Motion Control

User Manual

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Introduction

Motion Control is an application which allows you to control the movement of Model 008A Dynamic Thorax Phantom, Model 008P Dynamic Pelvis Phantom, Model 008PL Dynamic Platform, Model 18023-A Xsight® Lung Tracking "XLT" Phantom Kit, Model 18043 4D Planning "4DP" Phantom, Model 008Z MRgRT Motion Management QA Phantom, Model 008C Dynamic Cardiac Phantom and Model 008PLX Enhanced Dynamic Phantom. With the Motion Control software, you can quickly set up a movement based on a library of pre-defined motions, including Sin, Cos^4 (2*cos^4-1), Cos^6 (2*cos^6-1), Sawtooth, Sharkfin and 3D Hysteresis (only models 008A, 18023-A, 18043-A, and 008Z) or Continuous Drift, Transient Excursion, Persistent Excursion, High-Frequency Excursion, and Irregular Movement (model 008P only). Alternatively, you can import custom motion data from any tab-delimited or comma-separated text file as well as motion tracking systems native recording formats. Motion Control also allows you to save any motion to easily access the same parameters for repeated calibration and testing.

Installation

The Motion Control application requires installing the Trio PC Motion library, which allows the computer to recognize the Trio controller board in the Dynamic Phantoms. To install the Trio PC Motion library, double-click *InstallTrioPCMotion (check https://www.cirsinc.com/software/motion-control/ for the latest version of TrioPCMotion)* and follow the steps in the InstallShield Wizard.

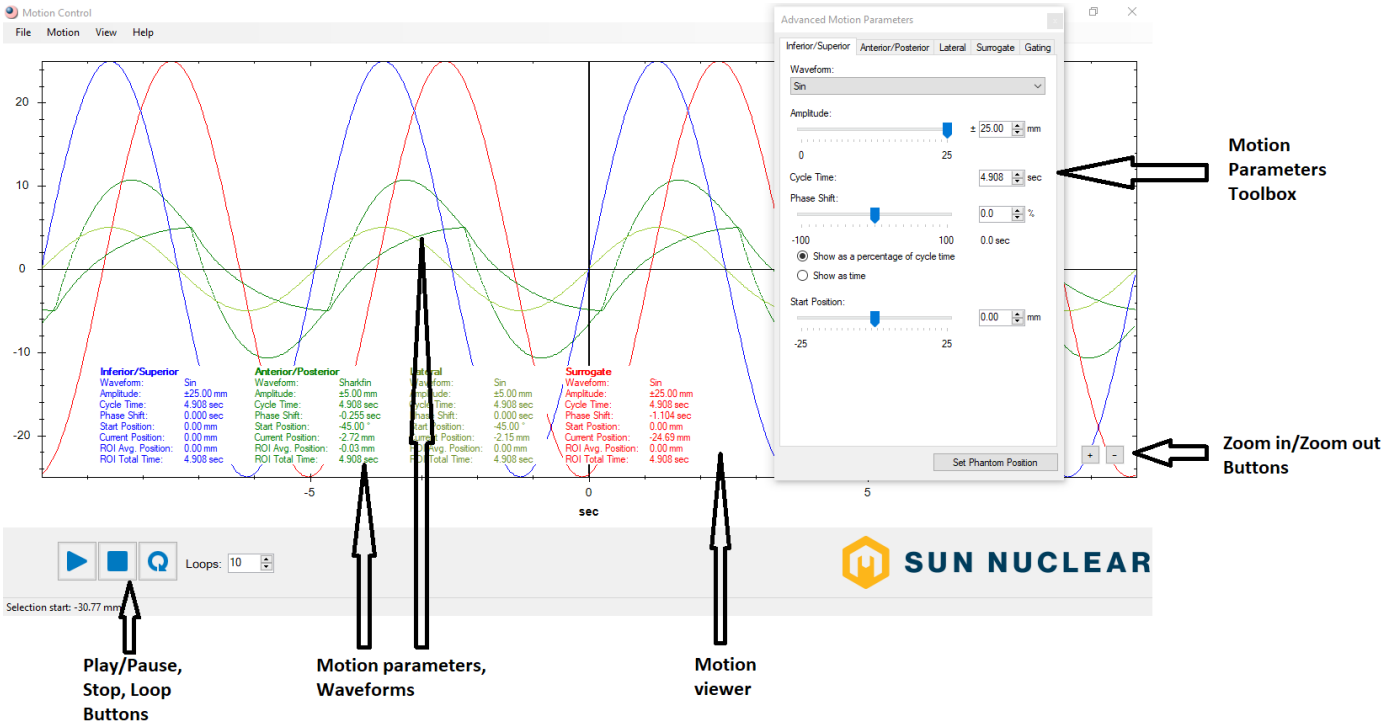
To install CIRS Motion Control, double-click *MotionControlSetup* or *Setup* and follow the steps in the Setup Wizard. The *Microsoft .NET Framework Version 4.8 is* required for the application to run.

Note

Not all software commands apply to all the phantoms that are controlled by the Motion Control software. Phantom specific commands will be identified throughout this user manual.

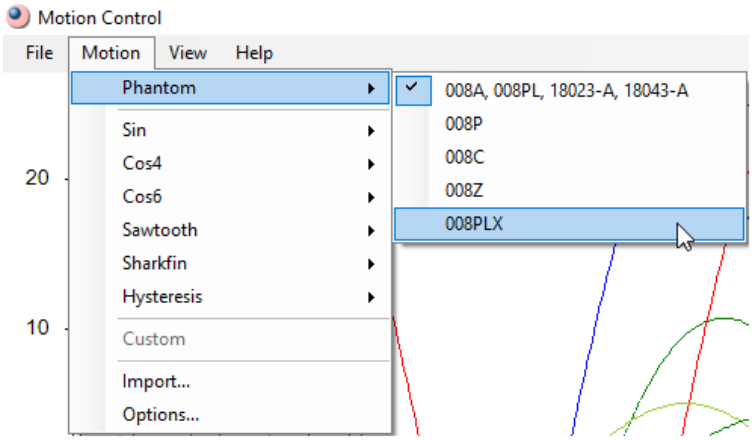
Interface

When you start CIRS Motion Control, you will see (depending on the phantom selected) the GUI (graphical user interface) shown below:



Phantom Selection

The phantom to be controlled by the software is selected from the *Motion* tab as shown below. *The 008A module* controls models 008A, 008PL, 18023-A and 18043-A. *The 008P module* controls model 008P. *The 008C module* controls model 008C. *The 008Z module* controls model 008Z and the *008PLX* module controls model 008PLX.



The *Motion Parameters Toolbox (basic and advanced)* allows you to adjust the parameters for each axis, including waveform, amplitude, cycle time, phase shift, and start position (baseline or rotational angle).

The *Motion Viewer* allows you to see both the shape of each motion as you adjust the parameters and the position of each axis as the motion runs:

For Model 008A, 18023-A, 18043-A, 008PL, 008Z and 008PLX

- The blue line and parameters in the graph represent the Inferior-Superior axis. The parameters are set using the *Linear* tab in the *Motion Parameters Toolbox*.
- The green lines and parameters in the graph represent the Anterior-Posterior and Lateral axis. The parameters are set using the *Anterior/Posterior* and *Lateral* tabs in the *Motion Parameters Toolbox*.
- The red line and parameters in the graph represent the Surrogate axis. The parameters are set using the *Surrogate* tab in the *Motion Parameters Toolbox*.
- There is no *Surrogate* tab for model 008Z.

For Model 008P

- The blue line and parameters in the graph represent the Inferior-Superior axis.
- The green lines and parameters in the graph represent the *Anterior-Posterior* axis. These parameters are set in *Motion Parameters Toolbox*. Due to geometry inherent to the mechanical design, both *Inferior-Superior* and *Anterior –Posterior* parameters are in a mathematical relationship that provides the values sent to the phantom's *Linear Actuator*, which in turn provides motion to the prostate cube insert.

For Model 008C

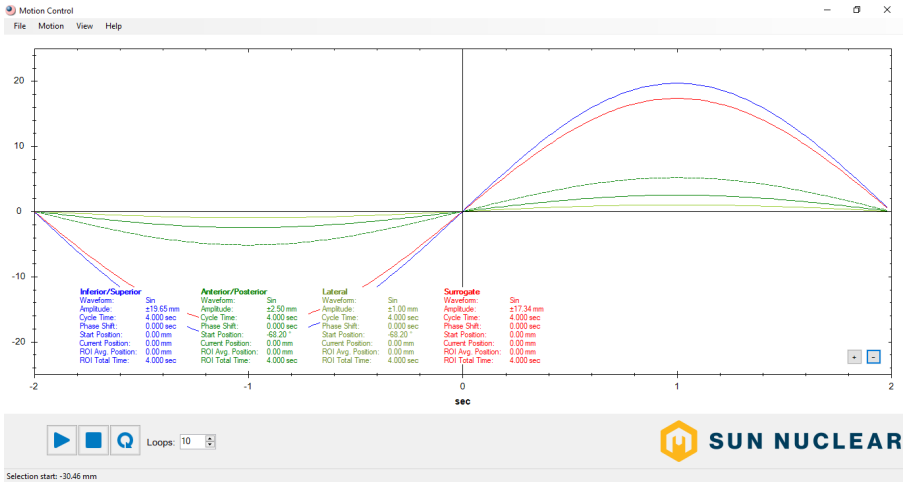
- The blue line and parameters in the graph represent the Inferior-Superior axis. The parameters are set using the *Linear* tab in the *Motion Parameters Toolbox*.
- The green lines and parameters in the graph represent the Anterior-Posterior and Lateral axis. The parameters are set using the *Anterior/Posterior* and *Lateral* tabs in the *Motion Parameters Toolbox*.
- The red line and parameters in the graph represent the Surrogate axis. The parameters are set using the *Surrogate* tab in the *Motion Parameters Toolbox*.
- The orange line and parameters in the graph represent the ECG signal, which is synchronized with the heart motion waveforms. The scale on the right side of the *Motion Viewer* is calibrated to mimic ECG signal printed on graph paper in a cardiologist's office.

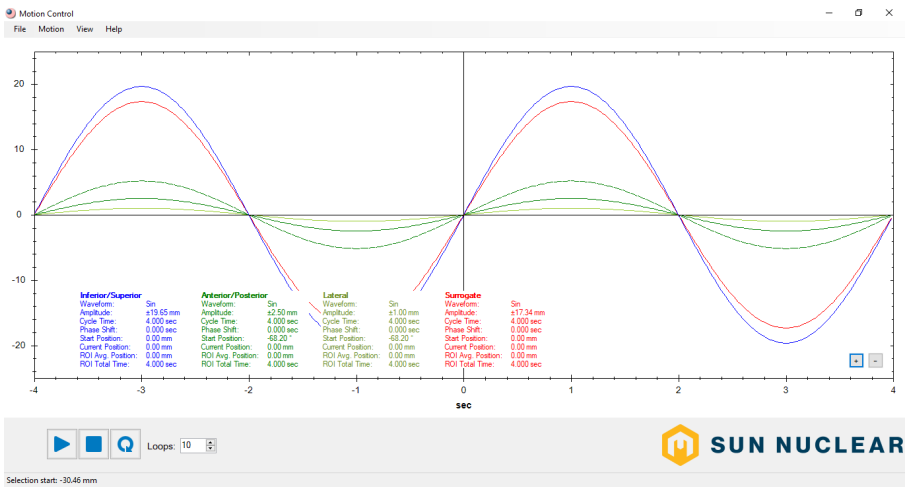
The *Play Button* starts running the motion. Once a motion is started it pauses and resumes it.

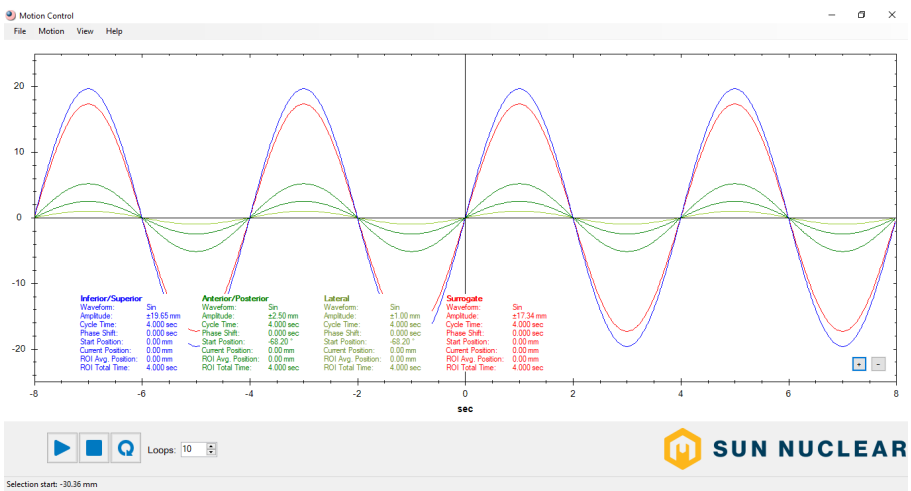
The *Stop Button* stops the running motion and returns the axes back to their starting positions.

The *Loop Button* toggles between running a motion continuously (up to 1,000,000 loops) and running a motion for the specified number of loops (up to 1000 loops).

The *Zoom in/Zoom out Buttons* allow the user to choose how many cycles are displayed in the *Motion Viewer* window by choosing between 1, 2, 4, 8 and 16 cycles.



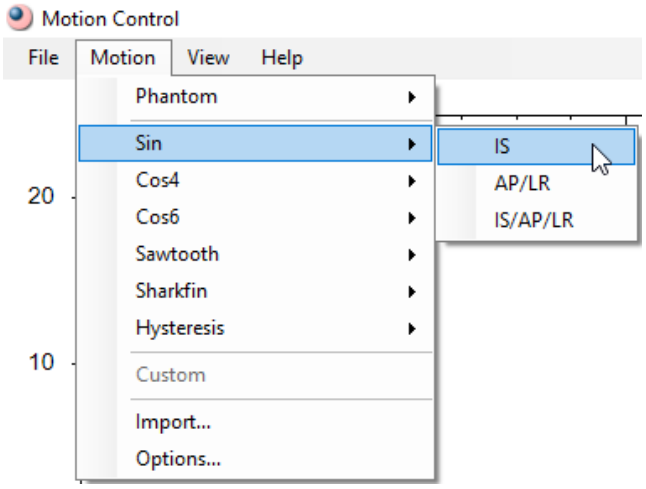




Using the Motion Library

For Model 008A, 008PL, 18023-A, 18043-A, 008Z and 008PLX

To set up a motion from the motion library, click the *Motion* menu, select the motion you want to run, and then click either *IS, AP/LR* or *IS/AP/LR*. The selected motion will appear in the *Motion Viewer*.

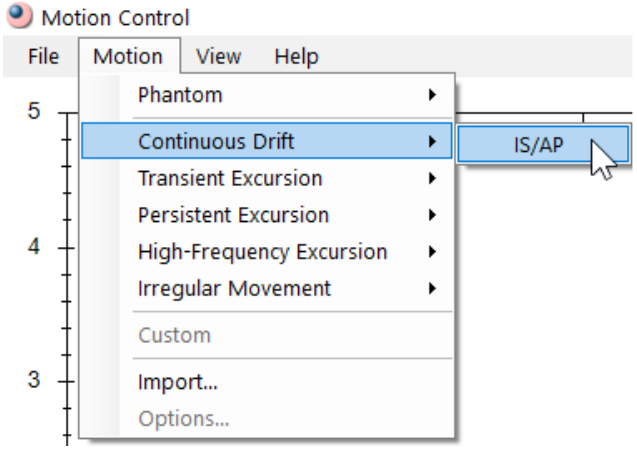


- *IS* sets up movement for the Inferior-Superior and Surrogate axes
- *AP/LR* sets up movement for the Anterior-Posterior/Lateral and Surrogate axes
- *IS/AP/LR* sets up movement for all axes (Inferior-Superior, Anterior-Posterior/Lateral and Surrogate axes)

You will not be able to set up *AP/LR* or *IS/AP/LR* movements on Dynamic Platforms (Model 008PL, 008PLX) because these phantoms do not have a physical rotational axis. Custom motions are only available when motion data has been imported from a file.

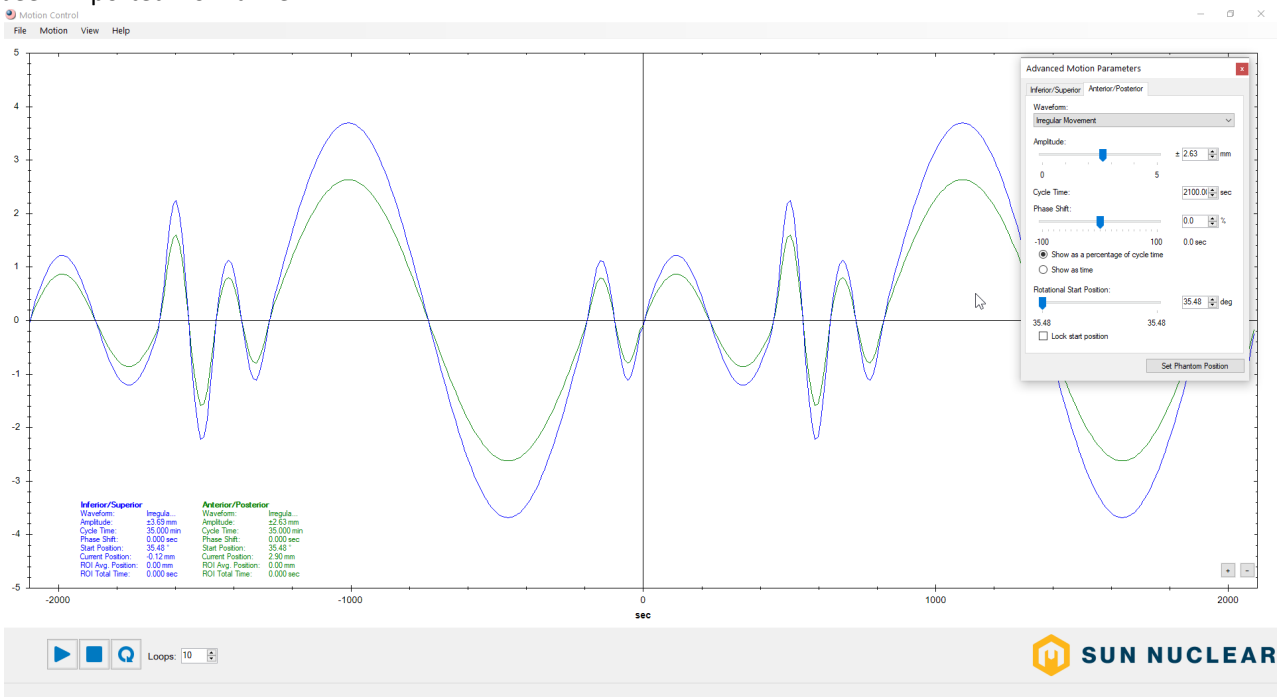
For Model 008P

To set up a motion from the motion library, click the *Motion* menu, select the motion you want to run. The selected motion will appear in the *Motion Viewer*.



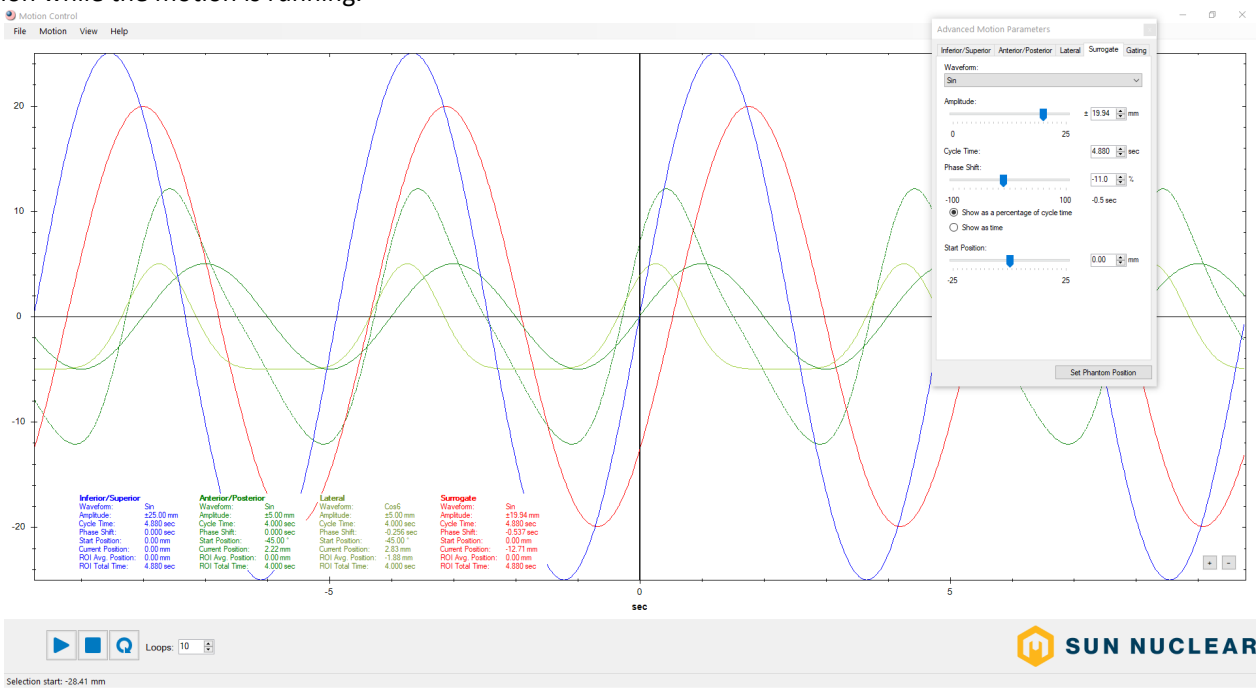
- *IS/AP* sets both *IS* and *AP* directions amplitudes of the centroid of the prostate, which are needed for the software to calculate the correct linear motion of the phantom's actuator.

As in the case of the *Dynamic Thorax module*, custom motions are only available when motion data has been imported from a file.



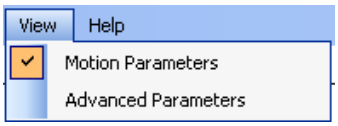
Running a Motion

To start a motion, click the *Play Button*. While a motion is running, you can click the *Play Button* to pause and resume a motion, and the *Stop Button* to stop the motion. The status bar at the bottom of the main window will indicate whether a motion is running, paused, or stopped; the number of loops that have been completed, and the running time of the motion (lower left corner). The *Motion Viewer* will update to show the real-time position of all the running axes. You will not be able to adjust the parameters of a motion while the motion is running.



Adjusting Motion Parameters

You can adjust the parameters of any motion using either the *Motion Parameters Toolbox* or the *Advanced Motion Parameters Toolbox*. You can switch between either toolbox at any time by clicking the *View* menu, and then clicking the toolbox you want to show.

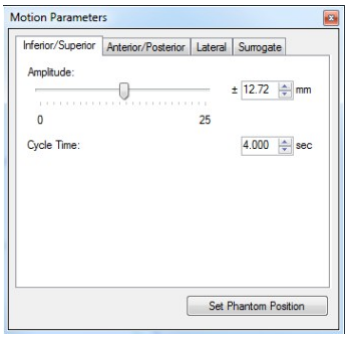


Motion Parameters Toolbox

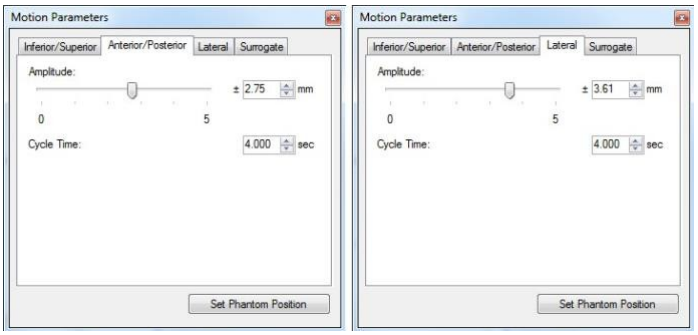
For Models 008A, 18023-A, 18043-A, 008PL, 008Z, and 008PLX

You can use the *Motion Parameters Toolbox* to adjust the basic parameters for each axis. Click the *Set Phantom Position* button to move the axes to the positions shown on the *Motion Viewer*.

The Linear tab allows you to adjust the Inferior-Superior axis amplitude and the cycle time for all three axes.

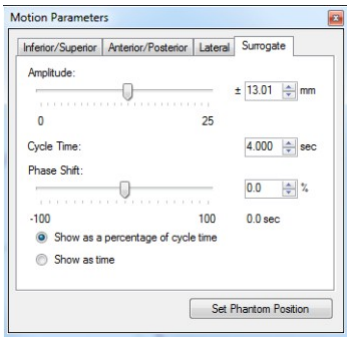


The Rotational tab allows you to adjust the Anterior-Posterior and Lateral axis amplitudes, and the cycle time for all three axes. Adjusting the parameters on the Rotational tab has no effect on the Dynamic Platform (model 008PL) due to the missing physical rotational axis.



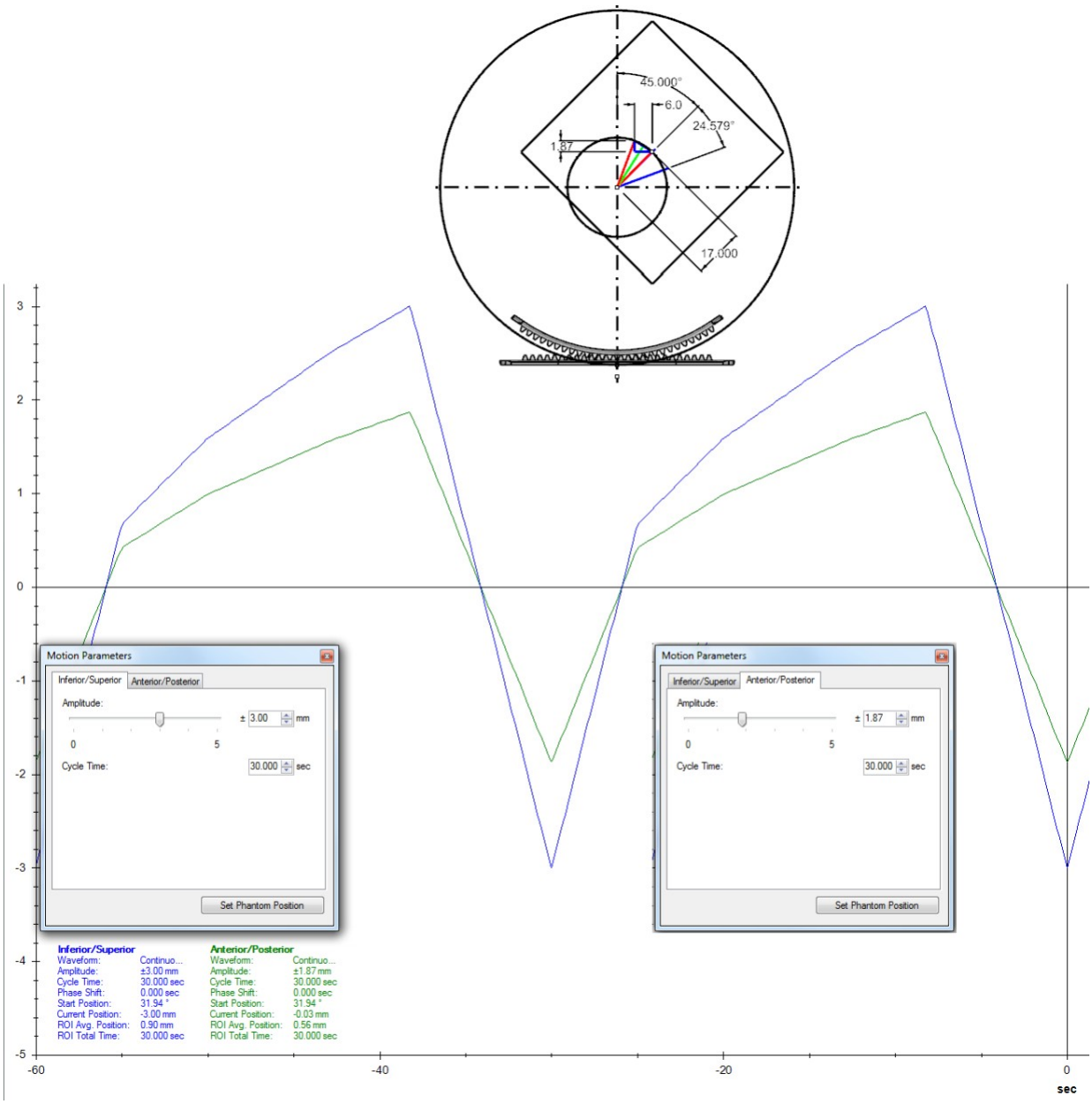
For model 008PLX: the Anterior/Posterior and Lateral motions are achievable only if the platform is set-up to use the AP Tilting plane (AP Wedge) and is rotated horizontally about the vertical axis of the couch. This means that the Anterior/Posterior and Lateral motions are mechanically related to the Inferior/Superior motion and as such any change in the motion profile for one of the motion's directions will lead to corresponding changes for the other two directions.

The Surrogate tab allows you to adjust the amplitude and phase shift of the surrogate axis, and the cycle time for all three axes.



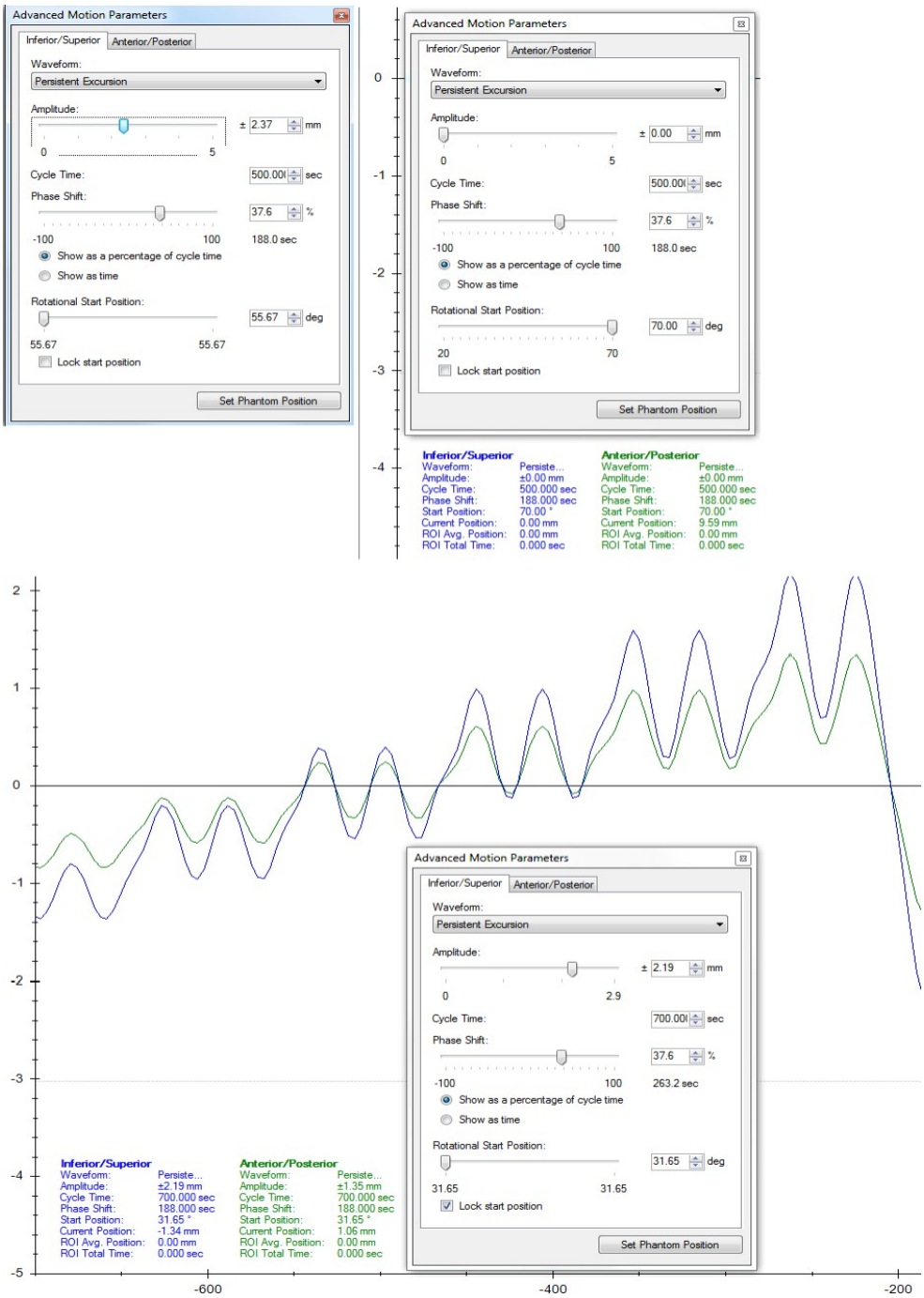
For Model 008P

The Inferior/Superior tab allows you to adjust the Inferior- Superior amplitude while the Anterior/Posterior tab allows you to adjust the Anterior-Posterior amplitude. Due to the mathematical relationship between the two components of the prostate motion shown in the sketch below, the adjustment of one of the amplitudes leads to automatic adjustment of the other amplitude. Either tab adjusts the cycle time for both components of the motion.



Adjusting the Inferior-Superior and Anterior-Posterior will set the related start position angle about which the prostate will oscillate in order to achieve these particular amplitudes.

To freely set the start position angle within its constraining range (20° to 70°), set both the Anterior-Posterior and Lateral amplitudes to zero then check the *Lock start position* box. Once the *Lock start position* box is checked the adjustment of one amplitude will adjust the other one so that the relationship *amplitudes – starting angle* is satisfied.



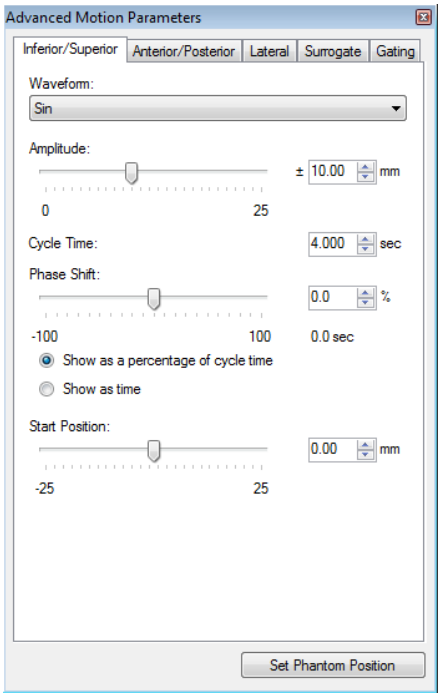
Advanced Motion Parameters Toolbox

You can use the *Advanced Motion Parameters Toolbox* to adjust all the parameters for each axis. Once done, click the *Set Phantom Position* button to move the axes to the positions shown on the *Motion Viewer*.

For Models 008A, 18023-A, 18043-A, 008PL, 008Z, and 008PLX

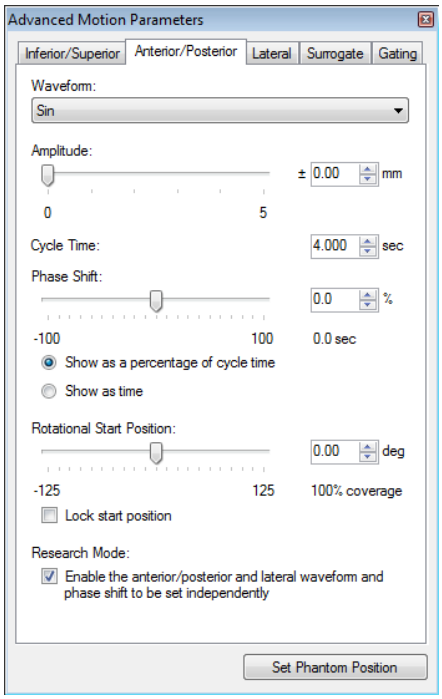
The Linear tab allows you to adjust the waveform, Inferior-Superior amplitude, cycle time, phase shift and start position (baseline) for the linear axis.

Any adjustment to the start position will also reduce the maximum Inferior-Superior amplitude because of the mechanical constraints of the Dynamic Phantoms or Platforms.

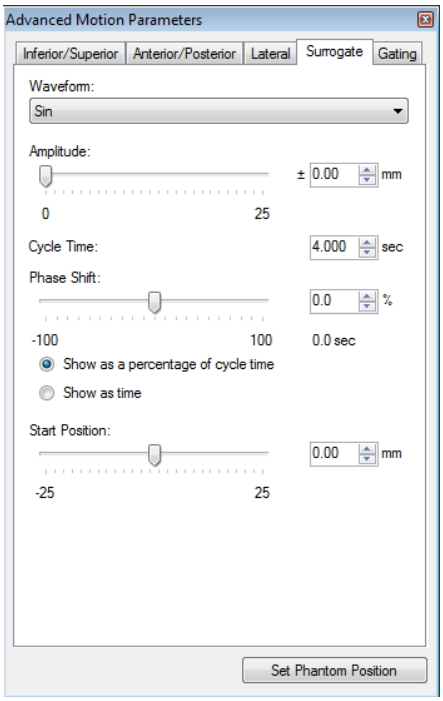


The Rotational tab allows you to adjust the waveform, Anterior-Posterior and Lateral amplitudes, cycle time, phase shift and start position (rotational angle) for the rotational axis.

Adjusting the Anterior-Posterior and Lateral amplitudes will set the related start position angle and allow you to select which quadrant to position the movement in (for models 008A, 18023-A, 18043-A and 008Z). If you click the *Lock start position* checkbox, any adjustment to either the Anterior-Posterior or Lateral amplitude will set both amplitudes at the same time in order to hold the start position angle (for models 008A, 18023-A, 18043-A and 008Z). To freely set the start position angle, set both the Anterior-Posterior and Lateral amplitudes to zero.

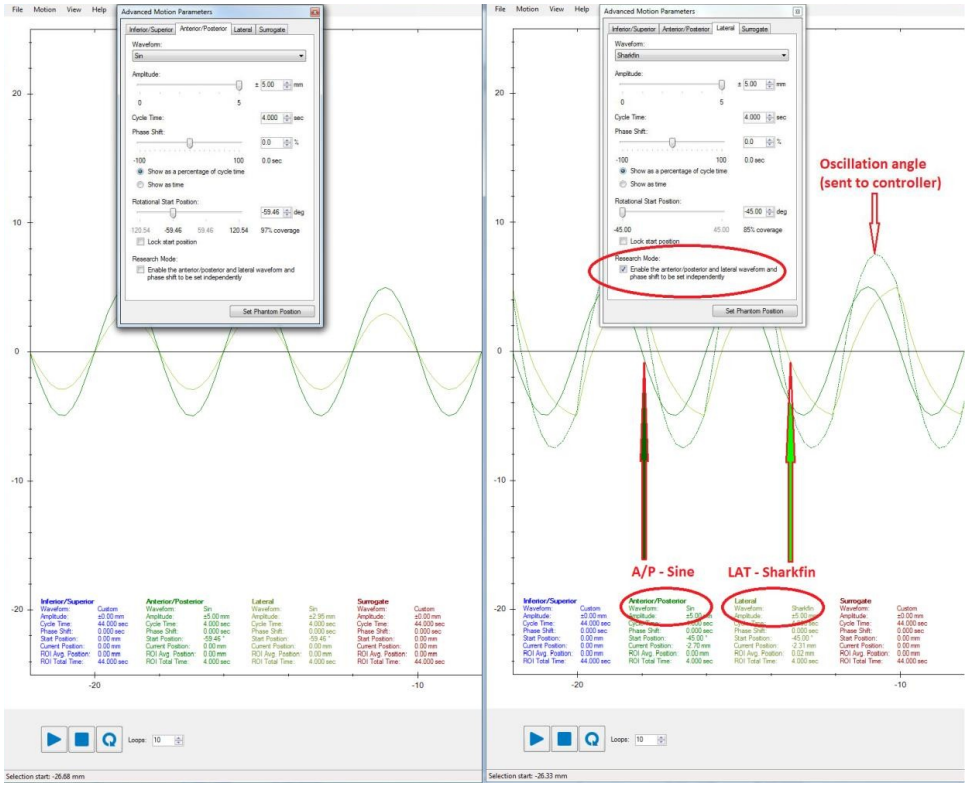


The Surrogate tab allows you to adjust the amplitude, cycle time and phase shift of the surrogate axis (not applicable for model 008Z).



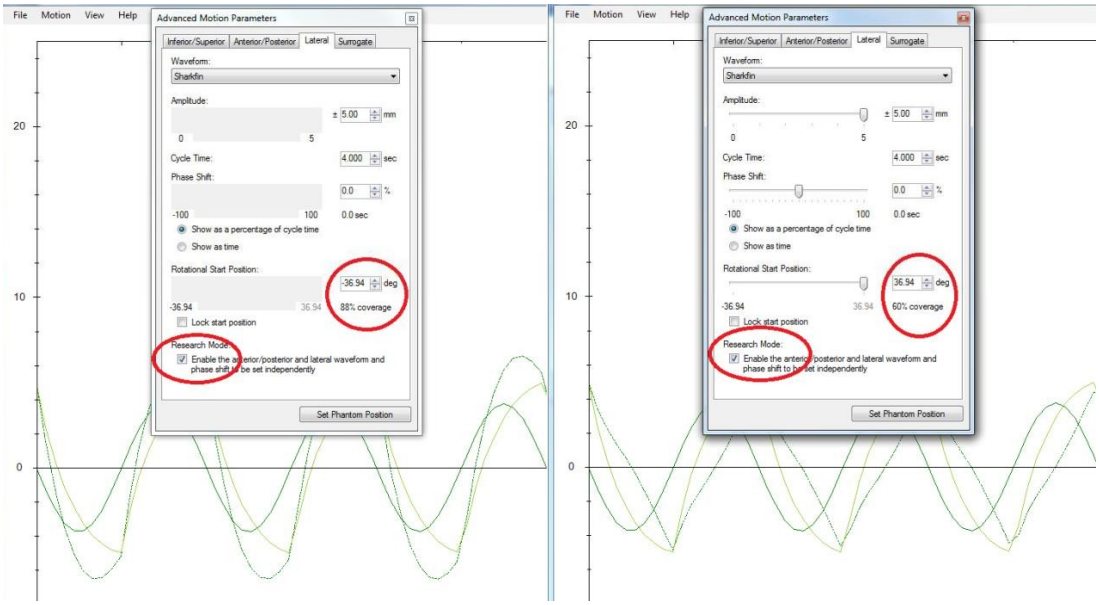
Advanced Motion Parameters Toolbox – Research Mode (for models 008A, 18023-A, 18043-A and 008Z)

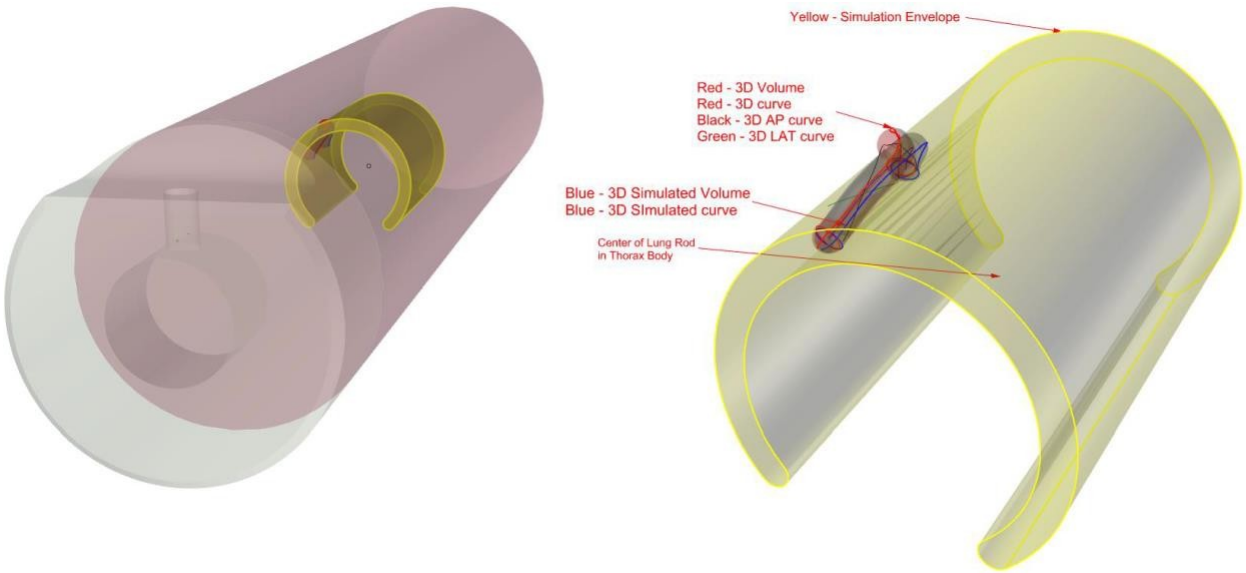
The *Research Mode* is available only from *Advanced Motion Parameters Toolbox* and allows the user to select different waveforms for *Anterior/Posterior* and *Lateral* amplitudes, which are used to calculate the Rotational Start Position and the oscillation angles about this starting angle.



The Research Mode calculates and defaults to the best scenario (angle to oscillate about) so that the maximum volumetric coverage of the real volume due to the tumor motion is achieved by the volume generated by the motion of the phantom's target. To perform the calculations the algorithm takes into account the current tumor position, the closest position achievable by the phantom's target for that point in time, along with the *Target Distance* and *Target Size* (which are setup in *Option*s menu).
Selecting the same waveform for *Anterior/Posterior* and *Lateral* amplitudes will provide the same results as if the *Research Mode* were not selected.

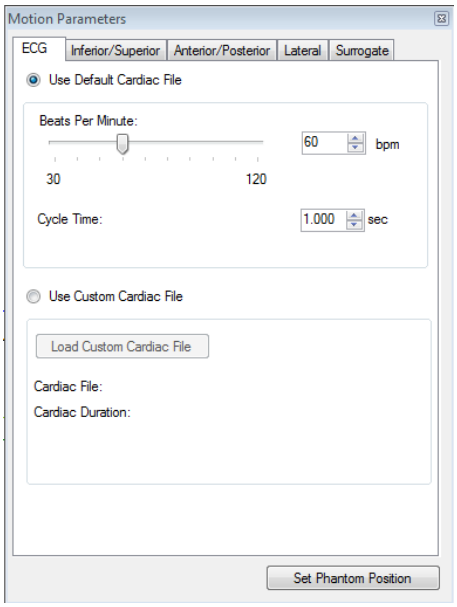
Due to symmetry of the arc of the circle on which the phantom's target can rotate, there are either two or four possible angles about which the target can rotate to achieve the *Anterior/Posterior* and *Lateral* amplitudes. Due to mechanical limitation of the phantom's design, if two symmetry angles fall into the safe zone of the moving rod rotation, which is located each side of 180° (0° is at zenith), then only two Rotational Start Position angles are available.


File Motion View Help
Advanced Motion Parameters
Inferior/Superior Anterior/Posterior Lateral Surrogate
Waveform:
Sharkfin
Amplitude:
± 5.00 mm
Cycle Time:
4.000 sec
Phase Shift:
0.0 %
0.0 sec
Show as a percentage of cycle time
Show as time
Rotational Start Position:
-36.94 deg
88% coverage
Lock start position
Research Mode:
Enable the anterior/posterior and lateral waveform and phase shift to be set independently
Set Phantom Position
60% coverage
20
10
0

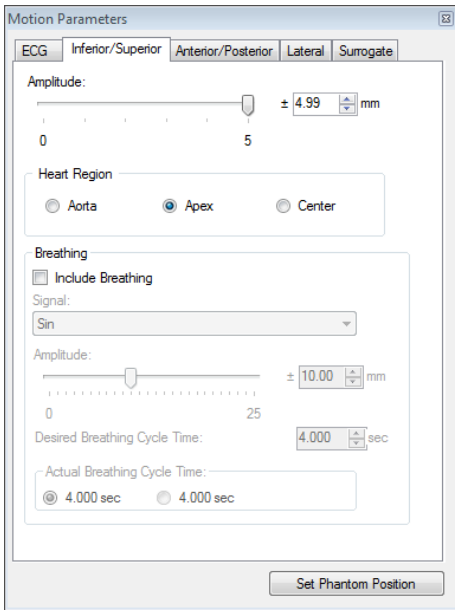

Yellow - Simulation Envelope
Red - 3D Volume
Red - 3D curve
Black - 3D AP curve
Green - 3D LAT curve
Blue - 3D Simulated Volume
Blue - 3D SImulated curve
Center of Lung Rod
in Thorax Body

For Model 008C

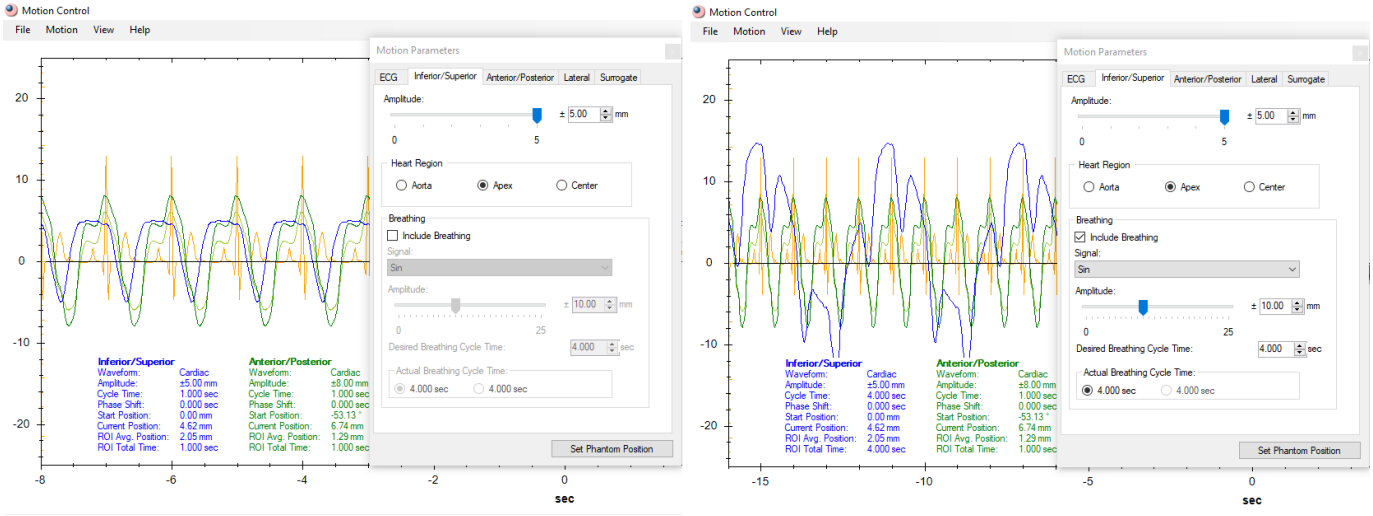
The ECG tab allows you to select the desired beats per minute rate (BPM). If no adjustments are made to the BPM the phantom will run at 60 BPM.
The ECG tab also allows the end user to import Custom Cardiac files that can be created to simulate various abnormal ECG signals. The rules and suggested way to create such Custom Cardiac files are presented in the *008C Apendix*



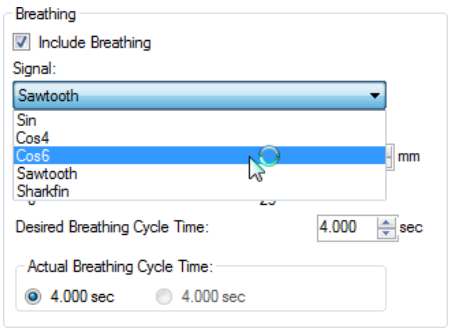
The Linear Inferior/Superior tab allows you to adjust Inferior-Superior amplitude of the motion profile of a heart region, Aorta, Apex (default) and Center respectively.

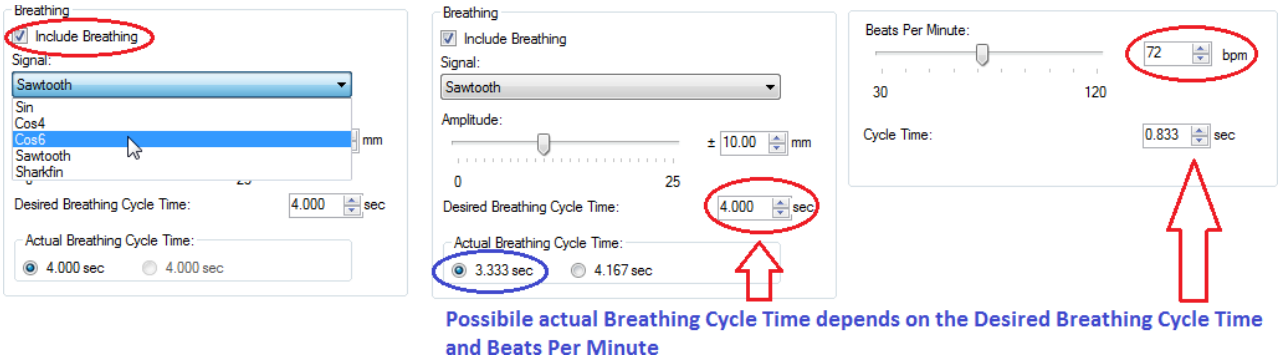


The Linear Inferior/Superior tab allows also the user to account for the movement of the heart due to the breathing.



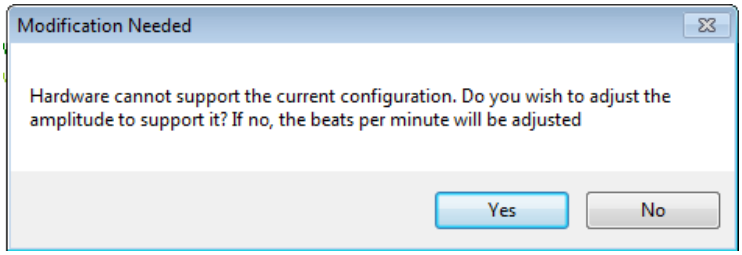
When the Include Breathing is selected in the Breathing section of the Inferior/Superior tab the heart moves in Inferior/Superior direction based on a waveform that results by adding the motion waveform due to heart beating to a built-in breathing waveform specific to the Dynamic Thorax. The built-in breathing waveform is selected from a drop-down box. Users can adjust the amplitude and the cycle time of the breathing. Based on breathing cycle time and heart rate (BPM) the actual possible cycle time of the breathing is calculated automatically.



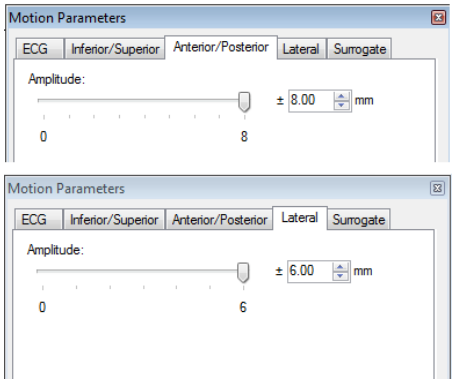


Note: There might be cases when the waveform to be run that when Include Breathing is selected requires accelerations/decelerations greater than the ones supported by the linear step motor. For such cases the user is presented with a Modification Needed *message windows upon pressing the Play button. There are two choices available.*

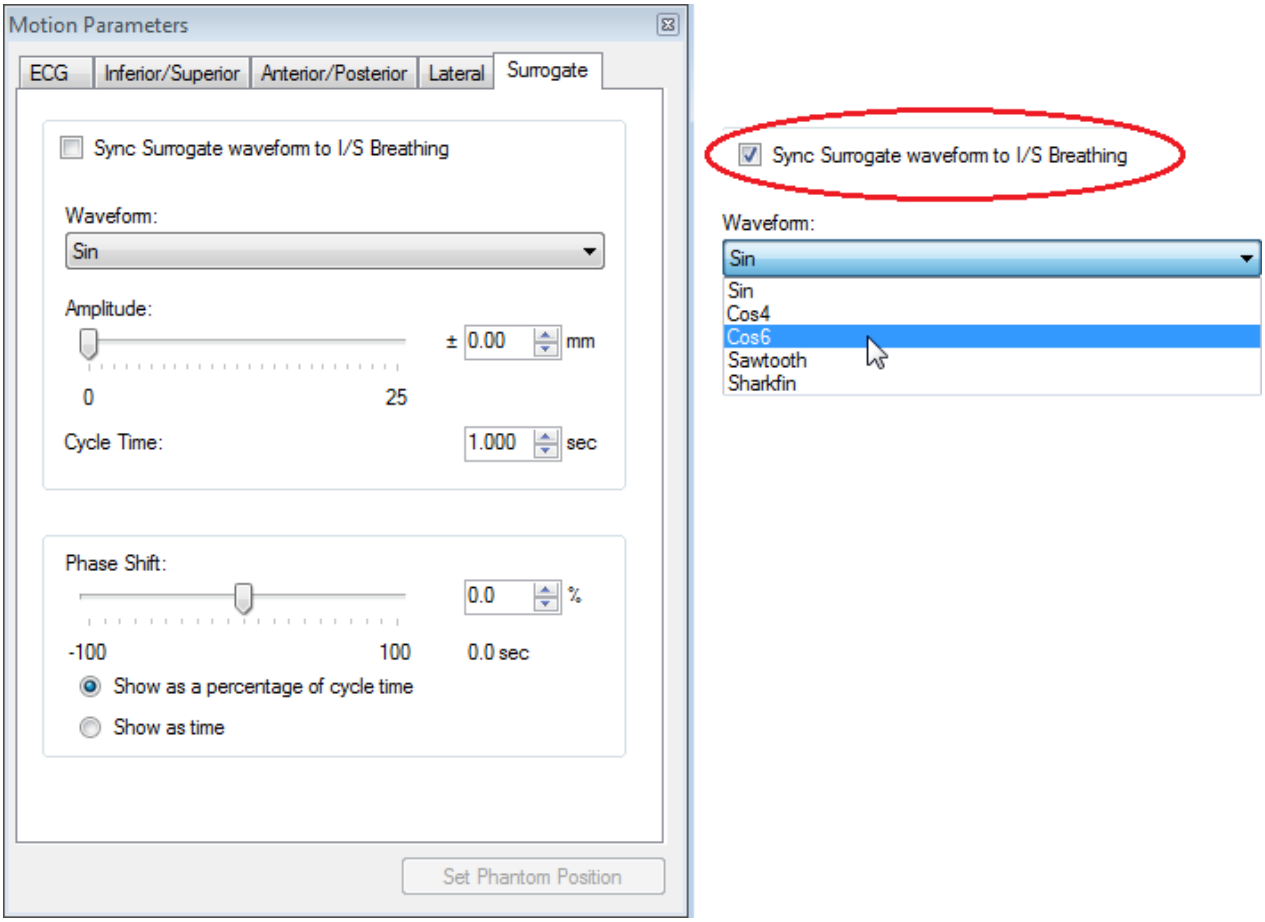
1. *Select Yes: Heart rate (BPM) is preserved while the amplitude is adjusted so that accelerations/decelerations required by running the waveform are less than maximum supported by the hardware.*
2. *Select No: Heart rate (BPM) is adjusted while the amplitude is preserved so that accelerations/decelerations required by running the waveform are less than maximum supported by the hardware.*



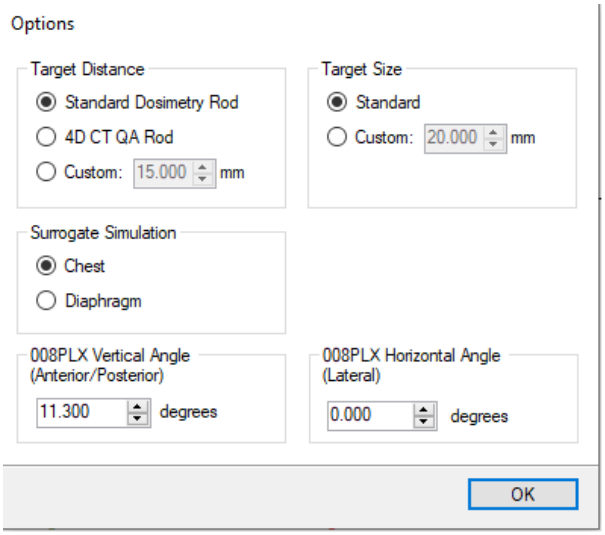
The Rotational tabs allows you to adjust the Anterior-Posterior and Lateral amplitudes.

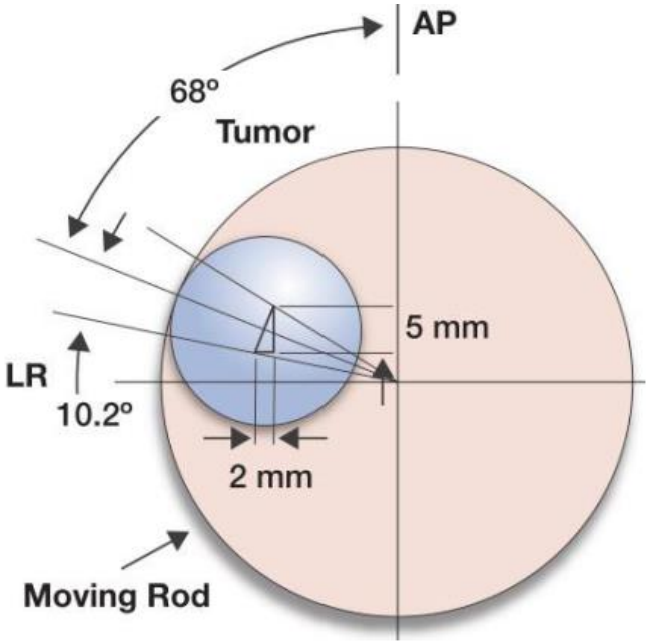


The Surrogate tab allows you to adjust the amplitude, cycle time and phase shift of the surrogate axis similar. The built-in breathing specific waveforms (the very same waveforms that are built-in for the model 008A Dynamic Thorax) can be selected from the drop-down box. In addition, you can select to have the Surrogate axis run the same waveform and parameters as the ones for the Inferior/Superior breathing by checking the Sync *Surrogate waveform to I/S Breathing* providing that the *Include Breathing* was selected in the *Inferior/Superior* tab.



Models 008A, 18023-A, 18043-A, 008Z, and 008PLX Options





The O*ptions menu* is launched from the tab *Motion* and contains overwriting parameters, which are read by the software's modules in order to perform the correct simulations and tumor position calculations.

- *Target Distance* sets up the distance between center of target and longitudinal axis of moving rod (Rotation axis; for models 008A, 18023-A, 18043-A, and 008Z)
  - *Standard Dosimetry Rod* is the distance used for all moving rods except for the 4D CT QA Rod. The default value of this parameter is 15mm. The default value of this parameter is 10mm for the moving rod of Model 008Z.
  - *4D CT QA Rod* is the distance from axis of rotation to cylindrical surface of inner moving rod, top of high contrast fiducial respectively. The default value of this parameter is 22.825mm.
  - *Custom* can take any value between 10mm and 100mm and is designed for research purposes.

- *Surrogate Simulation* allows the surrogate platform to simulate the chest when the surrogate actuator is attached in a vertical position to the liner actuator or the diaphragm when it is attached in a horizontal position. The appropriate selection of this parameter will ensure that the surrogate platform moves in the correct direction for a supine orientation (for models 008A. 18023-A, 18043-A, 008PL, and 008PLX).

- *Target Size* is used by the *Research Mode* algorithm to calculate the volumetric percentage coverage (for models 008A, 18023-A, 18043-A). The default value of this parameter is 20m.

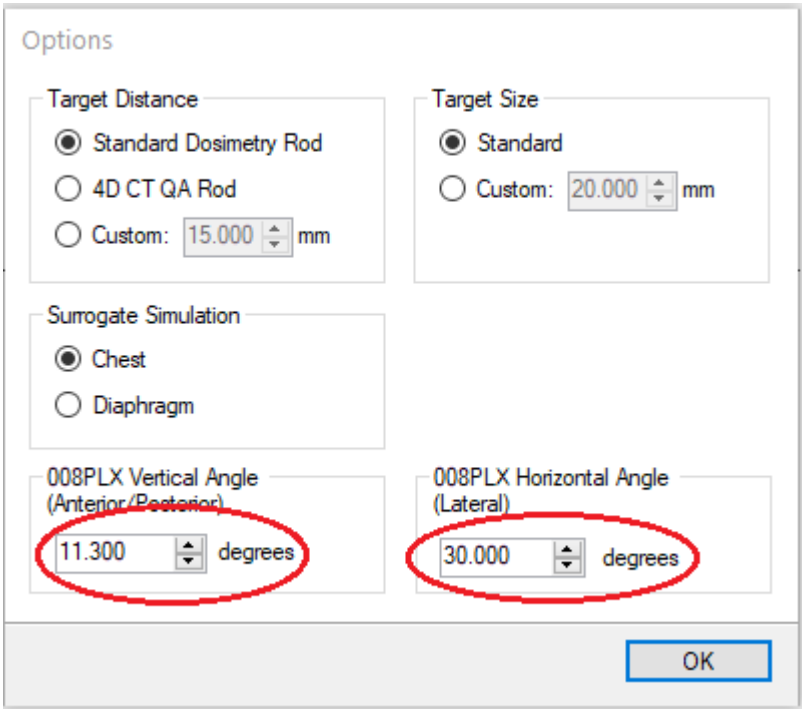
Note: - *Model 008Z doesn't use a 4D CT QA Rod or allows for Custom ones. Therefore, the Standard Dosimetry Rod should be checked only for this phantom.*

- *Model 008Z doesn't need a Surrogate since it is designed for real time motion tracking with MR imaging and as such there is no Surrogate Simulation for it. Also, the* Standard Dosimetry Rod *for model 008Z is 10mm due to the simulated tumor sizes.*
- *Because the* Target Distance *is not changed when a new phantom is selected, it is recommended that the desired* Target Distance *is set up in the* Options *every time a new phantom is selected.*

For Model 008PLX

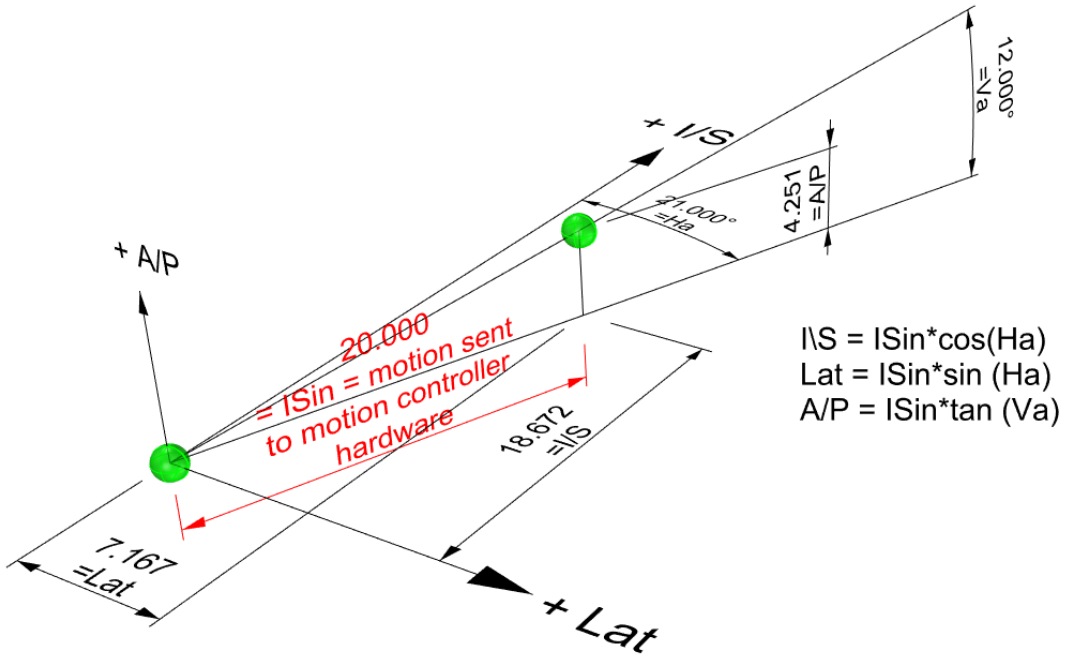
Model 008PLX can be set up so that its *moving plate* (on which phantoms or measuring devices are placed so that they account for motion) moves parallel to a linac's couch or at different angles with respect to the couch. There are four possible different setups:

- 008PLX with its moving plate parallel to the couch => input 0° in 008PLX Vertical Angle box and in 008PLX Horizontal Angle box
- 008PLX with its moving plate parallel to the couch but also moving in AP direction due to the use of the AP wedge => input 11.3° in 008PLX Vertical Angle box and 0° in 008PLX Horizontal Angle box
- 008PLX with its moving plate moving at 30° with respect to the longitudinal axis of the couch but no movement in AP direction (no AP wedge use) => input 0° in 008PLX Vertical Angle box and 30° in 008PLX Horizontal Angle box
- 008PLX with its moving plate moving at 30° with respect to the longitudinal axis of the couch but also moving in AP direction due to the use of the AP wedge => input 0° in 008PLX Vertical Angle box and 30° in 008PLX Horizontal Angle box



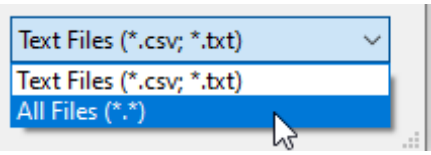
Note:

- *The 008PLX Vertical and Horizontal Angles are values that are stored from one running session to another one. Therefore, if the setup of model 008PLX is changed the user must change these values in concordance with the physical setup of the phantom.*
- *The motion of the moving plate of 008PLX in IS, AP and Lateral is obtained through physical/mechanical means (the AP Wedge and the horizontal setup at 30°) so that the software will use the trigonometric relationships between the linear motion of the actuator to calculate the actual motion in IS, AP and lateral direction based on the angles inputted for the 008PLX Vertical and Horizontal angles. To account for possible 008PLX-couch spatial orientation the user can input any value between 0° and 15° for the 008PLX Vertical Angle and between 0° and 30° for the 008PLX Horizontal Angle.*
- *008PLX cannot be programmed to achieve motion profiles (waveforms) for the IS, AP and Lateral directions that are different due to the mechanical connections mentioned above. Therefore, any change to the motion parameters to one of any of the motion directions leads automatically to changes to parameters for the other two motion directions. The motion profile of the Surrogate is however programmed independently from that of the moving plate.*

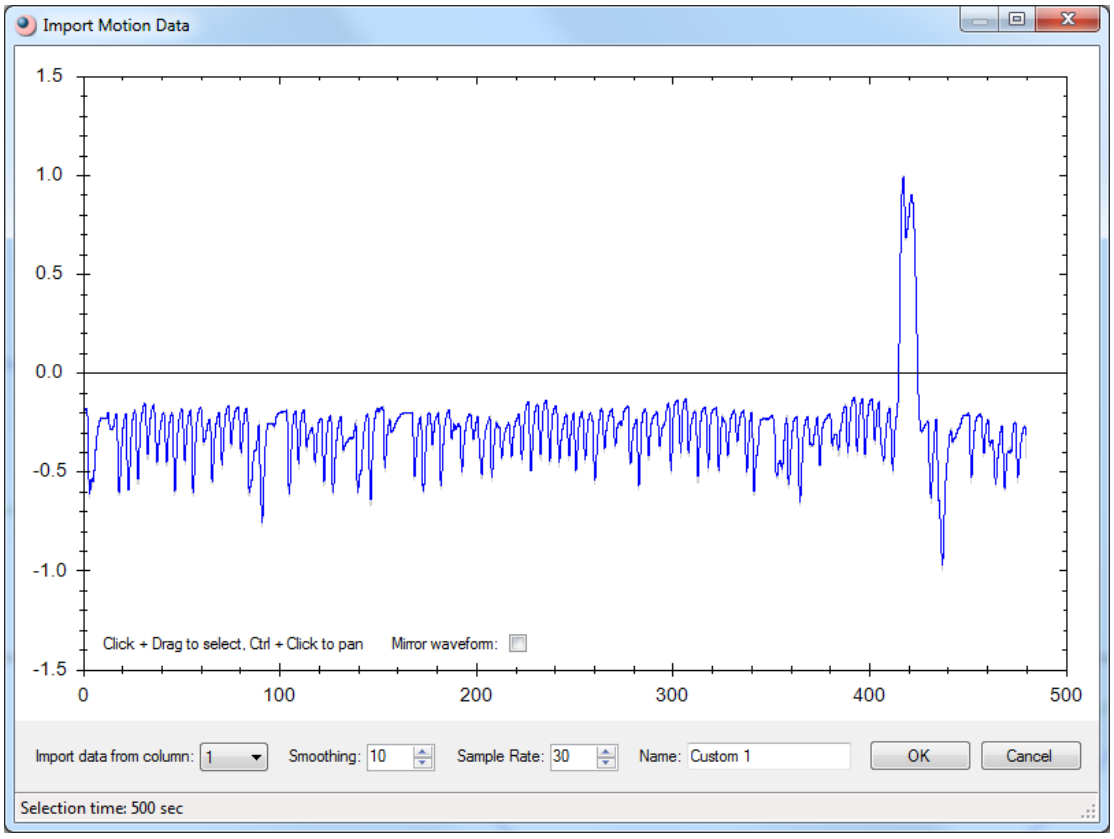


Importing Motions

You can import motion data from any tab-delimited, comma-separated or other fixed column format text file. To import motion data, click the *Motion* menu and then click *Import*. If you don not see your native format recorded file select All Files in the *Import Motion* window.



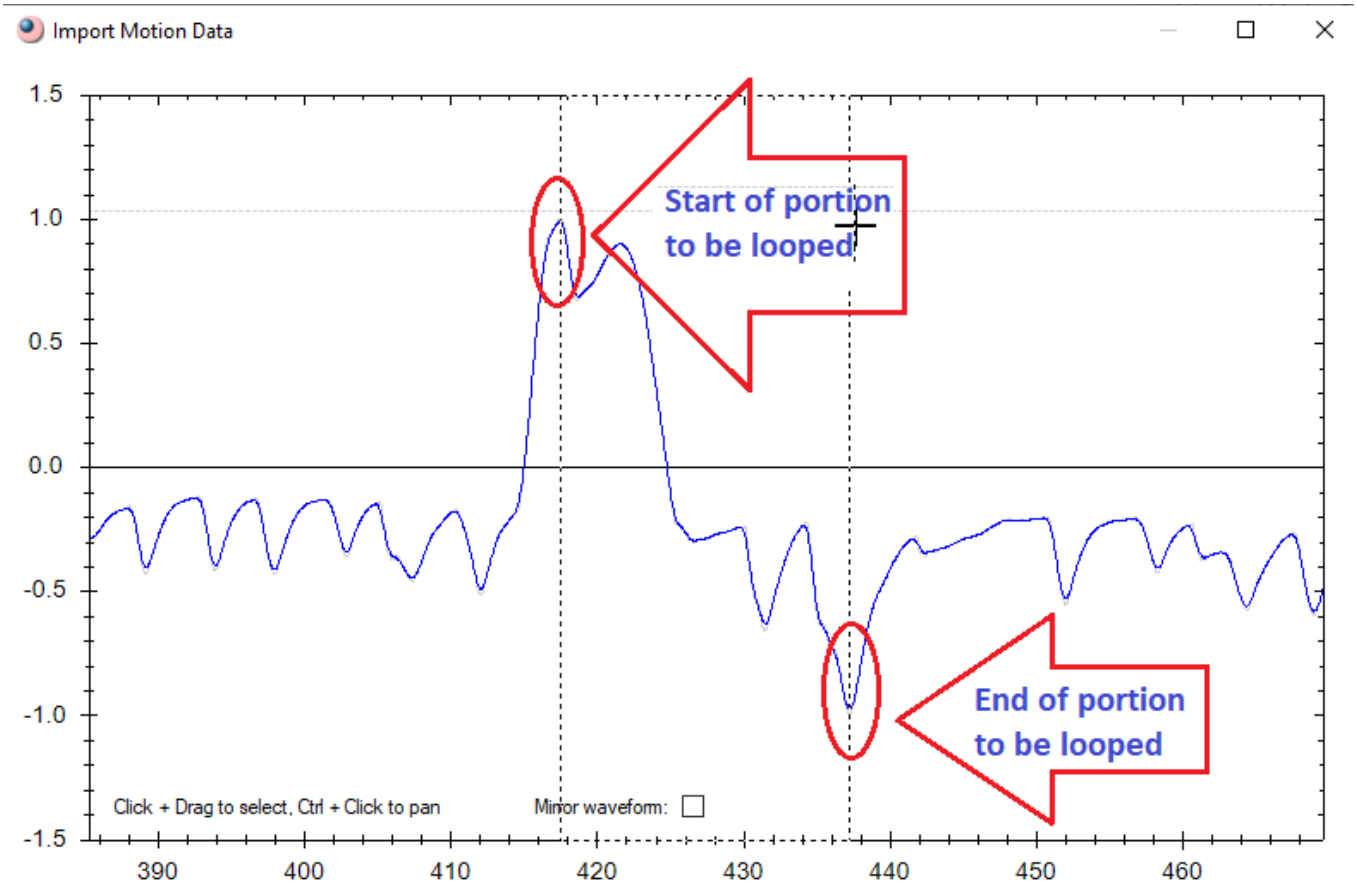
Then select the file you want to import motion data from and then click the *Open* button. You can view any column of data that appears in the file in the *Import Motion Data* window:



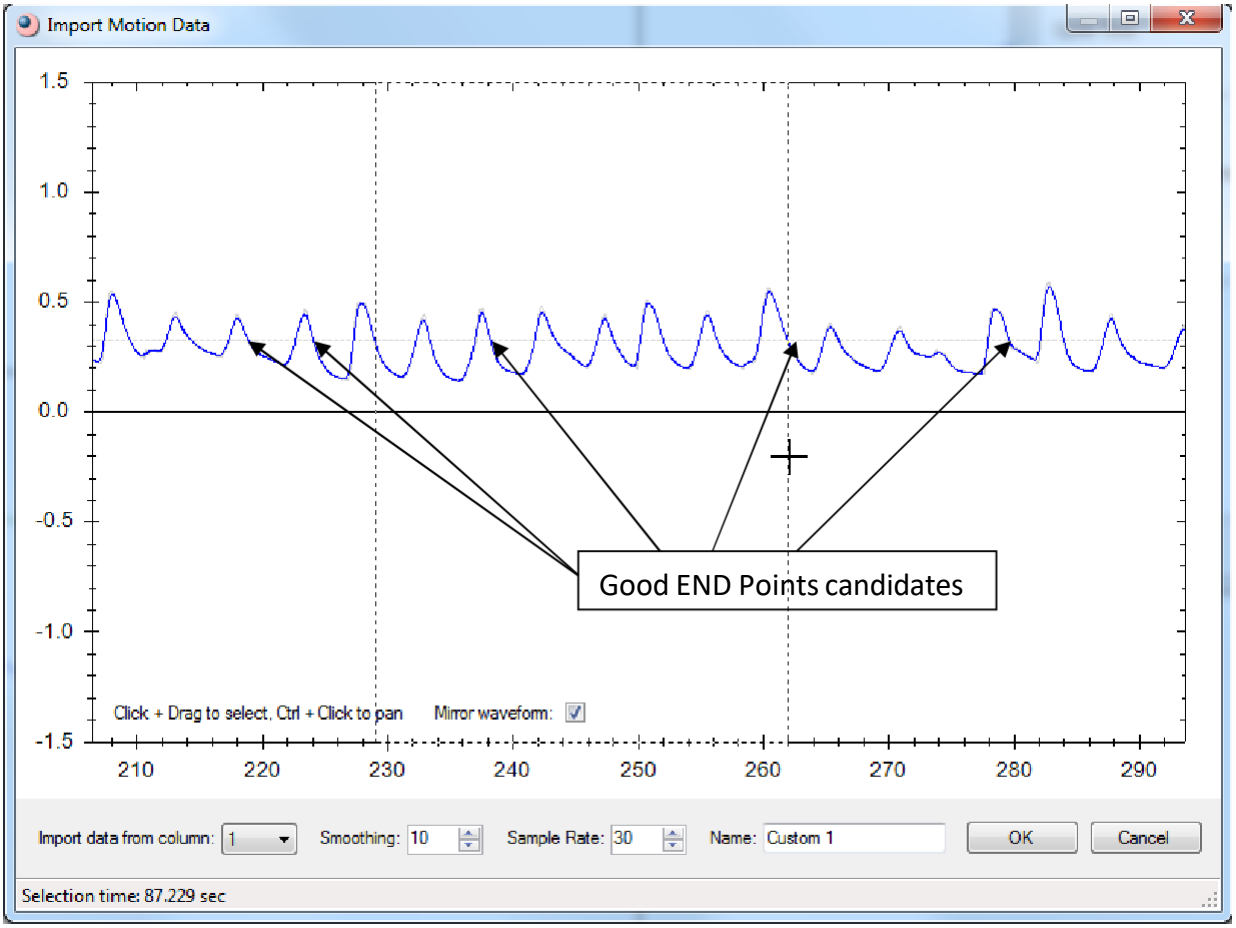
Because the software allows different waveforms to run for each of the phantom's axes, the user has to import the data from each column, which contains tumor positions in a 3D space, separately in order to be able to select the appropriate waveform for each of the phantom's motions.

If the file has more than one column of data, you can select which column to view by clicking the *Import data from column* drop-down box. The gray line in the graph represents the actual data from the file. The blue line represents the data that has been smoothed. The data is smoothed using a rolling average, and you can adjust the amount of smoothing (from degree 0, which is equal with the raw data to 100). The smoothing degree is set by default to 10.

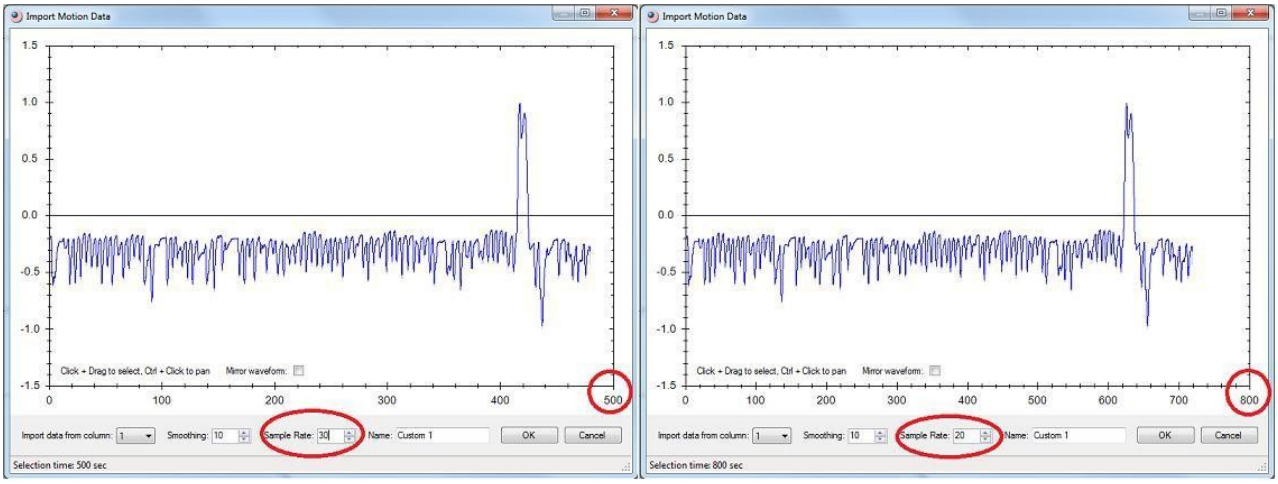
When importing only a portion of the patient specific recorded data it is recommended that user selects the START and END points so that they have close amplitudes. Selecting START and END points with very different amplitude will cause the system to fill-in between the END and START points when the looping function is used (see the following screenshots).



This fill-in will therefore modify the original data and such its extent should be minimized as much as possible. If the left mouse button is kept pressed when the START point is selected a horizontal line is created, which crosses the data at the same amplitude. Counting either side of the START point all even intersection points are therefore good candidates for being the END point. Keep the left mouse button pressed while moving along the horizontal line to select an END point, which is done by releasing the mouse left button.

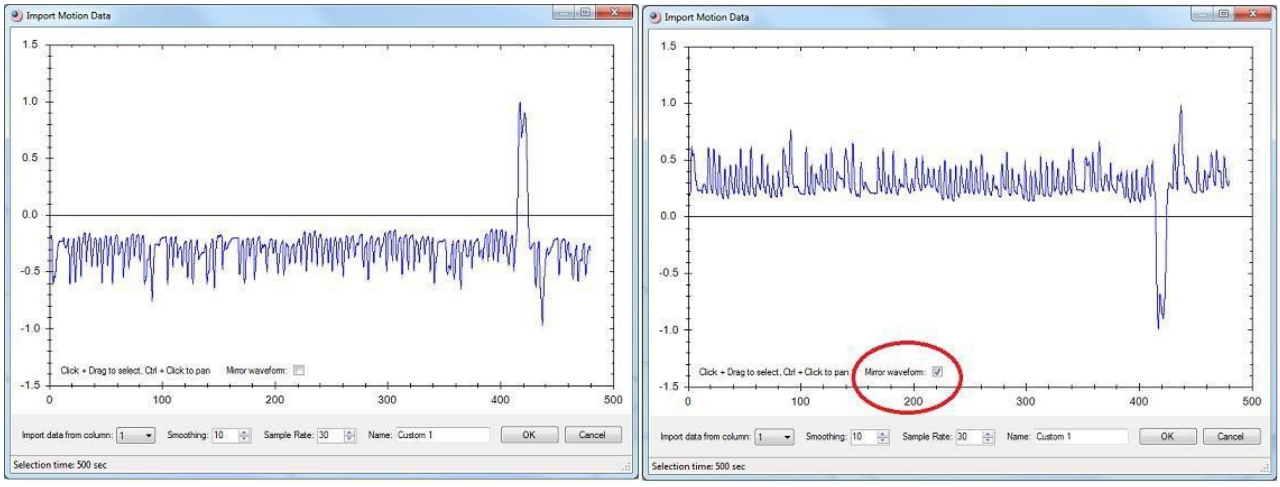


The *Sample Rate* is the sampling rate of the Motion Control software and represents the number of points used to reconstruct the original waveform. If the sampling rate of the recorded data is specified in the file header that contains the tracking data, then the software will read that value and default to it. If this sampling rate is not specified, then the software will default to 30 samples per second. It is recommended that the user identify the actual sampling rate of the original recorded data and input it into the *Sample Rate* box so that the correct cycle time is calculated for the imported waveform.



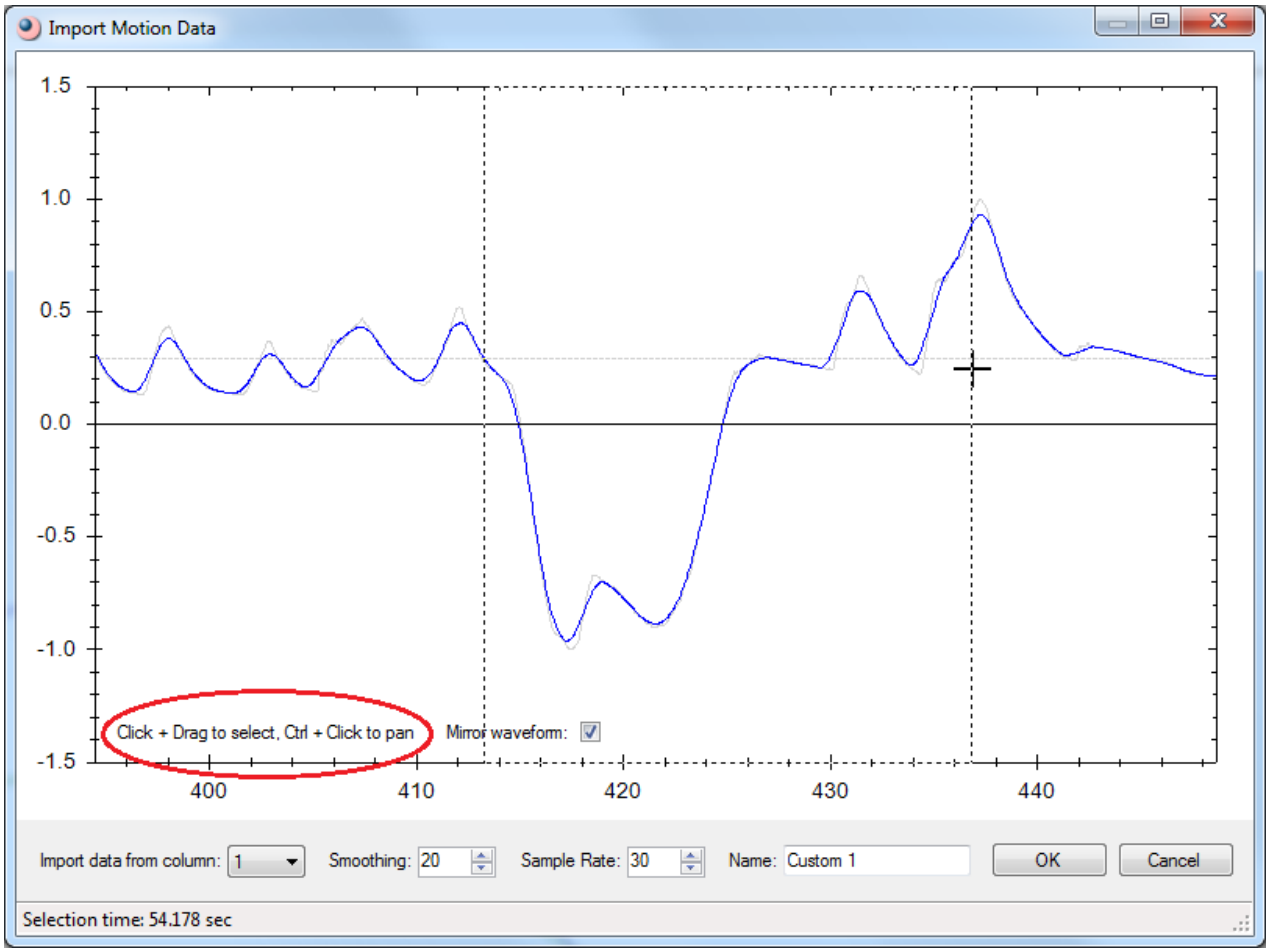
The import function also allows for assigning custom or default names to the imported waveforms.

At the bottom of the *Import Motion Data graph window* there is a *Mirror Waveform* check box, which when checked will mirror the waveform about the time axis:



This function could be useful for cases when the export of the original waveform was done “upside down”.

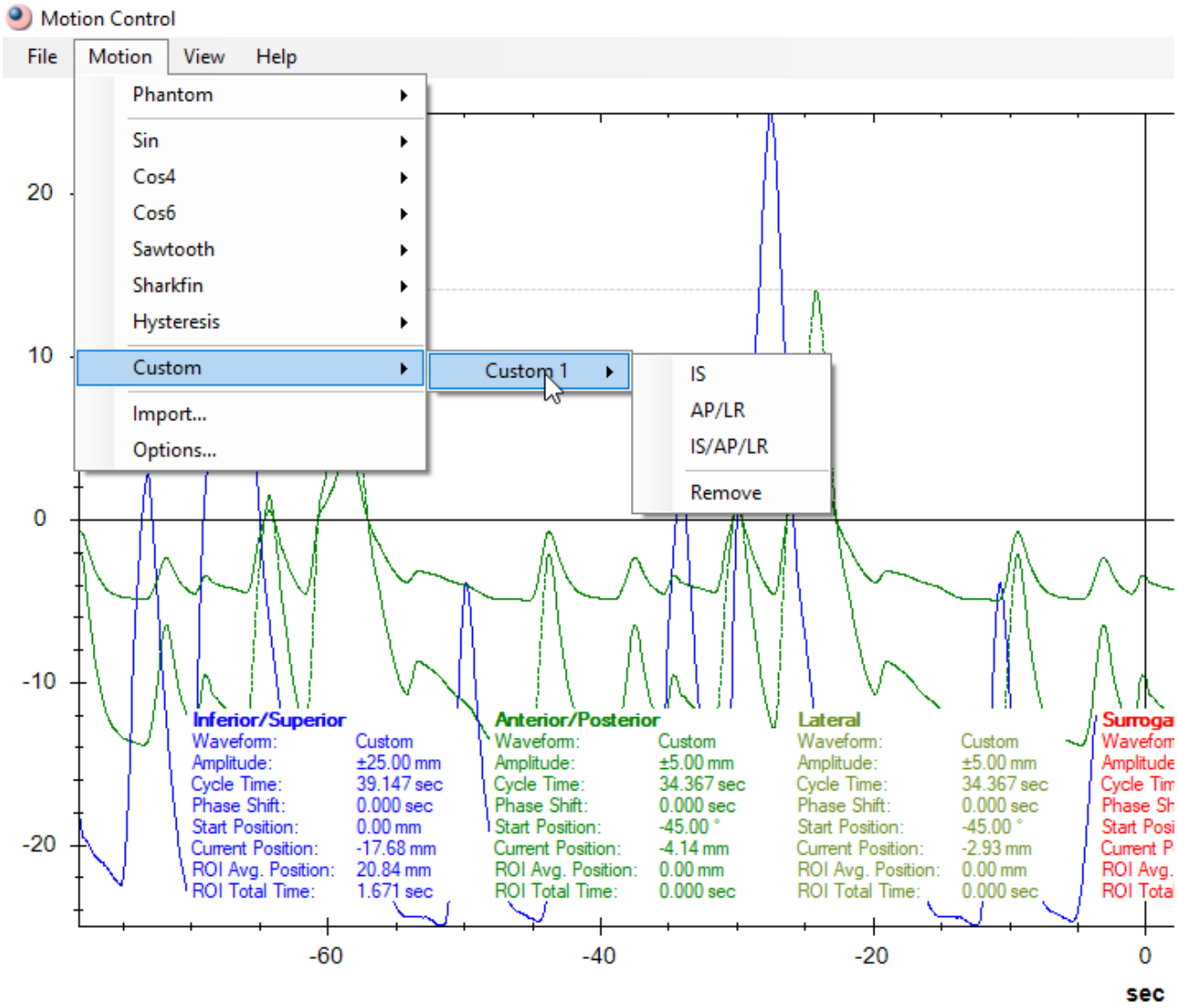
To zoom in on the graph, or to select a region of data to import, click and drag the mouse in the graph. A marquee appears around the selected region, and a gray horizontal line shows all the amplitudes that match where you started your selection, to assist you in creating a suitable loop (as explained before):



To pan the selected region, hold down the *Ctrl* key and then click and drag the mouse. When you are ready to import the data that appears in the graph, click the *OK* button. The selected region is normalized from -1 to 1, the starting and ending points are adjusted to match, and the custom data is loaded into the *Motion Viewer*.

You can also zoom in or out on the graph using the mouse wheel. Left click inside the import window and use the mouse wheel.

After data is imported from a file, the *Custom* menu option in the *Motion* menu becomes available.



For Model 008A,18023-A, 18023-A, 008PL,008Z, and 008PLX

If the tracking motion file header specifies the scale factor used, then the actual amplitudes are imported providing that they are not larger than the mechanical limits of the phantom's motion. In that case, the larger amplitudes are scaled to the limits of motion range. When the recorded breathing waveform files do not have a specified scale factor the imported *Linear* and *Surrogate amplitude* are scaled by default to +/-10mm while the *Rotational amplitudes* are scaled, also by default, to +/-2.50mm for *Anterior/Posterior*, respectively to +/-1.00mm for *Lateral*

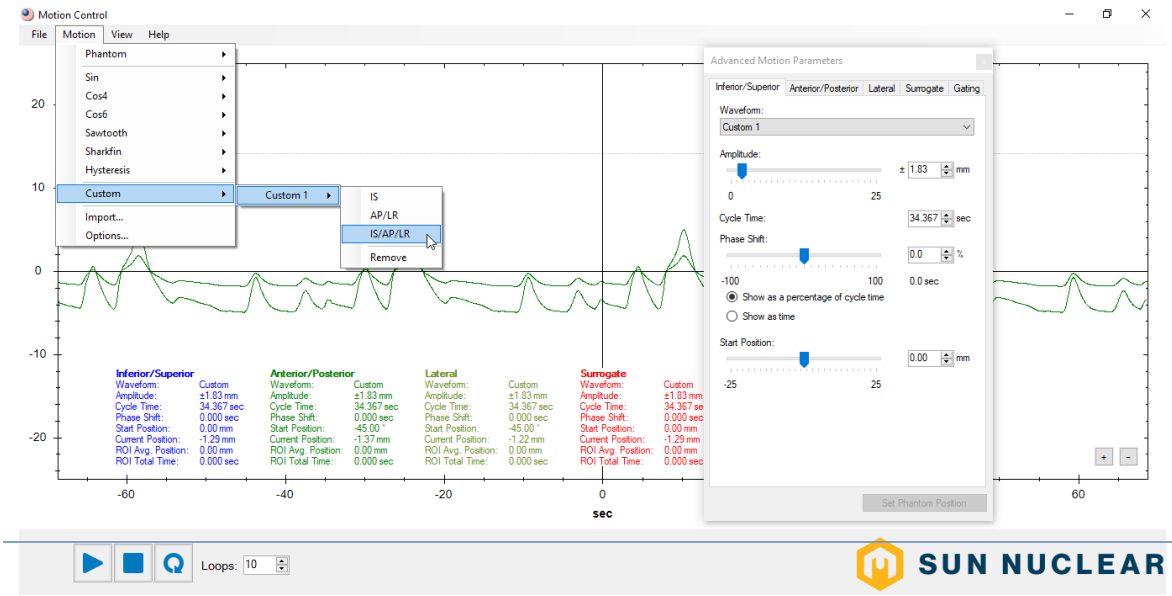
For Model 008P

If the tracking motion file header specifies the scale factor used, then the actual amplitudes are imported providing that they are not larger than the mechanical limits of the phantom's motion. In that case the larger amplitudes are scaled to the limits of motion range. The algorithm then calculates the angle about which the prostate oscillates in order to achieve the Inferior-Superior and Anterior-Posterior amplitudes such that the Inferior-Superior amplitude is the one equal to the maximum amplitude from the imported waveform or scaled to the maximum mechanical limit of prostate's motion while the other one is calculated based on the mathematical relationship between the amplitudes and rotational starting angle.

Info about the parameters of the imported waveforms is presented (color coded) in the lower left corner of the *Motion Viewer* window of Motion Control GUI.

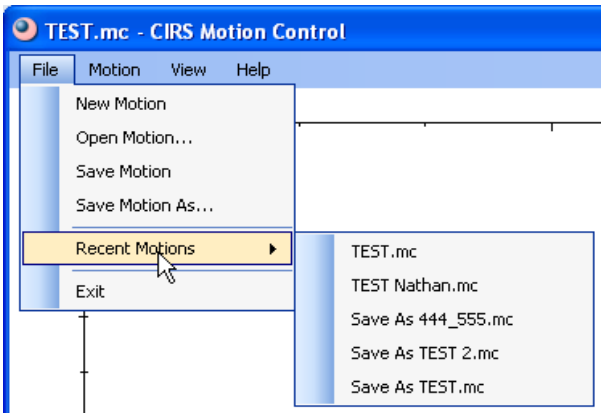
Save/Save As of Imported Motions

Even though the user could use an unlimited number of imported motions as custom motions (waveforms) during one running session these imported motions are not automatically saved when the running session is closed. In consequence if the user plans to reuse the imported motions then *Save Motion* and/or *Save Motion As* should be used.



When *Save Motion* is used for the first time the user is prompted for a name and a location for the file.

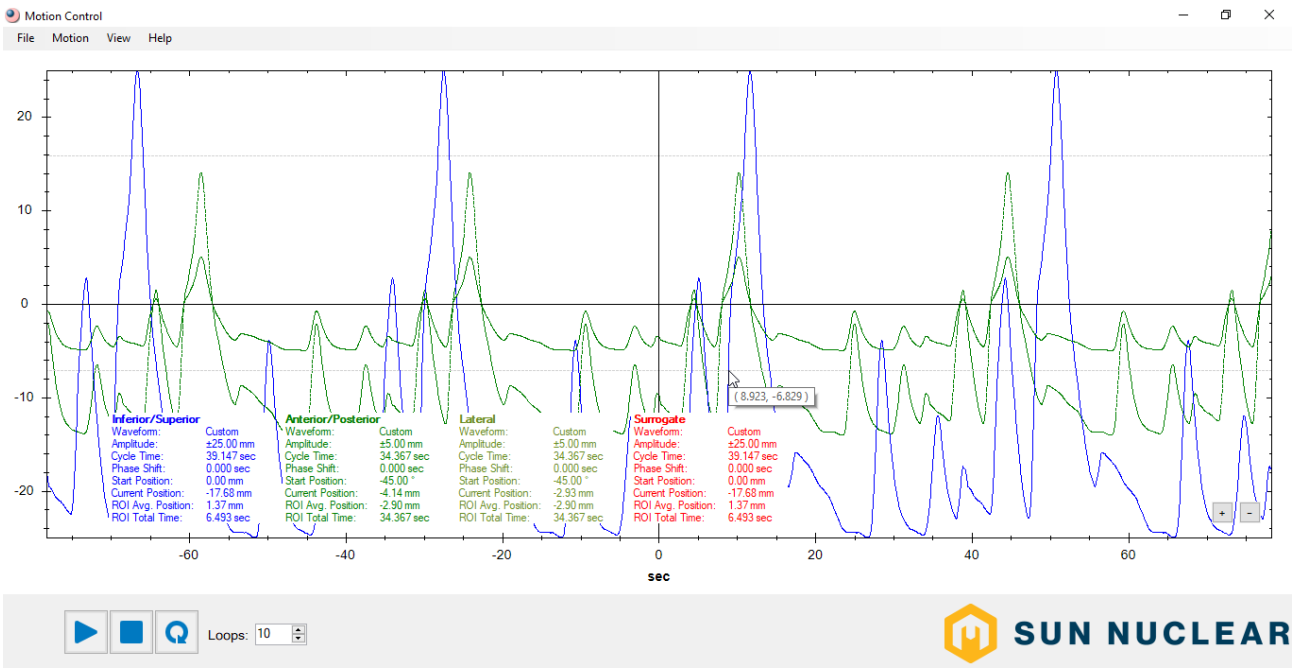
Once a file is saved it becomes available to be open using either *Open Motion* or *Recent Motions*.



If modifications are performed to a motion in a saved file and the user wishes to keep both the original motion and the modified one then *Save Motion As* should be used instead of *Save Motion,* which will save the modifications without prompting the user to give a new name to the file. Like in most other Windows applications *Save* saves the modifications without warning.

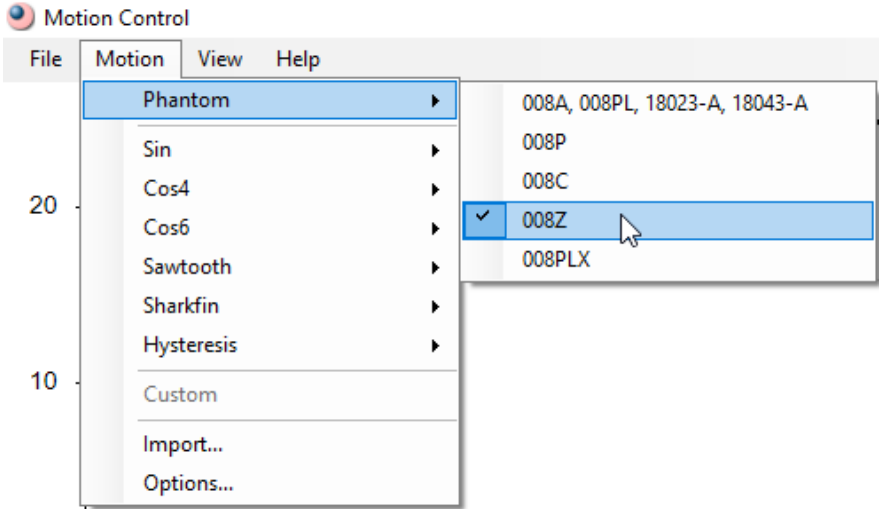
Region of Interest (ROI) Waveform Analysis

In addition to displaying the *Linear, Rotational* and *Surrogate* parameters, the *Motion Viewer* also displays the *ROI Average Position* and *ROI Total Time*. To select a ROI, move the mouse over the graph and either click-and-drag the mouse, or click once to set the starting amplitude and then click again to set the ending amplitude. The status bar displays the position of the mouse cursor in the graph. To adjust the size of the ROI, you can click-and-drag either of the two lines to a new position. To unselect the ROI, click anywhere else on the graph. When no selection is visible, the ROI is assumed to be the entire region of the graph.



Beam Latency Testing for model 008Z

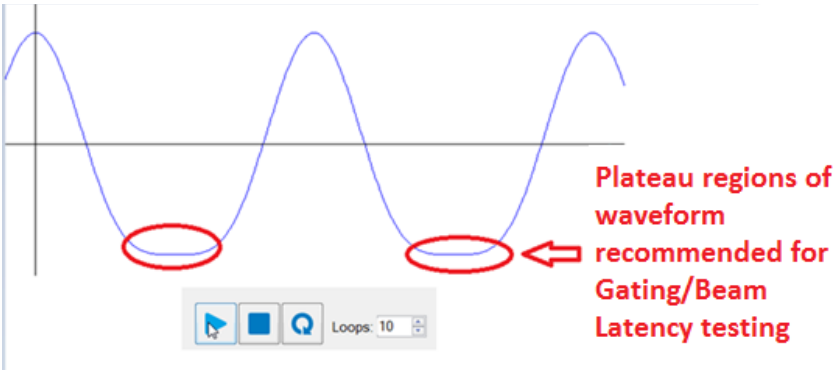
1. Make sure the *008Z module* is selected in the Motion Control software (see below).
   Note: The Gating tab is implemented for the other phantoms models for further hardware/software developments.



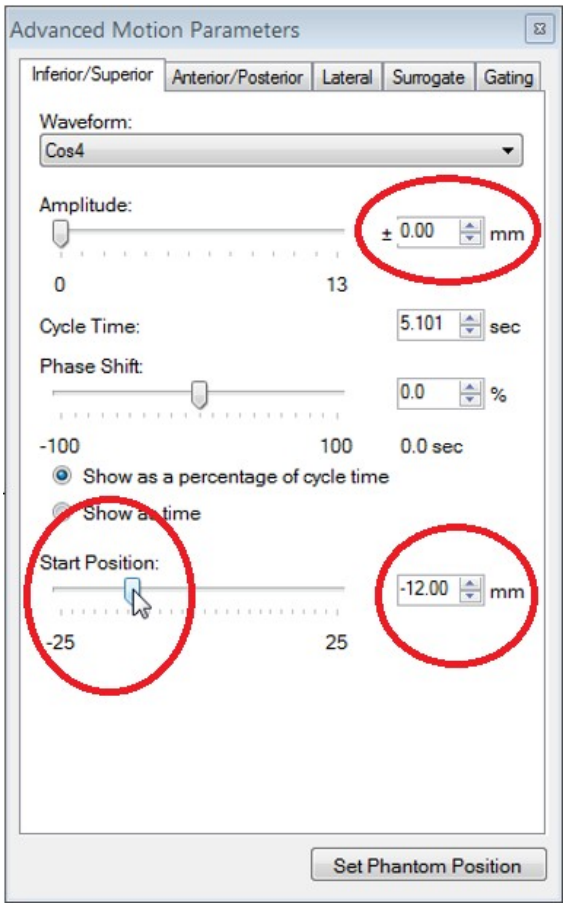
2. Chose a built-in waveform to run for the Beam Latency testing. CIRS strongly suggest that Cos^4 (or Cos^6) waveform is chosen to do the gating of the Inferior/Superior motion and subsequently the Beam Latency testing due to its profile, which resembles a human breathing closer than the other built-in waveforms.

3. Chose the IS option for the waveform as this option will have no rotation component for the target motion.

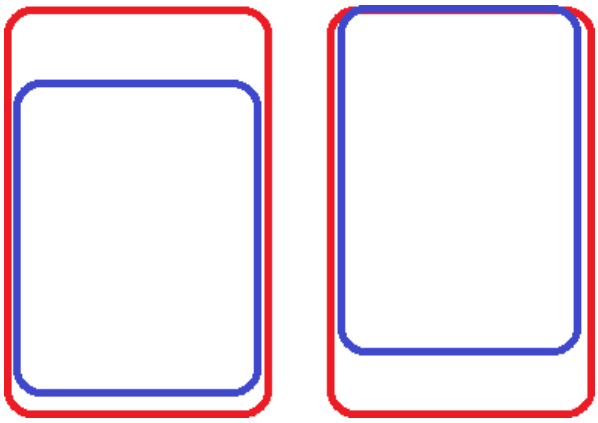
4. To put the target in the position where you want to deliver the beam you can either:
   - Start the motion and use the pause button to pause the motion on the bottom plateau regions of the waveform.



   - Send the target to the amplitude corresponding to the plateau regions from Start Position slider bar/entry box (see below). Before doing this make the amplitude of Inferior/Superior zero.

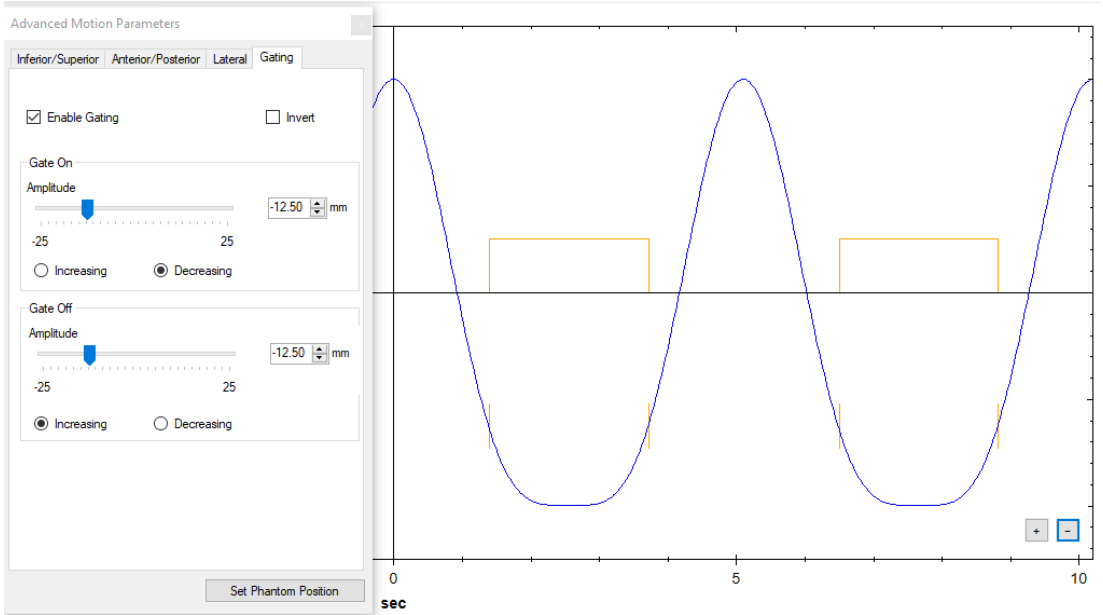


5. Acquire images of the target in the spatial position where the motion is to be gated, contour the target and establish the boundary for the beam ON. To find the exact location where the beam is to be cut off (Beam OFF) use again the Start Position to move the target (in blue) like is shown in the right pictorial below. Note the Start positions (Beam On, Beam Off) for which the target overlaps the Beam ON boundary.

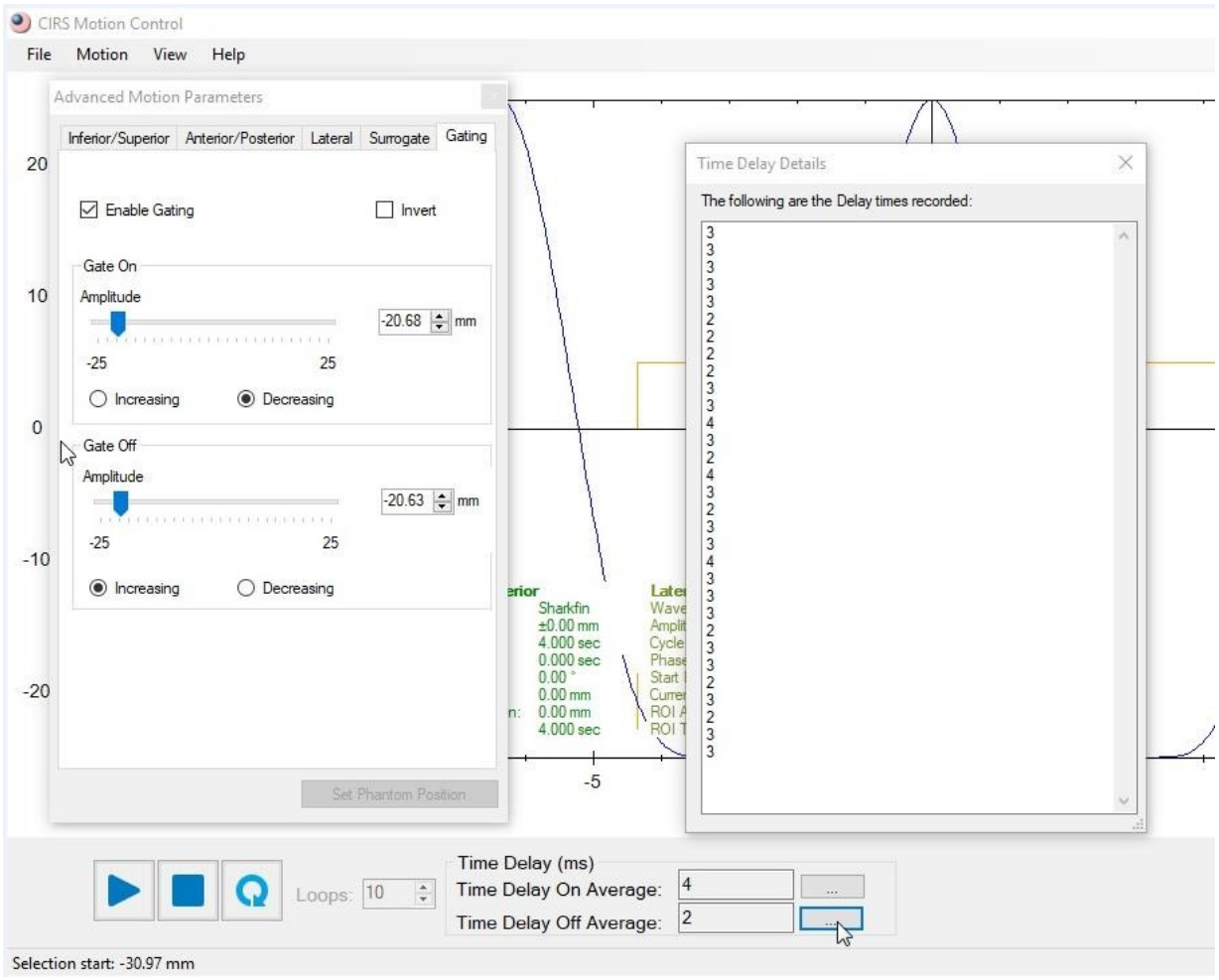


6. Bring the Start Position back to zero and setup back the amplitude of the waveform that was chosen at the beginning.

7. Setup the gating window so that it starts and ends at the desired amplitudes (this amplitude is known from previous step; the Beam On and Beam Off can be setup with the same amplitude or with different ones (the interface of the Gating tab should be self-explanatory). For example if the amplitude of the waveform was chosen to be -/+20 and the target overlaps the Beam ON boundary at -12.5 then the gating should be setup as shown below (notice the two markings on the waveform corresponding to an amplitude of -12.5 and the gating square waveform in orange on the image below).

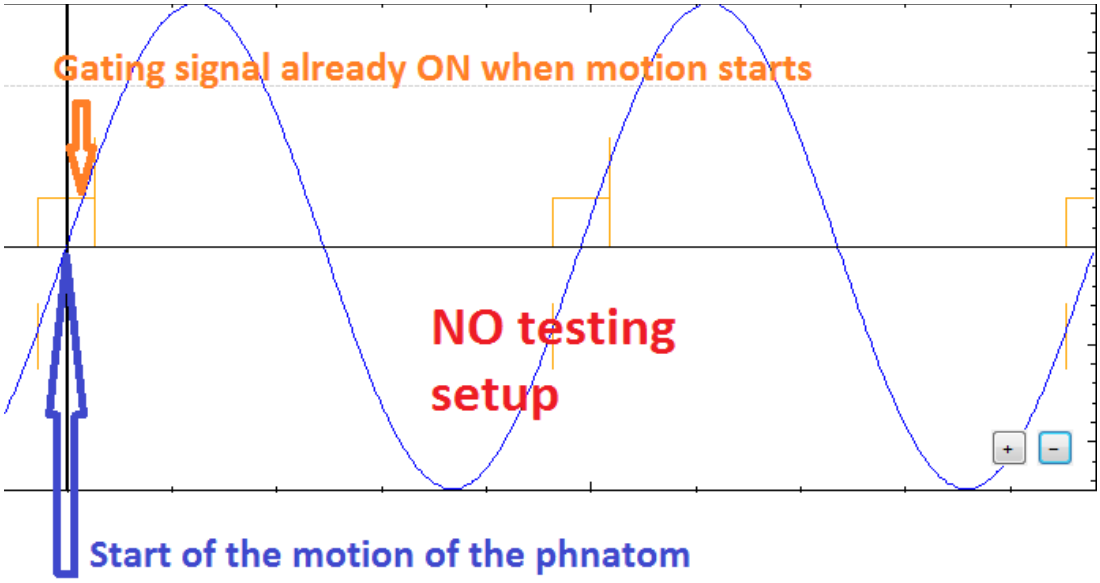


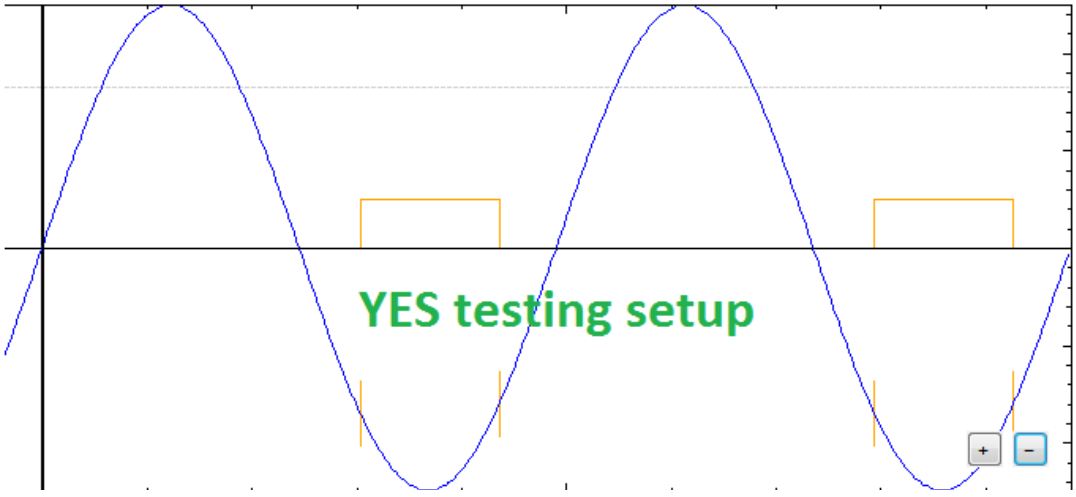
8. Start the real time imaging/motion tracking of the MRI-Linac and then start the motion of the phantom. The Beam Latency (in ms) is displayed next to the run command buttons in the ribbon of the display window of Motion Control software (see below). The values are averages of the Time Delay On (or Off) for the cycles of the waveform that were already executed. If one wants to look at individual time delays for individual cycles of the waveform then one needs to first stop the motion and then click on the ellipsis button for either Time Delay On or Time Delay Off.



Note:

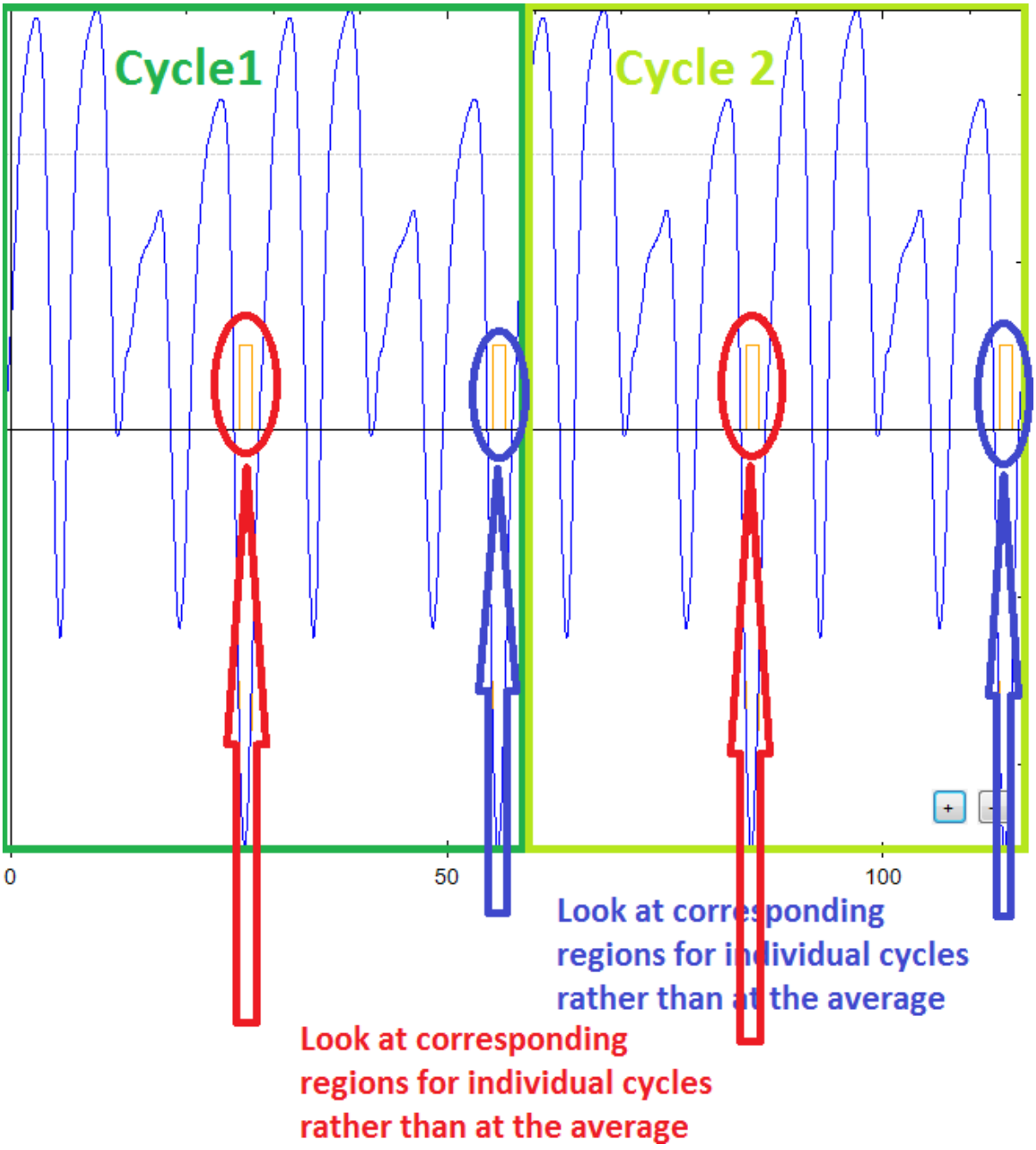
- *It is not recommended to do Beam Latency testing **such that** the Gating Signal, respectively the square-wave generated by the software (based on selected gating amplitudes), against which the Beam On, Beam Off signal coming from the MRI-linac is compared to compute the Beam Latency, **is already on** when the motion of the phantom is started. In such cases the software algorithm might not properly distinguish between Beam On and Beam Off time delay (due to inherent electronic signal noise) and as such wrong information regarding theses parameters could be provided.*





- *Beam Latency testing can be also performed on patient specific breathing waveforms. Of course, such waveforms are not recommended for commissioning or ongoing QA testing since irregular waveforms will have various speed profiles which will lead to different values for Beam On and Beam Off time delays depending on where the gating window intersects the waveform. In case of use of an irregular waveform one must pay attention that the Gating Signal is not on when the motion of the phantom starts (see above note). Also one must be aware that one must look at the individual Beam On and Beam Off time delays computed when the Gating Signal intersects the irregular waveform in the same regions for each loop cycle executed*

rather than the average calculated by the software. Therefore, one should look at the values shown in the pop-up windows that appears in the main display after clicking on the ellipsis *button (see page 42 and below).*



Log File

The software create a Log File that records events like *Application started, Application Initialized, Loading motion data to the controller, Motion Started (with info about the motion profile/waveform), Motion stopped and Application closed* (see below).

```
11/19/2019      1:27:42 PM      Information     Application started
11/19/2019      1:27:43 PM      Information     Application initialized
11/19/2019      1:28:24 PM      Information     Loading motion data to the controller
11/19/2019      1:28:31 PM      Information     Loading motion data to the controller
11/19/2019      1:28:31 PM      Information     Motion started: linWaveform=Sin, linWaveformName=Sin,
11/19/2019      1:31:00 PM      Information     Motion stopped
11/19/2019      1:31:11 PM      Information     Loading motion data to the controller
11/19/2019      1:31:11 PM      Information     Motion started: linWaveform=Sin, linWaveformName=Sin,
11/19/2019      1:32:01 PM      Information     Motion stopped
11/19/2019      1:32:07 PM      Information     Loading motion data to the controller
11/19/2019      1:32:08 PM      Information     Motion started: linWaveform=Sin, linWaveformName=Sin,
11/19/2019      1:32:58 PM      Information     Motion stopped
11/19/2019      1:33:01 PM      Information     Application closed
```

Under normal installation the log file is stored in ***C:\Users\Admin\AppData\Roaming\Sun Nuclear***. For custom installation as windows search for a file call ***MotionControl.log*** can be used.