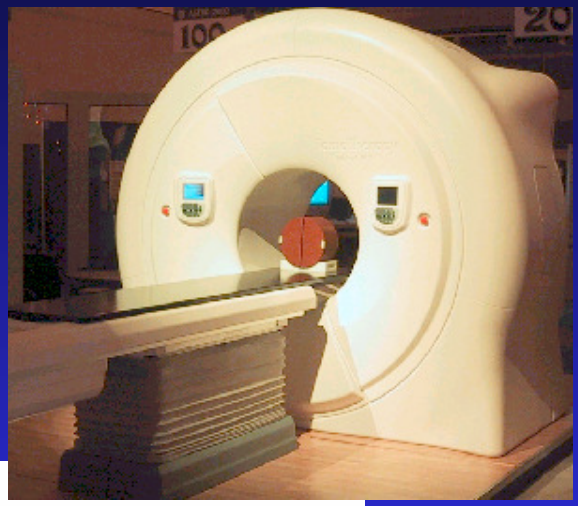
Movie of VMAT treatment

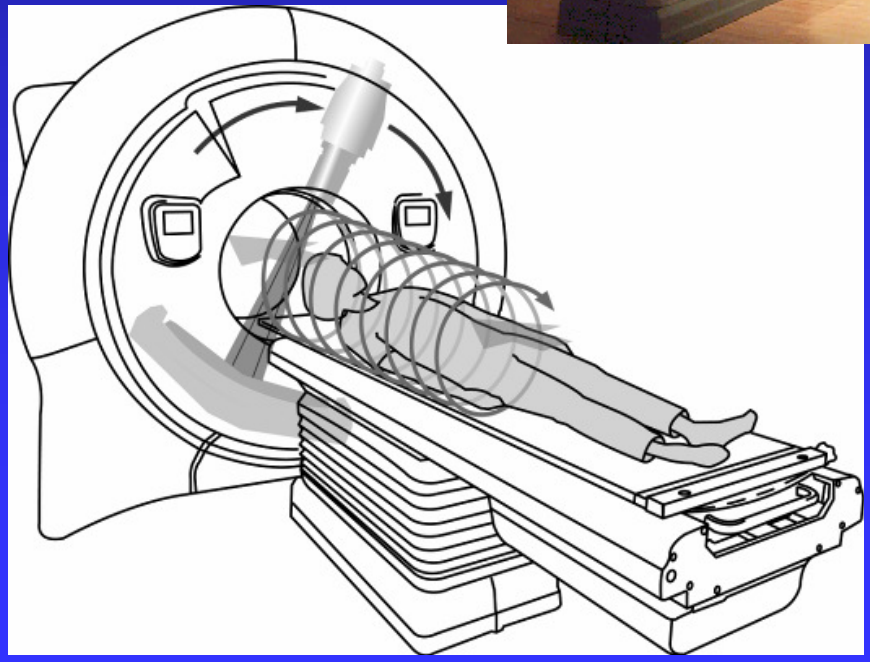
EPID movie

Fraction 1

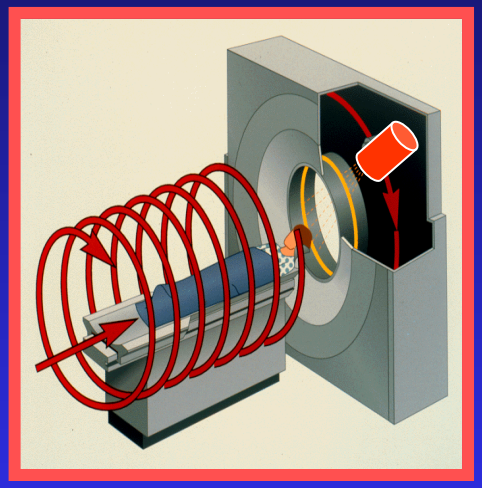
Helical tomotherapy

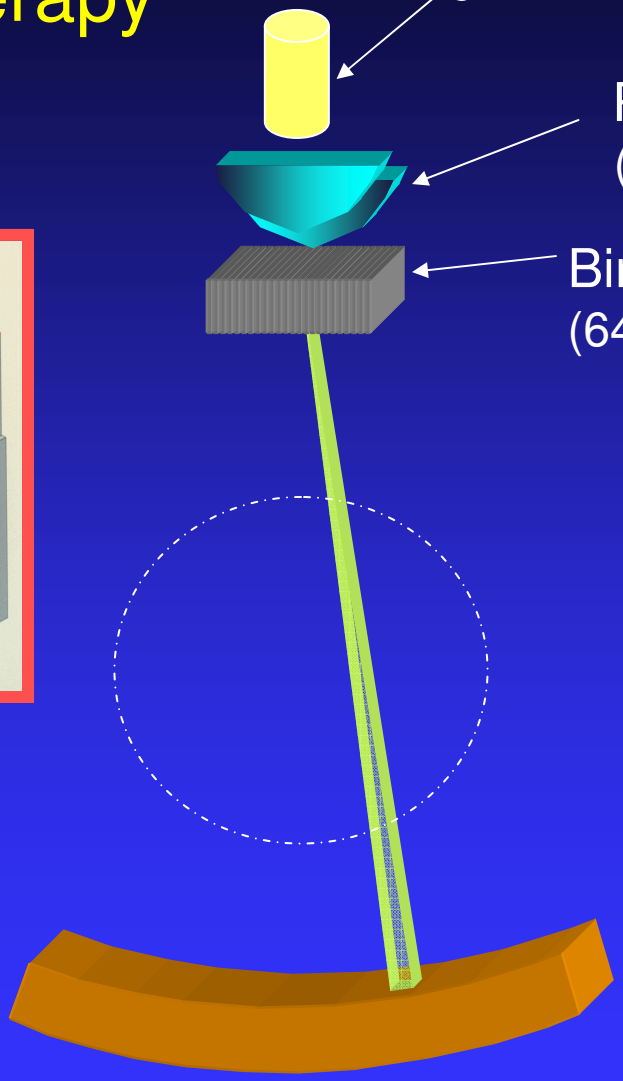


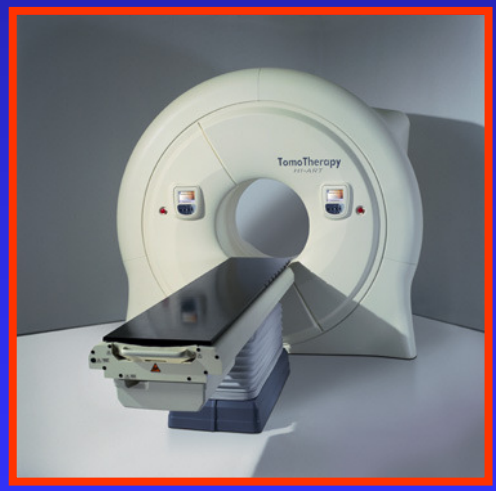




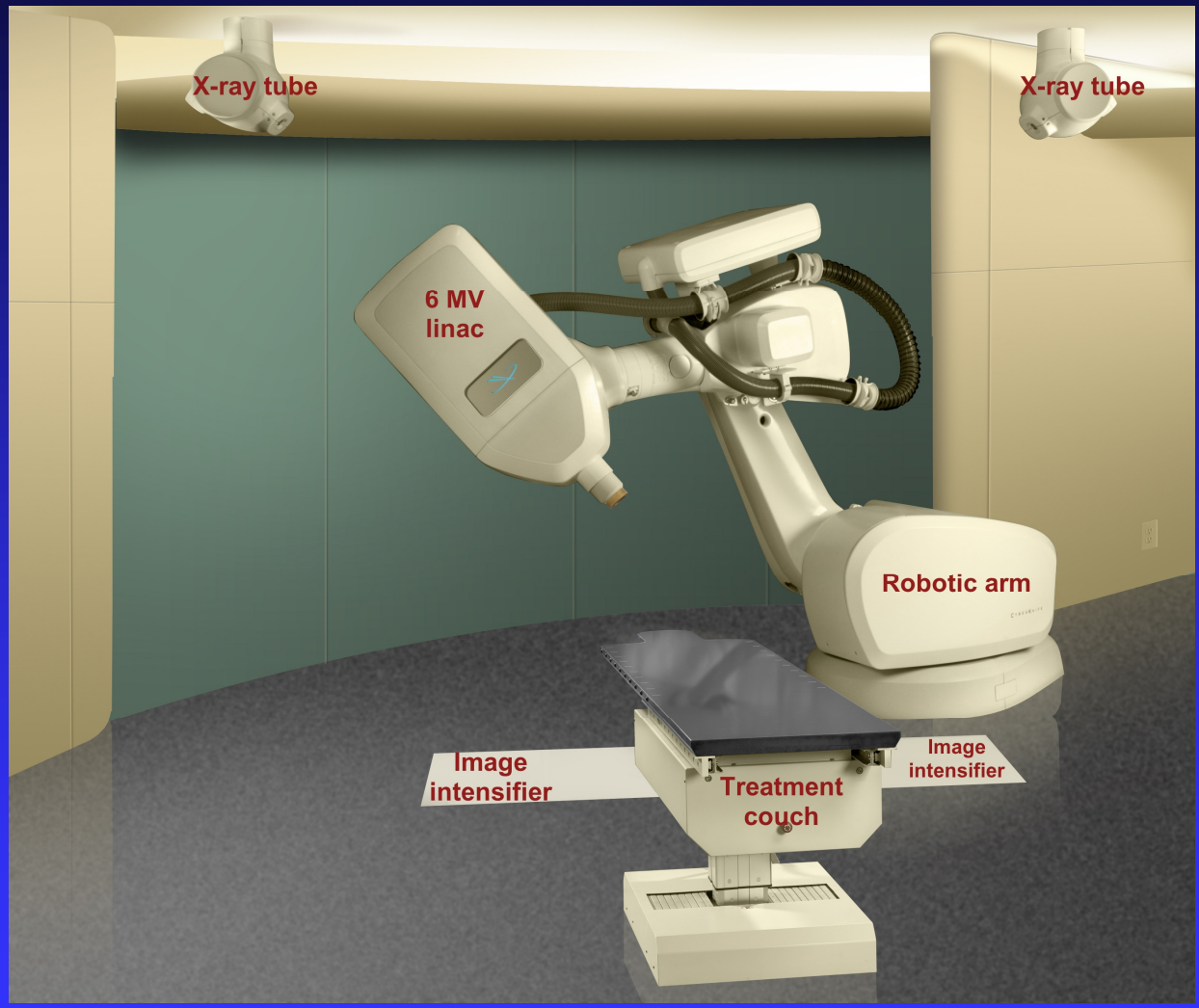
Helical tomotherapy





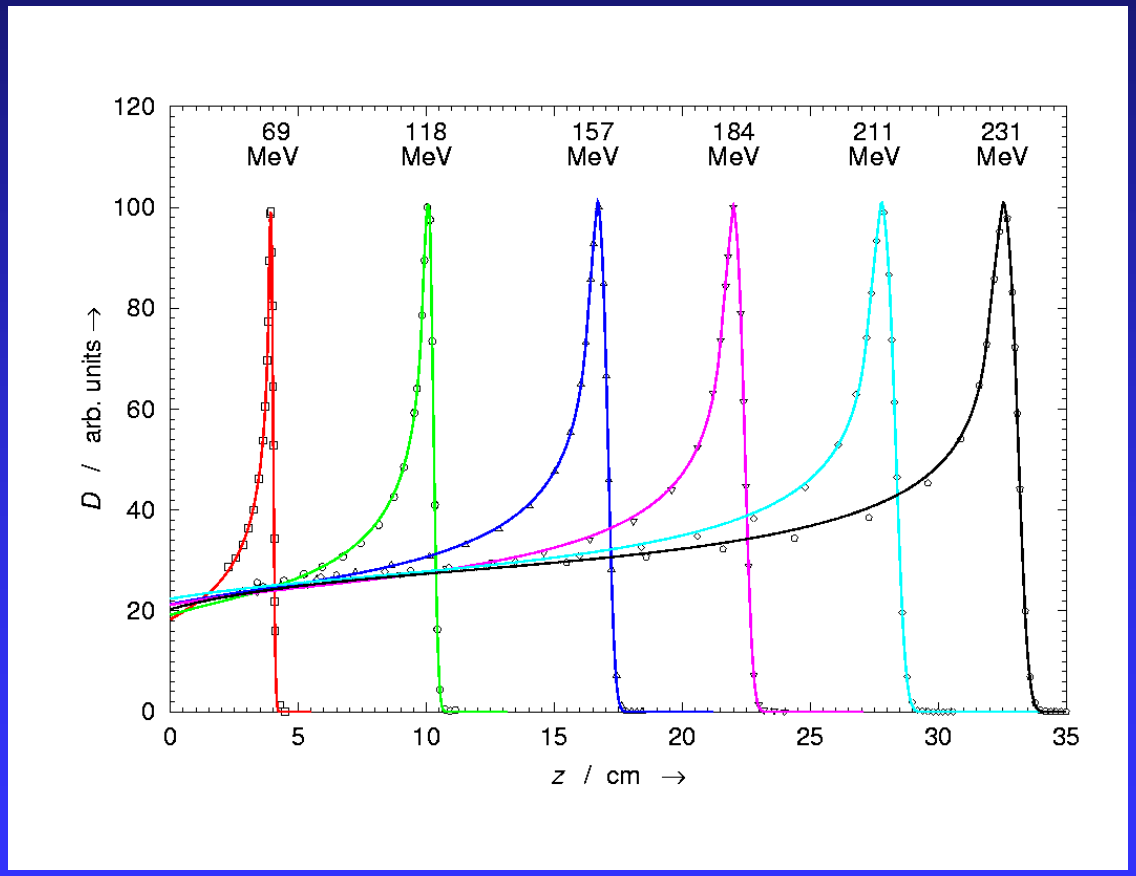


CyberKnife



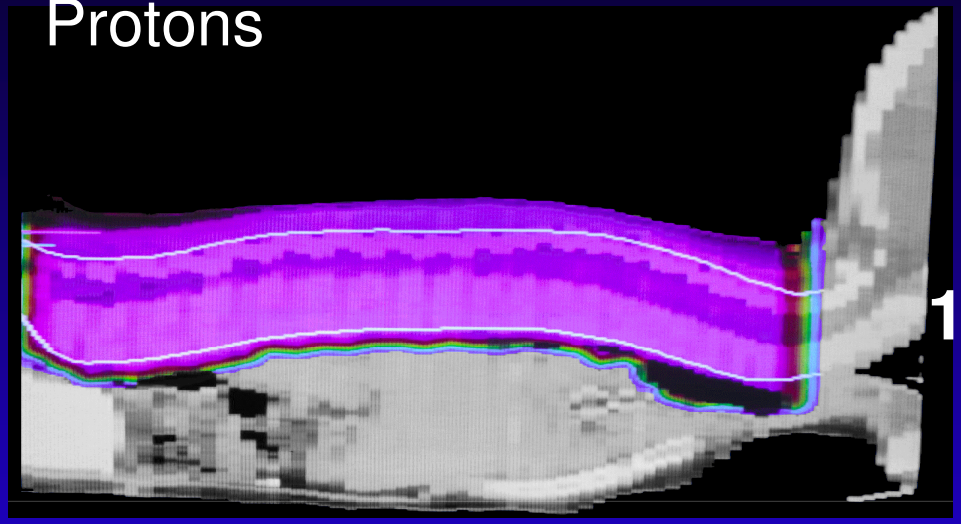
Miniature linac mounted on a robotic arm

Proton beams with variable energy: steep distal fall-off

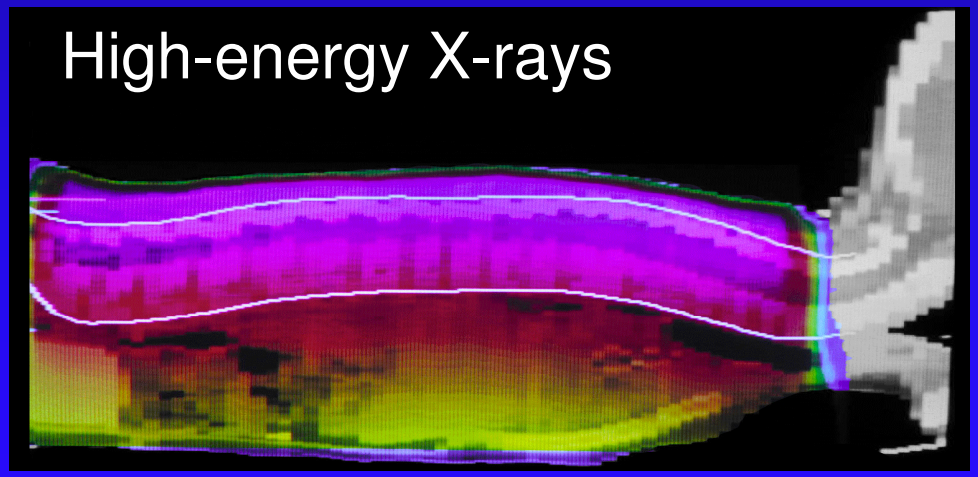


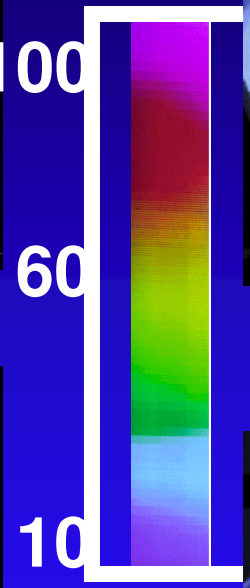
Medulloblastoma

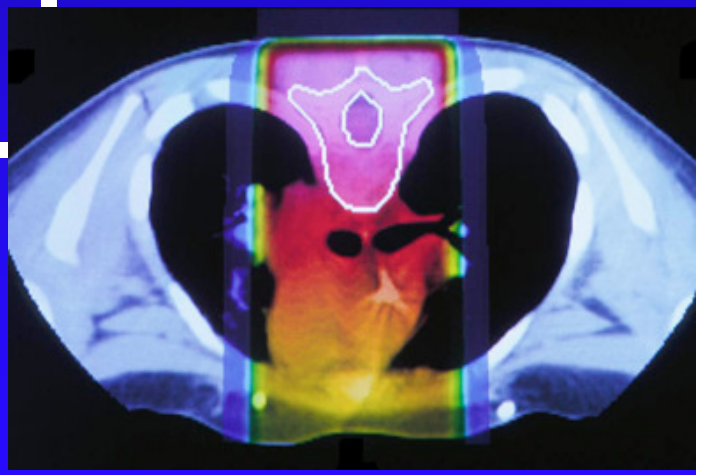
Protons



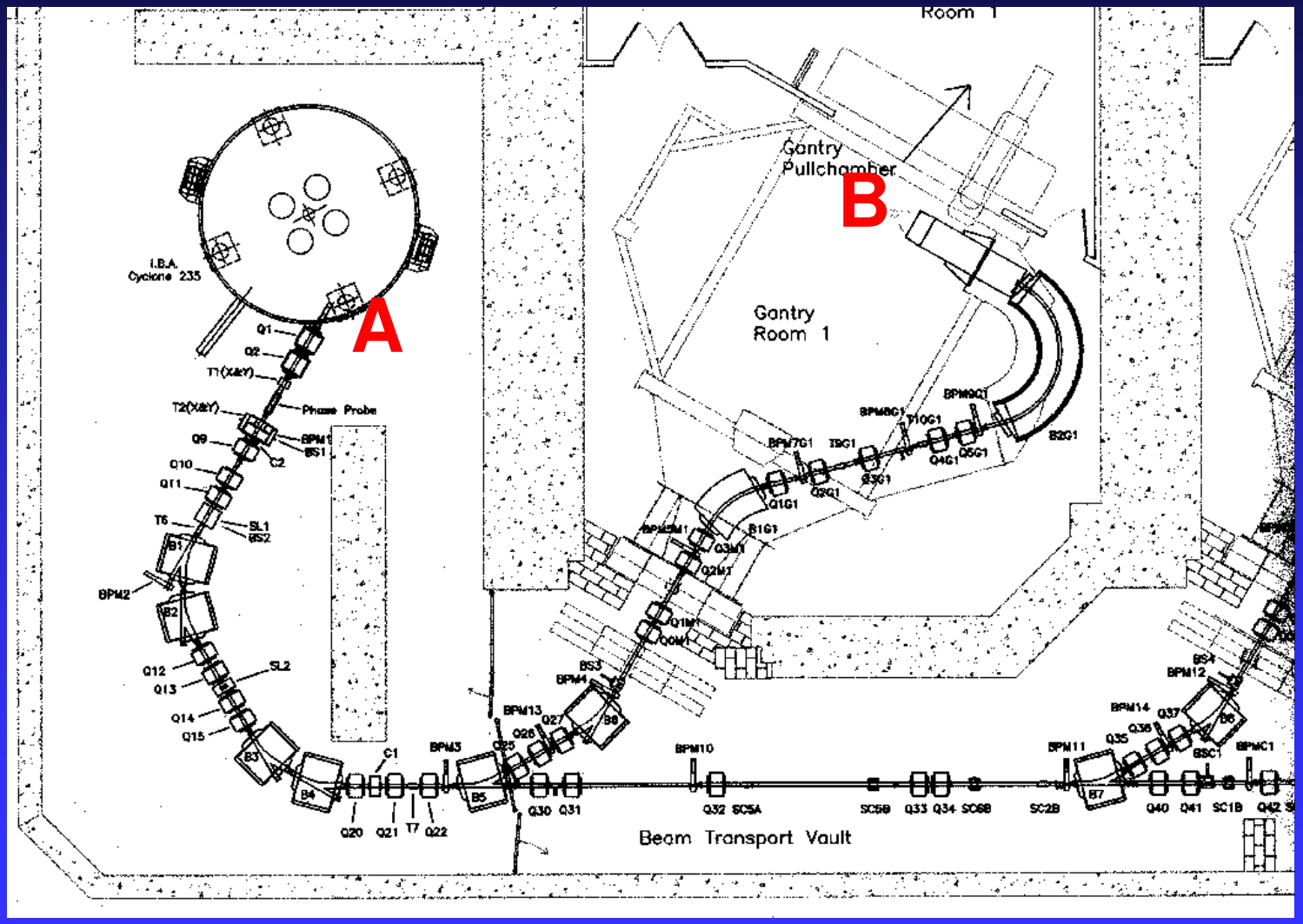
High-energy X-rays







Beamline: “Point A to B”



Massachusetts General Hospital, Boston, USA

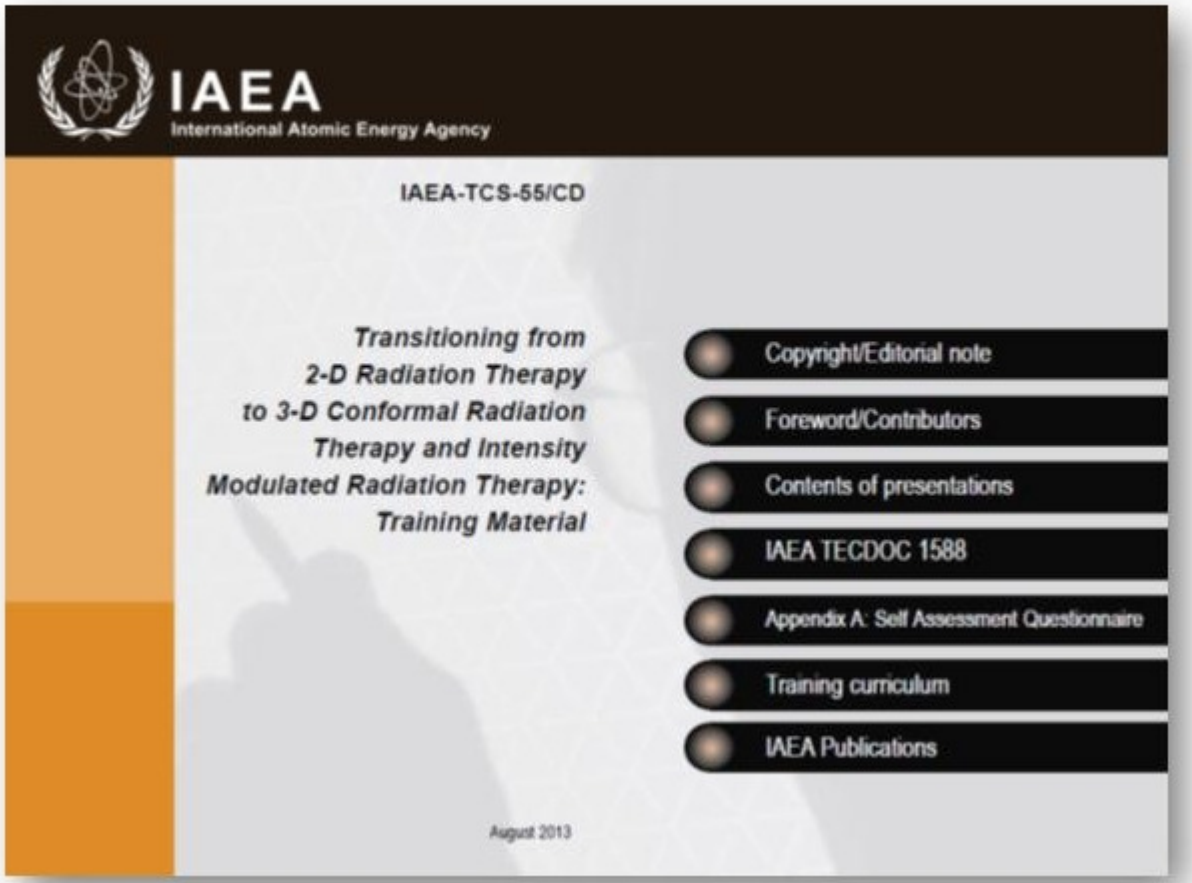
Outline

- 3-D treatment conformal radiotherapy (3-D CRT)
- Intensity-modulated radiotherapy (IMRT)
- Image-guided radiotherapy (IGRT)

To be discussed in my lecture on
"Prevention of accidents in radiotherapy"

Website Transitioning from 2D RT to 3D CRT and IMRT

http://www-pub.iaea.org/MTCD/publications/PDF/TCS-55_CD/Start.pdf



Many thanks for your attention!

Ben Mijnheer

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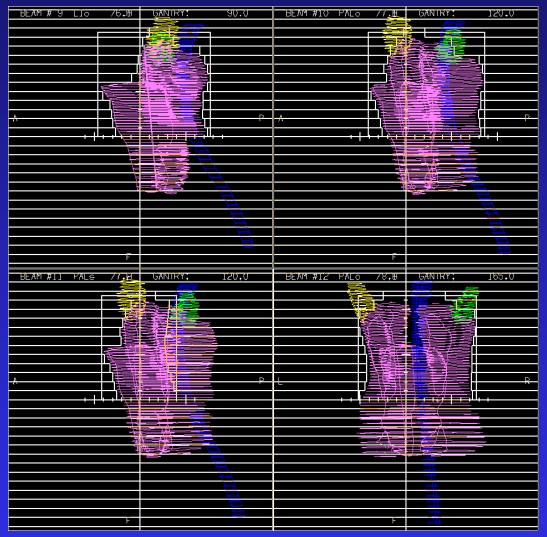

for borrowing their slides!