User Guide for Varian Medical Systems BrachyVision™ Algorithm Testing

Breast case

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I Introduction

The American Association of Physicists in Medicine (AAPM) Task Group 186 report [1] provided general guidance for early adopters of model-based dose calculation algorithms (MBDCAs) for brachytherapy (BT) treatment planning. The report's aim was to facilitate uniformity of clinical practice. Among its recommendations was 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 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 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.

This user manual provides guidelines for level 2 testing of the Varian Medical Systems BrachyVision[TM] Algorithm with a test case mimicking a clinical scenario of interstitial HDR breast BT.

The breast test case comprises:

- a computational patient phantom model in Digital Imaging and Communications in Medicine (DICOM) format,
- a treatment plan for the model using the WG generic HDR ^{192}Ir source including the corresponding reference TPS dose distribution obtained with BrachyVision,
- a three-dimensional reference dose distribution calculated using Monte Carlo (MC) simulation in the model, using information parsed from the treatment plan exported from the TPS in DICOM radiation therapy (RT) format.

The patient phantom model was prepared based on a representative Accelerated Partial Breast Irradiation (APBI) case [4]. Regions of interest (ROIs) including the external contour, the planning target volume (PTV) mimicking the original left-sided lesion, the lungs, the skin, the heart, and the ribs, were contoured and digitized on the axial patient CT images. A uniform density was assigned to these ROIs using nominal data in the ICRU report No. 46 [5] and the model was written to a series of DICOM CT images. The central axial image of the model is presented in Figure 1. More details on the test case can be found in a corresponding Medical Physics dataset article ("A

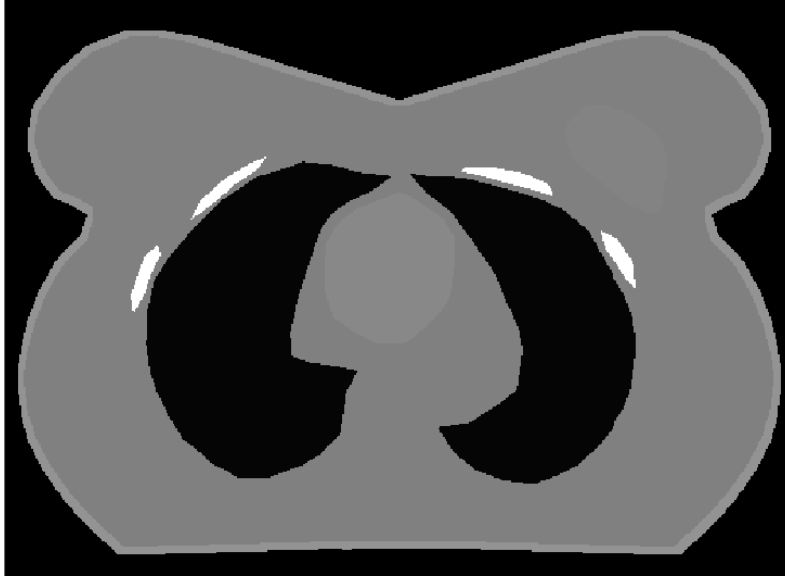test case for commissioning model-based dose calculation in interstitial HDR breast brachytherapy").

Figure 1. Central axial image of the computational patient phantom model

These guidelines follow the recommendations in "Commissioning of Model-Based Dose Calculation Algorithms in Brachytherapy: A Joint AAPM, ESTRO, ABG, and ABS Report" which was at the final stage of review at the time of writing.

In overview, the testing process involves downloading the breast test case treatment plan and the associated reference MC dose distribution and importing them into BrachyVision (Sec. II), locally calculating a dose distribution using the BrachyVision algorithm of the TPS (Sec. III), and then (Sec. IV) comparing the locally calculated and reference TPS dose distributions (TPS validation phase) as well as the locally calculated TPS and reference MC dose distributions (MBDCA validation phase).

II Case Import breast case

A. Accessing the Test Case Repository

Data for the breast test cases will be made available via a web-accessible repository located at: https://doi.org/10.52519/00005 (click on "Link to full text")

The main page contains links to Reference Data generated using the MC code EGS, and to TPS-specific data for Elekta and Varian users.

B. Downloading Test Case

Select the "Breast test case" then Varian (as highlighted in the figure above) to see the database files. The user can download each file individually or download all data as a single file.

The file "varian.zip" (this is the file name when all data is downloaded as a single file) contains three folders. 1) MC files (MCNP6 and EGS simulation files); 2) Reference MC – 43 DICOM files including a 3D reference radiotherapy dose (RD) matrix calculated using EGS Monte Carlo simulation. 3) Reference TPS - 43 DICOM files including a 3D reference radiotherapy dose (RD) matrix calculated using ACUROS. The DICOM files also include a radiotherapy plan (RP), and a radiotherapy structure set (RS) for both MC and TPS folders.
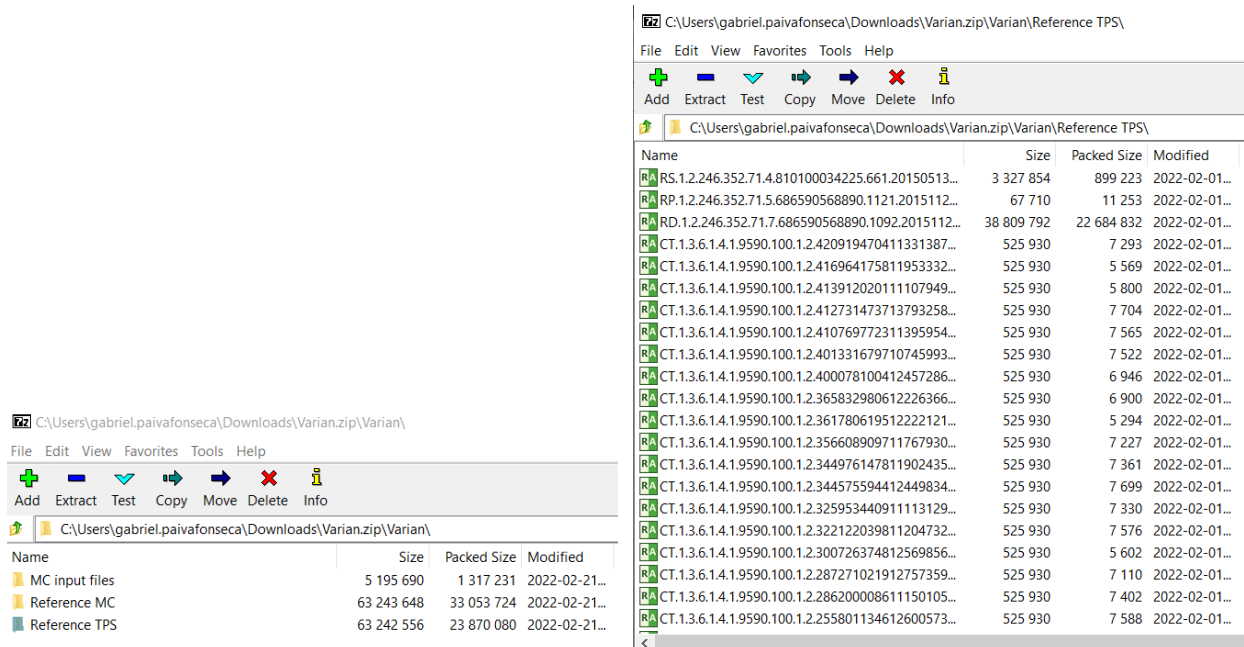
Extract all files from the test case .zip folder to a local or network folder accessible to the BrachyVision workstation.

C. Importing Test Case into BrachyVision

The description below might slightly deviate for different versions of BrachyVision.

- Open BrachyVision
- Click on the 'File → Import '.
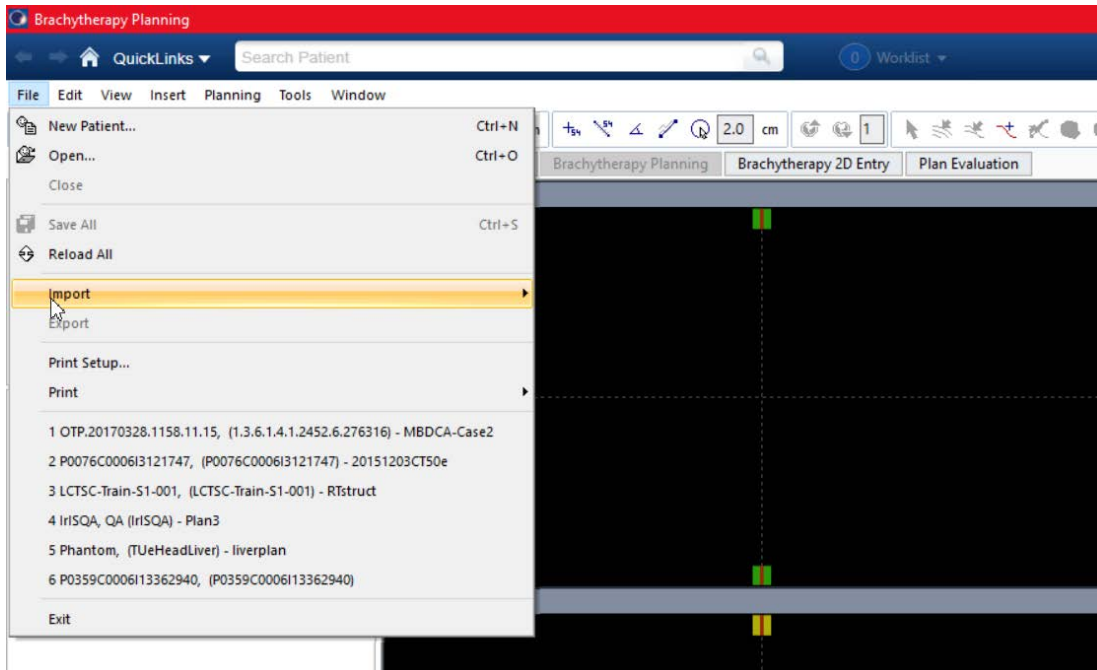
- The import of the test case will occur in two steps, firstly importing the pre-calculated ACUROS plan & dose and then importing the reference MC dose.
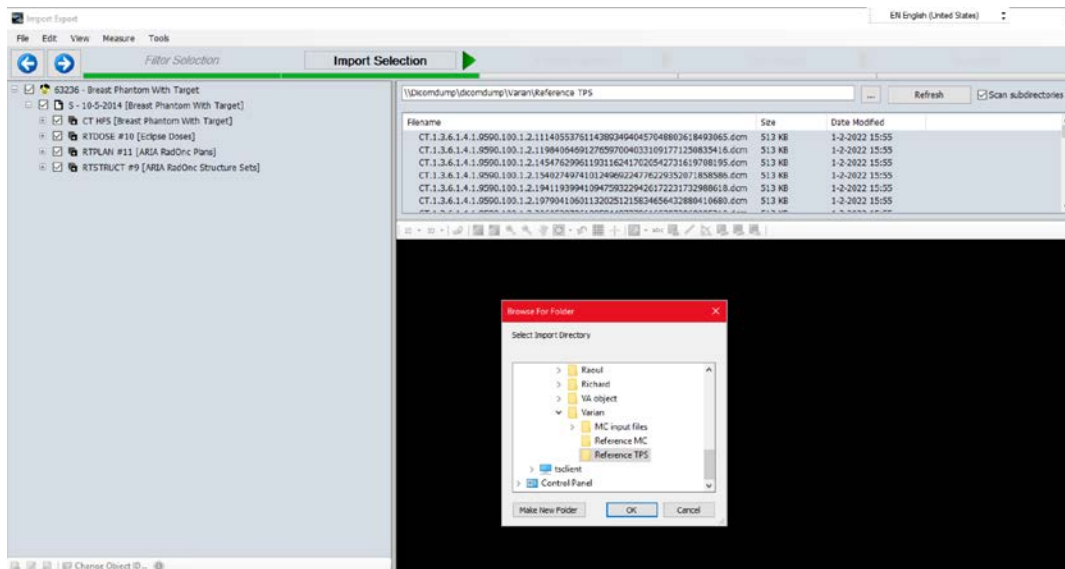
- Click the [...] button and browse to the folder containing the unzipped test case, '…\Reference TPS\'.

- The system will display a list of CT Image data, RT Plan, RT Structure Set and RT Dose.

- Select all files then click on ⊙ so the system will read and validate the data ready for import.
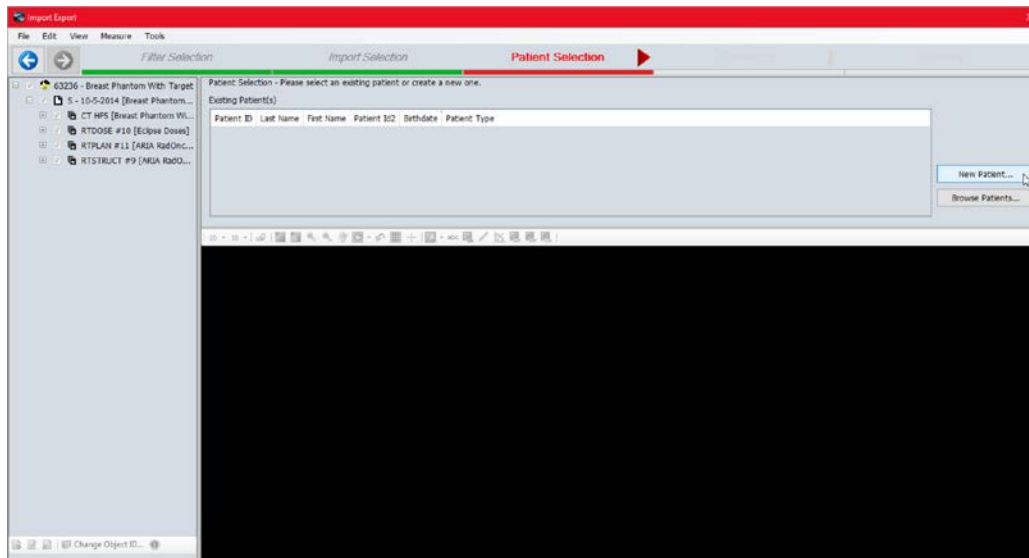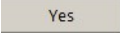
- Create a new patient.

- Confirm the test case information (do not adjust the information to avoid issues while importing the MC dose files) and press ✓ OK .

- Then the 'Log Details' window appears with a message: "DVH import is not supported - histogram(s) will be skipped". In some cases a message 'Source TG-186 was matched to a source model that is not approved.' can appear. Click Yes to continue.

- Click 🔄 to finalize the import.

- The plan opens when the import is complete.
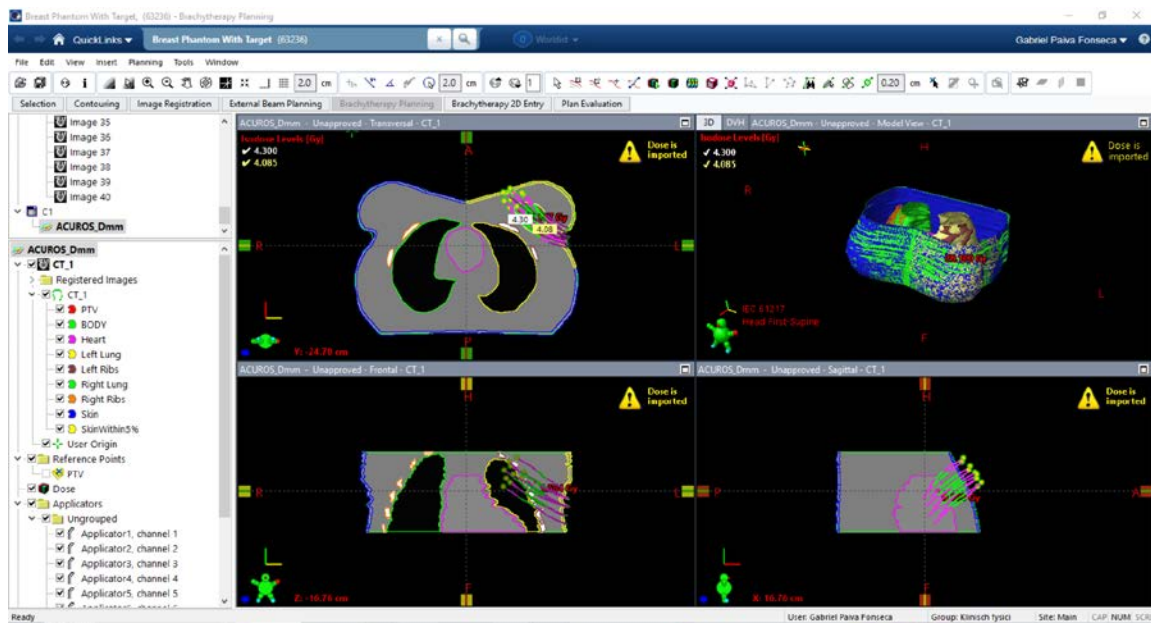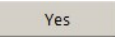
- Right-click on the plan name, select properties and confirm the dose per fraction (4.30 Gy) and the number of fractions (1). If it is not correct, adjust the values.
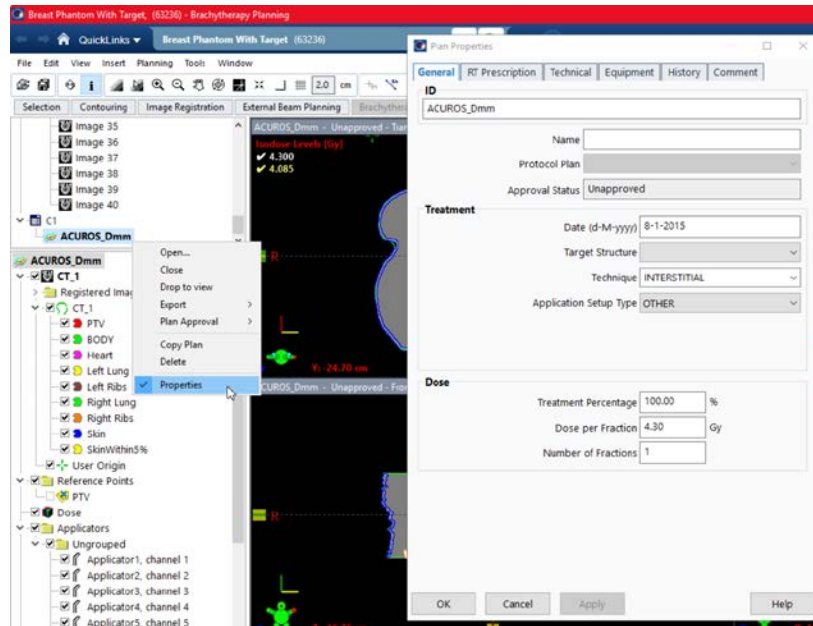
To import the reference MC dose file follow the next steps:

- Click the 'File → Import' button again and select the folder containing the unzipped test case with the MC data files, '…\Reference MC\'.

- **The system will display a list of CT Image data, 'RT Dose' and 'RT Plan' and 'RT Structure Set'**

- Select the 'RT Dose' and 'RT Plan' and 'RT Structure Set'. Click the and the system will read and validate the data ready for import and find an exactly matching patient.
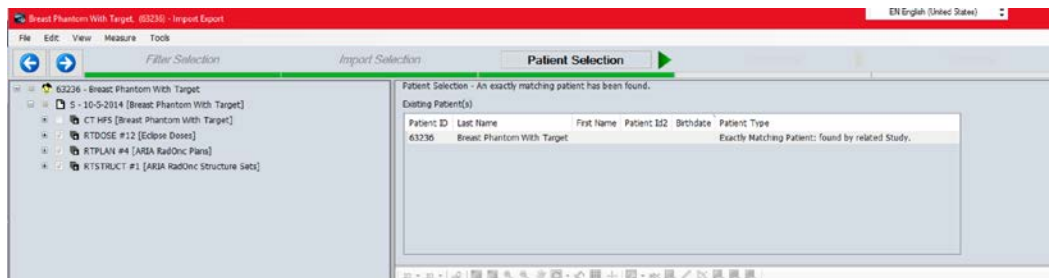
- The same 'Log Details' window appears with the message: "DVH import is not supported - histogram(s) will be skipped". In some cases a message 'Source TG-186 was matched to a source model that is not approved.' can appear. Click [Yes] to continue.

- If an error appears indicating the dose has a reference to an invalid plan, select the Plan ID =>

  "EGS_Brachy (C1)" and proceed
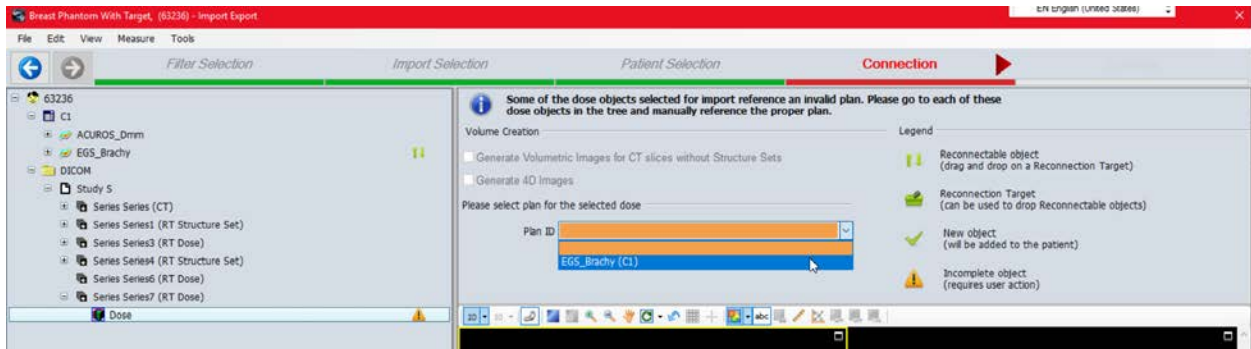
The data for Breast Case has been imported.
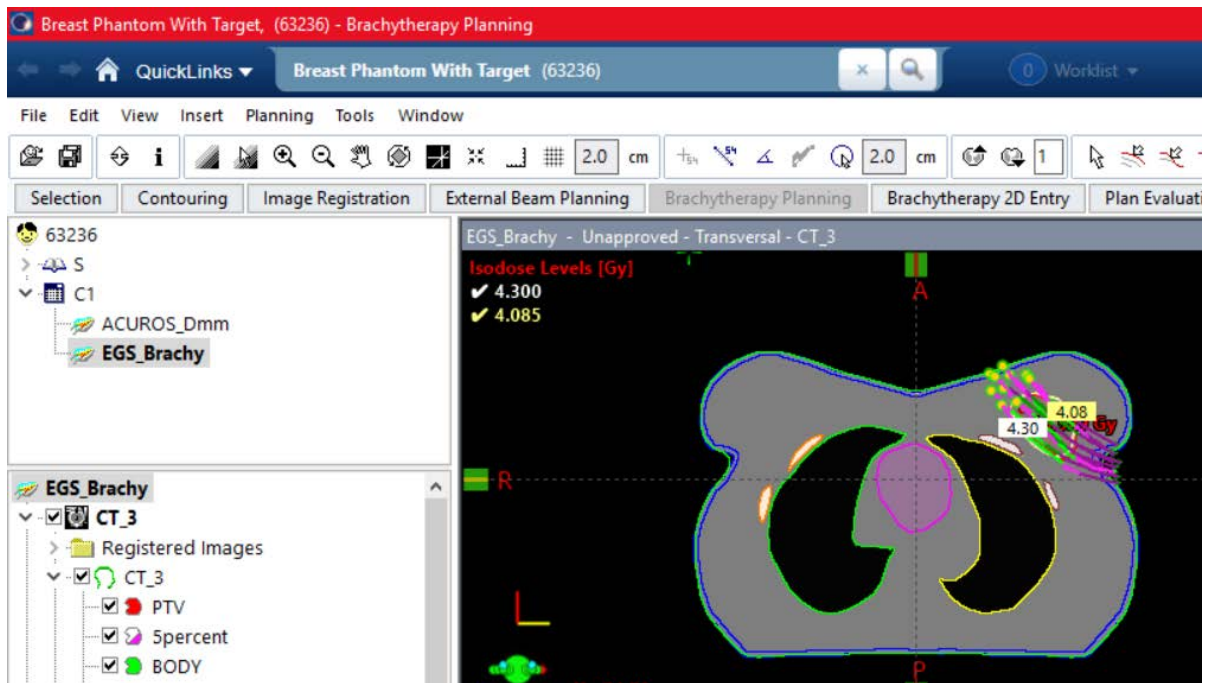
A local working copy of the ACUROS plan will now be created for the local user to calculate the dose which will be then used for comparison with the reference EGS_Brachy dose.

- Select the 'ACUROS_Dmm' plan, right-click on it and select the 'Copy Plan' option.
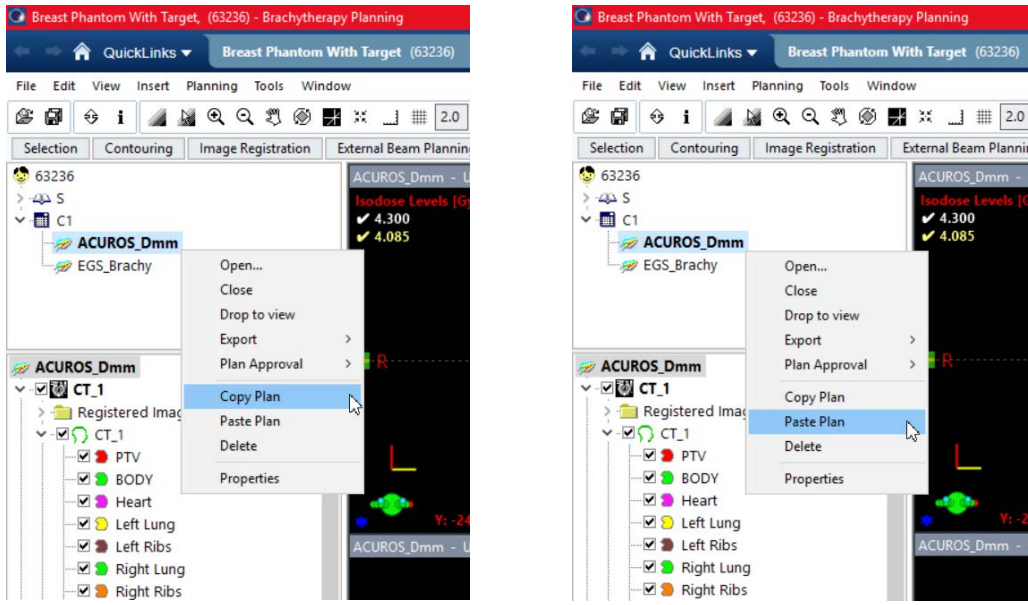
- Select the 'ACUROS_Dmm' plan, right-click on it and select the 'Paste Plan' option.

- The 'Plan Properties' window opens.

- Enter 'LocalUser' in the ID field, 'LocalUser' in the Name field and Click ⟨ OK ⟩. Confirm the dose per fraction and number of fractions.

The import process and local plan creation are complete.

- Click 'Save all' (shortcut "CTRL + S").

III Dose Calculation

A. Confirming the Plan Properties

Note BrachyVision supports standard, IEC-61217 and user-defined coordinate systems. Therefore, the axes might be swapped (see section IV) but it does not require any adjustments or affect the results. The user should not change the configuration of BrachyVision, but be aware of the adopted coordinate system.

- Right-click on 'LocalUser' plan and -> 'Drop to view'.

- Select 'Window -> Brief Report Window'.

- Check, if the Total prescription (4.3 Gy in 1 fraction), Source nominal activity (10000 mCi) and Total treatment time (173.60 s) are correct.
- Close the 'Brief Report' Window.
- Select the 'Dose', right-click on it and select 'Properties'. Confirm the 'Dose Matrix Properties' as shown below. Click OK . See section IV for additional information on the DICOM coordinates.
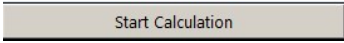
B. Performing the ACUROS Dose Calculation

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 'LocalUser' plan.

- To perform an ACUROS dose calculation, click the [icon] button.
- Select a valid imaging device and press OK. See section V on how to add a specific CT calibration.


- If an error about the material table appears, select and right-click on the structure set "CT_1" open the Properties menu then the select "Physical Material Table AcurosBV -13.0".
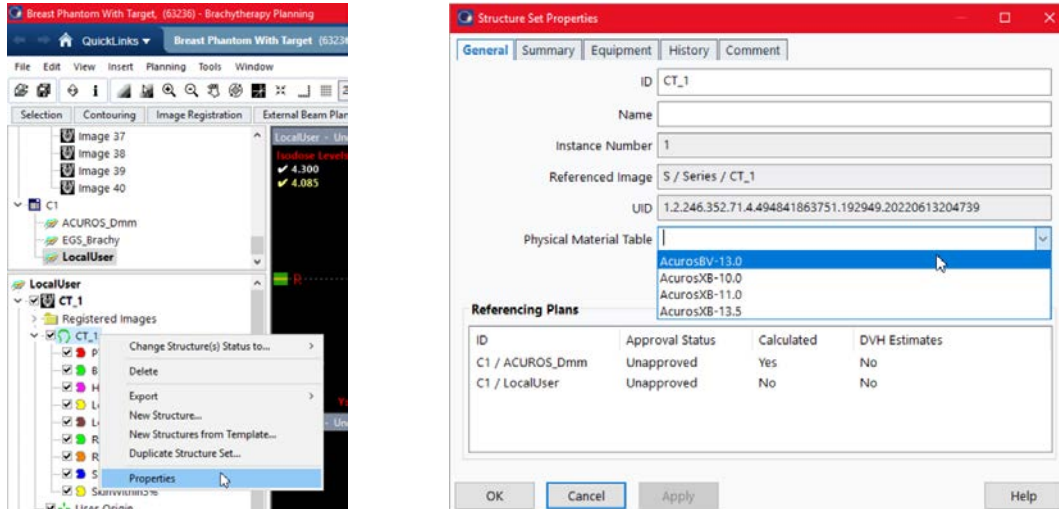
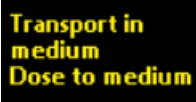- The ACUROS dose calculation window will appear. Confirm that for the calculation medium the 'CT values' are used and click [Start Calculation] button to begin the ACUROS calculation.
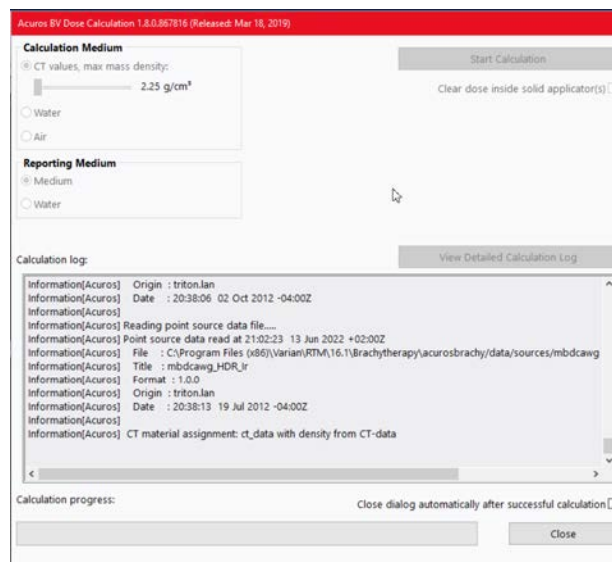
- When the calculation is completed, a warning message appears.
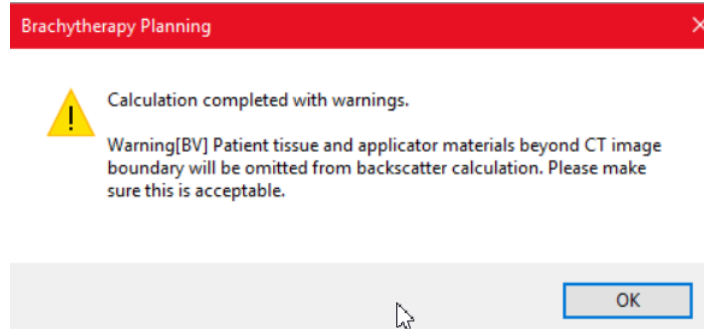
- Click [OK] and close the calculation window. The display will be updated with isodoses for the ACUROS calculation. The display will also specify the calculation algorithm 'Transport in medium. Dose to medium'.

- Click 'Planning → Isodose Levels' to change the isodose line values and properly see the dose distribution. Click [OK]. Dose values exist inside the dose matrix defined. Click the button to see the dose matrix.
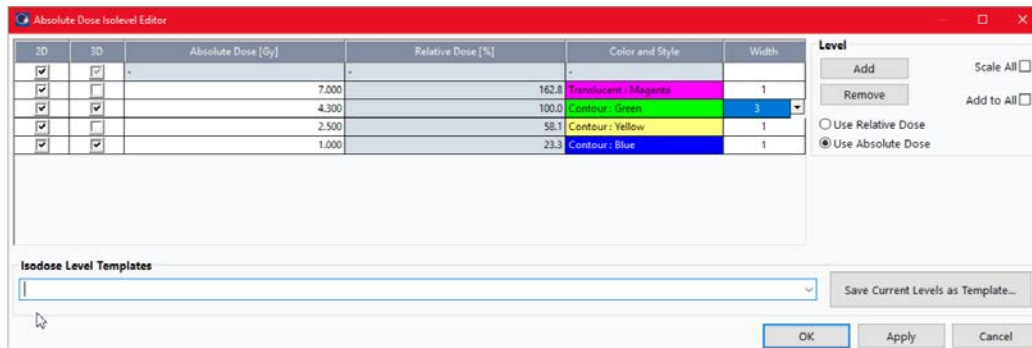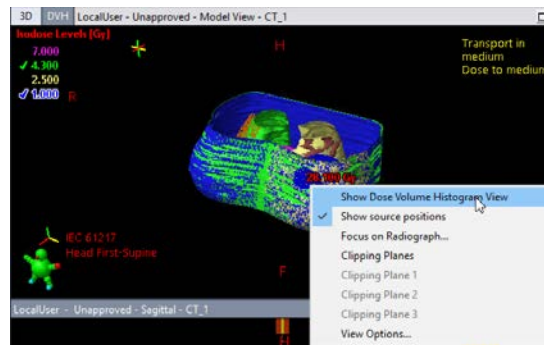

Save the plan by clicking File → 'Save All' .

The test case is ready for comparison as defined in section IV, Dose Distribution Comparison.

IV Dose Distribution Comparison

The breast test case is evaluated by using DVH parameters.

- To obtain a value from the DVH right-click in the 3D window and click 'Show Dose Volume Histogram View'.

- Increase the size of the 'Dose Volume Histogram' window to have a better view and select a reference contour (e.g. PTV)

- For evaluating DVH indices as described in the manuscript *A test case for commissioning model-based dose calculation in interstitial HDR breast brachytherapy* use 'Show Cross-hair'.
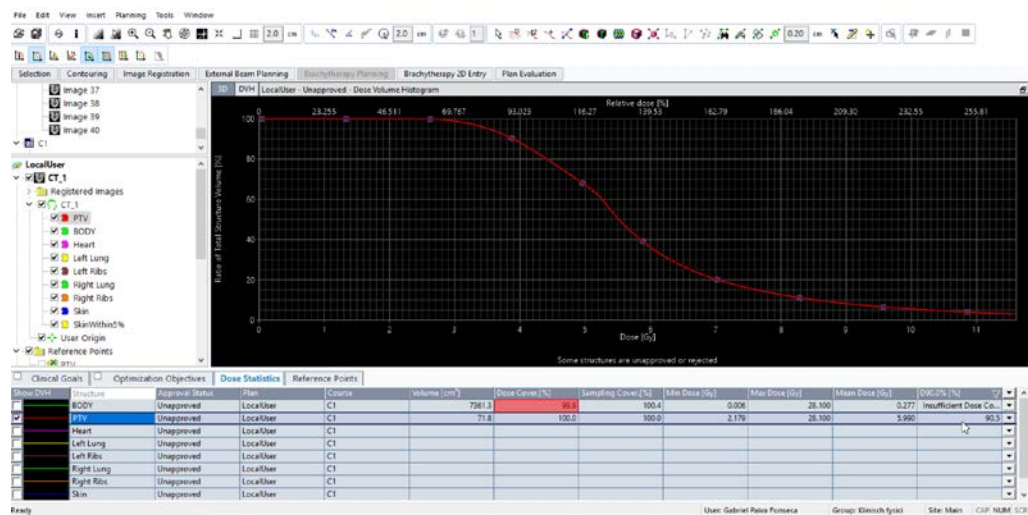
- In the figure above the D90 of PTV [%] is measured. For this, in the DVH the appropriate organ must be selected. Using the Cross-hair or entering D90% in the Dose Statistics tab gives a D90 of 90.5%.

- Proceed like this for all necessary DVH indices given in table V of the manuscript. Note that small differences (second decimal place) might be observed due to software version and/or settings.

V. BrachyVision coordinates

BrachyVision supports standard, IEC-61217, and user-defined coordinate systems as illustrated below. This user-guide adopted the standard coordinate system. Therefore, systems using the IEC-61217 coordinate system will display swapped Y and Z axes with inverted Z axis, in relation to the standard coordinate system. **Note the user should not change the configuration of BrachyVision, but be aware of the adopted coordinate system.**

The coordinate system can be checked in Aria/BrachyVision in Administration -> RT Administration. Press **System and Facilities**. In the System Properties, the current Planning Coordinate System is shown.
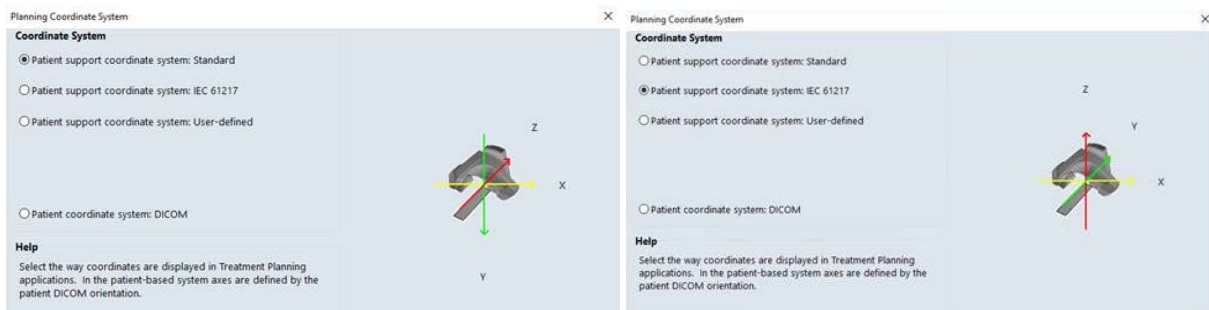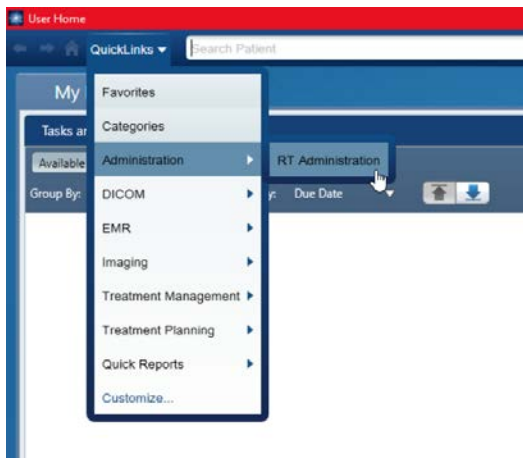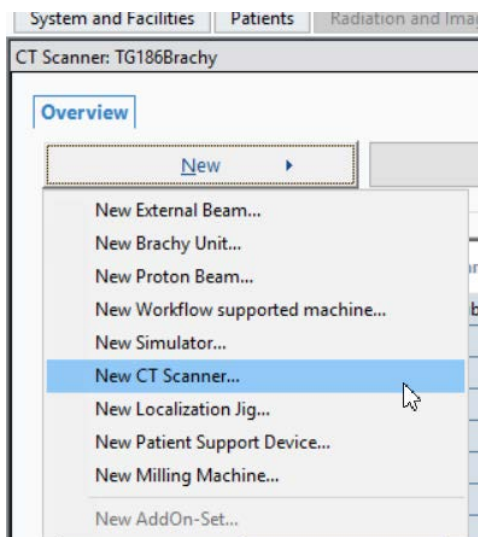
VI. Adding a CT calibration

Please check the regulations and safety requirements of your institution before adding a new CT calibration since an incorrect imaging device selection can affect treatment planning calculations.

It is necessary to create a new "CT Scanner" for which admin rights will be required.
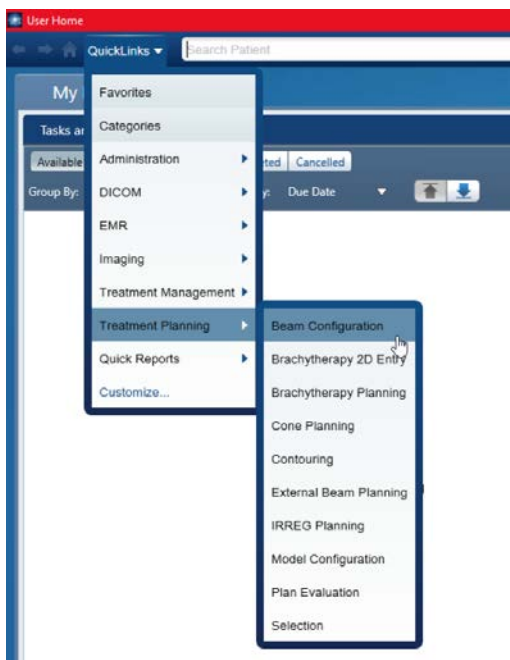
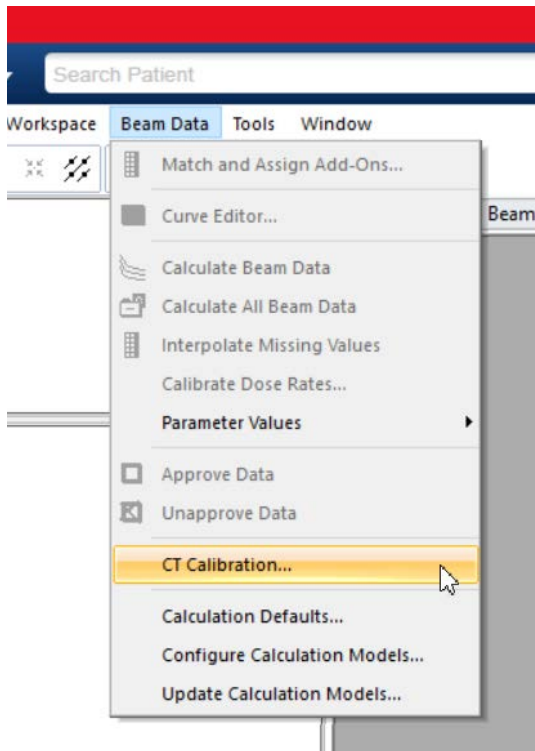- Open the RT administration

- Select "New" then "New CT Scanner"

- Define the properties using a meaningful name and press OK.

- To add the CT calibration open "Treatment Planning" then "Beam Configuration"

- In the "Beam Data" menu select CT calibration

- Select the CT device that was just created then "Mass_Density" and click on Edit.
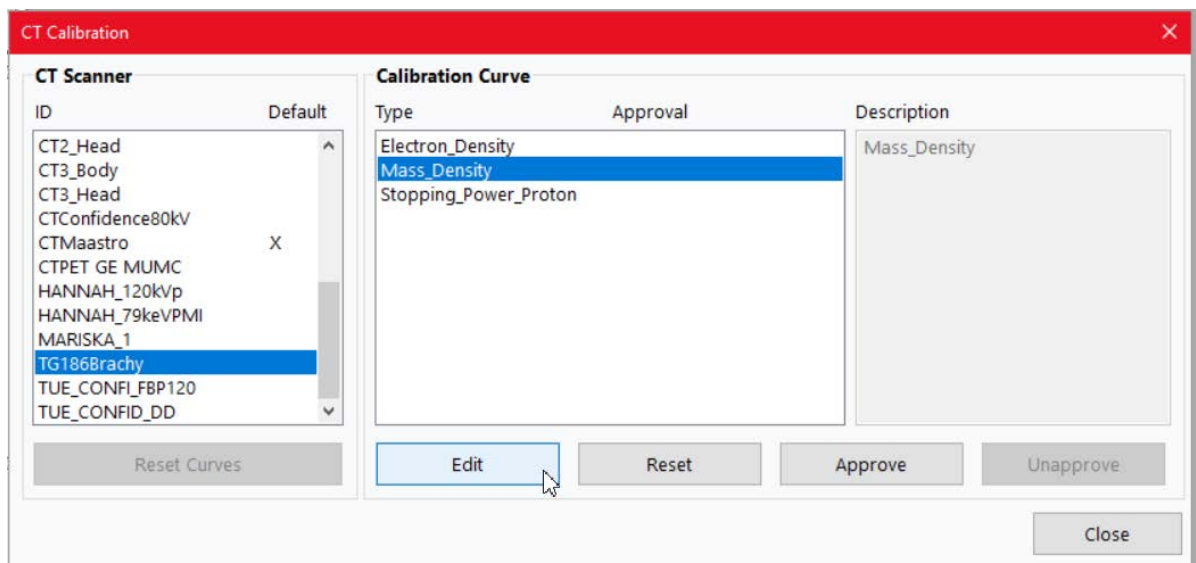
- Include the values shown below and press OK.

HU Value [HU]	Density [g/cm3]
-1000.000	0.001
-480.000	0.500
-96.000	0.950
0.000	1.000
48.000	1.050
128.000	1.100
528.000	1.334
976.000	1.603
1488.000	1.850
1824.000	2.100
2224.000	2.400
2640.000	2.700
2832.000	2.830
3500.000	3.555
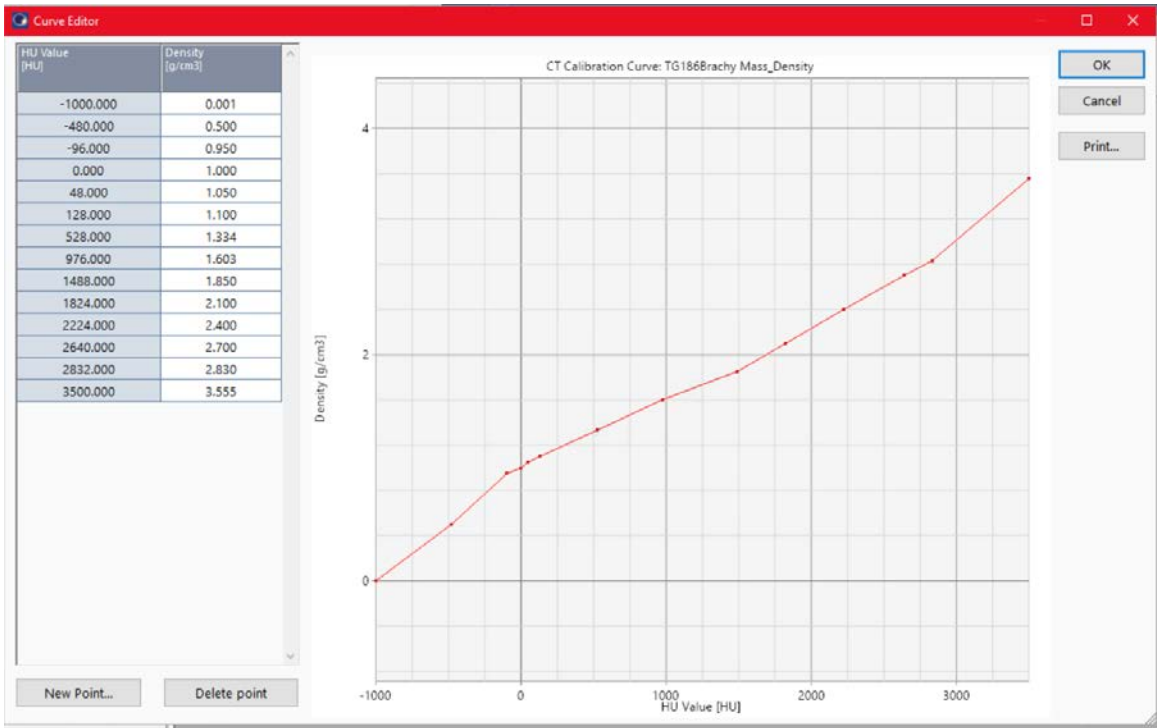
- Click on "Approve" and close the "Beam Configuration" software.

This CT calibration can now be used to perform dose calculations with Acuros.

[1]   L. Beaulieu *et al.*, "Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation," *Med. Phys.*, vol. 39, no. 10, pp. 6208–6236, Oct. 2012, doi: 10.1118/1.4747264.

[2]   "WGDCAB." [Online]. Available: http://www.aapm.org/org/structure/default.asp?committee_code=WGDCAB.

[3]   F. Ballester *et al.*, "A generic high-dose rate 192Ir brachytherapy source for evaluation of model-based dose calculations beyond the TG-43 formalism," *Med. Phys.*, vol. 42, no. 6, pp. 3048–3062, Jun. 2015, doi: 10.1118/1.4921020.

[4]   V. Peppa, E. E. Pantelis, E. Pappas, V. Lahanas, C. Loukas, and P. Papagiannis, "A user-oriented procedure for the commissioning and quality assurance testing of treatment planning system dosimetry in high-dose-rate brachytherapy.," *Brachytherapy*, vol. 15, no. 2, pp. 252–62, Mar. 2016, doi: 10.1016/j.brachy.2015.11.001.

[5]   ICRU, "International Commission on Radiation Units and Measurements. Photon, Electron, proton and Neutron Interaction Data for Body Tissues. ICRU Report 46," Bethesda, MD, 1992.