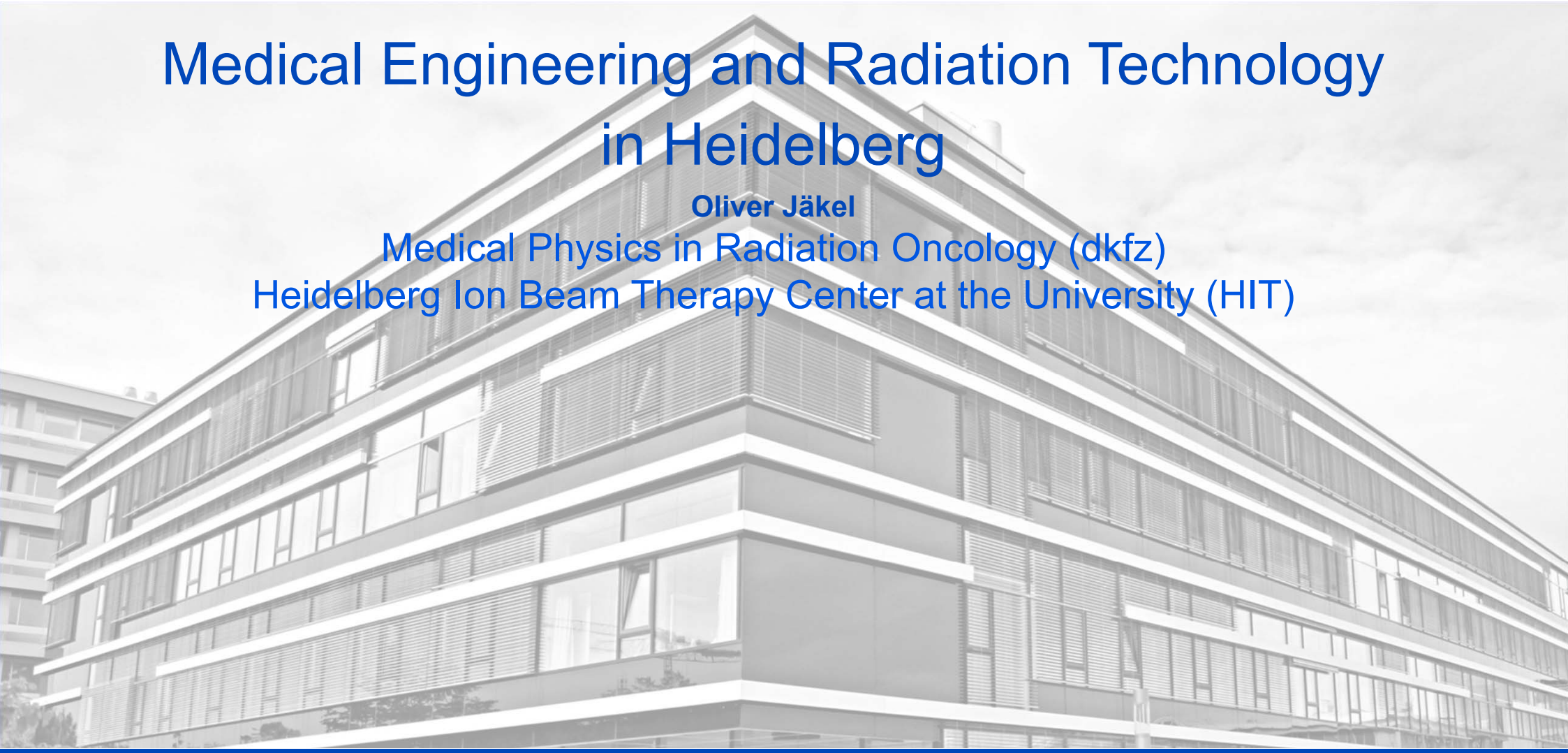
Medical Engineering and Radiation Technology in Heidelberg

Oliver Jäkel
Medical Physics in Radiation Oncology (dkfz)
Heidelberg Ion Beam Therapy Center at the University (HIT)



dkfz.
GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION
Research for a Life without Cancer

Medical ~~Engineering and Radiation Technology~~ Physics in Heidelberg

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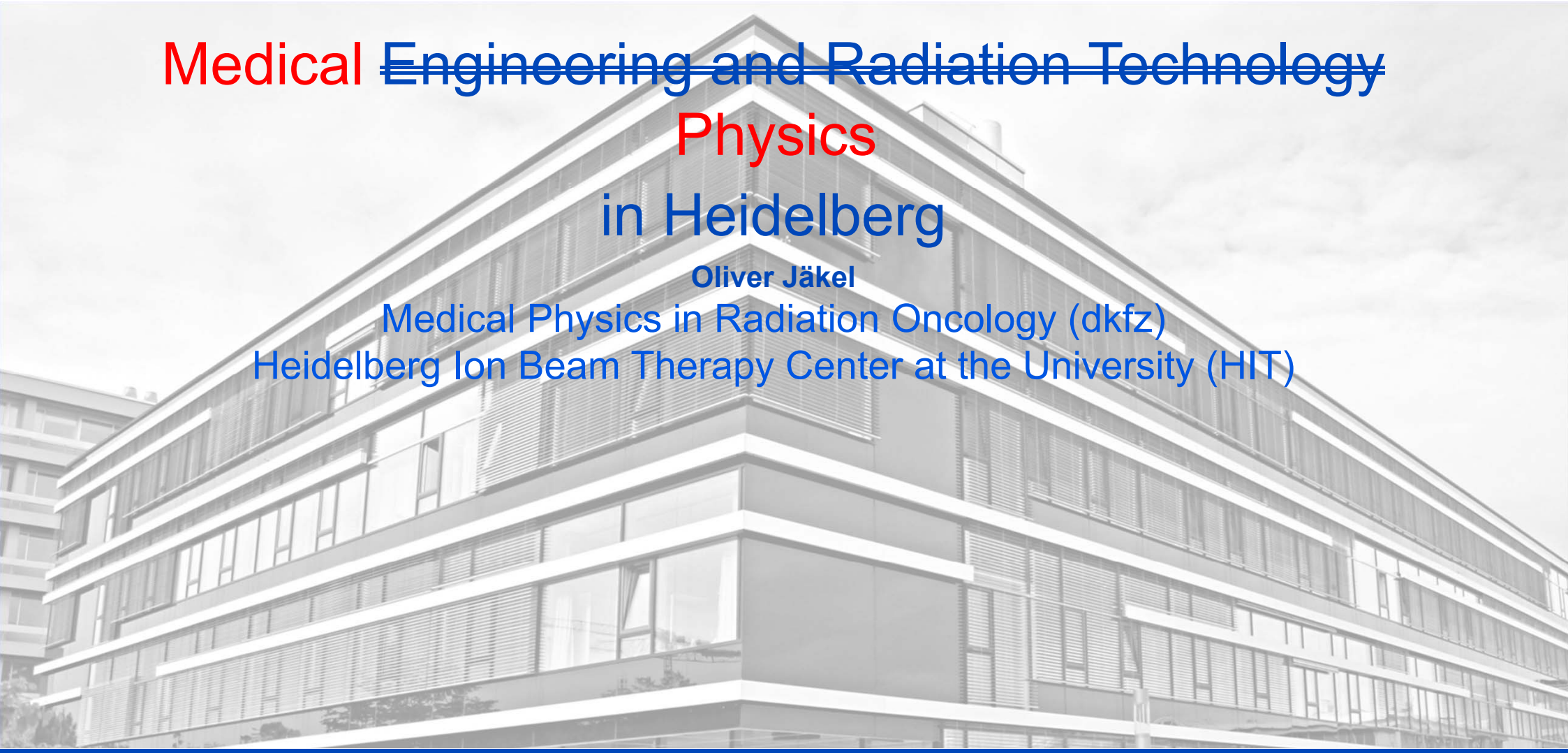


Working areas for medical physicists

- Radiation Therapy (65%)
- Radiological imaging (CT, MRI, US) (15%)
- Nuclear medicine (imaging and therapy, 10%)
- Audiology (<5%)
- Medical laser applications (<5%)

Medical physics experts work in the clinic, in reserach and industry

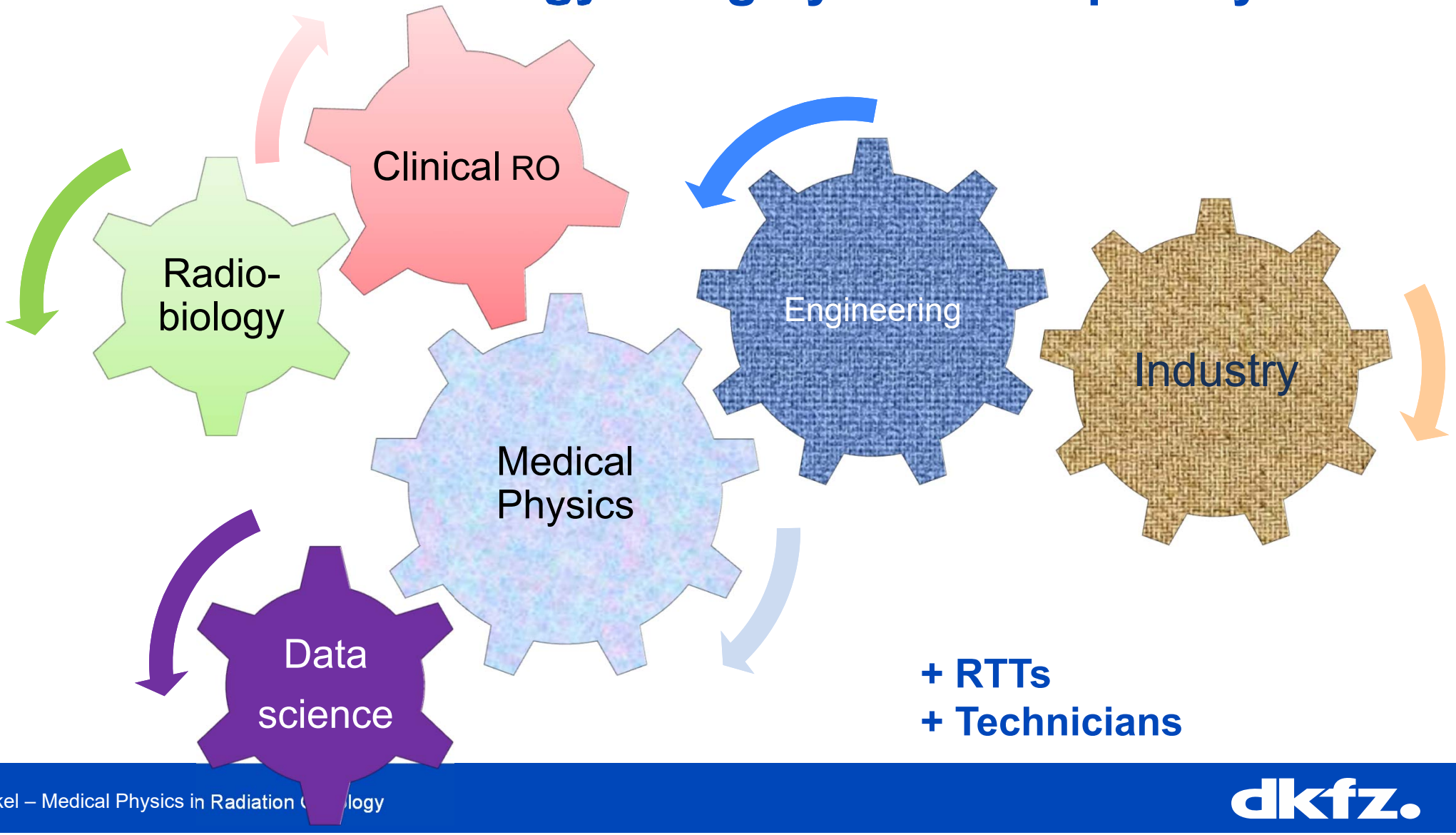
Radiation Oncology

- the single most **important** cancer therapy
  (>70% of patients receive RT)
- Driven by technological developments
- These advances heavly rely on physics

This makes Radiation Oncolgy extremely **precise** (5% dose, 1mm in space), **predictable** (control rates and side effects), extremely **safe**

Radiation Oncology is the medical discipline, where science and technology has the biggest impact and potential

A Radiation Oncology is highly interdisciplinary



+ RTTs
+ Technicians

Requirements for medical physicists

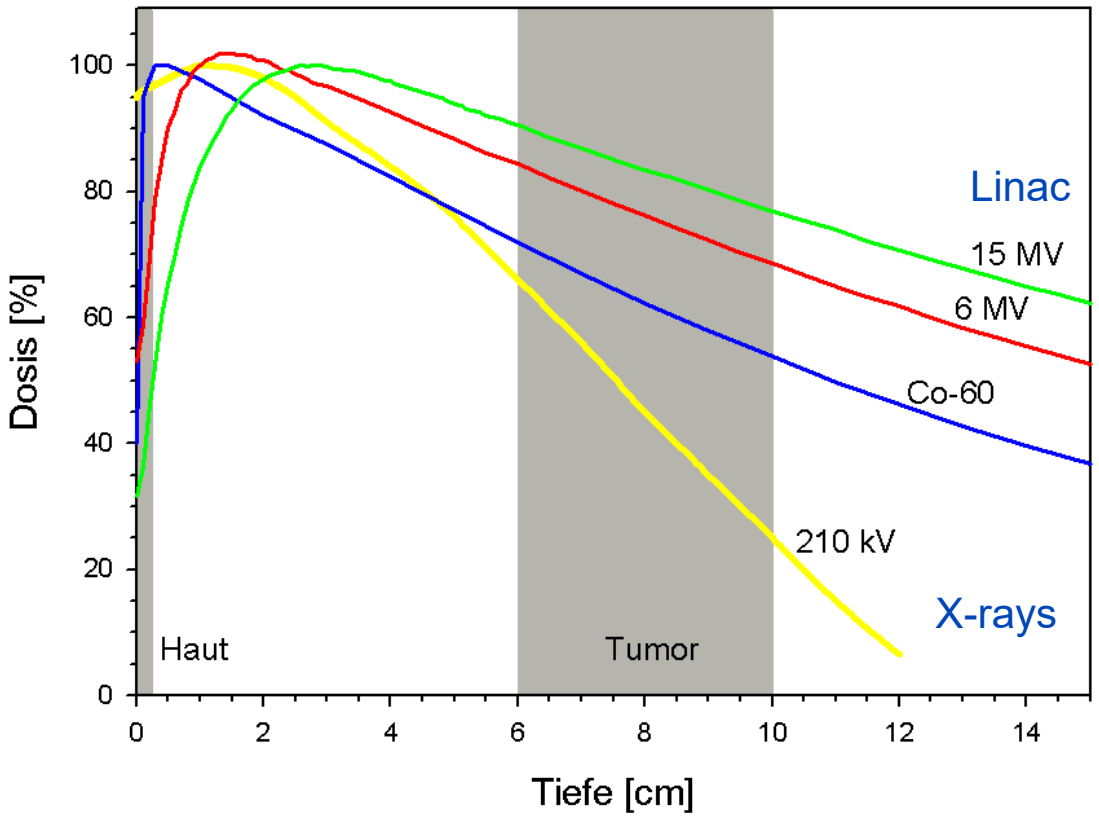
- Solid background in **physics**

Basics of

- Anatomy, physiology, pathology, oncology
- Radiobiology, radiation protection
- Biomathematics, legal aspects, hospital organization
- Medical informatics, practical **computer science**
- Medical technology

Some historic examples of physics results that improved RT

Why energy matters: Improvement of depth dose



Skin a dose-limiting organ for RT

Table 1. Clinical Symptoms and Time of Onset of Acute Radiation Dermatitis

Skin Reaction	Time of Onset	Radiation Dose at Onset
Hyperpigmentation/ erythema	1 to 2 wk after RT	10 to 40 Gy
Dry desquamation	3 to 4 wk after RT	20 to 30 Gy
Moist desquamation	≥ 4 wk after RT	30 to 40 Gy

RT = radiation therapy.

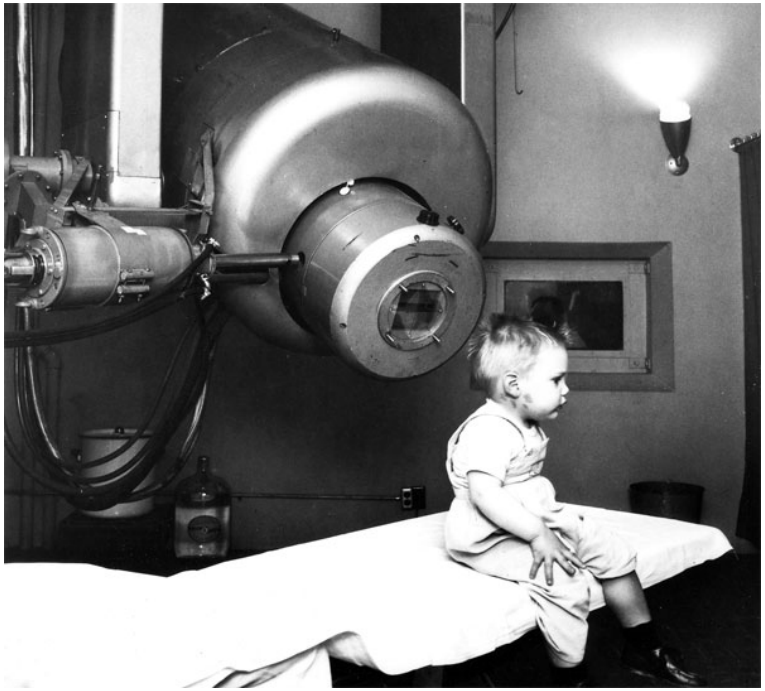
Grade 1 Grade 2 Grade 3

www.cancernetwork.com/view/radiation-dermatitis-recognition-prevention-and-management

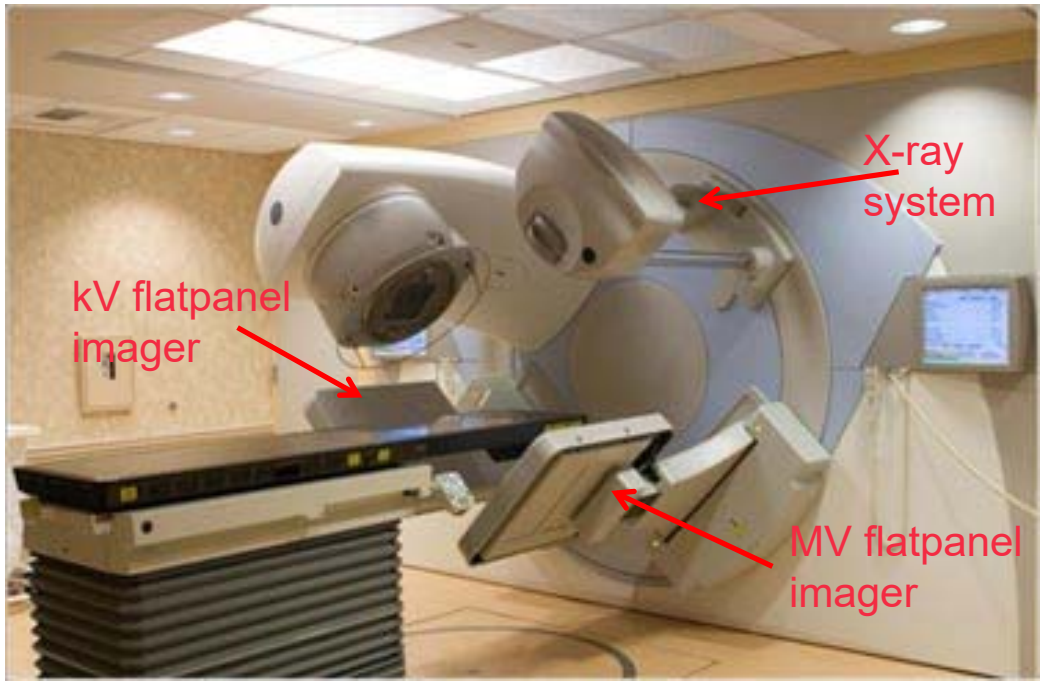
Better skin sparing allows for higher doses!

Development of medical Linacs

1957: H. Kaplan treats 1st patient with 6MV-Linac (Stanford): 2yr old boy (retinoblastoma)

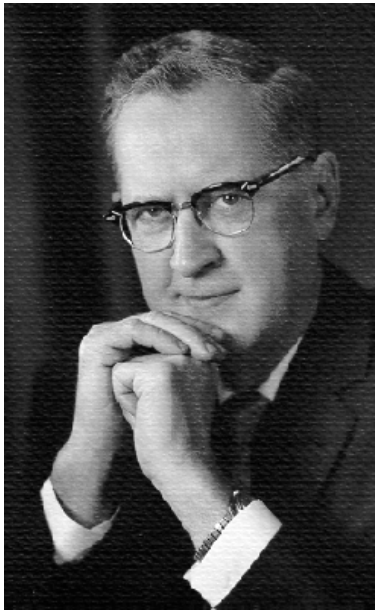


Elekta Synergy with X-ray cone beam CT, fluoroscopy and portal imaging functionalty



Gordon Isaacs is still alive and has vision on his left eye

The problem of radiotherapy planning



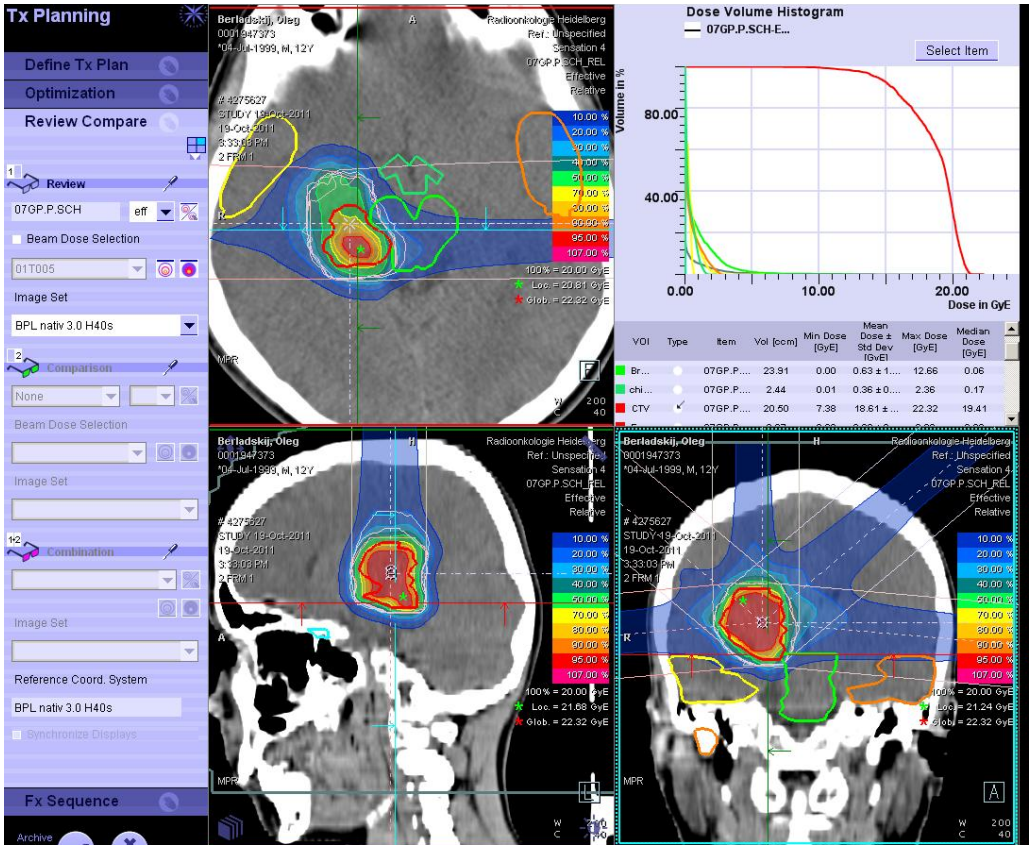
If you can‘t see it you can‘t hit it.

If you can‘t hit it, you can‘t cure it.

Harold Johns,
Canadian Physicist
(1915-1998)

3D Imaging and Planning

1972 First CT scanner (Hounsfield)
1971 Principle of NMR (Damadian)
1980 First Clinical MRT (Lauterbur, Mansfield)
1990 Virtual simulation

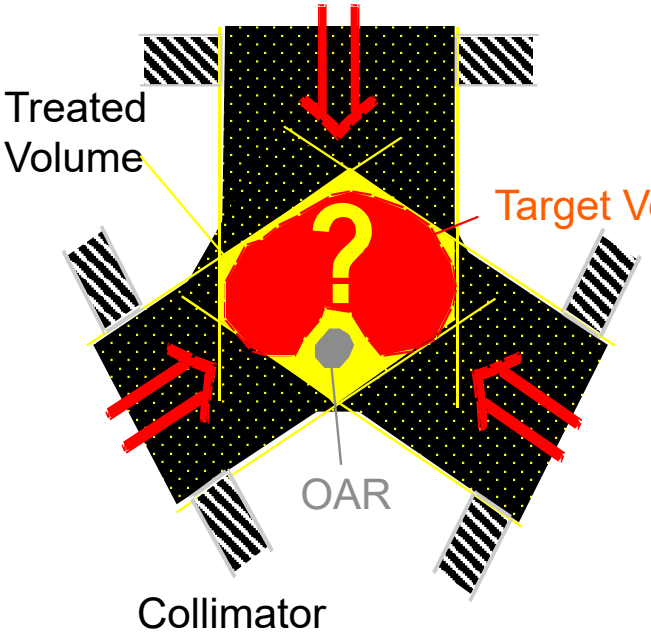


Heavy Ion therapy planning 2015

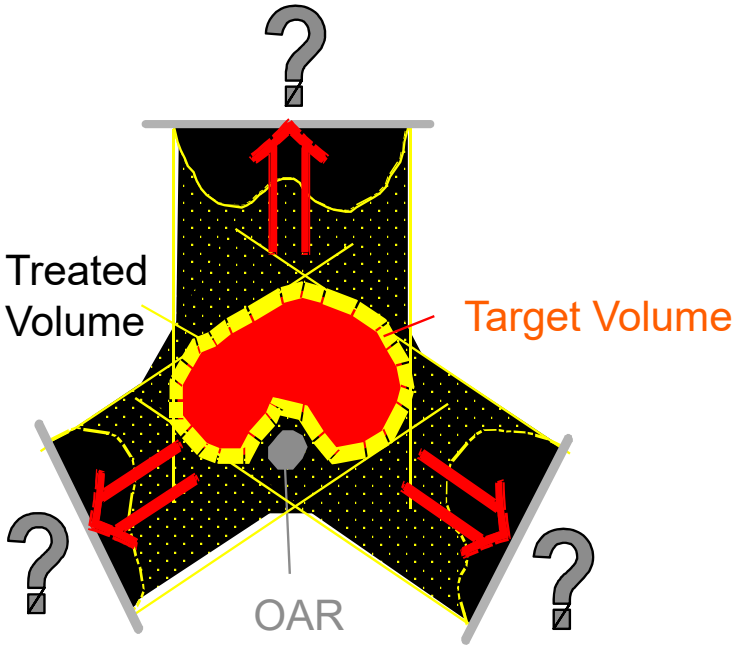
RT becomes precise, predictable and safe

Mathematical optimization: Inverse Planning or Intensity Modulated RT (IMRT, Brahme 1988)

"Conventional" Planning

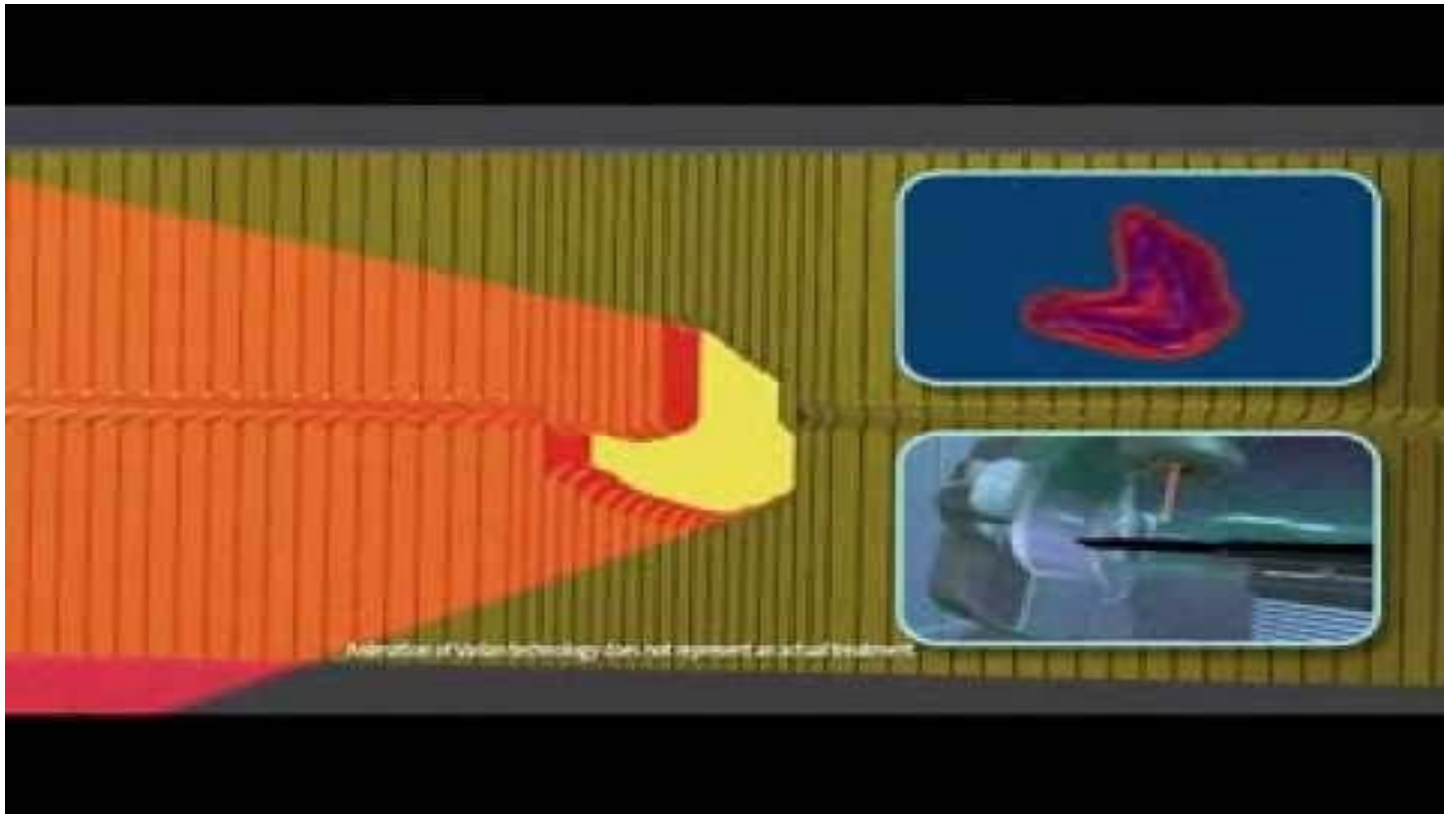


Inverse Planning



Bortfeld 1990

Dynamic multileaf collimation



- Adaption of the aperture to the target
- Modulation of intensity by speed of leaf motion

A recent success story: The MR-Linac

Typical MRI cage construction

Shielding of RF from ouside and B-field from inside

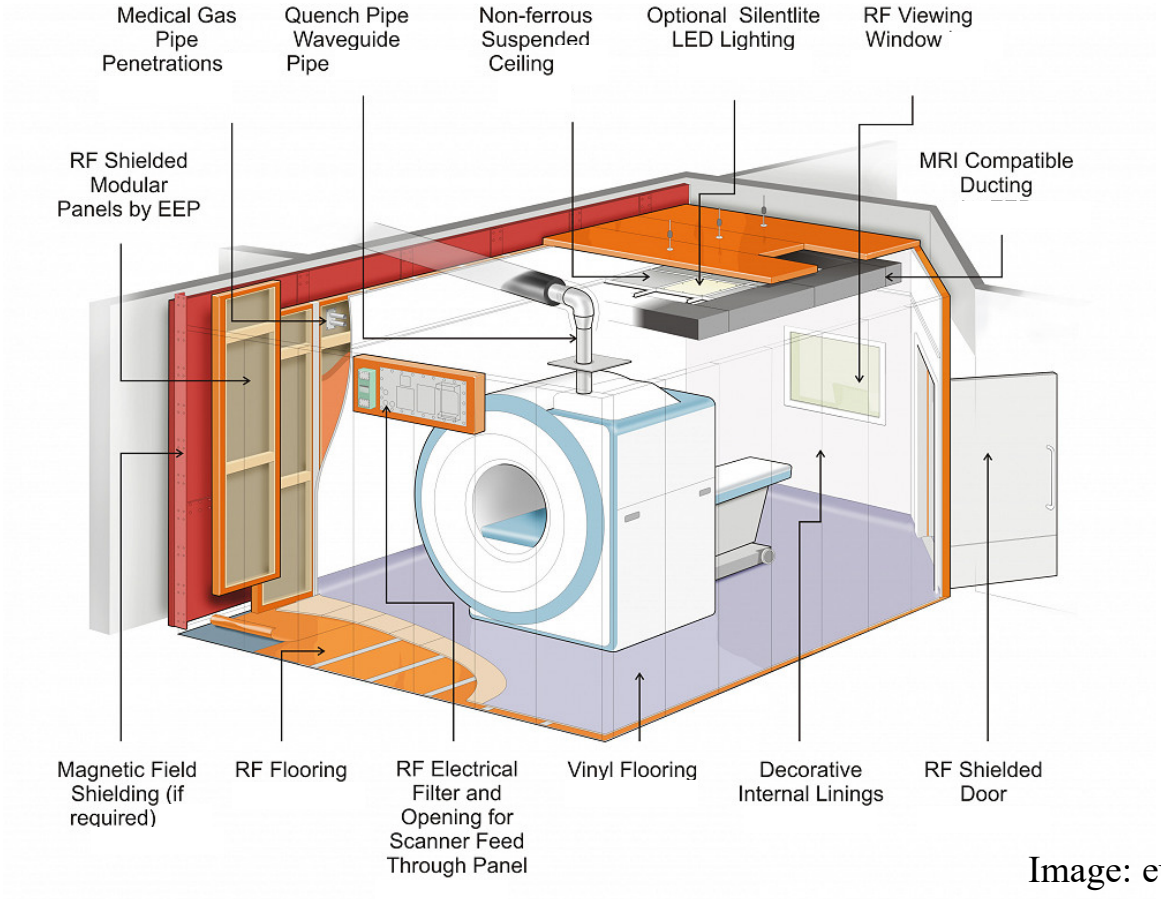
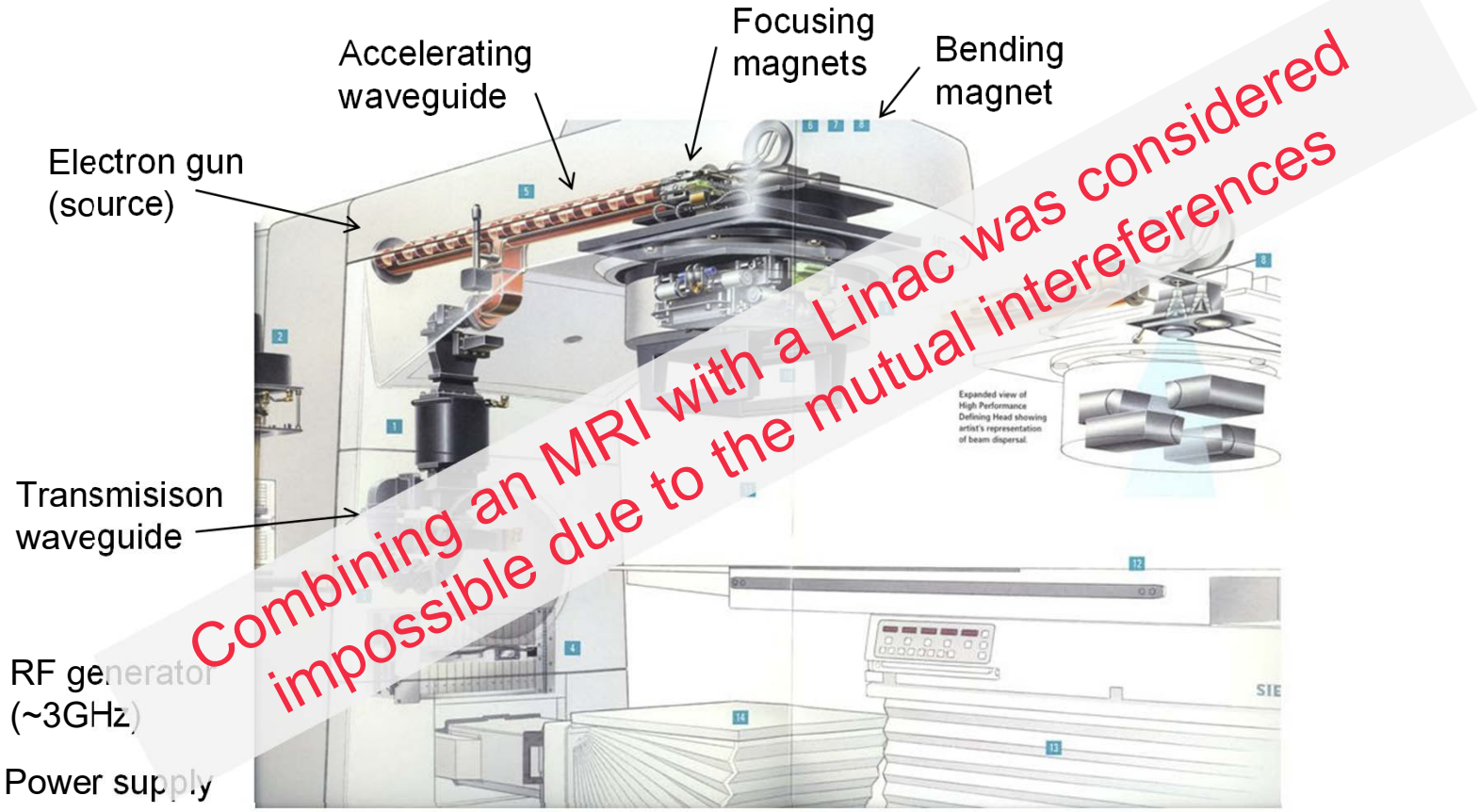


Image: euro-emc.co.uk/

The RF frequency at 1.5T magnetic field strength is ~64MHz

Standard linac components

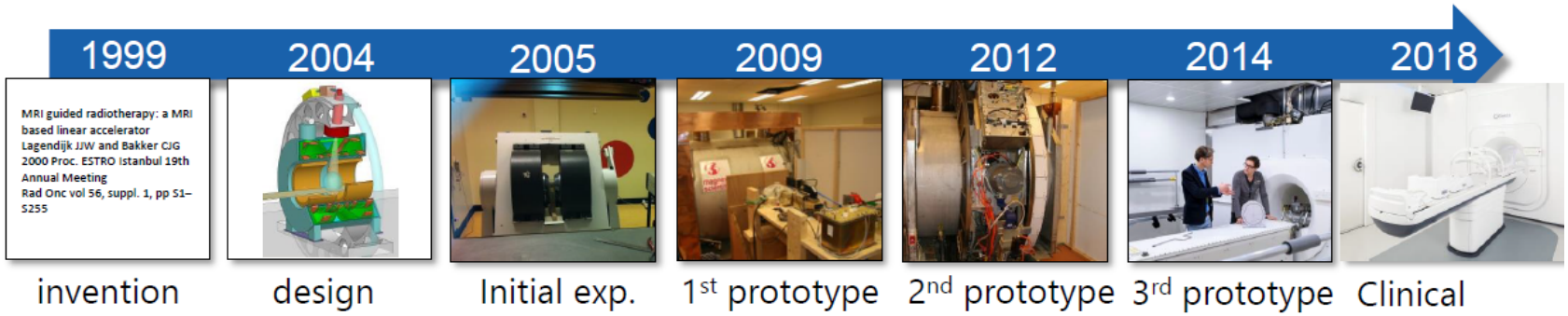


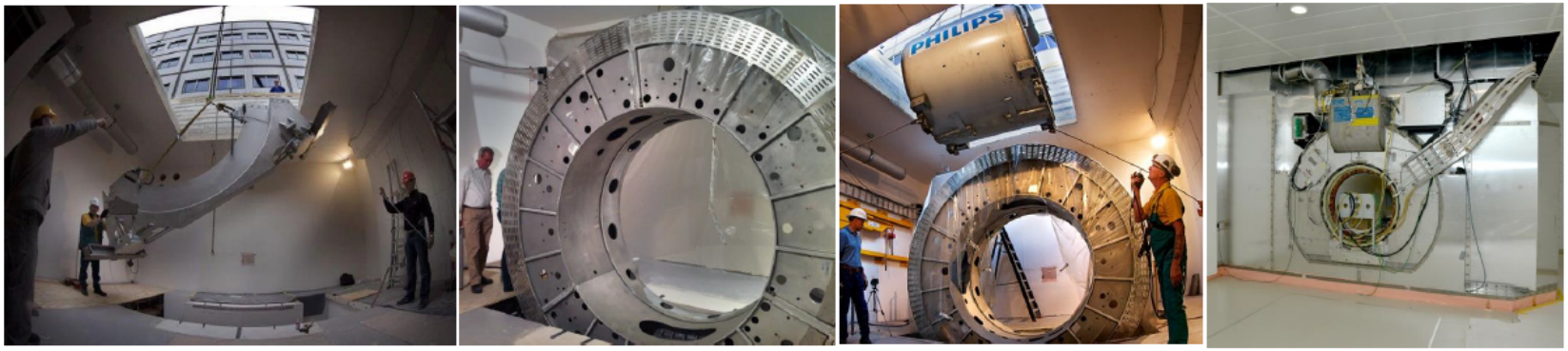
Maximum B-field allowed for linac operation: 0.5mT

A physicist said: let‘s try it anyway!

Jan Lagendijk, Proceedings of ESTRO 2000 meeting

MRL development timeline

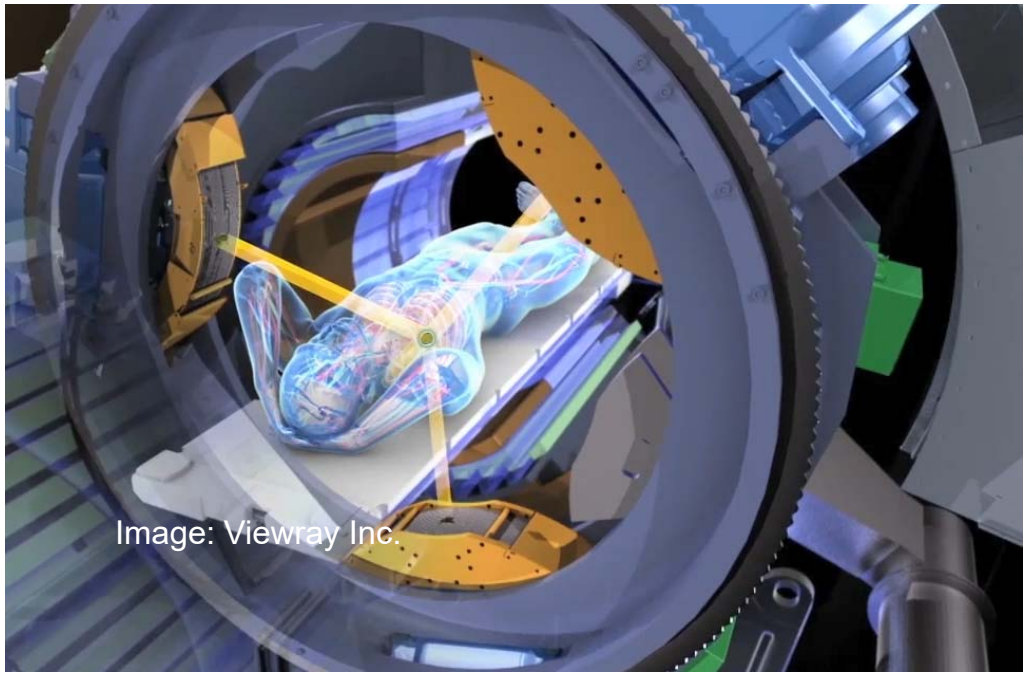


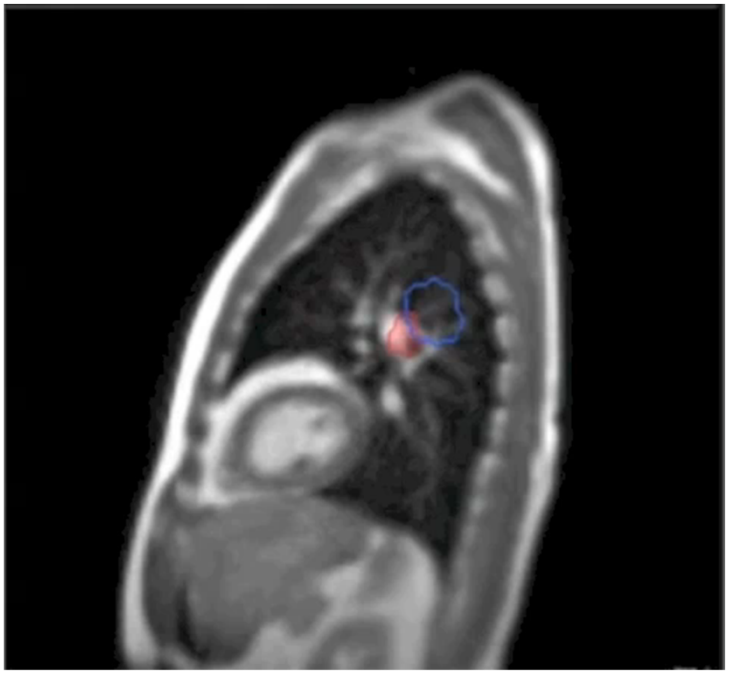


A shift of paradigms in RO:

For the first time in RT we can see what we treat, while we treat

Started by integration of Cobalt sources into an 0.35T Siemens MRI (01/2014)

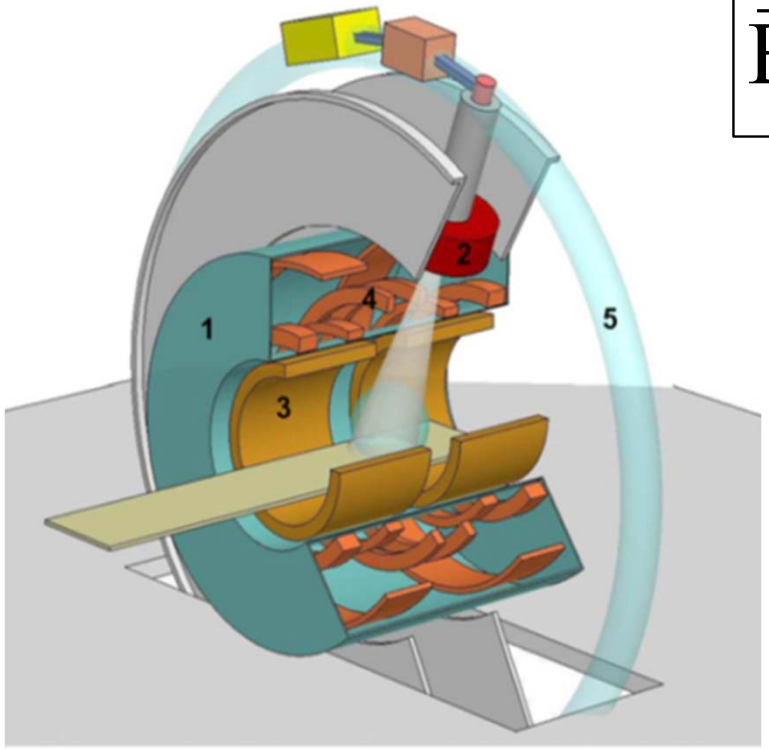




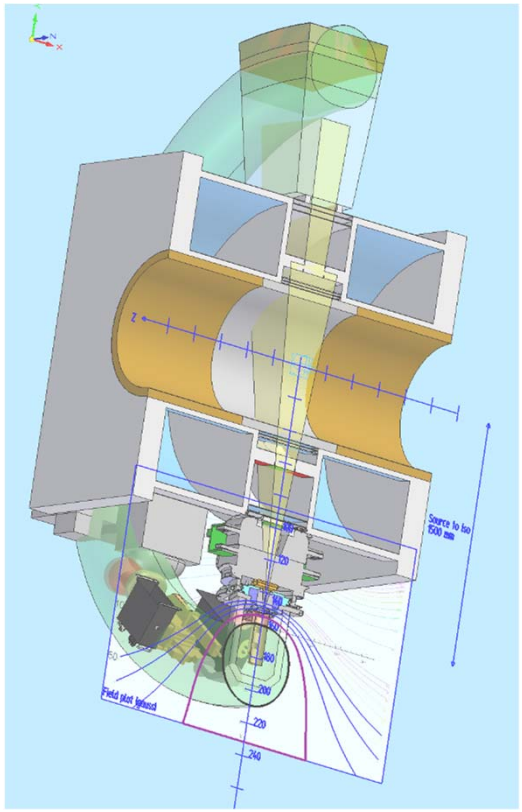
Video: Washington University

1st patient treated at Madison Wisconsin, Wash. Univ. 05.02.2014

Design of the first integrated device



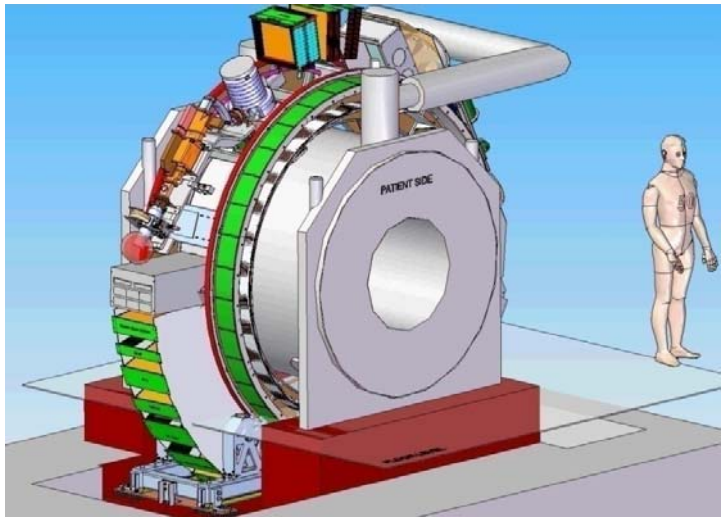
$$\vec{B} \perp \vec{v}_{\gamma}$$



Univ. of Utrecht, Netherlands, based on a modified 6 MV Elekta, 1.5T Philips closed-bore MRI magnet; split gradient coils; **beam transmitted through cryostate**

First patient treated on protoype in 2017

The Elekta Unity



1st patient in August 2018

Elekta

Press release: June 1, 2021

100th Elekta Unity MR-Linac goes to St George's Hospital in New Zealand

CHRISTCHURCH – Elekta (EKTA-B.ST) announces that St George's Hospital in Christchurch, New Zealand, has ordered an Elekta Unity MR-Linac, making it the 100th device sold since introduction. Today, the innovative radiation therapy device is found in 14 countries across five continents.

Challenges and Potential of MRI in RT

- B-field affects dose distribution (ERE)
- Variability of MR images
- Pseudo-CT needed for dose calculation
- Image distortions may occur
- Inter-modality registration (CT-MRI)
- Reliable deformable image registration
- Auto-segmentation of volumes
- Other (dose calc., dosimetry, QA)
- Real-time solutions for ART (future)

- **Automatization and standardization**
- Online plan **adaption** and QA (MC based)
- Early **response assessment** based on MRI/fMRI
- **Dose painting** in hypoxic areas
- **Model building** for TCP/NTCP
- Multi-modal tumor characterization (**Radiomics**)
- …

There is a huge potential for AI/ML applications!

Course Archive

Virtual Summer School 2021: Image Guided Radiation Therapy (IGRT) and Advanced Treatment Techniques
(Sep. 20th - Nov. 19th 2021)

3rd Virtual Summer School in Medical Physics: Computational Methods for Radiotherapy
(Sep. 06th - Oct. 08th 2021)

Workshop "MITK" (external link)
(Mar. 09th - Mar. 10th 2020 in Santiago de Chile)

Workshop "Experimental Radiobiology: Physics meets Biology and Medicine" (external link)
Mar. 05th - Mar. 06th 2020 in Santiago de Chile)

Summer School in Medical Physics on "Imaging for Radiotherapy" (external link)
(Apr. 01st - Apr. 03rd 2019 in Santiago de Chile)

Workshop: RADIOLOGY MEETS RADIOTHERAPY OR VICEVERSA (external link)
(Apr. 04th - Apr. 05th 2019 in Santiago de Chile)

Medical Physics Workshop on "IGRT Workflows - From Contouring to Treatment" in Santiago de Chile (external link)
(Nov. 14th - Nov. 17th 2018)

2nd Summer School 2018 "Novel Methods in Image Guided Radiotherapy" at the DKFZ
(Sep. 11. - Sep. 14th 2018)

"Workshops in Medical Physics" in Santiago de Chile, Chile (Heidelberg Center for Latin America; external link)
(Nov. 16th - Nov. 25th 2017)

1. Sommerschule 2017: „Status und Perspektiven der Ionenstrahl- und Protonentherapie“
(Sep. 25th - Sep. 30th 2017)

dkfz.
DEUTSCHES KREBSFORSCHUNGSZENTRUM
IN DER HELMHOLTZ-GEMEINSCHAFT

Forschen für ein Leben ohne Krebs

HIRO
Heidelberger Institut für Radioonkologie

UNIVERSITÄTS KLINIKUM HEIDELBERG

HIT
Heidelberger Ionenstrahl-Therapiezentrum

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

More information about further education:

dkfz.de/medphys_edu

PhD-Programm

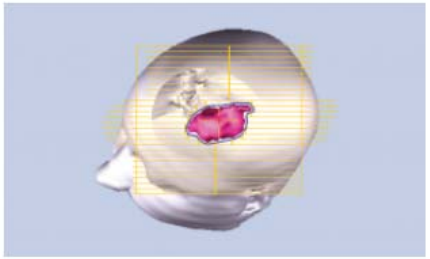
Further information on the DKFZ **PhD-Program** in the area of Medical Physics for physicists can be found here or here.

Additionally, you can find more information about the "*Helmholtz International Graduate School for Cancer Research in Heidelberg*" at the DKFZ here: https://www.dkfz.de/en/phd-program/index.html

Further Education

A list of our certified **courses**, **workshops** or **summer** and **winter schools** (in English or German) for graduates and young scientists in the area of Medical Physcis is available below. The list will be updated from time to time:

Medizinische Physik für Physiker:innen (Universität Heidelberg; external Link)



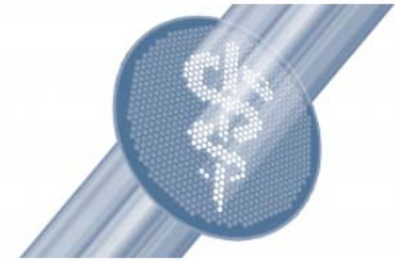
Advanced Training

More information concerning our certified **advanced training**s and **specialized courses** (in German or English) for Radiooncologists and Medical Physics Experts is available below:

Courses in the field of Particle therapy (e.g. "Spezialkurs im Strahlenschutz für die Partikeltherapie")

Medizinische Physik und Technik für Radioonkolog:innen (Universität Heidelberg; externer Link)

Aktualisierungskurse zum Erhalt der Fachkunde im Strahlenschutz nach § 48 StrlSchV (in German only)



HIRO Courses

More information on the HIRO/OncoRay Lecture Series "Radiation Research in Oncology" is available here:

HIRO-Lecture

HIRO
Heidelberg Institute
for Radiation Oncology

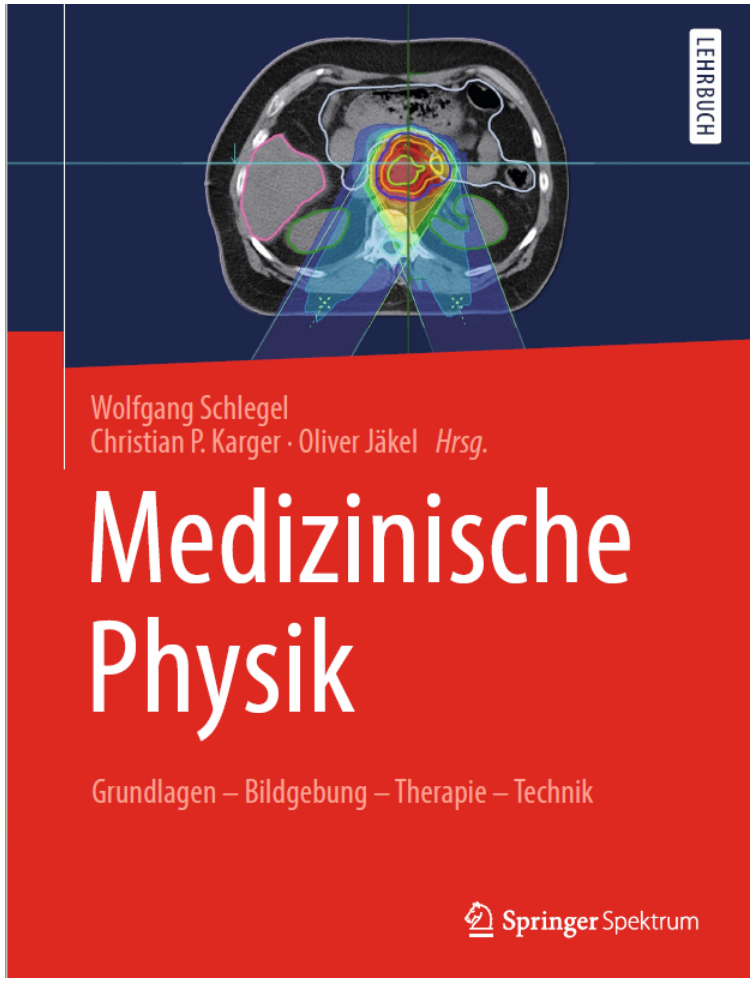
Springer-Book

Medizinische Physik. Grundlagen – Bildgebung – Therapie – Technik

Editors: *Schlegel, Wolfgang, Karger, Christian P., Jäkel, Oliver*

Please note: the book is only available in German language. Further information about the book is available on the following website:

www.dkfz.de/springerbuch



Thank you for your attention !