Workshop Los Angeles — December 2024

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Once you have successfully installed and tested Brainstorm, proceed to download the data to be used in the workshop.

- Download the **raw data**:
  - https://box.bic.mni.mcgill.ca/s/vJWC1ak9CW1M6YU
- Unzip the downloaded raw data on your desktop: it will create a new folder named **workshopLAX_raw**

OUTLINE OF TOPICS COVERED IN THIS WORKSHOP

1. **Introduction to Brainstorm Interface**
2. **EEG and MEG Analysis**
   a. Import anatomy
   b. Review Raw recordings
   c. Import events
   d. Frequency filters
   e. Artifact detection and correction
   f. Sensor level analysis
      i. Import recordings
      ii. Review trials
      iii. Trial averages
   g. Source estimation
      i. Forward model (aka Head model)
      ii. Noise covariance matrix
      iii. Computing inverse models
      iv. Atlases and Scouts
3. **SEEG Analysis**
   a. Import anatomy
   b. Coregister and Normalize images to standard MNI space
   c. SEEG contact localization
   d. Review Raw recordings
   e. Modeling interictal spikes using Min-Norm Imaging
   f. Modeling ictal onset with Low Voltage Fast Activity (LVFA) using fingerprint analysis (Sensor Space)
   g. Appendix: How to run CAT12 segmentation from Brainstorm
   h. Appendix: Remove power line noise

Preparing your dataset to be imported to Brainstorm

- MRI DICOM files have to be converted to NIfTI format.
- EEG data can be imported to Brainstorm in native format or EDF file conversions.

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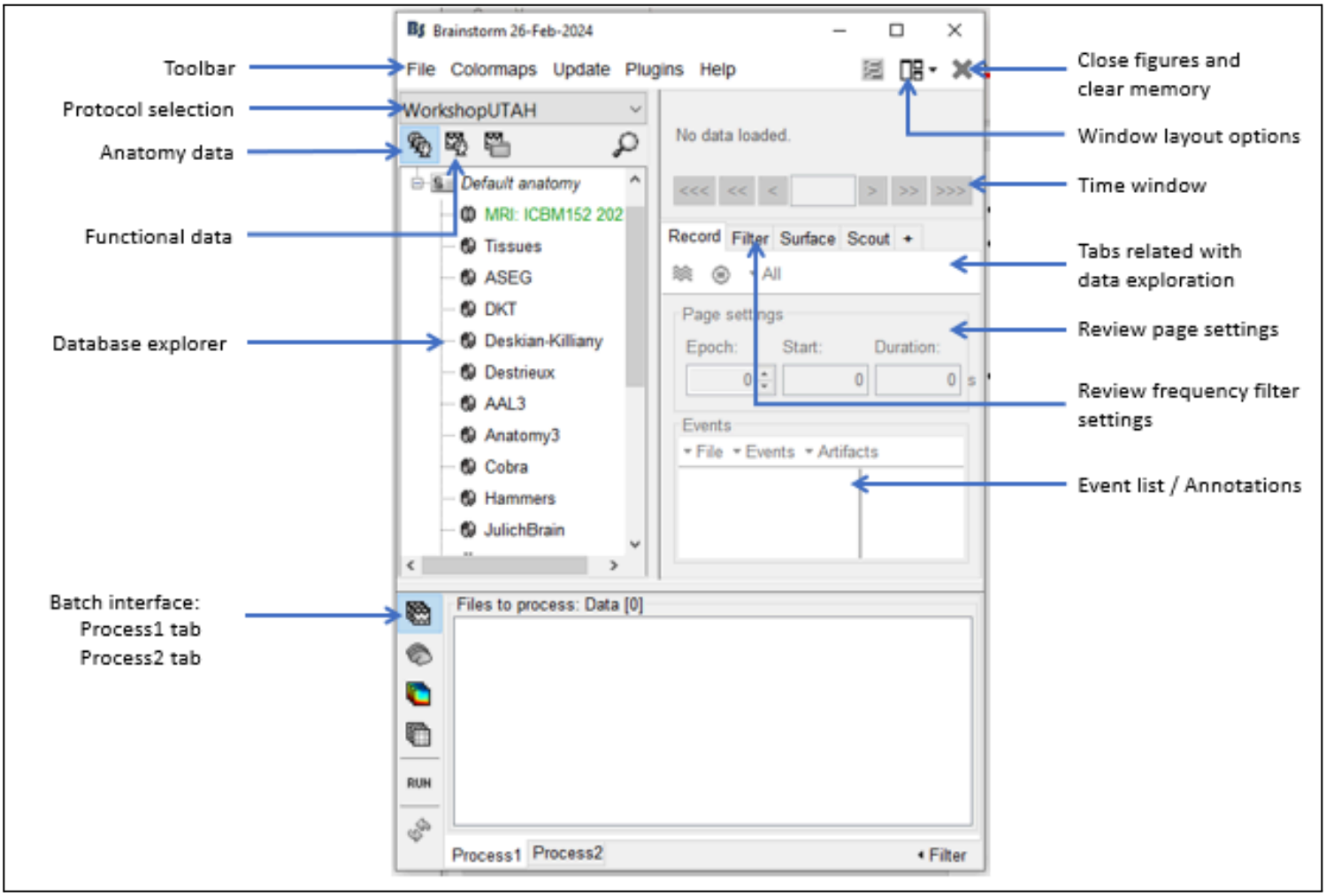
1. Introduction to Brainstorm Interface

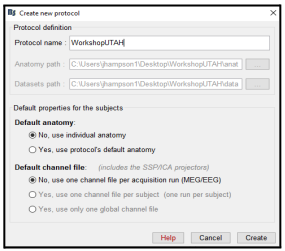
- CLOSE ALL YOUR APPLICATIONS, INCLUDING WEB BROWSERS
- Start Brainstorm: from Matlab or using the stand-alone application.



*** red highlighted texts are processing steps we will be skipping during this workshop to save time***

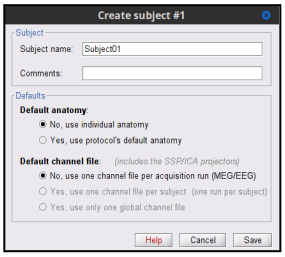
2. EEG and MEG Analysis: Import Anatomy

- Select File > New protocol: **WorkshopLAX**

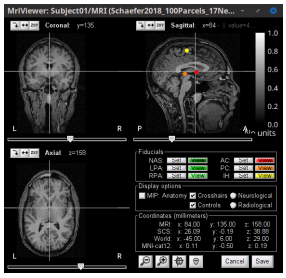


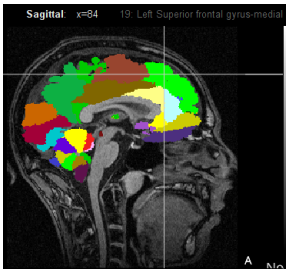
  - **No**, use individual anatomy
  - **No**, use one channel file per acquisition run (MEG/EEG)
- Introduction to database explorer (list of protocols, exploration modes...)

- Switch to anatomy view: (1st button, on top of the database explorer)
- Right-click on protocol top node > New subject: **Subject01** (use Defaults)
- Right-click on the created subject > Import anatomy folder **(Do not select the (auto) option)**
  - *Files of Type* **CAT12**
  - Select the **anatomy** folder in **Desktop/workshop_lax/**
  - For *Number of vertices* set **15000**

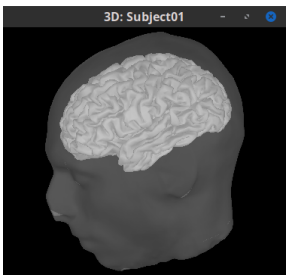


- Once the MRI viewer opens
  - Explain fiducial points and the coordinates (MRI, SCS, MNI)
  - Set coordinates: , set fiducials:
    (MRI coords) **NAS [125, 230, 64] LPA [48, 141, 44] RPA [215, 140, 59]**
- Exploring MRI ( ): double-click or right-click > *Display* > *MRI Viewer*
  - Exploring the volume (click, mouse wheel, sliders)
  - Anatomical atlases, colormaps, colorbar, figure popup menu
- Exploring MRI ( ): right-click > *Display* > *3D orthogonal slices*
- Display cortex ( ): double-click or right-click > *Display*
  - 3D figure: rotation, zoom
  - Predefined views and keyboard shortcuts: left, right, top, etc
  - Surface tab: smooth, sulci, edges
  - Scouts tab: atlases and scouts



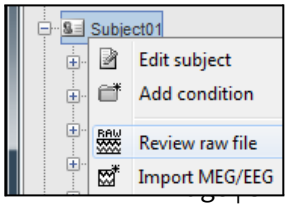


- Close all figures (button at top-right): close all figures and empty the memory

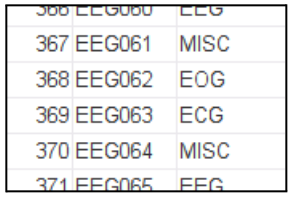


3. EEG and MEG Analysis: Review Raw recordings

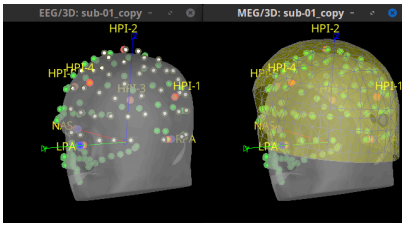
- Switch to functional view: (2nd button, on top of the database explorer)
- Create **Link to raw file**: right-click on Subject01 >
  - *Files of Type* **MEG/EEG: Yokogawa/KIT (*.sqd; *.con; *.raw; *.ave; *.mrk)**



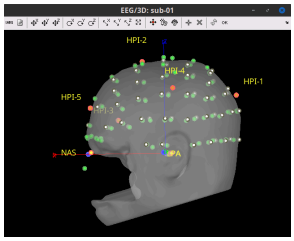
  - Select the file **SEF_000-export.con** in the **data** folder in **Desktop/workshop_lax/**
  - Click on **Open**
- In the popup for **Refining registration**, click on **No**
- The sensor coregistration will show, close it for now

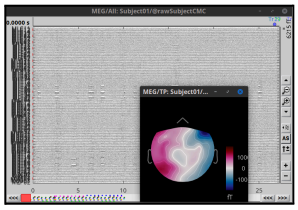


- Change the type of some channels, right-click on the channel file > *Edit channel file*:
  - Channel **EO1** (208) and **EO2** (209): Change the type to **EOG**
  - Channel **EKG+** (214): Change the type to **ECG**
  - Channel **E** (231): Change the type to **Misc**
  - Close the figure and accept to save the modifications

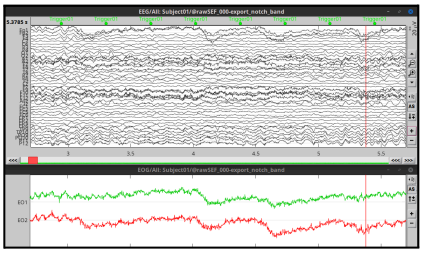


- Check sensor coregistration
  - right-click > *MRI registration* > *EEG:Check*
    Some electrodes are above or inside the head surface
  - right-click > *MRI registration* > *EEG: Edit*
    - Select **Project electrodes on surface**
    - Click **OK** and save
  - right-click > *MRI registration* > *MEG:Check*
  - Close figures



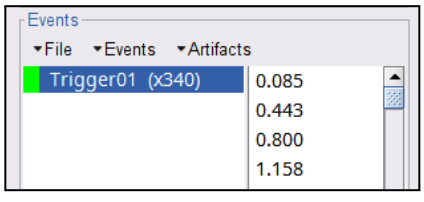


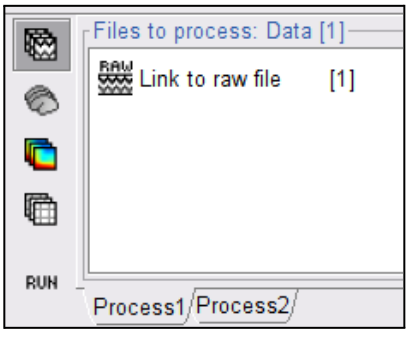
- Review EEG signals: RAW right-click > *EEG* > *Display time series*
  - Display in columns ( ), display windows of 10s
  - Amplitude gain: buttons and shortcuts
  - Add a topography and set the window layout to weighted
- Review MEG signals
- Review EOG signals
- Review EEG and EOG signals simultaneously
- Close all figures



4. EEG and MEG Analysis: Import events

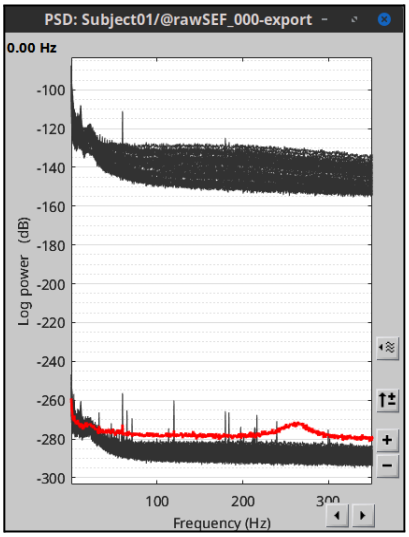
- Different ways of Importing events
- Right-click on Link to *raw file* > *TRIGGER* > *Display time series*
  - Display in columns. Notice that Trigger01 contains the information of the electric stimuli
- In the Record tab, menu *File* > *Read events from channel*
  - Event channel = **Trigger01**
  - Option = **TTL: detect peaks of 5V/12V on an analog channel**
  - Do **NOT** check the option **Accept zeros as trigger values**
- Close the figure with the timeseries to save modifications



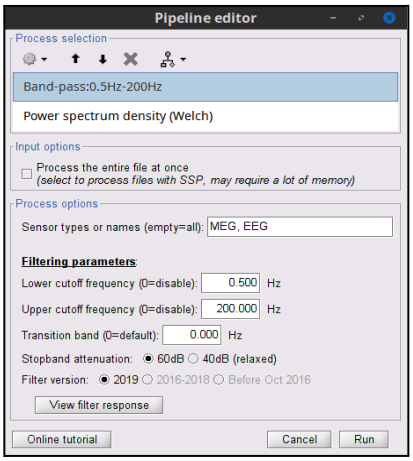


5. EEG and MEG Analysis: Frequency filters

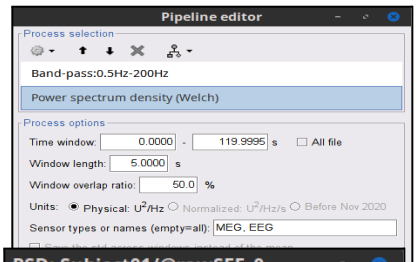
- Process section
  - Tabs **Process1**, **Process2**
  - File types: recordings, sources, time-freq, and matrices



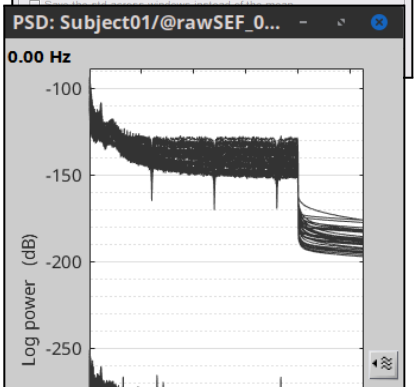
- EEG and MEG: Filter power line artifact
  - Close all the figures
  - Drag-and-drop (RAW) raw file in *Process 1*, click [RUN]
  - Add the process: *Frequency, Power spectrum density (Welch)*
    - *Time window* = **All file**, *Window length* = **5s**, *Overlap* = **50%**
    - *Units* = **Physical**
    - *Sensor types* = **EEG, MEG**
  - Click on **Run**
- Open the new ( ) PSD file
  - Two PSD groups, from top to bottom: **EEG** and **MEG** sensors
  - Peak around 11 Hz: alpha waves from the subject's brain
  - Peaks at 60Hz, 120Hz, 180Hz on EEG and MEG: Power lines (60Hz+harmonics)
  - Smaller peaks at 35Hz, 65Hz, 70Hz, 183Hz, 197Hz on MEG only: Unknown source
  - MEG sensor **LC11** appears to have a higher level of noise than all the other MEG sensors.
    Select the channel (it becomes red), right-click and *Mark selected as bad*
    This is often an indication of a bad channel, we can verify this by reviewing MEG signals



- Notch filter the raw file: Select: **Pre-process > Notch filter**
  - *Frequencies to remove (Hz)* = **60, 120, 180 Hz**
  - *Sensor types* = **EEG, MEG**
  - Compute the PSD for the notch-filtered raw file, and open the new PSD file



- EEG and MEG: Bandpass filter
  - Drag-and-drop notch-filtered raw file in Process , click [RUN]
  - Add the process *Pre-process > Band-pass filter*
    - *Sensor types* = **EEG, MEG**, *Lower cutoff freq* = **0.5 Hz**, *Upper cutoff freq* = **200 Hz**
    - Click **View filter response** to see the filter properties
  - Select: **Frequency, Power spectrum density (Welch)**

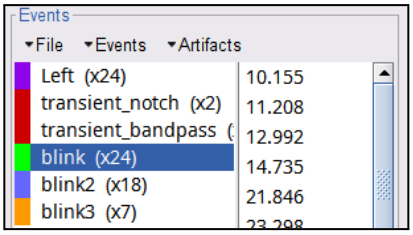


- Add the process: *Frequency, Power spectrum density (Welch)*
- **Run** the pipeline

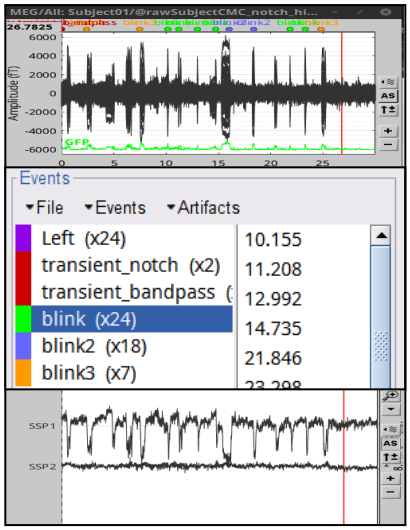
- EEG: re-reference to Average
  - Open the EEG timeseries for the bandpass filtered raw file (in folder **_notch_band**)
- Click on *Artifacts* > *Re-reference EEG* and use **AVERAGE** as EEG reference channel

- Delete intermediate files that won't be needed anymore:
  - Select folder **SEF_000-export_notch**
  - Press the Delete key (or right-click > *File* > *Delete*)

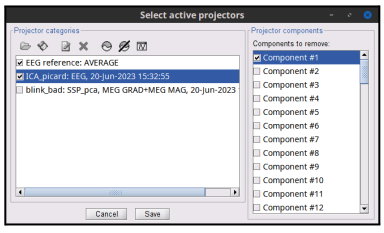
6. EEG and MEG Analysis: Eye-movement related artifacts and other artifacts

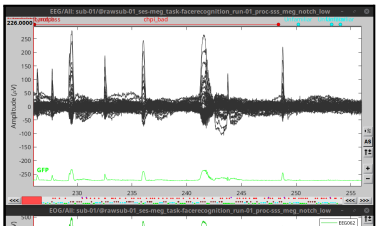


- Detect eye-movement events
  - Open the time series for EEG and EOG
  - In the Record tab, select *Artifacts* > *Detect eye blinks*, and use the parameters:
    - *Channel name* = **EO2**, *Time window* = **All file**, *Event name* = **blink**
  - Display MEG signals (along EOG) and see some blink occurrences
  - Merge all the **blink** event groups in a **blinks** group
- Detect heartbeat events
  - Open the time series for EEG and ECG
  - In the Record tab, select *Artifacts* > *Detect heartbeats*, and use the parameters:
    - *Channel name* = **EKG+**, *Time window* = **All file**, *Event name* = **cardiac**
- Handle simultaneous events
  - In the Record tab, select *Artifacts* > *Remove simultaneous:*
    - Remove events named: **cardiac**
    - When too close to events: **blinks**
    - Minimum delay between events: **250 ms**

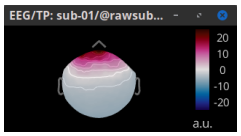


- Remove blink artifacts from EEG with ICA
  - Open the time series for EEG
  - In the Record tab, select *Artifacts* > *ICA components*, and use the parameters:
    - *Time window* = **All file**, *Band-pass filter* = **[0, 0]**, *Resample* = **0***ICA algorithm* = **Picard**, *Number of ICA components* = **0** *Sort components based on correlation with* = **EOG, ECG**



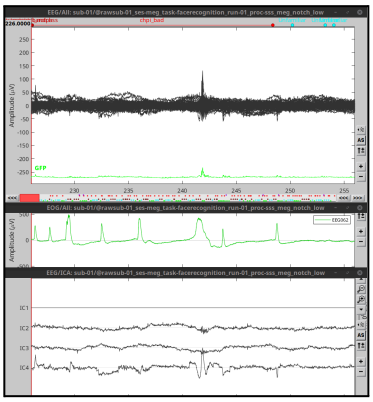


- In the *Select active projectors* window, **uncheck** all ICA components, highlight the first eight and plot their time series ( ), and topologies
- Open EEG and EOG time series and disable **auto scaling** (AS) in the 3 plots
- Check **Component #1** which is related to the ECG signal and verify the impact of removing it from the EEG signal



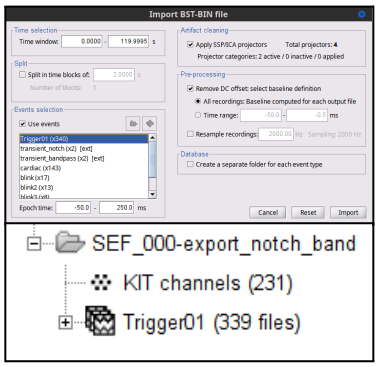
- Check **Component #2** which seem related to the EOG signal and verify the impact of removing it from the EEG signal
- Click on **Save**, close all figures

- Remove blink artifacts from MEG with SSP
  - Open the time series for MEG
  - In the Record tab, select *Artifacts* > *SSP: Eye blinks*, and use the parameters:
    - *Event name* = **blinks**, *Sensors* = **MEG**
  - In the *Select active projectors* window, **uncheck** all components, highlight the first two and plot them ( )
  - Open MEG (all) and EOG time series and disable **auto scaling** (AS) in the 3 plots
  - Check **Component #1** to verify the impact of removing it from the MEG signal
  - Click on **Save**, close all figures

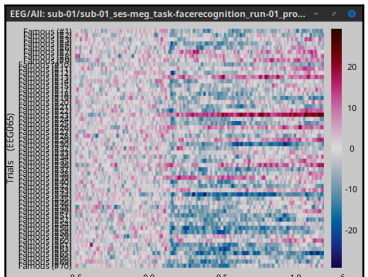


7. EEG and MEG Analysis: Import recordings

- Import in database
  - Right-click on the pre-processed file > *Import in database*, and use the parameters:
    - *Time window* = **0 - 119.9995 s**
    - Do **NOT** check **Split in time blocks**
    - Check **Use events** and select **Trigger01 (x340)**
    - *Epoch time* = **-50 to 250 ms**
    - Check **Apply SSP/ICA projectors**
    - Check **Remove DC offset**, select **All recordings**
  - Answer **Yes** to this question to discard the last epoch.
  - A new folder named **SEF_000-export_notch_band** is created (no more **raw** indicator)

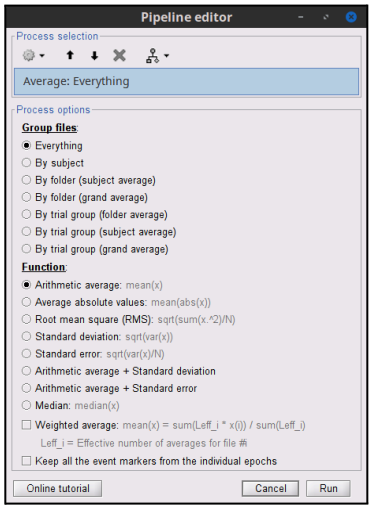


- Review trials
  - Trials groups ( ), contain same-name trials (often imported from with the same event)

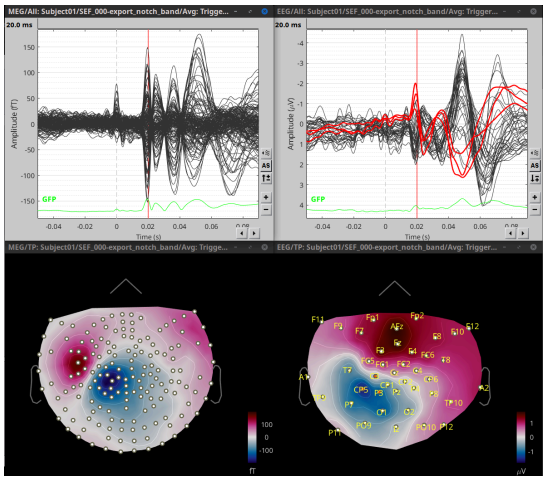


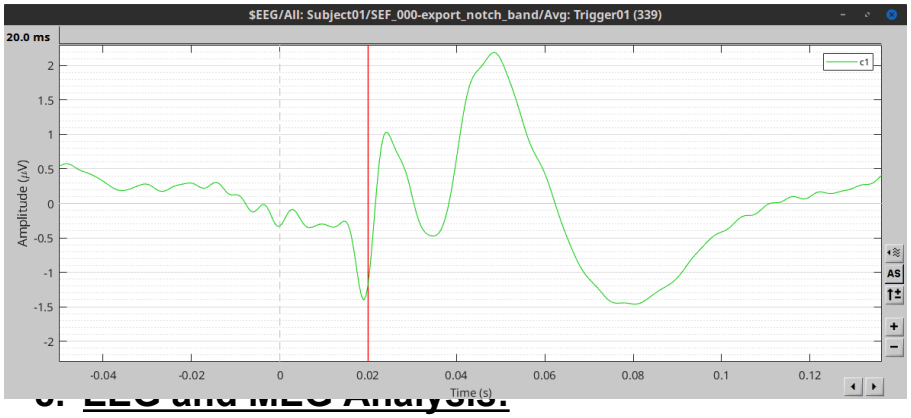
- Trials containing an bad event (with **bad** in its name) are labeled as bad ( )
- Rastre plots: Right-click on trial group > *Display as image* > *EEG* select channel **CP5** in the Display Tab

- Average trials
  - Drag and drop all the trial groups in Process1
  - Run process *Average* > *Average files*:
    - *Group files* = **Everything**, *Function* = **Arithmetic average**



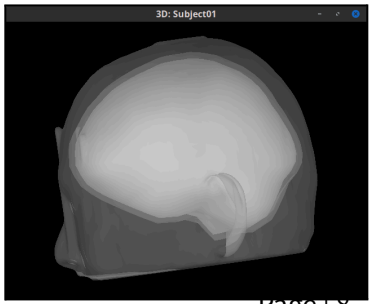
- Check different plots for the average somatosensory evoked potential (SEP) in **EEG** signals, and the somatosensory evoked fields (SEF) in **MEG** signals. Plot both topographies
- Create a sensor cluster
  - Open the *Cluster* tab by clicking on the plus sign (**+**) at the right of *Record* tab
  - Click on to create a new cluster by indicating the sensor names, use **C3, CP5** and **P3**
  - Plot the cluster time series with on the plot button ( )
- Observe Components N20, P25, N33 and P45 visible over left somatosensory cortex in EEG and their respective fields in MEG
- Close all figures. Do not save the created cluster
-





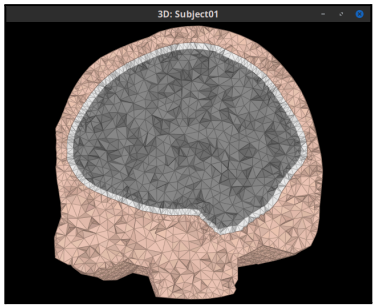
Forward model (aka Head model)

- Computing boundary element (BEM) layers
  - Go to the anatomy view
  - Right-click on **Subject01** folder > *MRI segmentation* > *Generate BEM surfaces*
    - Select **Brainstorm**



    - Number of vertices: *Scalp* = **1082**, *Outer skull* = **642** and *Inner skull* = **642**
    - Thickness of layers, Skull (mm) **4**
    - **Note:** This number of vertices is selected to avoid long computations during the workshop. Otherwise, values of **1922 vertices** can be used.
  - Right-click on the default cortex (in green) > *Force inside skull*
  - The **fix** cortex is now selected as default
- Compute the head model for EEG and MEG

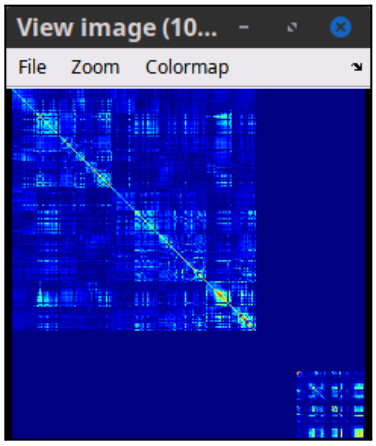
  - Go back to the functional data view
  - Right-click on the channel file ( ) in the imported data folder > *Compute head model*
    - *Source space* = **Cortex surface**
    - *Forward model* = **MEG: Overlapping spheres** and **EEG: OpenMEEG BEM**
    - Click on **OK**
      - Use default BEM layers and conductivities
      - Use default OpenMEEG options
    - The process may take up to 5 min



- Demo: the forward model can be computed also using the FEM method
  - Computation of FEM meshes from BEM surfaces. They can be computed from volumes
- Forward model can be computed with the DUNEuro plugin

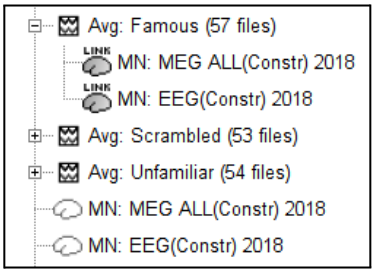
9. EEG and MEG Analysis: Noise covariance matrix

- Compute noise covariance for EEG and MEG from pre-stimulus baselines
  - Select the trial group, right-click > *Noise covariance* > *Compute from recordings:*
    - *Baseline* = **[-50, 0] ms**, *Sensors* = **EEG** and **MEG**
  - Select **Block by block**



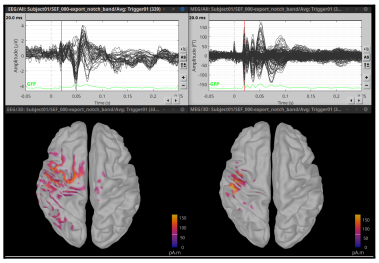
10. EEG and MEG Analysis: Computing inverse models

- Compute inverse model (EEG)
  - Right-click on the head model ( ) > *Compute sources*, use these parameters:
    - Select **Minimum norm imaging,** Select **Current density map**
    - Select **Constrained: Normal to the cortex**
    - *Sensors* = **EEG**



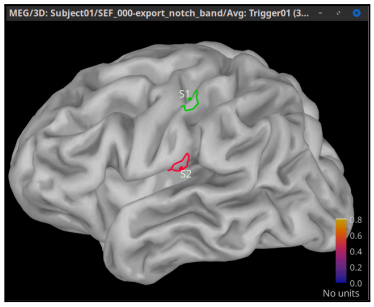
  - Compute inverse model (MEG)
    - Right-click on the head model ( ) > *Compute sources*, use these parameters:
      - Select **Minimum norm imaging,** Select **Current density map**

- Select **Constrained: Normal to the cortex**
- *Sensors* = **MEG**

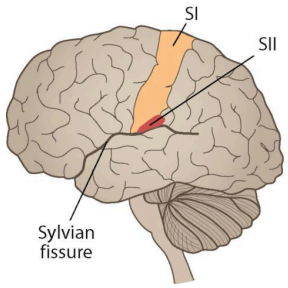


- Explanation on the inversion kernel ( ) and link ( ) files in the database
- Explore the estimated average **Avg: Trigger (339)** at 20ms
  - Display EEG and MEG **time series** (butterfly mode)
  - Display the **sources** derived from EEG and from MEG data
  - Set the colormap to local maximum (maximum in that time slice)
    - Right-click on the colorbar > Colormap: sources > Maximum Local
  - Set time to **100 ms**
  - Set *Smooth* = **30%** and **Amplitude** threshold to **40%** (both in Surface tab)
- Explore other times, and the evolution of the brain activity

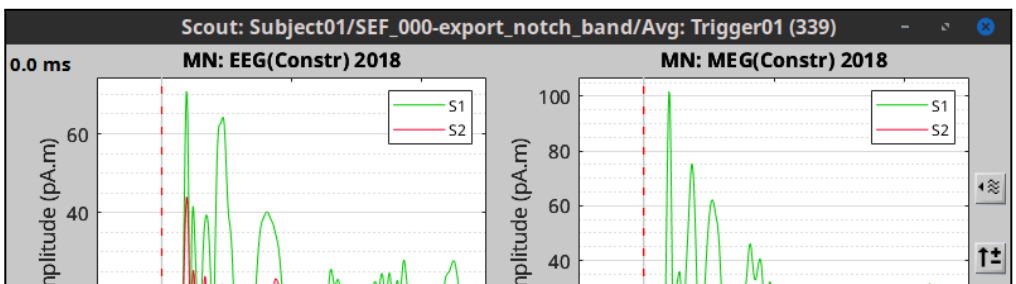
11. EEG and MEG Analysis: Atlases and Scouts



- Display the **sources** derived from EEG and MEG data
  - In the Scout tab, use the dropbox to select different Atlases
  - Operations with Atlases and Scouts
- Create Scouts
  - Open the sources (from MEG) for the average, left view
  - Select the **User Scouts** atlas
  - Create scout **S1** (primary somatosensory cortex) on the left hemisphere
    - Go to Time **20 ms**, Amplitude threshold **60%** Smooth = **30%**
    - Scout tab: Click on *Select point* ( ), then point on activity in the post central gyrus
    - Grow Scout to 20 vertices
    - Rename to S1 (double-click on the scout in the list)
    - Review trace: Absolute values

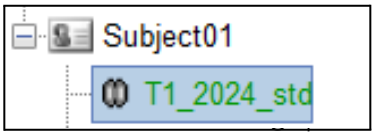


- Create a second scout **S2** (secondary somatosensory cortex) on the left hemisphere
  - Go to Time **50 ms**, Amplitude threshold **20%** Smooth = **30%**
  - Scout tab: Click on *Select point* ( ), then point on activity in the bottom part of the post central gyrus, which is the anatomical location of S2.
- Review S1 and S2 traces together in absolute values. For sources from EEG and MEG



12. SEEG Analysis: Import Anatomy

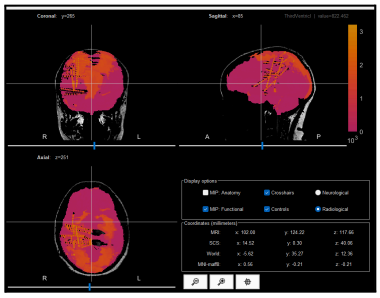
- **Import T1 pre-implantation: (5 mins)**
  - Right-click on **Subject01 > Import MRI**
  - Select format: **MRI: NifTI**
  - Select file: **T1_2024_std.nii.gz**
  - Introduction to the MRI viewer: Click, mouse wheel, color bar, popup
  - In the MRI Viewer, click on **Compute MNI normalization** and select



the **maff8** algorithm. This sets default positions for the fiducials Coordinate systems: MRI, SCS, World, MNI and also does MNI normalization

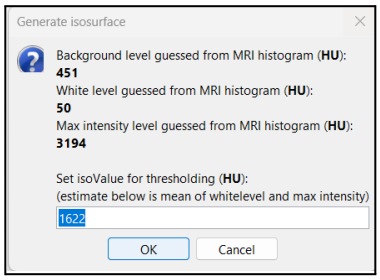
- Click **Save**

- **Import post-implant CT: (10 mins)**
  - Prerequisites: **BrainSuite** , **ct2mrireg** plugin
  - Right-click on the **Subject01 > Import CT**
  - Select format: **MRI: Nifti**
  - Select file: **CTpost_std.nii.gz** (pre registered **CTpost_reg.nii.gz**)

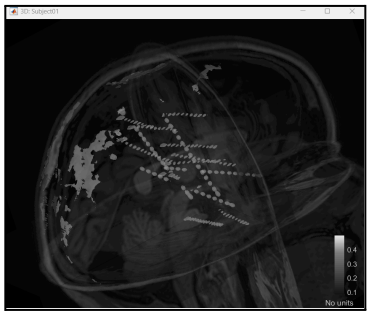


13. SEEG Analysis: Coregister and Normalize images to standard MNI space

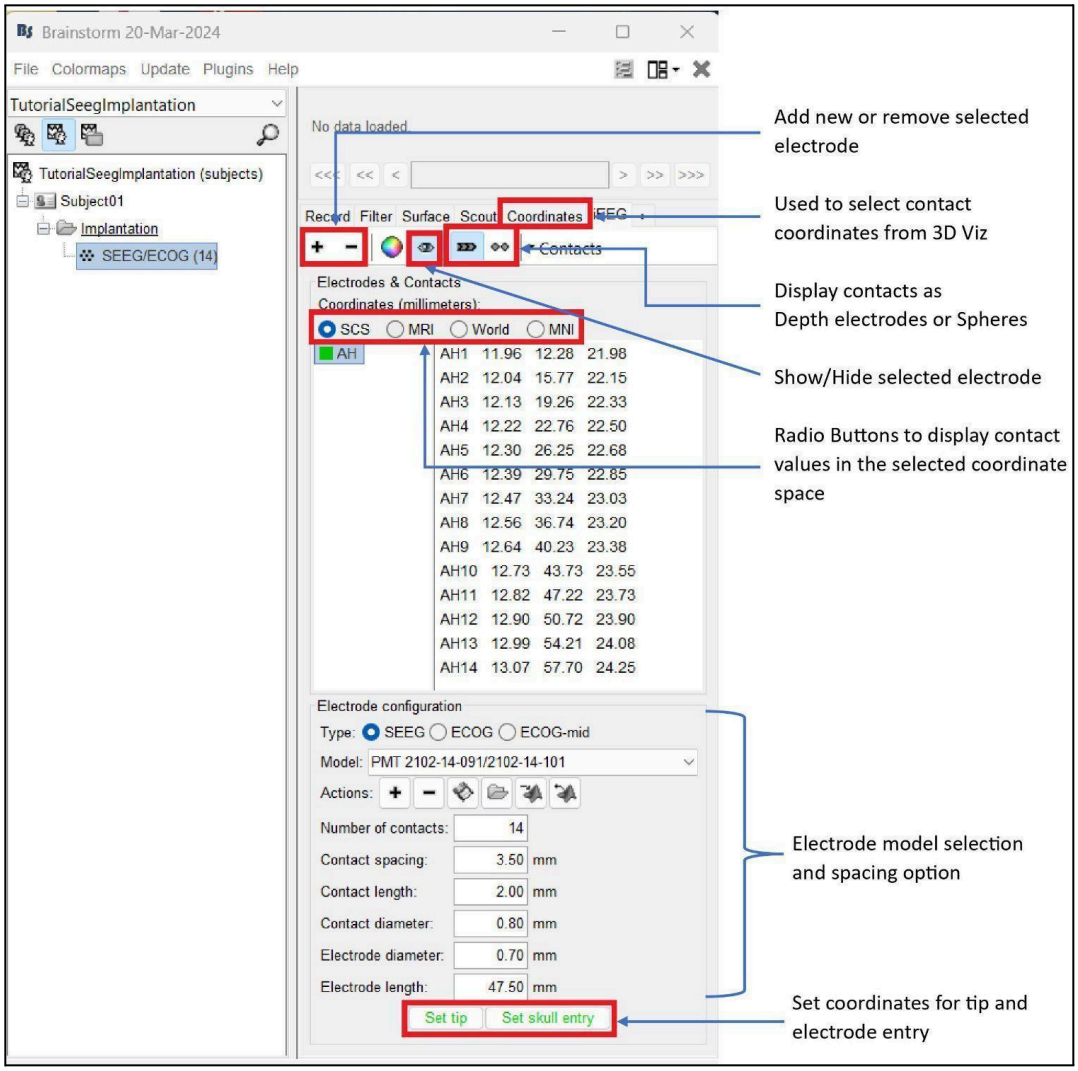
- Select coregister using **CT2MRI** and select **Yes** both to reslice volume and clean CT volume. (Select **Ignore** and select **No** for reslice volume as the CT is already co-registered.)
- The MRI viewer opens automatically, showing the post-implantation CT volume as a colored layer on top of the previous volume. Use this display to validate that the co-registration of the two volumes is correct (all the parts of the head must align well).



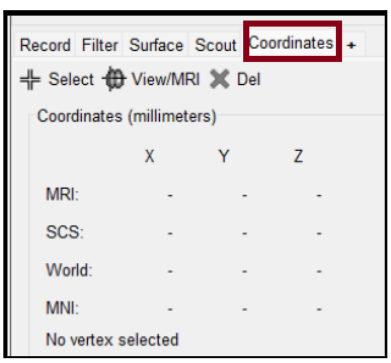
- **Generate isoSurface (2 mins)**
  - This creates a thresholded mesh from the CT to separate the contacts from the rest. This aids the user towards localization of the electrodes and its contacts more accurately.
  - Right click on **CTpost_reg> CT segmentation > Generate threshold mesh from CT**
  - Set the isoValue for thresholding, the estimation is from the mean of white level and max intensity of the CT. You can leave it as default, select **OK**
  - An isosurface is generated showing the contact as blobs overlayed on the 3D MRI slices. The **Thresh** slider under **Surface options** can be used to fine tune and regenerate mesh with different isoValues.



14. SEEG Analysis: Contact localization



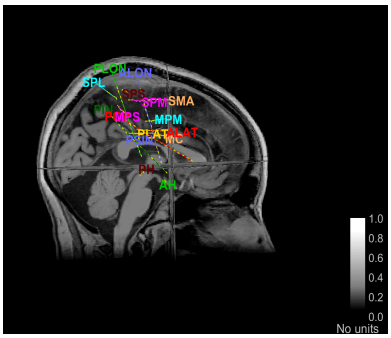
- **Manual contact labeling (30 mins)**
  - Right click on **CTpost_reg** and choose **SEEG/ECOG implantation**. This takes you to the functional tab and **Subject01 > Implantation > SEEG/ECOG (0)** channel gets created. The MRI Viewer (CT overlayed MRI) and 3D Viz (isoSurface+3D MRI Slices) load up as well along with the **Panel iEEG**.
  - Click the **+** icon from the list of panel tabs and choose **Add: Coordinates**. This adds the **Panel Coordinates** which will be used to select points from the 3D Viz.
  - On **Panel iEEG** Click on the **+ (Add new electrode)**. This opens up the **Add electrode** window. Enter anything under the **Electrode label** based on your convention. For this e.g., enter **AH** and press **OK**.
  - Select **SEEG**, and choose the electrode model (**PMT**



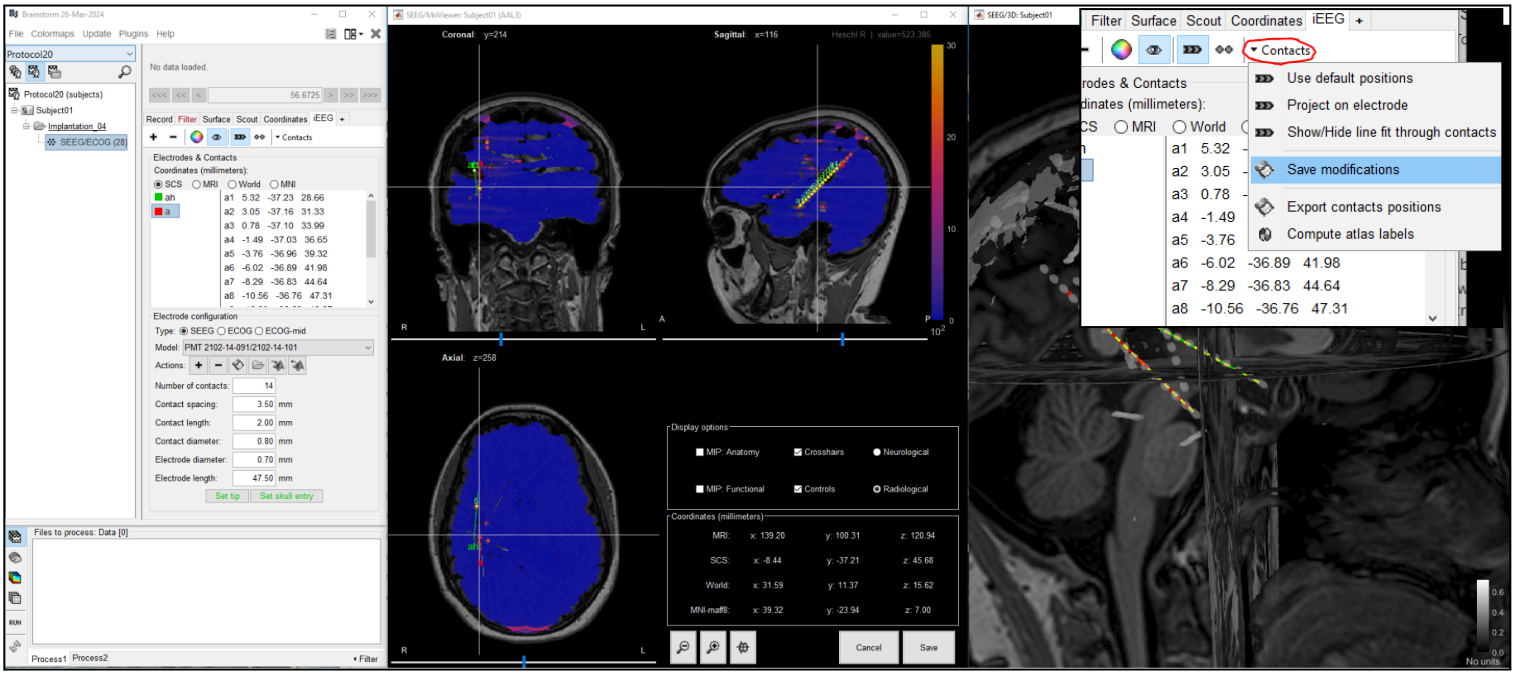
2102-14-091/2102-14-101 which is a 14 contact electrode.

- Switch to the **Coordinates** panel, click **Select** and choose the deepest contact from the isosurface in 3Dviz. This should plot a yellow crosshair marker point on the contact blob and also update the crosshair in the MRI Viewer.

***Note:** You can play around with the **Thresh** slider under **Surface** tab to get better visibility of the contacts as required*



- Switch back to the iEEG panel and click **Set tip** and the button turns green, indicating that the tip has been set. This point in 3D is at the centroid of the blob, which gives a more accurate location of the contact.
- Go back to the **Coordinates** tab and repeat the steps above for the skull entry
- Now click **Set skull entry** and the button turns green indicating that the entry point has been set. The MRI Viewer gets updated with the electrode.



- Click on **Save** in the MRI Viewer. This saves the new channel file and updates the number of channels in the database explorer. Click **Yes** for any other **Save** windows that pop up.
- Double-click the **Implantation > SEEG/ECOG** channel in the Functional tab to get an updated 3D Viz and MRI Viewer with all the electrodes.
- Repeat these steps for each SEEG electrode except the last step of saving.
- For saving all the further electrodes, click on **Contacts > Save Modifications** to update the

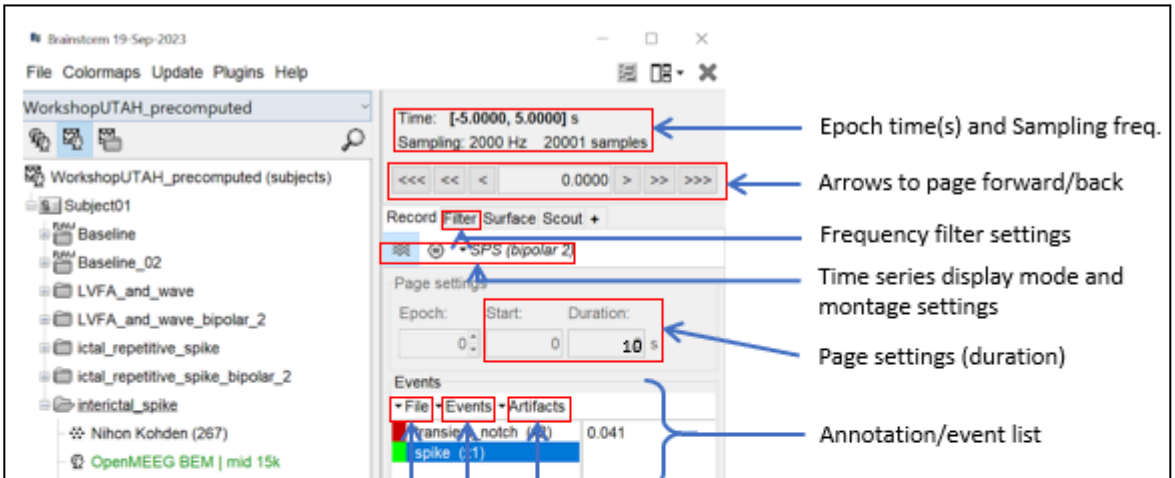
channel information and that saves the changes to the database.

- **Anatomical labeling (5 mins)**
  - Switch to the anatomy view.
  - Right-click on **Subject01 > Add MNI parcellation > AAL3**. Repeat with parcellation: **Hammers83**, **Hammers95.**
  - Close all the figures. Switch back to the Functional view.
  - Right-click on the channel file **> iEEG atlas labels**
  - Create **Subject01.tsv** and click **OK**. **Select all the available options: coordinates in various coordinate systems, volume parcellations, surface parcellations**.
  - The output is a table, one row per sensor contact in the channel file, for each sensor: coordinate location in the parcellation atlas and probability of the label .

SEEG contact labels

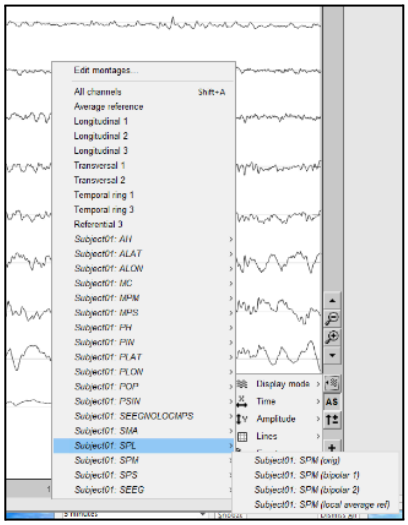
Channel	MNI	AAL3 (MNI-linear)	AAL3 (MNI-linear)_prob	Hammers95 (MNI-linear)	Hammers95 (MNI-linear)_prob
ah1	[39.877,11.669,-5.910]	Insula R	82%	insula_ant_inf_c R	88%
ah2	[40.176,8.912,-3.437]	Insula R	66%	G_insula_mid R	69%
ah3	[40.475,6.155,-0.964]	Insula R	62%	G_insula_post R	62%
ah4	[40.773,3.398,1.509]	Insula R	96%	G_insula_post R	92%
ah5	[41.072,0.641,3.982]	Insula R	89%	G_insula_post R	98%
ah6	[41.371,-2.116,6.456]	Insula R	89%	G_insula_post R	80%
ah7	[41.670,-4.873,8.929]	Rolandic_Oper R	64%	G_insula_post R	60%
ah8	[41.968,-7.630,11.402]	Rolandic_Oper R	52%	PL_postce_G R	86%
ah9	[42.267,-10.387,13.875]	Rolandic_Oper R	59%	PL_postce_G R	94%
ah10	[42.566,-13.144,16.348]	Rolandic_Oper R	88%	PL_postce_G R	98%
ah11	[42.864,-15.901,18.822]	Rolandic_Oper R	100%	PL_postce_G R	100%
ah12	[43.163,-18.658,21.295]	Rolandic_Oper R	82%	PL_postce_G R	97%
ah13	[43.462,-21.415,23.768]	N/A	N/A	PL_supramarginal_gyrus R	99%
ah14	[43.761,-24.172,26.241]	N/A	N/A	PL_supramarginal_gyrus R	100%

15. SEEG Analysis: Review Raw recordings (15 mins)

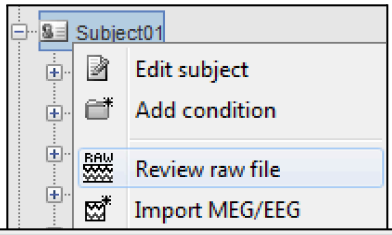


- In the functional view:  (2nd button, on top of the database explorer)
- Create Link to raw file: right-click on **Subject01 > Review raw file**
- Files of Type **EEG: EDF/EDF+**
  - Select the file **Baseline.edf** in the data folder
  - Click on **Open**

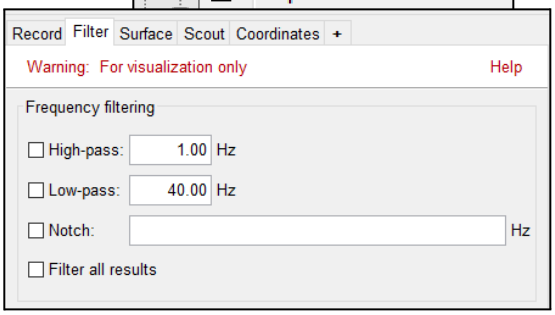
- Review SEEG: Right-click on **Link to raw file > SEEG > Display time series**



  - Display in columns: Button  in the Record tab **> Display mode > Column**
    - **Amplitude**: Buttons and shortcuts, Display menu
    - **Time**: Display windows of 15 seconds, Scroll with F3, Auto-Scale button
  - Select bad channels + right click **> Channels > Mark selected as bad** (if needed)
  - Montages: click **Display configuration**  **> Montage > Subject01: SEEG > Subject01 SEEG: (bipolar 2)**
    - Select the montage for the dataset (Average, Referential, Transversal or longitudinal)
    - For the SEEG dataset, select **bipolar 2** montage for continuous chain.

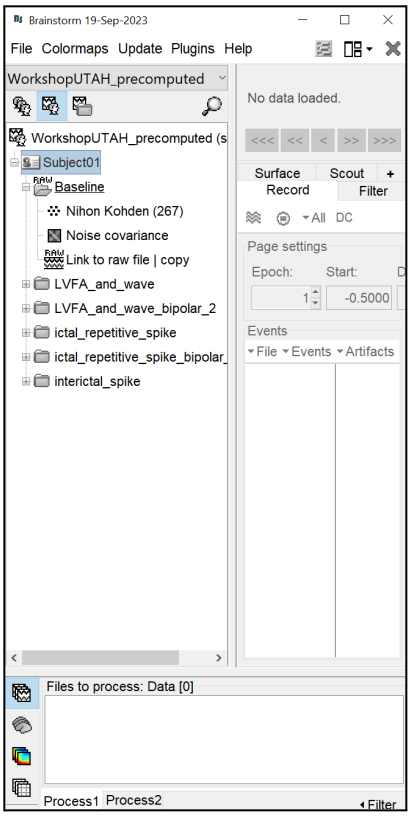


  - Filter settings for review are set under the **Filter** tab in the panel
    - this is only for visualization
    - Select the checkbox to turn ON the high or low frequency filter.



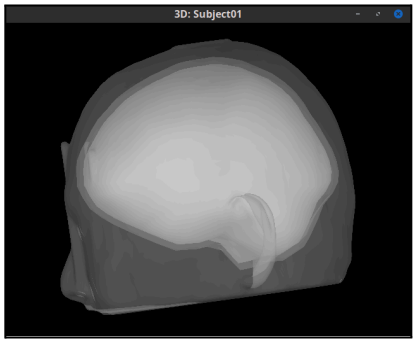
  - Add annotations:
    - Got to record view **> Events > Add Group > Event A**
    - Select 2 peaks and press **E**
    - Got to record view **> Events > Add Group > Extended**
    - Drag across the window
    - Press **E**
    - Save annotation: **File** > **Save modifications**

16. SEEG Analysis: Import precomputed Brainstorm protocol (5 mins)

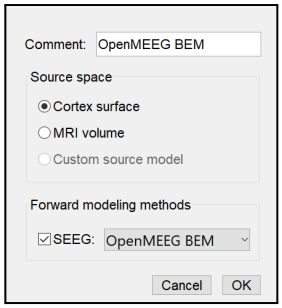


- Prerequisite: Download from the zip file from url: https://box.bic.mni.mcgill.ca/s/Yqjt3sciljtHMqF
- Open Brainstorm
- Click **File > Load Protocol > Load from zip file**
- Click on ..., and point to the downloaded zipped file: **WorkshopUTAH_precomputed.zip**
- Protocol called **WorkshopUTAH_precomputed** should appear

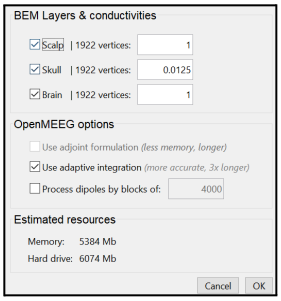
17. SEEG Analysis: Modeling interictal spikes using Min-Norm Imaging (Yash Vakilna)



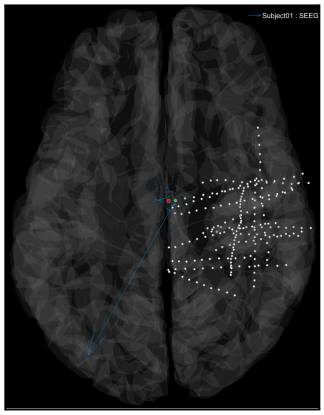
- **Compute Forward Model (aka Head Model) (10 mins)**
  - Computing boundary element (BEM) layers
    - Prerequisite: **OpenMEEG** plugin
    - Go to the anatomy view
    - Right-click on **Subject01 folder > MRI segmentation > Generate BEM surfaces**
      - Select Brainstorm
      - Number of vertices: Scalp = **1922**, Outer skull = **1922** and Inner skull = **1922**
      - Thickness of layers, Skull (mm)= **4**
      - **DON'T CLICK [OK]**
    - Double-click on **mid_15002V** to make it as the default cortex (in green). If already green, no need to double-click.
  - Compute the head model for SEEG



- Go back to the functional data view, navigate to the **interictal_spike** folder and expand it
- Right-click on the **Nihon Kohden channel file** (⁘)**> Compute head model**
  - Source space = **Cortex surface**, Forward model = **SEEG: OpenMEEG BEM**, click **OK**
  - Use default BEM layers and conductivities.
  - Use default OpenMEEG options.
  - **DON'T CLICK [OK]**

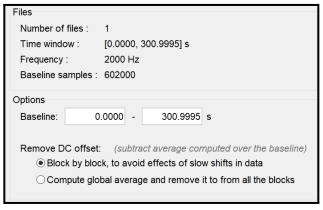


- Copy the head model files to the other folders
  - Right-click on the head-model file (**OpenMEEG BEM | mid 15k**)**> Copy to other folders**



- View Leadfield vectors
  - Right-click on head-model file ( ) **> View SEEG leadfield vectors**
  - Select reference=**MC2**, click **OK**
  - Make sure scouts are unselected
    - Go to the Scout tab, and make sure **ALL** and **SEL** are unselected
    - Go back to the **Surface** tab
  - Select Transparency = **90**, and **Press Shift+Up arrow** till the arrows are visible
  - Press E to show the electrode
  - Press **Up/down** to change the Reference electrode, **right/left** to change the Target
  - Press ✖ to close all figures

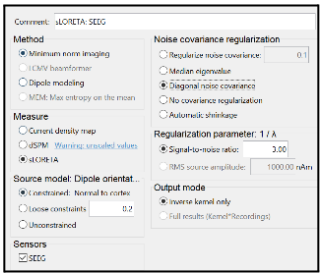
- **Compute Noise Covariance Matrix (for SEEG) (15 mins)**
  - Explain Process section
    - Tabs Process1, Process2
    - File types: recordings, sources, time-freq, and matrices



  - Switch to **Baseline folder**
  - Compute **Link to raw file | copy** ( ) for sEEG from Baseline recording
    - Select the trial group, right-click **> Noise covariance > Compute from recordings**:
      - Baseline = **[0, 301] s**
      - Select **Block by block**
      - **DON'T CLICK [OK]**

- Copy the Noise Covariance ( )across other folder
  - Right-click noise covariance file > **Copy to other folders**

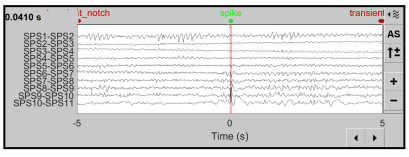
- **Compute Inverse Model (5 mins)**
  - Switch to the **interictal_spike folder,**
  - Right-click on the head model ( ) **> Compute sources**, use these parameters:
    - Click on **Show Details**
    - Select **Minimum norm imaging**, Select Measure: **sLORETA**
    - Select **Constrained: Normal to Cortex**
    - Select Noise covariance regularization: **Diagonal noise covariance**
    - Sensors = **SEEG**
    - **DON'T CLICK [OK]**



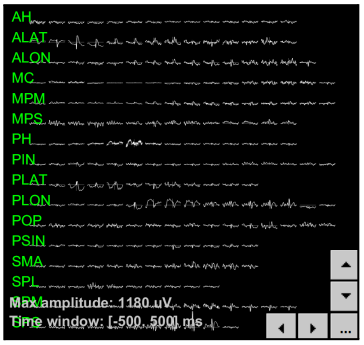
  - Explanation of the **inversion kernel** ( ) and **link** ( ) files in the database

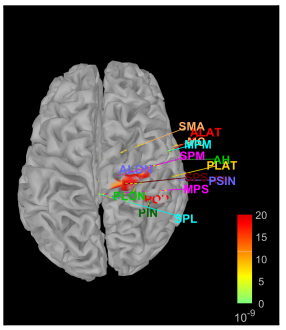
- **Display sensor time series (5 mins)**
  - Display time series
    - Right-click on **Recording** (**Spike (#1) …)> SEEG> Display time series**
    - On the right side of the figure,

    Select ( ) **> Montage > Subject01: SPS >Subject01: SPS (bipolar 2)**
    - Select the first peak of **SPS10-SPS11 (Time 0.041s)**

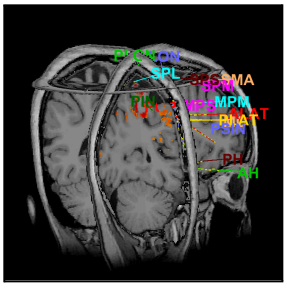


  - Display 2D Layout of the spike
    - Right-click on **Recording** ( )**> SEEG> 2D Layout**
    - Click ... on the corner and select **[-500, 500]**

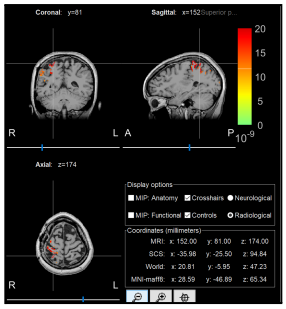




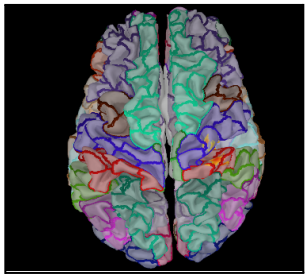
- **View Inverse Modeling results (10 mins)**
  - Display on Cortex
    - Right-click on link (LINK **sLORETA …**) **> Cortical activations > Display on cortex**
    - Show sensors:
      - **Ctrl+L** – SEEG contacts, **Ctrl+E** – for sensors
    - Show colormap Bar: Right Click on **Colorbar > Colormap: Sources > Permanent menu**
      - Select **Maximum: Custom [0, 2]**
      - **Contrast: -18, Brightness: 99**
      - Switch to Surface tab, Select **Amplitude: 56%**



  - Display on 3D MRI Viewer
    - Right Click on link (LINK) **> Cortical activations > Display on MRI (3D)**
    - Right Click and drag to select Axial, Coronal, and Sagittal slices
    - Press **M** to go to voxel with Maximum Intensity
  - Display on MRI viewer
    - Right Click on link (LINK) **> Cortical activations > Display on MRI (MRI Viewer)**
    - Right Click on **Colorbar > Electrodes > SEEG contacts**
    - Show colormap Bar: Right Click on **Colorbar > Colormap : Sources > Permanent menu**
    - Explain Radiological and Neurological view
    - Explain MIP function and MIP anatomical

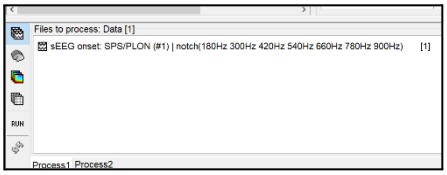


- **Atlases and Scouts (5 mins)**
  - Display sources on the Cortical surface
    - Right-click on link (LINK) **> Cortical activations > Display on cortex**
    - In the **Scout** tab, use the dropbox to select different Atlases
    - Display **Desikan-Killiany** and **Destrieux**
    - Subdivided Desikan-Killiany
      - **Atlas > Subdivide atlas> Area > Area of the sub-regions (cm^2): 5**
      - **DON'T CLICK [OK]**

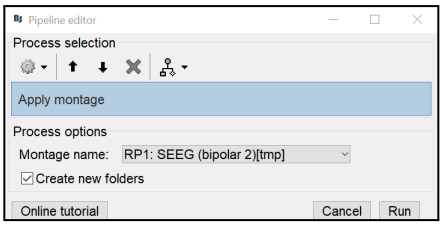


- Press ✖ to close all figures

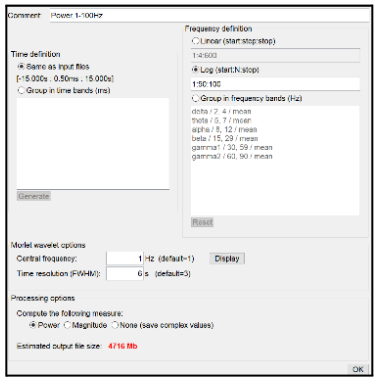
18. SEEG Analysis: Modeling ictal onset with Low Voltage Fast Activity (LVFA) using fingerprint analysis (Sensor Space) (Yash Vakilna)



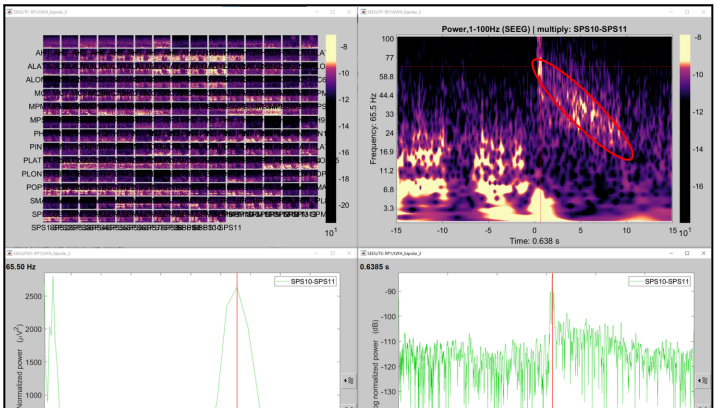
- **Compute Bipolar Montage (5 mins)**
  - Navigate and expand **LVFA_and_wave** folder
  - Press ✖ to close all figures
  - Drag-and-drop ( ) recording file in **Process 1, click [RUN]**
  - Add the process: **Standardize>Apply Montage**
    - Montage name: **Subject01: SEEG (bipolar 2)[tmp]**
    - Select **Create new folders**
    - **DON'T CLICK [RUN]**
  - A new folder with **bipolar_2** suffix will appear



- **Compute Time-Frequency decomposition (5 mins)**
  - Navigate and expand **LVFA_and_wave_bipolar_2** folder
  - Delete any previous recordings in the Process 1 tab below
  - Drag-and-drop ( ) recording file in **Process 1, click [RUN]**
  - Add the process: **Frequency>Time-Frequency (Morlet wavelets)**
    - Sensor type: **SEEG**
    - Select **Spectral flattening: Multiply output power values by frequency**
    - Click **Edit …**
      - Frequency definition: **Log (start:N:stop)**, **1:25:100**
      - Central Frequency: **1 Hz**, Time resolution (FWHM): **6s**
      - Click **[OK]**
      - **DON'T CLICK [RUN]**



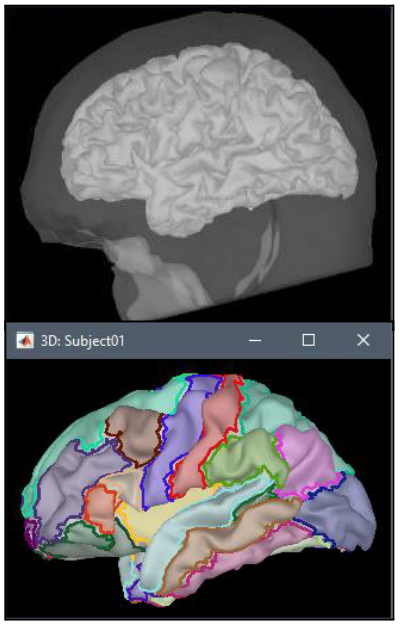
- **View Time-frequency maps (10 mins)**
  - Expand (sEEG onset …) recording file, right-click on **Power ( )**, and select **All channels**
  - Click on **Smooth display, Log(Power)**
  - Click on **SPS8-SPS9**
  - Right-click on **Colorbar>Colormap**: **Timefreq >Permanent menu**
  - Set Turn-off **[Absolute Value]**(if on), **Maximum: Local**, **Contrast: 49**, **Brightness: -65**
  - Demonstrate Left-click and Drag on colorbar to select appropriate Brightness and Contrast



- Right-click on the colored time-frequency plot > **Power Spectrum, Time Series**
- Click to ✖ close all figures

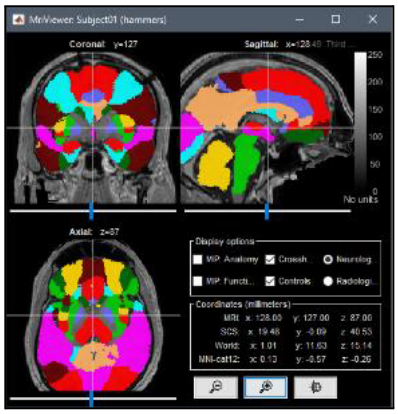
SEEG Analysis: Appendix

- **How to run CAT12 segmentation from Brainstorm**
  - Display cortex:
  - Close figure, double-click on **cortex_15002V** (low-resolution pial surface)
  - 3D figure: **Rotation, zoom, predefined views**
  - Surface tab: **Smooth slider, sulci, edges**
  - Scout tab: **Parcellations of the surface vertices**
  - Volume parcellations: **AAL3, Hammers, tissues**
  - Adjust transparency, change the atlas, non-linear MNI transformation
  - Add MNI parcellation: **Schaefer2018_100_7net**



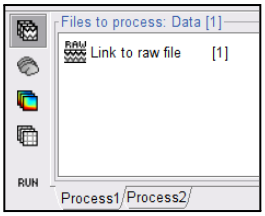
Import T1 post-implantation:

  - Right-click on **Subject01 > Import MRI**
  - Select file: **/xxx/xxxx/xxxxx.nii.gz**
  - Apply transformation: **YES**
  - How to register: **IGNORE** (volumes are already co-registered with SPM)
  - Reslice the volume: **YES** (so we can overlay them)
  - Surface tab: Adjust threshold with slider **Data options: Amplitude**



Close all: Big cross on the top-right, close all the figures and empty memory.

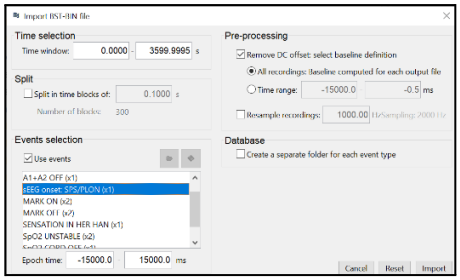
- **Remove power line noise.**
  - Compute Periodogram
    - Close all the figures
    - Drag-and-drop (RAW) raw file in **Process 1, click [RUN]**
    - Add the process: Frequency, Power spectrum density (Welch)
    - Time window = **All file**, Window length = **_ s**, Overlap = **50%**
    - Units = **Physical**
    - Sensor types = **SEEG**
    - Click on **Run**



  - Review Periodogram
    - Peaks at 60Hz, 120Hz, 180Hz on EEG and MEG: Power lines (60Hz+harmonics)

- Process Notch filter
  - Select: **Pre-process > Notch filter**
  - Frequencies to remove (Hz) = **180, 300, 420, 540, 660, 780, 900Hz**
  - Sensor types = **SEEG**

- **Import recordings**
  - Import in database
    - Right-click on the pre-processed file > Import in database, and use the parameters:
      - Time window = **0 - 119.9995 s**
      - Do NOT check Split in time blocks
      - Check **Use events** and select **s**EEG onset
      - Epoch time = **-15000 to 15000 ms**
      - Check Remove DC offset, select **All recordings**



    - A new folder named _ is created (no more **raw** indicator)