Example: Photon Treatment Plan

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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 based on the VMC++ Monte Carlo algorithm (iii) how to inversly optimize the beamlet intensities directly from command window in MATLAB. (iv) how to visualize the result

Patient Data Import

Let's begin with a clear Matlab environment. First, import the boxphantom 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('BOXPHANTOM.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: {[160×160×160 double]}
    resolution: [1×1 struct]
       cubeDim: [160 160 160]
  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, 2 structures are defined in the cst

```
cst
```

```
cst =

  2×6 cell array

  Columns 1 through 5

    [0]    'BODY'           'OAR'       {1×1 cell}    [1×1 struct]
    [1]    'OuterTarget'    'TARGET'    {1×1 cell}    [1×1 struct]

  Column 6

    [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 'photons_Generic.mat' in our root directory and will use the data provided in there for dose calculation

```
pln.radiationMode = 'photons';
pln.machine       = 'Generic';
```

Define the flavour of biological optimization 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, we 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 one single beam from 0 degree gantry angle and 0 degree couch angle. Moreover, we set the bixelWidth to 10, which results in a beamlet size of 10 x 10 mm. The number of fractions is set to 30. Be advised that matRad is always optimizing the fraction dose.

```
pln.gantryAngles    = [0];
pln.couchAngles     = [0];
```

```
pln.bixelWidth      = 10;
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);
```

Disable sequencing and direct aperture optimization (DAO) for now. The application of the sequencing algorithm and DAO optimization is shown in a seperate example.

```
pln.runSequencing = 0;
pln.runDAO        = 0;
```

and et voila our treatment plan is ready. Lets have a look at it:

```
pln
```

```
pln =

  struct with fields:

      radiationMode: 'photons'
            machine: 'Generic'
    bioOptimization: 'none'
       gantryAngles: 0
        couchAngles: 0
         bixelWidth: 10
     numOfFractions: 30
         numOfBeams: 1
        numOfVoxels: 4096000
    voxelDimensions: [160 160 160]
          isoCenter: [240 240 240]
      runSequencing: 0
             runDAO: 0
```

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 %
```

Dose Calculation

Calculate dose influence matrix for unit pencil beam intensities. using the VMC++ monte carlo algorithm. We define the number of photons simulated per beamlet to be 700. Make sure to download VMC++

files from http://www.cerr.info/download.php into the matRadrootDirectory\vmc++ to run the following function.

```
nCasePerBixel = 700;
dij = matRad_calcPhotonDoseVmc(ct,stf,pln,cst,700,1);

matRad: VMC++ photon dose calculation...


Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,22.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                    Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
```

```
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 24442  27174
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                  Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.359 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.045  70  70
+++finished batch 6 cpu time: 0.055  70  70
+++finished batch 7 cpu time: 0.065  70  70
+++finished batch 8 cpu time: 0.075  70  70
+++finished batch 9 cpu time: 0.085  70  70
+++finished batch 10 cpu time: 0.095  70  70
```

```
finished simulation, cpu time = 0.102 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.102
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0372868 in region 1803247
    ICRU-2K efficiency: 1056.38 1/s
+++ total
    max dose is 0.0372868 in region 1803247
    ICRU-2K efficiency: 1056.38 1/s
====================================================
Completed 1 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,23)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
```

```
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 3810  27402
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================================
                 Scoring and output options
================================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.338 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source
```

```
Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.092  70  70
finished simulation, cpu time = 0.099 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.099
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0376496 in region 1880047
    ICRU-2K efficiency: 1054.04 1/s
+++ total
    max dose is 0.0376496 in region 1880047
    ICRU-2K efficiency: 1054.04 1/s
====================================================
Completed 2 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,23.5)
============================================================
============================================================
              XYZ Geometry
```

```
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 18971  2927
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
```

```
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.342 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.081  70  70
+++finished batch 10 cpu time: 0.092  70  70
finished simulation, cpu time = 0.1 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.1
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0388407 in region 1956847
    ICRU-2K efficiency: 1038.49 1/s
+++ total
    max dose is 0.0388407 in region 1956847
    ICRU-2K efficiency: 1038.49 1/s
====================================================
Completed 3 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
```

```
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,24)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                    Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 8355  16407
================================================
================================================================
                    Variance Reduction
================================================================

 f_repeat           = 0.251
 split photons      = 1
```

```
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.349 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.034  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.064  70  70
+++finished batch 8 cpu time: 0.075  70  70
+++finished batch 9 cpu time: 0.085  70  70
+++finished batch 10 cpu time: 0.095  70  70
finished simulation, cpu time = 0.103 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ===================
 geometry: CT
 cpu time: 0.103
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0374707 in region 2033647
    ICRU-2K efficiency: 1061.29 1/s
+++ total
    max dose is 0.0374707 in region 2033647
    ICRU-2K efficiency: 1061.29 1/s
================================================
Completed 4 of 49 beamlets...
```

```
Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,24.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                  Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
```

```
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 28726  28947
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.359 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.034  70  70
+++finished batch 5 cpu time: 0.044  70  70
+++finished batch 6 cpu time: 0.055  70  70
+++finished batch 7 cpu time: 0.064  70  70
+++finished batch 8 cpu time: 0.075  70  70
+++finished batch 9 cpu time: 0.085  70  70
+++finished batch 10 cpu time: 0.095  70  70
finished simulation, cpu time = 0.102 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
```

```
 geometry: CT
 cpu time: 0.102
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0380877 in region 2110447
    ICRU-2K efficiency: 1072.03 1/s
+++ total
    max dose is 0.0380877 in region 2110447
    ICRU-2K efficiency: 1072.03 1/s
================================================
Completed 5 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,25)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                   Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
```

```
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 4729  29118
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                  Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.355 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.033  70  70
```

```
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.092  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0386789 in region 2187247
    ICRU-2K efficiency: 1163.33 1/s
+++ total
    max dose is 0.0386789 in region 2187247
    ICRU-2K efficiency: 1163.33 1/s
==================================================
Completed 6 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,22.5,25.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
```

```
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 28716  14562
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.362 seconds
```

```
Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.025  70  70
+++finished batch 4 cpu time: 0.036  70  70
+++finished batch 5 cpu time: 0.046  70  70
+++finished batch 6 cpu time: 0.058  70  70
+++finished batch 7 cpu time: 0.067  70  70
+++finished batch 8 cpu time: 0.077  70  70
+++finished batch 9 cpu time: 0.087  70  70
+++finished batch 10 cpu time: 0.097  70  70
finished simulation, cpu time = 0.103 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.103
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0385553 in region 2264047
    ICRU-2K efficiency: 1023.34 1/s
+++ total
    max dose is 0.0385553 in region 2264047
    ICRU-2K efficiency: 1023.34 1/s
==================================================
Completed 7 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
```

```
      Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,22.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 24009  4257
================================================
============================================================
                   Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                   Quasi Random Numbers
============================================================
 number of generators: 1
```

```
                1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.358 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.093  70  70
finished simulation, cpu time = 0.099 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.099
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0391293 in region 1803727
    ICRU-2K efficiency: 1122.07 1/s
+++ total
    max dose is 0.0391293 in region 1803727
    ICRU-2K efficiency: 1122.07 1/s
================================================
Completed 8 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
```

```
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,23)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 12653  27473
================================================
```

```
=====================================================================
                    Variance Reduction
=====================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
=====================================================================
=====================================================================
                    Quasi Random Numbers
=====================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
=====================================================================
=====================================================================
                  Scoring and output options
=====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.369 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.015  70  70
+++finished batch 3 cpu time: 0.025  70  70
+++finished batch 4 cpu time: 0.035  70  70
+++finished batch 5 cpu time: 0.045  70  70
+++finished batch 6 cpu time: 0.056  70  70
+++finished batch 7 cpu time: 0.065  70  70
+++finished batch 8 cpu time: 0.075  70  70
+++finished batch 9 cpu time: 0.085  70  70
+++finished batch 10 cpu time: 0.094  70  70
finished simulation, cpu time = 0.102 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.102
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0385753 in region 1880527
```

```
    ICRU-2K efficiency: 1083.91 1/s
+++ total
    max dose is 0.0385753 in region 1880527
    ICRU-2K efficiency: 1083.91 1/s
================================================
Completed 9 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,23.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
```

```
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 23767  28785
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                  Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.314 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.044  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.092  70  70
```

```
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0378762 in region 1957327
    ICRU-2K efficiency: 1112.72 1/s
+++ total
    max dose is 0.0378762 in region 1957327
    ICRU-2K efficiency: 1112.72 1/s
====================================================
Completed 10 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,24)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
```

```
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 19673  1072
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================================
                 Scoring and output options
================================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.333 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source
```

```
Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0390439 in region 2034127
    ICRU-2K efficiency: 1154.44 1/s
+++ total
    max dose is 0.0390439 in region 2034127
    ICRU-2K efficiency: 1154.44 1/s
====================================================
Completed 11 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,24.5)
============================================================
============================================================
              XYZ Geometry
```

```
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 25474  28020
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
```

```
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.315 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.071  70  70
+++finished batch 9 cpu time: 0.081  70  70
+++finished batch 10 cpu time: 0.091  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0378966 in region 2110927
    ICRU-2K efficiency: 1162.87 1/s
+++ total
    max dose is 0.0378966 in region 2110927
    ICRU-2K efficiency: 1162.87 1/s
====================================================
Completed 12 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
```

```
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,25)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                    Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 20363  22733
================================================
====================================================================
                    Variance Reduction
====================================================================

 f_repeat           = 0.251
 split photons      = 1
```

```
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.344 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.034  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.092  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ===================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0375397 in region 2187727
    ICRU-2K efficiency: 1220.1 1/s
+++ total
    max dose is 0.0375397 in region 2187727
    ICRU-2K efficiency: 1220.1 1/s
================================================
Completed 13 of 49 beamlets...
```

```
Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23,25.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
```

```
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 22294  11767
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.316 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.071  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.097 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
```

```
 geometry: CT
 cpu time: 0.097
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0376161 in region 2264527
    ICRU-2K efficiency: 1130.64 1/s
+++ total
    max dose is 0.0376161 in region 2264527
    ICRU-2K efficiency: 1130.64 1/s
==================================================
Completed 14 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,22.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
```

```
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

=============================================================
=================================================
                MC_Control
=================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 19665  5136
=================================================
=============================================================
                   Variance Reduction
=============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
=============================================================
=============================================================
                   Quasi Random Numbers
=============================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
=============================================================
=====================================================================
                 Scoring and output options
=====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.377 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.035  70  70
```

```
+++finished batch 5 cpu time: 0.046  70  70
+++finished batch 6 cpu time: 0.057  70  70
+++finished batch 7 cpu time: 0.066  70  70
+++finished batch 8 cpu time: 0.078  70  70
+++finished batch 9 cpu time: 0.09  70  70
+++finished batch 10 cpu time: 0.1  70  70
finished simulation, cpu time = 0.107 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.107
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0382175 in region 1804207
    ICRU-2K efficiency: 1000.34 1/s
+++ total
    max dose is 0.0382175 in region 1804207
    ICRU-2K efficiency: 1000.34 1/s
==================================================
Completed 15 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,23)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
```

```
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 21182  955
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.303 seconds
```

```
Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ===================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0376251 in region 1881007
    ICRU-2K efficiency: 1083.4 1/s
+++ total
    max dose is 0.0376251 in region 1881007
    ICRU-2K efficiency: 1083.4 1/s
=================================================
Completed 16 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
```

```
      Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,23.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 8308  1386
================================================
============================================================
                   Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                   Quasi Random Numbers
============================================================
 number of generators: 1
```

```
                1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.298 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0386409 in region 1957807
    ICRU-2K efficiency: 1085.01 1/s
+++ total
    max dose is 0.0386409 in region 1957807
    ICRU-2K efficiency: 1085.01 1/s
================================================
Completed 17 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
```

```
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,24)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 2914  24704
================================================
```

```
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.305 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.05  70  70
+++finished batch 7 cpu time: 0.059  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.079  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0395884 in region 2034607
```

```
    ICRU-2K efficiency: 1164.84 1/s
+++ total
    max dose is 0.0395884 in region 2034607
    ICRU-2K efficiency: 1164.84 1/s
==================================================
Completed 18 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,24.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
```

```
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 20845  9513
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                  Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.301 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.071  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.091  70  70
```

```
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0389809 in region 2111407
    ICRU-2K efficiency: 1101.05 1/s
+++ total
    max dose is 0.0389809 in region 2111407
    ICRU-2K efficiency: 1101.05 1/s
====================================================
Completed 19 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,25)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
```

```
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 28507  1034
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================================
                Scoring and output options
================================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.308 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source
```

```
Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.05  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0374017 in region 2188207
    ICRU-2K efficiency: 1206.62 1/s
+++ total
    max dose is 0.0374017 in region 2188207
    ICRU-2K efficiency: 1206.62 1/s
====================================================
Completed 20 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,23.5,25.5)
============================================================
============================================================
              XYZ Geometry
```

```
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 13163  11447
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
```

```
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.305 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0381957 in region 2265007
    ICRU-2K efficiency: 1120.01 1/s
+++ total
    max dose is 0.0381957 in region 2265007
    ICRU-2K efficiency: 1120.01 1/s
====================================================
Completed 21 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
```

```
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,22.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                    Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 22966  23856
================================================
================================================================
                    Variance Reduction
================================================================

 f_repeat           = 0.251
 split photons      = 1
```

```
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.306 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.083  70  70
+++finished batch 10 cpu time: 0.092  70  70
finished simulation, cpu time = 0.099 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.099
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0369034 in region 1804687
    ICRU-2K efficiency: 1021.96 1/s
+++ total
    max dose is 0.0369034 in region 1804687
    ICRU-2K efficiency: 1021.96 1/s
================================================
Completed 22 of 49 beamlets...
```

```
Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,23)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================================
                  Monte Carlo Parameter
============================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================================
================================================
               MC_Control
================================================
```

```
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 5607  14693
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.324 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.091  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
```

```
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0379846 in region 1881487
    ICRU-2K efficiency: 1076.06 1/s
+++ total
    max dose is 0.0379846 in region 1881487
    ICRU-2K efficiency: 1076.06 1/s
================================================
Completed 23 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,23.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                   Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
```

```
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
==============================================
               MC_Control
==============================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 13368  19390
==============================================
============================================================
                  Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                  Quasi Random Numbers
============================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
============================================================
========================================================================
                 Scoring and output options
========================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.328 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
```

```
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.083  70  70
+++finished batch 10 cpu time: 0.093  70  70
finished simulation, cpu time = 0.1 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.1
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0380079 in region 1958287
    ICRU-2K efficiency: 1046.23 1/s
+++ total
    max dose is 0.0380079 in region 1958287
    ICRU-2K efficiency: 1046.23 1/s
================================================
Completed 24 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,24)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
```

```
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 21281  22641
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.332 seconds
```

```
Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.034  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.054  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.091  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0393287 in region 2035087
    ICRU-2K efficiency: 1112.5 1/s
+++ total
    max dose is 0.0393287 in region 2035087
    ICRU-2K efficiency: 1112.5 1/s
=================================================
Completed 25 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
```

```
      Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,24.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 8281  20392
================================================
============================================================
                   Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                   Quasi Random Numbers
============================================================
 number of generators: 1
```

```
                1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.303 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0379302 in region 2111887
    ICRU-2K efficiency: 1105.26 1/s
+++ total
    max dose is 0.0379302 in region 2111887
    ICRU-2K efficiency: 1105.26 1/s
================================================
Completed 26 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
```

```
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,25)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 19653  4879
================================================
```

```
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.306 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.031  70  70
+++finished batch 5 cpu time: 0.04  70  70
+++finished batch 6 cpu time: 0.05  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.071  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.097 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.097
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0385447 in region 2188687
```

```
    ICRU-2K efficiency: 1115.32 1/s
+++ total
    max dose is 0.0385447 in region 2188687
    ICRU-2K efficiency: 1115.32 1/s
==================================================
Completed 27 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24,25.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
```

```
 Electron transport mode            :   VMC++

============================================================
============================================
                MC_Control
============================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 3570  14951
============================================
============================================================
                   Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                   Quasi Random Numbers
============================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
============================================================
========================================================================
                  Scoring and output options
========================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.331 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.071  70  70
+++finished batch 9 cpu time: 0.081  70  70
+++finished batch 10 cpu time: 0.091  70  70
```

```
finished simulation, cpu time = 0.097 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.097
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0382828 in region 2265487
    ICRU-2K efficiency: 1056.23 1/s
+++ total
    max dose is 0.0382828 in region 2265487
    ICRU-2K efficiency: 1056.23 1/s
====================================================
Completed 28 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,22.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                   Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
```

```
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 28793  10212
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================================
                 Scoring and output options
================================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.315 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source
```

```
Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.054  70  70
+++finished batch 7 cpu time: 0.064  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.084  70  70
+++finished batch 10 cpu time: 0.093  70  70
finished simulation, cpu time = 0.099 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.099
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.037456 in region 1805167
    ICRU-2K efficiency: 1085.8 1/s
+++ total
    max dose is 0.037456 in region 1805167
    ICRU-2K efficiency: 1085.8 1/s
=====================================================
Completed 29 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,23)
============================================================
============================================================
              XYZ Geometry
```

```
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 17559  6715
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
```

```
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.329 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0368158 in region 1881966
    ICRU-2K efficiency: 1121.88 1/s
+++ total
    max dose is 0.0368158 in region 1881966
    ICRU-2K efficiency: 1121.88 1/s
====================================================
Completed 30 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
```

```
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,23.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                    Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 22539  7653
================================================
====================================================================
                    Variance Reduction
====================================================================

 f_repeat           = 0.251
 split photons      = 1
```

```
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.31 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.031  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ===================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.038908 in region 1958767
    ICRU-2K efficiency: 1191.82 1/s
+++ total
    max dose is 0.038908 in region 1958767
    ICRU-2K efficiency: 1191.82 1/s
================================================
Completed 31 of 49 beamlets...
```

```
Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,24)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================================
                  Monte Carlo Parameter
============================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================================
================================================
               MC_Control
================================================
```

```
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 15179  20973
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.312 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
```

```
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0375922 in region 2035567
    ICRU-2K efficiency: 1200.59 1/s
+++ total
    max dose is 0.0375922 in region 2035567
    ICRU-2K efficiency: 1200.59 1/s
=================================================
Completed 32 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,24.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
```

```
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
==================================================
                MC_Control
==================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 26728  28779
==================================================
============================================================
                   Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                   Quasi Random Numbers
============================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
============================================================
========================================================================
                  Scoring and output options
========================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.331 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
```

```
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.079  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0389452 in region 2112367
    ICRU-2K efficiency: 1215.01 1/s
+++ total
    max dose is 0.0389452 in region 2112367
    ICRU-2K efficiency: 1215.01 1/s
================================================
Completed 33 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,25)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
```

```
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 16417  4159
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.315 seconds
```

```
Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.079  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ===================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0385814 in region 2189167
    ICRU-2K efficiency: 1159.55 1/s
+++ total
    max dose is 0.0385814 in region 2189167
    ICRU-2K efficiency: 1159.55 1/s
=====================================================
Completed 34 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
```

```
      Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,24.5,25.5)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                   Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 4479  7726
================================================
============================================================
                   Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                   Quasi Random Numbers
============================================================
 number of generators: 1
```

```
                1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.31 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.021  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0385168 in region 2265967
    ICRU-2K efficiency: 1159.02 1/s
+++ total
    max dose is 0.0385168 in region 2265967
    ICRU-2K efficiency: 1159.02 1/s
================================================
Completed 35 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
```

```
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,22.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 25222  7629
================================================
```

```
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.309 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.054  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.091  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0376269 in region 1805647
```

```
    ICRU-2K efficiency: 1086.72 1/s
+++ total
    max dose is 0.0376269 in region 1805647
    ICRU-2K efficiency: 1086.72 1/s
==================================================
Completed 36 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,23)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
```

```
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 24429  7306
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
==========================================================================
                  Scoring and output options
==========================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.315 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.093  70  70
```

```
finished simulation, cpu time = 0.1 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.1
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0380494 in region 1882447
    ICRU-2K efficiency: 1140.32 1/s
+++ total
    max dose is 0.0380494 in region 1882447
    ICRU-2K efficiency: 1140.32 1/s
====================================================
Completed 37 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,23.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                   Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
```

```
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 27878  10500
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================================
                 Scoring and output options
================================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.312 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source
```

```
Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.031  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0373512 in region 1959247
    ICRU-2K efficiency: 1104.83 1/s
+++ total
    max dose is 0.0373512 in region 1959247
    ICRU-2K efficiency: 1104.83 1/s
=====================================================
Completed 38 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,24)
============================================================
============================================================
              XYZ Geometry
```

```
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 5898  7533
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
```

```
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.311 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.069  70  70
+++finished batch 9 cpu time: 0.078  70  70
+++finished batch 10 cpu time: 0.088  70  70
finished simulation, cpu time = 0.094 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.094
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0394999 in region 2036047
    ICRU-2K efficiency: 1221.19 1/s
+++ total
    max dose is 0.0394999 in region 2036047
    ICRU-2K efficiency: 1221.19 1/s
====================================================
Completed 39 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
```

```
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,24.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                    Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 18482  14199
================================================
================================================================
                    Variance Reduction
================================================================

 f_repeat           = 0.251
 split photons      = 1
```

```
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.321 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.034  70  70
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.053  70  70
+++finished batch 7 cpu time: 0.063  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.084  70  70
+++finished batch 10 cpu time: 0.094  70  70
finished simulation, cpu time = 0.101 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.101
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0376824 in region 2112847
    ICRU-2K efficiency: 1046.86 1/s
+++ total
    max dose is 0.0376824 in region 2112847
    ICRU-2K efficiency: 1046.86 1/s
================================================
Completed 40 of 49 beamlets...
```

```
Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,25)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                  Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
```

```
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 10550  24925
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.316 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.083  70  70
+++finished batch 10 cpu time: 0.092  70  70
finished simulation, cpu time = 0.1 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
```

```
 geometry: CT
 cpu time: 0.1
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0372181 in region 2189647
    ICRU-2K efficiency: 1102.01 1/s
+++ total
    max dose is 0.0372181 in region 2189647
    ICRU-2K efficiency: 1102.01 1/s
================================================
Completed 41 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25,25.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                   Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
```

```
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

=============================================================
=================================================
                MC_Control
=================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 17558  16492
=================================================
=============================================================
                   Variance Reduction
=============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
=============================================================
=============================================================
                   Quasi Random Numbers
=============================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
=============================================================
=====================================================================
                 Scoring and output options
=====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.322 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
```

```
+++finished batch 5 cpu time: 0.043  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.082  70  70
+++finished batch 10 cpu time: 0.091  70  70
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0382575 in region 2266447
    ICRU-2K efficiency: 1049.28 1/s
+++ total
    max dose is 0.0382575 in region 2266447
    ICRU-2K efficiency: 1049.28 1/s
==================================================
Completed 42 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,22.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
```

```
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 27516  8576
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.3 seconds
```

```
Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.012  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.031  70  70
+++finished batch 5 cpu time: 0.04  70  70
+++finished batch 6 cpu time: 0.05  70  70
+++finished batch 7 cpu time: 0.059  70  70
+++finished batch 8 cpu time: 0.068  70  70
+++finished batch 9 cpu time: 0.078  70  70
+++finished batch 10 cpu time: 0.089  70  70
finished simulation, cpu time = 0.095 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.095
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0365287 in region 1806127
    ICRU-2K efficiency: 1142.12 1/s
+++ total
    max dose is 0.0365287 in region 1806127
    ICRU-2K efficiency: 1142.12 1/s
==================================================
Completed 43 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
```

```
      Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,23)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 22717  22612
================================================
============================================================
                  Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                  Quasi Random Numbers
============================================================
 number of generators: 1
```

```
                1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.295 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.031  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.05  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.07  70  70
+++finished batch 9 cpu time: 0.08  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.097 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.097
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0383494 in region 1882927
    ICRU-2K efficiency: 1082.79 1/s
+++ total
    max dose is 0.0383494 in region 1882927
    ICRU-2K efficiency: 1082.79 1/s
================================================
Completed 44 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
```

```
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,23.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                  Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 11414  17035
================================================
```

```
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.293 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.061  70  70
+++finished batch 8 cpu time: 0.071  70  70
+++finished batch 9 cpu time: 0.081  70  70
+++finished batch 10 cpu time: 0.09  70  70
finished simulation, cpu time = 0.096 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.096
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0368155 in region 1959727
```

```
    ICRU-2K efficiency: 1059.88 1/s
+++ total
    max dose is 0.0368155 in region 1959727
    ICRU-2K efficiency: 1059.88 1/s
==================================================
Completed 45 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                  Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,24)
============================================================
============================================================
              XYZ Geometry
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
```

```
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 2276  1619
================================================
================================================================
                   Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
====================================================================
                  Scoring and output options
====================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.337 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.042  70  70
+++finished batch 6 cpu time: 0.052  70  70
+++finished batch 7 cpu time: 0.062  70  70
+++finished batch 8 cpu time: 0.072  70  70
+++finished batch 9 cpu time: 0.081  70  70
+++finished batch 10 cpu time: 0.092  70  70
```

```
finished simulation, cpu time = 0.098 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.098
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0382325 in region 2036527
    ICRU-2K efficiency: 1123.49 1/s
+++ total
    max dose is 0.0382325 in region 2036527
    ICRU-2K efficiency: 1123.49 1/s
====================================================
Completed 46 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,24.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
================================================================
                   Monte Carlo Parameter
================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
```

```
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

================================================================
================================================
                MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 15924  23376
================================================
================================================================
                  Variance Reduction
================================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
================================================================
================================================================
                  Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================================
                 Scoring and output options
================================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.309 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source
```

```
Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.004  70  70
+++finished batch 2 cpu time: 0.014  70  70
+++finished batch 3 cpu time: 0.024  70  70
+++finished batch 4 cpu time: 0.035  70  70
+++finished batch 5 cpu time: 0.045  70  70
+++finished batch 6 cpu time: 0.054  70  70
+++finished batch 7 cpu time: 0.064  70  70
+++finished batch 8 cpu time: 0.073  70  70
+++finished batch 9 cpu time: 0.083  70  70
+++finished batch 10 cpu time: 0.094  70  70
finished simulation, cpu time = 0.1 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.1
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.036899 in region 2113327
    ICRU-2K efficiency: 1072.2 1/s
+++ total
    max dose is 0.036899 in region 2113327
    ICRU-2K efficiency: 1072.2 1/s
==================================================
Completed 47 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
Initializing cross sections ...  OK
============================================================
                   Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,25)
============================================================
============================================================
              XYZ Geometry
```

```
============================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
============================================================
                  Monte Carlo Parameter
============================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

============================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 28021  3898
================================================
============================================================
                  Variance Reduction
============================================================

 f_repeat            = 0.251
 split photons       = 1
 photon split factor = -40
============================================================
============================================================
                  Quasi Random Numbers
============================================================
 number of generators: 1
                 1st:  base = 2 dimensions = 60 warm-up = 1
============================================================
============================================================
                Scoring and output options
============================================================
  number of dose scoring objects: 1
```

```
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.327 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.022  70  70
+++finished batch 4 cpu time: 0.032  70  70
+++finished batch 5 cpu time: 0.041  70  70
+++finished batch 6 cpu time: 0.051  70  70
+++finished batch 7 cpu time: 0.06  70  70
+++finished batch 8 cpu time: 0.069  70  70
+++finished batch 9 cpu time: 0.079  70  70
+++finished batch 10 cpu time: 0.088  70  70
finished simulation, cpu time = 0.094 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.094
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0377187 in region 2190127
    ICRU-2K efficiency: 1170.77 1/s
+++ total
    max dose is 0.0377187 in region 2190127
    ICRU-2K efficiency: 1170.77 1/s
====================================================
Completed 48 of 49 beamlets...



Input file is: C:\Users\wieserh\Documents\matlab\matRad\vmc++\runs/
MCpencilbeam_temp_1.vmc
Reading MS data ...  OK
Parsing input file ... construct_mmc_geometry: urs = 1
DE_GeometryFactory::get_region_size():
get_region_size: urs = 1 ignore = 1
region size: 0.3
 geometry 1 region size: 0.3
 OK
```

```
Initializing cross sections ...  OK
============================================================
                    Beamlet Source
============================================================
       charge = 0
 virtual source position = (-76,24,24)
       Energy = 6 MeV
 number of beamlets = 1
 beamlet 1: size = 0.5x0.5 cm**2 midpoint = (-26,25.5,25.5)
============================================================
================================================================
              XYZ Geometry
================================================================
   name: CT  id: 0
   global smax: 1e+030
  Number of x-planes: 160  uniform with Xo = 0.15 Dx = 0.3
  Number of y-planes: 160  uniform with Yo = 0.15 Dx = 0.3
  Number of z-planes: 160  uniform with Zo = 0.15 Dx = 0.3
====================================================================
                    Monte Carlo Parameter
====================================================================

 Delta particle production threshold:   0.447479 MeV
 Bremsstrahlung production threshold:   0.05 MeV
 Min. electron transport energy     :   0.447479 MeV
 Min. photon transport energy       :   0.05 MeV
 Local track-end energy deposition  :   0
 Cut-off energy for KERMA approx.   :   1.10239 MeV
 Bremsstrahlung transport mode      :   1
 CSDA approximation                 :   0
 Fractional energy loss/step at Ep  :   10%
 Max. 1st elastic moment per step   :   0.5
 Max. acceptable energy loss/step   :   0.6 MeV
 alpha and beta                     :   0.0298764  0.420741
 Fano calculation                   :   0
 Exact Compton                      :   0
 Electron transport mode            :   VMC++

====================================================================
================================================
               MC_Control
================================================
  will use fixed number of histories
  number of batches   : 10
  histories per batch : 70
  total histories     : 700
  initial rng seeds   : 17065  14082
================================================
====================================================================
                    Variance Reduction
====================================================================

 f_repeat           = 0.251
 split photons      = 1
```

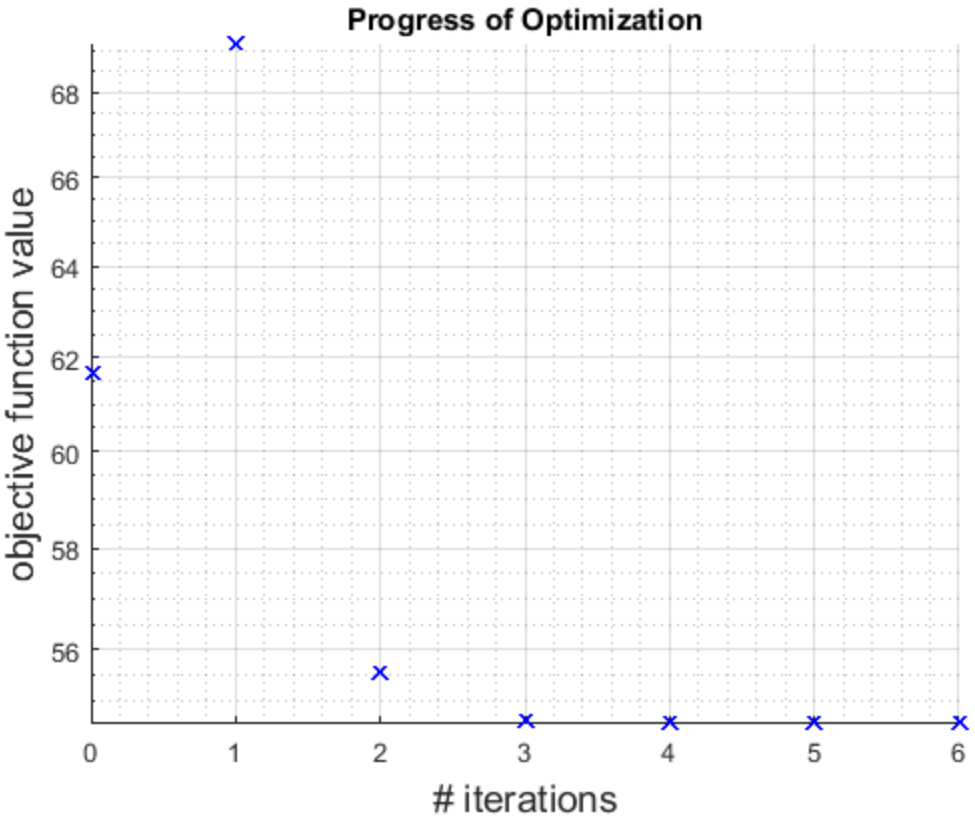
```
 photon split factor = -40
================================================================
================================================================
                   Quasi Random Numbers
================================================================
 number of generators: 1
                  1st:  base = 2 dimensions = 60 warm-up = 1
================================================================
================================================================
                 Scoring and output options
================================================================
  number of dose scoring objects: 1
  dose output options for geometry CT
     dump dose: 2
     dose scans:


CPU time so far: 1.318 seconds

Will run approximately 700 particle sets
   with 1 particles per set on average
will use 2 quasi numbers to sample the source


Starting MC simulation
Running part 1 of 1 ...
+++finished batch 1 cpu time: 0.003  70  70
+++finished batch 2 cpu time: 0.013  70  70
+++finished batch 3 cpu time: 0.023  70  70
+++finished batch 4 cpu time: 0.033  70  70
+++finished batch 5 cpu time: 0.044  70  70
+++finished batch 6 cpu time: 0.054  70  70
+++finished batch 7 cpu time: 0.065  70  70
+++finished batch 8 cpu time: 0.075  70  70
+++finished batch 9 cpu time: 0.084  70  70
+++finished batch 10 cpu time: 0.094  70  70
finished simulation, cpu time = 0.101 seconds
total particle fluence from the source: 2800
total number of particle sets: 700
total number of particles: 700
average sampled energy: 6 +/- 0
============ DE_ScoreDose::analyze ==================
 geometry: CT
 cpu time: 0.101
 number of histories: 700
 number of batches: 10
+++ beamlet 0
    max dose is 0.0367436 in region 2266927
    ICRU-2K efficiency: 1017.33 1/s
+++ total
    max dose is 0.0367436 in region 2266927
    ICRU-2K efficiency: 1017.33 1/s
================================================
Completed 49 of 49 beamlets...
```

Inverse Optimizaiton for IMRT

The goal of the fluence optimization is to find a set of bixel/spot weights which yield the best possible dose distribution according to the clinical objectives and constraints underlying the radiation treatment.

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

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............................:       49
                     variables with only lower bounds:       49
                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 6.1682705e+001 0.00e+000 1.67e+001   0.0 0.00e+000    -  0.00e
+000 0.00e+000   0
   1 6.9151634e+001 0.00e+000 2.06e+001   0.8 7.05e+000    -
 5.32e-001 1.51e-002f  5
   2 5.5544138e+001 0.00e+000 1.21e+001   0.3 5.67e-002    -  1.00e
+000 1.00e+000f  1
   3 5.4632309e+001 0.00e+000 1.53e+000  -1.0 2.01e-002    -
 9.98e-001 1.00e+000f  1
   4 5.4600721e+001 0.00e+000 1.07e+000  -2.7 4.81e-003    -
 9.98e-001 1.00e+000f  1
   5 5.4570186e+001 0.00e+000 3.25e-001  -4.3 1.28e-002    -  1.00e
+000 1.00e+000f  1
   6 5.4569142e+001 0.00e+000 4.20e-001  -5.9 4.60e-003    -  1.00e
+000 1.00e+000f  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:  5.4569141774764034e+001
 5.4569141774764034e+001
Dual infeasibility......:  4.1999906083566546e-001
 4.1999906083566546e-001
Constraint violation....:  0.0000000000000000e+000
 0.0000000000000000e+000
Complementarity.........:  1.6455539744837722e-006
 1.6455539744837722e-006
Overall NLP error.......:  4.1999906083566546e-001
 4.1999906083566546e-001
```

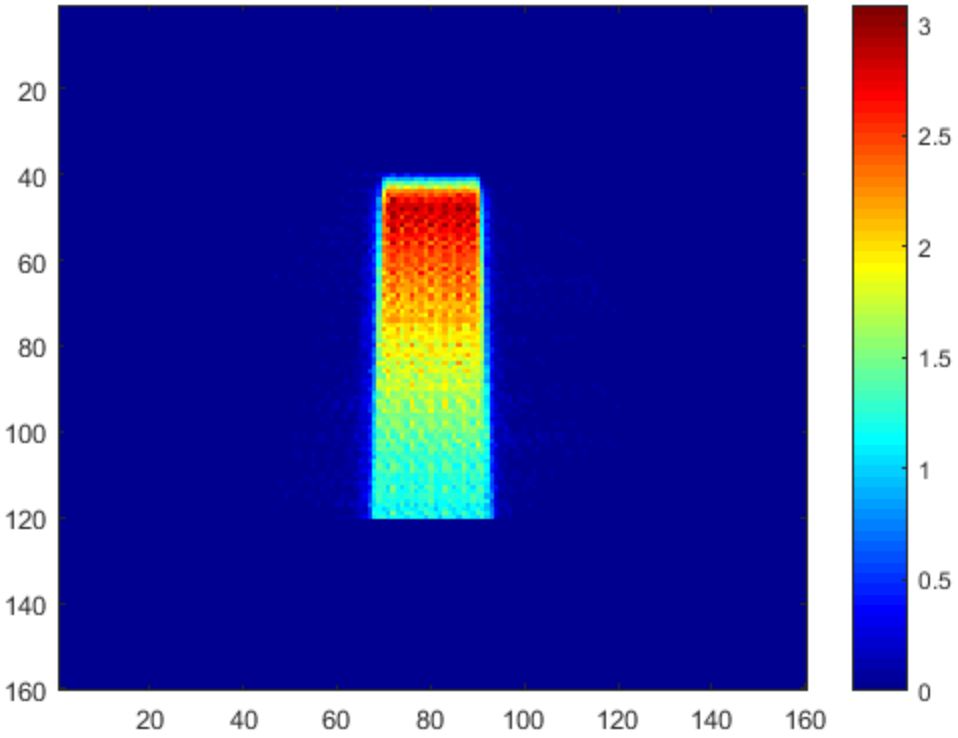
```
Number of objective function evaluations             = 15
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 0
Number of equality constraint Jacobian evaluations   = 0
Number of inequality constraint Jacobian evaluations = 0
Number of Lagrangian Hessian evaluations             = 0
Total CPU secs in IPOPT (w/o function evaluations)   =      0.290
Total CPU secs in NLP function evaluations           =      0.554

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



Plot the Resulting Dose Slice

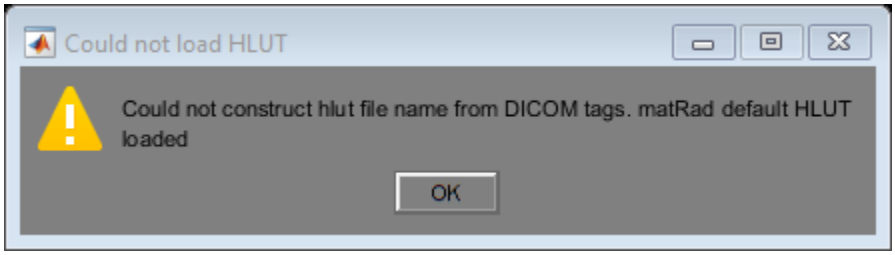
Just let's plot the transversal iso-center dose slice

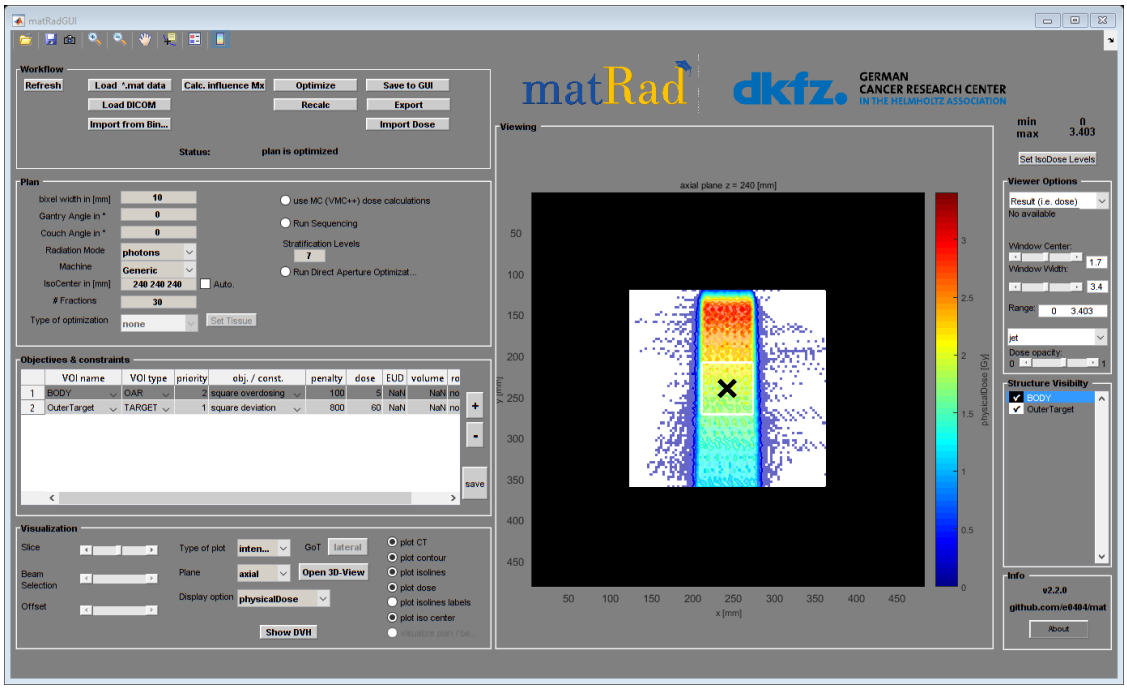
```
slice = round(pln.isoCenter(1,3)./ct.resolution.z);
figure,
imagesc(resultGUI.physicalDose(:,:,slice)),colorbar, colormap(jet)
```



Start the GUI for Visualization

```
matRadGUI

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





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