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Brachytherapy and particle therapy

CRISTER CEBERG

Types of radiotherapy

- External beam radiotherapy (teletherapy)
  - Cobalt unit
  - Linear accelerator (linac)
  - Particle beams
- Brachytherapy
  - Sealed sources (capsules, needles, ”seeds”)
- Radiopharmacological therapy
  - Non-sealed sources

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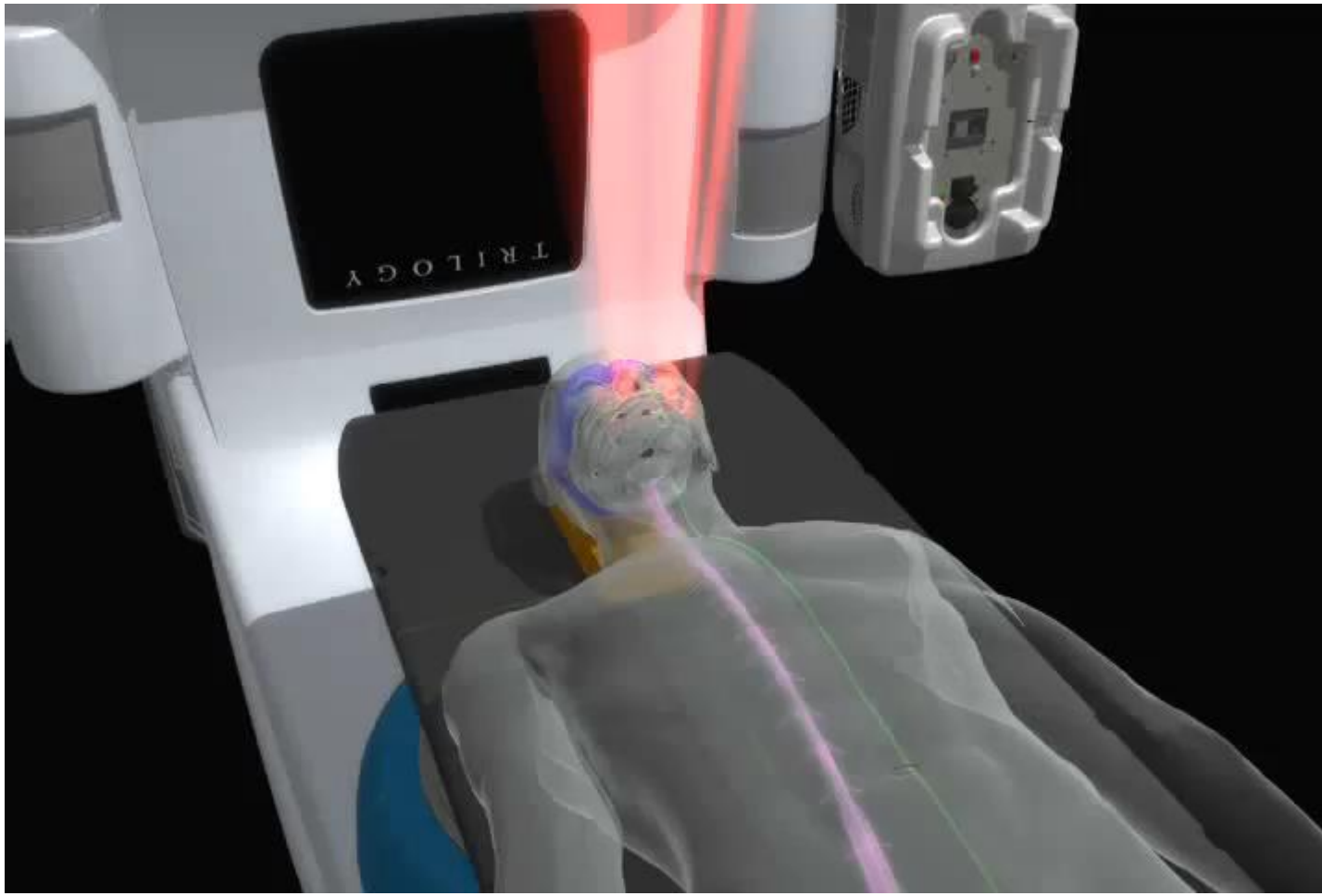
Varian’s RapidArc technology



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Particle radiotherapy

» External radiotherapy is also given with

- Protons
- Heavy ions
- Neutrons

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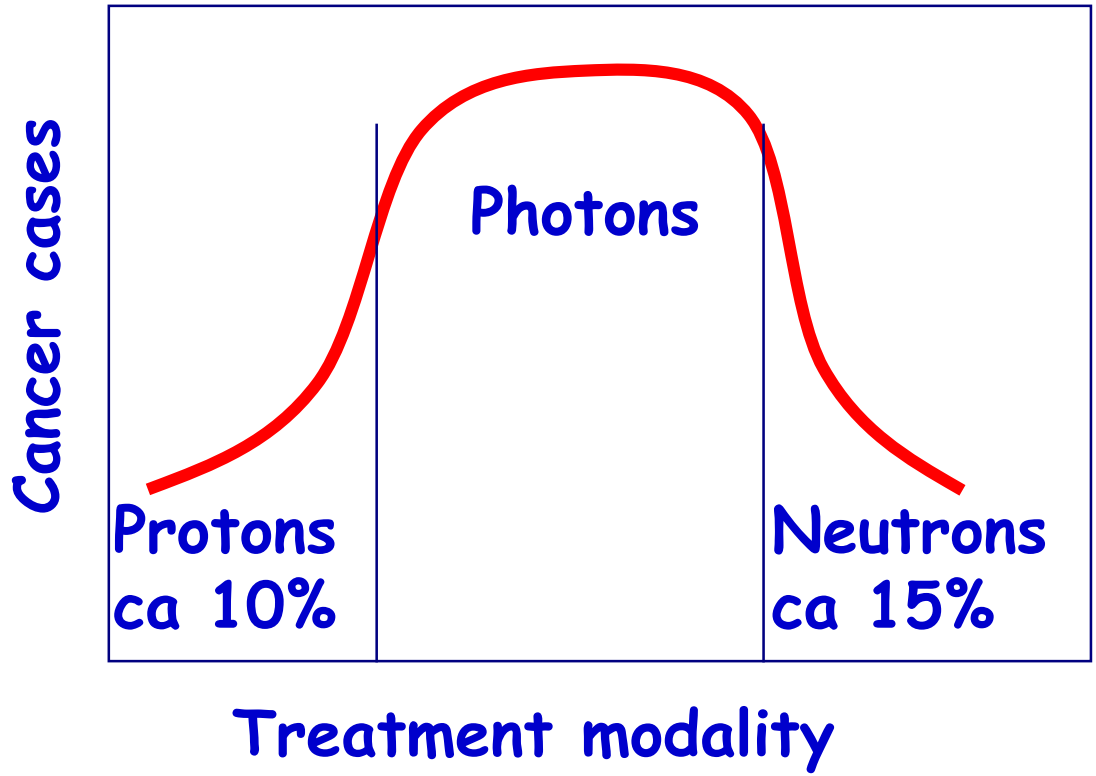
Alternative radiotherapy



Arlene Lennox, Fermilab, 2003

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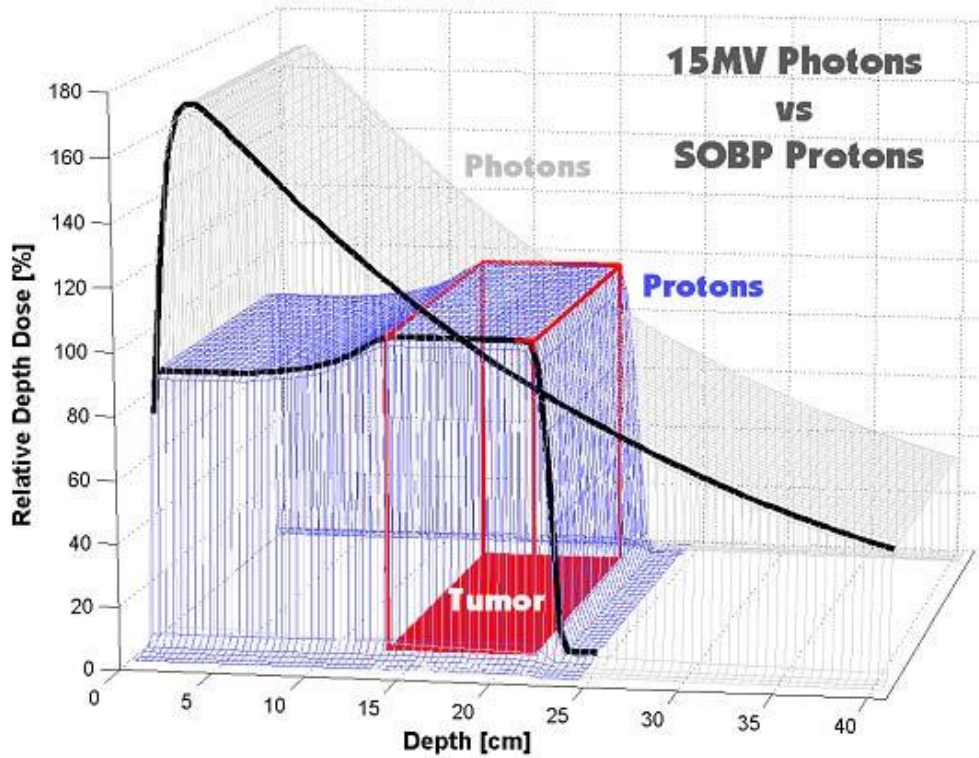
Protons

» Better geometric precision



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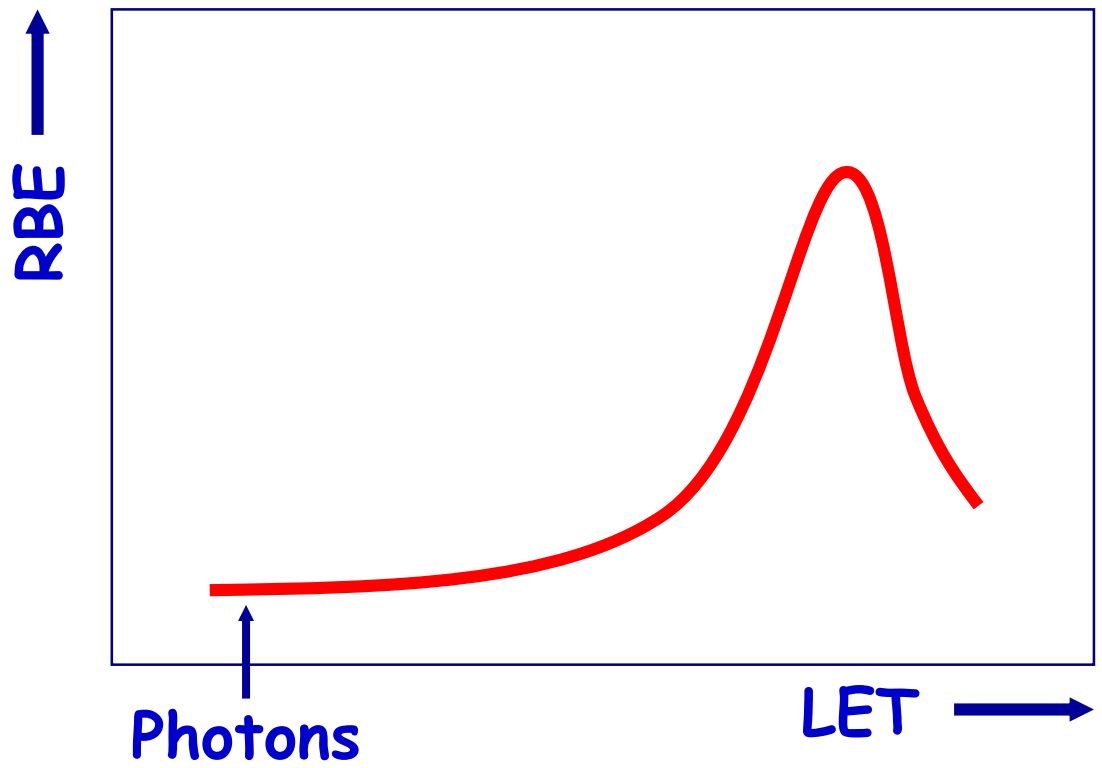
Neutroner

» Higher biological effect



E.J. Hall, 1978

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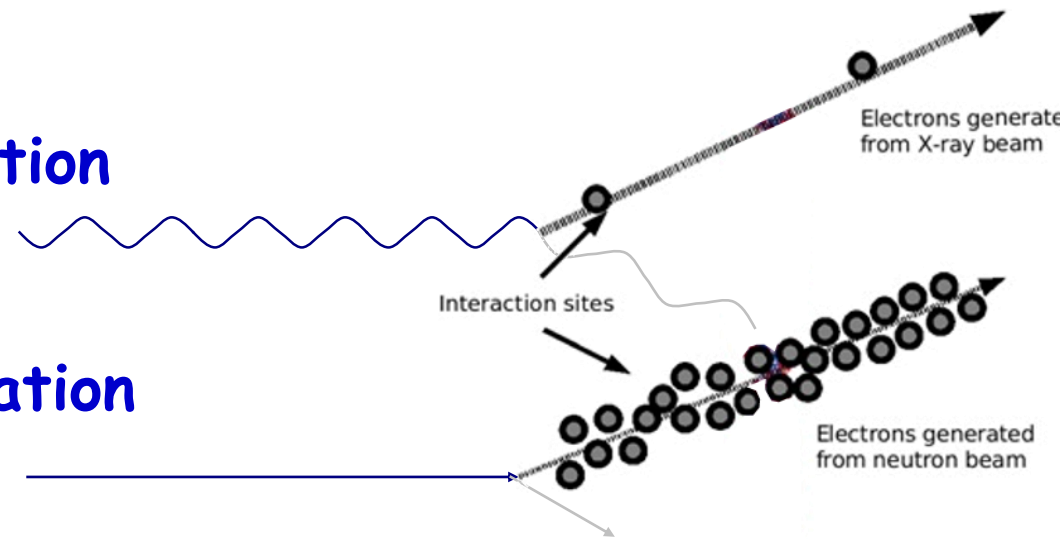
Linear energy transfer (LET)

Low-LET radiation
e.g. photons

High-LET radiation
e.g. neutrons



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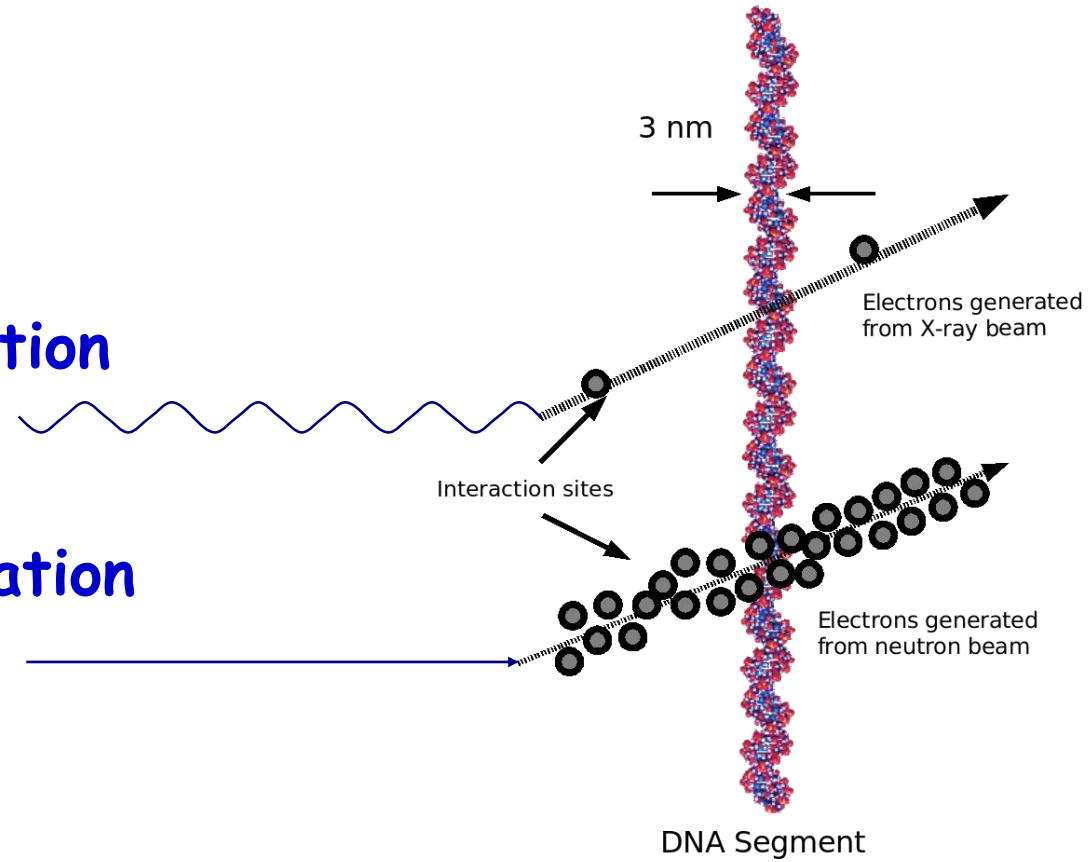
Relative biological effect (RBE)

Low-LET radiation
e.g. photons

High-LET radiation
e.g. neutrons



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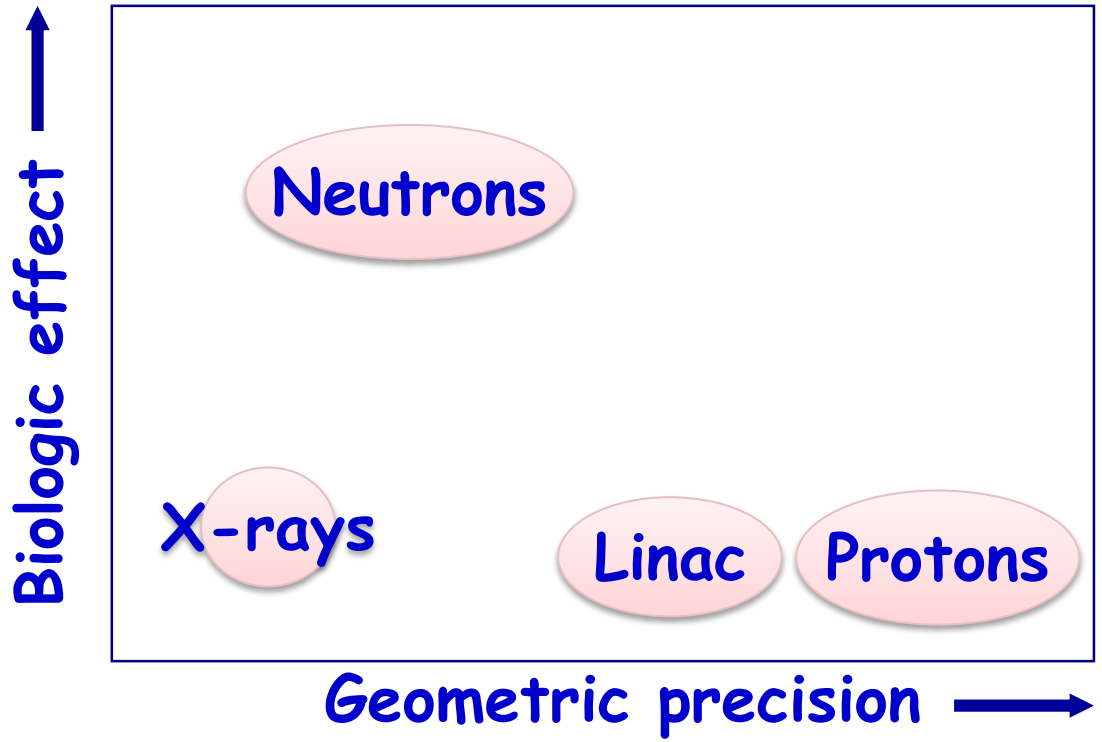
Precision *vs.* effectiveness



E.J. Hall, 1978

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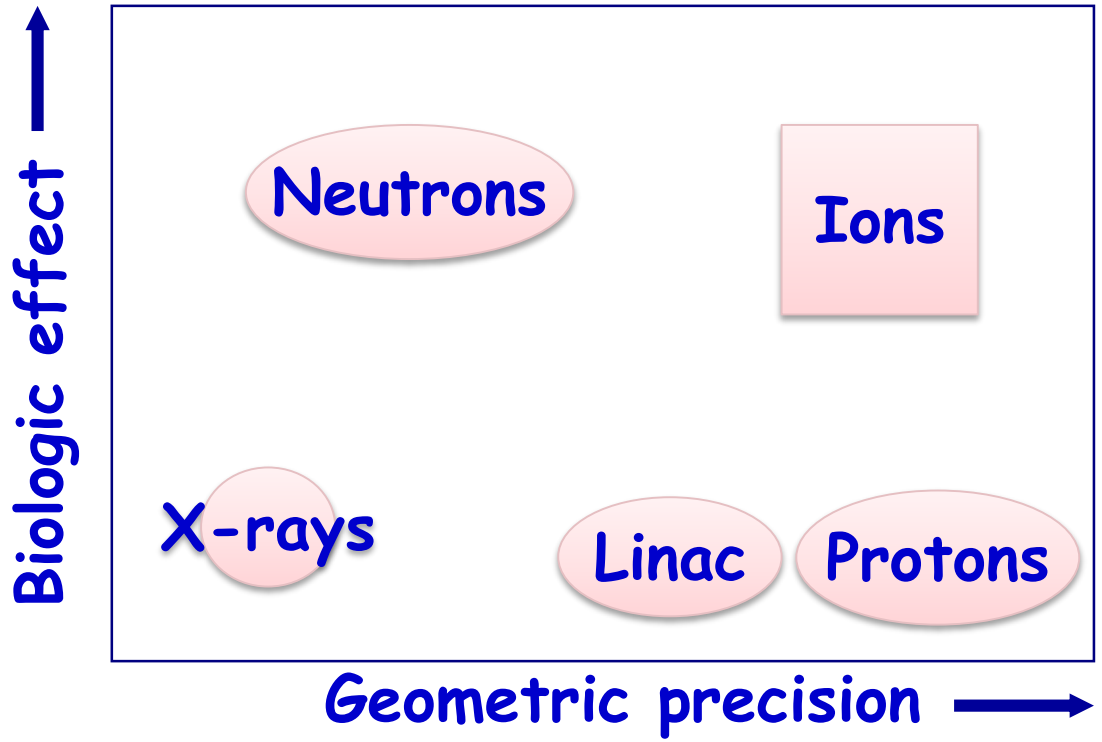
Precision *and* effectiveness?



E.J. Hall, 1978

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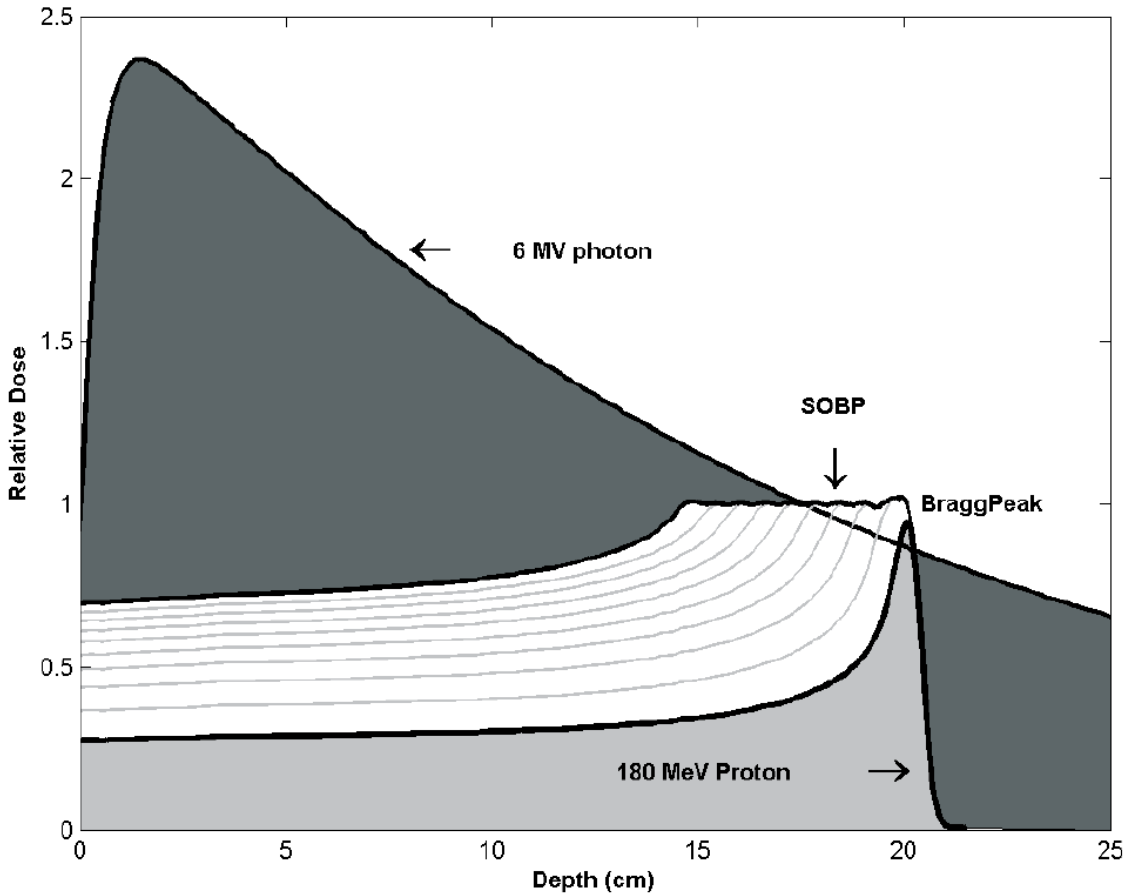
Proton radiotherapy



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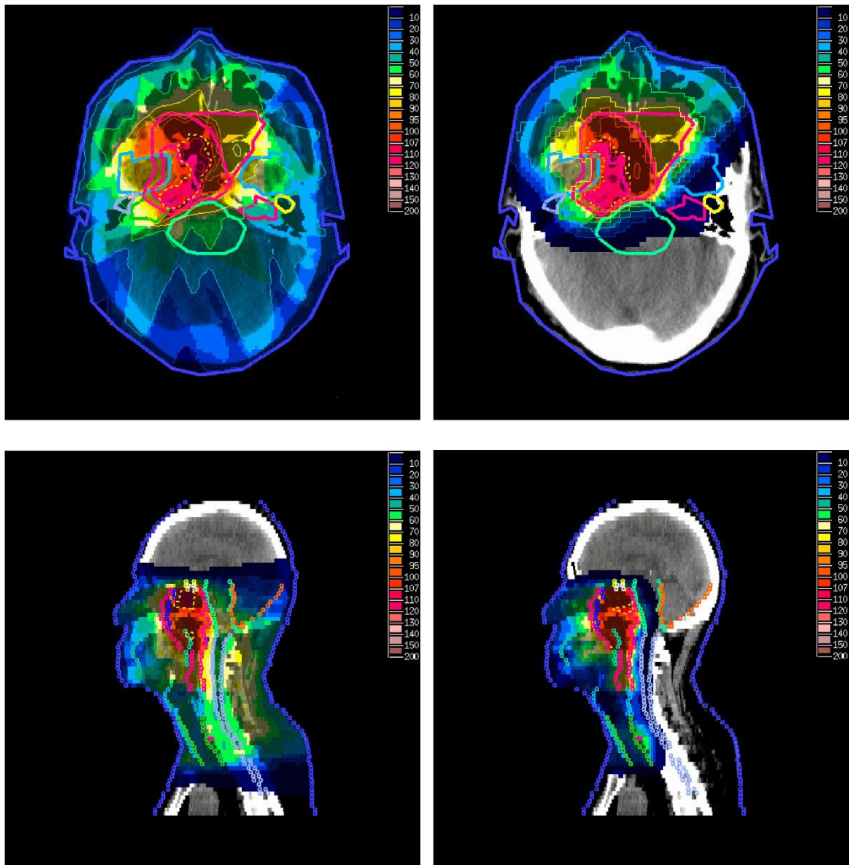
Improved conformity

Photon plan **Proton plan**



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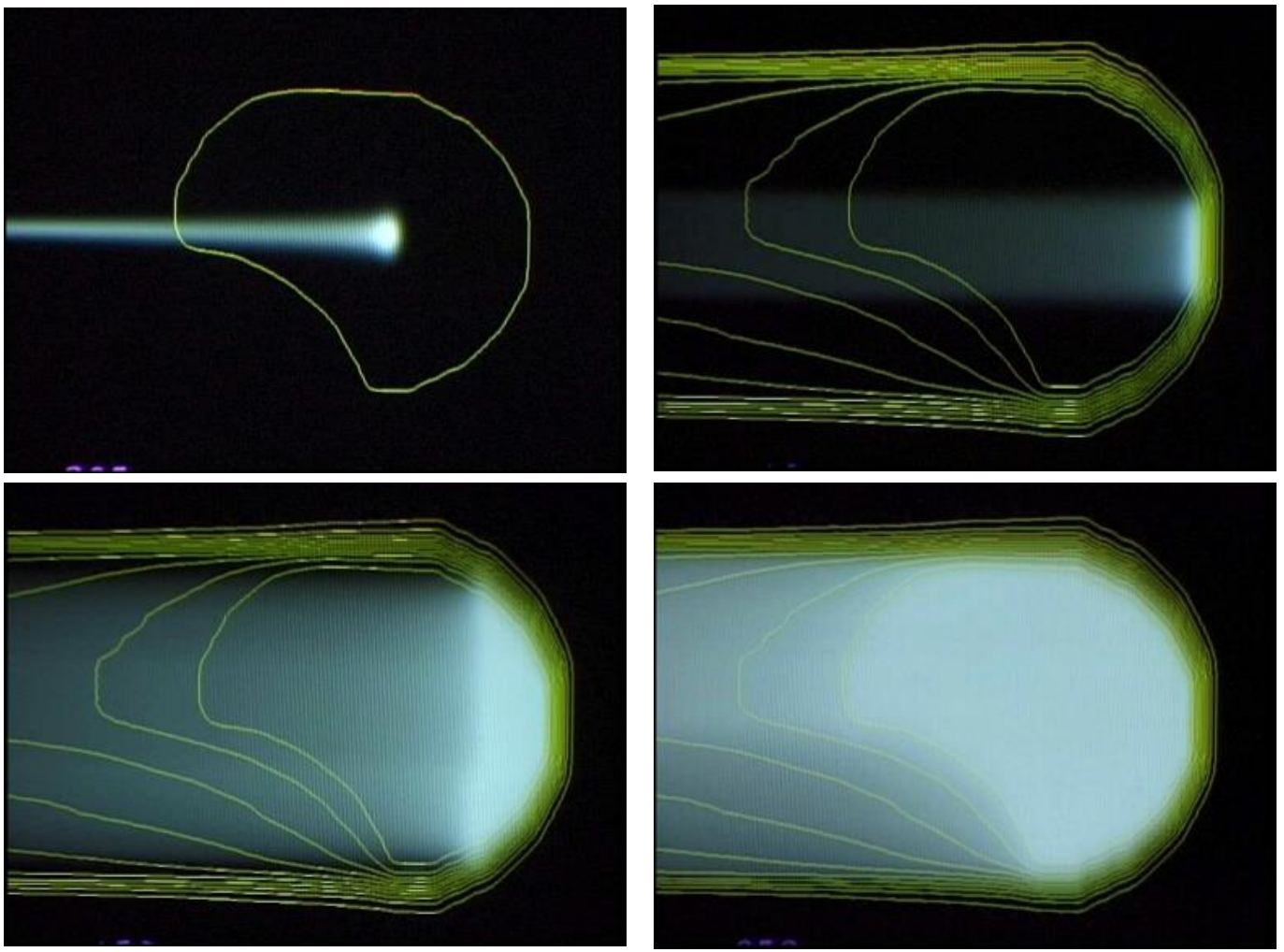
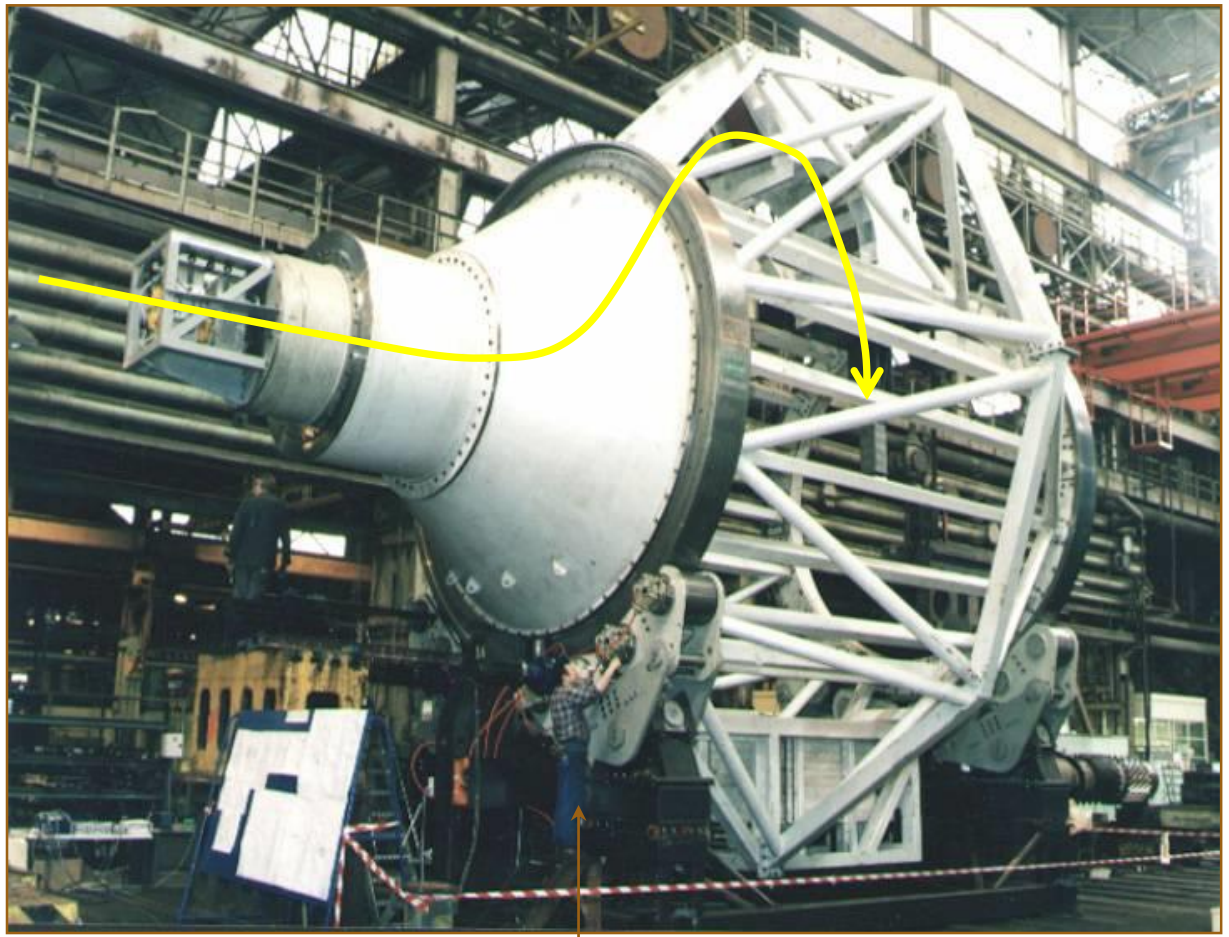
Spot scanning

Spot scanning

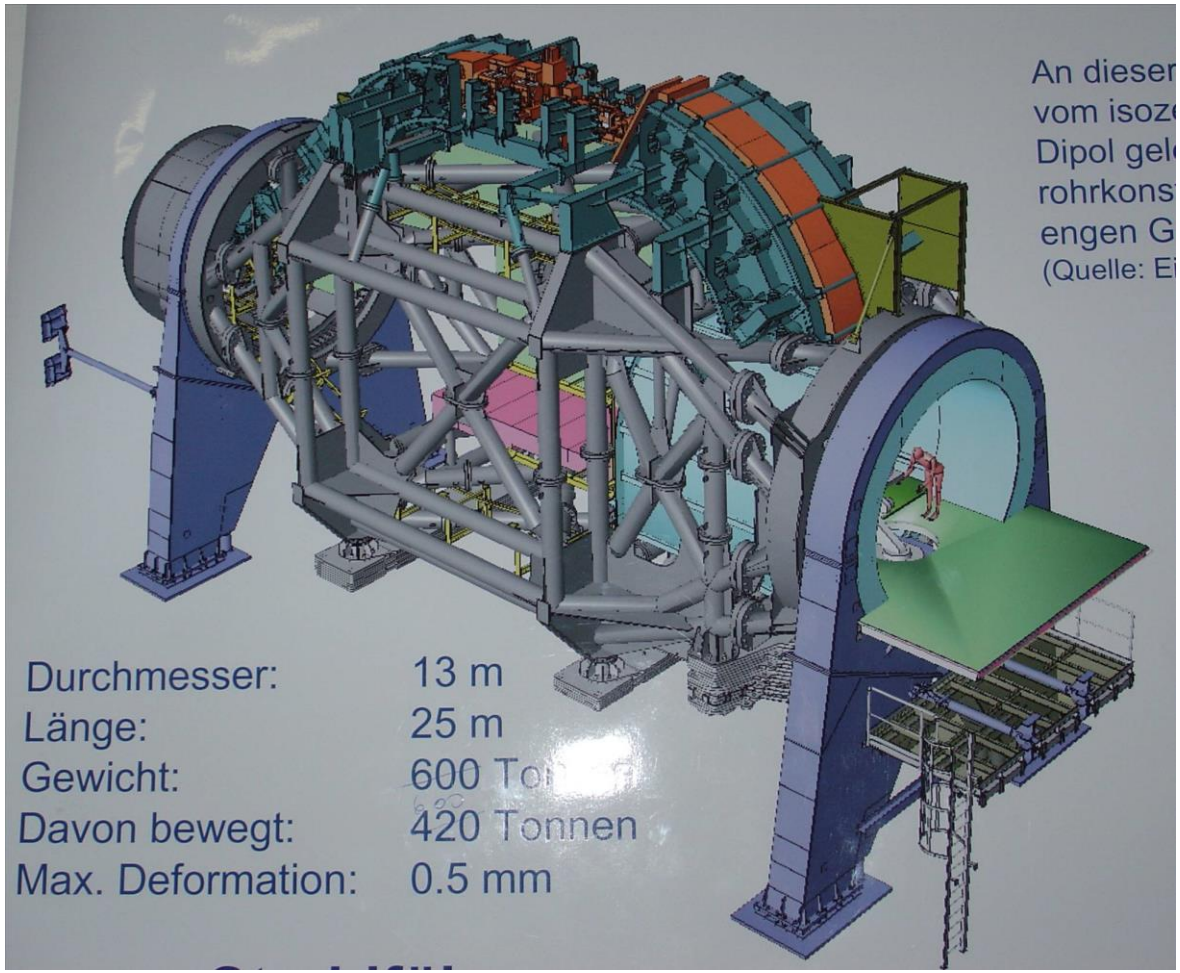


Proton gantry



Diameter ca 10 m, weight ca 120 ton

Proton gantry



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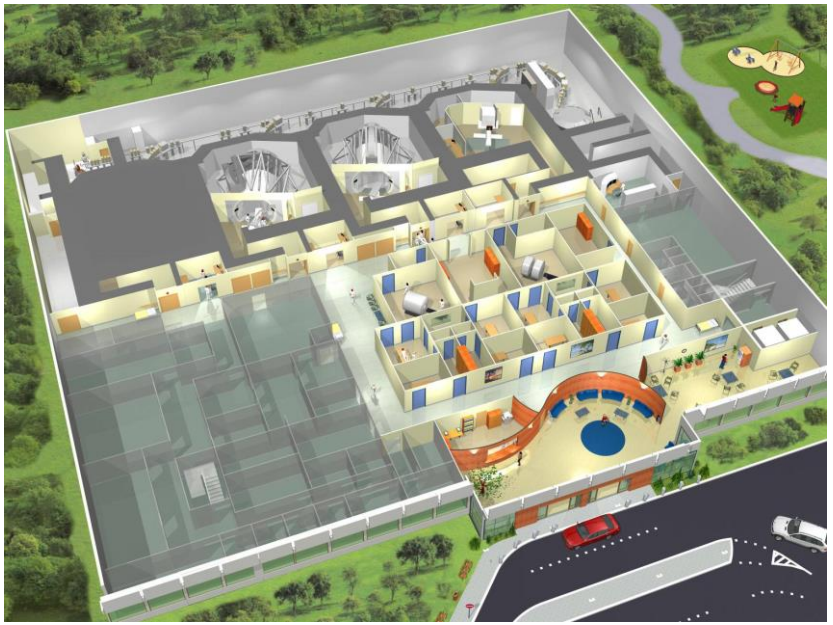
The Skandion clinic



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Neutron radiotherapy

- Robert Stone started clinical trials at Berkely in 1938
- After WWII, Mary Catterall restarted clinical trials at Hammersmith in 1965
- Neutron therapy may improve local control
- It was realized that high energies are required (>30 MeV)

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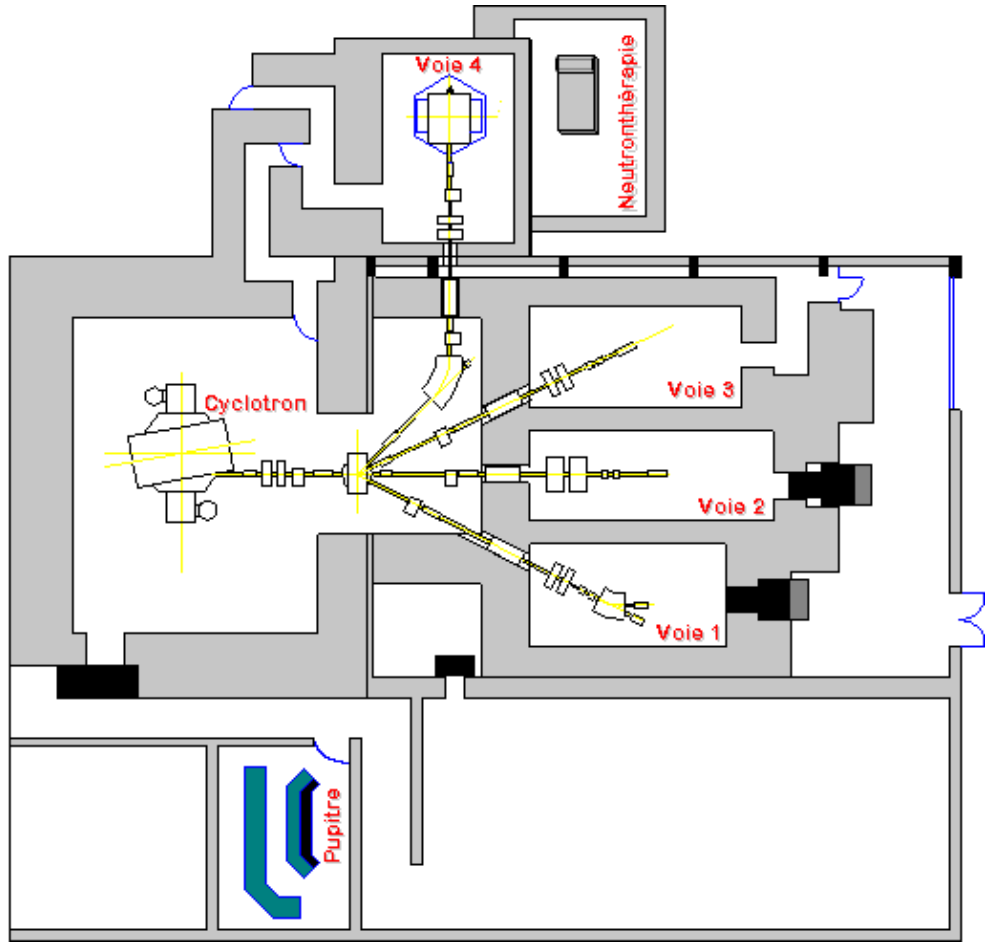
Orleans



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Fixed horisontal beam at Fermilab

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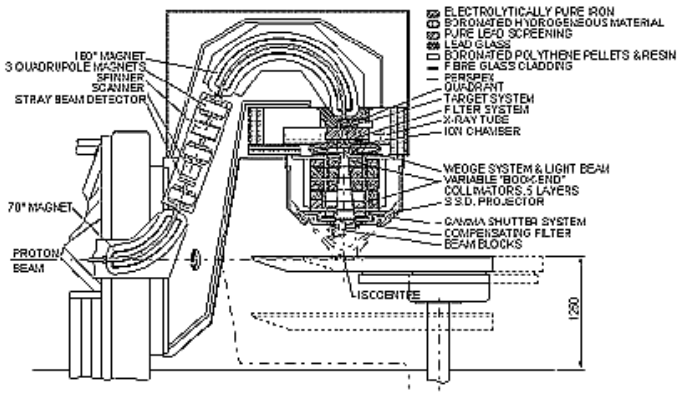
Isocentric gantry in Faure



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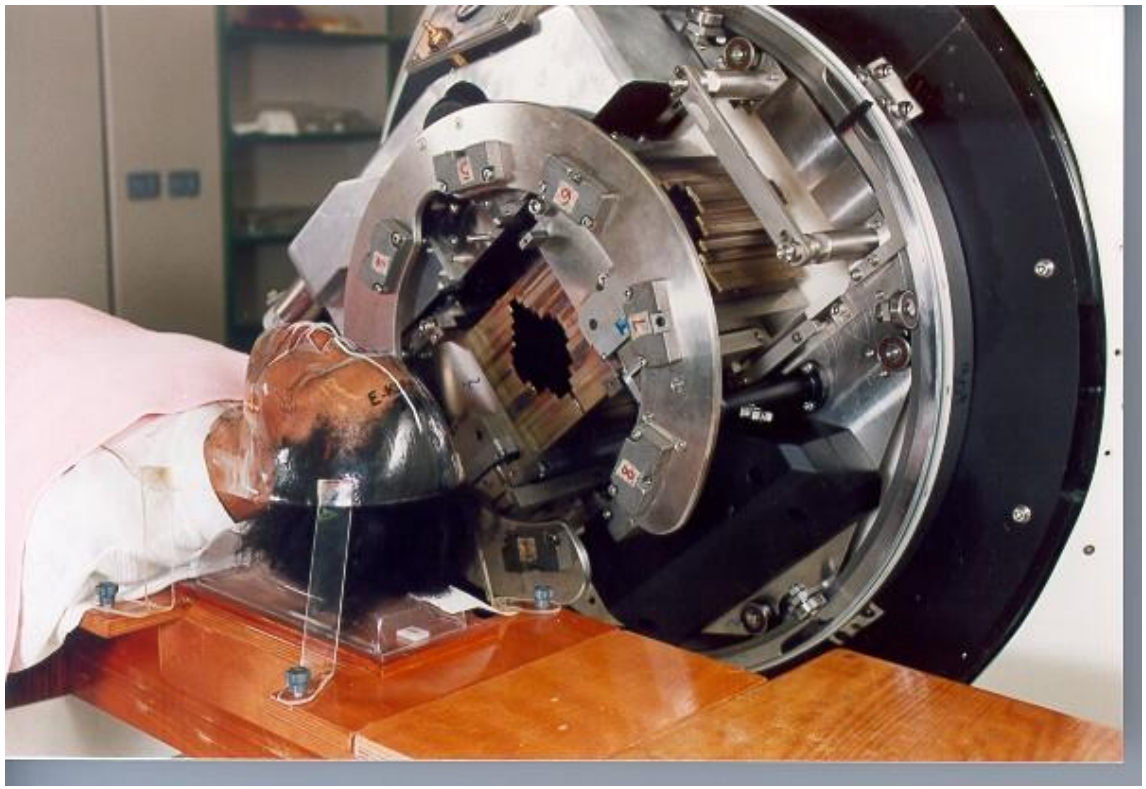
MLC in Faure



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Isocentric gantry in Detroit

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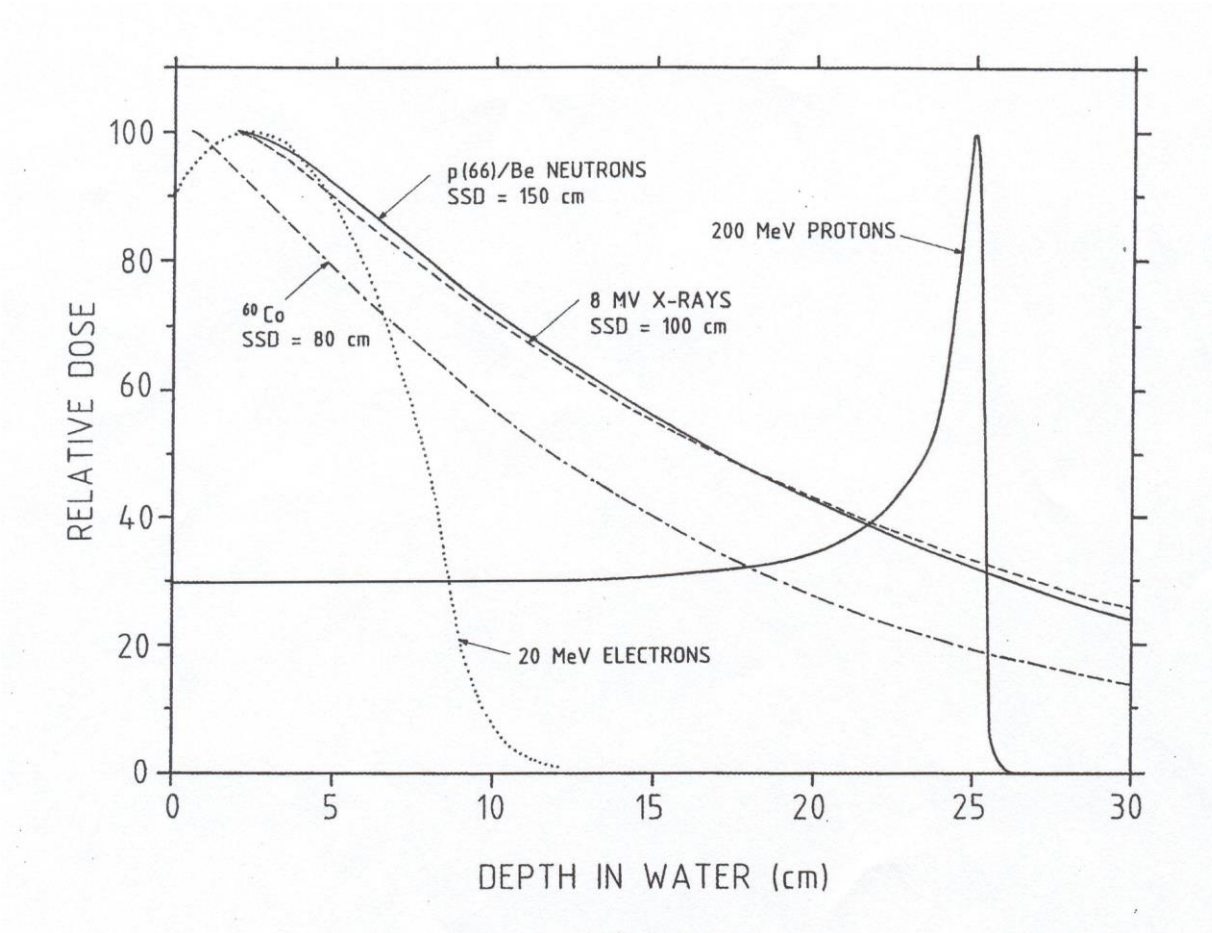
Depth dose curves



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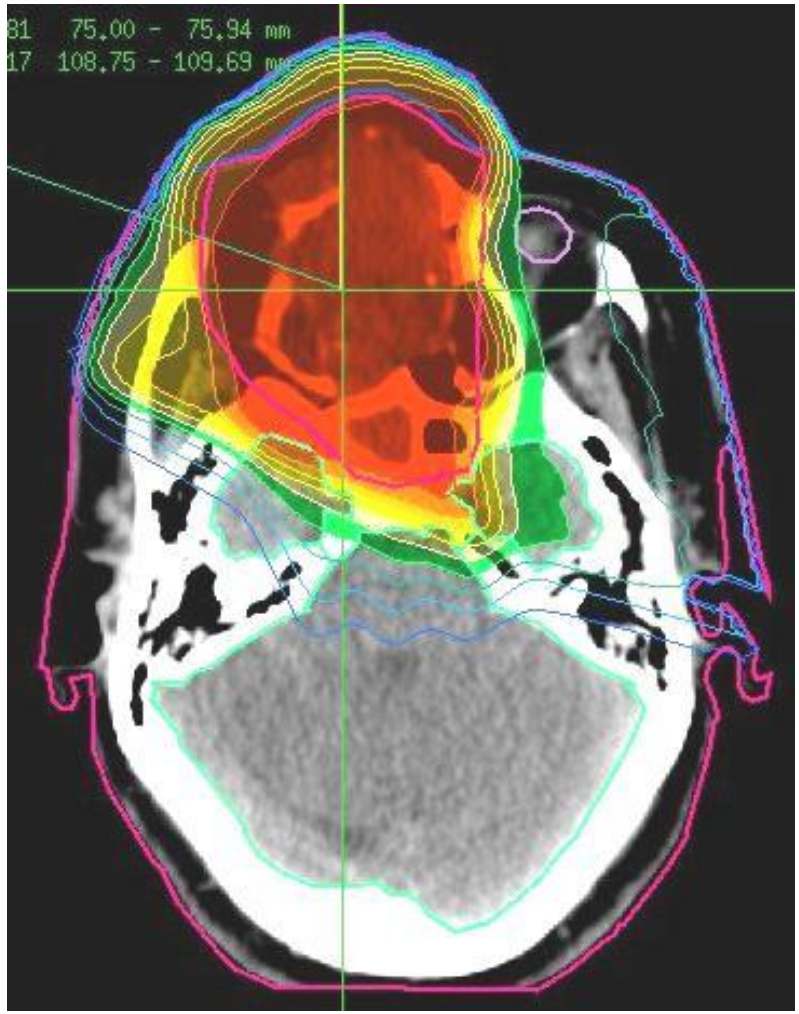
Treatment plan (Faure)



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Neutrons *vs.* photons

» Higher LET

» RBE about 3

» Less oxygen effect

» Less cell-cycle effect

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Clinical implications

- Radioresistent tumours
- Large, poorly oxygenated tumours
- Slowly growing tumours with a small fraction of cells in mitosis
- Less reason for fractionation may lead to shorter treatment times
- Possibly useful for salivary gland neoplasms and for prostate cancer

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Conclusion

- Previous lack of understanding lead to inappropriate use of neutron therapy
  - Dosimetry
  - Difference in radiation sensitivity
- Some patient may benefit from neutron radiotherapy
  - Predictive assays are needed

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Neutron radiotherapy facilities

Centre	Country	Neutron source	Patients treated	Comments
FRM II Munich	Germany	Reactor	80	
Snezhinsk	Russia		990	2 treatment rooms (one vertical and one horizontal beam). No multi-leaf collimator
Tomsk	Russia		1,200	
iThemba Labs	South Africa	Separated Sector Cyclotron, 66MeV p+ on a Be target	1,700	Isocentric unit with Multi-blade trimmer.
Detroit	USA	Cyclotron d(48.5)+Be	2,200	
Fermilab	USA	Proton Linear Accelerator ~70MeV	3,000+	Currently some 30-40 patients annually
Seattle	USA	Cyclotron 50 MeV	2,750	

http://www.neutrontherapy.com/

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Brachytherapy

- Intracavitary
  - Gynaecological cancer
  - Nasopharynx
  - Endoluminal treatments
- Interstitial
  - Head-and-neck tumours
  - Anal cancer
  - Prostate cancer
  - Breast cancer
- Surface applicators
  - Eye melanoma

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Brachytherapy

Isotope	Half-life	Energy (MeV)	Clinical use
137Cs	30 y	0.66 (γ)	LDR interstital and intracavitary
60Co	5.3 y	1.25 (γ)	HDR intracavitary
192Ir	73.8 d	0.397 (γ)	LDR interstitial HDR interstital and intracavitary
125I	60 d	0.028 (γ)	Permanent interstitial implants (”seeds”)
103Pd	17 d	0.02 (β)	Permanent interstitial implants (”seeds”)
32P	14.3 d	1.71 (β)	Surface applicator

LDR: 0.4 – 2.0 Gy/h
HDR: 1-2 Gy/min

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HDR afterloader

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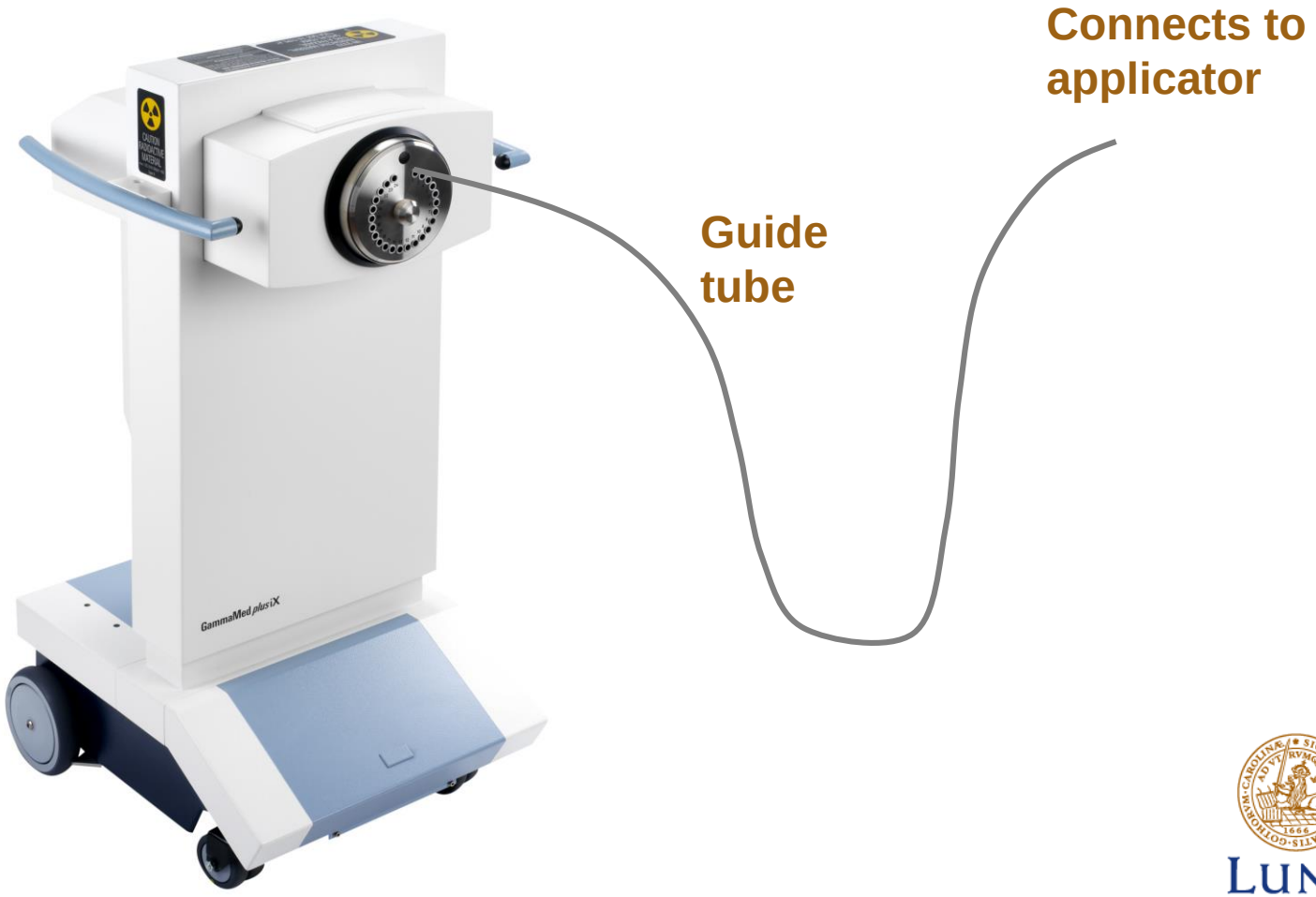
HDR afterloader



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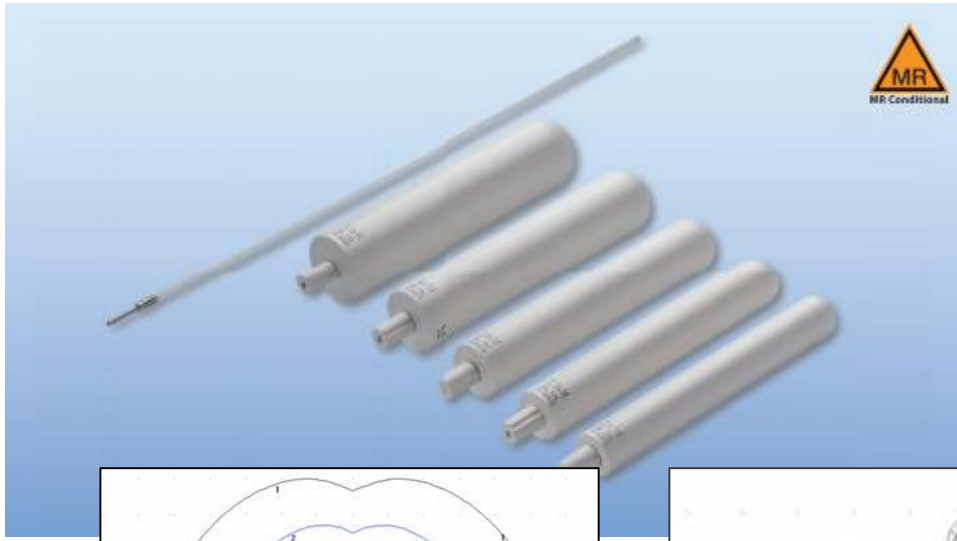
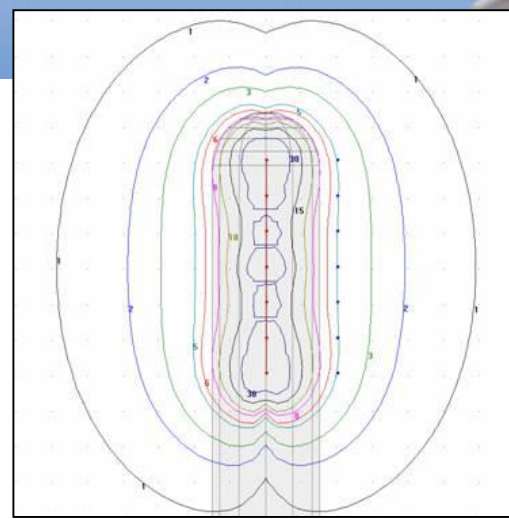
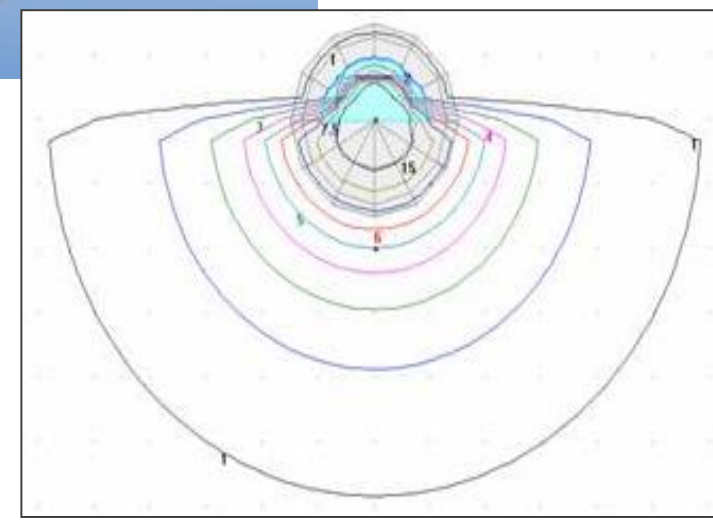
Intracavitary applicator







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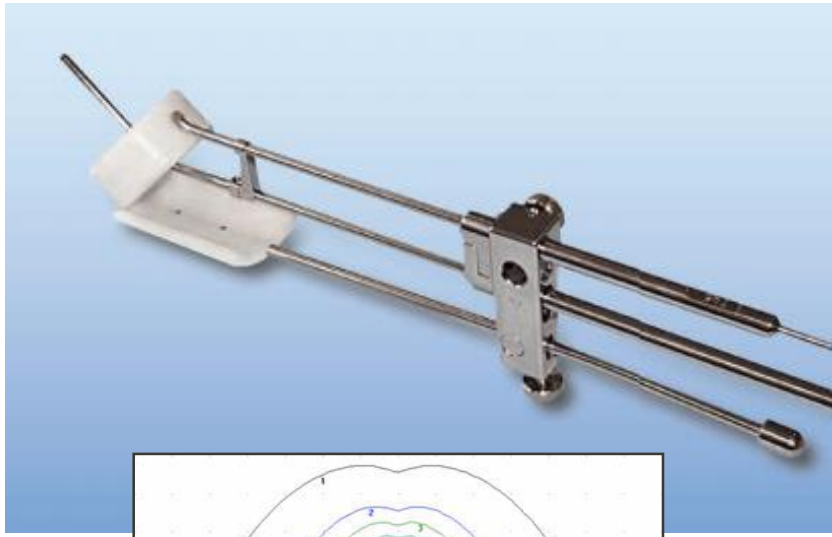
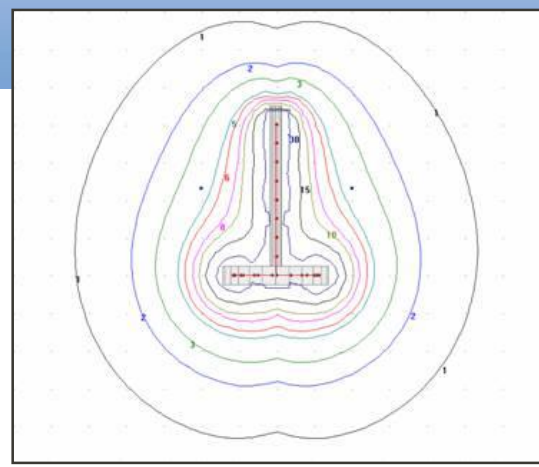
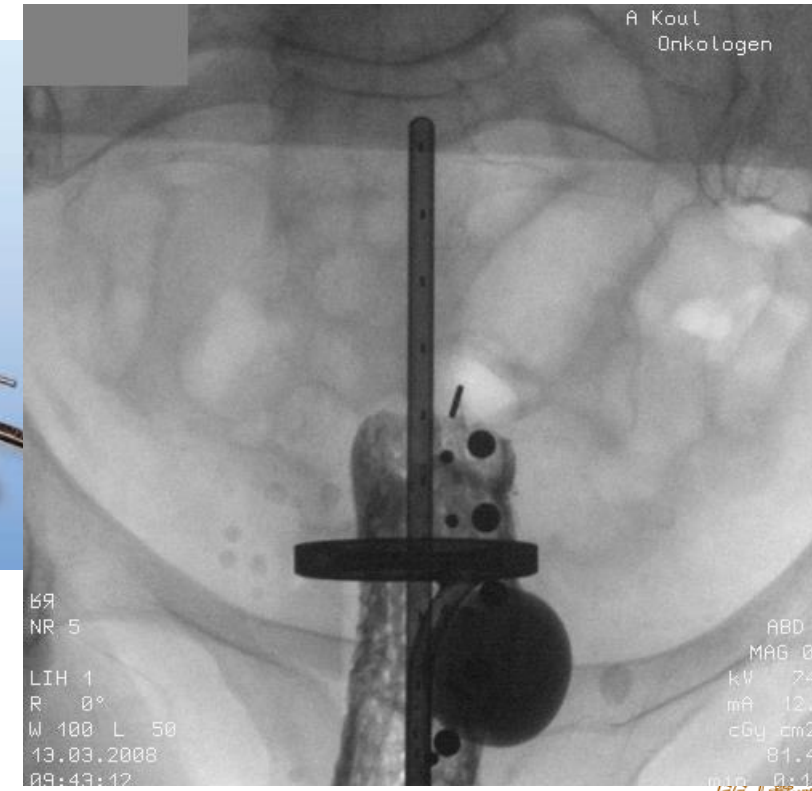
Intracavitary applicator







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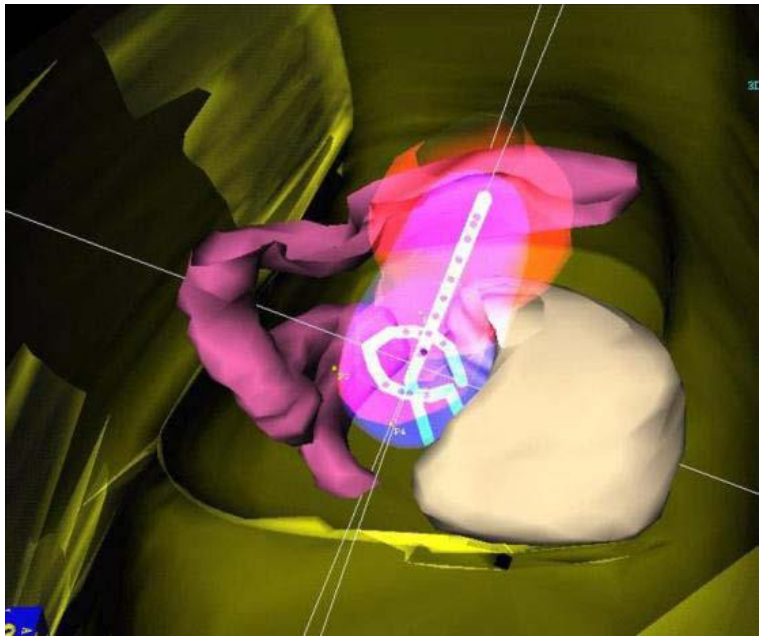
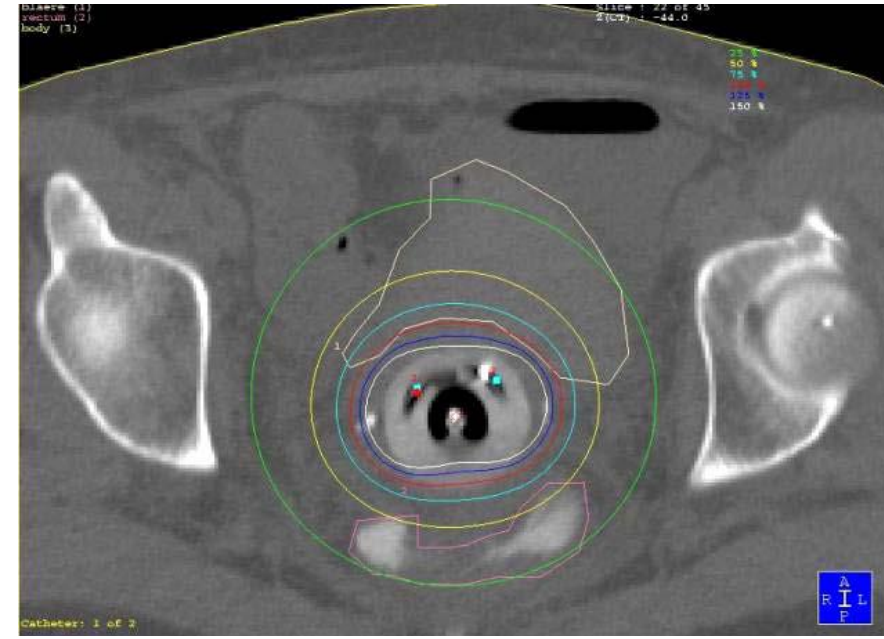
Intracavitary applicator





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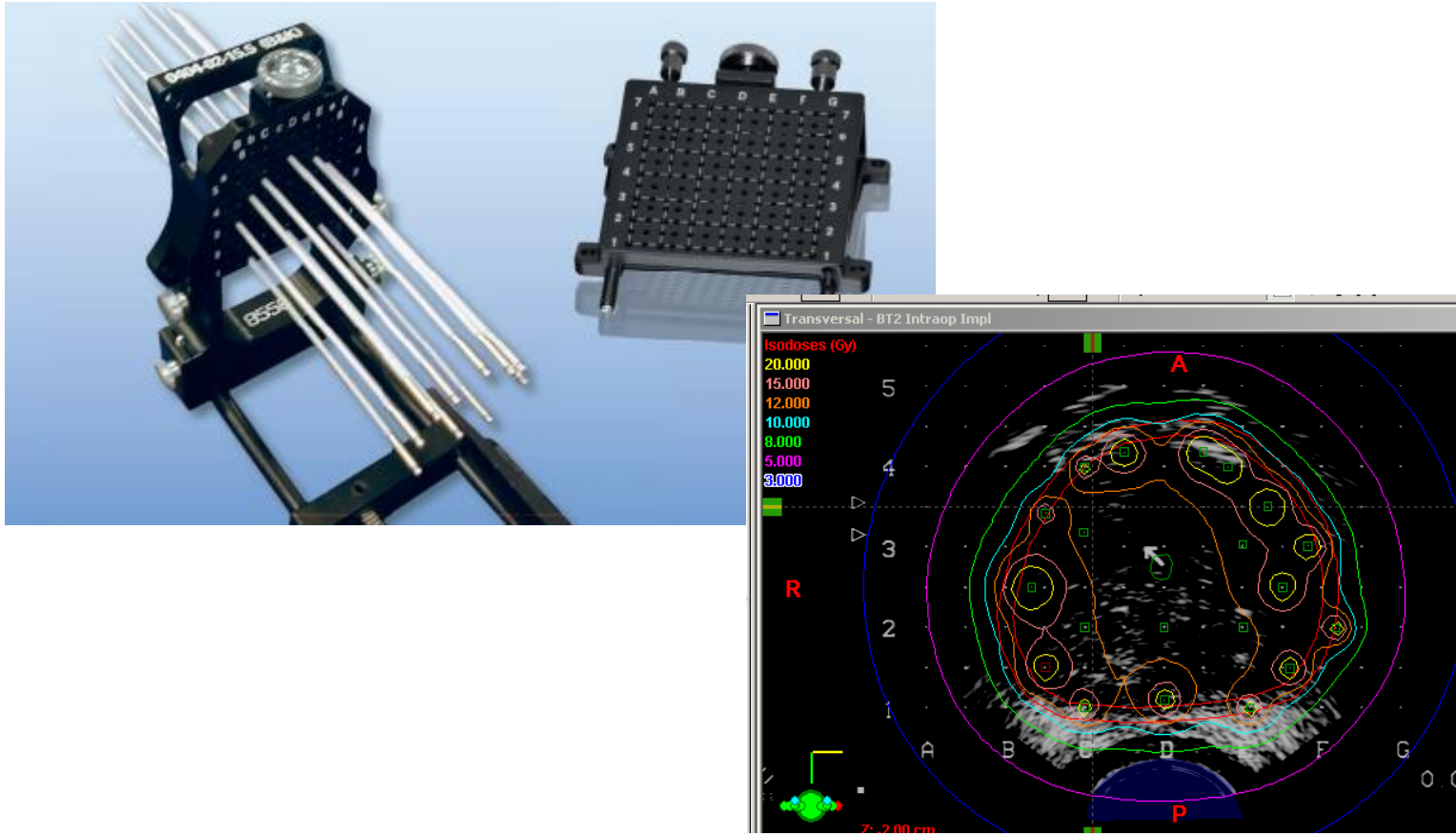
Interstitial applicator



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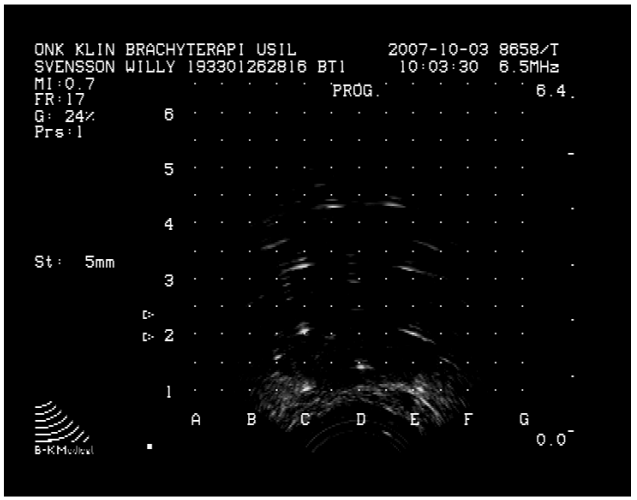
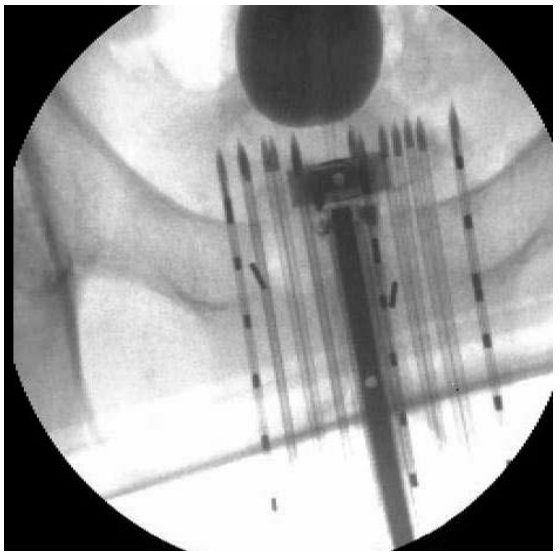
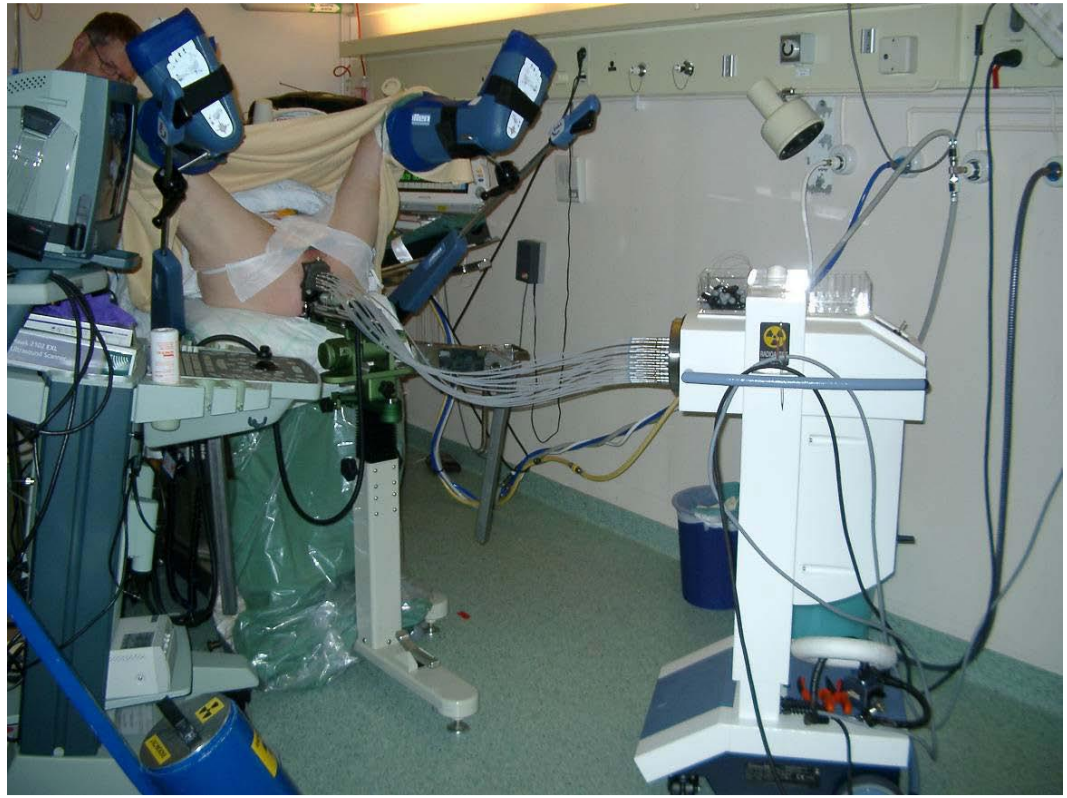
Interstitial applicator





Treatment delivery



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Treatment delivery

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