



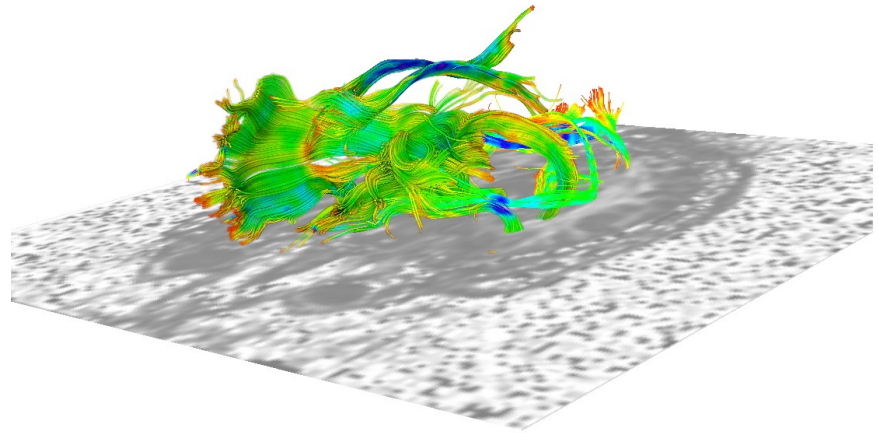
Diffusion Tensor Imaging Tutorial

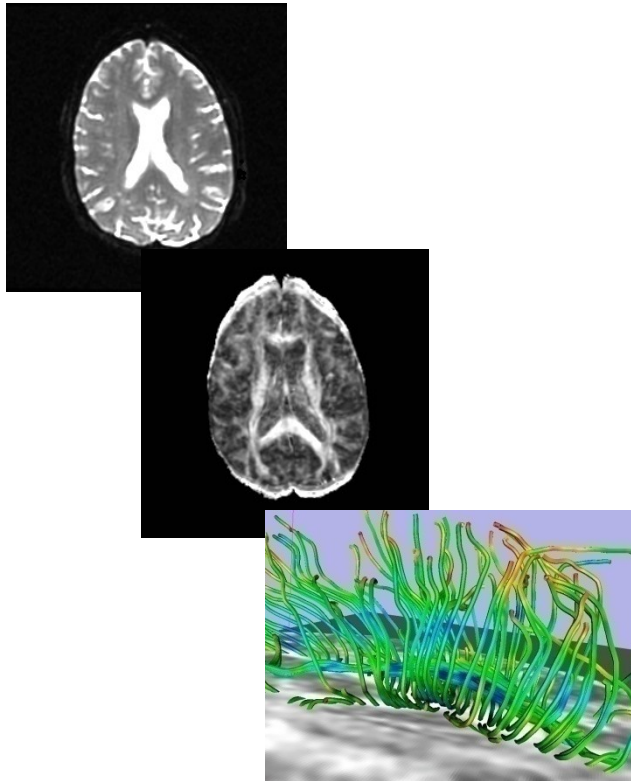
Sonia Pujol, Ph.D.

Surgical Planning Laboratory
Harvard University



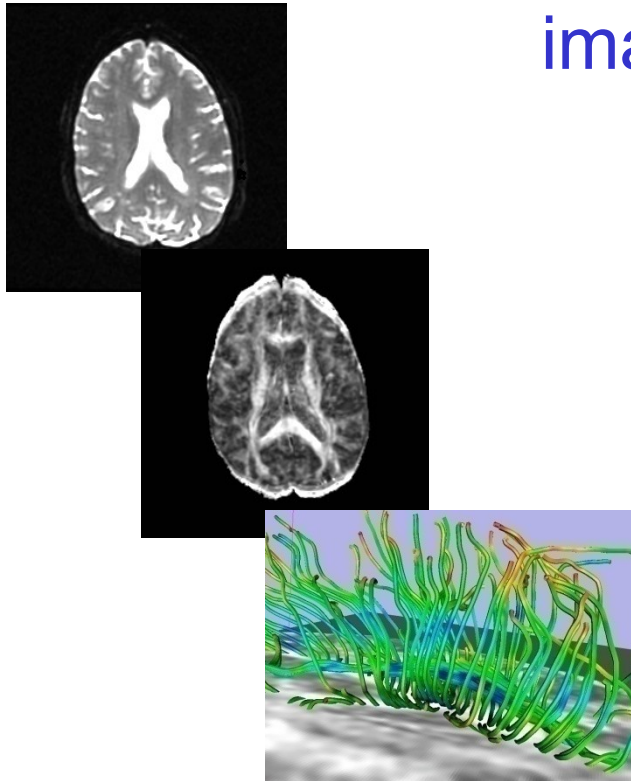
This tutorial is an introduction to the advanced **Diffusion MR** capabilities of the **Slicer3** software for medical image analysis.





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

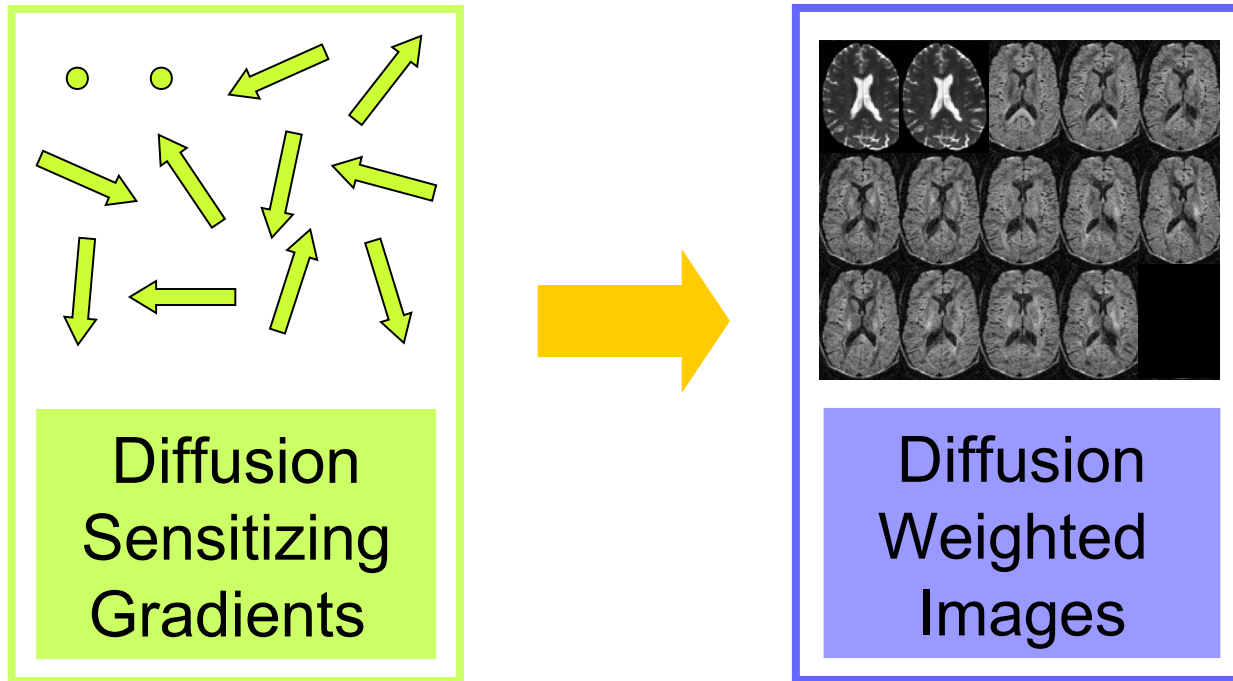
The processing pipeline uses **9** image analysis modules of Slicer3.4



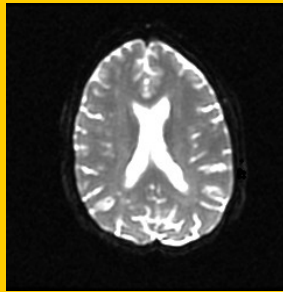
- 1.Data
- 2.Volumes
- 3.Diffusion Tensor Estimation
- 4.Diffusion Tensor Scalar Measurements
- 5.Editor
- 6.LabelMap Seeding
- 7.Fiber Bundles
- 8.Fiducials
- 9.Fiducial Seeding

Tutorial Dataset

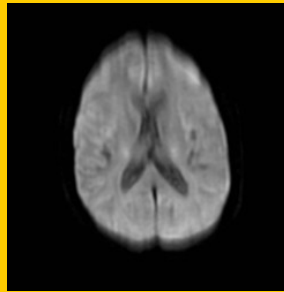
The Diffusion MR tutorial dataset is composed of a **Diffusion Weighted MR scan** of the brain acquired with 2 baseline and 12 gradient directions.



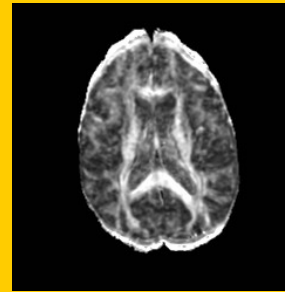
DTI Processing Pipeline



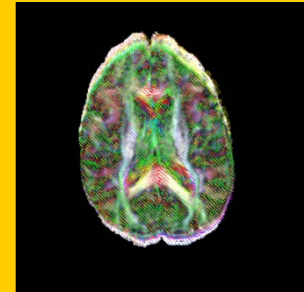
DWI
Acquisition



Tensor
Calculation



Scalar
Maps

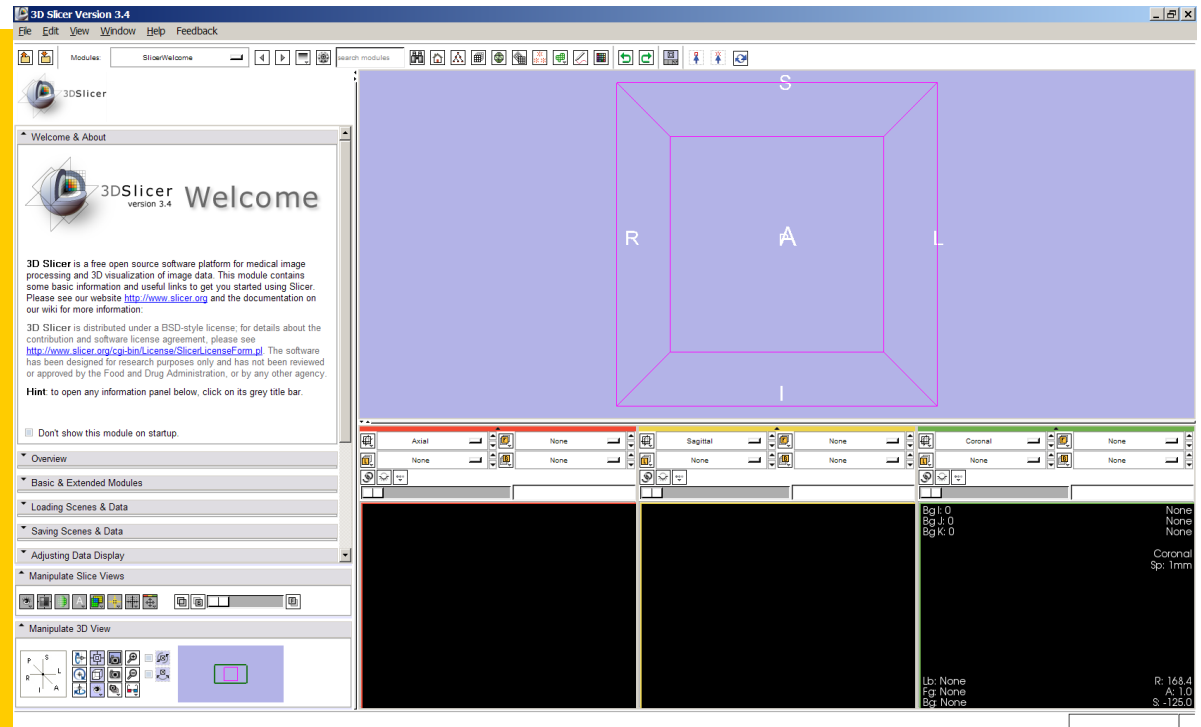


3D
Visualization

Linux/Mac users
Launch the Slicer3
executable located in
the Slicer3.4 directory

Windows users
Select

Start → All Programs
→ Slicer3 3.4 2009-05-21 → 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 functionality.

3D Slicer Version 3.4
File Edit View Window Help Feedback

Modules: SlicerWelcome

Welcome & About

3DSlicer version 3.4 **Welcome**

3D Slicer is a free open source software platform for medical image processing and 3D visualization of image data. This module contains some basic information and useful links to get you started using Slicer. Please see our website <http://www.slicer.org> and the documentation on our wiki for more information:

3D Slicer is distributed under a BSD-style license; for details about the contribution and software license agreement, please see <http://www.slicer.org/cgi-bin/License/SlicerLicenseForm.pl>. The software has been designed for research purposes only and has not been reviewed or approved by the Food and Drug Administration, or by any other regulatory agency.

Hint: to open any information panel below, click on its grey title bar.

Don't show this module on startup.

Overview

- Basic & Extended Modules
- Loading Scenes & Data
- Saving Scenes & Data
- Adjusting Data Display
- Manipulate Slice Views
- Manipulate 3D View

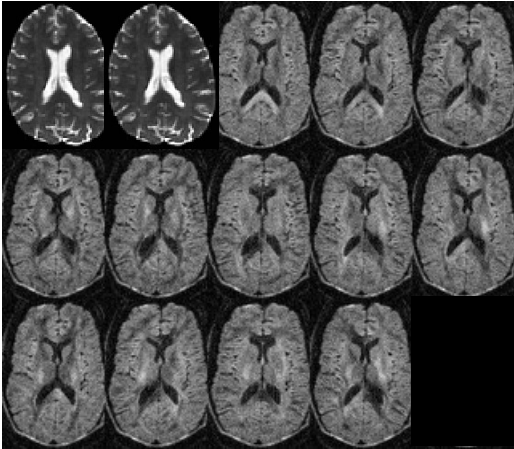
None None None None

Bg I: 0
Bg J: 0
Bg K: 0

Coronal
Sp: 1mm

Lb: None
Fg: None
Bg: None

R: 168.4
A: 1.0
S: -125.0



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

Part 1: Diffusion data loading and tensor estimation



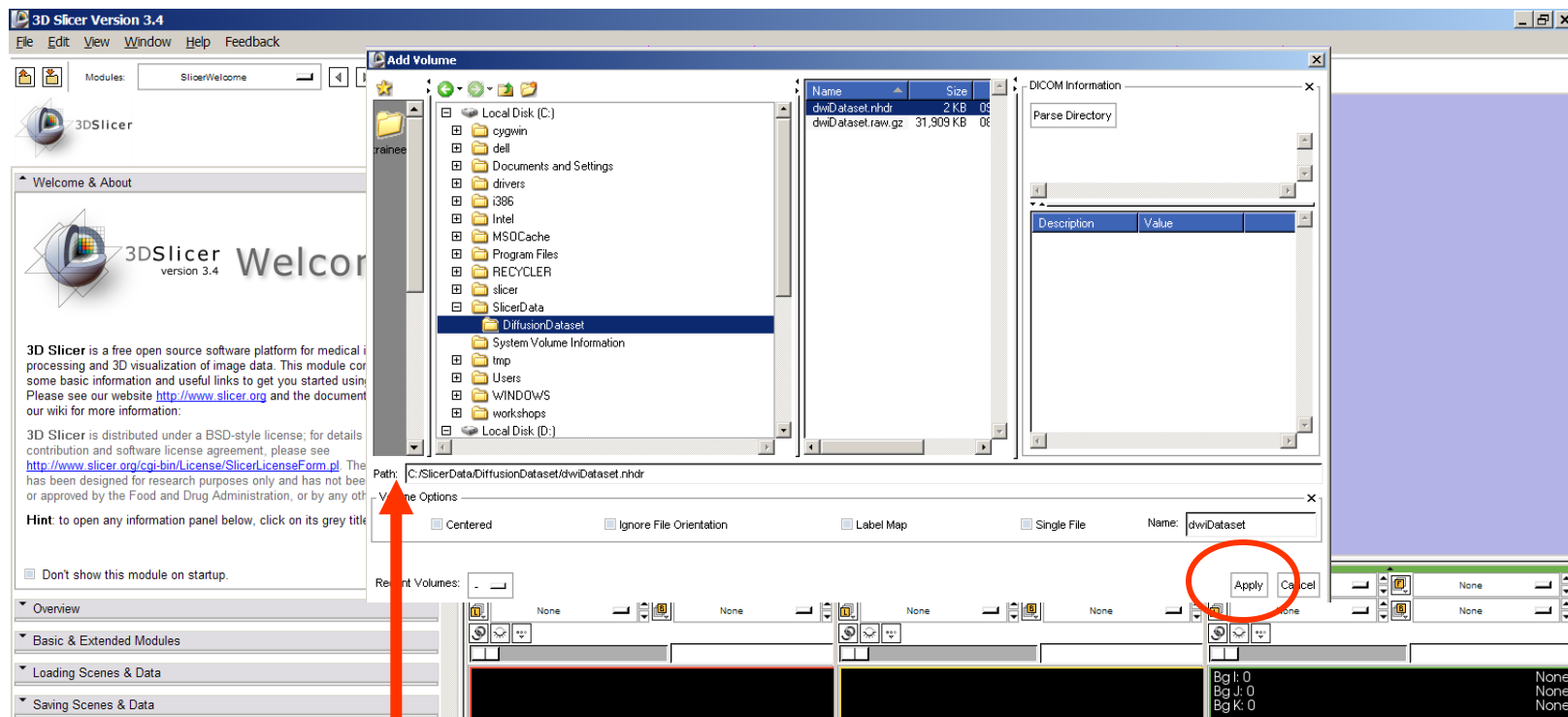
Loading the DWI volume

Select Add Volume from the File menu

The screenshot shows the 3DSlicer Version 3.4 interface. A red arrow points from the 'File' menu in the top-left corner to a yellow callout box containing the text 'Select Add Volume from the File menu'. The main window displays a 3D view of a volume with a purple bounding box and axes labeled S, R, A, L, I. The bottom-right corner shows a status panel with the following information:

Bg I: 0	None	None	None
Bg J: 0	None	None	None
Bg K: 0	None	None	None
Coronal			
Sp: 1mm			
Lb: None	R: 168.4		
Fg: None	A: 1.0		
Bg: None	S: -125.0		

Loading the DWI volume



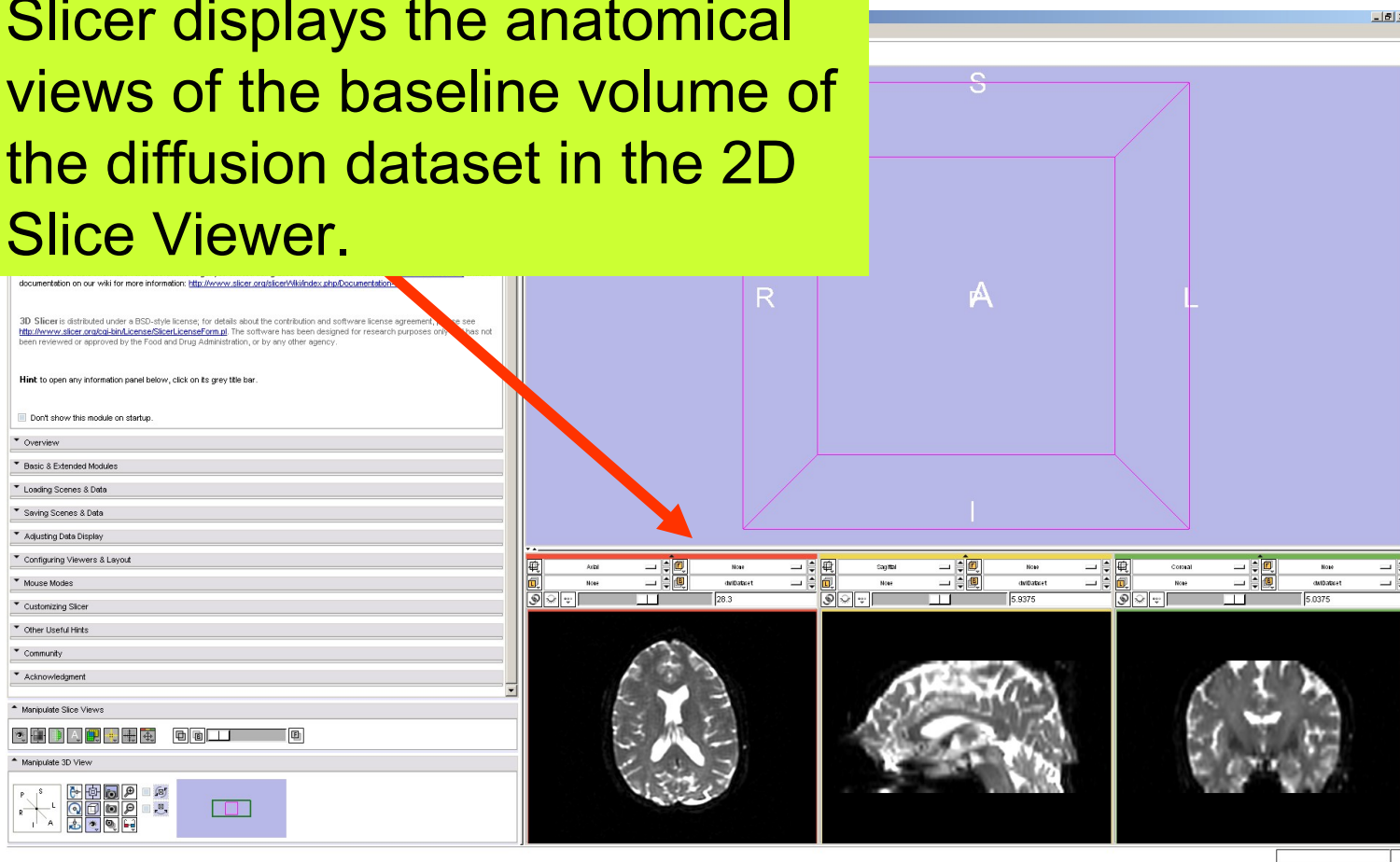
The screenshot shows the 3D Slicer 3.4 interface with the 'Add Volume' dialog box open. The file explorer displays the directory structure, with 'DiffusionDataset' selected. The file 'dwidataset.nhdr' is highlighted. The 'Apply' button is circled in red. A red arrow points to the 'DiffusionDataset' folder.

Browse to the location of the Diffusion tutorial dataset directory and select the `dwidataset.nhdr` file

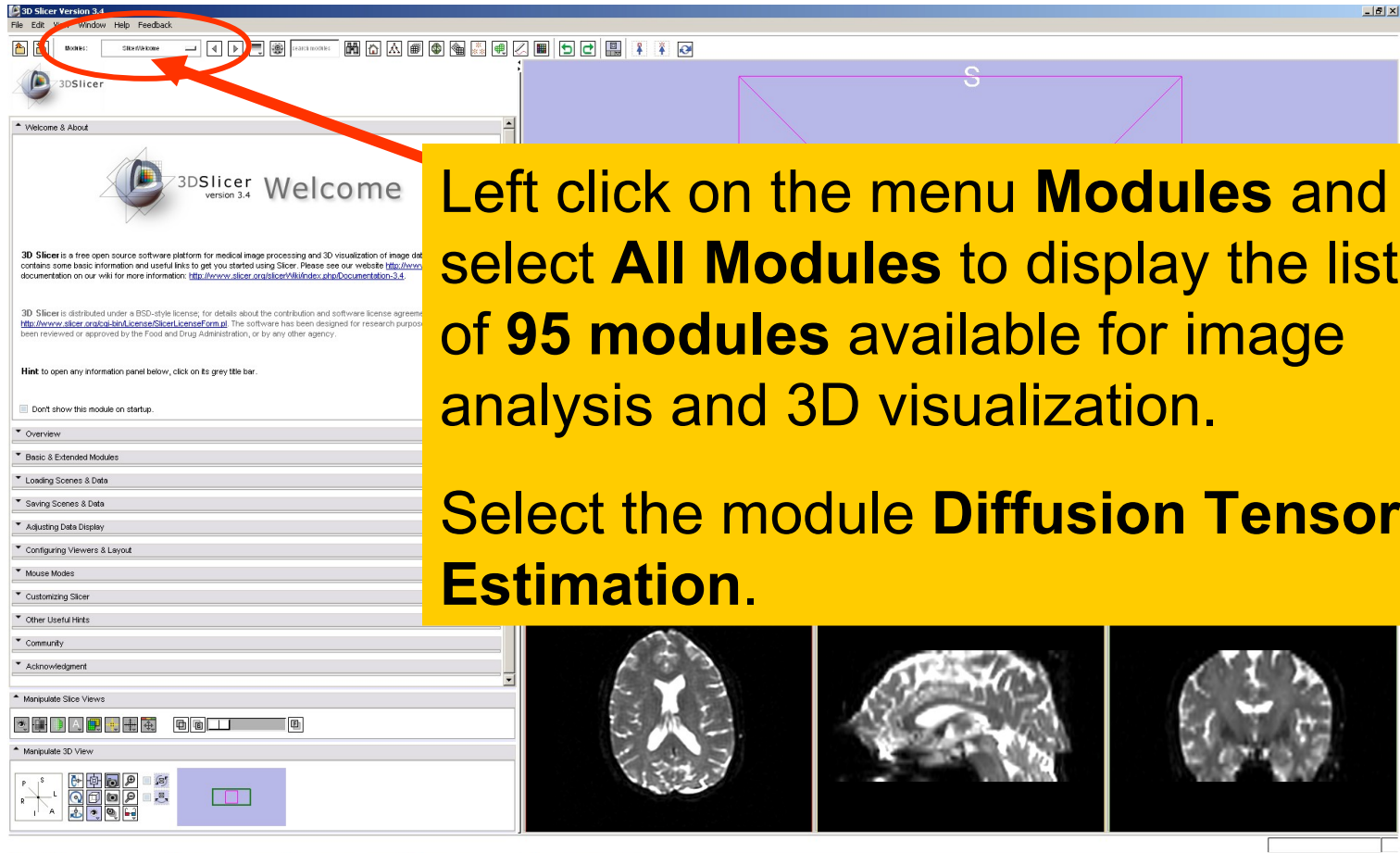
Click on **Apply to load the volume**

Loading the DWI volume

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



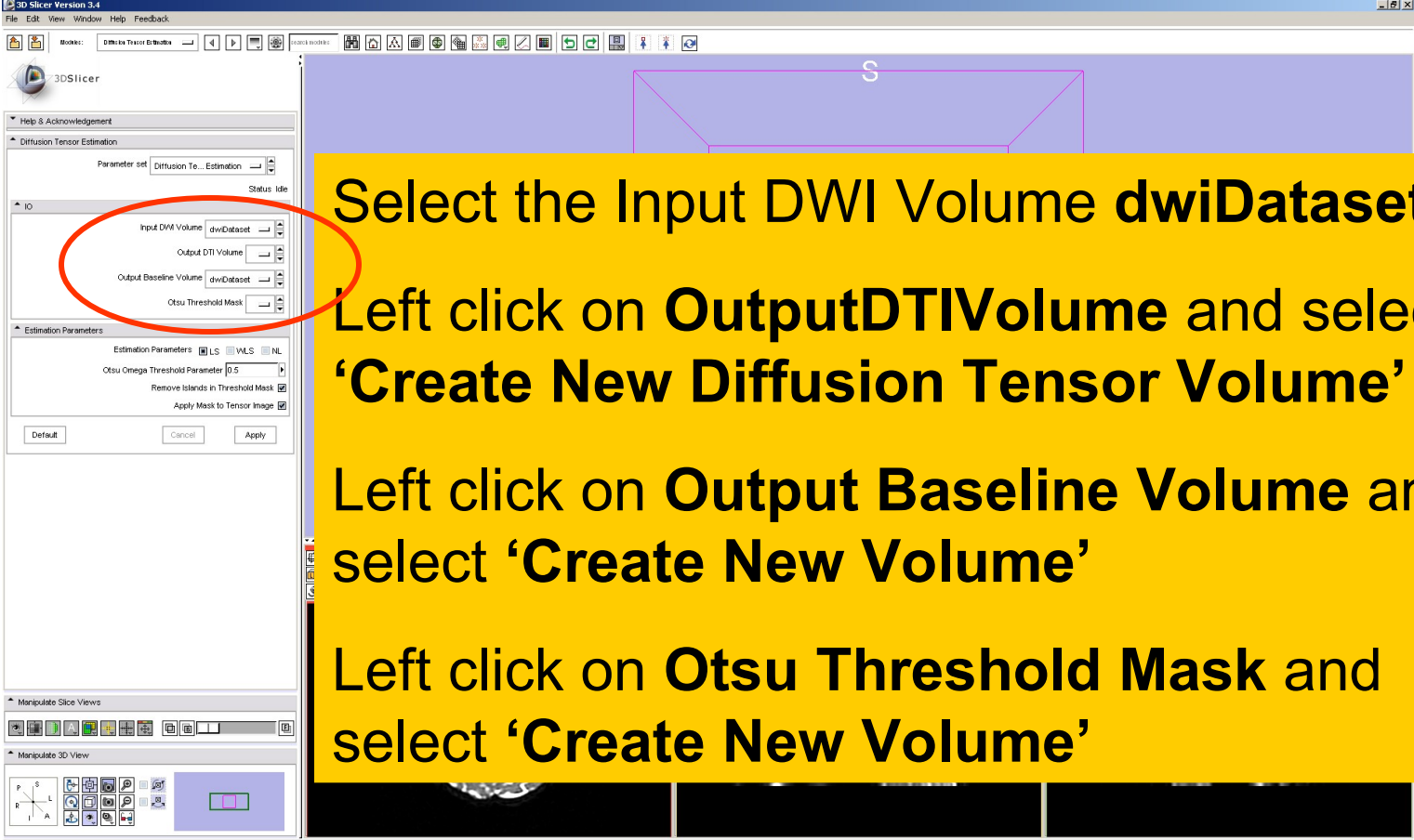
Tensor Estimation



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



The screenshot shows the 'Diffusion Tensor Estimation' panel in 3D Slicer 3.4. The 'IO' section is circled in red, highlighting the 'Input DWI Volume' dropdown menu which is set to 'dwiDataset'. Other dropdowns in the 'IO' section include 'Output DTI Volume', 'Output Baseline Volume', and 'Otsu Threshold Mask'. The 'Estimation Parameters' section below has checkboxes for 'LS', 'WLS', and 'NL', with 'LS' selected. The 'Otsu Omega Threshold Parameter' is set to 0.5. There are 'Default', 'Cancel', and 'Apply' buttons at the bottom of the panel.

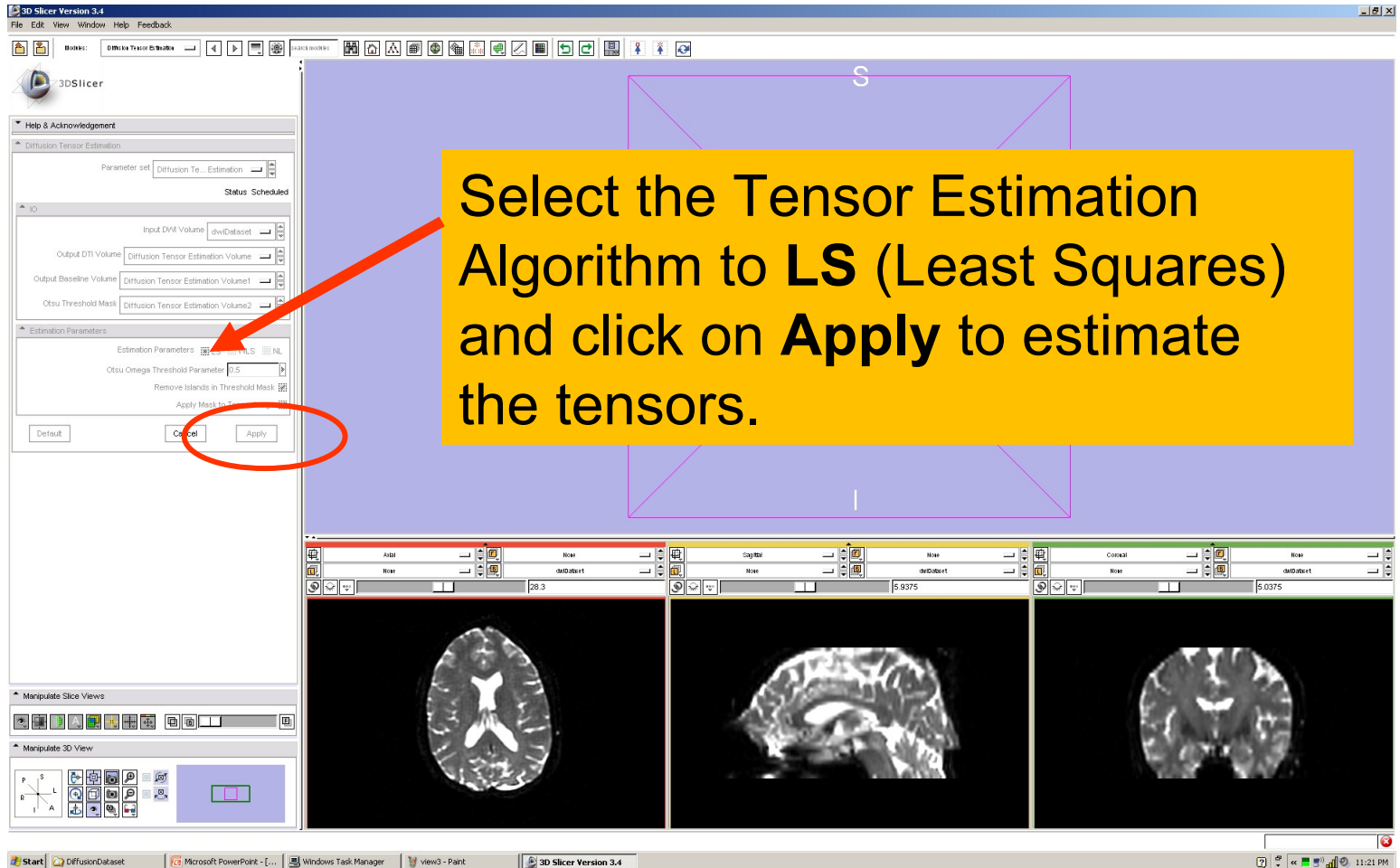
Select the Input DWI Volume **dwiDataset**

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

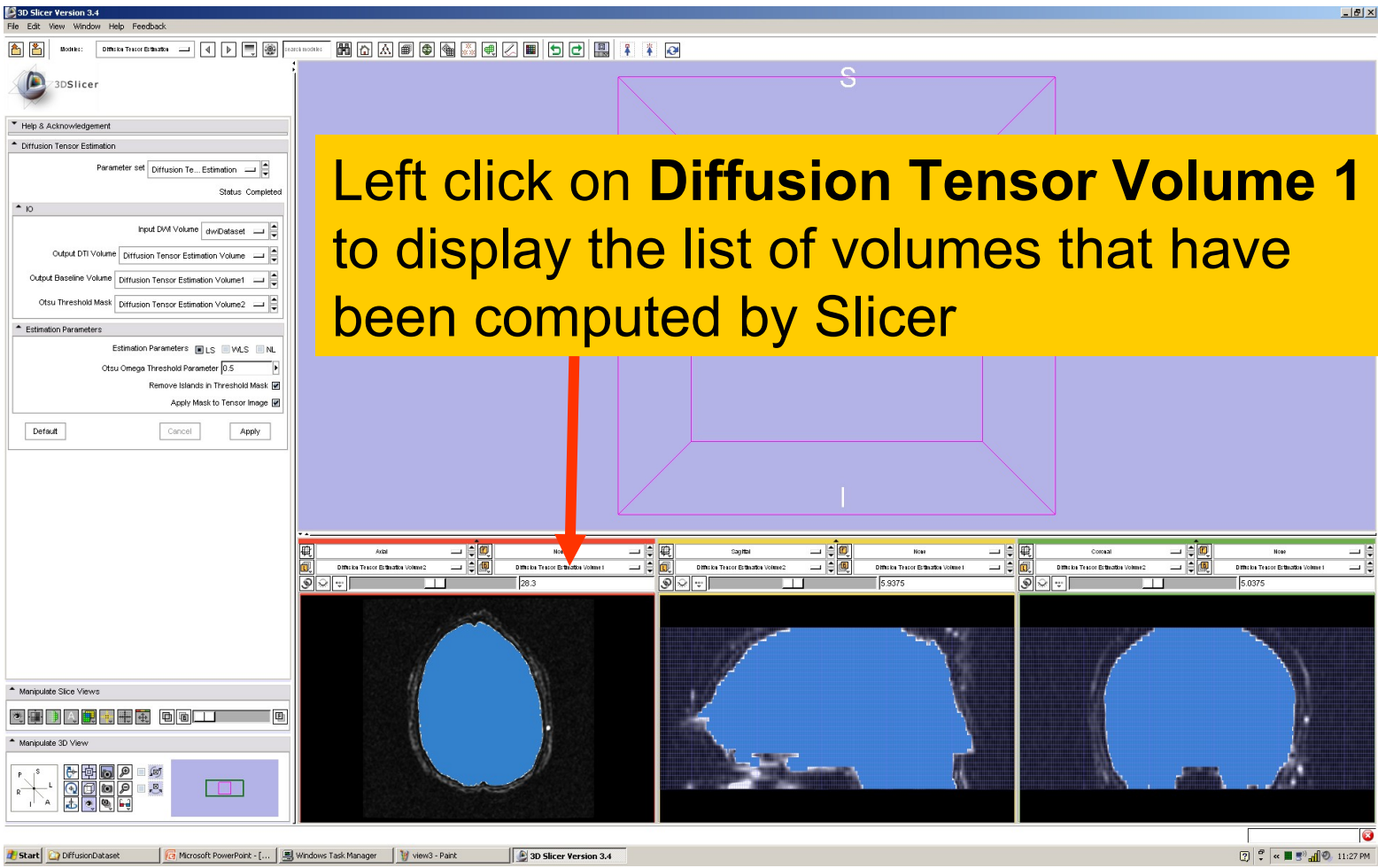
Left click on **Output Baseline Volume** and select **‘Create New Volume’**

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

Tensor Estimation



Tensor Estimation

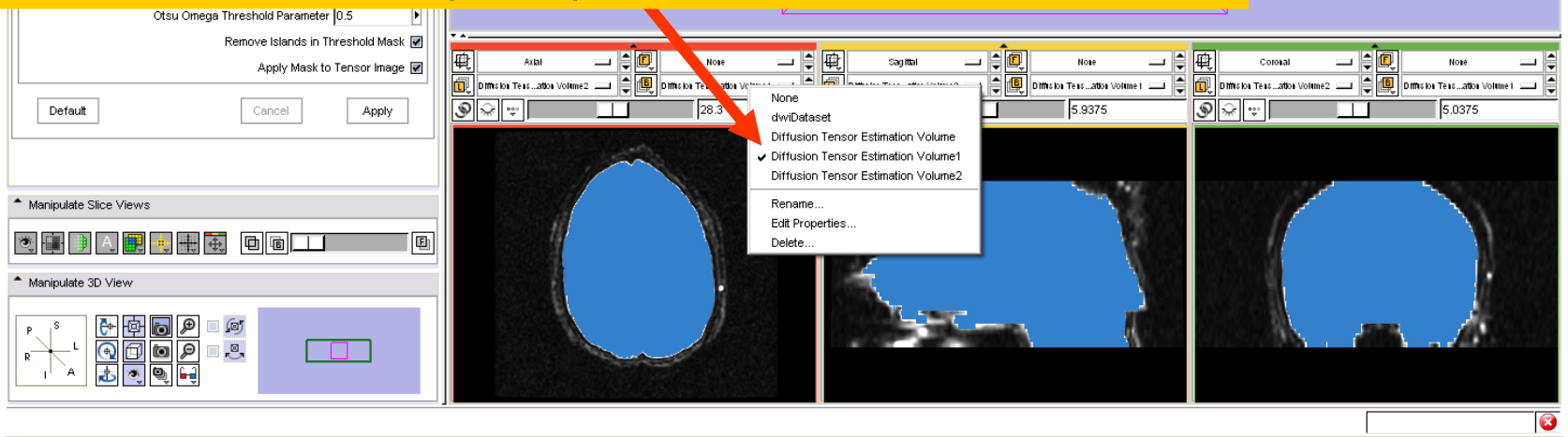


Tensor Estimation

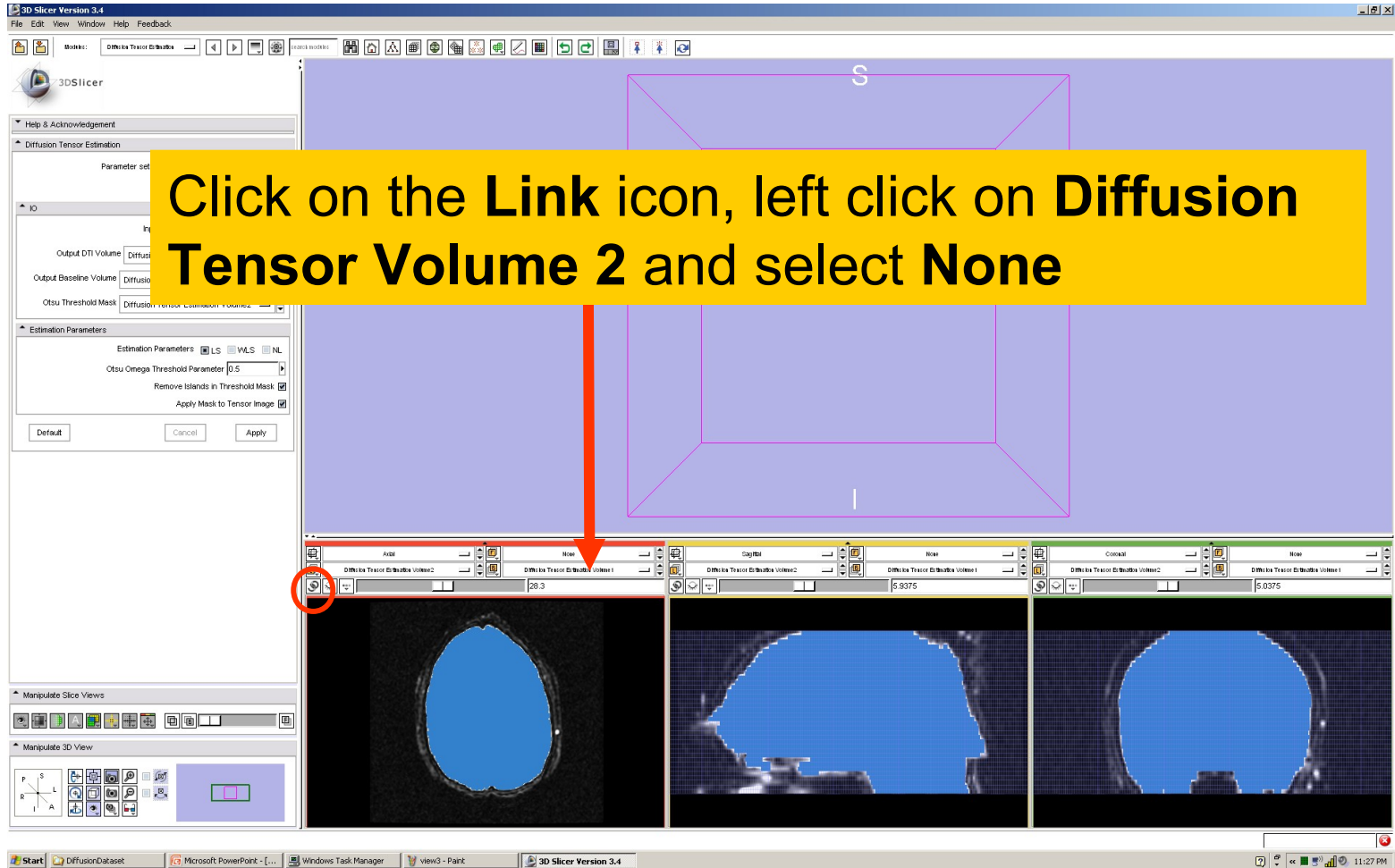
Diffusion Tensor Estimation Volume is the volume of estimated tensors

Diffusion Tensor Estimation Volume 1 is the Baseline volume

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



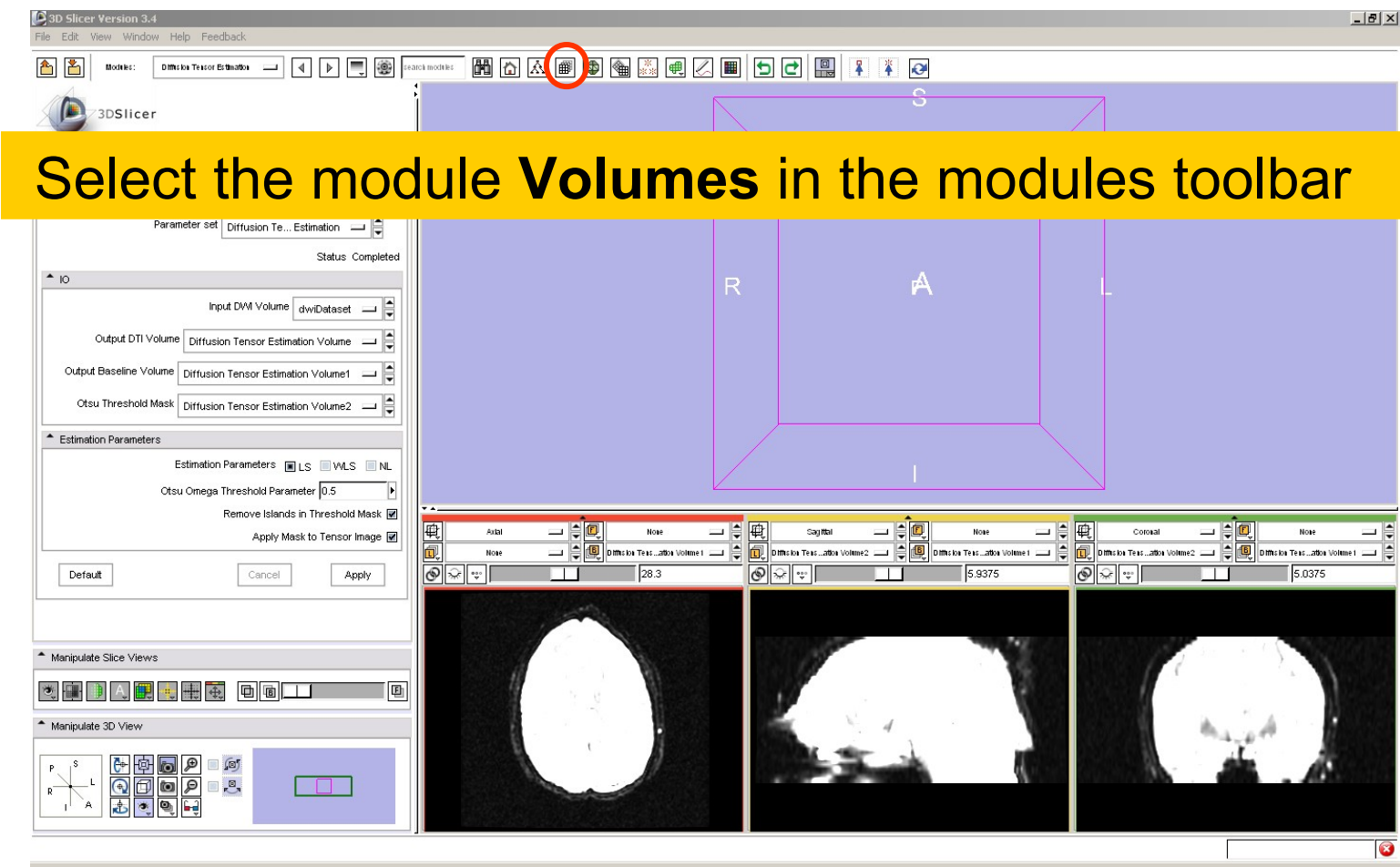
Tensor Estimation



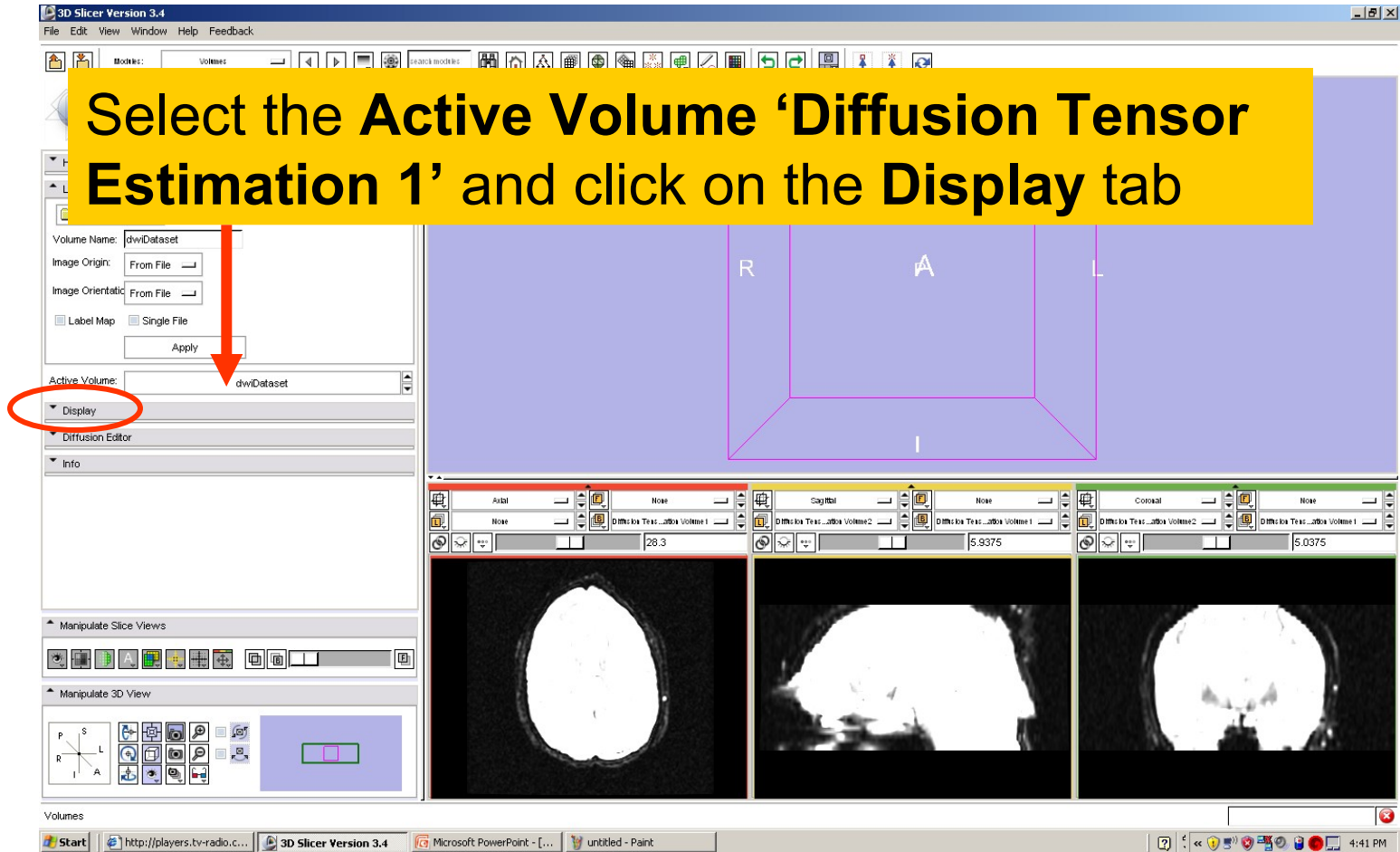
Click on the Link icon, left click on Diffusion Tensor Volume 2 and select None

The screenshot shows the 3D Slicer 3.4 interface. The main window displays a 3D view of a brain slice with a purple bounding box. The left sidebar contains the Diffusion Tensor Estimation panel, which is currently set to 'None'. A yellow box with black text provides instructions: 'Click on the Link icon, left click on Diffusion Tensor Volume 2 and select None'. A red arrow points from the text to the 'Link' icon (a chain link) in the bottom toolbar. Below the toolbar, three slice views are visible: a sagittal view, a coronal view, and an axial view, all showing a blue brain slice. The bottom status bar shows the Windows taskbar with the Start button, taskbar icons for 'DiffusionDataset', 'Microsoft PowerPoint - [...]', 'Windows Task Manager', 'view3 - Paint', and '3D Slicer Version 3.4', and a system tray with the time '11:27 PM'.

Tensor Estimation

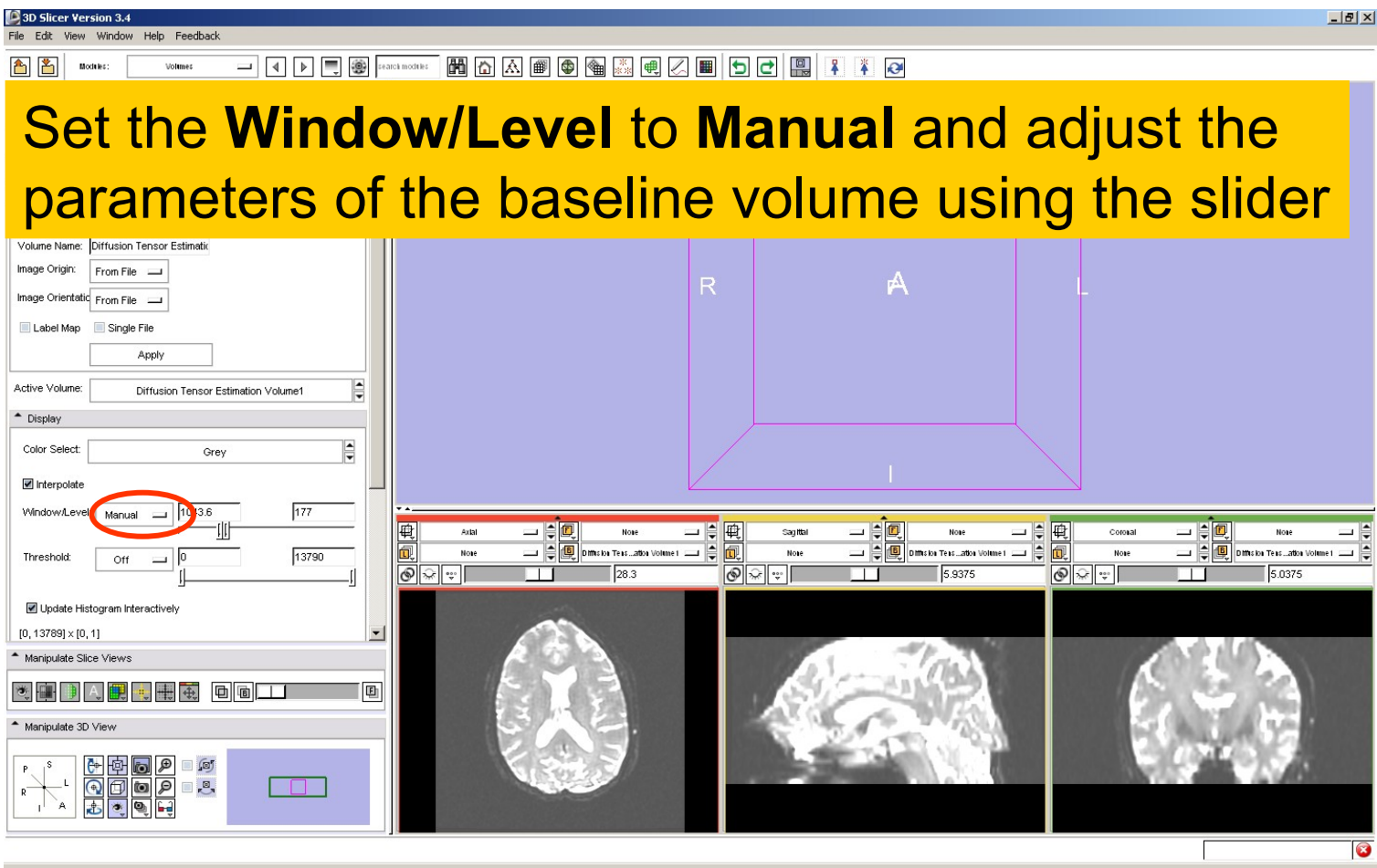


Tensor Estimation



Tensor Estimation

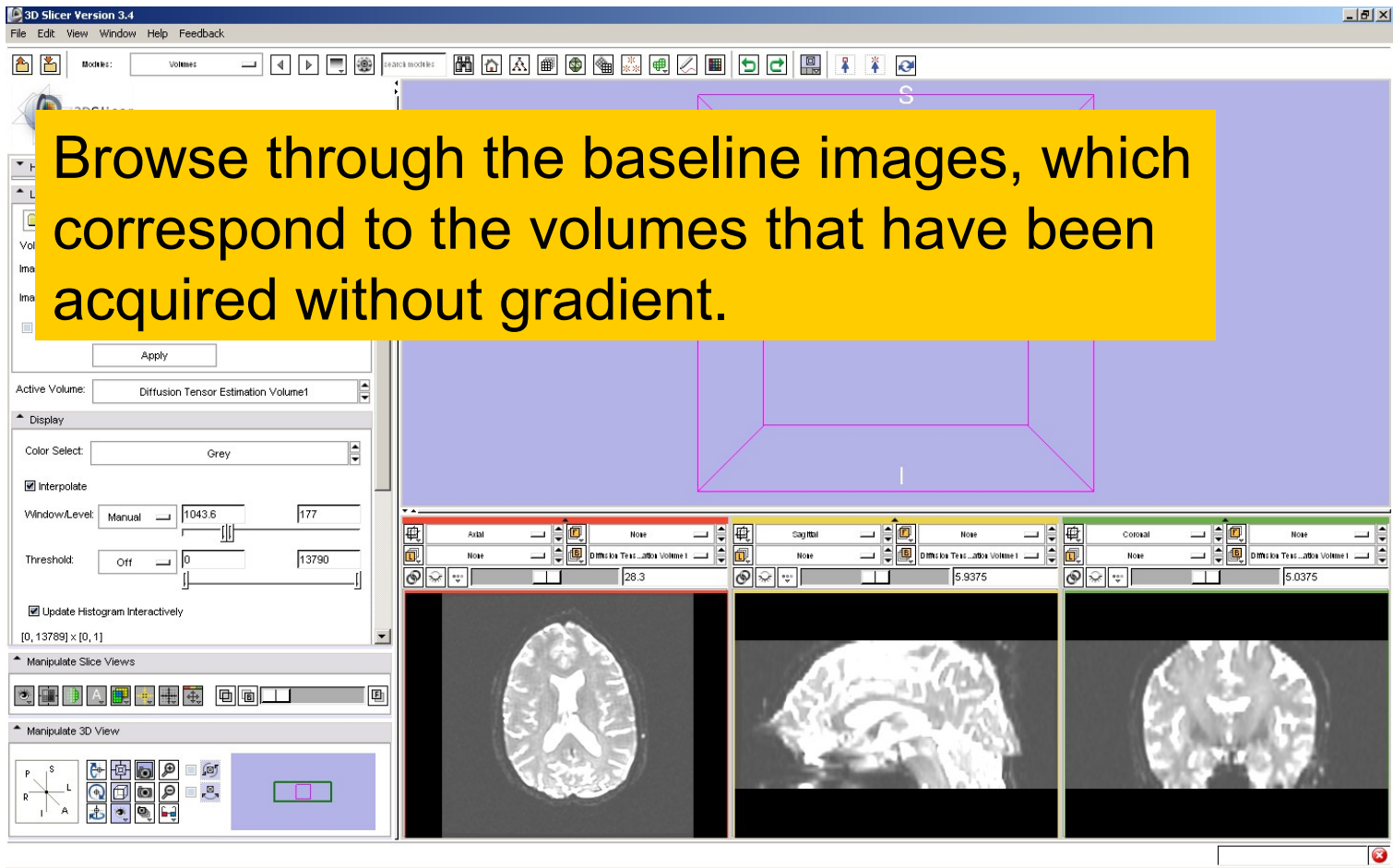
Set the **Window/Level to **Manual** and adjust the parameters of the baseline volume using the slider**

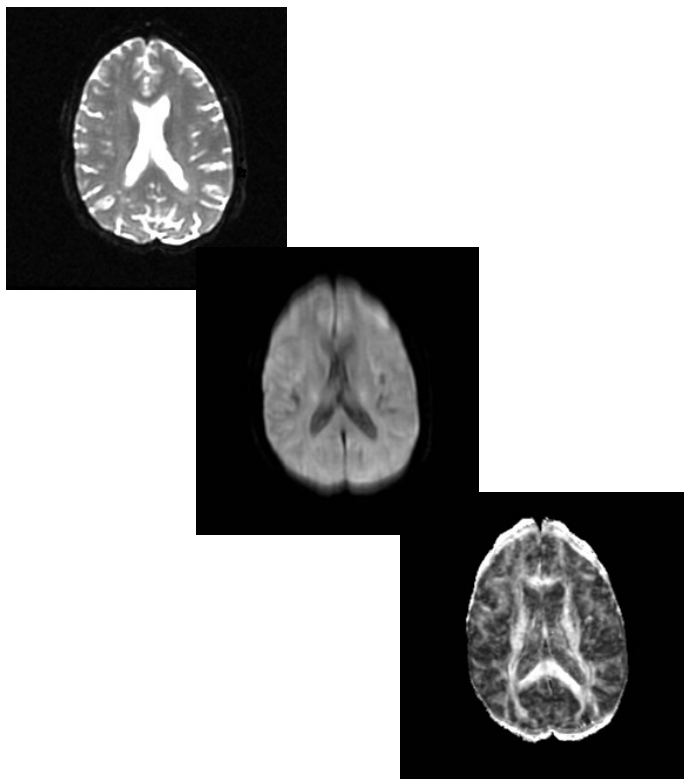


The screenshot displays the 3D Slicer Version 3.4 interface. The main window shows a 3D view of a brain slice with a purple wireframe bounding box. The left sidebar contains the 'Diffusion Tensor Estimation' volume settings. The 'Window/Level' dropdown is set to 'Manual', and the 'Threshold' is set to 'Off'. The 'Color Select' is set to 'Grey'. The 'Active Volume' is 'Diffusion Tensor Estimation Volume1'. The 'Display' section shows 'Interpolate' checked and 'Update Histogram Interactively' checked. The 'Manipulate Slice Views' section shows three views: Axial, Sagittal, and Coronal. The 'Manipulate 3D View' section shows a 3D view of the brain slice with a purple wireframe bounding box.

Tensor Estimation

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





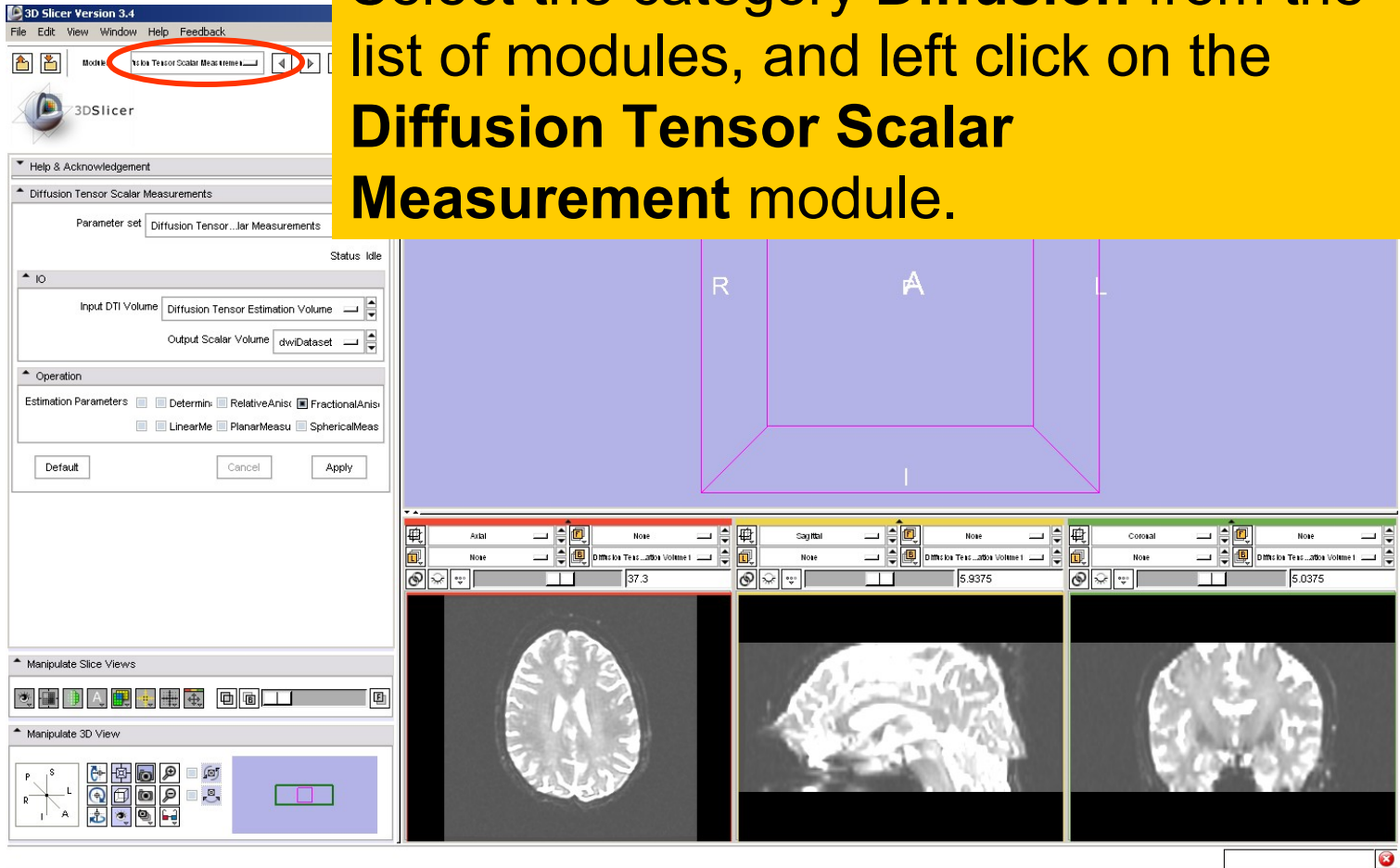
Part2:

Scalar

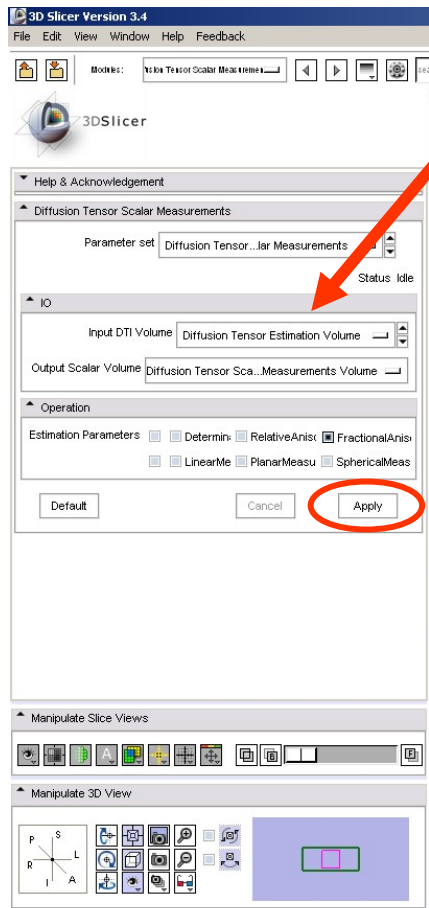
Measurements

Scalar Measurements

Select the category **Diffusion** from the list of modules, and left click on the **Diffusion Tensor Scalar Measurement** module.



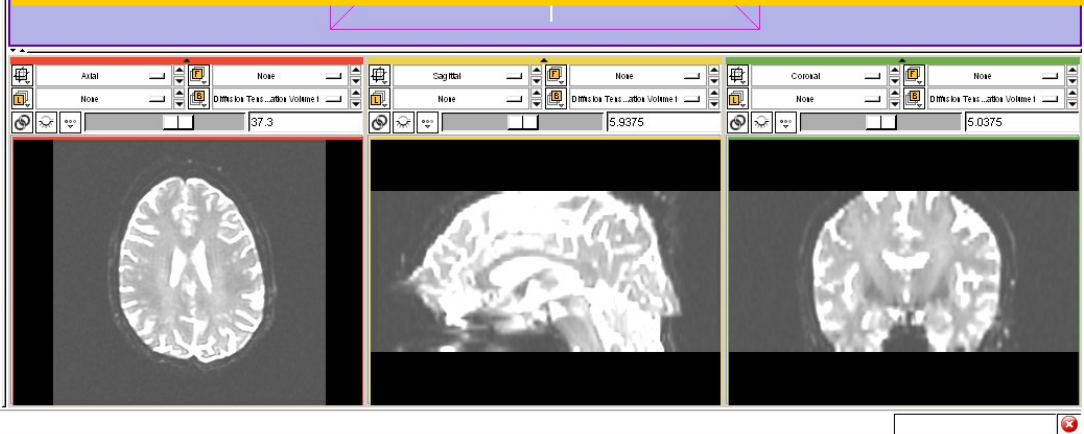
Scalar Measurements



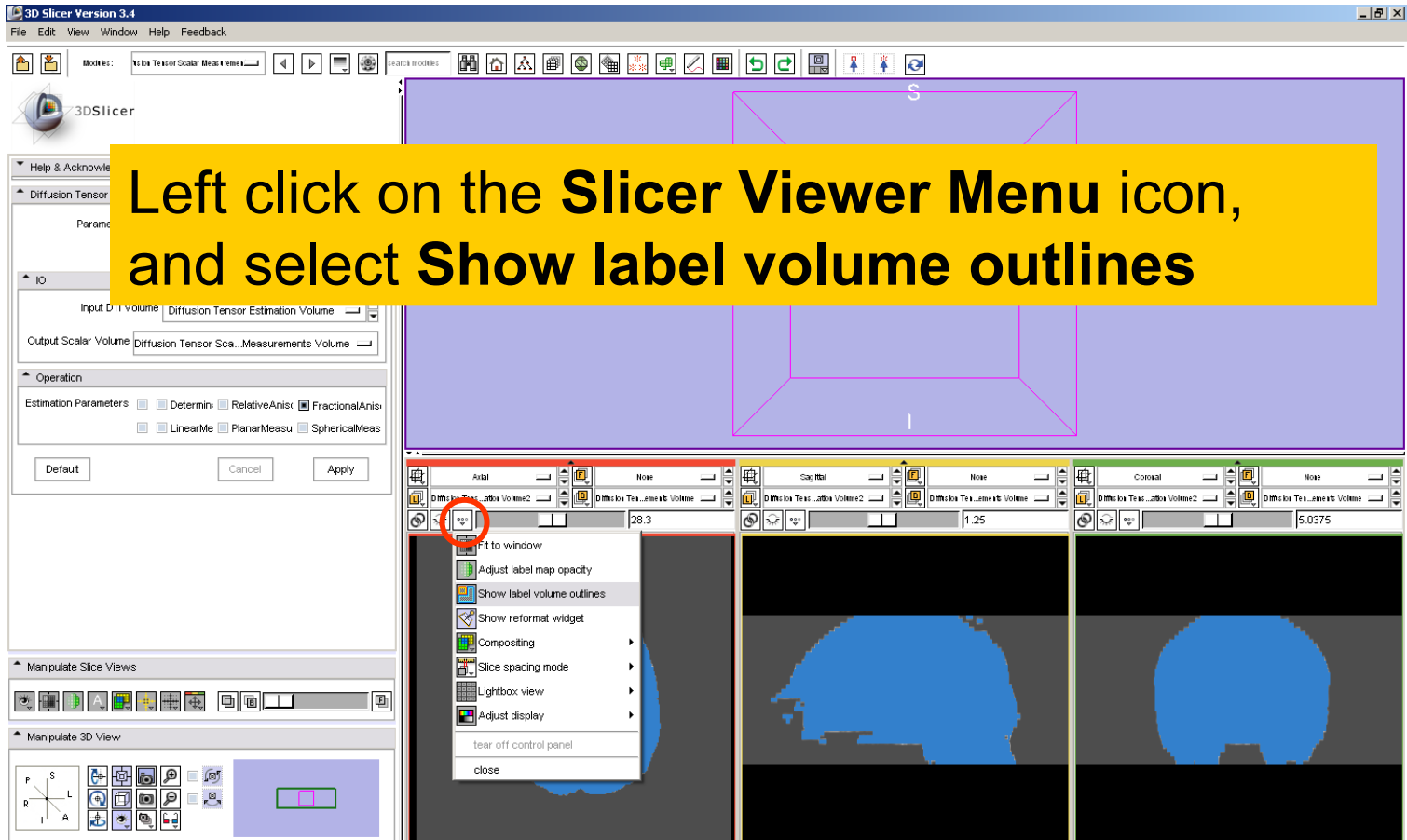
Select the Input DTI Volume to **Diffusion Tensor Estimation Volume**

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

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



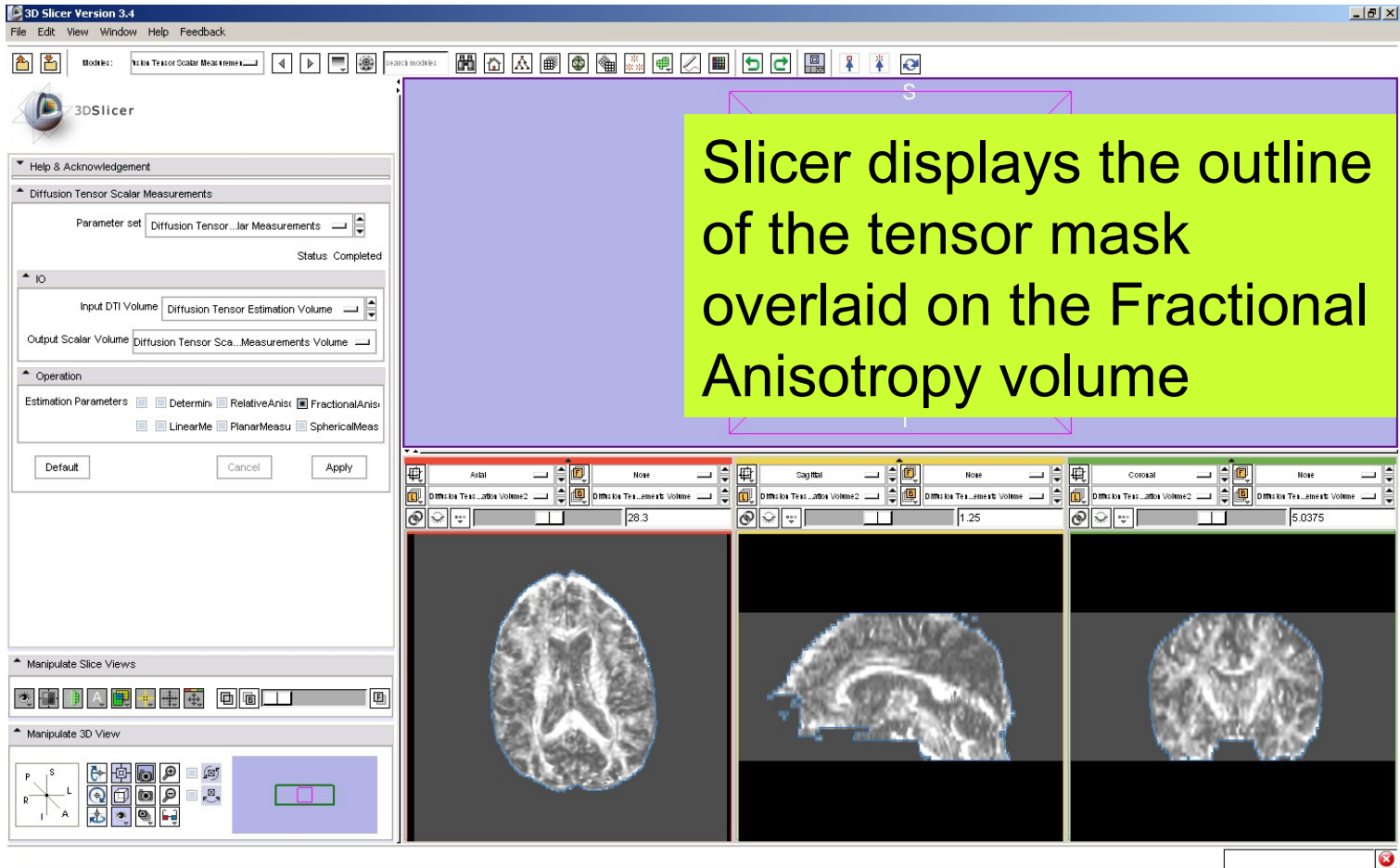
Fractional Anisotropy Volume



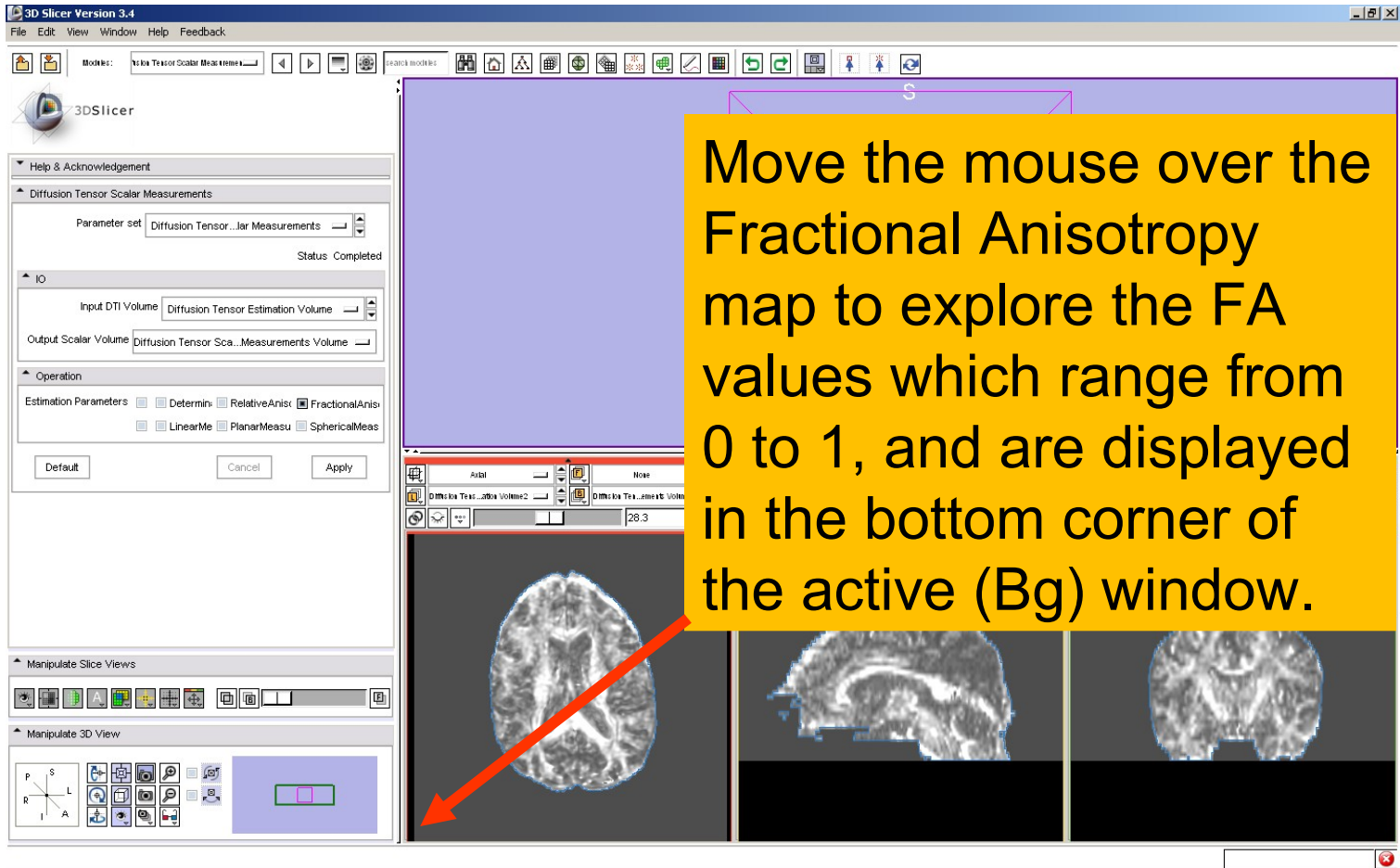
Left click on the **Slicer Viewer Menu** icon, and select **Show label volume outlines**

The screenshot shows the 3D Slicer 3.4 interface. A yellow box highlights the instruction: "Left click on the Slicer Viewer Menu icon, and select Show label volume outlines". The Slicer Viewer Menu icon is circled in red in the bottom-left corner of the interface. The menu is open, showing options like "Fit to window", "Adjust label map opacity", "Show label volume outlines", "Show reformat widget", "Compositing", "Slice spacing mode", "Lightbox view", "Adjust display", "tear off control panel", and "close". The main 3D view shows a brain slice with a blue volume and a purple outline. The bottom-right corner shows three slice views: Axial, Sagittal, and Coronal, each with a blue volume and a purple outline.

Fractional Anisotropy Volume



Fractional Anisotropy Volume

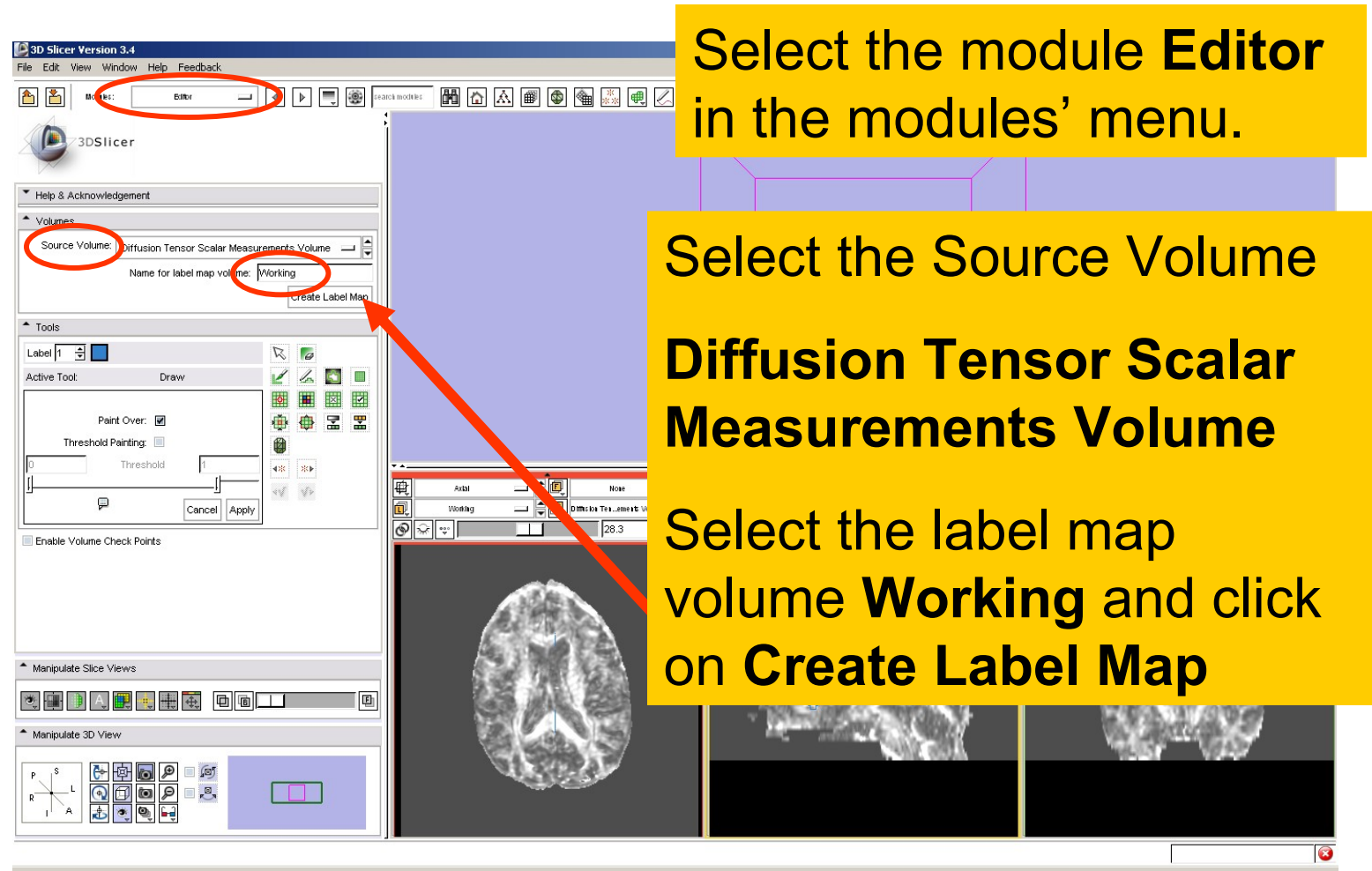




Part 3:

*Region of
Interest based
Tractography*

LabelMap Generation



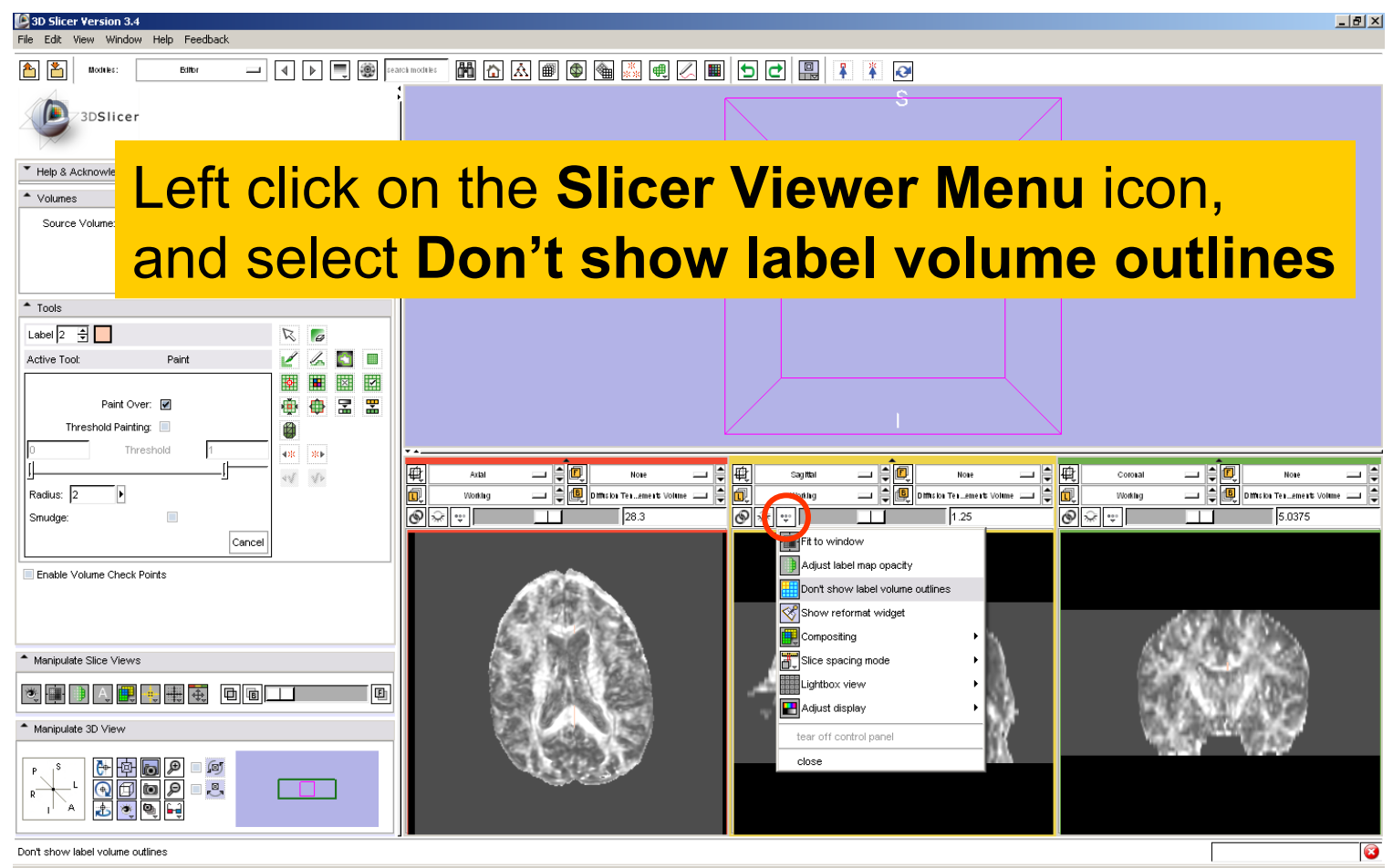
The screenshot shows the 3D Slicer software interface. The 'Editor' module is selected in the top toolbar. In the 'Volumes' panel, the 'Source Volume' is set to 'Diffusion Tensor Scalar Measurements Volume' and the 'Name for label map volume' is 'Working'. The 'Create Label Map' button is highlighted with a red arrow. The 'Tools' panel shows the 'Draw' tool active, with 'Paint Over' checked and 'Threshold Painting' unchecked. The 'Manipulate Slice Views' and 'Manipulate 3D View' panels are also visible.

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

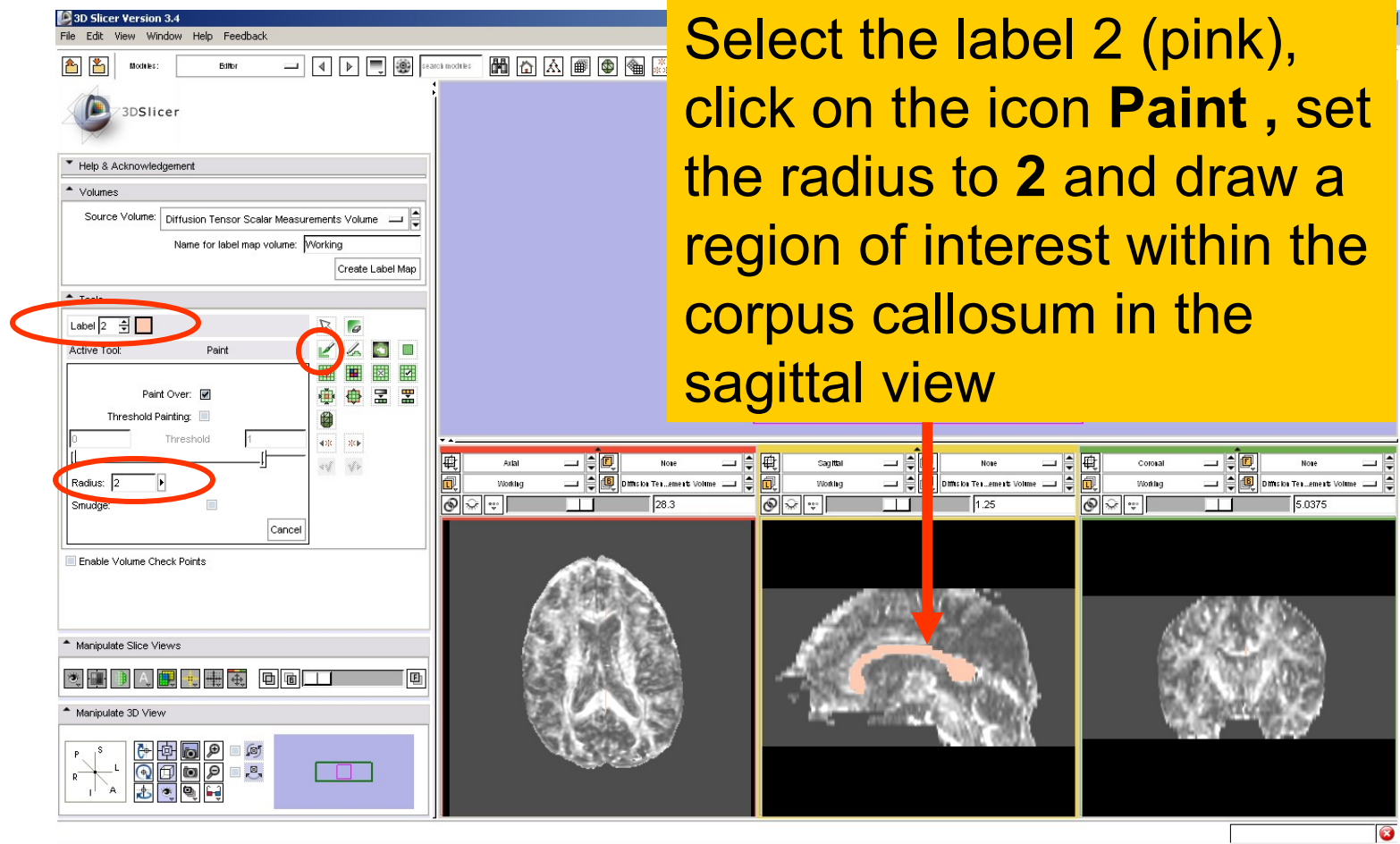
Select the Source Volume **Diffusion Tensor Scalar Measurements Volume**

Select the label map volume **Working** and click on **Create Label Map**

LabelMap Generation



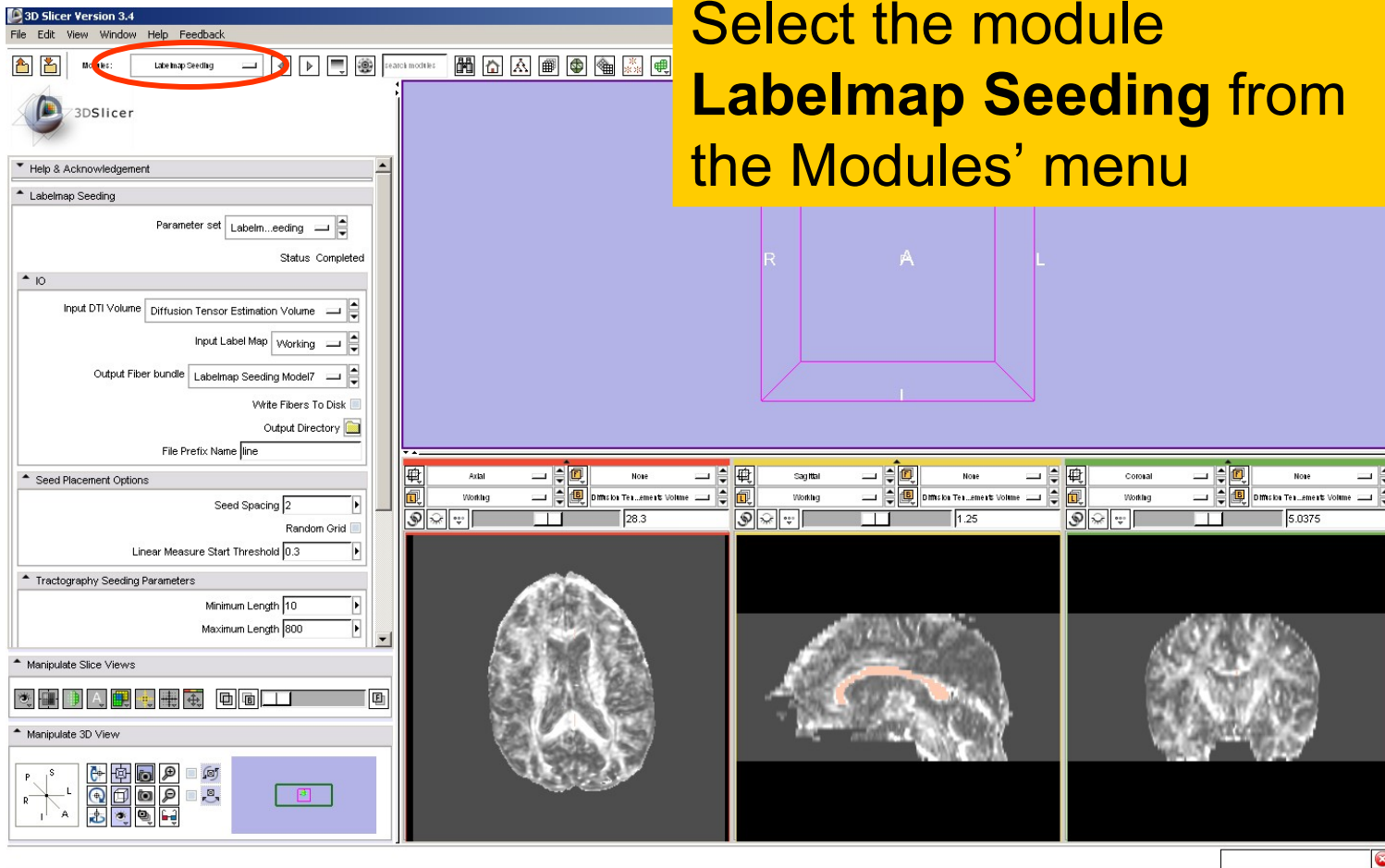
LabelMap Generation



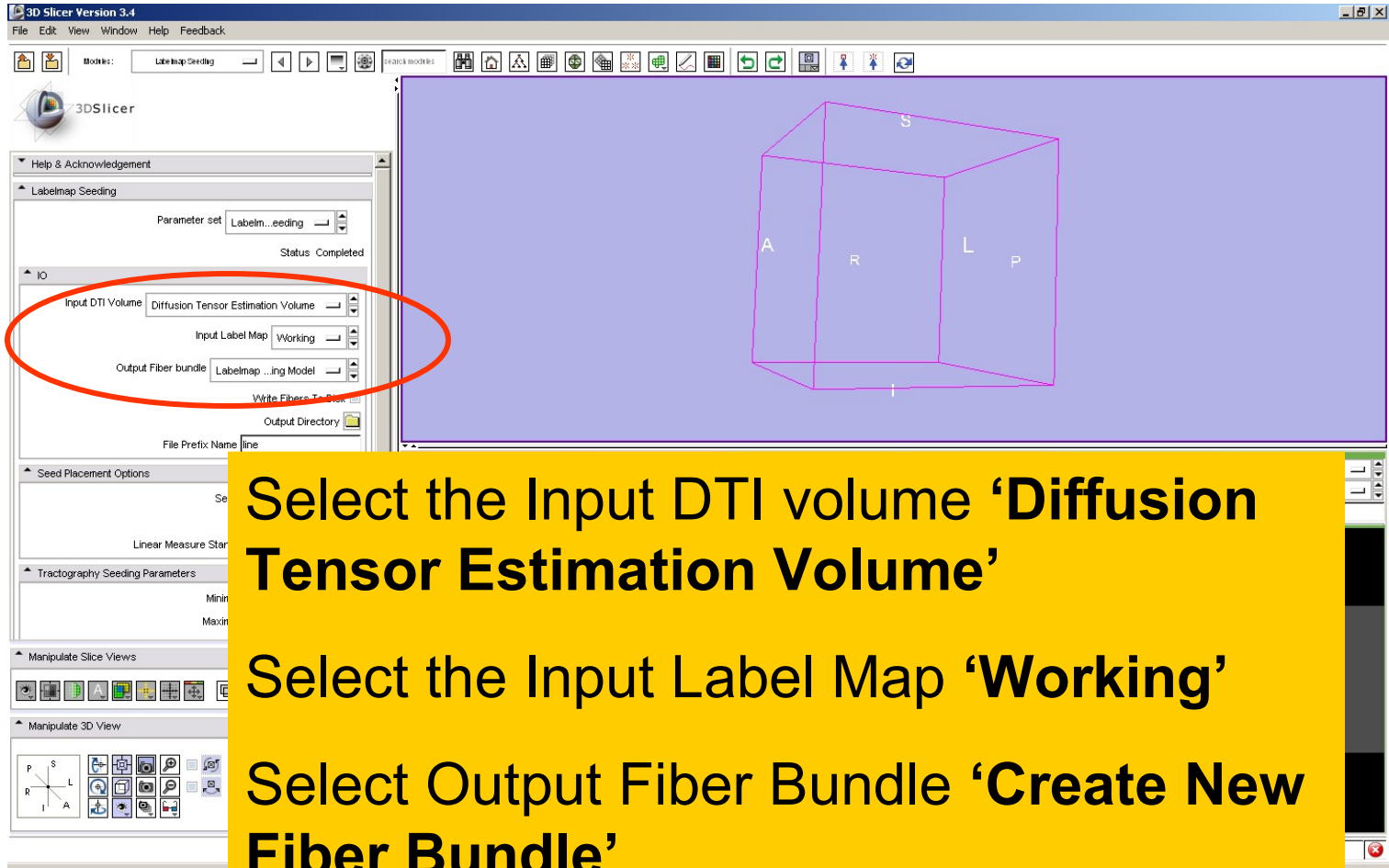
Select the label 2 (pink), click on the icon **Paint**, set the radius to **2** and draw a region of interest within the corpus callosum in the sagittal view

LabelMap Seeding

Select the module
Labelmap Seeding from
the Modules' menu



LabelMap Seeding

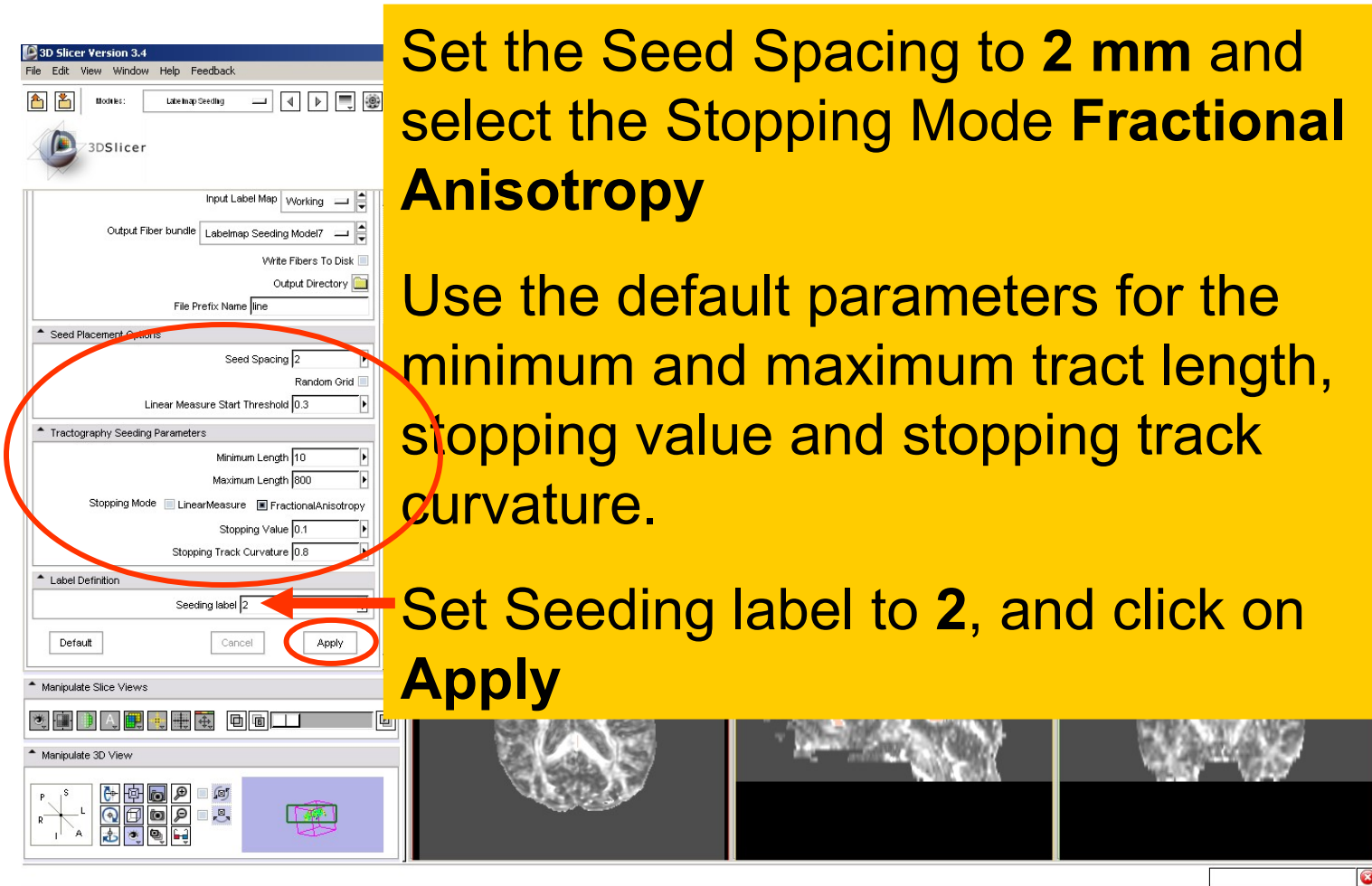


Select the Input DTI volume 'Diffusion Tensor Estimation Volume'

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**

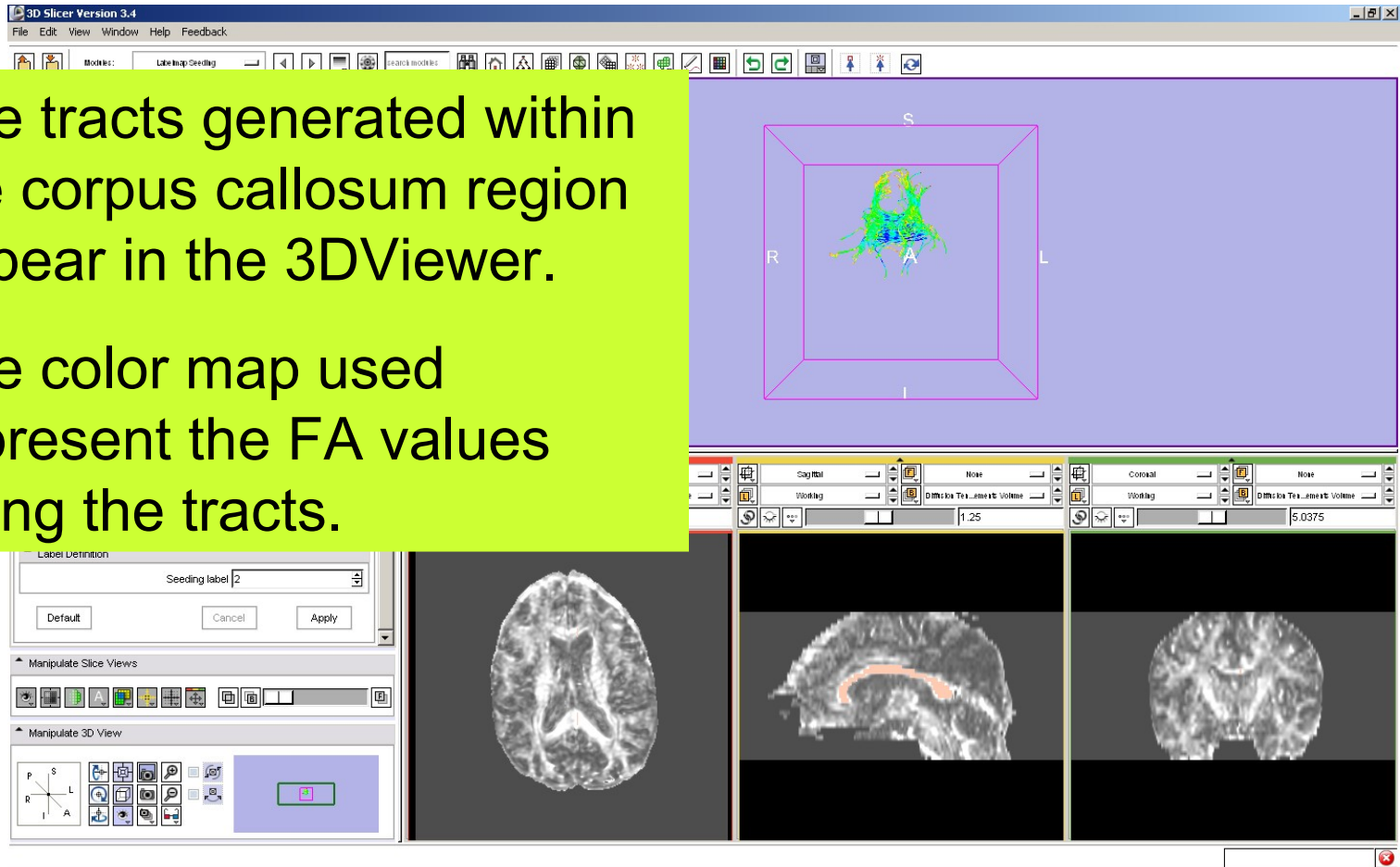
Use the default parameters for the minimum and maximum tract length, stopping value and stopping track curvature.

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

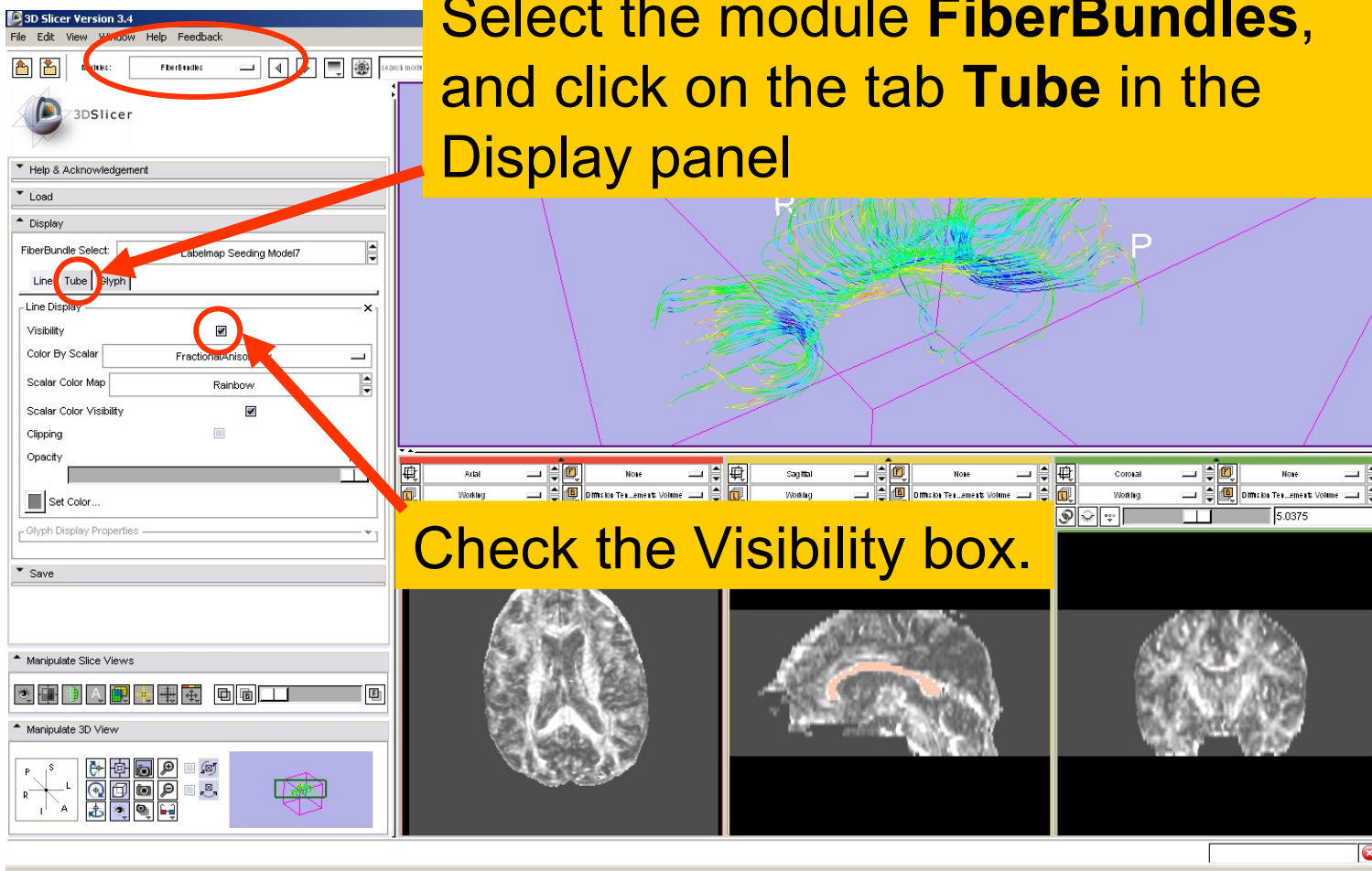
LabelMap Seeding

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

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



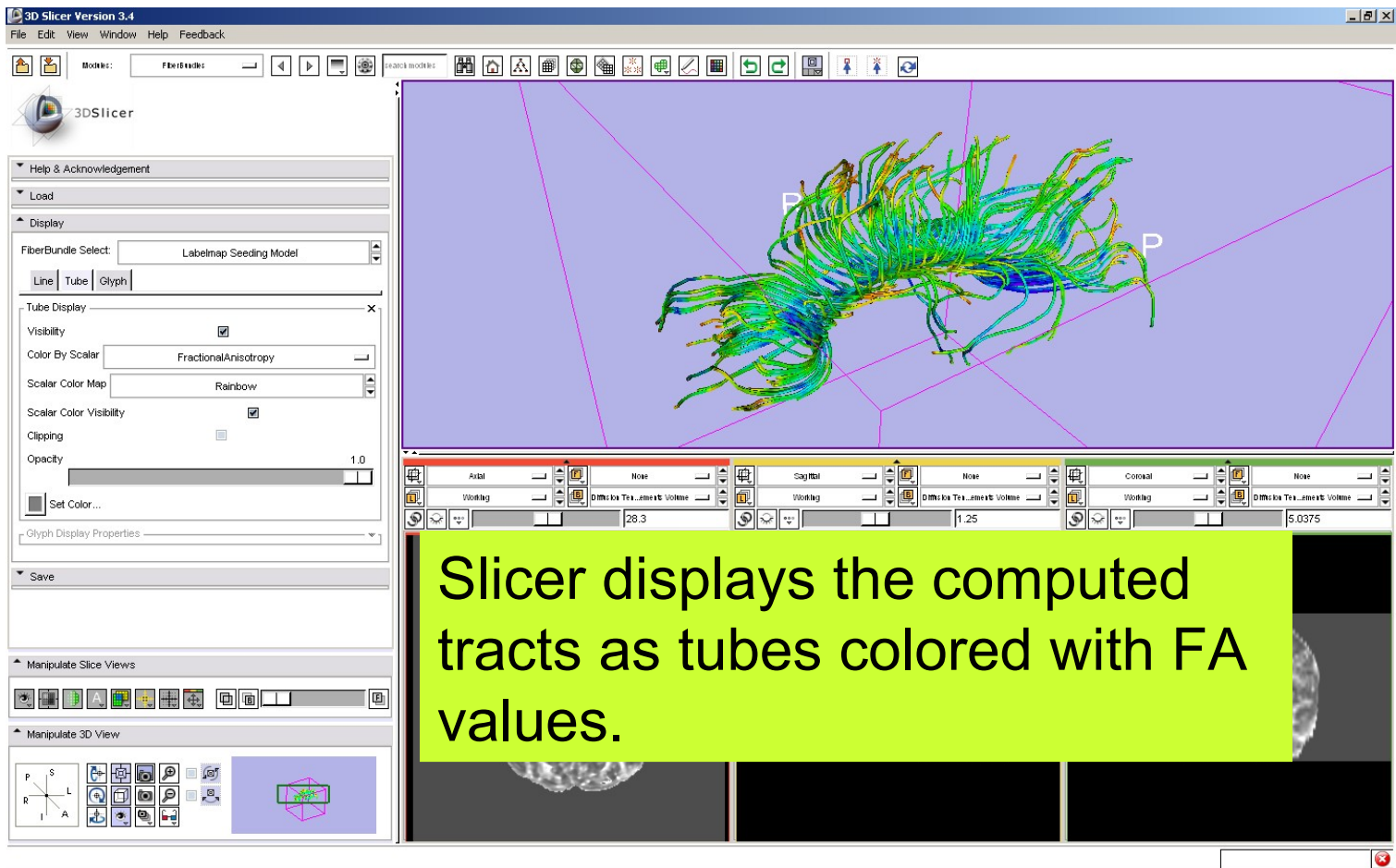
LabelMap Seeding

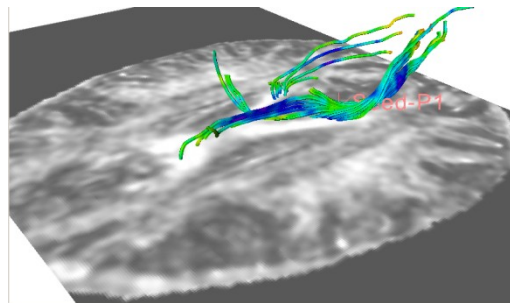
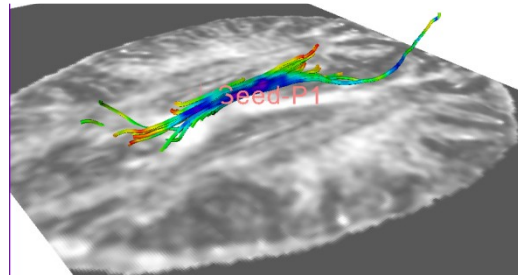
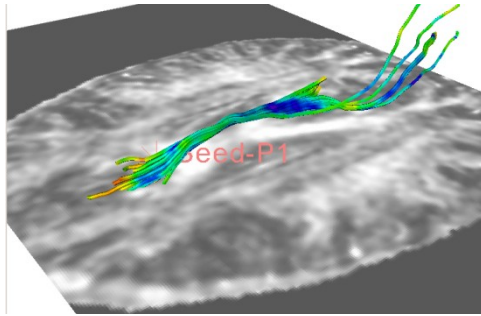


Select the module **FiberBundles**, and click on the tab **Tube** in the Display panel

Check the **Visibility** box.

LabelMap Seeding

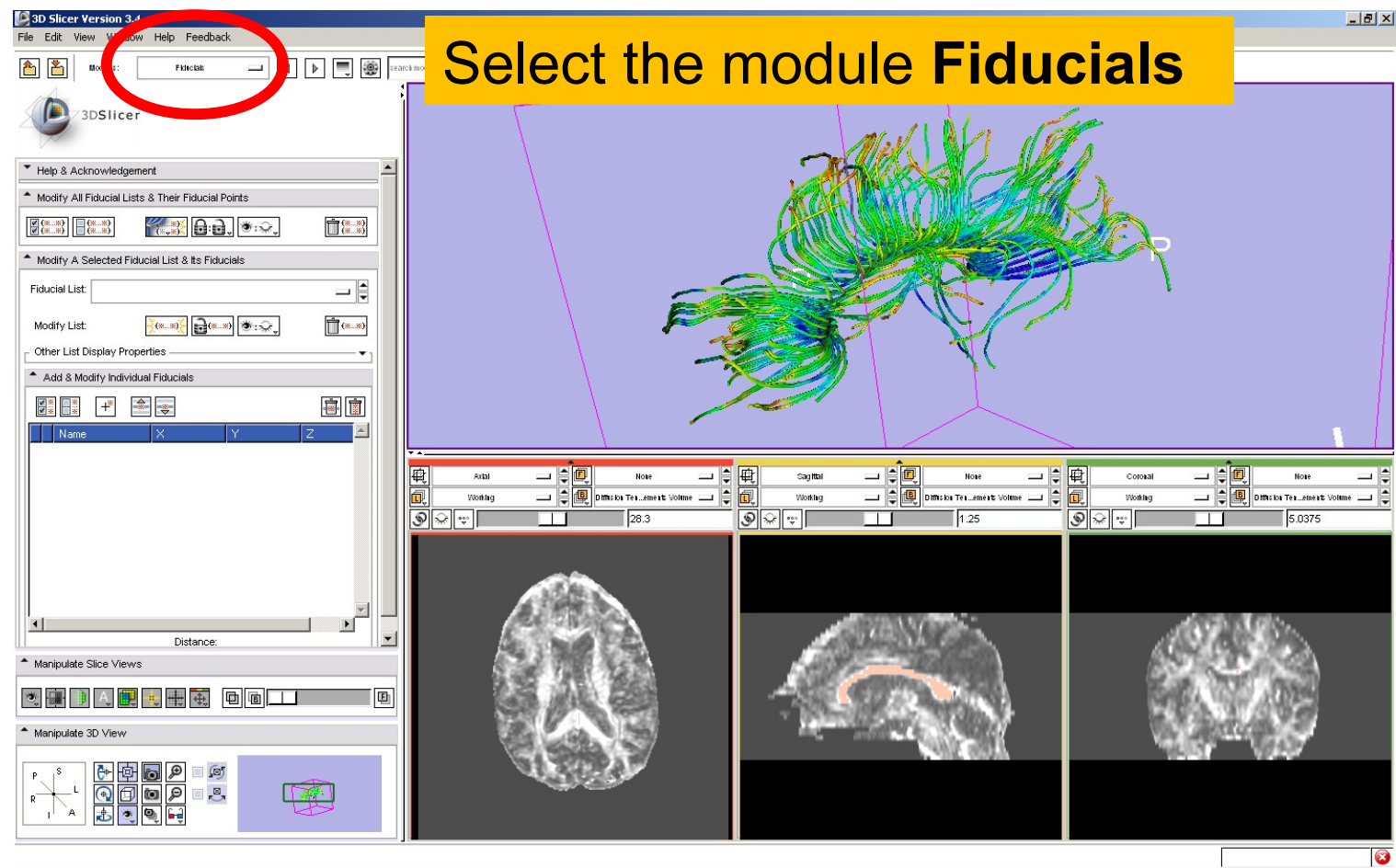




Part 4:

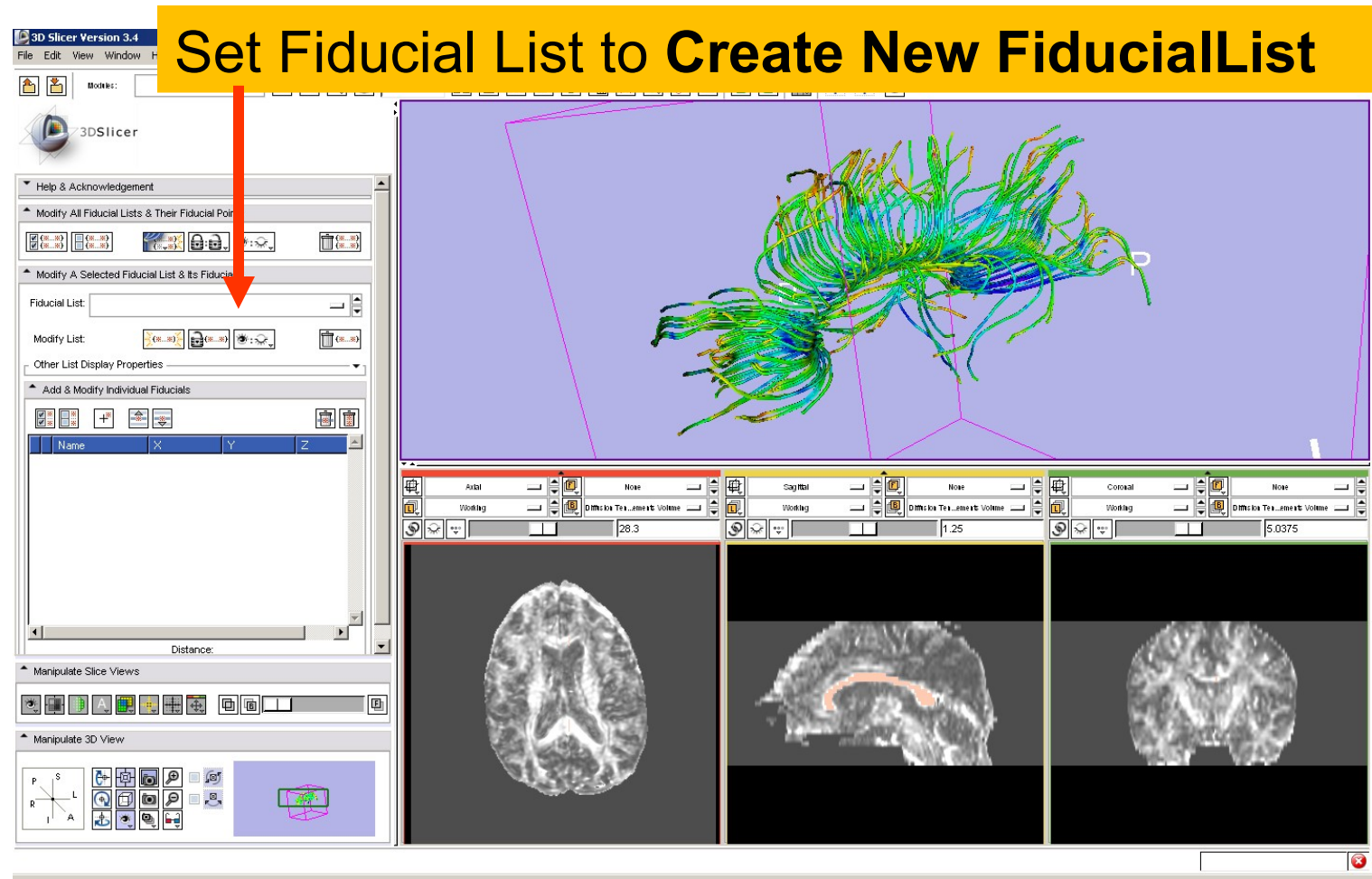
Tractography on-the-fly

Fiducial Seeding



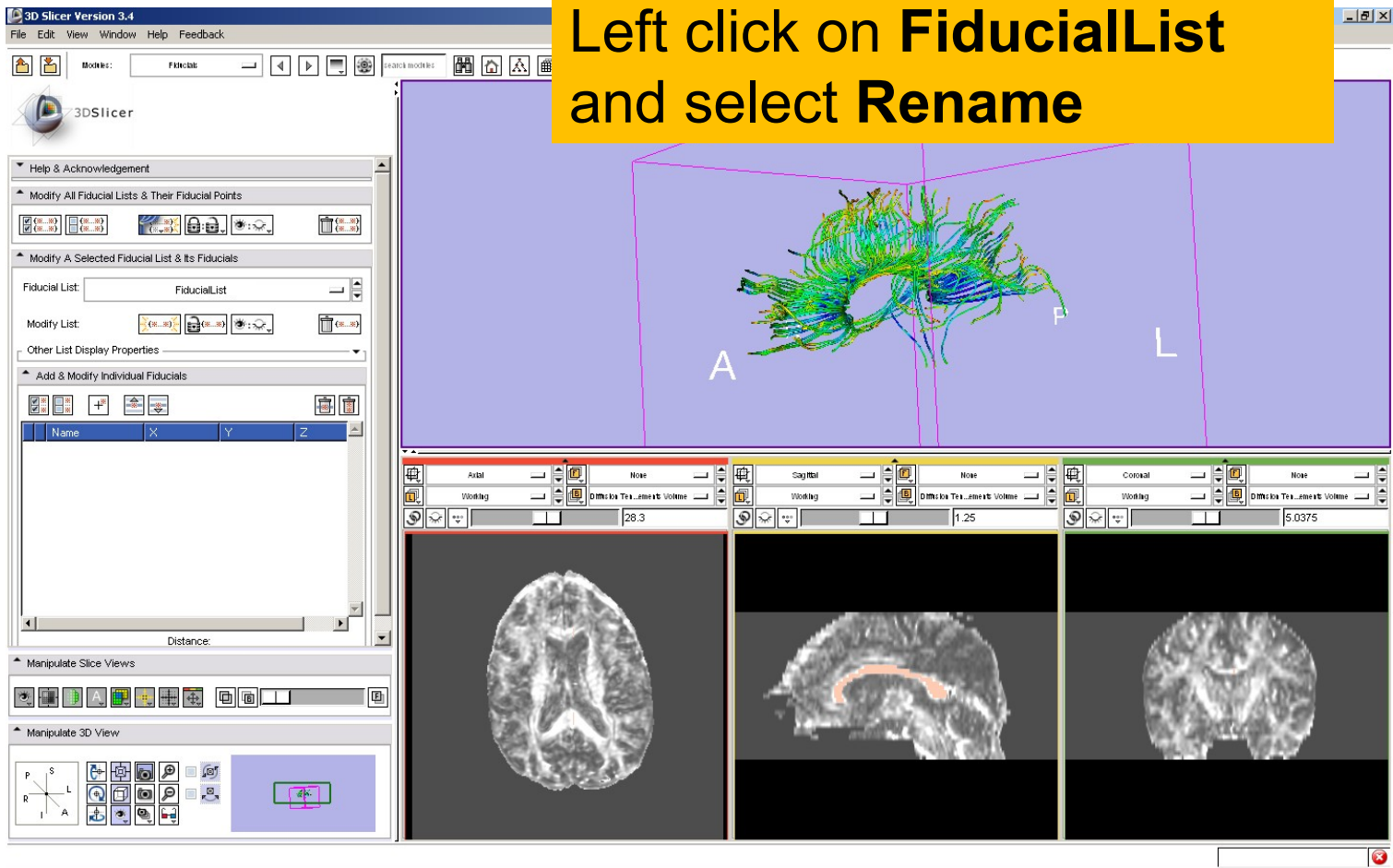
Fiducial Seeding

Set Fiducial List to Create New FiducialList

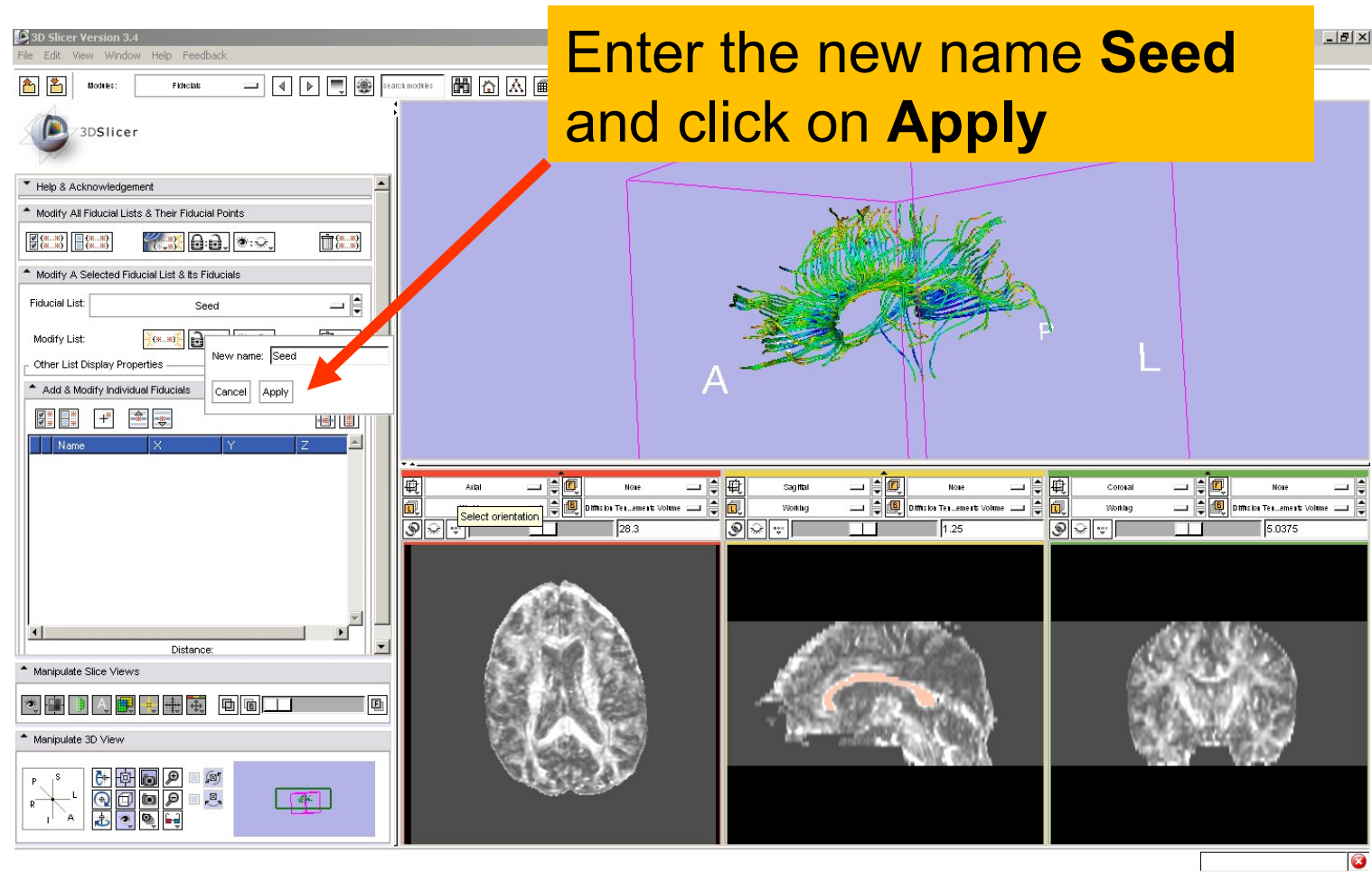


The screenshot displays the 3D Slicer Version 3.4 interface. A yellow banner at the top contains the text "Set Fiducial List to Create New FiducialList" with a red arrow pointing to the "Fiducial List" dropdown menu in the "Modify A Selected Fiducial List & Its Fiducials" panel. The 3D view shows a brain model with numerous green and blue lines representing seeded fiducials. The bottom of the interface features three slice views: Axial, Sagittal, and Coronal, each with a "Working" volume and a "Distance" value (28.3, 1.25, and 5.0375 respectively).

Fiducial Seeding



Fiducial Seeding



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

3D Slicer Version 3.4

File Edit View Window Help Feedback

3DSlicer

Help & Acknowledgement

Modify All Fiducial Lists & Their Fiducial Points

Modify A Selected Fiducial List & Its Fiducials

Fiducial List: Seed

Modify List:

Other List Display Properties

New name: Seed

Add & Modify Individual Fiducials

Name	X	Y	Z
------	---	---	---

Distance:

Manipulate Slice Views

Manipulate 3D View

Axial: None 28.3

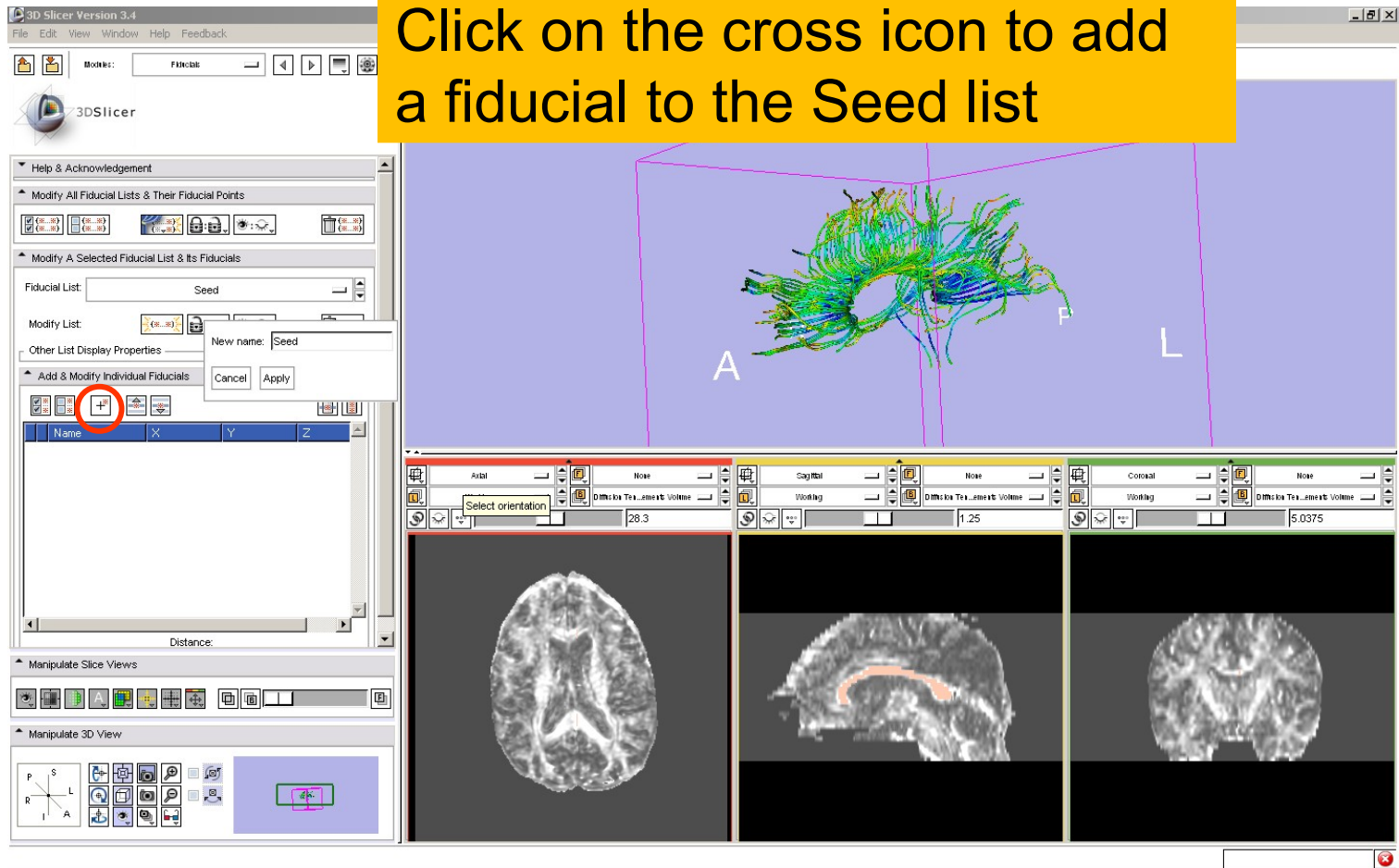
Sagittal: None 1.25

Coronal: None 5.0375

Working: Dijkstra Test... Volume

Fiducial Seeding

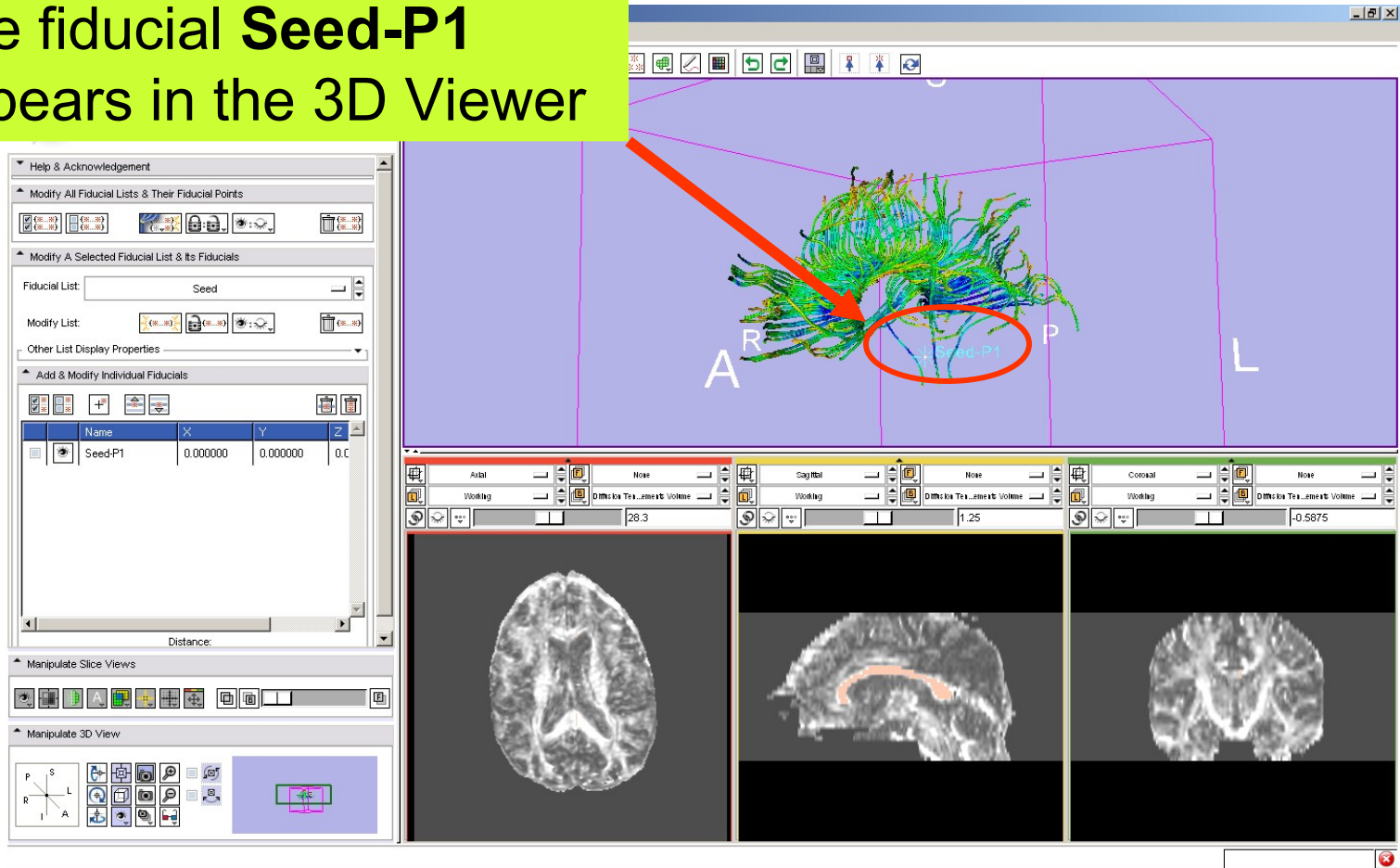
Click on the cross icon to add a fiducial to the Seed list



The screenshot displays the 3D Slicer 3.4 interface. The main 3D view shows a brain with a green and blue fiber-like structure. The bottom panel shows three orthogonal slice views: Axial, Sagittal, and Coronal. The 'Add & Modify Individual Fiducials' panel is open, and a red circle highlights the cross icon used to add a fiducial. The 'Seed' list is visible in the 'Modify A Selected Fiducial List & Its Fiducials' panel.

Fiducial Seeding

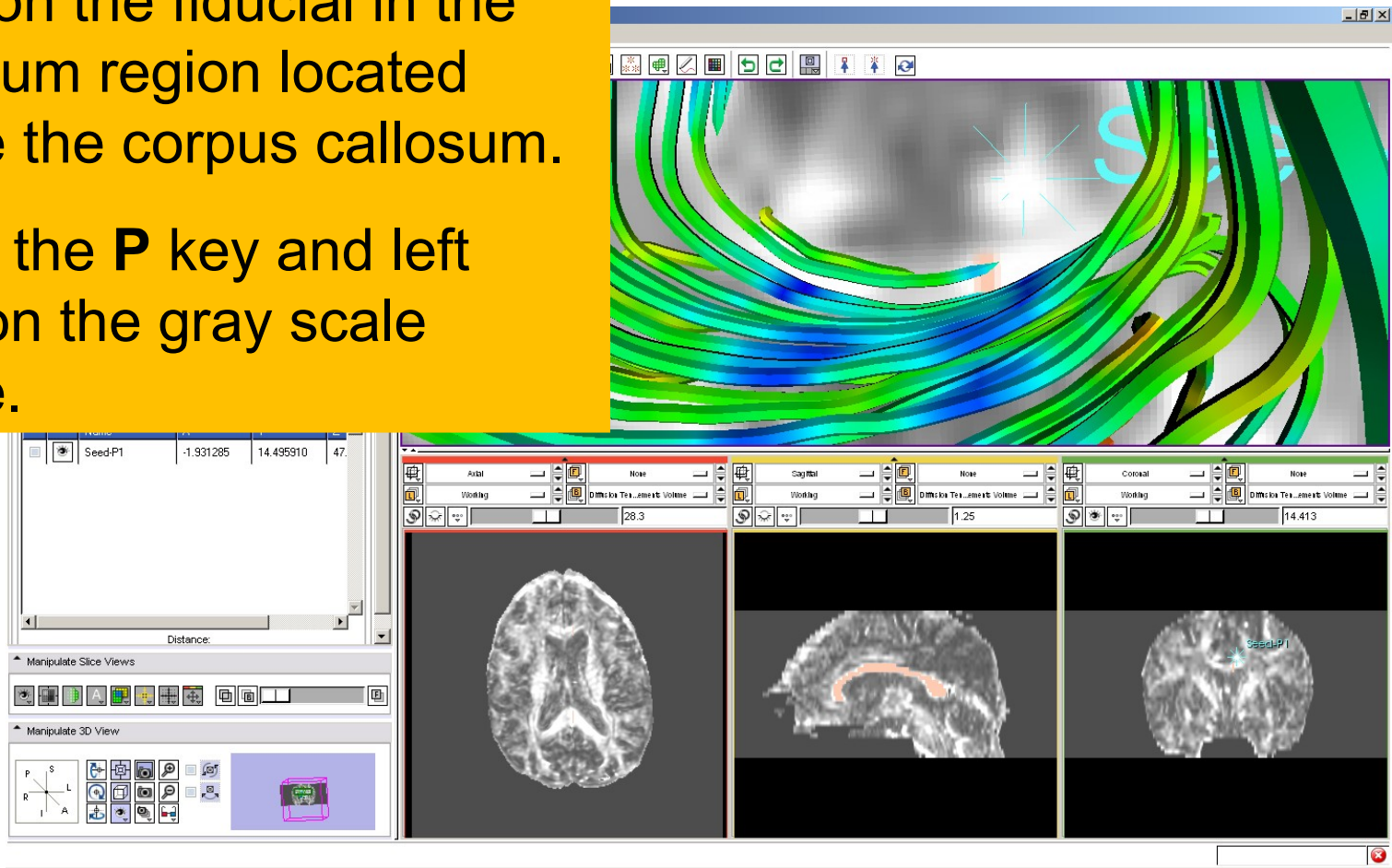
The fiducial **Seed-P1** appears in the 3D Viewer



Fiducial Seeding

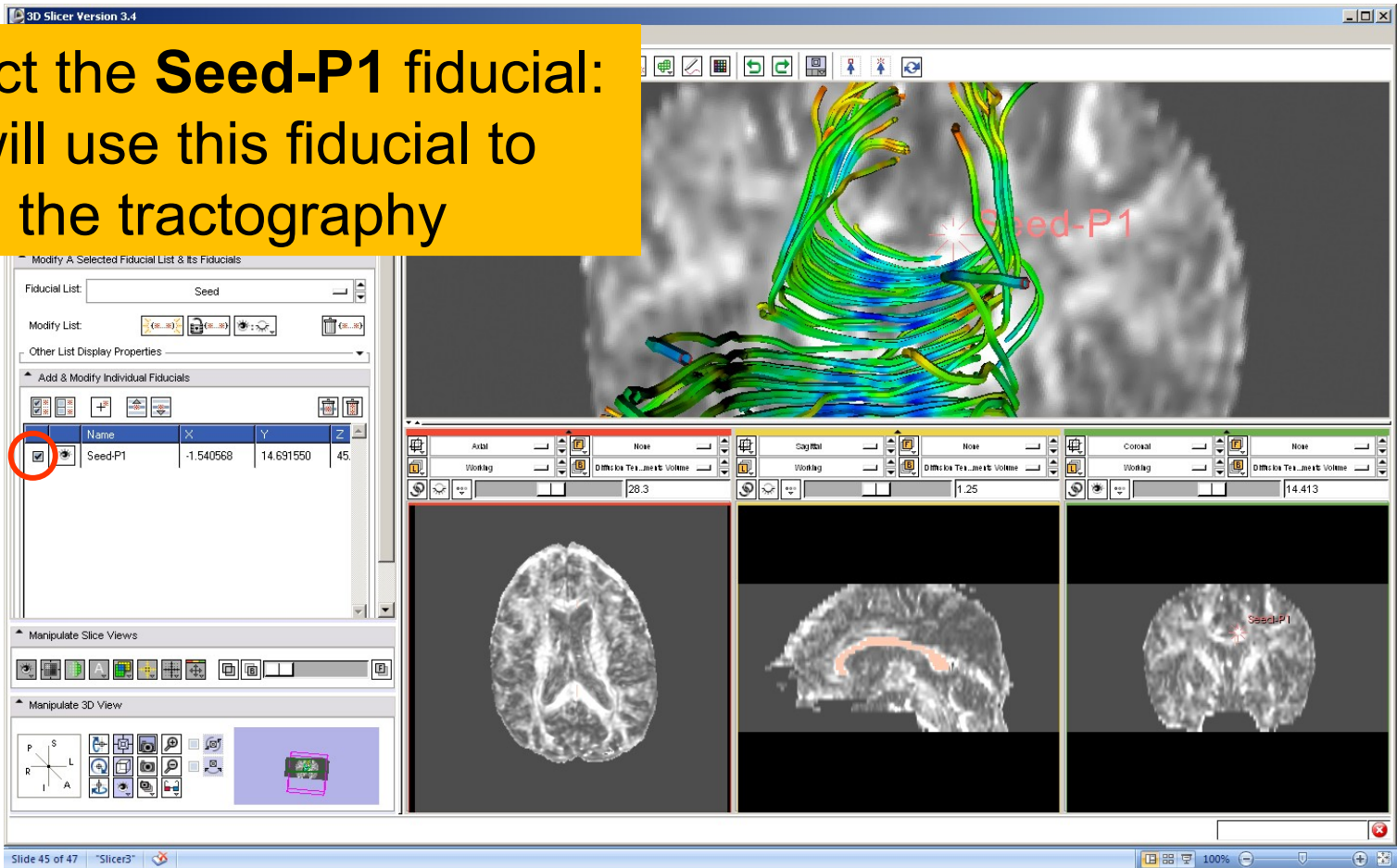
Position the fiducial in the cingulum region located above the corpus callosum.

Press the **P** key and left click on the gray scale image.

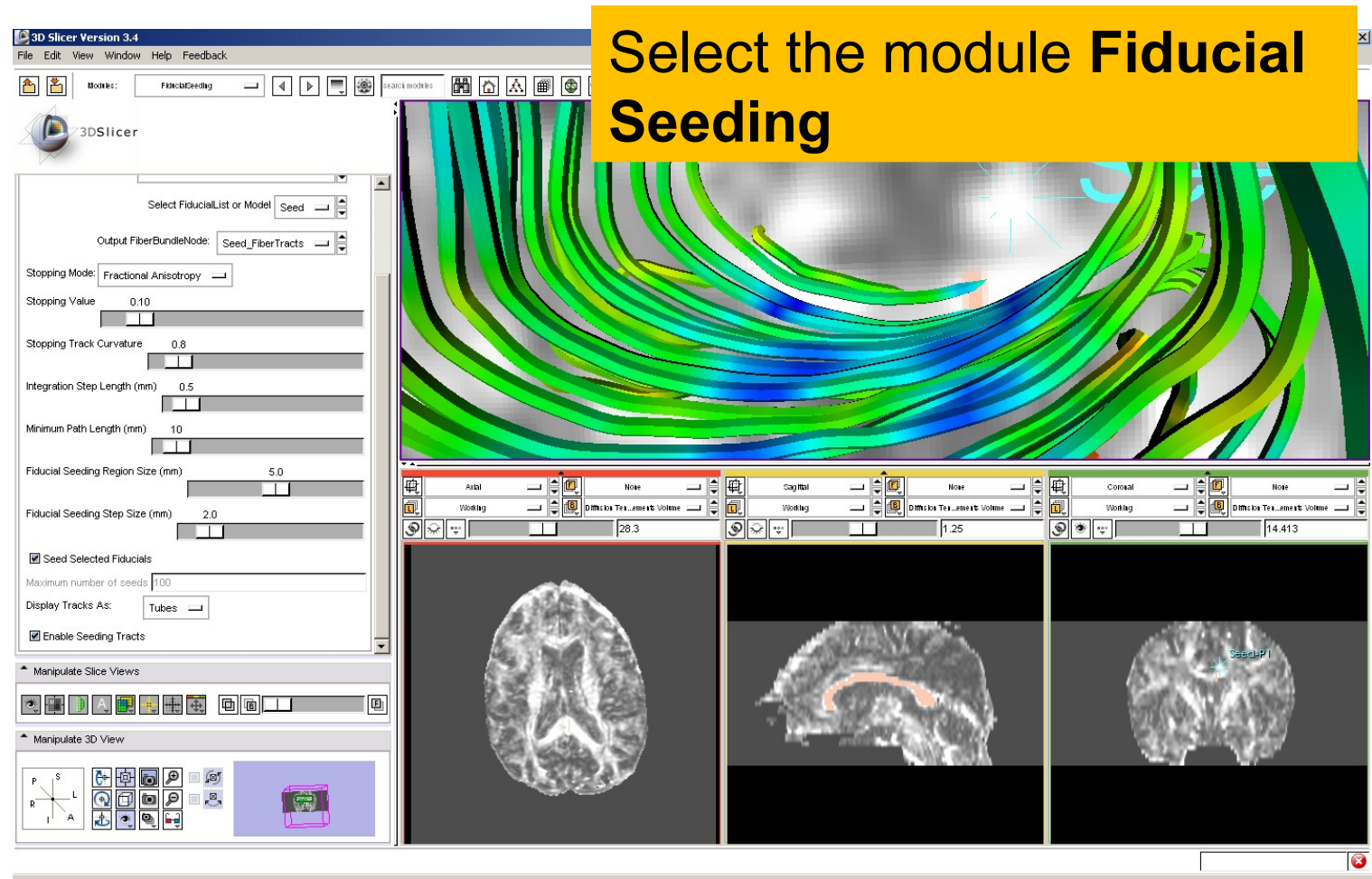


Fiducial Seeding

Select the **Seed-P1** fiducial: we will use this fiducial to drive the tractography



Fiducial Seeding



Select the module Fiducial Seeding

The screenshot displays the 3D Slicer Version 3.4 interface. The 'FiducialSeeding' module is active, showing various parameters for fiber tract seeding. The 3D view shows a brain with green and blue fiber tracts. The slice views at the bottom show axial, sagittal, and coronal slices of the brain with a red curved line indicating the seeding region.

Module Parameters:

- Select FiducialList or Model: Seed
- Output FiberBundleNode: Seed_FiberTracts
- Stopping Mode: Fractional Anisotropy
- Stopping Value: 0.10
- Stopping Track Curvature: 0.8
- Integration Step Length (mm): 0.5
- Minimum Path Length (mm): 10
- Fiducial Seeding Region Size (mm): 5.0
- Fiducial Seeding Step Size (mm): 2.0
- Seed Selected Fiducials
- Maximum number of seeds: 100
- Display Tracks As: Tubes
- Enable Seeding Tracks

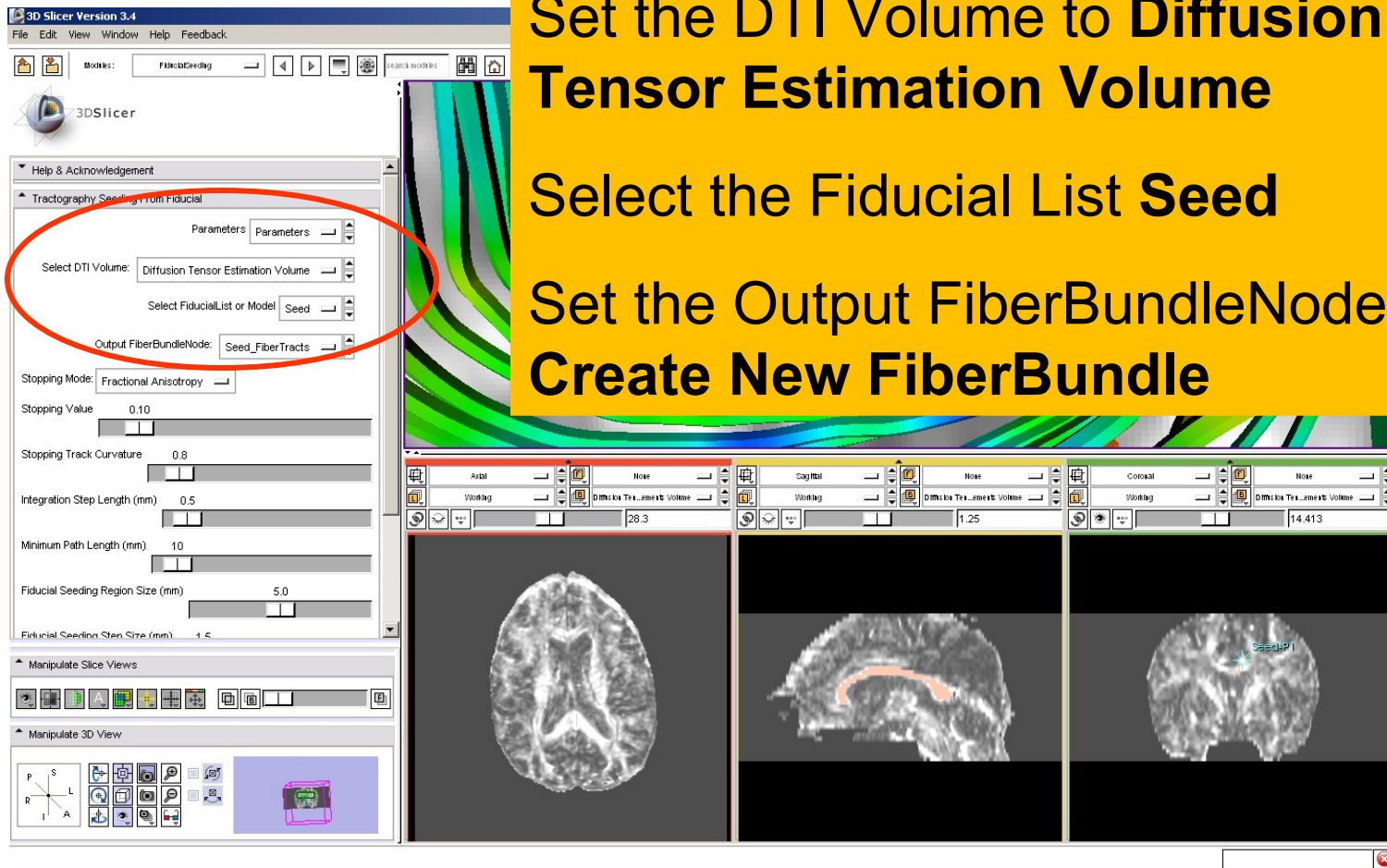
Manipulate Slice Views:

- Axial: Working, 28.3
- Sagittal: Working, 1.25
- Coronal: Working, 14.413

Manipulate 3D View:

- Orientation: P (Posterior), S (Superior), L (Left), R (Right), I (Inferior), A (Anterior)

Fiducial Seeding

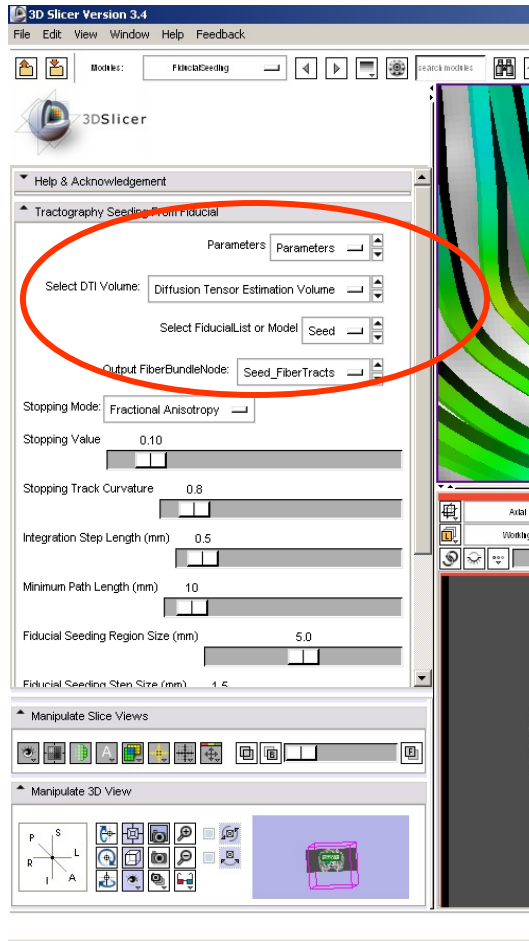


Set the DTI Volume to Diffusion Tensor Estimation Volume

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

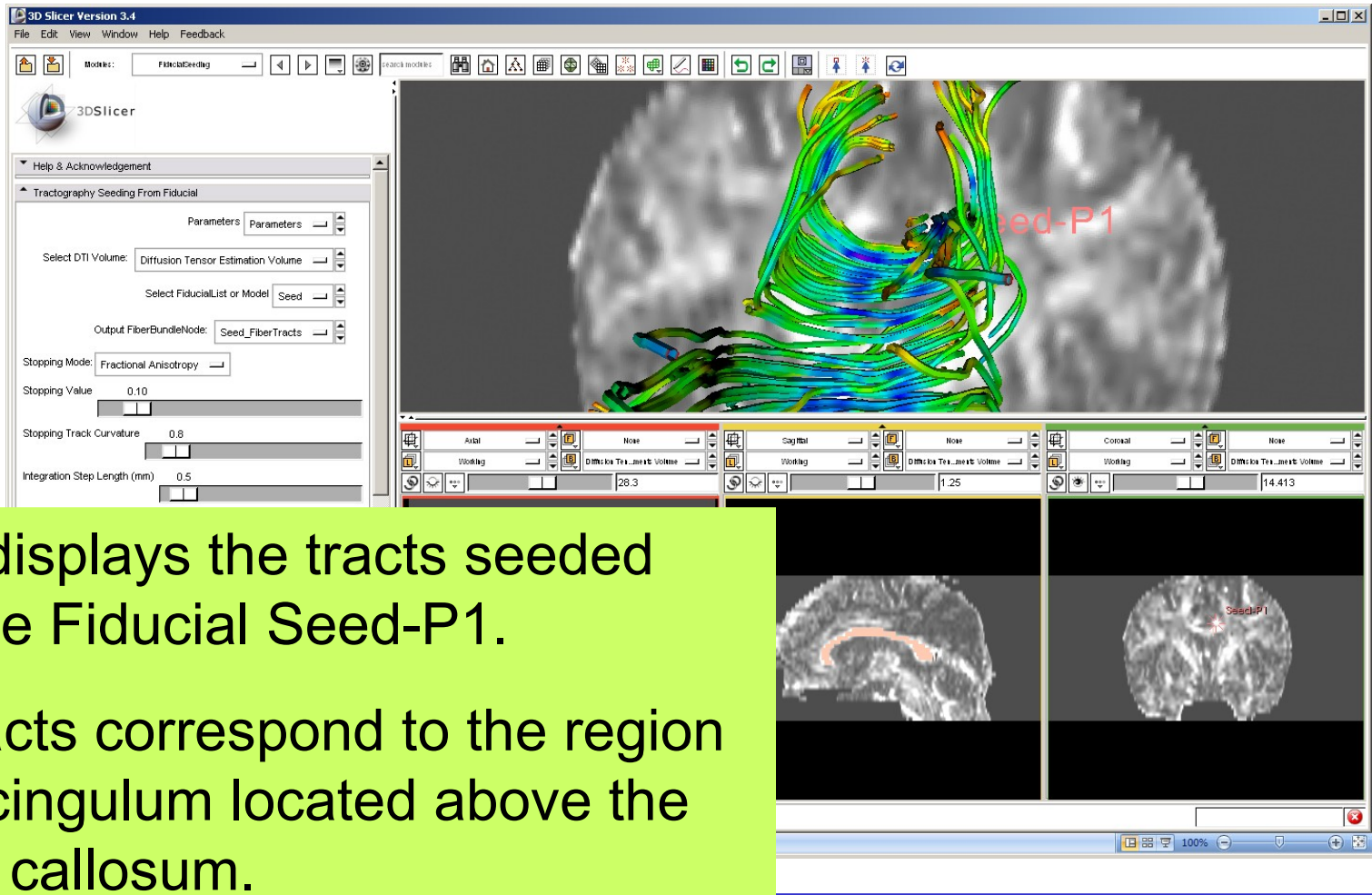
Stopping Track Curvature: 0.8

Step Length: 0.8 mm

Minimum Length: 10 mm

Fiducial Stepping Size: 1.5 mm

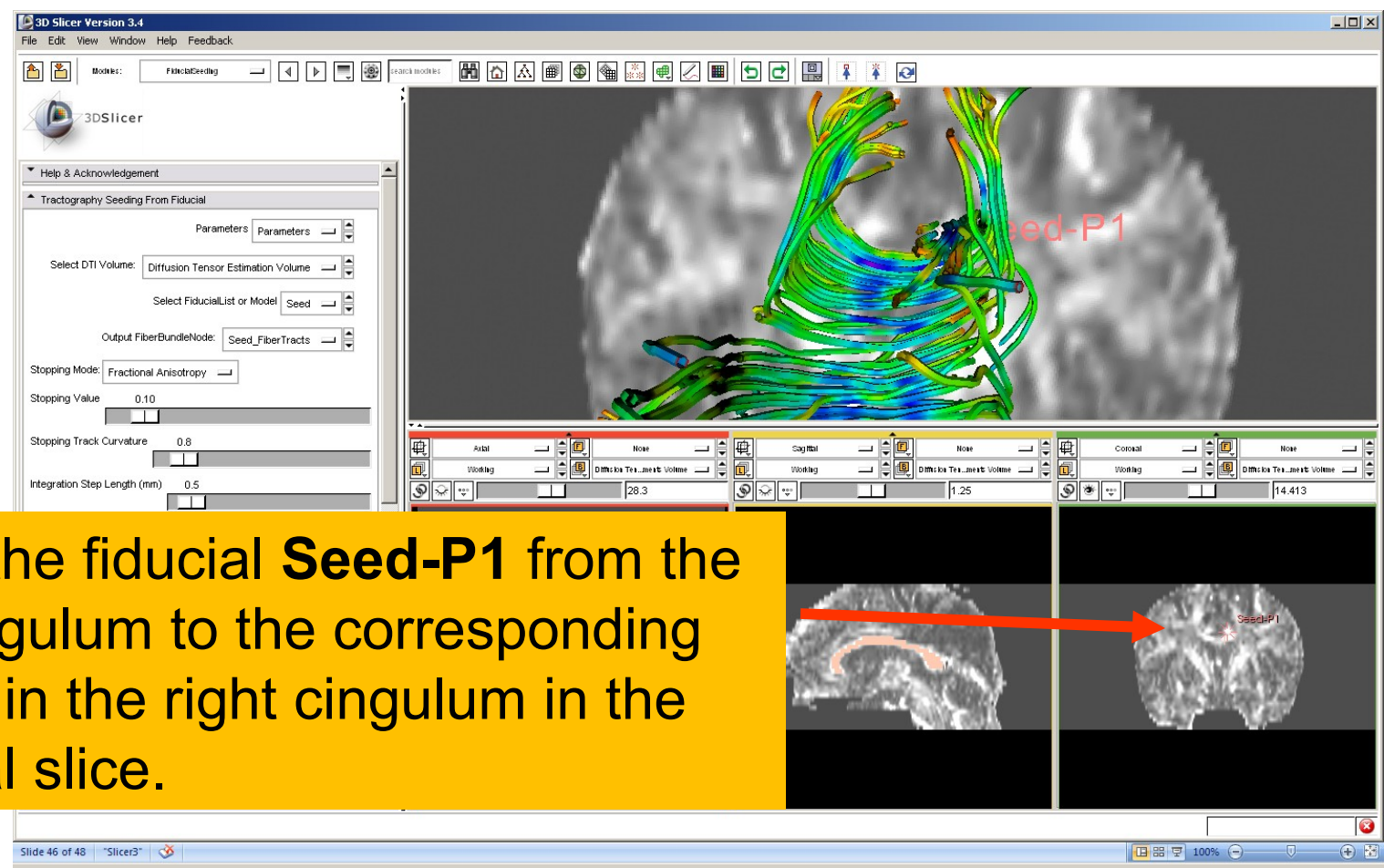
Fiducial Seeding



Slicer displays the tracts seeded from the Fiducial Seed-P1.

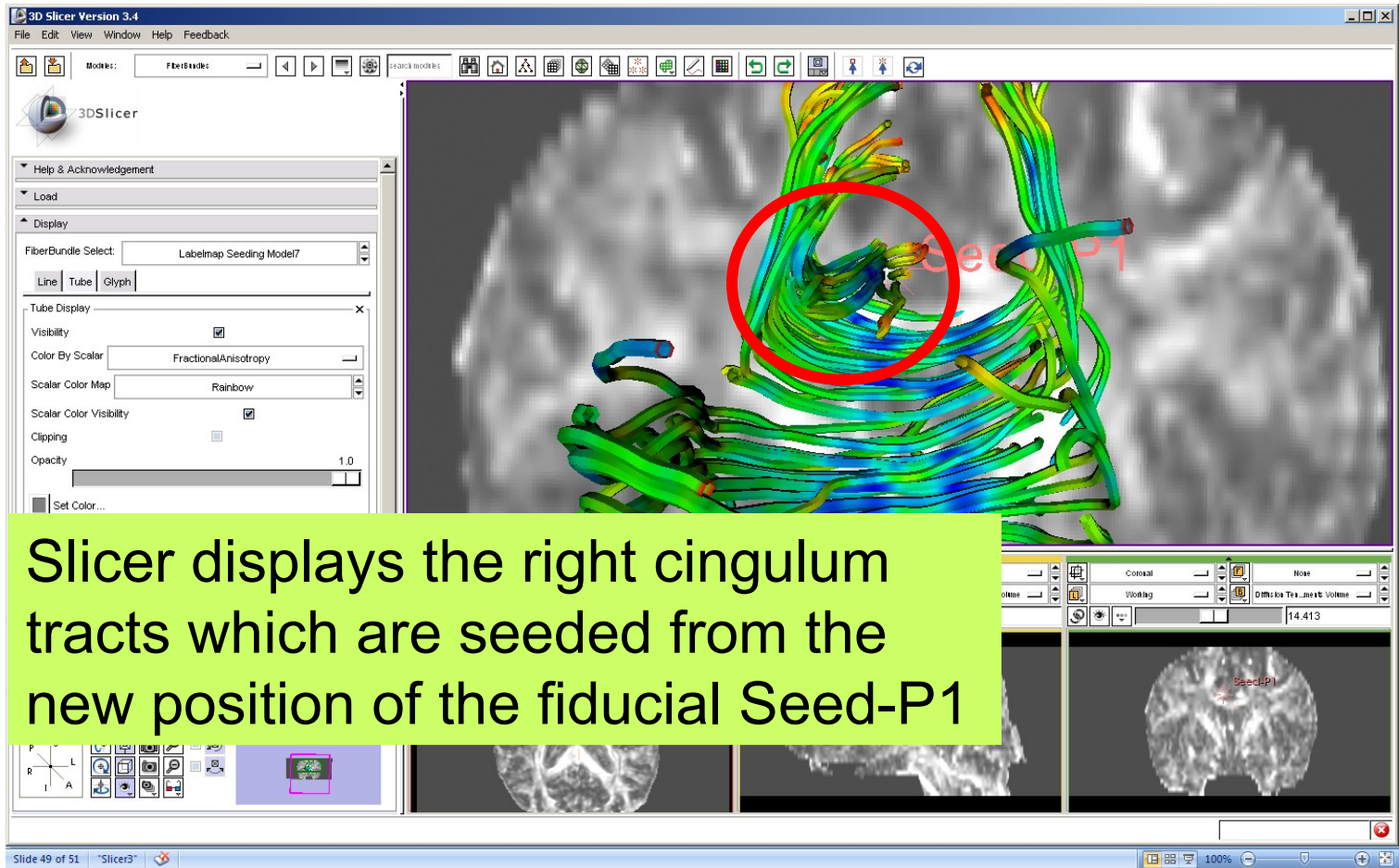
The tracts correspond to the region of the cingulum located above the corpus callosum.

Fiducial Seeding



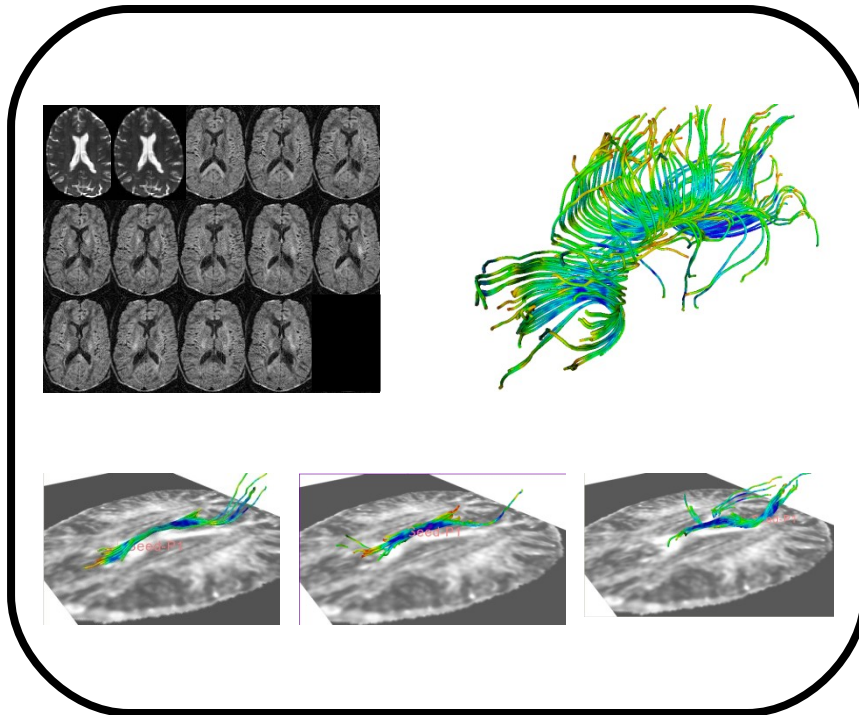
Move the fiducial **Seed-P1** from the left cingulum to the corresponding region in the right cingulum in the coronal slice.

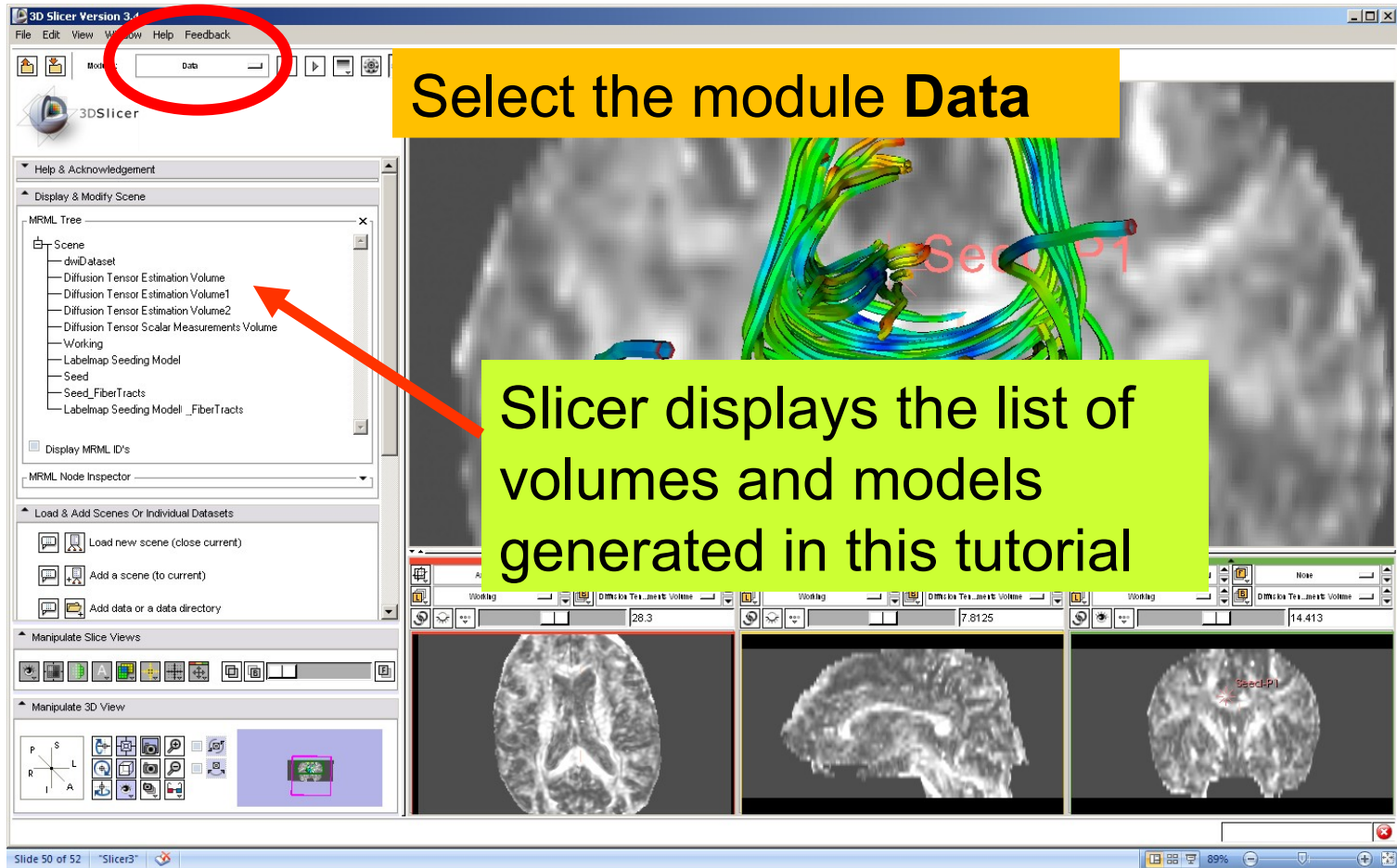
Fiducial Seeding



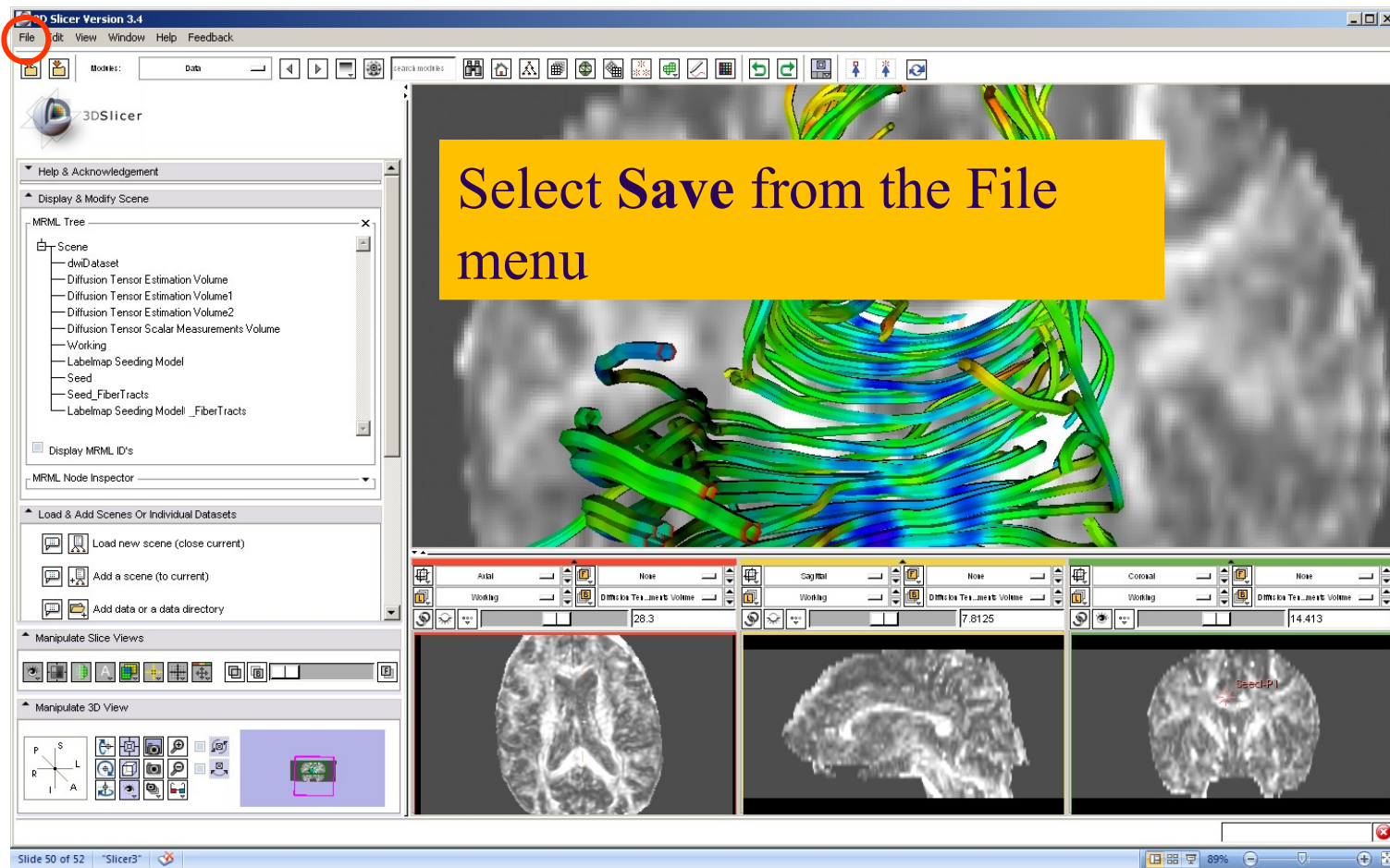
Part 5:

Saving a DTI Scene



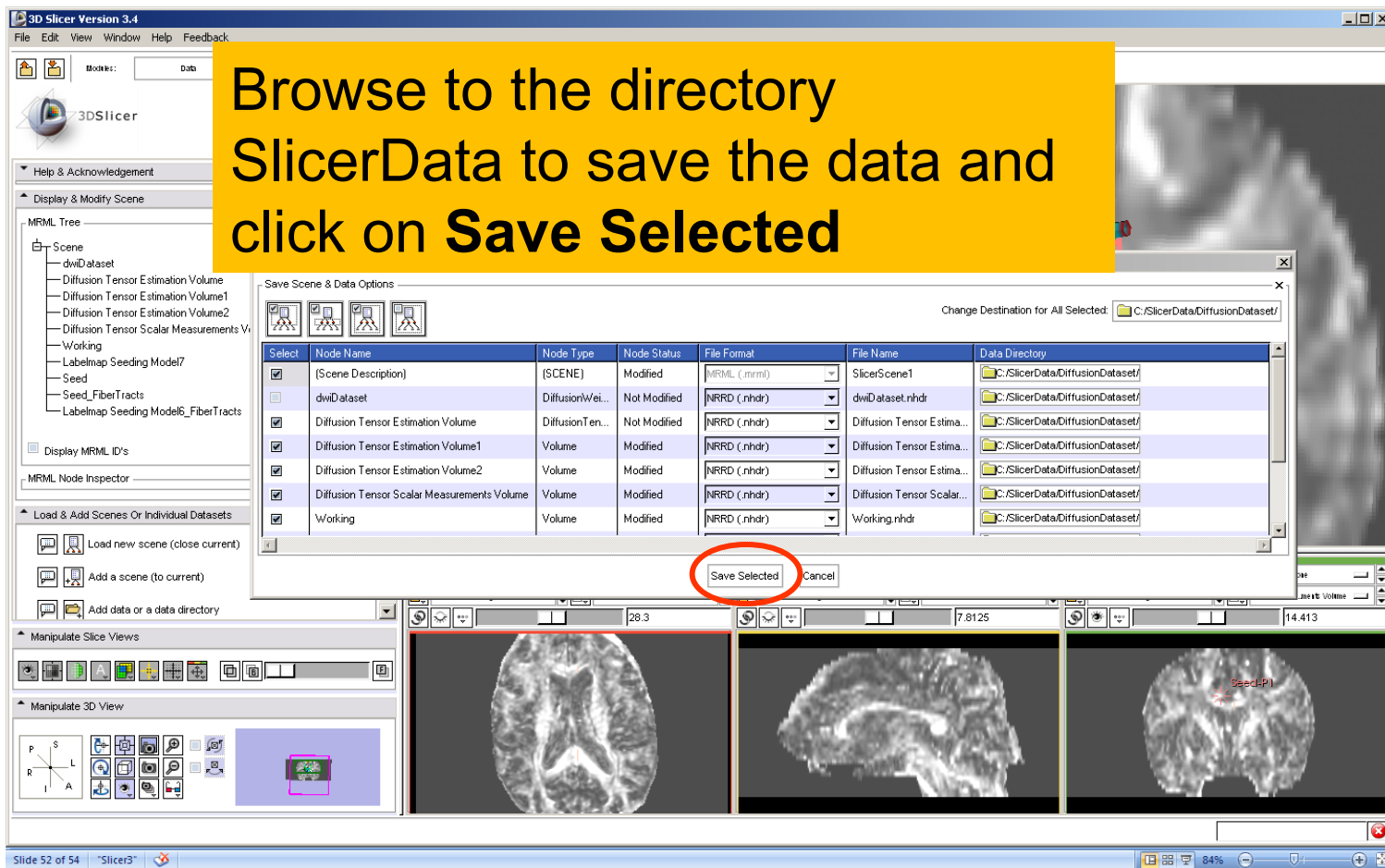


Saving a DTI Scene



Saving a DTI Scene

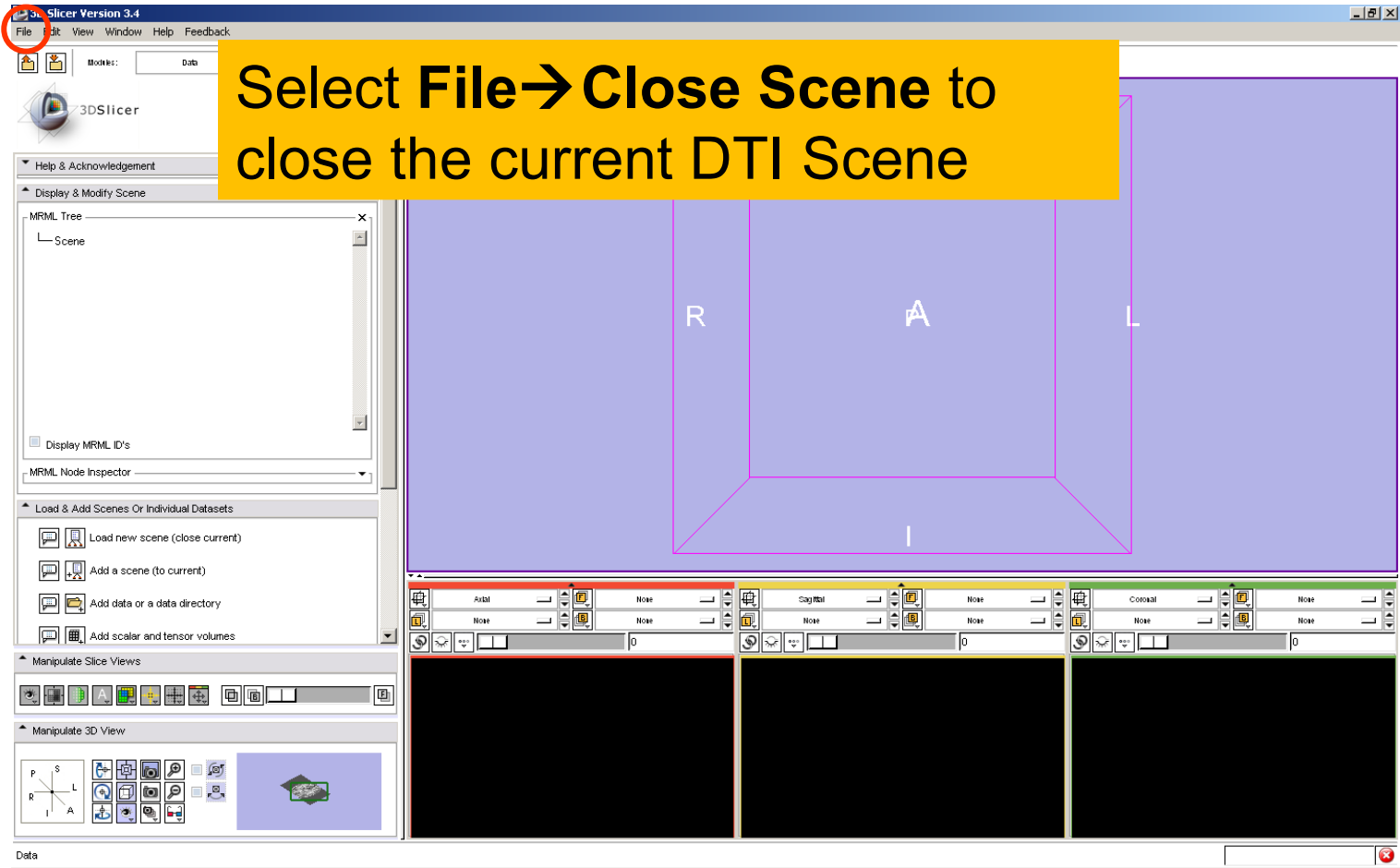
Browse to the directory SlicerData to save the data and click on **Save Selected**



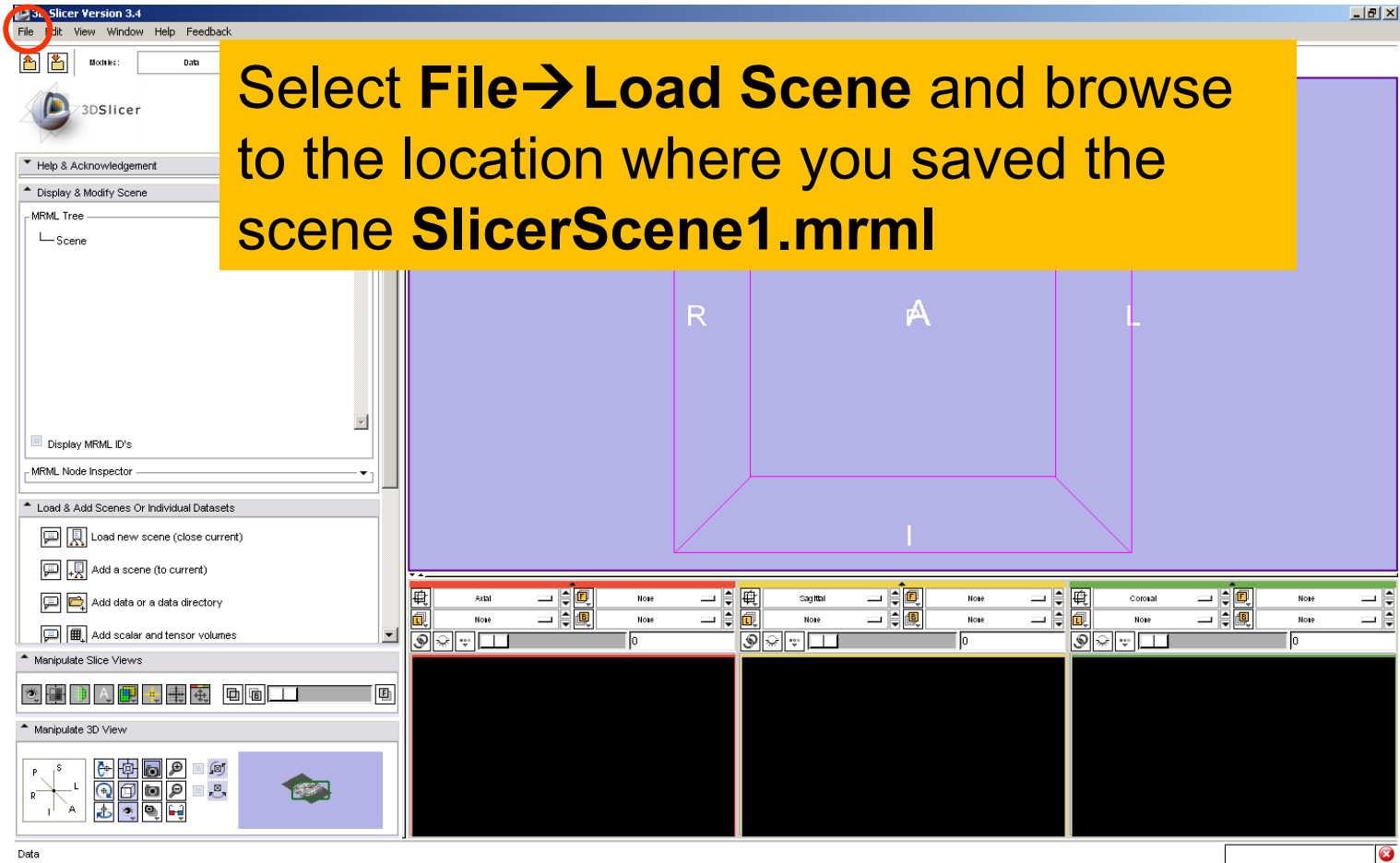
The screenshot shows the 3D Slicer 3.4 interface with the 'Save Scene & Data Options' dialog box open. The dialog box has a table with the following columns: Select, Node Name, Node Type, Node Status, File Format, File Name, and Data Directory. The 'Save Selected' button is circled in red.

Select	Node Name	Node Type	Node Status	File Format	File Name	Data Directory
<input checked="" type="checkbox"/>	(Scene Description)	(SCENE)	Modified	MRML (.mrm)	SlicerScene1	C:/SlicerData/DiffusionDataset/
<input type="checkbox"/>	dwiDataset	DiffusionWei...	Not Modified	NRRD (.nhdr)	dwiDataset.nhdr	C:/SlicerData/DiffusionDataset/
<input checked="" type="checkbox"/>	Diffusion Tensor Estimation Volume	DiffusionTen...	Not Modified	NRRD (.nhdr)	Diffusion Tensor Estima...	C:/SlicerData/DiffusionDataset/
<input checked="" type="checkbox"/>	Diffusion Tensor Estimation Volume1	Volume	Modified	NRRD (.nhdr)	Diffusion Tensor Estima...	C:/SlicerData/DiffusionDataset/
<input checked="" type="checkbox"/>	Diffusion Tensor Estimation Volume2	Volume	Modified	NRRD (.nhdr)	Diffusion Tensor Estima...	C:/SlicerData/DiffusionDataset/
<input checked="" type="checkbox"/>	Diffusion Tensor Scalar Measurements Volume	Volume	Modified	NRRD (.nhdr)	Diffusion Tensor Scalar...	C:/SlicerData/DiffusionDataset/
<input checked="" type="checkbox"/>	Working	Volume	Modified	NRRD (.nhdr)	Working.nhdr	C:/SlicerData/DiffusionDataset/

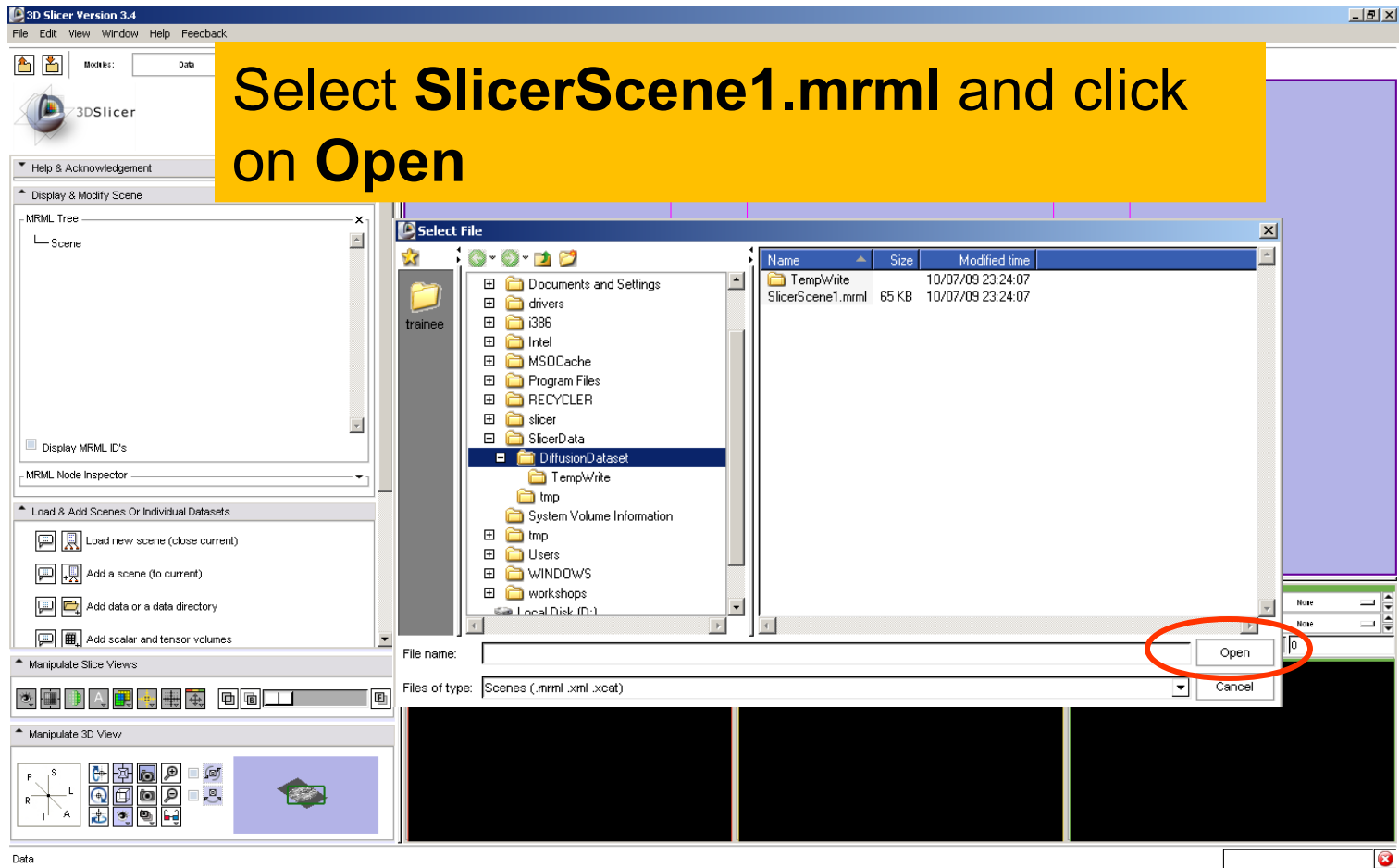
Saving a DTI Scene



Loading a DTI Scene

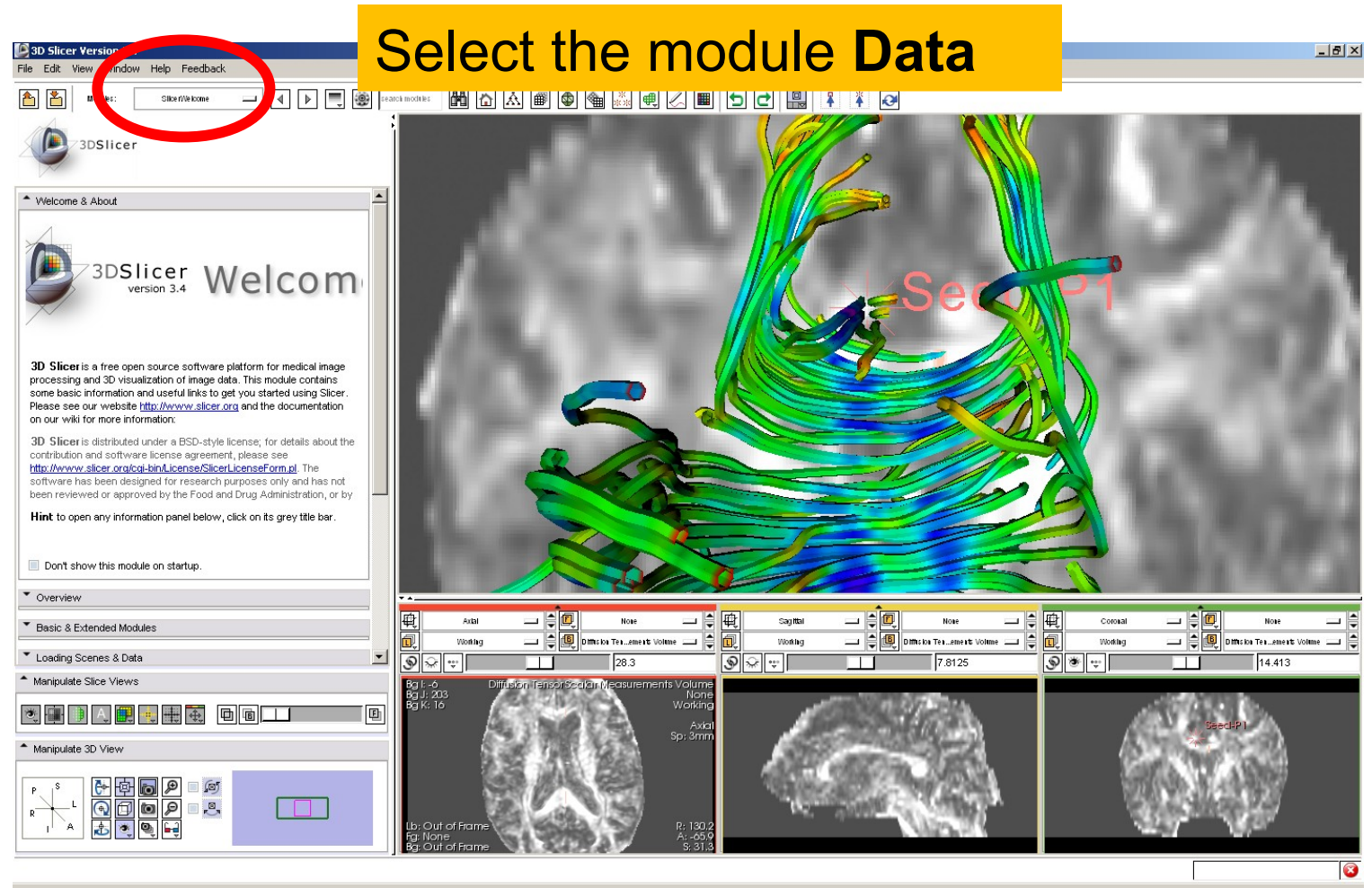


Loading a DTI Scene



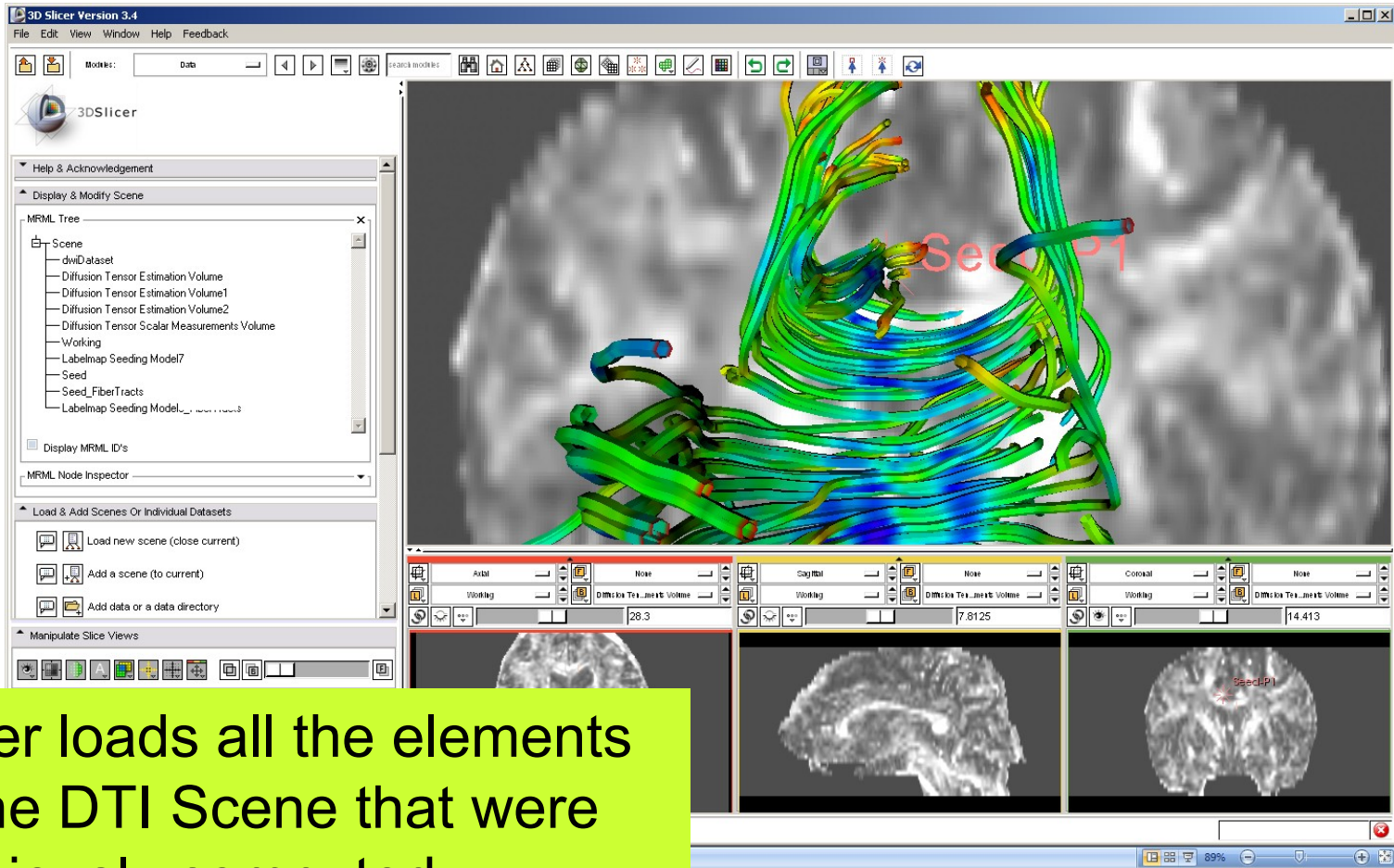
Loading a DTI Scene

Select the module Data



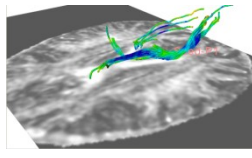
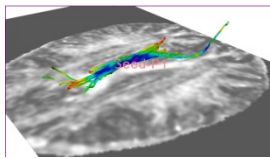
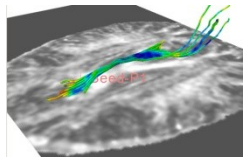
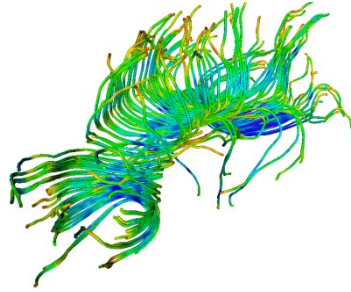
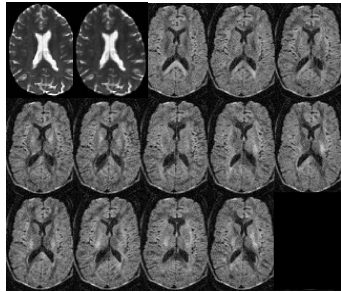
The screenshot displays the 3D Slicer interface. The top toolbar contains various modules, with the 'Data' module highlighted by a red circle. The main 3D view shows a brain slice with fiber tracking, labeled 'Seed P1'. The bottom panel shows three orthogonal views (Axial, Sagittal, Coronal) of the brain slice, with the 'Data' module selected in each view. The interface also includes a 'Welcome & About' panel on the left and a 'Loading Scenes & Data' panel in the bottom left.

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.

For more tutorials and teaching events, please visit

spujol@bwh.harvard.edu

www.slicer.org

www.na-mic.org/Wiki/index.php/Events



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