

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

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

Foreword: This note describes implementation of OCTAVIUS 4D with Varian Eclipse. The workflow for data export might be a little bit different for other TPS. However, the basic procedure is the same.

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

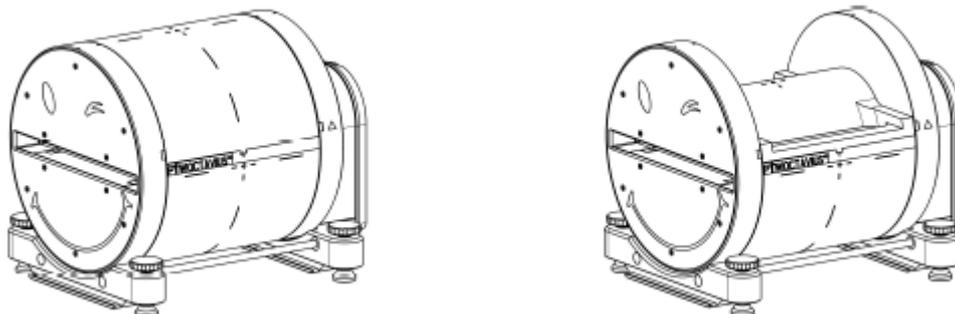
1. VeriSoft basic beam data acquisition
2. Importing the OCTAVIUS 4D phantom into the TPS
3. Preparing the cross calibration procedure and basic validation.

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), the RU top SRS (diameter of RU cylinder: 17 cm) or the RU top SRS plus (diameter of RU cylinder: 21cm). 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, with a RU top SRS 92 cm and with a RU top SRS plus 90 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 chambers. The following field sizes and SSD adjustments for PDD measurements are required:

SSD (Source Surface Distance):

- when using the accessory Rotation Unit: 85 cm
- when using the accessory Rotation Unit SRS: 92 cm
- when using the accessory Rotation Unit SRS plus: 90 cm

Required field sizes (at isocenter with SID of 100 cm):

- when using the accessory Rotation Unit: 4 cm x 4 cm, 5 cm x 5 cm, 10 cm x 10 cm, 15 cm x 15 cm and 26 cm x 26 cm
- when using the accessory Rotation Unit SRS: 4 cm x 4 cm, 5 cm x 5 cm, 8 cm x 8 cm, 10 cm x 10 cm, 14 cm x 14 cm and 18 cm x 18 cm
- when using the accessory Rotation Unit SRS plus: 4 cm x 4 cm, 5 cm x 5 cm, 8 cm x 8 cm, 10 cm x 10 cm, 14 cm x 14 cm, 18 cm x 18 cm and 21 cm x 21 cm

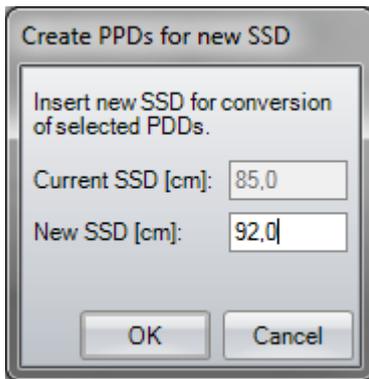
Once the measurements for a certain setup have been acquired, process them as follows:

- 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 sizes down to 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.

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, 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)

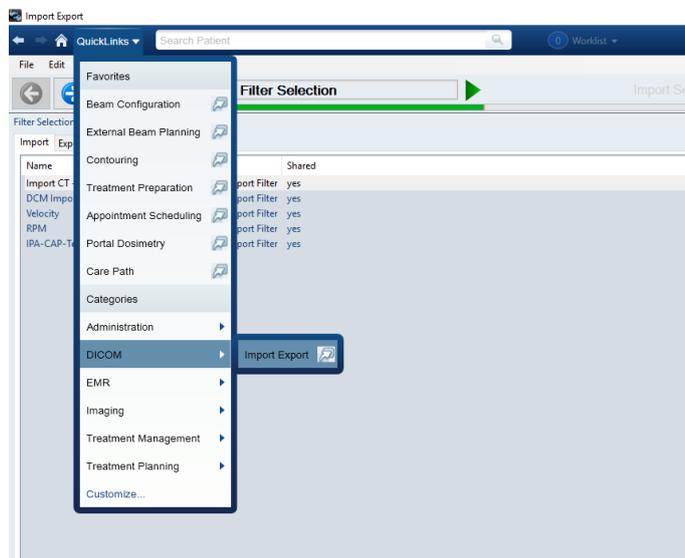
- Open the VeriSoft software and select the menu “*Tools → Options... → 4D Dosimetry*”
- Load all .mcc files of the measured depth dose curves by clicking on “*Select Folder ...*” or “*Add File(s) ...*” and click on “*Merge and complete PDD file*” (VeriSoft automatically interpolates the missing field sizes in increments of 1 cm, extrapolates values for the field sizes down to 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:



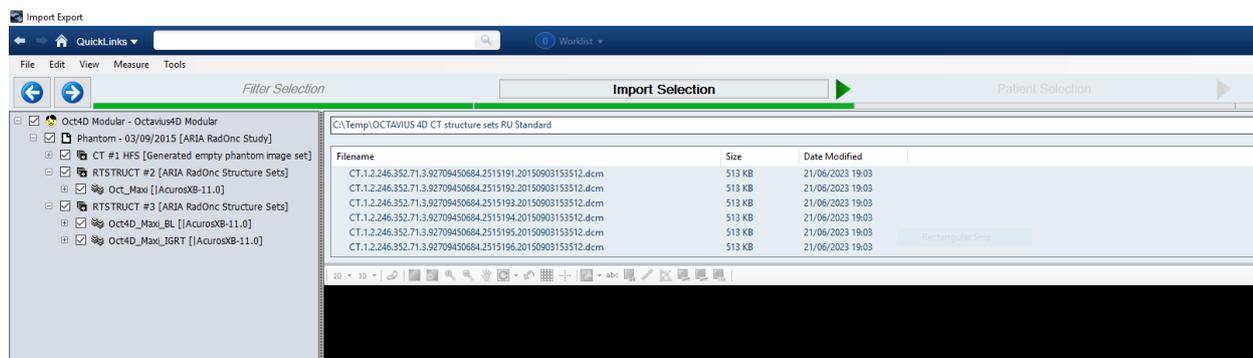
- Save the converted PDD file in your PDD directory. The default directory is '<PTWdocuments>\VeriSoft\Data\PDData'. You can change the path in the menu "Tools → Options... → 4D Dosimetry"
- Create a PDD file for each radiation unit and energy. Name the PDD files so that the assignment is unambiguous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

2 Importing the phantom into the TPS

Import the OCTAVIUS 4D artificial CT provided by PTW into the TPS:
(Download here: <https://www.ptwdosimetry.com/en/octavius-4d-ct-scans>)

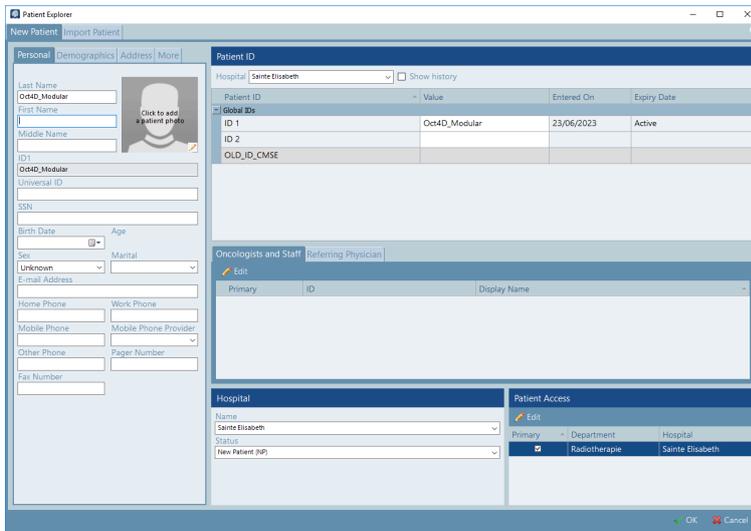


Use a Dicom Media File import filter and navigate to the directory containing the OCTAVIUS 4D images:

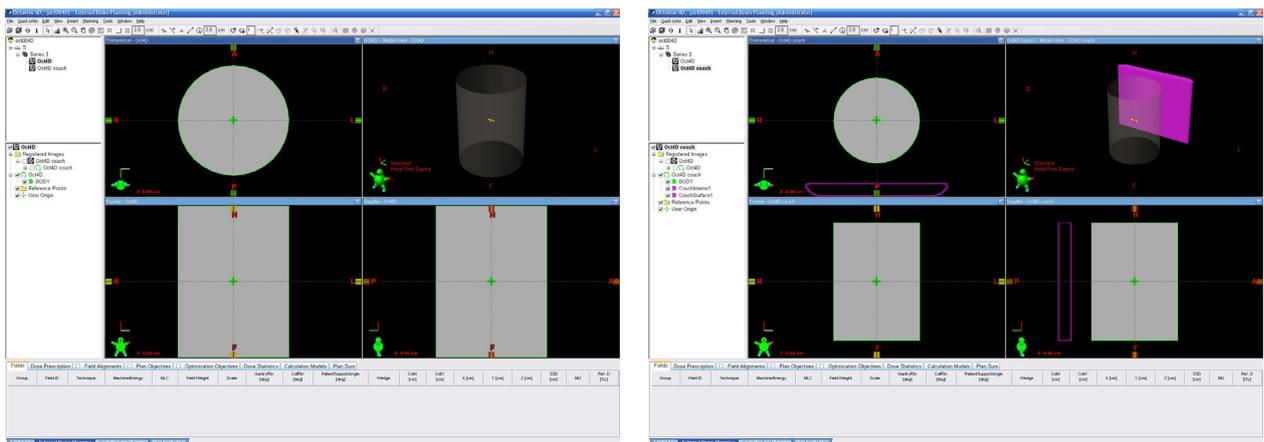


Hint: The oct004D directory contains the artificial CT slices and structure sets with and without treatment couch.

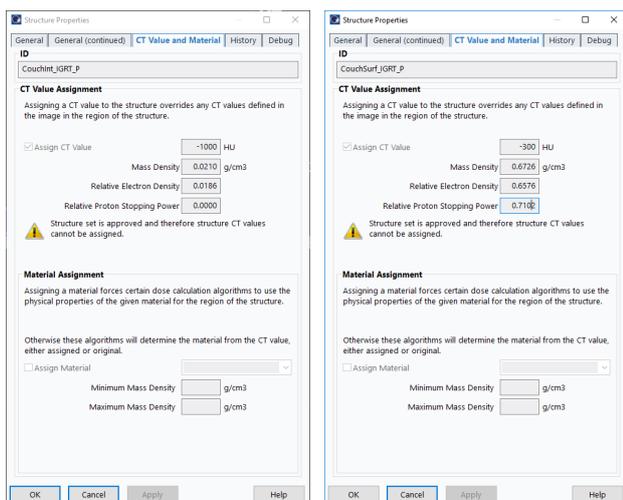
Create a new patient to import the data into:



You have now imported a structure set containing the phantom only and structure set(s) containing the phantom as well as the Varian IGRT treatment couch:



If you wish to add your own treatment couch to the phantom, you can use the first structure set to create a structure set with the couch of your choice. If you use the Varian IGRT couch, you can simply use the second set. Verify that the distance between the bottom of the phantom and the couch in the CT correspond to the actual distance measured on your Octavius phantom. If necessary, move the couch to match the correct distance. While the actual couch position may not be very important for VMAT treatments, it can be for static IMRT field verification at posterior oblique gantry angles. Verify that the HU values assigned to the couch have been imported correctly. If not, you can set them manually in the properties window of each of the structures:



Note: The above HU values for the couch can be set to the locally used values if necessary.

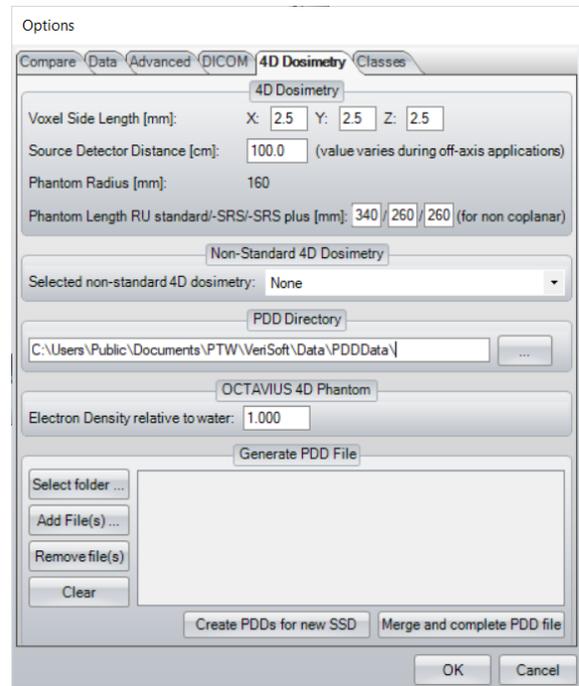
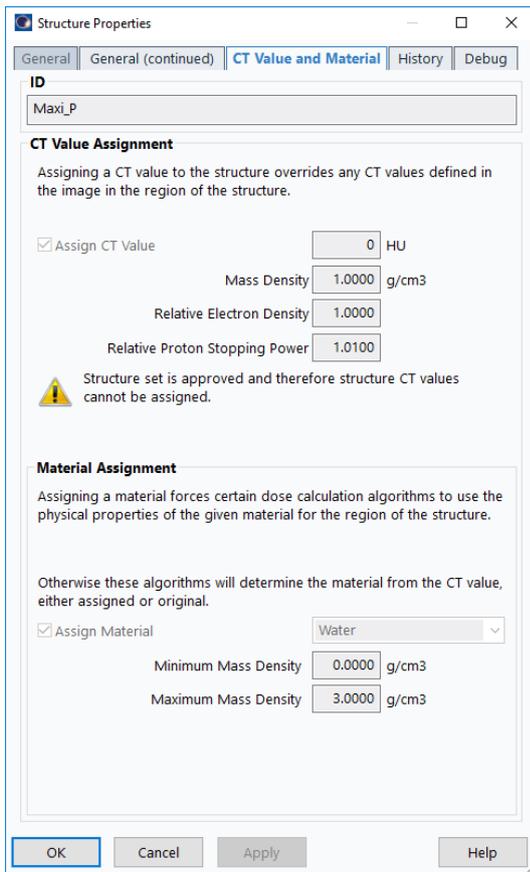
Please check the HU Values for the phantom. Depending on your TPS you can decide to assign water or to assign the actual material properties as listed below:

Parameter	Value
Electron density relative to water	1.016
Physical density (synonym: mass density)	1.05 g/cm ³
Material	PS (Polystyrene)

When using Acuros as dose calculation algorithm, you should not only assign the HU to the phantom, but also declare the material. As the OCTAVIUS material is near water equivalent, you can either declare it to be water or declare it to be polystyrene with the appropriate density. Both choices are valid, but it is important to be consistent in VeriSoft. Depending on the choice you make in Eclipse, make sure you set the same electron density in VeriSoft.

Option 1:

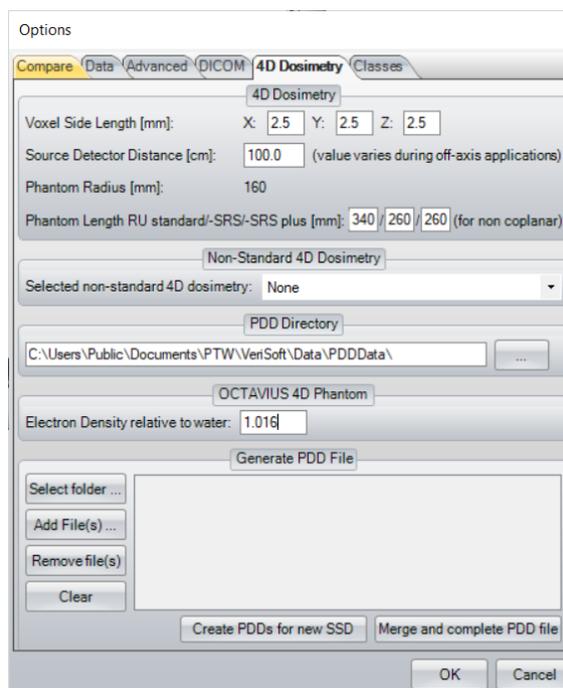
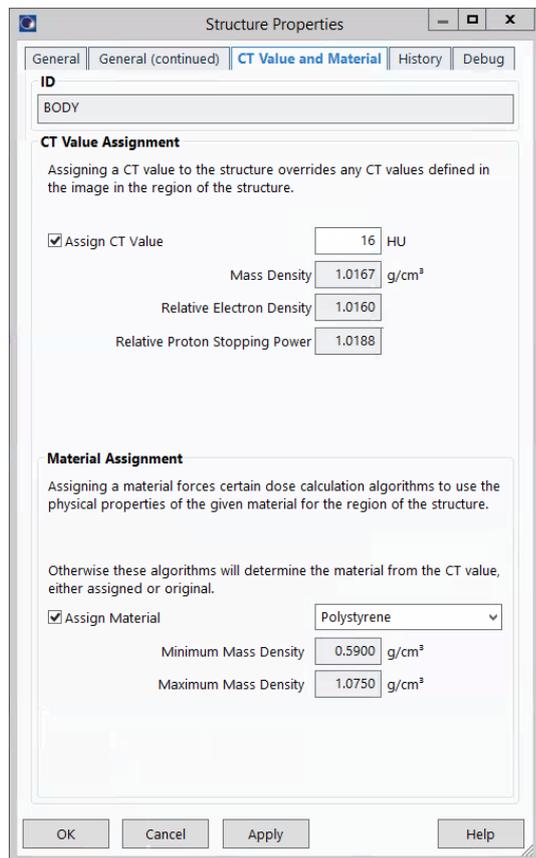
Assign 'Water' as material. In theory, your CT-calibration curve should display an electron density of 1.000 to 0 HU. If this is not the case, adjust the HU to obtain 1.000 Relative Electron Density. In the VeriSoft Options, set electron density to 1.000.



Option 2:

Assign 'Polystyrene' as material. Modify the HU value to obtain an electron density of 1.016. The desired HU will depend on your CT-calibration curve.

(Note that the corresponding mass density of the OCTAVIUS phantom will also depend on your CT-calibration curve and will most likely not correspond to the real mass density of 1.05 g/cm³. The impact of this difference is not relevant in the 3D dose distribution and a cross calibration method will remove any impact on the absolute dose level.)



Please check whether setting the density was successful by doing the following: Have your TPS calculate the dose on the OCTAVIUS 4D phantom. Create a printout of the plan. Have a look at the geometrical depth of the isocenter (should be 16.0 cm) and at the radiological depth (or “water-equivalent depth”) of the isocenter, e.g., 16.26 cm. Calculate the ratio of radiological depth over the geometrical depth; this will yield the electron density. In this example: $16.26 / 16.0 = 1.016$

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”

Note: The artificial phantom is created such that the center of the cylinder coincides with the DICOM image origin.

Note: If you want to use the phantom CT in an Ethos TPS, it is necessary to set a new point (Type: ‘Marker’) at the isocenter position. The Ethos TPS needs such a point for the phantom CT.

3 Preparing the cross calibration and basic validation

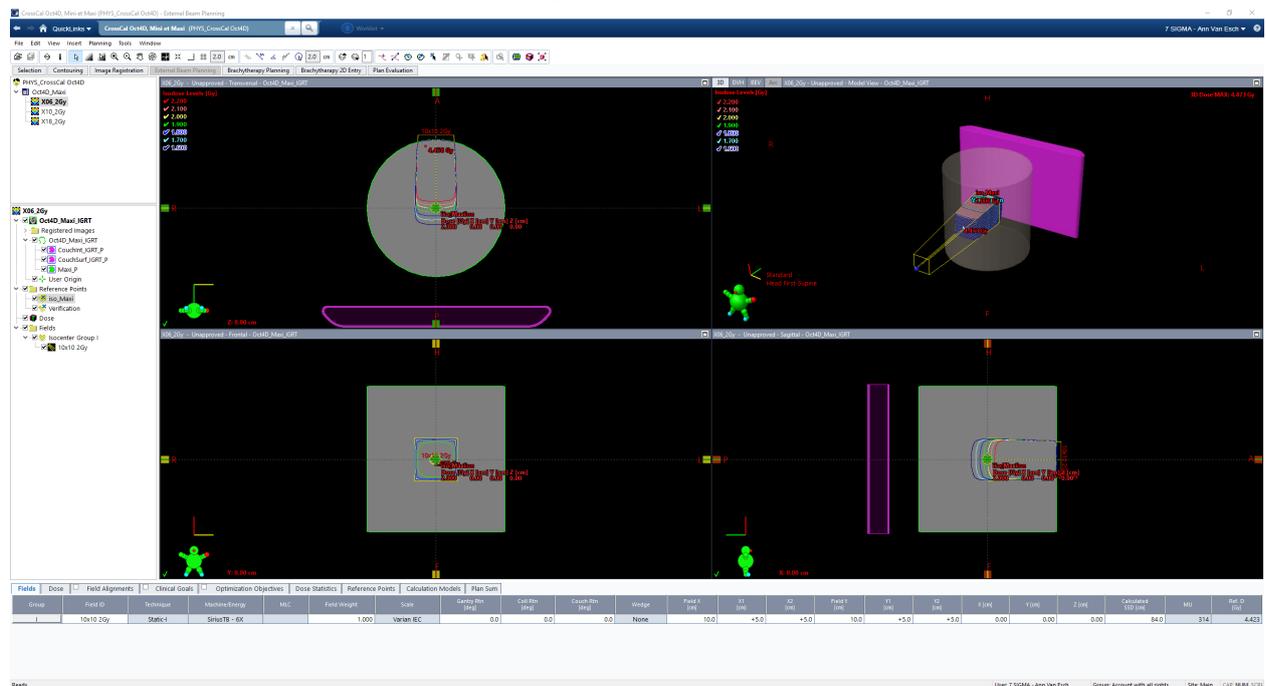
3.1 Cross calibration:

You can either perform a cross calibration by measuring the dose in the phantom using a chamber plate or calculate the expected dose by means of your TPS. If you perform a cross calibration to the TPS dose

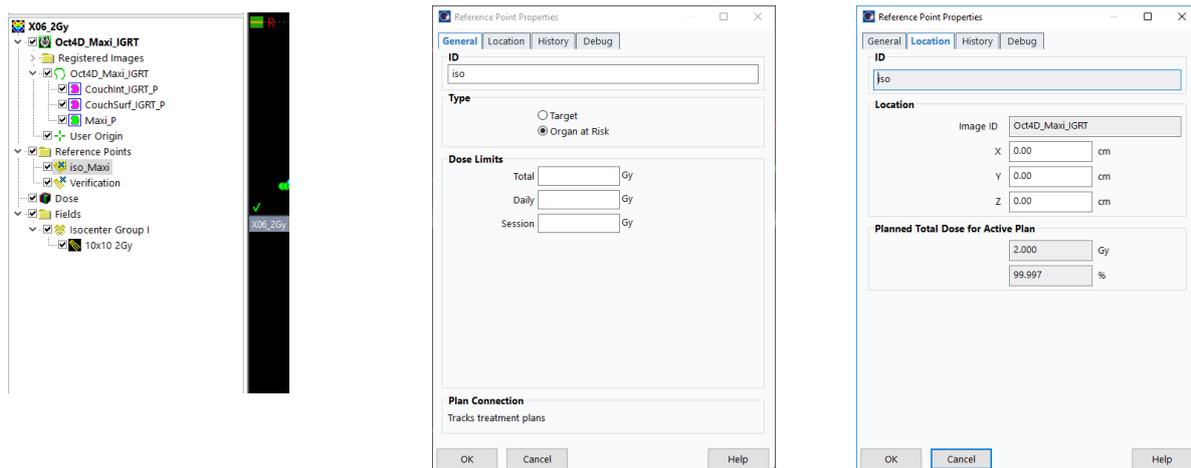
calculation, making sure you use the same algorithm as used for the calculation of the patient treatment plan to be measured.

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 1600^{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 MUs required to deliver f.ex. 2Gy at isocenter or calculate the dose for f.ex. 200MU.



Create a reference point at the isocenter to easily read out the isocentric dose:



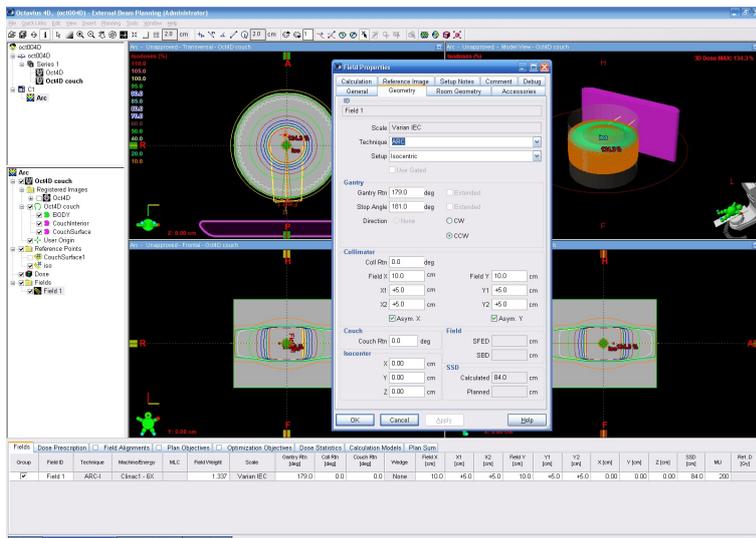
Copy the dose to the isocenter on a nice and clean Post-it selected for this purpose only.

'Planning approve' the plan and make sure all the appropriate parameters (tolerance table, time, etc.) are filled out in RT chart if you wish to deliver the field in QA mode on the LINAC.

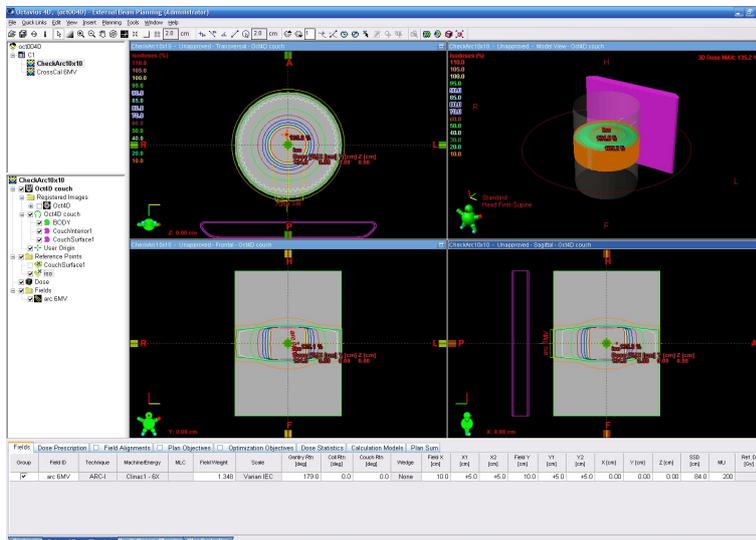
Repeat this for every photon energy you intend to use.

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 cm² arc field. Again, make sure the isocenter is at the DICOM image origin (0,0,0):



Calculate the dose for the fixed value of 200MU:



Export the calculated dose matrix through an appropriate DICOM export filter. You can configure the filter to either export the field doses or the plan dose, according to your needs or preferences. If you have performed an *Acuros plan dose calculation*, however, field doses will not be available and you need to select the plan dose distribution in the export filter.

'Planning approve' the plan and make sure all the appropriate parameters (tolerance table, time, etc.) are filled out in RT chart if you wish to deliver the field in QA mode on the LINAC.

(It is advisable to repeat the above open arc verification for every photon energy you wish to use.)

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.

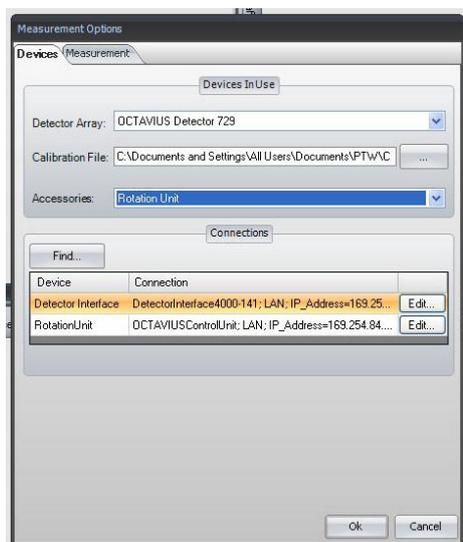
Mount the inclinometer to the gantry. Choose a flat part of the gantry and mount the inclinometer as close as possible to the rotation axis. Establish the Bluetooth connection between inclinometer and control unit. Make sure all cables are properly connected and initialize the phantom.

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:

Launch the VeriSoft application. 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.

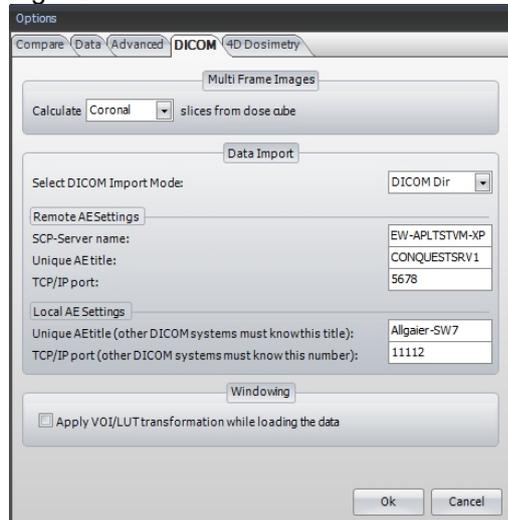
If there is no connection to the devices possible, it might be your firewall that prohibits the connection to an external device. In this case press **Ctrl + Alt + A**. A button "Firewall" appears. This button allows you to stop your local firewall.

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?&cld=3571)

In the 'Options' menu, set the preferences:

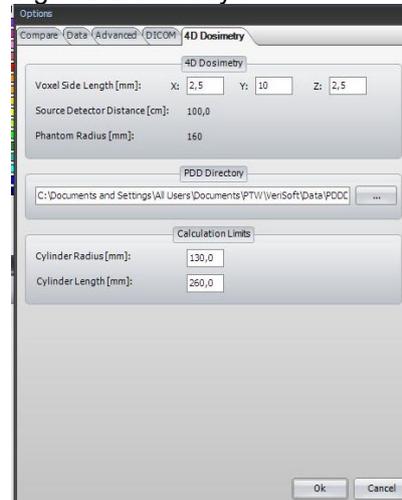
e.g. 'DICOM':



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':



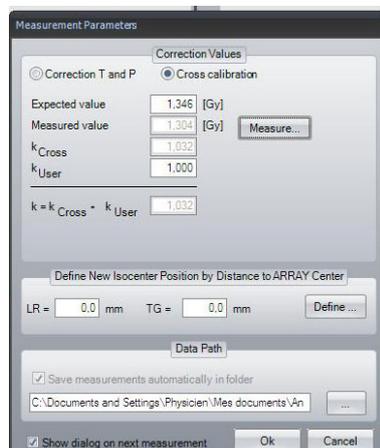
The above settings reconstruct the OCTAVIUS dose measurement in the xz (transversal) planes with a 2.5 mm resolution commonly used in the Eclipse dose calculation. In the longitudinal direction (y) for the parameter values above, dose planes are only reconstructed in planes in which a line of ion chambers 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 from Eclipse 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 cm² 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 through the 'planning approved' cross calibration plan.

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 cm² 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:

Setup the 10x10 cm² posterior field (200MU, gantry 180°) on the accelerator, either in Service mode or in clinical QA mode through the 'planning approved' plan.

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

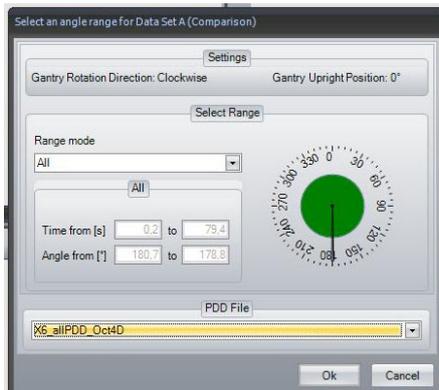
Open arc verification:

Setup the 10x10 cm² open arc field (200MU) on the accelerator, either in Service mode or in clinical QA mode through the 'planning approved' plan.

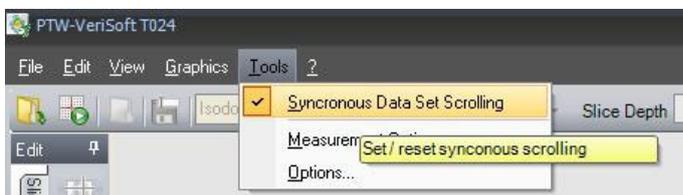
Perform the measurement and save it as *.XCC format to maintain the angular information in the measurement file.

'Accept' the measurement to automatically return to the VeriSoft analysis software.

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:



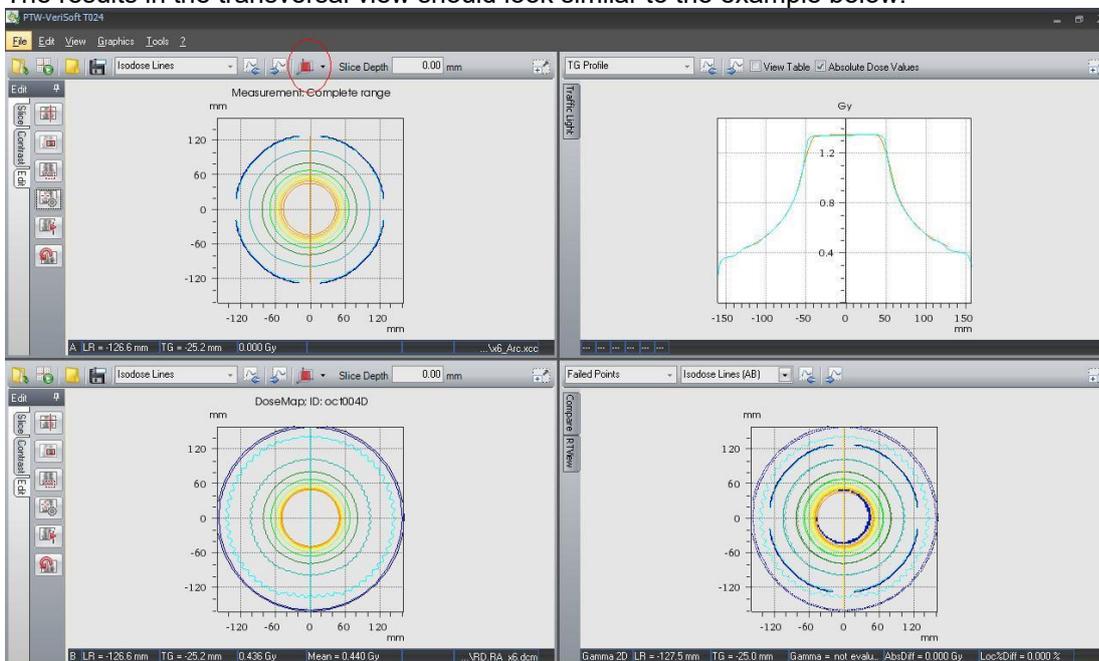
Activate the 'Synchronous data scrolling' in the Tools menu:



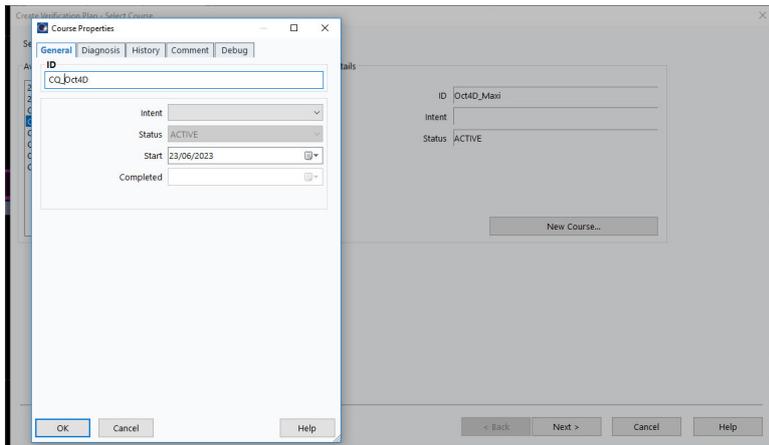
Open the calculated 3D dose export in the 'Data Set B' window.

Select the planar view of your choice.

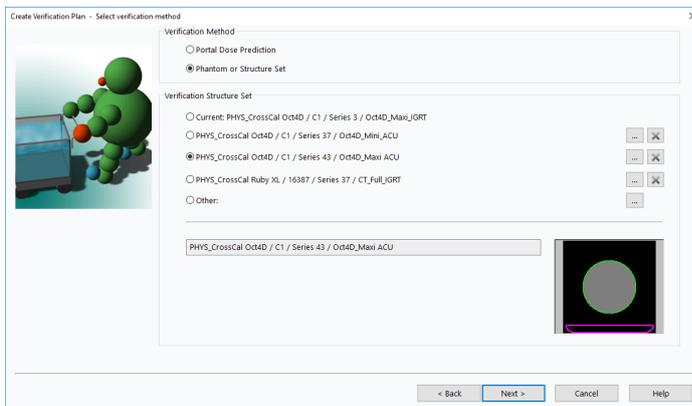
The results in the transversal view should look similar to the example below:



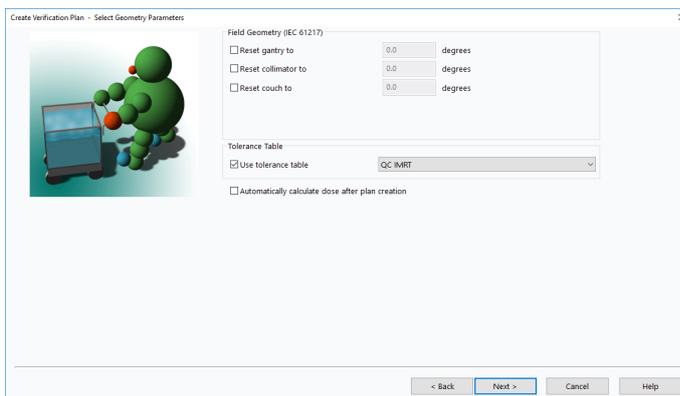
In the coronal view, the effect of the linear interpolation between measurement points can be seen in the penumbra area:



Browse to the imported OCTAVIUS 4D CT set and select the structure set you wish to use:
(In most cases, this will be the 'Oct4D couch' structure set)

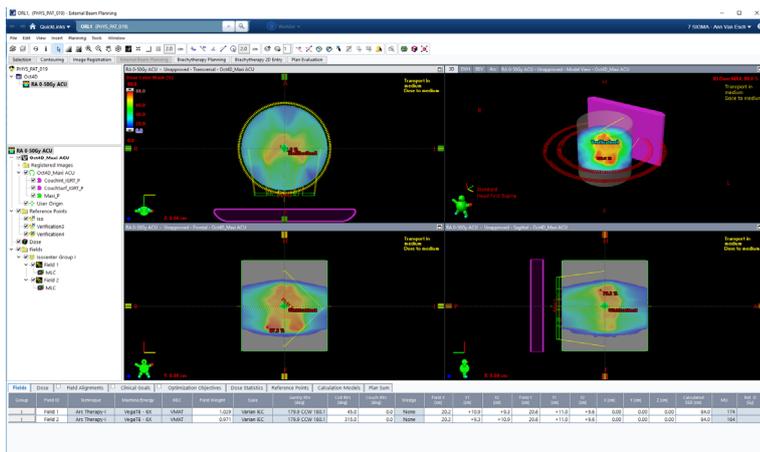


If you are totally confident that the default isocenter placement on the phantom is correct, you can allow automatic dose calculation after plan creation. If not, it is wise to unselect the automatic dose calculation and verify the isocenter position before launching the dose calculation:



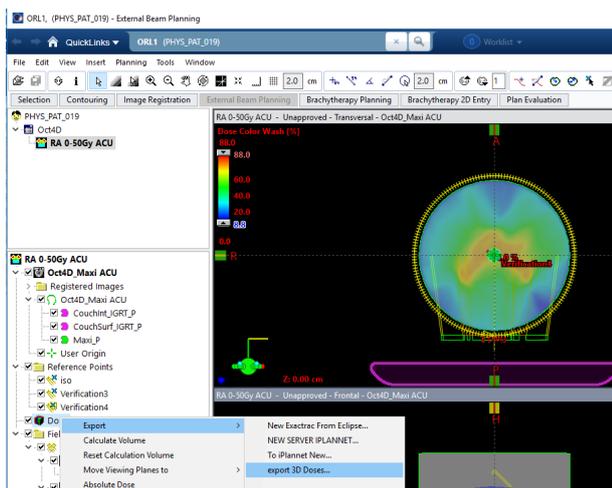
Complete the process of the verification plan creation.

Make sure the isocenter is positioned at the dicom image origin $(x,y,z)=(0,0,0)$ and $SSD=84$ cm (± 0.1 cm). The SSD depends on the used phantom top. Then launch the dose calculation.

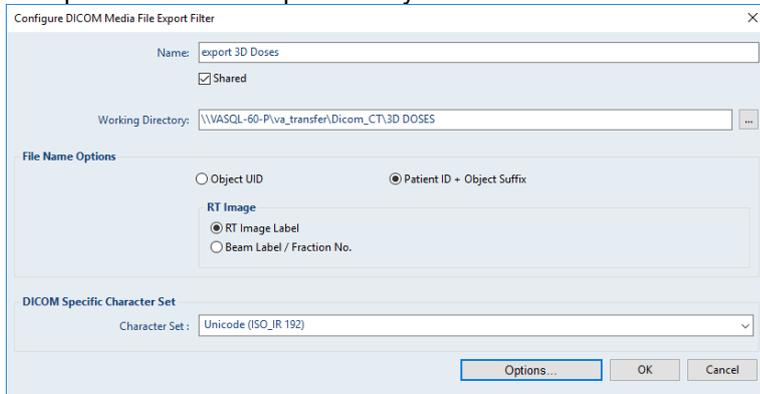


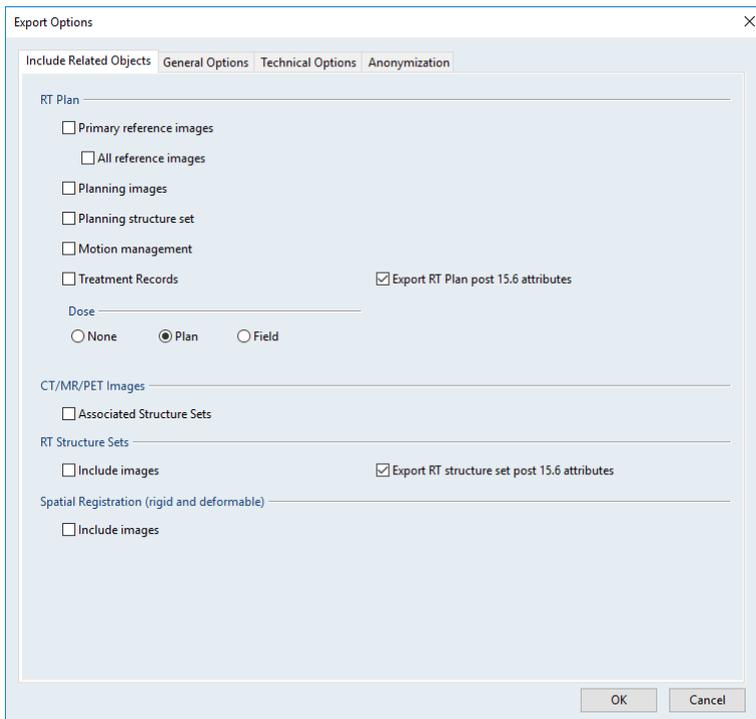
Export the 3D dose matrix:

If the isocenter coincides with the image origin, there is no need to export the dicom plan to obtain the isocenter coordinates when importing the dose into VeriSoft. You can then simply export the dicom dose by right-clicking on the dose icon and selecting 'Export':

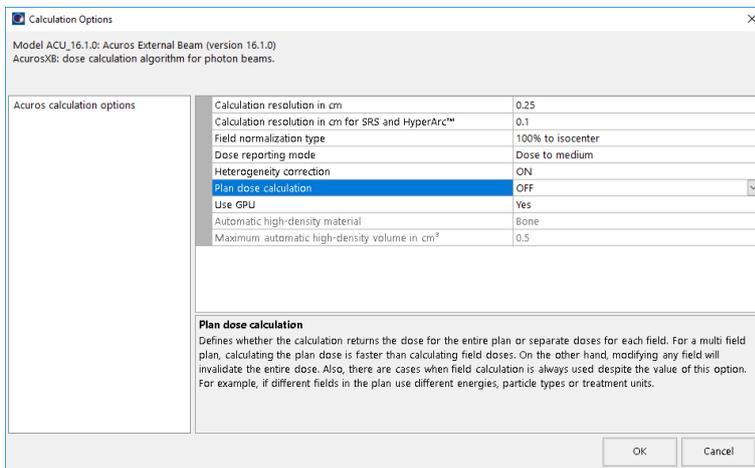


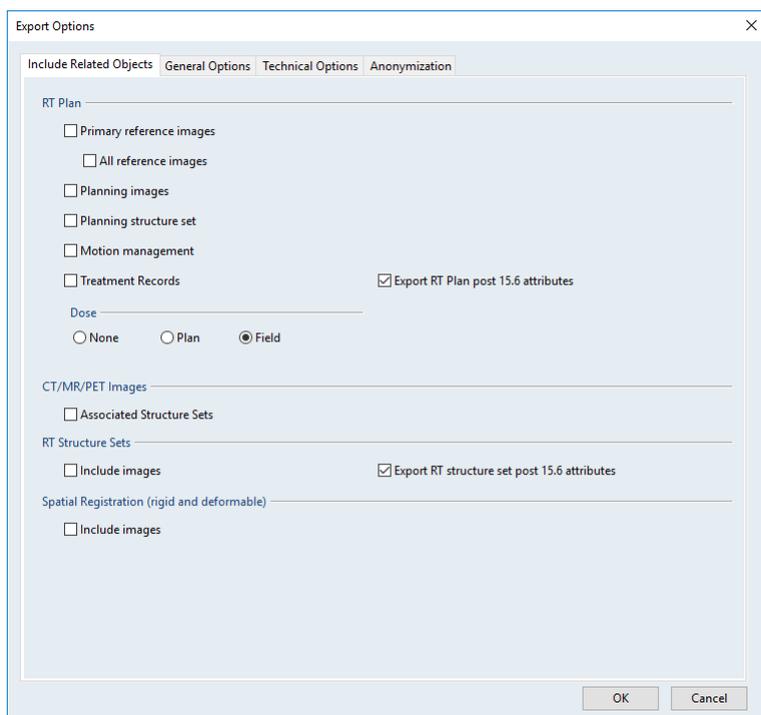
If you are going to evaluate the total plan dose rather than the individual field doses, you should select the total plan dose to be exported only:





Should you wish to evaluate or investigate the individual fields or arcs separately, you need to export the individual field doses. Beware, if you have calculated the plan dose with Acuros, individually calculated field doses are not available. If you wish to have them, it is necessary to (re-)calculate with the plan dose calculation set to 'OFF' in the Acuros dose calculation options:

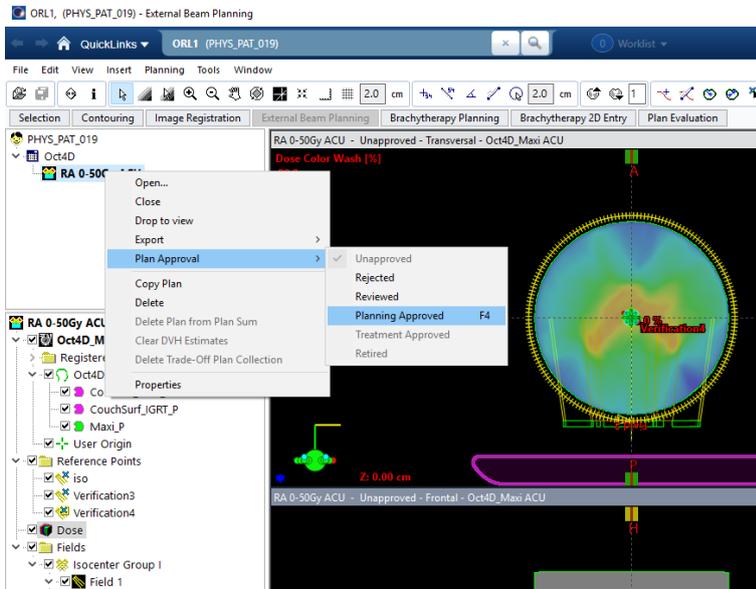




Note: If you have used a phantom for which the dcm image origin does not coincide with the isocenter, you must export both the dicom plan (RP..dcm) and dicom dose (RD.*.dcm). In this case, it is more efficient to select the verification plan, dicom export the plan and select the option of including the total plan dose in the export procedure.*

Prepare the plan for delivery at the treatment console:

You must now 'Planning approve' the plan to make it available for treatment in QA mode on the treatment console. You can either choose to 'Planning approve' the verification plan, or you can 'Planning approve' the original patient treatment plan. Both options have their pros and cons, but the two plans should in any case be identical. In the below example, we have chosen to use the patient plan for the actual delivery.



In RT Chart, make sure all parameters required for the delivery in QA mode are filled out.

4.1.2 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.

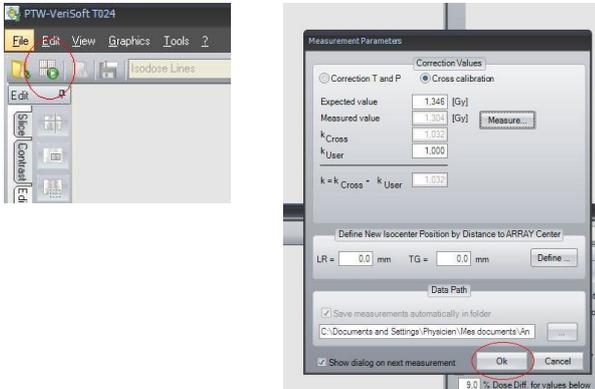
Perform the cross calibration by means of a static 10 x 10 cm² field (4 x 4 cm² for OCTAVIUS Detector 1600^{SRS}) with fixed 200 MU value, using the now famous expected dose value on the Post-it. Repeat the acquisition 3 to 4 times to make sure the system has stabilized before accepting the cross calibration measurement.

Repeat and save the static 10x10 cm² field (4 x 4 cm² for OCTAVIUS Detector 1600^{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.

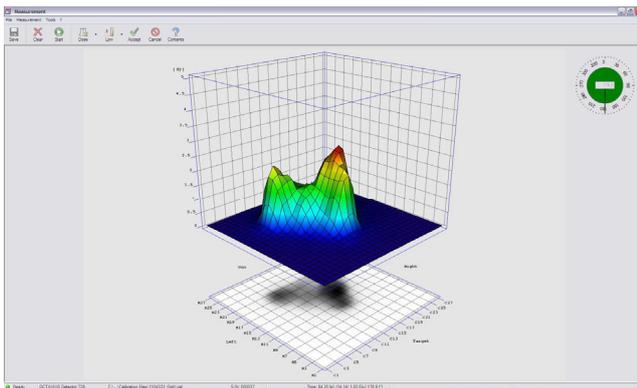
'Mode up' the plan and move the gantry to its starting position.

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.



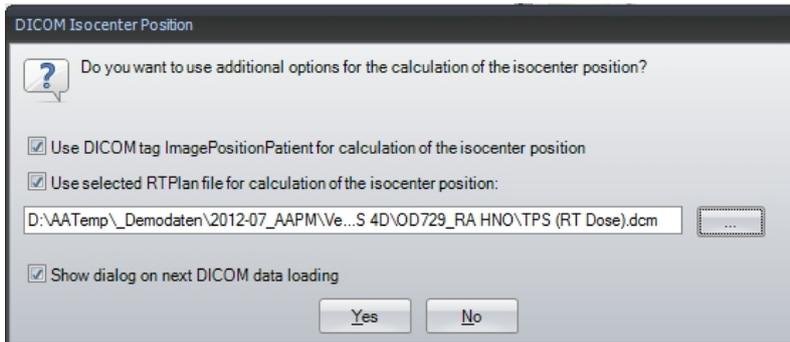
'Accept' the measurement to automatically return to the VeriSoft analysis software.

4.1.3 OCTAVIUS 4D dose evaluation

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

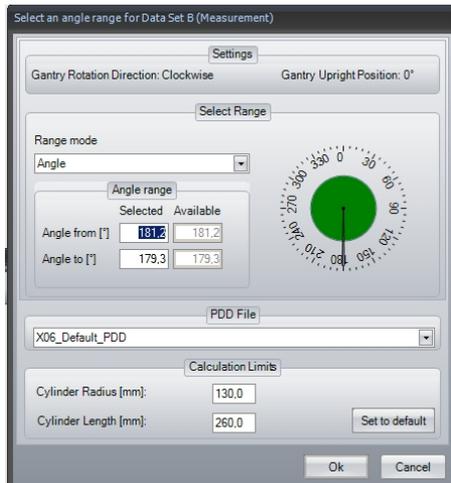
When the dcm image origin coincides with the isocenter, there is no need to import the corresponding RTplan. Selecting the first option only 'Use DICOM tag ImagePositionPatient ...' will then suffice to assure correct 3D alignment between measured and imported 3D dose.

If the dcm image origin not coincides with the isocenter select additionally the second option and select the appropriate path to the RTPlan file.



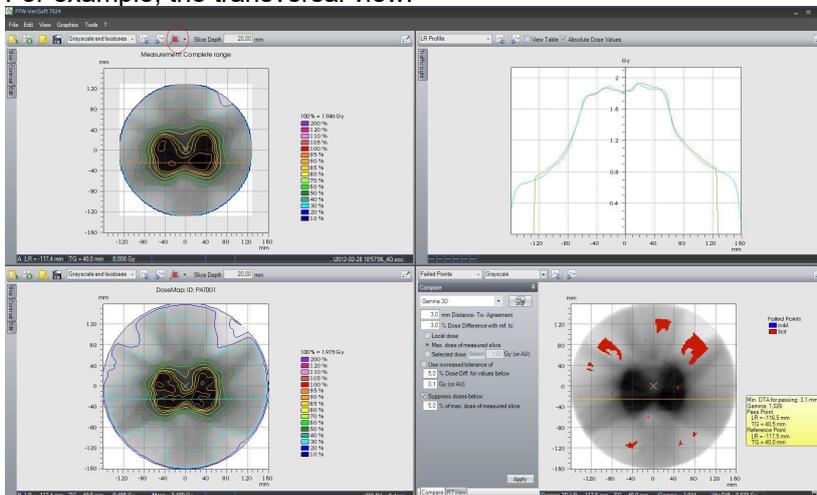
Open the measurement in 'Data Set B' window (File – Data Set B - Open... *Select your path*)
Alternatively you can start the measurement (File – Data Set B "Measure"). See 4.1.2 for details.

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:

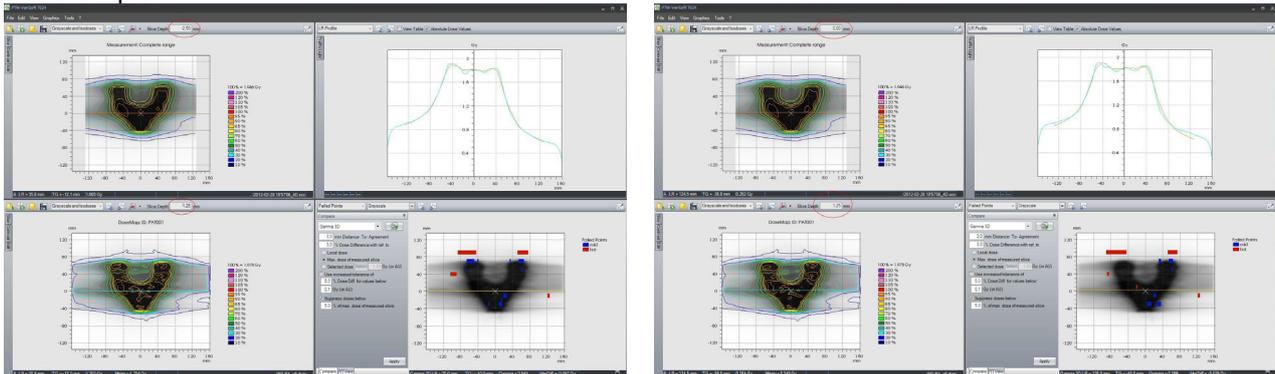
For example, the transversal view:



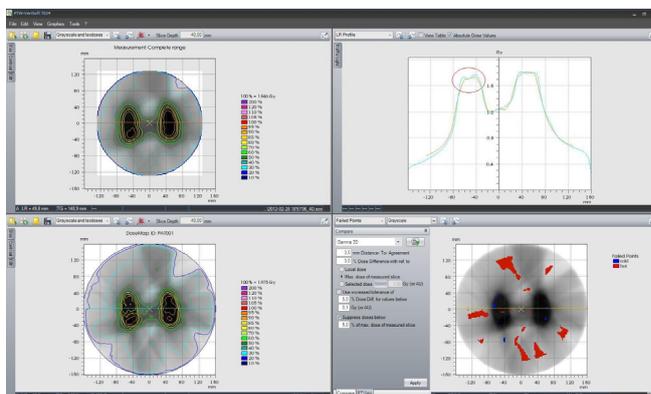
Some advice:

- 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 Eclipse.

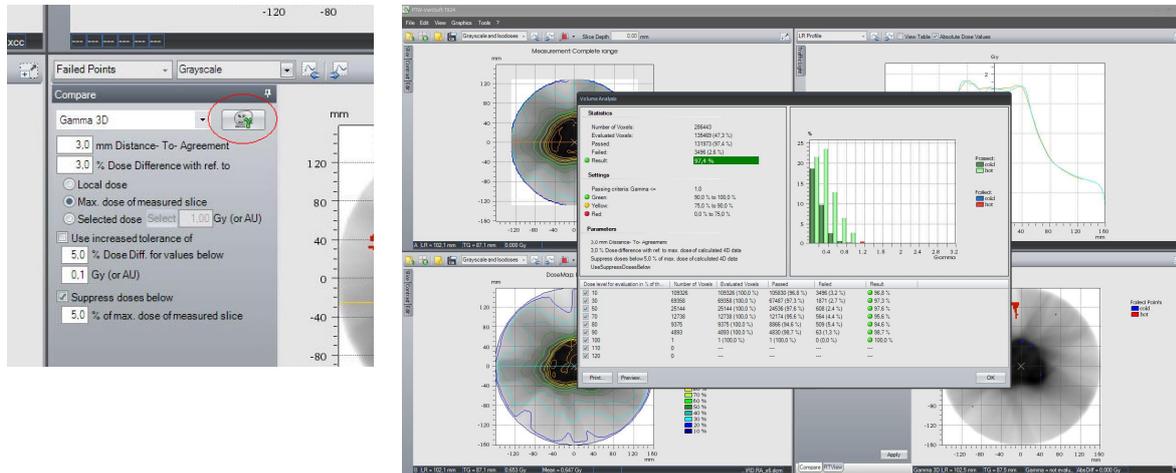
For example:



- 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 smoothed 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 Ann van Esch from 7Sigma, Belgium, 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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