



Exploring Peritumoral White Matter Fibers for Neurosurgical Planning

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Harvard University

Clinical Goal

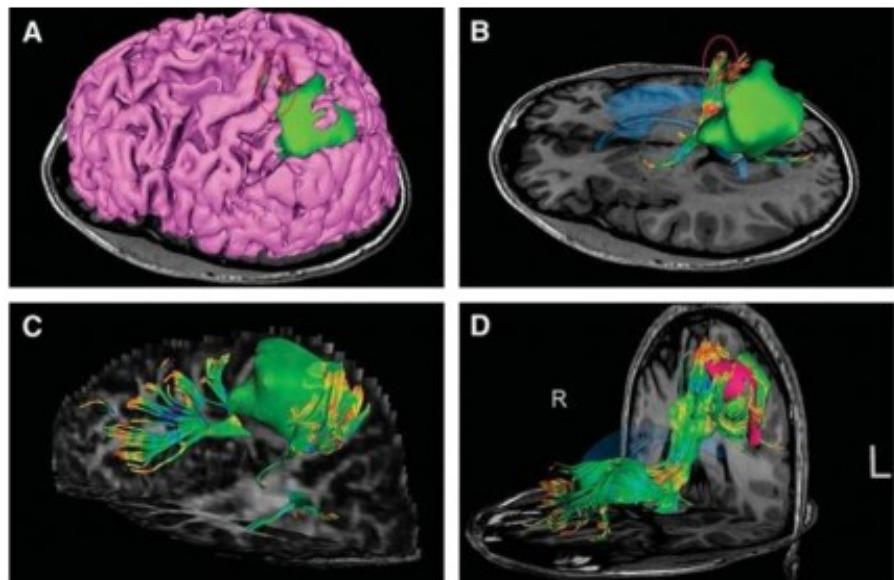
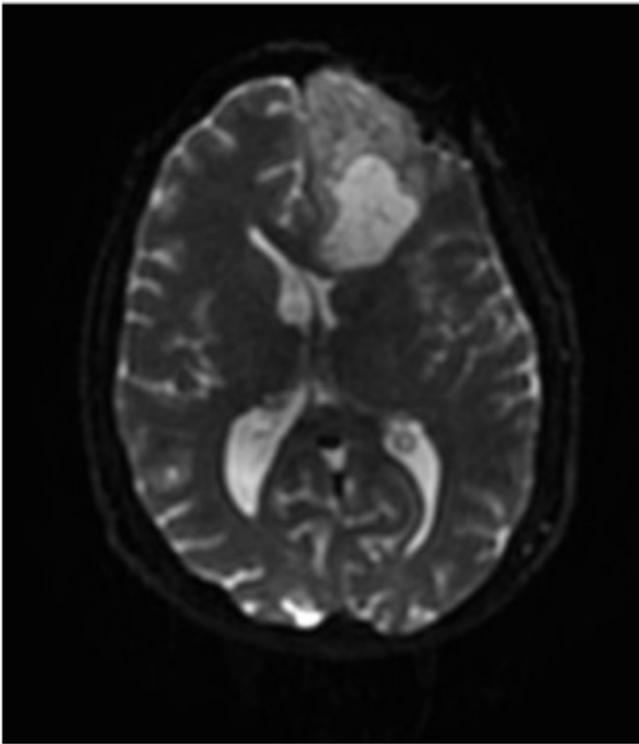


Image Courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital, Boston, MA..

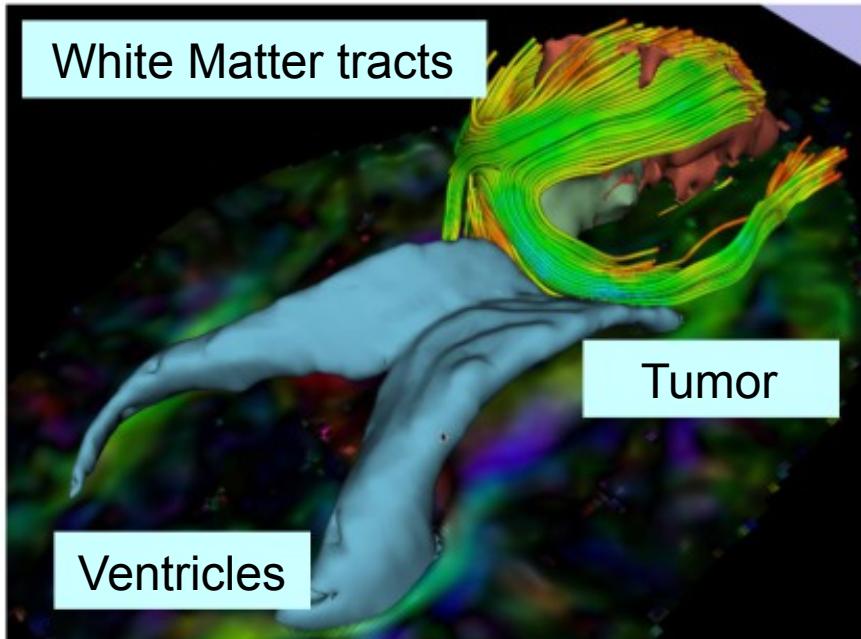
Diffusion Tensor Imaging (DTI) Tractography has the potential to bring valuable spatial information on tumor infiltration and tract displacement for neurosurgical planning of tumor resection.

Clinical Case



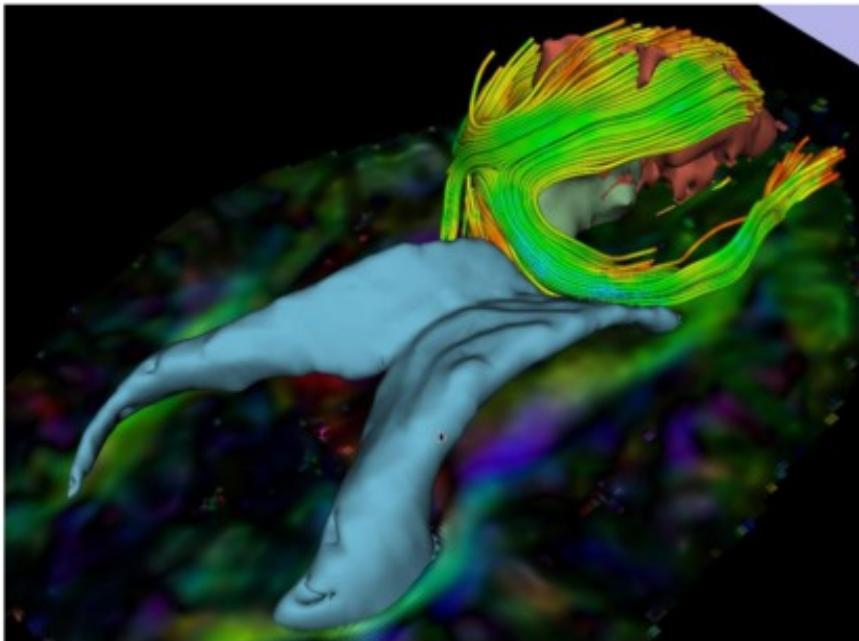
- 35 year-old male diagnosed with **Glioblastoma multiform (GBM)**
- Diffusion Weighted Imaging (DWI) acquisition for neurosurgical planning

Clinical Goal



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

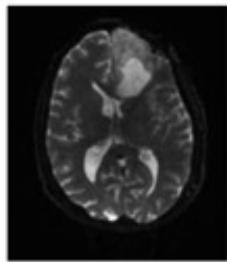
Image Analysis Pipeline



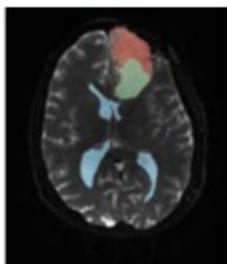
The image analysis pipeline described in this tutorial uses three different algorithms:

- 1) Grow Cut algorithm for segmentation of the tumor parts
- 2) Marching Cube algorithm for surface modeling
- 3) Single tensor streamline tractography algorithm for tract generation.

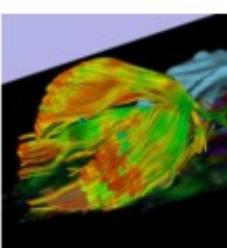
Overview of the analysis pipeline



Part 1: Loading & Visualization of Diffusion Data



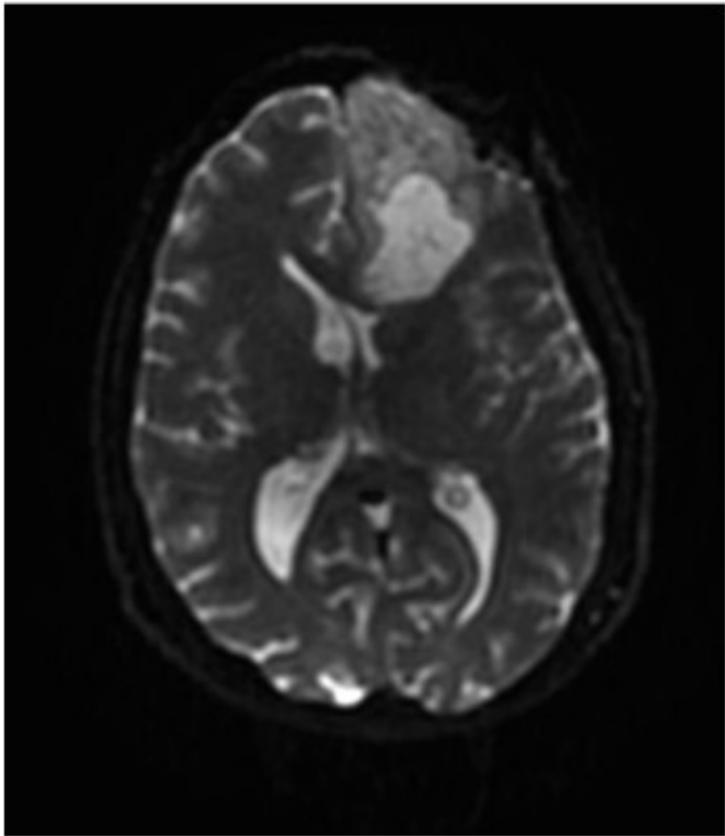
Part 2: Segmentation of lat. ventricles, and solid and cystic parts of the tumor



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

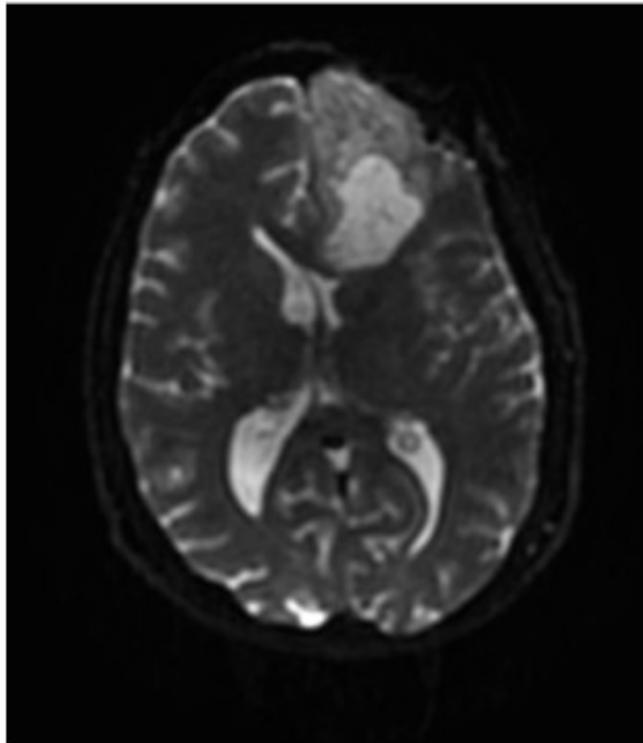


Part 4: Tractography exploration of the ipsilateral and contralateral side



Part 1: Loading and Visualization of Diffusion Data

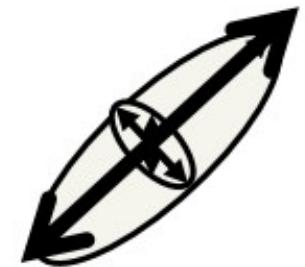
Diffusion Tensor Imaging



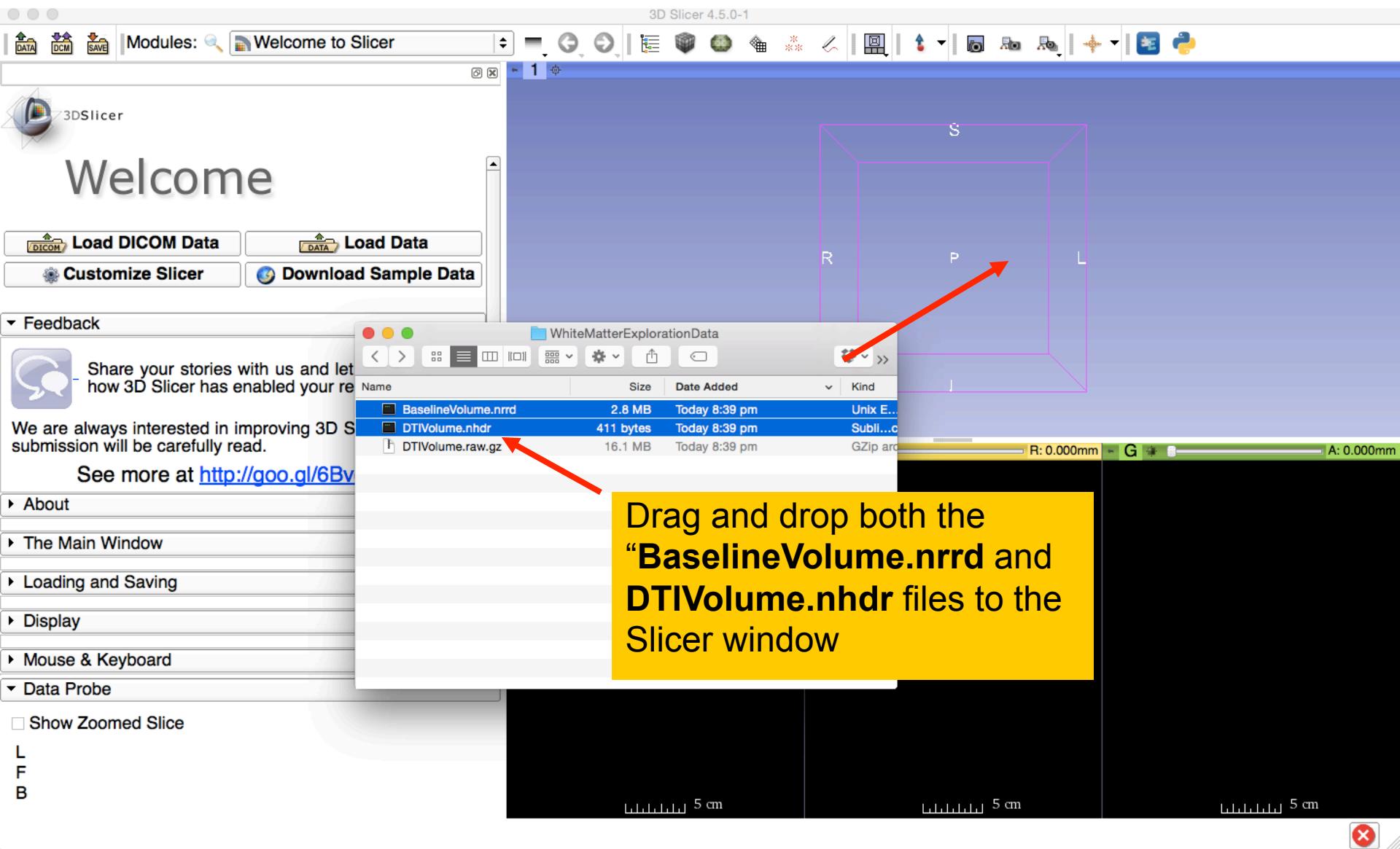
$$S_i = S_0 e^{-b \hat{g}_i^T D \hat{g}_i}$$

(Stejskal and Tanner 1965, Basser 1994)

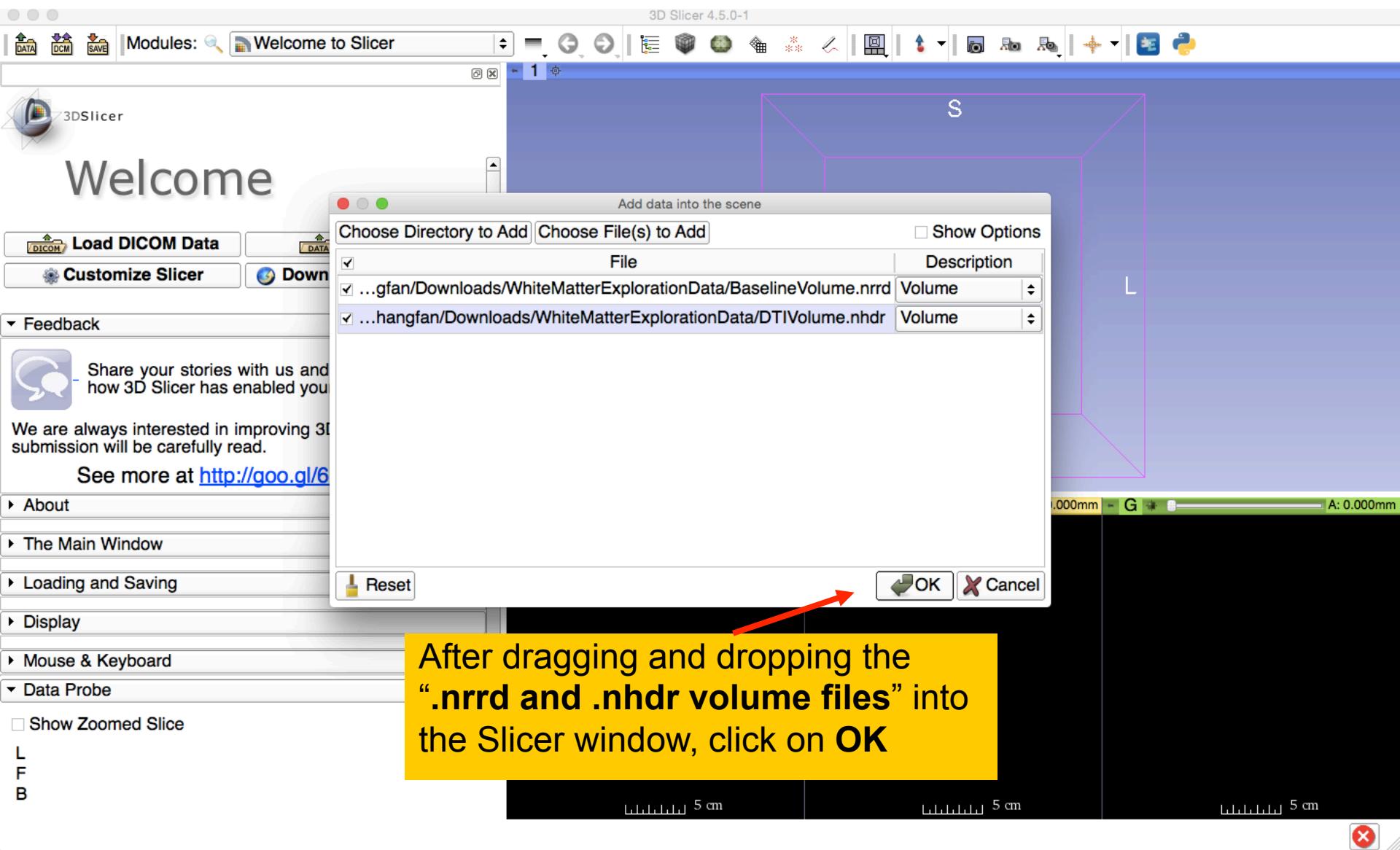
$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$



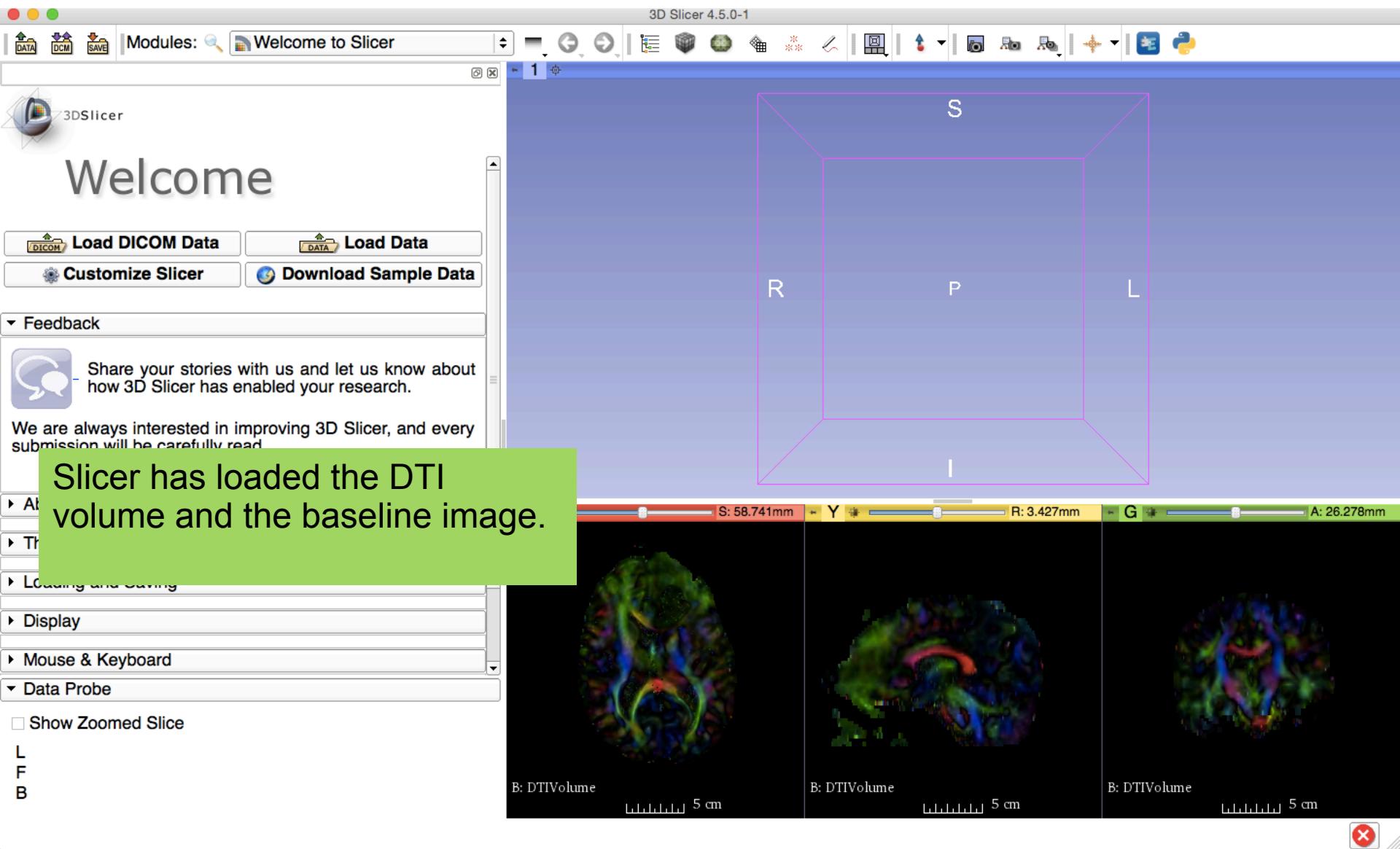
Loading DTI and Baseline Data



Loading DTI and Baseline Data



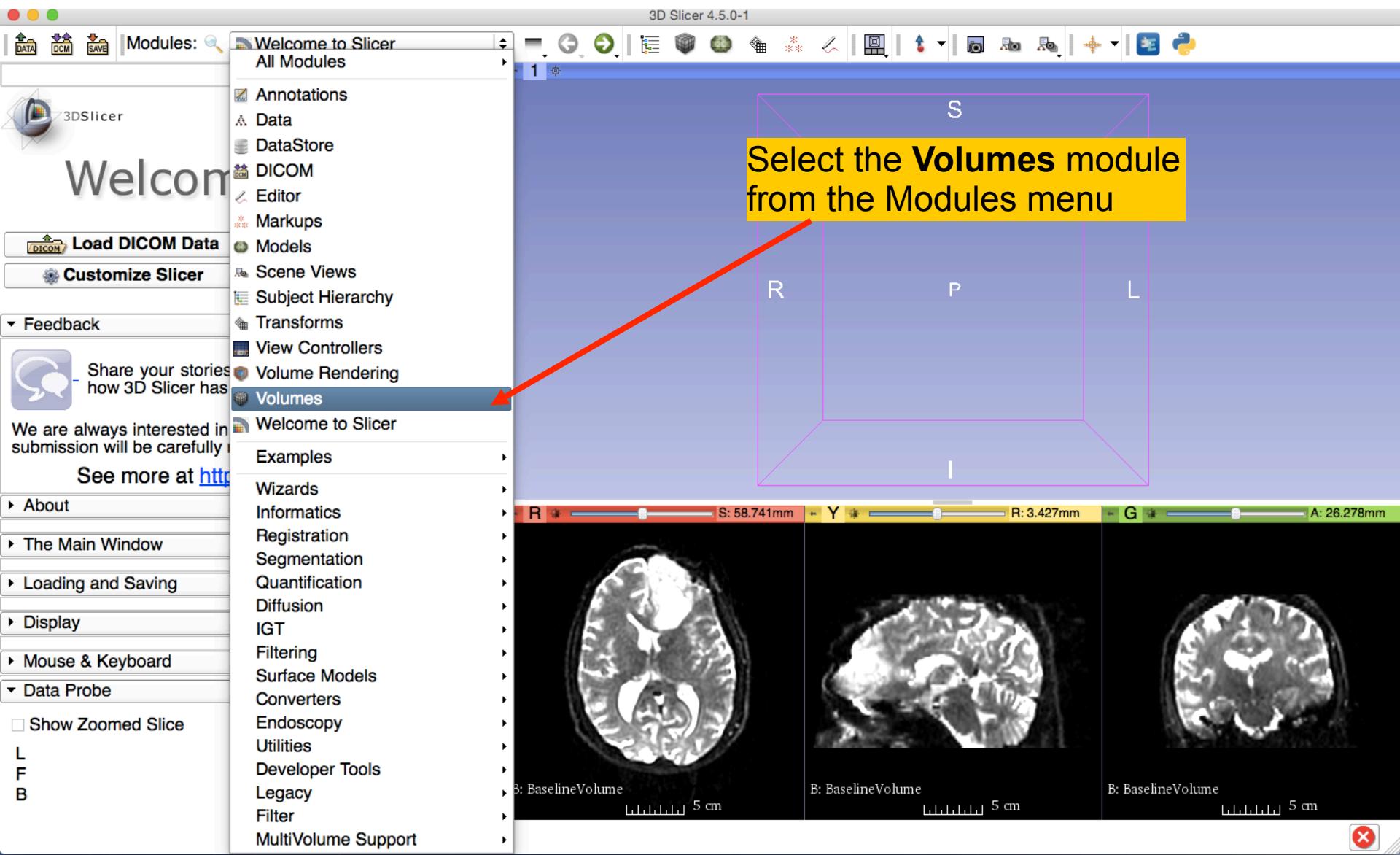
Loading DTI and Baseline Data



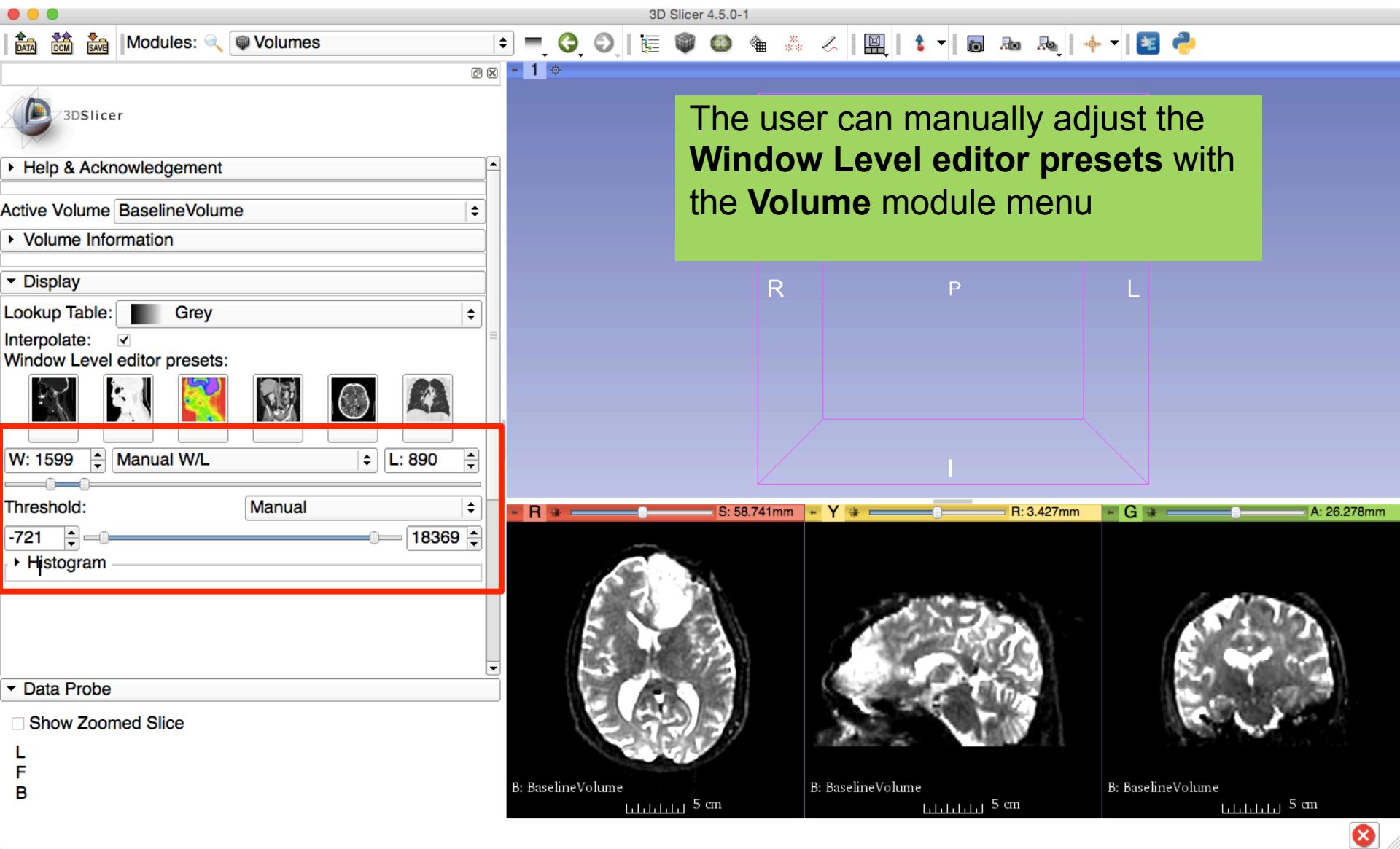
Loading DTI and Baseline Data



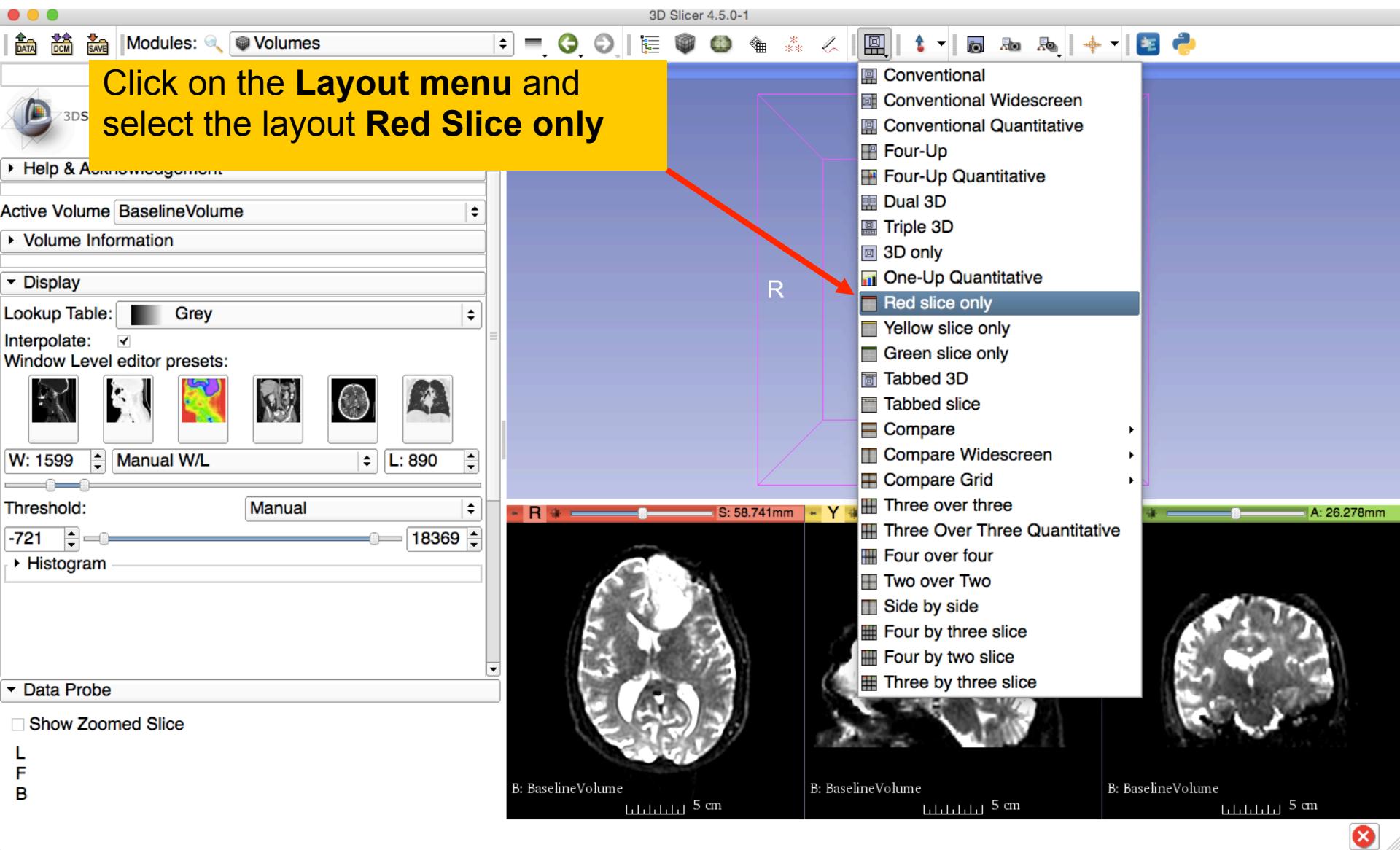
Loading DTI and Baseline Data

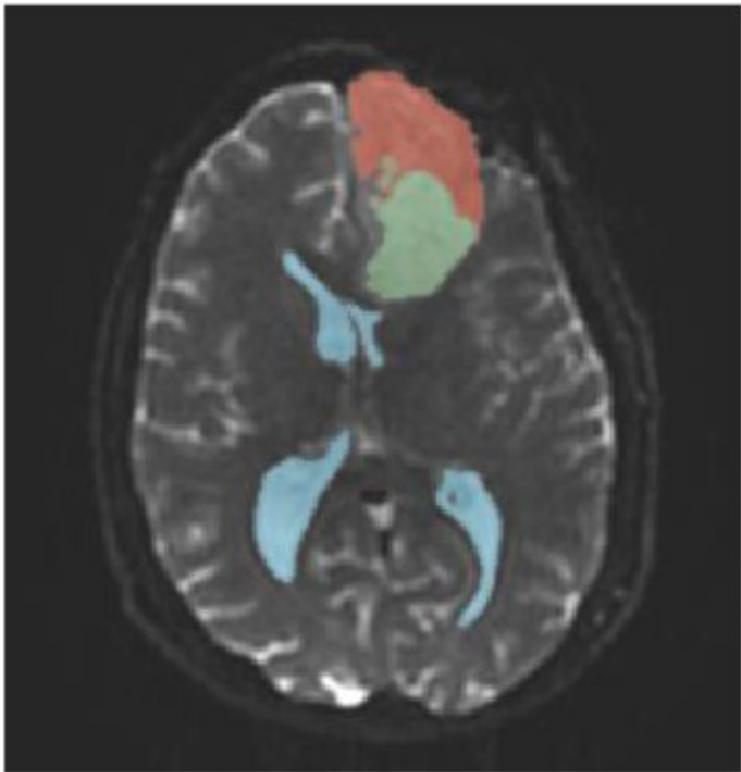


Loading DTI and Baseline Data



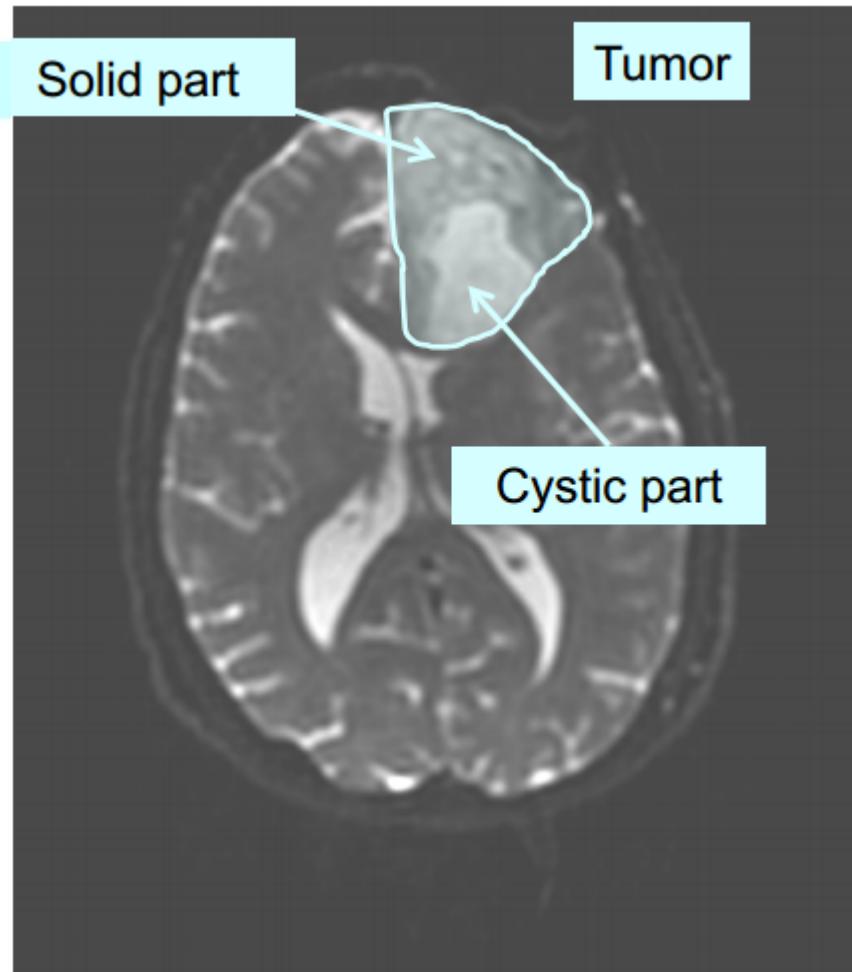
Loading DTI and Baseline Data





Part 1: Segmenting the tumor and ventricles

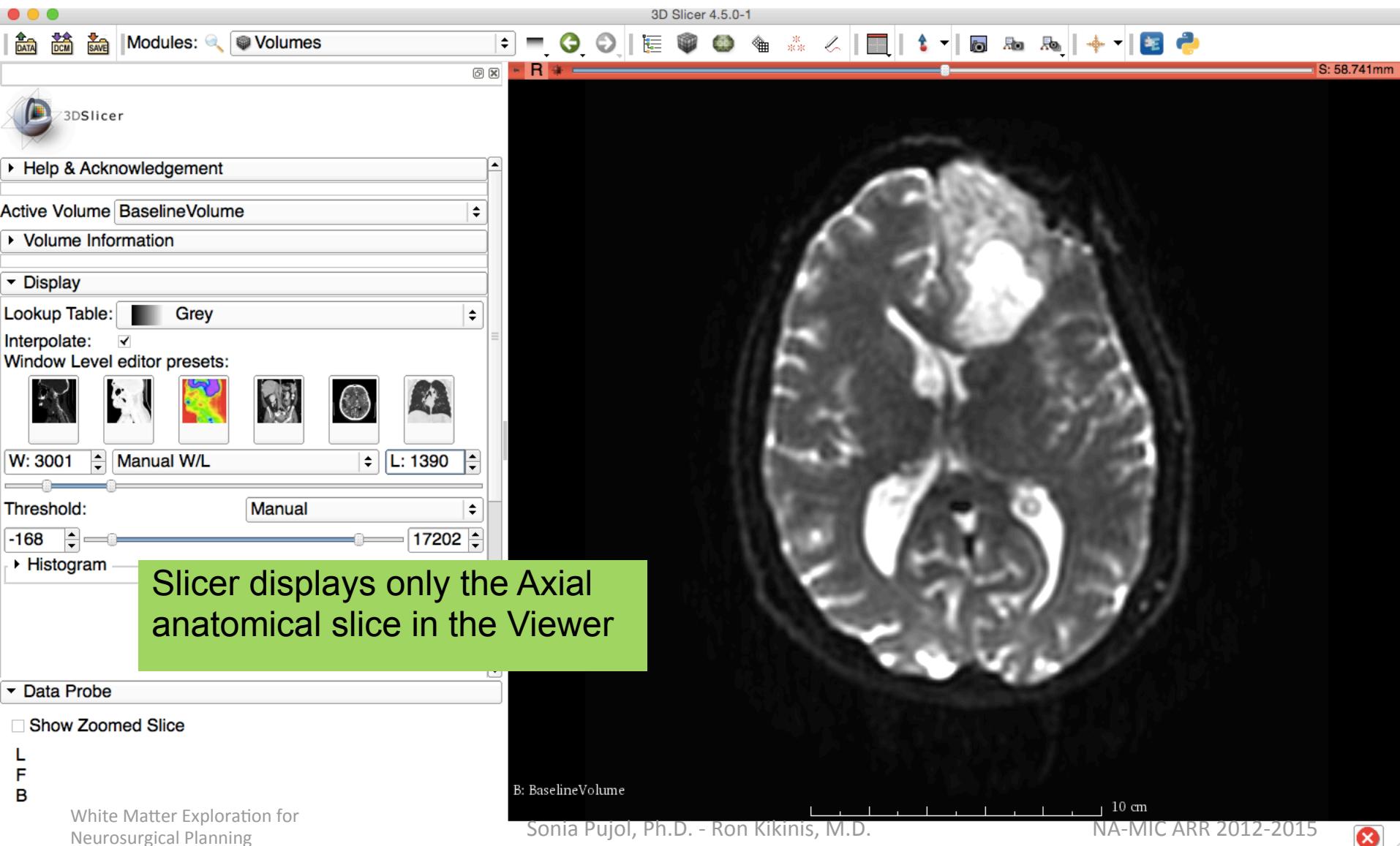
Tumor Segmentation



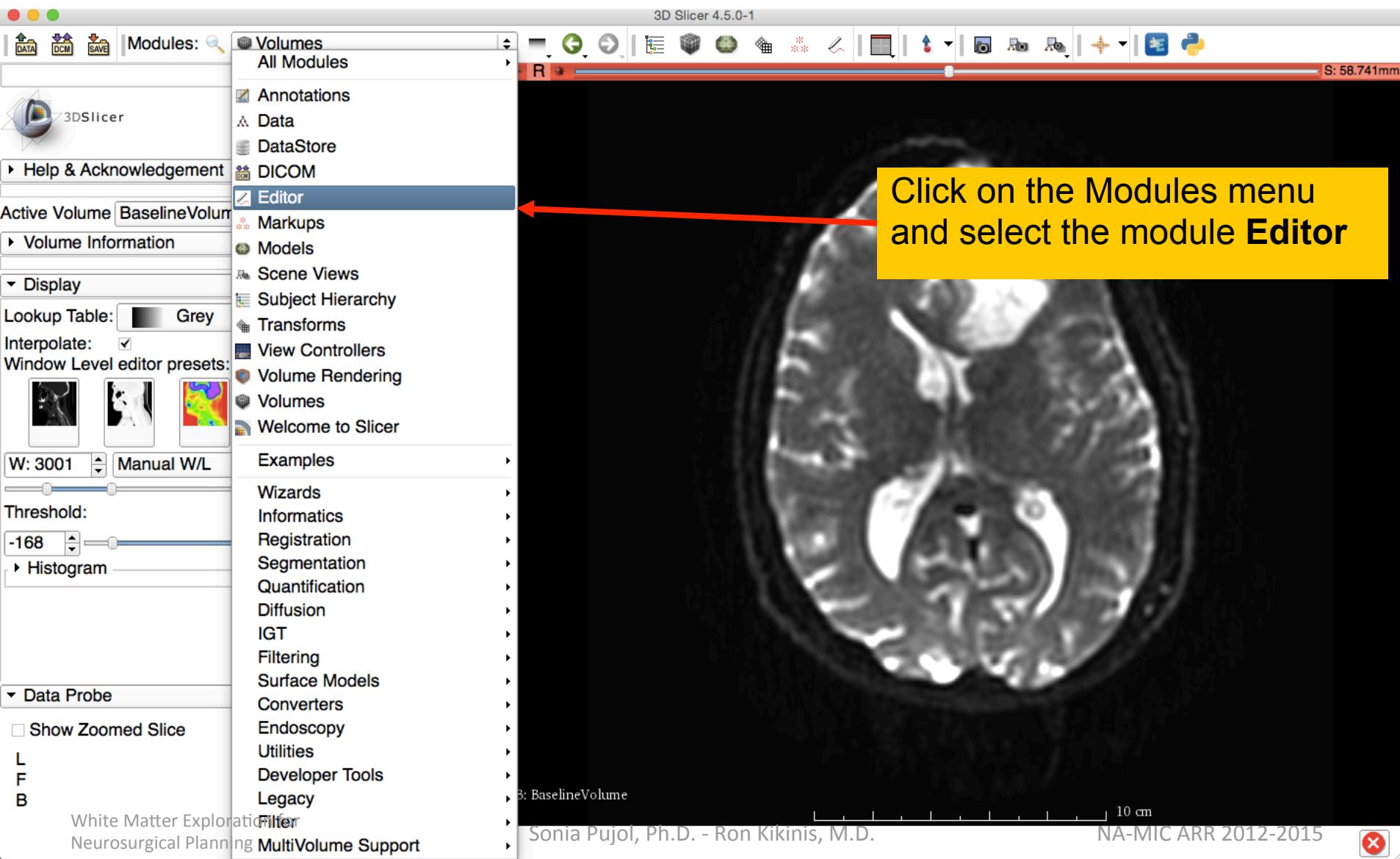
The tumor in this clinical case is composed of two parts: a solid part, and a cystic part.

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

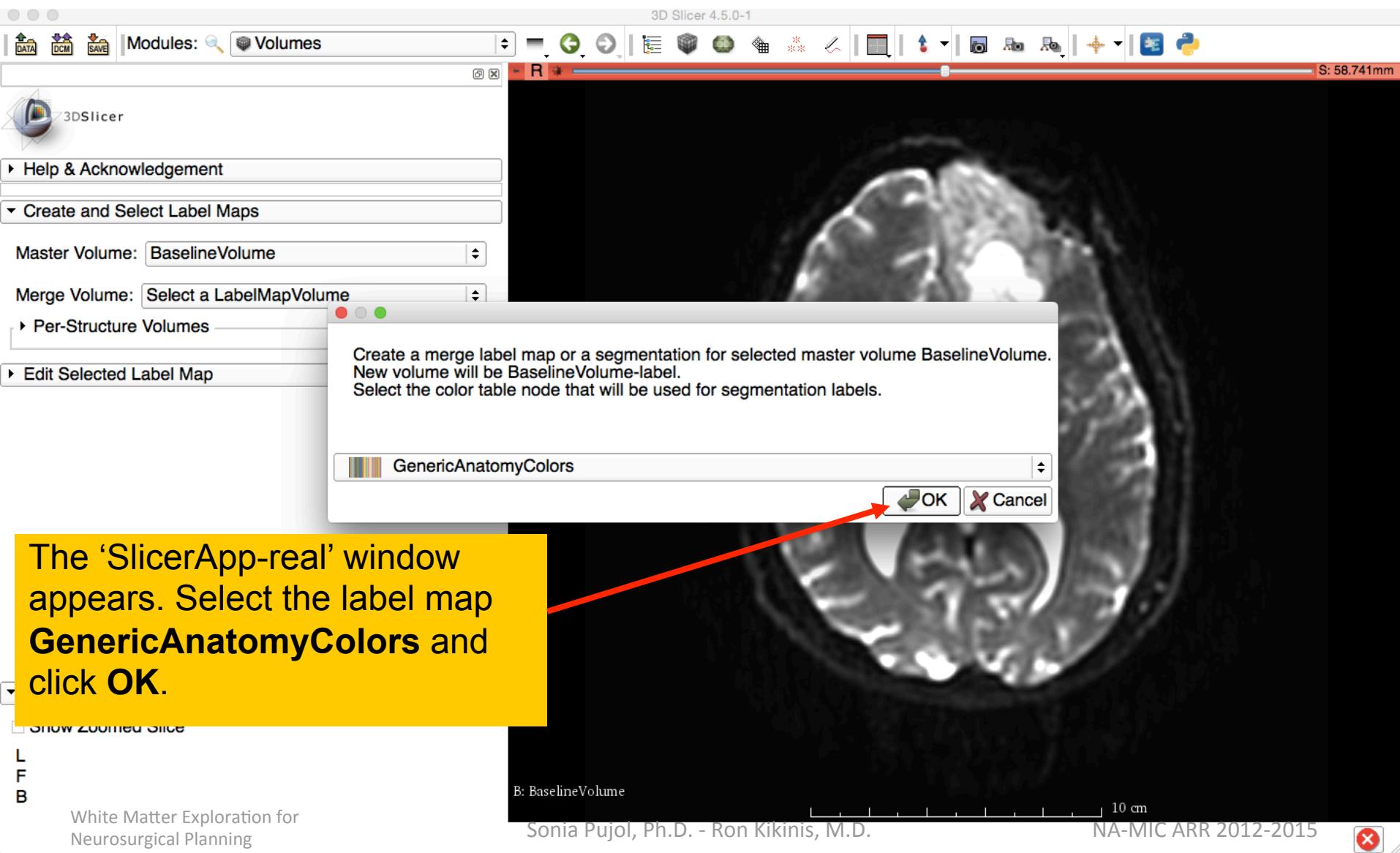
Tumor Segmentation



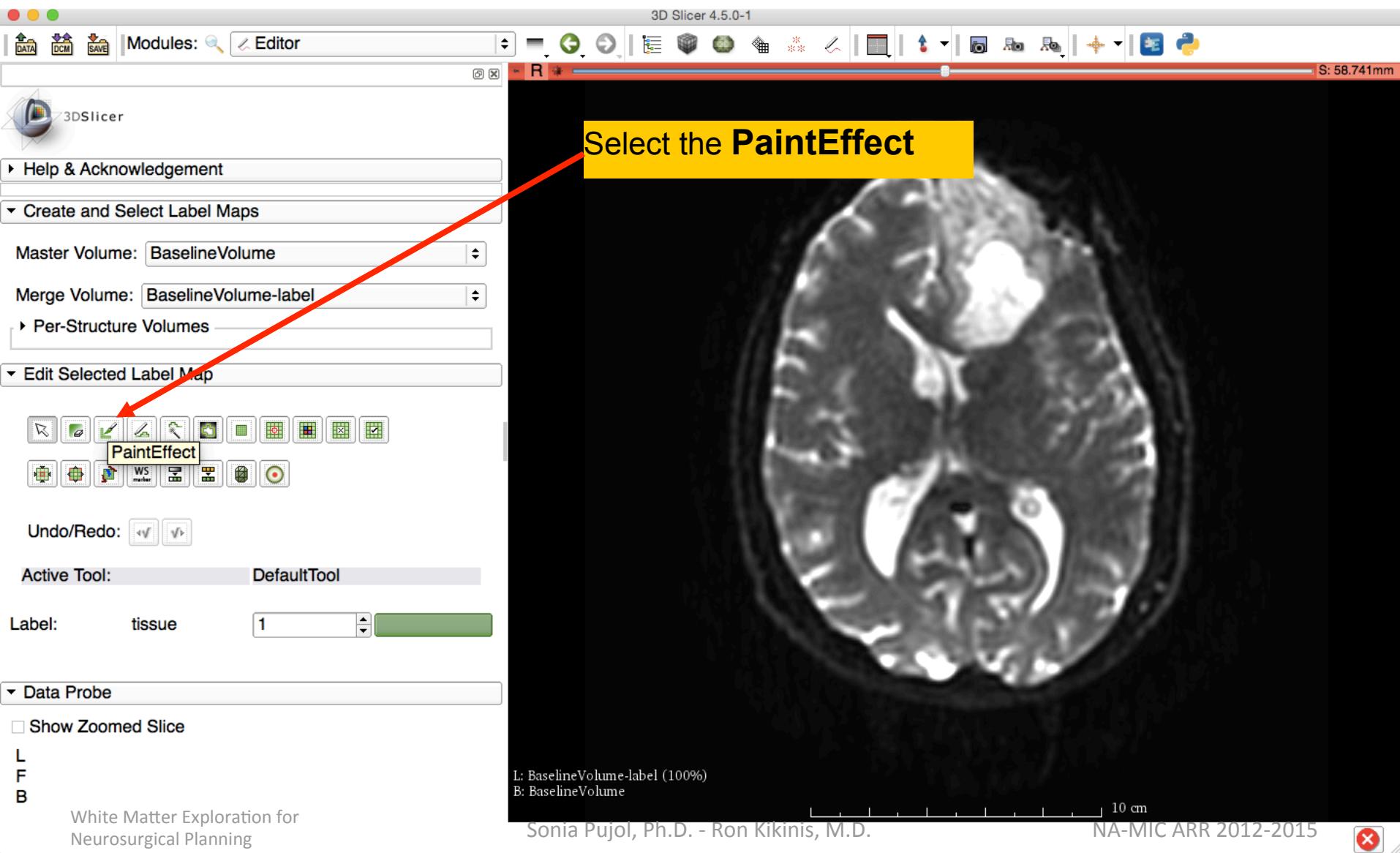
Tumor Segmentation



Tumor Segmentation



Tumor Segmentation



Tumor Segmentation

DA

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

R S: 58.741mm

Help & Acknowledgement

Create and Select Label Maps

Edit Selected Label Map

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

3D Slicer 4.5.0-1

Search: []

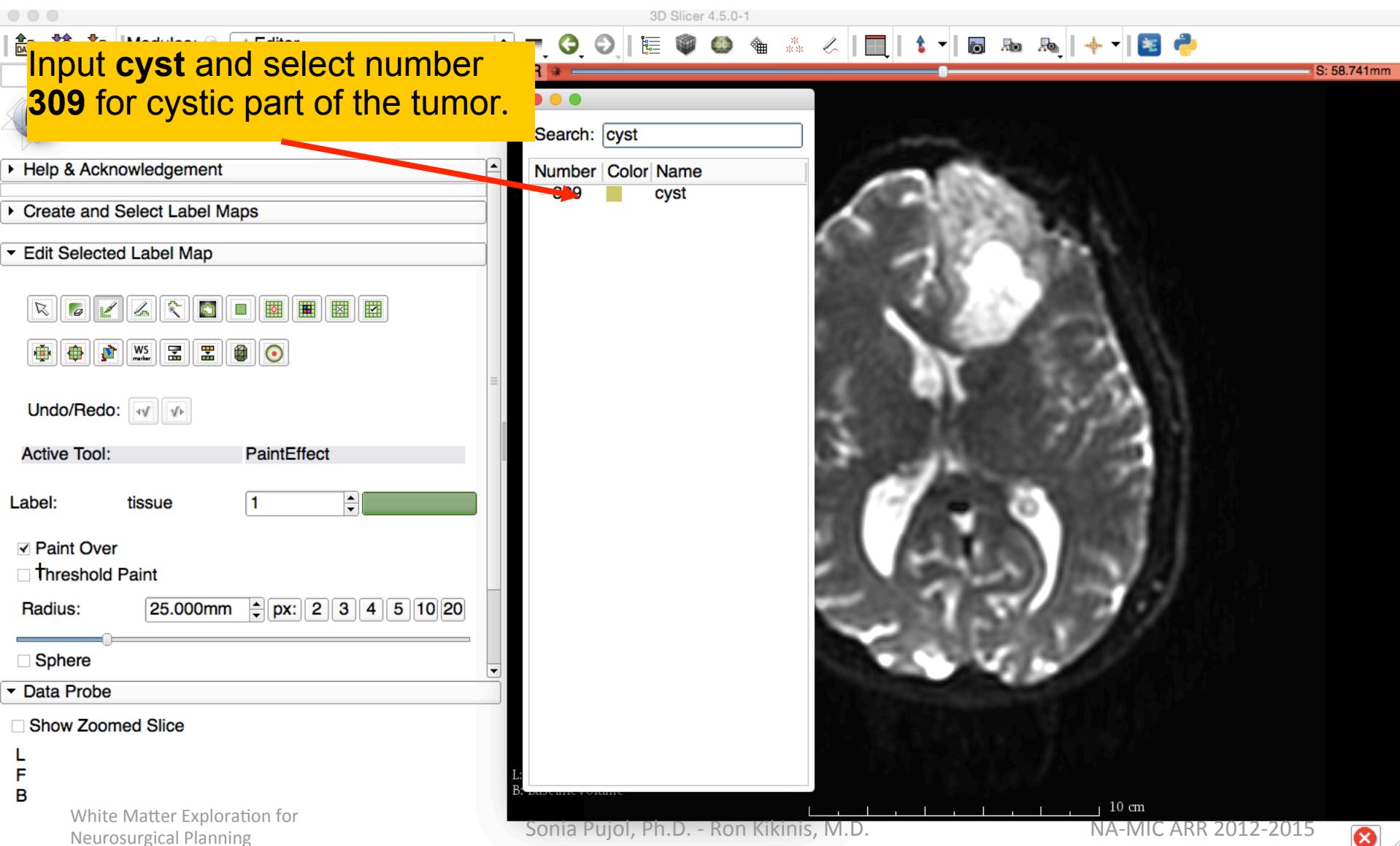
Number	Color	Name
0	[Black]	background
1	[Green]	tissue
2	[Yellow]	bone
3	[Brown]	skin
4	[Blue]	connective tissue
5	[Red]	blood
6	[Orange]	organ
7	[Light Green]	mass
8	[Dark Red]	muscle
9	[Yellow-Green]	foreign object
10	[Dark Brown]	waste
11	[Light Orange]	teeth
12	[Light Yellow]	fat
13	[Light Blue]	gray matter
14	[White]	white matter
15	[Dark Blue]	nerve
16	[Medium Blue]	vein
17	[Red]	artery
18	[Purple]	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	[Dark Green]	bile
27	[Light Green]	urine
28	[Dark Brown]	feces
29	[Light Blue]	gas
30	[Light Blue]	fluid
31	[Light Blue]	edema
32	[Red]	bleeding
33	[Light Blue]	hemorrhage

10 cm

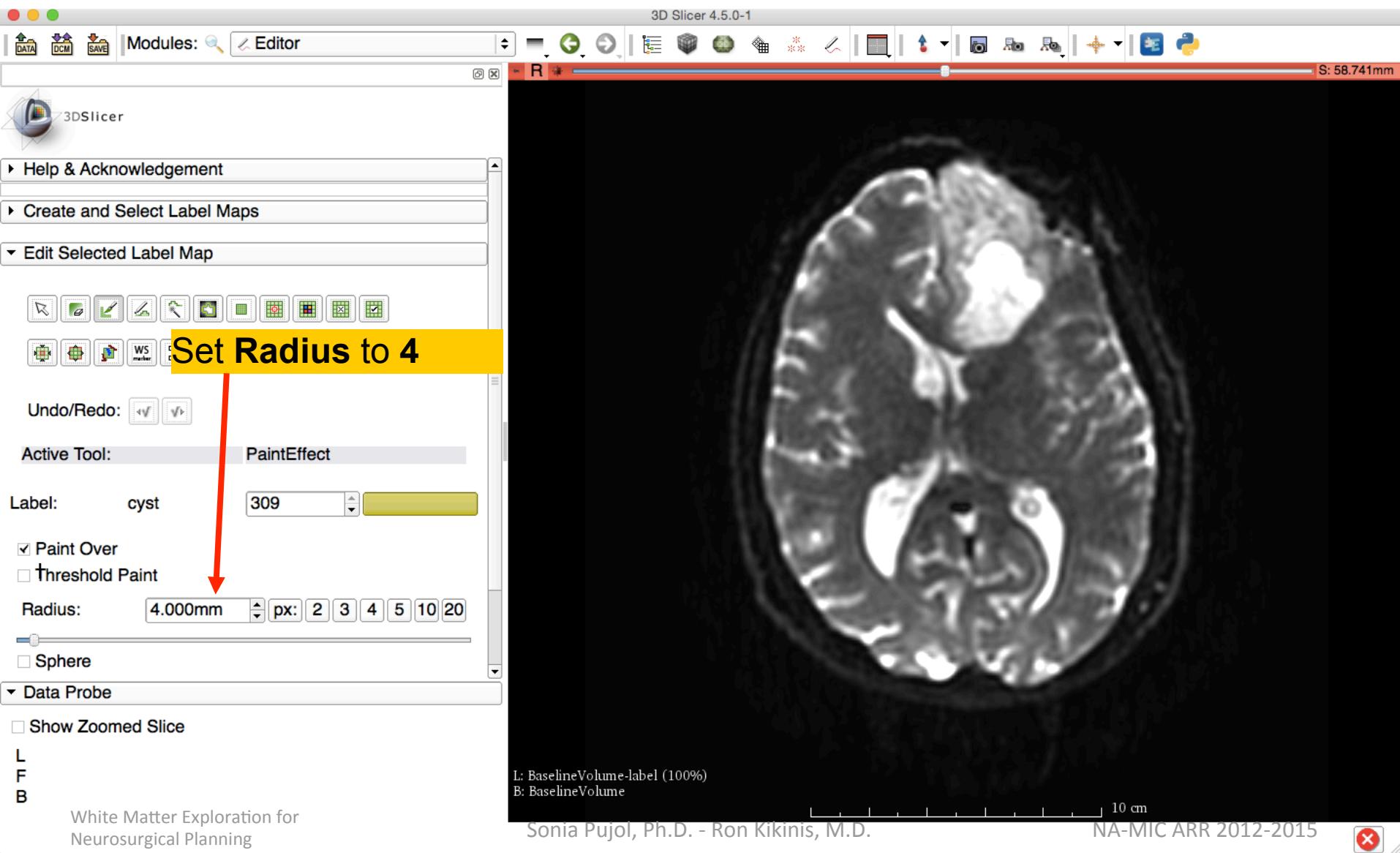
Sonia Pujol, Ph.D. - Ron Kikinis, M.D.

NA-MIC ARR 2012-2015

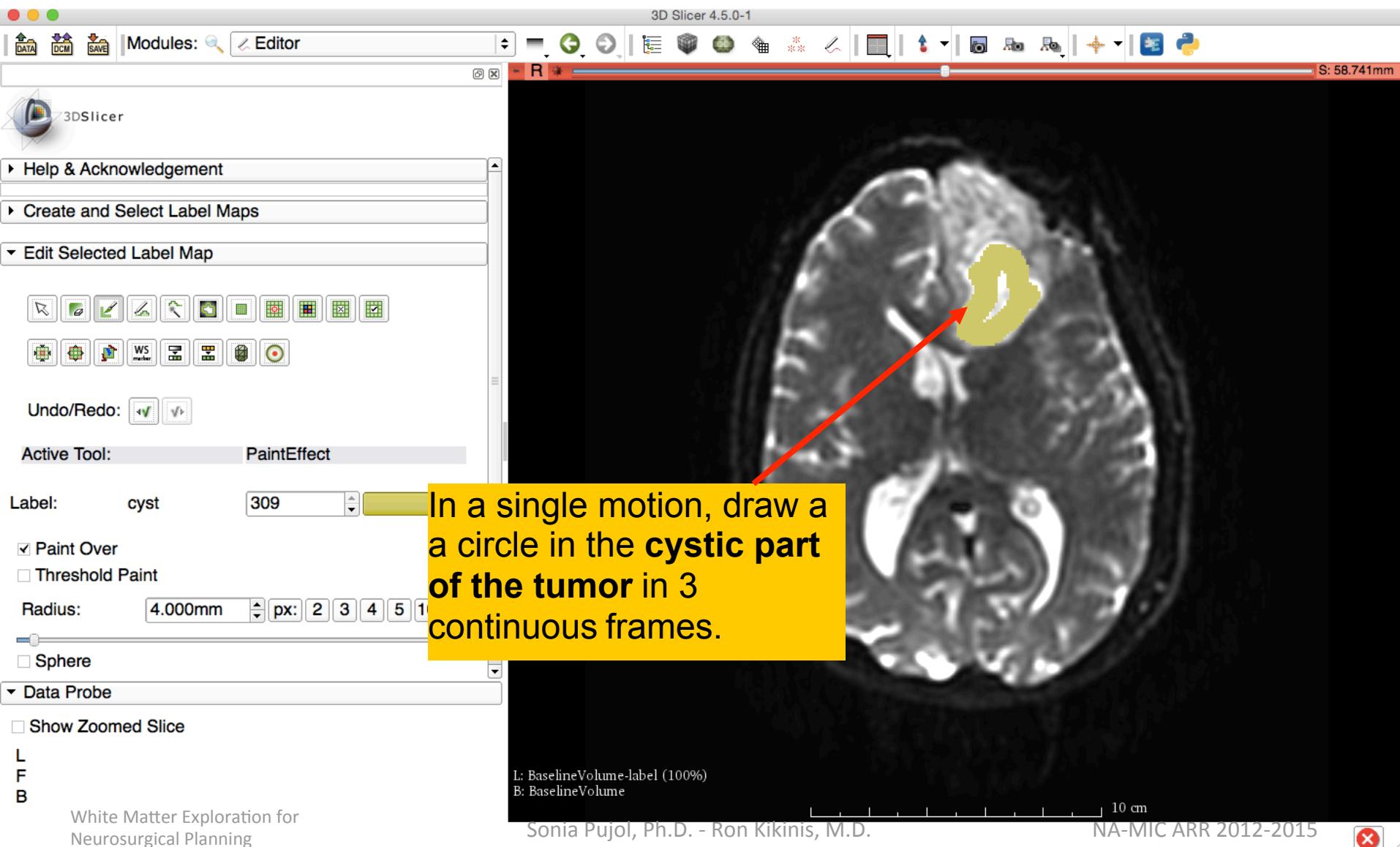
Tumor Segmentation



Tumor Segmentation



Tumor Segmentation



Tumor Segmentation

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

3D Slicer 4.5.0-1

S: 58.741mm

DA Modules Editor

Help & Acknowledgement

Create and Select Label Maps

Edit Selected Label Map

Search: mass

Number	Color	Name
309	Yellow	cyst
7	Green	mass
7	Green	mass

PaintEffect

Label: mass 7

Paint Over

Threshold Paint

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

Sphere

Data Probe

Show Zoomed Slice

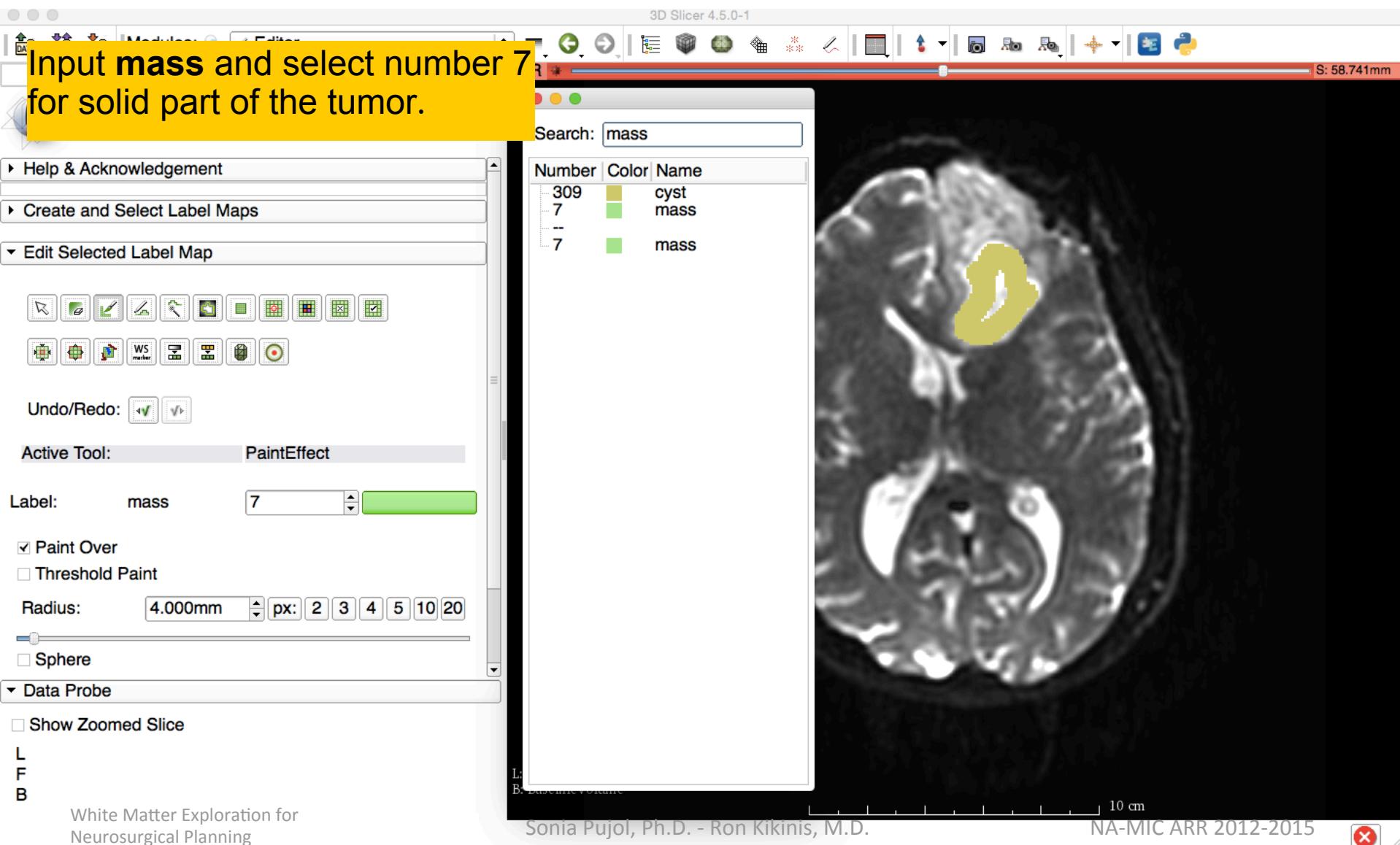
L
F
B

White Matter Exploration for Neurosurgical Planning

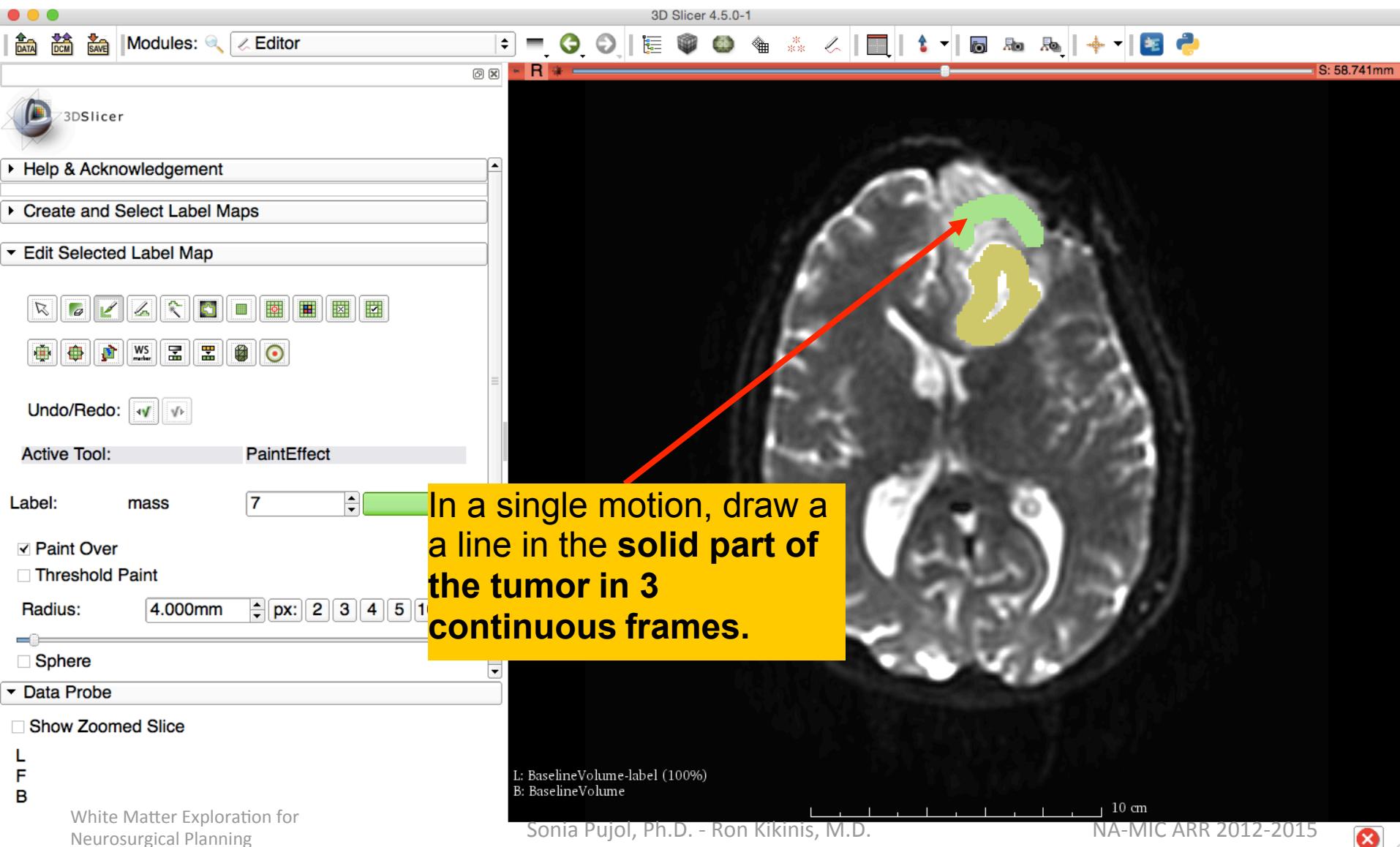
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10 cm

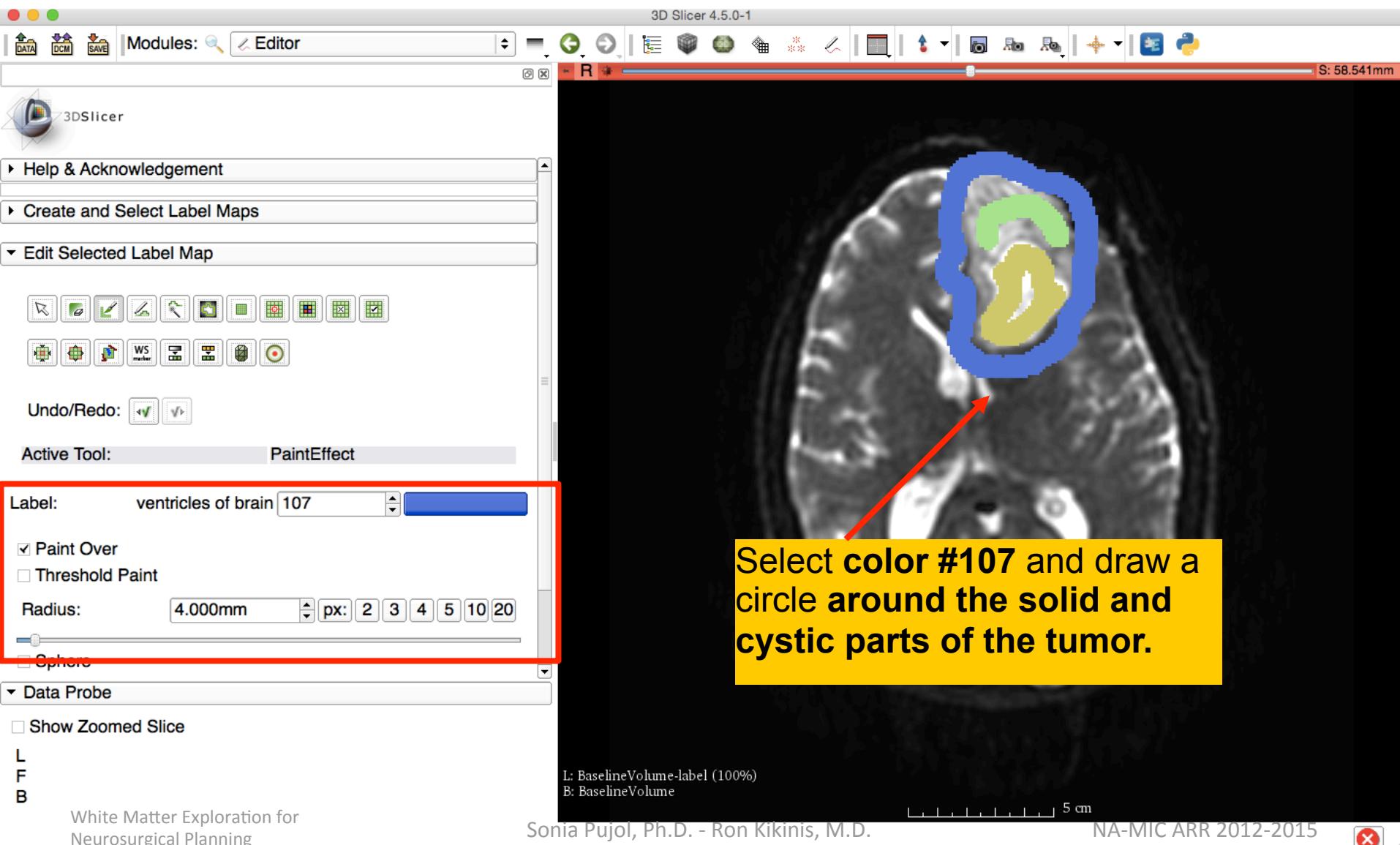
NA-MIC ARR 2012-2015



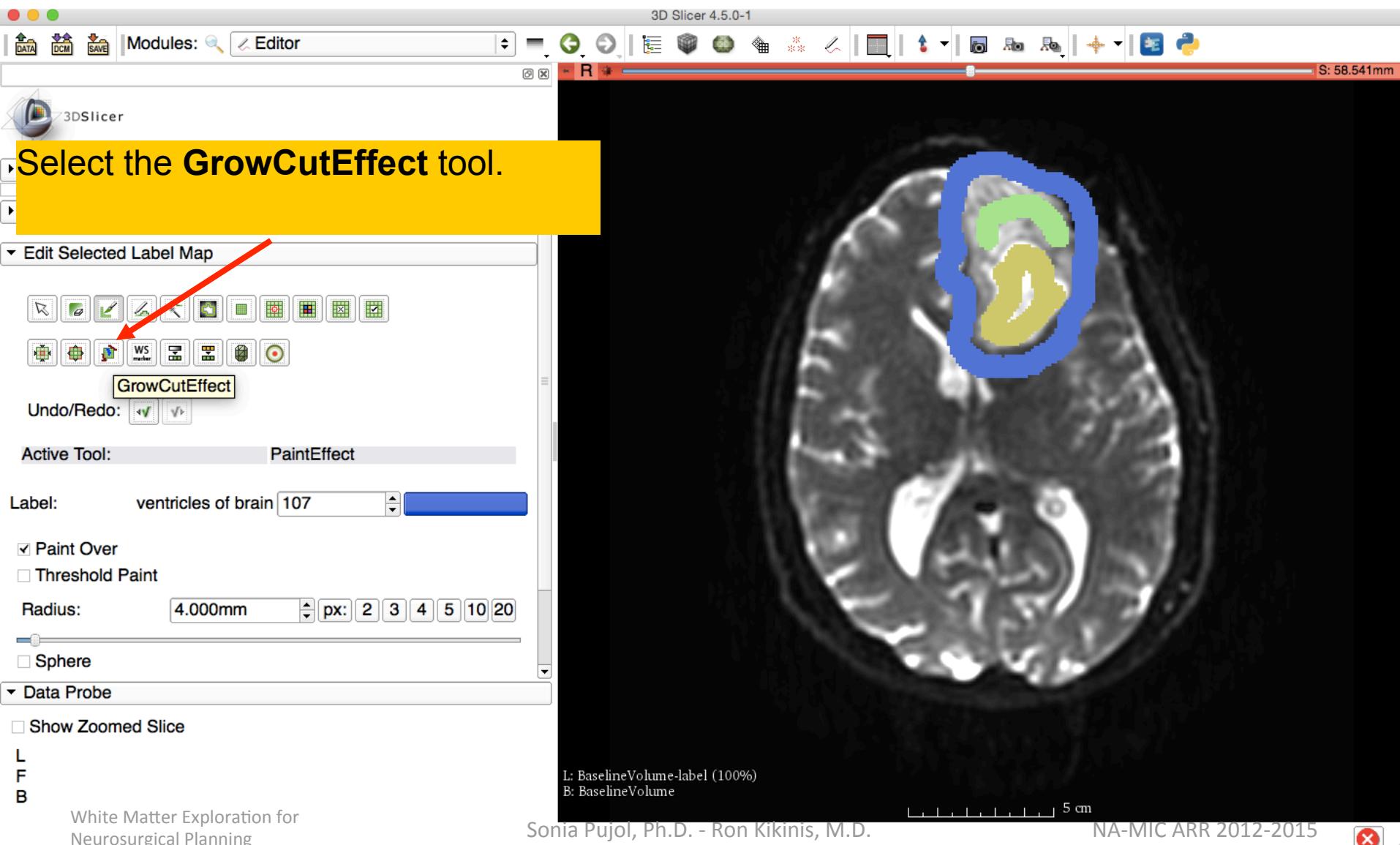
Tumor Segmentation



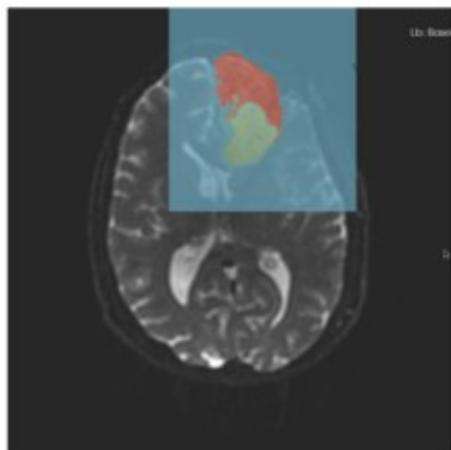
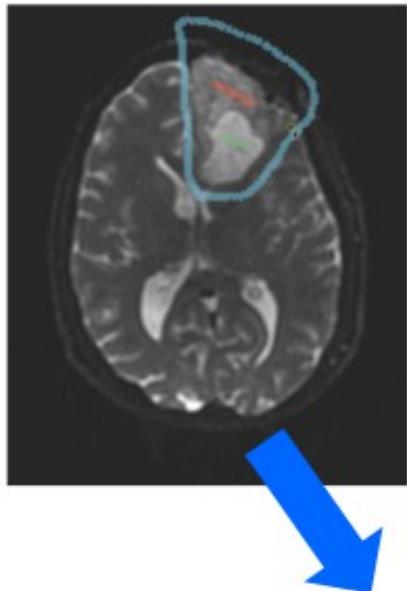
Tumor Segmentation



Tumor Segmentation

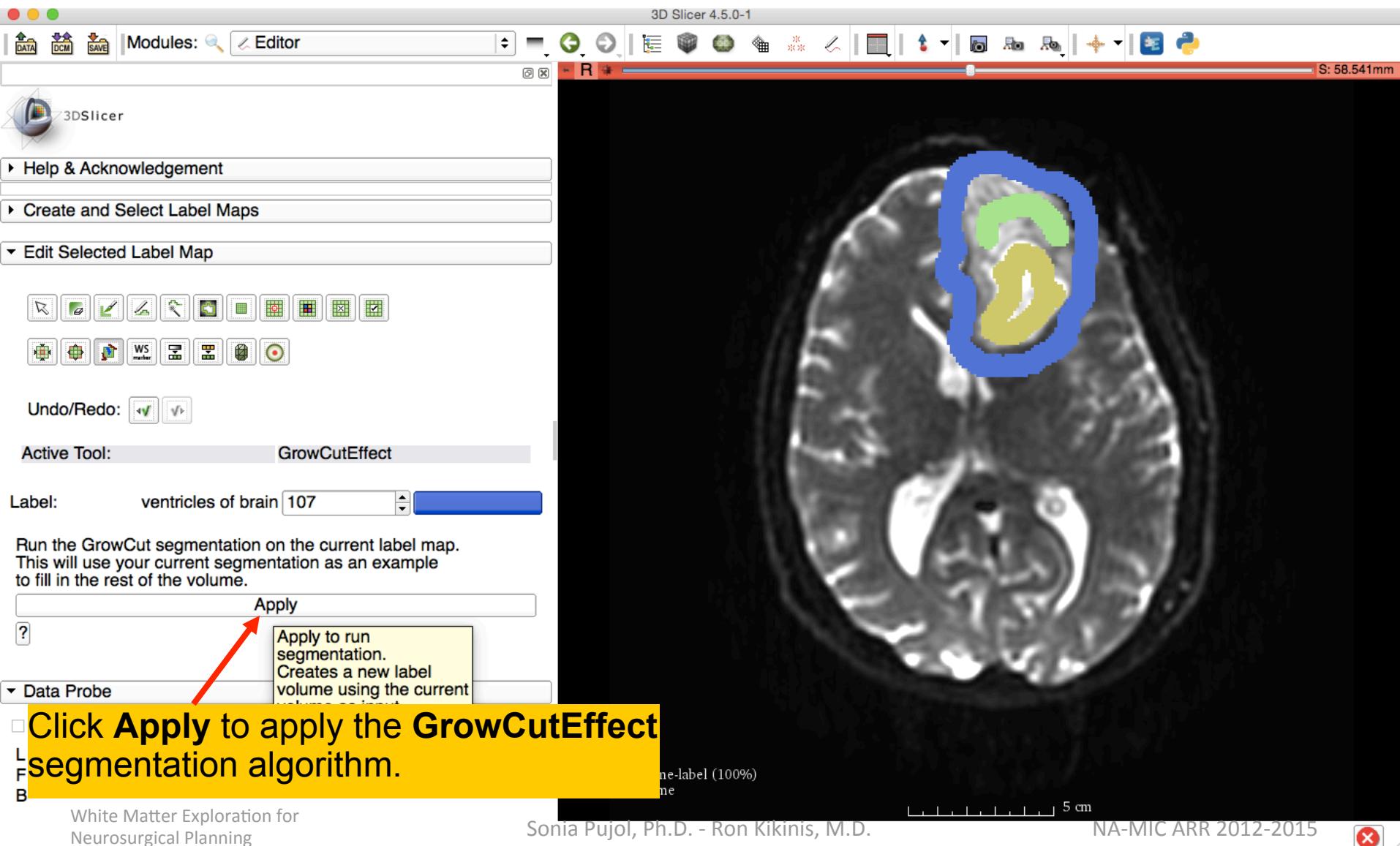


Grow Cut Segmentation

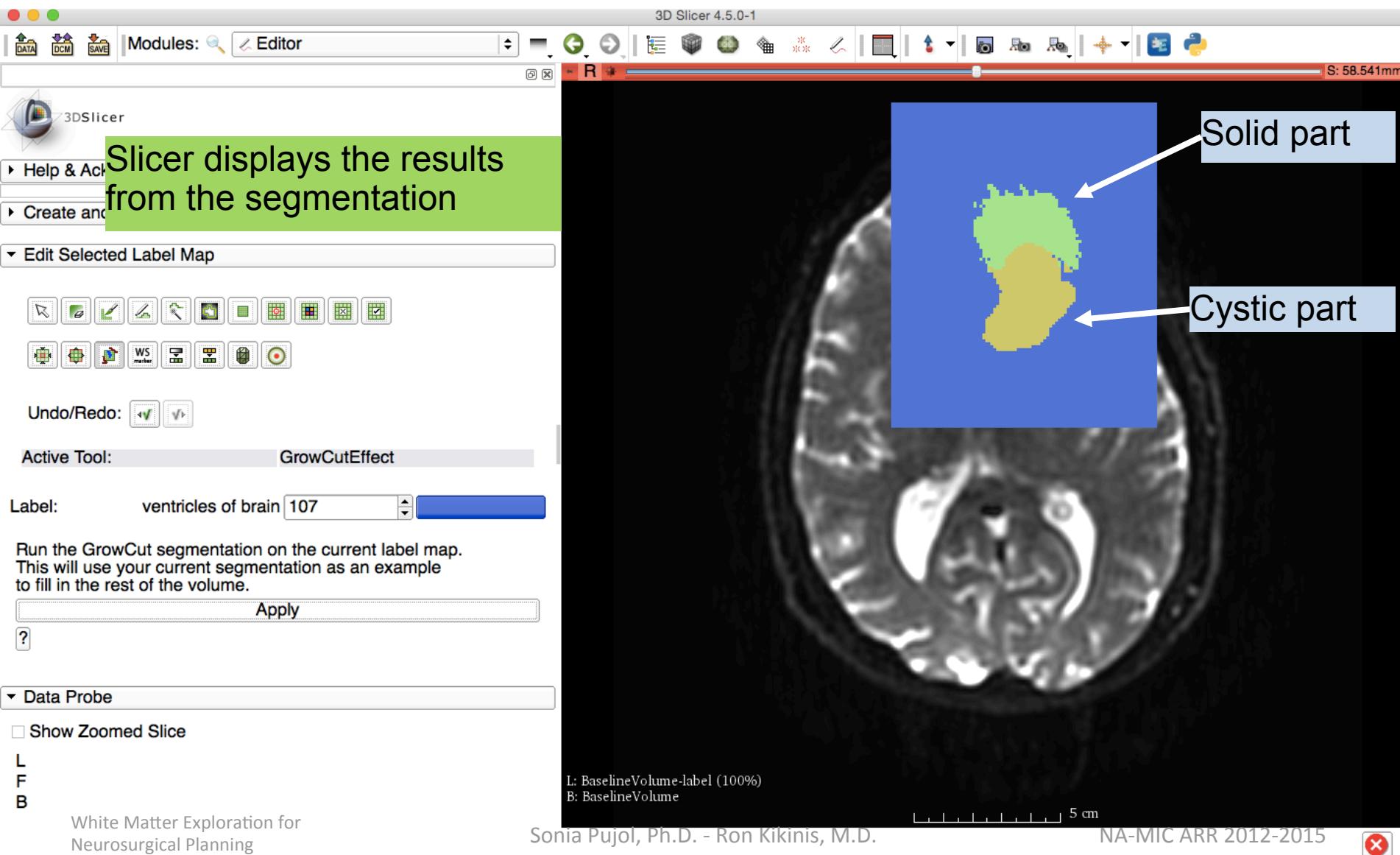


- The Grow Cut Segmentation method is a competitive region growing algorithm using Cellular Automata.
- The algorithm performs multi-label image segmentation using a set of user input scribbles.
- V. Vezhnevets, V. Konouchine. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". Proc. Graphicon.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

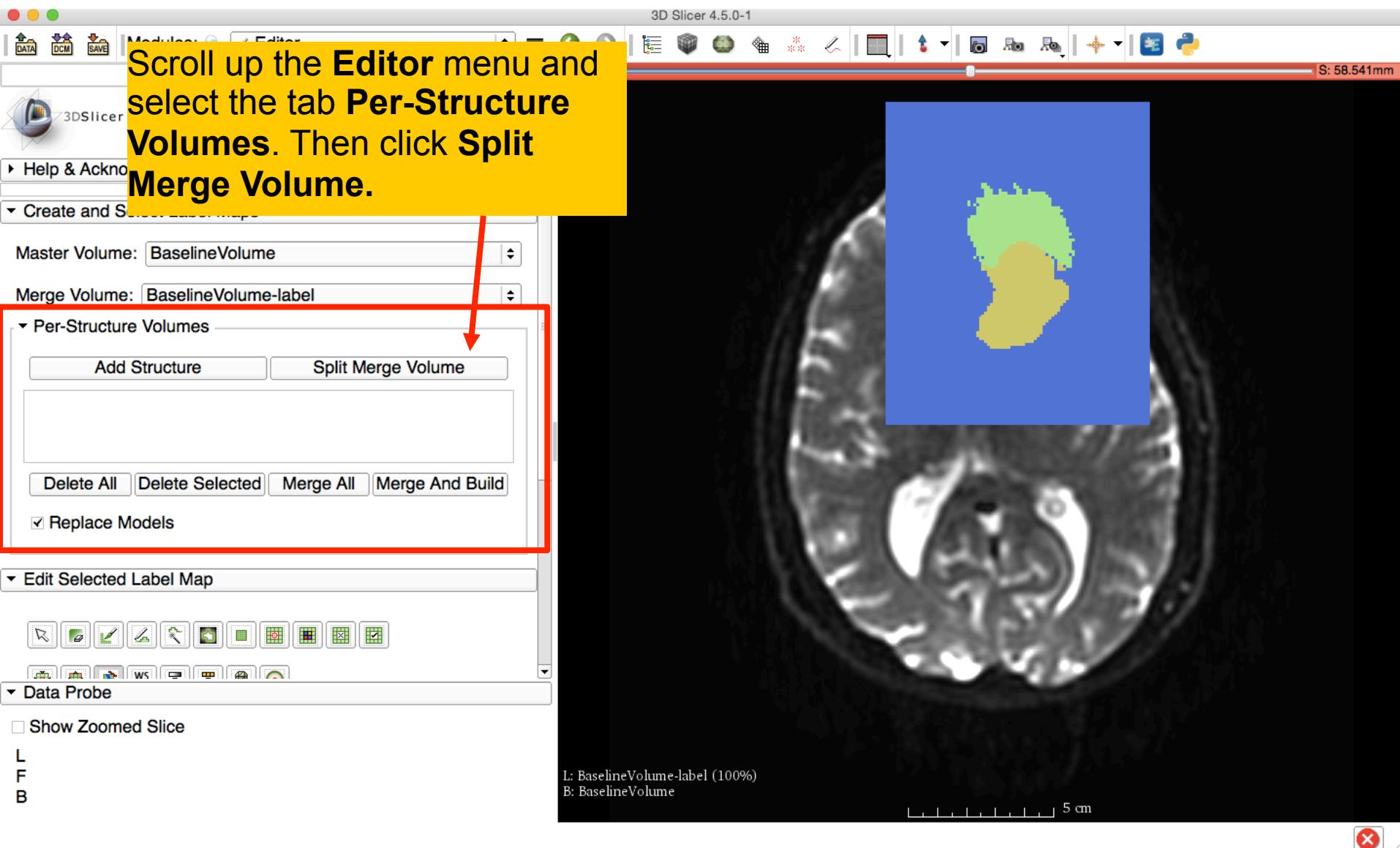
Tumor Segmentation



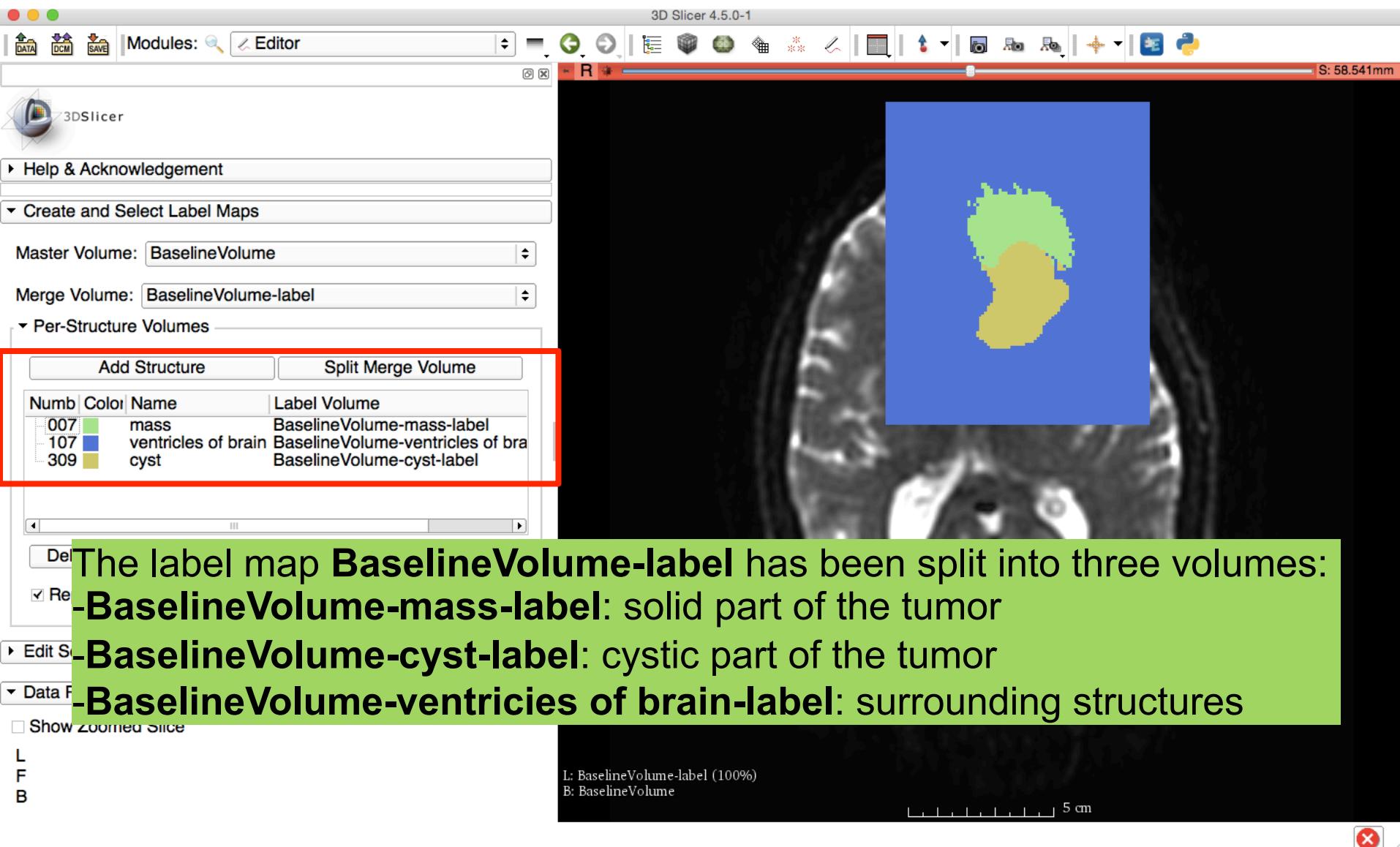
Tumor Segmentation



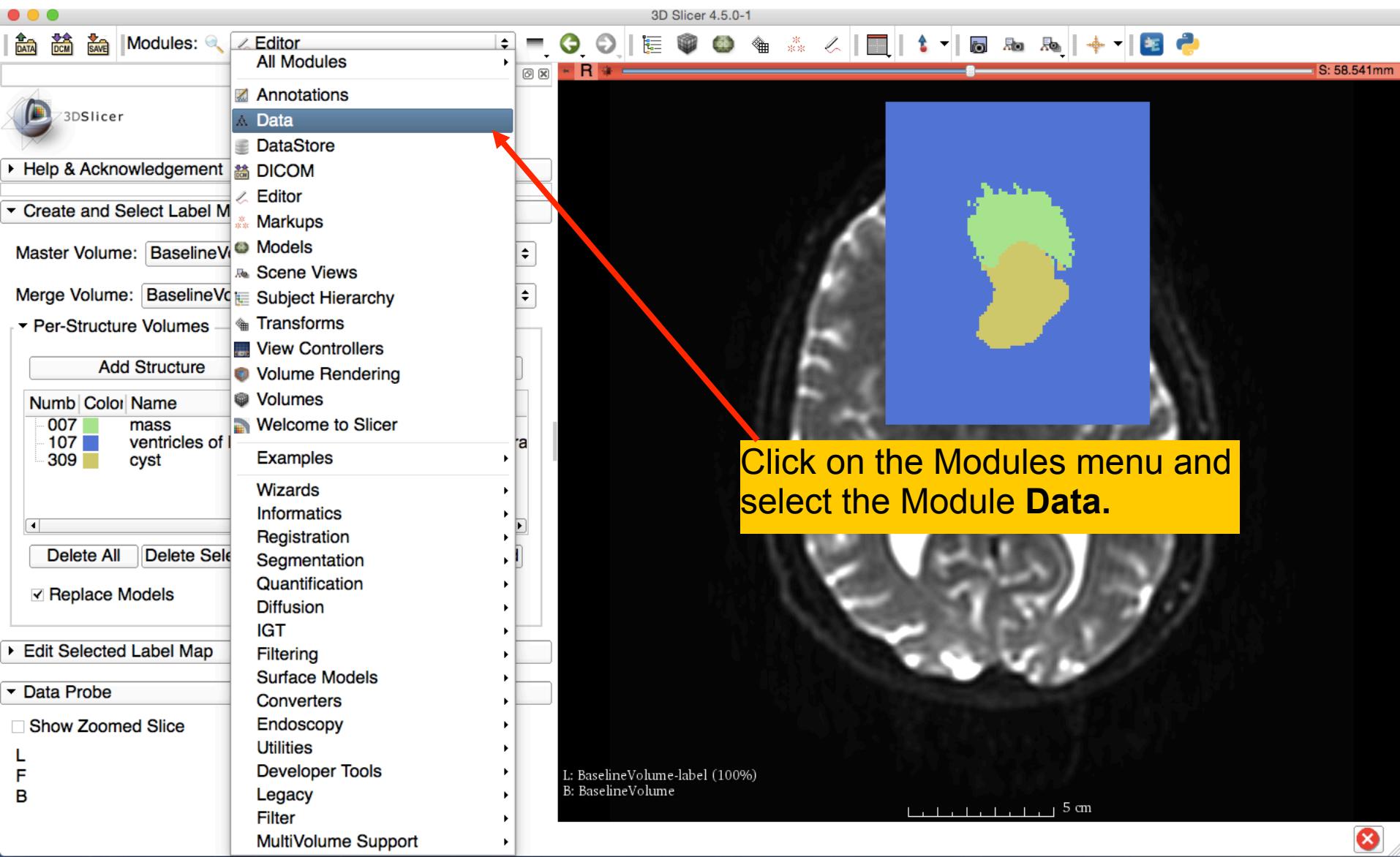
Tumor Segmentation



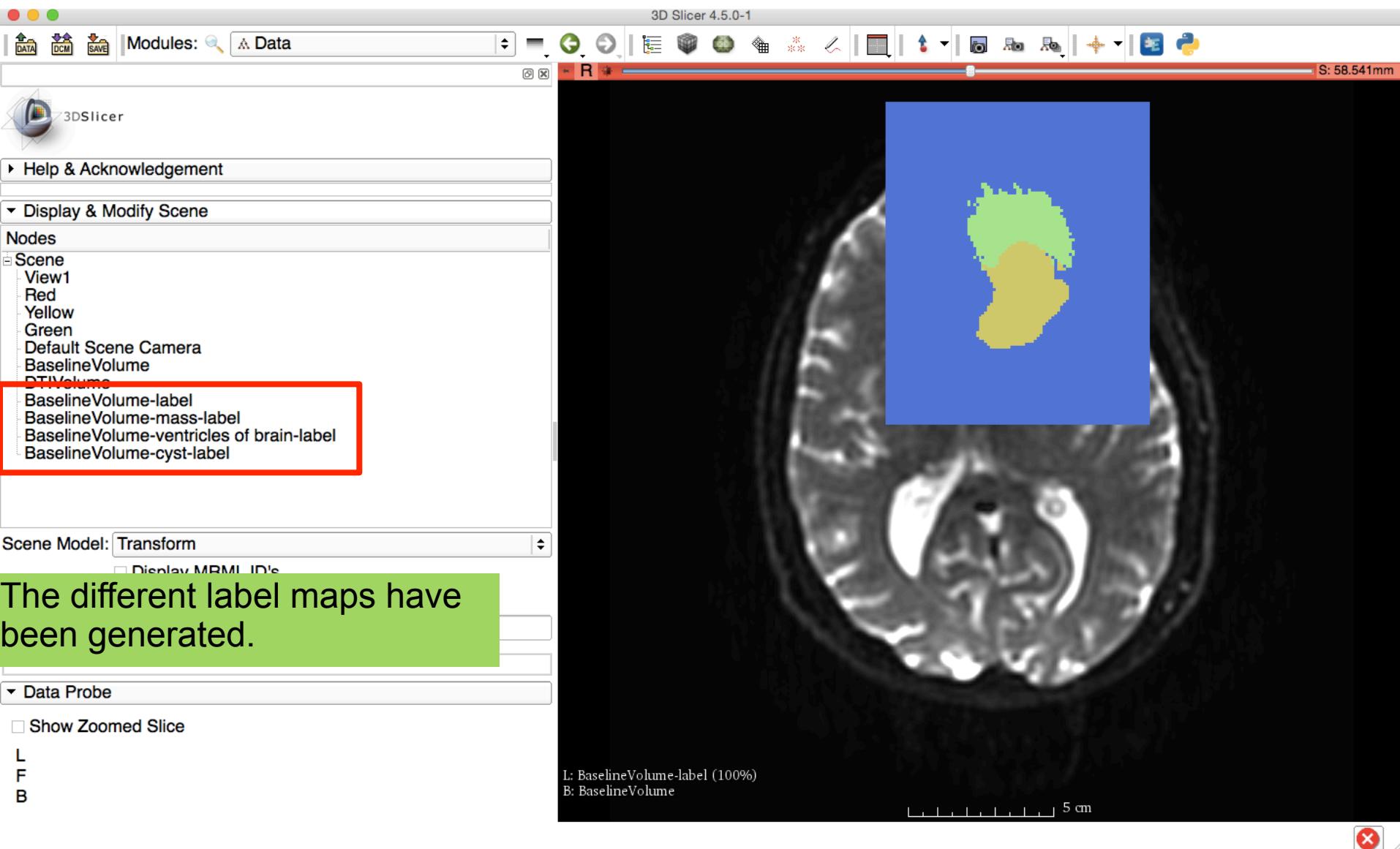
Tumor Segmentation



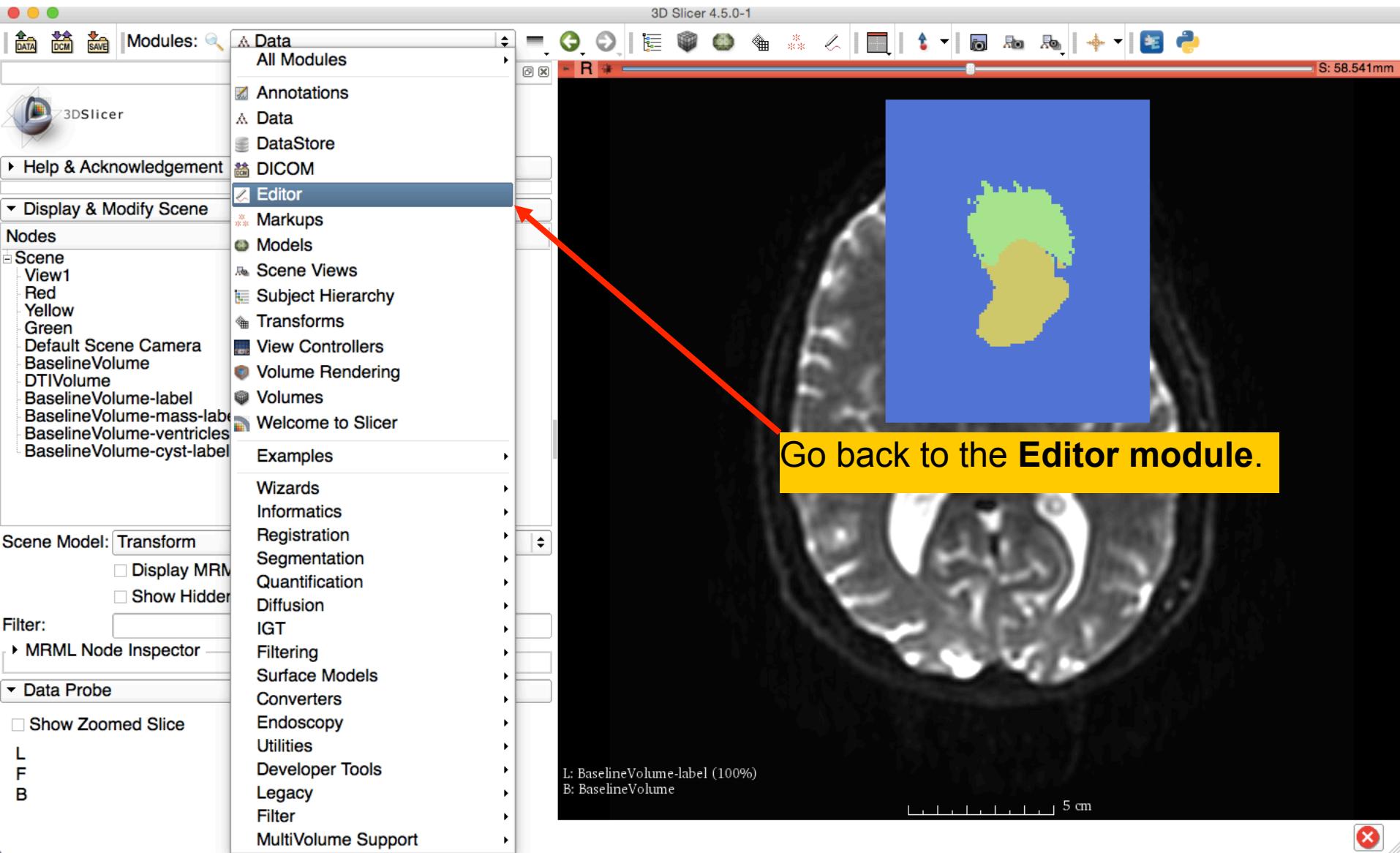
Tumor Segmentation



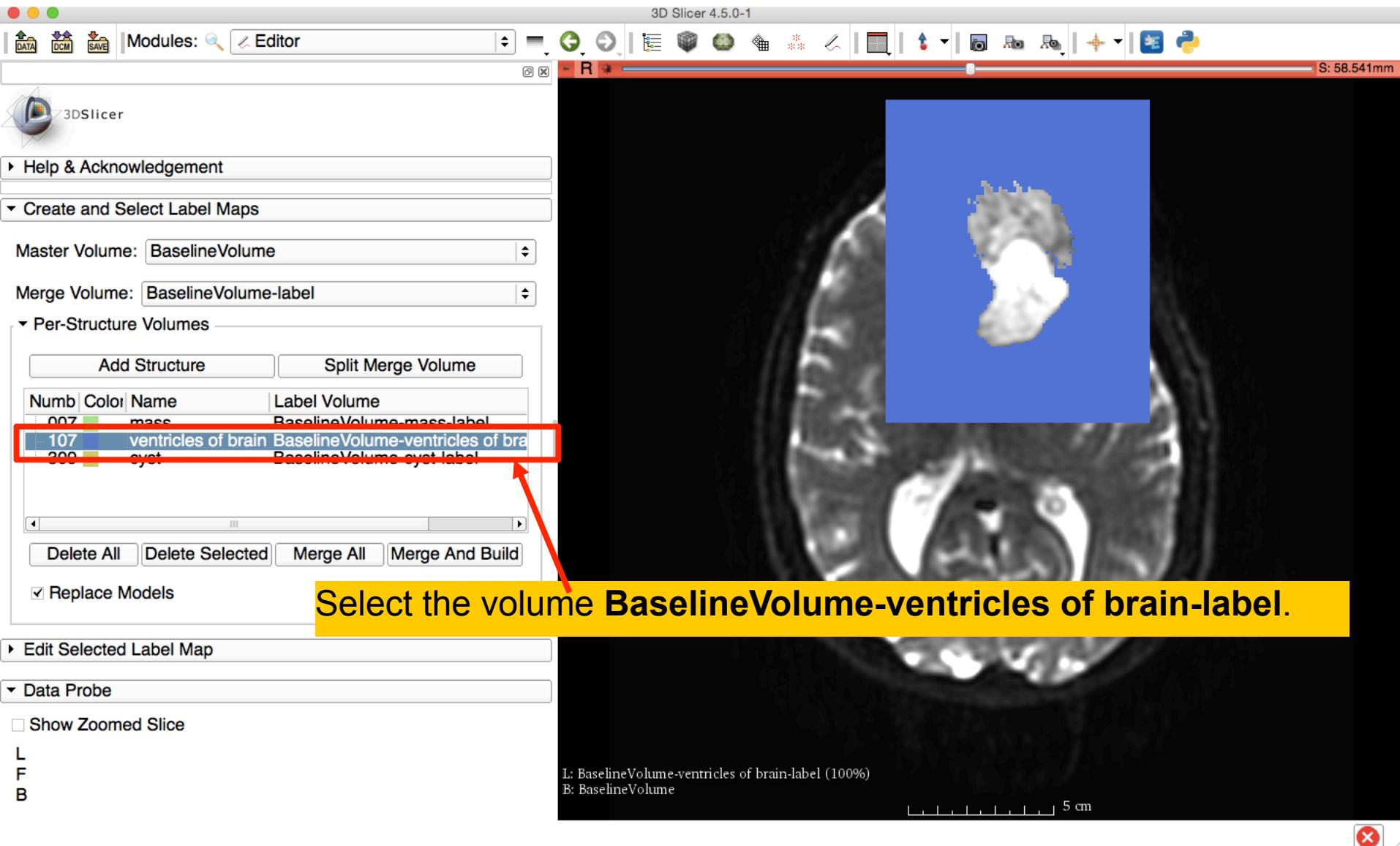
Tumor Segmentation



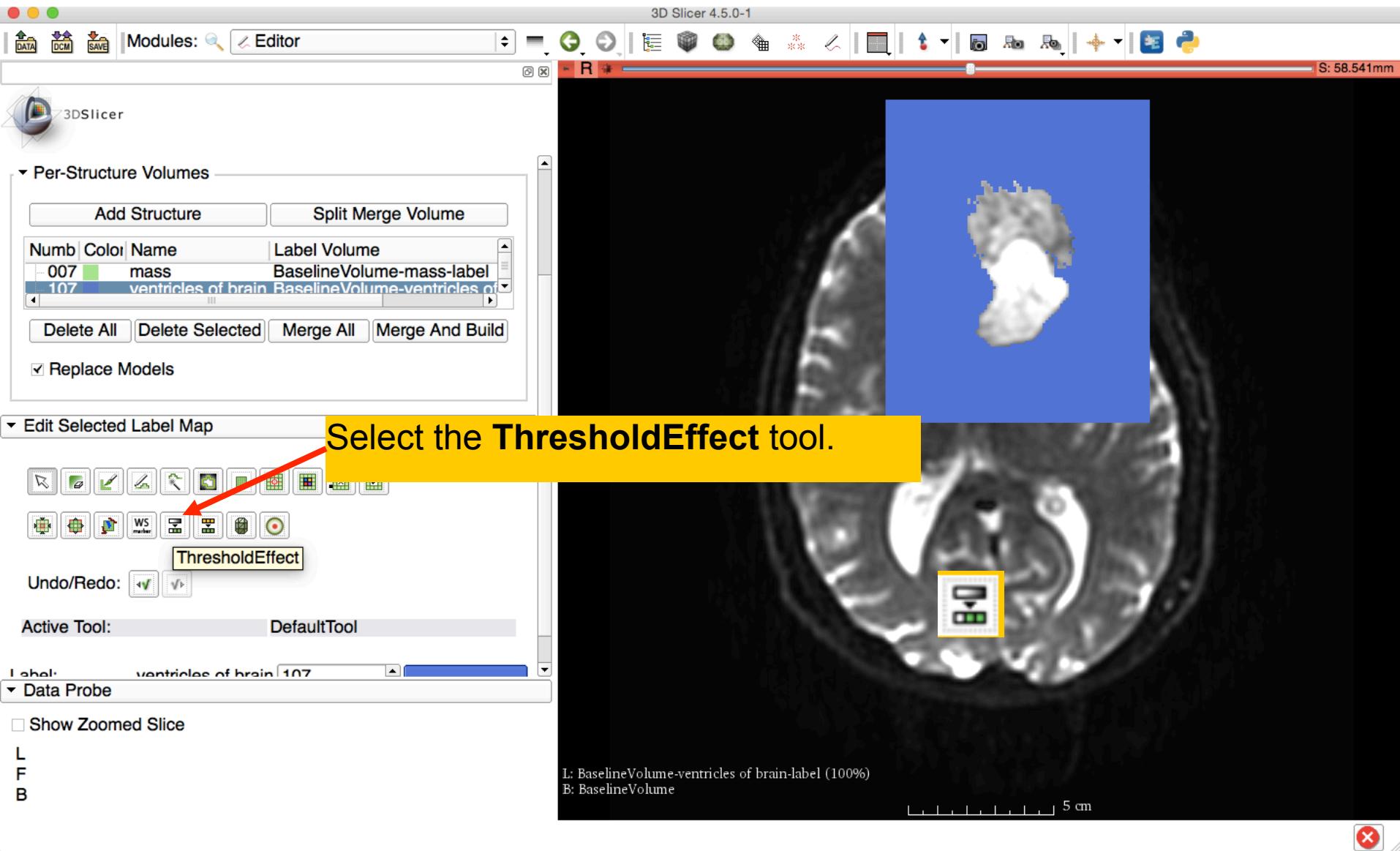
Ventricles Segmentation



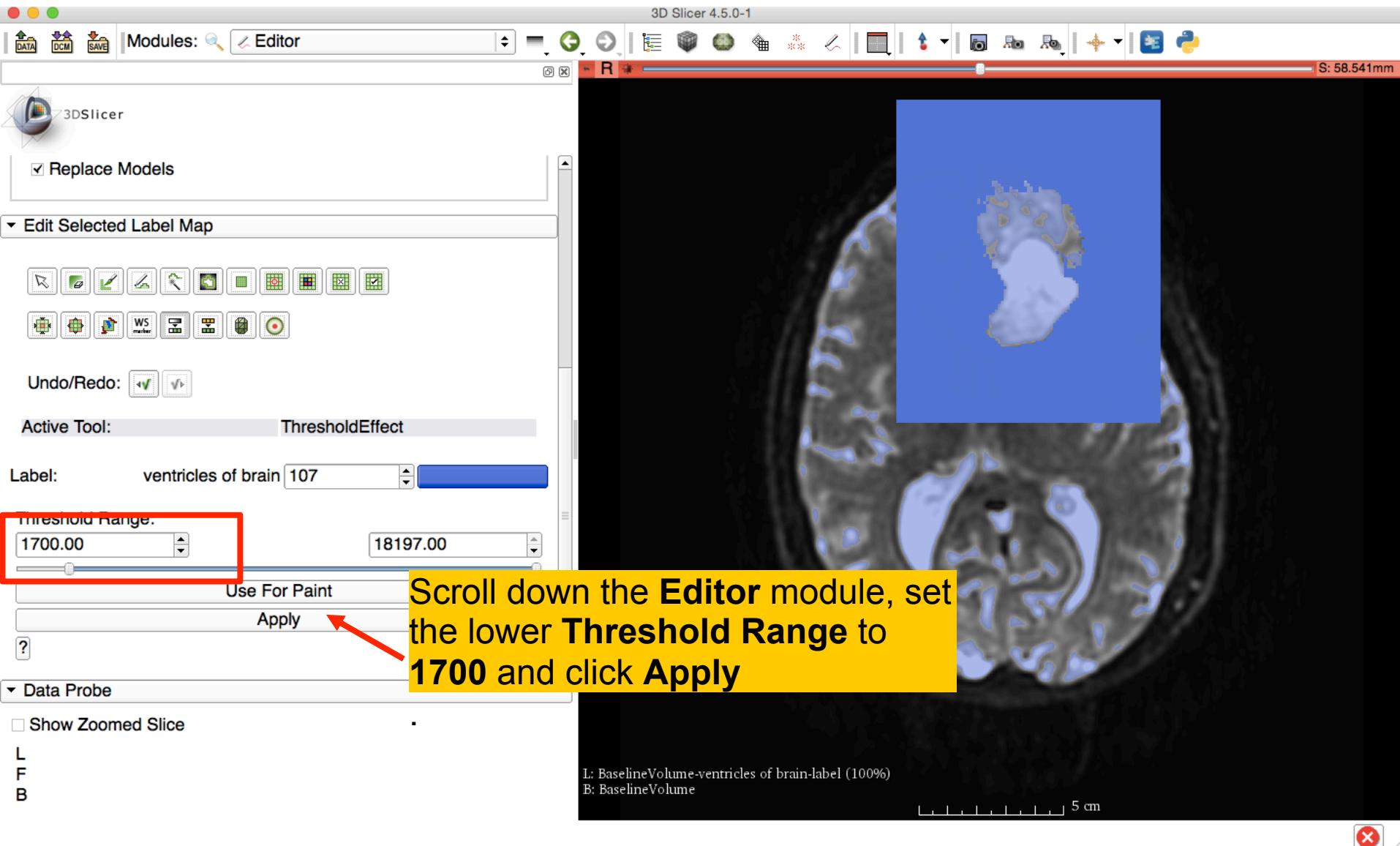
Ventricles Segmentation



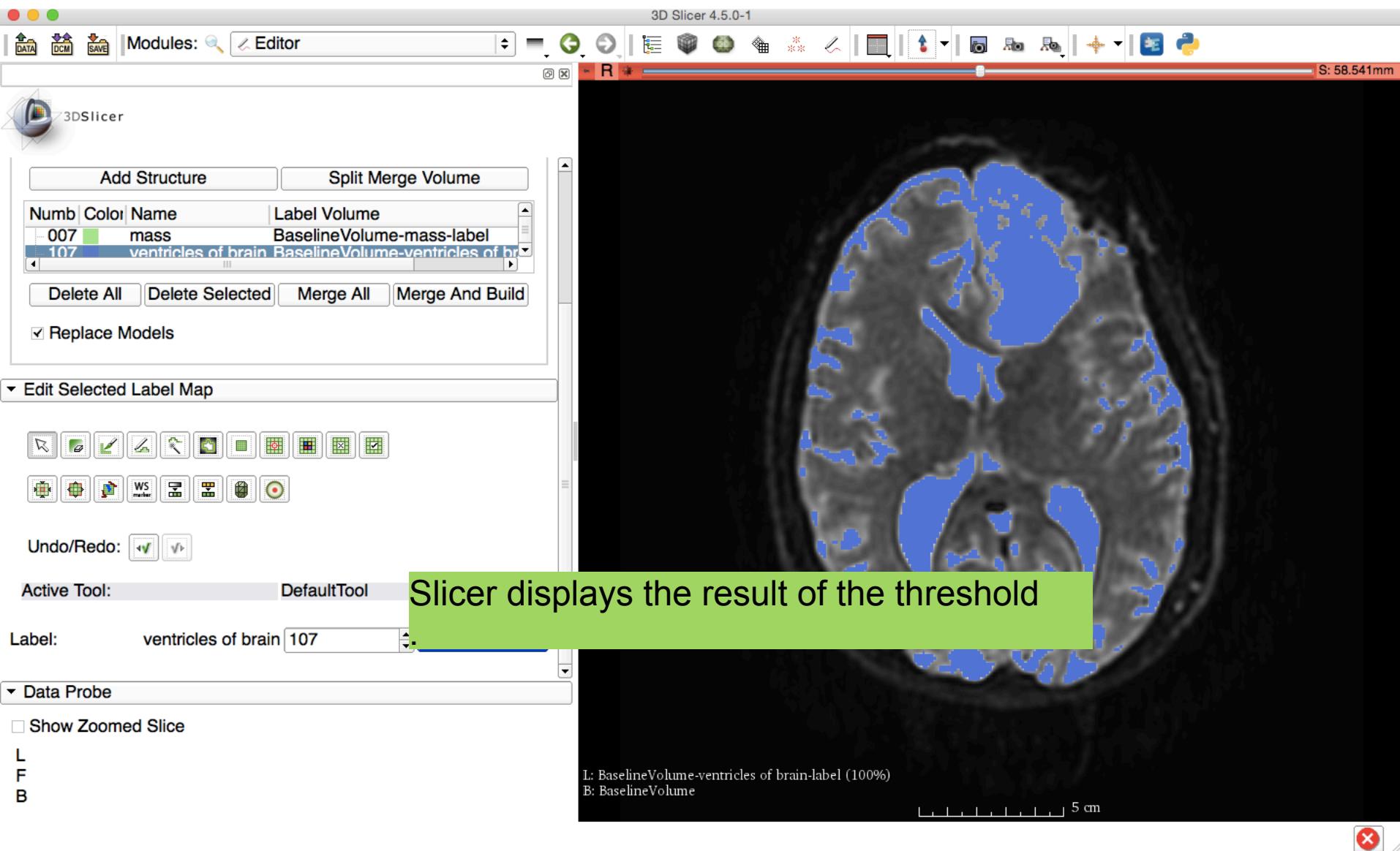
Ventricles Segmentation



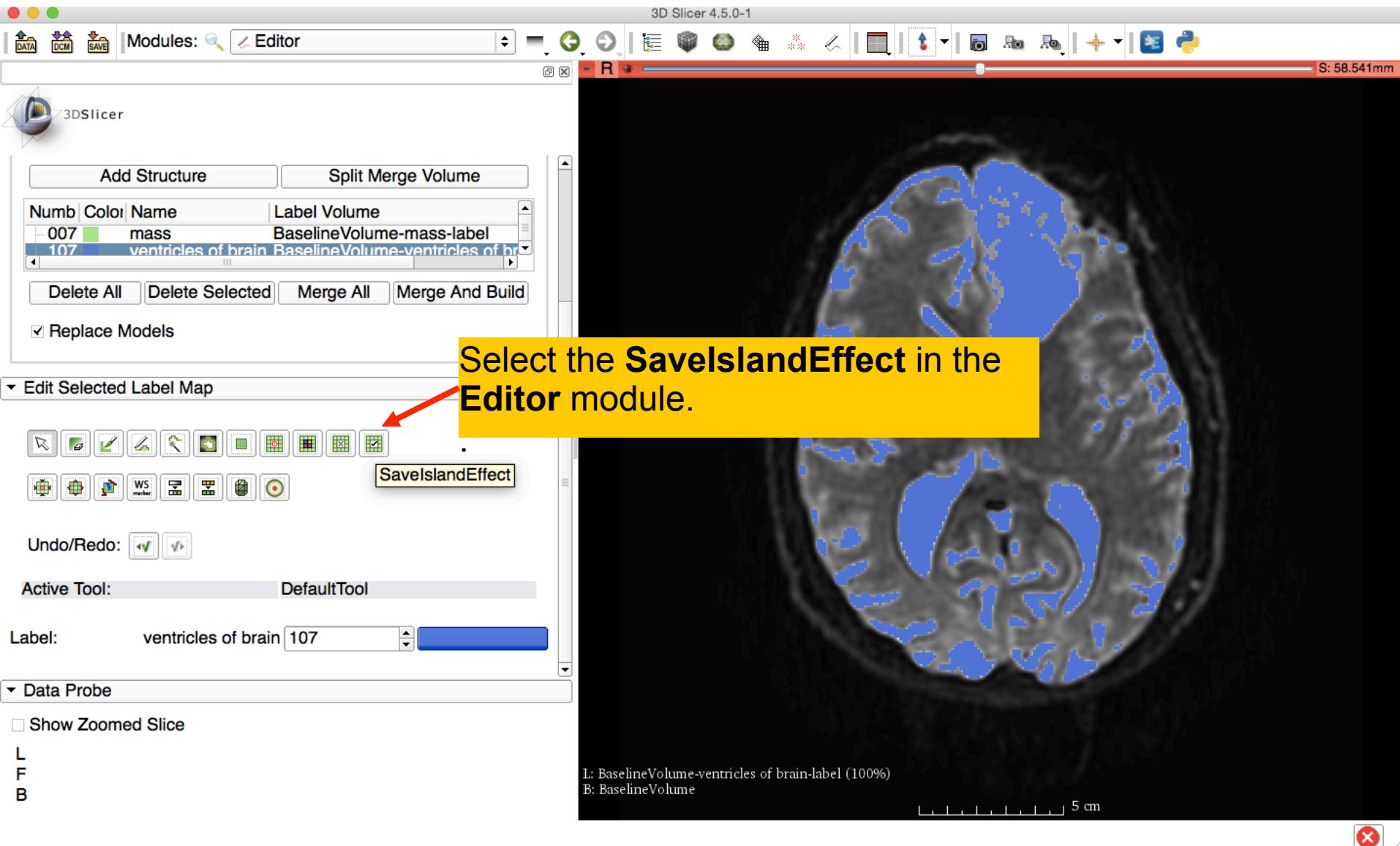
Ventricles Segmentation



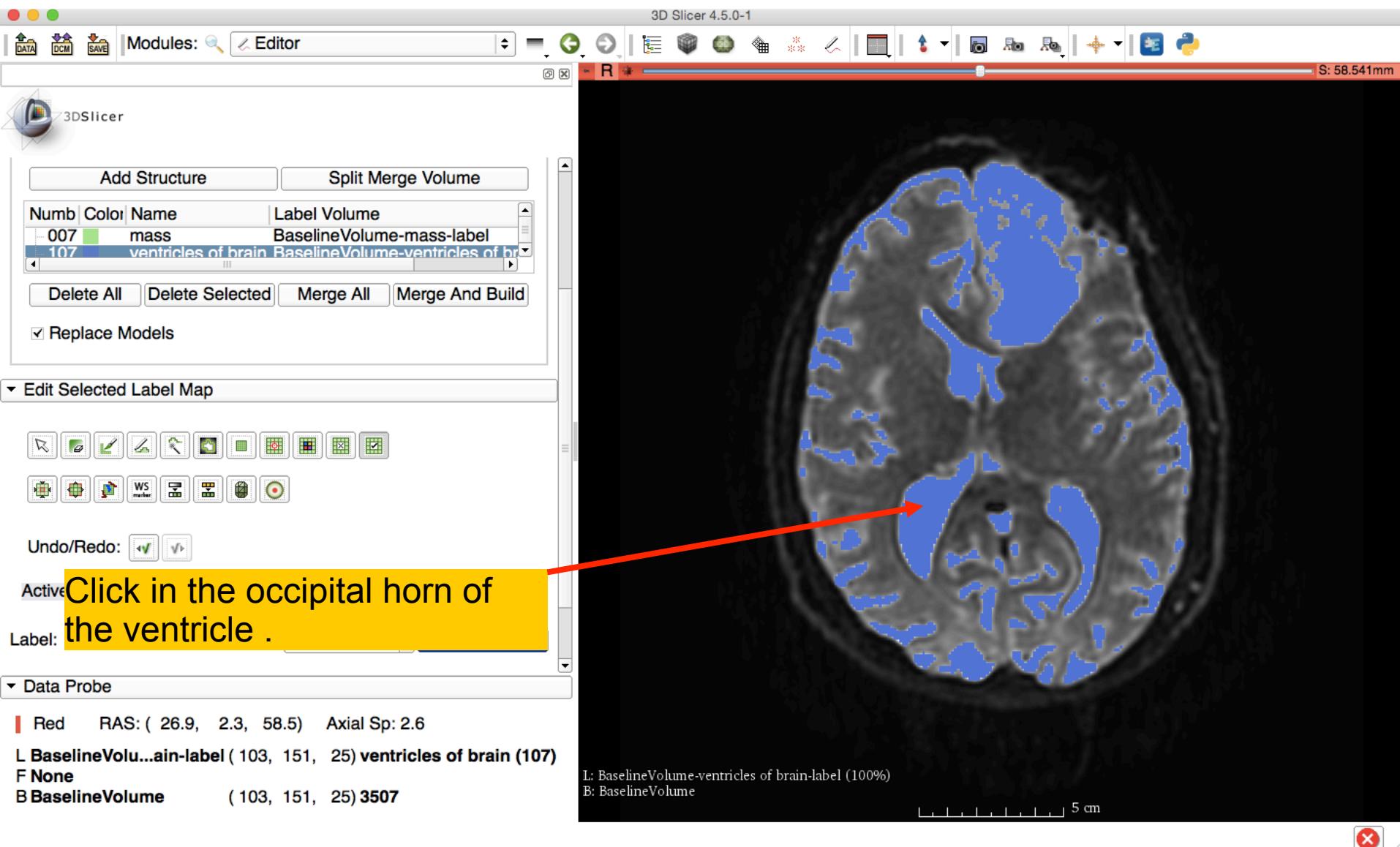
Ventricles Segmentation



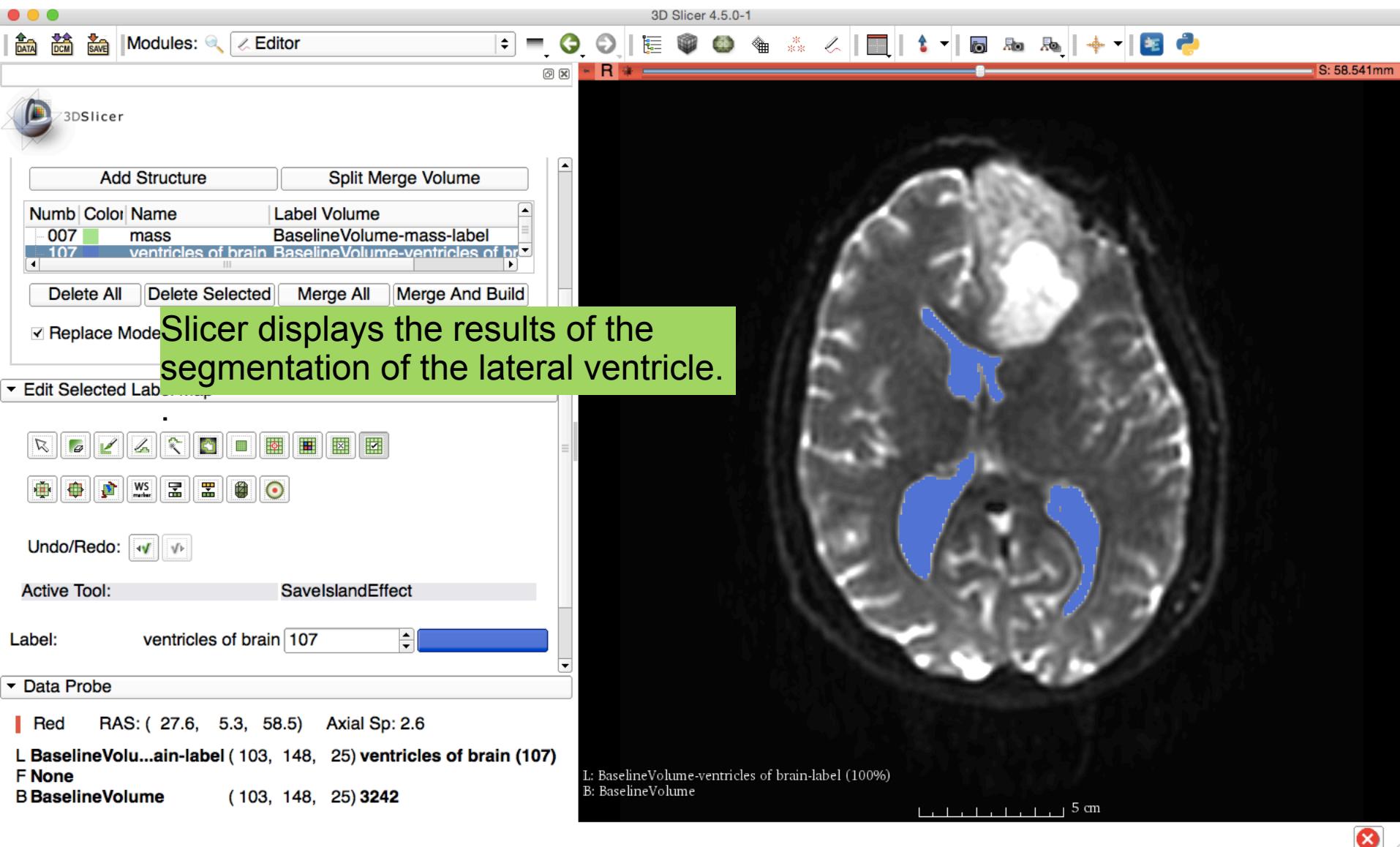
Ventricles Segmentation



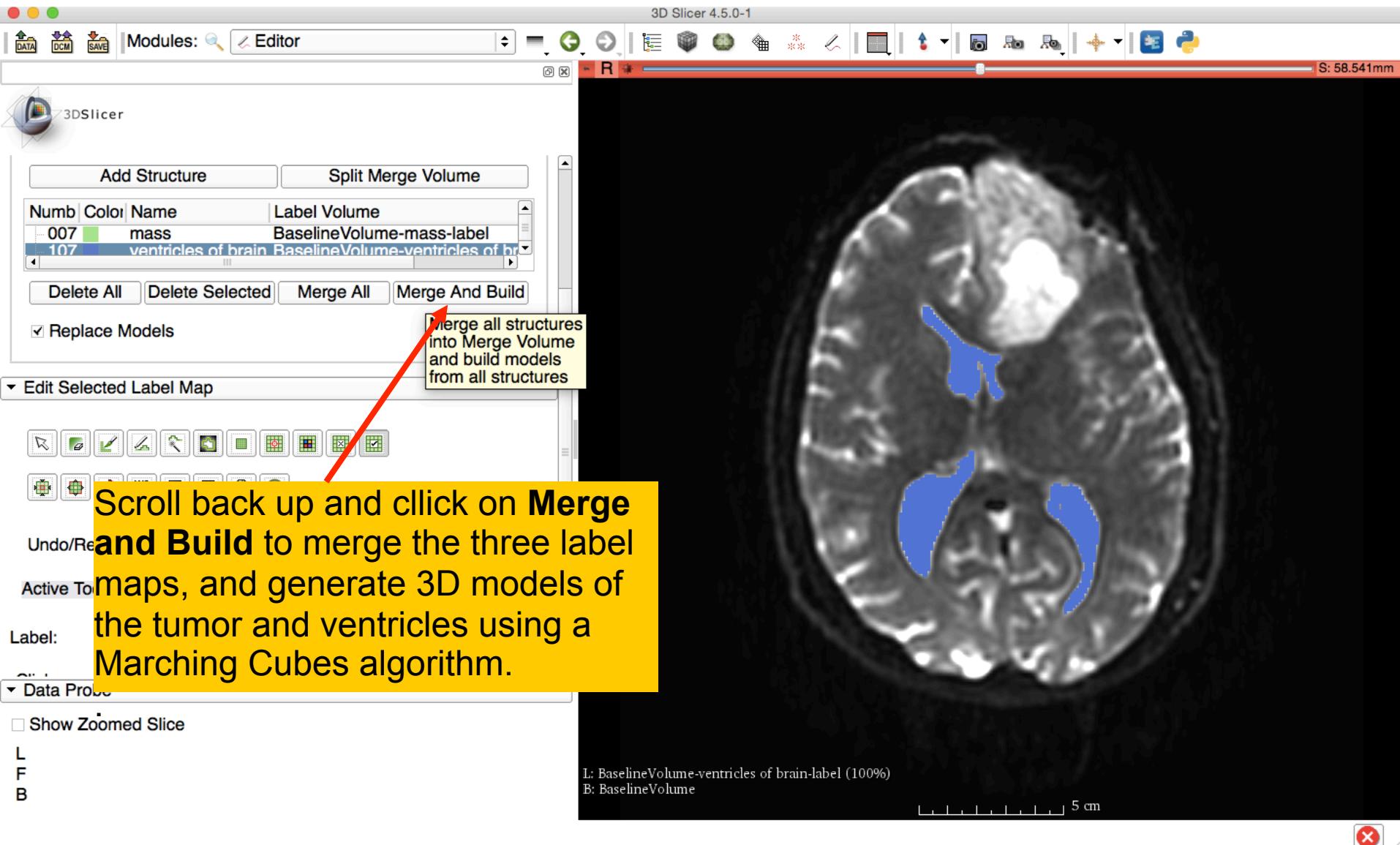
Ventricles Segmentation



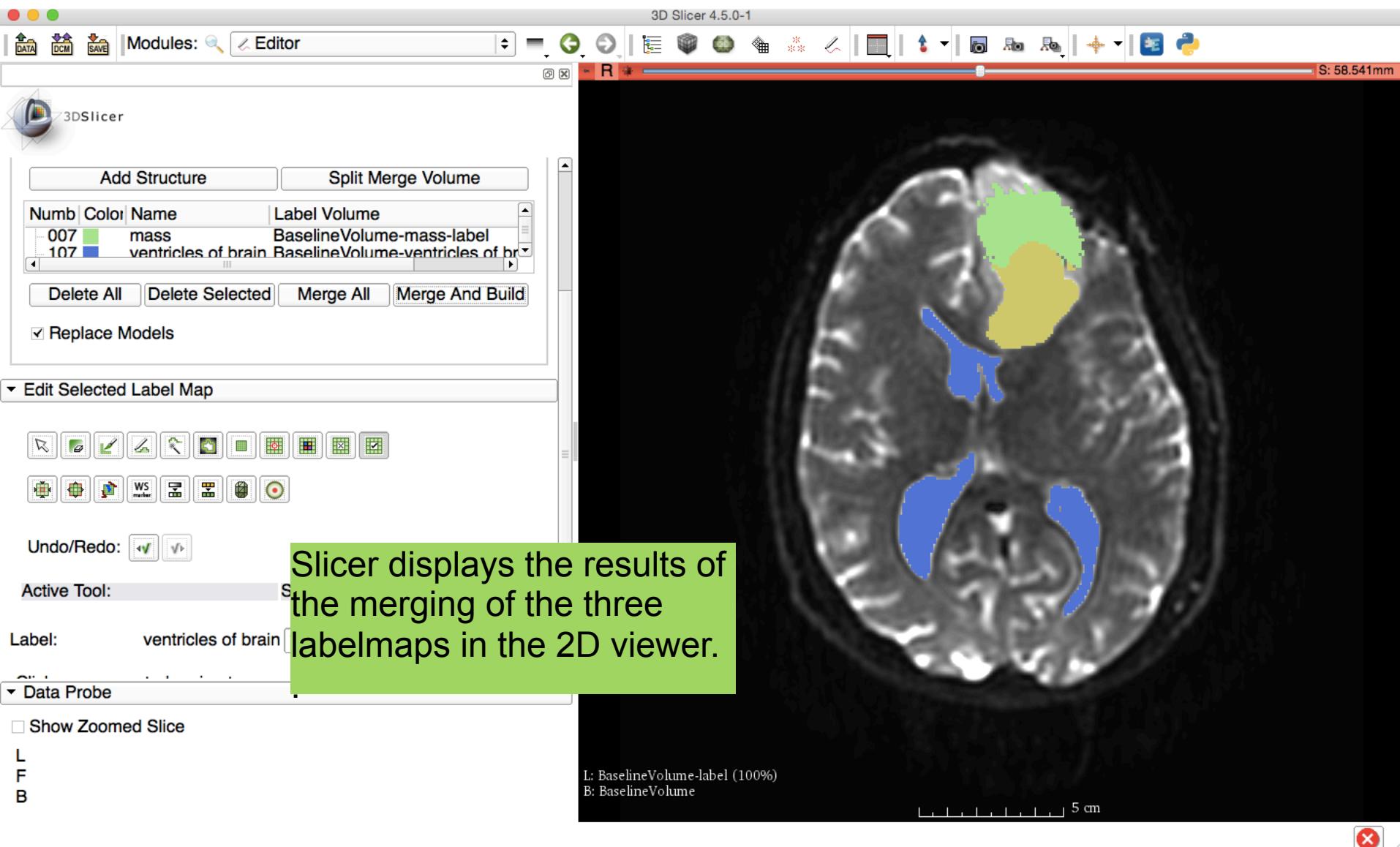
Ventricles Segmentation



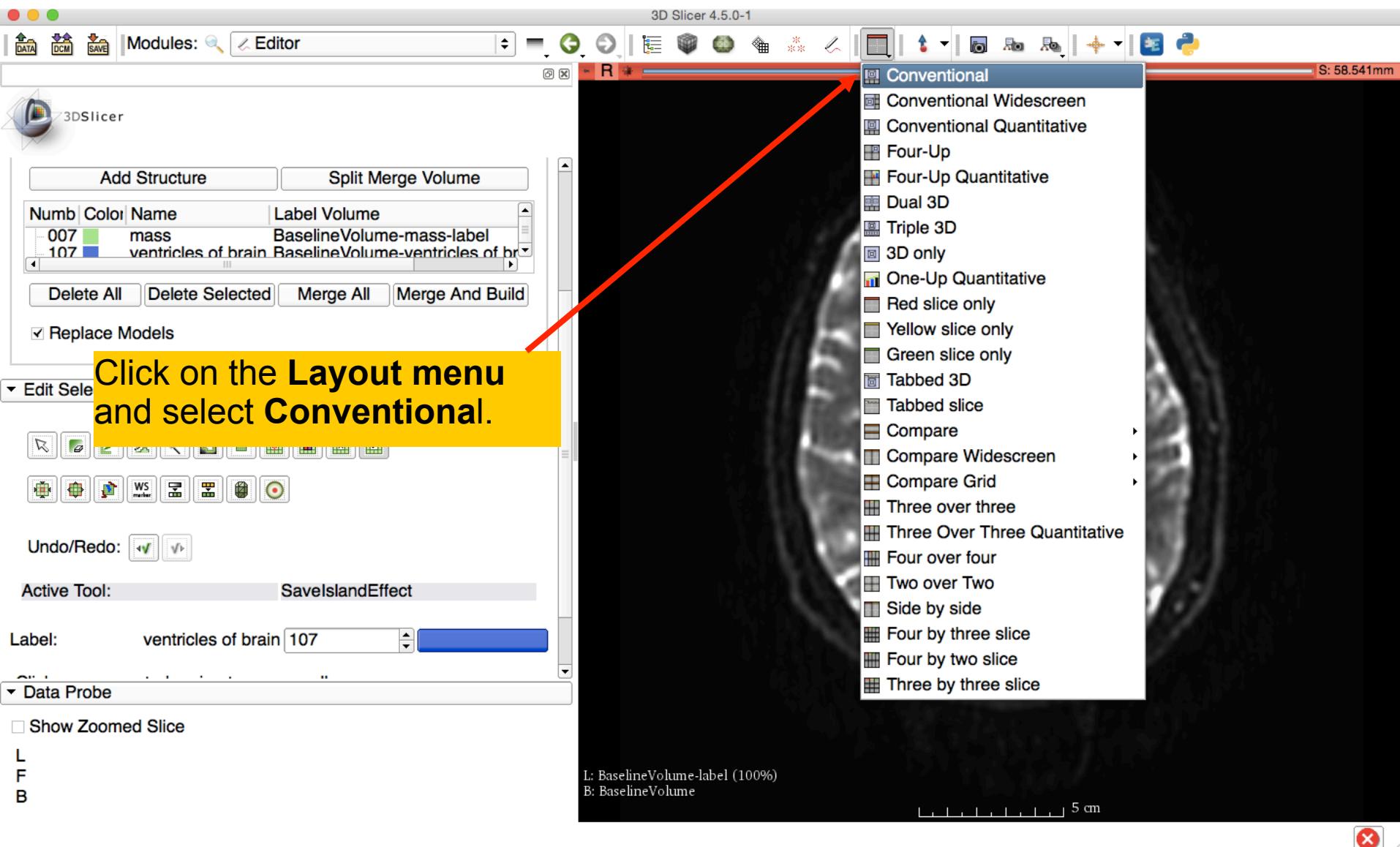
Ventricles Segmentation



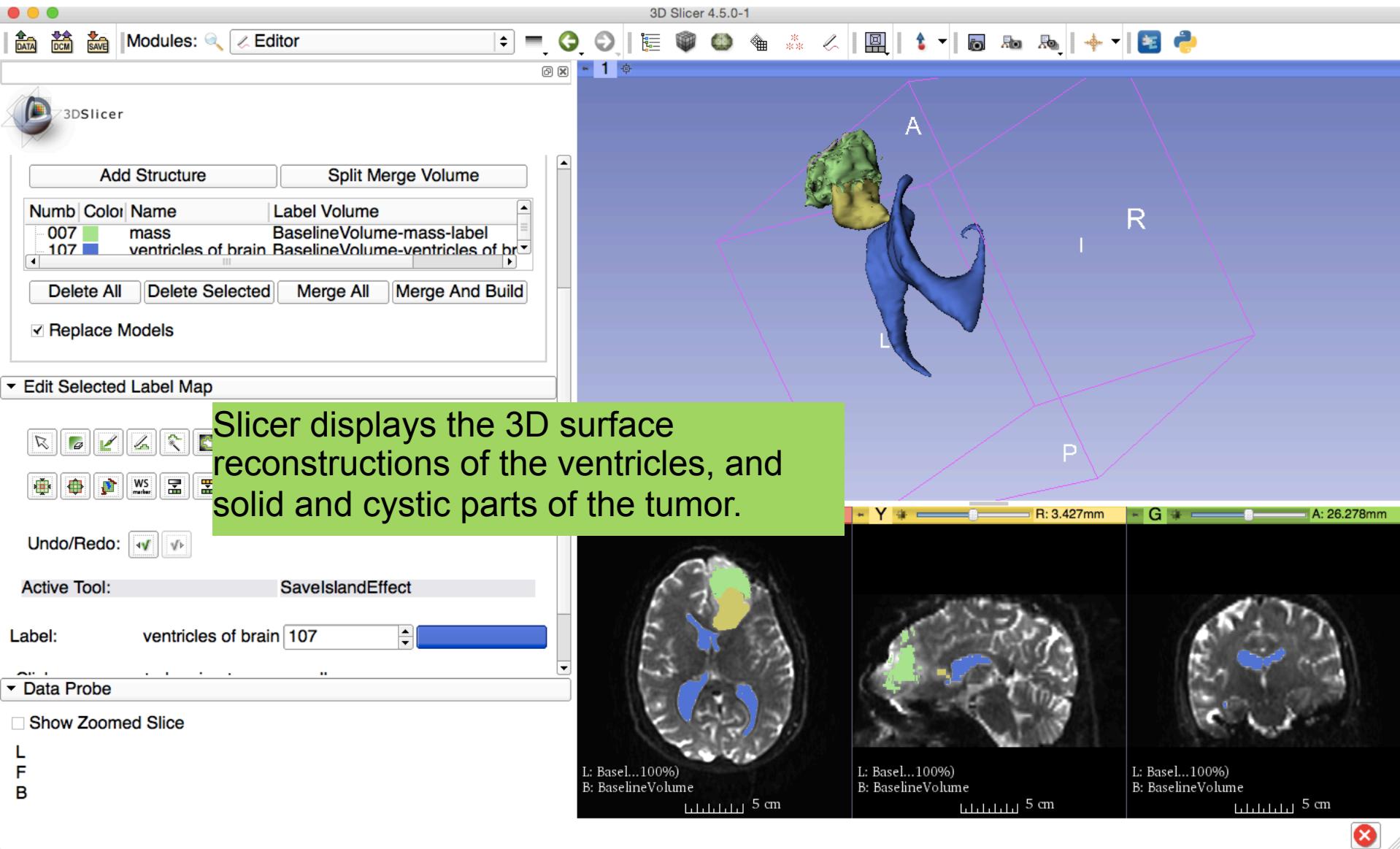
Final Result of Segmentation



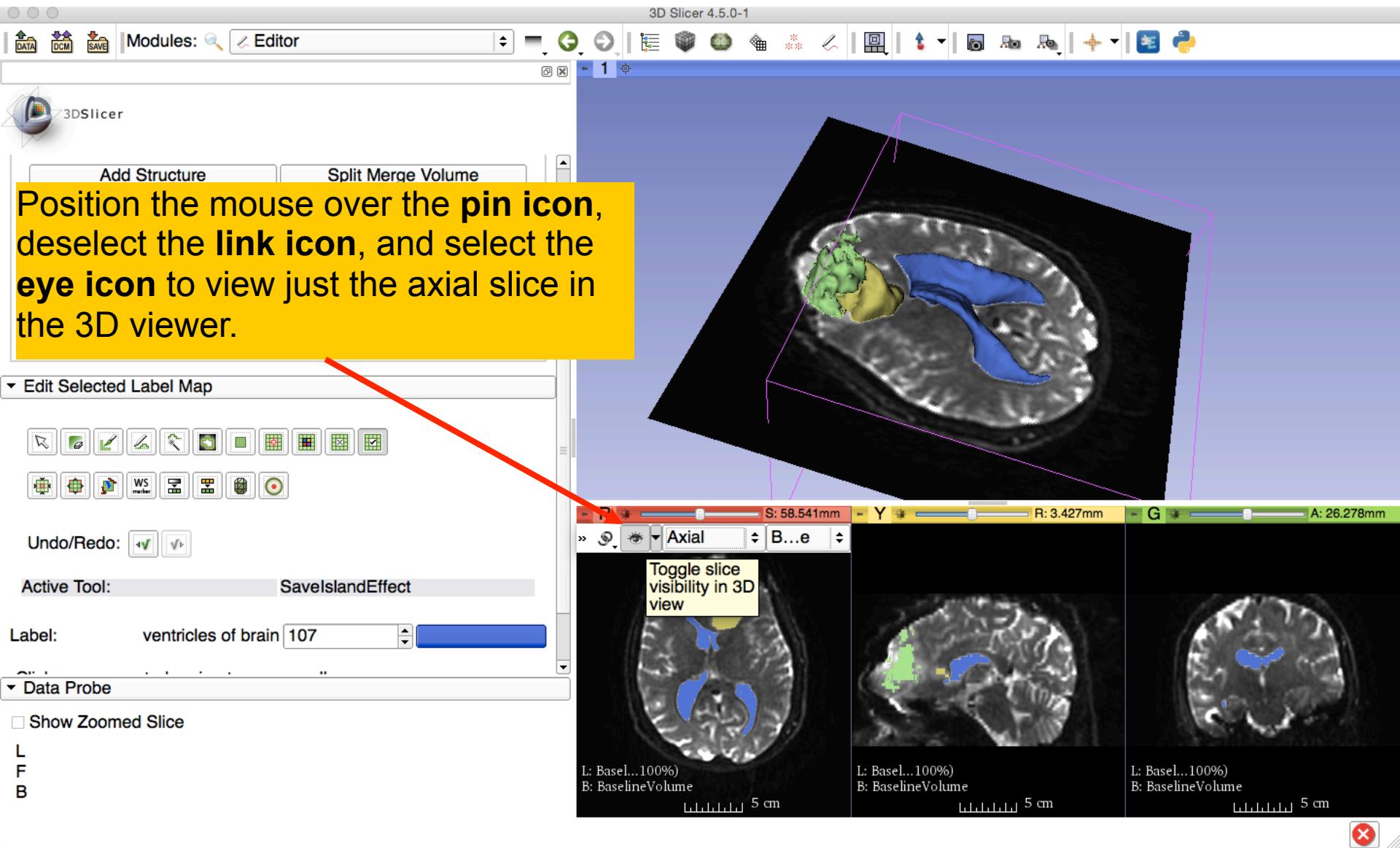
Final Result of Segmentation



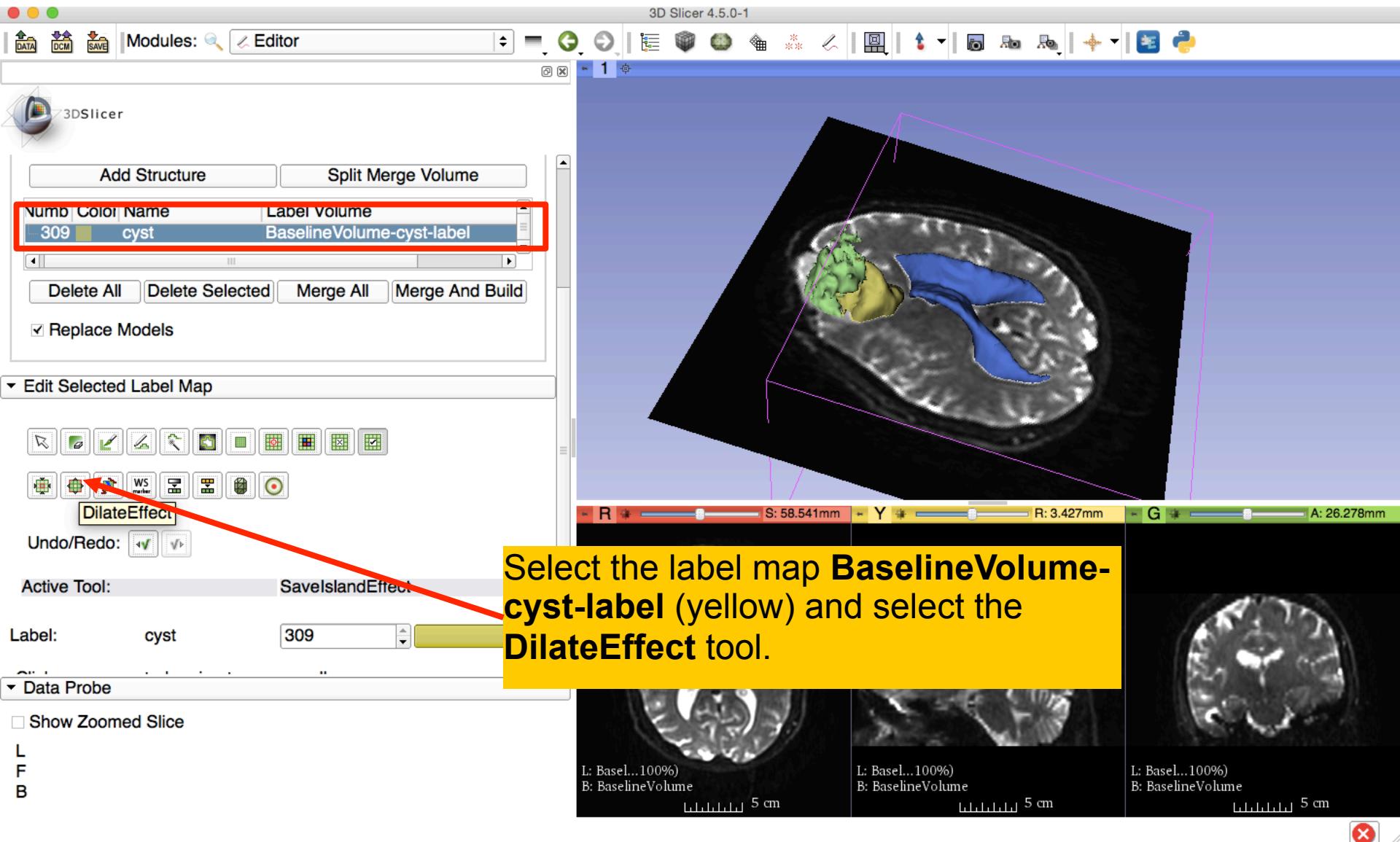
Final Result of Segmentation



Definition of peri-tumoral volume



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

Note the dilation of the cystic part of the tuor in the 3D Viewer.

3D Slicer 4.5.0-1

DATA DCM SAVE Modules: Editor

Edit Selected Label Map

Active Tool: DilateEffect

Label: cyst 309

Eight Neighbors Four Neighbors

Apply

?

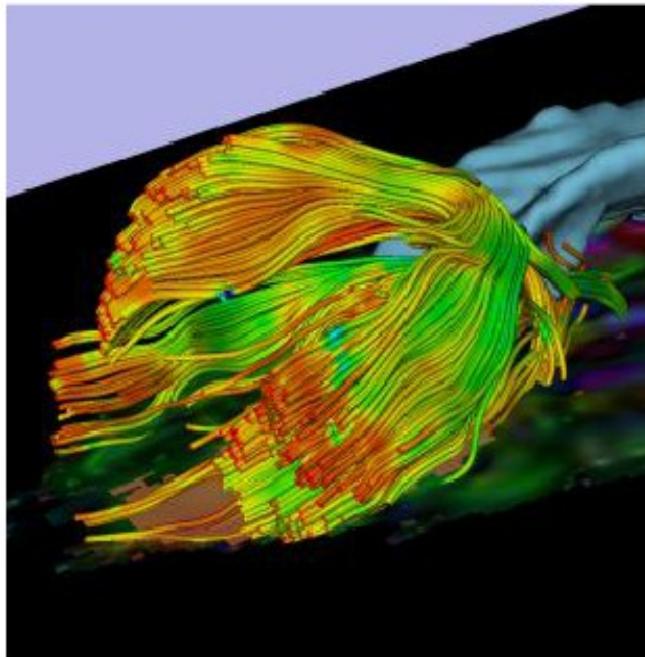
Data Probe

Show Zoomed Slice L F B

L: Baseline...100% B: BaselineVolume 5 cm

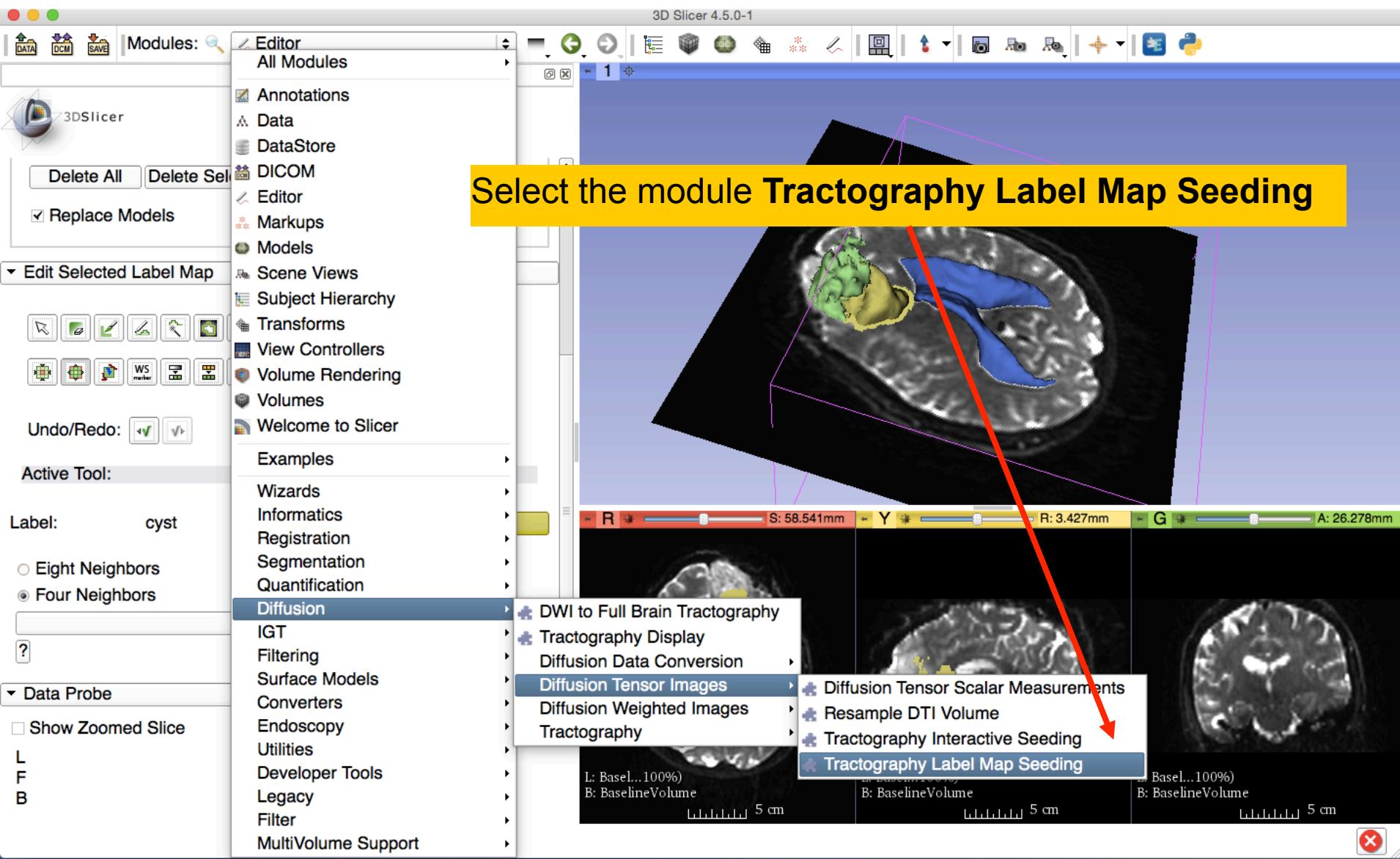
L: Baseline...100% B: BaselineVolume 5 cm

L: Baseline...100% B: BaselineVolume 5 cm



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

Tractography LabelMap Seeding



Tractography LabelMap Seeding

3D Slicer 4.5.0-1

DATA DCM SAVE Modules: Tractography Label Map Seeding

3DSlicer

Help & Acknowledgement

Tractography Label Map Seeding

Parameter set: Tractography Label Map Seeding

IO

- Input DTI Volume: DTIVolume
- Input Label Map: BaselineVolume-cyst-label
- Output Fiber Bundle: newFiberBundle

Seed Placement Options

Use Index Space

Seed Spacing: 2.00

Random Grid

Linear Measure Start Threshold: 0.3

Tractography Seeding Parameters

Minimum Path Length: 20.00

Maximum Length: 800.00

Stopping Criteria: LinearMeasure

Status: Idle

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L F B

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

R S: 58.541mm Y R: 3.427mm G A: 26.278mm

L: Bas... 100% B: BaselineVolume 5 cm

L: Bas... 100% B: BaselineVolume 5 cm

L: Bas... 100% B: BaselineVolume 5 cm

Tractography LabelMap Seeding

3D Slicer 4.5.0-1

Modules: Tractography Label Map Seeding

3DSlicer

Help & Acknowledgement

Tractography Label Map Seeding

Parameter set: Tractography Label Map Seeding

IO

Input DTI Volume: DTIVolume

Input Label Map: BaselineVolume-cyst-label

Output Fiber Bundle: newFiberBundle

Seed Placement Options

Use Index Space:

Seed Spacing: 2.00

Random Grid:

Linear Measure Start Threshold: 0.3

Tractography Seeding Parameters

Minimum Path Length: 20.00

Maximum Length: 800.00

Stopping Criteria: LinearMeasure

Status: Idle

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice L F B

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

- Check **Use Index Space**

R S: 58.541mm Y R: 3.427mm G A: 26.278mm

L: Bas...100% B: BaselineVolume 5 cm

L: Bas...100% B: BaselineVolume 5 cm

L: Bas...100% B: BaselineVolume 5 cm

Tractography LabelMap Seeding

The screenshot shows the 3D Slicer application window with the 'Tractography Label Map Seeding' module selected. The left panel displays various parameters for tractography seeding:

- Tractography Seeding Parameters**:
 - Minimum Path Length: 20.00
 - Maximum Length: 300.00
 - Stopping Criteria:
 - LinearMeasure
 - FractionalAnisotropy
 - Stopping Value: 0.15
 - Stopping Track Curvature: 0.7
 - Integration Step Length(mm): 0.5
- Label definition**:
 - Seeding label: 309
 - Multiple File Output
 - Write Fibers To Disk:
 - Output Directory: /Applications
 - File Prefix Name: line
- Data Probe**:
 - Show Zoomed Slice:

A red box highlights the 'Stopping Criteria' and 'Stopping Value' sections, and another red box highlights the 'Label definition' section. A red arrow points from the text 'Click on Apply' to the 'Apply' button at the bottom right of the dialog.

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

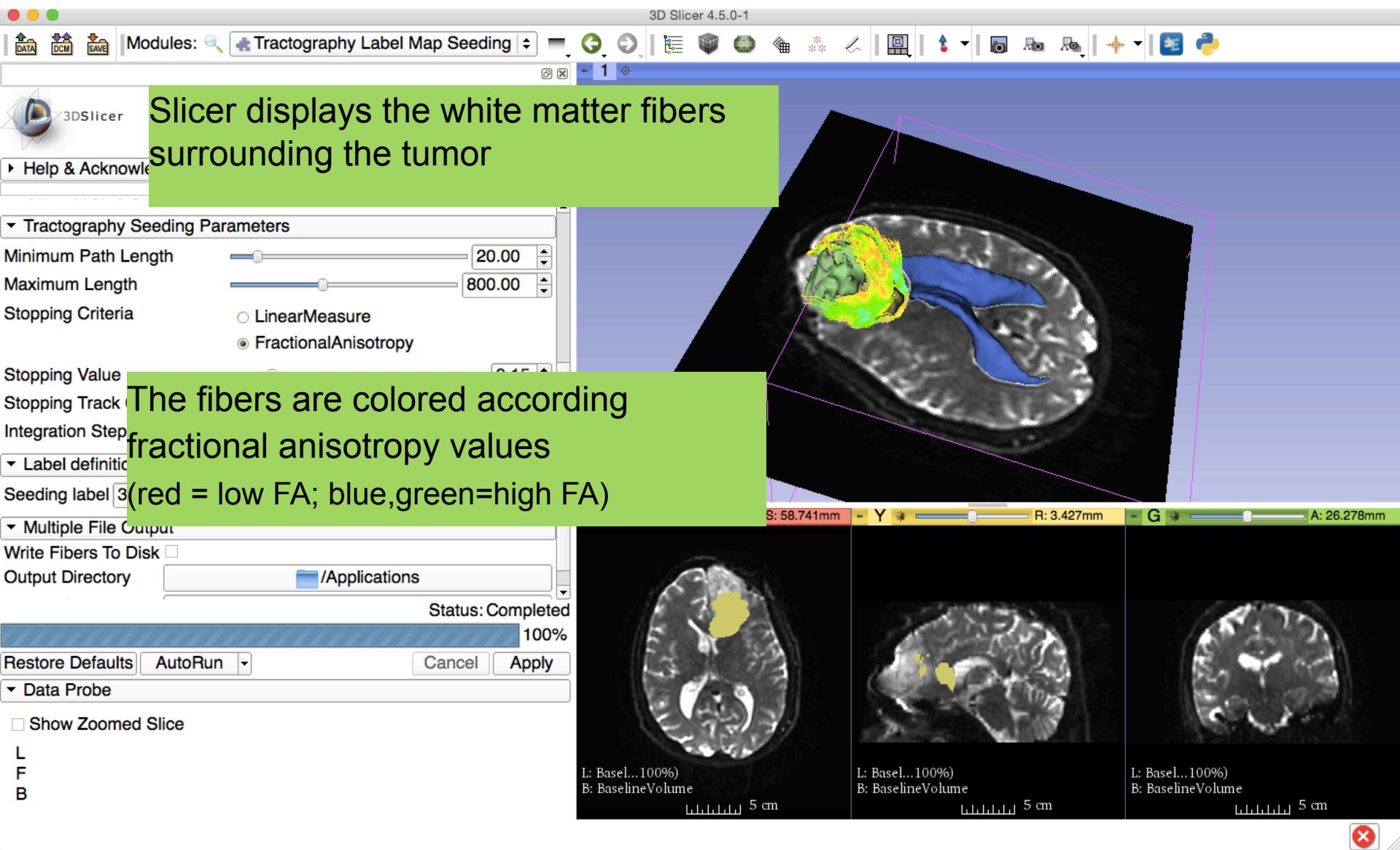
- Set **Stopping Criteria** to **FractionalAnisotropy**
- Set **Stopping Value** to **0.15**

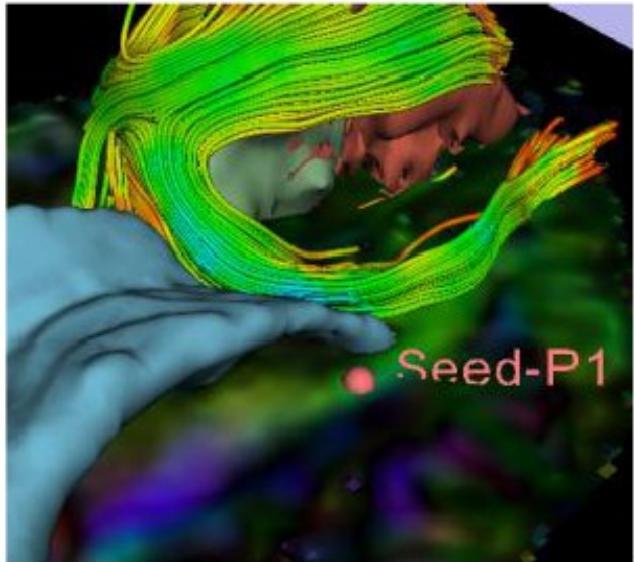
Scroll down to Label Definition and set the following values:

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

Click on Apply

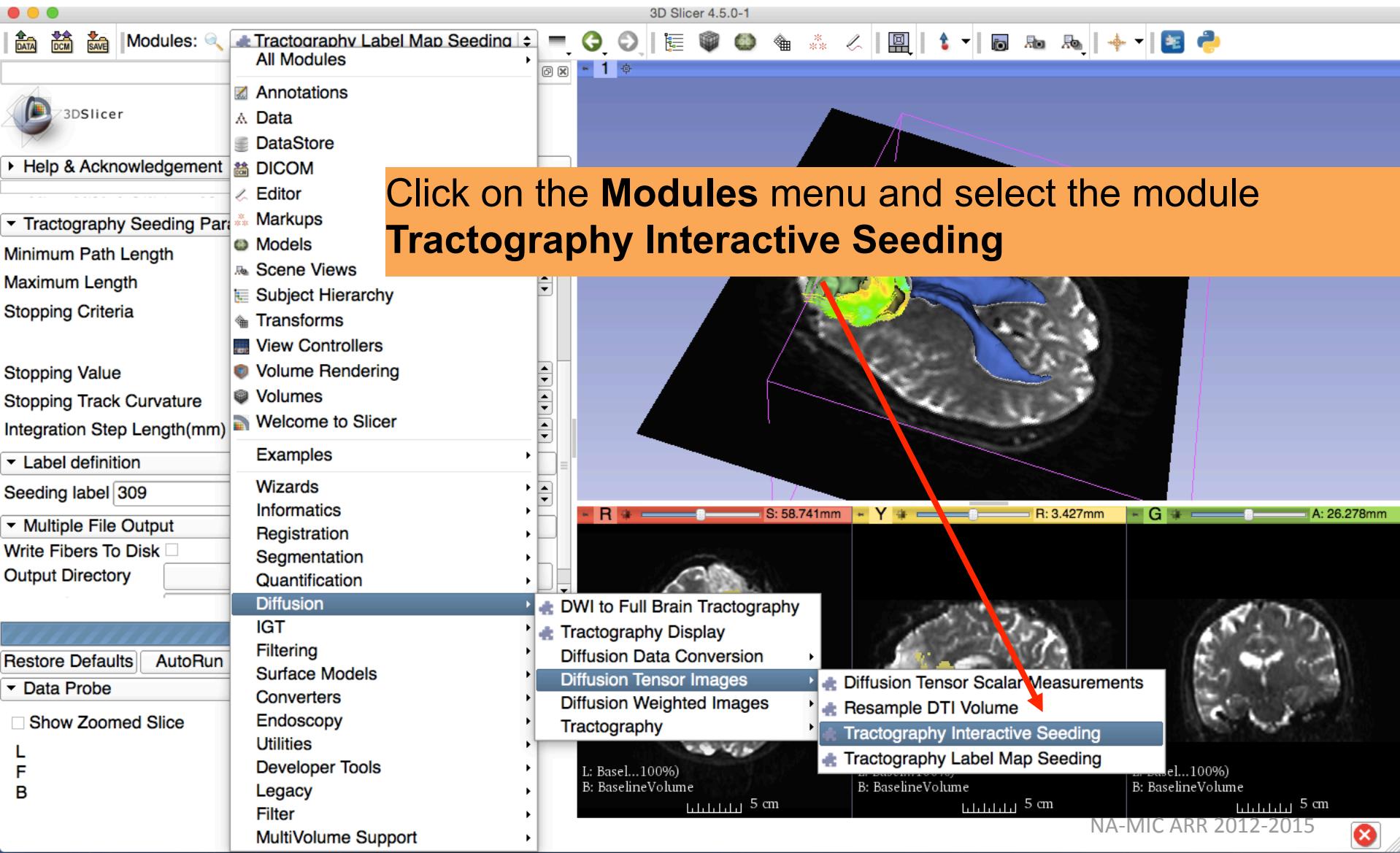
Tractography LabelMap Seeding



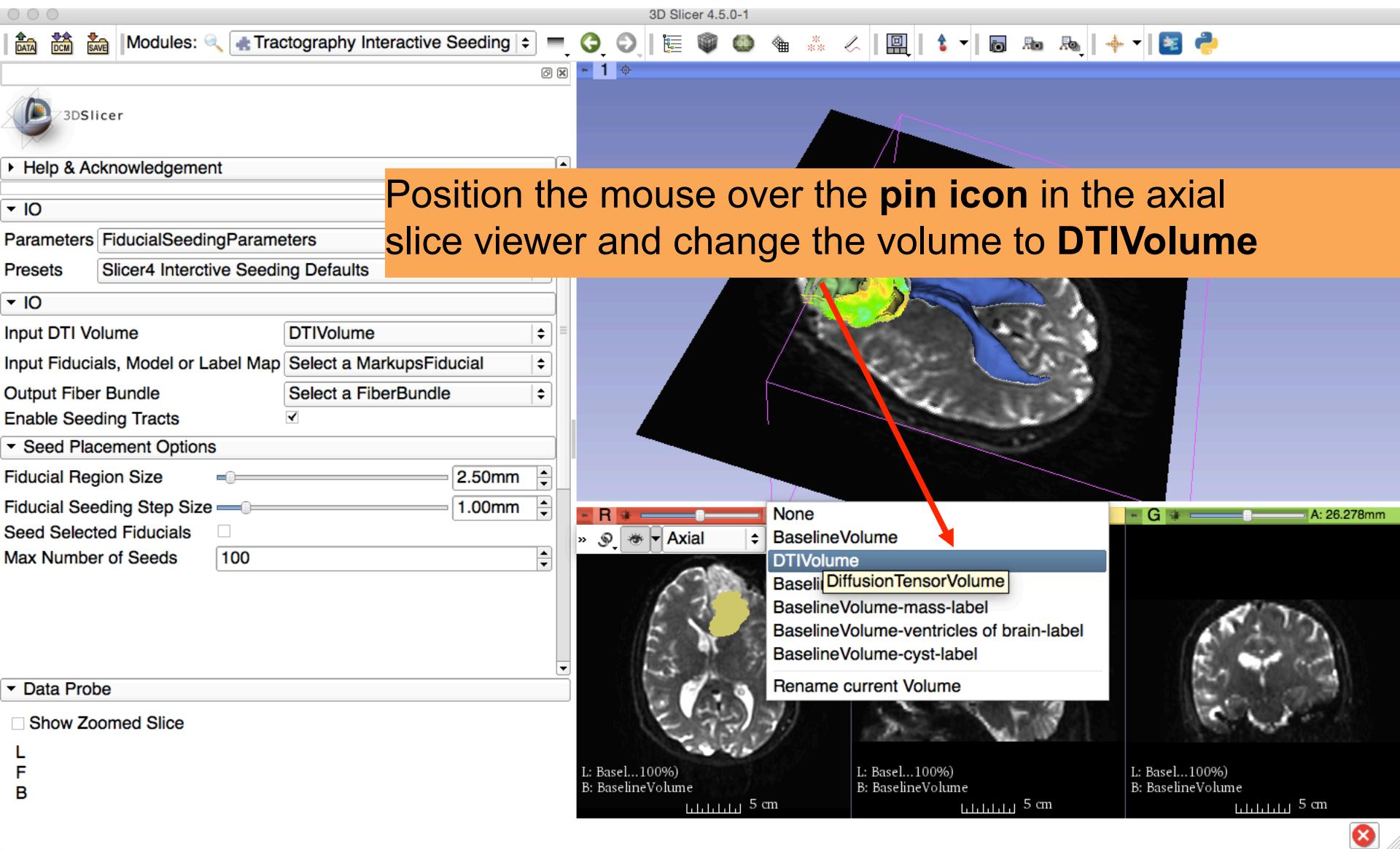


Part 4: Tractography exploration of the ipsilateral and contralateral side

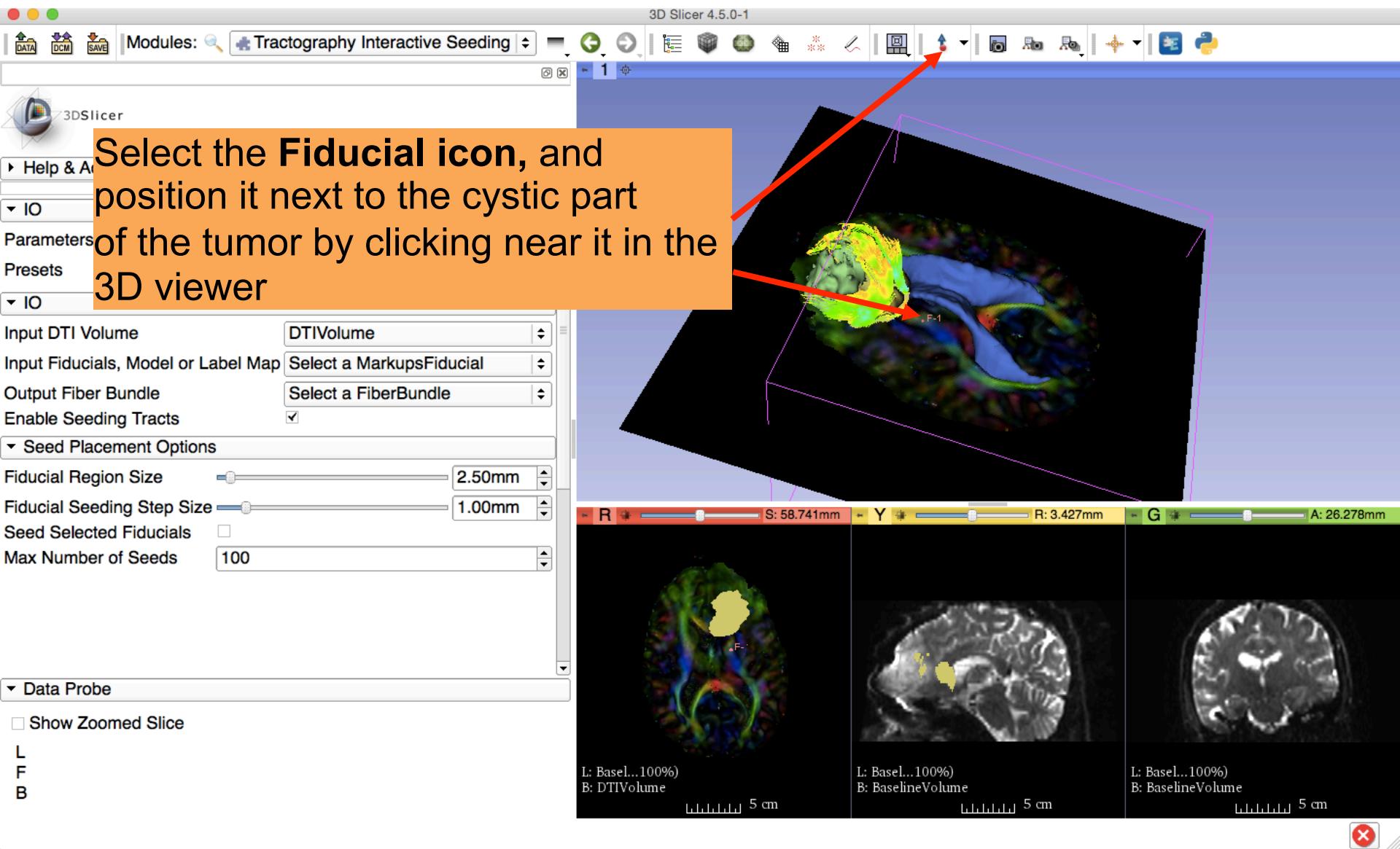
Tractography on-the-fly



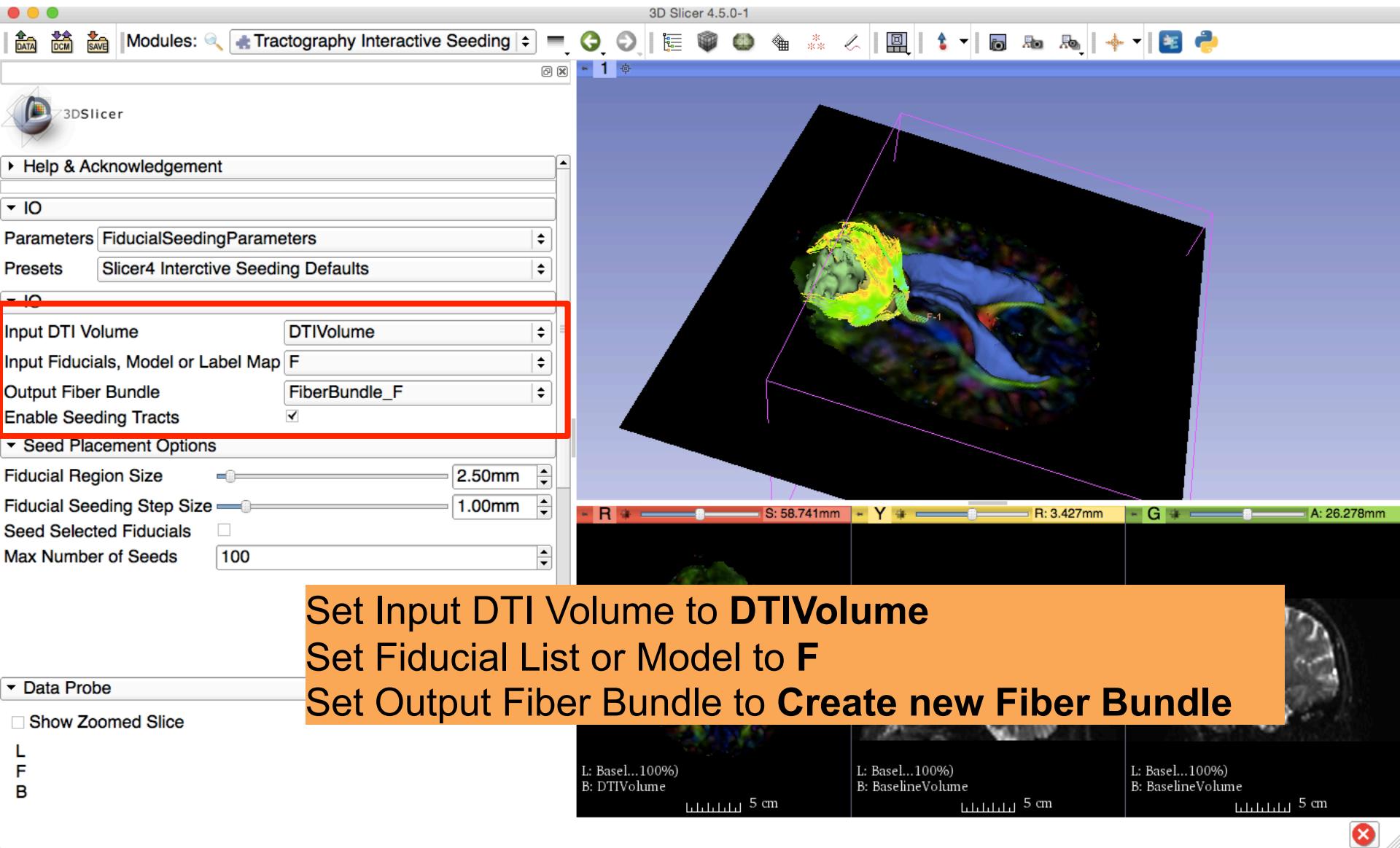
Tractography on-the-fly



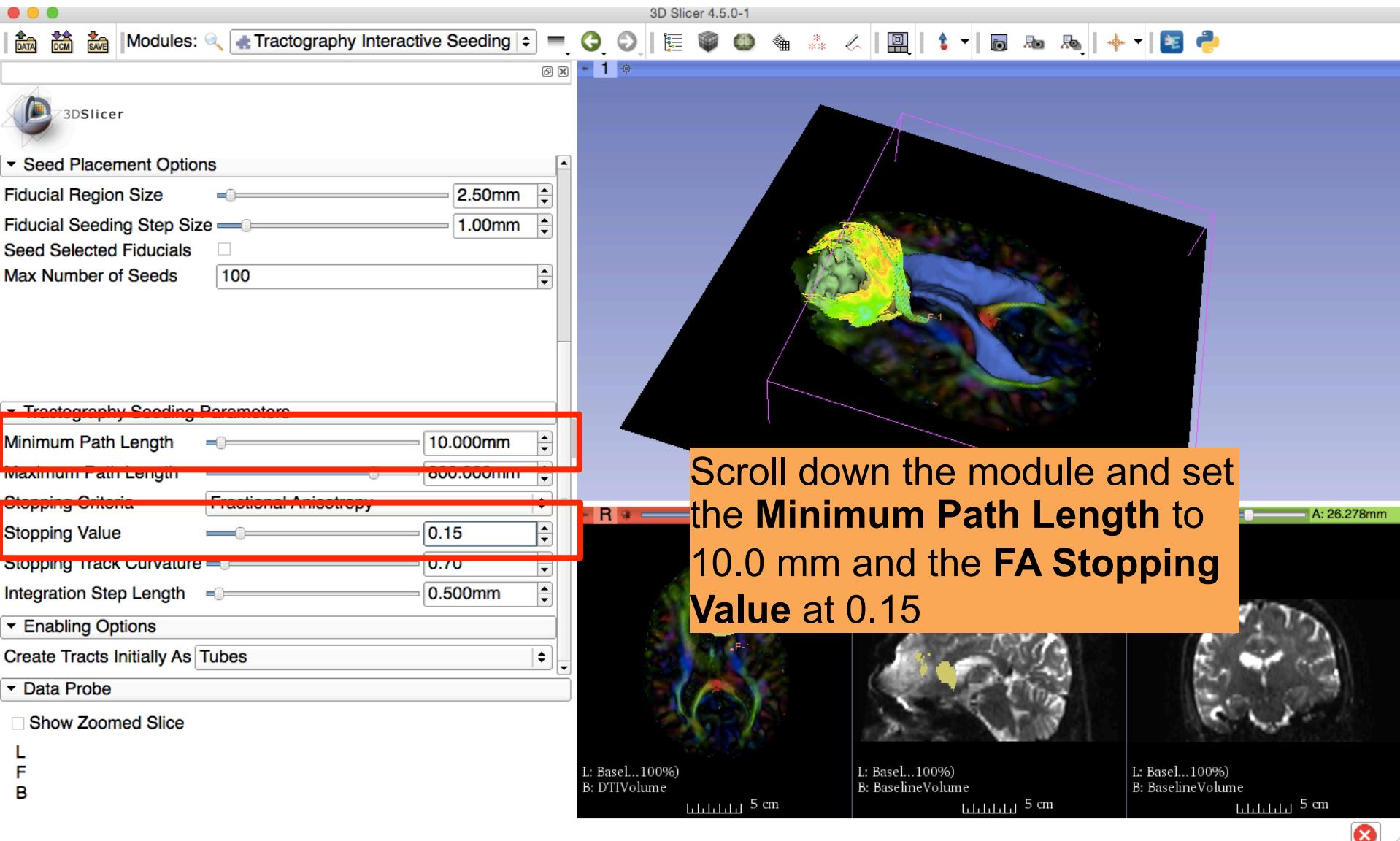
Tractography on-the-fly



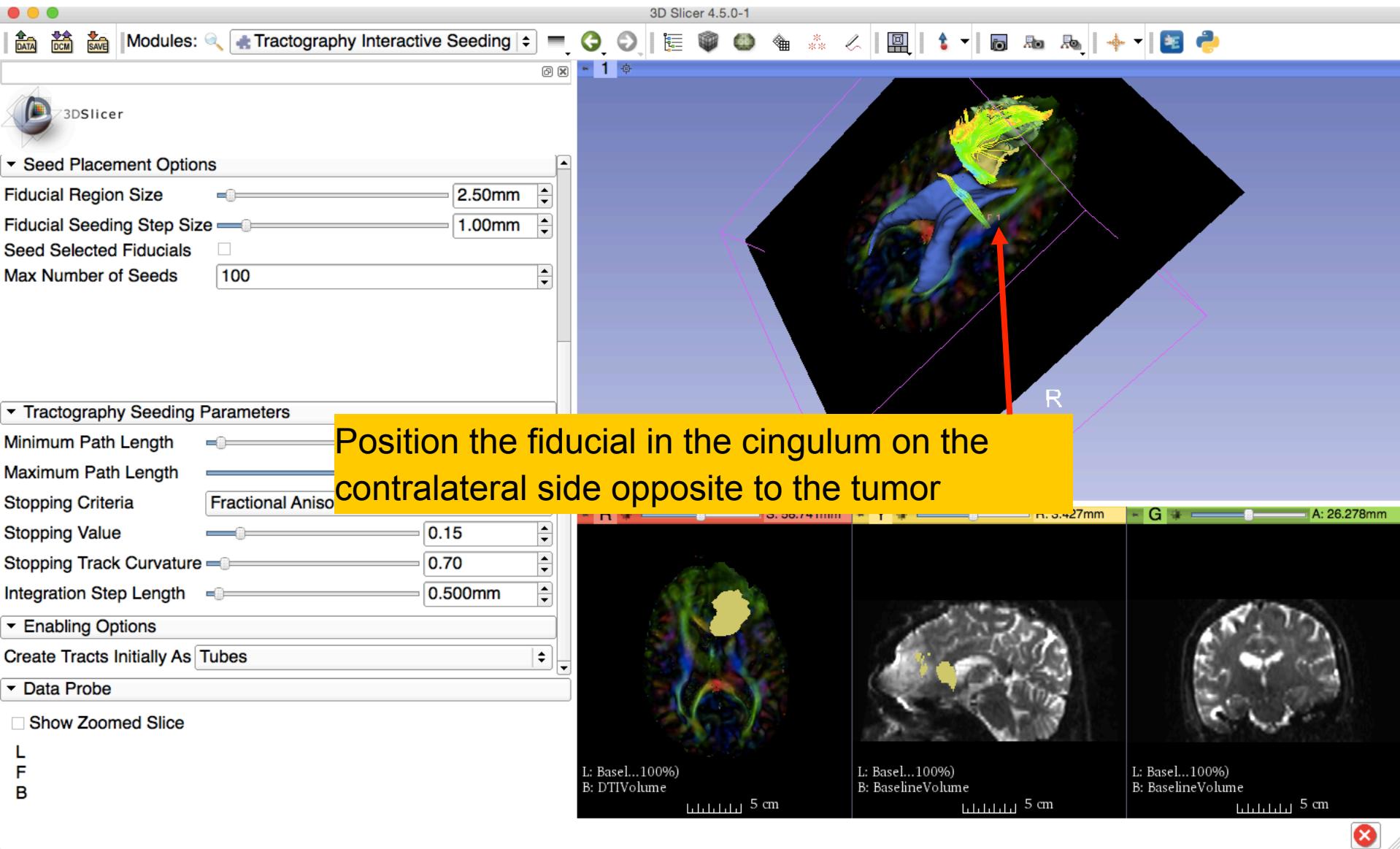
Tractography on-the-fly



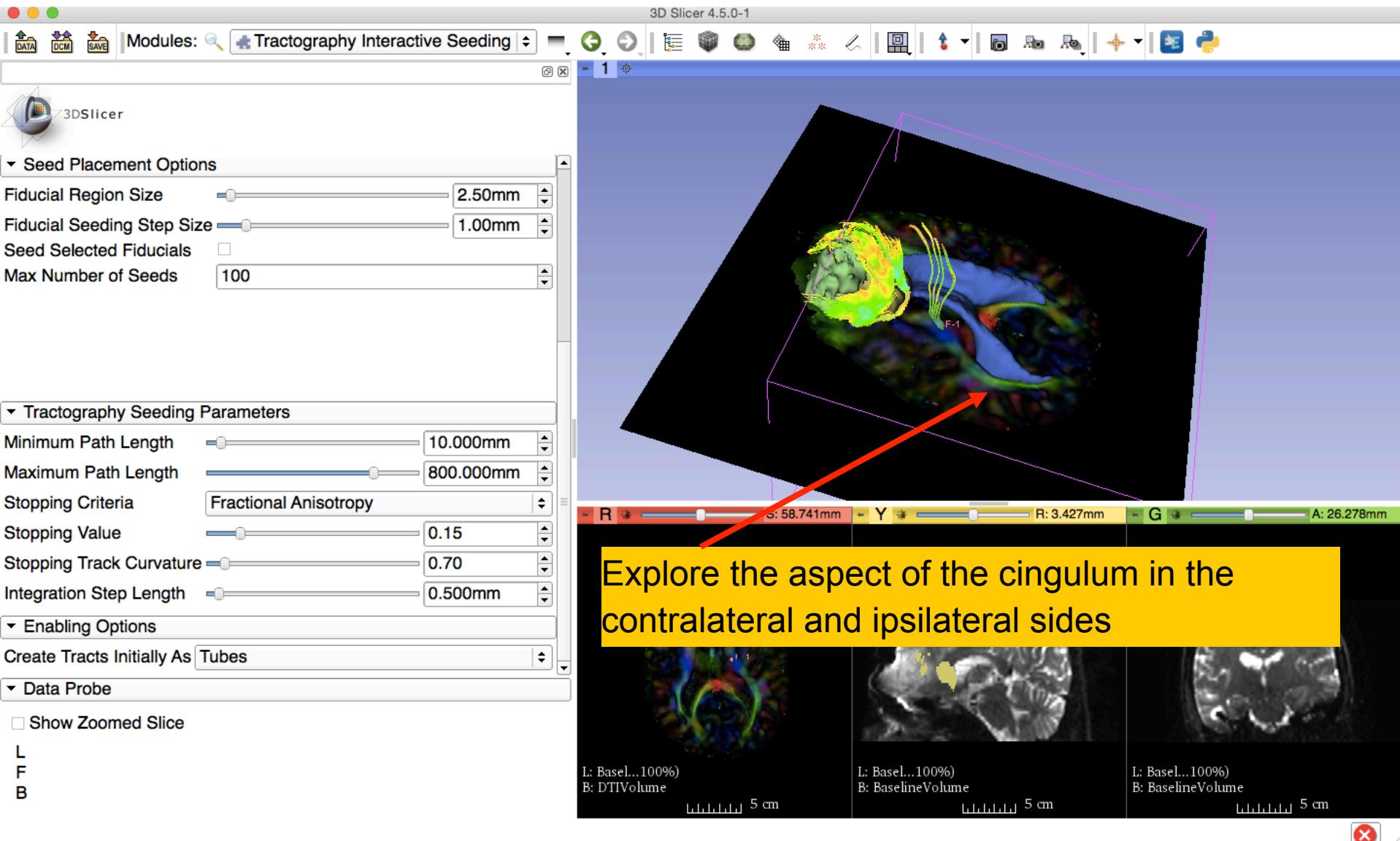
Tractography on-the-fly



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

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