



Exploring Peritumoral White Matter Fibers for Neurosurgical Planning

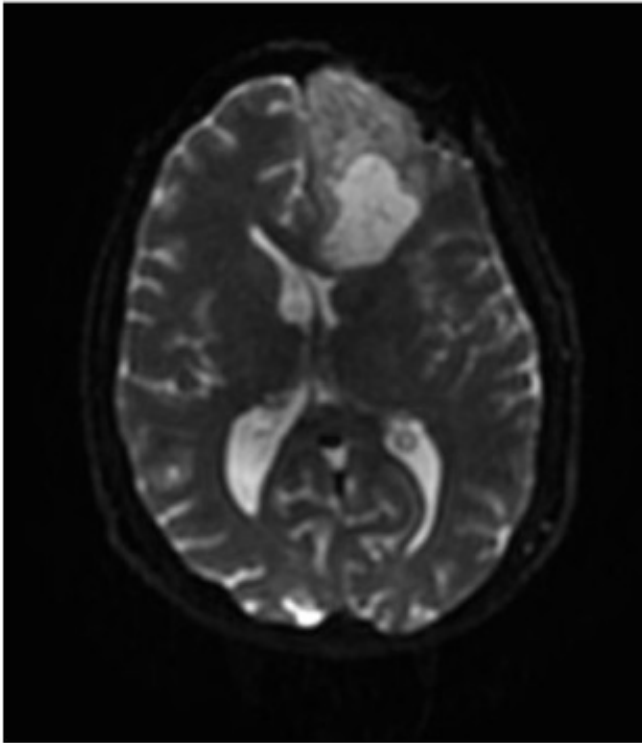
Sonia Pujol, Ph.D.

Ron Kikinis, M.D.

Surgical Planning Laboratory

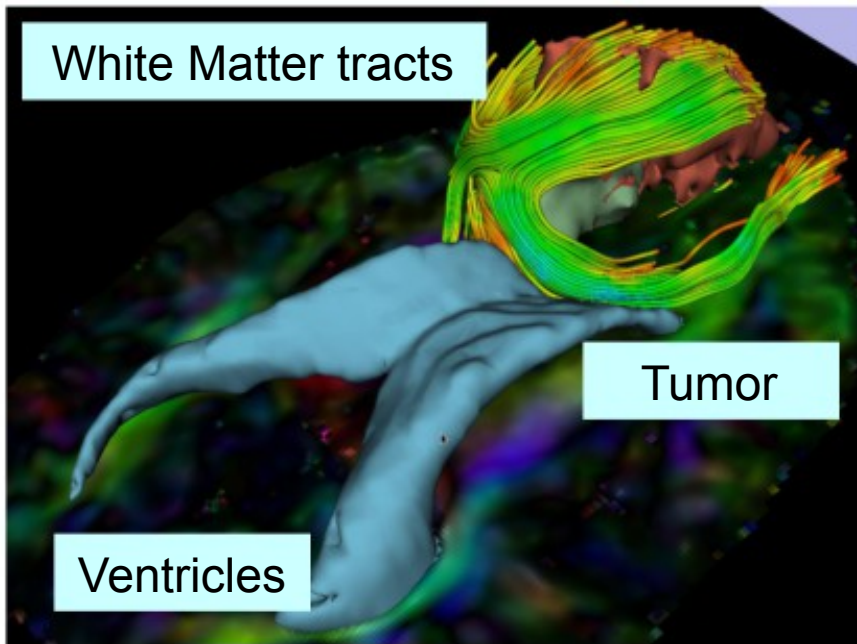
Harvard University

Clinical Case



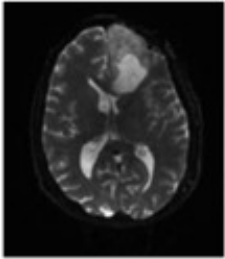
- 35 year-old male diagnosed with Glioblastoma multiform (GBM)
- Diffusion Weighted Imaging (DWI) acquisition for neurosurgical planning

Clinical Goal

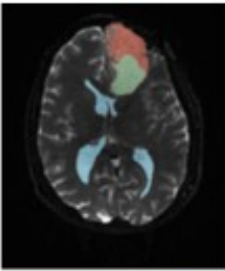


The goal of this tutorial is to explore white matter fibers surrounding a tumor using Diffusion Tensor Imaging (DTI) Tractography.

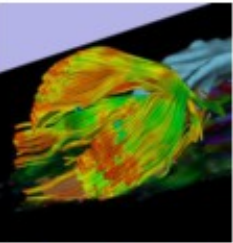
Overview of the analysis pipeline



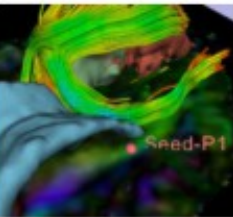
Part 1: Loading & Visualization of Diffusion Data



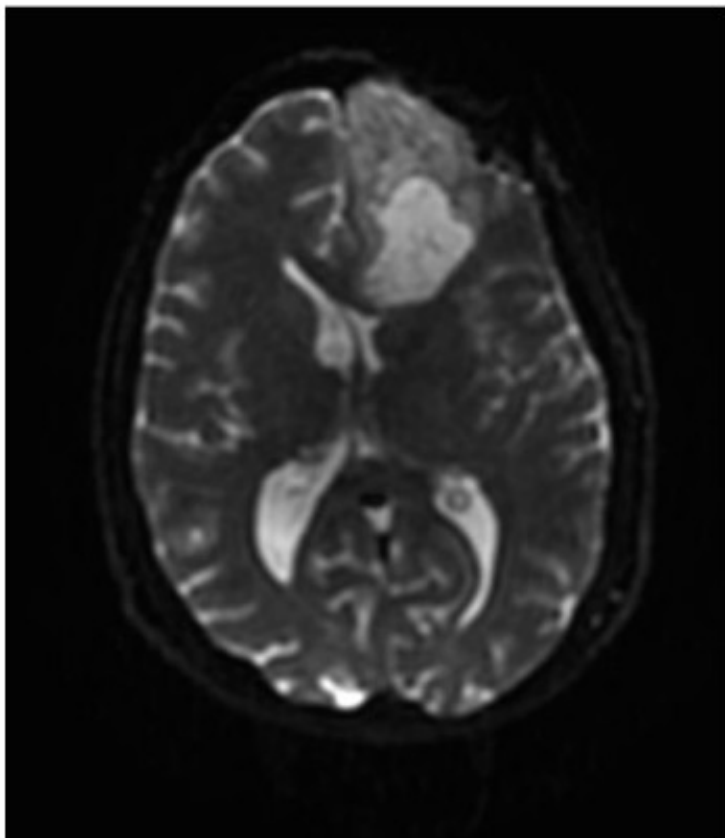
Part 2: Segmentation of lat. ventricles, and solid and cystic parts of the tumor



Part 3: Tractography reconstruction of white matter fibers in the peri-tumoral volume

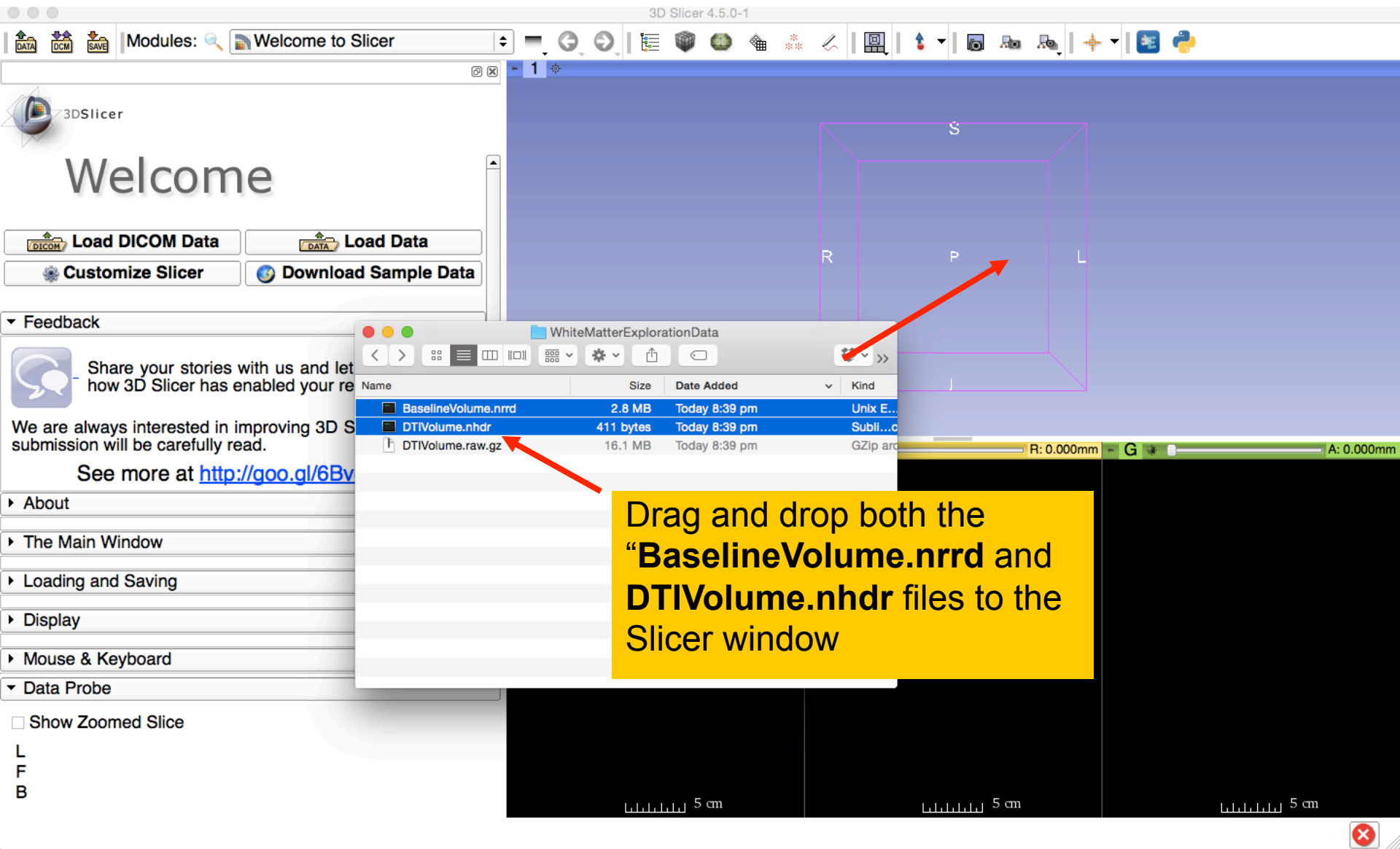


Part 4: Tractography exploration of the ipsilateral and contralateral side

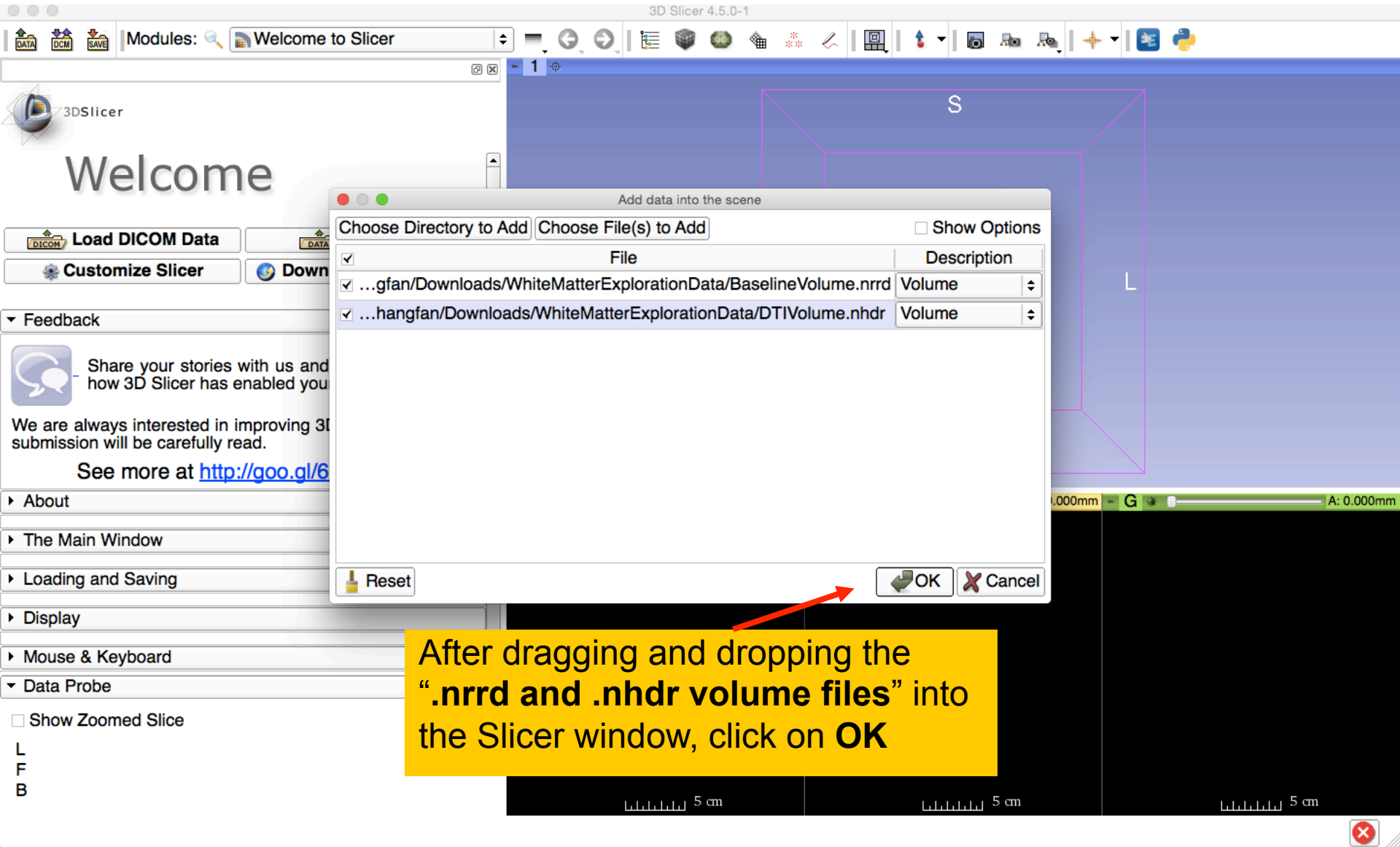


Part 1: Loading and Visualization of Diffusion Data

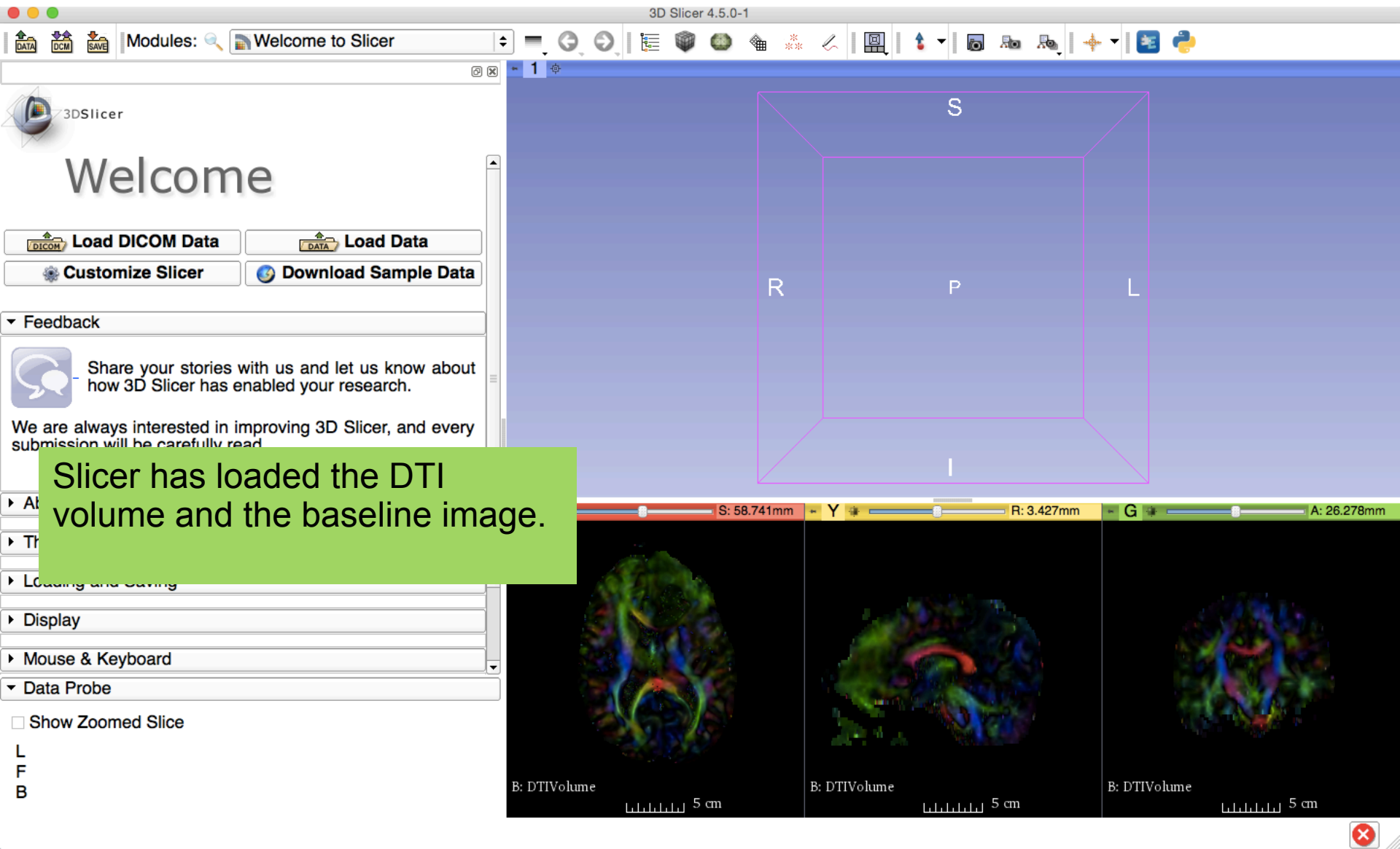
Loading DTI and Baseline Data



Loading DTI and Baseline Data



Loading DTI and Baseline Data



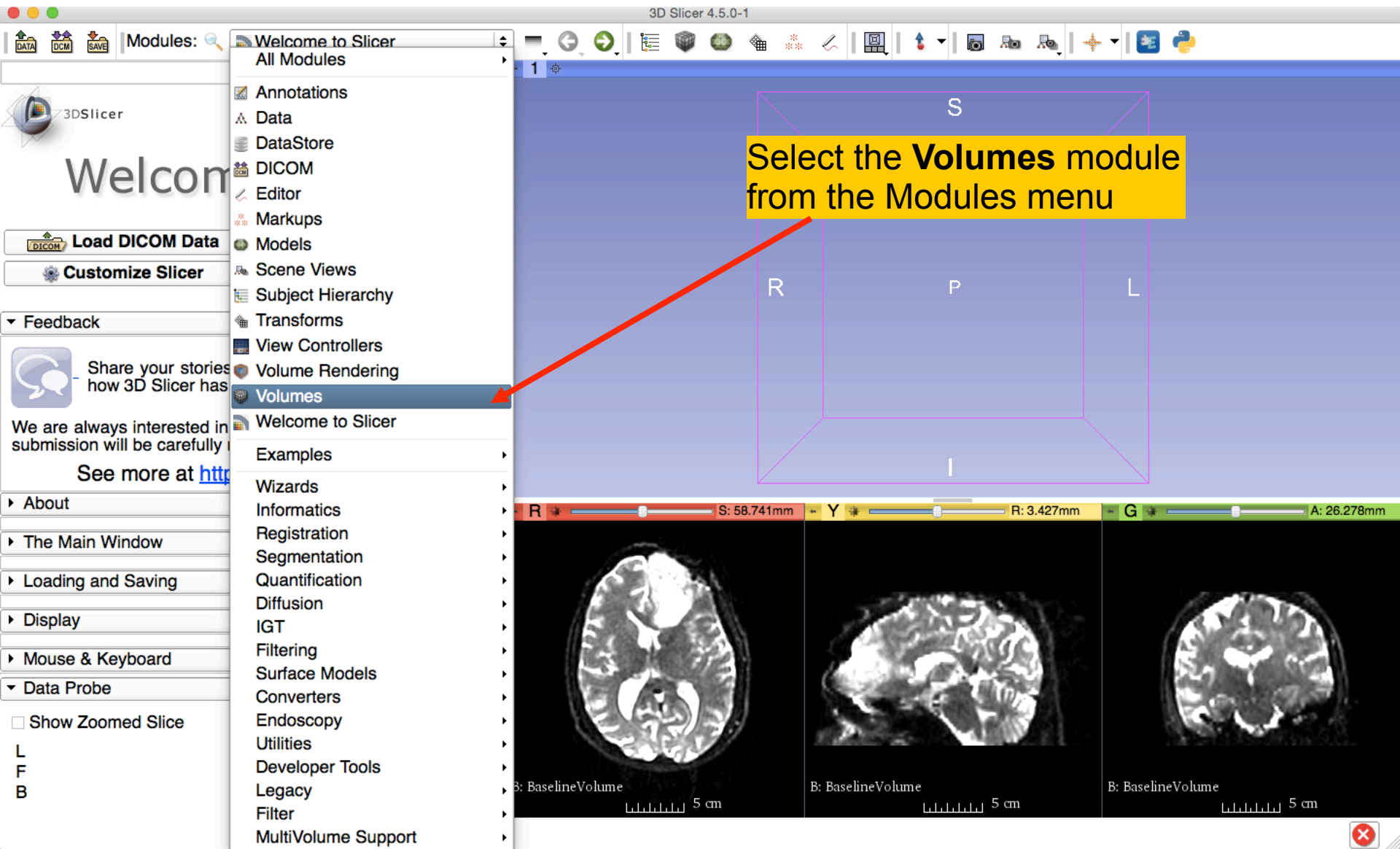
Loading DTI and Baseline Data

The screenshot displays the 3D Slicer 4.5.0-1 interface. On the left, the 'Modules' panel is open, showing 'Welcome to Slicer' and a list of modules including 'Data', 'DICOM', 'SAVE', 'Feeder', 'About', 'The Main Window', 'Loading and Saving', 'Display', 'Mouse & Keyboard', and 'Data Probe'. A yellow text box with a red arrow pointing to the 'Data' module icon contains the following instructions:

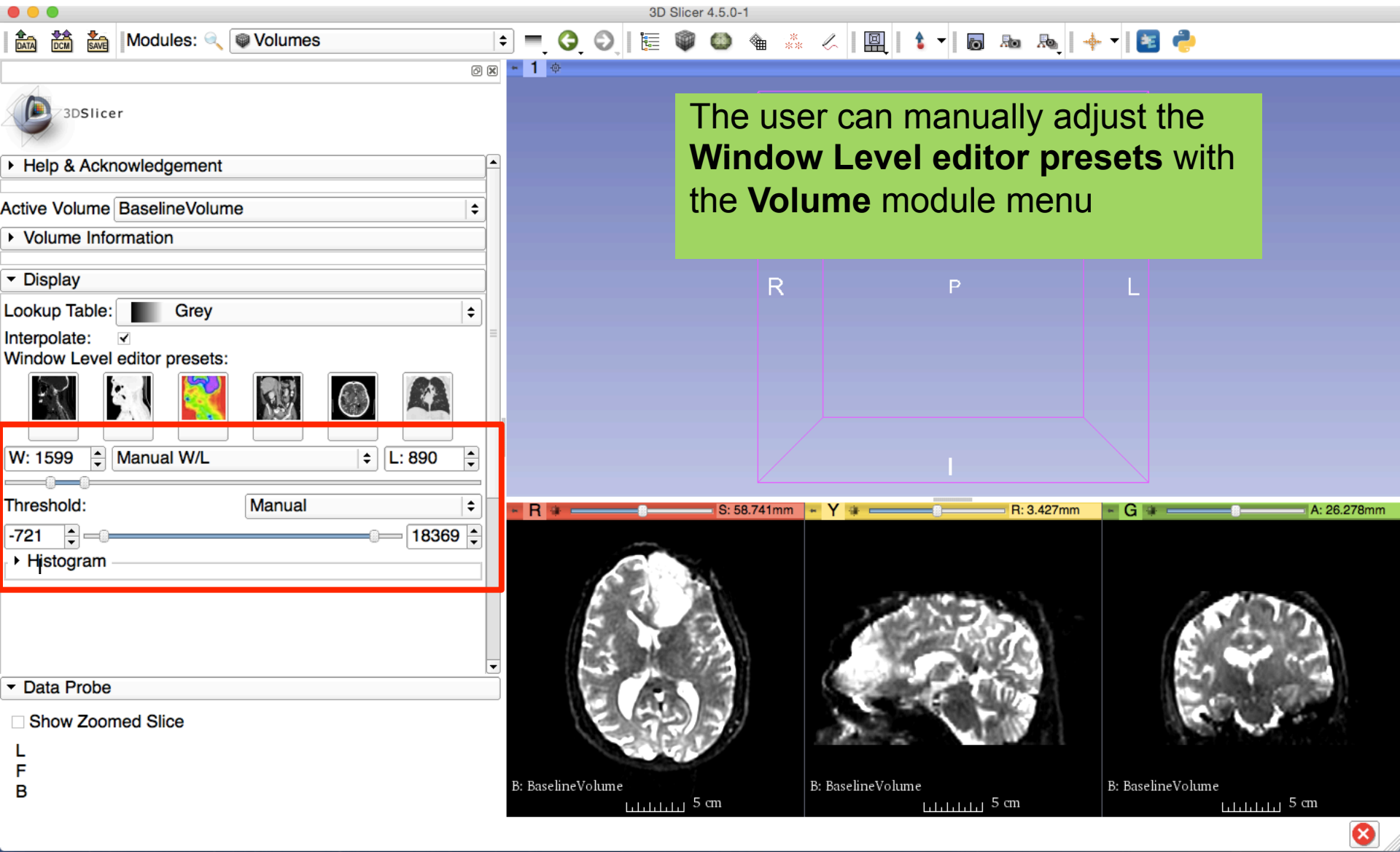
Click on the **pin icon** to display the slice menu, then click on the **link icon** to link the 3 anatomical viewers. Then change the background so it is set to **BaselineVolume**

The main 3D view shows a wireframe box with axes labeled S (Superior), R (Right), P (Posterior), L (Left), and I (Inferior). Below the 3D view, the 'Data' panel is open, showing a list of volumes: 'None', 'BaselineVolume', 'DTIVolume', and 'Rename current Volume'. The 'BaselineVolume' is selected. The 'DTIVolume' is also visible in the list. The 'Data' panel also shows a 'Show Zoomed Slice' checkbox and a 'Data Probe' section with 'L', 'F', and 'B' options. The bottom of the interface shows three anatomical views (Axial, Coronal, and Sagittal) of the DTIVolume, each with a 5 cm scale bar. The 'BaselineVolume' is also visible in the background of these views.

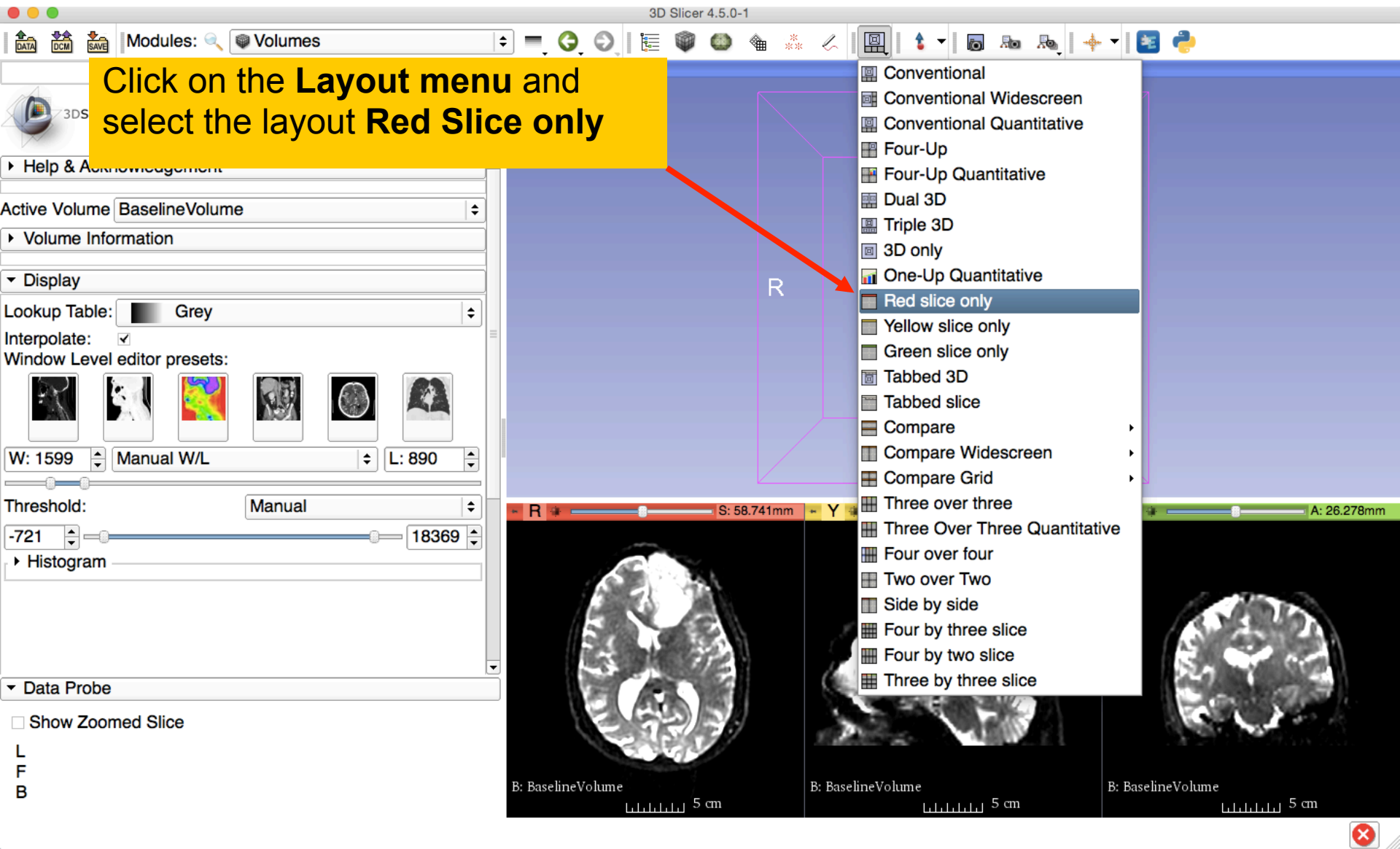
Loading DTI and Baseline Data

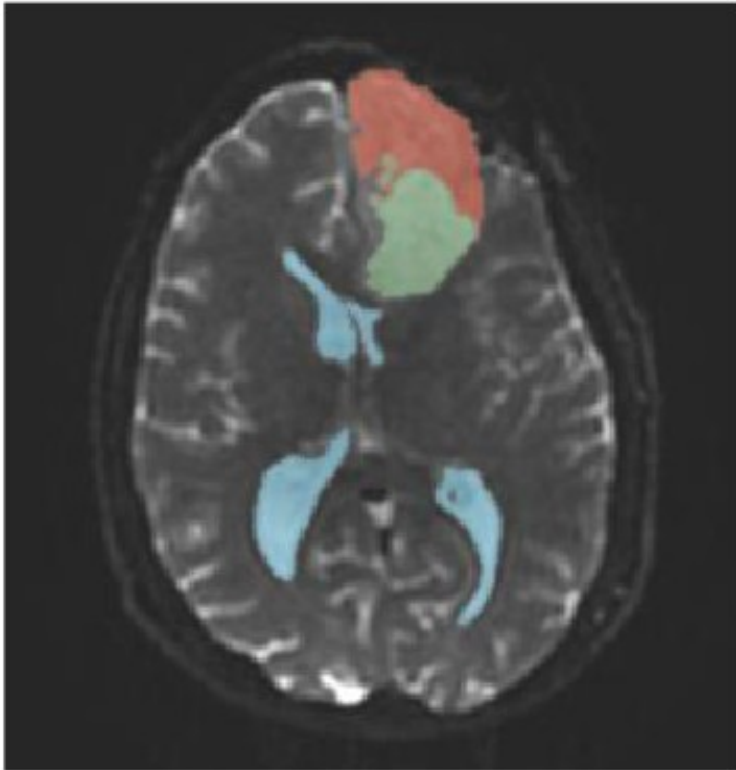


Loading DTI and Baseline Data



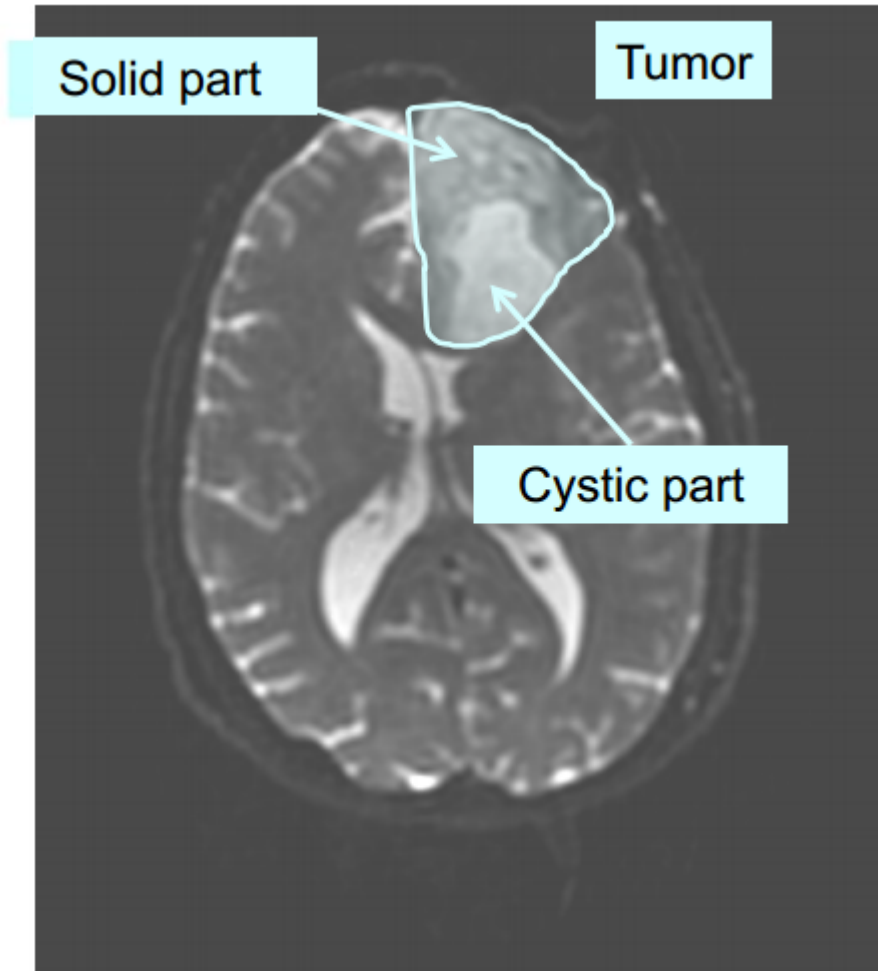
Loading DTI and Baseline Data





Part 1:
Segmenting the
tumor and ventricles

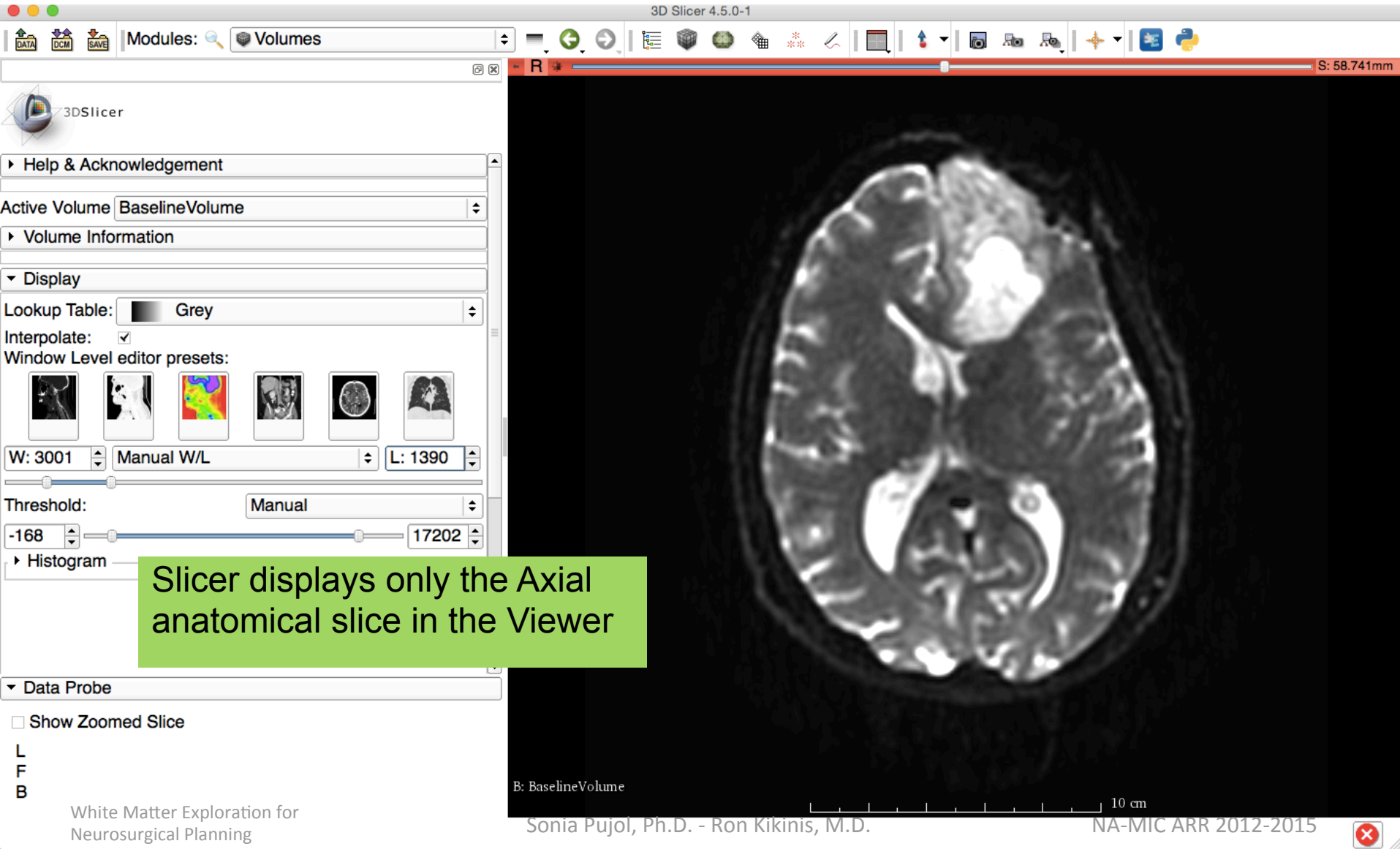
Tumor Segmentation



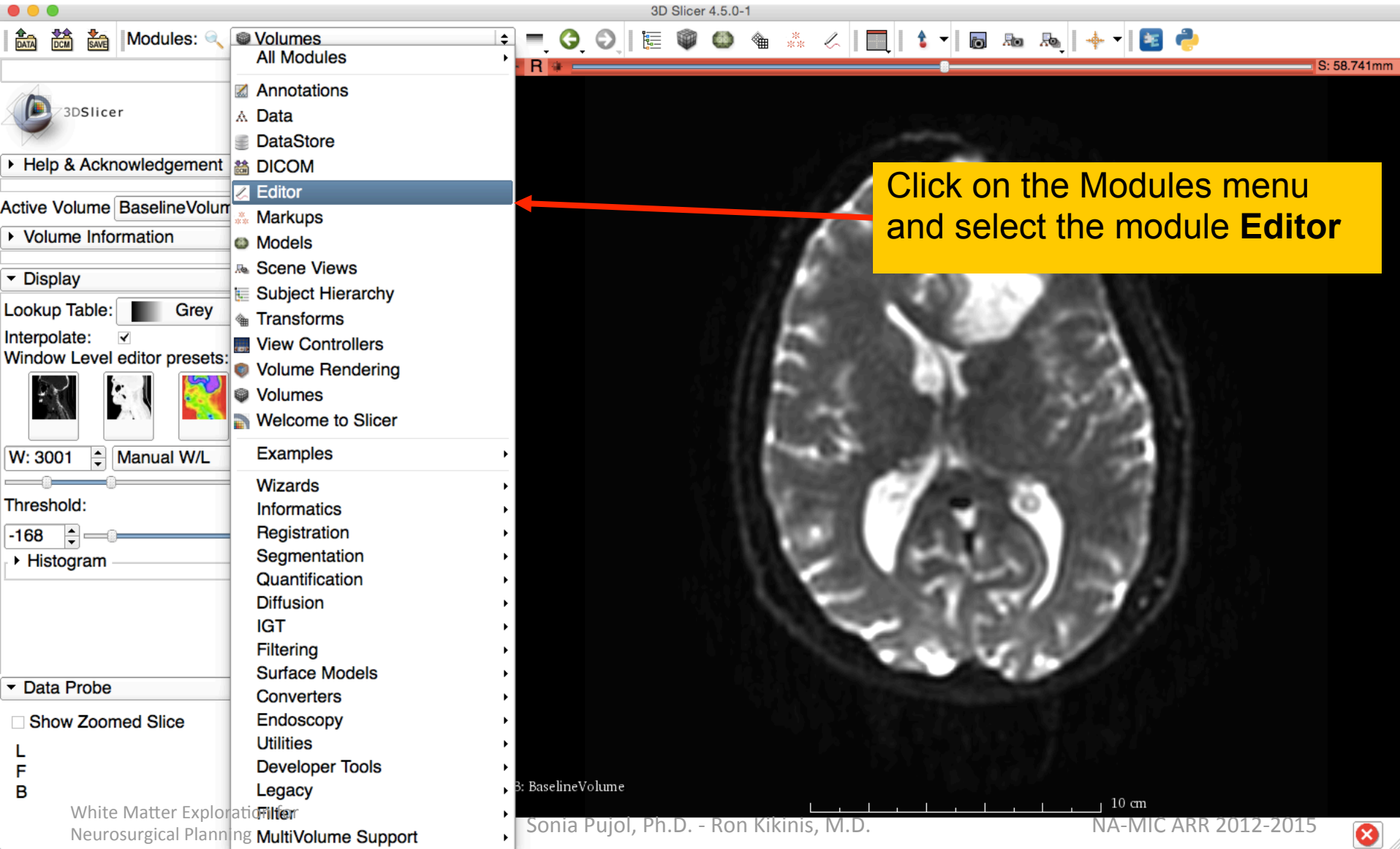
The tumor in this clinical case is composed of two parts: a solid part, and a cystic part.

In this section, we will segment the different parts of the tumor using a Grow Cut Segmentation algorithm.

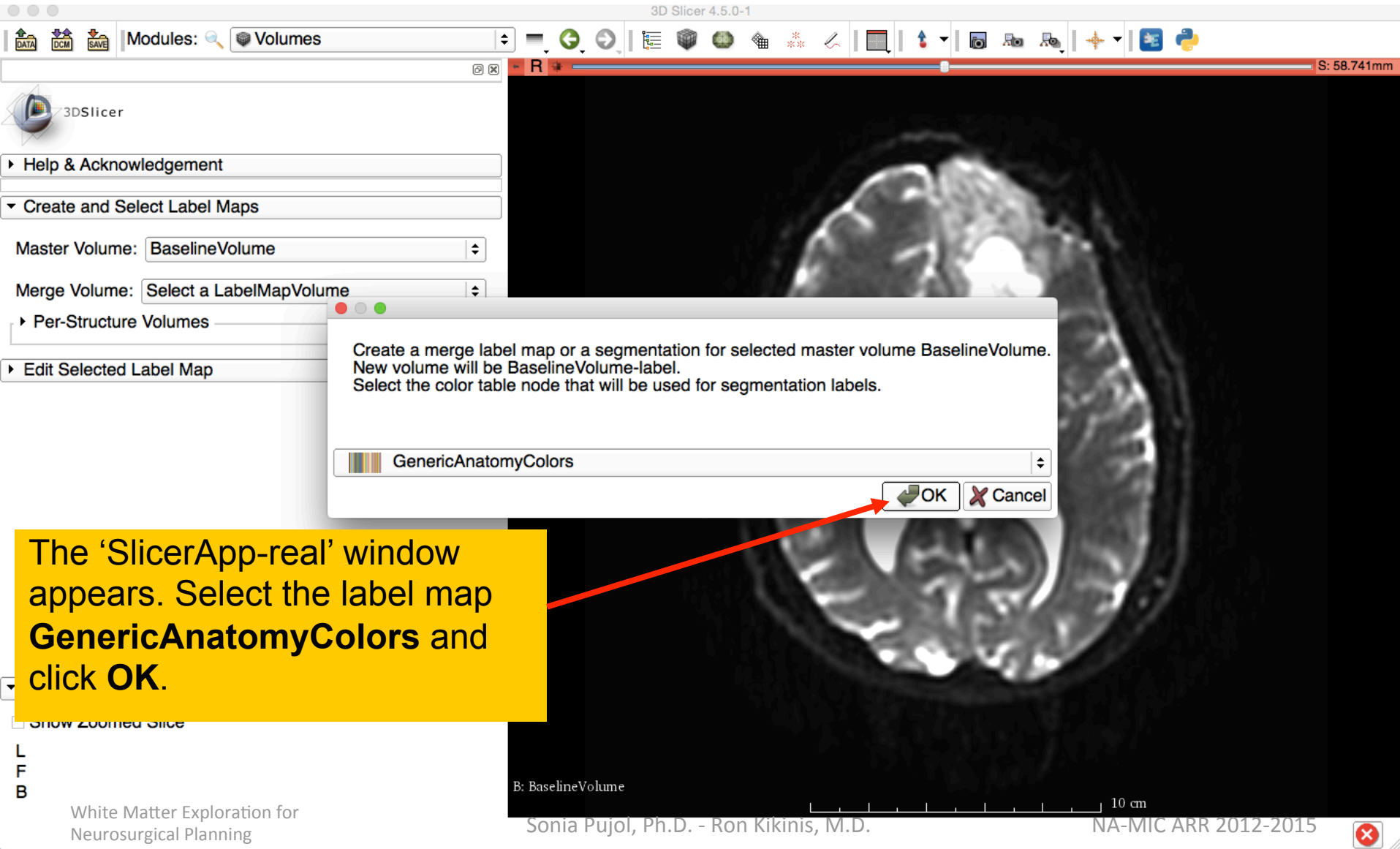
Tumor Segmentation



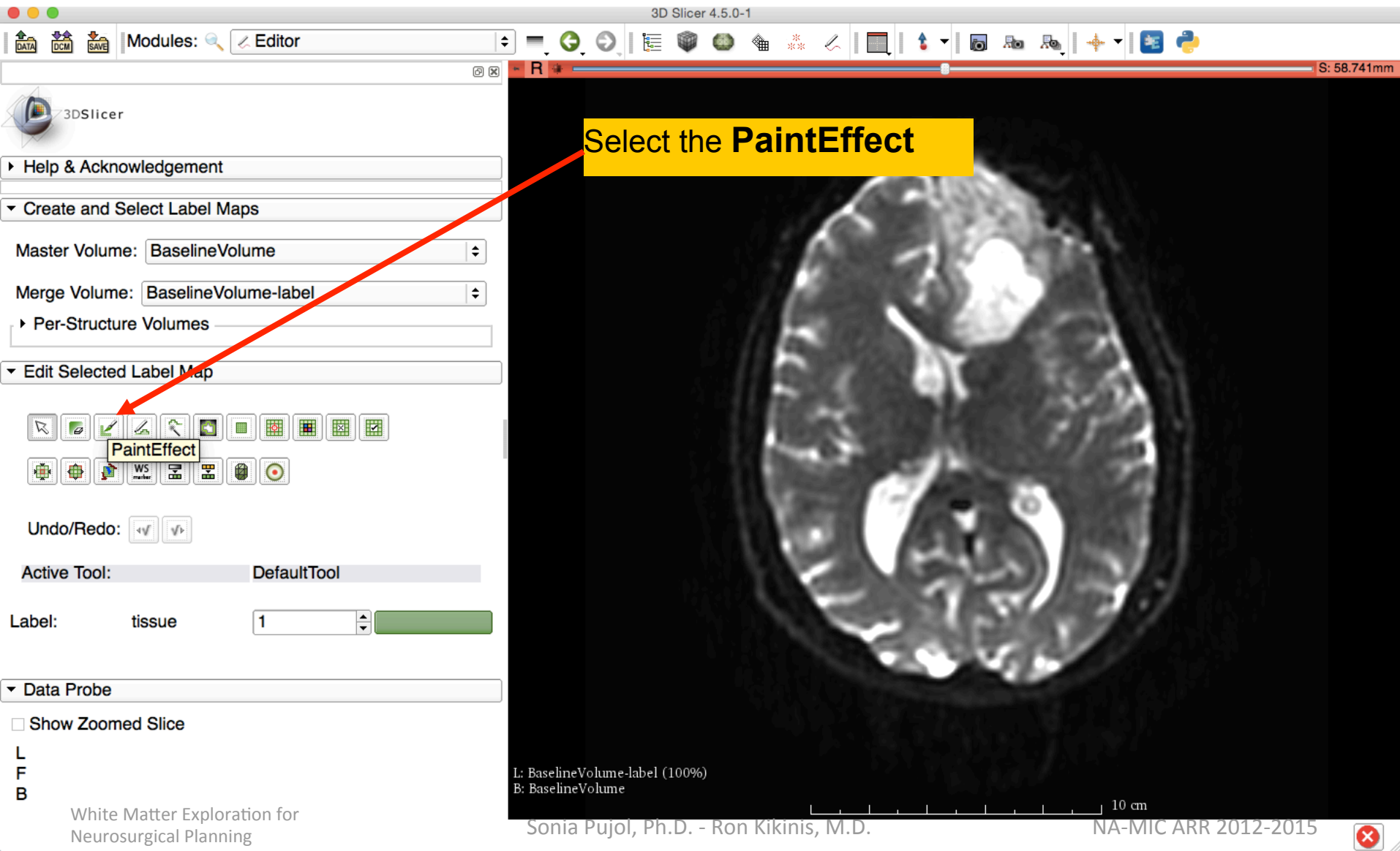
Tumor Segmentation



Tumor Segmentation



Tumor Segmentation



The image shows the 3D Slicer 4.5.0-1 interface. The left sidebar contains the 'Modules' panel with 'Editor' selected. Below it, the 'Create and Select Label Maps' section shows 'Master Volume: BaselineVolume' and 'Merge Volume: BaselineVolume-label'. The 'Edit Selected Label Map' section is active, displaying a toolbar with various tools. A red arrow points from a yellow text box 'Select the PaintEffect' to the 'PaintEffect' icon in the toolbar. Below the toolbar, the 'Undo/Redo' section shows 'Active Tool: DefaultTool' and 'Label: tissue' with a value of '1'. The 'Data Probe' section is at the bottom left. The main window displays an axial MRI slice of a brain with a white tumor region. A scale bar at the bottom right indicates 10 cm. The status bar at the bottom shows 'L: BaselineVolume-label (100%)' and 'B: BaselineVolume'.

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Master Volume: BaselineVolume

Merge Volume: BaselineVolume-label

Per-Structure Volumes

Edit Selected Label Map

PaintEffect

Undo/Redo: [Undo] [Redo]

Active Tool: DefaultTool

Label: tissue 1

Data Probe

Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

Select the PaintEffect

L: BaselineVolume-label (100%)
B: BaselineVolume

10 cm

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Tumor Segmentation

Scroll down the **Editor** module.
Click the **color bar** to search
the pre-defined label.

The screenshot displays the 3D Slicer 4.5.0-1 interface. On the left, the **Editor** module is active, showing a list of tools and a color bar. A red arrow points from the text overlay to the color bar. The color bar is a vertical list of 33 items, each with a number, a color swatch, and a name. The items are:

Number	Color	Name
0	Black	background
1	Dark Green	tissue
2	Light Green	bone
3	Yellow	skin
4	Blue	connective tissue
5	Red	blood
6	Orange	organ
7	Light Blue	mass
8	Dark Blue	muscle
9	Light Green	foreign object
10	Dark Green	waste
11	Yellow	teeth
12	Light Green	fat
13	Light Blue	gray matter
14	Yellow	white matter
15	Yellow	nerve
16	Blue	vein
17	Red	artery
18	Light Blue	capillary
19	Light Blue	ligament
20	Light Blue	tendon
21	Light Blue	cartilage
22	Light Blue	meniscus
23	Light Green	lymph node
24	Light Green	lymphatic vessel
25	Light Blue	cerebro-spinal ...
26	Light Green	bile
27	Light Green	urine
28	Light Green	feces
29	Light Green	gas
30	Light Blue	fluid
31	Light Blue	edema
32	Light Blue	bleeding
33	Light Blue	residual

The right side of the interface shows a 3D rendering of a brain slice with a tumor. The tumor is highlighted in white. The interface also includes a search bar, a list of tools, and a color bar. The bottom of the interface shows the text "White Matter Exploration for Neurosurgical Planning" and "Sonia Pujol, Ph.D. - Ron Kikinis, M.D.".

Tumor Segmentation

Input **cyst** and select number **309** for cystic part of the tumor.

3D Slicer 4.5.0-1

Search: cyst

Number	Color	Name
309		cyst

Help & Acknowledgement

Create and Select Label Maps

Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: PaintEffect

Label: tissue 1

☒ Paint Over

☐ Threshold Paint

Radius: 25.000mm px: 2 3 4 5 10 20

☐ Sphere

Data Probe

☐ Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

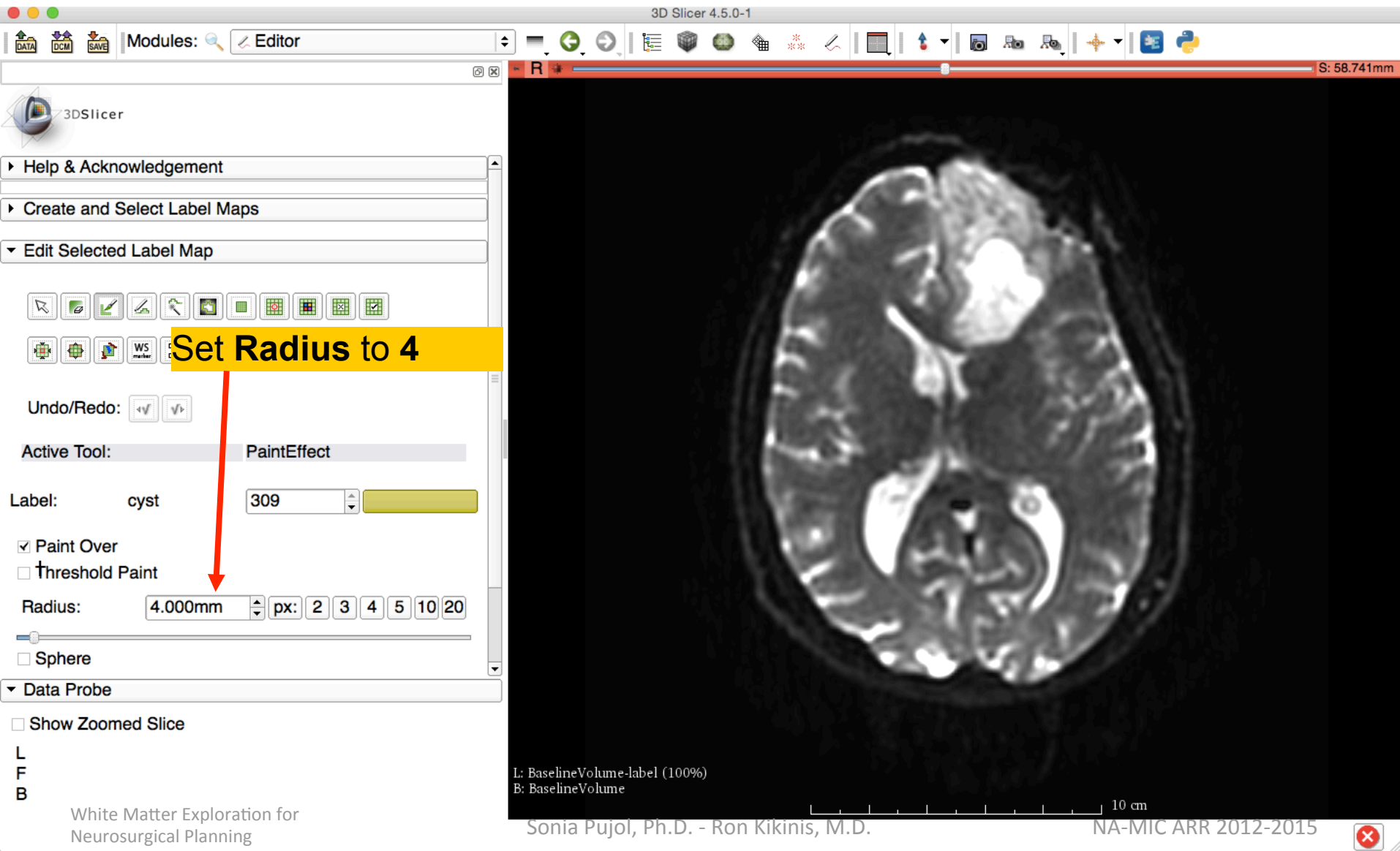
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10 cm

S: 58.741mm

Tumor Segmentation



The screenshot displays the 3D Slicer 4.5.0-1 software interface. The left sidebar contains the 'Modules' panel with 'Editor' selected. Below it, the 'Edit Selected Label Map' section is active, showing a toolbar with various painting tools. A yellow callout box with the text 'Set Radius to 4' has a red arrow pointing to the 'Radius' field, which is currently set to '4.000mm'. The 'Active Tool' is 'PaintEffect', and the 'Label' is 'cyst' with a value of '309'. The 'Paint Over' checkbox is checked, and the 'Threshold Paint' checkbox is unchecked. The 'Data Probe' section at the bottom left shows 'Show Zoomed Slice' unchecked. The main 3D view displays an axial MRI slice of a brain with a white, segmented tumor region. The bottom status bar indicates 'L: BaselineVolume-label (100%)' and 'B: BaselineVolume'. A scale bar at the bottom right shows '10 cm'.

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Help & Acknowledgement

Create and Select Label Maps

Edit Selected Label Map

Set Radius to 4

Undo/Redo: [Undo] [Redo]

Active Tool: PaintEffect

Label: cyst 309

☒ Paint Over

☐ Threshold Paint

Radius: 4.000mm px: 2 3 4 5 10 20

☐ Sphere

Data Probe

☐ Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

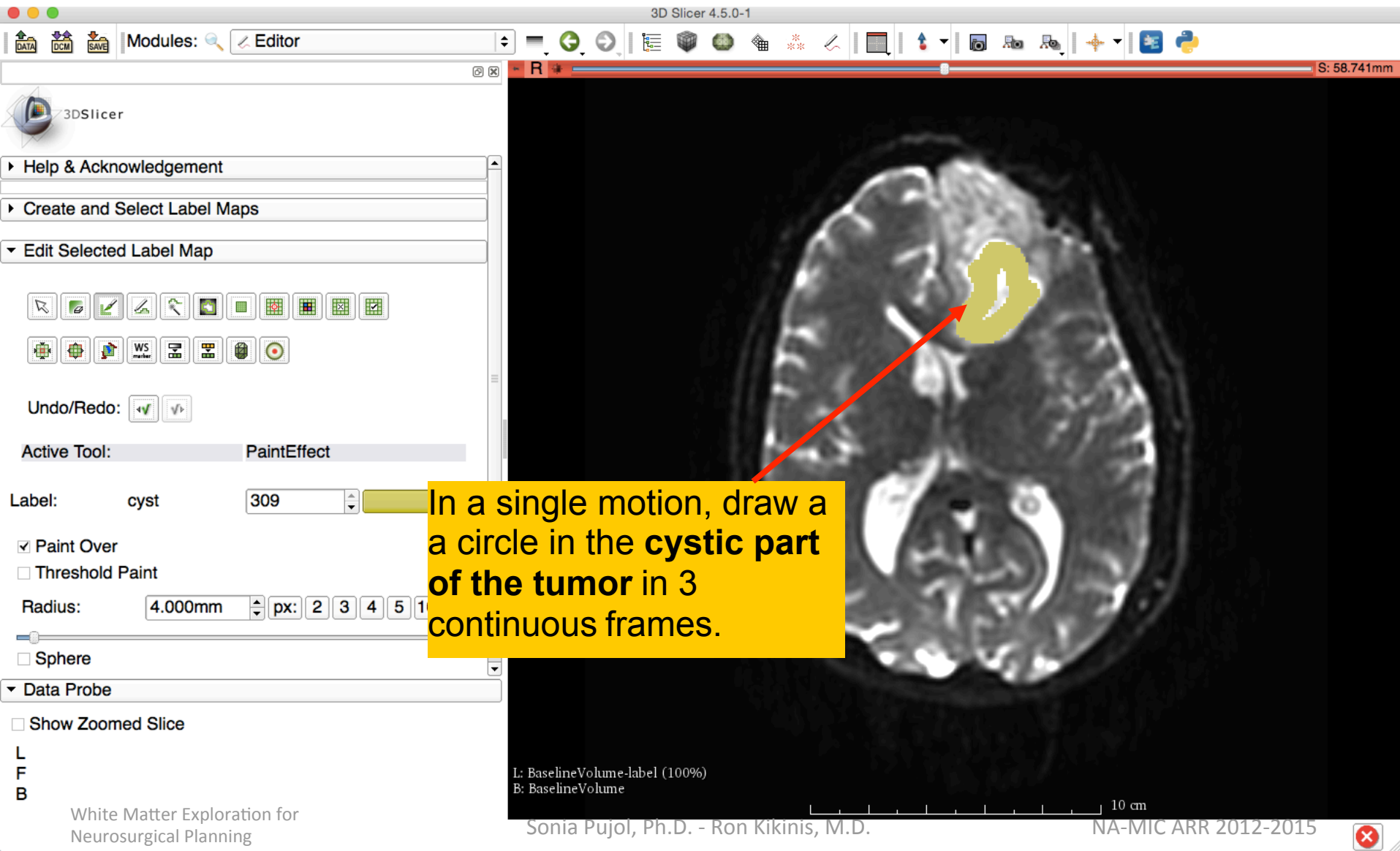
L: BaselineVolume-label (100%)
B: BaselineVolume

10 cm

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Tumor Segmentation



Tumor Segmentation

Input **mass** and select number 7 for solid part of the tumor.

3D Slicer 4.5.0-1

Search: mass

Number	Color	Name
309		cyst
7		mass
7		mass

Label: mass 7

Active Tool: PaintEffect

Radius: 4.000mm px: 2 3 4 5 10 20

Undo/Redo: [Undo] [Redo]

Paint Over [checked] Threshold Paint [unchecked]

Data Probe [unchecked]

Show Zoomed Slice [unchecked]

L F B

White Matter Exploration for Neurosurgical Planning

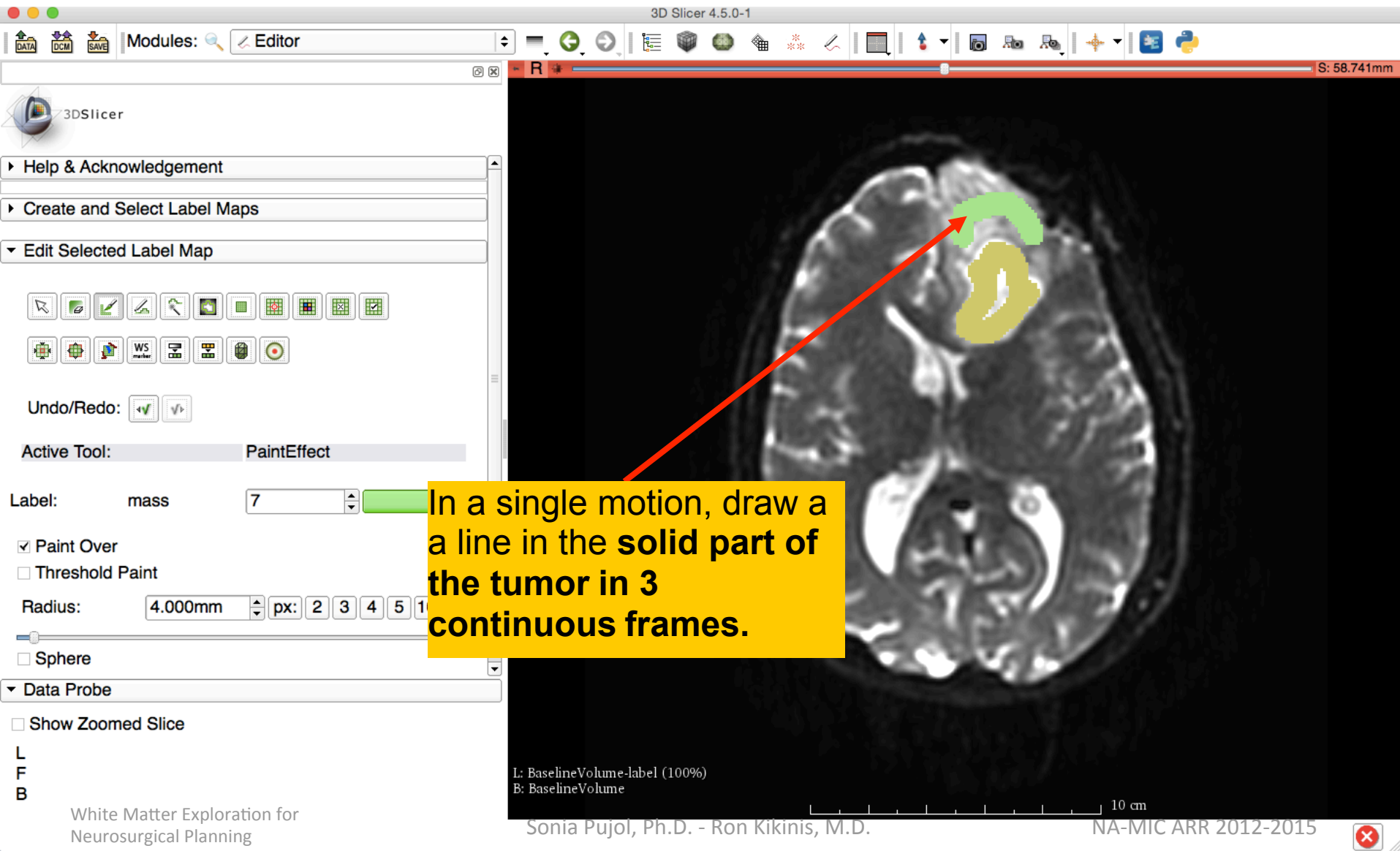
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10 cm

S: 58.741mm

Tumor Segmentation



Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

► Help & Acknowledgement

► Create and Select Label Maps

▼ Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: PaintEffect

Label: ventricles of brain 107

☒ Paint Over

☐ Threshold Paint

Radius: 4.000mm px: 2 3 4 5 10 20

☐ Sphere

▼ Data Probe

☐ Show Zoomed Slice

L
F
B

White Matter Exploration for
Neurosurgical Planning

L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

S: 58.541mm

Select color #107 and draw a circle around the solid and cystic parts of the tumor.

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Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

S: 58.541mm

Select the **GrowCutEffect** tool.

Edit Selected Label Map

GrowCutEffect

Undo/Redo: [Undo] [Redo]

Active Tool: PaintEffect

Label: ventricles of brain 107

☒ Paint Over
☐ Threshold Paint

Radius: 4.000mm px: 2 3 4 5 10 20

☐ Sphere

Data Probe

☐ Show Zoomed Slice

L
F
B

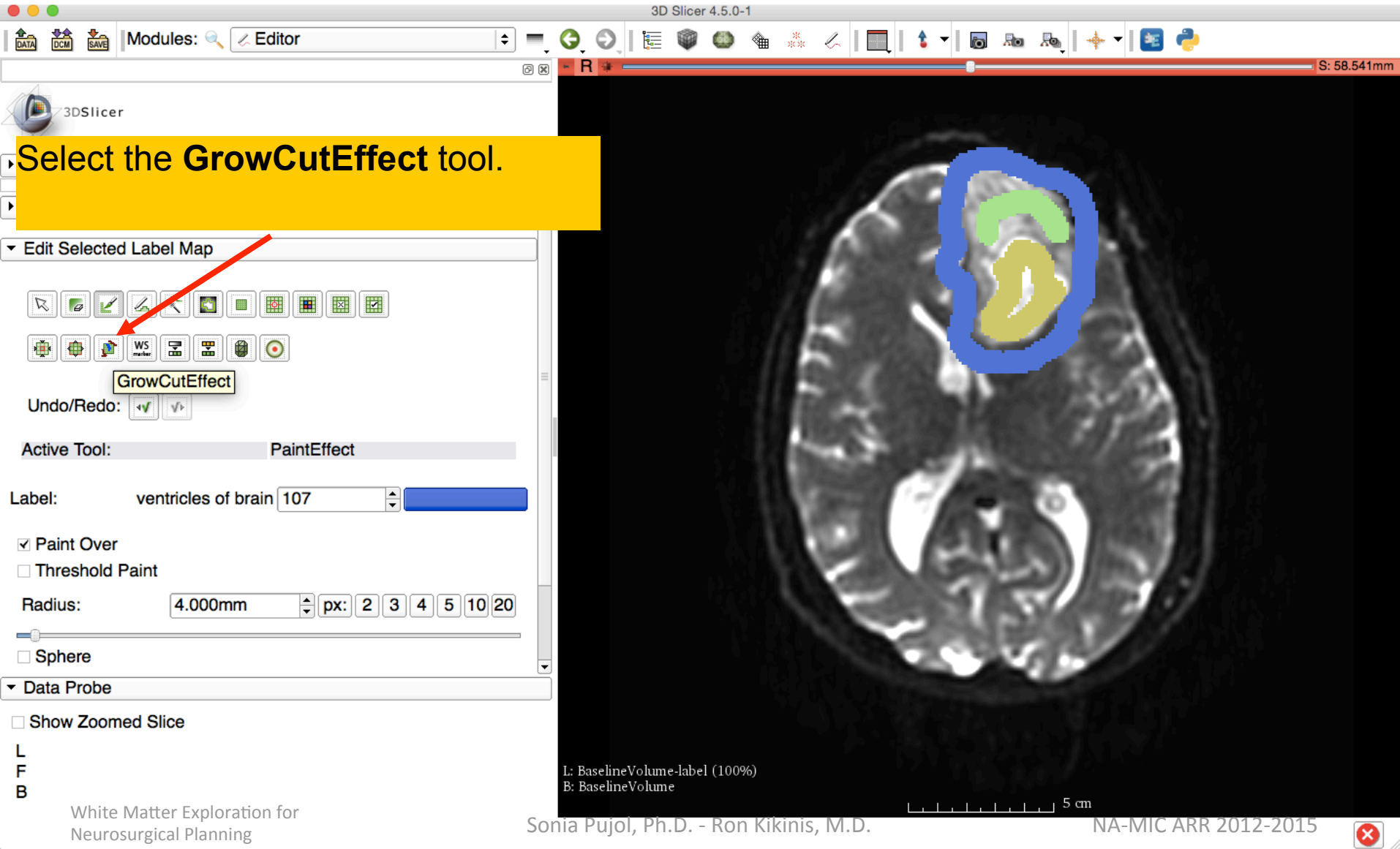
White Matter Exploration for
Neurosurgical Planning

L: BaselineVolume-label (100%)
B: BaselineVolume

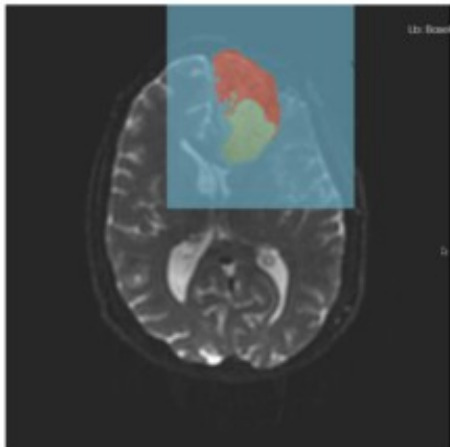
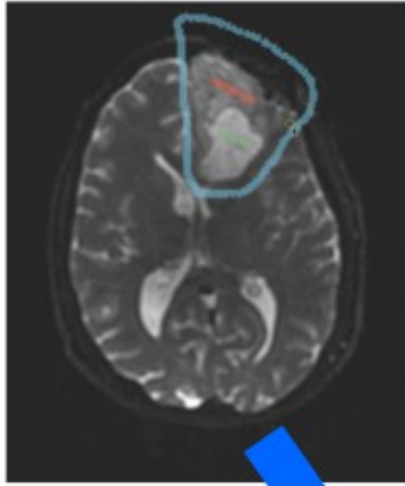
5 cm

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Grow Cut Segmentation



- The Grow Cut Segmentation method is a competitive region growing algorithm using Cellular Automata.
- The algorithm performs multi-label image segmentation using a set of user input scribbles.
- V. Vezhnevets, V. Konouchine. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". Proc. Graphicon. 2005 . pp. 150-156.

Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

- Help & Acknowledgement
- Create and Select Label Maps
- Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: GrowCutEffect

Label: ventricles of brain 107

Run the GrowCut segmentation on the current label map. This will use your current segmentation as an example to fill in the rest of the volume.

Apply

Apply to run segmentation. Creates a new label volume using the current

Click **Apply** to apply the **GrowCutEffect** segmentation algorithm.

White Matter Exploration for Neurosurgical Planning

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Tumor Segmentation

3D Slicer 4.5.0-1

Modules: Editor

Slicer displays the results from the segmentation

Help & Ack
Create and
Edit Selected Label Map

Undo/Redo: [Undo] [Redo]

Active Tool: GrowCutEffect

Label: ventricles of brain 107

Run the GrowCut segmentation on the current label map. This will use your current segmentation as an example to fill in the rest of the volume.

Apply

Data Probe

☐ Show Zoomed Slice

L
F
B

White Matter Exploration for Neurosurgical Planning

Solid part

Cystic part

L: BaselineVolume-label (100%)
B: BaselineVolume

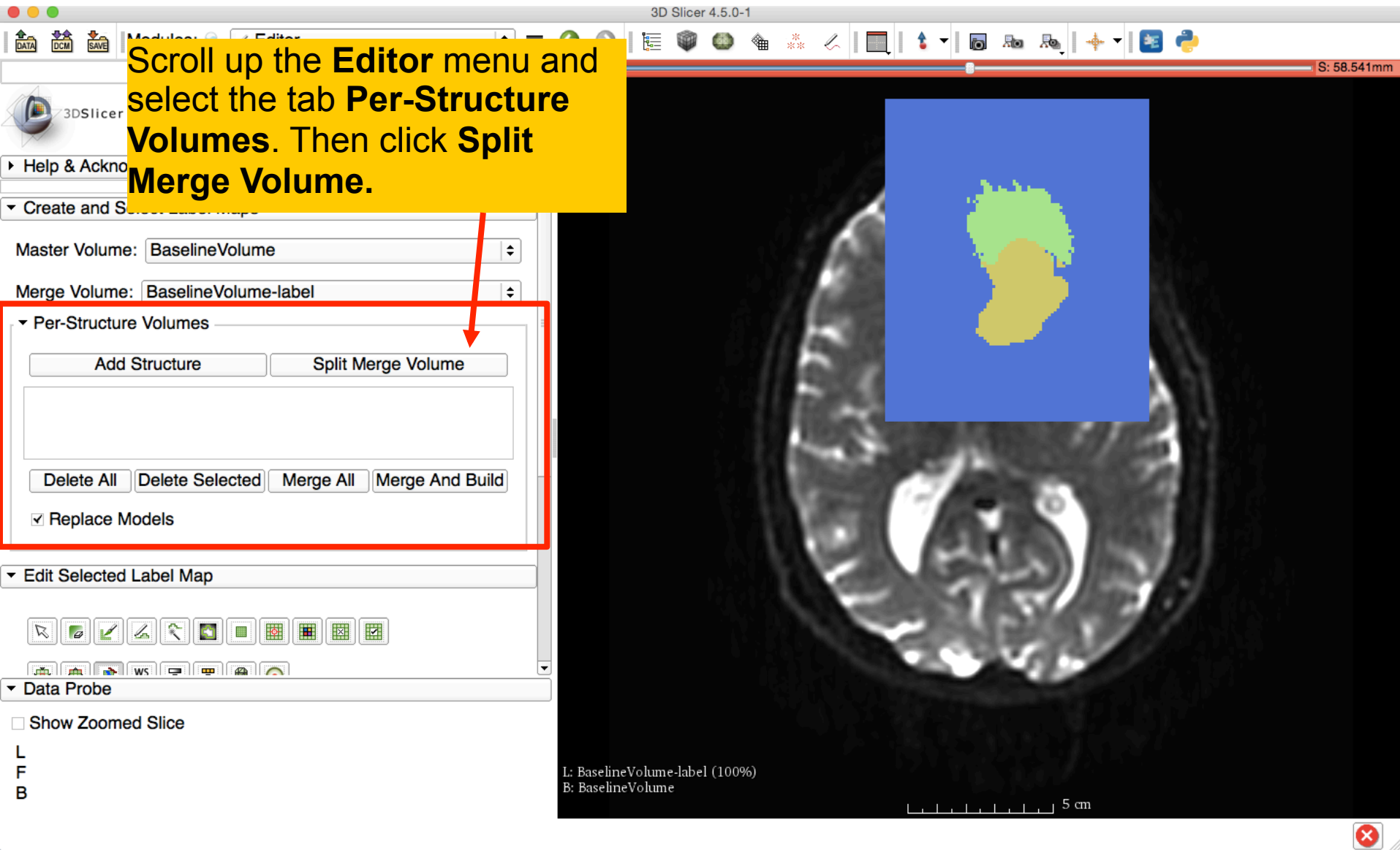
5 cm

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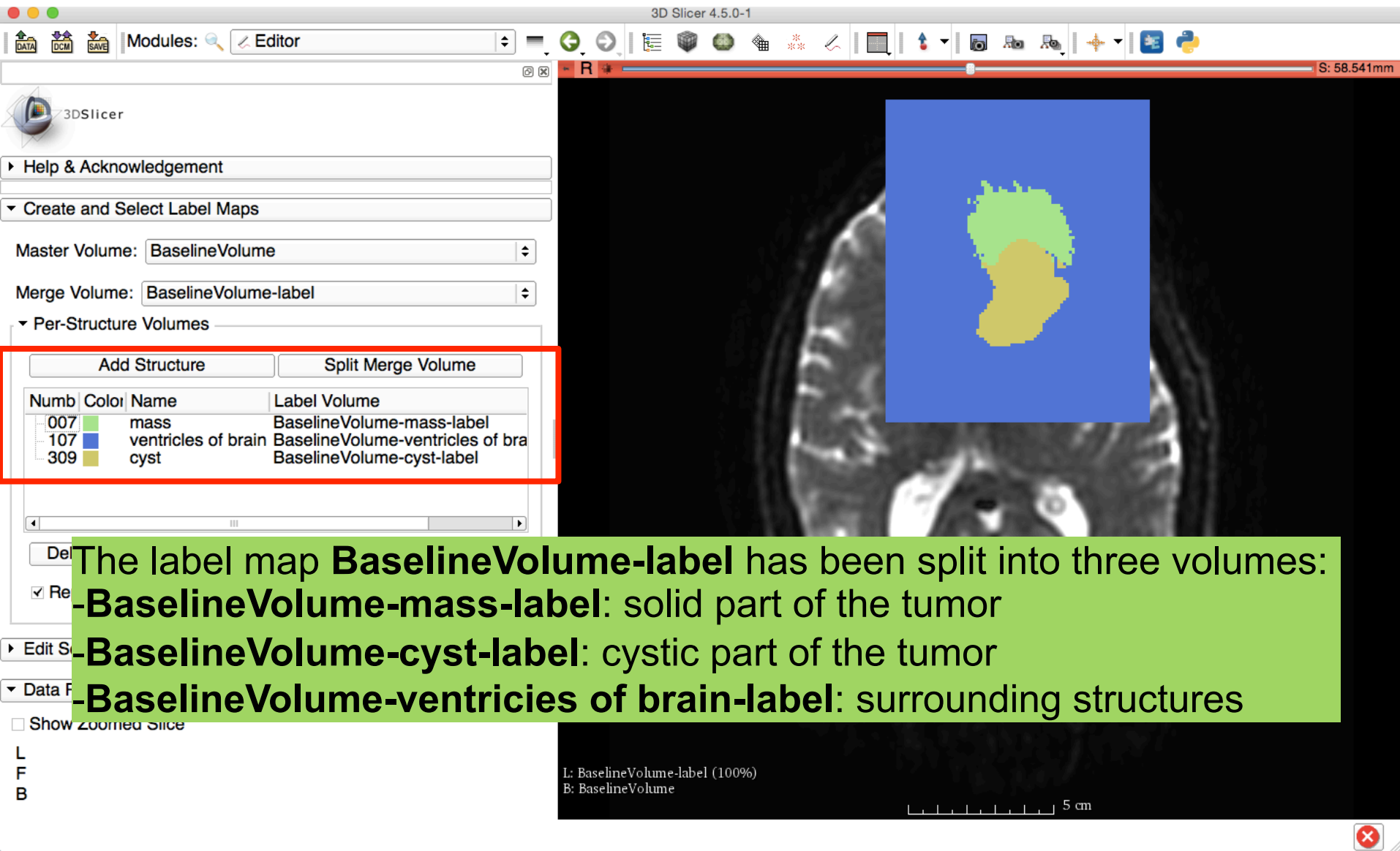
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Tumor Segmentation

Scroll up the **Editor** menu and select the tab **Per-Structure Volumes**. Then click **Split Merge Volume**.



Tumor Segmentation



3D Slicer 4.5.0-1

Modules: Editor

Help & Acknowledgement

Create and Select Label Maps

Master Volume: BaselineVolume

Merge Volume: BaselineVolume-label

Per-Structure Volumes

Numb	Color	Name	Label Volume
007	Green	mass	BaselineVolume-mass-label
107	Blue	ventricles of brain	BaselineVolume-ventricles of bra
309	Yellow	cyst	BaselineVolume-cyst-label

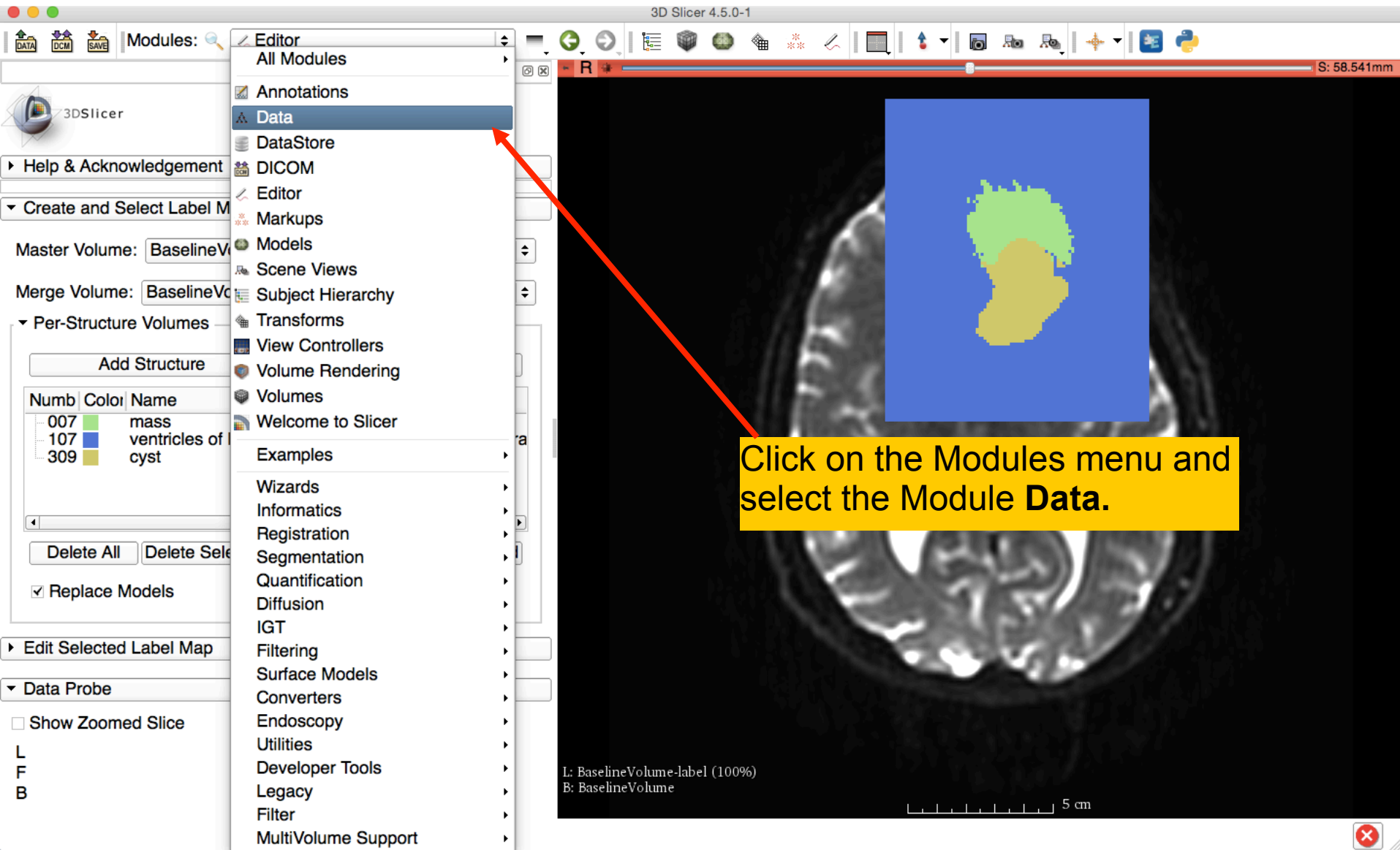
The label map **BaselineVolume-label** has been split into three volumes:

- BaselineVolume-mass-label**: solid part of the tumor
- BaselineVolume-cyst-label**: cystic part of the tumor
- BaselineVolume-ventricles of brain-label**: surrounding structures

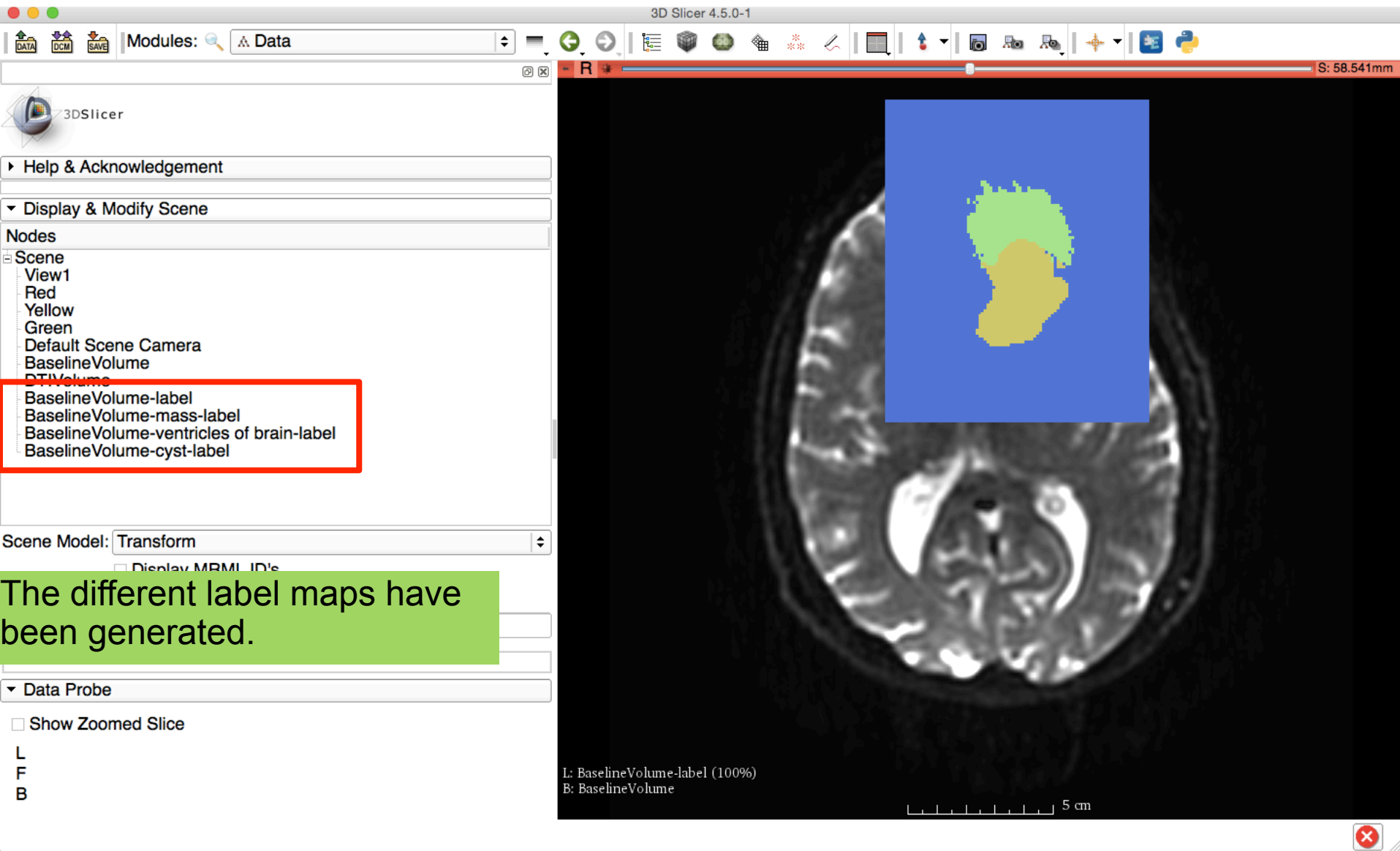
L: BaselineVolume-label (100%)
B: BaselineVolume

5 cm

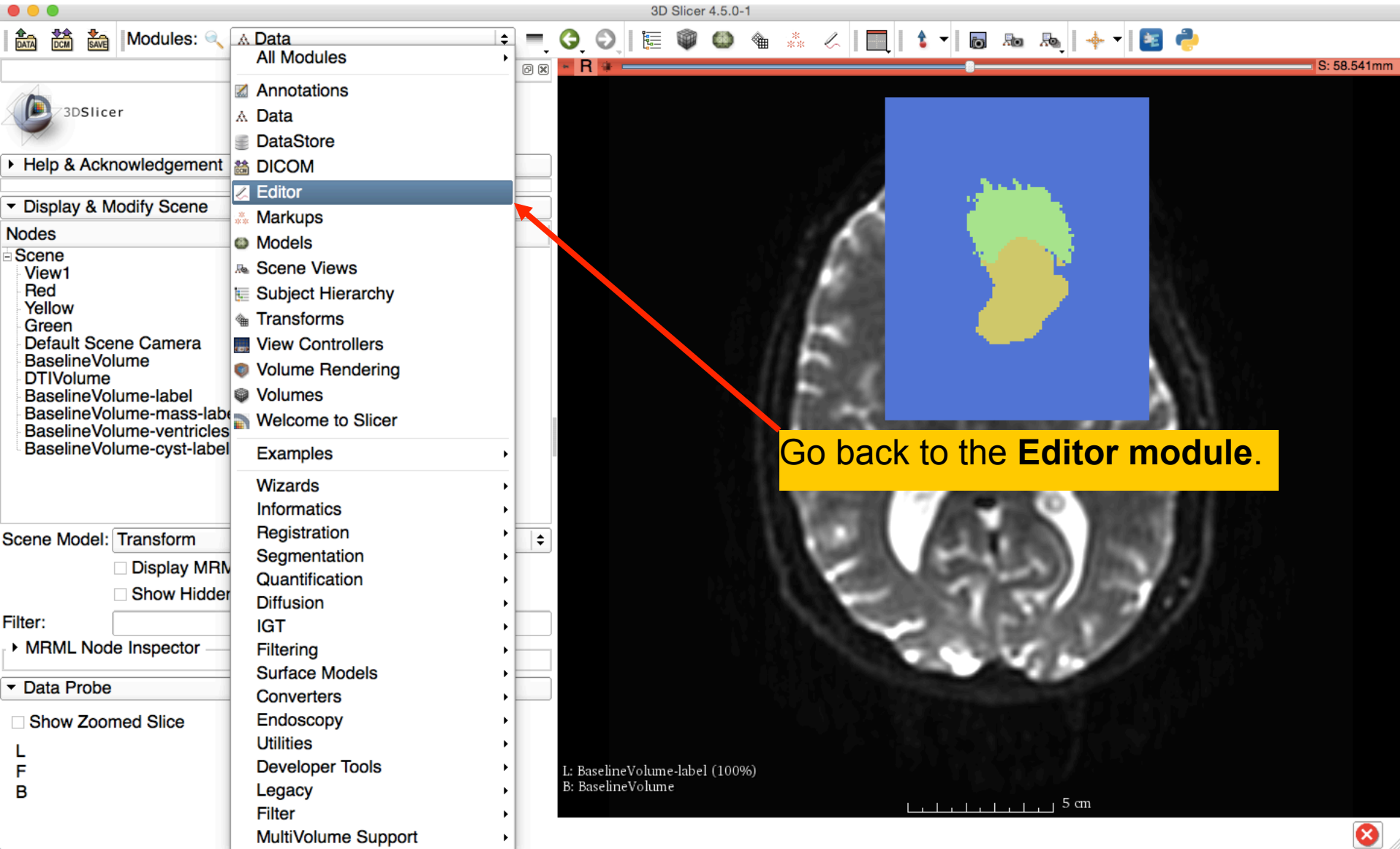
Tumor Segmentation



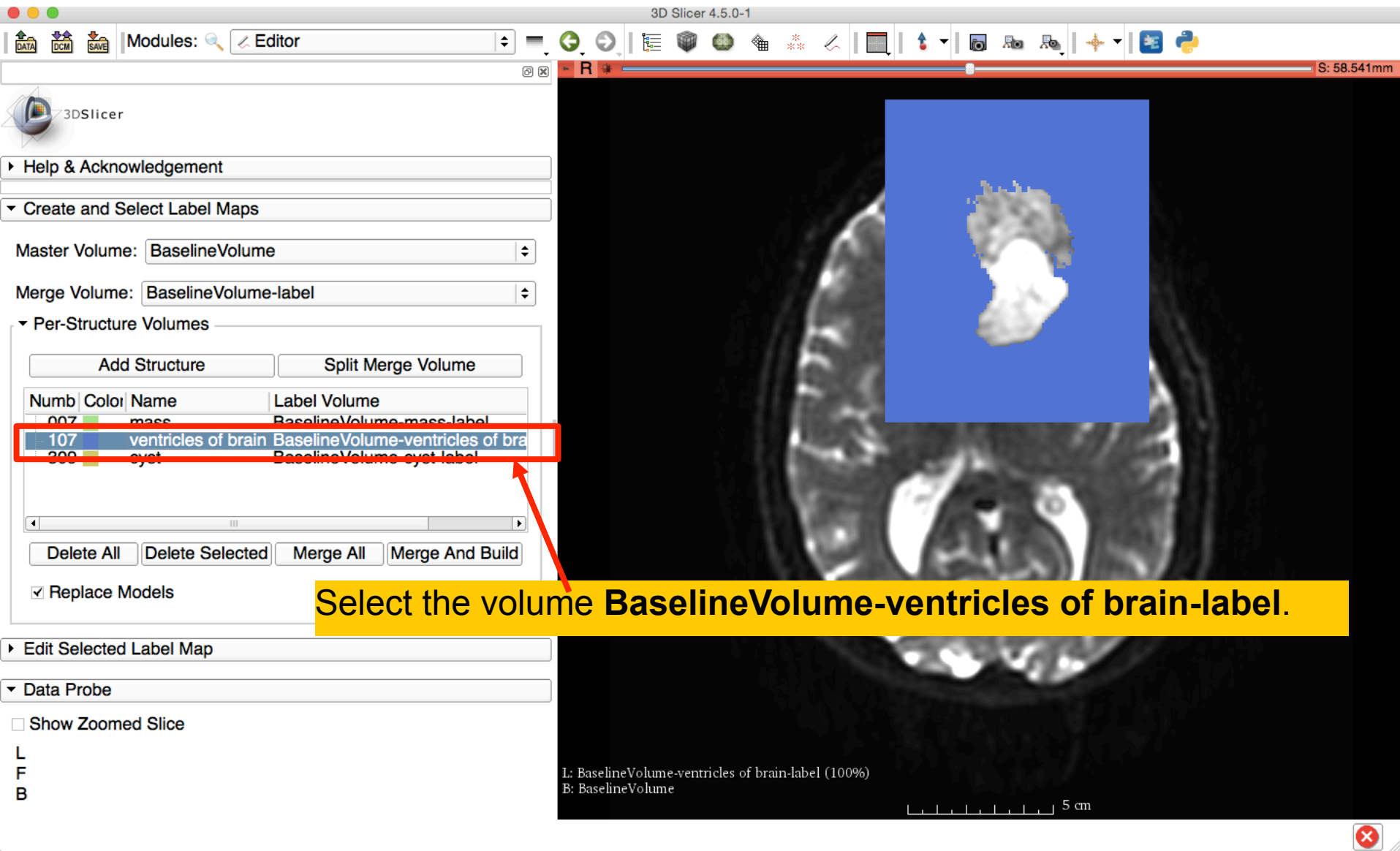
Tumor Segmentation



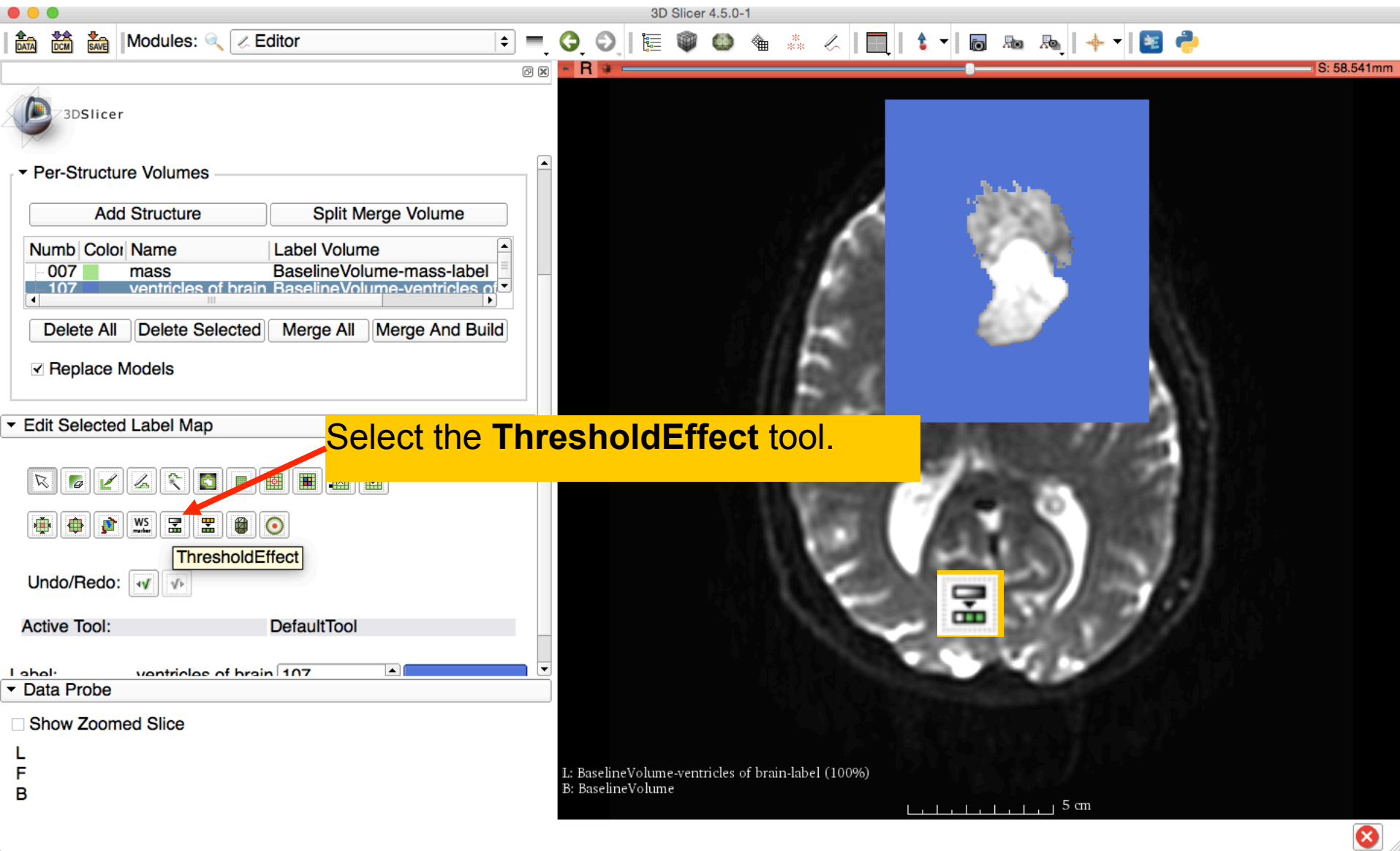
Ventricles Segmentation



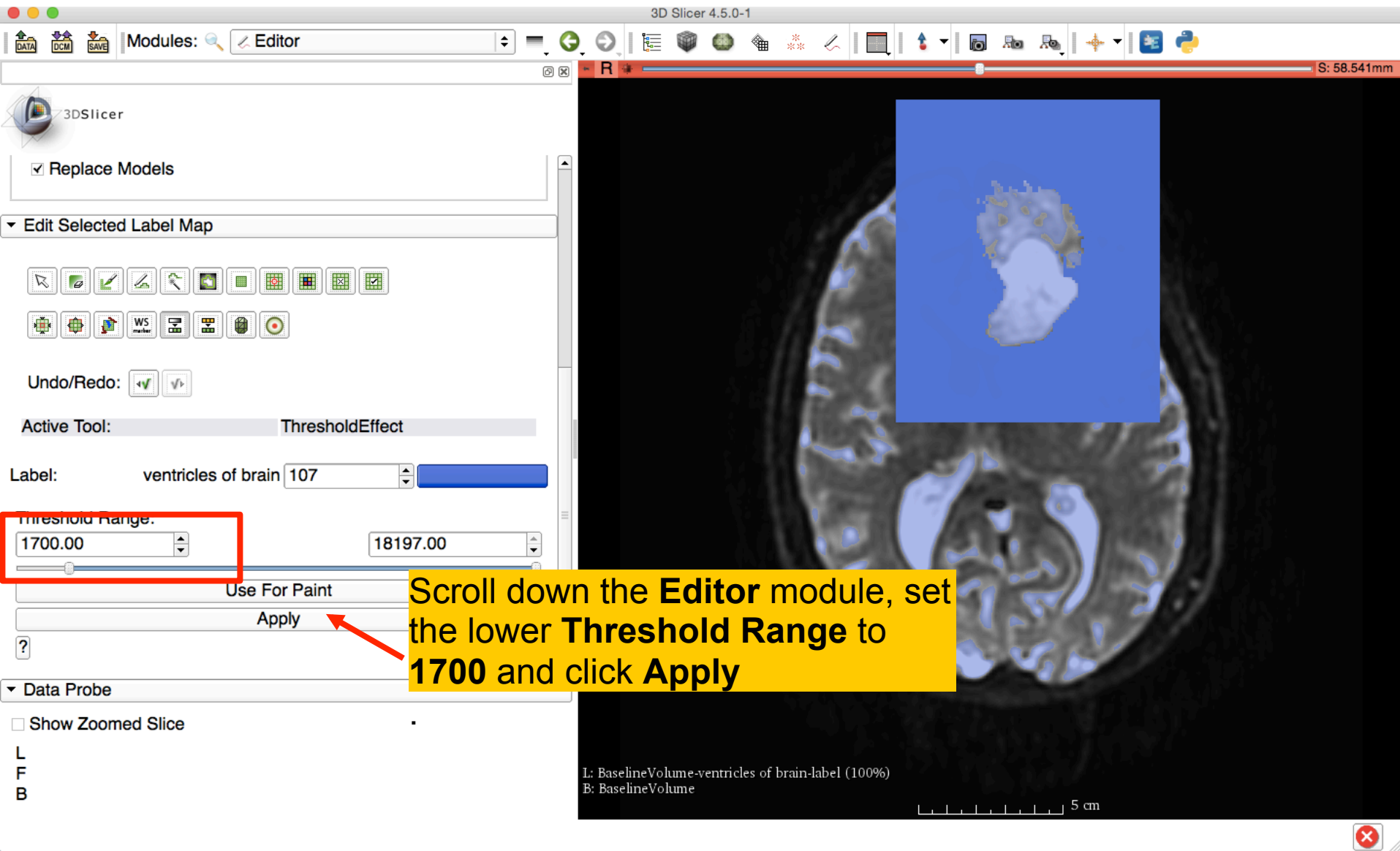
Ventricles Segmentation



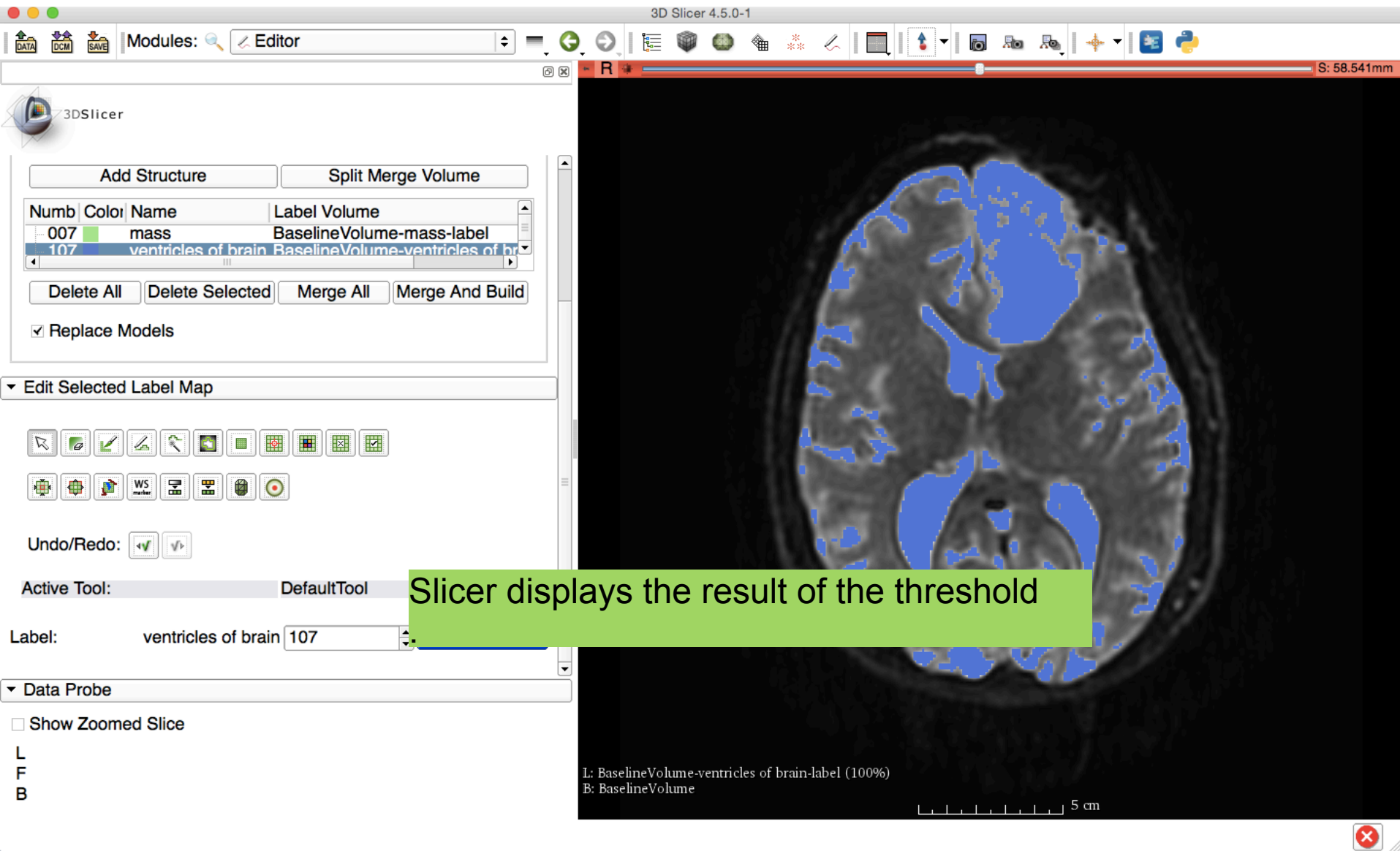
Ventricles Segmentation



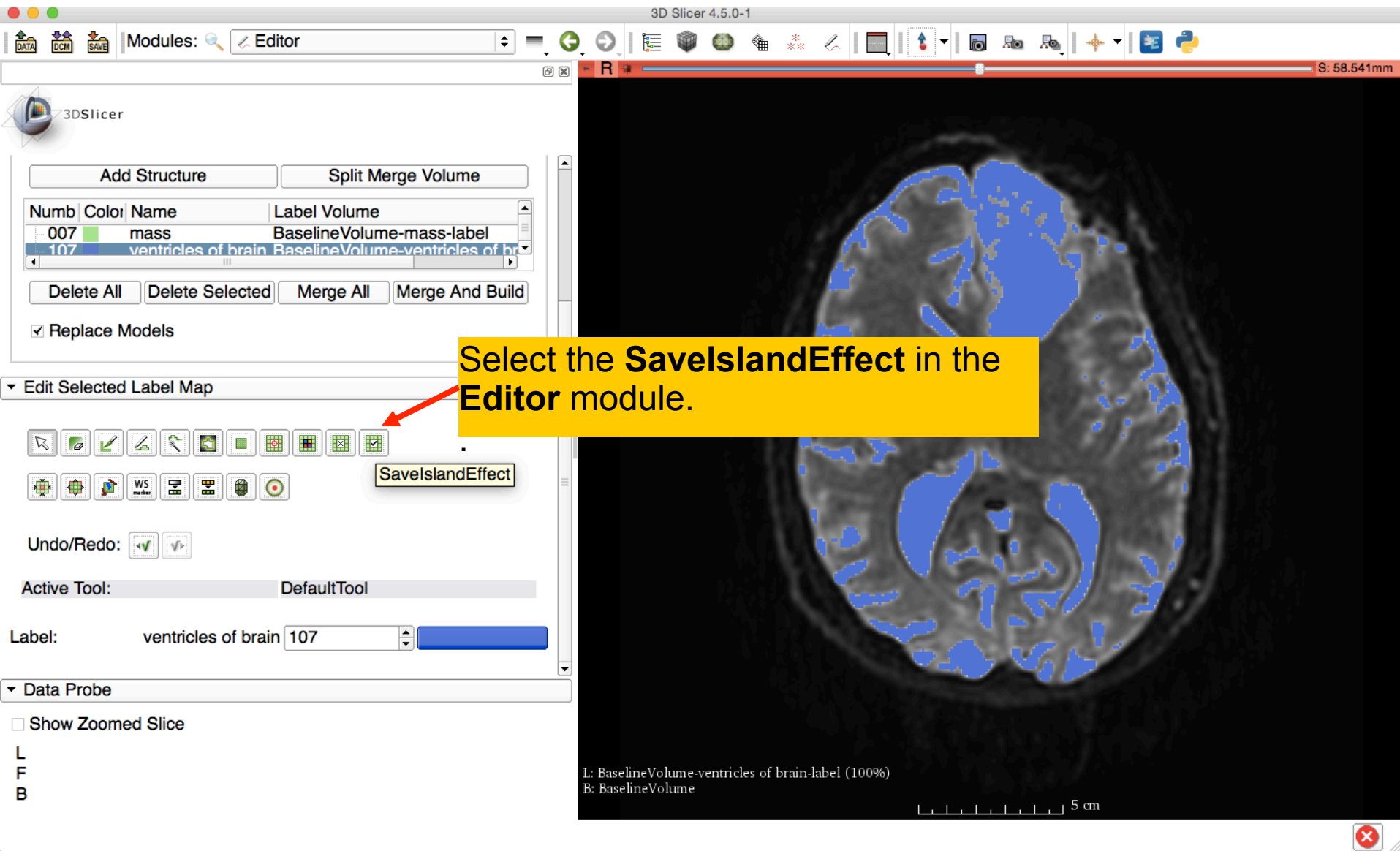
Ventricles Segmentation



Ventricles Segmentation



Ventricles Segmentation



Ventricles Segmentation

The screenshot displays the 3D Slicer 4.5.0-1 interface. The main window shows an axial MRI slice of a brain with segmented ventricles highlighted in blue. A red arrow points to the occipital horn of the ventricle. The left sidebar contains the 'Add Structure' and 'Split Merge Volume' buttons, a table of structures, and the 'Edit Selected Label Map' section. The bottom status bar shows the current slice and volume information.

3D Slicer 4.5.0-1

Modules: Editor

3DSlicer

Add Structure Split Merge Volume

Numb	Color	Name	Label Volume
007		mass	BaselineVolume-mass-label
107		ventricles of brain	BaselineVolume-ventricles of brain-label

Delete All Delete Selected Merge All Merge And Build

☒ Replace Models

▼ Edit Selected Label Map

Undo/Redo: ☒ ☐

Active Label: Click in the occipital horn of the ventricle .

▼ Data Probe

Red RAS: (26.9, 2.3, 58.5) Axial Sp: 2.6

L BaselineVolume-mass-label (103, 151, 25) ventricles of brain (107)

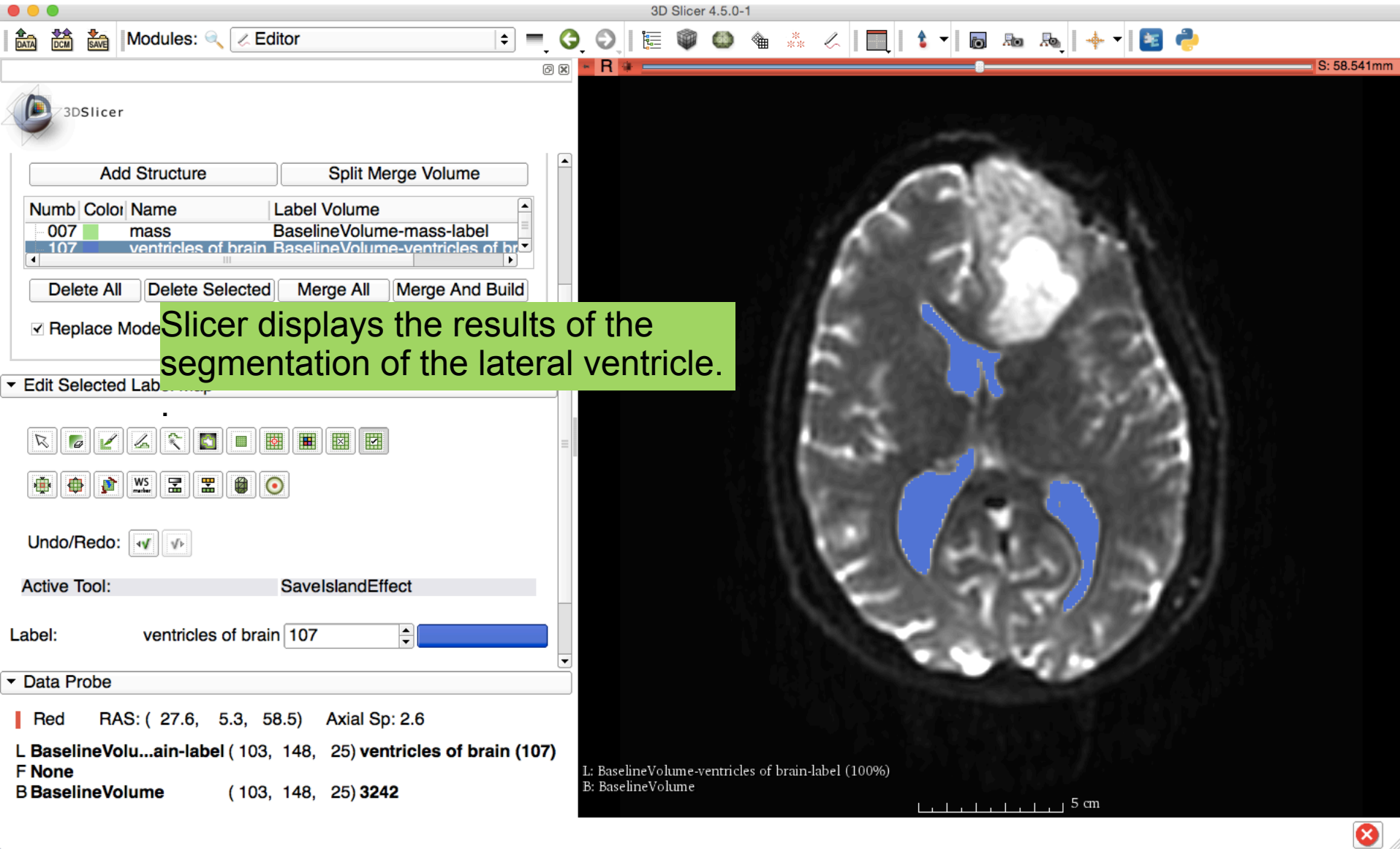
F None

B BaselineVolume (103, 151, 25) 3507

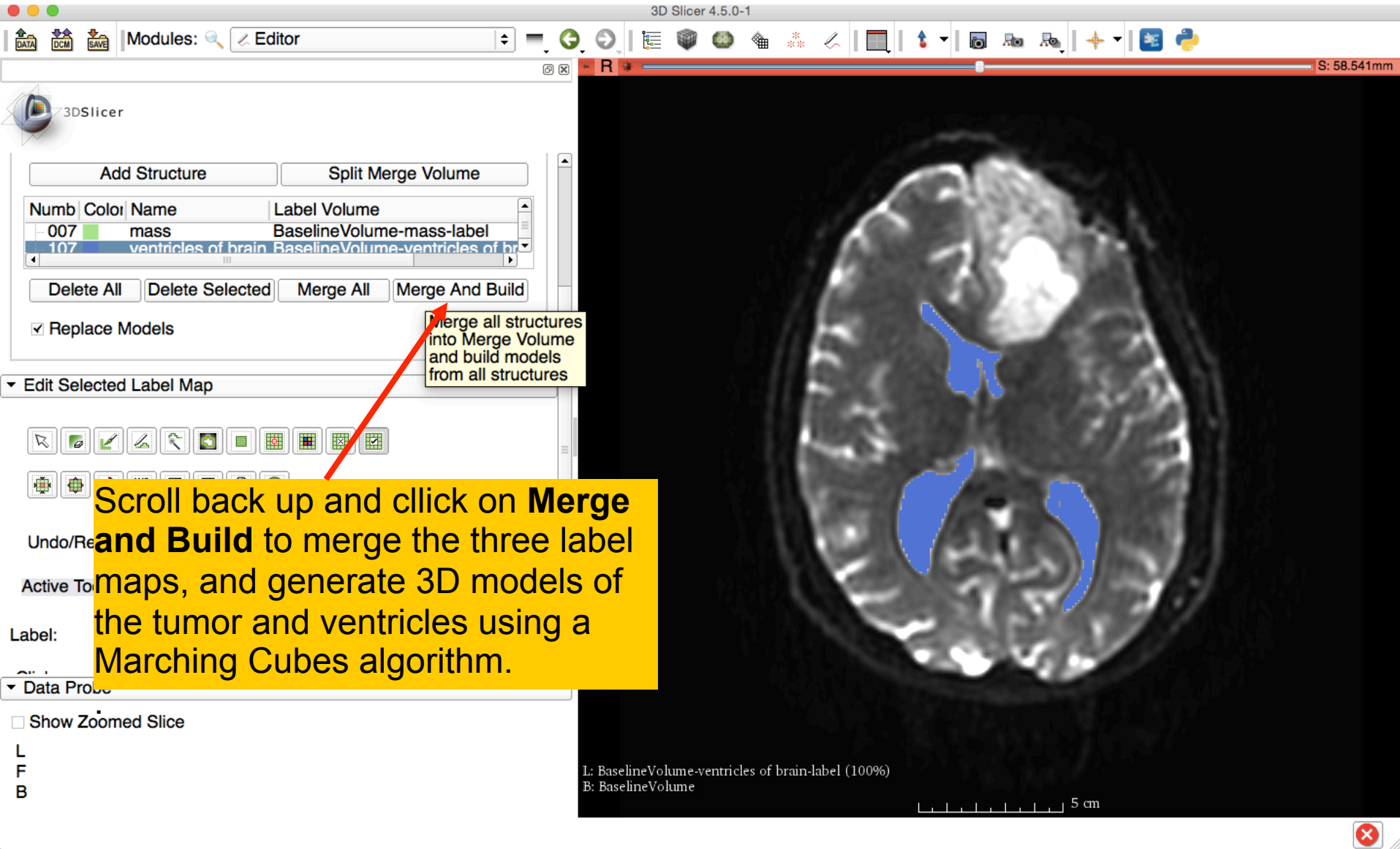
L: BaselineVolume-ventricles of brain-label (100%)
B: BaselineVolume

5 cm

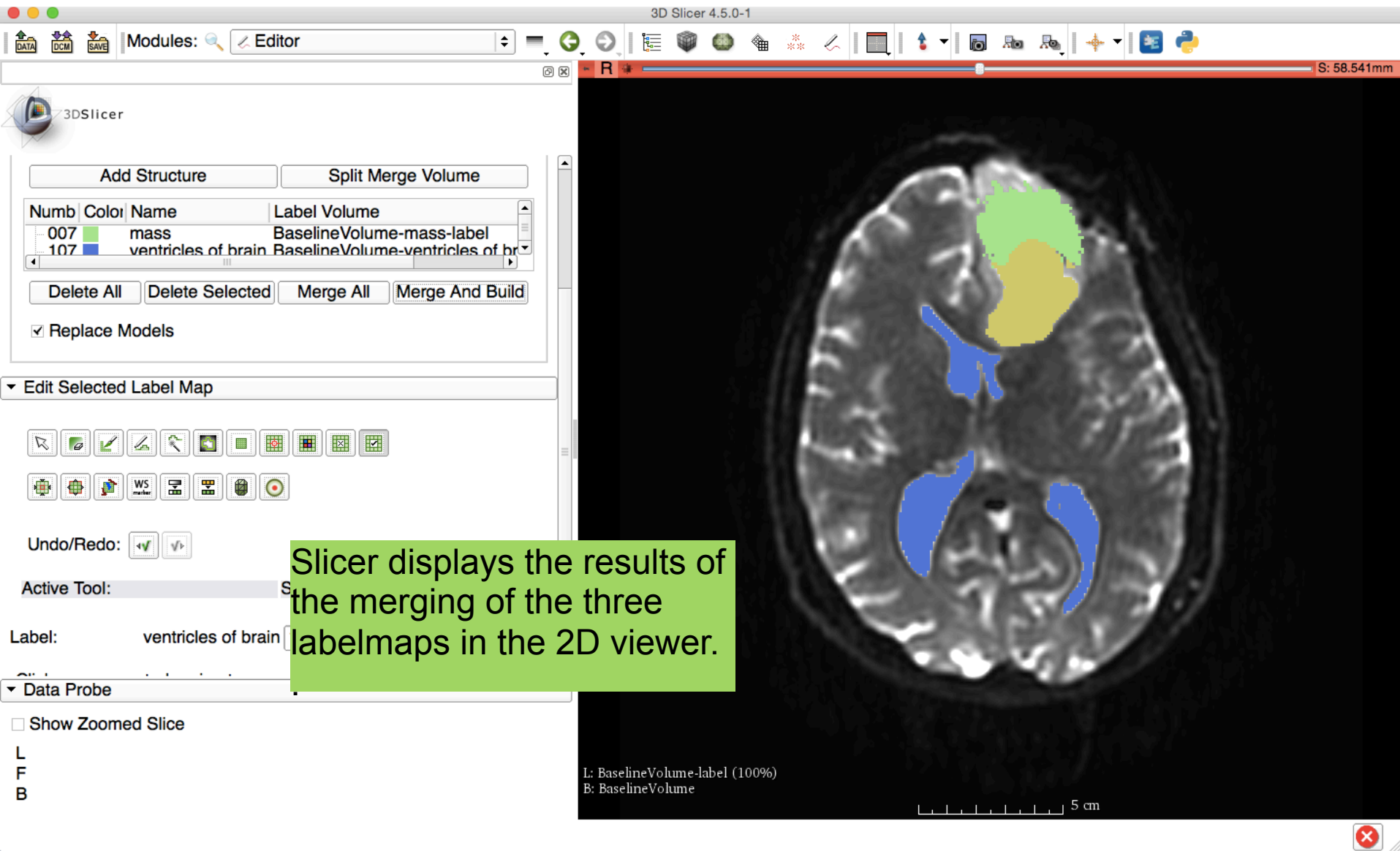
Ventricles Segmentation



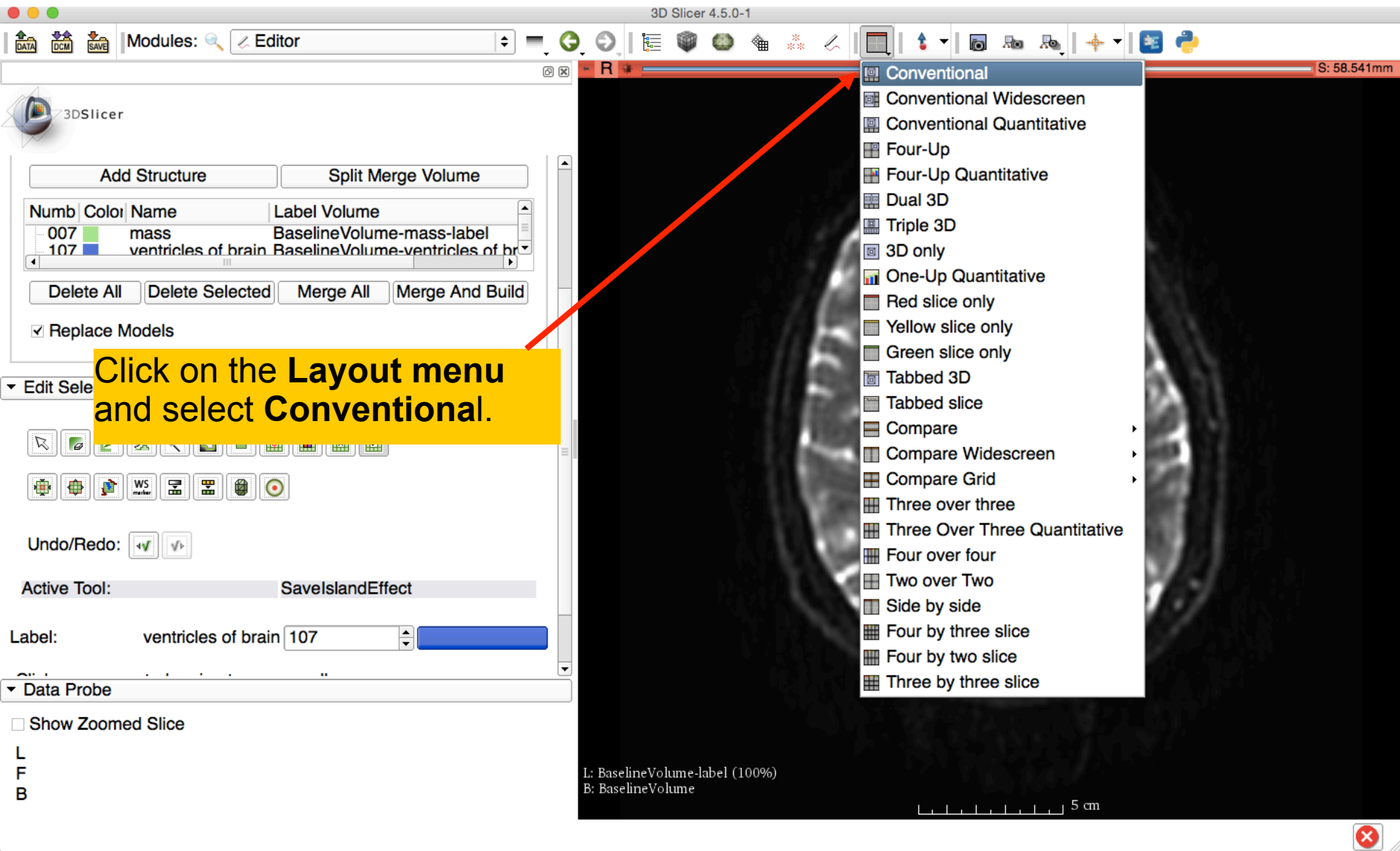
Ventricles Segmentation



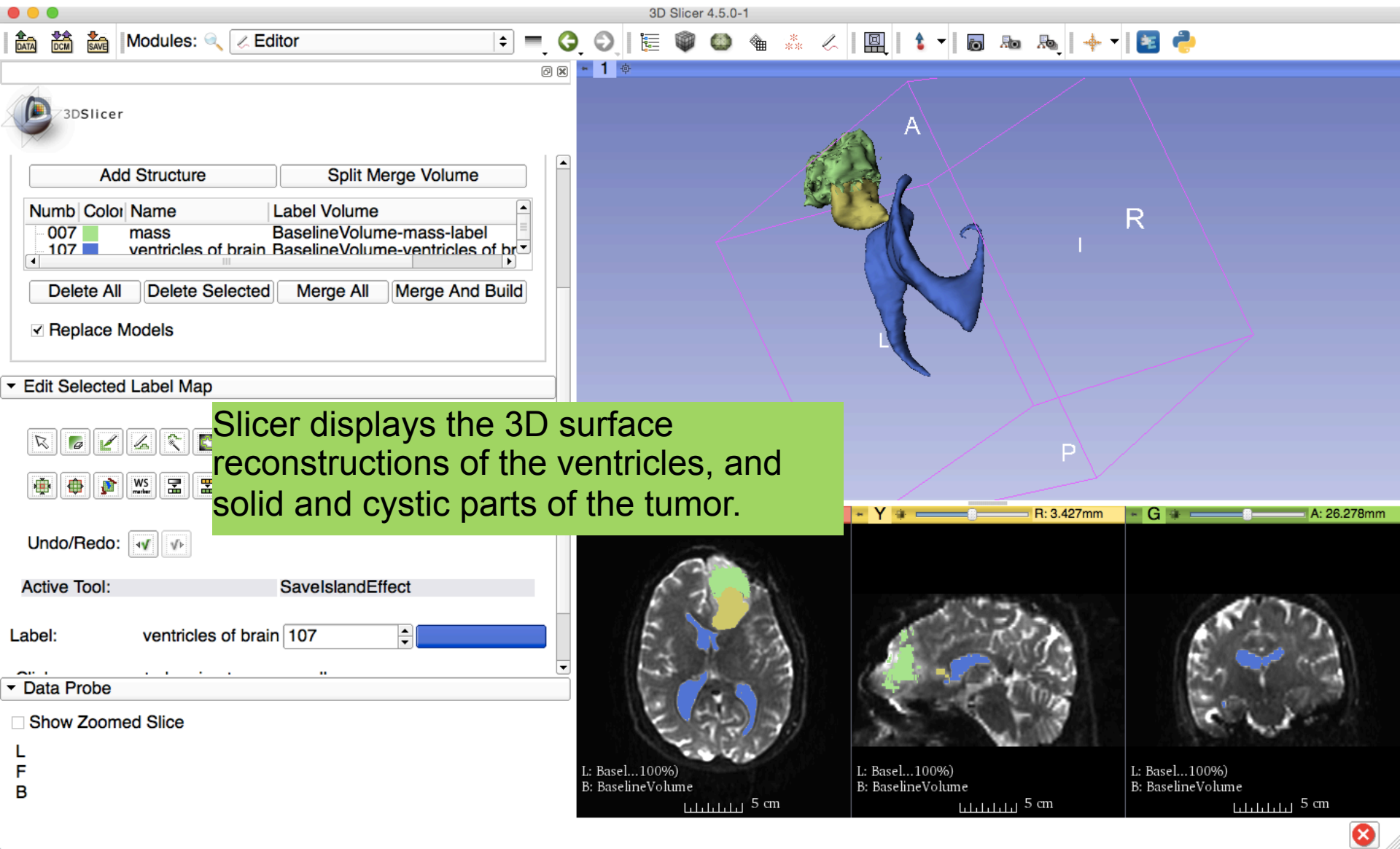
Final Result of Segmentation



Final Result of Segmentation



Final Result of Segmentation



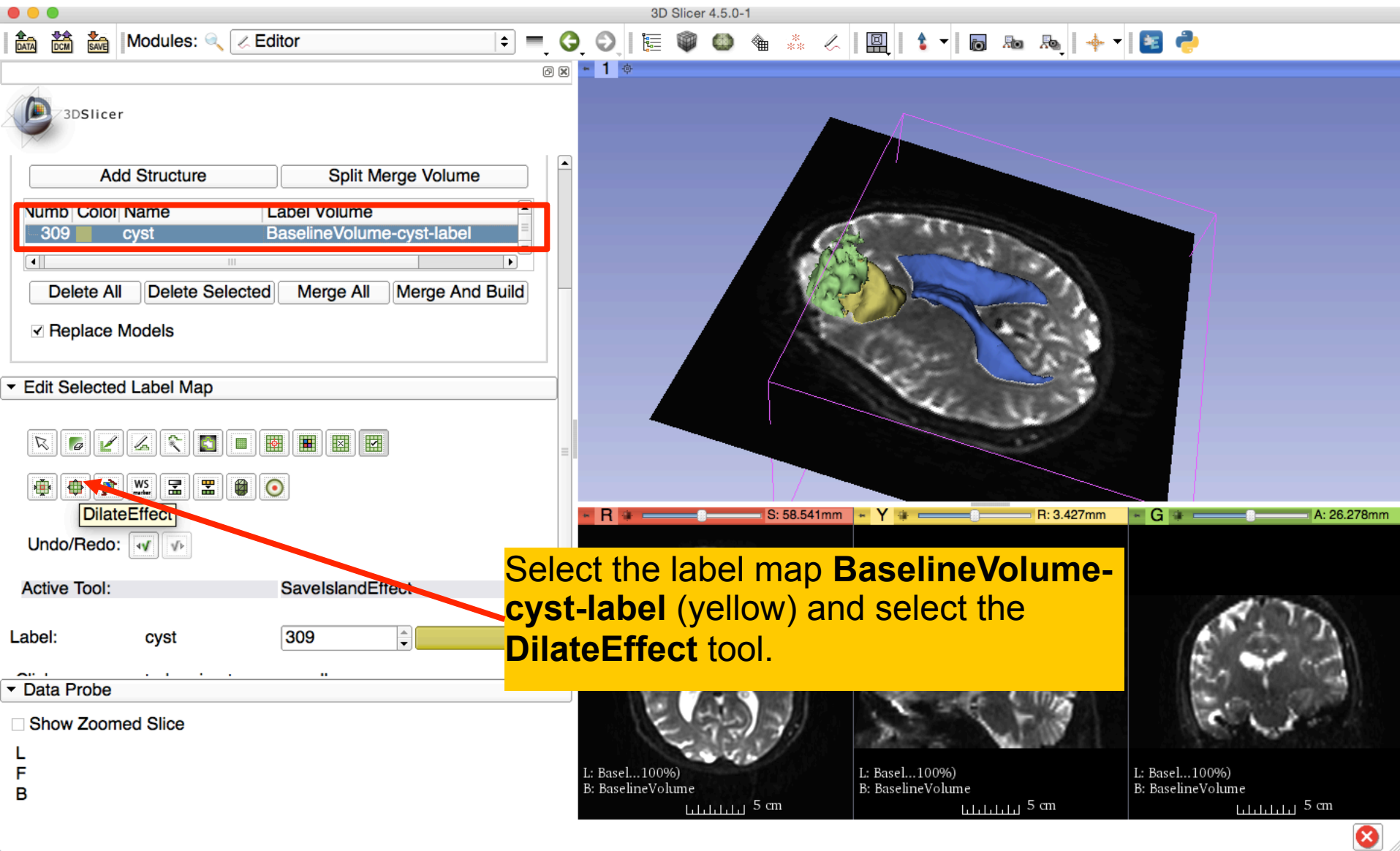
Position the mouse over the **pin icon**, deselect the **link icon**, and select the **eye icon** to view just the axial slice in the 3D viewer.

The screenshot shows the 3D Slicer 4.5.0-1 interface. The main 3D viewer displays a brain MRI with segmented ventricles (blue and green). A yellow callout box points to the 'eye' icon in the bottom toolbar, which is used to toggle slice visibility in the 3D view. The bottom toolbar also shows the 'Toggle slice visibility in 3D view' button. The left sidebar shows the 'Edit Selected Label Map' panel with the 'ventricles of brain' label selected. The bottom right corner shows three orthogonal views (Axial, Sagittal, Coronal) of the brain MRI.

Position the mouse over the **pin icon**, deselect the **link icon**, and select the **eye icon** to view just the axial slice in the 3D viewer.

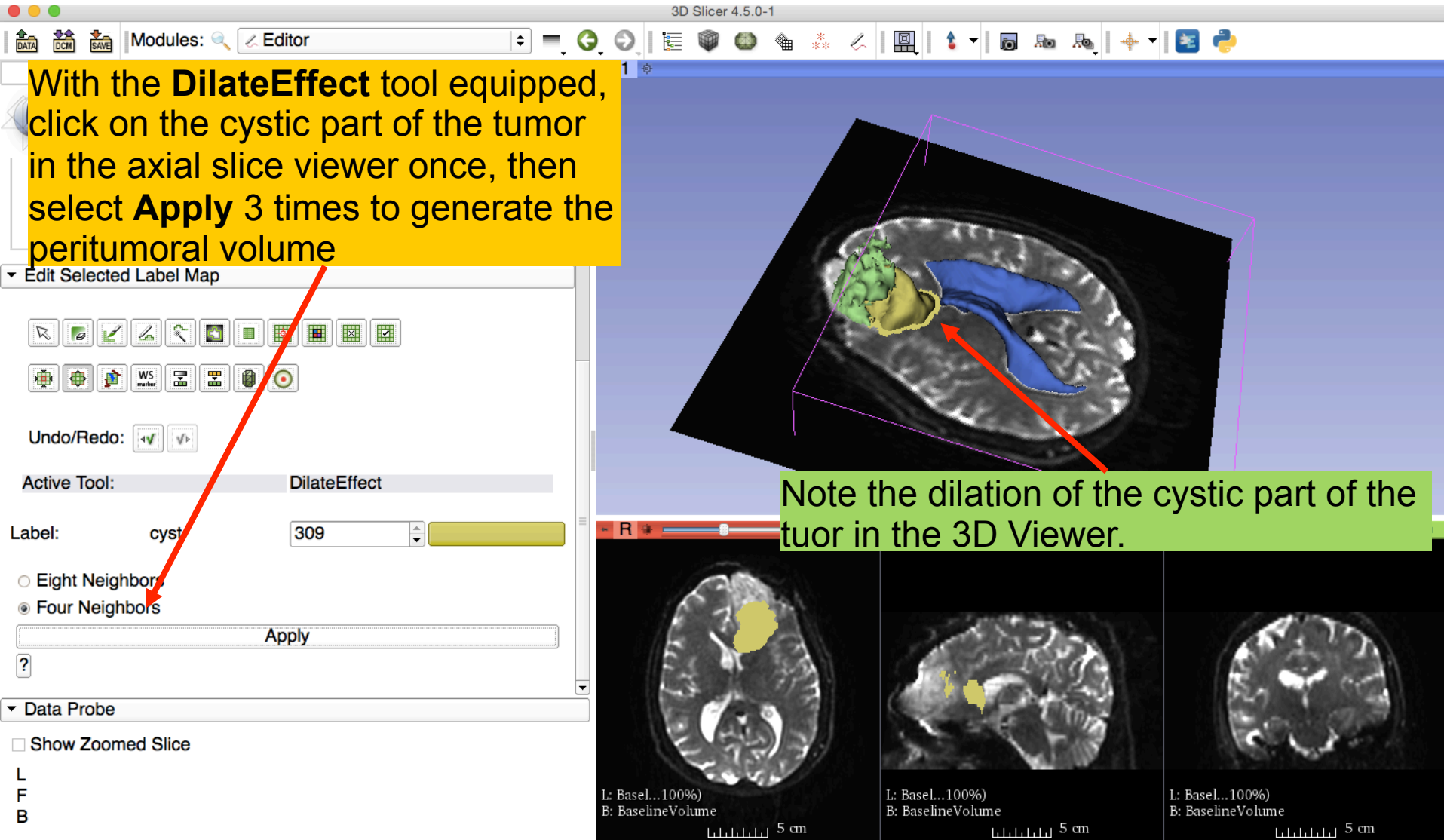
Figure 1 displays three panels of brain MRI slices, showing the segmentation of lesions. The top row shows the original MRI slices (Axial, Sagittal, and Coronal views) with a 5 cm scale bar. The bottom row shows the same slices with a 3D toggle slice visibility in 3D view. Each panel includes a legend: L: Baseline...100%, B: BaselineVolume.

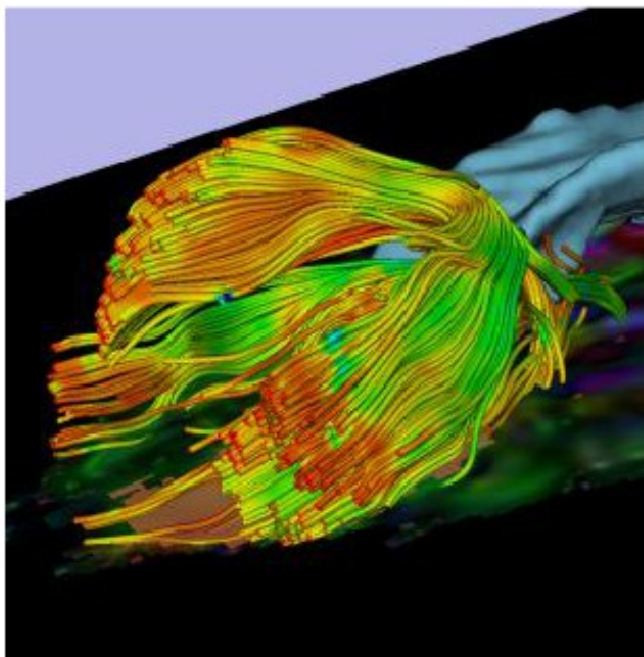
Definition of peri-tumoral volume



Definition of peri-tumoral volume

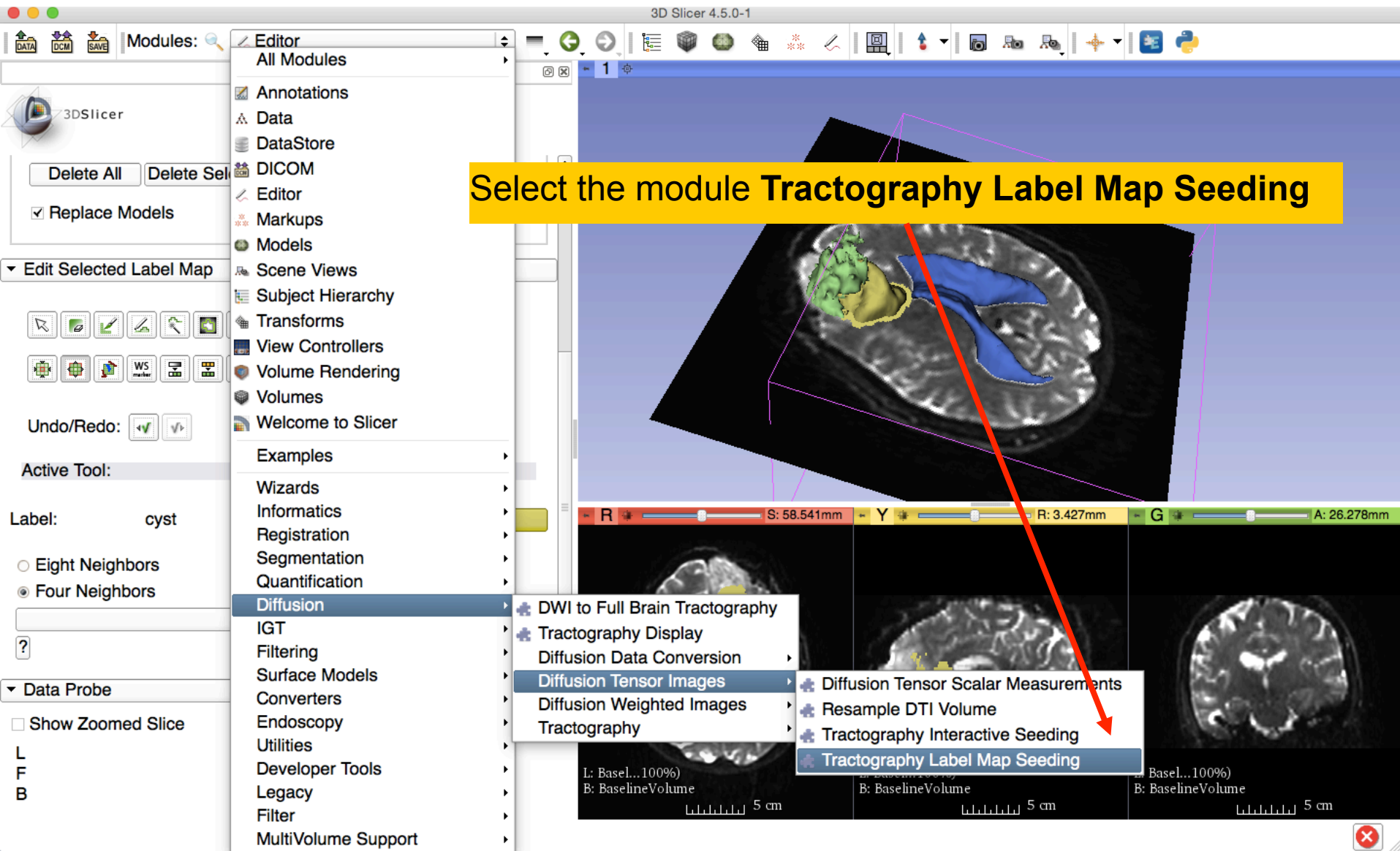
With the **DilateEffect** tool equipped, click on the cystic part of the tumor in the axial slice viewer once, then select **Apply** 3 times to generate the peritumoral volume



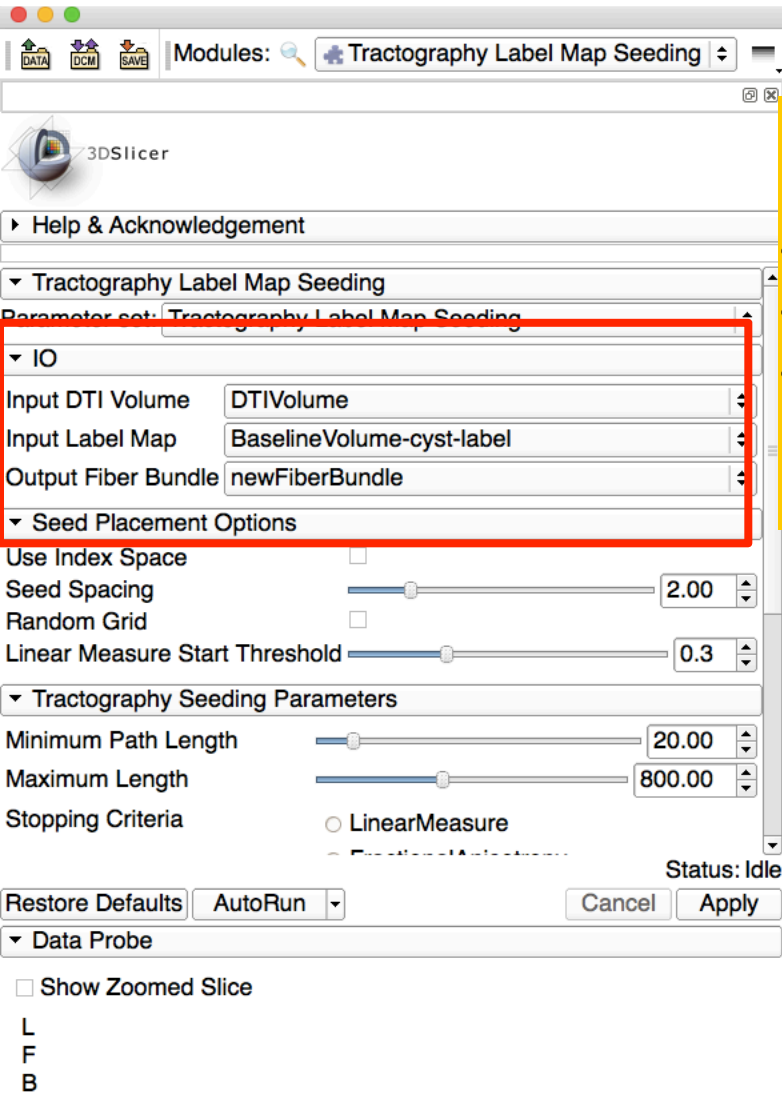


Part 2: Tractography exploration of peri- tumoral white matter fibers

Tractography LabelMap Seeding

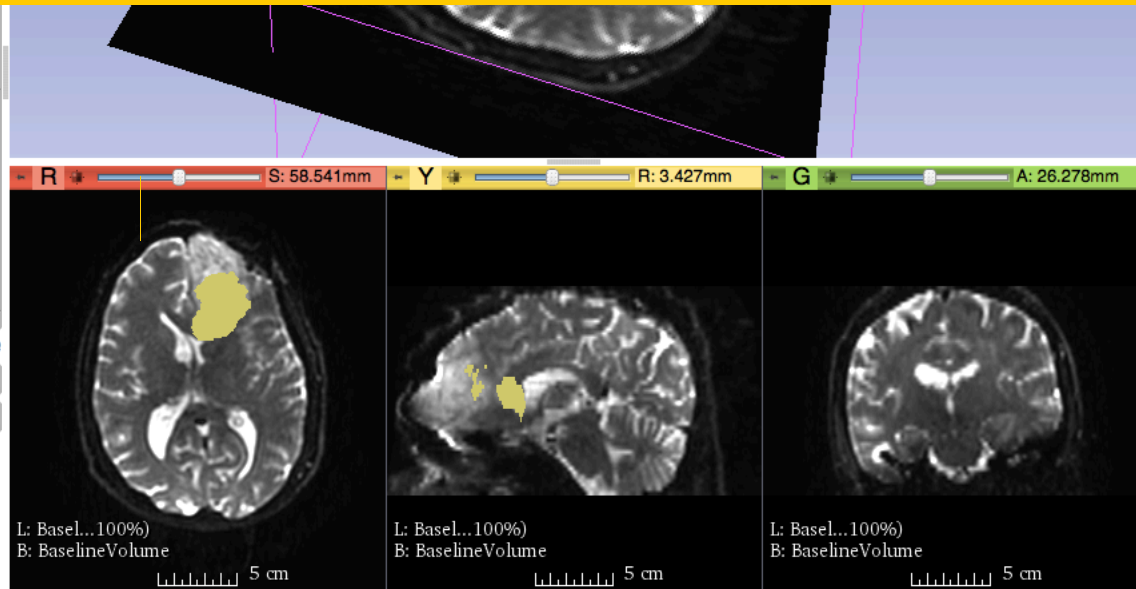


Tractography LabelMap Seeding

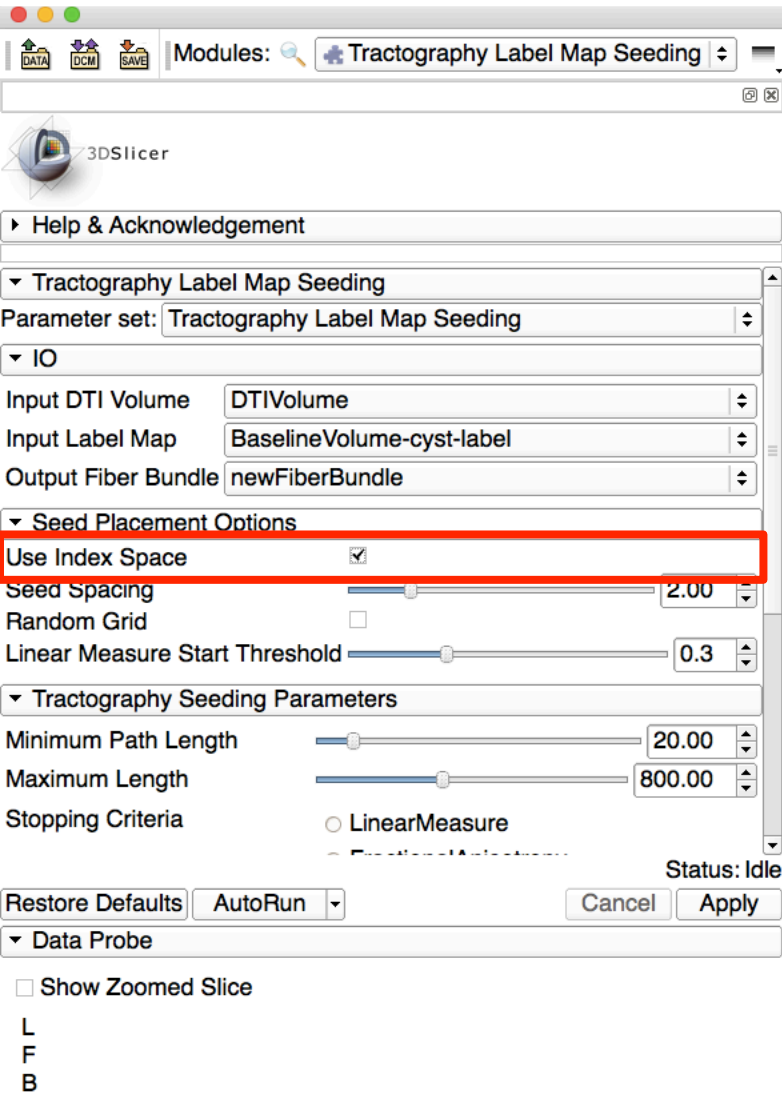


Go to **I/O** and set the following values:

- **Input DTI Volume:** DTIVolume
- **Input Label Map:** BaselineVolume-cyst-label
- **Output Fiber Bundle:** Create and rename newFiberBundle

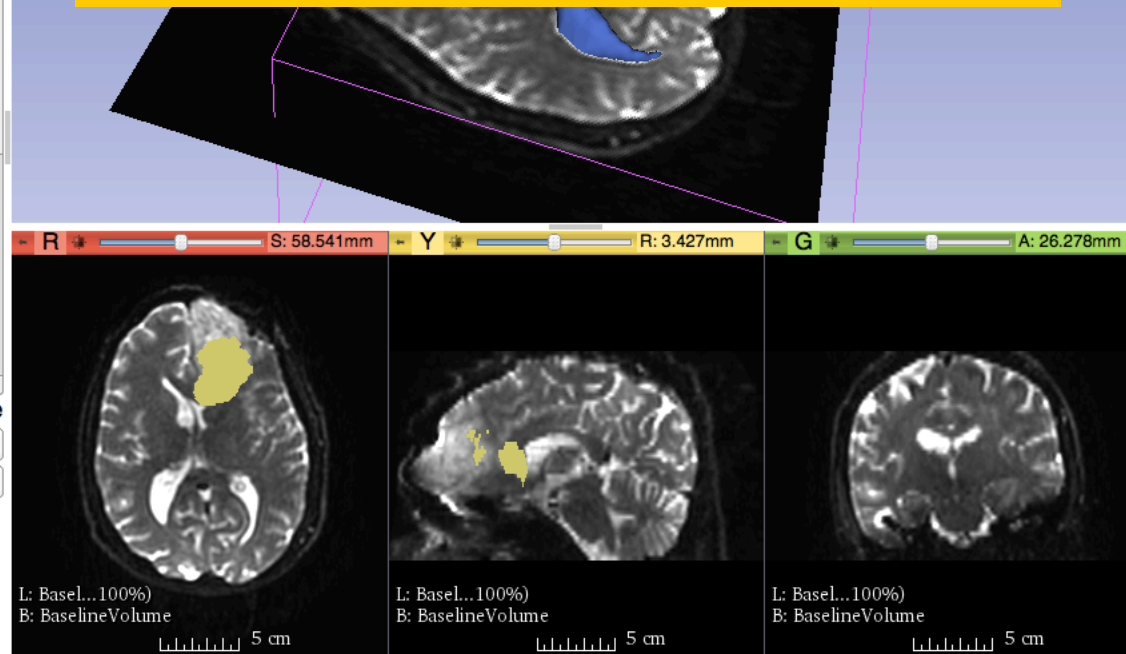


Tractography LabelMap Seeding

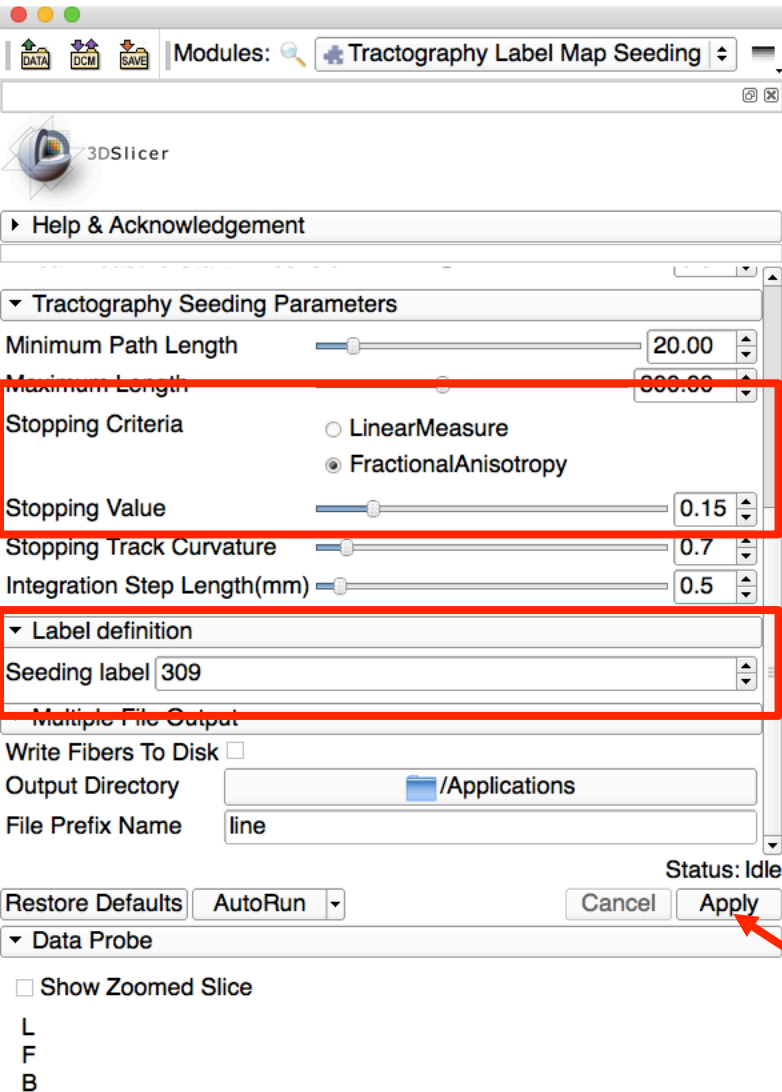


Scroll down to **Seed Placement Options** and set the following values:

- Check **Use Index Space**



Tractography LabelMap Seeding



Scroll down to **Tractography Seeding Parameters** and set the following values:

- Set **Stopping Criteria** to **FractionalAnisotropy**
- Set **Stopping Value** to **0.15**

Scroll down to **Label Definition** and set the following values:

- Set **Seeding Label** to **309 (cyst)**

Click on **Apply**

L: Basel...100%)
B: BaselineVolume

L: Basel...100%)
B: BaselineVolume

L: Basel...100%)
B: BaselineVolume

5 cm

5 cm

5 cm

Tractography LabelMap Seeding

Slicer displays the white matter fibers surrounding the tumor

The fibers are colored according to fractional anisotropy values (red = low FA; blue, green = high FA)

Tractography Seeding Parameters

- Minimum Path Length: 20.00
- Maximum Length: 800.00
- Stopping Criteria:
 - ☐ LinearMeasure
 - ☒ FractionalAnisotropy
- Stopping Value: 0.15

Status: Completed 100%

Write Fibers To Disk ☐

Output Directory: /Applications

Restore Defaults AutoRun Cancel Apply

Data Probe

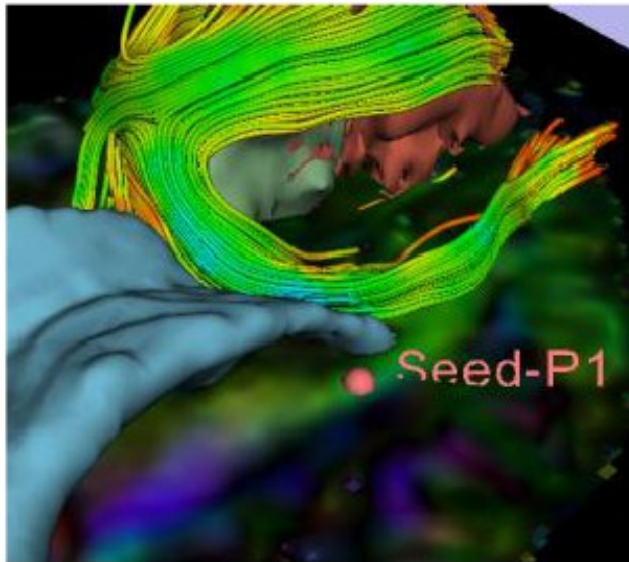
- ☐ Show Zoomed Slice

L F B

L: BaselineVolume 5 cm

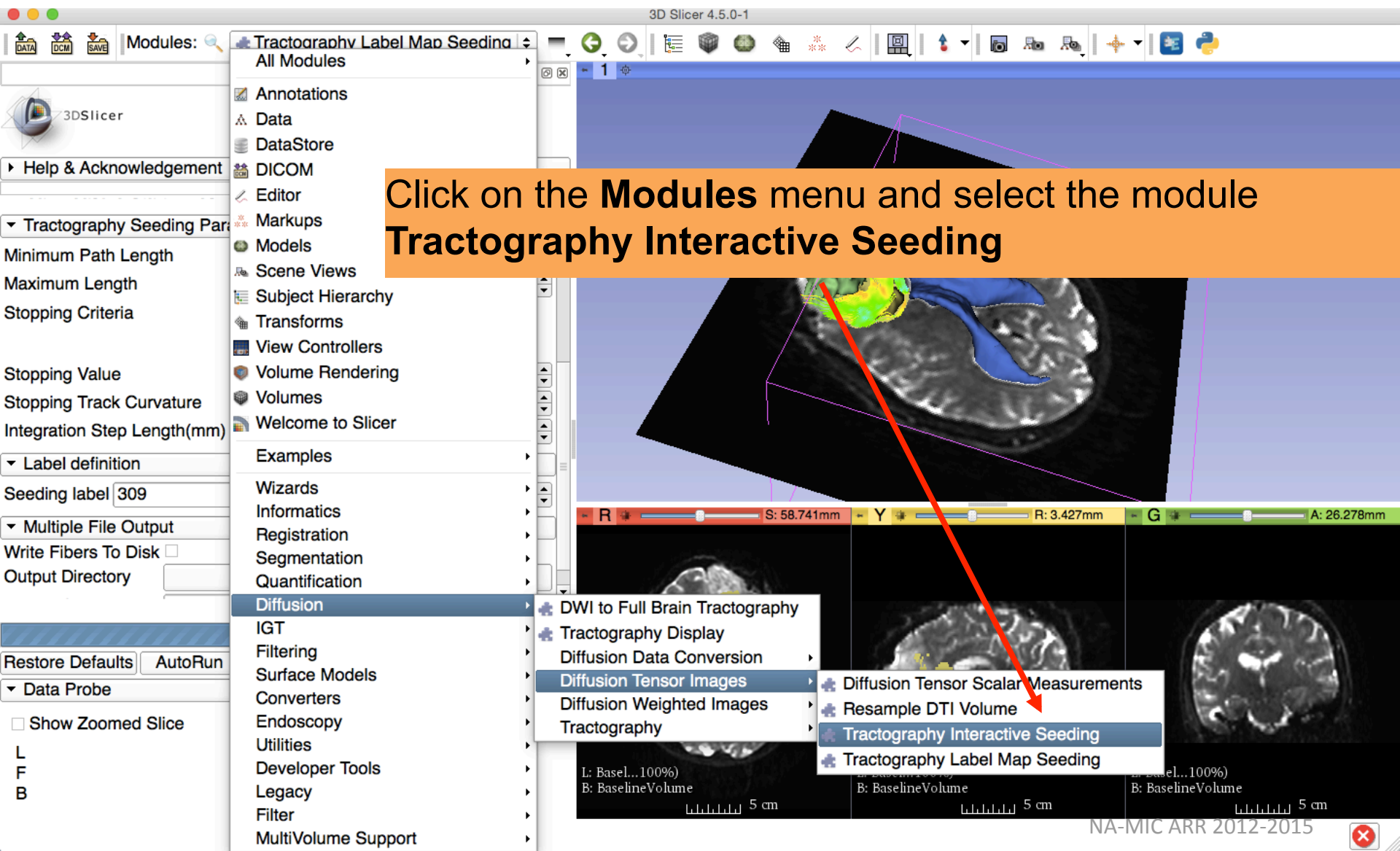
L: BaselineVolume 5 cm

L: BaselineVolume 5 cm

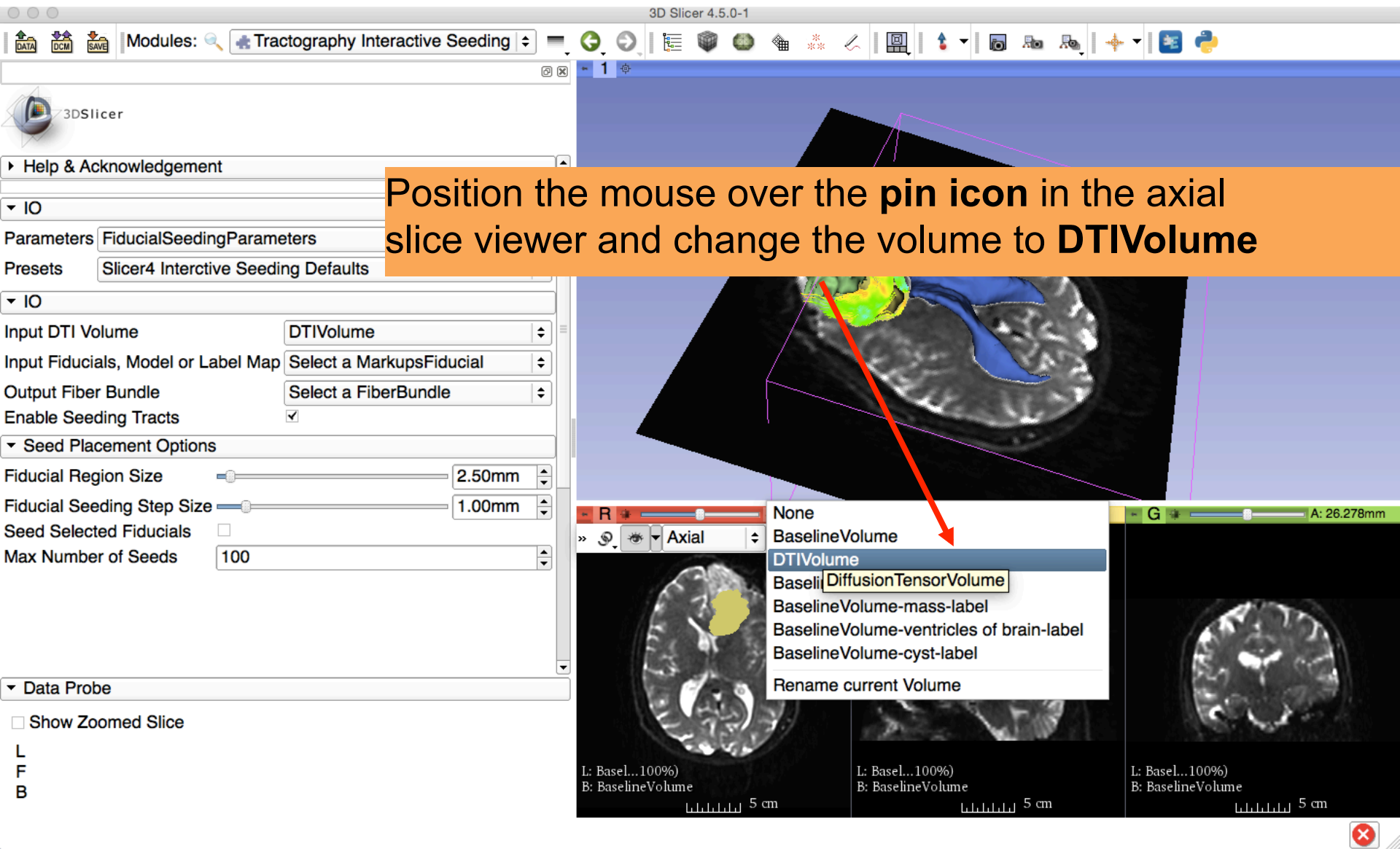


Part 4: Tractography exploration of the ipsilateral and contralateral side

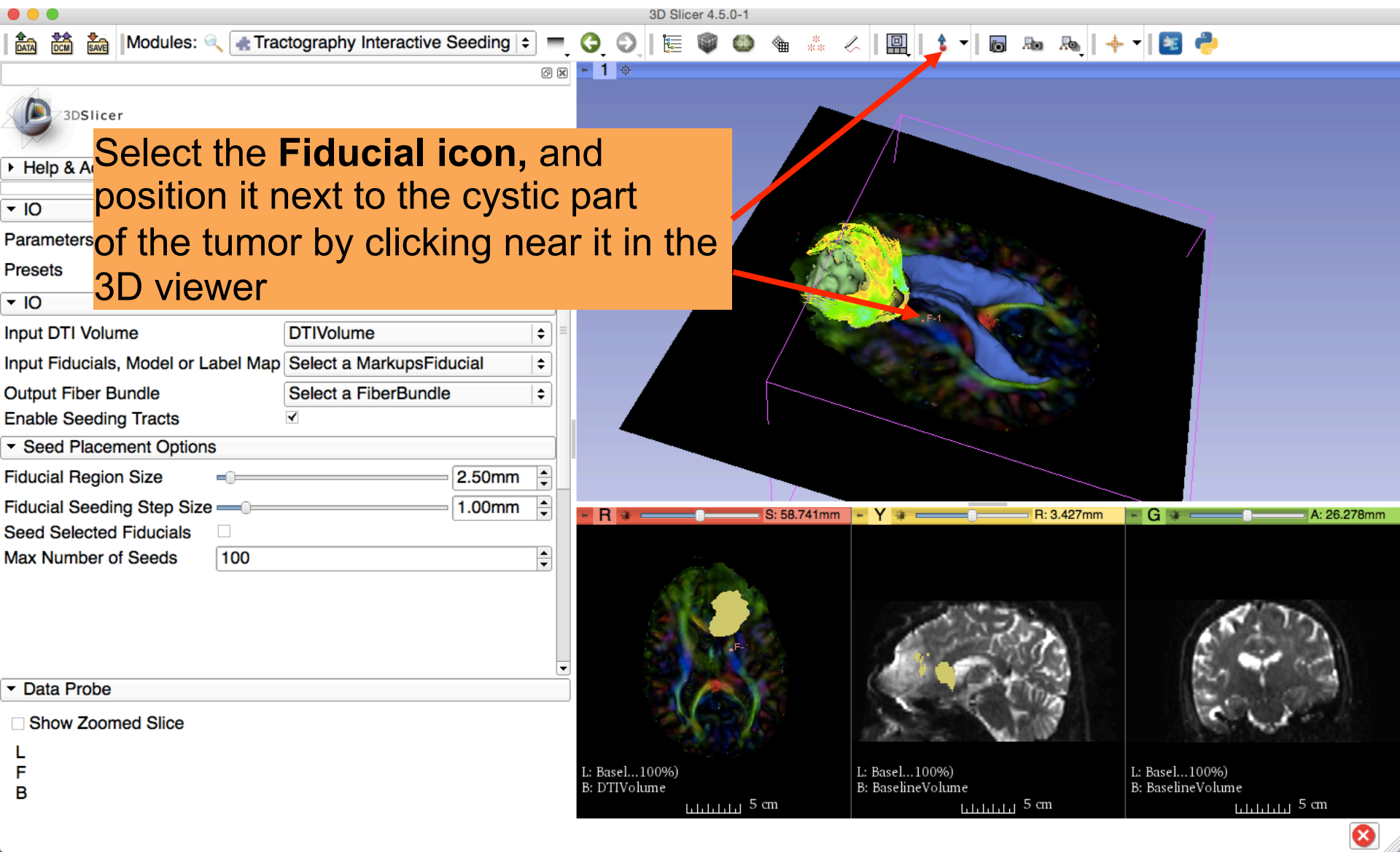
Tractography on-the-fly



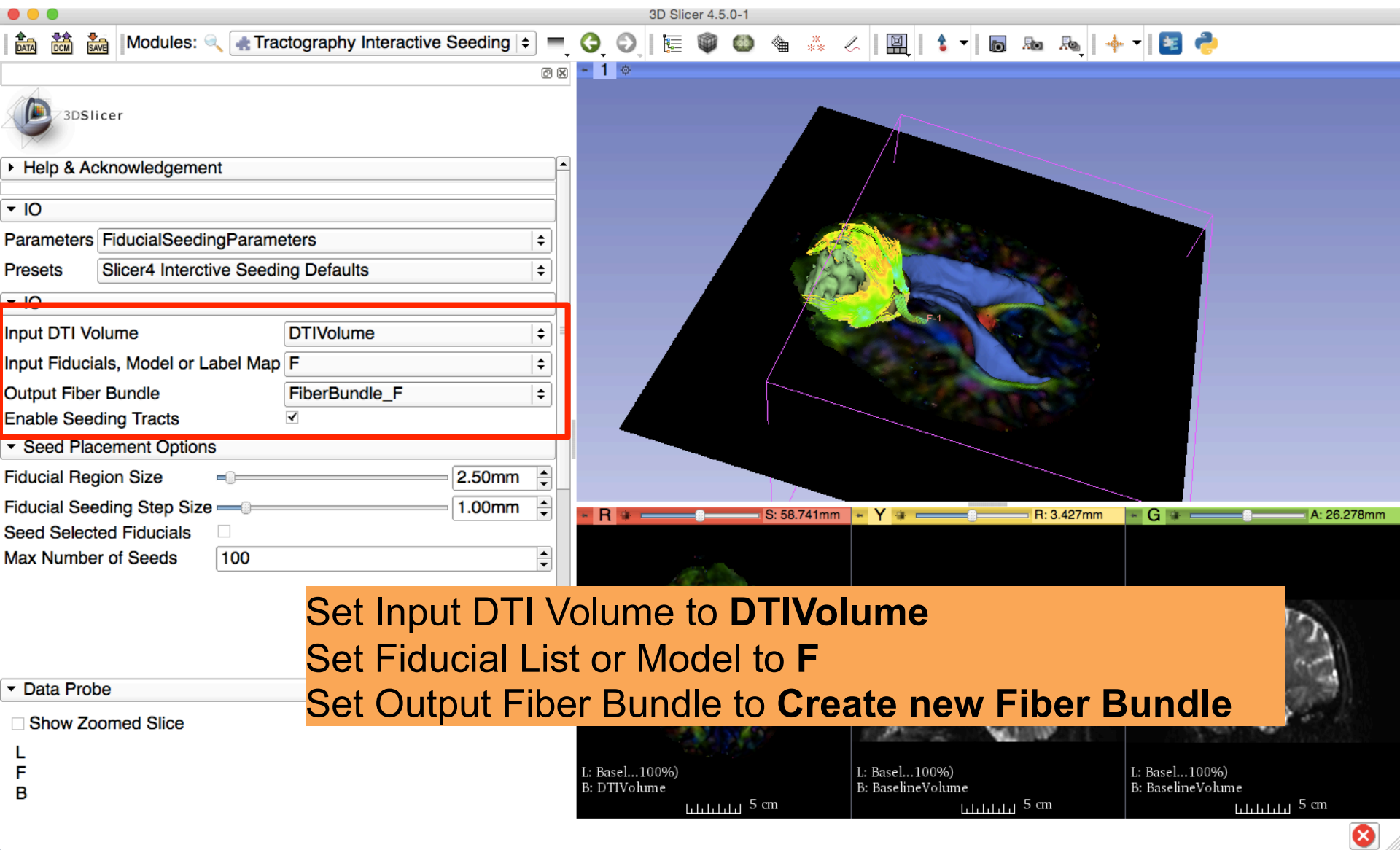
Tractography on-the-fly



Tractography on-the-fly

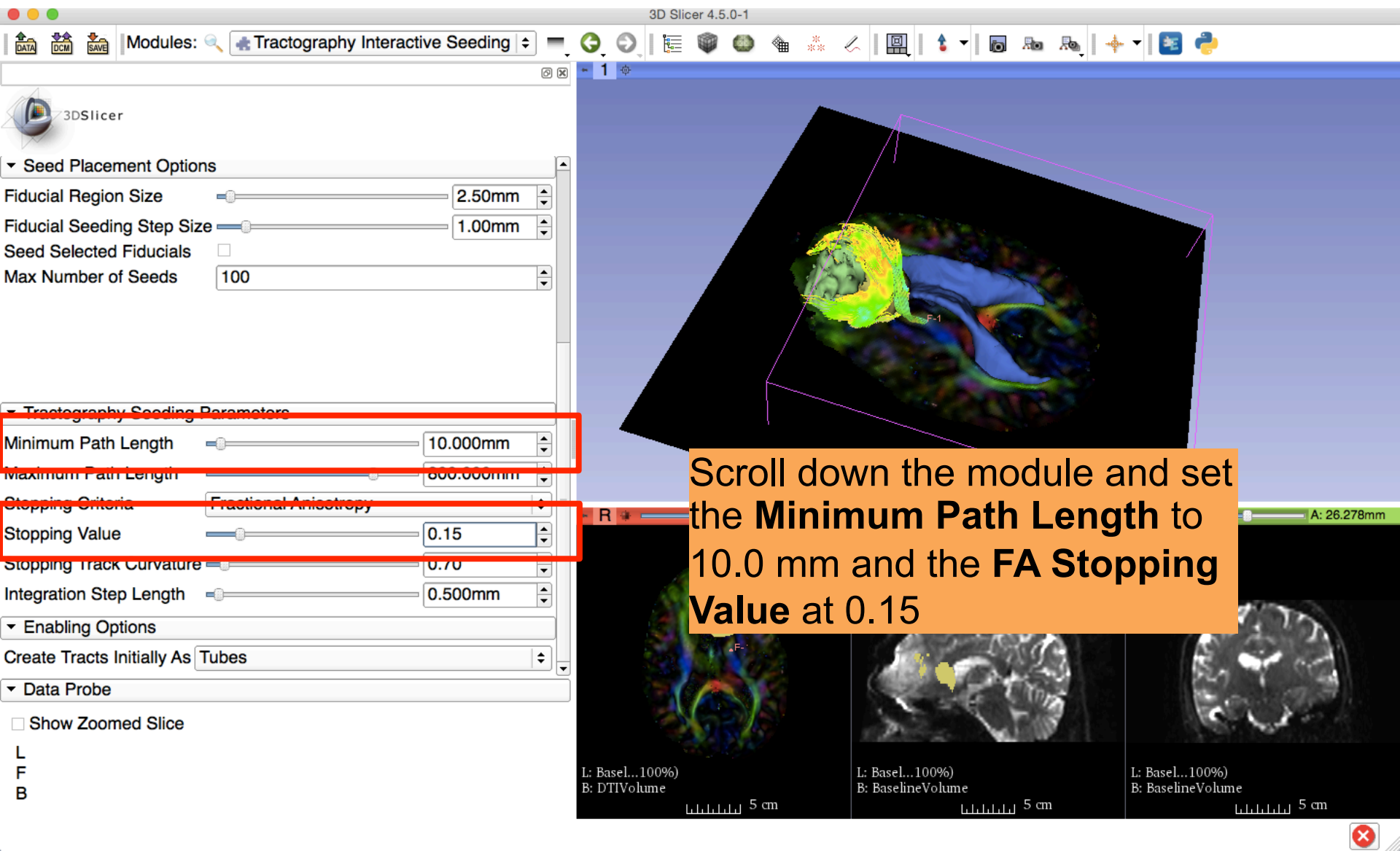


Tractography on-the-fly

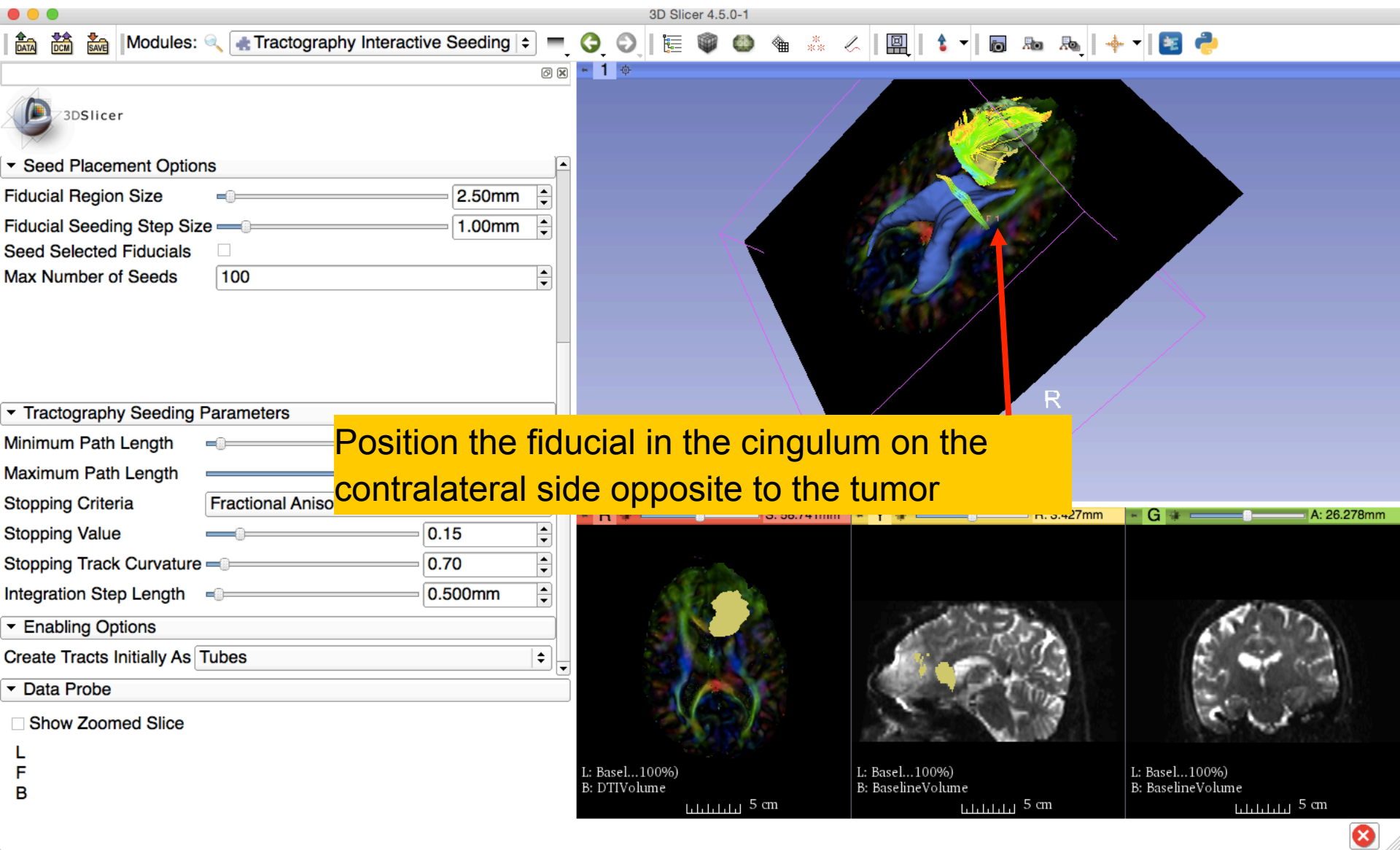


Set Input DTI Volume to **DTIVolume**
Set Fiducial List or Model to **F**
Set Output Fiber Bundle to **Create new Fiber Bundle**

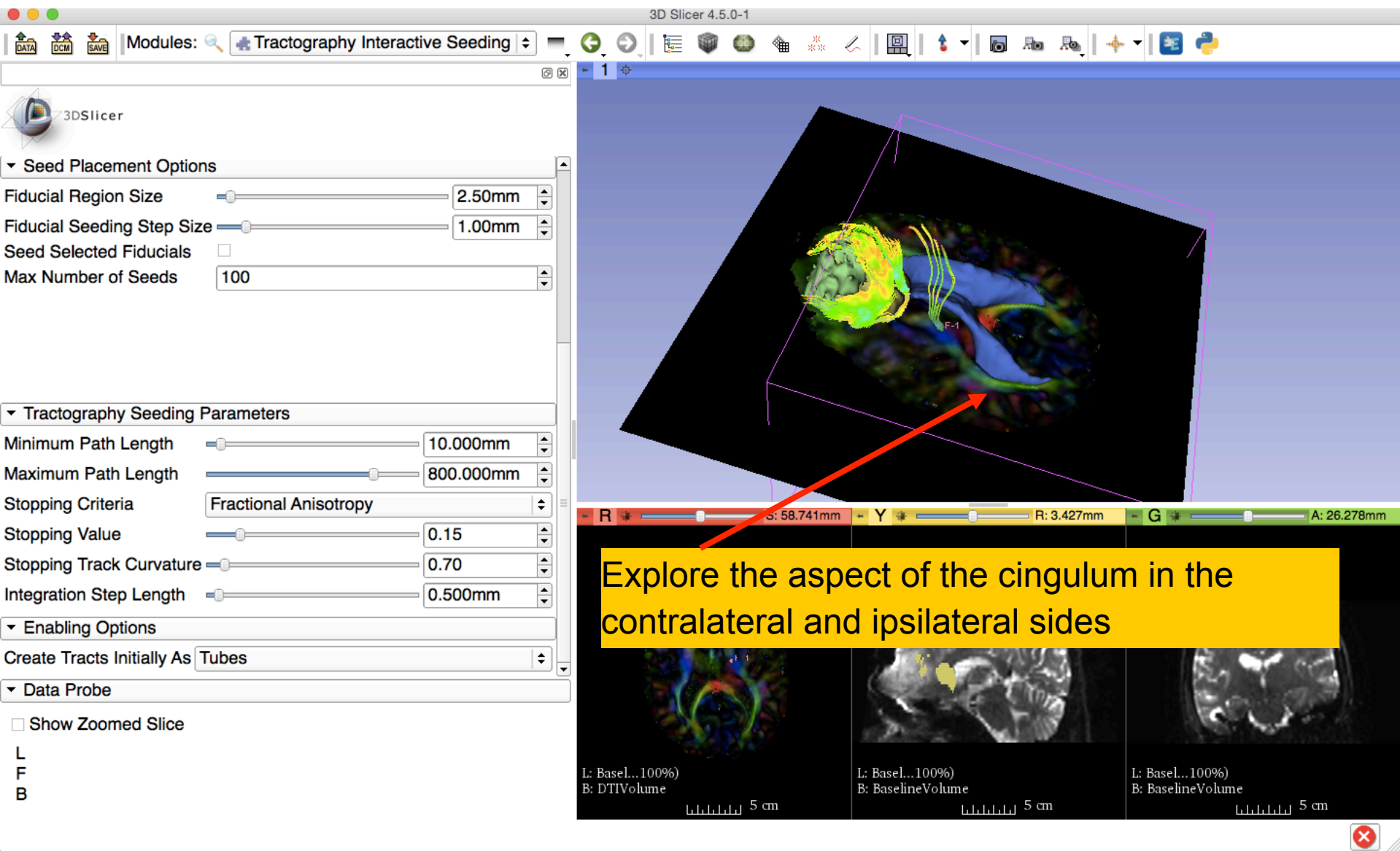
Tractography on-the-fly



Tractography on-the-fly



Tractography on-the-fly



Conclusion

- Fully integrated pipeline for semi-automated tumor segmentation and white matter tract reconstruction
- 3D interactive exploration of the white matter tracts surrounding a tumor (peritumoral tracts) for neurosurgical planning

Acknowledgments

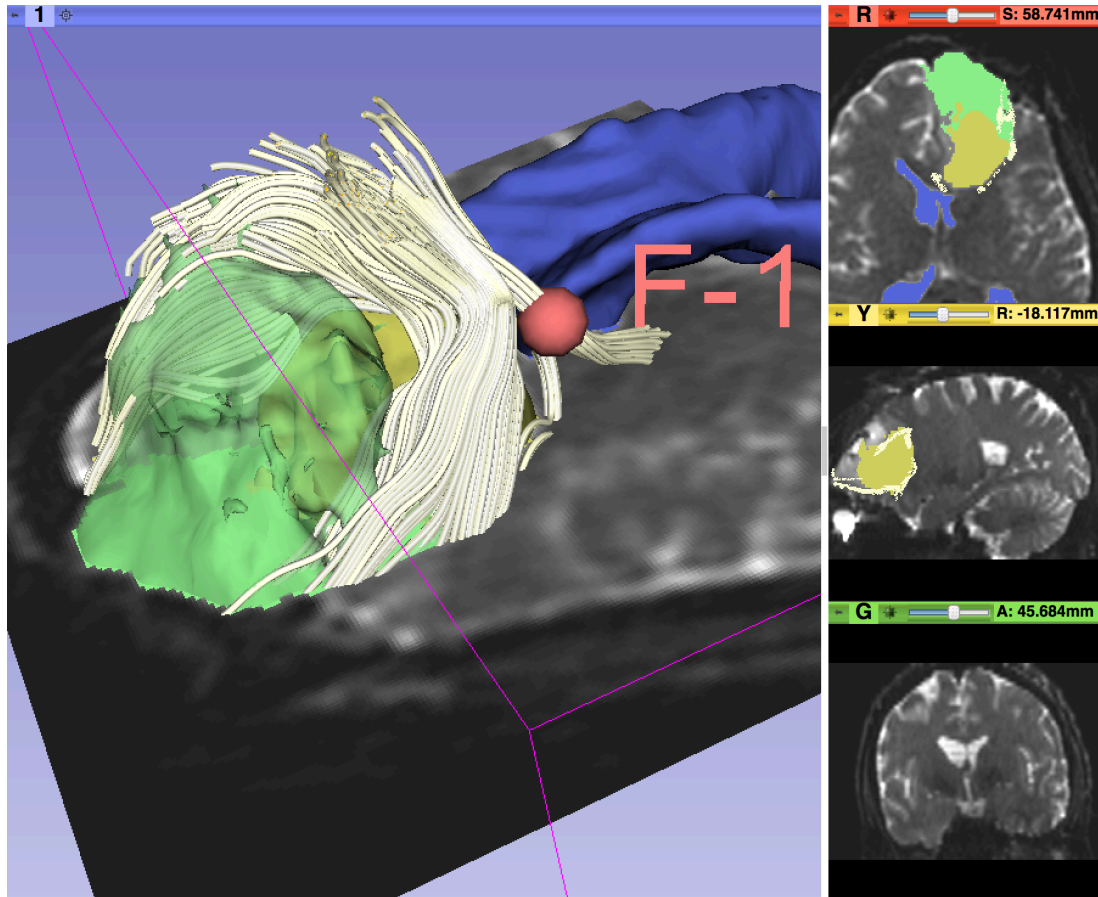


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Questions/Comments



Contact: spujol@bwh.harvard.edu