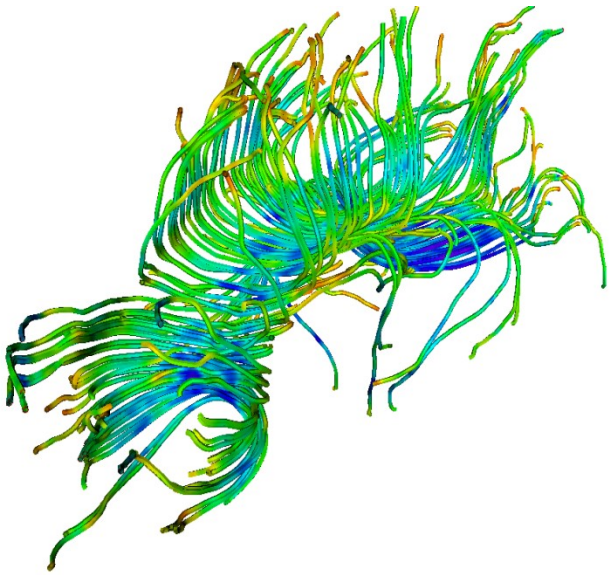
Diffusion Tensor Imaging tutorial



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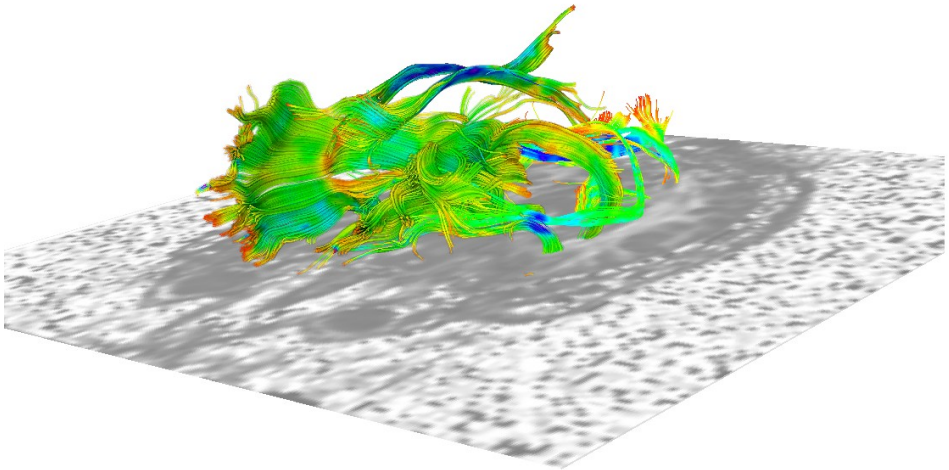
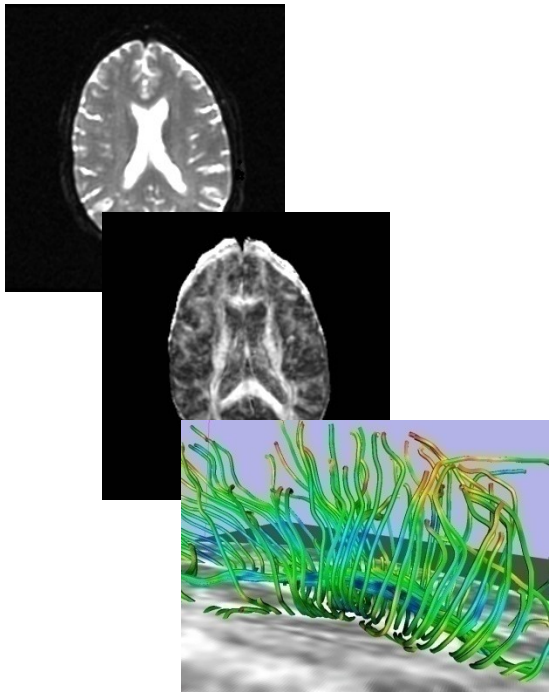
Harvard University

DTI tutorial

This tutorial is an introduction to the advanced Diffusion MR capabilities of the Slicer3 software for medical image analysis.

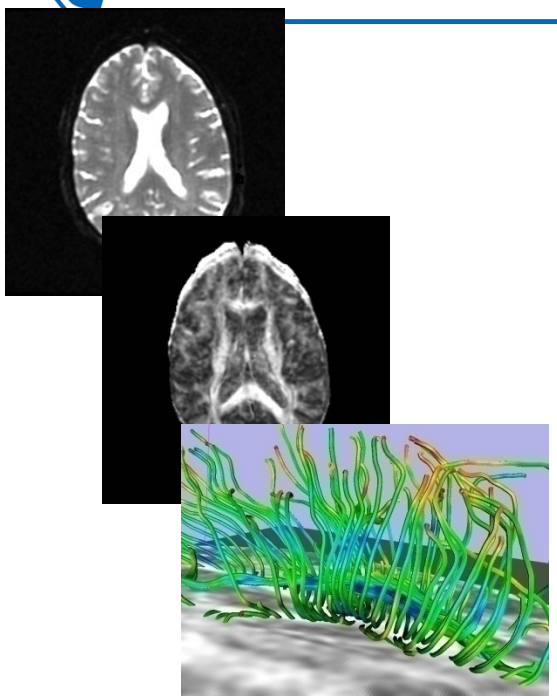


Outline



This tutorial guides you through the process of loading diffusion MR data, estimating diffusion tensors, and performing tractography of white matter bundles.

Outline

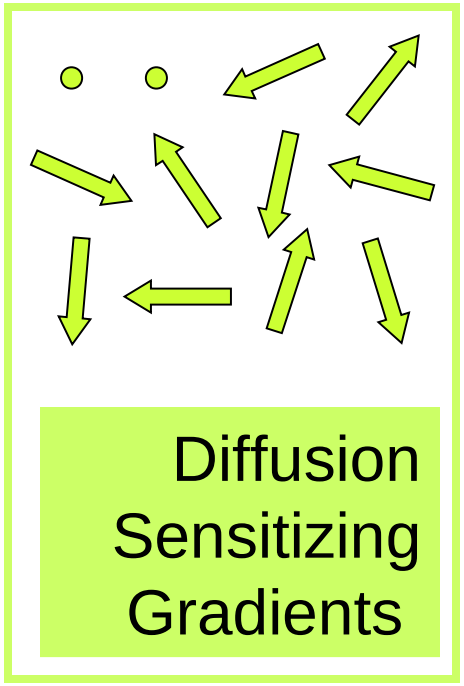


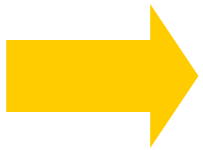
The processing pipeline uses 9 image analysis modules of Slicer3.6

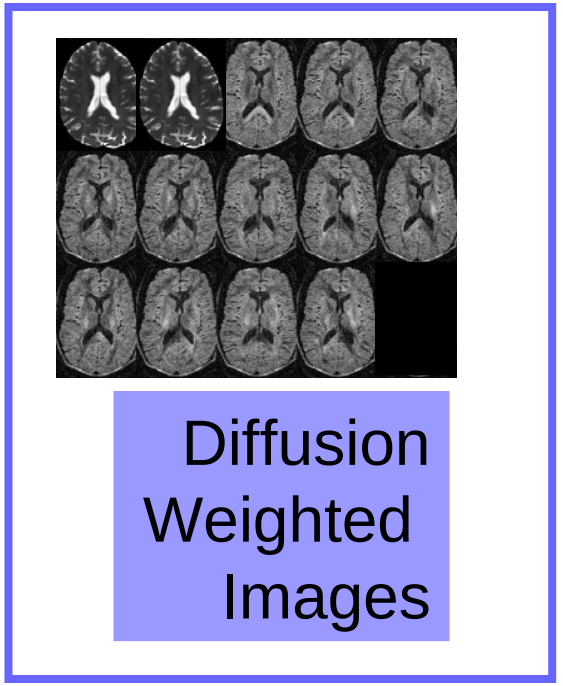
1. Data
2. Volumes
3. Diffusion Tensor Estimation
4. Diffusion Tensor Scalar Measurements
5. Editor
6. LabelMap Seeding
7. Fiber Bundles
8. Fiducials
9. Fiducial Seeding

Tutorial Dataset

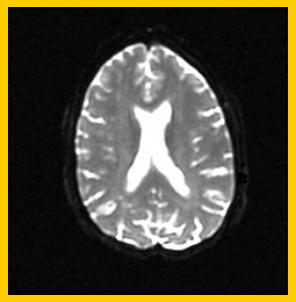
The Diffusion MR tutorial dataset is composed of a Diffusion Weighted MR scan of the brain acquired with 12 gradient directions and 2 baseline.



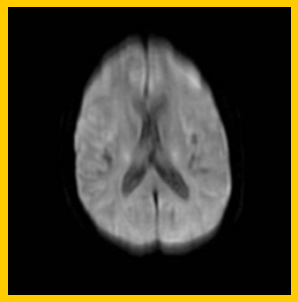




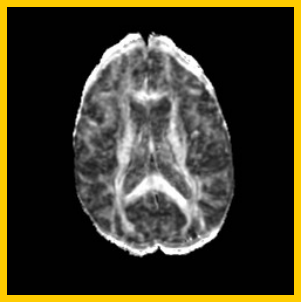
DTI Processing Pipeline



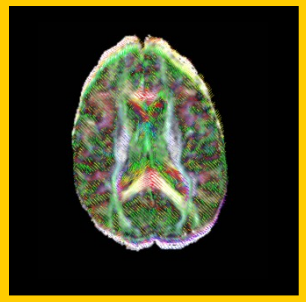
DWI
Acquisition



Tensor
Calculation



Scalar
Maps



3D
Visualization

Start Slicer3

Linux/Mac users

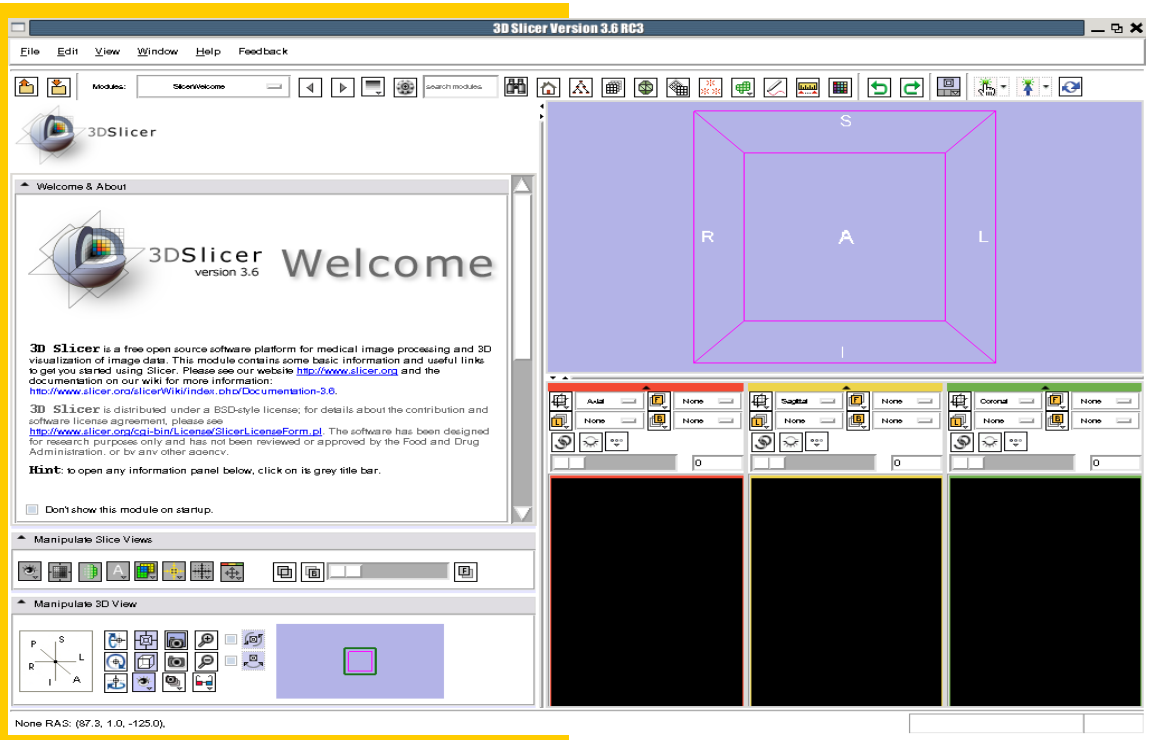
Launch the Slicer3 executable located in the Slicer3.6 directory

Windows users

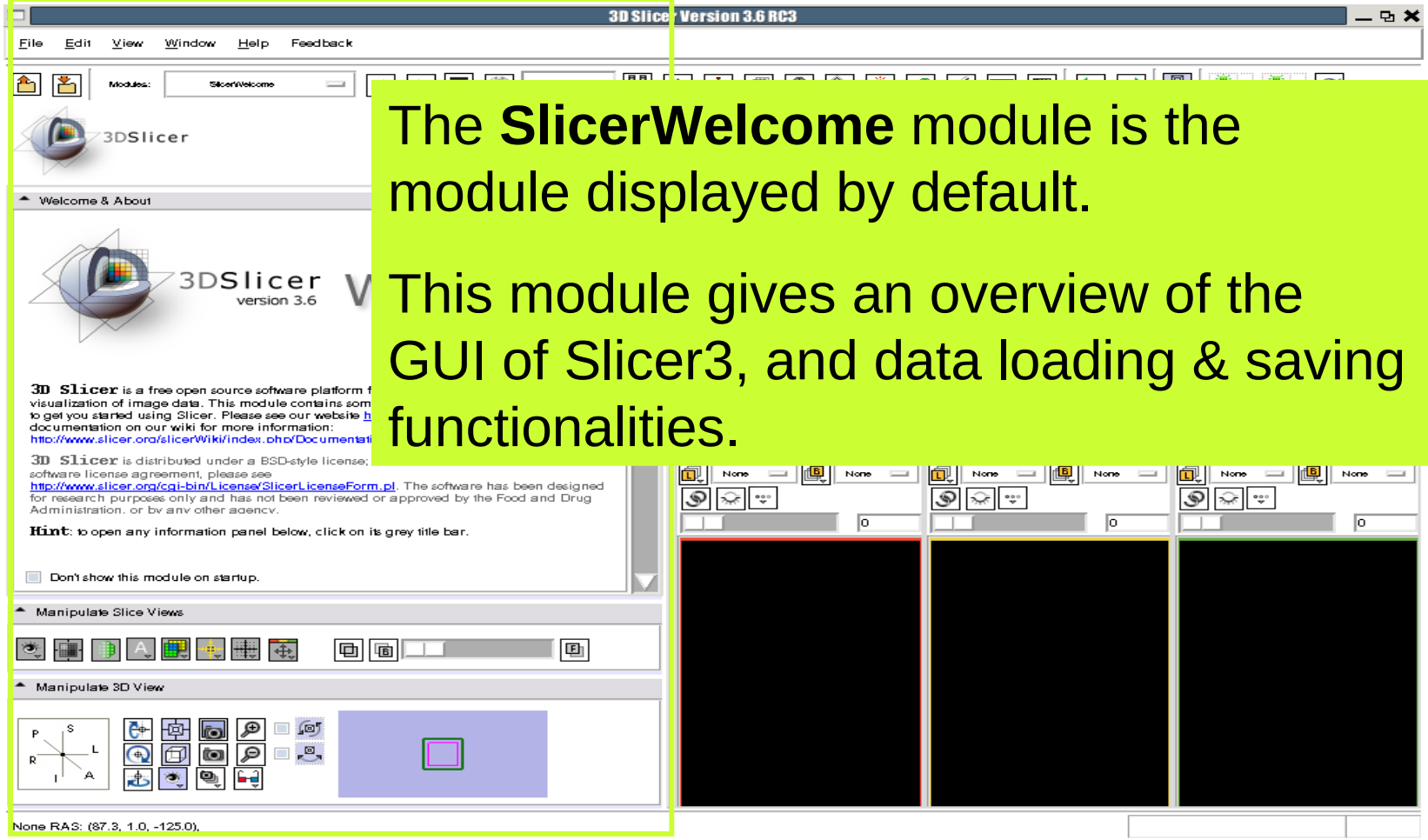
Select

Start → All Programs

→ Slicer3-3.6-RC3-2010-06-04→Slicer3

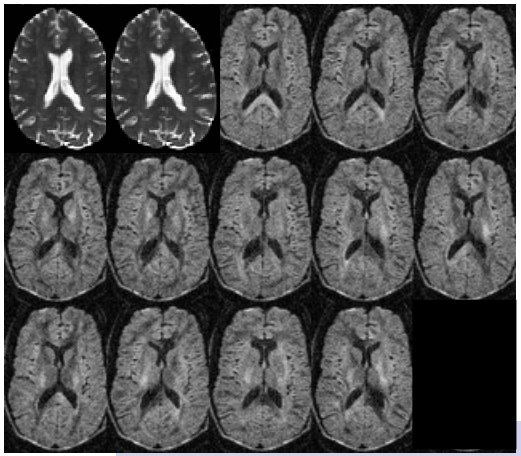


Slicer Welcome



The **SlicerWelcome** module is the module displayed by default.

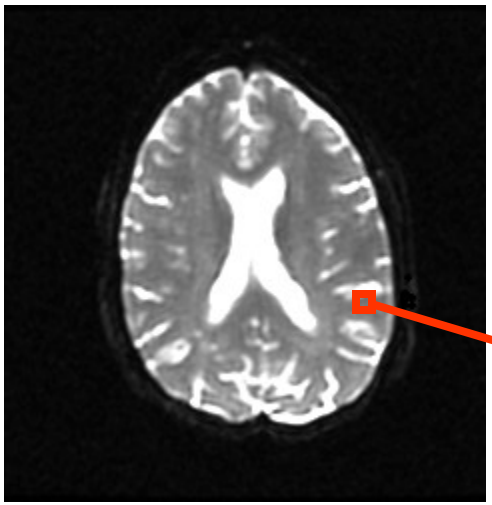
This module gives an overview of the GUI of Slicer3, and data loading & saving functionalities.



Part 1:

Diffusion data loading and tensor estimation

Diffusion Tensor

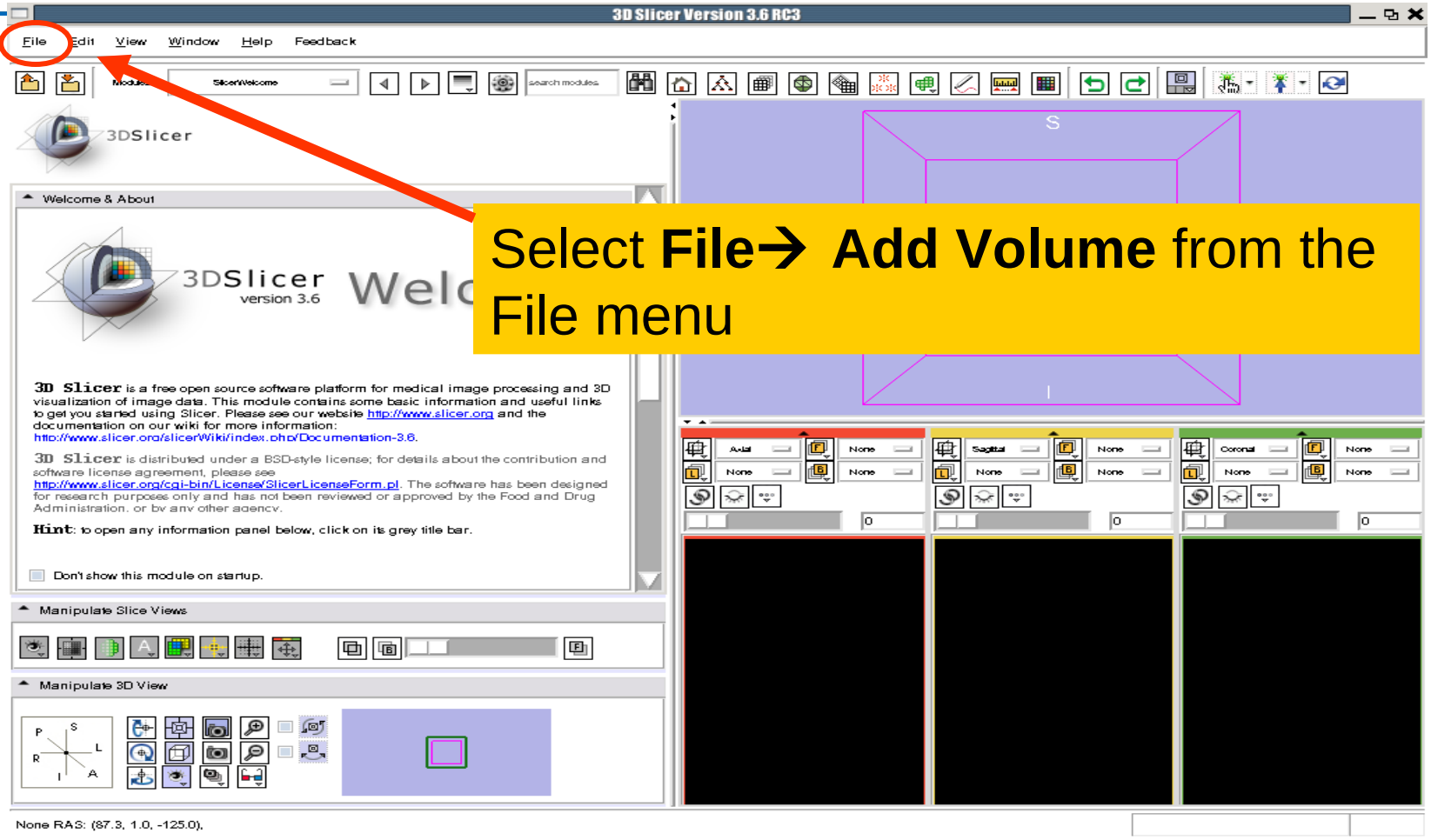


Stejskal-Tanner

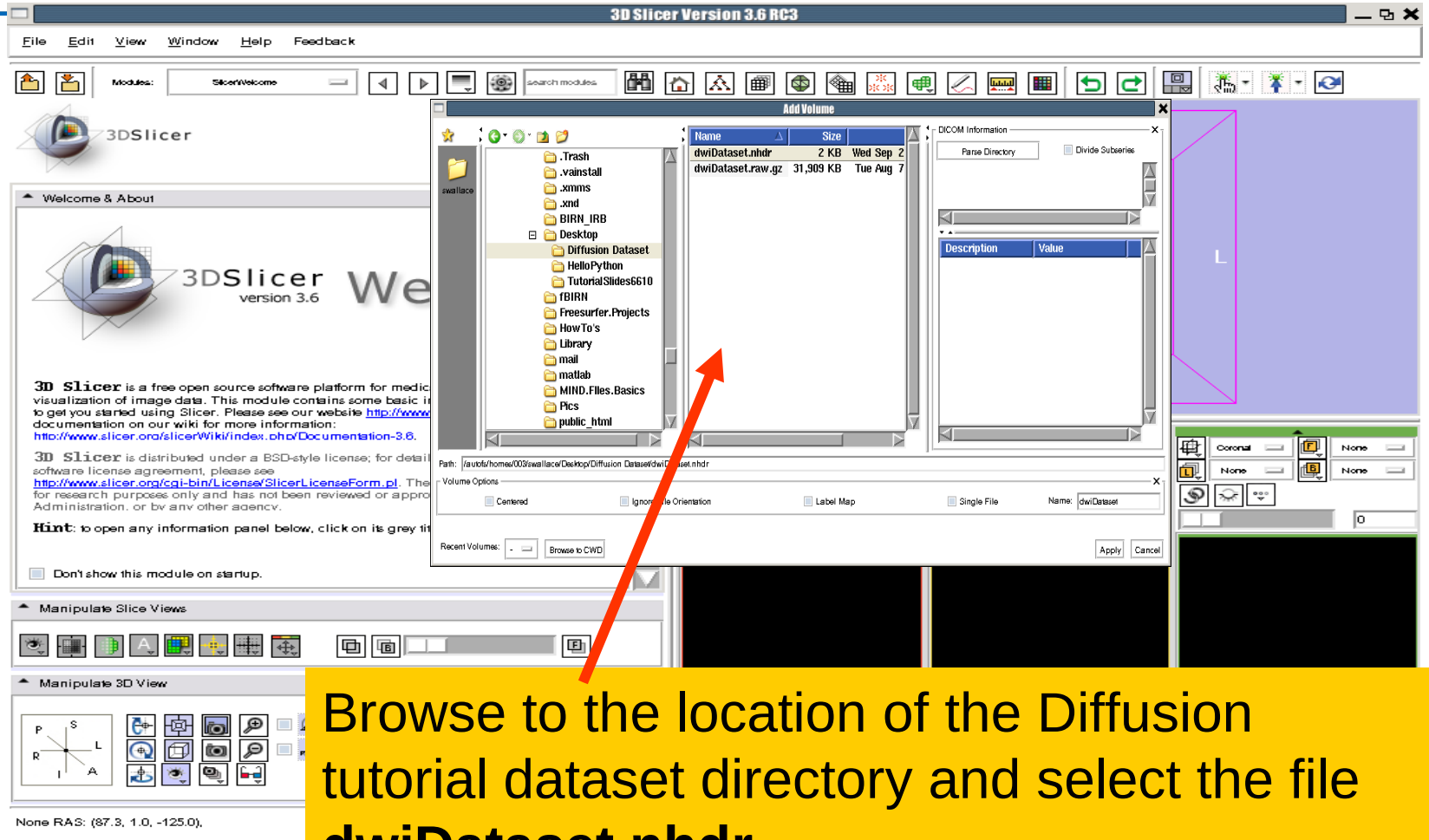
$$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$$

$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$

Loading the DWI volume



Loading the DWI volume

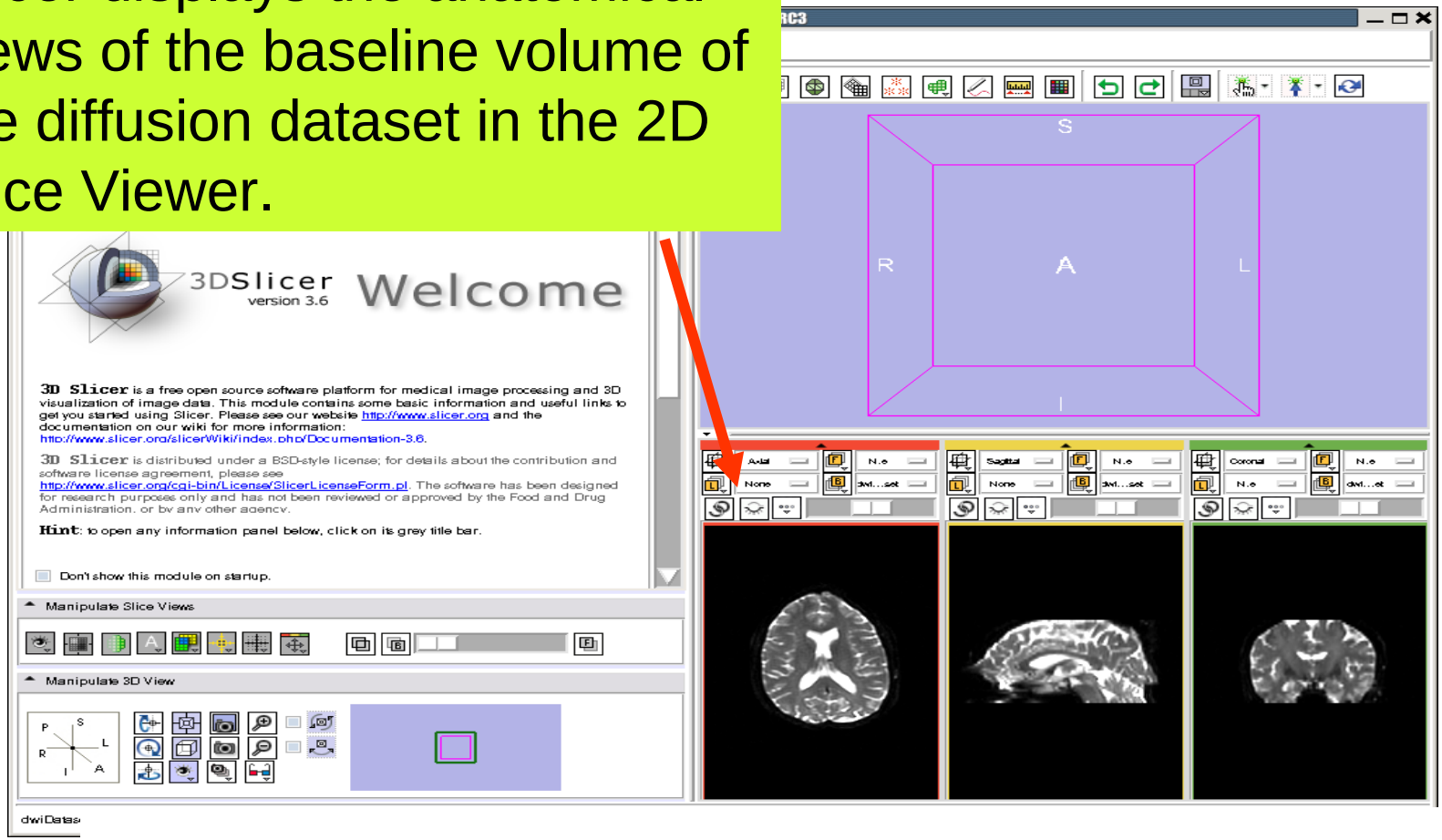


Browse to the location of the Diffusion tutorial dataset directory and select the file **dwiDataset.nhdr**

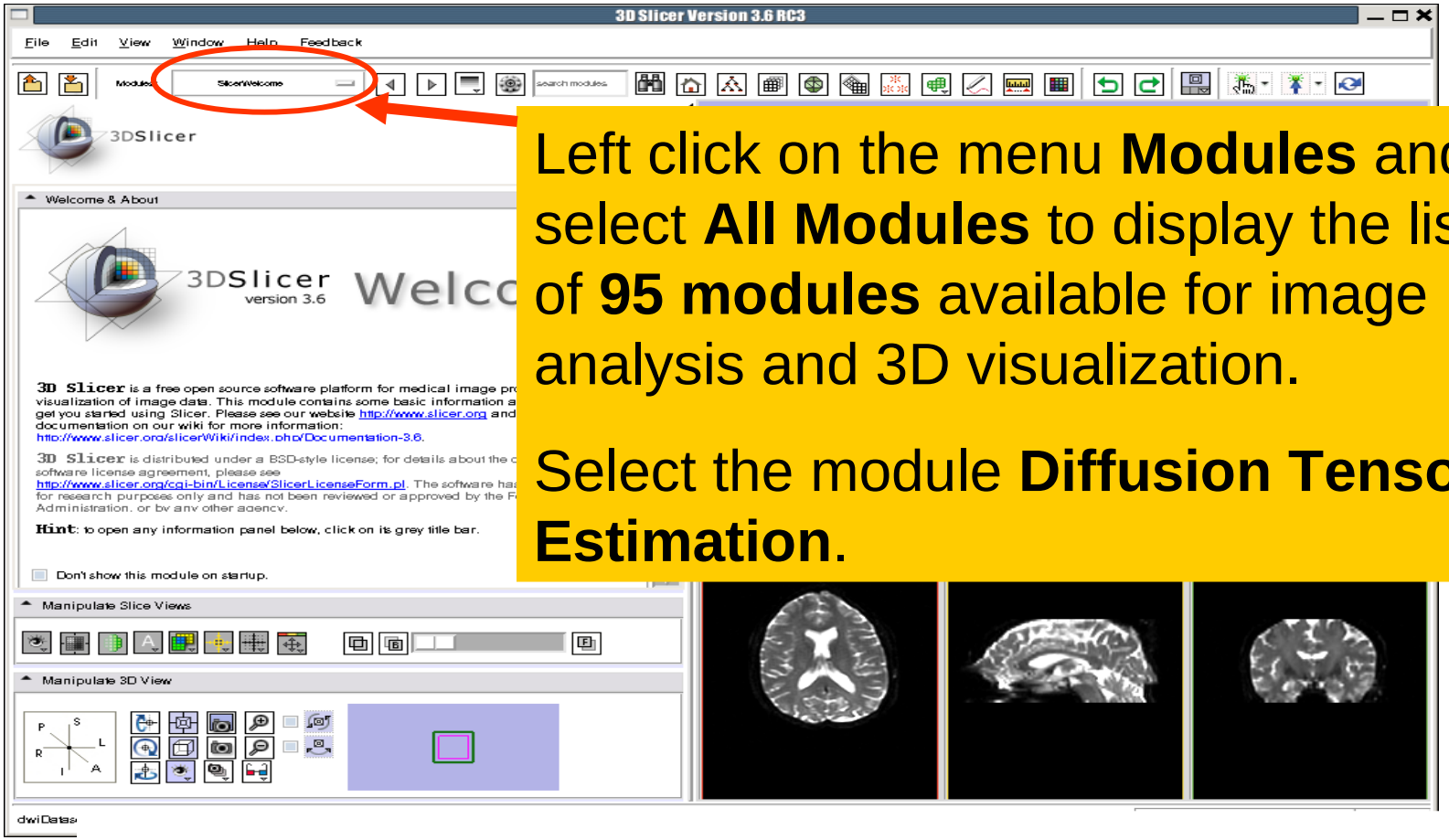
Click on **Apply** to load the volume

Loading the DWI volume

Slicer displays the anatomical views of the baseline volume of the diffusion dataset in the 2D Slice Viewer.



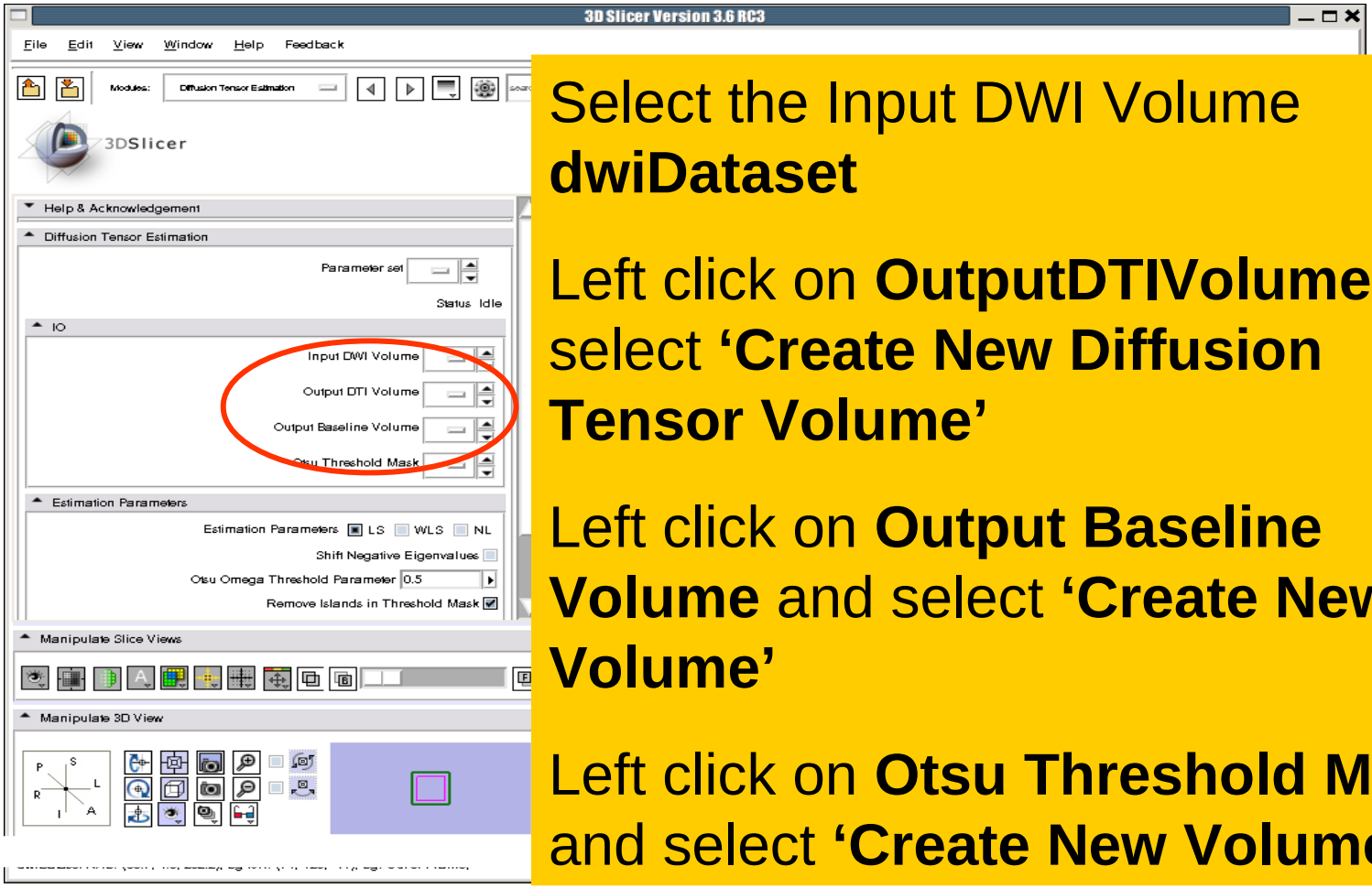
Tensor Estimation



Left click on the menu **Modules** and select **All Modules** to display the list of **95 modules** available for image analysis and 3D visualization.

Select the module **Diffusion Tensor Estimation**.

Tensor Estimation



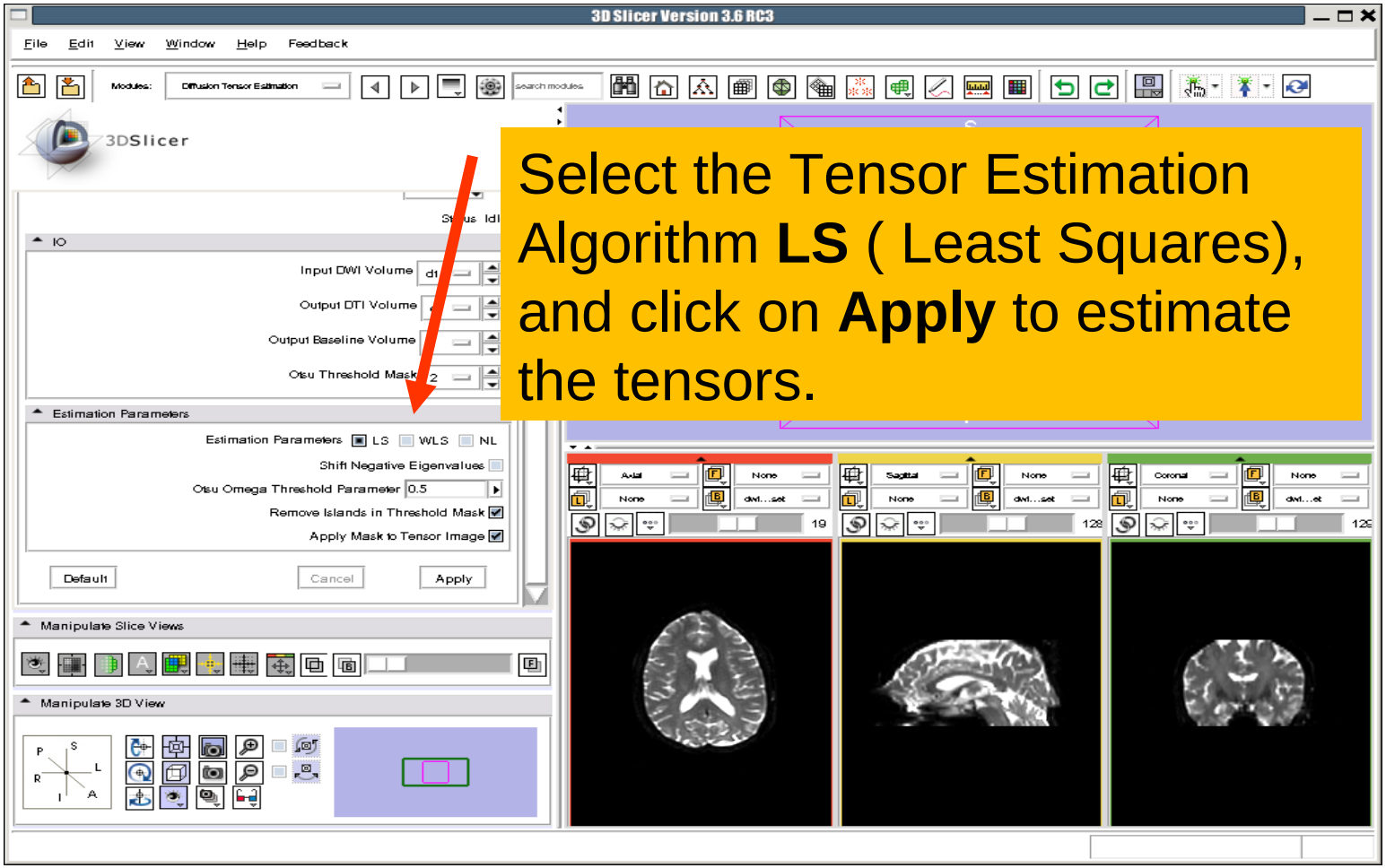
Select the Input DWI Volume **dwiDataset**

Left click on **OutputDTIVolume** and select **'Create New Diffusion Tensor Volume'**

Left click on **Output Baseline Volume** and select **'Create New Volume'**

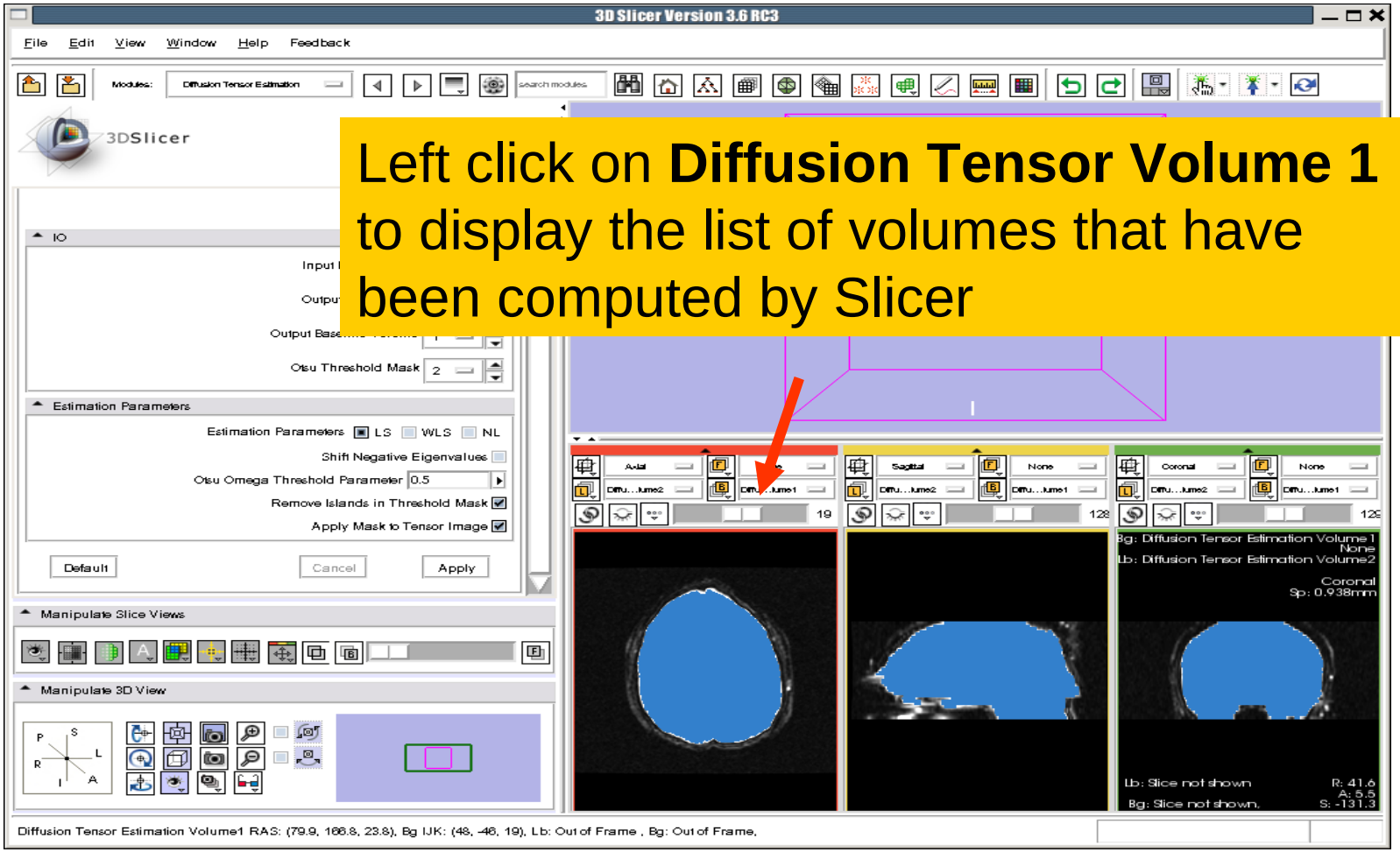
Left click on **Otsu Threshold Mask** and select **'Create New Volume'**

Tensor Estimation



Select the Tensor Estimation Algorithm **LS** (Least Squares), and click on **Apply** to estimate the tensors.

Tensor Estimation



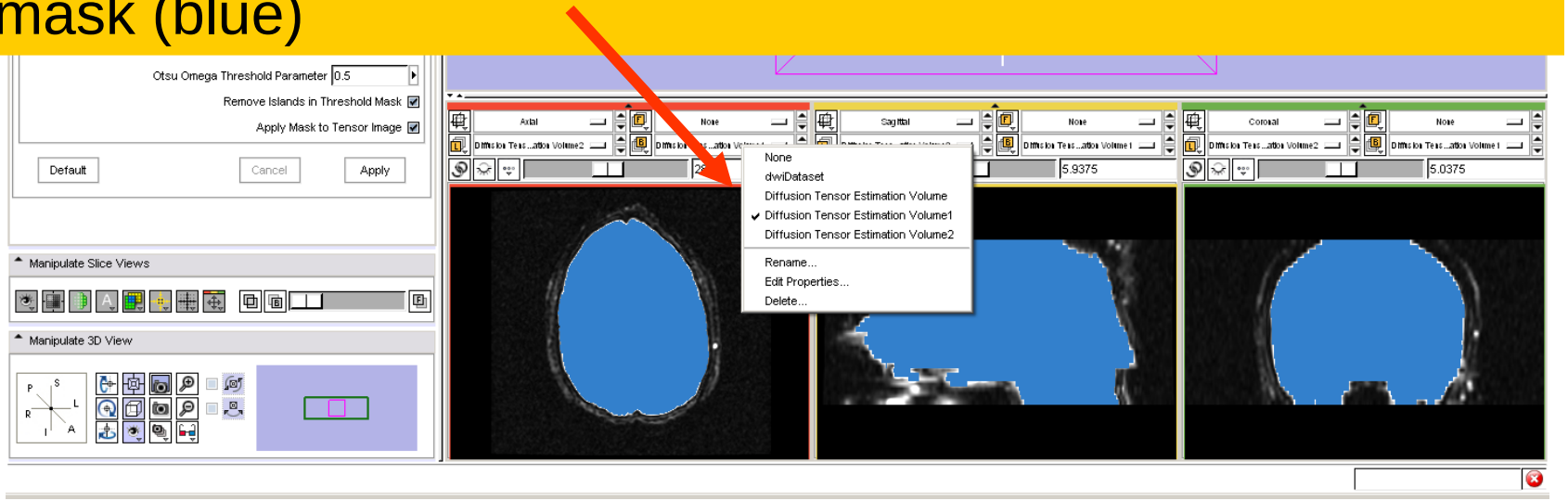
Left click on **Diffusion Tensor Volume 1** to display the list of volumes that have been computed by Slicer

Tensor Estimation

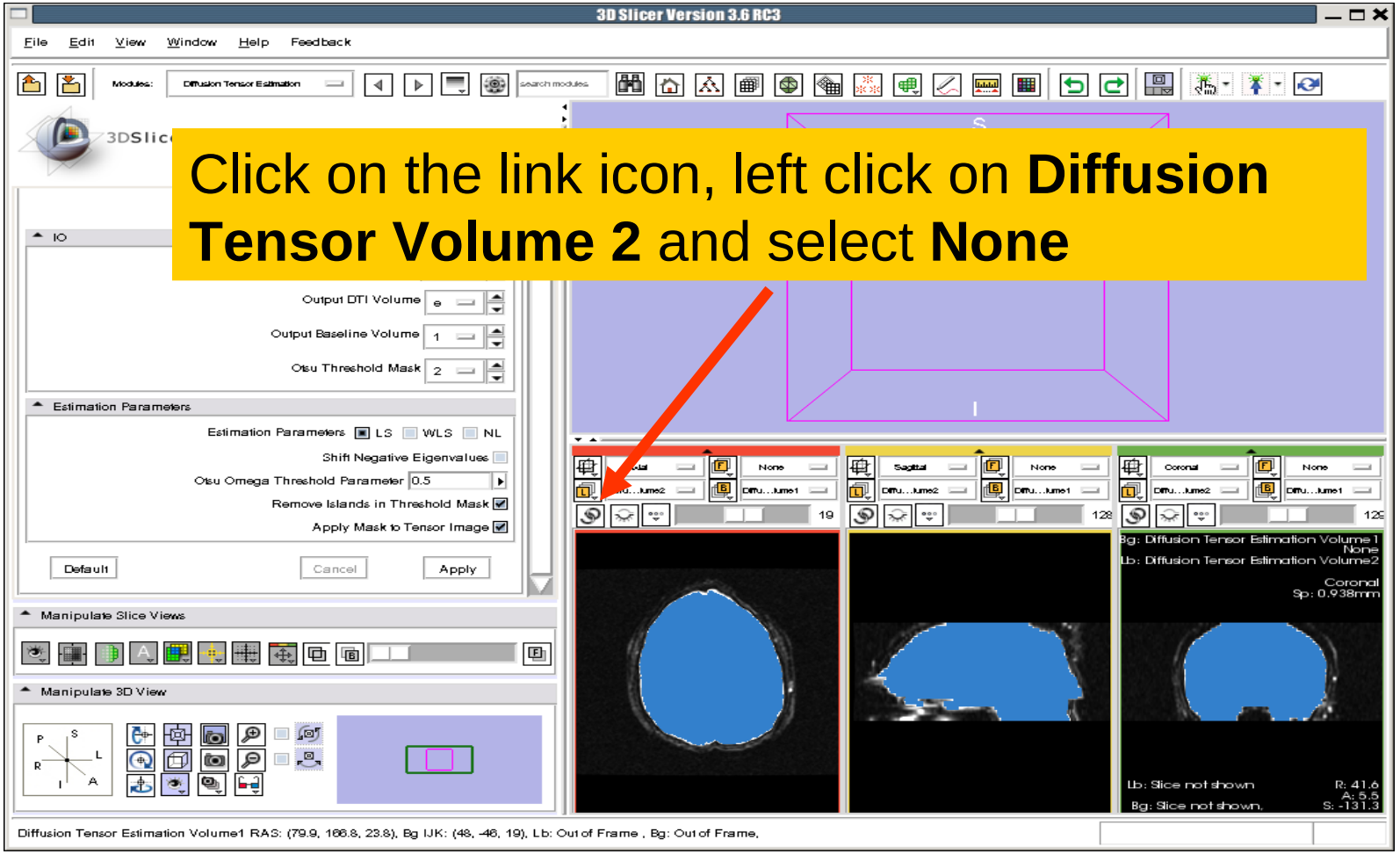
Diffusion Tensor Estimation Volume is the volume of estimated tensors

Diffusion Tensor Estimation Volume 1 is the Baseline volume

Diffusion Tensor Estimation Volume 2 is the tensor mask (blue)

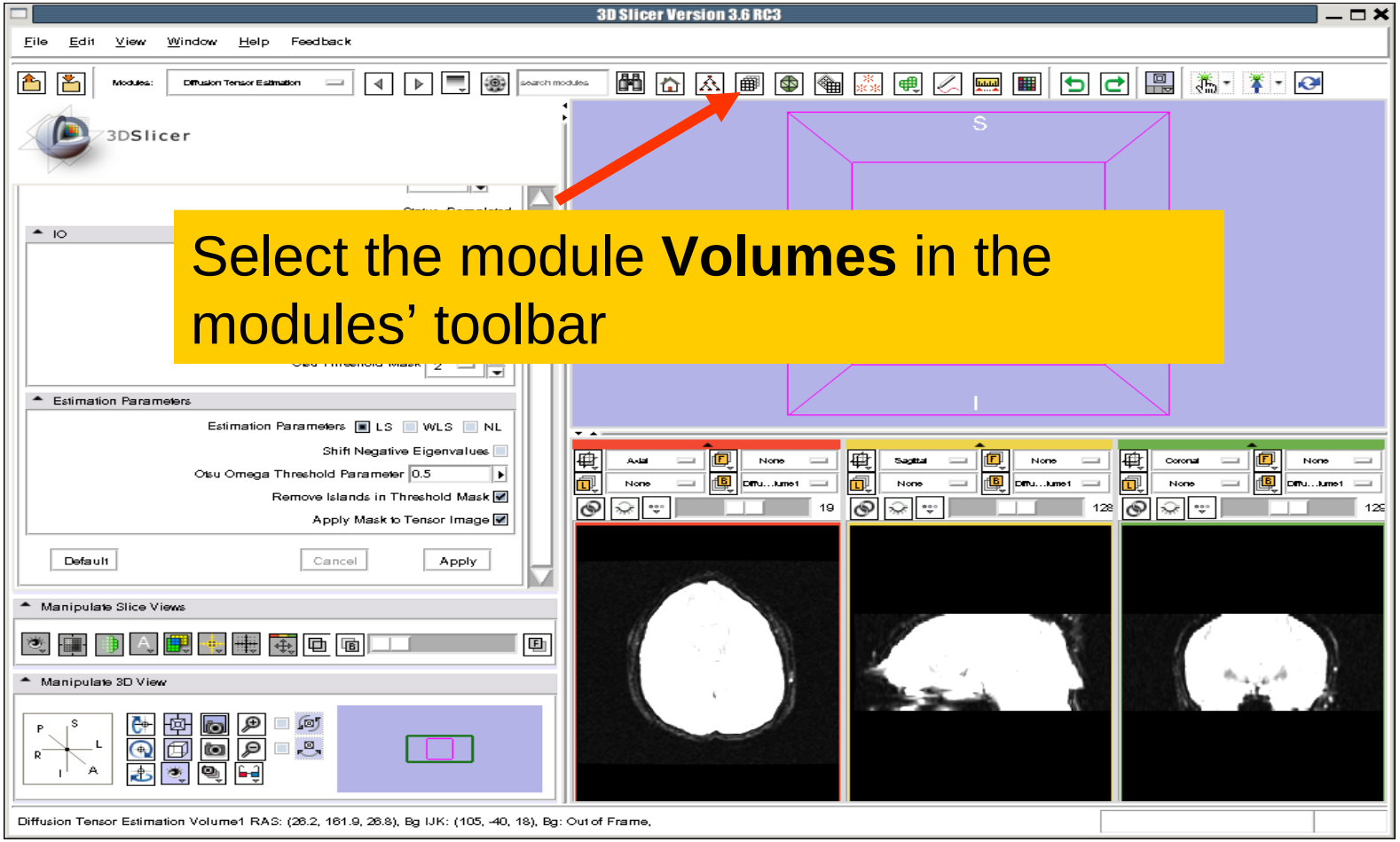


Tensor Estimation



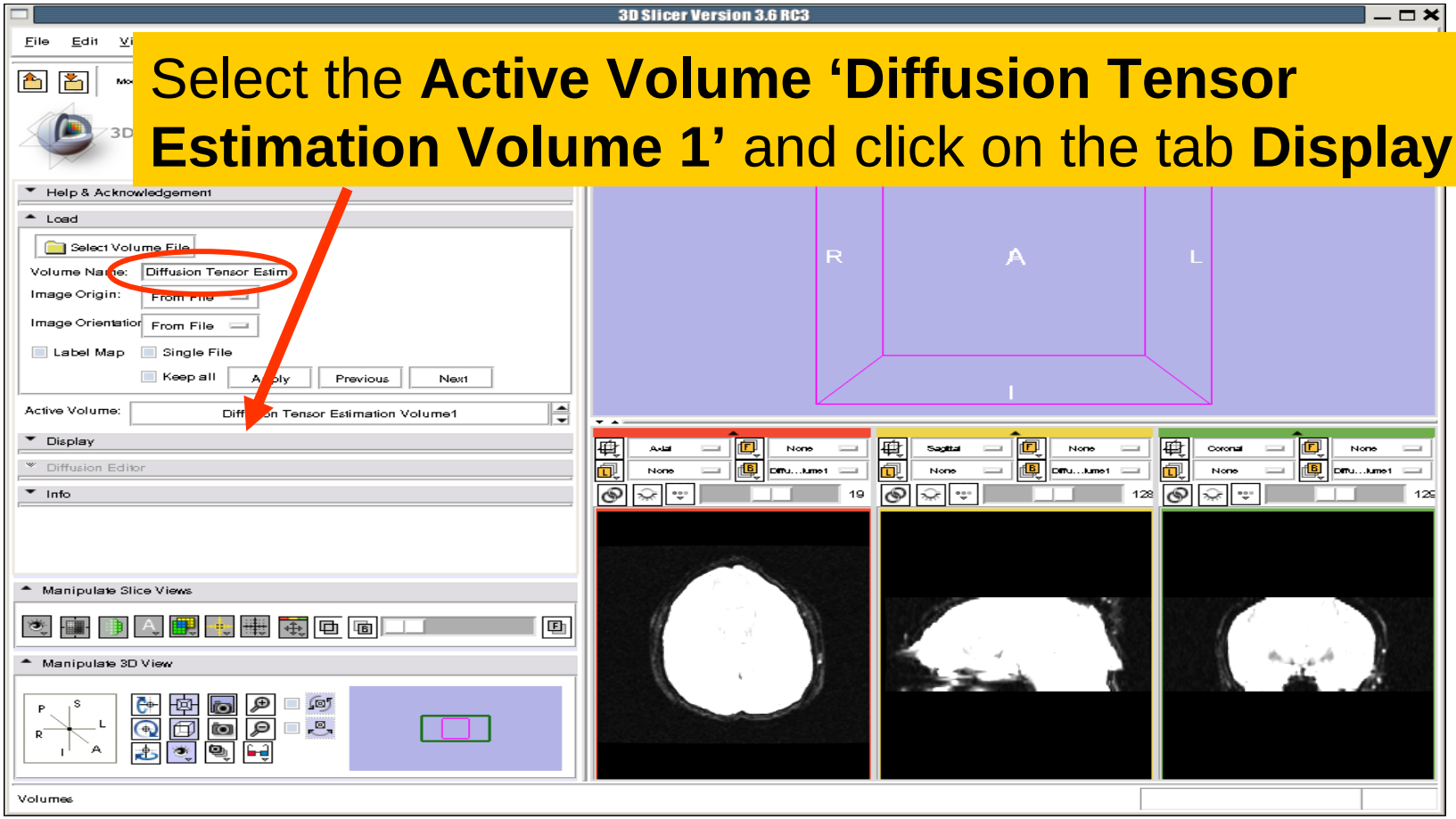
Click on the link icon, left click on **Diffusion Tensor Volume 2** and select **None**

Tensor Estimation



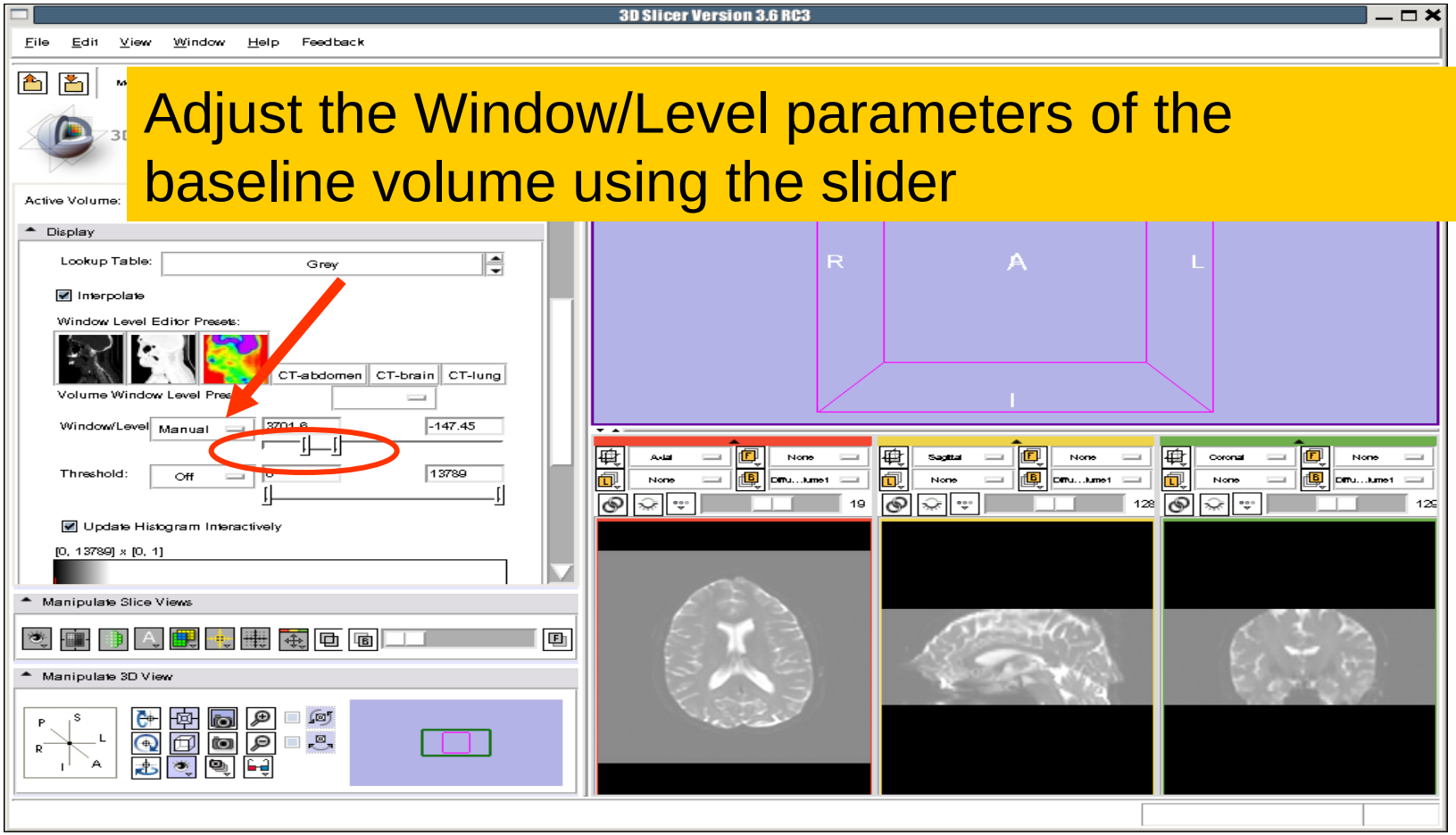
Select the module **Volumes** in the modules' toolbar

Tensor Estimation



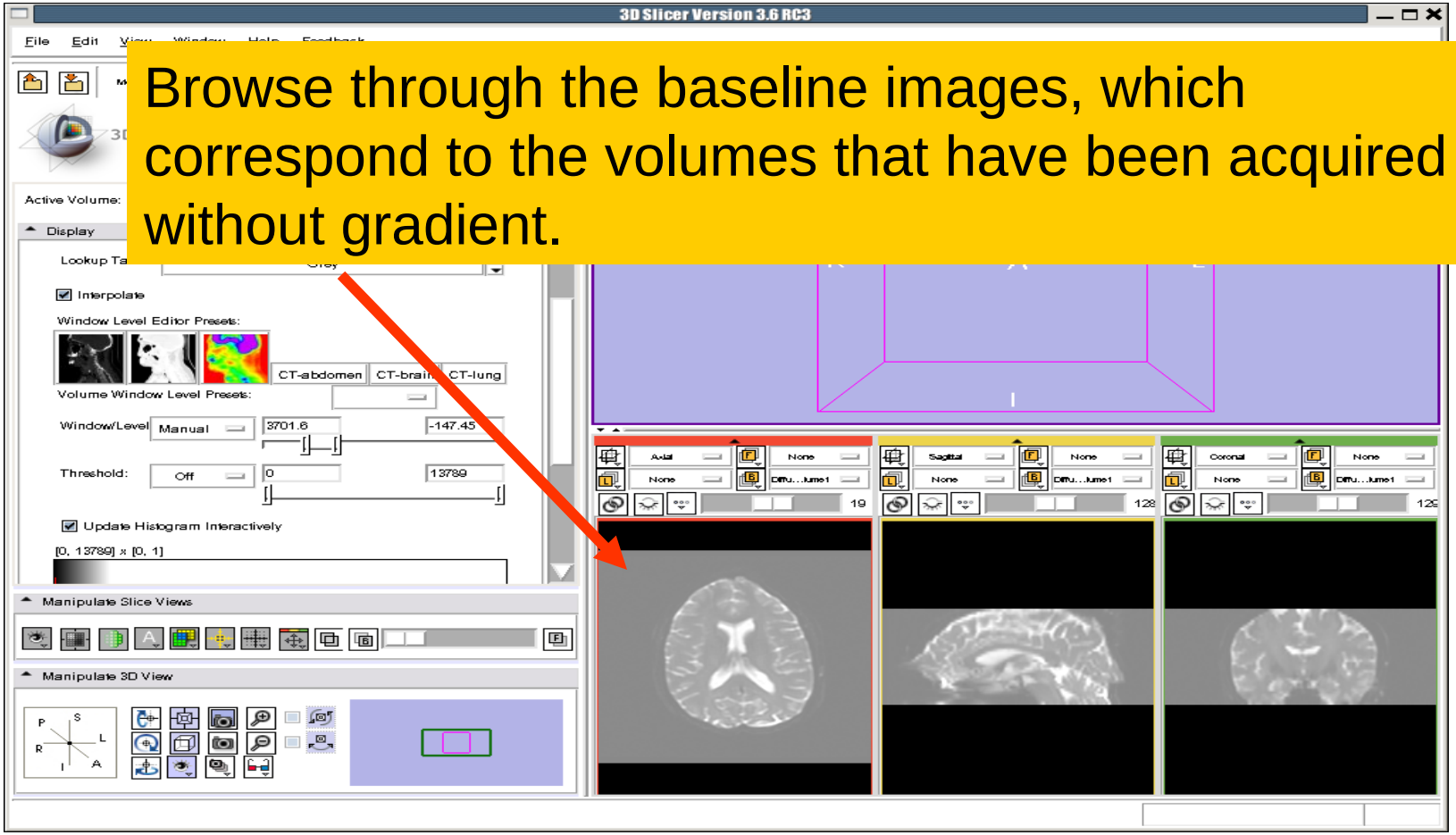
Select the **Active Volume 'Diffusion Tensor Estimation Volume 1'** and click on the tab **Display**

Tensor Estimation

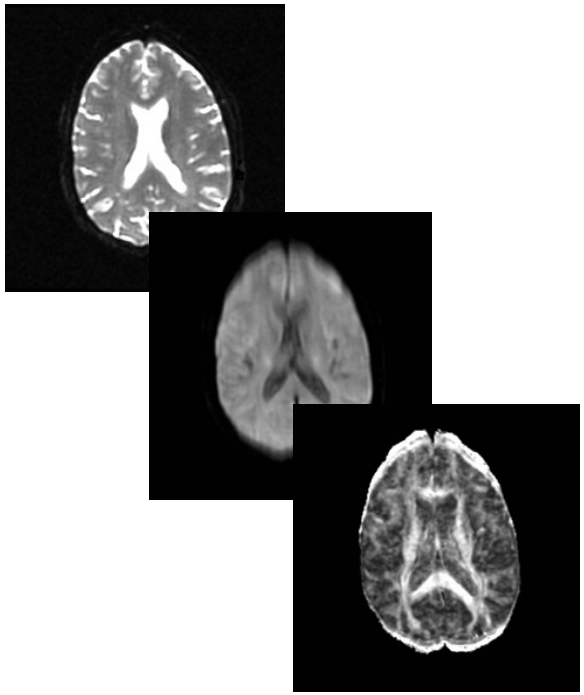


Adjust the Window/Level parameters of the baseline volume using the slider

Tensor Estimation



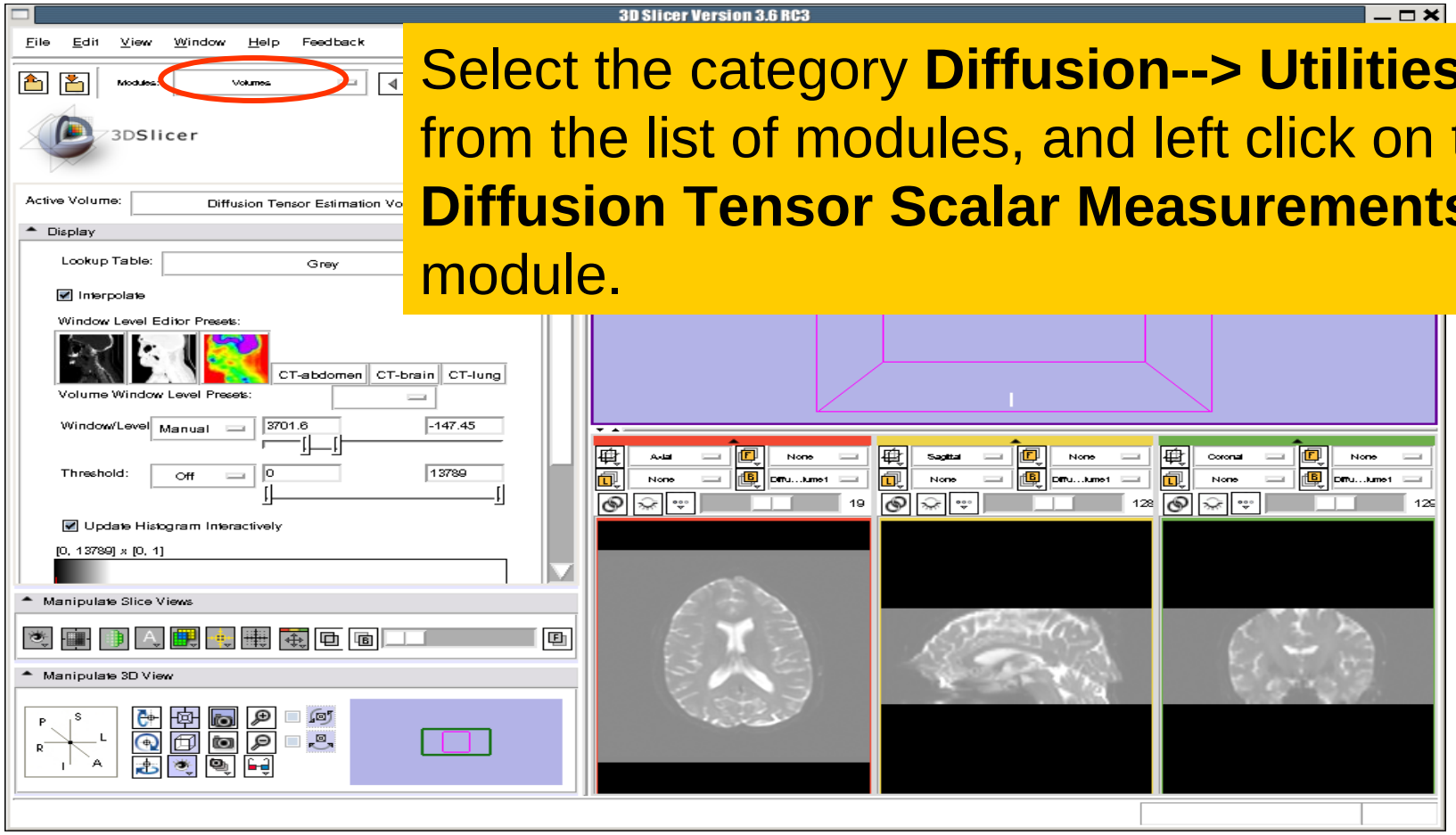
Browse through the baseline images, which correspond to the volumes that have been acquired without gradient.



Part2:

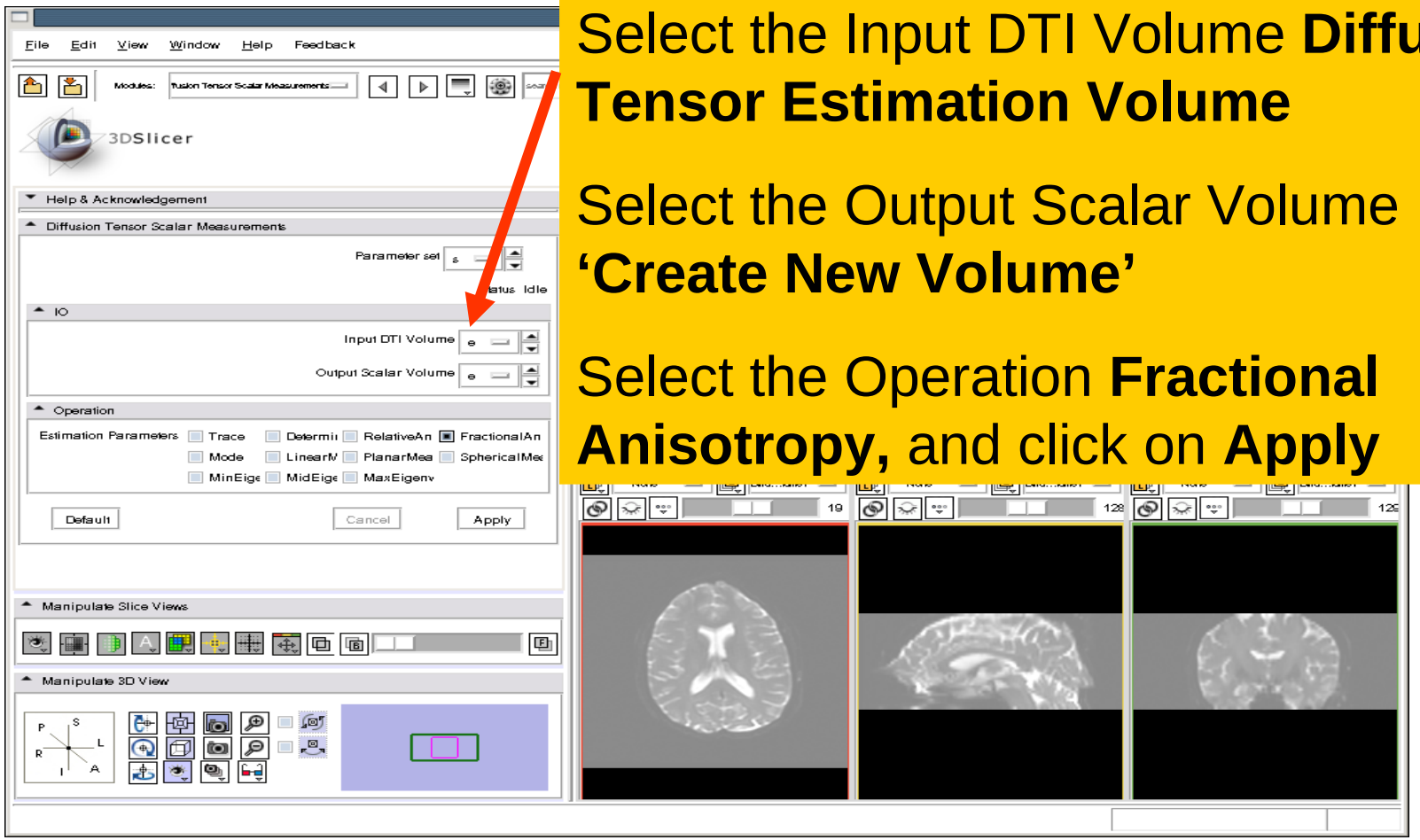
Scalar Measurements

Scalar Measurements



Select the category **Diffusion--> Utilities** from the list of modules, and left click on the **Diffusion Tensor Scalar Measurements** module.

Scalar Measurements

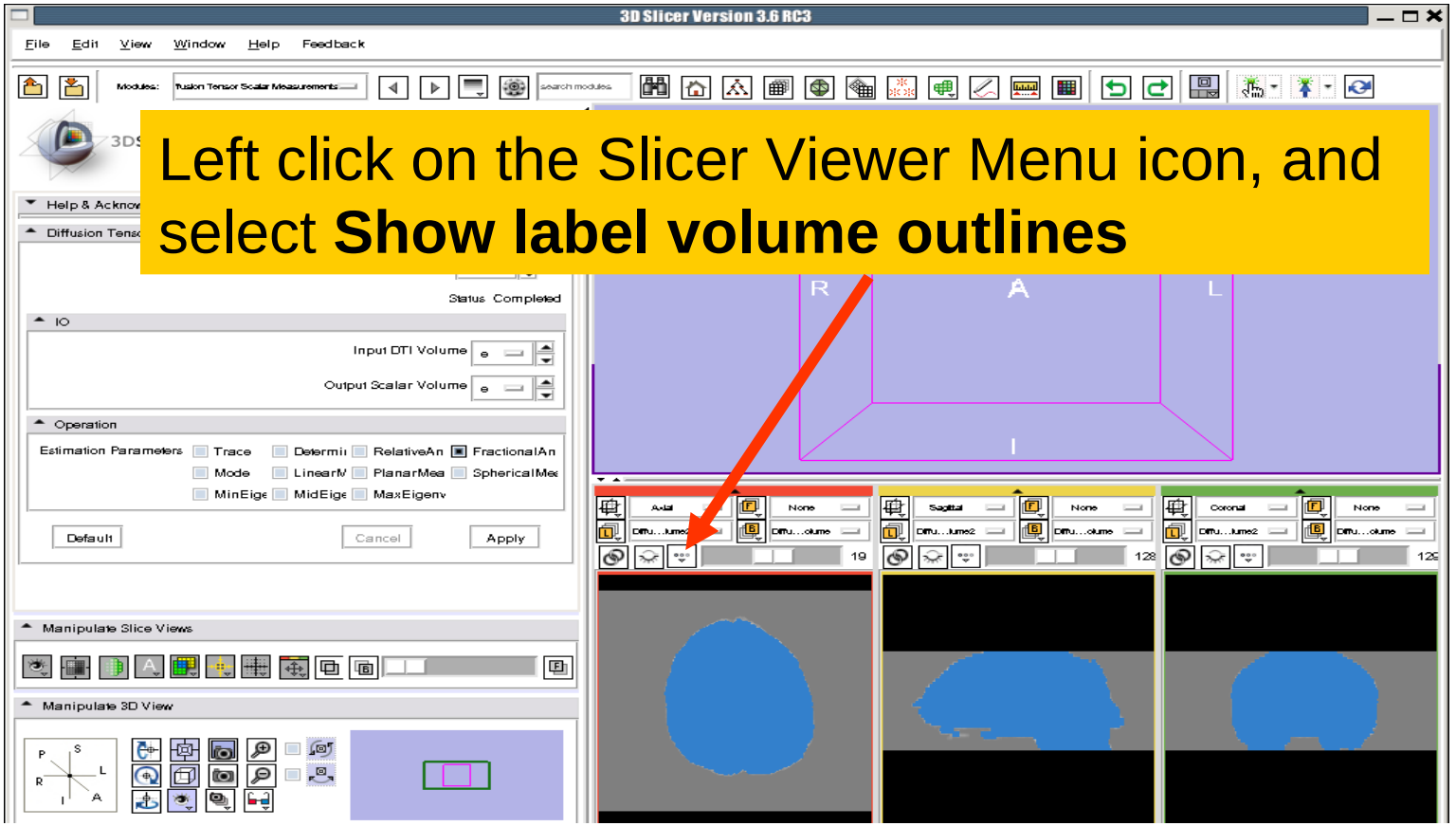


Select the Input DTI Volume **Diffusion Tensor Estimation Volume**

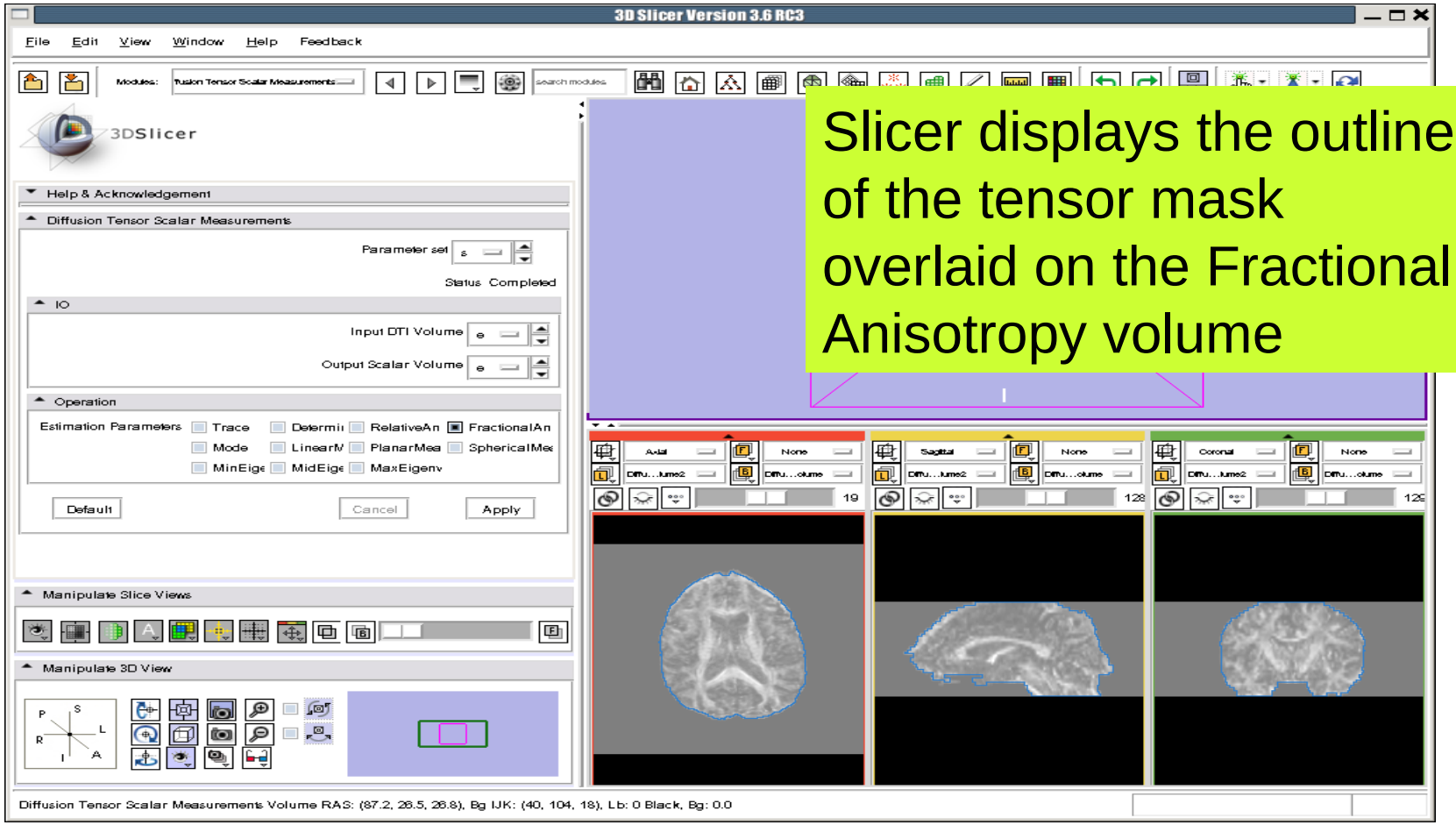
Select the Output Scalar Volume **'Create New Volume'**

Select the Operation **Fractional Anisotropy,** and click on **Apply**

Fractional Anisotropy Volume

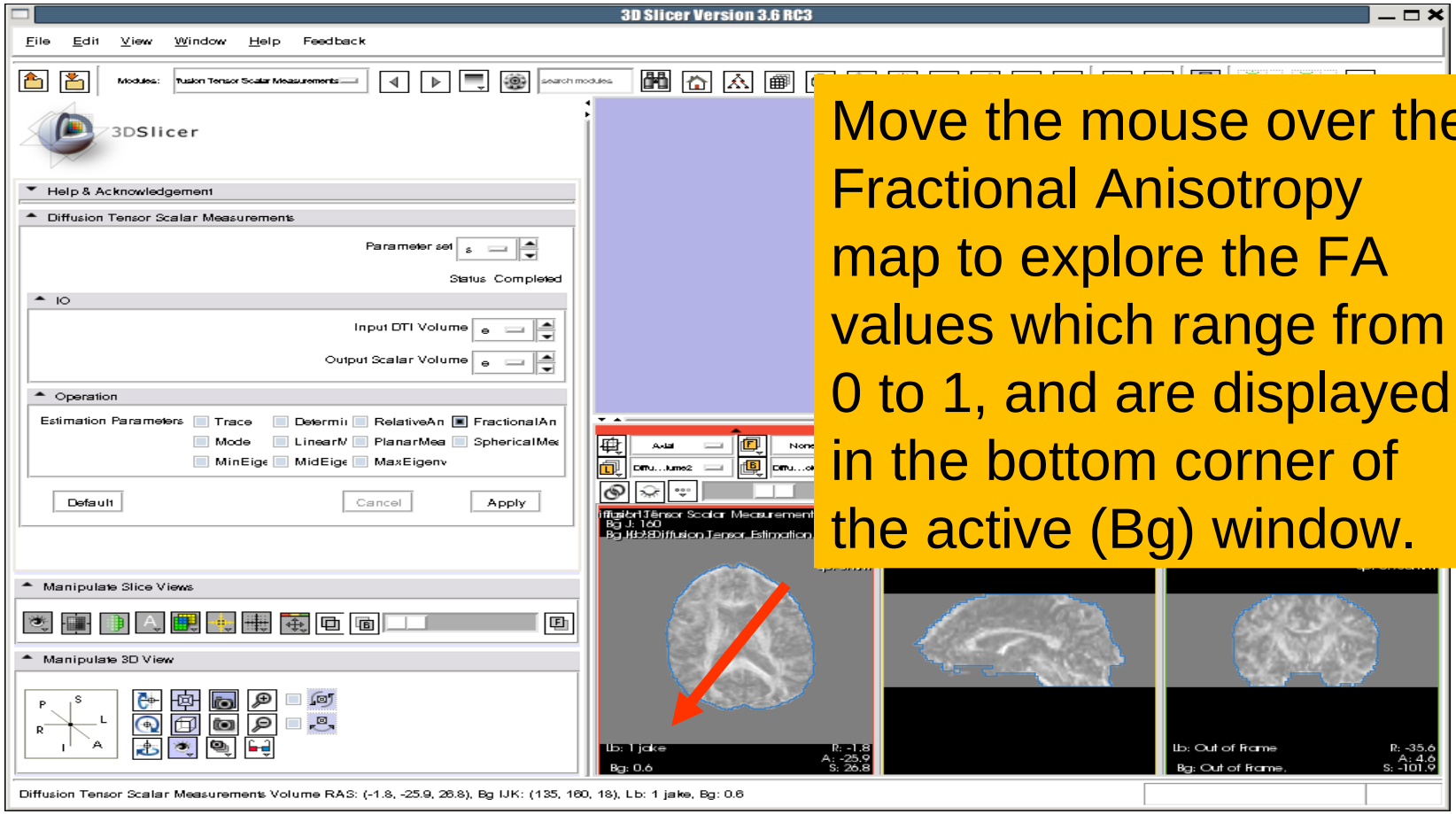


Fractional Anisotropy Volume

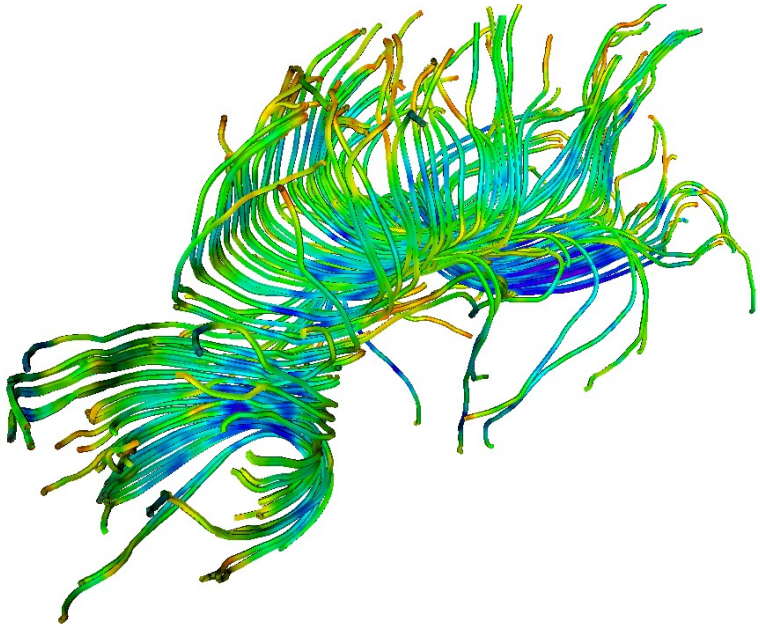


Slicer displays the outline of the tensor mask overlaid on the Fractional Anisotropy volume

Fractional Anisotropy Volume



Move the mouse over the Fractional Anisotropy map to explore the FA values which range from 0 to 1, and are displayed in the bottom corner of the active (Bg) window.

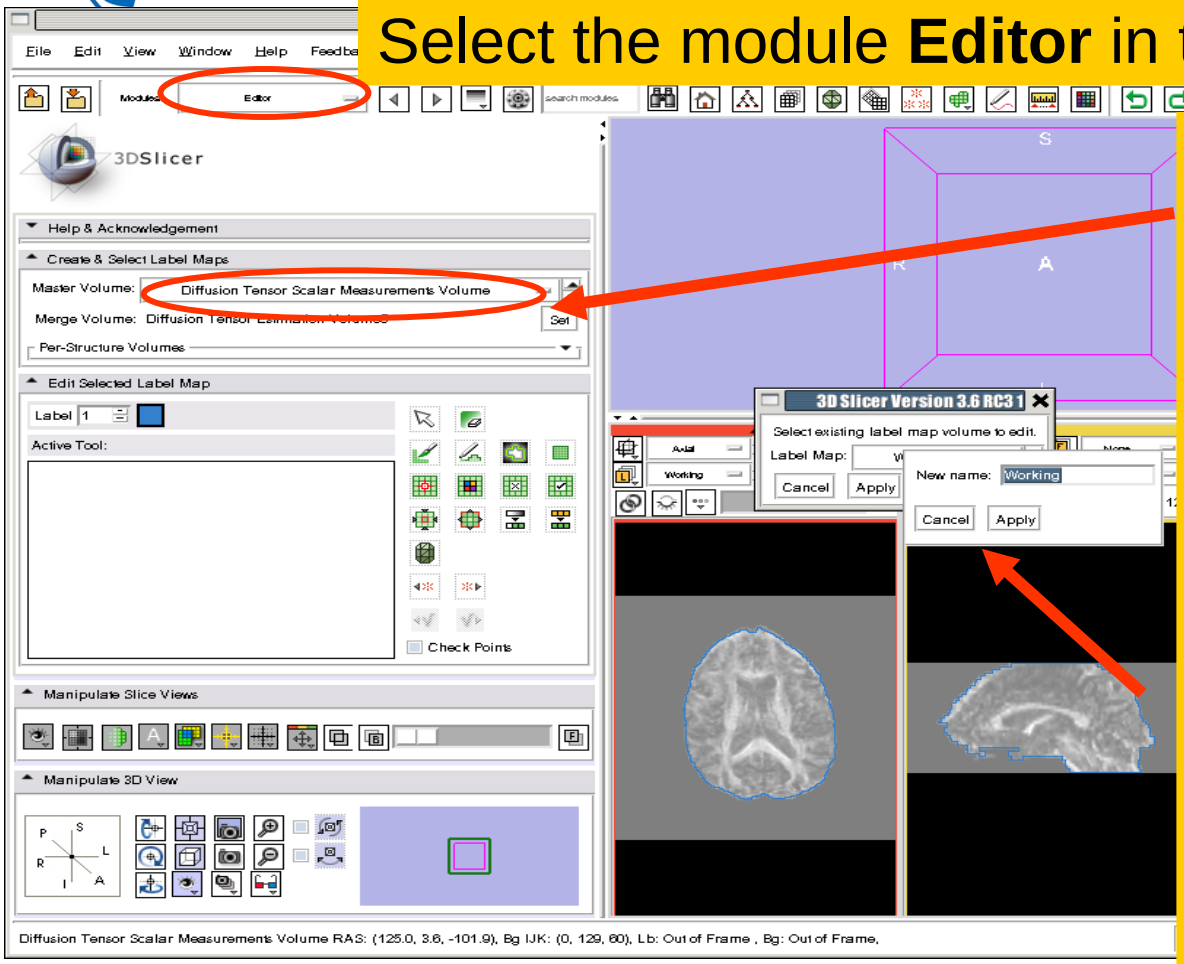


Part 3:

Region of Interest based Tractography

LabelMap Generation

Select the module **Editor** in the modules menu.

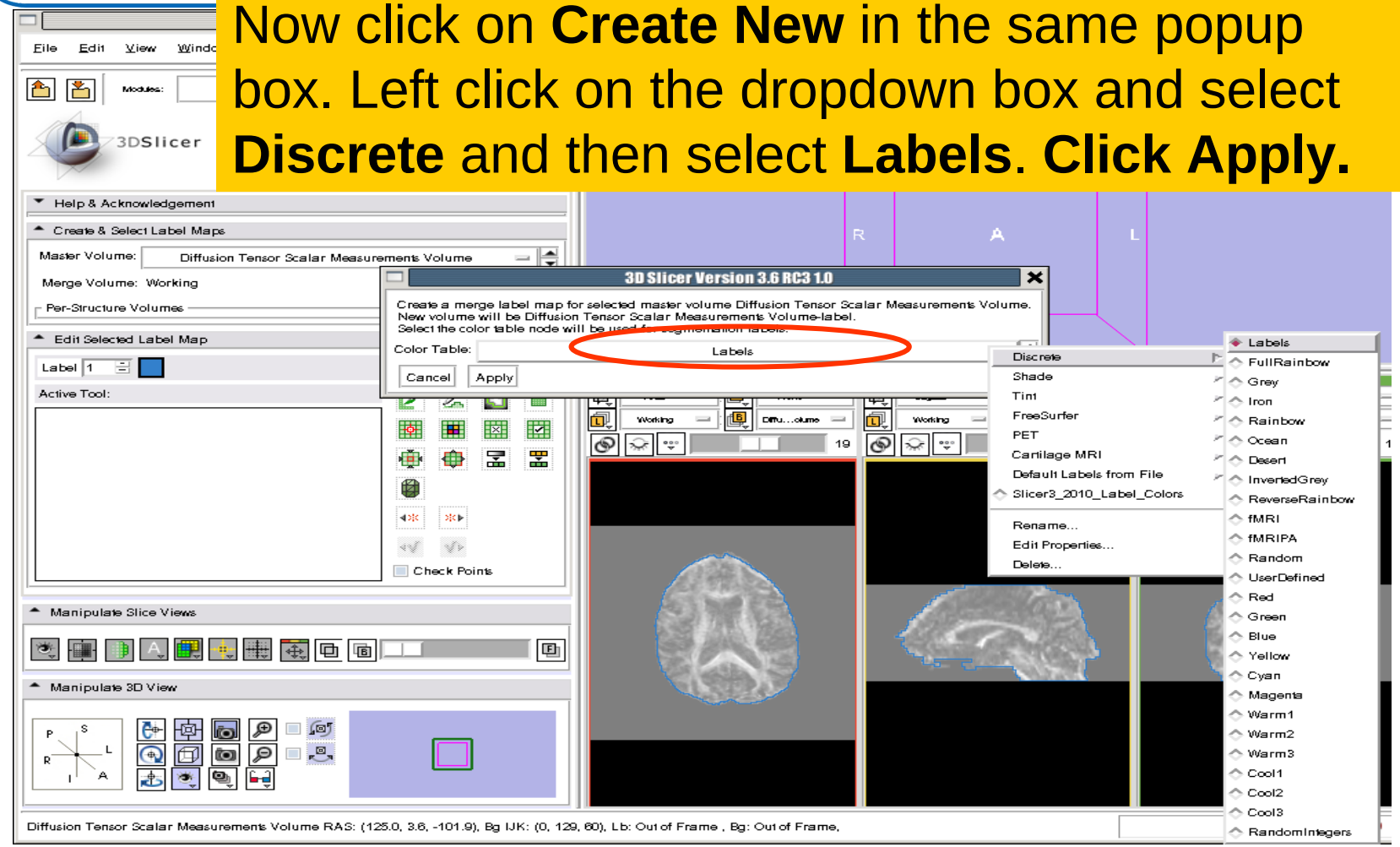


Select the Master Volume as **Diffusion Tensor Scalar Measurements Volume**

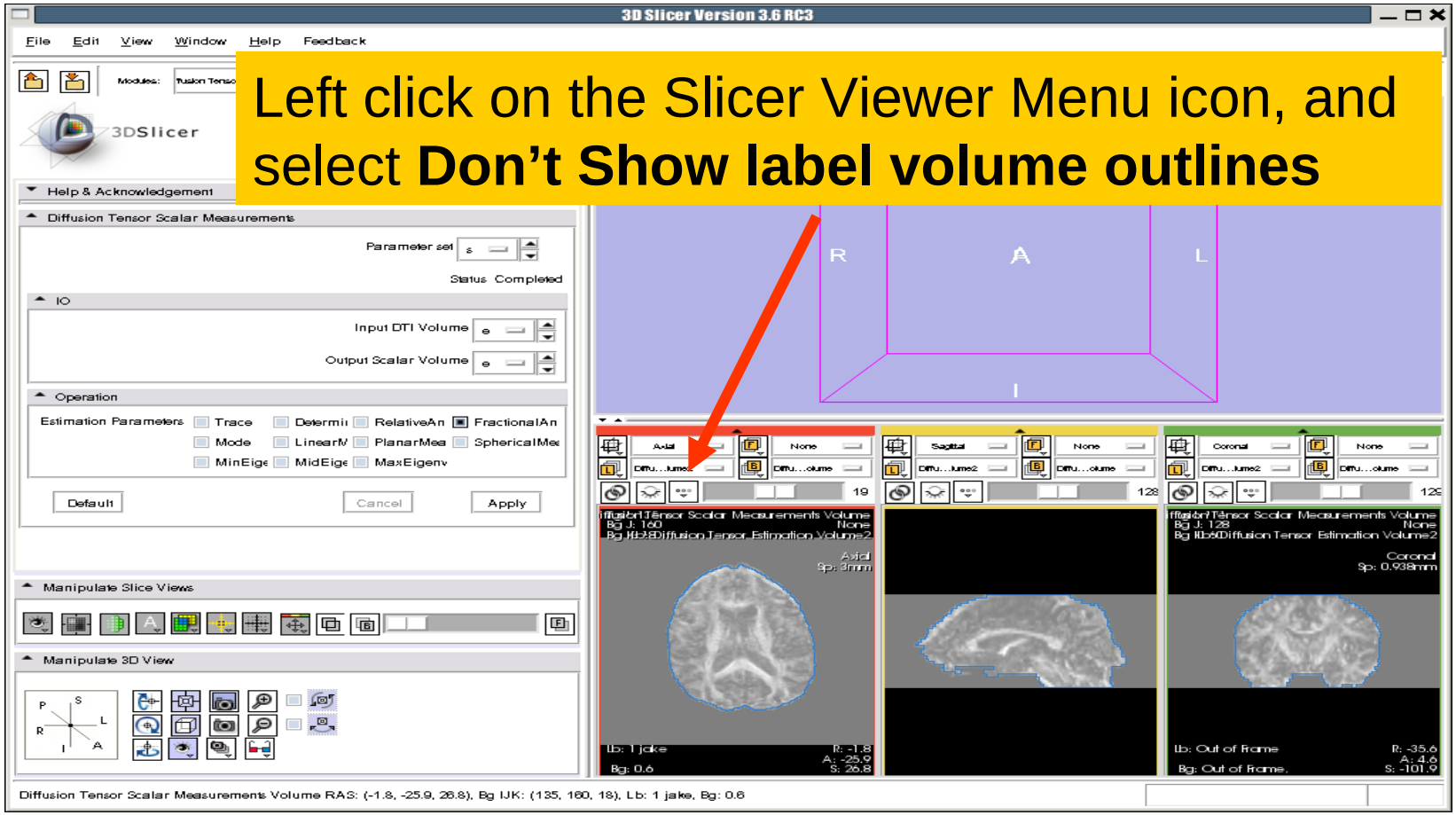
Click '**Set**', then left click on 'Diffusion Tensor Estimation Volume 2' in the popup box. Click '**Rename**' and rename it as '**Working**'

LabelMap Generation

Now click on **Create New** in the same popup box. Left click on the dropdown box and select **Discrete** and then select **Labels**. **Click Apply.**

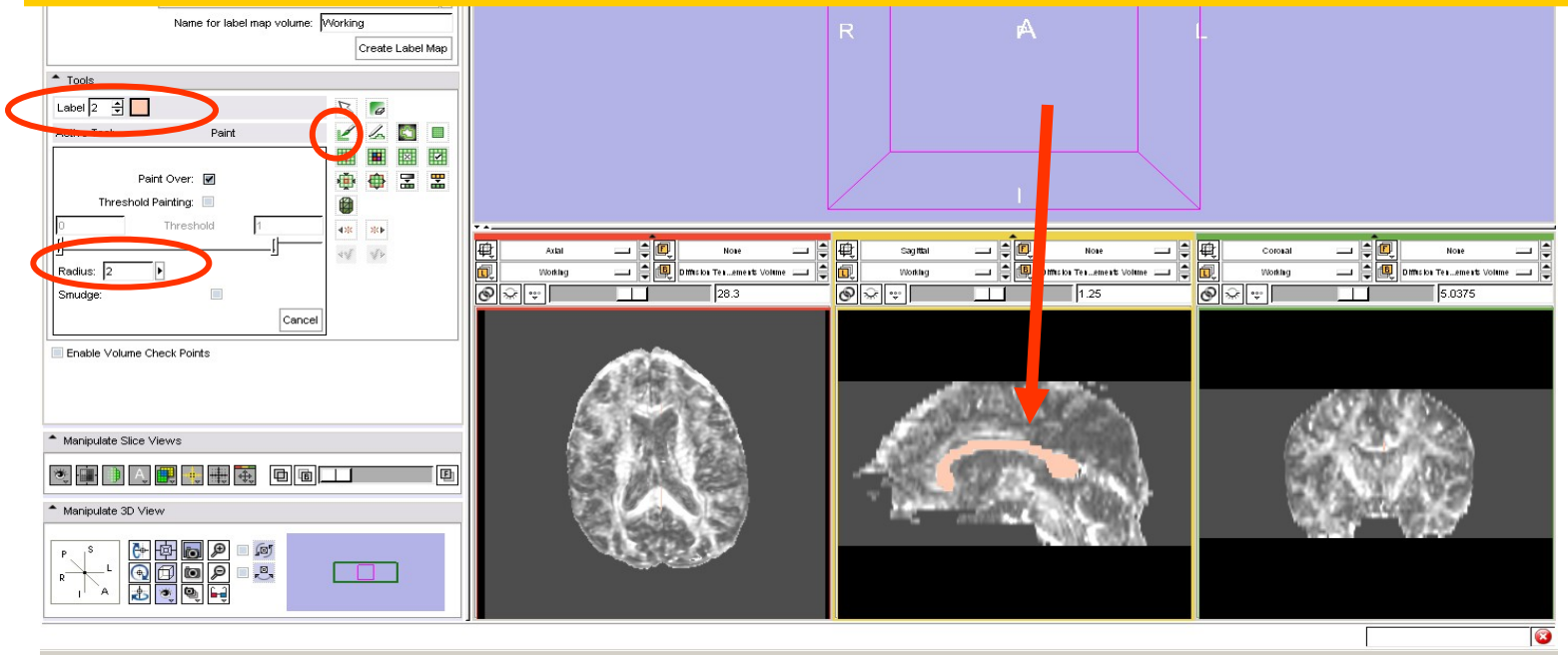


LabelMap Generation

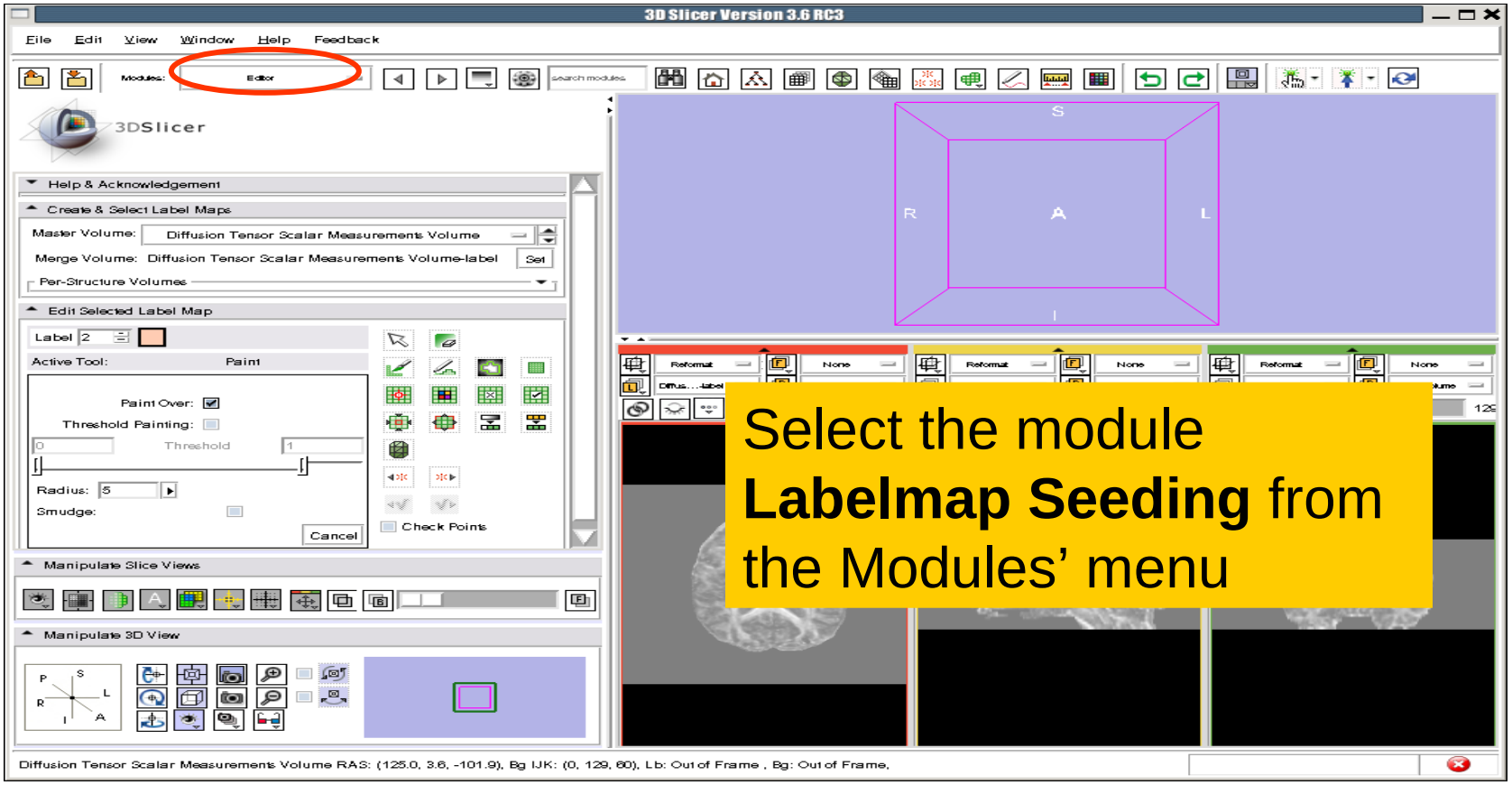


LabelMap Generation

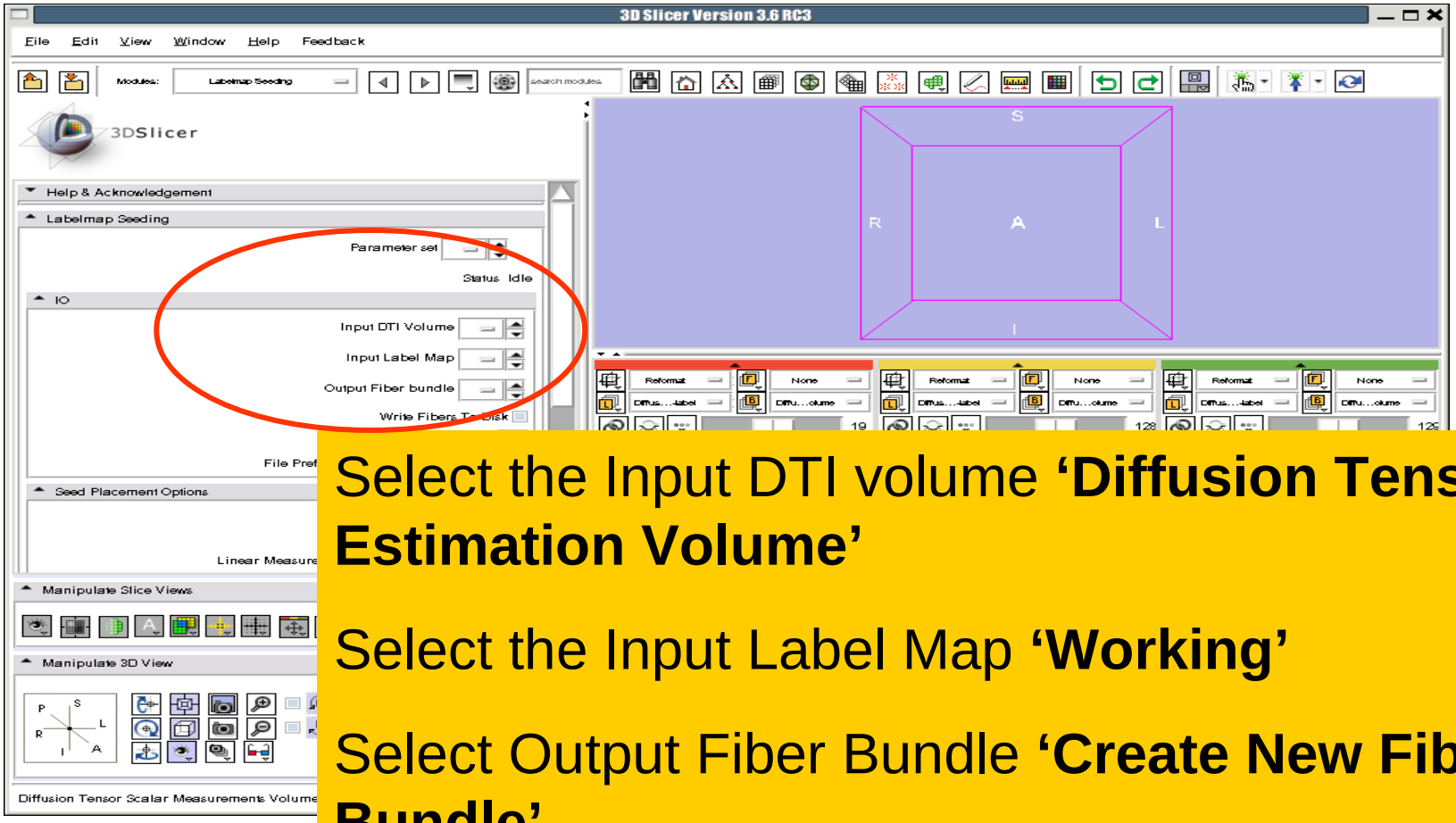
Select the label 2 (pink), click on the icon **Paint ,** set the radius to **2** and draw a region of interest within the corpus callosum in the sagittal view on a few slices



LabelMap Seeding



LabelMap Seeding

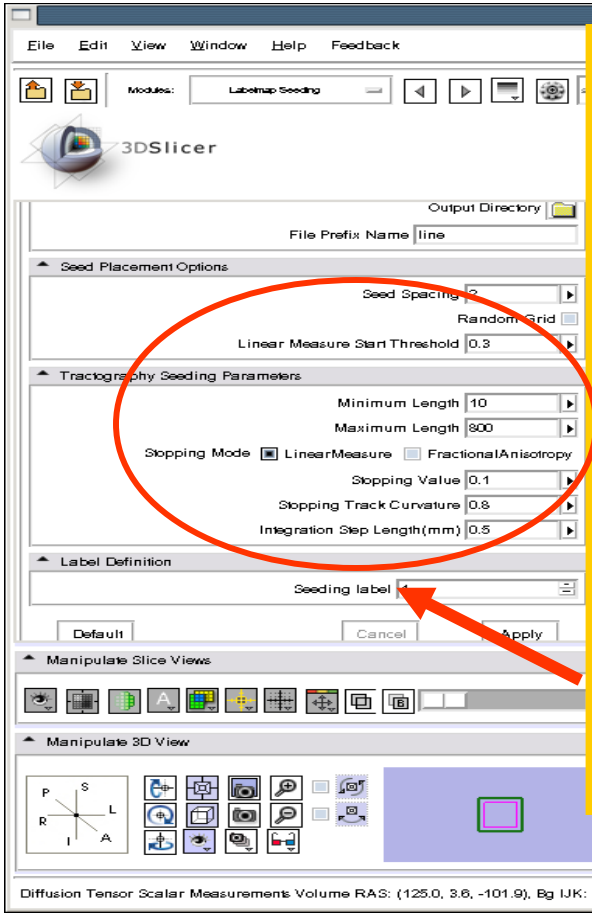


Select the Input DTI volume **'Diffusion Tensor Estimation Volume'**

Select the Input Label Map **'Working'**

Select Output Fiber Bundle **'Create New Fiber Bundle'**

LabelMap Seeding



Set the Seed Spacing to **2 mm** and select the Stopping Mode **Fractional Anisotropy**

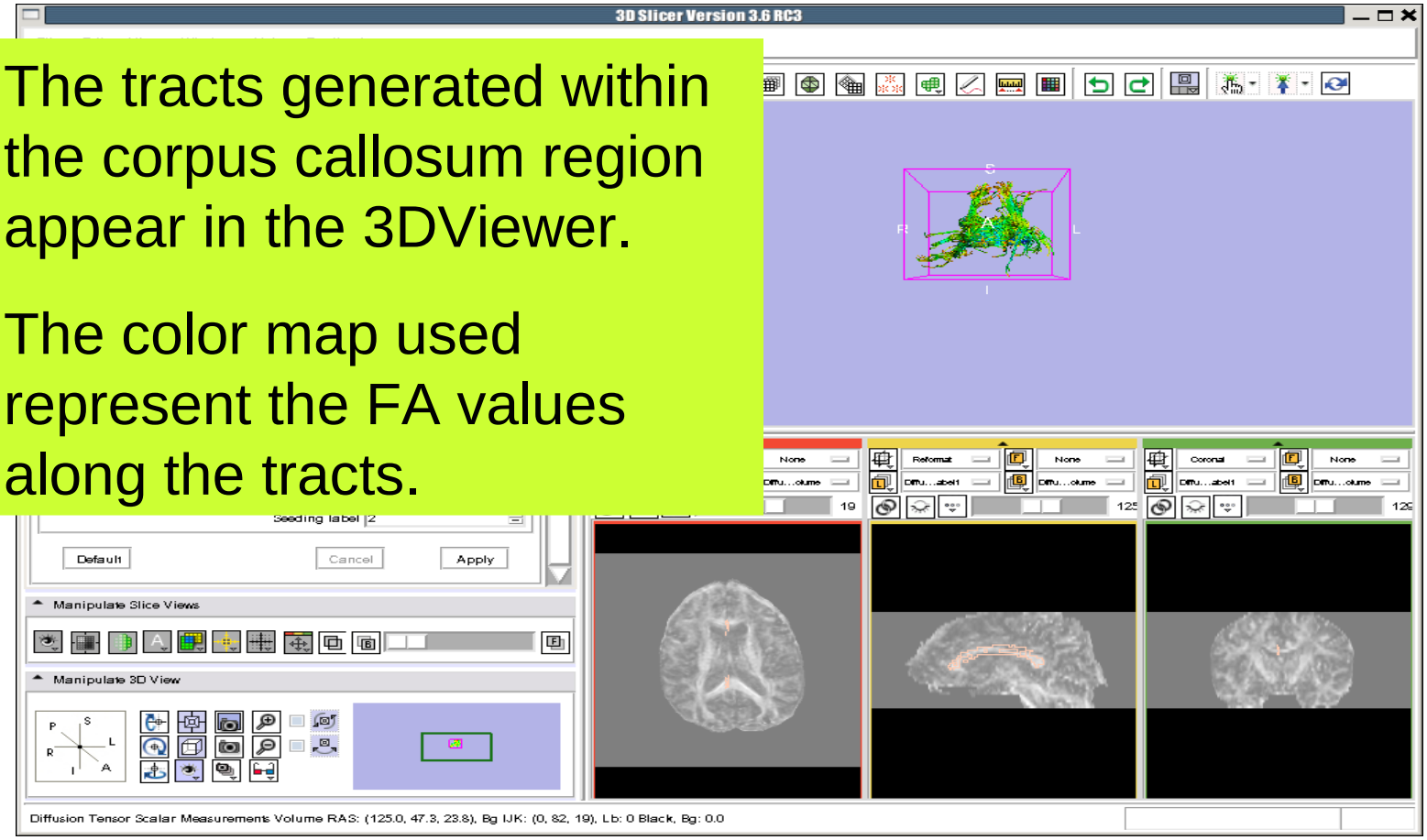
Use the default parameters for the minimum and maximum tract length, stopping value and stopping track curvature.

Set Seeding label to label 2, and click on **Apply**

LabelMap Seeding

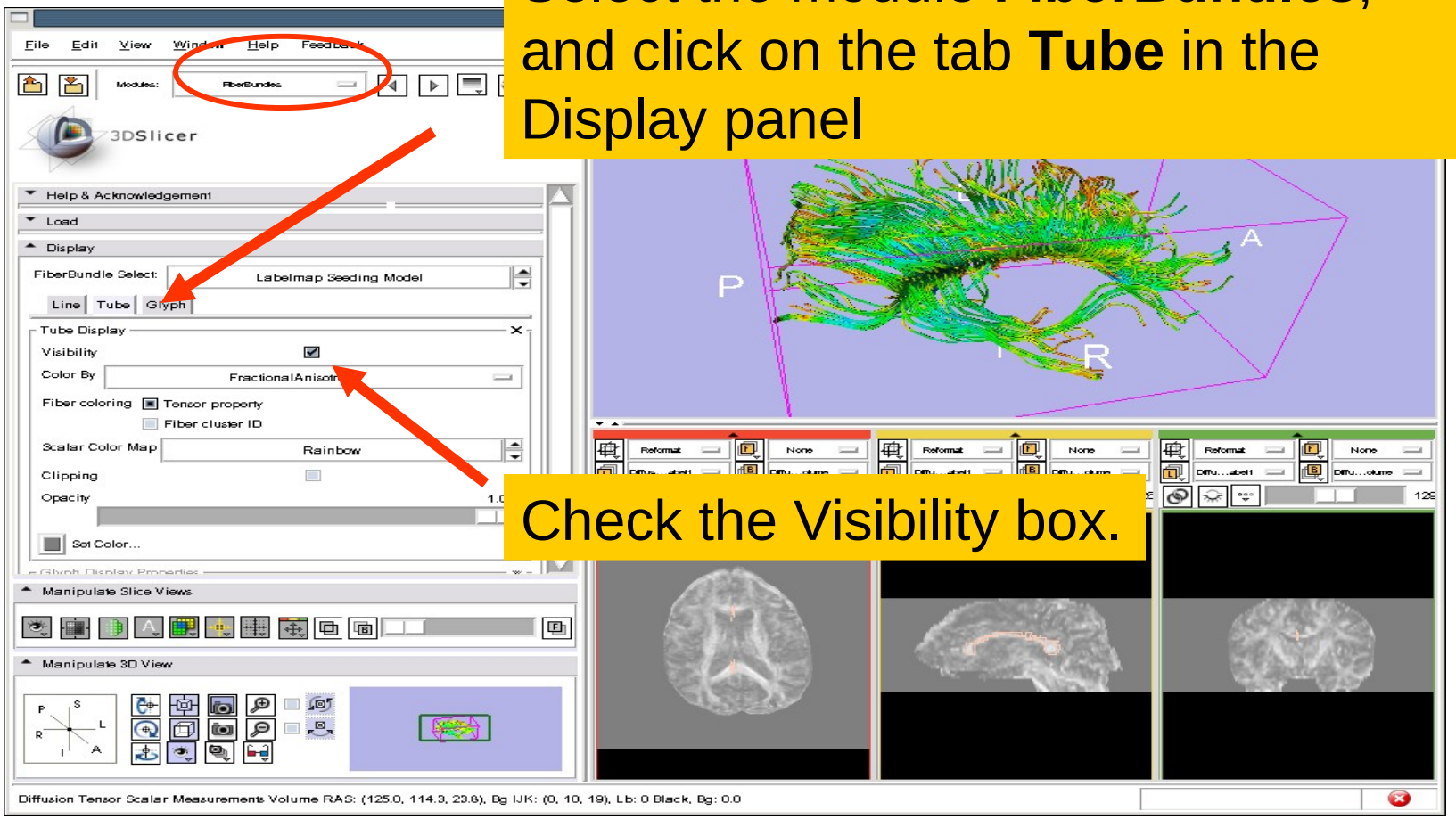
The tracts generated within the corpus callosum region appear in the 3DViewer.

The color map used represent the FA values along the tracts.



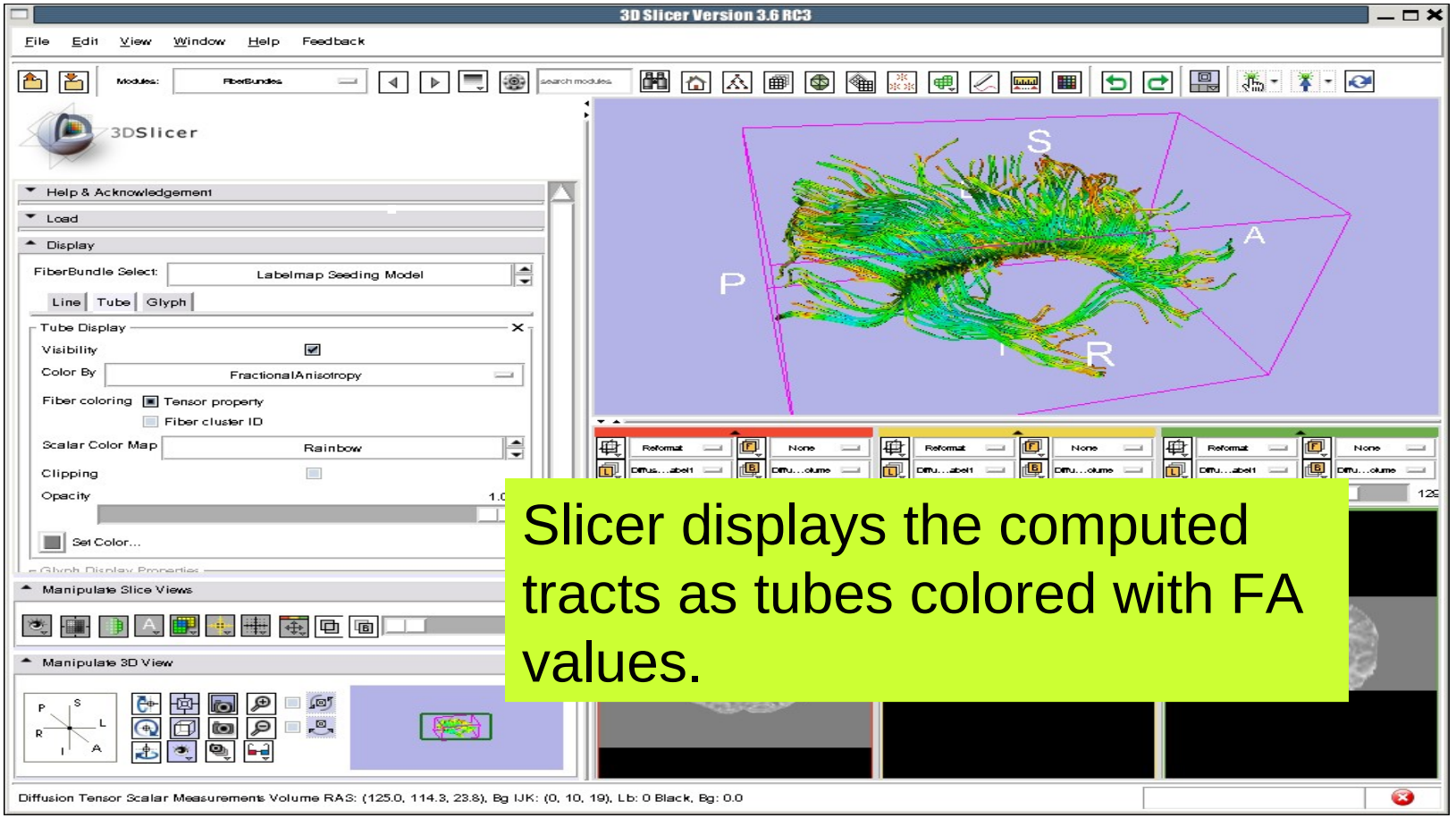
LabelMap Seeding

Select the module **FiberBundles**, and click on the tab **Tube** in the Display panel

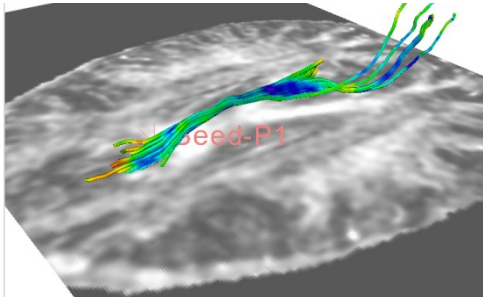


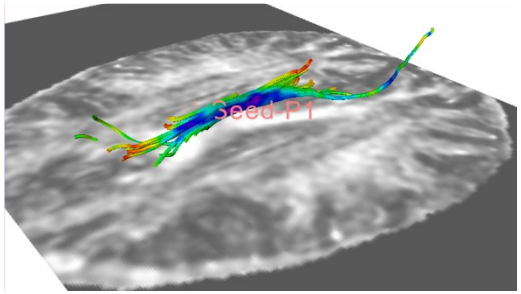
Check the Visibility box.

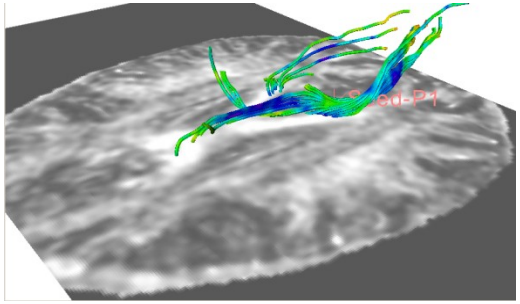
LabelMap Seeding



Slicer displays the computed tracts as tubes colored with FA values.



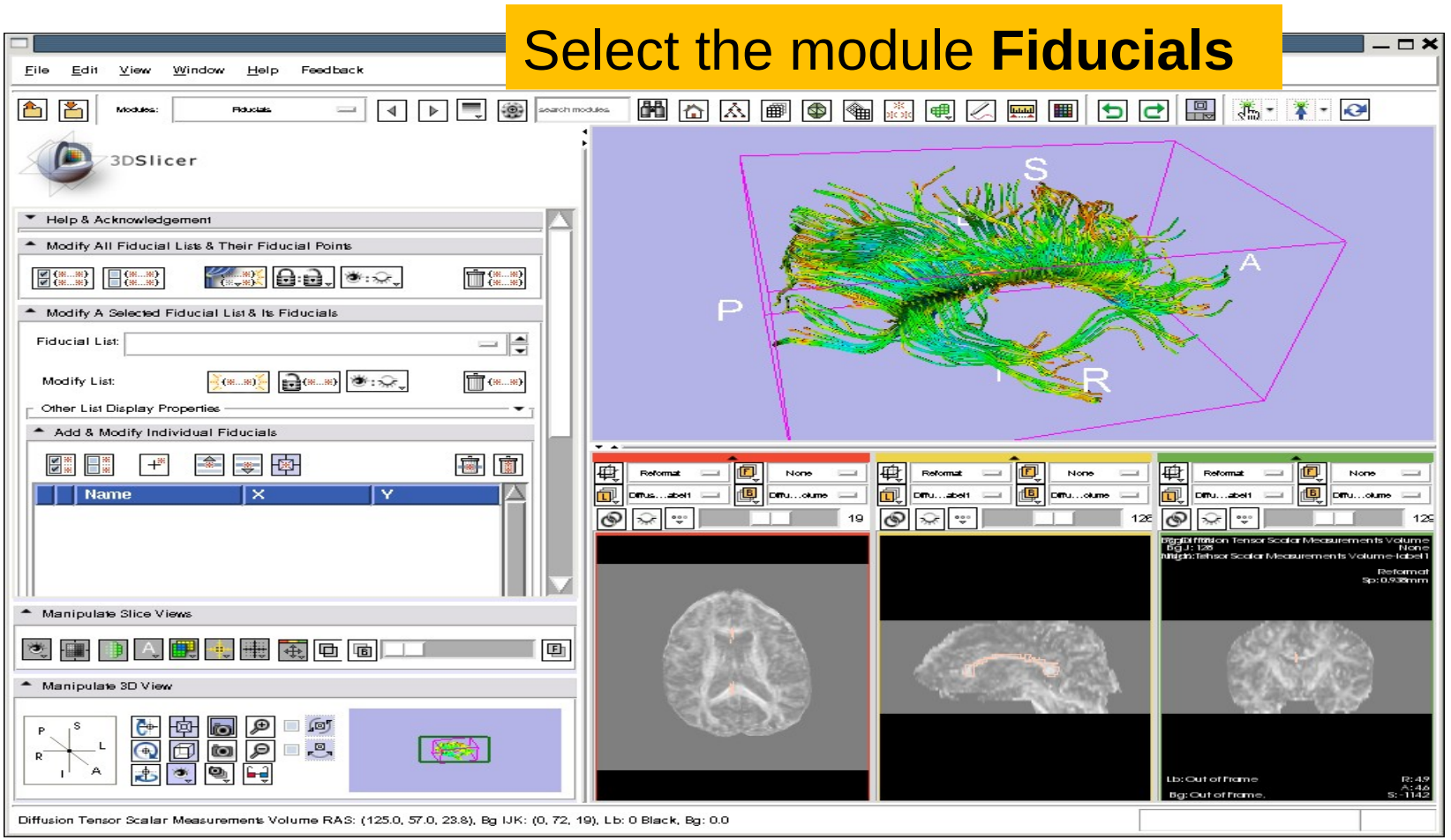




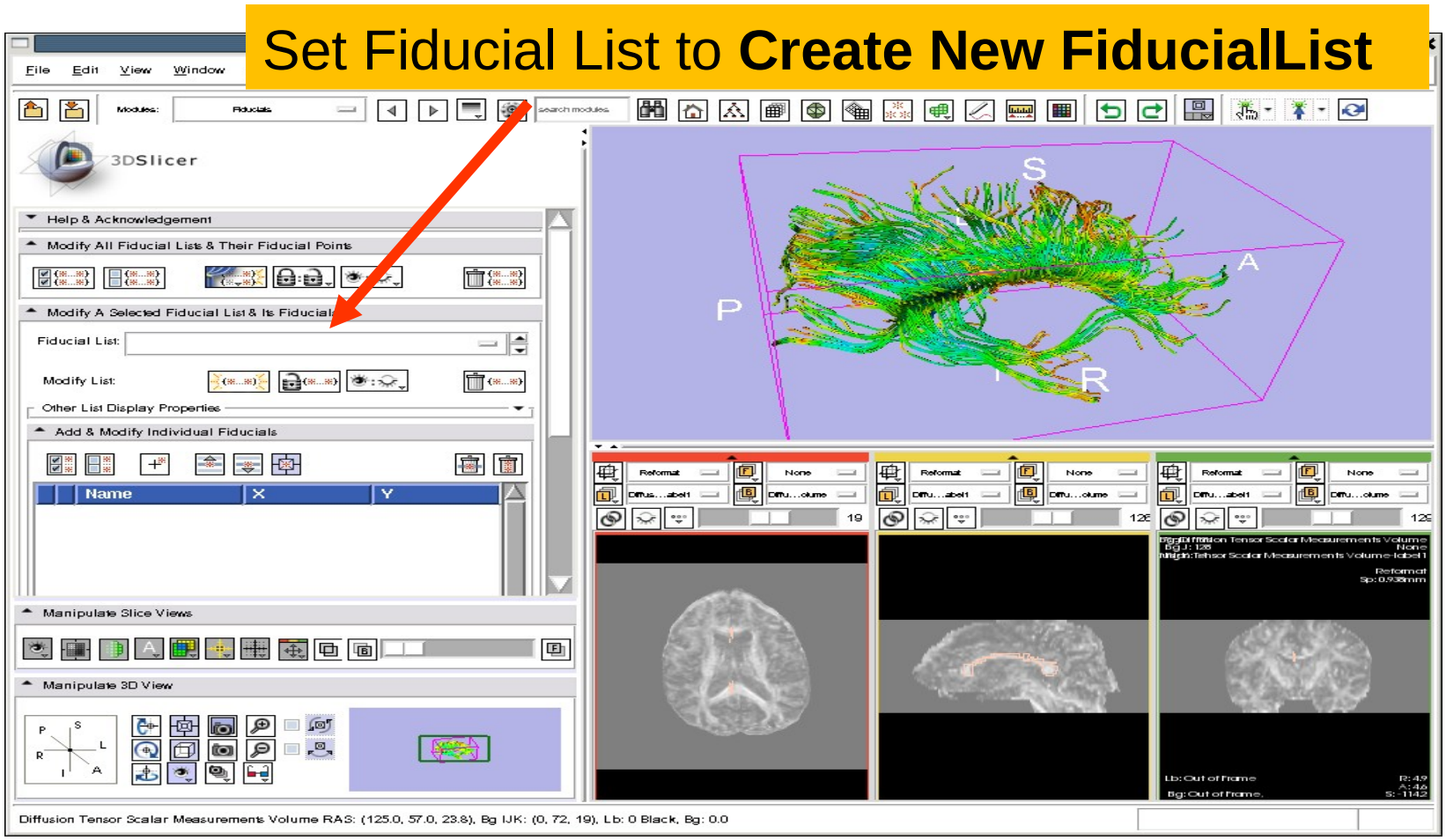
Part 4:

Tractography on-the-fly

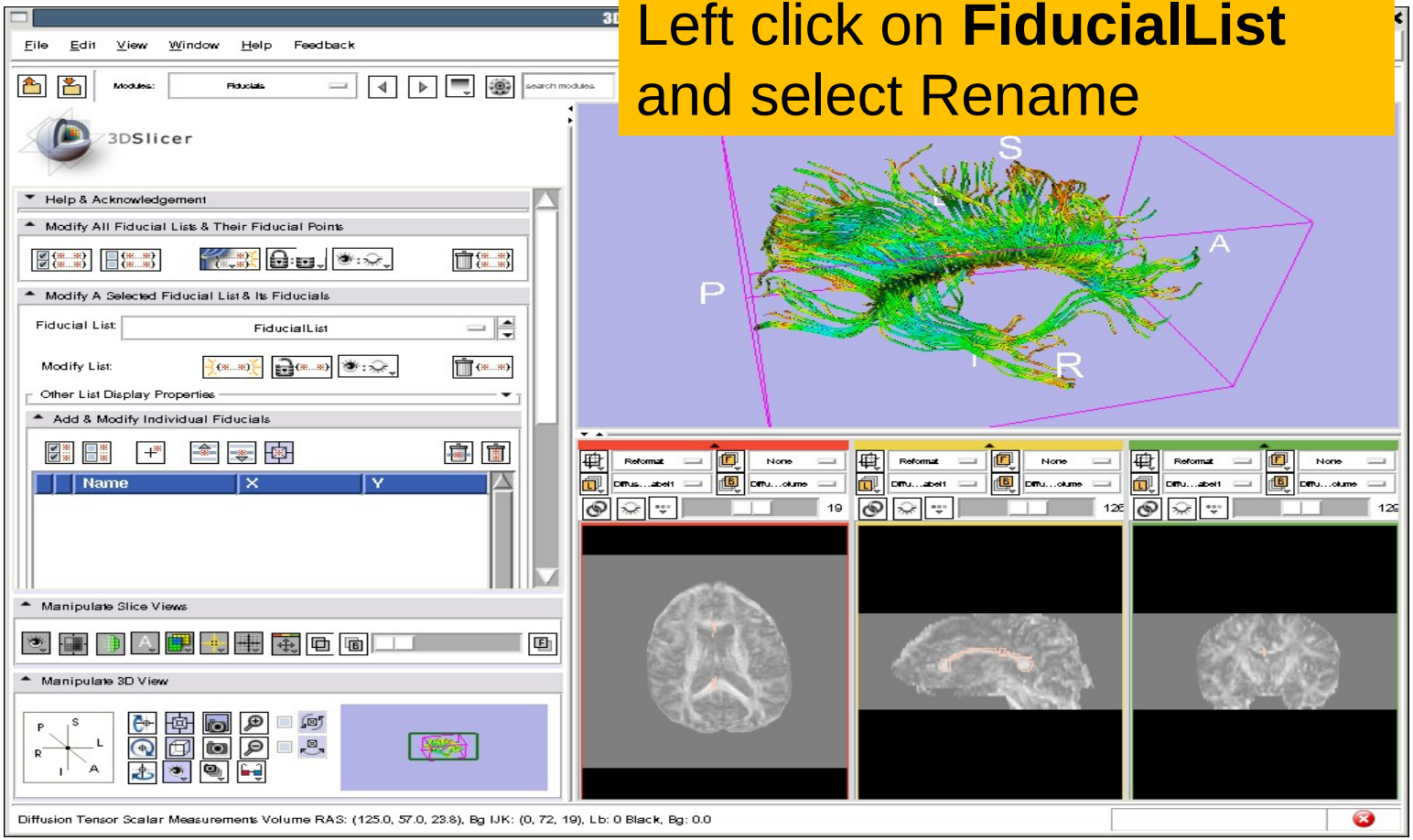
Fiducial Seeding



Fiducial Seeding

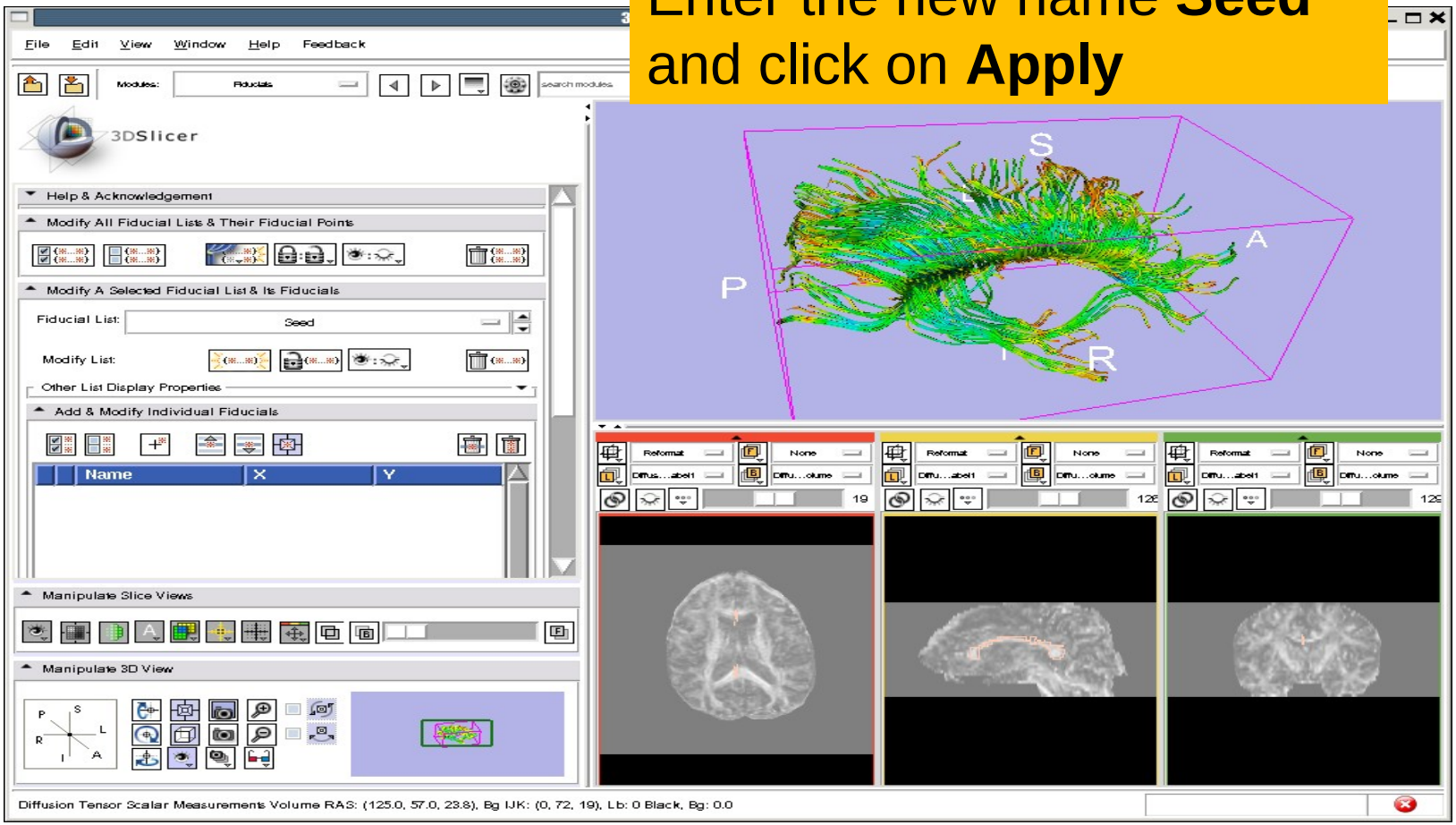


Fiducial Seeding

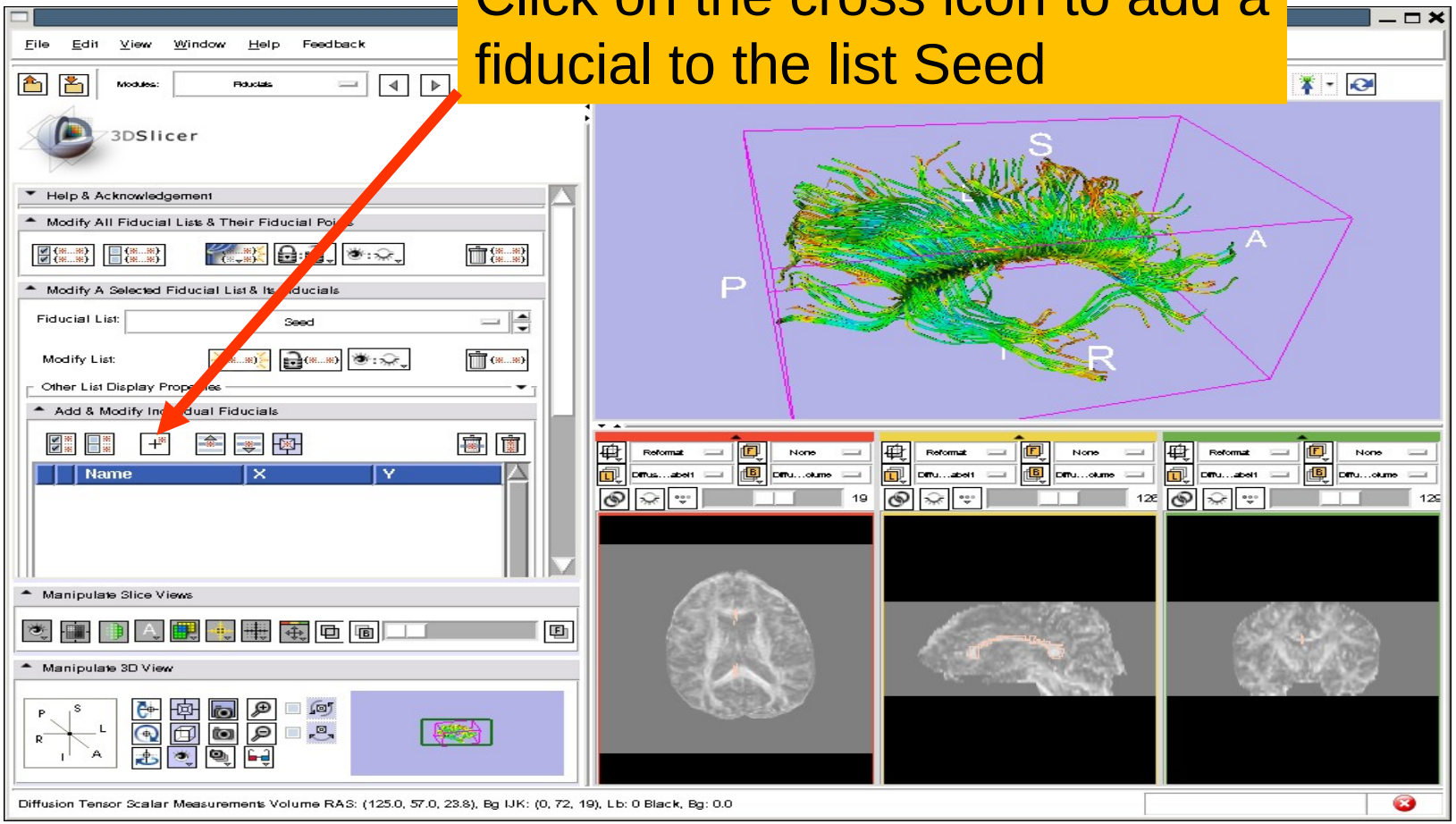


Fiducial Seeding

Enter the new name **Seed** and click on **Apply**

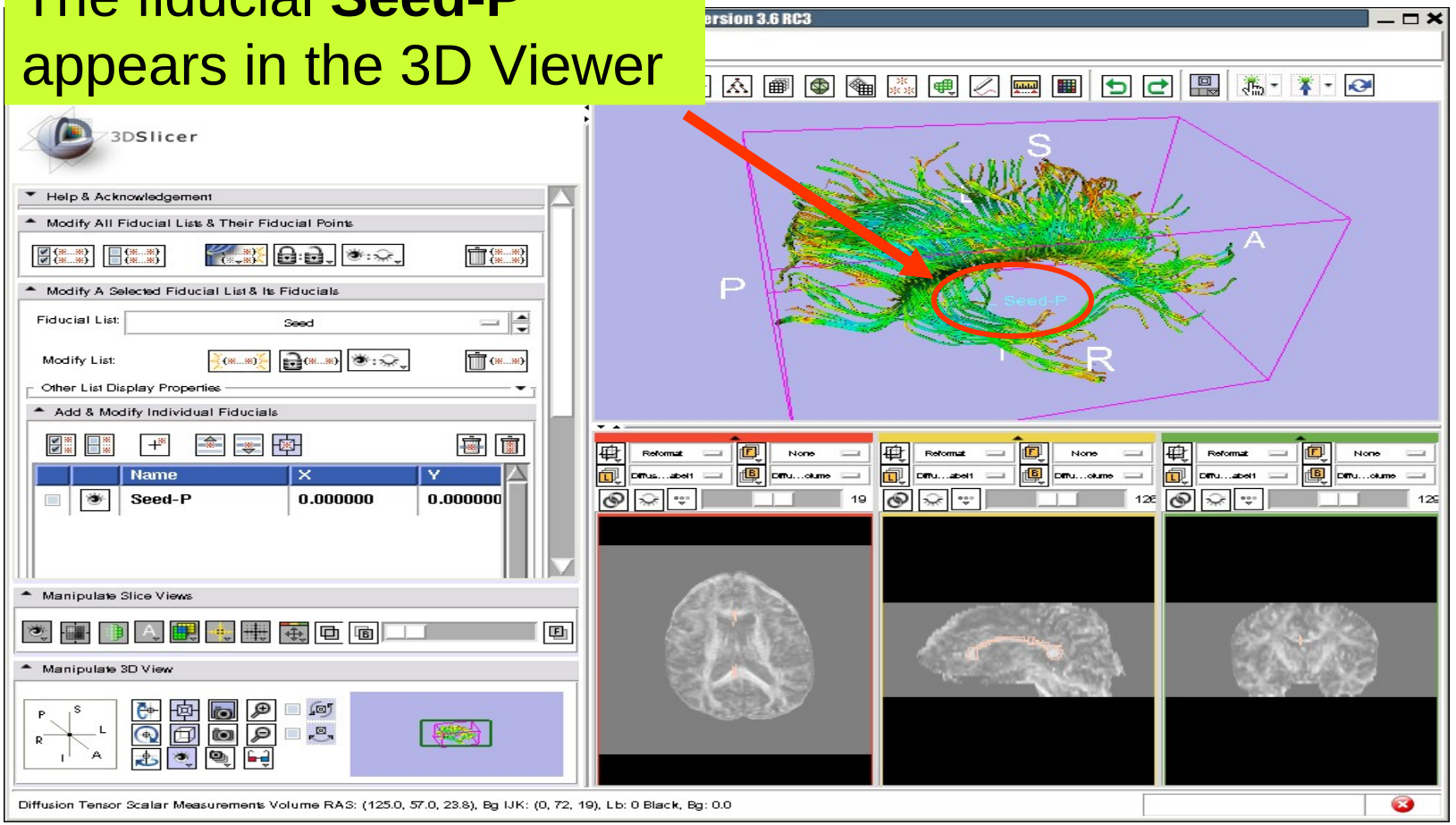


Fiducial Seeding



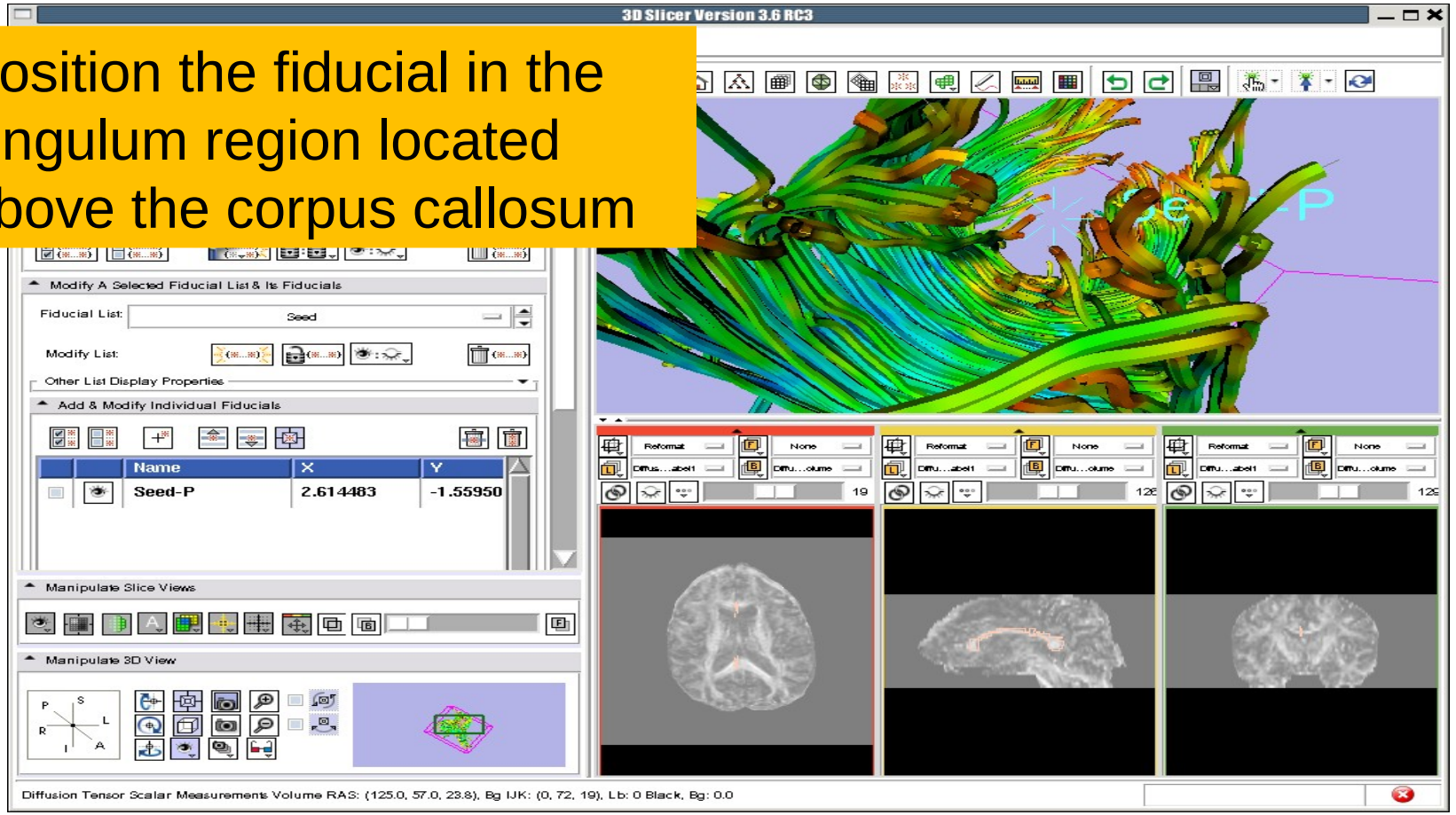
Fiducial Seeding

The fiducial **Seed-P** appears in the 3D Viewer



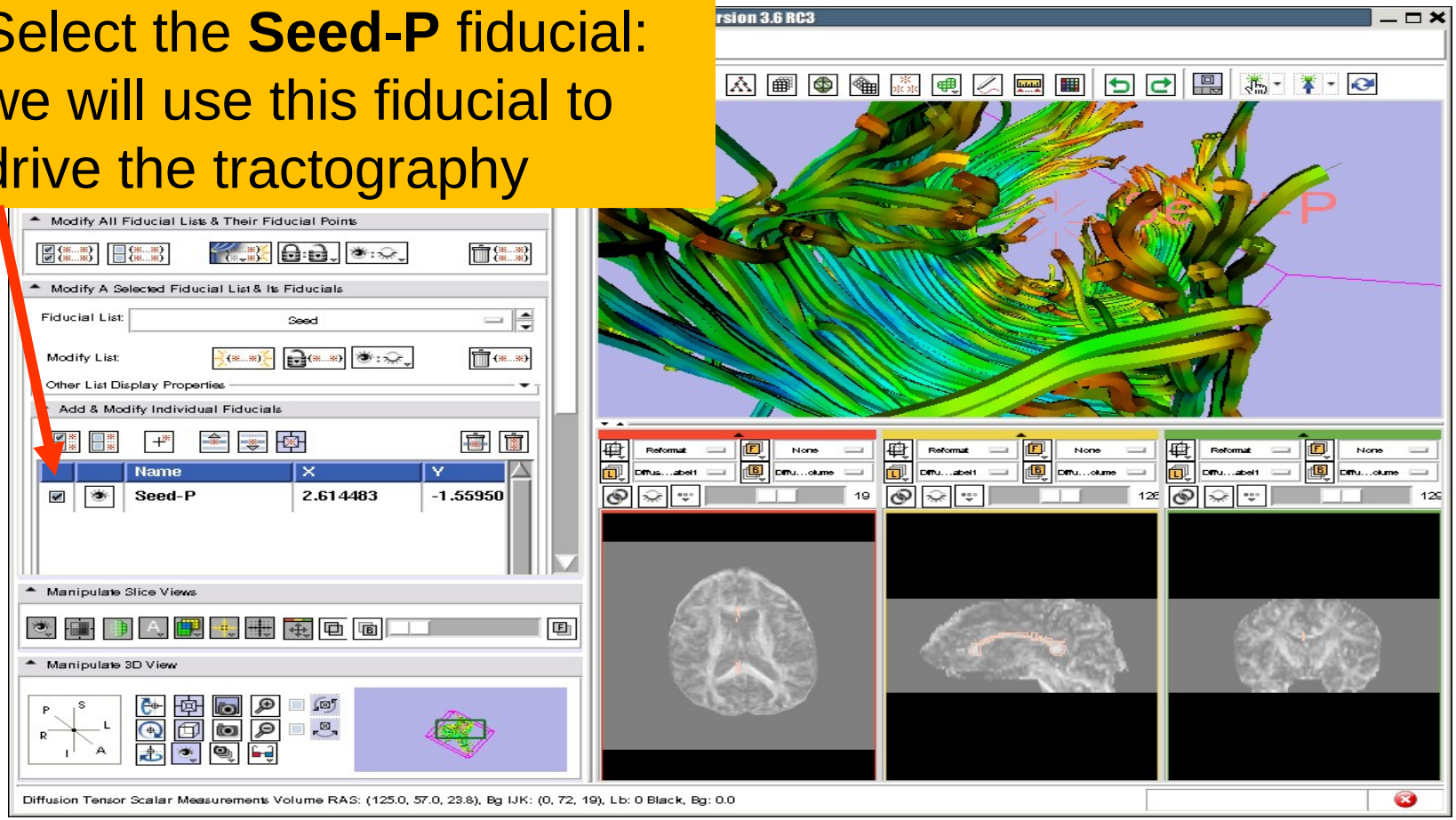
Fiducial Seeding

Position the fiducial in the cingulum region located above the corpus callosum



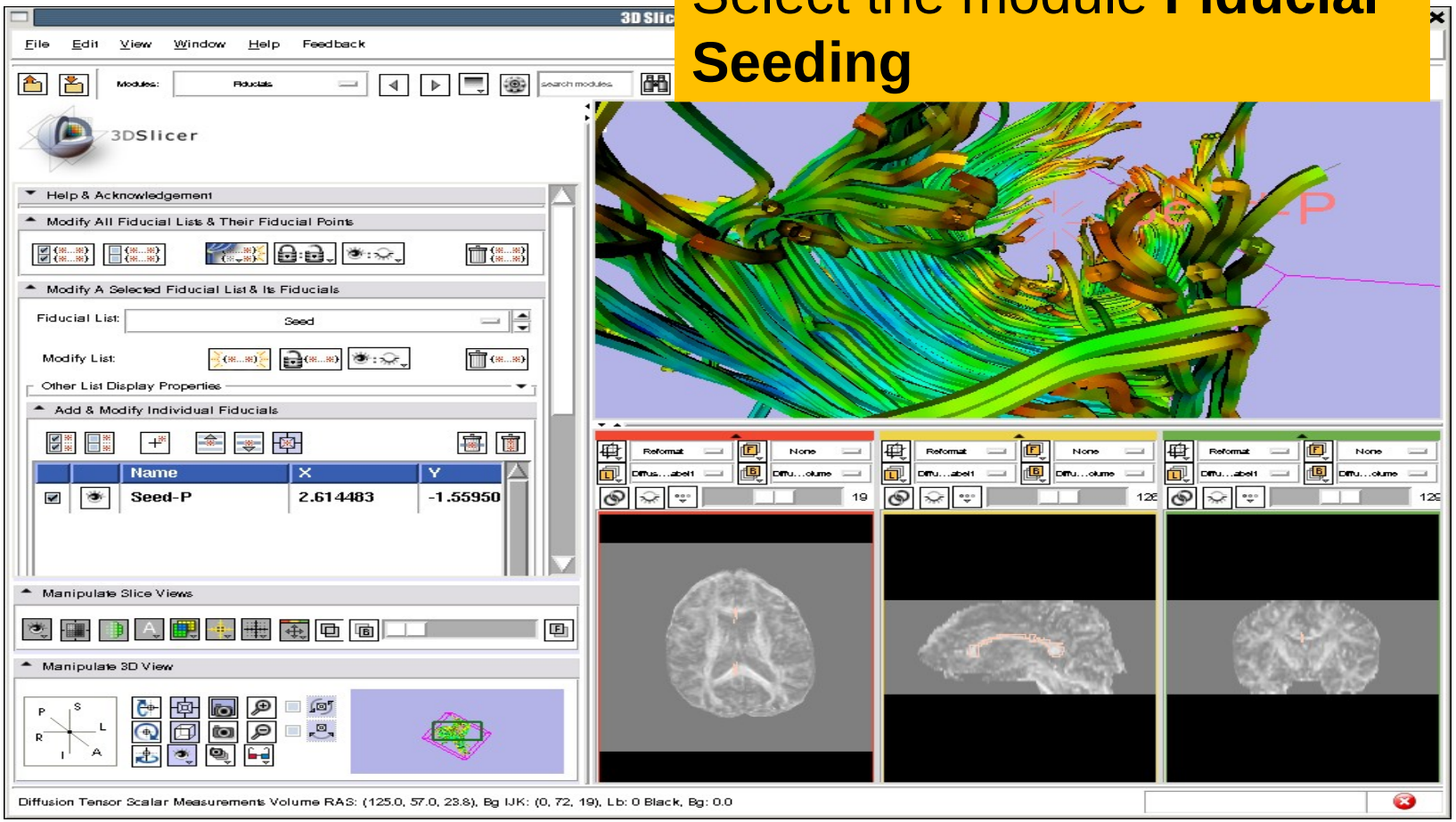
Fiducial Seeding

Select the **Seed-P** fiducial: we will use this fiducial to drive the tractography

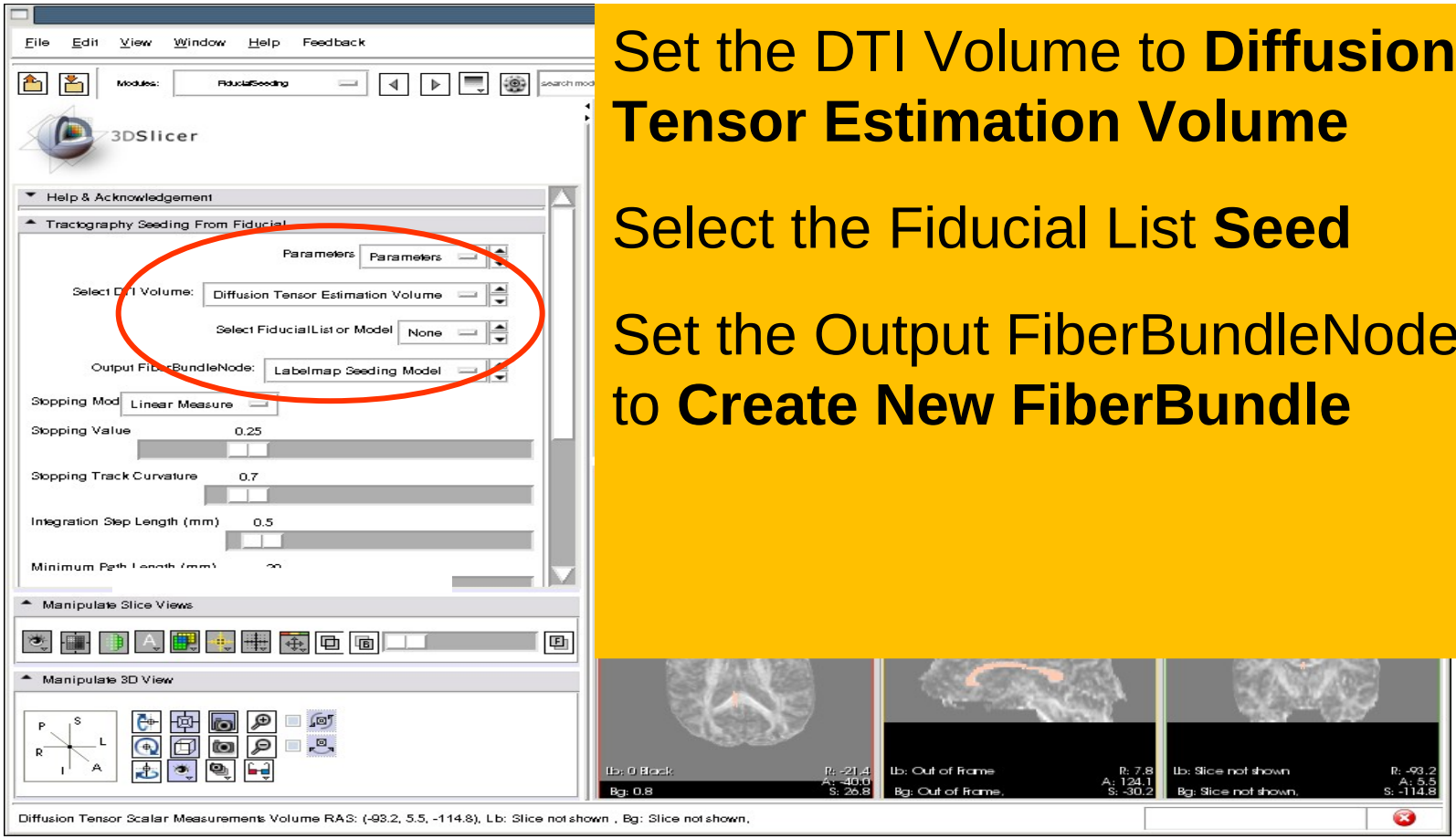


Fiducial Seeding

Select the module **Fiducial Seeding**



Fiducial Seeding

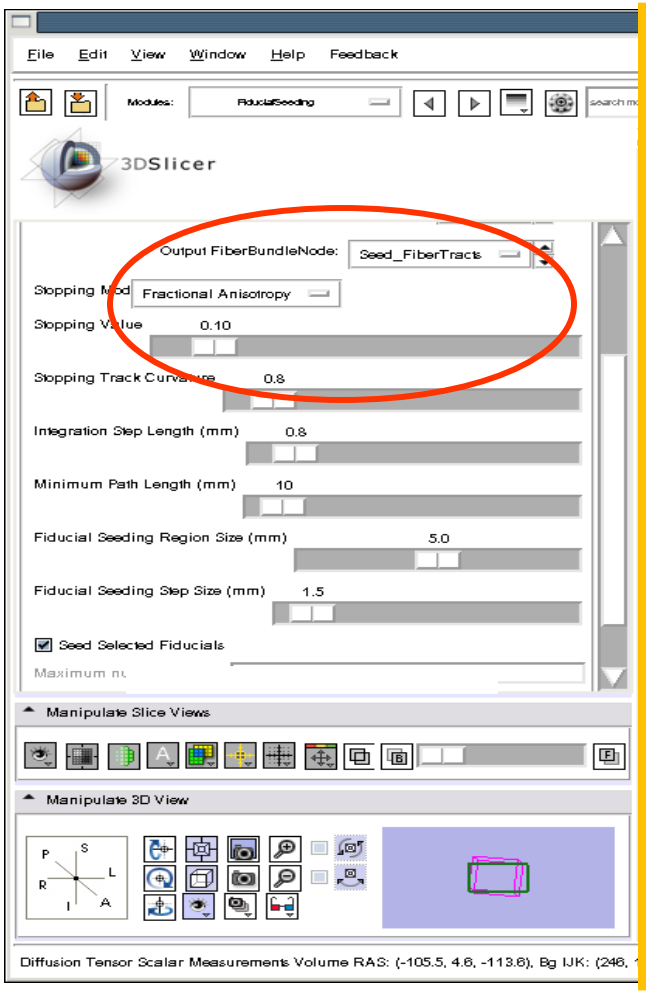


Set the DTI Volume to **Diffusion Tensor Estimation Volume**

Select the Fiducial List **Seed**

Set the Output FiberBundleNode to **Create New FiberBundle**

Fiducial Seeding



Set the Stopping Mode to Fractional Anisotropy and set the tractography parameters to the values that we used for the corpus callosum:

Stopping Value: 0.1

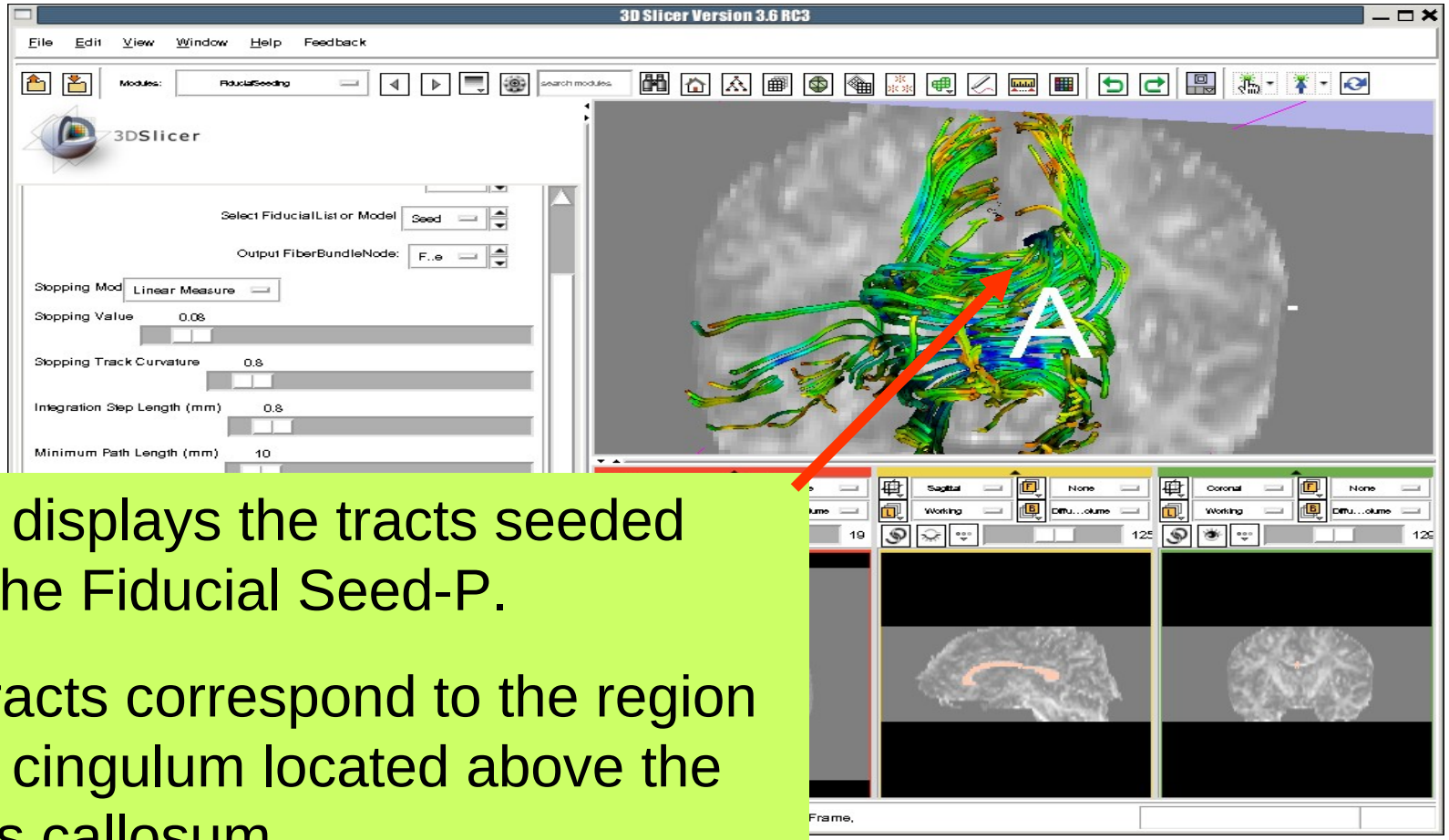
Stopping Track Curvature: 0.8

Step Length: 0.8 mm

Minimum Path Length: 10 mm

Fiducial Stepping Size: 1.5 mm

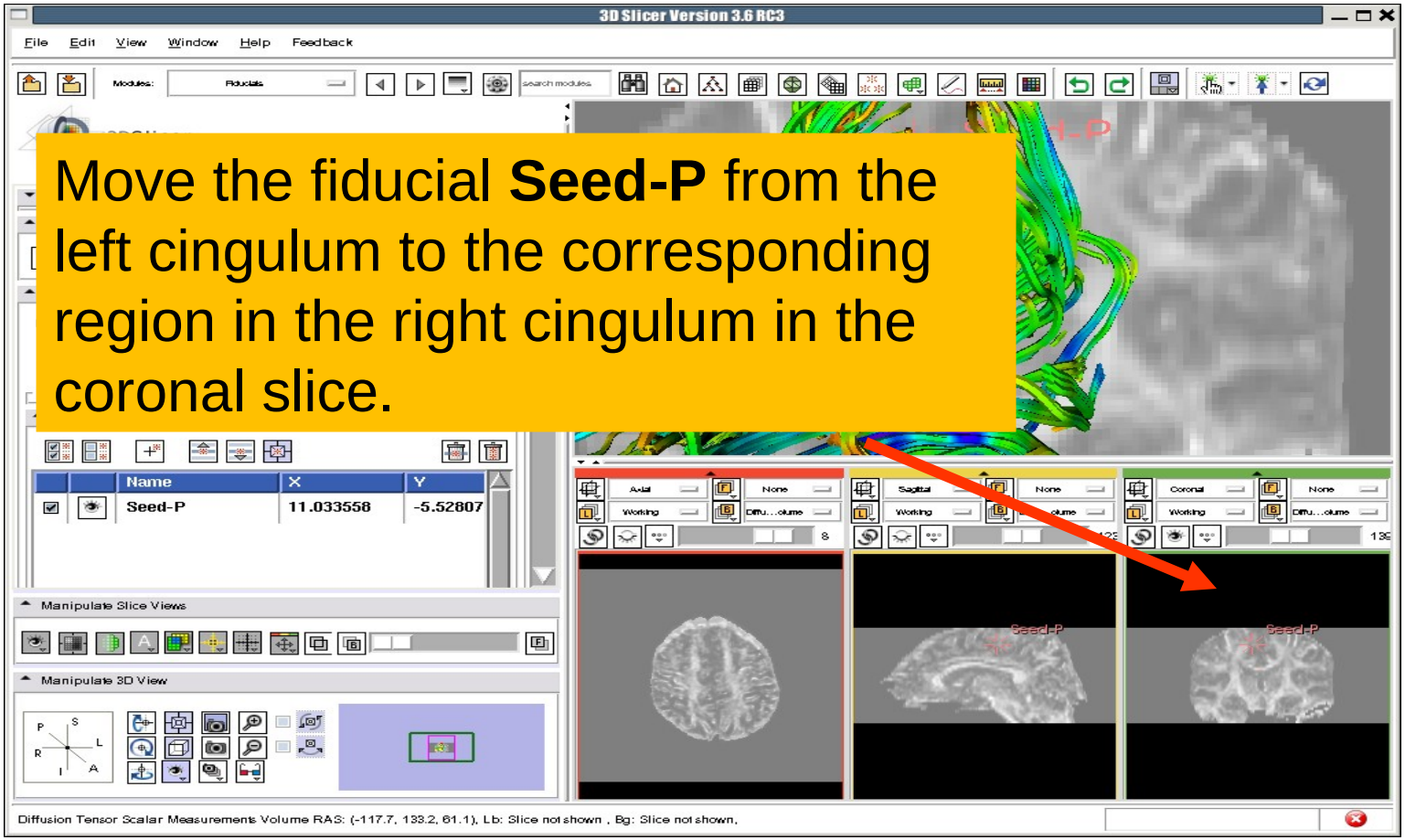
Fiducial Seeding



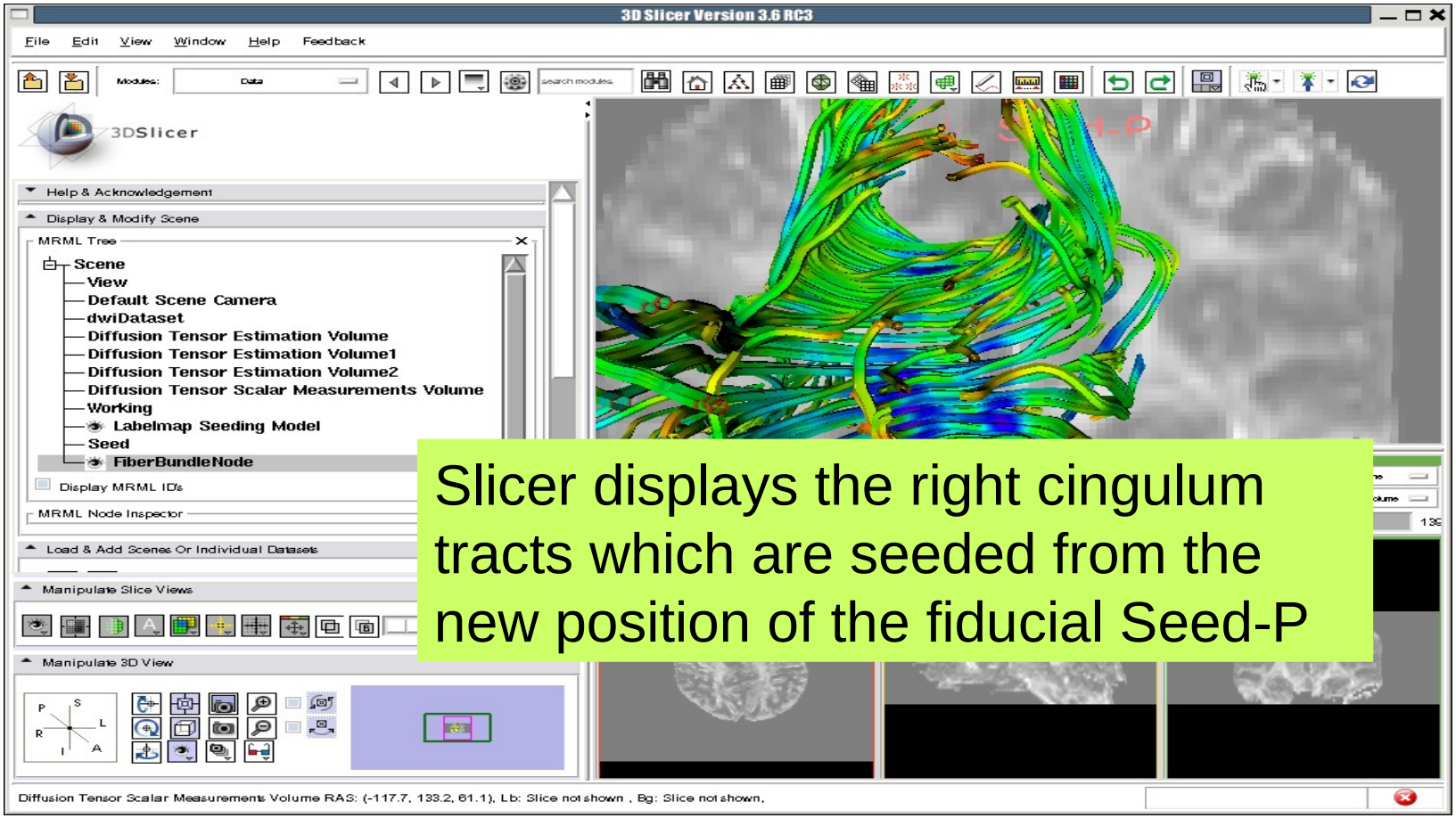
Slicer displays the tracts seeded from the Fiducial Seed-P.

The tracts correspond to the region of the cingulum located above the corpus callosum.

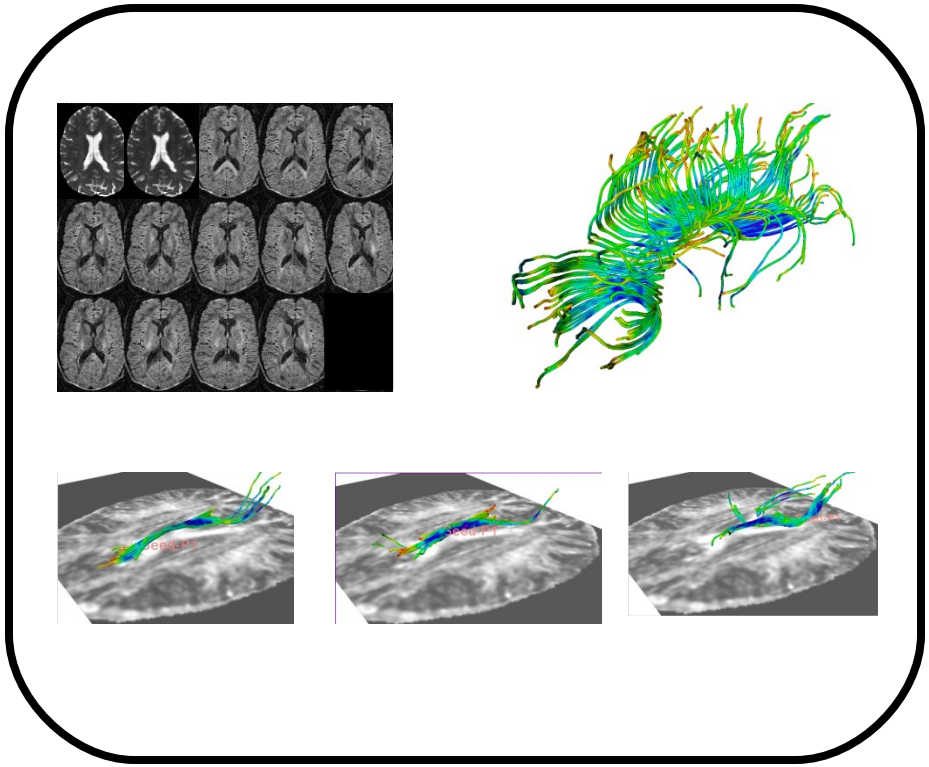
Fiducial Seeding



Fiducial Seeding



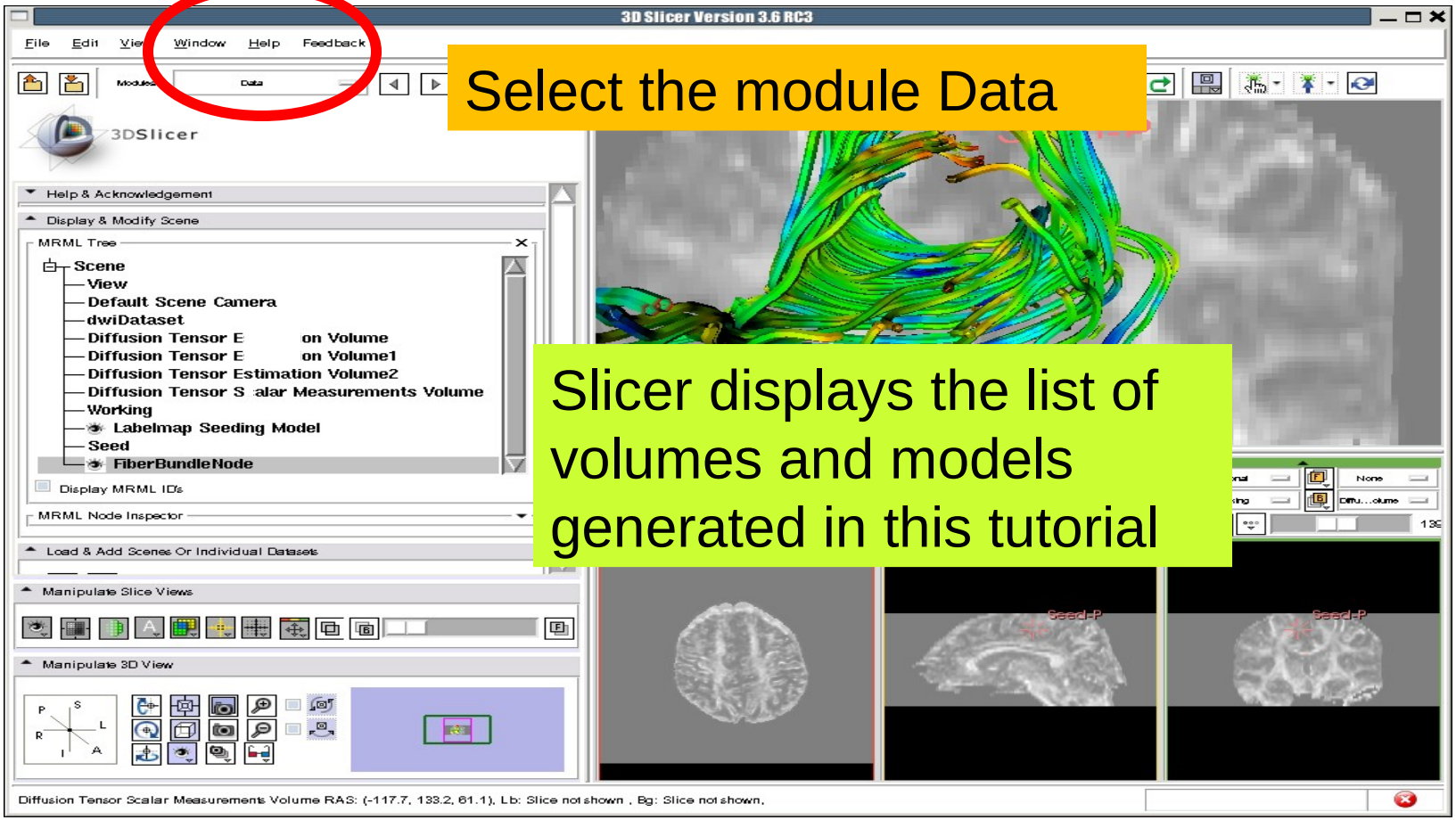
Slicer displays the right cingulum tracts which are seeded from the new position of the fiducial Seed-P



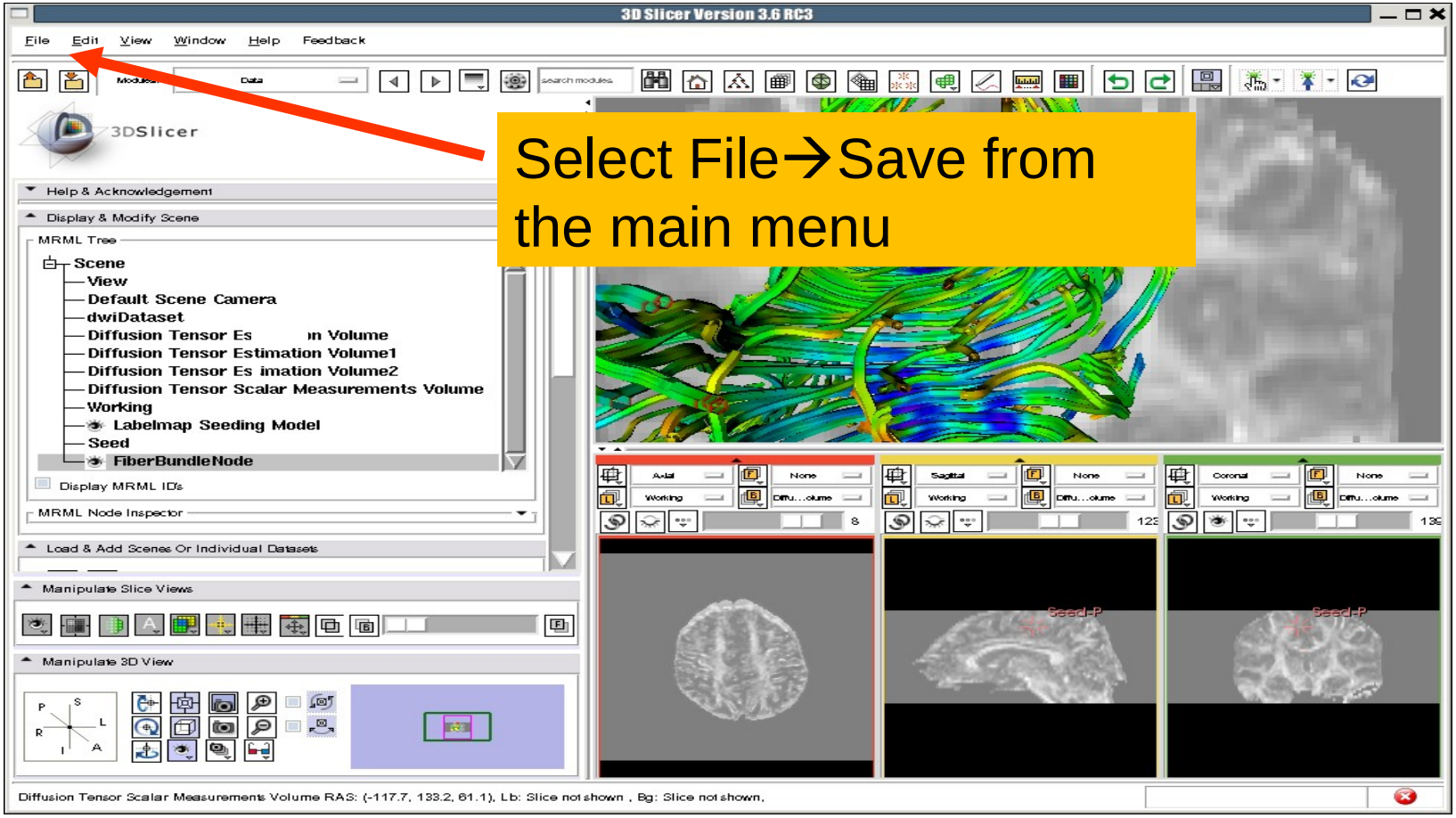
Part 5:

Saving a DTI Scene

DTI Scene



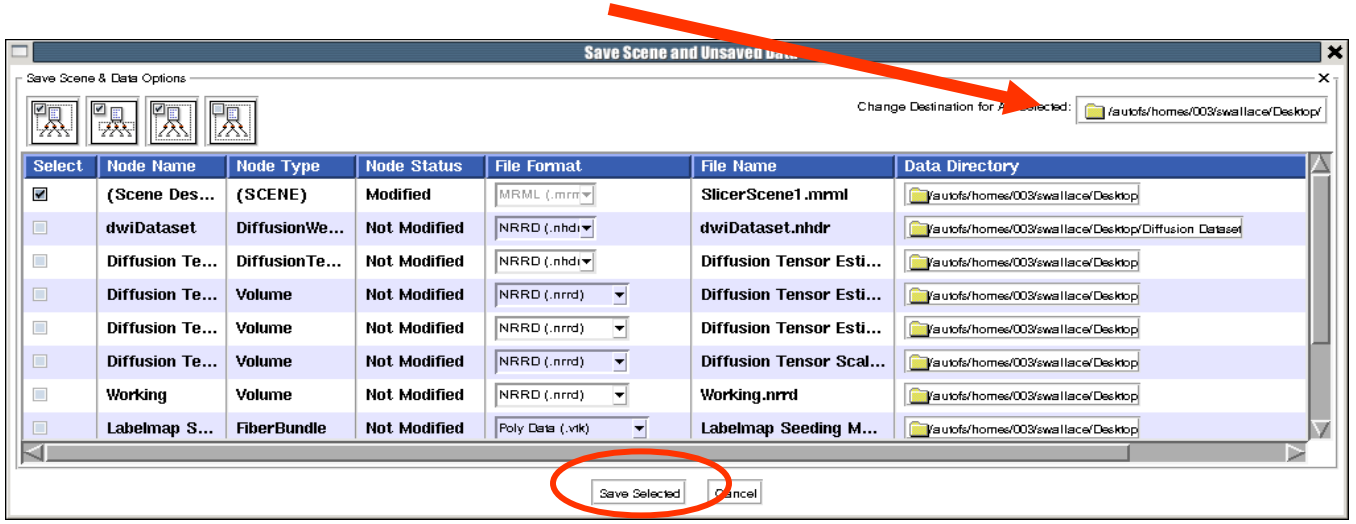
Saving a DTI Scene



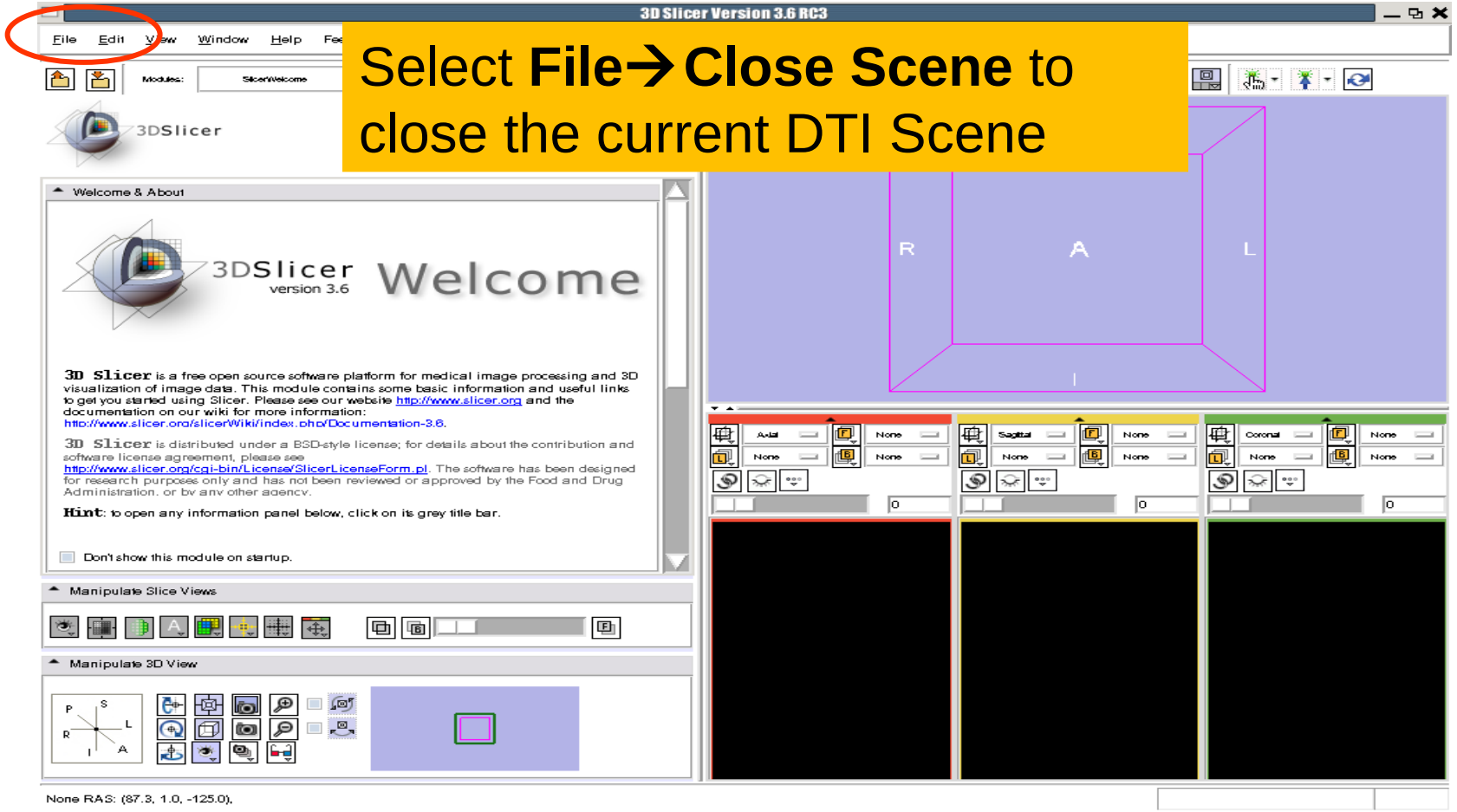
Select File→Save from the main menu

Saving a DTI Scene

Browse to a directory where you would like to save the data. Once you have selected a directory, click on **Save Selected**

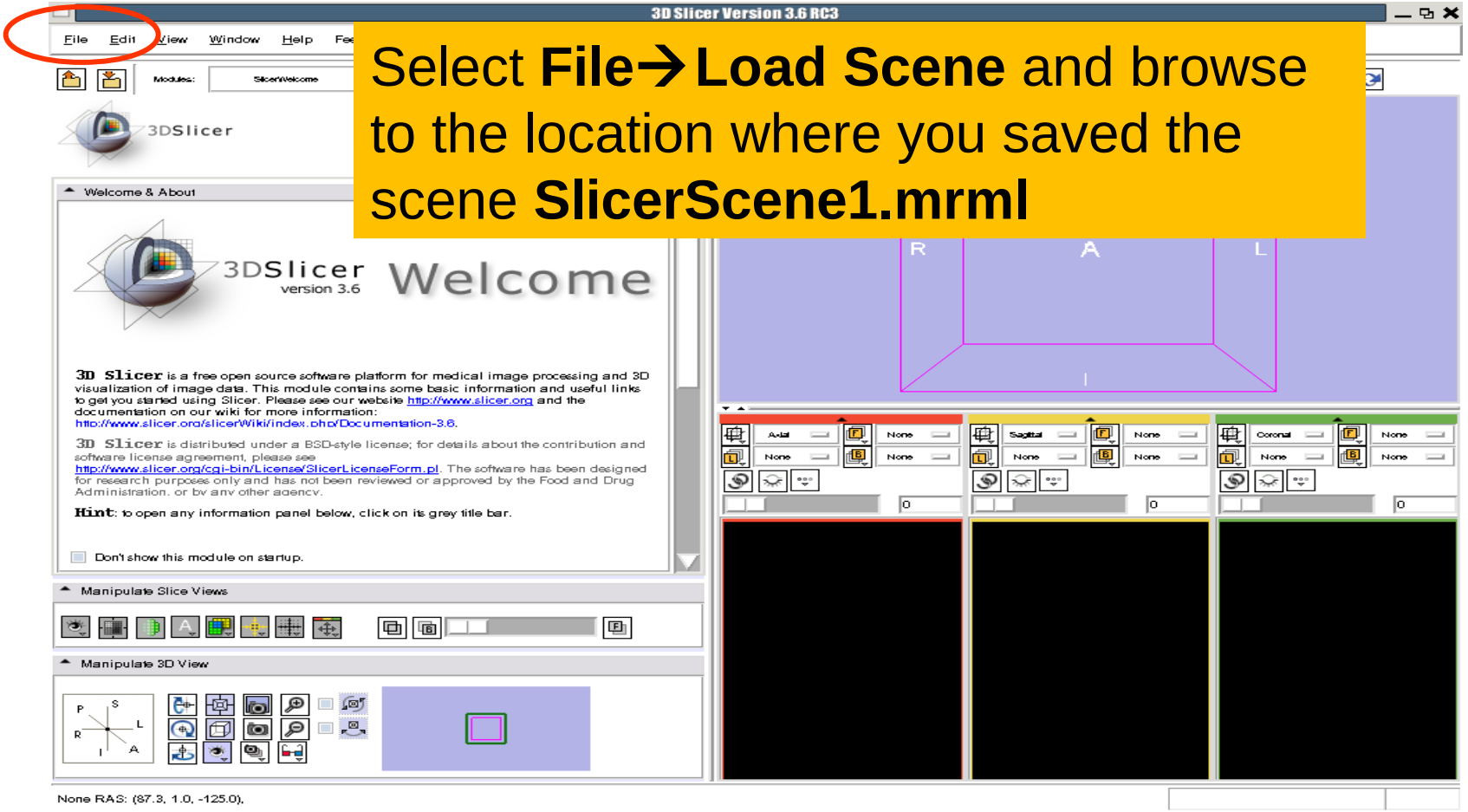


Saving a DTI Scene



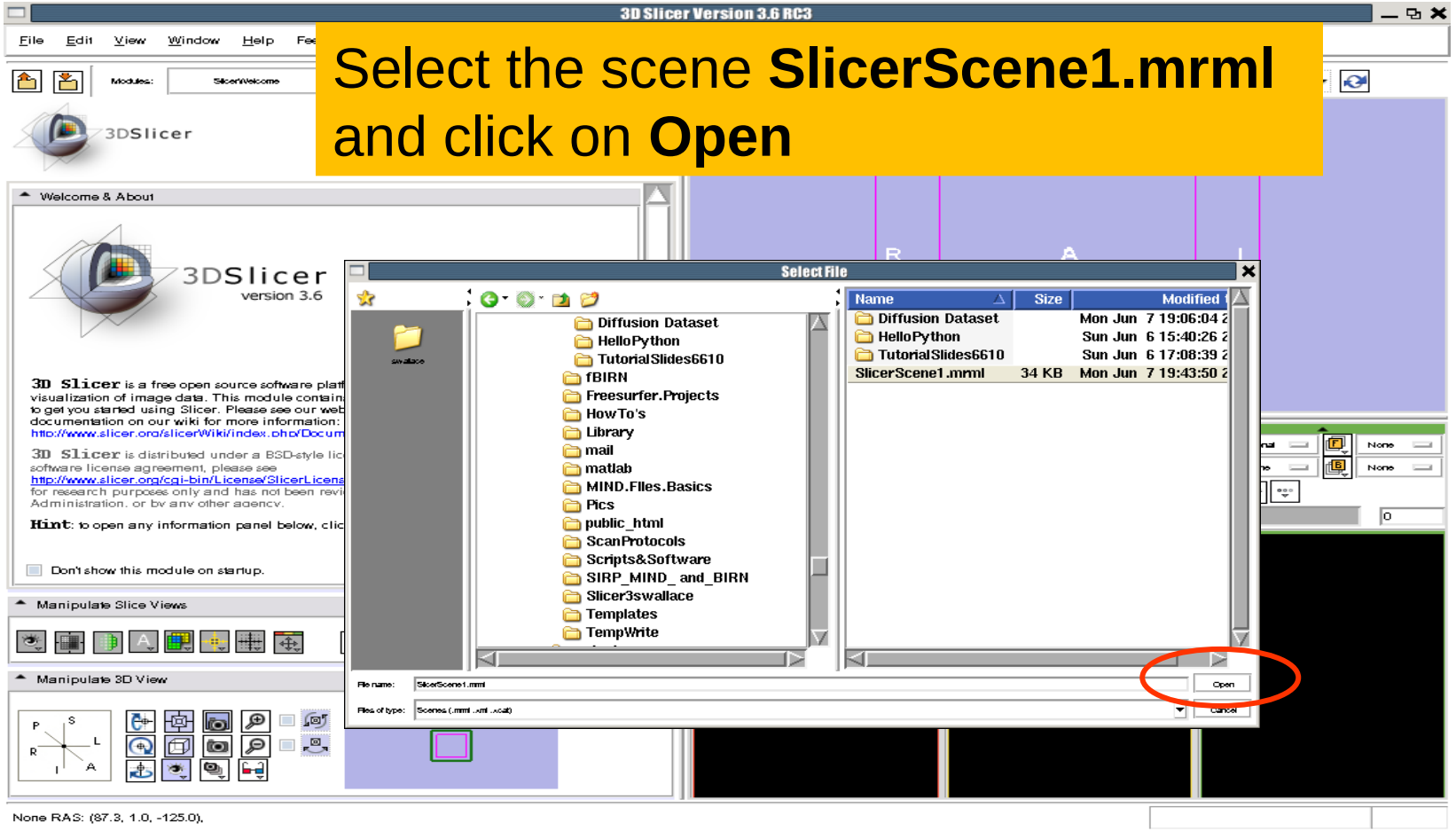
Select **File→Close Scene** to close the current DTI Scene

Loading a DTI Scene



Select **File→Load Scene** and browse to the location where you saved the scene **SlicerScene1.mrml**

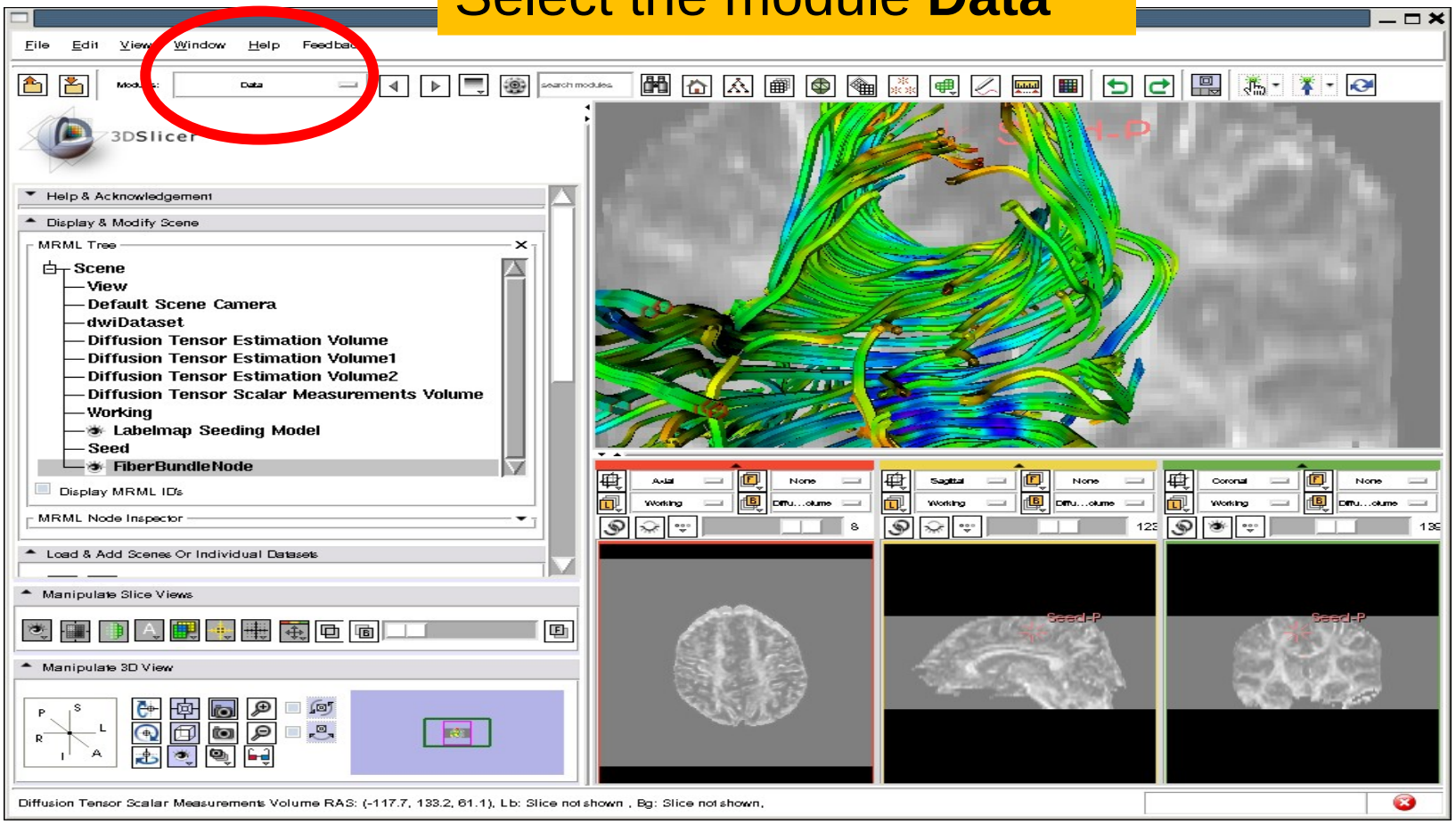
Loading a DTI Scene



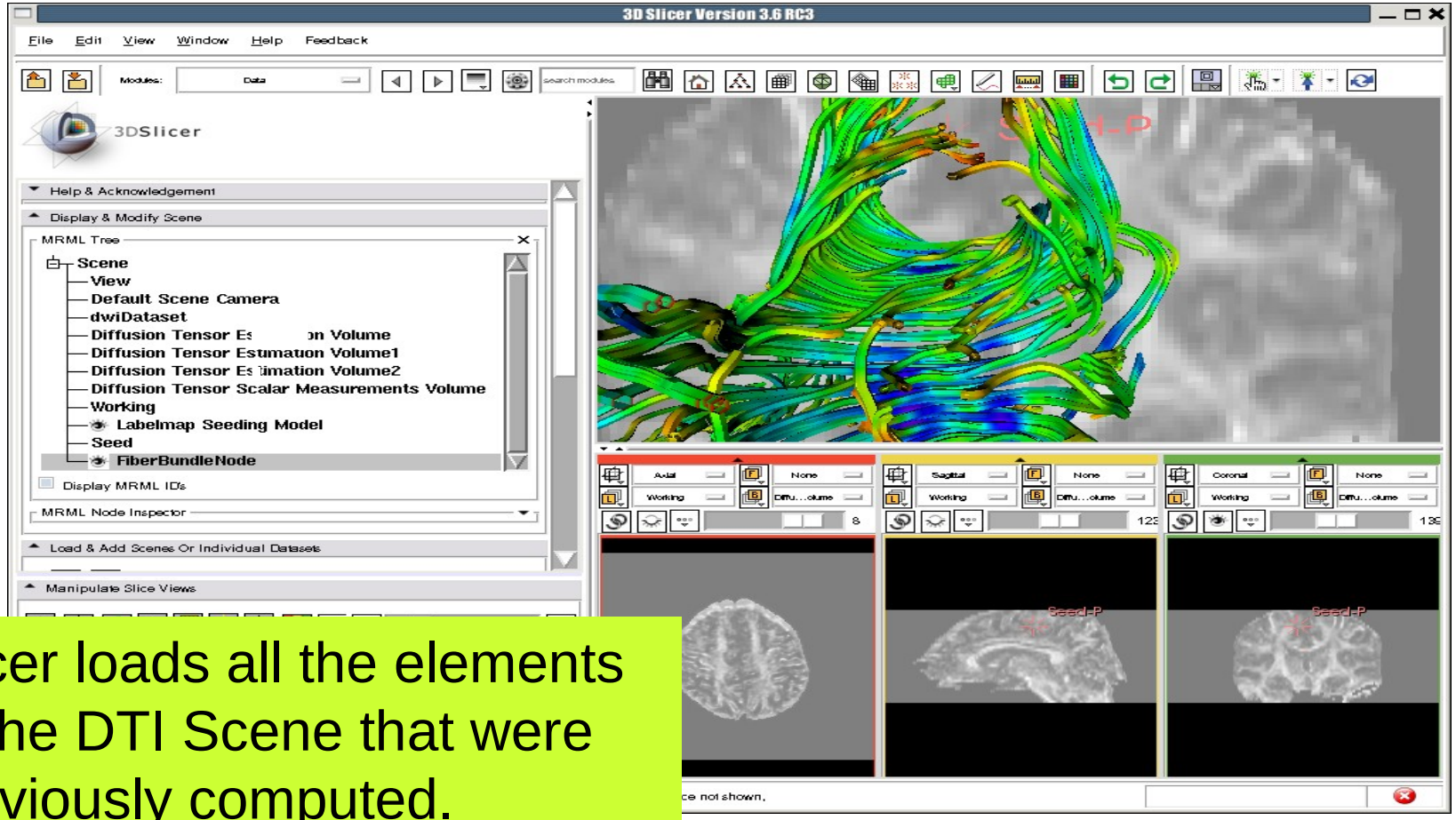
Select the scene **SlicerScene1.mrml** and click on **Open**

Loading a DTI Scene

Select the module **Data**

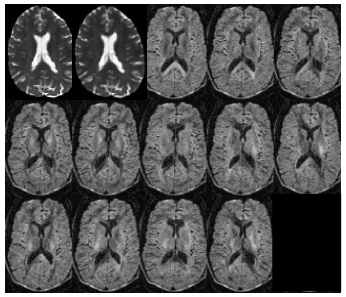


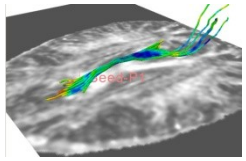
Loading a DTI Scene

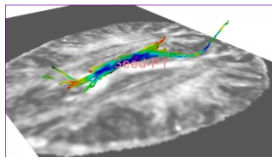


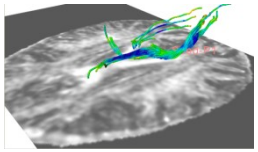
Slicer loads all the elements of the DTI Scene that were previously computed.

Conclusion









This tutorial guided you through some of the Diffusion MR capabilities of the Slicer3 software.

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