User Guide for Elekta Brachytherapy ACE© Algorithm Testing

Contents

I Introduction

The American Association of Physicists in Medicine (AAPM) Task Group 186 report [1] provides general guidance for early adopters of model-based dose calculation algorithms (MBDCAs) for brachytherapy (BT) treatment planning. The report's aim is to facilitate uniformity of clinical practice. Among its recommendations is a two-level approach to commissioning MBDCAs embedded in BT treatment planning systems (TPSs) insofar as specific tasks relating to the dose calculation algorithm are concerned. In commissioning level 1, the clinical physicist should assess agreement of MBDCA TPS-derived absolute dose or dose rate with the dose or dose rate obtained in the TPS using AAPM-recommended consensus TG-43 dosimetry parameters for a given BT source model. In commissioning level 2, the physicist should compare 3D dose distributions calculated with the MBDCA-based TPS for specific virtual phantoms mimicking clinical scenarios against benchmark dose distributions derived independently from the same phantom geometries.

The AAPM Working Group on Dose Calculation Algorithms in Brachytherapy (WG-DCAB) [2] was created to facilitate implementation of the recommendations for MBDCA commissioning made in the TG-186 report. One of its charges is to develop a small number of prototypical virtual phantoms and corresponding benchmark dose distributions for use in level 1 and 2 commissioning of high dose rate (HDR) Ir-192 BT sources. These sources can be dealt with collectively by virtue of their similar photon emission properties, and therefore the WG-DCAB has designated a generic HDR Ir-192 virtual source for the express purpose of MBDCA commissioning [3]. At present, this source model has been implemented by two MBDCA-based TPS vendors and hence is available to test the commissioning process described in the TG-186 report. Four treatment plans using virtual phantom geometries, designated Test Cases 1 – 4, have also been created by the WG for commissioning purposes and are described below.

Test Cases 1 - 4, which have been prepared by the WG, are based on a voxelized computational model of a homogeneous water cube (20.1 cm side) set inside either a water or an air cube (51.1 cm side), represented as a CT DICOM image series. Both cubes have a common center located at $(x, y, z) = (0, 0, 0)$ cm and their sides are parallel. The dimensions, in-plane resolution, and number of images were chosen so that 511×511×511 cubic voxels $(1\ \text{mm})^3$ fill the space. The patient coordinate system origin, as defined in the Image Position Patient (0020, 0032) and Image Orientation Patient (0020, 0037) DICOM tags, coincides with the cube centers which facilitates calculations and precludes comparison bias, i.e., the center voxel indices are (255, 255, 255) with the ordering [0:510]. An odd number of voxels was chosen so that the center of a voxel coincides with the geometrical center of the phantom. The four Test Cases are summarized in Table 1.

Table 1: Test case geometries for ACE algorithm testing

Test Case	Inner cube material 'Cube'	Outer cube material 'BgBOX'	Ir-192 source center location	Ir-192 source orientation	Applicator
1	H_2O	H_2O	(0, 0, 0) cm	+y	none
2	H_2O	air	(0, 0, 0) cm	+y	none
3	H_2O	air	(7, 0, 0) cm	+y	none
4	H_2O	air	(0, 0, 0) cm	+z	Generic WG applicator

The geometry for Test Case 3 is depicted in the figure below as an example.

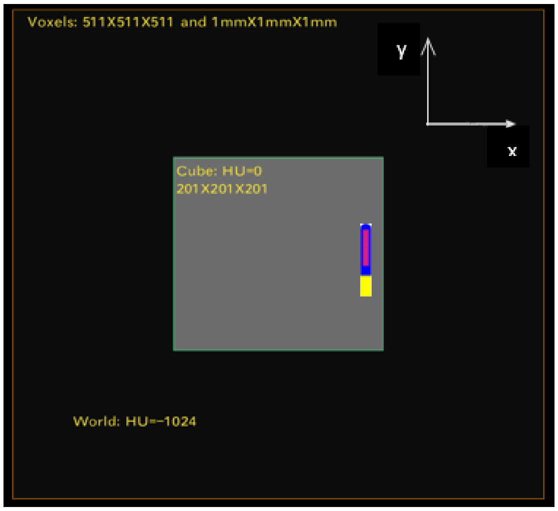
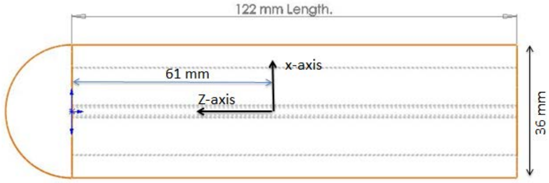
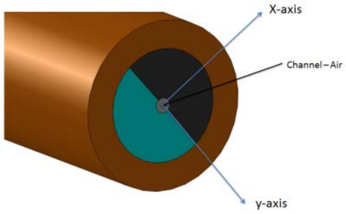


Fig. 1. The geometry for Test Case 3 consists of a generic Ir-192 source located at coordinates (7, 0, 0) cm within a (20.1 cm)^3 water-filled cube ('Cube', gray) embedded in a (50.1 cm)^3 air-filled box ('BgBOX', black).

The applicator in Test Case 4 is a generic virtual shielded cylinder prepared by the WG-DCAB for the purpose of MBDCA commissioning. Its basic features are illustrated in the following figure.



(a)



(b)

Fig. 2. PMMA shielded applicator. (a) Dimensions and the origin of coordinates. (b) The black portion is a tungsten shield and the blue portion represents air.

Elekta Brachytherapy (Veenendaal, The Netherlands), has implemented the WG-DCAB Ir-192 source and applicator in version 4.5.2 of their Oncentra Brachy planning system which incorporates the Advanced Collapsed-cone Engine (ACE©) algorithm. The ACE© algorithm is based on a dose calculation method originally developed for external beam radiotherapy by Ahnesjö [4] and refined for brachytherapy by Carlsson and Ahnesjö [5]. In this method the dose deposited by primary, singly-scattered, and multiply-scattered photons is calculated separately and summed. Implementation of the ACE© algorithm is described in a white paper available from the vendor [6] and by Ahnesjö et al. [7]. Its use in treatment planning is detailed in Oncentra user documentation [8]. The present Guide has been prepared for experienced Oncentra Brachy users participating in testing the TG-186 commissioning process for the ACE© algorithm and the WG-DCAB HDR Ir-192 virtual source.

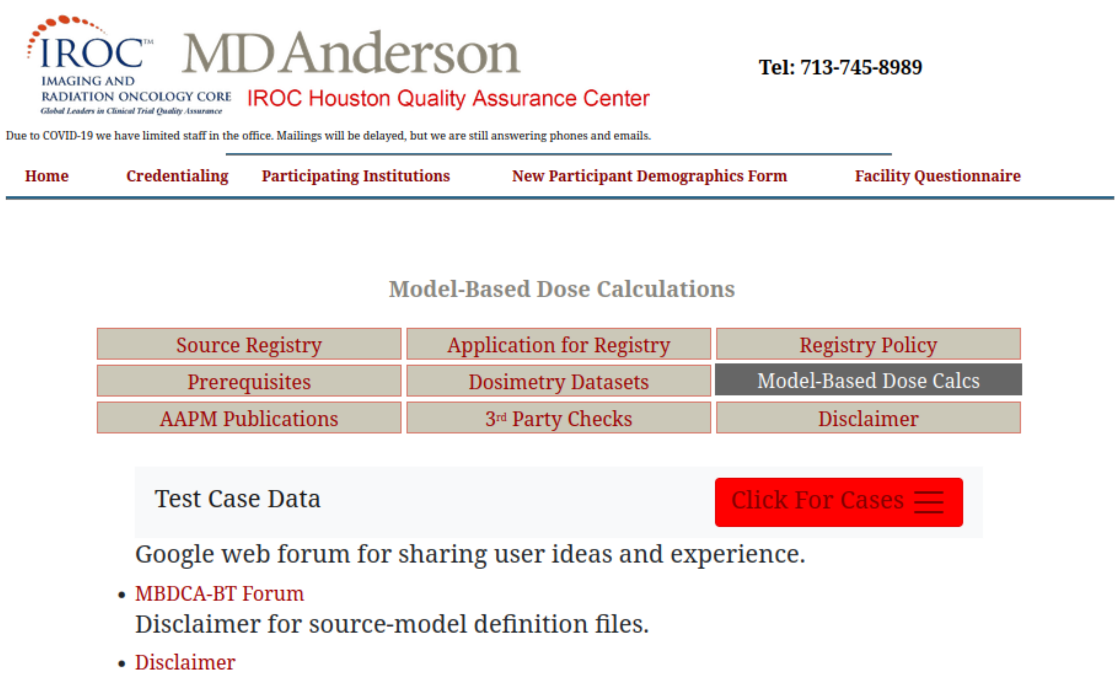
In overview, the testing process involves downloading a Test Case treatment plan and an associated reference dose distribution and importing them into Oncentra Brachy (Sec. II), locally calculating a dose distribution using ACE (Sec. III), comparing the locally calculated and reference dose distributions (Sec. IV), and finally reporting the results of the dose comparison (Sec. V). As a "sanity check", a second reference dose distribution generated by the WG-DCAB using the ACE algorithm has been made available in the Test Case repository. Comparison of this latter reference dose distribution with the locally calculated one should not yield any dose differences. Dose distributions has been obtained with ACE version 4.5.334.106.

II Test Case Import

In order to perform Test Case import and dose calculation for commissioning purposes, the WG generic source and Flexitron afterloader must be available in your Oncentra Brachy system (!). *Installation of these items must occur before performing the set-up and dose calculation steps for a Test Case plan*. To install this afterloader and WG source follow the instructions given in Appendix 1.

A. Accessing the Test Case Repository

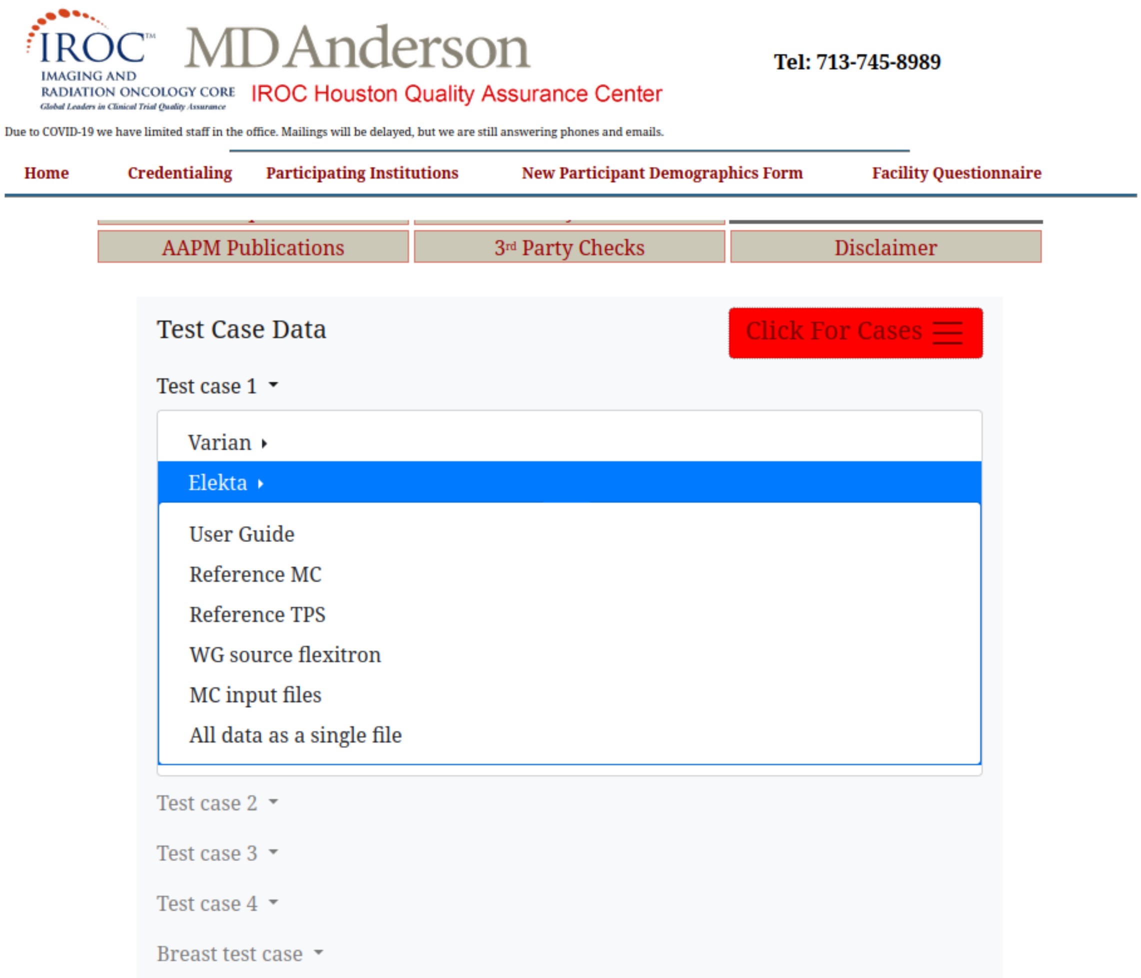
Test Cases 1 - 4 are available from the IROC Houston file server at https://doi.org/10.52519/00005.



The links relevant to the Elekta Oncentra Brachy testing are under the "Click for Cases" tab for each Test Case. 'Reference TPS' containing the data for each Test Case and 'Reference MC' containing the MCNP6 reference dose data for comparison with the local dose calculation. Monte Carlo input files for those users interesting in reproducing the Monte Carlo reference data are under the MC 'input files' link.

B. Downloading a Test Case

Navigating the Click for Cases tab, you will be presented with four folders, Case 1 to Case 4. Open each folder and download the zip file under "Reference TPS" (*Case-X-OCB.zip*), saving it to your local computer. Then, in the same locations download each zip file under "Reference MC" (*CaseX-OCB-MCNP6.zip*), saving it also to your local computer.



Each *Case-X-OCB.zip* file contains 517 files including 511 virtual phantom CT slices, a radiotherapy plan (RP), a radiotherapy structure set (RS), and a 3D dose matrix (RD) calculated remotely using the ACE© algorithm (all in DICOM format). The .zip file also includes a text file, *DP_source_centered.txt* (Cases 1, 2 and 4) or *DP_source_displaced.txt* (Case 3), containing dose point definitions that can be copied directly to the Case Explorer, and an isodose line definition file, *Test_case_isolines.xml*. The latter three files are provided to facilitate uniformity in dose reporting and comparison.

Each *CaseX-OCB-MCNP6.zip* file contains 514 files including 511 virtual phantom CT slices, a radiotherapy plan (RP), a radiotherapy structure set (RS), and a 3D dose matrix (RD) calculated using the MCNP6 Monte Carlo code (all in DICOM format).

Extract all files from each Case .zip folder to a corresponding local folder on the OCB workstation.

It is suggested that the following directory structure be used:

..\DICOMIMPORTDATA\Case 1\Case-1-OCB\

…………\Case_1_MCNP6\

..\DICOMIMPORTDATA\Case 2\Case-2-OCB\

…………\Case_2_MCNP6\

..\DICOMIMPORTDATA\Case 3\Case-3-OCB\

…………\Case_3_MCNP6\

..\DICOMIMPORTDATA\Case 4\Case-4-OCB\

…………\Case_4_MCNP6\

C. Importing a Test Case into Oncentra Brachy

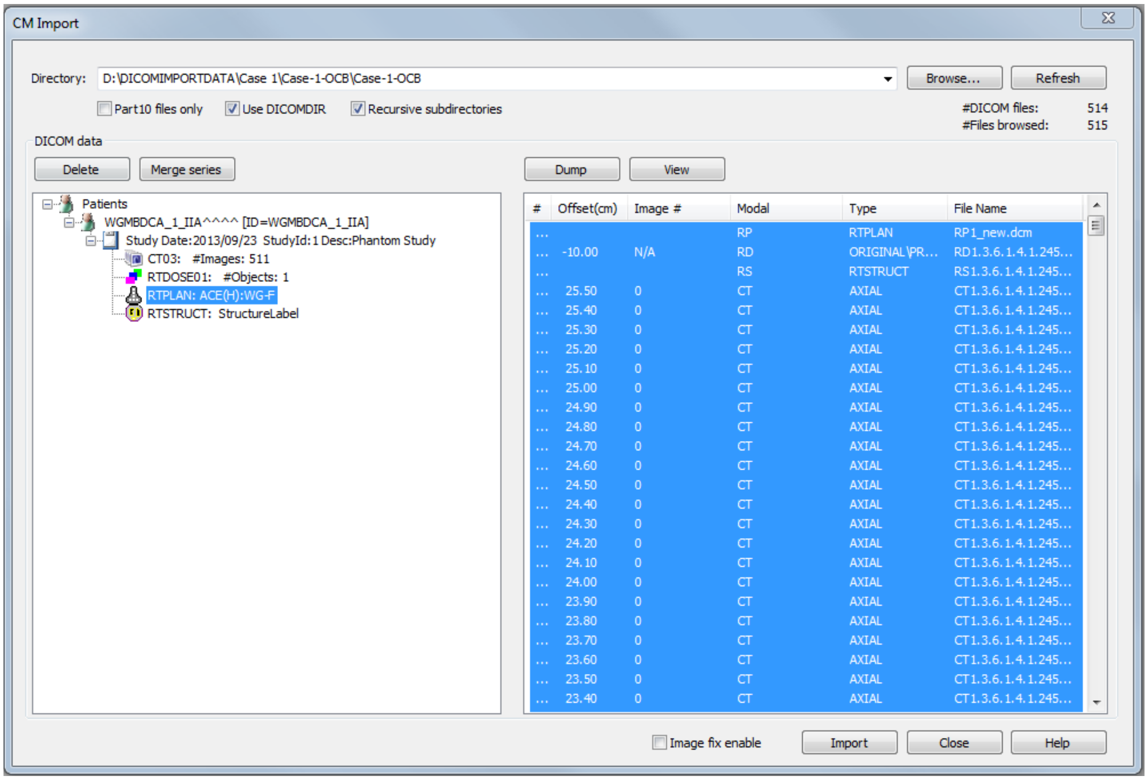
Note: The following steps use Test Case 1 to illustrate the case import process. The same import process is used for all test cases.

The import of the Test Case will occur in two steps, firstly importing the pre-calculated ACE© plan & dose and then importing the reference MCNP6 plan & dose.

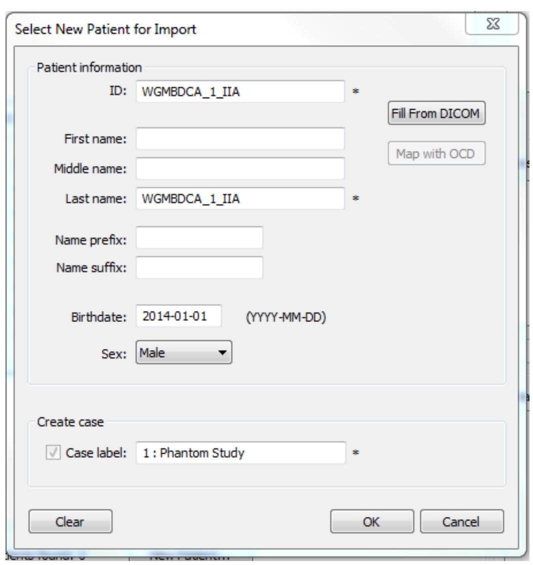
a. Importing ACE© Images, Plan, Structure Set & Dose Data

- Click on the Import Activity  button.
- Click the 'Browse...' button and select the folder containing the unzipped Test Case, '...\Case 1\Case-1-OCB\Case-1-OCB\'

- The system will display a list of CT data, RTPlan, RTSTRUCT and RTDOSE files.



- Click the 'Import' button; the system will read and validate the data ready for import.
- When the import window appears, select the 'New Patient…' button. The Patient Information will automatically populate the fields (as shown below).

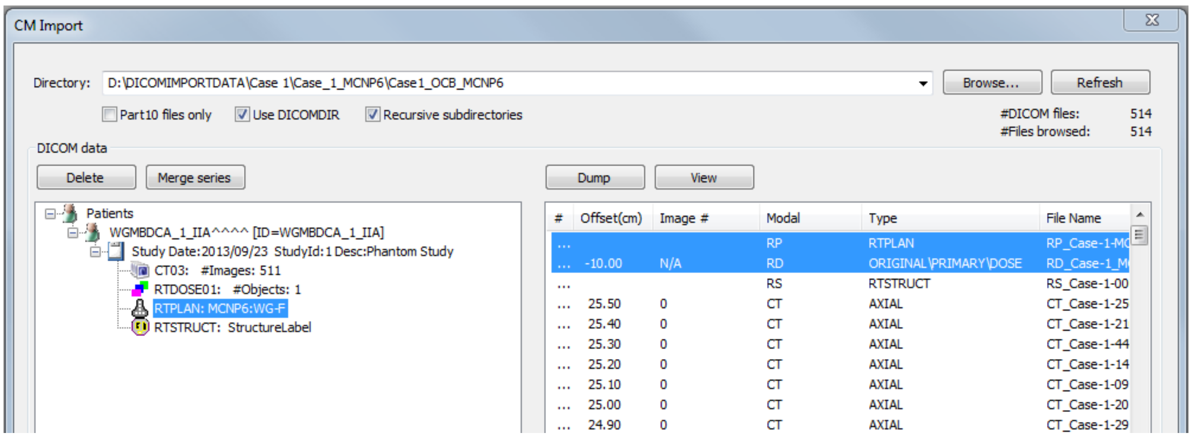


- Click the 'OK' button to import the new patient data.

- A 'Successful Import' message will appear when the import is complete. Uncheck the 'Open Case' box and click OK.

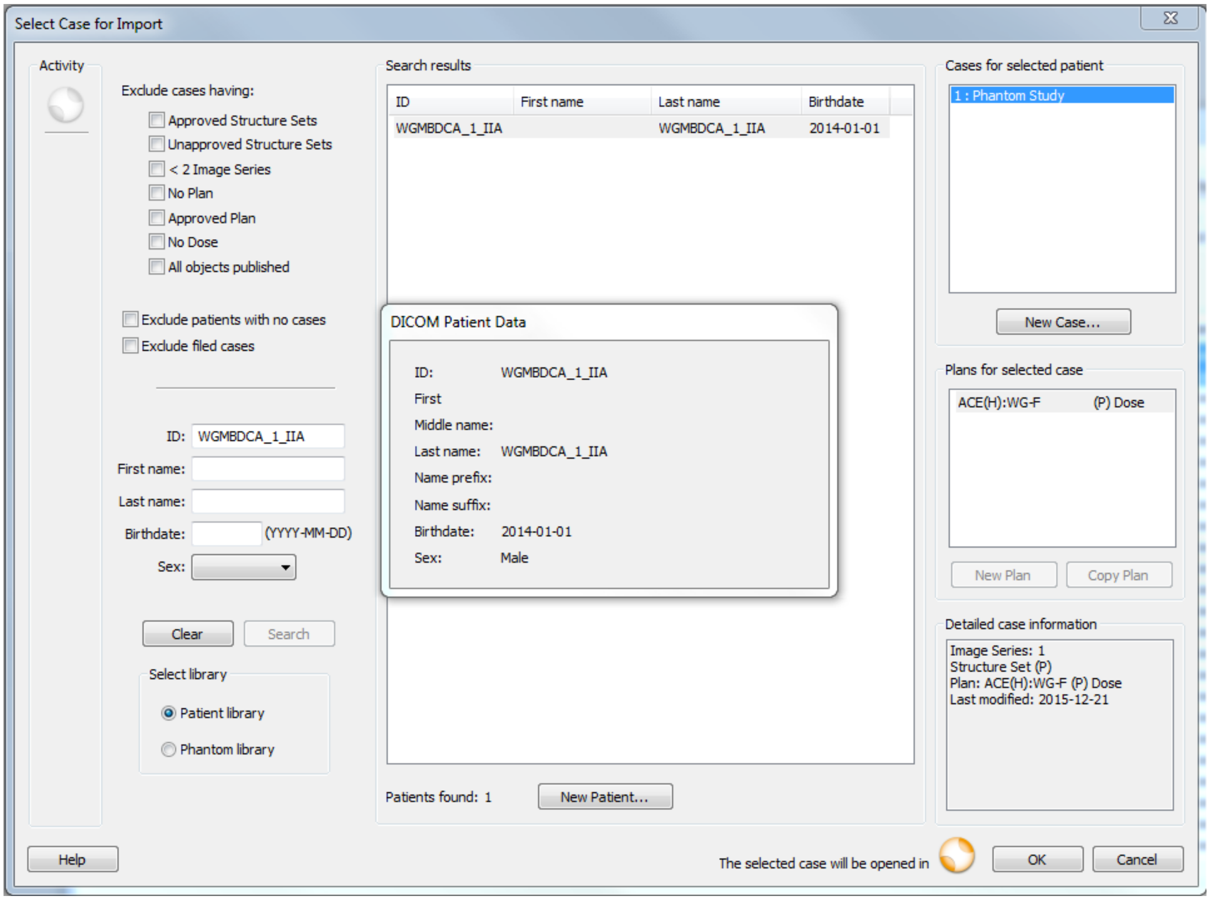
b. Importing MCNP6 Plan & Dose Data

- Click the 'Browse...' button again and select the folder containing the unzipped Test Case with the MCNP6 data files, '...\Case 1\Case_1_MCNP6\Case1_OCB_MCNP6\'
- The system will display all DICOM objects. Select only the RTPlan and RTDOSE files as shown in the figure below.

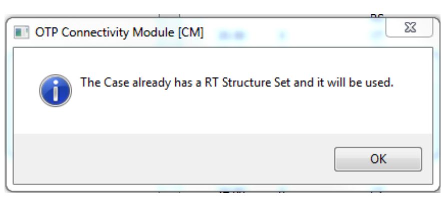


- Click the 'Import' button; the system will read and validate the data ready for import.
- The system will attempt to match the patient details with an existing patient already in the Oncentra Brachy database. Check that the correct patient has been identified; for the above illustration ID = 'WGMBDCA_1_IIA', with Case = '1:Phantom Study' and Plan = 'ACE(H):WG-F (P) Dose'.

  If the system has not identified the correct patient, click the 'Clear' button and then the 'Search' button to browse the database for the correct patient.



- Click the ‘OK’ button to start the import of the MCNP6 data.
- A message will appear ‘The Case already has a RT Structure Set and it will be used.’

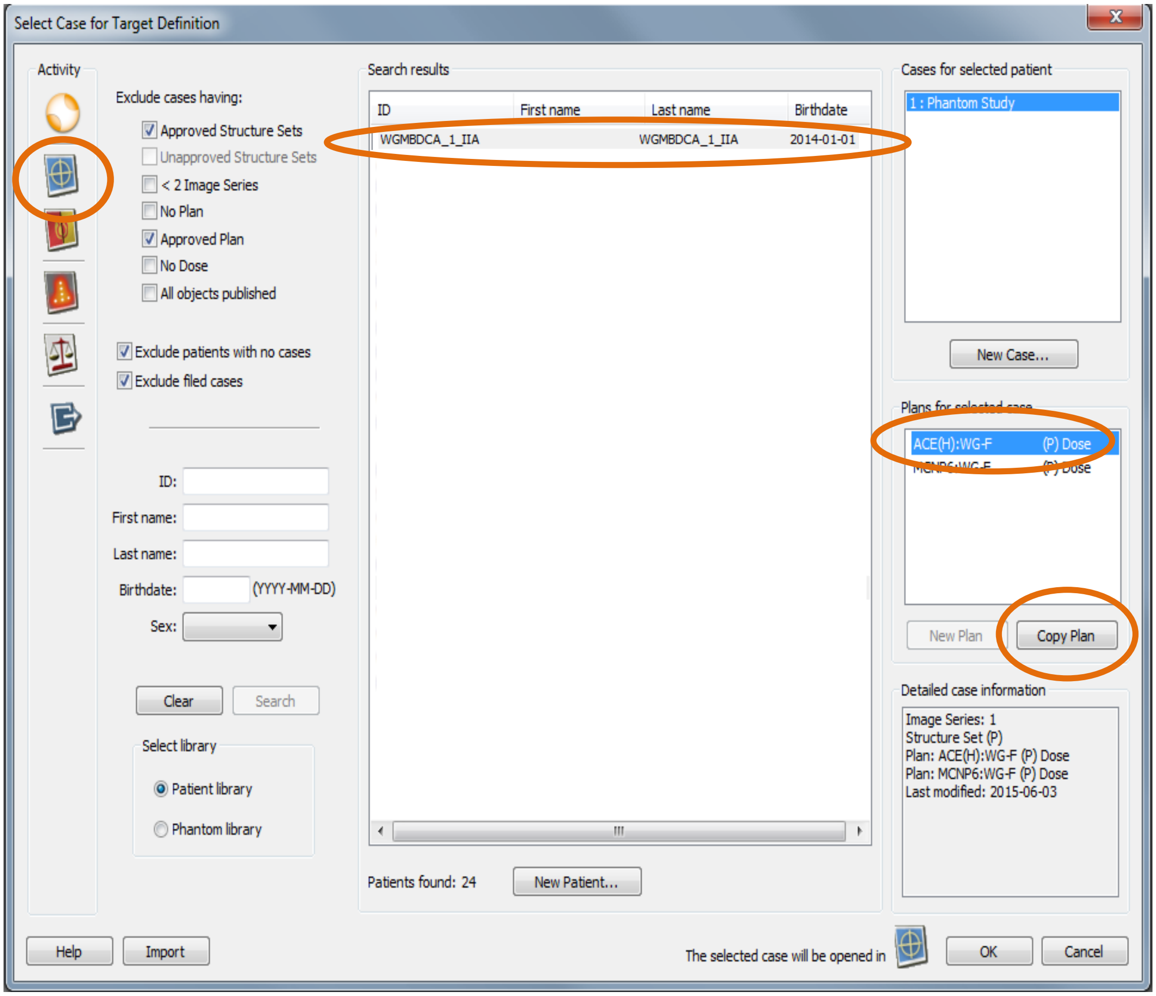


- Click the ‘OK’ button to continue.
- A ‘Successful Import’ message will appear when the import is complete. Uncheck the ‘Open Case’ box and click OK.
- Click ‘Close’ on the Import Activity window.

The data for Test Case 1 has now been imported.

Next a local working copy of the ACE(H) plan will be created for the local user to calculate dose, which will then be used for comparison with the reference MCNP6 dose.

- Select the ‘Open Case’ ( ) window and click the ‘Target Definition’ activity ( ) icon.



- Select the Patient ID 'WGMBDCA_1_IIA' and select the plan 'ACE(H):WG-F (P)Dose'.
- Click the 'Copy Plan' button and enter a new plan label: 'ACE LocalUser'.
- Click Ok. The 'Target Definition' activity will open.
- In the Case Explorer at the bottom of the window, confirm that the material definitions specified for each Case match those in the table below. (Note: In Case 1 BgBox and Cube are both specified as Water. For Cases 2,3 and 4 BgBox should be specified as Air.)

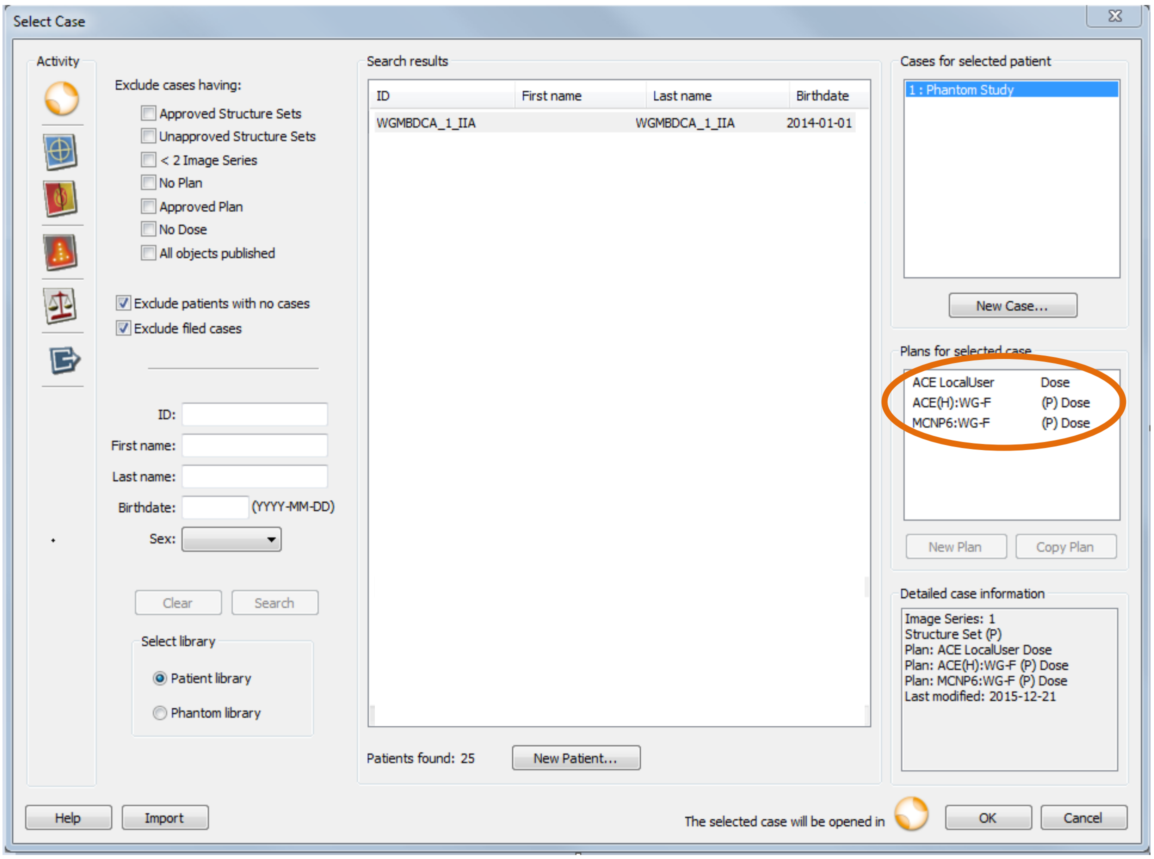
Name	Series	Volume [ccm]	Material	Mass Density	CC Priority	DICOM Type
BgBOX	CT 01	133163.21	Water	Uniform 1.000	2	Patient organ
Cube	CT 01	8060.11	Water	Uniform 1.000	1	Patient organ

- The correct 'CC Priority' must be selected as all of these Test Cases have overlapping structures. In order to modify the 'CC Priority', set the 'DICOM Type' for both structures to 'Patient organ'.
- If the 'CC Priority' is not already set, double click the 'CC Priority' and set structure 'Cube' = 1 and structure 'BgBOX' = 2.

Note: if structures intersect with each other, the properties of the intersecting volume will be assigned based on the structure with the highest priority (in order of 1,2,3…etc).

- Click File →Close Case, Save the changes on exit.

- Select the 'Open Case' ( ) window and confirm the imported Test Case 1 now has three plans: 'ACE LocalUser', 'ACE(H):WG-F' and 'MCNP6:WG-F'.



The case imports and local plan creation process is now complete. Repeat the same process to import Test Cases 2, 3 and 4. These three Test Cases represent a geometry of water phantom in air, therefore the material definition for 'BgBox' should appear as:

Name	Series	Volume [ccm]	Material	Mass Density	CC Priority	
BgBOX	CT 01	133163.21	Air	Uniform 0.001	2	Patient organ
Cube	CT 01	8060.11	Water	Uniform 1.000	1	Patient organ

When complete the following four patients should each contain three plan files: WGMBDCA_1_IIA, WGMBDCA_2_IIB, WGMBDCA_3_IIC and WGMBDCA_4_III.

III Dose Calculation

A. Process Overview

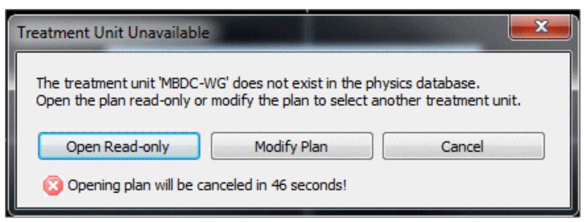
Level 2 MBDCA commissioning involves comparing a TPS calculated dose distribution with a reference one, both distributions ideally having been obtained for the same value of total reference air kerma (TRAK) emitted by the radiation source. TRAK can be expressed as a product of the source air kerma rate constant [$\mu Gy \cdot m^2 \cdot h^{-1} \cdot MBq^{-1}$], source activity [MBq], source total dwell time [s], and a units conversion factor ($(3.6 \times 10^8)^{-1}$ [$Gy \cdot \mu Gy^{-1}\, h \cdot s^{-1}$]. The air kerma rate constant for the generic Ir-192 WG source is 0.098 [$\mu Gy \cdot m^2 \cdot h^{-1} \cdot MBq^{-1}$] [3]; for purposes of MBDCA commissioning, the source activity has been specified as 3.7×10^5 MBq (10.0 Ci). Accordingly, preparing for local dose calculation requires that you manually set a single dwell time for a single dwell position for each Test Case. In this manner the TRAK is fixed to the same value used to normalize the corresponding reference dose distribution, enabling direct comparison of the locally calculated and reference dose distributions.

B. Test Case 1

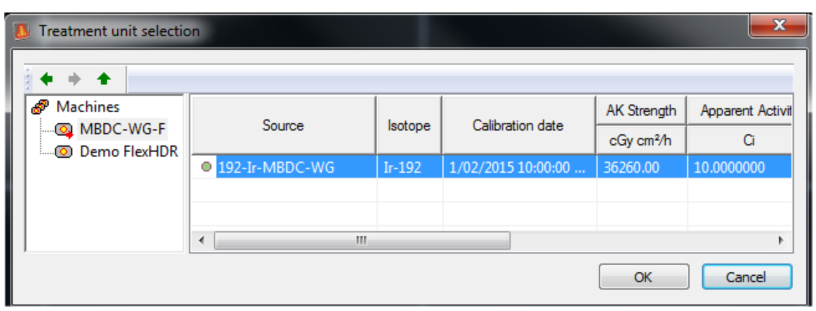
a. Selecting the Plan & Setting the Virtual Source

- Select the Brachy Planning activity, then select patient 'WGMBDCA_1_IIA' and plan 'ACE LocalUser' and click the 'OK' button.

- A warning message will appear stating the treatment unit in the Test Case does not appear in the local physics database. Click the 'Modify Plan' button.

- 

- Select 'MBDC-WG-F' from the available treatment units, previously installed (Appendix 1).



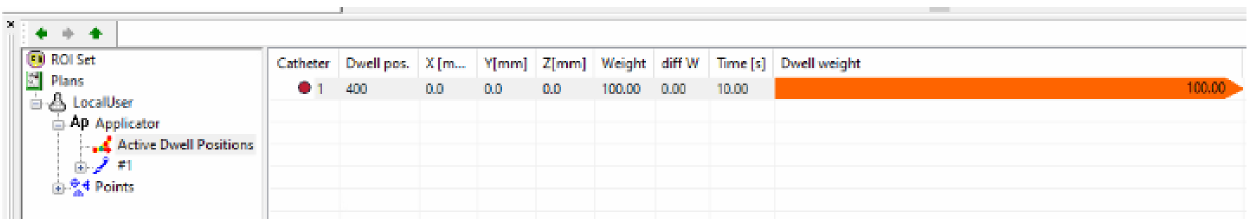
- Click OK to continue; the Test Case will load.

- Open the Prescription tab and set the prescription dose to 100 cGy.

- If necessary, set the treatment date/time to match the source calibration date/time (01 Apr 2016 10:00:00) to achieve an Air Kerma Strength of 36260.00 cGy cm^2/h (Apparent Source Activity 10.000 Ci)

b. Setting the Source Dwell Time

- Using the Case Explorer confirm the active source dwell position is at the centre of the cube (0.0, 0.0, 0.0).
- Open the Optimization tab and select the ‘Manual dwell weight/time’ option.
- Change the active dwell position dwell time to 10 seconds by double clicking the ‘Time [s]’ cell in the Case Explorer.



c. Setting the Dose Calculation Accuracy & Performing the Calculation

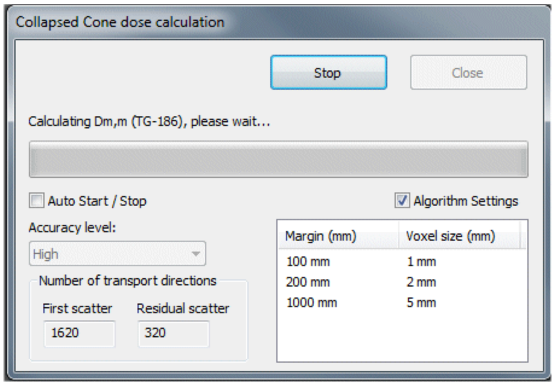
The loaded ‘ACE LocalUser’ plan will have dose defined already as this is a copy from the downloaded data set *(This dose will be overwritten by the local ACE calculation).*

The end user will now perform a local model-based dose calculation using the geometry defined by the selected case, overwriting any previous dose contained in the ‘ACE LocalUser’ plan.

- To perform an Advanced Collapsed Cone Engine (ACE©) dose calculation, click the ‘186’ button 

.
- The Collapsed Cone dose calculation window will appear. Un-tick the Auto start/stop option and tick the Algorithm settings option.
- Set the Accuracy level to ‘High’. Click ‘Start’ to begin the ACE© calculation. (Note: It may be a few minutes before movement is seen on the progress bar)

When the calculation starts, the number of First and Residual scatter transport directions will be displayed along with the Margin and Voxel parameters (see [6] for details). This calculation typically takes 5 - 10 minutes.

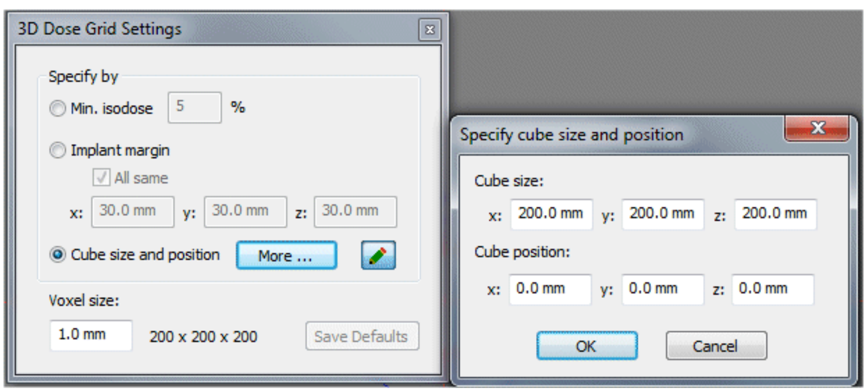


- When the dose calculation is complete close the window. The display will be updated with isodoses for the ACE© calculation.
- The display will also specify the calculation algorithm .

d. Creating a 3D Dose Distribution

A 3D dose grid must be created in order to perform a comparison with the reference dose data.

- Click the '3D dose grid setting'  button.
- Select the 'Cube size and position' option and click the 'More…' button to set the cube size to be 200x200x200 mm centered at (0, 0, 0).



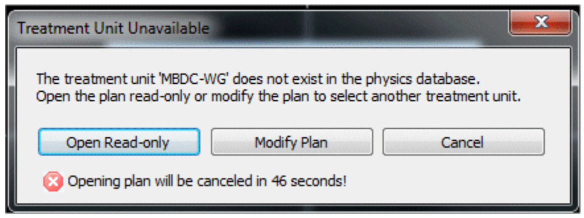
- Click 'OK' when done.
- Click the 'Calculate 3D dose grid'  button to create the 3D dose grid with the specified parameters. This step must be done after every TG43 or TG186 dose re-calculation in order to create a 3D dose distribution for use in the Plan Analysis window (!).
- Save the plan by clicking File → Save.
- Close the Brachy Planning Activity by clicking File→ Close Case.

Test Case 1 is now ready for comparison as defined in section IV Dose Distribution Comparison.

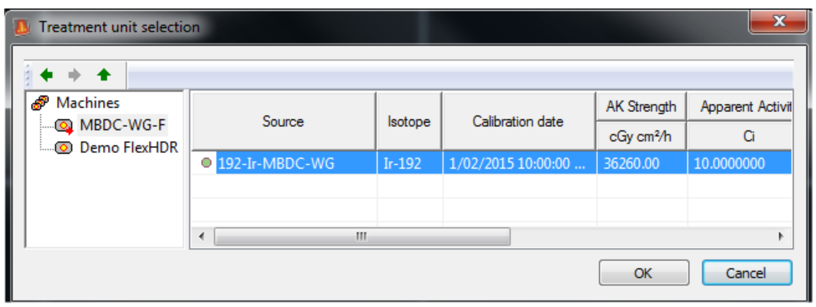
C. Test Case 2

a. Selecting the Plan & Setting the Virtual Source

- Select the Brachy Planning activity, then select patient 'WGMBDCA_2_IIB' and plan 'ACE LocalUser' and click the 'OK' button.
- A warning message will appear stating the treatment unit in the Test Case does not appear in the local physics database. Click the 'Modify Plan' button.



- Select 'MBDC-WG-F' from the available treatment units, previously installed (Appendix 1).

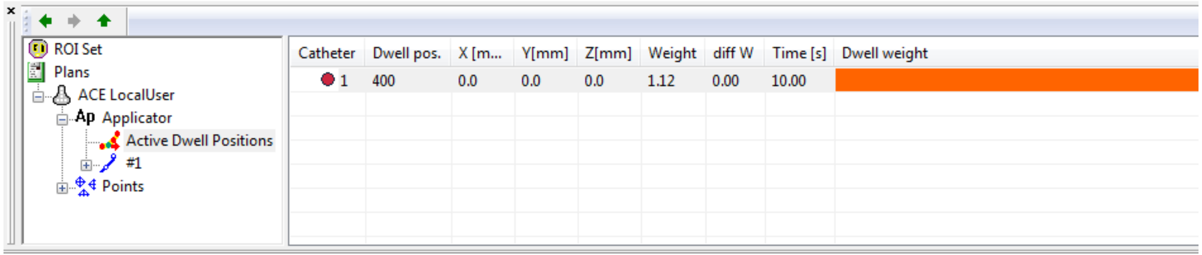


- Click OK to continue; the Test Case will load.
- Open the Prescription tab, set the prescription dose to 100 cGy.
- If necessary, set the treatment date/time to match the source calibration date/time (01 Apr 2016 10:00:00) to achieve an Air Kerma Strength of 36260.00 cGy cm^2/h (Apparent Source Activity 10.000 Ci)

b. Setting the Source Dwell Time

- Using the Case Explorer confirm the active source dwell position is at the centre of the cube (0.0, 0.0, 0.0).
- Open the Optimization tab and select the 'Manual dwell weight/time' option.

  Change the active dwell position dwell time to 10 seconds by double clicking the 'Time [s]' cell in the Case Explorer.



c. Setting the Dose Calculation Accuracy & Performing the Calculation

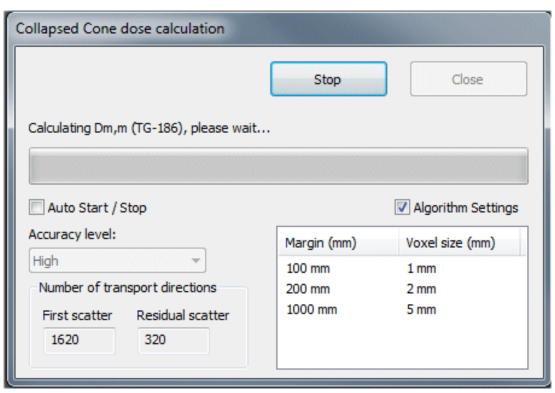
The loaded 'ACE LocalUser' plan will have dose defined already as this is a copy from the downloaded data set *(This dose will be overwritten by the local ACE© calculation).*

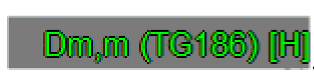
The end user will now perform a local model-based dose calculation using the geometry defined by the selected case, overwriting any previous dose contained in the 'ACE LocalUser' plan.

- To perform an Advanced Collapsed cone Engine (ACE©) dose calculation, click the '186' button 

.
- The Collapsed Cone dose calculation window will appear. Un-tick the Auto start/stop option and tick the Algorithm settings option.
- Set the Accuracy level to 'High'. Click 'Start' to begin the ACE© calculation. (Note: It may be a few minutes before movement is seen on the progress bar)

When the calculation starts, the number of First and Residual scatter transport directions will be displayed along with the Margin and Voxel parameters (see [6] for details). This calculation typically takes 5 - 10 minutes.



- When the dose calculation is complete close the window. The display will be updated with isodoses for the ACE© calculation.
- The display will also specify the calculation algorithm 

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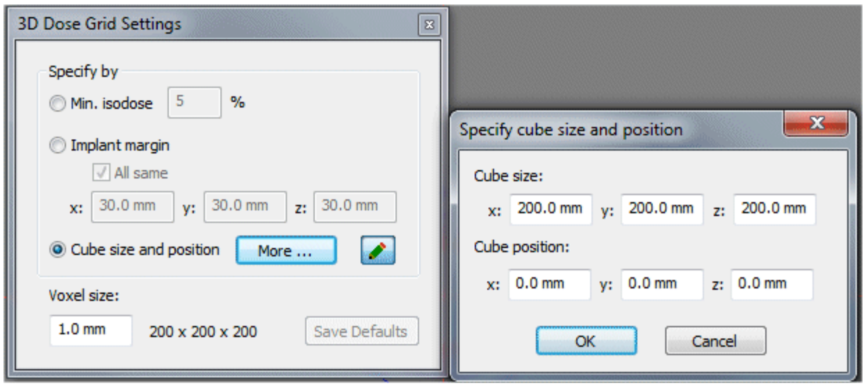
d. Creating a 3D Dose Distribution

A 3D dose grid must be created in order to perform a comparison with the reference dose data.

- Click the '3D dose grid setting' button.
- Select the 'Cube size and position' option and click the 'More…' button to set the cube size to be 200x200x200 mm centered at (0, 0, 0).



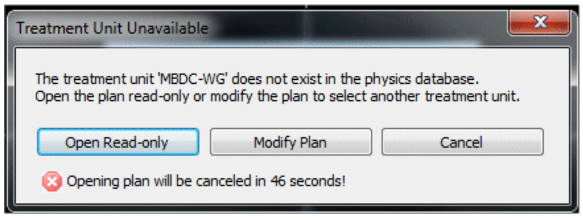
- Click 'OK' when done.
- Click the 'Calculate 3D dose grid' button, to create the dose grid with the specified parameters. This step must be done after every TG43 or TG186 dose re-calculation in order to create a 3D dose distribution for use in the Plan Analysis window (!).
- Save the plan by clicking File → Save.
- Close the Brachy Planning Activity by clicking File→ Close Case.

Test Case 2 is now ready for comparison as defined in section IV Dose Distribution Comparison.

<u>D. Test Case 3</u>

<u>a. Selecting the Plan & Setting the Virtual Source</u>

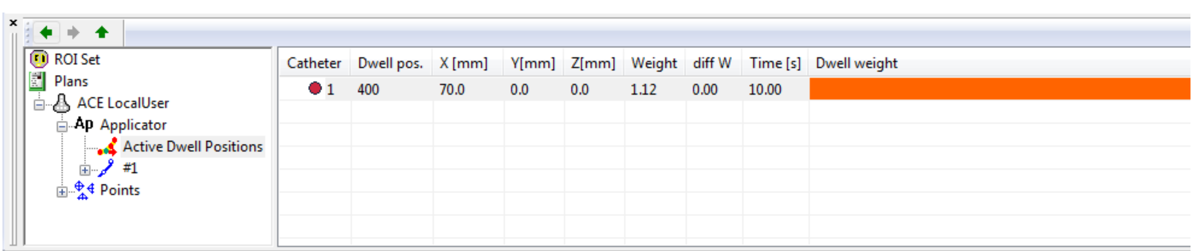
- Select the Brachy Planning activity, then select patient 'WGMBDCA_3_IIC' and plan 'ACE LocalUser' and click the 'OK' button.
- A warning message will appear stating the treatment unit in the Test Case does not appear in the local physics database. Click the 'Modify Plan' button.



- Select the 'MBDC-WG-F' from the available treatment units, previously installed (Appendix 1).
- Click OK to continue; the Test Case will load.
- Open the Prescription tab, set the prescription dose to 100 cGy.
- If necessary, set the treatment date/time to match the source calibration date/time (01 Apr 2016 10:00:00) to achieve an Air Kerma Strength of 36260.00 cGy cm^2/h (Apparent Source Activity 10.000 Ci)

<u>b. Setting the Source Dwell Time</u>

- Using the Case Explorer confirm the active source dwell position is offset from the centre of the cube (70.0, 0.0, 0.0).
- Open the Optimization tab and select the 'Manual dwell weight/time' option.
- Change the active dwell position dwell time to 10 seconds by double clicking the 'Time [s]' cell in the Case Explorer.



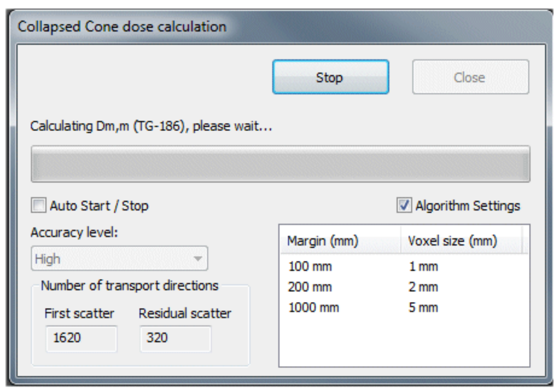
c. Setting the Dose Calculation Accuracy & Performing the Calculation

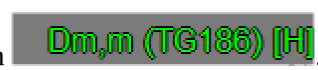
The loaded 'ACE LocalUser' plan will have dose defined already as this is a copy from the downloaded data set *(This dose will be overwritten by the local ACE© calculation).*

The end user will now perform a local model-based dose calculation using the geometry defined by the selected case, overwriting any previous dose contained in the 'ACE LocalUser' plan.

- To perform an Advanced Collapsed Cone Engine (ACE©) dose calculation, click the '186' button 
.
- The Collapsed Cone dose calculation window will appear. Un-tick the Auto start/stop option and tick the Algorithm settings option.
- Set the Accuracy level to 'High'. Click 'Start' to begin the ACE© calculation. (Note: It may be a few minutes before movement is seen on the progress bar)

When the calculation starts, the number of First and Residual scatter transport directions will be displayed along with the Margin and Voxel parameters (see [6] for details). This calculation typically takes 5 - 10 minutes.

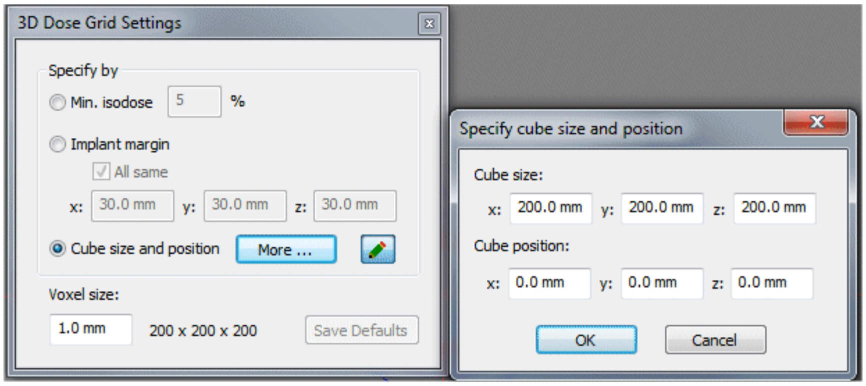


- When the dose calculation is complete close the window. The display will be updated with isodoses for the ACE© calculation.
- The display will also specify the calculation algorithm 
.

d. Creating a 3D Dose Distribution

A dose grid must be created in order to perform a comparison with the reference dose data.

- Click the '3D dose grid setting'  button.
- Select the 'Cube size and position' option and click the 'More…' button to set the cube size to be 200x200x200 mm centered at (0, 0, 0).



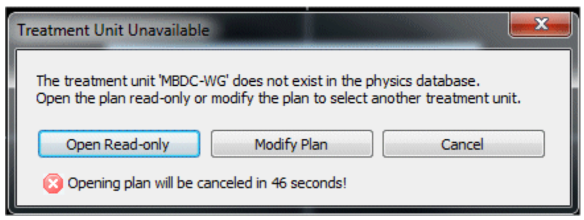
- Click ‘OK’ when done.
- Click the ‘Calculate 3D dose grid’ button to create the dose grid with the specified parameters. This step must be done after every TG43 or TG186 dose re-calculation in order to create a 3D dose distribution for use in the Plan Analysis window (!).
- Save the plan by clicking File → Save.
- Close the Brachy Planning Activity by clicking File→ Close Case.

Test Case 3 is now ready for comparison as defined in section IV Dose Distribution Comparison.

E. Test Case 4

An Applicator Modelling license is required to perform the set-up and calculations for Test Case 4. The user should confirm that Applicator Modelling is installed on their Oncentra Brachy system prior to working through Test Case 4.

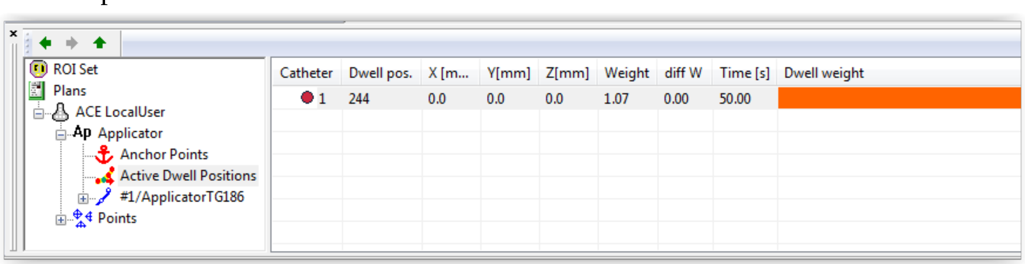
a. Selecting the Plan & Setting the Virtual Source

- Select the Brachy Planning activity, then select patient 'WGMBDCA_4_III' and plan 'ACE LocalUser' and click the 'OK' button.
- A warning message will appear stating the treatment unit in the Test Case does not appear in the local physics database. Click the 'Modify Plan' button.
- 

- Select the 'MBDC-WG-F' from the available treatment units, previously installed (Appendix 1).
- Click OK to continue; the Test Case will load.
- Open the Prescription tab, set the prescription dose to 100 cGy.
- If necessary, set the treatment date/time to match the source calibration date/time (01 Apr 2016 10:00:00) to achieve an Air Kerma Strength of 36260.00 cGy cm^2/h (Apparent Source Activity 10.000 Ci)

b. Setting the Source Dwell Time

- Using the Case Explorer confirm the active source dwell position is at the centre of the cube (0.0, 0.0, 0.0).
- Open the Optimization tab and select the 'Manual dwell weight/time' option.
- Change the active dwell position dwell time to 50 seconds by double clicking the 'Time [s]' cell in the Case Explorer.



c. Setting the Dose Calculation Accuracy & Performing the Calculation

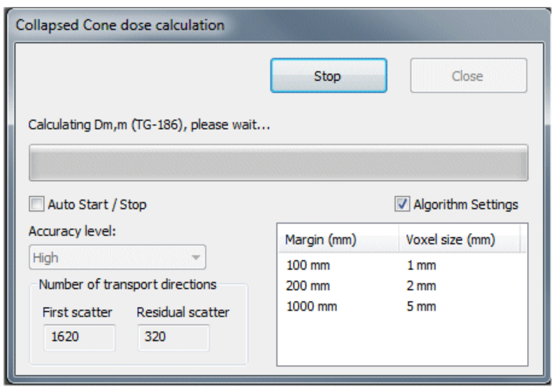
The loaded 'ACE LocalUser' plan will have dose defined already as this is a copy from the downloaded data set *(This dose will be overwritten by the local ACE© calculation).*

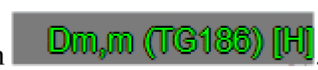
The end user will now perform a local model-based dose calculation using the geometry defined by the selected case, overwriting any previous dose contained in the 'ACE LocalUser' plan.

- To perform an Advanced Collapsed Cone Engine (ACE©) dose calculation, click the '186' button 

.
- The Collapsed Cone dose calculation window will appear. Un-tick the Auto start/stop option and tick the Algorithm settings option.
- Set the Accuracy level to 'High'. Click 'Start' to begin the ACE© calculation. (Note: It may be a few minutes before movement is seen on the progress bar)

When the calculation starts, the number of First and Residual scatter transport directions will be displayed along with the Margin and Voxel parameters (see [6] for details). This calculation typically takes 1.5 - 2 hours.



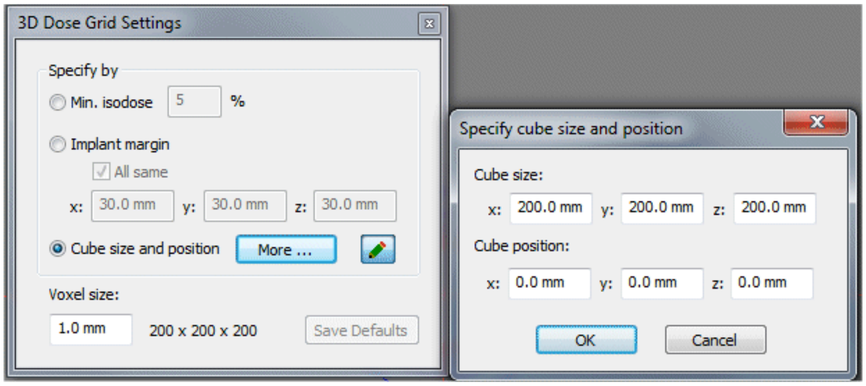
- When the dose calculation is complete close the window. The display will be updated with isodoses for the ACE© calculation.
- The display will also specify the calculation algorithm 

.

d. Creating a 3D Dose Distribution

A dose grid must be created in order to perform a comparison with the reference dose data.

- Click the '3D dose grid setting'  button.
- Select the 'Cube size and position' option and click the 'More…' button to set the cube size to be 200x200x200 mm centered at (0, 0, 0).



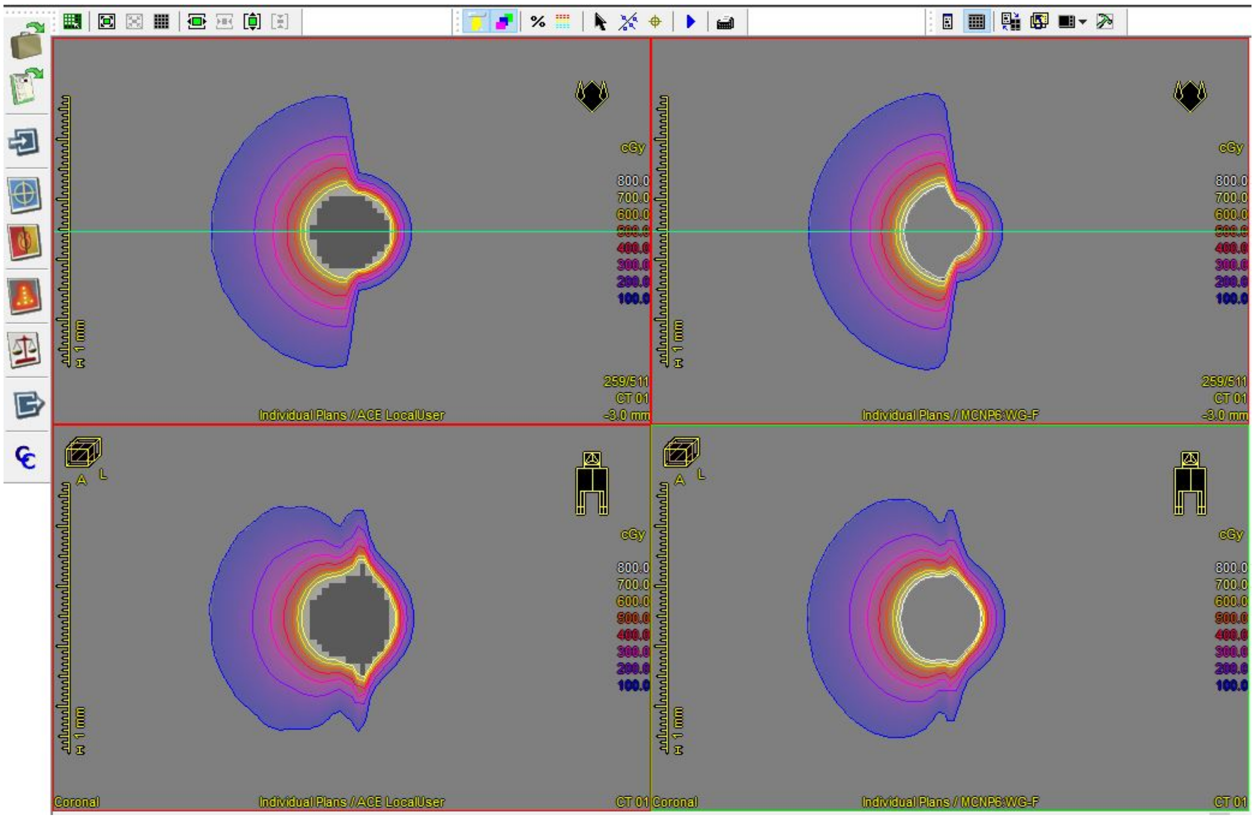
- Click ‘OK’ when done.
- Click the ‘Calculate 3D dose grid’  button to create the dose grid with the specified parameters. This step must be done after every TG43 or TG186 dose re-calculation in order to create a 3D dose distribution for use in the Plan Analysis window (!).
- Save the plan by clicking File → Save.
- Close the Brachy Planning Activity by clicking File→ Close Case.

Test Case 4 is now ready for comparison as defined in section IV Dose Distribution Comparison.

IV Dose Distribution Comparison

A. Process Overview

The comparison of 3D dose distributions is typically done at specified points, in selected planes (dose maps), or within defined volumes. Commonly used comparative metrics include dose differences, dose ratios, and the gamma index [9]. The comparison tools available within the Oncentra Brachy treatment planning system are limited to those based solely on dose differences; correspondingly, the detailed dose comparison and reporting guidance provided below is restricted to dose differences.



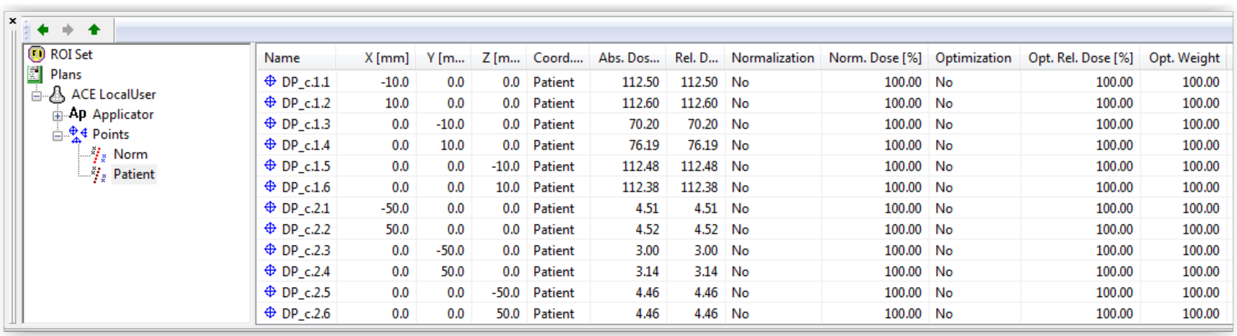
To augment the dose comparison tools currently available in Oncentra Brachy, end-users can optionally make use of third-party software of their choice and report their experiences using it. In this regard, public-domain software such as BrachyGuide v2 [10] (available at: http://www.rdl.gr/downloads) and SlicerRT [11] (available at: http://slicerrt.github.io/) may be of interest. Note that the use of third-party software for dose comparison within the current context, although encouraged, is not required.

B. Doses at Specified Points

The tab-delimited text file *DP_source_centered.txt* or *DP_source_displaced.txt* downloaded from the Elekta database with the other Test Case data defines two sets of six dose points to be used as comparison standards. For both source positions, the two sets contain points centered on the faces of cubes of sides 20 mm and 100 mm, respectively; the cubes in turn are centered at the radiation source. For the source displaced geometry and the large cube, the dose point at (x, y, z) = (120, 0, 0) mm has been moved to (x, y, z) = (100, 0, 0) mm to keep it within the water-filled part of the phantom.

To import a dose point set into the Case Explorer in Oncentra Brachy:

- Open the 'ACE LocalUser' plan for the Test Case of interest in the Brachy Planning activity.
- Create a new Patient point set by clicking the 'Add new point set' button, select point set Type 'Patient points' from the drop-down menu in the dialogue box, and click 'OK'.
- Open the appropriate DP text file, highlight the points of interest *in their entirety* (if you do not highlight all of the columns, Oncentra Brachy will report "Invalid Format" when you try to paste the data into Case Explorer), right-click, and then select Copy from the drop-down menu.
- Right-click in the right-hand pane of Case Explorer and select Paste from the drop-down menu. The screen shot following shows point doses so obtained for TG186 calculation of Test Case 1.



Name	X [mm]	Y [m...	Z [m...	Coord....	Abs. Dos...	Rel. D...	Normalization	Norm. Dose [%]	Optimization	Opt. Rel. Dose [%]	Opt. Weight
DP_c.1.1	-10.0	0.0	0.0	Patient	112.50	112.50	No	100.00	No	100.00	100.00
DP_c.1.2	10.0	0.0	0.0	Patient	112.60	112.60	No	100.00	No	100.00	100.00
DP_c.1.3	0.0	-10.0	0.0	Patient	70.20	70.20	No	100.00	No	100.00	100.00
DP_c.1.4	0.0	10.0	0.0	Patient	76.19	76.19	No	100.00	No	100.00	100.00
DP_c.1.5	0.0	0.0	-10.0	Patient	112.48	112.48	No	100.00	No	100.00	100.00
DP_c.1.6	0.0	0.0	10.0	Patient	112.38	112.38	No	100.00	No	100.00	100.00
DP_c.2.1	-50.0	0.0	0.0	Patient	4.51	4.51	No	100.00	No	100.00	100.00
DP_c.2.2	50.0	0.0	0.0	Patient	4.52	4.52	No	100.00	No	100.00	100.00
DP_c.2.3	0.0	-50.0	0.0	Patient	3.00	3.00	No	100.00	No	100.00	100.00
DP_c.2.4	0.0	50.0	0.0	Patient	3.14	3.14	No	100.00	No	100.00	100.00
DP_c.2.5	0.0	0.0	-50.0	Patient	4.46	4.46	No	100.00	No	100.00	100.00
DP_c.2.6	0.0	0.0	50.0	Patient	4.46	4.46	No	100.00	No	100.00	100.00

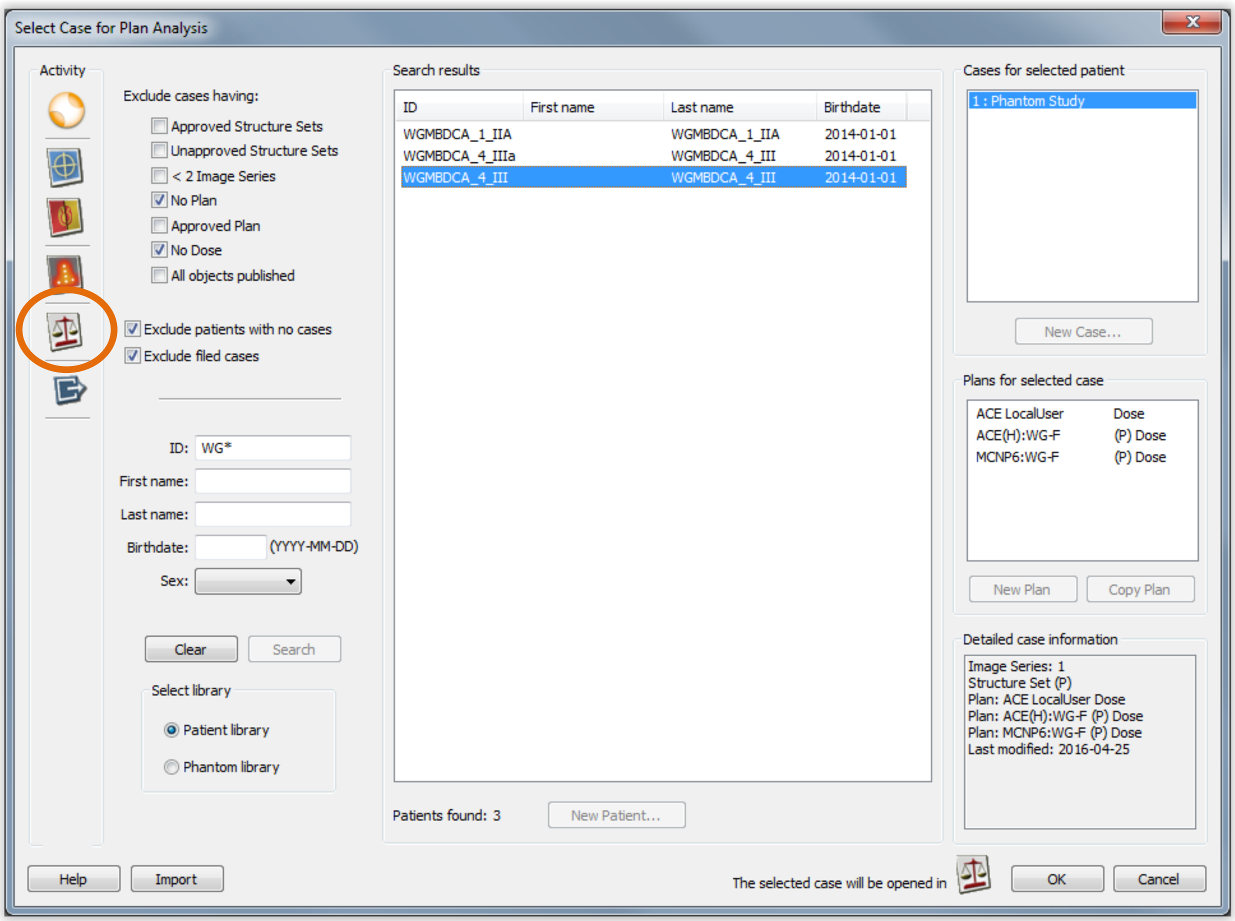
To obtain dose values at other points in the phantom that may also be of interest, edit the DP text file to include the coordinates of these points. Then highlight these additional points *in their entirety*, right-click and select 'Copy' from the drop-down menu, right-click in the right-hand pane of Case Explorer and select 'Paste insert' from the drop-down menu.

For each Test Case, a summary table of DP text file point dose differences (%) between locally calculated and MCNP6 reference dose values should be compiled and reported. The MCNP6 reference dose values for each Test Case can be found in Appendix 2.

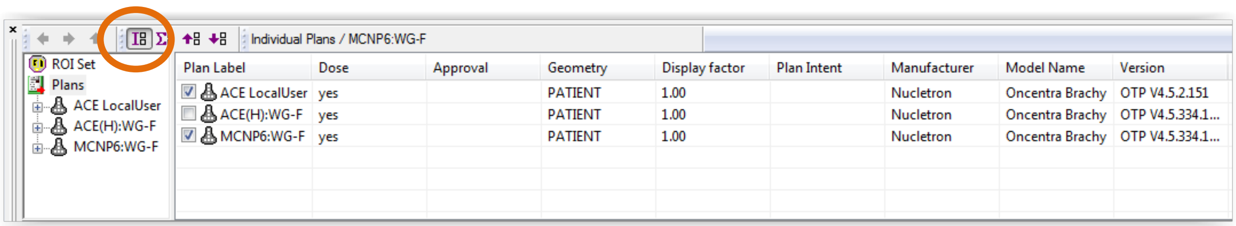
C. 2D Dose Maps & 1D Dose Profiles

To set up a side-by-side display of a locally calculated and a reference dose distribution:

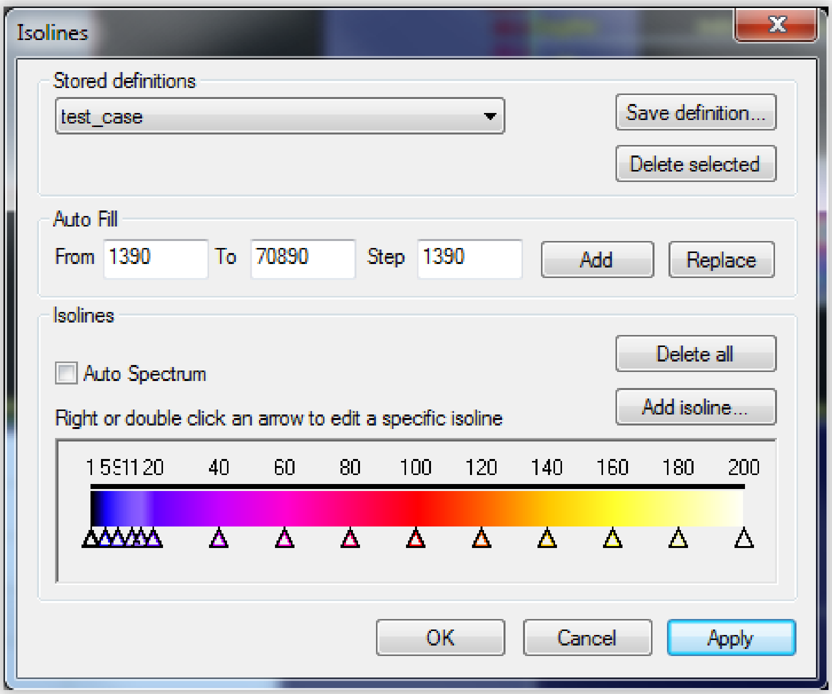
- Open the Test Case of interest by clicking Open case, and in the 'Select Case' window first click the Plan Analysis activity, then select the patient and case and click 'OK'.



- When the Plan Analysis activity opens click the 'Individual Plans' icon at the top of the Case Explorer window, navigate to the locally calculated and reference plans in the Case Explorer, and select both plans for comparison by checking the box for each plan.



- Choose or define an appropriate set of isolines for dose display by selecting Plan → Edit Isolines from the main menu. A pre-defined set of isolines labeled "test_case" is available in file Test_case_isolines.xml downloaded with the Elekta database Test Case data. This set of isolines can be made accessible to Oncentra Brachy by navigating to directory C:\Program Files\Nucletron\Brachy\Isolines, renaming existing file isolines.xml to isolines_x.xml (for example), copying file Test_case_isolines.xml to the directory, and finally renaming this latter file isolines.xml. A similar renaming process can be used to restore access to the definitions in isolines_x.xml. (Alternatively, if the end-user is familiar with the XML language and has access to an XML editor, the "test_case" isoline set can simply be copied from Test_case_isolines.xml and appended to isolines.xml.) Apply the "test_case" isoline set by selecting it from the 'Stored definitions' drop-down box in the Isolines window and clicking 'Apply' followed by 'OK'.



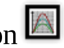
- Create a 2 x 2 display grid using the grid definition tool in the toolbar.

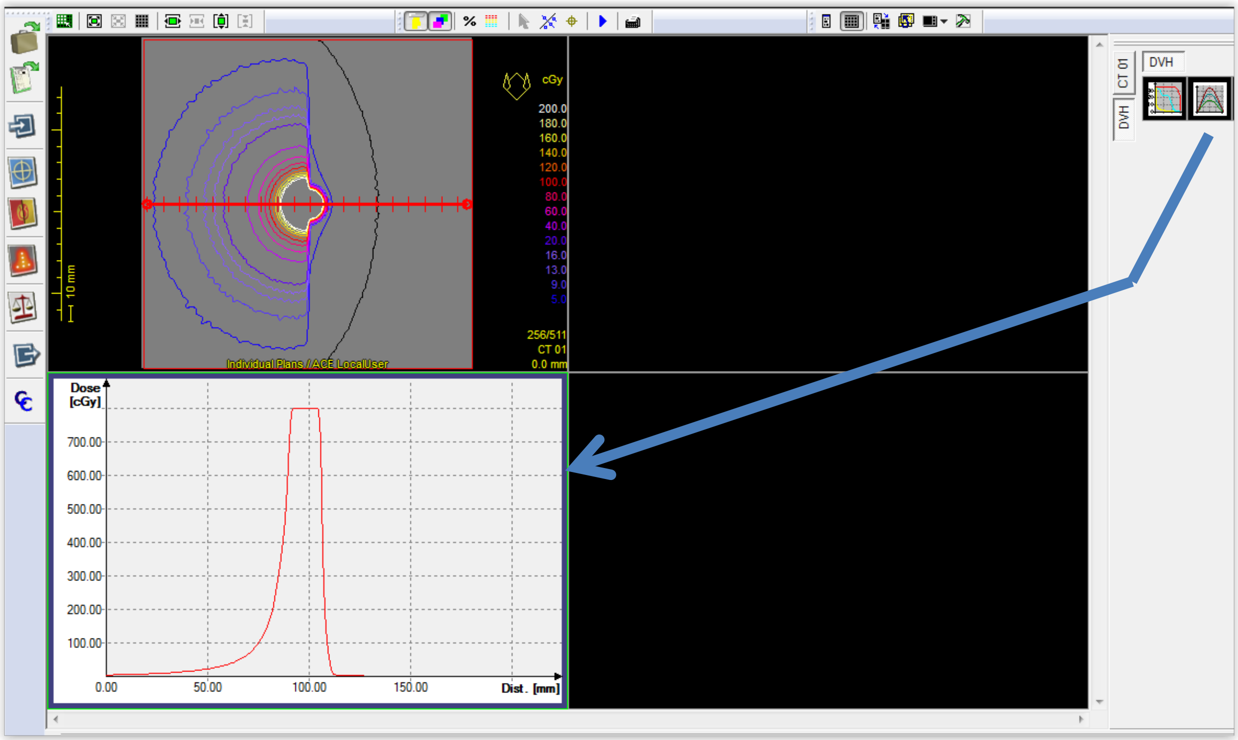
- If the ACE LocalUser plan is not displayed in the upper left panel of the display grid, click the 'Next object' button at the top of the Case Explorer window.

- Click in the upper left panel of the display grid to activate the axial dose image. For greater clarity in viewing, turn off the reconstructed points display by clicking the 'Show-hide reconstructed points' button if need be. Using the mouse wheel, scroll to an axial slice of interest. Then right-click the image to access the menu to activate zoom/pan operations. Zoom/pan the image to display an area of dosimetric interest, and then right-click and Stop zoom/pan.

- Create a dose profile for the displayed image. Detailed guidance on creating a dose profile in Plan Analysis is available in Oncentra Brachy online help (Help→Brachy Help) under the heading

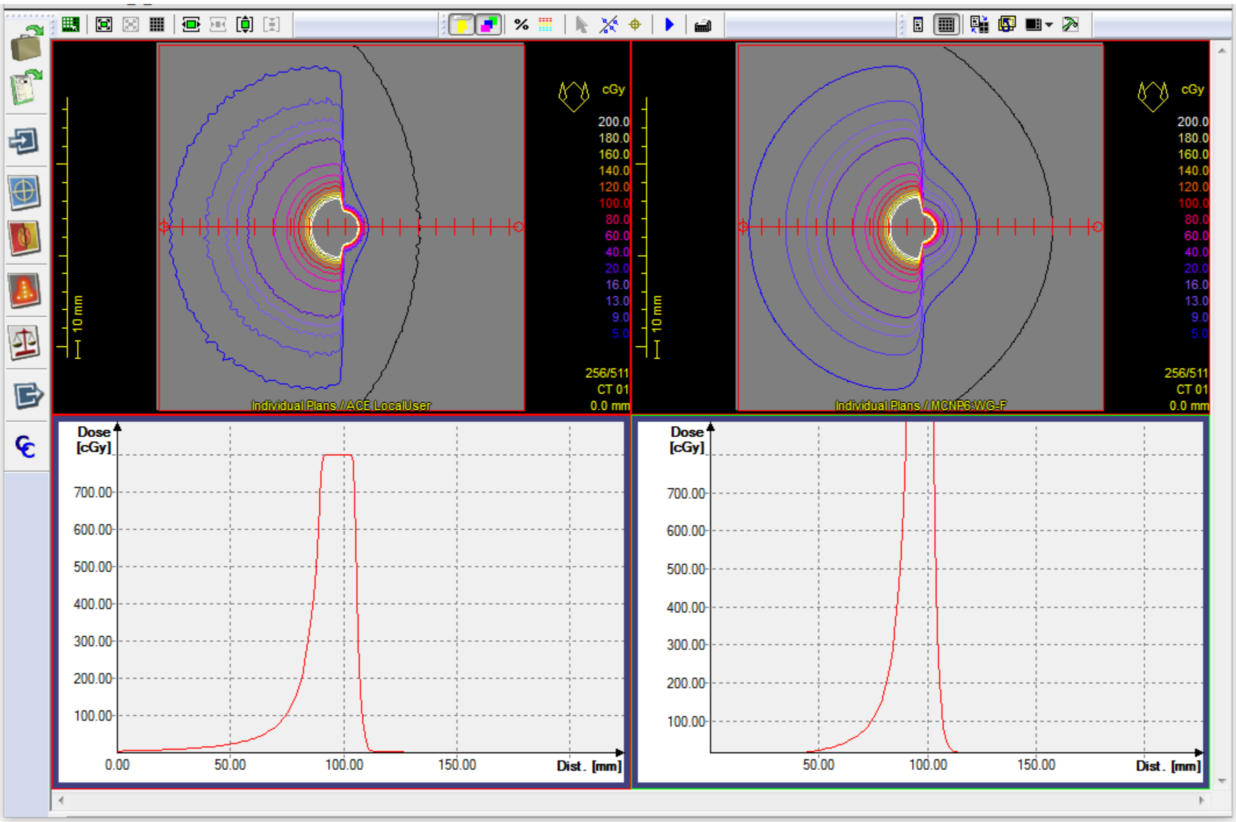
"Creating a dose profile [PA]". Although the endpoint coordinates of a profile line cannot be specified numerically, the orientation of the line can be refined by turning on the cm grid (keyboard shortcut <Ctrl+K>) to provide spatial reference.

- Display the dose profile in the lower left panel by dragging the dose profile icon  from the Thumbnail palette into the panel.



- Create a side-by-side display of 2D doses in the locally calculated and reference plans by clicking in the upper left panel and selecting Tools → Create Object Sequence from the main menu.

- Create a side-by-side display of dose profiles in the locally calculated and reference plans by clicking in the lower left panel and selecting Tools → Create Object Sequence from the main menu. Note that in the locally calculated 3D dose matrix, the maximum dose is limited to a value of 8x the prescription dose (set earlier to 100 cGy), which results in the 'flat top' feature observed in the locally calculated dose profile. (In clinical practice, this maximum dose value is normally confined to the interior of the applicator.) To change the vertical scale of the MCNP6 dose profile, right-click in the lower right panel and select 'Zoom rectangle' from the menu. Apply this tool several times to the lower portion of the MCNP6 dose profile until the vertical scale matches that for the locally calculated dose profile.



- Click in either of the upper panels and scroll through the corresponding locally calculated and MCNP6 slices to visually compare the 2D dose distributions throughout the phantom.

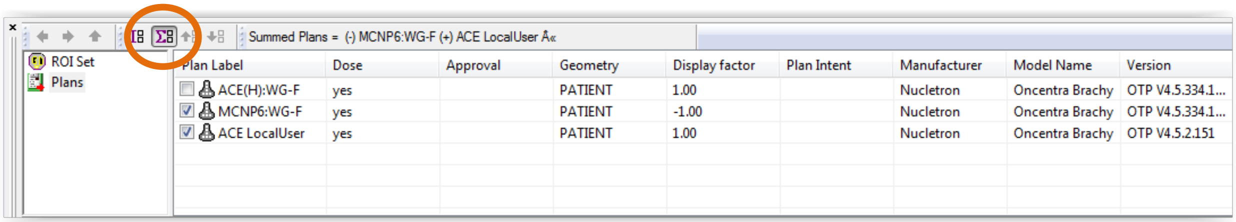
- For the source centered geometry (Test Cases 1, 2 and 4), dose maps and "horizontal" dose profiles through the center of the source should be generated and recorded using screen capture software in planes *x* = 0 mm, *y* = 0 mm, and *z* = 0 mm. For the source displaced geometry (Test Case 3), dose maps and "horizontal" dose profiles through the center of the source should be created and recorded in planes *x* = 70 mm, *y* = 0 mm, and *z* = 0 mm.

D. 2D Dose Map Differences

To display differences between a locally calculated and a reference dose distribution:

- Open the Test Case of interest by clicking Open case, and in the 'Select Case' window first click the Plan Analysis activity, then select the patient and case and click 'OK'.

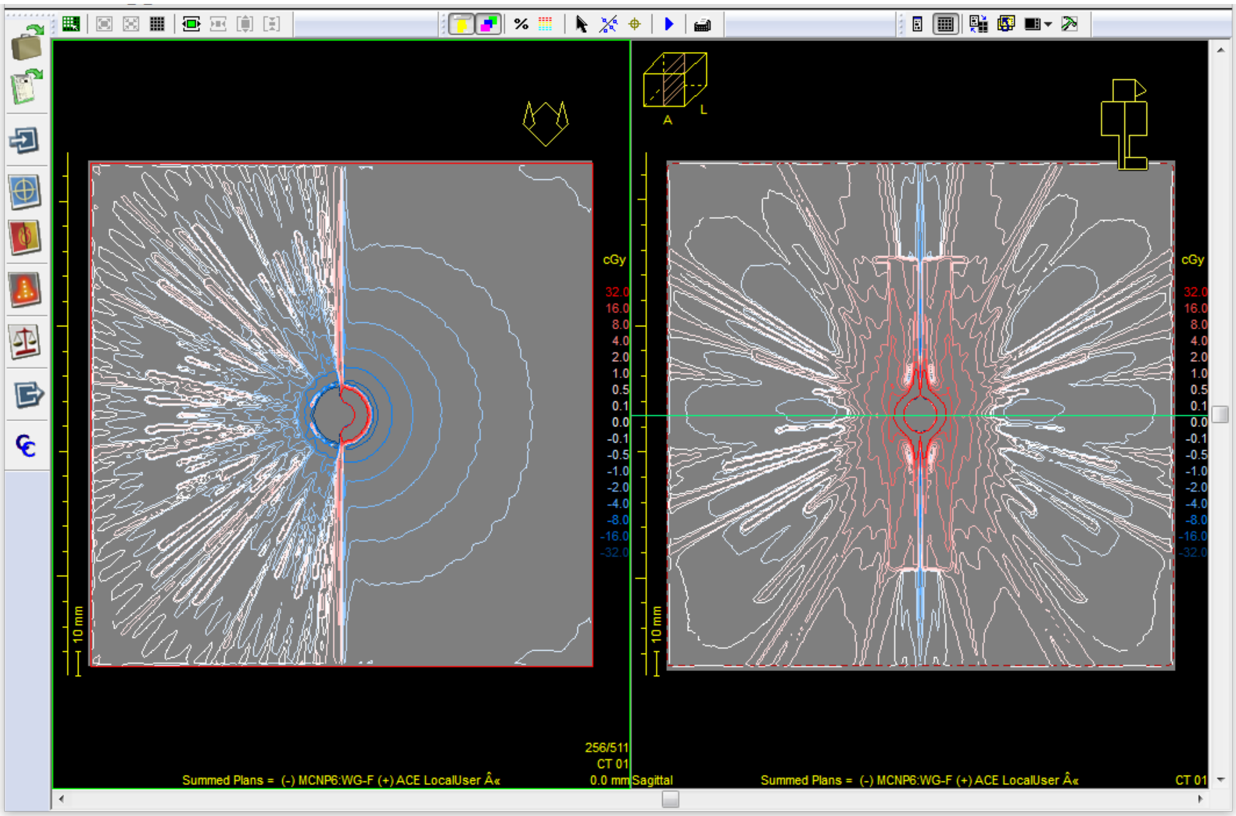
- When the Plan Analysis activity opens click the 'Summed Plans' icon at the top of the Case Explorer window, navigate to the locally calculated and reference plans in the Case Explorer, and select the plans for comparison by checking the box for each. Set the 'Display Factor' for the reference plan to -1; this yields the difference in the locally calculated dose distribution relative to the reference distribution.



- Choose or define an appropriate set of isolines for dose difference display by selecting Plan → Edit Isolines from the main menu. A pre-defined set of isolines labeled "cold-hot" is available in file Test_case_isolines.xml downloaded with the Test Case data. This set of isolines can be made accessible to Oncentra Brachy by navigating to directory C:\Program Files\Nucletron\Brachy\Isolines, renaming existing file isolines.xml to isolines_x.xml (for example), copying file Test_case_isolines.xml to the directory, and finally renaming this latter file isolines.xml. A similar renaming process can be used to restore access to the definitions in isolines_x.xml. (Alternatively, if the end-user is familiar with XML and has access to an XML editor, the "cold-hot" isoline set can simply be copied from Test_case_isolines.xml and appended to isolines.xml.) Apply the "cold-hot" isoline set by selecting it from the 'Stored definitions' drop-down box in the Isolines window and clicking 'Apply' followed by 'OK'.

- Create a 1 x 2 display grid using the grid definition tool in the toolbar.

- Load axial and sagittal (or coronal) reconstructed views into the grid panels by dragging them from the 'Reconstructed images' tab on the Thumbnail palette. Turn off reconstructed points display to unclutter the dose difference display panels.



- Scroll through the slices to inspect 2D dose differences throughout the phantom.

- For the source centered geometry (Test Cases 1, 2 and 4), dose difference maps through the center of the source should be generated and recorded using screen capture software in planes $x = 0$ mm, $y = 0$ mm, and $z = 0$ mm. For the source displaced geometry (Test Case 3), dose difference maps through the center of the source should be created and recorded in planes $x = 70$ mm, $y = 0$ mm, and $z = 0$ mm.

V Test Case Recording

Systematic recording of test case outcomes is intended to provide: (1) end-user generated dosimetric data for inter-comparison purposes; and (2) a basis for standardizing feedback on the commissioning process itself. Both types of information are valuable for refining the detailed TG-186 Level 2 commissioning procedures described in this Guide.

Dosimetric data to be recorded for each test case should include:

- Doses at points in the pre-defined DP sets described in Sec. IV.B, in tab-delimited text file format (.txt)
- Dose maps and "horizontal" dose profiles in the planes indicated in Sec. IV.C, in screen capture file format (.jpg, .tiff, .png)
- Dose difference maps in the planes indicated in Sec. IV.D, in screen capture file format (.jpg, .tiff, .png)
- Any other dose data highlighting an issue that you believe requires attention, in tab-delimited text file or screen capture file format, along with a concise description of the issue
- Any other dose data obtained using third-party software that you believe would improve the commissioning process, in tab-delimited text file or screen capture file format, along with a concise description of the improvement

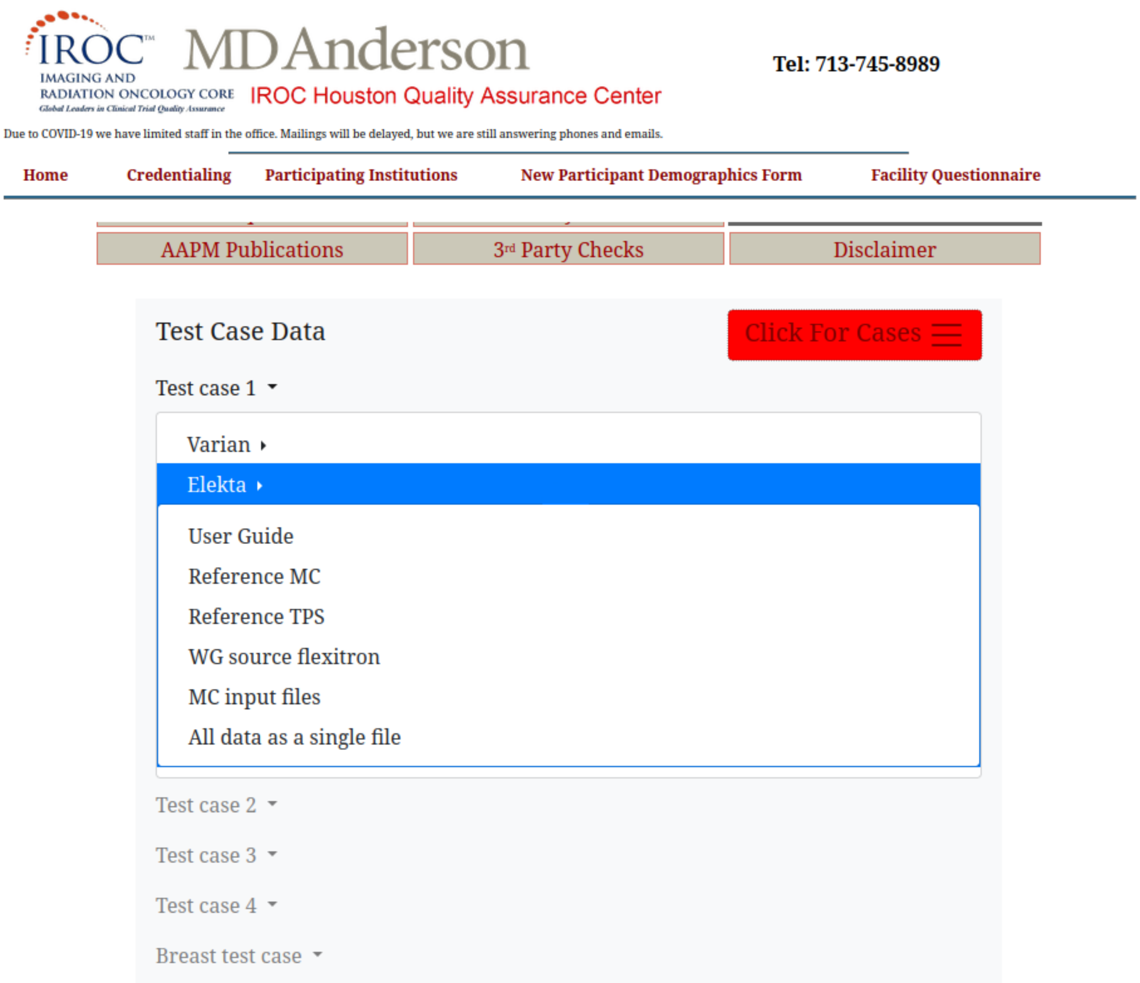
Written feedback on the commissioning process itself should include:

- A description of any procedural issues encountered trying to execute a Test Case import, calculation set up, dose calculation, or dose display procedure, etc.
- A description of any difficulties encountered in trying to follow the instructions in this User Guide
- Suggestions for improving the commissioning process and/or the User Guide.

Feedback can be sent directly to the WG-DCAB; contact information is available at the URL in Ref. [2].

VI Appendix 1: Installation of WG Generic Source & Flexitron Afterloader

The WG generic source and Flexitron afterloader definition files are available from the IROC Houston file server located at https://doi.org/10.52519/00005.



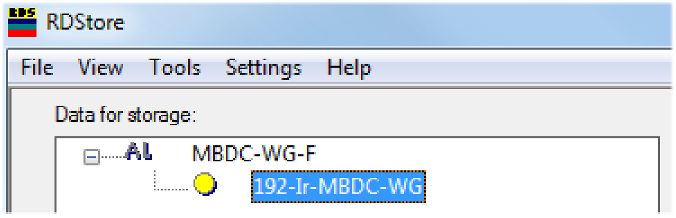
Select the 'WG Source flexitron' link. Save the '*WGSourceFlexitron.zip*' file to the TPS and extract the source and afterloader definition files (*MBDC-WG-F.xml* & *MBDC-WG-F.xml.md5*) to a local directory on the TPS.

Open the RD Store application (Start -> Oncentra Brachy – Treatment Device Administration - RDStore)

In RDStore window click File -> Select File…

Browse to the local directory, where the xml and the checksum files were placed, and click Open.

The data set for the MBDC-WG "afterloader" with the associated 192-Ir-MBDC-WG source will be available for calibration in the left pane of the RDStore window.



Leave the afterloader name as "MBDC-WG-F". Right click on the source name, select 'Modify Source', and enter the source calibration data as: Calibration Date: 01 Apr 2016, Calibration time: 10:00:00 and Air Kerma Strength 36260.00 (cGy cm^2/h) (~ 10Ci Apparent Activity). Click OK.

Drag and drop the "MBDC-WG-F" afterloader from the left pane to the right pane of RDStore. The RDStore username and password will be required to confirm this transfer.

The Flexitron afterloader and WG generic source will now be available in the Oncentra Brachy system.

Close the RDStore application.

VII Appendix 2: MCNP6 Point Dose Values

DP_MCNP6_Test_Case_1_GP

Name	X [mm]	Y [mm]	Z [mm]	Dose [cGy]
Source centered, Dose Point set #1				
DP_c.1.1	-10.0	0.0	0.0	112.1476
DP_c.1.2	10.0	0.0	0.0	112.1678
DP_c.1.3	0.0	-10.0	0.0	68.2935
DP_c.1.4	0.0	10.0	0.0	73.8211
DP_c.1.5	0.0	0.0	-10.0	112.1375
DP_c.1.6	00	0.0	10.0	112.1678
Source centered, Dose Point set #2				
DP_c.2.1	-50.0	0.0	0.0	4.5468
DP_c.2.2	50.0	0.0	0.0	4.5479
DP_c.2.3	0.0	-50.0	0.0	3.0322
DP_c.2.4	0.0	50.0	0.0	3.1805
DP_c.2.5	0.0	0.0	-50.0	4.5460
DP_c.2.6	0.0	0.0	50.0	4.5477

DP_MCNP6_Test_Case_2_GP

Name	X [mm]	Y [mm]	Z [mm]	Dose [cGy]
Source centered, Dose Point set #1				
DP_c.1.1	-10.0	0.0	0.0	112.0466
DP_c.1.2	10.0	0.0	0.0	112.0567
DP_c.1.3	0.0	-10.0	0.0	68.1915
DP_c.1.4	0.0	10.0	0.0	73.7211
DP_c.1.5	0.0	0.0	-10.0	112.0466
DP_c.1.6	00	0.0	10.0	112.0769
Source centered, Dose Point set #2				
DP_c.2.1	-50.0	0.0	0.0	4.4367
DP_c.2.2	50.0	0.0	0.0	4.4363
DP_c.2.3	0.0	-50.0	0.0	2.9224
DP_c.2.4	0.0	50.0	0.0	3.0700
DP_c.2.5	0.0	0.0	-50.0	4.4340
DP_c.2.6	0.0	0.0	50.0	4.4359

DP_MCNP6_Test_Case_3_GP

Name	X [mm]	Y [mm]	Z [mm]	Dose [cGy]
Source displaced, Dose Point set #1				
DP_d.1.1	60.0	0.0	0.0	110.8200
DP_d.1.2	80.0	0.0	0.0	110.7200
DP_d.1.3	70.0	-10.0	0.0	67.3520
DP_d.1.4	70.0	10.0	0.0	72.8280
DP_d.1.5	70.0	0.0	-10.0	110.7700
DP_d.1.6	70.0	0.0	10.0	110.8000
Source displaced, Dose Point set #2				
DP_d.2.1	20.0	0.0	0.0	4.3655
DP_d.2.2	100.0	0.0	0.0	11.8630
DP_d.2.3	70.0	-50.0	0.0	2.7705
DP_d.2.4	70.0	50.0	0.0	2.9164
DP_d.2.5	70.0	0.0	-50.0	4.2666
DP_d.2.6	70.0	0.0	50.0	4.2682

DP_MCNP6_Test_Case_4_GP

Name	X [mm]	Y [mm]	Z [mm]	Dose [cGy]
Source centered, Dose Point set #1				
DP_c.1.1	-10.0	0.0	0.0	555.0318
DP_c.1.2	10.0	0.0	0.0	65.4464
DP_c.1.3	0.0	-10.0	0.0	389.2949
DP_c.1.4	0.0	10.0	0.0	428.8506
DP_c.1.5	0.0	0.0	-10.0	266.4971
DP_c.1.6	00	0.0	10.0	266.5122
Source centered, Dose Point set #2				
DP_c.2.1	-50.0	0.0	0.0	21.5781
DP_c.2.2	50.0	0.0	0.0	2.0410
DP_c.2.3	0.0	-50.0	0.0	12.8767
DP_c.2.4	0.0	50.0	0.0	14.1947
DP_c.2.5	0.0	0.0	-50.0	11.2047
DP_c.2.6	0.0	0.0	50.0	11.1971

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