

4.1 INTRODUCTION TO PARTICLE THERAPY TREATMENT PLANNING SIMULATIONS

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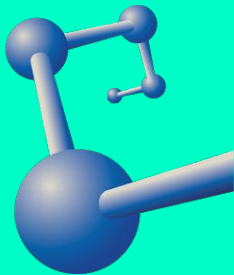
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IPPOG's Member

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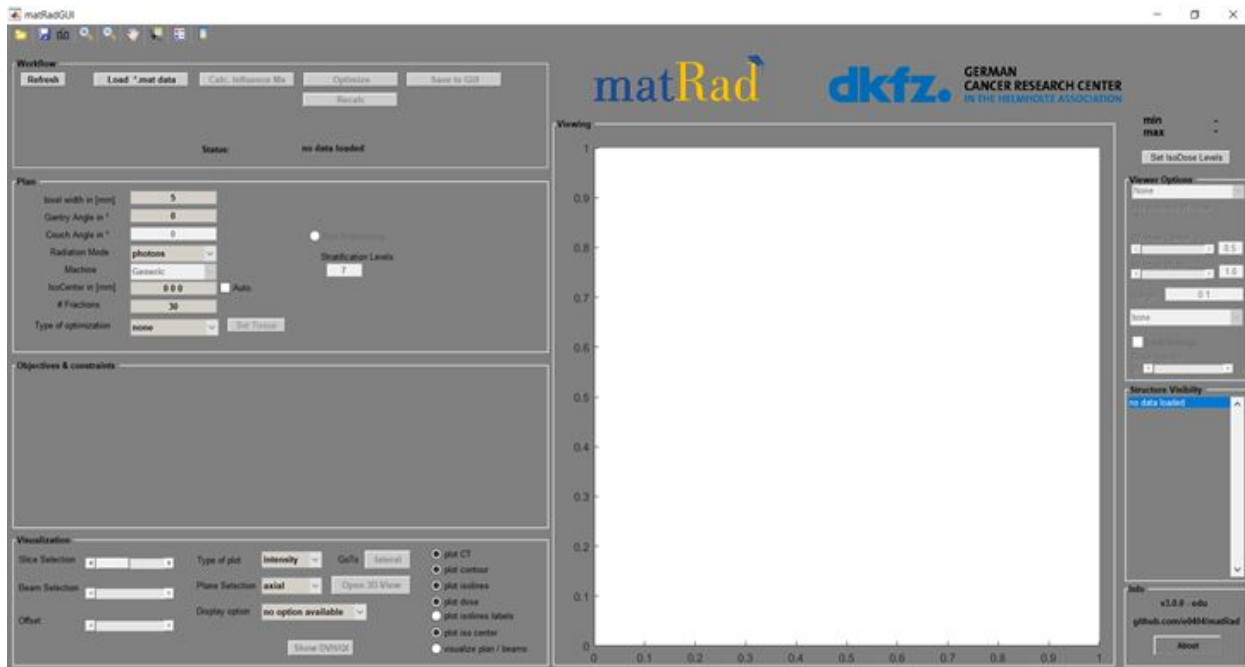
ARISTOTLE
UNIVERSITY OF
THESSALONIKI



DEMO

WHAT IS MATRAD?

MatRad is a computer software for treatment planning, developed by DKFZ.



The data available for matRad software include the cases of:

- I. TG 119 or C-phantom
- II. Liver
- III. Head & Neck (H&N)

1. WHAT SHALL WE DO?

- First we will provide necessary definitions and describe **what one should see** once matRad is installed.
- Then we will explain **what is the function of each button**.
- Finally you will run your **first simulation**.



See



Test

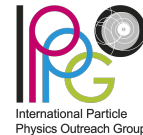


Play

We will let you know one slide before the *right answer appears* with a “Spoiler alert” sign.

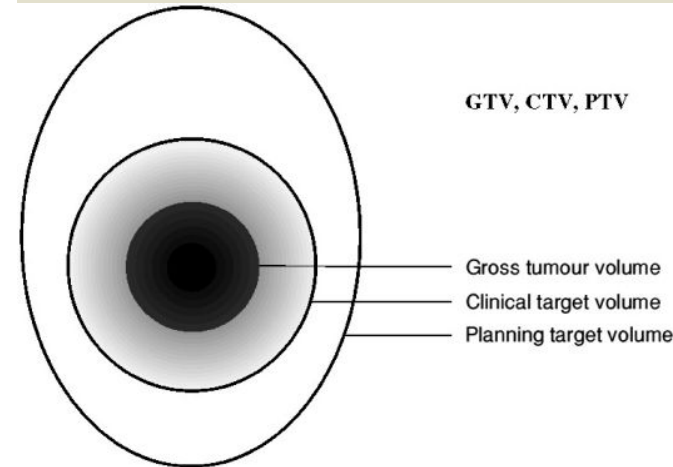
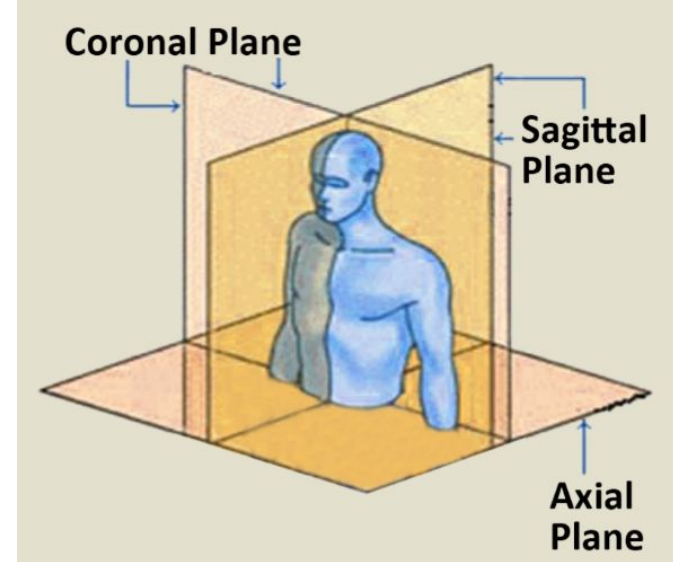


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1.1 DEFINITIONS

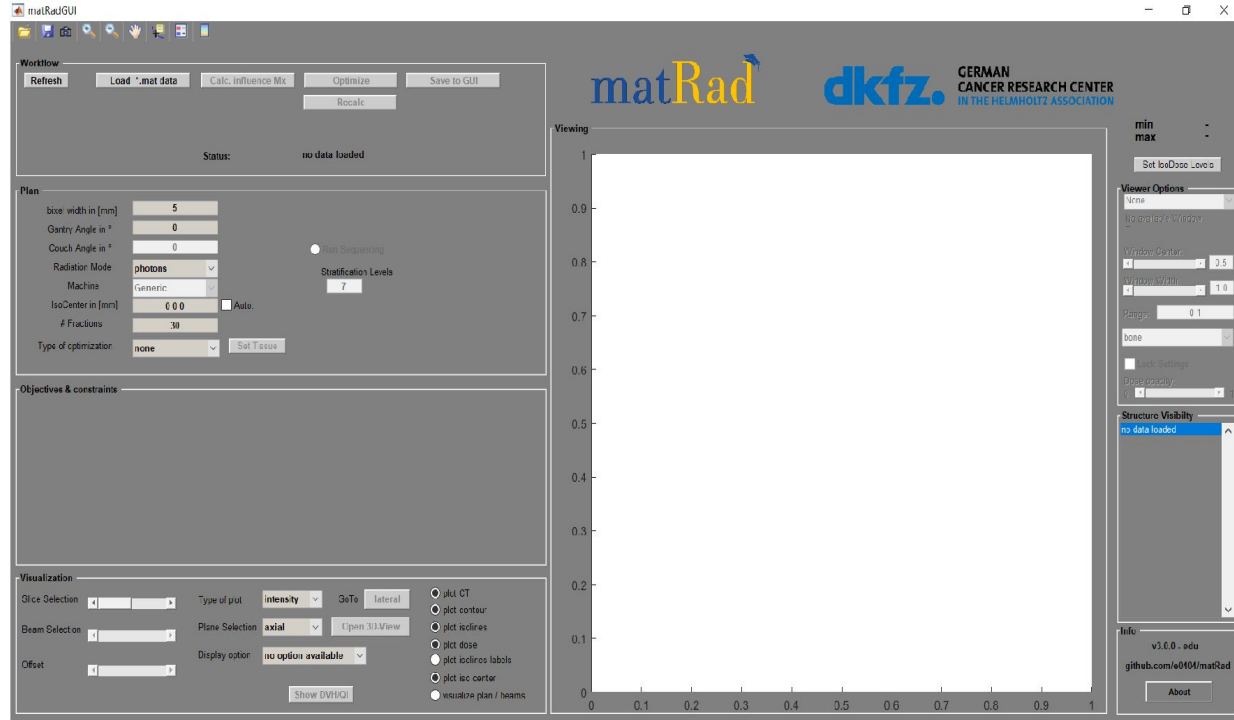
- GTV is the gross tumor volume (what in general can be seen on the image).
- CTV is the clinical target volume (where the physician thinks there is still cancerous tissue despite being directly visible in the image).
- PTV is the "Planning Target Volume" that should be irradiated.
- OAR means "Organ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



2. HOW TO START: MATRAD INTERFACE

When you open matRad you should see the the initial software panel. Note its different fields and their titles.

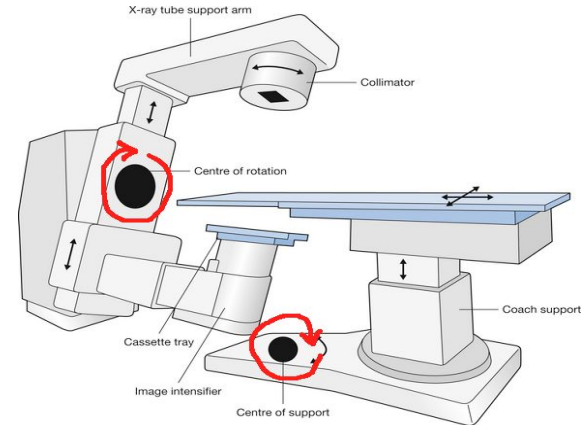
In the following slides, we will describe them after we insert the data.



2. HOW TO START: PLAN

- **Bixel width:** square size.
- **Gantry and couch angles:** *It sets ordered pairs of values both for Gantry and couch angles if you set 5 Gantry angles, you will need 5 bed angles. The angles can be from 0° to 359° .*
- **Radiation mode:** choose which particle to use.
- **Isocenter:** Verify the automatic isocenter is set to true.
- **Fractions:** The number of fractions is the number of “slices” that will be used to display 3D graphics.
- **Run sequencing:** is used for collimating the beam.

bixel width in [mm]	5
Gantry Angle in °	0 72 144 216 288
Couch Angle in °	0 0 0 0 0
Radiation Mode	photons
Machine	Generic
IsoCenter in [mm]	251.3 236.4 162.8
# Fractions	30
Type of optimization	none



2. HOW TO START: PLAN

The collimator works shaping the area of the particle flux that should reach the target according to the target shape.

We will set it to false, but you can try it later.

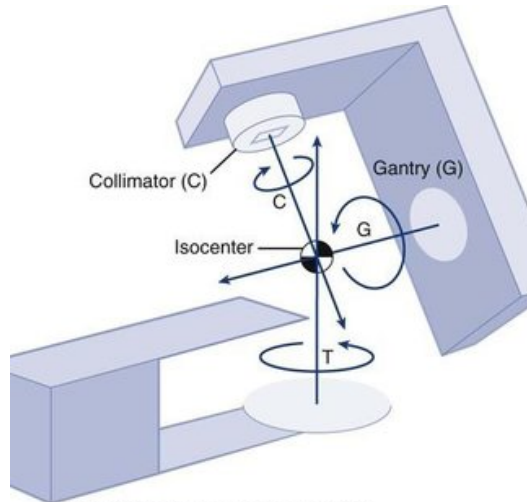
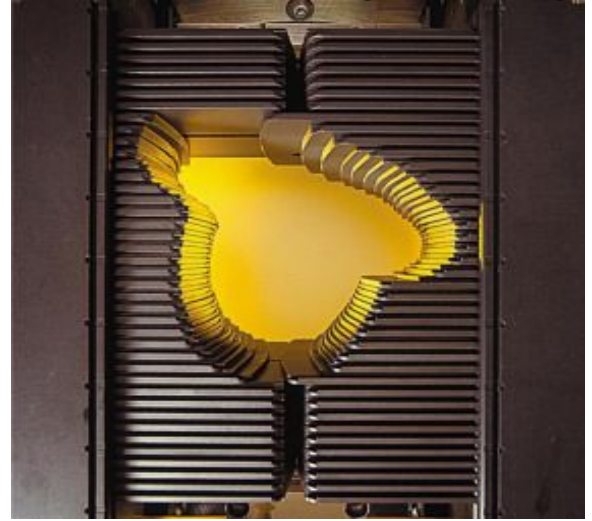




Table (T) (patient support assembly)

The isocenter is the point from which, the central rays of the irradiation beam passes.

For simplicity the developers have blocked the couch angles.

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Workflow: Refresh Load *.mat data Calc. influence Mx Optimize Save to GUI Recalc

Status: ready for dose calculation

Plan

bical width in [mm]: 5

Gantry Angle in °: 0 72 144 216 288

Couch Angle in °: 0 0 0 0 0 Run Sequencing

Radiation Mode: photons Stratification Levels: 7

Machine: Generic

IsoCenter in [mm]: 251.3 236.4 162.6 Auto.

Fractions: 30

Type of optimization: none Get T dose

Objectives & constraints

±/∓	VOI name	VOI type	OP	Function	p	Parameters
-	Core	OAR	2	Squared Overdosing	300	d_{max}^{25}
-	OuterTarget	TARG...	1	Squared Deviation	1000	d_{50}^{50}
-	BODY	OAR	3	Squared Overdosing	100	d_{max}^{30}

Core

Visualization

Slice Selection: [] Type of plot: intensity Go To: lateral plot CT

Beam Selection: [] Plane Selection: axial plot contour

Offset: [] Display option: no option available plot isoclines

plot dose

plot isoclines labels

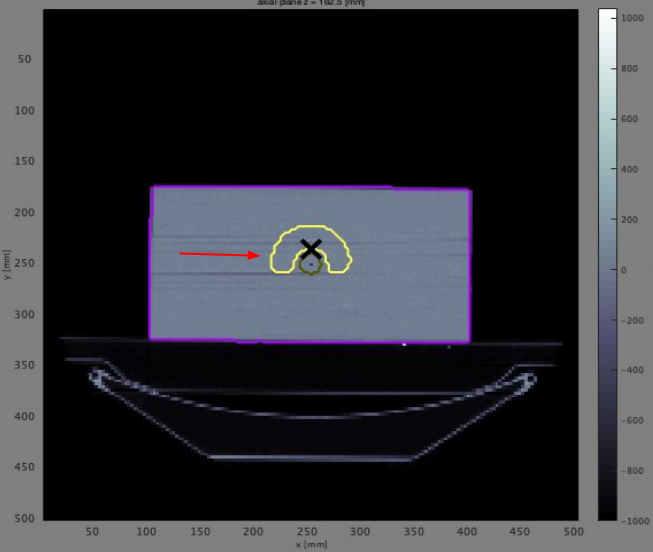
plot iso center

visualize plan / beams

Show DVH/OT

Viewing

axial plane z = 162.5 [mm]



min value: -1000
max: 1040

Set IsoDose Levels

Viewer Options

CT (HU)

Window Preset: Custom

Window Center: 20.2

Window Width: 2.04e

Range: -1000 1040

bone

Lock Settings

Dose opacity: 1

Structure Visibility

- Core
- OuterTarget
- BODY

Info

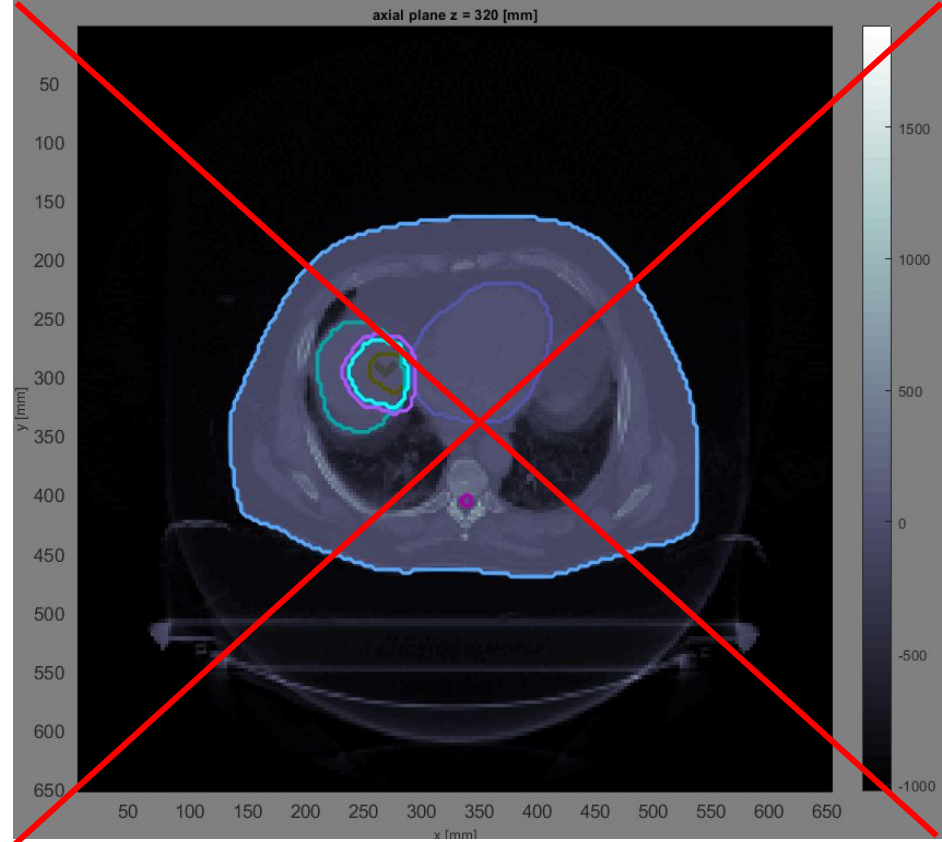
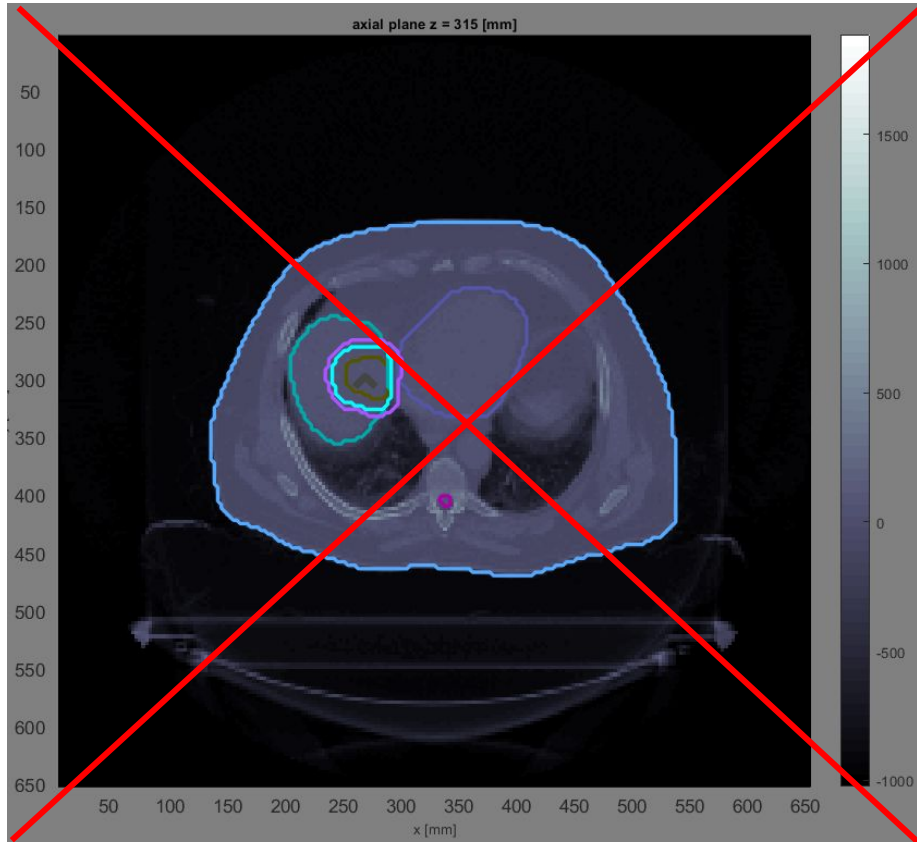
v3.0.0 - edu

github.com/0404/matRad

About

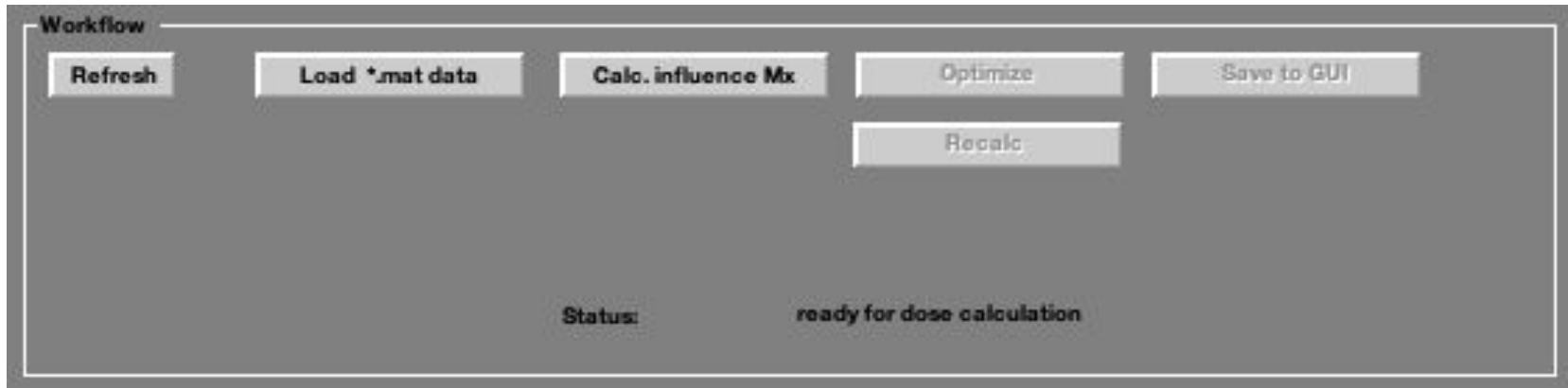
In each simulation remember to find the isocenter sign (X), by moving the slices from the visualization panel.

Wrong figures of isocenter sign!



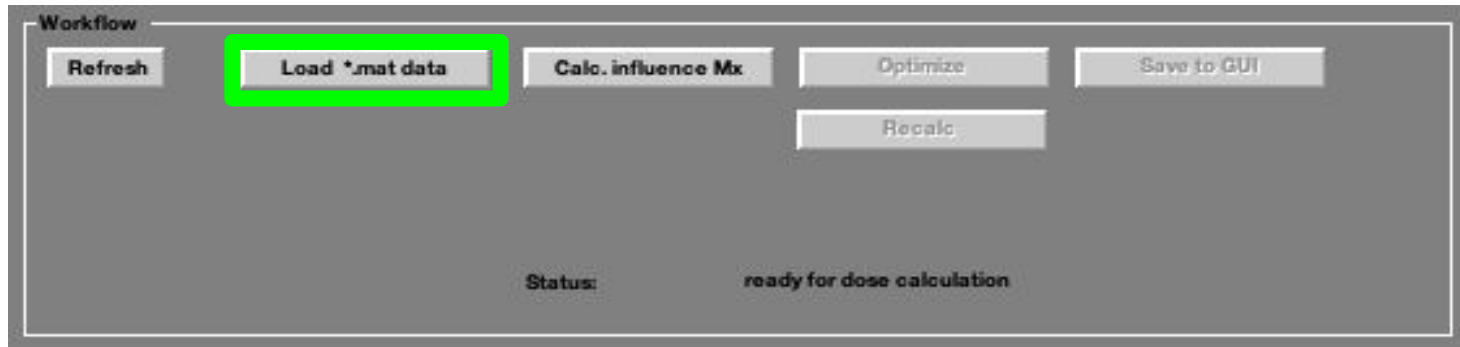
2. HOW TO START: WORKFLOW

The workflow panel has options to set commands to run the treatment planning simulation.



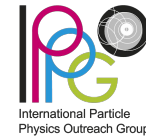
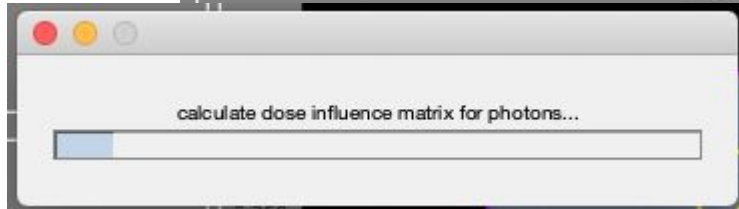
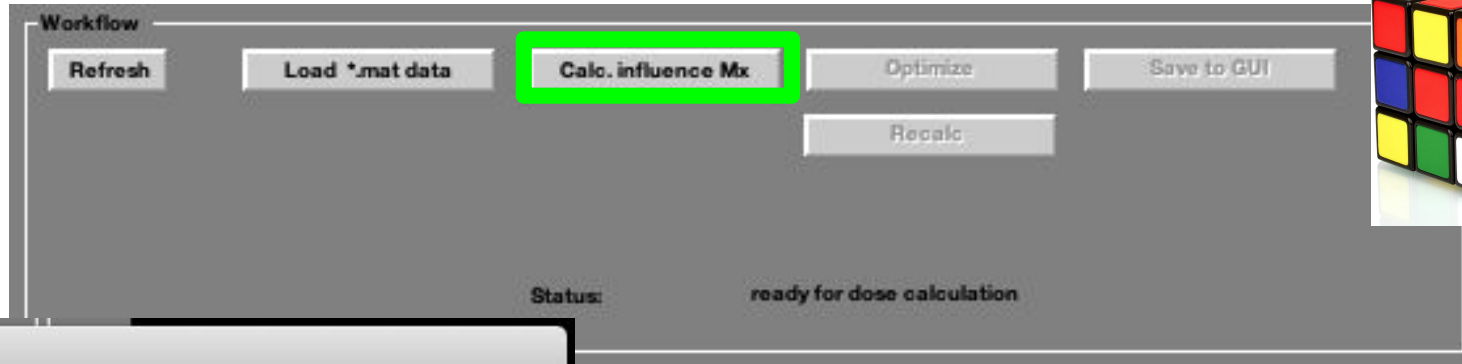
2. HOW TO START: WORKFLOW

Load *.mat data: It loads the data contained for each case of study. It has info about the target tissue as well as the surrounding healthy tissue, covering a “big portion of the body”. You will see it in the big panel at the right part of the visualization screen.



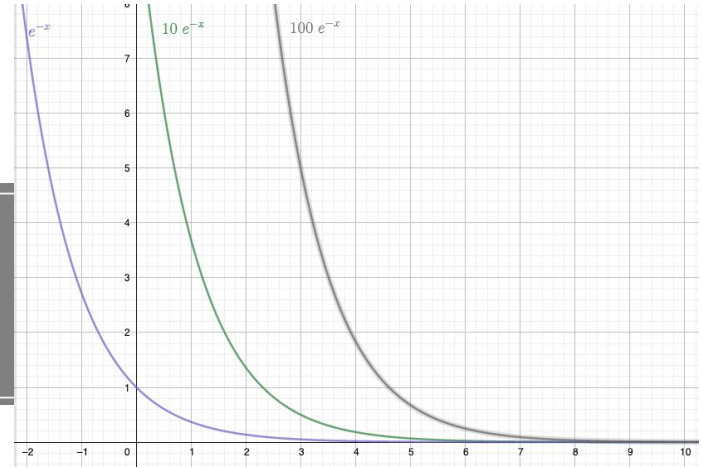
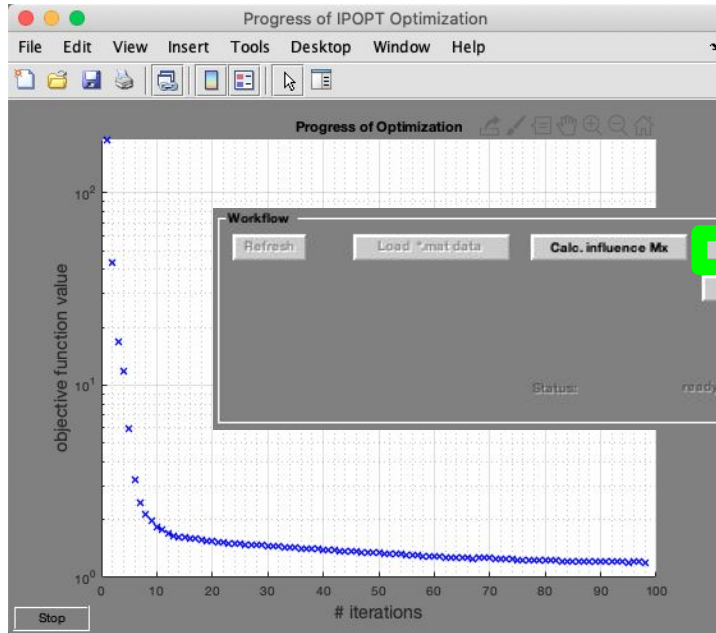
2. HOW TO START: WORKFLOW

Calc. influence Mx: It is the command to calculate the matrix of influence (of the radiation). The tissue is formed by “cubes” bixel-sized. Once you click, it will display a charging bar.

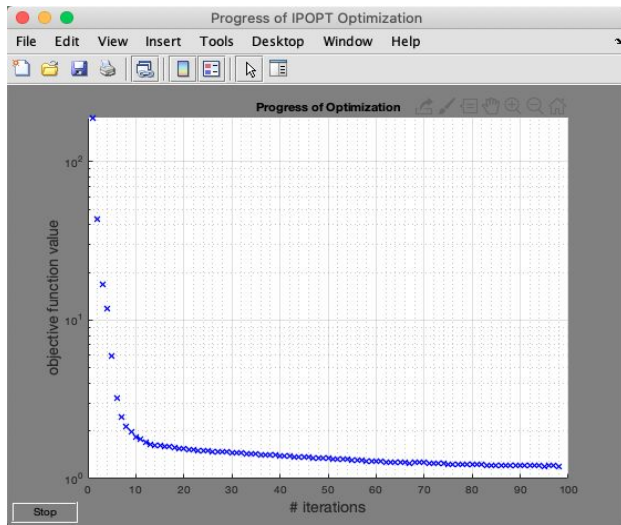


2. HOW TO START: WORKFLOW

Optimize: It is unlocked once the previous step is done. Here the program will look for the minimum radiation flux per bixel. After clicking you will see a graph, observe the y-axis and its values. The plot has an exponential form.



2. HOW TO START: WORKFLOW-EXPONENTIAL DISTRIBUTION



The optimizer optimizes a non-linear constrained optimization problem with an interior-point algorithm. The objective function and constraint functions are built from the specific objectives one can set in the table.

Objectives & constraints						
+/-	VOI name	VOI type	OP	Function	p	Parameters
-	Core	OAR	2	Squared Overdosing	300	d^{\max} : 25
-	OuterTarget	TAR...	1	Squared Deviation	1000	d^{ref} : 50
-	BODY	OAR	3	Squared Overdosing	100	d^{\max} : 30
+	Core					

Objectives and constraints include the organs of interest (e.g target), as well as the organs at risk (e.g body, core etc.) that are about to be irradiated and also, we want to avoid obtaining more dose.

2. HOW TO START: WORKFLOW

Save to GUI: It will save what you have set up and will ask you to give it a name. This step is essential for displaying the DVH.



2. HOW TO START: VISUALIZATION

Show DVH/QI: It shows the dose-volume histogram related to your designed plan.

Visualization

Slice Selection: [Slider]

Beam Selection: [Slider]

Offset: [Slider]

Type of plot: intensity

Plane Selection: axial

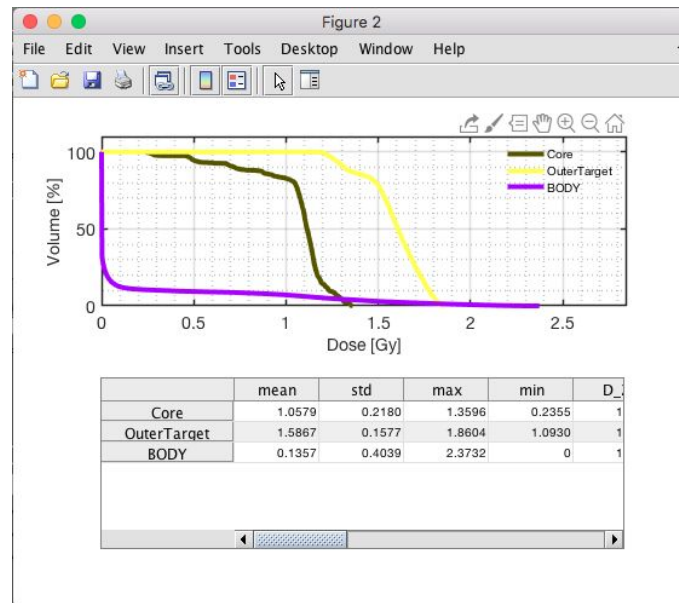
Display option: physicalDose

GoTo: lateral

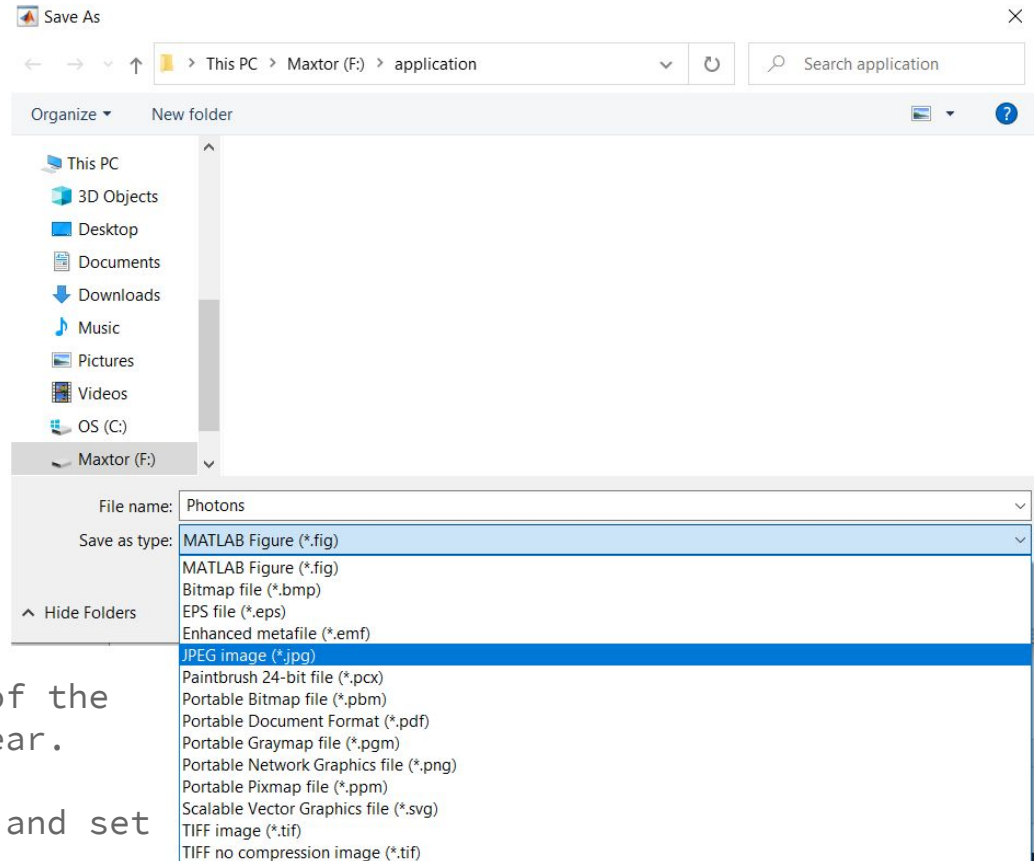
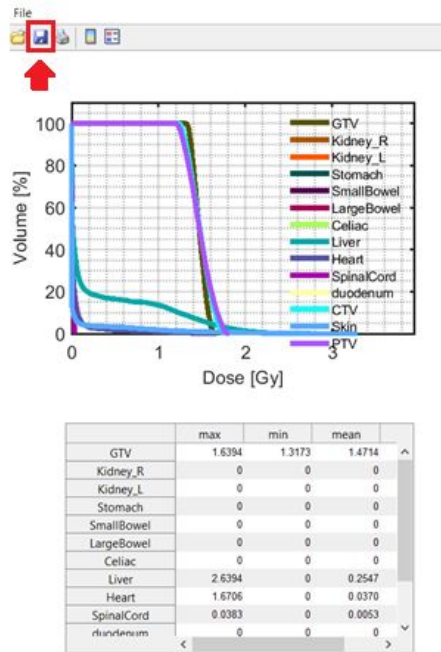
Open 3D-View

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

Show DVH/QI



2. HOW TO SAVE: DVH-HISTOGRAM FOR EACH CASE



Click the disk sign on the upper part of the histogram, a “Save As” window will appear.

Name the file with an appropriate name and set the type as a JPEG image.

APPROPRIATE NAMES FOR THE SAVED FILES

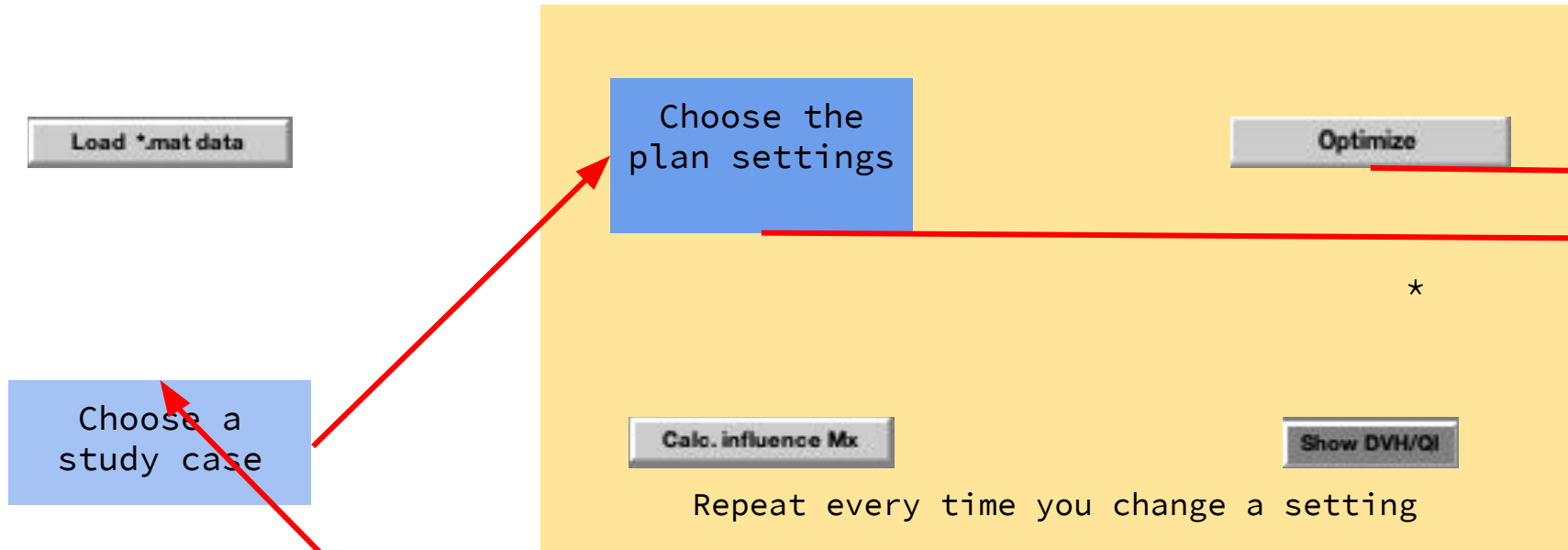
The names that can be set to represent the saved image or file, should mention the case of study e.g. C for C-phantom, L for Liver and H for Head and Neck.

Additionally, the number of radiation beams should be included together with the radiation mode e.g. C_1_photons for 1 radiation beam of photons on a C-phantom sample.

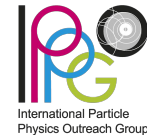
In the end, give the name of the respective faculty that you belong e.g. C_1_photons_AUTH for Aristotle University of Thessaloniki.

The final result should look like this: C_1_photons_AUTH

2. HOW TO START: SUMMARY



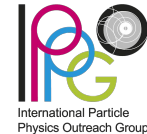
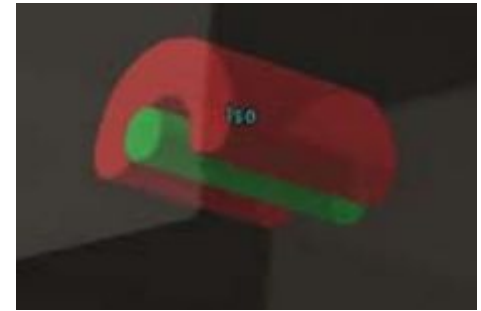
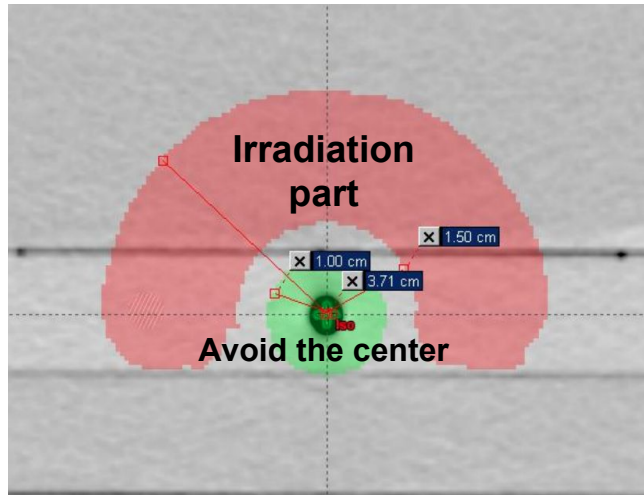
* We'll give you a tip before the DVH so you can understand it easier



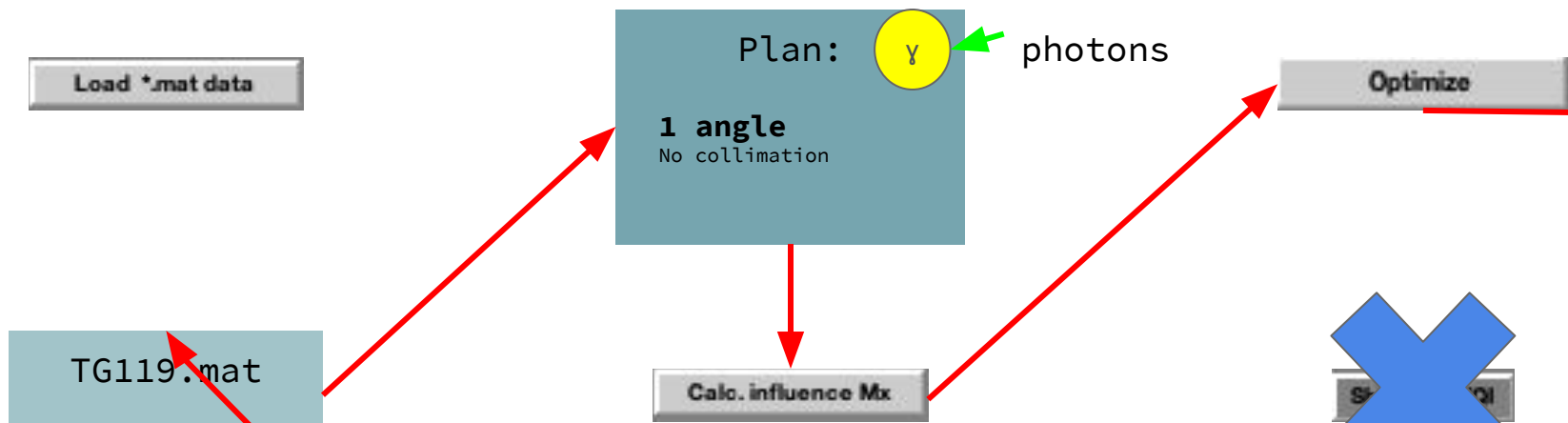
3.1 TRAINING SIMULATION: TG119

The TG119 or C-phantom is an acrylic shape used by professionals to verify if the equipment is working well. It has standard shape and dimensions.

The aim is to avoid the central bar and irradiate (target) only the C shape.

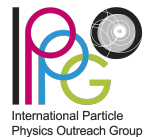


3.1.1 TRAINING SIMULATION: TG119 PLAN 1




We'll skip the DVH for now

Save your results in the file 4_Simulations, in the subfile 1 or in your Desktop. You can name it by the number or angles and particle used. Play with the visualization options, "visualize plan" is great help.



3.1.2 TRAINING SIMULATION: TG119 PLAN 2

Plan: 

**5 angles
(equidistant)**
No collimation

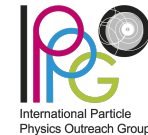
Optimize

Calc. influence Mx

Remember, the angles are from 0° to 359° ($360^\circ = 0^\circ$).



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3.1.3 TRAINING SIMULATION: TG119 PLAN 3

Plan: 

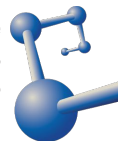
7 angles
(equidistantes)
No collimation


Optimize

Calc. influence Mx

If your PC has not enough RAM (less than 8GB) then, the optimization will take a lot of time. In general, it is possible to use up to 15 angles but it will take a long time. Bigger RAM memory, better software performance.

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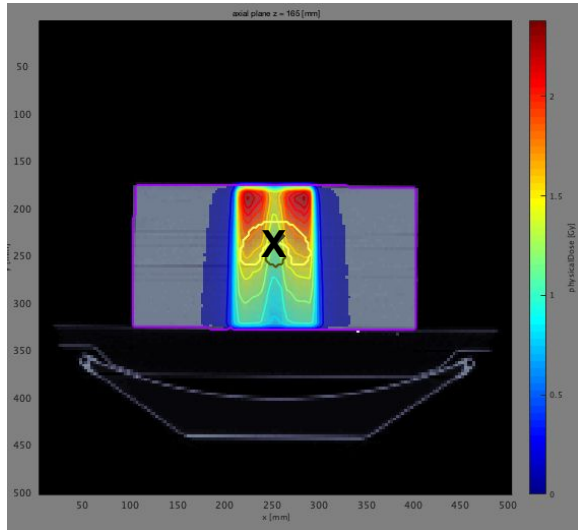


3.1.2 TRAINING SIMULATION: TG119 PLAN 3

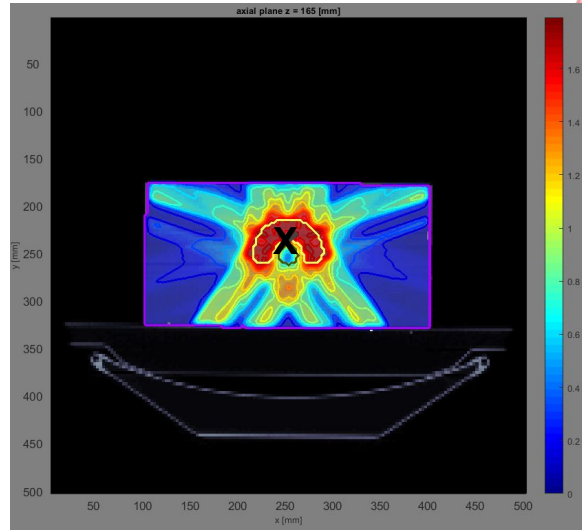


The right answer is about to appear..!!

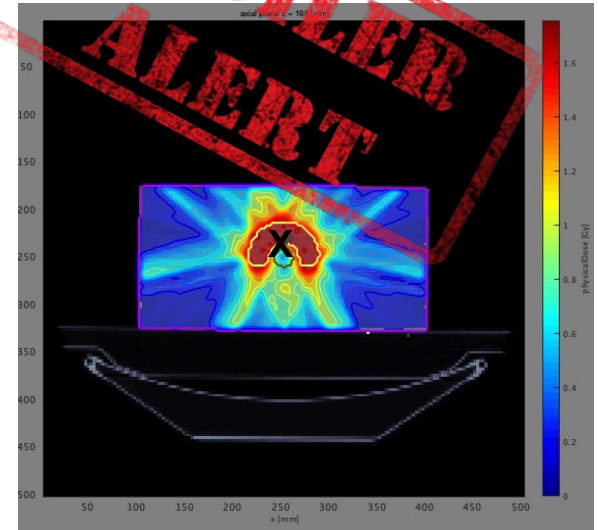
3.1.3 PHOTON TREATMENT PLAN COMPARISON



1 angle (every 0°)



5 angles (every 72°)

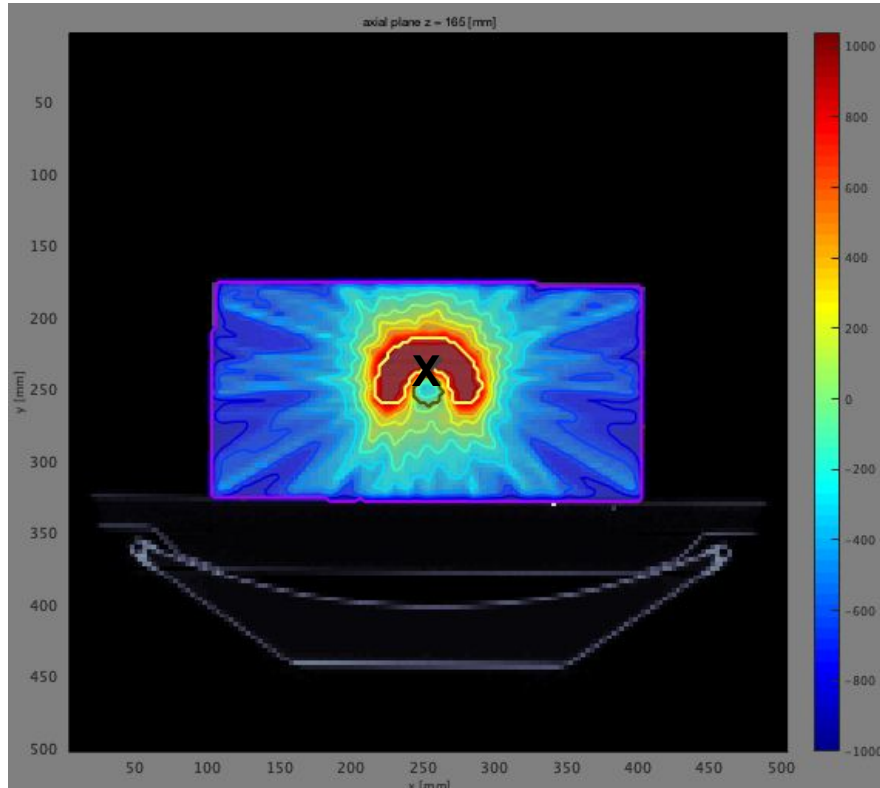


7 angles (every 51.4°)

The red zones are the most irradiated, the blue ones are the least and the gray are not irradiated.



3.1.3 THE BEST PLAN WE FOUND



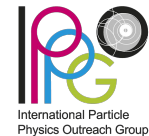
15 angles, every 24° : with 16 GB of RAM.

It is better to set an *odd* number of angles.

The beams are focused almost only in the c-shape of the target, which is the part that we want to irradiate.

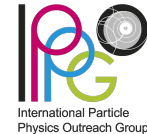


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3.2 COMPARING PARTICLES ON TG119

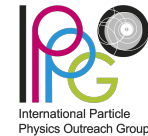
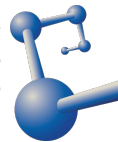
Repeat the best plan using protons and then repeat it using carbon ions. What do you observe?



3.2 COMPARING PARTICLES ON TGI19

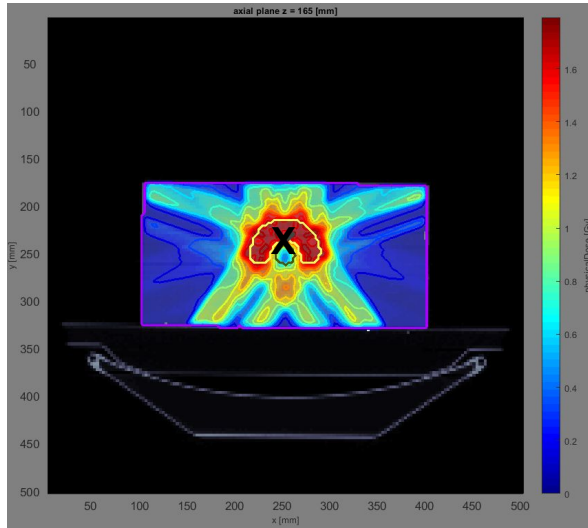


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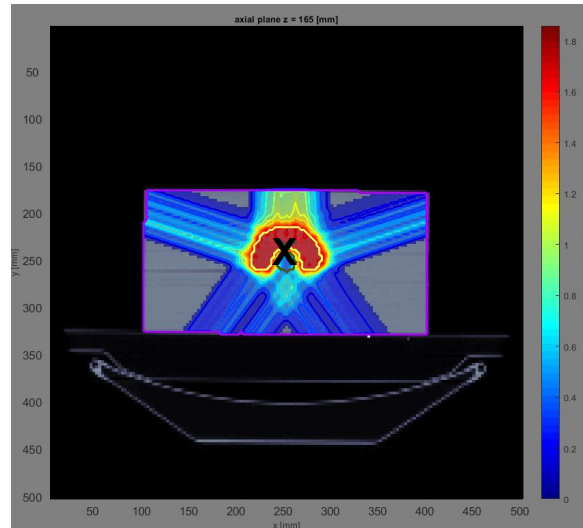


3.2 COMPARING PARTICLES ON TG119

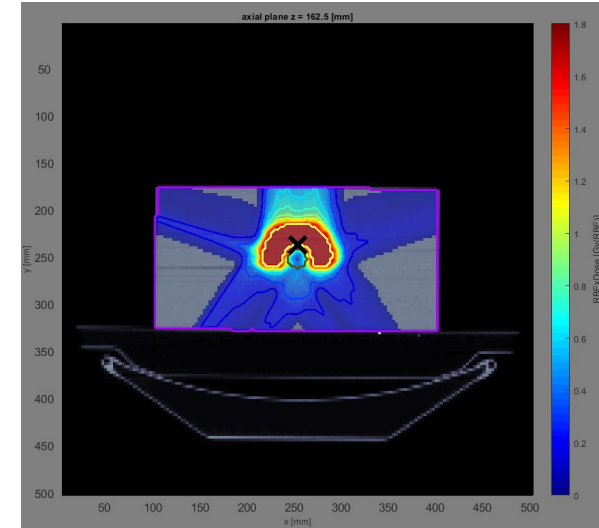
Using 5 angles,



Photons



Protons



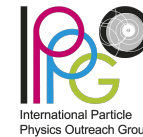
Carbon ions

The red zones are the most irradiated, the blues are the least and the gray are not irradiated.

x2



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4. THE IMPORTANCE OF TREATMENT PLANNING SOFTWARE

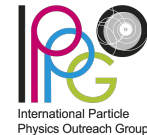
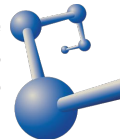
The whole procedure of designing and implementing a treatment plan it is not as easy as pressing a simple button. It requires the combination of mathematical and probabilistic theories that is applied to design these treatments.

A wide range of expertise are offering their knowledge, in order to achieve the most efficient outcome.

In the end, we are all working to reach a common goal, which is to save as more lives as possible.

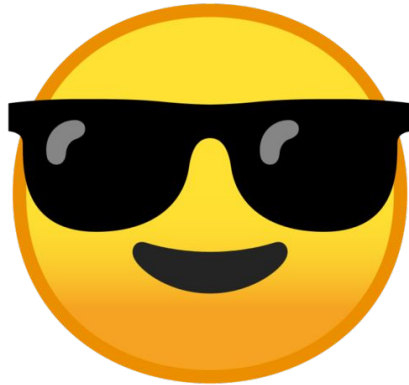


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EXTRA ADVICE

If you want to explore options such as Objectives & Constraints, we suggest you to do it at the end, using TG119.



WE CAN GO TO THE
LIVER CASE!

Go to the subfile
"4.2_Liver"