Example Proton Treatment Plan with Manipulated CT values

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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 inversly 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 evalute the result

Patient Data Import

Let's begin with a clear Matlab environment. First, import the head & neck patient into your workspace. The phantom is comprised of a 'ct' and 'cst' structure defining the CT images and the structure set. Make sure the matRad root directory with all its SUBDIRECTORIES is added to the Matlab search path.

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

Let's check the two variables, we have just imported. First, the 'ct' variable comprises the ct cube along with some meta information describing properties of the ct cube (cube dimensions, resolution, number of CT scenarios). Please note that mutiple ct cubes (e.g. 4D CT) can be stored in the cell array ct.cube{}

```
ct
```

```
ct =
```

```
  struct with fields:

            cube: {[160×160×67 double]}
      resolution: [1×1 struct]
         cubeDim: [160 160 67]
     numOfCtScen: 1
```

The 'cst' cell array defines volumes of interests along with information required for optimization. Each row belongs to one certain VOI, whereas each column defines different proprties. Specifically, the second and third column show the name and the type of the structure. The tpe can be set to OAR, TARGET or IGNORED. The fourth column depicts a linear index vector depicting voxels in the CT cube that are covered by the corresponding VOI. In total, 24 structures are defined in the cst

```
cst
```

```
cst =

  24×6 cell array

  Columns 1 through 5

    [ 0]    'BRAIN STEM PRV'    'OAR'        {1×1 cell}    [1×1 
 struct]
    [ 1]    'BRAIN STEM'        'OAR'        {1×1 cell}    [1×1 
 struct]
    [ 2]    'CEREBELLUM'        'OAR'        {1×1 cell}    [1×1 
 struct]
    [ 3]    'CHIASMA'           'IGNORED'    {1×1 cell}    [1×1 
 struct]
    [ 4]    'CTV56'             'TARGET'     {1×1 cell}    [1×1 
 struct]
    [ 5]    'CTV63'             'TARGET'     {1×1 cell}    [1×1 
 struct]
    [ 6]    'External'          'OAR'        {1×1 cell}    [1×1 
 struct]
    [ 7]    'GTV'               'OAR'        {1×1 cell}    [1×1 
 struct]
    [ 8]    'LARYNX'            'OAR'        {1×1 cell}    [1×1 
 struct]
    [ 9]    'LENS LT'           'OAR'        {1×1 cell}    [1×1 
 struct]
    [10]    'LENS RT'           'OAR'        {1×1 cell}    [1×1 
 struct]
    [11]    'LIPS'              'OAR'        {1×1 cell}    [1×1 
 struct]
    [12]    'OPTIC NRV LT'      'OAR'        {1×1 cell}    [1×1 
 struct]
    [13]    'OPTIC NRV RT'      'OAR'        {1×1 cell}    [1×1 
 struct]
    [14]    'PAROTID LT'        'OAR'        {1×1 cell}    [1×1 
 struct]
    [15]    'PAROTID RT'        'OAR'        {1×1 cell}    [1×1 
 struct]
```

```
   [16]    'PTV56'             'TARGET'     {1×1 cell}    [1×1
struct]
   [17]    'PTV63'             'TARGET'     {1×1 cell}    [1×1
struct]
   [18]    'PTV70'             'TARGET'     {1×1 cell}    [1×1
struct]
   [19]    'SPINAL CORD'       'OAR'        {1×1 cell}    [1×1
struct]
   [20]    'SPINL CRD PRV'     'OAR'        {1×1 cell}    [1×1
struct]
   [21]    'TEMP LOBE LT'      'OAR'        {1×1 cell}    [1×1
struct]
   [22]    'TEMP LOBE RT'      'OAR'        {1×1 cell}    [1×1
struct]
   [23]    'TM JOINT LT'       'IGNORED'    {1×1 cell}    [1×1
struct]

  Column 6

              []
              []
              []
              []
              []
              []
    [1×1 struct]
              []
              []
              []
              []
              []
              []
              []
    [1×1 struct]
    [1×1 struct]
    [1×1 struct]
    [1×1 struct]
    [1×1 struct]
              []
              []
              []
              []
              []
```

Treatment Plan

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

First of all, we need to define what kind of radiation modality we would like to use. Possible values are photons, protons or carbon. In this case we want to use photons. Then, we need to define a treatment machine to correctly load the corresponding base data. Since we provide generic base data we set the machine to 'Genereric. By this means matRad will look for 'proton_Generic.mat' in our root directory and will use the data provided in there for dose calculation

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

Define the flavour of biological optimization for treatment planning along with the quantity that should be used for optimizaion. Possible values are (none: physical optimization; const_RBExD: constant RBE of 1.1; LEMIV_effect: effect-based optimization; LEMIV_RBExD: optimization of RBE-weighted dose. As we are using photons, simply set the parameter to 'none' thereby indicating the physical dose should be optimized.

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

Now we have to set some beam parameters. We can define multiple beam angles for the treatment and pass these to the plan as a vector.matRad will then interpret the vector as multiple beams. In this case, we define linear spaced beams from 0 degree to 359 degree in 30 degree steps. This results in 12 beams. All corresponding couch angles are set to 0 at this point. Moreover, we set the bixelWidth to 5, which results in a beamlet size of 5 x 5 mm. The number of fractions is set to 30. Be advised that matRad is always optimizing the fraction dose.

```
pln.gantryAngles    = [0:40:359];
pln.couchAngles     = [0 0 0 0 0 0 0 0 0];
pln.bixelWidth      = 5;
pln.numOfFractions  = 30;
```

Obtain the number of beams and voxels from the existing variables and calculate the iso-center which is per default the mass of gravity of all target voxels.

```
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;
```

y listo our treatment plan is ready. Lets have a look at it:

```
pln
```

```
pln = 

  struct with fields:

      radiationMode: 'photons'
            machine: 'Generic'
    bioOptimization: 'none'
       gantryAngles: [0 40 80 120 160 200 240 280 320]
        couchAngles: [0 0 0 0 0 0 0 0 0]
         bixelWidth: 5
     numOfFractions: 30
         numOfBeams: 9
        numOfVoxels: 1715200
```

```
voxelDimensions: [160 160 67]
      isoCenter: [9×3 double]
  runSequencing: 1
         runDAO: 1
```

Generatet Beam Geometry STF

This acronym stands for steering file and comprises the complet beam geomtry along with ray position, beamlet positions, source to axis distance (SAD) etc.

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

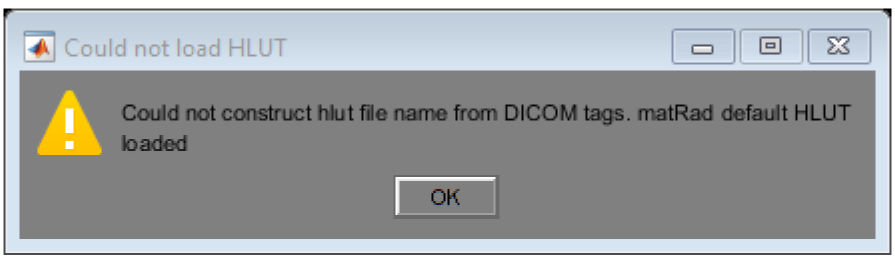
matRad: Generating stf struct... Progress: 100.00 %

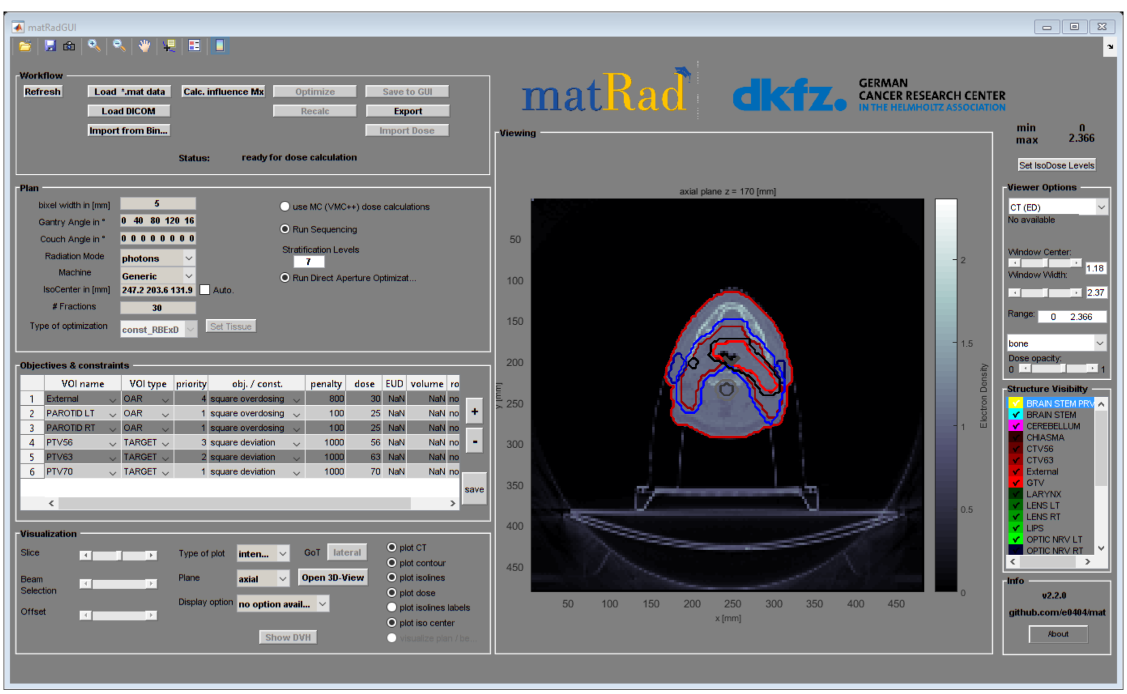
Start the GUI for Visualization

Show the ct cube along with contours

```
matRadGUI
```

Warning: matRad default HLUT loaded
Reconversion of HU values could not be done because HLUT is not bijective.





Dose Calculation

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

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

```
matRad: Photon dose calculation...
Beam 1 of 9:
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 9:
matRad: calculate radiological depth cube...done
                   SSD = 944mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 944 mm ...
Progress: 100.00 %
Beam 3 of 9:
matRad: calculate radiological depth cube...done
                   SSD = 942mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 942 mm ...
Progress: 100.00 %
Beam 4 of 9:
matRad: calculate radiological depth cube...done
                   SSD = 948mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 948 mm ...
Progress: 100.00 %
Beam 5 of 9:
matRad: calculate radiological depth cube...done
                   SSD = 918mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 918 mm ...
Progress: 100.00 %
Beam 6 of 9:
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 7 of 9:
matRad: calculate radiological depth cube...done
                   SSD = 917mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 917 mm ...
Progress: 100.00 %
Beam 8 of 9:
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 9 of 9:
matRad: calculate radiological depth cube...done
                   SSD = 940mm
matRad: Uniform primary photon fluence -> pre-compute kernel
 convolution for SSD = 940 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
```

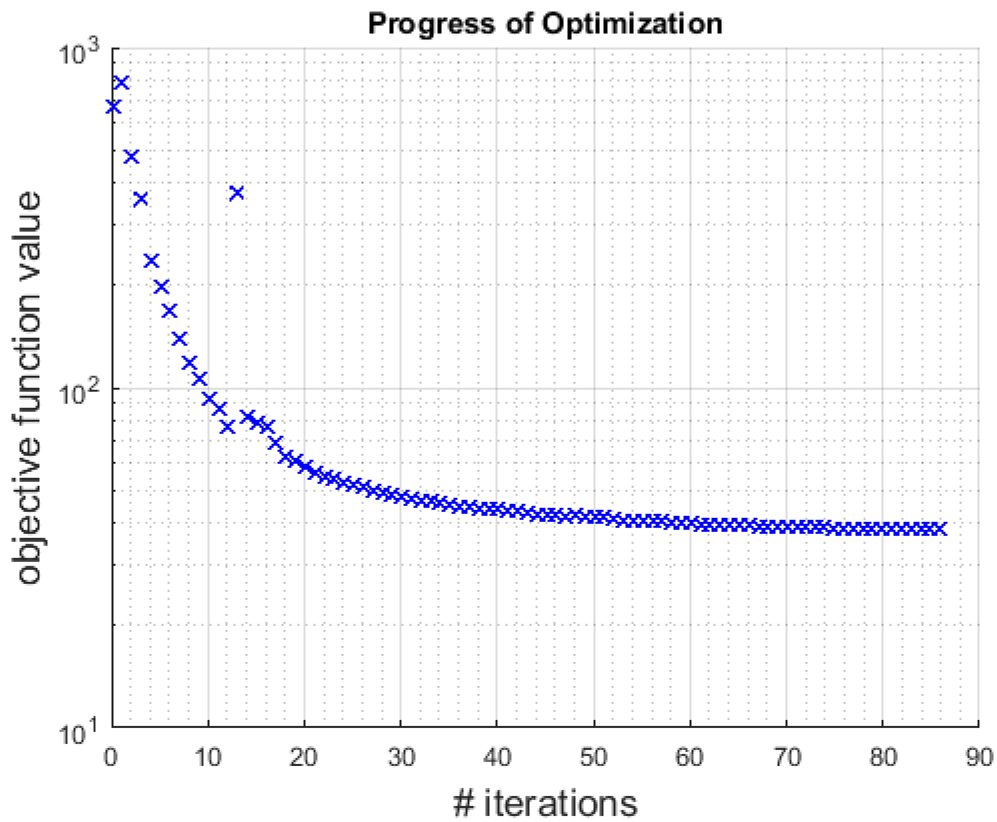
```

******************************************************************************
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............................:     9854
                     variables with only lower bounds:     9854
                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 6.7341955e+002 0.00e+000 9.72e+000   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
   1 7.9229313e+002 0.00e+000 1.11e+001  -0.2 1.94e+000    -
 8.06e-001 1.53e-001f  1
   2 4.7755257e+002 0.00e+000 5.53e+000  -0.5 1.57e-001    -  1.00e
+000 1.00e+000f  1
   3 3.5982658e+002 0.00e+000 2.96e+000  -0.9 4.97e-002    -
 9.71e-001 1.00e+000f  1
```

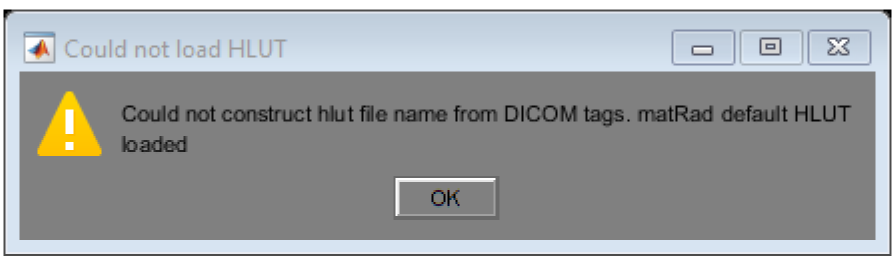
```
   4 2.3506027e+002 0.00e+000 2.30e+000  -1.5 7.18e-002    -  1.00e
+000 1.00e+000f  1
   5 1.9721535e+002 0.00e+000 1.35e+000  -1.8 8.16e-002    -
 9.95e-001 6.16e-001f  1
   6 1.6871309e+002 0.00e+000 1.27e+000  -2.5 8.30e-002    -  1.00e
+000 6.12e-001f  1
   7 1.4013853e+002 0.00e+000 1.29e+000  -2.7 1.39e-001    -  1.00e
+000 4.88e-001f  1
   8 1.1863580e+002 0.00e+000 1.66e+000  -2.6 2.80e-001    -
 9.95e-001 3.17e-001f  1
   9 1.0573317e+002 0.00e+000 1.67e+000  -2.8 1.66e-001    -  1.00e
+000 3.24e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  10 9.3192643e+001 0.00e+000 9.29e-001  -3.2 2.05e-001    -  1.00e
+000 3.37e-001f  1
  11 8.6330133e+001 0.00e+000 1.52e+000  -3.3 2.73e-001    -  1.00e
+000 1.49e-001f  1
  12 7.6907502e+001 0.00e+000 1.62e+000  -2.5 1.72e-001    -
 7.76e-001 4.27e-001f  1
  13 3.7347541e+002 0.00e+000 7.43e+000  -0.6 1.03e+001    -
 3.62e-002 1.48e-001f  1
  14 8.1792253e+001 0.00e+000 2.75e+000  -1.8 1.28e+000    -  1.00e
+000 9.33e-001f  1
  15 7.9284058e+001 0.00e+000 2.94e+000  -1.8 1.01e-001    -  1.00e
+000 1.00e+000f  1
  16 7.6901150e+001 0.00e+000 3.99e-001  -1.8 1.52e-002    -  1.00e
+000 1.00e+000f  1
  17 6.9153961e+001 0.00e+000 8.15e-001  -2.5 1.30e-001    -
 9.97e-001 8.13e-001f  1
  18 6.2901114e+001 0.00e+000 5.72e-001  -3.3 2.07e-001    -  1.00e
+000 6.38e-001f  1
  19 6.0908630e+001 0.00e+000 5.69e-001  -2.5 8.47e-002    -
 9.69e-001 3.94e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  20 5.8926134e+001 0.00e+000 4.23e+000  -2.9 7.33e-002    -  1.00e
+000 4.27e-001f  1
  21 5.6244478e+001 0.00e+000 1.04e+000  -2.5 1.00e-001    -
 9.70e-001 7.43e-001f  1
  22 5.5026697e+001 0.00e+000 9.19e-001  -3.3 8.01e-002    -
 8.68e-001 2.89e-001f  1
  23 5.3641465e+001 0.00e+000 7.48e-001  -3.0 6.95e-002    -
 8.24e-001 4.58e-001f  1
  24 5.2829589e+001 0.00e+000 9.18e-001  -3.7 8.10e-002    -
 9.80e-001 2.64e-001f  1
  25 5.1790510e+001 0.00e+000 8.45e-001  -4.7 1.03e-001    -
 9.96e-001 2.86e-001f  1
  26 5.1055334e+001 0.00e+000 7.47e-001  -5.3 1.18e-001    -
 9.46e-001 1.89e-001f  1
  27 4.9993988e+001 0.00e+000 6.53e-001  -3.8 1.46e-001    -
 8.74e-001 2.43e-001f  1
  28 4.9428098e+001 0.00e+000 7.44e-001  -3.5 8.33e-002    -
 6.47e-001 2.31e-001f  1
```

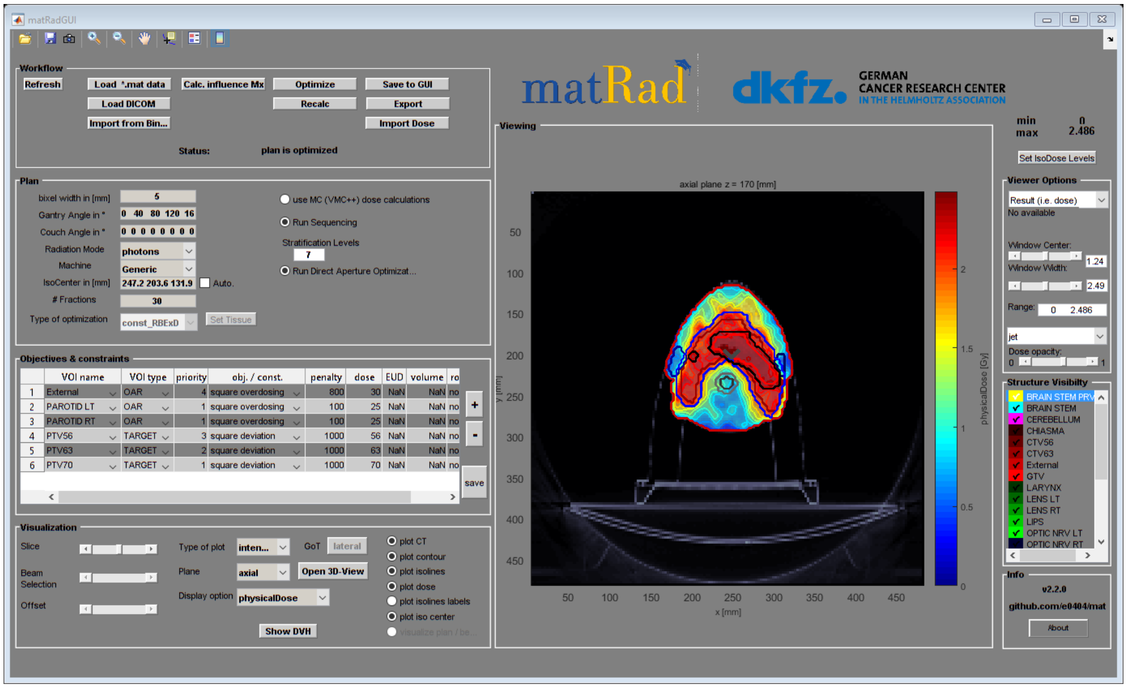
```
  29 4.8514321e+001 0.00e+000 3.93e-001  -4.0 1.72e-001    -
 9.56e-001 1.90e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  30 4.7773355e+001 0.00e+000 4.86e-001  -3.5 1.73e-001    -
 6.51e-001 1.57e-001f  1
  31 4.7320081e+001 0.00e+000 4.29e-001  -3.6 1.02e-001    -
 3.44e-001 1.66e-001f  1
  32 4.6631039e+001 0.00e+000 3.57e-001  -9.6 1.50e-001    -
 3.19e-001 1.77e-001f  1
  33 4.6234952e+001 0.00e+000 1.01e+000  -3.9 1.63e-001    -
 7.34e-001 1.01e-001f  1
  34 4.5595975e+001 0.00e+000 4.55e-001  -3.4 1.16e-001    -
 4.69e-001 2.41e-001f  1
  35 4.5236015e+001 0.00e+000 5.06e-001  -3.2 9.44e-002    -
 7.47e-001 1.94e-001f  1
  36 4.4625363e+001 0.00e+000 3.70e-001  -3.3 1.17e-001    -
 6.37e-001 3.01e-001f  1
  37 4.4552940e+001 0.00e+000 1.15e+000  -9.3 6.45e-002    -
 5.79e-001 5.42e-002f  1
  38 4.3947436e+001 0.00e+000 5.38e-001  -3.4 1.41e-001    -
 6.72e-001 2.80e-001f  1
  39 4.4079456e+001 0.00e+000 4.33e-001  -2.9 5.73e-002    -
 6.15e-001 9.09e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  40 4.3829527e+001 0.00e+000 4.98e-001  -3.1 2.93e-002    -
 6.72e-001 5.51e-001f  1
  41 4.3614786e+001 0.00e+000 9.19e-001  -3.1 2.64e-002    -
 6.47e-001 1.00e+000f  1
  42 4.3219103e+001 0.00e+000 2.68e-001  -3.6 2.87e-002    -  1.00e
+000 5.56e-001f  1
  43 4.2886059e+001 0.00e+000 4.87e-001  -3.9 5.73e-002    -  1.00e
+000 2.72e-001f  1
  44 4.2365673e+001 0.00e+000 4.50e-001  -4.5 1.04e-001    -
 8.71e-001 2.78e-001f  1
  45 4.2179556e+001 0.00e+000 5.00e-001  -3.4 5.92e-002    -
 6.95e-001 2.36e-001f  1
  46 4.2305155e+001 0.00e+000 1.19e-001  -3.1 4.74e-002    -
 4.38e-001 8.33e-001f  1
  47 4.1999737e+001 0.00e+000 3.47e-001  -3.3 5.27e-002    -
 5.84e-001 4.33e-001f  1
  48 4.2244186e+001 0.00e+000 1.56e-001  -3.0 2.89e-002    -
 4.89e-001 8.05e-001f  1
  49 4.1807367e+001 0.00e+000 6.10e-001  -3.2 4.44e-002    -  1.00e
+000 7.33e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  50 4.1715110e+001 0.00e+000 3.53e-001  -3.2 3.61e-002    -
 8.15e-001 2.44e-001f  1
  51 4.1512391e+001 0.00e+000 1.31e+000  -3.8 4.13e-002    -  1.00e
+000 2.20e-001f  1
  52 4.1201907e+001 0.00e+000 7.30e-001  -5.0 7.97e-002    -
 6.76e-001 2.24e-001f  1
```

```
 53 4.0731148e+001 0.00e+000 3.02e-001  -5.1 1.04e-001    -
 9.16e-001 3.08e-001f  1
 54 4.0544123e+001 0.00e+000 1.94e-001  -3.6 8.13e-002    -
 3.65e-001 2.88e-001f  1
 55 4.0808047e+001 0.00e+000 1.53e-001  -3.3 3.95e-002    -
 3.52e-001 1.00e+000f  1
 56 4.0533049e+001 0.00e+000 1.46e-001  -3.6 6.33e-002    -
 4.90e-001 3.96e-001f  1
 57 4.0554115e+001 0.00e+000 1.43e-001  -3.3 2.36e-002    -
 6.54e-001 3.64e-001f  1
 58 4.0345017e+001 0.00e+000 1.71e-001  -3.5 3.46e-002    -
 5.58e-001 6.13e-001f  1
 59 4.0297914e+001 0.00e+000 2.94e-001  -3.5 2.63e-002    -
 9.97e-001 2.17e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
 60 4.0028759e+001 0.00e+000 1.98e-001  -3.6 5.53e-002    -
 6.56e-001 5.93e-001f  1
 61 3.9793441e+001 0.00e+000 3.27e-001  -4.2 6.29e-002    -
 6.78e-001 3.05e-001f  1
 62 3.9695060e+001 0.00e+000 2.01e-001  -4.8 5.27e-002    -
 7.14e-001 1.54e-001f  1
 63 3.9514595e+001 0.00e+000 2.47e-001  -5.0 9.65e-002    -  1.00e
+000 2.01e-001f  1
 64 3.9323535e+001 0.00e+000 3.90e-001  -4.5 9.57e-002    -
 6.36e-001 2.38e-001f  1
 65 3.9355343e+001 0.00e+000 5.16e-001  -3.6 8.02e-002    -
 5.35e-001 8.36e-001f  1
 66 3.9313330e+001 0.00e+000 5.00e-001  -3.9 2.26e-002    -
 8.37e-001 2.00e-001f  1
 67 3.9208774e+001 0.00e+000 2.32e-001  -3.8 2.54e-002    -
 5.71e-001 5.44e-001f  1
 68 3.9127741e+001 0.00e+000 3.47e-001  -4.3 3.14e-002    -
 9.11e-001 2.82e-001f  1
 69 3.9028333e+001 0.00e+000 2.47e-001  -4.2 2.88e-002    -
 8.61e-001 4.05e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
 70 3.8979688e+001 0.00e+000 4.84e-001 -10.1 4.04e-002    -
 8.23e-001 1.36e-001f  1
 71 3.8927982e+001 0.00e+000 4.07e-001  -4.0 4.37e-002    -  1.00e
+000 4.29e-001f  1
 72 3.8847708e+001 0.00e+000 2.45e-001 -10.0 7.38e-002    -
 5.39e-001 2.08e-001f  1
 73 3.8807264e+001 0.00e+000 1.68e-001  -4.0 7.56e-002    -
 5.12e-001 3.08e-001f  1
 74 3.8794587e+001 0.00e+000 2.04e-001 -10.1 7.73e-002    -
 4.78e-001 3.27e-002f  1
 75 3.8702172e+001 0.00e+000 1.40e-001  -4.6 1.15e-001    -
 5.35e-001 1.88e-001f  1
 76 3.8647511e+001 0.00e+000 2.58e-001  -4.1 9.50e-002    -
 4.64e-001 2.56e-001f  1
 77 3.8626078e+001 0.00e+000 1.17e-001  -4.3 9.46e-002    -
 3.72e-001 7.36e-002f  1
```

```
  78 3.8585275e+001 0.00e+000 3.66e-001  -4.2 7.53e-002    -
 3.62e-001 1.87e-001f  1
  79 3.8547317e+001 0.00e+000 2.63e-001  -4.2 8.65e-002    -
 7.18e-001 1.51e-001f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  80 3.8485306e+001 0.00e+000 1.30e-001  -4.2 1.10e-001    -
 4.07e-001 1.99e-001f  1
  81 3.8469746e+001 0.00e+000 4.44e-001 -10.2 5.43e-002    -
 4.07e-001 5.92e-002f  1
  82 3.8392699e+001 0.00e+000 1.56e-001  -4.1 7.37e-002    -
 8.75e-001 2.83e-001f  1
  83 3.8335166e+001 0.00e+000 2.44e-001  -4.3 4.87e-002    -
 4.56e-001 2.96e-001f  1
  84 3.8313732e+001 0.00e+000 1.18e-001  -4.2 4.89e-002    -
 4.77e-001 1.24e-001f  1
  85 3.8291355e+001 0.00e+000 1.12e-001  -3.9 5.40e-002    -
 3.37e-001 2.47e-001f  1
  86 3.8268082e+001 0.00e+000 3.58e-001  -4.2 4.03e-002    -
 5.47e-001 1.96e-001f  1

Number of Iterations....: 86

                                   (scaled)                 (unscaled)
Objective...............:  3.8268082305604501e+001
 3.8268082305604501e+001
Dual infeasibility......:  3.5778489541548653e-001
 3.5778489541548653e-001
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
Complementarity.........:  1.2298962104281009e-004
 1.2298962104281009e-004
Overall NLP error.......:  3.5778489541548653e-001
 3.5778489541548653e-001


Number of objective function evaluations             = 87
Number of objective gradient evaluations             = 87
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)   =      2.799
Total CPU secs in NLP function evaluations           =     41.785

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.
```


Progress of Optimization
objective function value
iterations
10^3
10^2
10^1
0
10
20
30
40
50
60
70
80
90


Could not load HLUT
Could not construct hlut file name from DICOM tags. matRad default HLUT loaded
OK



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; according to Siochi (1999).

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

DAO - Direct Aperture Optimization

The Direct Aperture Optimization is an automated planning system, only possibble for photons in which we bypass the traditional intensity optimization, and instead directly optimize the shapes and the weights of the apertures. This technique allows the user to specify the maximum number of apertures per beam direction, and hence provides significant control over the complexity of the treatment delivery.

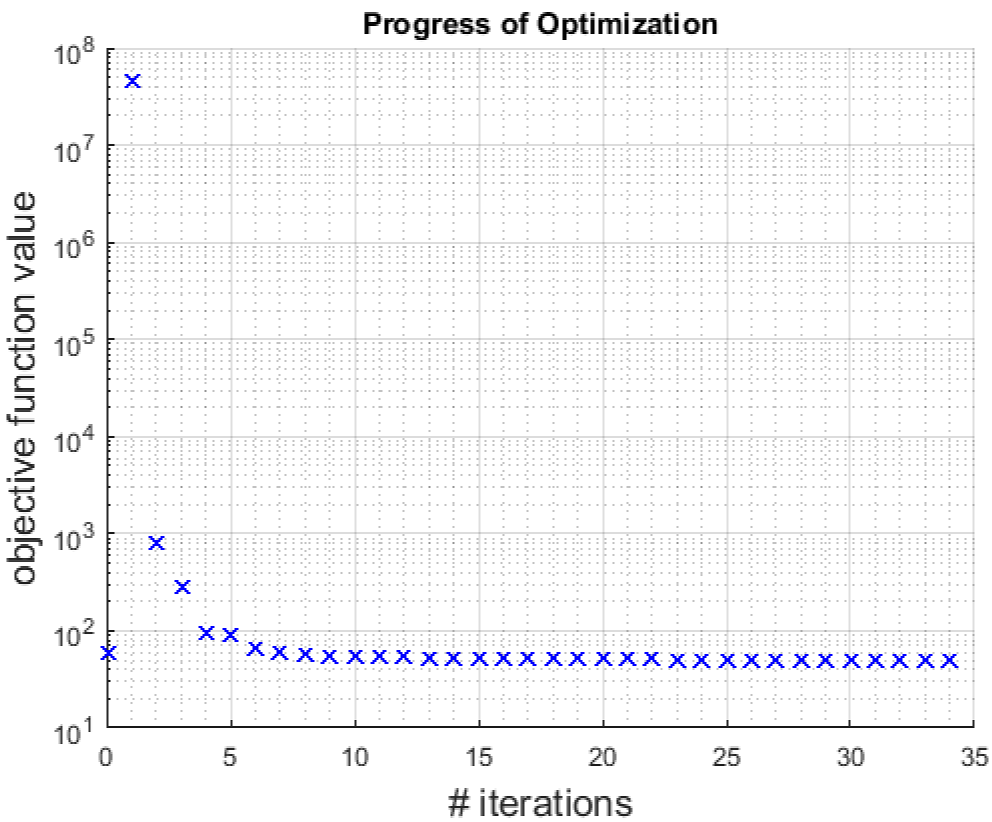
```
resultGUI =
 matRad_directApertureOptimization(dij,cst,resultGUI.apertureInfo,resultGUI,pln);
matRad_visApertureInfo(resultGUI.apertureInfo);
```

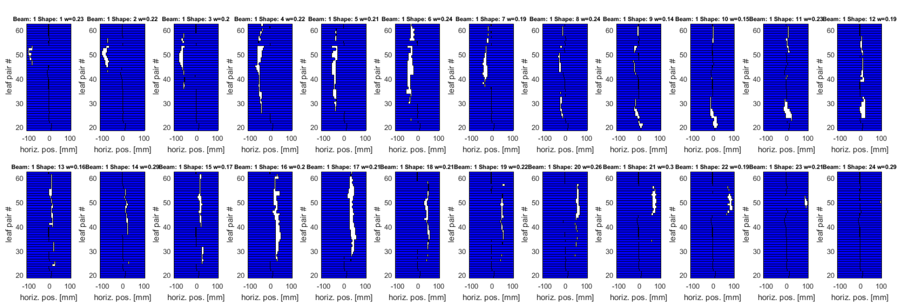
```
******************************************************************************
This program contains Ipopt, a library for large-scale nonlinear
 optimization.
 Ipopt is released as open source code under the Eclipse Public
 License (EPL).
         For more information visit http://projects.coin-or.org/Ipopt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

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

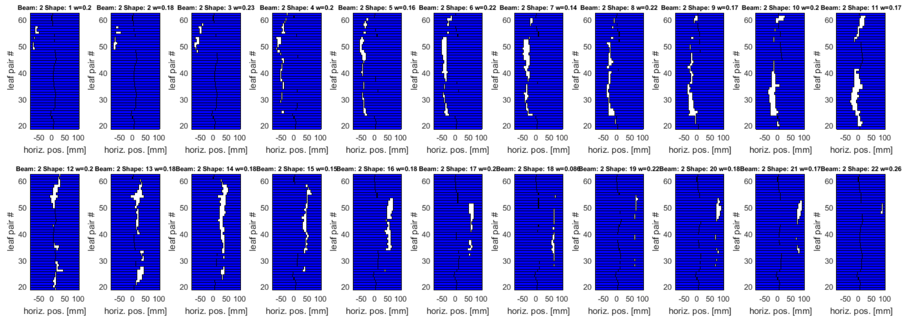
```
Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:    14696
Number of nonzeros in Lagrangian Hessian.............:        0

Total number of variables............................:    14863
                     variables with only lower bounds:      167
                variables with lower and upper bounds:    14696
                     variables with only upper bounds:        0
Total number of equality constraints.................:        0
Total number of inequality constraints...............:     7348
        inequality constraints with only lower bounds:     7348
   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 5.8108960e+001 0.00e+000 5.74e+001   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
   1 4.6344587e+007 0.00e+000 2.16e+005   1.7 5.09e+001    -
 1.52e-001 1.69e-001h  1
   2 8.0764382e+002 0.00e+000 8.34e+002   1.2 8.59e+000    -  1.00e
+000 9.93e-001f  1
   3 2.8311827e+002 0.00e+000 4.10e+002  -0.7 6.38e-002    -
 9.98e-001 1.00e+000f  1
   4 9.5367774e+001 0.00e+000 4.45e+001  -2.0 6.09e-002    -  1.00e
+000 1.00e+000f  1
   5 8.9071793e+001 0.00e+000 3.73e+001  -2.6 6.72e-003    -  1.00e
+000 1.00e+000f  1
   6 6.4274058e+001 0.00e+000 2.98e+001  -3.4 4.58e-002    -  1.00e
+000 1.00e+000f  1
   7 5.9408462e+001 0.00e+000 1.61e+001  -4.1 2.13e-002    -  1.00e
+000 1.00e+000f  1
   8 5.7060799e+001 0.00e+000 2.76e+001  -4.9 3.17e-002    -  1.00e
+000 1.00e+000f  1
   9 5.5085996e+001 0.00e+000 1.36e+001  -5.9 1.35e-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 5.4474750e+001 0.00e+000 9.97e+000  -7.4 7.28e-003    -  1.00e
+000 1.00e+000f  1
  11 5.3162820e+001 0.00e+000 1.27e+001  -8.6 2.13e-002    -  1.00e
+000 1.00e+000f  1
  12 5.2735107e+001 0.00e+000 1.08e+001  -9.7 3.53e-002    -  1.00e
+000 2.50e-001f  3
  13 5.2426507e+001 0.00e+000 6.98e+000 -11.0 6.02e-003    -  1.00e
+000 1.00e+000f  1
  14 5.1973736e+001 0.00e+000 6.90e+000 -11.0 1.10e-002    -  1.00e
+000 1.00e+000f  1
  15 5.1577340e+001 0.00e+000 5.15e+000 -11.0 1.07e-002    -  1.00e
+000 1.00e+000f  1
  16 5.1040251e+001 0.00e+000 5.51e+000 -11.0 1.64e-002    -  1.00e
+000 1.00e+000f  1
  17 5.0985994e+001 0.00e+000 1.31e+001 -11.0 3.28e-002    -  1.00e
+000 5.00e-001f  2
```

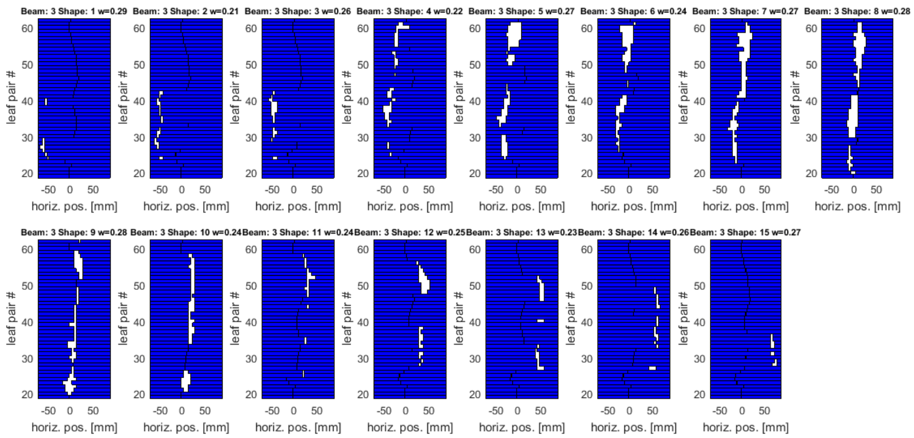
```
  18 5.0651010e+001 0.00e+000 3.01e+000 -11.0 7.36e-003    -  1.00e
+000 1.00e+000f  1
  19 5.0542039e+001 0.00e+000 2.61e+000 -11.0 4.07e-003    -  1.00e
+000 1.00e+000f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  20 5.0396102e+001 0.00e+000 3.87e+000 -11.0 9.85e-003    -  1.00e
+000 1.00e+000f  1
  21 5.0313434e+001 0.00e+000 6.34e+000 -11.0 2.02e-002    -  1.00e
+000 5.00e-001f  2
  22 5.0227231e+001 0.00e+000 3.76e+000 -11.0 4.67e-003    -  1.00e
+000 1.00e+000f  1
  23 5.0114611e+001 0.00e+000 3.19e+000 -11.0 9.94e-003    -  1.00e
+000 1.00e+000f  1
  24 5.0046818e+001 0.00e+000 3.28e+000 -11.0 6.99e-003    -  1.00e
+000 1.00e+000f  1
  25 4.9892819e+001 0.00e+000 4.98e+000 -11.0 2.25e-002    -  1.00e
+000 1.00e+000f  1
  26 4.9851363e+001 0.00e+000 5.31e+000 -11.0 2.46e-002    -  1.00e
+000 5.00e-001f  2
  27 4.9790202e+001 0.00e+000 2.86e+000 -11.0 3.17e-003    -  1.00e
+000 1.00e+000f  1
  28 4.9742637e+001 0.00e+000 1.98e+000 -11.0 4.52e-003    -  1.00e
+000 1.00e+000f  1
  29 4.9683578e+001 0.00e+000 3.03e+000 -11.0 9.43e-003    -  1.00e
+000 1.00e+000f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
 alpha_pr  ls
  30 4.9677190e+001 0.00e+000 9.53e+000 -11.0 2.56e-002    -  1.00e
+000 5.00e-001f  2
  31 4.9607711e+001 0.00e+000 4.40e+000 -11.0 6.01e-003    -  1.00e
+000 1.00e+000f  1
  32 4.9583219e+001 0.00e+000 1.67e+000 -11.0 4.53e-003    -  1.00e
+000 1.00e+000f  1
  33 4.9562003e+001 0.00e+000 1.92e+000 -11.0 5.87e-003    -  1.00e
+000 1.00e+000f  1
  34 4.9526949e+001 0.00e+000 2.13e+000 -11.0 8.91e-003    -  1.00e
+000 1.00e+000f  1

Number of Iterations....: 34

                                   (scaled)                 (unscaled)
Objective...............:  4.9526948978520231e+001
 4.9526948978520231e+001
Dual infeasibility......:  2.1273297103142301e+000
 2.1273297103142301e+000
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
Complementarity.........:  1.0000000000000003e-011
 1.0000000000000003e-011
Overall NLP error.......:  2.1273297103142301e+000
 2.1273297103142301e+000
```

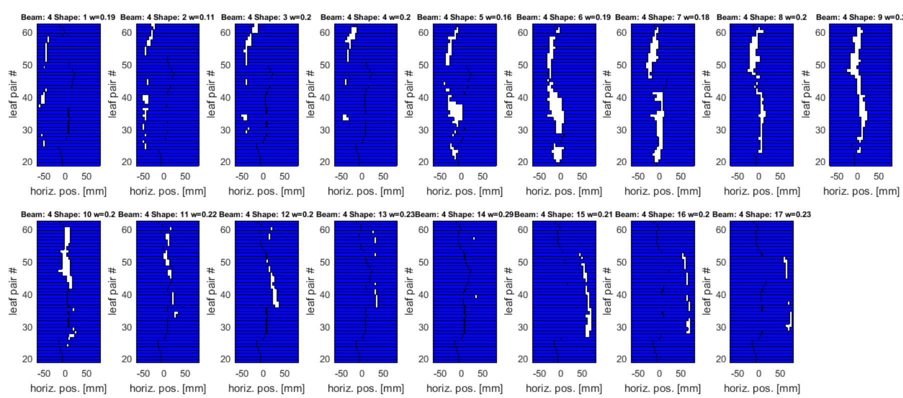
```
Number of objective function evaluations             = 50
Number of objective gradient evaluations             = 35
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 50
Number of equality constraint Jacobian evaluations   = 0
Number of inequality constraint Jacobian evaluations = 35
Number of Lagrangian Hessian evaluations             = 0
Total CPU secs in IPOPT (w/o function evaluations)   =      2.167
Total CPU secs in NLP function evaluations           =     33.585

EXIT: Solved To Acceptable Level.
```

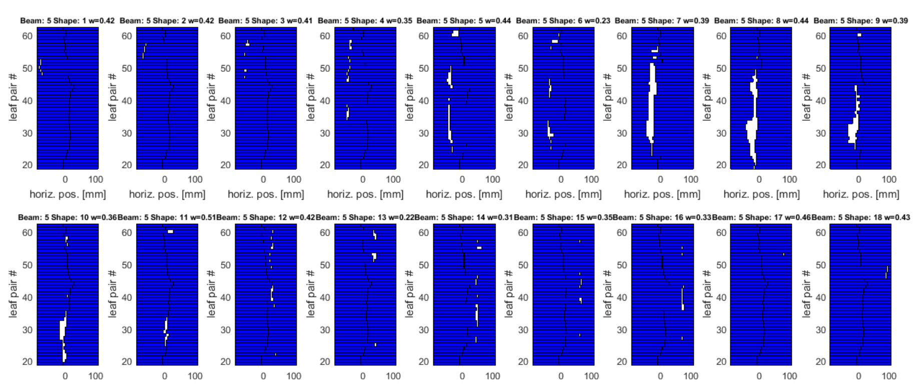


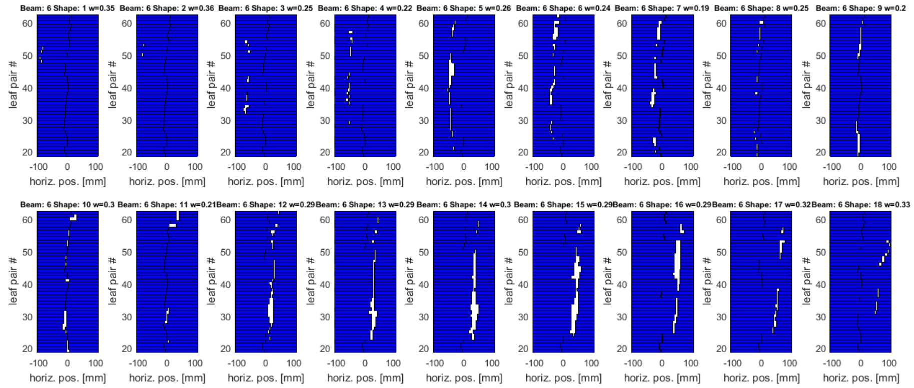


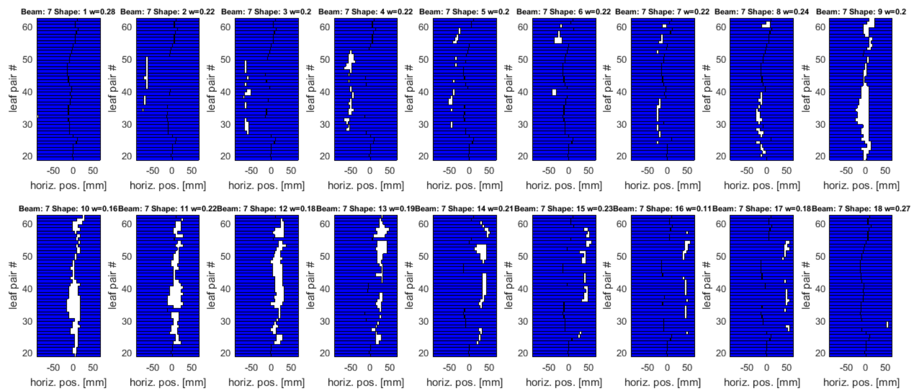

Beam: 2 Shape: 1 w=0.2
Beam: 2 Shape: 2 w=0.18
Beam: 2 Shape: 3 w=0.23
Beam: 2 Shape: 4 w=0.2
Beam: 2 Shape: 5 w=0.16
Beam: 2 Shape: 6 w=0.22
Beam: 2 Shape: 7 w=0.14
Beam: 2 Shape: 8 w=0.22
Beam: 2 Shape: 9 w=0.17
Beam: 2 Shape: 10 w=0.2
Beam: 2 Shape: 11 w=0.17
Beam: 2 Shape: 12 w=0.2
Beam: 2 Shape: 13 w=0.18
Beam: 2 Shape: 14 w=0.18
Beam: 2 Shape: 15 w=0.15
Beam: 2 Shape: 16 w=0.18
Beam: 2 Shape: 17 w=0.2
Beam: 2 Shape: 18 w=0.08
Beam: 2 Shape: 19 w=0.22
Beam: 2 Shape: 20 w=0.18
Beam: 2 Shape: 21 w=0.17
Beam: 2 Shape: 22 w=0.26
leaf pair #
horiz. pos. [mm]

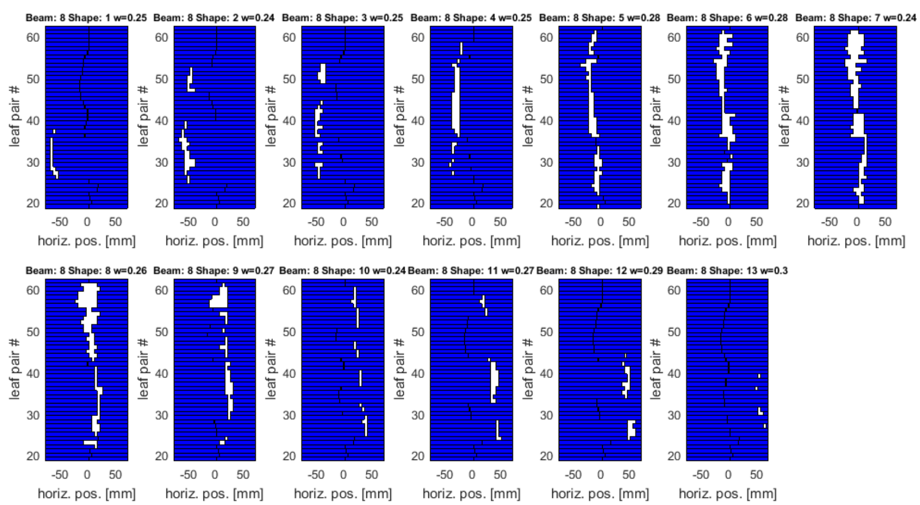

Beam: 3 Shape: 1 w=0.29
Beam: 3 Shape: 2 w=0.21
Beam: 3 Shape: 3 w=0.26
Beam: 3 Shape: 4 w=0.22
Beam: 3 Shape: 5 w=0.27
Beam: 3 Shape: 6 w=0.24
Beam: 3 Shape: 7 w=0.27
Beam: 3 Shape: 8 w=0.28
Beam: 3 Shape: 9 w=0.28
Beam: 3 Shape: 10 w=0.24
Beam: 3 Shape: 11 w=0.24
Beam: 3 Shape: 12 w=0.25
Beam: 3 Shape: 13 w=0.23
Beam: 3 Shape: 14 w=0.26
Beam: 3 Shape: 15 w=0.27
leaf pair #
horiz. pos. [mm]

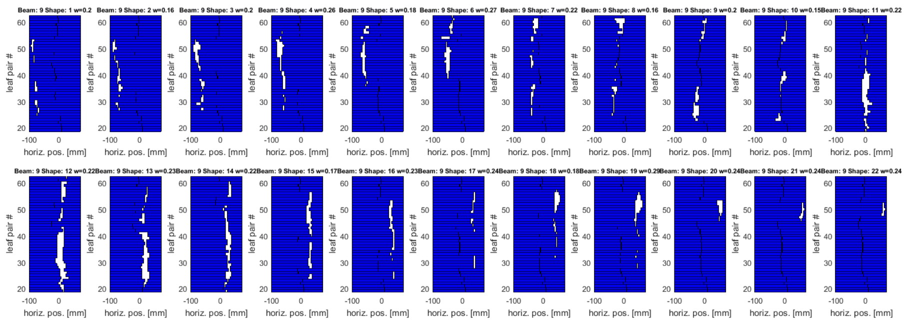

Beam: 4 Shape: 1 w=0.19
Beam: 4 Shape: 2 w=0.11
Beam: 4 Shape: 3 w=0.2
Beam: 4 Shape: 4 w=0.2
Beam: 4 Shape: 5 w=0.16
Beam: 4 Shape: 6 w=0.19
Beam: 4 Shape: 7 w=0.18
Beam: 4 Shape: 8 w=0.2
Beam: 4 Shape: 9 w=0.2
Beam: 4 Shape: 10 w=0.2
Beam: 4 Shape: 11 w=0.22
Beam: 4 Shape: 12 w=0.2
Beam: 4 Shape: 13 w=0.23
Beam: 4 Shape: 14 w=0.29
Beam: 4 Shape: 15 w=0.21
Beam: 4 Shape: 16 w=0.2
Beam: 4 Shape: 17 w=0.23
leaf pair #
horiz. pos. [mm]


Beam: 5 Shape: 1 w=0.42
Beam: 5 Shape: 2 w=0.42
Beam: 5 Shape: 3 w=0.41
Beam: 5 Shape: 4 w=0.35
Beam: 5 Shape: 5 w=0.44
Beam: 5 Shape: 6 w=0.23
Beam: 5 Shape: 7 w=0.39
Beam: 5 Shape: 8 w=0.44
Beam: 5 Shape: 9 w=0.39
Beam: 5 Shape: 10 w=0.36
Beam: 5 Shape: 11 w=0.51
Beam: 5 Shape: 12 w=0.42
Beam: 5 Shape: 13 w=0.22
Beam: 5 Shape: 14 w=0.31
Beam: 5 Shape: 15 w=0.35
Beam: 5 Shape: 16 w=0.33
Beam: 5 Shape: 17 w=0.46
Beam: 5 Shape: 18 w=0.43
leaf pair #
horiz. pos. [mm]


Beam: 6 Shape: 1 w=0.35
Beam: 6 Shape: 2 w=0.36
Beam: 6 Shape: 3 w=0.25
Beam: 6 Shape: 4 w=0.22
Beam: 6 Shape: 5 w=0.26
Beam: 6 Shape: 6 w=0.24
Beam: 6 Shape: 7 w=0.19
Beam: 6 Shape: 8 w=0.25
Beam: 6 Shape: 9 w=0.2
Beam: 6 Shape: 10 w=0.3
Beam: 6 Shape: 11 w=0.21
Beam: 6 Shape: 12 w=0.29
Beam: 6 Shape: 13 w=0.29
Beam: 6 Shape: 14 w=0.3
Beam: 6 Shape: 15 w=0.29
Beam: 6 Shape: 16 w=0.29
Beam: 6 Shape: 17 w=0.32
Beam: 6 Shape: 18 w=0.33
leaf pair #
horiz. pos. [mm]


Beam: 7 Shape: 1 w=0.28
Beam: 7 Shape: 2 w=0.22
Beam: 7 Shape: 3 w=0.2
Beam: 7 Shape: 4 w=0.22
Beam: 7 Shape: 5 w=0.2
Beam: 7 Shape: 6 w=0.22
Beam: 7 Shape: 7 w=0.22
Beam: 7 Shape: 8 w=0.24
Beam: 7 Shape: 9 w=0.2
Beam: 7 Shape: 10 w=0.16
Beam: 7 Shape: 11 w=0.22
Beam: 7 Shape: 12 w=0.18
Beam: 7 Shape: 13 w=0.19
Beam: 7 Shape: 14 w=0.21
Beam: 7 Shape: 15 w=0.23
Beam: 7 Shape: 16 w=0.11
Beam: 7 Shape: 17 w=0.18
Beam: 7 Shape: 18 w=0.27
leaf pair #
horiz. pos. [mm]


Beam: 8 Shape: 1 w=0.25
Beam: 8 Shape: 2 w=0.24
Beam: 8 Shape: 3 w=0.25
Beam: 8 Shape: 4 w=0.25
Beam: 8 Shape: 5 w=0.28
Beam: 8 Shape: 6 w=0.28
Beam: 8 Shape: 7 w=0.24
Beam: 8 Shape: 8 w=0.26
Beam: 8 Shape: 9 w=0.27
Beam: 8 Shape: 10 w=0.24
Beam: 8 Shape: 11 w=0.27
Beam: 8 Shape: 12 w=0.29
Beam: 8 Shape: 13 w=0.3
leaf pair #
horiz. pos. [mm]



Indicator Calculation

Here we call the indicator wrapper function that is just a wrapper function to calculate multiple quality indicators like D98, D95. One basically calculates default quality indicators for a given dose distribution. If you don't see clearly the images, go in the folder 'html' in your working folder and you should look at the images, starting with the same name of this file, numbered from 3 to 11.

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

```
  0        BRAIN STEM PRV - Mean dose =  0.35 Gy +/-  0.30 Gy (Max dose
 =  1.13 Gy, Min dose =  0.02 Gy)
                          D2% =  1.00 Gy, D5% =  0.92 Gy, D98% =
 0.02 Gy, D95% =  0.03 Gy,
                          V0Gy = 100.00%, V0.526Gy =  28.15%, V1.05Gy
 =   0.77%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

  1            BRAIN STEM - Mean dose =  0.36 Gy +/-  0.29 Gy (Max dose
 =  1.06 Gy, Min dose =  0.03 Gy)
                          D2% =  0.99 Gy, D5% =  0.91 Gy, D98% =
 0.03 Gy, D95% =  0.04 Gy,
                          V0Gy = 100.00%, V0.526Gy =  28.13%, V1.05Gy
 =   0.24%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

  2            CEREBELLUM - Mean dose =  0.52 Gy +/-  0.27 Gy (Max dose
 =  1.59 Gy, Min dose =  0.03 Gy)
                          D2% =  1.11 Gy, D5% =  1.01 Gy, D98% =
 0.05 Gy, D95% =  0.14 Gy,
                          V0Gy = 100.00%, V0.526Gy =  47.40%, V1.05Gy
 =   3.15%, V1.58Gy =   0.04%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

  3               CHIASMA - Mean dose =  0.07 Gy +/-  0.02 Gy (Max dose
 =  0.10 Gy, Min dose =  0.05 Gy)
                          D2% =  0.10 Gy, D5% =  0.10 Gy, D98% =
 0.05 Gy, D95% =  0.05 Gy,
                          V0Gy = 100.00%, V0.526Gy =   0.00%, V1.05Gy
 =   0.00%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

  4                 CTV56 - Mean dose =  1.93 Gy +/-  0.13 Gy (Max dose
 =  2.32 Gy, Min dose =  1.72 Gy)
                          D2% =  2.22 Gy, D5% =  2.19 Gy, D98% =
 1.77 Gy, D95% =  1.78 Gy,
```

```
                          V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy
= 100.00%, V1.58Gy = 100.00%, V2.11Gy =  16.74%, V2.63Gy =   0.00%,
                          Warning: target has no objective that
penalizes underdosage,
 5                CTV63 - Mean dose =  2.14 Gy +/-  0.15 Gy (Max dose
=  2.63 Gy, Min dose =  1.07 Gy)
                          D2% =  2.43 Gy, D5% =  2.38 Gy, D98% =
1.79 Gy, D95% =  1.93 Gy,
                          V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy
= 100.00%, V1.58Gy =  99.41%, V2.11Gy =  57.88%, V2.63Gy =   0.01%,
                          Warning: target has no objective that
penalizes underdosage,
 6             External - Mean dose =  0.58 Gy +/-  0.68 Gy (Max dose
=  2.63 Gy, Min dose =  0.00 Gy)
                          D2% =  2.27 Gy, D5% =  2.11 Gy, D98% =
0.00 Gy, D95% =  0.00 Gy,
                          V0Gy = 100.00%, V0.526Gy =  39.58%, V1.05Gy
=  20.58%, V1.58Gy =  12.57%, V2.11Gy =   5.23%, V2.63Gy =   0.00%,

 7                  GTV - Mean dose =  2.34 Gy +/-  0.07 Gy (Max dose
=  2.59 Gy, Min dose =  2.07 Gy)
                          D2% =  2.48 Gy, D5% =  2.45 Gy, D98% =
2.18 Gy, D95% =  2.22 Gy,
                          V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy
= 100.00%, V1.58Gy = 100.00%, V2.11Gy =  99.77%, V2.63Gy =   0.00%,

 8               LARYNX - Mean dose =  1.11 Gy +/-  0.15 Gy (Max dose
=  1.50 Gy, Min dose =  0.79 Gy)
                          D2% =  1.44 Gy, D5% =  1.36 Gy, D98% =
0.82 Gy, D95% =  0.83 Gy,
                          V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy
=  67.63%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

 9              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, D98% =
0.00 Gy, D95% =  0.00 Gy,
                          V0Gy = 100.00%, V0.526Gy =   0.00%, V1.05Gy
=   0.00%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

10              LENS RT - Mean dose =  0.00 Gy +/-  0.00 Gy (Max dose
=  0.01 Gy, Min dose =  0.00 Gy)
                          D2% =  0.01 Gy, D5% =  0.01 Gy, D98% =
0.00 Gy, D95% =  0.00 Gy,
                          V0Gy = 100.00%, V0.526Gy =   0.00%, V1.05Gy
=   0.00%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

11                 LIPS - Mean dose =  1.15 Gy +/-  0.20 Gy (Max dose
=  1.68 Gy, Min dose =  0.59 Gy)
                          D2% =  1.56 Gy, D5% =  1.43 Gy, D98% =
0.62 Gy, D95% =  0.74 Gy,
                          V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy
=  74.29%, V1.58Gy =   1.43%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,
```

12 OPTIC NRV LT - Mean dose = 0.05 Gy +/- 0.03 Gy (Max dose = 0.11 Gy, Min dose = 0.02 Gy)
D2% = 0.11 Gy, D5% = 0.11 Gy, D98% = 0.02 Gy, D95% = 0.02 Gy,
V0Gy = 100.00%, V0.526Gy = 0.00%, V1.05Gy = 0.00%, V1.58Gy = 0.00%, V2.11Gy = 0.00%, V2.63Gy = 0.00%,

13 OPTIC NRV RT - Mean dose = 0.03 Gy +/- 0.02 Gy (Max dose = 0.08 Gy, Min dose = 0.01 Gy)
D2% = 0.07 Gy, D5% = 0.07 Gy, D98% = 0.01 Gy, D95% = 0.01 Gy,
V0Gy = 100.00%, V0.526Gy = 0.00%, V1.05Gy = 0.00%, V1.58Gy = 0.00%, V2.11Gy = 0.00%, V2.63Gy = 0.00%,

14 PAROTID LT - Mean dose = 0.69 Gy +/- 0.24 Gy (Max dose = 1.63 Gy, Min dose = 0.30 Gy)
D2% = 1.29 Gy, D5% = 1.18 Gy, D98% = 0.36 Gy, D95% = 0.40 Gy,
V0Gy = 100.00%, V0.526Gy = 73.73%, V1.05Gy = 8.99%, V1.58Gy = 0.46%, V2.11Gy = 0.00%, V2.63Gy = 0.00%,

15 PAROTID RT - Mean dose = 0.73 Gy +/- 0.22 Gy (Max dose = 1.52 Gy, Min dose = 0.18 Gy)
D2% = 1.26 Gy, D5% = 1.17 Gy, D98% = 0.29 Gy, D95% = 0.37 Gy,
V0Gy = 100.00%, V0.526Gy = 82.68%, V1.05Gy = 8.33%, V1.58Gy = 0.00%, V2.11Gy = 0.00%, V2.63Gy = 0.00%,

16 PTV56 - Mean dose = 1.92 Gy +/- 0.12 Gy (Max dose = 2.32 Gy, Min dose = 1.69 Gy)
D2% = 2.21 Gy, D5% = 2.18 Gy, D98% = 1.76 Gy, D95% = 1.78 Gy,
V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy = 100.00%, V1.58Gy = 100.00%, V2.11Gy = 14.78%, V2.63Gy = 0.00%,
CI = 0.0707, HI = 21.51 for reference dose of 1.9 Gy

17 PTV63 - Mean dose = 2.12 Gy +/- 0.18 Gy (Max dose = 2.63 Gy, Min dose = 0.55 Gy)
D2% = 2.43 Gy, D5% = 2.38 Gy, D98% = 1.76 Gy, D95% = 1.87 Gy,
V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy = 99.57%, V1.58Gy = 98.79%, V2.11Gy = 52.72%, V2.63Gy = 0.00%,
CI = 0.7623, HI = 24.25 for reference dose of 2.1 Gy

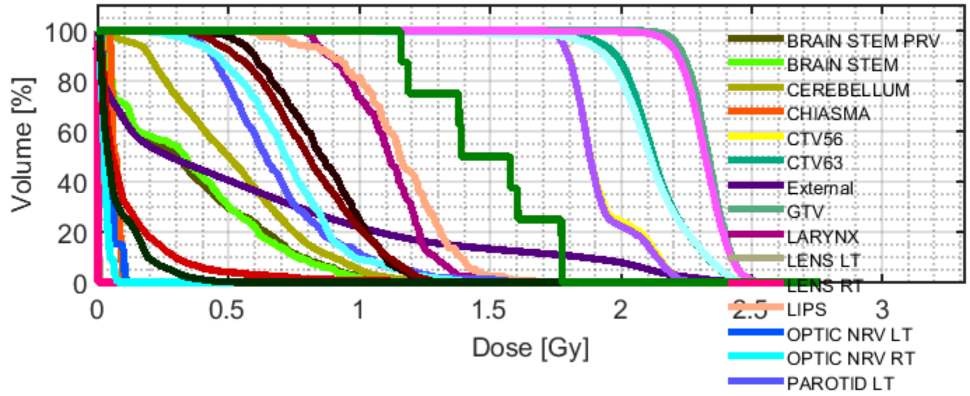
18 PTV70 - Mean dose = 2.32 Gy +/- 0.09 Gy (Max dose = 2.63 Gy, Min dose = 1.57 Gy)
D2% = 2.48 Gy, D5% = 2.45 Gy, D98% = 2.14 Gy, D95% = 2.18 Gy,
V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy = 100.00%, V1.58Gy = 99.98%, V2.11Gy = 98.87%, V2.63Gy = 0.02%,
CI = 0.6934, HI = 11.38 for reference dose of 2.3 Gy

```
19          SPINAL CORD - Mean dose =  0.86 Gy +/-  0.19 Gy (Max dose
=  1.28 Gy, Min dose =  0.42 Gy)
                          D2% =  1.21 Gy, D5% =  1.16 Gy, D98% =
0.49 Gy, D95% =  0.55 Gy,
                          V0Gy = 100.00%, V0.526Gy =  96.32%, V1.05Gy
=  16.32%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

20        SPINL CRD PRV - Mean dose =  0.82 Gy +/-  0.22 Gy (Max dose
=  1.35 Gy, Min dose =  0.35 Gy)
                          D2% =  1.23 Gy, D5% =  1.19 Gy, D98% =
0.40 Gy, D95% =  0.46 Gy,
                          V0Gy = 100.00%, V0.526Gy =  90.55%, V1.05Gy
=  16.13%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

21         TEMP LOBE LT - Mean dose =  0.13 Gy +/-  0.18 Gy (Max dose
=  1.62 Gy, Min dose =  0.01 Gy)
                          D2% =  0.74 Gy, D5% =  0.44 Gy, D98% =
0.01 Gy, D95% =  0.02 Gy,
                          V0Gy = 100.00%, V0.526Gy =   3.88%, V1.05Gy
=   0.62%, V1.58Gy =   0.05%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

22         TEMP LOBE RT - Mean dose =  0.08 Gy +/-  0.09 Gy (Max dose
=  0.55 Gy, Min dose =  0.01 Gy)
                          D2% =  0.35 Gy, D5% =  0.28 Gy, D98% =
0.01 Gy, D95% =  0.01 Gy,
                          V0Gy = 100.00%, V0.526Gy =   0.05%, V1.05Gy
=   0.00%, V1.58Gy =   0.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,

23          TM JOINT LT - Mean dose =  1.48 Gy +/-  0.24 Gy (Max dose
=  1.78 Gy, Min dose =  1.16 Gy)
                          D2% =  1.78 Gy, D5% =  1.78 Gy, D98% =
1.16 Gy, D95% =  1.16 Gy,
                          V0Gy = 100.00%, V0.526Gy = 100.00%, V1.05Gy
= 100.00%, V1.58Gy =  50.00%, V2.11Gy =   0.00%, V2.63Gy =   0.00%,
```

Show DVH and QI

This last function allow you to plot the Dose Volume Histogram and the dose statistics of all the VOIs in side the ct.

```
matRad_showDVH(cst,pln)
```



VOIs	mean	std	max	min	D2	D5
BRAIN STEM PRV	0.3456	0.2995	1.1288	0.0185	1.0044	0.9157
BRAIN STEM	0.3559	0.2858	1.0573	0.0285	0.9863	0.9068
CEREBELLUM	0.5229	0.2725	1.5935	0.0266	1.1117	1.0077
CHIASMA	0.0729	0.0165	0.1032	0.0502	0.1032	0.1023
CTV56	1.9297	0.1283	2.3201	1.7199	2.2211	2.1877
CTV63	2.1367	0.1468	2.6320	1.0725	2.4255	2.3813
External	0.5824	0.6794	2.6320	0	2.2682	2.1139
GTV	2.3369	0.0730	2.5904	2.0658	2.4835	2.4531
LARYNX	1.1092	0.1513	1.4960	0.7920	1.4437	1.3561

dose statistics

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