Introduction to treatment planning

Aafke Kraan

Slides partly adapted from Aristeidis Mamara

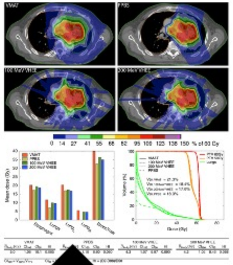
Introduction to Treatment planning

- Questa mattina abbiamo visto che la radiazione puo’ essere usato per eliminare cellule cancrose
- La radiazione non danneggia soltanto le cellule cancrose, ma anche quelli sani…
- Il tessuto sano in generale e’ piu’ capace di ripararsi
- Ma la radiazione deve essere minimo nei tessuti sani…
- Come lo facciamo? Con un piano di trattamento!

What is treatment planning?

Second phase: treatment planning

Consultation → Treatment planning



CT scan: "TAC"
Structures
Dose prescription

- How can we realize the dose prescription?
- From which direction(s)?
- How can we spare the sensitive organs as well as possible?
- Is the plan not too sensitive?

This is done with help of dedicated software (and highly expertise personnel!): treatment planning system

matRad

WHAT IS A TREATMENT PLANNING?

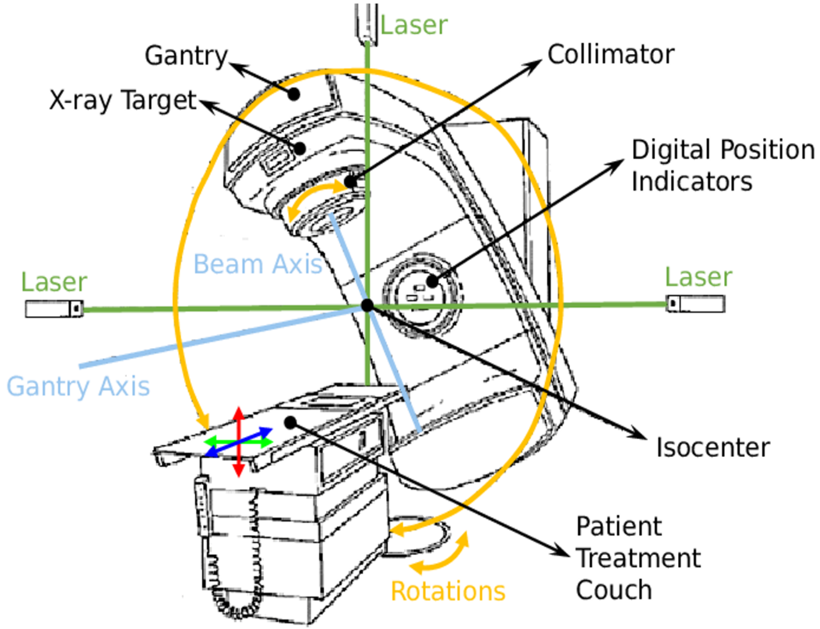
INPUT

Dose prescritta nel tumore
Dose per gli organi a rischio
TAC
Strutture
Angoli

treatment planning system

OUTPUT

Fasci di particelle (beams)
Energie delle particelle
Posizioni e quantita’
Angoli del lettino (‘couch’)
Angoli del gantry



gantry angles: moves the radiation source around the patient
coach: rotates the patient

What is a treatment planning?

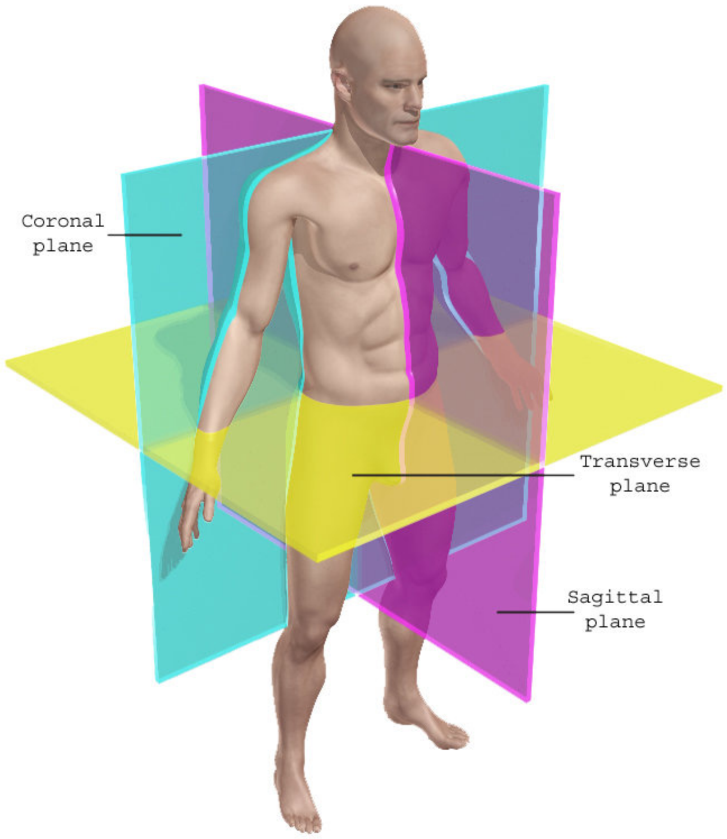
INPUT

Dose prescritta nel tumore
Dose per gli organi a rischio
TAC
Strutture
Angoli

↓ treatment planning system

OUTPUT

Fasci di particelle (beams)
Energie delle particelle
Posizioni e quantita’
Angoli del lettino (‘couch’)
Angoli del gantry



gantry angles: moves the radiation source around the
patient coach: rotates the patient

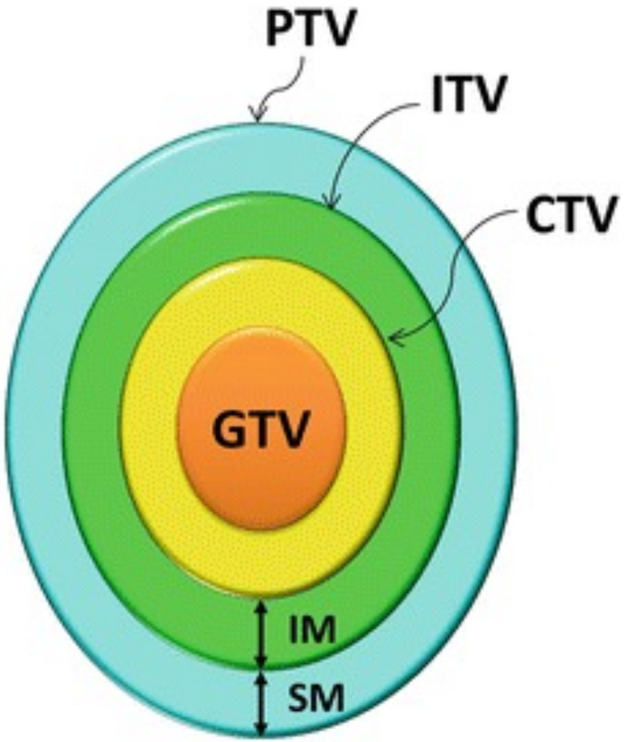
Tumor region

GTV: gross tumor volume, defined as visible tumor volume in images

CTV: clinical target volume, defined as GTV + subclinical/invisible invasion

ITV: internal target volume, defined as CTV + IM (internal margin for organ motion)

PTV: planning target volume, defined as ITV + SM (setup margin for setup error)



What software will we use?: MATRAD

Elaborated by:
Viridiana Badillo
Student of Biomedical Systems Engineering FI-UNAM (Mexico)
Enrique Sánchez
Student of Mechatronics Engineering FI-UNAM (Mexico)
Aris Mamaras
Student of Computational Physics, AUTh (Greece)

Supervised by:
Ph.D. Yiota Foka
IPPOG's Member

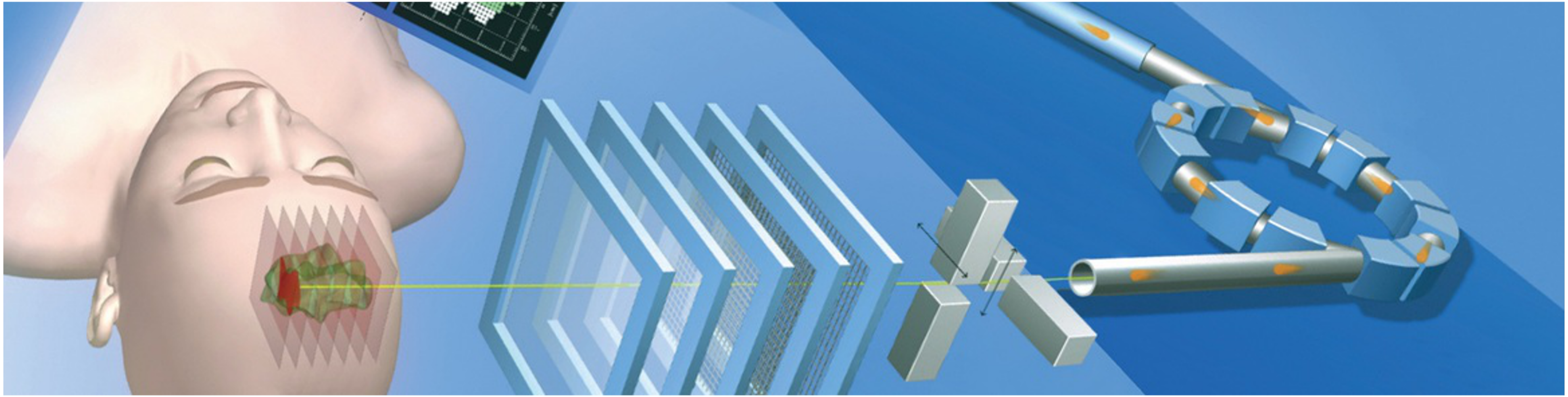
Instituto de Ciencias Nucleares UNAM

International Particle Physics Outreach Group

ARISTOTLE UNIVERSITY OF THESSALONIKI

UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO

What is Matrad?



matRad is a tool kit allowing optimization of treatment planning with photons, protons, ions for educational and research purposes.

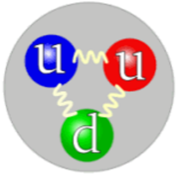
matRad

Instituto de Ciencias Nucleares UNAM

International Particle Physics Outreach Group

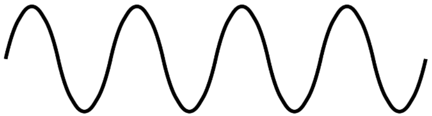
matRad

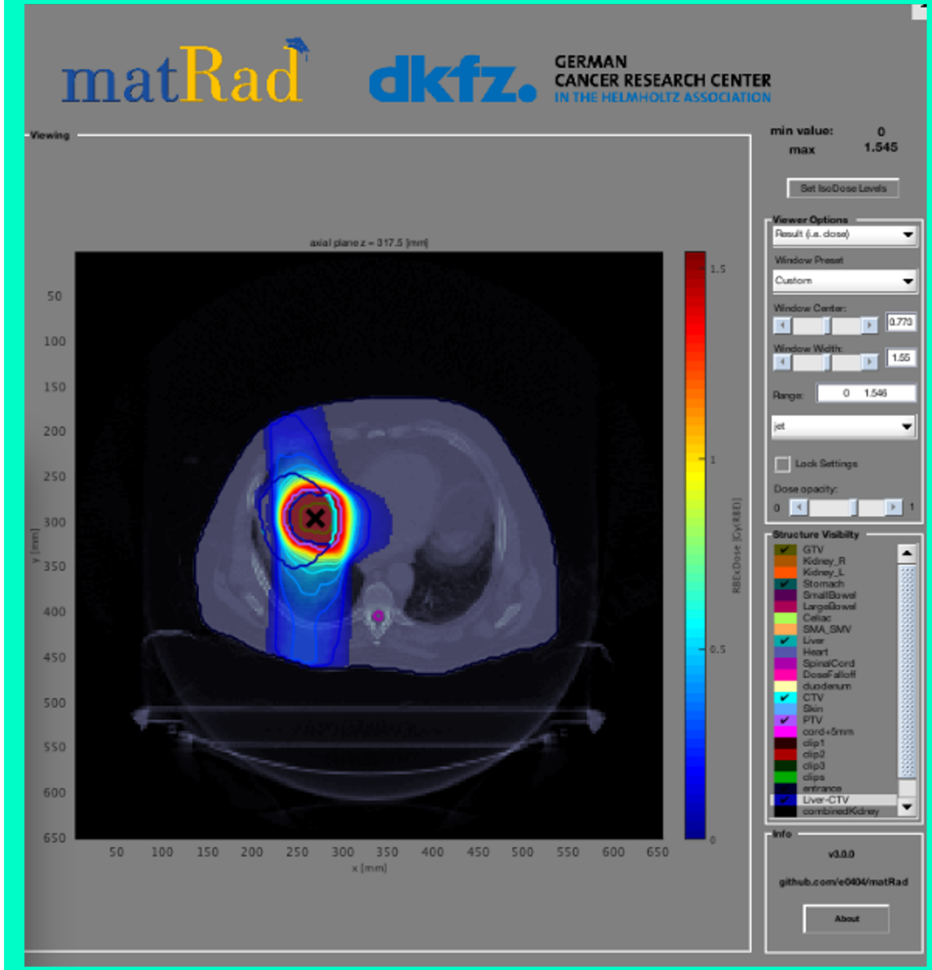
The matRad educational and research software was developed by the German Cancer Research Center in order to handle treatment planning in an easy way with protons, photons and carbon ions.



Proton

γ



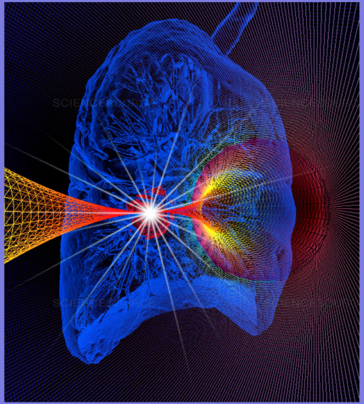


Where is MATRAD used today?

+30 INSTITUTIONS

Currently MATRAD is used by more than 30 official institutions, among them research groups and a variety of universities internationally recognized for their high performance and excellent results globally.

Here you can see some of the institutions we are talking about



matRad – community

TECHNISCHE UNIVERSITÄT MÜNCHEN

MEDICAL UNIVERSITY OF VIENNA

大阪大学 OSAKA UNIVERSITY

dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

THE UNIVERSITY OF TEXAS MD Anderson ~~Cancer~~ Center Proton Therapy

UNIVERSIDAD COMPLUTENSE MADRID

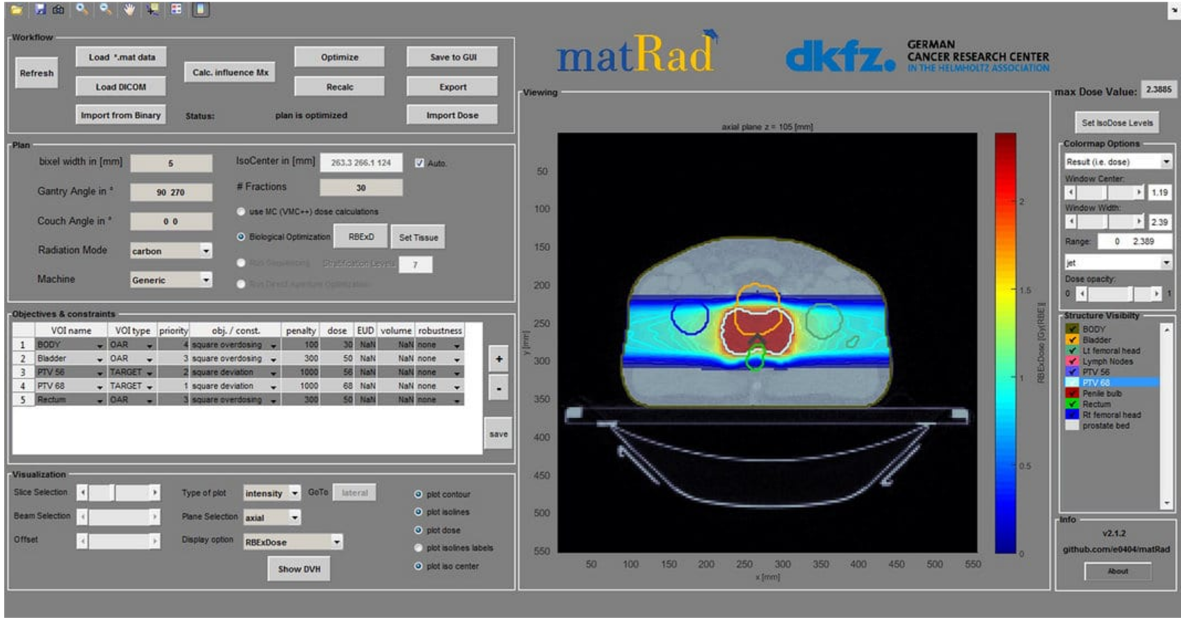
UNIVERSITY OF OXFORD

Universität Zürich UZH

For more information, you can consult the following map: https://bit.ly/matRadUsers

In what ways can the software be executed?

It can be executed through Matlab or with the matRad application for Windows:



What form of execution is recommended for Matrad?

Educational purposes

⚡⚡⚡

- Processing power

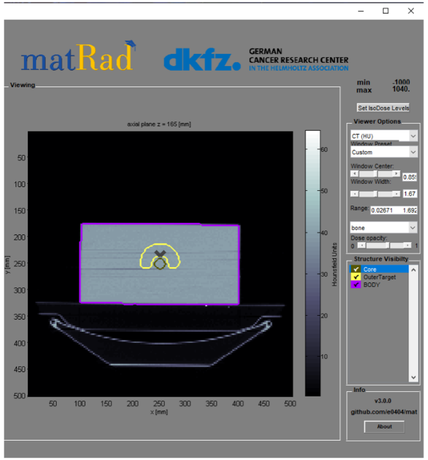


Image of matrad executed from windows app

Research

⚡⚡⚡⚡⚡⚡

+Processing power

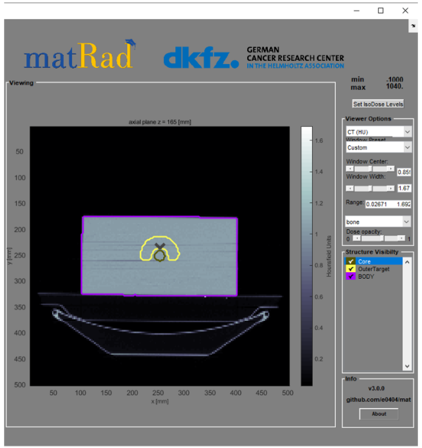


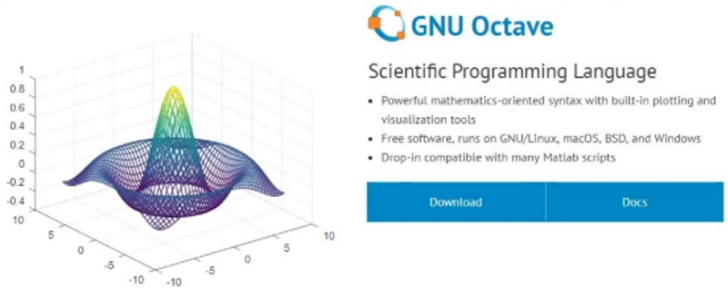
Image of matrad executed from matlab

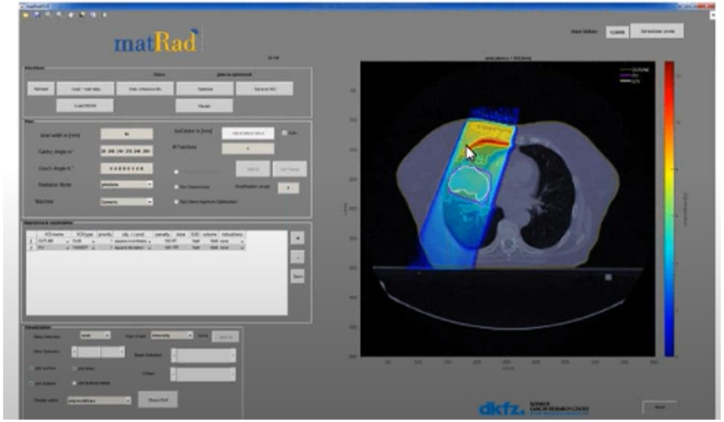
For educational purposes the use of matrad as a Windows application is recommended, as it takes up less storage space and does not require an IDE (integrated development environment) to use the software.

For research purposes, which involves testing treatments with specific parameters that lead to more realistic simulations, it is recommended to use matlab to perform a more detailed analysis. This requires a higher processing power.

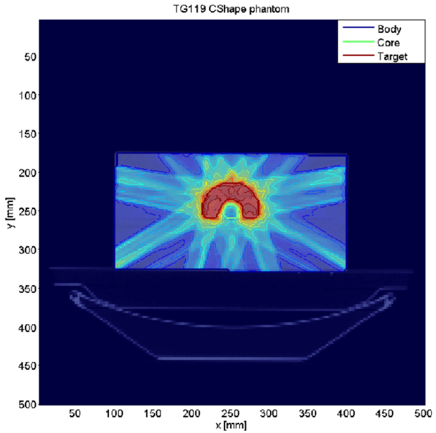
Two peculiar facts

- In case one needs to use MATLAB IDE for further analysis and a MATLAB license is absent, one can use GNU Octave, which is written in C / C ++ and is compatible with MATLAB syntax.
- The graphical user interface (GUI) is the same when executing matRad from any of the available options. however... it is more efficient to execute it through the IDE.





Why is matRad based on MATLAB?

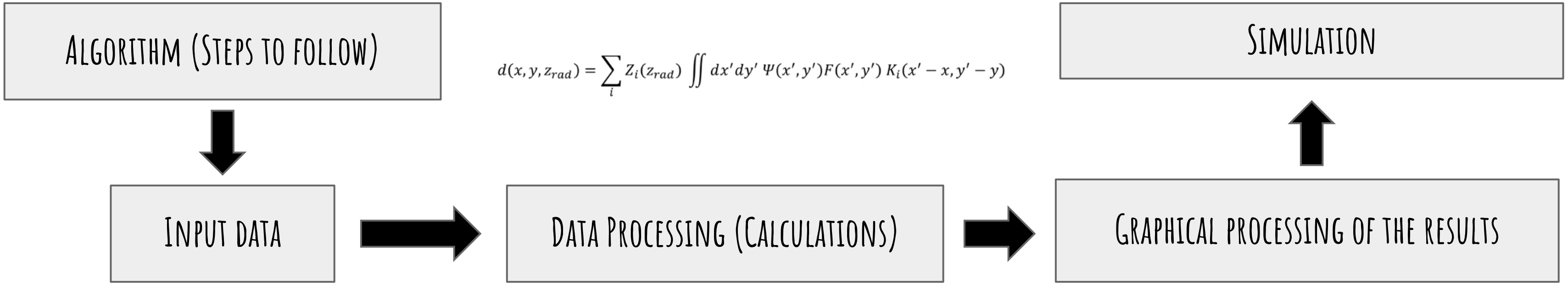


- Easy to use data visualization
- Optimized debugging
- Allows fast development of treatment prototypes
- Well known software in the medical physics community for its effectiveness.
- Simple syntax compared to abstract programming in languages like C ++
- Allows a standalone executable (matRad.exe), which can be used without a license.

HOW DOES THIS SOFTWARE WORK?

THE OPERATION OF THIS SOFTWARE IS POSSIBLE THANKS TO THE ALGORITHMS DEVELOPED BY THE PROFESSIONALS FROM INTERDISCIPLINARY AREAS WHO ARE PART OF THIS PROJECT.

THANKS TO THE PROCEDURES PREVIOUSLY PROGRAMMED, THE INPUT DATA IS USED TO PERFORM THE CALCULATIONS AND THUS, DISPLAY THE OPTIMIZED RESULTS OF THE SIMULATIONS ON THE VISUALIZATION PANEL.



$$d(x, y, z_{rad}) = \sum_i Z_i(z_{rad}) \iint dx'dy' \; \Psi(x', y')F(x', y') \; K_i(x' - x, y' - y)$$

How is data processing carried out?

In the previously mentioned algorithms, the input data are taken as variables, which already have a certain memory location reserved. Later these are stored in different types of data structures through matrices, vectors, etc., and then they are processed according to the mathematical procedure that each of them must follow according to the algorithm and its parameters. Finally, the results are stored in a reserved space.

cst | ct | ct.x | stf

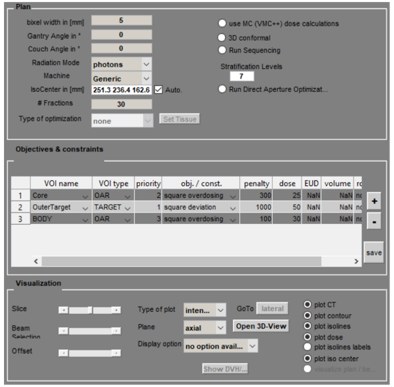
1x17 struct with 12 fields

Fields	gantryAngle	couchAngle	bixelWidth	radiationMode	SAD	isoCenter	numOfRays	ray	sourcePoint_bev	sourcePoint	numOfBixelsPerRay
1	0	30	5	'photons'	1000	[251.3089,23...	302	1x302 struct	[0,-1000,0]	[0,-1000,0]	1x302 double
2	21.1700	47.1400	5	'photons'	1000	[251.3089,23...	309	1x309 struct	[0,-1000,0]	[245.6483,-932....	1x309 double
3	42.3400	64.2800	5	'photons'	1000	[251.3089,23...	300	1x300 struct	[0,-1000,0]	[292.2937,-739....	1x300 double
4	63.5100	81.4200	5	'photons'	1000	[251.3089,23...	248	1x248 struct	[0,-1000,0]	[133.5270,-446....	1x248 double
5	84.6800	98.5600	5	'photons'	1000	[251.3089,23...	180	1x180 struct	[0,-1000,0]	[-148.2039,-92....	1x180 double
6	105.8500	115.7000	5	'photons'	1000	[251.3089,23...	247	1x247 struct	[0,-1000,0]	[-417.1714,273....	1x247 double
7	127.0200	132.8400	5	'photons'	1000	[251.3089,23...	293	1x293 struct	[0,-1000,0]	[-542.8920,602....	1x293 double
8	148.1900	149.9800	5	'photons'	1000	[251.3089,23...	308	1x308 struct	[0,-1000,0]	[-456.3935,849....	1x308 double
9	169.3600	210	5	'photons'	1000	[251.3089,23...	314	1x314 struct	[0,-1000,0]	[-159.9008,982....	1x314 double
10	190.5300	225	5	'photons'	1000	[251.3089,23...	313	1x313 struct	[0,-1000,0]	[129.2240,983.1....	1x313 double
11	211.7000	240	5	'photons'	1000	[251.3089,23...	314	1x314 struct	[0,-1000,0]	[262.7358,850.8....	1x314 double
12	232.8700	255	5	'photons'	1000	[251.3089,23...	286	1x286 struct	[0,-1000,0]	[206.3481,603.6....	1x286 double
13	254.0400	270	5	'photons'	1000	[251.3089,23...	215	1x215 struct	[0,-1000,0]	[0,274.9662,-96...	1x215 double
14	275.2100	285	5	'photons'	1000	[251.3089,23...	202	1x202 struct	[0,-1000,0]	[-257.7498,-90....	1x202 double
15	296.3800	300	5	'photons'	1000	[251.3089,23...	270	1x270 struct	[0,-1000,0]	[-447.9335,-444...	1x270 double
16	317.5500	315	5	'photons'	1000	[251.3089,23...	309	1x309 struct	[0,-1000,0]	[-477.2593,-737...	1x309 double
17	338.7200	330	5	'photons'	1000	[251.3089,23...	307	1x307 struct	[0,-1000,0]	[-314.3031,-931...	1x307 double

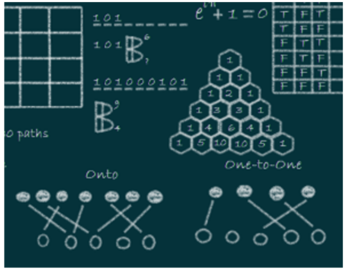
Field	Value	Min	Max
numOfBeams	2	2	2
numOfVoxels	3047040	30...	30...
resolution	1x1 struct		
numOfRaysPerBeam	[303 303]	303	303
totalNumOfRays	606	606	606
totalNumOfBixels	16448	16...	16...
dimensions	[184 184 90]	90	184
numOfScenarios	1	1	1
bixelNum	16448x1 double	1	43
rayNum	16448x1 double	1	303
beamNum	16448x1 double	1	2
physicalDose	1x1 cell		

8. How is data processing carried out?

Input



Storage of variables trough data structures



Processing

$$\min f(d(w)), w \in \mathbb{R}^n$$

$$f = \sum_i p_i f_i$$

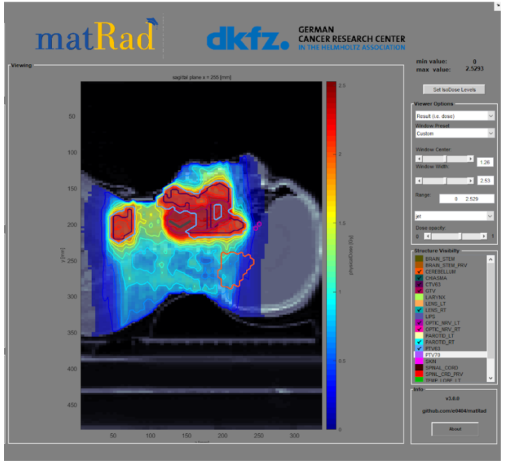
$$s.t. \qquad d = Dw$$

$$c_l \leq c(w) \leq c_u$$

$$w_l \leq w \quad \leq w_u$$

$$f(w): \mathbb{R}^n \rightarrow \mathbb{R} \quad , c(w): \mathbb{R}^n \rightarrow \mathbb{R}^m$$

Results storage and visual processing



Procedure

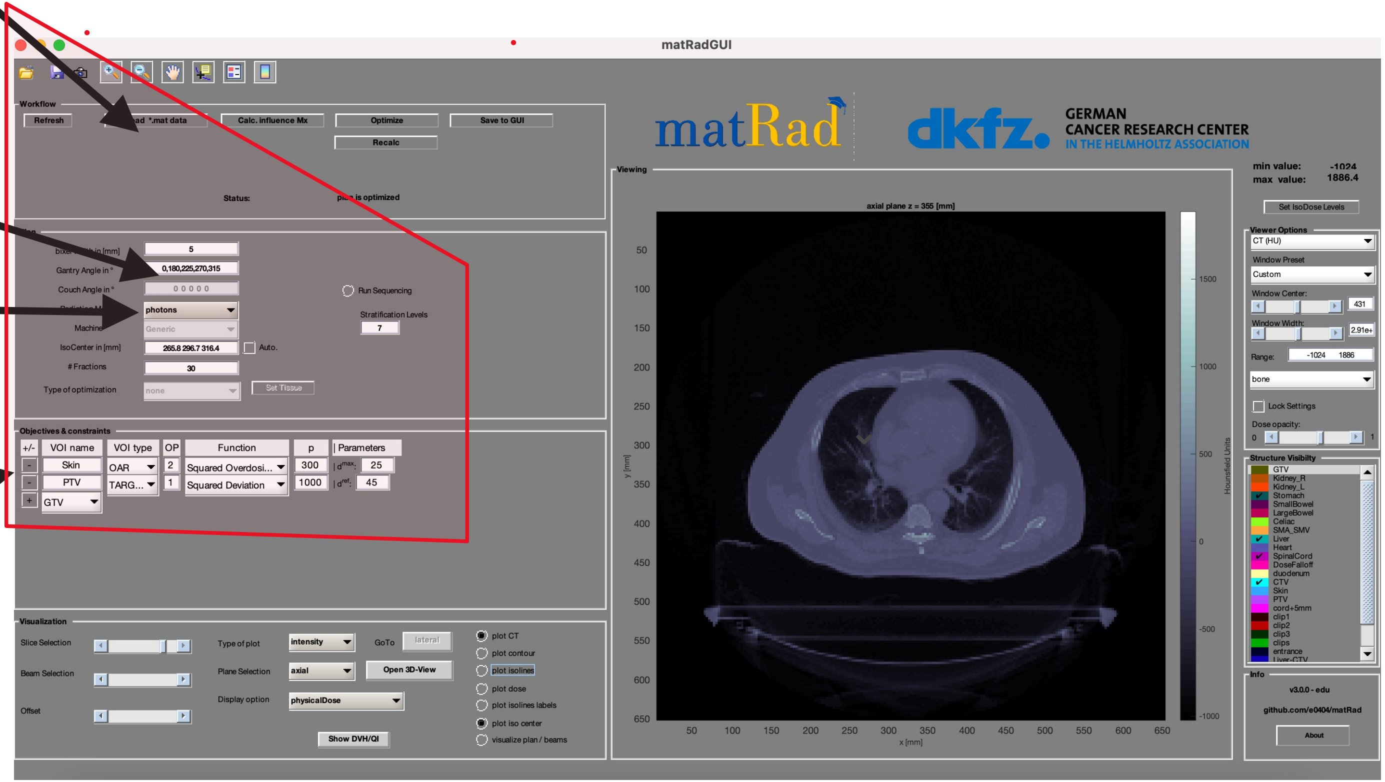
INPUT

TAC

Angoli del lettino e del gantry

Tipo: p, C, photon

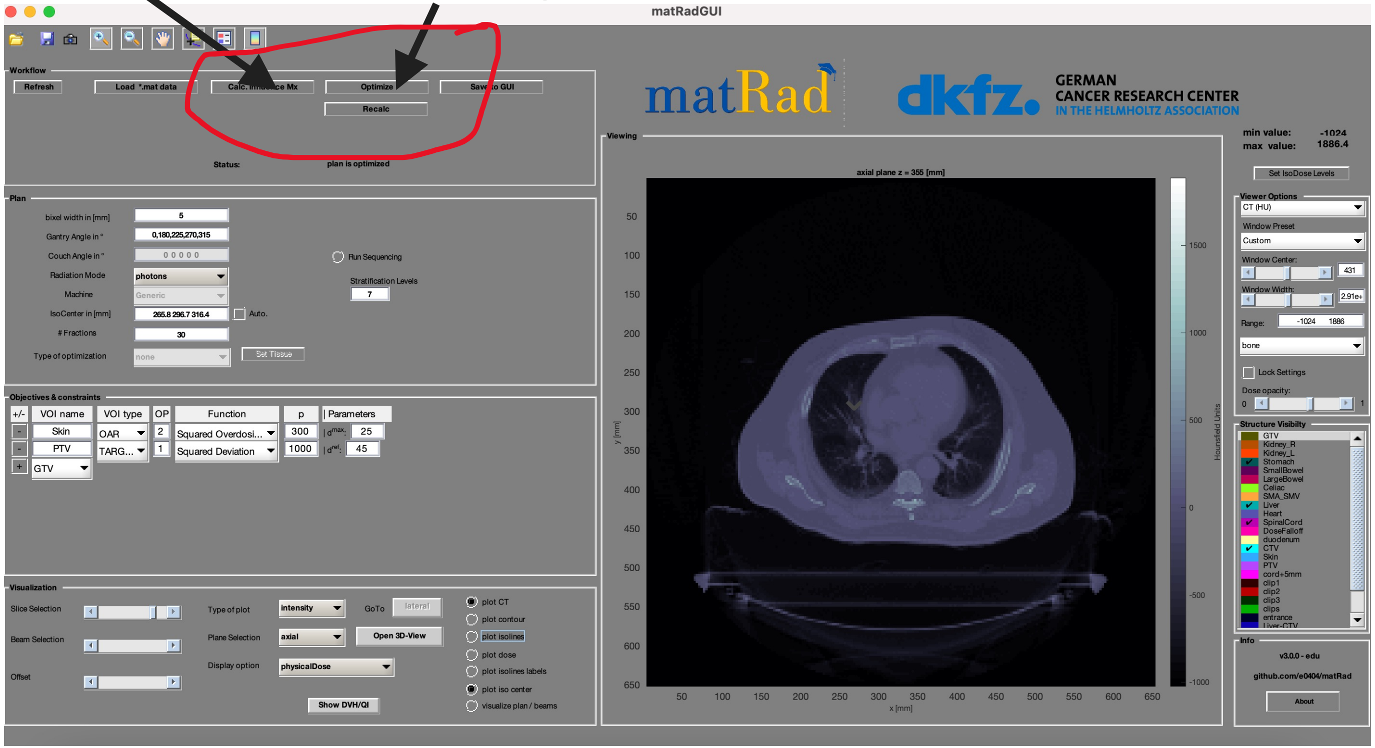
Limiti di dose per zona tumorale e organi a rischio



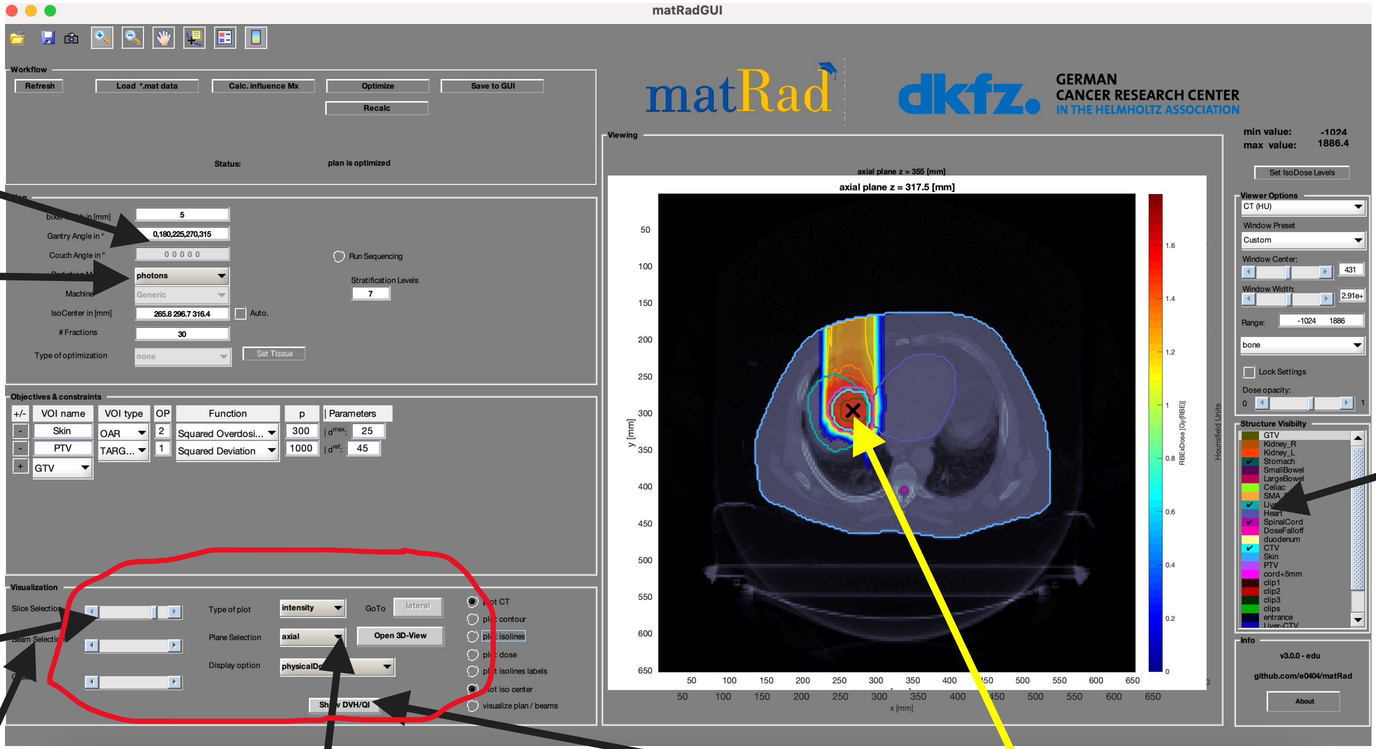
DOSE CALCULATION

Calculate
influence matrix

Optimize all the beams →
calculate the plan



OUTPUT



TAC slicer

Visualize: what field (direction)

Visualize: sagittal, axial, coronal

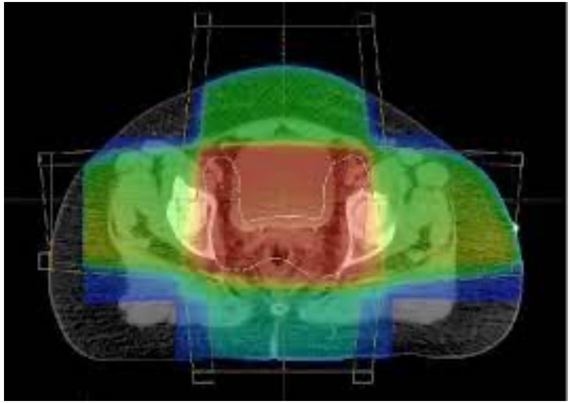
DVH: See next

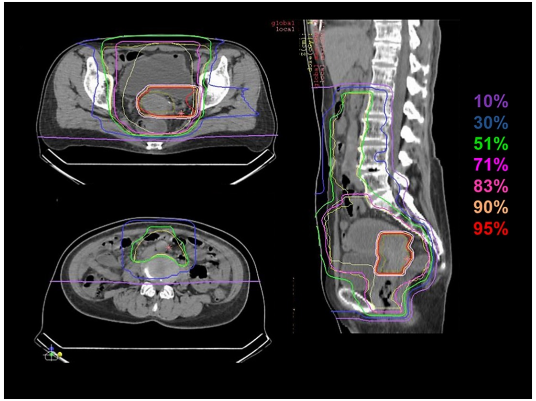
Dose

Structures

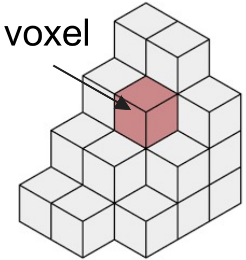
DOSE

- Per valutare un piano di trattamento, guardare la dose in 3D sulla CT e’ il modo piu’ diretto per valutare la qualita’



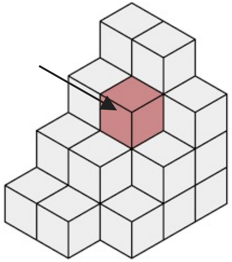


Dimension of dose is Gy [Joule per kg]



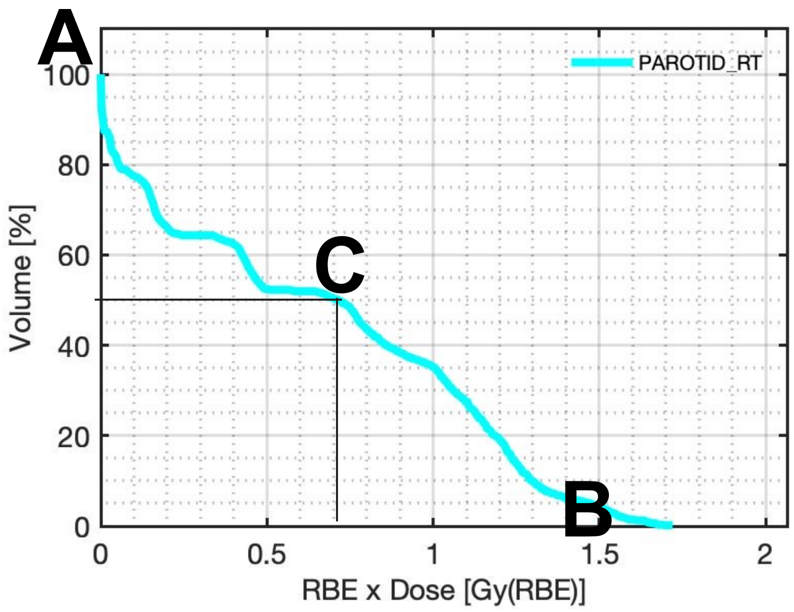
- Svantaggio: virtuale, impegnativo guardare tutti gli slices… tipicamente ~100 CT slices, ~500000 voxels…

DVH



- Dose Volume Histogram: un metodo per valutare velocemente la qualita' della distribuzione di dose
- Tutte le structuree della TAC + informazione sulla dose in poche line!
- In ogni voxel della struttura, valutare la dose --> DHV
- Quindi 1 linea per 1 struttura/organo

Blue line
A: 100% of voxels get at least 0 Gy
B: 0% of voxels receive at least 1.7 Gy
C: … % of voxels receive at least … Gy

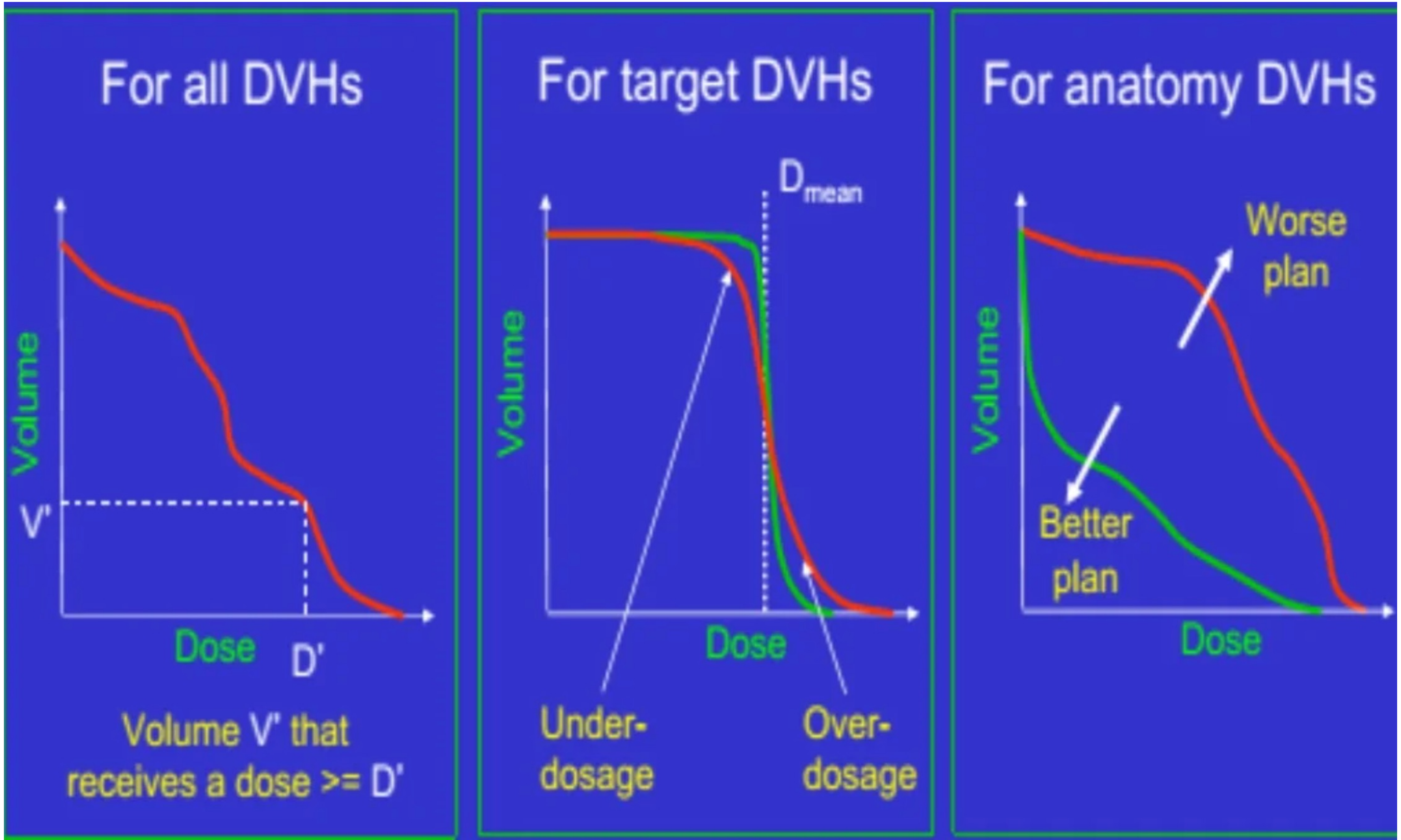


Svantaggi:
- DVH reduce una distribuzione 3D in una linea
- Un po' di informazioni si perdono…

Valutare e comparare piani di trattamento con DVH

Scopo:
- Se la dose al tumore ('target') prescritta e' D_p, 100% di quella zona deve ricevere esattamente $D_{p} \rightarrow$ linea verticale

- Organi a rischio: verso le zero



9. Where does all that really apply?

Everything learned in this masterclass is applied professionally in health centers where specialized equipment is available to perform various clinical procedures through radiotherapy in order to help the treatment of a wide variety of diseases, instead of more complicated and painful procedures.

10. How are the facilities of a particle therapy center?

To learn more about the elements of a particle therapy facility, you can visit the following link:

http://www.cern.nymus3d.nl/maps

We're ready for the afternoon session


BUON PRANZO!