

# **MASTERCLASS ZA HADRONSKU TERAPIJU**

**Planiranje radioterapijskih tretmana u  
MatRadu**

**Instrukcije**

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# 1. Zadatak

- Korištenje TG119 fantoma
- Planiranje radioterapijskog tretmana pomoću fotona, protona i ugljikovih iona
- Analiza i poređenje dobivenih rezultata

# 1. Zadatak

- Korištenje TG119 fantoma
- Planiranje radioterapijskog tretmana pomoću fotona, protona i ugljikovih iona
- Analiza i poređenje dobivenih rezultata

# 1. Učitajte TG119 fantom pomoću opcije Load \* .mat (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 and highlighted 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 for radiation mode, machine, and optimization, as well as a visualization section with plot options and a graph.

**Workflow**

Refresh Load \*.mat data Load \*.COM Import from 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. Odaberite fotone kao vrstu zračenja, te odredite jedan ugao snopa (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  
 # 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	+
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 no option avail...  
 Show DVH/Q

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

Viewing axial plane z = 165 [mm]

min max 1000 1040.  
 Set IsoDose Levels

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  
 About

### 3. Pokrenite proračun doze pomoću opcije („Calc. Influence Mx“). Zatim započnite obrnutu optimizaciju klikom na („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', '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 Panel:** Includes input fields for '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), and '# Fractions' (30). 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 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	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 Panel:** Includes 'Slice' and 'Beam' selection, 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (no option avail...). It also has 'GoTo lateral' and 'Open 3D-View' buttons, and a 'Show DVH/QI' button.
- Viewing Panel:** Shows an axial CT scan slice at z = 165 [mm]. The x and y axes range from 50 to 500 mm. A color scale on the right indicates Hounsfield Units from 10 to 60. The 'Viewer Options' panel on the right shows 'CT (HU)' as the window, with 'Window Center' at 0.85 and 'Window Width' at 1.67. The 'Structure Visibility' panel shows 'Core', 'OuterTarget', and 'BODY' as visible structures.

## 4. Analizirajte rezultujuću raspodjelu doze

**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]

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](https://github.com/e0404/mat)

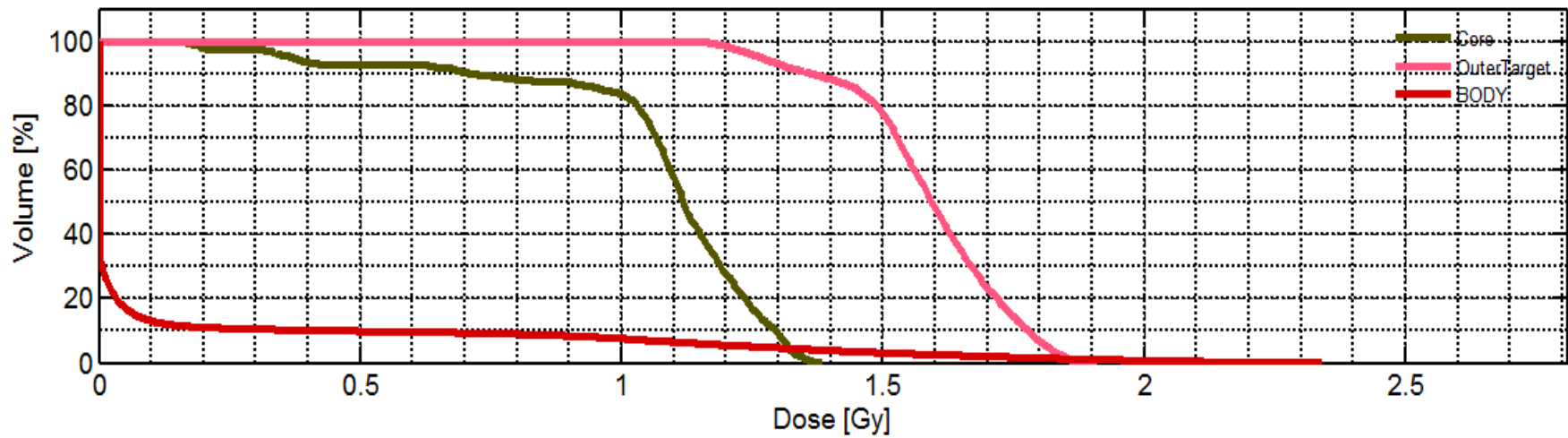
## 5. Spremite rezultat optimizacije putem („Save to GUI“), te prikažite DVH pomoću („Show DVH/QI“).

The screenshot displays the matRad software interface, which is used for radiation therapy optimization. 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 Dose. A red arrow points to the "Save to GUI" button. The status below indicates "plan is optimized".
- Plan:** Contains various parameters for optimization, including bixel width (10 mm), Gantry Angle (0°), Couch Angle (0°), Radiation Mode (photons), Machine (Generic), IsoCenter (251.3, 236.4, 162.6 mm), # 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 VOI names, types, priorities, and constraints.
- Visualization:** Contains options for Slice, Beam, Offset, Type of plot (intensity), Plane (axial), and Display option (physicalDose). A red arrow points to the "Show DVH/QI" button.
- Viewing:** Displays a dose distribution plot for an axial plane at z = 165 mm. The plot shows a color-coded dose distribution with a color scale on the right ranging from 0 to 60 Gy. The plot is overlaid on a CT scan of a patient's head and neck. The axes are labeled x [mm] and y [mm].
- Viewer Options:** Contains options for Result (i.e. dose), Window Preset (Custom), Window Center (1.17), Window Width (2.34), Range (0 to 2.342), jet color map, and Dose opacity (1).
- Structure Visibility:** A list of structures with checkboxes: Core (checked), OuterTarget (checked), and BODY (checked).
- 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	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





	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. Promijenite vrstu zračenja u Proton i ostavite uglove snopa nepromijenjenim

**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 photons  
 IsoCenter in [mm] protons **←**  
 # Fractions carbon  
 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

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...

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axial plane z = 165 [mm]

min 0  
max 2.342

Set IsoDose Levels

**Viewer Options**

Result (i.e. dose) Window Doseat 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](https://github.com/e0404/mat)  
 About

# 7. Pokrenite proračun doze pomoću opcije („Calc. Influence Mx“) i započnite obrnutu optimizaciju klikom na („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...

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

Viewing axial plane z = 165 [mm]

min max n 2.342

Set IsoDose Levels

Viewer Options

Result (i.e. dose) Window Presest 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. Spremite rezultat optimizacije putem („Save to GUI“) i prikažite DVH pomoću („Show DVH/QI“)

The screenshot displays the matRad software interface. The top left shows the workflow menu with 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. Below this is the 'Plan' section with various parameters like bixel width, Gantry Angle, Couch Angle, Radiation Mode (protons), Machine (Generic), IsoCenter, # Fractions (30), and Type of optimization (const\_RBExD). The 'Objectives & constraints' section contains a table with 3 rows: Core (OAR), OuterTarget (TARGET), and BODY (OAR). The 'Visualization' section at the bottom left has a 'Show DVH/QI' button, which is highlighted with a red arrow labeled '2'. The main viewing area shows an axial plane at z = 165 mm with a color-coded dose distribution plot. The plot shows a central target area (red/yellow) surrounded by organs at risk (blue/green). A color scale on the right indicates RBE x Dose [Gy(RBE)] from 0 to 60. The bottom right panel shows viewer options like 'Result (i.e. dose)', 'Window: Default', 'Custom', and 'Structure Visibility' with 'Core', 'OuterTarget', and 'BODY' checked.

**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 protons  
Machine Generic  
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 RBExDose

plot CT  
plot contour  
plot isolines  
plot dose  
plot isolines labels  
plot iso center

Show DVH/QI

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

min max 0 2.710  
Set IsoDose Levels

**Viewer Options**

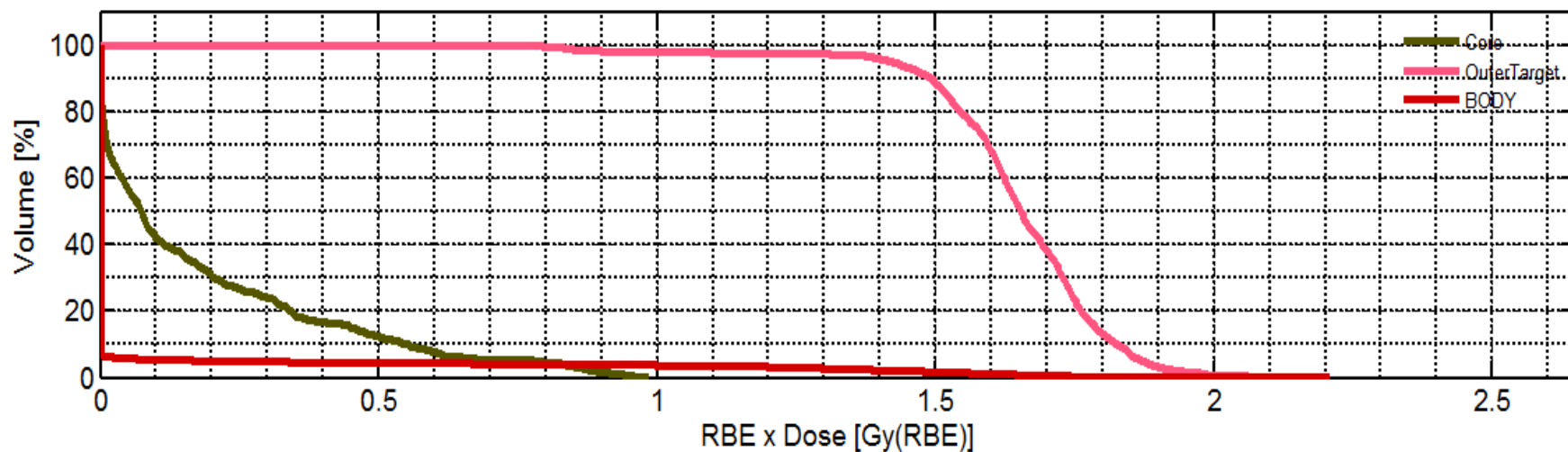
Result (i.e. dose)  
Window: Default  
Custom  
Window Center: 1.11  
Window Width: 2.21  
Range: 0 2.21  
jet  
Dose opacity: 1

**Structure Visibility**

Core  
 OuterTarget  
 BODY

**Info**

v3.0.0  
github.com/e0404/mat  
About



	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

# Rezultati

- Srednje doze po regionima (Gy):

Region/Zračenje	Fotoni	Protoni
Osjetljivi region	1.0665	0.1815
Vanjska meta	1.5852	1.6449
Tijelo	0.1443	0.0640

- Fotoni daju najveću dozu na površini
- Protoni daju najveću dozu na meti (tumoru) uz maksimalnu zaštitu osjetljivih regiona

# 9. Pokušajte definisati bolji plan tretmana fotonima pomoću većeg broja uglova snopa (npr. ekvivalentni razmak [0, 72, 144, 216, 288]. Pokrenite proračun doze i započnite obrnutu optimizaciju.

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

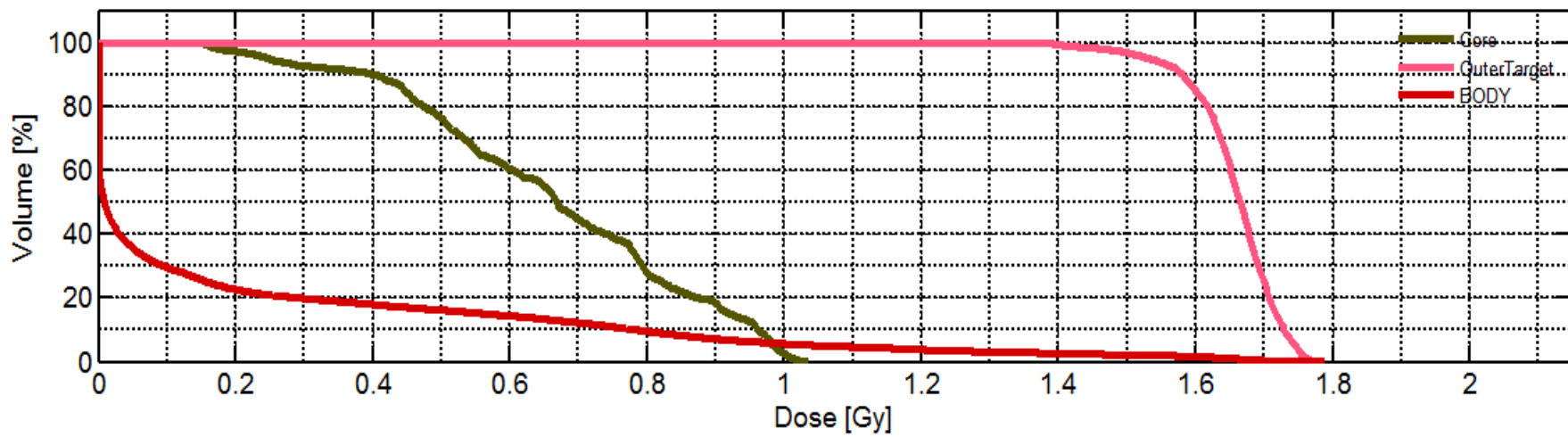
Info v3.0.0  
 github.com/e0404/mat  
 About

# 10. Spremite rezultat optimizacije putem („Save to GUI“) i prikažite DVH pomoću („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 panels:

- Workflow Panel:** 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 Panel:** Includes fields for bixel width (10), Gantry Angle (0 72 144 216 288), Couch Angle (0 0 0 0), Radiation Mode (photons), Machine (Generic), IsoCenter (251.3 236.4 162.6), # Fractions (30), and Type of optimization (none). It also has radio buttons for MC (VMC++) dose calculations, 3D conformal, Run Sequencing, and Run Direct Aperture Optimizat..., and a Stratification Levels field set to 7.
- Objectives & constraints Panel:** Contains a table with columns for VOI name, VOI type, priority, obj. / const., penalty, dose, EUD, volume, and ro. The table lists three VOIs: Core, OuterTarget, and BODY.
- Visualization Panel:** Includes fields for Slice, Beam, and Offset, and dropdowns for Type of plot (intentional), Plane (axial), and Display option (physicalDose). It also has buttons for GoTo (lateral) and Open 3D-View, and a "Show DVH/QI" button with a red arrow pointing to it.
- Viewer Panel:** Shows a dose distribution plot for an axial plane at z = 165 [mm]. The plot displays a color-coded dose distribution with a central target area. A color scale on the right indicates physical dose in Gy, ranging from 0 to 60. The plot axes are labeled x [mm] and y [mm].
- Viewer Options Panel:** Includes fields for min, max, and n (1.789), a "Set IsoDose Levels" button, and a "Viewer Options" section with dropdowns for Result (i.e. dose), Window preset (Custom), Window Center (0.89), Window Width (1.79), Range (0 to 1.79), jet color map, and Dose opacity (1).
- Structure Visibility Panel:** Contains checkboxes for Core, OuterTarget, and BODY, all of which are checked.
- Info Panel:** Shows the version (v3.0.0) and the GitHub repository (github.com/e0404/mat), along with an "About" button.





	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

# Rezultati

- Srednje doze po regionima (Gy):

Region/Zračenje(uglovi)	Fotoni(0)	Protoni(0)	Fotoni (0,72,144,216,288)
Osjetljivi region	1.0665	0.1815	0.6625
Vanjska meta	1.5852	1.6449	1.6563
Tijelo	0.1443	0.0640	0.1968

- Plan tretmana sa više snopova fotona daje bolje rezultate nego sa jednim snopom fotona.
- Najbolji rezultati su dobiveni korištenjem protona.

# 11. Promijenite cilj optimizacije za poboljšanje plana liječenja protonima. Koristite tabelu („Objectives & constraints“) i dodajte ograničenje (npr. maksimalna doza u meti ili minimalna doza u vanjskoj ciljnoj strukturi).

**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	5	NaN	NaN	no +
2	OuterTarget	TARGET	1	min dose constraint	10	10	NaN	NaN	no -
3	BODY	OAR	3	square overdosing	100	30	NaN	NaN	no

save

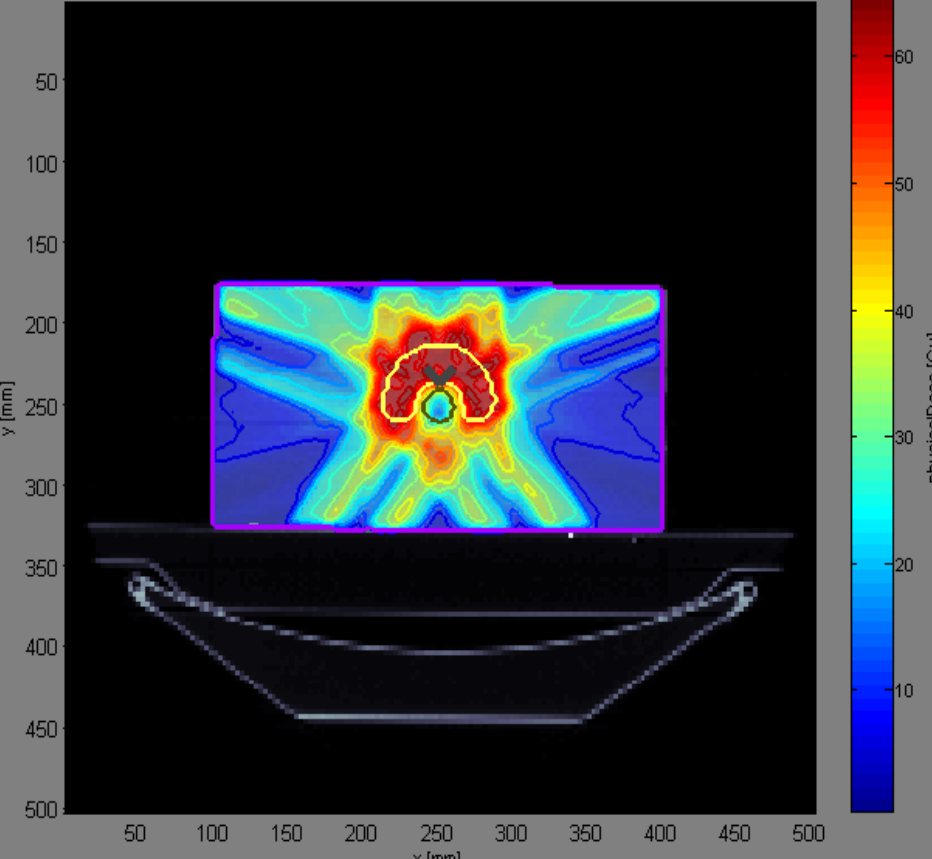
**Visualization**

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...



axial plane z = 165 [mm]



min max n  
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

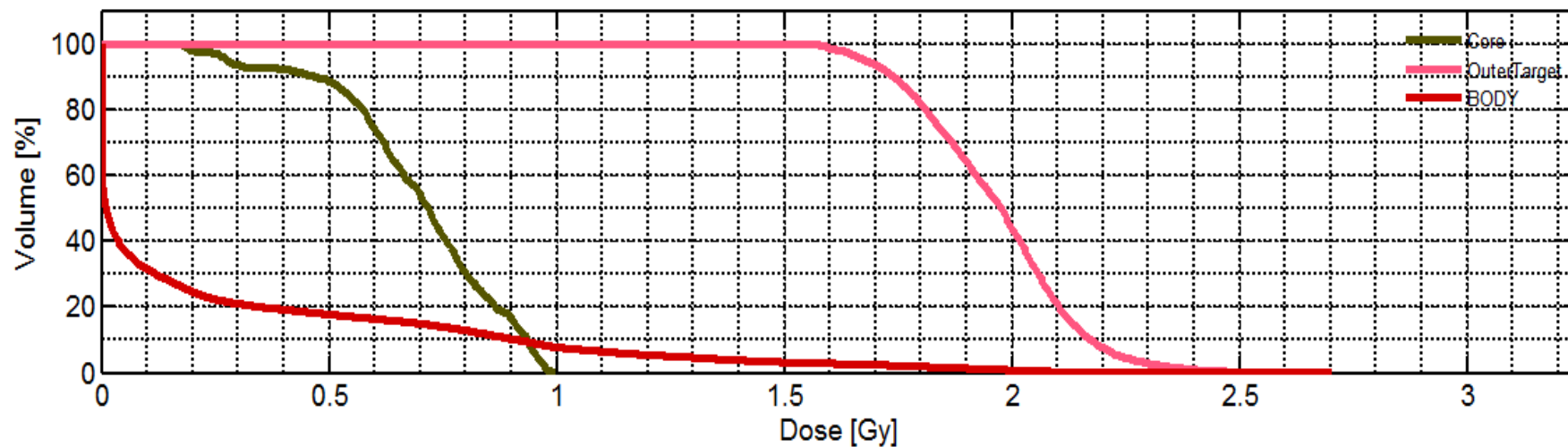
**Info**

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

## 12. Pokrenite proračun doze pomoću opcije („Calc. Influence Mx“) i započnite obrnutu optimizaciju klikom na („Optimize“). Zatim spremite rezultat optimizacije putem („Save to GUI“) i prikažite DVH pomoću („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 sections:

- Workflow:** Contains buttons for Refresh, Load \*.mat data, Calc. influence Mx, Optimize, Save to GUI, Load DICOM, Export, and Import dose. Red arrows point to the 'Calc. influence Mx', 'Optimize', and 'Save to GUI' buttons. The status bar indicates 'plan is optimized'.
- Plan:** Includes parameters for bixel width (10 mm), Gantry Angle (0 72 144 216 288), Couch Angle (0 0 0 0), Radiation Mode (photons), Machine (Generic), IsoCenter (251.3 236.4 162.6), # Fractions (30), and Type of optimization (none). It also has options for MC (VMC++) dose calculations, 3D conformal, Run Sequencing, Stratification Levels (7), and Run Direct Aperture Optimization.
- Objectives & constraints:** A table with columns for VOI name, VOI type, priority, obj. / const., penalty, dose, EUD, volume, and ro. The table lists three objectives: Core (max dose constraint), OuterTarget (min dose constraint), and BODY (square overdosing).
- Visualization:** Includes options for Slice, Beam, Offset, Type of plot (intensity), Plane (axial), Dislay option (physicalDose), and various plot options like plot CT, plot contour, plot isolines, plot dose, plot isolines labels, plot iso center, and visualize plan / be... A red arrow points to the 'Show DVH/QI' button.
- Viewing:** Shows an axial plane at z = 165 mm. The plot displays a dose distribution with a color scale from 0 to 60 Gy. The plot is overlaid on a CT scan of a head and neck region.
- Viewer Options:** Includes options for Result (i.e. dose), Window Preset (Custom), Window Center (1.35), Window Width (2.71), Range (0 to 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:** Shows version v3.0.0 and the GitHub repository link qithub.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	

# Rezultati

- Srednje doze po regionima (Gy) dobivene pomoću 5 snopova fotona sa i bez ograničenja:

Region/Zračenje	Bez ograničenja	Sa ograničenjima
Osjetljivi region	0.6625	0.6974
Vanjska meta	1.6563	1.9652
Tijelo	0.1968	0.2343

## 2. Zadatak

- Plan liječenja bolesti jetre ugljikovim ionima
- Definisanje vlastitog plana liječenja fotonima i protonima
- Analiza i poređenje različitih planova liječenja

# 1. Učitajte jetru pacijenta pomoću opcije Load \*.mat (LIVER.mat)

The screenshot displays the matRad software interface. The top navigation bar includes the matRad logo and the DKFZ German Cancer Research Center logo. 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.
- 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 the file explorer. The 'LIVER' file is selected, and a red arrow points to it. The file name 'LIVER' is entered in the 'File name' field, and the file type is set to 'MAT-files (\*.mat)'. The 'Open' button is visible.

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

File 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
<b>LIVER</b>	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



## 2. Definišite vlastiti plan liječenja fotonima sa 4-5 uglova snopa

**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 1

Gantry Angle in ° 0 180 225 270 315 2

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 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

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 = 317.5 [mm]

min 0  
max 3.706

Set IsoDose Levels

**Viewer Options**

Result (i.e. dose) Window Doseat Custom  
 Window Center: 1.85  
 Window Width: 3.71  
 Range: 0 3.706  
 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](https://github.com/e0404/mat)  
 About

### 3. Pokrenite proračun doze pomoću opcije („Calc. Influence Mx“) i započnite obrnutu optimizaciju klikom na („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', 'Optimize', 'Save to GUI', 'Export', and 'Import Dose'. Red arrows point to 'Calc. influence Mx' (labeled '1') and 'Optimize' (labeled '2'). The status below indicates 'ready for optimization'.
- Plan Panel:** Includes parameters 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 options for 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', 'Stratification Levels' (7), and 'Run Direct Aperture Optimizat...'. A 'Set Tissue' button is also present.
- Objectives & constraints Panel:** Contains a table with the following data:

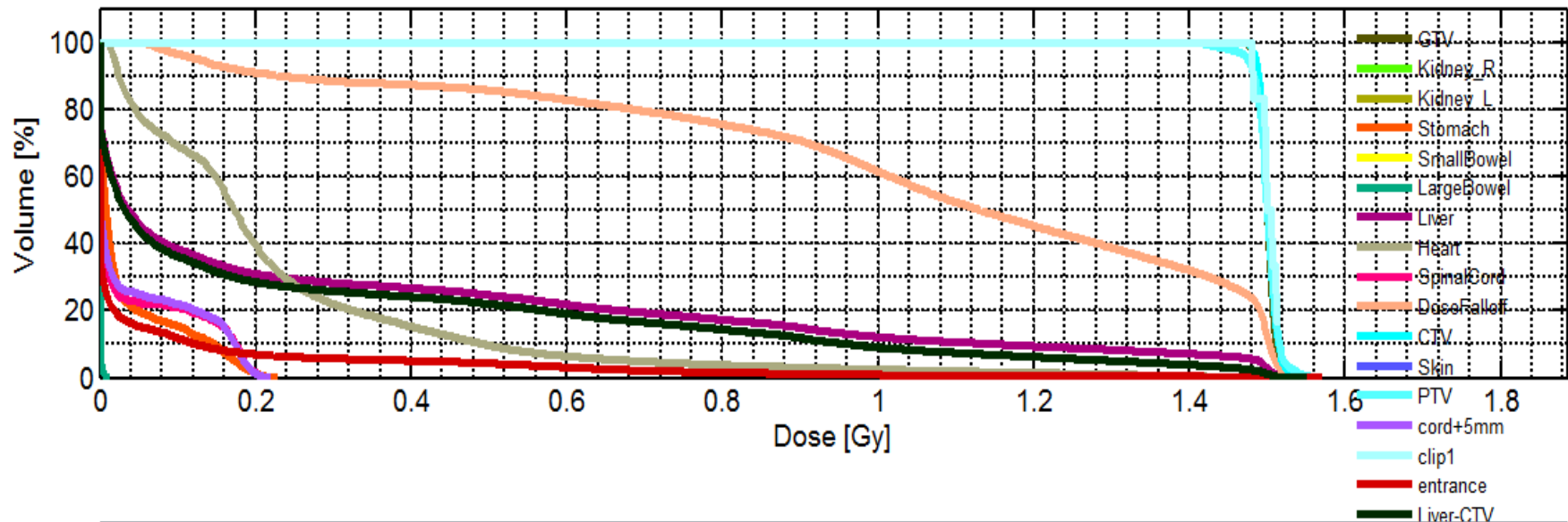
	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume	ro
1	Skin	OAR	2	square overdosing	300	25	NaN	NaN	no
2	PTV	TARGET	1	square deviation	1000	45	NaN	NaN	no
- Visualization Panel:** Shows 'Slice' and 'Beam' settings, 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (physicalDose). It includes a 'GoTo' button set to 'lateral' and an 'Open 3D-View' button. A legend on the right lists various structures: plot CT, plot contour, plot isolines, plot dose, plot isolines labels, plot iso center, and visualize plan / be... The 'Show DVH/QI' button is also visible.
- 3D Visualization:** Displays an axial CT scan of a patient's head and neck. A color scale on the right indicates 'physicalDose [Gy]' ranging from 0 to 60. The image shows a target volume (PTV) and organs at risk (OAR) with various contours. A color bar on the right shows the dose distribution, with a maximum of 3.706 Gy and a minimum of 0 Gy.
- Viewer Options Panel:** Includes 'Set IsoDose Levels', 'Viewer Options' (Result (i.e. dose), Window, Custom), 'Window Center' (1.85), 'Window Width' (3.71), 'Range' (0 3.706), 'jet' color map, and 'Dose opacity' (1).
- Structure Visibility Panel:** Lists visible structures: GTV, Kidney\_R, Kidney\_L, Stomach, SmallBowel, LargeBowel, Cellac, SMA\_SMV, Liver, Heart, SpinalCord, and DoseFalloff.
- Info Panel:** Shows version 'v3.0.0' and the GitHub repository 'github.com/e0404/mat'. An 'About' button is also present.

# 4. Spremite rezultat optimizacije putem („Save to GUI“) i prikažite DVH pomoću („Show DVH/QI“)

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

- Workflow Panel:** 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, labeled with the number '1'.
- Plan Panel:** Shows optimization parameters such as '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), and '# Fractions' (30). It also includes options for 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', and 'Stratification Levels' (7).
- Objectives & constraints Panel:** Contains a table with columns for 'VOI name', 'VOI type', 'priority', 'obj. / const.', 'penalty', 'dose', 'EUD', 'volume', and 'ro'. Two rows are visible:
 

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:** Includes 'Slice', 'Beam', and 'Offset' controls. The 'Type of plot' is set to 'inten...', 'Plane' is 'axial', and 'Dislay option' is 'physicalDose'. A red arrow points to the 'Show DVH/QI' button, labeled with the number '2'. 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 on the right lists various organs at risk (GTV, Kidney\_R, Kidney\_L, Stomach, SmallBowel, LargeBowel, Celiac, SMA\_SMV, Liver, Heart, SpinalCord, DoseFalloff) with checkboxes for visibility.
- Viewing Panel:** Shows a 2D axial dose distribution plot for 'axial plane z = 317.5 [mm]'. The plot displays a color-coded dose distribution over a cross-section of a head and neck. A color scale on the right indicates 'physicalDose [Gy]' ranging from 0 to 60. The plot axes are labeled 'x [mm]' and 'y [mm]'. The 'min' dose is 0 and the 'max' dose is 1.572.



	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. Definišite vlastiti plan liječenja protonima s jednim snopom, npr. 315 °, te pokrenite proračun doze pomoću opcije („Calc. Influence Mx“) i obrnutu optimizaciju klikom na („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

**Viewing**

axial plane z = 317.5 [mm]

physicalDose [Gy]

min max n  
 max 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. Spremite rezultat optimizacije putem („Save to GUI“) i prikažite DVH pomoću („Show DVH/QI“)

**GERMAN  
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IN THE HELMHOLTZ ASSOCIATION**

**Workflow**

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

Load DICOM
Recalc
Export

Import from Bin...
Import

Status: plan is optimized 1

**Plan**

bixel width in [mm]	10	<input type="radio"/> use MC (VMC++) dose calculations
Gantry Angle in °	315	<input type="radio"/> 3D conformal
Couch Angle in °	0	<input type="radio"/> Run Sequencing
Radiation Mode	protons	Stratification Levels
Machine	Generic	7
IsoCenter in [mm]	265.8 296.7 316.4 <input checked="" type="checkbox"/> Auto.	<input type="radio"/> Run Direct Aperture Optimizat...
# Fractions	30	
Type of optimization	const_RBExD <input type="button" value="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**

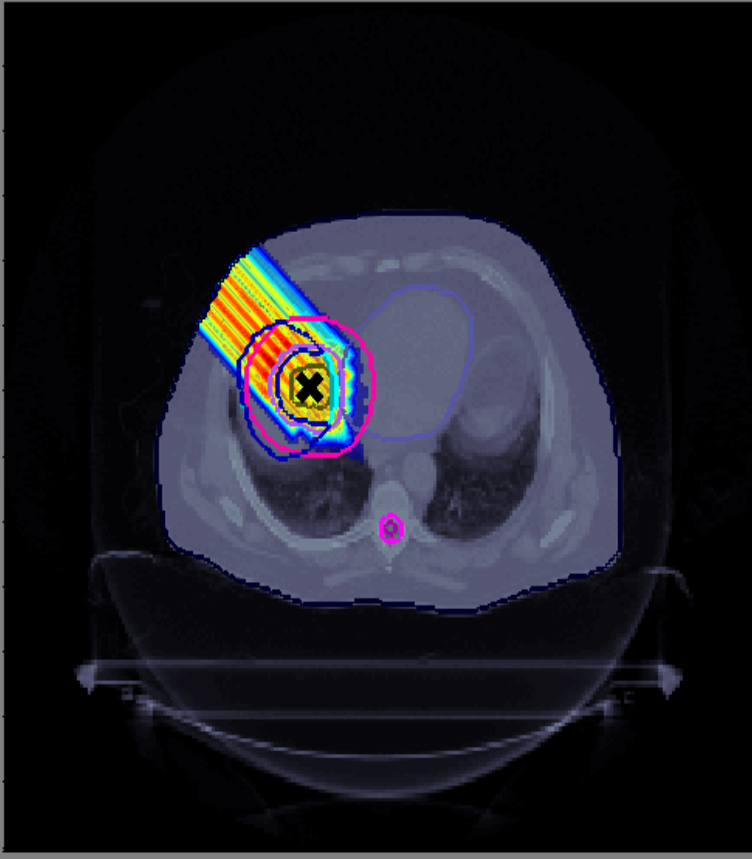
Slice	<input type="text"/>	Type of plot	inten...	GoTo	lateral
Beam	<input type="text"/>	Plane	axial	Open 3D-View	
Offset	<input type="text"/>	Dislay option	RBExDose		

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

2

**Viewing**

axial plane z = 317.5 [mm]



y [mm]

50

100

150

200

250

300

350

400

450

500

550

600

650

x [mm]

50

100

150

200

250

300

350

400

450

500

550

600

650

min max n

2.501

**Viewer Options**

Result (i.e. dose)

Custom

Window Center:

Window Width:

Range: 0 2.501

jet

Dose opacity:

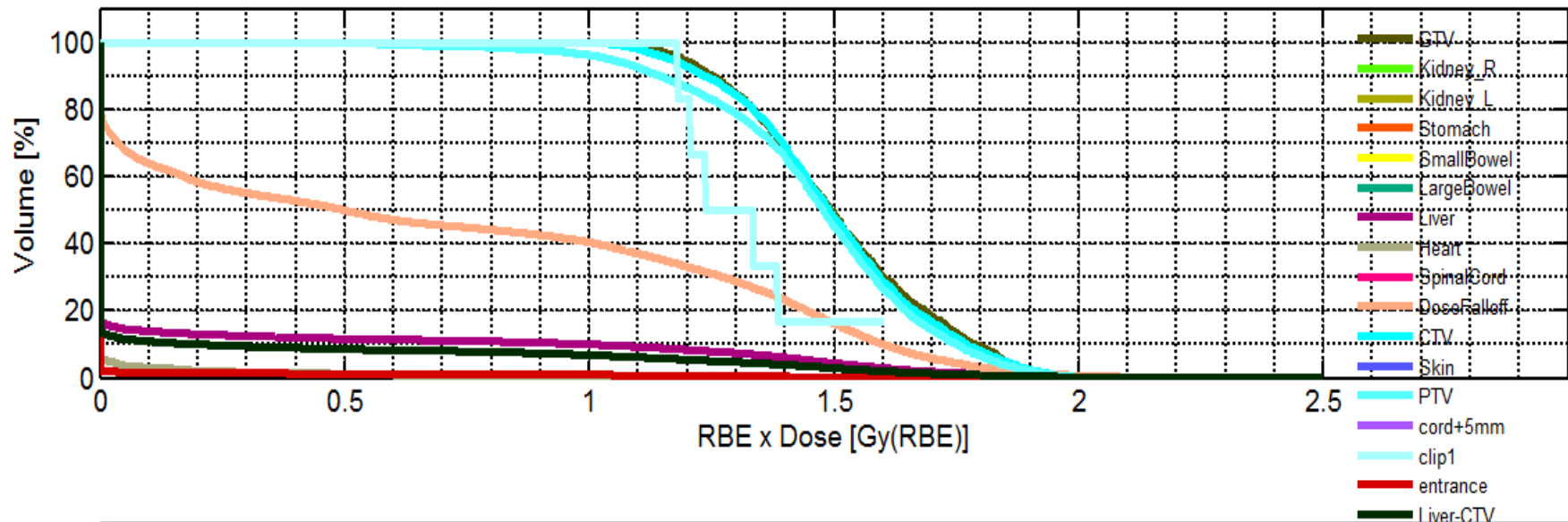
**Structure Visibility**

- GTV
- Kidney\_R
- Kidney\_L
- Stomach
- SmallBowel
- LargeBowel
- Celiac
- SMA\_SMV
- Liver
- Heart
- SpinalCord
- DoseFalloff

**Info**

v3.0.0

[github.com/e0404/mat](https://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. Napravite tretman ugljikovim jonima sa tačno istim postavkama kao za plan protonskog tretmana

**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

↑ 2   ↑ 3

**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   carbon   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    plot CT

Beam   Plane   axial   Open 3D-View    plot contour

Offset   Dislay option   RBExDose    plot isolines

plot dose

plot isolines labels

plot iso center

visualize plan / be...

Show DVH/QI

matRad   dkfz.   GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 317.5 [mm]

min   0

max   2.501

Set IsoDose Levels

Viewer Options

Result (i.e. dose)   Window   Custom

Window Center:   1.25

Window Width:   2.5

Range:   0   2.501

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

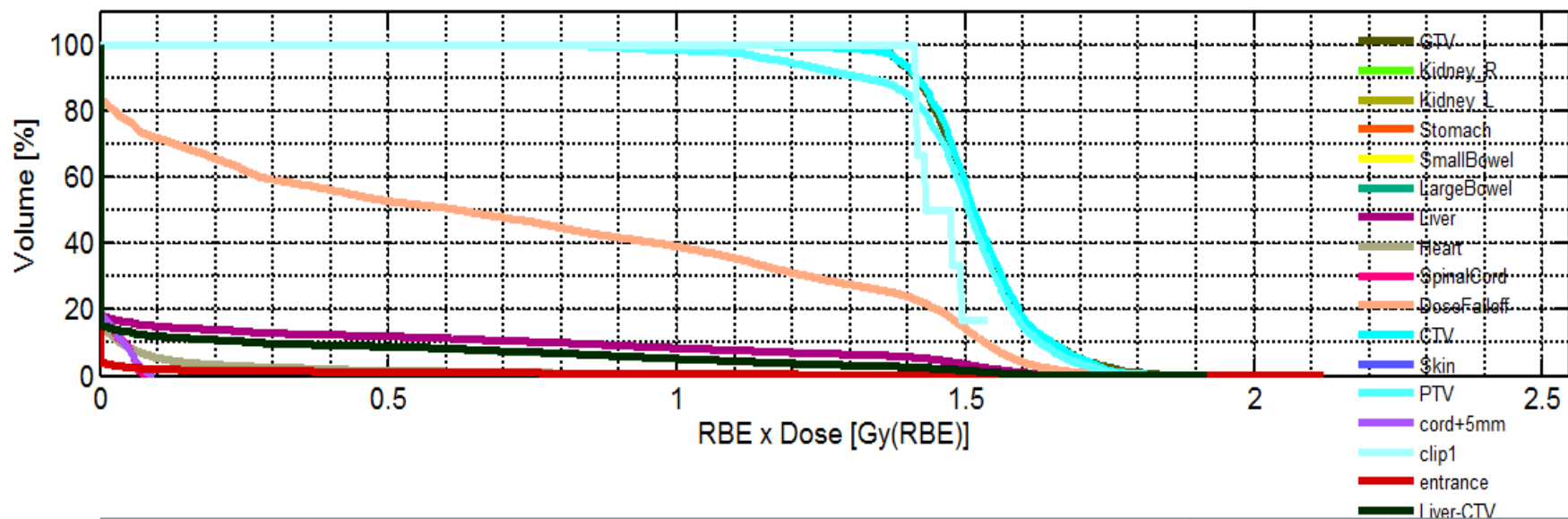


# 8. Spremite rezultat optimizacije putem („Save to GUI“) i prikažite DVH pomoću („Show DVH/QI“)

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, 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.
- Plan:** Includes parameters for bixel width (10 mm), Gantry Angle (315°), Couch Angle (0°), Radiation Mode (carbon), Machine (Generic), IsoCenter (265.8, 296.7, 316.4 mm), # Fractions (30), and Type of optimization (LEMIV\_RBExD). It also has checkboxes 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 constraints for VOI name, type, priority, and penalty.
 

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:** Shows settings for Slice, Beam, and Offset. It includes a 'Type of plot' dropdown (set to 'inten...'), 'GoTo' (lateral), and 'Plane' (axial). A 'Dislay option' dropdown is set to 'RBExDose'. A red arrow labeled '2' points to the 'Show DVH/QI' button.
- Viewing:** Displays a 3D axial plane at z = 317.5 mm. The plot shows a color-coded dose distribution (RBExDose) with a color scale from 0 to 60 Gy(RBE). A red 'X' marks the beam entrance point. The axes are labeled x [mm] and y [mm].
- Right Panel:** Contains 'min max' values (0, 2.123), 'Set IsoDose Levels', 'Viewer Options' (Result: dose, Window: Custom, Range: 0 to 2.123), 'Structure Visibility' (checkboxes for GTV, Kidney, Stomach, SmallBow, LargeBow, Celiac, SMA\_SMV, Liver, Heart, SpinalCord, DoseFalloff), and 'Info' (v3.0.0, 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	

# Rezultati

- Srednje doze po regionima (Gy) dobivene pomoću 5 snopova fotona, jednog snopa protona i iona karbona:

Region/Zračenje(uglovi)	Fotoni(0,180,225,270,315)	Protoni(315)	Karbon(315)
GTV	1.5	1.5053	1.5212
Bubrezi	0	0	0
Stomak	0.0342	0	0
Jetra	0.3033	0.1694	0.1570
Srce	0.2296	0.0172	0.0277
Kičmena moždina	0.0391	0	0.0077
CTV	1.5015	1.4981	1.5236
PTV	1.4991	1.4595	1.4868
Koža	0.0568	0.0179	0.0162

# 3. Zadatak

- Neizvjesnosti u planiranju liječenja
- Planiranje protonske terapije za glavu pacijenta
- Simuliranje greške u postavljanju pacijenta
- Analiza i upoređivanje rezultujućih raspodjela doze

# 1. Učitajte glavu pacijenta pomoću opcije Load \* .mat (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', 'Calc. influence Mx', 'Optimize', 'Save to GUI', 'Load COM', 'Recalc', 'Export', 'Import Dose', and 'Import Dose'. A red arrow points to the 'Load \*.mat data' button. The 'Plan' section shows 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', and 'volume'. The 'Visualization' section includes 'Slice', 'Beam', 'Offset', 'Type of plot', 'Plane', 'Disolav option', and 'Show DVH/QI'. 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 Calc. influence Mx Optimize Save to GUI  
Load COM Recalc Export  
Import Dose 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 Show DVH/QI

**Select File to Open**

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

Open Cancel

## 2. Dodajte tri ugla za protonske snopove po vašoj želji. Izračunajte i optimizirajte dozu („Calc. Influence Mx“ & „Optimize“).

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

- Workflow:** Contains buttons for 'Refresh', 'Load \*.mat data', 'Load DICOM', 'Import from Bin...', 'Calc. influence Mx' (marked with a red arrow and '2'), 'Optimize' (marked with a red arrow and '3'), 'Save to GUI', 'Export', and 'Import Dose'. The status below indicates 'ready for dose calculation'.
- Plan:** Contains various parameters for treatment planning:
  - bixel width in [mm]: 10
  - Gantry Angle in °: 90 180 270 (marked with red arrows and '1')
  - Couch Angle in °: 0 0 0 (marked with red arrows and '1')
  - Radiation Mode: protons (marked with a red arrow and '1')
  - Machine: Generic
  - IsoCenter in [mm]: 250.4 205.3 138.5 (checked 'Auto')
  - # Fractions: 30
  - Type of optimization: const\_RBExD
  - 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 various VOIs (Volume of Interest):
 

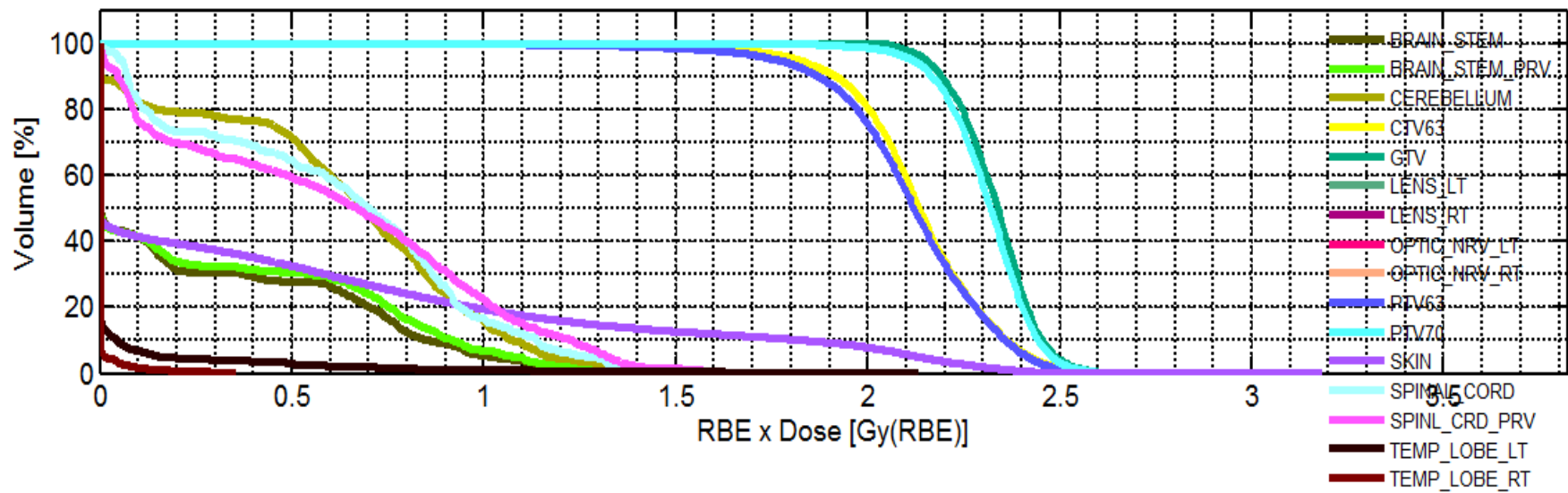
	VOI name	VOI type	priority	obj. / const.	penalty	dose	EUD	volume
1	PAROTID_LT	OAR	1	square overdosing	100	25	NaN	NaN
2	PAROTID_RT	OAR	1	square overdosing	100	25	NaN	NaN
3	PTV63	TARGET	2	square deviation	1000	63	NaN	NaN
4	PTV70	TARGET	1	square deviation	1000	70	NaN	NaN
- Visualization:** Contains settings for the current view:
  - Slice: [Slider]
  - Beam: [Slider]
  - Offset: [Slider]
  - Type of plot: inten...
  - Plane: axial
  - Dislay option: [Slider]
  - Options: 'plot CT', 'plot contour', 'plot isolines', 'plot dose', 'plot isolines labels', 'plot iso center', and 'visualize plan / be...'
- Viewing:** Shows an axial CT scan slice at z = 140 [mm]. The image displays the patient's head and neck with various structures outlined in different colors (magenta, cyan, red, black). A color scale on the right indicates Hounsfield Units from 0 to 60.
- Right Panel:** Contains 'Viewer Options' and 'Structure Visibility' settings:
  - min: 1024, max: 3071
  - Set IsoDose Levels
  - 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, About

### 3. Analizirajte rezultat (doza i DVH) i sačuvajte („Save to GUI“)

The screenshot displays the matRad software interface, which is used for radiation therapy planning. 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.
- Status:** Indicates 'plan is optimized'.
- Plan:** Includes input fields for 'bixel width in [mm]' (10), 'Gantry Angle in °' (90 180 270), 'Couch Angle in °' (0 0 0), 'Radiation Mode' (protons), 'Machine' (Generic), 'IsoCenter in [mm]' (250.4 205.3 138.5), '# Fractions' (30), and 'Type of optimization' (const\_RBExD). There are also radio buttons for 'use MC (VMC++) dose calculations', '3D conformal', 'Run Sequencing', and 'Run Direct Aperture Optimizat...'. A 'Stratification Levels' dropdown is set to '7'.
- Objectives & constraints:** A table listing various VOI (Volume of Interest) names, types, priorities, and associated constraints.
- Visualization:** Includes controls for 'Slice', 'Beam', 'Offset', 'Type of plot' (intensity), 'Plane' (axial), and 'Dislay option' (RBExDose). A 'Show DVH/QI' button is highlighted with a red arrow.
- Viewing:** Shows an axial plane at z = 140 [mm]. The central visualization is a color-coded dose distribution map of a head slice, with a color scale on the right ranging from 0 to 60 Gy(RBE). The x and y axes are labeled in mm.
- Viewer Options:** Includes 'Result (i.e. dose)', 'Window Center', 'Window Width', 'Range', and 'Dose opacity' settings.
- Structure Visibility:** A list of anatomical structures with checkboxes for visibility, 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



	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	0.9973
GTV	2.3305	0.1036	2.7047	1.9940	2.5353	2.4898	2.3381	2.1496	2.0935	1	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	0.2585
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. Simulirajte grešku u postavljanju pacijenta: Uklonite kvakicu u checkboxa za auto-izocentar i odredite novi izocentar. Preračunajte dozu klikom na dugme („Recalc“)

The screenshot displays the matRad software interface, which is used for proton therapy treatment planning. 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', 'Recalc', 'Export', 'Import Dose', and 'Save to GUI'. A red arrow labeled '2' points to the 'Recalc' button.
- Plan:** Contains various parameters for treatment planning, including 'bixel width in [mm]', 'Gantry Angle in °', 'Couch Angle in °', 'Radiation Mode', 'Machine', 'IsoCenter in [mm]', '# Fractions', and 'Type of optimization'. A red arrow labeled '1' points to the 'Auto' checkbox, which is currently unchecked.
- Objectives & constraints:** A table listing treatment objectives and constraints.
- Visualization:** Controls for displaying the treatment plan, including 'Slice', 'Beam', 'Offset', 'Type of plot', 'Plane', and 'Dislay option'. A 'Show DVH/QI' button is also present.
- Viewing:** Shows an axial cross-section of a patient's head at z = 140 [mm]. A color scale on the right indicates the dose distribution in Gy(RBE), ranging from 0 to 60. A red 'X' marks the isocenter.
- Right Panel:** Contains 'Viewer Options' (Result, Window, Range, Dose opacity) and 'Structure Visibility' (a list of anatomical structures with checkboxes).

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

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



**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

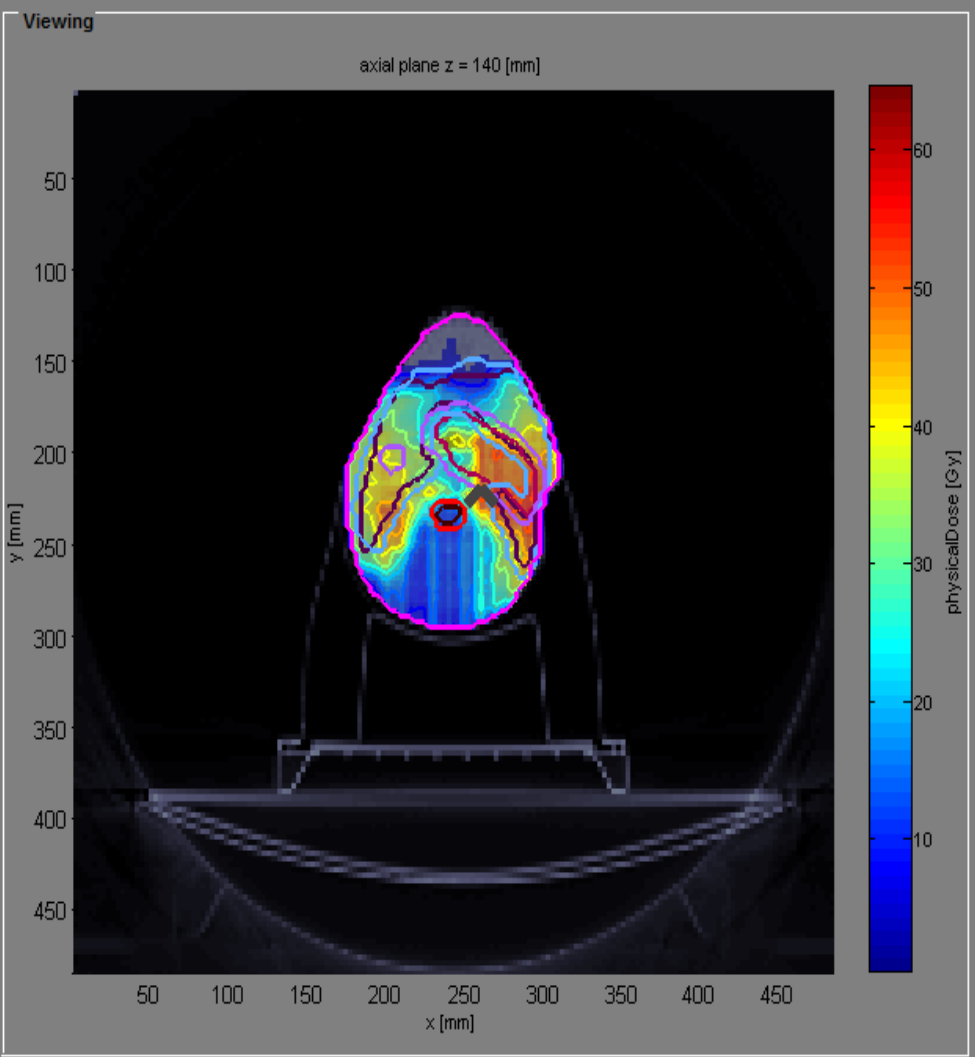
Show DVH/Q!

- 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. Podešavanjem opcije “Slice” pronađite izocentar te analizirajte i uporedite rezultirajuću raspodjelu doze (doza i DVH)

**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  
 plot dose  
 plot isolines labels  
 plot iso center  
 visualize plan / be...  
 Show DVH/QI

matRad dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

axial plane z = 150 [mm]

physicalDose [Gy]

min 0 max 3.186

Set IsoDose Levels

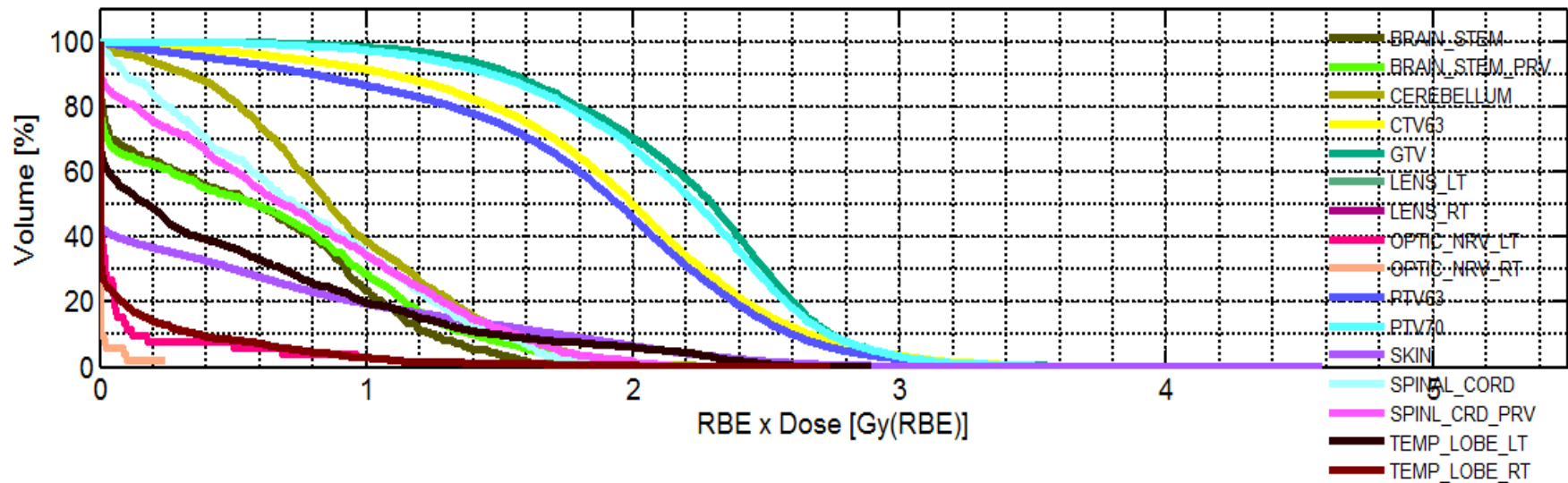
**Viewer Options**

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	

# Rezultati

- Srednje doze po regionima (Gy) dobivene pomoću tri snopa protona, sa i bez pomijeranja:

Region/Izocentar	Bez pomijeranja	Sa pomijeranjem
Moždano stablo	0.2645	0.5784
Mali mozak	0.6355	0.9112
CTV63	2.1304	1.9376
GTV	2.3305	2.2150
Leće (L,D)	0,0	0,0
Koža	0.4682	0.4555
Optički nerv (L,D)	0,0	0.0775, 0.0092
Kičmena moždina	0.6268	0.7466
PTV63	2.1092	1.8369
PTV70	2.3102	2.1671

**Hvala na pažnji :)**