INTRABEAM TEST CASE:

User Guide for GMV RADIANCE© Algorithm Testing

Contents

I. Introduction

The report published by the American Association of Physicists in Medicine (AAPM) Task Group 186 [1] presented general guidance to assist early adopters of model-based dose calculation algorithms (MBDCAs) in brachytherapy (BT) treatment planning. The primary objective of the report was to promote consistency in clinical practice. One of the recommendations put forth was a two-tiered approach to the implementation of MBDCAs within BT treatment planning systems (TPSs), focusing on the tasks associated with the dose calculation algorithm.

During commissioning level 1, the clinical physicist's responsibility is to evaluate the agreement between the absolute dose, or dose rate, obtained from the MBDCAs implemented in the TPS and that calculated using AAPM-recommended consensus TG-43 dosimetry parameters for a specific BT source model. Moving on to commissioning level 2, the physicist is required to compare the 3D dose distributions computed by the MBDCAs-based TPS for virtual phantoms representing 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) was created to facilitate implementation of the recommendations for MBDCA commissioning made in the TG-186 report. Therefore, one of its main charges is to develop test cases for realistic clinical scenarios to facilitate commissioning of MBDCAs incorporated in clinical treatment planning systems, and to allow users to independently assess potential differences expected in moving from the current TG-43-based standard of clinical practice in treatment planning dosimetry to the use of a MBDCA.

This User Guide corresponds to two Test Cases for electronic brachytherapy (eBT) using the INTRABEAM system (Carl Zeiss Meditec AG, Jena, Germany). INTRABEAM is an advanced electronic brachytherapy system that enables precise and localized radiation therapy by means of a miniature set of X-ray sources. A dedicated treatment planning system called Radiance© is used [2]. Hence, in the following this manual provides guidelines for levels 1 and 2 testing of the GMV Radiance© Algorithm with two test cases mimicking partially TG-43 (Test Case I) and a clinical surface eBT brachytherapy scenario (Test Case II). They are based on a voxelized computational model of a cube (20 cm side) centered in a $(50\ cm)^3$ cube of air (NIST, dry near sea level. $1.2 \times 10^{-3}\ g/cm^3$) using the INTRABEAM Surface 30 mm applicator. Then, one will have:

- Test Case I: Water phantom: $(20\ cm)^3$ of homogeneous water, density $0.998\ g/cm^3$.
- Test Case II: Surface eBT: $(20\ cm)^3$ of a skin model with the following layers. In head first supine position, in AP-PA direction:
    - 3 mm skin (ICRU 46 Adult $1.09\ g/cm^3$), with the upper face in z = 0.
    - 2 mm adipose (ICRU 46 adult #2. $0.95\ g/cm^3$).
    - 5 mm of cortical bone (ICRU 46 adult. $1.92\ g/cm^3$).
    - 190 mm Average soft tissue (ICRU 44 adult male. $1.03\ g/cm^3$).

The compositions will be given in Table I

Mat	Depth (mm)	H	C	N	O	Na	Mg	P	S	Cl	Ar	k	Ca
Skin	3	10.0	20.4	4.2	64.5	0.2	--	0.1	0.2	0.3	--	0.1	--
Adip.	2	11.4	59.8	0.7	27.8	0.1	--	--	0.1	0.1	--	--	--
Bone	5	3.4	15.5	4.2	43.5	0.1	0.2	10.3	0.3	--	--	--	22.5
Av. Soft	190	10.5	25.6	2.7	60.2	0.1	--	0.2	0.3	0.2	--	0.2	--
Air	--	--	0.01	75.53	23.18	--	--	--	--	--	1.28	--	--

Table I. Phantom materials composition.

A diagrammatical can be found in Figure 2.

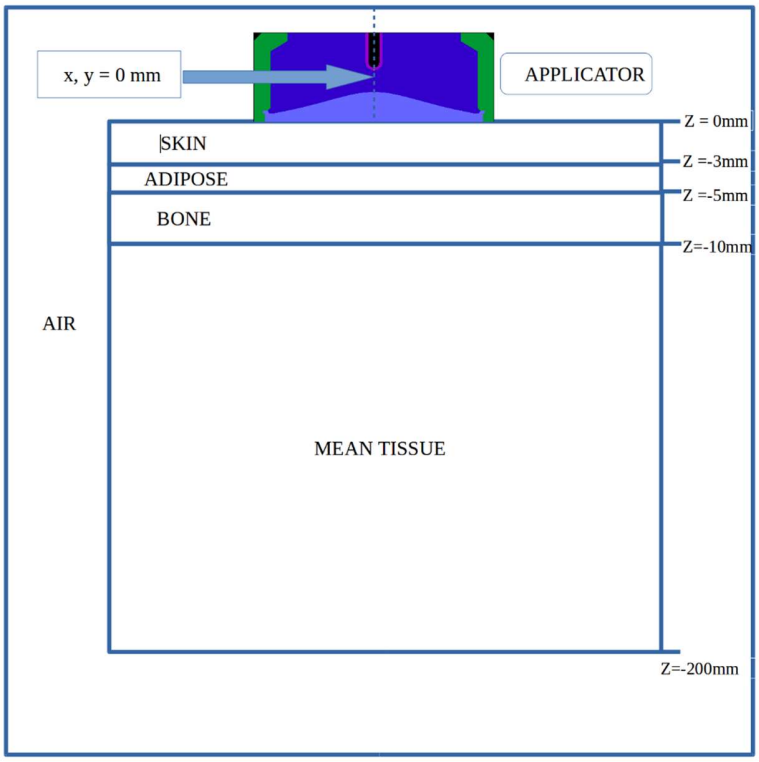


Figure 2: heterogeneous phantom simulation.

These guidelines follow the recommendations given in "AAPM WGDCAB Report 372: a joint AAPM, ESTRO, ABG and ABS report on commissioning of model-based dose calculation algorithms in brachytherapy" [3]. In overview, the testing process involves downloading the pre-designed LINAC, the test cases, and the corresponding DICOM files and importing them into Radiance© (Sec. II), locally calculating a dose distribution using the Radiance© 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. Intrabeam Test Case import

A. Accessing the Test Case Repository

The test cases are available from the IROC Houston file server located at https://doi.org/10.52519/00005 under the tab "Click for cases" →" Test Cases: LDR COMS eye plaque".

B. Downloading the Intrabeam Cases

Navigating the "Click for cases" tab allows access to download links for the eBT test case files. Selecting a link will initiate the download of the corresponding zip file(s) to your local computer.

This includes:

- "MBDCA-23-5-2003" containing a proprietary file to be imported containing CT images of both the computational TG-43 partially compliant geometry (Test Case I) and the skin model (Test Case II), the plans corresponding to both test cases, the LINAC modelization and the CT calibration table.
- "Reference TPS" containing the data corresponding to reference results obtained using Radiance© for both Test Cases.
- "Reference MC" containing the same files as above but with data corresponding to reference results of Monte Carlo simulations using Penelope2018.

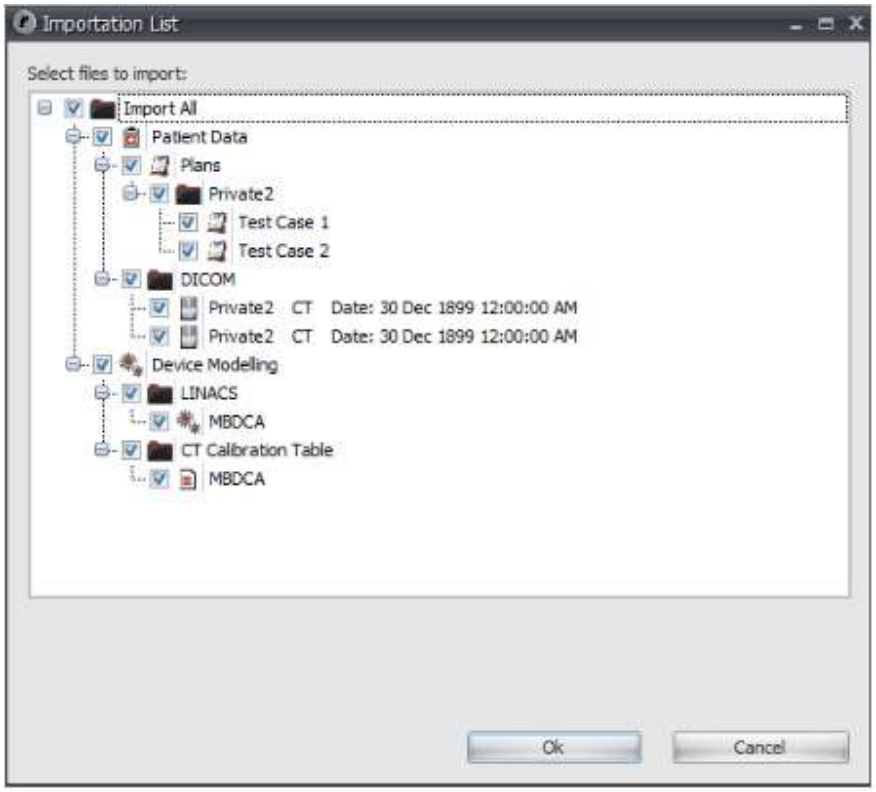
A link to download "MC input files" containing the input files used for preparing and benchmarking the reference data is also provided for interested users. Since the data required for modeling the applicator is proprietary, a phase space file containing the photons and electrons arriving to the phantom is given. A link to download all the above files in a single zip file is also provided for convenience.

C. Importing the Test Cases into Radiance

The following steps are associated with Radiance© V4.0.8 and might slightly differ for different versions of the TPS. The first step includes importing all data contained in the file "MBDCA-23-5-2003". To do so:

- Click the Import button 

and browse to the folder containing the "MBDCA-23-5-2003" file. Confirm that the imported data include: Plans (2), DICOM files (2), the MBDCA LINAC (1) and CT Calibration Table (1).



- Click the 'Ok' button. The system will read and validate the data ready for import.

III. Dose Calculation

The following steps are associated with Radiance© V4.0.8 and might slightly differ for different versions of the TPS.

A. Opening the local plans

The two prepared plans will appear on the right hand side of the treatment planning system, while the corresponding DICOM file should be visible on the left hand side:

PLANS

Drag a column header here to group by that column

Patient ID	Patient Name	Plan Name	Plan Description	Site	Last Modification Date	Status	Approval User	Applicator Type
Private2	Private2	Test Case 1			03 May 2023 11:18:32 AM	SIMULATED		Surface
Private2	Private2	Test Case 2			23 May 2023 11:46:49 AM	SIMULATED		Surface

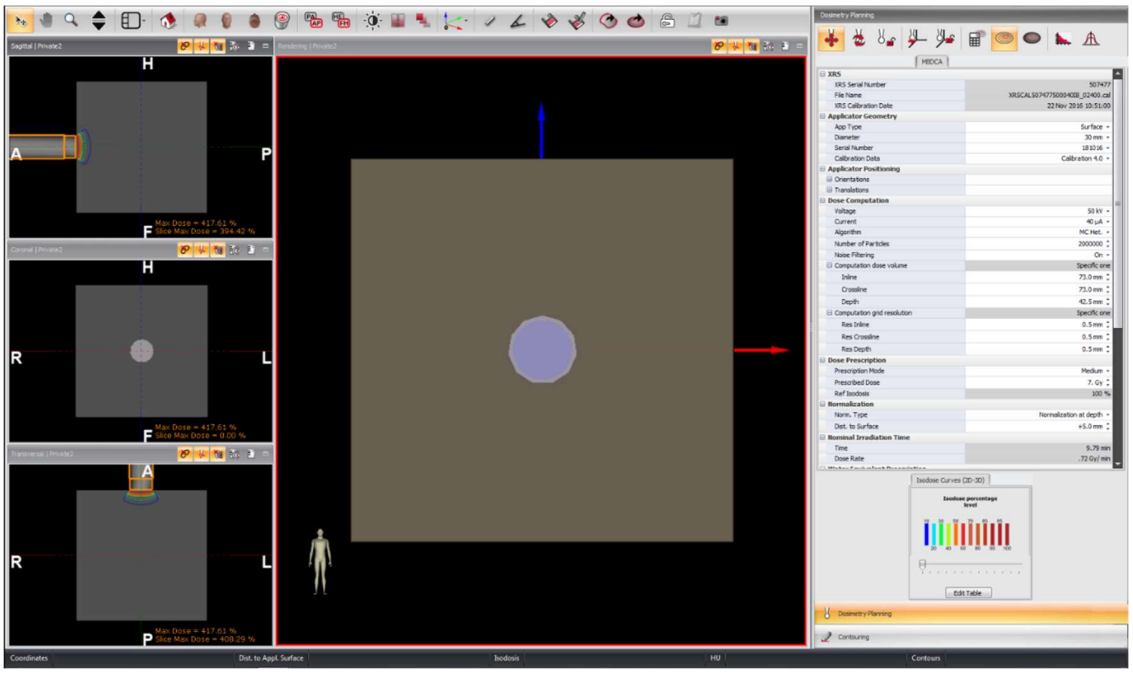
DICOM IMAGES AND STRUCTURES

Drag a column header here to group by that column

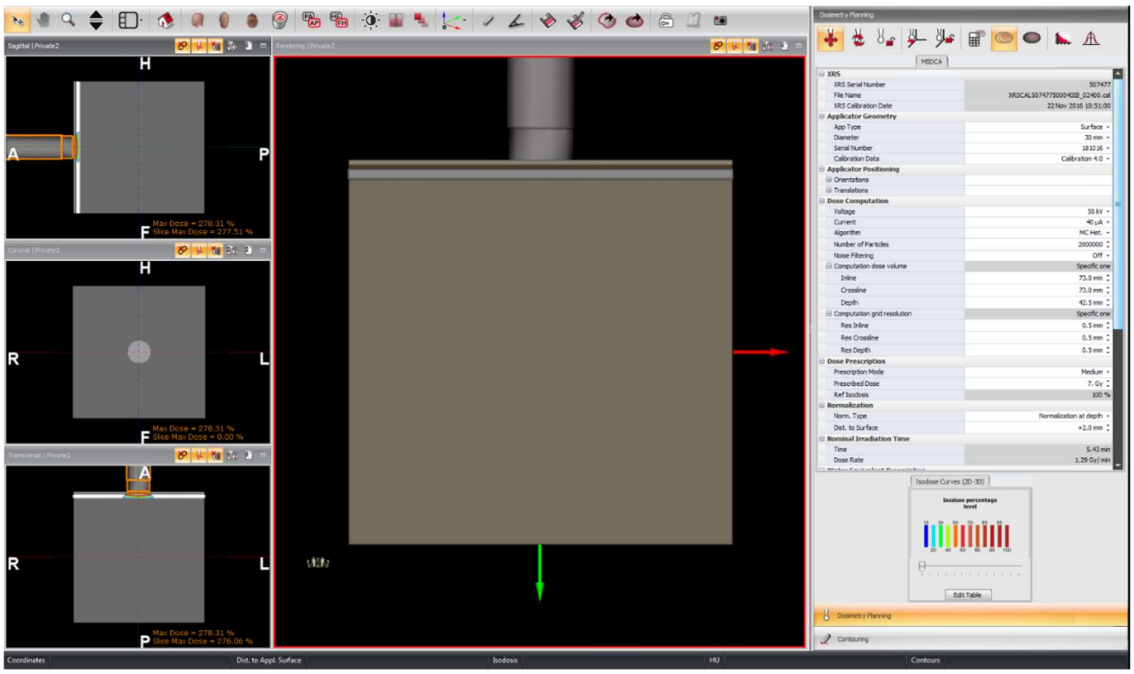
Patient ID	Patient Name	Modality	Acquisition Date	Referring Physician	Description	CT - HU Table
Private2	Private2	CT	30 Dec 1899 12:00:00 AM		skin_phantom	MBDCA
Private2	Private2	CT	30 Dec 1899 12:00:00 AM		water_phantom	MBDCA

- Double clik on the desired Test Case and the following windows will open.

- For *Test Case I: TG-43 compliant geometry*:



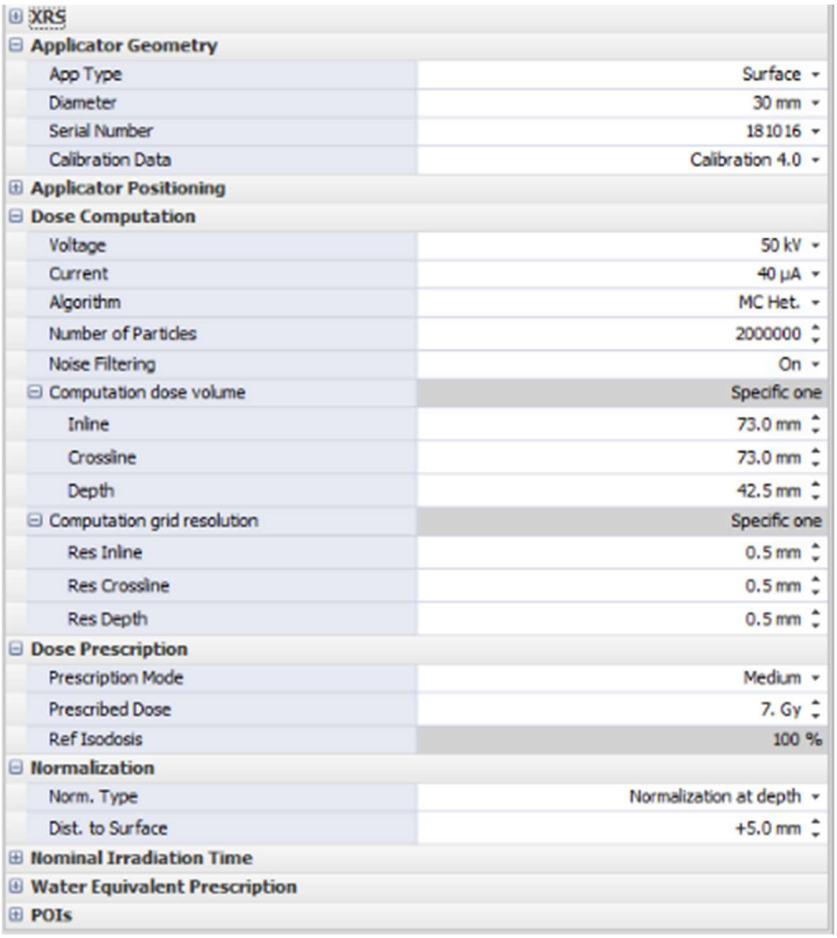
- For *Test Case II: Surface eBT*:



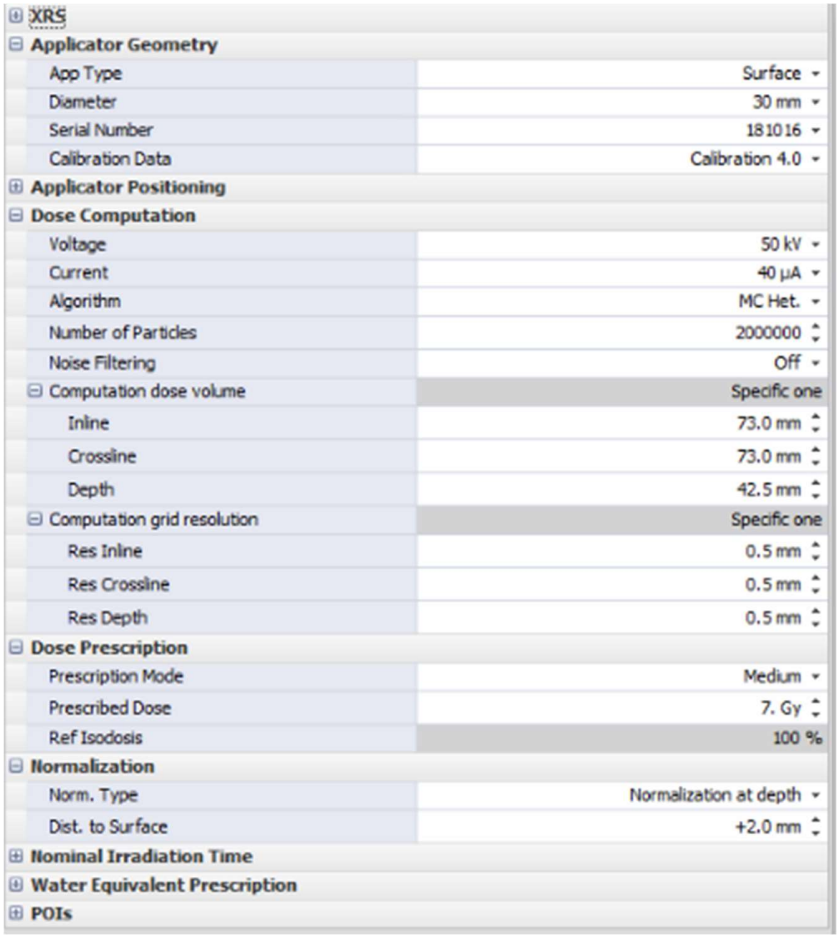
B. Confirming the Plan Properties

Confirm that all parameters correspond to the ones shown in the figures below. Note that two of them differ from one Test Case to the other, “Noise Filtering” should be “On” in Test Case I and “Off” in Test Case II, and “Dist. to Surface” is set to “+5.0 mm” for Test Case I and to “+2.0 mm” for Test Case II.

- For *Test Case I: TG-43 compliant geometry*:



- For *Test Case II: Surface eBT*:



C. Performing the Calculation

The loaded plan will have a dose evaluation already calculated *(this dose will be overwritten by the local calculation)*. To perform the Radiance© dose calculation, click the 'Dose Calculation' button  . The 'Dosimetry Calculation' window will be opened until the calculation is finished. The following values should be obtained for each Test Case.

- For *Test Case I: TG-43 compliant geometry*:

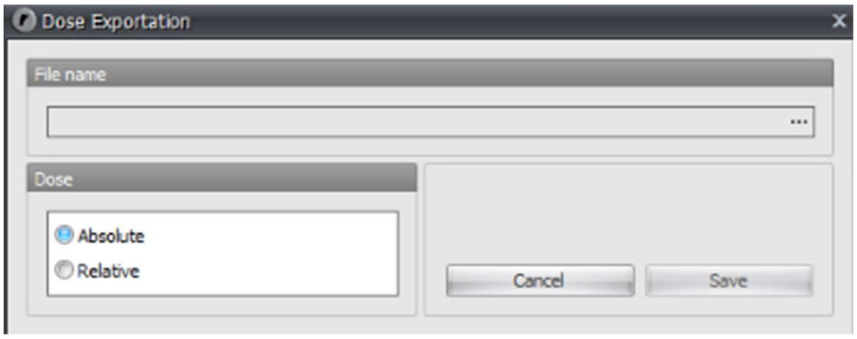
Nominal Irradiation Time	
Time	9.8 min
Dose Rate	.71 Gy/min
Water Equivalent Prescription	
Equivalent Dose	7.31 Gy
Equivalent Depth	5.0 mm
Equivalent Dose Rate	.75 Gy/min

- For *Test Case II: Surface eBT*:

Nominal Irradiation Time	
Time	5.43 min
Dose Rate	1.29 Gy/min
Water Equivalent Prescription	
Equivalent Dose	8.23 Gy
Equivalent Depth	2.0 mm
Equivalent Dose Rate	1.52 Gy/min

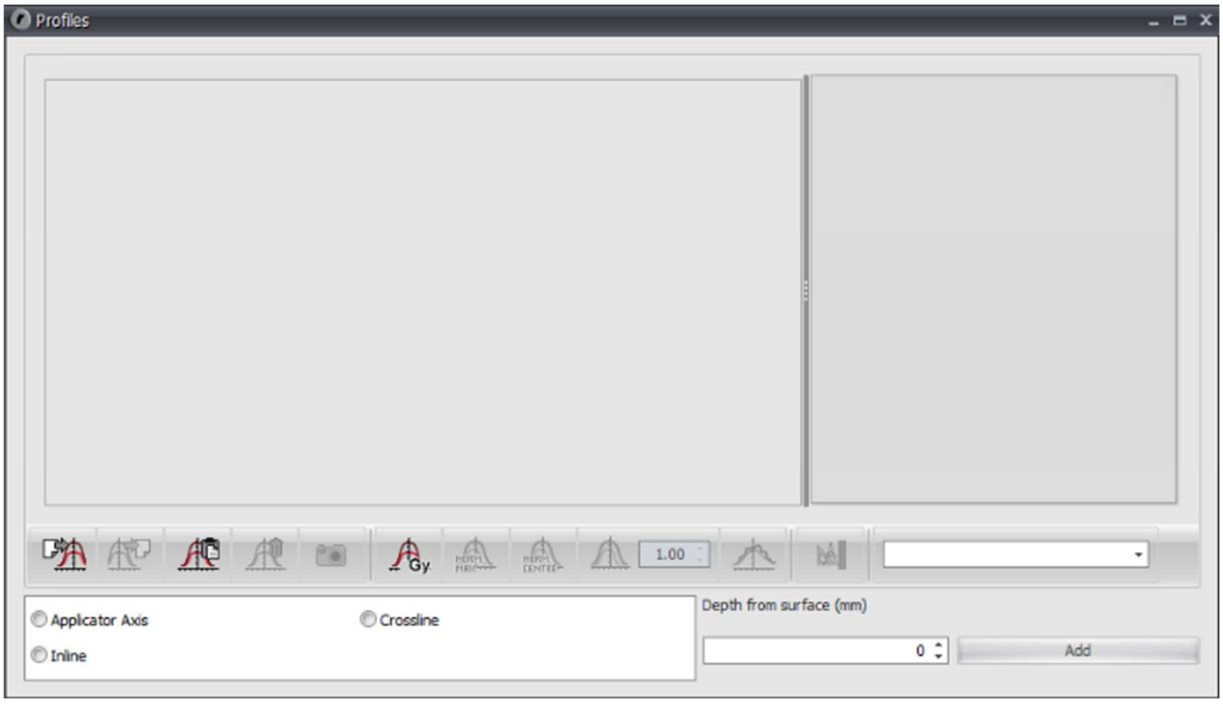
D. Creating a 3D Dose Distribution

A full dose distribution in DICOM RT format can be obtained by clicking the "Export Dose in DICOM format" button  .

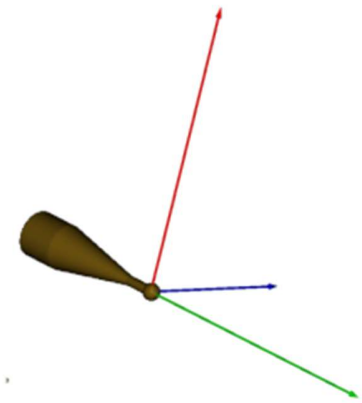


The user should navigate in "File name" button to locate the destination of the files and to input their names. Two possibilities are offered: Absolute, dose in Gy, or Relative, dose normalized at the "Dist to surface" value.

Profiles and PDDs can be obtained from the Profile Viewing button  .



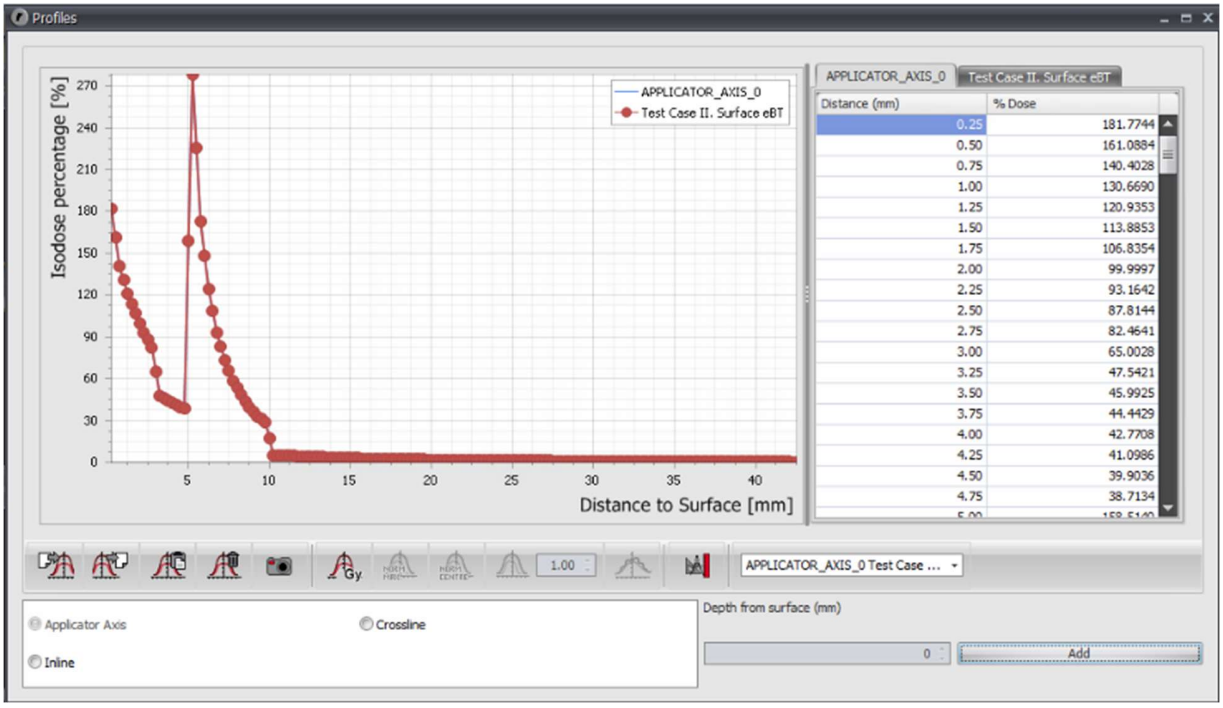
Dose along the applicator axis (PDD) can be obtained by selecting "Applicator Axis" → "Add". Values can be exported to an ascii file by using the "Export button"  . Crossile and Inline profiles (see figure below) can be obtained by selecting the corresponding option. Once selected the "Depth from the surface" value in mm has to be expecified" → "Add". Different profiles can be shown. Their values can be exported by using the "Export button".



- **Depth**: this is the longitudinal direction of the applicator – in green-.
- **Inline**: One of the axes in the plane perpendicular to depth axis – in blue-.
- **Crossline**: perpendicular to both above defining a Cartesian system – in red-.

IV. Dose Distribution Comparison

Radiance© only incorporates the possibility of visually inspect PDD and profile curves. ASCII files including the PDDs for both test cases (TestCaseI-PDD.dat and TestCaseII-PDD.dat) are included in the "Reference TPS" files. To do so the user should access the Profile Viewing button  and after creating the corresponding PDD following the instruction given in Section III.D import the PDD provied using the "Import" button  .



More elaborate comparisons follow the recommendations in "AAPM WGDCAB Report 372: a joint AAPM, ESTRO, ABG and ABS report on commissioning of model-based dose calculation algorithms in brachytherapy" [3]. Until the vendors implement all the necessary tools, this report recommends that the end-users adopt freely available third-party software such as SlicerRT [4] or brachytherapy specific tools such as BrachyGuide [5] and AMIGO [6] to enable more in-depth comparison of dose distributions generated by the TPS MBDCA (or TG-43) to reference MC datasets.

[1] Beaulieu L, Tedgren ÅC, Carrier J, 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. 39, 6208–6236 (2012).

[2] M. F. Valdivieso-Casique et al., "RADIANCE—A planning software for intra-operative radiation therapy," Transl. Cancer Res., vol. 4, no. 2, pp. 196–209, 2015, doi: 10.21037/4288.

[3] Beaulieu L, Ballester F, Granero D, et al. AAPM WGDCAB Report 372: a joint AAPM, ESTRO, ABG and ABS report on commissioning of model-based dose calculation algorithms in brachytherapy. Med Phys., 1-15 2023 DOI: 10.1002/mp.16571

[4] Pinter C, Lasso A, Wang A, Jaffray D, Fichtinger G. SlicerRT: Radiation therapy research toolkit for 3D Slicer. Med. Phys. **39**, 6332–6338 (2012).

[5] Pantelis E, Peppa V, Lahanas V, Pappas E, Papagiannis P. BrachyGuide: a brachytherapy-dedicated DICOM RT viewer and interface to Monte Carlo simulation software. J. Appl. Clin. Med. Phys. **16**, 208–218 (2015).

[6] Fonseca GP, Reniers B, Landry G, et al. A medical image-based graphical platform-Features, applications and relevance for brachytherapy. Brachytherapy **13,** 632–639 (2014).