The relationship between imaging and RT

How imaging has changed radiotherapy linac design

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Chief Engineer

Elekta

Outline of talk

- Precision and radiotherapy
- Benefits of radiobiology
- Targeting and conformality
- Seeing the target
- Seeing the target at treatment time
- Seeing moving target
- Future challenges

The relationship to radiotherapy and Precision

- Radiotherapy did not begin as a precision treatment
  - Early radiotherapy was targeted at superficial tumours or exploited the benefit that tumours were more susceptible to radiation than healthy tissue.
  - This was much improved by discovering the benefits of fractionation
  - For many years radiotherapy relied on limited imaging and radiotherapy worked for organs that had favourable therapeutic ratios (e.g. lymphomas)
  - Tumours without favourable therapeutic ratio where left to other modalities.
    - E.g. kidneys where treated by surgery rather than radiotherapy.

Radiosurgery

An early practitioner of precision

- Outside of radiotherapy the neurosurgeons looked at things differently
- Neurosurgery often requires very precise interventions.
  - AVM, Acoustic neuroma
  - Here the benefit of radiation was avoiding damage that the surgeon's knife might do.
  - Radiosurgery differs from radiotherapy because it does benefit from therapeutic ratio or fractionation.
  - But for certain neurological disorders it has advantages over surgery.
- The Elekta story….

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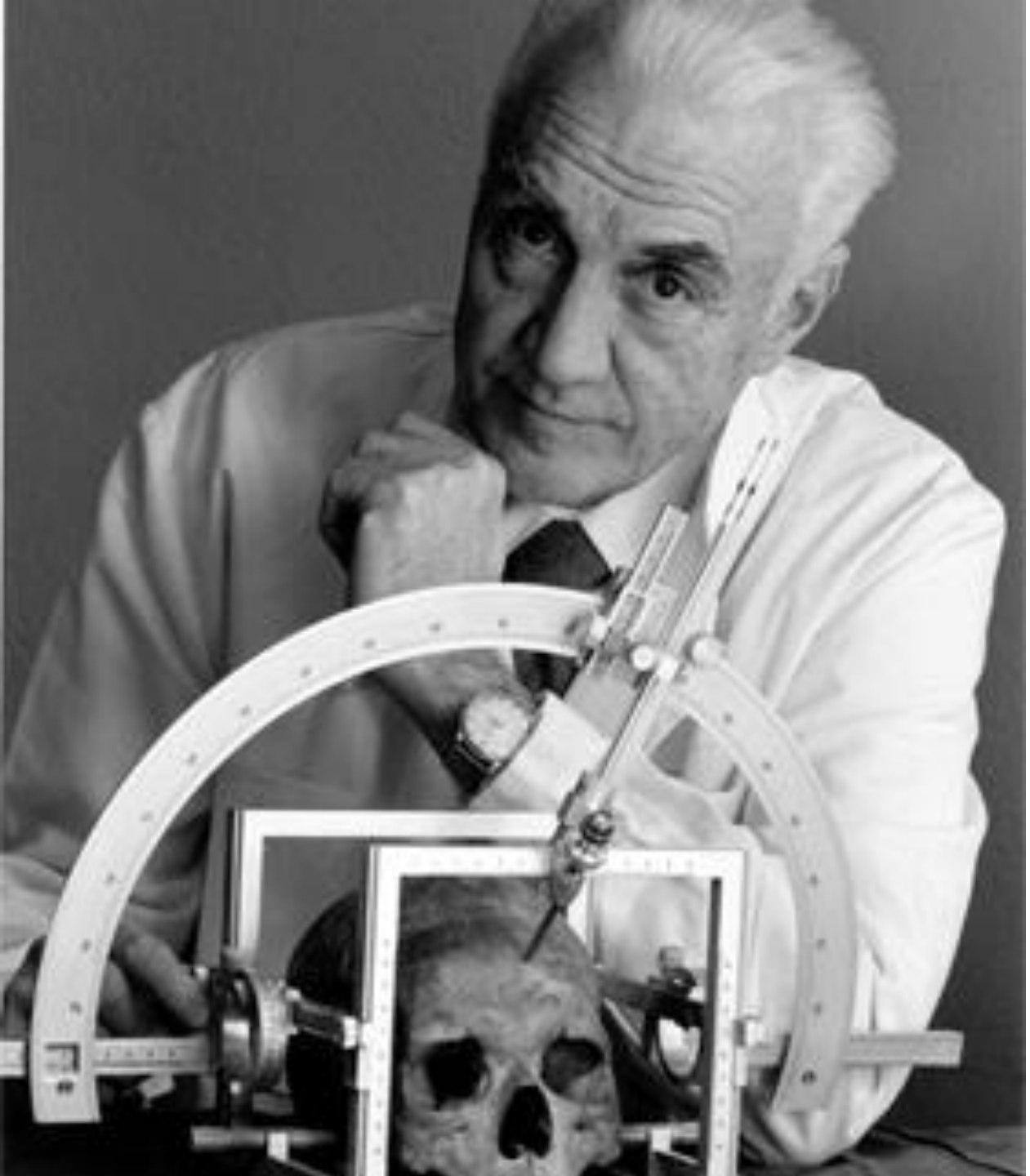


Our history is what drives us forward

Elekta was founded by Lars Leksell more than 45 years ago. We have dedicated ourselves to pioneering advancements for cancer care.

Dr. Lars Leksell (1907 – 1986)
Professor of Neurosurgery

Although RT had used imaging, that relationship was not a numerical one.

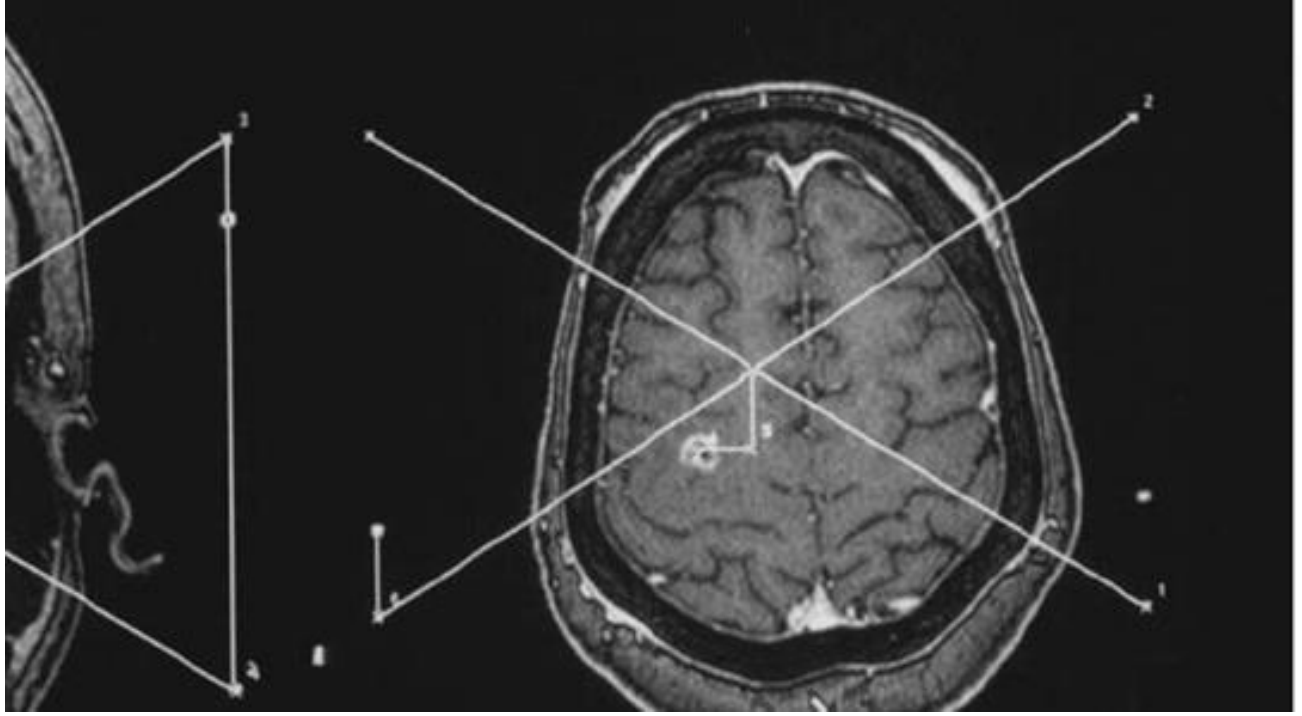
X-ray films and fluoroscopy were analogue the medical objectives were also analogue.

Stereotactic treatment required coordinates, to localise the target.

The key enabling technology for these technique was CT

CT may be though of as a imaging modality but it also brought numerical images to the clinic.

For the fist time the image existed as numbers in a computer and this presented new opportunities.



What did stereotaxy bring to RT?

NUMBERS

CT and radiotherapy

Changes in planning came first

- CT would go on revolutionise RT as well as radiosurgery
- RT was already well established but the benefits of imaging evolved slowly
- CT coincided with the development of computerised treatment planning.
- This allowed more complex RT techniques, with greater conformity.
- However the reproducibility of patient position and motion remained unaccounted uncertainties.
- This era fostered a false picture of radiotherapy being a static problem.

Computer reconstructed DRR, despite using CT for planning alignment checks at treatment time still relied on simple planar imaging.

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Imaging at treatment time.

- Until the early 2000s imaging at treatment time was limited.
- A portal image of the treatment field could was taken
- Confirms the correct field shape
- Patient position cannot be confirmed, unless bony anatomy is in the beam.
- Movement in soft tissue went unnoticed.

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Cone Beam CT

3D images at treatment time

- 2003 saw a significant revolution in radiotherapy.
- By adding cone beam CT to a treatment linac it was now possible to see detail 3D images immediately before treatment
- This development was facilitated buy the development of large area amorphous silicon detectors
- Cone beam CT differs from conventional CT by collecting the whole volume in a single revolution
- A scan before treatment takes about 1 minute

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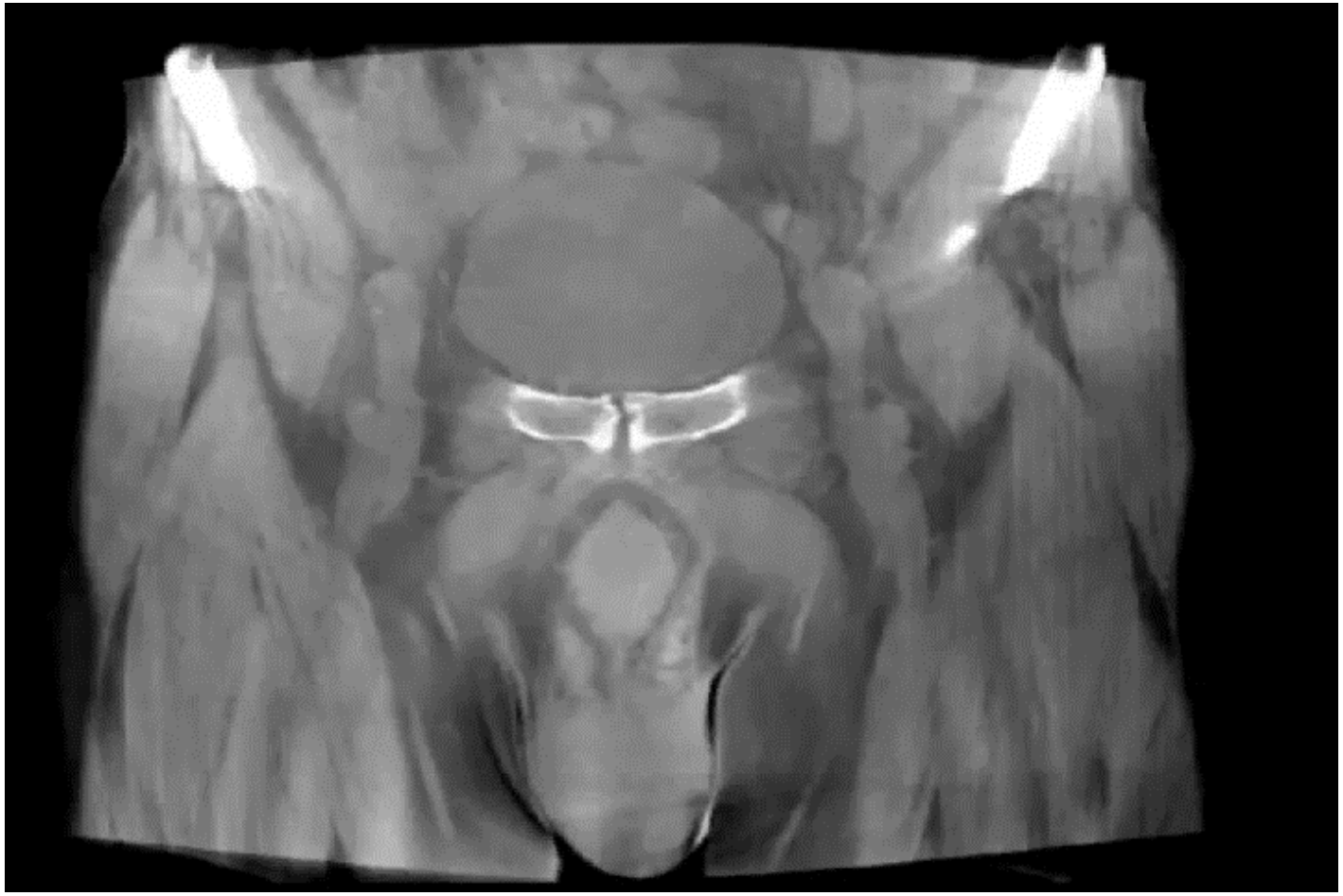
Image Quality really does matter

Patient position v target position

Old style DRR



3D volume from cone beam CT

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Extending cone beam to handle motion

4D cone beam

- Where there is good contrast it is possible to pages bin cone beam projections to create a moving view by phase binning

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Today IGRT is the standard of care

- IGRT has
  - Allowed dose escalation
  - Resulted in less toxicity
  - Resulted in better long-term survival
  - Allowed more conformal plan to be design with increasing the risk of mistreatment.

Why CT is not enough

Radiotherapy is not the standard of care for all tumour sites

- Limited Soft tissue resolution
  - Organ level not tumour level
  - Limited ability to handle motion
  - Cannot image during treatment
  - Additional imaging dose

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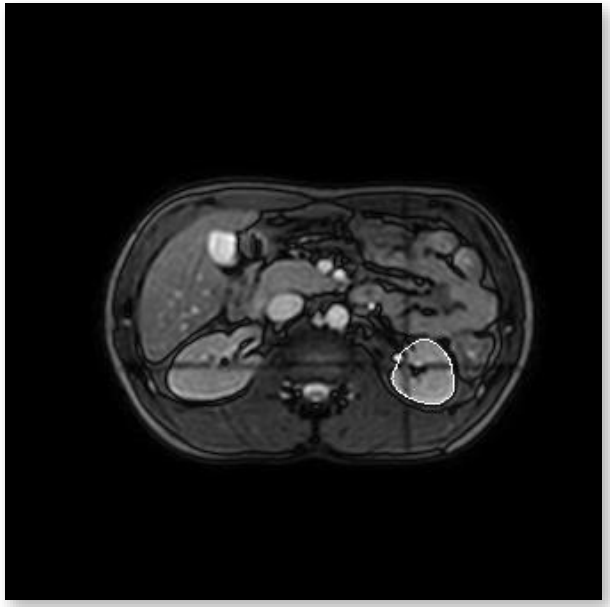
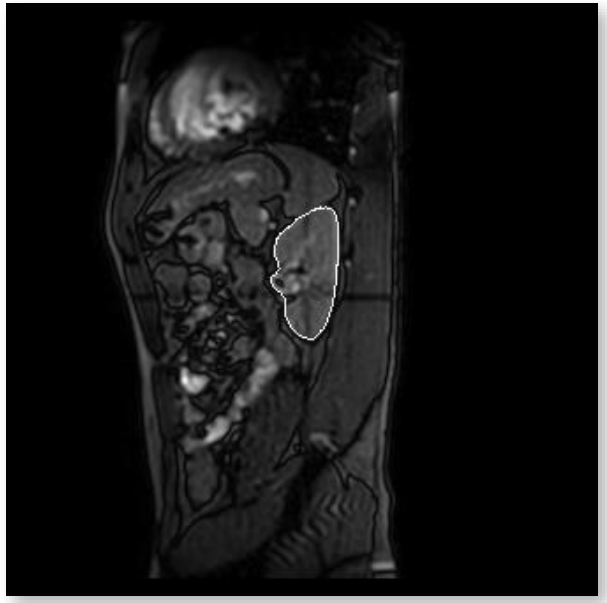
MRI a soft tissue revolution

MR imaging has many advantages over CT

- Excellent soft tissue contrast
- Ability to acquire images in arbitrary planes or volumes
- Ability to image during radiation-on





Images courtesy of Philips, segmentation by Elekta software

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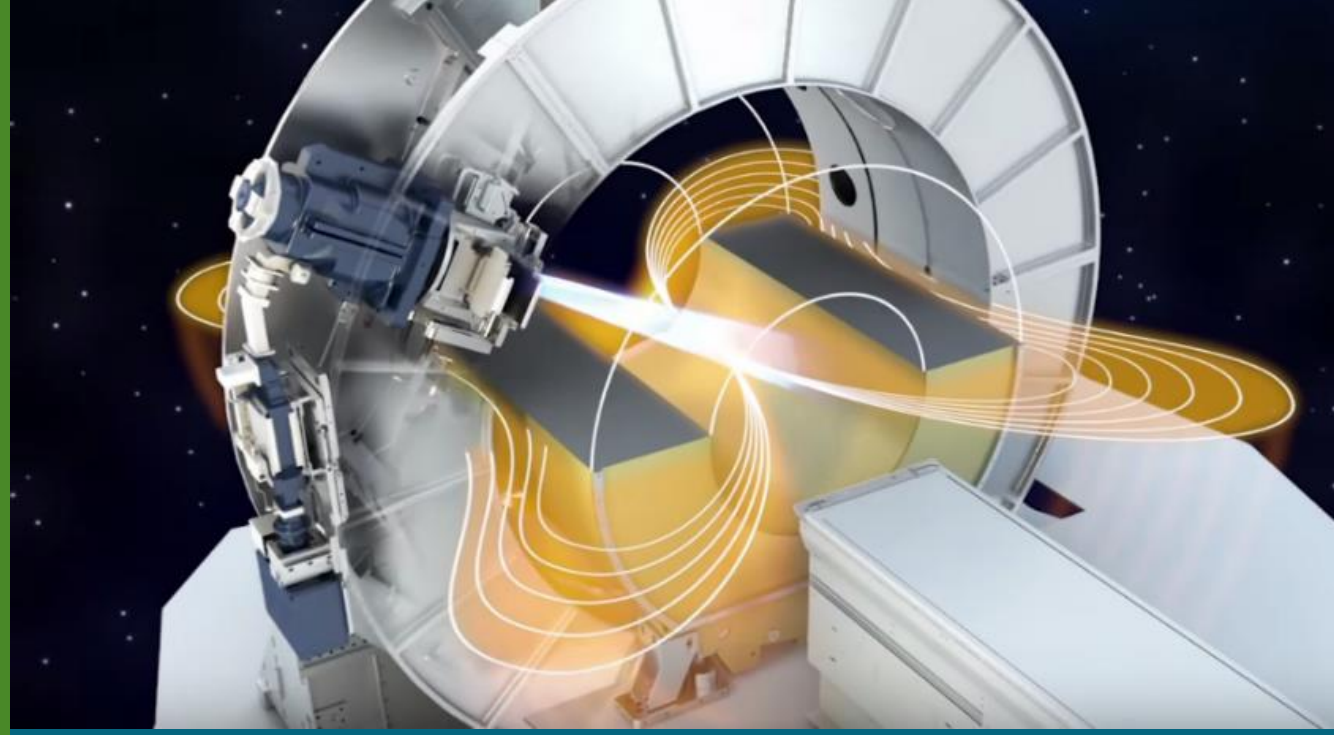
Combine MR & linac

Cannot just put two pieces of equipment in the same room

- High magnetic field required for MRI
- MRI requires RF shielding
- MR requires uniform B-field
- Linacs require some ferromagnetic material which moves in the MR fringe field



Solution:

Design a special linac

MR linac

A big technical challenge but huge potential benefits

- Unlike Cone beam CT an MR linac requires a specially designed linac
- Some design challenges
  - Linac must operate near a high field magnet
  - Cryogen tank surrounds patient during imaging
  - MR requires a room free from RF interference
  - Treatment planning needs to correct for magnetic field
    - (Lorentz force on secondary electrons)

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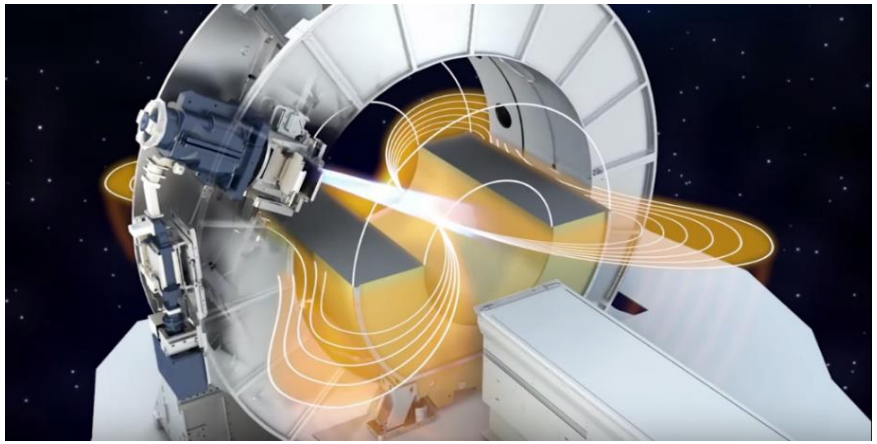
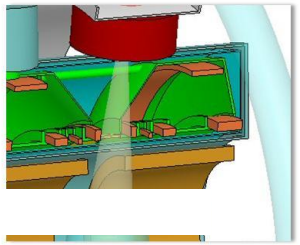
Elekta MR-linac system

Technology platform

1.5T Cylindrical Magnet

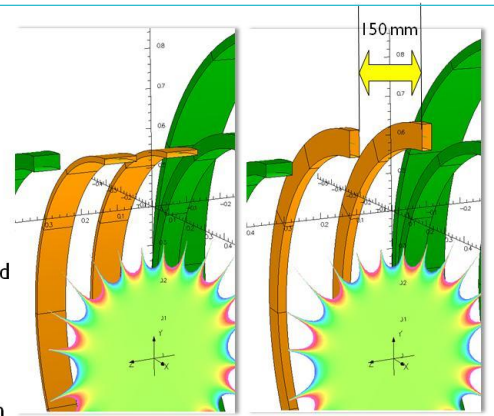




Gap between central coils increased to ~ 150 mm

Possible without compromising homogeneity

Cryostat with reduced and uniform gamma attenuation



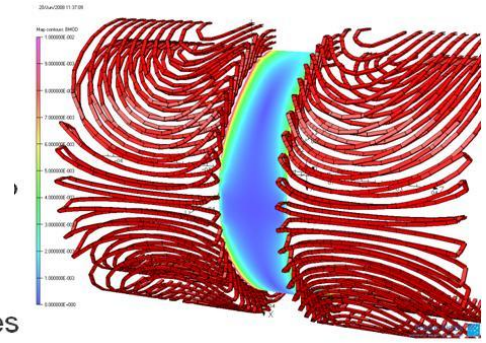
"Standard" MR/RT design

Split Gradient Coil with gap

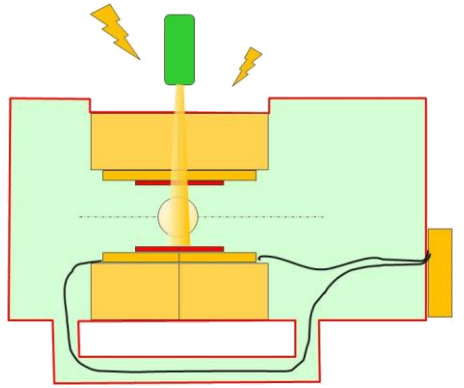
Actively shielded coil system

Central gap

No electrical or cooling interconnections between halves



RF shielding

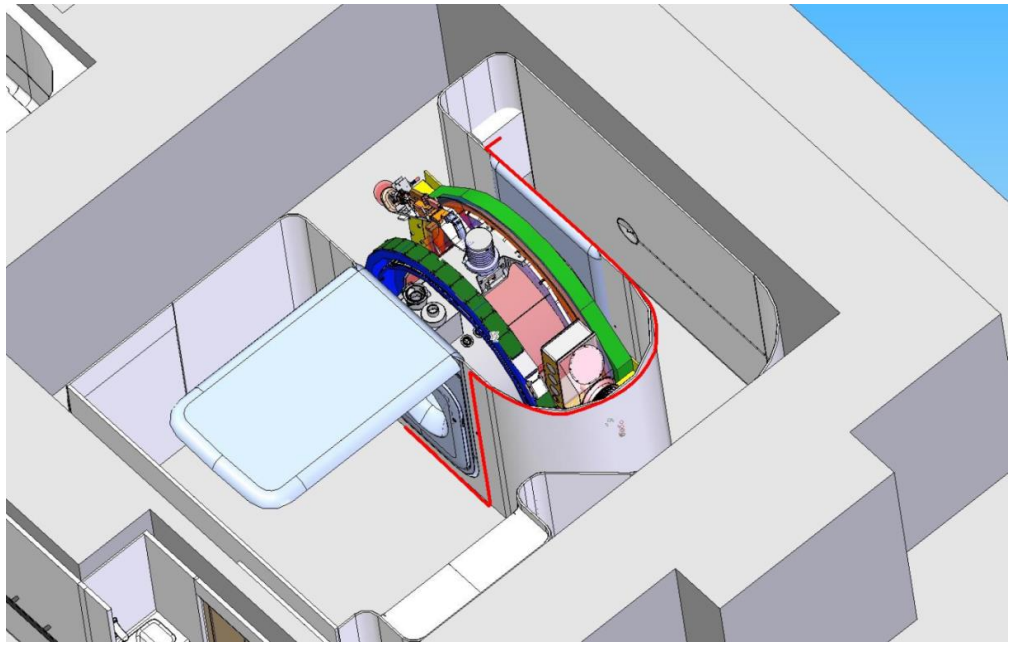


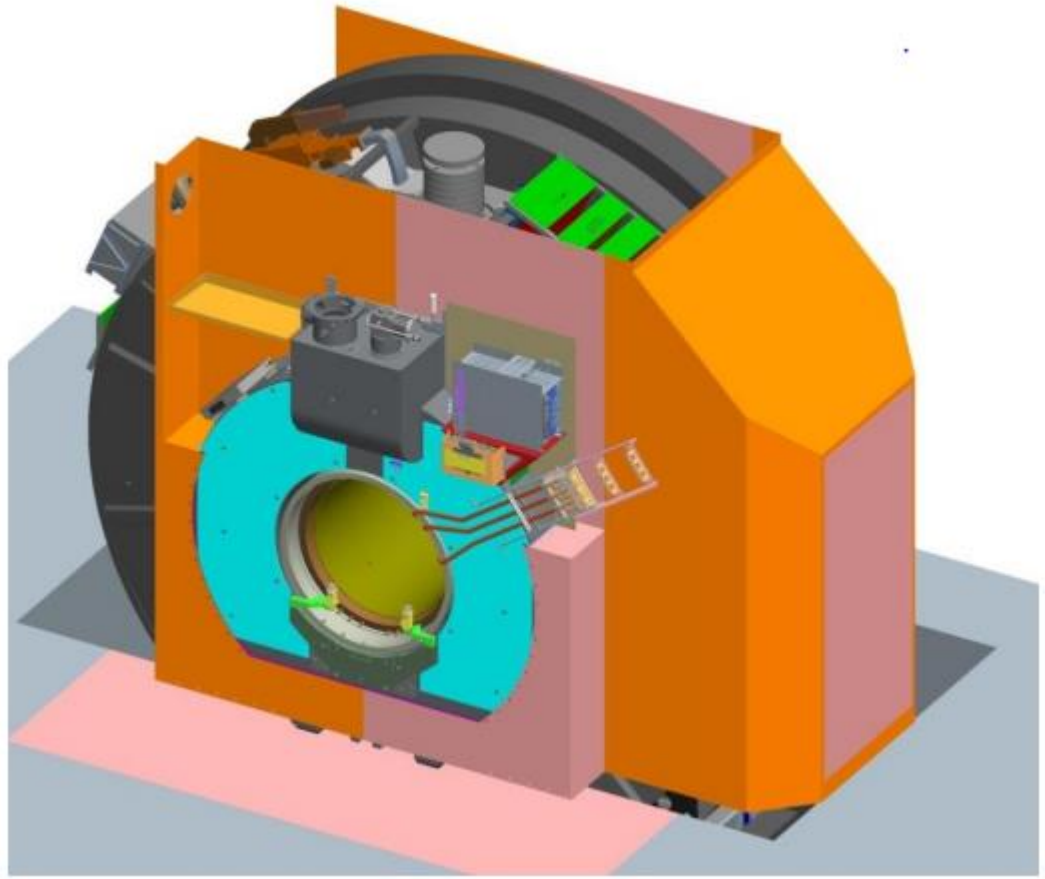
MR-Linac is a research program. It is not available for sale and its future availability cannot be guaranteed

Room within a Room Concept

There is a RF shield Room inside the Radiation bunker

- All gantry systems are outside the RF room





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MR Guided Radiotherapy system

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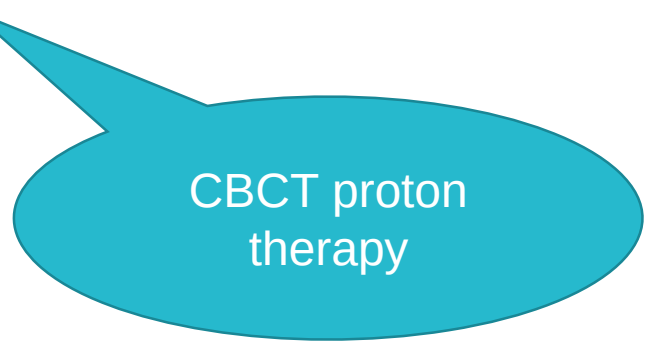
Provocative debate topic at this year's ESTRO Meeting in Vienna

- **"This house believes that proton guided photons will be superior to photon guided protons"**



…an interesting way to think about the role of protons in RT.

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Questions?

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More than….

- 3000 linac systems in hospitals worldwide
- 1.5M people treated every year
- 140000 patients a day interacting with Elekta’s solutions