

# **PARTICLE THERAPY MASTERCLASS**

**Hands-On Treatment Planning with matRad**

**Workflow step by step instructions**

# 3<sup>rd</sup> Exercise

- Treatment planning uncertainties
- Proton radiotherapy plan for patients head
- Simulating a patient positioning error
- Analysing and comparing resulting dose distributions

# 1. Load a head patient case (HEAD\_AND\_NECK or ALDERSON.mat)

The screenshot displays the matRad software interface. The main window shows the 'Workflow' section with buttons for 'Refresh', 'Load \*.mat data', 'Load \*.COM', 'Import Bin...', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Recalc', 'Export', and 'Import Dose'. A red arrow points to the 'Load \*.mat data' button. The 'Plan' section contains various parameters such as 'bixel width in [mm]', 'Gantry Angle in °', 'Couch Angle in °', 'Radiation Mode', 'Machine', 'IsoCenter in [mm]', '# Fractions', and 'Type of optimization'. The 'Objectives & constraints' section includes a table with columns for 'VOI name', 'VOI type', 'priority', 'obj. / const.', 'penalty', 'dose', 'EUD', and 'volume'. The 'Visualization' section has options for 'Slice', 'Beam', and 'Offset', along with 'Type of plot', 'Plane', and 'Disolav option'. A 'Select File to Open' dialog box is open, showing a file list with 'HEAD\_AND\_NECK' selected. The dialog box also shows the file name 'HEAD\_AND\_NECK' and the file type 'MAT-files (\*.mat)'. The background shows the matRad logo and the DKFZ logo (GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION).

Workflow

Refresh Load \*.mat data Load \*.COM Import Bin... Calc. influence Mx Optimize Save to GUI Recalc Export Import Dose

Status: plan is optimized

Plan

bixel width in [mm] 10 use MC (VMC++) dose calculations  
Gantry Angle in ° 315 3D conformal  
Couch Angle in ° 0 Run Sequencing  
Radiation Mode carbon Stratification Levels 7  
Machine Generic Run Direct Aperture Optimizat...  
IsoCenter in [mm] 265.8 296.7 316.4 Auto.  
# Fractions 30  
Type of optimization LEMIV\_RBExD Set Tissue

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN

Visualization

Slice Type of plot inten... GoTo lateral plot CT  
Beam Plane axial Open 3D-View plot contour  
Offset Disolav option RBExDose plot isolines  
Show DVH/QI plot dose  
plot isolines labels  
plot iso center  
visualize plan / be...

min max 2.177  
Set IsoDose Levels  
Viewer Options  
Result (i.e. dose)  
Window: Dose  
Custom  
Window Center:  
Window Width: 1.06  
Range: 0 2.123  
jet  
Dose opacity: 0 1  
Structure Visibility  
GTV  
Kidney\_R  
Kidney\_L  
Stomach  
SmallBowel  
LargeBowel  
Celiac  
SMA\_SMV  
Liver  
Heart  
SpinalCord  
DoseFalloff  
Info  
v3.0.0  
github.com/e0404/mat  
About

Select File to Open

Organize New folder

Name Date modified Type

- standalone 6/19/2019 8:34 AM File folder
- tools 6/19/2019 8:34 AM File folder
- unitTest 6/19/2019 8:34 AM File folder
- vmc++ 6/19/2019 8:34 AM File folder
- BOXPHANTOM 6/19/2019 8:33 AM MAT File
- carbon\_Generic 6/19/2019 8:34 AM MAT File
- HEAD\_AND\_NECK 6/19/2019 8:33 AM MAT File
- LIVER 6/19/2019 8:33 AM MAT File
- photons\_Generic 6/19/2019 8:34 AM MAT File
- PROSTATE 6/19/2019 8:33 AM MAT File
- protons\_Generic 6/19/2019 8:34 AM MAT File
- TG119 6/19/2019 8:34 AM MAT File

File name: HEAD\_AND\_NECK MAT-files (\*.mat)

Open Cancel

## 2. Add three proton beam angles on your own. Calculate and optimize the dose („Calc. Influence Mx“ & „Optimize“).

The screenshot displays the matRad software interface, which is used for proton therapy planning. The interface is divided into several panels:

- Workflow:** Contains buttons for 'Refresh', 'Load \*.mat data', 'Load DICOM', 'Import from Bin...', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Export', and 'Import Dose'. Red arrows point to 'Calc. influence Mx' (labeled '2') and 'Optimize' (labeled '3'). The status below indicates 'ready for dose calculation'.
- Plan:** Contains input fields for 'bixel width in [mm]' (10), 'Gantry Angle in °' (90 180 270), 'Couch Angle in °' (0 0 0), 'Radiation Mode' (protons), 'Machine' (Generic), 'IsoCenter in [mm]' (250.4 205.3 138.5), '# Fractions' (30), and 'Type of optimization' (const\_RBExD). Red arrows point to the Gantry Angle and Couch Angle fields (labeled '1'). There are also radio buttons for 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', and 'Run Direct Aperture Optimizat...'. A 'Stratification Levels' field is set to 7.
- Objectives & constraints:** A table with columns: VOI name, VOI type, priority, obj. / const., penalty, dose, EUD, volume. It lists four objectives for parotid glands and two for target volumes (PTV63, PTV70).
- Visualization:** Contains settings for 'Slice', 'Beam', 'Offset', 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option'. There are checkboxes for 'plot CT', 'plot contour', 'plot isolines', 'plot dose', 'plot isolines labels', 'plot iso center', and 'visualize plan / be...'. A 'Show DVH/Q' button is also present.
- Viewing:** Shows an axial CT slice at z = 140 [mm]. The x and y axes range from 50 to 450 mm. A color scale on the right indicates Hounsfield Units from 0 to 60. The target and organs at risk are outlined in various colors.
- Viewer Options:** Includes 'Set IsoDose Levels', 'Window Center' (1.27), 'Window Width' (2.53), 'Range' (0.00324 - 2.531), and 'Structure Visibility' (listing various anatomical structures like BRAIN\_STEM, GTV, LARYNX, etc.).

Logos for 'matRad' and 'dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION' are visible at the top.



### 3. Analyze the result (dose & DVH) and save it („Save to GUI“).

**Workflow**

Refresh Load \*.mat data Calc. influence Mx Optimize Save to GUI  
 Load DICOM Recalc Export  
 Import from Bin... Import Dose

Status: plan is optimized

**Plan**

bixel width in [mm] 10  
 Gantry Angle in ° 90 180 270  
 Couch Angle in ° 0 0 0  
 Radiation Mode protons  
 Machine Generic  
 IsoCenter in [mm] 250.4 205.3 138.5  Auto.  
 # Fractions 30  
 Type of optimization const\_RBExD Set Tissue

**Objectives & constraints**

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1	PAROTID_LT	OAR	1	square overdosing	100	25	NaN	NaN
2	PAROTID_RT	OAR	1	square overdosing	100	25	NaN	NaN
3	PTV63	TARGET	2	square deviation	1000	63	NaN	NaN
4	PTV70	TARGET	1	square deviation	1000	70	NaN	NaN

**Visualization**

Slice Type of plot inten... GoTo lateral  
 Beam Plane axial Open 3D-View  
 Offset Display option RBExDose

plot CT  
 plot contour  
 plot isolines  
 plot dose  
 plot isolines labels  
 plot iso center  
 visualize plan / be...

Show DVH/QI

**matRad** **dkfz.** GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 140 [mm]

min 0  
max 3.186

Set IsoDose Levels

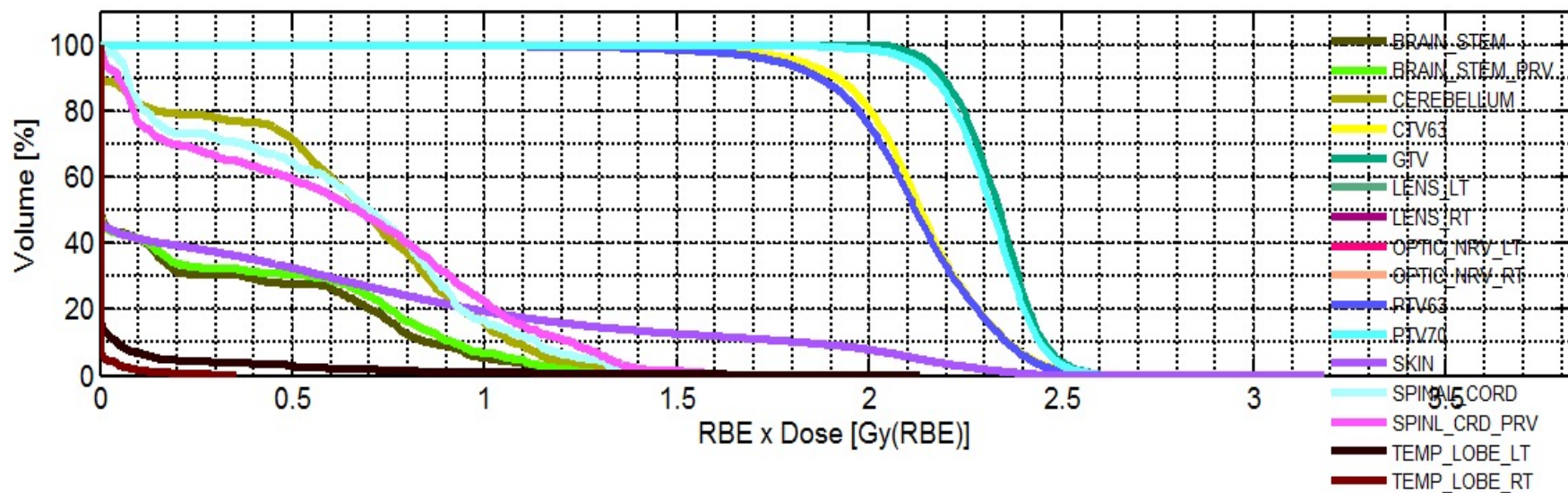
**Viewer Options**

Result (i.e. dose)  
 Window: Dose  
 Custom  
 Window Center: 1.59  
 Window Width: 3.19  
 Range: 0 3.186  
 jet  
 Dose opacity: 1

**Structure Visibility**

- BRAIN\_STEM
- BRAIN\_STEM\_PR
- CEREBELLUM
- CHIASSMA
- CTV63
- GTV
- LARYNX
- LENS\_LT
- LENS\_RT
- LIPS
- OPTIC\_NRV\_LT
- OPTIC\_NRV\_RT

Info  
 v3.0.0  
 github.com/e0404/mat  
 About



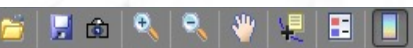
	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.6Gy	V_1.2Gy	V_1.9Gy
BRAIN_STEM	0.2645	0.3831	1.5408	0	1.1597	1.0153	0.0030	0	0	1	0.2649	0.0167	
BRAIN_STEM_PRV	0.2906	0.4099	1.5754	0	1.2980	1.0952	0.0016	0	0	1	0.2896	0.0251	
CEREBELLUM	0.6355	0.3774	2.0785	0	1.3512	1.1661	0.6933	0	0	1	0.5998	0.0469	7.3233
CHIASMA	0	0	0	0	0	0	0	0	0	1	0	0	
CTV63	2.1304	0.1945	3.1861	0.9407	2.4868	2.4230	2.1346	1.8175	1.6587	1	1	0.9973	0.0000
GTV	2.3305	0.1036	2.7047	1.9940	2.5353	2.4898	2.3381	2.1496	2.0935	1	1	1	
LARYNX	0.9230	0.4283	1.9861	0.2391	1.8607	1.7473	0.8058	0.3375	0.2819	1	0.7891	0.2585	0.0000
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	0.0157	0.0412	0.2352	1.1603e-35	0.1705	0.1231	5.8836e-06	4.7064e-25	6.6316e-30	1	0	0	
OPTIC_NRV_LT	0	0	0	0	0	0	0	0	0	1	0	0	



## 4. Simulate a patient positioning error: Remove the hook at the auto iso-center checkbox and define a new iso-center. Recalculate the dose by clicking on the „Recalc“.

The screenshot displays the matRad software interface, which is part of the German Cancer Research Center (dkfz) in the Helmholtz Association. The interface is divided into several panels:

- Workflow:** Contains buttons for Refresh, Load \*.mat data, Calc. influence Mx, Optimize, Save to GUI, Load DICOM, Recalc, Export, Import from Bin..., and Import Dose. A red arrow labeled '2' points to the 'Recalc' button.
- Plan:** Contains various parameters for treatment planning, including:
  - bixel width in [mm]: 10
  - Gantry Angle in °: 90 180 270
  - Couch Angle in °: 0 0 0
  - Radiation Mode: protons
  - Machine: Generic
  - IsoCenter in [mm]: 260 220 150
  - # Fractions: 30
  - Type of optimization: const\_RBExD
  - Auto checkbox: Unchecked (indicated by a red arrow labeled '1')
  - Stratification Levels: 7
- Objectives & constraints:** A table listing various objectives and constraints for the treatment plan.
- Visualization:** Contains controls for slice, beam, and offset, as well as plot options like 'intensity', 'axial', and 'RBExDose'. A 'Show DVH/QI' button is also present.
- Viewing:** Shows an axial plane at z = 140 [mm]. The central image displays a color-coded dose distribution (RBExDose) over a patient's head and neck region. A color scale on the right ranges from 0 to 60 Gy(RBE). The axes are labeled x [mm] and y [mm].
- Viewer Options:** Includes settings for 'Result (i.e. dose)', 'Window Center', 'Window Width', 'Range', and 'Dose opacity'.
- Structure Visibility:** A list of anatomical structures with checkboxes for visibility, including BRAIN\_STEM, BRAIN\_STEM\_PR, CEREBELLUM, CHIASSMA, CTV63, GTV, LARYNX, LENS\_LT, LENS\_RT, LIPS, OPTIC\_NRV\_LT, and OPTIC\_NRV\_RT.
- Info:** Displays the version number (v3.0.0) and the GitHub repository link (github.com/e0404/mat).



**Workflow**

Refresh    Load \*.mat data    Calc. influence Mx    Optimize    Save to GUI

Load DICOM    Recalc    Export

Import from Bin...    Import Dose

Status:    plan is optimized

**Plan**

bixel width in [mm]    10     use MC (VMC++) dose calculations

Gantry Angle in °    90 180 270     3D conformal

Couch Angle in °    0 0 0     Run Sequencing

Radiation Mode    protons    Stratification Levels    7

Machine    Generic

IsoCenter in [mm]    260 220 150     Auto.     Run Direct Aperture Optimizat...

# Fractions    30

Type of optimization    const\_RBExD    Set Tissue

**Objectives & constraints**

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1	PAROTID_LT	OAR	1	square overdosing	100	25	NaN	NaN
2	PAROTID_RT	OAR	1	square overdosing	100	25	NaN	NaN
3	PTV63	TARGET	2	square deviation	1000	63	NaN	NaN
4	PTV70	TARGET	1	square deviation	1000	70	NaN	NaN
5	SKIN	OAR	2	square overdosing	1000	20	NaN	NaN

save

**Visualization**

Slice    Type of plot    inten...    GoTo    lateral

Beam    Plane    axial    Open 3D-View

Offset    Displav option    physicalDose

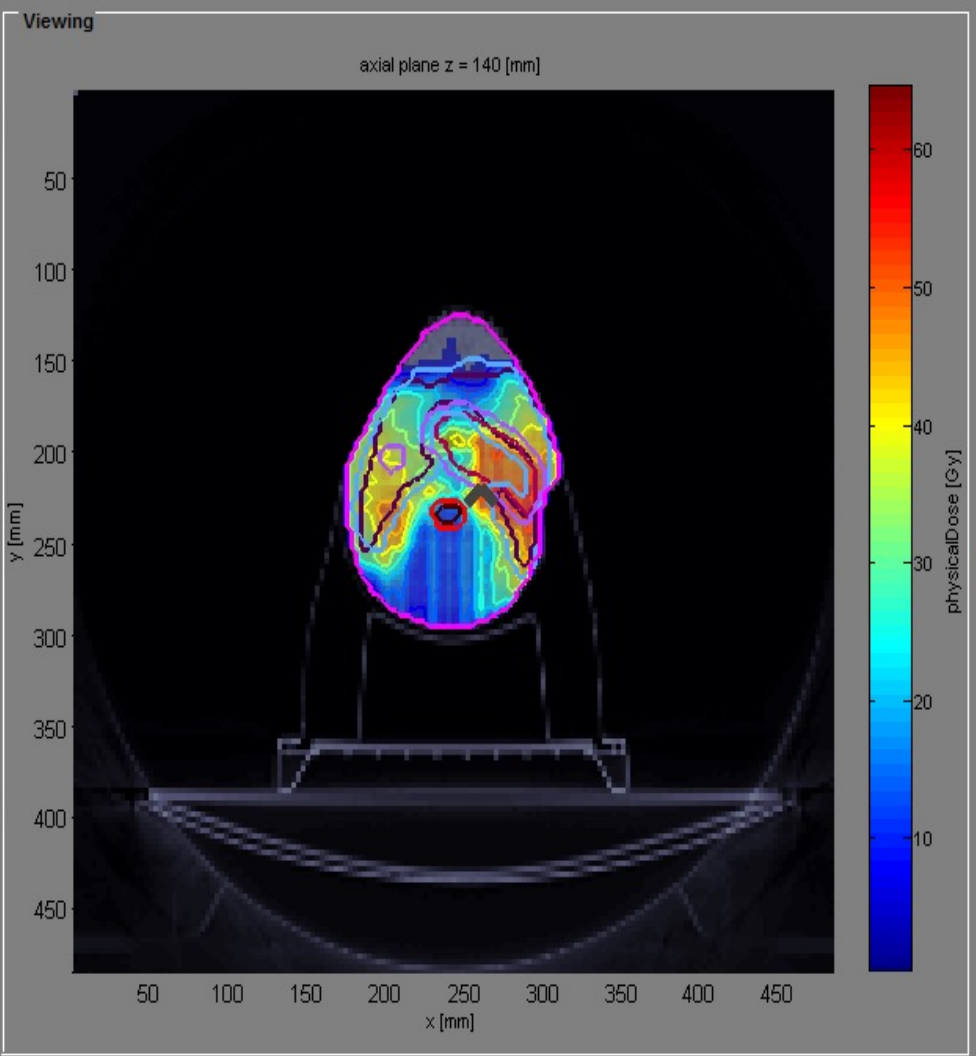
Show DVH/Q!

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

matRad

dkfz.

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## 5. Moving “Slice” option find iso-center and analyze and compare the resulting dose distribution.

**Workflow**

Refresh Load \*.mat data Calc. influence Mx Optimize Save to GUI  
 Load DICOM Recalc Export  
 Import from Bin... Import Dose

Status: plan is optimized

**Plan**

bixel width in [mm] 10  
 Gantry Angle in ° 90 180 270  
 Couch Angle in ° 0 0 0  
 Radiation Mode protons  
 Machine Generic  
 IsoCenter in [mm] 260 220 150  Auto.  
 # Fractions 30  
 Type of optimization const\_RBExD

use MC (VMC++) dose calculations  
 3D conformal  
 Run Sequencing  
 Stratification Levels 7  
 Run Direct Aperture Optimizat...

**Objectives & constraints**

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1	PAROTID_LT	OAR	1	square overdosing	100	25	NaN	NaN
2	PAROTID_RT	OAR	1	square overdosing	100	25	NaN	NaN
3	PTV63	TARGET	2	square deviation	1000	63	NaN	NaN
4	PTV70	TARGET	1	square deviation	1000	70	NaN	NaN

**Visualization**

Slice     
 Beam  Plane 1  
 Offset    visualize plan / be...

plot CT  
 plot contour  
 plot isolines  
 plot dose  
 plot isolines labels  
 plot iso center  
 visualize plan / be...

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 150 [mm]

physicalDose [Gy]

min 0 max 3.186

Set IsoDose Levels

Viewer Options

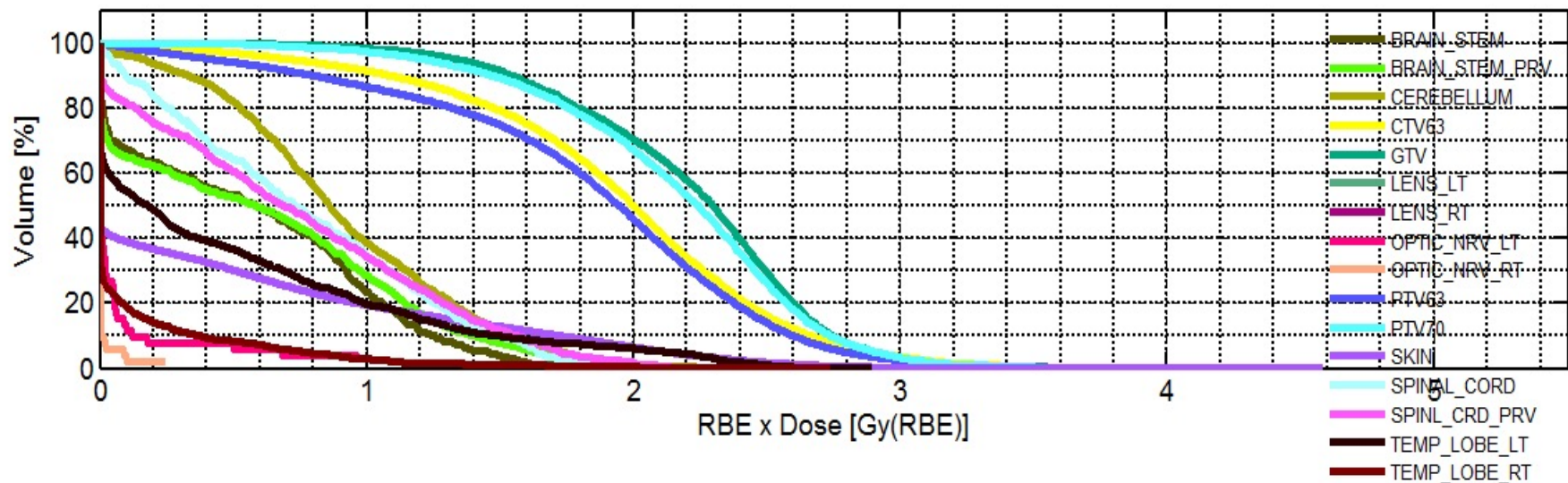
Result (i.e. dose)   
 Window Center: 1.59  
 Window Width: 3.19  
 Range: 0 3.186  
 jet  
 Dose opacity: 1

Structure Visibility

- BRAIN\_STEM
- BRAIN\_STEM\_PR
- CEREBELLUM
- CHIASMA
- CTV63
- GTV
- LARYNX
- LENS\_LT
- LENS\_RT
- LIPS
- OPTIC\_NRV\_LT
- OPTIC\_NRV\_RT

Info

v3.0.0  
[github.com/e0404/mat](https://github.com/e0404/mat)



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.9Gy	V_1.8Gy	V_2.7Gy
BRAIN_STEM	0.5784	0.5092	1.8823	0	1.5814	1.4499	0.5847	0	0	1	0.3294	0.0048	
BRAIN_STEM_PRV	0.6153	0.5759	2.3528	0	1.8157	1.6326	0.5786	0	0	1	0.3519	0.0240	
CEREBELLUM	0.9112	0.4681	2.5823	0	1.9049	1.7408	0.8620	0.1636	0.0032	1	0.4588	0.0373	
CHIASMA	0.2487	0.2353	0.8091	0.0071	0.7505	0.6536	0.2672	0.0169	0.0118	1	0	0	
CTV63	1.9376	0.6348	4.0525	0.0093	3.1482	2.8966	1.9997	0.7051	0.3469	1	0.9282	0.6441	0
GTV	2.2150	0.4918	3.9825	0.4100	3.1008	2.8992	2.2980	1.3330	1.0648	1	0.9886	0.7991	0
LARYNX	0.5702	0.3493	1.7209	0.0422	1.5158	1.2552	0.4717	0.1262	0.1006	1	0.1769	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	0.0064	0.0261	0.2268	0	0.0963	0.0371	8.7893e-18	0	0	1	0	0	
OPTIC_NRV_LT	0.0775	0.2143	0.9674	0	0.9571	0.5805	7.5343e-04	0	0	1	0.0385	0	

# Results

- Mean doses for different regions (Gy) using three proton beams, with and without patients movement:

Region/Iso-center	Without movement	With movement
Brain Stem	0.2645	0.5784
Cerebellum	0.6355	0.9112
CTV63	2.1304	1.9376
GTV	2.3305	2.2150
Lenses (L,D)	0,0	0,0
Skin	0.4682	0.4555
Optic Nerv (L,D)	0,0	0.0775, 0.0092
Spinal Cord	0.6268	0.7466
PTV63	2.1092	1.8369
PTV70	2.3102	2.1671



**Thank you :)**