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.bioOptimization = 'none';
pln.gantryAngles    = [0:72:359];
```

```
pln.couchAngles     = [0 0 0 0 0];
pln.bixelWidth      = 5;
pln.numOfFractions  = 30;
pln.numOfBeams      = numel(pln.gantryAngles);
pln.numOfVoxels     = prod(ct.cubeDim);
pln.voxelDimensions = ct.cubeDim;
pln.isoCenter       = ones(pln.numOfBeams,1) *
 matRad_getIsoCenter(cst,ct,0);
```

Enable sequencing and direct aperture optimization (DAO).

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

Generate Beam Geometry STF

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

```
matRad: Generating stf struct... 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);
```

```
matRad: Photon dose calculation...
Beam 1 of 5:
matRad: calculate radiological depth cube...done
                   SSD = 933mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 933 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 = 909mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 909 mm ...
Progress: 100.00 %
Beam 5 of 5:
```

```
matRad: calculate radiological depth cube...done
                  SSD = 937mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 937 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;
```

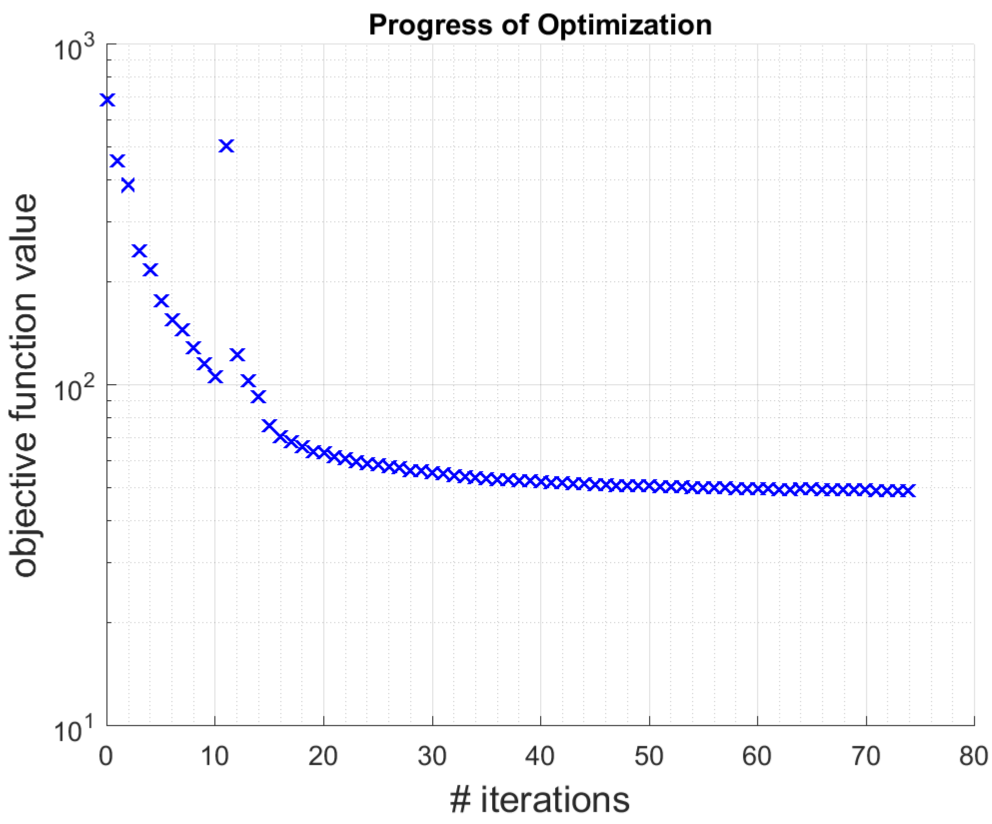
```

******************************************************************************
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............................:     5509
                     variables with only lower bounds:     5509
                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 6.8882708e+002 0.00e+000 9.32e+000   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
   1 4.5494442e+002 0.00e+000 2.39e+001  -6.3 3.59e+000    -
 9.78e-001 1.47e-001f  1
   2 3.8714260e+002 0.00e+000 4.07e+000  -0.1 2.17e-001    -
 7.98e-001 1.00e+000f  1
   3 2.4812628e+002 0.00e+000 2.43e+000  -1.5 1.49e-001    -
 9.88e-001 8.71e-001f  1
   4 2.1758854e+002 0.00e+000 2.64e+000  -2.0 1.33e-001    -
 9.97e-001 4.22e-001f  1
   5 1.7702810e+002 0.00e+000 1.59e+000  -2.6 2.26e-001    -  1.00e
+000 5.57e-001f  1
```

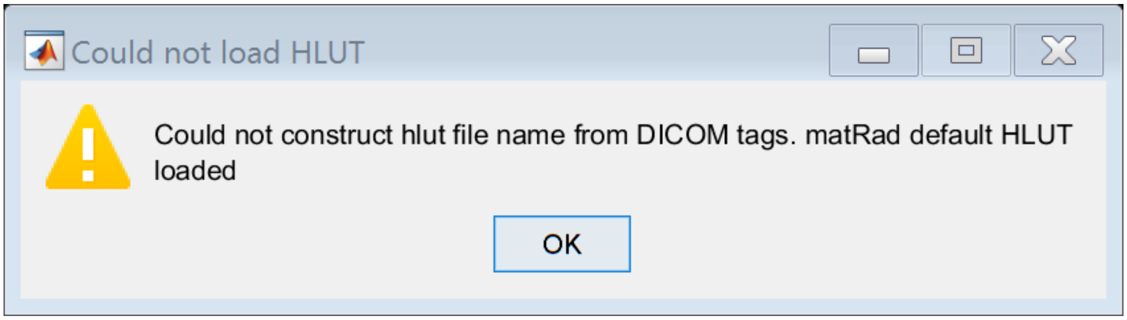
```
   6 1.5571072e+002 0.00e+000 1.98e+000  -3.2 2.45e-001    -  1.00e
+000 3.81e-001f  1
   7 1.4525952e+002 0.00e+000 3.47e+000  -3.8 1.94e-001    -  1.00e
+000 2.72e-001f  1
   8 1.2857140e+002 0.00e+000 1.46e+000  -4.1 2.78e-001    -  1.00e
+000 3.36e-001f  1
   9 1.1553325e+002 0.00e+000 1.82e+000  -4.4 4.25e-001    -  1.00e
+000 2.13e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  10 1.0604180e+002 0.00e+000 4.61e+000  -2.2 2.88e-001    -
 9.95e-001 2.42e-001f  1
  11 5.0547363e+002 0.00e+000 1.13e+001  -0.2 7.17e+000    -
 6.93e-002 2.08e-001f  1
  12 1.2276085e+002 0.00e+000 3.64e+000  -1.2 1.17e+000    -
 5.05e-001 8.65e-001f  1
  13 1.0336376e+002 0.00e+000 4.41e+000  -1.2 1.99e-001    -  1.00e
+000 1.00e+000f  1
  14 9.2405567e+001 0.00e+000 1.32e+000  -2.7 2.30e-001    -
 7.72e-001 4.31e-001f  1
  15 7.6082865e+001 0.00e+000 1.03e+000  -2.3 2.16e-001    -
 9.93e-001 8.58e-001f  1
  16 7.0741978e+001 0.00e+000 5.18e-001  -3.0 1.95e-001    -
 9.98e-001 3.70e-001f  1
  17 6.8403719e+001 0.00e+000 8.95e-001  -3.4 9.81e-002    -  1.00e
+000 5.20e-001f  1
  18 6.6036005e+001 0.00e+000 6.10e-001  -3.5 1.77e-001    -
 8.94e-001 3.62e-001f  1
  19 6.4000118e+001 0.00e+000 1.74e+000  -2.5 1.63e-001    -
 7.19e-001 6.54e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  20 6.3321589e+001 0.00e+000 4.15e-001  -2.3 6.37e-002    -
 6.27e-001 1.00e+000f  1
  21 6.1677307e+001 0.00e+000 3.28e-001  -2.8 1.04e-001    -
 6.89e-001 6.10e-001f  1
  22 6.1082144e+001 0.00e+000 8.12e-001  -3.2 1.04e-001    -  1.00e
+000 1.89e-001f  1
  23 5.9694823e+001 0.00e+000 6.40e-001  -4.2 1.72e-001    -
 7.74e-001 2.94e-001f  1
  24 5.8825288e+001 0.00e+000 4.43e-001  -4.6 1.94e-001    -
 7.35e-001 1.56e-001f  1
  25 5.8542424e+001 0.00e+000 9.06e-001  -2.5 1.00e-001    -
 4.48e-001 1.00e+000f  1
  26 5.7723320e+001 0.00e+000 5.66e-001  -3.3 8.97e-002    -
 9.84e-001 3.25e-001f  1
  27 5.7367550e+001 0.00e+000 9.97e-001  -4.1 1.01e-001    -
 9.74e-001 1.40e-001f  1
  28 5.6256513e+001 0.00e+000 4.54e-001  -4.6 1.51e-001    -  1.00e
+000 3.22e-001f  1
  29 5.5962775e+001 0.00e+000 5.41e-001  -4.6 1.52e-001    -  1.00e
+000 8.96e-002f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
```

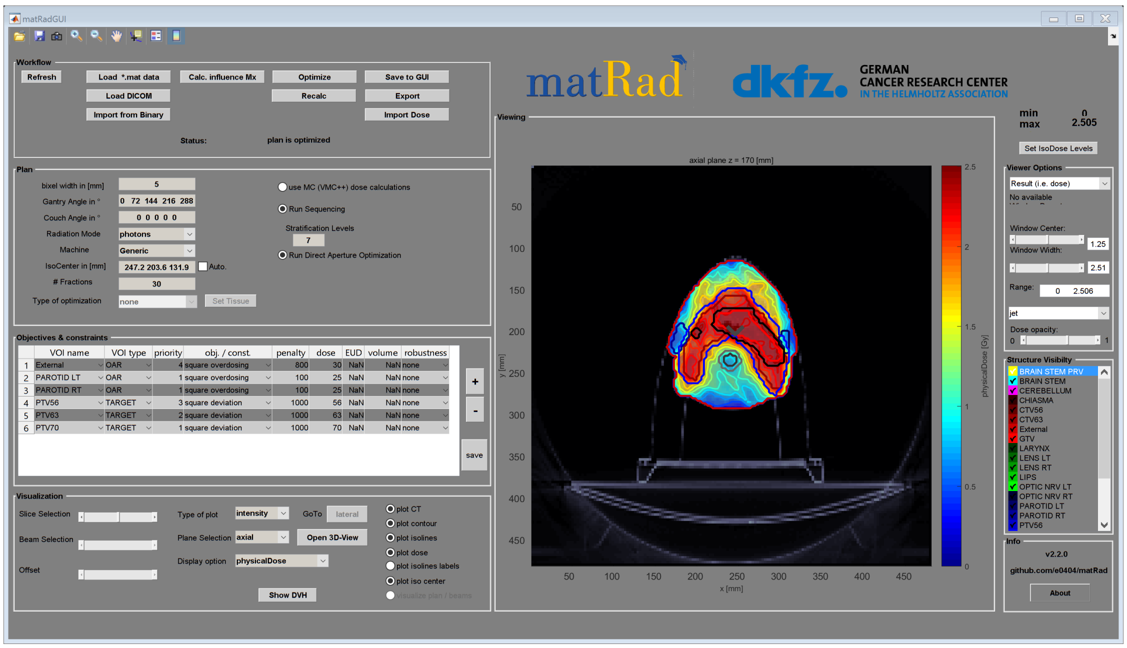
```
  30 5.5361254e+001 0.00e+000 3.40e-001  -2.9 6.76e-002    -
 6.90e-001 5.77e-001f  1
  31 5.4929332e+001 0.00e+000 3.66e-001  -3.1 1.04e-001    -
 9.14e-001 3.10e-001f  1
  32 5.4360853e+001 0.00e+000 3.33e-001  -3.1 1.64e-001    -
 6.40e-001 3.31e-001f  1
  33 5.3992746e+001 0.00e+000 4.32e-001  -3.6 1.70e-001    -
 8.32e-001 1.92e-001f  1
  34 5.3483912e+001 0.00e+000 4.00e-001  -5.5 1.64e-001    -
 6.33e-001 2.44e-001f  1
  35 5.3275247e+001 0.00e+000 5.60e-001  -5.6 1.38e-001    -
 8.06e-001 1.19e-001f  1
  36 5.2928604e+001 0.00e+000 1.42e+000  -3.2 2.24e-001    -
 8.57e-001 3.18e-001f  1
  37 5.2763067e+001 0.00e+000 5.54e-001  -3.2 4.34e-002    -
 6.62e-001 3.53e-001f  1
  38 5.2632590e+001 0.00e+000 2.07e-001  -3.0 8.04e-002    -
 5.00e-001 3.63e-001f  1
  39 5.2415117e+001 0.00e+000 6.25e-001  -3.1 9.19e-002    -
 6.07e-001 6.03e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  40 5.2251280e+001 0.00e+000 4.46e-001  -3.5 6.16e-002    -
 9.19e-001 3.17e-001f  1
  41 5.1927740e+001 0.00e+000 2.86e-001  -4.3 1.09e-001    -
 8.21e-001 2.88e-001f  1
  42 5.1669907e+001 0.00e+000 4.25e-001  -3.2 7.30e-002    -
 8.15e-001 5.01e-001f  1
  43 5.1561416e+001 0.00e+000 3.28e-001  -4.0 7.51e-002    -
 5.48e-001 1.39e-001f  1
  44 5.1294910e+001 0.00e+000 2.72e-001  -3.8 8.81e-002    -
 4.79e-001 2.94e-001f  1
  45 5.1129004e+001 0.00e+000 1.46e-001  -3.3 8.01e-002    -
 8.45e-001 3.30e-001f  1
  46 5.0981941e+001 0.00e+000 2.93e-001  -3.8 6.91e-002    -
 5.37e-001 2.88e-001f  1
  47 5.0901426e+001 0.00e+000 2.94e-001  -3.5 6.76e-002    -
 4.93e-001 2.29e-001f  1
  48 5.0790775e+001 0.00e+000 1.84e-001  -3.3 9.27e-002    -
 8.10e-001 4.64e-001f  1
  49 5.0742311e+001 0.00e+000 4.61e-001  -3.5 5.89e-002    -
 7.94e-001 1.84e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  50 5.0564001e+001 0.00e+000 2.99e-001  -5.6 8.91e-002    -
 6.43e-001 3.01e-001f  1
  51 5.0429336e+001 0.00e+000 3.36e-001  -5.7 8.96e-002    -
 6.63e-001 2.02e-001f  1
  52 5.0359257e+001 0.00e+000 2.74e-001  -5.0 8.70e-002    -
 6.60e-001 9.73e-002f  1
  53 5.0238824e+001 0.00e+000 4.22e-001  -3.4 6.30e-002    -
 8.97e-001 4.14e-001f  1
  54 5.0130618e+001 0.00e+000 2.52e-001  -4.3 7.25e-002    -
 5.37e-001 2.30e-001f  1
```

```
  55 5.0067933e+001 0.00e+000 3.48e-001  -4.2 5.79e-002    -
 7.37e-001 1.79e-001f  1
  56 4.9964110e+001 0.00e+000 2.09e-001  -3.9 6.88e-002    -
 6.63e-001 2.69e-001f  1
  57 4.9887348e+001 0.00e+000 3.42e-001  -4.3 9.66e-002    -
 9.10e-001 1.45e-001f  1
  58 4.9786089e+001 0.00e+000 2.30e-001  -3.8 7.28e-002    -
 3.42e-001 3.10e-001f  1
  59 4.9724506e+001 0.00e+000 1.40e-001  -4.5 8.41e-002    -
 4.21e-001 1.46e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  60 4.9663774e+001 0.00e+000 1.68e-001  -3.8 7.33e-002    -
 5.67e-001 1.89e-001f  1
  61 4.9602508e+001 0.00e+000 2.03e-001  -4.1 9.64e-002    -
 5.93e-001 1.43e-001f  1
  62 4.9538466e+001 0.00e+000 1.83e-001  -5.2 8.23e-002    -
 2.73e-001 1.66e-001f  1
  63 4.9459492e+001 0.00e+000 2.20e-001  -4.4 1.28e-001    -
 8.84e-001 1.87e-001f  1
  64 4.9593548e+001 0.00e+000 2.56e-001  -3.4 3.68e-002    -
 4.99e-001 1.00e+000f  1
  65 4.9560918e+001 0.00e+000 3.08e-001  -3.7 3.65e-002    -
 7.85e-001 2.35e-001f  1
  66 4.9480231e+001 0.00e+000 2.18e-001  -3.7 6.85e-002    -  1.00e
+000 5.00e-001f  1
  67 4.9454339e+001 0.00e+000 2.80e-001  -3.7 2.29e-002    -
 9.02e-001 3.18e-001f  1
  68 4.9328713e+001 0.00e+000 5.14e-001  -3.9 2.79e-002    -
 6.34e-001 7.40e-001f  1
  69 4.9290009e+001 0.00e+000 2.79e-001  -9.8 3.92e-002    -
 4.60e-001 1.81e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  70 4.9254861e+001 0.00e+000 2.77e-001  -4.8 5.09e-002    -
 8.71e-001 1.50e-001f  1
  71 4.9191540e+001 0.00e+000 2.10e-001  -4.4 6.44e-002    -
 8.18e-001 2.53e-001f  1
  72 4.9176861e+001 0.00e+000 2.86e-001  -3.7 5.56e-002    -
 6.96e-001 4.93e-001f  1
  73 4.9162780e+001 0.00e+000 2.04e-001  -4.0 2.58e-002    -
 6.24e-001 1.83e-001f  1
  74 4.9126416e+001 0.00e+000 2.45e-001  -4.0 4.42e-002    -
 4.39e-001 3.43e-001f  1

Number of Iterations....: 74

                                   (scaled)                 (unscaled)
Objective...............:  4.9126415715814112e+001
 4.9126415715814112e+001
Dual infeasibility......:  2.4547369232709243e-001
 2.4547369232709243e-001
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
```

```
Complementarity.........:  1.4602197203241181e-004
 1.4602197203241181e-004
Overall NLP error.......:  2.4547369232709243e-001
 2.4547369232709243e-001


Number of objective function evaluations             = 75
Number of objective gradient evaluations             = 75
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)   =      3.508
Total CPU secs in NLP function evaluations           =     29.392

EXIT: Solved To Acceptable Level.
Calculating final cubes...
Warning: matRad default HLUT loaded
Reconversion of HU values could not be done because HLUT is not
 bijective.
Warning: 'popupmenu' control requires that 'Value' be an integer
 within
String range
Control will not be rendered until all of its parameter values are
 valid
```







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

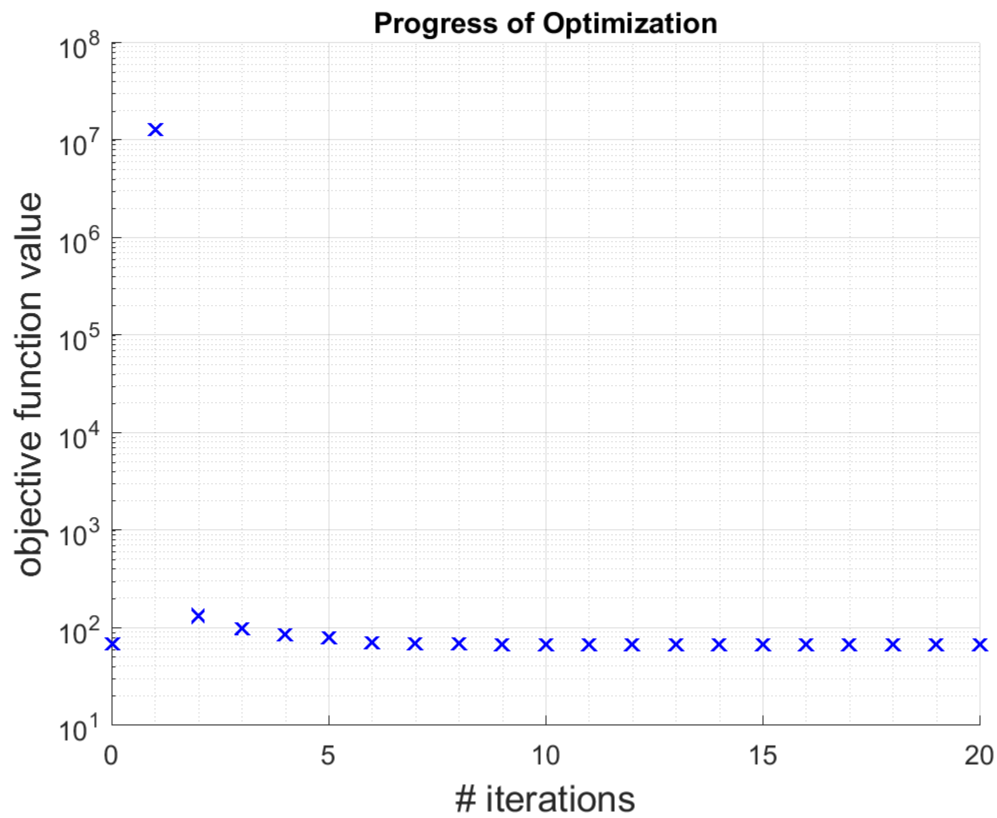
The Direct Aperture Optimization is an optimization approach where we directly optimize aperture shapes and weights.

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

```
******************************************************************************
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.:     7128
Number of nonzeros in Lagrangian Hessian.............:        0

Total number of variables............................:     7209
                     variables with only lower bounds:       81
                variables with lower and upper bounds:     7128
                     variables with only upper bounds:        0
Total number of equality constraints.................:        0
Total number of inequality constraints...............:     3564
        inequality constraints with only lower bounds:     3564
   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 6.9369217e+001 0.00e+000 4.90e+001   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
   1 1.3077691e+007 0.00e+000 1.74e+005   1.7 4.58e+001    -
 3.08e-001 1.85e-001h  1
   2 1.3292392e+002 0.00e+000 2.61e+002   1.4 8.49e+000    -  1.00e
+000 9.99e-001f  1
   3 9.8151748e+001 0.00e+000 9.55e+001  -0.7 1.90e-002    -
 9.96e-001 1.00e+000f  1
   4 8.4068803e+001 0.00e+000 5.72e+001  -2.1 1.67e-002    -  1.00e
+000 1.00e+000f  1
   5 7.9642609e+001 0.00e+000 6.66e+001  -3.2 9.19e-003    -  1.00e
+000 1.00e+000f  1
   6 7.0742250e+001 0.00e+000 2.49e+001  -4.5 3.77e-002    -  1.00e
+000 1.00e+000f  1
   7 6.8833776e+001 0.00e+000 1.44e+001  -5.6 1.45e-002    -  1.00e
+000 1.00e+000f  1
   8 6.8076661e+001 0.00e+000 1.13e+001  -7.0 1.34e-002    -  1.00e
+000 1.00e+000f  1
   9 6.7717758e+001 0.00e+000 1.12e+001  -8.5 1.02e-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 6.7210271e+001 0.00e+000 5.98e+000  -9.9 1.71e-002    -  1.00e
+000 1.00e+000f  1
  11 6.7043449e+001 0.00e+000 7.42e+000 -11.0 7.98e-003    -  1.00e
+000 1.00e+000f  1
  12 6.6936348e+001 0.00e+000 4.35e+000 -11.0 7.82e-003    -  1.00e
+000 1.00e+000f  1
  13 6.6814278e+001 0.00e+000 6.18e+000 -11.0 9.12e-003    -  1.00e
+000 1.00e+000f  1
  14 6.6697559e+001 0.00e+000 3.78e+000 -11.0 9.06e-003    -  1.00e
+000 1.00e+000f  1
```

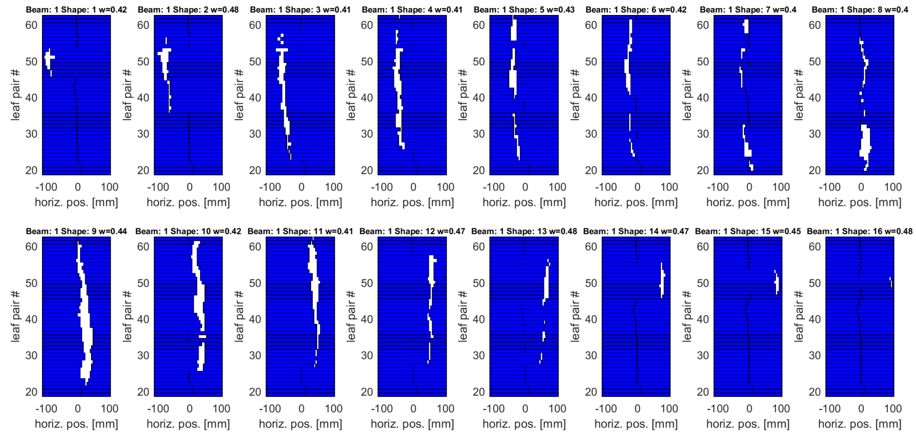
```
  15 6.6615375e+001 0.00e+000 2.76e+000 -11.0 7.84e-003    -  1.00e
+000 1.00e+000f  1
  16 6.6527901e+001 0.00e+000 2.46e+000 -11.0 9.00e-003    -  1.00e
+000 1.00e+000f  1
  17 6.6424043e+001 0.00e+000 2.48e+000 -11.0 1.53e-002    -  1.00e
+000 1.00e+000f  1
  18 6.6388172e+001 0.00e+000 2.66e+000 -11.0 1.80e-002    -  1.00e
+000 5.00e-001f  2
  19 6.6353083e+001 0.00e+000 2.80e+000 -11.0 4.65e-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 6.6327339e+001 0.00e+000 3.81e+000 -11.0 5.09e-003    -  1.00e
+000 1.00e+000f  1

Number of Iterations....: 20

                                   (scaled)                 (unscaled)
Objective...............:  6.6327338562769668e+001
 6.6327338562769668e+001
Dual infeasibility......:  3.8117802671924021e+000
 3.8117802671924021e+000
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
Complementarity.........:  1.0000000000000001e-011
 1.0000000000000001e-011
Overall NLP error.......:  3.8117802671924021e+000
 3.8117802671924021e+000


Number of objective function evaluations             = 25
Number of objective gradient evaluations             = 21
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 25
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)   =      2.068
Total CPU secs in NLP function evaluations           =     14.445

EXIT: Solved To Acceptable Level.
```

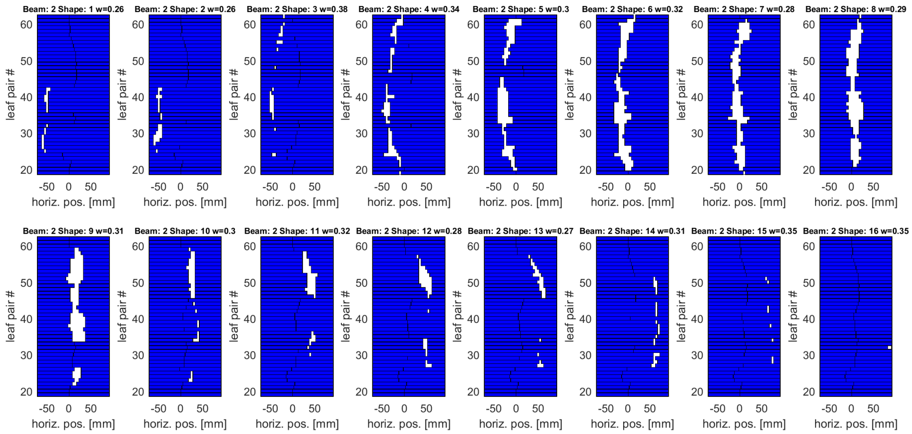


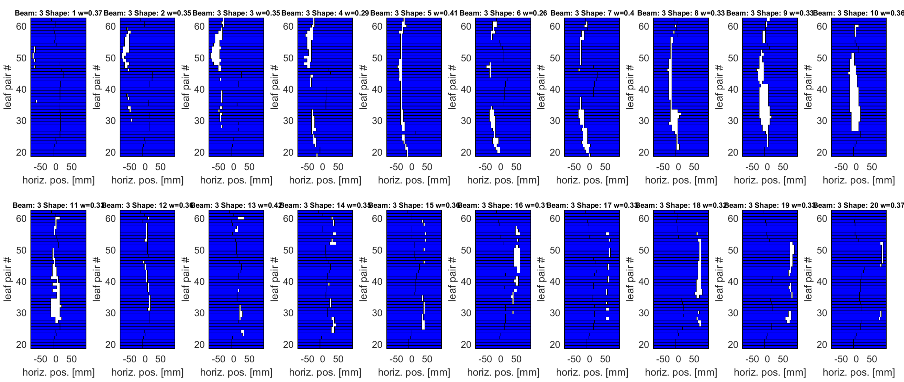
Aperture visualization

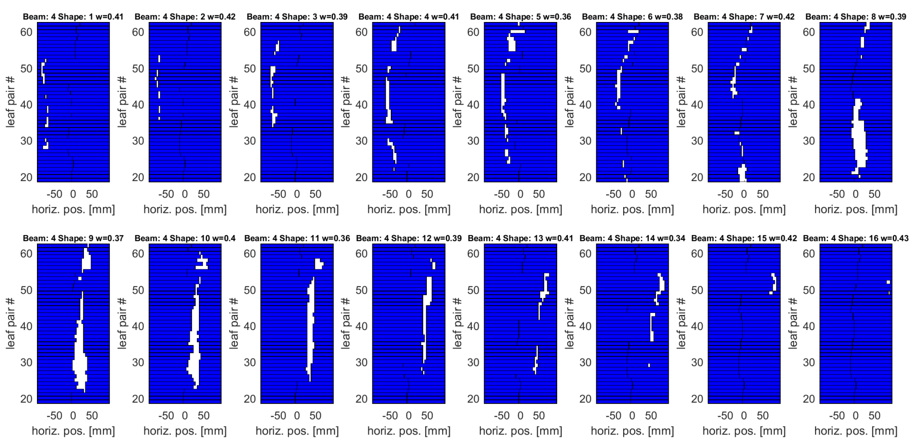
Use a matrad function to visualize the resulting aperture shapes

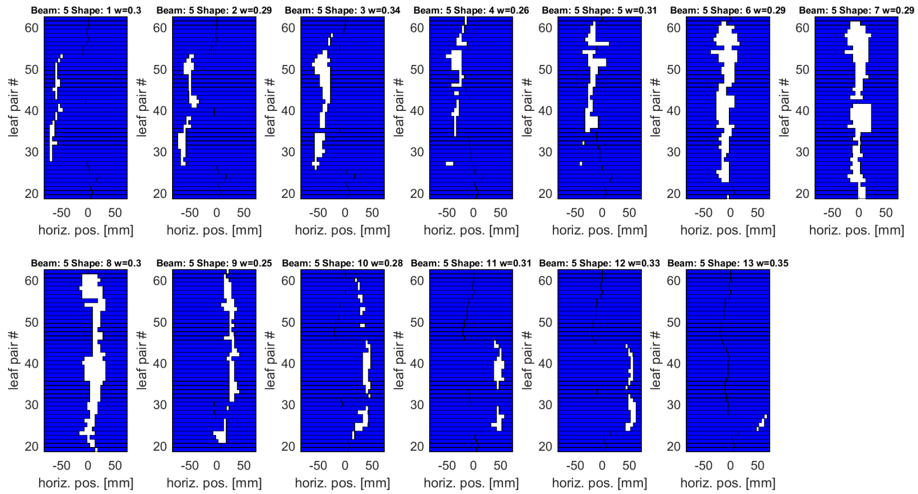
```
matRad_visApertureInfo(resultGUI.apertureInfo);
```




Beam: 2 Shape: 1 w=0.26
Beam: 2 Shape: 2 w=0.26
Beam: 2 Shape: 3 w=0.38
Beam: 2 Shape: 4 w=0.34
Beam: 2 Shape: 5 w=0.3
Beam: 2 Shape: 6 w=0.32
Beam: 2 Shape: 7 w=0.28
Beam: 2 Shape: 8 w=0.29
Beam: 2 Shape: 9 w=0.31
Beam: 2 Shape: 10 w=0.3
Beam: 2 Shape: 11 w=0.32
Beam: 2 Shape: 12 w=0.28
Beam: 2 Shape: 13 w=0.27
Beam: 2 Shape: 14 w=0.31
Beam: 2 Shape: 15 w=0.35
Beam: 2 Shape: 16 w=0.35
leaf pair #
horiz. pos. [mm]


Beam: 3 Shape: 1 w=0.37
Beam: 3 Shape: 2 w=0.35
Beam: 3 Shape: 3 w=0.35
Beam: 3 Shape: 4 w=0.29
Beam: 3 Shape: 5 w=0.41
Beam: 3 Shape: 6 w=0.26
Beam: 3 Shape: 7 w=0.4
Beam: 3 Shape: 8 w=0.33
Beam: 3 Shape: 10 w=0.36
Beam: 3 Shape: 20 w=0.37
leaf pair #
horiz. pos. [mm]


Beam: 4 Shape: 1 w=0.41
Beam: 4 Shape: 2 w=0.42
Beam: 4 Shape: 3 w=0.39
Beam: 4 Shape: 4 w=0.41
Beam: 4 Shape: 5 w=0.36
Beam: 4 Shape: 6 w=0.38
Beam: 4 Shape: 7 w=0.42
Beam: 4 Shape: 8 w=0.39
Beam: 4 Shape: 9 w=0.37
Beam: 4 Shape: 10 w=0.4
Beam: 4 Shape: 11 w=0.36
Beam: 4 Shape: 12 w=0.39
Beam: 4 Shape: 13 w=0.41
Beam: 4 Shape: 14 w=0.34
Beam: 4 Shape: 15 w=0.42
Beam: 4 Shape: 16 w=0.43
leaf pair #
horiz. pos. [mm]



Indicator Calculation and display of DVH and QI

```
cst = matRad_indicatorWrapper(cst,pln,resultGUI);
matRad_showDVH(cst,pln);
```

```
 0        BRAIN STEM PRV - Mean dose =  0.36 Gy +/-  0.33 Gy (Max dose
=  1.34 Gy, Min dose =  0.02 Gy)
                          D2% =  1.16 Gy, D5% =  1.02 Gy, D50% =
0.28 Gy, D95% =  0.03 Gy, D98% =  0.03 Gy,
                          V0Gy = 100.00%, V0.5Gy =  29.36%, V1Gy =
5.41%, V1.5Gy =   0.00%, V2.1Gy =   0.00%, V2.6Gy =   0.00%,

 1            BRAIN STEM - Mean dose =  0.35 Gy +/-  0.30 Gy (Max dose
=  1.30 Gy, Min dose =  0.03 Gy)
                          D2% =  1.09 Gy, D5% =  0.92 Gy, D50% =
0.31 Gy, D95% =  0.04 Gy, D98% =  0.03 Gy,
                          V0Gy = 100.00%, V0.5Gy =  27.42%, V1Gy =
4.02%, V1.5Gy =   0.00%, V2.1Gy =   0.00%, V2.6Gy =   0.00%,

 2            CEREBELLUM - Mean dose =  0.57 Gy +/-  0.32 Gy (Max dose
=  1.85 Gy, Min dose =  0.02 Gy)
                          D2% =  1.31 Gy, D5% =  1.14 Gy, D50% =
0.54 Gy, D95% =  0.09 Gy, D98% =  0.05 Gy,
                          V0Gy = 100.00%, V0.5Gy =  55.04%, V1Gy =
10.34%, V1.5Gy =   0.76%, V2.1Gy =   0.00%, V2.6Gy =   0.00%,

 3               CHIASMA - Mean dose =  0.08 Gy +/-  0.02 Gy (Max dose
=  0.11 Gy, Min dose =  0.06 Gy)
                          D2% =  0.11 Gy, D5% =  0.11 Gy, D50% =
0.09 Gy, D95% =  0.06 Gy, D98% =  0.06 Gy,
                          V0Gy = 100.00%, V0.5Gy =   0.00%, V1Gy =
0.00%, V1.5Gy =   0.00%, V2.1Gy =   0.00%, V2.6Gy =   0.00%,
```

4 CTV56 - Mean dose = 1.92 Gy +/- 0.12 Gy (Max dose = 2.29 Gy, Min dose = 1.70 Gy)
D2% = 2.19 Gy, D5% = 2.17 Gy, D50% = 1.90 Gy, D95% = 1.75 Gy, D98% = 1.73 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 100.00%, V1.5Gy = 100.00%, V2.1Gy = 12.45%, V2.6Gy = 0.00%,
Warning: target has no objective that penalizes underdosage,
5 CTV63 - Mean dose = 2.14 Gy +/- 0.15 Gy (Max dose = 2.64 Gy, Min dose = 0.93 Gy)
D2% = 2.44 Gy, D5% = 2.39 Gy, D50% = 2.14 Gy, D95% = 1.90 Gy, D98% = 1.82 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 99.99%, V1.5Gy = 99.79%, V2.1Gy = 61.34%, V2.6Gy = 0.04%,
Warning: target has no objective that penalizes underdosage,
6 External - Mean dose = 0.59 Gy +/- 0.69 Gy (Max dose = 2.64 Gy, Min dose = 0.00 Gy)
D2% = 2.27 Gy, D5% = 2.12 Gy, D50% = 0.25 Gy, D95% = 0.00 Gy, D98% = 0.00 Gy,
V0Gy = 100.00%, V0.5Gy = 39.34%, V1Gy = 23.91%, V1.5Gy = 14.16%, V2.1Gy = 5.39%, V2.6Gy = 0.00%,

7 GTV - Mean dose = 2.34 Gy +/- 0.08 Gy (Max dose = 2.63 Gy, Min dose = 1.98 Gy)
D2% = 2.51 Gy, D5% = 2.47 Gy, D50% = 2.34 Gy, D95% = 2.21 Gy, D98% = 2.17 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 100.00%, V1.5Gy = 100.00%, V2.1Gy = 99.73%, V2.6Gy = 0.07%,

8 LARYNX - Mean dose = 1.27 Gy +/- 0.26 Gy (Max dose = 1.80 Gy, Min dose = 0.74 Gy)
D2% = 1.73 Gy, D5% = 1.70 Gy, D50% = 1.26 Gy, D95% = 0.80 Gy, D98% = 0.76 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 83.45%, V1.5Gy = 19.42%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

9 LENS LT - 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%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

10 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%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

11 LIPS - Mean dose = 1.06 Gy +/- 0.39 Gy (Max dose = 1.96 Gy, Min dose = 0.30 Gy)

D2% = 1.84 Gy, D5% = 1.71 Gy, D50% = 1.04 Gy, D95% = 0.42 Gy, D98% = 0.36 Gy,
V0Gy = 100.00%, V0.5Gy = 93.57%, V1Gy = 55.00%, V1.5Gy = 15.71%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

12 OPTIC NRV LT - Mean dose = 0.06 Gy +/- 0.03 Gy (Max dose = 0.13 Gy, Min dose = 0.02 Gy)
D2% = 0.13 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%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

13 OPTIC NRV RT - Mean dose = 0.04 Gy +/- 0.02 Gy (Max dose = 0.09 Gy, Min dose = 0.01 Gy)
D2% = 0.09 Gy, D5% = 0.08 Gy, D50% = 0.03 Gy, D95% = 0.01 Gy, D98% = 0.01 Gy,
V0Gy = 100.00%, V0.5Gy = 0.00%, V1Gy = 0.00%, V1.5Gy = 0.00%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

14 PAROTID LT - Mean dose = 0.68 Gy +/- 0.29 Gy (Max dose = 1.69 Gy, Min dose = 0.22 Gy)
D2% = 1.44 Gy, D5% = 1.21 Gy, D50% = 0.67 Gy, D95% = 0.29 Gy, D98% = 0.27 Gy,
V0Gy = 100.00%, V0.5Gy = 68.66%, V1Gy = 13.82%, V1.5Gy = 1.38%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

15 PAROTID RT - Mean dose = 0.67 Gy +/- 0.25 Gy (Max dose = 1.49 Gy, Min dose = 0.30 Gy)
D2% = 1.31 Gy, D5% = 1.19 Gy, D50% = 0.60 Gy, D95% = 0.38 Gy, D98% = 0.36 Gy,
V0Gy = 100.00%, V0.5Gy = 68.14%, V1Gy = 11.44%, V1.5Gy = 0.00%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

16 PTV56 - Mean dose = 1.91 Gy +/- 0.12 Gy (Max dose = 2.29 Gy, Min dose = 1.65 Gy)
D2% = 2.19 Gy, D5% = 2.16 Gy, D50% = 1.88 Gy, D95% = 1.75 Gy, D98% = 1.72 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 100.00%, V1.5Gy = 100.00%, V2.1Gy = 9.98%, V2.6Gy = 0.00%,
CI = 0.0614, HI = 22.28 for reference dose of 1.9 Gy

17 PTV63 - Mean dose = 2.11 Gy +/- 0.19 Gy (Max dose = 2.64 Gy, Min dose = 0.58 Gy)
D2% = 2.44 Gy, D5% = 2.39 Gy, D50% = 2.12 Gy, D95% = 1.83 Gy, D98% = 1.72 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 99.69%, V1.5Gy = 99.04%, V2.1Gy = 54.14%, V2.6Gy = 0.03%,
CI = 0.7066, HI = 26.59 for reference dose of 2.1 Gy

18 PTV70 - Mean dose = 2.32 Gy +/- 0.10 Gy (Max dose = 2.64 Gy, Min dose = 1.56 Gy)

D2% = 2.50 Gy, D5% = 2.47 Gy, D50% = 2.32 Gy, D95% = 2.16 Gy, D98% = 2.11 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 100.00%, V1.5Gy = 100.00%, V2.1Gy = 98.34%, V2.6Gy = 0.10%,
CI = 0.5879, HI = 13.25 for reference dose of 2.3 Gy

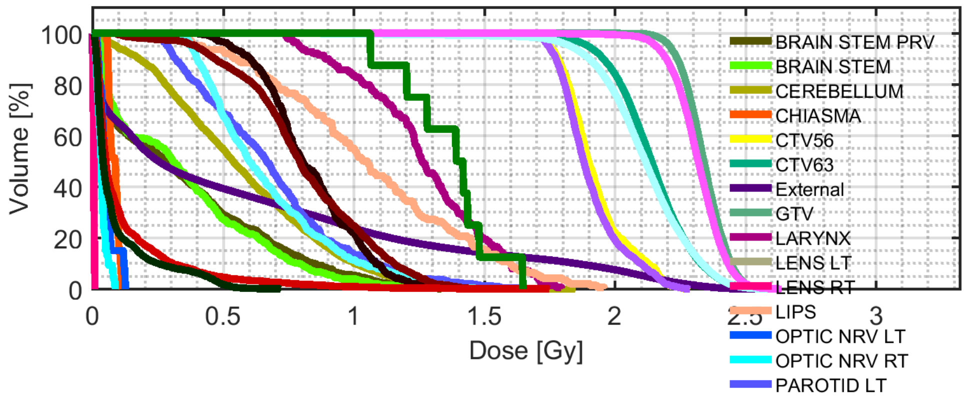
19 SPINAL CORD - Mean dose = 0.83 Gy +/- 0.19 Gy (Max dose = 1.35 Gy, Min dose = 0.40 Gy)
D2% = 1.23 Gy, D5% = 1.15 Gy, D50% = 0.81 Gy, D95% = 0.53 Gy, D98% = 0.47 Gy,
V0Gy = 100.00%, V0.5Gy = 96.58%, V1Gy = 21.84%, V1.5Gy = 0.00%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

20 SPINL CRD PRV - Mean dose = 0.81 Gy +/- 0.26 Gy (Max dose = 1.46 Gy, Min dose = 0.08 Gy)
D2% = 1.31 Gy, D5% = 1.25 Gy, D50% = 0.79 Gy, D95% = 0.40 Gy, D98% = 0.20 Gy,
V0Gy = 100.00%, V0.5Gy = 88.00%, V1Gy = 24.76%, V1.5Gy = 0.00%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

21 TEMP LOBE LT - Mean dose = 0.13 Gy +/- 0.19 Gy (Max dose = 1.75 Gy, Min dose = 0.01 Gy)
D2% = 0.78 Gy, D5% = 0.47 Gy, D50% = 0.05 Gy, D95% = 0.02 Gy, D98% = 0.01 Gy,
V0Gy = 100.00%, V0.5Gy = 4.66%, V1Gy = 0.93%, V1.5Gy = 0.21%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

22 TEMP LOBE RT - Mean dose = 0.09 Gy +/- 0.12 Gy (Max dose = 0.72 Gy, Min dose = 0.00 Gy)
D2% = 0.50 Gy, D5% = 0.44 Gy, D50% = 0.04 Gy, D95% = 0.01 Gy, D98% = 0.01 Gy,
V0Gy = 100.00%, V0.5Gy = 1.89%, V1Gy = 0.00%, V1.5Gy = 0.00%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,

23 TM JOINT LT - Mean dose = 1.37 Gy +/- 0.18 Gy (Max dose = 1.65 Gy, Min dose = 1.07 Gy)
D2% = 1.62 Gy, D5% = 1.59 Gy, D50% = 1.41 Gy, D95% = 1.11 Gy, D98% = 1.09 Gy,
V0Gy = 100.00%, V0.5Gy = 100.00%, V1Gy = 100.00%, V1.5Gy = 12.50%, V2.1Gy = 0.00%, V2.6Gy = 0.00%,



VOIs	mean	std	max	min	D_2	D_5	D
BRAIN STEM PRV	0.3574	0.3288	1.3379	0.0178	1.1607	1.0195	
BRAIN STEM	0.3532	0.3025	1.3029	0.0264	1.0854	0.9242	
CEREBELLUM	0.5742	0.3232	1.8508	0.0244	1.3104	1.1394	
CHIASMA	0.0829	0.0188	0.1147	0.0572	0.1139	0.1129	
CTV56	1.9248	0.1232	2.2864	1.6954	2.1943	2.1728	
CTV63	2.1395	0.1530	2.6368	0.9345	2.4405	2.3867	
External	0.5895	0.6930	2.6368	0	2.2729	2.1185	
GTV	2.3423	0.0811	2.6314	1.9822	2.5053	2.4746	
LARYNX	1.2693	0.2564	1.7969	0.7406	1.7257	1.7009	
LENS LT	0.0080	5.9706e-04	0.0089	0.0073	0.0088	0.0087	

dose statistics

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