Intensity Modulated RadioTherapy

A clinical application of a small accelerator

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Aims

- Introduction to radiotherapy
- The place of IMRT in radiotherapy
- The place of linac design in IMRT

- Realization of IMRT
- IMRT clinical examples

Mechanism of radiotherapy

Treatment beam

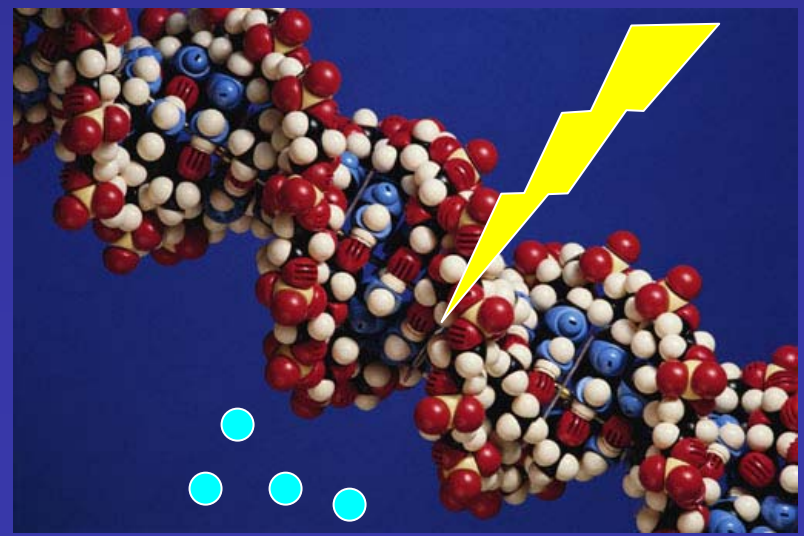
Photons

Charged particles

Ionization tracks

Damage to DNA

treatment beam



Introduction: a patient's view

Localisator

CT

Simulator

Linac: multiple fractions

Behind the screens

Localisator

CT

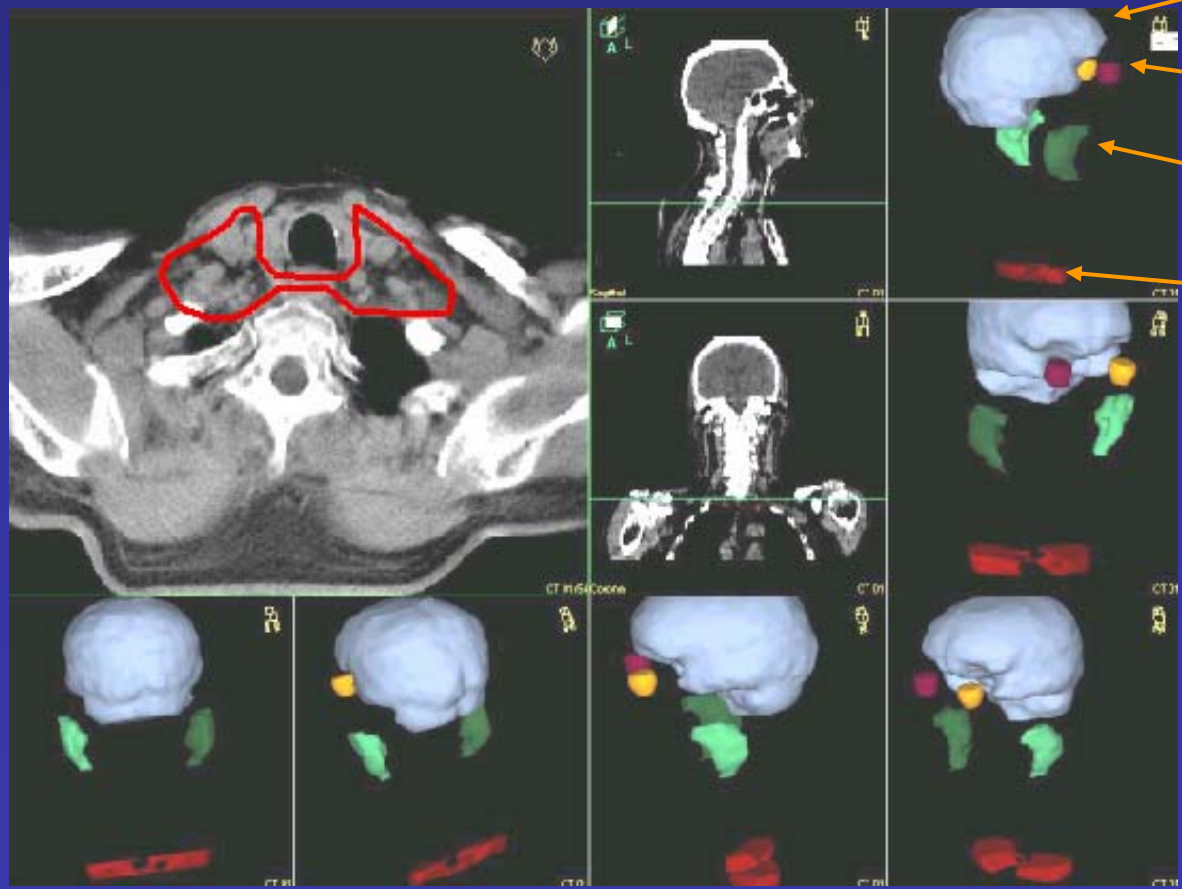
Treatment planning

Simulator

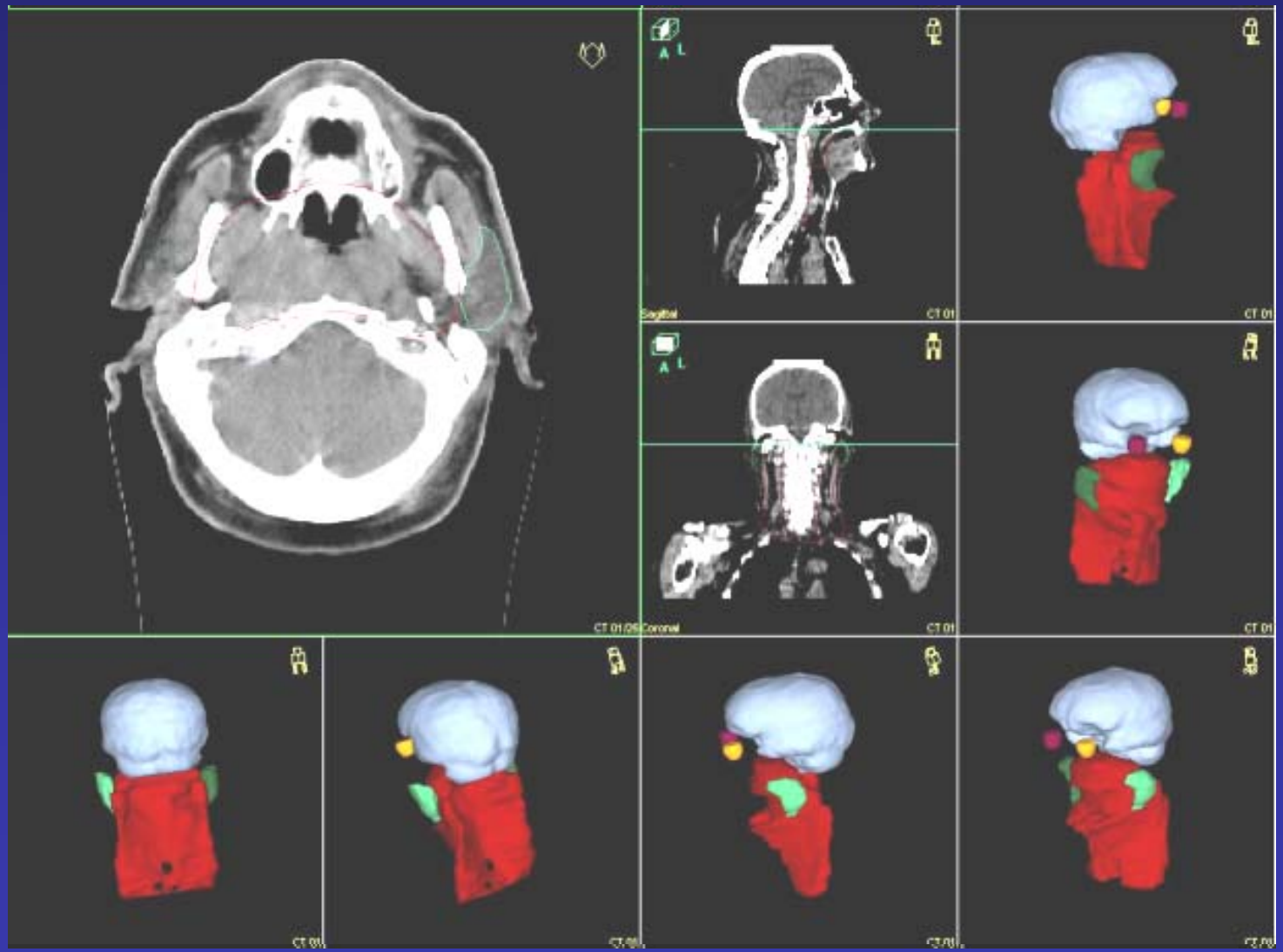
Linac: multiple fractions

Treatment planning: step 1

- Definition of targets and critical structures



Treatment planning: step 1



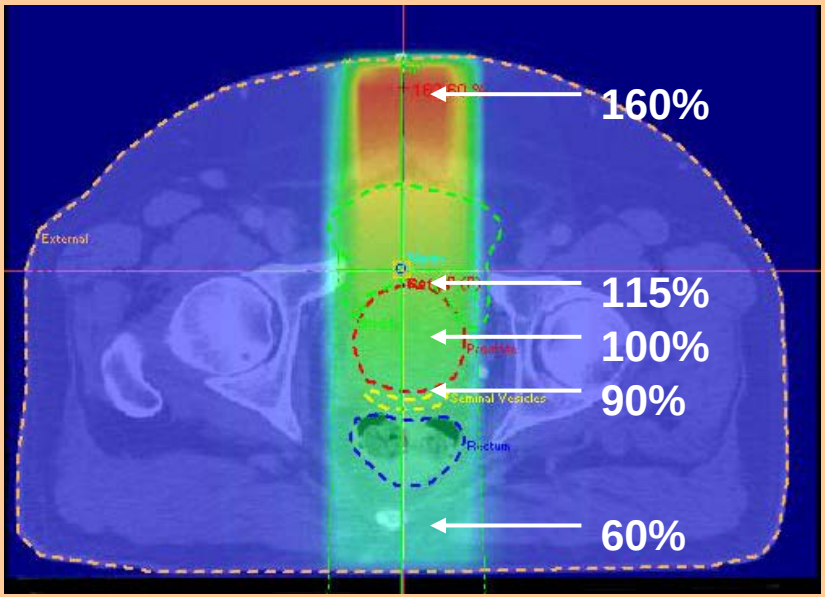
Treatment planning: step 2

- Design of treatment technique
  - Number of beams and their directions
  - Modality: photons/electrons and energy
- Design of multiple beams
  - Beam shape
- Design of treatment plan
  - Weighting of beam contribution
- Example
  - Nasopharynx + bilateral neck nodes
  - Max. 85% dose (50 Gy) to spinal cord
  - 10 beams (4 shown)

BTW: why so many beams?

By the way: why so many beams??

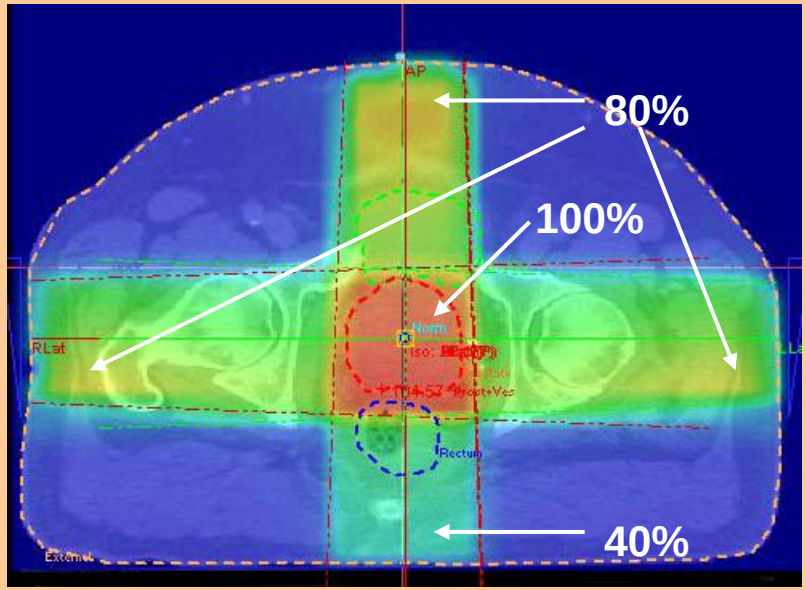
Single beam



Very high dose to normal tissue

Inhomogeneous target dose

Multiple beams

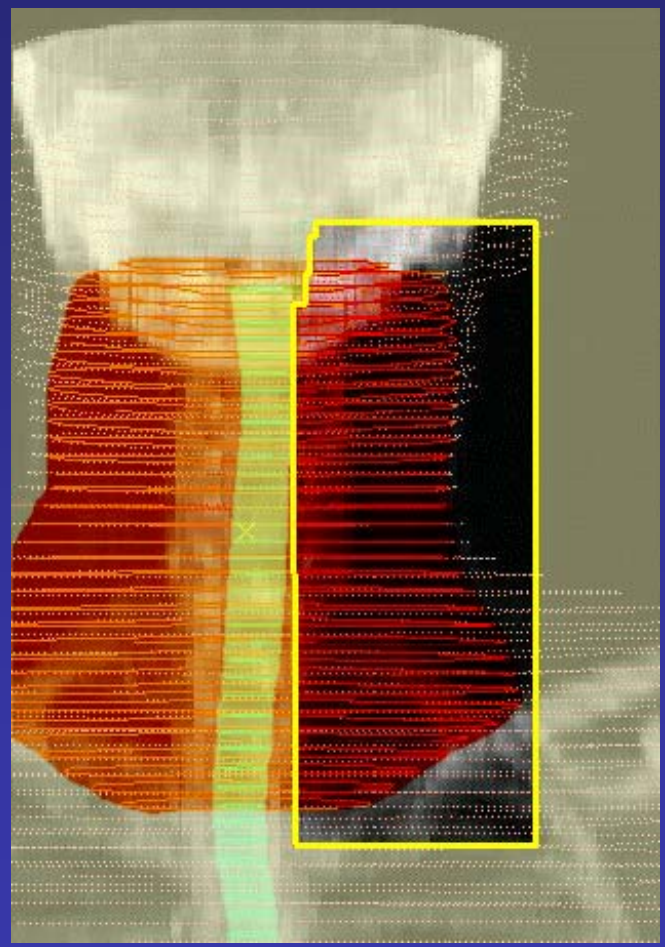


Accepted dose to normal tissue

Homogeneous target dose

Treatment beams in Beam's-Eye-View*

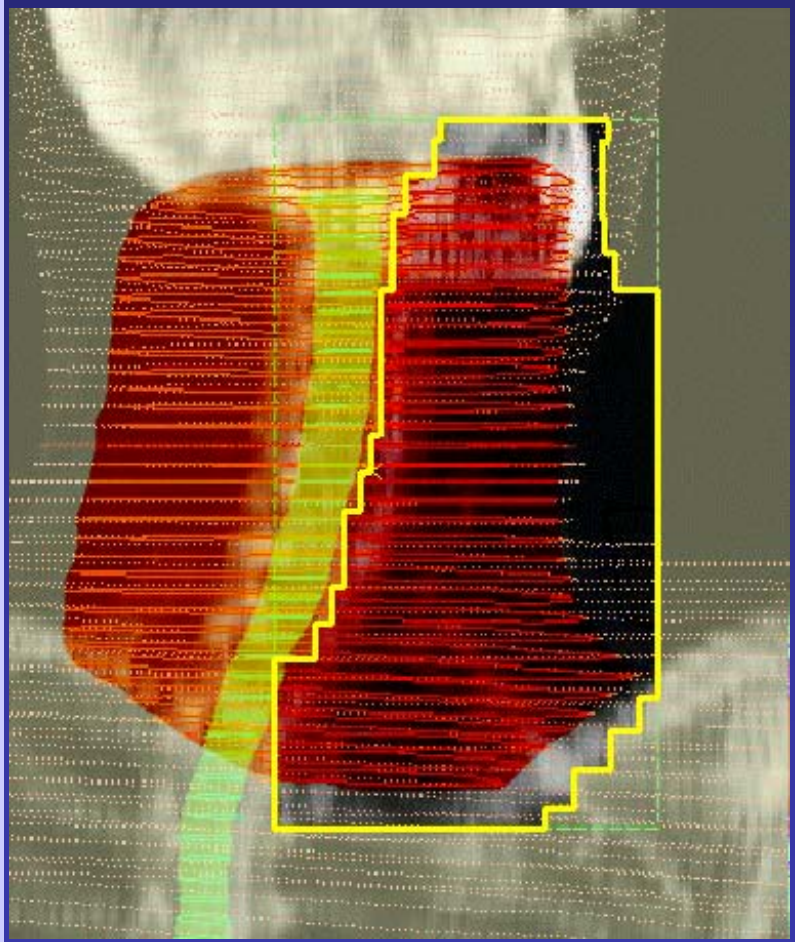
Lateral



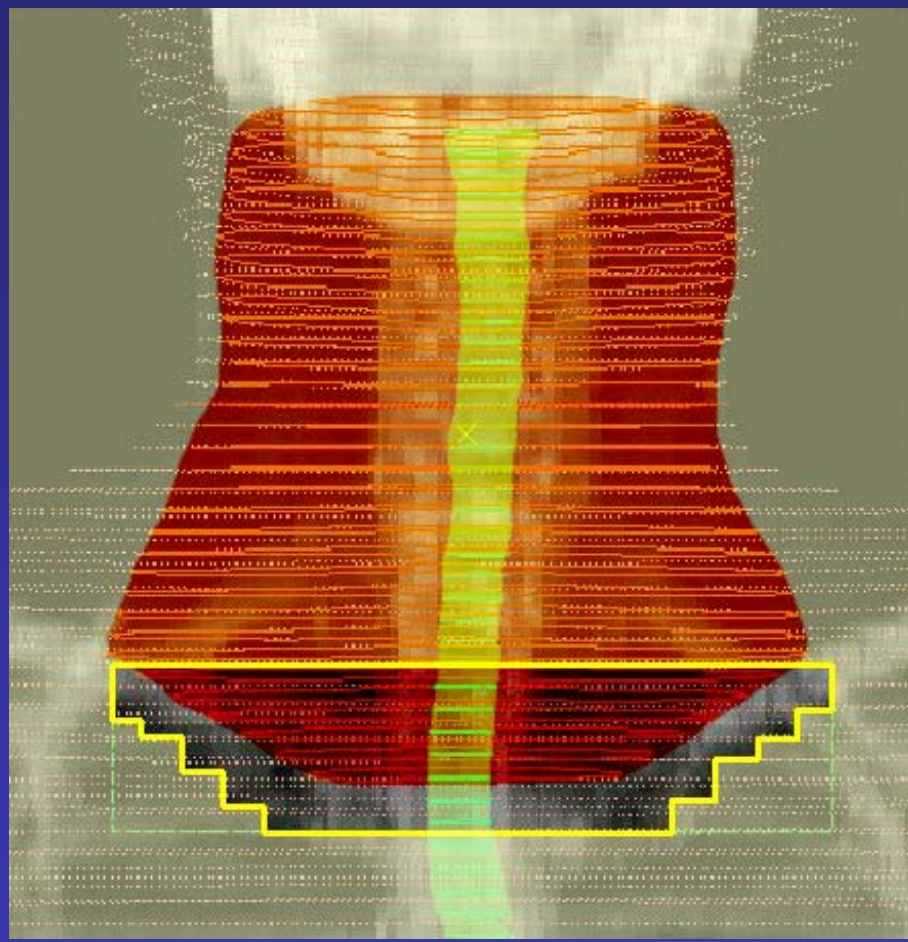
Posterior

**Projection of the patient as seen by the linac target*

Treatment beams in Beam's-Eye-View



Lateral oblique



Caudal

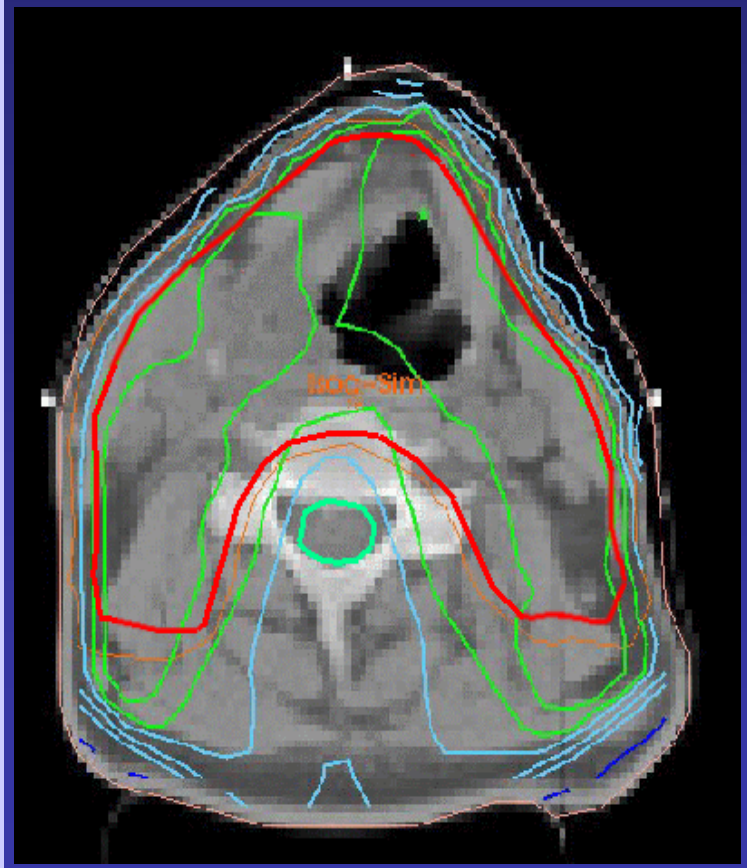
Treatment planning: step 3

- Calculate dose distribution

Treatment planning: step 4

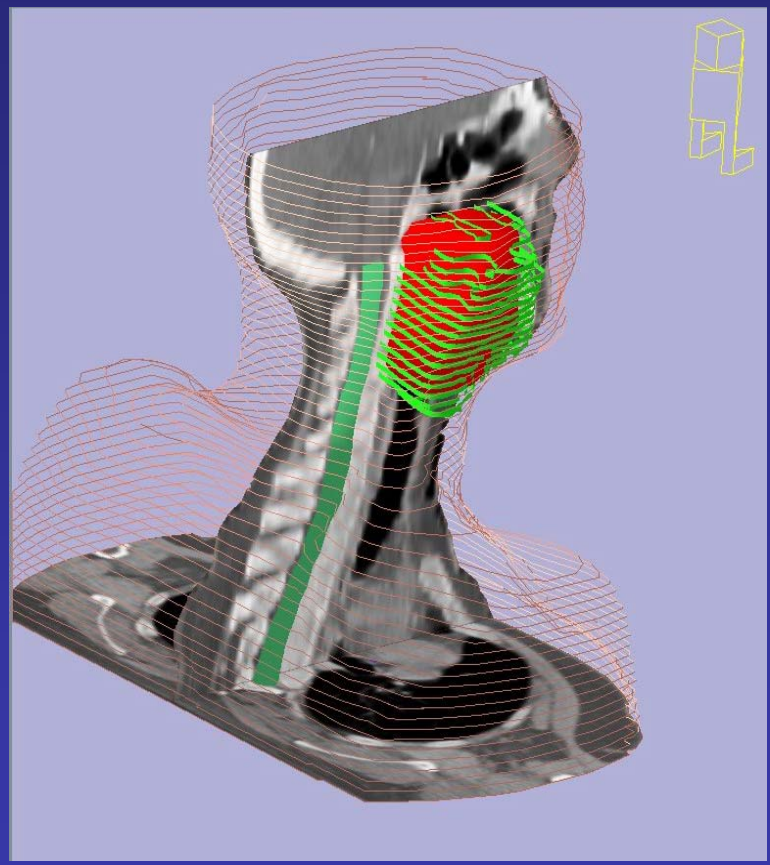
- Evaluate dose distribution
- Adapt treatment plan (step 2) until acceptable

Treatment planning: step 4



Acceptable spinal cord dose

50% 70% 80% 90% 95% 100%

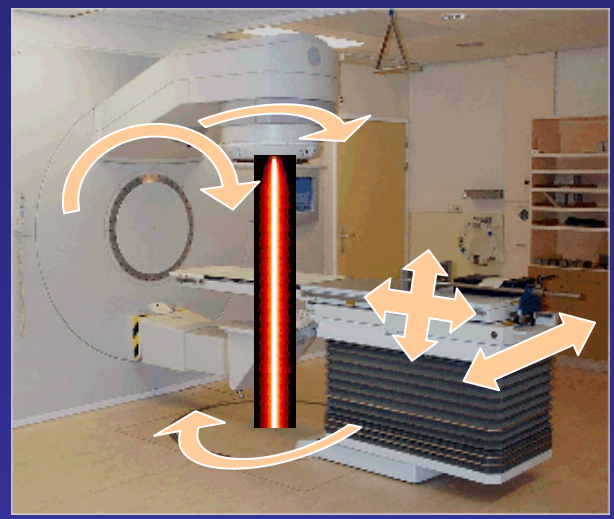


Conformality to target

95%

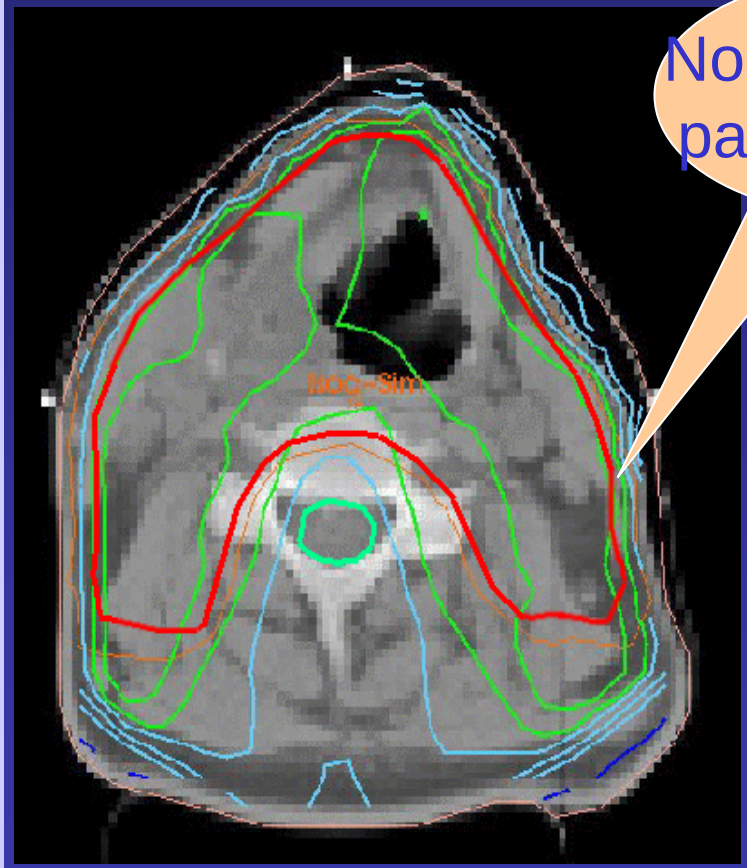
Treatment plan = linac recipe

- Photon or electron beams
- 6 degrees of freedom ...
- … all around the isocentre

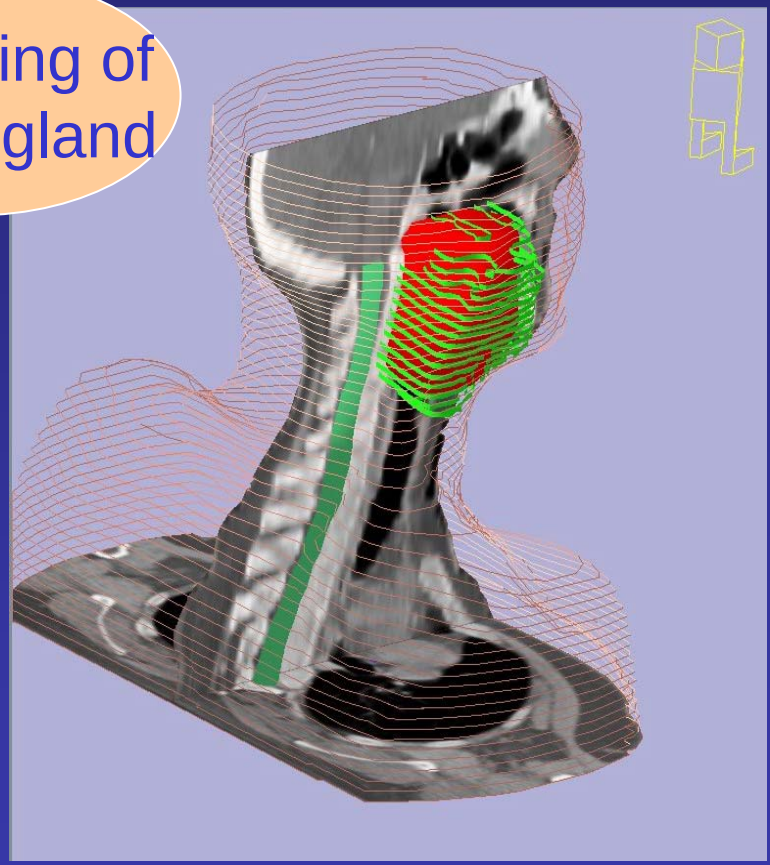


treatment beam

Treatment planning: a step further needed



No sparing of parotid gland



Acceptable spinal cord dose

50% 70% 80% 90% 95% 100%

Conformality to target

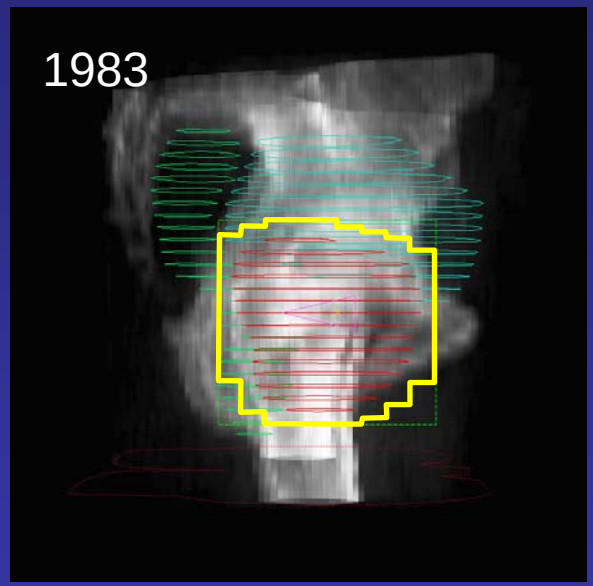
95%

Radiotherapy develops towards ...

- Progress in radiotherapy depends on three areas in conjunction:
  - Medical knowledge — *Medicine*
  - Dose calculation — *Physics*
  - Technical facilities — *Engineering*

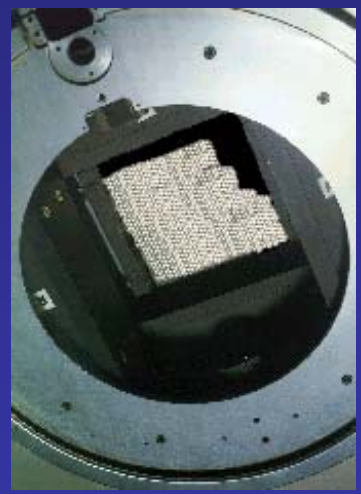
Radiotherapy develops towards ...

- … more conformal treatment

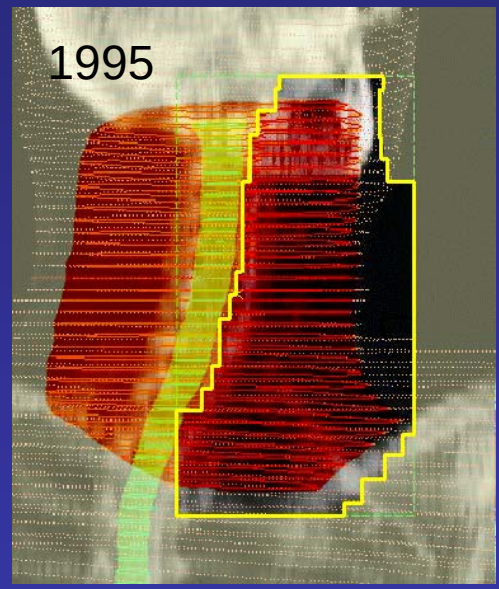


Beam's-Eye-View with simple dose calculation

Beams must conform to target



MLC: Multi-Leaf Collimator allows more and better shaped beams

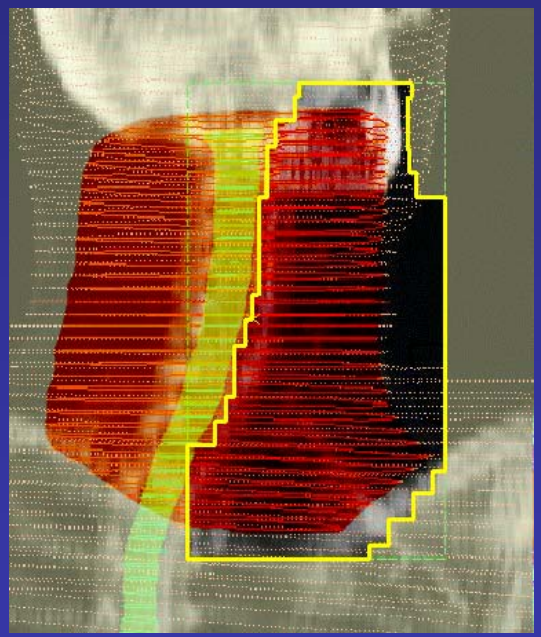


Dose calculation with physics of linac model

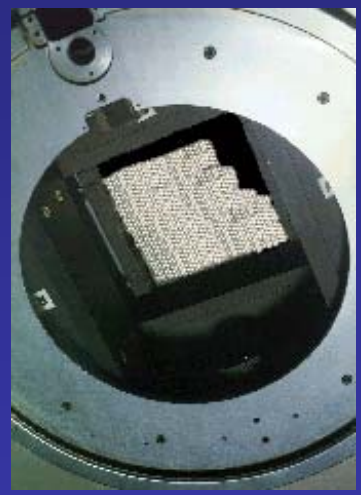
High dose must conform to target

Radiotherapy develops towards ...

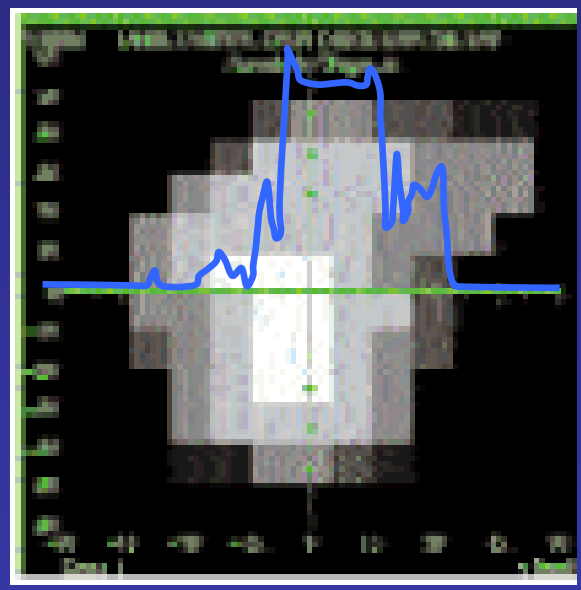
- … IMRT



Homogeneous fluence/beam

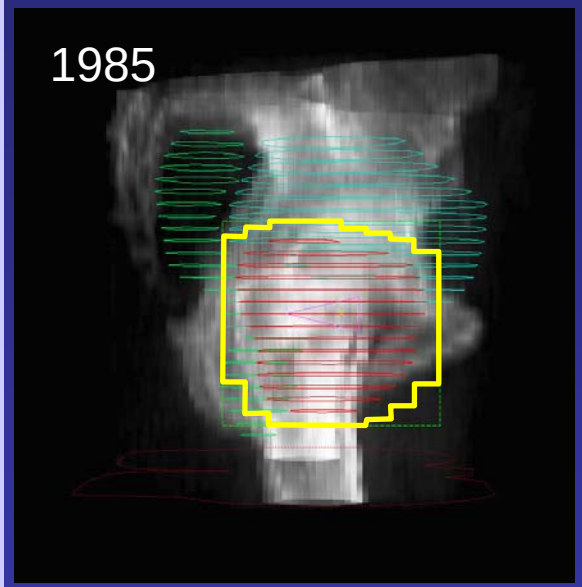


Multi-Leaf Collimator allows modulation of a beam



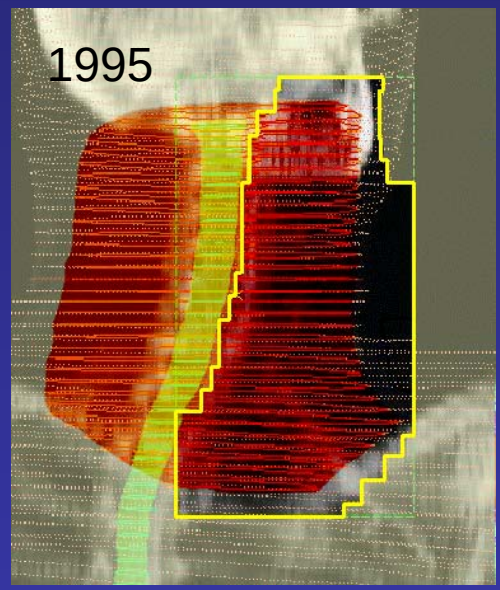
Intensity modulated radiotherapy (IMRT)

Radiotherapy develops towards IMRT



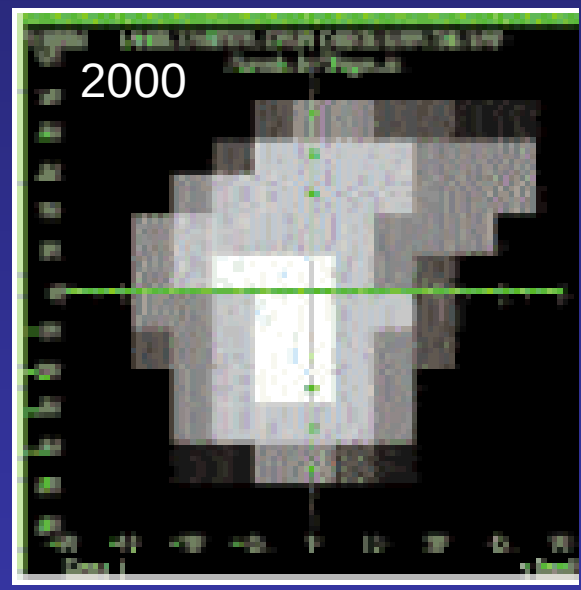
Beam's-Eye-View with simple dose calculation

Beams must conform to target



Dose calculation with physics of linac model

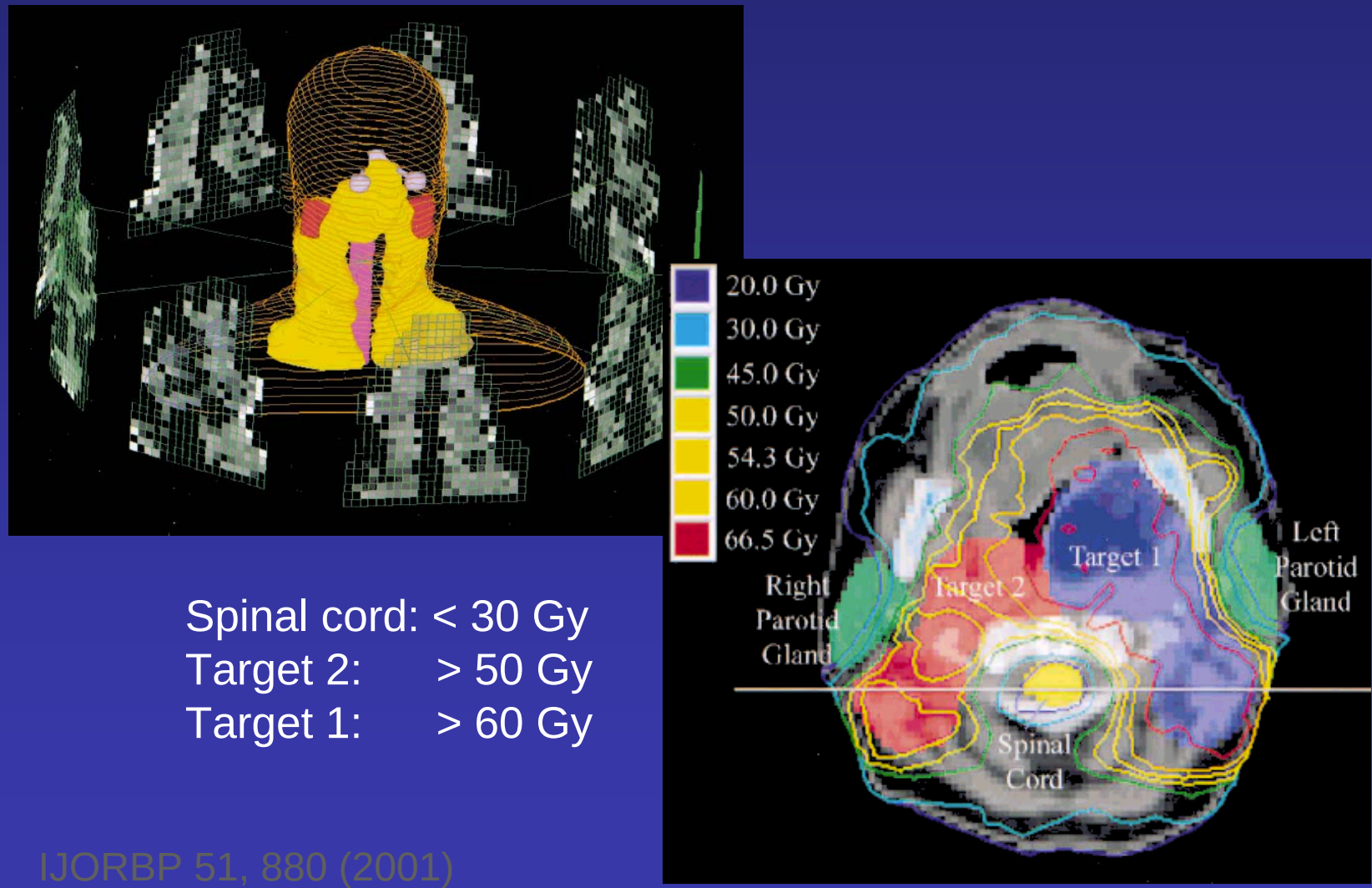
High dose must conform to target



Math. optimization & linac construction

Dose distribution must conform to constraints

The place of IMRT in radiotherapy

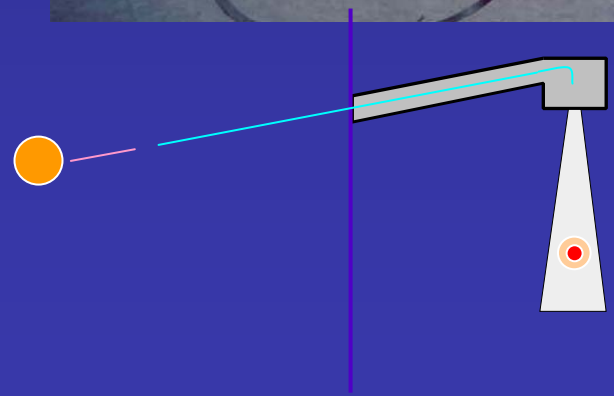


Spinal cord: < 30 Gy
Target 2: > 50 Gy
Target 1: > 60 Gy

IJORBP 51, 880 (2001)

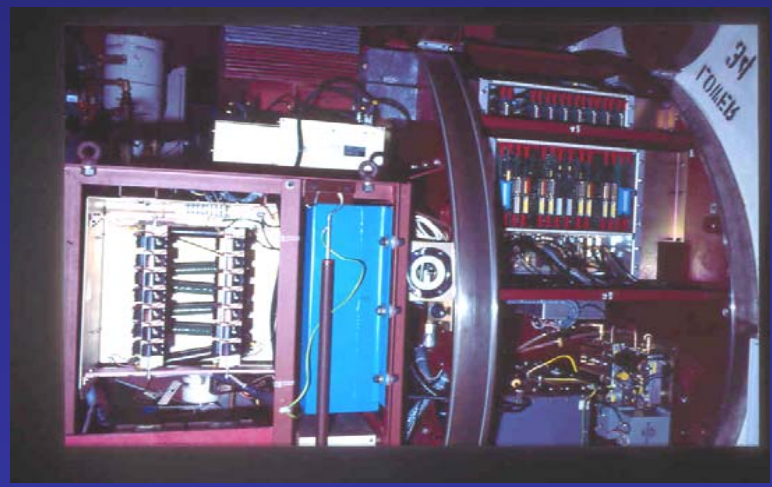
The place of linac design in IMRT

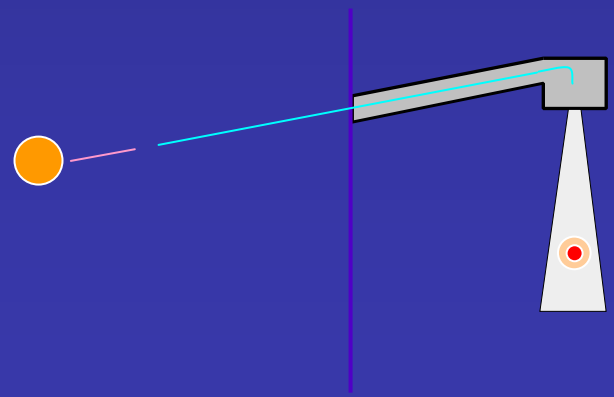
- Linear accelerator



Linac construction

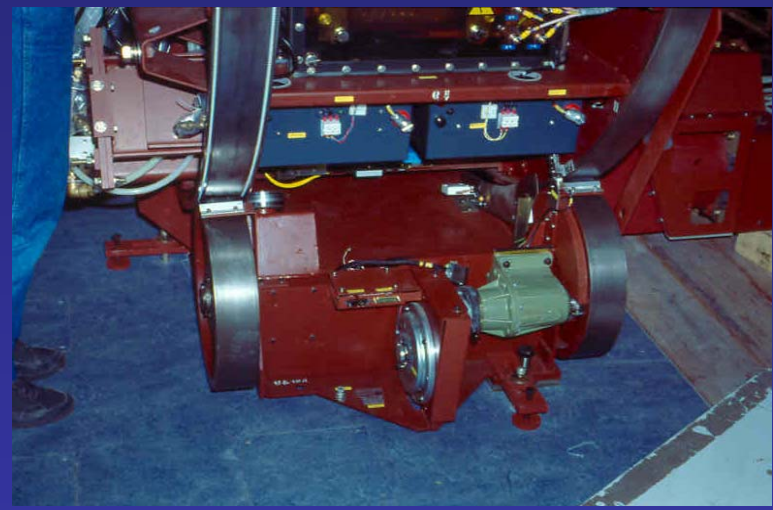
- Linear accelerator
  - Vacuum technology
  - High-voltage circuits
  - RF wave guide
  - (Fine) mechanics
  - Electronic control circuits

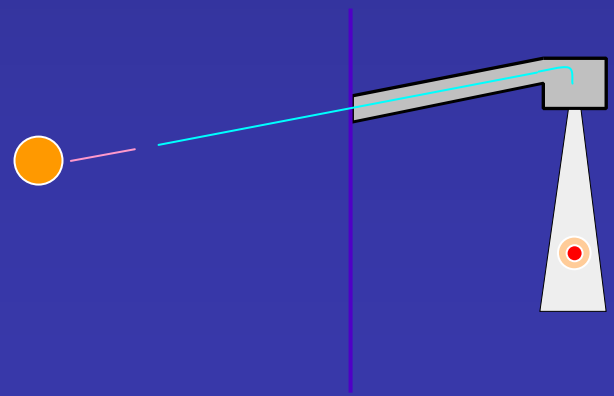




Linac construction

- Linear accelerator
  - Vacuum technology
  - High-voltage circuits
  - EM wave guide
  - (Fine) mechanics
  - Electronic control circuits
  - Rotatable over 360°
- In-house maintenance & support
  - 5 engineers
  - automatic checks (servo)
  - weekly & monthly checks



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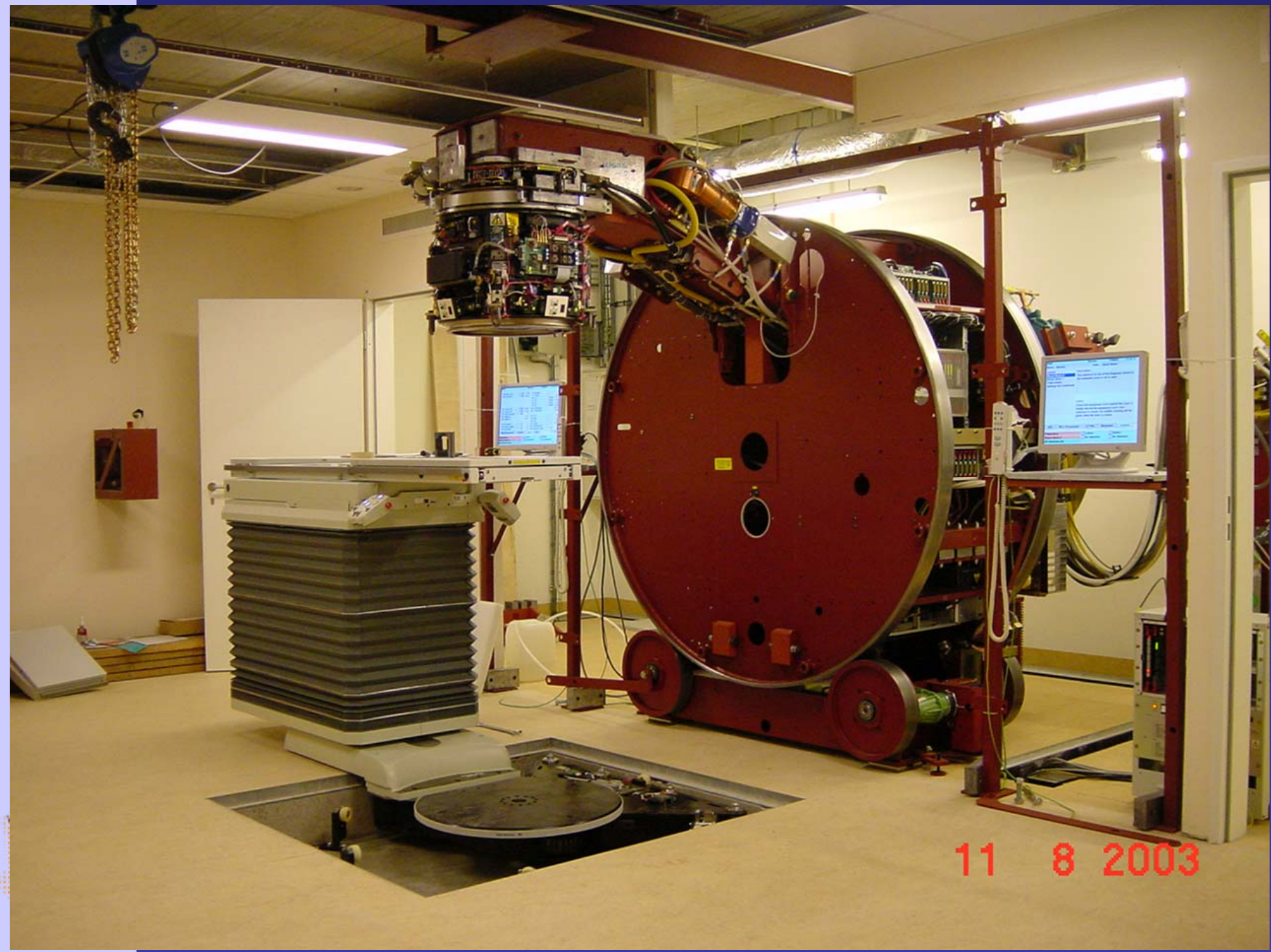
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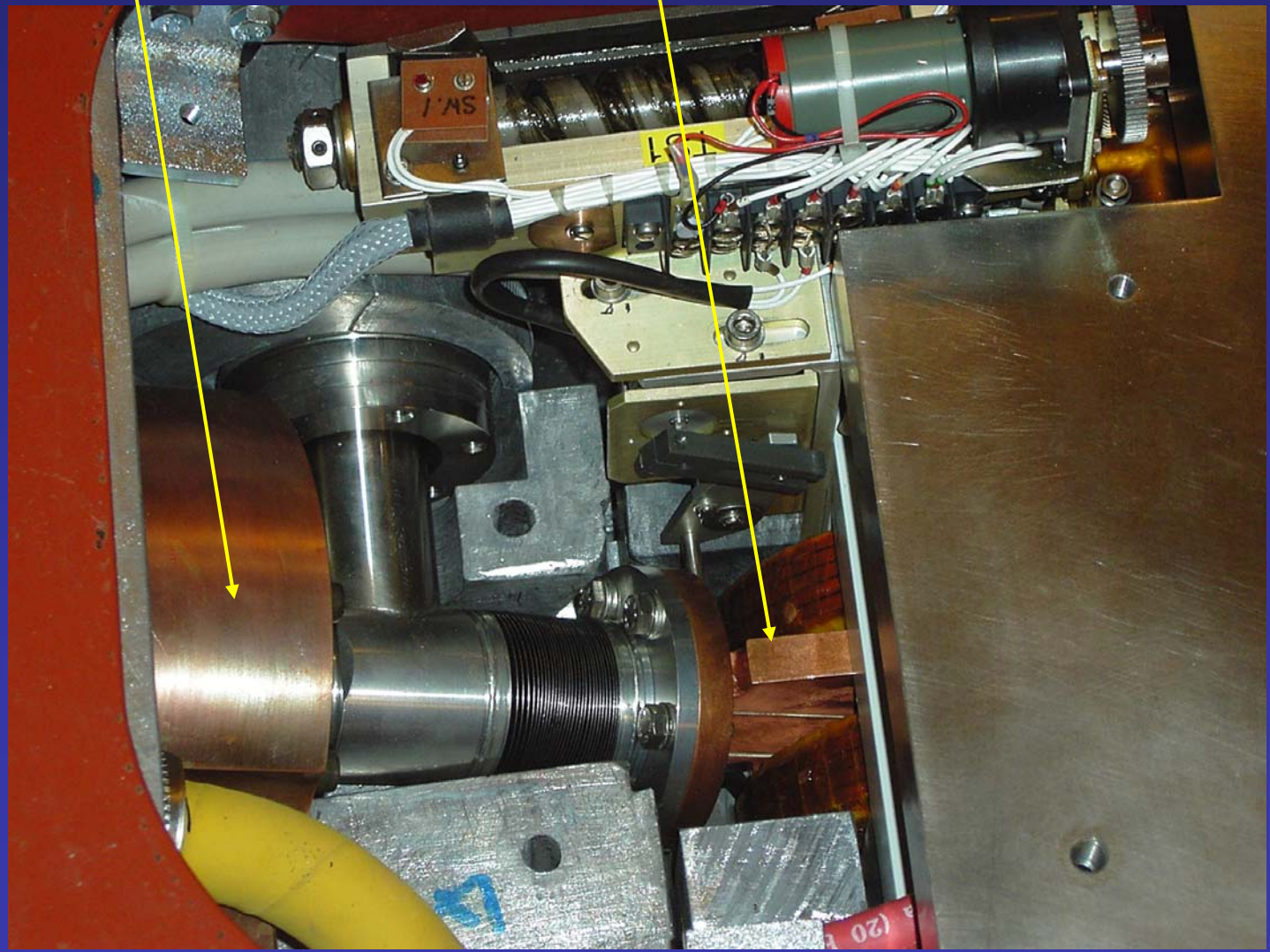
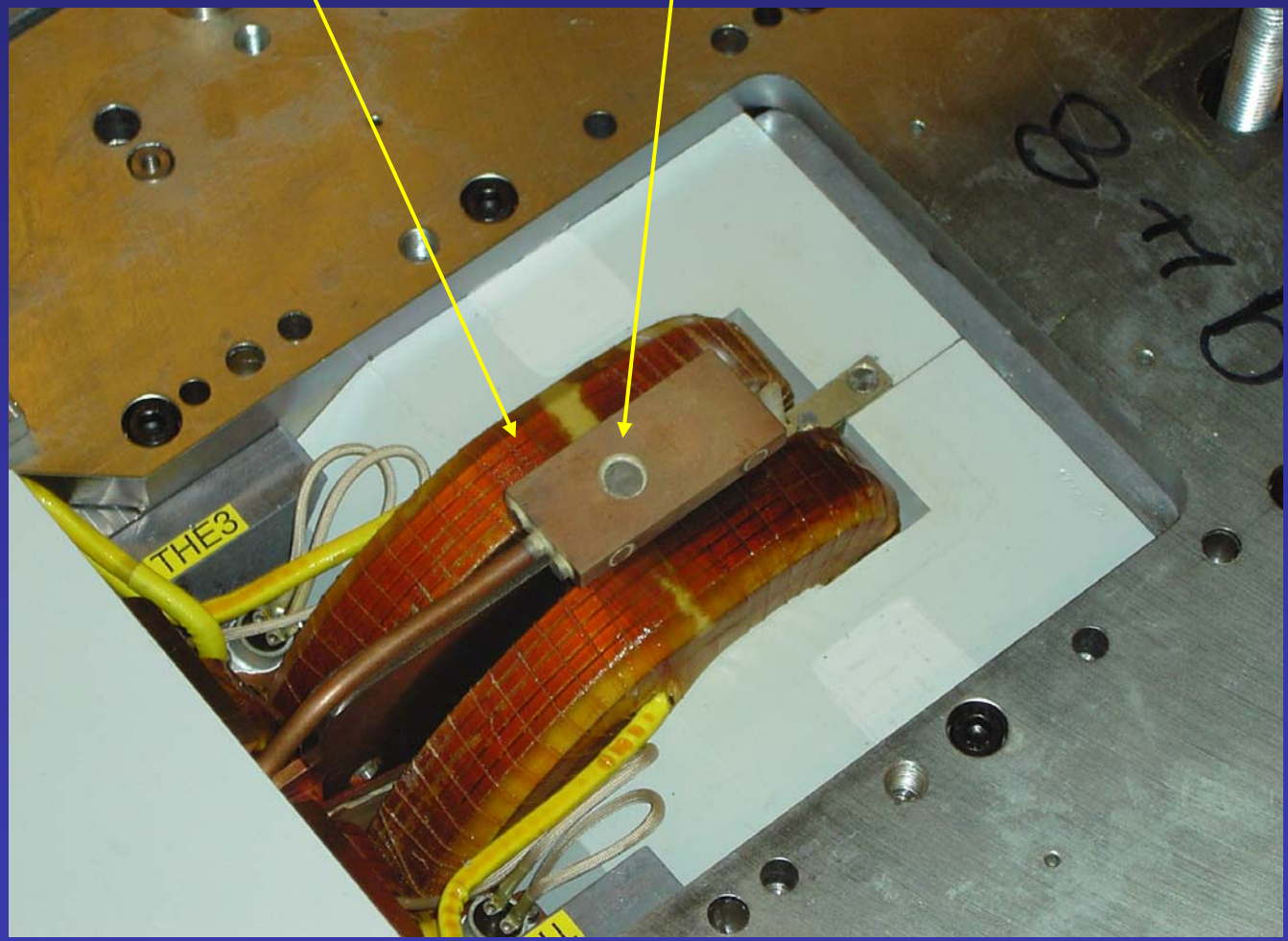
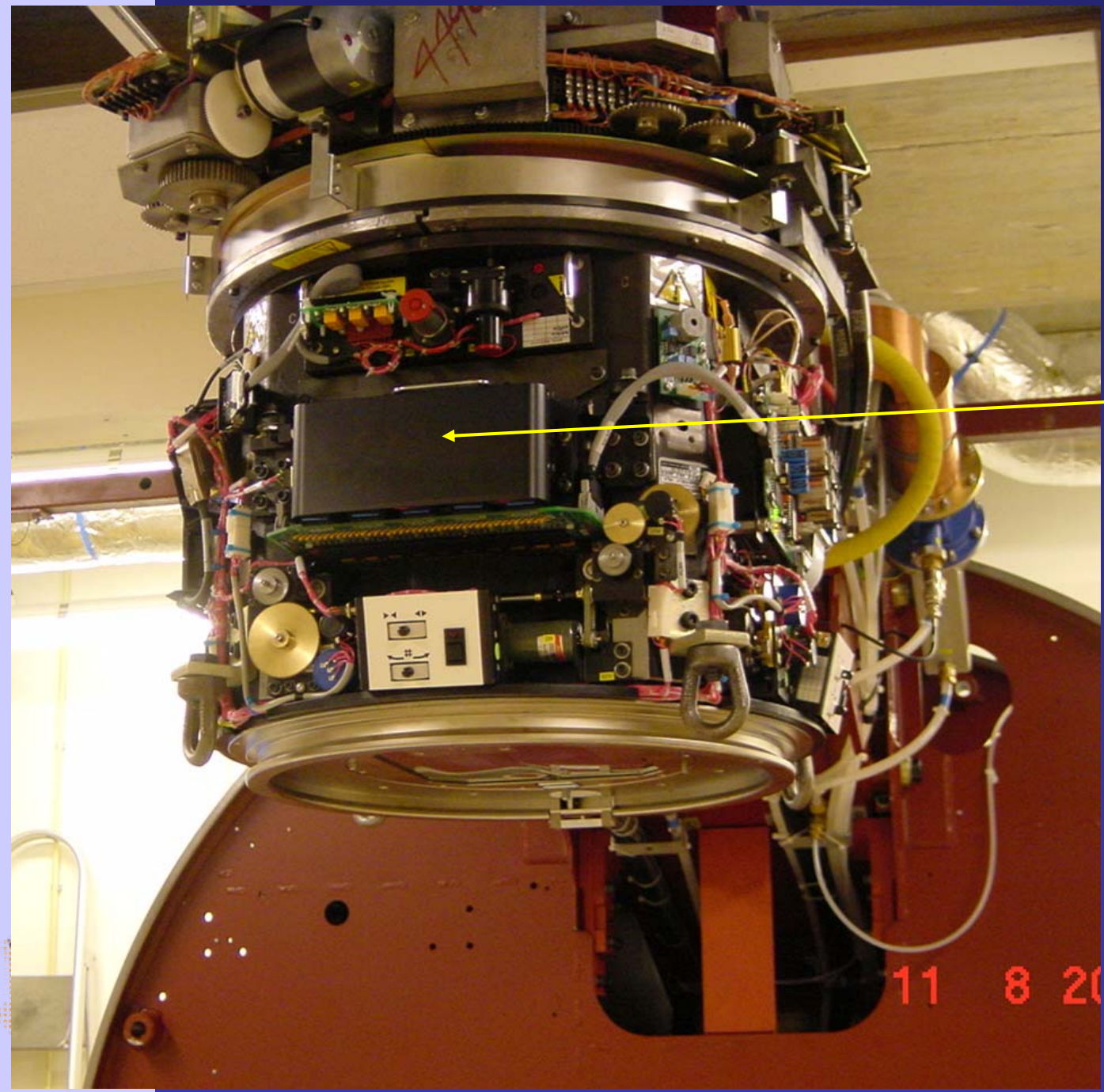
Wave guide and flight tube



Bending magnet, electron window

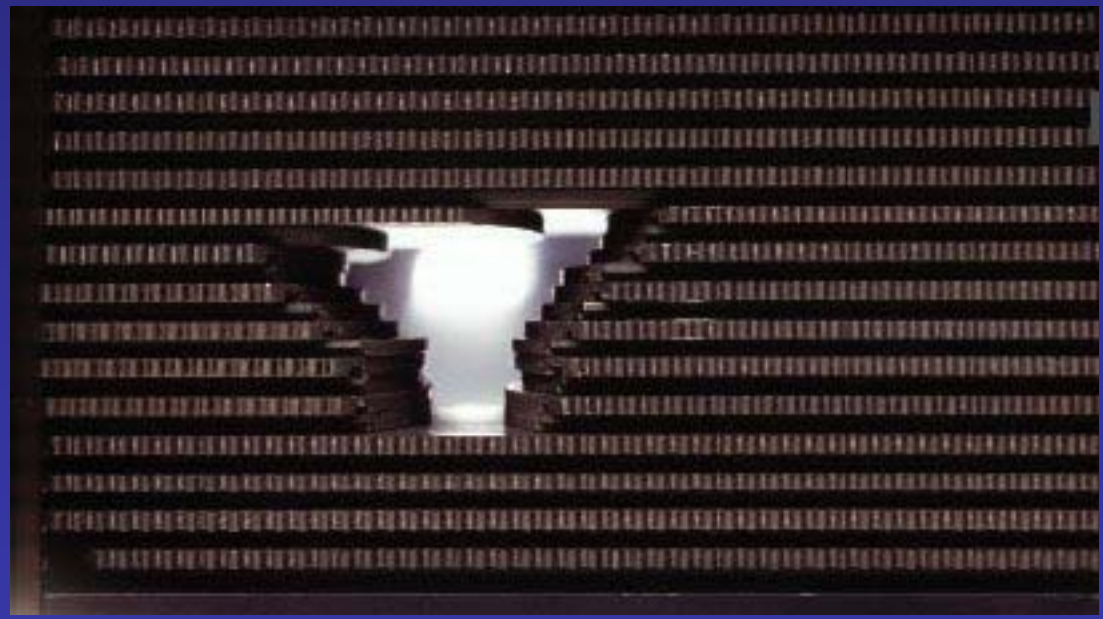


Filter carrousel and monitor ion chamber

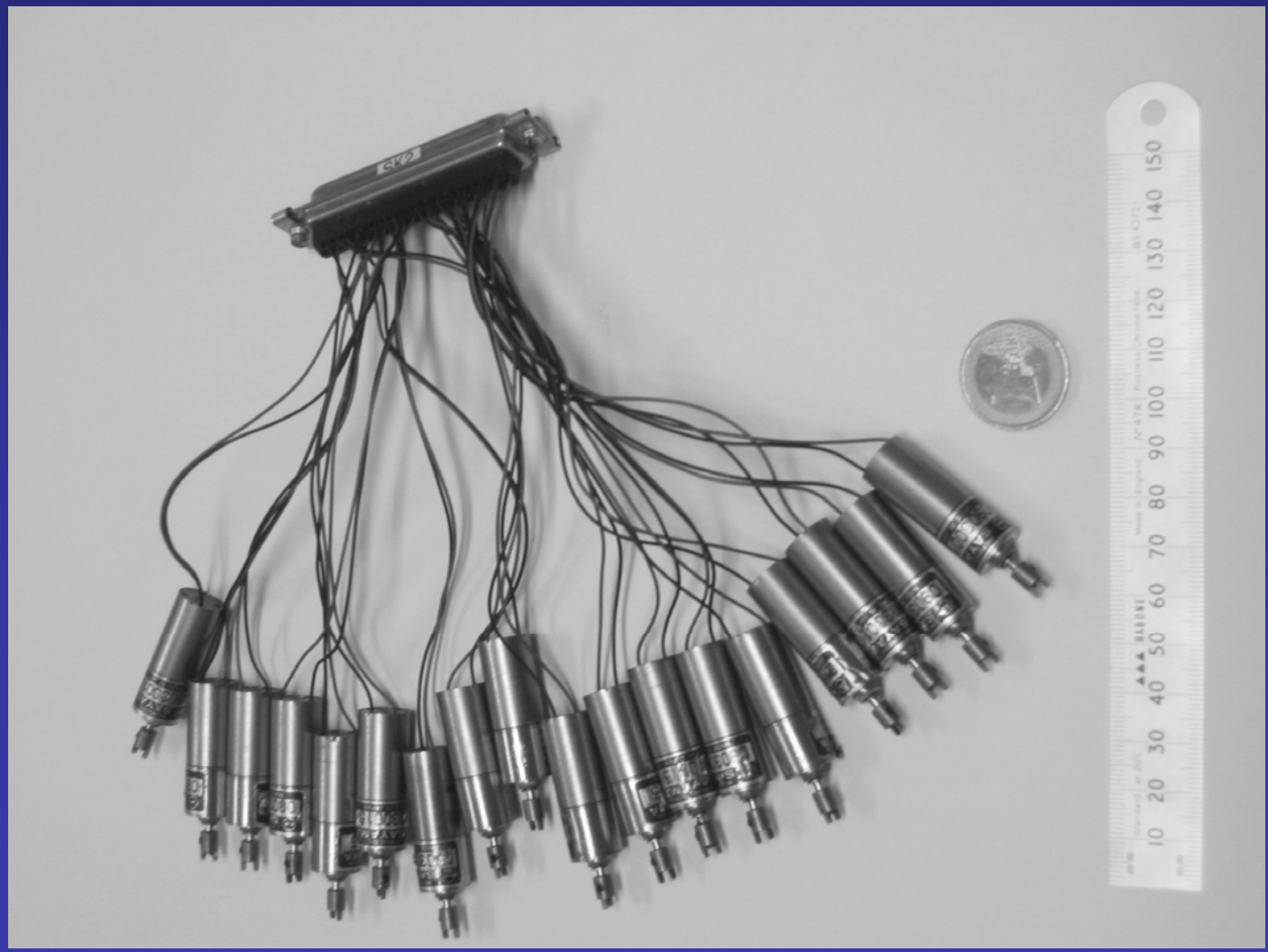


Housing of 40 leafs of MLC with motors

Multi-Leaf Collimator (Elekta BM)



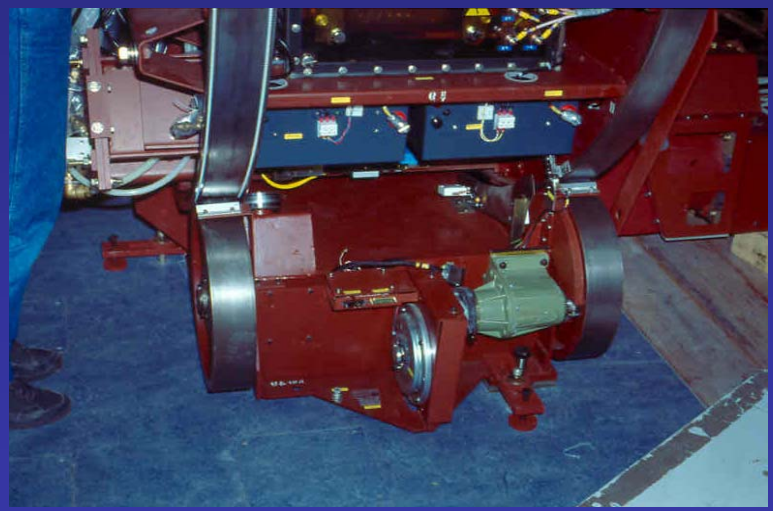
MLC motors



The place of linac design in IMRT

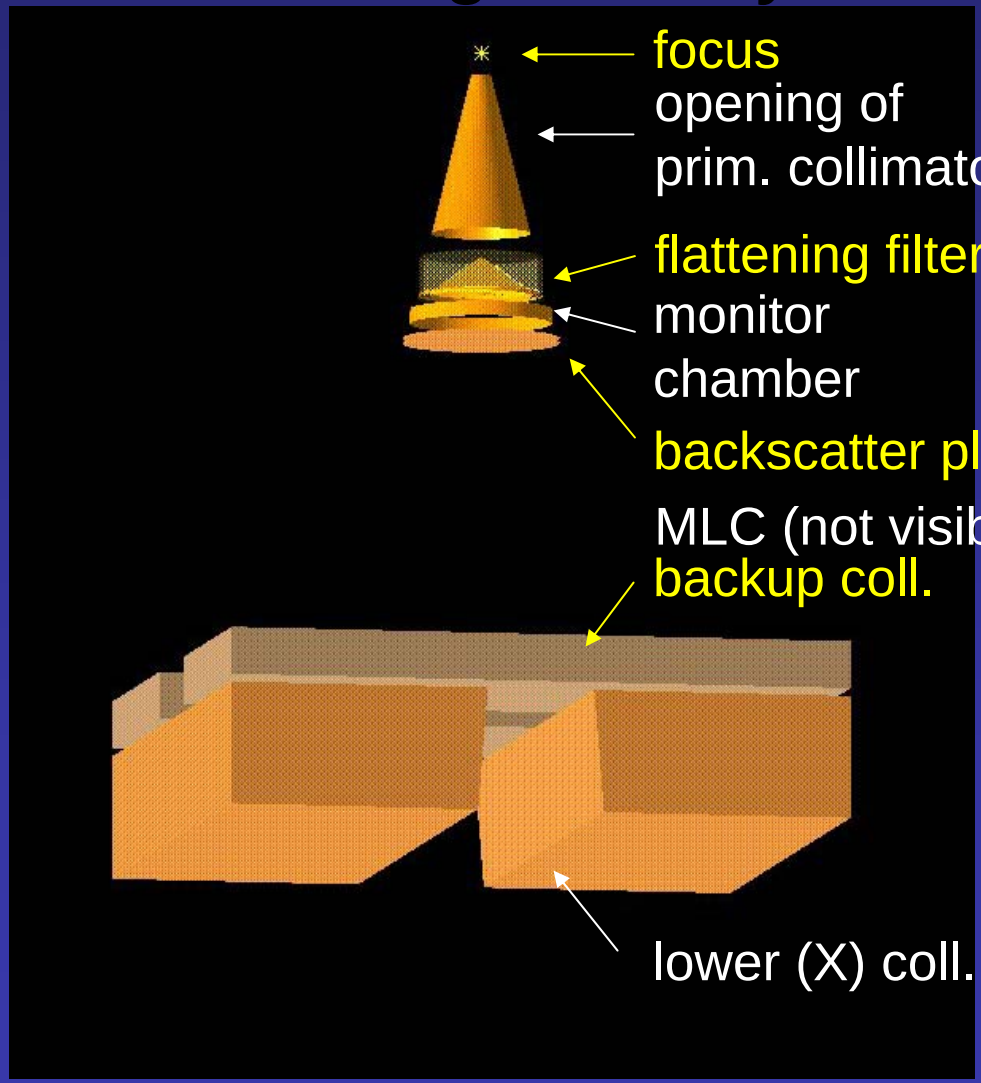
- Better isocentric stability: 1 mm
- Fast beam startup: coil sets magnetron plunger
- Beam starting stability: slitless without servos
- Multi-leafs: fast change beam shape
- Multi-leaf specification: leakage, travel range, speed
- Leaf calibration: field junction dose
- Geometry and materials: must be well-known for dose calculation in treatment planning system

Improved mechanics and gantry motors



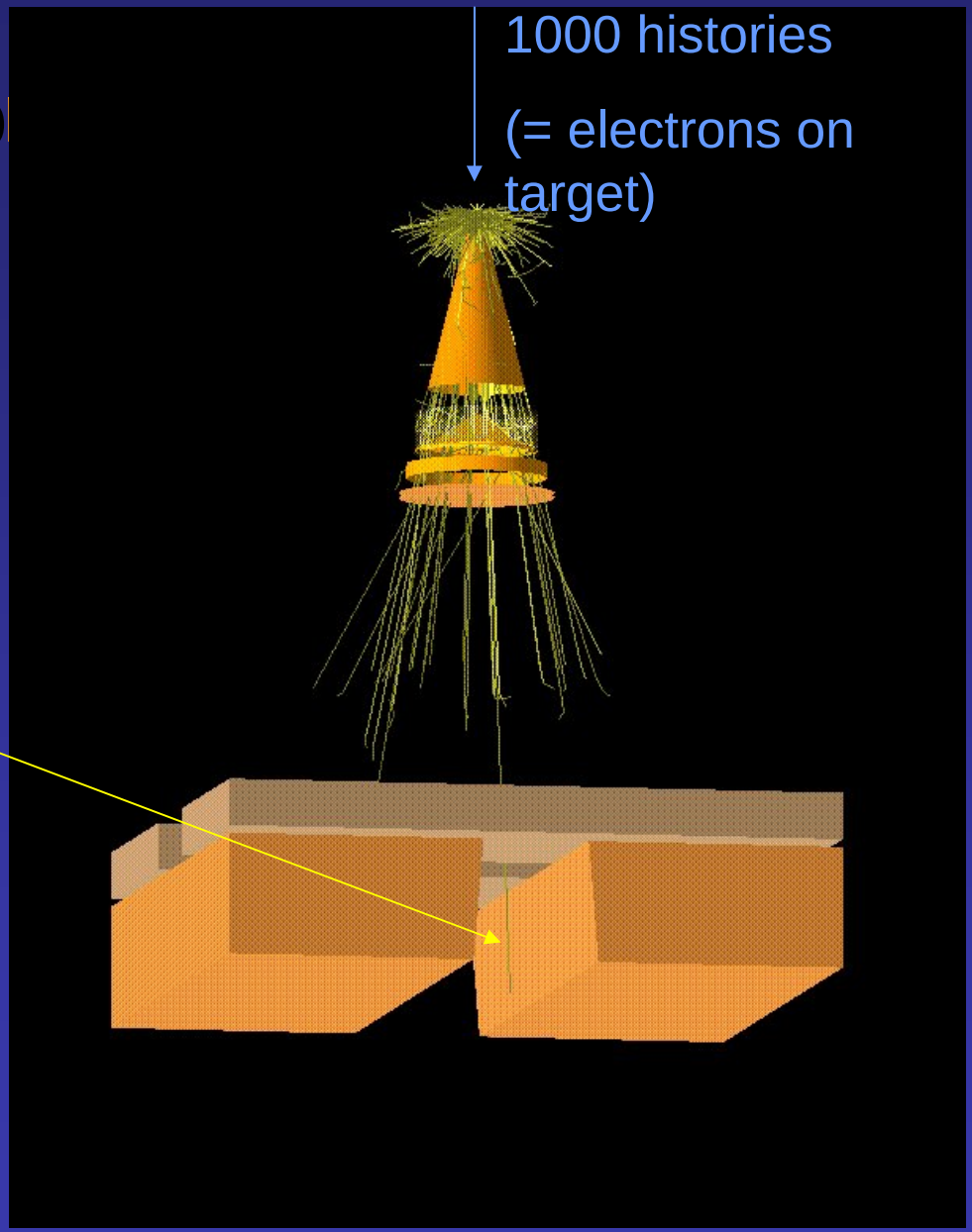
Dose calculation and linac geometry

- Construction of Elekta Sli linac model for calculation of a 6 MV-X 3x3cm^2 photon beam
  - BEAM Monte Carlo model



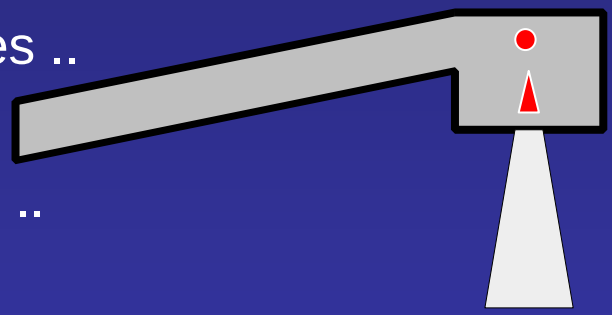
Dose calculatio

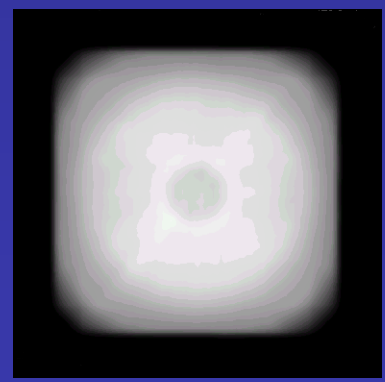
- Construction of Elekta Sli linac model
- Photon exiting linac head
- Characteristics of exiting photons is determined by linac geometry



Dose calculation and linac geometry

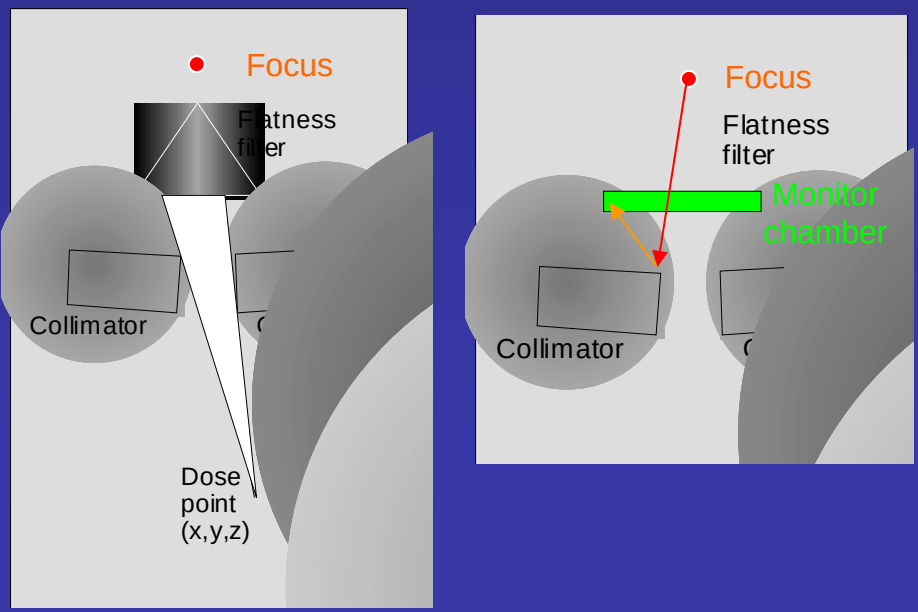
- Linac model in treatment planning system should yield:
  - 2D energy fluence distribution ..
  - .. i.e. the number of particles ..
  - .. times their energy ..
  - .. for all relevant linac parts ..
  - .. at actual field shape ..





Dose calculation and linac geometry

- Treatment planning system should distinguish
  - Head scatter contribution from linac head components
  - Based on dose-point's-eye-view backprojection
  - MU calculation including backscatter into monitor chamber



Two other possibilities for IMRT

- Tomotherapy: CT-scan and linac in one
- CyberKnife: linac on a robotic arm

Tomotherapy at John Hopkins

CyberKnife

Conclusions first part

- IMRT offers new possibilities to better spare critical organs and/or enhance tumor dose
- The design of the linear accelerator plays a critical role in:
  - facilitating new treatment techniques
  - treatment accuracy
  - dose calculation
- Maintenance and quality control of RT apparatus such as a linac is of eminent importance