Outline: GSI accelerator medical application

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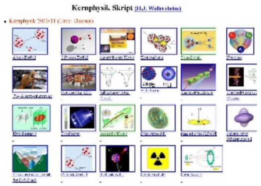
web-page: https://web-docs.gsi.de/~wolle/ and click on

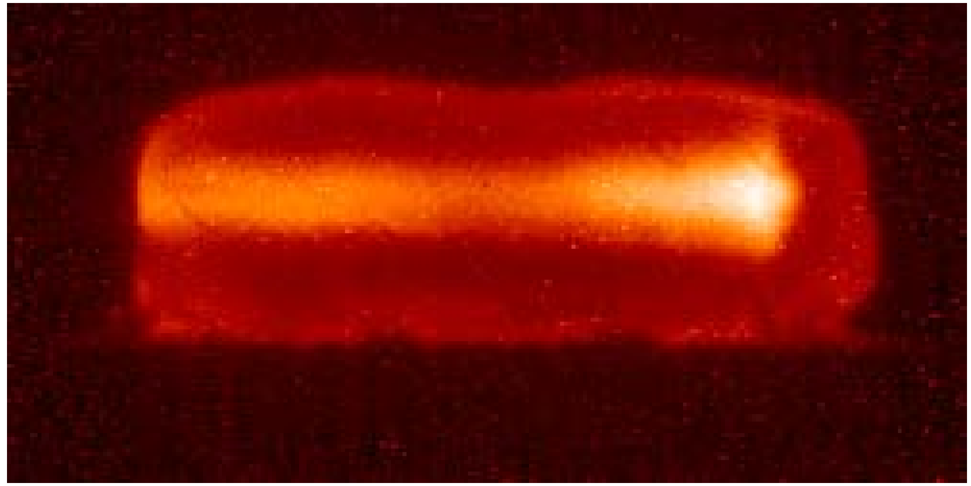


1. interaction of ions with matter
2. physics and biology of radiation therapy
3. ion beam therapy
4. radiopharmaceuticals, radioisotopes

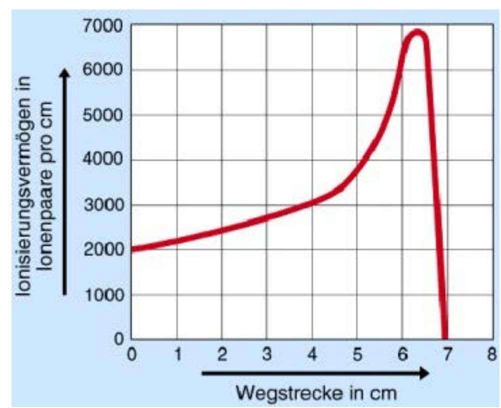
Interaction of Ions with Matter

Matter block

Intensive
heavy ion pulse

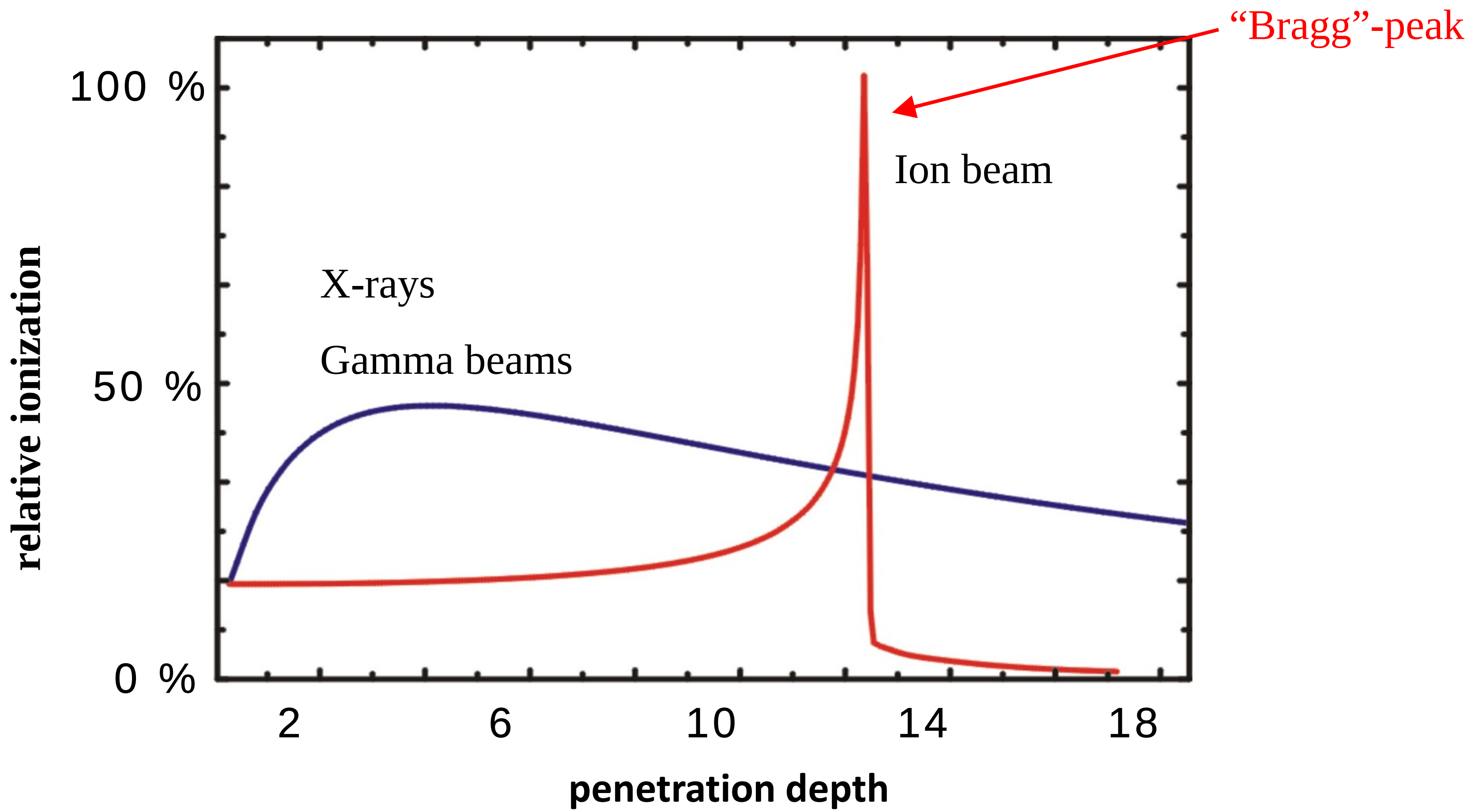


30 mm



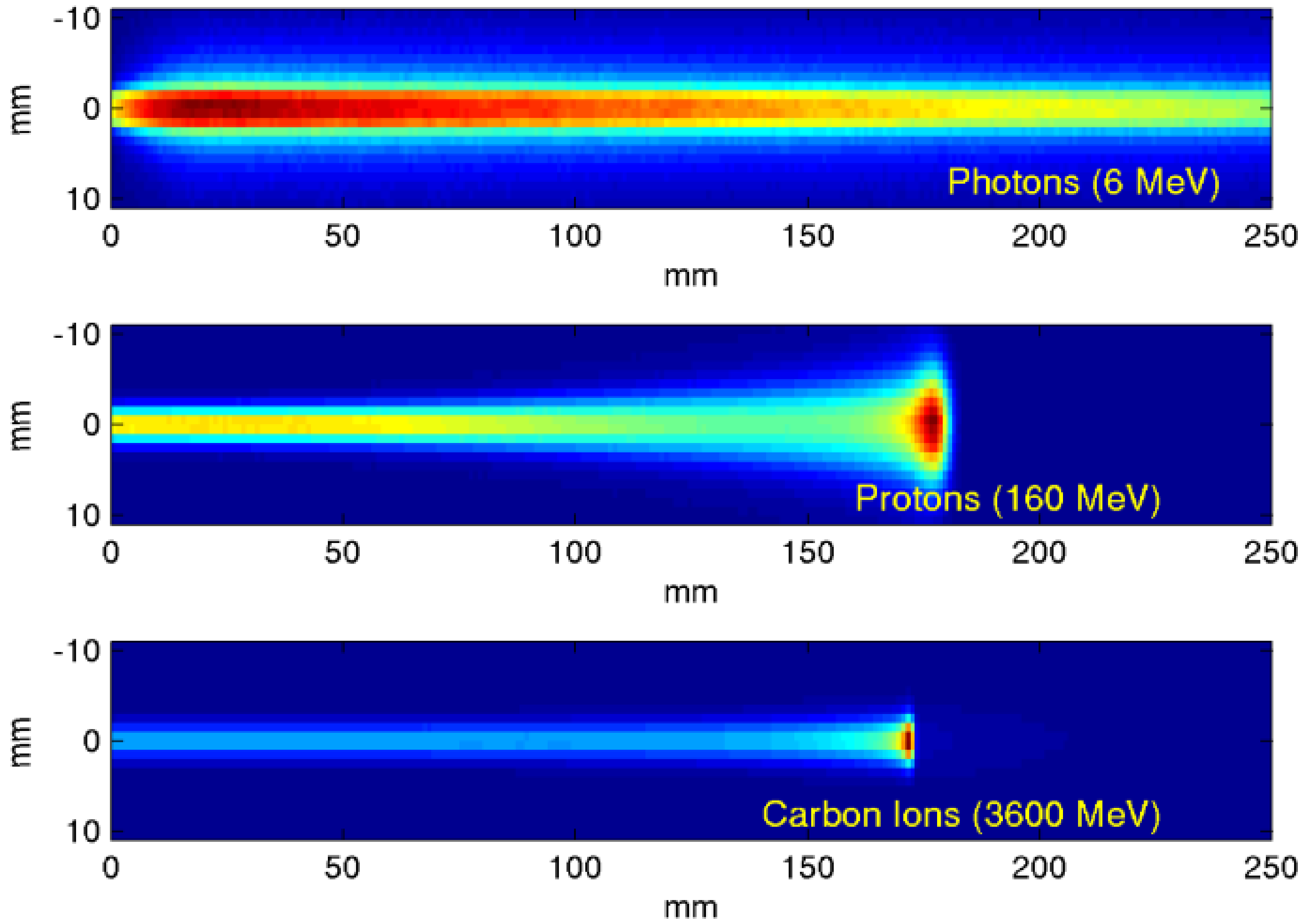
Hadron beams slow down and stop, depositing the energy at the very end of the pass

Radiation Effects

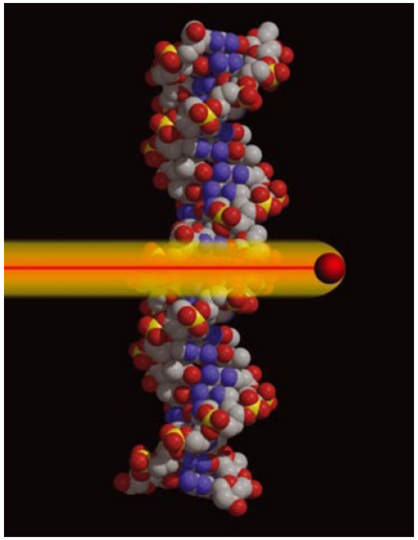


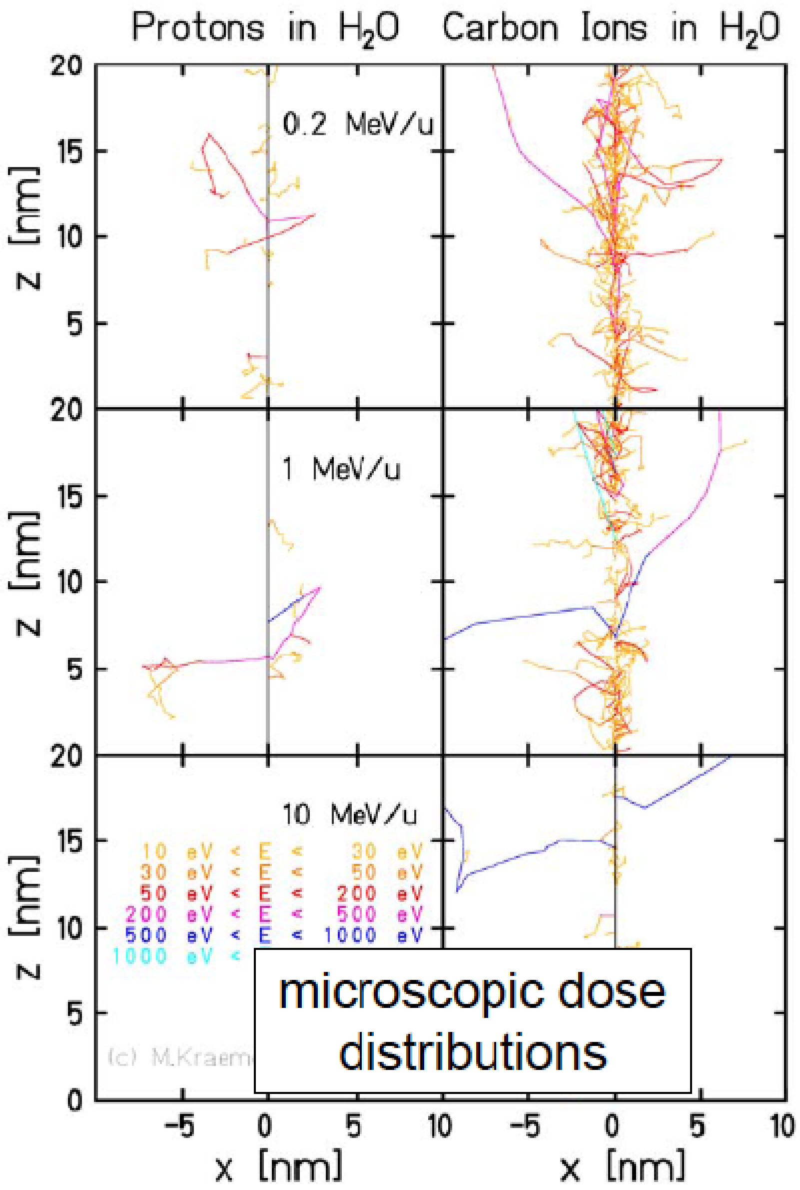
- Hadron beams slow down and stop, depositing the energy at the very end of the pass.
- γ-rays deposit the energy evenly through the tissue.

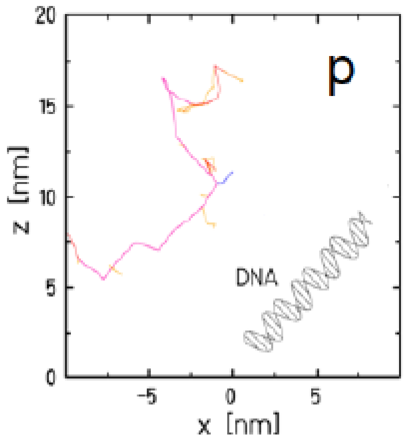
Radiation Effects

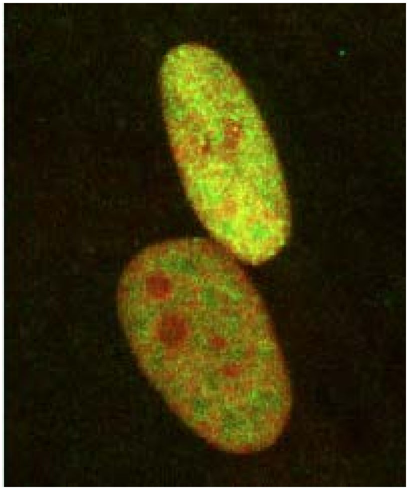


Basic effect of radiation on cells: Energy loss in matter leads to defects in the DNA – double strand breaks of the DNA kills the cell. Tumor cells have less repair capabilities than normal cells.



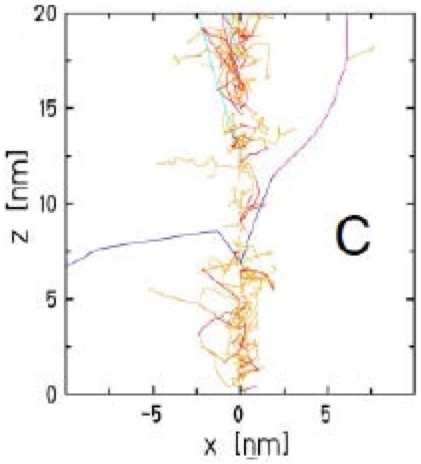


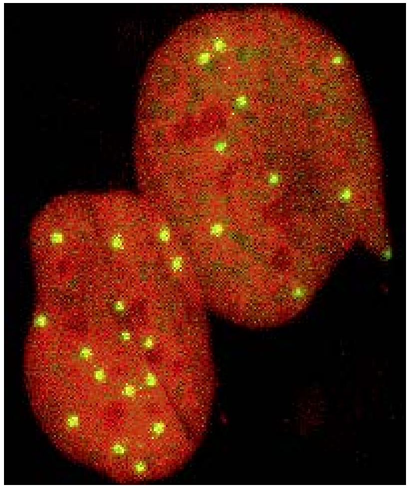




Low LET

homogeneous deposition of dose



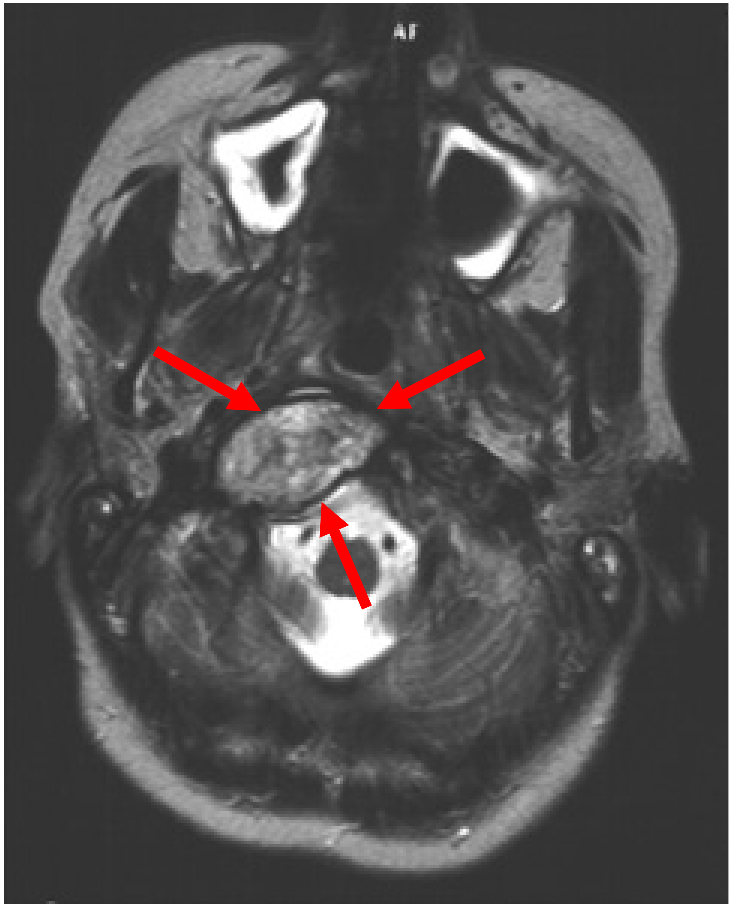


High LET

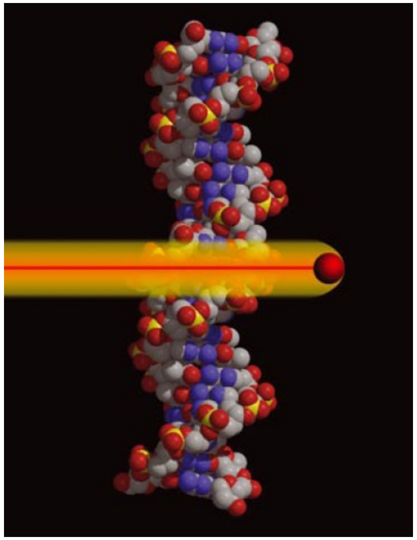
Local deposition of high doses

LET: linear energy transfer

Treatment of Disease

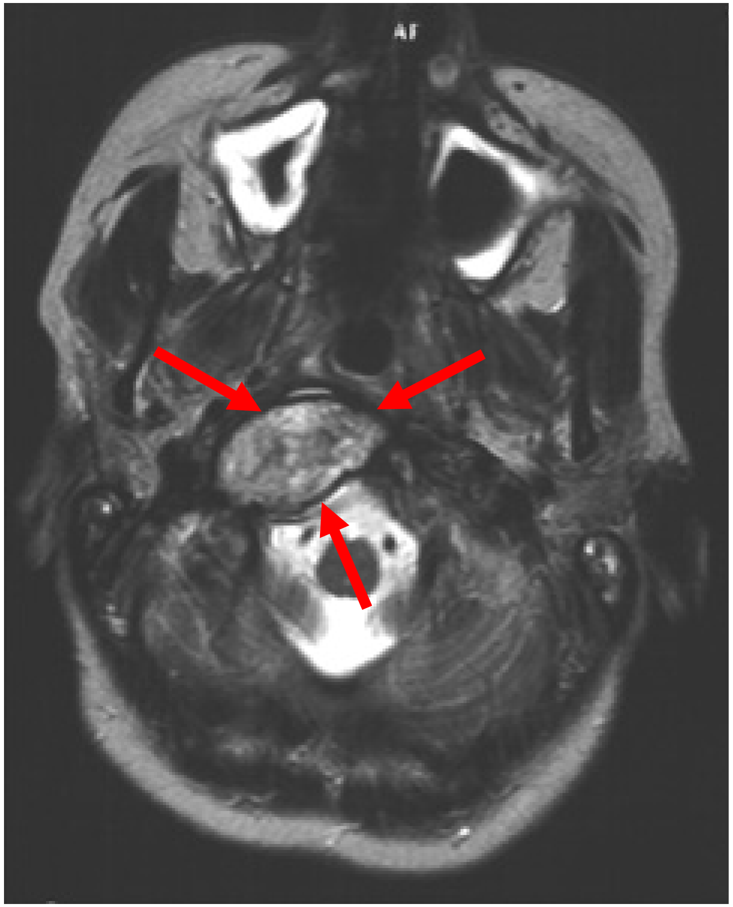


before treatment

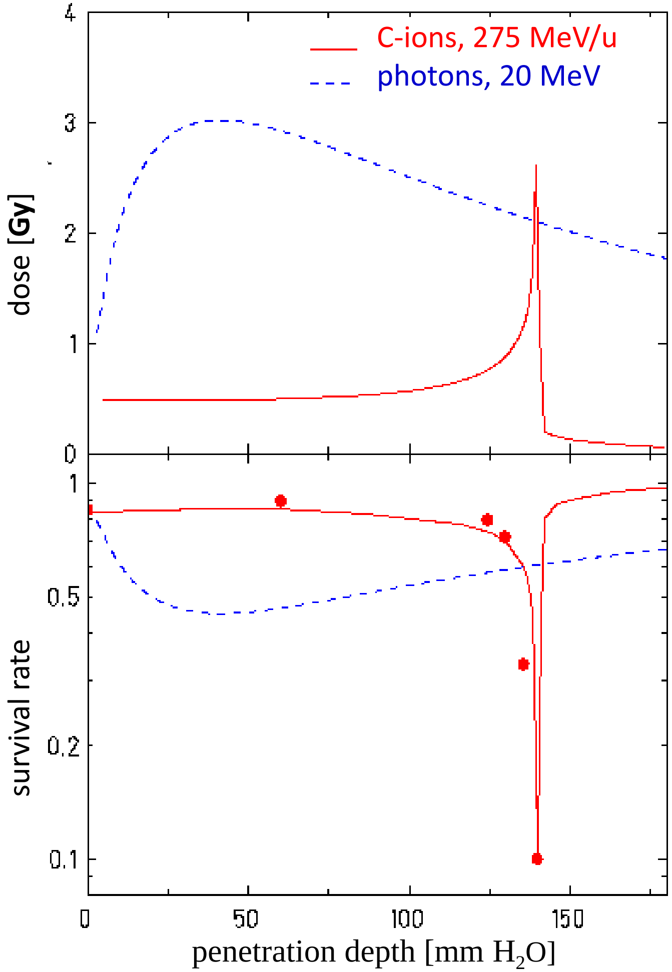


DNA-molecule
with a passing C-ion

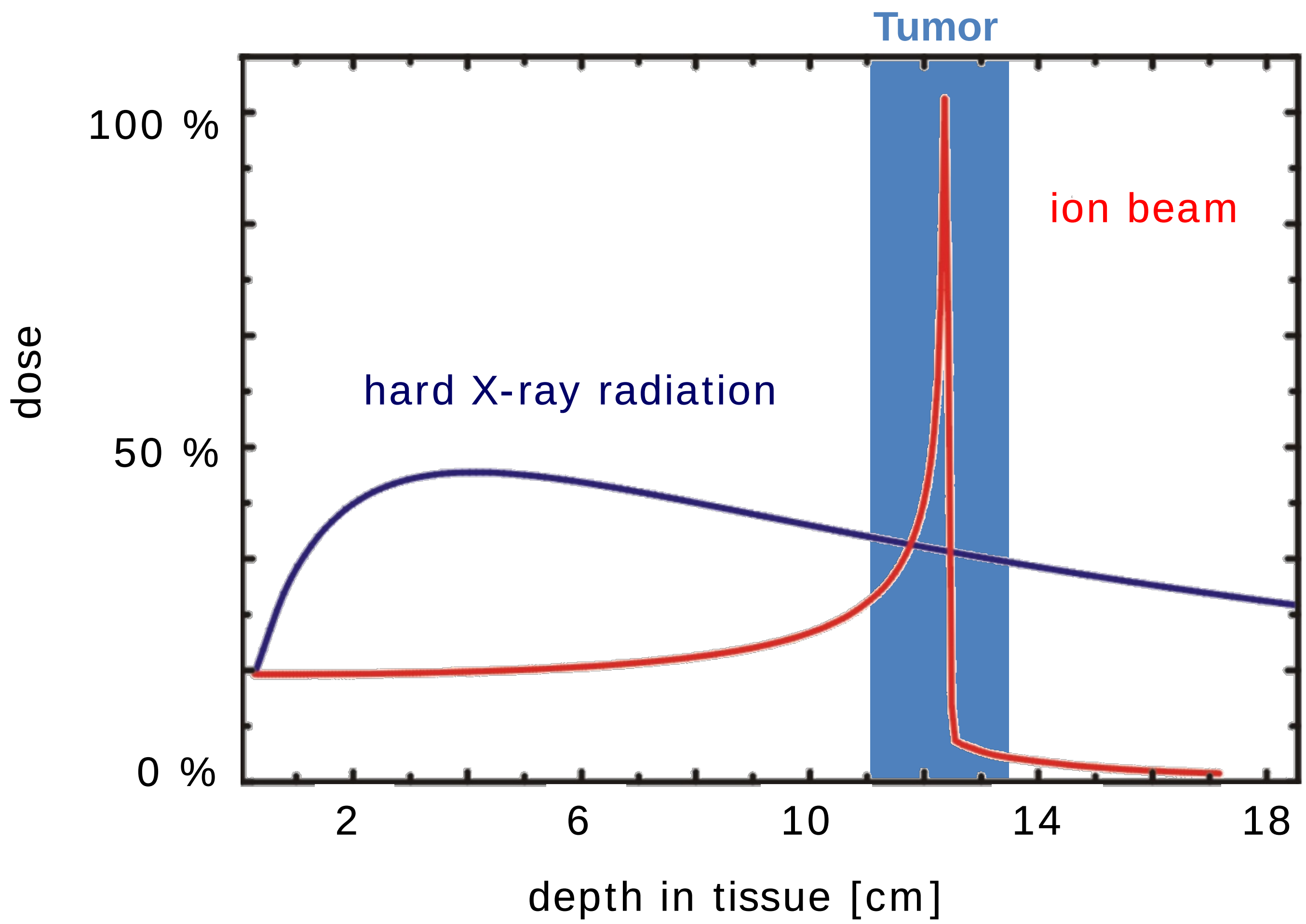
Treatment of Disease



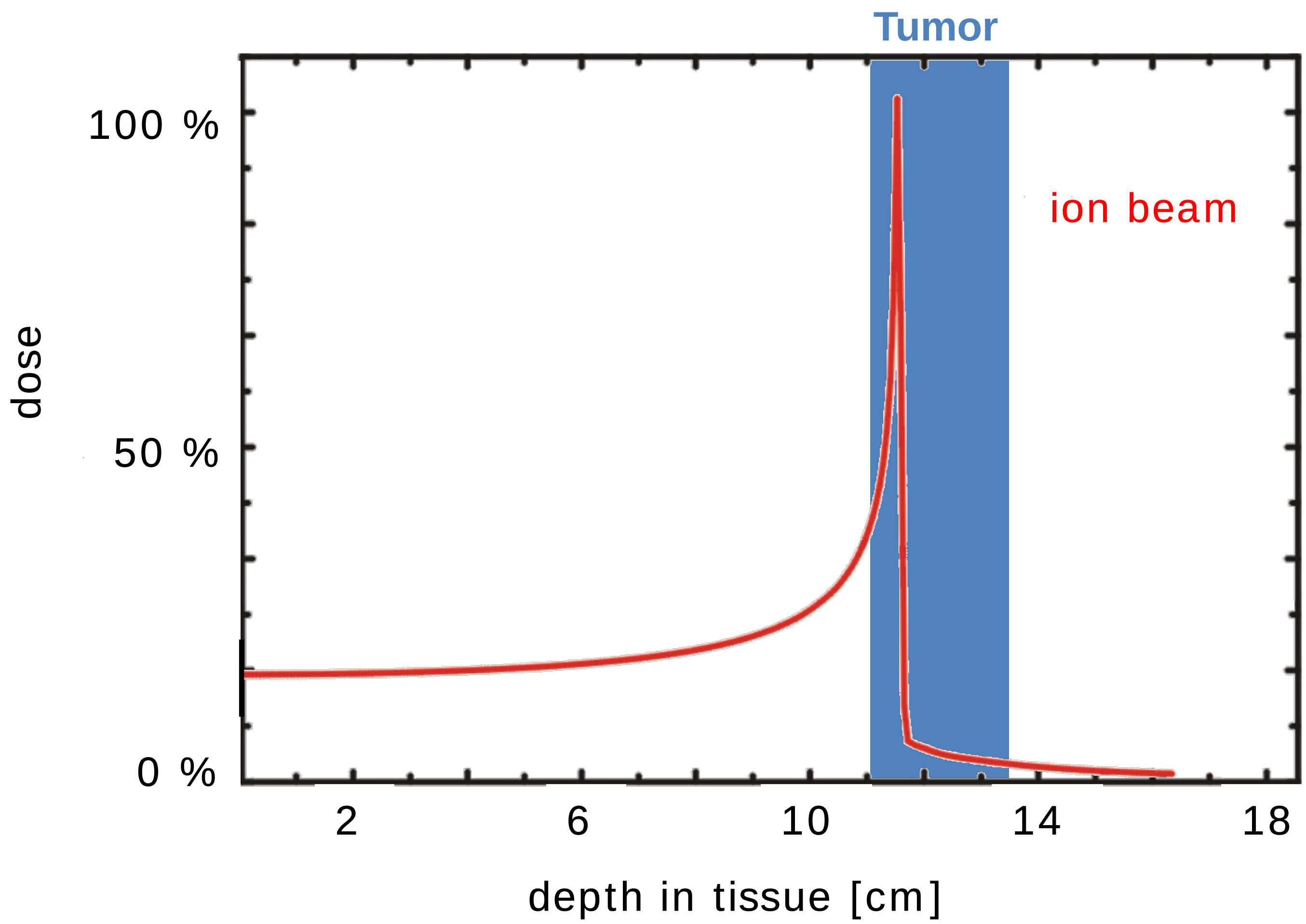
before treatment

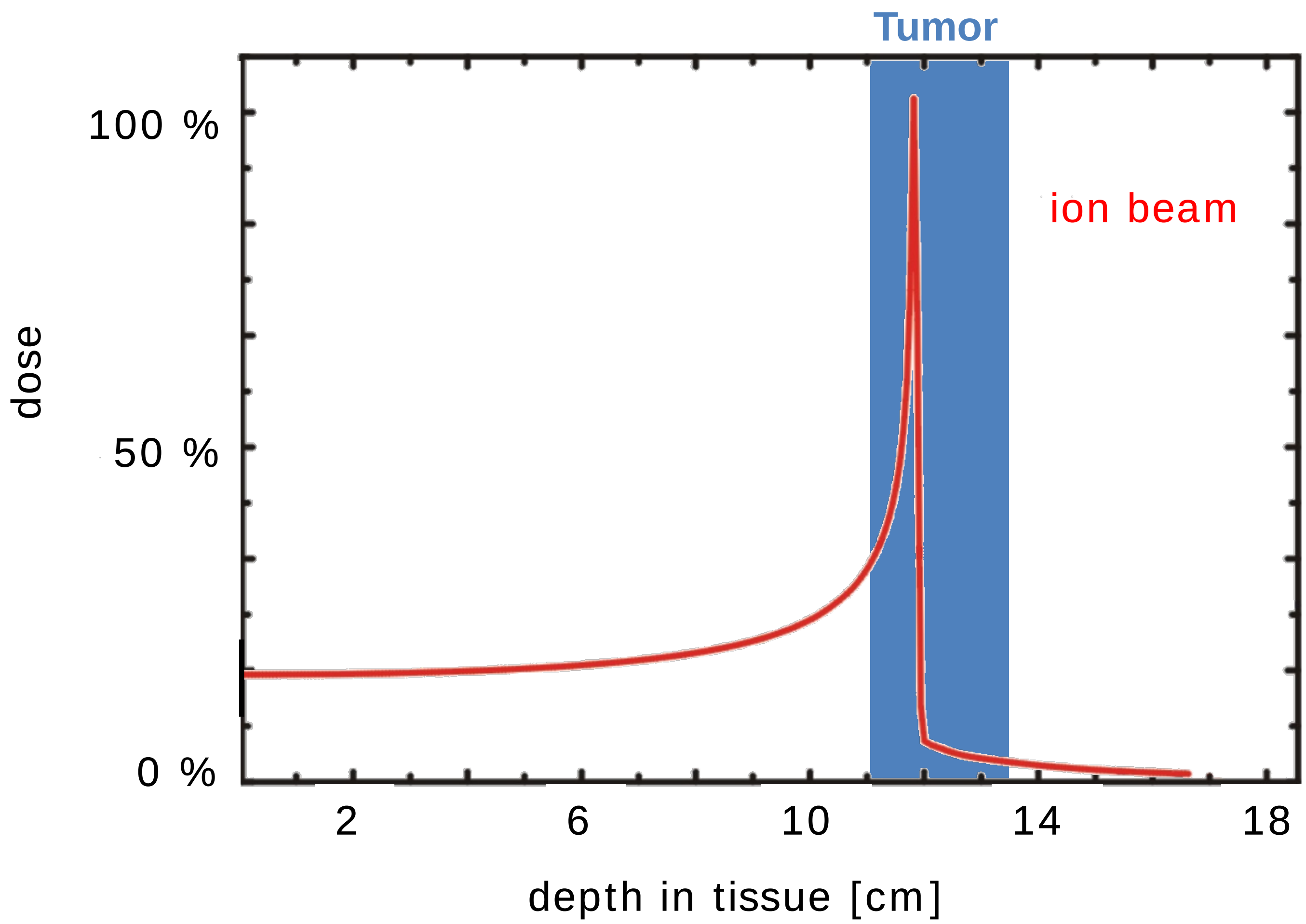


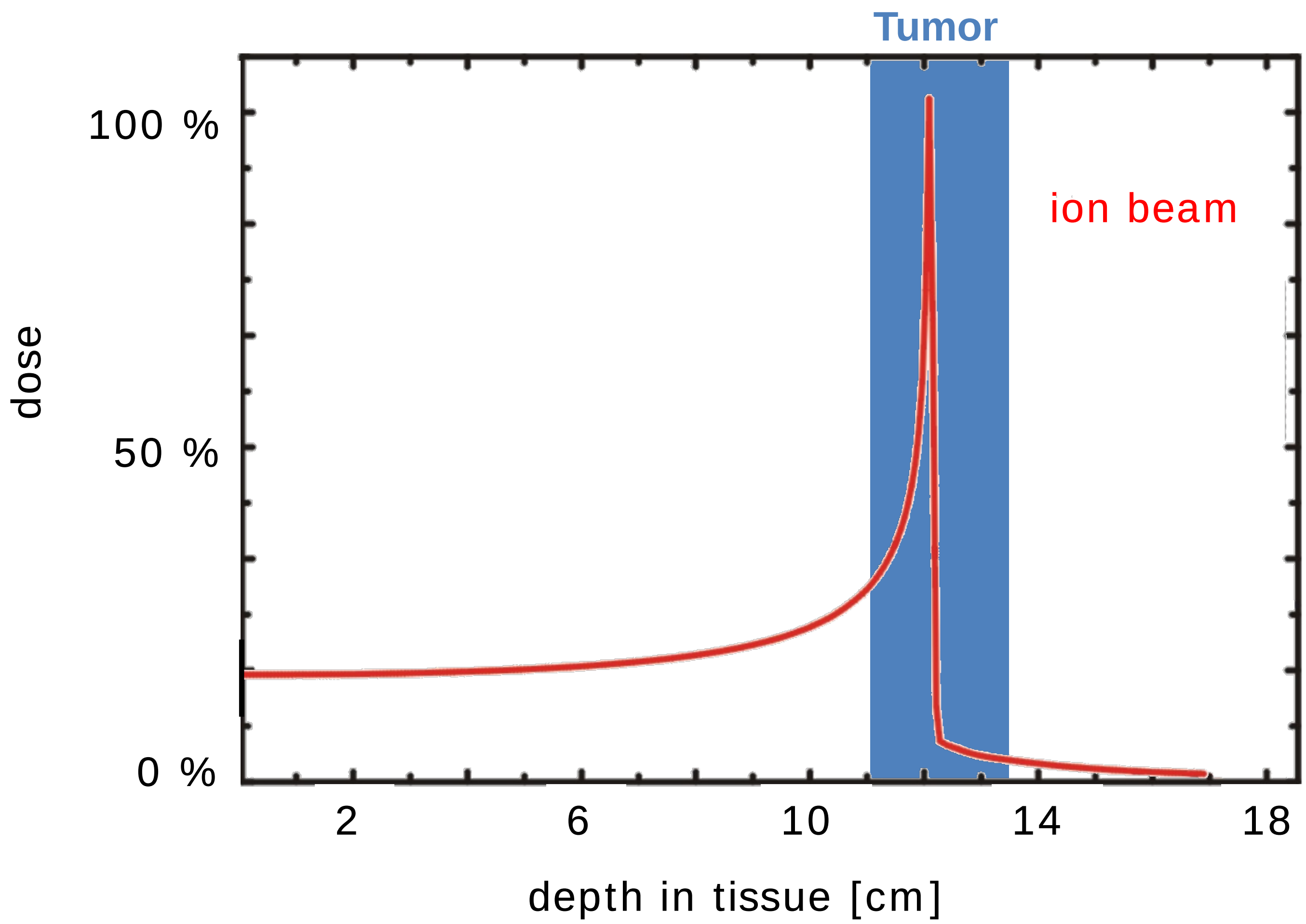
Radiation Effects



Radiation Effects




Tumor
ion beam
100 %
50 %
0 %
dose
2
6
10
14
18
depth in tissue [cm]


Tumor
100 %
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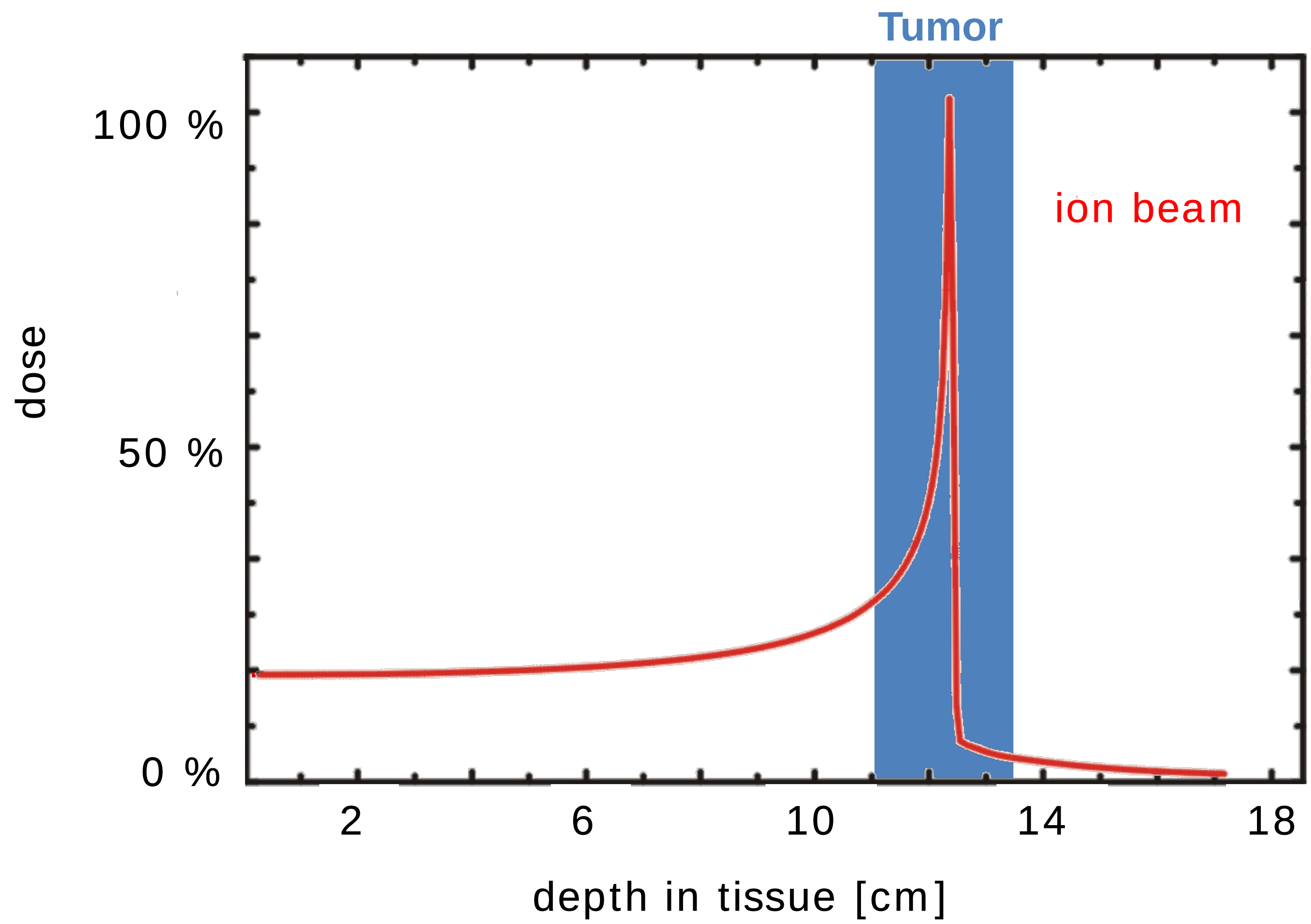
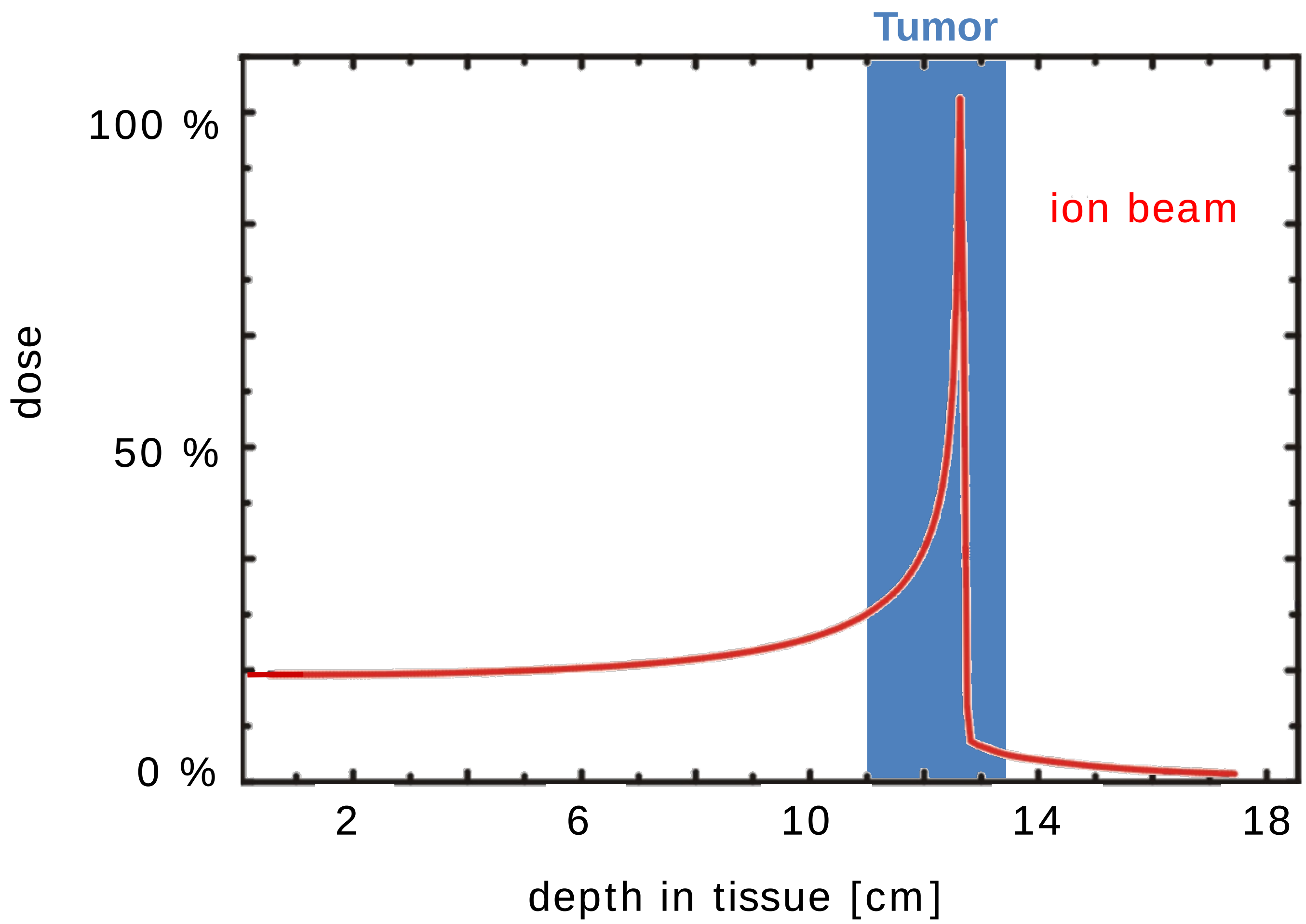
depth in tissue [cm]

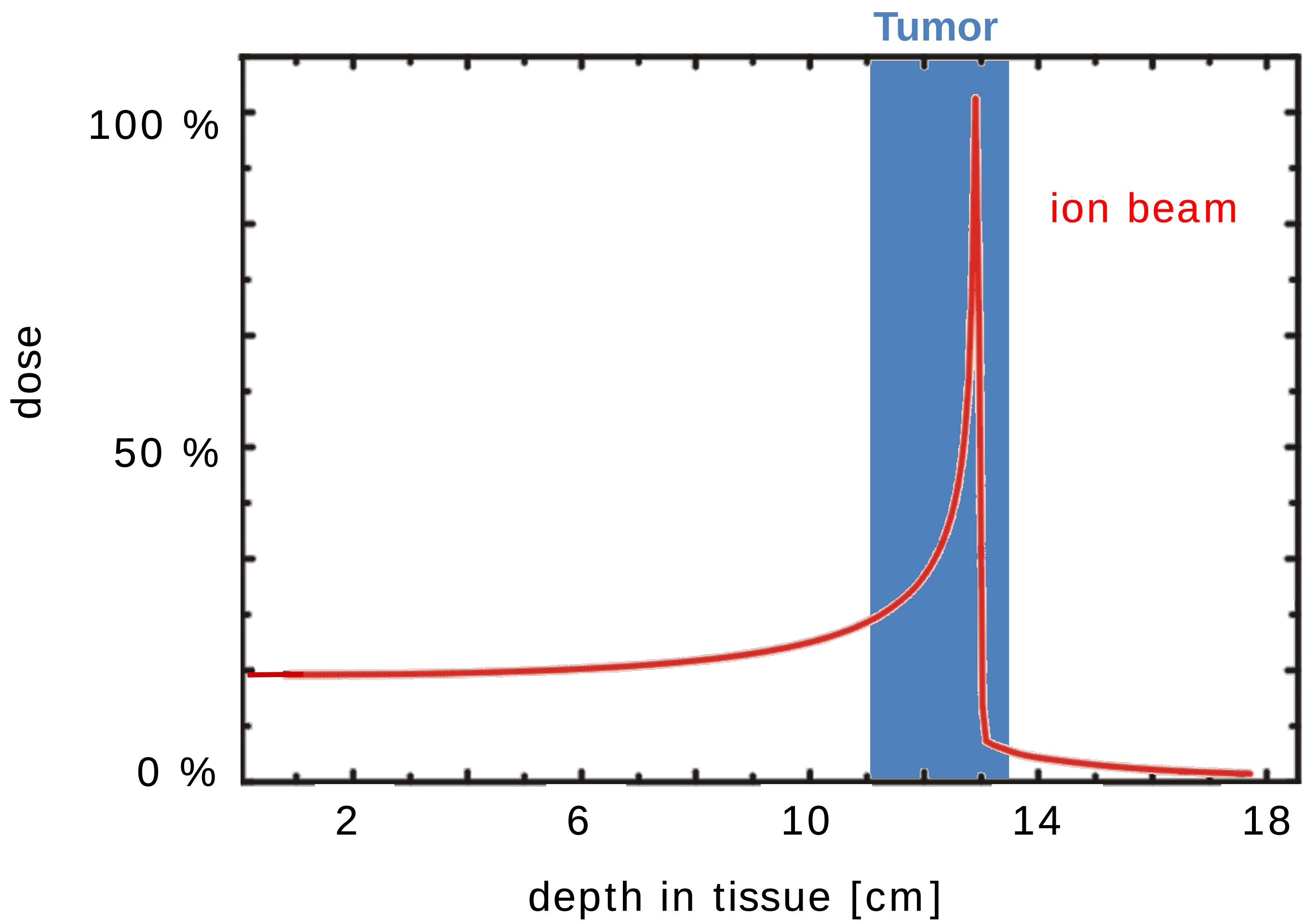
Radiation Effects

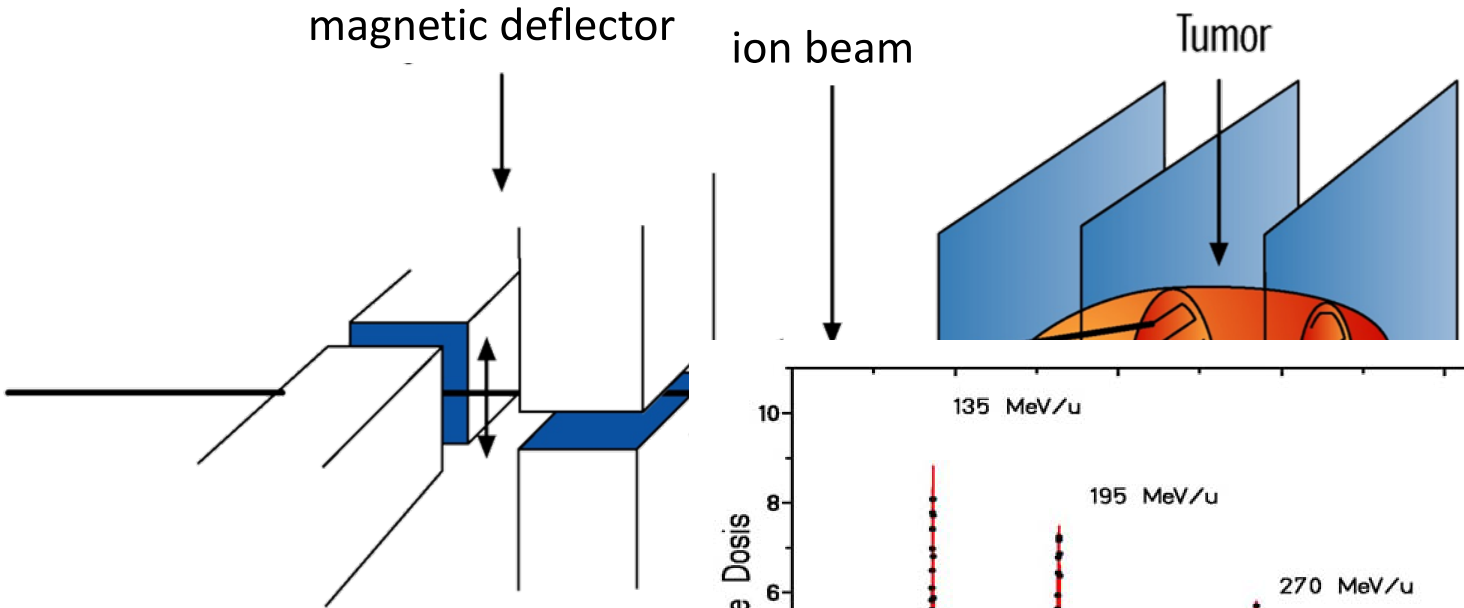


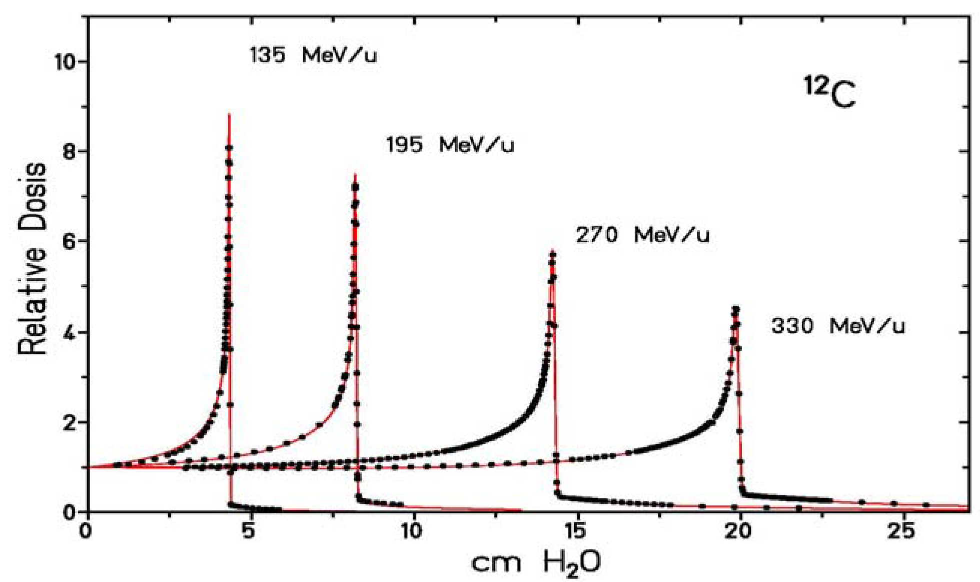
Radiation Effects



Radiation Effects



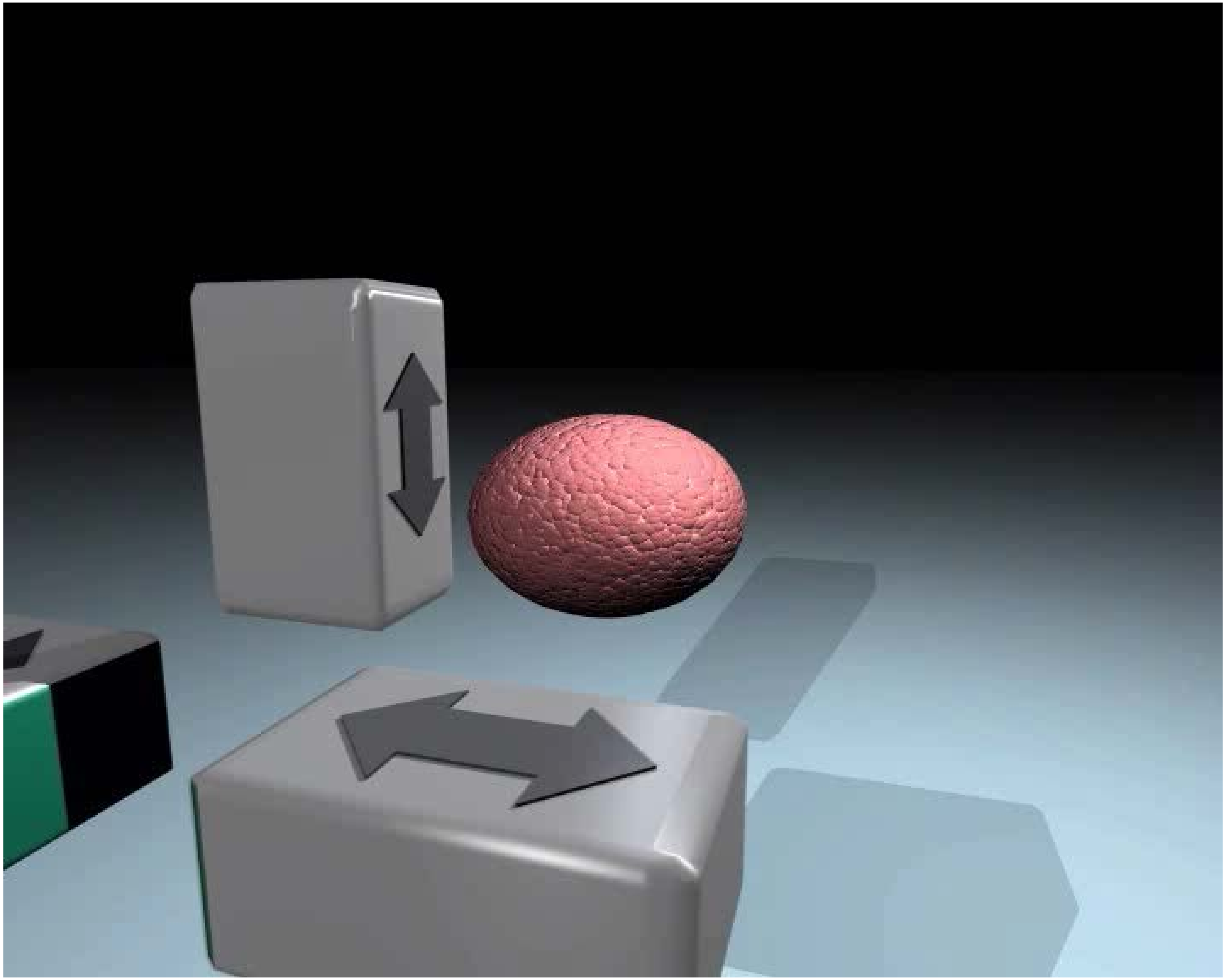




intensity controlled

raster scan procedure

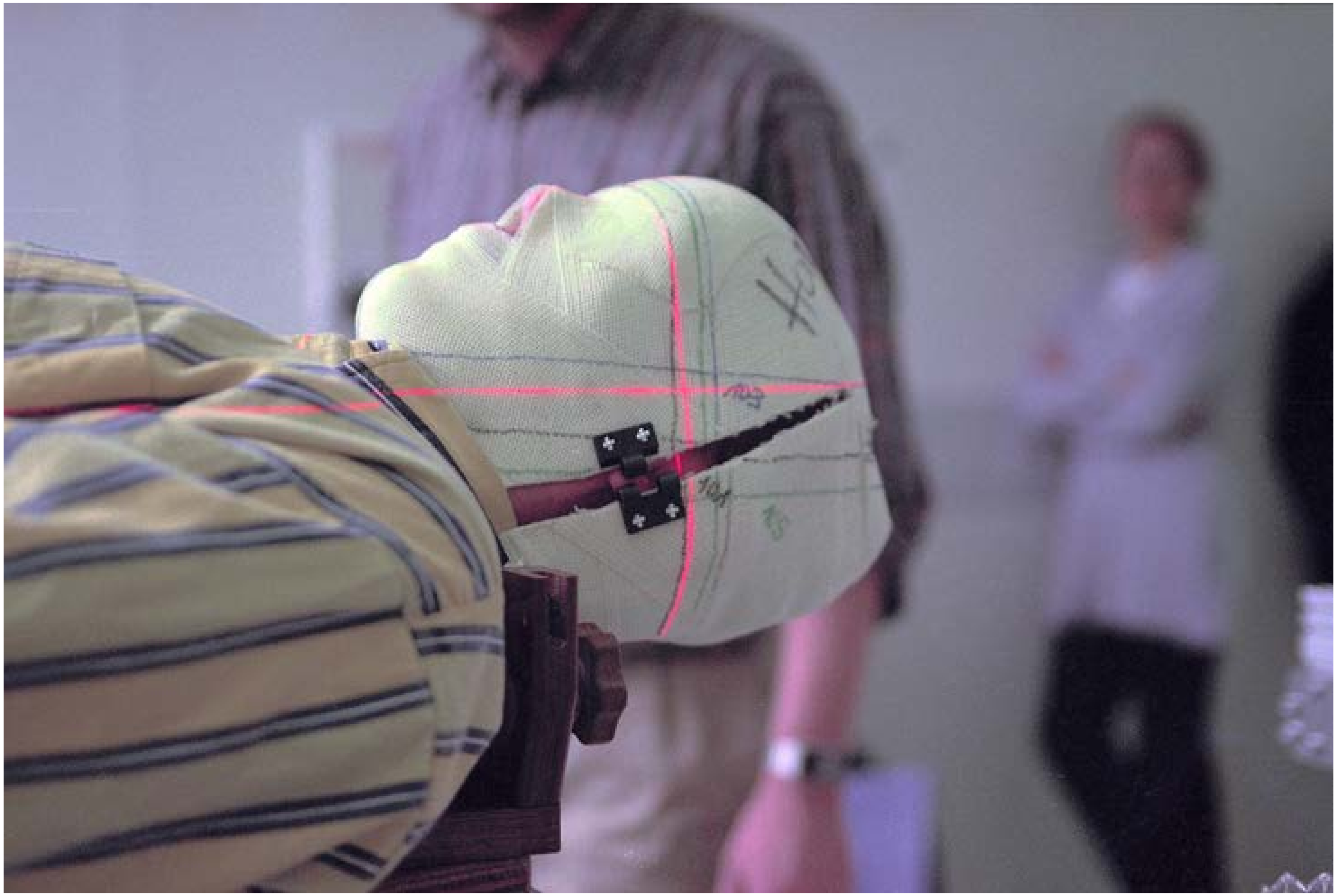
Ion Beam Therapy



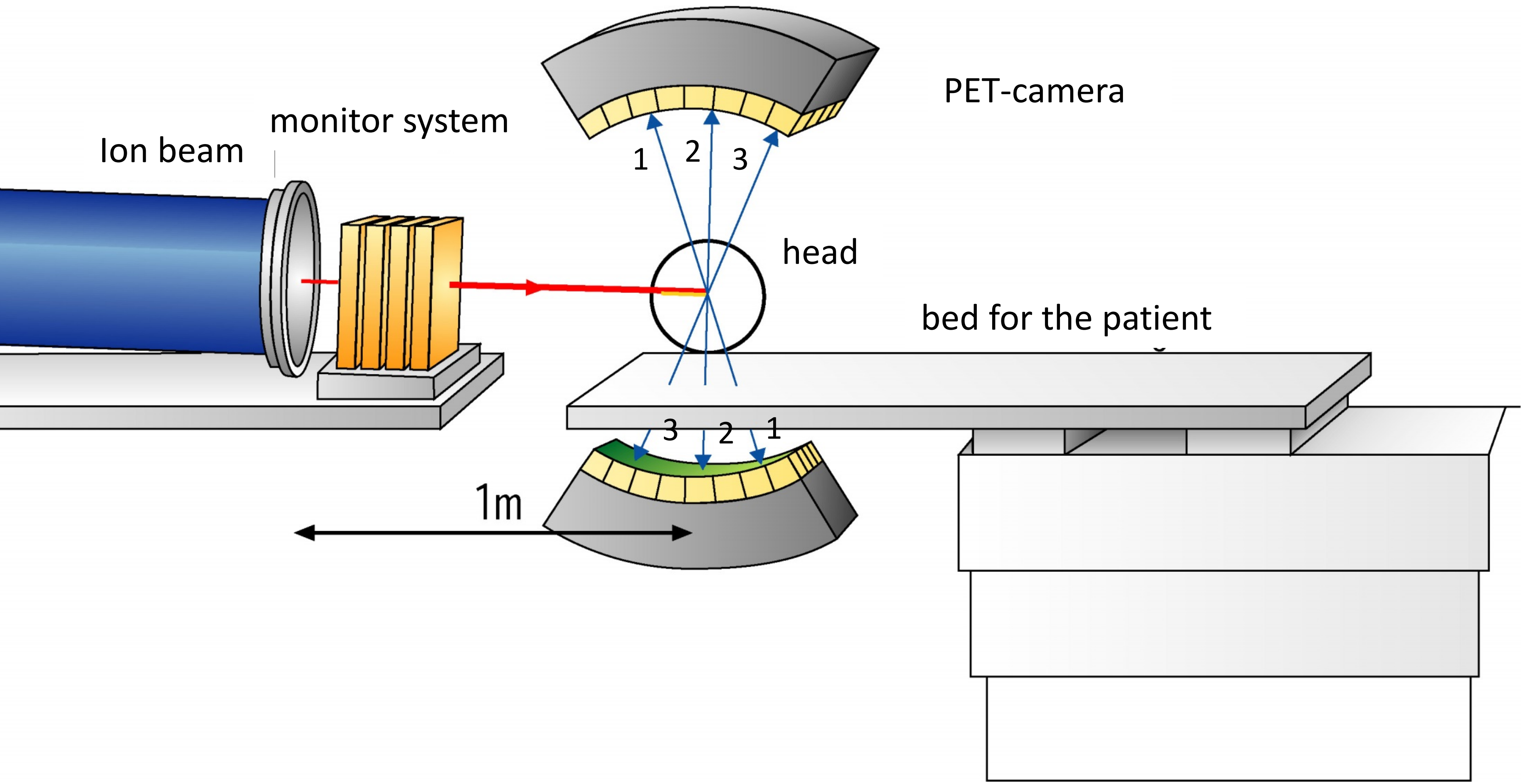
Ion Beam Therapy

448 patients were treated with carbon beams from 1997 – 2008 using raster scanning technique

Ion Beam Therapy

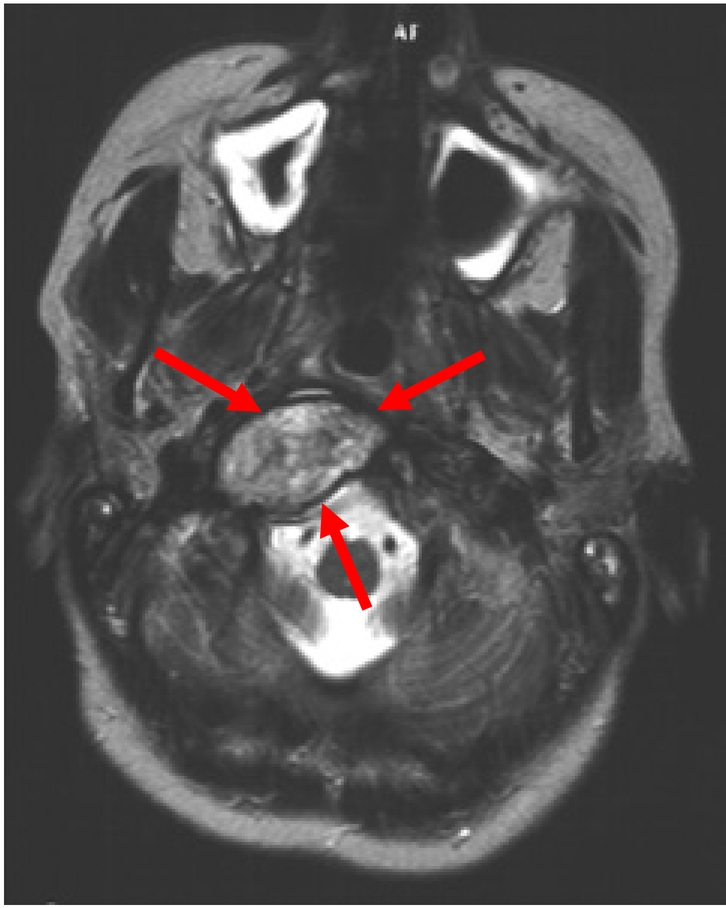


PET - Camera

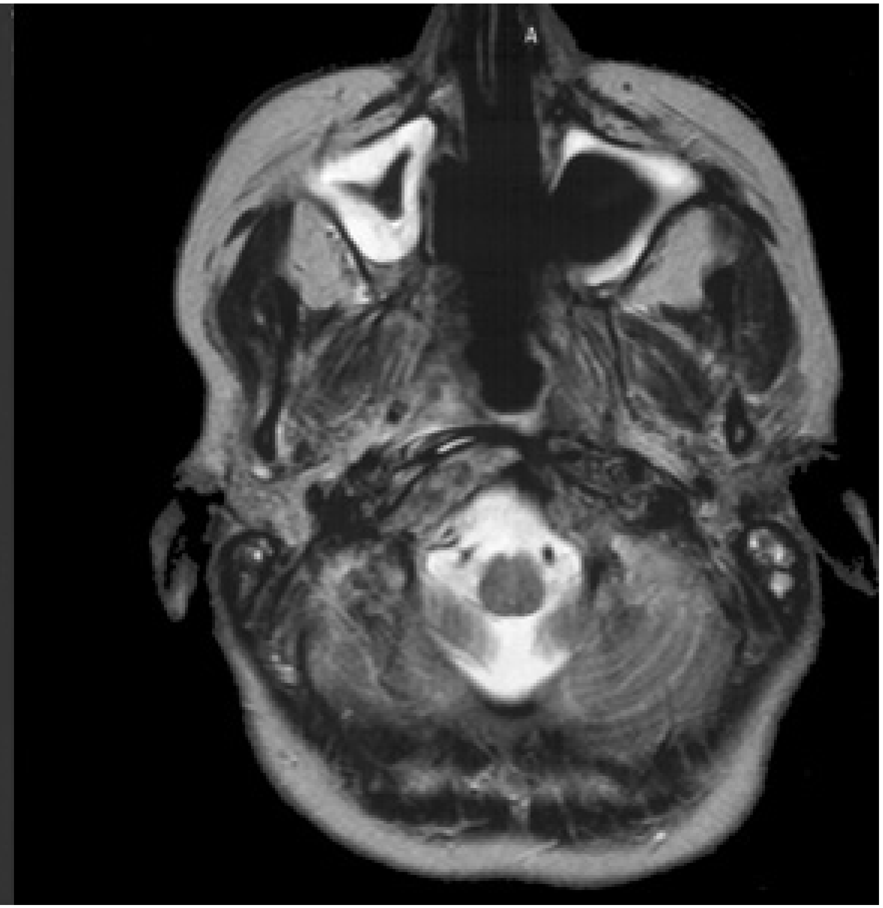


PET-camera
monitor system
Ion beam
1
2
3
head
bed for the patient
3
2
1
1m

Course of Disease



before treatment



after treatment with ion beam

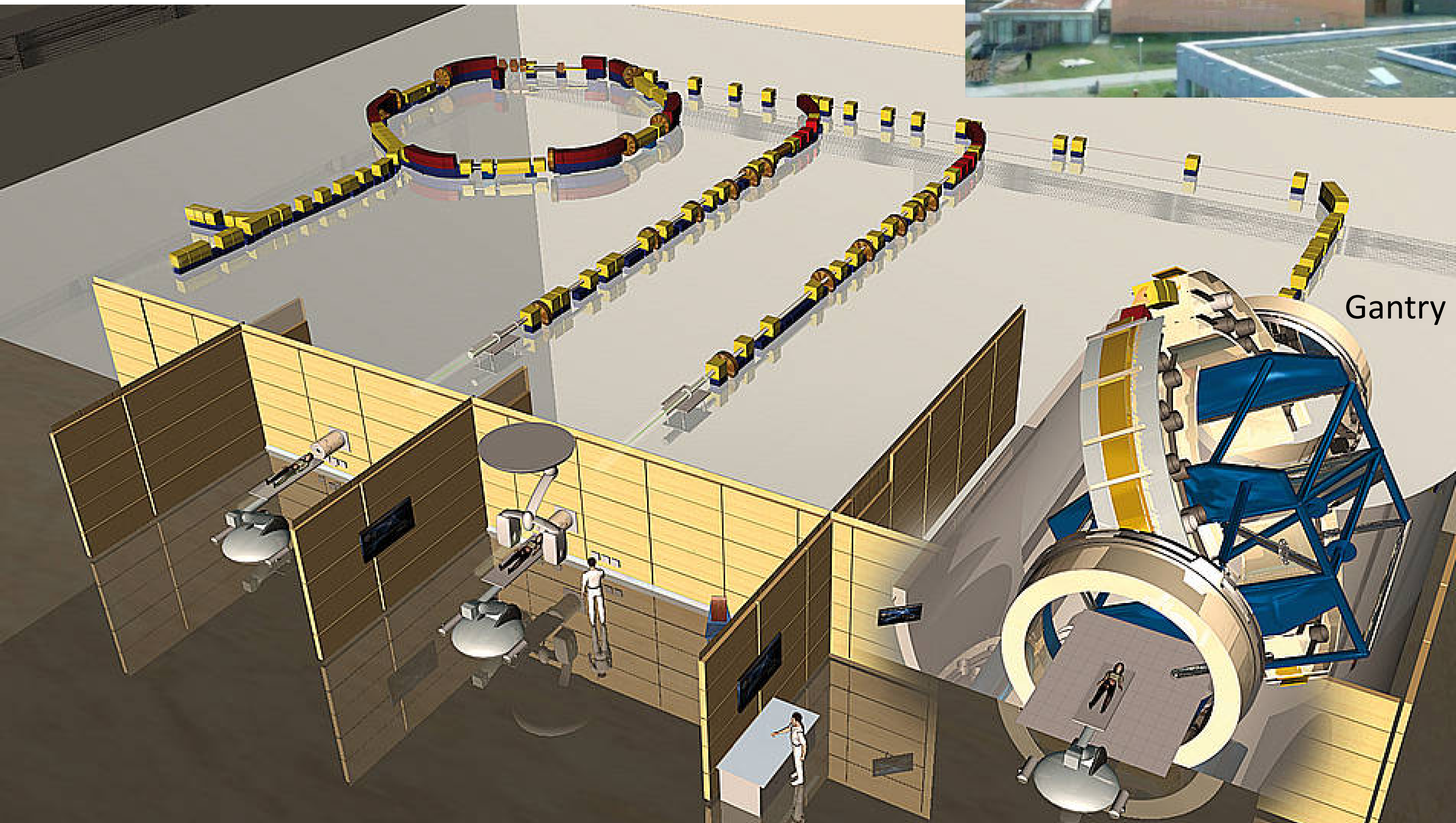
Course of Disease

before treatment

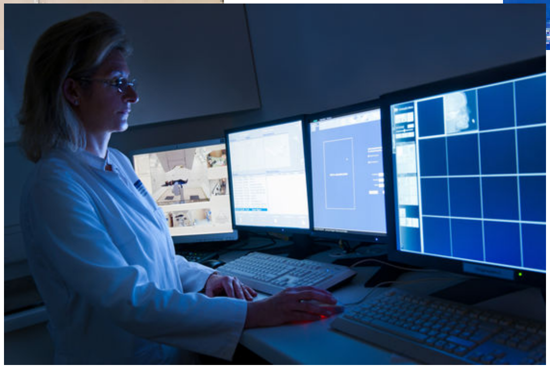
6 weeks after treatment
with Carbon ion beam

Heidelberg Ion-Beam Therapy Center (HIT)

Heidelberg Ion-Beam Therapy Center (HIT)



Heidelberg Ion-Beam Therapy Center (HIT)



p, d, ^{3}He, ^{4}He beams

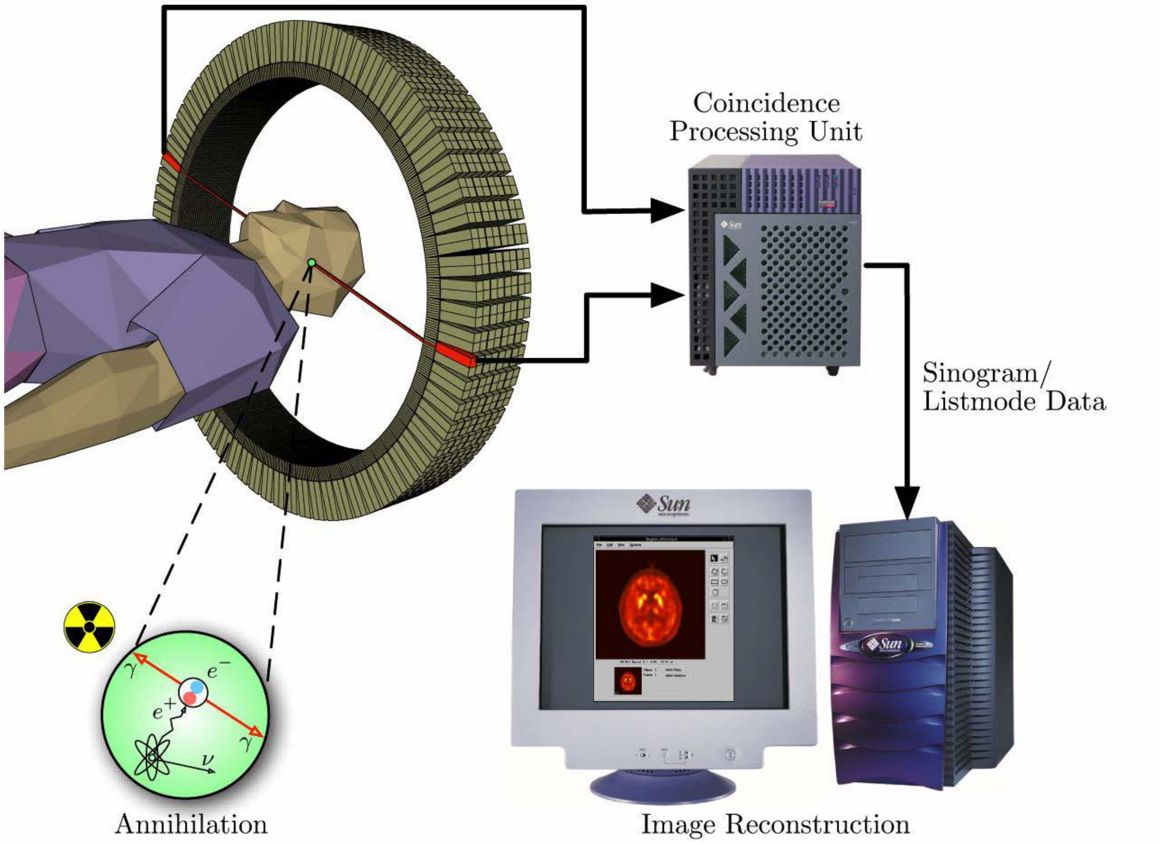
Isotopes used for PET, SPECT and Brachytherapy etc.

TABLE 2.1. THE RADIOISOTOPES THAT HAVE BEEN USED AS TRACERS IN THE PHYSICAL AND BIOLOGICAL SCIENCES

Isotope	Isotope	Isotope
Actinium-225	**Fluorine-18**	**Oxygen-15**
Arsenic-73	**Gallium-67**	**Palladium-103**
Arsenic-74	**Germanium-68**	**Sodium-22**
Astatine-211	Indium-110	**Strontium-82**
Beryllium-7	**Indium-111**	Technetium-94m
Bismuth-213	Indium-114m	**Thallium-201**
Bromine-75	Iodine-120g	Tungsten-178
Bromine-76	Iodine-121	Vanadium-48
Bromine-77	**Iodine-123**	Xenon-122
Cadmium-109	**Iodine-124**	Xenon-127
Carbon-11	Iron-52	**Yttrium-86**
Chlorine-34m	Iron-55	Yttrium-88
Cobalt-55	**Krypton-81m**	Zinc-62
Cobalt-57	Lead-201	Zinc-63
Copper-61	Lead-203	Zirconium-89
Copper-64	Mercury-195m	
Copper-67	**Nitrogen-13**	

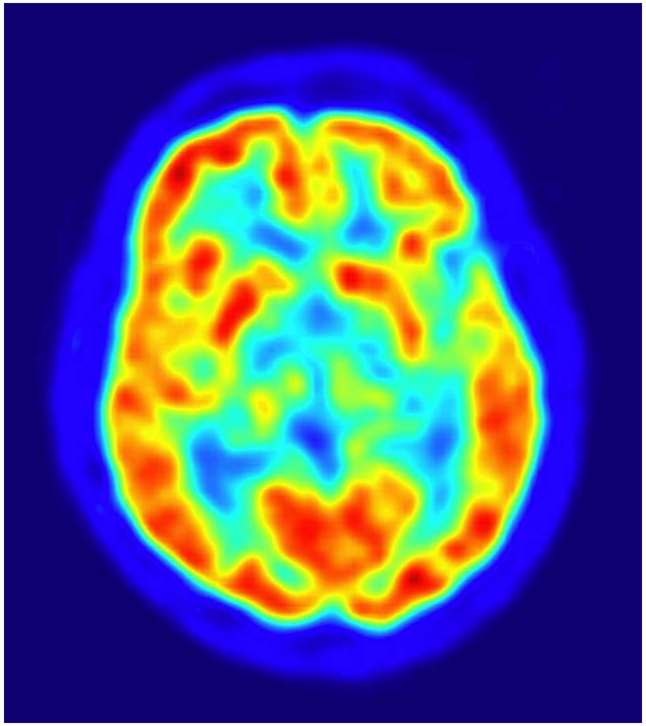
Radioisotope production

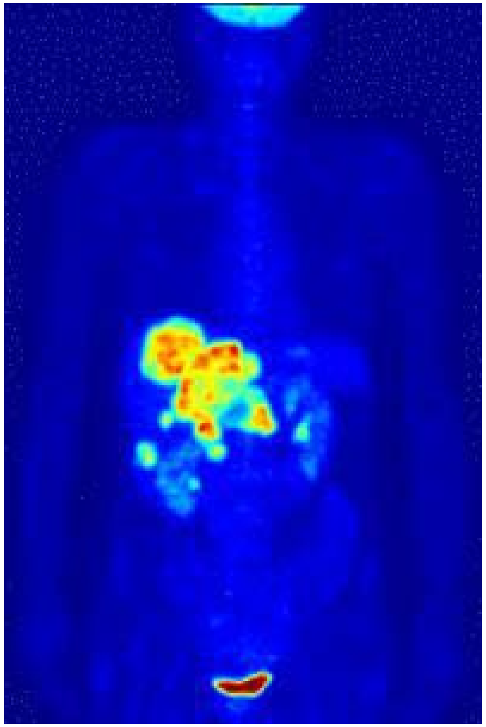
- Accelerators (compact cyclotrons or linacs) are used to produce radio-isotopes for medical imaging.
- 7-11 MeV protons for short-lived isotopes for imaging
- 70-100 MeV or higher for longer lived isotopes.



- Positron emission tomography (PET) uses Fluorine-18, half life of ~ 110 min

Radioisotope production





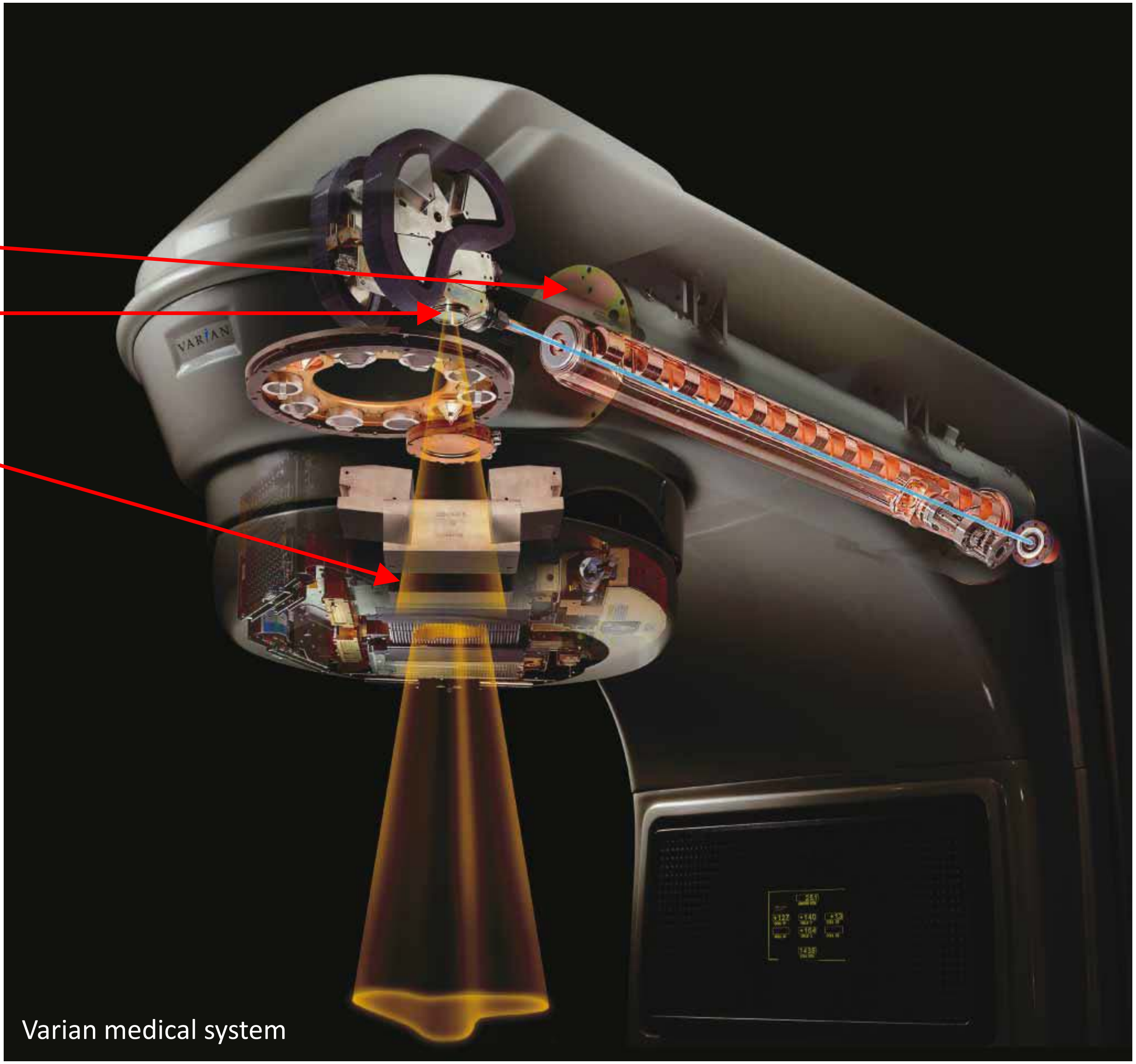
- Fluorodeoxyglucose or FDG carries the 18F to areas of high metabolic activity
- 90% of PET scans are in clinical oncology

X-Ray Radiotherapy

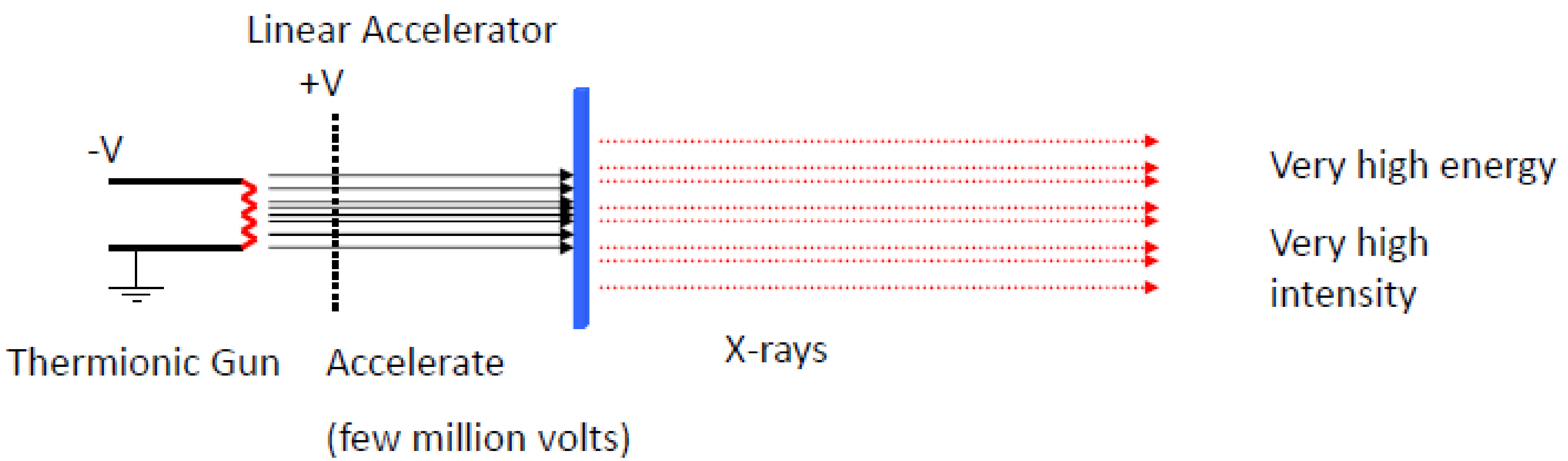
Linac

Foil to produce X-rays

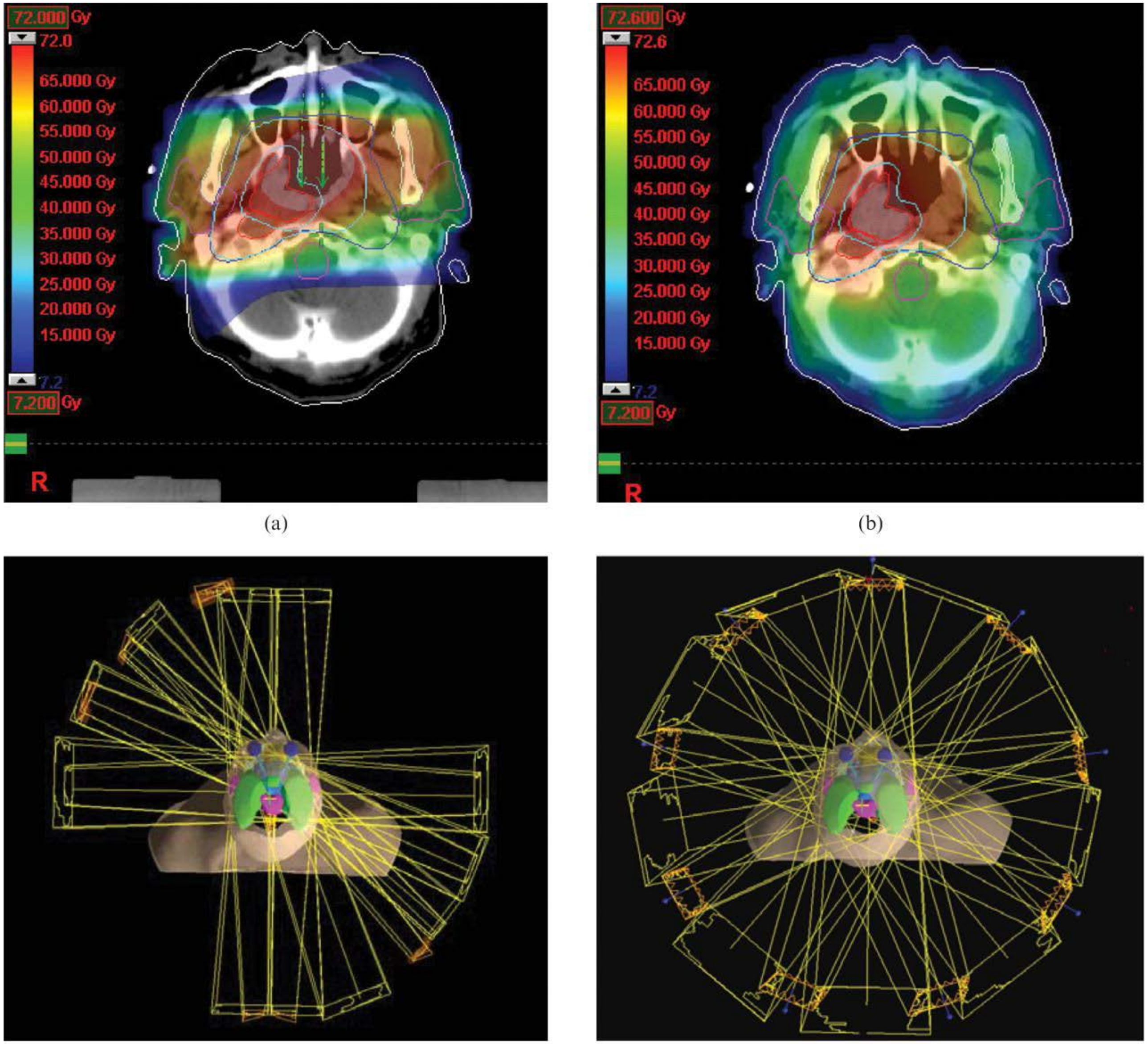
Collimation system



X-Ray Radiotherapy



X-ray radiotherapy source


72.000 Gy
72.0
65.000 Gy
60.000 Gy
55.000 Gy
50.000 Gy
45.000 Gy
40.000 Gy
35.000 Gy
30.000 Gy
25.000 Gy
20.000 Gy
15.000 Gy
7.2
7.200 Gy
R
72.600 Gy
72.6
65.000 Gy
60.000 Gy
55.000 Gy
50.000 Gy
45.000 Gy
40.000 Gy
35.000 Gy
30.000 Gy
25.000 Gy
20.000 Gy
15.000 Gy
7.2
7.200 Gy
R

(a) (b)

(c) (d)

Equipment Sterilization

Manufacturers of medical disposables have to kill every germ on syringes, bandages, surgical tools and other gear, without altering the material itself.

E-beam sterilization works best on simple, low density products.

Advantages: takes only a few seconds (gamma irradiation can take hours)

Disadvantages: limited penetration depth, works best on simple, low density products (syringes)

The IBA rhodotron – a commercial accelerator used for e-beam sterilization