

3

Manually Reconstructing a Tomography Dataset

This chapter introduces the Scout-and-Scan™ Control System Reconstructor Application interface and describes how to use it to manually reconstruct a tomography dataset when any of the following conditions exist:

- Recipe was run with **Recon** type set to *Manual* on the **Advanced Acquisition** tab within the **Scan** view
- Recipe was run with **Recon** type set to *Automatic* on the **Advanced Acquisition** tab within the **Scan** view, but automatic reconstruction failed
- 3D reconstructed images not acceptable due to un-optimized reconstruction parameters

Tomographic reconstruction is the process of mathematically combining the 2D projection images acquired over many angles during a tomography data acquisition in order to create a 3D image volume.

NOTE Scout-and-Scan™ Control System Reconstructor can only be used to reconstruct images that are reference corrected.

NOTE During reconstruction, the amount of free space required on the hard disk drive must be at least 1 GB more than the file size of the tomography (projection) dataset.

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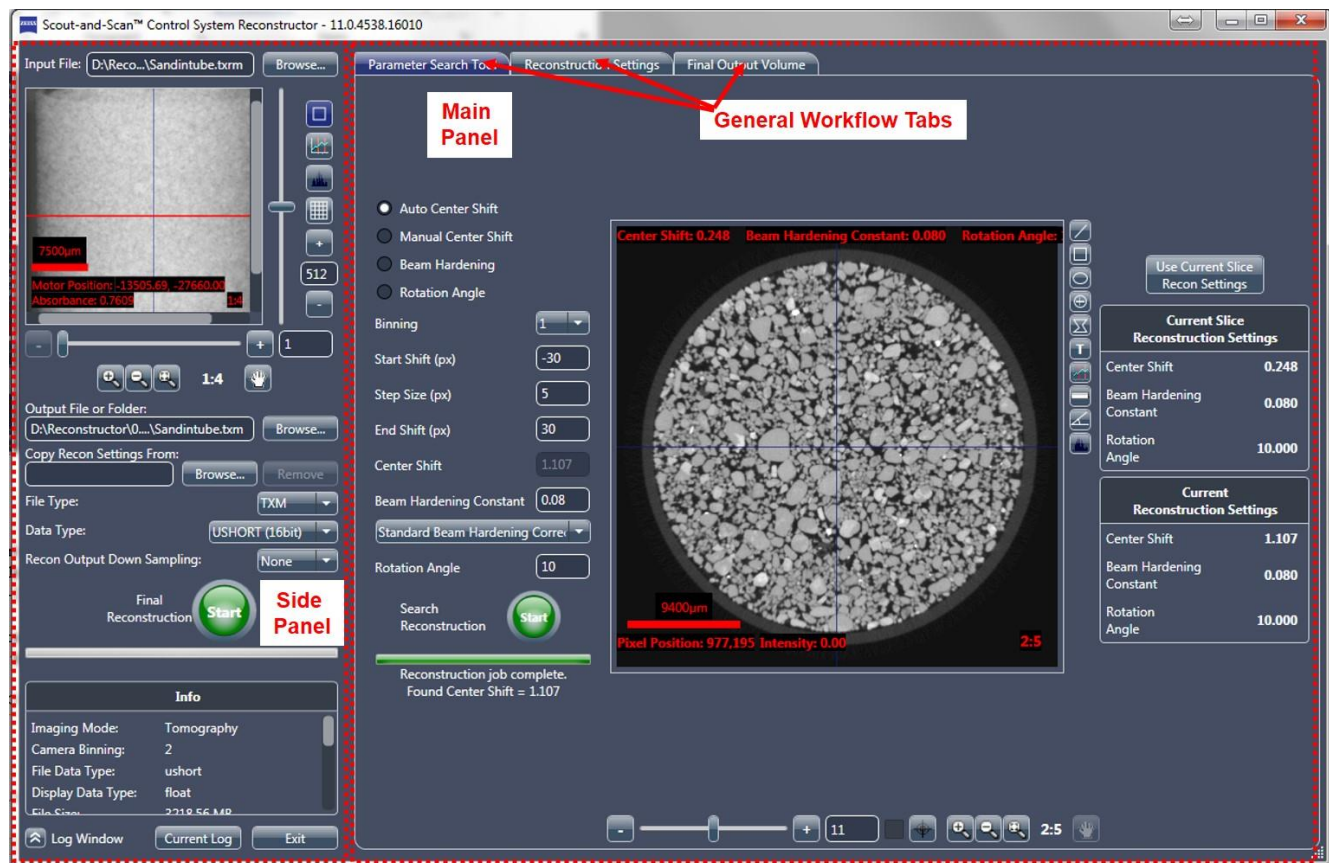
I. Interface Overview

The Scout-and-Scan™ Control System Reconstructor is an interface that allows the user to manually reconstruct raw tomography files obtained from the Zeiss Versa family of systems.

The interface can be divided into two parts (refer to Figure 3-1)

- The side panel and
- The main panel

Figure 3-1 Scout-and-Scan™ Reconstructor Main Window after load file

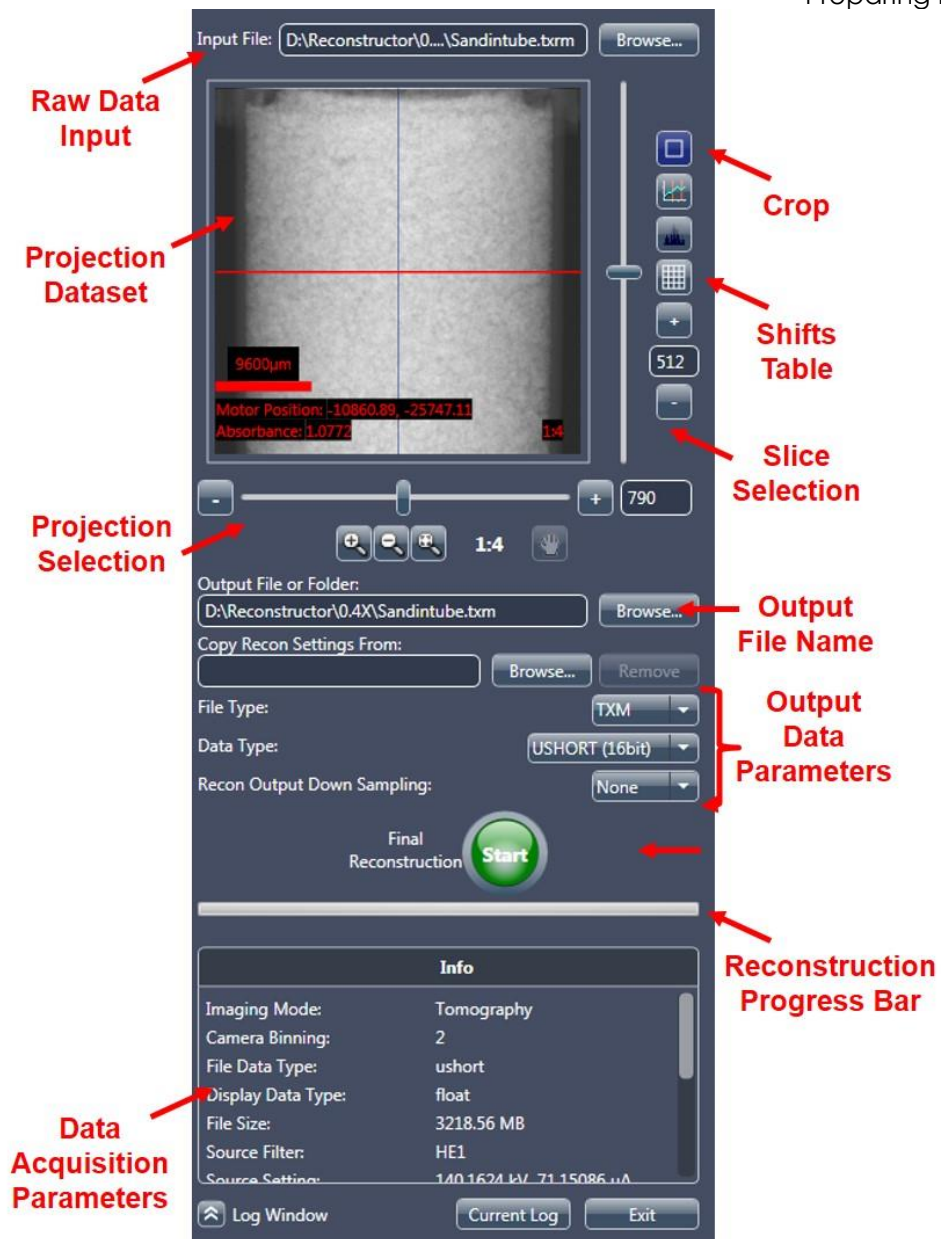


A. The Side Panel

The **side panel** is the first part of the workflow where the user begins the preparation for reconstruction. Selection of the input file, naming the output file, selection of file/ data type etc. are done here. (Refer to figure 3-2)

The information of the raw tomography dataset (.txrm) is also available in the *Info* box at the bottom of the side panel, which lists the data acquisition parameters.

Figure 3-2 Side Panel - Overview

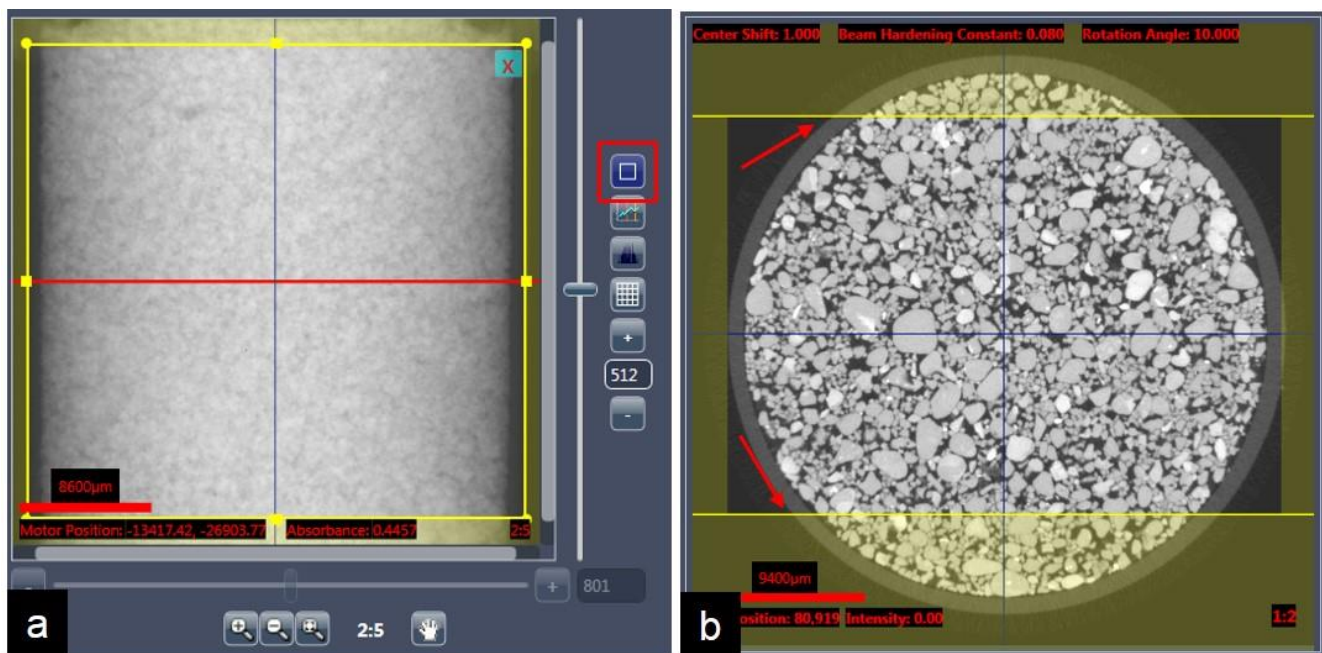


Most of the parameters are discussed as they are used in the reconstruction workflow. Two optional functions seen in the side bar are:

1. Crop

- a) The crop tool is enabled by default (dark blue). If the user desires to reconstruct only a part of the tomography file, left click in the projections window and drag the mouse to draw a rectangle covering the required area. Only the region within the borders will be reconstructed. (refer to figure 3-3a)
- b) To crop in the other plane, after drawing the crop region as shown above, go to the Reconstruction Settings tab. Once the preview slice is available, drag the lines from the upper and lower edges of the reconstructed slice image window, to crop as desired. The parts of the image highlighted in yellow will not be reconstructed. (refer to figure 3-3b)
- c) Clicking the crop button again, will disable editing capabilities of the crop region.
- d) In order to delete the crop, click on the X at the top right corner of the annotation.

Figure 3-3 Side Panel – Crop Tool



2. Shifts Table

The shifts table is accessible by pressing the ‘grid’ icon to the right of the projection image. The shifts table gives the user the ability to manipulate the raw data file by:

a) Checking on Select Projections, to decide the # of projections to incorporate for the reconstruction. (refer to figure 3-4). Common use cases are:

- (1) Simulation of scans running faster than the original time, e.g. skipping every 2nd projection simulates the quality of scan achieved by running the scan approximately twice as fast.
- (2) Conversion of a 360° scan to a 180° +fan angle in case where too much motion was observed in the beginning/end of the scan, to try and obtain a reconstruction with less motion artifacts.

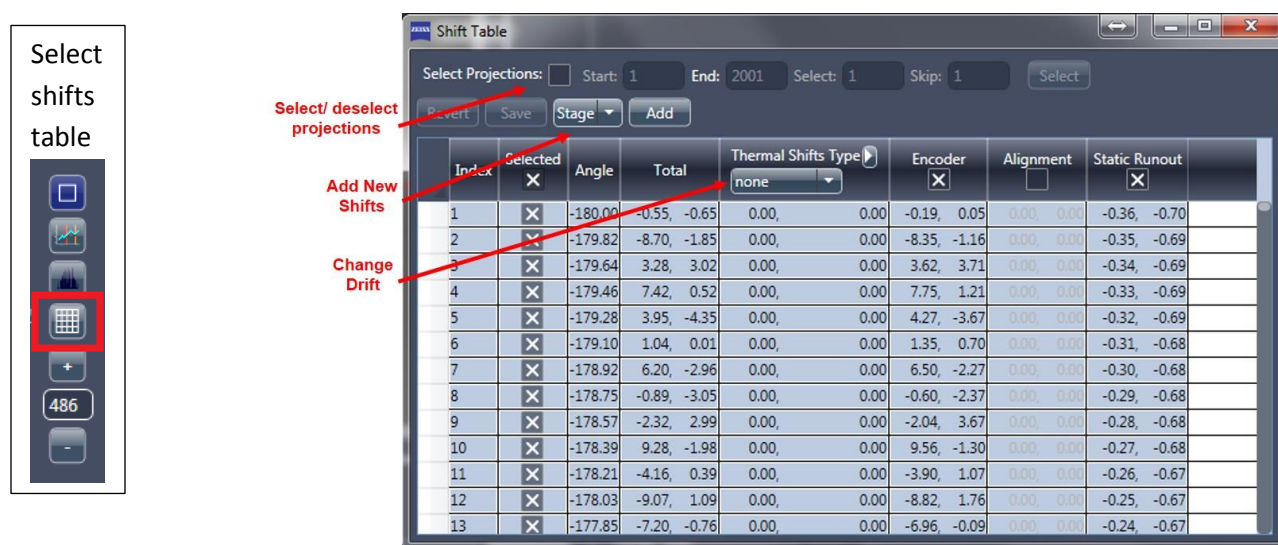
NOTE: Deselecting random projections may lead to artifacts in the reconstruction.

- b) Changing shifts between thermal, AMC and sample drift (if collected) if large sample drifts are noticed in the scan. These are particularly recommended for high resolution scans, to enable reconstruction with less motion artifacts. (refer to figure 3-4)
- c) Adding shifts tables when available e.g. stage, user defined, etc. (refer to figure 3-4)

Please click the “Save” button once the desired shifts table is selected, to apply the selection to the raw data.

NOTE: Data can be reconstructed with only one shifts table applied at a time.

Figure 3-4 Side Panel – Shifts Table



B. The Main Panel

The **main panel** is arranged to aid the workflow of the reconstruction process (refer to figure 3-1), namely:

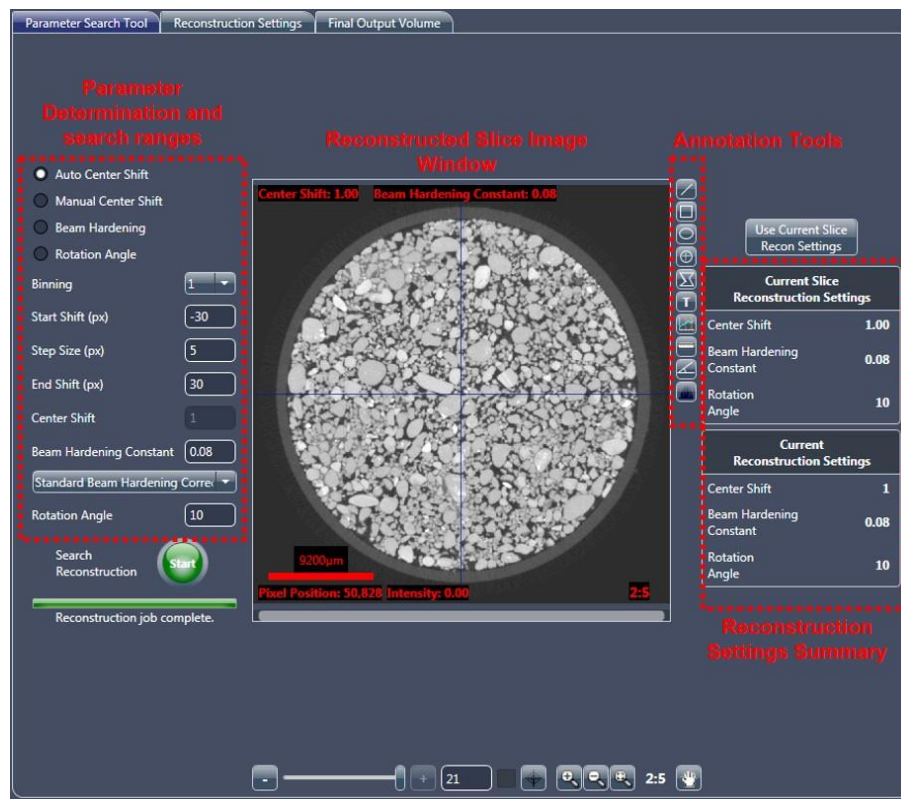
- *Parameter Search Tool* – First, the three main reconstruction parameters, Center Shift, Beam Hardening Correction and Rotation Angle, are determined by the user.
- *Reconstruction Settings* – Second, reconstruction parameters are entered and finalized.

- *Final Output Volume* – After reconstruction, the reconstructed volume can be visualized as a stack of axial 2D image slices.

1. Parameter Search Tool

The Parameter Search tool (refer to figure 3-5) is the first step in the reconstruction workflow to determine the search ranges and the best values for Auto or Manual Center Shift, Beam Hardening Correction and Rotation Angle (optional). The Parameter Search Tool contains three main controls, the Parameter Determination and Search Ranges, the Reconstructed Slice Image Window, and the Reconstruction Settings Summary.

Figure 3-5 Parameter Search Tool Panel



a) Parameter Determination and Search Ranges

- (1) The user first selects the type of search, Auto Center Shift, Manual Center Shift, Beam Hardening, or Rotation Angle.
- (2) Then the user enters in the desired Range and Step Size for each search, or accepts the default parameters. Then press 'Start' to begin the search, and the images will appear in the Reconstructed Slice Image Window.

b) Reconstructed Slice Image Window

The slices reconstructed for the specified search are shown in the **Reconstructed Slice Image** window, in the center. The scroll bars are used to scroll through the images for the user to find the best suited parameters. The annotation tools are explained individually later in this document as and when they are used in the process. The rest are generic and provided for when the user desires them.

c) Reconstruction Settings Summary

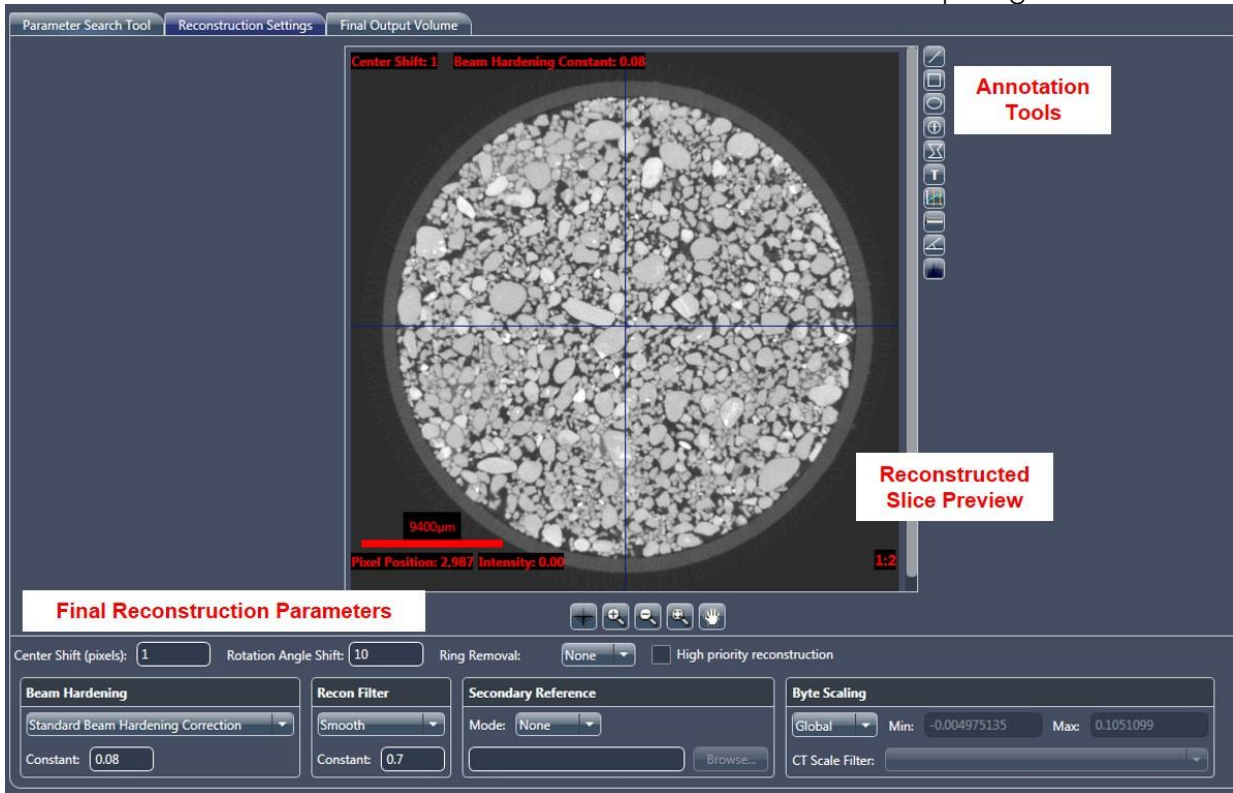
The Reconstruction Settings Summary consists of two sets of the parameters for Center Shift, Beam Hardening Constant and Rotation Angle:

- (1) The "**Current Slice Reconstruction Settings**" are the parameters used to reconstruct the current slice displayed in the Reconstruction Slice Image window.
- (2) The "**Current Reconstruction Settings**" displays the parameters that will be used for the final reconstruction of the data. These parameters get populated in the following 3 scenarios:
 - (a) When the user presses the button "**Use current slice recon settings**", the "Current Slice Reconstruction Settings" parameters get copied into the "Current Reconstruction Settings".
 - (b) When the user directly enters the values under the next "**Reconstruction Settings**" Tab.
 - (c) When the user enters a file in the "**Copy Recon Settings From**" text box, the "Current Reconstruction Settings" will be populated with those used to reconstruct the entered file.

2. Reconstruction Settings

A preview of the reconstructed slice is shown in the center of this tab (refer to figure 3-6). The Final Reconstruction parameters may also be changed here.

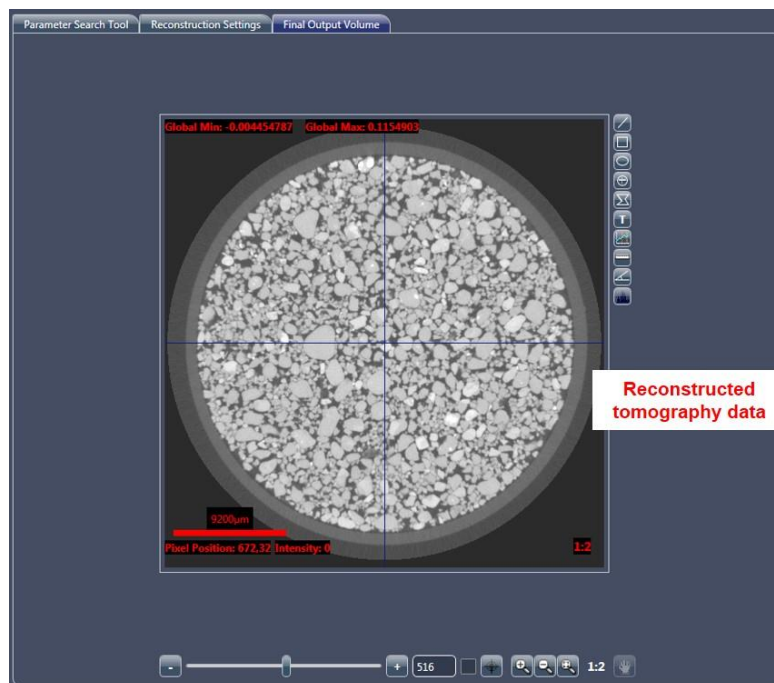
Figure 3-6 Reconstruction Settings Panel



3. Final Output Volume

The reconstructed tomography dataset can be visualized in this tab as a virtual stack of 2D axial slices (refer to figure 3-7). The scroll bars are used to scroll through the slices. Annotation tools including ROI selection and analysis are available on this tab.

Figure 3-7 Reconstruction Settings Panel



II. Process Overview

The process of manually reconstructing a tomography dataset is comprised of the following sub-processes:

1. [Preparing for Reconstruction.](#)
2. [Finding Center Shift.](#)
3. [Finding a Constant for Beam Hardening Correction.](#)
4. [Changing the Rotation Angle \(optional\).](#)
5. [Finalizing the Reconstruction parameters.](#)

A. Preparing for Reconstruction

This process describes how to start Scout-and-Scan™ Control System Reconstructor, load the data and define the initial parameters.

To prepare for reconstruction

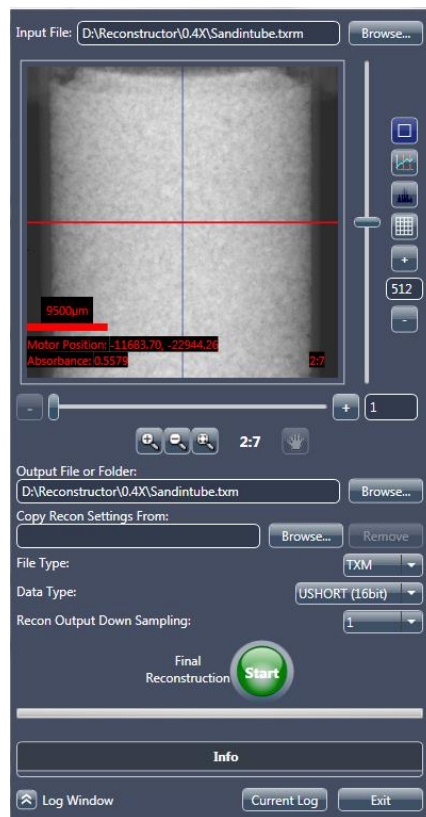
1. Select Start > All Programs > Carl Zeiss X-Ray Microscopy > Xradia Versa 11.x > Reconstructor Scout-and-Scan 11.x from the Windows taskbar.

The **Scout-and-Scan™ Control System Reconstructor** main window opens.

NOTE “x” is the program's current version number.

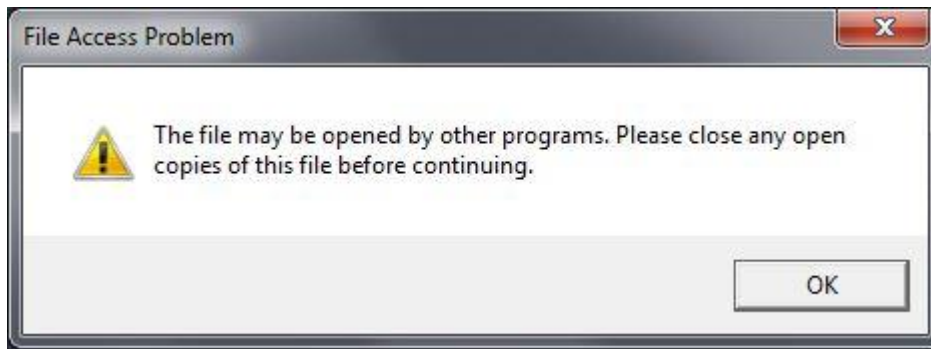
2. Load the file to reconstruct using the Input File dialog box. Click on the **Browse** option and select the raw tomography dataset (*.txrm file). (refer to Figure 3-8)

Figure 3-8 Preparation for Reconstruction



NOTE: If the “The file may be opened by other programs. Please close any open copies of this file before continuing” Warning dialog box opens (refer to Figure 3-9), click OK, close the file in the other program and reload the data as shown in step 2.

Figure 3-9 Reconstructor Warning Dialog Boxes- This file may be opened by other programs and Invalid file for reconstruction



NOTE: If the warning “Invalid file for reconstruction. Only reference corrected files supported. The file header indicates the original data is not reference corrected, and there is no separate reference data available.” Is seen in the logs, the tomography file has not been reference corrected yet. Click OK, then apply a reference image to the file, according to the process described in “Applying the Reference Image,” on page 147, in Chapter vii. If you have not acquired a reference image yet, collect one according to the processes described in “Acquiring a Reference Image,” on page 143, in Chapter vii, then apply it to the tomography file. Upon completing either or both tasks, reload the data as shown in step 2.

3. At the **Output File or Folder** option, click on **Browse** and input the name for the reconstructed tomography dataset (*.txm file). (refer to [Figure 3-8](#))

NOTE A suggested file name is to use the same name as the tomography dataset, but append a “recon” suffix at the end of the file name.

4. If the user wants to reconstruct the tomography file, using settings (Center Shift, Beam Hardening Correction, Rotation Angle, Recon Filter, Byte Scaling) used to reconstruct a previously reconstructed dataset, select browse under the “**Copy Recon settings from**” tab and choose the file (.txrm or .txm). (refer to [Figure 3-8](#))

NOTE: Suggested use cases are manual reconstruction of datasets collected for vertical stitching.

5. The default **File Type** is XRM proprietary file type - .txm. The other output file type options available are BIN, TIFF and DICOM.

NOTE: Datasets of file type .txm ONLY can be opened in the “Final Output Volume” tab of the Reconstructor, the XMController and the XM3DViewer.

6. The default Data Type is ushort (unsigned 16 bit, values from 0-65535). If desired the user can change to uchar (8bit, values from 0-255) and float (32bit).
7. The default Recon Output Down sampling is 1. If user desires to down sample and reconstruct, the options available are 2 and 4.

Proceed to “[Finding Center Shift.](#)”

B. Finding Center Shift

This process describes how to find the center shift. *Center shift* is the amount, in pixels, that the axis of rotation is offset from the center column of the detector. The center shift is used later,

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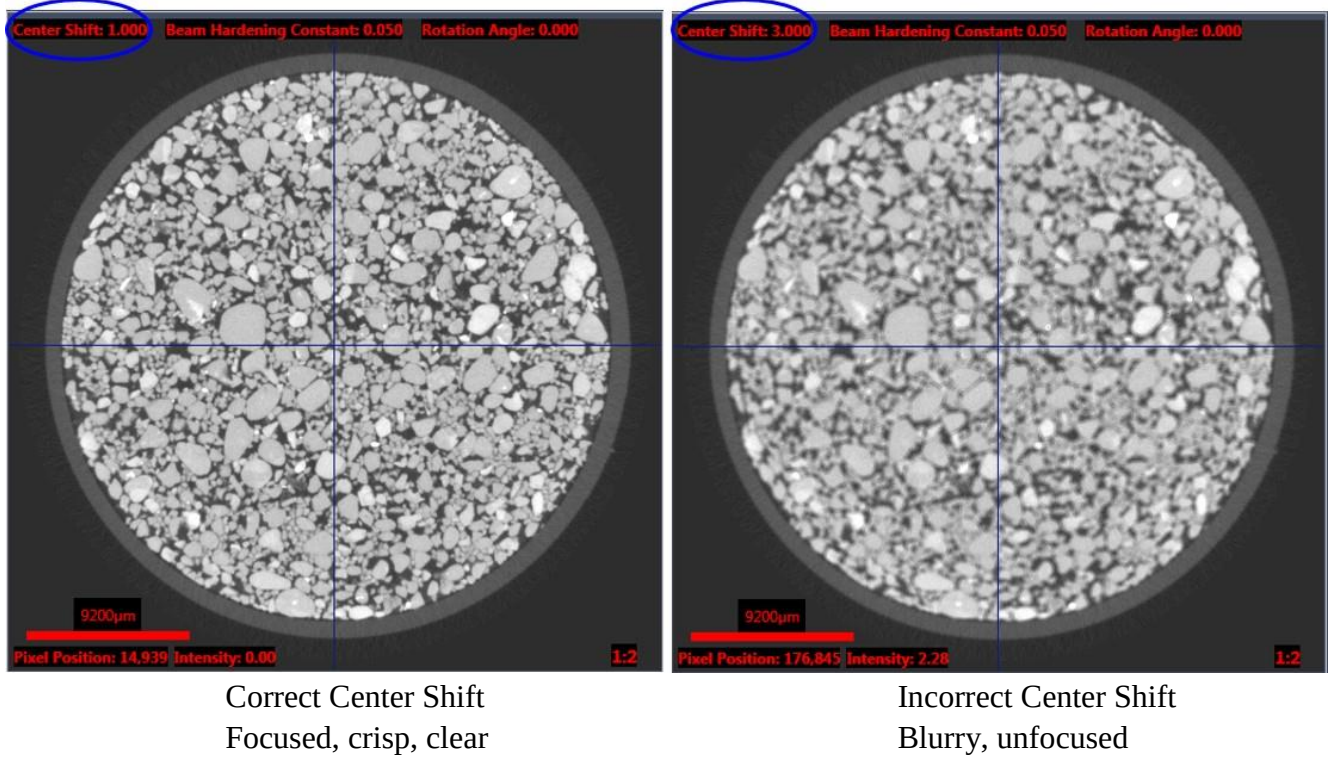
when finding the beam hardening correction and when reconstructing the data.

Images with good center shift are focused and clear, with clean edges and crisp features.

Images with bad center shift are unfocused and blurry.

The center shift value appears in **red** at the top of the images (Refer to [Figure 3-10](#).)

Figure 3-10 Comparison between Good and Bad Center Shift Results



To find center shift for the open *.txrm file

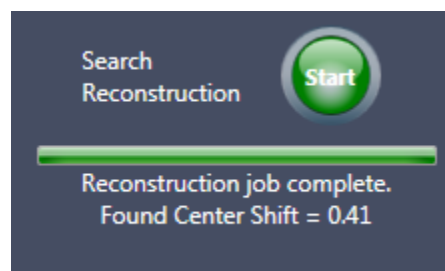
Center Shift can be obtained using either “Auto Center Shift” or the “Manual Center Shift” options.

1. Auto Center Shift

- a) Under the Parameter Search Tool tab, select the Auto Center Shift option.

Figure 3-11 Auto Center Shift - Option Selected

- b) The default values for the search range are ± 30 pixels with a step size of 5 pixels (refer to Figure 3-11). If prior sample knowledge is available, the user can change these values, else use default.
- c) Click on Start to begin the Center Shift Search. When completed, the center shift value will be displayed. (refer to Figure 3-12)

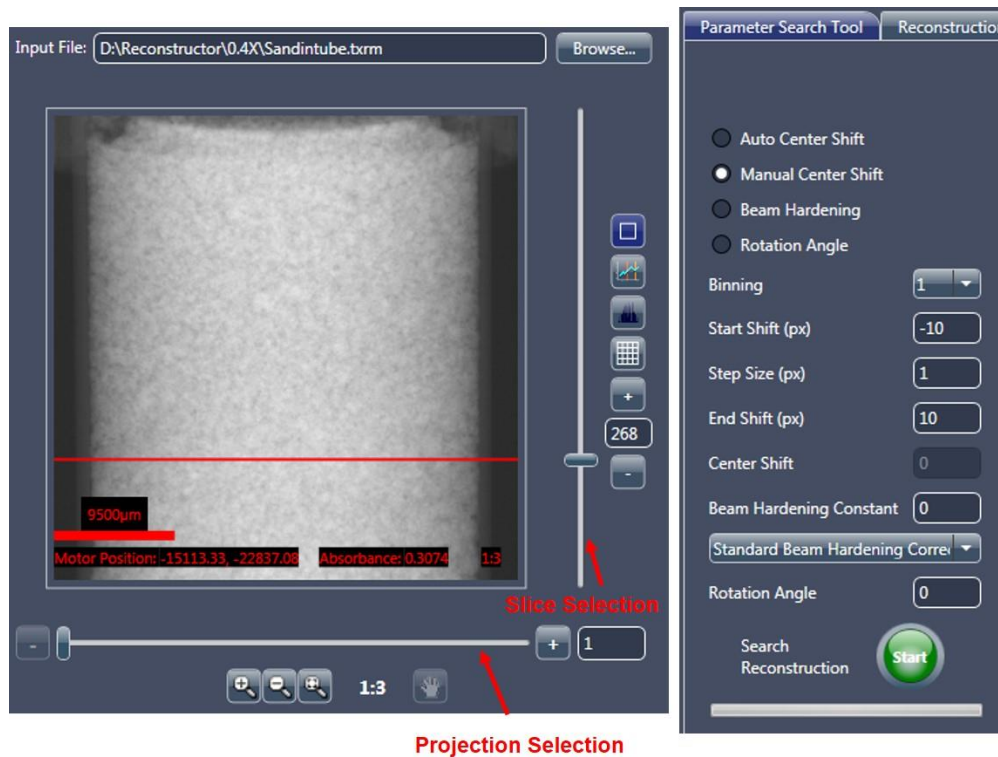
Figure 3-12 Auto Center Shift – Found Center Shift

If the center shift value determined looks incorrect (unfocused features) the user can determine the center shift manually by referring to [Manual Center Shift](#). If the user is satisfied with the auto center shift results, proceed to [“Finding Beam Hardening Correction”](#).

2. Manual Center Shift

The process of manual center shift is a 2 step process:

- Coarse focusing to find an approximately focused image
- Fine focusing to find the best focused image.

Figure 3-13 Slice Selection and Manual Center Shift - Option Selected

a) Coarse Focusing

- (1) If desired, drag the **red** slice selection line to change the slice to cross a high-contrast feature, if present. (refer to [Figure 3-13](#))
- (2) Under the Parameter Search Tool tab, select the Manual Center Shift option. The default values for the search range are ± 10 pixels with a step size of 1 pixel (refer to [Figure 3-13](#)). If prior sample knowledge is available, the user can change these values, else use default.
- (3) Click on Start to begin the Center Shift Search. A **Reconstructed Slice Image** window opens.



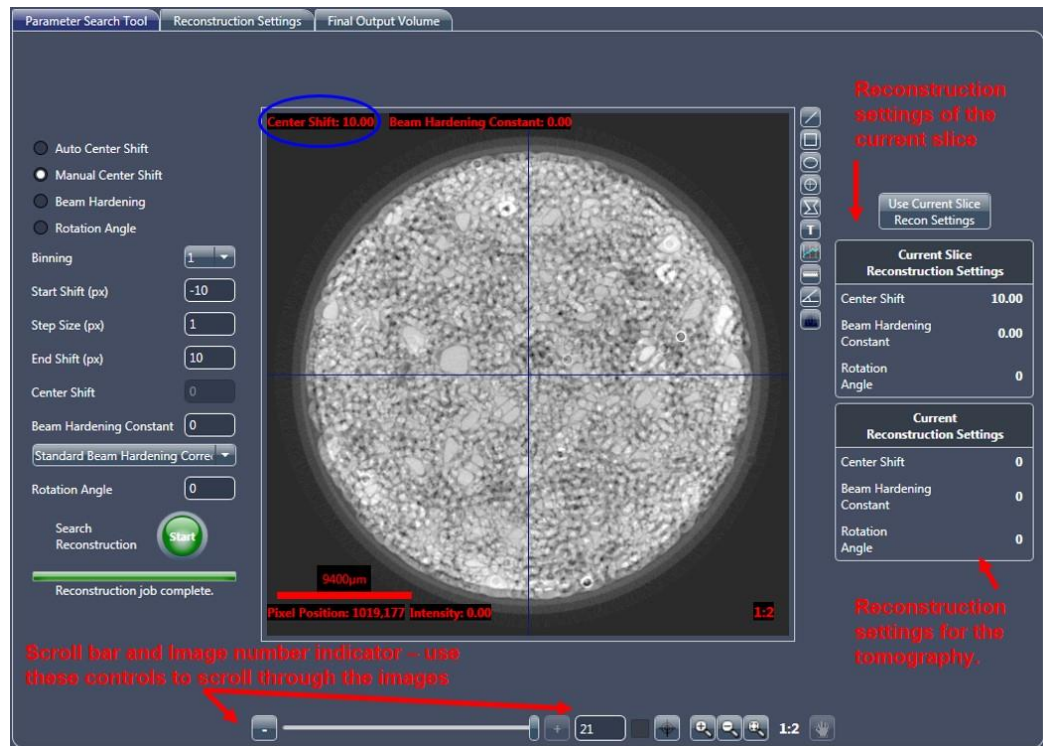
NOTE If you need to abort the Center Shift Find process before it completes,

click  button.

The **Reconstructed Slice Image** window shows a series of 2D reconstructed slices with increasing center shift being created, starting from the shift range specified in the **Start Shift (pixels)** text box, increasing in intervals, according to **Step Size (pixels)**, and ending in the shift specified in the **End Shift (pixels)** text box. The amount that each image is shifted is indicated as “**Center Shift = xxx**” (upper left corner). The scroll bar and/or the image number indicator can be used to scroll through the images (refer to [Figure 3-14](#))

Wait while the image finishes center-shifting through the range. The status under the Parameter Search tool tab changes to Reconstruction Job Complete at the end of the process.

Figure 3-14 Reconstructed Slice Image Window



(4) Scroll through the multiple images in the **Reconstructed Slice Image** window, using the slider in the scroll bar or the image number control (click the – or + symbols) at the bottom of the window, to locate and identify the image with the crispest features (sharpest focus).

(5) Note the *center shift* (indicated as **Center Shift**, top left corner of the **Reconstructed Slice Image** window) of the image with the sharpest focus. This is the coarse center shift number.



NOTE If a good center shift is not found within the specified Start and End Shift range, repeat steps 1 through 5, but in step 2, change the *Start and/or End Shift* setting, to search over a different range.

(6) In cases where there are areas on the image that are all white or black, use the Recon Histogram tool (refer to [Figure 3-15](#)) to adjust image contrast and brightness, such that detailed features within the all white/black areas can be observed.

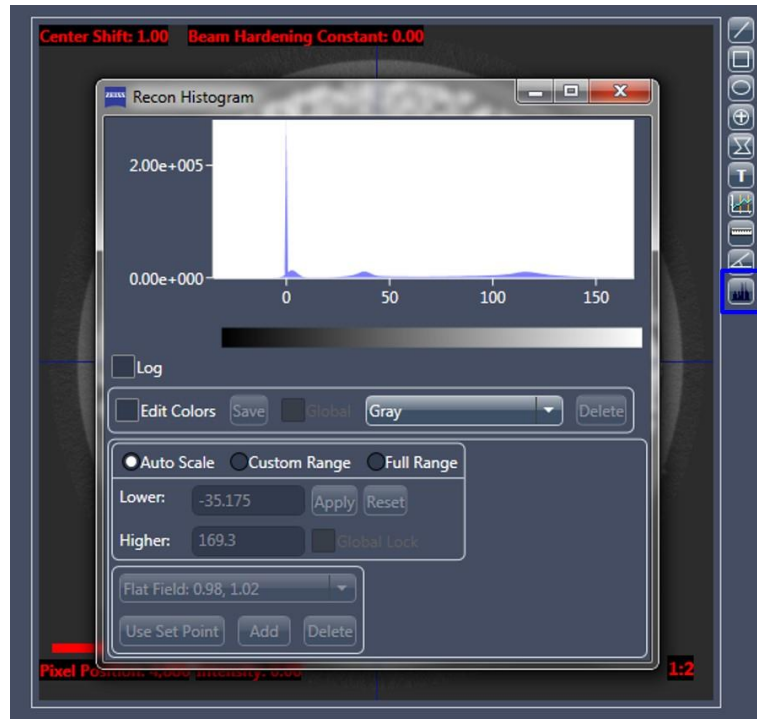


NOTE A complete description of how to use the Histogram tool is provided in “XMReconstructor Histogram Tool,” on page 205, in Appendix D.

Follow steps **a** and **b** below, to adjust contrast and brightness:

- (7) Click  next to the image (refer to [Figure 3-15](#)). The **Recon Histogram** tool opens.

Figure 3-15 **Recon Histogram** Panel



- (8) Click Custom Range. Next, use the mouse pointer to click and drag to the RIGHT and/or LEFT within the white area of the Histogram panel, to adjust image contrast and brightness.

✓ **NOTE** The **Auto-Scaling** option can be selected to automatically estimate the best contrast and brightness for the image; however, the results may not provide what you want; therefore, manual adjustment are available.

b) Fine focusing

- (1) Change the input values for the search range such that the range is about ± 2 -3 pixels of the coarse center shift number found in Step 6. Change the **step size** to **0.2** pixels.

Eg: If the coarse center shift number determined is (-2), use the following parameters for fine center shift determination.

Parameter	Value
Start Shift (px)	-5
Shift Size (px)	0.2

End Shift (px)	1
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- (2) Click on Start to begin the Center Shift Search. Once completed, scroll through the images and select the center shift number of the best focused image.

The window “Current Slice Reconstruction Settings” displays the reconstruction parameters used for the selected slice. The window “Current Reconstruction Settings” displays the parameters selected for the final reconstruction of the tomography. (refer to [Figure 3-14](#)).

- (3) Go to image selected with the best focused features and click on “Use current slice recon settings”. The “Current reconstruction settings” will now match the “slice reconstruction settings”.

Proceed to [“Finding Beam Hardening Correction.”](#)

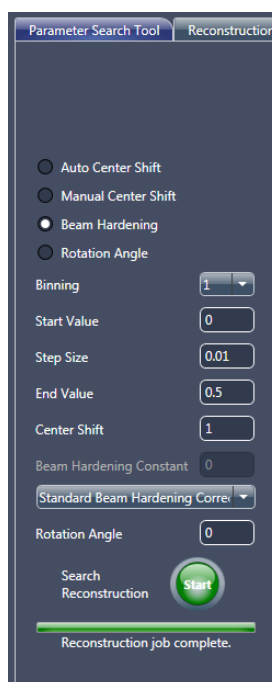
C. Finding Beam Hardening Correction

This process describes how to find the beam hardening correction.

Beam hardening is the result of the change in spectrum characteristic as the X-rays pass through the sample, where the sample density remains the same, but the light changes – one area of a same material is darker than another area.

NOTE The typical beam hardening correction is usually between 0.01 to 0.2, if the correct X-ray source filter is used for Full field of view scans. For interior tomographies the numbers can be 0.

Figure 3-16 Beam Hardening - Option Selected



To identify beam hardening correction in the open *.txrm file

1. Under the Parameter Search Tool tab, select the Beam Hardening Constant option. (refer to [Figure 3-16](#))
2. The default values for the search range are as follows

Option	Setting
Binning	1
Start value	0
Step for Beam Hardening	0.01
End value	0.5
Center Shift	Center shift noted in " Finding Center Shift ,"
File	Standard Beam Hardening Correction

If prior sample knowledge is available, the user can change these values, else use default.

- Click on Start to begin the Beam Hardening Constant Search. A **Reconstructed Slice Image** window opens.

✓ **NOTE** If you need to abort the Beam Hardening Constant Search process

before it completes, click  button.

The **Reconstructed Slice Image** window shows a series of 2D reconstructed slices with increasing beam hardening correction constants being created, starting from the setting specified in the **Beam Hardening Constant** option, **Start value** text box, increasing in intervals, according to **Step Size** and ending in the setting specified in the **End value** text box. The amount that each slice is corrected (Beam Hardening Constant) is indicated as **Beam Hardening Constant** (upper left corner).

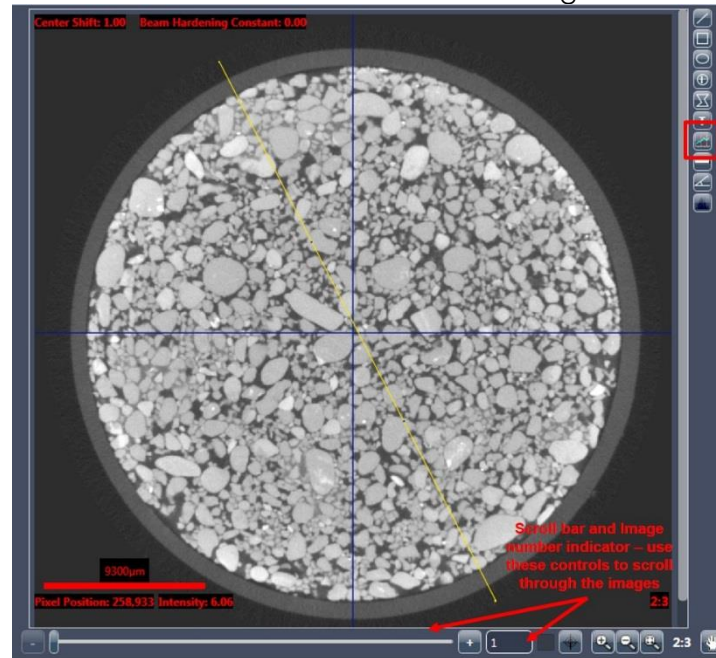
Wait while the image finishes center-shifting through the range. The status under the Parameter Search tool tab changes to **Reconstruction Job Complete** at the end of the process.

- Adjust image contrast and brightness using the Histogram tool, if necessary, as described in “Finding Center Shift”.

NOTE A complete description of how to use the Histogram tool is provided in [“XMReconstructor Histogram Tool,” on page 205, in Appendix D.](#)

- Click  to enable the Line Plot annotation tool.
- Draw a line across the 2D reconstructed slice, by using the mouse pointer to click and drag within the **Reconstructed Slice Image** window. The line should span materials of similar density. (refer to [Figure 3-17](#)). The **Line Graph** window opens.

Figure 3-17 **Reconstructed Slice Image Window - Window with annotation line**



7. To reduce noise on the plot (by averaging more lines, and thereby smoothing out the graph), use the line width scroll bar to get a value between 10 and 100 (maximum) in the Line Width text box, to widen the graph line width. (Refer to [Figure 3-18](#).)

Figure 3-18 Plot of line profile across image



8. In the **Reconstructed Slice Image** window, use the slider to scroll through the 2D reconstructed slices. As you scroll, watch the graph in the **Line Graph** window. The slice with the optimum beam hardening correction value in the **Reconstructed Slice Image** window will have the flattest graph ($BH=0.08$ in this example) in the **Line Graph** window. (Refer to [Figure 3-19](#).)

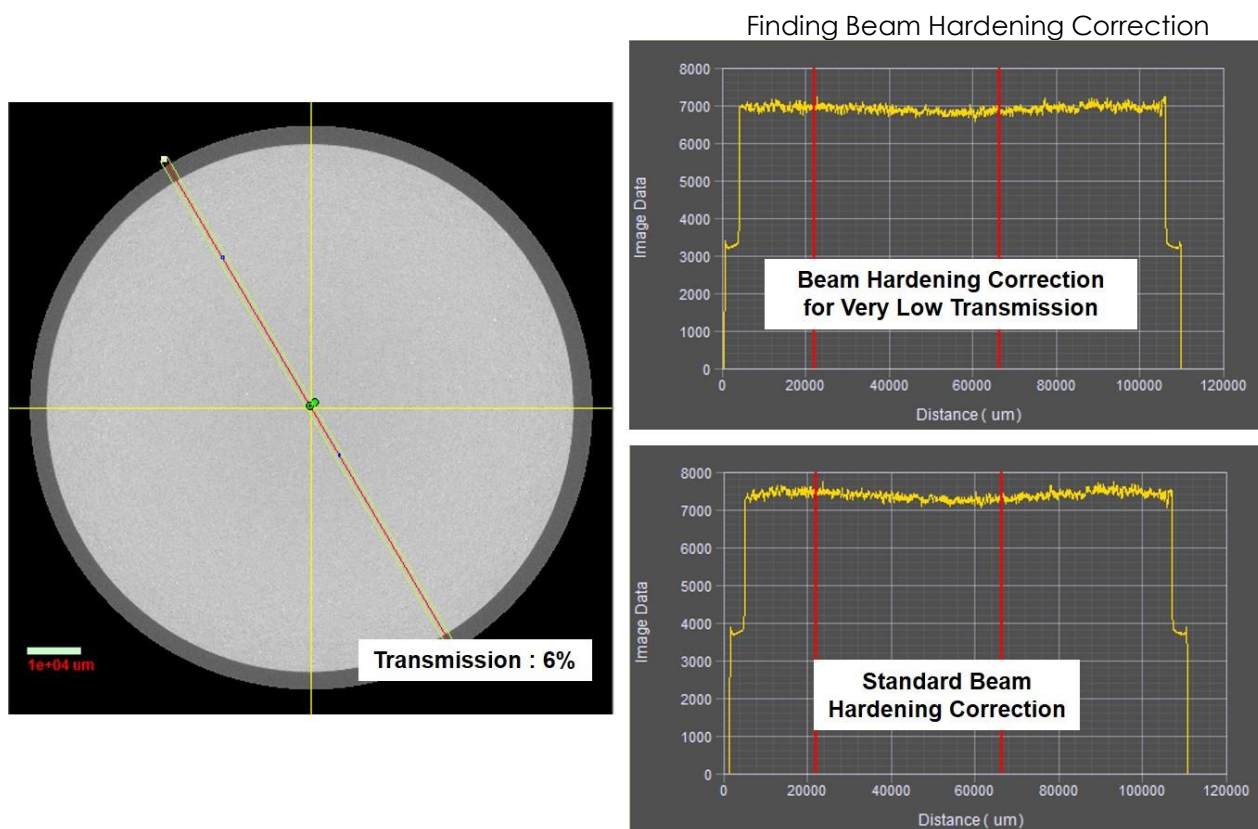
The 'Best' beam hardening is when the line profile drawn across the images is as flat as possible, with no overall curvature in the line. The center picture above is the flattest.

Figure 3-19 Understanding Beam Hardening

9. Go to the image with the selected beam hardening constant and click on “Use current slice recon settings”. The “Current reconstruction settings” will now match the “slice reconstruction settings”.
10. Close the Line Graph window (click , top right corner).
11. The “Standard Beam Hardening Correction” file is selected as default and used for most applications. For very low transmission samples, the user can select the “BH Correction for Very Low Transmission” file from the drop-down menu and carry out the BH search procedure.

As shown in [Figure 3-20](#), using the “BH Correction for Very Low Transmission” file for a large sample with only 6% transmission through it, gives a much flatter BH response along the entire thickness of the sample, as compared to the one obtained using the “Standard Beam Hardening Correction” file.

Figure 3-20 Beam Hardening for very low transmission samples.



Proceed to “Changing Rotation.”

D. Changing Rotation Angle

This process describes how to change the rotation of the axial slices (looking top - down of the sample) of the tomography data.

Rotation of the sample is useful if a certain orientation of the slices in the axial plane is desired. This is especially required when dealing with flat samples to increase the slice orthogonality.

To change rotation of the slices in the axial orientation

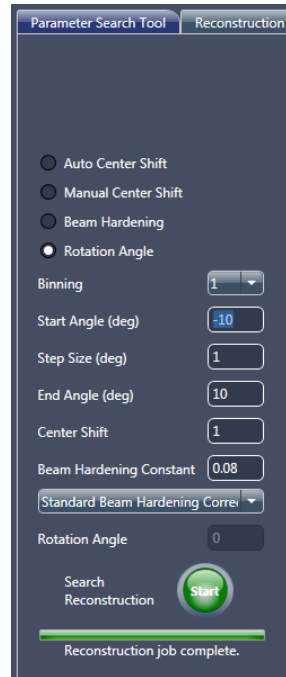
1. Under the Parameter Search Tool tab, select the Rotation option. (refer to [Figure 3-21](#))
2. The default values for the search range are as follows:

Option	Setting
Binning	1
Start angle (deg)	-10
Step Size (deg)	1
End angle (deg)	10
Center Shift	Center shift noted in “ Finding Center Shift ”

Beam Hardening	Beam Hardening Constant noted in <i>"Finding Beam Hardening Correction"</i>
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If prior sample knowledge is available, the user can change these values, else use default.

Figure 3-21 Changing the Rotation Angle



- Click on Start to begin the Rotation angle Search. A **Reconstructed Slice Image** window opens.



NOTE If you need to abort the Rotation Search process before it completes,



click  button.

The **Reconstructed Slice Image** window shows a series of 2D reconstructed slices with different rotation angles being applied, starting from the setting specified in the **Rotation** tab, **Start angle** text box, increasing in intervals, according to **Step for Rotation**, and ending in the setting specified in the **End angle** text box. The amount that each slice is rotated is indicated as **Rotation** under Current Slice Reconstruction Settings.

Wait while the image finishes rotating through the range. The status under the Parameter Search tool tab changes to **Reconstruction Job Complete** at the end of the process.

- In the Reconstructed Slice Image window, use the slider to scroll through the 2D reconstructed slices. Select the image with the desired orientation. (refer to [Figure 3-22](#)) For flat samples, select the rotation such that the plane of the sample

orthogonality is increased. (refer to [Figure 3-23](#))

Figure 3-22 Rotation to achieve desired orientation

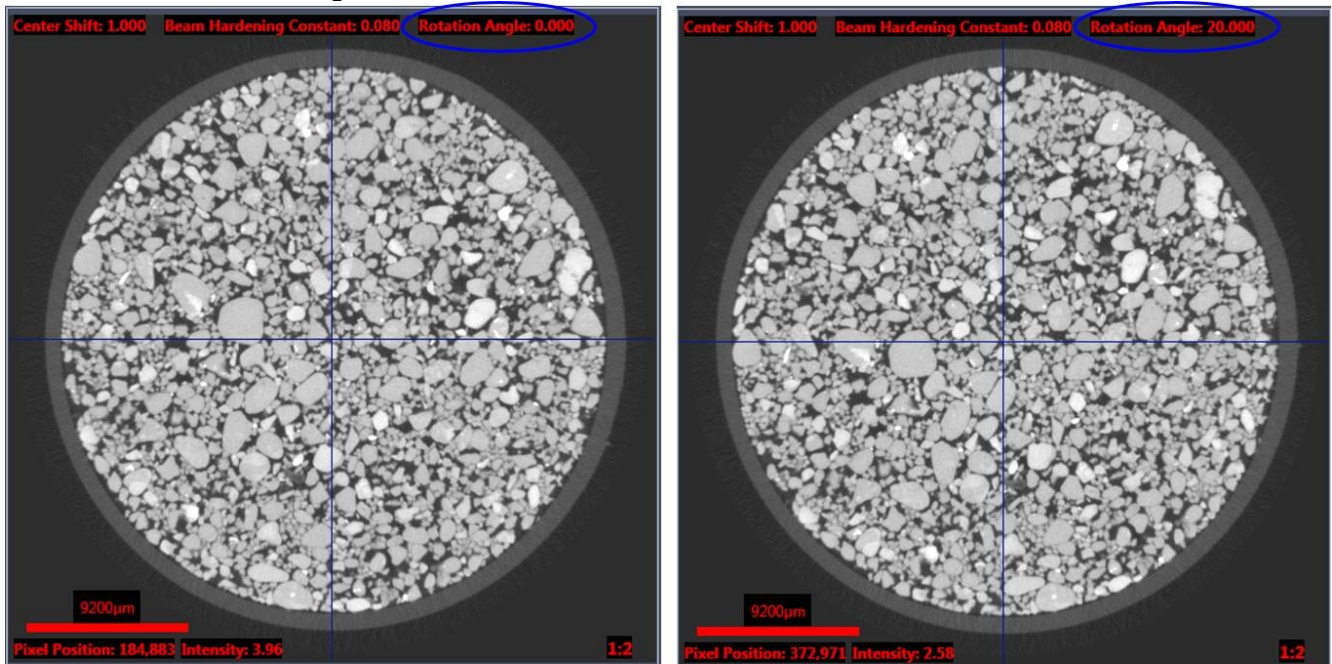
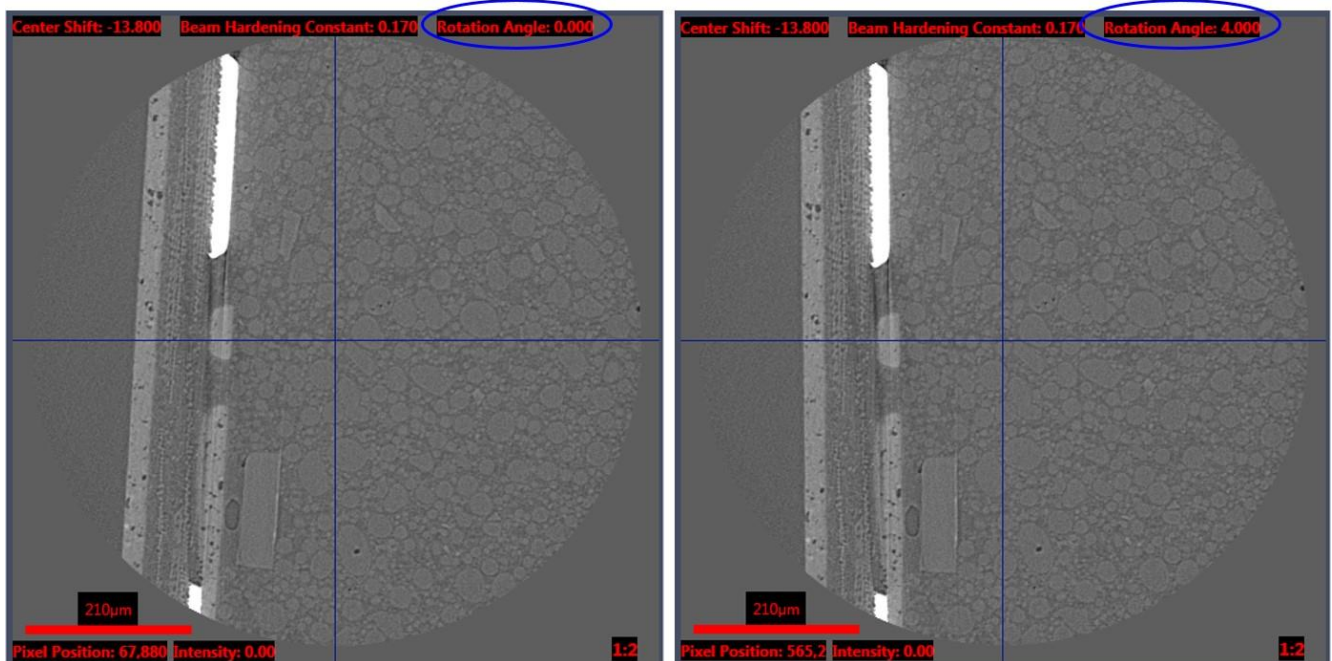


Figure 3-23 Rotation to make axial plane flat to axis



5. The step 2 settings can also be changed, to look at smaller or larger rotation angle ranges with finer or coarser rotation angles. The angle tool  can also be used to calculate the required sample rotation.
6. Go to the image with the preferred axial rotation and click on “Use current slice

Finding Beam Hardening Correction recon settings”. The “Current reconstruction settings” will now match the “slice reconstruction settings”.

Proceed to “[Reconstructing the tomography data.](#)”

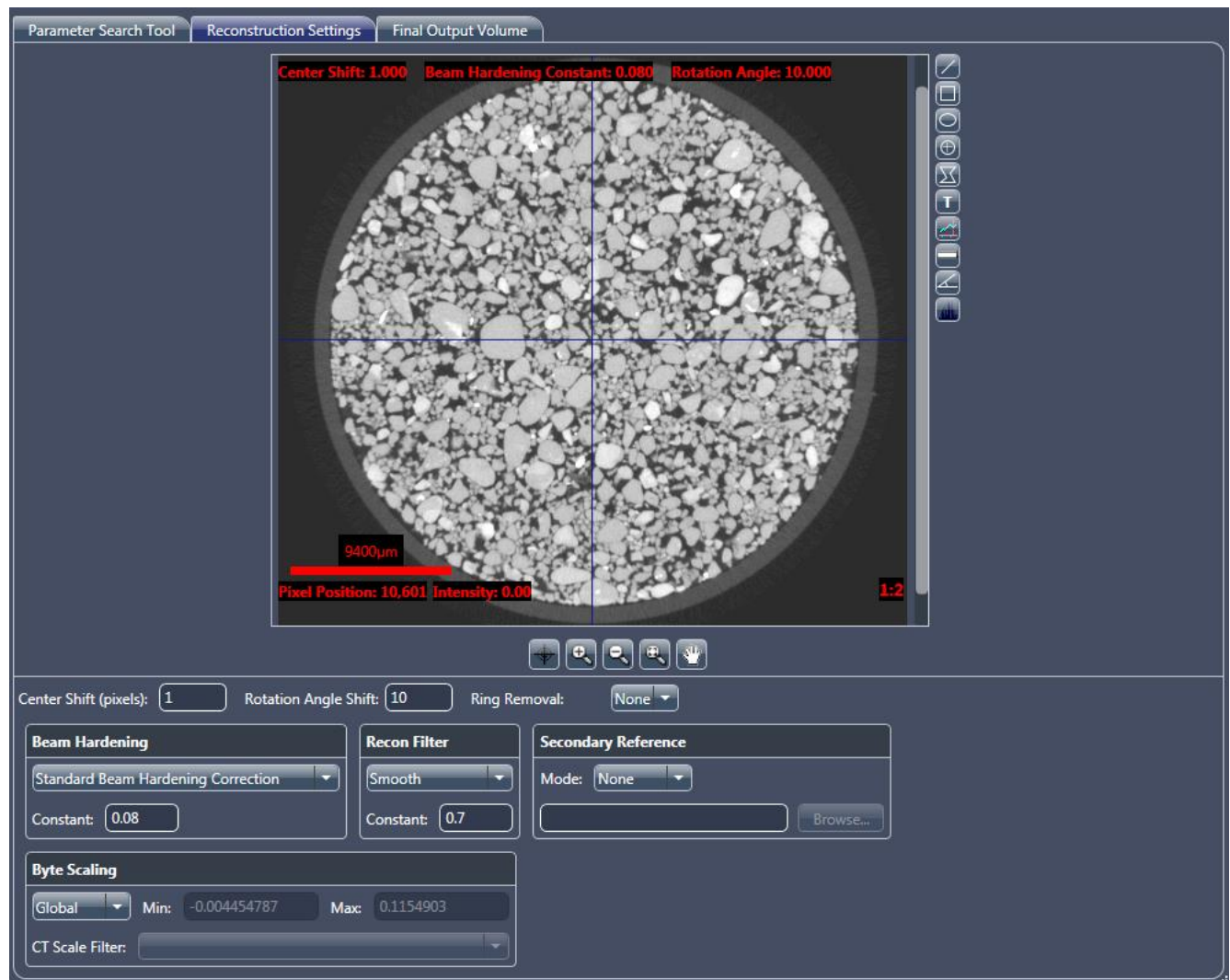
E. Reconstructing the Tomography Data

This process describes how to reconstruct the tomography data, after finding the center shift, constant for beam hardening correction and the rotation angle (if desired).

*To reconstruct the open *.txrm file*

1. Select the “Reconstruction Settings” tab (refer to [Figure 3-24](#)) in the main panel

Figure 3-24 Reconstruction Settings tab



If the user has clicked on the “Use current slice recon settings” or manually input the parameters while

searching for center shift, beam hardening or rotation, those parameters will be already populated.

2. Select one of the following *options* from the **Ring Removal** drop-down list box:

Option	Usage
None: No Ring Removal	Use this option if DRR is enabled.
Low contrast	Use this option if DRR is disabled, for bone, rock, plastic, carbon composite, or composite material samples.
High contrast	Use this option if DRR is disabled, for high-contrast samples, such as semiconductors, or if the other two options do not apply.

NOTE The High contrast ring removal option is known to sometimes add rings when there are regularly repeating high-contrast features.

3. Select a *software filter* from the **Recon Filters** drop-down list box.
The minimum filter available is Smooth (Kernel Size = 0.5); if unsure, start with *Smooth (Kernel Size = 0.7)*.

NOTE The **Recon Filters** value is magnification lens- and sample-dependent.

NOTE Determine which *software filter* provides the most satisfactory **balance** between image resolution and noise (through your own experience); using the correct software filter provides for significant noise reduction, but has a minimal impact on resolution.

NOTE Do **not** use **None** nor **Sharp (Shepp-Logan)**.

4. If the **Secondary Reference** was collected automatically using the Zeiss Versa 520, it should be shown as “Embedded” by default. If the user collected a secondary reference manually, select the “Use File” option to browse for and apply the reference. Leave the option as “None” if no secondary reference correction is to be applied.

NOTE Refer to *Secondary Reference procedure*

5. Unless for special cases, leave Global scaling as default under Byte Scaling.
 - i. Use the Custom option only if Global minimum and maximum byte scaling values are known from a prior similar sample (scan acquired at the same settings (X-ray source power, detector and X-ray source distances, number of projections, exposure times, binning, and magnification)). Type the minimum and maximum byte scaling values in their respective text boxes. E.g: Manually reconstructing datasets acquired for Vertical stitching
 - ii. Dataset is to be CT-scaled and CT scaling calibration is complete. Select Apply CT Scale, then select the correct software filter from the CTScale Filter drop-down list box.

NOTE Refer to *CT Scaling Instructions (G000135)*, included with the

NOTE: For further information on manual reconstruction for Vertical Stitched datasets, please refer the technical procedure for Vertical Stitch.

6. Start the reconstruction of the tomography data by clicking the Final Reconstruction Start button placed in the side panel. The progress bar indicates the progress of the reconstruction.

NOTE If you need to abort the Reconstruction process before it completes, click



in the icon toolbar.

NOTE If the error message 'ERROR: The disk where you are storing the Windows Temporary file(C:) is critically low in free space. Required space is xxxx MB. Aborting...' appears, please make the required space in the C drive before restarting the reconstruction.

7. When reconstruction is complete, the Final reconstruction status changes to "Reconstruction job completed".
8. The tomography is now reconstructed, and ready for viewing under the "Final Output Volume" tab.

Proceed to [Chapter 4, "Viewing and Editing Tomographies."](#)

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