CIRS Motion Control
User Guide

CIRS Motion Control User Guide

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Contents

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1 Introduction

Motion Control is an application that allows you to control the movement of the following:

- 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
- Model 008PLX Enhanced Dynamic Phantom

With the Motion Control software, you can quickly set up a movement based on a library of predefined 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 (only Model 008P). 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 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** (see https://www.cirsinc.com/software/motion-control/ for the latest version of *TrioPCMotion*) and follow the steps in the InstallShield Wizard.

To install Motion Control, double-click **MotionControlSetup** or **Setup** and follow the steps in the Setup Wizard. 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.*

2 User Interface

User Interface

When you start Motion Control, you will see the following window (depending on the phantom selected).

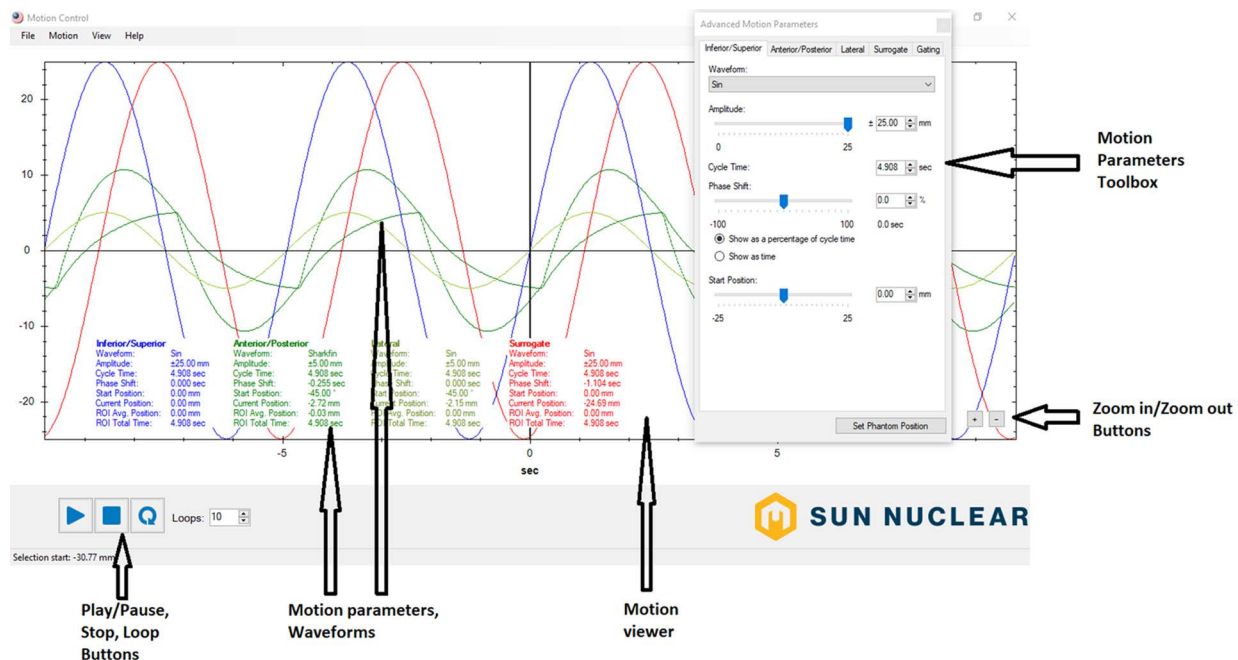*Figure 2-1. Motion Control Window*

Phantom Selection

The phantom to be controlled by the software is selected from the *Motion* menu 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.
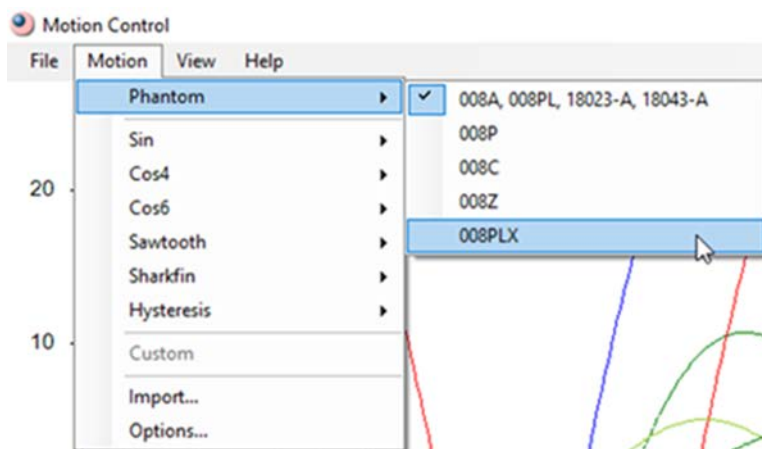

Figure 2-2. Motion Menu

Motion Control Window

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 Models 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 Inferior/Superior 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 axis. These parameters are set in the *Motion Parameters Toolbox*. Due to geometry inherent to the mechanical design, both Inferior/Superior and Anterior 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 Inferior/Superior 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 an ECG signal printed on graph paper in a cardiologist's office.

The Play button starts running a motion. Once motion is started, it pauses and resumes it.

The Stop button stops a 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.
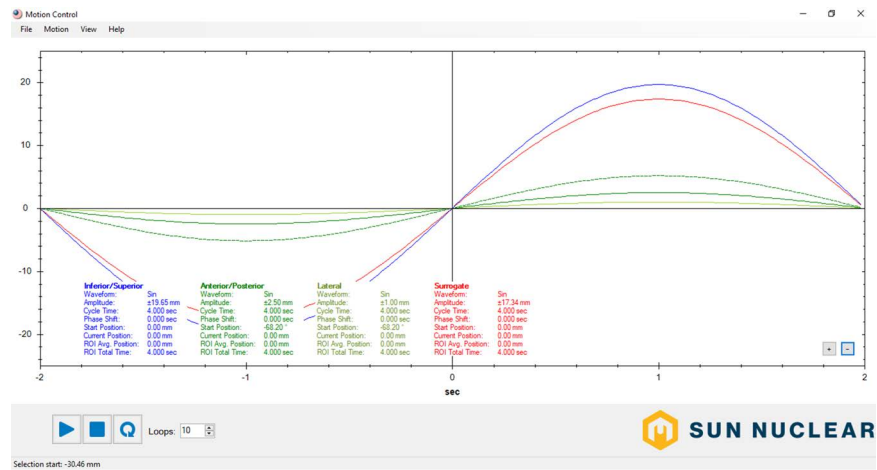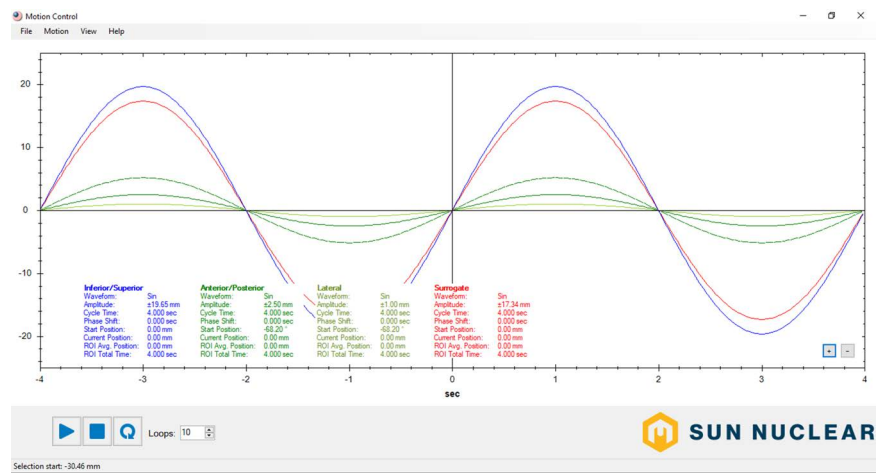
Figure 2-3. Motion Viewer Displaying 1 Cycle

Figure 2-4. Motion Viewer Displaying 2 Cycles
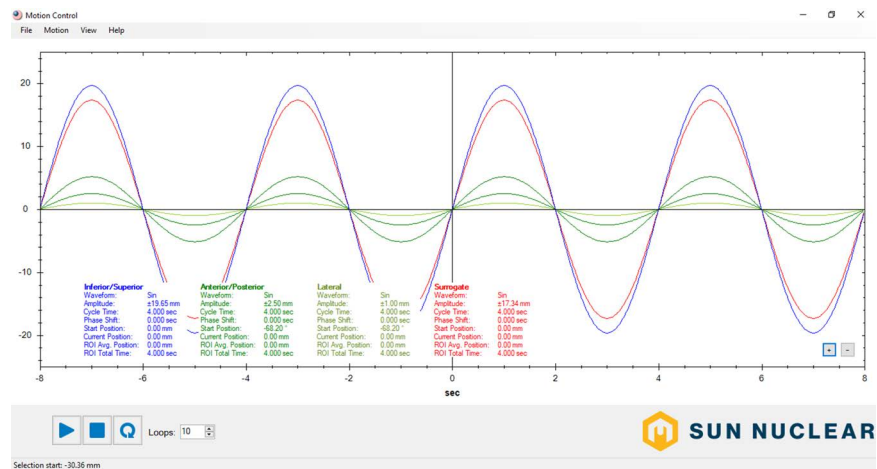
Figure 2-5. Motion Viewer Displaying 4 Cycles

3 Motion Setup

Using the Motion Library

For Models 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, and then click **IS**, **AP/LR**, or **IS/AP/LR**. The selected motion will appear in the *Motion Viewer*.
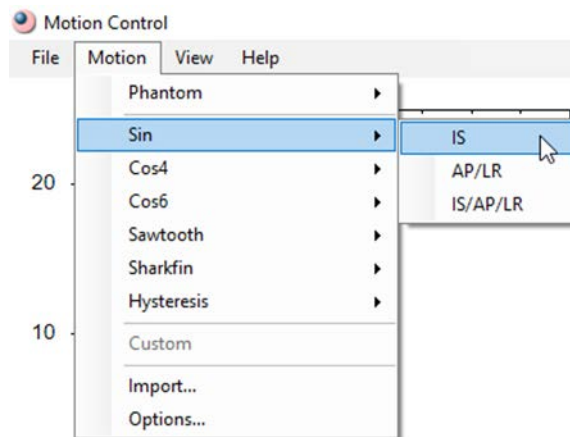
Figure 3-1. Selecting a Motion

- *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.

You will not be able to set up *AP/LR* or *IS/AP/LR* movements on Dynamic Platforms (Models 008PL and 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, and select the motion you want to run. The selected motion will appear in the *Motion Viewer*.
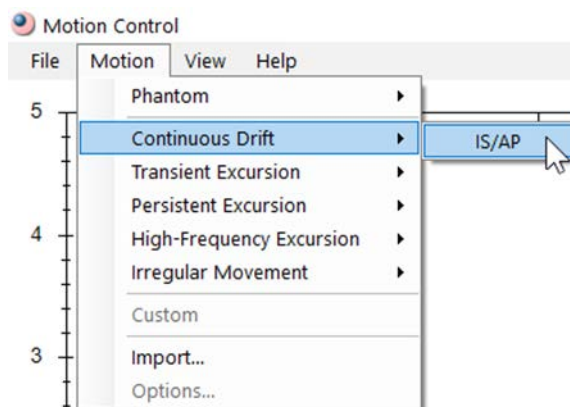
Figure 3-2. Selecting a Motion for Model 008P

IS/AP sets both IS and AP direction 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.
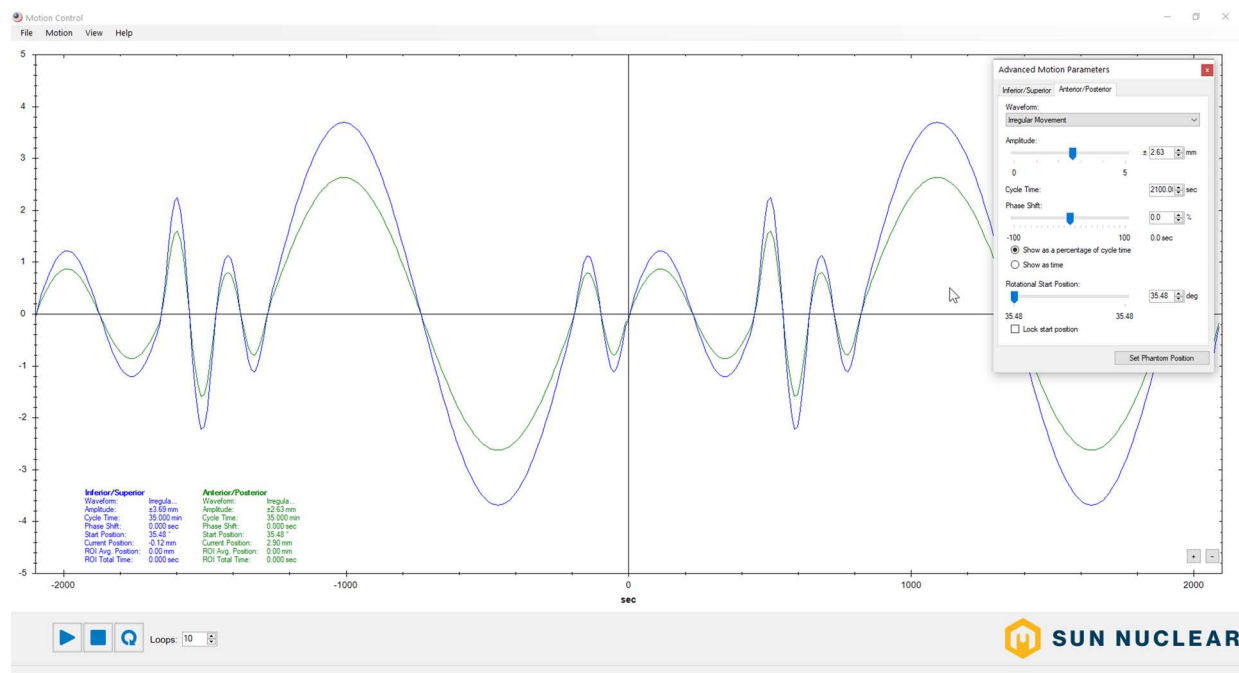
Figure 3-3. Custom Motions

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.
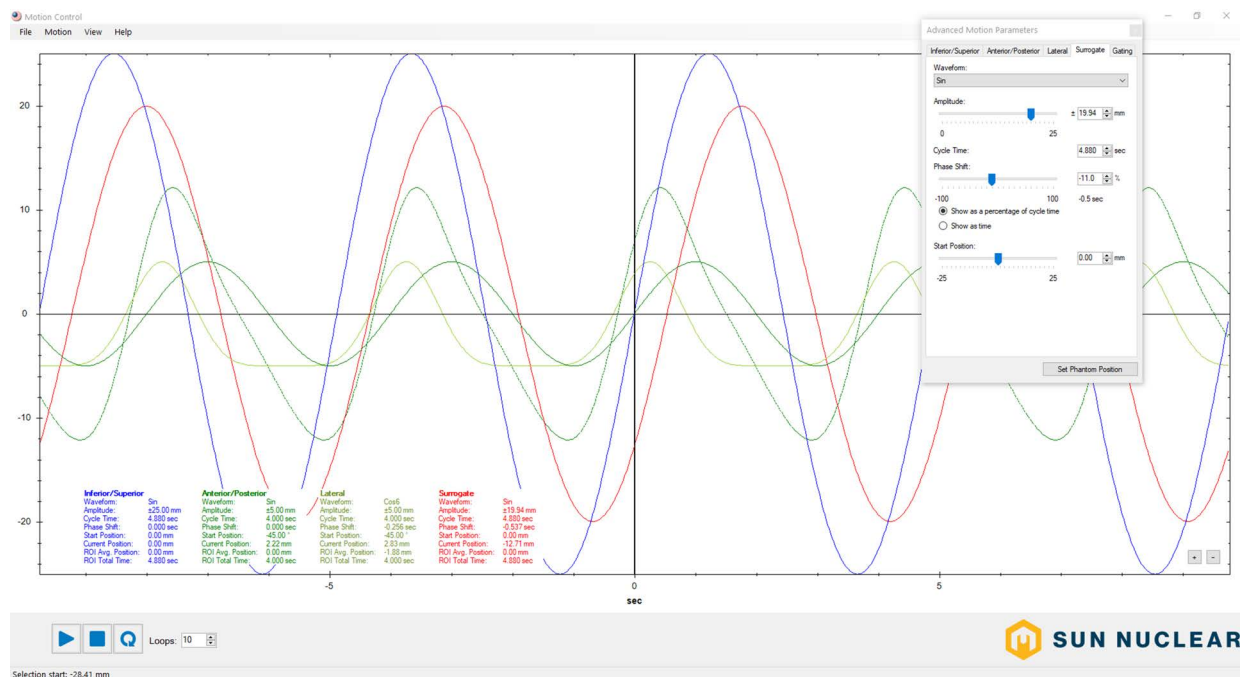
Figure 3-4. Running a Motion

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.
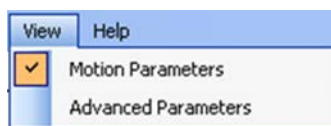
Figure 3-5. View Menu

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 Inferior/Superior tab allows you to adjust the Inferior/Superior axis amplitude and the cycle time for all three axes.
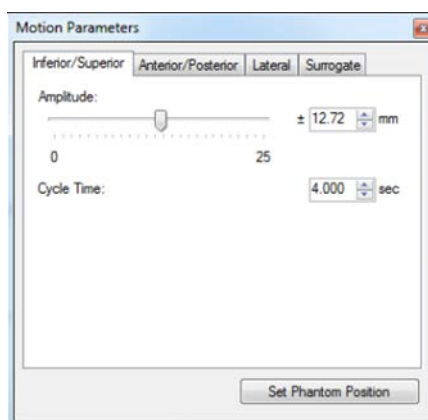
Figure 3-6. Inferior/Superior Tab

The Anterior/Posterior and Lateral tabs allow you to adjust the Anterior/Posterior and Lateral axis amplitudes, and the cycle time for all three axes. Adjusting the parameters on the Anterior/Posterior and Lateral tabs 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.

Figure 3-7. Anterior/Posterior and Lateral Tabs

The Surrogate tab allows you to adjust the amplitude and phase shift of the surrogate axis and the cycle time for all three axes.
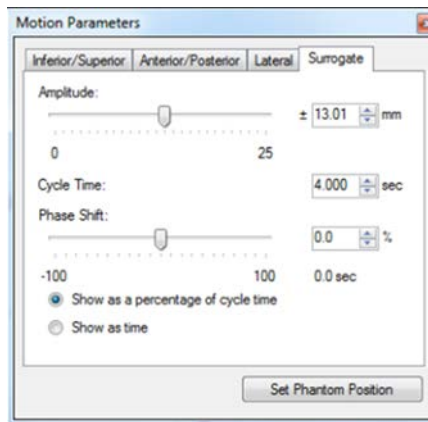
Figure 3-8. Surrogate Tab

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.
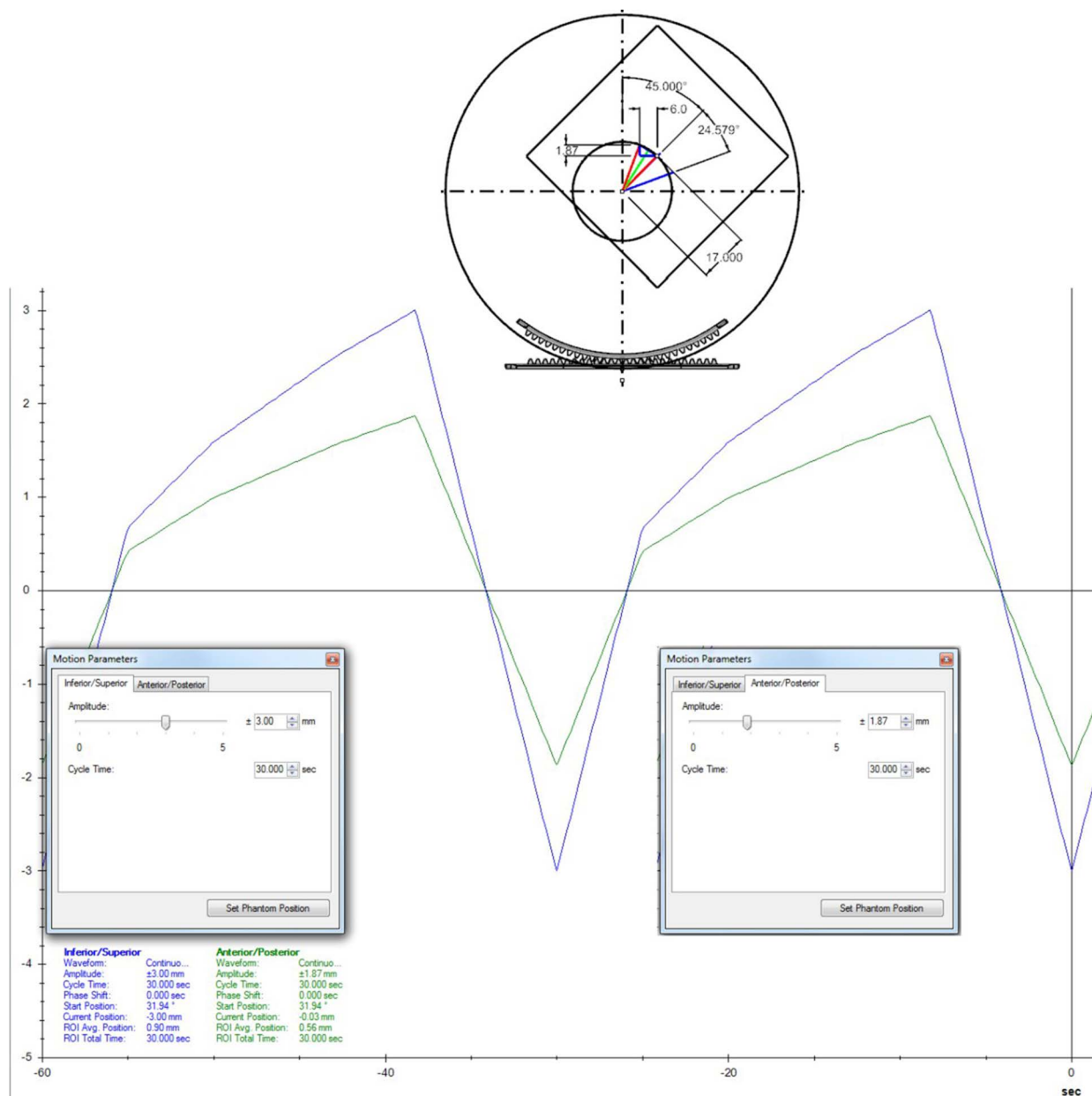
Figure 3-9. Adjusting Amplitudes For Model 008P

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 (20º to 70º), set both the Anterior/Posterior and Lateral amplitudes to zero, and then select the **Lock start position** checkbox. Once *Lock start position* is selected, the adjustment of one amplitude will adjust the other one so that the relationship *amplitudes – starting angle* is satisfied.
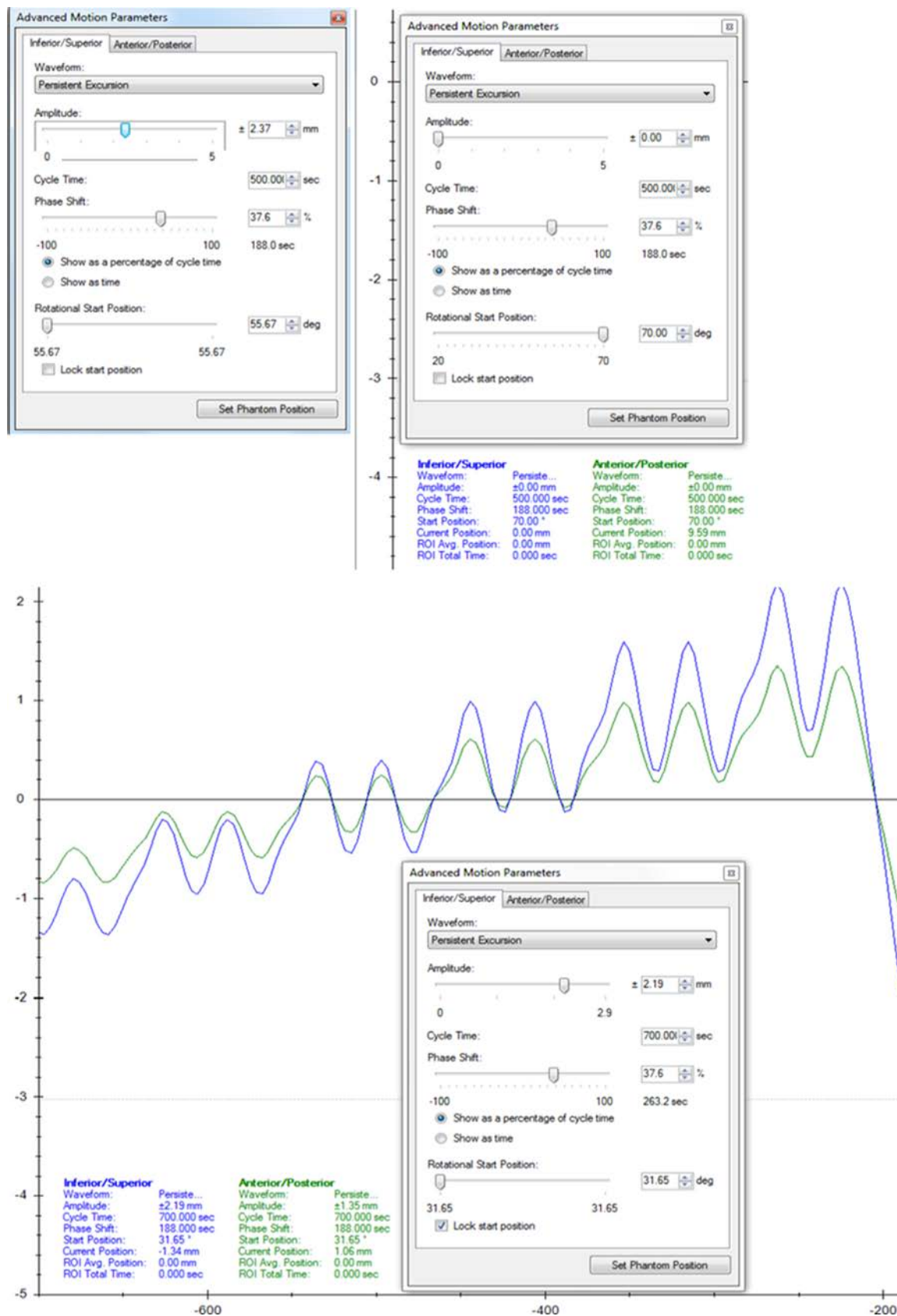
Figure 3-10. Setting Start Position Angle

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 Inferior/Superior 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.
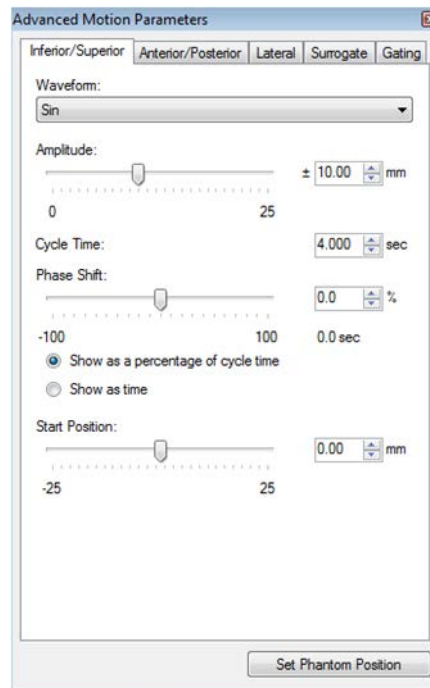
Figure 3-11. Inferior/Superior Tab

The Anterior/Posterior and Lateral tabs allow 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, an 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. To freely set the start position angle, set both the Anterior/Posterior and Lateral amplitudes to zero.
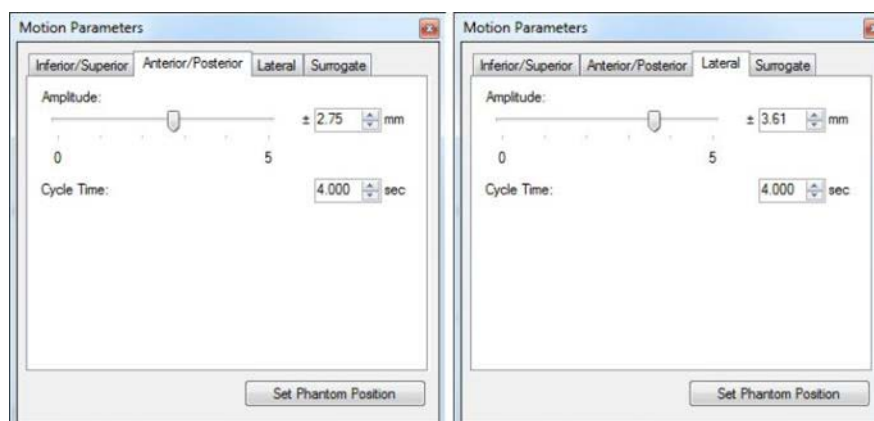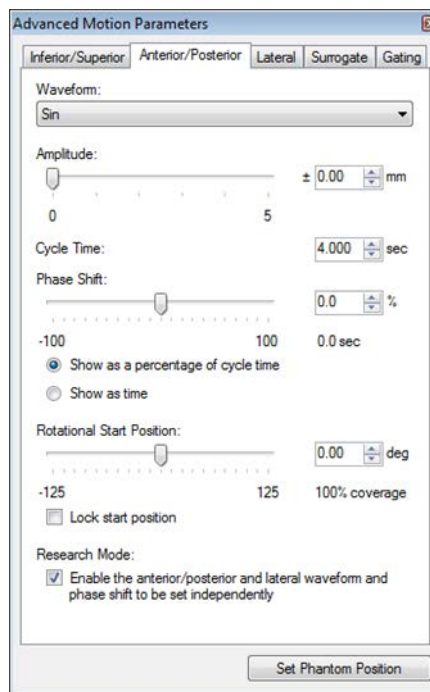
Figure 3-12. Anterior/Posterior Tab

The Surrogate tab allows you to adjust the amplitude, cycle time, and phase shift of the Surrogate axis (not applicable for Model 008Z).
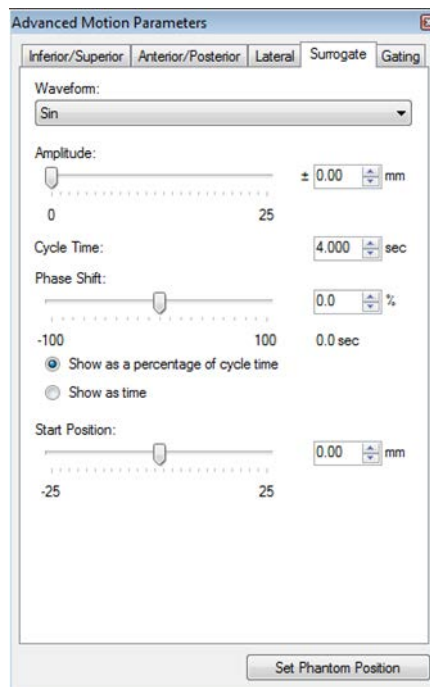
Figure 3-13. Surrogate Tab

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

The *Research Mode* is available only from the *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.
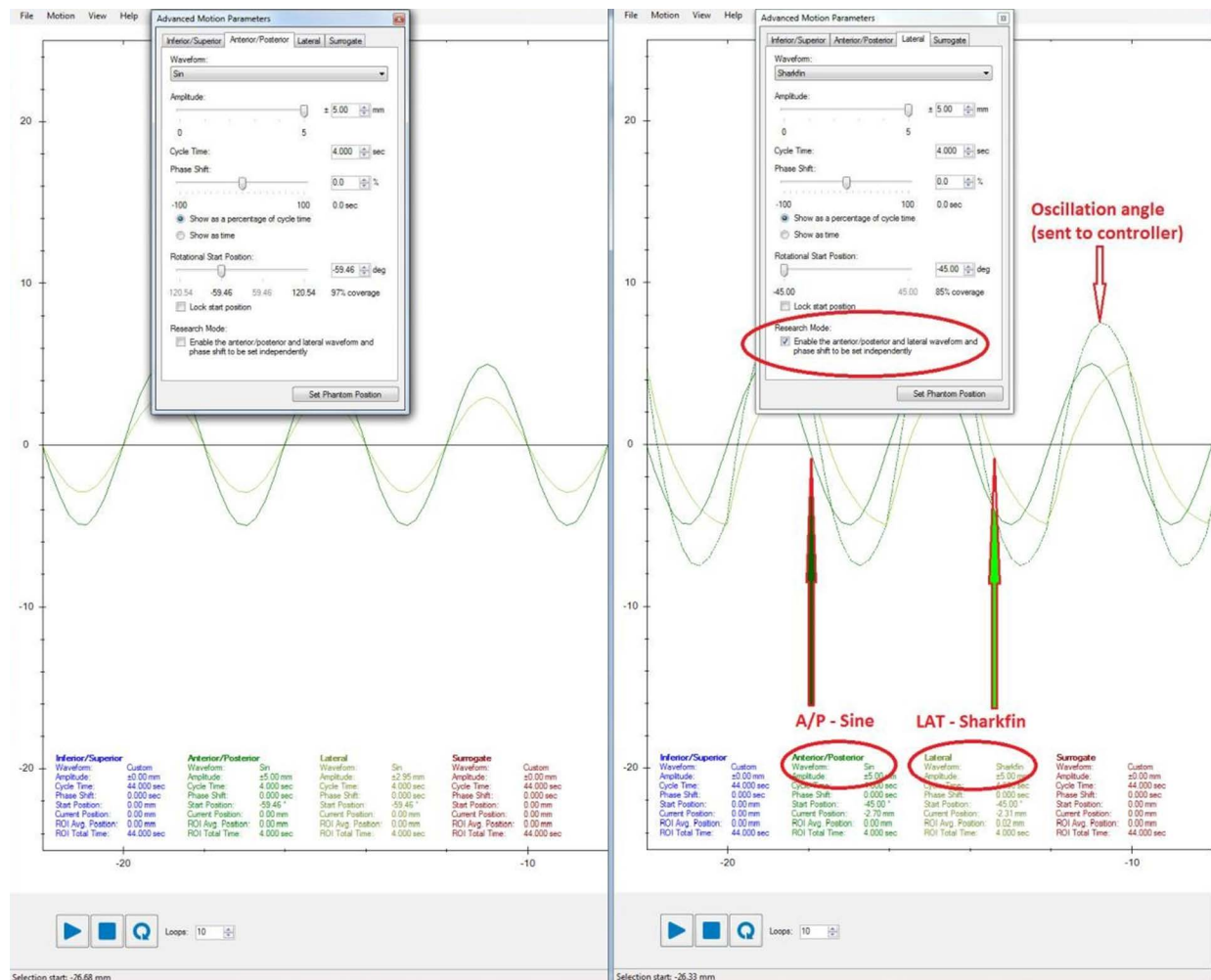
Figure 3-14. Enable Research Mode

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 set up in the Options 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 the 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 the mechanical limitation of the phantom's design, if two symmetry angles fall into the safe zone of the moving rod rotation, which is located on each side of 180º (0º is at zenith), then only two Rotational Start Position angles are available.
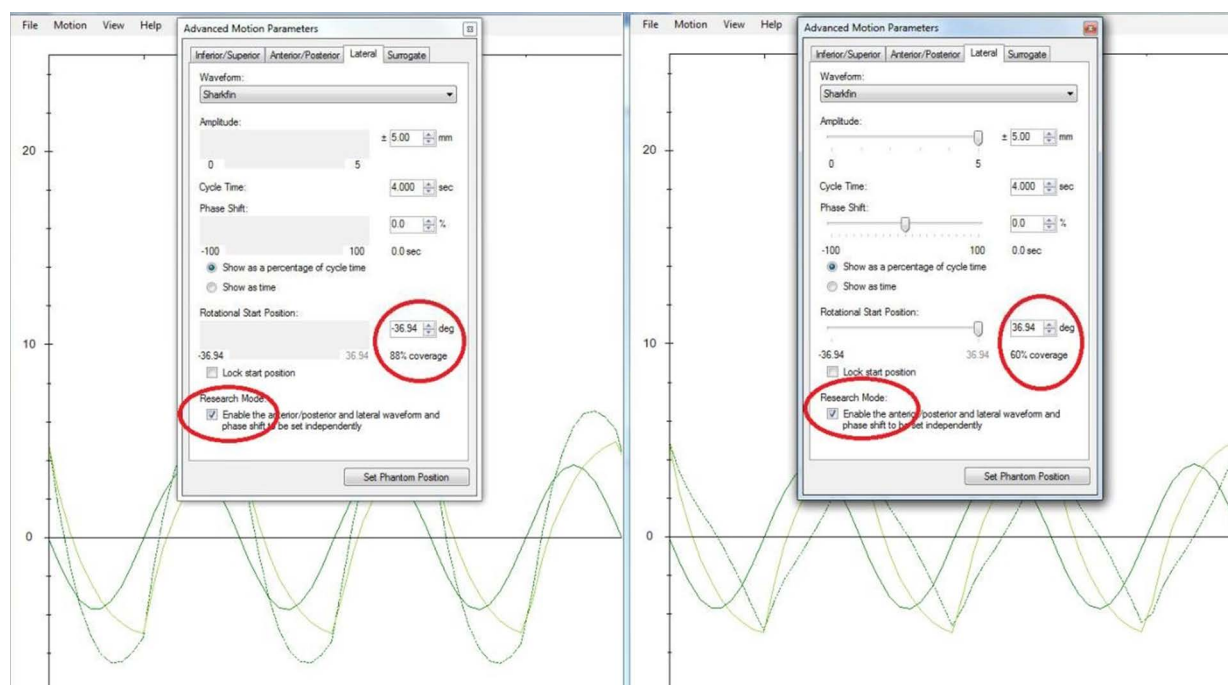
Figure 3-15. Research Mode Calculates Best Coverage
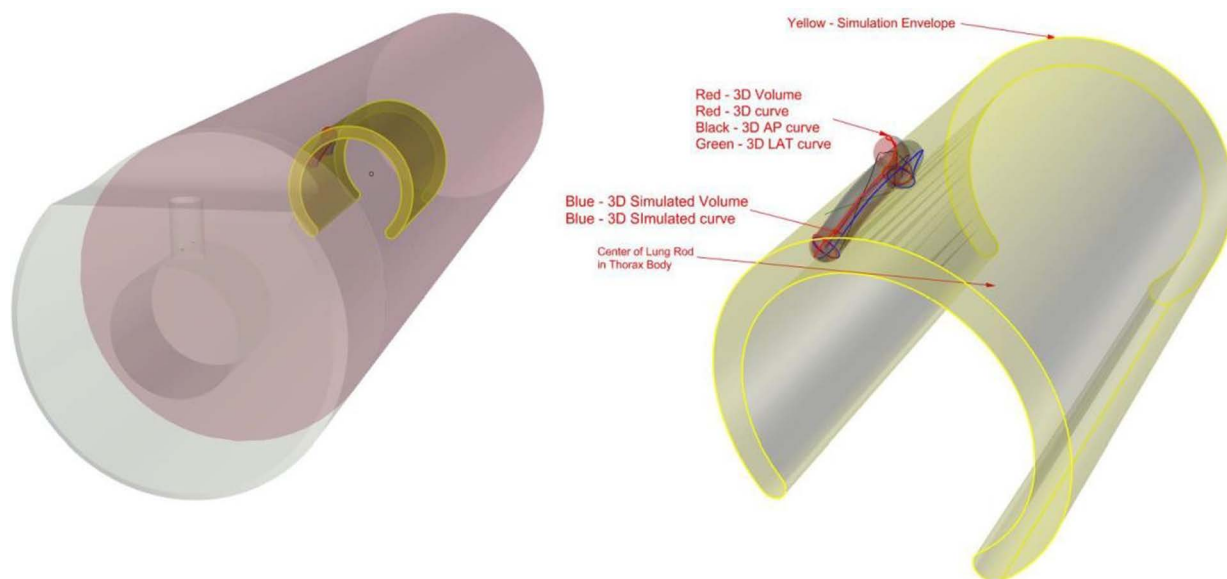
Figure 3-16. Simulation

For Model 008C

The ECG tab allows you to select the desired beats per minute (BPM) rate. If no adjustments are made to the BPM, the phantom will run at 60 BPM.
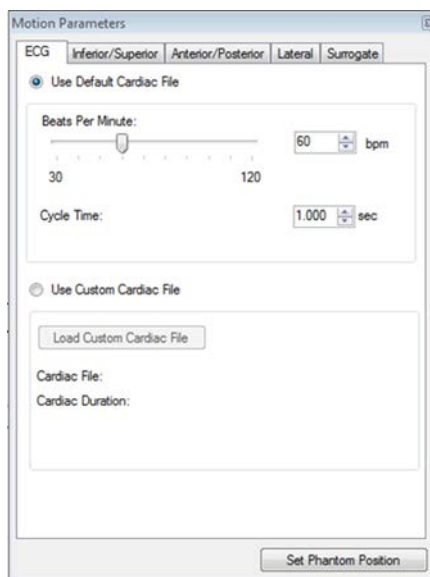
Figure 3-17. Select Beats Per Minute

The Inferior/Superior tab allows you to adjust the Inferior/Superior amplitude of the motion profile of a heart region, Aorta, Apex (default), and Center respectively.
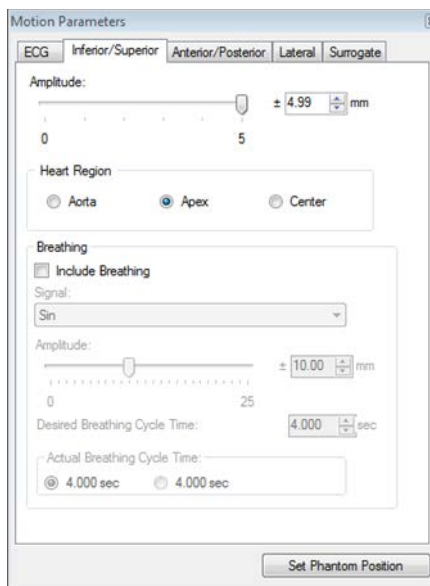
Figure 3-18. Adjust Heart Region

The Inferior/Superior tab also allows the user to account for the movement of the heart due to breathing.
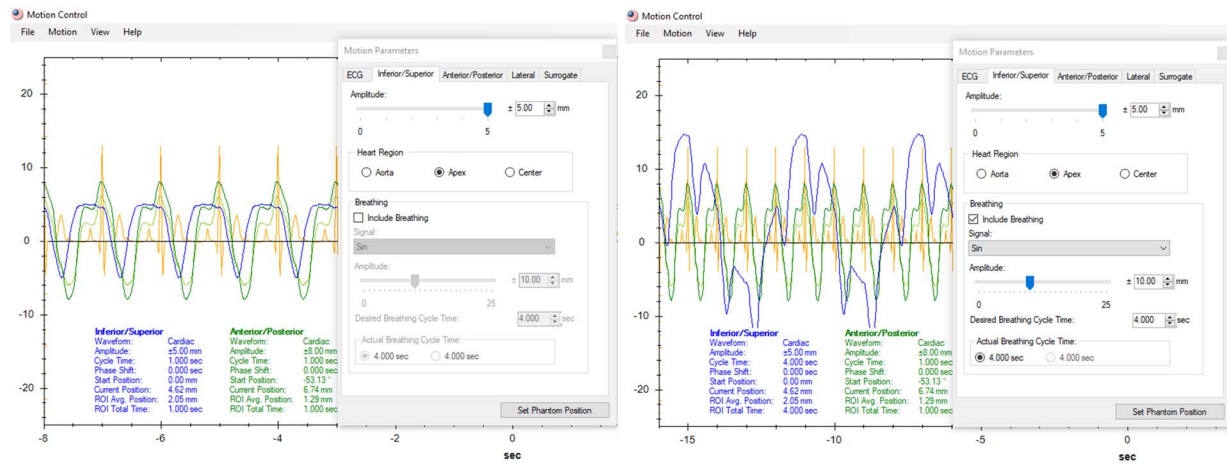
Figure 3-19. Movement of Heart Due to Breathing

When **Include Breathing** is selected in the Breathing section of the Inferior/Superior tab, the heart moves in an Inferior/Superior direction based on a waveform that results from adding the motion waveform due to the heart beating to a built-in waveform specific to the Dynamic Thorax. The built-in breathing waveform is selected from a drop-down box. The user can adjust the amplitude and cycle time of the breathing. Based on the breathing cycle time and heart rate (BPM), the actual possible cycle time is calculated automatically.
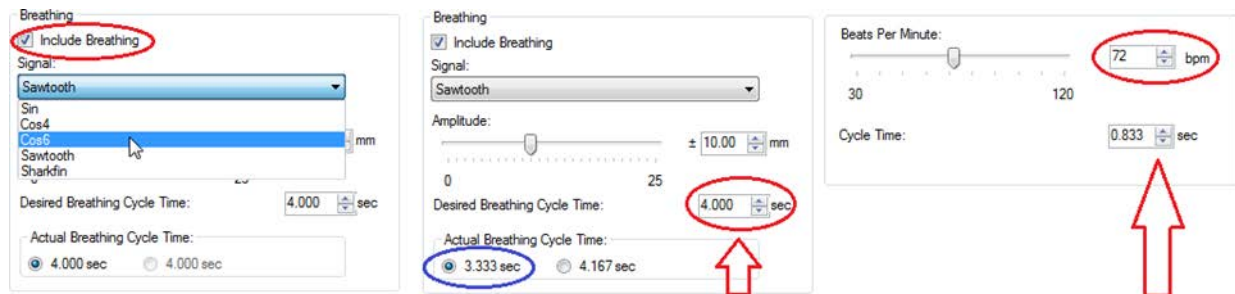
Possibile actual Breathing Cycle Time depends on the Desired Breathing Cycle Time and Beats Per Minute

Figure 3-20. Actual Breathing Cycle Time Calculation

Note: There might be cases when Include Breathing is selected that the waveform to be run requires accelerations/decelerations greater than the ones supported by the linear step motor. In these cases, the user is presented with a Modifications Needed message upon pressing the Play button. The two choices below are available.

- *Select **Yes**: Heart rate (BPM) is preserved while the amplitude is adjusted so that accelerations/decelerations required by running the waveform are less than the maximum supported by the hardware.*

- *Select **No**: Heart rate (BPM) is adjusted while the amplitude is preserved so that accelerations/decelerations required by running the waveform are less than the maximum supported by the hardware.*
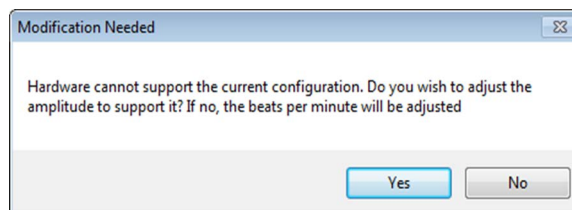
Figure 3-21. Modifications Needed Message

The Anterior/Posterior and Lateral tabs allow you to adjust the Anterior/Posterior and Lateral amplitudes.
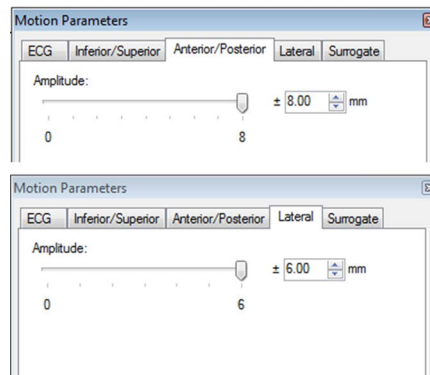
Figure 3-22. Adjust Anterior/Posterior and Lateral Amplitudes

The Surrogate tab allows you to adjust the amplitude, cycle time, and phase shift of the Surrogate axis similarly. The built-in breathing specific waveforms (same waveforms that are built-in for 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 selecting **Sync Surrogate waveform to I/S Breathing** provided that **Include Breathing** was selected on the Inferior/Superior tab.
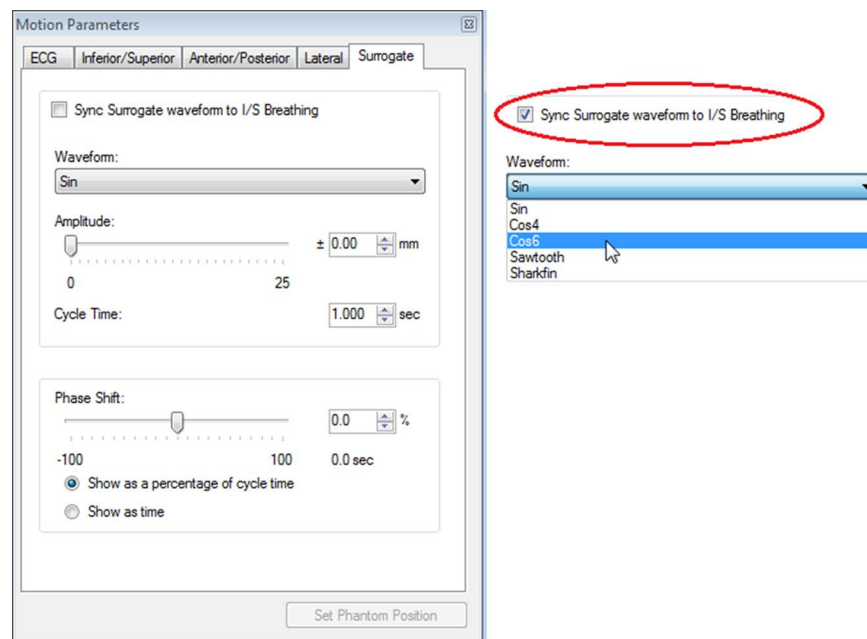
Figure 3-23. Sync Surrogate Waveform to I/S Breathing

The *Options* dialog is launched from the *Motion* menu and contains overwriting parameters, which are read by the software's modules in order to perform the correct simulations and tumor position calculations.
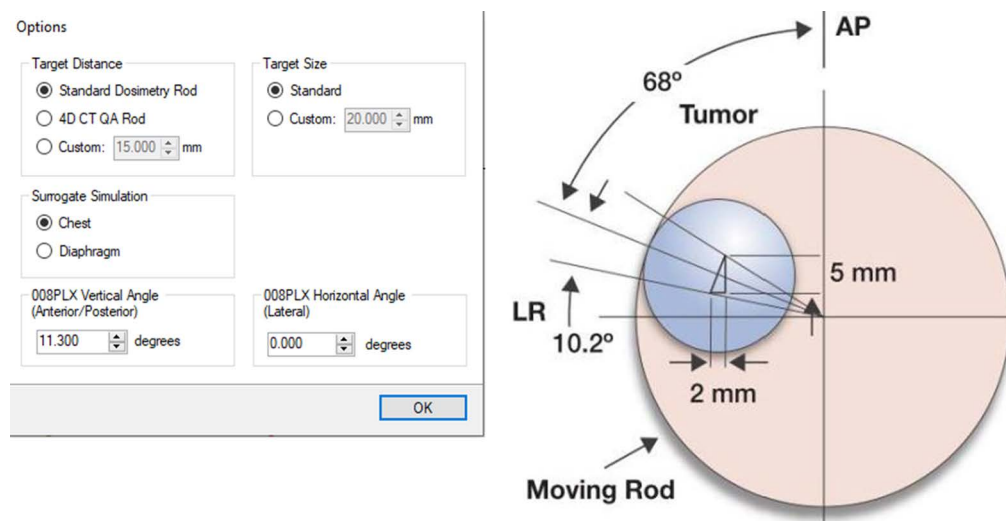
Figure 3-24. Options Dialog

- *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 15 mm. The default value of this parameter is 10 mm 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 and top of high contrast fiducial, respectively. The default value of this parameter is 22.825 mm.
  - *Custom* can take any value between 10 mm and 100 mm 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, and 18043-A). The default value of this parameter is 20 mm.

Note:

- *Model 008M does not use a 4D CT QA Rod or allow for Custom ones. Therefore, the Standard Dosimetry Rod should be checked only for this phantom.*
- *Model 008Z does not 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 10 mm 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 be set up in 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^o 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

Figure 3-25. Motion Options for Model 008PLX

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 entered 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.*

Figure 3-26. Motion of 008PLX in IS, AP, and Lateral Directions

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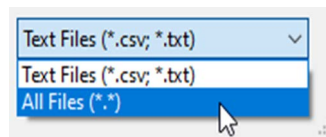

Figure 3-27. Importing Motion Files

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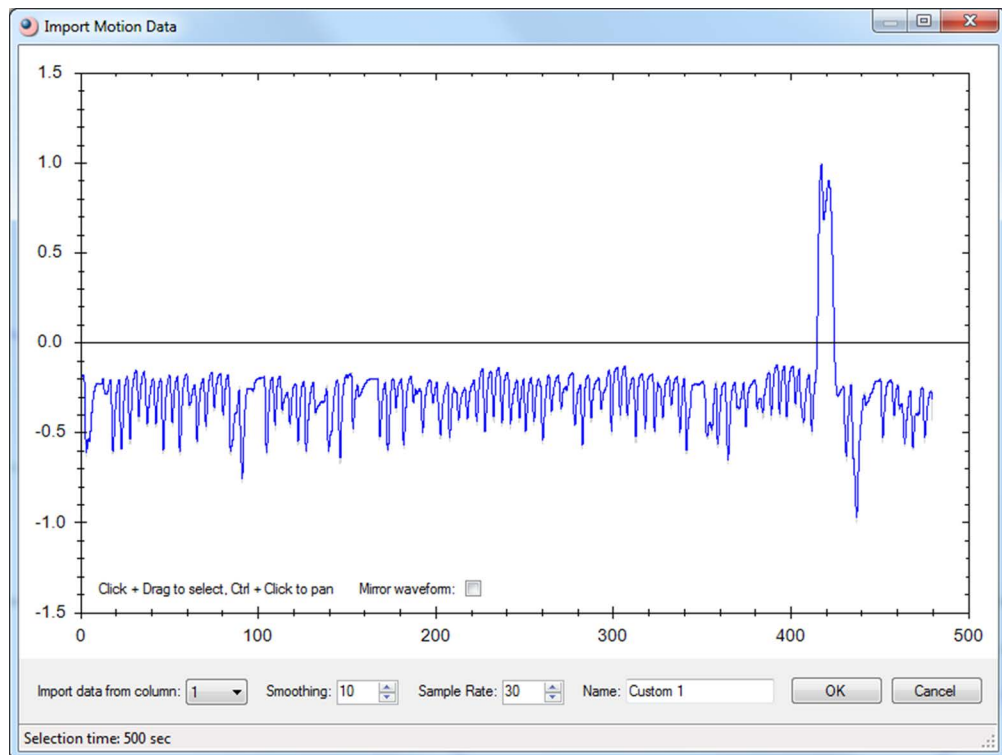

Figure 3-28. Imported Motion Data

Because the software allows different waveforms to run for each of the phantom's axes, import the data from each column that contains tumor positions in a 3D space separately, in order 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 to 10 by default.

When importing only a portion of the patient-specific recorded data, it is recommended that you select the START and END points so that they have close amplitudes. Selecting START and END points with very different amplitudes will cause the system to fill in between the END and START points when the looping function is used (see Figure 3-29 and Figure 3-30).
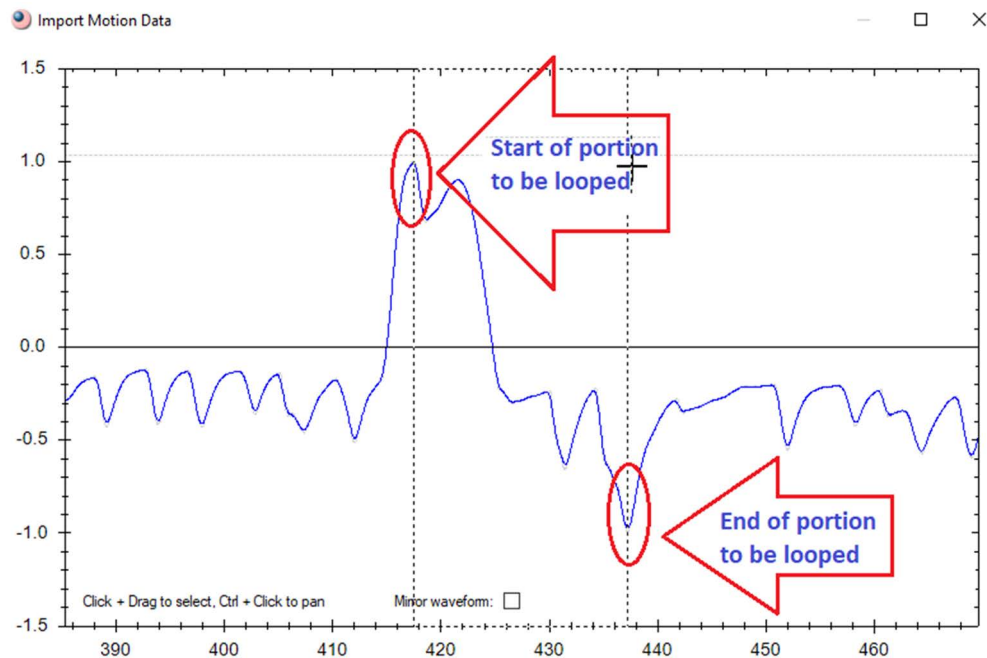
Figure 3-29. Start and End Points With Very Different Amplitudes

This fill-in will therefore modify the original data, and therefore, 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 left mouse button.

Figure 3-30. Good End Point Candidates

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 samplin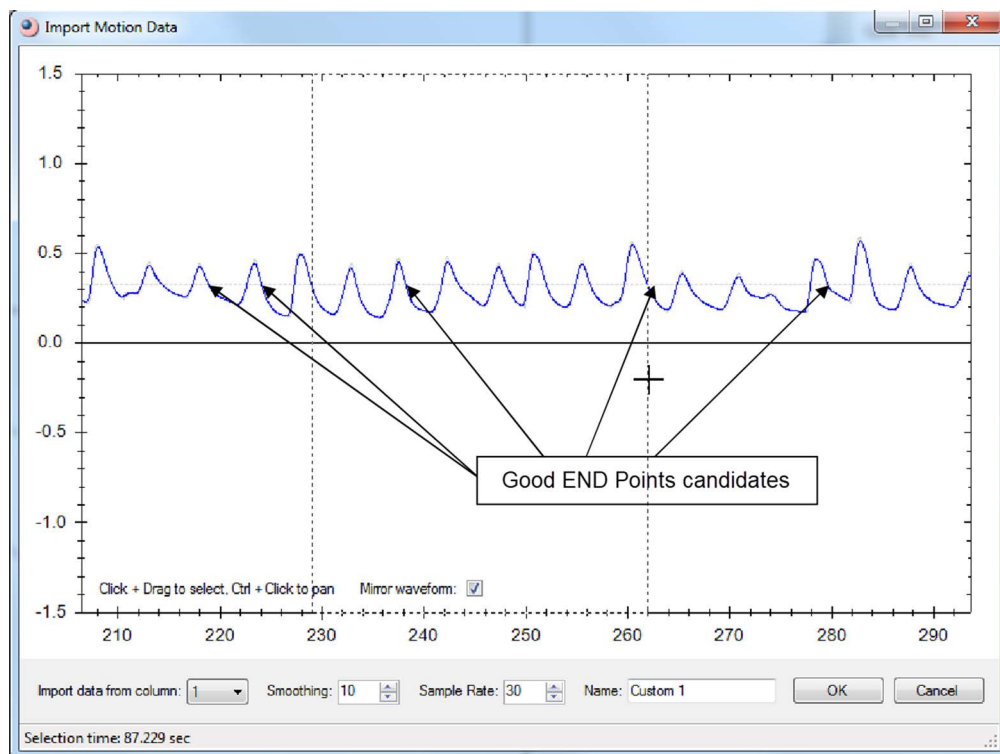g rate is not specified, then the software will default to 30 samples per second. It is recommended that the user identify the actual sampling rate of the original recorded data and input it into the *Sample Rate* box so that the correct cycle time is calculated for the imported waveform.
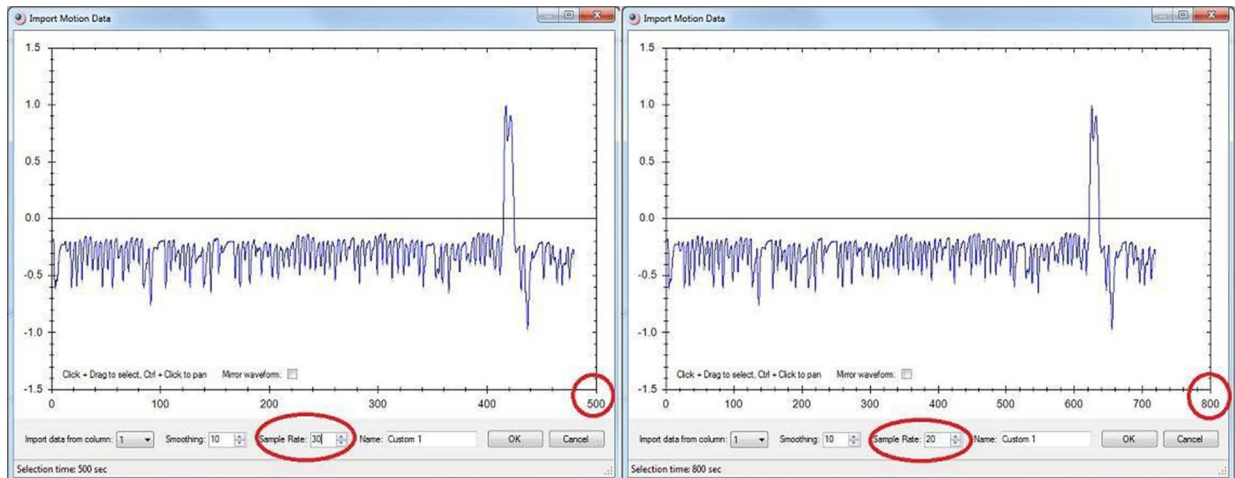
Figure 3-31. Sampling Rate

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

At the bottom of the *Import Motion Data* window, there is a *Mirror Waveform* checkbox, which when selected will mirror the waveform about the time axis.
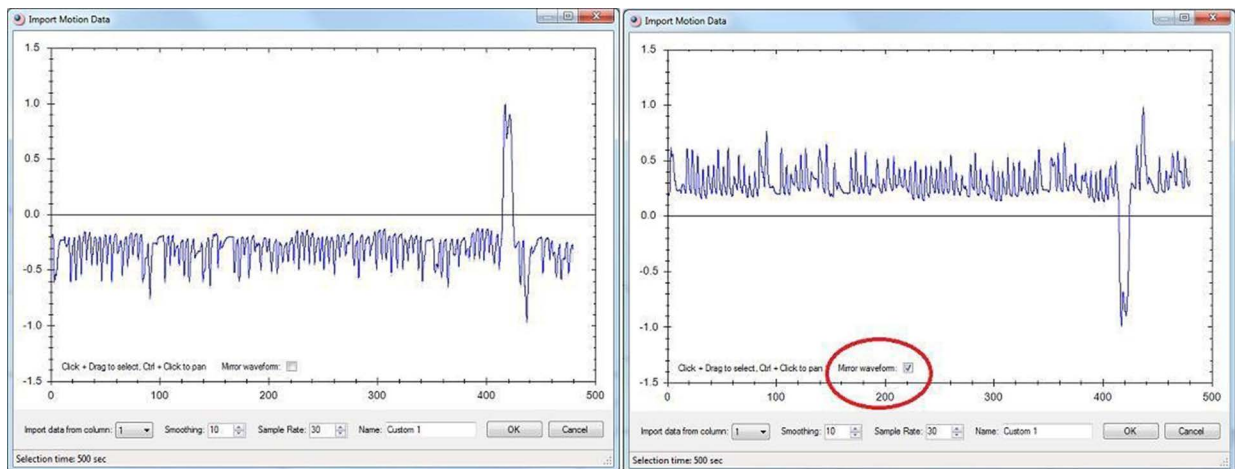
Figure 3-32. Mirror Waveform

This function could be useful in cases where 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 above).
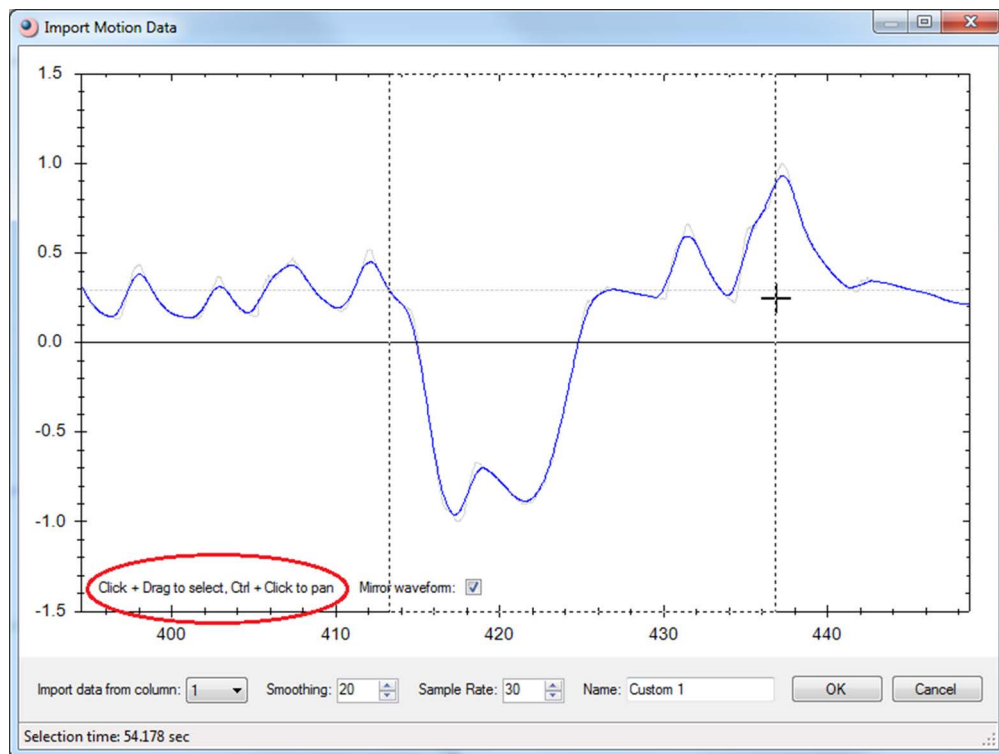
Figure 3-33. Zoom In on Graph

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.

Figure 3-34. Custom Menu Option

For Models 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, provided 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 the motion range. When the recorded breathing waveform files do not have a specified scale factor, the imported Linear and Surrogate amplitudes are scaled to ± 10 mm by default, w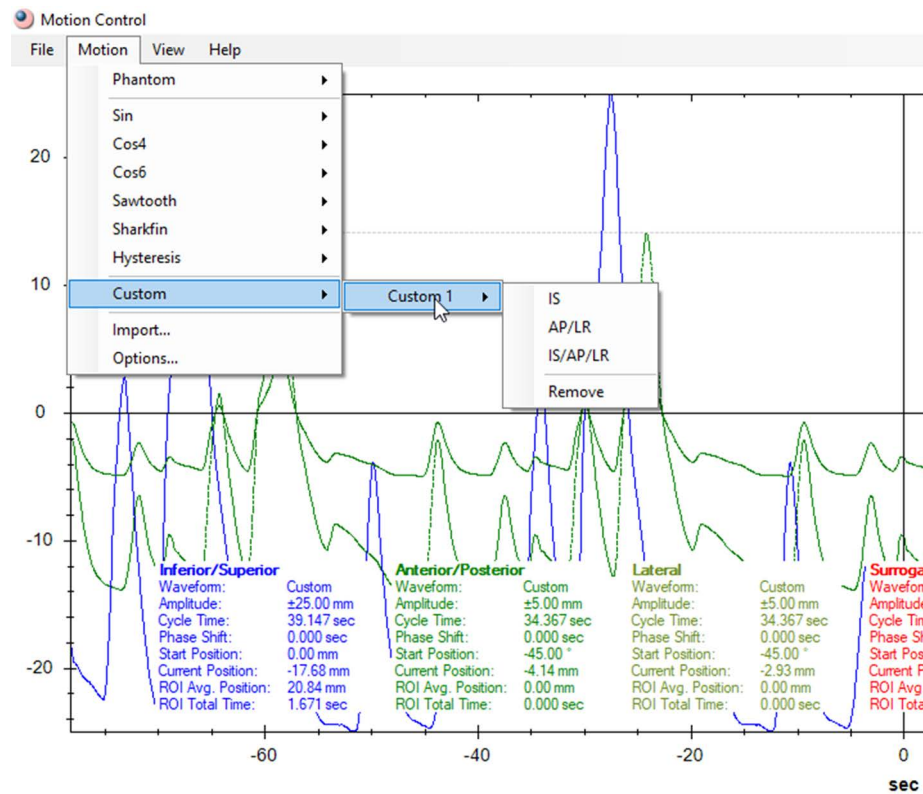hile the Rotational amplitudes are scaled also to ± 2.50 mm by default for Anterior/Posterior and to ± 1.00 mm for Lateral.

For Model 008P

If the tracking motion file header specifies the scale factor used, then the actual amplitudes are imported, provided 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 the motion range. The algorithm used to determine the angle of oscillation for the prostate is designed to achieve both the Inferior/Superior and Anterior/Posterior amplitudes. Specifically, the Inferior/Superior amplitude is either set equal to the maximum amplitude from the waveform input or scaled to the maximum mechanical limit of the prostate's motion. The Anterior/Posterior amplitude is calculated using a mathematical relationship between the amplitudes and rotational starting angle.

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

Figure 3-35. Imported Waveform Parameters

Saving Imported Motions

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

Figure 3-36. Custom Motion

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

Once a file is saved, it can be opened using either *Open Motion* or *Recent Motions*.
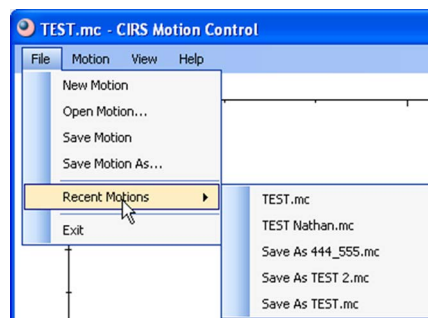

Figure 3-37. Open Imported Motion File

If modifications are performed to a motion in a saved file and you wish to keep both the original motion and the modified one, then use *Save Motion As* instead of *Save Motion*. This will save the modifications without prompting for a new file name. Like in most other Windows applications, *Save* saves the modifications without warning.

4 Analysis

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 an 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 deselect 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.
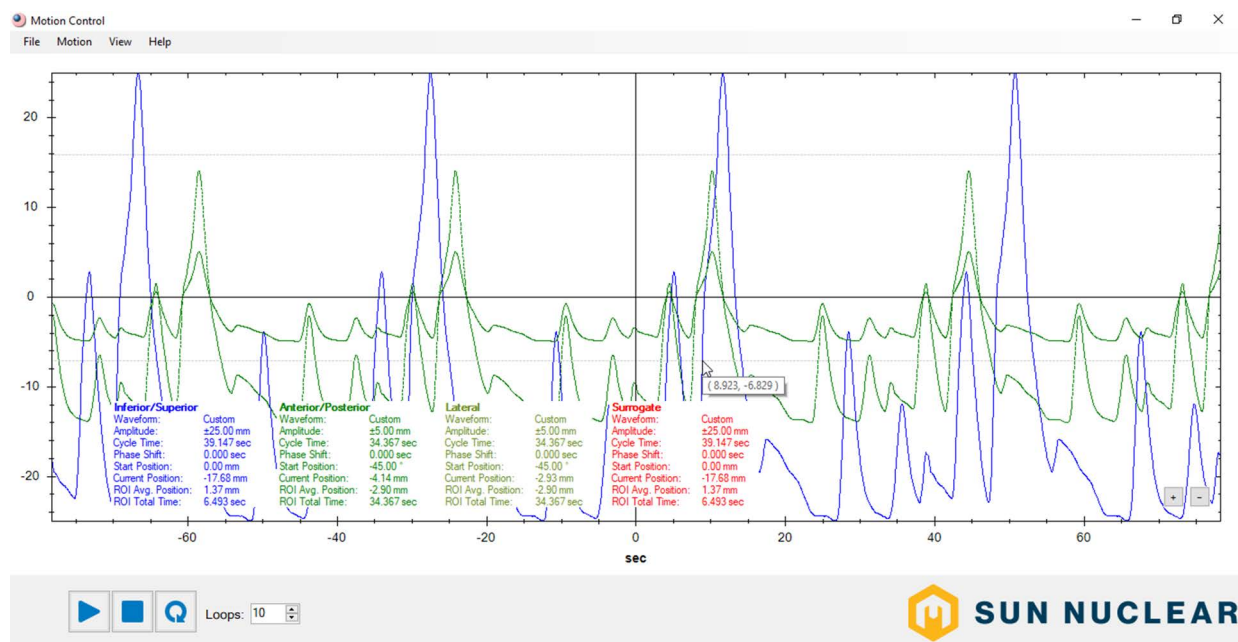

Figure 4-1. Select Region of Interest

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 phantom models for further hard-ware/software developments.
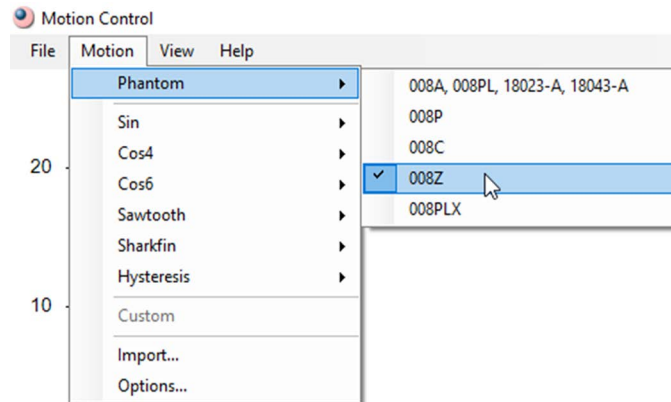

Figure 5-1. Select Phantom

2 Chose a built-in waveform to run for the Beam Latency testing. CIRS strongly suggests that the 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 do one of the following:

- Start the motion and use the Pause button to pause the motion on the bottom plateau regions of the waveform.

Figure 5-2. Pause Motion on Bottom Plateau Regions

- Send the target to the amplitude corresponding to the plateau regions from the Start Position slider bar/entry box (see below). Before doing this, make the amplitude of Inferior/Superior zero.
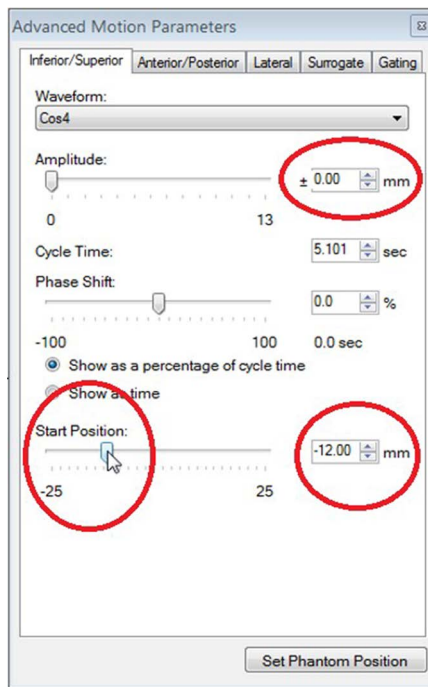
Figure 5-3. Use Amplitude Corresponding to Start Position of Plateau Regions

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 the Start Position again to move the target (in blue) as shown in the right image below. Note the Start position for which the target overlaps the Beam On boundary.
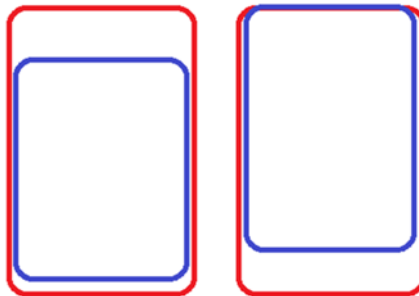
Figure 5-4. Move Target Using Start Position

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

7 Set up the gating window so that it starts and ends at the desired amplitudes (this amplitude is known from the previous step; the Beam On and Beam Off can be set up 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 $\pm$ 20, and the target overlaps the Beam On boundary at -12.5, then the gating should be set up 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.)
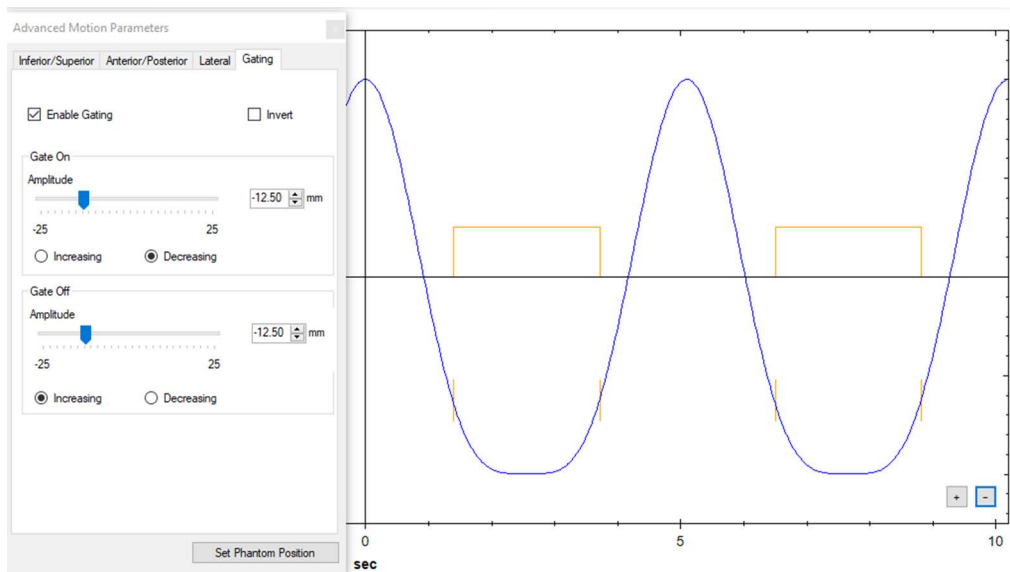
Figure 5-5. Set up Gating

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 Motion Control window (see below). The values are averages of the *Time Delay On* (or *Off*) for the cycles of the waveform that were already executed. If you want to look at individual time delays for individual cycles of the waveform, then you need to first stop the motion and then click the ellipsis button for either *Time Delay On* or *Time Delay Off*.

Figure 5-6. Time Delays for Individual Cycles

Note: *It is not recommended to conduct Beam Latency testing when the Gating Signal, produced by the software using selected gating amplitudes, is already active before initiating the motion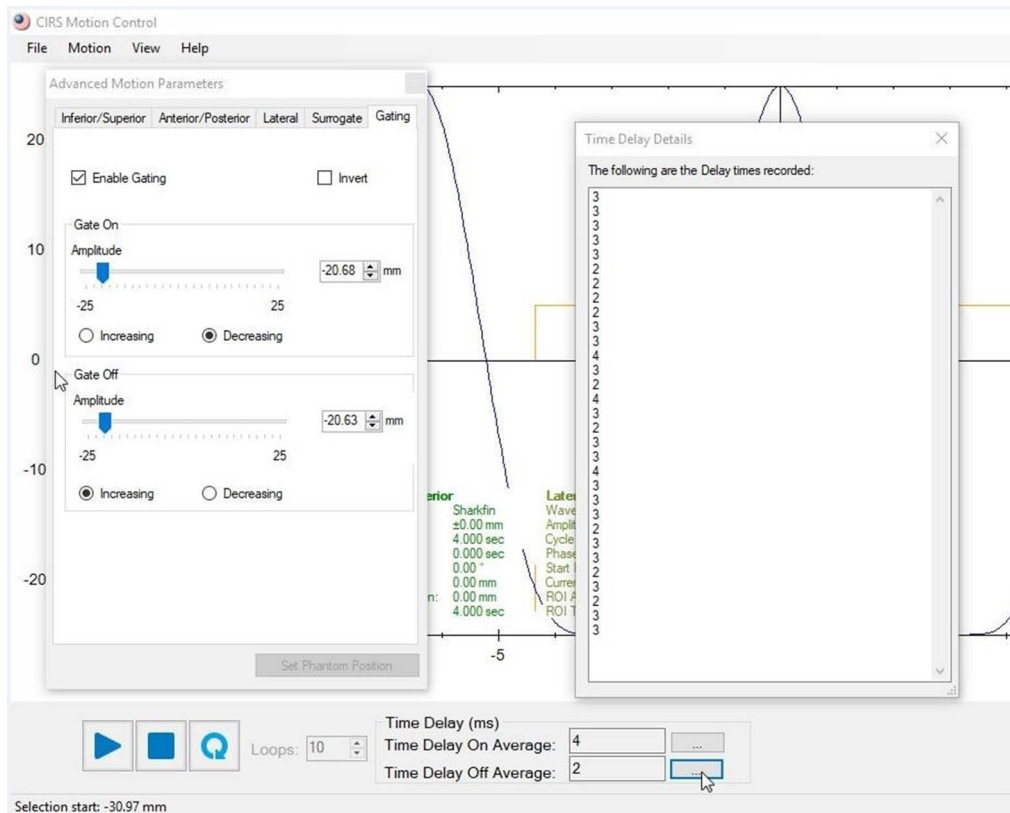 of the phantom. This is because the comparison between the Beam On and Beam Off signal from the MRI-Linac and Gating Signal may yield inaccurate results. In this case, the software algorithm cannot distinguish between Beam On and Beam Off time delays, and as such, wrong information regarding theses parameters could be provided.*
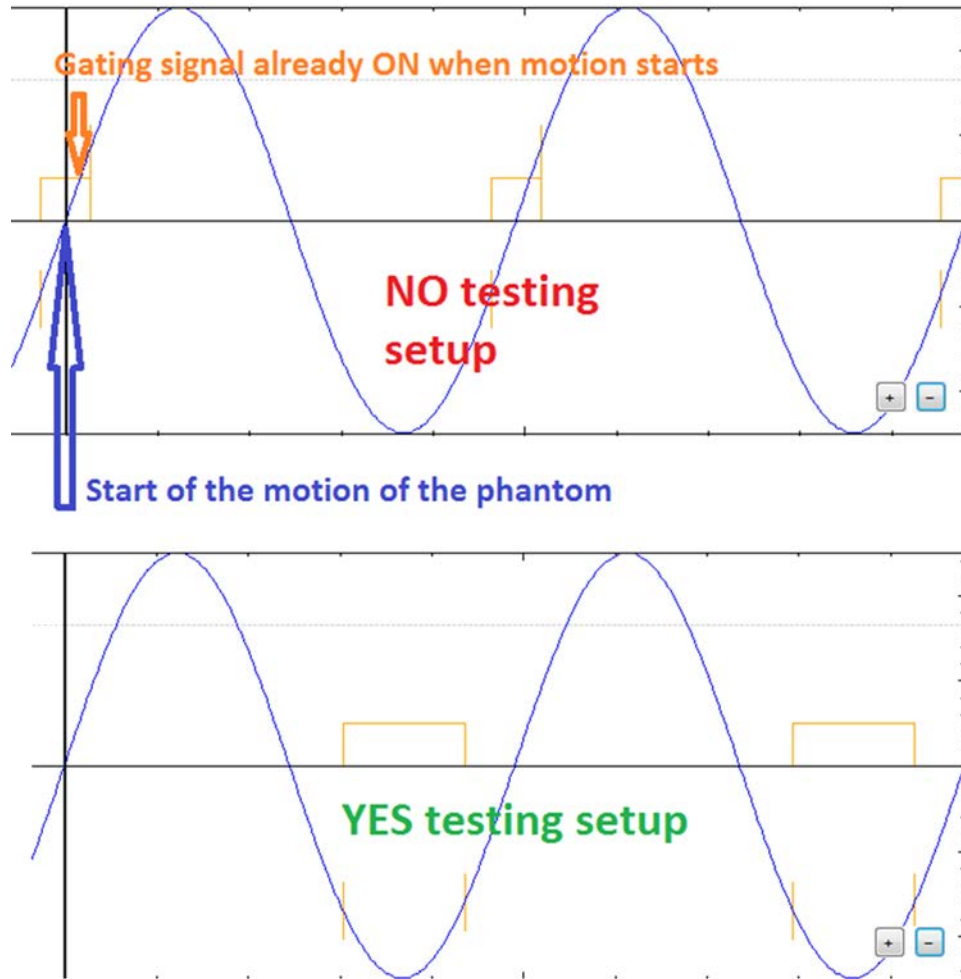

Figure 5-7. Gating Signal

Note: *Beam Latency testing can be performed also 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. This will lead to different values for Beam On and Beam Off time delays depending on where the gating window intersects the waveform. If using an irregular waveform, the user must ensure the Gating Signal is not on when the motion of the phantom starts (see note above). Also the user 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, the user should look at the values shown in the pop-up windows that appear in the main display after clicking the ellipsis button (see below).*
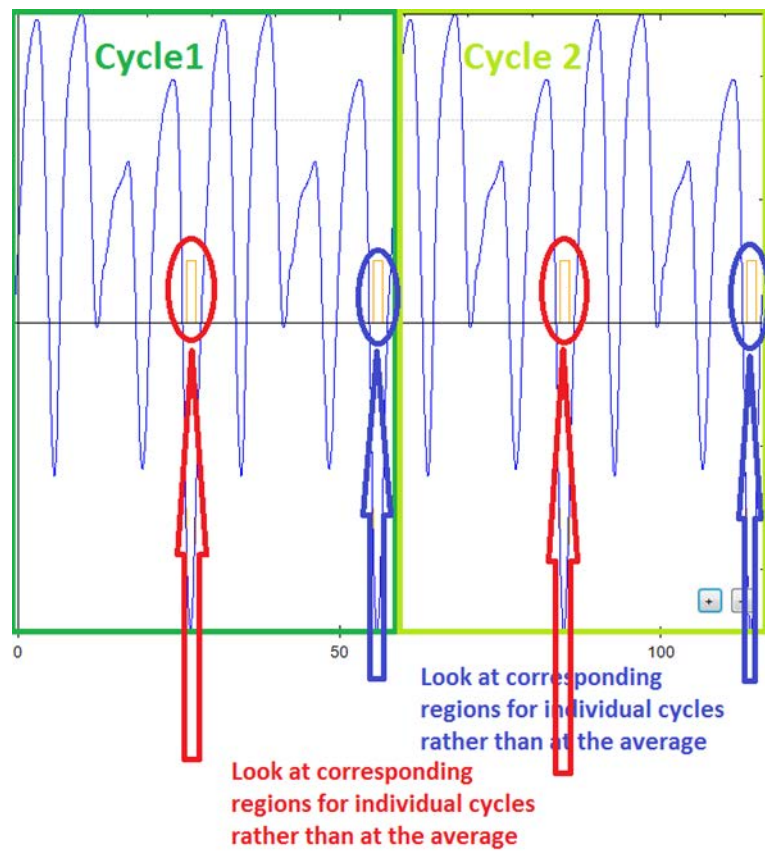
Figure 5-8. Look at Corresponding Regions for Individual Cycles

6 Support and Maintenance

Maintaining Software

For assistance with software installation and maintenance, contact Sun Nuclear Support.

Log File

The software creates a log file that records events such as Application started, Application initialized, Loading motion data to the controller, Motion started (with information 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
```

Figure 6-1. Log File Events

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

Contacting Sun Nuclear Support

You may request support in two ways:
- Submit a support request using our online form. See *Support Website* below.
- Contact the Sun Nuclear Support team by telephone:
  - U.S.A.: +1 321-259-6862, Option 3
  - Netherlands: +31 20 399 90 41, Option 1
  - Germany: +49 61 02 50 49 500, Option 2

Support Website

1 Open an internet browser and navigate to www.sunnuclear.com/support.

2 Enter your email address and password and then click **Login**.

- To download product information, click **Products and Devices**, select the product, and then select the download type.
- To open a Support request, click **Open New Case**, complete the form, and then click **Create Case**.

Appendix A: Regulatory Supplement

Sun Nuclear Corporation Symbols

The following symbols are used in this guide and in Sun Nuclear Corporation's product labels.

⚠	**WARNING: This symbol indicates a risk of electric shock. (EN ISO 7010, W012)**
⚠	**WARNING: This symbol indicates a hazard that could result in major injury or equipment damage. (EN ISO 7010, W001)**
⚠	**CAUTION: This symbol indicates a potential hazard that could result in minor injury or equipment damage. (EN ISO 15223-1, 5.4.4)**
⚠	**CAUTION: This symbol indicates a pinch hazard. (EN ISO 7010, W024)**
	Note: Important or supporting information.
	Manufacturer's Identification (name and address). (EN ISO 15223-1, 5.1.1)
	Date of Manufacture. (EN ISO 15223-1, 5.1.3)
	Temperature limitation. (EN ISO 15223-1, 5.3.7)
	Humidity limitation. (EN ISO 15223-1, 5.3.8)
	Atmospheric pressure limitation. (EN ISO 15223-1, 5.3.9)
REF	*Catalog Number. (EN ISO 15223-1, 5.1.6)*
	Consult instructions for use. This equipment must be used in accordance with the instructions in this manual. Read all instructions and safety labels before use. (EN ISO 15223-1, 5.4.3)

 Do not throw in trash; dispose of in an environmentally friendly way. (EN 50419)

 This symbol indicates a general mandatory action. (EN ISO 7010, M001)

Operator Responsibility

The instructions in this manual are intended for trained clinical personnel. The operator is solely responsible for the accurate setup and use of the device.

Reporting Health or Safety Related Issues or Concerns

A notice to the user and/or patient that any serious incident that has occurred in relation to the device should be reported to the manufacturer and the competent authority of the Member State in which the user and/or patient is established.

To report any safety or health related issues or concerns regarding the use of Sun Nuclear products, contact Sun Nuclear directly.

Modifications to Equipment

Any changes or modifications to the device that are not expressly approved by Sun Nuclear Corporation could void your warranty.