

PARTICLE THERAPY MASTERCLASS

Hands-On Treatment Planning with matRad

Workflow step by step instructions

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1st Exercise

- First steps on the TG119 phantom
- Radiotherapy treatment - photons vs. protons vs. carbon ions
- Analysing and comparing results

1. Load the TG119 phantom via the Load *.mat button (TG119.mat).

The screenshot displays a software interface with a 'Workflow' section on the left. The 'Load *.mat data' button is highlighted with a red arrow. A 'Select File to Open' dialog box is open, showing a file list with 'TG119' selected, also indicated by a red arrow. The dialog box shows the file name 'TG119' and the file type 'MAT-files (*.mat)'. The background interface includes various settings and a visualization area.

Workflow

Refresh Load *.mat data Load *.COM Import Bin...

Status: no data loaded

Plan

bixel width in [mm] 5 use M
Gantry Angle in ° 0 3D c
Couch Angle in ° 0 Run
Radiation Mode photons
Machine Generic Stratific
IsoCenter in [mm] 0 0 0 Auto. Run
Fractions 30
Type of optimization none Set Tissue

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.
1				
2				
3				
4				

Visualization

Slice Type of plot inten... GoTo lateral
Beam Plane axial Open 3D-View
Offset Dislav option no option avail...
Show DVH/Q

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

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: TG119 MAT-files (*.mat)

Open Cancel

min max

Set IsoDose Levels

Viewer Options

None No available

Window Center: 0.5
Window Width: 1.0
Range: 0 1

bone Dose opacity: 0 1

Structure Visibility

no data loaded

Info

v3.0.0
github.com/e0404/mat
About

2. Set radiation modality to Photons and define one beam angle (gantry angle).

Workflow

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

Status: ready for dose calculation

Plan

bixel width in [mm] 10
 Gantry Angle in ° 0
 Couch Angle in ° 0
 Radiation Mode photons
 Machine Generic
 IsoCenter in [mm] 251.3 236.4 162.6 Auto.
 # Fractions 30
 Type of optimization none

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	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no +
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no -

Visualization

Slice Type of plot inten... GoTo lateral
 Beam Plane axial
 Offset Dislay option no option avail...
 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 = 165 [mm]

min 1000 max 1040.

Viewer Options

CT (HU) Custom
 Window Center: 0.851
 Window Width: 1.67
 Range: 0.02671 1.692
 bone
 Dose opacity: 1

Structure Visibility

Core
 OuterTarget
 BODY

Info

v3.0.0
github.com/e0404/mat

3. Trigger dose calculation via button („Calc. Influence Mx“) and start inverse optimization by clicking on („Optimize“).

The screenshot displays the matRad software interface, which is used for radiation 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 the "Calc. influence Mx" and "Optimize" buttons. The status below these buttons reads "Status: ready for optimization".
- Plan:** Contains various parameters for the treatment plan, such as "bixel width in [mm]" (10), "Gantry Angle in °" (0), "Couch Angle in °" (0), "Radiation Mode" (photons), "Machine" (Generic), "IsoCenter in [mm]" (251.3 236.4 162.6), "# Fractions" (30), and "Type of optimization" (none). There are also radio buttons for "use MC (VMC++) dose calculations", "3D conformal", "Run Sequencing", "Stratification Levels" (7), and "Run Direct Aperture Optimizat...".
- Objectives & constraints:** A table listing objectives and constraints for the plan.
- Visualization:** Contains options for "Slice", "Beam", "Offset", "Type of plot", "Plane", "Dislay option", and "Show DVH/QI". There are also radio buttons for "plot CT", "plot contour", "plot isolines", "plot dose", "plot isolines labels", "plot iso center", and "visualize plan / be...".
- Viewing:** A 2D axial view of a patient's head and neck, showing the target (yellow outline) and organs at risk (blue outline). The view is labeled "axial plane z = 165 [mm]". The axes are labeled "x [mm]" and "y [mm]".
- Viewer Options:** Contains options for "CT (HU)", "Window, Dose", "Custom", "Window Center", "Window Width", "Range", "bone", "Dose opacity", and "Structure Visibility".
- Info:** Contains the version number "v3.0.0" and the GitHub repository "github.com/e0404/mat".

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

4. Analyze 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 ° 0

Couch Angle in ° 0

Radiation Mode photons

Machine Generic

IsoCenter in [mm] 251.3 236.4 162.6 Auto.

Fractions 30

Type of optimization none

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	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no


Visualization

Slice Type of plot inten... GoTo lateral

Beam Plane axial Open 3D-View

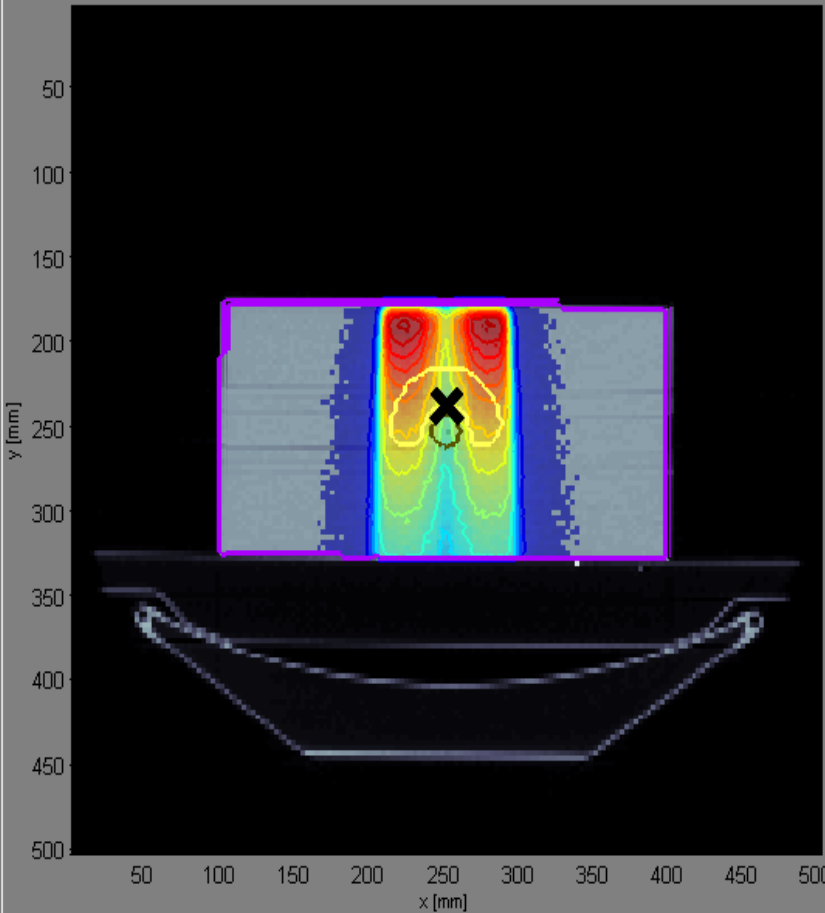
Offset Dislay option physicalDose

- 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

Viewing axial plane z = 165 [mm]



physicalDose [Gy]

min max n 2.342

Viewer Options

Result (i.e. dose)

Window:

Range: 0 2.342

jet

Dose opacity:

Structure Visibility

- Core
- OuterTarget
- BODY

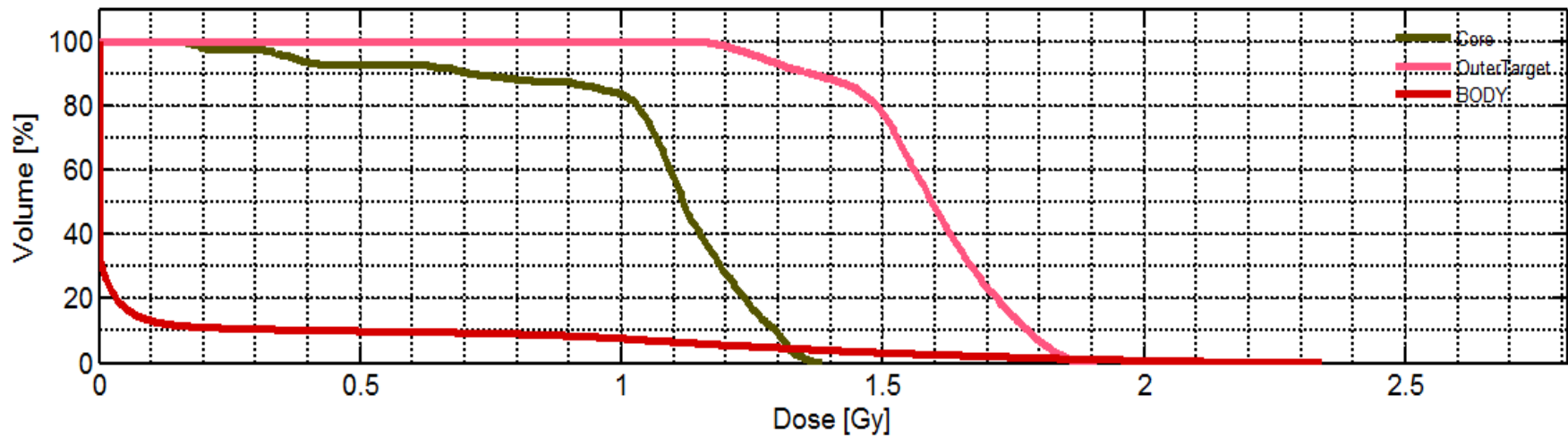
Info

v3.0.0

github.com/e0404/mat

5. Save the optimization result via („Save to GUI“). Next, show the DVH by („Show DVH/QI“).

The screenshot displays the matRad software interface. The top left contains a 'Workflow' section with buttons for 'Refresh', 'Load *.mat data', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Load DICOM', 'Recalc', 'Export', and 'Import Dose'. A red arrow points to the 'Save to GUI' button. Below this is the 'Plan' section with various parameters like '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 contains a table with columns for 'VOI name', 'VOI type', 'priority', 'obj. / const.', 'penalty', 'dose', 'EUD', 'volume', and 'ro'. The 'Visualization' section at the bottom left has options for 'Slice', 'Beam', 'Offset', 'Type of plot', 'Plane', 'Dislay option', and 'Show DVH/QI', with a red arrow pointing to the 'Show DVH/QI' button. The main viewing area shows an axial plane at z = 165 [mm] with a color-coded dose distribution plot. The y-axis is labeled 'y [mm]' and the x-axis is 'x [mm]'. A color scale on the right indicates 'physicalDose [Gy]' from 0 to 60. The top right corner features the 'matRad' and 'dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION' logos. The bottom right corner includes 'Viewer Options' (Result, Window, Range, Dose opacity), 'Structure Visibility' (Core, OuterTarget, BODY), and '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_0.4Gy	V_0.9Gy	V_1.4Gy	V_1.9Gy
Core	1.0665	0.2554	1.3860	0.1329	1.3434	1.3187	1.1183	0.3706	0.1988	1	0.9341	0.8727	0	0
OuterTarget	1.5852	0.1536	1.9115	1.0935	1.8453	1.8153	1.5941	1.2663	1.2077	1	1	1	0.8824	0
BODY	0.1443	0.4168	2.3420	0	1.7203	1.2694	0	0	0	1	0.1019	0.0846	0.0393	0

6. Change the radiation modality to: Protons and leave the beam angles unchanged.

The screenshot displays the matRad software interface. The 'Plan' section on the left shows the 'Radiation Mode' dropdown menu set to 'protons', with a red arrow pointing to it. The 'Workflow' section includes buttons for 'Refresh', 'Load *.mat data', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Load DICOM', 'Recalc', 'Export', 'Import from Bin...', and 'Import Dose'. The status indicates 'plan is optimized'. The 'Objectives & constraints' table is as follows:

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

The 'Visualization' section shows the 'Type of plot' set to 'intensity', 'Plane' set to 'axial', and 'Dislay option' set to 'physicalDose'. The 'Viewing' section shows an axial plane at z = 165 [mm] with a color scale for physical dose from 0 to 60 Gy. The 'Structure Visibility' section shows 'Core', 'OuterTarget', and 'BODY' checked. The 'Info' section shows version v3.0.0 and the GitHub repository link.

7. Trigger dose calculation via button („Calc. InfluenceMx“) and start inverse optimization by clicking on („Optimize“).

Workflow

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

Status: 1 ready for optimization 2

Plan

bixel width in [mm] 10 use MC (VMC++) dose calculations
 Gantry Angle in ° 0 3D conformal
 Couch Angle in ° 0 Run Sequencing
 Radiation Mode protons Stratification Levels 7
 Machine Generic Run Direct Aperture Optimizat...
 IsoCenter in [mm] 251.3 236.4 162.6 Auto.
 # Fractions 30
 Type of optimization const_RBExD Set Tissue

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

Visualization

Slice Type of plot inten... GoTo lateral
 Beam Plane axial Open 3D-View
 Offset Dislay option physicalDose
 Show DVH/QI

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

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Viewing axial plane z = 165 [mm]

min max n 2.342

Set IsoDose Levels

Viewer Options

Result (i.e. dose) Window Precept Custom
 Window Center: Window Width: 1.17
 Range: 0 2.342
 jet Dose opacity: 1
 Structure Visibility
 Core
 OuterTarget
 BODY

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

8. Save the optimization result via („Save to GUI“). Next, show the DVH by („Show DVH/QI“). Analyze the dose distribution.

The screenshot displays the matRad GUI interface. The top left shows the workflow buttons: Refresh, Load *.mat data, Calc. influence Mx, Optimize, Save to GUI, Load DICOM, Recalc, Export, and Import dose. A red arrow labeled '1' points to the 'Save to GUI' button. The status bar indicates 'plan is optimized'.

The 'Plan' section contains various parameters:

- bixel width in [mm]: 10
- Gantry Angle in °: 0
- Couch Angle in °: 0
- Radiation Mode: protons
- Machine: Generic
- IsoCenter in [mm]: 251.3 236.4 162.6 (with 'Auto.' checked)
- # Fractions: 30
- Type of optimization: const_RBExD

The 'Objectives & constraints' table is as follows:

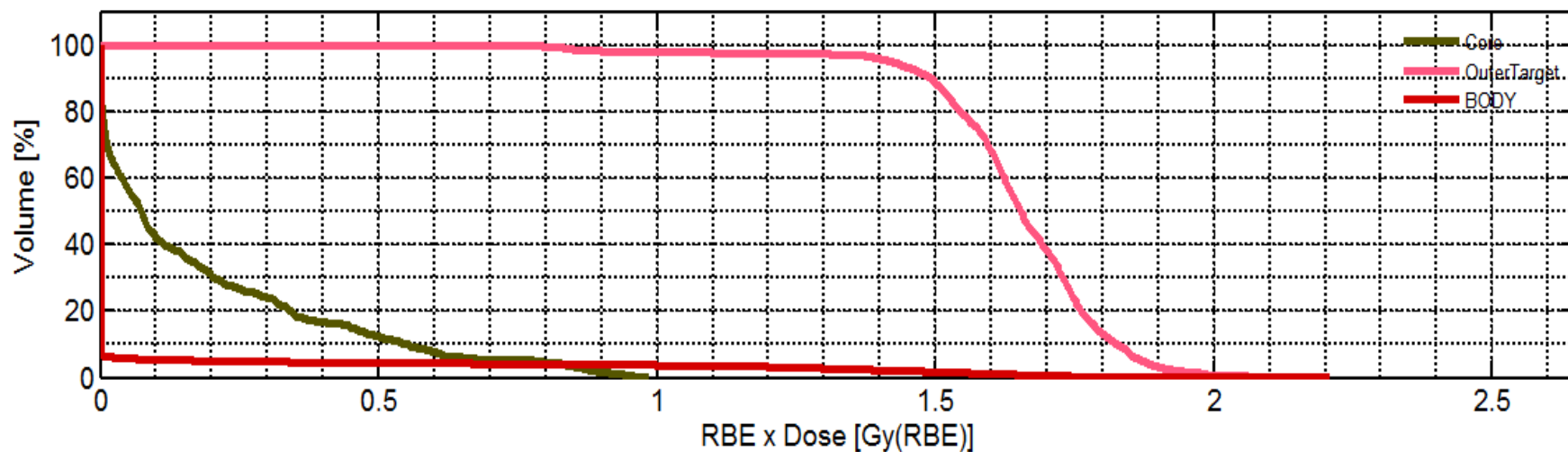
	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

The 'Visualization' section at the bottom left includes:

- Slice: [input field]
- Beam: [input field]
- Offset: [input field]
- Type of plot: inten...
- Plane: axial
- Dislay option: RBExDose
- Show DVH/QI: [button with red arrow labeled '2']

The main viewing area shows an axial plane at z = 165 [mm]. The plot displays a dose distribution with a color scale for RBExDose [Gy(RBE)] ranging from 0 to 60. A red arrow labeled '1' points to the 'Save to GUI' button in the workflow section. A red arrow labeled '2' points to the 'Show DVH/QI' button in the visualization section.

Logos for matRad and dkfz (GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION) are visible at the top. The right sidebar contains viewer options like 'Result (i.e. dose)', 'Window: Default', 'Custom', 'Window Center: 1.11', 'Window Width: 2.21', 'Range: 0 2.21', 'jet' color map, 'Dose opacity: 1', and 'Structure Visibility' (Core, OuterTarget, BODY).



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.4Gy	V_0.8Gy	V_1.3Gy	V_1.8Gy
Core	0.1815	0.2396	0.9866	2.0386e-09	0.8909	0.7849	0.0744	2.4933e-05	6.0723e-07	1	0.1682	0.0470	0	0
OuterTarget	1.6449	0.1770	2.1789	0.7475	1.9408	1.8726	1.6533	1.4205	0.9187	1	1	0.9949	0.9722	0.9222
BODY	0.0640	0.2912	2.2101	0	1.4572	0.2364	0	0	0	1	0.0462	0.0405	0.0282	0.0182

Results

- Mean doses for different regions (Gy):

Region/Radiation	Photons	Protons
Core	1.0665	0.1815
Outer Target	1.5852	1.6449
Body	0.1443	0.0640

- Photons deliver highest dose at the surface
- Protons deliver highest dose at the target (tumor) and protect sensitive organs

9. Try to define a better photon treatment plan by defining more beam angles (e.g. [0, 72, 144, 216, 288]). Trigger dose calculation („Calc. Influence Mx“) and start inverse optimization („Optimize“).

Workflow

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

Status: ready for dose calculation

Plan

bixel width in [mm] 10
 Gantry Angle in ° 0 72 144 216 288
 Couch Angle in ° 0 0 0 0
 Radiation Mode photons
 Machine Generic
 IsoCenter in [mm] 251.3 236.4 162.6 Auto.
 # Fractions 30
 Type of optimization none Set Tissue

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	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

Visualization

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

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

Show DVH/QI

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Viewing axial plane z = 165 [mm]

min max 1.902
 Set IsoDose Levels
 Viewer Options
 Result (i.e. dose)
 Window: Breast Custom
 Window Center: 0.95
 Window Width: 1.9
 Range: 0 1.903
 jet
 Dose opacity: 1
 Structure Visibility
 Core
 OuterTarget
 BODY
 Info
 v3.0.0
 github.com/e0404/mat
 About

10. Save the optimization result via („Save to GUI“). Show the DVH by („Show DVH/QI“). Analyze resulting dose distribution.

Workflow

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

Load DICOM Recalc

Import from Bin...

Status: plan is optimized

Plan

bixel width in [mm] 10

Gantry Angle in ° 0 72 144 216 288

Couch Angle in ° 0 0 0 0

Radiation Mode photons

Machine Generic

IsoCenter in [mm] 251.3 236.4 162.6 Auto.

Fractions 30

Type of optimization none

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	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	no
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

Visualization

Slice

Beam

Offset

Type of plot inten... GoTo lateral

Plane axial

Dislay option physicalDose

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

Viewing axial plane z = 165 [mm]

min max n 1.789

Viewer Options

Result (i.e. dose) Custom

Window Center: 0.89

Window Width: 1.79

Range: 0 1.79

jet

Dose opacity: 1

Structure Visibility

Core

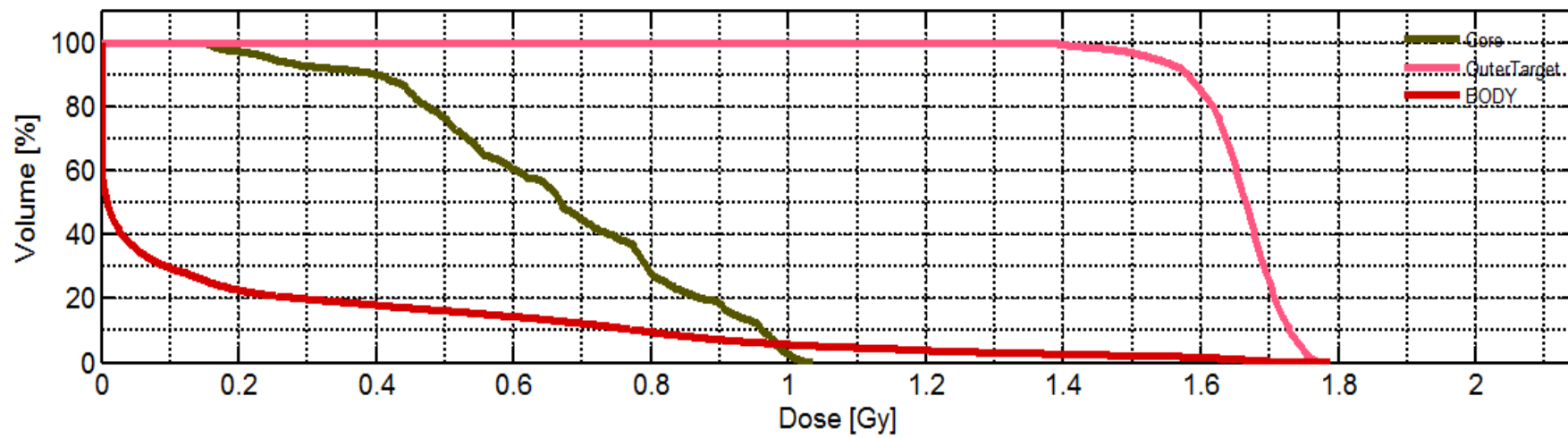
OuterTarget

BODY

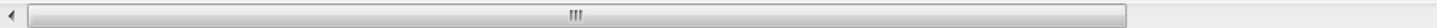
Info

v3.0.0

qithub.com/e0404/mat



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.7Gy	V_1Gy	V_1.5Gy
Core	0.6625	0.2176	1.0370	0.1450	1.0030	0.9853	0.6686	0.2460	0.1755	1	0.9265	0.4477	0.0250	0.0000
OuterTarget	1.6563	0.0659	1.7897	1.2866	1.7566	1.7450	1.6652	1.5323	1.4636	1	1	1	1	0.0000
BODY	0.1968	0.3777	1.7897	0	1.5510	1.0629	0.0091	0	0	1	0.1986	0.1230	0.0568	0.0000



Results

- Mean doses for different regions (Gy):

Region/Radiation(angles)	Photons(0)	Protons(0)	Photons (0,72,144,216,288)
Core	1.0665	0.1815	0.6625
Outer Target	1.5852	1.6449	1.6563
Body	0.1443	0.0640	0.1968

- Treatment plan using multiple photon beams gives better results than single photon beam.
- Best results are obtained using protons.

11. Change optimization objective to improve the photon treatment plan. Use Table („Objectives & constraints“) and add for e.g. maximal dose for the core or minimal dose for the outer target.

Workflow

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

Status: ready for optimization

Plan

bixel width in [mm] 10 use MC (VMC++) dose calculations
 Gantry Angle in ° 0 72 144 216 288 3D conformal
 Couch Angle in ° 0 0 0 0 0 Run Sequencing
 Radiation Mode photons Stratification Levels 7
 Machine Generic Run Direct Aperture Optimizat...
 IsoCenter in [mm] 251.3 236.4 162.6 Auto.
 # Fractions 30
 Type of optimization none Set Tissue

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	max dose constraint	5	NaN	NaN	no	+
2	OuterTarget	TARGET	1	min dose constraint	10	NaN	NaN	no	-
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

save

Visualization

Slice Type of plot inten... GoTo lateral
 Beam Plane axial Open 3D-View
 Offset Dislay option physicalDose
 Show DVH/QI

- 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 = 165 [mm]

min max n
0 1.789

Set IsoDose Levels

Viewer Options

Result (i.e. dose) Window Preset Custom
 Window Center: 0.89
 Window Width: 1.79
 Range: 0 1.79
 jet Dose opacity: 1

Structure Visibility

- Core
- OuterTarget
- BODY

Info

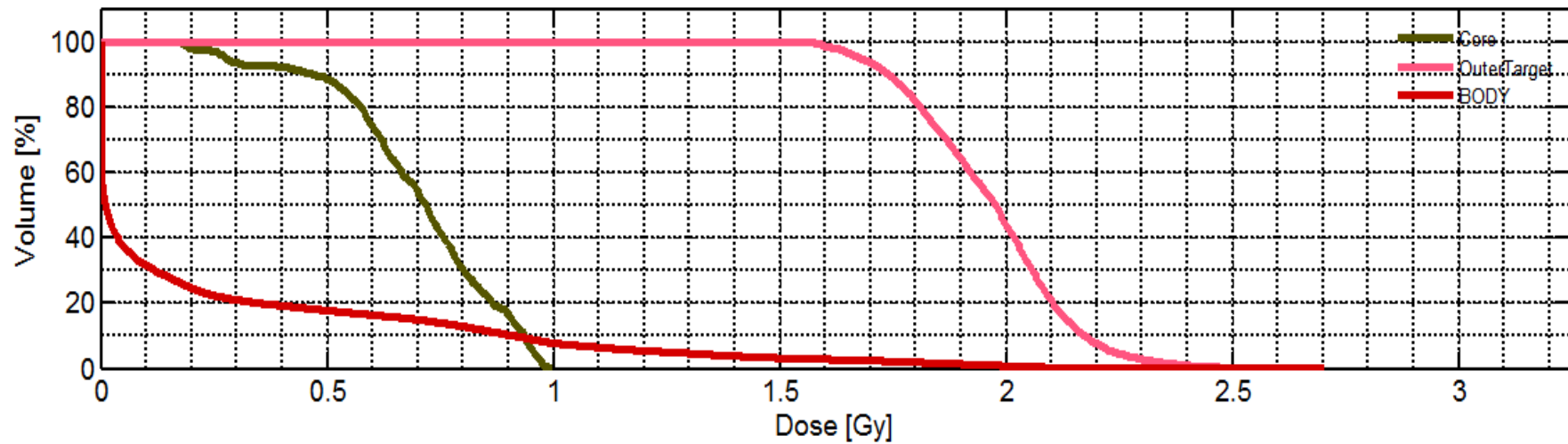
v3.0.0
github.com/e0404/mat
 About

12. Trigger dose calculation („Calc. Influence Mx“) and start inverse optimization („Optimize“). Save the optimization result via („Save to GUI“). Next, show the DVH by („Show DVH/QI“).

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 functional areas:

- Workflow:** Contains buttons for 'Refresh', 'Load *.mat data', 'Load DICOM', 'Import from Bin...', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Replac...', 'Export', and 'Import dose'. Red arrows point to 'Calc. influence Mx', 'Optimize', and 'Save to GUI'. The status below indicates 'plan is optimized'.
- Plan:** A configuration panel with various parameters:
 - bixel width in [mm]: 10
 - Gantry Angle in °: 0 72 144 216 288
 - Couch Angle in °: 0 0 0 0
 - Radiation Mode: photons
 - Machine: Generic
 - IsoCenter in [mm]: 251.3 236.4 162.6 (with 'Auto.' checked)
 - # Fractions: 30
 - Type of optimization: none
 - Options: 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', 'Stratification Levels: 7', and 'Run Direct Aperture Optimizat...'
- Objectives & constraints:** A table defining constraints for different VOI types:

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	max dose constraint	NaN	25	NaN	NaN	no
2	OuterTarget	TARGET	1	min dose constraint	NaN	50	NaN	NaN	no
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no
- Visualization:** Controls for the plot, including 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (physicalDose). A red arrow points to the 'Show DVH/QI' button.
- Viewing:** A central plot showing an axial plane at z = 165 [mm]. The plot displays a color-coded dose distribution with a central target area (Core) and surrounding structures (OuterTarget, BODY). A color scale on the right indicates physical dose in Gy, ranging from 0 to 60.
- Viewer Options:** Includes 'Result (i.e. dose)', 'Window: Default', 'Custom', 'Window Center: 1.35', 'Window Width: 2.71', 'Range: 0 2.705', 'jet' color map, and 'Dose opacity: 1'.
- Structure Visibility:** A list of structures with checkboxes: Core (checked), OuterTarget (checked), and BODY (checked).
- Info:** Version v3.0.0 and a link to github.com/e0404/mat.



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.5Gy	V_1Gy	V_1.6Gy	V_...
Core	0.6974	0.1876	0.9986	0.1704	0.9743	0.9563	0.7189	0.2781	0.1981	1	0.8848	0	0	
OuterTarget	1.9652	0.1732	2.7054	1.5511	2.3409	2.2397	1.9766	1.6761	1.6190	1	1	1	0.9857	
BODY	0.2343	0.4481	2.7054	0	1.7993	1.2658	0.0110	0	0	1	0.1780	0.0784	0.0288	

Results

- Mean doses for different regions (Gy) using 5 beams with and without constraints:

Region/Radiation	With constraints	Without constraints
Core	0.6625	0.6974
Outer Target	1.6563	1.9652
Body	0.1968	0.2343

2nd Exercise

- Carbon ion treatment plan for a liver patient
- Defining treatment plan using photons and protons
- Analysing and comparing different treatment plans

1. Load the liver patient case via the Load *.mat button (LIVER.mat)

The screenshot displays the matRad software interface. The top navigation bar includes the matRad logo, the dkfz logo, and the text 'GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION'. The main interface is divided into several panels:

- Workflow:** Contains buttons for 'Refresh', 'Load *.mat data' (highlighted with a red arrow), 'Load *.COM', 'Import Plan Bin...', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Recalc', 'Export', and 'Import Dose'.
- Plan:** Includes input fields for 'bixel width in [mm]' (20), 'Gantry Angle in °' (0 72 144 216 288), 'Couch Angle in °' (0 0 0 0), 'Radiation Mode' (protons), 'Machine' (Generic), 'IsoCenter in [mm]' (251.3 236.4 162.6), '# Fractions' (30), and 'Type of optimization' (const_RBExD).
- Objectives & constraints:** A table with columns for 'VOI name', 'VOI type', 'priority', 'obj. / const.', 'penalty', 'dose', 'EUD', and 'volume'. It lists three objectives: Core, OuterTarget, and BODY.
- Visualization:** Includes 'Slice' and 'Beam' controls, 'Type of plot' (intensity), 'Plane' (axial), and 'Displav option' (RBExDose).

A 'Select File to Open' dialog box is open, showing a file explorer view of the directory 'e0404-matRad-2957fcc'. The file 'LIVER' (MAT File) is selected and highlighted with a red arrow. The 'File name' field contains 'LIVER' and the file type is set to 'MAT-files (*.mat)'. The 'Open' button is visible at the bottom of the dialog.

VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1 Core	OAR	2	max dose constraint	NaN	25	NaN	NaN
2 OuterTarget	TARGET	1	min dose constraint	NaN	50	NaN	NaN
3 BODY	OAR	3	square overdosing	100	30	NaN	NaN

2. Define your own photon treatment plan with approx. 4-5 beam directions.

Workflow

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

Load DICOM Recalc Export

Import from Bin... Import Dose

Status: ready for optimization

Plan

bixel width in [mm] 1

Gantry Angle in ° 2

Couch Angle in °

Radiation Mode

Machine

IsoCenter in [mm] Auto.

Fractions

Type of optimization

use MC (VMC++) dose calculations

3D conformal

Run Sequencing

Stratification Levels

Run Direct Aperture Optimizat...

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Skin	OAR	2	square over dosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no

Visualization

Slice Type of plot GoTo

Beam Plane

Offset Dislay option

plot CT

plot contour



plot isolines

plot dose

plot isolines labels

plot iso center

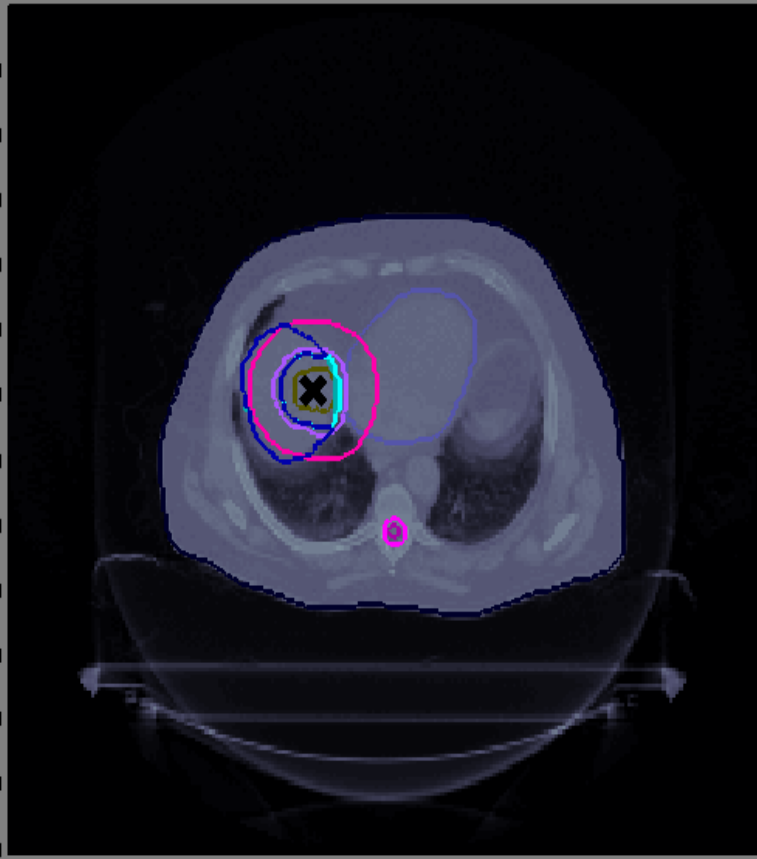
visualize plan / be...

GERMAN CANCER RESEARCH CENTER
IN THE HELMHOLTZ ASSOCIATION

Viewing

axial plane z = 317.5 [mm]



min 0
max 3.706

Viewer Options

Result (i.e. dose)

Window Center:

Window Width:

Range:

Dose opacity:

Structure Visibility

- GTV
- Kidney_R
- Kidney_L
- Stomach
- SmallBowel
- LargeBowel
- Cellac
- SMA_SMV
- Liver
- Heart
- SpinalCord
- DoseFalloff

Info

v3.0.0

github.com/e0404/mat

3. Trigger dose calculation („Calc. Influence Mx“) and start inverse optimization („Optimize“).

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

- Workflow Panel:** Contains buttons for 'Refresh', 'Load *.mat data', 'Load DICOM', 'Import from Bin...', 'Calc. influence Mx' (indicated by a red arrow and '1'), 'Optimize' (indicated by a red arrow and '2'), 'Save to GUI', 'Export', and 'Import Dose'. The status below these buttons reads 'Status: ready for optimization'.
- Plan Panel:** Includes input fields for 'bixel width in [mm]' (10), 'Gantry Angle in °' (0 180 225 270 315), 'Couch Angle in °' (0 0 0 0), 'Radiation Mode' (photons), 'Machine' (Generic), 'IsoCenter in [mm]' (265.8 296.7 316.4), '# Fractions' (30), and 'Type of optimization' (none). It also has 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 Panel:** Contains a table with the following data:

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no
- Visualization Panel:** Shows a 3D axial view of a patient's head and neck at 'axial plane z = 317.5 [mm]'. The y-axis ranges from 50 to 650 mm, and the x-axis ranges from 50 to 650 mm. A color scale on the right indicates 'physicalDose [Gy]' from 0 to 60. The 'Structure Visibility' list includes GTV, Kidney_R, Kidney_L, Stomach, SmallBowel, LargeBowel, Cellac, SMA_SMV, Liver, Heart, SpinalCord, and DoseFalloff. The 'Info' panel at the bottom right shows 'v3.0.0' and 'github.com/e0404/mat'.

4. Save the optimization result via („Save to GUI“). Next, show the DVH by („Show DVH/QI“). Analyze dose distribution.

Workflow

Refresh Load *.mat data Calc. influence Mx Optimize **Save to GUI** Export Import dose

Load DICOM Recalc

Import from Bin...

Status: plan is optimized

1 (arrow pointing to Save to GUI)

Plan

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

Gantry Angle in °: 0 180 225 270 315 3D conformal

Couch Angle in °: 0 0 0 0 Run Sequencing

Radiation Mode: photons Stratification Levels: 7

Machine: Generic Run Direct Aperture Optimizat...

IsoCenter in [mm]: 265.8 296.7 316.4 Auto.

Fractions: 30

Type of optimization: none Set Tissue

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no

save

Visualization

Slice: Type of plot: inten... GoTo: lateral plot CT

Beam: Plane: axial Open 3D-View plot contour

Offset: Dislay option: physicalDose **2** (arrow pointing to Show DVH/QI) plot isolines

Show DVH/QI plot dose

plot isolines labels

plot iso center

visualize plan / be...

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 317.5 [mm]

min max 0 1.572

Set IsoDose Levels

Viewer Options

Result (i.e. dose): Window: Default Custom

Window Center: Window Width: 0.781 Range: 0 1.572

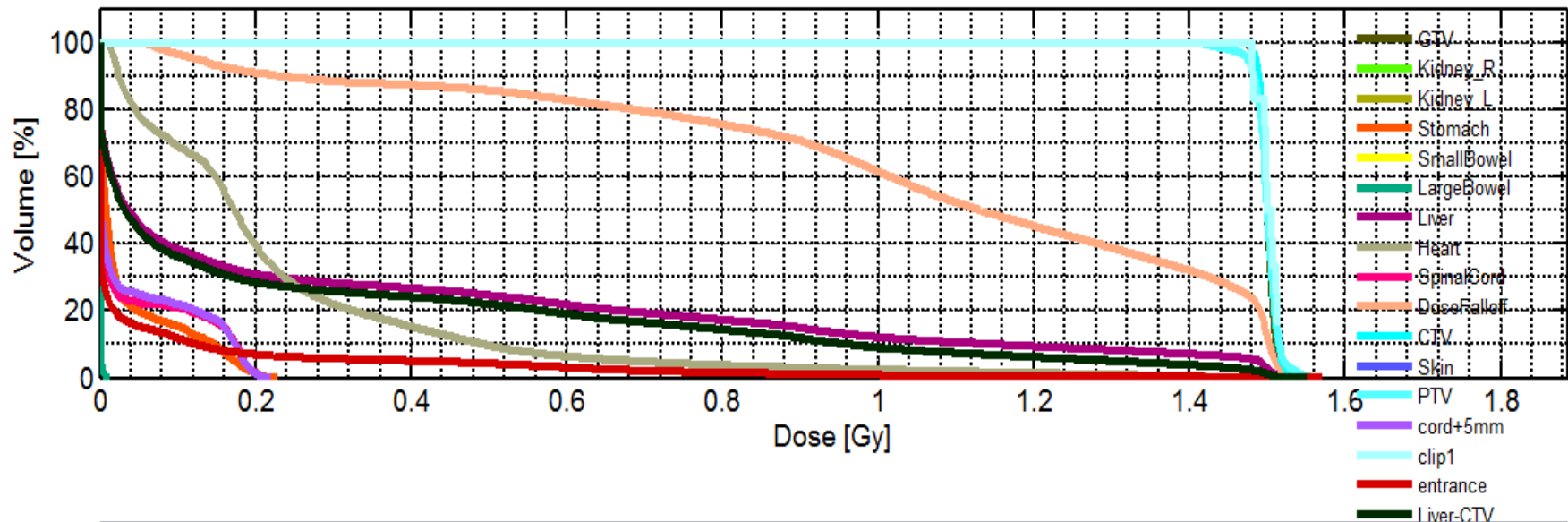
jet Dose opacity: 1

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



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.3Gy	V_0.6Gy	V_0.9Gy
GTV	1.5000	0.0090	1.5281	1.4727	1.5188	1.5148	1.5002	1.4851	1.4796	1	1	1	
Kidney_R	0	0	0	0	0	0	0	0	0	1	0	0	0
Kidney_L	0	0	0	0	0	0	0	0	0	1	0	0	0
Stomach	0.0342	0.0566	0.2310	0	0.1940	0.1736	0.0082	0	0	1	0	0	0
SmallBowel	0	0	0	0	0	0	0	0	0	1	0	0	0
LargeBowel	2.6018e-04	0.0012	0.0147	0	0.0047	0.0019	0	0	0	1	0	0	0
Celiac	0	0	0	0	0	0	0	0	0	1	0	0	0
SMA_SMV	0	0	0	0	0	0	0	0	0	1	0	0	0
Liver	0.3033	0.4713	1.5526	0	1.5042	1.4889	0.0367	0	0	1	0.2838	0.2190	0
Heart	0.2296	0.2426	1.5232	0.0066	1.1065	0.6913	0.1728	0.0182	0.0141	1	0.2202	0.0650	0
SpinalCord	0.0391	0.0686	0.2167	0	0.1969	0.1856	0	0	0	1	0	0	0

5. Define your own proton treatment plan with one beam from e.g. 315°. Then trigger dose calculation („Calc. Influence Mx“) and start inverse optimization („Optimize“).

Workflow

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

Status: ready for dose calculation

Plan

bixel width in [mm]: 10
 Gantry Angle in °: 315
 Couch Angle in °: 0
 Radiation Mode: protons
 Machine: Generic
 IsoCenter in [mm]: 265.8 296.7 316.4
 # Fractions: 30
 Type of optimization: const_RBExD

Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no

Visualization

Slice: Type of plot: inten... | GoTo: lateral
 Beam: Plane: axial | Open 3D-View
 Offset: Dislay option: physicalDose

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

Viewing: axial plane z = 317.5 [mm]

min max n 1.572
 Set IsoDose Levels

Viewer Options

Result (i.e. dose): Window Dose: Custom
 Window Center: 0.781
 Window Width: 1.57
 Range: 0 1.572
 jet
 Dose opacity: 1

Structure Visibility

- GTV
- Kidney_R
- Kidney_L
- Stomach
- SmallBowel
- LargeBowel
- Celiac
- SMA_SMV
- Liver
- Heart
- SpinalCord
- DoseFalloff

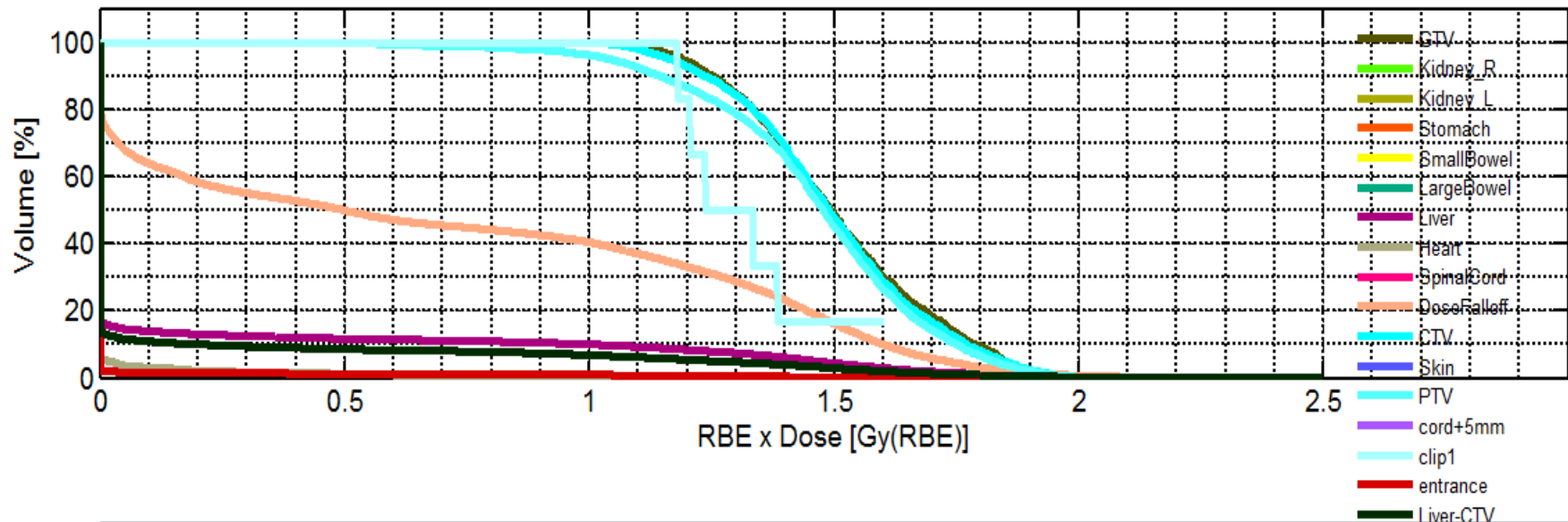
Info: v3.0.0 | github.com/e0404/mat | About

6. Save the optimization result via („Save to GUI“). Next, show the DVH by („Show DVH/QI“). Analyze the resulting dose distribution.

The screenshot displays the matRad software interface. At the top, logos for matRad and dkfz (German Cancer Research Center) are visible. 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, and Import from Bin... A red arrow points to the 'Save to GUI' button.
- Status:** Indicates 'plan is optimized' with a '1' next to it.
- Plan:** Lists parameters such as 'bixel width in [mm]' (10), 'Gantry Angle in °' (315), 'Couch Angle in °' (0), 'Radiation Mode' (protons), 'Machine' (Generic), 'IsoCenter in [mm]' (265.8 296.7 316.4), '# Fractions' (30), and 'Type of optimization' (const_RBExD).
- Objectives & constraints:** A table with columns for VOI name, type, priority, objective/constraint, penalty, dose, EUD, and volume.

VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1 Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2 PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no
- Visualization:** Includes 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (RBExDose). A red arrow points to the 'Show DVH/QI' button.
- Viewing:** Shows a 2D axial plane at z = 317.5 [mm]. The plot displays a color-coded dose distribution (RBExDose [Gy(RBE)]) with a color scale from 0 to 60. A red 'X' marks a specific point in the target area.
- Viewer Options:** Includes 'Result (i.e. dose)', 'Window: Default', 'Custom', 'Window Center', 'Window Width', 'Range: 0 2.501', 'jet' color map, and 'Dose opacity'.
- Structure Visibility:** A list of anatomical structures with checkboxes, including GTV, Kidney_R, Kidney_L, Stomach, SmallBowel, LargeBowel, Celiac, SMA_SMV, Liver, Heart, SpinalCord, and DoseFalloff.
- Info:** Shows version v3.0.0 and the GitHub repository link github.com/e0404/mat.



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.5Gy	V_1Gy	V_1.5Gy
GTV	1.5053	0.1981	2.0110	1.0341	1.8973	1.8506	1.4947	1.1921	1.1231	1	1	1	0
Kidney_R	0	0	0	0	0	0	0	0	0	1	0	0	0
Kidney_L	0	0	0	0	0	0	0	0	0	1	0	0	0
Stomach	0	0	0	0	0	0	0	0	0	1	0	0	0
SmallBowel	0	0	0	0	0	0	0	0	0	1	0	0	0
LargeBowel	0	0	0	0	0	0	0	0	0	1	0	0	0
Celiac	0	0	0	0	0	0	0	0	0	1	0	0	0
SMA_SMV	0	0	0	0	0	0	0	0	0	1	0	0	0
Liver	0.1694	0.4605	2.5011	0	1.6940	1.4688	0	0	0	1	0.1177	0.1008	0
Heart	0.0172	0.1143	1.8597	0	0.2483	0.0195	0	0	0	1	0.0127	0.0050	0
SpinalCord	0	0	0	0	0	0	0	0	0	1	0	0	0

7. Create a carbon ion treatment with the exact same settings as used for the proton treatment plan – What difference can now be observed?

Workflow

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

Status: ready for dose calculation

Plan

bixel width in [mm]: 10
 Gantry Angle in °: 315
 Couch Angle in °: 0
 Radiation Mode: carbon
 Machine: photons
 IsoCenter in [mm]:
 # Fractions:
 Type of optimization: LEMIV_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	ro
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no

Visualization

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

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 = 317.5 [mm]

min 0
max 2.501

Set IsoDose Levels

Viewer Options

Result (i.e. dose)
 Window: Default
 Custom
 Window Center:
 Window Width: 1.25
 Range: 0 2.501
 jet
 Dose opacity: 1

Structure Visibility

- GTV
- Kidney_R
- Kidney_L
- Stomach
- SmallBowel
- LargeBowel
- Cellac
- SMA_SMV
- Liver
- Heart
- SpinalCord
- DoseFalloff

Info

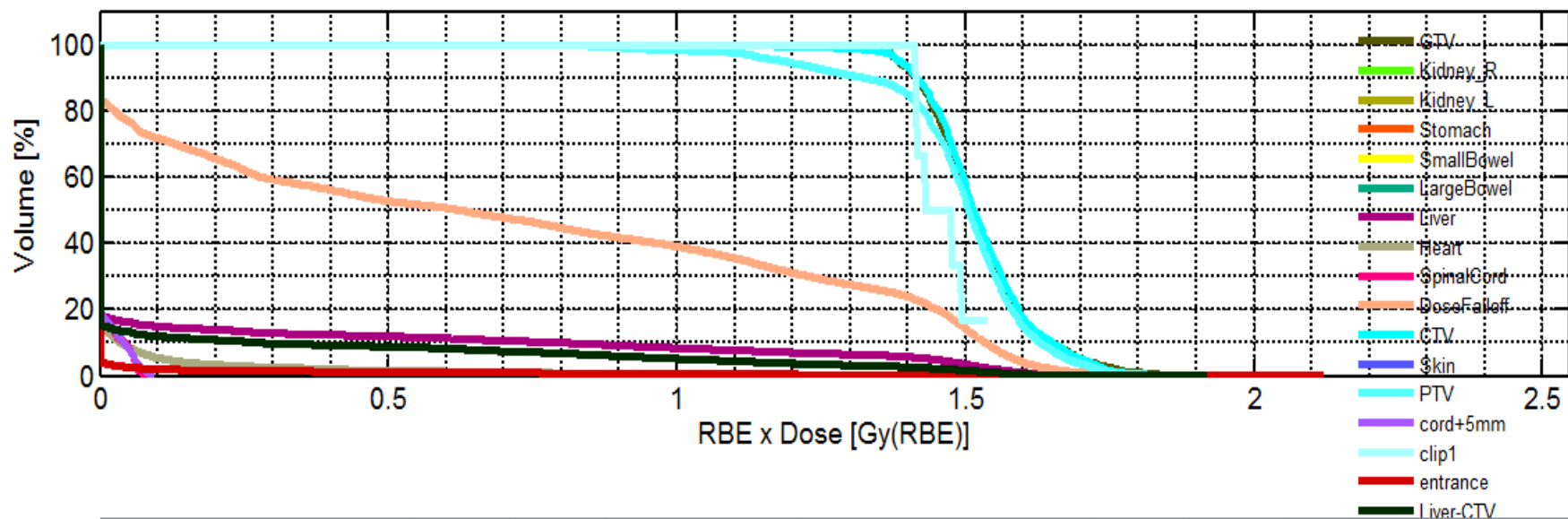
v3.0.0
 github.com/e0404/mat
 About

8. Save the optimization result via („Save to GUI“). Next, show the DVH by („Show DVH/QI“). Analyze the resulting dose distribution.

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 functional areas:

- Workflow:** Contains buttons for Refresh, Load *.mat data, Calc. influence Mx, Optimize, Save to GUI, Load DICOM, Recalc, Export, and Import dose. A red arrow labeled '1' points to the 'Save to GUI' button. The status below indicates 'plan is optimized'.
- Plan:** Lists parameters such as 'bixel width in [mm]' (10), 'Gantry Angle in °' (315), 'Couch Angle in °' (0), 'Radiation Mode' (carbon), 'Machine' (Generic), 'IsoCenter in [mm]' (265.8, 296.7, 316.4), '# Fractions' (30), and 'Type of optimization' (LEMIV_RBExD). It also includes options for 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', 'Stratification Levels' (7), and 'Run Direct Aperture Optimizat...'.
- Objectives & constraints:** A table with columns for VOI name, VOI type, priority, obj. / const., penalty, dose, EUD, volume, and ro.

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no
- Visualization:** Includes controls for 'Slice', 'Beam', 'Offset', 'Type of plot' (intentional), 'Plane' (axial), 'Dislay option' (RBExDose), and 'GoTo' (lateral). A red arrow labeled '2' points to the 'Show DVH/QI' button. Other options include 'plot CT', 'plot contour', 'plot isolines', 'plot dose', 'plot isolines labels', 'plot iso center', and 'visualize plan / be...'.
- Viewing:** Shows an axial plane at z = 317.5 [mm]. The central image displays a 3D dose distribution with a color scale for RBExDose [Gy(RBE)] ranging from 0 to 60. The axes are labeled x [mm] and y [mm].
- Right Panel:** Contains 'min max' (0, 2.122), 'Set IsoDose Levels', 'Viewer Options' (Result (i.e. dose), Window, Custom, Window Center, Window Width, Range, jet, Dose opacity), 'Structure Visibility' (checkboxes for GTV, Kidney_R, Kidney_L, Stomach, SmallBowel, LargeBowel, Celiac, SMA_SMV, Liver, Heart, SpinalCord, DoseFalloff), and '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_0.4Gy	V_0.8Gy	V_1.2Gy
GTV	1.5212	0.0930	1.8920	1.2809	1.7595	1.7032	1.5090	1.3845	1.3641	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	0.1570	0.4178	1.9880	0	1.5533	1.4456	0	0	0	1	0.1243	0.1004	0.0000
Heart	0.0277	0.1314	1.8137	0	0.4139	0.1145	0	0	0	1	0.0212	0.0088	0.0000
SpinalCord	0.0077	0.0187	0.0855	0	0.0659	0.0582	0	0	0	1	0	0	

Results

- Mean doses for different regions (Gy) using 5 photon beams, single proton beam and carbon ion beam:

Region/Radiation(angles)	Photons(0,180,225,270,315)	Protons(315)	Carbon(315)
GTV	1.5	1.5053	1.5212
Kidneys	0	0	0
Stomach	0.0342	0	0
Liver	0.3033	0.1694	0.1570
Heart	0.2296	0.0172	0.0277
Spinal Cord	0.0391	0	0.0077
CTV	1.5015	1.4981	1.5236
PTV	1.4991	1.4595	1.4868
Skin	0.0568	0.0179	0.0162

3rd 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 top left shows a workflow menu with buttons: Refresh, Load *.mat data (highlighted with a red arrow), Load COM, Import Bin..., Calc. influence Mx, Optimize, Save to GUI, Recalc, Export, and Import Dose. The status bar indicates 'plan is optimized'. The main window shows a 3D visualization of a patient case with the text 'axial plane z = 317.5 [mm]'. A 'Select File to Open' dialog box is open, showing a file list with 'HEAD_AND_NECK' selected (highlighted with a red arrow). The file list includes folders like standalone, tools, unitTest, vmc++ and files like BOXPHANTOM, carbon_Generic, HEAD_AND_NECK, LIVER, photons_Generic, PROSTATE, protons_Generic, and TG119. The file name field contains 'HEAD_AND_NECK' and the file type is 'MAT-files (*.mat)'. The background interface includes various settings for Plan, Objectives & constraints, and Visualization.

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
Gantry Angle in ° 315
Couch Angle in ° 0
Radiation Mode carbon
Machine Generic
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
Beam Plane axial Open 3D-View
Offset Disolav option RBExDose

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

min max 0 2.127
Set IsoDose Levels
Viewer Options
Result (i.e. dose) Custom
Window Center: 1.06
Window Width: 2.12
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

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 beam therapy planning. The interface is divided into several sections:

- 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 various parameters for the treatment plan. Red arrows point to 'Gantry Angle in °' (set to 90, 180, 270, labeled '1'), 'Couch Angle in °' (set to 0, 0, 0), and 'Radiation Mode' (set to protons). Other parameters include 'Machine' (Generic), 'IsoCenter in [mm]' (250.4, 205.3, 138.5), '# Fractions' (30), and 'Type of optimization' (const_RBExD).
- Objectives & constraints:** A table listing various objectives and constraints for the treatment plan.
- Visualization:** Contains settings for the visualization of the treatment plan, including 'Slice', 'Beam', 'Offset', 'Type of plot', 'Plane', and 'Dislay option'.

The central part of the interface shows a viewing window with the following details:

- matRad** and **dkfz.** logos are visible at the top.
- GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION** logo is also present.
- The viewing window shows an axial plane at $z = 140$ [mm].
- The image displays a cross-section of a patient's head and neck, with various structures outlined in different colors (e.g., brain, parotid glands, target areas).
- A color scale on the right indicates Hounsfield Units, ranging from 0 to 60.
- Viewer options on the right include 'CT (HU)', 'Window: Breast', 'Window Center: 1.27', 'Window Width: 2.53', 'Range: 0.00324 2.531', 'bone', 'Dose opacity: 1', and 'Structure Visibility' (listing various anatomical structures like BRAIN_STEM, CEREBELLUM, etc.).
- Info at the bottom right shows 'v3.0.0' and 'github.com/e0404/mat'.

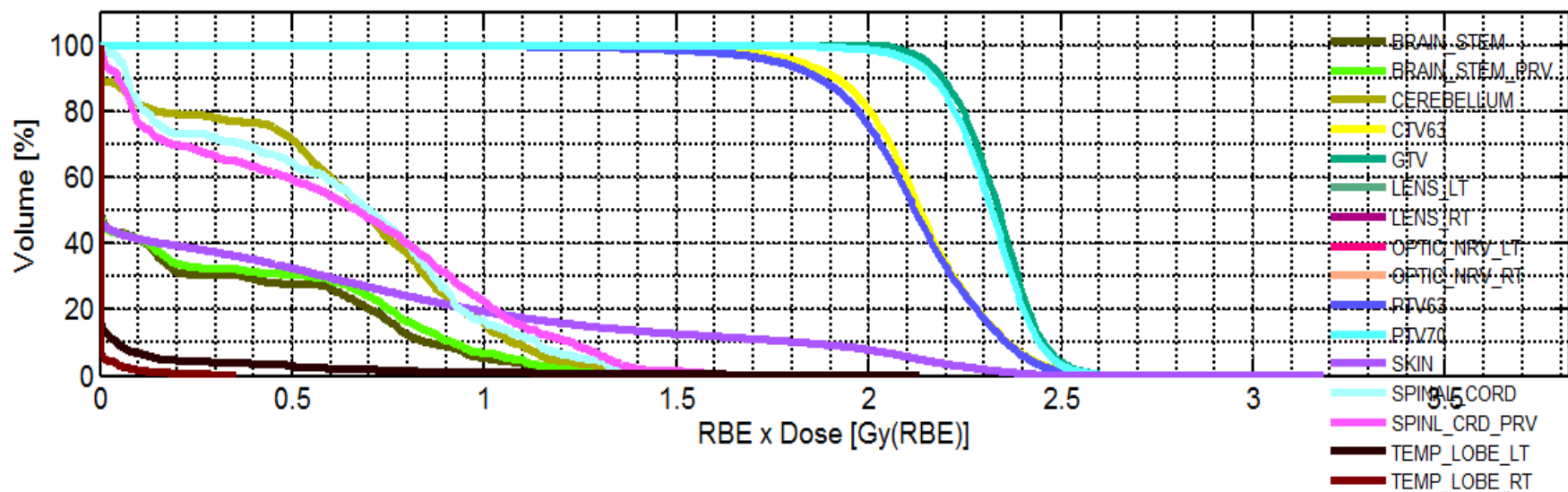
	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1	PAROTID_LT	OAR	1	square overdosing	100	25	NaN	NaN
2	PAROTID_RT	OAR	1	square overdosing	100	25	NaN	NaN
3	PTV63	TARGET	2	square deviation	1000	63	NaN	NaN
4	PTV70	TARGET	1	square deviation	1000	70	NaN	NaN

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

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

- Workflow:** Contains buttons for Refresh, Load *.mat data, Calc. influence Mx, Optimize, Save to GUI, Load DICOM, Recalc, Export, and Import dose. A red arrow points to the "Save to GUI" button.
- Status:** Indicates "plan is optimized".
- Plan:** Shows parameters for biixel width (10 mm), Gantry Angle (90, 180, 270 degrees), Couch Angle (0, 0, 0 degrees), Radiation Mode (protons), Machine (Generic), IsoCenter (250.4, 205.3, 138.5 mm), # Fractions (30), and Type of optimization (const_RBExD). It also includes options for MC dose calculations, 3D conformal, Run Sequencing, Stratification Levels (7), and Run Direct Aperture Optimizat...
- Objectives & constraints:** A table listing VOI names, types, priorities, objectives, penalties, doses, EUD values, and volumes.

	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:** Includes controls for Slice, Beam, Offset, Type of plot (intensity), Plane (axial), Dislay option (RBExDose), and a "Show DVH/QI" button with a red arrow pointing to it. There are also checkboxes for plot CT, plot contour, plot isolines, plot dose, plot isolines labels, plot iso center, and visualize plan / be...
- Viewing:** Shows an axial plane at z = 140 mm. The visualization displays the dose distribution (RBExDose) in Gy(RBE) on a color scale from 0 to 60. The x and y axes range from 50 to 450 mm.
- Viewer Options:** Includes "Set IsoDose Levels", "Result (i.e. dose)", "Window Center" (1.59), "Window Width" (3.19), "Range" (0 to 3.186), "jet" color map, and "Dose opacity" (1).
- Structure Visibility:** A list of anatomical structures with checkboxes for visibility: BRAIN_STEM, BRAIN_STEM_PR, CEREBELLUM, CHIASMA, CTV63, GTV, LARYNX, LENS_LT, LENS_RT, LIPS, OPTIC_NRV_LT, and OPTIC_NRV_RT.
- Info:** Shows version v3.0.0 and the GitHub repository link github.com/e0404/mat.



	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“.

Workflow

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

Status: ready for dose calculation

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 Set Tissue

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

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 Dislay option RBExDose Show DVH/QI

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 = 140 [mm]

min 0
 max 3.186

Set IsoDose Levels

Viewer Options

Result (i.e. dose) Window Precept 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



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 Run Direct Aperture Optimizat...

IsoCenter in [mm] 260 220 150 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

save

Visualization

Slice Type of plot inten... GoTo lateral

Beam Plane axial Open 3D-View

Offset Disolv option physicalDose

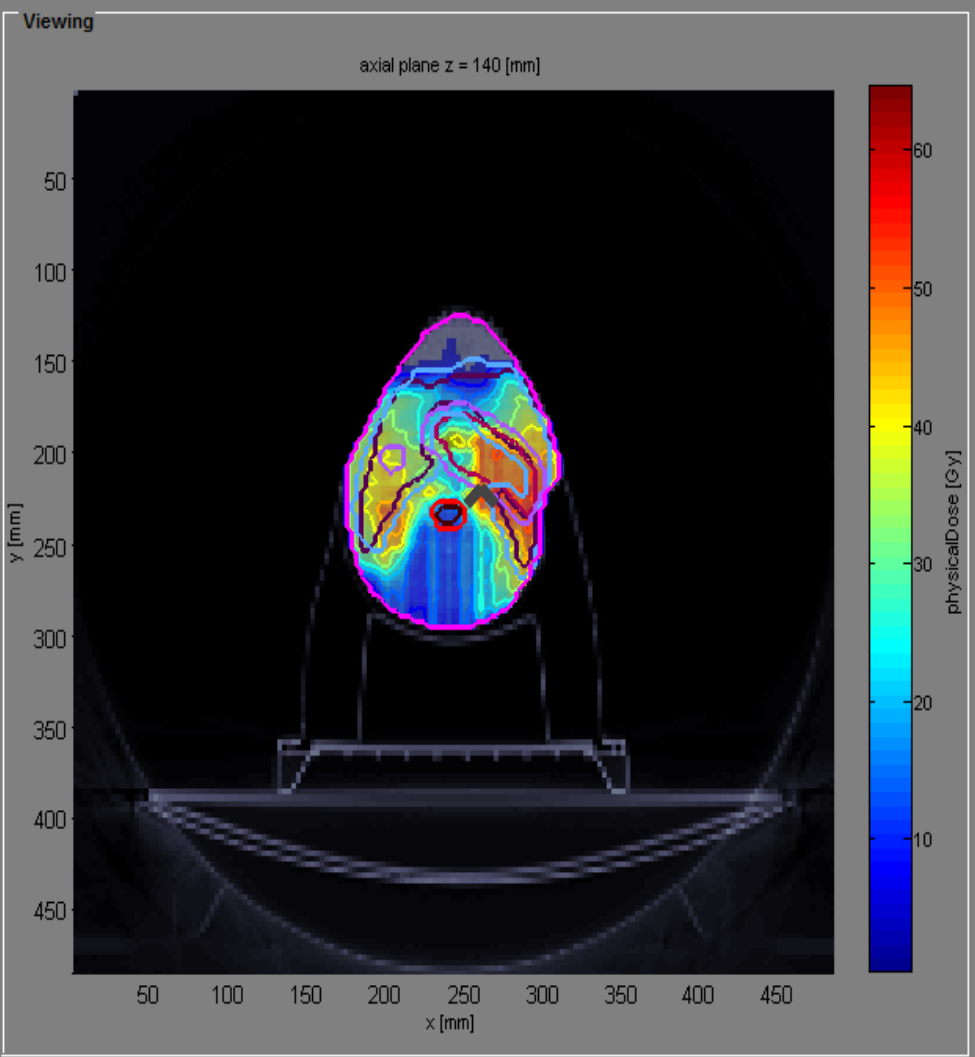
Show DVH/Q!

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

matRad

dkfz.

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min 0

max 3.186

Set IsoDose Levels

Viewer Options

Result (i.e. 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

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 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 Run Direct Aperture Optimizat...
 IsoCenter in [mm] 260 220 150 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 inten... GoTo lateral plot CT
 Beam Plane 1 axial Open 3D-View plot contour
 Offset Dislay option physicalDose plot isolines
 Show DVH/QI plot dose labels
 plot iso center
 visualize plan / be...

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 150 [mm]

min 0 max 3.186

Set IsoDose Levels

Viewer Options

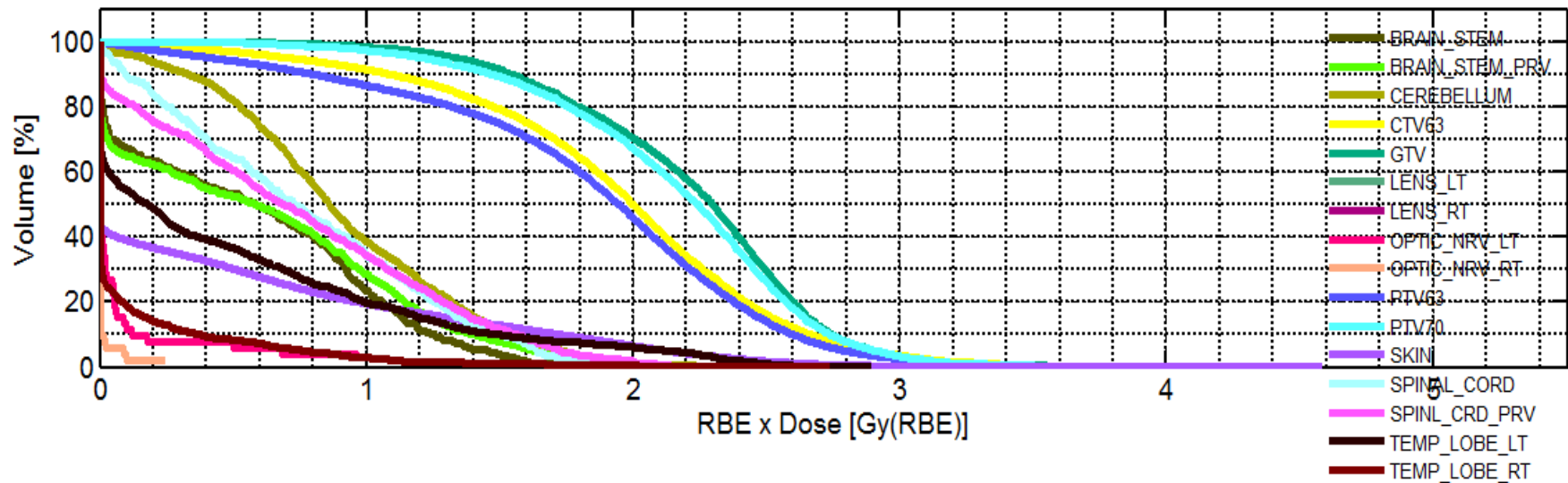
Result (i.e. dose) Window Doseat Custom
 Window Center: 1.59
 Window Width: 3.19
 Range: 0 3.186
 jet Dose opacity: 1

Structure Visibility

- BRAIN_STEM
- BRAIN_STEM_PR
- CEREBELLUM
- CHIASMA
- 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_0.9Gy	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 :)