4.1 Introduction to particle therapy treatment planning simulations

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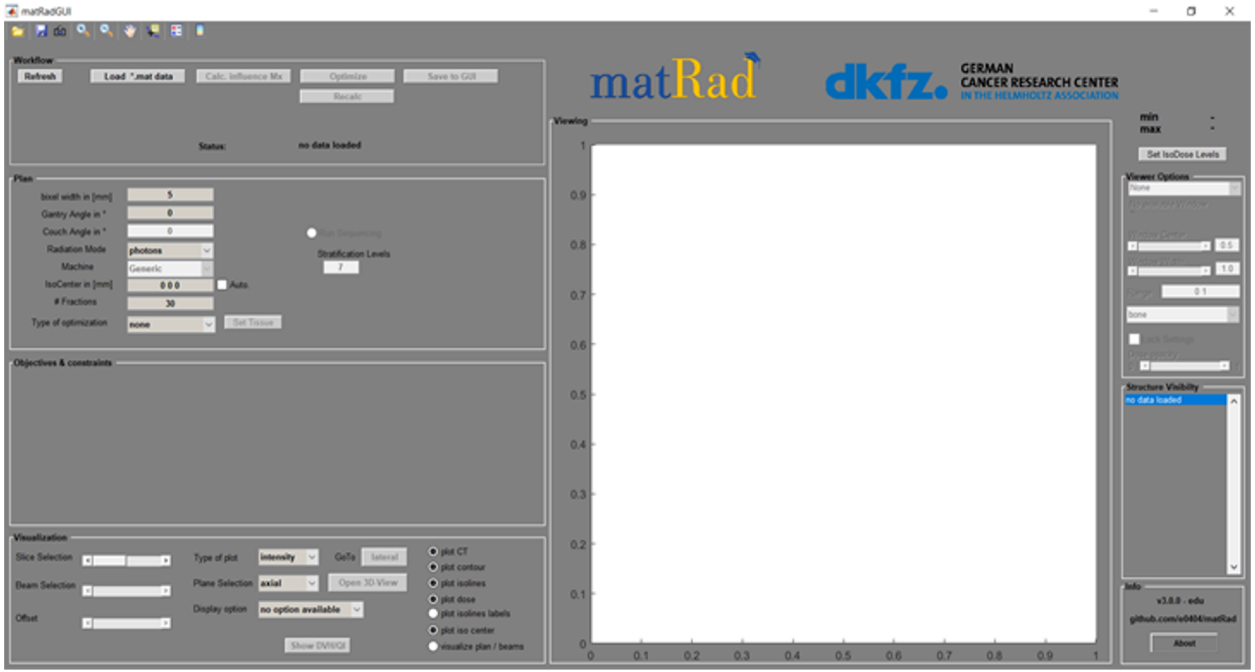
DEMO

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)

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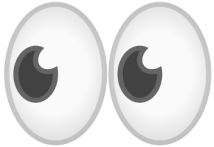
1. What shall we do?

-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 *expected answer appears with a "Spoiler alert" sign.*

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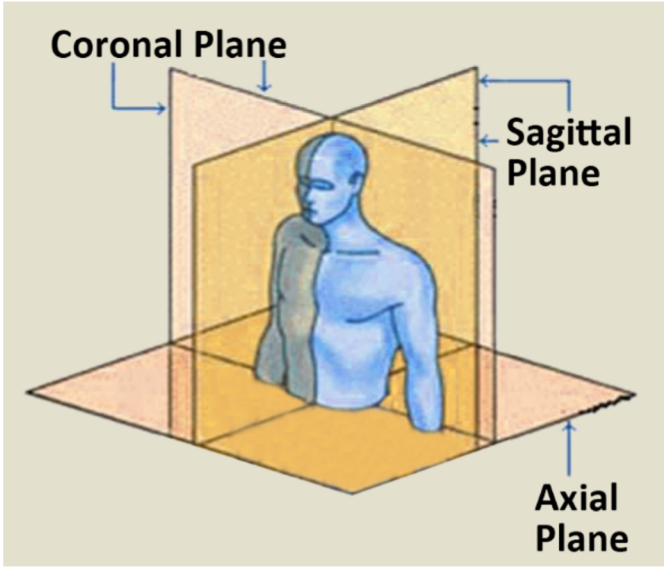
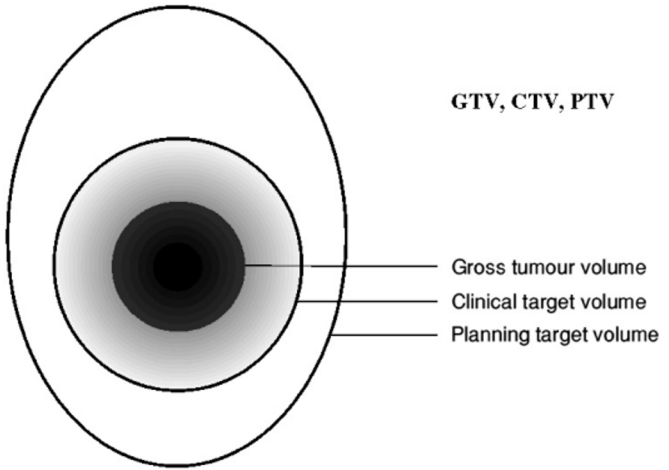
1.1 Definitions

- **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.

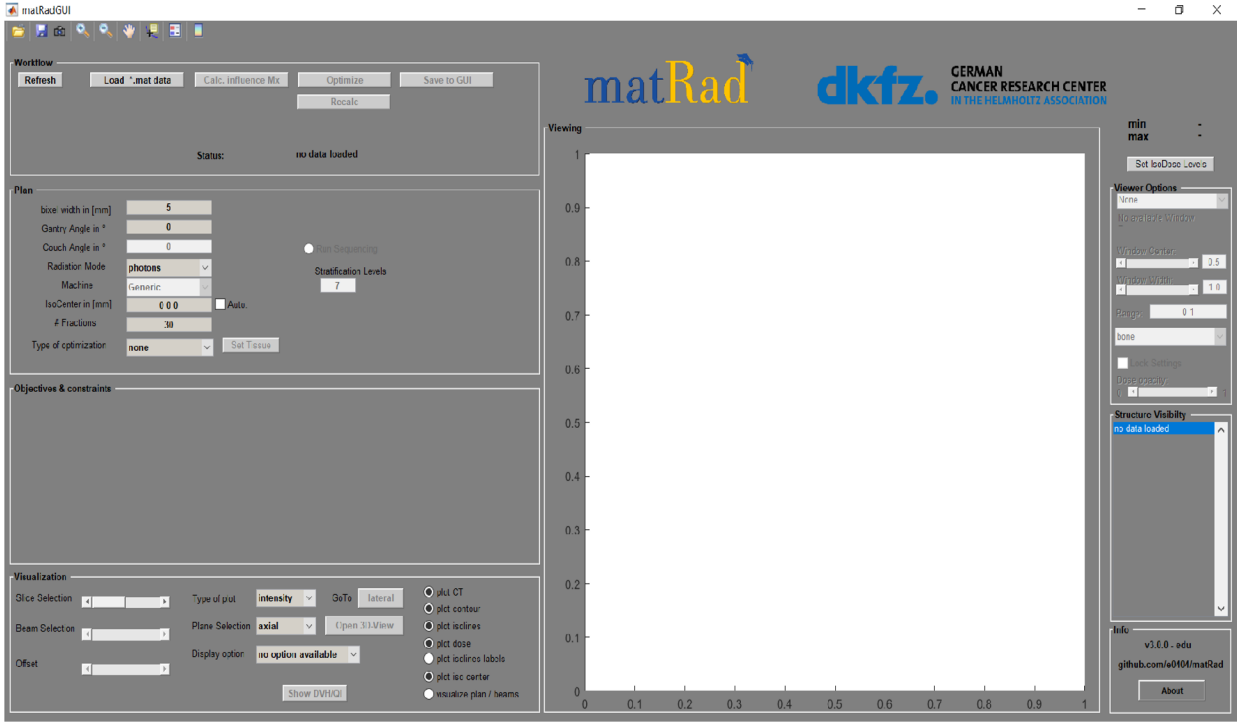




2. How to start: matRad Interface

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.



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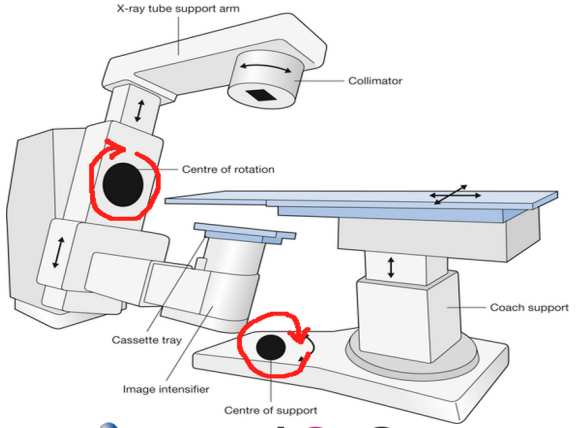
2. How to start: Plan

- **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.



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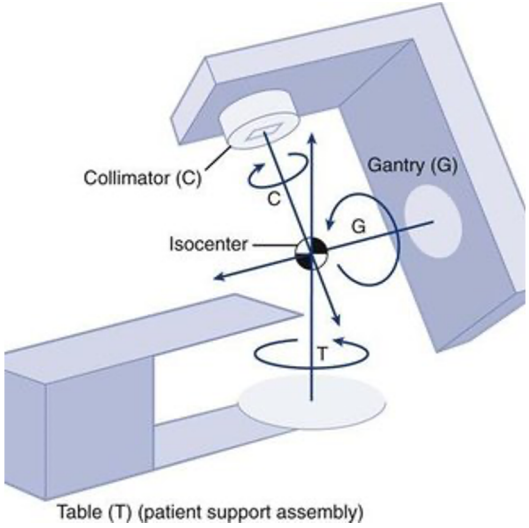
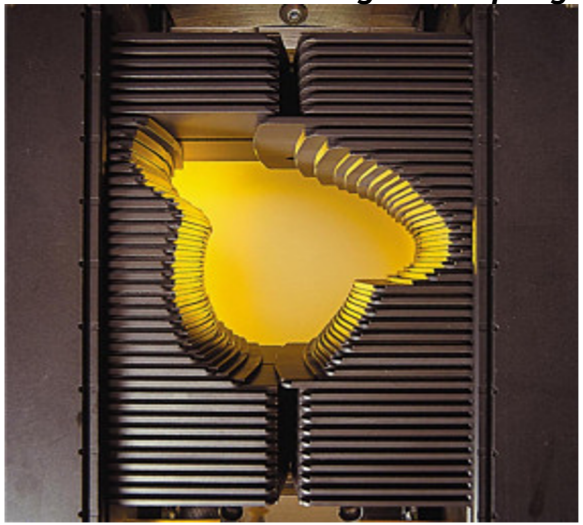
2. How to Start: Plan

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.

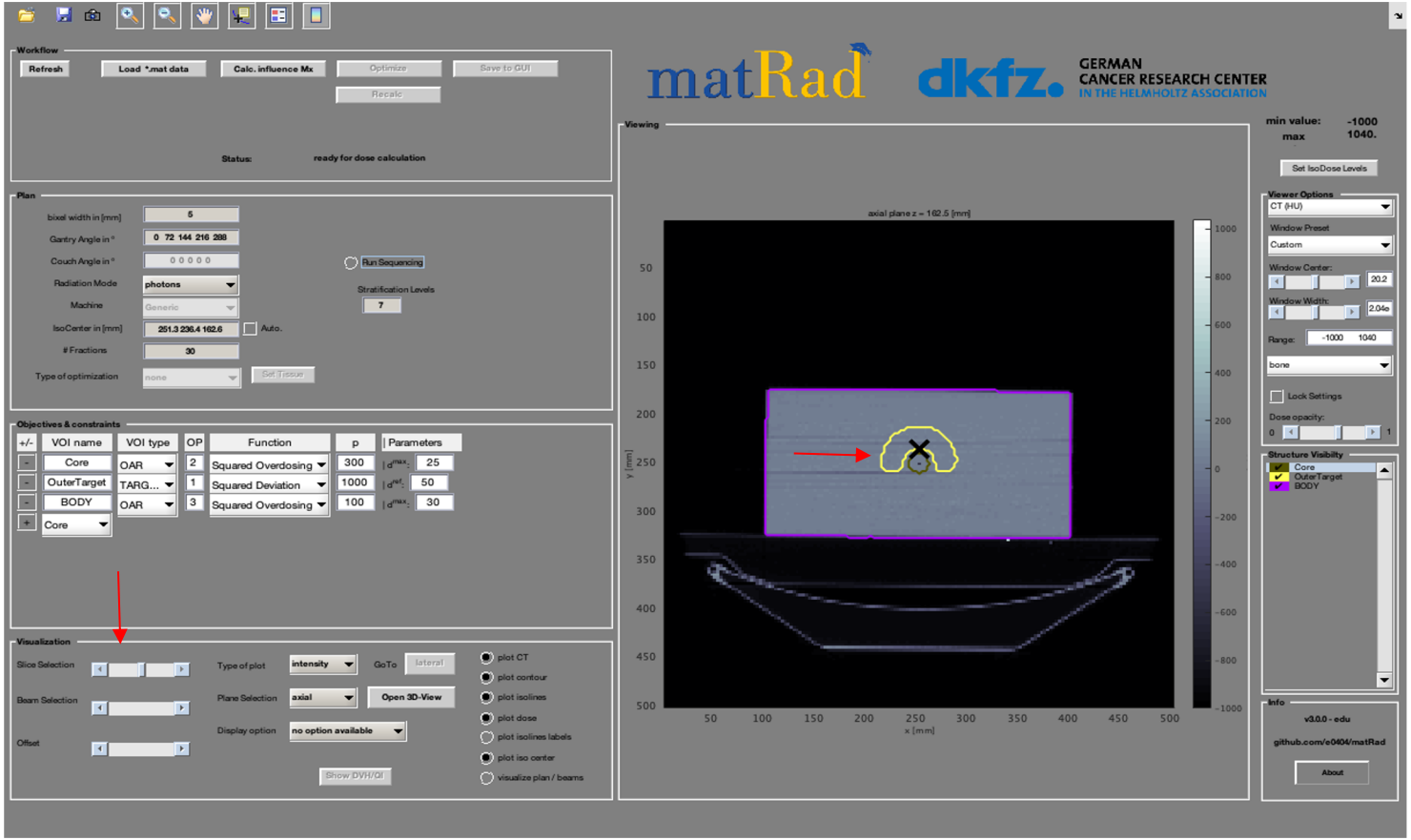


Collimator and target shaping



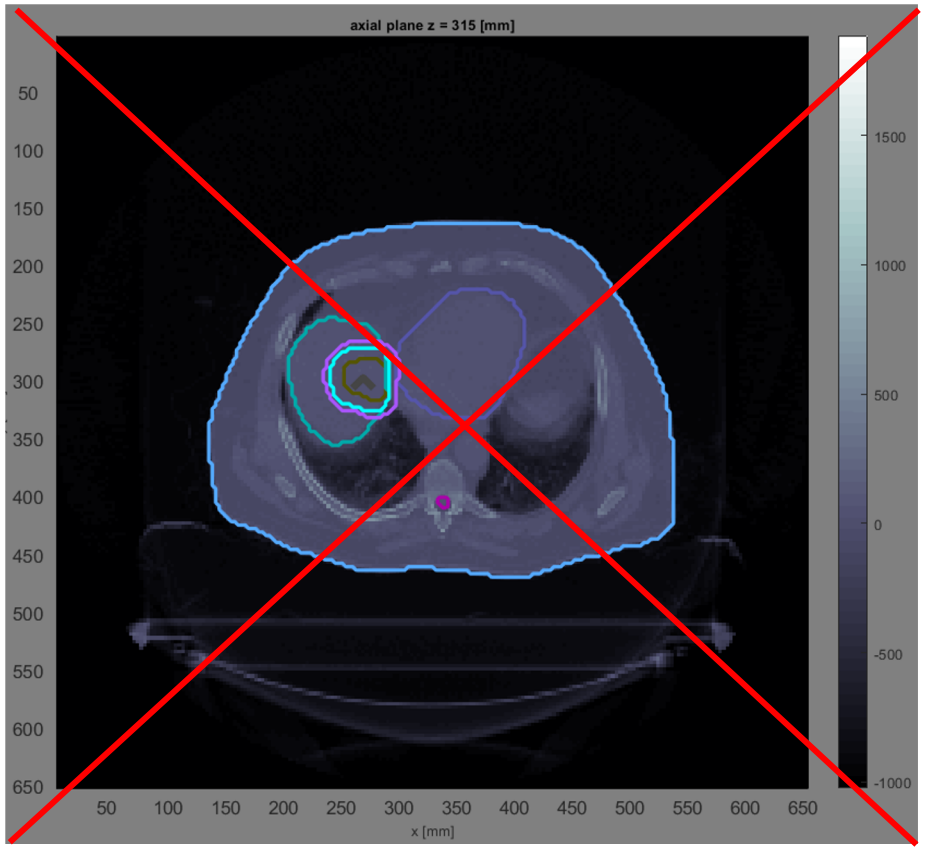
The isocenter is the point from which, the central rays of the irradiation beam passes.

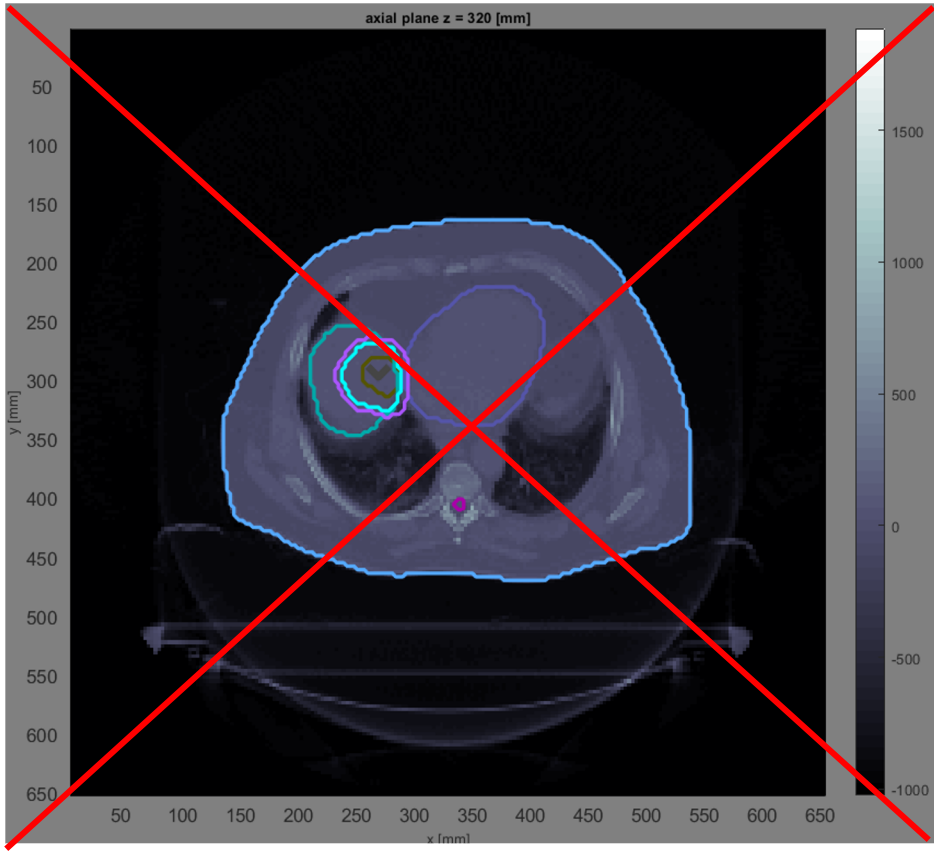
For simplicity the developers have blocked the couch angles.



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

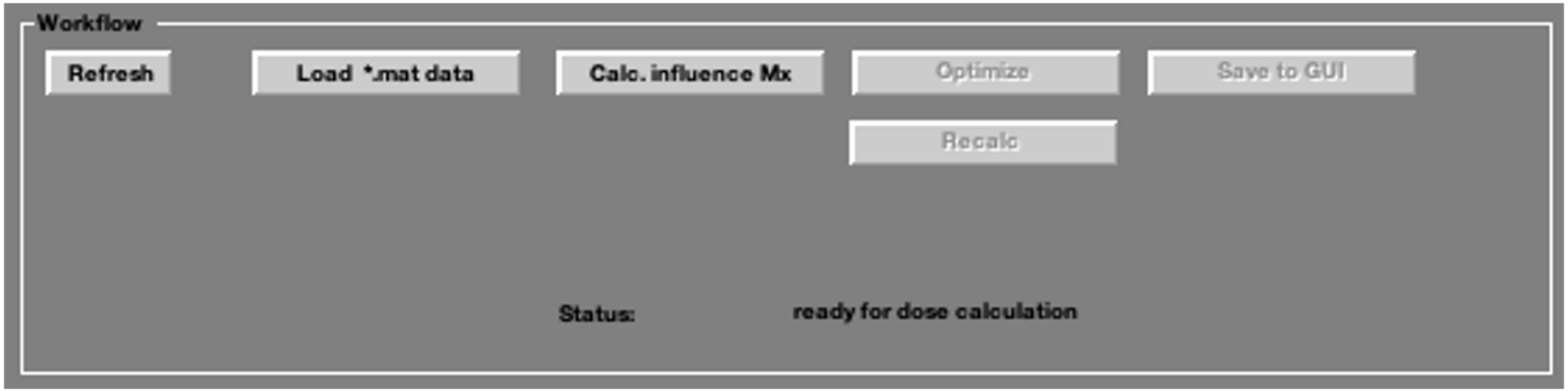
Wrong figures of isocenter sign!





2. How to start: workflow

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



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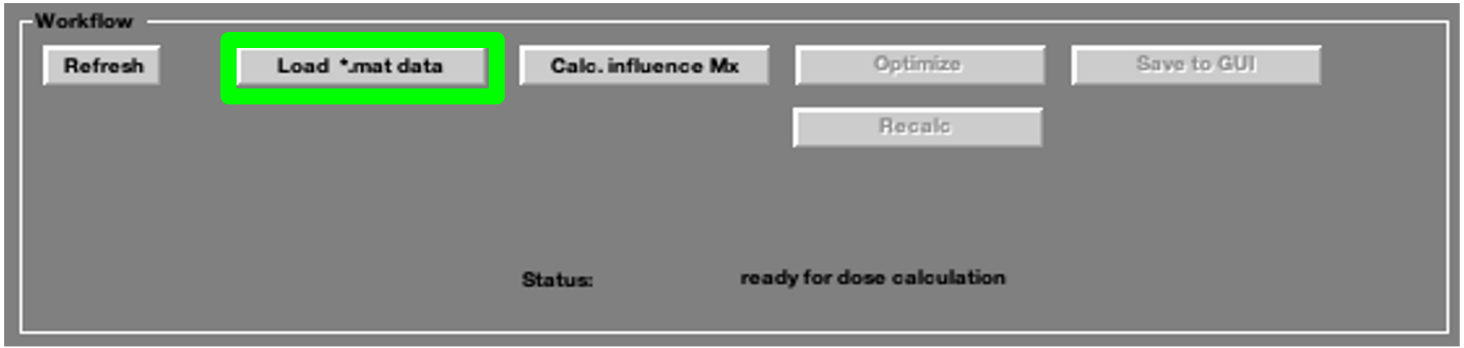
2. How to start: workflow

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.



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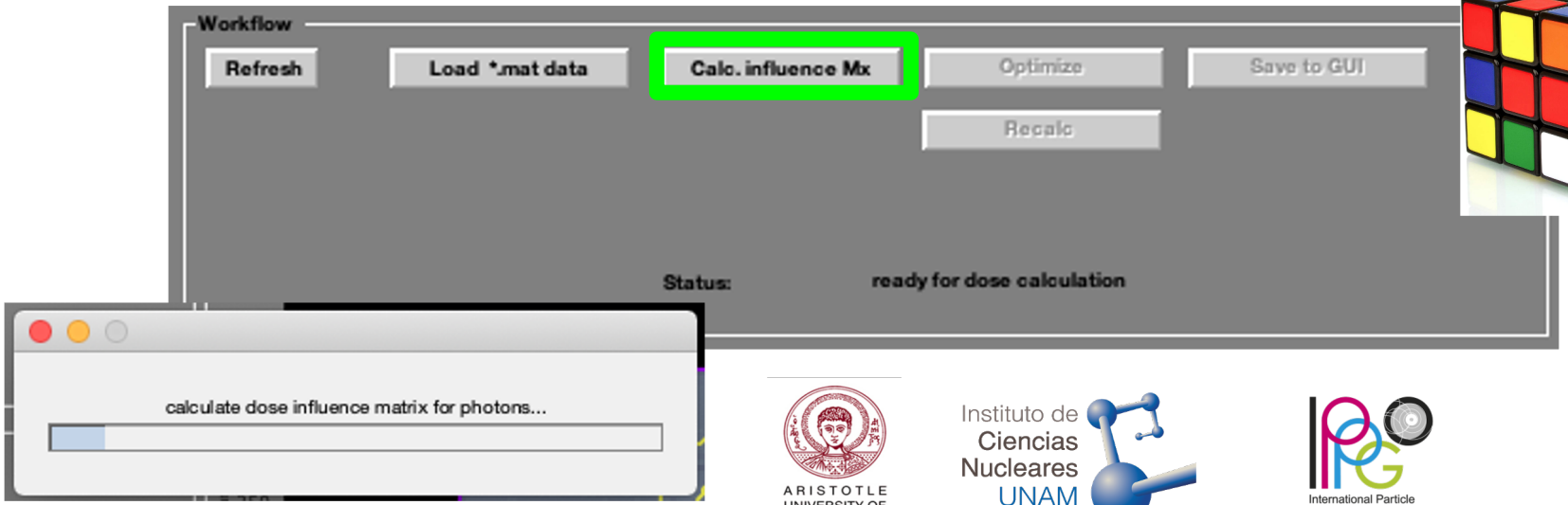
2. How to start: workflow

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.



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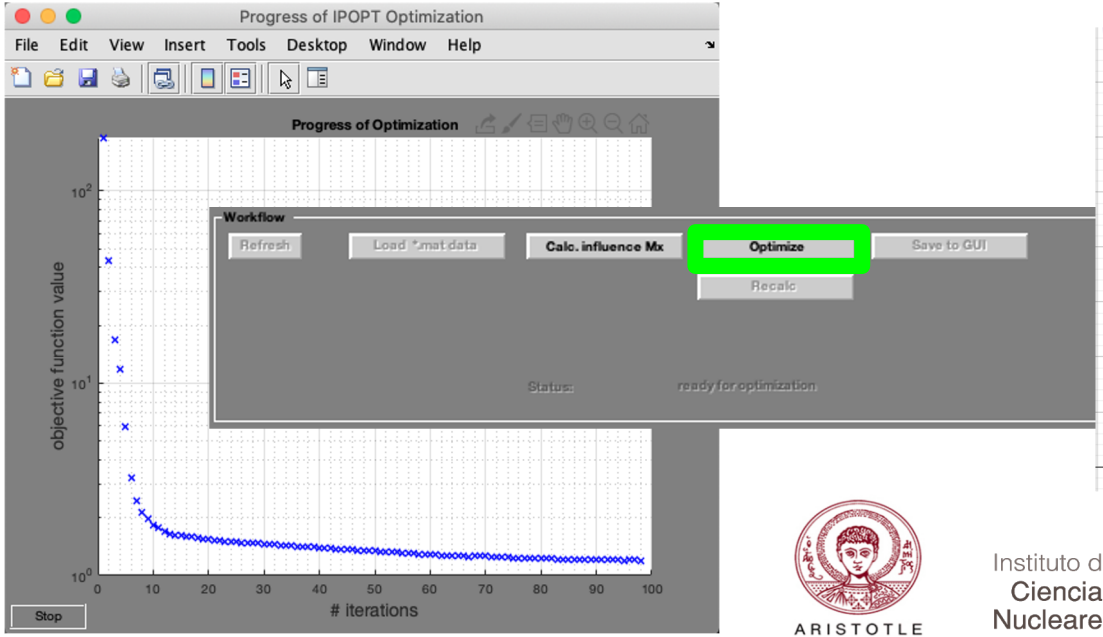
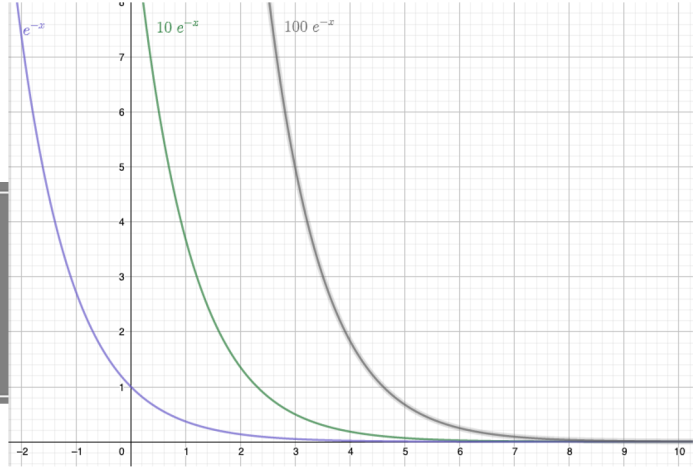
2. How to start: workflow

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.





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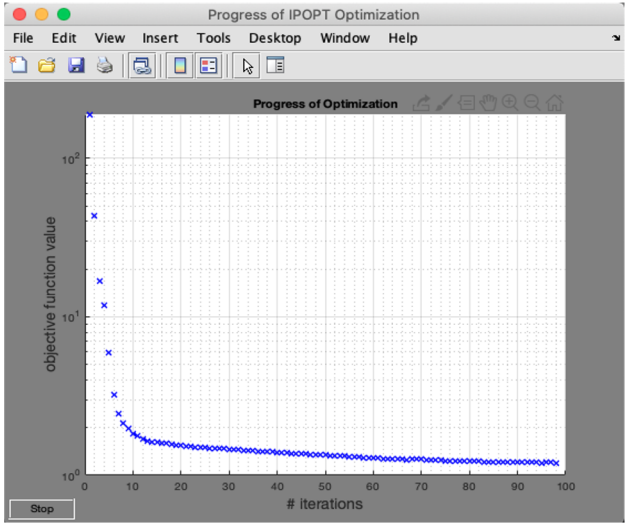
2. How to start: workflow-exponential distribution



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.

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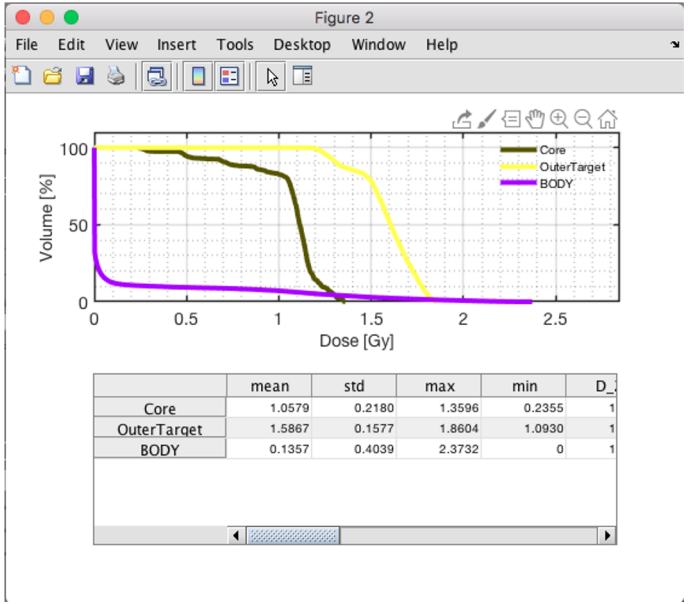
2. How to start: Visualization

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



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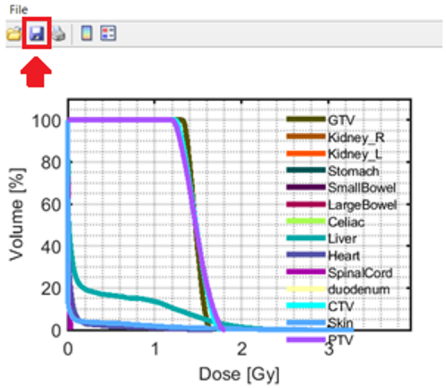
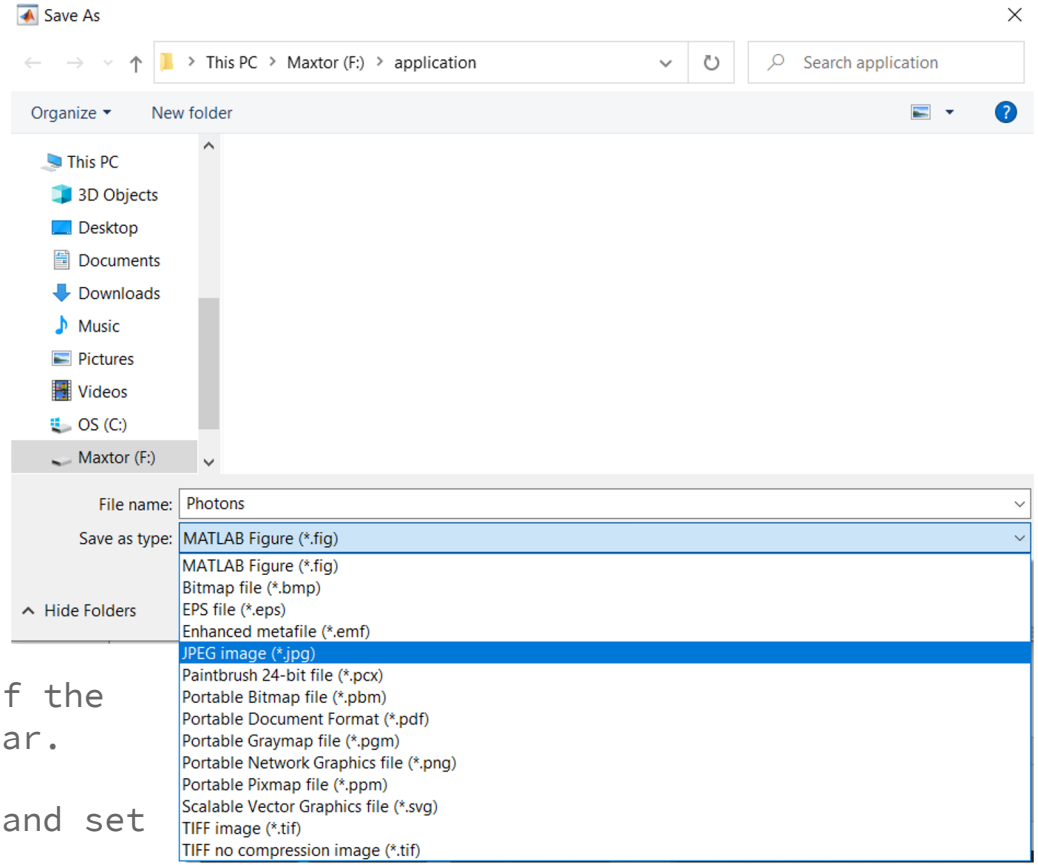
2. How to save: DVH-histogram for each case



	max	min	mean
GTV	1.6394	1.3173	1.4714
Kidney_R	0	0	0
Kidney_L	0	0	0
Stomach	0	0	0
SmallBowel	0	0	0
LargeBowel	0	0	0
Celiac	0	0	0
Liver	2.6394	0	0.2547
Heart	1.6706	0	0.0370
SpinalCord	0.0383	0	0.0053
duodenum	0	0	0



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

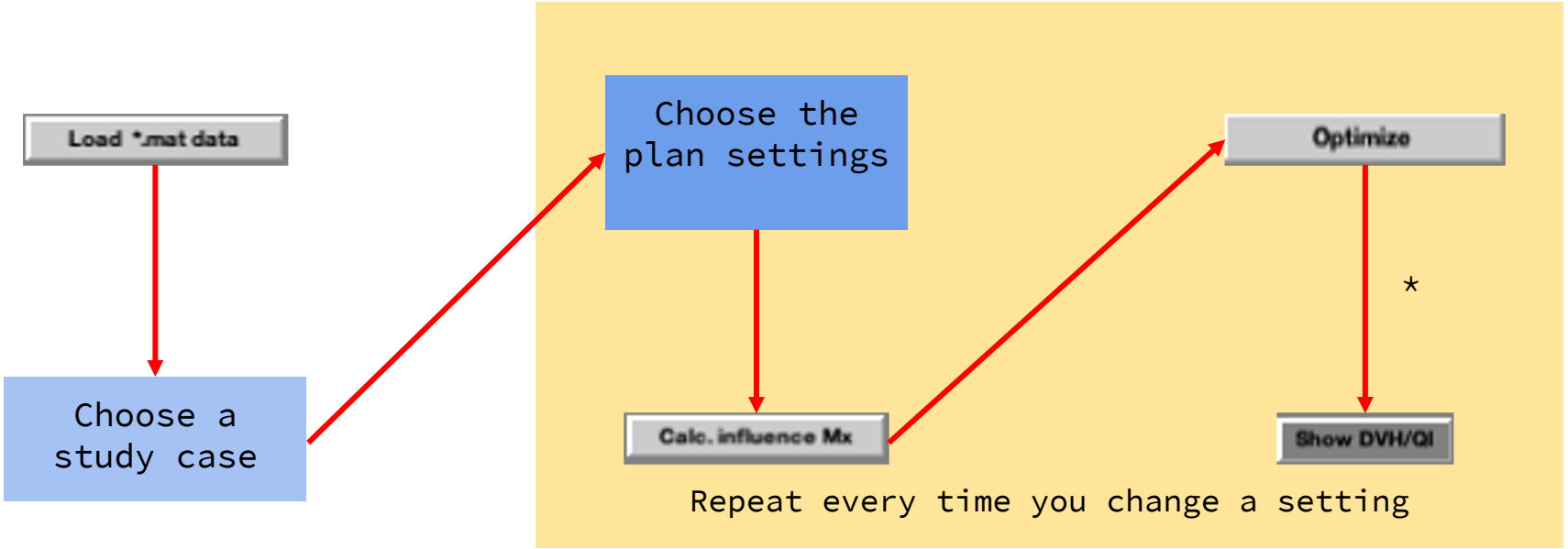
The names that can be set to represent the saved image or file, should mention the case of study e.g. C for C-phantom, L for Liver and H for Head and Neck.

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

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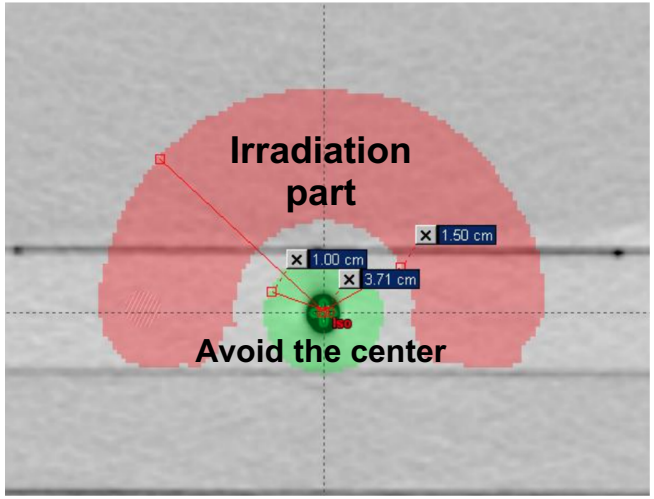
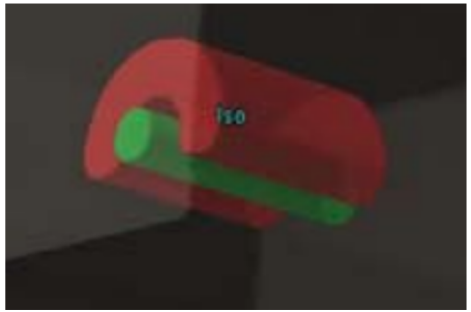
3.1 Training simulation: TG119

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.





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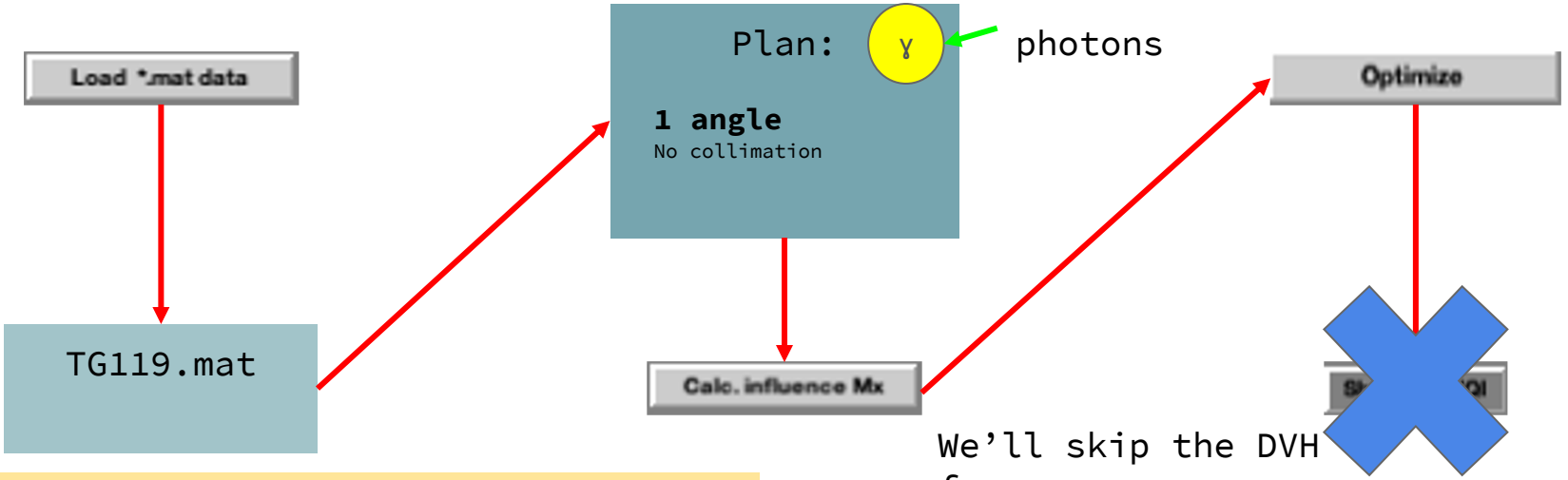
3.1.1 TRAINING SIMULATION: TG119 PLAN 1



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.

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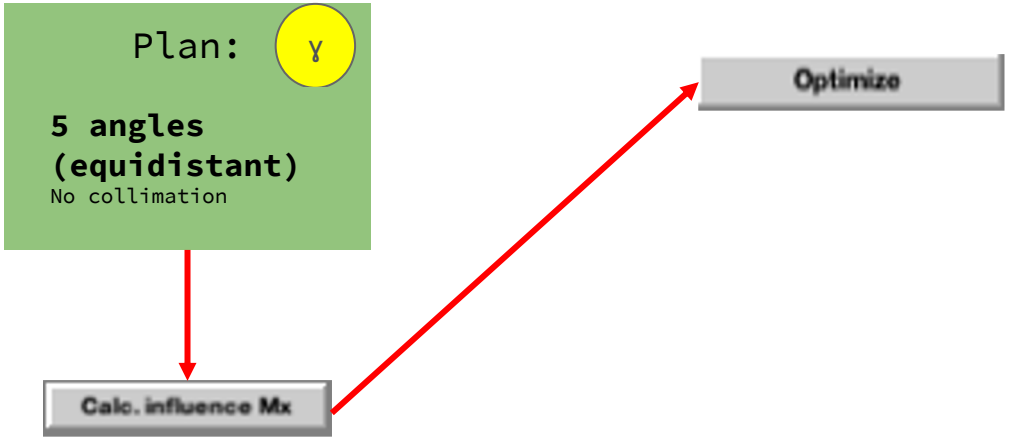
3.1.2 Training simulation: TG119 Plan 2



Remember, the angles are from 0° to 359° (360° = 0°).

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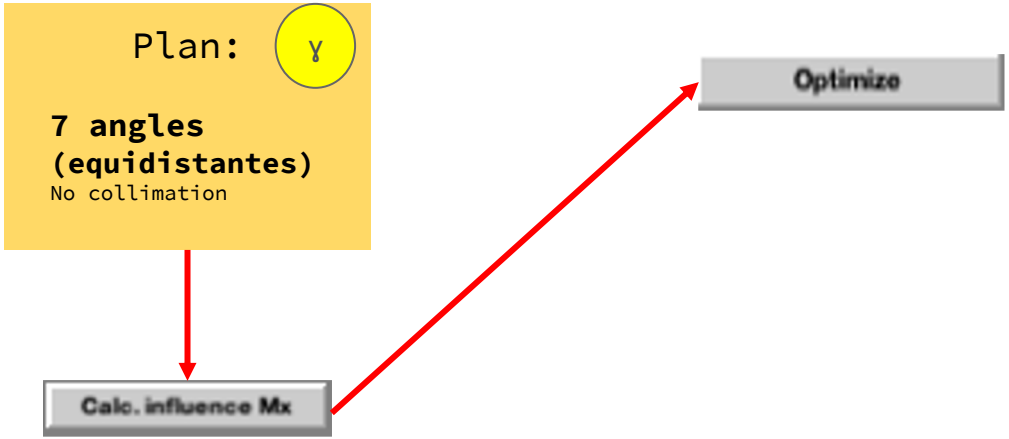
3.1.3 TRAINING SIMULATION: TG119 PLAN 3



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..!!

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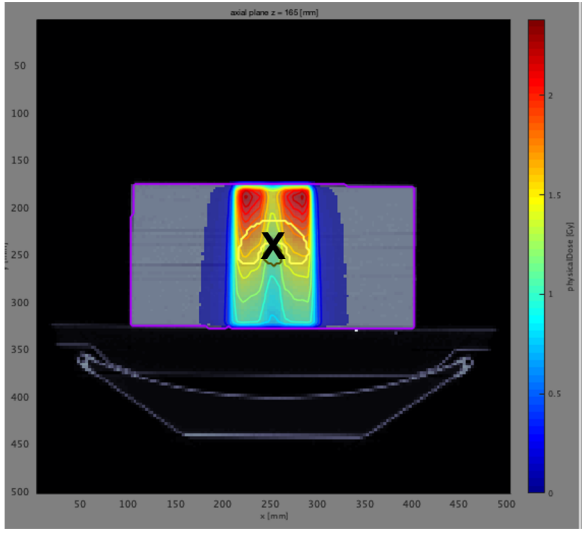
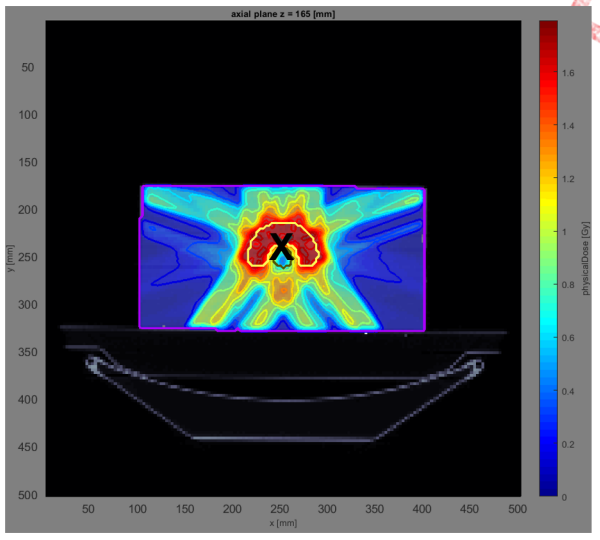
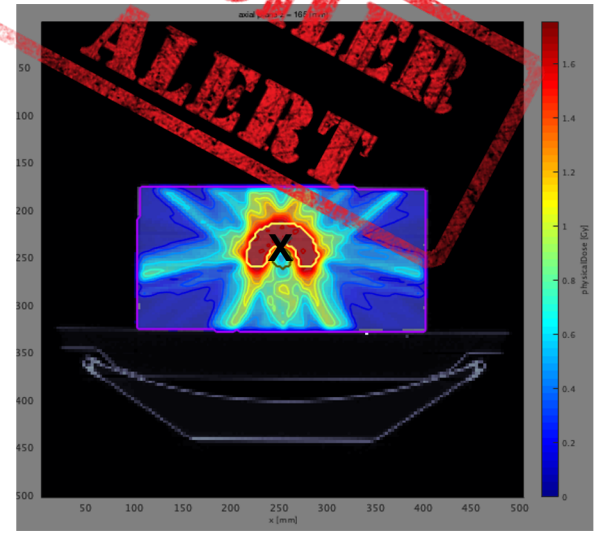
3.1.3 Photon treatment plan comparison



1 angle (every 0°)



5 angles (every 72°)



7 angles (every 51.4°)

SPOILER ALERT

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

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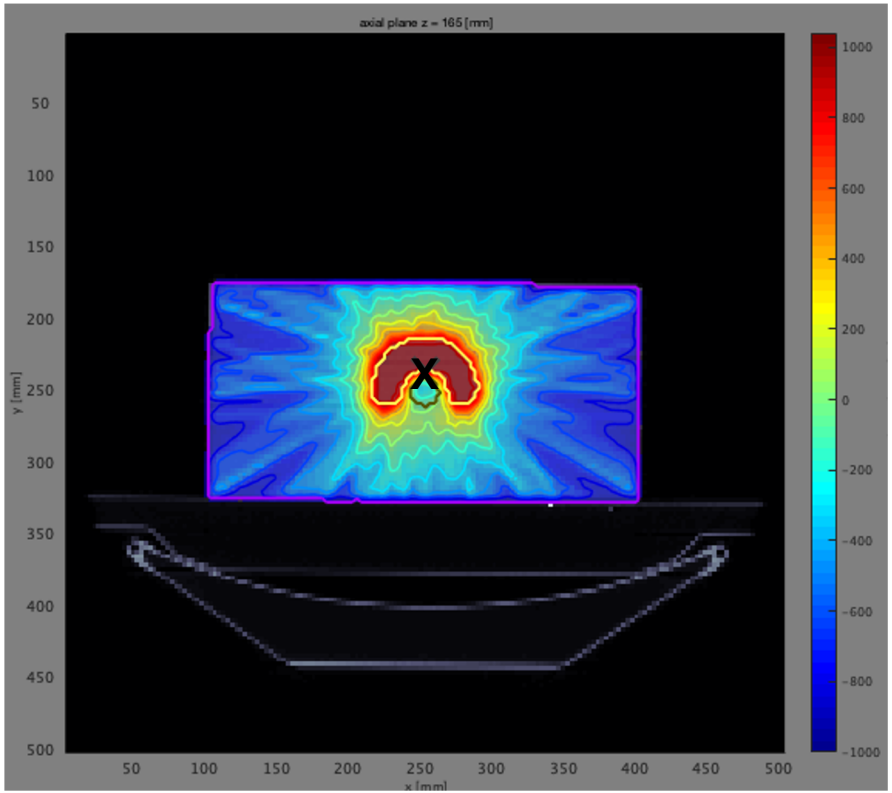
3.1.3 The best plan we found



SPOILER ALERT

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?

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3.2 Comparing particles on tg119

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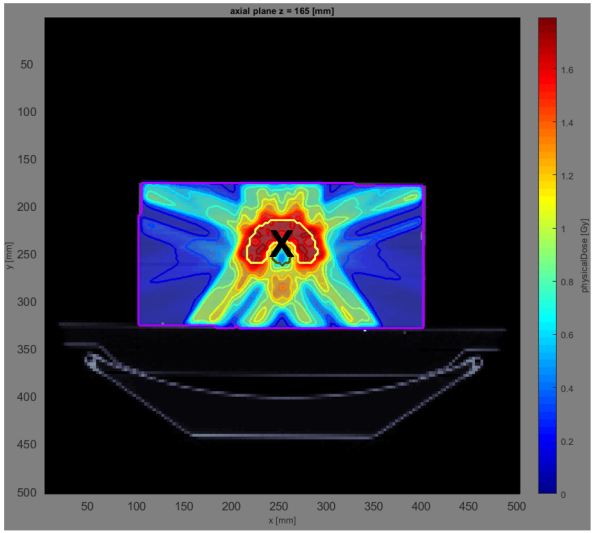
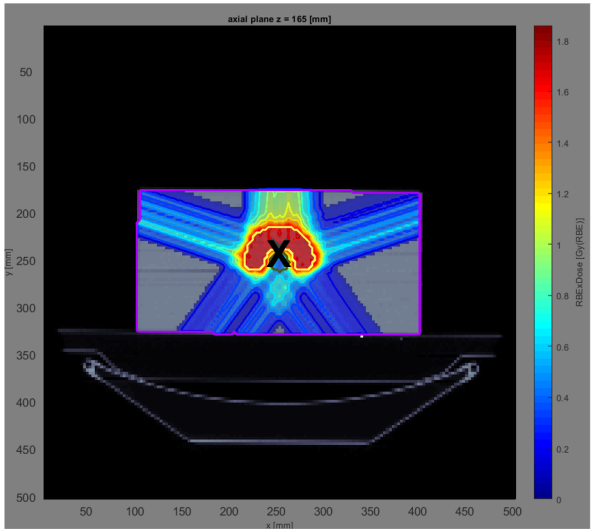
3.2 Comparing particles on tg119

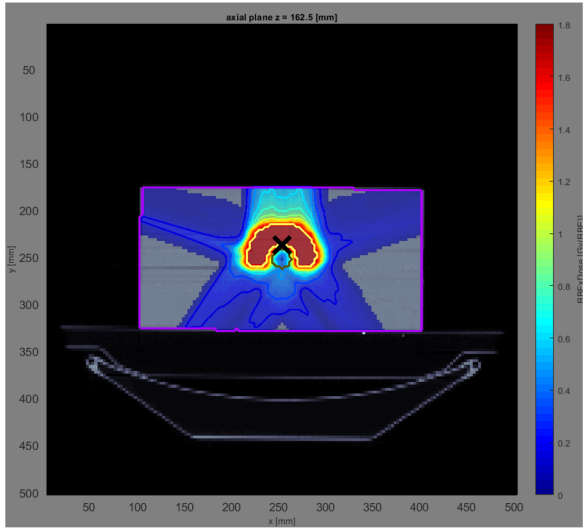
Using 5 angles,



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 are applied to design these treatments.

A wide range of experts 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 many 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"