21.03.2023

DPG
SMuK Frühjahrstagung

The Particle Therapy Masterclass

Targeted education and outreach on real-world application of fundamental physics

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INTERNATIONAL MASTERCLASSES
hands on particle physics

NETZWERK TEILCHENWELT

GSI

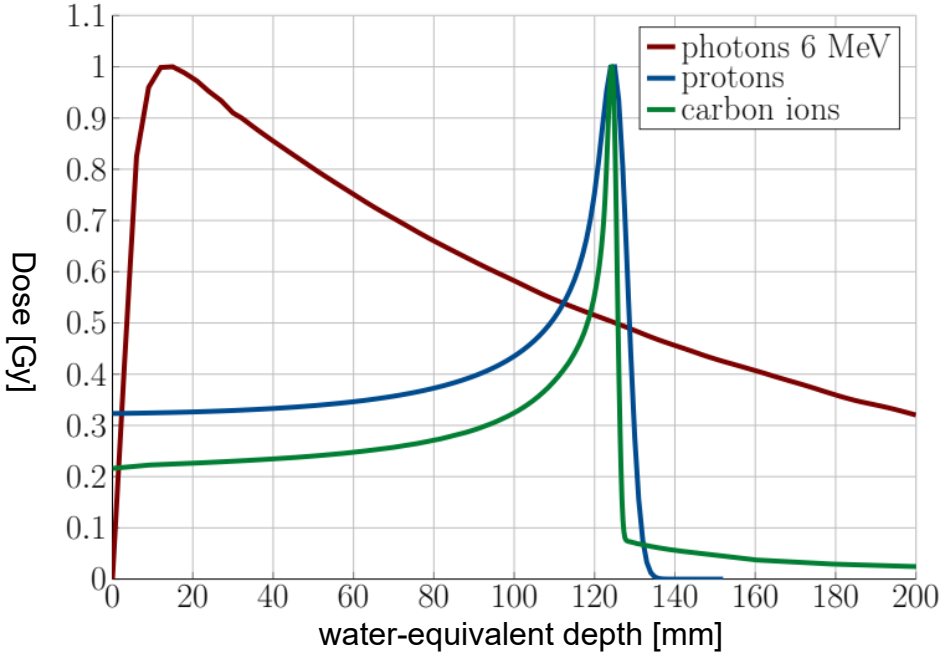
CERN

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

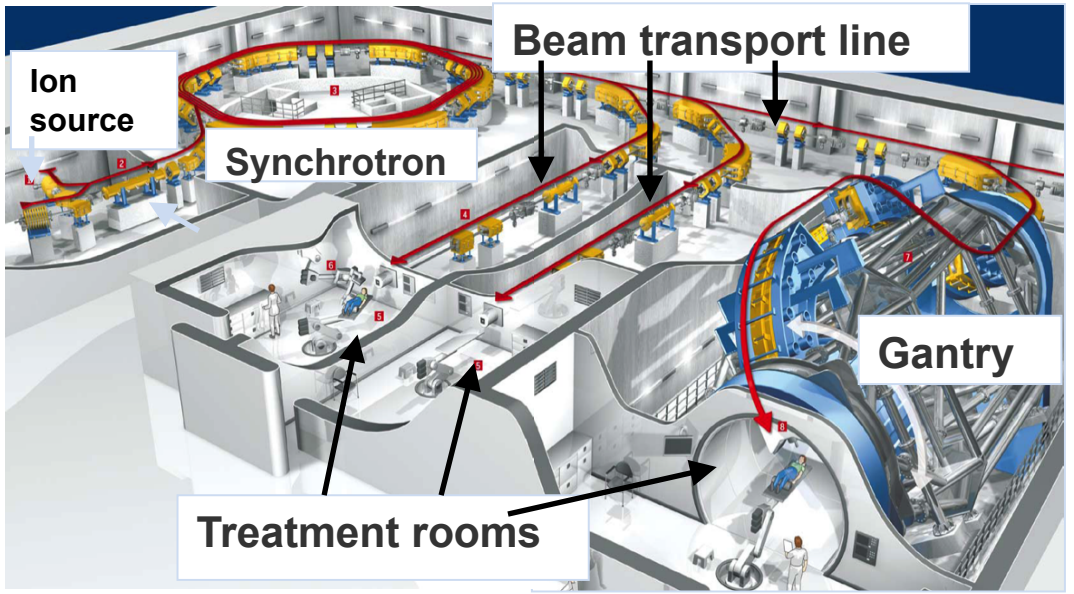
What is particle therapy?

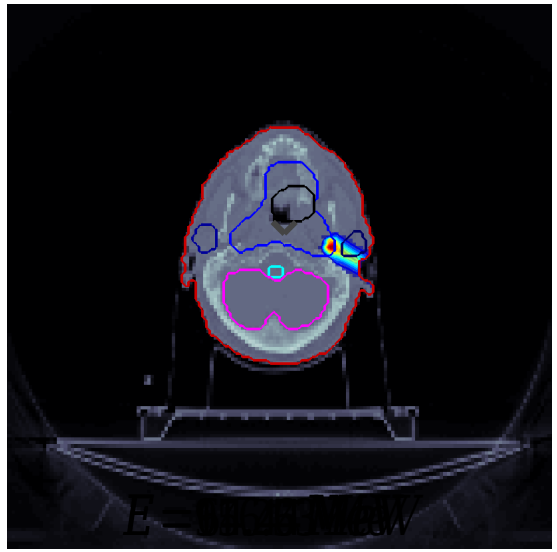
- Particle therapy uses charged particles,
  i. e., protons / light ions, to irradiate cancerous tissue

➢ The Bragg-peak facilitates highly conformal dose deposition



- Typical Facility:
  - Imaging (CT, MRI etc.)
  - Synchrotron / Cyclotron
  - Scanning Beamlines
    (Clinical / Experimental)



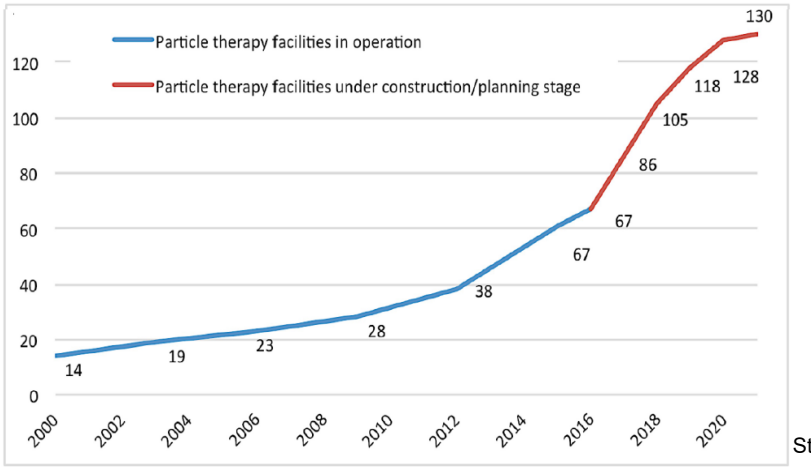


A Particle Therapy Masterclass within the IPPOG International Physics Masterclasses
Why?

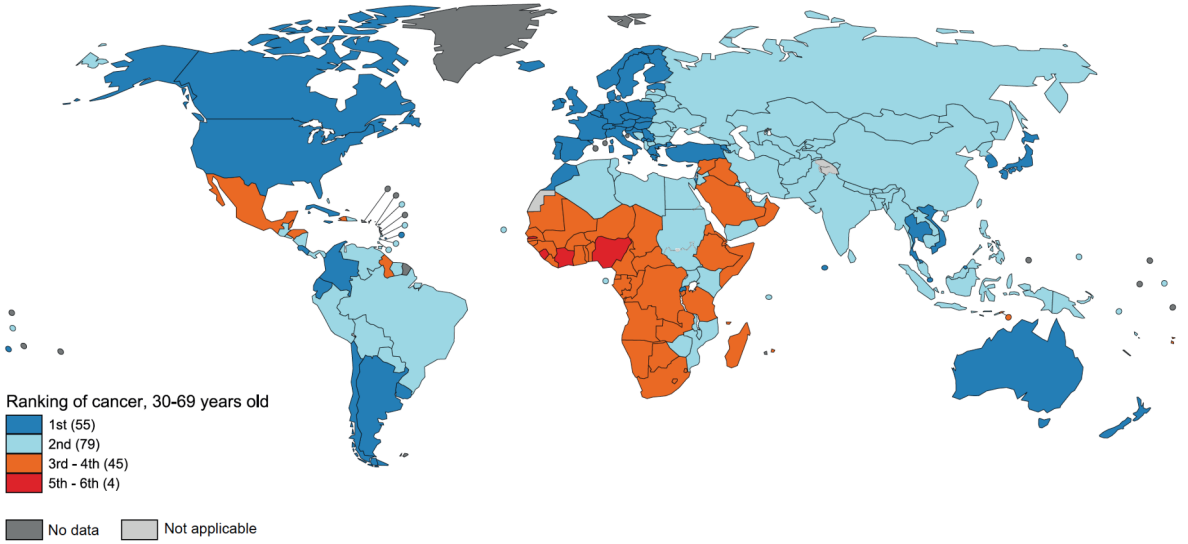
Particle therapy is a tangible “real-world” application of particle/hadron physics principles and instruments developed for research

- Has left the experimental stage and is clinically accepted/used (esp. proton therapy)
- Cancer is a widespread disease and almost everybody is/will somehow relate to it (family, friends, etc.) → societal impact

- The nature of cancer and/or radiotherapy is often not well explained / understood at school level



Statistics by PTCOG



Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries

Dark blue: Cancer is the leading cause of death for age 30-69y

General Schedule

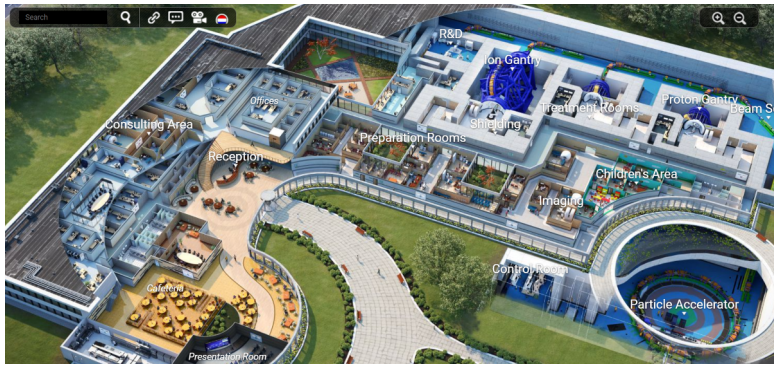
- 9:15 – 11:30: Lectures on **physics background & treatment planning**

  → We propose two lectures, but alternative schedules are also welcome

- 11:30 – 12:15: Lunch

- 12:30 – 13:30: (Virtual) visit to therapy center or lab

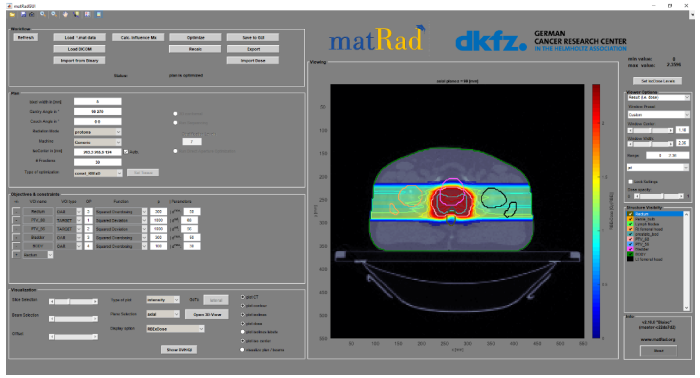
  → Videos/Web-material available



https://cern.nymus3d.nl/

- 13:45 – 16:00: Hands-on Treatment Planning matRad

- 16:00 – 17:00: Videoconference / Quiz with other Masterclasses



www.matrad.org

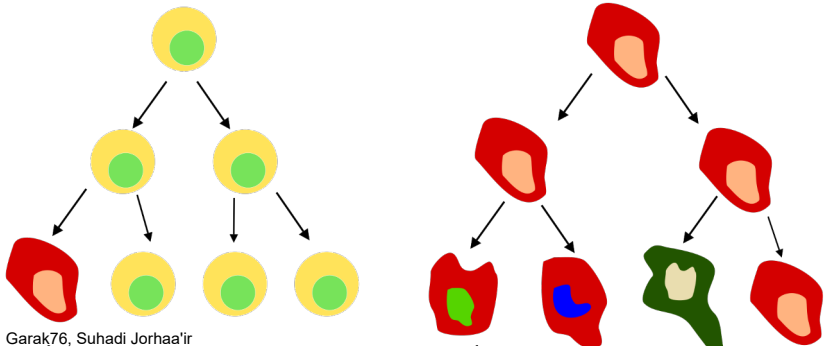
Proposed Introductory Lectures:
1st lecture – From particle physics to radiation dose

- What is cancer? How can we treat it? Why radiation therapy?
- What is radiation dose?

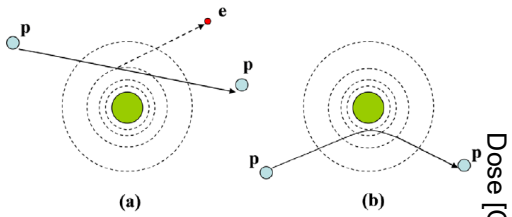
  → Interactions of particles with matter

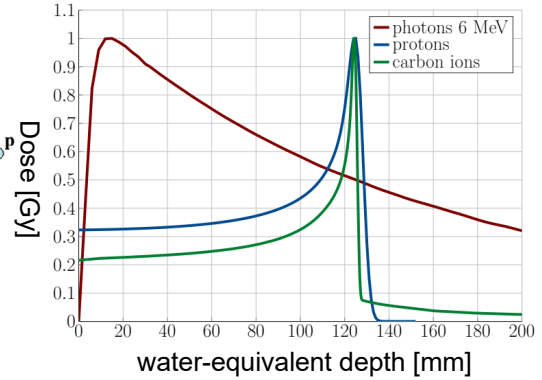
  → different irradiation modalities (photons vs. charged particles)
- How do we produce radiation dose clinically

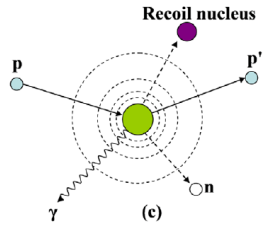
  → accelerators (LINACs, synchrotrons, cyclotrons?)



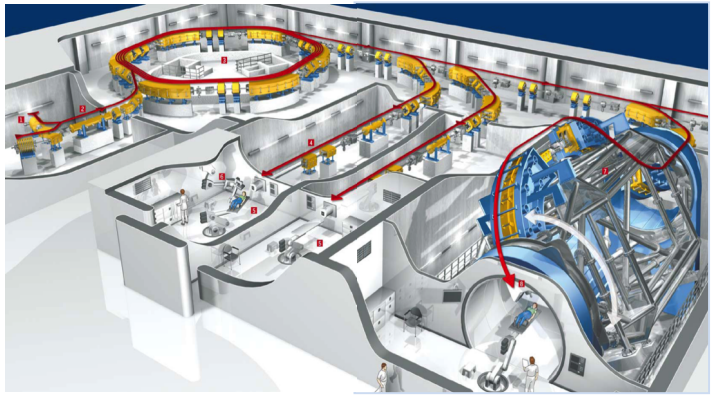
Garak76, Suhadi Jorhaa'ir (https://commons.wikimedia.org/wiki/File:Zellteilung_normal_im_Gegensatz_zu_Krebs.svg), „Zellteilung normal im Gegensatz zu Krebs“







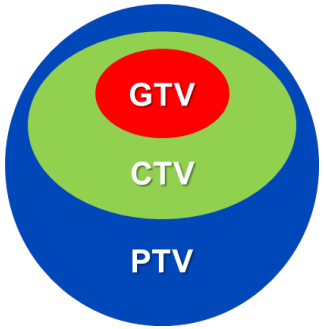
Newhauser, D. W., & Zhang, R. (2015). The physics of proton therapy. 60(8). Phys. Med. Biol., p. 158.



Depending on the presenting expert, focus may be shifted between, e.g., biomedical, hadron/particle, and accelerator physics

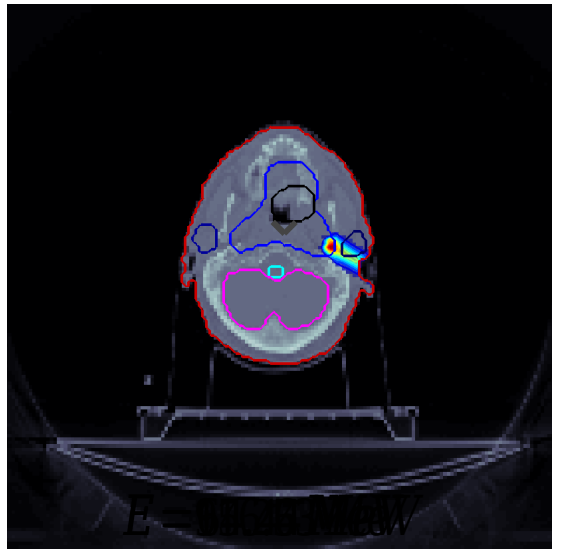
Proposed Introductory Lectures:
2nd lecture – Treatment Planning

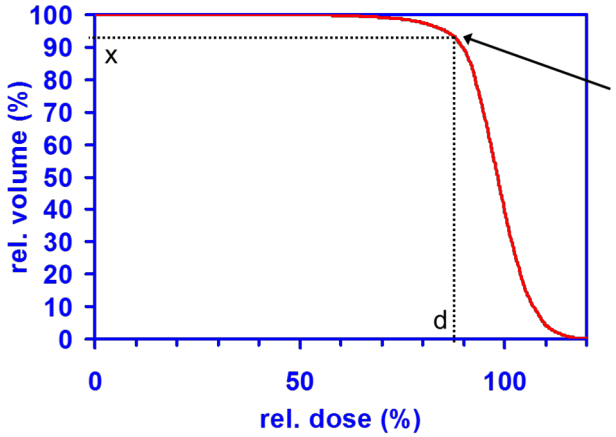
- How do we see inside the body? → Imaging (CT)
- How do we find the tumor/organs? → Segmentation
- **How do we plan the treatment?**
  - How do we prescribe clinical goals?
  - How to select the beam angles?
  - How do we calculate & optimize dose?
  - How do we evaluate the treatment plan?



„Cover the target homogeneously with 54 Gy... “

„…while keeping the dose to the organs at a minimum… “





Hands-On Treatment Planning with matRad

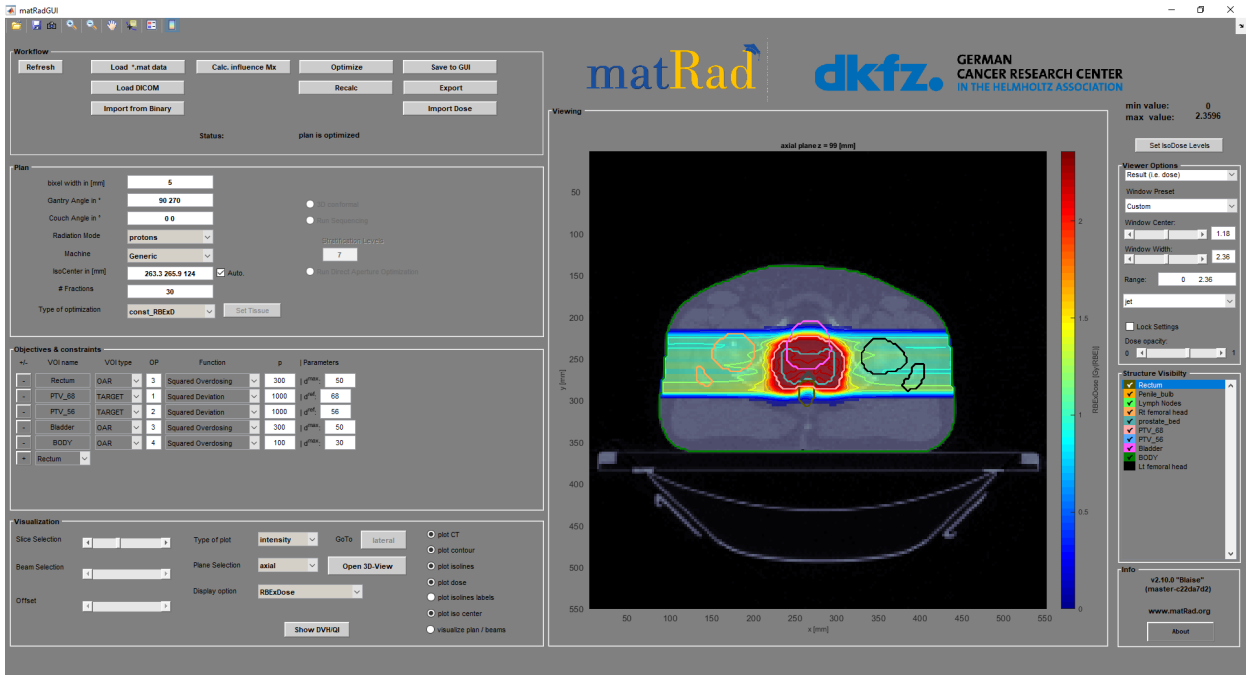
- matRad is an open-source toolkit for three-dimensional intensity-modulated treatment planning for photons, protons, helium and carbon ions

➢ Available on GitHub

➢ open patient / phantom dataset

➢ validated dose calculation with machine data

➢ Visualization and plan analysis tools



- Written in Matlab

  → Students use a precompiled standalone

- Can usually run on an average laptop!

GPL v3 Free Software
Free as in Freedom

www.matrad.org

GitHub

dkfz.

matRad

dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

Workflow

Refresh | Load *.mat data | Calc. influence Mx | Optimize | Save to GUI
Load DICOM | Recalc | Export
Import from Binary | Import Dose

Status: plan is optimized

Plan

bixel width in [mm]	5
Gantry Angle in °	90 270
Couch Angle in °	0 0
Radiation Mode	protons
Machine	Generic
IsoCenter in [mm]	263.3 265.9 124 (Auto.)
# Fractions	30
Type of optimization	const_RBExD (Set Tissue)

3D conformal
Run Sequencing
Stratification Levels: 7
Run Direct Aperture Optimization

Objectives & constraints

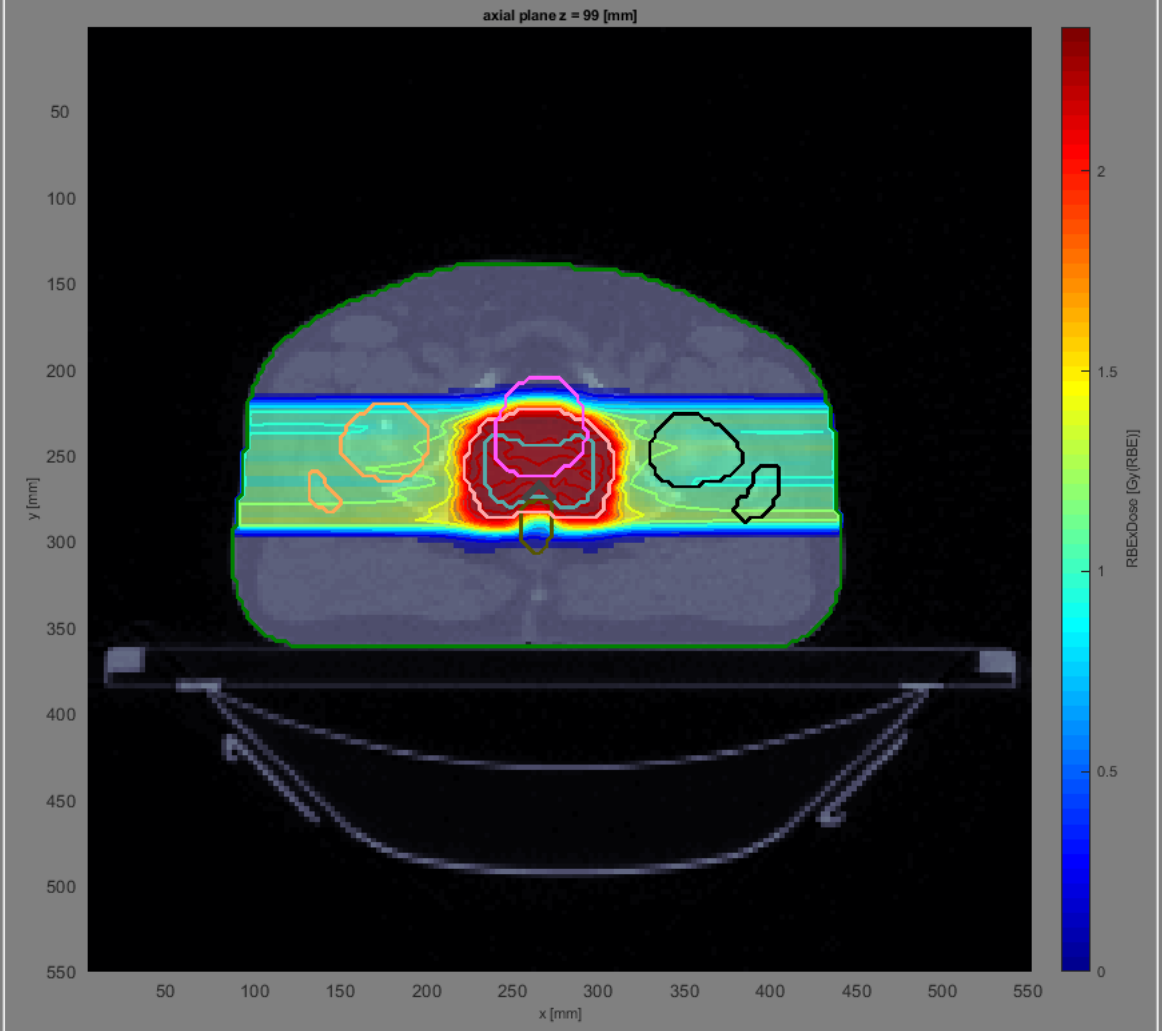
+/-	VOI name	VOI type	OP	Function	p	Parameters
-	Rectum	OAR	3	Squared Overdosing	300	d^{max}: 50
-	PTV_68	TARGET	1	Squared Deviation	1000	d^{ref}: 68
-	PTV_56	TARGET	2	Squared Deviation	1000	d^{ref}: 56
-	Bladder	OAR	3	Squared Overdosing	300	d^{max}: 50
-	BODY	OAR	4	Squared Overdosing	100	d^{max}: 30
+	Rectum					

Visualization

Slice Selection
Beam Selection
Offset
Type of plot: intensity | GoTo: lateral
Plane Selection: axial | Open 3D-View
Display option: RBExDose
Show DVH/QI

plot CT
plot contour
plot isolines
plot dose
plot isolines labels
plot iso center
visualize plan / beams

Viewing



min value: 0
max value: 2.3596

Set IsoDose Levels

Viewer Options

Result (i.e. dose)
Window Preset: Custom
Window Center: 1.18
Window Width: 2.36
Range: 0 2.36
jet
Lock Settings
Dose opacity: 0 1

Structure Visibilty

- Rectum
- Penile_bulb
- Lymph Nodes
- Rt femoral head
- prostate_bed
- PTV_68
- PTV_56
- Bladder
- BODY
- Lt femoral head

Info

v2.10.0 "Blaise" (master-c22da7d2)
www.matRad.org
About

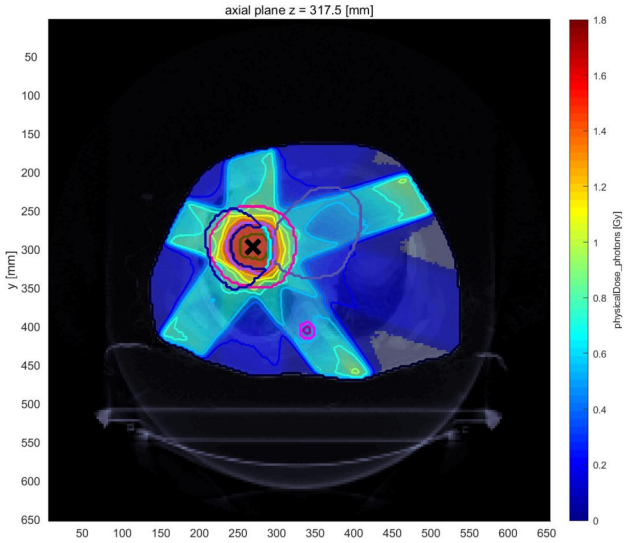
dkfz.

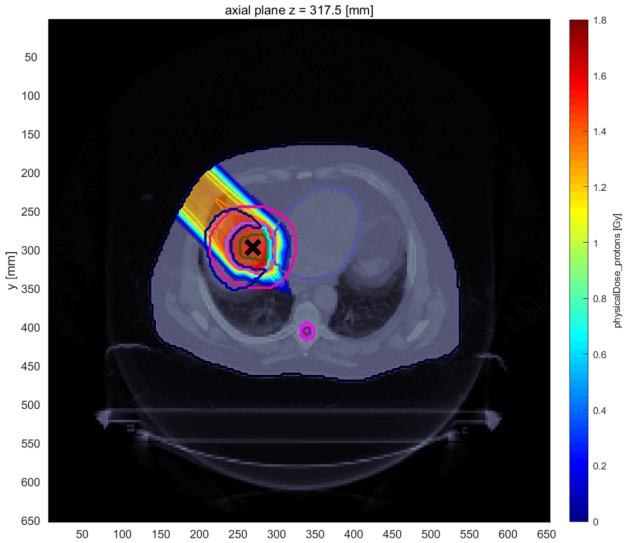
Hands-On Treatment Planning with matRad

- Proposed workflow for participants:
  1. Treatment planning with photons (IMRT)

     → “Common” radiotherapy (50% of cancer patients)
  2. Treatment planning with protons (IMPT)

     → show advantage/potential of particle treatment plans
  3. Peculiarities of particle therapy planning
     - biological treatment planning with carbon ions
     - impact of treatment uncertainties





Particle Therapy Masterclass Timeline

Online PTMCs:
- 6 sessions
- >30 institutes
- 20 countries
- >1000 students

Extra PTMC with Netzwerk Teilchenwelt (Aug, Mainz)

Individualized PTMC with Netzwerk Teilchenwelt for German school's project days (Sep, Online)

First Pilots at GSI, CERN & DKFZ

2019 | 2020 | 2021 | 2022 | 2023?

First "round" of PTMCs within IPPOG's IMCs → Covid-19 cancellations

Modified PTMC for public outreach at "Physik am Samstag" (Feb, Online)

One week HITRIplus PTMC School for higher education (May, Online)

Online/hybrid PTMCs:
- 6 sessions
- >30 institutes
- 22 countries
- >1000 students

Currently ongoing
- 7 sessions

Summary & Discussion

- Experience so far:
  - Tangible translation of fundamental physics research to application in medicine
  - Multiple successful “rounds” since 2019
  - Integrated into the international Masterclasses
  - additional efforts demonstrated tailoring to different educational levels (middle & upper school levels, higher education, public outreach)

- Biggest challenge:
  - Radiotherapy & esp. particle therapy are comparably small research fields
    → limited number of experts available (few centers in Europe)
    → dedicated training sessions for tutors at interested institutes

- Future Plans/Ideas:
  - Better promotion / streamline organization
  - Bigger involvement of other Netzwerk Teilchenwelt hubs
  - Web-based interface for matRad

Contact

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- Niklas Wahl
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Links

- Current indico website:
  https://indico.cern.ch/event/840212/ (or via https://physicsmasterclasses.org/)
  → “PTMC in a kit” provides materials / setup instructions

- matRad
  www.matRad.org