Example Photon Treatment Plan with Direct aperture optimization

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In this example we will show (i) how to load patient data into matRad (ii) how to setup a photon dose calculation and (iii) how to inversely optimize directly from command window in MatLab. (iv) how to apply a sequencing algorithm (v) how to run a direct aperture optimization (iv) how to visually and quantitatively evaluate the result

Patient Data Import

Let's begin with a clear Matlab environment and import the head & neck patient into your workspace.

```
clc,clear,close all;
load('HEAD_AND_NECK.mat');
```

Treatment Plan

The next step is to define your treatment plan labeled as 'pln'. This structure requires input from the treatment planner and defines the most important cornerstones of your treatment plan.

```
pln.radiationMode   = 'photons';   % either photons / protons / carbon
pln.machine         = 'Generic';
pln.numOfFractions  = 30;

pln.propOpt.bioOptimization = 'none';
```

```
pln.propStf.gantryAngles    = [0:72:359];
pln.propStf.couchAngles     = [0 0 0 0 0];
pln.propStf.bixelWidth      = 5;
pln.propStf.numOfBeams      = numel(pln.propStf.gantryAngles);
pln.propStf.isoCenter       = ones(pln.propStf.numOfBeams,1) *
 matRad_getIsoCenter(cst,ct,0);

% dose calculation settings
pln.propDoseCalc.doseGrid.resolution.x = 3; % [mm]
pln.propDoseCalc.doseGrid.resolution.y = 3; % [mm]
pln.propDoseCalc.doseGrid.resolution.z = 3; % [mm]
```

Enable sequencing and direct aperture optimization (DAO).

```
pln.propOpt.runSequencing = 1;
pln.propOpt.runDAO        = 1;
```

Generate Beam Geometry STF

```
stf = matRad_generateStf(ct,cst,pln);
```

```
matRad: Generating stf struct... Warning: Could not find HLUT  in
 hlutLibrary folder. matRad default HLUT loaded
Progress: 100.00 %
```

Dose Calculation

Lets generate dosimetric information by pre-computing dose influence matrices for unit beamlet intensities. Having dose influences available allows for subsequent inverse optimization.

```
dij = matRad_calcPhotonDose(ct,stf,pln,cst);
```

```
Warning: Could not find HLUT  in hlutLibrary folder. matRad default
 HLUT loaded
Warning: ray does not hit patient. Trying to fix afterwards...matRad:
 Photon dose calculation...
Beam 1 of 5:
matRad: calculate radiological depth cube...done.
                   SSD = 928mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 928 mm ...
Progress: 100.00 %
Beam 2 of 5:
matRad: calculate radiological depth cube...done.
                   SSD = 946mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 946 mm ...
Progress: 100.00 %
Beam 3 of 5:
matRad: calculate radiological depth cube...done.
                   SSD = 928mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 928 mm ...
Progress: 100.00 %
```

```
Beam 4 of 5:
matRad: calculate radiological depth cube...done.
                   SSD = 908mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 908 mm ...
Progress: 100.00 %
Beam 5 of 5:
matRad: calculate radiological depth cube...done.
                   SSD = 934mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 934 mm ...
Progress: 100.00 %
```

Inverse Planning for IMRT

The goal of the fluence optimization is to find a set of beamlet weights which yield the best possible dose distribution according to the predefined clinical objectives and constraints underlying the radiation treatment. Once the optimization has finished, trigger once the GUI to visualize the optimized dose cubes.

```
resultGUI = matRad_fluenceOptimization(dij,cst,pln);
matRadGUI;
```

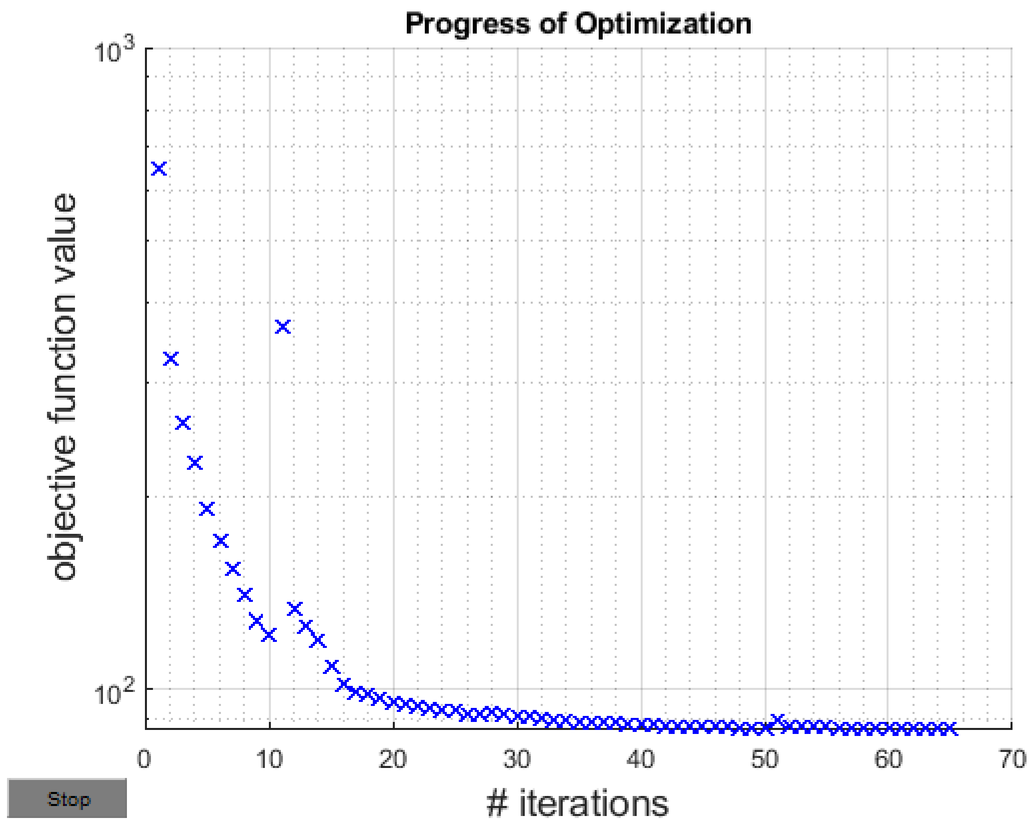
```
Optimzation initiating...
Press q to terminate the optimization...

******************************************************************************
This program contains Ipopt, a library for large-scale nonlinear
 optimization.
 Ipopt is released as open source code under the Eclipse Public
 License (EPL).
         For more information visit http://projects.coin-or.org/Ipopt
******************************************************************************

This is Ipopt version 3.11.8, running with linear solver ma57.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:        0
Number of nonzeros in Lagrangian Hessian.............:        0

Total number of variables............................:     5154
                     variables with only lower bounds:     5154
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:        0
Total number of inequality constraints...............:        0
        inequality constraints with only lower bounds:        0
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        0

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
   0 6.4771531e+002 0.00e+000 9.21e+000   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
```

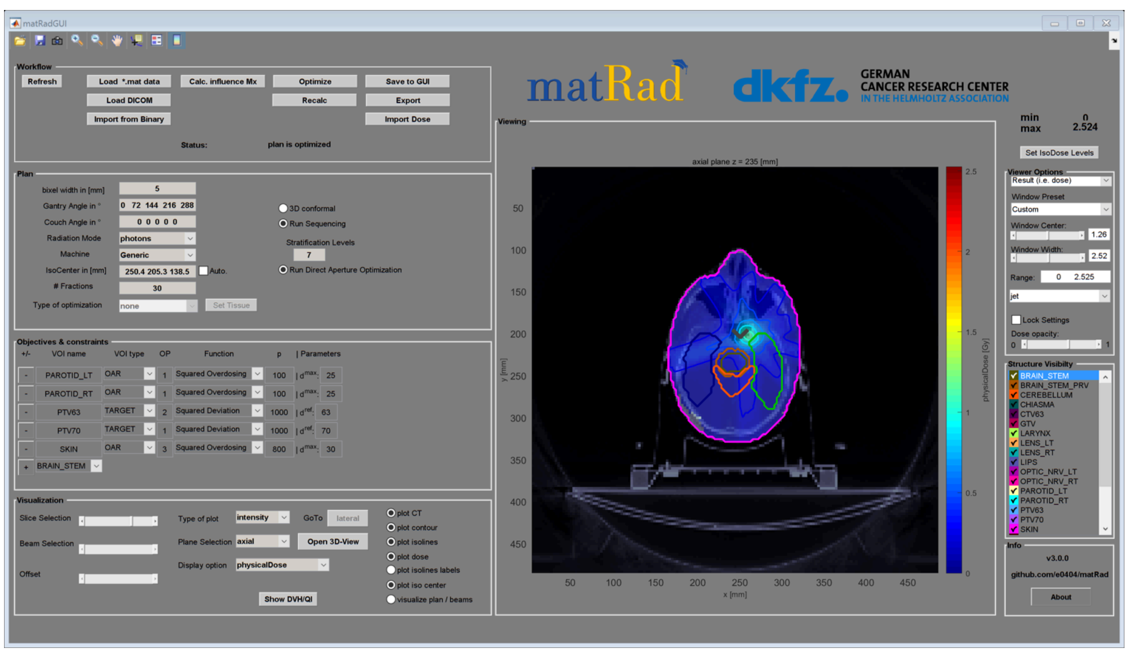
```
   1 3.2860766e+002 0.00e+000 7.93e+000  -1.4 3.53e+000    -
 8.67e-001 1.50e-001f  1
   2 2.5990806e+002 0.00e+000 2.39e+000  -0.6 1.53e-001    -
 9.34e-001 1.00e+000f  1
   3 2.2505426e+002 0.00e+000 1.70e+000  -1.6 9.14e-002    -
 9.99e-001 1.00e+000f  1
   4 1.9102452e+002 0.00e+000 9.65e-001  -2.3 2.30e-001    -
 9.97e-001 6.30e-001f  1
   5 1.7088062e+002 0.00e+000 1.03e+000  -3.0 2.45e-001    -  1.00e
+000 3.98e-001f  1
   6 1.5449708e+002 0.00e+000 2.46e+000  -3.5 4.15e-001    -  1.00e
+000 2.90e-001f  1
   7 1.4044168e+002 0.00e+000 1.38e+000  -3.8 3.59e-001    -  1.00e
+000 3.12e-001f  1
   8 1.2771270e+002 0.00e+000 1.01e+000  -4.0 3.65e-001    -  1.00e
+000 3.07e-001f  1
   9 1.2148594e+002 0.00e+000 1.44e+000  -2.3 4.01e-001    -
 9.91e-001 1.52e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  10 3.6712098e+002 0.00e+000 5.34e+000  -0.3 8.11e+000    -
 5.37e-002 2.33e-001f  1
  11 1.3414426e+002 0.00e+000 1.29e+000  -1.4 1.40e+000    -  1.00e
+000 8.62e-001f  1
  12 1.2564833e+002 0.00e+000 2.41e+000  -1.4 2.40e-001    -  1.00e
+000 5.00e-001f  2
  13 1.1927263e+002 0.00e+000 8.94e-001  -1.4 1.10e-001    -  1.00e
+000 1.00e+000f  1
  14 1.0845231e+002 0.00e+000 7.47e-001  -2.2 2.57e-001    -
 9.84e-001 8.95e-001f  1
  15 1.0199360e+002 0.00e+000 5.46e-001  -2.4 1.70e-001    -
 9.84e-001 1.00e+000f  1
  16 9.8662486e+001 0.00e+000 3.25e-001  -3.1 1.31e-001    -
 9.99e-001 6.05e-001f  1
  17 9.8203457e+001 0.00e+000 1.35e+000  -3.9 6.49e-002    -  1.00e
+000 1.83e-001f  1
  18 9.6541088e+001 0.00e+000 3.45e-001  -4.2 1.67e-001    -  1.00e
+000 2.97e-001f  1
  19 9.5230975e+001 0.00e+000 3.96e-001  -3.2 1.81e-001    -  1.00e
+000 2.62e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  20 9.4673018e+001 0.00e+000 6.73e-001  -3.4 1.16e-001    -  1.00e
+000 1.91e-001f  1
  21 9.3796020e+001 0.00e+000 3.16e-001  -2.8 1.01e-001    -
 7.60e-001 4.68e-001f  1
  22 9.3342164e+001 0.00e+000 4.59e-001  -8.8 9.99e-002    -
 6.19e-001 2.09e-001f  1
  23 9.2914720e+001 0.00e+000 7.43e-001  -4.3 9.72e-002    -
 8.35e-001 2.06e-001f  1
  24 9.2678388e+001 0.00e+000 4.81e-001  -4.8 1.21e-001    -
 9.79e-001 8.52e-002f  1
  25 9.1706231e+001 0.00e+000 4.49e-001  -5.0 1.84e-001    -
 9.05e-001 2.60e-001f  1
```

```
  26 9.1354083e+001 0.00e+000 4.92e-001  -3.5 1.02e-001    -
 7.45e-001 1.97e-001f  1
  27 9.2153984e+001 0.00e+000 3.11e-001  -2.5 9.37e-002    -
 5.79e-001 1.00e+000f  1
  28 9.1418215e+001 0.00e+000 1.89e-001  -2.8 7.46e-002    -  1.00e
+000 6.75e-001f  1
  29 9.0921978e+001 0.00e+000 2.58e-001  -2.8 5.31e-002    -
 7.29e-001 1.00e+000f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  30 9.0562327e+001 0.00e+000 4.70e-001  -3.5 6.80e-002    -
 9.54e-001 2.98e-001f  1
  31 8.9993608e+001 0.00e+000 2.62e-001  -4.4 9.87e-002    -  1.00e
+000 3.69e-001f  1
  32 8.9551052e+001 0.00e+000 3.09e-001  -4.8 1.12e-001    -  1.00e
+000 3.06e-001f  1
  33 8.9461517e+001 0.00e+000 2.04e-001  -3.0 4.80e-002    -
 8.31e-001 3.33e-001f  1
  34 8.9150352e+001 0.00e+000 2.32e-001  -3.4 9.76e-002    -
 6.22e-001 3.32e-001f  1
  35 8.9046492e+001 0.00e+000 2.04e-001  -2.9 6.45e-002    -
 4.89e-001 5.23e-001f  1
  36 8.8852833e+001 0.00e+000 2.74e-001  -3.1 4.29e-002    -
 6.53e-001 6.72e-001f  1
  37 8.8646192e+001 0.00e+000 2.29e-001  -3.8 5.17e-002    -
 8.17e-001 2.68e-001f  1
  38 8.8377508e+001 0.00e+000 3.03e-001  -4.0 8.15e-002    -
 8.35e-001 2.67e-001f  1
  39 8.8020911e+001 0.00e+000 2.24e-001  -4.8 1.33e-001    -
 7.62e-001 3.06e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  40 8.7978443e+001 0.00e+000 1.80e-001  -5.5 5.47e-002    -
 1.77e-001 7.16e-002f  1
  41 8.7866486e+001 0.00e+000 1.43e-001  -6.2 9.28e-002    -
 3.77e-001 1.29e-001f  1
  42 8.7716209e+001 0.00e+000 2.18e-001  -3.9 8.27e-002    -
 7.31e-001 2.21e-001f  1
  43 8.7624656e+001 0.00e+000 2.15e-001  -4.0 6.12e-002    -
 4.72e-001 1.87e-001f  1
  44 8.7578000e+001 0.00e+000 1.52e-001  -3.4 2.87e-002    -
 4.61e-001 4.28e-001f  1
  45 8.7515203e+001 0.00e+000 2.22e-001  -3.6 4.49e-002    -
 6.52e-001 2.81e-001f  1
  46 8.7383040e+001 0.00e+000 2.23e-001  -3.9 8.18e-002    -
 9.21e-001 2.83e-001f  1
  47 8.7255724e+001 0.00e+000 2.06e-001  -4.6 1.21e-001    -
 6.78e-001 1.77e-001f  1
  48 8.7198146e+001 0.00e+000 1.83e-001  -4.1 6.69e-002    -
 2.48e-001 1.56e-001f  1
  49 8.7127630e+001 0.00e+000 1.09e-001  -6.1 1.34e-001    -
 5.84e-001 9.82e-002f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
```

```
  50 8.9367743e+001 0.00e+000 5.75e-001  -2.3 2.01e+000    -
 4.83e-002 2.32e-001f  1
  51 8.7774914e+001 0.00e+000 3.45e-001  -3.4 2.93e-001    -  1.00e
+000 6.15e-001f  1
  52 8.7555960e+001 0.00e+000 2.32e-001  -3.4 1.31e-001    -
 3.59e-001 2.66e-001f  2
  53 8.7399237e+001 0.00e+000 3.03e-001  -3.4 7.08e-002    -
 7.97e-001 3.05e-001f  1
  54 8.7279269e+001 0.00e+000 1.76e-001  -3.4 4.68e-002    -
 9.30e-001 3.81e-001f  1
  55 8.7164595e+001 0.00e+000 2.95e-001  -3.4 2.86e-002    -  1.00e
+000 7.17e-001f  1
  56 8.7122841e+001 0.00e+000 2.78e-001  -3.4 1.48e-002    -
 8.31e-001 8.11e-001f  1
  57 8.7083317e+001 0.00e+000 6.70e-001  -4.3 3.31e-002    -
 9.38e-001 1.93e-001f  1
  58 8.6932450e+001 0.00e+000 1.74e-001  -4.1 1.08e-001    -
 8.81e-001 2.24e-001f  1
  59 8.6851951e+001 0.00e+000 1.30e-001  -4.3 6.39e-002    -
 4.06e-001 1.90e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  60 8.6737784e+001 0.00e+000 1.30e-001  -4.0 6.90e-002    -
 9.25e-001 3.03e-001f  1
  61 8.6834525e+001 0.00e+000 2.12e-001  -3.4 6.42e-002    -
 6.33e-001 1.00e+000f  1
  62 8.6764152e+001 0.00e+000 7.62e-002  -3.6 4.09e-002    -
 5.23e-001 4.81e-001f  1
  63 8.6709537e+001 0.00e+000 1.94e-001  -3.6 3.54e-002    -
 6.82e-001 6.08e-001f  1
  64 8.6633824e+001 0.00e+000 2.89e-001  -3.9 4.92e-002    -
 6.55e-001 4.03e-001f  1

Number of Iterations....: 64

                                   (scaled)                 (unscaled)
Objective...............:  8.6633823721386804e+001
 8.6633823721386804e+001
Dual infeasibility......:  2.8896098463969461e-001
 2.8896098463969461e-001
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
Complementarity.........:  2.9163500281725727e-004
 2.9163500281725727e-004
Overall NLP error.......:  2.8896098463969461e-001
 2.8896098463969461e-001


Number of objective function evaluations             = 75
Number of objective gradient evaluations             = 65
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 0
Number of equality constraint Jacobian evaluations   = 0
Number of inequality constraint Jacobian evaluations = 0
```

```
Number of Lagrangian Hessian evaluations             = 0
Total CPU secs in IPOPT (w/o function evaluations)   =      8.069
Total CPU secs in NLP function evaluations           =     49.797

EXIT: Solved To Acceptable Level.
```





Sequencing

This is a multileaf collimator leaf sequencing algorithm that is used in order to modulate the intensity of the beams with multiple static segments, so that translates each intensity map into a set of deliverable aperture shapes.

```
resultGUI = matRad_siochiLeafSequencing(resultGUI,stf,dij,5);
```

DAO - Direct Aperture Optimization

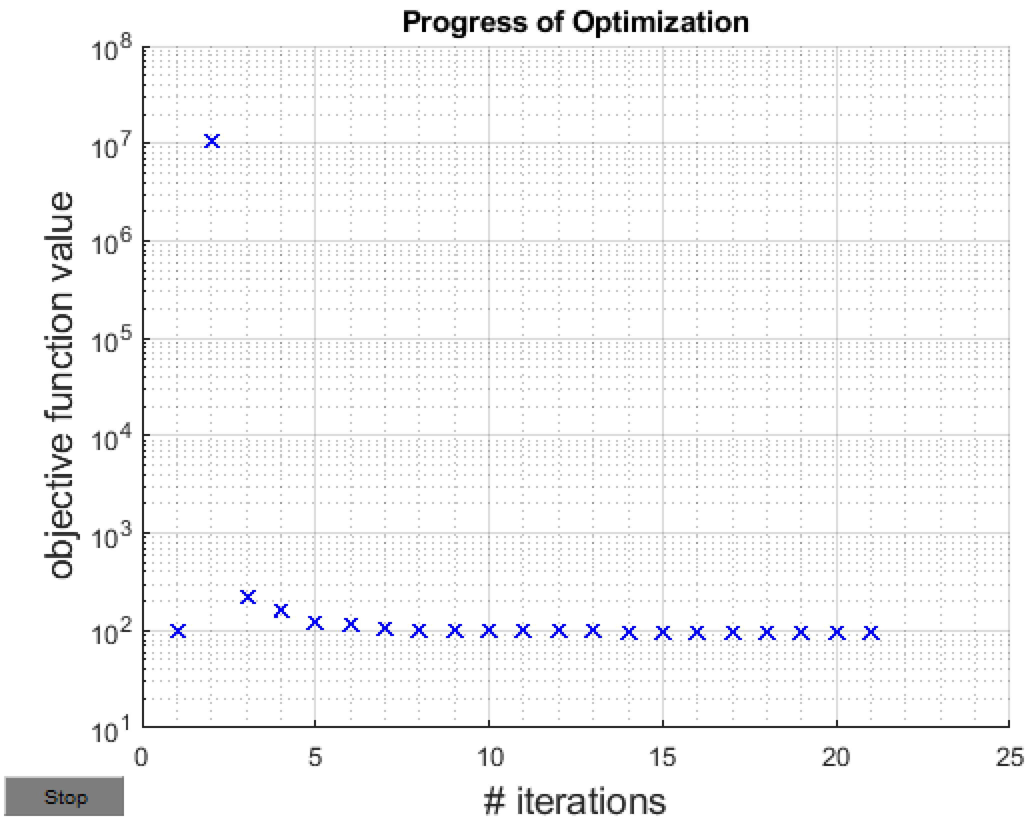
The Direct Aperture Optimization is an optimization approach where we directly optimize aperture shapes and weights.

```
resultGUI =
 matRad_directApertureOptimization(dij,cst,resultGUI.apertureInfo,resultGUI,pln);
```

```
Optimzation initiating...
Press q to terminate the optimization...

******************************************************************************
This program contains Ipopt, a library for large-scale nonlinear
 optimization.
 Ipopt is released as open source code under the Eclipse Public
 License (EPL).
         For more information visit http://projects.coin-or.org/Ipopt
******************************************************************************

This is Ipopt version 3.11.8, running with linear solver ma57.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:     7384
Number of nonzeros in Lagrangian Hessian.............:        0

Total number of variables............................:     7474
                     variables with only lower bounds:       90
                variables with lower and upper bounds:     7384
                     variables with only upper bounds:        0
Total number of equality constraints.................:        0
Total number of inequality constraints...............:     3692
        inequality constraints with only lower bounds:     3692
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        0

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
   0 9.7895119e+001 0.00e+000 3.36e+001   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
   1 1.0772252e+007 0.00e+000 1.03e+005   1.5 3.20e+001    -
 6.10e-001 2.56e-001h  1
   2 2.2610959e+002 0.00e+000 2.43e+002   1.5 8.20e+000    -  1.00e
+000 1.00e+000f  1
```

```
   3 1.5512683e+002 0.00e+000 1.54e+002  -0.6 3.33e-002    -
 9.96e-001 1.00e+000f  1
   4 1.1980575e+002 0.00e+000 5.39e+001  -2.3 4.77e-002    -  1.00e
+000 1.00e+000f  1
   5 1.1315833e+002 0.00e+000 4.37e+001  -3.2 1.47e-002    -  1.00e
+000 1.00e+000f  1
   6 1.0278904e+002 0.00e+000 3.03e+001  -4.3 3.70e-002    -  1.00e
+000 1.00e+000f  1
   7 9.9341316e+001 0.00e+000 2.12e+001  -5.0 2.75e-002    -  1.00e
+000 1.00e+000f  1
   8 9.8073848e+001 0.00e+000 1.24e+001  -6.1 2.66e-002    -  1.00e
+000 1.00e+000f  1
   9 9.7477377e+001 0.00e+000 1.04e+001  -7.4 1.14e-002    -  1.00e
+000 1.00e+000f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  10 9.7243063e+001 0.00e+000 4.77e+000  -9.0 6.86e-003    -  1.00e
+000 1.00e+000f  1
  11 9.6905121e+001 0.00e+000 5.39e+000 -10.3 1.89e-002    -  1.00e
+000 1.00e+000f  1
  12 9.6784784e+001 0.00e+000 1.31e+001 -11.0 2.49e-002    -  1.00e
+000 5.00e-001f  2
  13 9.6614417e+001 0.00e+000 6.01e+000 -11.0 5.98e-003    -  1.00e
+000 1.00e+000f  1
  14 9.6505616e+001 0.00e+000 3.99e+000 -11.0 7.29e-003    -  1.00e
+000 1.00e+000f  1
  15 9.6452649e+001 0.00e+000 4.96e+000 -11.0 4.77e-003    -  1.00e
+000 1.00e+000f  1
  16 9.6347945e+001 0.00e+000 4.17e+000 -11.0 9.26e-003    -  1.00e
+000 1.00e+000f  1
  17 9.6235791e+001 0.00e+000 3.55e+000 -11.0 1.05e-002    -  1.00e
+000 1.00e+000f  1
  18 9.6193240e+001 0.00e+000 5.10e+000 -11.0 1.52e-002    -  1.00e
+000 5.00e-001f  2
  19 9.6144118e+001 0.00e+000 2.11e+000 -11.0 2.21e-003    -  1.00e
+000 1.00e+000f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  20 9.6104548e+001 0.00e+000 2.60e+000 -11.0 3.54e-003    -  1.00e
+000 1.00e+000f  1

Number of Iterations....: 20

                                   (scaled)                 (unscaled)
Objective...............:  9.6104548398403637e+001
 9.6104548398403637e+001
Dual infeasibility......:  2.6026485789285587e+000
 2.6026485789285587e+000
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
Complementarity.........:  1.0000000000000004e-011
 1.0000000000000004e-011
Overall NLP error.......:  2.6026485789285587e+000
 2.6026485789285587e+000
```

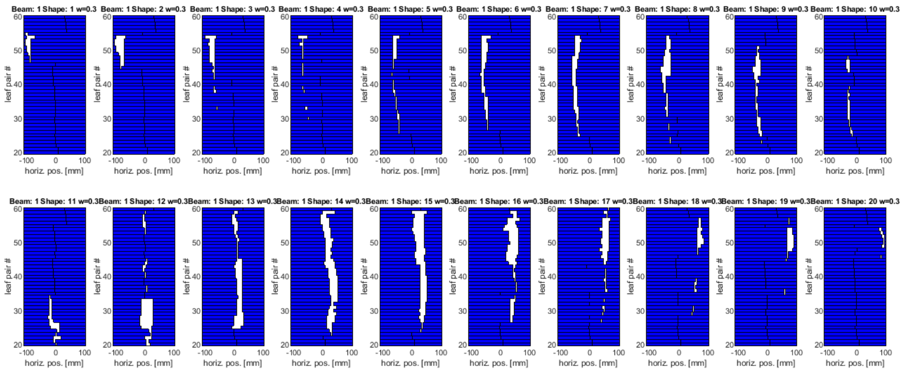
```
Number of objective function evaluations             = 29
Number of objective gradient evaluations             = 21
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 29
Number of equality constraint Jacobian evaluations   = 0
Number of inequality constraint Jacobian evaluations = 21
Number of Lagrangian Hessian evaluations             = 0
Total CPU secs in IPOPT (w/o function evaluations)   =      3.337
Total CPU secs in NLP function evaluations           =     28.775

EXIT: Solved To Acceptable Level.
Calculating final cubes...
```

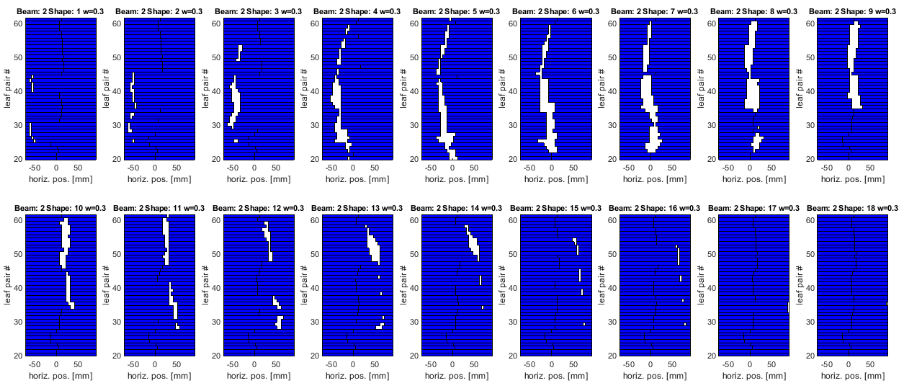


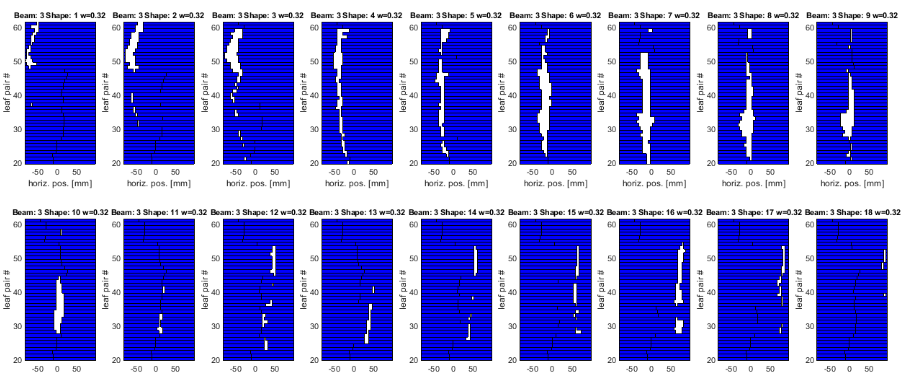
Aperture visualization

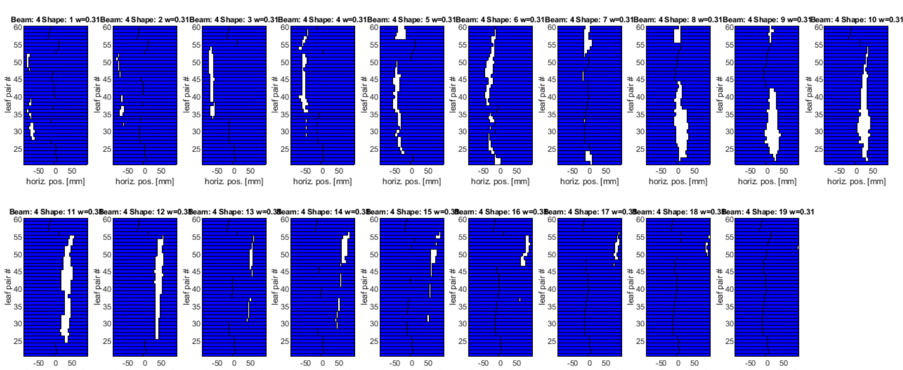
Use a matrad function to visualize the resulting aperture shapes

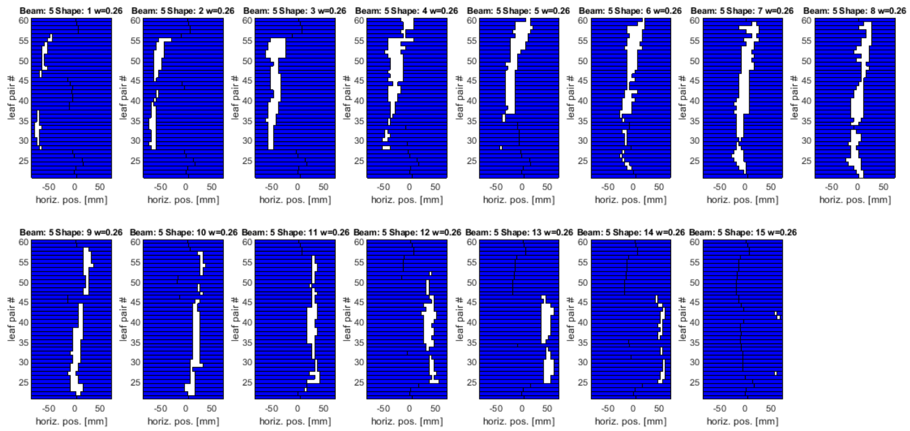
```
matRad_visApertureInfo(resultGUI.apertureInfo);
```


Beam: 1 Shape: 1 w=0.3
Beam: 1 Shape: 2 w=0.3
Beam: 1 Shape: 3 w=0.3
Beam: 1 Shape: 4 w=0.3
Beam: 1 Shape: 5 w=0.3
Beam: 1 Shape: 6 w=0.3
Beam: 1 Shape: 7 w=0.3
Beam: 1 Shape: 8 w=0.3
Beam: 1 Shape: 9 w=0.3
Beam: 1 Shape: 10 w=0.3
Beam: 1 Shape: 11 w=0.3
Beam: 1 Shape: 12 w=0.3
Beam: 1 Shape: 13 w=0.3
Beam: 1 Shape: 14 w=0.3
Beam: 1 Shape: 15 w=0.3
Beam: 1 Shape: 16 w=0.3
Beam: 1 Shape: 17 w=0.3
Beam: 1 Shape: 18 w=0.3
Beam: 1 Shape: 19 w=0.3
Beam: 1 Shape: 20 w=0.3
leaf pair #
horiz. pos. [mm]


Beam: 2 Shape: 1 w=0.3
Beam: 2 Shape: 2 w=0.3
Beam: 2 Shape: 3 w=0.3
Beam: 2 Shape: 4 w=0.3
Beam: 2 Shape: 5 w=0.3
Beam: 2 Shape: 6 w=0.3
Beam: 2 Shape: 7 w=0.3
Beam: 2 Shape: 8 w=0.3
Beam: 2 Shape: 9 w=0.3
Beam: 2 Shape: 10 w=0.3
Beam: 2 Shape: 11 w=0.3
Beam: 2 Shape: 12 w=0.3
Beam: 2 Shape: 13 w=0.3
Beam: 2 Shape: 14 w=0.3
Beam: 2 Shape: 15 w=0.3
Beam: 2 Shape: 16 w=0.3
Beam: 2 Shape: 17 w=0.3
Beam: 2 Shape: 18 w=0.3
leaf pair #
horiz. pos. [mm]


Beam: 3 Shape: 1 w=0.32
Beam: 3 Shape: 2 w=0.32
Beam: 3 Shape: 3 w=0.32
Beam: 3 Shape: 4 w=0.32
Beam: 3 Shape: 5 w=0.32
Beam: 3 Shape: 6 w=0.32
Beam: 3 Shape: 7 w=0.32
Beam: 3 Shape: 8 w=0.32
Beam: 3 Shape: 9 w=0.32
Beam: 3 Shape: 10 w=0.32
Beam: 3 Shape: 11 w=0.32
Beam: 3 Shape: 12 w=0.32
Beam: 3 Shape: 13 w=0.32
Beam: 3 Shape: 14 w=0.32
Beam: 3 Shape: 15 w=0.32
Beam: 3 Shape: 16 w=0.32
Beam: 3 Shape: 17 w=0.32
Beam: 3 Shape: 18 w=0.32
leaf pair #
horiz. pos. [mm]


Beam: 4 Shape: 1 w=0.31
Beam: 4 Shape: 2 w=0.31
Beam: 4 Shape: 3 w=0.31
Beam: 4 Shape: 4 w=0.31
Beam: 4 Shape: 5 w=0.31
Beam: 4 Shape: 6 w=0.31
Beam: 4 Shape: 7 w=0.31
Beam: 4 Shape: 8 w=0.31
Beam: 4 Shape: 9 w=0.31
Beam: 4 Shape: 10 w=0.31
Beam: 4 Shape: 11 w=0.31
Beam: 4 Shape: 12 w=0.31
Beam: 4 Shape: 13 w=0.31
Beam: 4 Shape: 14 w=0.31
Beam: 4 Shape: 15 w=0.31
Beam: 4 Shape: 16 w=0.31
Beam: 4 Shape: 17 w=0.31
Beam: 4 Shape: 18 w=0.31
Beam: 4 Shape: 19 w=0.31
leaf pair #
horiz. pos. [mm]



Indicator Calculation and display of DVH and QI

```
[dvh,qi] = matRad_indicatorWrapper(cst,pln,resultGUI);
```

```
 0           BRAIN_STEM - Mean dose =  0.35 Gy +/-  0.30 Gy (Max dose
=  1.18 Gy, Min dose =  0.03 Gy)
                          D2% =  1.06 Gy, D5% =  0.94 Gy, D50% =
0.24 Gy, D95% =  0.04 Gy, D98% =  0.04 Gy,
                          V0Gy = 100.00%, V0.5Gy =  28.88%, V1Gy =
3.58%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

 1       BRAIN_STEM_PRV - Mean dose =  0.35 Gy +/-  0.32 Gy (Max dose
=  1.27 Gy, Min dose =  0.02 Gy)
                          D2% =  1.09 Gy, D5% =  0.97 Gy, D50% =
0.24 Gy, D95% =  0.03 Gy, D98% =  0.03 Gy,
                          V0Gy = 100.00%, V0.5Gy =  30.49%, V1Gy =
4.15%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

 2           CEREBELLUM - Mean dose =  0.58 Gy +/-  0.32 Gy (Max dose
=  1.70 Gy, Min dose =  0.03 Gy)
                          D2% =  1.32 Gy, D5% =  1.15 Gy, D50% =
0.55 Gy, D95% =  0.11 Gy, D98% =  0.06 Gy,
                          V0Gy = 100.00%, V0.5Gy =  56.06%, V1Gy =
11.79%, V1.5Gy =   0.55%, V2Gy =   0.00%, V2.5Gy =   0.00%,

 3              CHIASMA - Mean dose =  0.10 Gy +/-  0.02 Gy (Max dose
=  0.13 Gy, Min dose =  0.06 Gy)
                          D2% =  0.13 Gy, D5% =  0.12 Gy, D50% =
0.11 Gy, D95% =  0.07 Gy, D98% =  0.06 Gy,
                          V0Gy = 100.00%, V0.5Gy =   0.00%, V1Gy =
0.00%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

 5                CTV63 - Mean dose =  2.11 Gy +/-  0.21 Gy (Max dose
=  2.51 Gy, Min dose =  0.52 Gy)
```

```
                          D2% =  2.40 Gy, D5% =  2.35 Gy, D50% =
2.13 Gy, D95% =  1.89 Gy, D98% =  1.60 Gy,
                          V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy =
99.10%, V1.5Gy =  98.27%, V2Gy =  85.33%, V2.5Gy =   0.02%,
                          Warning: target has no objective that
penalizes underdosage,
 6                  GTV - Mean dose =  2.31 Gy +/-  0.08 Gy (Max dose
=  2.52 Gy, Min dose =  2.09 Gy)
                          D2% =  2.47 Gy, D5% =  2.44 Gy, D50% =
2.31 Gy, D95% =  2.19 Gy, D98% =  2.16 Gy,
                          V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy =
100.00%, V1.5Gy = 100.00%, V2Gy = 100.00%, V2.5Gy =   0.20%,
                          Warning: target has no objective that
penalizes underdosage,
 7               LARYNX - Mean dose =  1.20 Gy +/-  0.23 Gy (Max dose
=  1.83 Gy, Min dose =  0.83 Gy)
                          D2% =  1.70 Gy, D5% =  1.68 Gy, D50% =
1.16 Gy, D95% =  0.89 Gy, D98% =  0.87 Gy,
                          V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy =
80.27%, V1.5Gy =  11.56%, V2Gy =   0.00%, V2.5Gy =   0.00%,

 8              LENS_LT - Mean dose =  0.01 Gy +/-  0.00 Gy (Max dose
=  0.01 Gy, Min dose =  0.00 Gy)
                          D2% =  0.01 Gy, D5% =  0.01 Gy, D50% =
0.01 Gy, D95% =  0.01 Gy, D98% =  0.00 Gy,
                          V0Gy = 100.00%, V0.5Gy =   0.00%, V1Gy =
0.00%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

 9              LENS_RT - Mean dose =  0.01 Gy +/-  0.00 Gy (Max dose
=  0.01 Gy, Min dose =  0.01 Gy)
                          D2% =  0.01 Gy, D5% =  0.01 Gy, D50% =
0.01 Gy, D95% =  0.01 Gy, D98% =  0.01 Gy,
                          V0Gy = 100.00%, V0.5Gy =   0.00%, V1Gy =
0.00%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

10                 LIPS - Mean dose =  0.96 Gy +/-  0.36 Gy (Max dose
=  2.09 Gy, Min dose =  0.25 Gy)
                          D2% =  1.76 Gy, D5% =  1.62 Gy, D50% =
0.94 Gy, D95% =  0.44 Gy, D98% =  0.36 Gy,
                          V0Gy = 100.00%, V0.5Gy =  91.40%, V1Gy =
44.09%, V1.5Gy =   7.53%, V2Gy =   1.08%, V2.5Gy =   0.00%,

11          OPTIC_NRV_LT - Mean dose =  0.06 Gy +/-  0.03 Gy (Max dose
=  0.14 Gy, Min dose =  0.02 Gy)
                          D2% =  0.14 Gy, D5% =  0.13 Gy, D50% =
0.05 Gy, D95% =  0.02 Gy, D98% =  0.02 Gy,
                          V0Gy = 100.00%, V0.5Gy =   0.00%, V1Gy =
0.00%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

12          OPTIC_NRV_RT - Mean dose =  0.05 Gy +/-  0.03 Gy (Max dose
=  0.12 Gy, Min dose =  0.01 Gy)
                          D2% =  0.12 Gy, D5% =  0.11 Gy, D50% =
0.04 Gy, D95% =  0.02 Gy, D98% =  0.02 Gy,
```

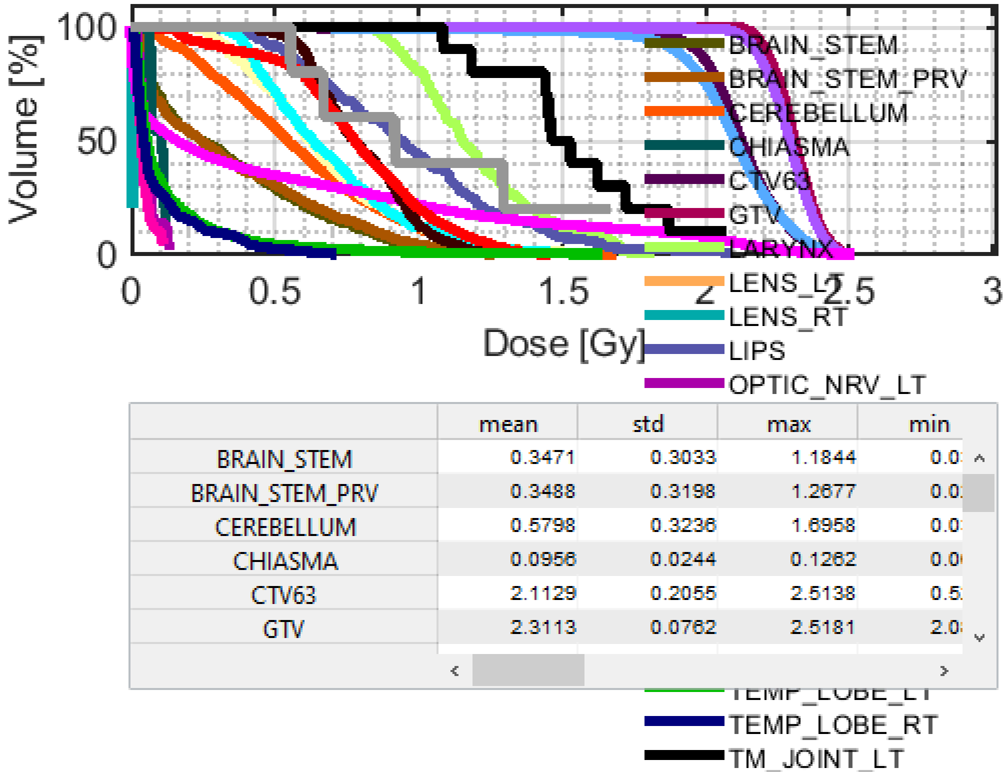
```
                          V0Gy = 100.00%, V0.5Gy =   0.00%, V1Gy =
0.00%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

13            PAROTID_LT - Mean dose =  0.66 Gy +/-  0.27 Gy (Max dose
=  1.61 Gy, Min dose =  0.21 Gy)
                          D2% =  1.31 Gy, D5% =  1.21 Gy, D50% =
0.63 Gy, D95% =  0.29 Gy, D98% =  0.26 Gy,
                          V0Gy = 100.00%, V0.5Gy =  70.72%, V1Gy =
12.39%, V1.5Gy =   0.90%, V2Gy =   0.00%, V2.5Gy =   0.00%,

14            PAROTID_RT - Mean dose =  0.69 Gy +/-  0.25 Gy (Max dose
=  1.57 Gy, Min dose =  0.30 Gy)
                          D2% =  1.29 Gy, D5% =  1.18 Gy, D50% =
0.63 Gy, D95% =  0.38 Gy, D98% =  0.35 Gy,
                          V0Gy = 100.00%, V0.5Gy =  72.37%, V1Gy =
12.09%, V1.5Gy =   0.16%, V2Gy =   0.00%, V2.5Gy =   0.00%,

16                 PTV63 - Mean dose =  2.09 Gy +/-  0.22 Gy (Max dose
=  2.51 Gy, Min dose =  0.55 Gy)
                          D2% =  2.40 Gy, D5% =  2.36 Gy, D50% =
2.10 Gy, D95% =  1.79 Gy, D98% =  1.51 Gy,
                          V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy =
99.12%, V1.5Gy =  98.04%, V2Gy =  75.61%, V2.5Gy =   0.03%,
                          Warning: target has no objective that
penalizes underdosage,
17                 PTV70 - Mean dose =  2.29 Gy +/-  0.11 Gy (Max dose
=  2.52 Gy, Min dose =  0.71 Gy)
                          D2% =  2.46 Gy, D5% =  2.43 Gy, D50% =
2.29 Gy, D95% =  2.14 Gy, D98% =  2.09 Gy,
                          V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy =
99.90%, V1.5Gy =  99.87%, V2Gy =  99.21%, V2.5Gy =   0.18%,
                          Warning: target has no objective that
penalizes underdosage,
18                  SKIN - Mean dose =  0.53 Gy +/-  0.69 Gy (Max dose
=  2.52 Gy, Min dose =  0.00 Gy)
                          D2% =  2.26 Gy, D5% =  2.11 Gy, D50% =
0.16 Gy, D95% =  0.00 Gy, D98% =  0.00 Gy,
                          V0Gy = 100.00%, V0.5Gy =  34.68%, V1Gy =
21.83%, V1.5Gy =  13.02%, V2Gy =   7.65%, V2.5Gy =   0.00%,

19           SPINAL_CORD - Mean dose =  0.80 Gy +/-  0.18 Gy (Max dose
=  1.30 Gy, Min dose =  0.43 Gy)
                          D2% =  1.17 Gy, D5% =  1.11 Gy, D50% =
0.78 Gy, D95% =  0.55 Gy, D98% =  0.48 Gy,
                          V0Gy = 100.00%, V0.5Gy =  97.18%, V1Gy =
13.65%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,

20          SPINL_CRD_PRV - Mean dose =  0.77 Gy +/-  0.28 Gy (Max dose
=  1.46 Gy, Min dose =  0.06 Gy)
                          D2% =  1.31 Gy, D5% =  1.24 Gy, D50% =
0.78 Gy, D95% =  0.19 Gy, D98% =  0.16 Gy,
                          V0Gy = 100.00%, V0.5Gy =  85.80%, V1Gy =
20.40%, V1.5Gy =   0.00%, V2Gy =   0.00%, V2.5Gy =   0.00%,
```

21 TEMP_LOBE_LT - Mean dose = 0.13 Gy +/- 0.18 Gy (Max dose = 1.64 Gy, Min dose = 0.01 Gy)
D2% = 0.75 Gy, D5% = 0.46 Gy, D50% = 0.06 Gy, D95% = 0.02 Gy, D98% = 0.01 Gy,
V0Gy = 100.00%, V0.5Gy = 4.26%, V1Gy = 0.83%, V1.5Gy = 0.16%, V2Gy = 0.00%, V2.5Gy = 0.00%,

22 TEMP_LOBE_RT - Mean dose = 0.10 Gy +/- 0.13 Gy (Max dose = 0.72 Gy, Min dose = 0.00 Gy)
D2% = 0.52 Gy, D5% = 0.41 Gy, D50% = 0.05 Gy, D95% = 0.01 Gy, D98% = 0.01 Gy,
V0Gy = 100.00%, V0.5Gy = 2.38%, V1Gy = 0.00%, V1.5Gy = 0.00%, V2Gy = 0.00%, V2.5Gy = 0.00%,

23 TM_JOINT_LT - Mean dose = 1.55 Gy +/- 0.30 Gy (Max dose = 2.07 Gy, Min dose = 1.09 Gy)
D2% = 2.04 Gy, D5% = 1.98 Gy, D50% = 1.50 Gy, D95% = 1.13 Gy, D98% = 1.10 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 100.00%, V1.5Gy = 50.00%, V2Gy = 10.00%, V2.5Gy = 0.00%,

24 TM_JOINT_RT - Mean dose = 1.02 Gy +/- 0.46 Gy (Max dose = 1.67 Gy, Min dose = 0.56 Gy)
D2% = 1.64 Gy, D5% = 1.60 Gy, D50% = 0.92 Gy, D95% = 0.58 Gy, D98% = 0.57 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 40.00%, V1.5Gy = 20.00%, V2Gy = 0.00%, V2.5Gy = 0.00%,



	mean	std	max	min
BRAIN_STEM	0.3471	0.3033	1.1844	0.0
BRAIN_STEM_PRV	0.3488	0.3198	1.2677	0.0
CEREBELLUM	0.5798	0.3236	1.6958	0.0
CHIASMA	0.0956	0.0244	0.1262	0.0
CTV63	2.1129	0.2055	2.5138	0.5
GTV	2.3113	0.0762	2.5181	2.0

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