



Exploring Peritumoral White Matter Fibers for Neurosurgical Planning

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Harvard University

Clinical Goal

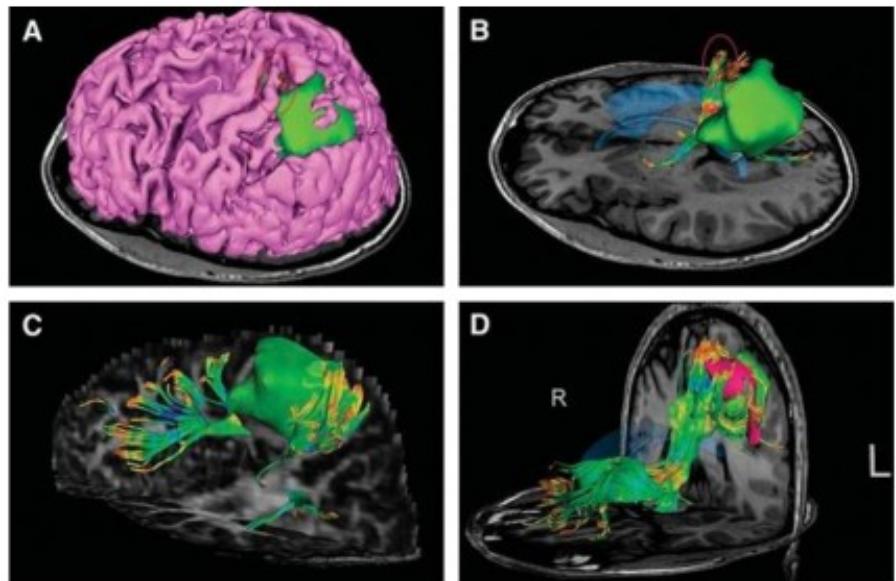
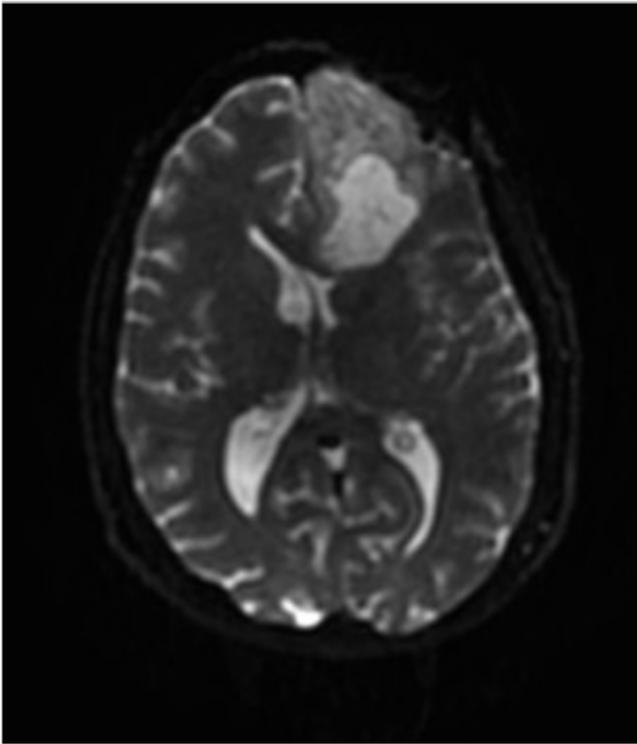


Image Courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital, Boston, MA..

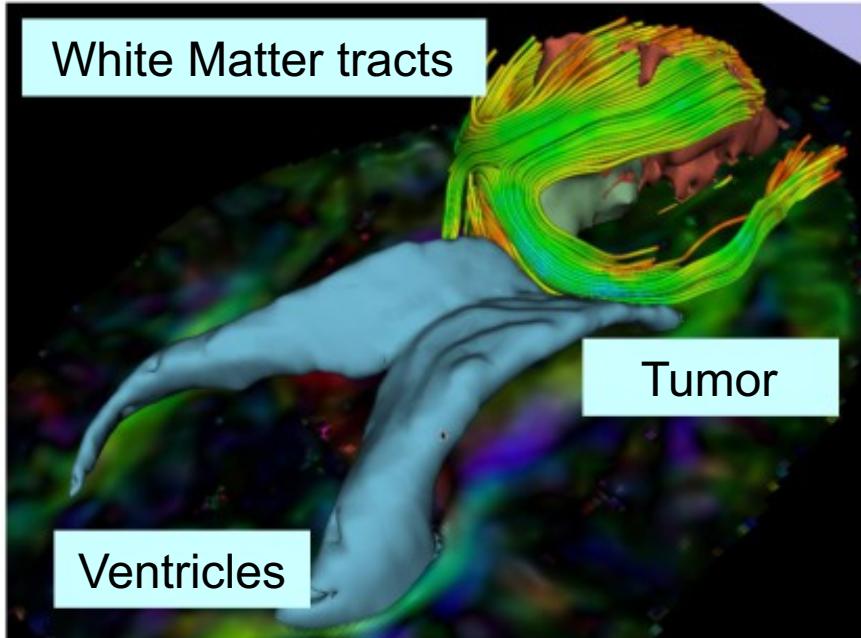
Diffusion Tensor Imaging (DTI) Tractography has the potential to bring valuable spatial information on tumor infiltration and tract displacement for neurosurgical planning of tumor resection.

Clinical Case

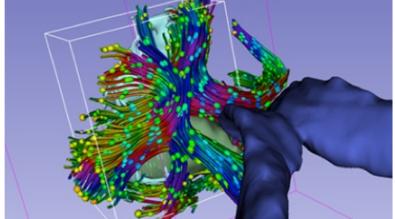


- 35 year-old male diagnosed with Glioblastoma multiform (GBM)
- Diffusion Weighted Imaging (DWI) acquisition for neurosurgical planning

Clinical Goal



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



Slicer DMRI

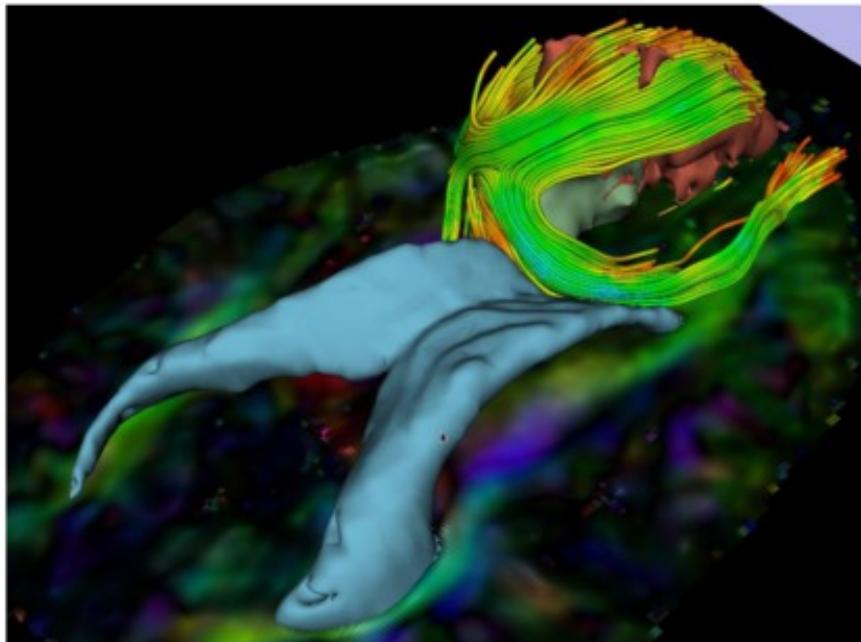
An open-source project to improve and extend diffusion magnetic resonance imaging software in 3D Slicer:

<http://dmri.slicer.org>

Please read the **Diffusion MRI Analysis** tutorial to install SlicerDMRI:

http://dmri.slicer.org/docs/diffusion_mri_analysis

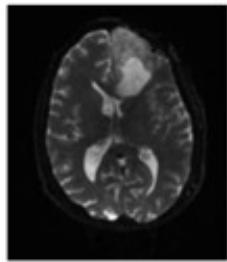
Image Analysis Pipeline



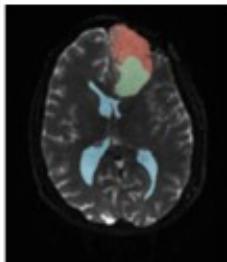
The image analysis pipeline described in this tutorial uses three different algorithms:

- 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.

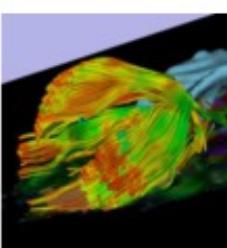
Overview of the analysis pipeline



Part 1: Loading & Visualization of Diffusion Data



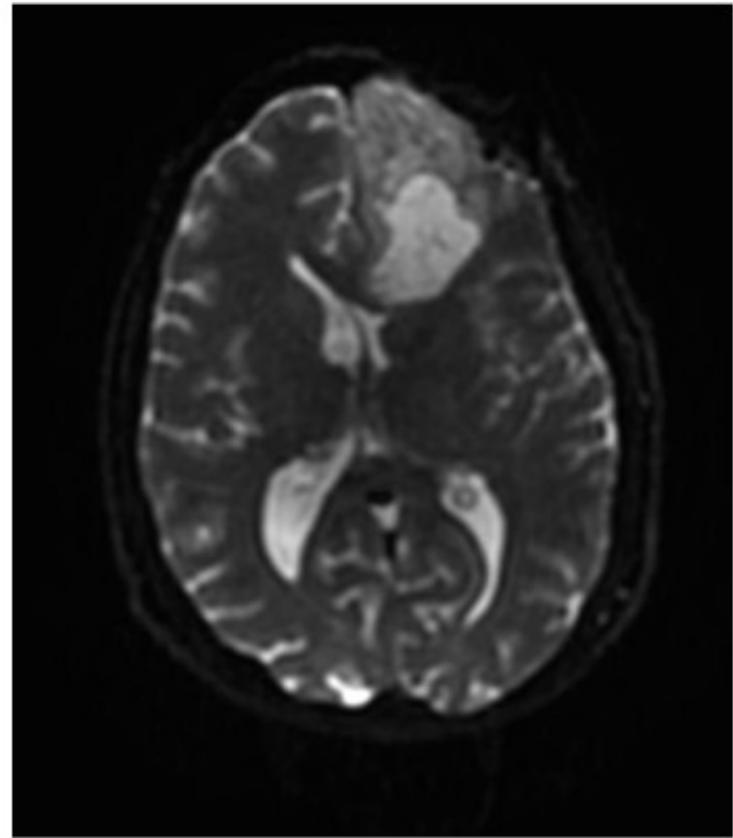
Part 2: Segmentation of lat. ventricles, and solid and cystic parts of the tumor



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

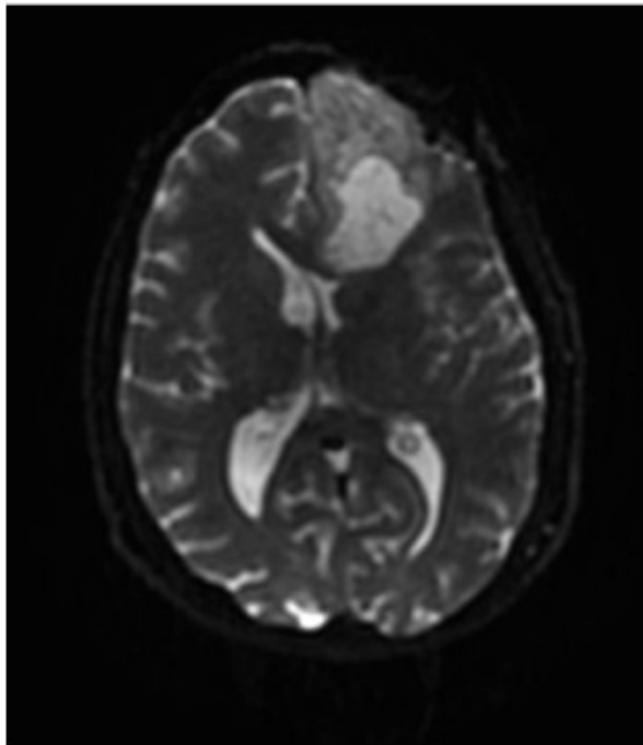


Part 4: Tractography exploration of the ipsilateral and contralateral side



Part 1: Loading and Visualization of Diffusion Data

Diffusion Tensor Imaging

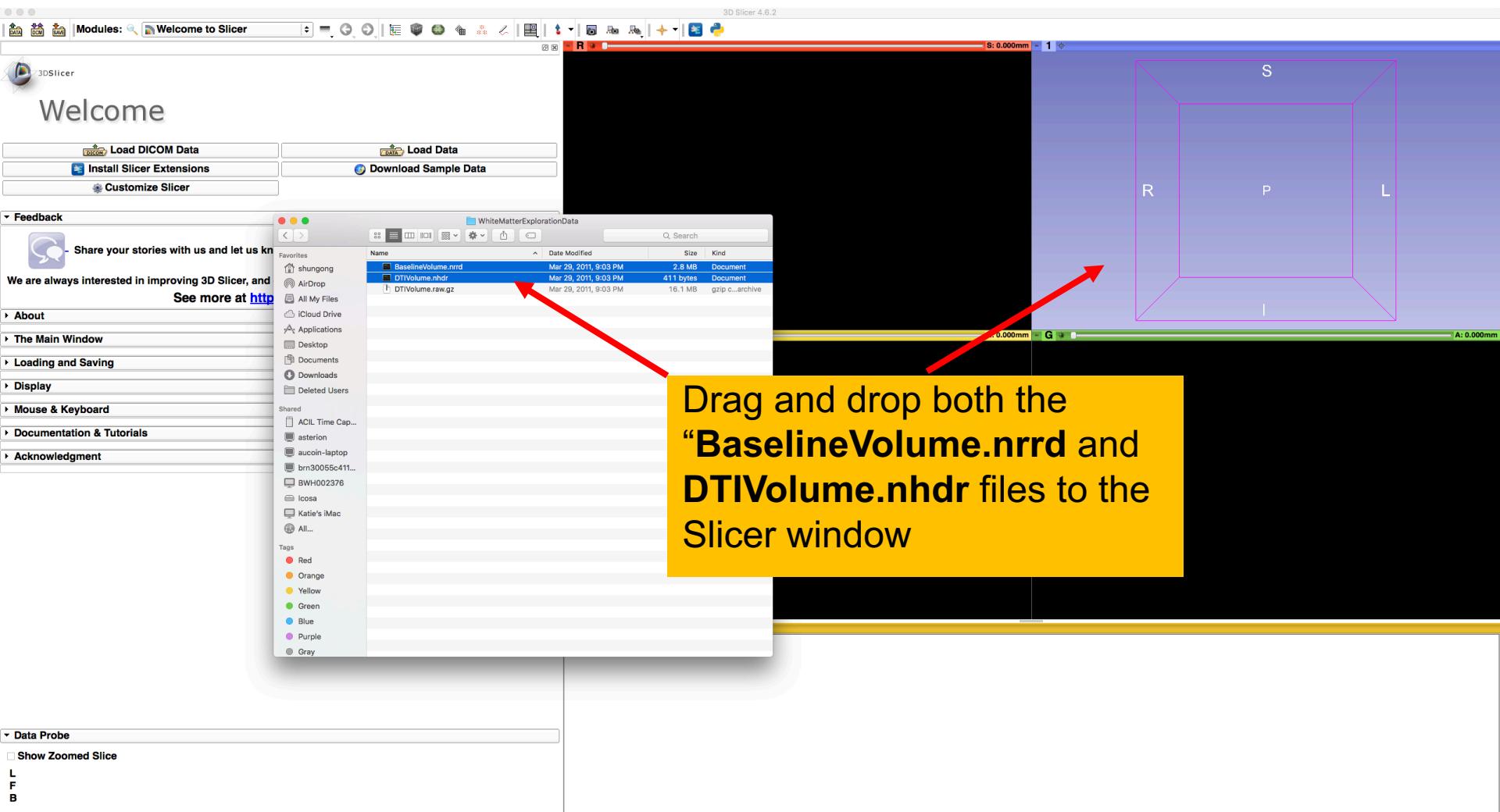


$$S_i = S_0 e^{-b \hat{g}^T D \hat{g}_i}$$

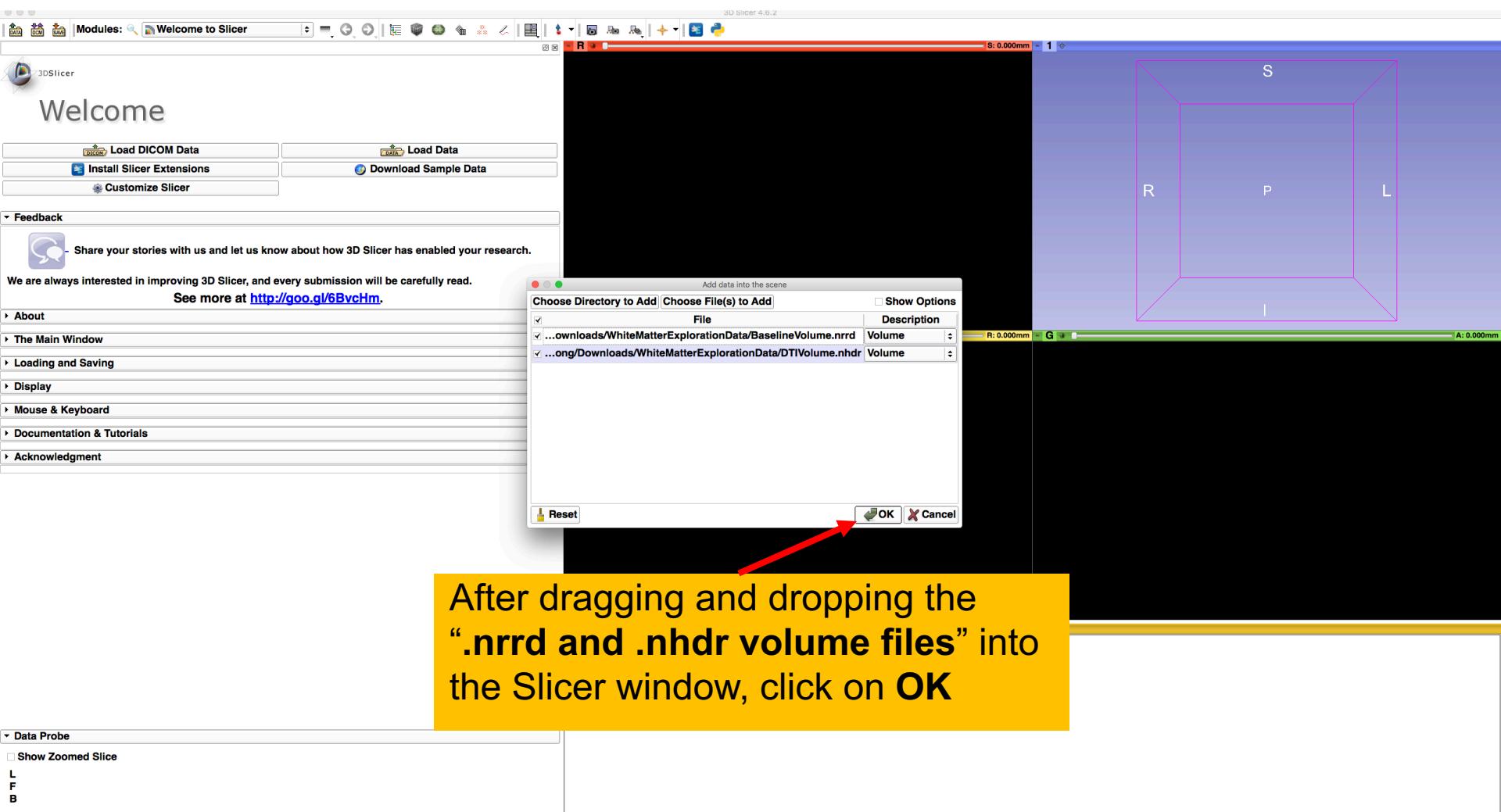
(Stejskal and Tanner 1965, Basser 1994)

$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$
A diagram of an ellipsoid representing a diffusion tensor. Three orthogonal arrows point along the major axes of the ellipsoid, indicating the principal directions of diffusion.

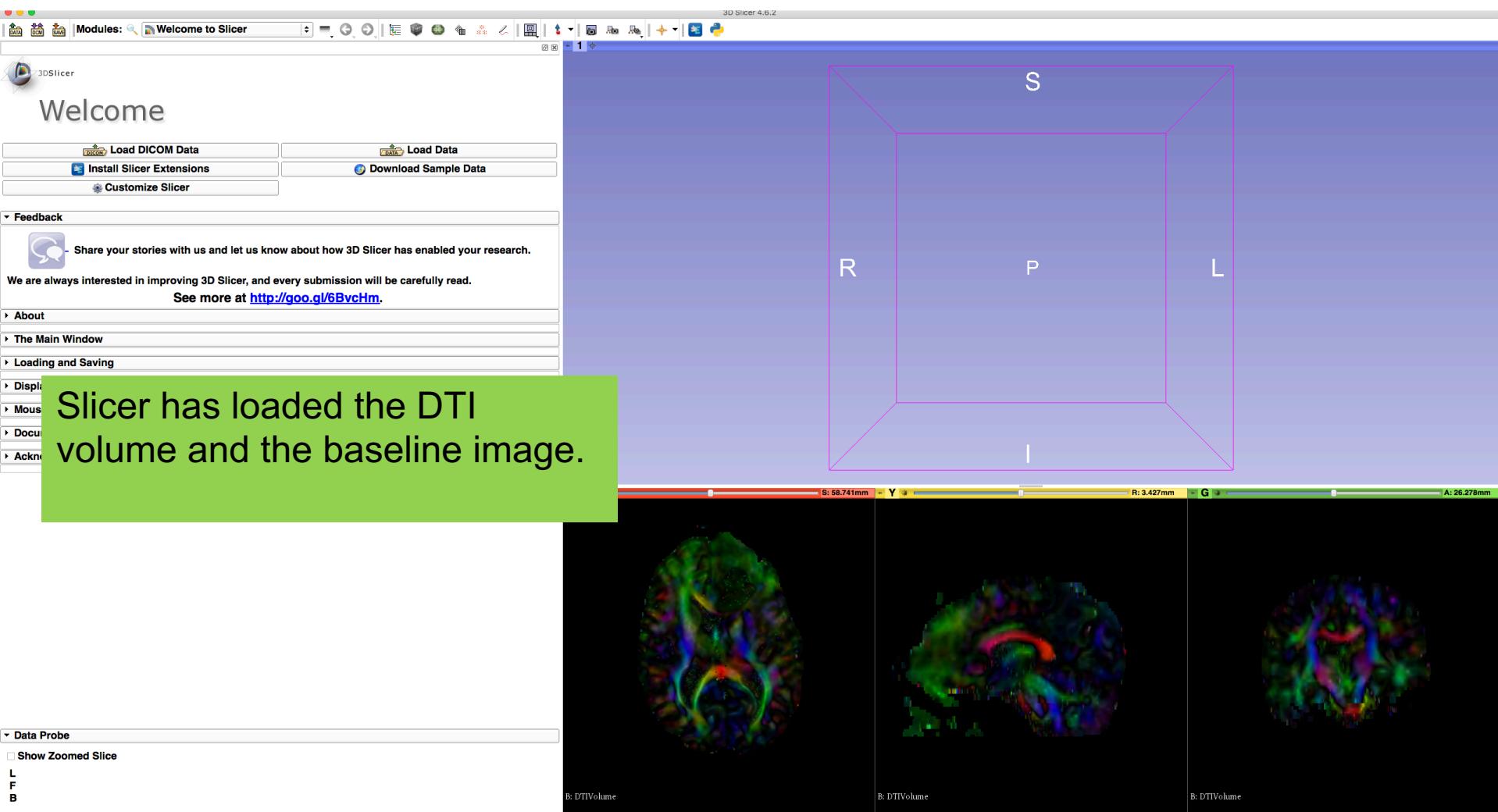
Loading DTI and Baseline Data



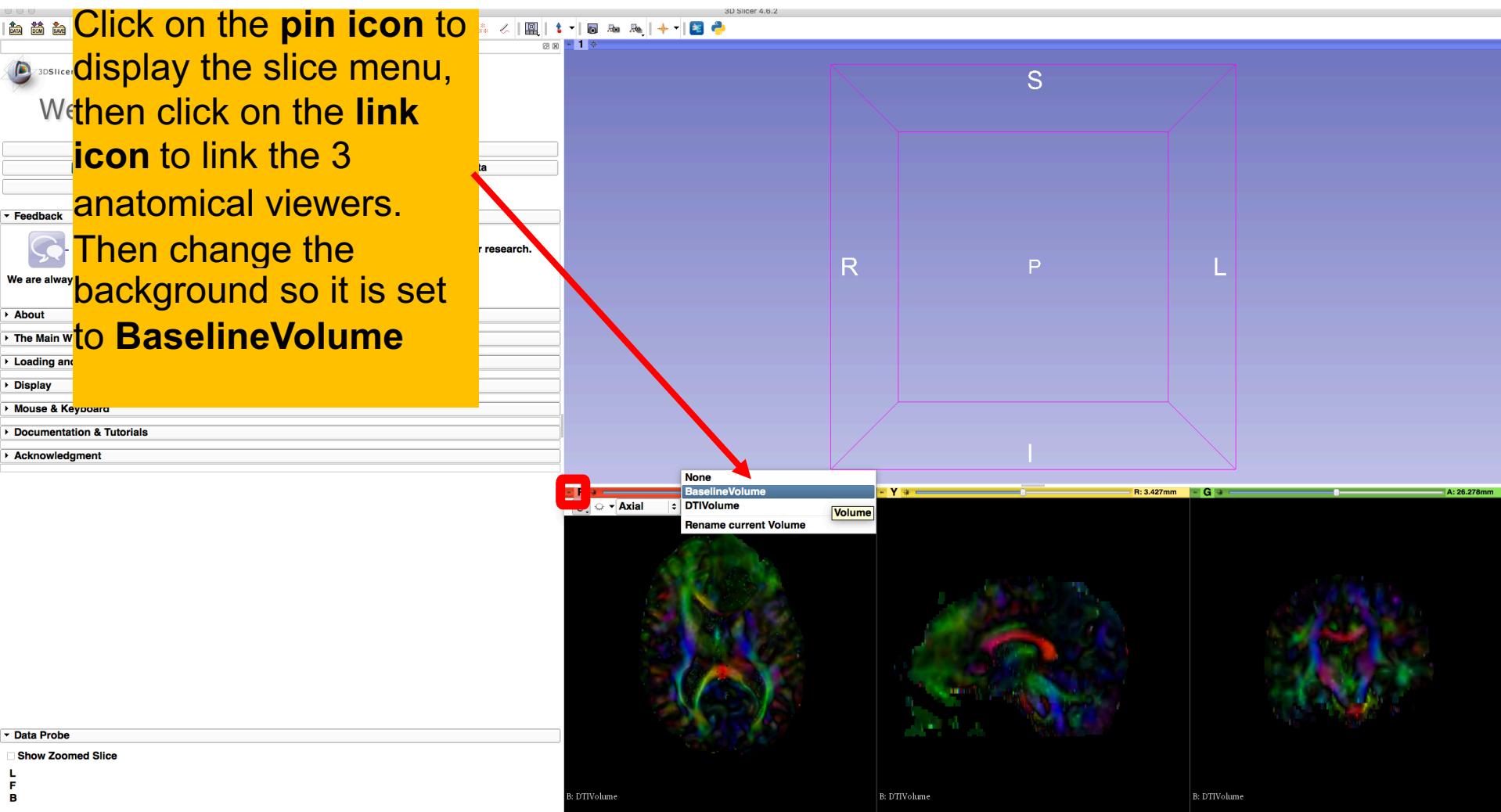
Loading DTI and Baseline Data



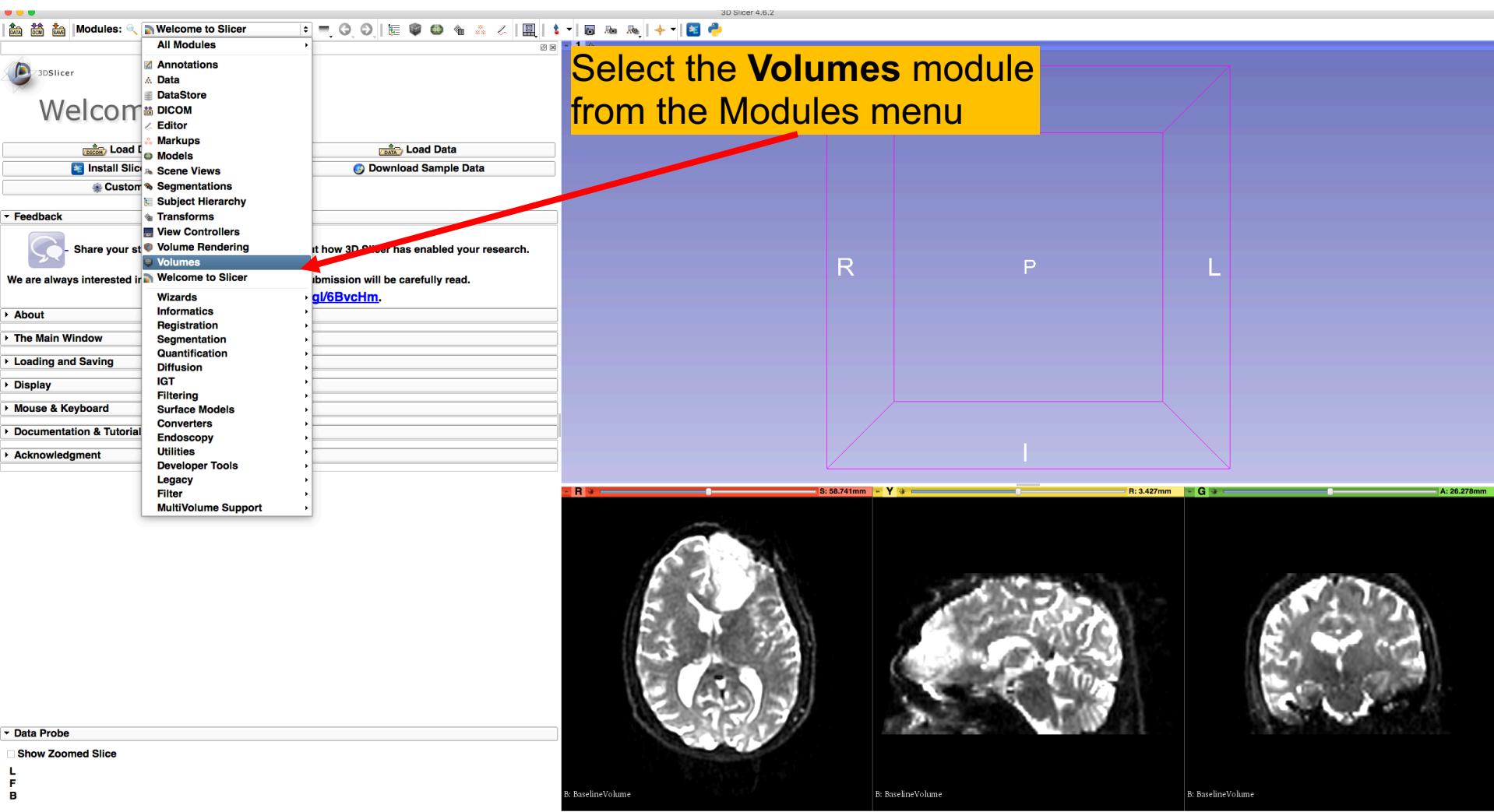
Loading DTI and Baseline Data



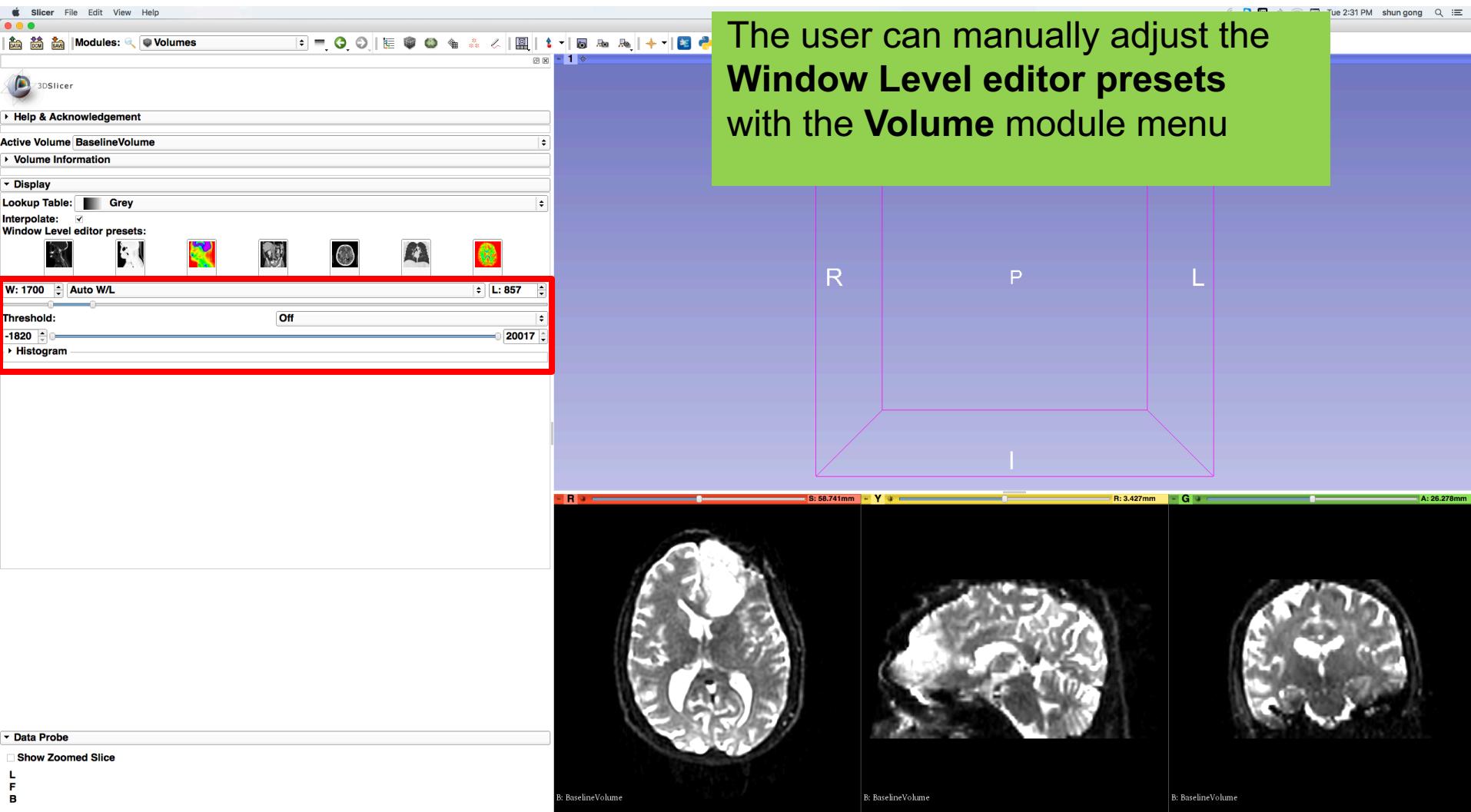
Loading DTI and Baseline Data



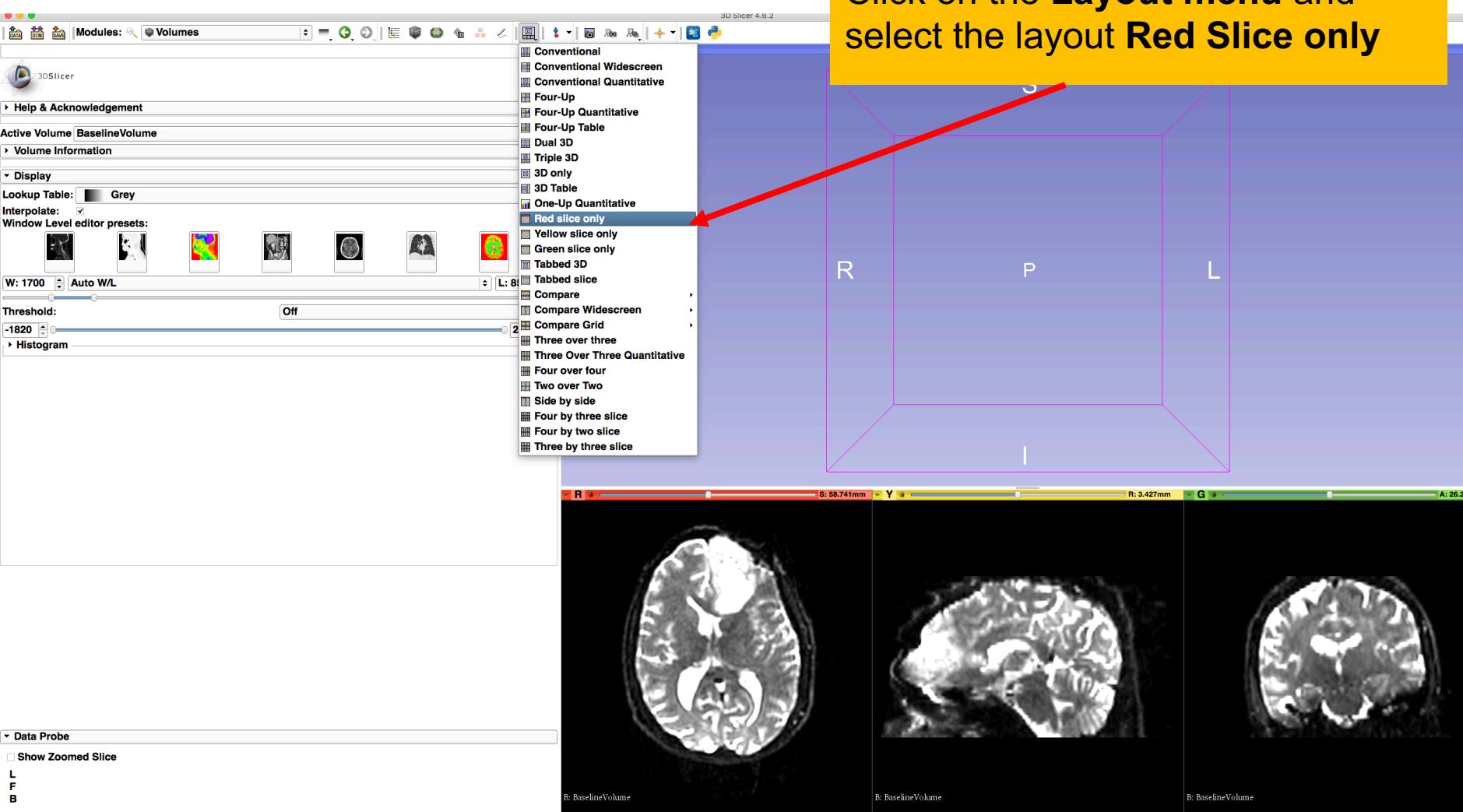
Loading DTI and Baseline Data

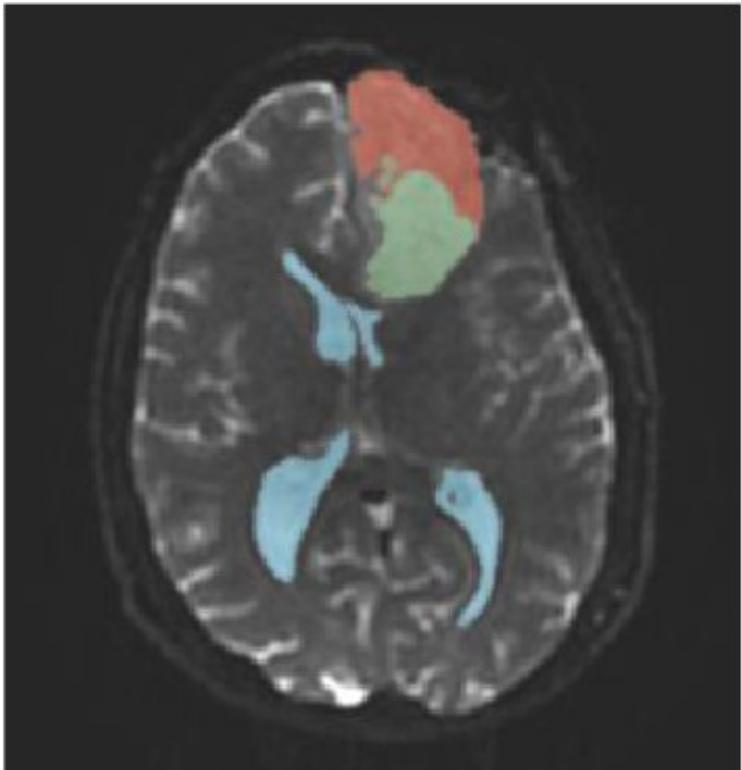


Loading DTI and Baseline Data



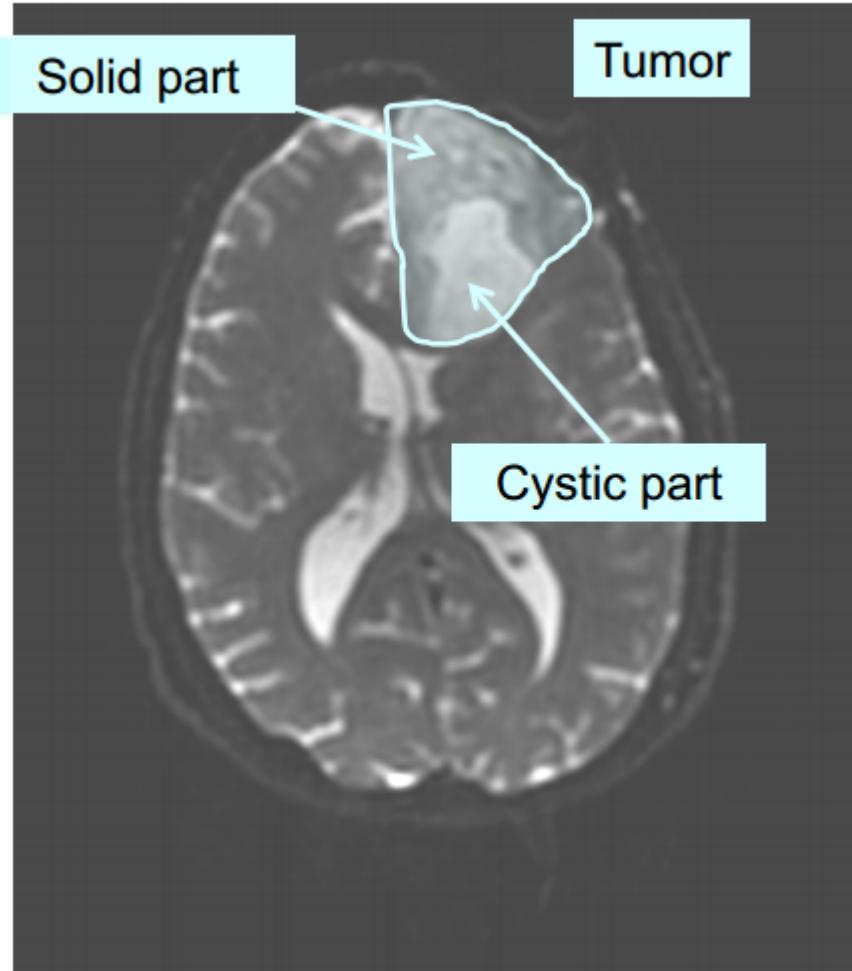
Loading DTI and Baseline Data





Part 1: Segmenting the tumor and ventricles

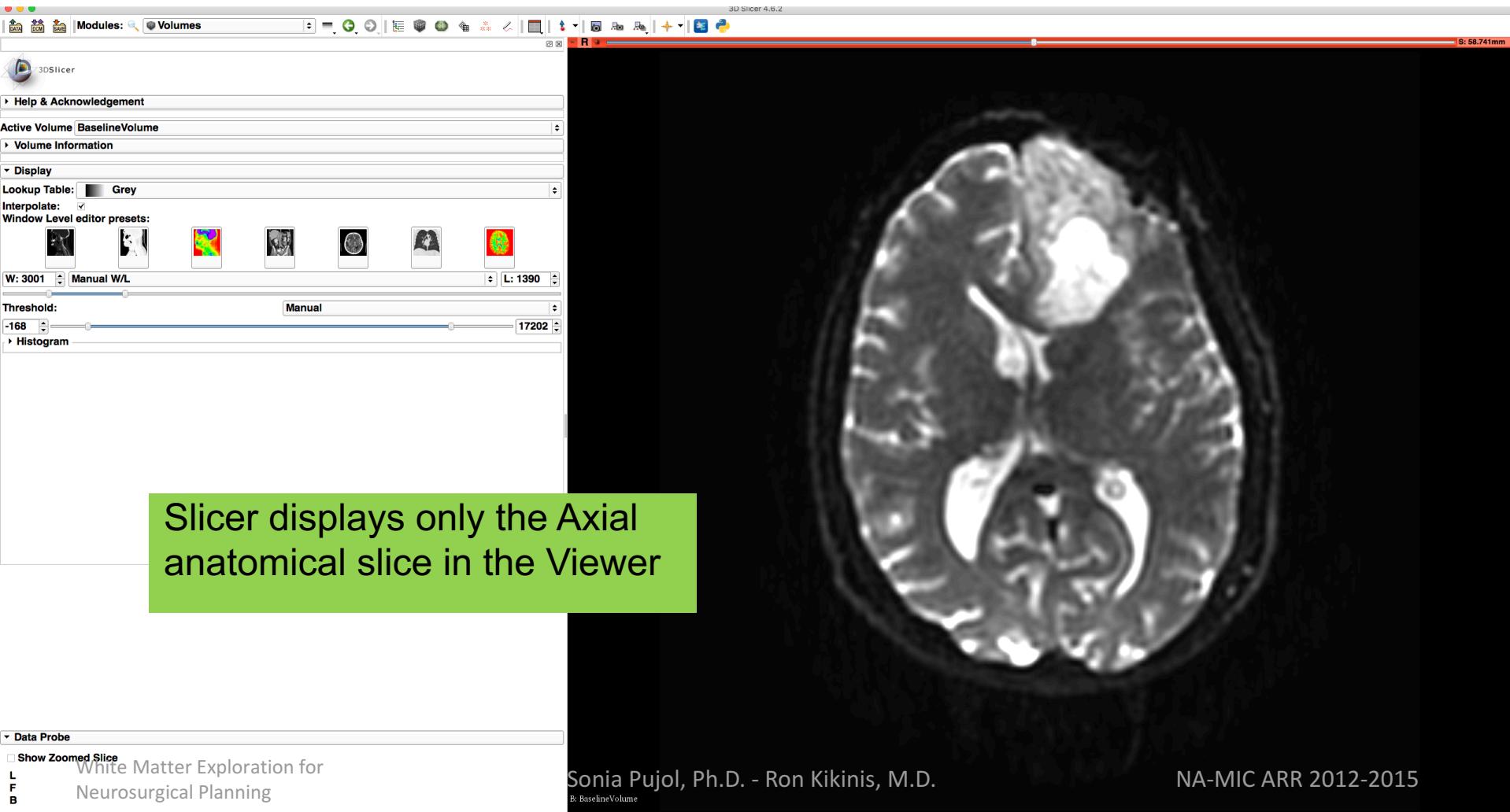
Tumor Segmentation



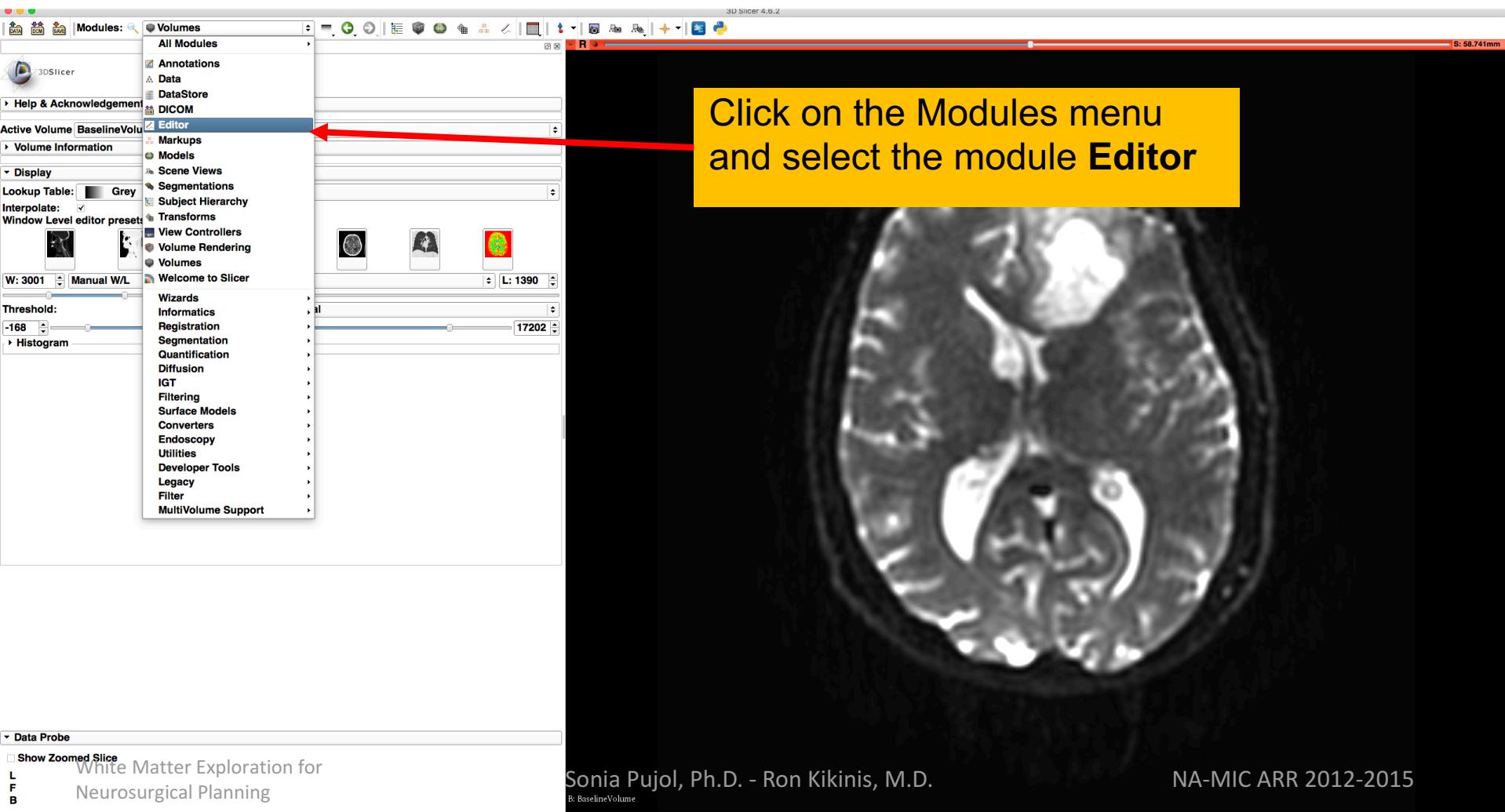
The tumor in this clinical case is composed of two parts: a solid part, and a cystic part.

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

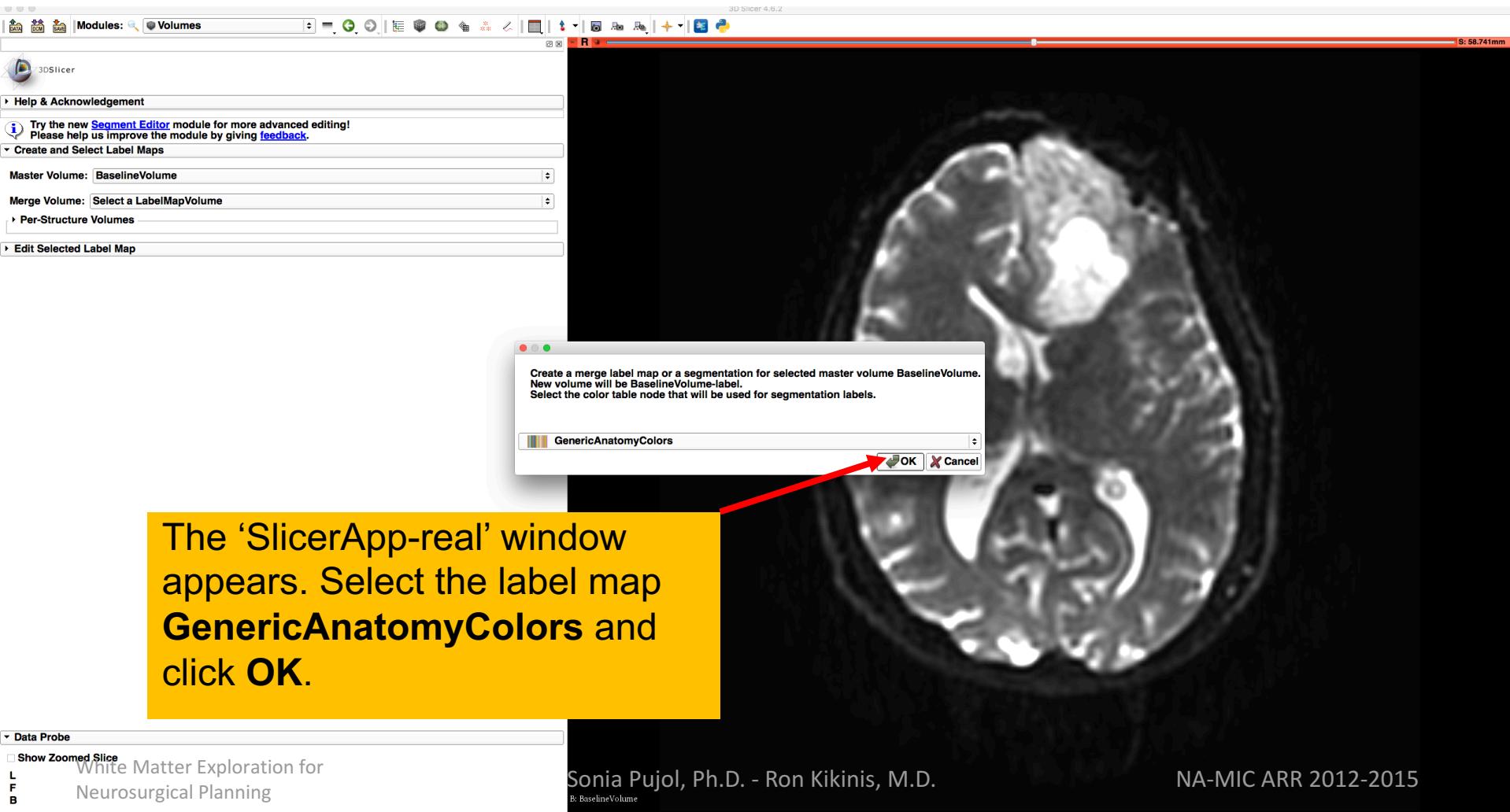
Tumor Segmentation



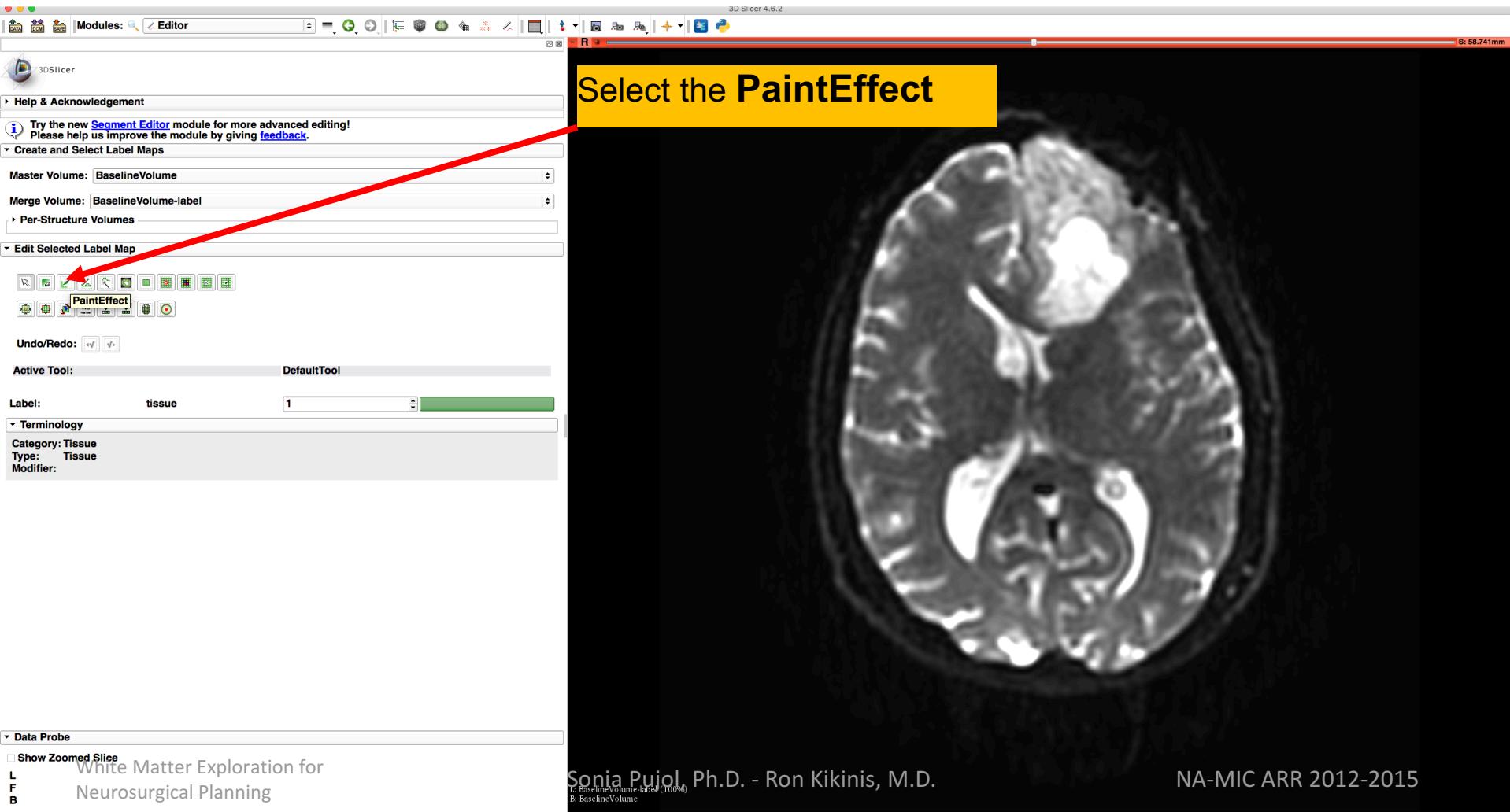
Tumor Segmentation



Tumor Segmentation



Tumor Segmentation



Tumor Segmentation

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

Help & Acknowledgement

Try the new Segment Editor module for more advanced editing.
Please help us improve the module by giving [feedback](#).

Create and Select Label Maps

Master Volume: BaselineVolume

Merge Volume: BaselineVolume-label

Per-Structure Volumes

Edit Selected Label Map

Tools:

Undo/Redo:

Active Tool: DefaultTool

Label: tissue 1

Terminology

Category: Tissue

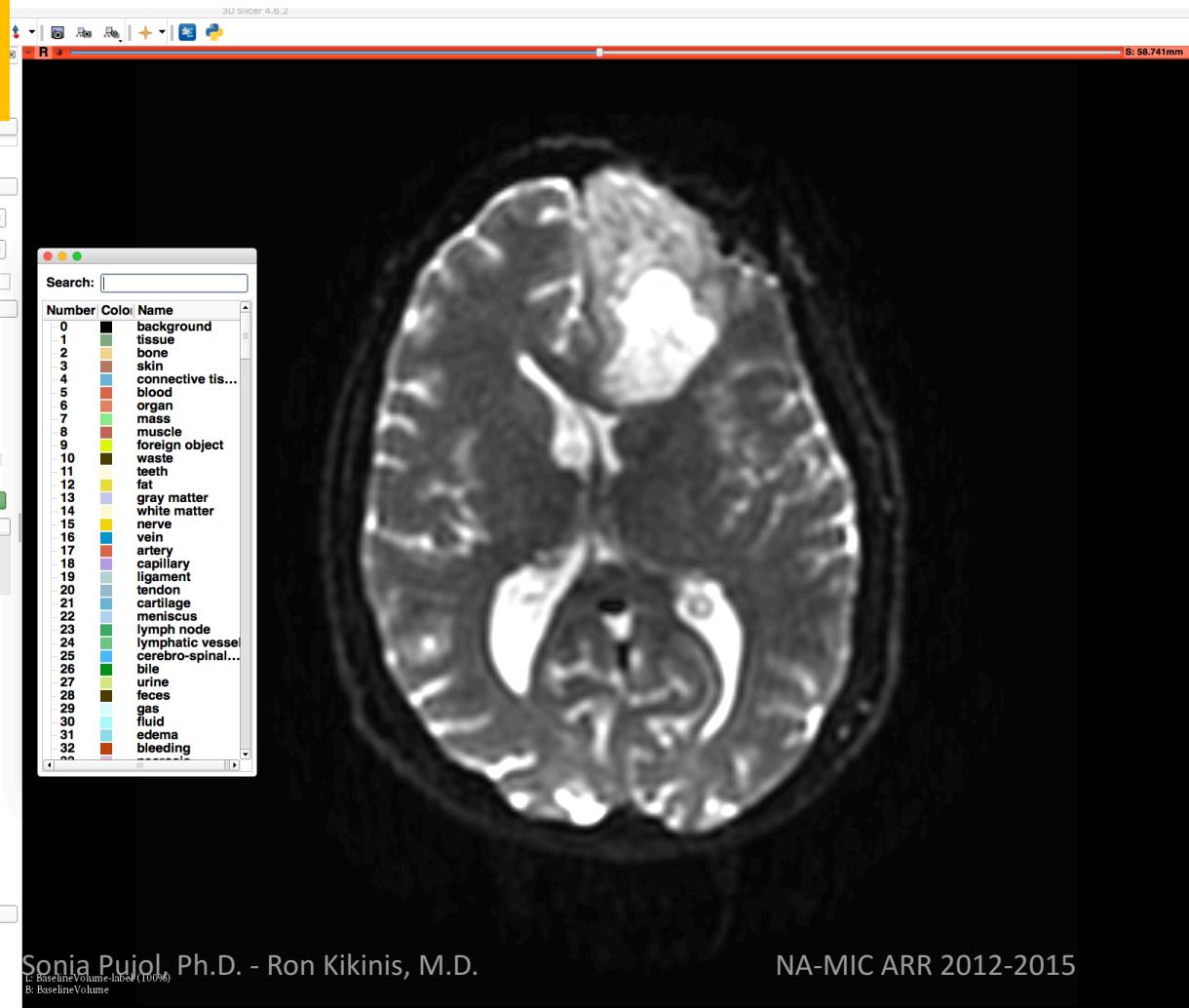
Type: Tissue

Modifier:

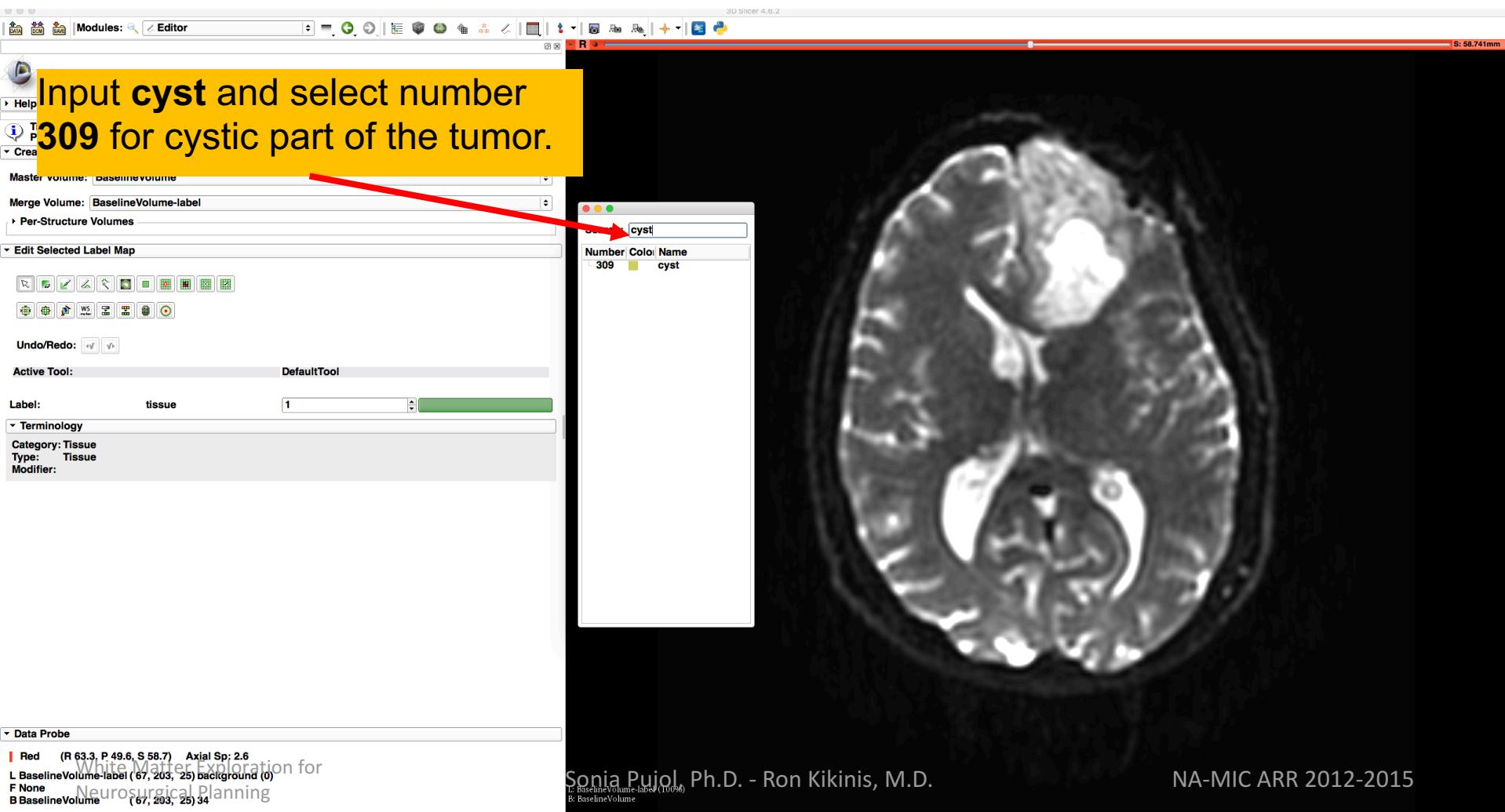
Data Probe

Show Zoomed Slice

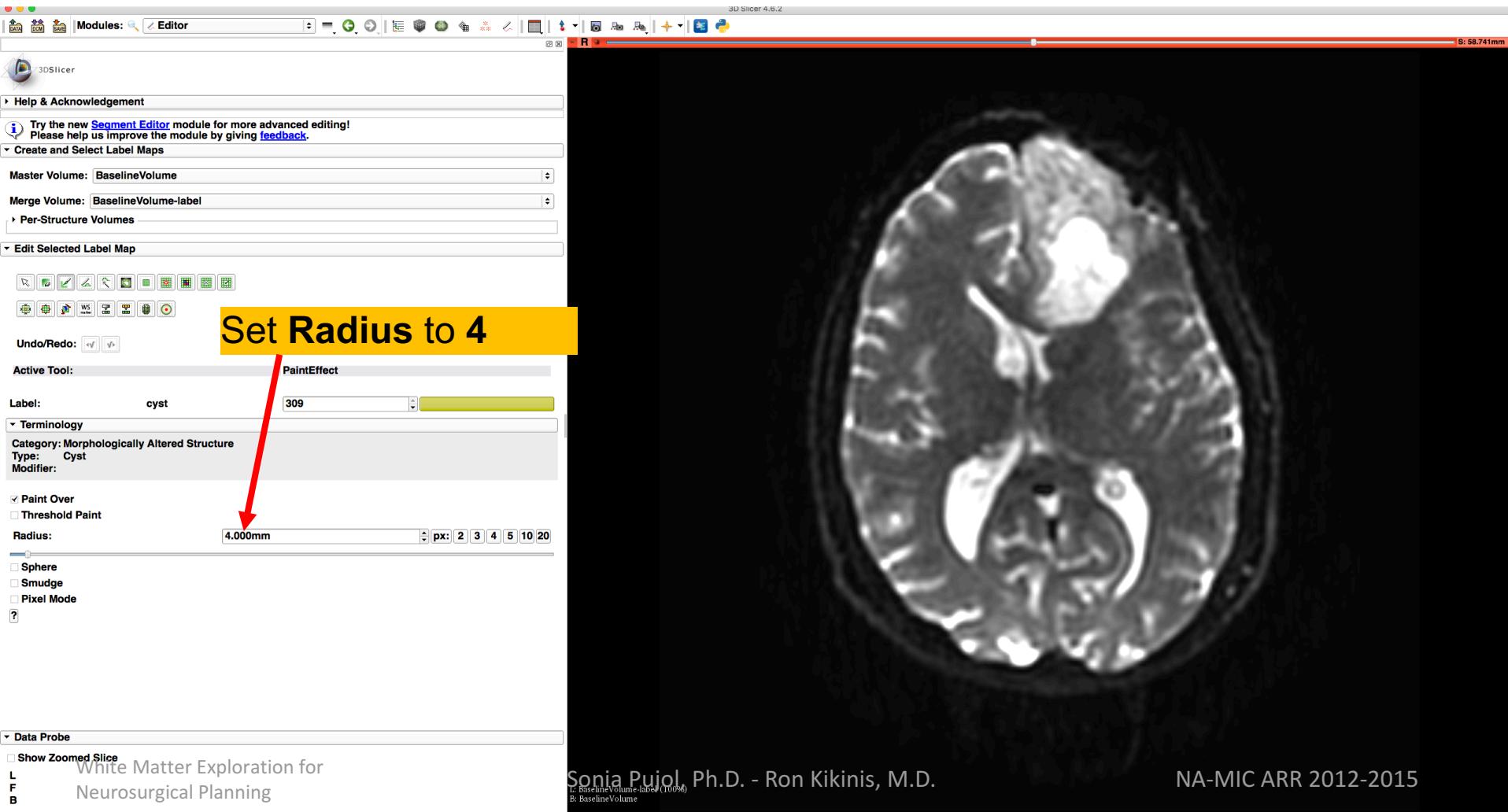
White Matter Exploration for
Neurosurgical Planning



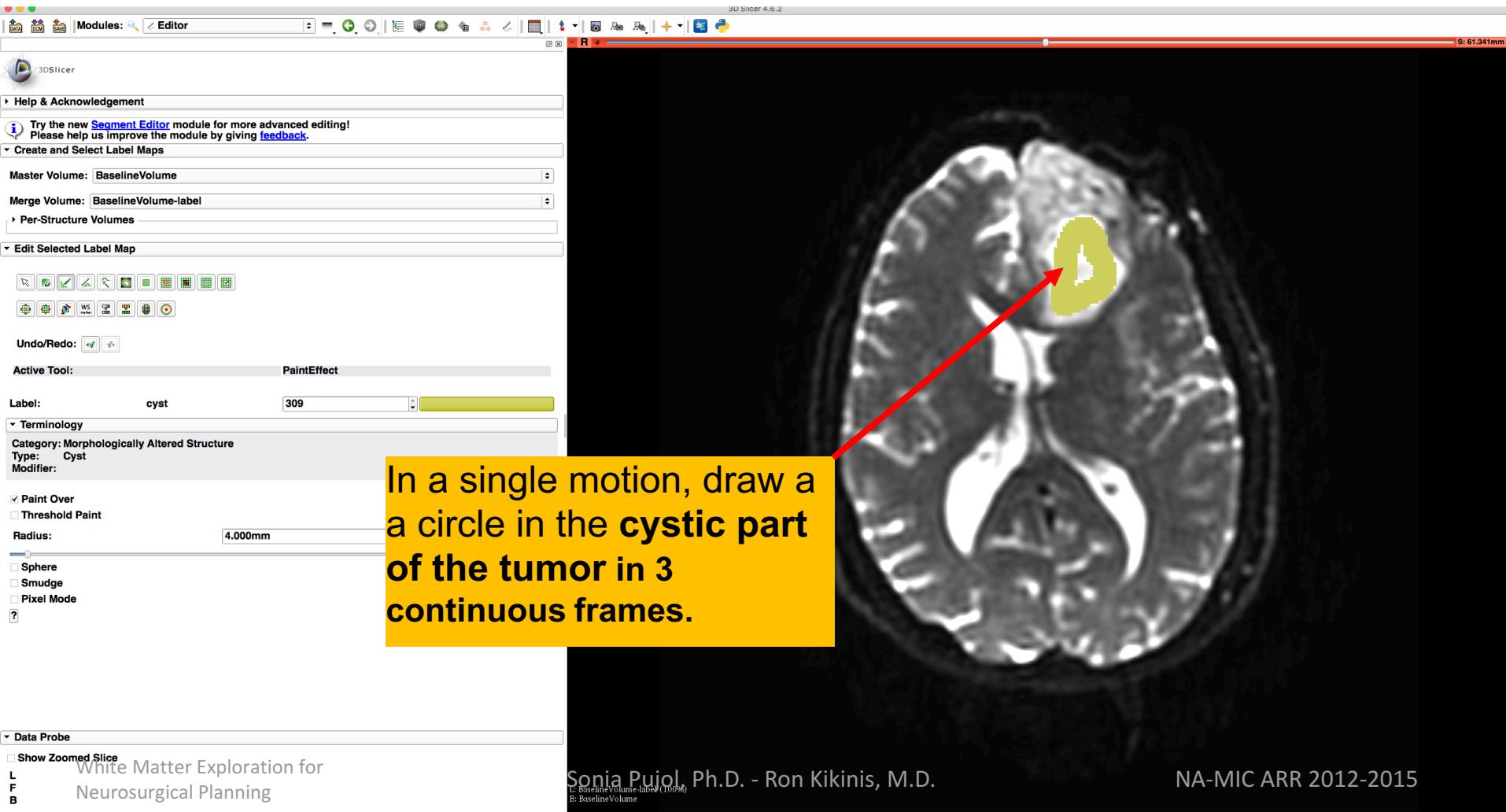
Tumor Segmentation



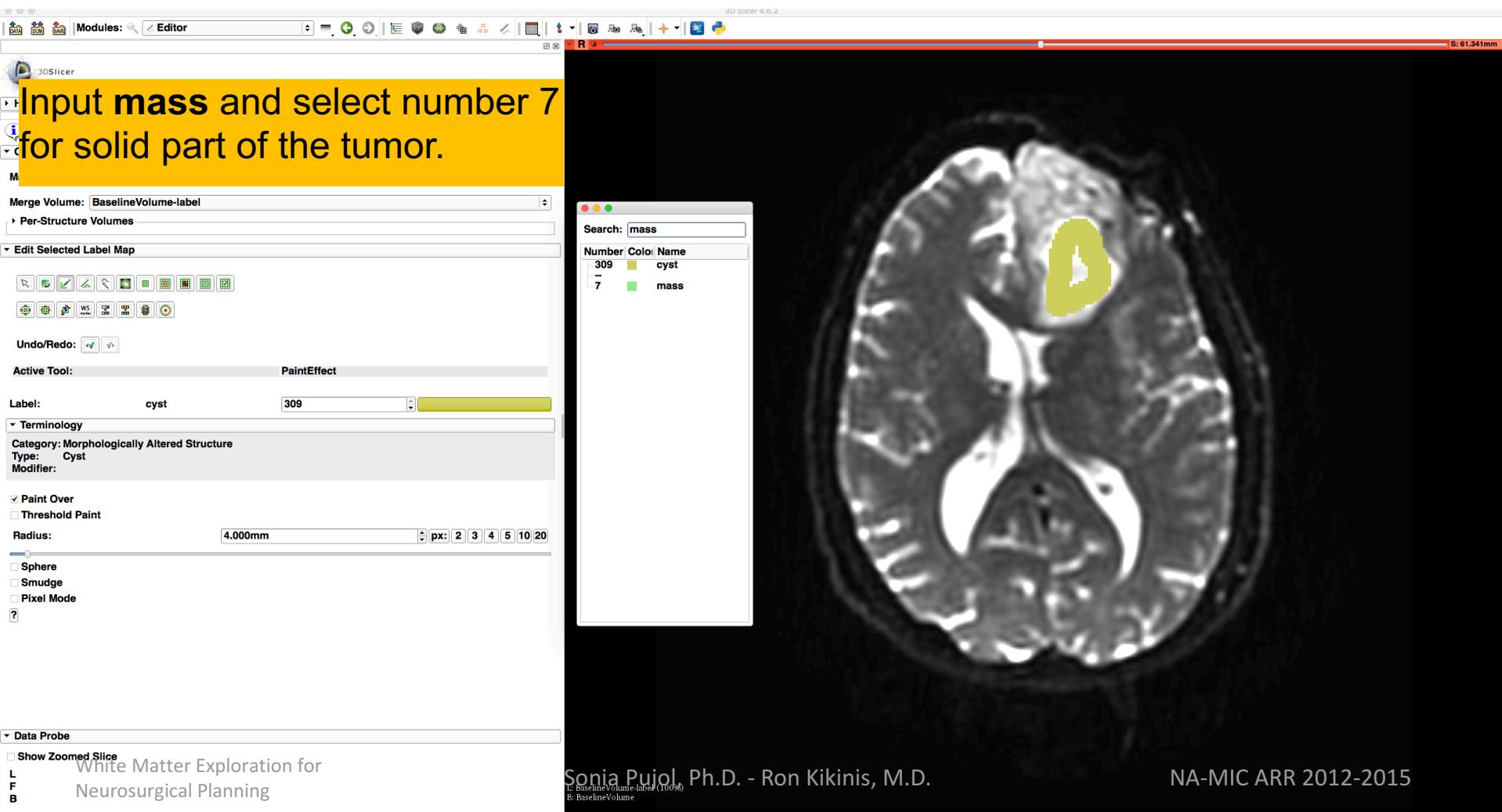
Tumor Segmentation



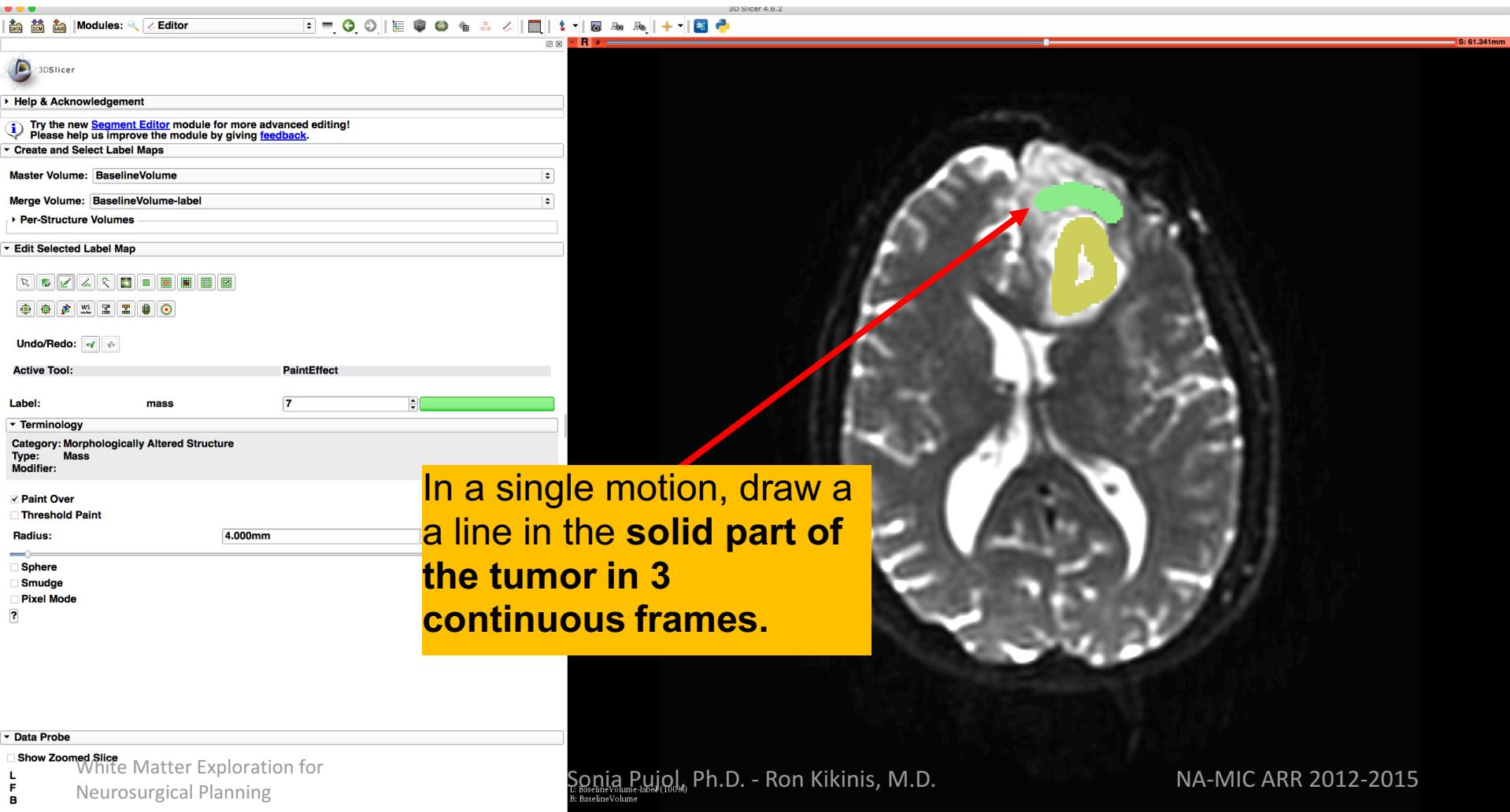
Tumor Segmentation



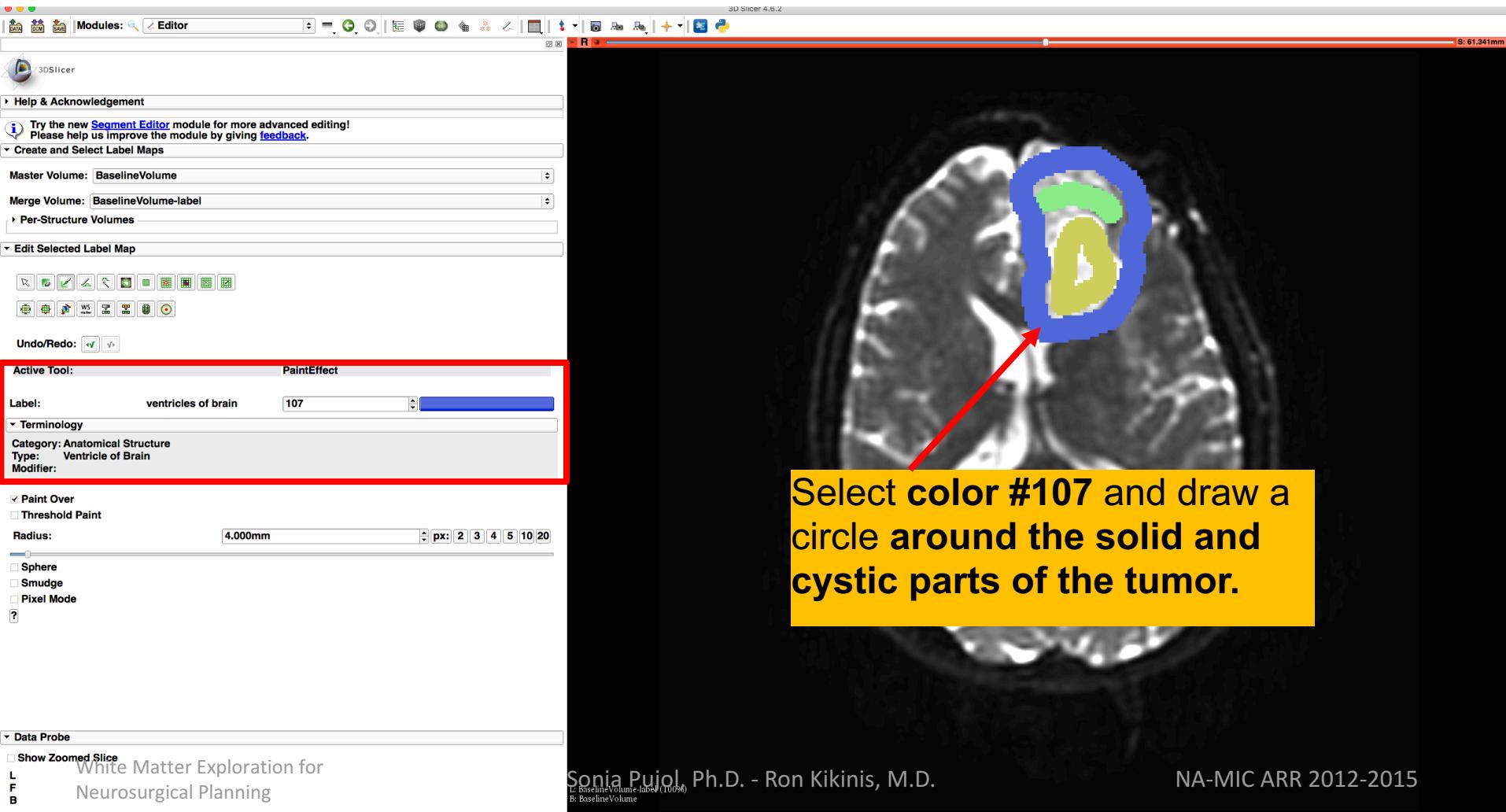
Tumor Segmentation



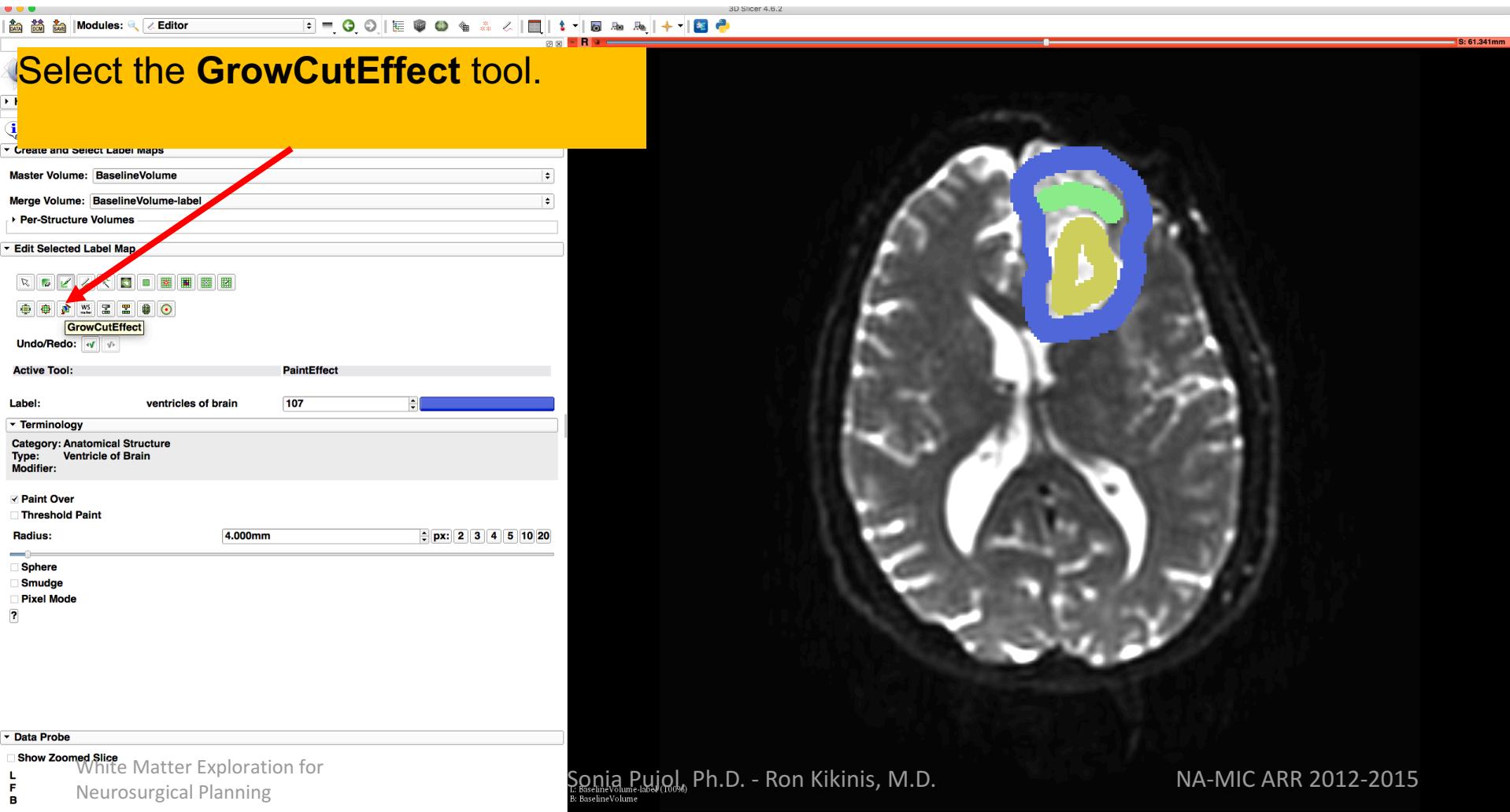
Tumor Segmentation



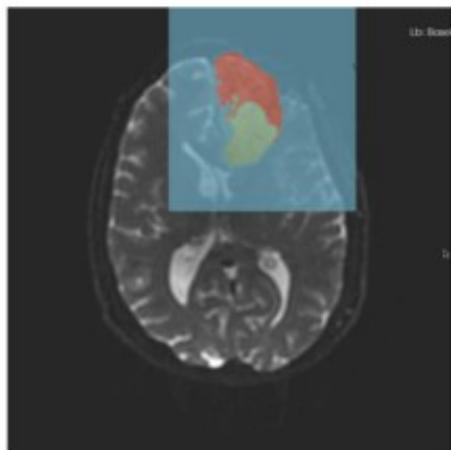
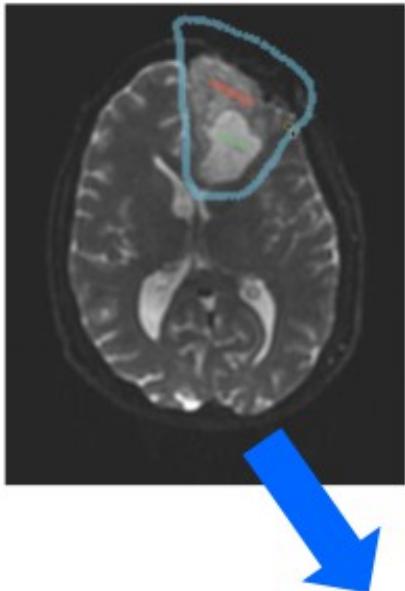
Tumor Segmentation



Tumor Segmentation

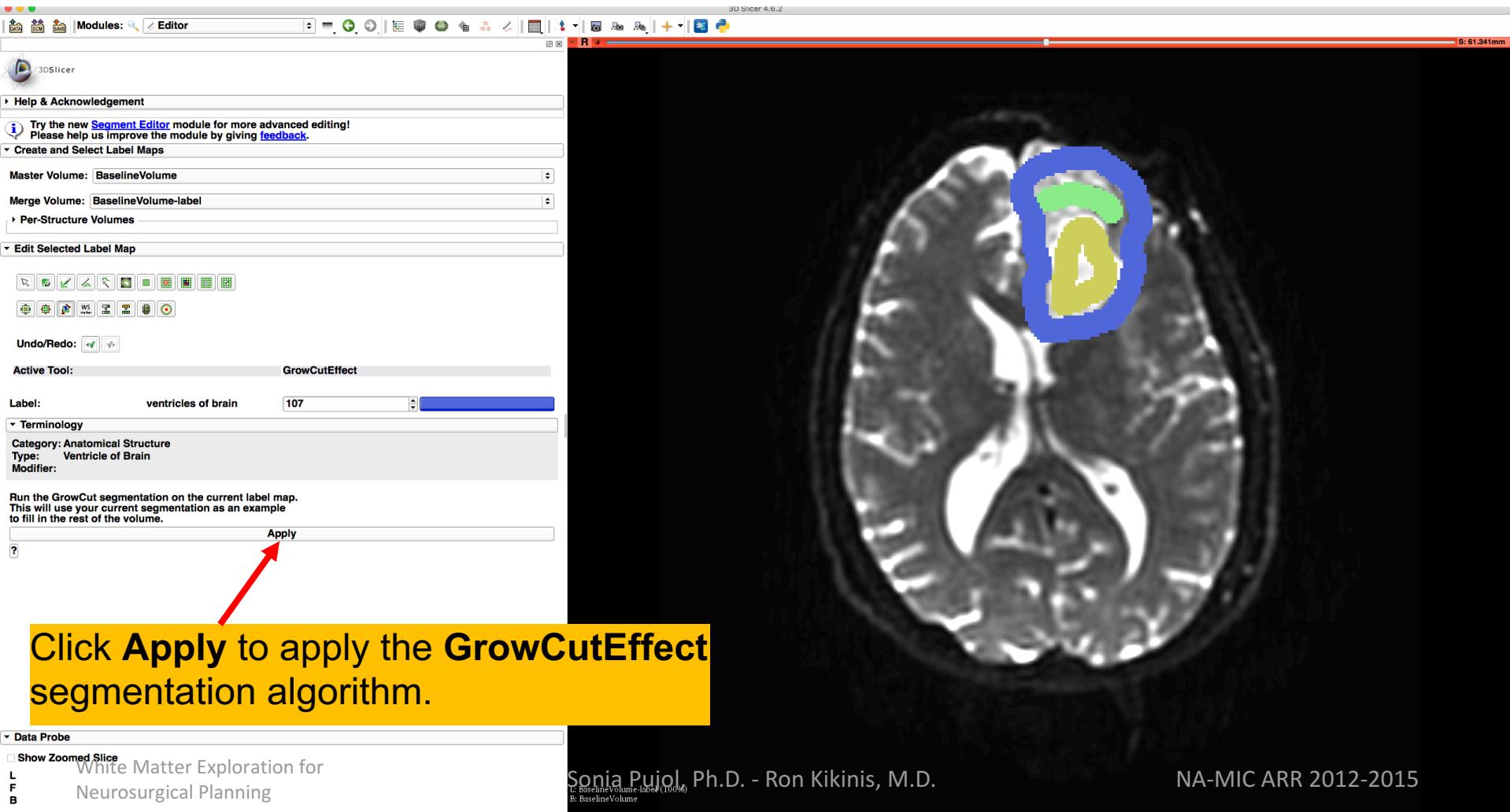


Grow Cut Segmentation

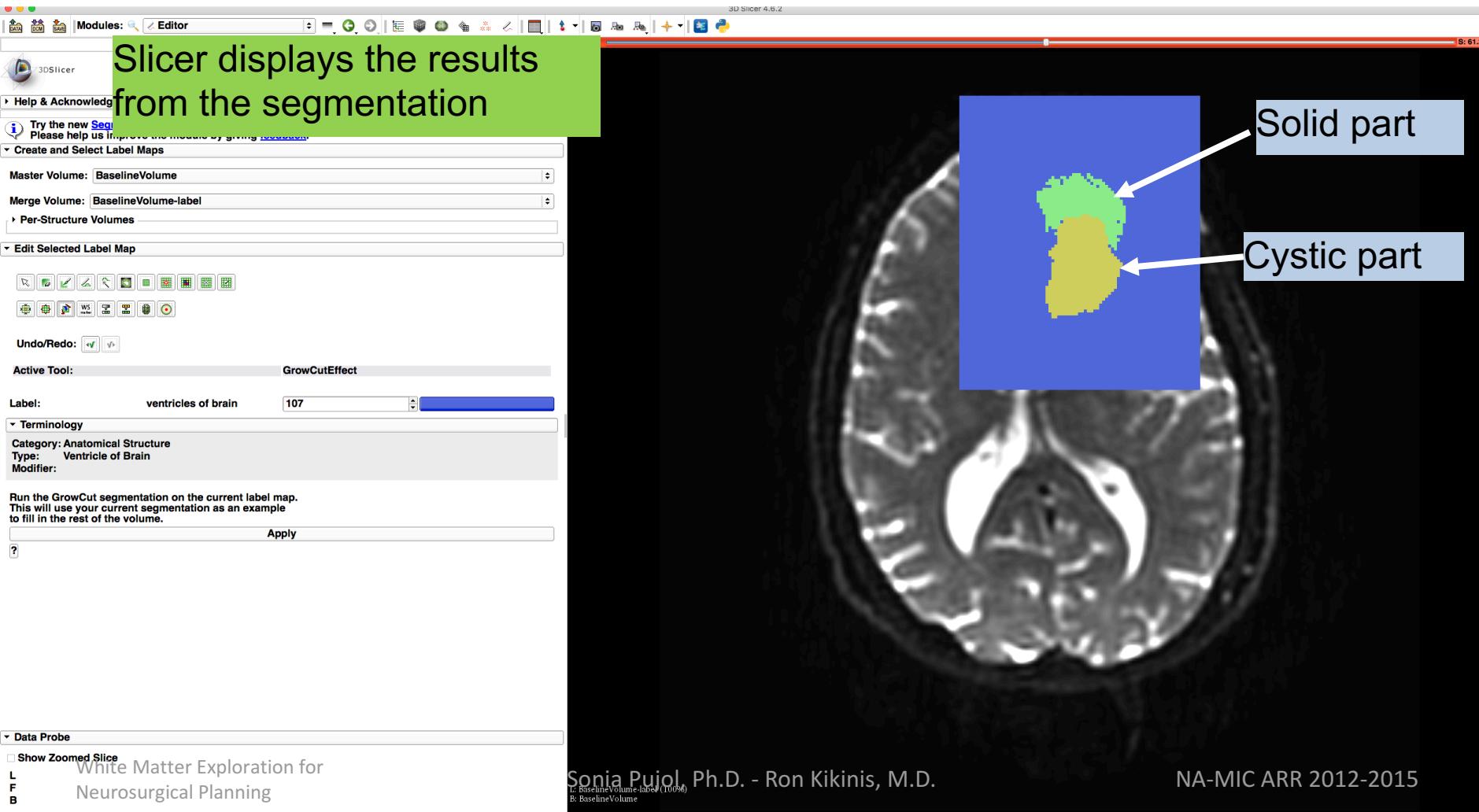


- The Grow Cut Segmentation method is a competitive region growing algorithm using Cellular Automata.
- The algorithm performs multi-label image segmentation using a set of user input scribbles.
- V. Vezhnevets, V. Konouchine. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". Proc. Graphicon.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

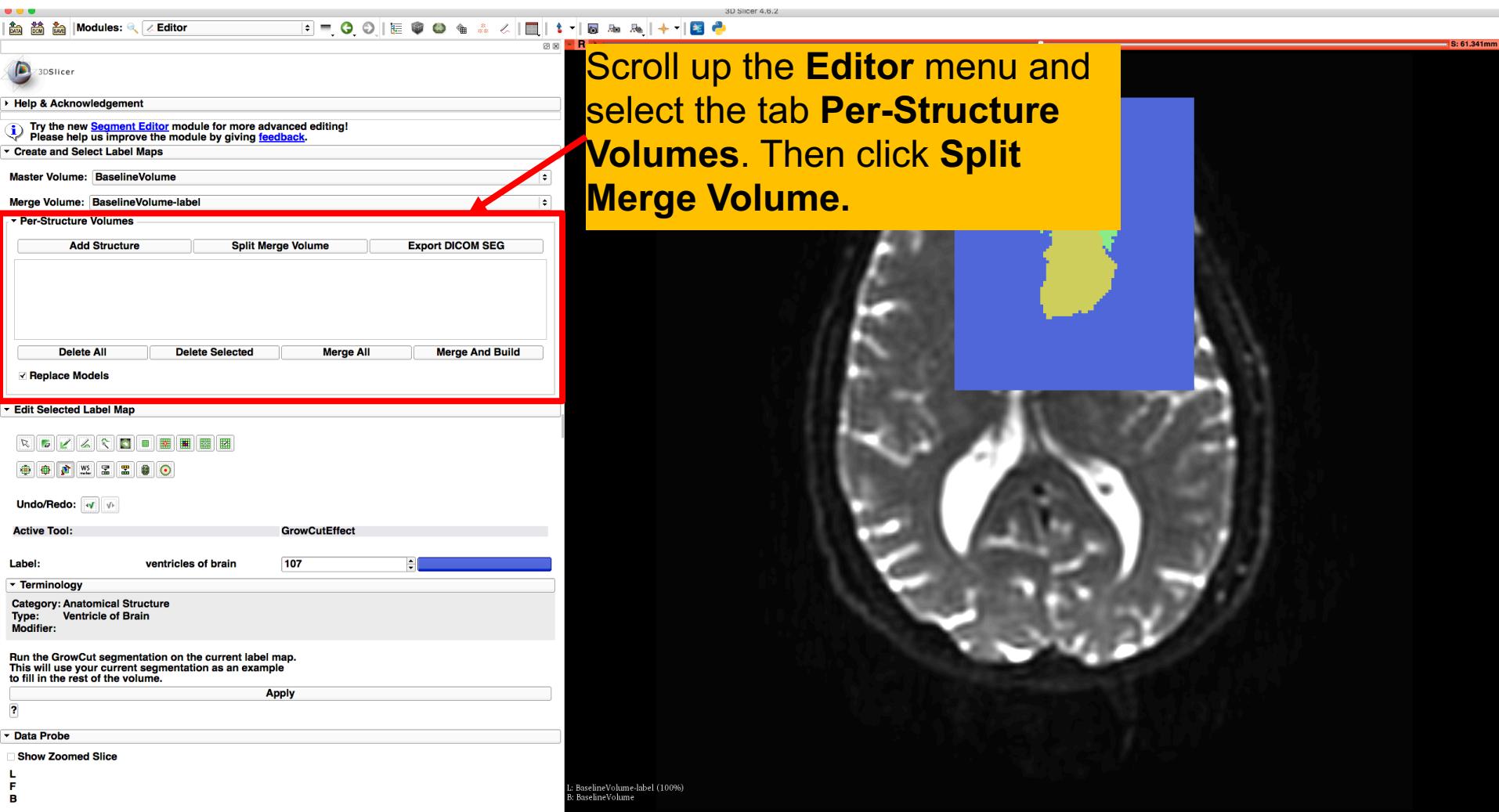
Tumor Segmentation



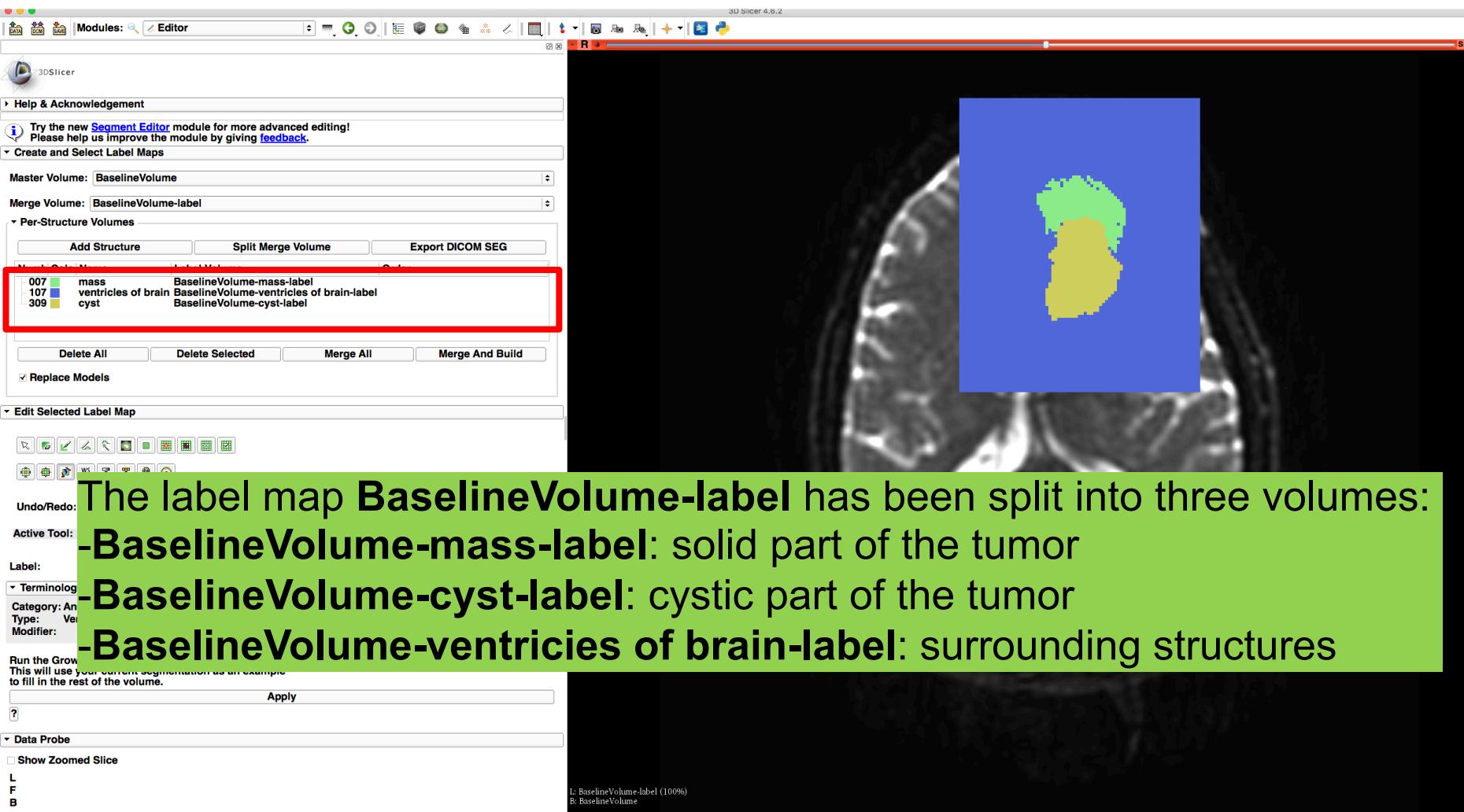
Tumor Segmentation



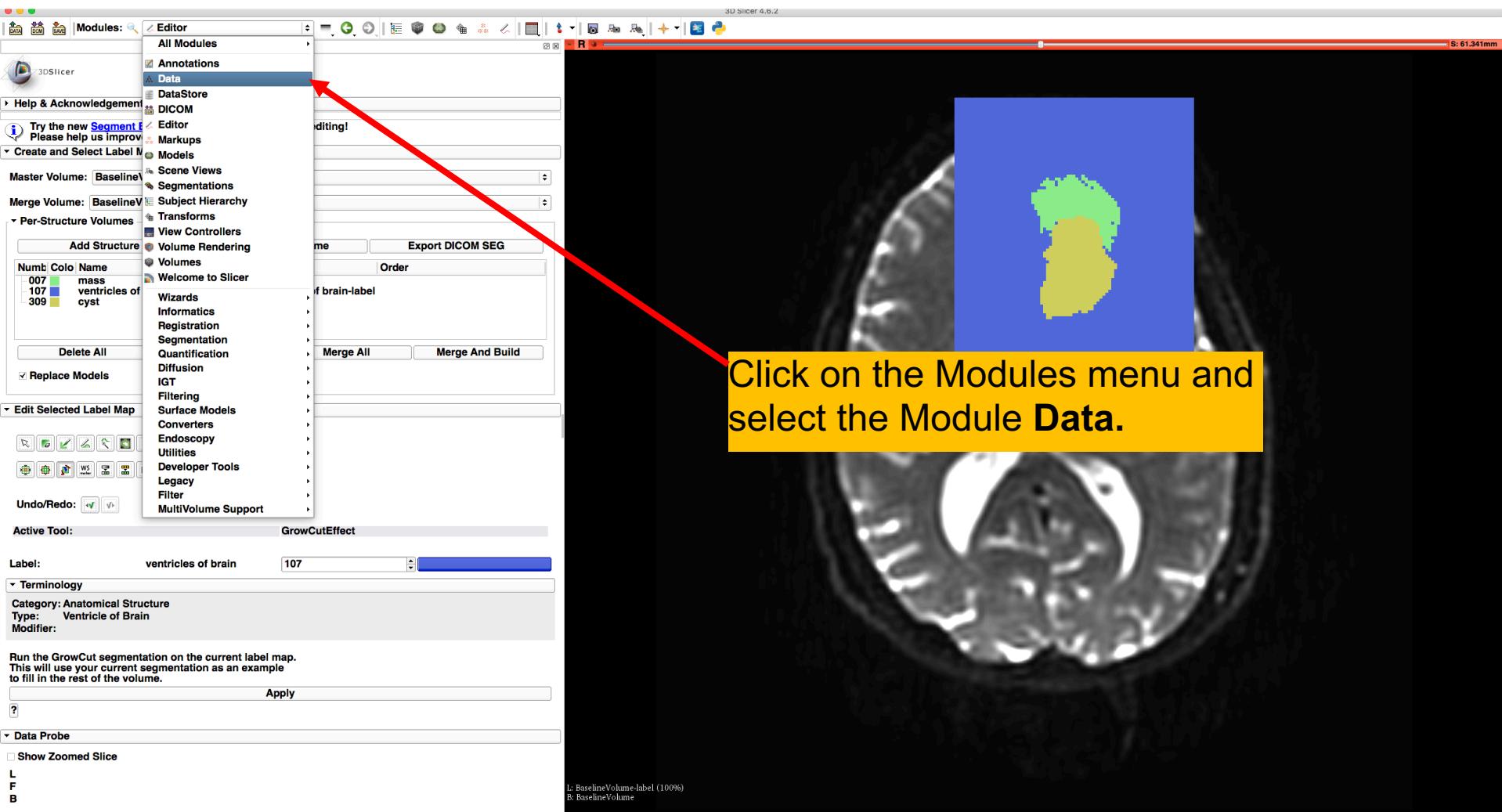
Tumor Segmentation



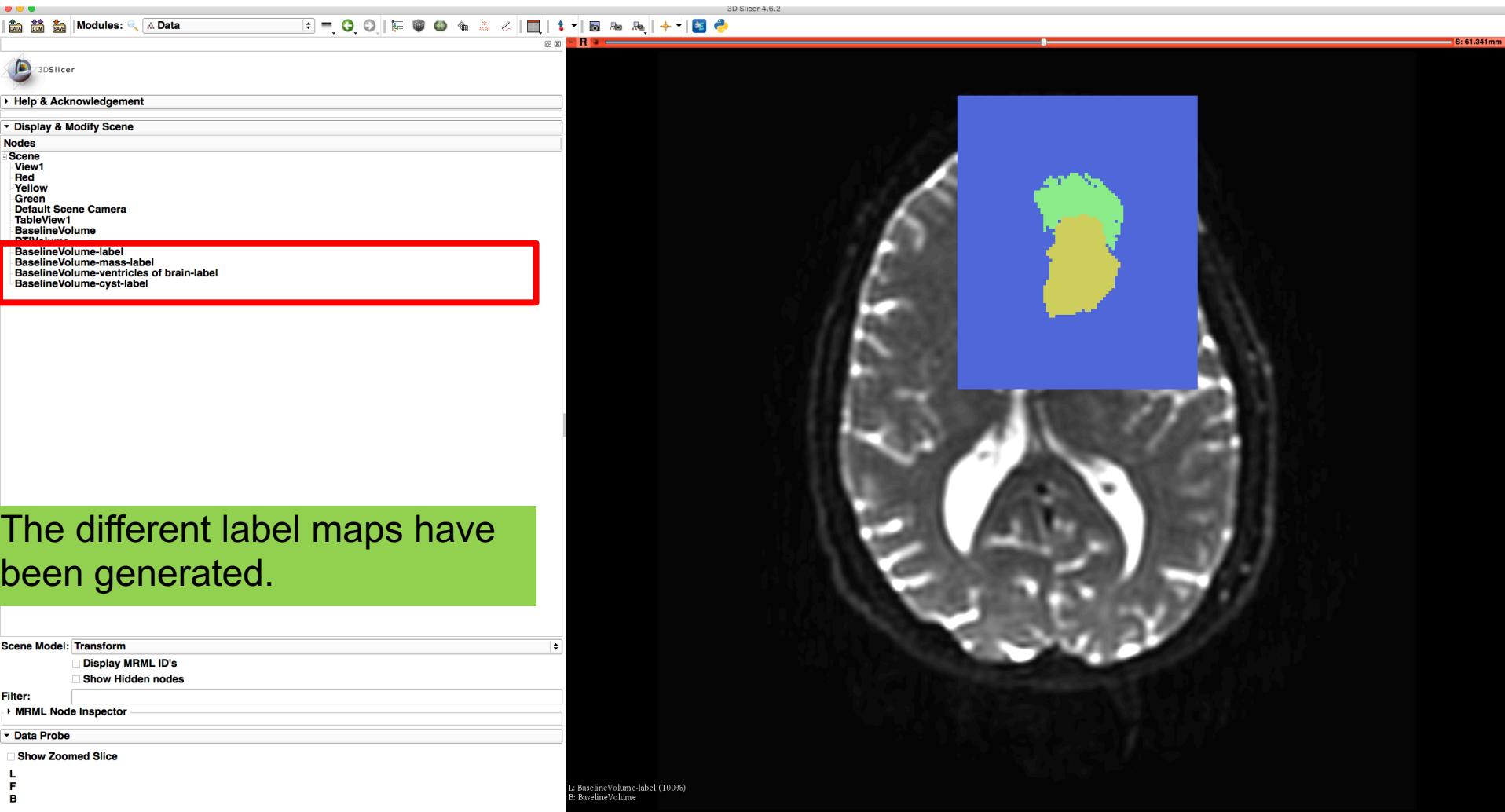
Tumor Segmentation



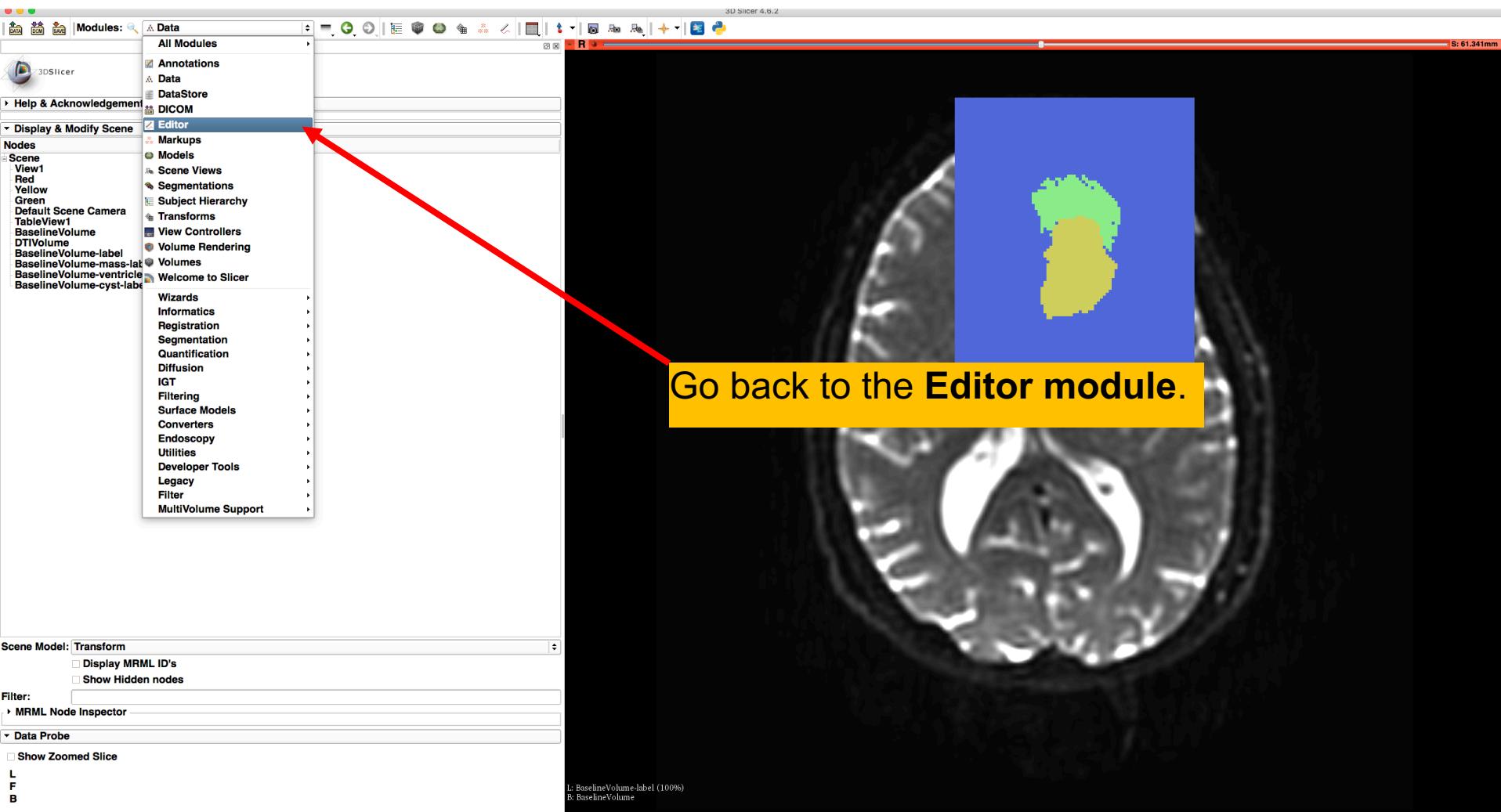
Tumor Segmentation



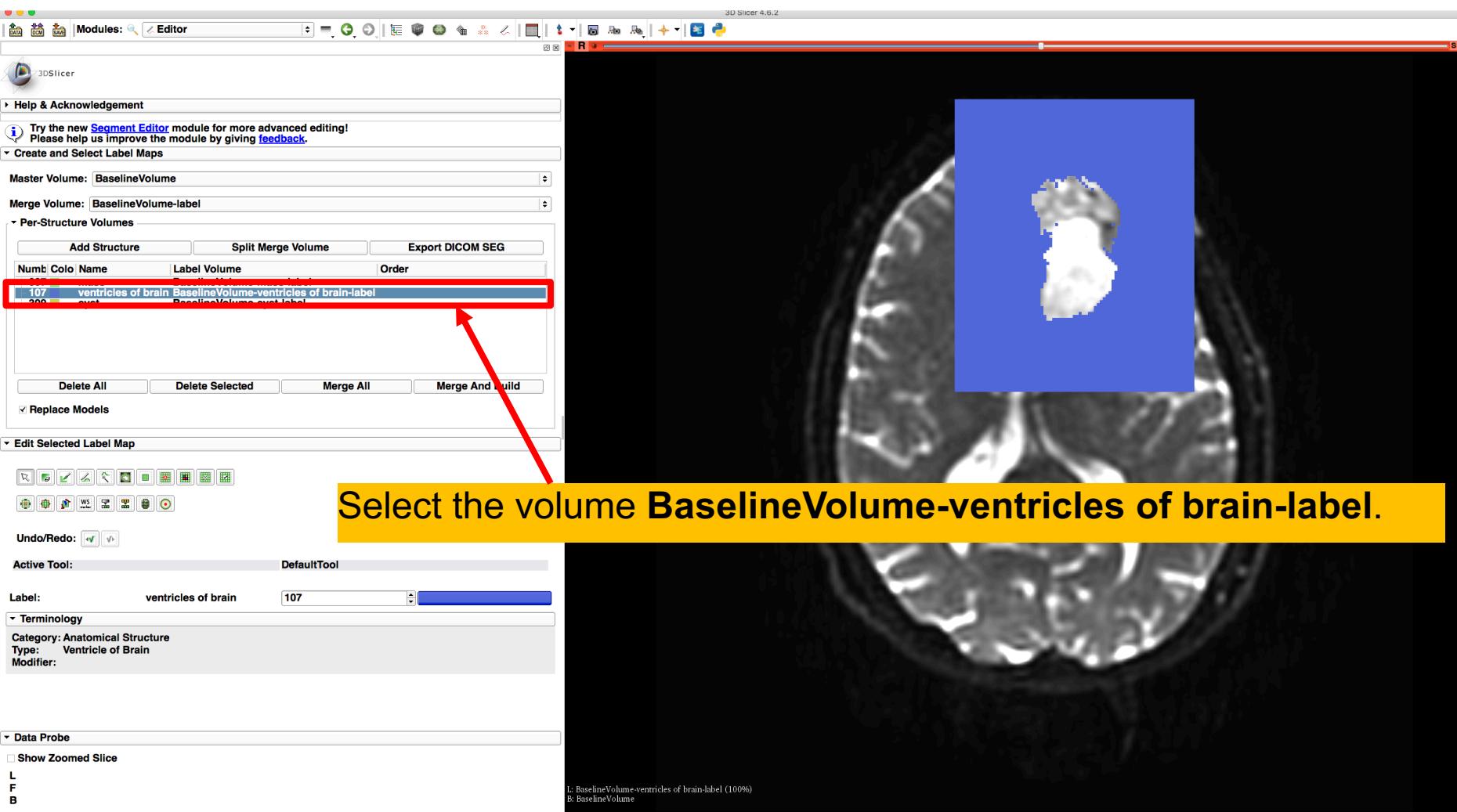
Tumor Segmentation



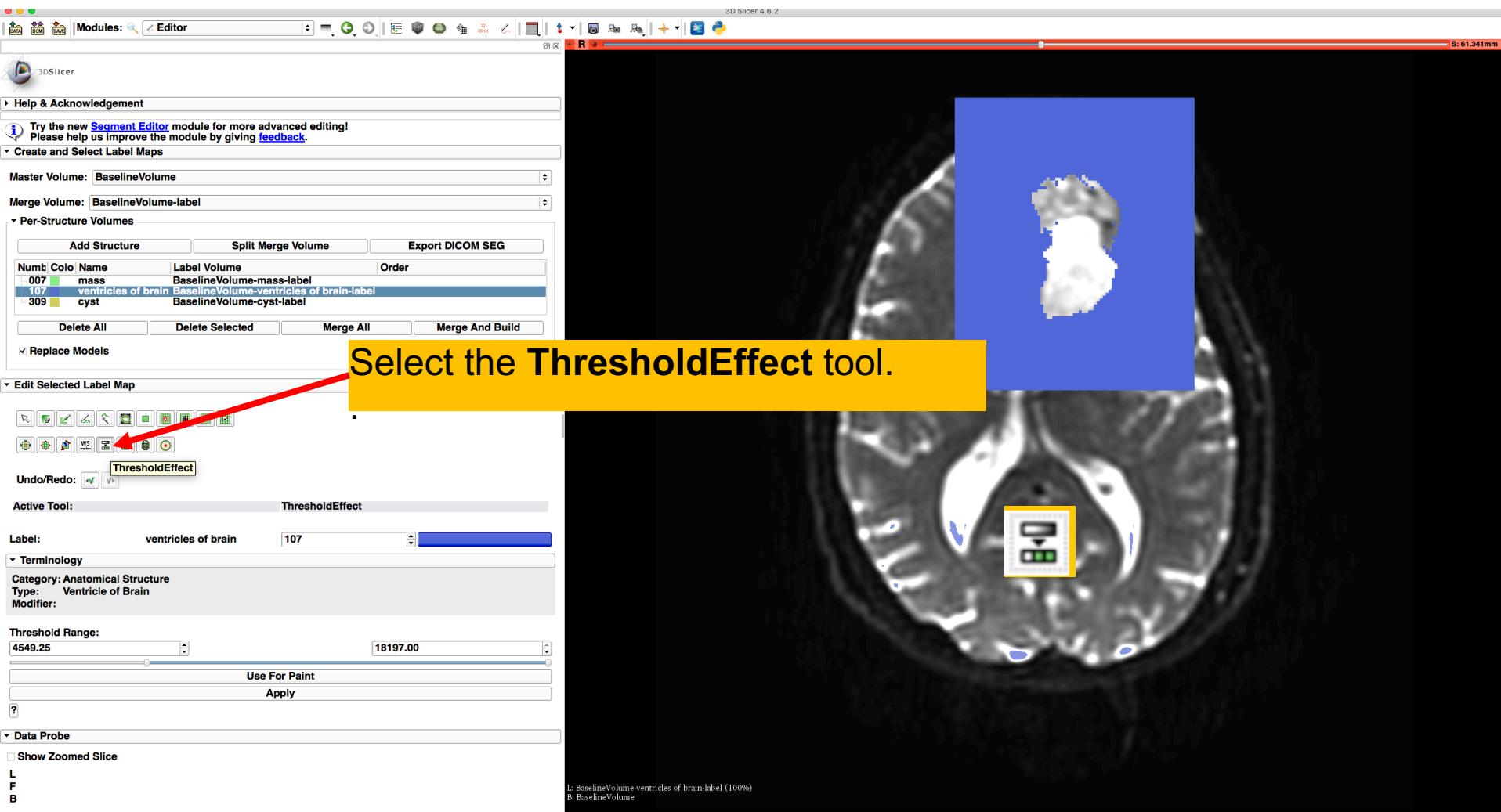
Ventricles Segmentation



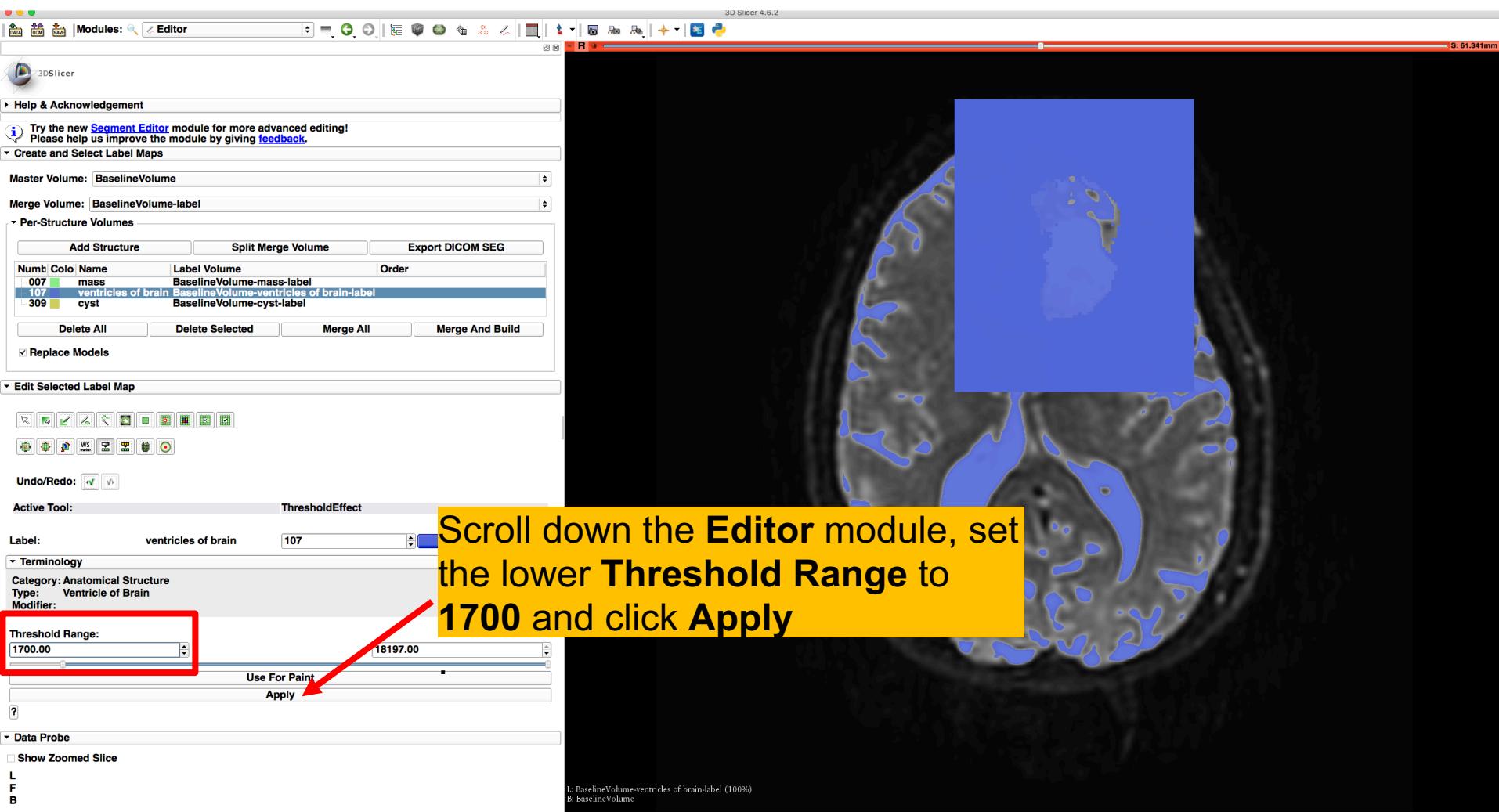
Ventricles Segmentation



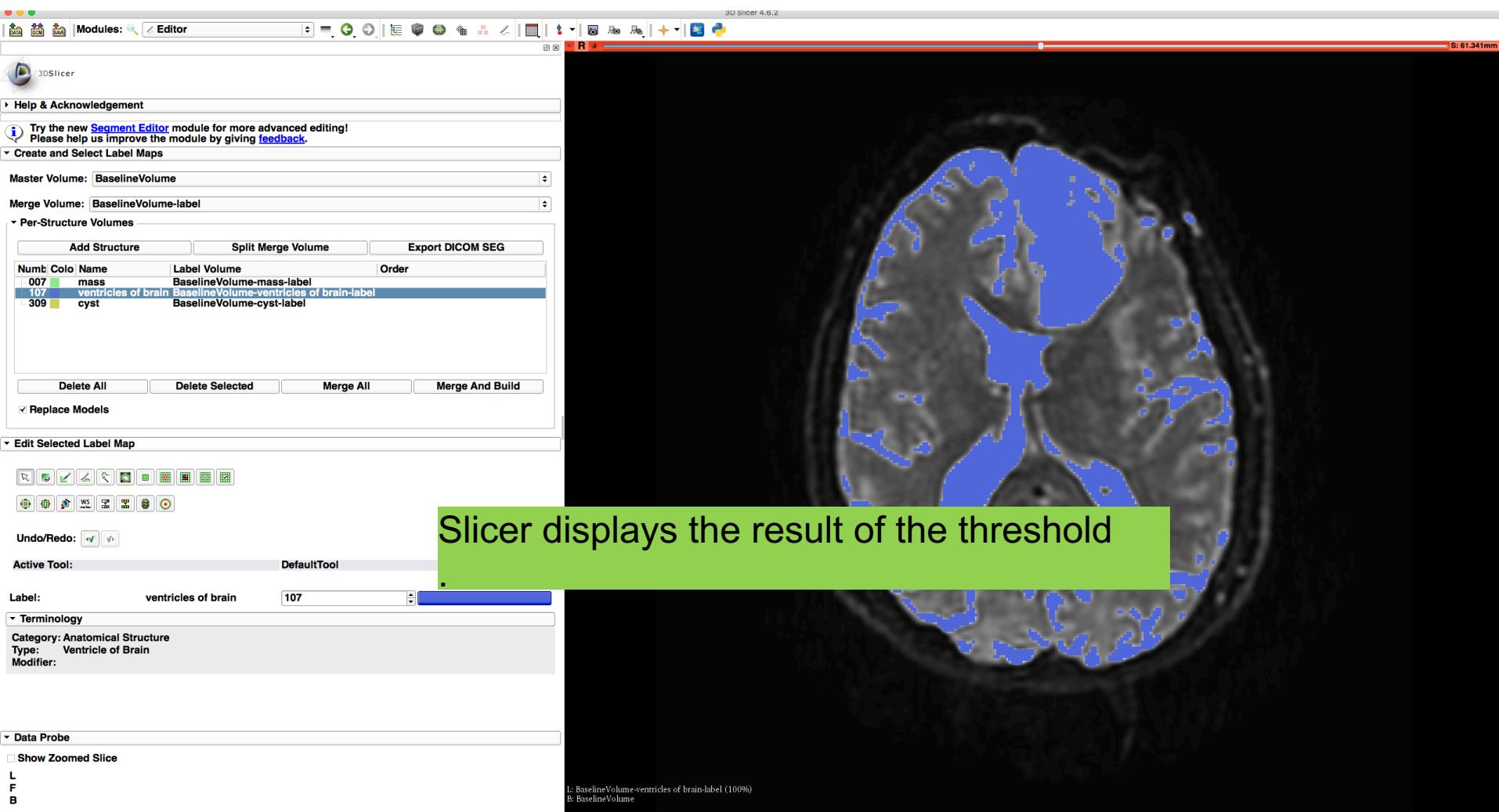
Ventricles Segmentation



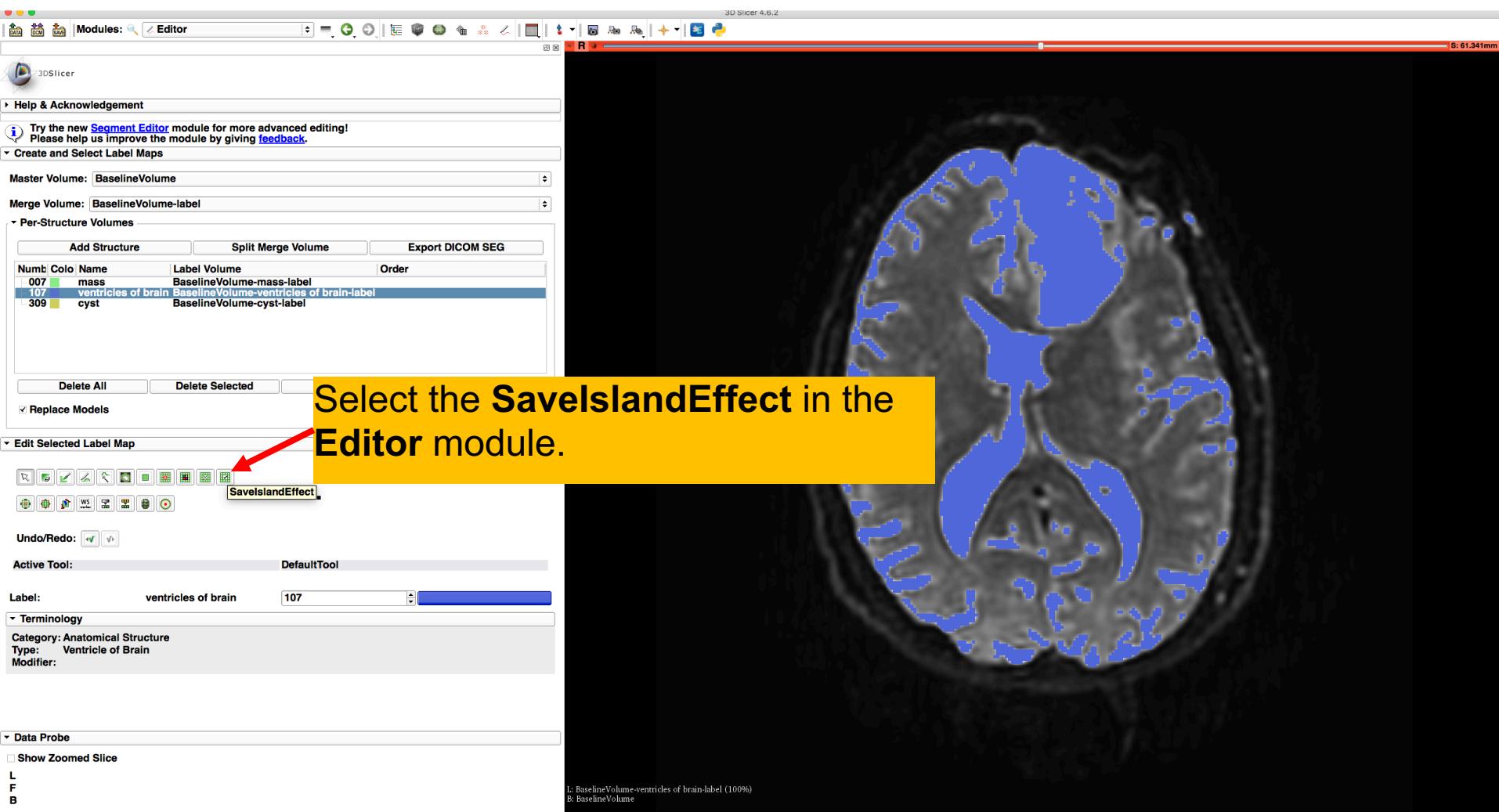
Ventricles Segmentation



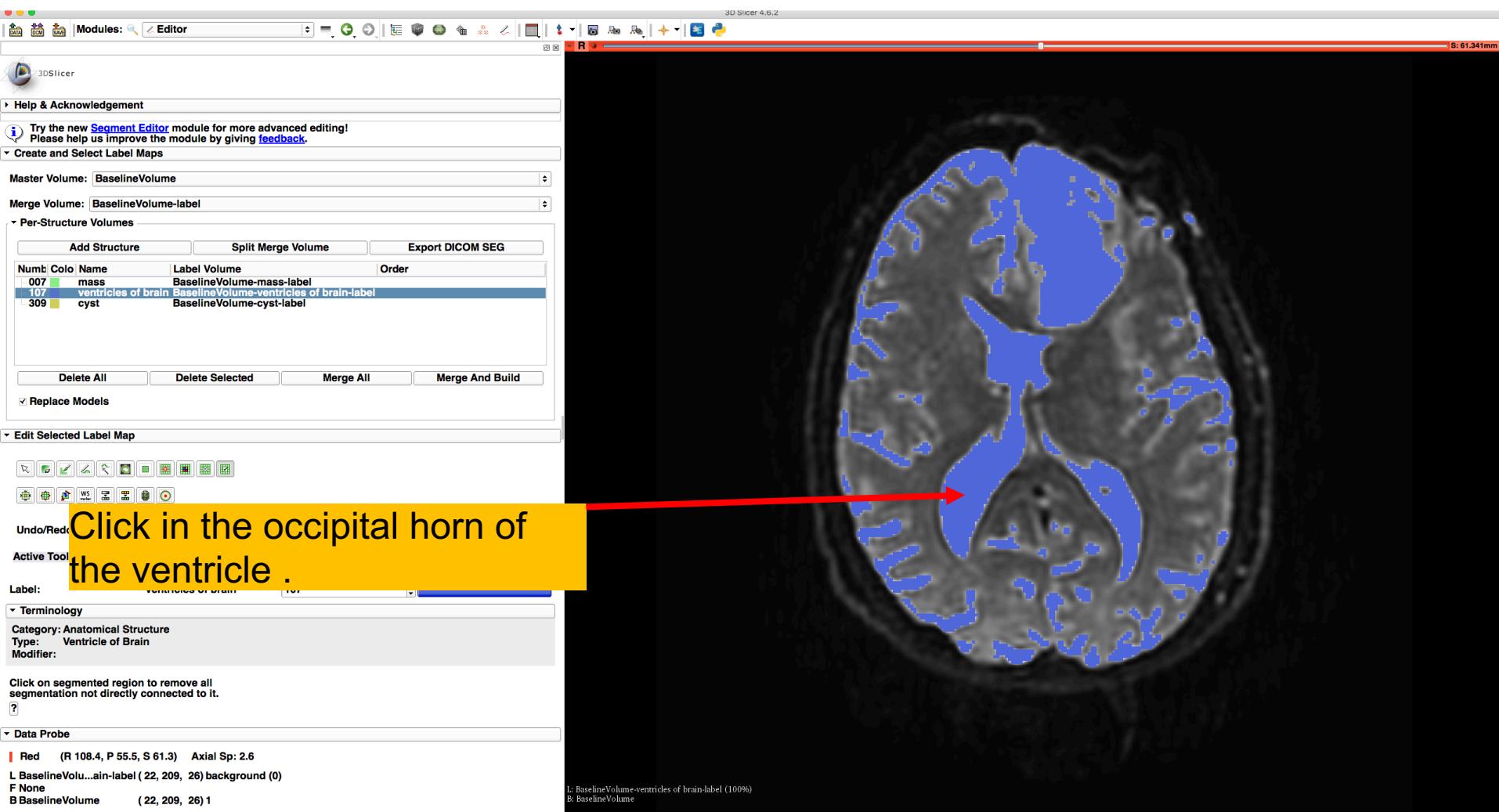
Ventricles Segmentation



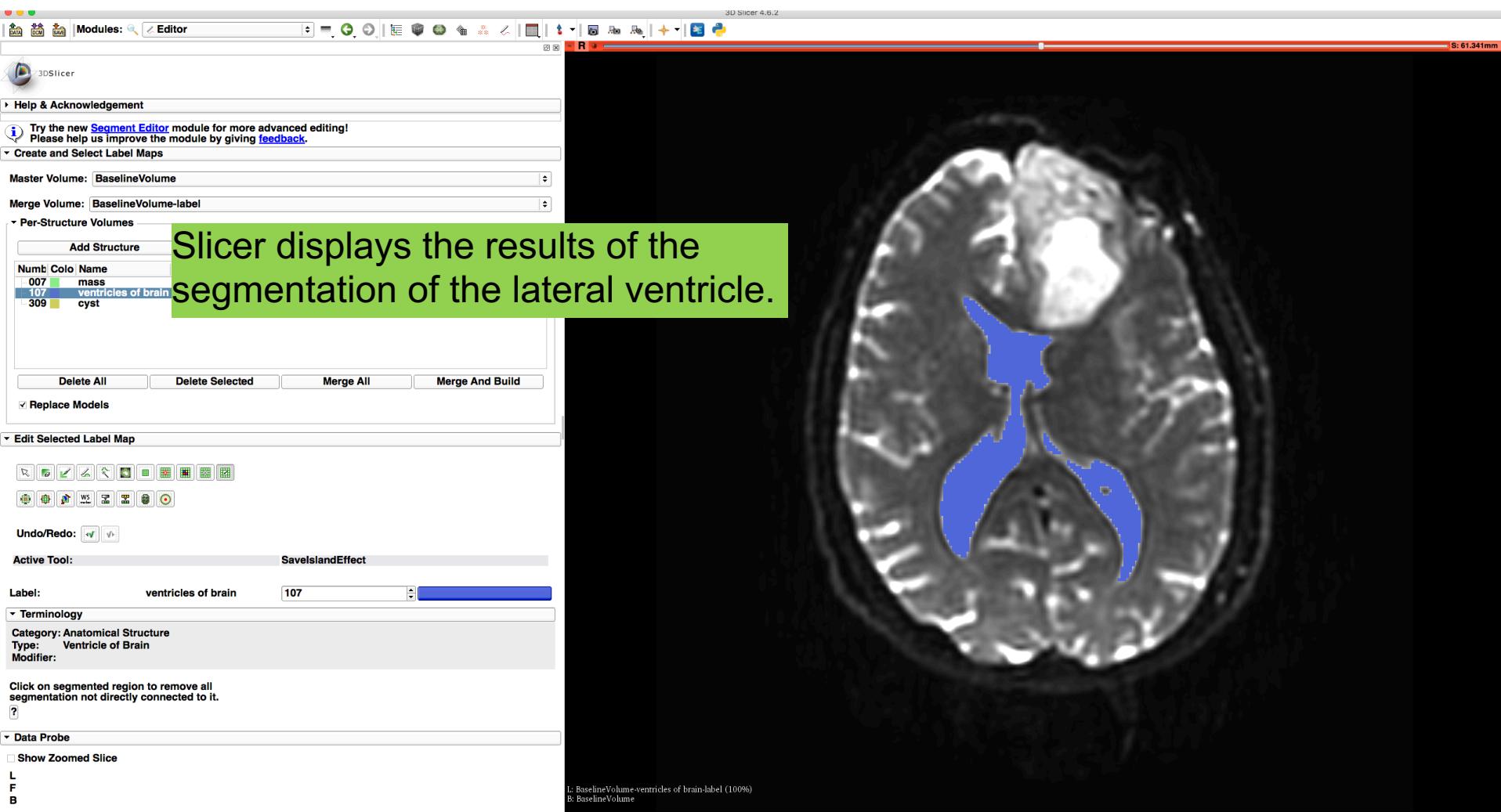
Ventricles Segmentation



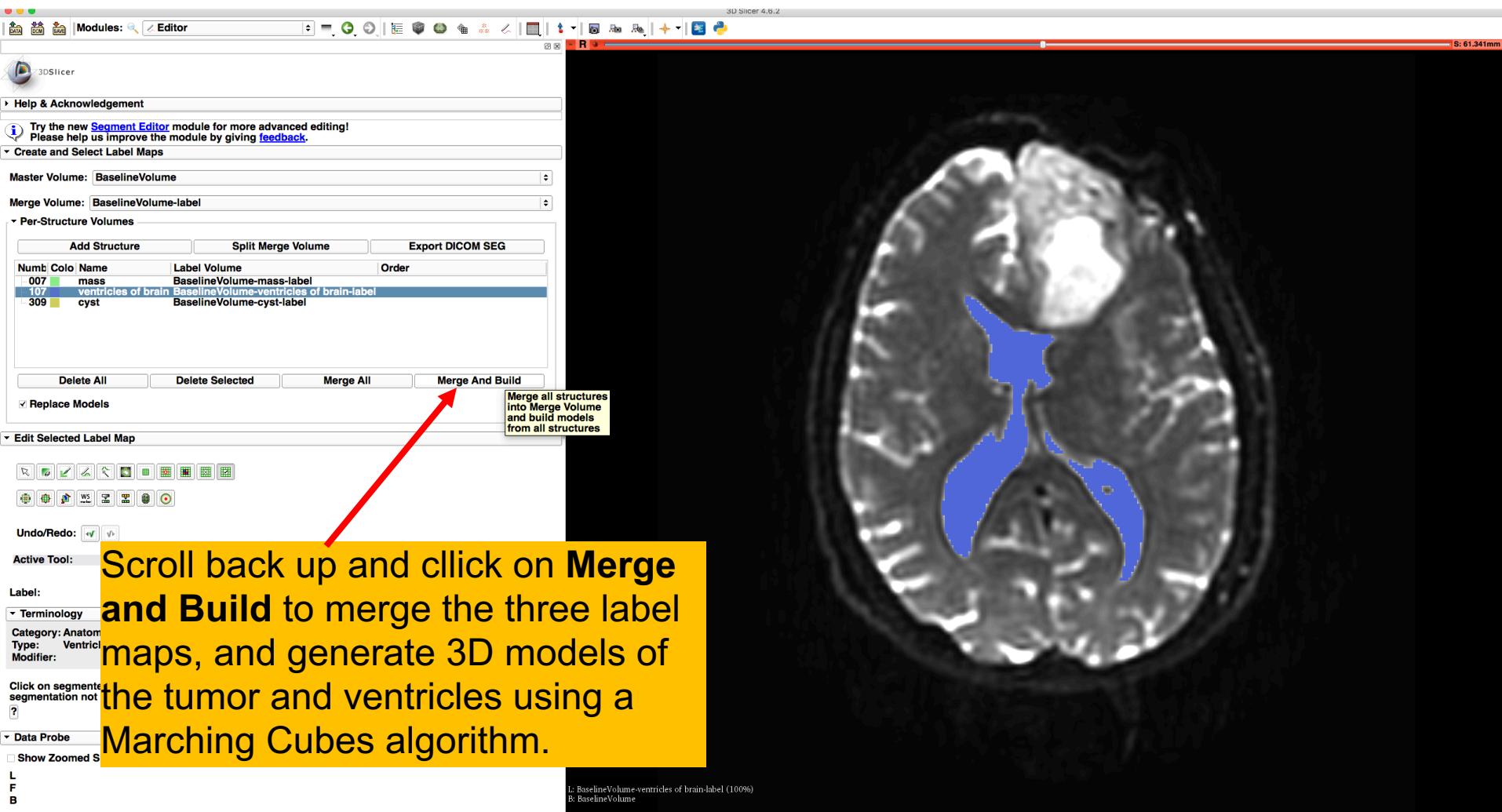
Ventricles Segmentation



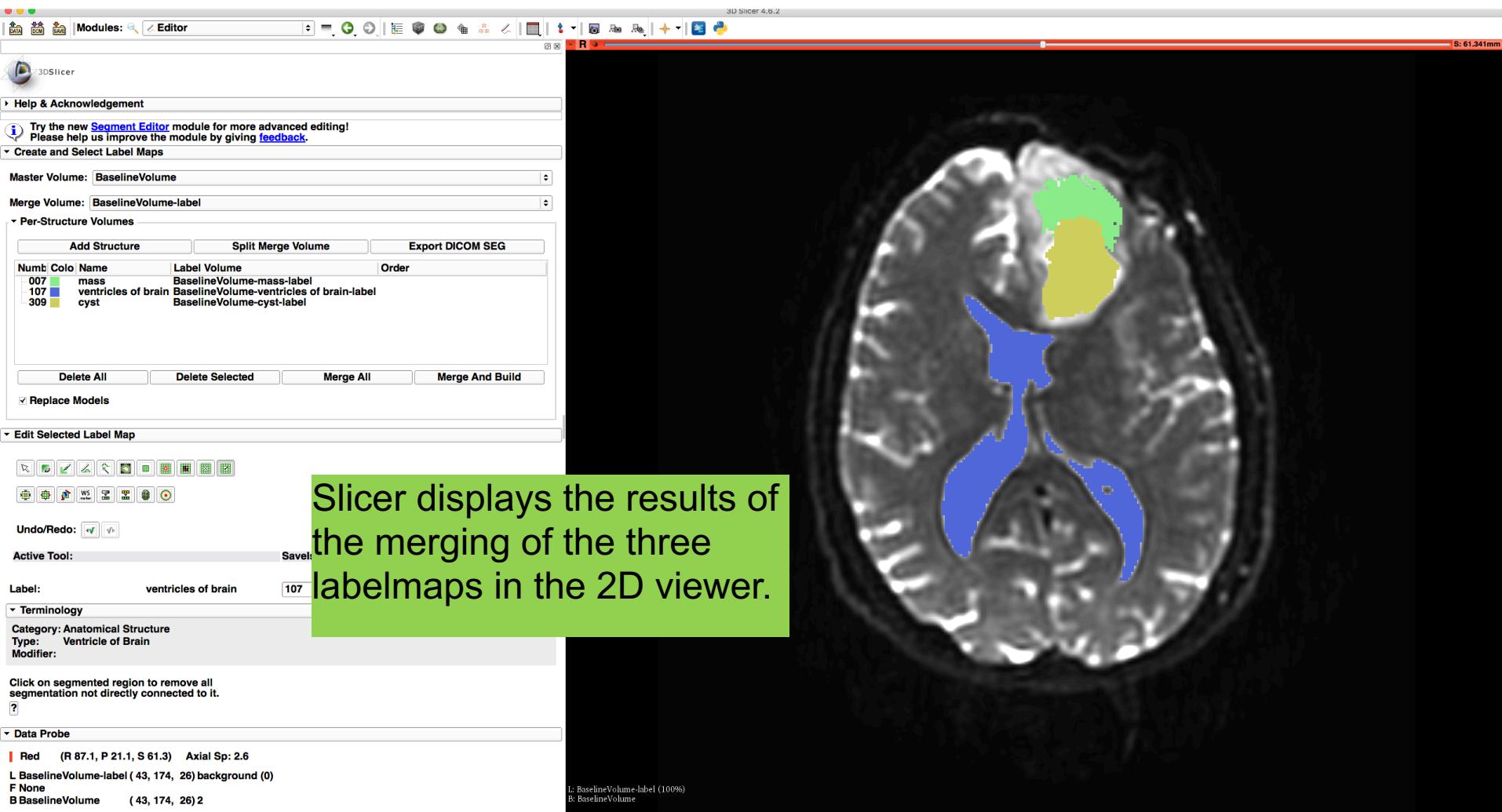
Ventricles Segmentation



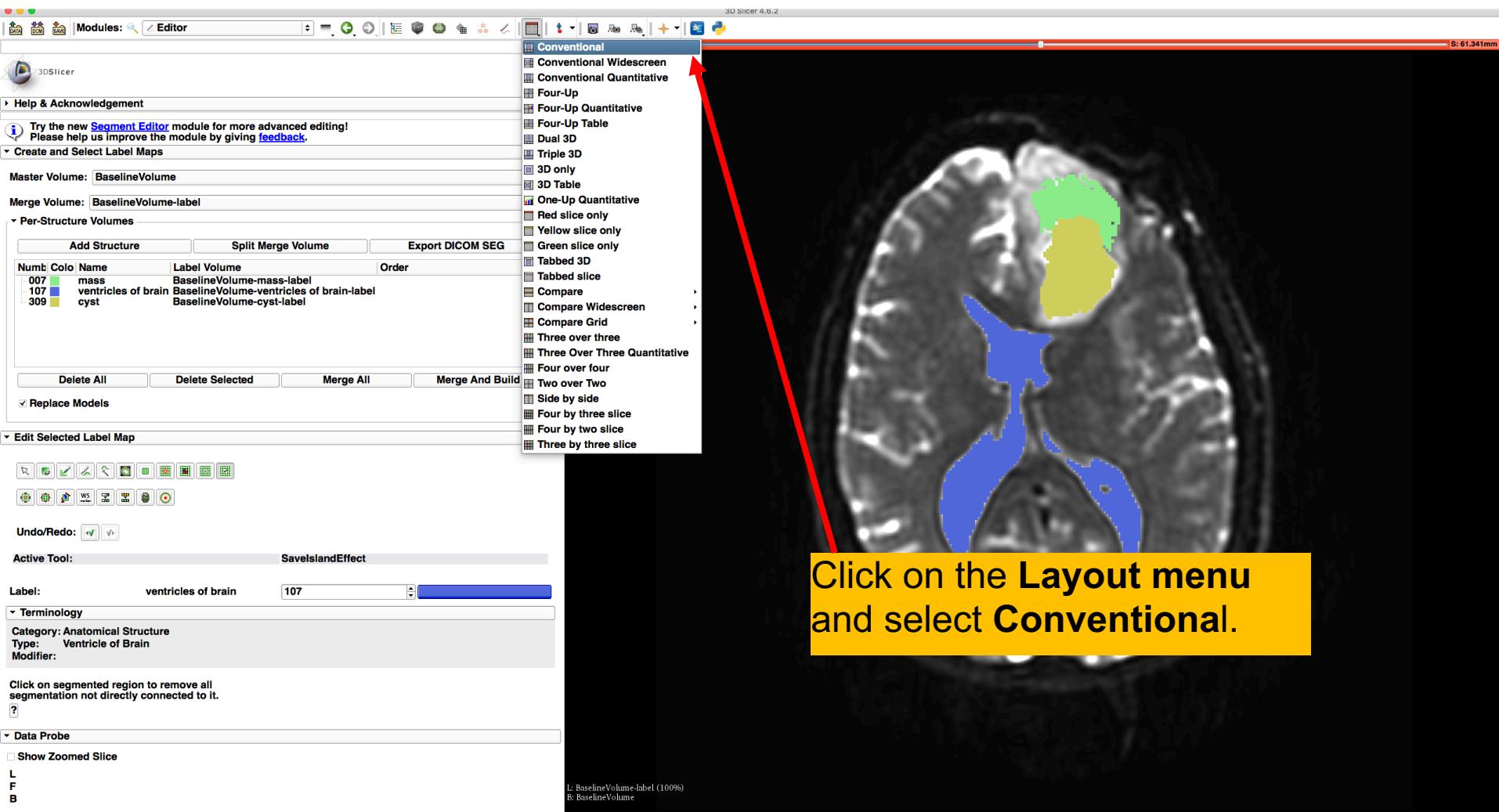
Ventricles Segmentation



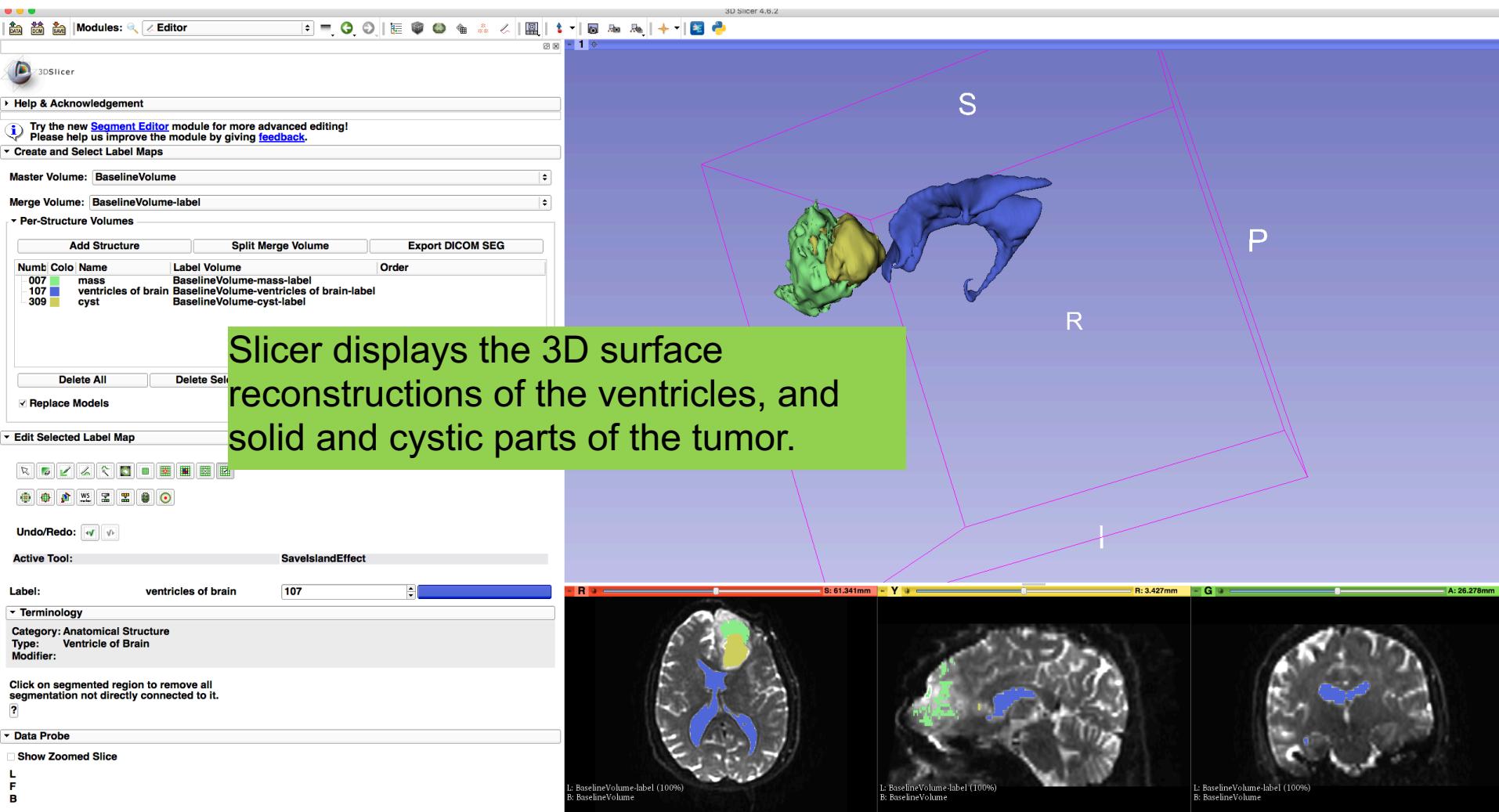
Final Result of Segmentation



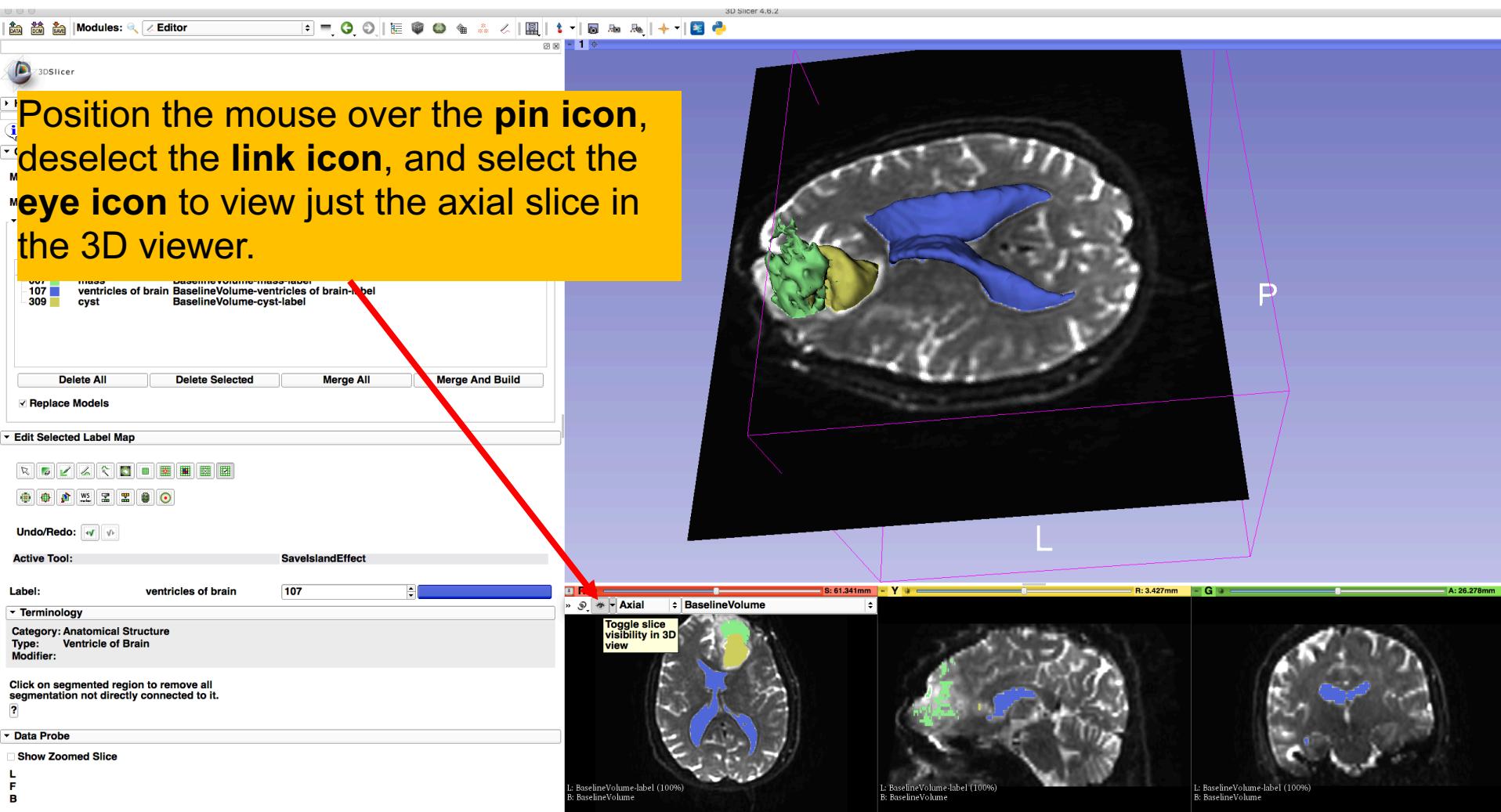
Final Result of Segmentation



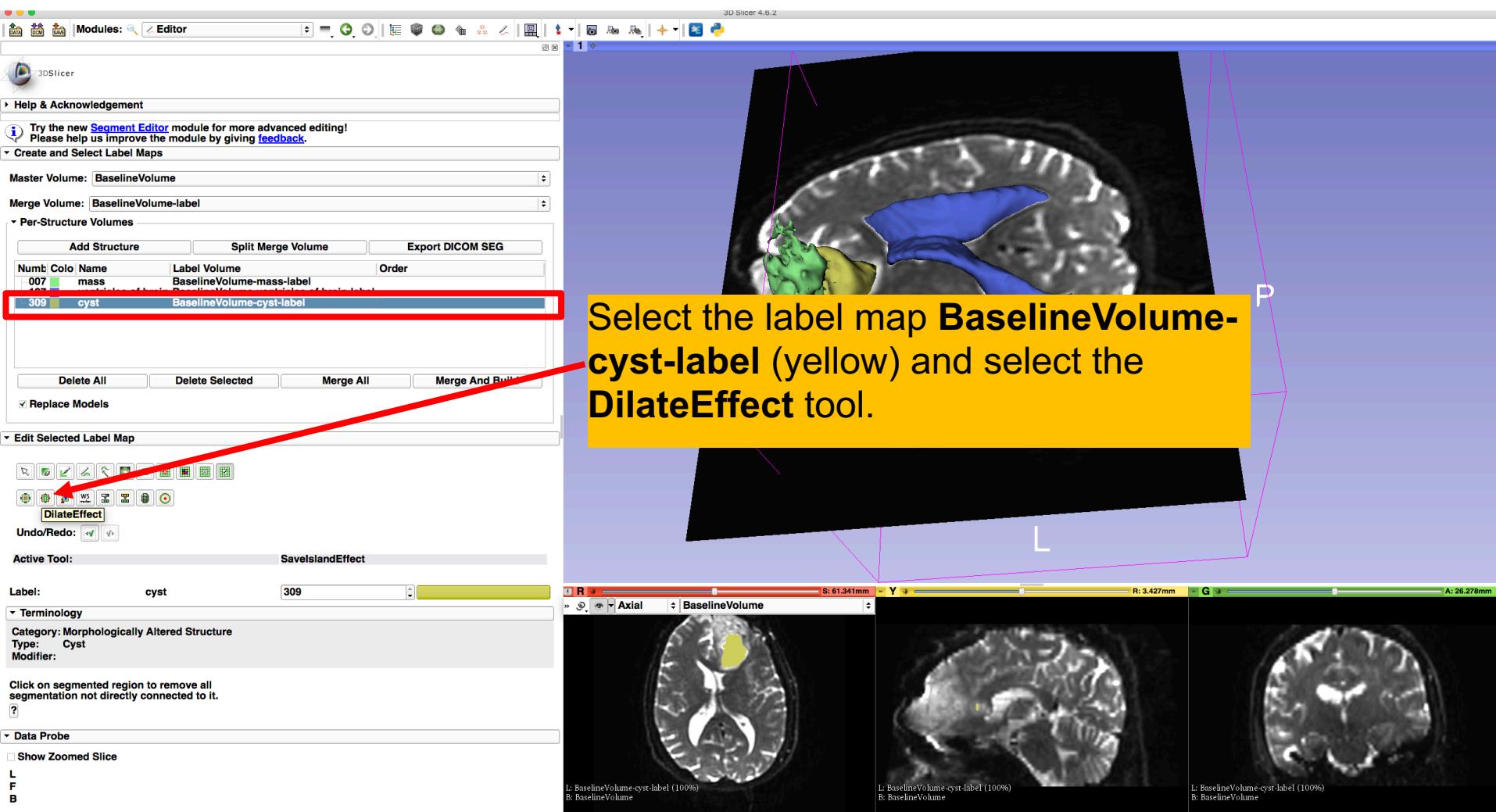
Final Result of Segmentation



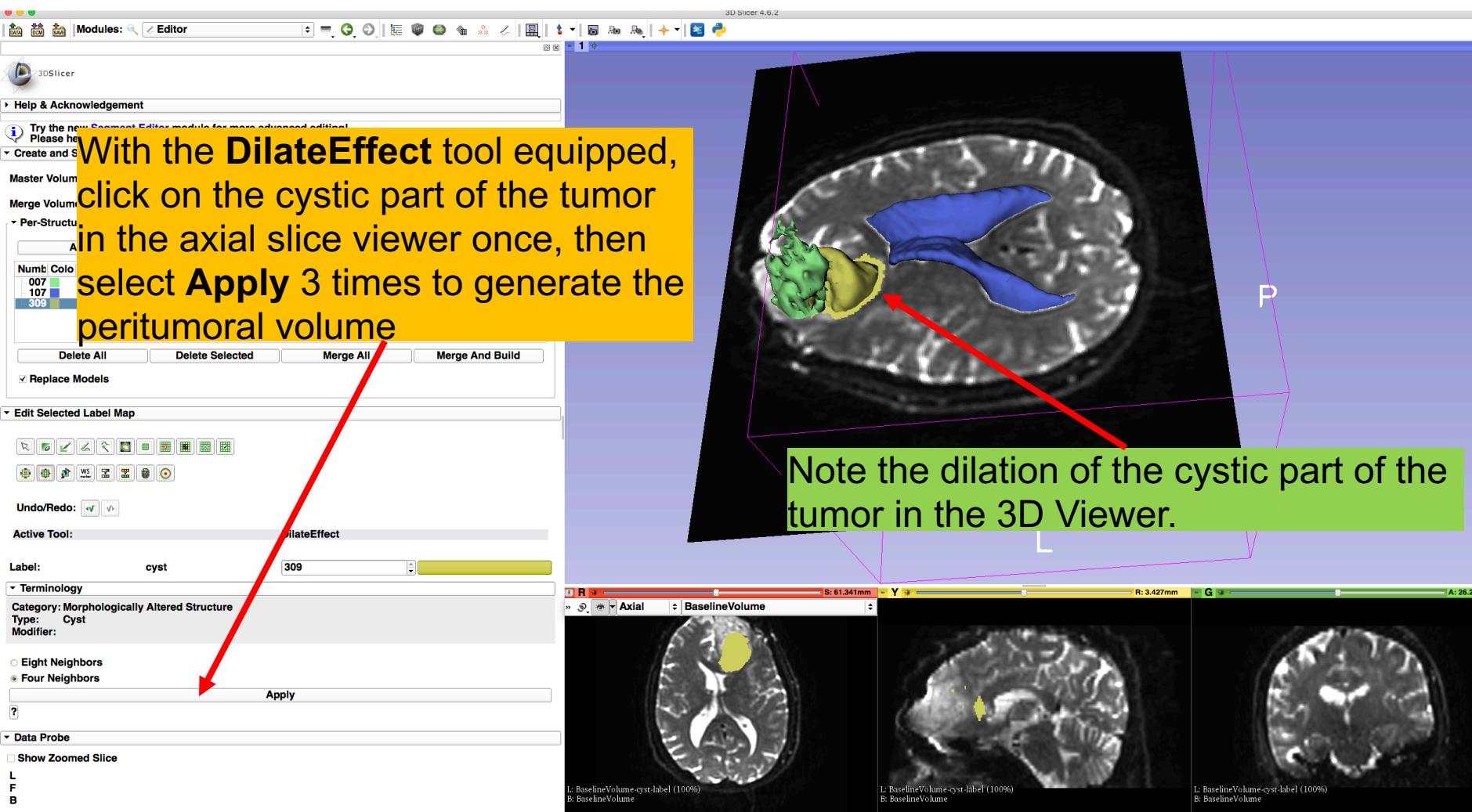
Definition of peri-tumoral volume

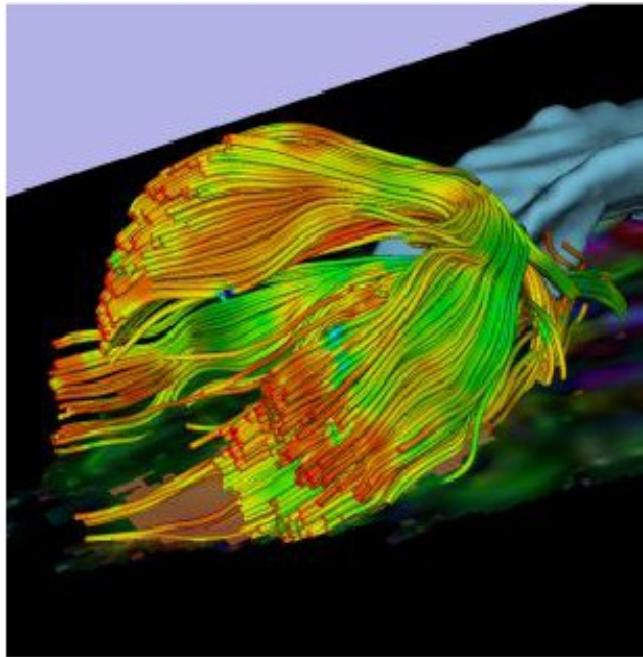


Definition of peri-tumoral volume



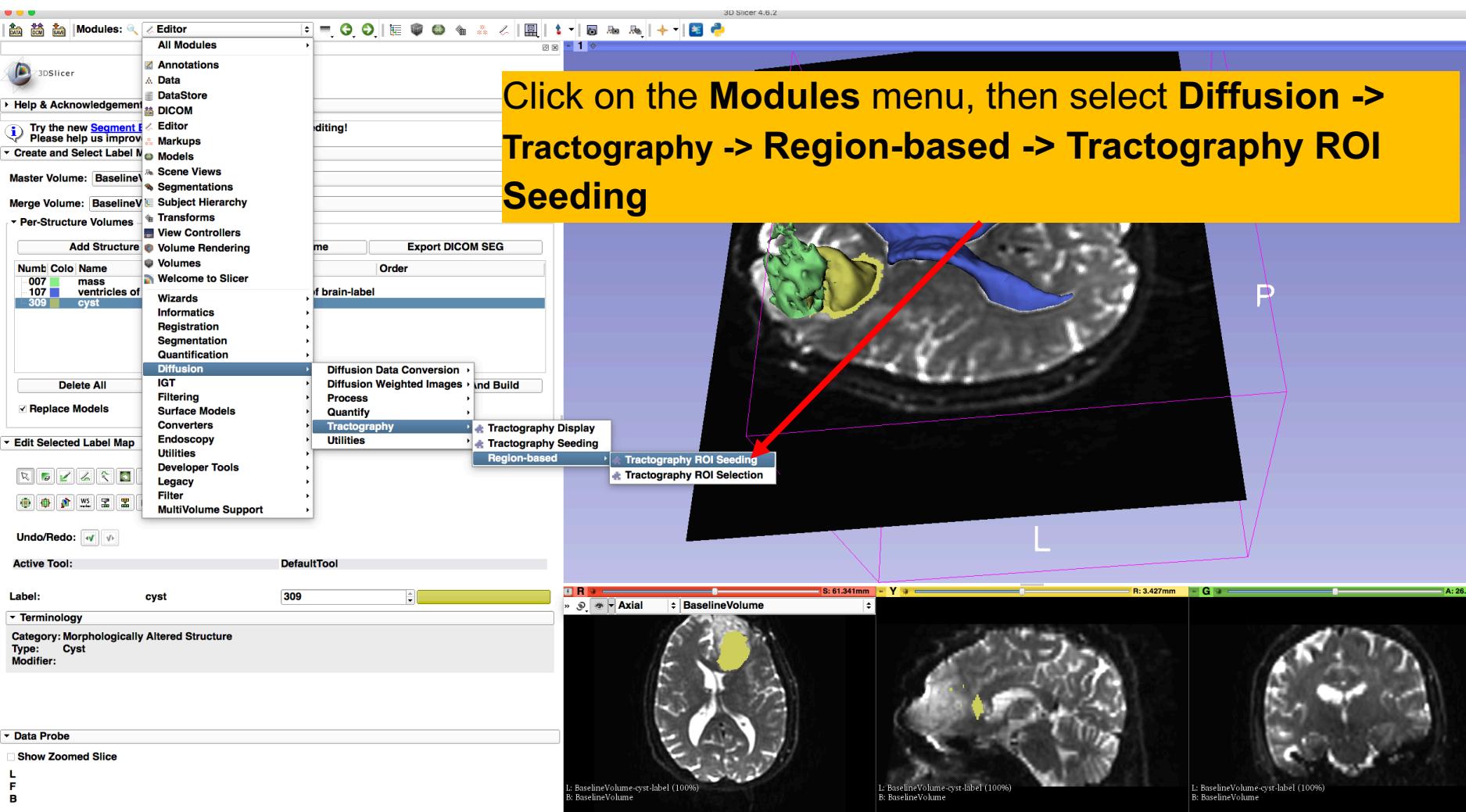
Definition of peri-tumoral volume



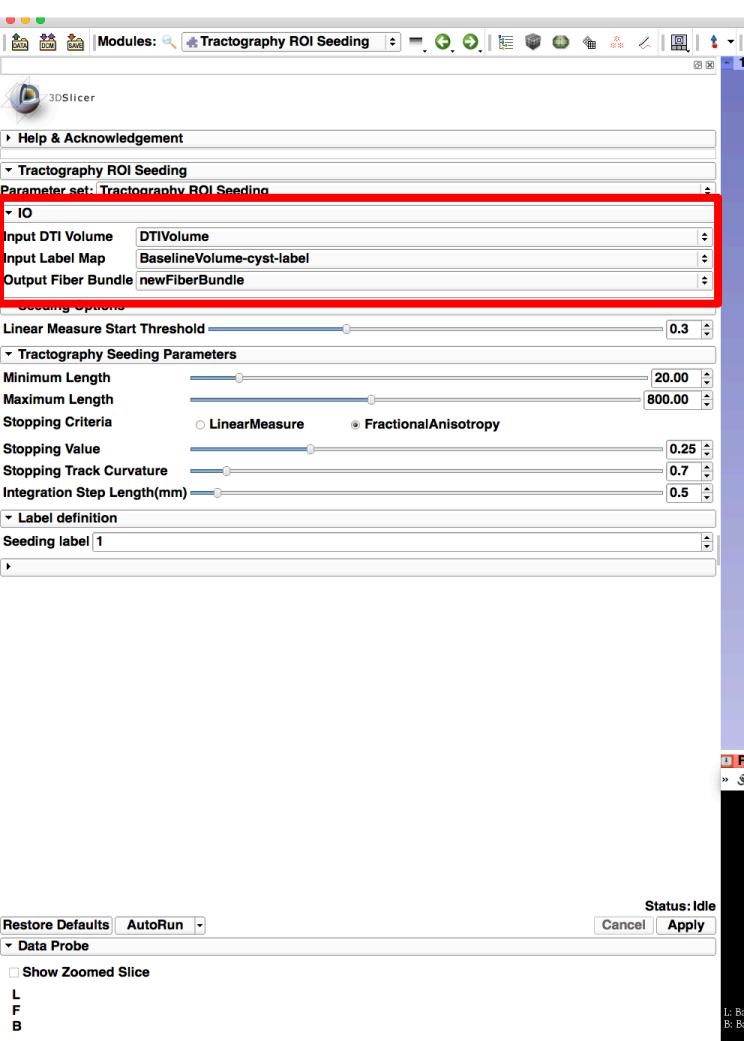


Part 2: Tractography exploration of peri- tumoral white matter fibers

Tractography LabelMap Seeding

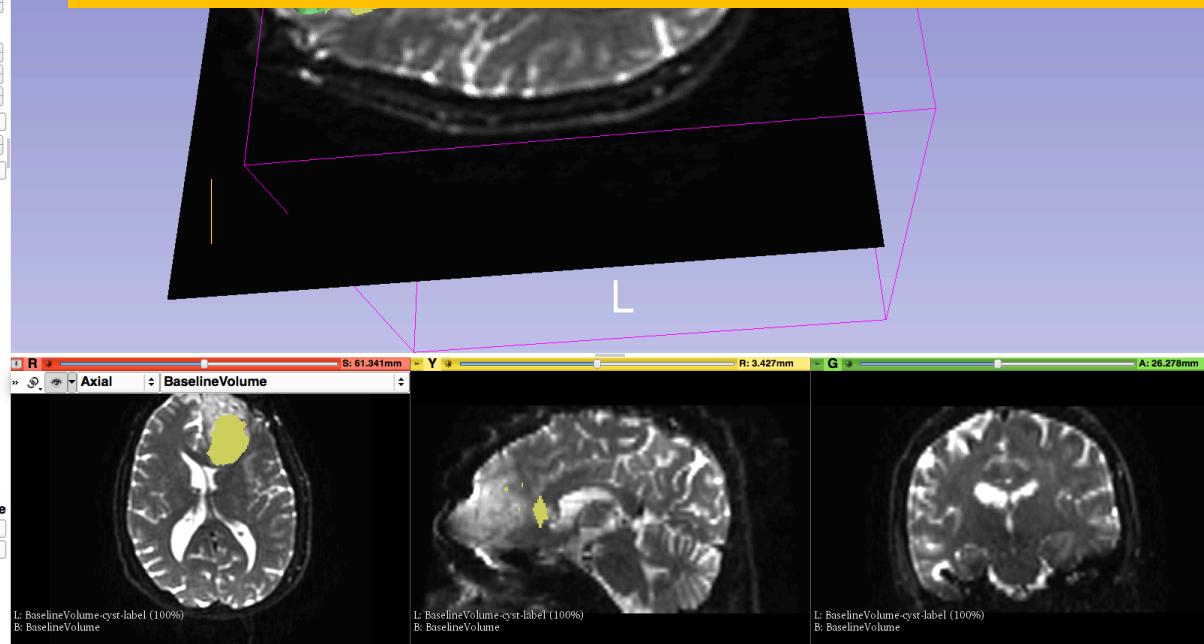


Tractography LabelMap Seeding



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

3D Slicer 4.6.2

Modules: Tractography ROI Seeding

Help & Acknowledgement

Tractography ROI Seeding

Parameter set: Tractography ROI Seeding

IO

Input DTI Volume: DTIVolume

Input Label Map: BaselineVolume-cyst-label

Output Fiber Bundle: newFiberBundle

Seeding Options

Linear Measure Start Threshold: 0.3

Tractography Seeding Parameters

Minimum Length: 20.00

Maximum Length: 800.00

Stopping Criteria: FractionalAnisotropy

Stopping Value: 0.15

Stopping Track Curvature: 0.7

Integration Step Length(mm): 0.5

Label definition

Seeding label: 309

Use Index Space

Random Grid

Restore Defaults AutoRun

Data Probe

Show Zoomed Slice L F B

Status: Idle Cancel Apply

3D Slicer 4.6.2

Scroll down and set the following values:

- Check Use Index Space

P

L

R: 61.341mm Y: 3.427mm G: 26.278mm

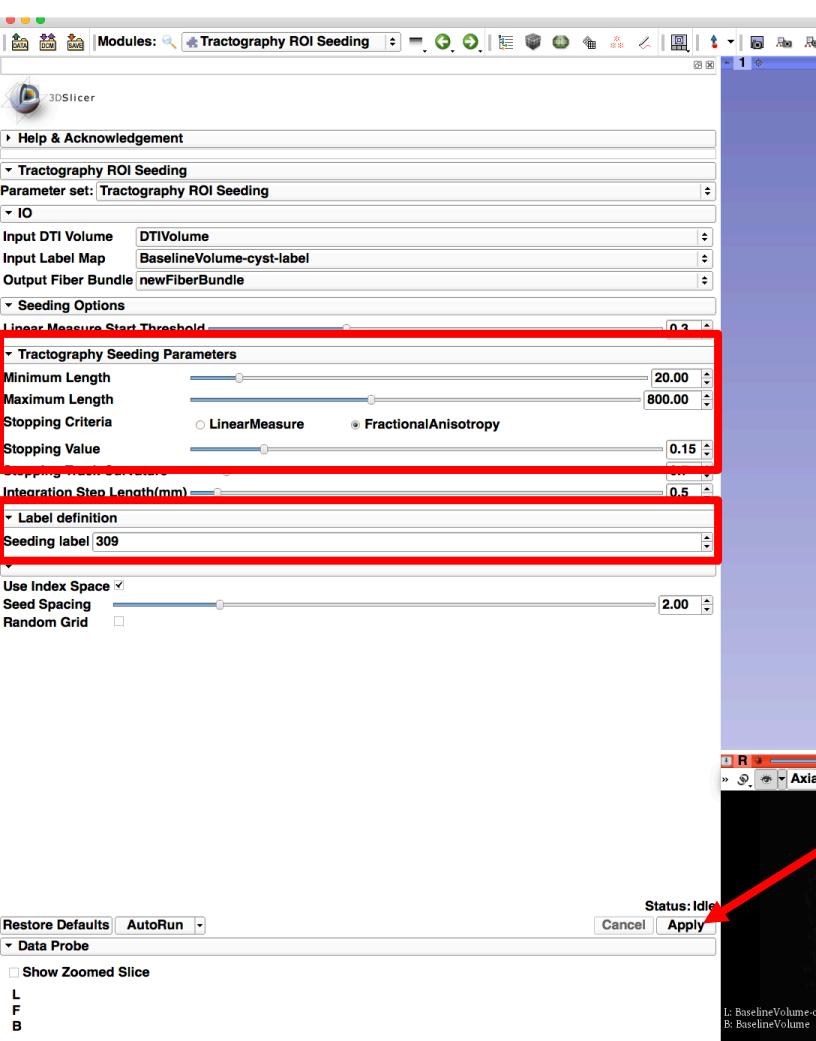
Axial BaselineVolume

L: BaselineVolume-cyst-label (100%) R: BaselineVolume

L: BaselineVolume-cyst-label (100%) R: BaselineVolume

L: BaselineVolume-cyst-label (100%) R: BaselineVolume

Tractography LabelMap Seeding



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

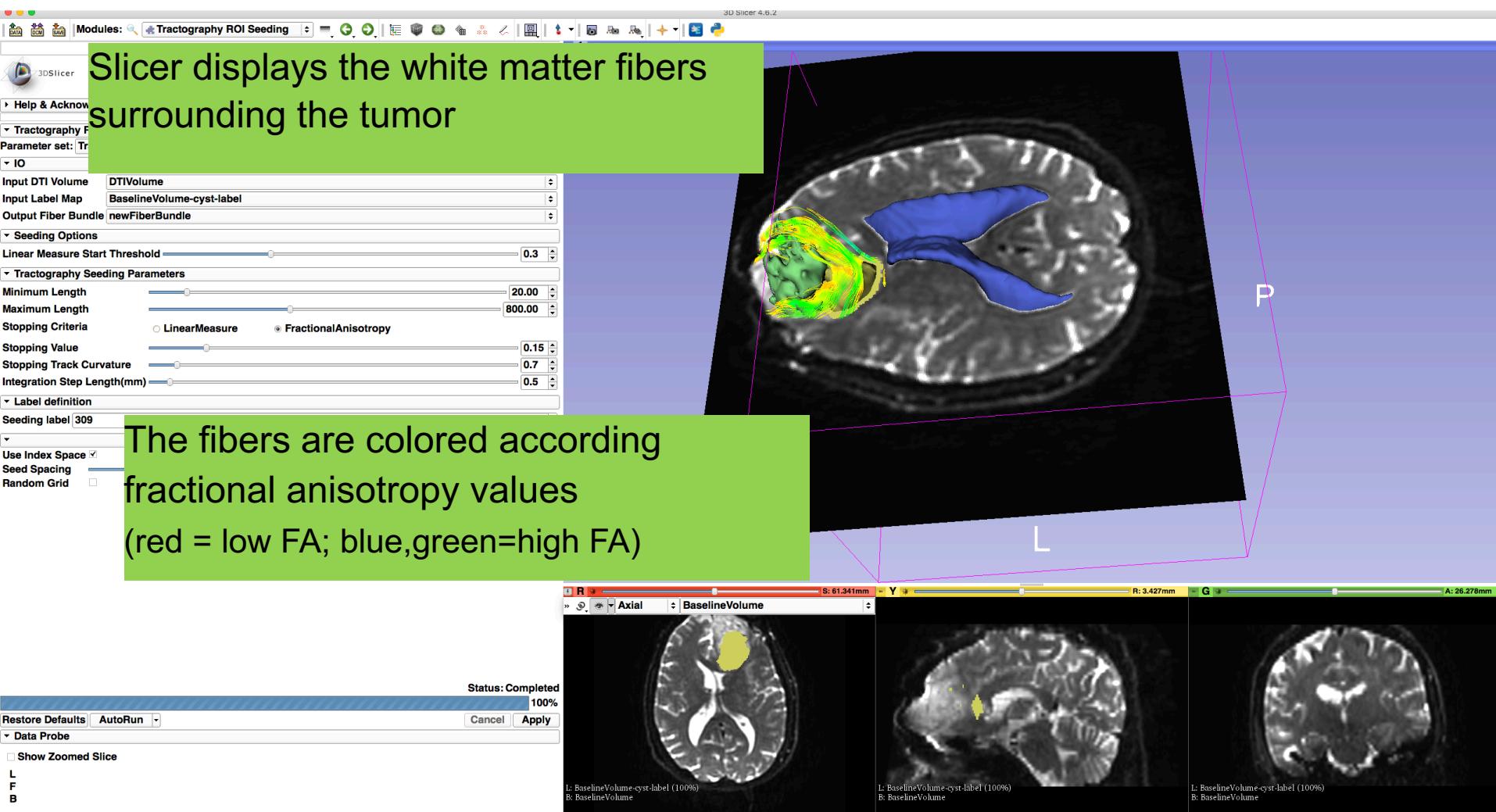
- Set **Stopping Criteria** to **FractionalAnisotropy**
- Set **Stopping Value** to **0.15**

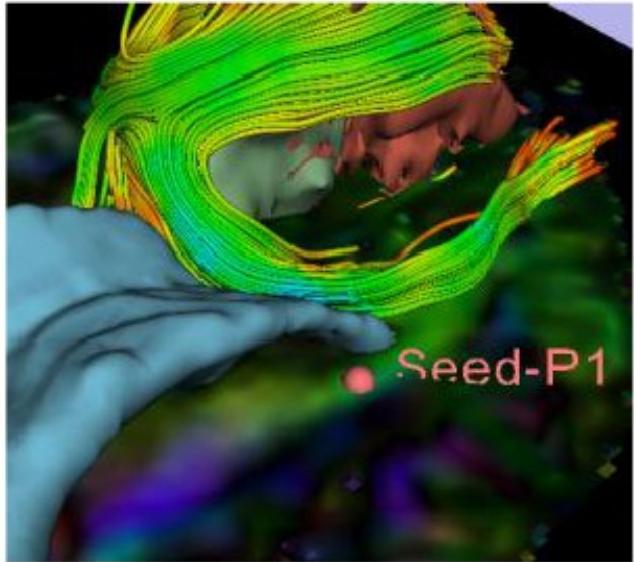
Scroll down to **Label Definition** and set the following values:

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

Click on **Apply**

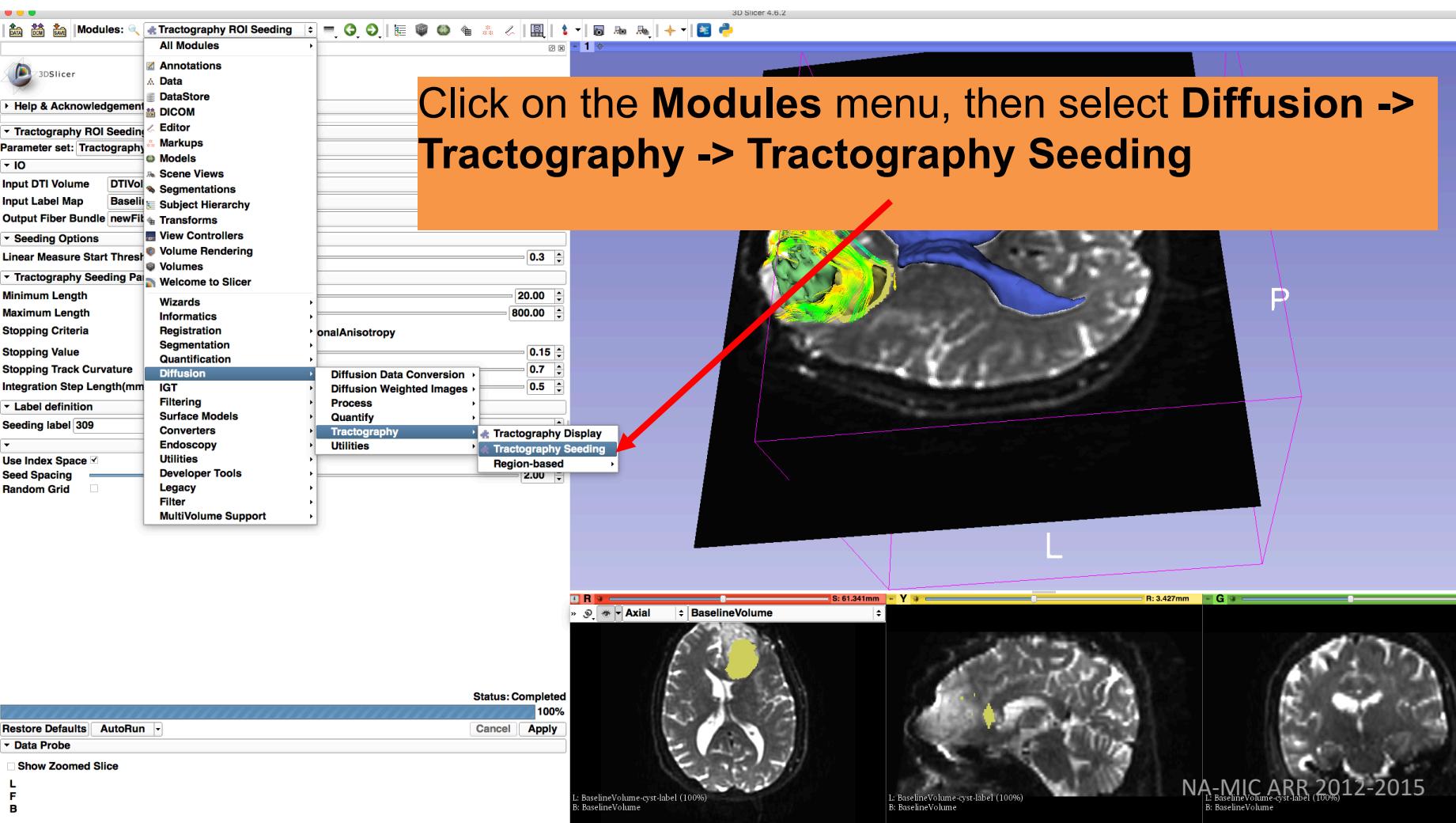
Tractography LabelMap Seeding



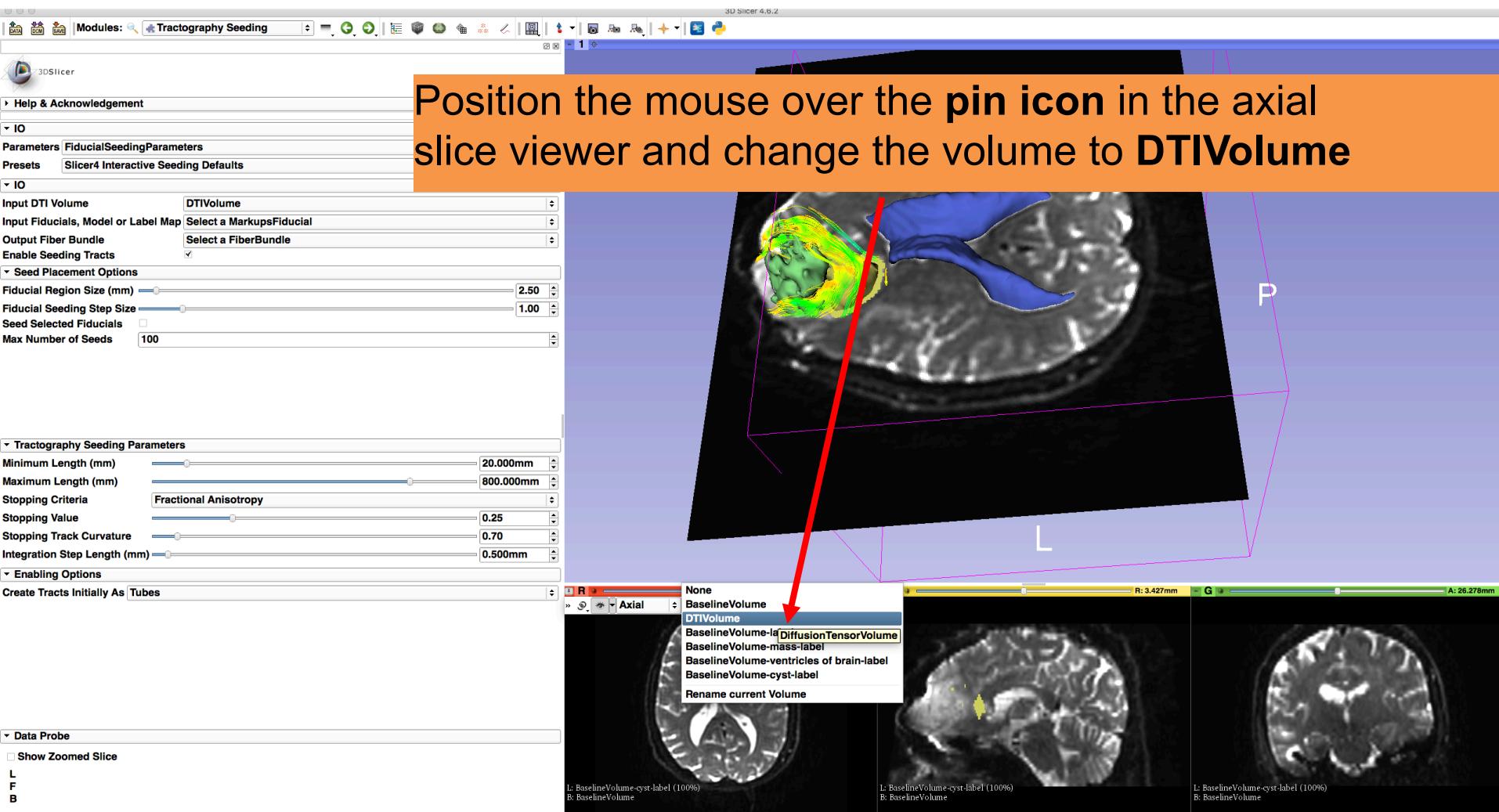


Part 4: Tractography exploration of the ipsilateral and contralateral side

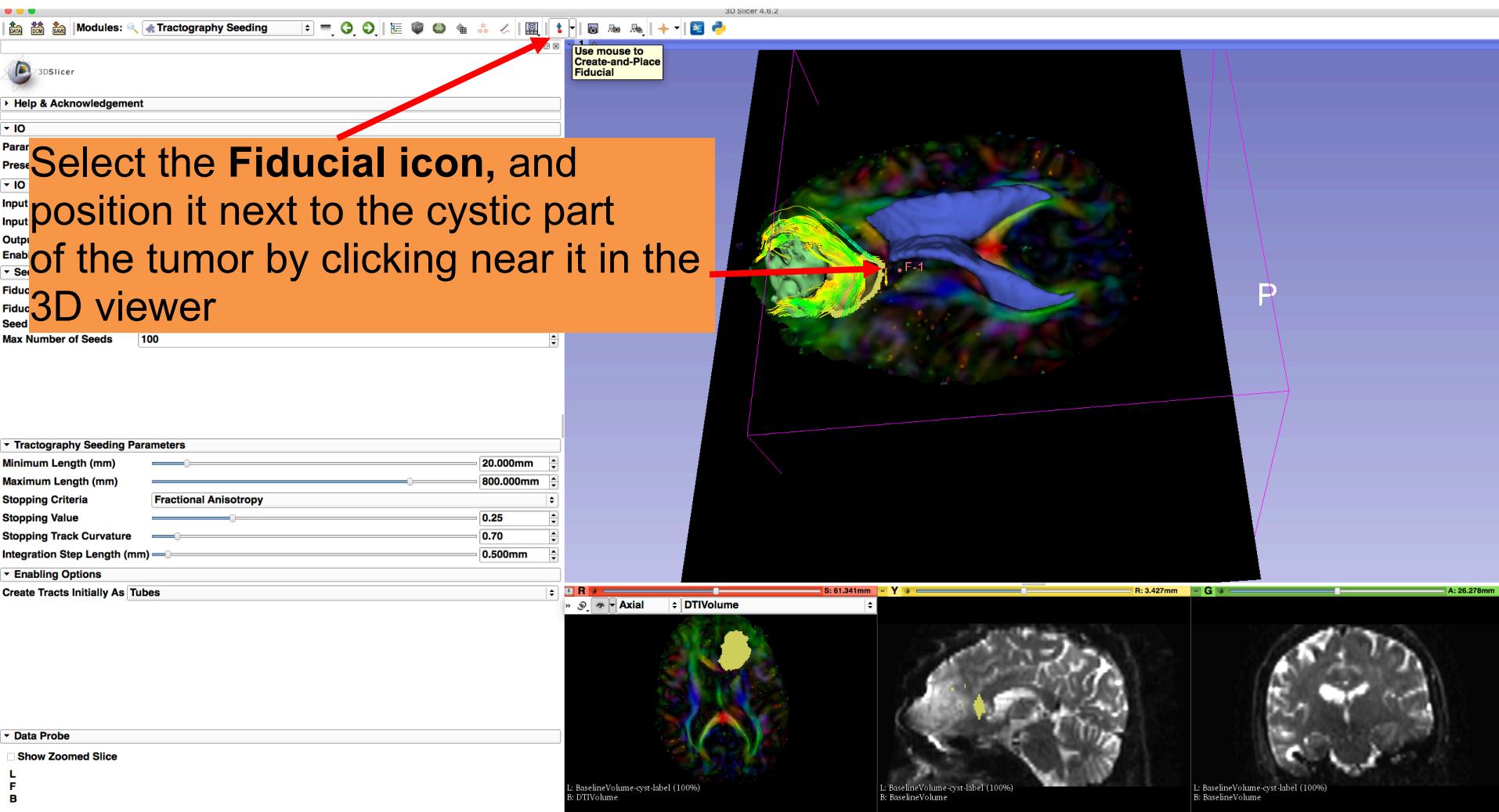
Tractography on-the-fly



Tractography on-the-fly



Tractography on-the-fly



Tractography on-the-fly

The screenshot shows the 3D Slicer interface with the "Tractography Seeding" module selected. On the left, the "Tractography Seeding Parameters" panel is open, displaying various settings. A red box highlights the "IO" section where the "Input DTI Volume" is set to "DTIVolume", the "Input Fiducials, Model or Label Map" is set to "F", and the "Output Fiber Bundle" is set to "FiberBundle_F". Below this, under "Tractography Seeding Parameters", the "Stopping Criteria" is set to "Fractional Anisotropy". An orange callout box contains the instructions: "Set Input DTI Volume to DTIVolume", "Set Fiducial List or Model to F", and "Set Output Fiber Bundle to Create new Fiber Bundle". The main window displays a 3D brain volume with a multi-colored fiber bundle tractography overlay. A pink coordinate system is shown with the letter "P" indicating the posterior direction. At the bottom, three axial slices show the tractography results overlaid on the brain volume.

3D Slicer 4.6.2

Modules: Tractography Seeding

Help & Acknowledgement

IO

Parameters: FiducialSeedingParameters

Presets: Slicer4 Interactive Seeding Defaults

Input DTI Volume: DTIVolume

Input Fiducials, Model or Label Map: F

Output Fiber Bundle: FiberBundle_F

Enable Seeding Tracts:

Seed Placement Options

Fiducial Region Size (mm): 2.50

Fiducial Seeding Step Size: 1.00

Seed Selected Fiducials:

Max Number of Seeds: 100

Tractography Seeding Parameters

Minimum Length (mm): 20.000

Maximum Length (mm): 20.000

Stopping Criteria: Fractional Anisotropy

Stopping Value: 0.000

Stopping Track Curvature: 0.000

Integration Step Length (mm): 0.000

Enabling Options

Create Tracts Initially As: Tubes

Data Probe

Show Zoomed Slice

L F B

P

Set Input DTI Volume to DTIVolume

Set Fiducial List or Model to F

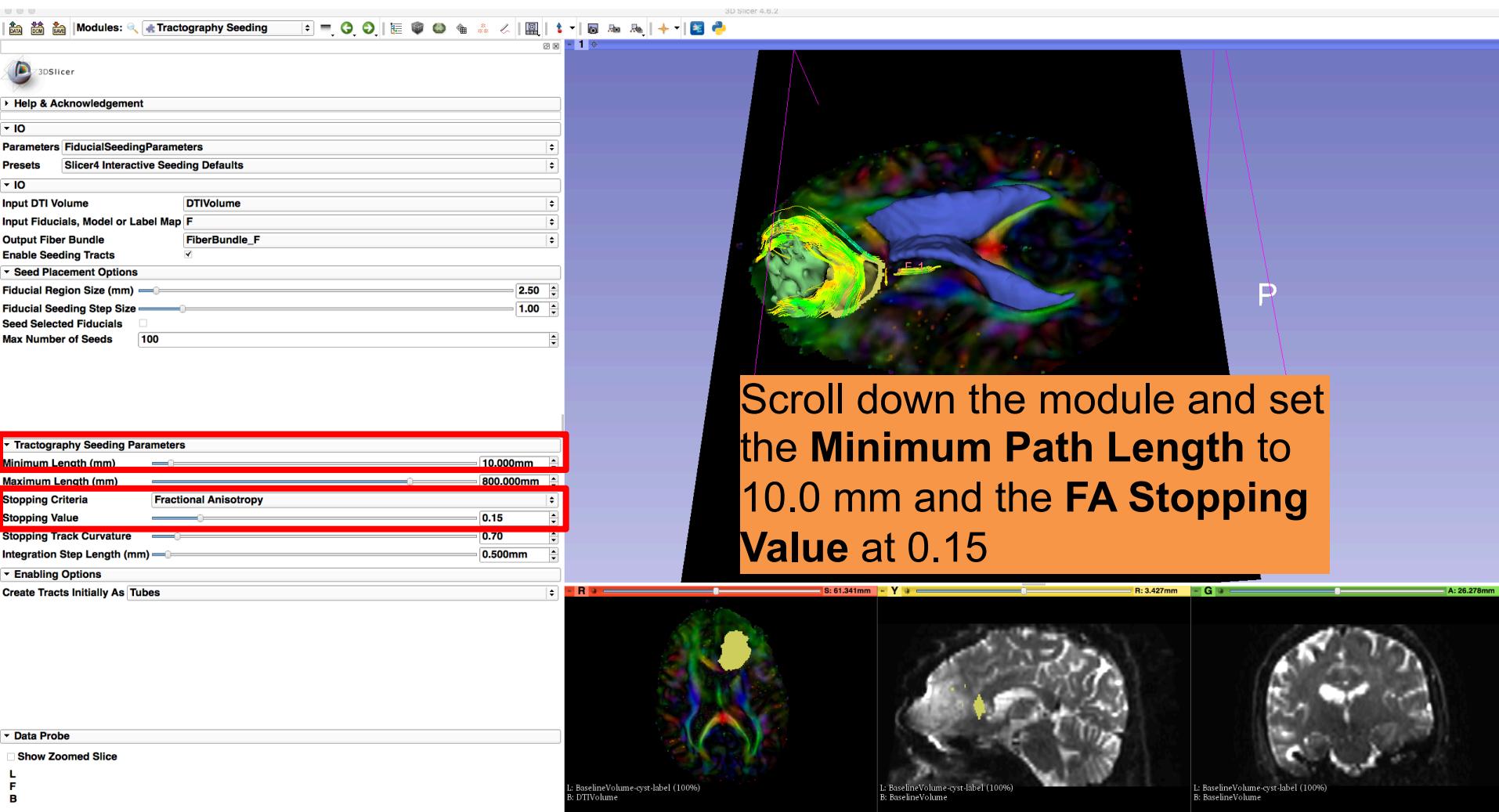
Set Output Fiber Bundle to Create new Fiber Bundle

L: BaselineVolume-cyst-label (100%)
R: DTIVolume

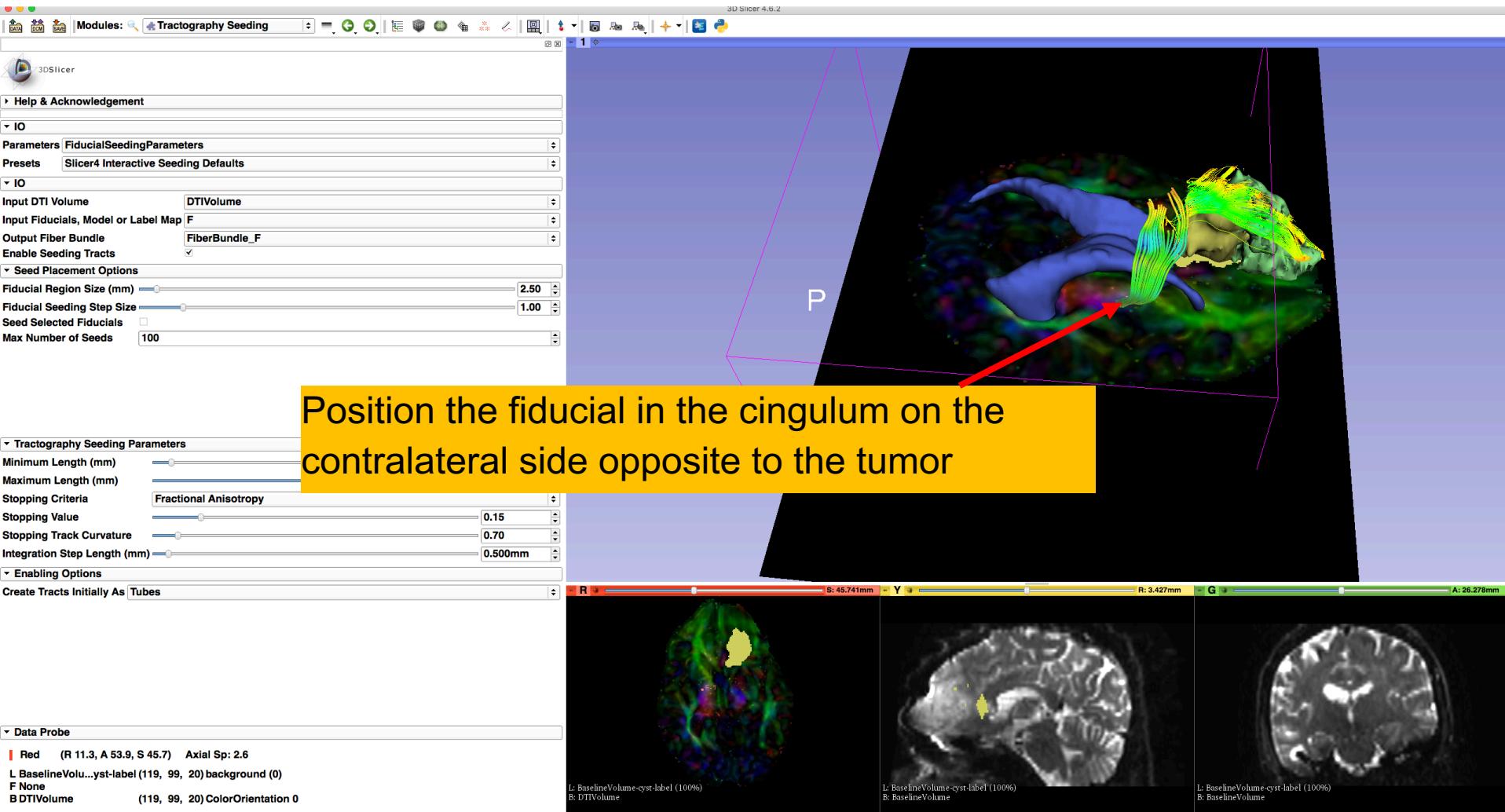
L: BaselineVolume-cyst-label (100%)
R: BaselineVolume

L: BaselineVolume-cyst-label (100%)
R: BaselineVolume

Tractography on-the-fly

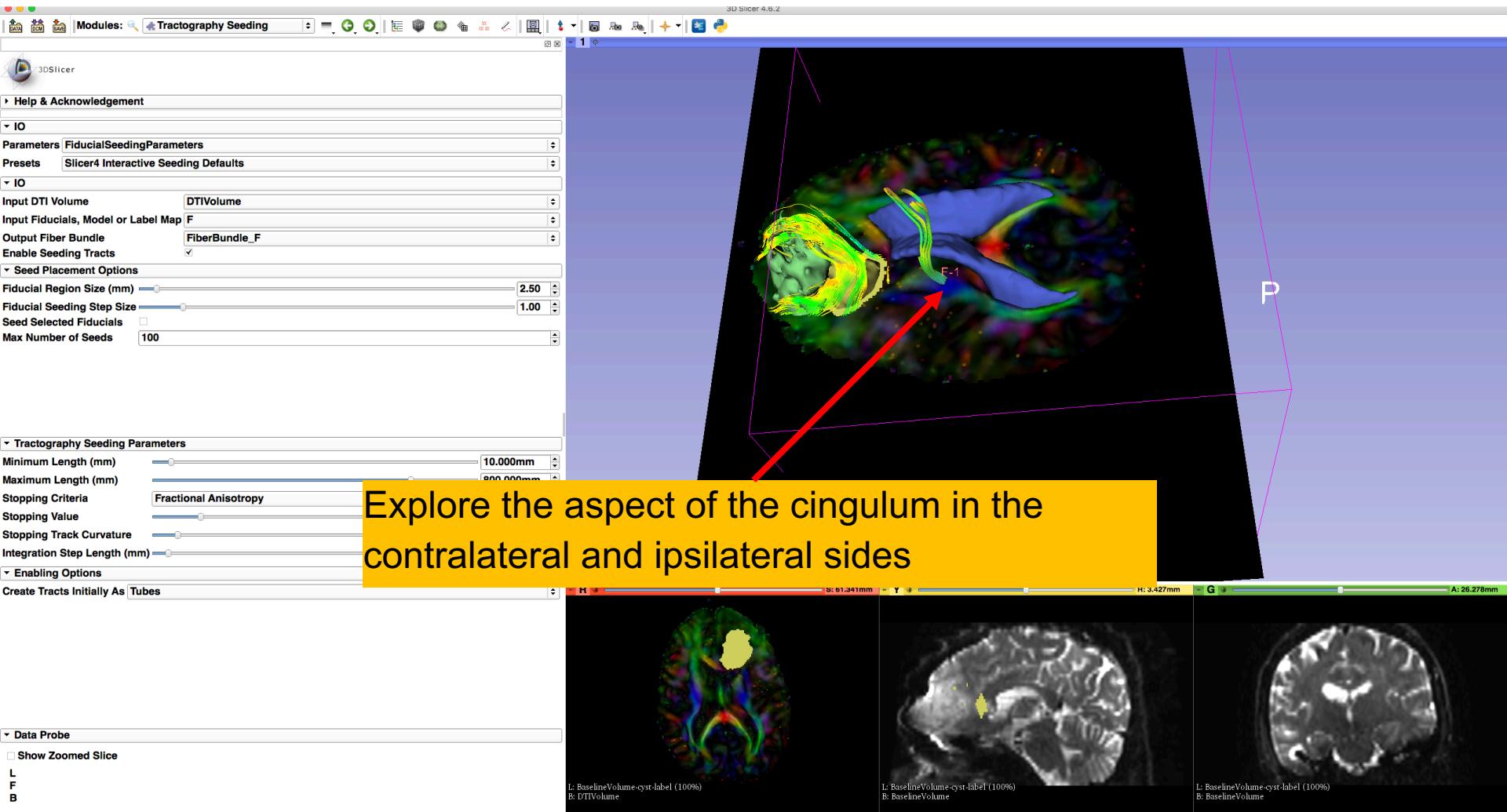


Tractography on-the-fly



Position the fiducial in the cingulum on the contralateral side opposite to the tumor

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

- National Alliance for Medical Image Computing (NA-MIC)
NIH U54EB005149

- Neuroimage Analysis Center (NAC)
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