Code of practice: OCTAVIUS 4D
How to start (Pinnacle)

Procedure for the implementation and routine use of IMRT patient plan verification

Foreword: This note describes implementation with Philips Pinnacle. The workflow for data export might be a little bit different for other TPS. However, the basic procedure is the same. It should be easy to adapt it to your TPS.

Implementation

The implementation of the OCTAVIUS 4D system requires the following actions:

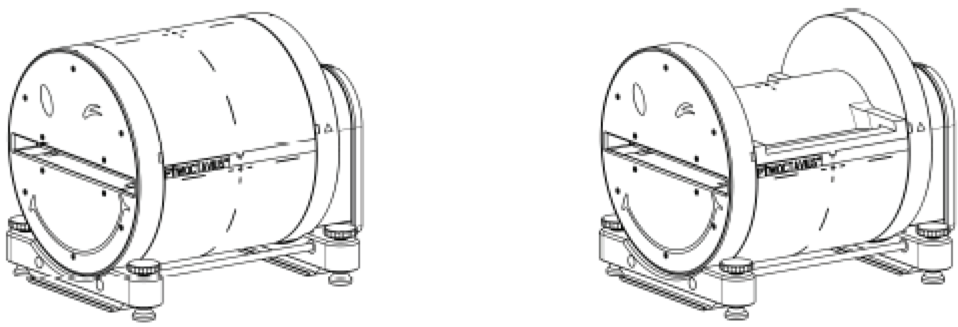
1. VeriSoft basic beam data acquisition
2. Importing the OCTAVIUS 4D phantom into the TPS
3. Preparing the cross calibration procedure and basic validation.

1 VeriSoft basic beam data acquisition

The OCTAVIUS 4D system acquires and stores the 2D array measurements as a function of time and gantry angle in intervals. For each measurement interval the 3D dose is reconstructed through the use of a simple set of depth dose (PDD) curves. The total dose in the OCTAVIUS 4D cylindrical phantom is then reconstructed as the sum of the different angular contributions.

Although it is possible to use the depth dose curves included in the VeriSoft software package (Default-PDD data sets), users are advised to acquire their own PDD dataset either by measurements in a water phantom (see chapter 1.1) or by re-calculation of already existing PDD curves (see chapter 1.2).

Generally, the depth dose curve acquisition depends on the type of the OCTAVIUS 4D rotation unit (RU). A number of tops for different measuring tasks can be mounted on the base phantom. Treatment plan verification can either be performed applying the RU top standard (diameter of RU cylinder: 32 cm) or the RU top SRS (diameter of RU cylinder: 17 cm) as shown in the figure below. With a source-isocenter-distance (SID) of 100 cm the average source-surface-distance (SSD) for the RU equipped with a RU top standard is 85 cm and with a RU top SRS 92 cm (round phantom surface is taken into account). For this reason PDD data sets based on different SSDs are necessary for dose reconstruction in VeriSoft.



Modular OCTAVIUS 4D RU equipped with *RU top standard* (left) and *RU top SRS* (right)

1.1 Measurement of PDD data

PDD data can be acquired in a water phantom by means of the commonly used ion chamber (e.g. PTW Semiflex chamber 0.125 cm³ T31010 for field size down to 4 x 4 cm²; PTW Dosimetry Diode E T60017 for smaller field sizes [*1]) for depth dose curve acquisition. Table 1 presents the required fieldsizes and SSD adjustments for PDD measurements.

Table 1: PDD data acquisition for 3D dose reconstruction in VeriSoft

	OCTAVIUS 4D combined with RU top standard	**OCTAVIUS 4D combined with RU top SRS**
Necessary fieldsizes defined SID 100 cm [cm x cm]	**4x4**, **5x5**, 8x8, **10x10**, 12x12, **15x15**, 20x20, **26x26**	3x3, **4x4, 5x5, 8x8, 10x10, 14x14, 18x18**
Source-surface-distance SSD [cm]	85	92

Additional information to table 1:

- *Only the field sizes in bold are mandatory, but once the water phantom is properly set up, it does not take much additional time to also acquire data for the other field sizes, so you may as well do so.)*
- *The field sizes 14x14 cm² and 18x18 cm² are included in the list of field sizes for OCTAVIUS 4D combined with RU top SRS for two reasons:*
    - *The SRS rotation unit cannot only be used with* OCTAVIUS Detector 1000 *SRS* *but also with OD 729/ OD 1500. Therefore, equivalent field sizes up to 18x18 cm² could be necessary to reconstruct the dose in the phantom.*
    - *For composed measurements with* OCTAVIUS Detector 1000 *SRS* *and RU SRS (i.e. verification of long irradiation fields) larger fieldsizes than the actual detector field of 11x11 cm² can occur.*

Once the measurements for a certain setup have been acquired, process them as follows:

- Open the VeriSoft software and select the menu "*Tools → Options… → 4D Dosimetry"*
- Load all .mcc files of the measured depth dose curves by clicking on *"Select Folder …"* or *"Add File(s) …"* and click on "*Merge and complete PDD file"* (VeriSoft automatically interpolates the missing field sizes in increments of 1 cm, extrapolates values for the field size 0x0 cm², normalizes the PDDs to their individual maximum and merges the data to a single PDD file.)
- Save the completed PDD file in your PDD directory. The default directory is '<PTWdocuments>\VeriSoft\Data\PDDData'. You can change the path in the menu "*Tools → Options… → 4D Dosimetry"*
- Create a PDD file for each radiation unit and energy. Name the PDD files so that the assignment is unambiguous (e.g. X06FFF_PDD_Linac1.mcc). These files are to be used in the OCTAVIUS 4D dose reconstruction procedure.

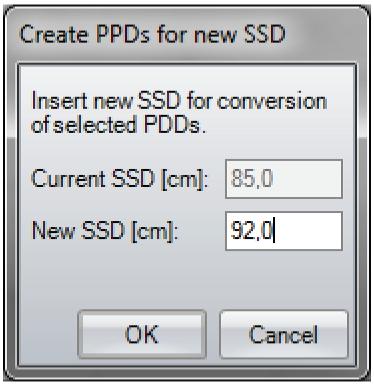
[*] *Diode detector T60018 or diamond detector T60019 are also suitable. For more information about small field dosimetry see PTW document D920.200.00/06*

1.2 SSD Conversion of existing PDD data

From VeriSoft version 7.1 PDD data can also be generated using already existing PDD curves. That could be for example PDD data measured in the water phantom with SSD 100 cm during basement data acquisition or PDD data acquired at the introduction of OCTAVIUS 4D with RU top standard. As long as the PDDs have been measured at least with the required field sizes listed in table 1, the VeriSoft conversion method can be applied to convert PDDs of a certain SSD to PDDs of a new SSD. (More information about the conversion method can be found in the VeriSoft user manual)

- Open the VeriSoft software and select the menu "*Tools → Options… → 4D Dosimetry*"
- Load all .mcc files of the measured depth dose curves by clicking on *"Select Folder …"* or *"Add File(s) …"* and click on "*Merge and complete PDD file*" (VeriSoft automatically interpolates the missing field sizes in increments of 1 cm, extrapolates values for the field size 0x0 cm², normalizes the PDDs to their individual maximum and merges the data to a single PDD file.)
- Save the completed PDD file in an arbitrary directory.

- Load the merged PDD file by clicking on "Add file(s)…". Then click on "Create PDDs for new SSD". (VeriSoft automatically reads out the SSD from the completed PDD file)
- Type in the desired SDD in the appearing dialogue (e.g. 92 cm for RU with top SRS) and click on *"OK"* to start the conversion process:



- Save the converted PDD file in your PDD directory. The default directory is '<PTWdocuments>\VeriSoft\Data\PDDData'. You can change the path in the menu "*Tools → Options… → 4D Dosimetry*"
- Create a PDD file for each radiation unit and energy. Name the PDD files so that the assignment is unambiguous (e.g. X06FFF_PDD_Linac1_SDD92cm.mcc). These files are to be used in the OCTAVIUS 4D dose reconstruction procedure.

2 Define the OCTAVIUS 4D QA phantom

The user has to define an OCTAVIUS 4D QA phantom for each patient orientation expected to treat. If the QA phantom orientation does not match the patient orientation in the plan, the plan itself will be incorrectly oriented with respect to the phantom and it will not be possible to verify the dose distribution.
You can use an own CT scan or a CT scan provided by PTW. If you use your own CT scan make sure you overwrite the entire phantom (including the cut outs on the backside of the phantom and the opening for the detector) with the density of the surrounding material. In the end you need a homogeneous phantom with a diameter of 32 cm and a length of 34 cm. The CT scans are available at http://www.ptw.de/index.php?id=2469.

1. In the **Patient Select** window, add a patient in which to store phantoms (Figure 1).

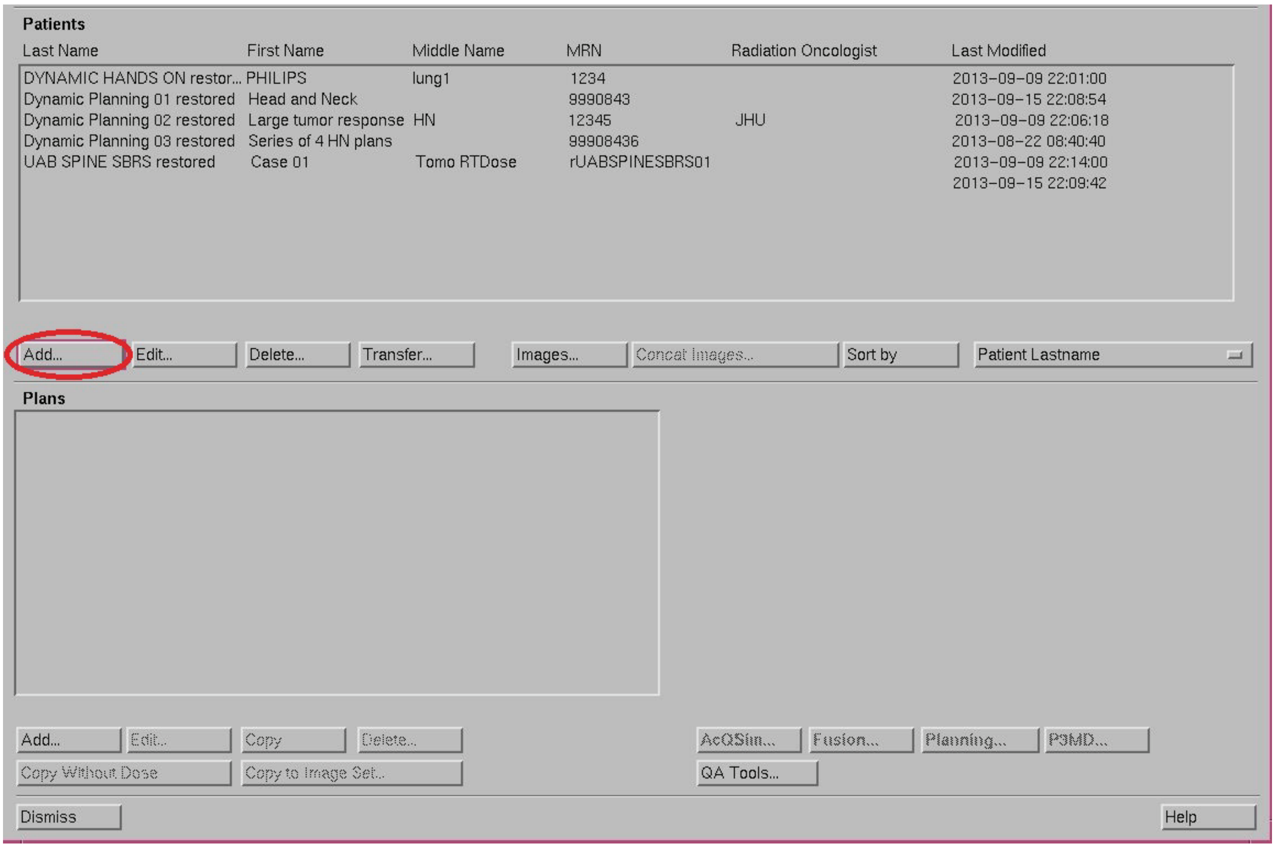


Fig. 2.1 Adding the phantom patient

2. Import the phantom images (Figure 2.2, 2.3, 2.4 and 2.5).

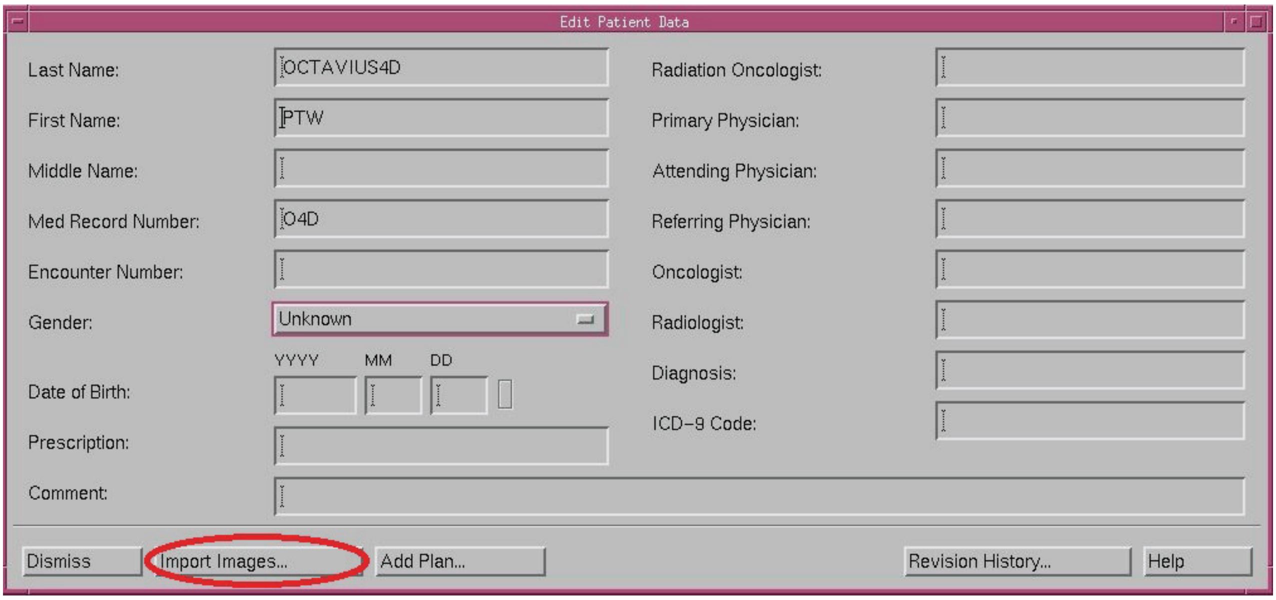


Fig. 2.2 Edit QA phantom data

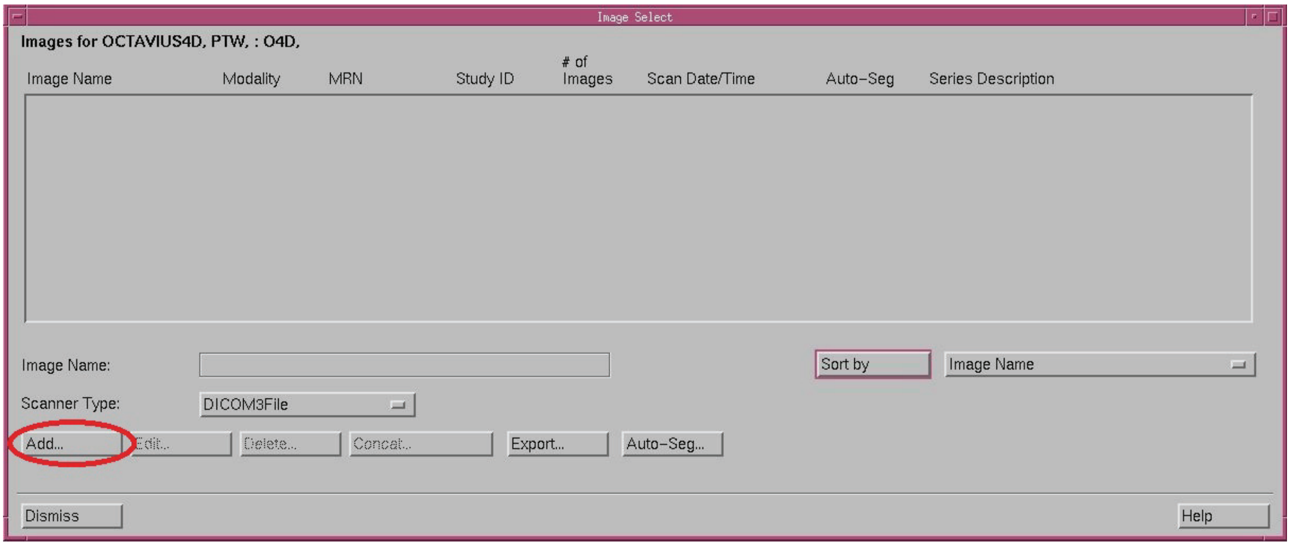


Fig. 2.3 QA phantom images selection

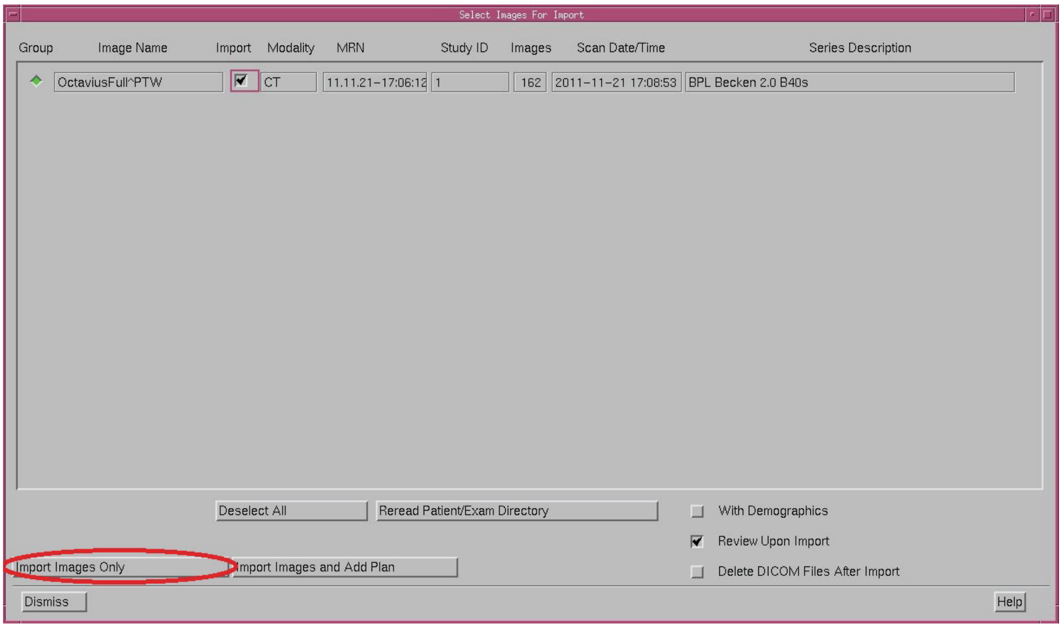


Fig.2.4: QA phantom images import

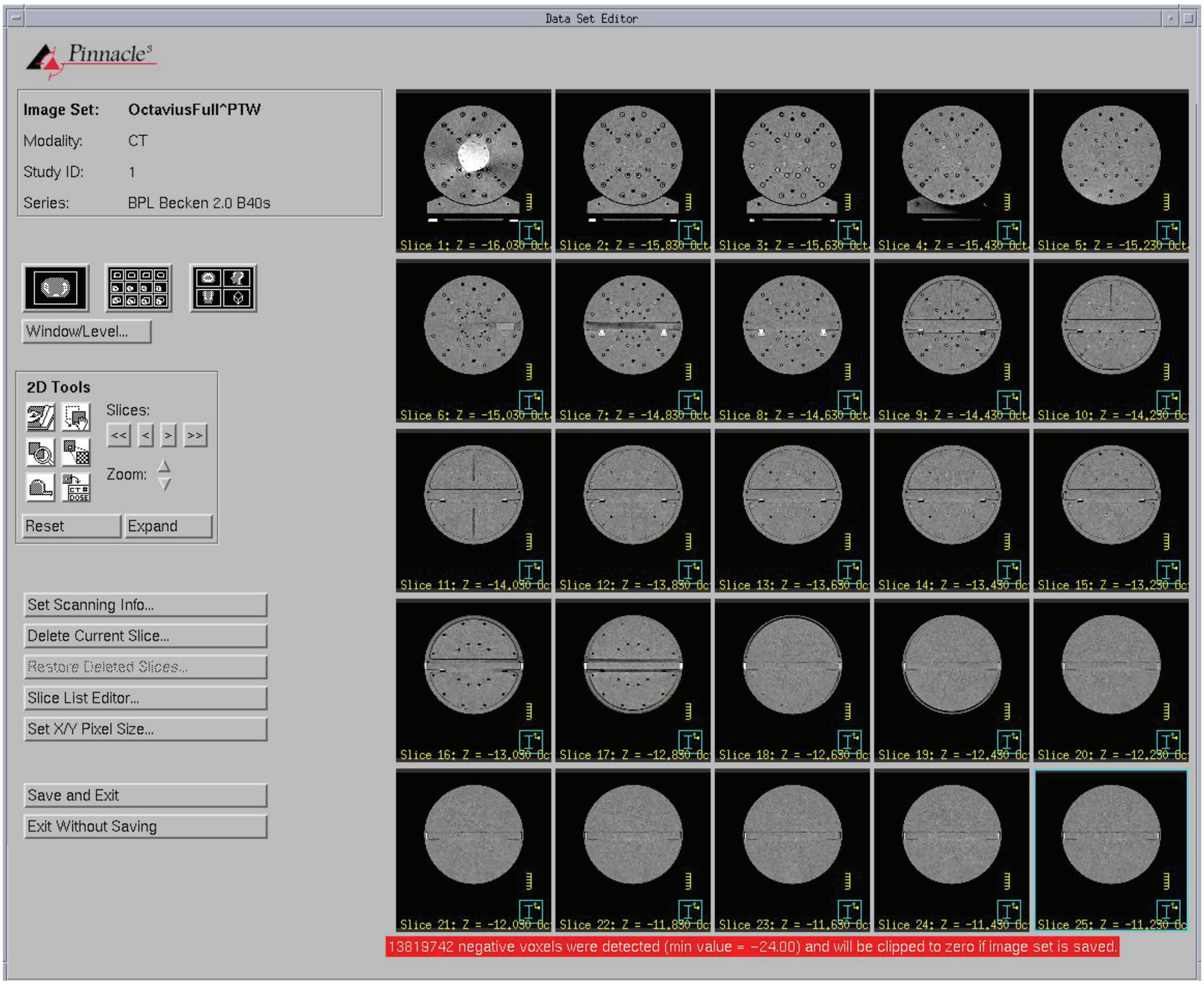


Fig.2.5 QA phantom data set editor

3. Add a plan which uses the images just imported (Figure 2.6).

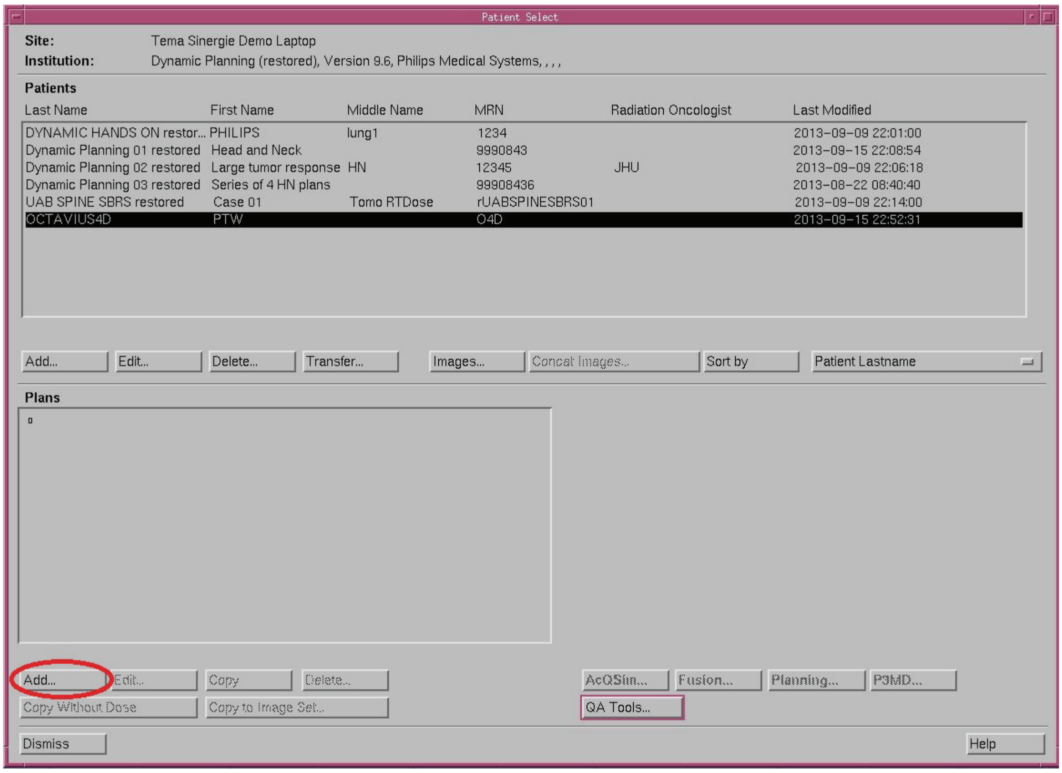


Fig. 2.6 Plan adding

4. Click the **Planning** button to enter the treatment planning software (Figure 2.7).

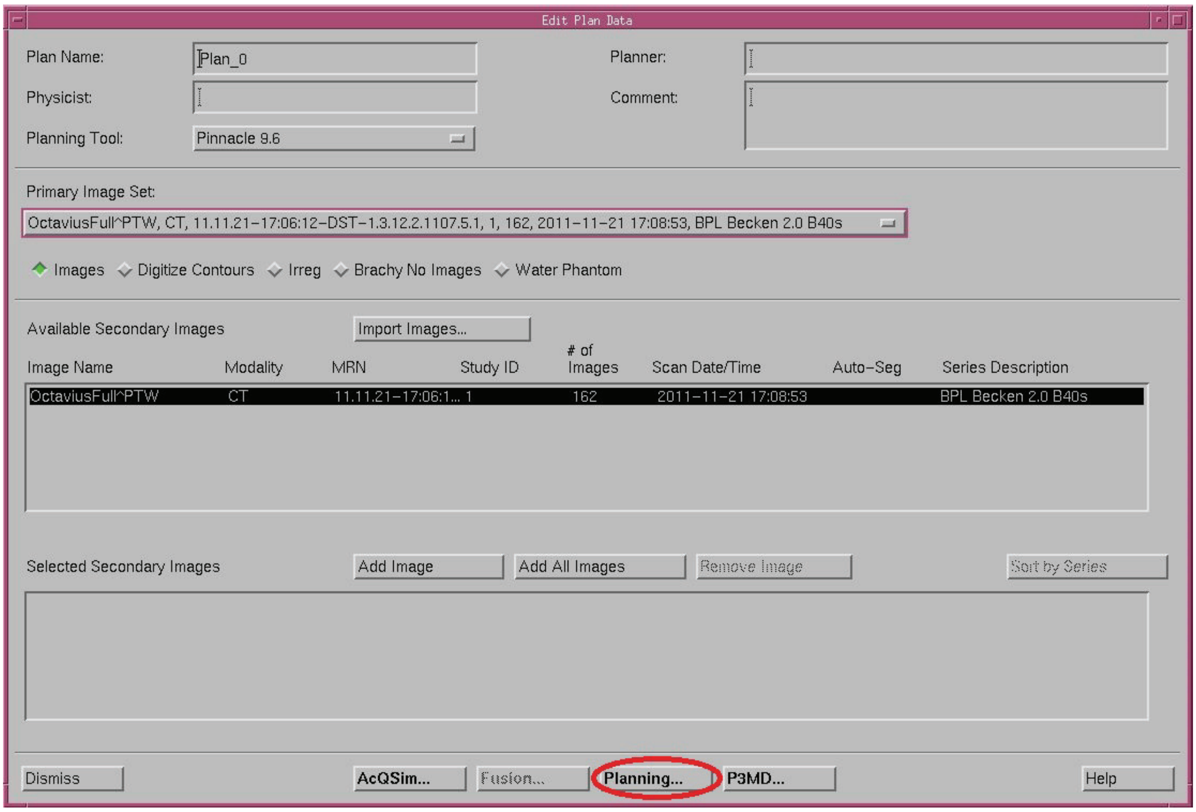


Fig. 2.7 Plan data editing

5. In the Confirm Plan Setup window, verify that the patient orientation is correct (Figure 2.8).

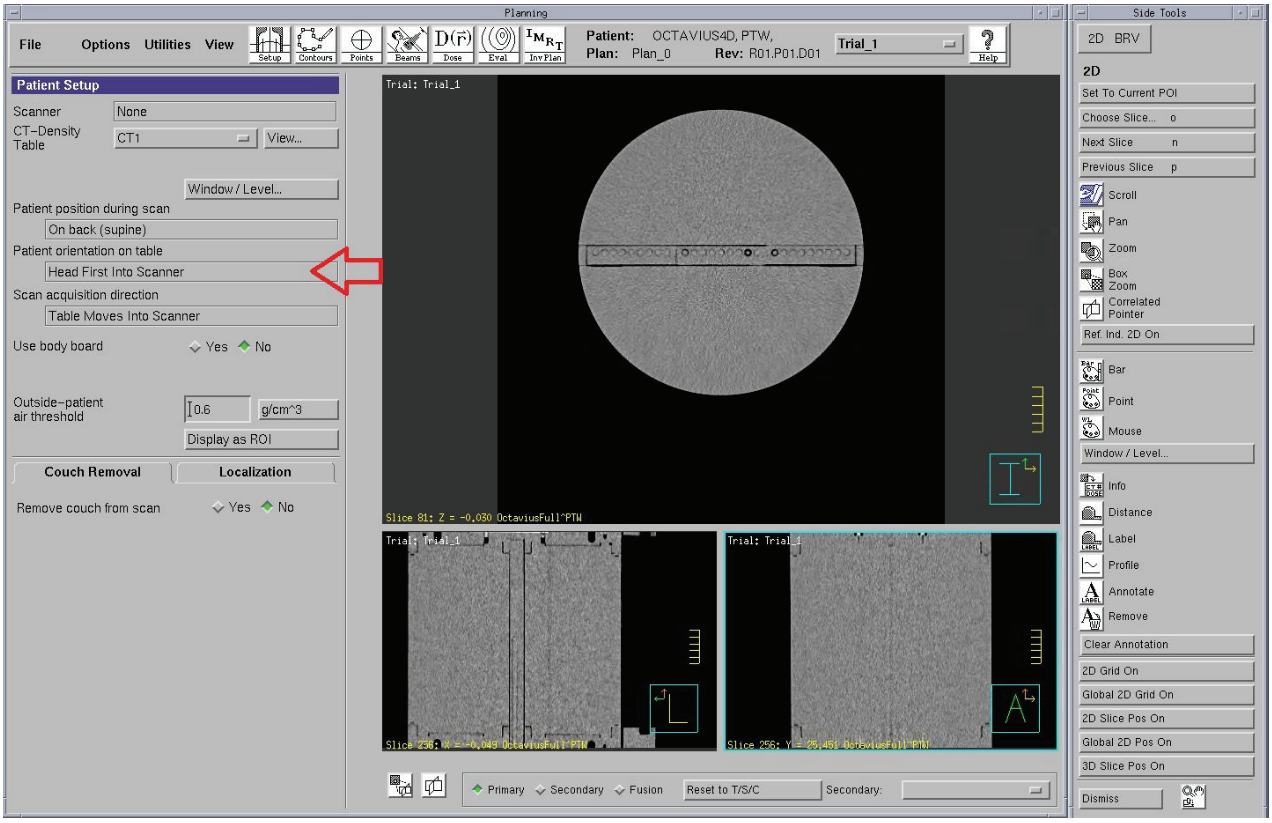


Fig. 2.8 QA phantom orientation verification

6. Add POIs (Point Of Interest) and ROIs (Region Of Interest) to the phantom, as necessary, choosing names different from names used in patient plans: in fact, during plan evaluation it will be easier to differentiate between phantom and patient POIs if they have different names.

   In particular, the isocenter point has to be placed exactly at the center of the OCTAVIUS 4D cylindric body ROI (Figure 2.9).

   NOTE: for an accurate dose evaluation, consider the adding of the ROI or the ROIs group representing the used couchtop.

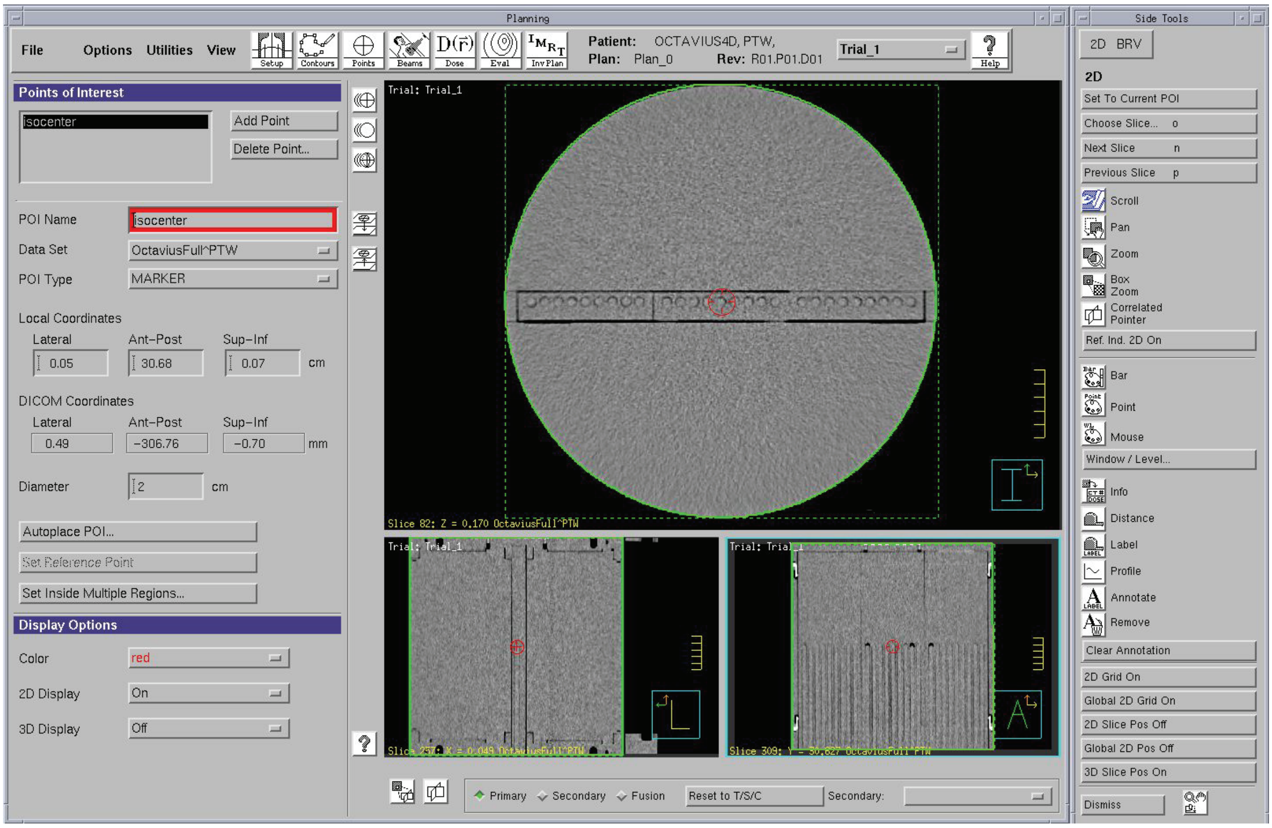


Fig. 2.9 QA phantom body ROI and isocenter creation

7. From the **Options** menu, select the **Density Override** option (Figure 2.10).

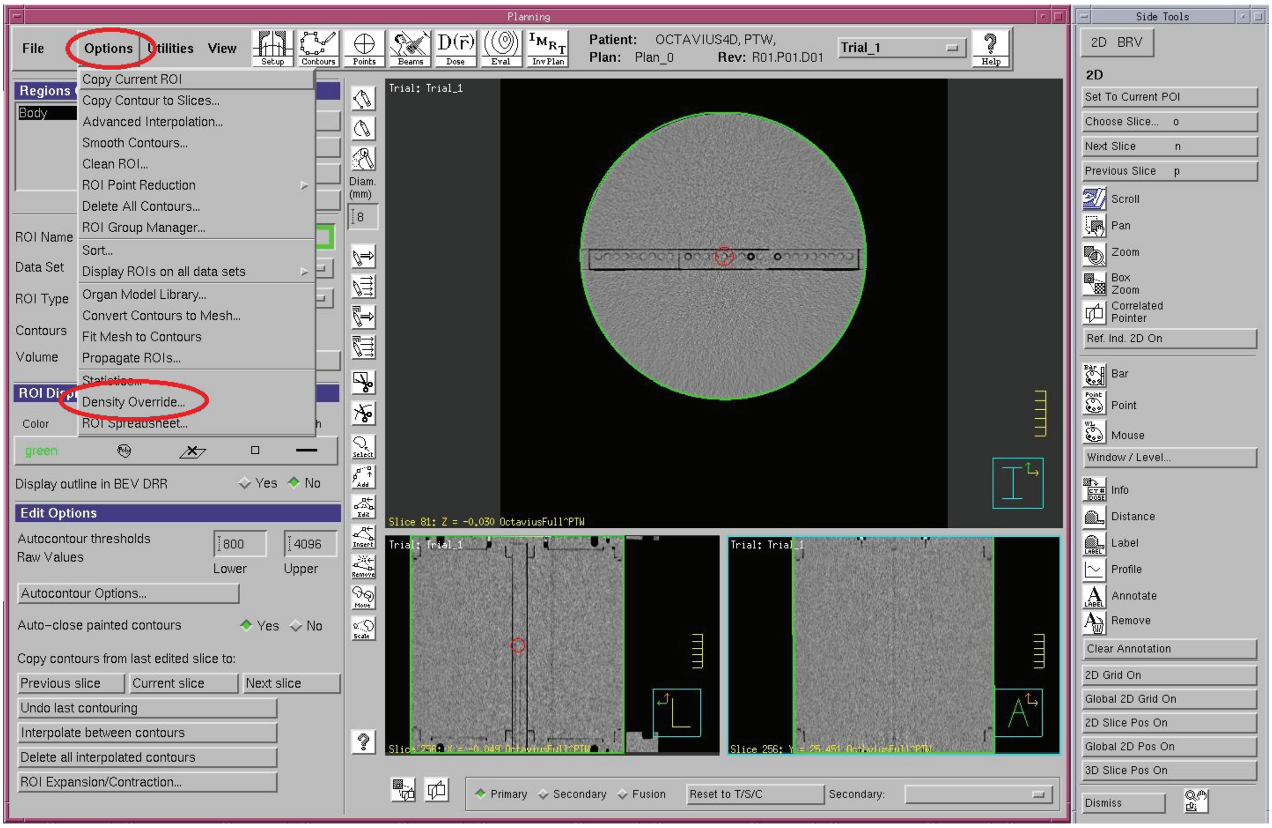


Fig. 2.10 Density override

8. The **Regions of Interest** window appears (Figure 2.11). Here, the phantom correct physical density (1.05 g/cm^3) has to be set.

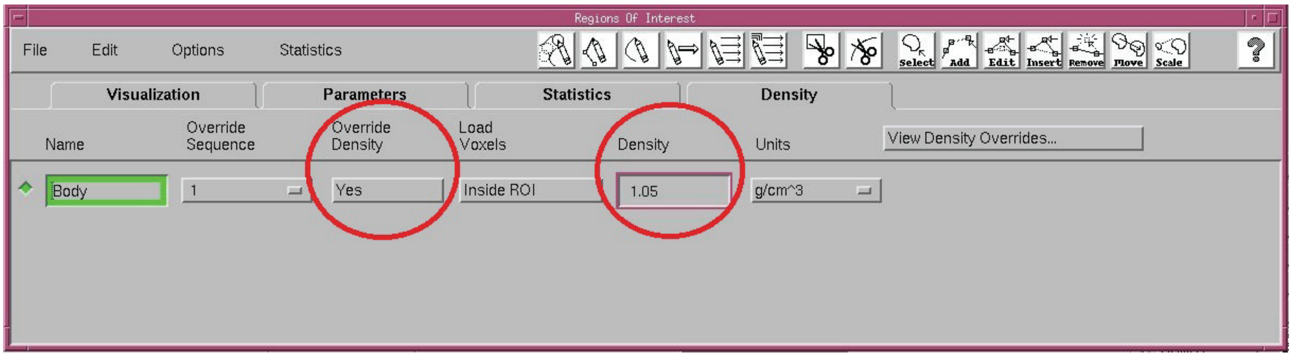


Fig. 2.11 Regions Of Interest window

Hint: For detailed information about setting the relative electron density, please see the technical note D913.200.03 "How to adjust the Relative Electron Density of OCTAVIUS 4D to match the TPS value"

9. End the planning session and save the data files.

10. In the **Patient Select** window, click the **QA Tools** button (Figure 2.12). The **QA Tools** window appears.

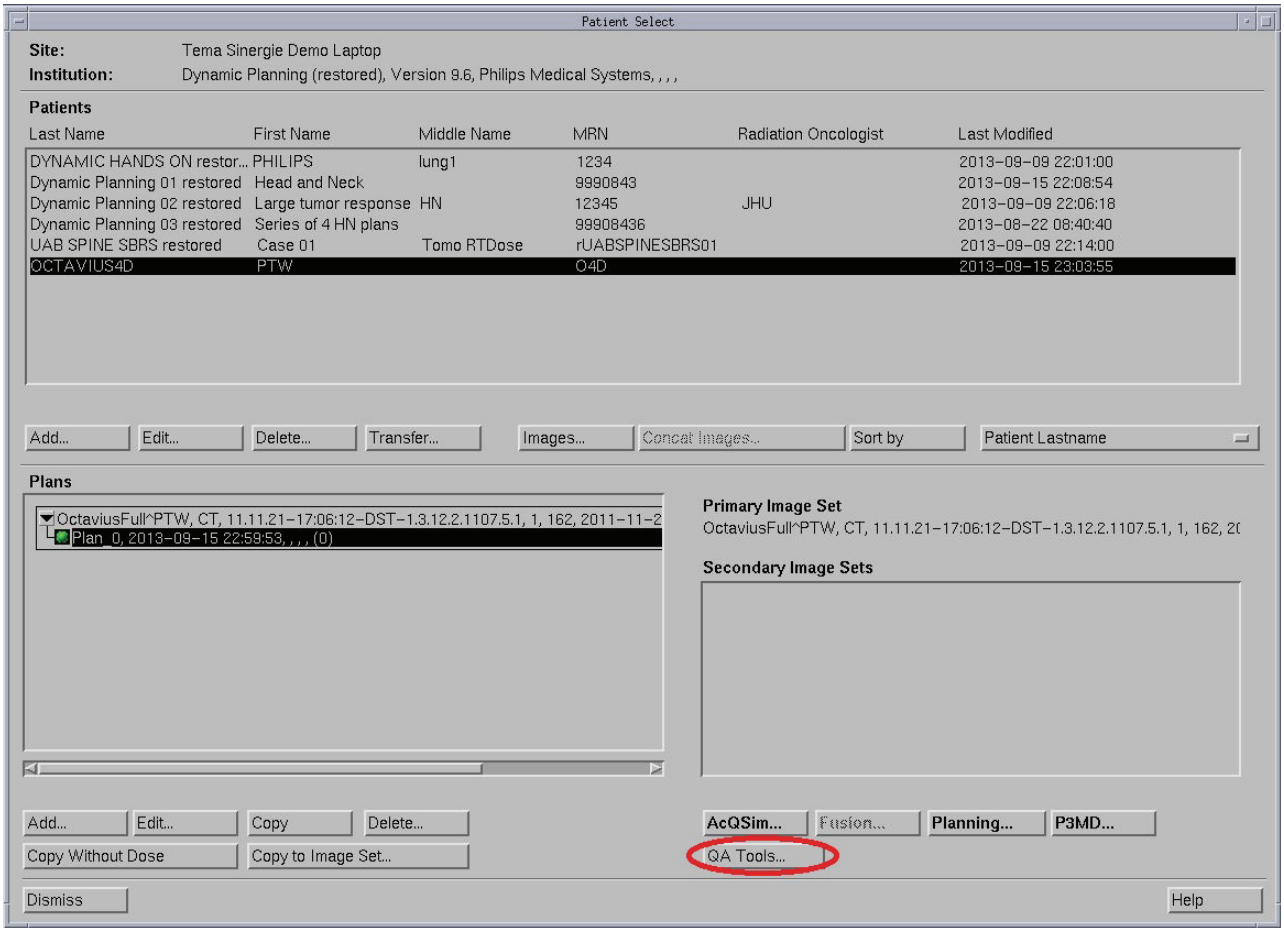


Fig. 2.12 Pinnacle^3 QA Tools

11. Click the **Save as Phantom** button (Figure 2.13).

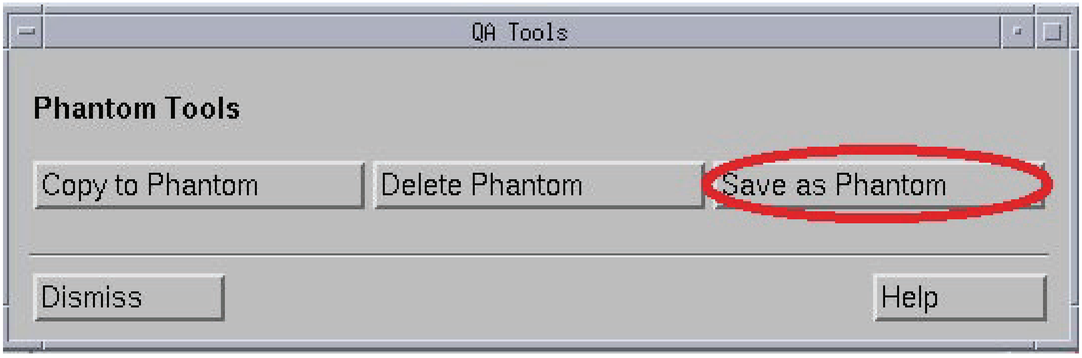


Fig. 2.13 Saving as Phantom the QA phantom

12. The **Save Phantom** window appear: enter a name for the phantom.
13. Click the **Save** button.

3 Preparing the cross calibration and basic validation

3.1 Cross calibration:

You can either perform a cross calibration by measuring the dose in the phantom using a chamber plate (available for Farmer chamber, Semiflex chamber T31010, Semiflex 3D T31021 and PinPoint 3D T31022) or calculate the expected dose by means of your TPS:
Insert a new plan to calculate the cross-calibration values for the OCTAVIUS Detector in the cylindrical phantom:

- Place a 10 x 10 cm² field (4 x 4 cm² for OCTAVIUS Detector 1000 ^{SRS}) onto the phantom, making sure the isocenter coincides with the image origin. This should correspond to an SSD value of 84 cm (+/- 1 mm).
- Calculate the dose for a fixed value of 200 MU
- Create a reference point at the isocenter to easily read out the isocentric dose
- Copy the dose to the isocenter on a nice and clean Post-it selected for this purpose only
- Repeat this for every photon energy you intend to use

3.2 Couch verification

To perform a basic validation of the couch attenuation, insert a static 10x10 cm² field at gantry 180°. Again, make sure the isocenter is at the image origin and SSD = 84 cm (+/- 1mm). Calculate the dose for a fixed value of 200 MU and copy down the dose reported to the isocenter.

3.3 Open arc verification:

To perform a basic validation of the dose calculation, import/export and measurement calibration procedure, prepare a calculation of a simple open arc in your TPS:

- Create an open 10x10 arc field. (Make sure the isocenter is at the dcm image origin (0,0,0))
- Now calculate the dose for the fixed value of 200MU
- Export the calculated dose matrix

4 Performing basic validation measurements

Experimental setup:

Set the gantry to 0°.

Carefully set up the phantom in the isocentric position.
To level the phantom with the adjustable legs, you can either use the circular spirit of the phantom, or you can place the OCTAVIUS Detector in the phantom and use a standard spirit level on the protruding part of the OCTAVIUS Detector surface.

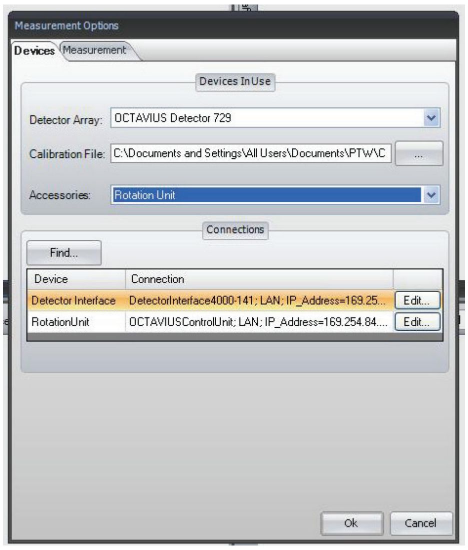
Mount the inclinometer to the gantry. Choose a flat part of the gantry and mount the inclinometer as close as possible to the rotation axis. Establish the Bluetooth connection between inclinometer and control unit. Make sure all cables are properly connected and initialize the phantom.

It is advisable to perform a test run (full gantry rotation) while inside the bunker to make sure that no cables get caught and no collisions occur during the gantry rotation.

VeriSoft setup:

Start VeriSoft. From the 'Tools' menu, make sure the correct devices are selected from the 'Measurement options' menu:

For example:



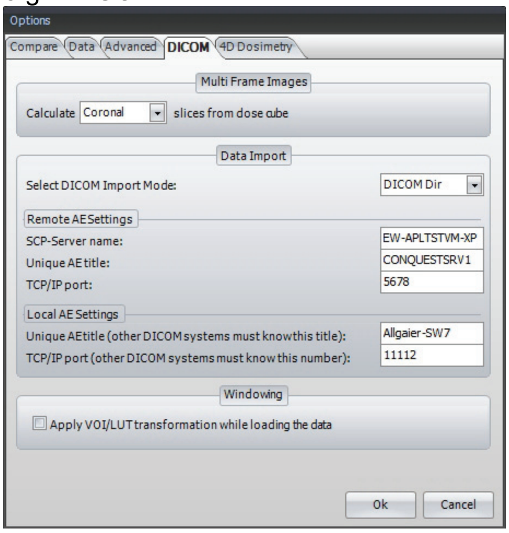
Make sure you have copied the detector calibration file to an accessible data folder and point the software to this 'Calibration File'.

Use the 'Find' button to automatically connect to the selected devices.
If there is no connection to the devices possible, it might be your firewall that prohibits the connection to an external device. In this case press **Ctrl** + **Alt** + **A**. A button "Firewall" appears. This button allows you to stop your local firewall.

Note: Make sure your firewall is switched on again if you use your computer for other purposes.
For detailed information about network connections with PTW devices visit the trouble shooting page on the PTW website (http://www.ptw.de/support_overview.html?&cId=3571)

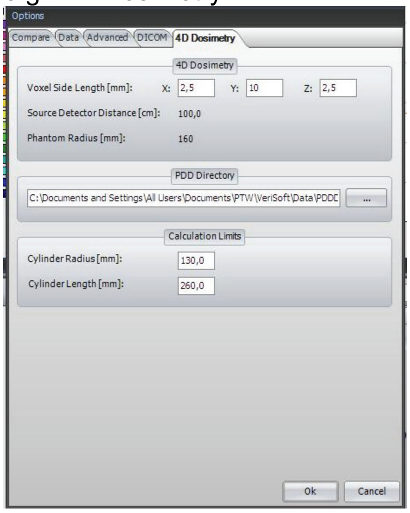
In the 'Options' menu, set the preferences:

e.g. 'DICOM':



Set up the connection to a DICOM server if you intend to connect VeriSoft to your DICOM server.
You might need help from your IT-department for the settings.

e.g. '4D Dosimetry':



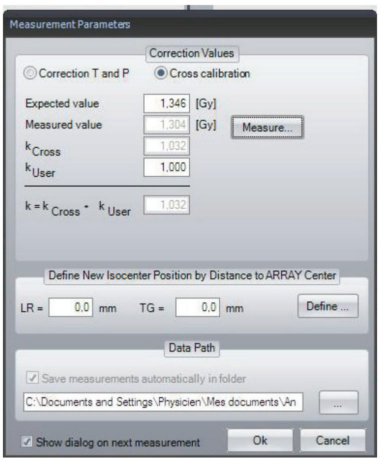
The above settings reconstruct the OCTAVIUS dose measurement in the xz (transversal) planes with a 2.5 mm resolution. In the longitudinal direction (y) for the parameter values above, dose planes are only reconstructed in planes in which a line of ion chambers is situated. When setting y=2.5 mm, the dose in between the planes of measurement will be interpolated linearly.

Cross Calibration:

Start the measurement with the green arrow or "File -> Data Set B -> Measure"

First, make sure the 'Show dialog on next measurement' is checked to prevent inadvertent use of inappropriate correction factors for absolute dosimetry during measurements.

Select the 'Cross calibration' option and fill out the 'Expected value' text box with the value you have neatly copied down on the clean and dedicated Post-it:



Note: In performing the cross calibration procedure like this, you assume that the TPS calculation for the 10x10 field is accurate at the isocenter and you avoid all impact from the daily output variations of the LINAC in your validation measurements.

Click on the 'Measure' button
The 'Measurement' window will now open automatically and if no zero measurement has been performed within the specified time period, you will be prompted to perform one before proceeding.

Setup the 10x10 cm² cross calibration field (200MU, gantry 0°) on the accelerator, either in service mode or in clinical QA mode.

Start the measurement.
Repeat the measurement at least three times to make sure the electronics and detector are well warmed up and the signal is stable. Press "Start" to do so. The measurement will be discarded.

Note: it is advisable to store the OCTAVIUS 4D phantom in an environment that has the same ambient temperature as the treatment room to avoid gradual temperature changes in the phantom during the course of the measurements.

Accept the measurement.
The cross calibration correction factor is now automatically calculated, filled out and this value will be used until explicitly modified again by the user.

Perform one additional verification measurement:
Re-measure the calibration field with the newly acquired cross calibration factor to make sure the measured value of the central chamber agrees with the expected TPS value within 0.5%.

*Note: It is good practice to store this static 10x10 verification measurement for every measurement session for possible future reference. For example, save. as '6MV_10x10_date.mcc'. The simple *.mcc format is largely sufficient for this purpose.*

Couch verification:
If you use a couch model for the planning:
Setup the 10x10 cm² posterior field (200MU, gantry 180°) on the accelerator, either in service mode or in clinical QA mode.

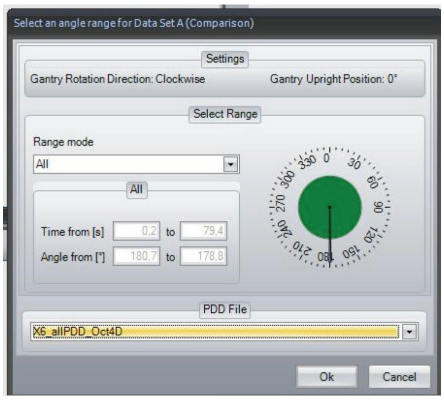
Perform the measurement and verify if the central chamber measurement agrees with the expected TPS value within ~1 %.

Open arc verification:

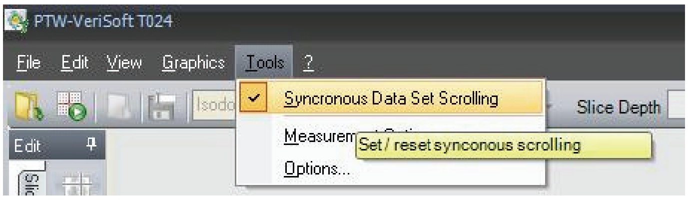
Setup the 10x10 cm² open arc field (200MU) on the accelerator, either in service mode or in clinical QA mode.

'Accept' the measurement.

Before displaying the measured dose in the 'Data Set B' window, VeriSoft will prompt you to select the appropriate PDD file based on the measurements performed under paragraph 1. Make sure you select the correct file and confirm your selection.



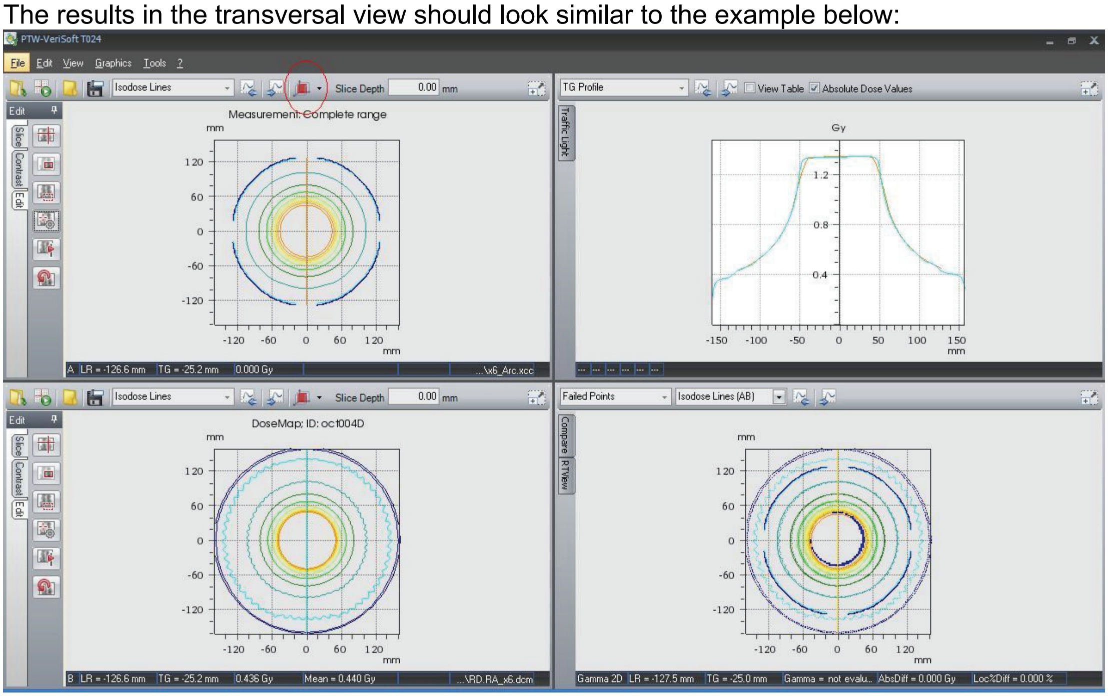
Activate the 'Synchronous data scrolling' in the Tools menu:



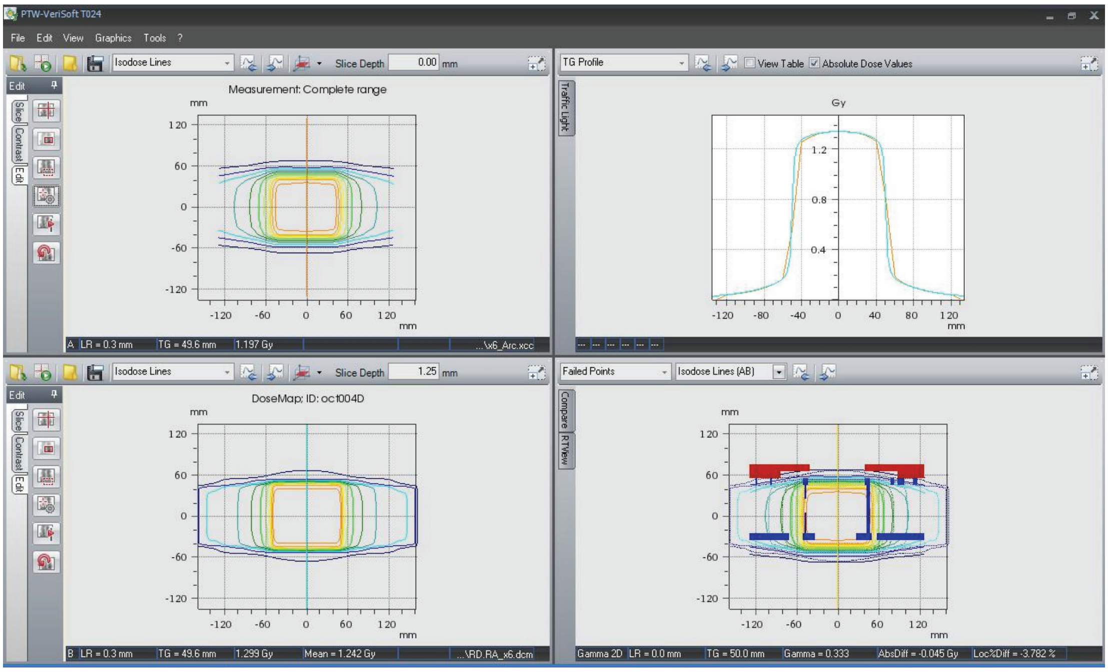
Open the calculated 3D dose export in the 'Data Set B' window.

Select the planar view of your choice.

The results in the transversal view should look similar to the example below:



In the coronal view, the effect of the linear interpolation between measurement points can be seen in the penumbra area:



If all is well, proceed to the VMAT treatment verification.

4.1 Treatment plan verification in clinical routine

4.1.1 Copy a plan to the OCTAVIUS 4D QA phantom

If a dataset has been saved as a QA phantom, it is possible to copy a plan to the phantom for quality assurance and plan verification.

IMPORTANT: it isn't possible to copy a plan that was created in Pinnacle[3] version 8.0 or earlier to a phantom that was created in Pinnacle[3] 9 or later.

1. In the **Patient Select** window, select a patient and the plan to copy (Figure 4.1).

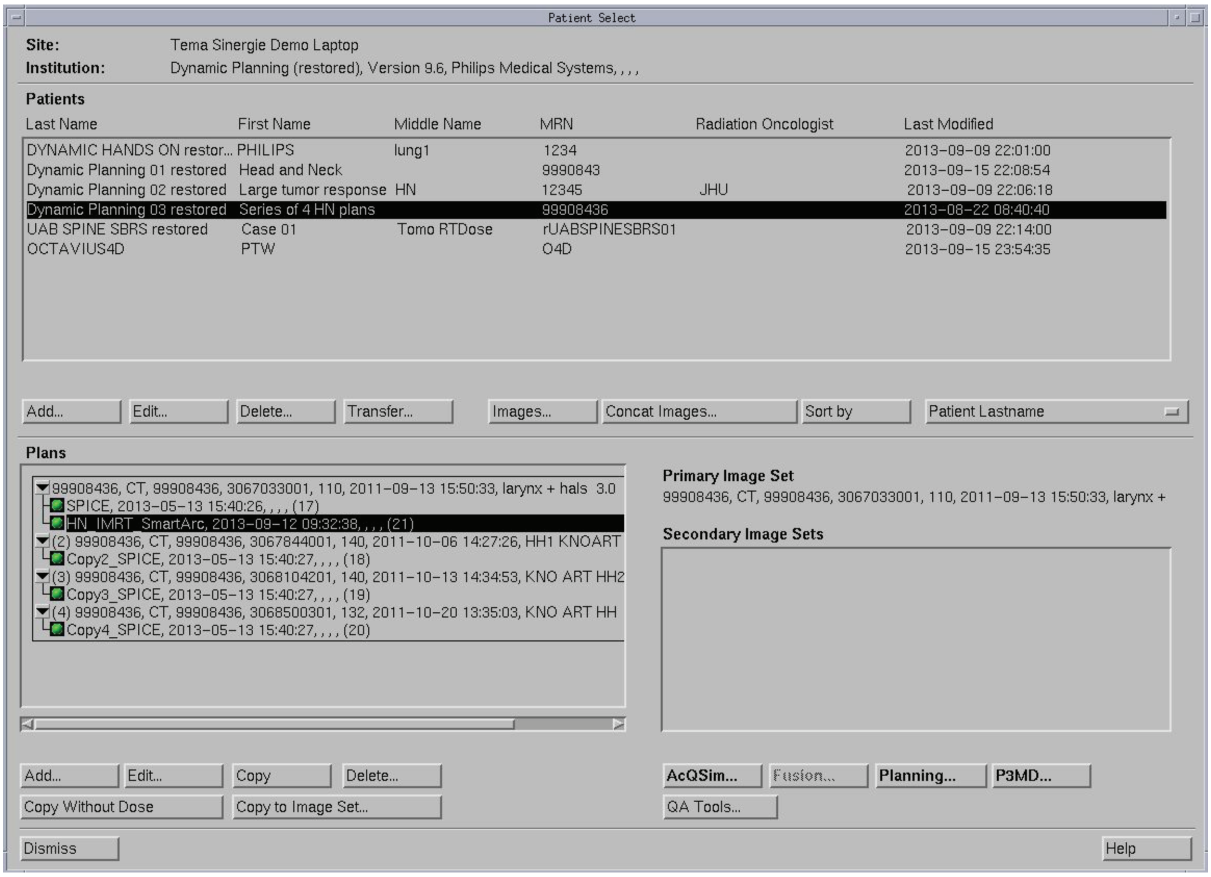


Fig. 4.1 Plan to be verified selection.

2. Click the **QA Tools** button (Figure 4.2). The **QA Tools** window appears.

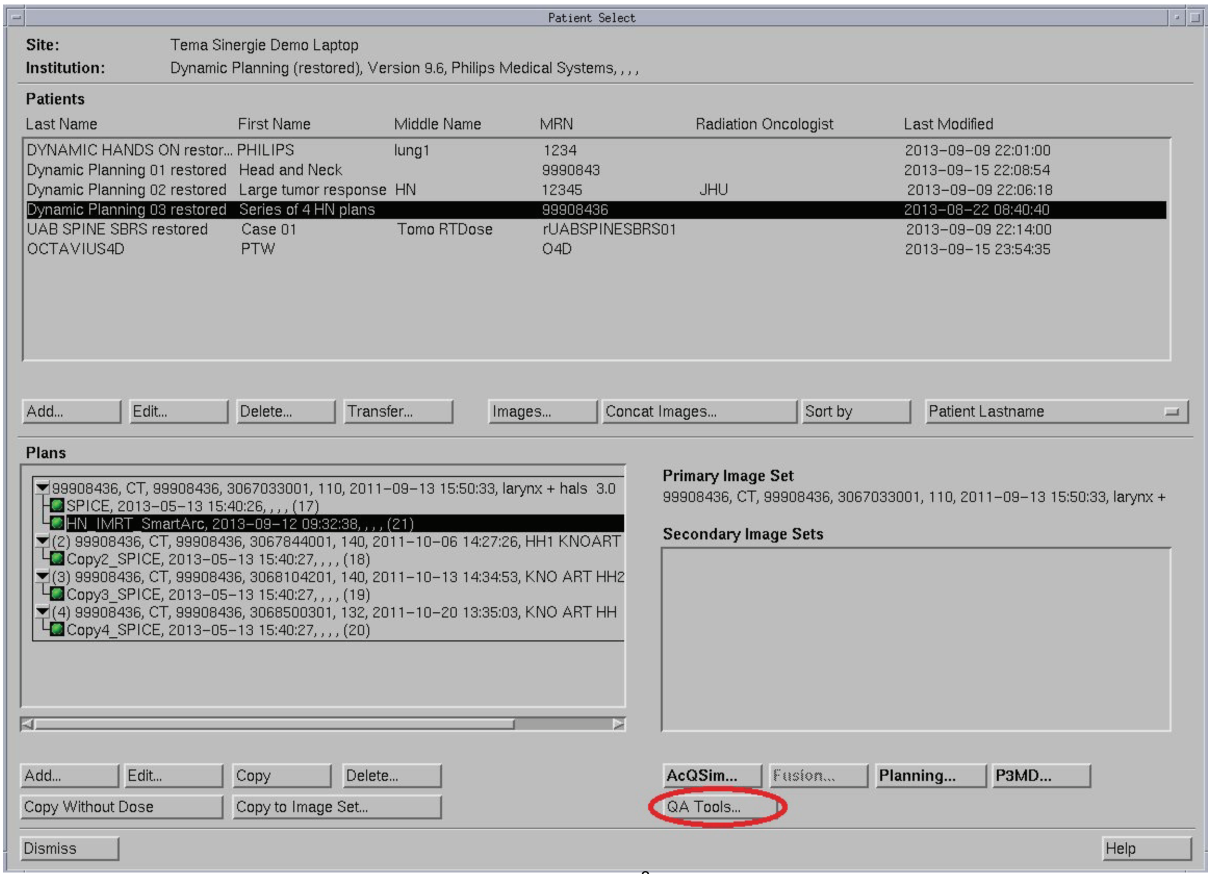


Fig. 4.2 Pinnacle[3] QA Tools

3. Click the **Copy to Phantom** button (Figure 4.3). The **CT Patient/Directory List** window appears.

Fig. 4.3 Copying to Phantom the plan to be verified

4. Select the phantom dataset to be used (Figure 4.4): use that one which has the same patient orientation as the selected patient plan (the **CT Patient/Directory List** window should list an “OCTAVIUS 4D.header” entry phantom for every treatment orientation used: for example, “OCTAVIUS 4DHF.header”, “OCTAVIUS 4DFF.header”, etc, properly saved as explained at paragraph 2-point 9). Then, click the **Import** button.

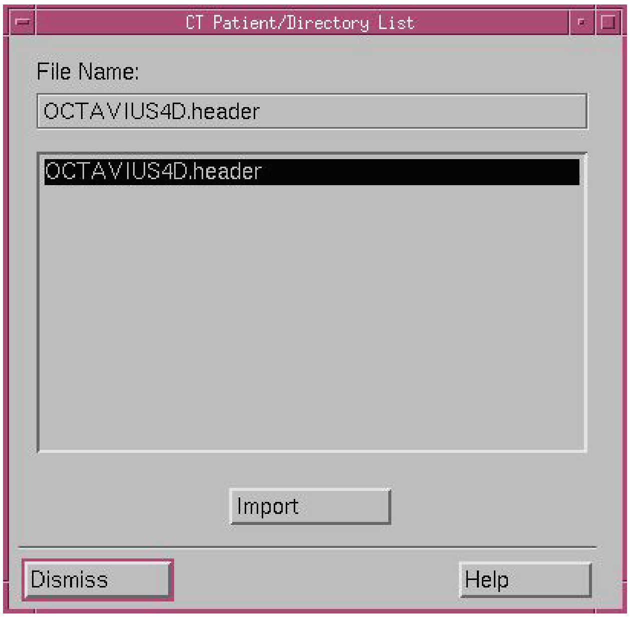


Fig. 4.4 CT Patient/Directory List window.

5. A new plan is added to the plans list (Figure 4.5). This new plan is the result of copying the patient plan to the phantom plan and is the plan to be used to validate the patient plan.

   NOTE: After copying a plan to a QA phantom, the software invalidates dose and removes all boluses from the plan.

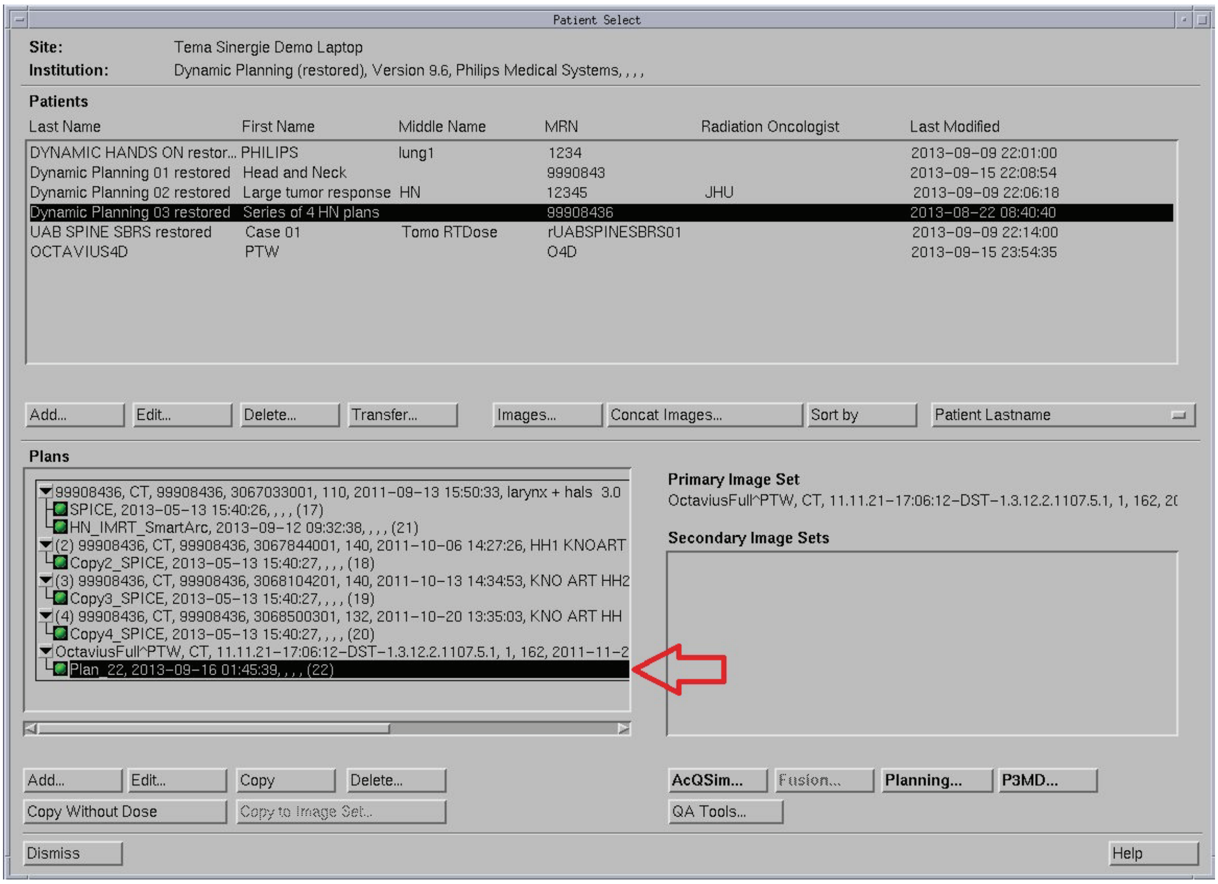


Fig. 4.5 Validation plan

4.1.2 Evaluate the plan

1. In the **Patient Select** window, select the plan which was created after having copied the patient's data to the phantom (Figure 4.5). Then click the **Planning** button.
2. The **Phantom POI Adjust** window appears (Figure 4.6). Use this window to align the coordinate system of the patient and phantom plans. In particular, after selecting the trial of interest:
   - in the **Target POI** option list, select the phantom POI to be used as the target POI.
   - in the **Target Beam** option list, select the beam to be aligned to the target POI coordinates.

   Click the **Move beams to new position** button: the software aligns the POI of the target beam to the target POI coordinates. The spatial relationship between all beams and their POIs is maintained.

   Click the **Dismiss** button.

   IMPORTANT: it isn't possible to return to the **Phantom POI Adjust** window once clicked the **Dismiss** button. Moreover, DO NOT change any beam or POI locations once dismissed the **Phantom POI Adjust** window: infact, if these setting are changed, the QA plan will no longer match the patient plan, and the dose calculation will not be valid for the patient plan.

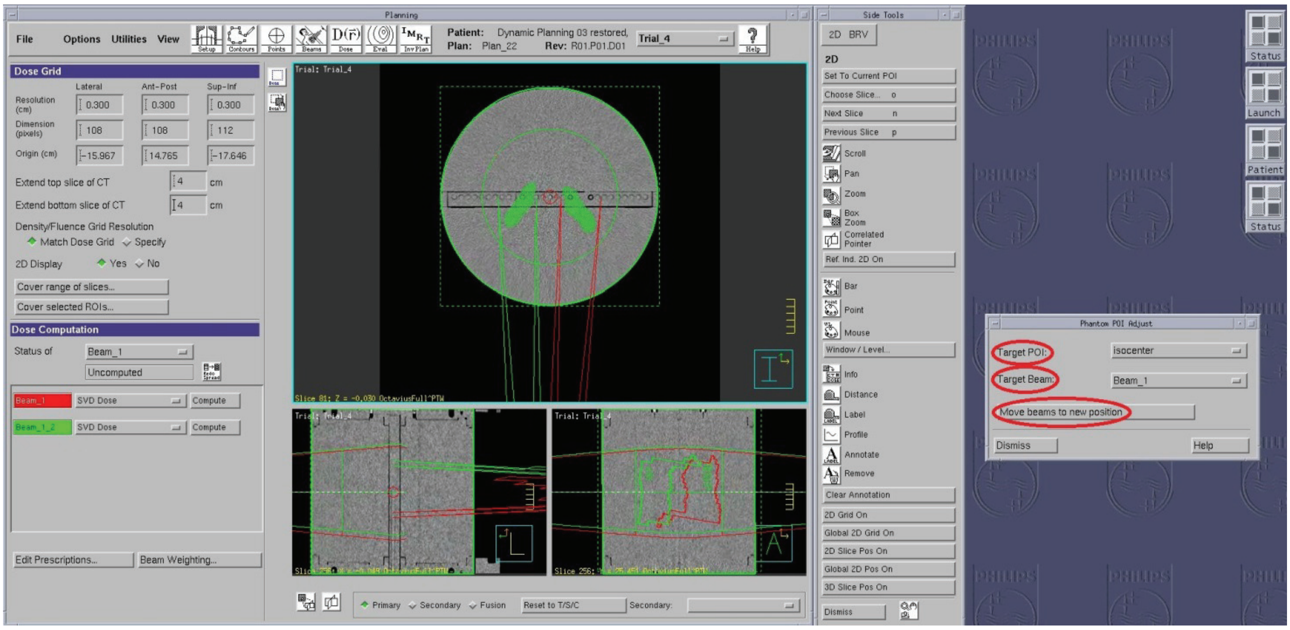


Fig. 4.6 Phantom POI Adjust window.

3. Specify the dose grid, and shape it so to include the OCTAVIUS 4D cylindric body ROI (Figure 4.7).

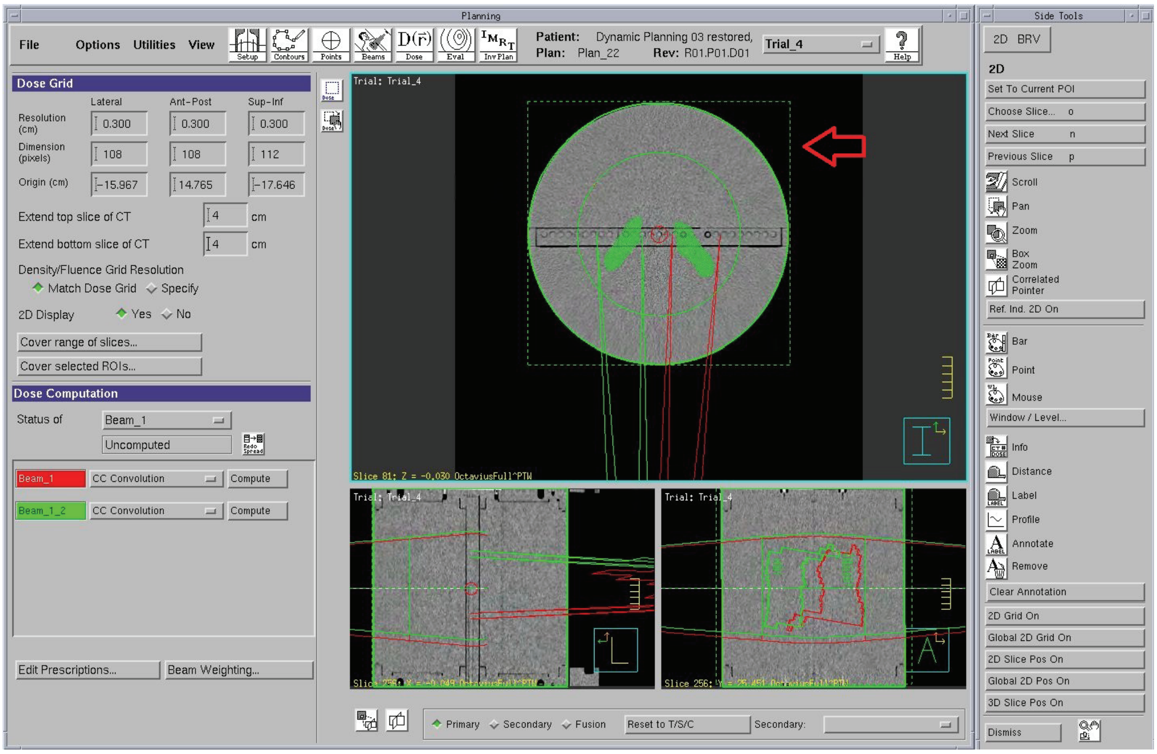


Fig. 4.7 Dose grid specification and shaping

4. Calculate dose for the beams (Figure 4.8).

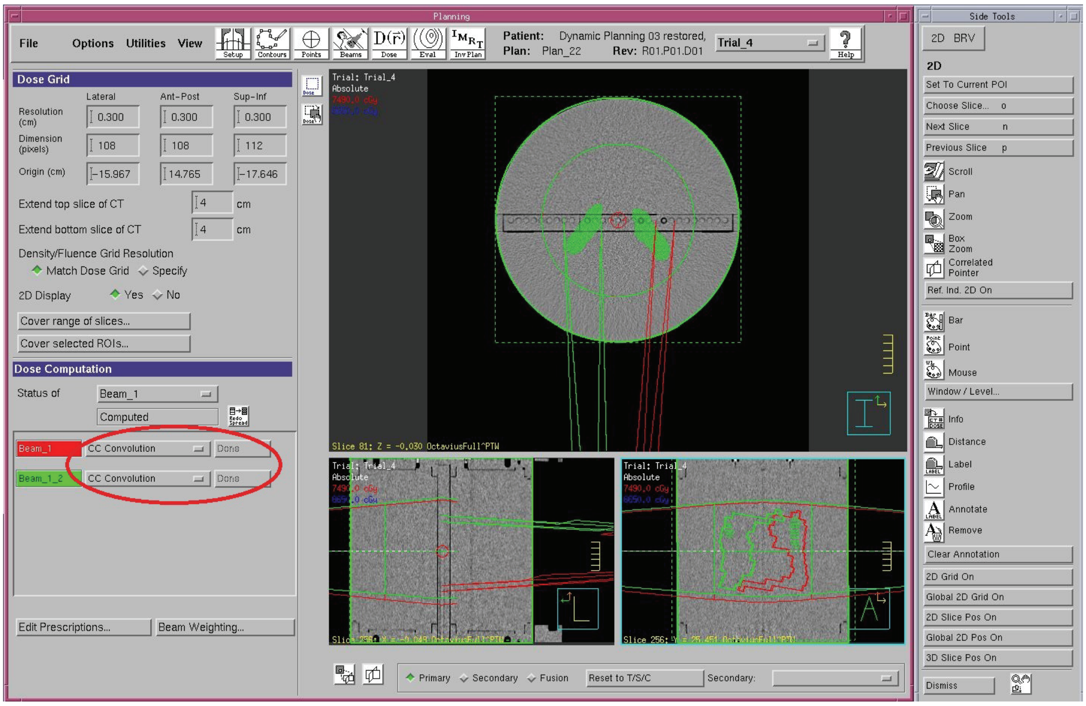


Fig. 4.8 Dose calculation

5. From the **File** menu, select **Export** and then **DICOM** to proceed with the plan RTDose and RTPlan export (Figure 4.9). The **DICOM Export** window appears.

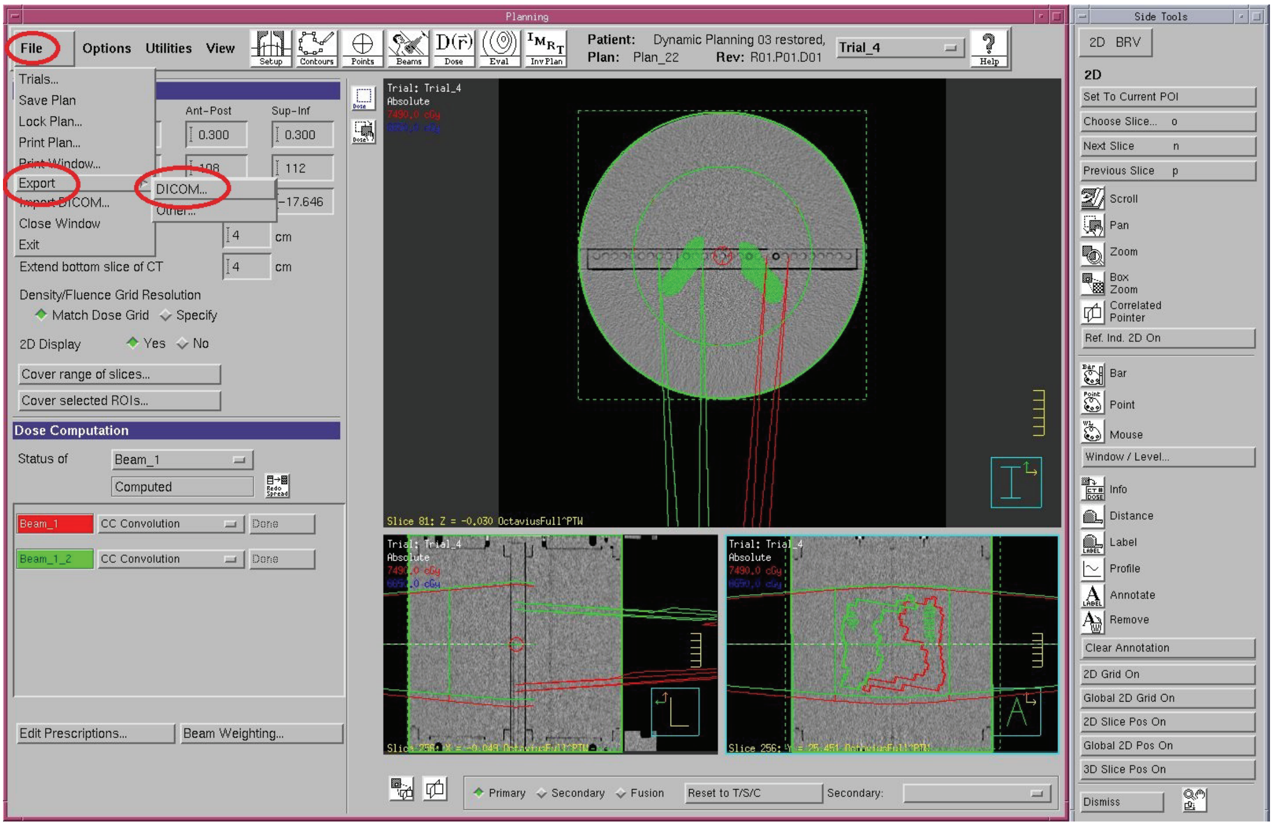


Fig. 4.9 DICOM export

6. In the **DICOM Export** window (Figure 4.10), confim the trial to export, and select
   - the receiving DICOM system (**Destination AE Title**)
   - the DICOM objects to use in VeriSoft for the dose distribution, the DVH calculation and Gamma analysis, that is
     - the RTDose corresponding to the calculated prescription
     - the RTPlan corresponding to the calculated prescription
     - the RTStructures
     - the CT dataset

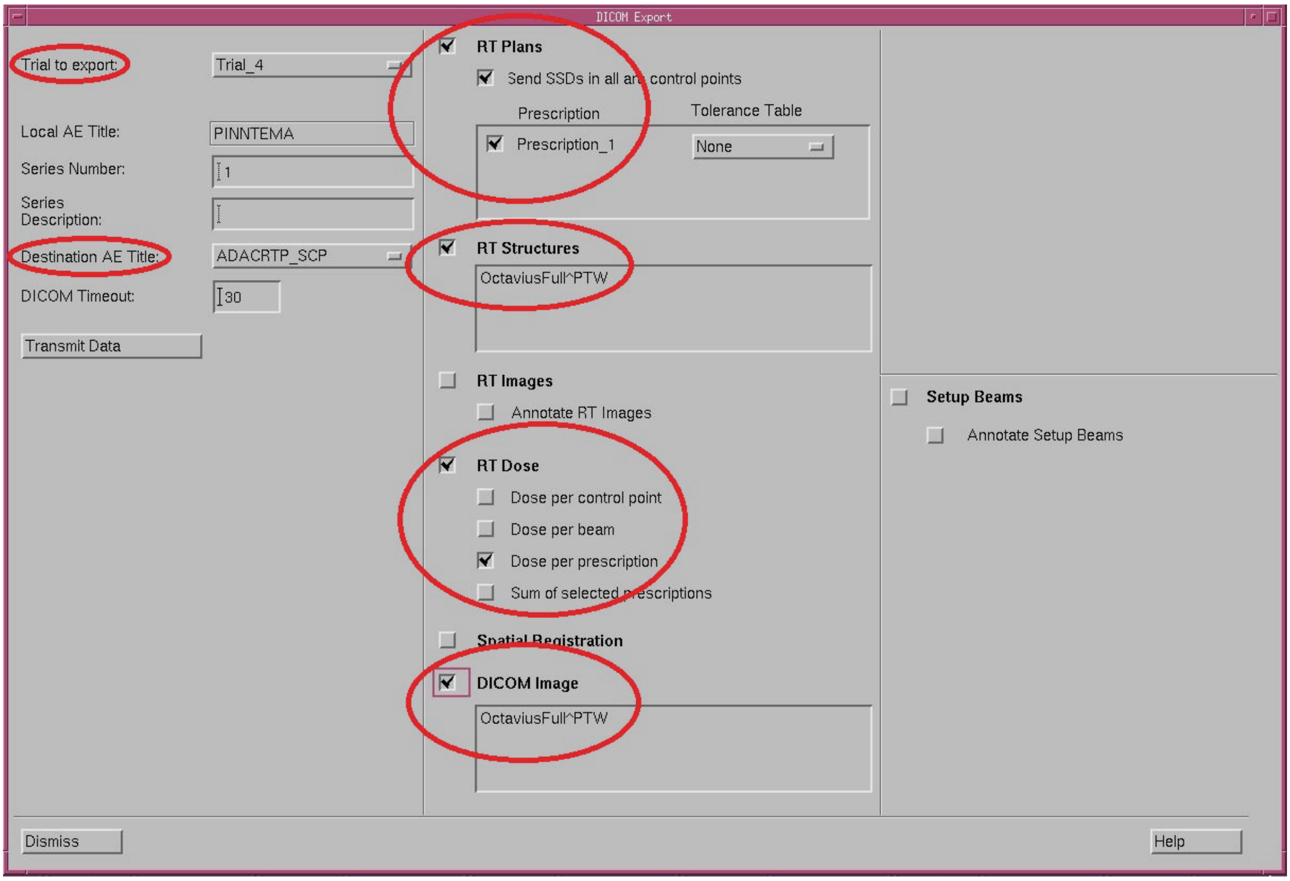


Fig. 4.10 DICOM Export window

4.1.3 OCTAVIUS 4D dose measurement

Set up the phantom and VeriSoft software as described in the paragraph on ‘Performing the basic validation measurements’.

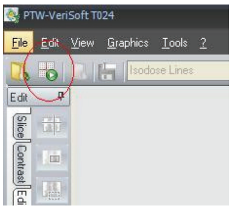
Open the ‘Measurement parameters’ from the ‘Edit’ menu to perform a cross-calibration.

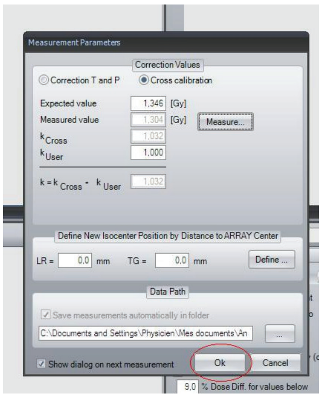
Perform the cross calibration by means of a static 10 x 10 cm² field (4 x 4 cm² for OCTAVIUS Detector 1000 ^{SRS}) with fixed 200 MU value, using the now famous expected dose value on the Post-it. Repeat the acquisition 3 to 4 times to make sure the system has stabilized before accepting the cross calibration measurement.

Repeat and save the static 10x10 cm² field (4 x 4 cm² for OCTAVIUS Detector 1000 ^{SRS}) measurement after the cross-calibration as an additional check and for possible future reference.
Open the patient plan in QA mode on the treatment console.

‘Mode up’ the plan and move the gantry to its starting position.

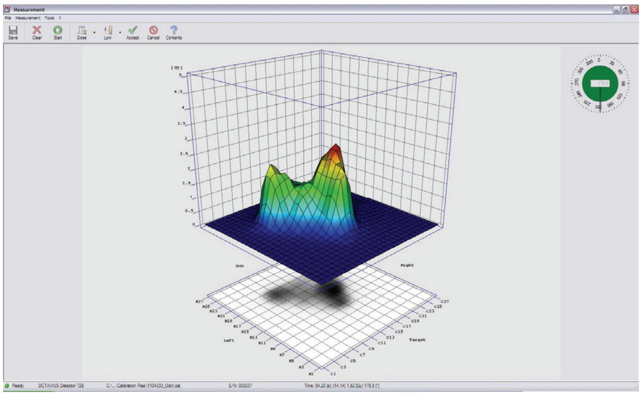
Start the OCTAVIUS 4D measurement:





Start the treatment delivery.

Stop the OCTAVIUS 4D measurement upon completion of the delivery and save it in *.xcc file format.

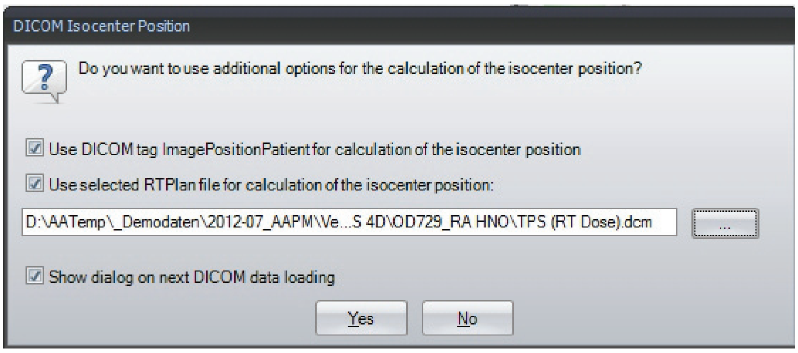


‘Accept’ the measurement to automatically return to the VeriSoft analysis software.

4.1.4 OCTAVIUS 4D dose evaluation

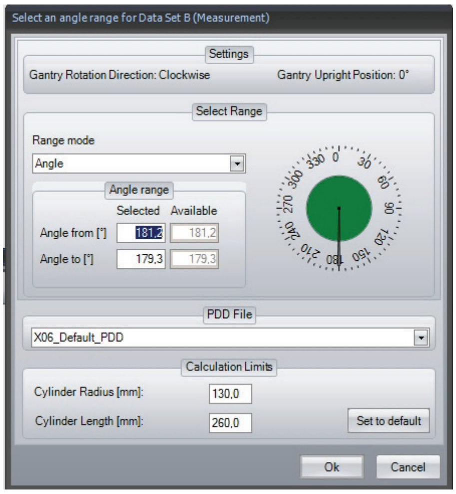
Open the calculated 3D dose export in the 'Data Set A' window (File – Data Set A - Open … *Select your path*).

When the dcm image origin coincides with the isocenter, there is no need to import the corresponding RTplan. Selecting the first option only 'Use DICOM tag ImagePositionPatient…' will then suffice to assure correct 3D alignment between measured and imported 3D dose.
If the dcm image origin not coincides with the isocenter select additionally the second option and select the appropriate path to the RTPlan file.



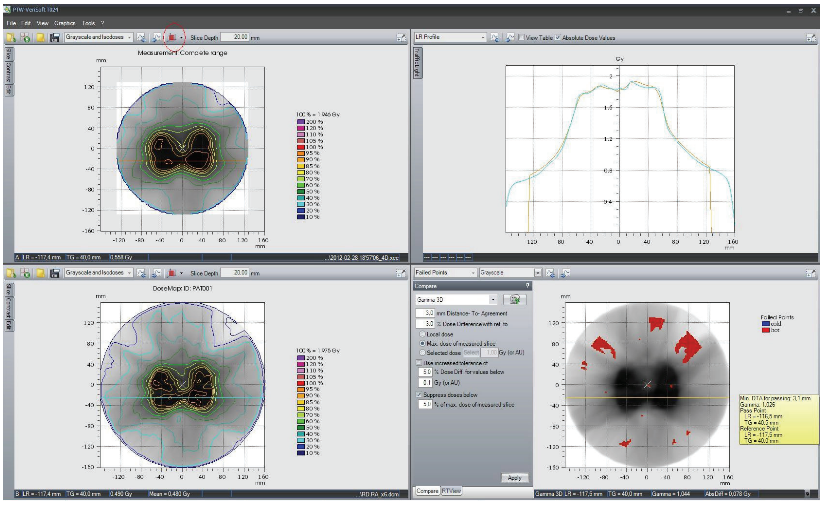
Open the measurement in ´Data Set B´ window (File – Data Set B - Open… *Select your path*)
Alternatively you can start the measurement (File – Data Set B "Measure"). See 4.1.2 for details.

Before displaying the measured dose in the 'Data Set B' window, VeriSoft will prompt you to select the appropriate PDD file. Confirm your selection.



Select the planar view of your choice

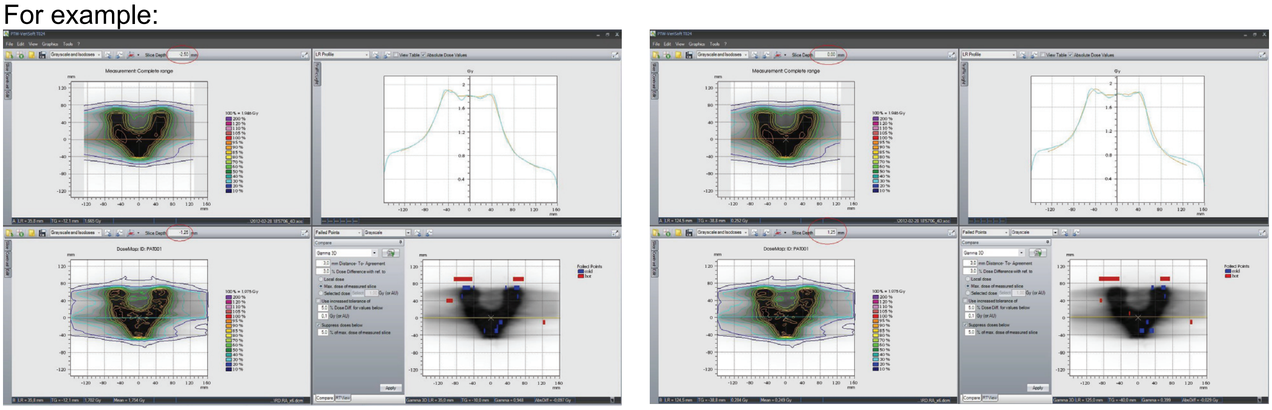
For example, the transversal view:



Some advice:

- The transversal view relates most easily to the treatment plan isodose displays on the transversal CT slices of the patient. In addition, once you have set the 3D dose reconstruction grid as described in the VeriSoft setup paragraph, the plane coordinates should always correspond between measurement and calculation. Note that this is not always the case in the coronal and transversal view, since you have very little or no control over the exact pixel positions in the calculated dose matrix exported from the TPS.

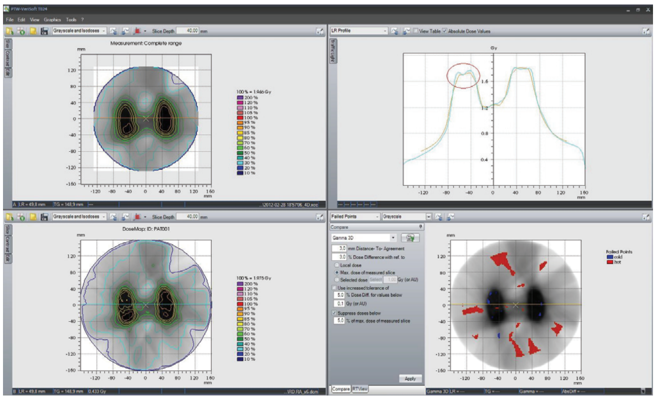
For example:



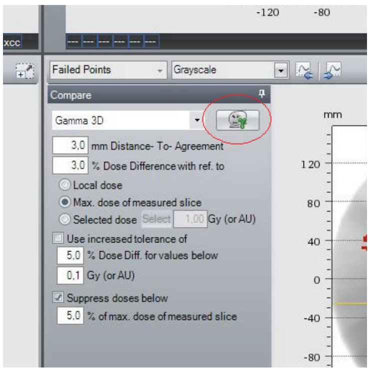
- Because the OCTAVIUS 4D system compares 3D dose matrices, it is most appropriate to use the 3D gamma evaluation. In general, the 3% dose difference criterion is often defined for composite plan evaluation with respect to the maximum plan dose or prescribed dose (e.g., 2Gy). It is up to the user to decide which criteria to use. In the above examples, we have selected the ‘Maximum dose of every slice’. It is stricter than the maximum plan dose or prescribed dose, but it is better suitable for integrated boost treatments (i.e., using multiple dose prescription levels within one treatment plan).

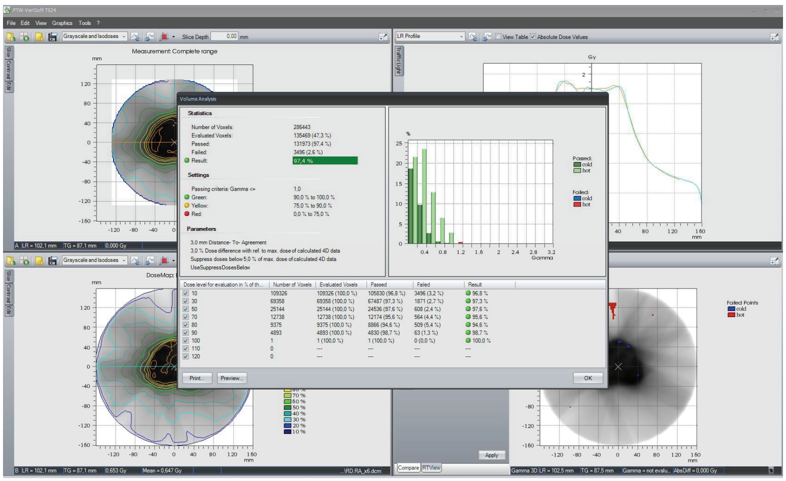
- Note that the linear interpolation between measurement points can give rise to overly smoothened 3D dose reconstructions. This is a limitation resulting from the combined effect of the detector resolution and the linear interpolation algorithm. A typical example is given below. The effect is most clearly observed in the line profile overlays.

The option “Use 2nd and 3rd pass” (Tools – Options – Compare) helps to avoid false positive results caused by the resolution of the detector. [Depuydt 2002].
The 3D gamma evaluation can help with the interpretation of the impact of deviations observed in individual line profiles in the final 3D dose comparison.



- Because the 3D dose comparisons contain a very large amount of information, it is often not feasible to assess the gamma evaluation for every slice in clinical routine. The Volumetric Gamma analysis provides a useful statistical overview of the 3D gamma calculation. The user can define different acceptance criteria with respect to the percentage of failed points for different dose levels:





Thank you to Davide Raspanti, Tema, Italy who provided most of this information.

Disclaimer

Although the information in this document has been carefully assembled, PTW-Freiburg does not guarantee that this document is free of errors. PTW-Freiburg shall not be liable in any way for any consequence of using this document.

[Depuydt 2002]:
Tom Depuydt, Ann Van Esch, Dominique Pierre Huyskens, “A quantitative evaluation of IMRT dose distributions: refinement and clinical assessment of the gamma evaluation”, Radiotherapy and Oncology **62** (2002) 309–319

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