Hands-On Treatment Planning with matRad

1stExercise – First steps on the TG119 phantom – photons vs. protons vs. carbon ions

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 viabutton („**Calc. Influence Mx**“)
4. Start inverse optimization by clicking on („**Optimize**“) and analyze the resulting dose distribution.
5. Save the optimization result via („**Save to GUI**“). 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 (e.g.equidistant beam angle spacing [0, 72, 144, 216, 288]).
9. Repeat steps 3-5 until the dose distribution is deemed satisfying and compare results.
10. Change optimization objective to improve the photon treatment plan.

Use Table („**Objectives &constraints**“) and add for instance a hard constraint (e.g. maximal dose for the core structure or minimal dose for the outer target structure).

1. Repeat steps 3-5 and compare results.
2. Optional: Increase lateral Bixel Width parameter to e.g. 20mm and repeatsteps 3-5

2nd Exercise – Carbon ion treatment plan for a liver patient

1. Load the liver patient case via the Load *.mat button (**LIVER.mat**)
2. Based on your experiences of exercise one, define your own photon treatment planwith approx. 4-5 beam directionsas well as your own proton treatment plan with one beam from e.g. 315°. (Hint: Use „**visualize plan / beams**” to trigger a beam angle visualization).
3. Analyze the differences of the optimized treatment plans. Don’t forget to save (**“Save to GUI**“).
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 / biologicaland physical dose).

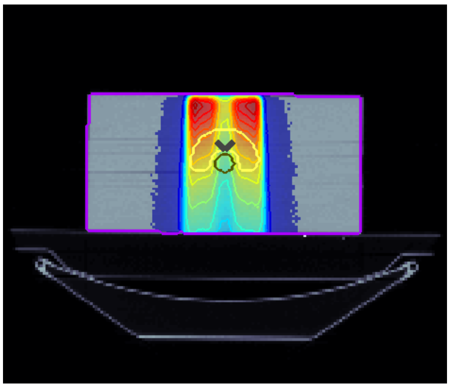
3rd Exercise – Treatment planning uncertainties

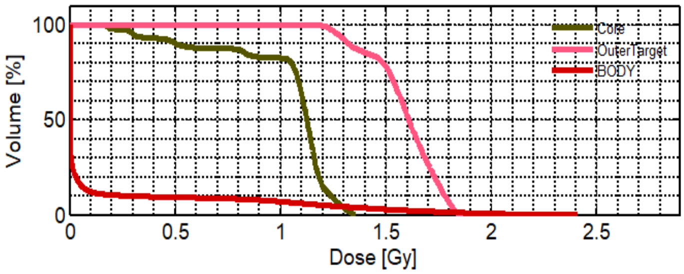
1. Load a head patient case (**HEAD_AND_NECK orALDERSON.mat**)
2. Add three proton beam angles on your own.
3. Calculate and optimize the dose („**Calc. Influence Mx**“ & „**Optimize**“).Analyze the result (dose& DVH) andsave it („**Save to GUI**“).
4. Simulate a patient positioning error:
   Remove the hook at the auto iso-center checkbox and define a new iso-center thereby introducing an offset.
5. Recalculate the dose based on the previously optimized pencil beam intensitiesby clicking on the button („**Recalc**“). Do not perform a new optimization.
6. Analyze and compare the resulting dose distribution. What changed ?

For Moderators:

1. Compare photons and protons distribution in phantom TG119.

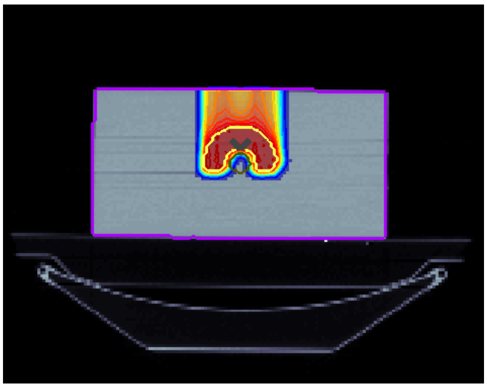
After loading the phantom you must choose one angle for a gantry for the photon's beam (the recommendation is to take a zero angle). The picture will appear and it will look like this:

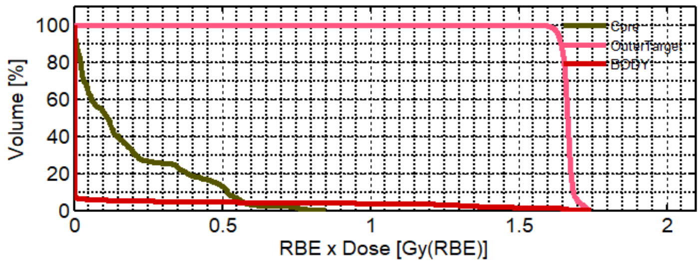




	mean	std	max	min	D_2	D_5	D_50
Core	1.0393	0.2699	1.3563	0.1582	1.3260	1.2855	1.1
OuterTarget	1.5900	0.1564	1.8659	1.1085	1.8307	1.8076	1.6
BODY	0.1359	0.4053	2.4106	0	1.6895	1.2229	

When we compare this distribution with the protons distribution we can see differences. The red region (high dose region) over region of interest with photons is damaged a lot, but with protons the distribution is concentrated in region which is simulation of a tumor and with this we spear patient's skin and healty surrounding tissues. The distribution with the protons looks like this



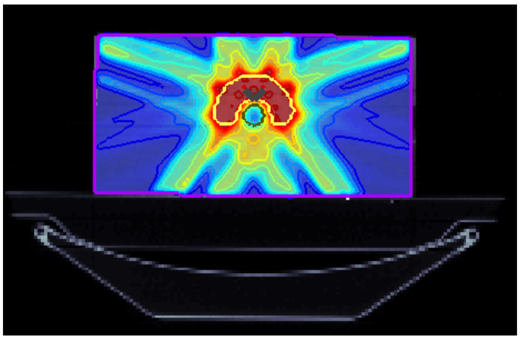


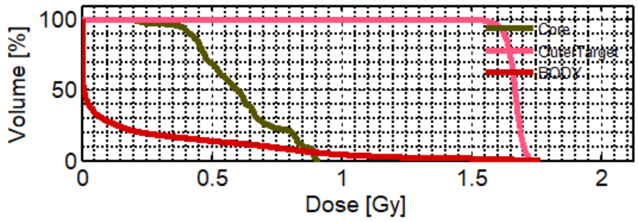
	mean	std	max	min	D_2	D_5	D_5
Core	0.1853	0.2019	0.8522	4.6661e-10	0.7417	0.5656	0
OuterTarget	1.6656	0.0207	1.7482	1.5438	1.7239	1.6993	1
BODY	0.0638	0.2860	1.7482	0	1.4032	0.2686	

On the right side are DVH diagrams where we can see how much percentages of the volume recive a dose. With the photons 100% of the outer target had recived 1.59 Grays compard to the protons outer target which recived 1.66 Grays. Also surrounding regions like the Core and Body recived a lower dose with protons unlike photons. This hapened because protons have the Bragg peak, and we assume that this precise dose distribution will appear in the human body. It is important to note that tissues under the sick region are totally speared.

This happened because protons have the Bragg peak and there are no more energy supplies which can provide the dose and deposition of energy under region of interest.

2. What is going on with the multifields photons distribution?



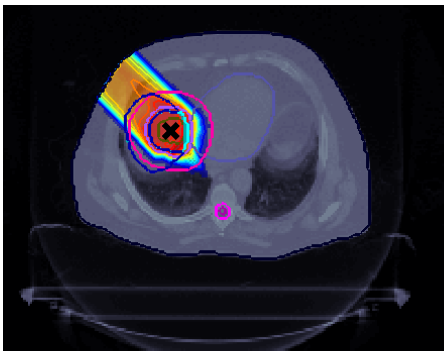


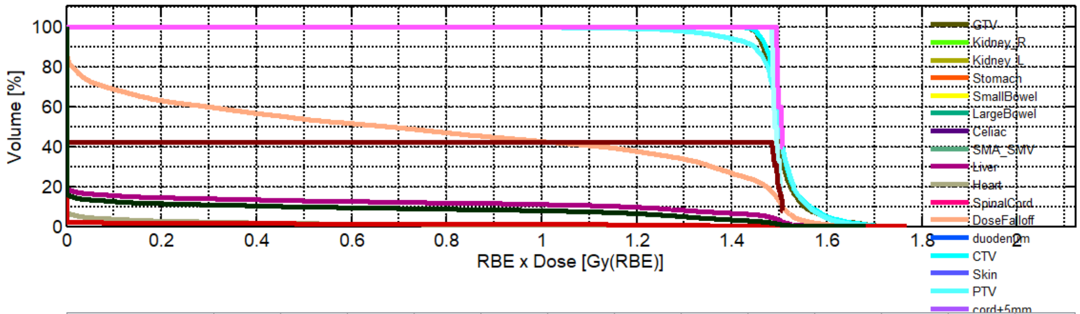
	mean	std	max	min	D_2
Core	0.6089	0.1660	0.9066	0.2005	0.896
OuterTarget	1.6643	0.0312	1.7688	1.5315	1.718
BODY	0.1754	0.3475	1.7688	0	1.394

In this case the photons distribution with 5 beams fits good to the volume of interest but surrounding regions didn't spare enough. Also an important part didn't recive the dose which is near 2 Grays. The two Grays are the optimal dose for one fraction of radiation. From the left picture we can see that the high dose region goes out of the boundaries from the outer target which is not good for the patient. This is the phantom but when we work with people and real patients, they can be endanger because a tumor can be near a sensitive organ and this exits from the assumed boundaries and this is very bad for the patients.

3. Discuss the dose distribution with carbon ions, and compare protons distribution and carbon ions distribution with one angle.

Protons

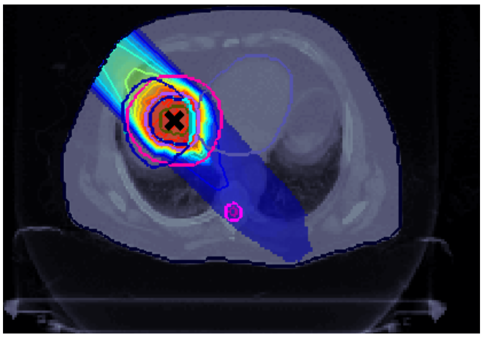


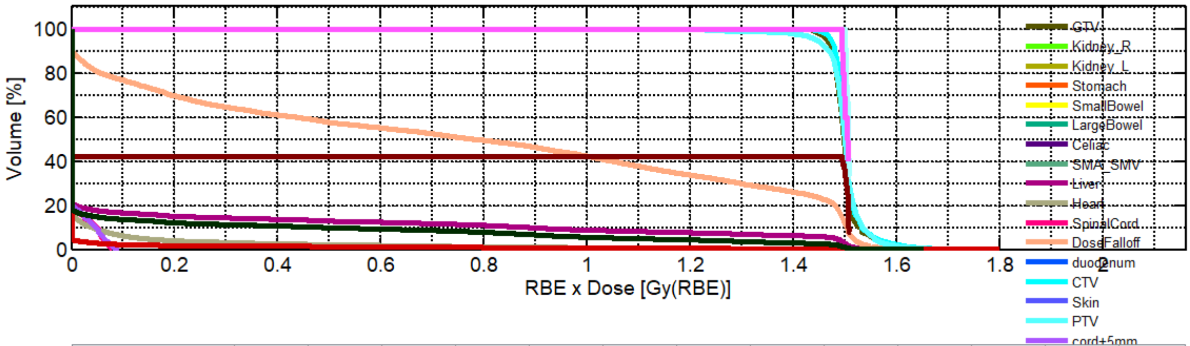


	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7Gy	V_1G
SMA_SMV	0	0	0	0	0	0	0	0	0	1	0	0	
Liver	0.1758	0.4466	1.7697	0	1.5099	1.4759	0	0	0	1	0.1388	0.1213	0.
Heart	0.0200	0.1197	1.4937	0	0.3644	0.0300	0	0	0	1	0.0228	0.0107	0.
SpinalCord	0	0	0	0	0	0	0	0	0	1	0	0	
DoseFalloff	0.7279	0.6319	1.7697	0	1.5681	1.5289	0.6733	0	0	1	0.5978	0.4938	0.
duodenum	0	0	0	0	0	0	0	0	0	1	0	0	
CTV	1.5108	0.0440	1.7697	1.2605	1.6460	1.5996	1.5019	1.4604	1.4487	1	1	1	
Skin	0.0183	0.1470	1.7697	0	0.0428	0	0	0	0	1	0.0159	0.0130	0.
PTV	1.4958	0.0748	1.7697	0.8305	1.6328	1.5926	1.5001	1.3788	1.2818	1	1	1	0.
cord+5mm	1.3576e-17	8.1084e-16	5.4136e-14	0	0	0	0	0	0	1	0	0	
clip1	1.4938	0.0080	1.5059	1.4858	1.5054	1.5046	1.4913	1.4863	1.4860	1	1	1	

From this image we can see that the high dose is around bold X which presents the position of the tumor. Dose distribution for protons is characterized by the Bragg peak which is recognized by the absence dose under volume of interest. This is important because this distribution spares the surrounding tissues, the skin and sensitives organs.

Carbon ions

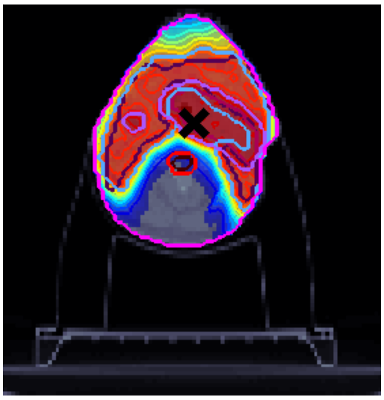


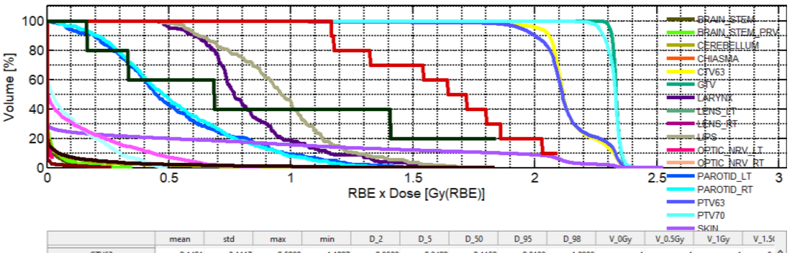


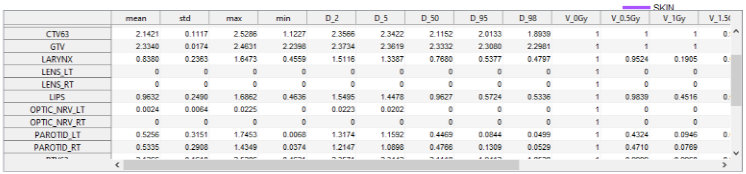
	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7Gy	V_1G
GTV	1.5006	0.0276	1.6742	1.4211	1.5883	1.5541	1.4977	1.4660	1.4487	1	1	1	
Kidney_R	0	0	0	0	0	0	0	0	0	1	0	0	
Kidney_L	0	0	0	0	0	0	0	0	0	1	0	0	
Stomach	0	0	0	0	0	0	0	0	0	1	0	0	
SmallBowel	0	0	0	0	0	0	0	0	0	1	0	0	
LargeBowel	0	0	0	0	0	0	0	0	0	1	0	0	
Celiac	0	0	0	0	0	0	0	0	0	1	0	0	
SMA_SMV	0	0	0	0	0	0	0	0	0	1	0	0	
Liver	0.1682	0.4235	1.7529	0	1.5051	1.4839	0	0	0	1	0.1434	0.1174	0.
Heart	0.0328	0.1482	1.5092	0	0.5759	0.1372	0	0	0	1	0.0323	0.0159	0.
SpinalCord	0.0086	0.0200	0.0799	0	0.0706	0.0614	0	0	0	1	0	0	

Carbon ions also have the Bragg peak but it is more expressed. This means that carbon ions spared more tissues through which they passed and this region is more blue, cold or region with lower dose unlike the protons distribution where this region is orange which means that this region has a higher dose. Also from the image we can see that the tumor has recived a higher dose with carbon ions unlike protons and the red region is much smaller in the carbon ions case. On DVH images on the y axis stands the RBExDose label which means that the dose on this scale includes the Relative Biological Efficiency.

4. Discuss the dose distribution with multiple fields with protons.





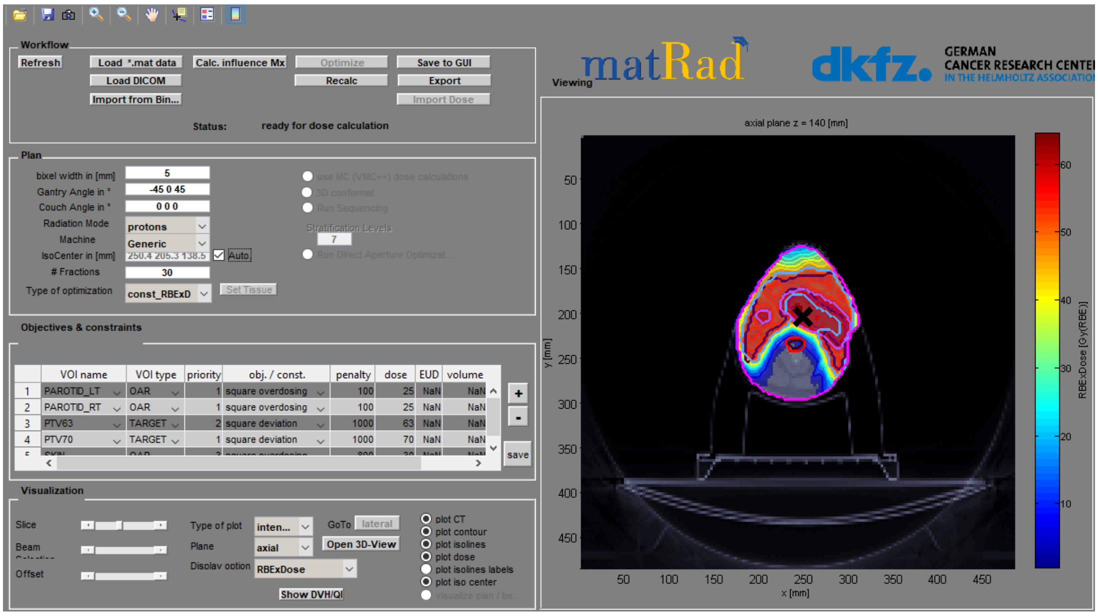


	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.5Gy	V_1Gy	V_1.5(
CTV63	2.1421	0.1117	2.5286	1.1227	2.3566	2.3422	2.1152	2.0133	1.8939	1	1	1	0.
GTV	2.3340	0.0174	2.4631	2.2398	2.3734	2.3619	2.3332	2.3080	2.2981	1	1	1	
LARYNX	0.8380	0.2363	1.6473	0.4559	1.5116	1.3387	0.7680	0.5377	0.4797	1	0.9524	0.1905	0.
LENS_LT	0	0	0	0	0	0	0	0	0	1	0	0	
LENS_RT	0	0	0	0	0	0	0	0	0	1	0	0	
LIPS	0.9632	0.2490	1.6862	0.4636	1.5495	1.4478	0.9627	0.5724	0.5336	1	0.9839	0.4516	0.
OPTIC_NRV_LT	0.0024	0.0064	0.0225	0	0.0223	0.0202	0	0	0	1	0	0	
OPTIC_NRV_RT	0	0	0	0	0	0	0	0	0	1	0	0	
PAROTID_LT	0.5256	0.3151	1.7453	0.0068	1.3174	1.1592	0.4469	0.0844	0.0499	1	0.4324	0.0946	0.
PAROTID_RT	0.5335	0.2908	1.4349	0.0374	1.2147	1.0898	0.4766	0.1309	0.0529	1	0.4710	0.0769	

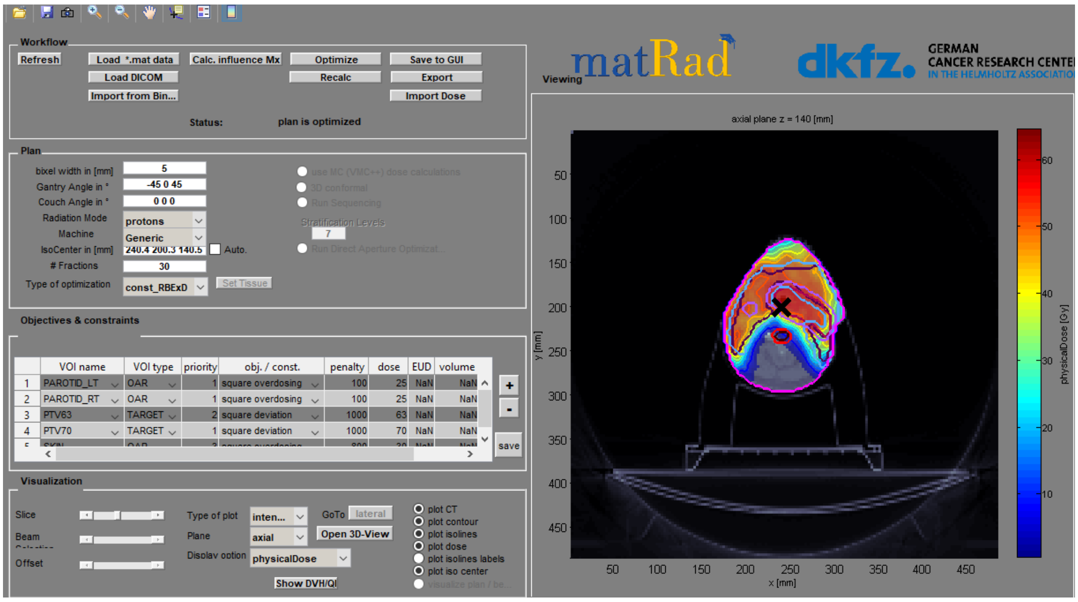
The tumor in this case is located in the head and it is very important to have a high level of precision. With multiple beams actually on this image we have presented three fields from three different angles -45 0 and 45 degrees. The distribution is good because a very small amount of radiation is out of the curve which presents the tumor's boundaries. This is important because in the head we have a lot of sensitve organs and regions like eye lenses, the spinal cord, Medula oblongata, the Cerebellum ect. From the DVH we can see that 100% of the tumor has recived around 2.3 Grays. Regions which recived a higher dose than expected are the regions around the mouth.

5. Compare the auto set-up of the isocenter and manually set-up with displacement.

Auto



Manually



The biggest effect of moving the isocenter is the change in dose distribution which makes a higher dose region out of the expected region and with this we can damage tissues and organs in the neighborhood. From this case we see that the tumor didn't become red enough which means that it didn't recive a good dose, also tissues over the tumor with a moved isocenter have recived a higher dose unlike the case with the auto isocenter.