

PARTICLE THERAPY MASTERCLASS 2024

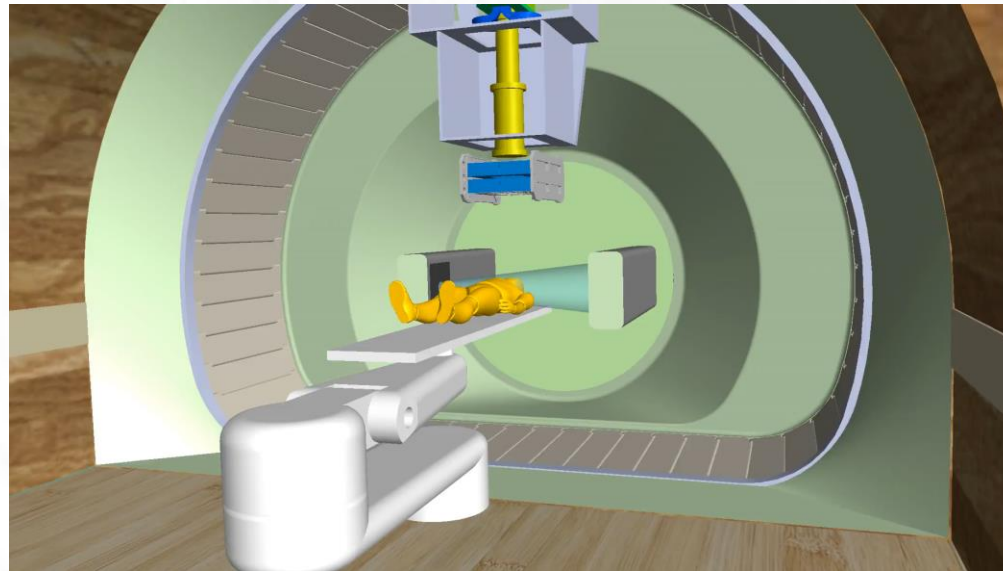
Session pratique avec le logiciel matRad

Instructions détaillés étape par étape

Luca Garolfi

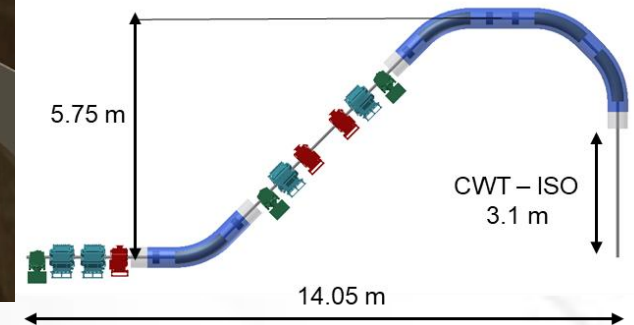
Gantries

Salle de traitement



Courtesy L. Piacentini (CERN, RTU),
E. Felcini, M. Pullia (CNAO)

4 aimants, rotation a 45° , 360°

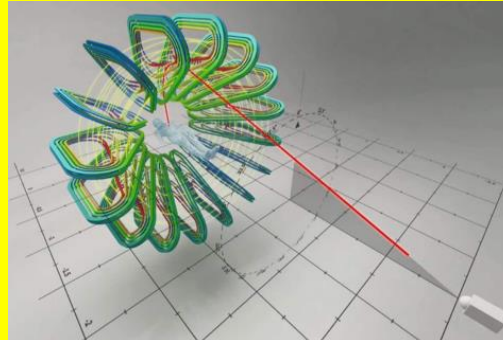


Développement d'un gantry Supra-conducteur rotatif pour les ions carbone :

- CERN-INFN-CNAO-MedAustron: aimants, dose delivery, range verification, systeme de scanning
- HITRIplus projet EU (CNAO, RTU, SEEIIST, CERN: design de l'optique et de la mécanique

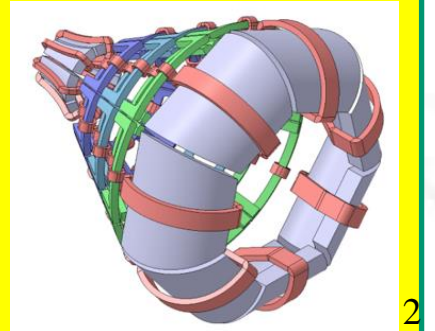
Développement d'un gantry toroidal (Gatoroid) au CERN.

- Etude des différentes versions pour proton and ion carbone.
- concentré sur une version non-supra pour électrons à tester avec des protons a faible énergie



Version VHEE du Gatoroid gantry, basée sur des aimants non-supra. Capabilité de la thérapie FLASH avec des traitements multidirectionnels. Design su CERN.

(image courtesy T. Lehtinen, L. Bottura)



1^{er} Exercice

- **Premiers pas sur le fantôme TG119**
- **Traitement par radiothérapie:**
 - **photons vs. protons vs. ions de carbone**
- **Analyser et comparer les résultats**

L'interface Graphique matRad

The screenshot displays the matRadGUI software interface. The title bar reads "matRadGUI". The main window features the "matRad" logo and the "dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION" branding.

Opérations (Operations): A row of buttons includes "Rafraîchir", "Charger donnée *.mat" (annotated with a red box and number 1), "Calc. matrice influence" (annotated with a red box and number 2), "Optimiser" (annotated with a red box and number 3), and "Sauvegarder figures" (annotated with a red box and number 4). Below these is a "Recalculer" button. The status below reads "Status: Aucune donnée".

Plan (Plan): Configuration parameters include:

- Largeur pixel [mm]: 5
- Angle de la gantry [°]: 0
- Angle du lit [°]: 0
- Type de particules: photons
- Machine: Generic
- IsoCentre [mm]: 0 0 0 (with an "Auto." checkbox)
- Fractions de dose [#]: 30
- Type d'optimisation: none (with a "Set Tissue" button)

Objectifs & contraintes (Objectives & constraints): This section is currently empty.

Visualisation (Visualization): Includes a "Tranche" slider, "Type de figure" dropdown (set to "intensi..."), "GoT" dropdown (set to "lateral"), and "Plan" dropdown (set to "axial"). There is an "Open 3D-View" button and an "Option d'affichage" dropdown (set to "no option avail..."). A "Show DVH!..." button is annotated with a red box and number 5. A list of visualization options with radio buttons includes:

- Tracer CT
- Tracer contour
- Tracer isolignes
- Tracer dose
- Label des isolignes
- isocentre
- Plan de visualisation (circled in red)

Affichage (Display): A large empty plot area with axes ranging from 0 to 1. The y-axis is labeled "Affichage".

Viewer Options (Viewer Options): Includes "Set IsoDose Lev...", "None" dropdown, "Window Center" (0.5), "Window Width" (1.0), "Range" (0 1), "bone" dropdown, "Lock Settings" checkbox, and "Dose opacity" (0 1).

Structure Visibility (Structure Visibility): Shows "no data loaded".

Info (Info): Displays "v3.0.0 - edu" and "aithub.com/e0404/mat".

The Windows taskbar at the bottom shows the system tray with the date "26/02/2021" and time "09:03".

1. Charger le fantôme TG119 via le bouton Load *.mat data (TG119.mat)

The screenshot displays a software interface with several panels and a central file selection dialog box.

Workflow Panel: Contains buttons for 'Refresh', 'Load *.mat data' (highlighted with a red arrow), 'Load *.COM', and 'Import from Bin...'. The status indicates 'no data loaded'.

Plan Panel: Includes settings for 'bixel width in [mm]' (5), 'Gantry Angle in °' (0), 'Couch Angle in °' (0), 'Radiation Mode' (photons), 'Machine' (Generic), 'IsoCenter in [mm]' (0 0 0), '# Fractions' (30), and 'Type of optimization' (none).

Objectives & constraints Panel: Features a table with columns 'VOI name', 'VOI type', 'priority', and 'obj. / const.'. The table is currently empty.

Visualization Panel: Includes 'Slice' and 'Beam' controls, 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (no option avail...). It also has checkboxes for 'plot CT', 'plot contour', 'plot isolines', 'plot dose', 'plot isolines labels', 'plot iso center', and 'visualize plan / be...'. A 'GoTo lateral' and 'Open 3D-View' button are also present.

Select File to Open Dialog: Shows the file path 'e0404-matRad-2.1... > e0404-matRad-2957fcc'. The file list includes folders like 'standalone', 'tools', 'unitTest', 'vmc++' and MAT files such as 'BOXPHANTOM', 'carbon_Generic', 'HEAD_AND_NECK', 'LIVER', 'photons_Generic', 'PROSTATE', 'protons_Generic', and 'TG119' (highlighted with a red arrow). The file name field contains 'TG119' and the file type is 'MAT-files (*.mat)'. The 'Open' button is visible.

Right Panel: Contains 'min max' controls, 'Set IsoDose Levels', 'Viewer Options' (None), 'Window Center' (0.5), 'Window Width' (1.0), 'Range' (0 1), 'bone' material selection, 'Dose opacity' (0 1), 'Structure Visibility' (no data loaded), and 'Info' (v3.0.0, github.com/e0404/mat, About button).

2. Analyse des contraintes et des objectives

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...

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 165 [mm]

min 1000 max 1040.

Viewer Options

CT (HU)
 Window: Default 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

Objectives et contraintes

	VOI name	VOI type	priority	obj. / const.	penalty	dose	UD	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

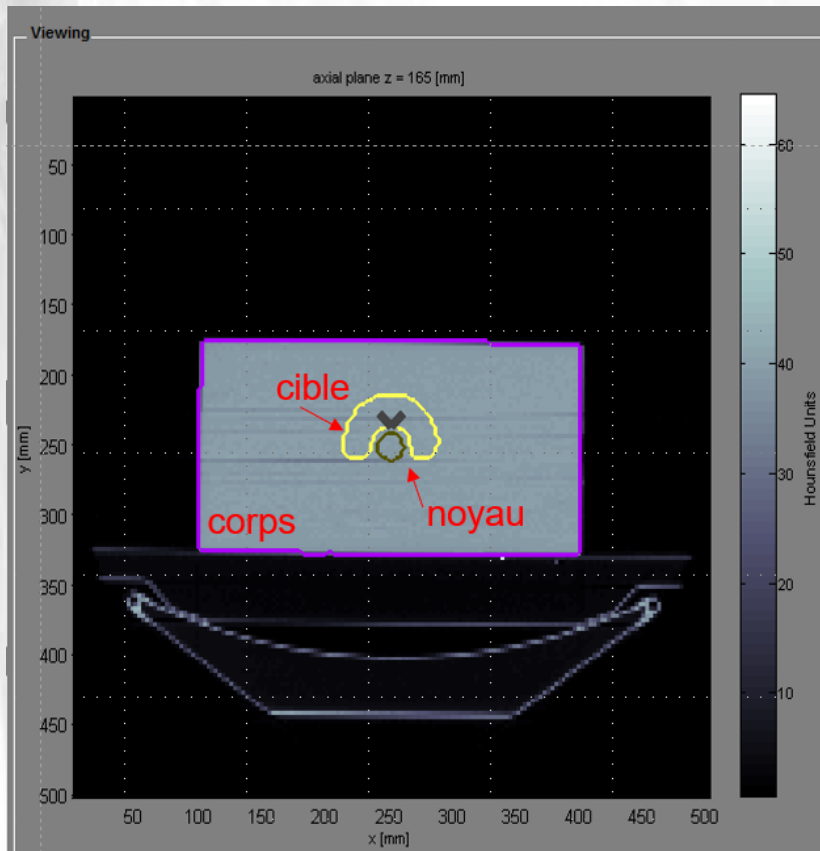
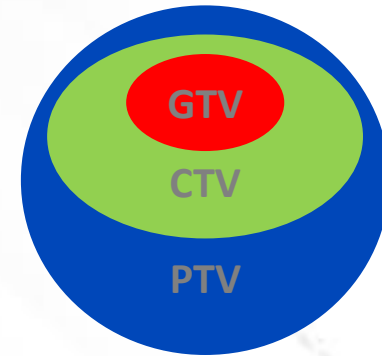
Slice Type of plot inten... GoTo lateral
 plot CT
 plot contour
 plot isolines
 plot dose
 plot isolines labels
 plot iso center
 visualize plan / be...

Beam Plane axial
 Selection Dislay option no option avail...
 Offset

Concept à retenir

	VOI name	VOI type	priority	obj. / const.	penalty	dose
1	Core	OAR	2	square overdosing	300	25
2	OuterTarget	TARGET	1	square deviation	1000	50
3	BODY	OAR	3	square overdosing	100	30

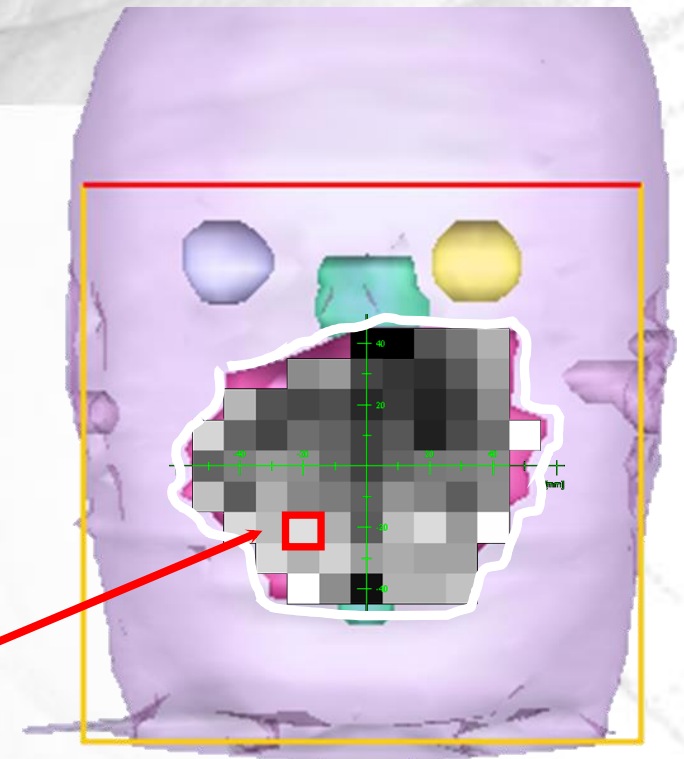
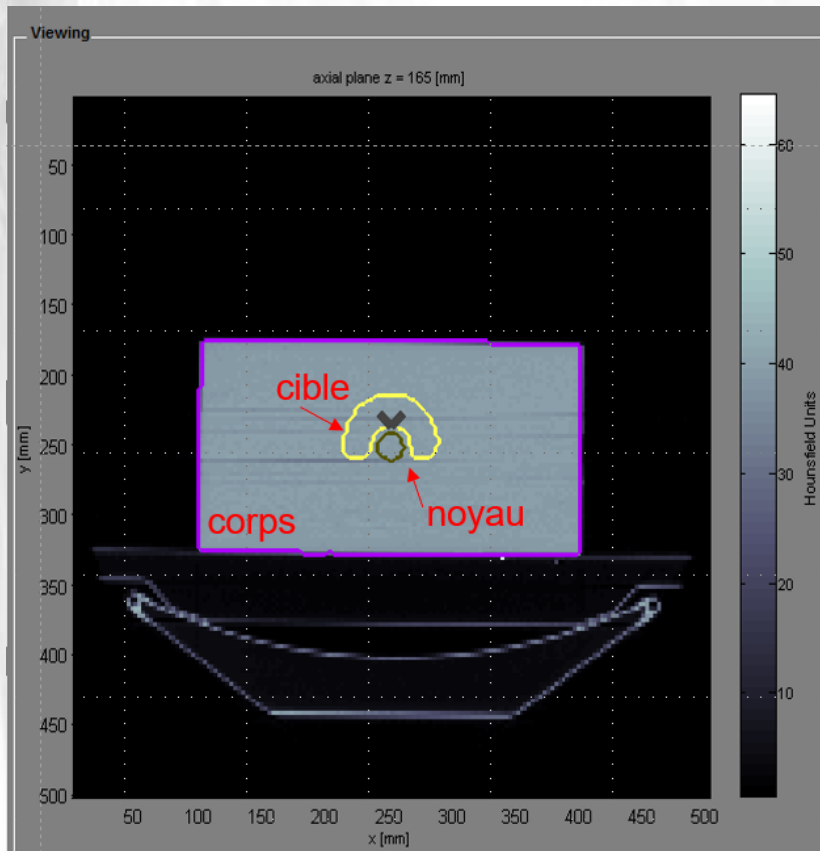
- **VOI:** volume d'intérêt
- **OAR:** organ at risk = organe à risque
- **TARGET** = cible



- **Gross Tumour Volume (GTV) =**
Volume tumoral visible sur les images
- **Clinical Target Volume (CTV) =**
Le volume du tissu, y compris la GTV et les régions où le tissu tumoral invisible est attendu
- **Planning Target Volume (PTV) =**
Comprend la GTV et la CTV ainsi qu'une marge de sécurité pour tenir compte des incertitudes.

Concept à retenir

	VOI name	VOI type	priority	obj. / const.	penalty	dose
1	Core	OAR	2	square overdosing	300	25
2	OuterTarget	TARGET	1	square deviation	1000	50
3	BODY	OAR	3	square overdosing	100	30



Bixel j

- **Dose absorbée** : énergie ionisante absorbée par unité de masse. Elle est mesurée en Gray (1 J/kg = 1 Gy)
- **Modulation d'intensité pour les photons avec pencil beams**
 "Pencil beams" forment un « pixel » dans la section transversale du faisceau (ou "fluence")
 = "bixel" (**B**eam + **P**ixel)
 Nous pondérons tous les pencil beams (plus/moins de photons) différemment
- **RBE : Efficacité biologique relative.** Facteur qui compare l'efficacité biologique (les dommages biologiques causés par) un type de rayonnement ionisant (p. ex., le rayonnement des particules) à l'efficacité biologique d'un rayonnement de référence (p. ex., le rayonnement de photons)

3. Régler la modalité de rayonnement sur Photons et définir un angle de faisceau (angle du gantry)

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 Set Tissue

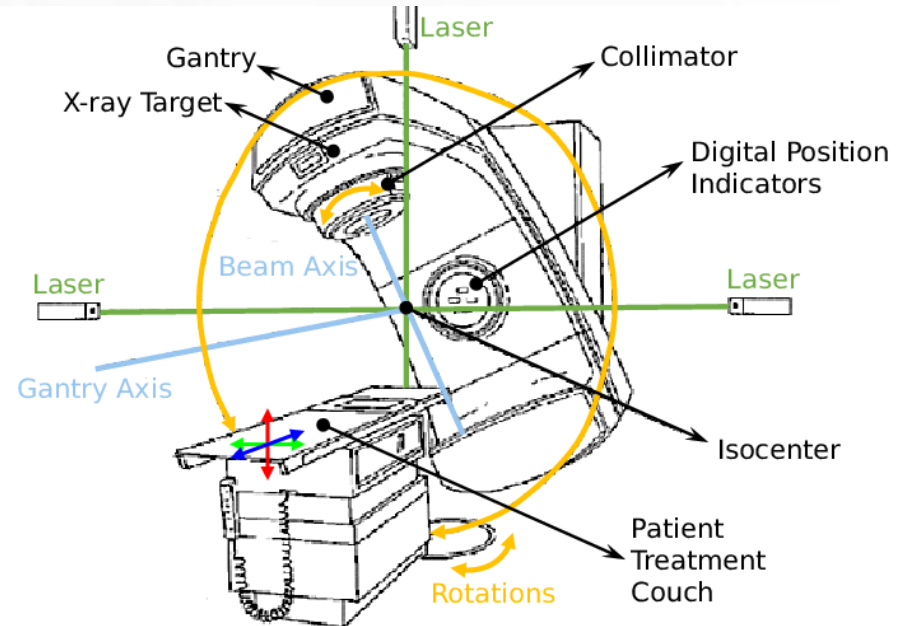
Objectives & constraints

	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Core	OAR	2	square overdosing	300	25	NaN	NaN	+
2	OuterTarget	TARGET	1	square deviation	1000	50	NaN	NaN	-
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	

Visualization

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

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



- **Photons** : sans masse, sans charge électrique et voyage toujours à la vitesse de la lumière
 - pas d'accélération, mais d'énergie dépendante de la fréquence
 - Comment générer? Nous pouvons accélérer les électrons!
 - les électrons accélérés touchent une cible
 - les électrons perdent de l'énergie en raison de « bremsstrahlung »
 - photons de haute énergie
- **gantry** : déplace la source de rayonnement autour du patient
- **lit** : fait pivoter le patient



4. Déclencher le calcul de la dose via le bouton (« Calc. Influence Mx ») et lancer l'optimisation inverse en cliquant sur (« Optimize »)

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', '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:** A configuration panel with various parameters:
 - 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 (with 'Auto.' checked)
 - # Fractions: 30
 - Type of optimization: none
 - Options: 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', 'Stratification Levels: 7', 'Run Direct Aperture Optimizat...'
- Objectives & constraints:** A table defining optimization goals:

	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:** Controls for the viewing window, including 'Slice', 'Beam', 'Offset', 'Type of plot', 'Plane', 'Dislay option', and 'Show DVH/QI'.
- Viewing:** A central window showing an axial CT scan at z = 165 [mm]. The x and y axes range from 50 to 500 mm. A purple rectangular region is overlaid on the scan, and a yellow contour is visible within it. A color scale on the right indicates Hounsfield Units from 10 to 60.
- Viewer Options:** Settings for the viewing window, including 'Window Center: 0.85', 'Window Width: 1.67', 'Range: 0.02671 1.692', and 'Structure Visibility' (Core, OuterTarget, BODY).
- Info:** Version information: v3.0.0, github.com/e0404/mat, and an 'About' button.

5. Analyser la distribution de dose résultante

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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 ° 0 3D conformal

Couch Angle in ° 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

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 plot CT

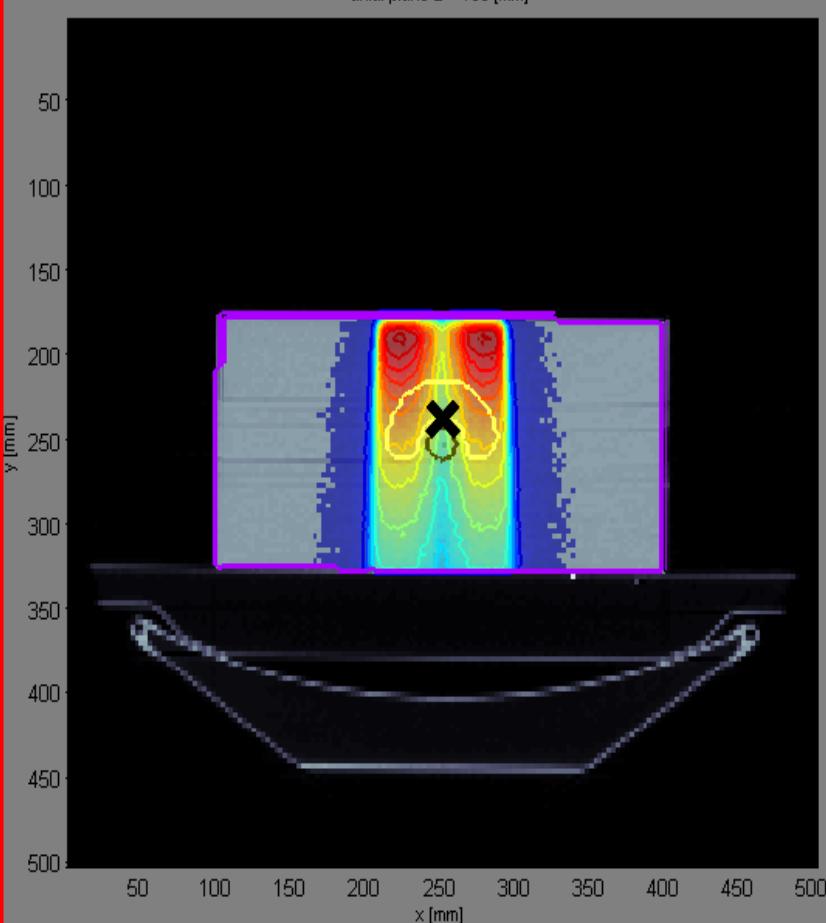
Beam Plane axial plot contour

Offset Dislay option physicalDose plot isolines

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

Viewing

axial plane z = 165 [mm]



min max n 2.342

Viewer Options

Result (i.e. dose) Window Preset Custom Window Center: 1.17 Window Width: 2.34 Range: 0 2.342 jet Dose opacity: 1

Structure Visibility

- Core
- OuterTarget
- BODY

Info

v3.0.0
github.com/e0404/mat

6. Enregistrer le résultat de l'optimisation via (« Save to GUI ») Ensuite, afficher le DVH par (« Show DVH/QI »)

The screenshot displays the matRad software interface. The top left contains a 'Workflow' panel 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 features 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 includes 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. A color scale on the right indicates 'physicalDose [Gy]' from 0 to 60. The 'Viewer Options' panel on the right includes 'Set IsoDose Levels', 'Viewer Options' (Result, Window, Window Center, Window Width, Range, jet, Dose opacity), 'Structure Visibility' (Core, OuterTarget, BODY), and '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 ° 0 3D conformal
Couch Angle in ° 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	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 plot CT
Beam Plane axial Open 3D-View plot contour
Selection Dislay option physicalDose plot isolines
Offset plot dose
Show DVH/QI plot isolines labels
visualize plan / be... 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 Default
Custom Window Center: 1.17
Window Width: 2.34
Range: 0 2.342
jet Dose opacity: 1

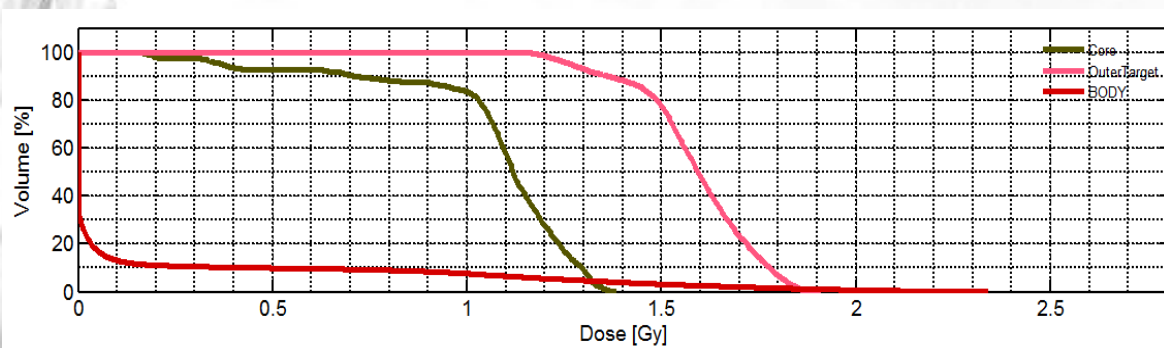
Structure Visibility

Core OuterTarget BODY

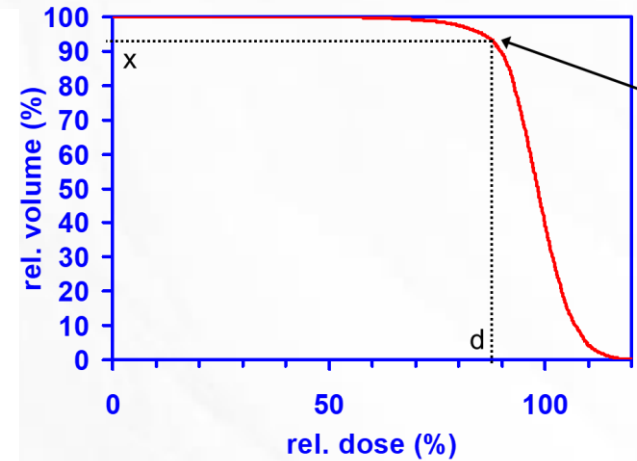
Info v3.0.0
github.com/e0404/mat About

Concept à retenir

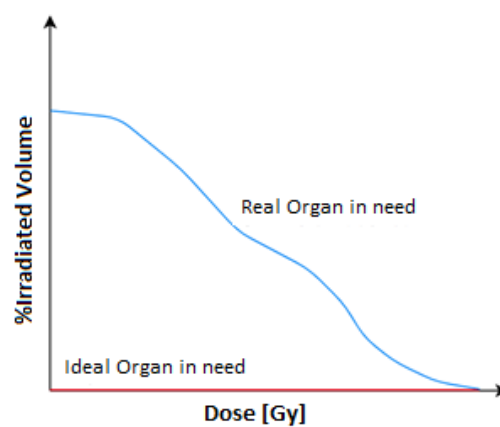
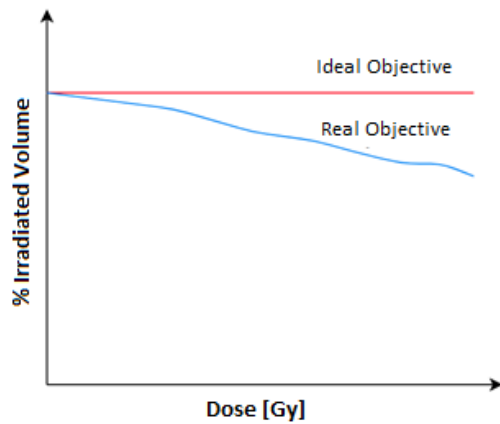
- Show DVH/QI: Histogram dose-volume



	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_...
Core	1.0665	0.2554	1.3860	0.1329	1.3434	1.3167	1.1183	0.3706	0.1988	1	0.9341	0.8727	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	
BODY	0.1443	0.4168	2.3420	0	1.7203	1.2694	0	0	0	1	0.1019	0.0846	0.0393	



x% du volume atteint au moins d% de la dose prescrite



DANS LE CAS IDÉAL, SEULE LA TUMEUR EST IRRADIÉE SANS AFFECTER LES AUTRES TISSUS (SAINS).

7. Remplacer la modalité de rayonnement par : Protons laisser les angles du faisceau inchangés.

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] use MC (VMC++) dose calculations
 Gantry Angle in ° 3D conformal
 Couch Angle in ° Run Sequencing
 Radiation Mode **photons** Stratification Levels
 Machine **photons** Run Direct Aperture Optimizat...
 IsoCenter in [mm] **protons**
 # Fractions **carbon**
 Type of optimization **none**

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

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axial plane z = 165 [mm]

min 0
max 2.342

Viewer Options

Result (i.e. dose) **Window Dose**
 Window Doseat **Custom**
 Window Center:
 Window Width:
 Range:
 jet
 Dose opacity:

Structure Visibility

Core
 OuterTarget
 BODY

Info

v3.0.0
github.com/e0404/mat

8. Déclencher le calcul de la dose via le bouton (« Calc. Influence Mx ») et lancer l'optimisation inverse en cliquant sur (« Optimize »)

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

- Workflow:** Contains buttons for 'Refresh', 'Load *.mat data', 'Calc. influence Mx' (indicated by a red arrow and the number 1), 'Optimize' (indicated by a red arrow and the number 2), 'Save to GUI', 'Load DICOM', 'Finalize', 'Export', 'Import from Bin...', and 'Import Dose'. The status below these buttons reads 'Status: ready for optimization'.
- Plan:** Contains various parameters for the treatment plan, including '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), '# Fractions' (30), and 'Type of optimization' (const_RBExD). 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 listing the objectives and constraints for the plan.
- Visualization:** Contains controls for the visualization of the plan, including 'Slice', 'Beam', 'Offset', 'Type of plot' (intentional), 'Plane' (axial), 'Dislay option' (physicalDose), and 'Show DVH/QI'. There are also checkboxes for 'plot CT', 'plot contour', 'plot isolines', 'plot dose', 'plot isolines labels', 'plot iso center', and 'visualize plan / be...'. A 'GoTo lateral' and 'Open 3D-View' button are also present.

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

- Viewing:** 'axial plane z = 165 [mm]'
- Y-axis:** 'y [mm]' ranging from 50 to 500.
- X-axis:** 'x [mm]' ranging from 50 to 500.
- Color Scale:** 'physicalDose [Gy]' ranging from 0 to 60.
- Structure Visibility:** A list of structures with checkboxes: 'Core' (checked), 'OuterTarget' (checked), and 'BODY' (checked).
- Info:** 'v3.0.0' and '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

9. Enregistrer le résultat de l'optimisation via (« Save to GUI ») Ensuite, afficher le DVH par (« Show DVH/QI »)

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

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	-

save

Visualization

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

Beam Plane axial Open 3D-View plot contour

Offset Dislay option RBExDose plot isolines

plot dose

plot isolines labels

plot iso center

Show DVH/QI **2**

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min 0 max 2.710

Set IsoDose Levels

Viewer Options

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

Window Center: 1.11

Window Width: 2.21

Range: 0 2.21

jet Dose opacity: 1

Structure Visibility

- Core
- OuterTarget
- BODY

Info

v3.0.0

github.com/e0404/mat

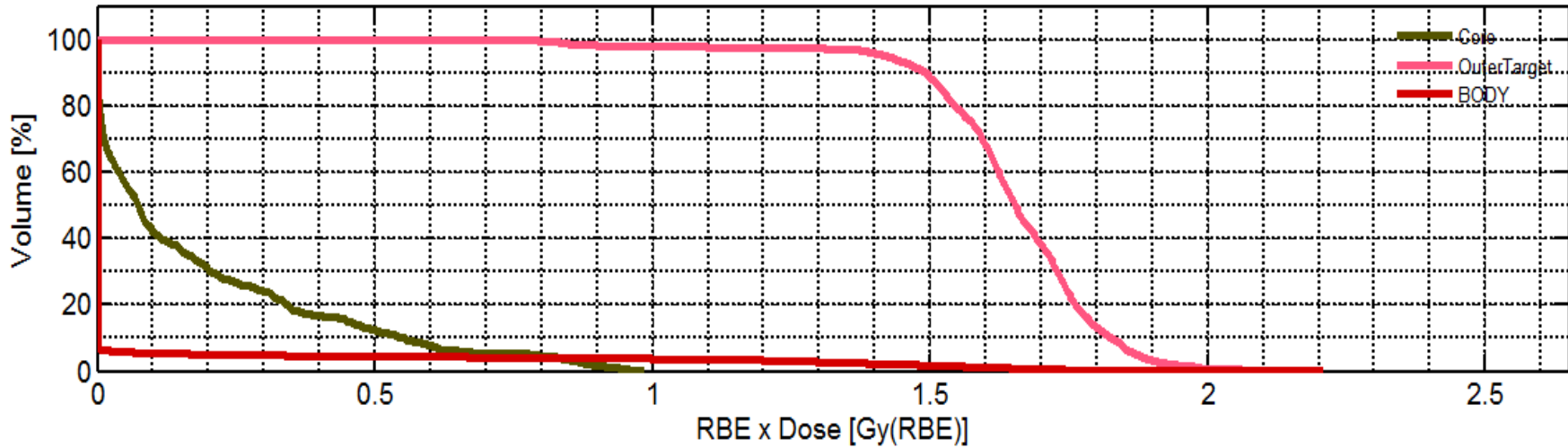
About

Viewing

axial plane z = 165 [mm]

y [mm] x [mm]

Show DVH/QI



	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_...
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	
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	
BODY	0.0640	0.2912	2.2101	0	1.4572	0.2364	0	0	0	1	0.0462	0.0405	0.0282	

Comparaison des résultats

- doses moyennes pour différent régions (Gy):

Region/Radiation	Photons	Protons
Base	1.0665	0.1815
Cible	1.5852	1.6449
Corps	0.1443	0.0640

- Le treatment par **Photons** délivre la dose la plus élevée à la surface
- Les **Protons** délivrent la dose la plus élevée à la cible (tumeur) et protègent les organes sensibles

C'est tout pour ce matin !

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] use MC (VMC++) dose calculations

Gantry Angle in ° 3D conformal

Couch Angle in ° Run Sequencing

Radiation Mode Stratification Levels Run Direct Aperture Optimizat...

Machine Auto.

IsoCenter in [mm] # Fractions Type of optimization

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 GoTo plot CT

Beam Plane plot contour

Offset Dislay option plot isodose

plot dose plot isodose labels plot iso center

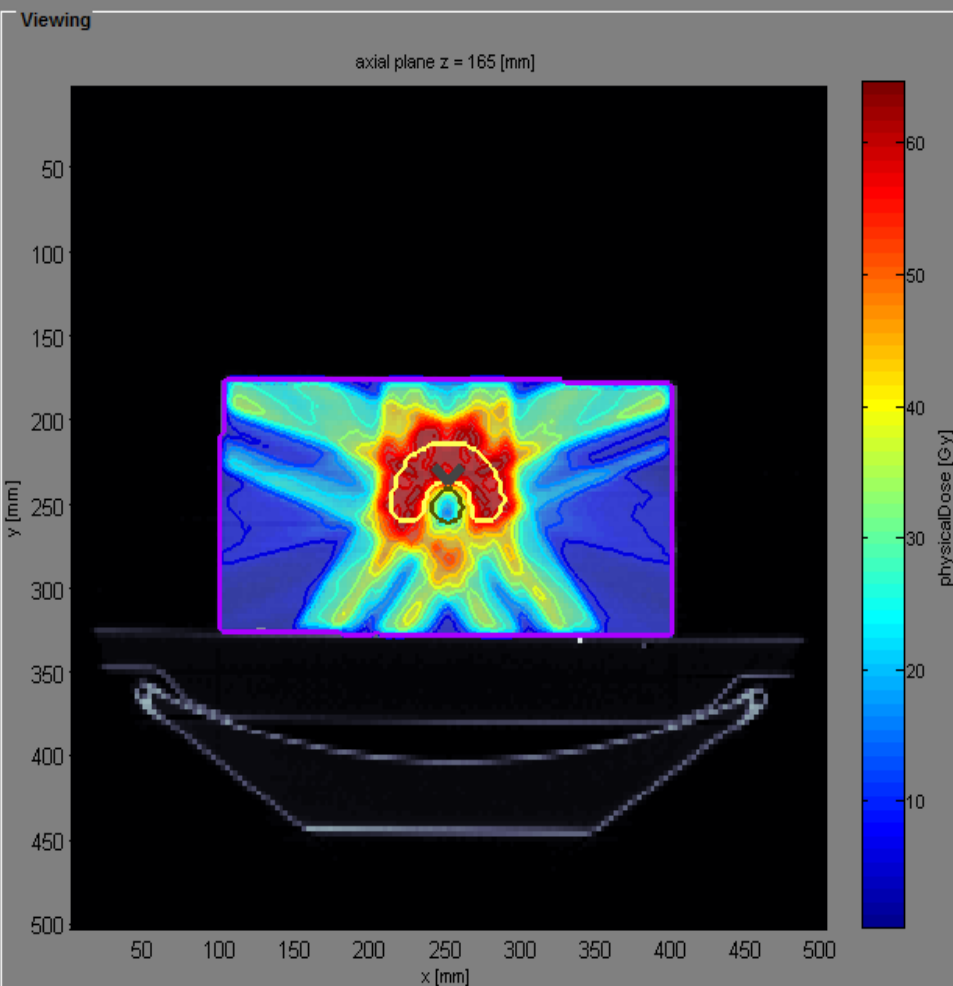
visualize plan / be...

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Viewing

axial plane z = 165 [mm]



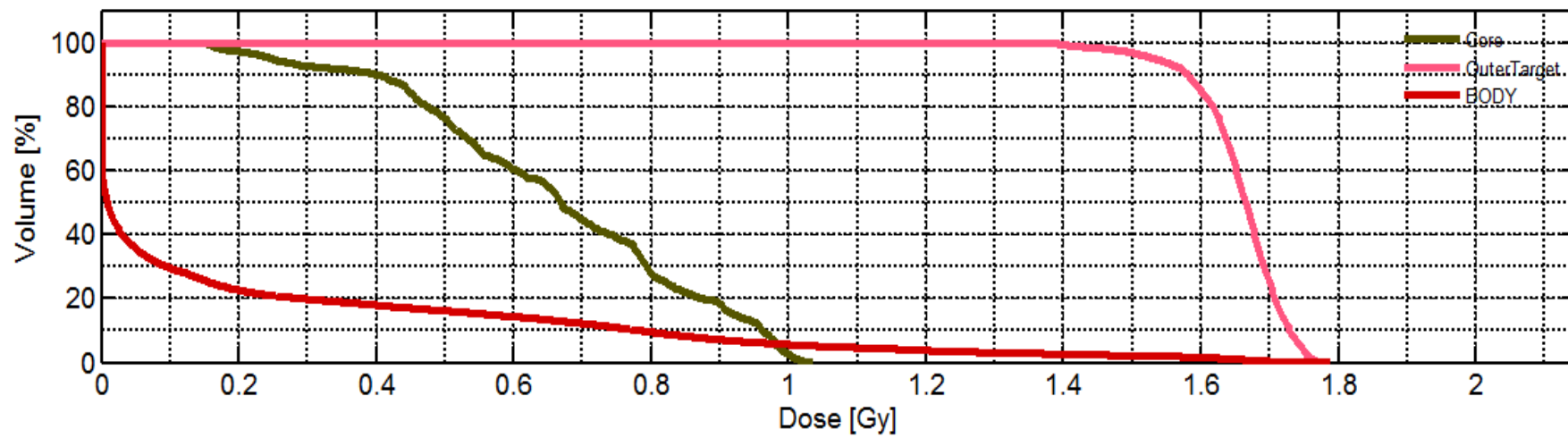
min max n 1.789

Viewer Options

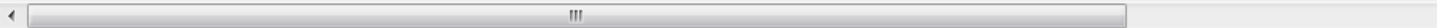
Result (i.e. dose) Window Center: Window Width: Range: jet Dose opacity: Structure Visibility: Core OuterTarget BODY

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 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 Display 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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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

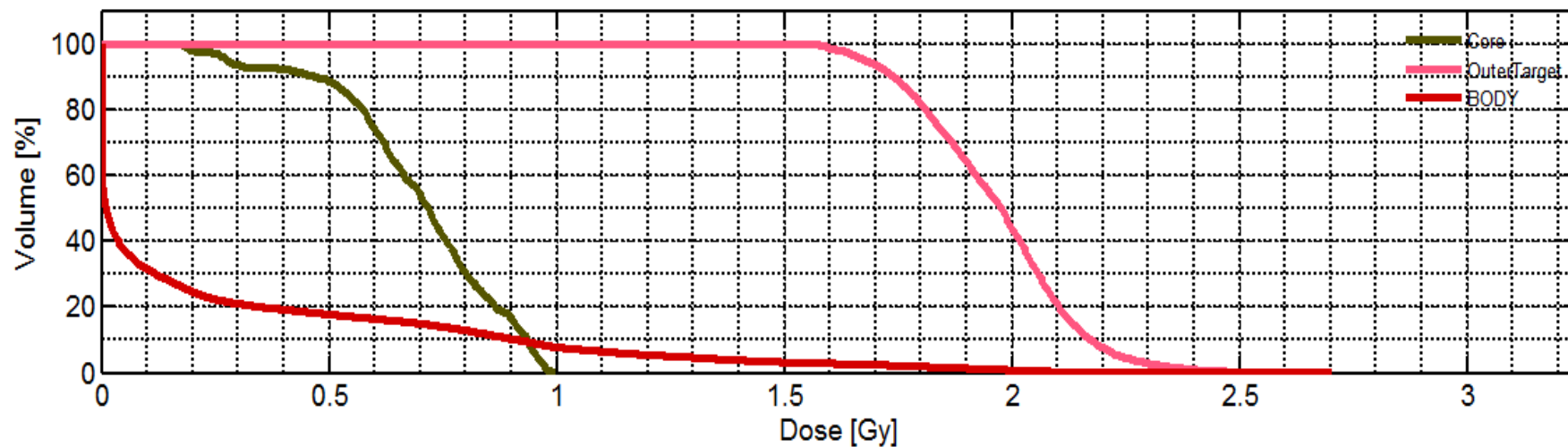
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github.com/e0404/mat
About

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', 'Recalc', 'Export', and 'Import dose'. Red arrows point to 'Calc. influence Mx', 'Optimize', and 'Save to GUI'. The status bar indicates 'plan is optimized'.
- Plan:** Includes parameters for '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), '# 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...', along with 'Stratification Levels' (7) and a 'Set Tissue' button.
- Objectives & constraints:** A table listing 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:** Shows 'Slice' and 'Beam' settings, 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (physicalDose). A 'Show DVH/QI' button is highlighted with a red arrow. Other options include 'GoTo lateral', 'Open 3D-View', and checkboxes for 'plot CT', 'plot contour', 'plot isolines', 'plot dose', 'plot isolines labels', 'plot iso center', and 'visualize plan / be...'. The 'Structure Visibility' panel shows 'Core', 'OuterTarget', and 'BODY' are visible.
- Viewing:** Displays an axial plane at z = 165 [mm]. The plot shows a color-coded dose distribution with a central target area (Core) and surrounding structures. A color scale on the right indicates 'physicalDose [Gy]' from 0 to 60. The axes are labeled 'x [mm]' and 'y [mm]'.
- Right Panel:** Includes 'min max' values (n 2.705), 'Set IsoDose Levels', 'Viewer Options' (Result (i.e. dose), Custom, Window Center: 1.35, Window Width: 2.71, Range: 0 2.705, jet, Dose opacity: 1), and 'Structure Visibility' (Core, OuterTarget, BODY). The 'Info' section shows 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 toolbar contains several buttons, with 'Load *.mat data' highlighted by a red arrow. Below the toolbar, the 'Plan' section shows various parameters such as 'bixel width in [mm]' (20), 'Gantry Angle in °' (0 72 144 216 288), and 'Radiation Mode' (protons). The 'Objectives & constraints' section contains a table with the following data:

	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

The 'Select File to Open' dialog box is open, showing a file list with 'LIVER' selected. 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 'LIVER' file is highlighted with a red arrow. The dialog box also shows the file name 'LIVER' and the file type 'MAT-files (*.mat)'. The background interface shows the 'Workflow' section with buttons like 'Refresh', 'Load *.mat data', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Load *.COM', 'Recalc', 'Export', 'Import Plan Bin...', and 'Import Dose'. The 'Status' is 'plan is optimized'. The 'Visualization' section at the bottom shows options for 'Slice', 'Beam', and 'Offset', along with 'Type of plot' (intensity), 'Plane' (axial), and 'Displav option' (RBExDose). The 'Structure Visibility' section on the right shows 'Core', 'OuterTarget', and 'BODY' checked. The bottom right corner shows the version 'v3.0.0' and the GitHub repository 'github.com/e0404/mat'.

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] 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 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	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 inten... GoTo lateral

Beam Plane axial Open 3D-View

Dislay option physicalDose

Show DVH/QI

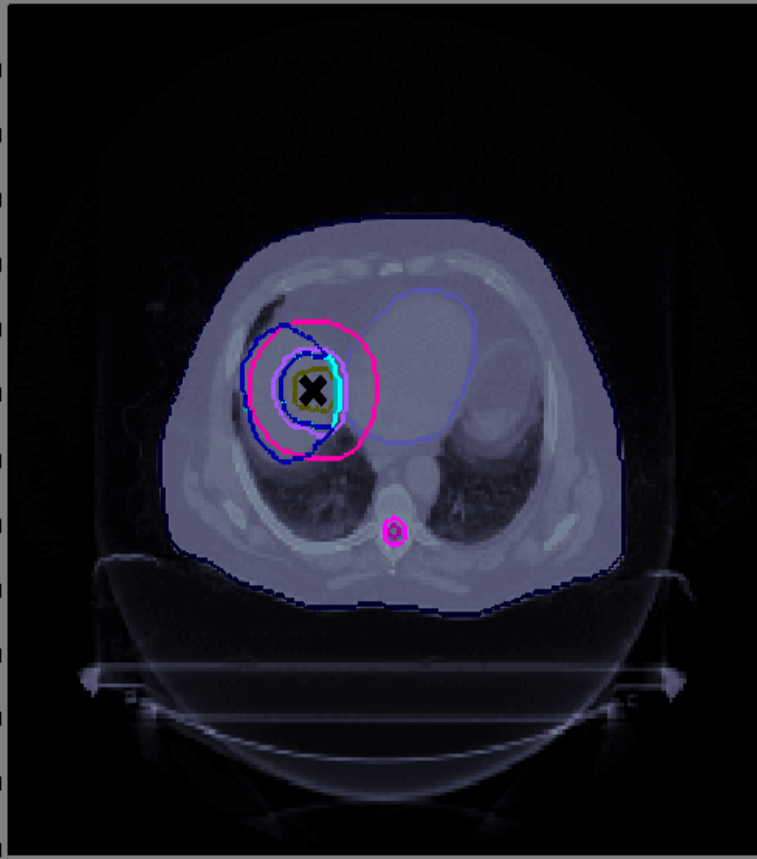
- plot CT
- plot contour
- plot isolines
- plot dose
- plot isolines labels
- plot iso center
- visualize plan / be...

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Viewing

axial plane z = 317.5 [mm]



min 0 max 3.706

Set IsoDose Levels

Viewer Options

Result (i.e. dose) Window Doseat Custom

Window Center: Window Width: 1.85 Range: 0 3.71

jet Dose opacity: 0 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

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 z = 317.5 [mm]. The x and y axes range from 50 to 650 mm. A color scale on the right indicates 'physicalDose [Gy]' from 0 to 60. The 'Structure Visibility' panel on the right lists various organs at risk (OAR) and target volumes (TV) with checkboxes: 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...

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Viewing axial plane z = 317.5 [mm]

min 0 max 1.572

Set IsoDose Levels

Viewer Options

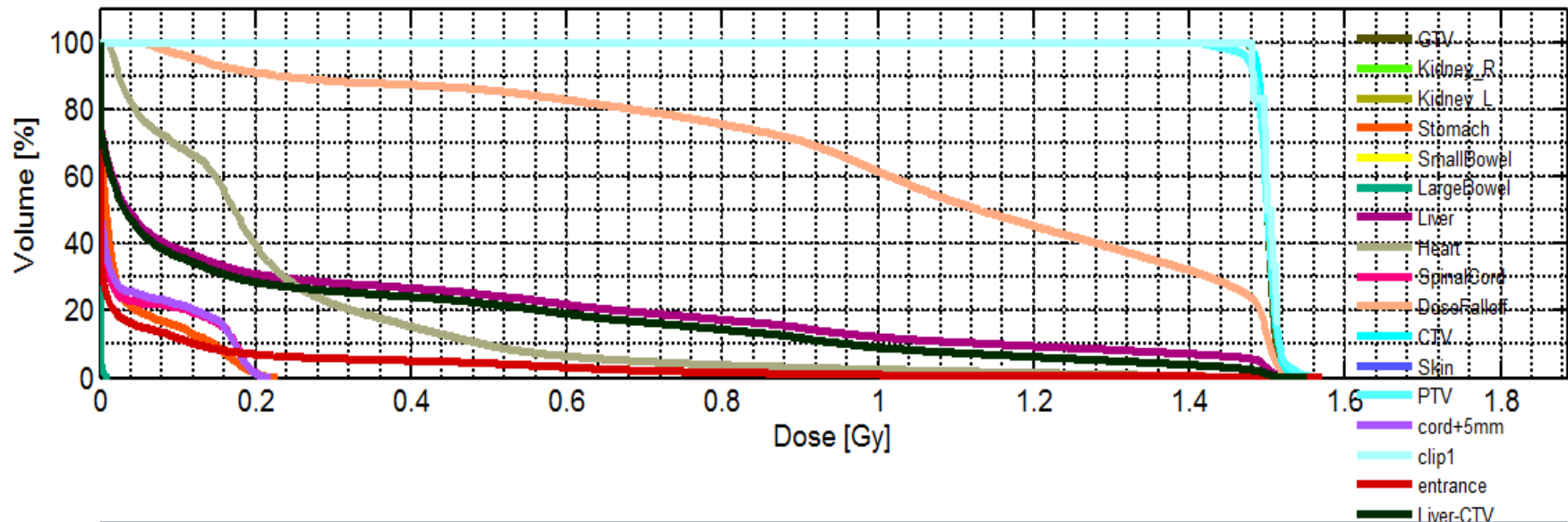
Result (i.e. dose): Window: Custom Window Center: 0.781 Window Width: 1.57 Range: 0 1.572 jet Dose opacity: 1

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



	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	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 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 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	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

axial plane z = 317.5 [mm]

physicalDose [Gy]

min max n
 0 1.572 1

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

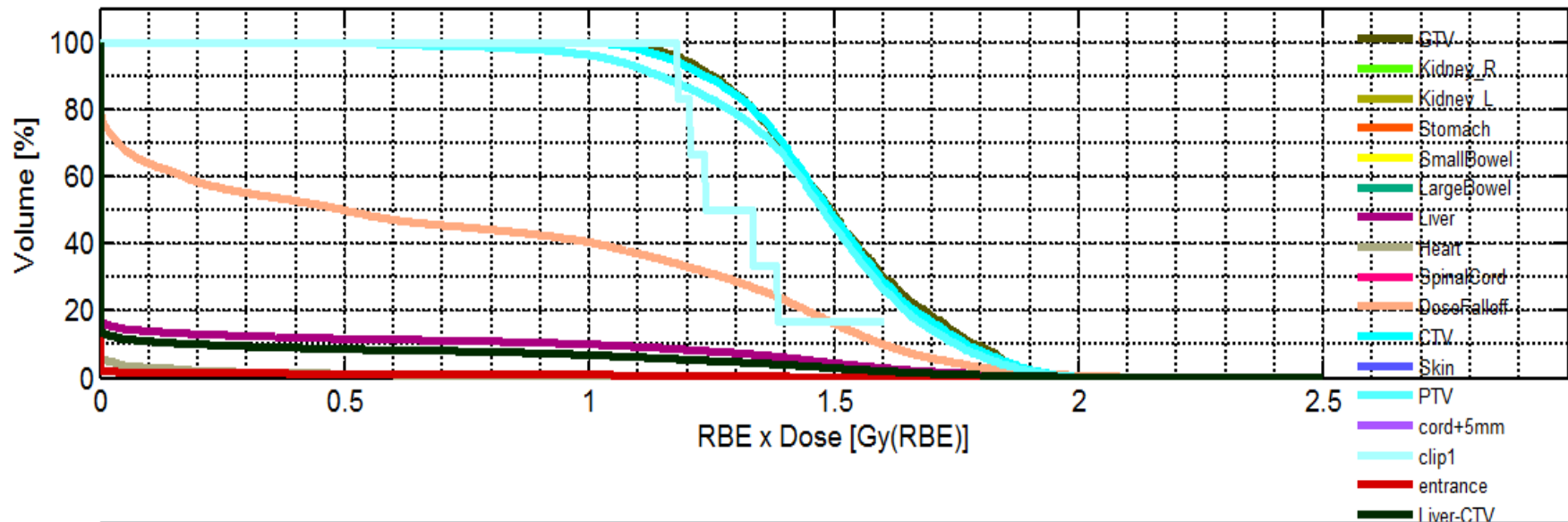
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 About

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, 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 from Bin... The status indicates "plan is optimized" with a count of 1. A red arrow points to the "Save to GUI" button.
- Plan:** Lists various 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). 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 defining the optimization goals:

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:** Controls for "Slice", "Beam", "Offset", "Type of plot" (intensity), "Plane" (axial), and "Dislay option" (RBExDose). It includes "GoTo" (lateral) and "Open 3D-View" buttons. A red arrow points to the "Show DVH/QI" button.
- Viewing:** Shows a 2D axial plane at z = 317.5 [mm]. The plot displays the dose distribution (RBExDose [Gy(RBE)]) with a color scale from 0 to 60. A red arrow points to the "Show DVH/QI" button.
- 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: GTV, Kidney_R, Kidney_L, Stomach, SmallBowel, LargeBowel, Celiac, SMA_SMV, Liver, Heart, SpinalCord, and DoseFalloff.
- Info:** Displays the version "v3.0.0" and the GitHub repository "github.com/e0404/matRad".



	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 use MC (VMC++) dose calculations

Gantry Angle in ° 315 3D conformal

Couch Angle in ° 0 Run Sequencing

Radiation Mode carbon Stratification Levels 7

Machine photons Auto. 1 Run Direct Aperture Optimizat...

IsoCenter in [mm] # Fractions Type of optimization LEMIV_RBExD 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

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

min 0 max 2.501

axial plane z = 317.5 [mm]

Viewer Options

Result (i.e. dose) Window Doseat Custom

Window Center: Window Width: 1.25

Range: 0 2.501

jet Dose opacity: 1

Structure Visibility

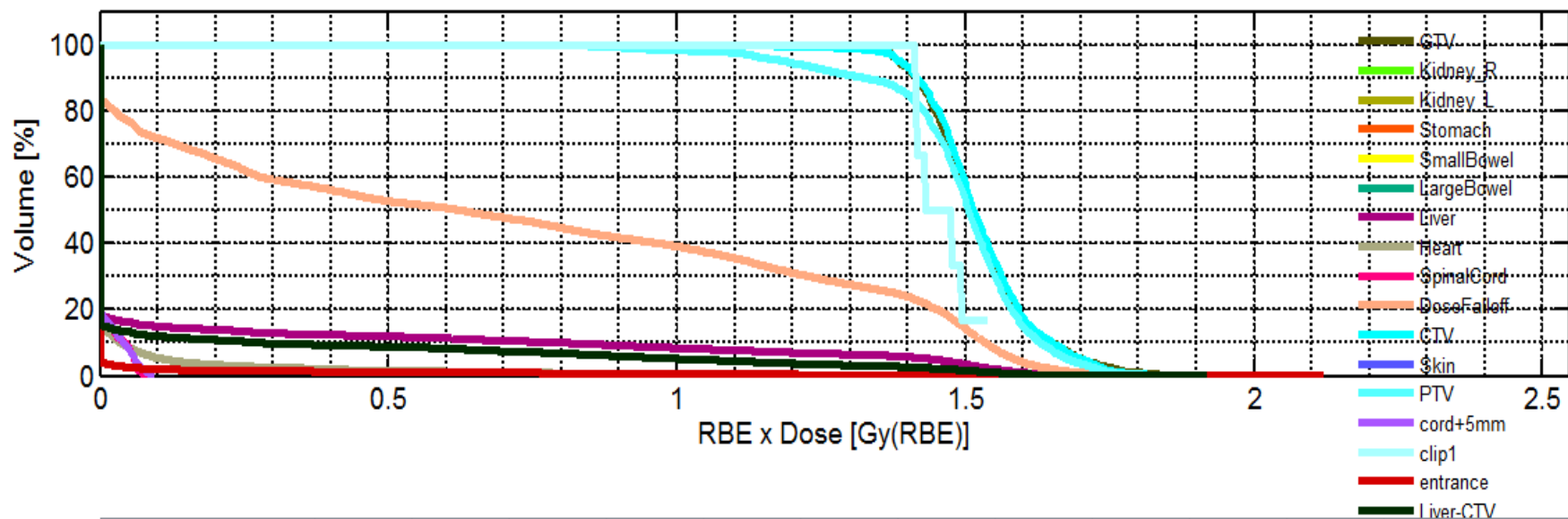
- GTV
- Kidney_R
- Kidney_L
- Stomach
- SmallBowel
- LargeBowel
- Cellac
- SMA_SMV
- Liver
- Heart
- SpinalCord
- DoseFalloff

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. The top left contains a 'Workflow' panel 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, which is labeled with a '1'. Below this is a 'Plan' section with various input fields for 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 controls for 'Slice', 'Beam', 'Offset', 'Type of plot', 'Plane', 'Dislay option', and 'Show DVH/QI'. A red arrow points to the 'Show DVH/QI' button, labeled with a '2'. The main area shows a 'Viewing' window with an axial CT scan of a head at z = 317.5 [mm]. A color scale on the right indicates 'RBExDose [Gy(RBE)]' from 0 to 60. The 'Structure Visibility' panel on the right lists various organs at risk (GTV, Kidney, Stomach, SmallBowel, LargeBowel, Celiac, SMA_SMV, Liver, Heart, SpinalCord, DoseFalloff) with checkboxes. The 'Info' panel at the bottom right shows the 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_0.4Gy	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 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 shows 'Slice', 'Beam', and 'Offset' settings, 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
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...

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

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
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github.com/e0404/mat
About

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

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 Type of plot inten... GoTo lateral

Beam Plane axial Open 3D-View

Offset Dislay option

plot CT

plot contour

plot isolines

plot dose

plot isolines labels

plot iso center

visualize plan / be...

axial plane z = 140 [mm]

x [mm] y [mm]

min 1024
max 3071

Viewer Options

CT (HU)

Window: Breast

Custom

Window Center: 1.27

Window Width: 2.53

Range: 0.00324 2.531

bone

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

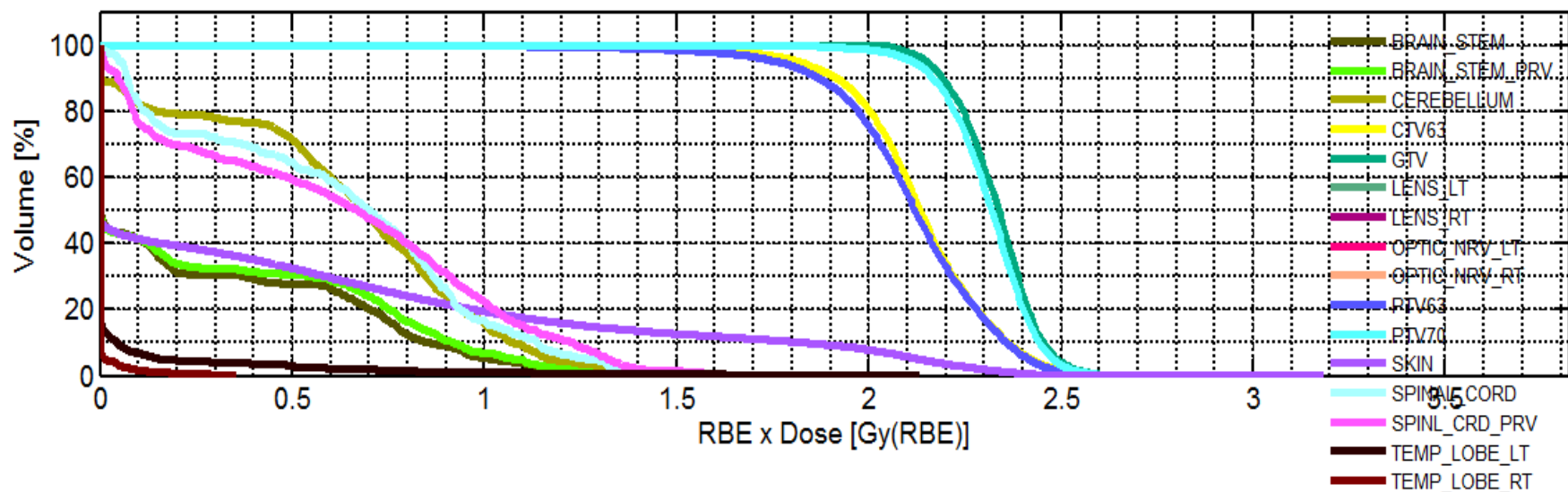
github.com/e0404/mat

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

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 points to the "Save to GUI" button. The status below indicates "plan is optimized".
- Plan:** Includes input fields for biixel width (10), Gantry Angle (90 180 270), Couch Angle (0 0 0), Radiation Mode (protons), Machine (Generic), IsoCenter (250.4 205.3 138.5), # Fractions (30), and Type of optimization (const_RBExD). It also has radio buttons for "use MC (VMC++) dose calculations", "3D conformal", "Run Sequencing", and "Run Direct Aperture Optimizat...".
- Objectives & constraints:** A table listing various VOI (Volume of Interest) with their types, priorities, and constraints.
- Visualization:** Features a "Show DVH/QI" button with a red arrow pointing to it, and options for "Type of plot" (intensity), "Plane" (axial), and "Dislay option" (RBExDose).
- Viewing:** Shows an axial cross-section of a head at z = 140 mm. A color scale on the right indicates RBExDose in Gy(RBE) from 0 to 60. The x and y axes are labeled in mm.
- Viewer Options:** Includes "Set IsoDose Levels", "Result (i.e. dose)", "Window Center", "Window Width", "Range", and "Dose opacity".
- Structure Visibility:** A list of anatomical structures with checkboxes, including BRAIN_STEM, CEREBELLUM, CHIASMA, CTV63, GTV, LARYNX, LENS, LIPS, and OPTIC NRV.
- Info:** Displays the version (v3.0.0) and the GitHub repository (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
5	SKIN	OAR	3	square overdosing	800	20	NaN	NaN



	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...

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Viewing

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

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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

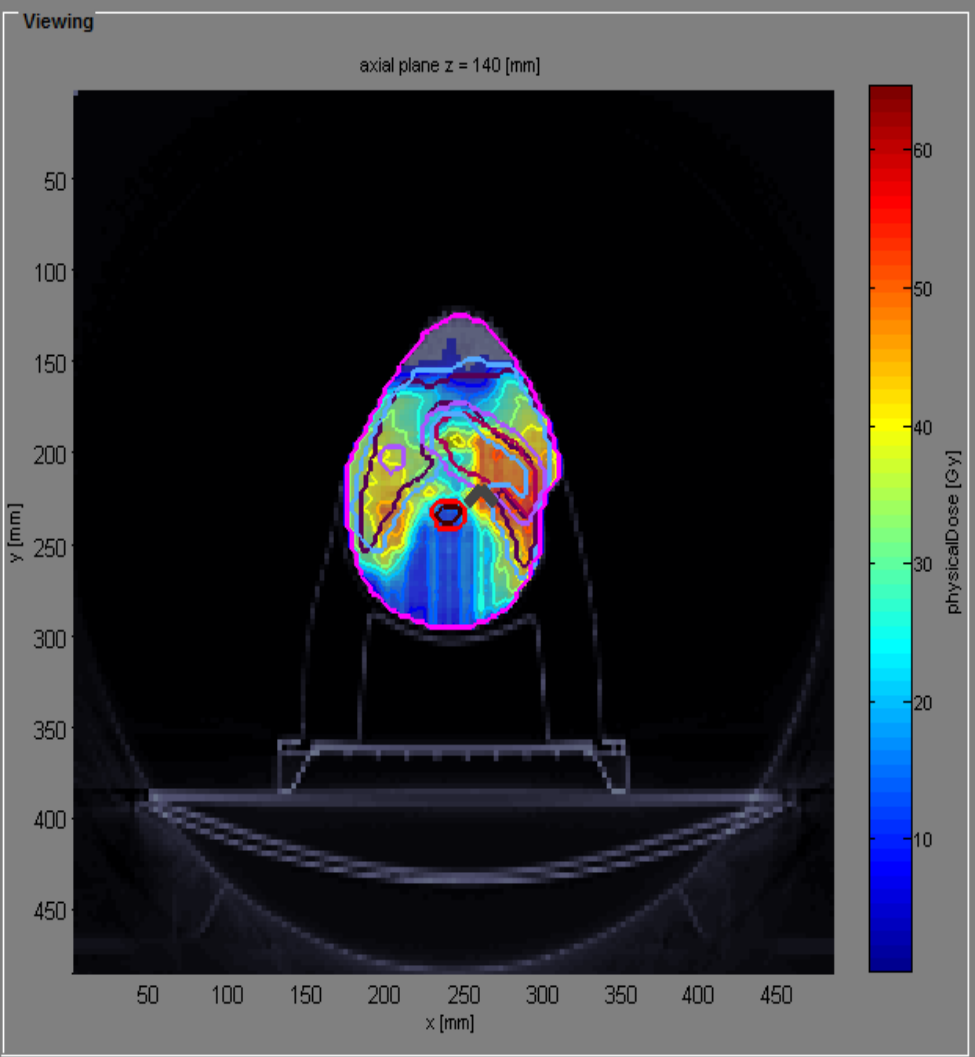
Slice Type of plot inten... GoTo lateral

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...



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
 - ✓ 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 [Slider] **intentional** GoTo lateral plot CT
 Beam [Slider] Plane 1 axial plot contour
 Offset [Slider] Dislay option physicalDose 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 = 150 [mm]

min 0 max 3.186

Set IsoDose Levels

Viewer Options

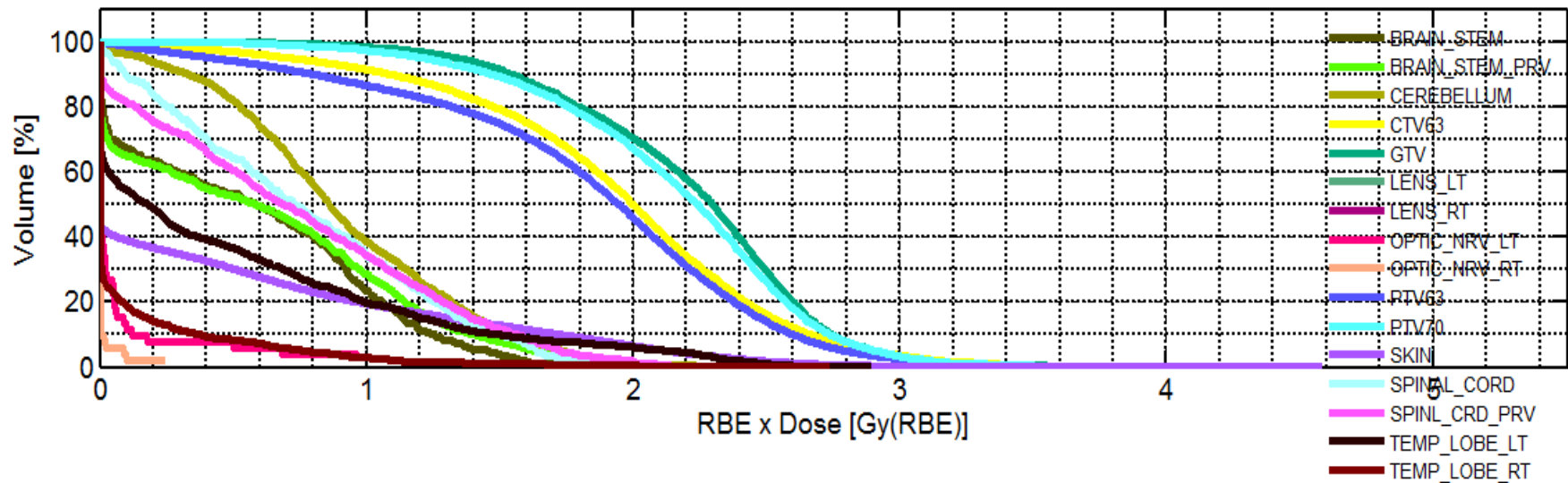
Result (i.e. dose) Window Doseat Custom
 Window Center: 1.59
 Window Width: 3.19
 Range: 0 3.186
 jet Dose opacity: 1

Structure Visibility

- BRAIN_STEM
- BRAIN_STEM_PR
- CEREBELLUM
- CHIASMA
- CTV63
- GTV
- LARYNX
- LENS_LT
- LENS_RT
- LIPS
- OPTIC_NRV_LT
- OPTIC_NRV_RT

Info

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 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 :)