SEEG and Multimodality Clinical Applications in Brainstorm

Jay Gavvala, MD, MSCI

Associate Professor, Department of Neurology

No relevant Financial Disclosures

Outline

Traditional SEEG analysis

Brainstorm Analysis

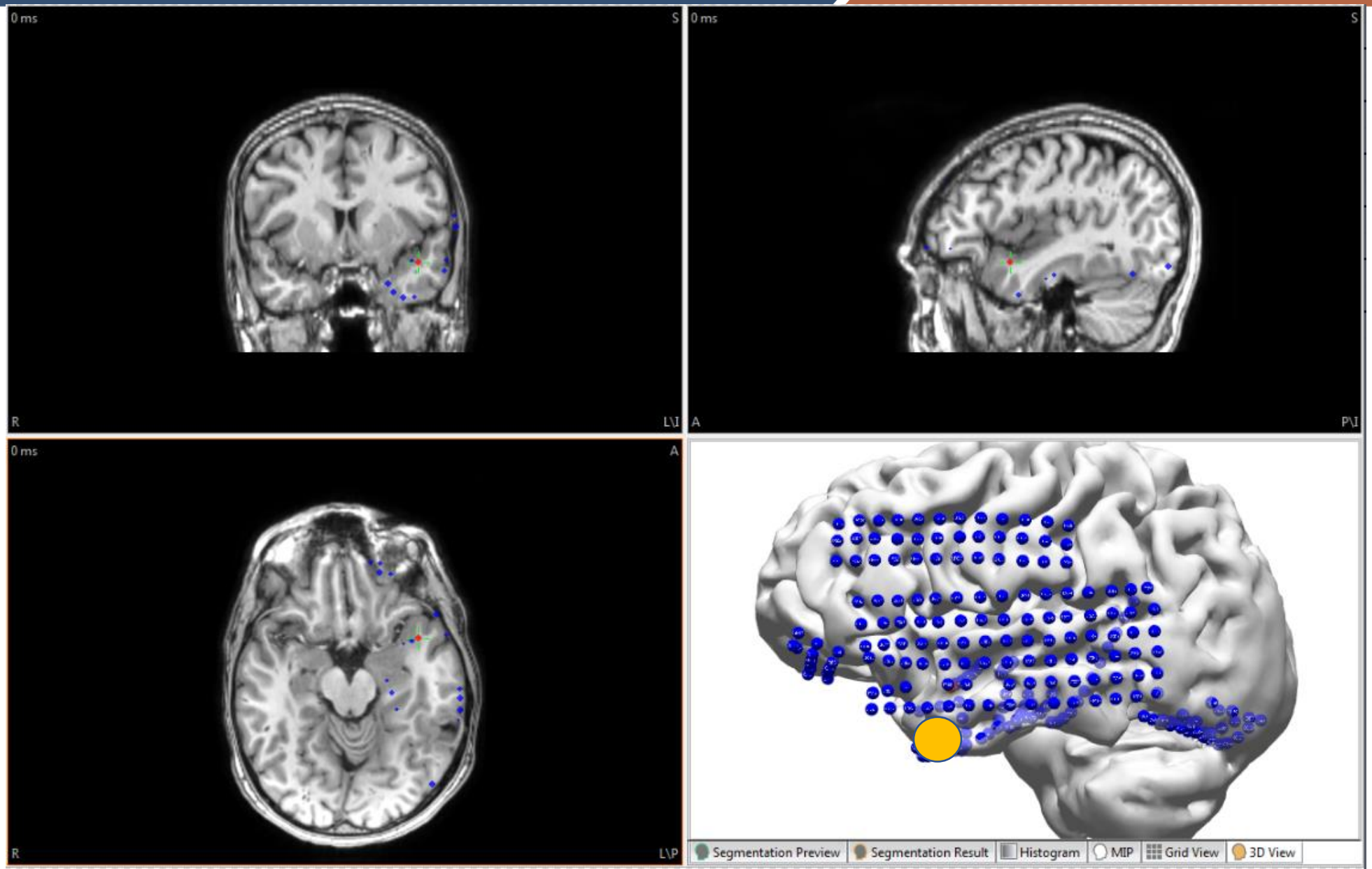
- Interictal
- Ictal
- Sensor vs Source Level
- Multimodal Integration

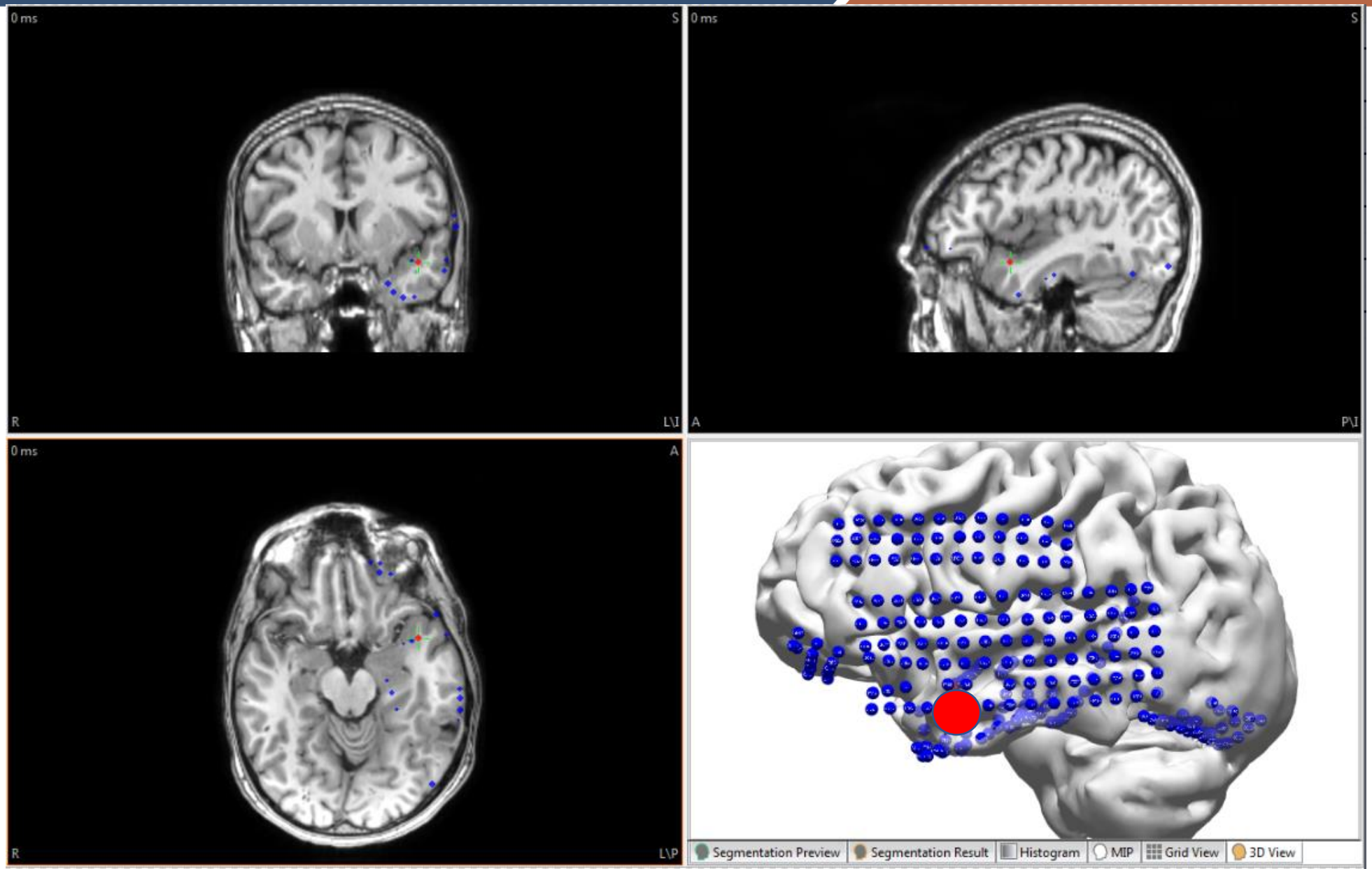
SEEG: Question of Scale

Intracranial EEG commonly referred to as “gold standard”

Recent literature highlights increasing adoption of SEEG as the intracranial EEG modality of choice

However, this trend can be problematic with an expectation to “Apply Subdural EEG principles to SEEG”


0 ms
S
R
L\I
0 ms
S
A
P\I
0 ms
A
R
L\P
Segmentation Preview
Segmentation Result
Histogram
MIP
Grid View
3D View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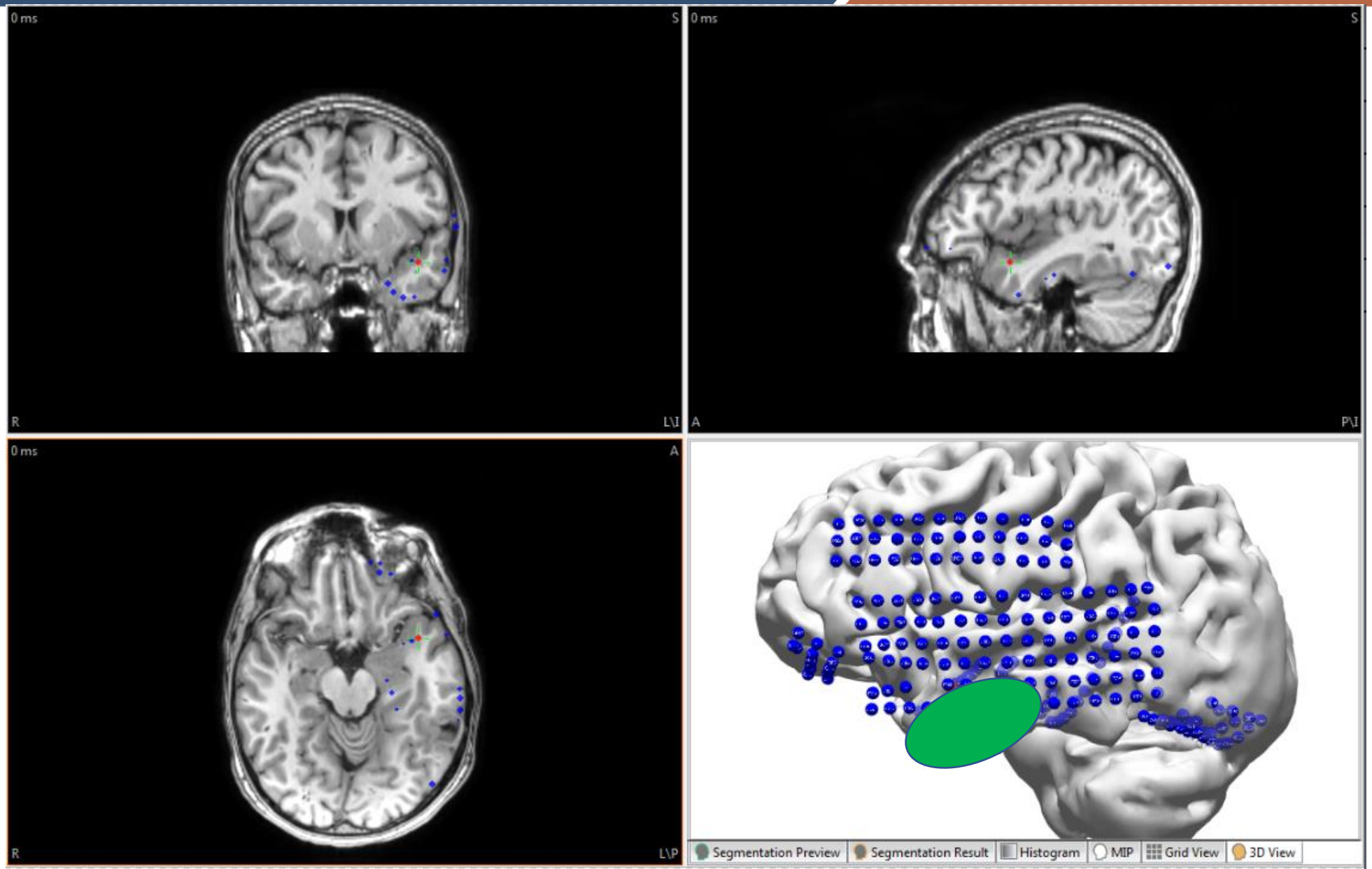
Segmentation Preview
Segmentation Result
Histogram
MIP
Grid View
3D View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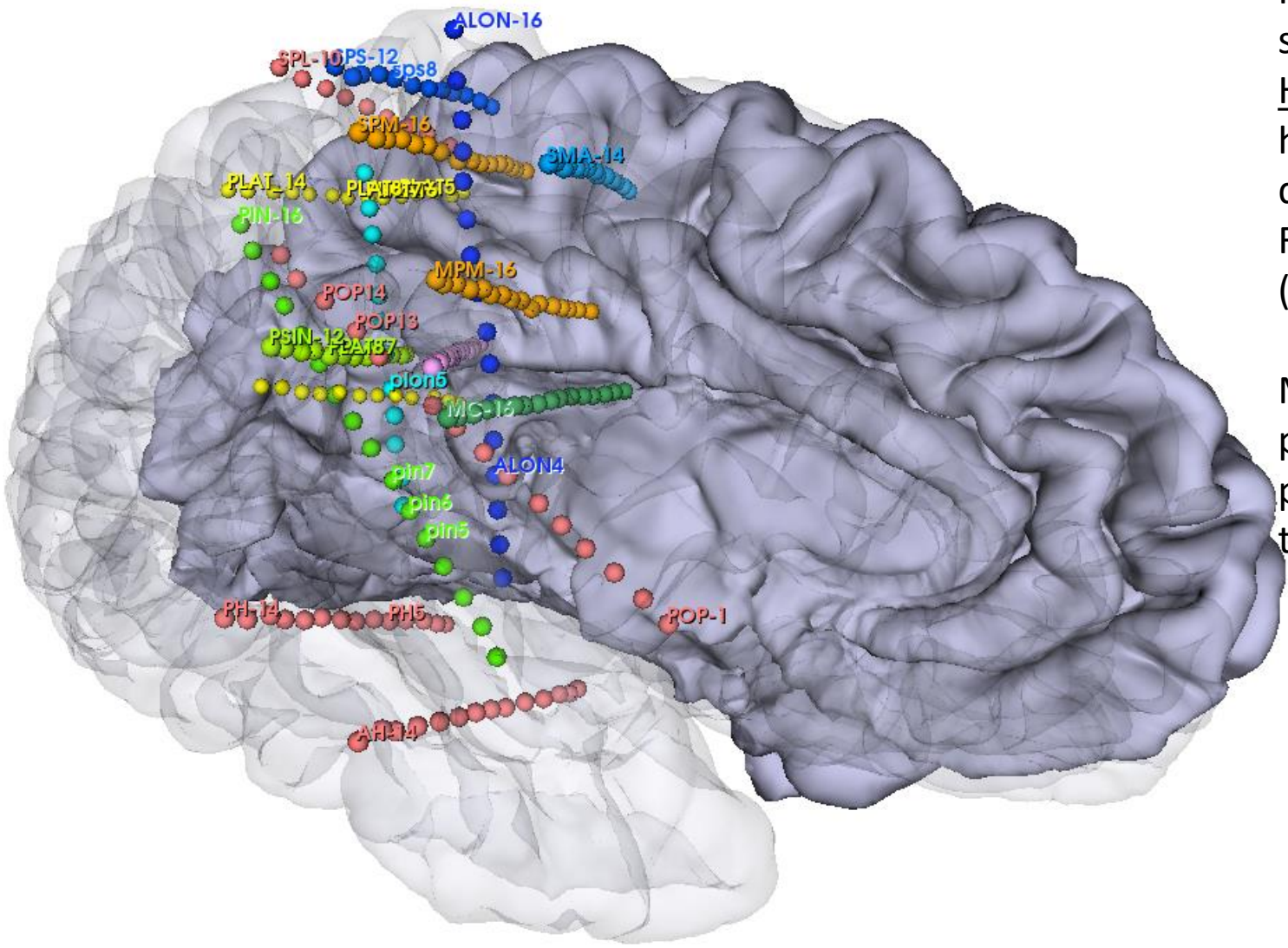
L\P
Segmentation Preview
Segmentation Result
Histogram
MIP
Grid View
3D View

LESIONAL
ALAT – Anterior lateral PMG
PLAT – Posterior lateral PMG
ALON – Anterior longitudinal PMG
PLON – Posterior longitudinal PMG

PIN – posterior insula
PSIN – posterior superior insula
POP – parietal operculum
SPL – Superior parietal

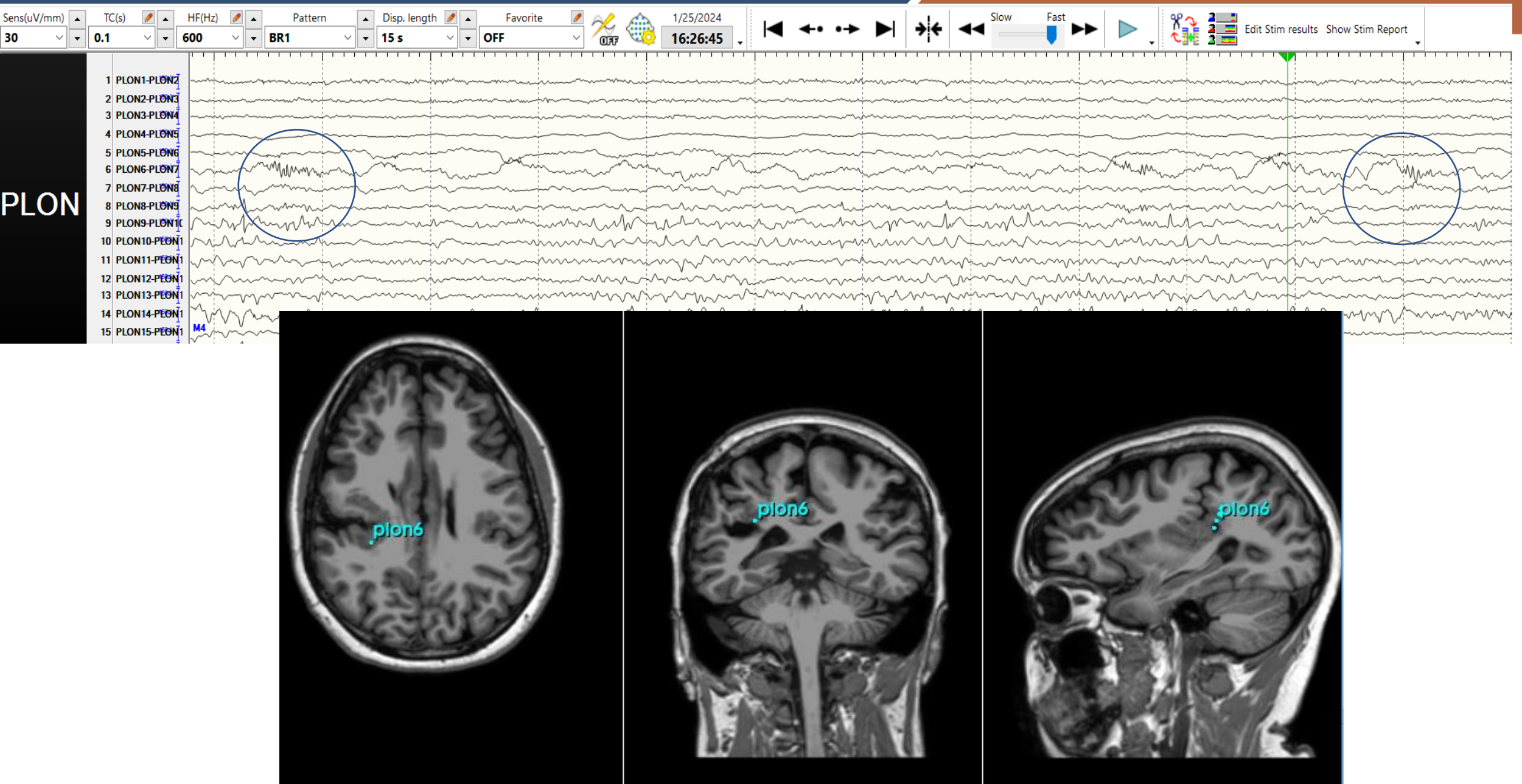
SPM – superior primary motor
MPM – mid primary motor
SPS – Superior primary sensory
MPS – Mid Primary Sensory

SMA – supplementary motor area
MC - Midcingulate
AH – Anterior hippocampal
PH – Posterior hippocampal

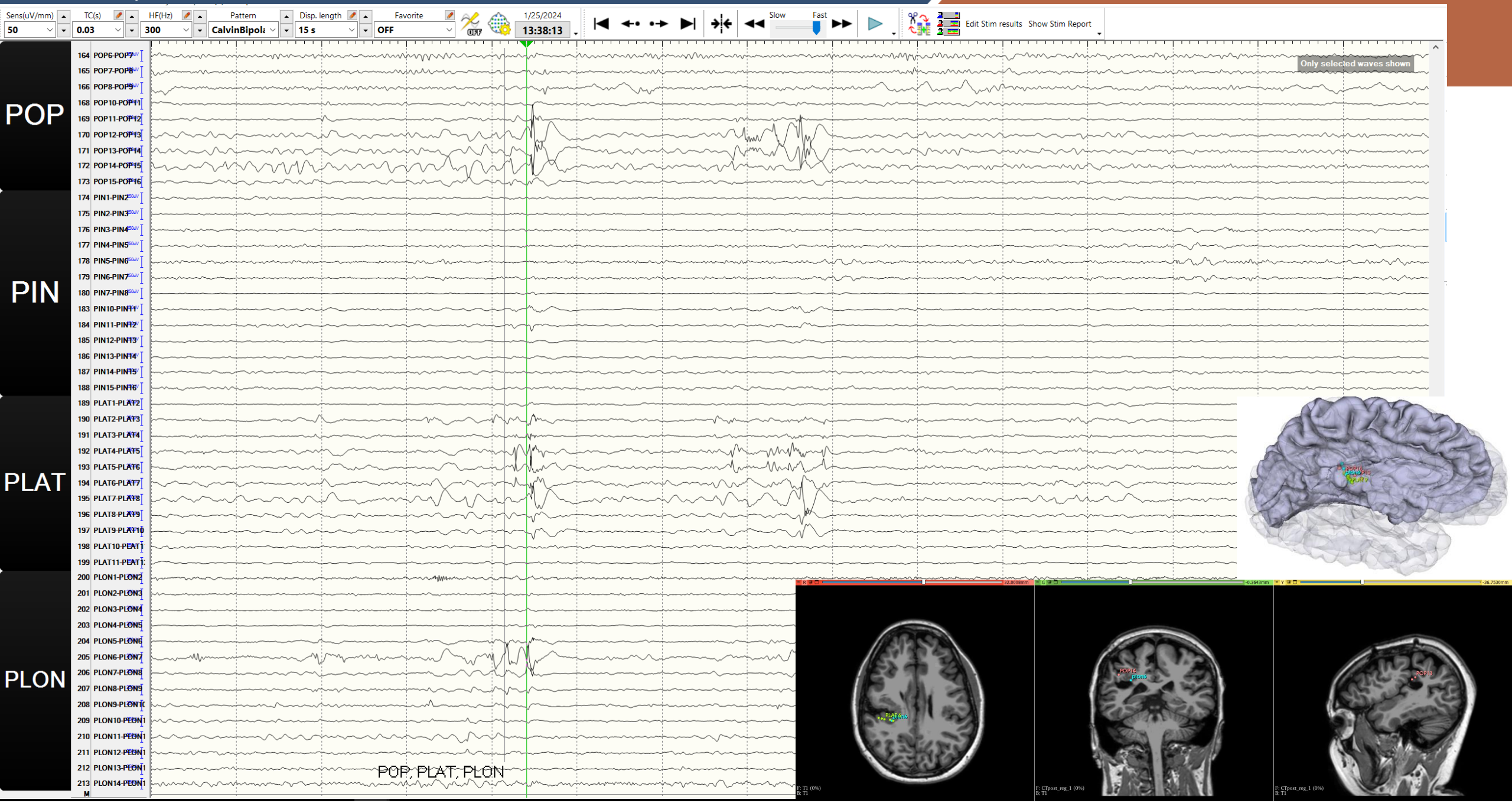


Right-handed F, with seizure onset at 6 y/o
Habitual seizures: left hand tingling → dyscognitive
Frequency: 1-2x per week (SS aura daily)

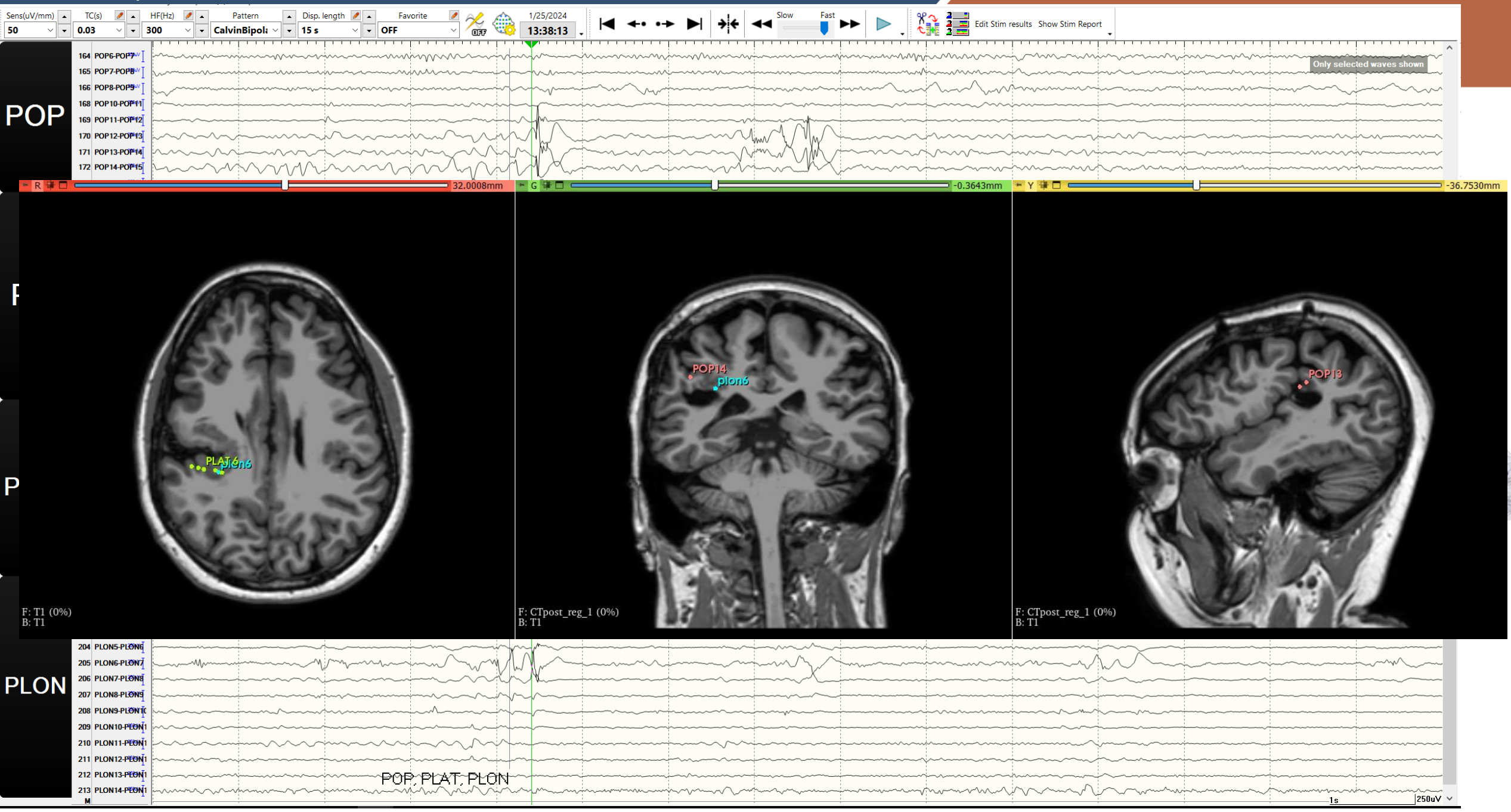
MRI: bilateral perisylvian polymicrogyria and pachygyria, right greater than left.


Sens(uV/mm)
30
TC(s)
0.1
HF(Hz)
600
Pattern
BR1
Disp. length
15 s
Favorite
OFF
1/25/2024
16:26:45
Slow
Fast
Edit Stim results
Show Stim Report
PLON
1 PLON1-PLON2
2 PLON2-PLON3
3 PLON3-PLON4
4 PLON4-PLON5
5 PLON5-PLON6
6 PLON6-PLON7
7 PLON7-PLON8
8 PLON8-PLON9
9 PLON9-PLON1
10 PLON10-PLON1
11 PLON11-PLON1
12 PLON12-PLON1
13 PLON13-PLON1
14 PLON14-PLON1
15 PLON15-PLON1
M4
plon6
plon6
plon6

Interictal Spikes: POP 12-15, PLAT 2-9, PLON 5-7 20%



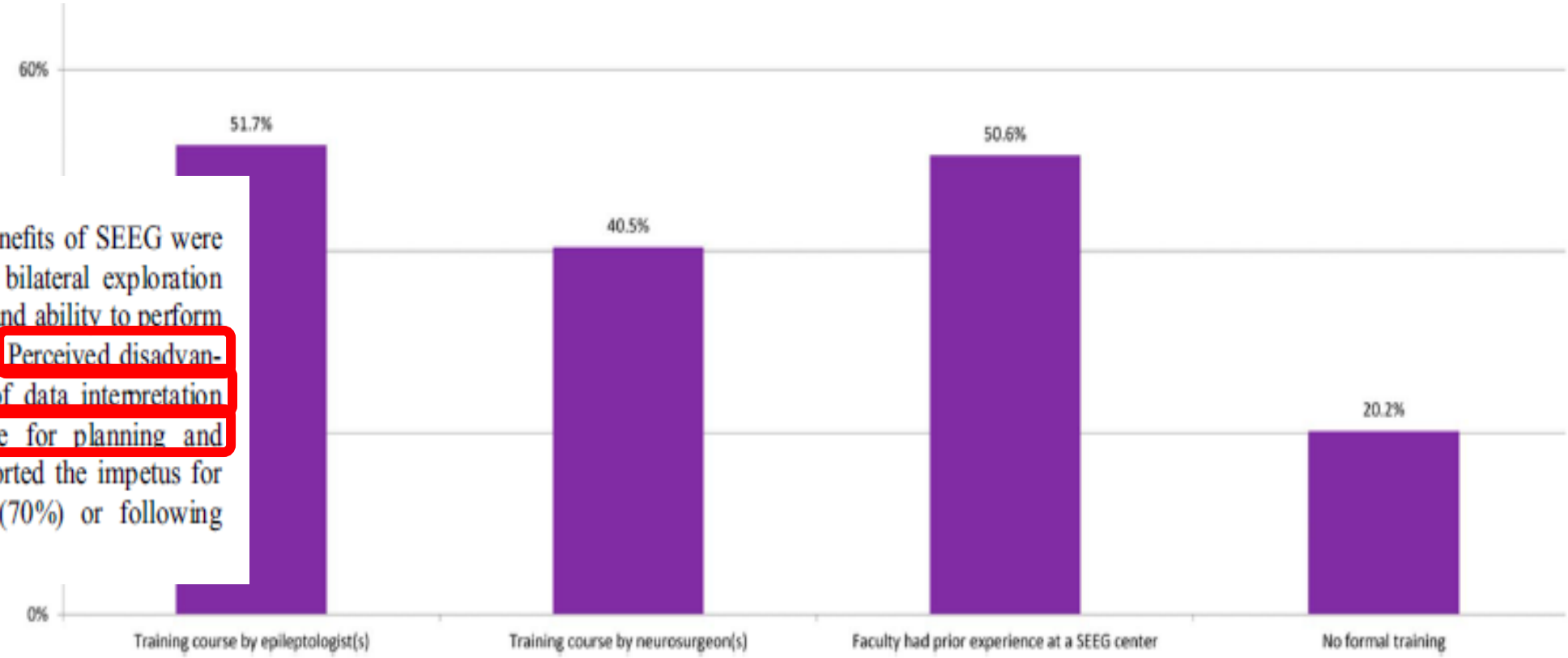
Interictal Spikes: POP 12-15, PLAT 2-9, PLON 5-7 20%



SEEG practice in the US

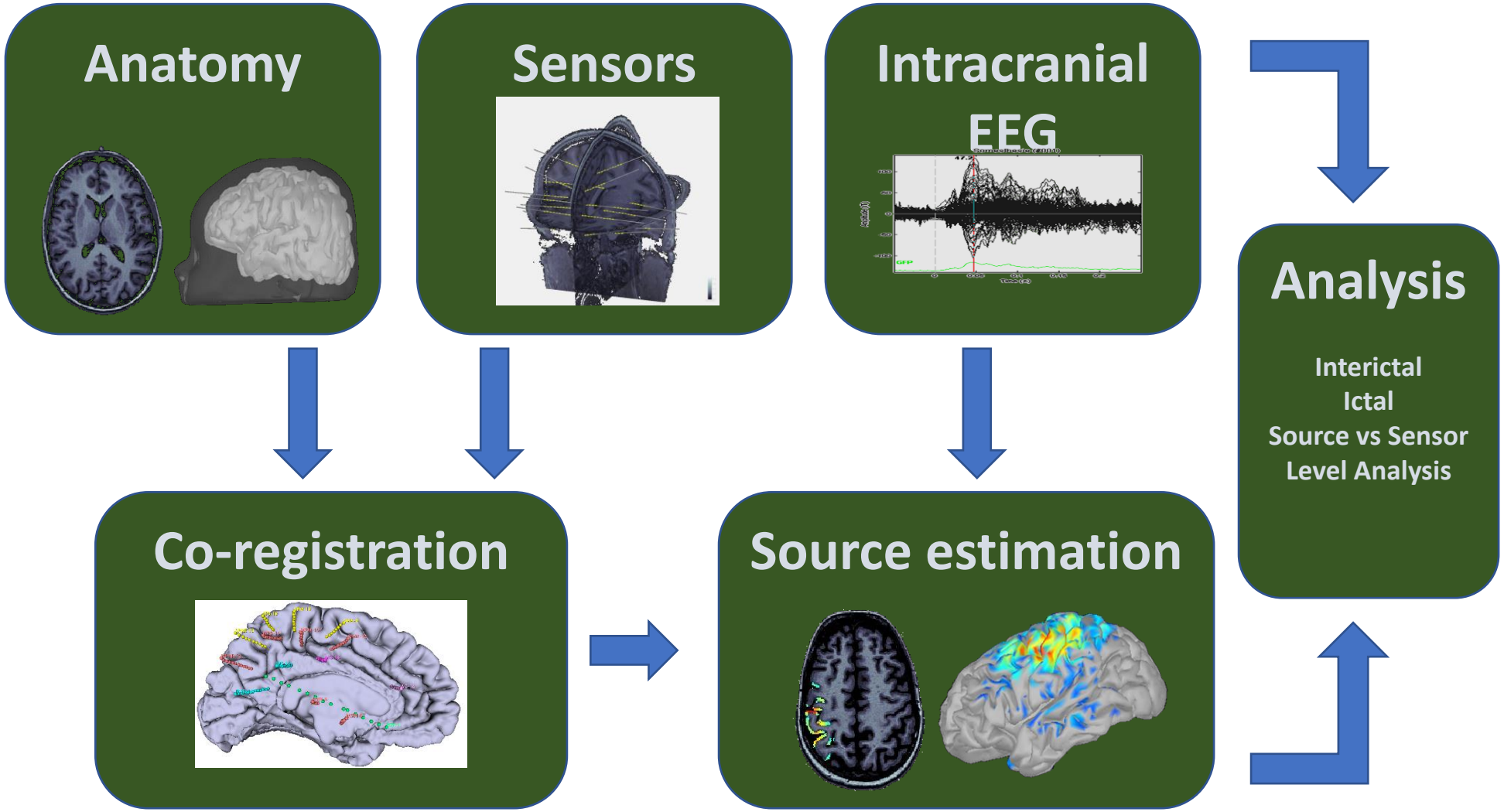
Physician Perceptions of SEEG

Most respondents believed that the benefits of SEEG were patient comfort (97%), ability to perform bilateral exploration (92%), testing multiple hypothesis (79%), and ability to perform repeat epilepsy surgery evaluations (77%). Perceived disadvantages of SEEG included the challenges of data interpretation (58%) and the need for additional time for planning and interpretation (49%). Centers variably reported the impetus for SEEG arising from emerging literature (70%) or following national trends (52%).



Gavvala et al Stereotactic EEG practices Journal of Clinical Neurophysiology 2022

Workflow


Anatomy
Sensors
Intracranial EEG
Analysis
Interictal
Ictal
Source vs Sensor Level Analysis
Co-registration
Source estimation

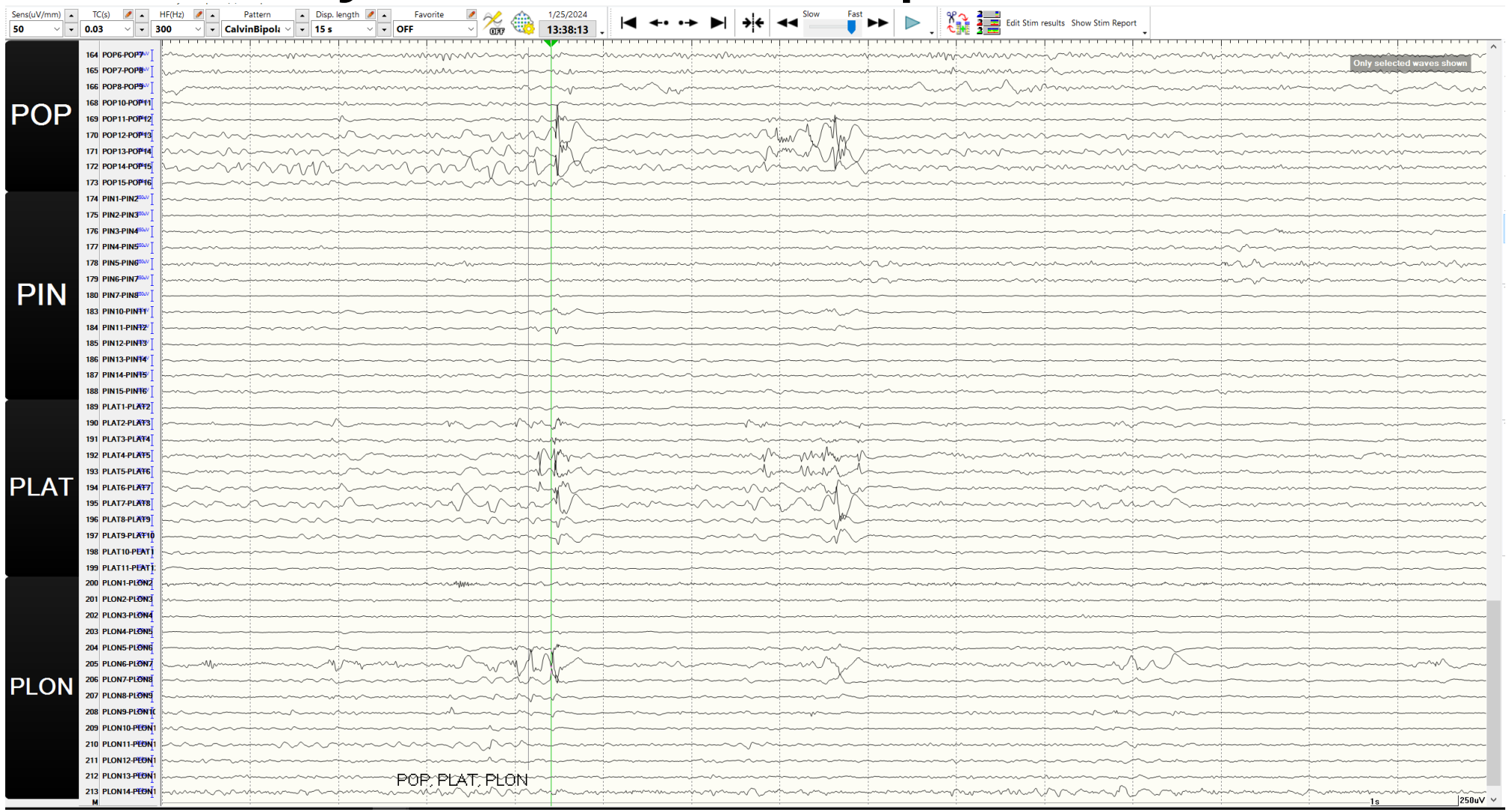
Interictal Processing

2D Spike Layout

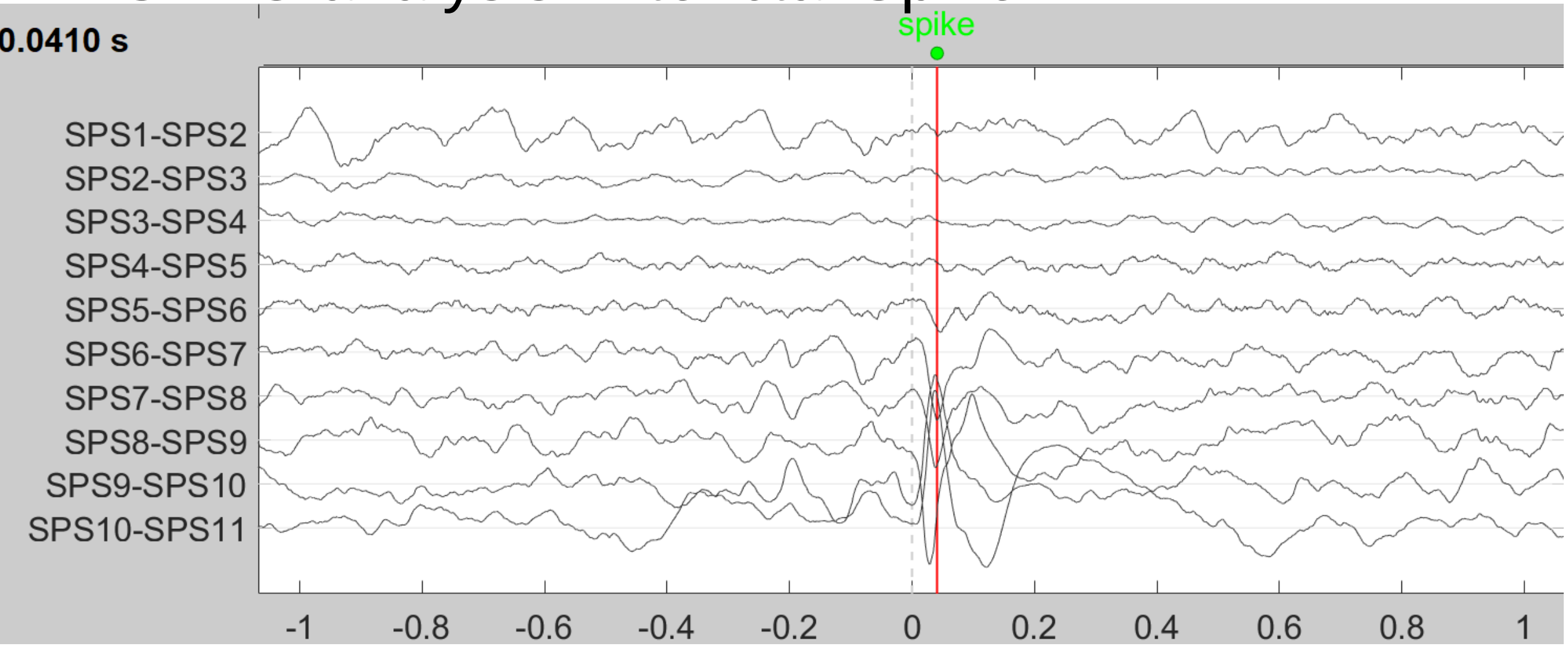
Source Localization of waveform (Is SNR sufficient?)

Source Level Interictal Processing (Frequency Band specific)

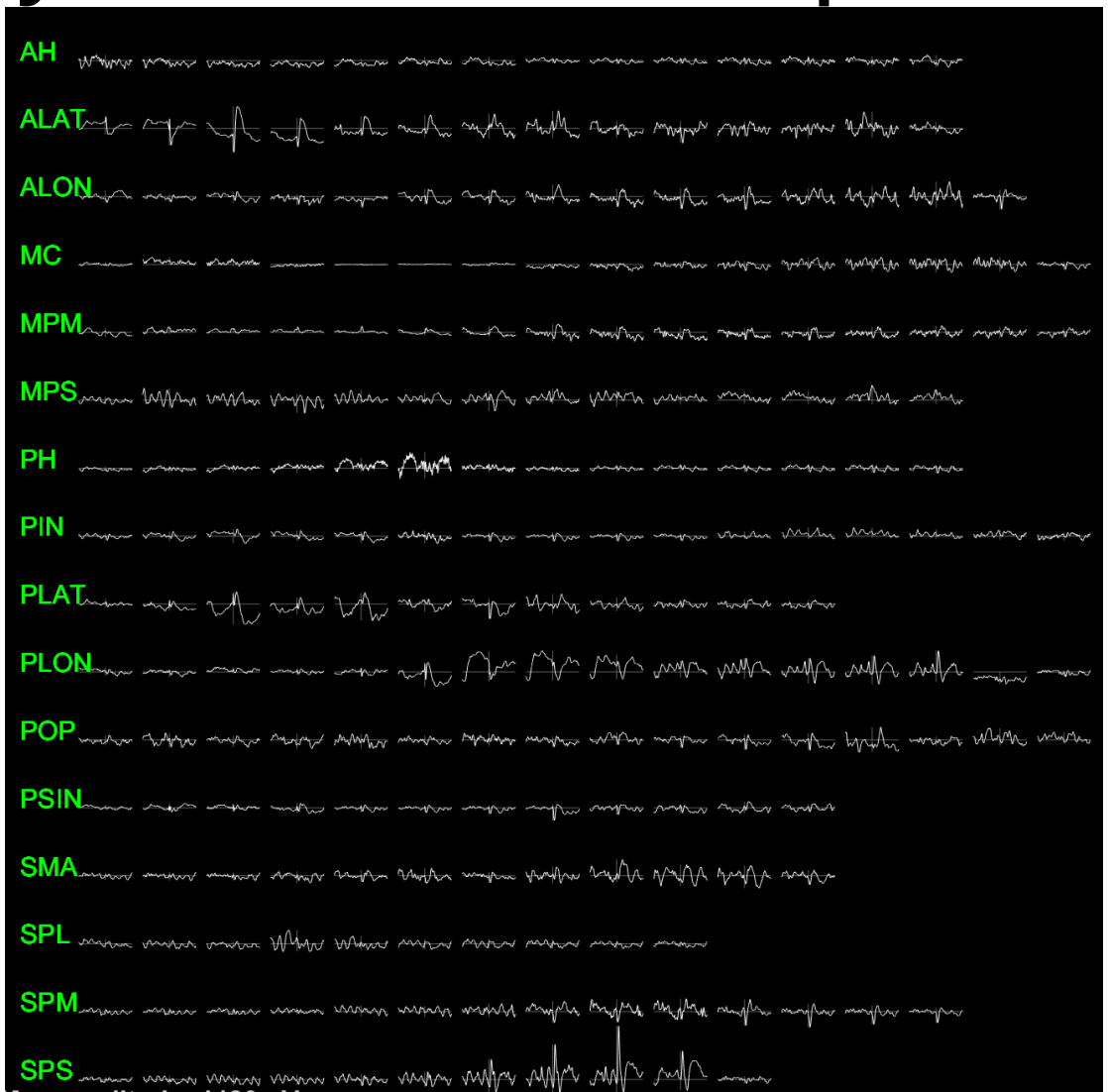
SEEG analysis: Interictal Spike



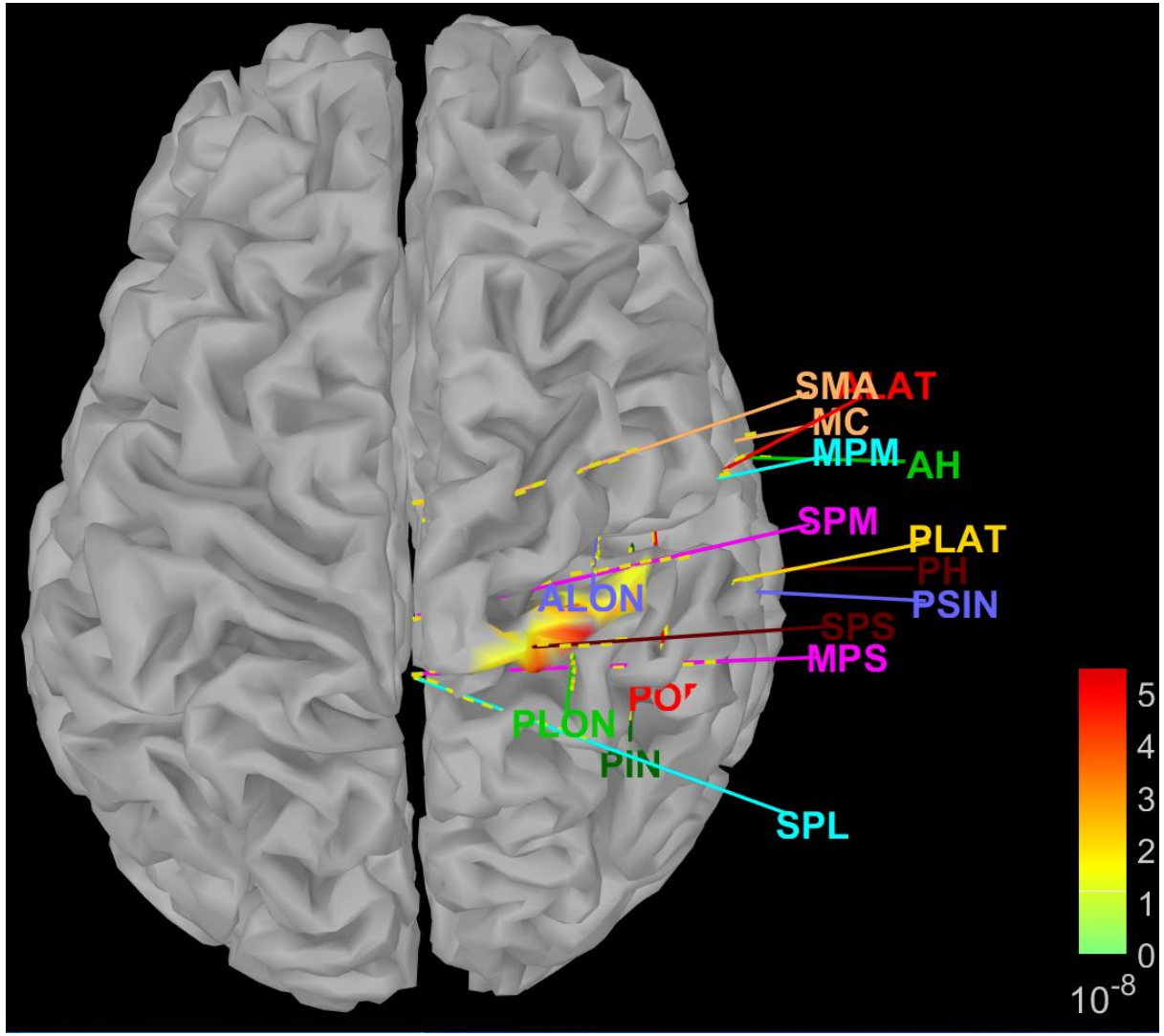
SEEG analysis: Interictal Spike

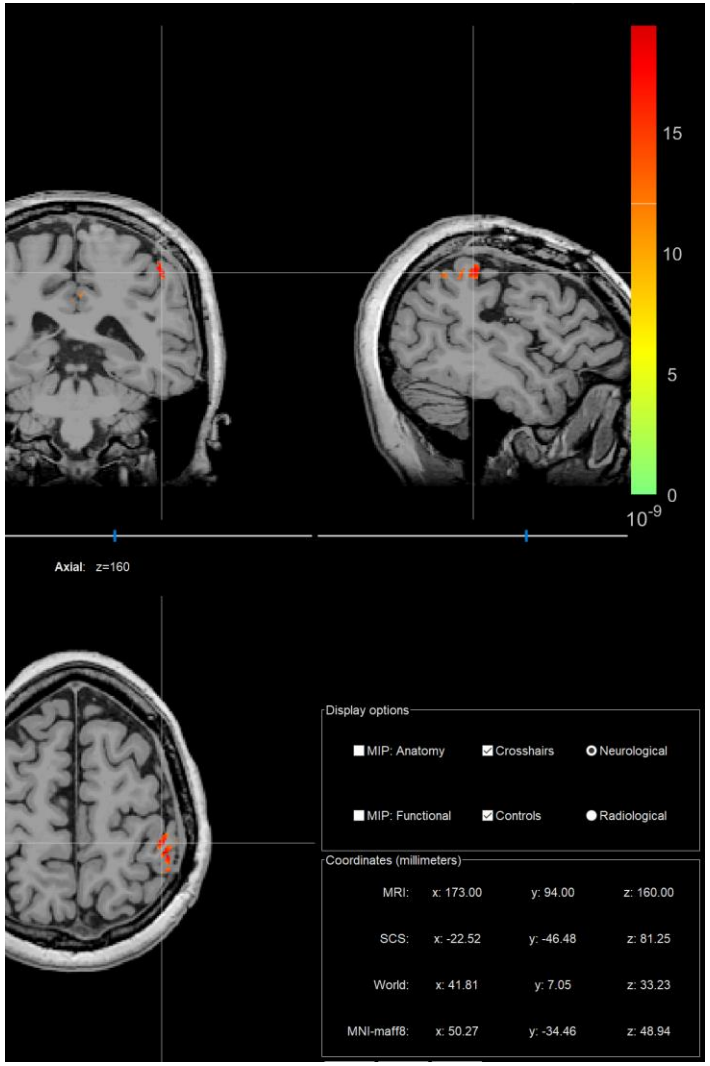


SEEG analysis: Interictal Spike 2D layout

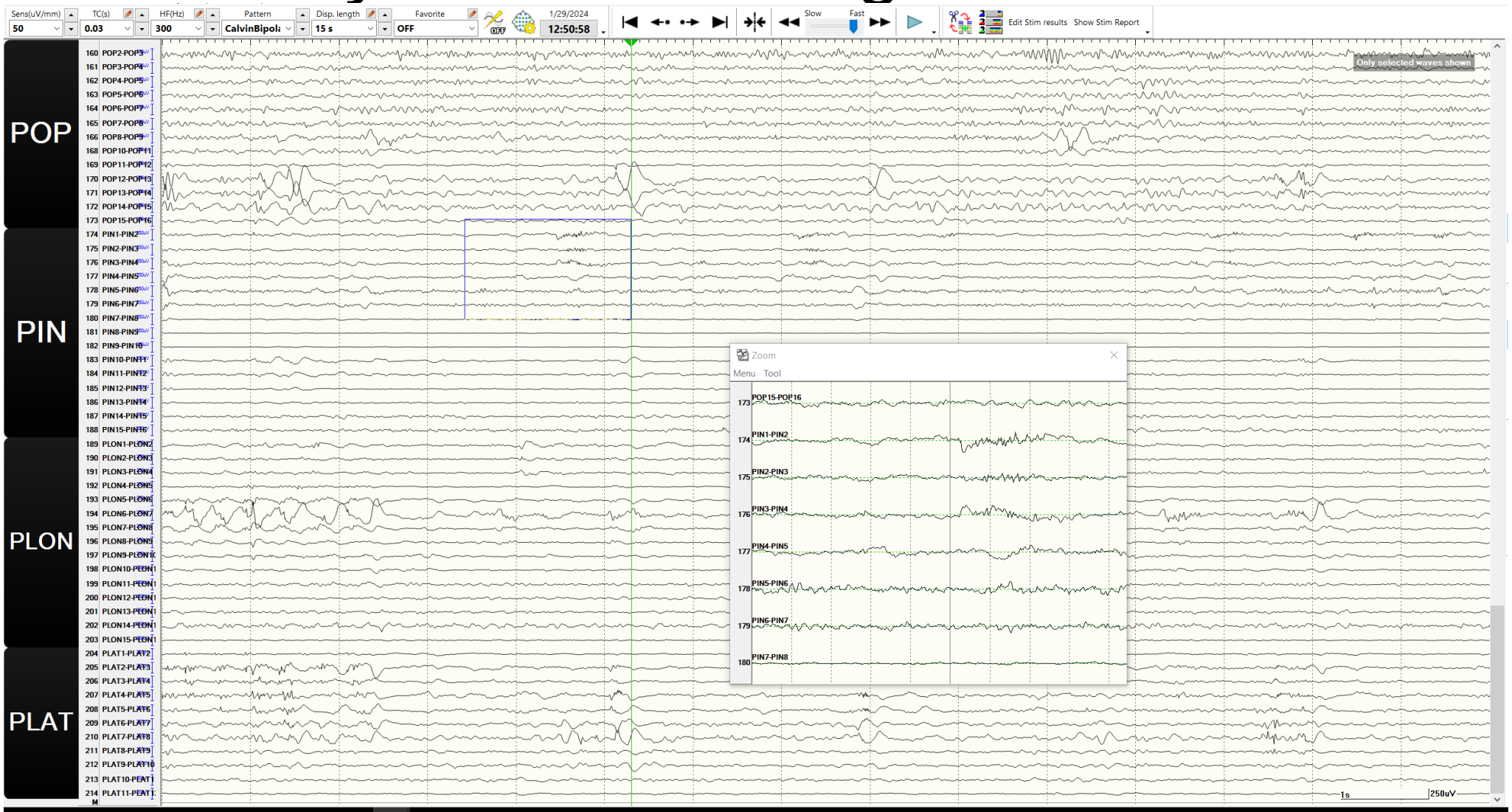


sLORETA on cortex and MRI viewer

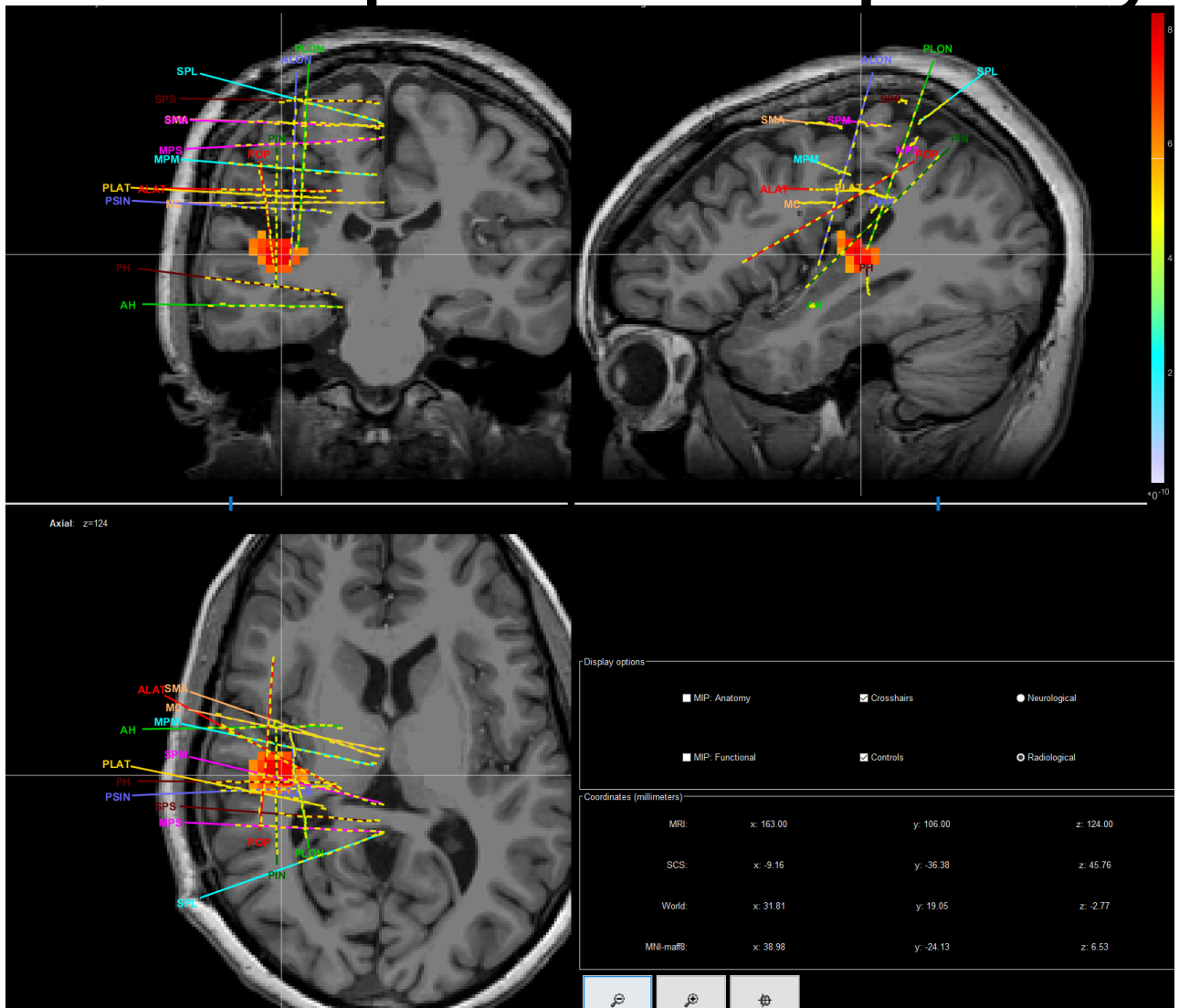




SEEG analysis: Low voltage Fast



sLORETA of a specific frequency band



Ictal Processing

Source Localization of waveform (Is SNR sufficient)?

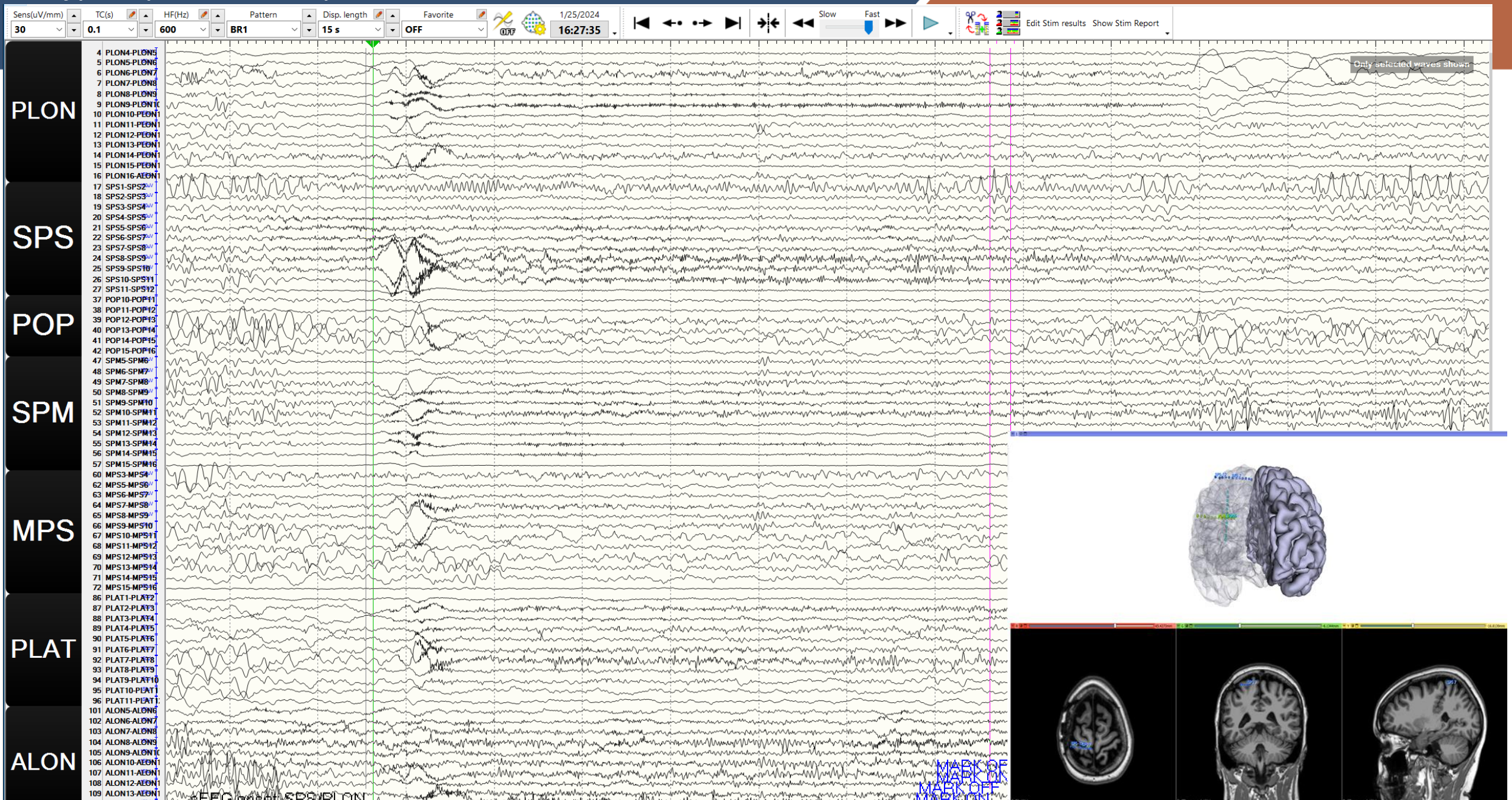
Sensor level Ictal processing

- Epileptogenic Index
- Epileptogenic Fingerprint

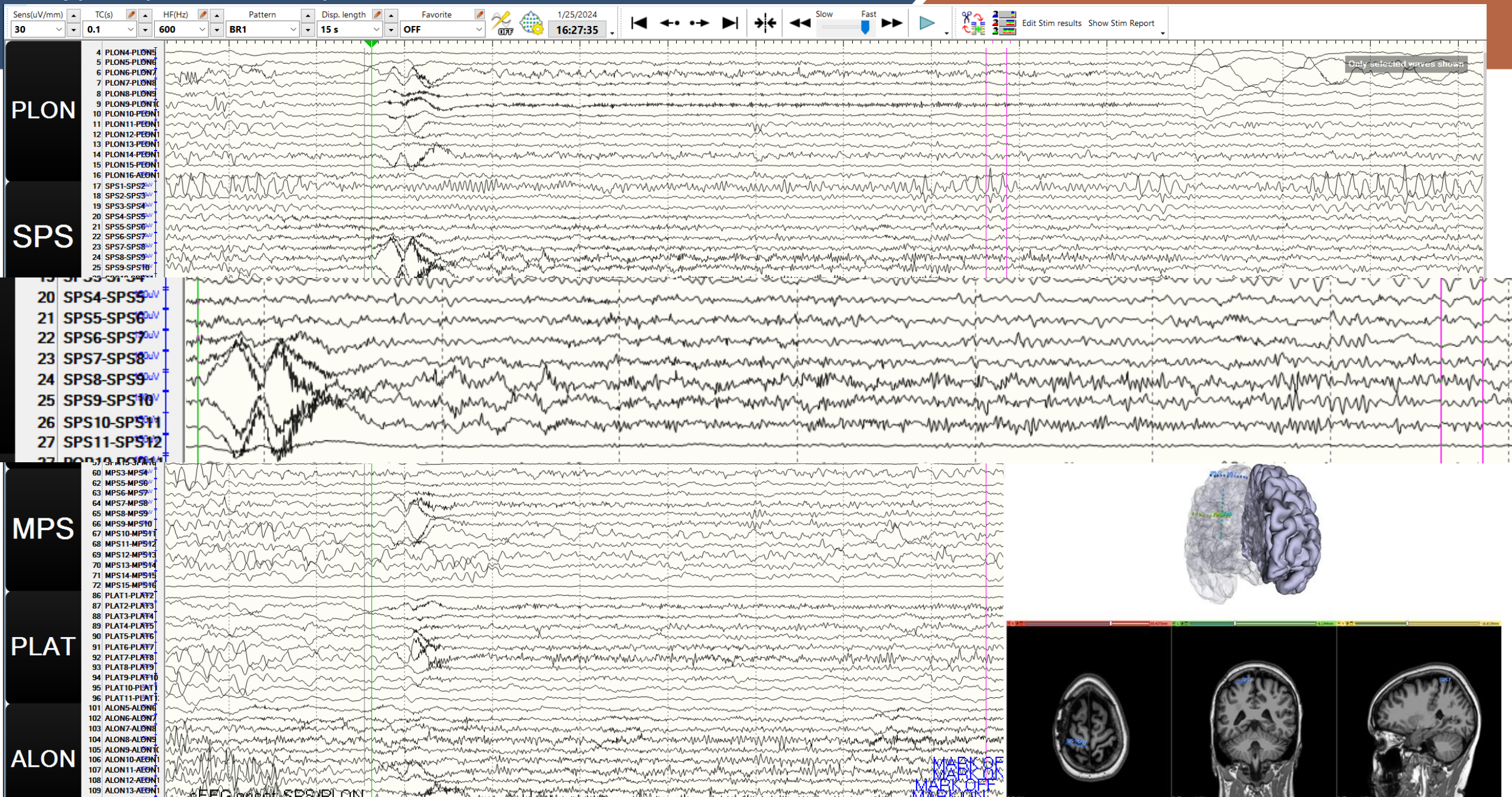
Source Level Ictal Processing

- Frequency Band specific
- Restricted Region of Interest

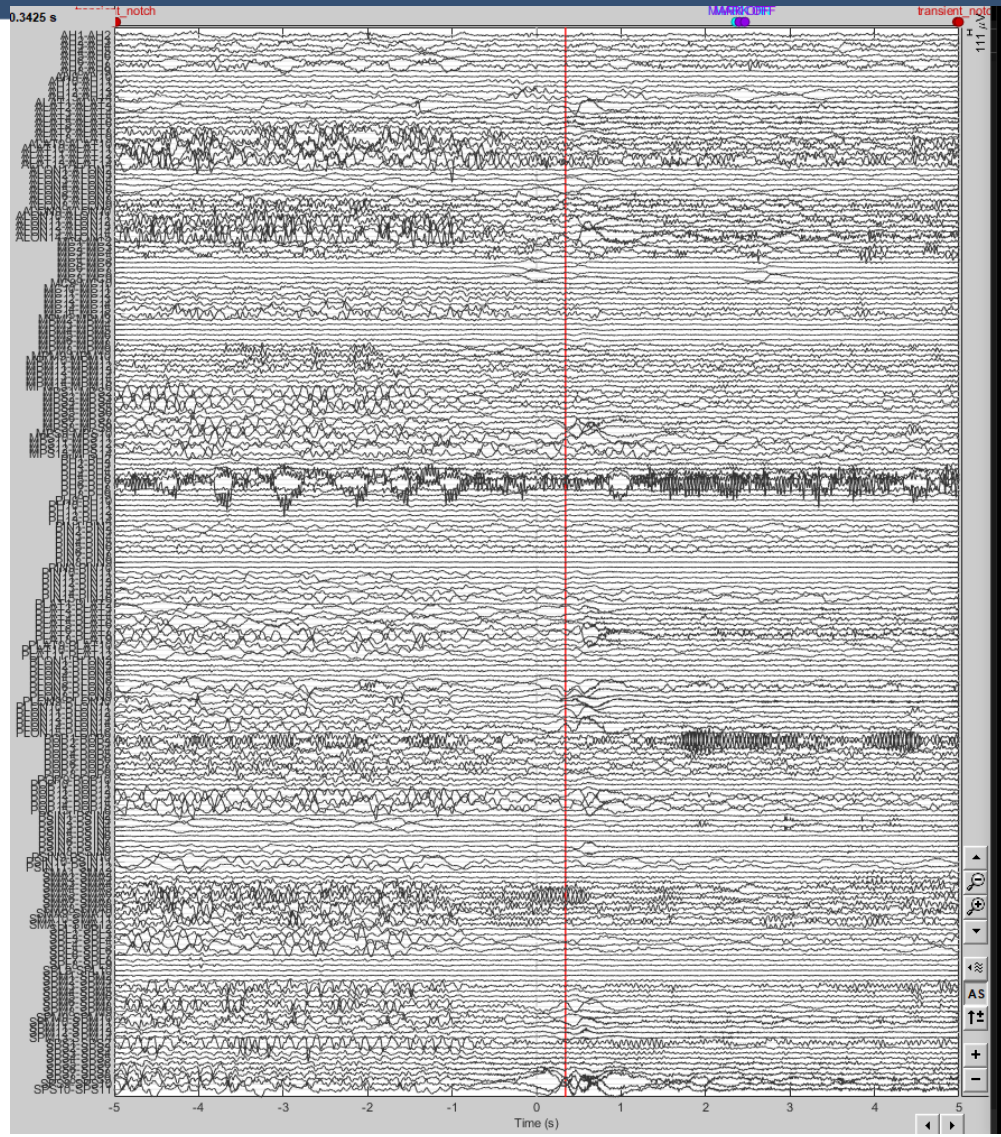
Sz type 1 (left hand aura): **Onset SPS 7-10/**PLON 6-16/PLAT 6-8



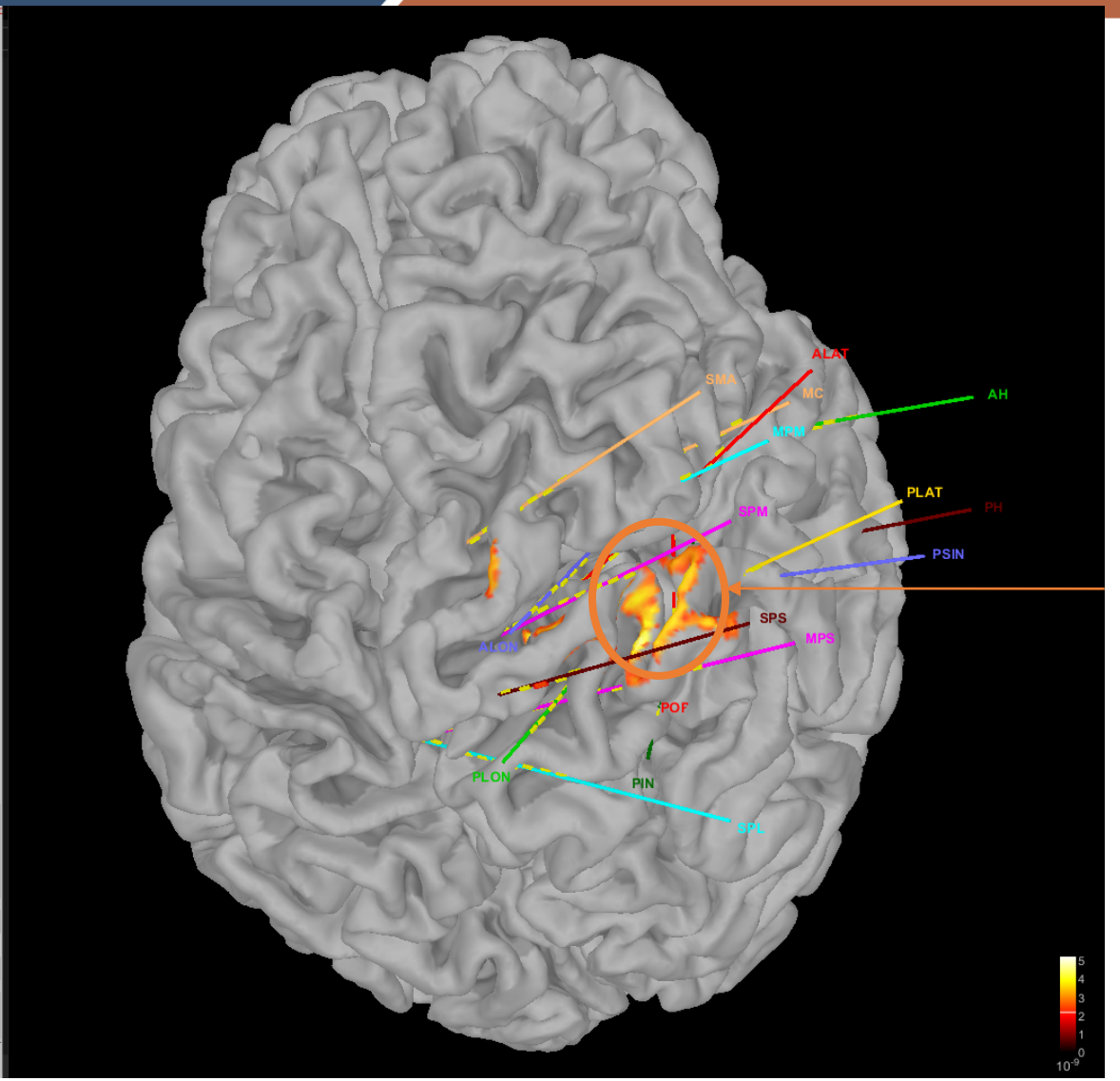
Sz type 1 (left hand aura): **Onset SPS 7-10/**PLON 6-16/PLAT 6-8



sLORETA on Cortex



10 s



Focus of source
Localized power

sLORETA results on MRI volume (sz 1)

doi:10.1093/brain/awn111 *Brain* (2008), **131**, 1818–1830

Epileptogenicity of brain structures in human temporal lobe epilepsy: a quantified study from intracerebral EEG

Fabrice Bartolomei,[1,2,3] Patrick Chauvel[1,2,3] and Fabrice Wendling[4,5]

Epileptogenic zone quantification offers real advantages for facilitating SEEG interpretation and predicting surgical outcome. Ictal (EI, cEI) or combined ictal–interictal (Spikes × EI, Spikes × cEI) SEEG markers overperformed the classical interictal markers (Spikes, HFO, Spikes × HFO), both for detecting the EZ and predicting the seizure freedom. Combining ictal and interictal markers in a single measure improved detection accuracy. Spikes × EI showed the best precision against the clinical analysis. The resection rate of the EZ defined by ictal markers and by Spikes × EI significantly correlated with surgical prognosis. However, complete EZ resection was not mandatory to control seizures.

The "Connectivity Epileptogenicity Index" (cEI), a method for mapping the different seizure onset patterns in StereoElectroEncephalography recorded seizures

Alexandra Balatskaya [a], Nicolas Roehri [a], Stanislas Lagarde [a,b], Francesca Pizzo [a,b], Samuel Medina [a,b], Fabrice Wendling [c,d], Christian-George Bénar [a,1], Fabrice Bartolomei [a,b,*,1]

[a] *Aix Marseille Univ, INSERM, INS, Inst Neurosci Syst, Marseille, France*
[b] *APHM, Timone Hospital, Epileptology and Cerebral Rhythmology, Marseille, France*
[c] *INSERM U1099, LTSI, Rennes, France*
[d] *Université de Rennes 1, LTSI, Rennes, France*

RESEARCH ARTICLE

The role of quantitative markers in surgical prognostication after stereoelectroencephalography

Julia Makhalova[1,2,3], Tanguy Madec[1], Samuel Medina Villalon[1,2], Aude Jegou[2], Stanislas Lagarde[1,2], Romain Carron[4], Didier Scavarda[5], Elodie Garnier[2], Christian G. Bénar[2] & Fabrice Bartolomei[1,2]

[1]APHM, Timone Hospital, Epileptology and Cerebral Rhythmology, Marseille, France
[2]Aix Marseille Univ, INSERM, INS, Inst Neurosci Syst, Marseille, France
[3]Aix Marseille Univ, CNRS, CRMBM, Marseille, France
[4]APHM, Timone Hospital, Functional, and Stereotactic Neurosurgery, Marseille, France
[5]APHM, Department of Pediatric Neurosurgery, Marseille, France

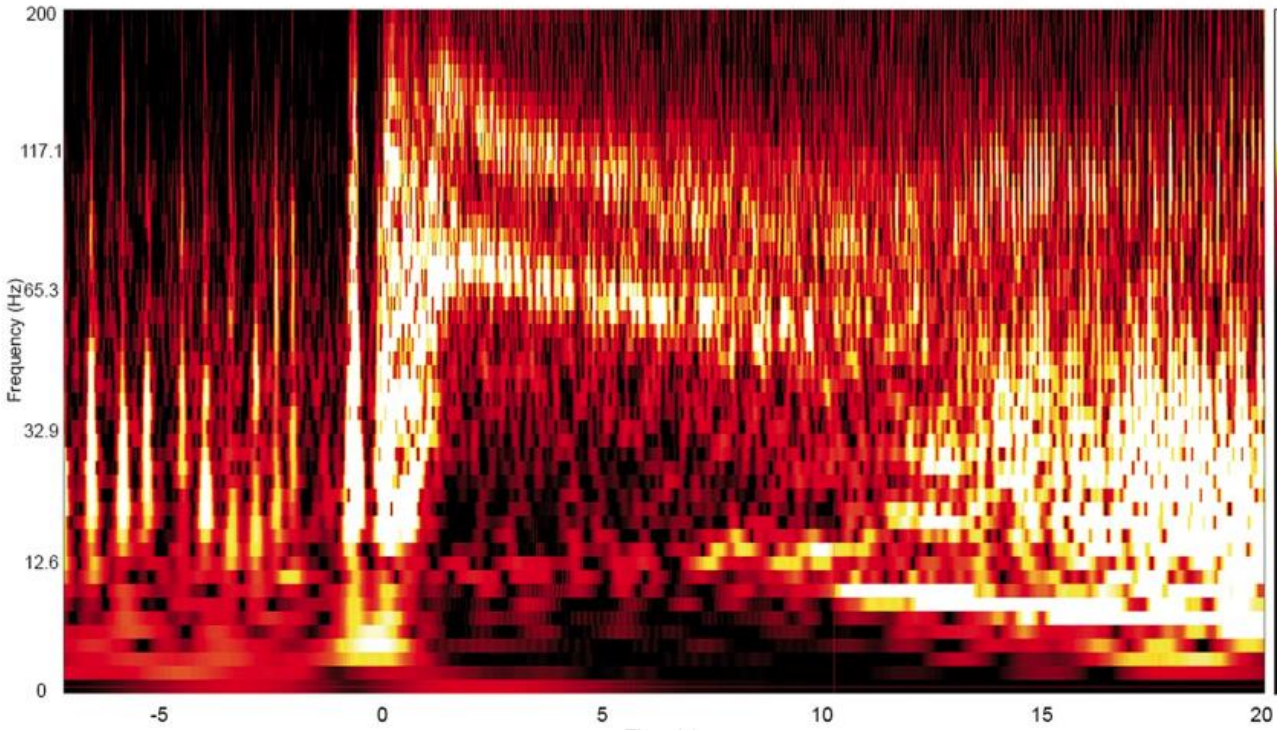
doi:10.1093/brain/awx306 BRAIN 2018: 141; 117–131 | 117

A fingerprint of the epileptogenic zone in human epilepsies

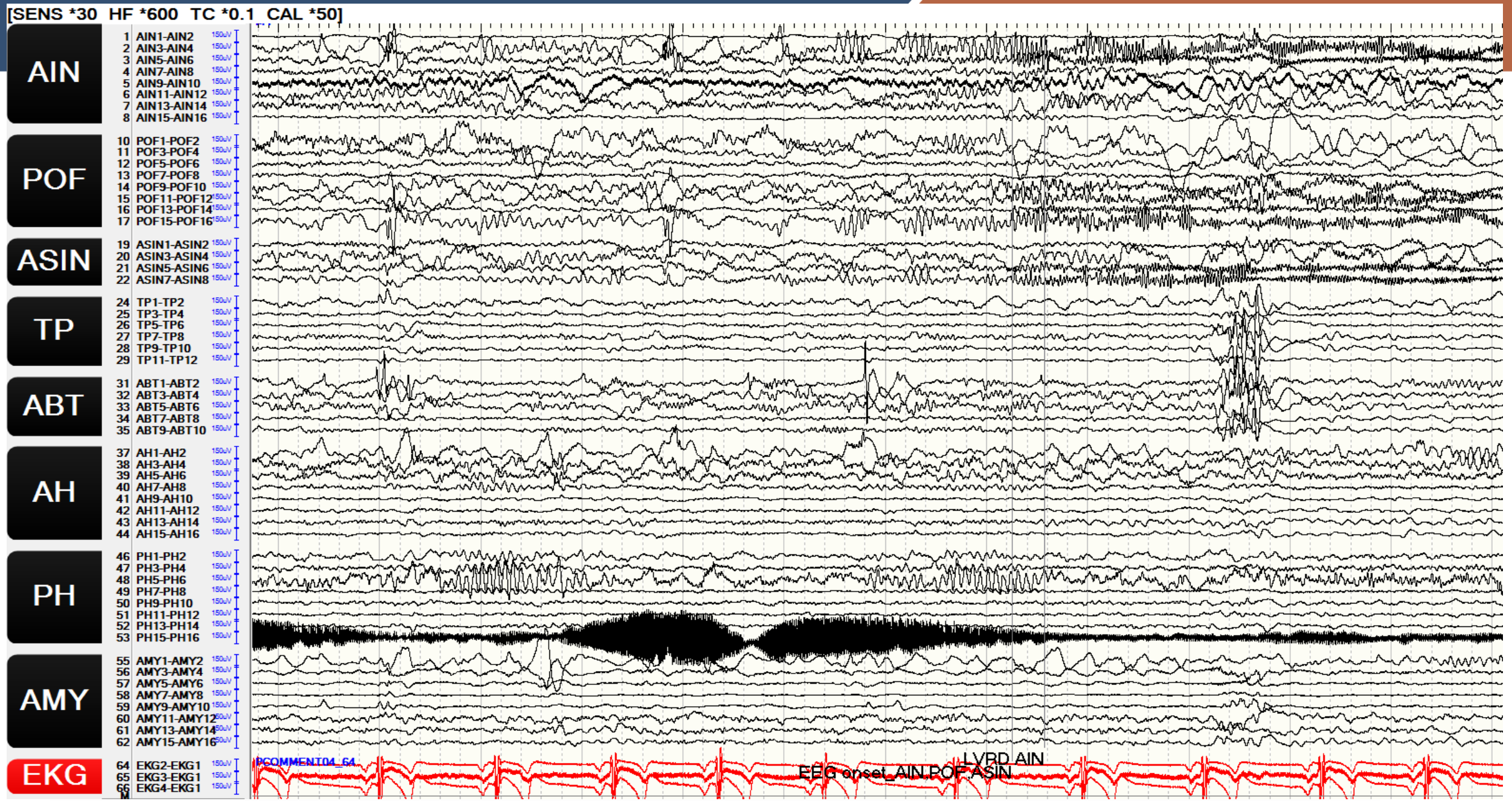
Olesya Grinenko,[1,*] Jian Li,[2,*] John C. Mosher,[1] Irene Z. Wang,[1] Juan C. Bulacio,[1] Jorge Gonzalez-Martinez,[1] Dileep Nair,[1] Imad Najm,[1] Richard M. Leahy[2] and Patrick Chauvel[1]

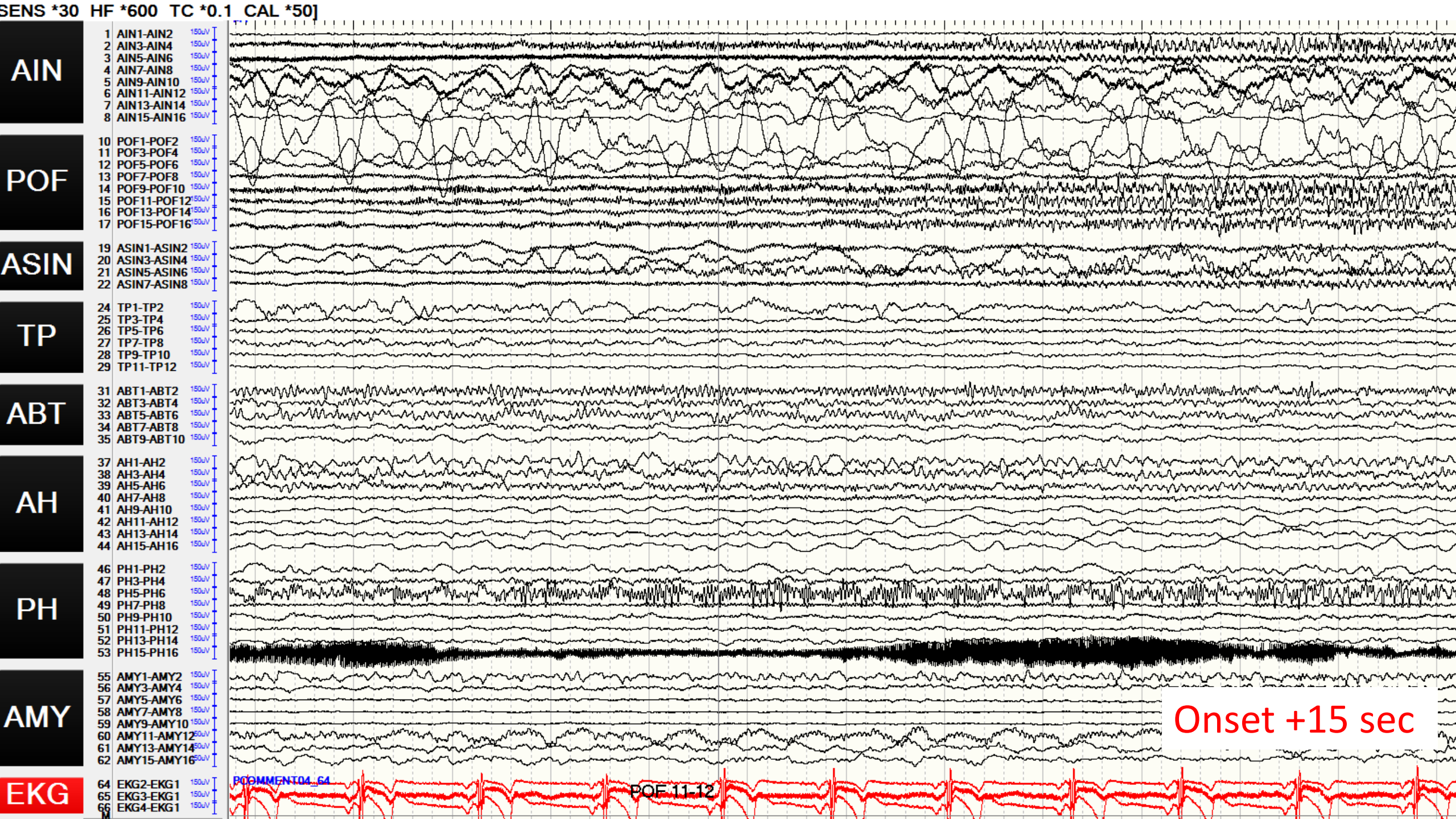
Characteristic time-frequency pattern emerged for contacts located inside epileptogenic zone.

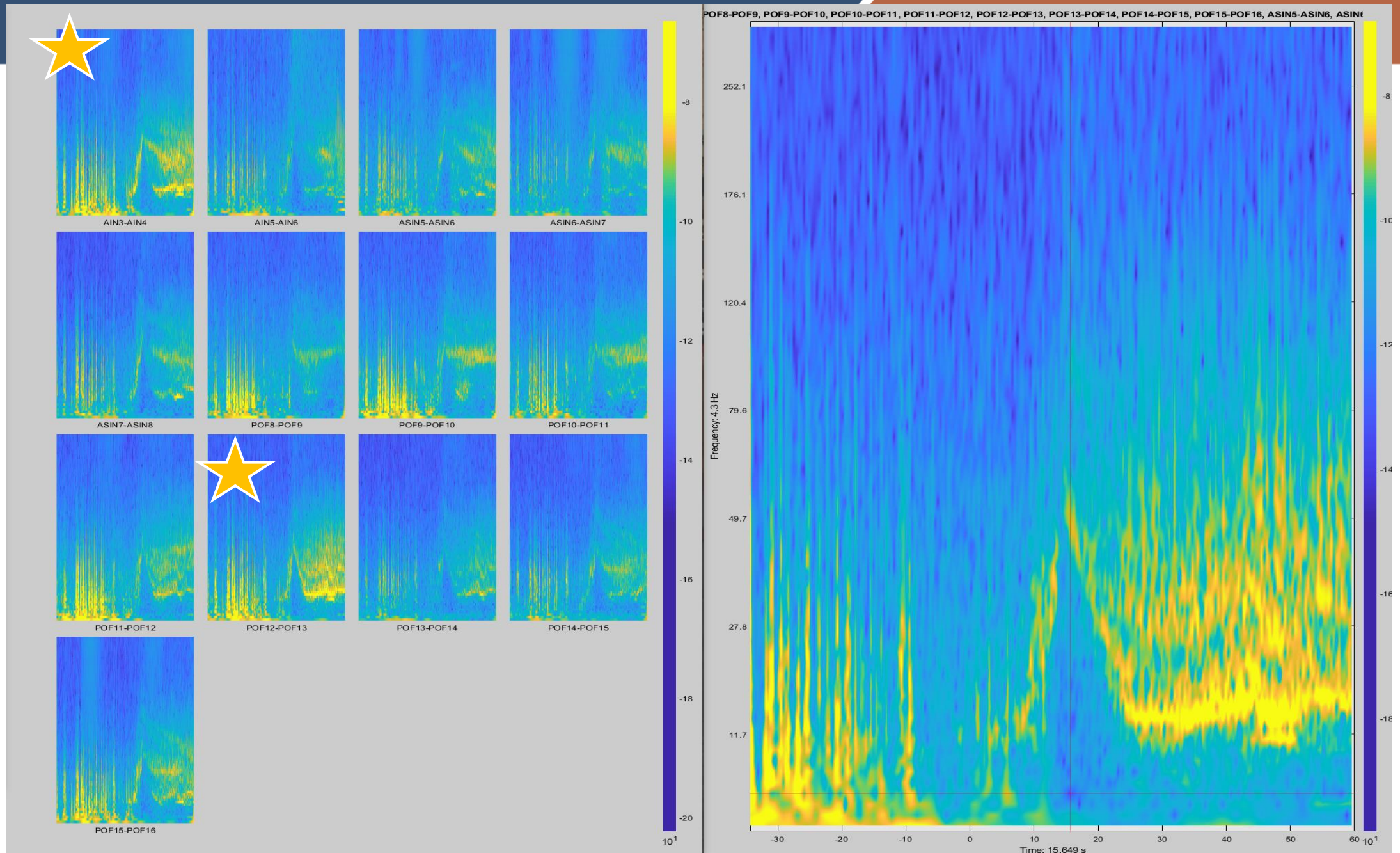
- single or multiple pre-ictal sharp transient(s) or spike(s)
- narrow frequency bands of fast activity
- simultaneous suppression of slow pre-ictal frequencies.



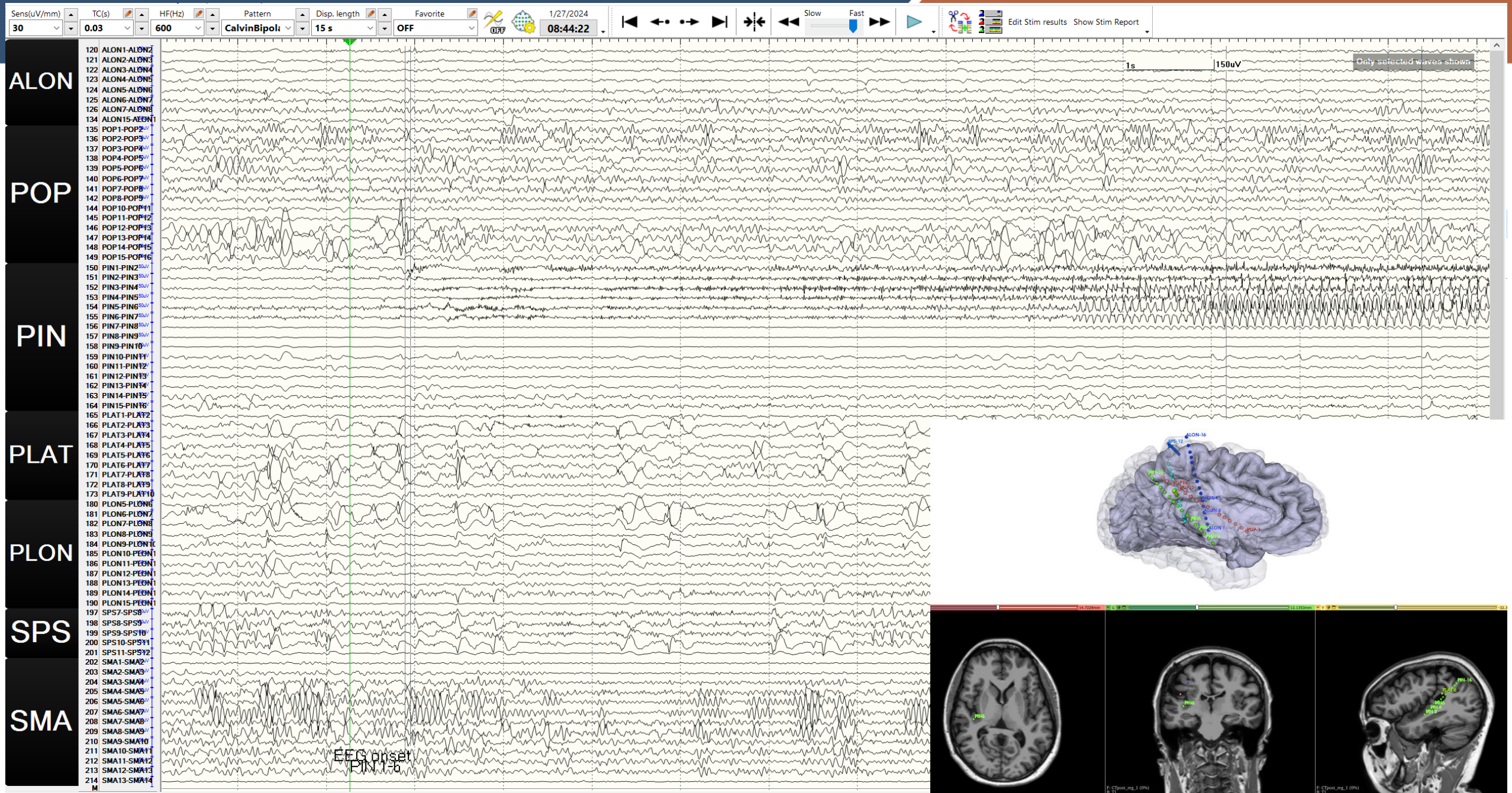
Sz onset – AIN 3-6,POF 9-16, ASIN 5-8



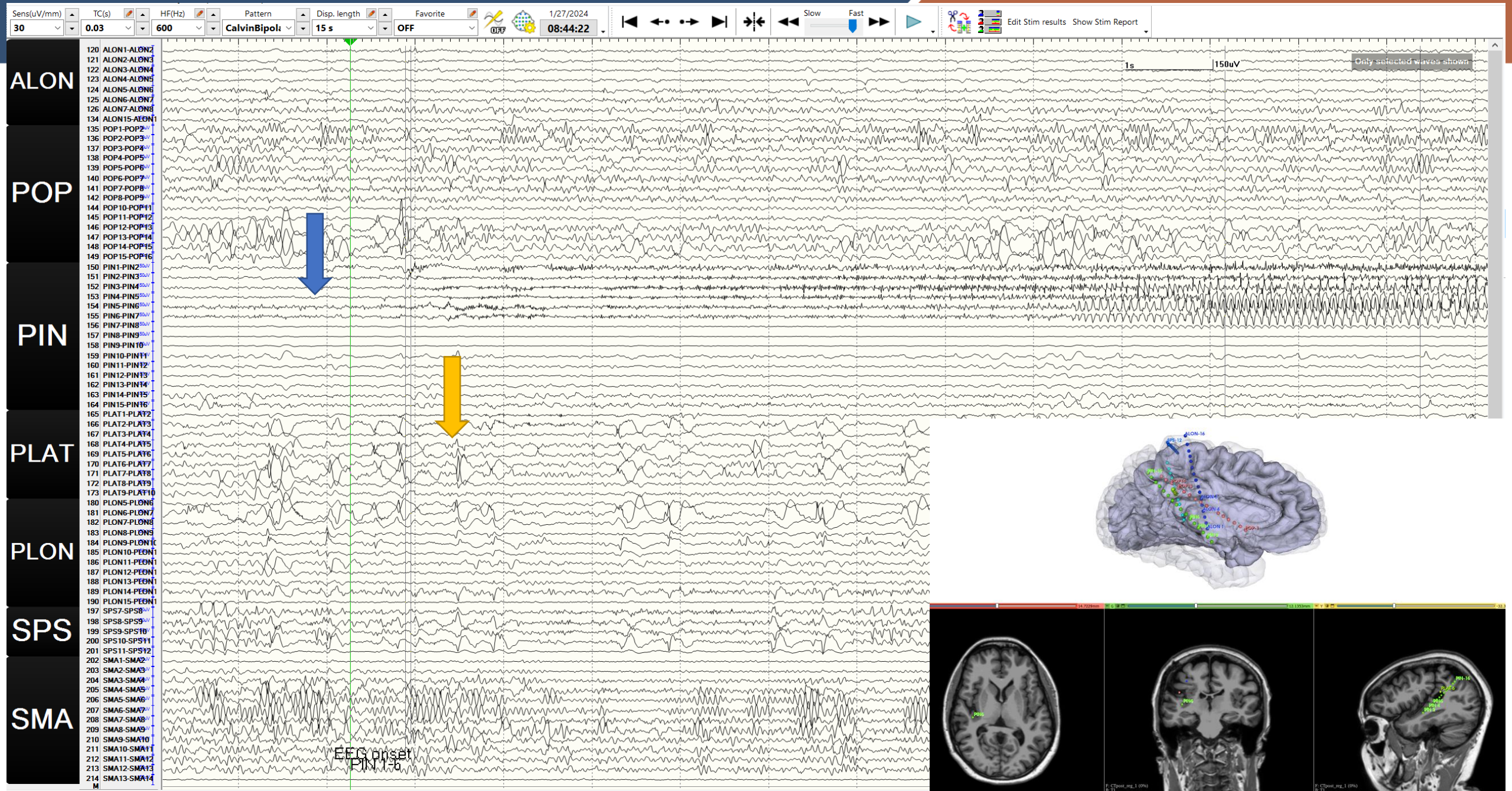

SENS *30 HF *600 TC *0.1 CAL *50]
AIN
1 AIN1-AIN2
2 AIN3-AIN4
3 AIN5-AIN6
4 AIN7-AIN8
5 AIN9-AIN10
6 AIN11-AIN12
7 AIN13-AIN14
8 AIN15-AIN16
POF
10 POF1-POF2
11 POF3-POF4
12 POF5-POF6
13 POF7-POF8
14 POF9-POF10
15 POF11-POF12
16 POF13-POF14
17 POF15-POF16
ASIN
19 ASIN1-ASIN2
20 ASIN3-ASIN4
21 ASIN5-ASIN6
22 ASIN7-ASIN8
TP
24 TP1-TP2
25 TP3-TP4
26 TP5-TP6
27 TP7-TP8
28 TP9-TP10
29 TP11-TP12
ABT
31 ABT1-ABT2
32 ABT3-ABT4
33 ABT5-ABT6
34 ABT7-ABT8
35 ABT9-ABT10
AH
37 AH1-AH2
38 AH3-AH4
39 AH5-AH6
40 AH7-AH8
41 AH9-AH10
42 AH11-AH12
43 AH13-AH14
44 AH15-AH16
PH
46 PH1-PH2
47 PH3-PH4
48 PH5-PH6
49 PH7-PH8
50 PH9-PH10
51 PH11-PH12
52 PH13-PH14
53 PH15-PH16
AMY
55 AMY1-AMY2
56 AMY3-AMY4
57 AMY5-AMY6
58 AMY7-AMY8
59 AMY9-AMY10
60 AMY11-AMY12
61 AMY13-AMY14
62 AMY15-AMY16
EKG
64 EKG2-EKG1
65 EKG3-EKG1
66 EKG4-EKG1
150uV
POF 11-12
Onset +15 sec


AIN3-AIN4
AIN5-AIN6
ASIN5-ASIN6
ASIN6-ASIN7
ASIN7-ASIN8
POF8-POF9
POF9-POF10
POF10-POF11
POF11-POF12
POF12-POF13
POF13-POF14
POF14-POF15
POF15-POF16
-8
-10
-12
-14
-16
-18
-20
10^1
POF8-POF9, POF9-POF10, POF10-POF11, POF11-POF12, POF12-POF13, POF13-POF14, POF14-POF15, POF15-POF16, ASIN5-ASIN6, ASIN
252.1
176.1
120.4
79.6
49.7
27.8
11.7
Frequency: 4.3 Hz
-30
-20
-10
0
10
20
30
40
50
60
Time: 15.649 s

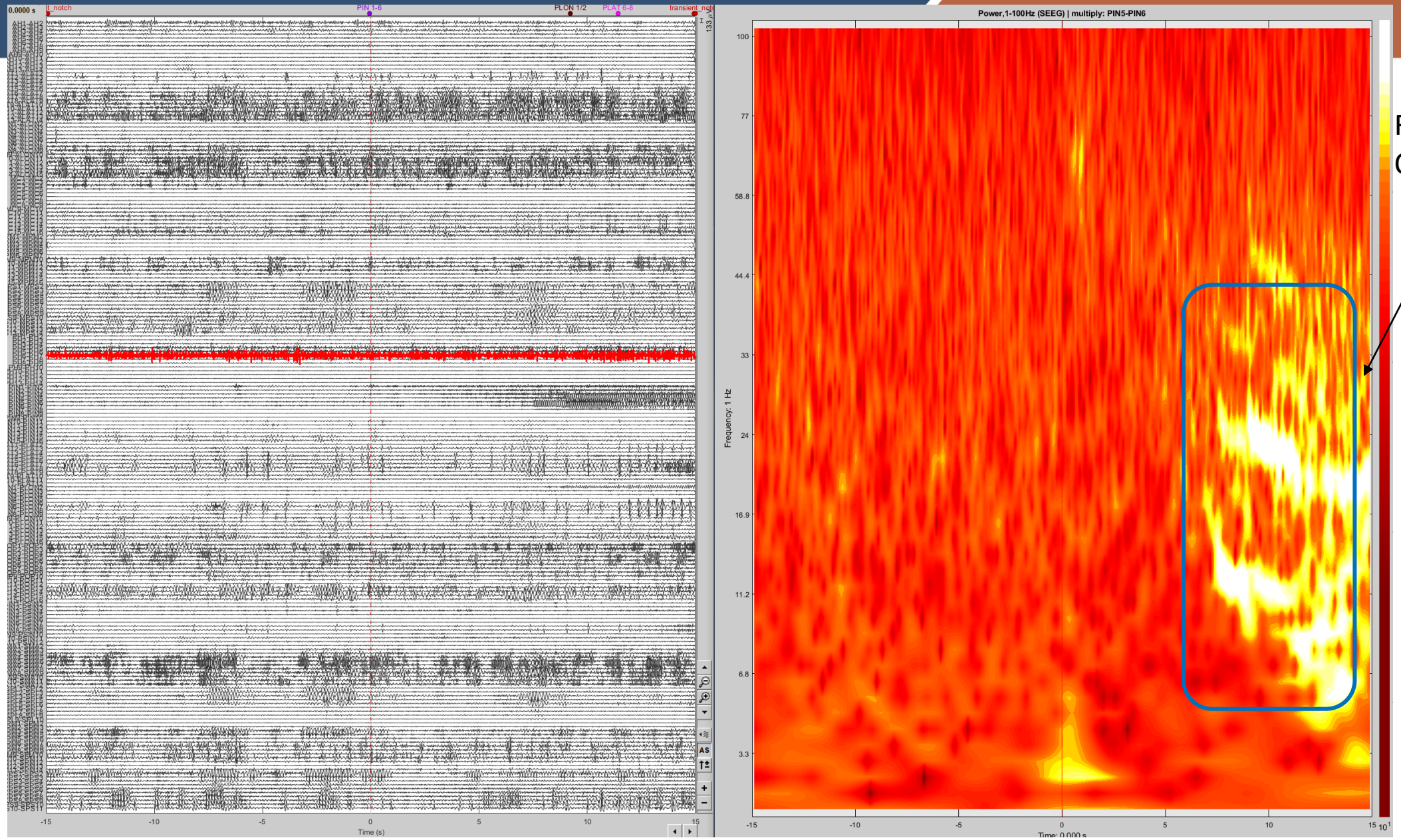
Source Level Ictal Analysis



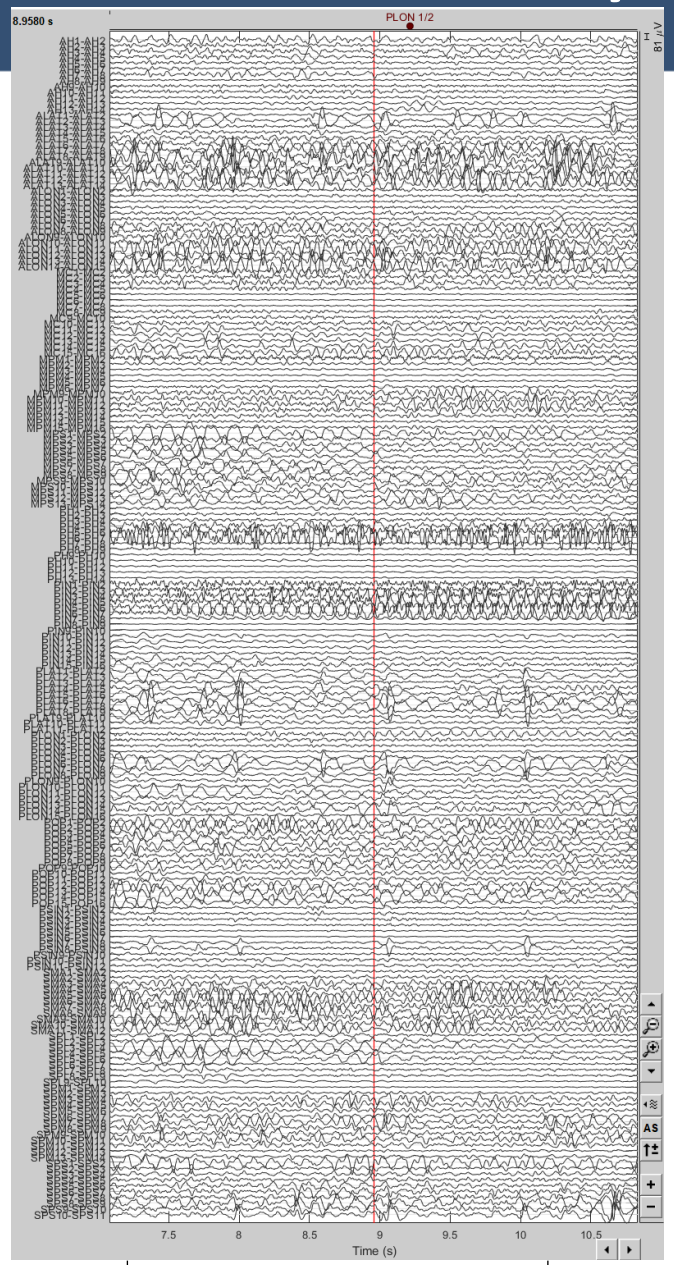
Source Level Ictal Analysis

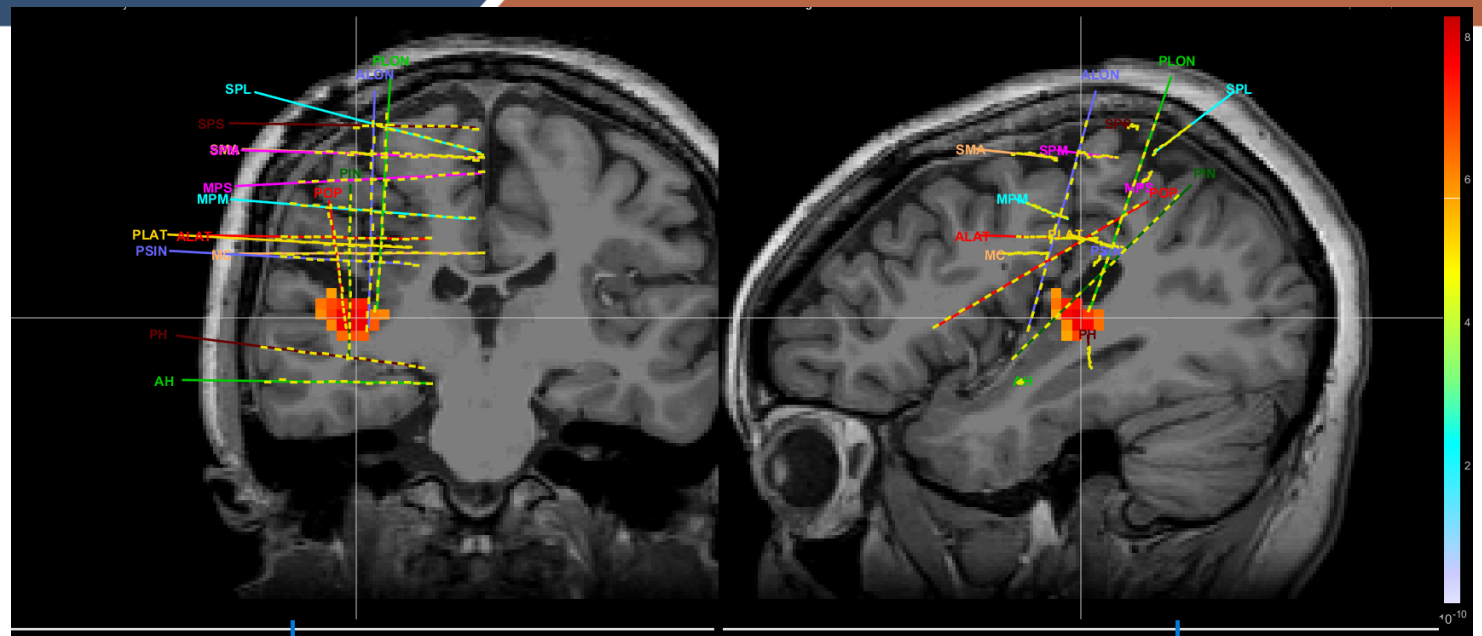


Time-frequency decomposition on PIN 5-6

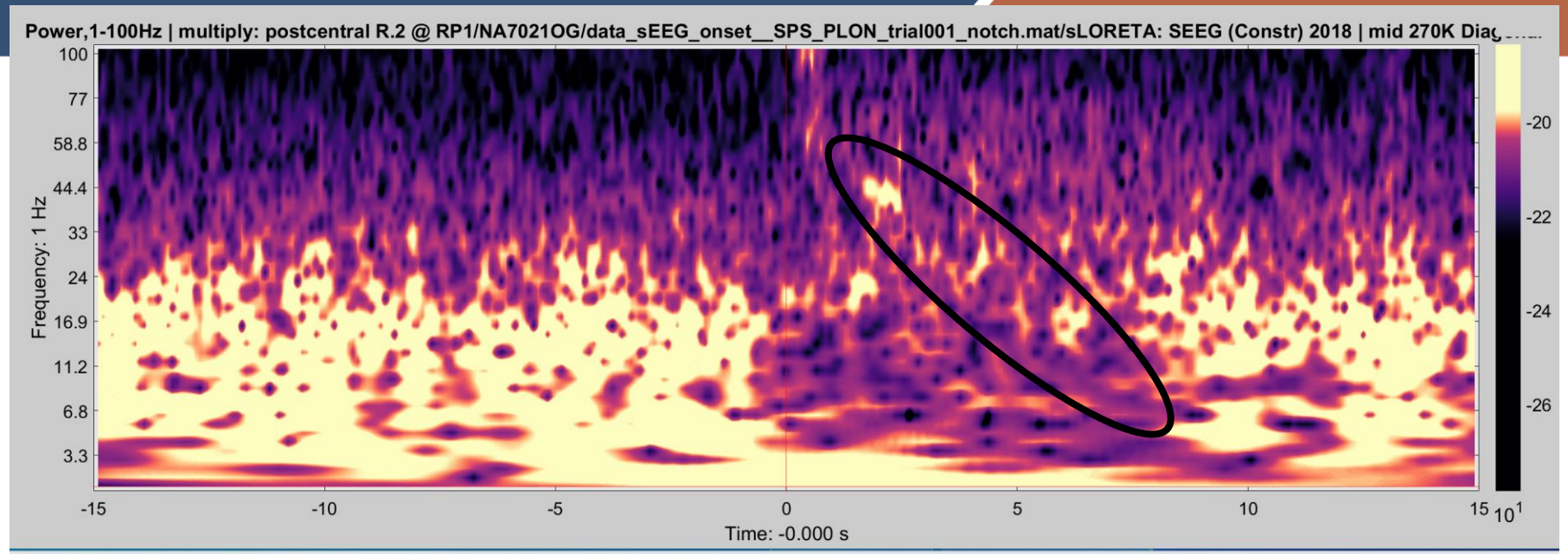


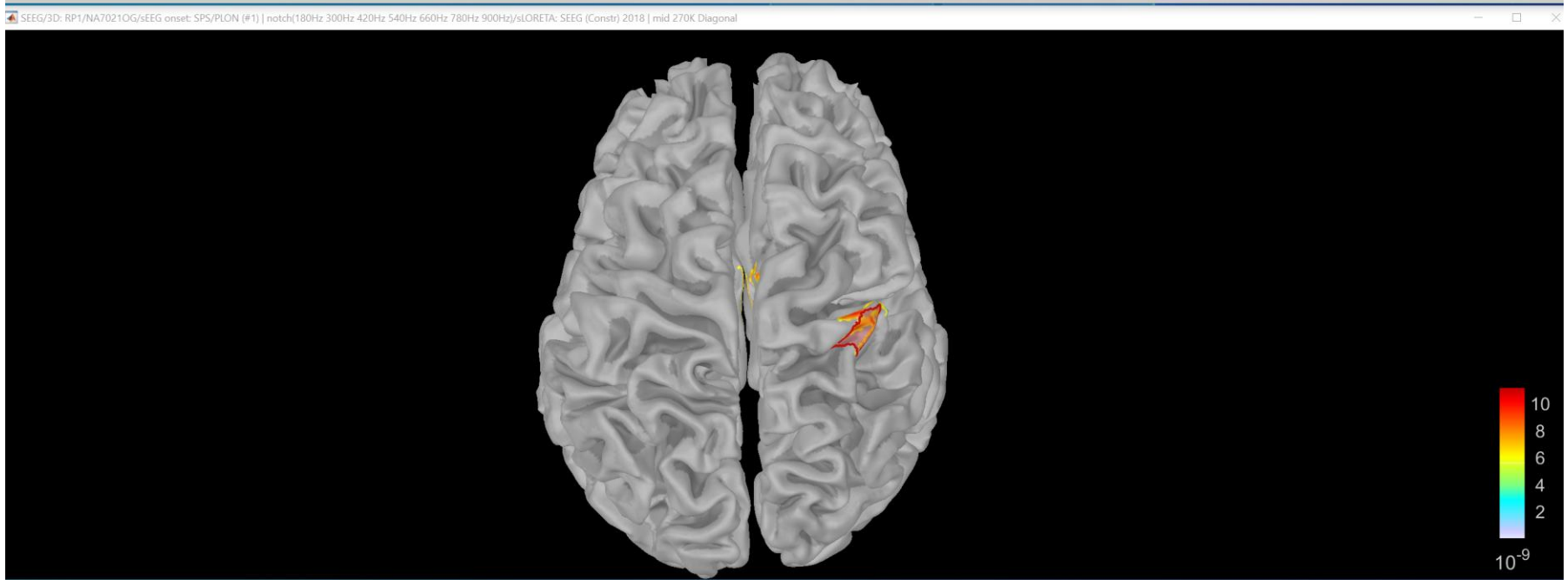
sLORETA of rhythmic activity using filter (5-55 Hz)



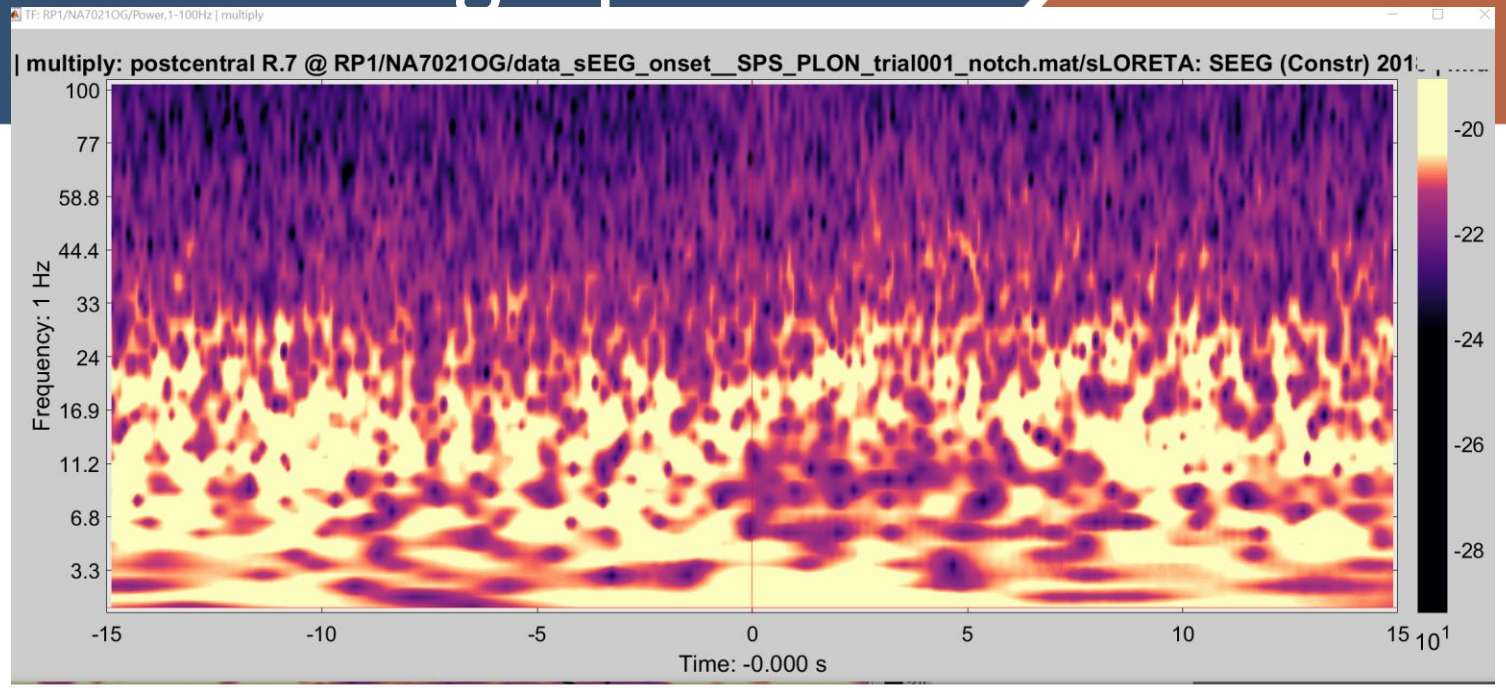


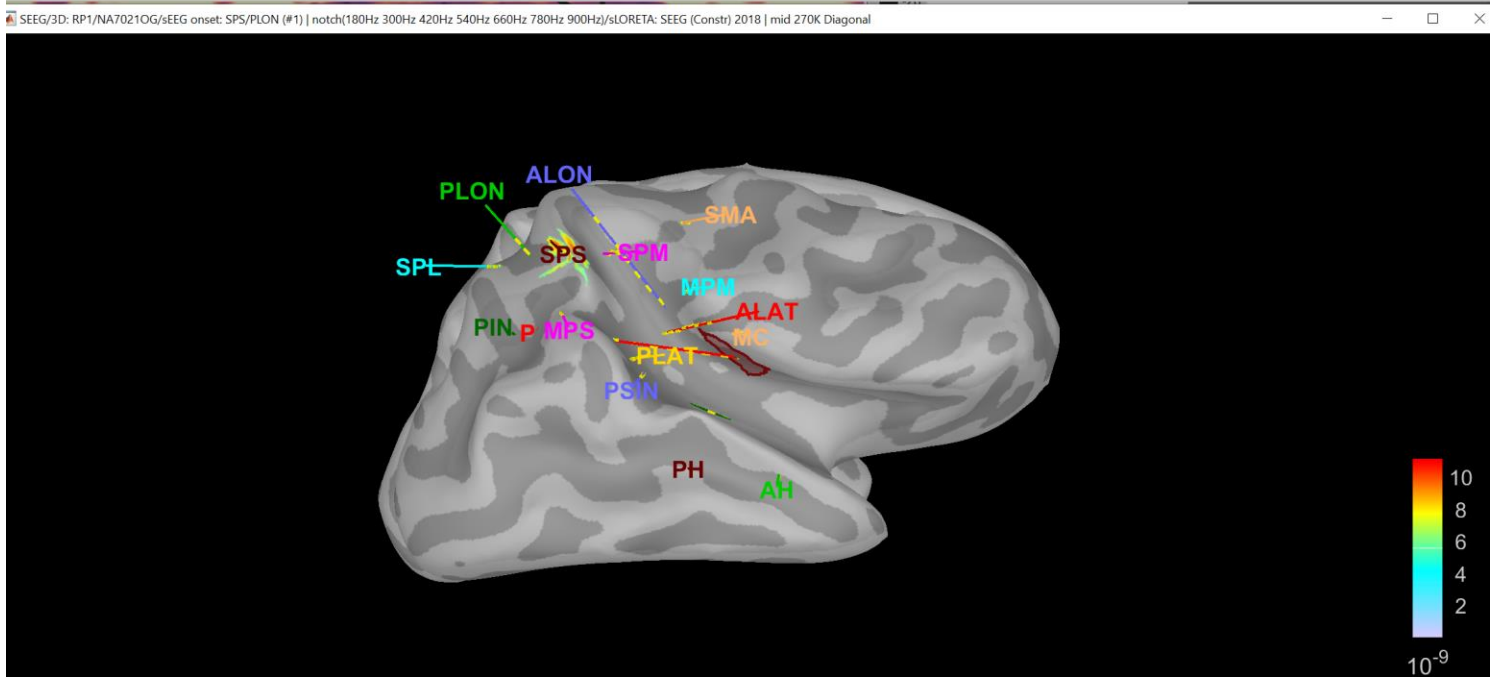
Seizure fingerprint on Source Level





Seizure fingerprint on Source Level





Multimodal Analysis: Case Example

Right-handed male onset of seizures as a child. Semiology: Staring, right arm immobility, left hand automatisms, unresponsiveness and hypermotor movements with post-ictal aphasia

MRI with L frontal opercular cortical dysplasia.

Underwent a phase II subdural evaluation ~ 15 years ago and was told he wasn’t a resective surgery candidate

Repeat Surgical Evaluation (External)

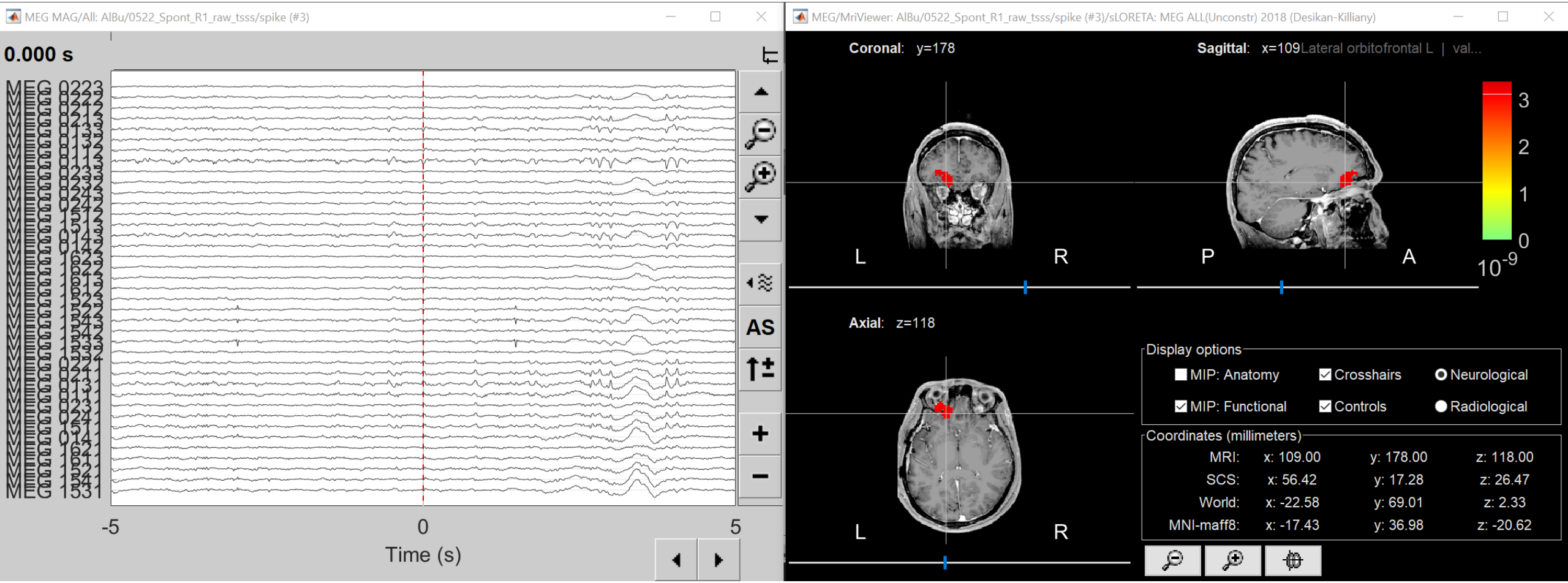
EMU:

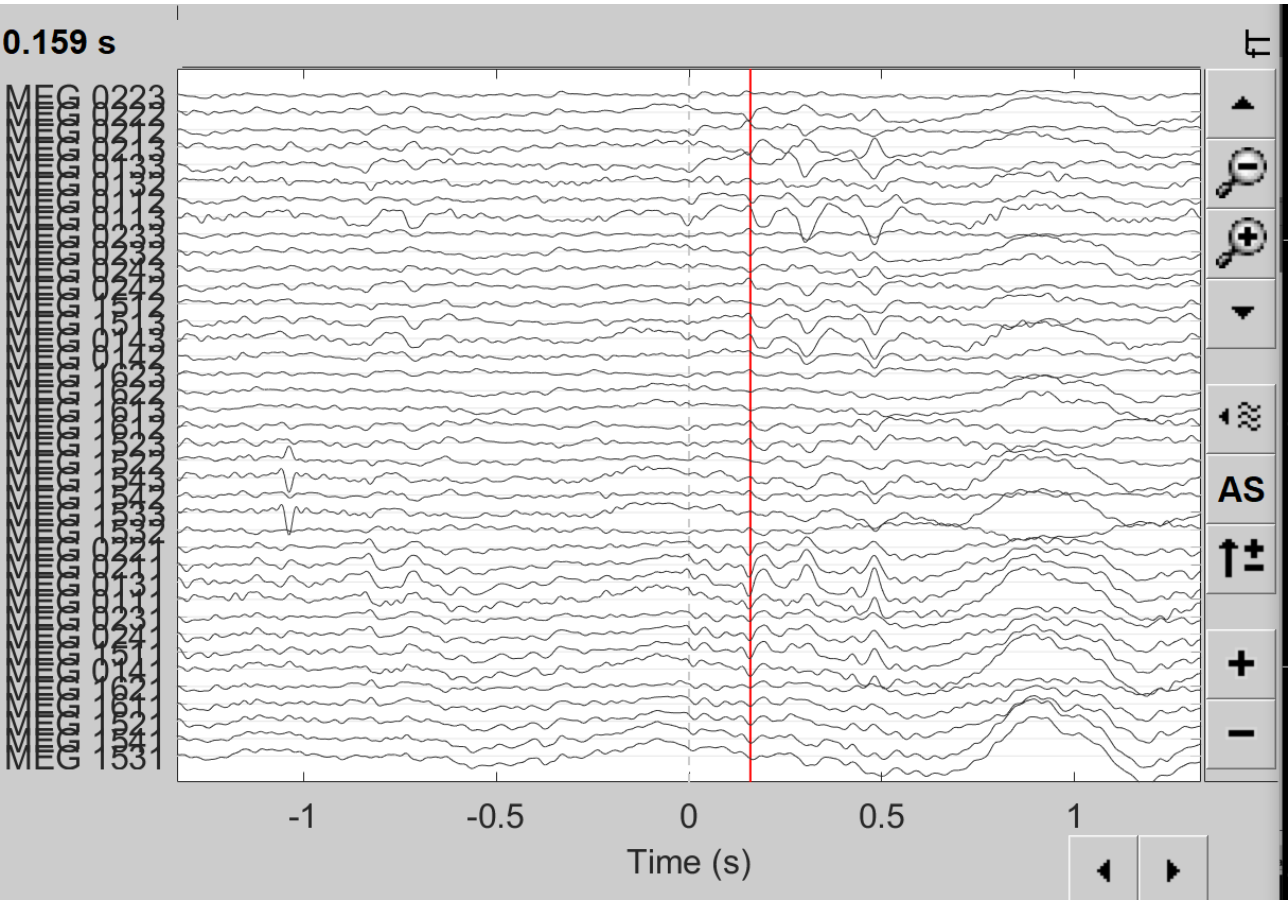
- Interictal abnormalities: Sharp waves: Left temporal
- Ictal:
    - Semiology: Staring, right arm immobility, left hand automatisms, unresponsiveness and hypermotor and post-ictal aphasia
    - EEG Seizure pattern: Left temporal delta activity

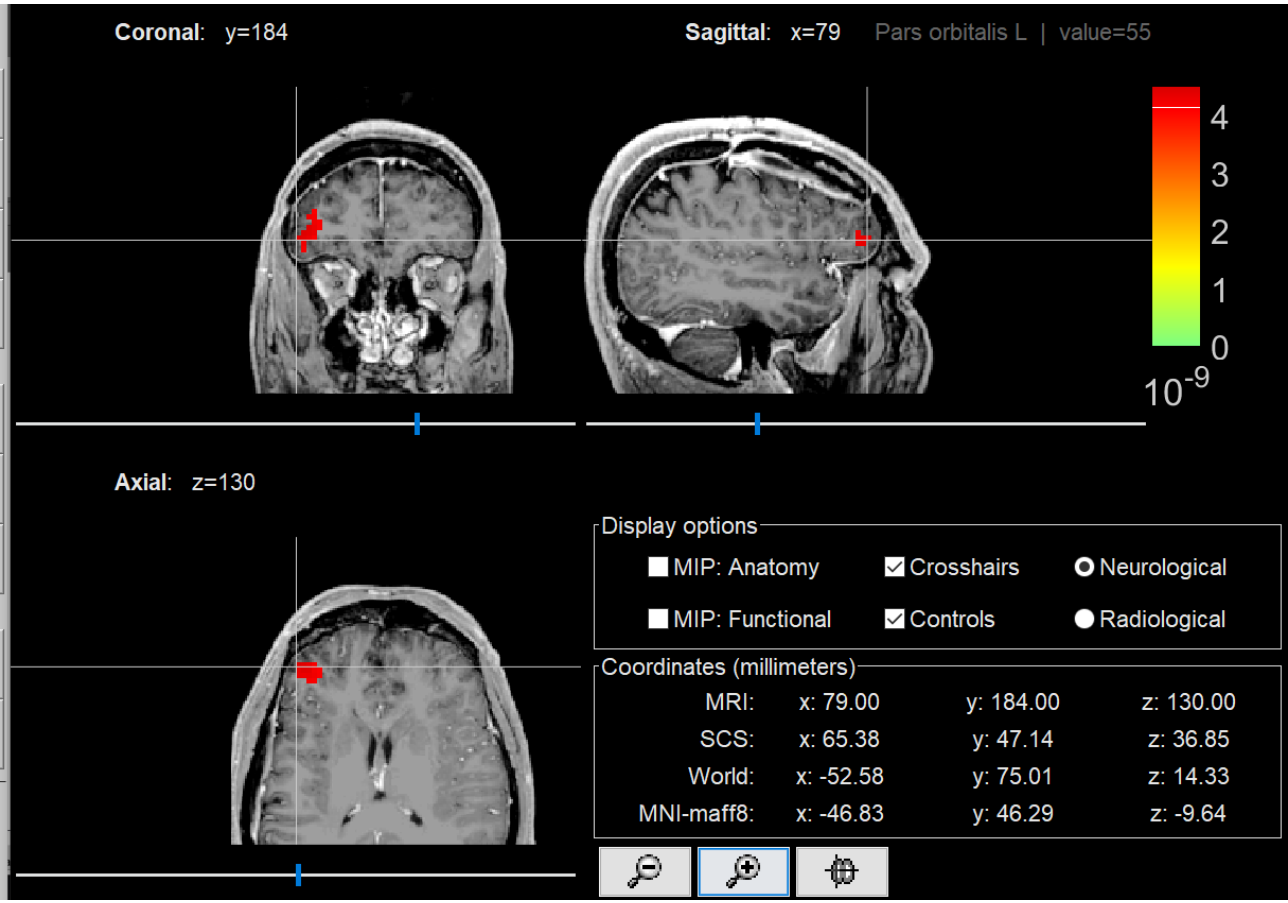
MRI: Post surgical changes of left craniotomy, no clear evidence of dysplasia

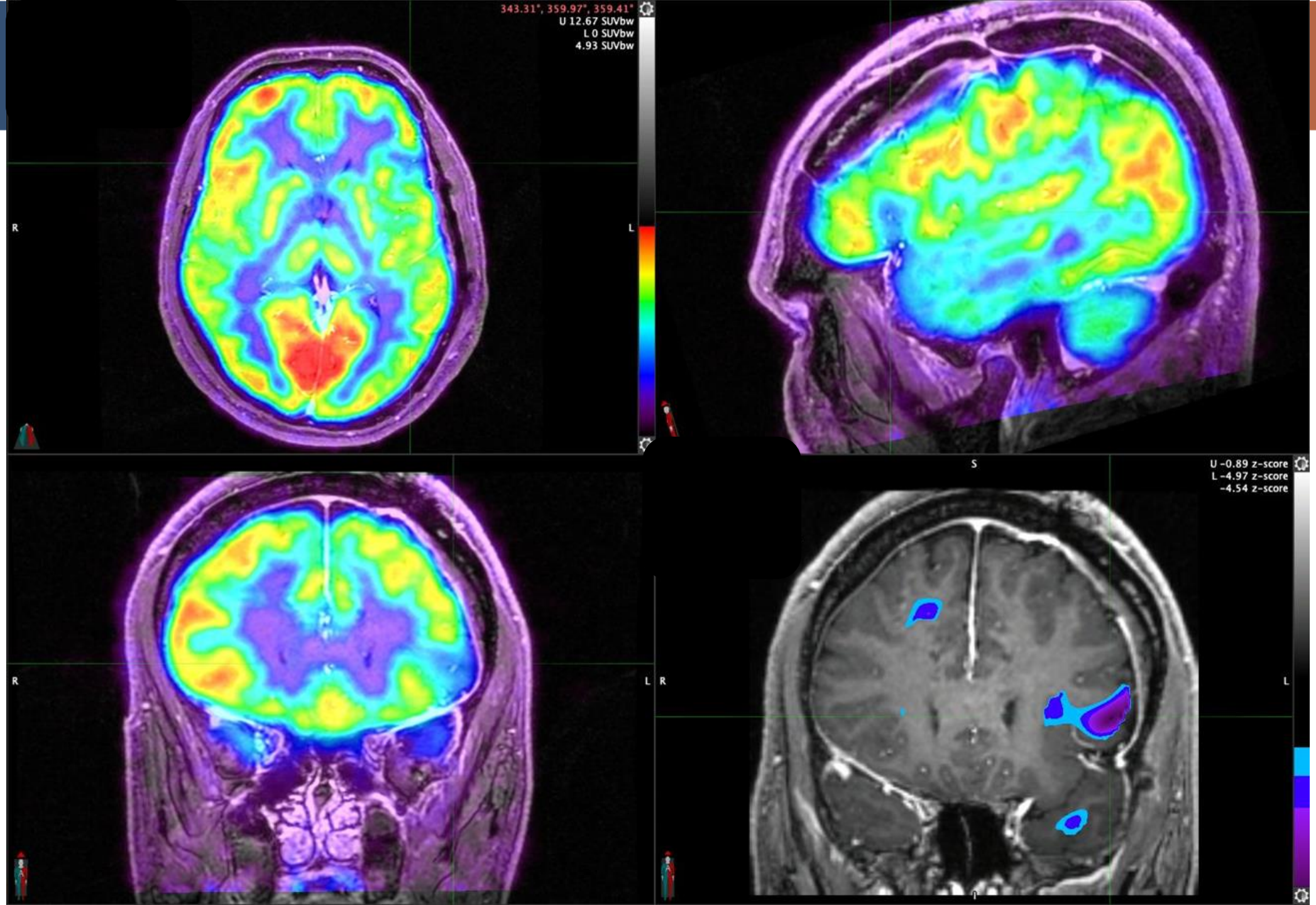
PET: left mesial/anterior temporal lobe hypometabolism

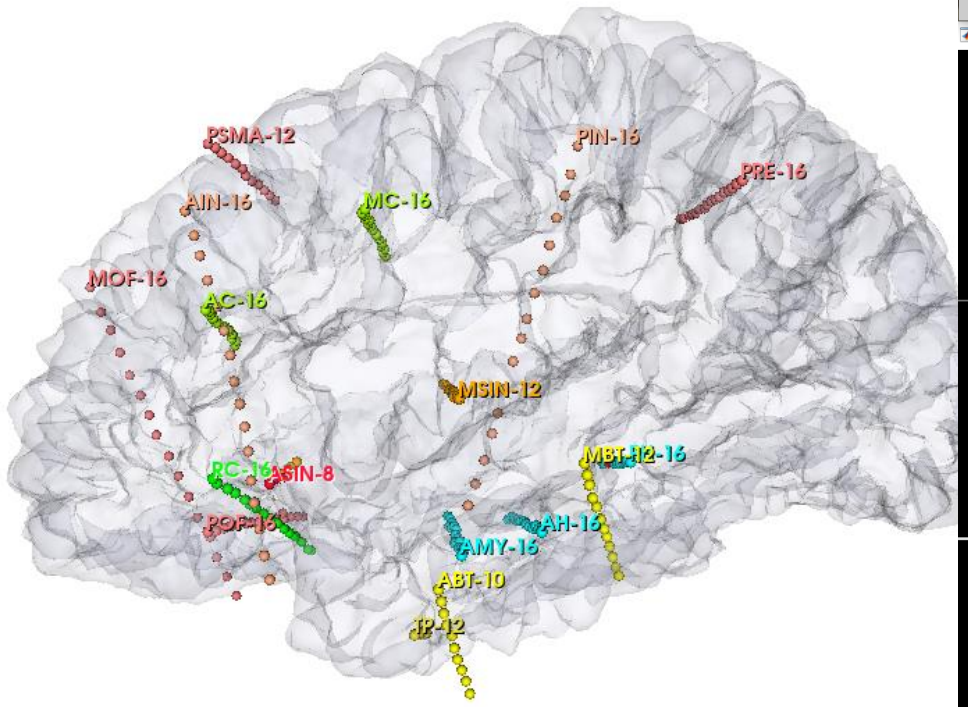
MEG: left temporal spike cluster

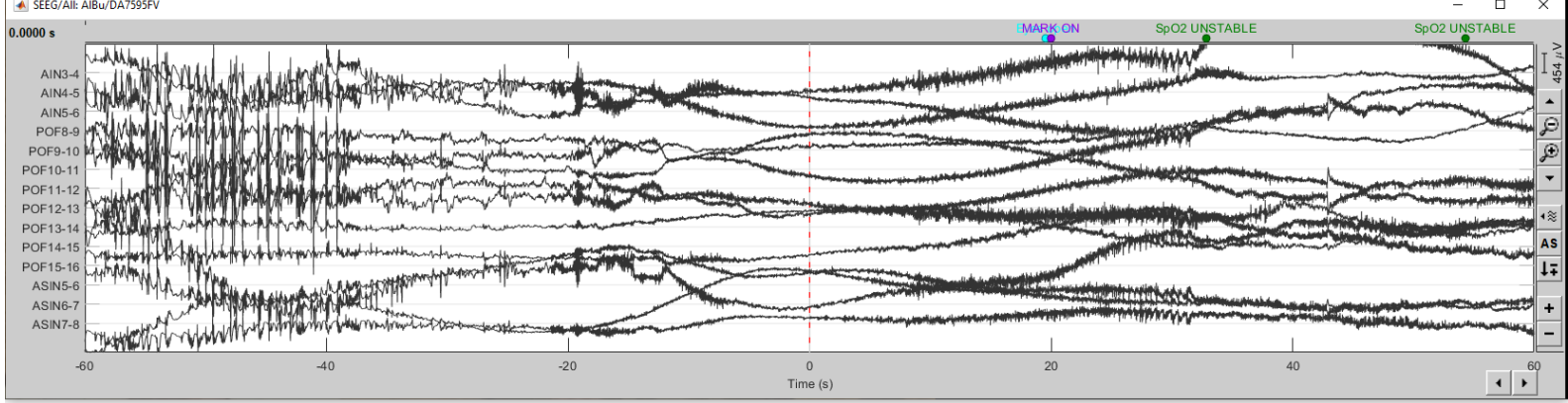

MEG MAG/All: AlBu/0522_Spont_R1_raw_tsss/spike (#3)
0.000 s
MEG 0223
MEG 0222
MEG 0212
MEG 0213
MEG 0133
MEG 0132
MEG 0113
MEG 0112
MEG 0233
MEG 0232
MEG 0243
MEG 0242
MEG 1512
MEG 1513
MEG 0143
MEG 0142
MEG 1623
MEG 1622
MEG 1613
MEG 1612
MEG 1623
MEG 1622
MEG 1543
MEG 1542
MEG 1533
MEG 1532
MEG 0224
MEG 0221
MEG 0223
MEG 0222
MEG 0213
MEG 0212
MEG 0241
MEG 0243
MEG 0242
MEG 1512
MEG 1513
MEG 1521
MEG 1522
MEG 1531
AS
-5
0
5
Time (s)
MEG/MriViewer: AlBu/0522_Spont_R1_raw_tsss/spike (#3)/sLORETA: MEG ALL(Unconstr) 2018 (Desikan-Killiany)
Coronal: y=178
Sagittal: x=109 Lateral orbitofrontal L | val...
L
R
P
A
3
2
1
0
10-9
Axial: z=118
L
R
Display options
MIP: Anatomy
Crosshairs
Neurological
MIP: Functional
Controls
Radiological
Coordinates (millimeters)
MRI: x: 109.00 y: 178.00 z: 118.00
SCS: x: 56.42 y: 17.28 z: 26.47
World: x: -22.58 y: 69.01 z: 2.33
MNI-maff8: x: -17.43 y: 36.98 z: -20.62

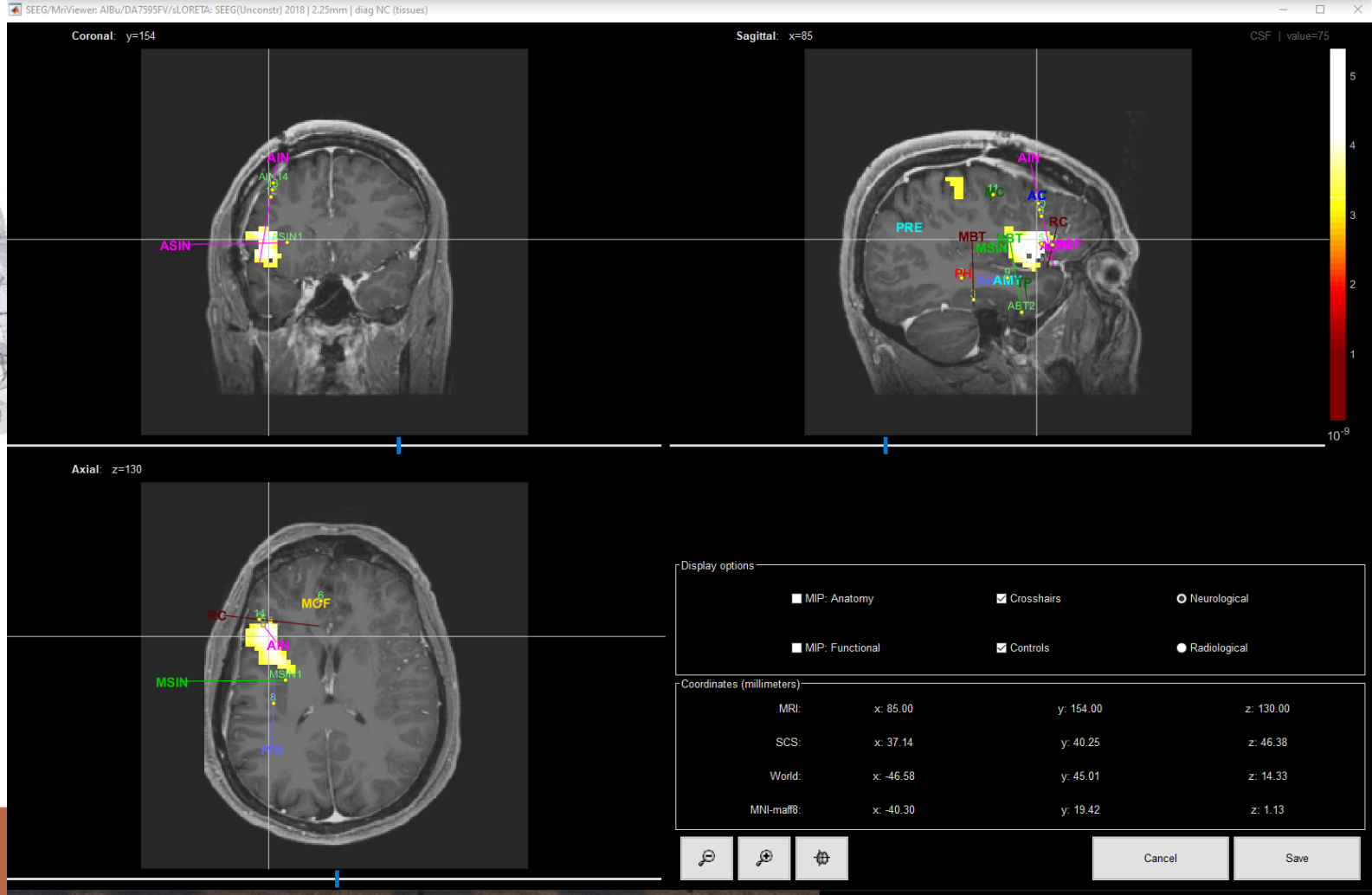

0.159 s
MEG 0223
MEG 1531
AS
-1
-0.5
0
0.5
1
Time (s)


Coronal: y=184
Sagittal: x=79
Pars orbitalis L | value=55
4
3
2
1
0
10-9
Axial: z=130
Display options
MIP: Anatomy
Crosshairs
Neurological
MIP: Functional
Controls
Radiological
Coordinates (millimeters)
MRI: x: 79.00 y: 184.00 z: 130.00
SCS: x: 65.38 y: 47.14 z: 36.85
World: x: -52.58 y: 75.01 z: 14.33
MNI-maff8: x: -46.83 y: 46.29 z: -9.64


343.31°, 359.97°, 359.41°
U 12.67 SUVbw
L 0 SUVbw
4.93 SUVbw
R
L
S
U -0.89 z-score
L -4.97 z-score
-4.54 z-score
R
L
R
L


PSMA-12
PIN-16
PRE-16
AIN-16
MC-16
MOF-16
AC-16
MSIN-12
MBT-12-16
RC-16
ASIN-8
POF-16
AH-16
AMY-16
ABT-10
IP-12


SEEG/All: AIBu/DA7595FV
0.0000 s
MARK ON
SpO2 UNSTABLE
SpO2 UNSTABLE
AIN3-4
AIN4-5
AIN5-6
POF8-9
POF9-10
POF10-11
POF11-12
POF12-13
POF13-14
POF14-15
POF15-16
ASIN5-6
ASIN6-7
ASIN7-8
454 µV
AS
-60
-40
-20
0
20
40
60
Time (s)


SEEG/MriViewer: AIBu/DA7595FV/sLORETA: SEEG(Unconstr) 2018 | 2.25mm | diag NC (tissues)
Coronal: y=154
Sagittal: x=85
CSF | value=75
Axial: z=130
AIN
ASIN
MSIN
PRE
MBT
RC
MOF
AMYP
PH
Display options
MIP: Anatomy
Crosshairs
Neurological
MIP: Functional
Controls
Radiological
Coordinates (millimeters)
MRI: x: 85.00 y: 154.00 z: 130.00
SCS: x: 37.14 y: 40.25 z: 46.38
World: x: -46.58 y: 45.01 z: 14.33
MNI-maff8: x: -40.30 y: 19.42 z: 1.13
Cancel
Save

Future Directions

Statistical Parameters to Validate the Reliability of Modeling Result

- Confidence Volume Ellipsoids
- Taking into account density of SEEG sampling

Automated Processing

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Health Science Center at Houston

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