3D ultrasound tutorial with Slicer 3D and PlusServer

Tutorial written by Aurélie SARCHER, Research Engineer

Aurelie.sarcher@gmail.com

Laboratory 'Motricité, Interactions, Performance' EA4334, Université de Nantes

Laboratoire
Motricité - Interactions - Performance
EA 4334 Nantes - Le Mans

Version dated 07/09/2022

UNIVERSITÉ DE NANTES

Thanks to Antoine Frouin & Hugo Guenanten for the huge help in establishing this tutorial

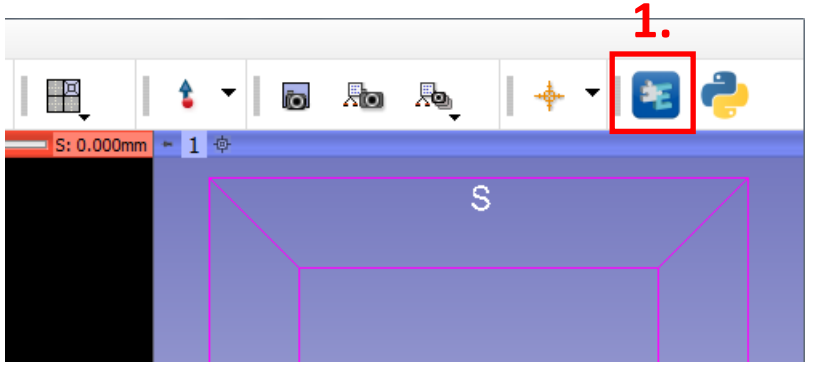
0 INSTALLATION

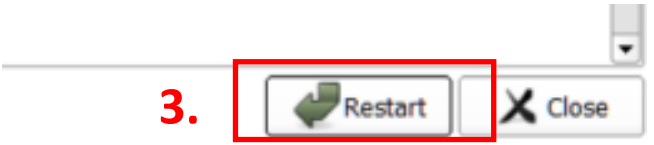
Installation of Slicer

Install Slicer 3d (tutorial tested with version **4.11.0 dated 24/08/2020**)

Installation of Slicer extensions

1. Open the ‘Slicer Extension Manager’
2. Click on ‘Install’ for the following extensions :
   - SlicerOpenIGTLink
   - SlicerIGT
   - SlicerIGSIO
3. Restart Slicer



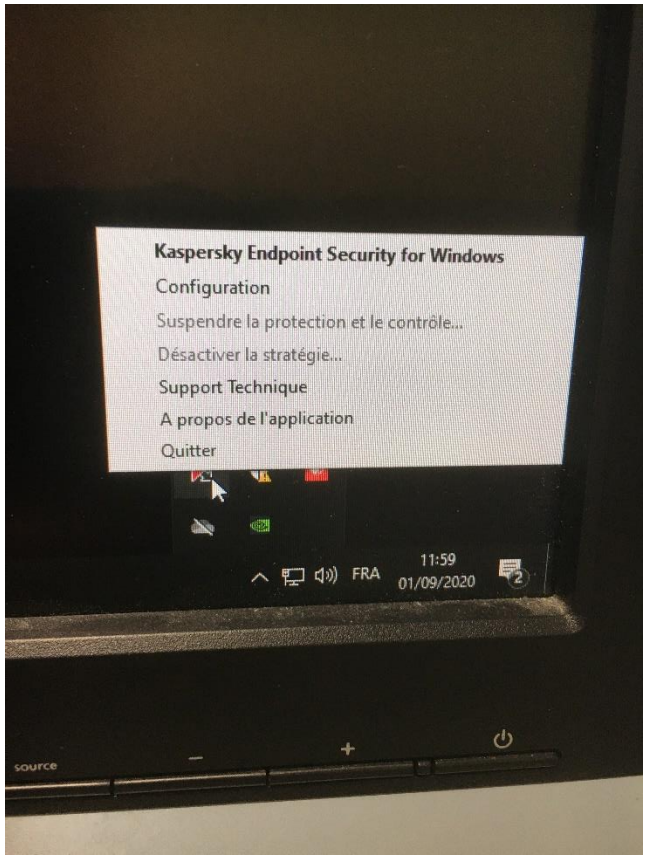


1.1 CAREFUL !

First step before anything

- Quit Kaspersky, which blocks the video streaming of the ultrasound

- Plug the frame grabber CAM LINK 4K and both USB plugs from the Optitrack cameras to USB 3.0 plugs (the blue ones).
- Possible bug linked to the sync RCA cable of the Optihubs: only half the cameras are recognized or instead of begin numbered from 1 to 11, the cameras are numbered with duplicate numbers (1-1, 2-2, 3-3, etc.). If this is the case, try adjusting the RCA cable.



1.2 OPTITRACK CALIBRATION

When to do it ?

- If the cameras have been moved …
- Recommendation : do it everytime

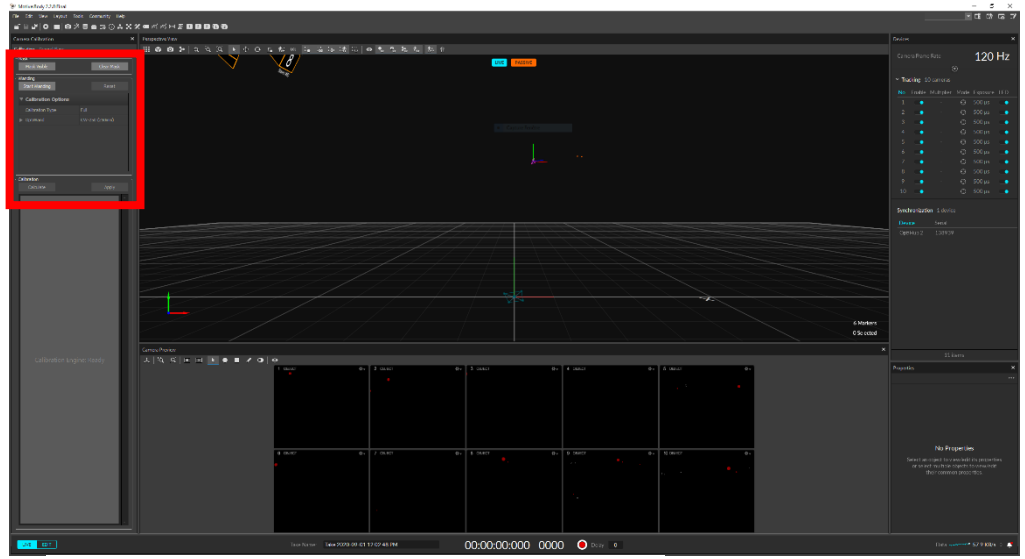
I have already calibrated the Optitrack system ?

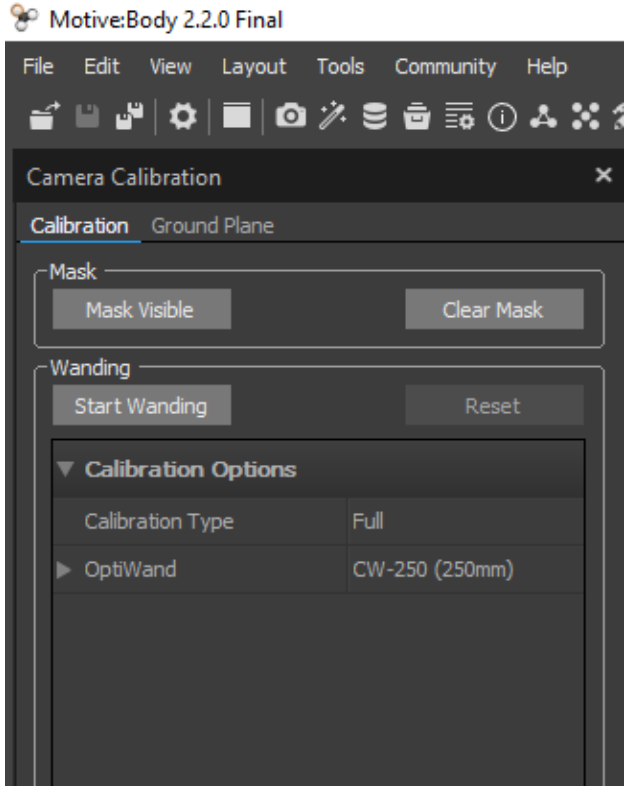
- Load the calibration into Motive and
- **Go to Slide 11**

OPTITRACK –MOTIVE SOFTWARE

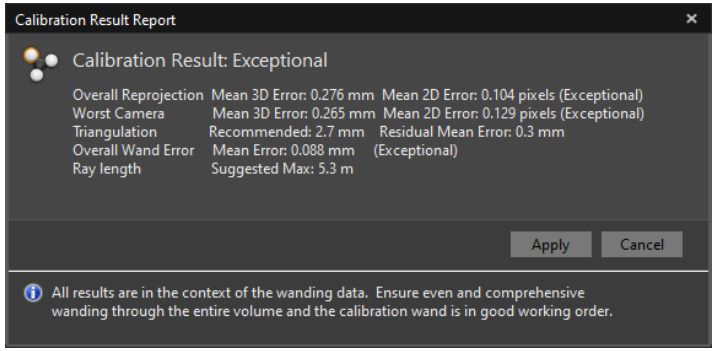
- Prepare the cameras and the capture volume
- Start Motive software with the USB key ‘ACQ’

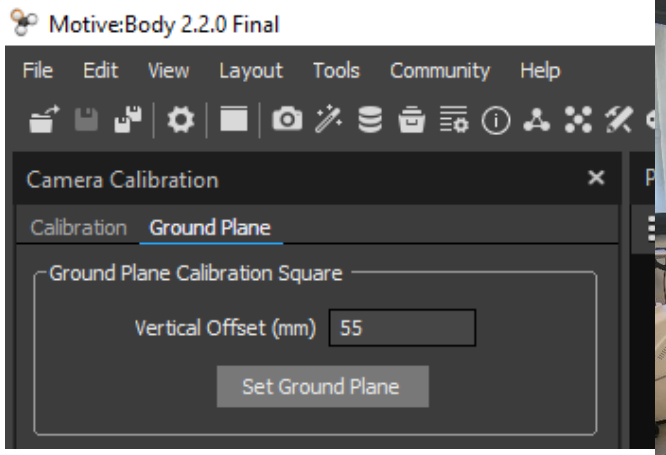
- Choose ‘Perform camera calibration’
- Set the camera settings :
  - Exposure : 200 microseconds
  - Threshold : 250
- Add a folder ‘File’ → ‘add session folder’ and create a new session folder.
- (Verify that no asset is present in the tab ‘Layout’ → ‘Capture’. If assets are presents in the upper left part of the window, delete them.)
- In the tab ‘layout’ → ‘calibration’
- Verify that the optiwand is set as ‘CW-250 (250mm)’
- Verify that the capture volume is empty of markers.
- Click on ‘clear mask’ to remove the existing mask.
- Click on ‘mask visible’ to create a camera mask (suppression of the pixels visible by the cameras).





- Click on ‘start wanding’ to perform the dynamic calibration of the cameras. Once the number of points is reached, click on ‘calculate’, and then ‘apply’ if the calibration is acceptable. Save the calibration into the session folder.
- The tab ‘ground plane’ opens automatically, click on ‘set ground plane’ after putting the reference wand on the ground (not the calibration wand).
- Then, put away the 2 wands.





CASE n°1 : CALIBRATION OF THE ULTRASOUND PROBE TRACKER

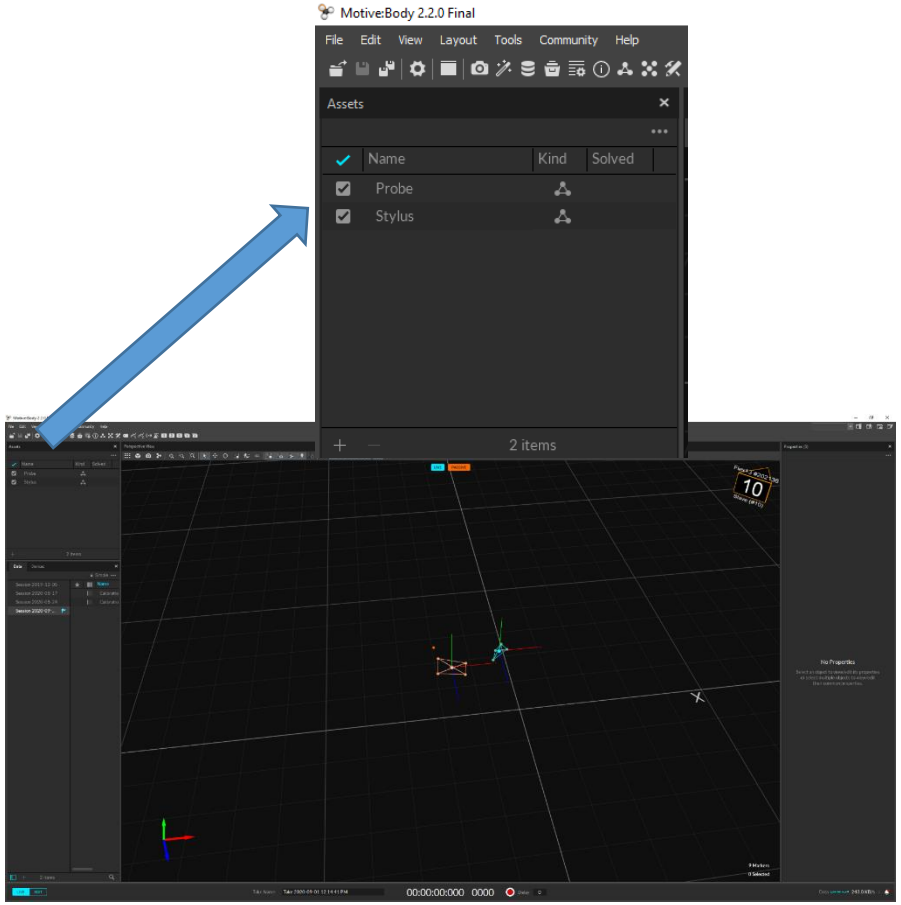
→ If the probe tracker has been moved
→ If some settings of the ultrasound (like depth) have been modified

CAS n°2 : DIRECT ACQUISITION WITHOUT RECALIBRATION OF THE ULTRASOUND PROBE TRACKER

- Click on ‘layout’ → ‘capture’
- Place the **ultrasound probe and the stylus** in the volume capture.
- If a rigid body already appears in the ‘asset’ tab, remove it.

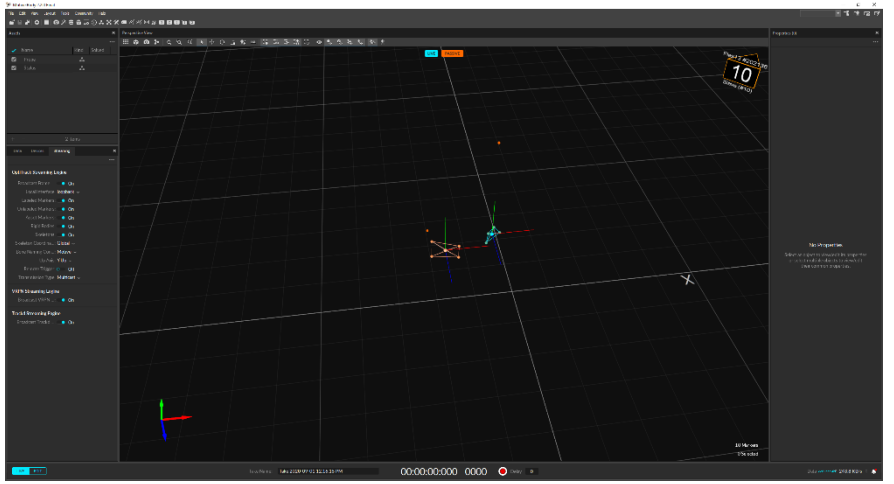
- Click on ‘layout’ → ‘capture’
- Place the **ultrasound probe** in the volume capture.
- If a rigid body already appears in the ‘asset’ tab, remove it.

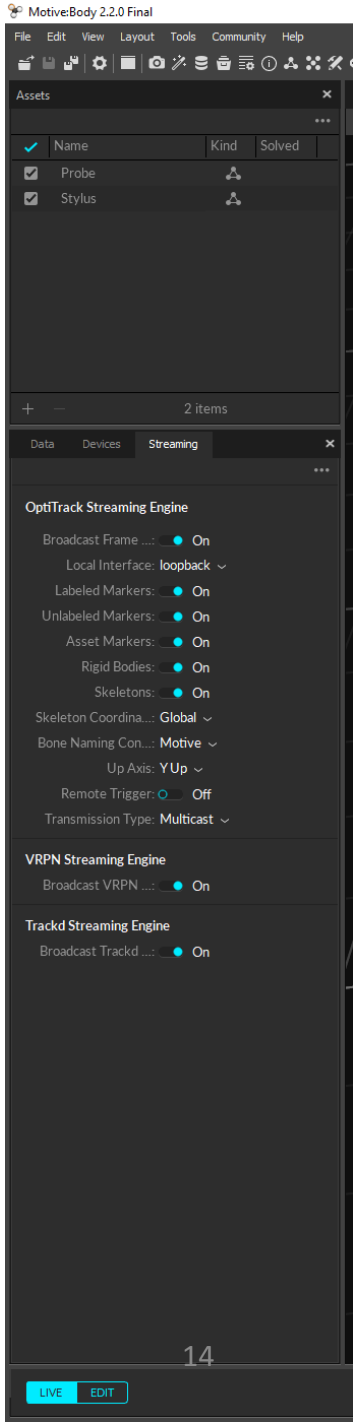
- Load into Motive **both rigid body ‘Probe.motive’ and ‘Stylus.motive’** located in the folder ‘C:/Users/Labo MIP/PlusApp-2.8.0.20191105-Win64/config’ (select them in Explorer and move them in the ‘Assets’ window)
- **The probe and the stylus** are normally automatically recognised as the rigidbody (move them and visualise the result in the 3D window of Motive).



- Load into Motive **the rigid body ‘Probe.motive’** located in the folder ‘C:/Users/Labo MIP/PlusApp-2.8.0.20191105-Win64/config’ (select it in Explorer and move it in the ‘Assets’ window)
- **The probe** is normally automatically recognised as the rigidbody (move it and visualise the result in the 3D window of Motive).

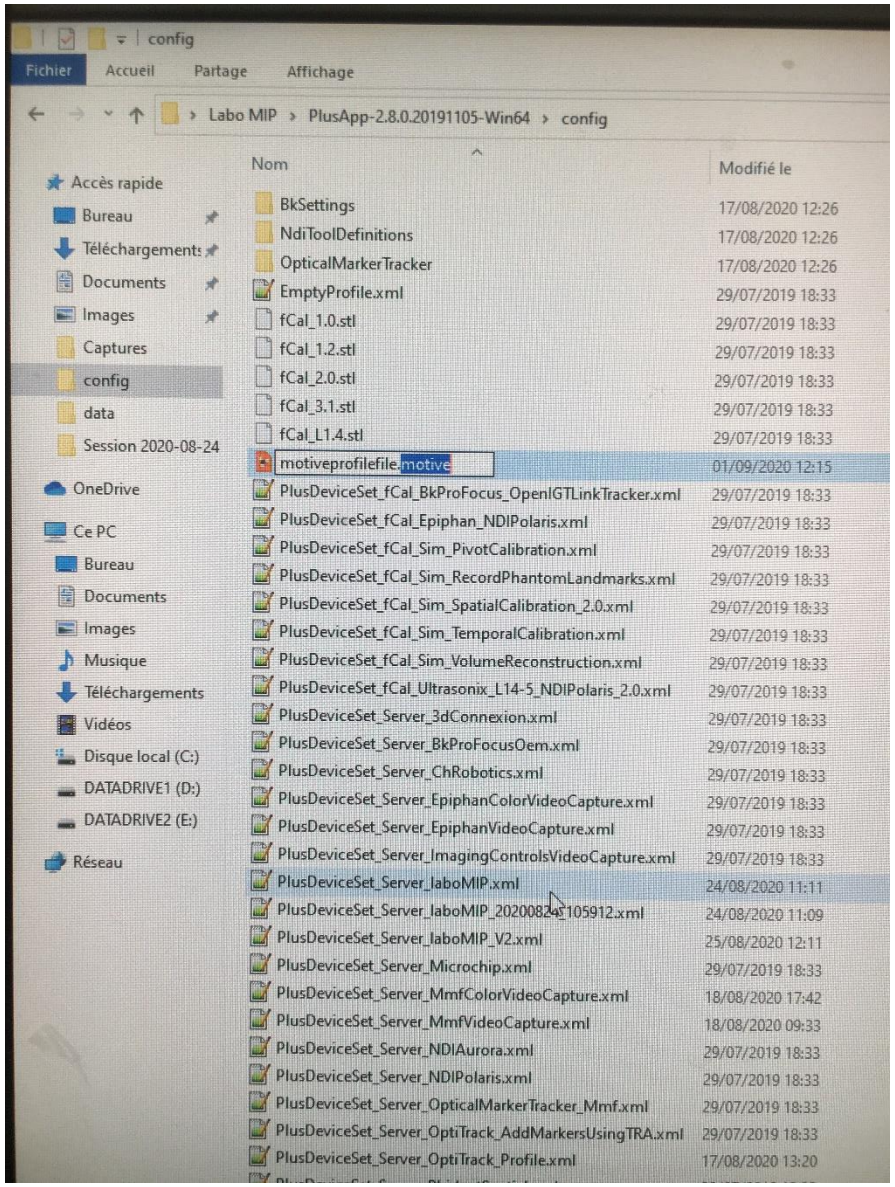
- Click on ‘file’ → ‘export profile file as’ and save the file in ‘C:/Users/Labo MIP/PlusApp-2.8.0.20191105-Win64/config’ by renaming it ‘motiveprofilefile’.
- Click on « View » → « Data Streaming Pane », then verify that « Broadcast Frame Data » is set to ‘ON’.
- **DO NOT QUIT MOTIVE.**





Windows explorer

- Rename the newly created file « motiveprofilefile.motive » as « motiveprofilefile.xml »



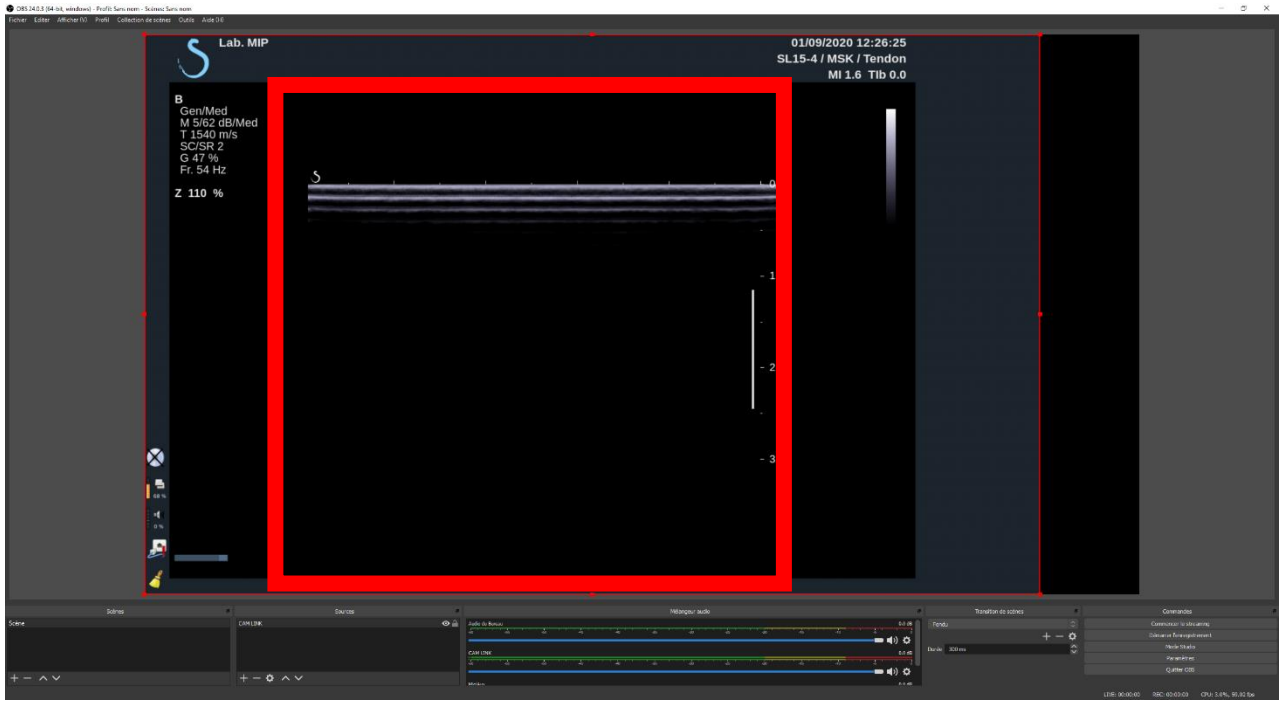
2. ULTRASOUND VIDEO

SuperShearing Imaging ultrasound

- Start the ultrasound
- For our setup, we use a video splitter in order to have the video signal both on the computer, through the video acquisition box (HDMI → USB), and on the screen of the ultrasound.

OBS software

- Start OBS
- Verify that the video signal is OK (all is already set up in the config file)
- Set the parameters of the ultrasound and of the probe and verify that the ultrasound image is well included in the limits in red (text from the ultrasound must not be in the limits).
- **QUIT OBS**



3. TEMPORAL CALIBRATION

What is its use ?

- To calculate the temporal offset between the tracking from Optitrack and the video stream from the ultrasound.

When to do it ?

- If different motion capture system
- If different video stream device
- If different ultrasound

I don’t need to perform the temporal calibration ?

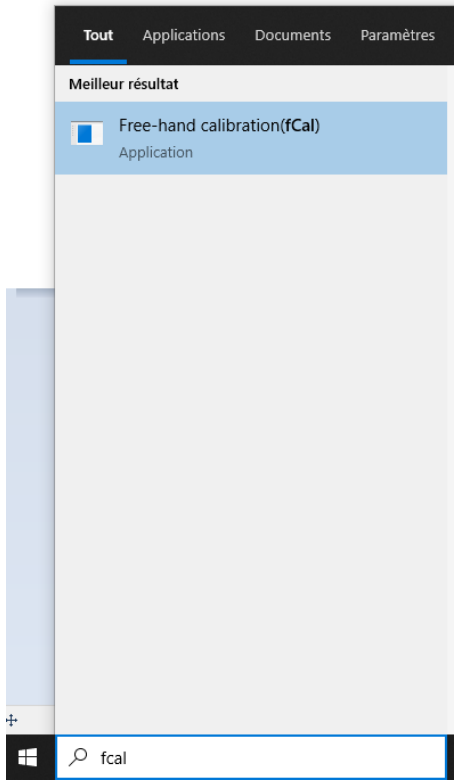
- **Go to Slide 24**

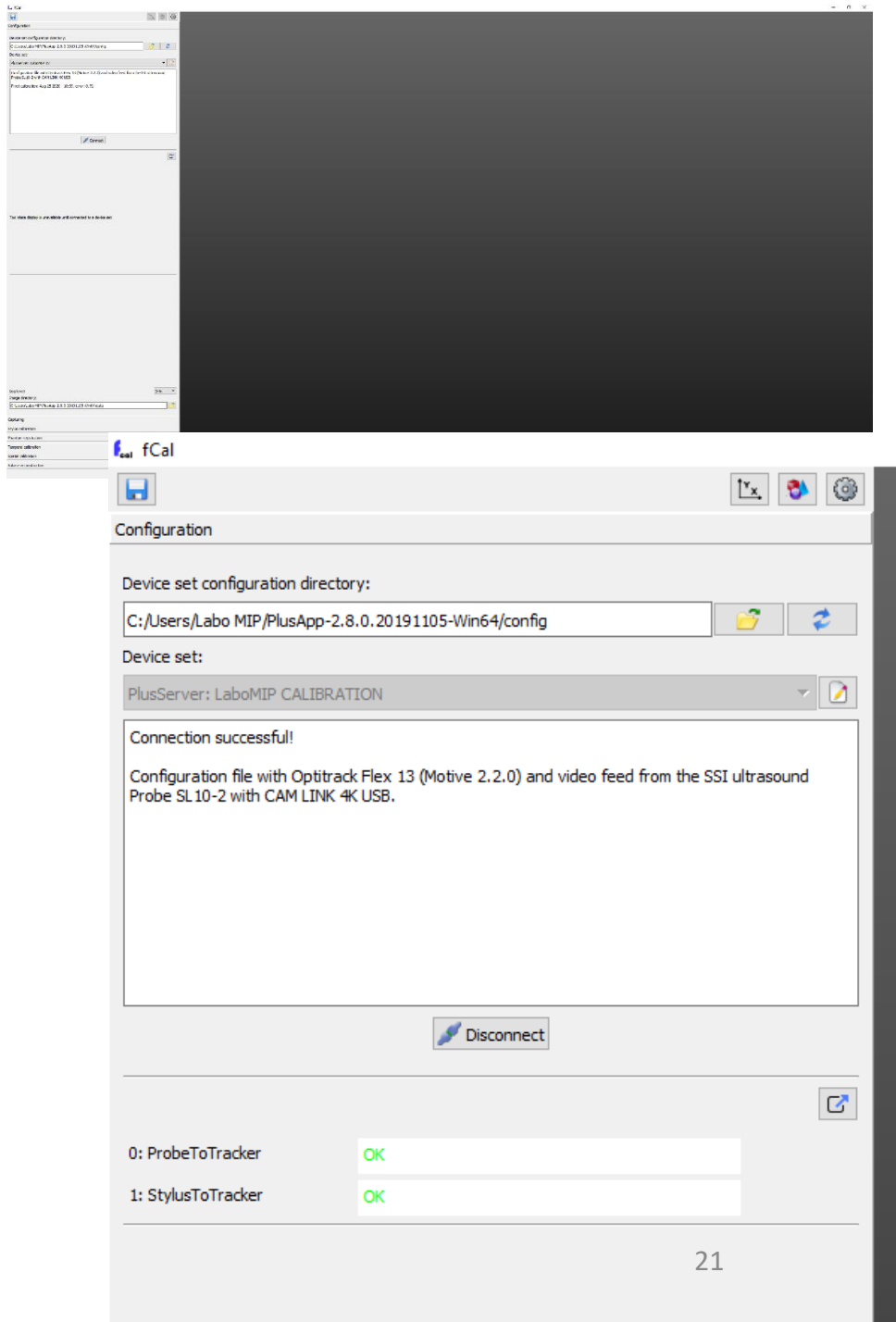
FCAL Software

- Start FCAL
- Select the config file

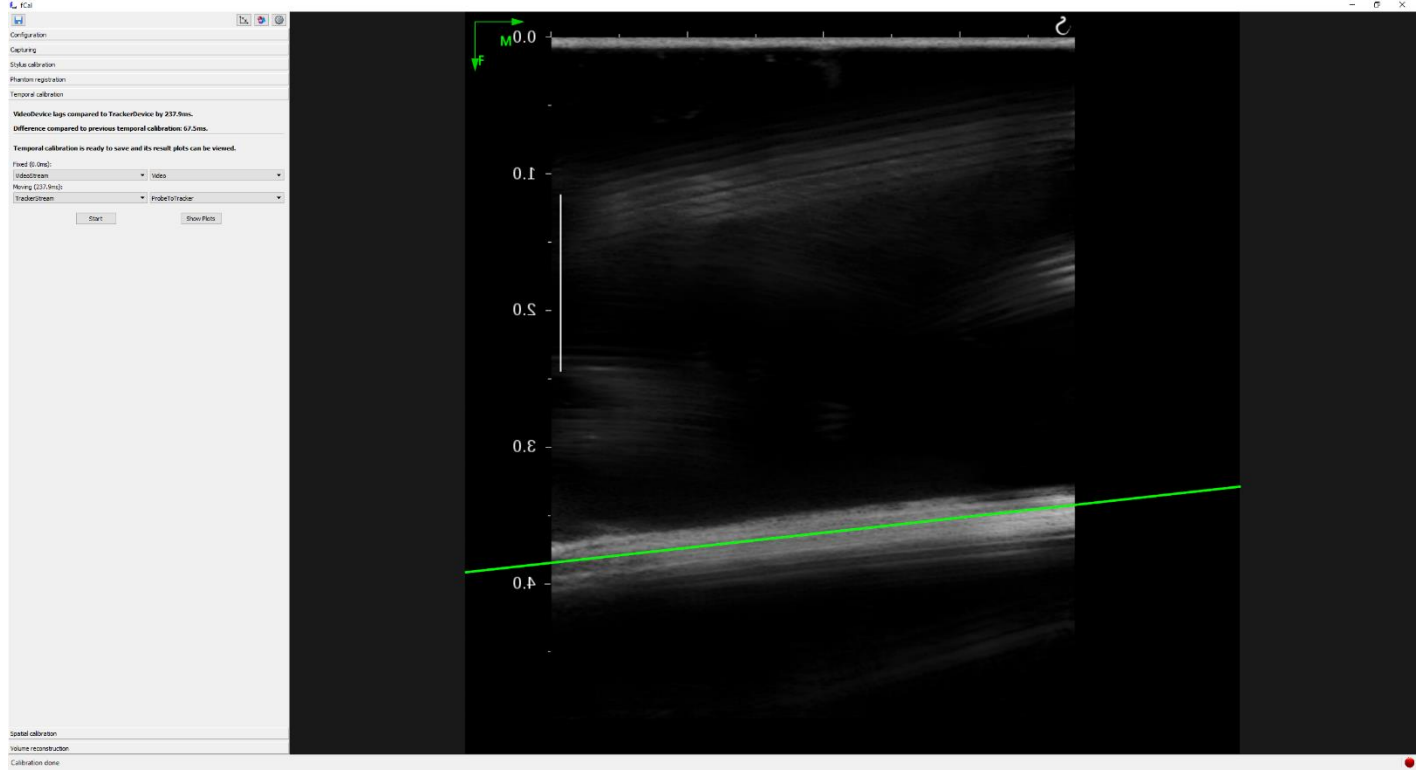
‘PlusServer : LaboMIP **CALIBRATION**’.

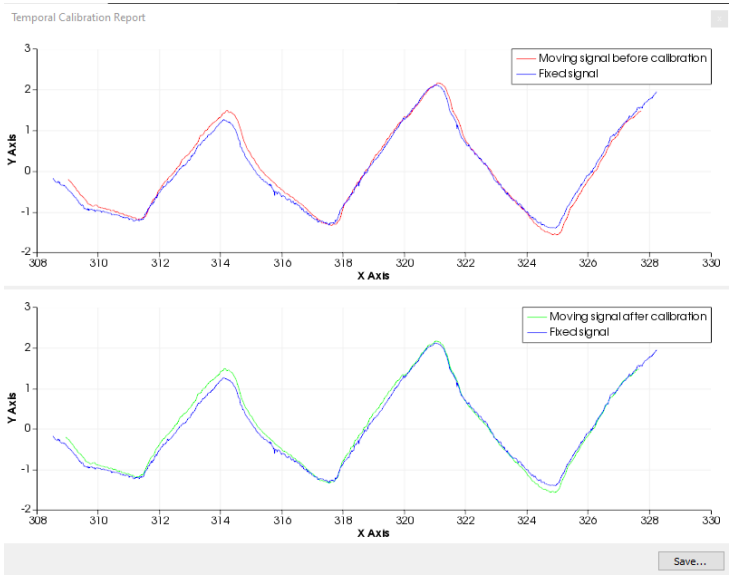
- Click on ‘connect’
- Both signals must be ‘OK’ : ProbeToTracker, StylusToTracker.





- Go to the tab ‘temporal calibration’
- Bring the basin of water in the center of the camera volume. Wait for the water to stabilize in the basin.
- Click on ‘start’.
- Rapidly and before the calibration starts, do a periodic movement from top to bottom with the ultrasound probe kept vertical in the water.
- Click on ‘show plots’ to check the quality of the calibration : the initial offset between the signals must be cancelled.

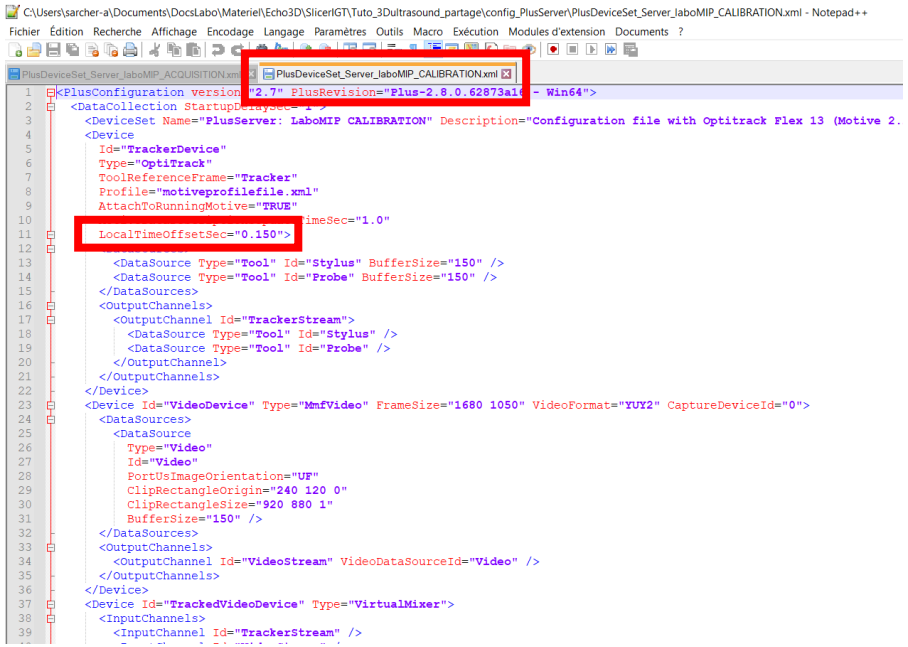


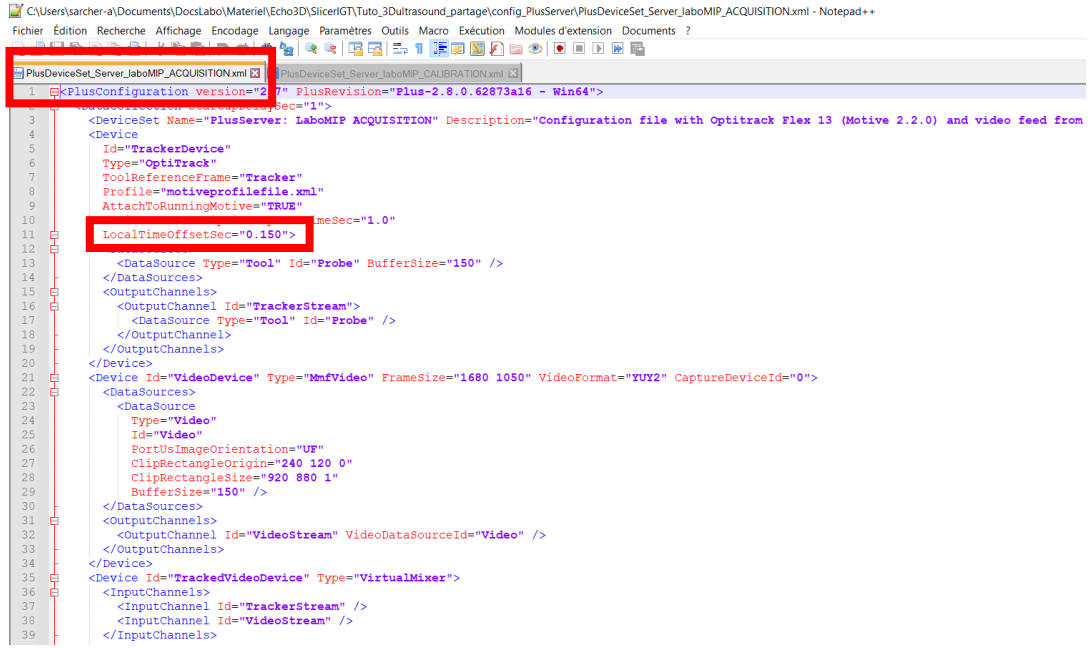


VIDEO

- Note the value obtained following temporal calibration, for example : ‘150ms’
- In windows explorer, open the files

‘PlusDeviceSet_Server_laboMIP_ACQUISITION’ and ‘PlusDeviceSet_Server_laboMIP_CALIBRATION’ using Notepad++.





- Copy the value ‘0.150’ after ‘LocalTimeOffsetSec’
- Save both files, and **QUIT NOTEPAD**.
- **QUIT FCAL**

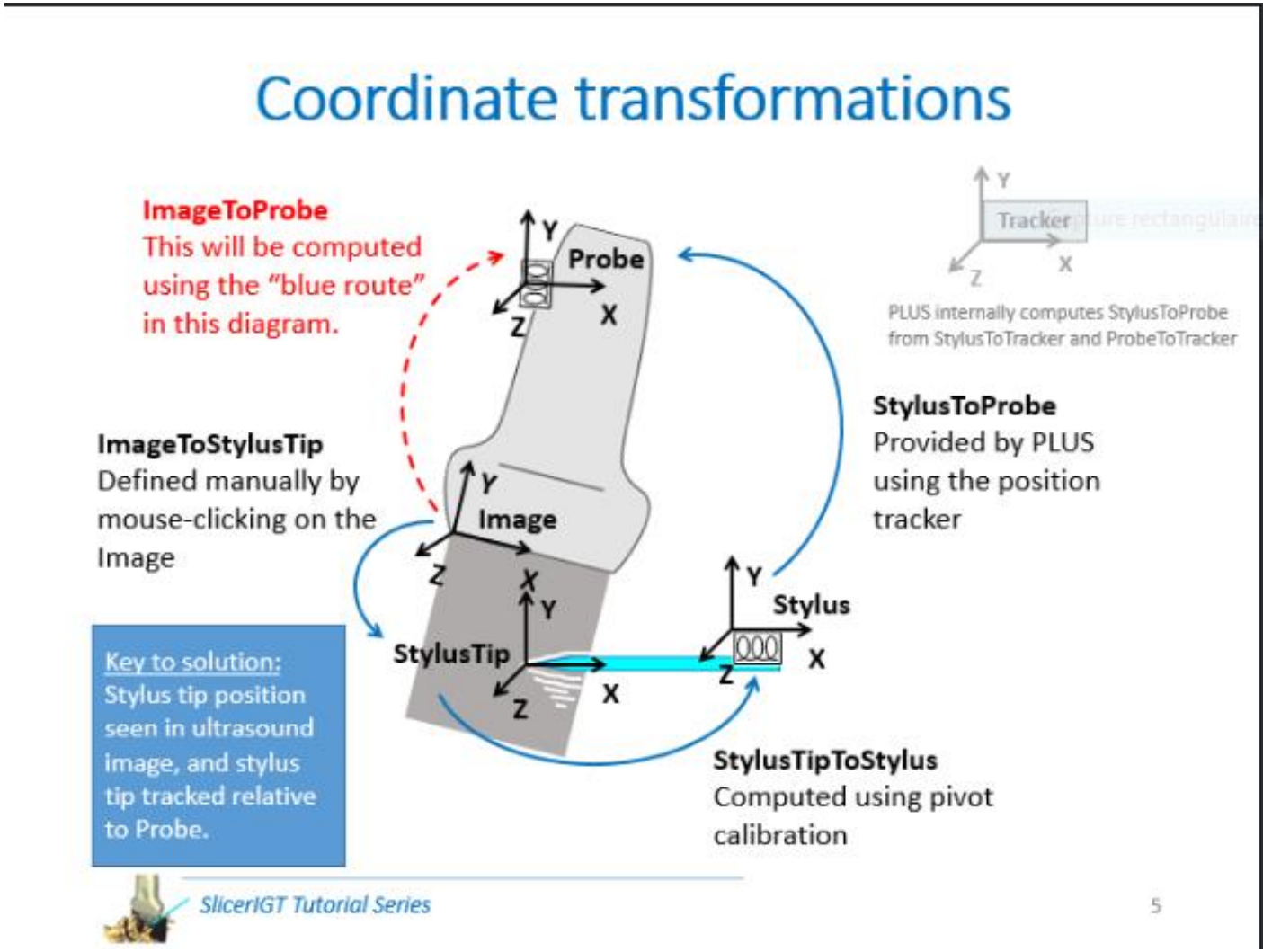
4. PROBE CALIBRATION

What is its use ?

- To calculate the transform matrix between the referential of the probe (the markers) and the ultrasound image.
- See explanations →

When to do it ?

- If the markers holder moved according to the probe
- If the settings of the probe (especially depth) have been changed



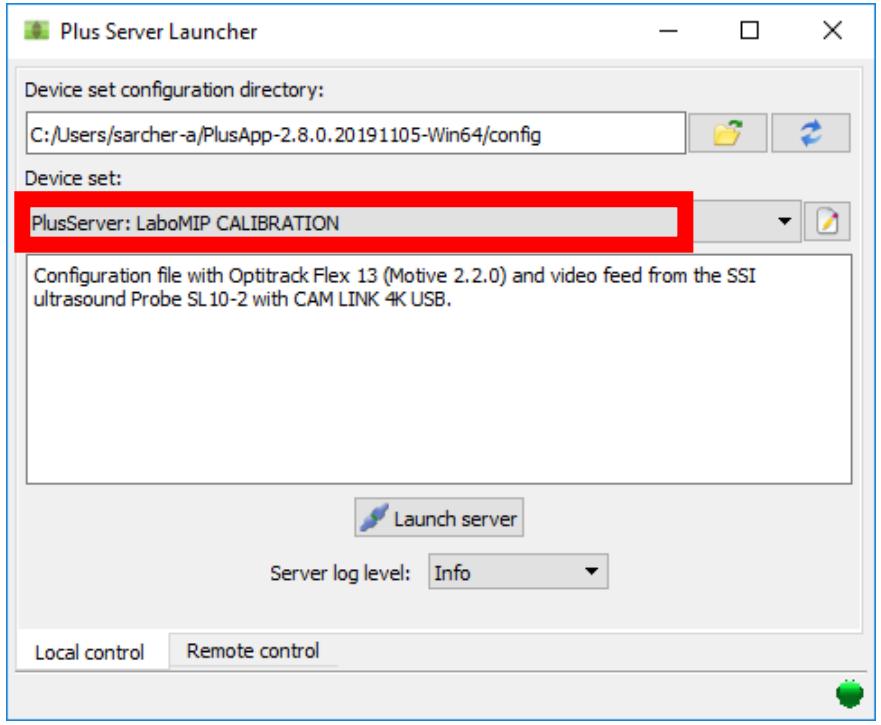
BE CAREFUL TO CORRECTLY SETUP THE SETTINGS OF THE PROBE AND THE ULTRASOUND, IT WILL NOT BE POSSIBLE AFTERWARDS

I don’t need to calibrate the probe ?

- Go to Slide 39

Plus Server Launcher software

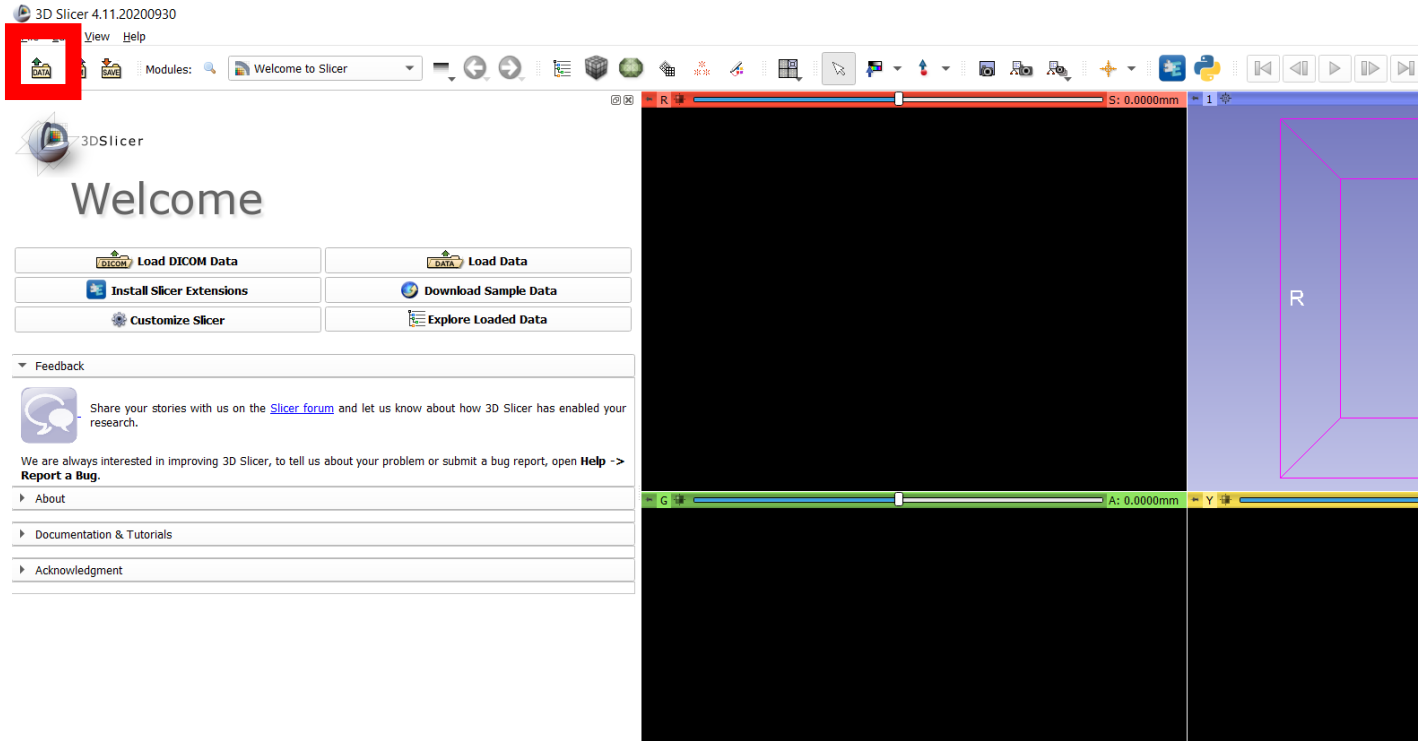
- Start Plus Server Launcher
- Load the file **LaboMIP CALIBRATION**
- Click on ‘Launch Server’
- **DO NOT QUIT ‘Plus server’**

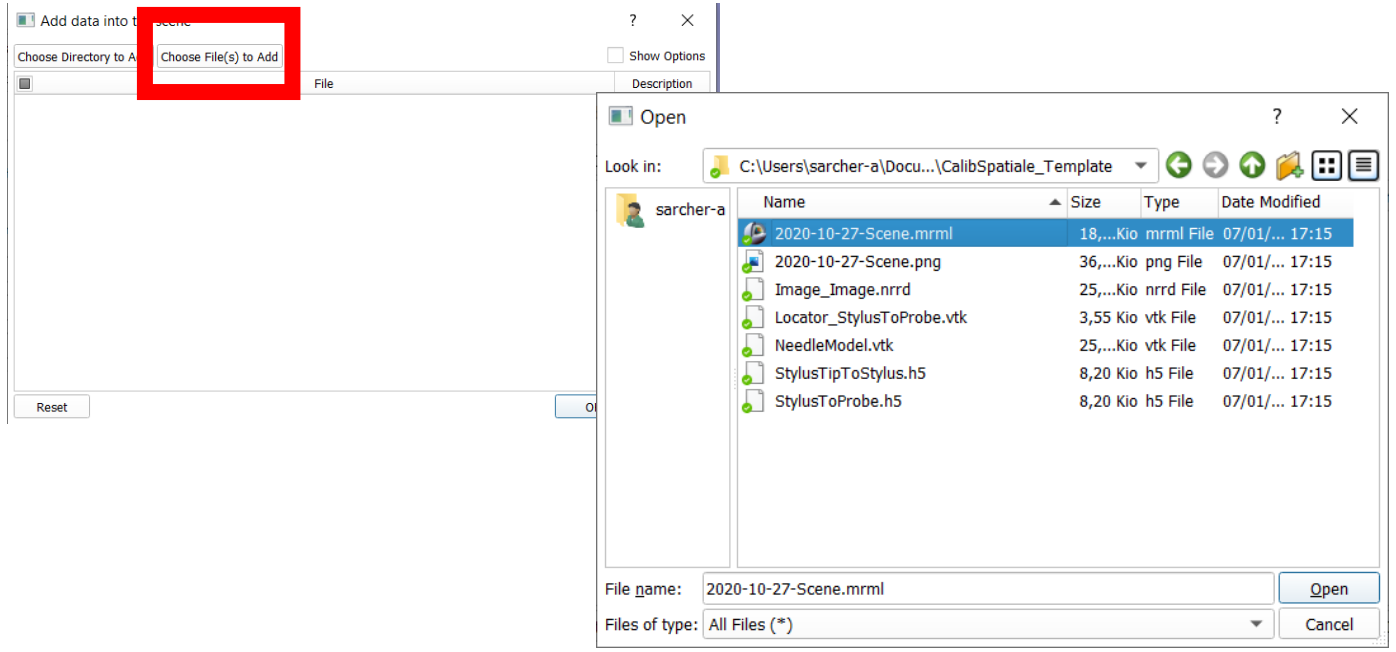


3D SLICER

- Launch 3D Slicer
- Click on 

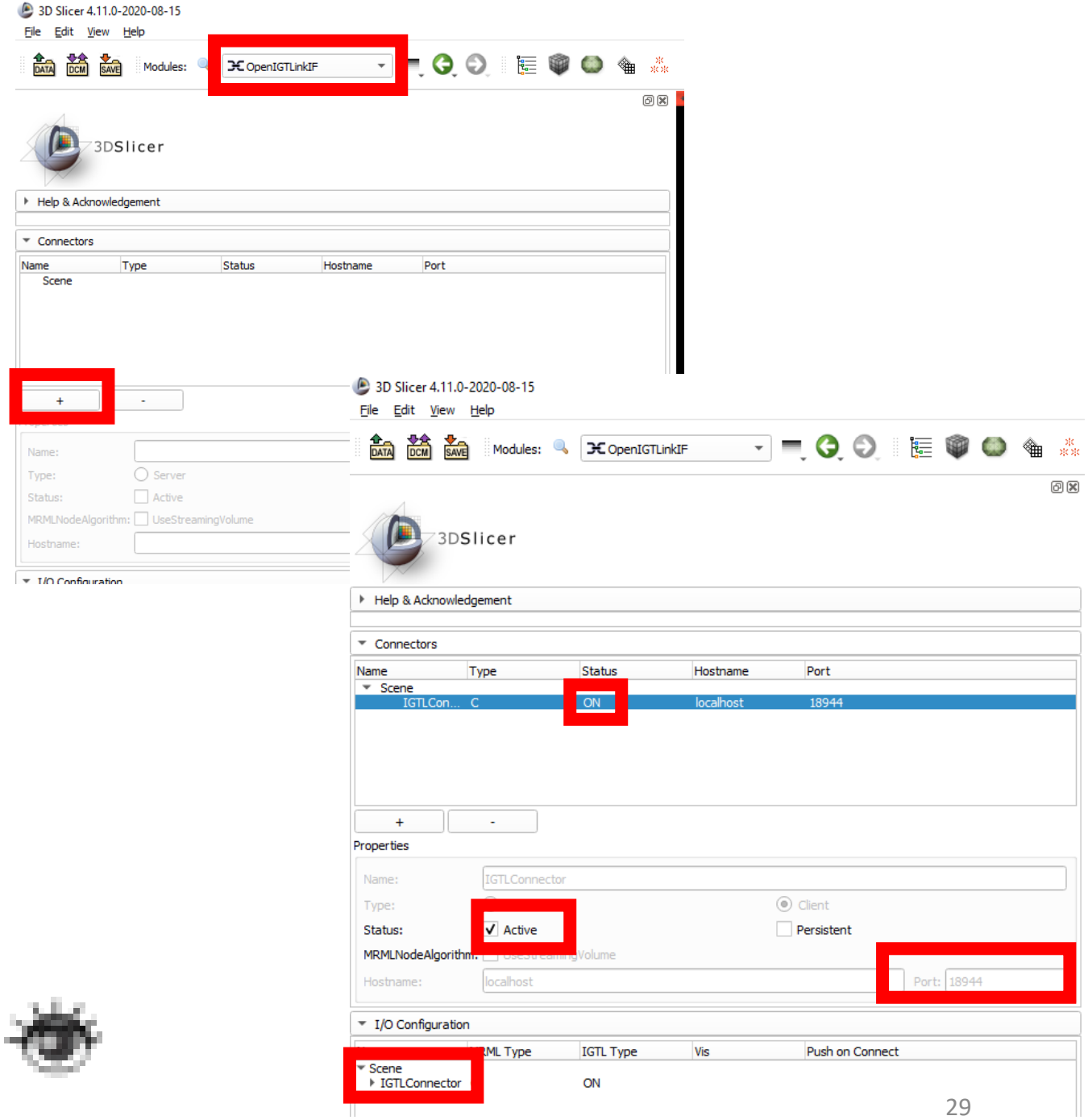
- Click on ‘Choose File(s) to Add’
- Load the scene file (file .mrml) in the folder ‘C:/Users/Labo MIP/PlusApp-2.8.0.20191105-Win64/config’ → ‘CalibSpatiale_Template’.
- This folder has been pre-configured with the StylusTipToStylus transform of the stylus used in the MIP laboratory.





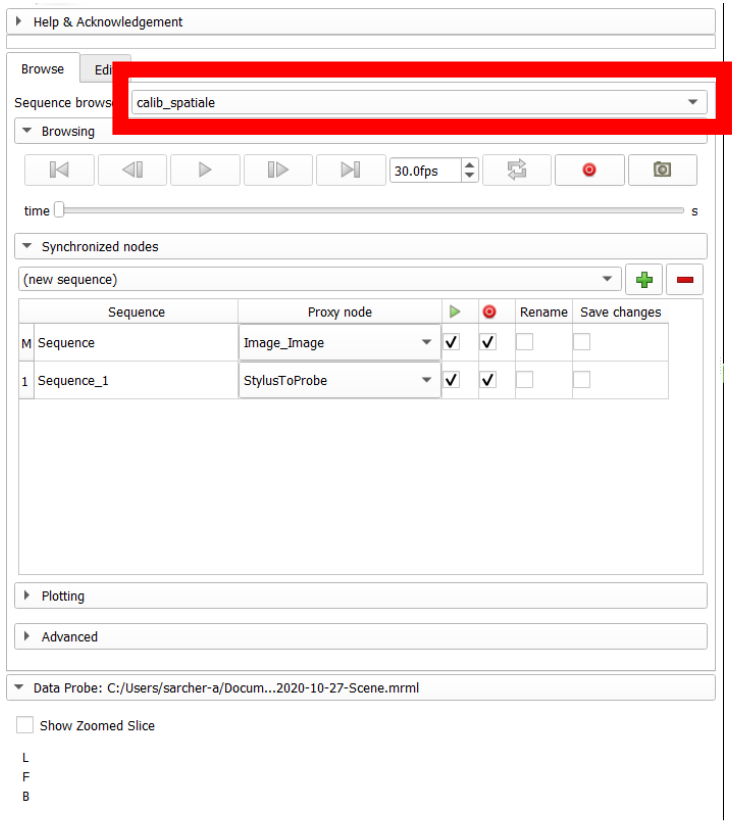
3D SLICER

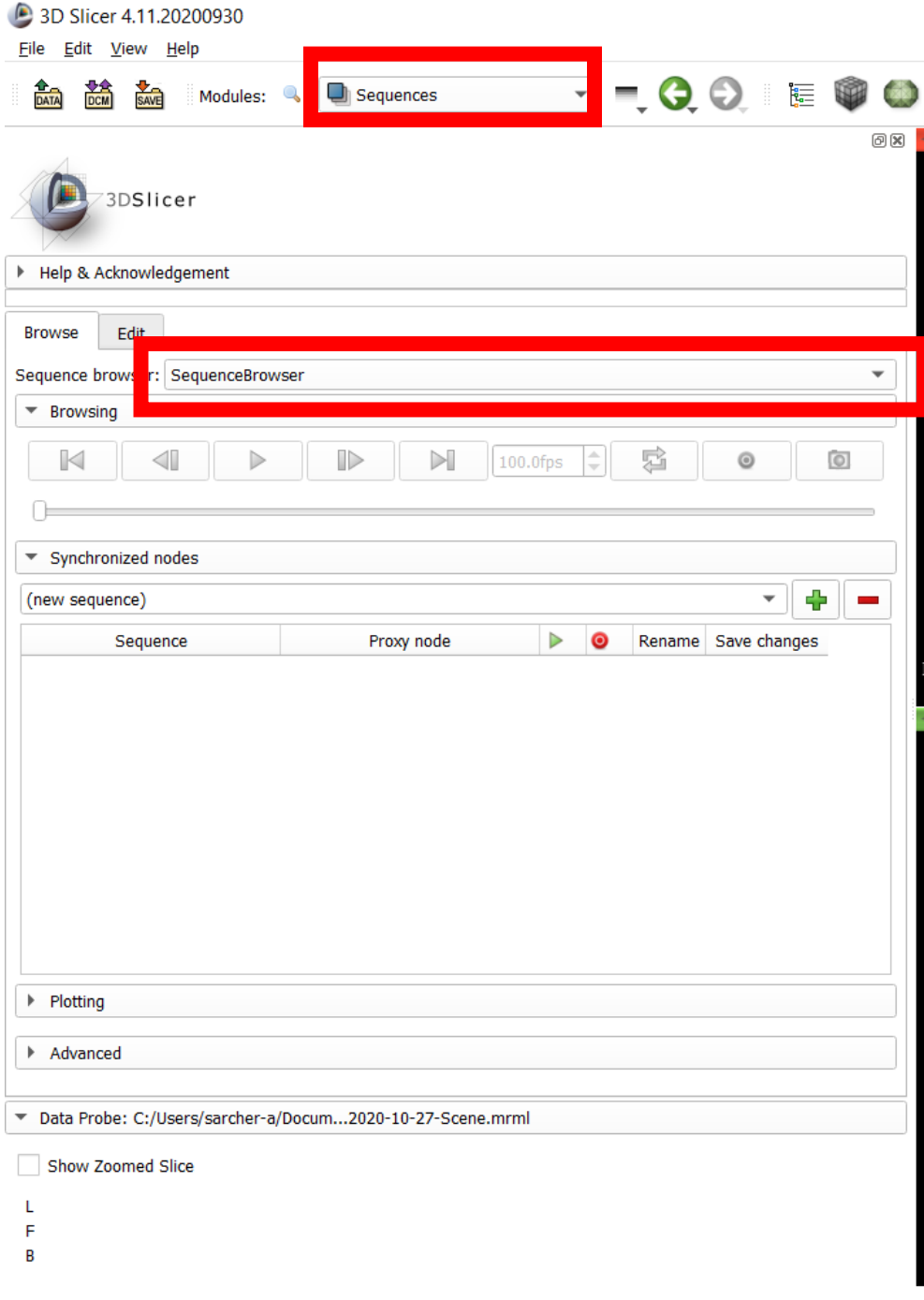
- Choose the module « IGT » → « OpenIGTLinkIF »
- Click on + (Add a connector).
- Verify that « Hostname » = « localhost », port = 18944
- Check « status » = « active ».
- The status indicator must be on « ON », Slicer is correctly connected to PLUS.
- Click on the arrow on the left of IGTLConnector, then on the arrow on the left of IN, to verify that both eyes are open :



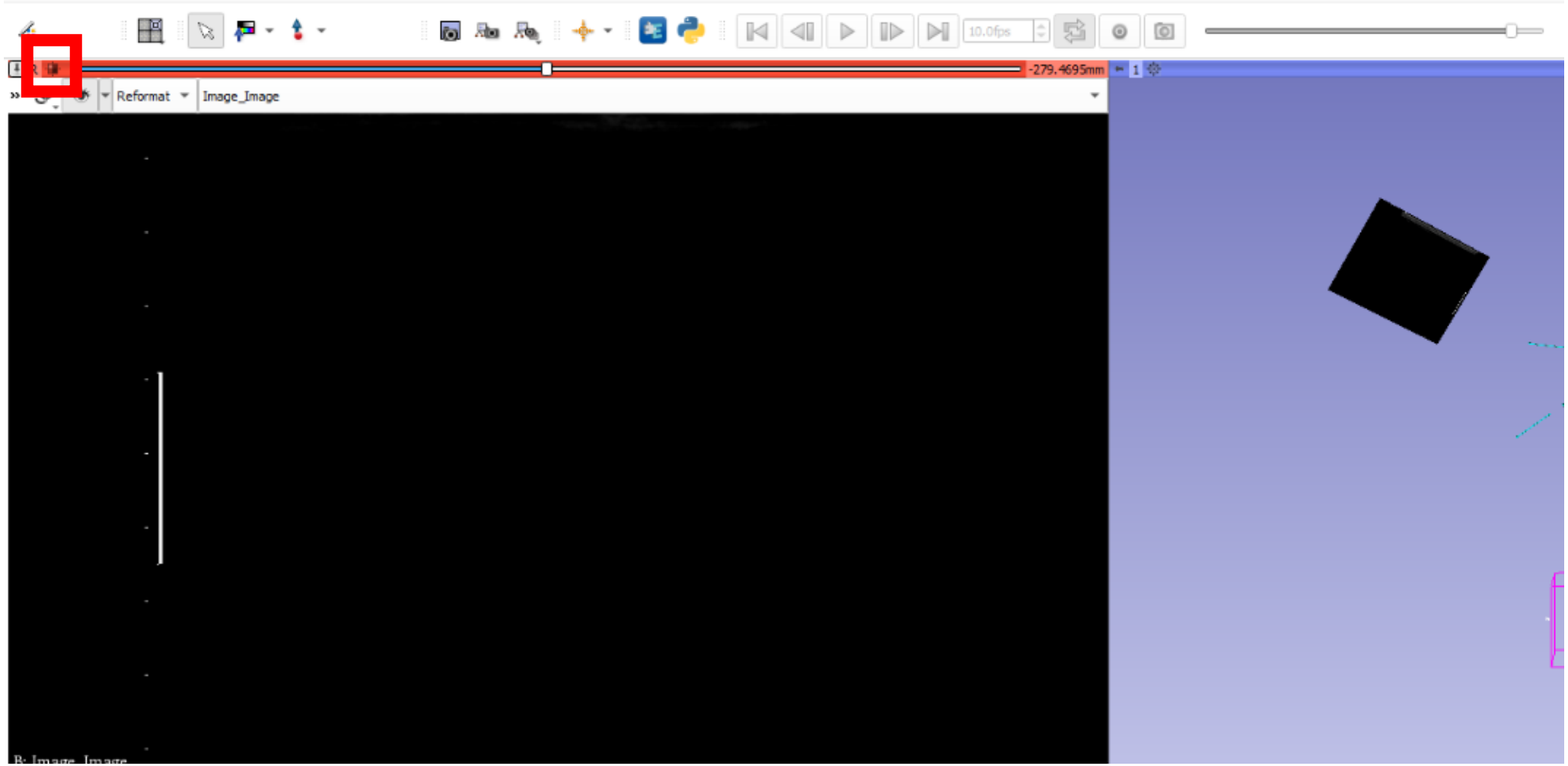
3D SLICER

- Choose the module « Sequences »
- Click on the drop-down menu ‘SequenceBrowser’
- Choose ‘calib_spatiale’

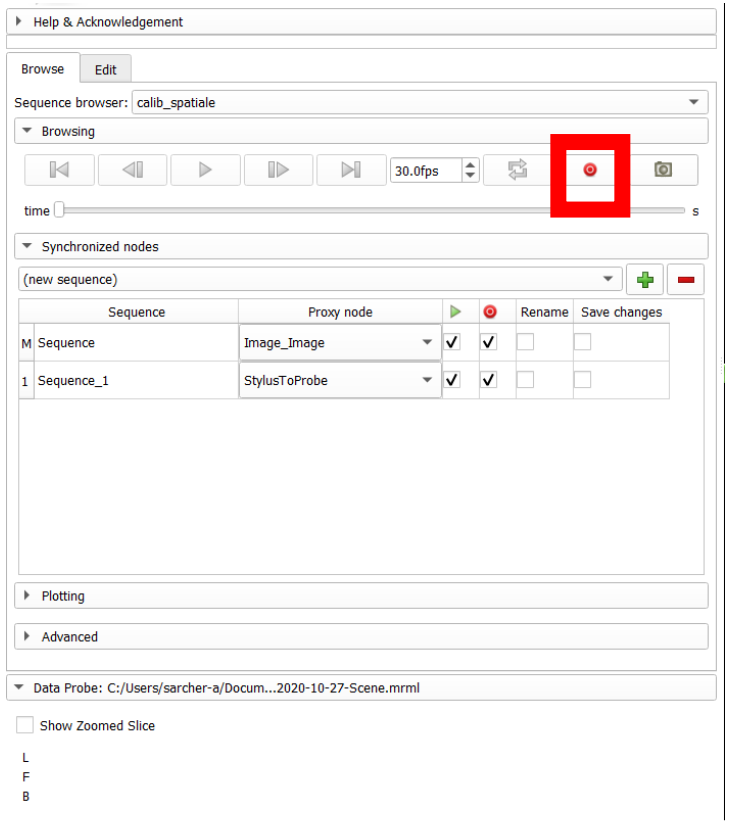




- To adjust the 2D ultrasound image to the screen, click on the square with the grey nuances

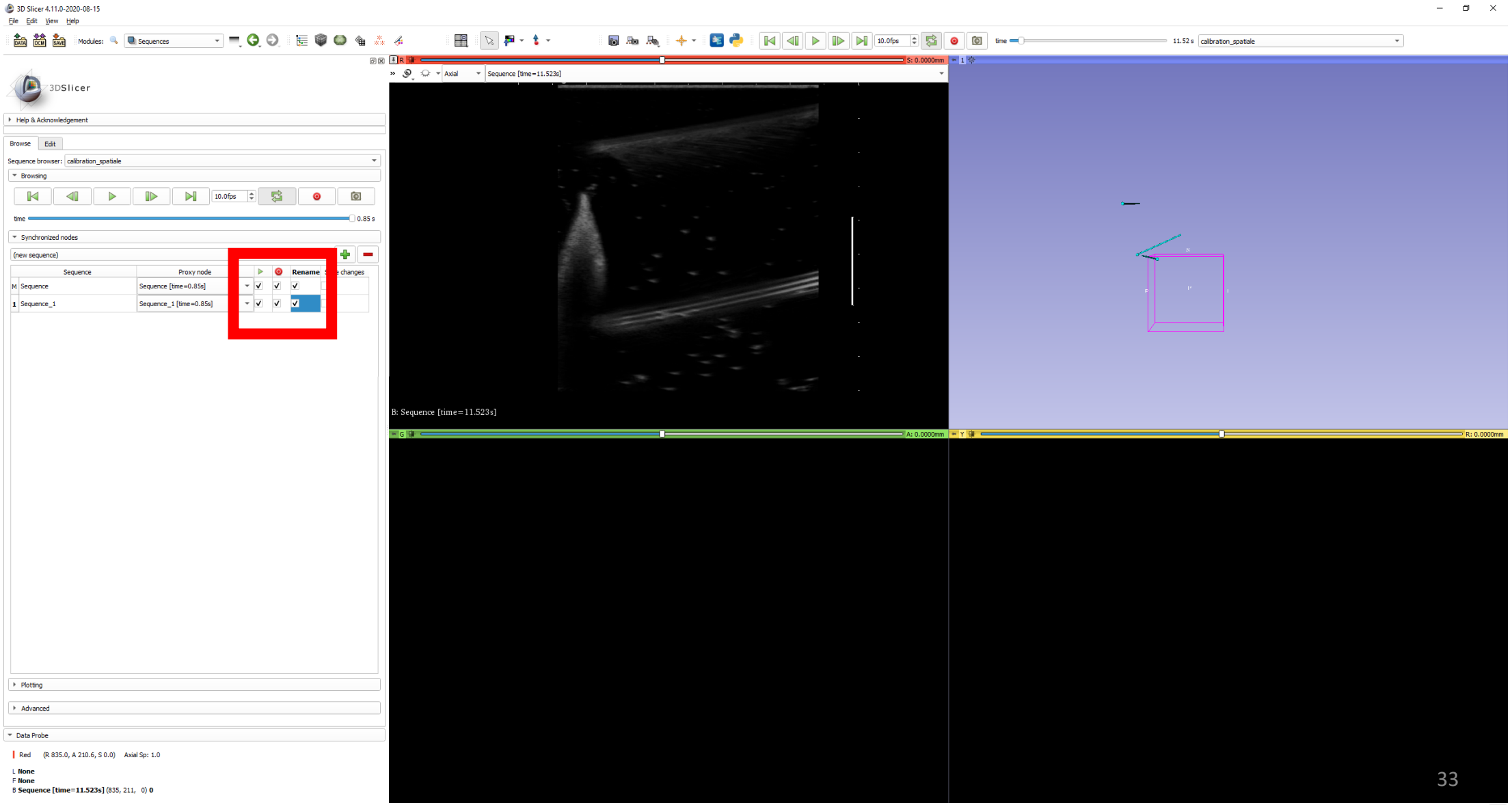


- Record the spatial calibration sequence by clicking on the red circle.
- The calibration sequence consists in making the stylus tip appear clearly on the ultrasound image, at least four times (in each corner of the ultrasound image).
- Then, rotate both stylus and probe at least 45° and redo the same (again at least 4 appearances of the stylus tip on the ultrasound image).

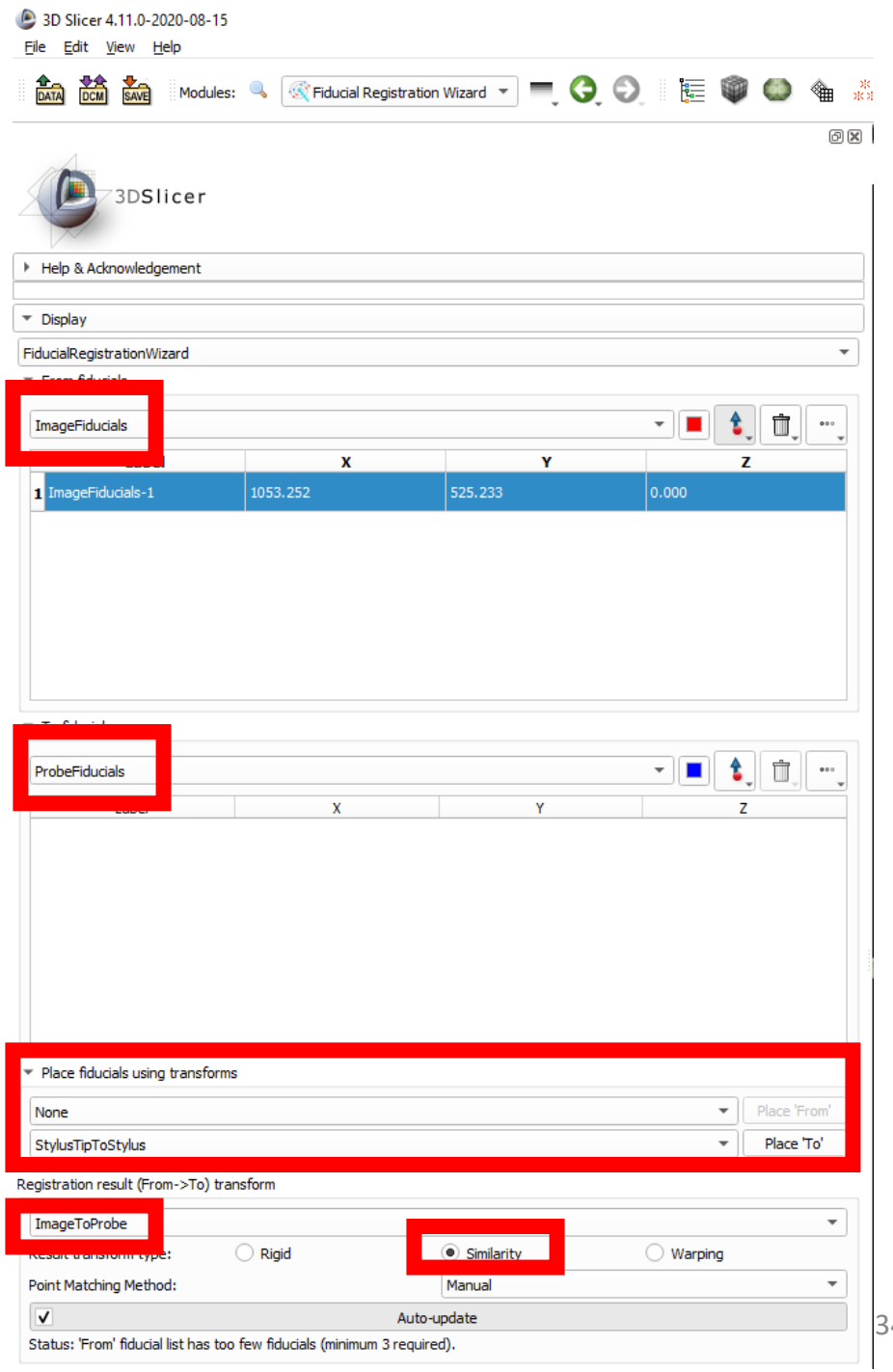


VIDEO

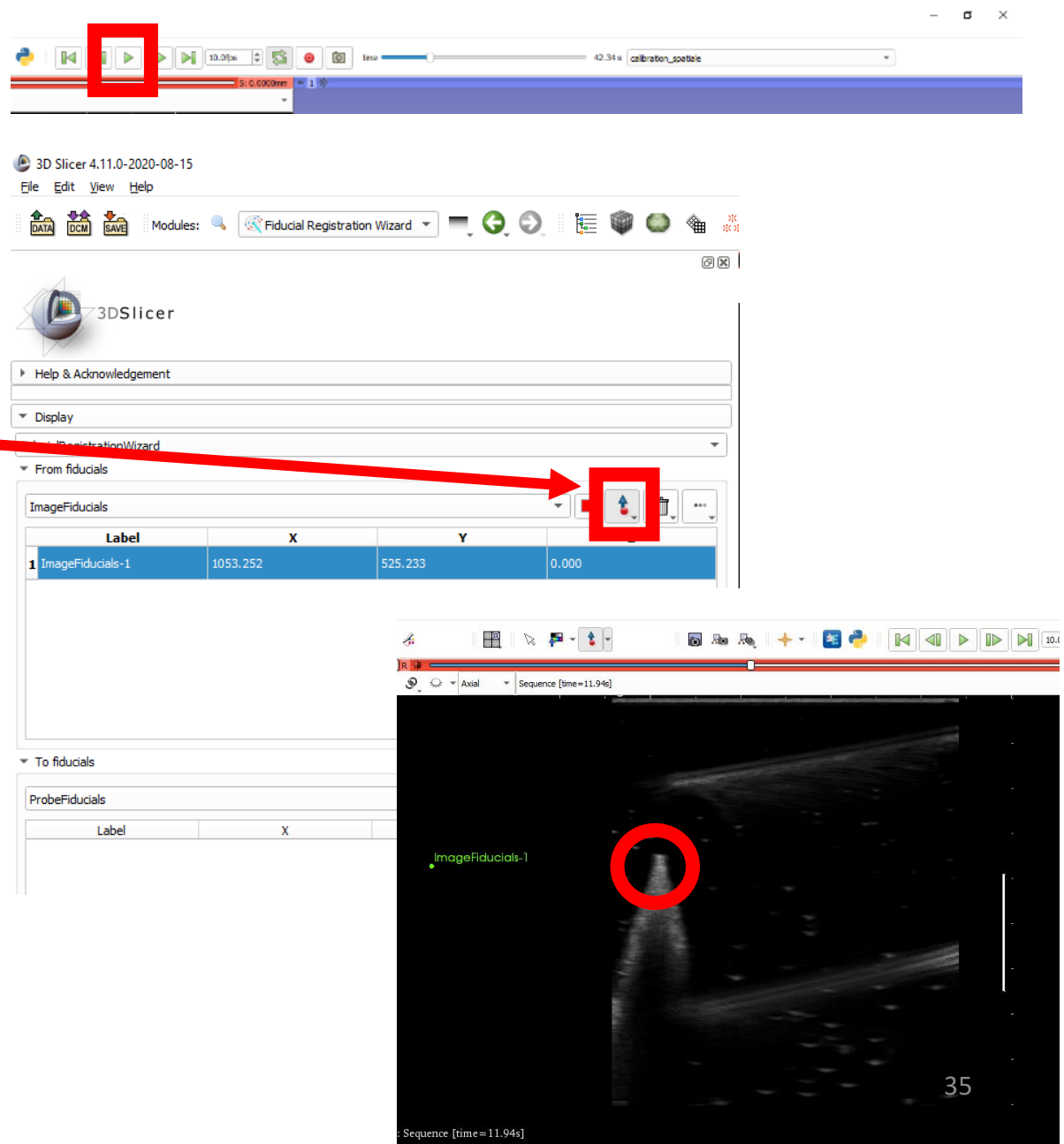
After acquisition, check the column ‘rename’ for both nodes.



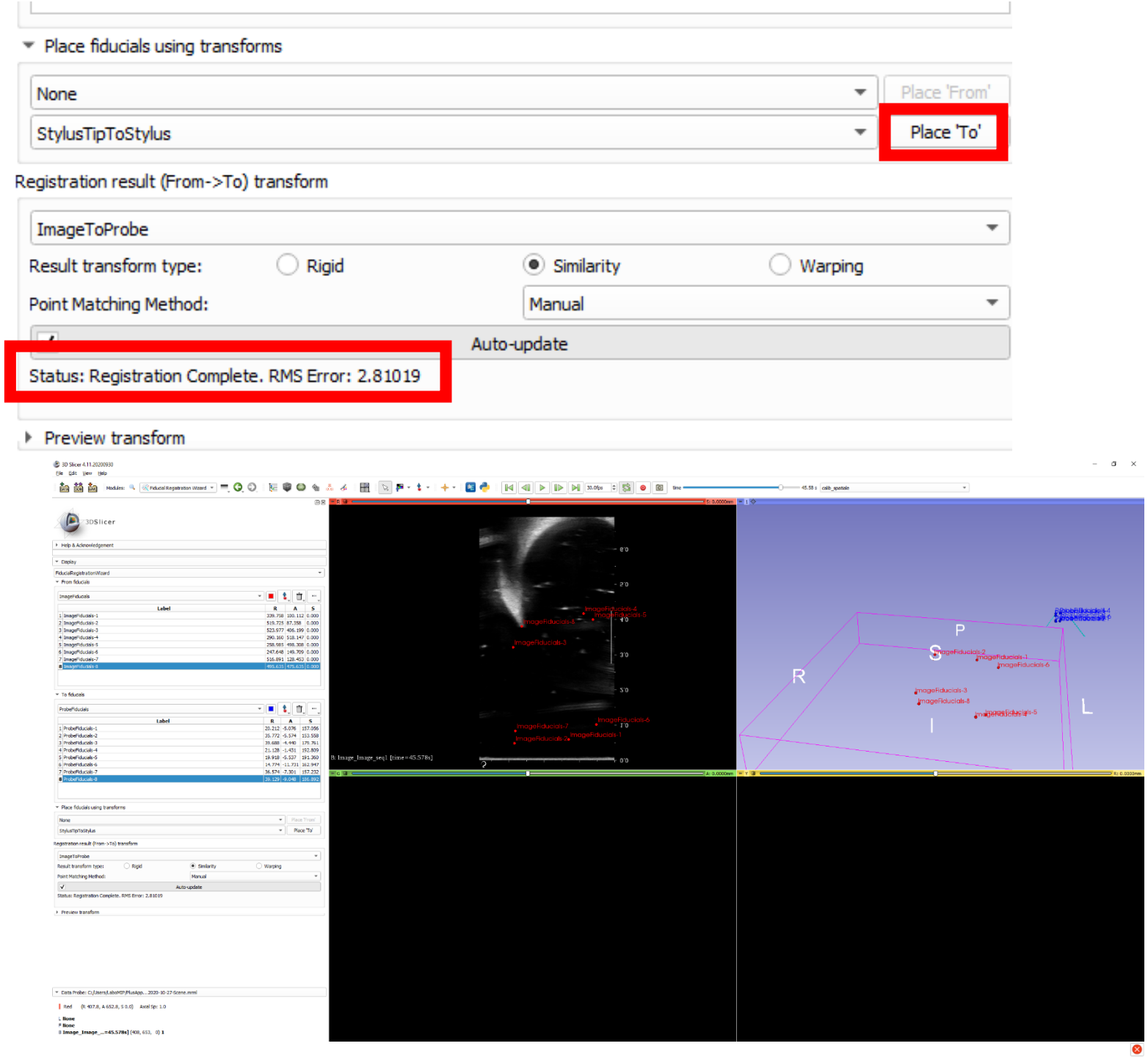
- Open the module ‘Fiducial Registration Wizard’
- ‘from fiducials’ → ‘create new markupsFiducial as…’ and rename ‘ImageFiducials’
- ‘to fiducials’ → ‘create new markupsFiducial as…’ and rename ‘ProbeFiducials’
- ‘place fiducials using transforms’ → first ‘none’ second ‘StylusTipToStylus’.
- ‘registration results’ → ‘create new transform as…’ and rename ‘ImageToProbe’
- Select ‘similarity’ and ‘manual update’.



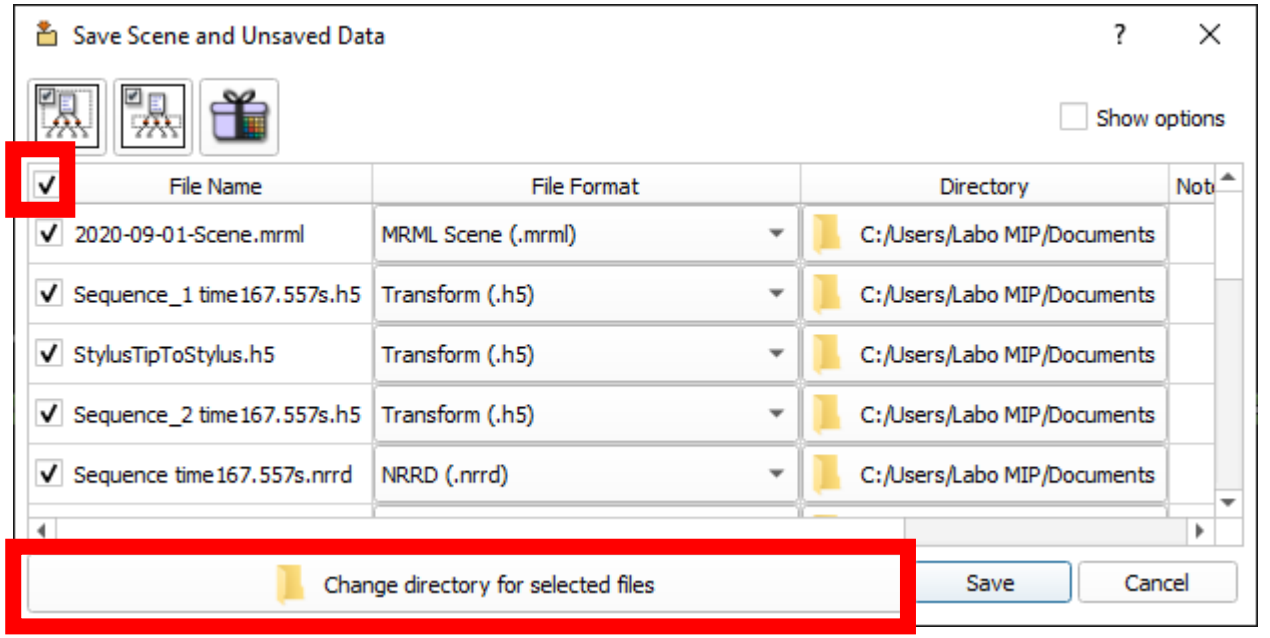
- Play the spatial calibration sequence.
- Press pause when the stylus tip appears on the ultrasound image.
- On the icon with the arrow upward corresponding to ‘ImageFiducials’
- Click on the ultrasound image on the stylus tip.



- Click on ‘place to’ for every fiducial added, so that the software can match the fiducial on the ultrasound image ‘image’ to a fiducial of the probe tracker ‘probe’.
- The transform ImageToProbe is automatically calculated (the RMS error is displayed).
- The RMS error must be between 1 and 3.



- Click on ‘File’ → ‘Save’
- Check all elements of the scene
- Choose the folder to save all the elements ‘Change directory for selected files’, for example ‘calibration_15092020’.
- Click on ‘Save’
- Wait, this step can take one or two minutes.



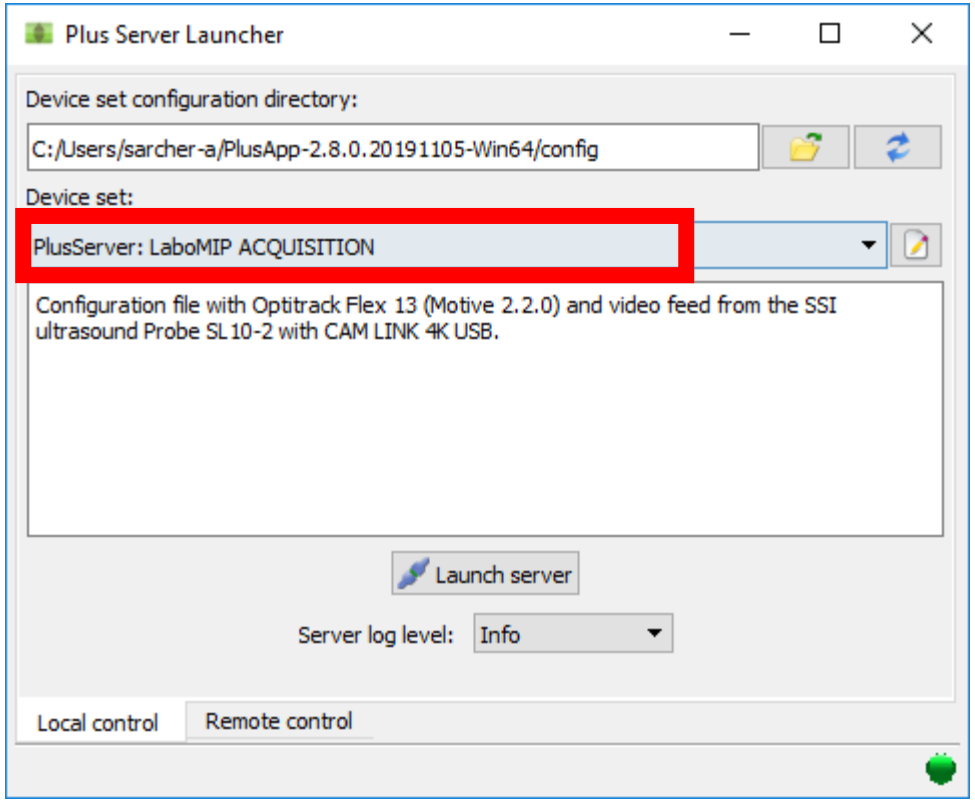
- **QUIT SLICER 3D AND PLUSSERVER**

- In Windows explorer, go to the folder in which the spatial calibration was just saved, and copy the file ‘ImageToProbe.h5’
- Paste this file in the folder ‘C:/Users/Labo MIP/PlusApp-2.8.0.20191105-Win64/config’ → ‘Scene_Template_Probe10-2_Prof4,5’, by modifying if needed the name of the folder to conform to the actual characteristics (probe model, depth, etc.)

5. ACQUISITION

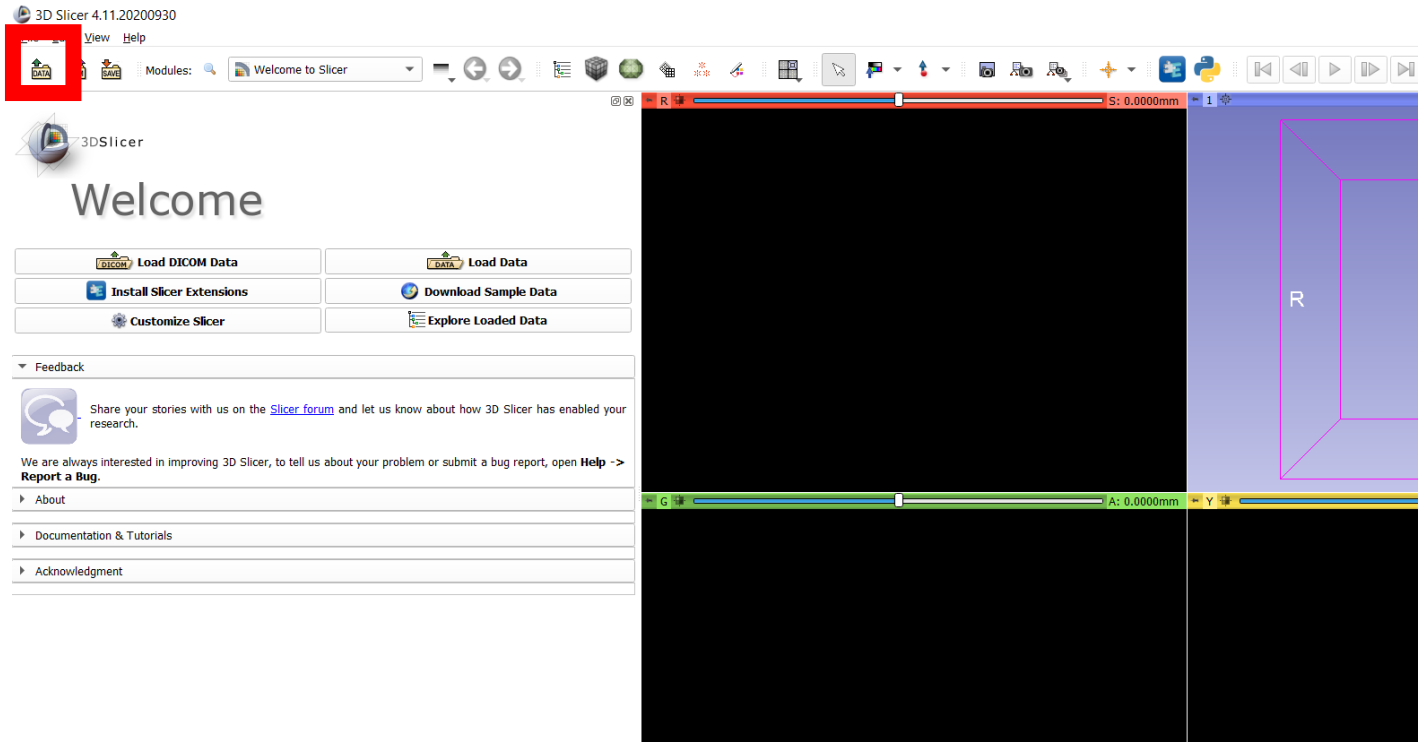
Plus Server Launcher Software

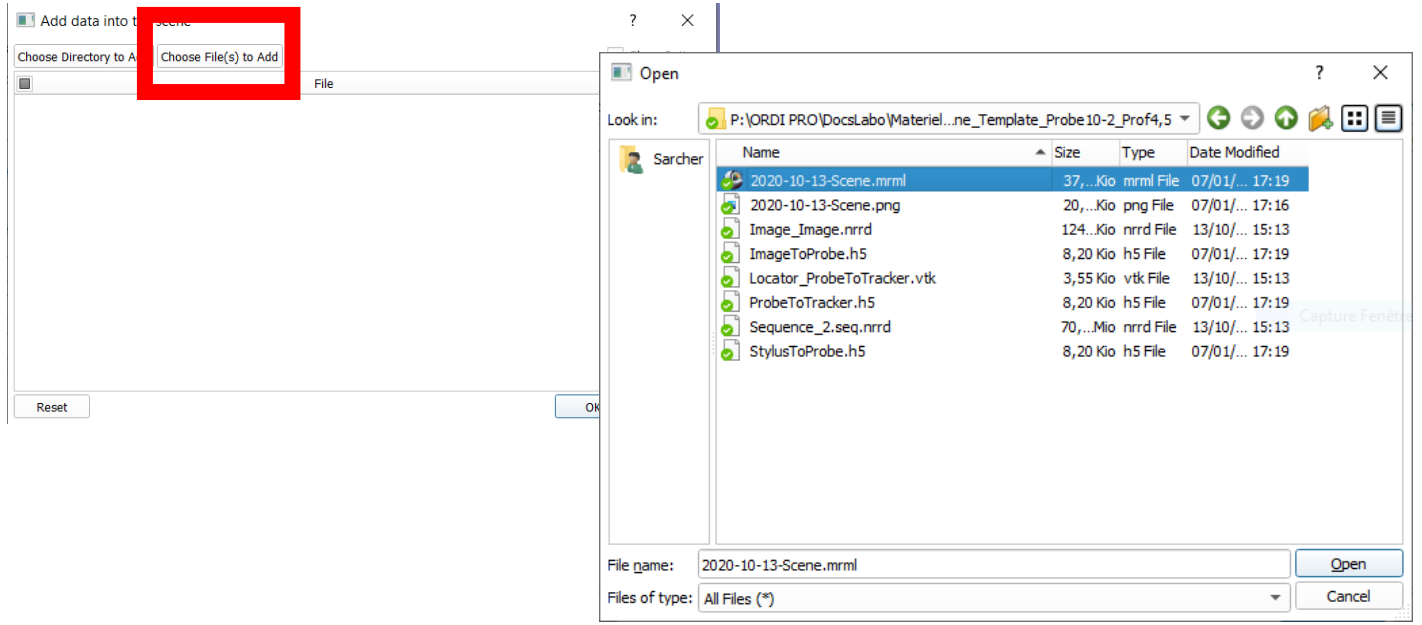
- Start Plus Server Launcher
- Load the file **LaboMIP ACQUISITION**
- Click on ‘Launch Server’
- **DO NOT QUIT ‘Plus server’**



3D SLICER

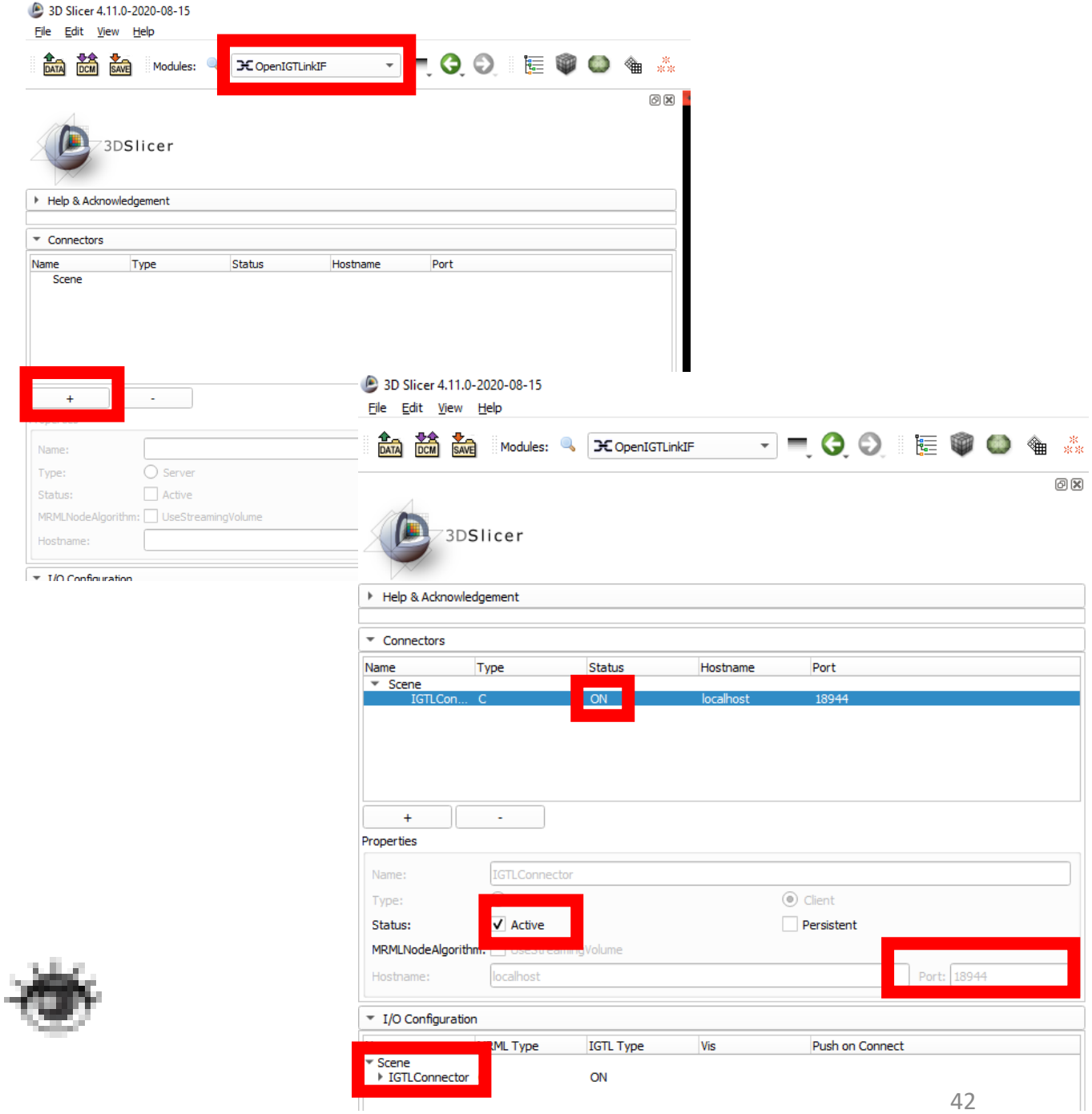
- Launch 3D Slicer
- Click on 
- Click on ‘Choose File(s) to Add’
- Load the file scene (fichier .mrml) in the folder ‘C:/Users/Labo MIP/PlusApp-2.8.0.20191105-Win64/config’ → ‘Scene_Template_Probe10-2_Prof4,5’ (or any other name depending on the probe and depth parameters)





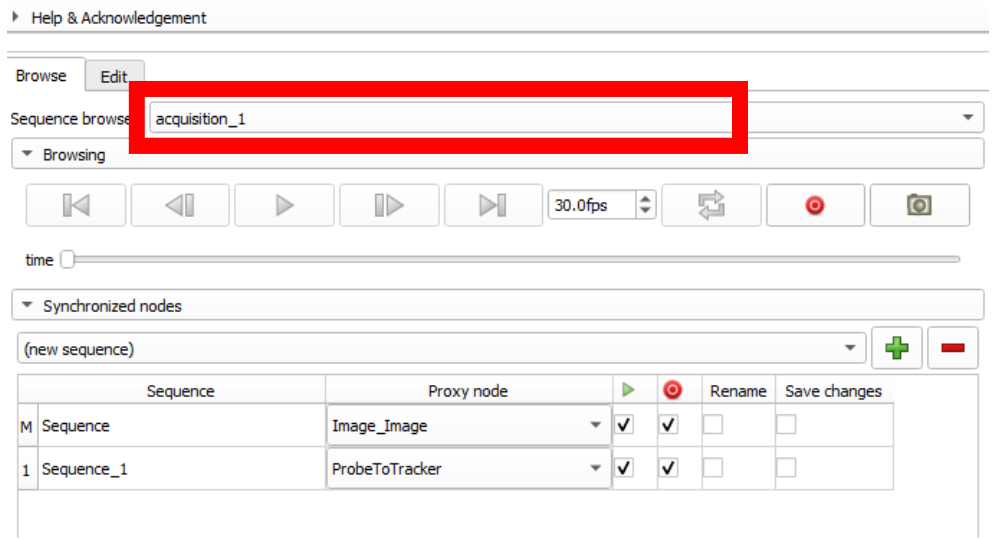
3D SLICER

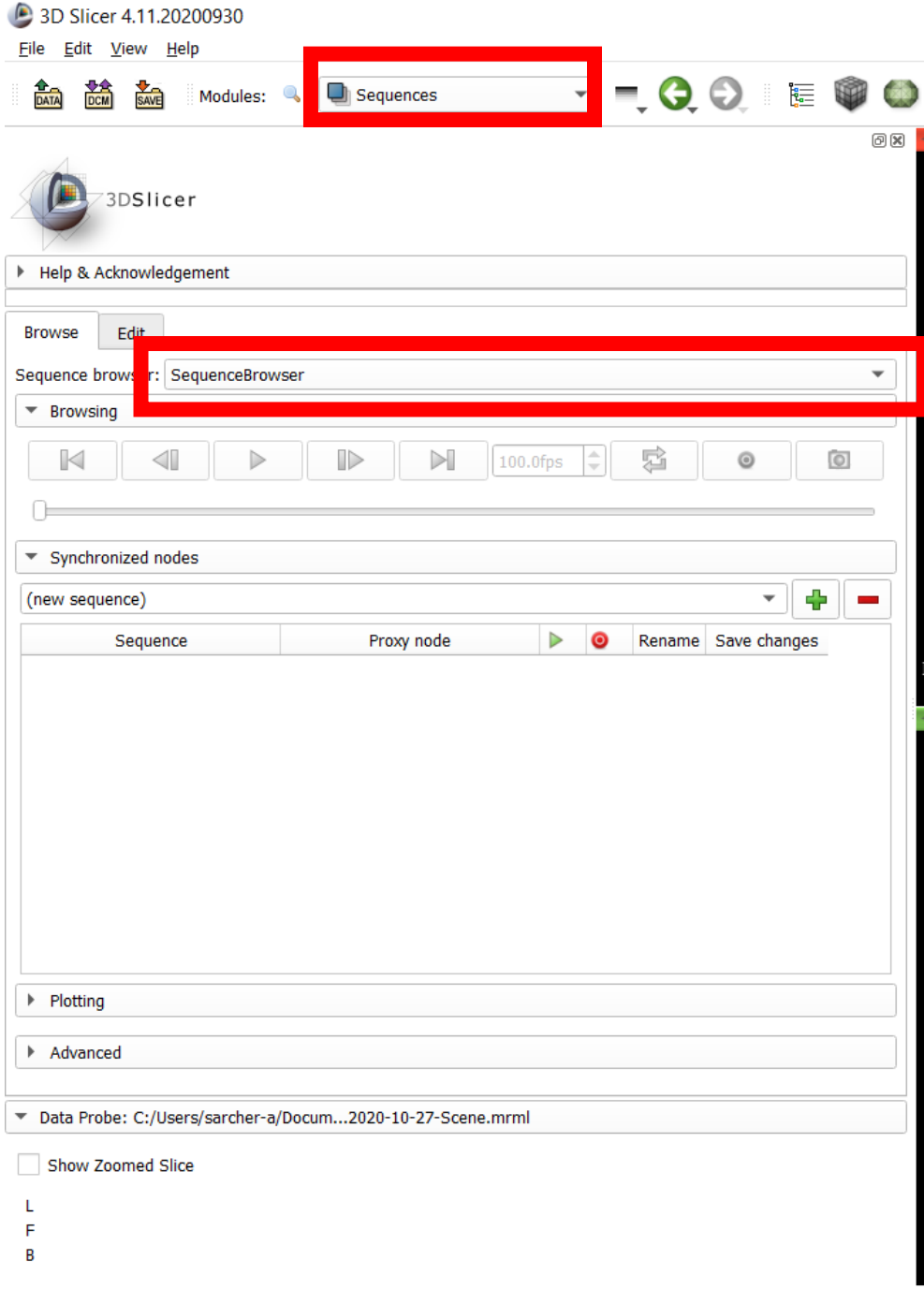
- Choose the module « IGT » → « OpenIGTLinkIF »
- Click on + (Add a connector).
- Verify that « Hostname » = « localhost », port = 18944
- Check « status » = « active ».
- The STATUS indicator must be on ‘ON’, indicating that Slicer is correctly connected to PLUS.
- Click on the arrow on the left of IGTLConnector, then on the arrow on the left of IN, to verify that both eyes are open :



3D SLICER

- Choose the module « Sequences »
- Click on the drop down menu ‘SequenceBrowser’
- Choose ‘acquisition_1’





- Do not check the columns ‘rename’ and ‘save changes’.
- Record the acquisition by clicking on the red dot.
- After the recording is finished, check the column ‘rename’ for both nodes.

6. VOLUME RECONSTRUCTION

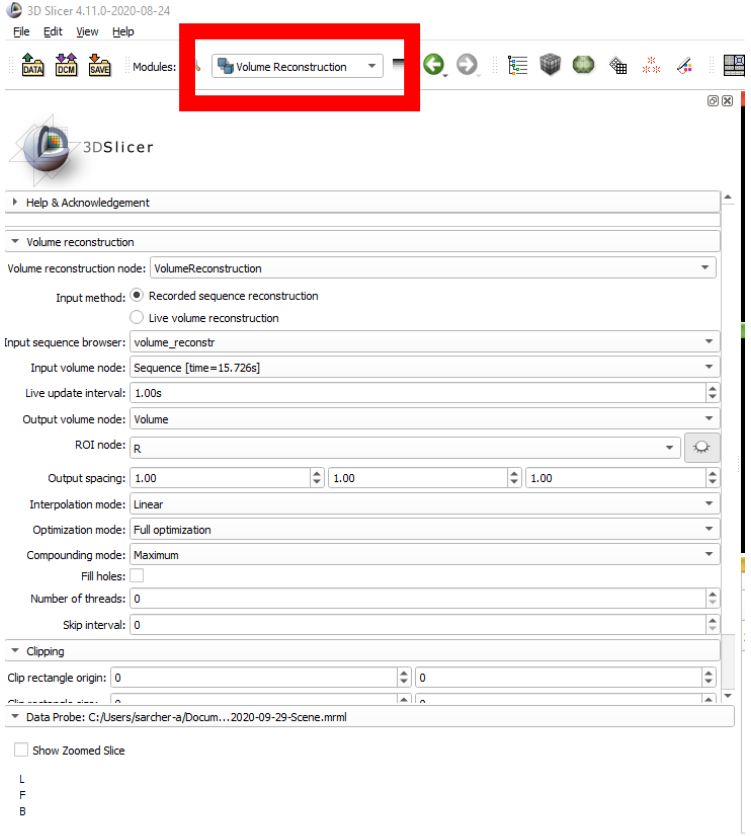
CASE 1 : I just performed an acquisition

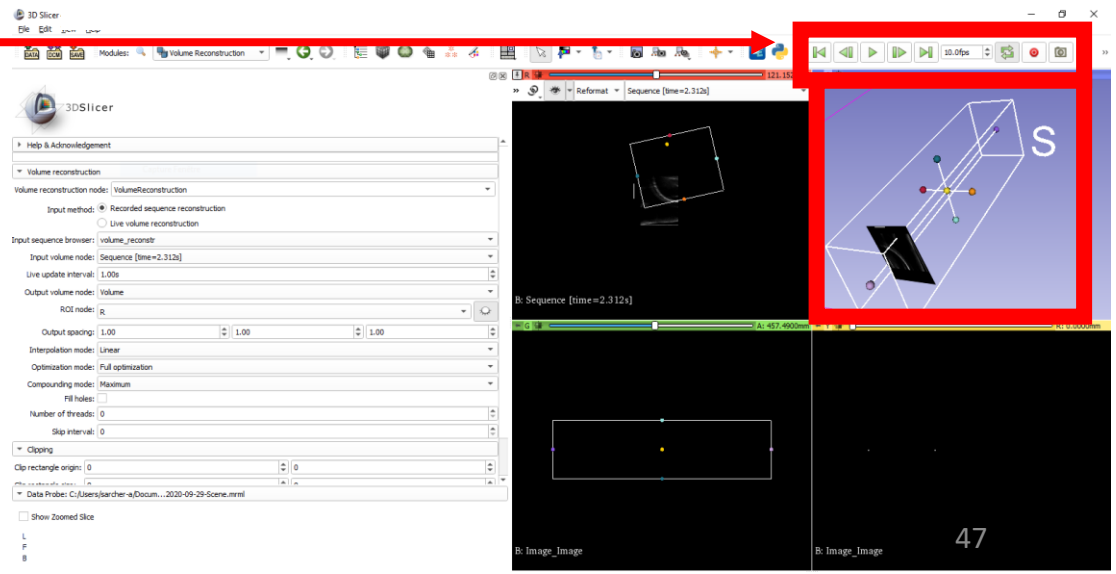
- **Go to the next slide.**

CASE 2 : I wish to process saved data

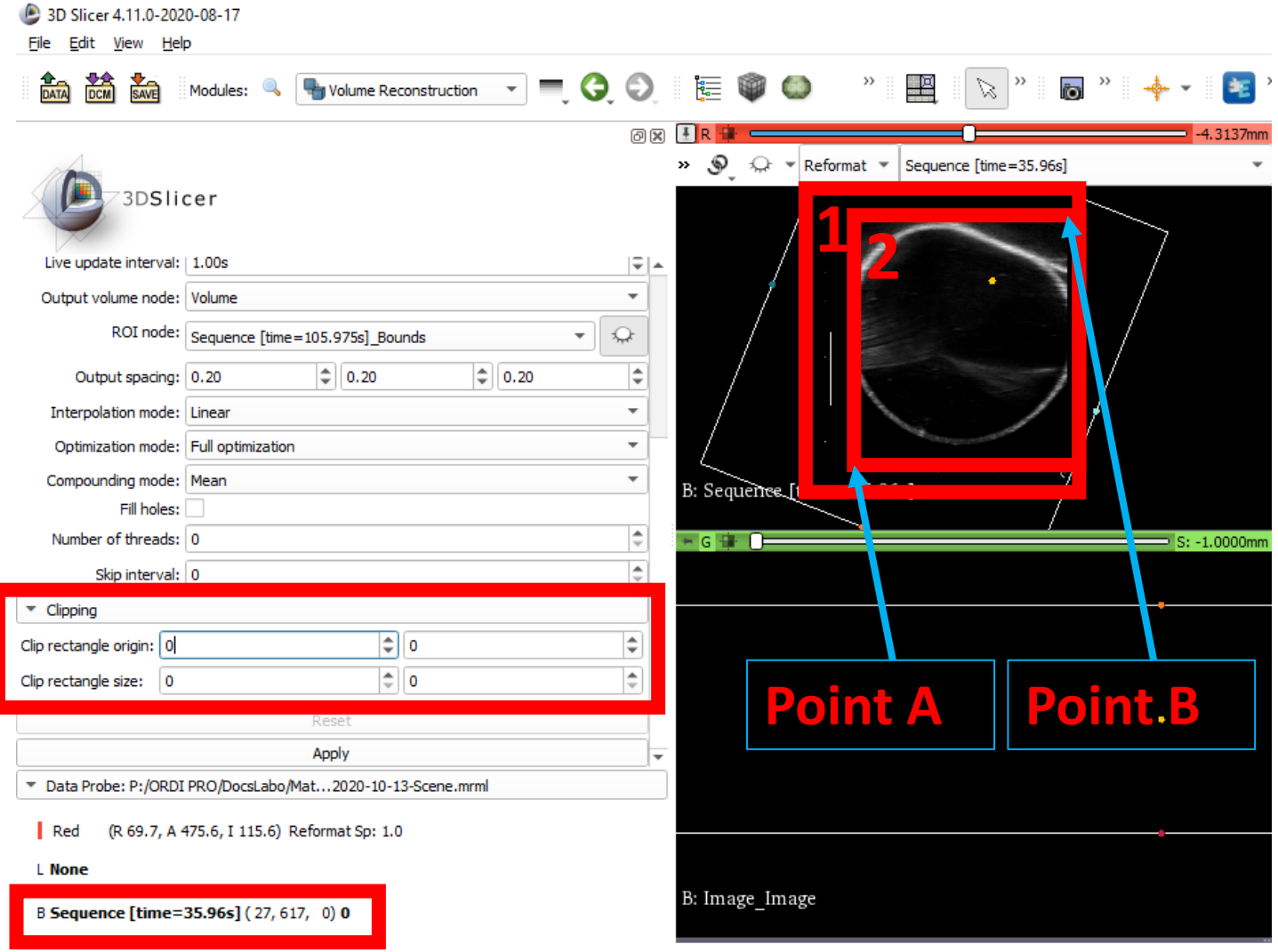
- Start Slicer 3D
- Click on ‘File’ → ‘Add data’ → ‘Choose File(s) to Add’
- Select in the folder with the saved data the file ‘Scene’ with the format ‘.mrml’
- The loading time can be a bit long.

- Go to the module ‘volume reconstruction’,
  - input method : ‘recorded sequence reconstruction’
  - Input sequence browser : choose the recorded sequence ;
  - input volume node : ‘Sequence [XXs]’,
  - output volume node : ‘create new volume as…’.
  - ROI node : ‘create new AnnotationROI’
  - In the 3D view, adjust manually the dimensions of the ROI to contour the volume scanned during the recording. If needed, display the ROI by clicking on the eye and by playing the recorded sequence (green bar at the top right of the screen)
  - Output spacing : between 0,10 and 1,00 (the smaller the value and the better the reconstruction quality, but also the longer). **Recommended value : 0,4**.
  - Interpolation mode : linear
  - Compounding mode : **mean**



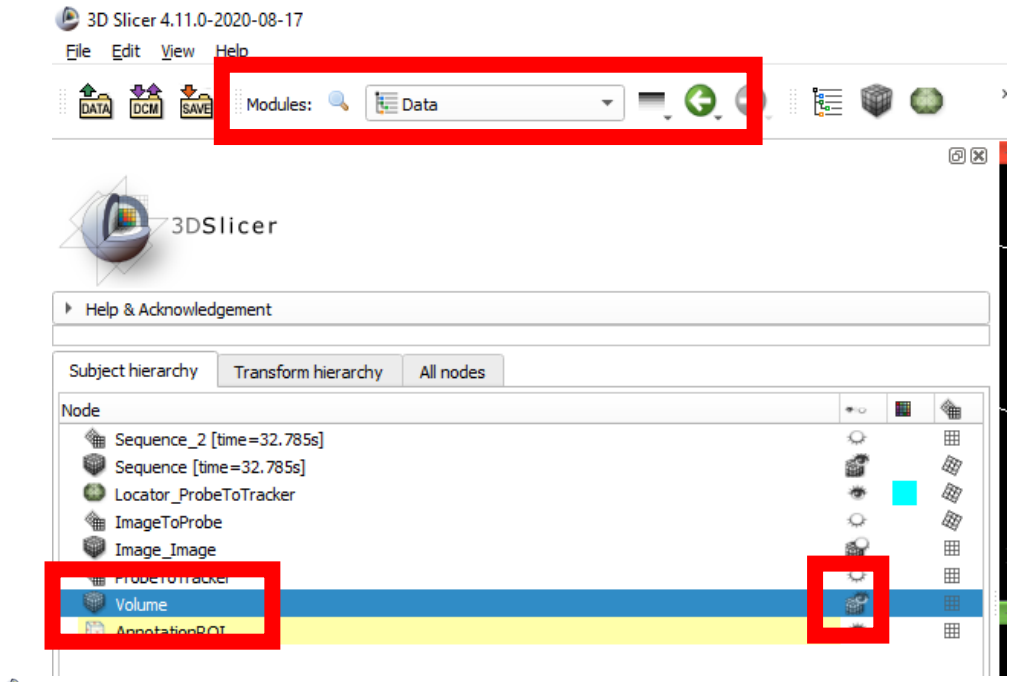


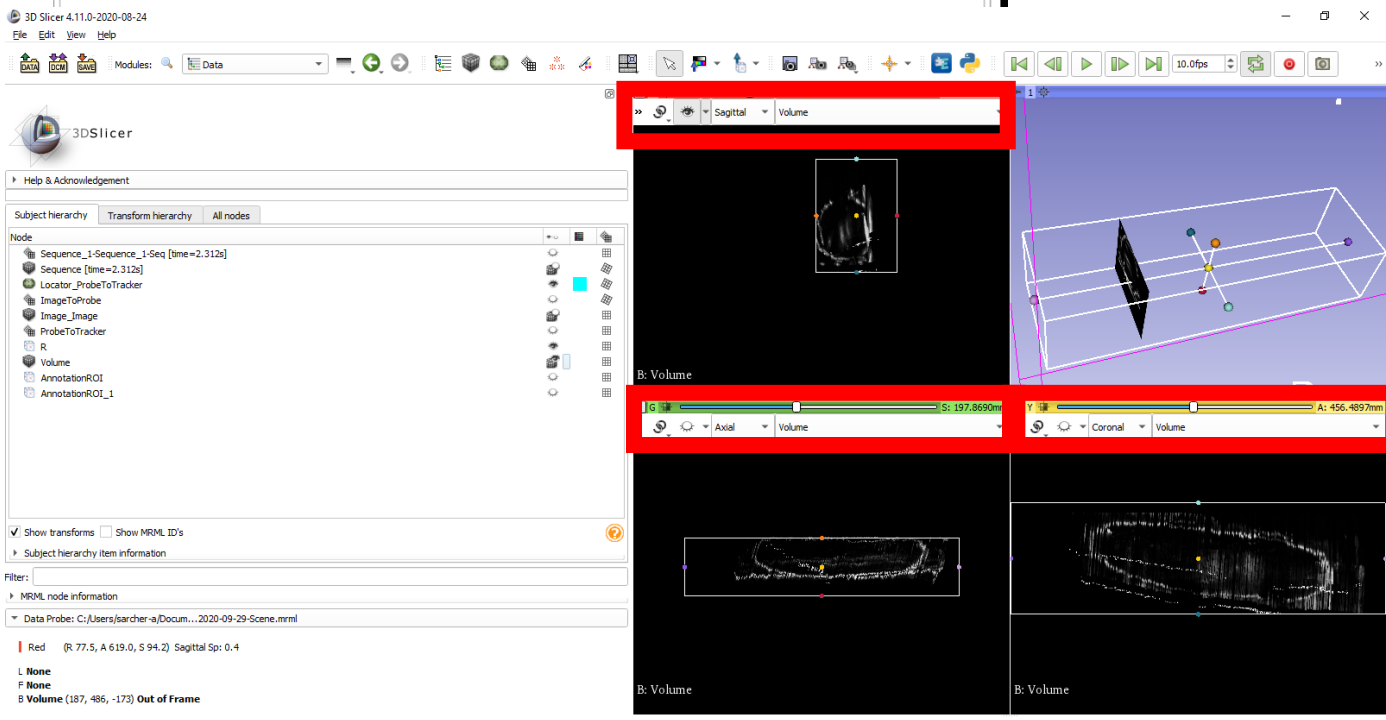
- **The ultrasound image included in the red window (rectangle 1) includes some writing, some marks, some black strips, etc. For the volume reconstruction, these elements must not be included, or else the volume won't be correctly reconstructed. The image must be clipped to select only the real ultrasound image (rectangle 2).**
- You can find the coordinates of your mouse by travelling on the ultrasound image in the bottom left part of the screen.
- Note the coordinates of the Point A which delimite the bottom left corner of the rectangle 2, and note these values in Clipping → Clip rectangle origin.
- Note the coordinates of the Point B which delimite the top right corner of the rectangle 2, and note the values [Point B – Point A] in Clipping → Clip rectangle size.
- Click on 'apply'.
- Note : At the end of the reconstruction, it is normal that the volume does not display automatically.



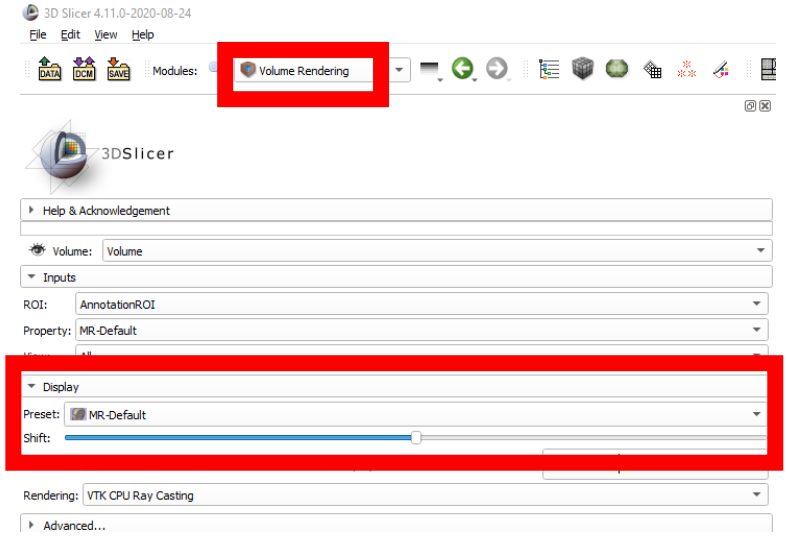
- Go back to the module ‘data’, go to the tab ‘Subject hierarchy’.

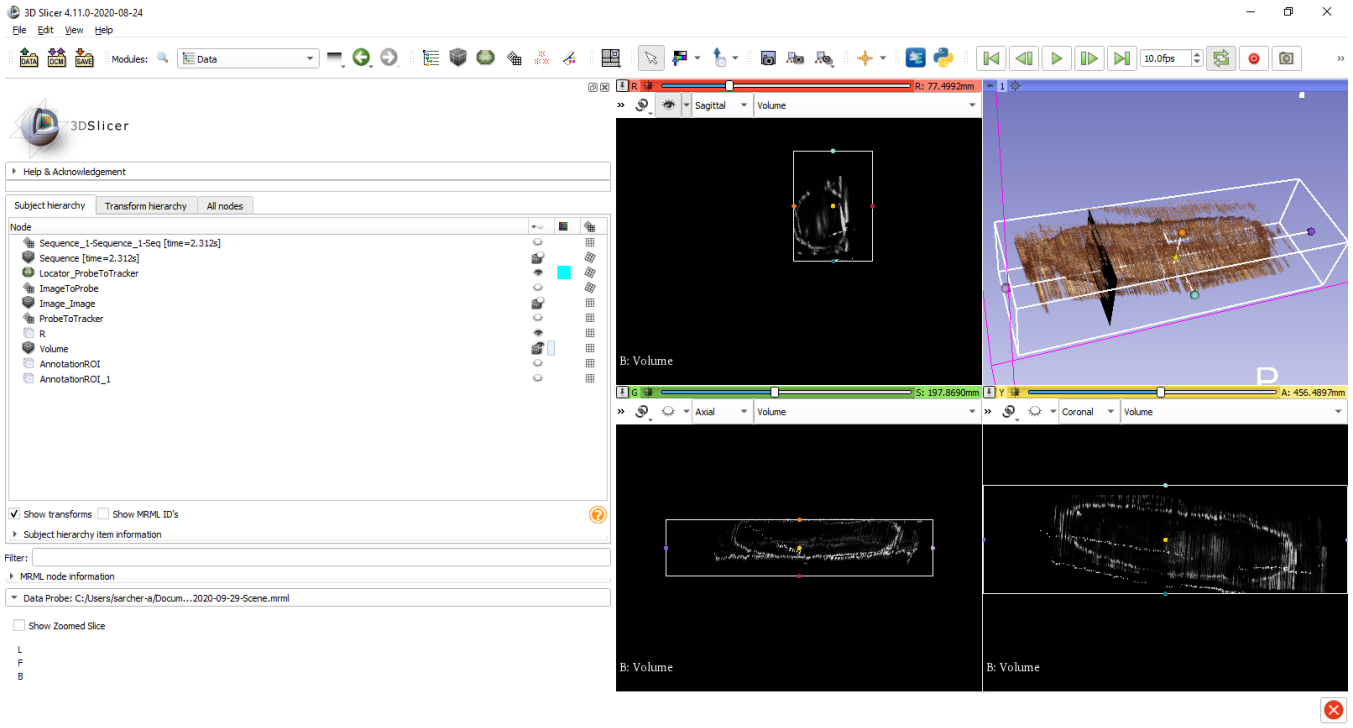
- Display the volume :
  - Left click on the eye displays the volume in the 2D views.
  - Change the view ‘reformat’ to ‘Sagittal’ or ‘axial’ or ‘coronal’ in the red view.
  - The volume can also be visualized in the yellow and green views.





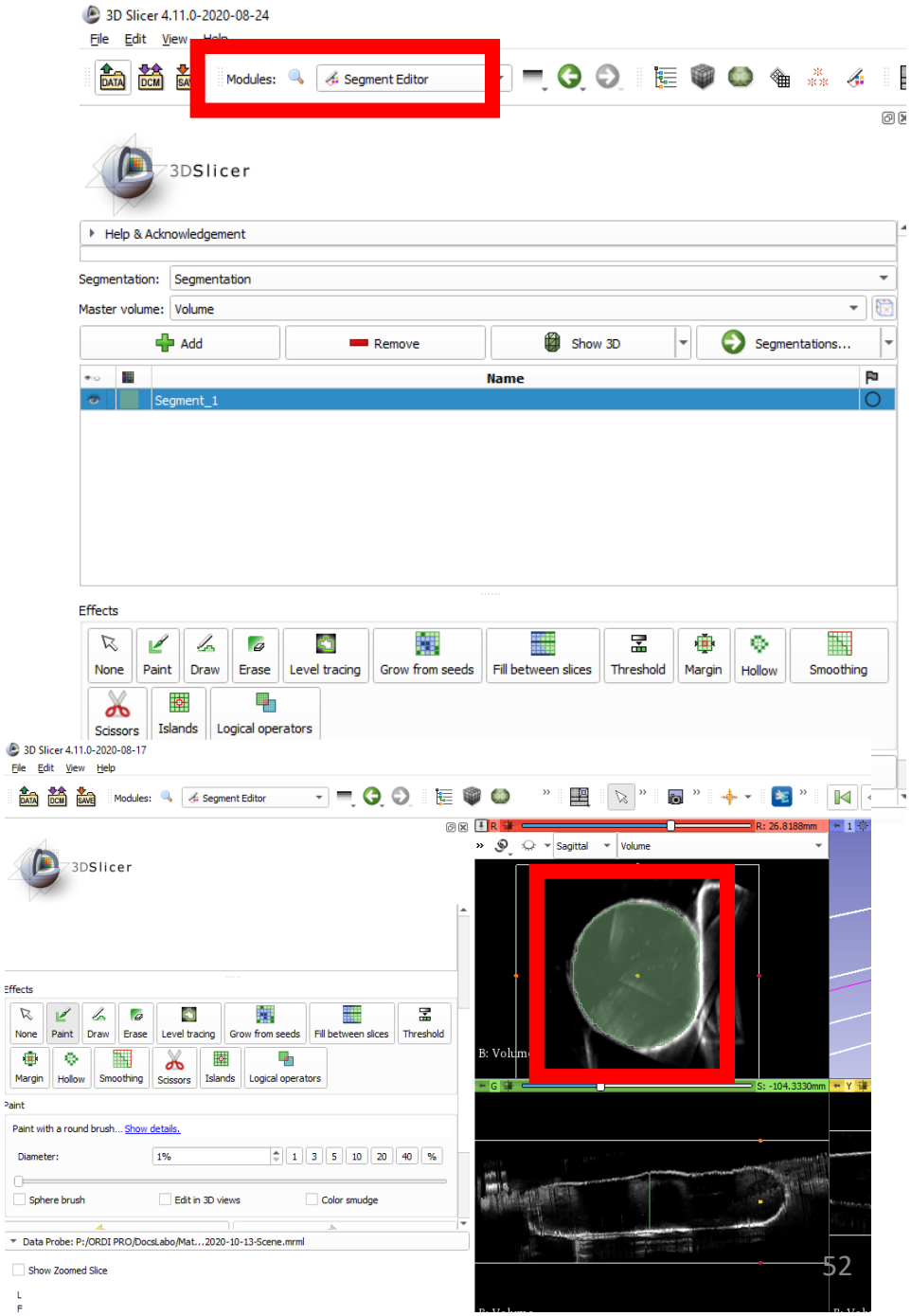
- For a 3D visualization of the volume, right click on the eye and select ‘show in 3D views as volume rendering’
- If the volume appears solid black in the 3D view, right click on the eye and then ‘volume rendering options’ or go to the module ‘volume rendering’ to change the volume visualization settings.
- The preset ‘MR-Default’ is usually working fine.
- The shift value can be modified to improve the rendering.



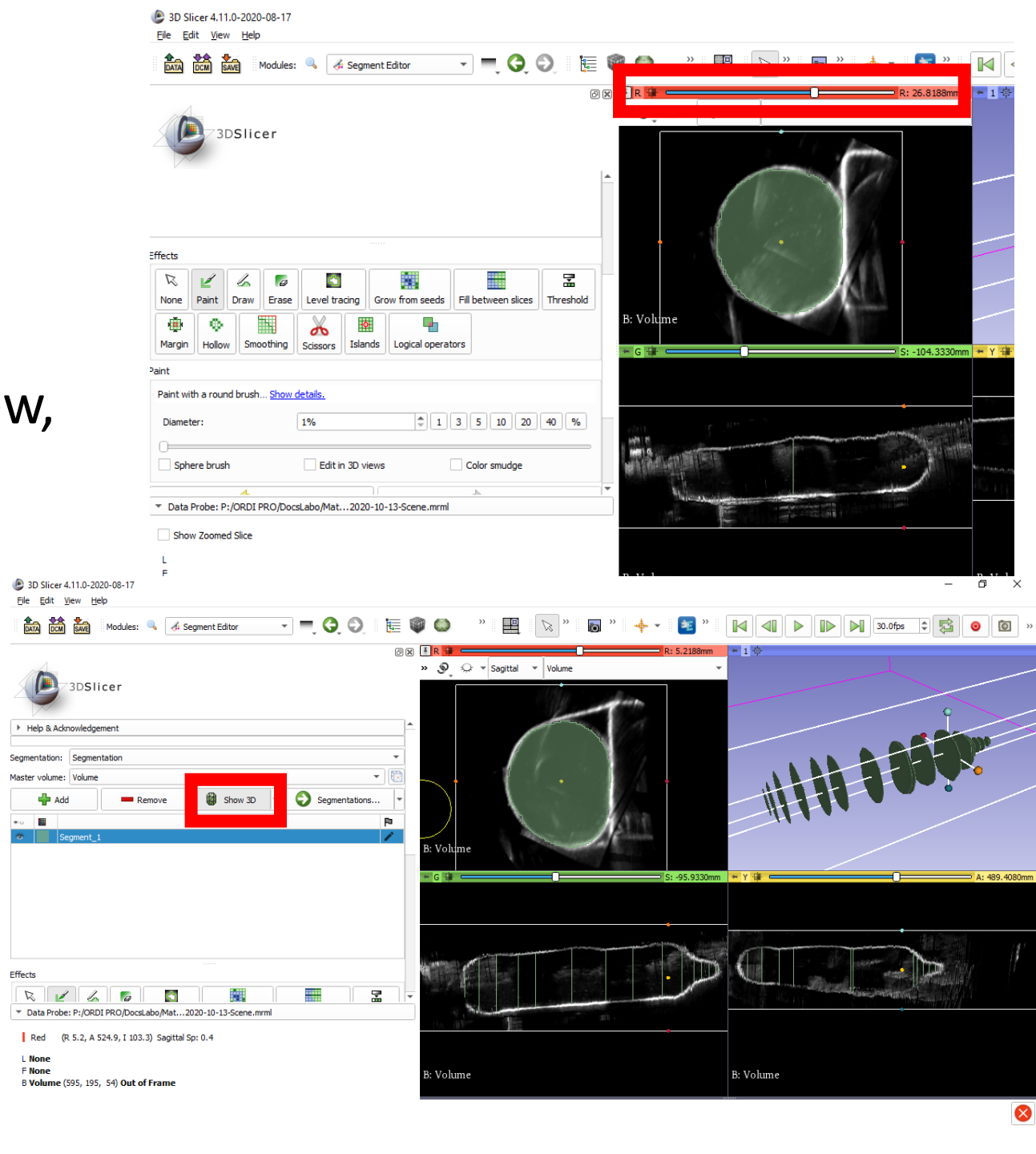


7. SEGMENTATION

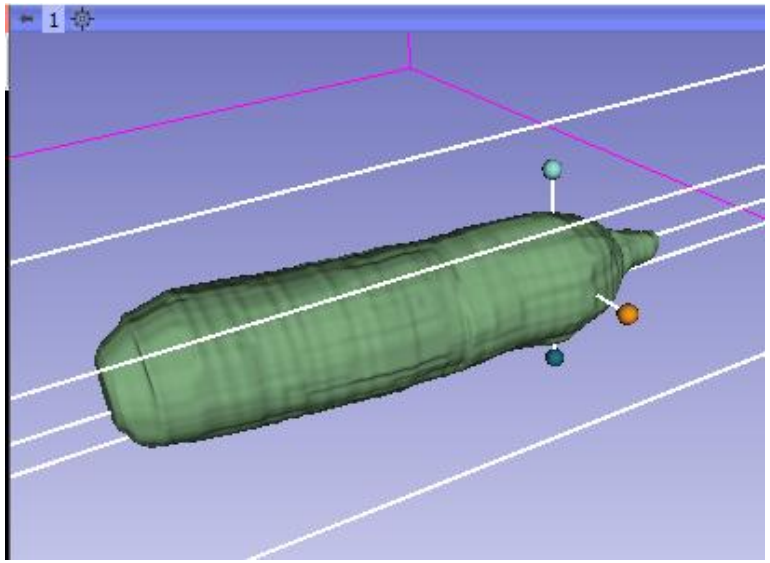
- Open the module ‘Segment Editor’
- Segmentation : create a new segmentation
- Master volume : choose the reconstructed volume
- Click on ‘Add’ to add a segment
- Choose the effect ‘Paint’ to draw the outline of the volume. The diameter of the brush can be modified between 1% and 40%. Zooming the 2D view can help being more precise.
- Draw with the mouse (click and maintain) the volume outline for this slice.
- Careful, the segmentation must be done in one of the plans ‘axial’ ‘sagittal’ or ‘coronal’ but not in the ‘reformat’ plan.

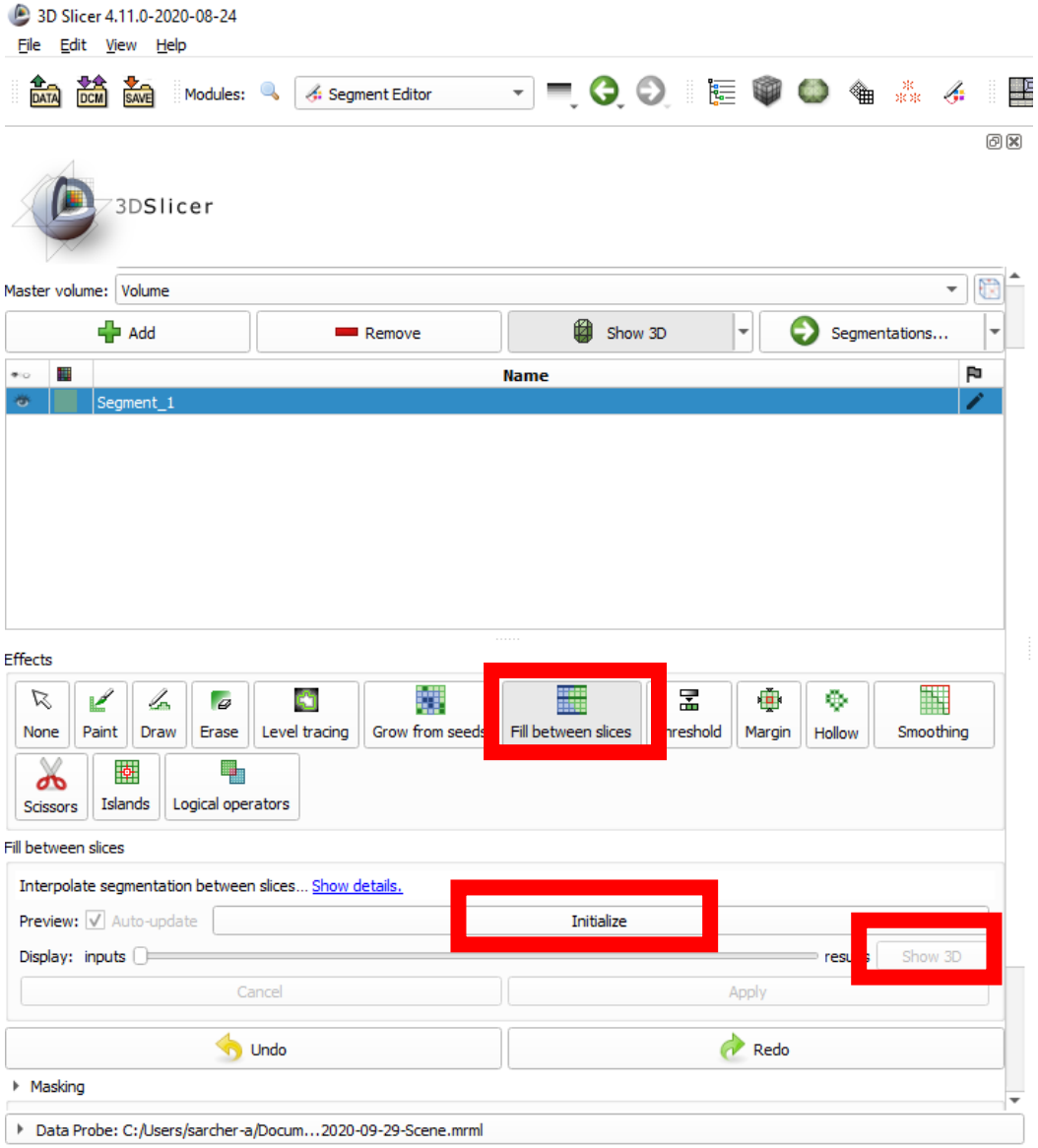


- Move inside the volume with the axis located just above the 2D views (displacement in space)
- Create all the volume outline needed.
- To see the segmentation in the 3D view, click on ‘Show 3D’.

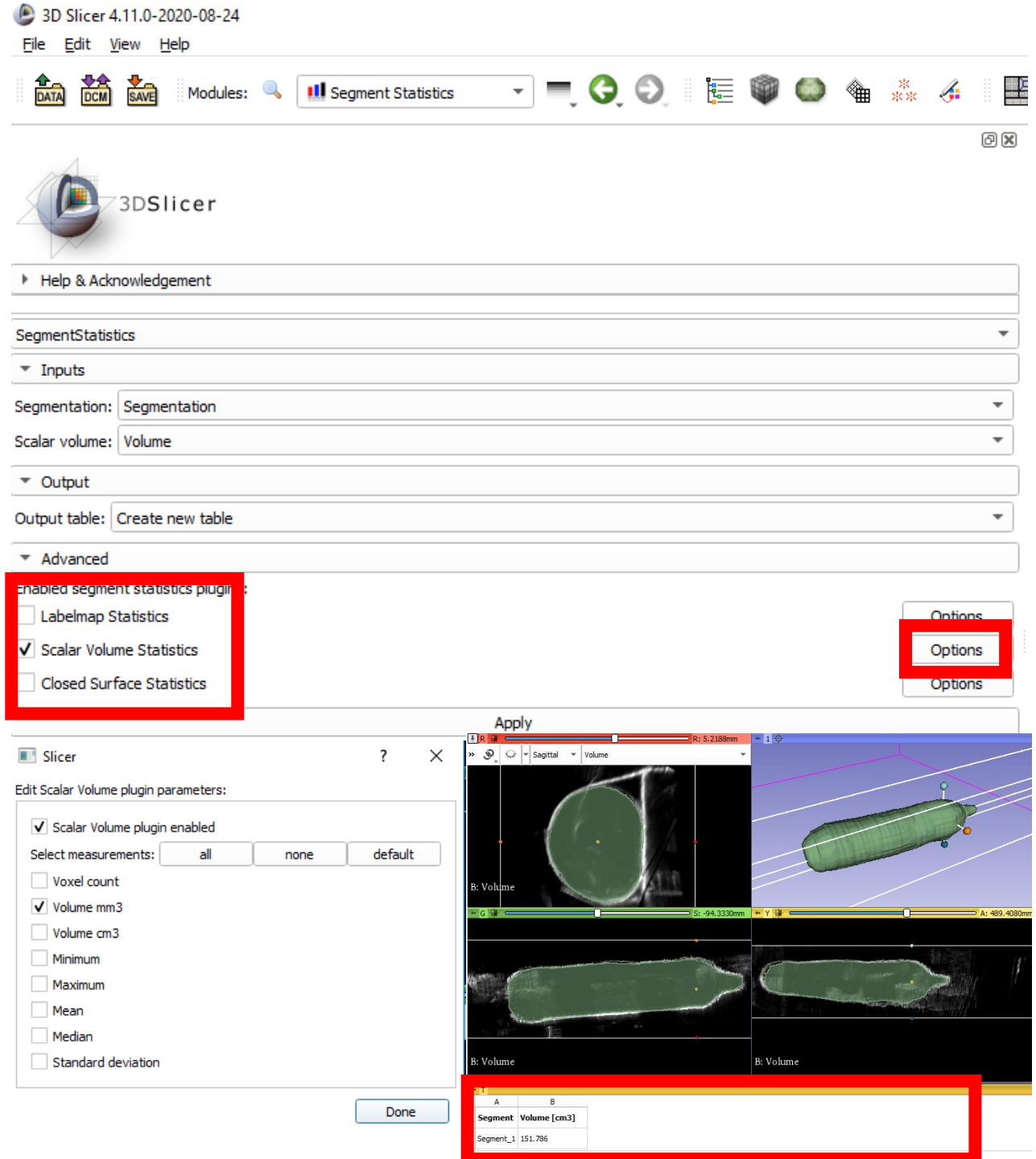


- Once all the outlines are drawn, choose the effect « Fill between slices »
- Click on ‘initialize’
- Click on ‘show 3D’ to get a preview in the 3D view.
- Click on ‘apply’
- The segmentation is then filled between the slices :





- To get informations about the segmentation (for example the volume)
- Open the module ‘Segment Statistics’
- Segmentation : choose the segmentation
- Scalar volume : choose the volume
- Output table : Create a new table
- Advanced :
  - Deactivate the ‘labelmap statistics’ and the ‘closed surface statistics’
  - Click on ‘options’ of ‘scalar volume statistics’ to choose the parameters.
  - Click on ‘apply’ to get the volume statistics.
  - The table is displayed under the 4 visualization windows.



8. APPENDICES

CONFIGURATION FILES

Configuration file ACQUISITION

```
<PlusConfiguration version="2.7" PlusRevision="Plus-2.8.0.62873a16 - Win64">
  <DataCollection StartupDelaySec="1">
    <DeviceSet Name="PlusServer: LaboMIP ACQUISITION ECHO0203" Description="Configuration file with Optitrack Flex 13 (Motive 2.2.0) and video feed from the SSI ultrasound Probe SL10-2 with CAM LINK 4K USB." />
    <Device
      Id="TrackerDevice"
      Type="OptiTrack"
      ToolReferenceFrame="Tracker"
      Profile="motiveprofilefile.xml"
      AttachToRunningMotive="TRUE"
      MotiveDataDescriptionsUpdateTimeSec="1.0"
      LocalTimeOffsetSec="0.148">
      <DataSources>
        <DataSource Type="Tool" Id="Probe" BufferSize="150" />
      </DataSources>
      <OutputChannels>
        <OutputChannel Id="TrackerStream">
          <DataSource Type="Tool" Id="Probe" />
        </OutputChannel>
      </OutputChannels>
    </Device>
    <Device Id="VideoDevice" Type="MmfVideo" FrameSize="1920 1080" VideoFormat="YUY2" CaptureDeviceId="0">
      <DataSources>
        <DataSource
          Type="Video"
          Id="Video"
          PortUsImageOrientation="UF"
          ClipRectangleOrigin="240 120 0"
          ClipRectangleSize="920 880 1"
          BufferSize="150" />
      </DataSources>
      <OutputChannels>
        <OutputChannel Id="VideoStream" VideoDataSourceId="Video" />
      </OutputChannels>
    </Device>
    <Device Id="TrackedVideoDevice" Type="VirtualMixer">
      <InputChannels>
        <InputChannel Id="TrackerStream" />
        <InputChannel Id="VideoStream" />
      </InputChannels>
      <OutputChannels>
        <OutputChannel Id="TrackedVideoStream" />
      </OutputChannels>
    </Device>
  </DataCollection>
```

Part which is about the calibration of Optitrack.
Nothing has to be changed except the time calculated during the temporal calibration : **LocalTimeOffsetSec=« ».**
For the acquisition part, only the position of the probe tracker is streamed by Optitrack. *A flux « TrackerStream » is created.*

Part which is about the configuration of the ultrasound video. The first line is specific to the video capture device used.
« ClipRectangleOrigin » et « ClipRectangleSize » is a first ultrasound video cropping to remove unnecessary parts fo the image. *A flux « VideoStream » is created.*

A flux « TrackedVideoStream » is created from both flux « TrackerStream » and « VideoStream ».

```
<PlusOpenIGTLinkServer MaxNumberOfIgtlMessagesToSend="1" MaxTimeSpentWithProcessingMs="50" ListeningPort="18944" SendValidTransformsOnly="TRUE" OutputChannelId="TrackedVideoStream">
  <DefaultClientInfo>
    <MessageTypes>
      <Message Type="IMAGE" />
      <Message Type="TRANSFORM" />
    </MessageTypes>
    <TransformNames>
      <Transform Name="ProbeToTracker" />
    </TransformNames>
    <ImageNames>
      <Image Name="Image" EmbeddedTransformToFrame="Image" />
    </ImageNames>
  </DefaultClientInfo>
</PlusOpenIGTLinkServer>
<fCal
  StylusModelId="StylusModel"
  ImageDisplayableObjectId="LiveImage"
  NumberOfCalibrationImagesToAcquire="200"
  NumberOfValidationImagesToAcquire="100"
  NumberOfStylusCalibrationPointsToAcquire="200"
  RecordingIntervalMs="100"
  MaxTimeSpentWithProcessingMs="70"
  ImageCoordinateFrame="Image"
  ProbeCoordinateFrame="Probe"
  ReferenceCoordinateFrame="Tracker"
  TransducerOriginCoordinateFrame="TransducerOrigin"
  TransducerOriginPixelCoordinateFrame="TransducerOriginPixel"
  TemporalCalibrationDurationSec="20"
  FixedChannelId="VideoStream"
  FixedSourceId="Video"
  MovingChannelId="TrackerStream"
  MovingSourceId="ProbeToTracker"
  DefaultSelectedChannelId="TrackedVideoStream"
  FreeHandStartupDelaySec="5" />
</PlusConfiguration>
```

The flux « TrackedVideoStream » is sent through PlusOpenIGTLinkServer by the port 18944 that you can modify with the option « ListeningPort ». The types of information sent are precised (IMAGE for the video and TRANSFORM for the probe tracker position).

Part which is about the configuration of fCal. In our case, only the temporal calibration is realised using fCal. The parameter « TemporalCalibrationDurationSec » allows to modify the length of the calibration.

Configuration file CALIBRATION

```
<PlusConfiguration version="2.7" PlusRevision="Plus-2.8.0.62873a16 - Win64">
  <DataCollection StartupDelaySec="1">
    <DeviceSet Name="PlusServer: LaboMIP CALIBRATION ECHO0203" Description="Configuration file with Optitrack Flex 13 (Motive 2.2.0) and video feed from the SSI ultrasound Probe SL10-2 with CAM LINK 4K USB." />
    <Device
      Id="TrackerDevice"
      Type="OptiTrack"
      ToolReferenceFrame="Tracker"
      Profile="motiveprofilefile.xml"
      AttachToRunningMotive="TRUE"
      MotiveDataDescriptionsUpdateTimeSec="1.0"
      LocalTimeOffsetSec="0.092">
      <DataSources>
        <DataSource Type="Tool" Id="Stylus" BufferSize="150" />
        <DataSource Type="Tool" Id="Probe" BufferSize="150" />
      </DataSources>
      <OutputChannels>
        <OutputChannel Id="TrackerStream">
          <DataSource Type="Tool" Id="Stylus" />
          <DataSource Type="Tool" Id="Probe" />
        </OutputChannel>
      </OutputChannels>
    </Device>
    <Device Id="VideoDevice" Type="MmfVideo" FrameSize="1920 1080" VideoFormat="YUY2" CaptureDeviceId="0">
      <DataSources>
        <DataSource
          Type="Video"
          Id="Video"
          PortUsImageOrientation="UF"
          ClipRectangleOrigin="240 120 0"
          ClipRectangleSize="920 880 1"
          BufferSize="150" />
      </DataSources>
      <OutputChannels>
        <OutputChannel Id="VideoStream" VideoDataSourceId="Video" />
      </OutputChannels>
    </Device>
    <Device Id="TrackedVideoDevice" Type="VirtualMixer">
      <InputChannels>
        <InputChannel Id="TrackerStream" />
        <InputChannel Id="VideoStream" />
      </InputChannels>
      <OutputChannels>
        <OutputChannel Id="TrackedVideoStream" />
      </OutputChannels>
    </Device>
  </DataCollection>
```

Part which is about the calibration of Optitrack.
Nothing has to be changed except the time calculated during the temporal calibration : **LocalTimeOffsetSec=« ».**
For the calibration, the probe tracker position « Probe », and the stylus position « Stylus » are streamed by Optitrack. *A flux « TrackerStream » is created with both positions.*

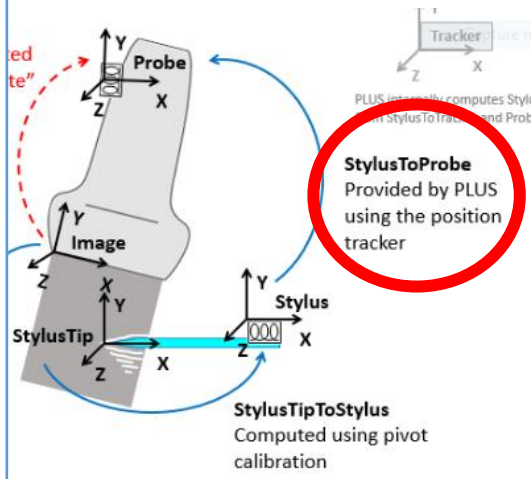
Part which is about the configuration of the ultrasound video. The first line is specific to the video capture device used.
« ClipRectangleOrigin » et « ClipRectangleSize » is a first ultrasound video cropping to remove unnecessary parts fo the image. *A flux « VideoStream » is created.*

A flux « TrackedVideoStream » is created from both flux « TrackerStream » and « VideoStream ».

```
<PlusOpenIGTLinkServer MaxNumberOfIgtlMessagesToSend="1" MaxTimeSpentWithProcessingMs="50" ListeningPort="18944" SendValidTransformsOnly="TRUE" OutputChannelId="TrackedVideoStream">
  <DefaultClientInfo>
    <MessageTypes>
      <Message Type="IMAGE" />
      <Message Type="TRANSFORM" />
    </MessageTypes>
    <TransformNames>
      <Transform Name="StylusToProbe" />
    </TransformNames>
    <ImageNames>
      <Image Name="Image" EmbeddedTransformToFrame="Image" />
    </ImageNames>
  </DefaultClientInfo>
</PlusOpenIGTLinkServer>
<fCal
  StylusModelId="StylusModel"
  ImageDisplayableObjectId="LiveImage"
  NumberOfCalibrationImagesToAcquire="200"
  NumberOfValidationImagesToAcquire="100"
  NumberOfStylusCalibrationPointsToAcquire="200"
  RecordingIntervalMs="100"
  MaxTimeSpentWithProcessingMs="70"
  ImageCoordinateFrame="Image"
  ProbeCoordinateFrame="Probe"
  ReferenceCoordinateFrame="Tracker"
  TransducerOriginCoordinateFrame="TransducerOrigin"
  TransducerOriginPixelCoordinateFrame="TransducerOriginPixel"
  TemporalCalibrationDurationSec="20"
  FixedChannelId="VideoStream"
  FixedSourceId="Video"
  MovingChannelId="TrackerStream"
  MovingSourceId="ProbeToTracker"
  DefaultSelectedChannelId="TrackedVideoStream"
  FreeHandStartupDelaySec="5" />
</PlusConfiguration>
```

The flux « TrackedVideoStream » is sent through PlusOpenIGTLinkServer by the port 18944 that you can modify with the option « ListeningPort ». The types of information sent are precised :

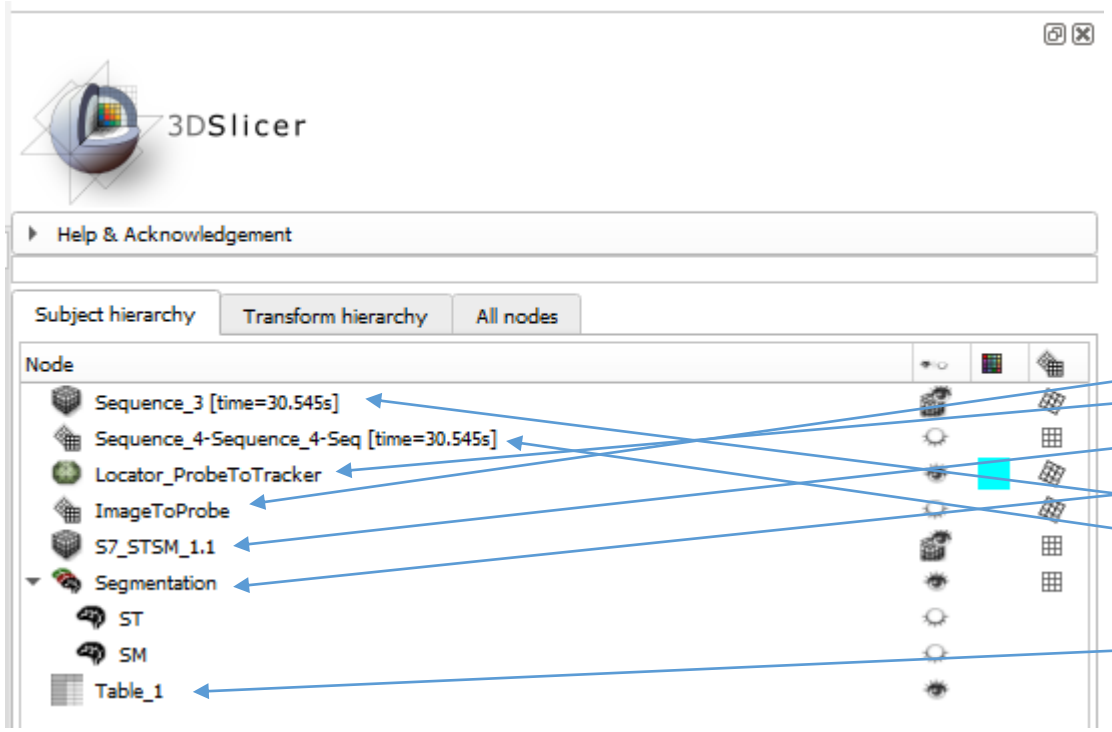
- IMAGE for the ultrasound video
- **TRANSFORM for the position of the probe tracker related to the position of the stylus.**

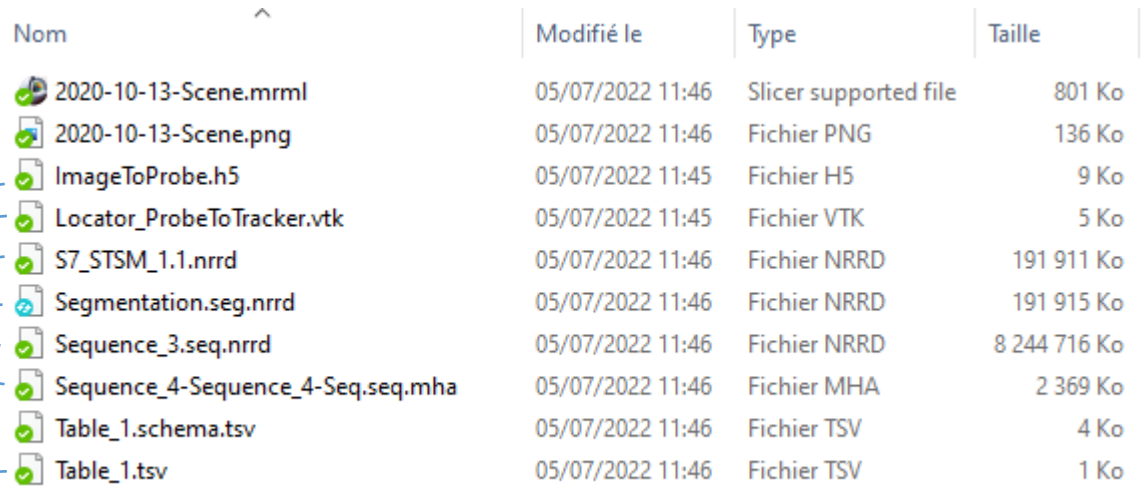


Part which is about the configuration of fCal. In our case, only the temporal calibration is realised using fCal. The parameter « TemporalCalibrationDurationSec » allows to modify the length of the calibration.

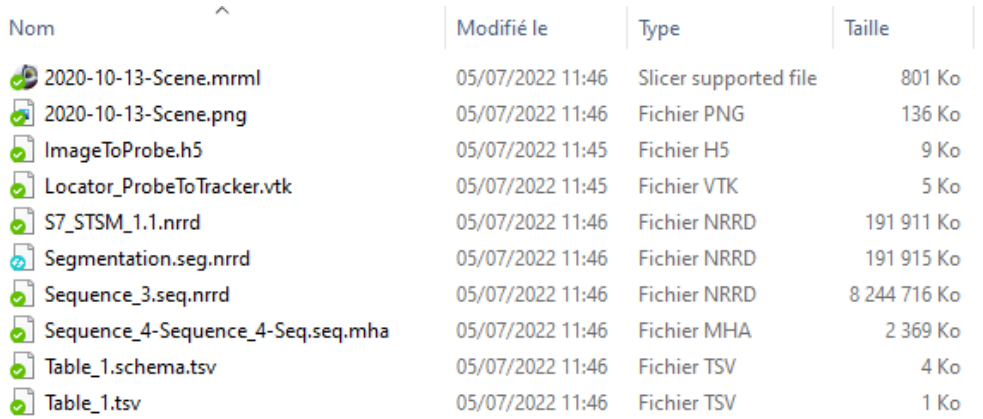
DATA HIERARCHY IN 3D SLICER

Data Slicer 3D





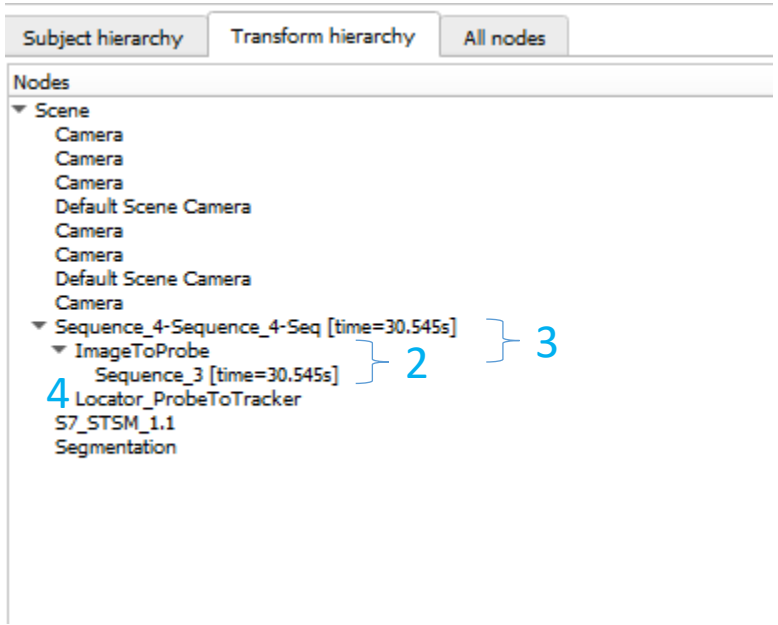
Data Slicer 3D



Nom	Modifié le	Type	Taille
2020-10-13-Scene.mrml	05/07/2022 11:46	Slicer supported file	801 Ko
2020-10-13-Scene.png	05/07/2022 11:46	Fichier PNG	136 Ko
ImageToProbe.h5	05/07/2022 11:45	Fichier H5	9 Ko
Locator_ProbeToTracker.vtk	05/07/2022 11:45	Fichier VTK	5 Ko
S7_STSM_1.1.nrrd	05/07/2022 11:46	Fichier NRRD	191 911 Ko
Segmentation.seg.nrrd	05/07/2022 11:46	Fichier NRRD	191 915 Ko
Sequence_3.seq.nrrd	05/07/2022 11:46	Fichier NRRD	8 244 716 Ko
Sequence_4-Sequence_4-Seq.seq.mha	05/07/2022 11:46	Fichier MHA	2 369 Ko
Table_1.schema.tsv	05/07/2022 11:46	Fichier TSV	4 Ko
Table_1.tsv	05/07/2022 11:46	Fichier TSV	1 Ko

- **2020-10-13-Scene.mrml :** global file of the « scene », which lists all elements that 3D slicer must load to display the full workspace (files h5, vtk, nrrd, mha, etc.)
- **ImageToProbe.h5** : fixed transform (that does not evolve with time) between the probe tracker and the referential of the ultrasound image. This file is created during probe calibration and can be modified after, to redo a 3D volume reconstruction.
- **Locator_ProbeToTracker.vtk** : 3D needle model (which, in this case, is associated to the probe tracker position)
- **S7_STSM_1.1.nrrd** : 3D volume reconstructed from multiple 2D ultrasound sweeps (created by the module « Volume reconstruction » of Slicer 3D).
- **Segmentation.seg.nrrd** : Segmentation which includes both segments ST and SM, done on the volume S7_STSM_1.1.nrrd
- **Sequence_3.seq.nrrd** : All 2D ultrasound images obtained during the acquisition (image + timestamps).
- **Sequence_4-Sequence_4-Seq.seq.mha** : All 3D positions of the probe tracker during the acquisition (transform related to the lab referential + timestamps).
- **Table_1.schema.tsv / Table_1.tsv** : results table (in this case, segmentation volumes).

Data Slicer 3D

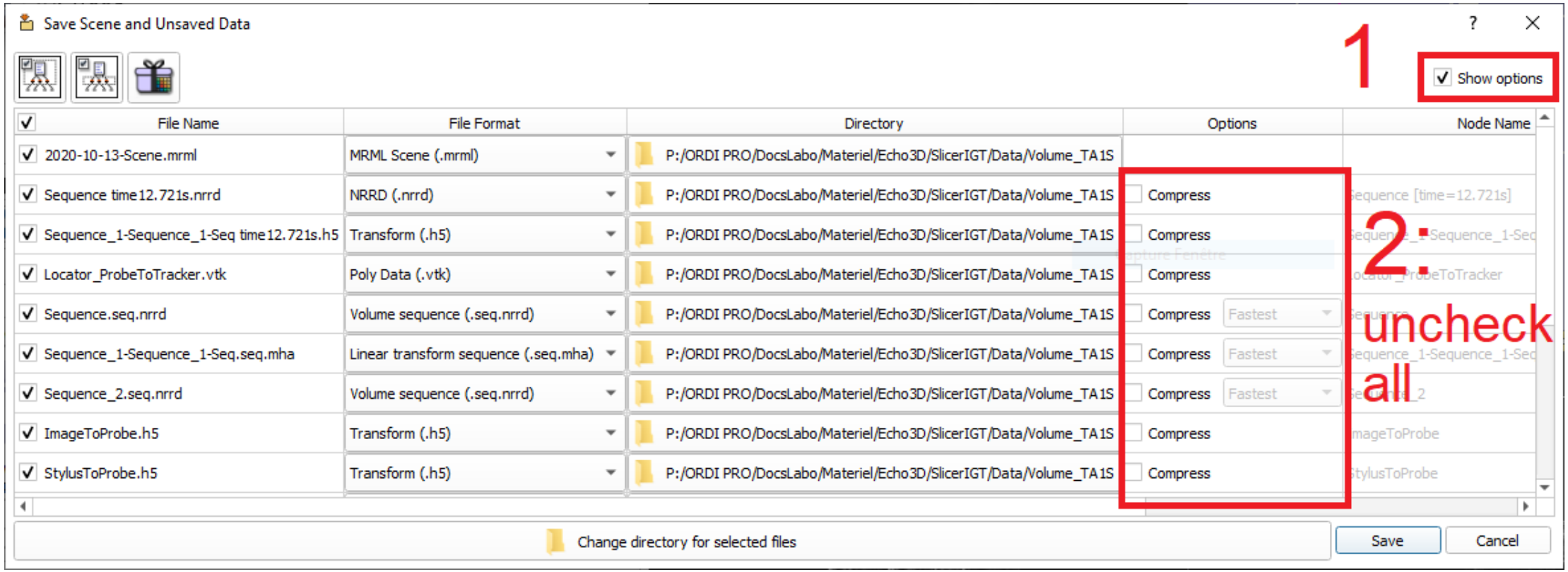


This hierarchy is defined in our 3D ultrasound templates.
Thanks to this hierarchy we can observe the data correctly and we are able to reconstruct the 3D volume using the ultrasound images **positioned in the lab referential**.
The 2D ultrasound images **Sequence_3** are raw, not positioned in a 3D referential (they are in their own referential « ultrasound image »).

1. We place these 2D ultrasound images in the referential « probe tracker » using the transform **ImageToProbe** which has been created during the spatial calibration of the probe.
2. We place these 2D ultrasound images (now located in the probe tracker referential) in the lab referential (which evolves with time due to the probe displacement), using the transforms **Sequence_4-Sequence_4-Seq**.
3. To visualise the probe tracker in 3D, we place the 3D needle model **Locator_ProbeToTracker** (initially neutral, in no referential), in the lab referential (dependent of the tracker 3D positions) so at the same level as ImageToProbe.
4. The other elements have no specific hierarchy

SAVING OPTION

Data saving



To save som time during data saving (this step can be long), it is possible to remove the « Compress » option, the data saving will be quicker however much heavier.

PIVOT CALIBRATION

PIVOT CALIBRATION

What is its use ?

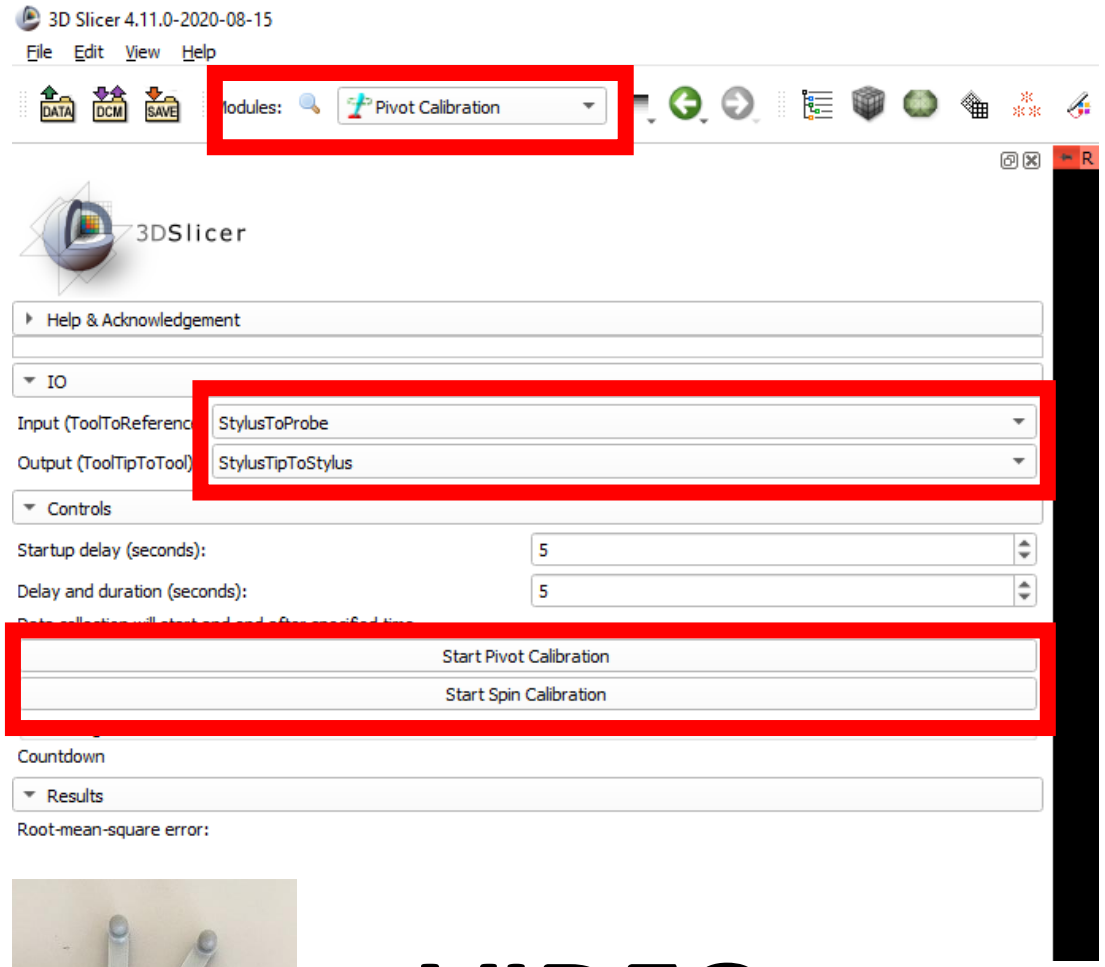
- To calculate the transform matrix between the referential of the stylus (markers on the stylus) and the stylus tip.

When to do it ?

- If the stylus used is different from the one from the lab (so usually never).

- Note: careful, the following tutorial is not complete however it summarizes the main steps of the procedure.

- Choose the module ‘pivot calibration’
- Choose input = StylusToProbe
- Choose output = ‘createnewlineartransform as…’ and name it ‘StylusTipToStylus’
- Click on ‘start pivot calibration’
- Keep the stylus tip in a **fixed** position and rotate the stylus around its tip.
- Click on ‘start spin calibration’ do the same movement. The ‘spin calibration’ is for non vertical stylus like the one used in the lab.



VIDEO

SPECIFIC TO SUPERSONIC IMAGING ULTRASOUND

- Technical notes regarding the resolution of the SuperShearing Imaging ultrasound (echo_01):
  - Resolution echo_01 SuperShearingImaging 1680x1050
  - Equivalent 42x26cm
  - Interest zone origin 10x4cm // **6x3cm**
  - Rectangle size 16x21cm // **23x22cm**
  - 42cm → 1680p