Exploring Peritumoral White Matter Fibers for Neurosurgical Planning

Sonia Pujol, Ph.D.

Ron Kikinis, M.D.

Surgical Planning Laboratory

Harvard University

Clinical Goal

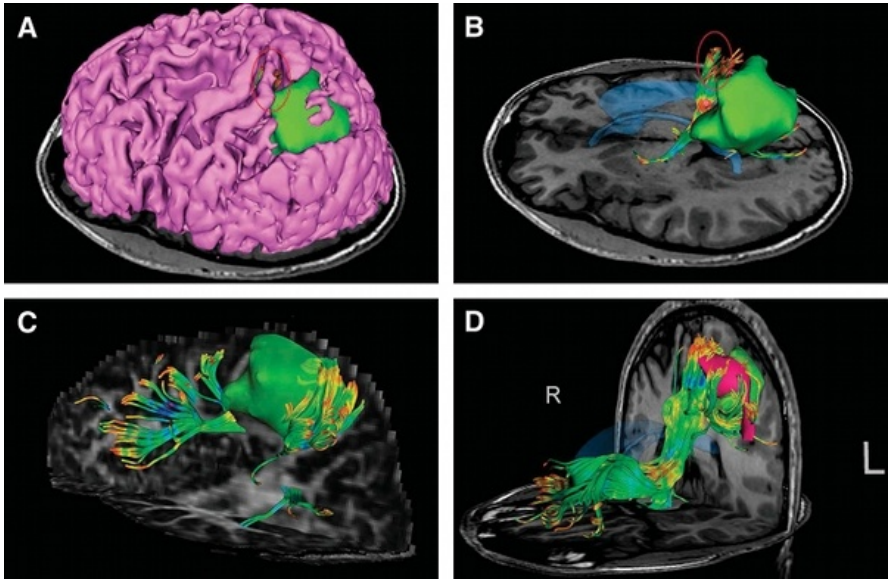
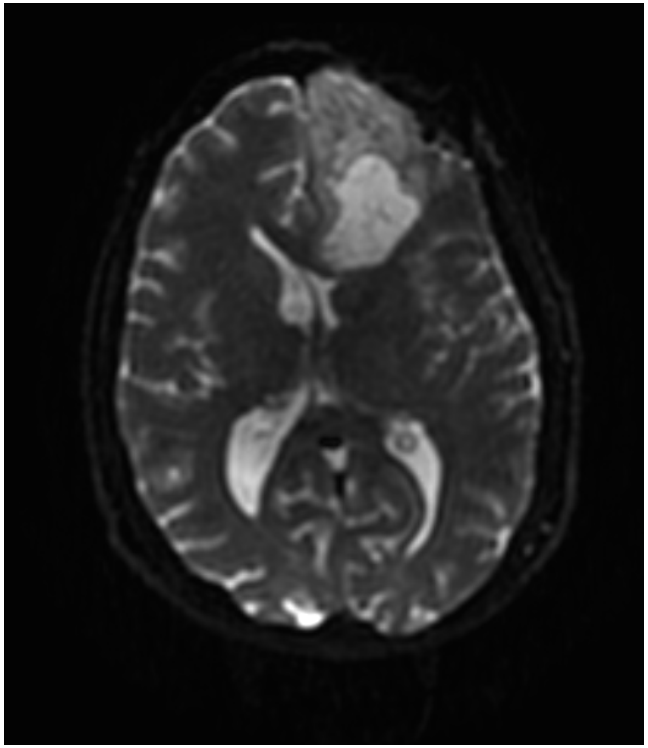


Image Courtesy of Dr. Alexandra Golby, Brigham and Women's Hospital, Boston, MA..

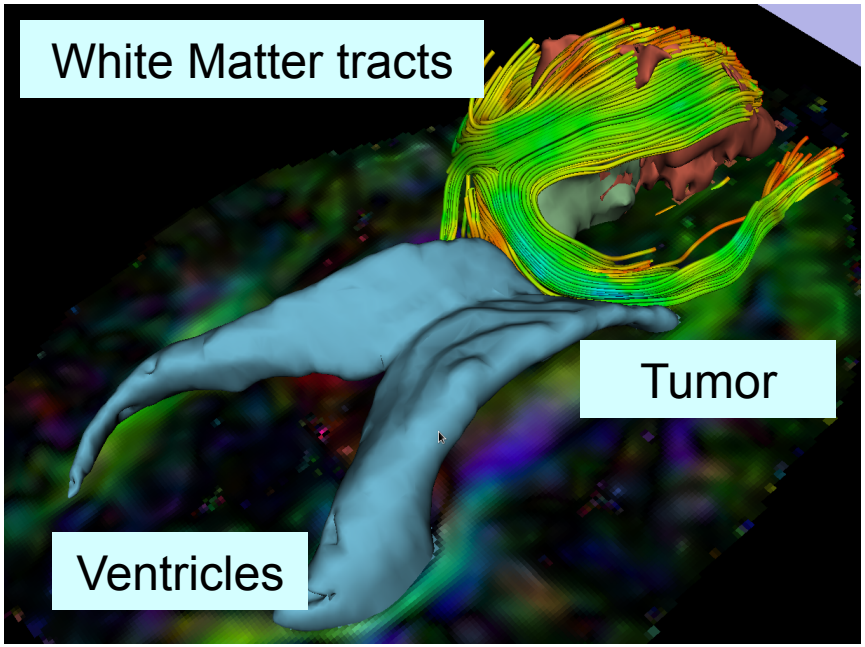
Diffusion Tensor Imaging (DTI) Tractography has the potential to bring valuable spatial information on tumor infiltration and tract displacement for neurosurgical planning of tumor resection.

Clinical Case



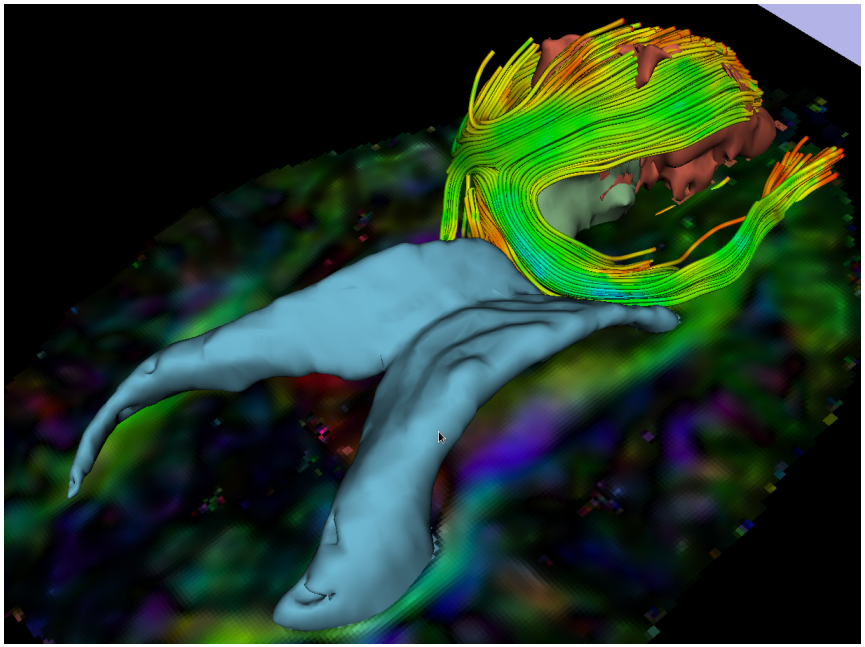
- 35 year-old male diagnosed with Glioblastoma multiforme (GBM)
- Diffusion Weighted Imaging (DWI) acquisition for neurosurgical planning

Clinical Goal



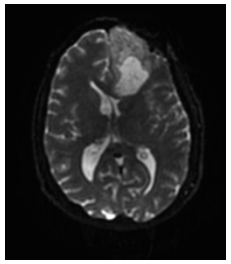
The goal of this tutorial is to explore white matter fibers surrounding a tumor using Diffusion Tensor Imaging (DTI) Tractography.

Image Analysis Pipeline

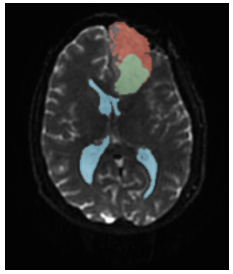


The image analysis pipeline described in this tutorial uses three different algorithms: the "Grow Cut" algorithm for segmentation of the tumor parts, the Marching Cube algorithm for surface modeling, and the single tensor streamline tractography algorithm for tract generation.

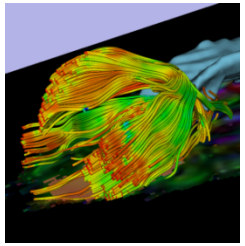
Overview of the analysis pipeline



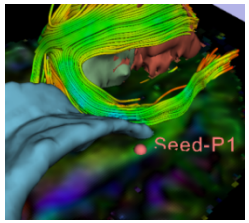
Part 1: Loading &Visualization of Diffusion Data



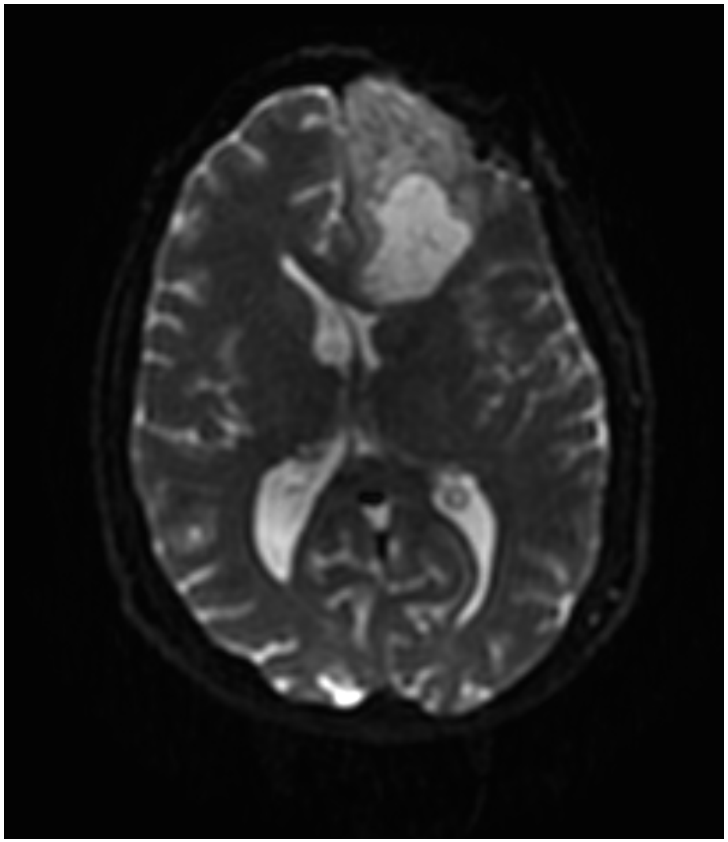
Part 2: Segmentation of the ventricles, and solid and cystic parts of the tumor



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

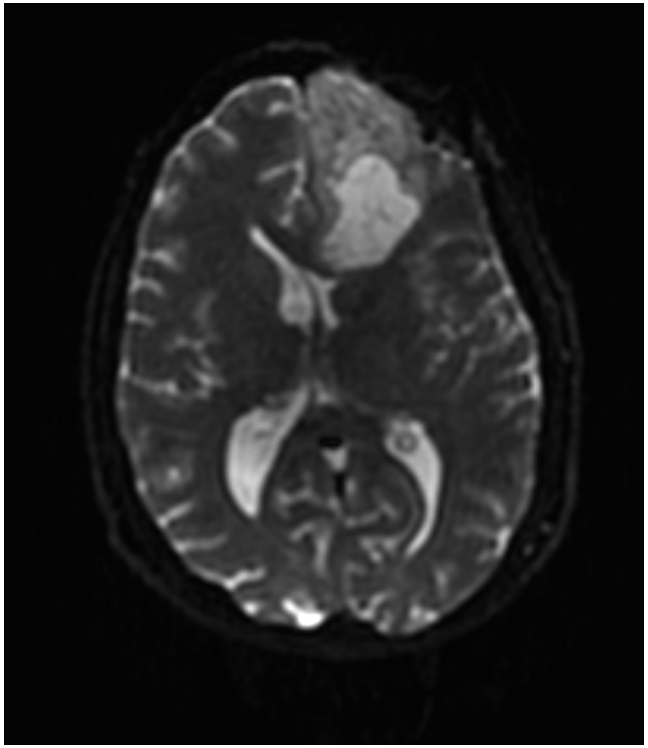


Part 4: Tractography exploration of the ipsilateral and contralateral side



Part 1: Loading and Visualization of Diffusion Data

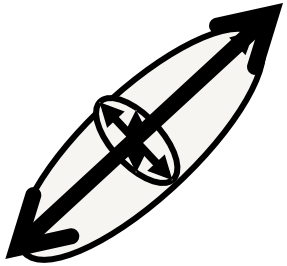
Diffusion Tensor Imaging



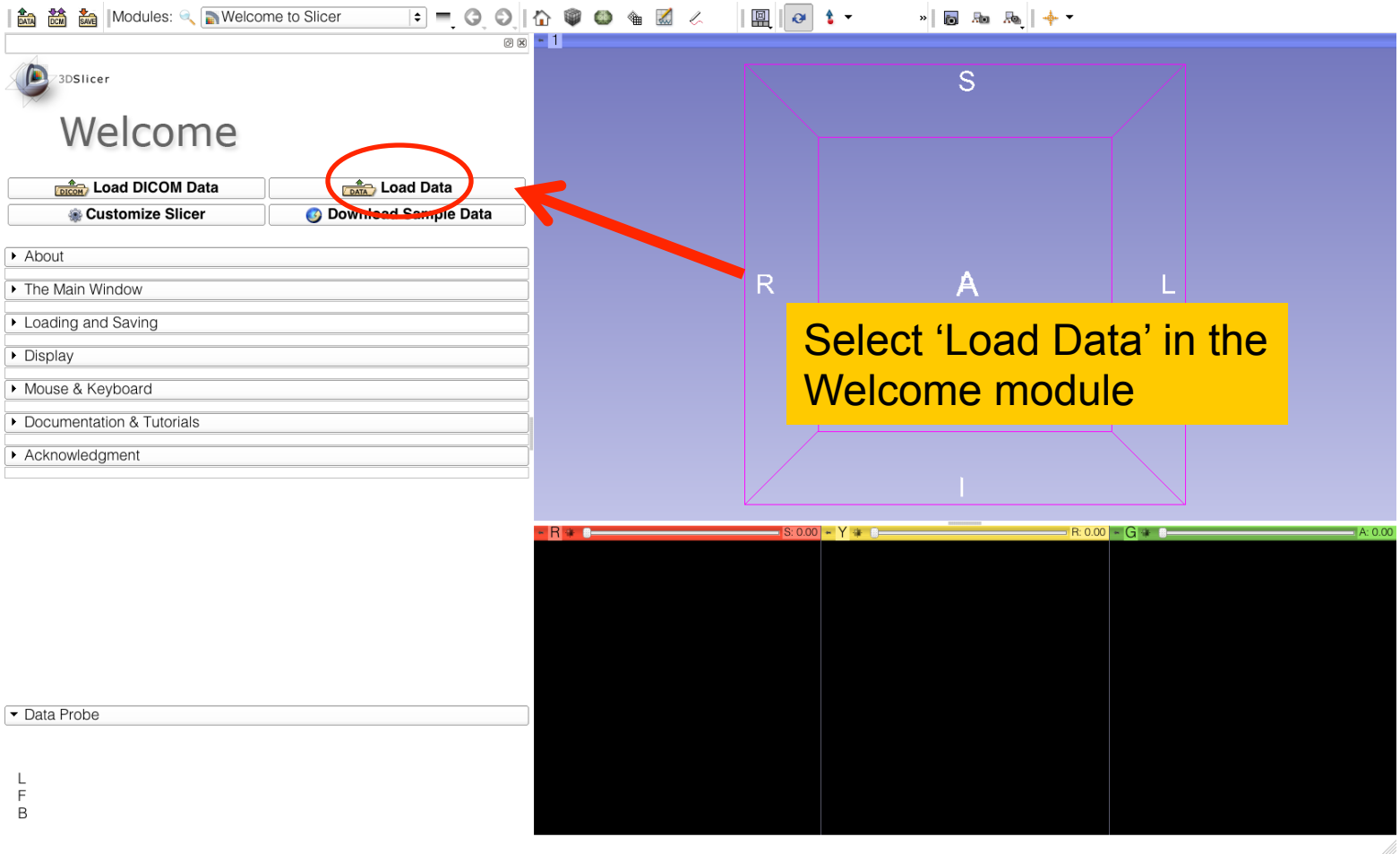
$$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$$

(Stejskal and Tanner 1965, Basser 1994)

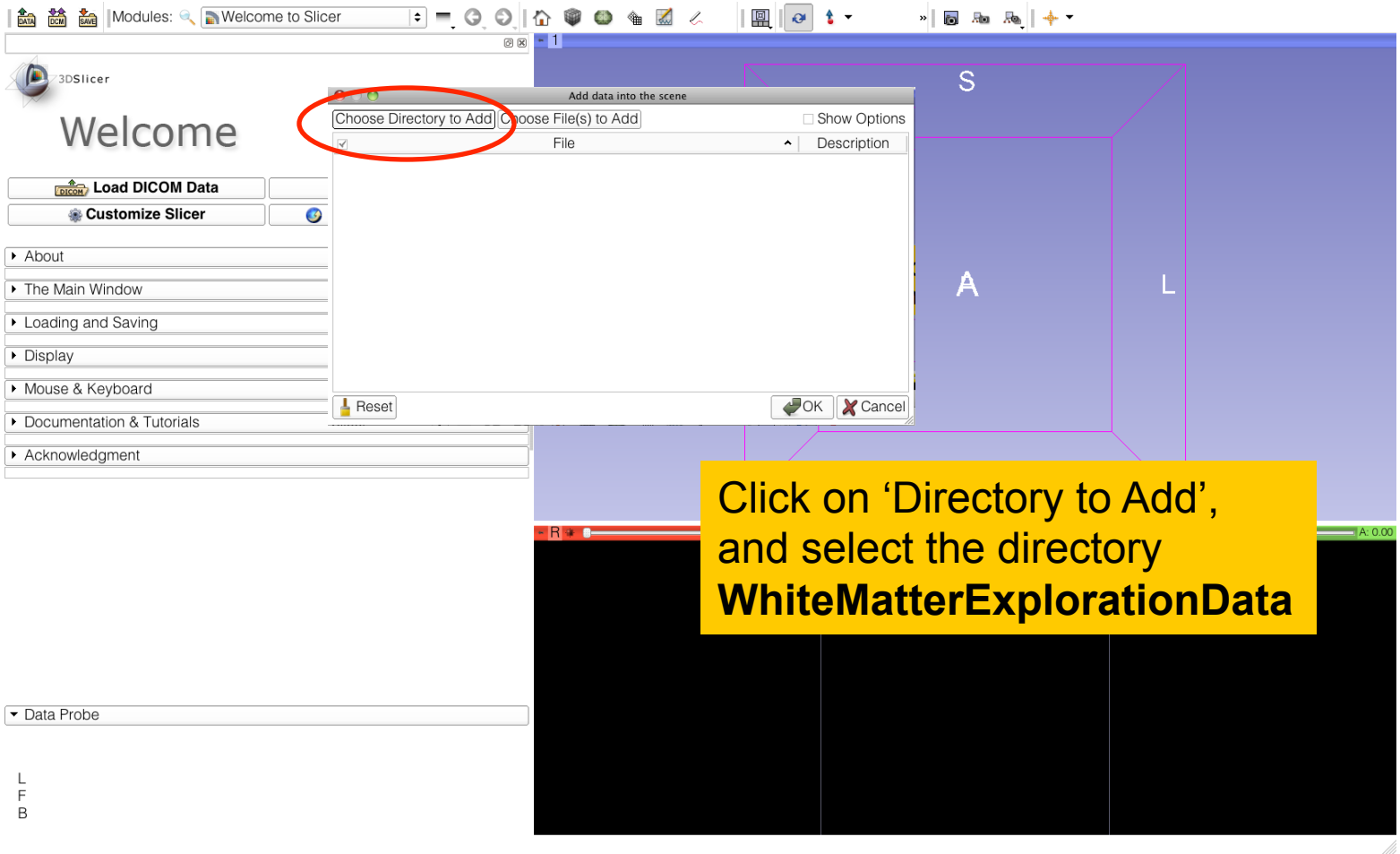
$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$



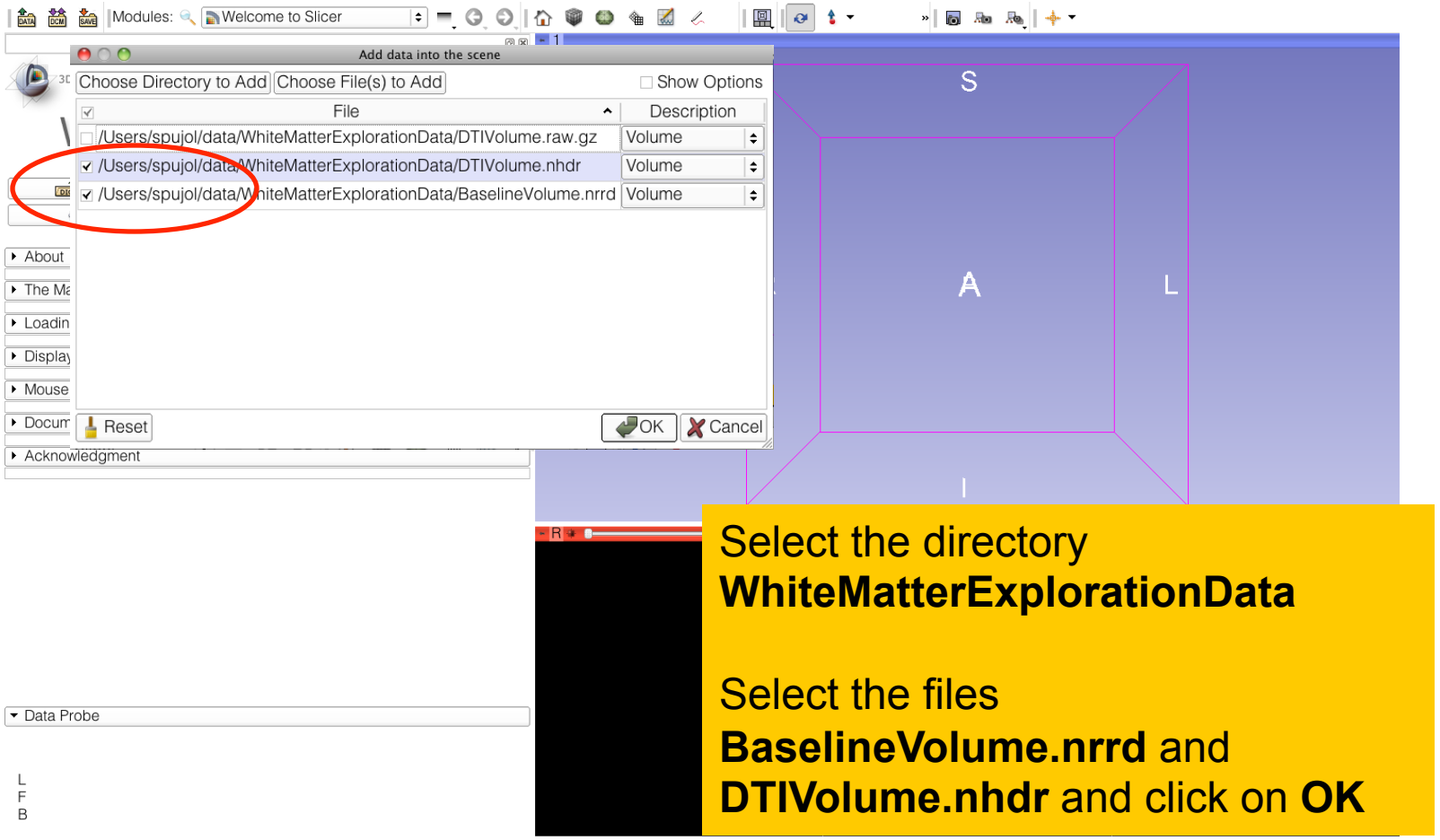
Loading DTI and Baseline Data



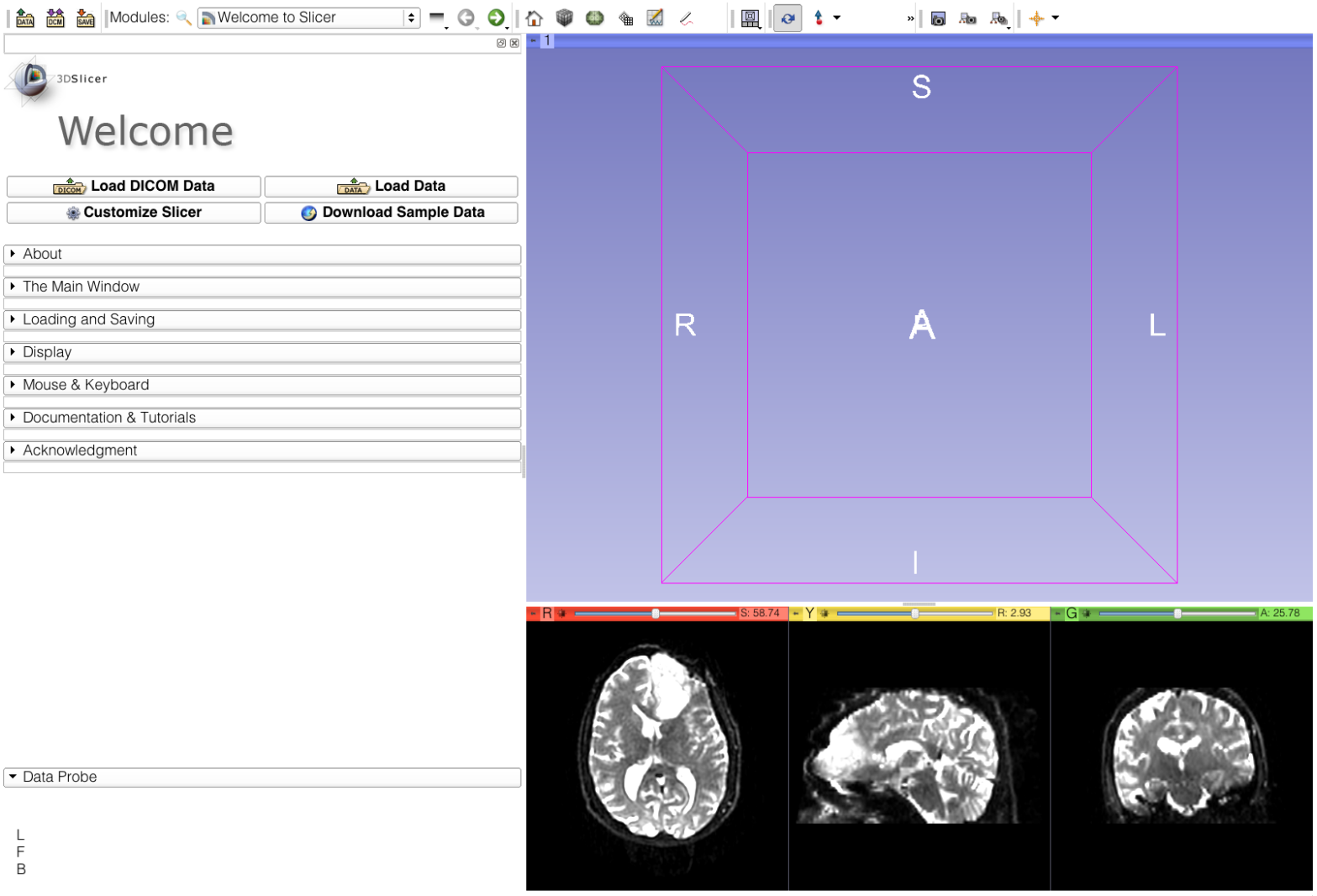
Loading DTI and Baseline Data



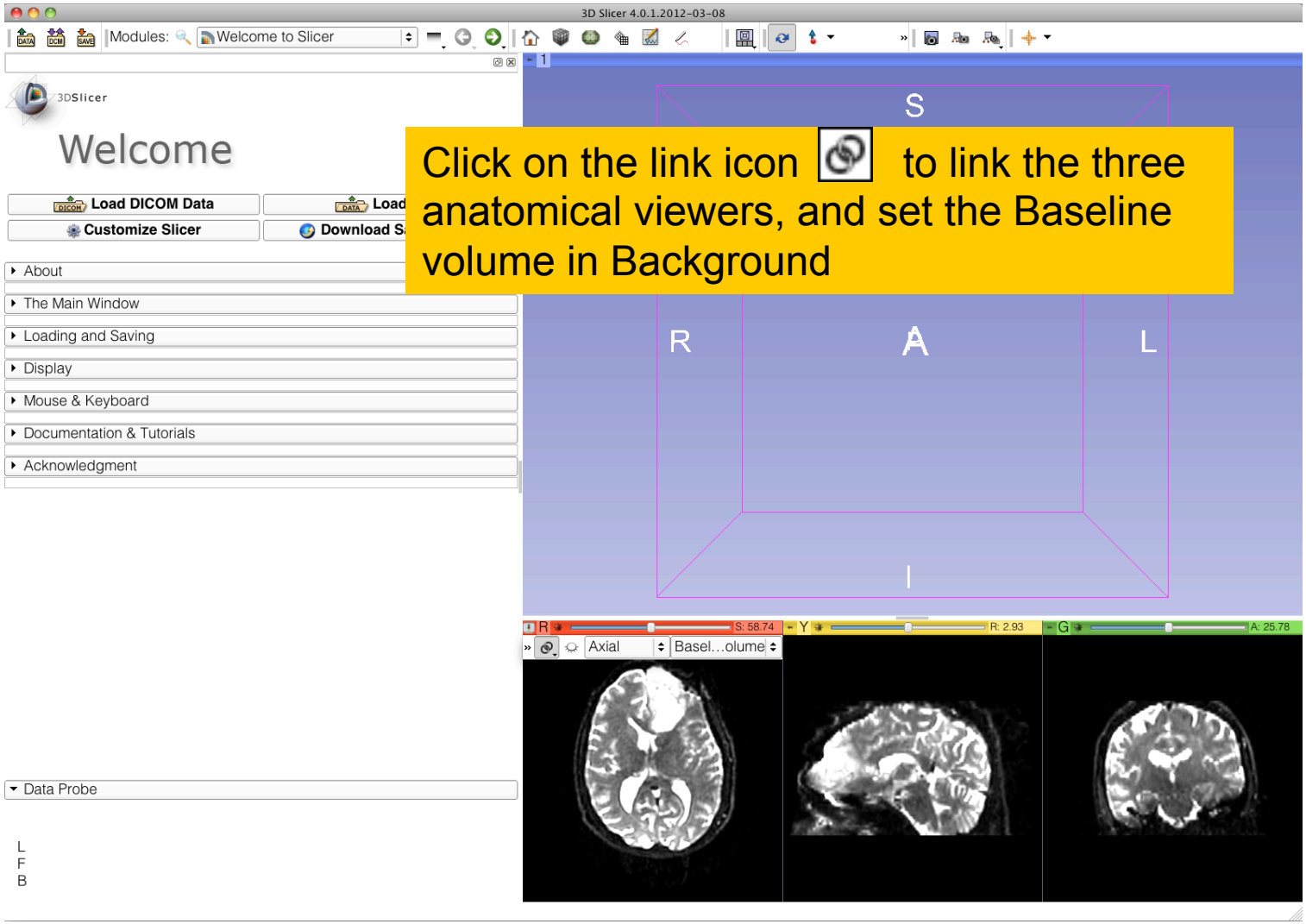
Loading DTI and Baseline Data



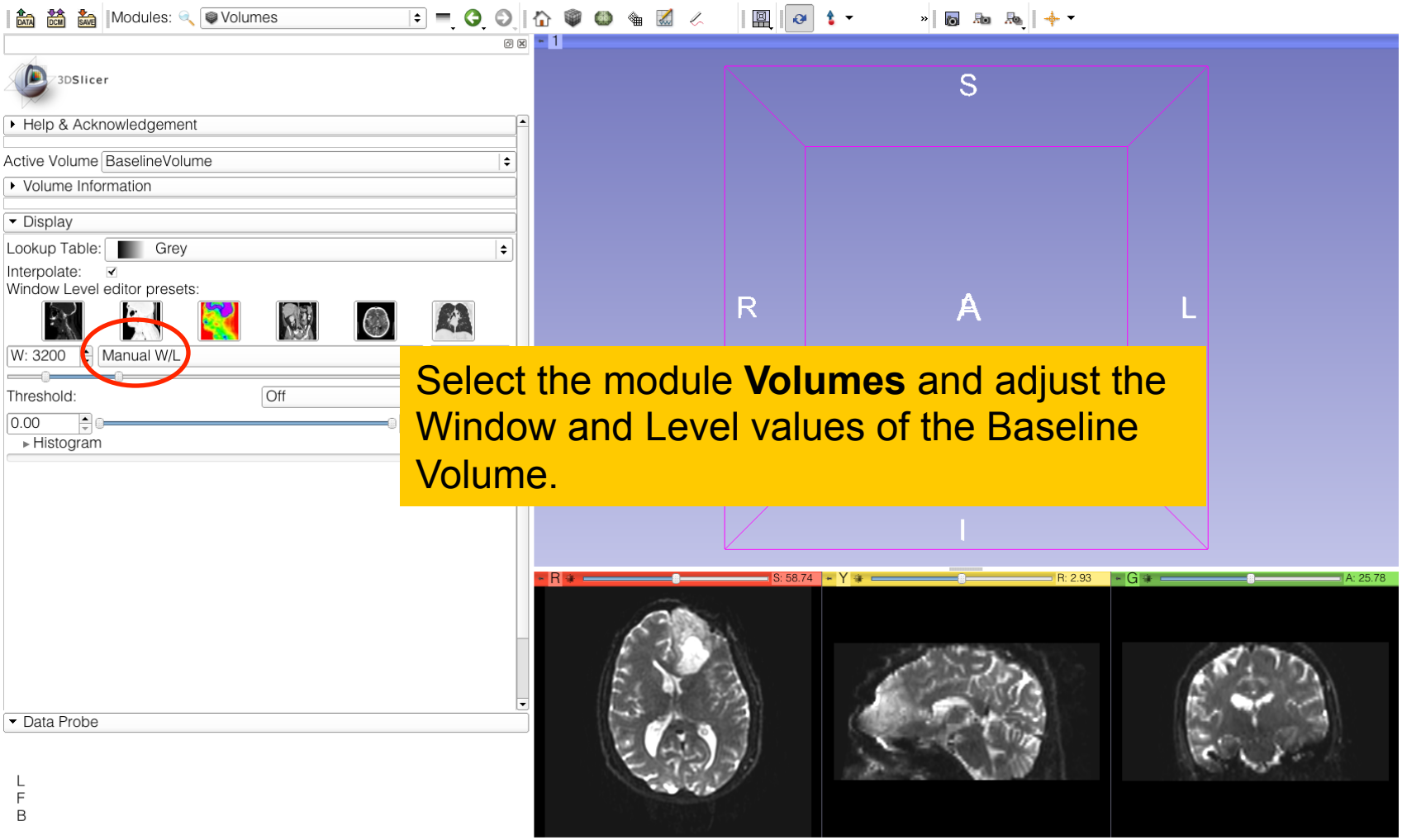
Loading DTI and Baseline Data



Loading DTI and Baseline Data

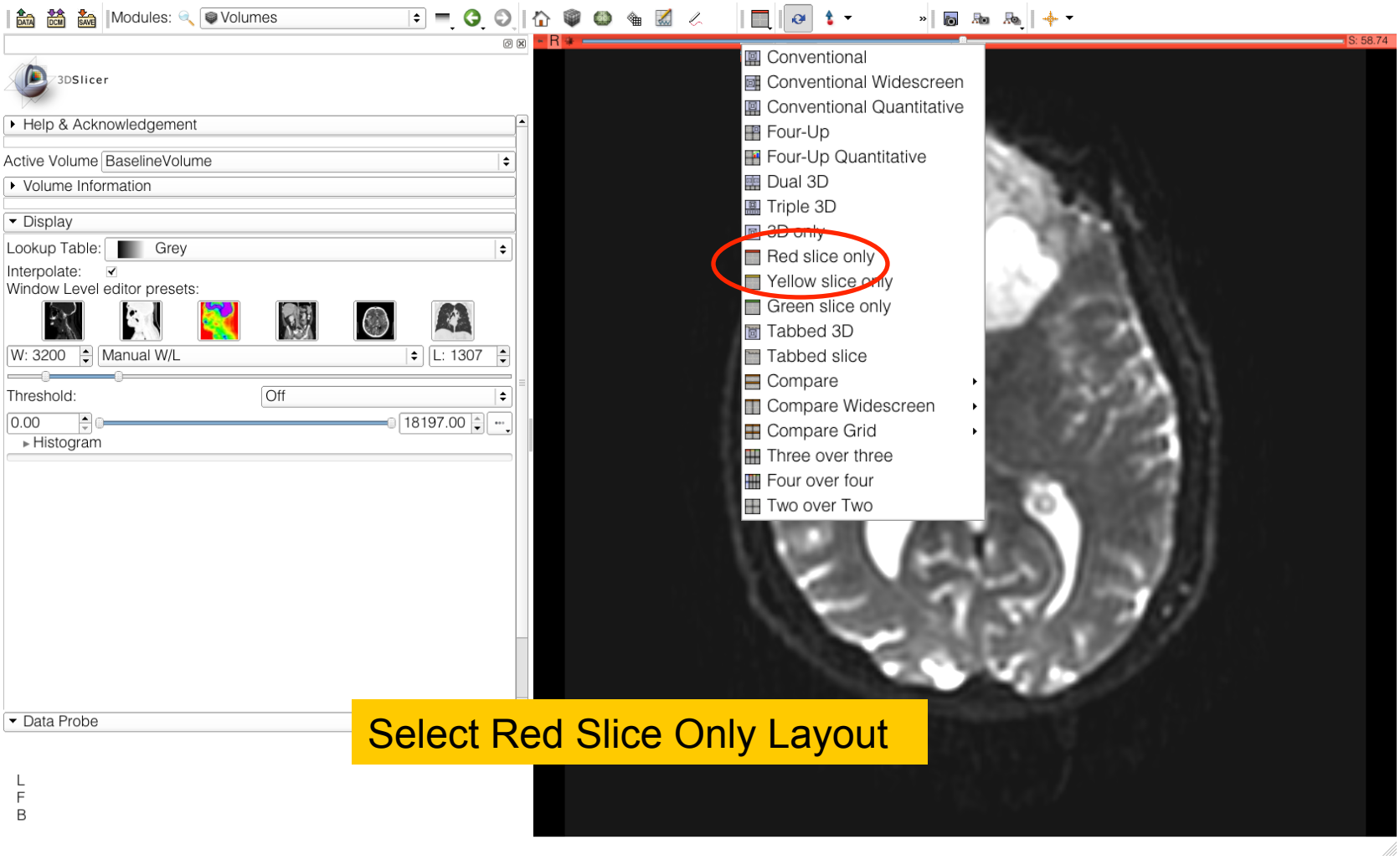


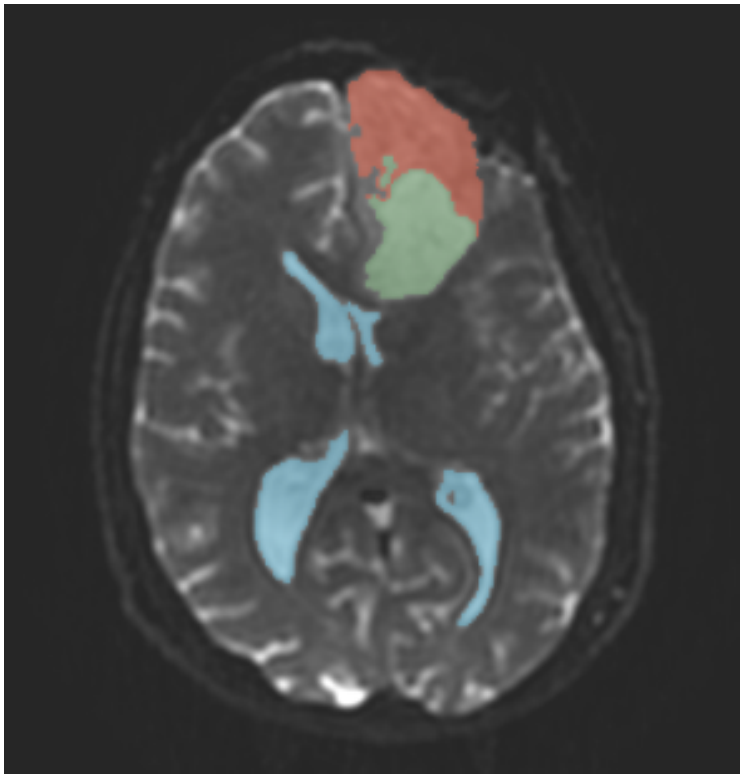
Loading DTI and Baseline Data



Select the module **Volumes** and adjust the Window and Level values of the Baseline Volume.

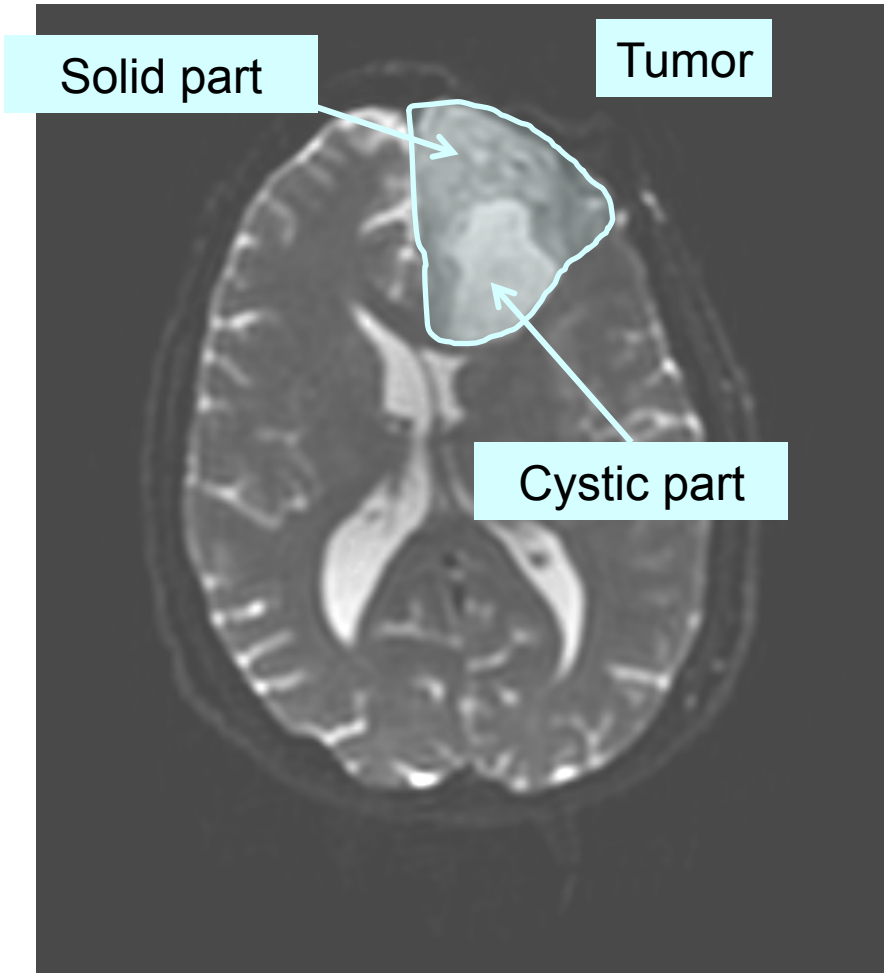
Loading DTI and Baseline Data





Part 1:
Segmenting the tumor and ventricles

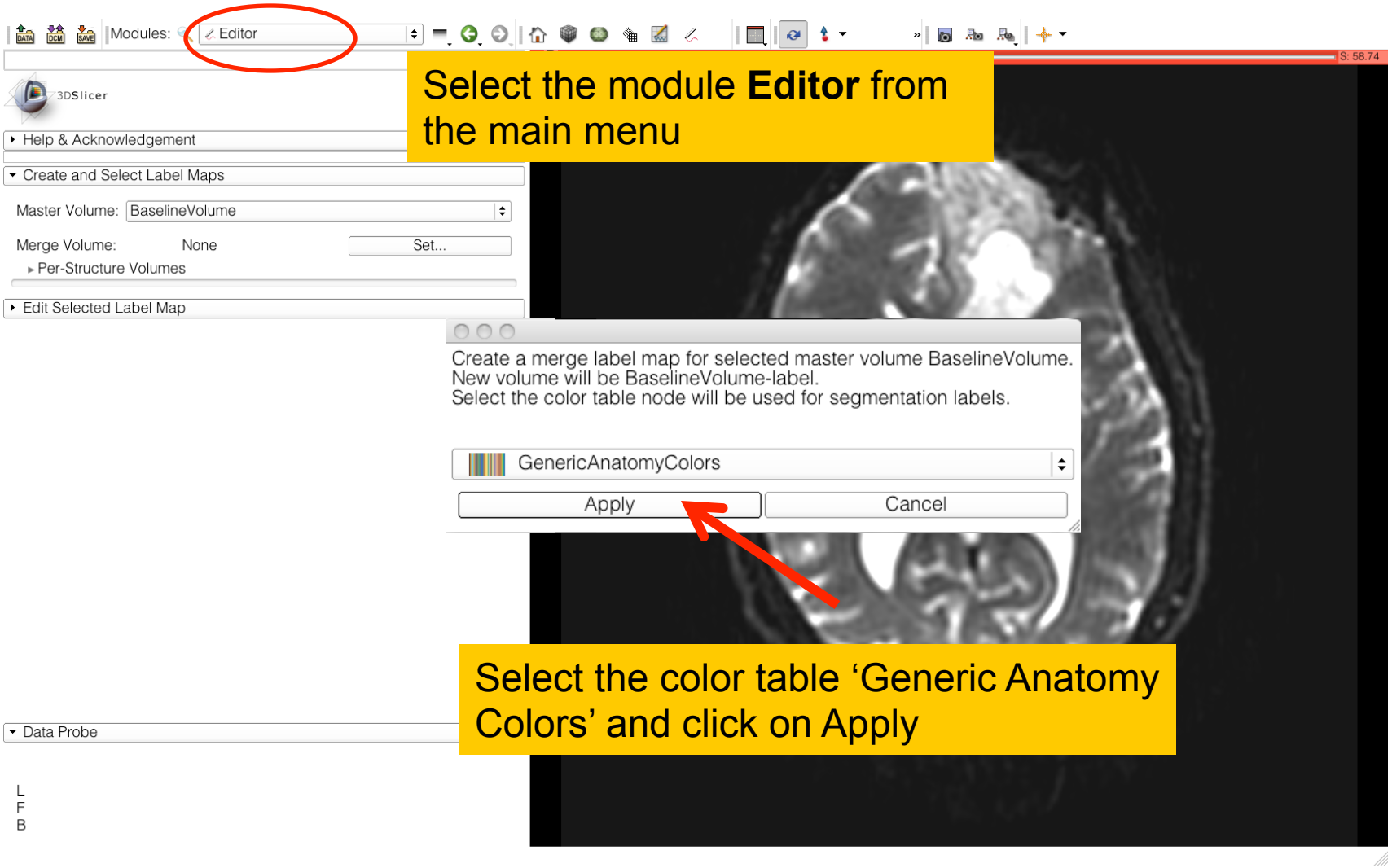
Tumor Segmentation



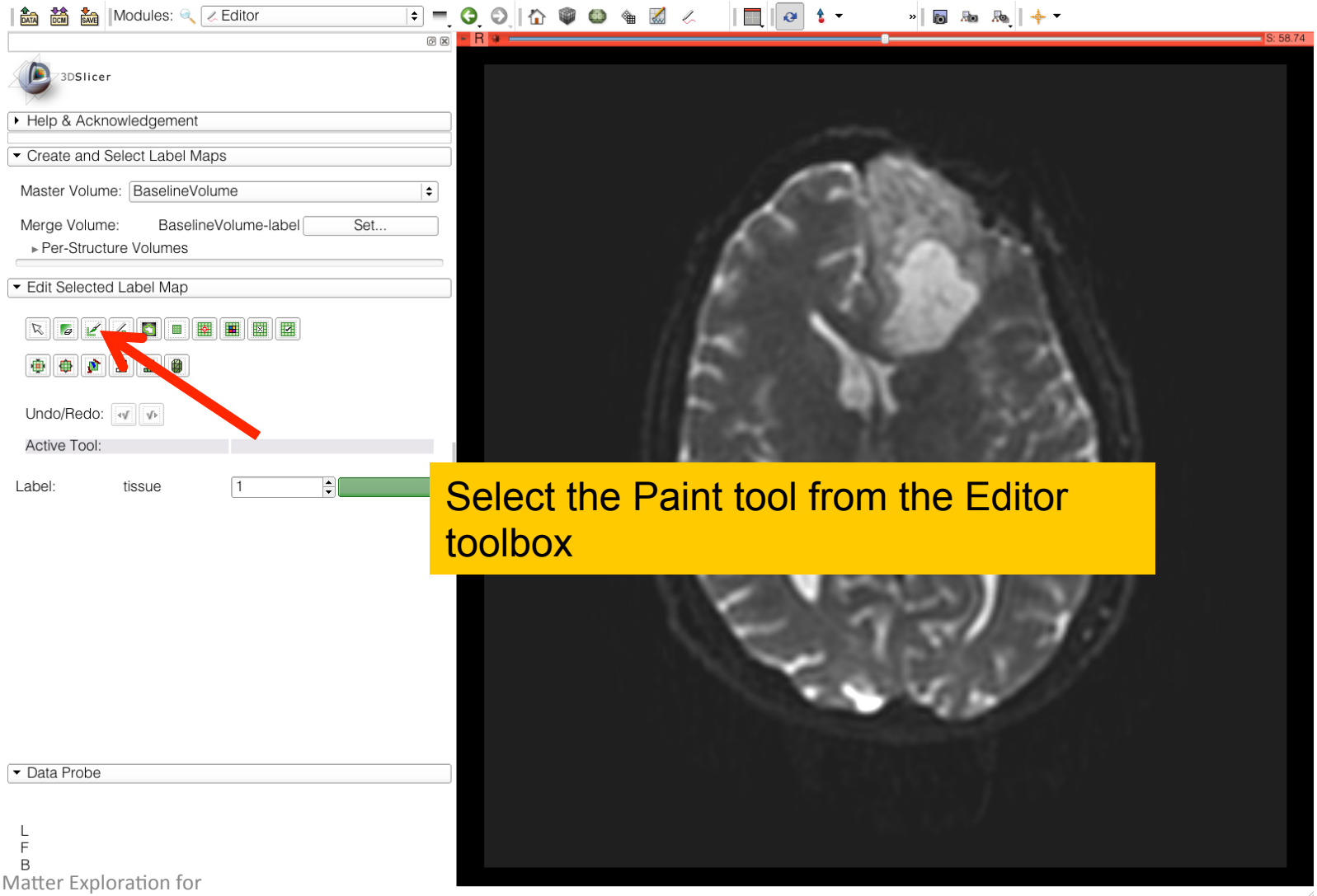
The tumor in this clinical case is composed of two parts: a solid part, and a cystic part.

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

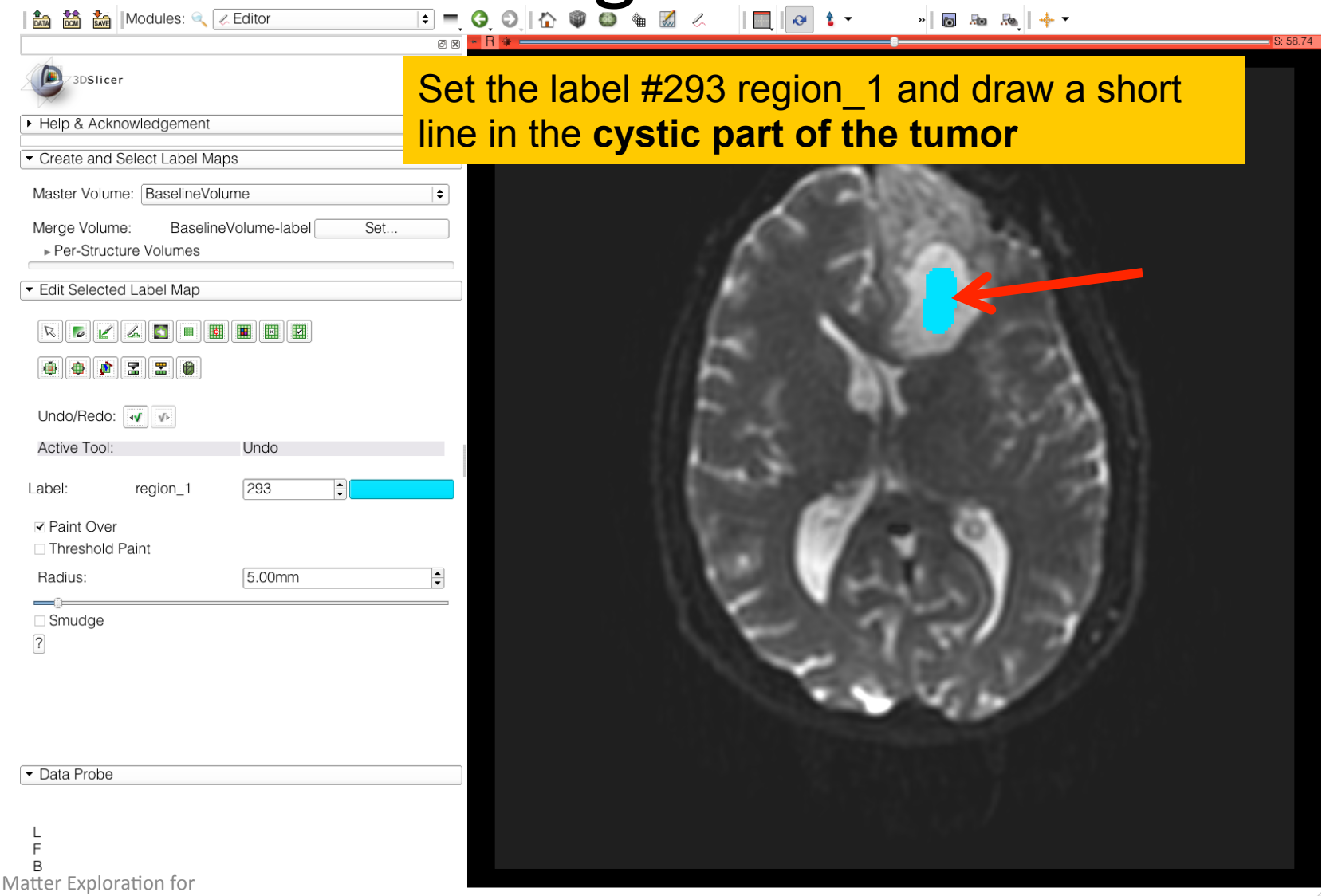
Tumor Segmentation



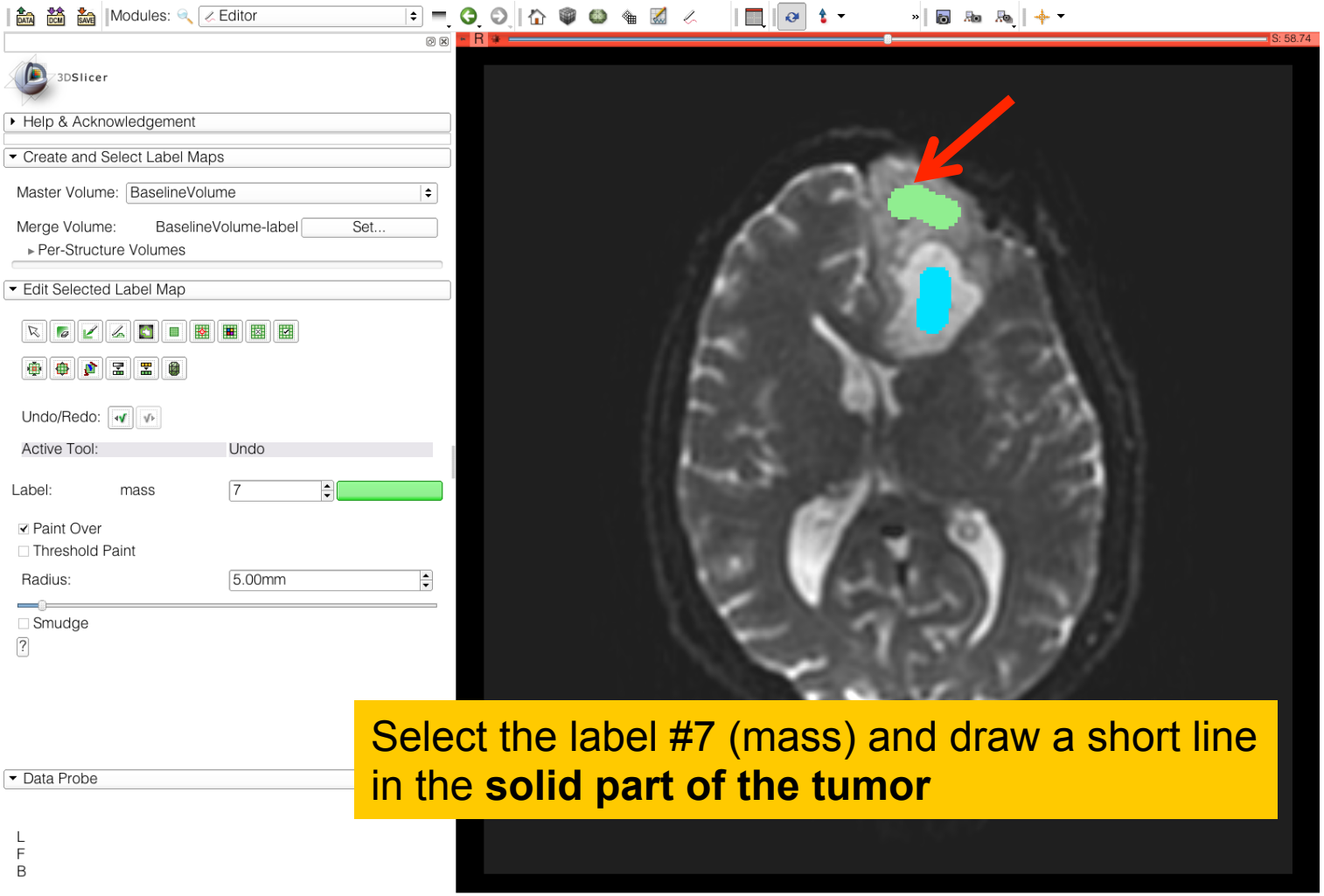
Tumor Segmentation



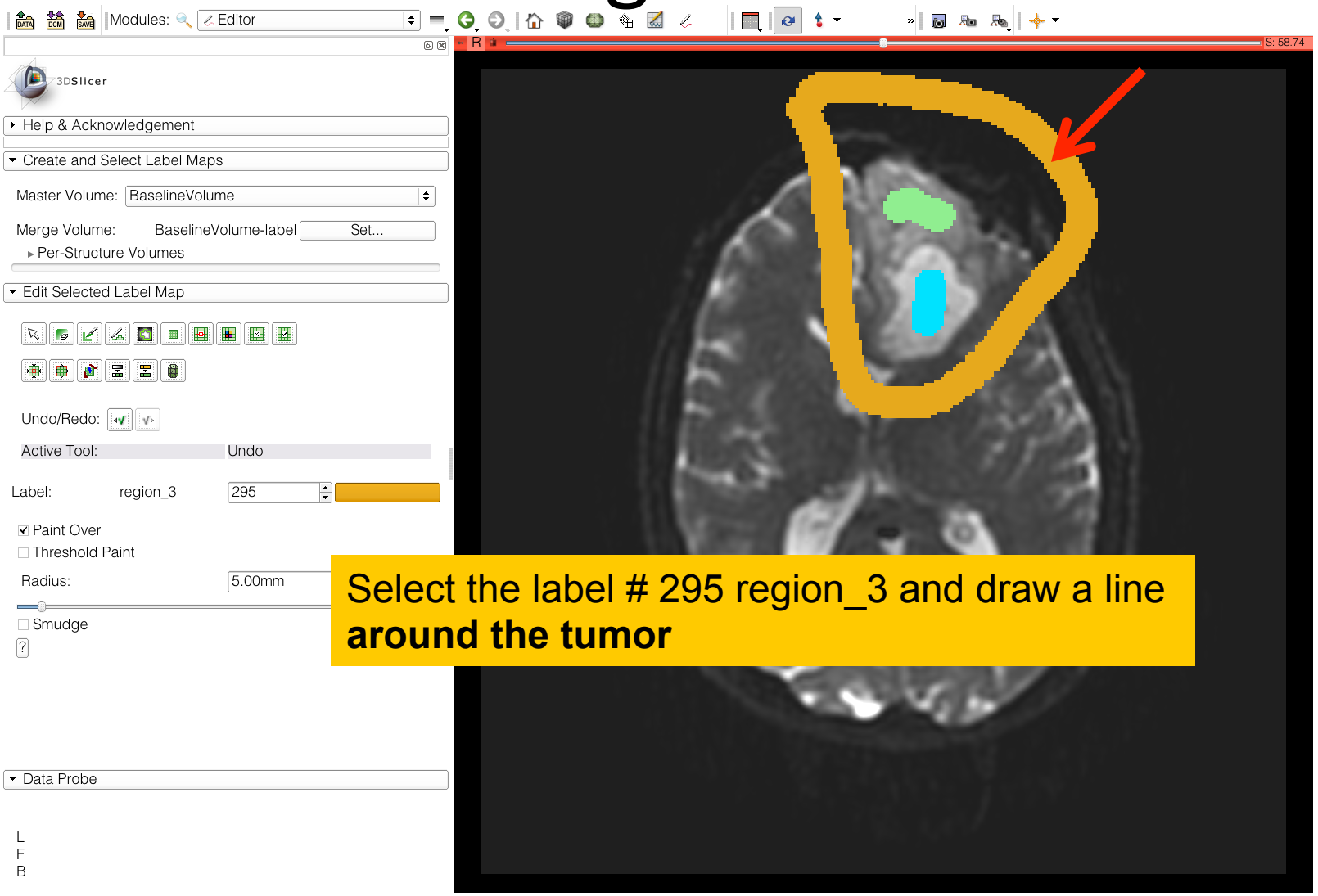
Tumor Segmentation



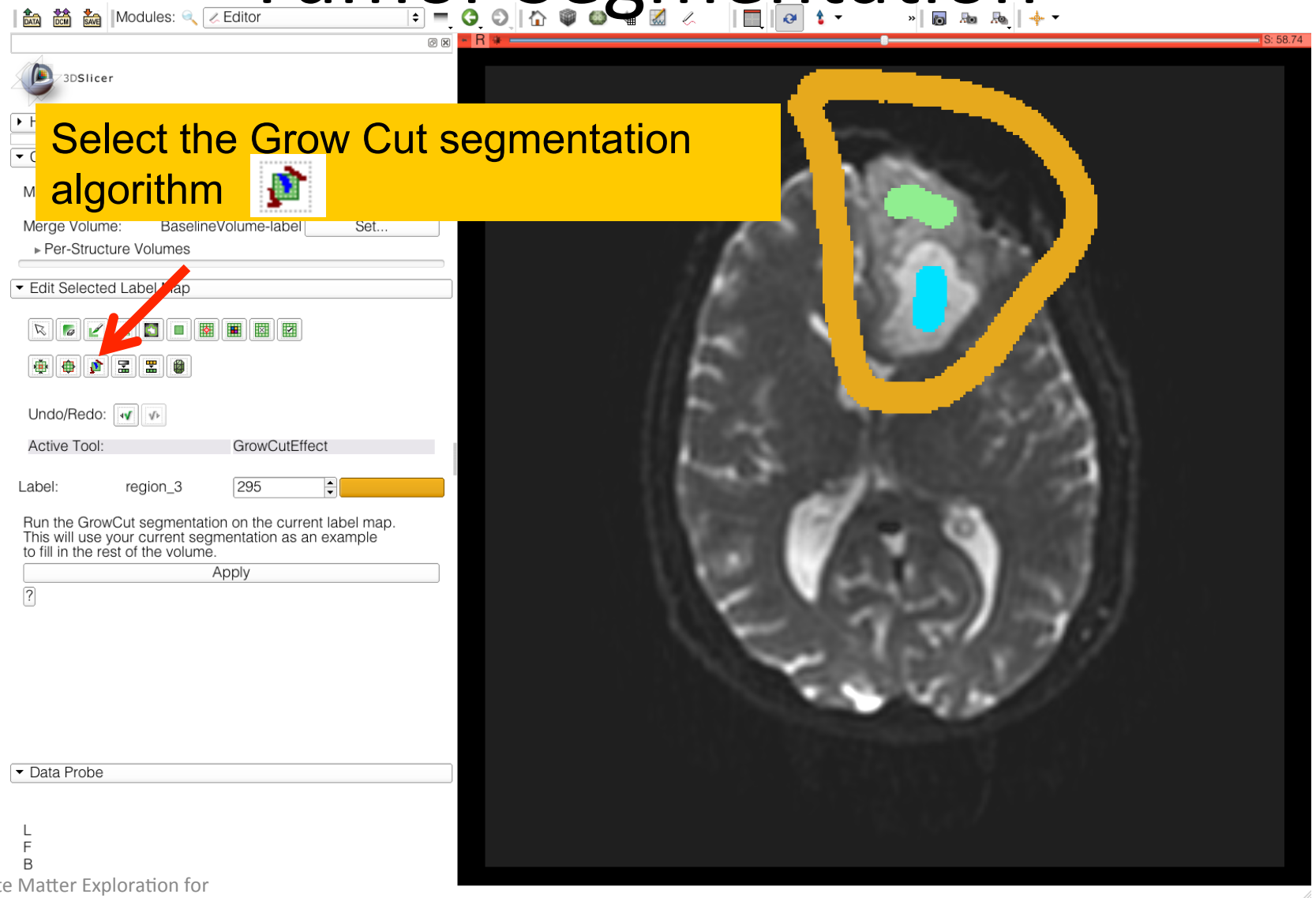
Tumor Segmentation



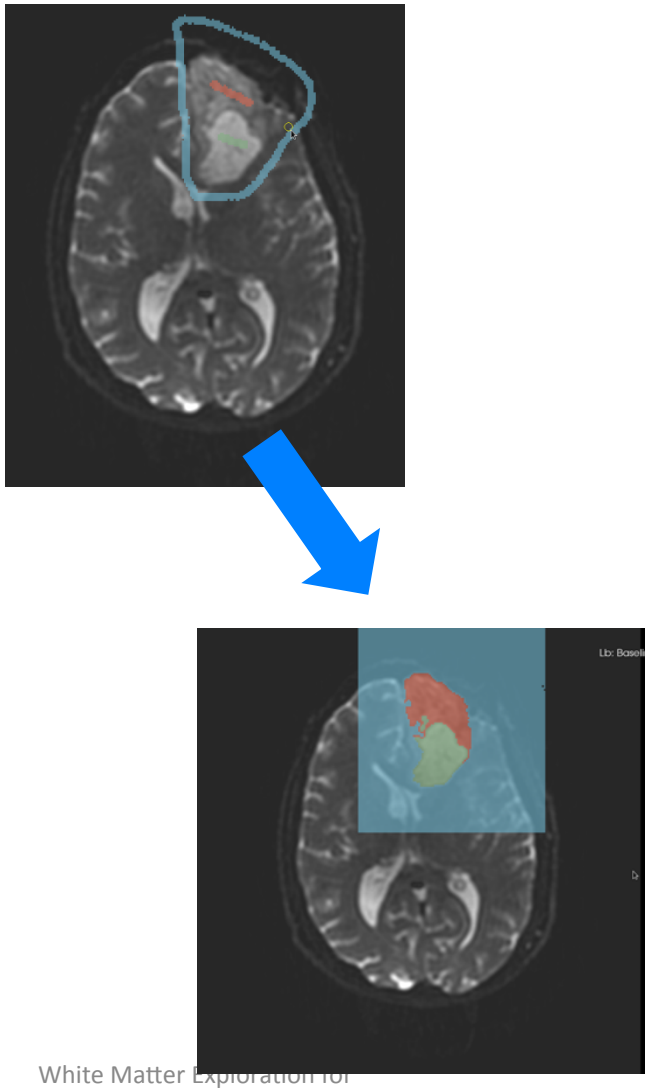
Tumor Segmentation



Tumor Segmentation

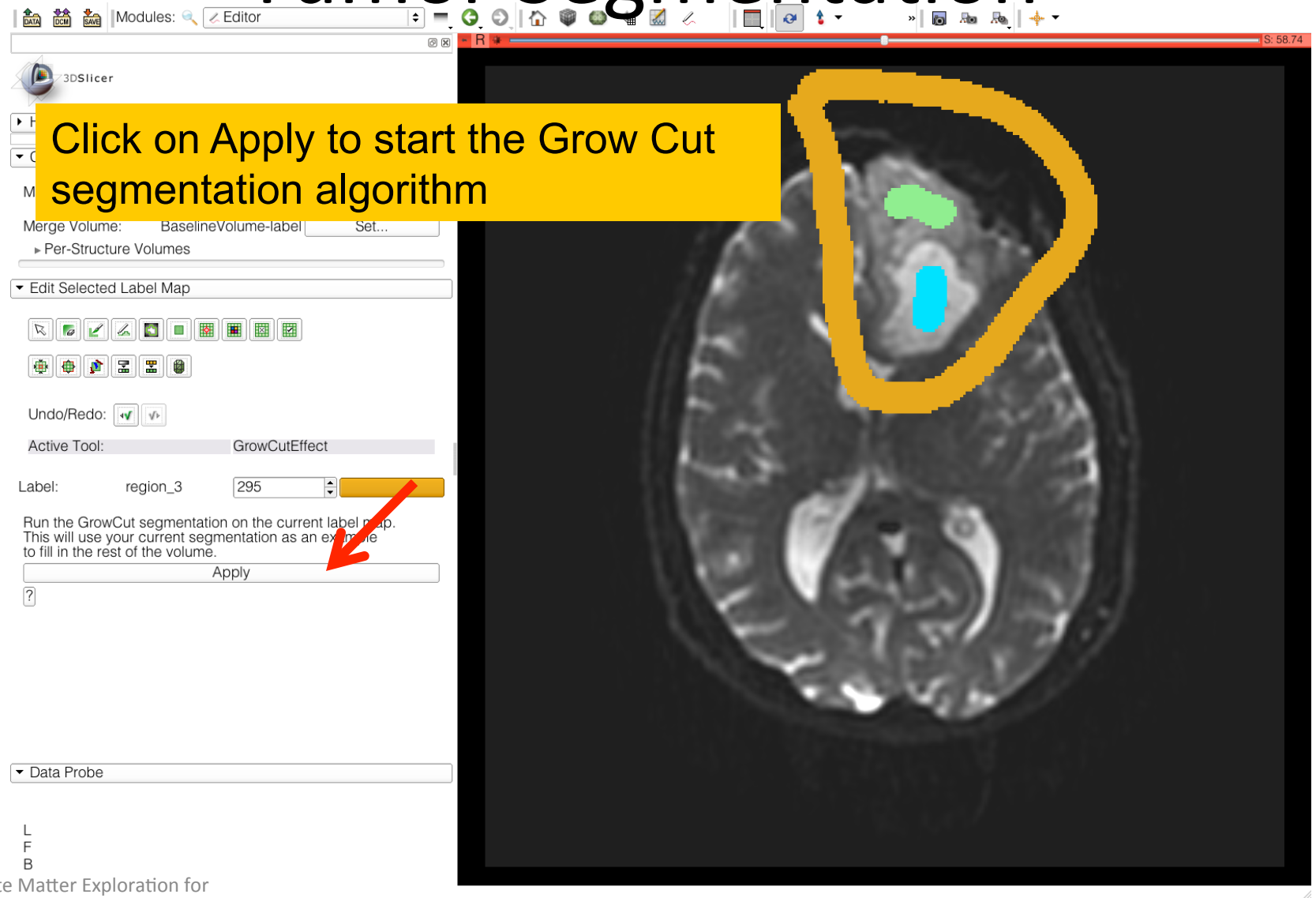


Grow Cut Segmentation

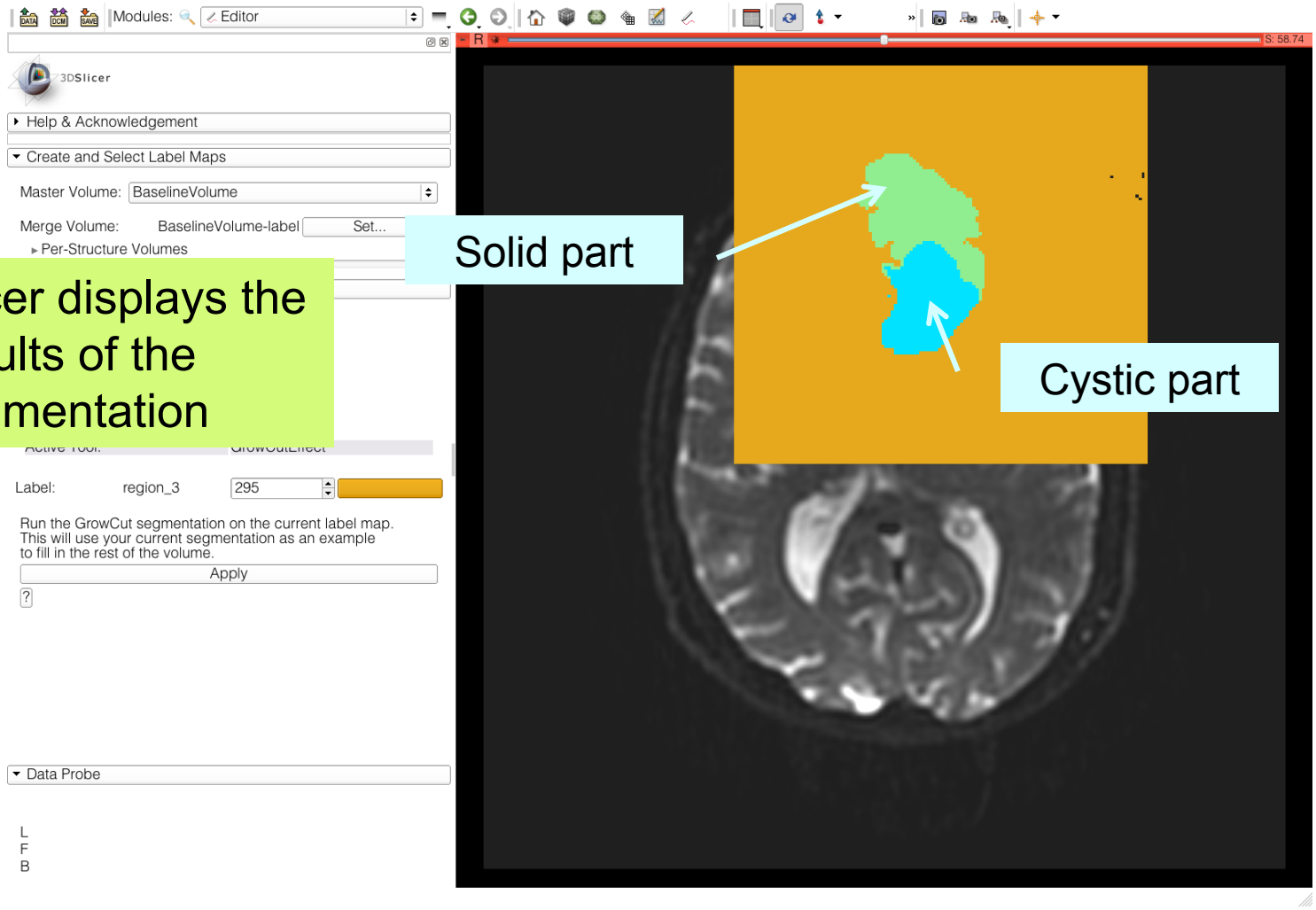


- The **Grow Cut Segmentation method** is a competitive region growing algorithm using Cellular Automata.
- The algorithm performs multi-label image segmentation using a set of user input scribbles.
- V. Vezhnevets, V. Konouchine. "Grow-Cut" - Interactive Multi-Label N-D Image Segmentation". *Proc. Graphicon*.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

Tumor Segmentation

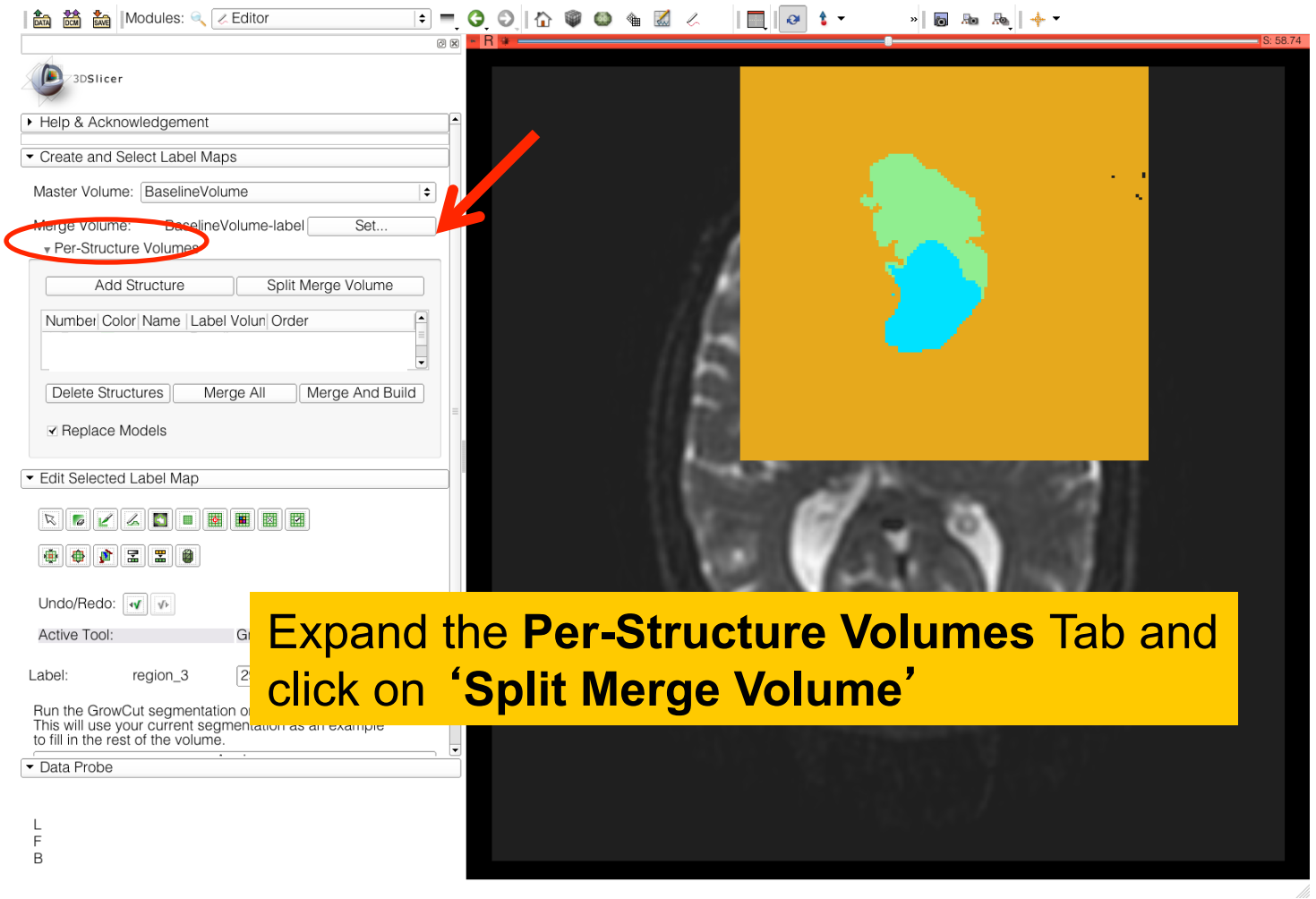


Tumor Segmentation

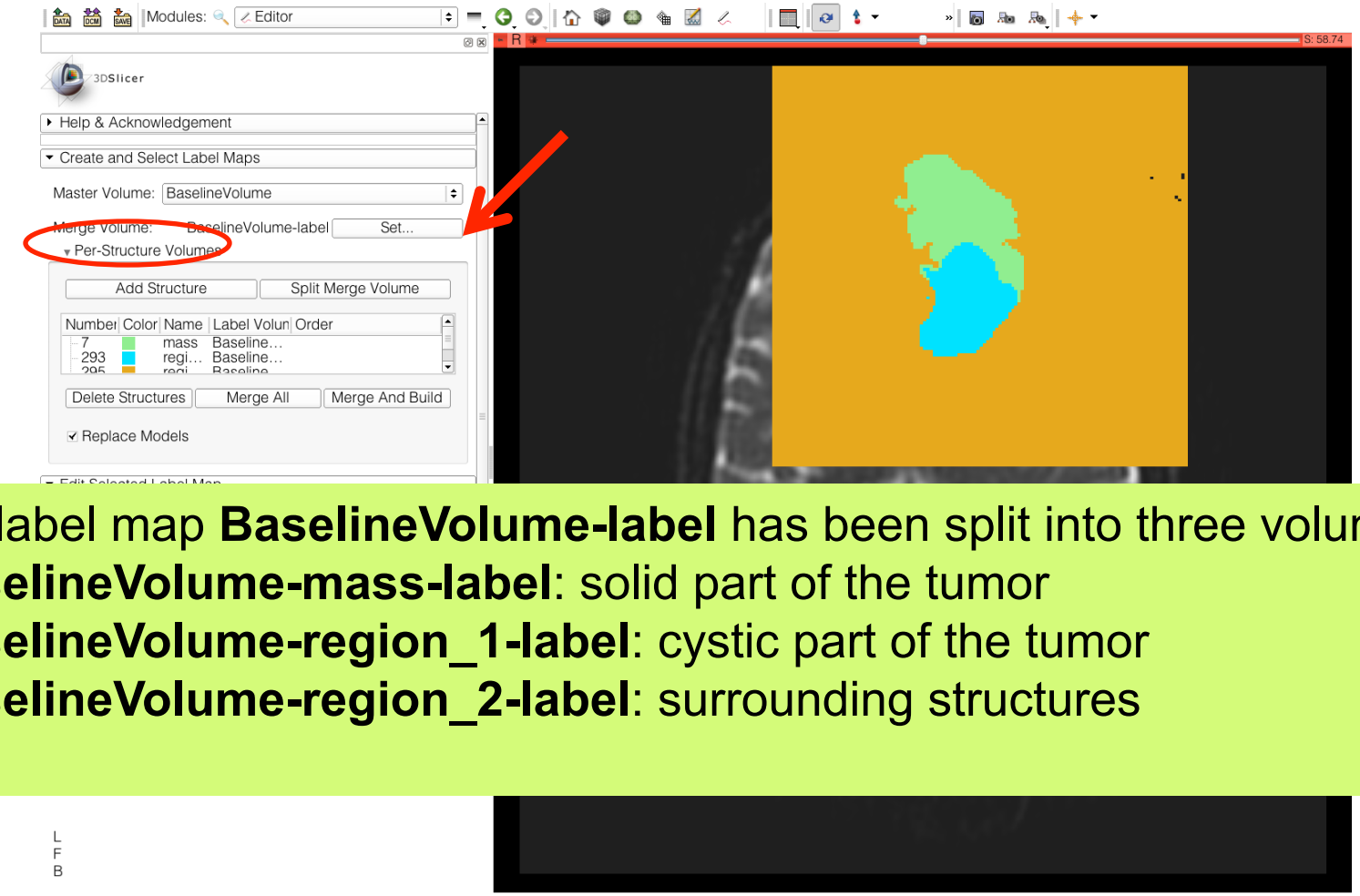


Slicer displays the results of the segmentation

Tumor Segmentation

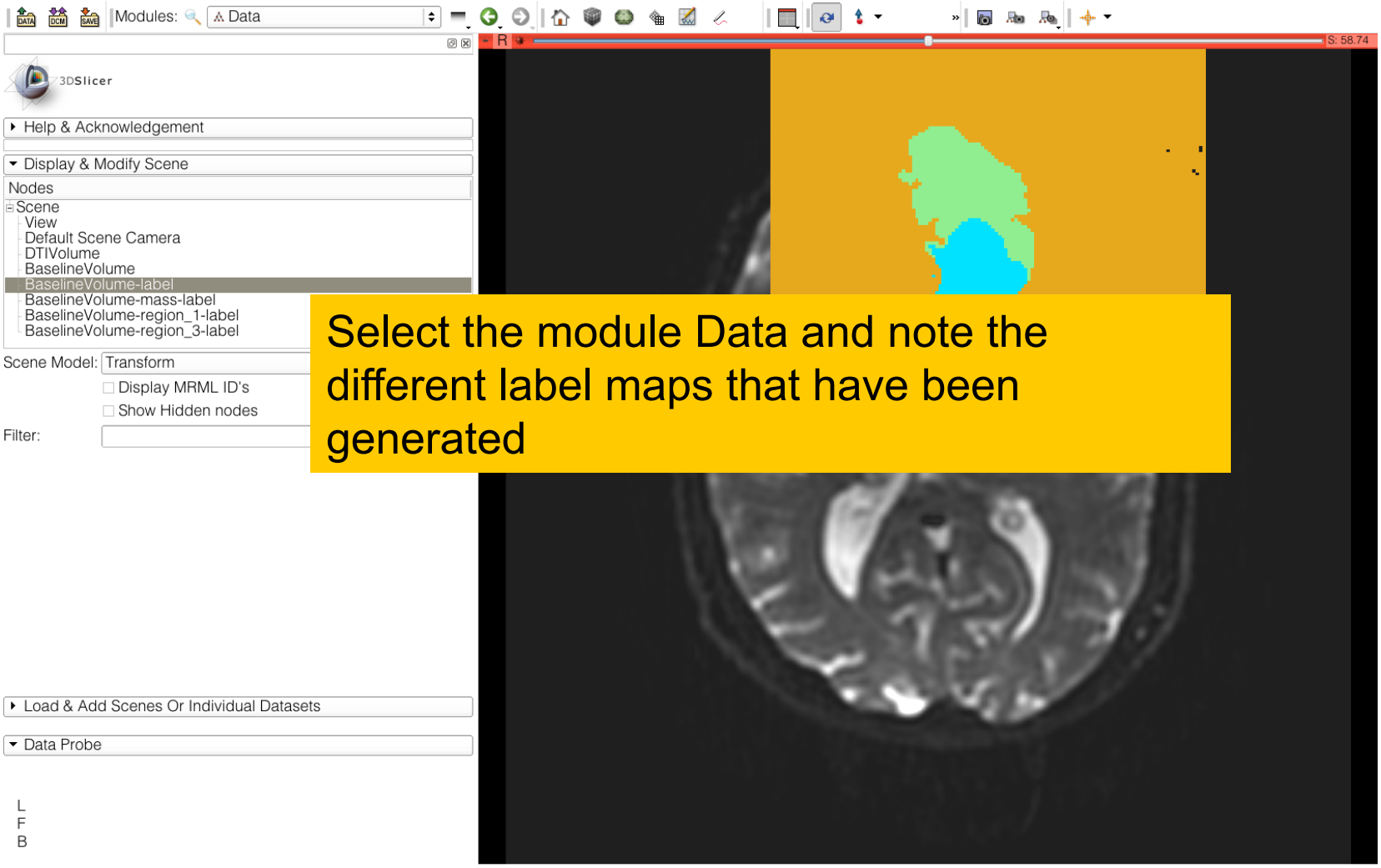


Tumor Segmentation

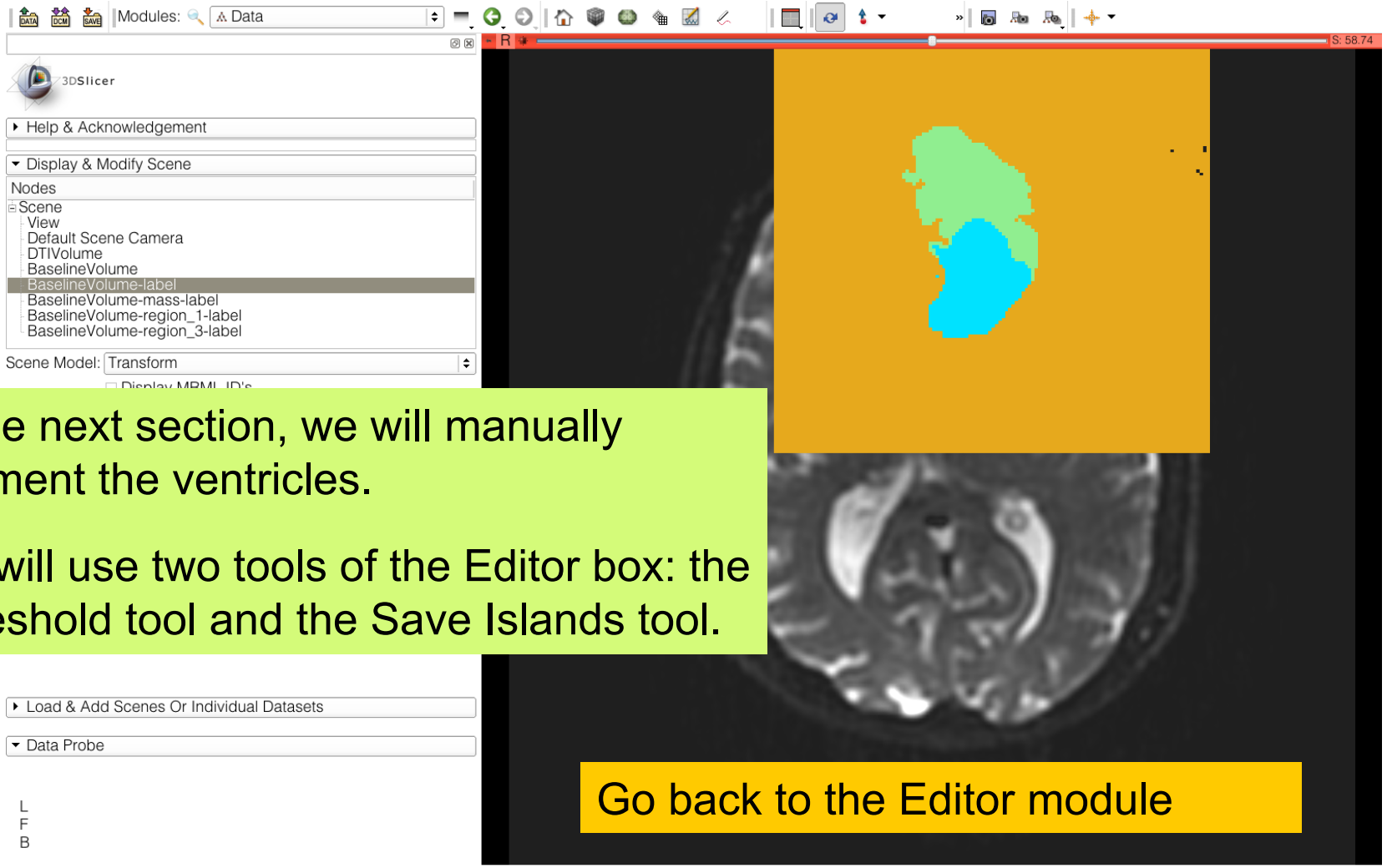


The label map **BaselineVolume-label** has been split into three volumes:
-**BaselineVolume-mass-label**: solid part of the tumor
-**BaselineVolume-region_1-label**: cystic part of the tumor
-**BaselineVolume-region_2-label**: surrounding structures

Tumor Segmentation

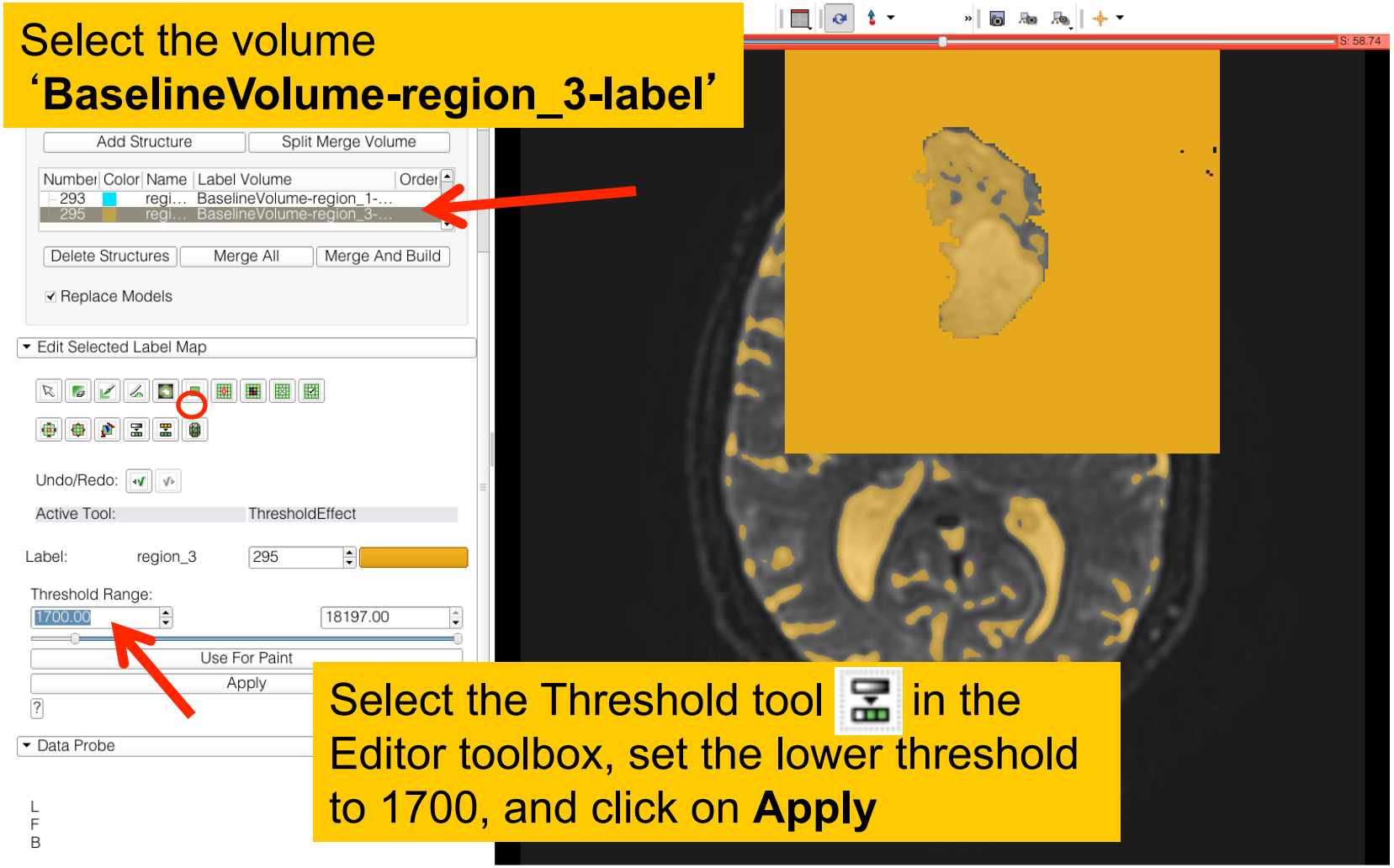


Ventricles Segmentation



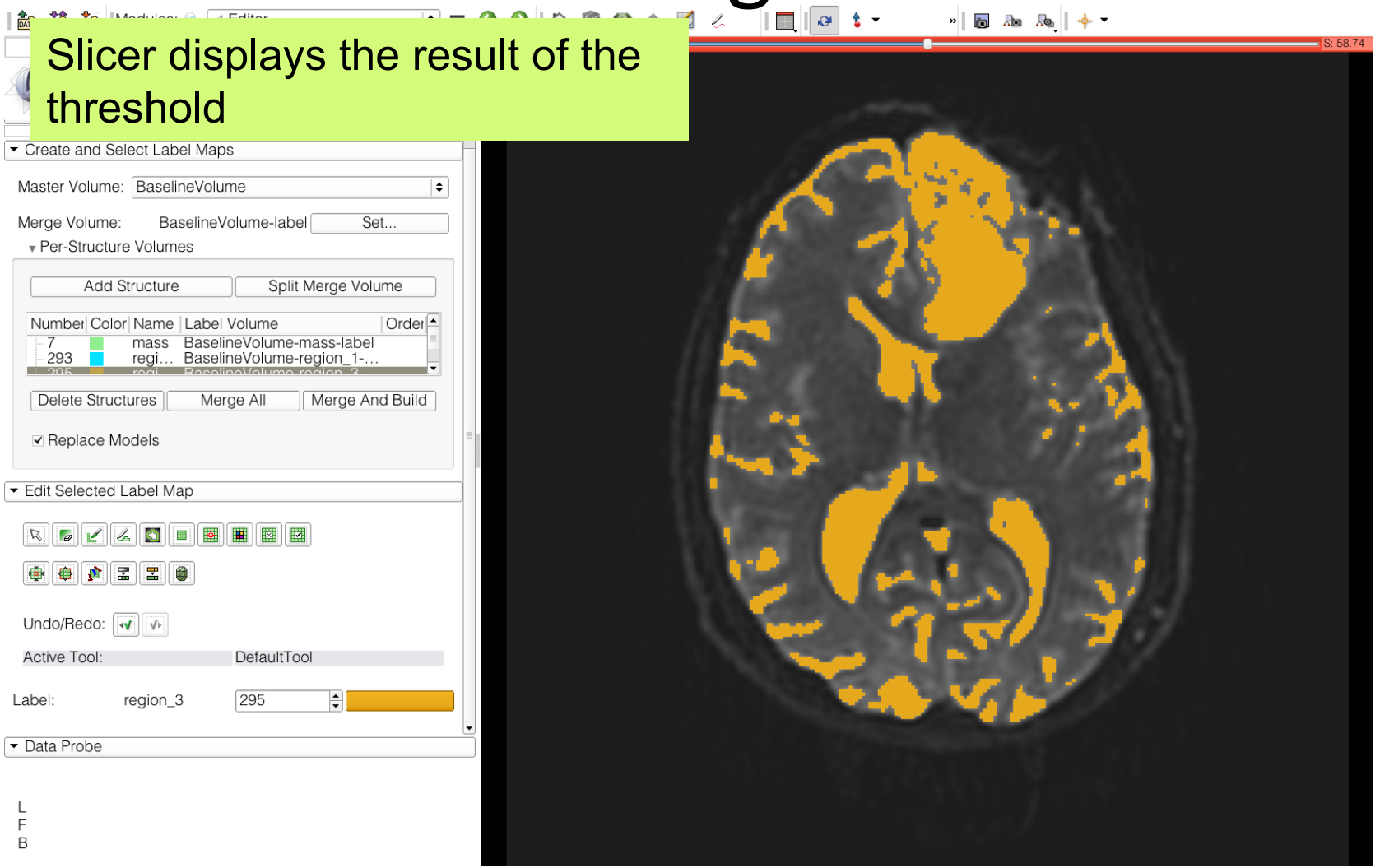
Ventricles Segmentation

Select the volume
'BaselineVolume-region_3-label'



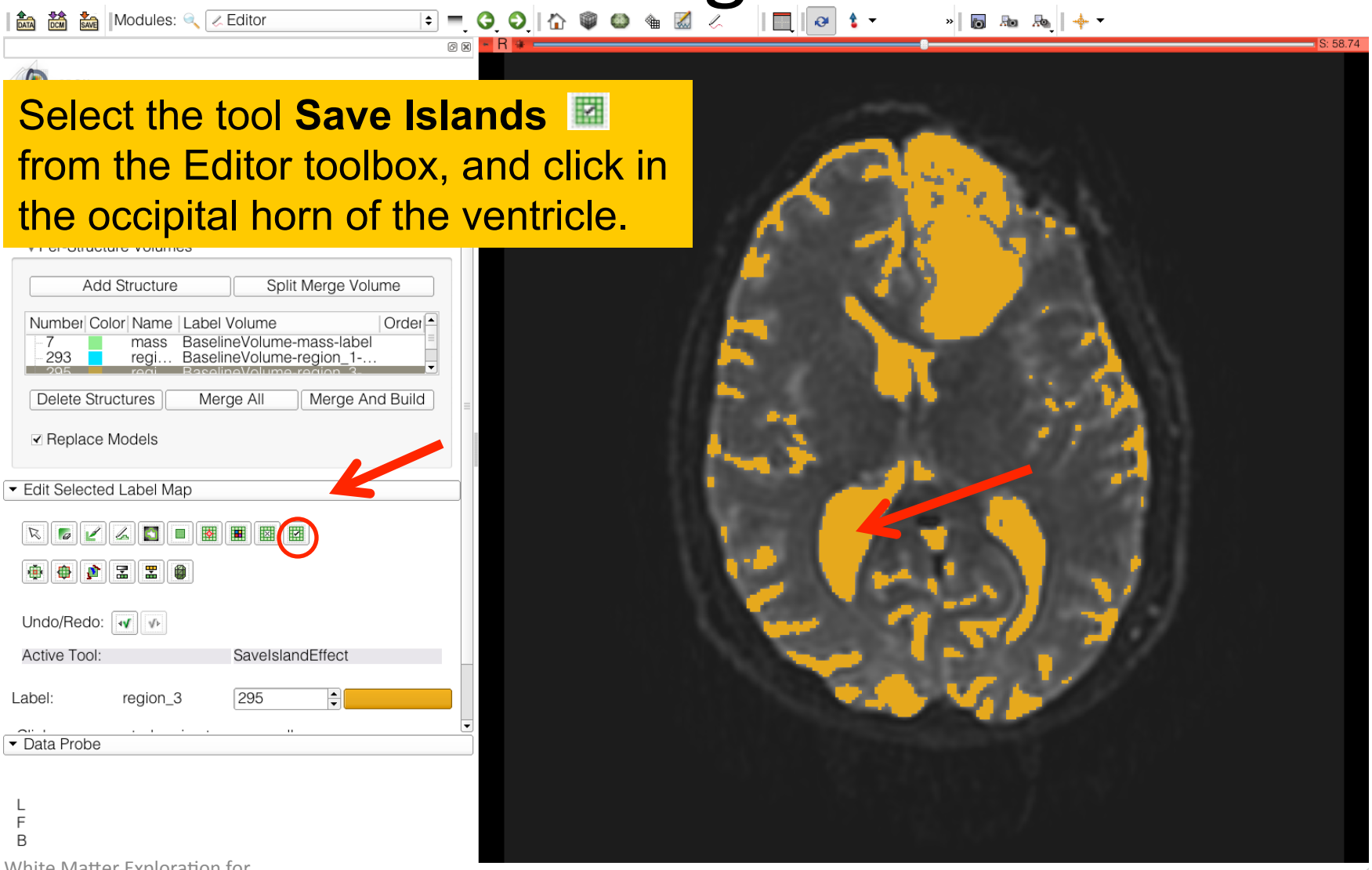
Select the Threshold tool in the Editor toolbox, set the lower threshold to 1700, and click on **Apply**

Ventricles Segmentation

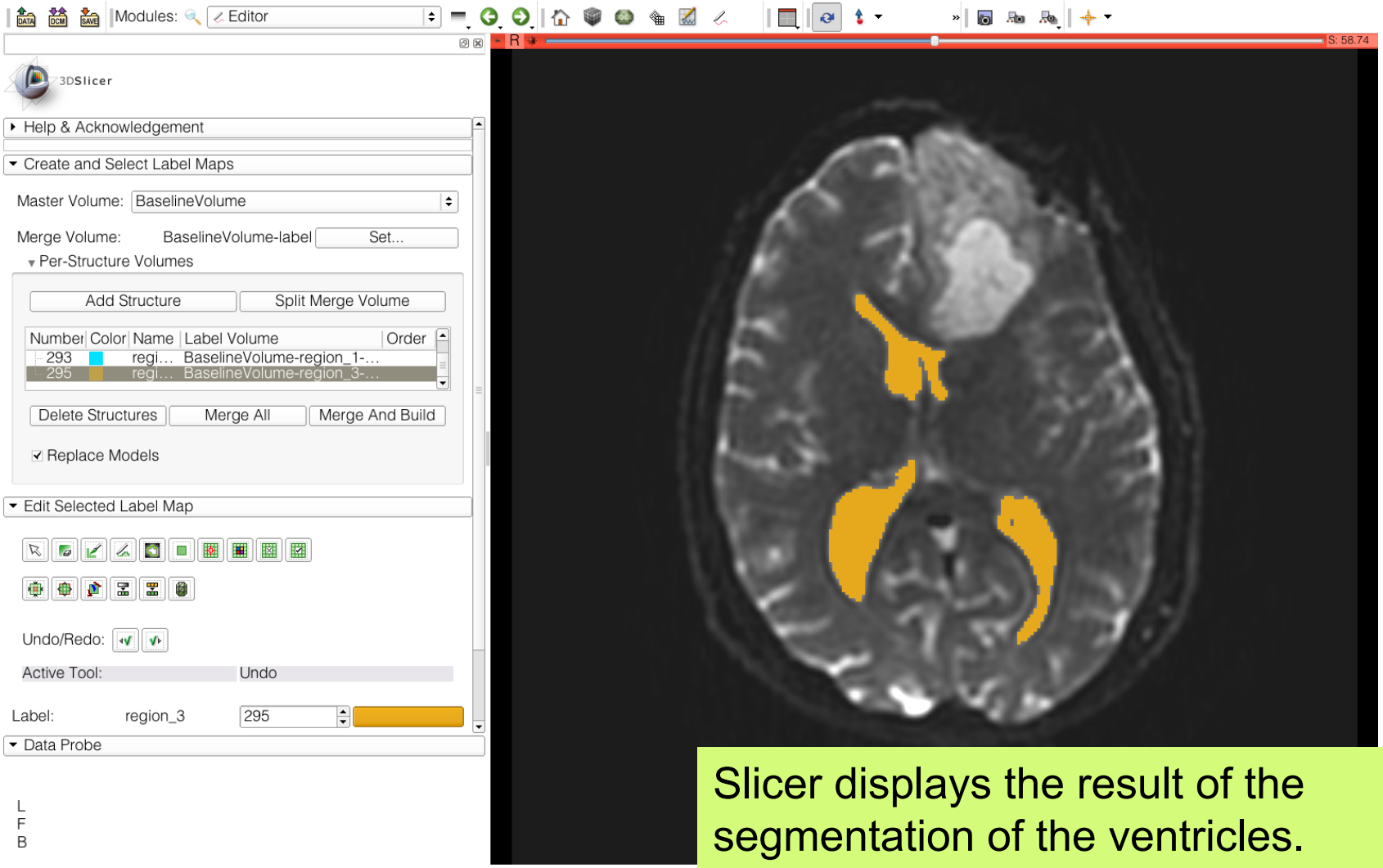


Ventricles Segmentation

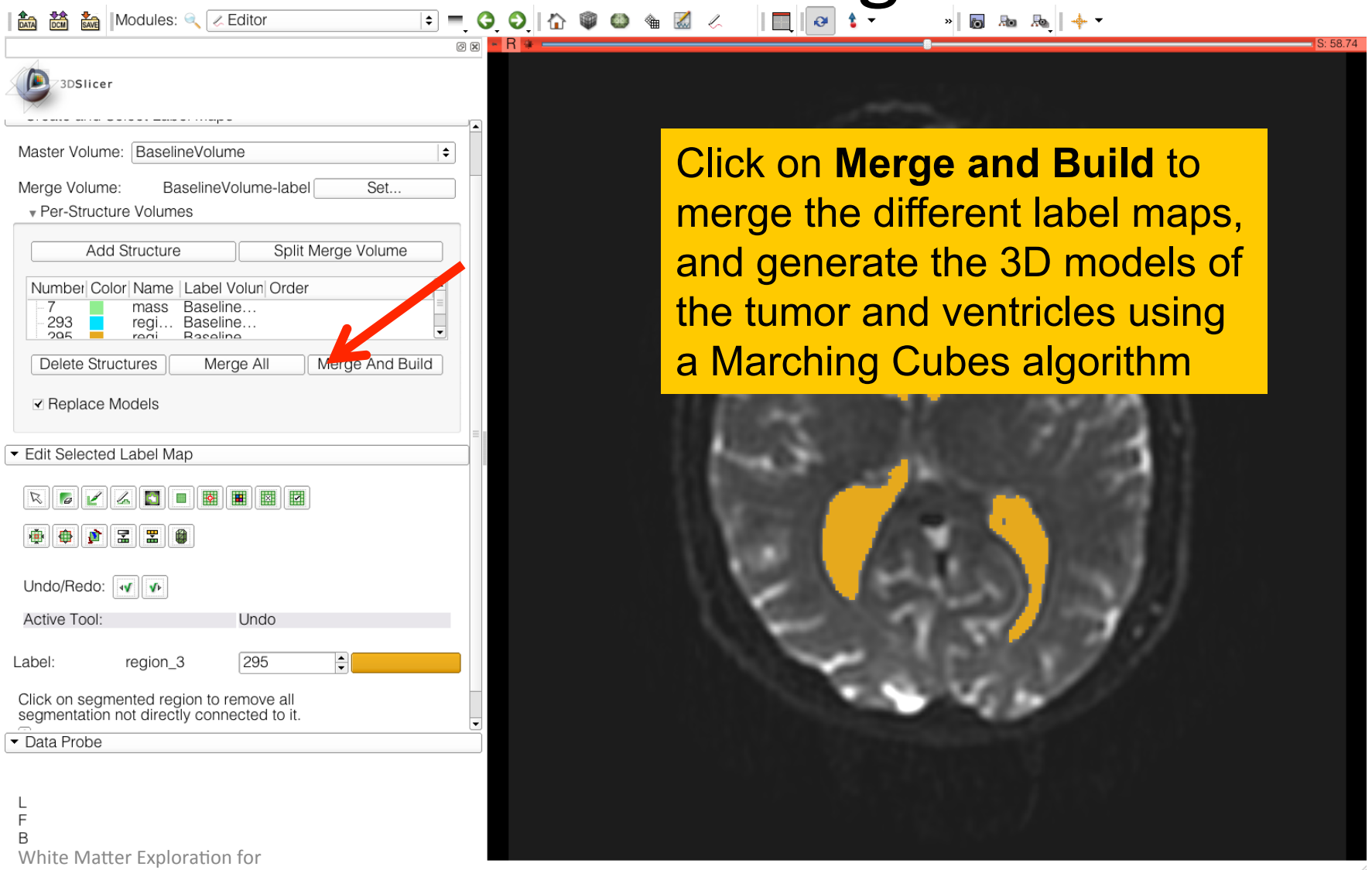
Select the tool **Save Islands** from the Editor toolbox, and click in the occipital horn of the ventricle.



Final Result of the Segmentation



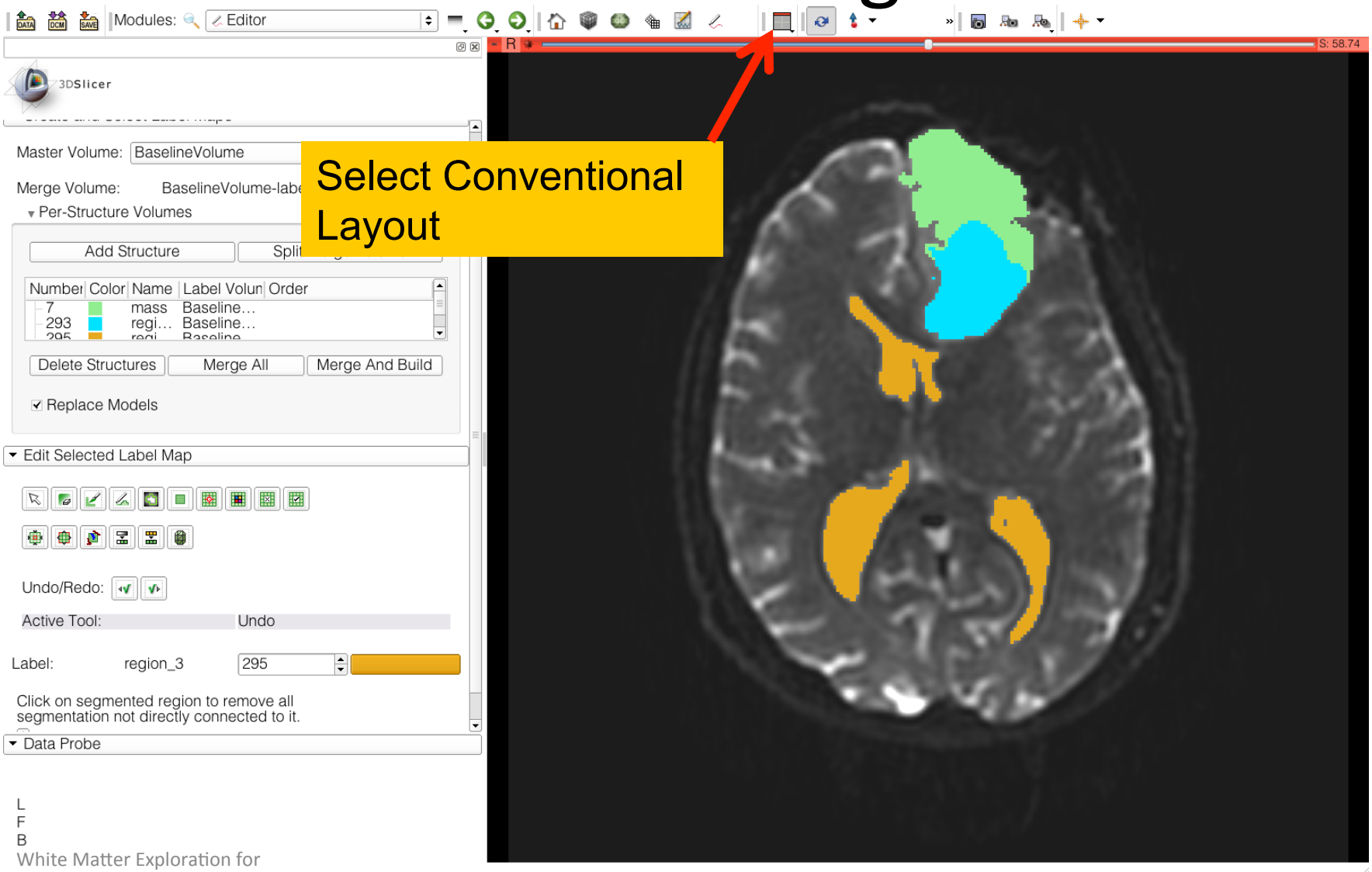
Final Result of the Segmentation



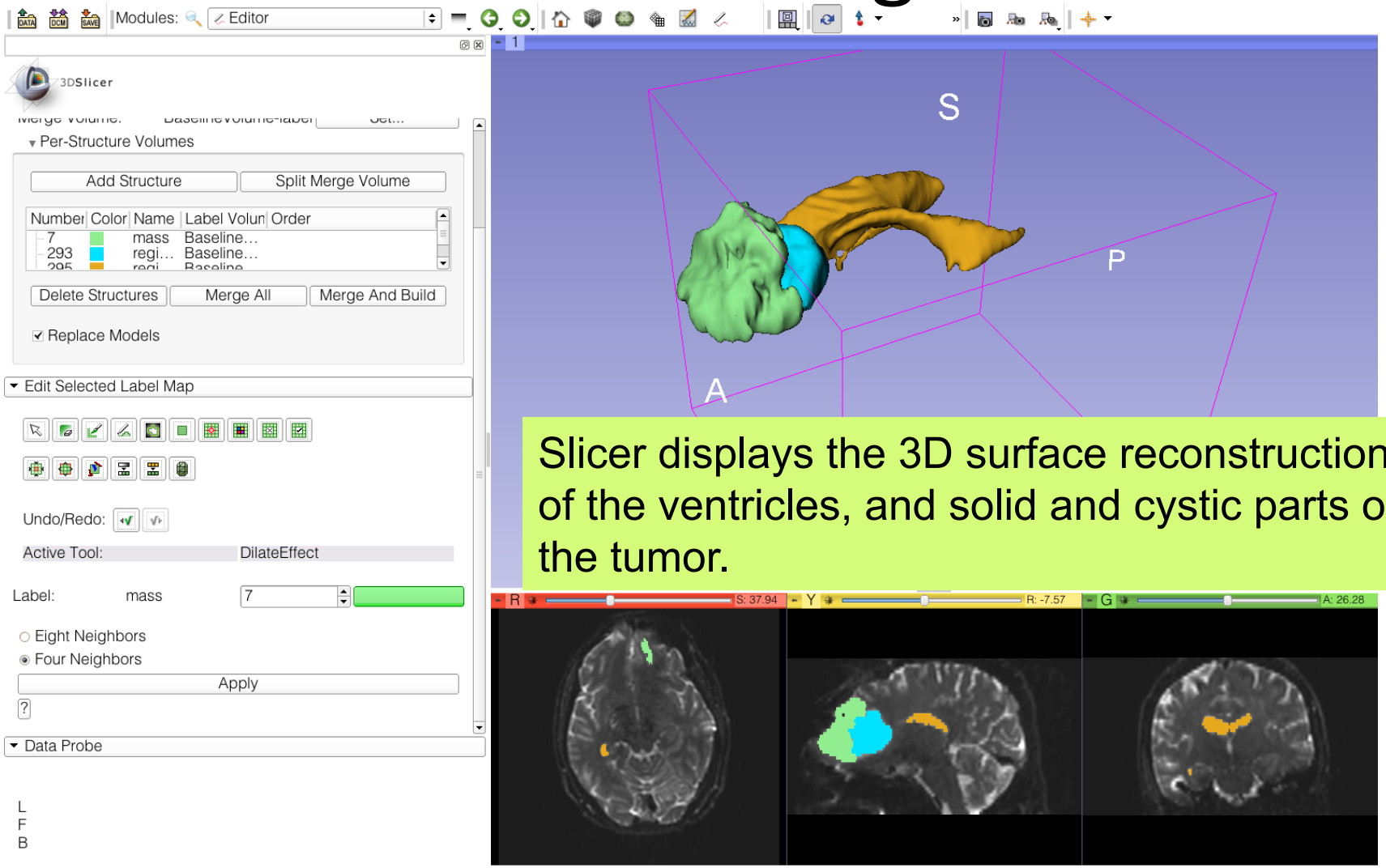
L
F
B

White Matter Exploration for Neurosurgical Planning

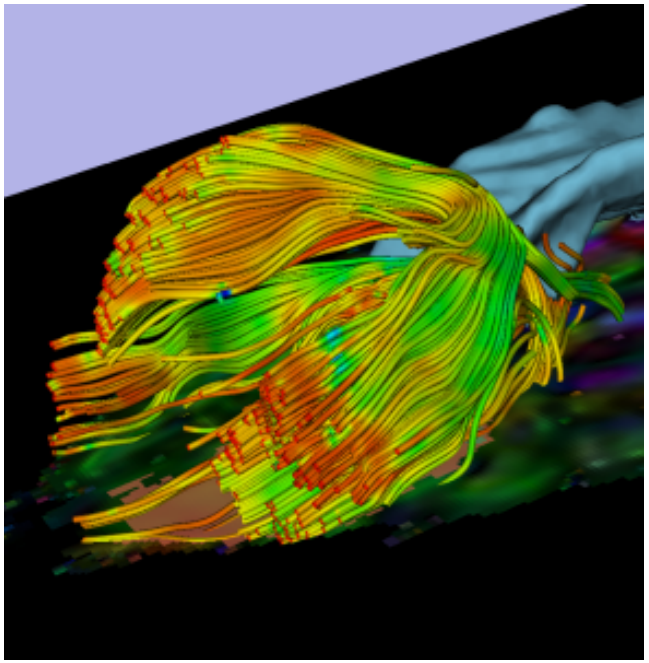
Final Result of the Segmentation



Final Result of the Segmentation

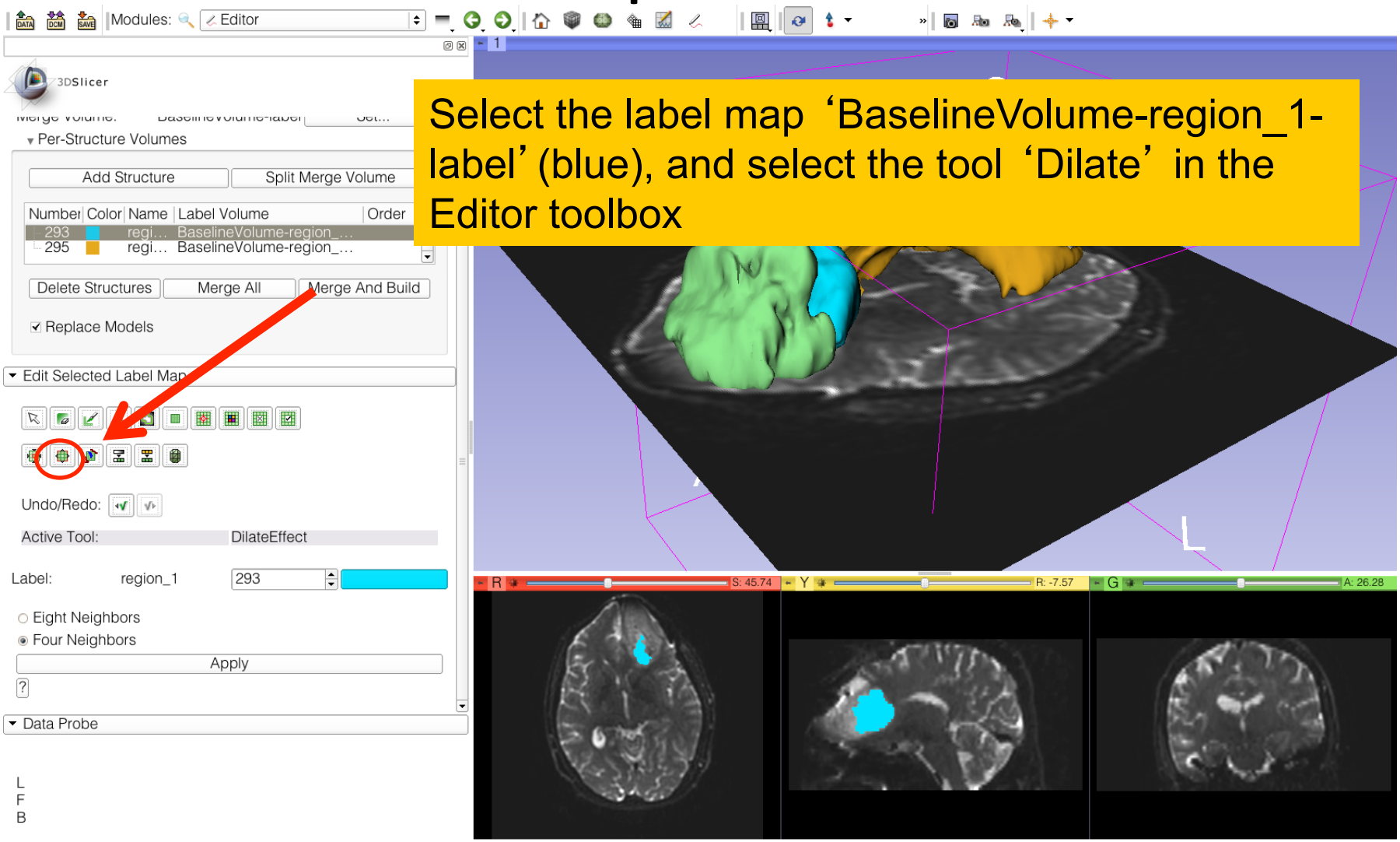


Slicer displays the 3D surface reconstructions of the ventricles, and solid and cystic parts of the tumor.

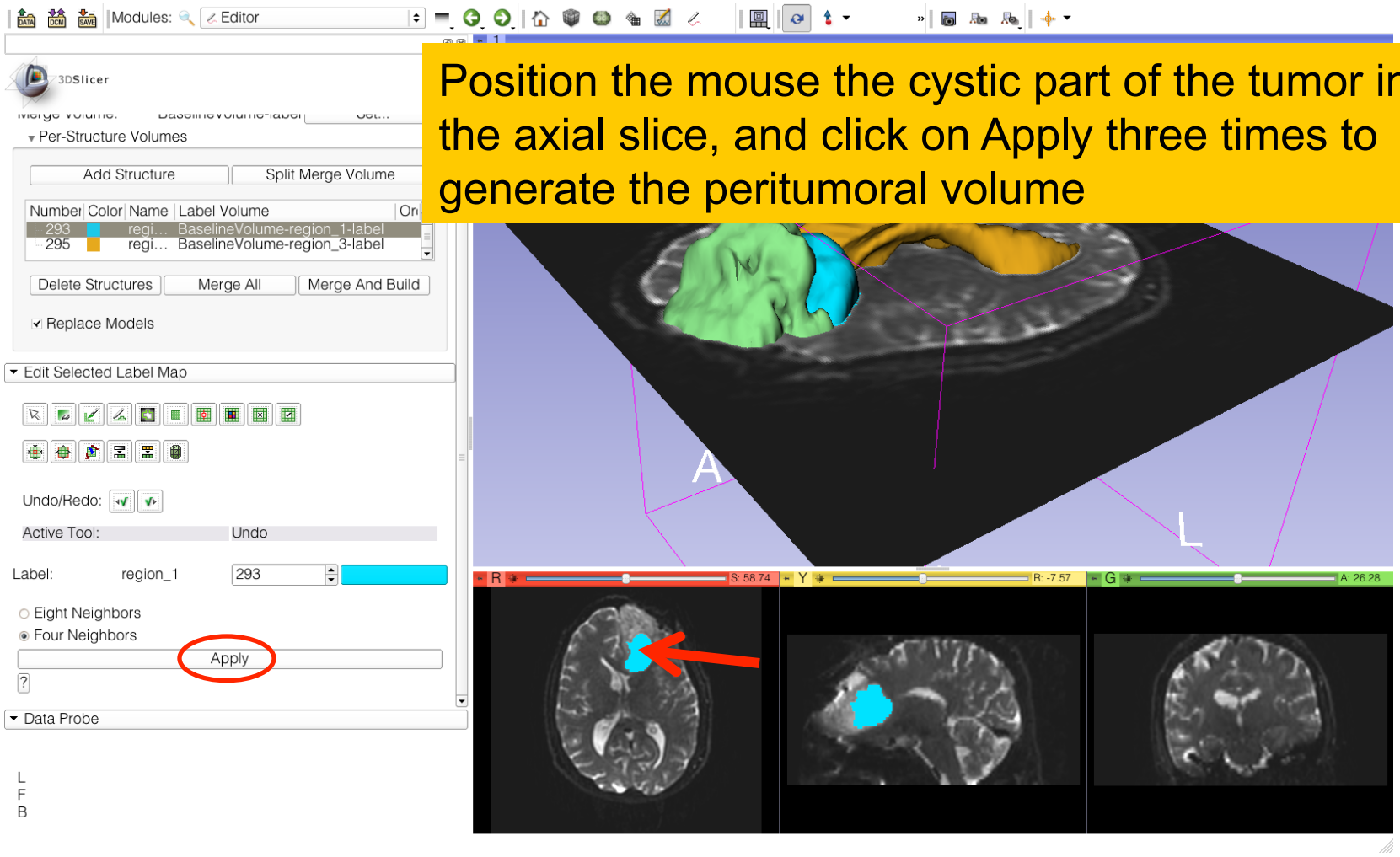


Part 2: Tractography exploration of peri-tumoral white matter fibers

Definition of the peri-tumoral volume

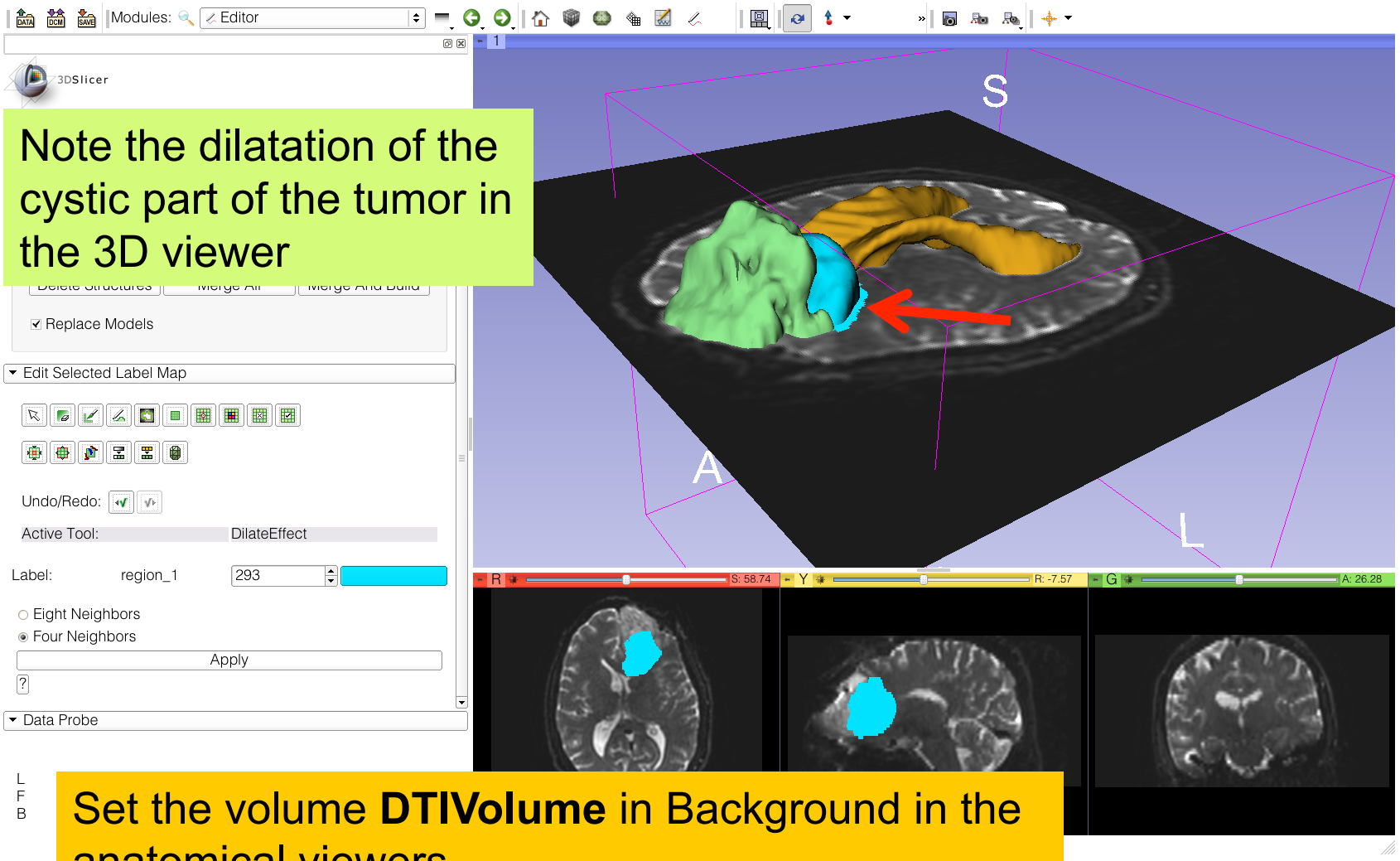


Definition of the peri-tumoral volume



Position the mouse the cystic part of the tumor in the axial slice, and click on Apply three times to generate the peritumoral volume

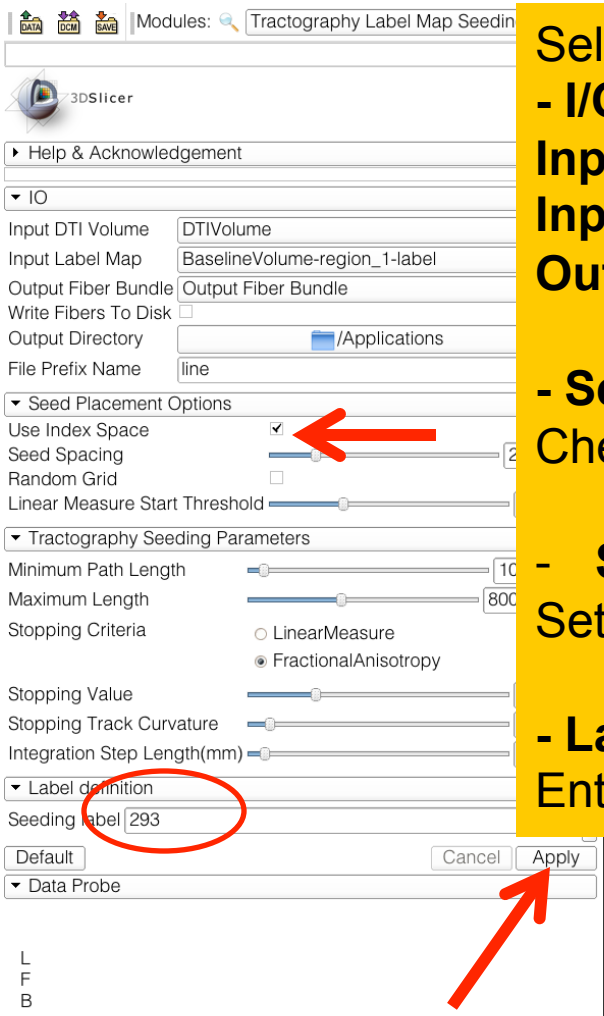
Visualization of the DTI Volume



Note the dilatation of the cystic part of the tumor in the 3D viewer

Set the volume **DTIVolume** in Background in the anatomical viewers

Tractography Parameters



Select the module **Tractography Label Map Seeding** ‘

- I/O: Set the following input and output volume:

Input DTI Volume: DTIVolume

Input Label Map: BaselineVolume-region_1-label

Output Fiber Bundle: Create New

- Seed Placement Options:

Check **Use Index Space**

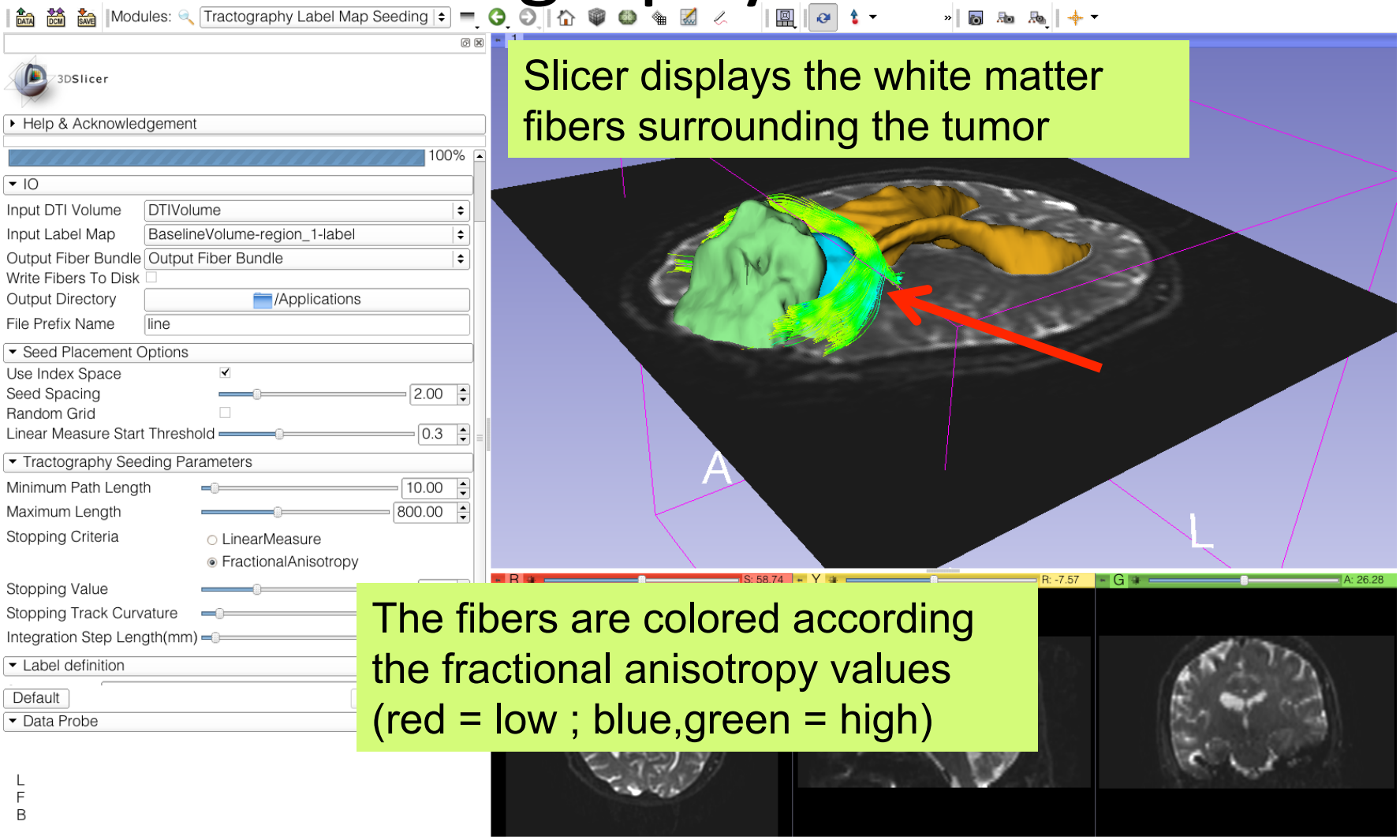
- **Stopping Value**

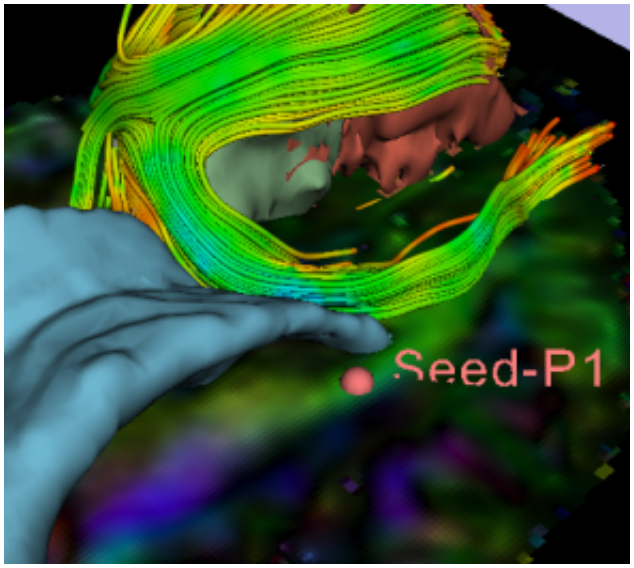
Set the FA threshold to 0.15

- Label Definition:

Enter Seeding Label **293**, and Click on **Apply**

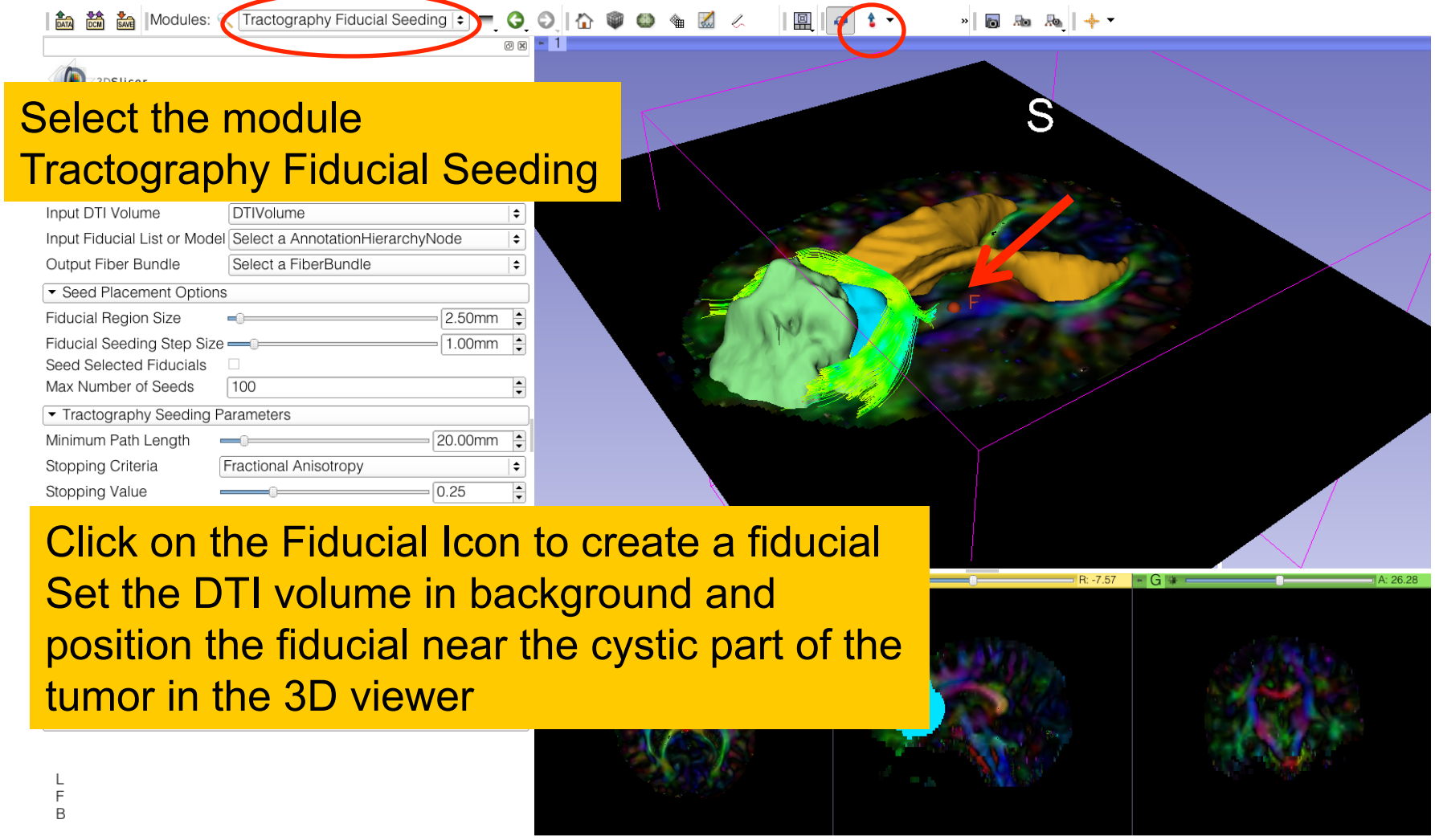
Tractography Results





Part 4: Tractography exploration of the ipsilateral and contralateral side

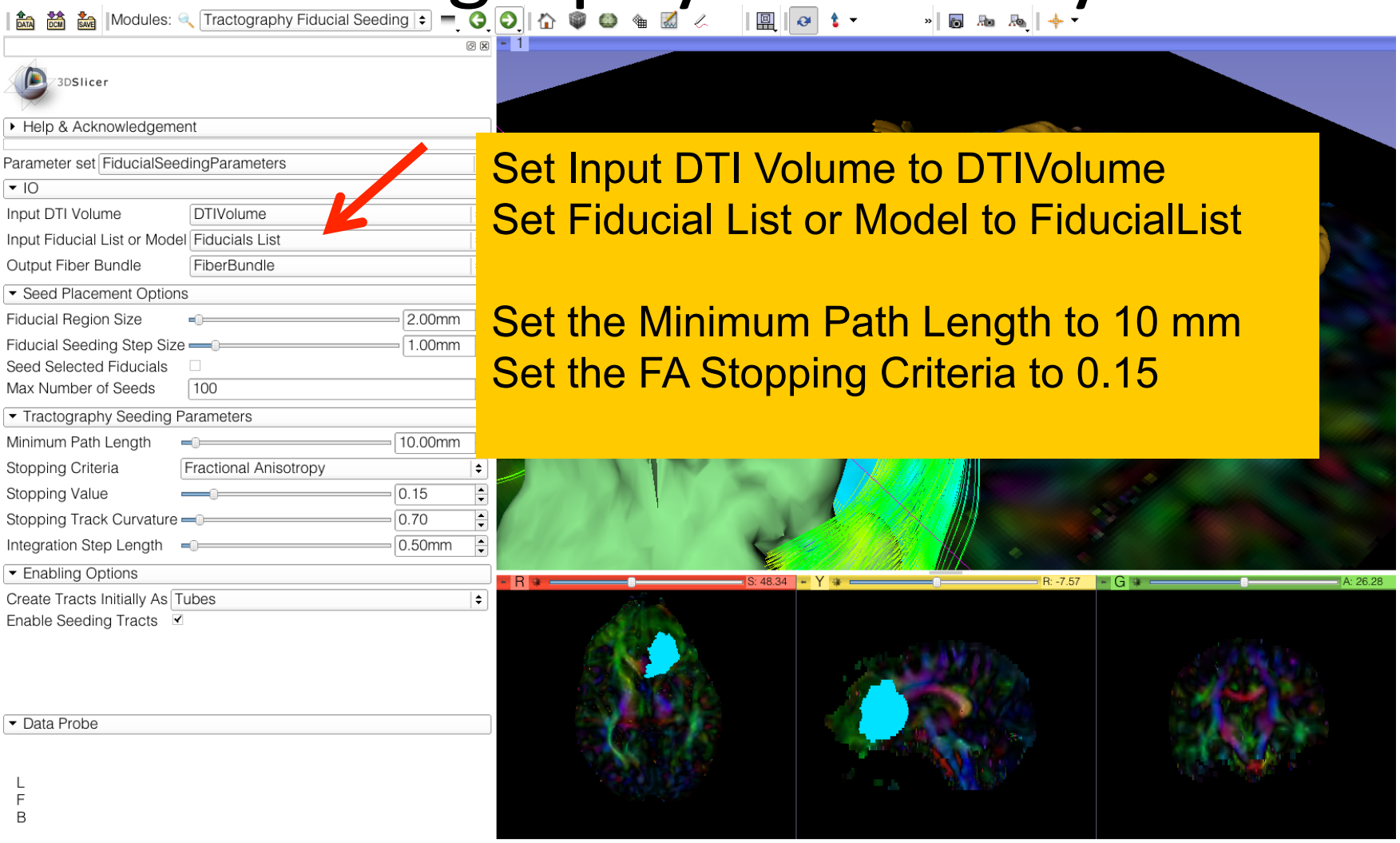
Tractography on-the-fly



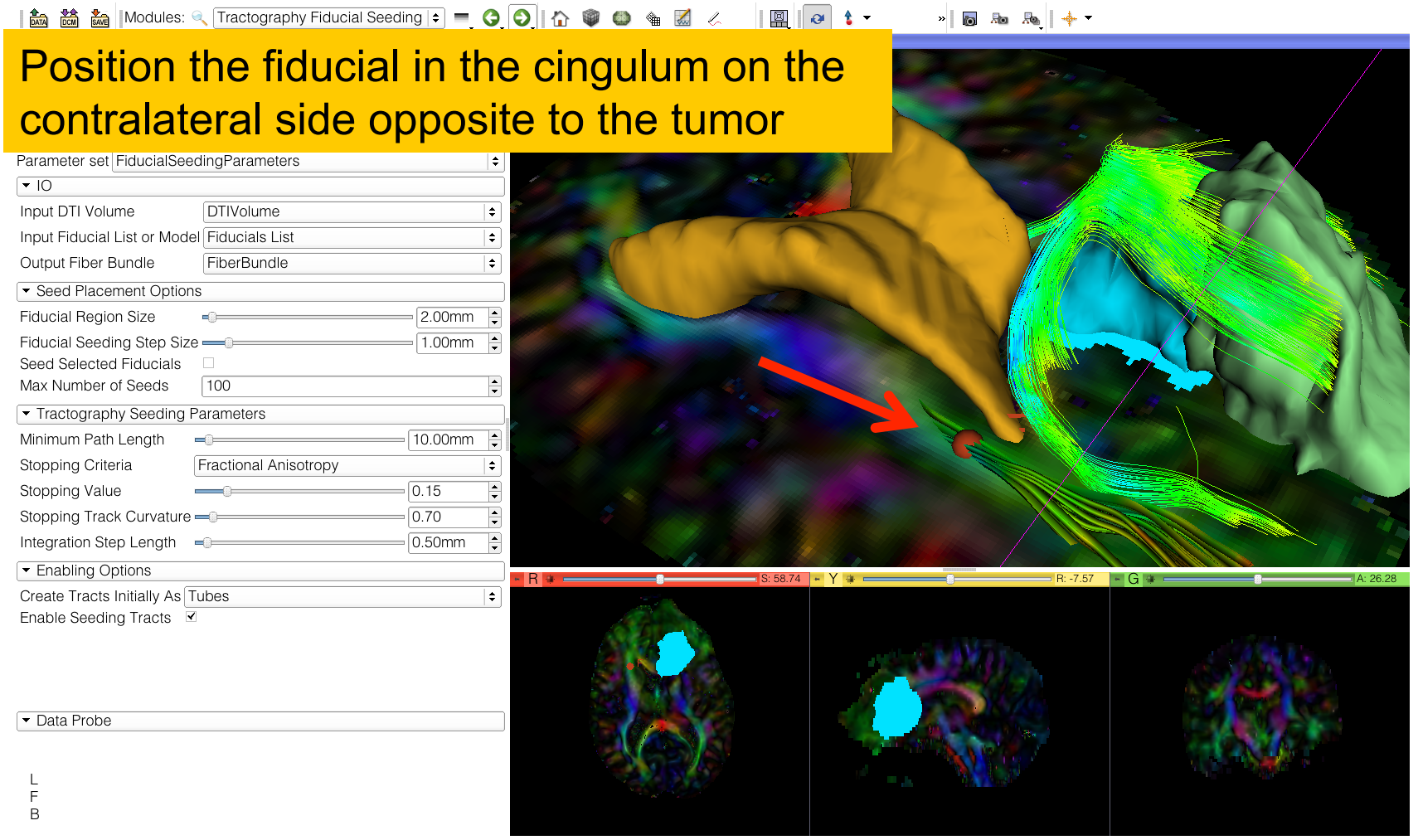
Select the module Tractography Fiducial Seeding

Click on the Fiducial Icon to create a fiducial
Set the DTI volume in background and position the fiducial near the cystic part of the tumor in the 3D viewer

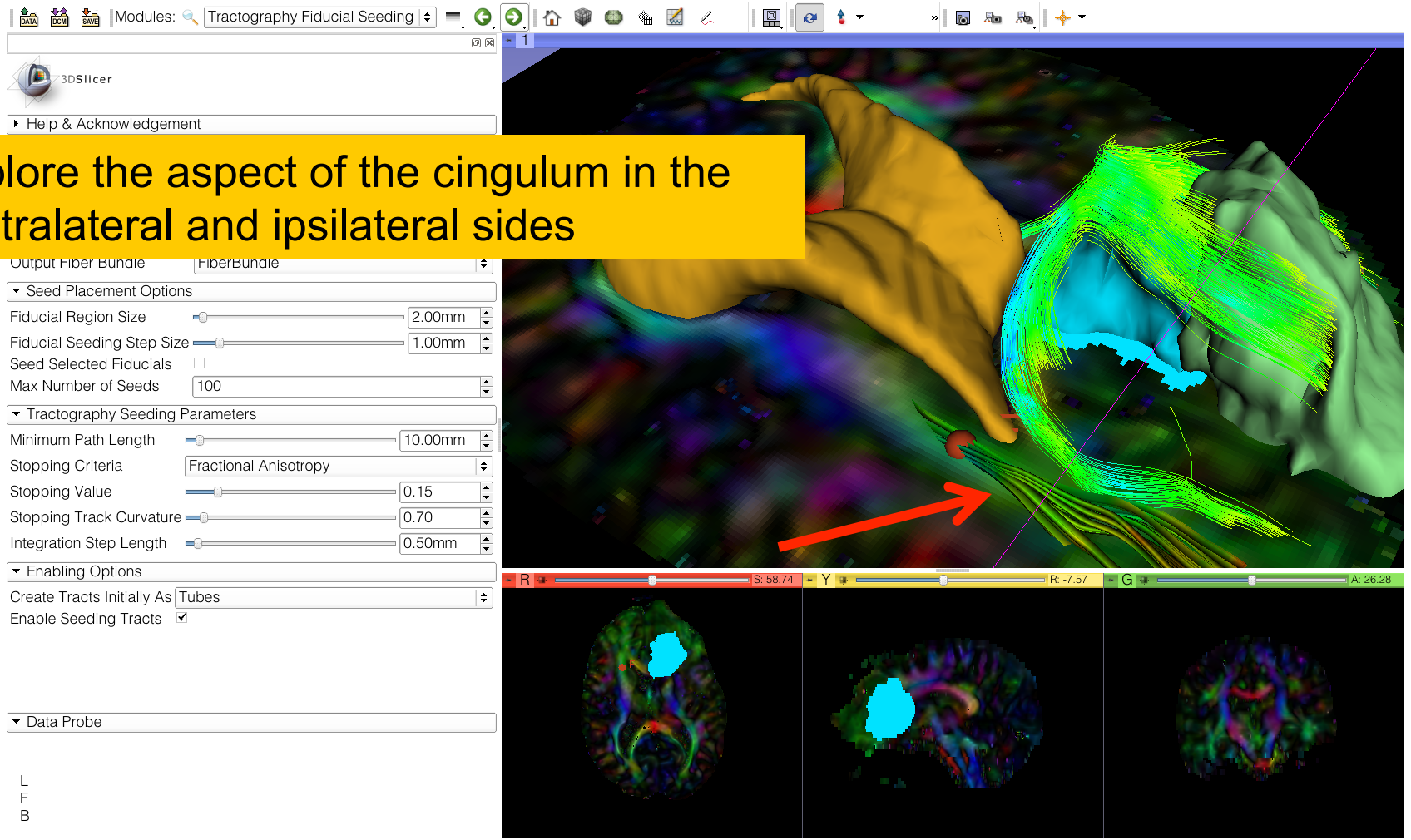
Tractography on-the-fly



Fiducial Seeding



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 (peri-tumoral tracts) for neurosurgical planning

Neurosurgical Planning Workshop,
October 1st, 2012 – Nice, France

DTI Tractography for Neurosurgical Planning: A Grand Challenge

MICCAI 2012 Conference
Acropolis Convention Center
Nice, France
wwww.miccai-org

Acknowledgments

National Alliance for Medical Image Computing (NA-MIC)

NIH U54EB005149

Neuroimage Analysis Center (NAC)

NIH P41RR013218