



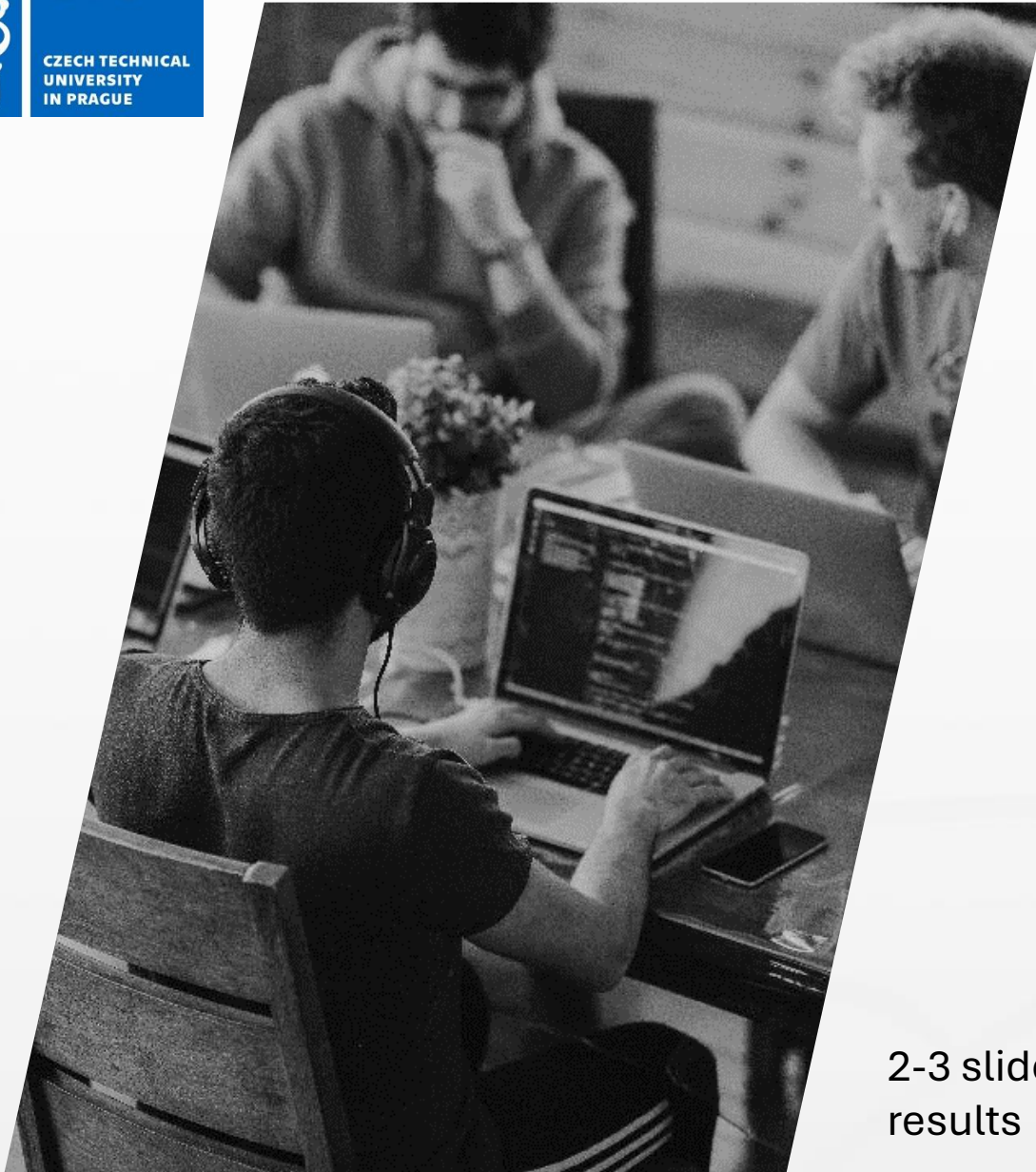
Hands-on treatment planning with matRad

Particle Therapy MasterClass PTMC

Andrea Vargas

CTU in Prague

13.03.2025



Agenda

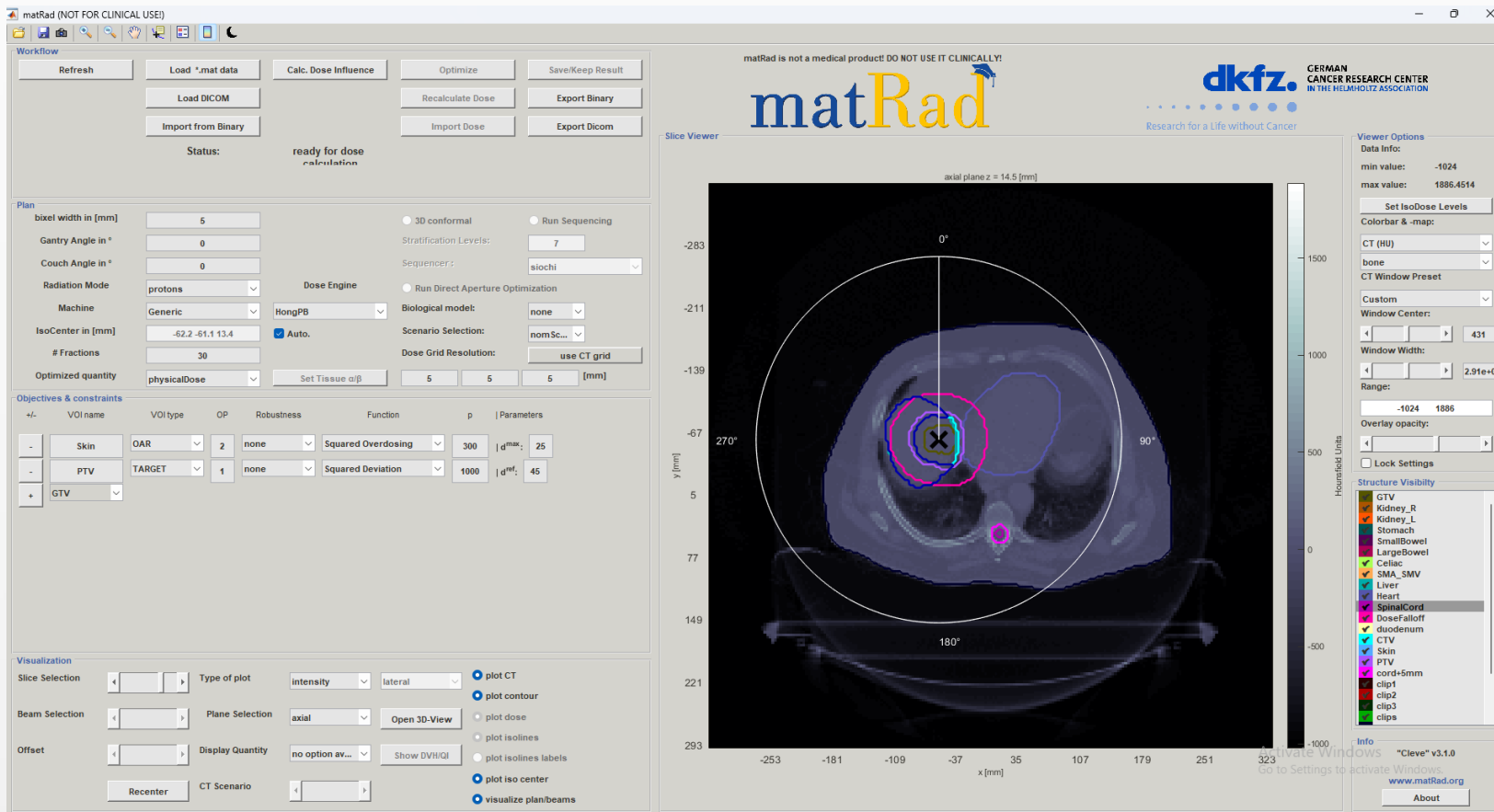
- Introduction
- 1st Exercise-TG119 phantom
- 2nd Exercise-Carbon ion TP for a liver patient
- 3rd Exercise-Head and Neck phantom
- Conclusions

2-3 slides should be prepared for at least 2 students to present the results

matRad is an open-source software for radiation treatment planning of intensity-modulated photon, proton, and carbon ion therapy.

matRad was developed for educational and research purposes and it is entirely written in MATLAB.

INTRODUCTION



latest version 3.1.0

<https://github.com/e0404/matRad/releases/tag/v3.1.0>

Workflow panel

matRad (NOT FOR CLINICAL USE)

Workflow

Refresh Load *.mat data Calc. Dose Influence Optimize Save/Keep Result

Load DICOM Recalculate Dose Export Binary

Import from Binary Import Dose Export Dicom

Status: ready for dose calculation

Plan selection

Plan

bixel width in [mm] 5 3D conformal Run Sequencing

Gantry Angle in ° 0 Stratification Levels: 7

Couch Angle in ° 0 Sequencer: siochi

Radiation Mode protons Dose Engine Run Direct Aperture Optimization

Machine Generic HongPB Biological model: none

IsoCenter in [mm] -62.2 -61.1 13.4 Auto. Scenario Selection: nomSc...

Fractions 30 Dose Grid Resolution: use CT grid

Optimized quantity physicalDose Set Tissue a/β 5 5 5 [mm]

Objectives and constraints panel

+/-	VOI name	VOI type	OP	Robustness	Function	p	Parameters
-	Skin	OAR	2	none	Squared Overdosing	300	d ^{max} : 25
-	PTV	TARGET	1	none	Squared Deviation	1000	d ^{ref} : 45
+	GTV						

Visualization panel

Visualization

Slice Selection Type of plot intensity lateral plot CT

Beam Selection Plane Selection axial Open 3D-View plot dose

Offset Display Quantity no option av... Show DVH/QI plot isolines

Recenter CT Scenario plot iso center visualize plan/beams

Viewing panel

matRad is not a medical product! DO NOT USE IT CLINICALLY!

matRad

dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

Research for a Life without Cancer

Slice Viewer

axial plane z = 14.5 [mm]

Viewer Options

Data Info: min value: -1024 max value: 1886.4514

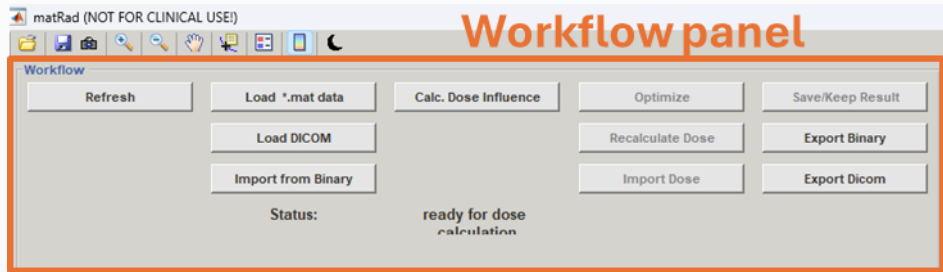
Set IsoDose Levels

Colorbar & -map: CT (HU) bone CT Window Preset Custom Window Center: 431 Window Width: 2.91e+04 Range: -1024 1886 Overlay opacity: Lock Settings

Structure Visibility

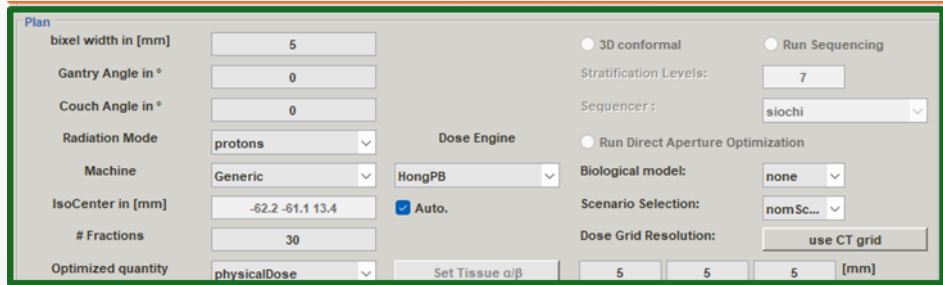
- GTV
- Kidney_R
- Kidney_L
- Stomach
- SmallBowel
- LargeBowel
- Celiac
- SMA_SMV
- Liver
- Heart
- SpinalCord
- DoseFalloff
- duodenum
- CTV
- Skin
- PTV
- cord-5mm
- clip1
- clip2
- clip3
- clips

Info "Cleve" v3.1.0 Go to Settings to activate Windows. www.matRad.org About



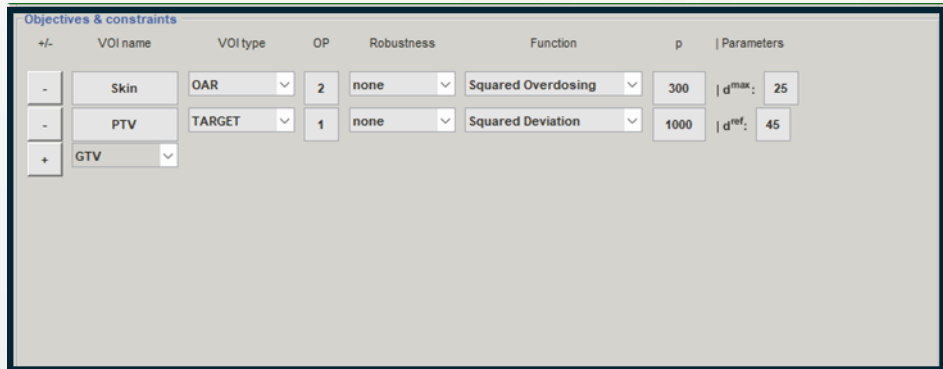
In this panel you can open the previously charged data, with Load *.mat data button. It will also charge information about the target tissue and the surrounding healthy organs.

Plan selection



Here you can change the gantry angles, and the couch angles will automatically set. Also, you can find the radiation mode button where you can select the particle beam for the therapy treatment. The isocenter that was verified, and number of fractions that are prescribed by the radiation oncologist.

Objectives and constraints panel



In this panel you will see (after you insert the data) the organs of interest (target), as well as the organs at risk that are about to be irradiated, and we want to avoid obtaining more dose.

Visualization panel

Visualization

Slice Selection:
 Type of plot: Intensity lateral
 plot CT

Beam Selection:
 Plane Selection: axial Open 3D-View
 plot contour

Offset:
 Display Quantity: no option av... Show DVH/QI
 plot dose

CT Scenario:
 plot isolines

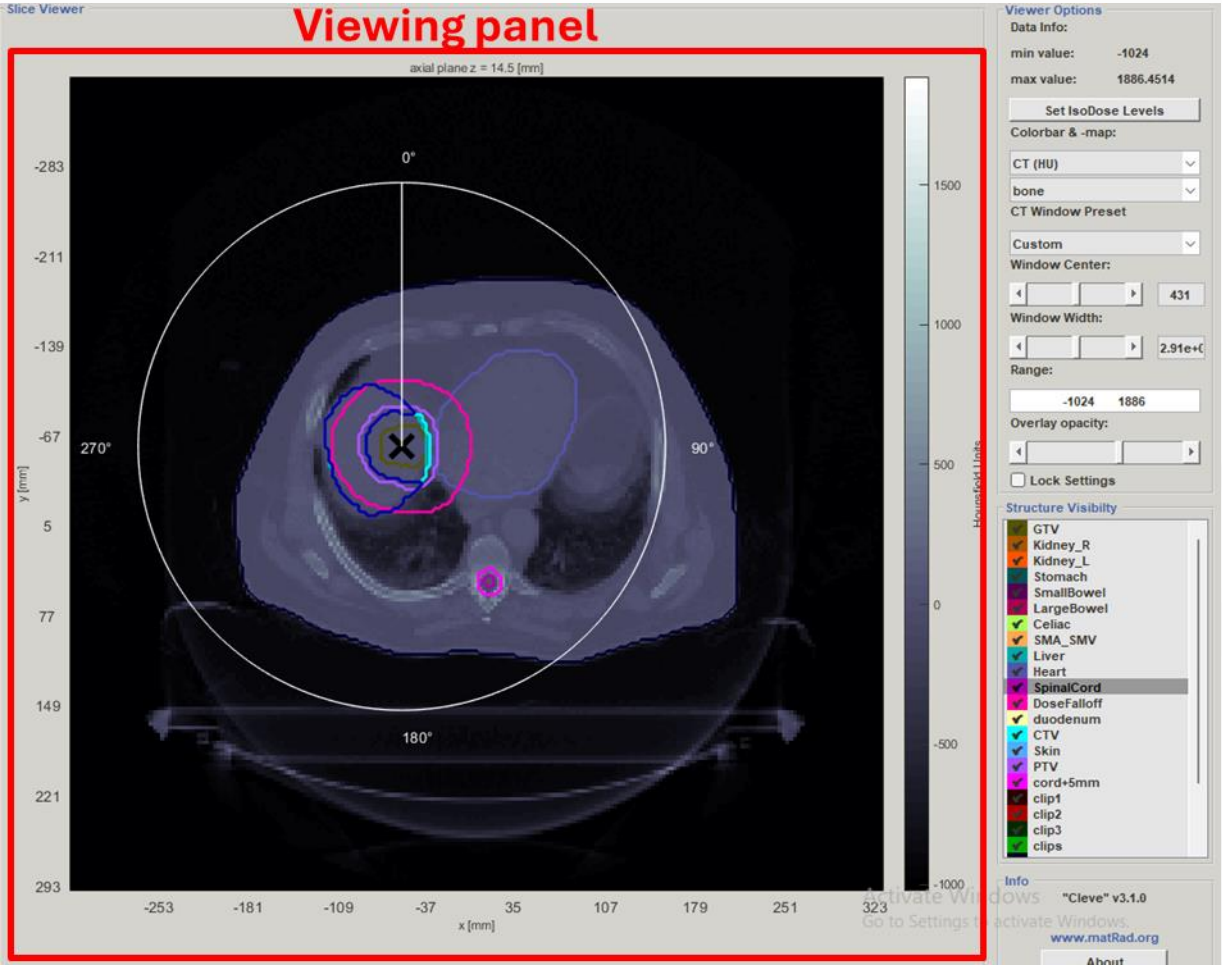
plot isolines labels
 plot iso center

visualize plan/beams

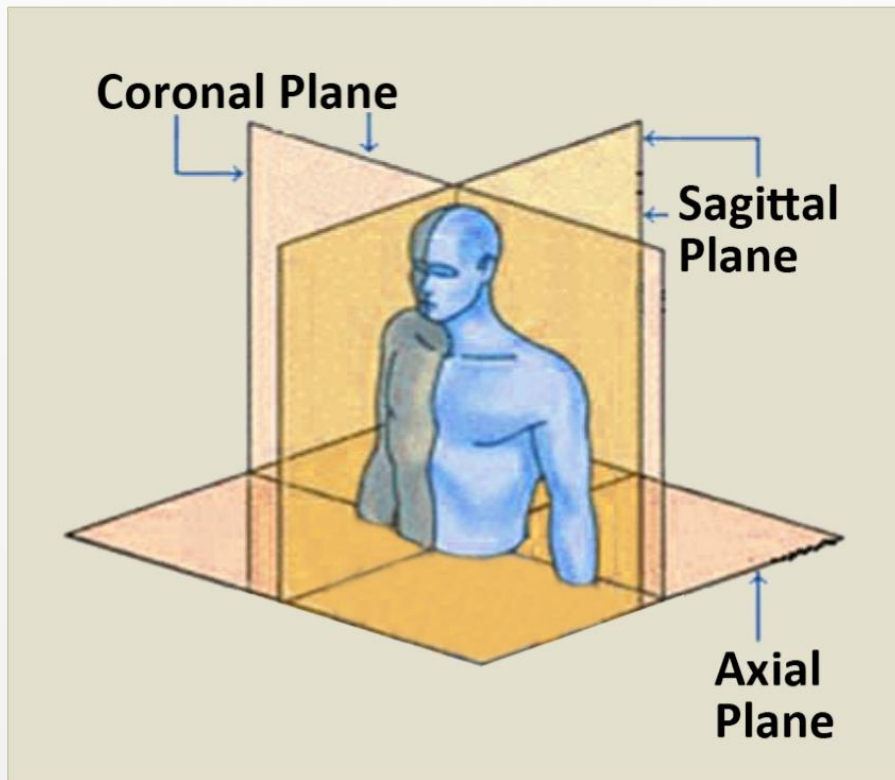
Here you can select what you will see in the viewing panel, for example, if you want to visualize the plan/beam for a better understanding of the different angles of the irradiation, plot the isocenter with an X, and so on.

Also, you can move within the 3D image to see the slice that you want.

In addition, there is a plain selection button with the choices of axial, sagittal and coronal.



Reconstruction planes



DEFINITIONS AND CLARIFICATIONS ON SOFTWARE:

- PTV is the "Planning Target Volume" that should be irradiated.
- GTV is the gross tumor volume (what in general can be seen on the image)
- CTV is the clinical target volume (where the physician thinks there is still cancerous tissue despite being directly visible in the image).
- OAR means "Organ at risk", basically organs that are more sensitive than the general healthy tissue.

1st Exercise-TG119

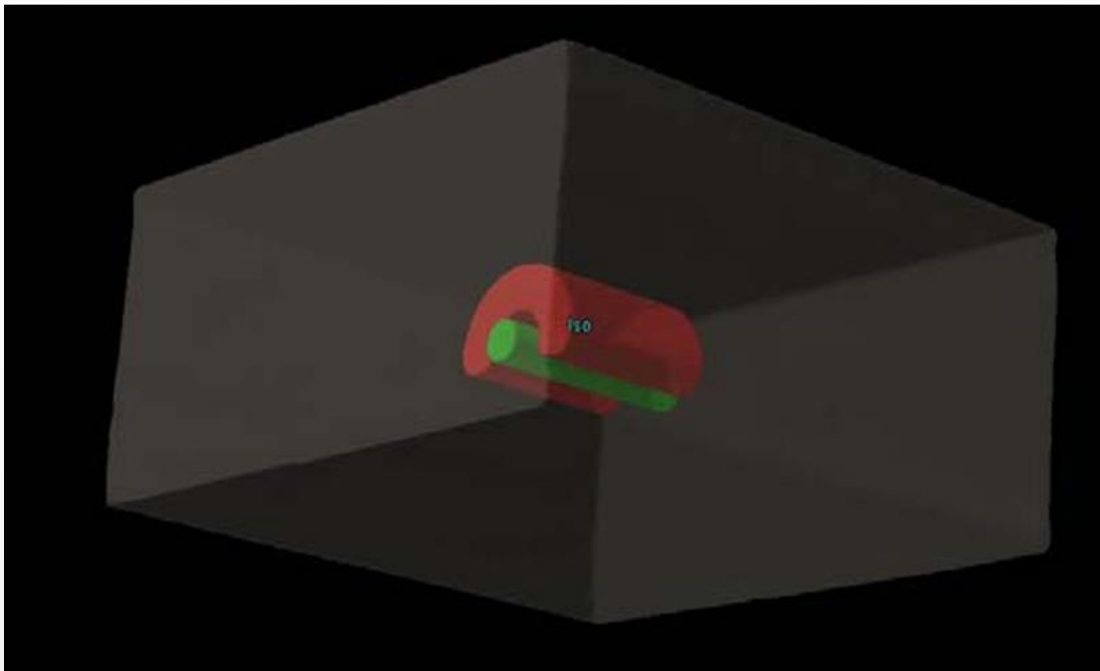
Phantom



OBJECTIVES

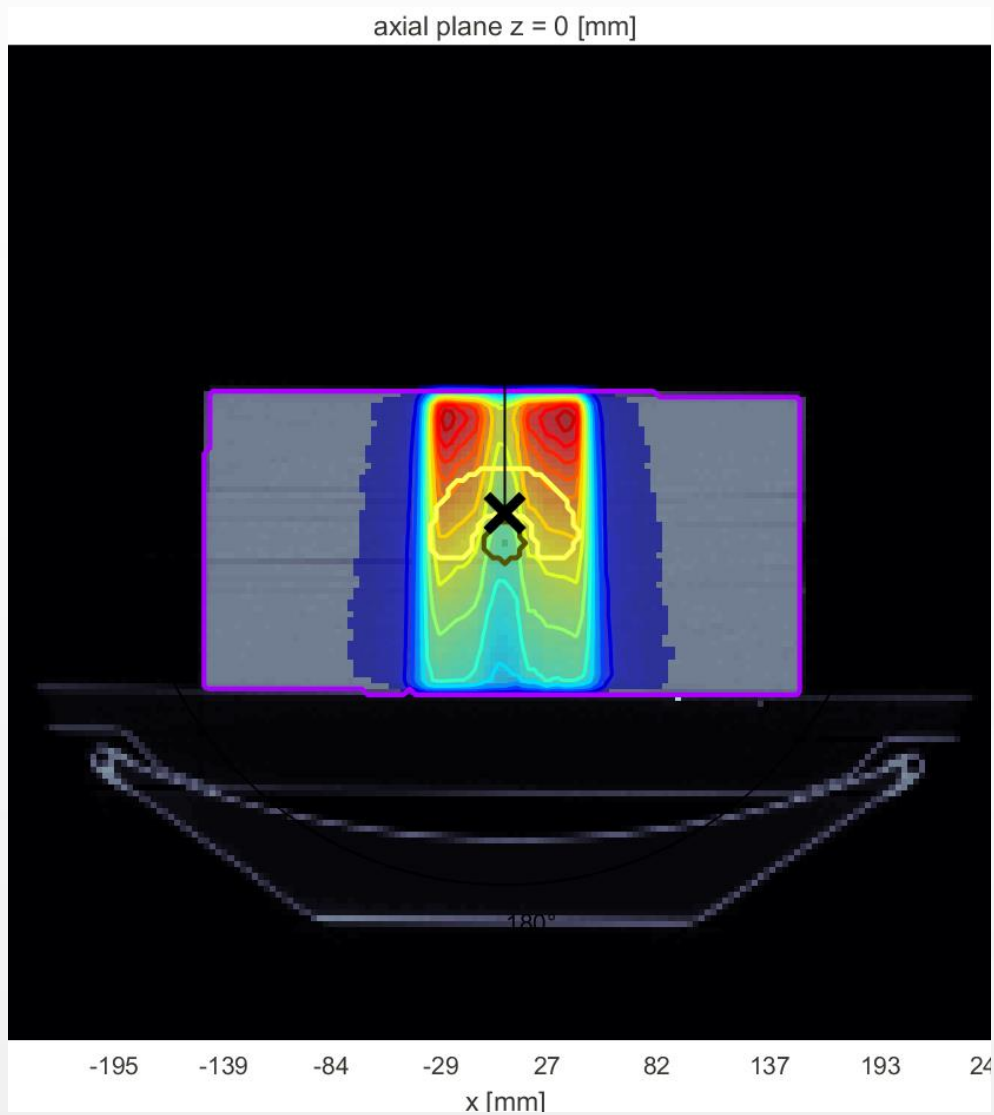
1. Load the TG119 phantom via the Load *.mat button (**TG119.mat**)
2. Set radiation modality to Photons and define **one** beam angle (**gantry angle**)
3. Trigger dose calculation via button (**Calc. Dose Influence**)
4. Start inverse optimization by click in on (**Optimize**) and analyze the resulting dose distribution
5. Save the optimization result via (**Save/Keep Result**). Next, show the DVH by (**Show DVH/QI**)
6. Change the radiation modality to: Protons and leave the beam angles unchanged
7. Repeat steps 3-5 and compare the dose distributions on the basis of photons and protons
8. Try to define a better photon treatment plan by defining more beam angles (0°, 72°, 144°, 216°, 288°)
9. Compare the results

TG119 PHANTOM



[Microsoft Word - TG119_Instructions_102109.doc](#)

The phantom is a box that contains a C-shape surrounded a cylinder (central avoidance structure). The center core is a cylinder 1 cm in radius.



Discussion

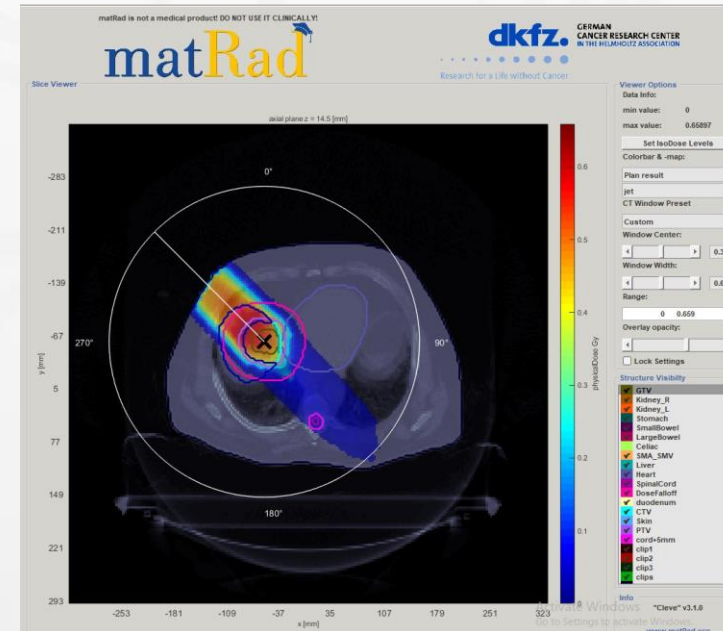
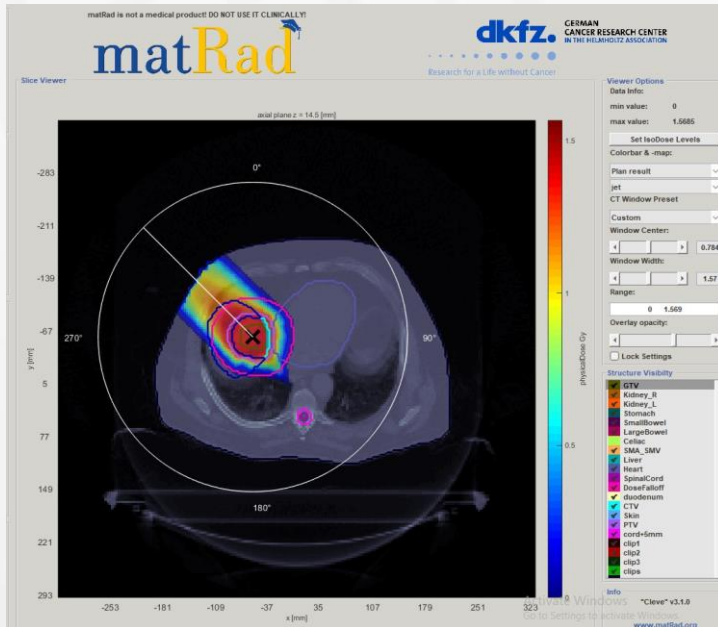
- What conclusions can be drawn from comparing photons and protons in the dose distribution?
- What insights can you share about the comparison of the histograms?

2nd Exercise-Carbon Ion TP for a liver patiente

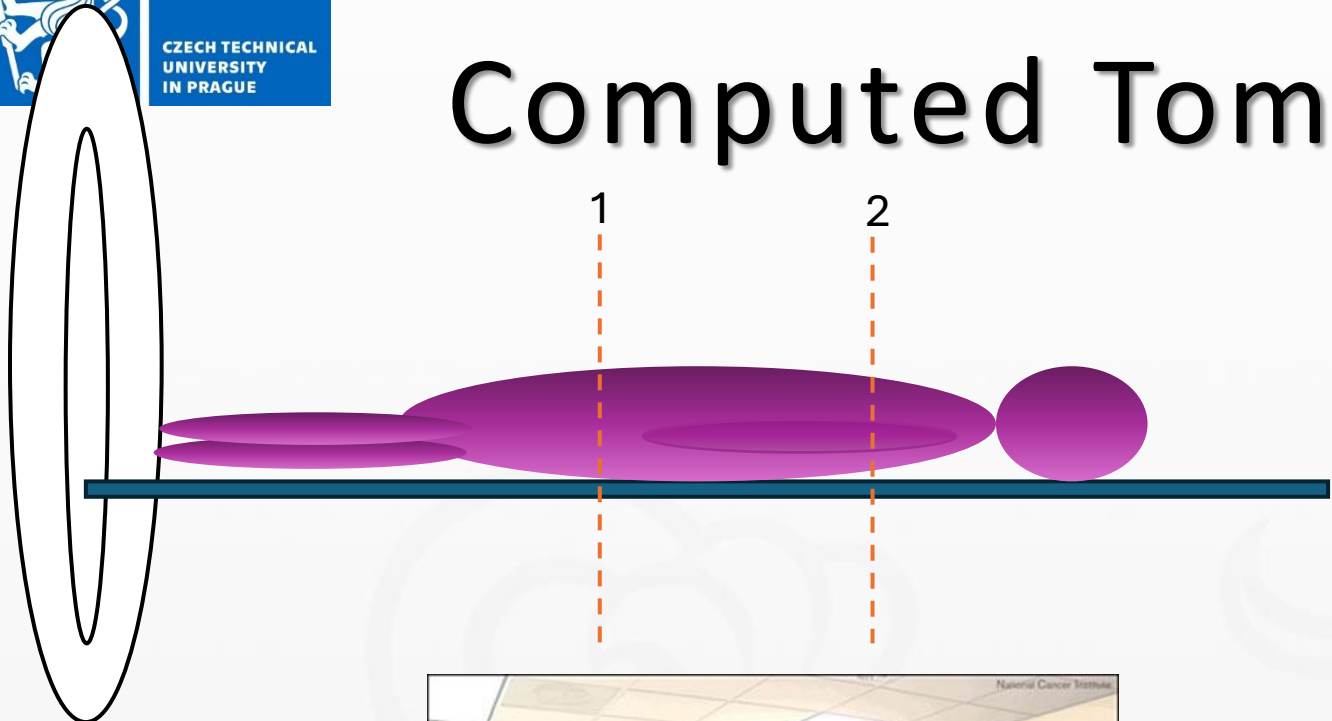


OBJECTIVES

1. Load the liver patient case via the Load *.mat button (**LIVER.mat**)
2. Define a photon treatment plan (0° , 72° , 144° , 216° , 288°) beam direction as well as a proton treatment plan with one beam from 315°
3. Analyze the differences of the optimized treatment plans
4. Create a carbon ion treatment with the exact same settings as used for the proton treatment plan – What difference can now be observed? (calculation time/dose distribution/ biological and physical dose)



Computed Tomography (CT) scan



Coronal view

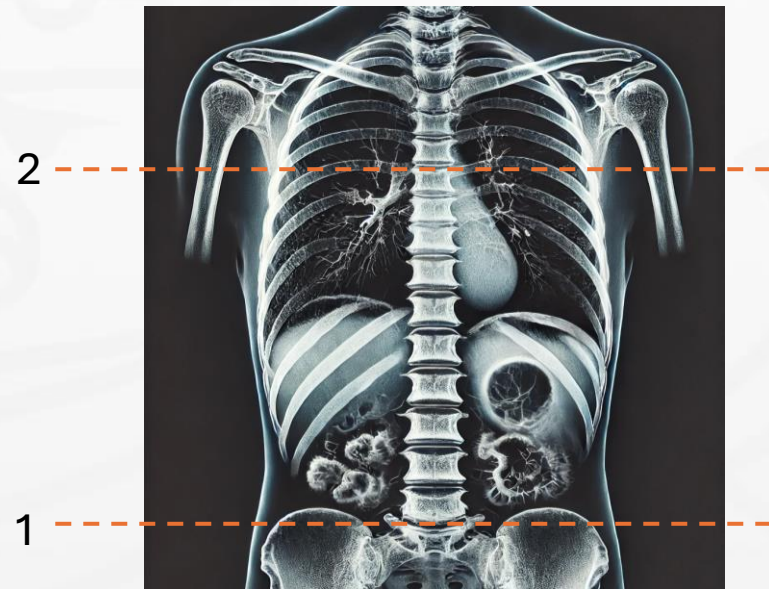
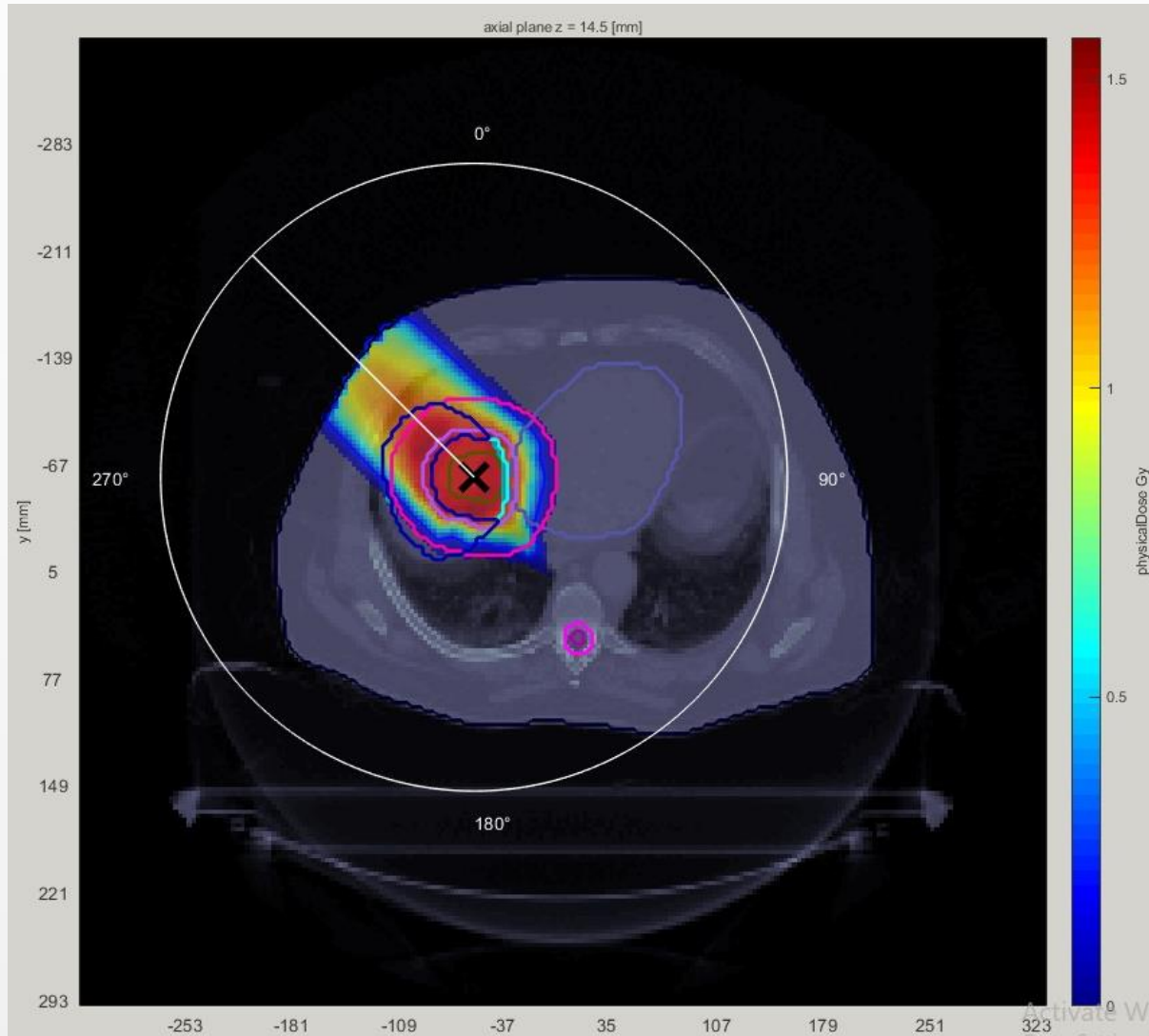


Image generated with AI



Discussion

- What differences can be observed with a carbon ion treatment compared with proton and photon treatment?
- Discuss about the calculation time, dose distribution, biological and physical dose.

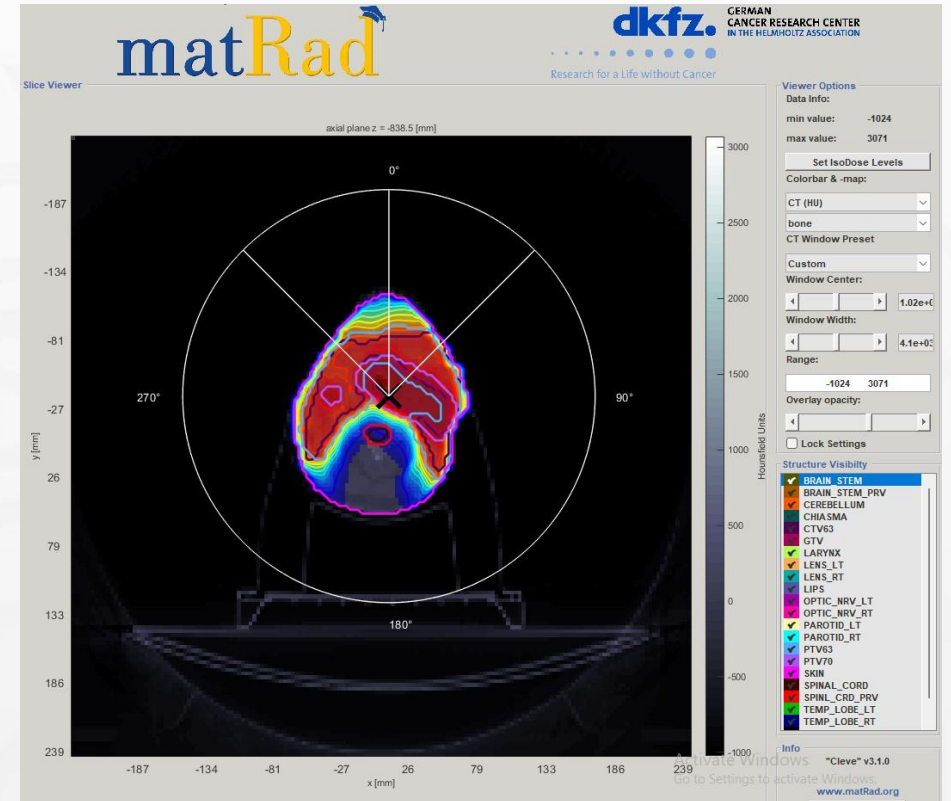
3rd Exercise-Head and Neck phantom

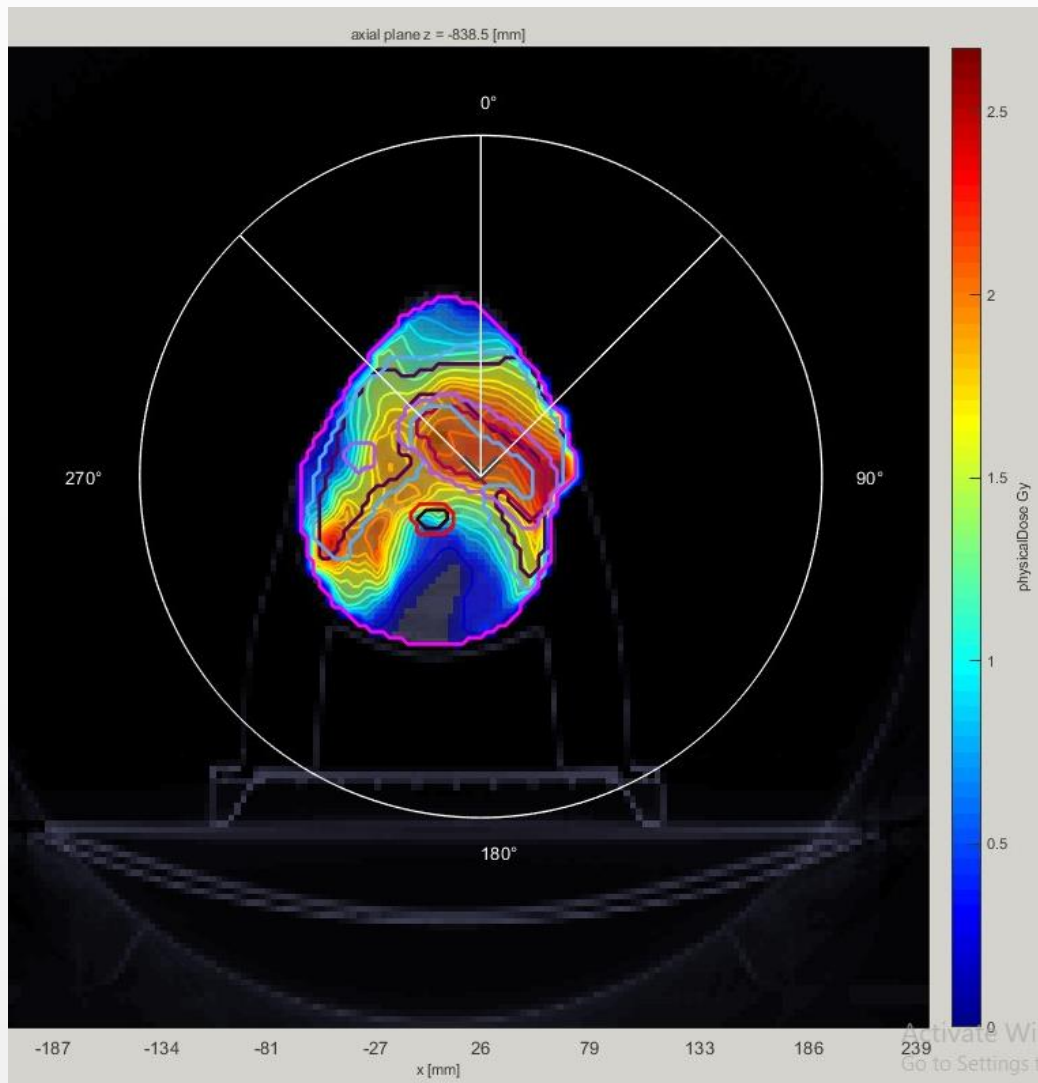


OBJECTIVES

- Load a head patient case (**HEAD_AND_NECK**)
- Add three proton beam angles on your own
- Calculate and optimize the dose and analyze the result (**Show DVH/QI**)
- Simulate a patient positioning error: Remove the hook at the auto iso-center checkbox and define a new iso-center thereby introducing an offset

CAUTION: Recalculate the dose based on the previously optimized pencil beam intensities by clicking on the button (**Recalc**). Do not perform a new optimization!





Discussion

- Analyze and compare the resulting dose distribution. What changed?

Questions?

Let's play with Kahoot



Kahoot!

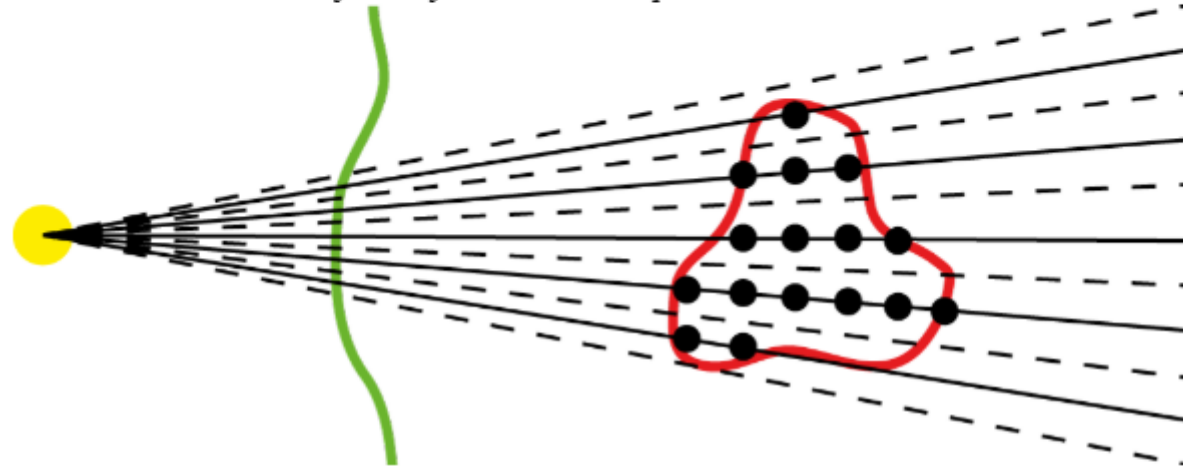
www.kahoot.it

Thank you for your attention!

Ray and bixel concept

The irradiation geometry is organized to a ray and bixel concept, which is schematically shown below.

Schematic visualization of the ray and bixel concept



From a virtual radiation source (yellow) the target volume (red) within the patient (green) is covered by equidistant rays (solid black). Note that only a two-dimensional cut through a three dimensional cone of rays is shown for clarity. In the isocenter plane (not shown) the distance of the individual rays corresponds to the bixel width (compare [pIn struct](#)). For photons, the term bixel refers to a discrete rectangular fluence element (the limits of the individual bixels are shown in dashed black). Together, all bixels cover the entire target volume.

For 3D IMPT for particles, we have an additional degree of freedom, namely the particle energy to be considered. This is accounted for during the stf-struct generation by determining the depth of the target volume on individual rays and placing spots (black dots) accordingly.

More information about the ray and bixel concept (though with slight variations in nomenclature) can be found in sections 2.3 and 2.5 [Nill \(2001\)](#).