Comparative and Combined MEG-EEG Source Modeling in Epilepsy Evaluations

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Background 1

Localization of the epileptogenic focus is the critical and rate-limiting step in an evaluation for epilepsy surgery.

A variety of non-invasive localization techniques are currently available – MRI, PET, SPECT, fMRI, MEG, EEG

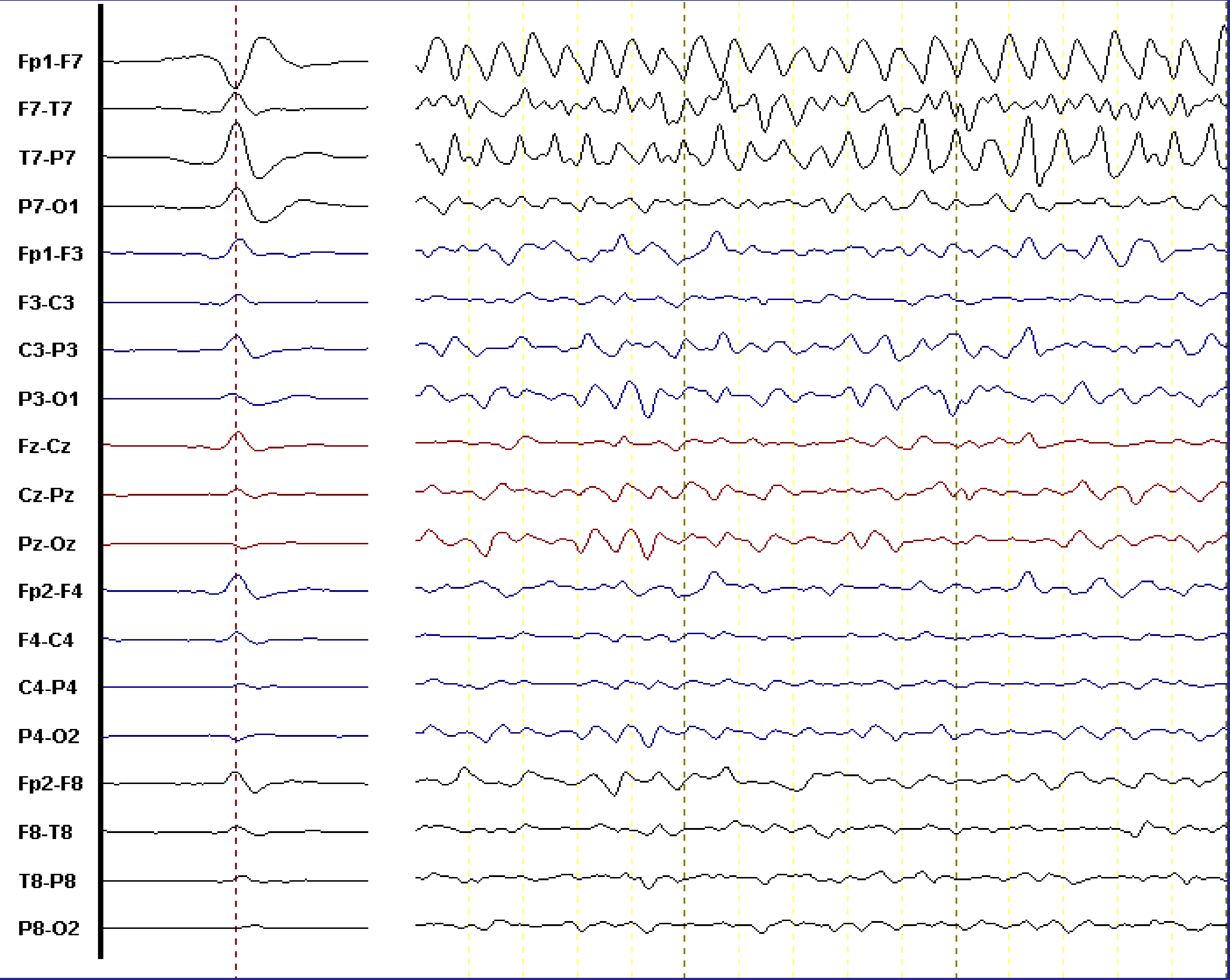
Background 2

Only EEG and MEG are:

- Direct measures of epileptic pathophysiology
- Performed in real time with msec resolution
- Provide temporal sequencing of activity, e.g. propagation

EEG Background

- EEG has an 80 year history and carries substantial “baggage”
- EEG evolved primarily as a pattern recognition technique; localization was secondary
- Traditional localization based on simplistic assumptions and techniques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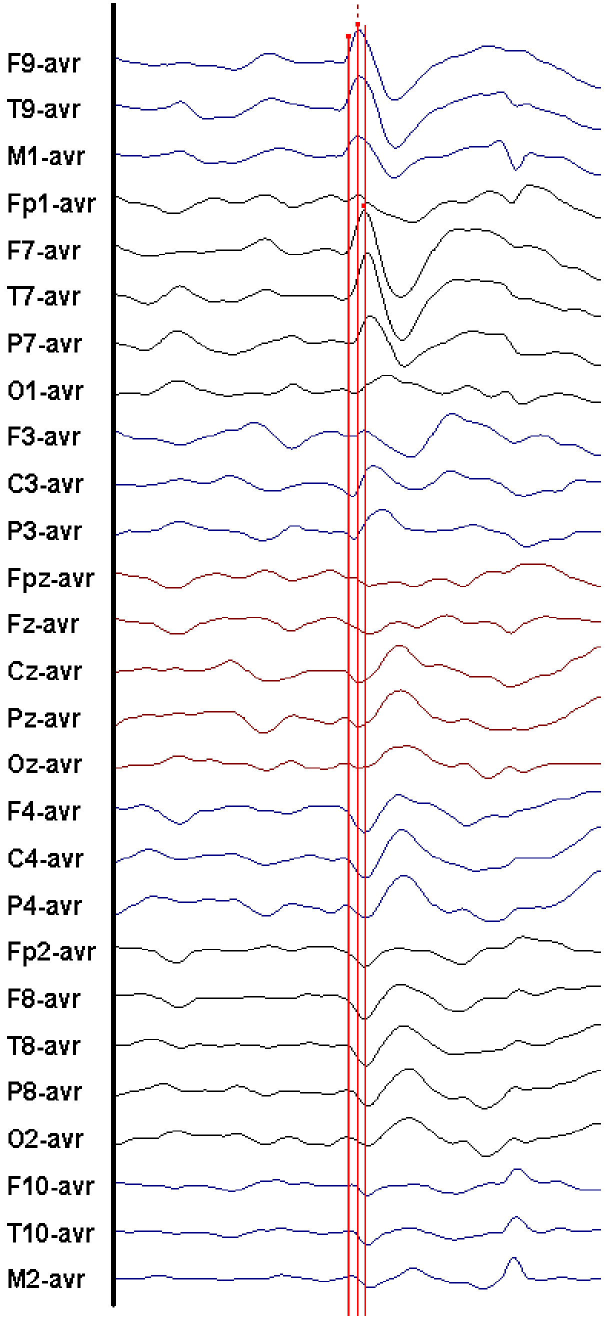
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Pz-Oz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2


F9-avr
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Fp1-avr
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C3-avr
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Fpz-avr
Fz-avr
Cz-avr
Pz-avr
Oz-avr
F4-avr
C4-avr
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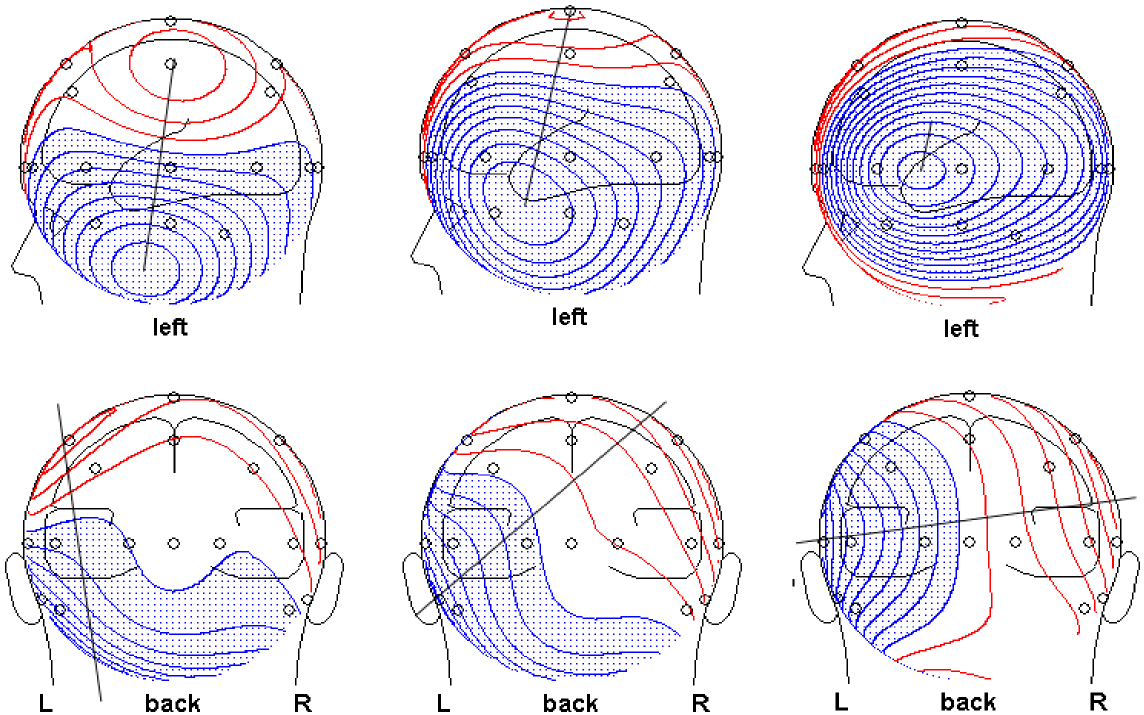
F10-avr
T10-avr
M2-avr


left
left
left
L
back
R
L
back
R
L
back
R

MEG Background

- MEG has evolved with little “baggage”
- Pattern recognition was secondary, localization was primary
- Localization from outset based on spatio-temporal analysis of magnetic fields using source models, such as dipoles
- From outset head/brain anatomy incorporated for both head models and results display

“In order to model a spike/seizure source properly, you must understand the character of the source and the strengths/weaknesses of your model”

Fact: Spike/seizure sources are large and spatio-temporally complex

EEG/MEG source models have complementary strengths

MEG/EEG Complements

Volume conductor effects - + MEG

Spatial sampling - + MEG

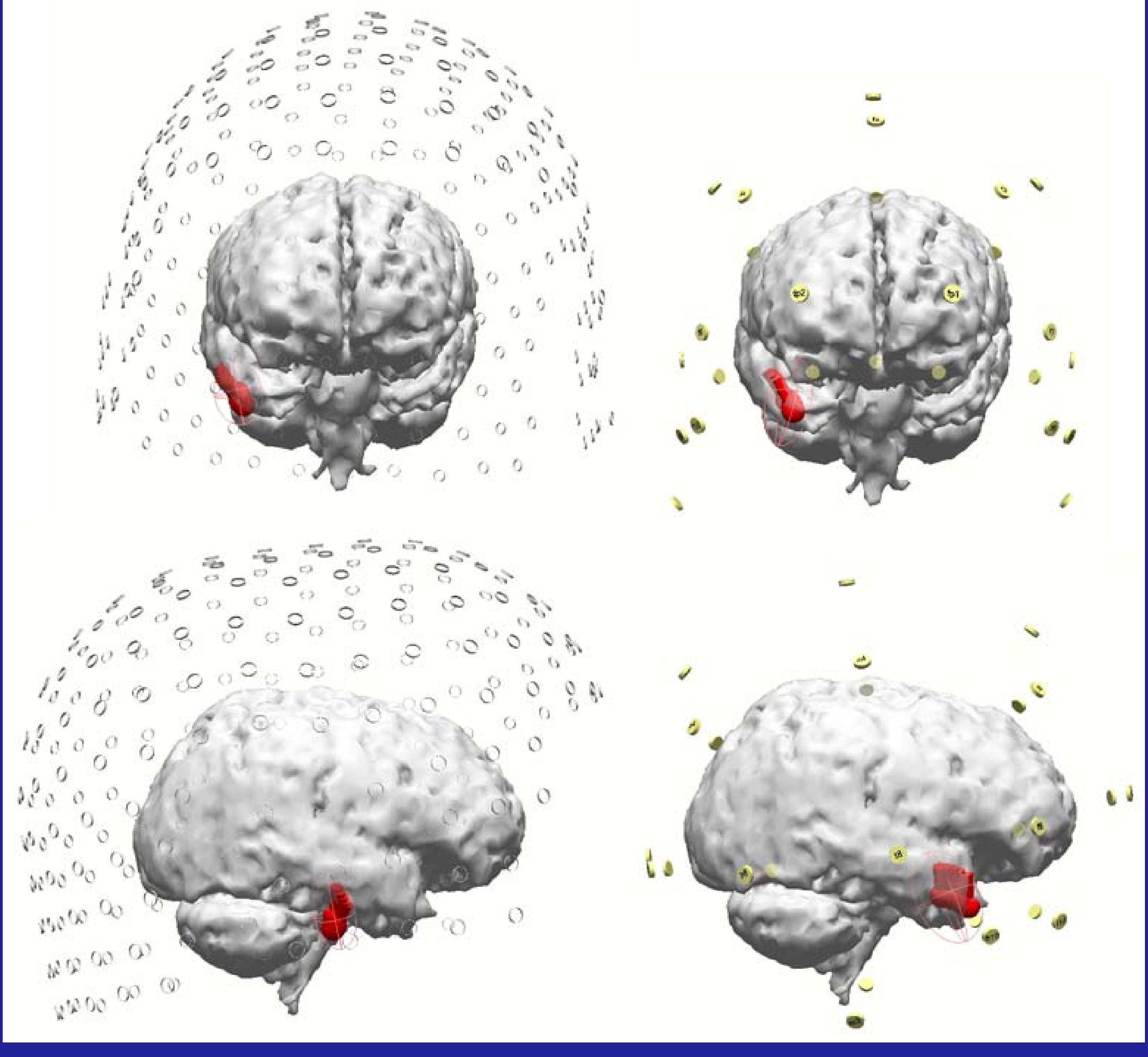
Temporal sampling - + EEG

Source area - + MEG

Radial sensitivity - + EEG

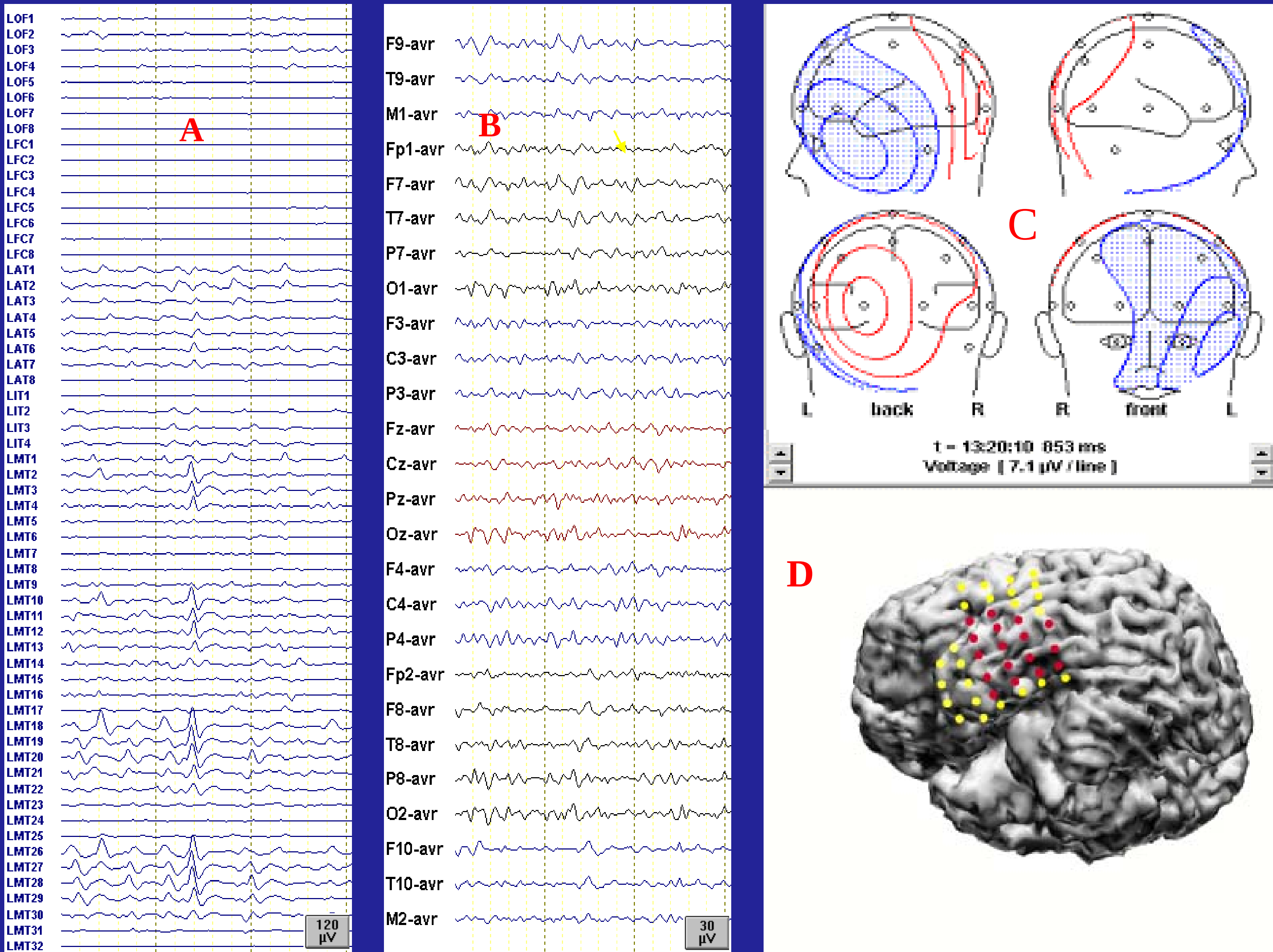
Tangential sensitivity - + MEG

Deep source sensitivity - + EEG



EEG Sensitivity

- EEG requires >10 sq cm
- EEG visualizes gyral and fissural sources, but not sulcal sources
- EEG source brain is lissencephalic
- EEG dipoles are deep to source cortex
- For large sources, EEG favors center of activity
- Sensitive to all source orientations, but radial more so than tangential


A
LOF1
LOF2
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LOF4
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LFC1
LFC2
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LFC5
LFC6
LFC7
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LAT1
LAT2
LAT3
LAT4
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LAT6
LAT7
LAT8
LIT1
LIT2
LIT3
LIT4
LMT1
LMT2
LMT3
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LMT6
LMT7
LMT8
LMT9
LMT10
LMT11
LMT12
LMT13
LMT14
LMT15
LMT16
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LMT18
LMT19
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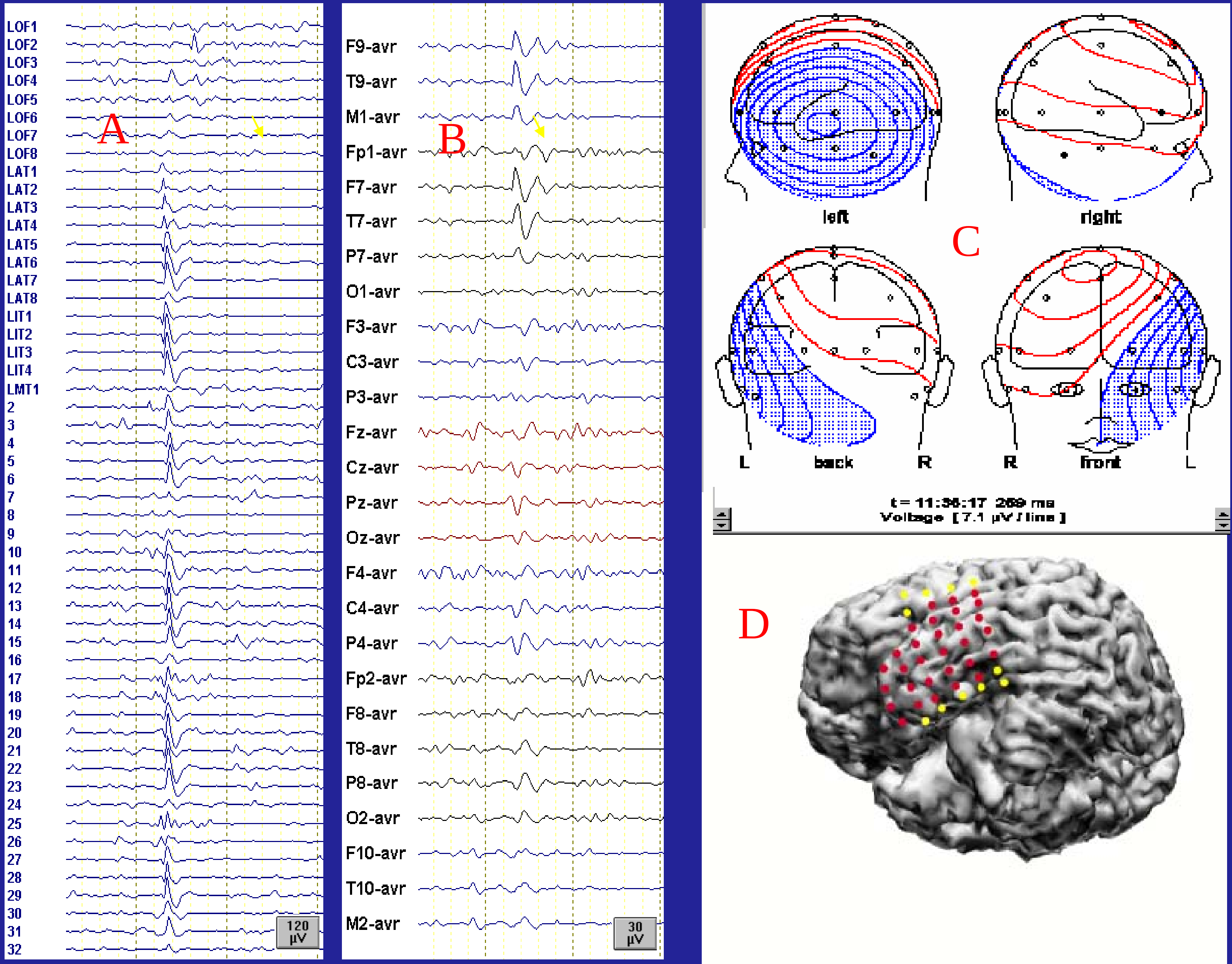
LMT21
LMT22
LMT23
LMT24
LMT25
LMT26
LMT27
LMT28
LMT29
LMT30
LMT31
LMT32
120 µV
B
F9-avr
T9-avr
M1-avr
Fp1-avr
F7-avr
T7-avr
P7-avr
O1-avr
F3-avr
C3-avr
P3-avr
Fz-avr
Cz-avr
Pz-avr
Oz-avr
F4-avr
C4-avr
P4-avr
Fp2-avr
F8-avr
T8-avr
P8-avr
O2-avr
F10-avr
T10-avr
M2-avr
30 µV
C
L
back
R
R
front
L
t = 13:20:10 853 ms
Voltage [7.1 µV / line]
D


A
LOF1
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LOF4
LOF5
LOF6
LOF7
LOF8
LAT1
LAT2
LAT3
LAT4
LAT5
LAT6
LAT7
LAT8
LIT1
LIT2
LIT3
LIT4
LMT1
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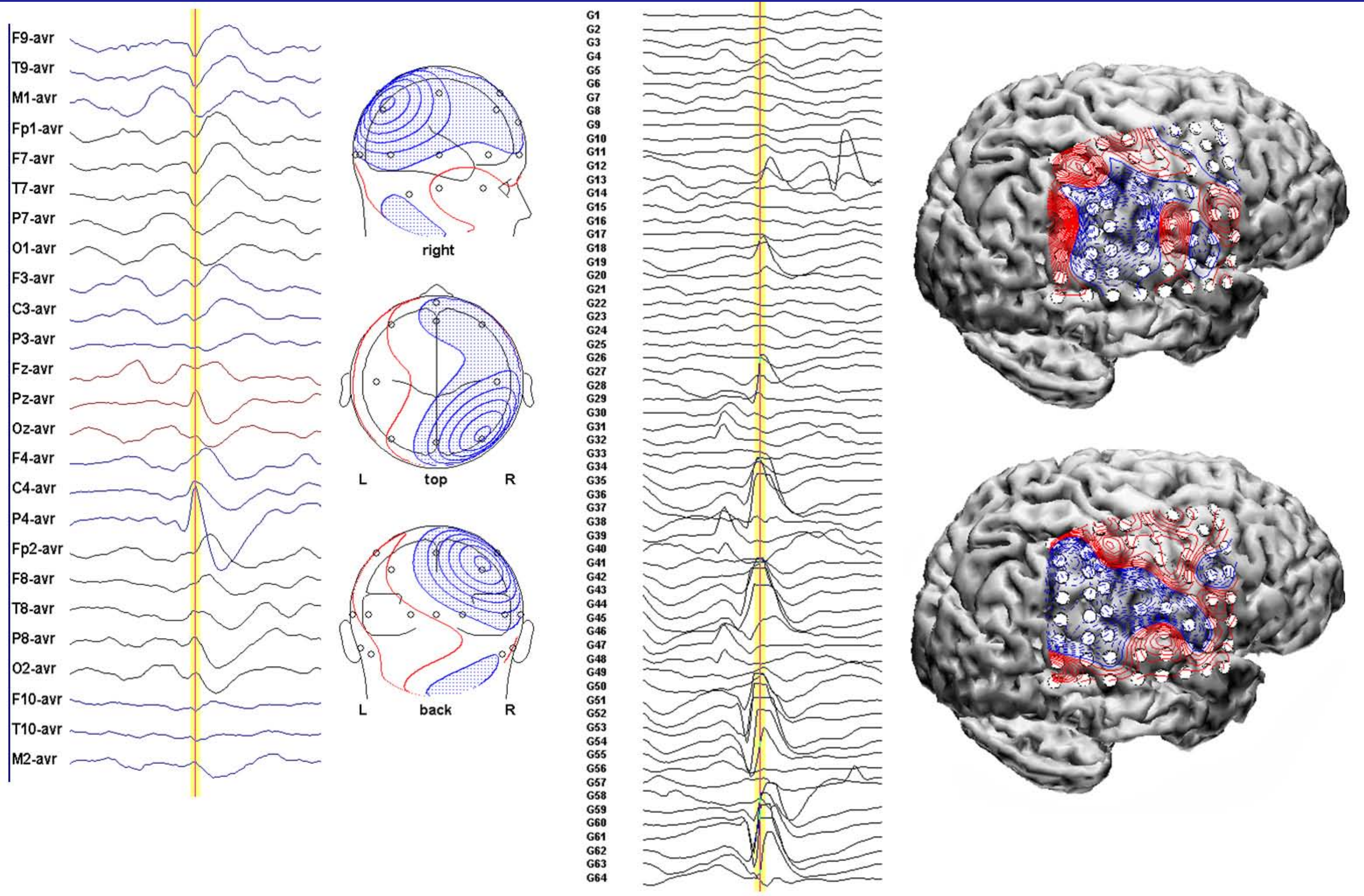
28
29
30
31
32
120 µV
B
F9-avr
T9-avr
M1-avr
Fp1-avr
F7-avr
T7-avr
P7-avr
O1-avr
F3-avr
C3-avr
P3-avr
Fz-avr
Cz-avr
Pz-avr
Oz-avr
F4-avr
C4-avr
P4-avr
Fp2-avr
F8-avr
T8-avr
P8-avr
O2-avr
F10-avr
T10-avr
M2-avr
30 µV
C
left
right
L
back
R
R
front
L
t = 11:36:17 269 ms
Voltage [7.1 µV / line]
D



F9-avr
T9-avr
M1-avr
Fp1-avr
F7-avr
T7-avr
P7-avr
O1-avr
F3-avr
C3-avr
P3-avr
Fz-avr
Pz-avr
Oz-avr
F4-avr
C4-avr
P4-avr
Fp2-avr
F8-avr
T8-avr
P8-avr
O2-avr
F10-avr
T10-avr
M2-avr
right
L
top
R
L
back
R
G1
G2
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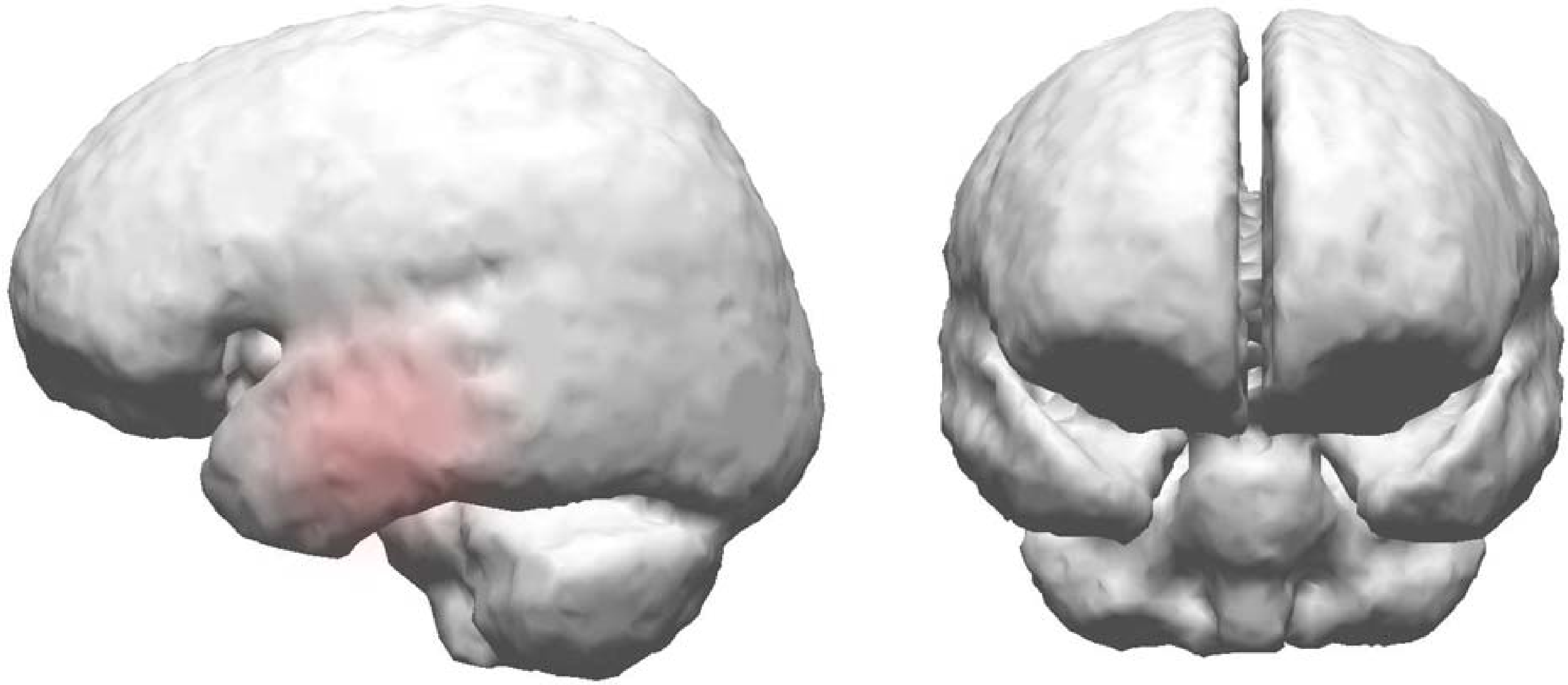
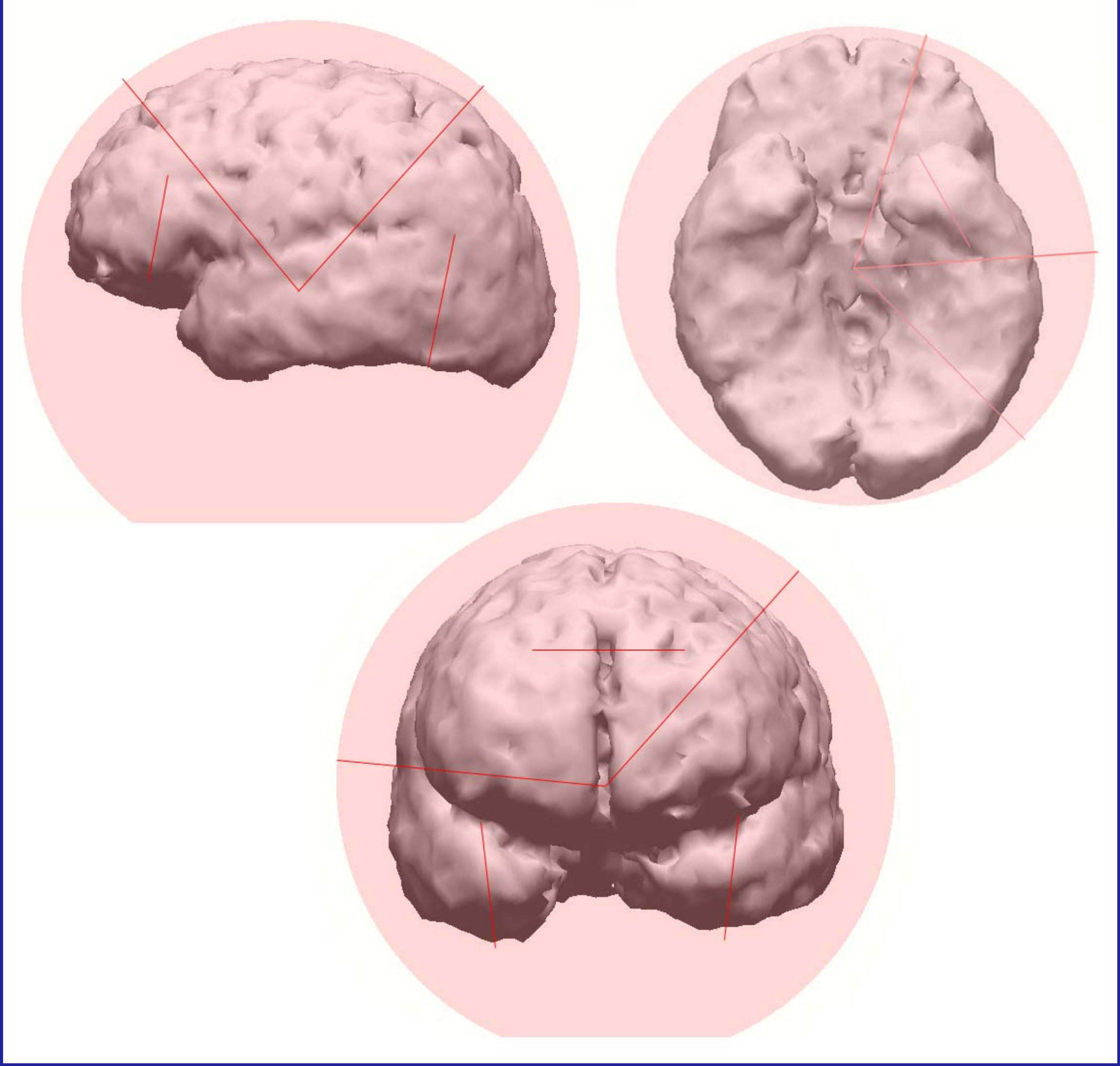




MEG Sensitivity

MEG requires 4-6 sq cm

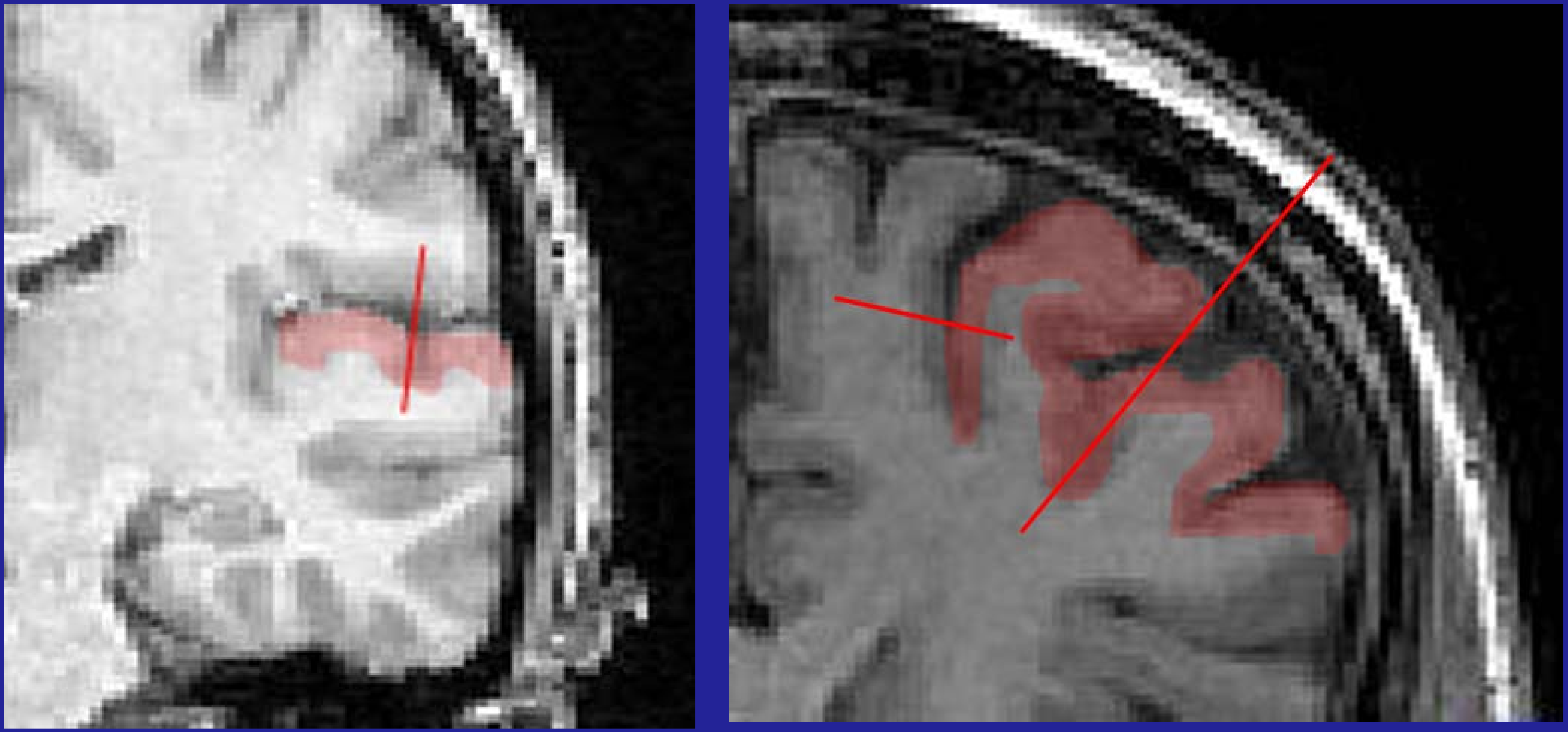
MEG visualizes large sulci, fissures, and tangential planes

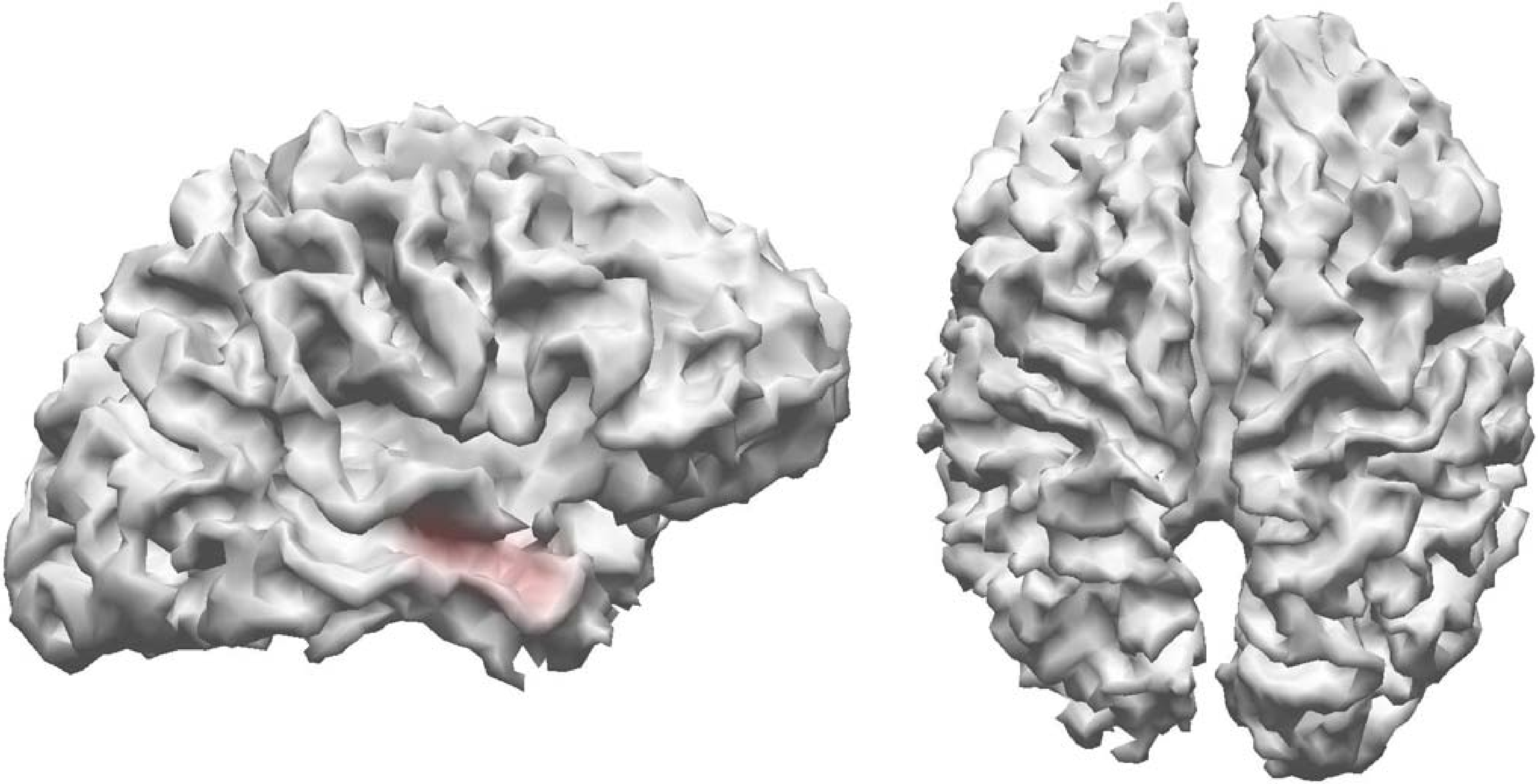
MEG source brain has eroded sulci

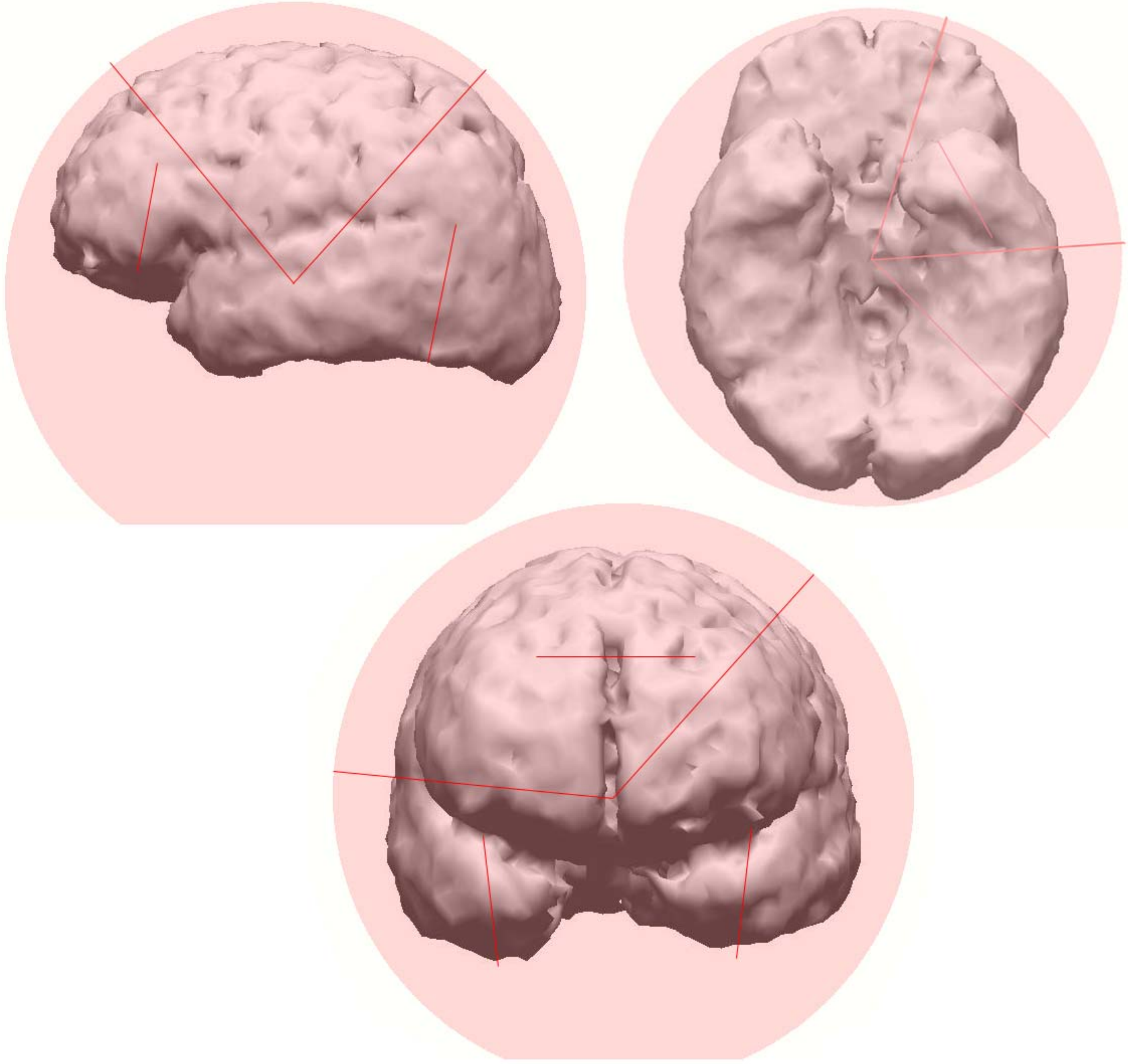
MEG dipoles more accurately reflect source depth

For large sources, MEG can favor an edge

Sensitive to a tangential source orientation







Source Reconstruction

3D reconstruction of cortical sources of EEG requires a biophysical model

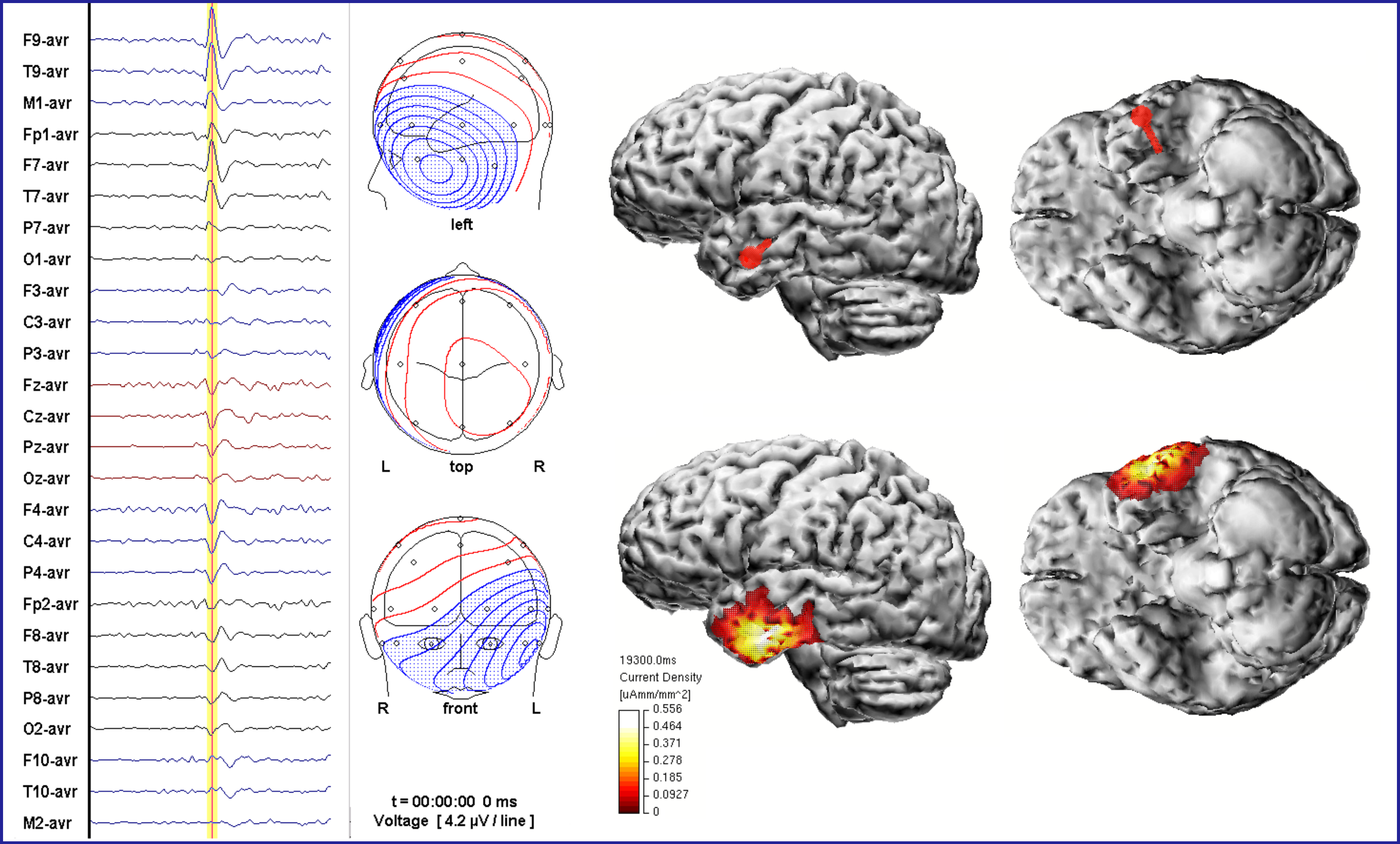
Multiple models:

Simple, point source – dipole

(unrealistic, easy to use and interpret)

Complex, extended source – current density

(pseudo-realistic, needs “thresholding”)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T9-avr
M1-avr
Fp1-avr
F7-avr
T7-avr
P7-avr
O1-avr
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C3-avr
P3-avr
Fz-avr
Cz-avr
Pz-avr
Oz-avr
F4-avr
C4-avr
P4-avr
Fp2-avr
F8-avr
T8-avr
P8-avr
O2-avr
F10-avr
T10-avr
M2-avr
left
L
top
R
R
front
L
t = 00:00:00 0 ms
Voltage [4.2 µV / line]
19300.0ms
Current Density
[uAmm/mm^2]
0.556
0.464
0.371
0.278
0.185
0.0927
0

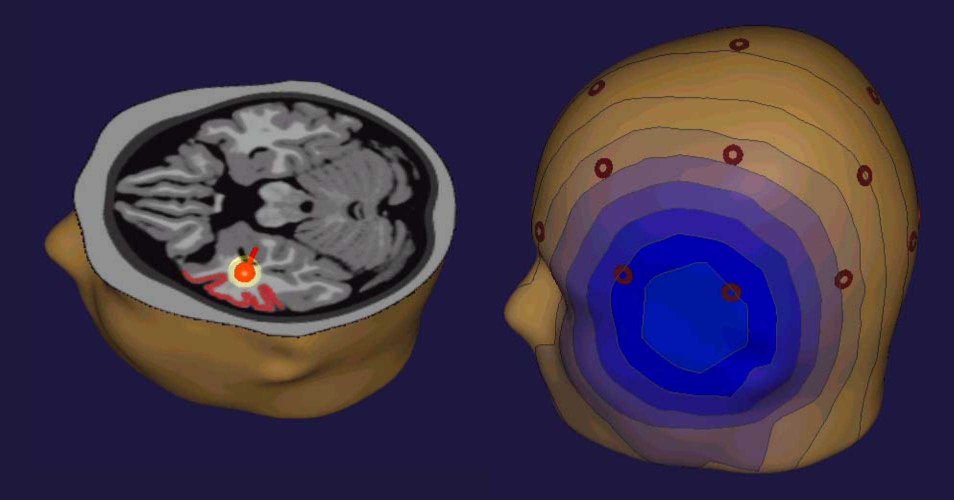
Models of Cerebral Sources

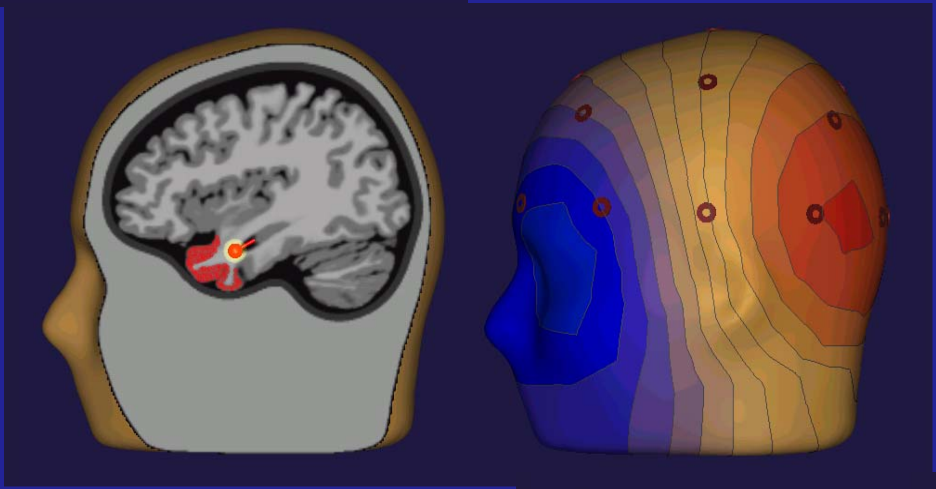
Equivalent Current Dipole

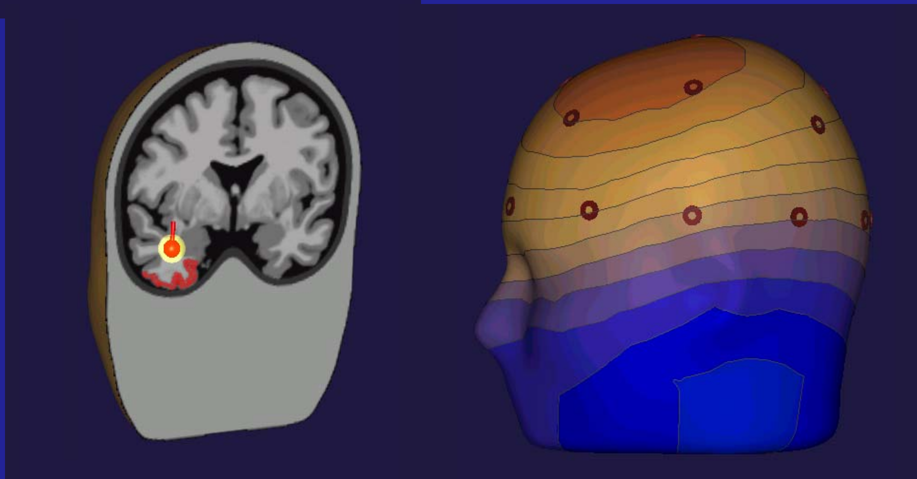
(aka Single or Moving Dipole) - the voltage or magnetic field at one moment is modeled by the best fitting single dipole

Each subsequent field measurement is modeled by another single dipole

Most commonly employed source model in clinical EEG and MEG

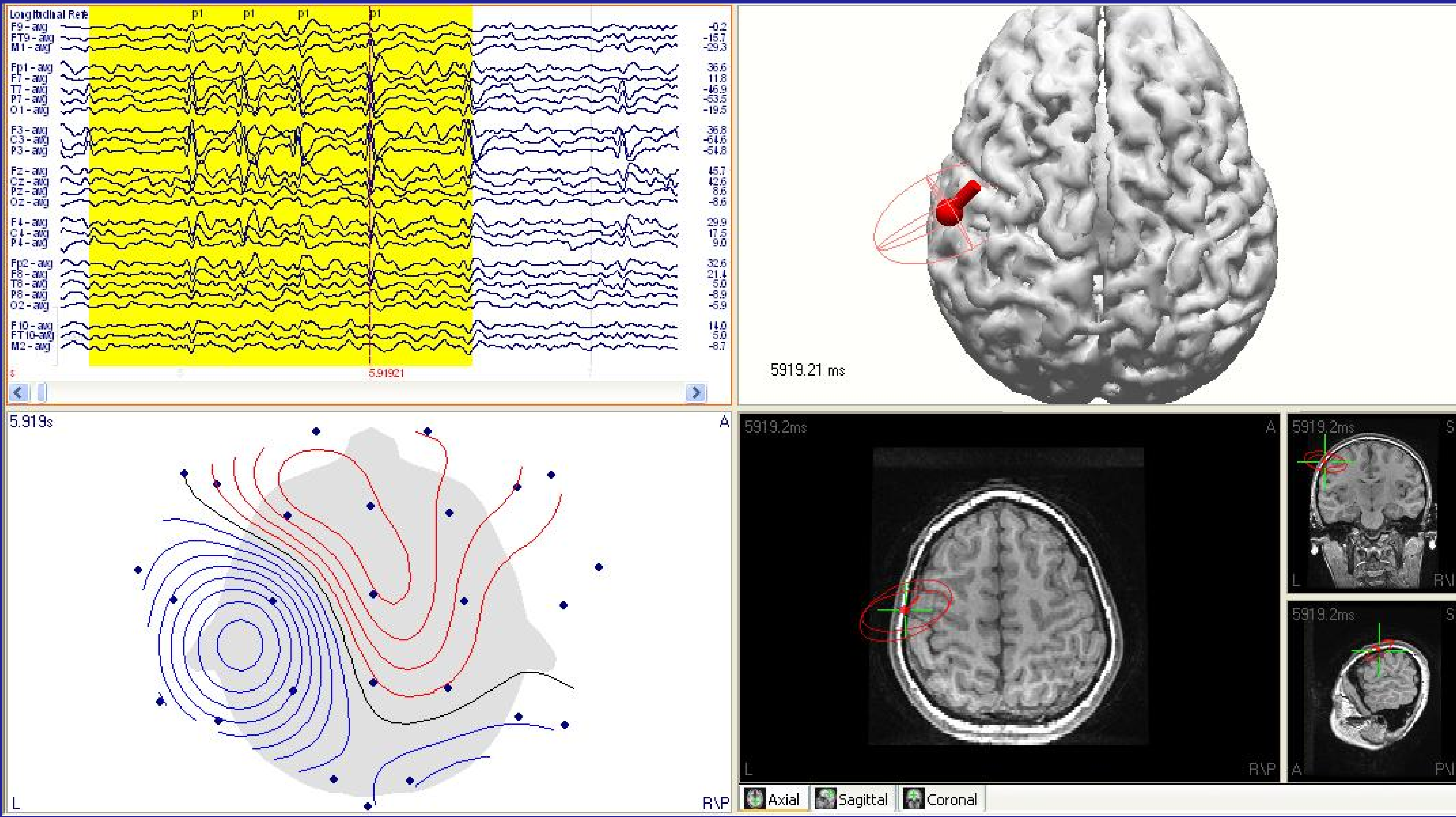




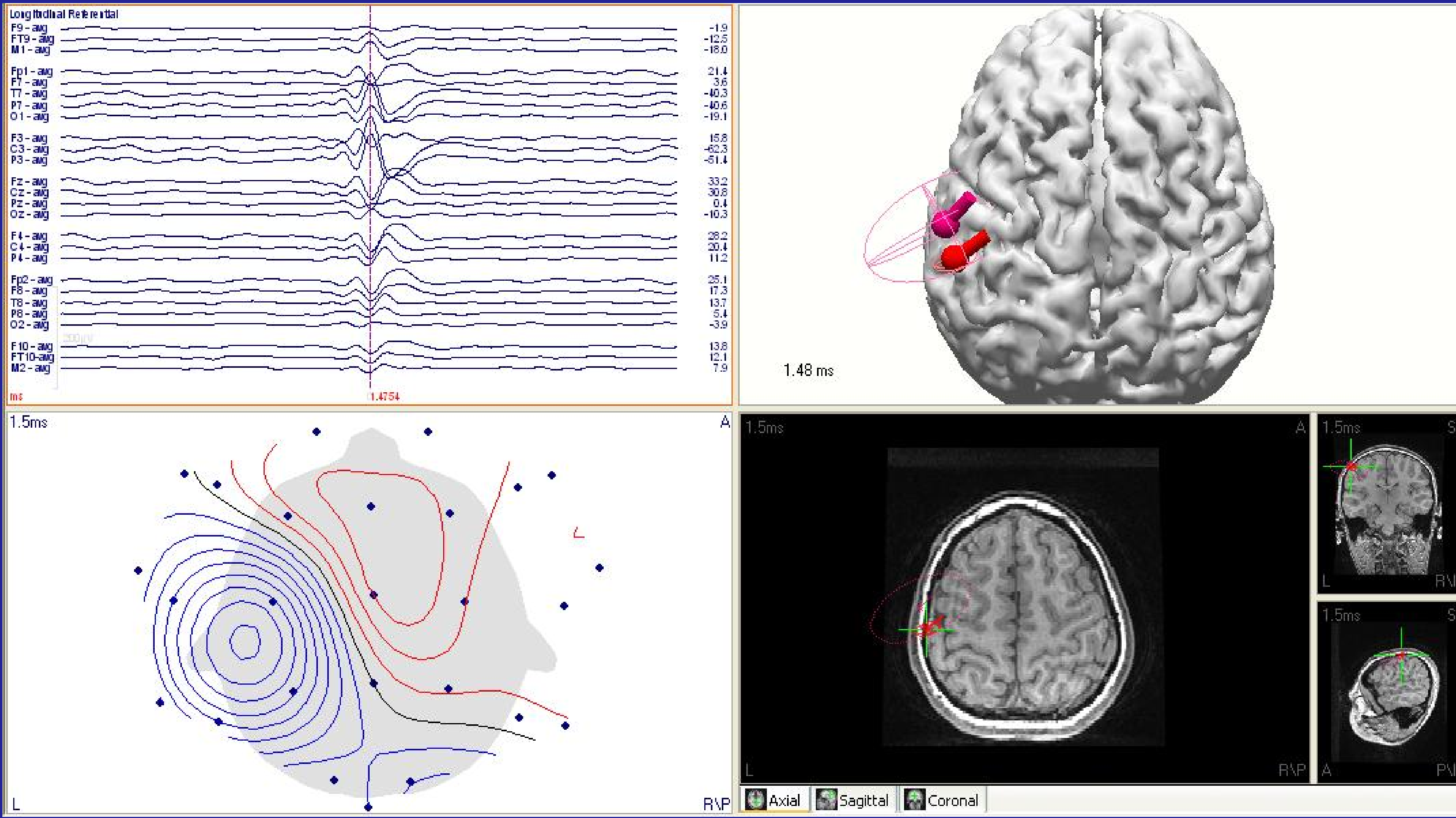


Dipole Interpretation Confidence

- Goodness of Fit
- Confidence Volume
  - Dependent upon goodness of fit, S/N, and number of electrodes/sensors
  - Ongoing background EEG/MEG is noise
  - Signal averaging improves S/N



Longitudinal Refs
p1
F9 - avg
FT9 - avg
M1 - avg
Fp1 - avg
F7 - avg
T7 - avg
P7 - avg
O1 - avg
F3 - avg
C3 - avg
P3 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
F4 - avg
C4 - avg
P4 - avg
Fp2 - avg
F8 - avg
T8 - avg
P8 - avg
O2 - avg
F10 - avg
FT10 - avg
M2 - avg
5.91921
5919.21 ms
5.919s
A
L
R\P
5919.2ms
S
R\I
P\I
Axial
Sagittal
Coronal


Longitudinal Referential
F9 - avg -1.9
FT9 - avg -12.5
M1 - avg -18.0
Fp1 - avg 21.4
F7 - avg 3.6
T7 - avg -40.3
P7 - avg -40.6
O1 - avg -19.1
F3 - avg 15.8
C3 - avg -62.3
P3 - avg -51.4
Fz - avg 33.2
Cz - avg 30.8
Pz - avg 0.4
Oz - avg -10.3
F4 - avg 28.2
C4 - avg 20.4
P4 - avg 11.2
Fp2 - avg 25.1
F8 - avg 17.3
T8 - avg 13.7
P8 - avg 5.4
O2 - avg -3.9
F10 - avg 13.8
FT10-avg 12.1
M2 - avg 7.9
ms
1.4754
1.48 ms
1.5ms
A
L
R\P
1.5ms
A
L
R\P
1.5ms
S
L
R\I
1.5ms
S
A
P\I
Axial
Sagittal
Coronal

MEG vs. EEG

- MEG and EEG source modeling are based on similar electro-magnetic principles
- Some still consider EEG modeling to be experimental, while MEG modeling is standard practice
- Despite complementary strengths, there are few systematic studies comparing the two

MEG vs. EEG

Most patients have both EEG spikes and MEG spikes

Their source models (dipoles) commonly differ by:

- Orientation
- Location
- Timing, lead or lag
- Confidence volume

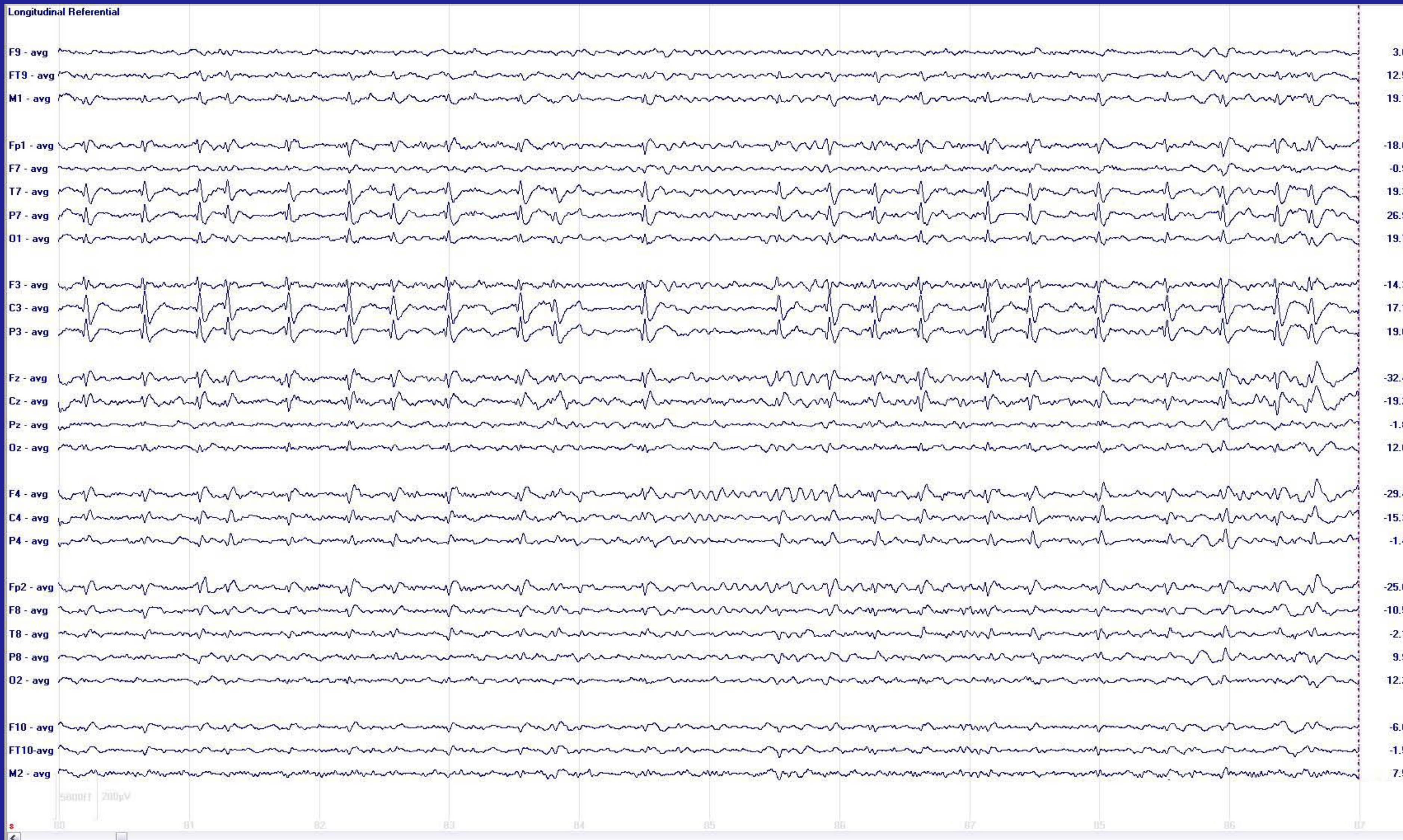
MEG vs. EEG Spike Dipole Models

Orientation – usually differ, unless EEG is pure tangential

Location – can differ by mm to cm, EEG commonly anterior

Timing – either can lead or lag

Confidence volume – MEG clusters tighter and volumes smaller


Longitudinal Referential
F9 - avg 3.6
FT9 - avg 12.5
M1 - avg 19.1
Fp1 - avg -18.6
F7 - avg -0.9
T7 - avg 19.3
P7 - avg 26.9
O1 - avg 19.7
F3 - avg -14.3
C3 - avg 17.1
P3 - avg 19.0
Fz - avg -32.4
Cz - avg -19.2
Pz - avg -1.8
Oz - avg 12.0
F4 - avg -29.4
C4 - avg -15.3
P4 - avg -1.4
Fp2 - avg -25.0
F8 - avg -10.5
T8 - avg -2.1
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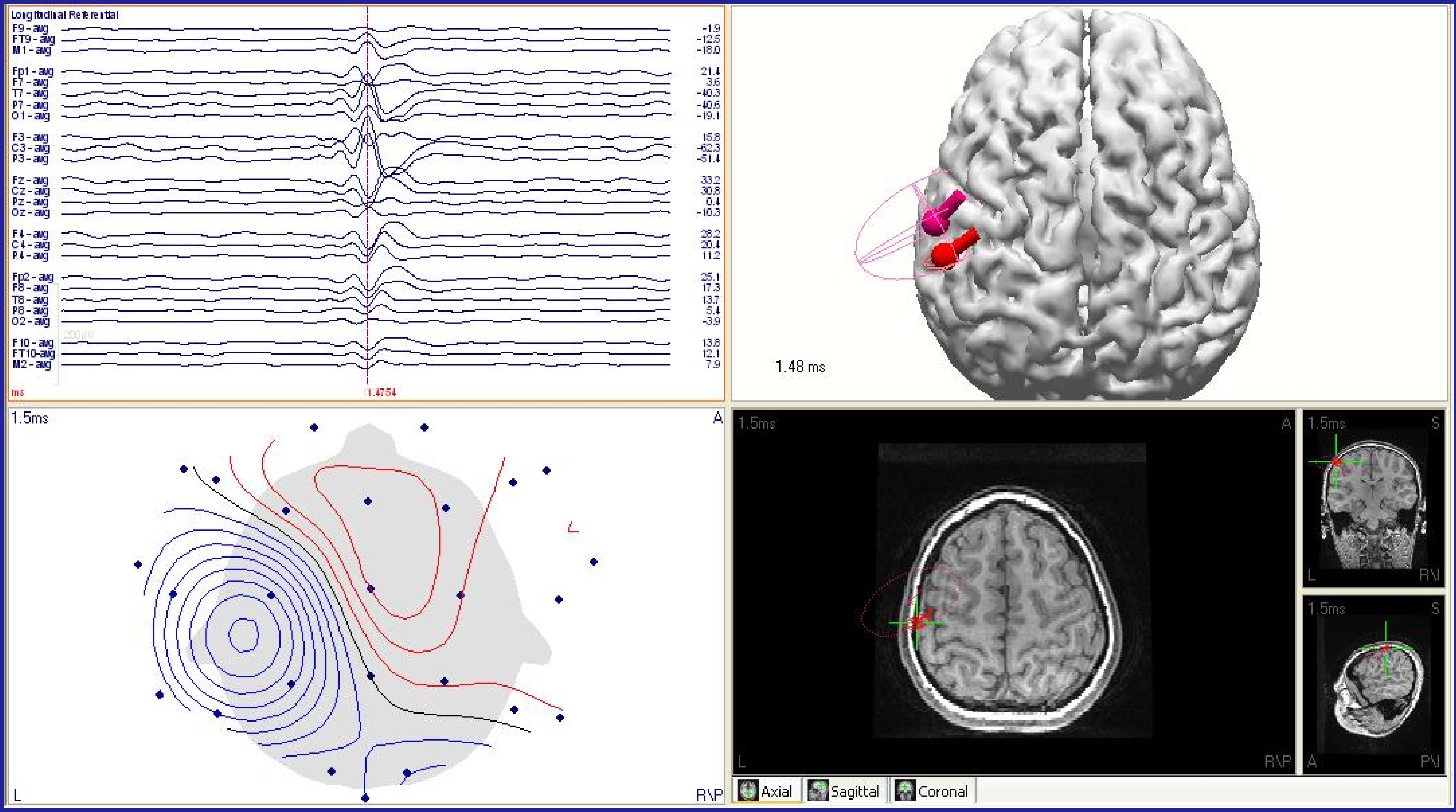
O2 - avg 12.2
F10 - avg -6.6
FT10-avg -1.5
M2 - avg 7.5



Longitudinal Referential
F9 - avg
FT9 - avg
M1 - avg
Fp1 - avg
F7 - avg
T7 - avg
P7 - avg
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F3 - avg
C3 - avg
P3 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
F4 - avg
C4 - avg
P4 - avg
Fp2 - avg
F8 - avg
T8 - avg
P8 - avg
O2 - avg
F10 - avg
FT10-avg
M2 - avg
-1.9
-12.5
-18.0
21.4
3.6
-40.3
-40.6
-19.1
15.8
-62.3
-51.4
33.2
30.8
0.4
-10.3
28.2
20.4
11.2
25.1
17.3
13.7
5.4
-3.9
13.8
12.1
7.9
ms
1.4754
1.48 ms
1.5ms
A
L
R\P
1.5ms
A
L
R\P
1.5ms
S
L
R\I
1.5ms
S
A
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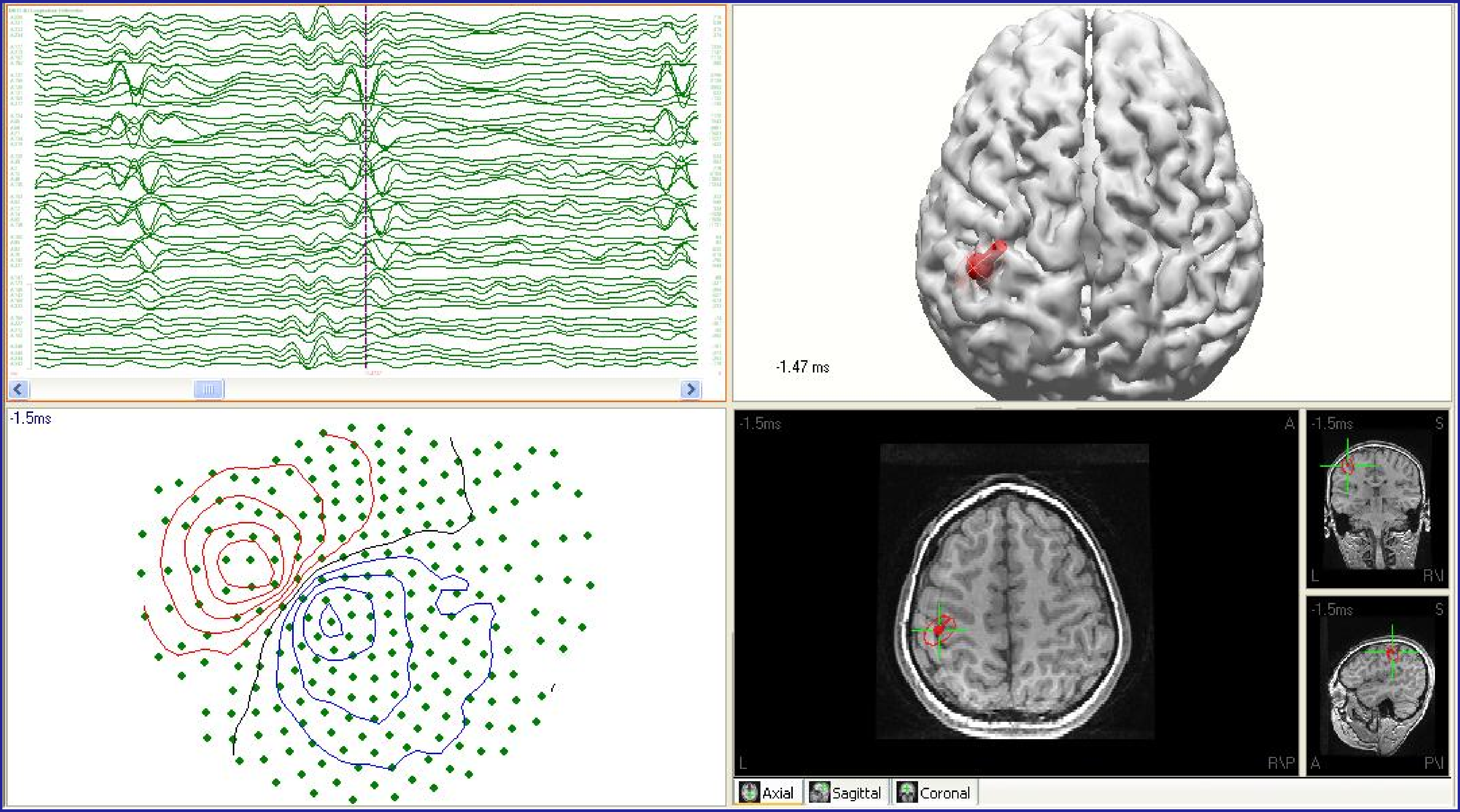
Axial
Sagittal
Coronal


-1.47 ms
-1.5ms
-1.5ms
A
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R\P
-1.5ms
S
L
R\I
-1.5ms
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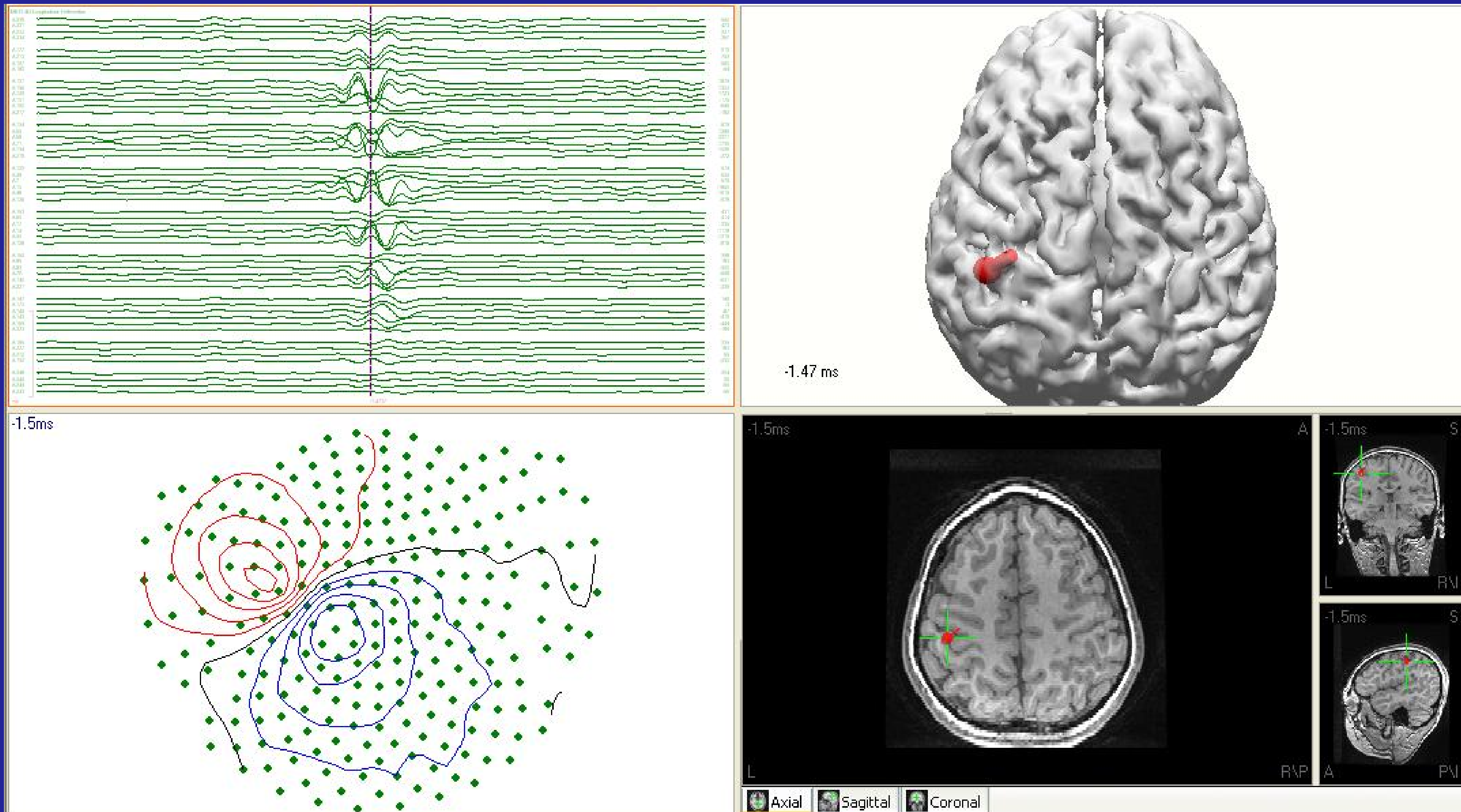
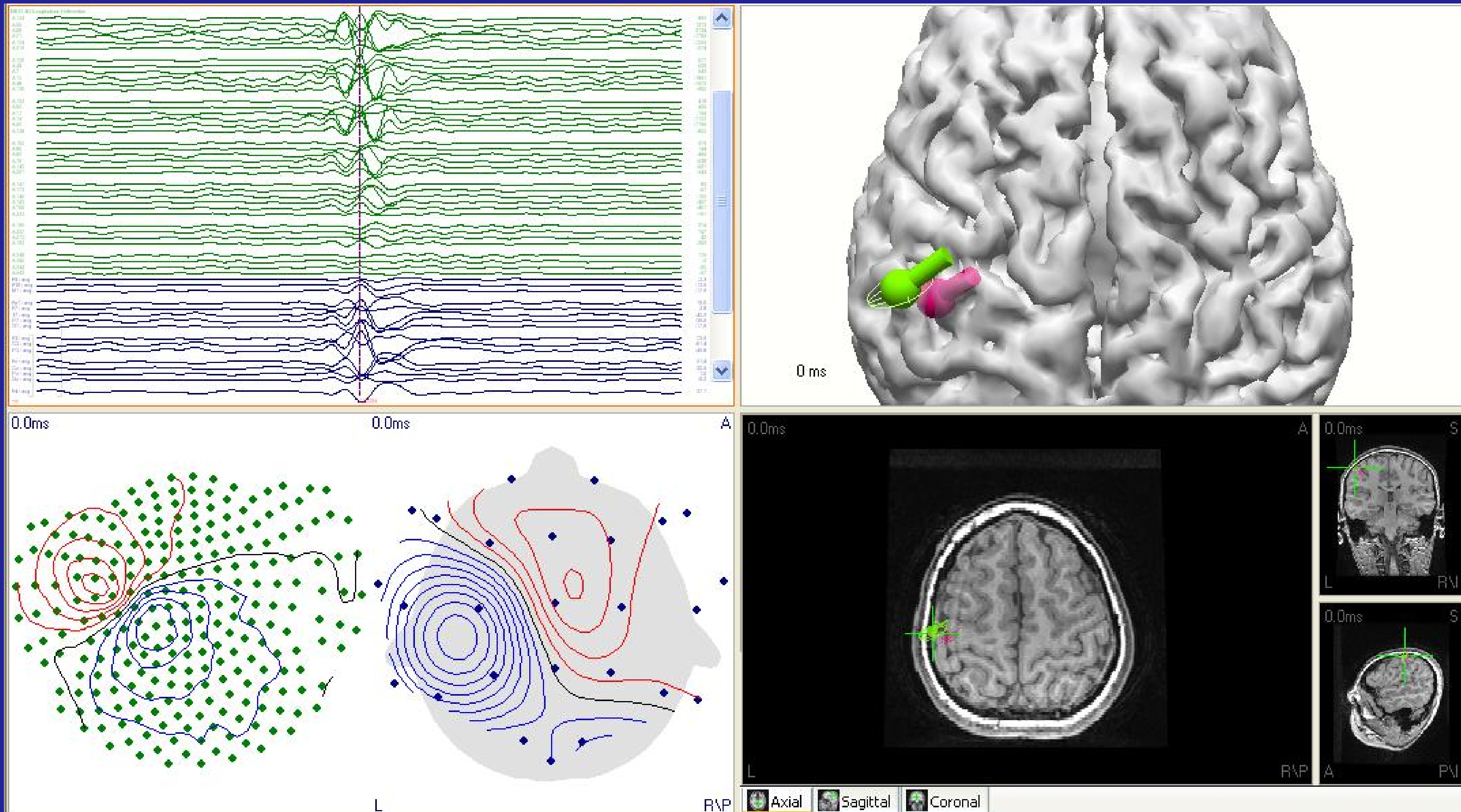
A
P\I
Axial
Sagittal
Coronal



-1.47 ms
-1.5ms
-1.5ms
A
L
R\P
-1.5ms
S
L
R\I
-1.5ms
S
A
P\I
Axial
Sagittal
Coronal


0 ms
0.0ms
0.0ms
A
L
R\P
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A
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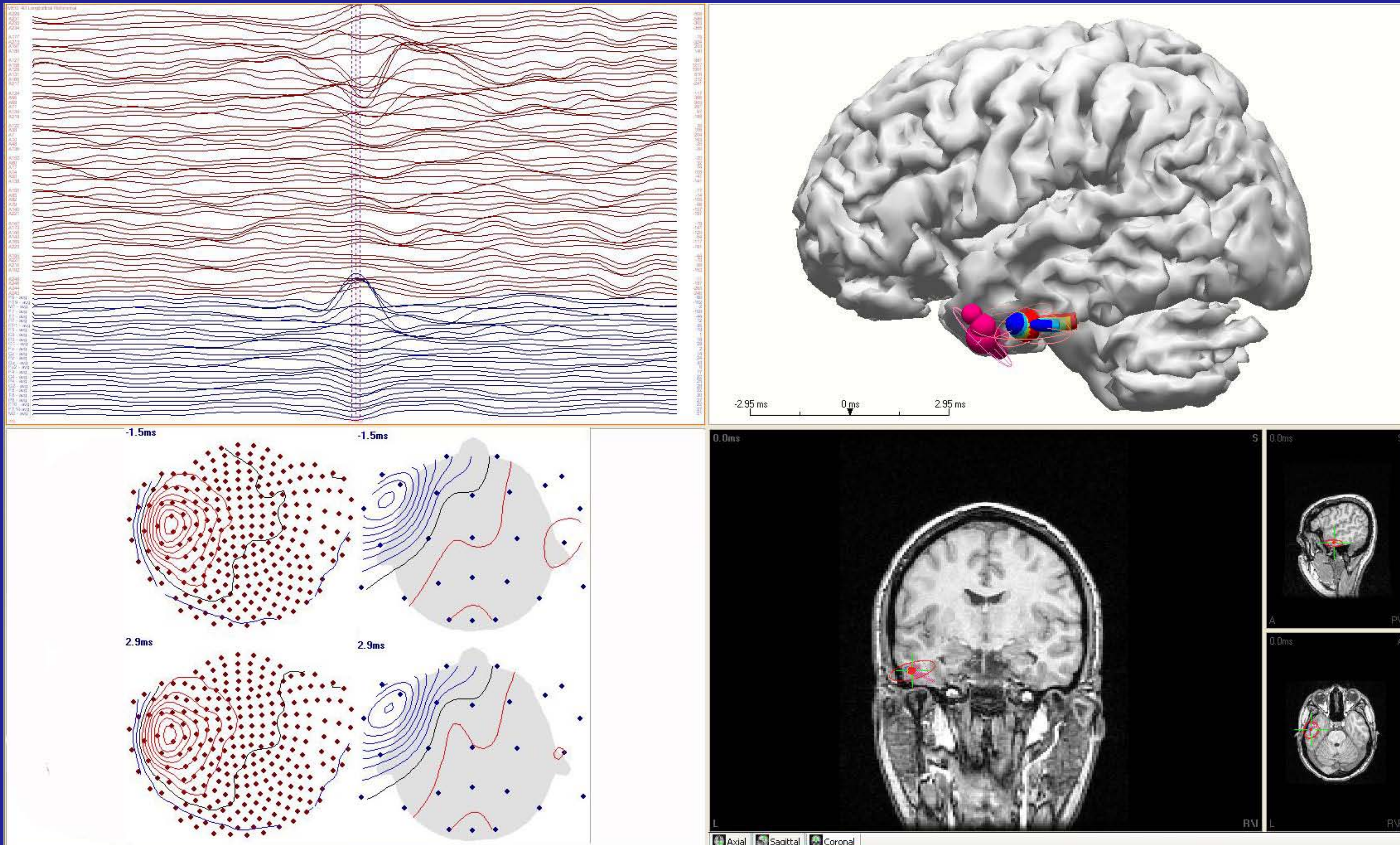
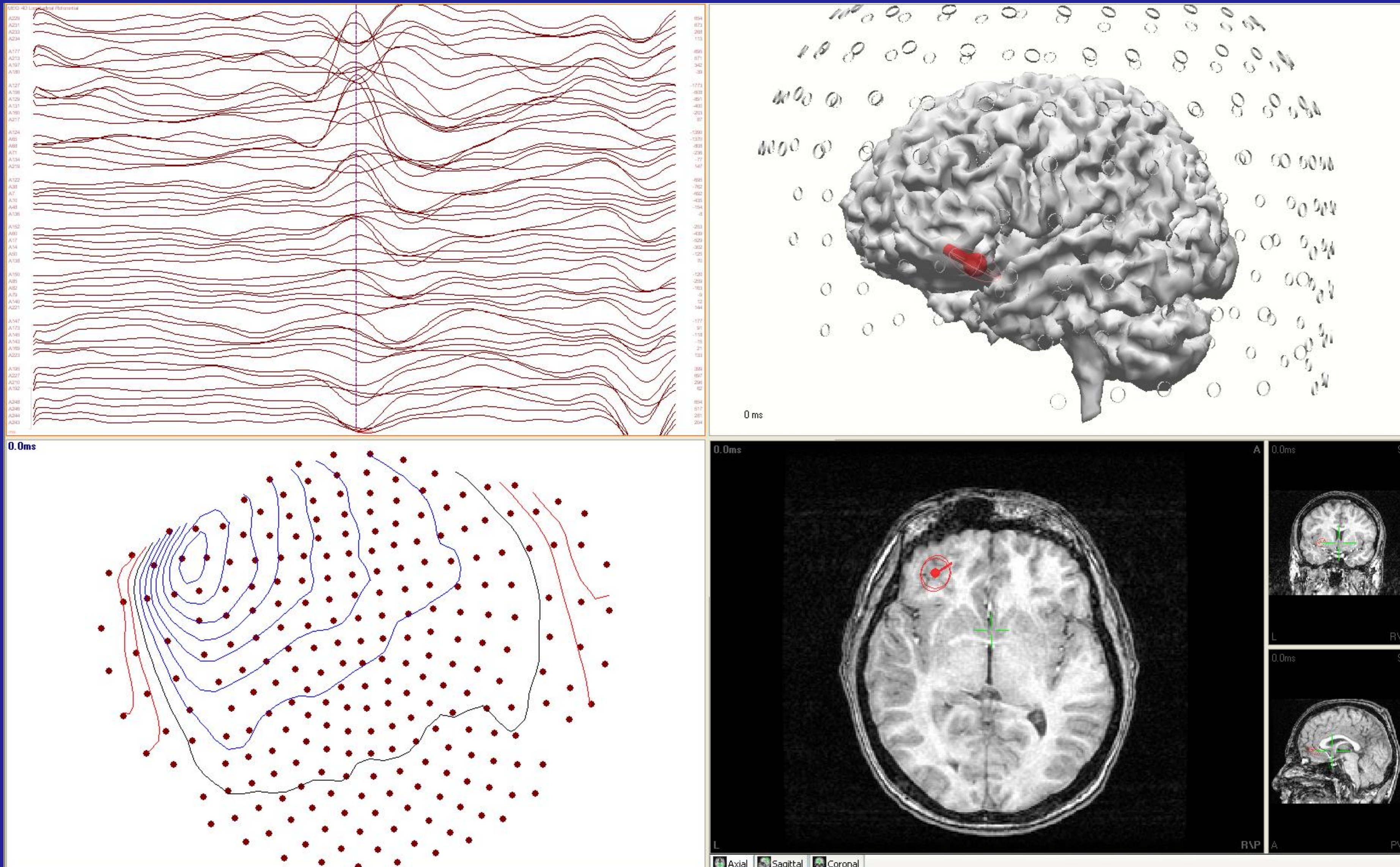
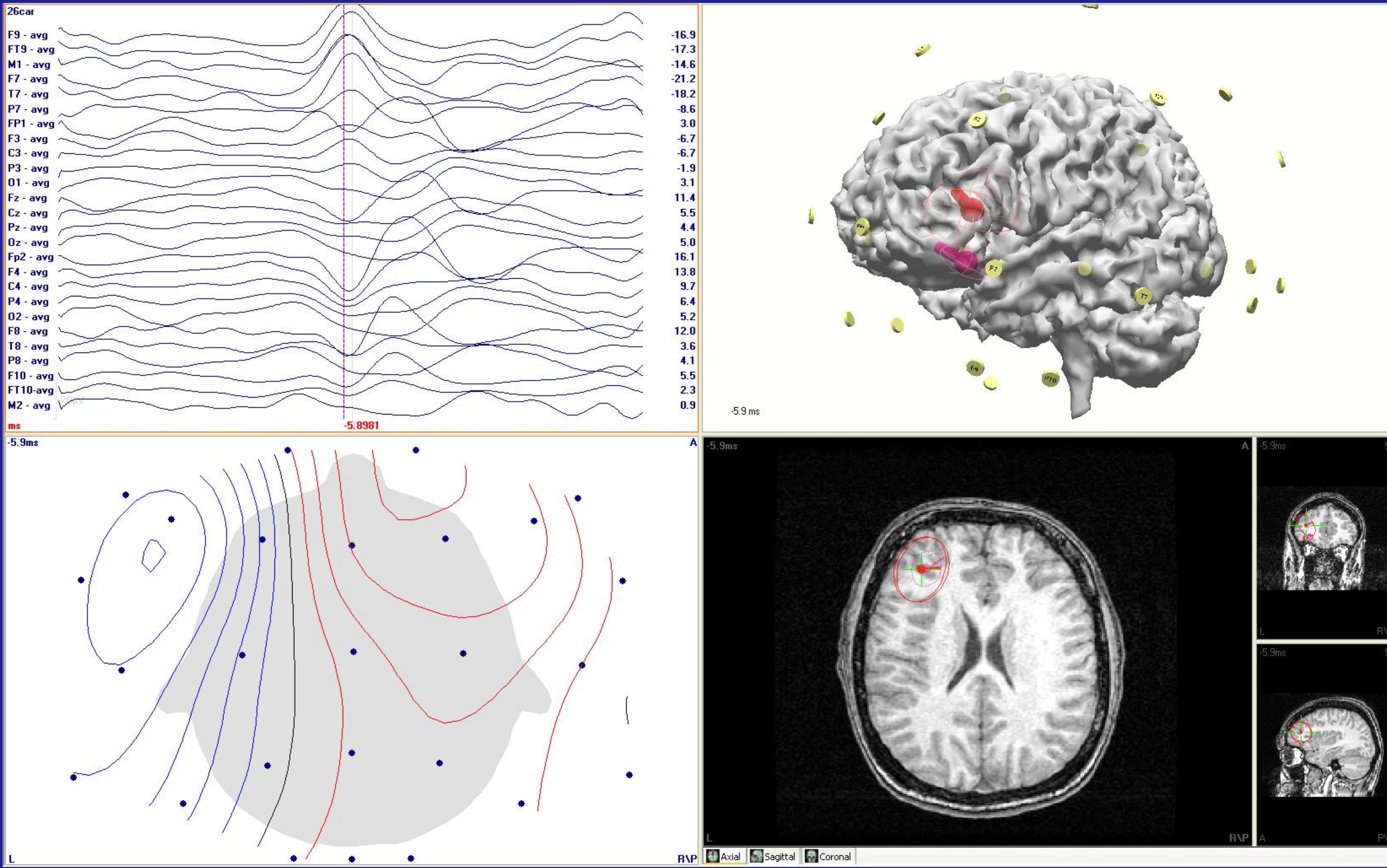
Axial
Sagittal
Coronal


-2.95 ms
0 ms
2.95 ms
-1.5ms
-1.5ms
2.9ms
2.9ms
0.0ms
S
Axial
Sagittal
Coronal


0 ms
0.0ms
0.0ms
A
L
R\P
Axial
Sagittal
Coronal


26car
F9 - avg
FT9 - avg
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T7 - avg
P7 - avg
FP1 - avg
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C3 - avg
P3 - avg
O1 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
Fp2 - avg
F4 - avg
C4 - avg
P4 - avg
O2 - avg
F8 - avg
T8 - avg
P8 - avg
F10 - avg
FT10-avg
M2 - avg
-16.9
-17.3
-14.6
-21.2
-18.2
-8.6
3.0
-6.7
-6.7
-1.9
3.1
11.4
5.5
4.4
5.0
16.1
13.8
9.7
6.4
5.2
12.0
3.6
4.1
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0.9
ms
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-5.9 ms
-5.9ms
A
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-5.9ms
A
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R\P
-5.9ms
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L
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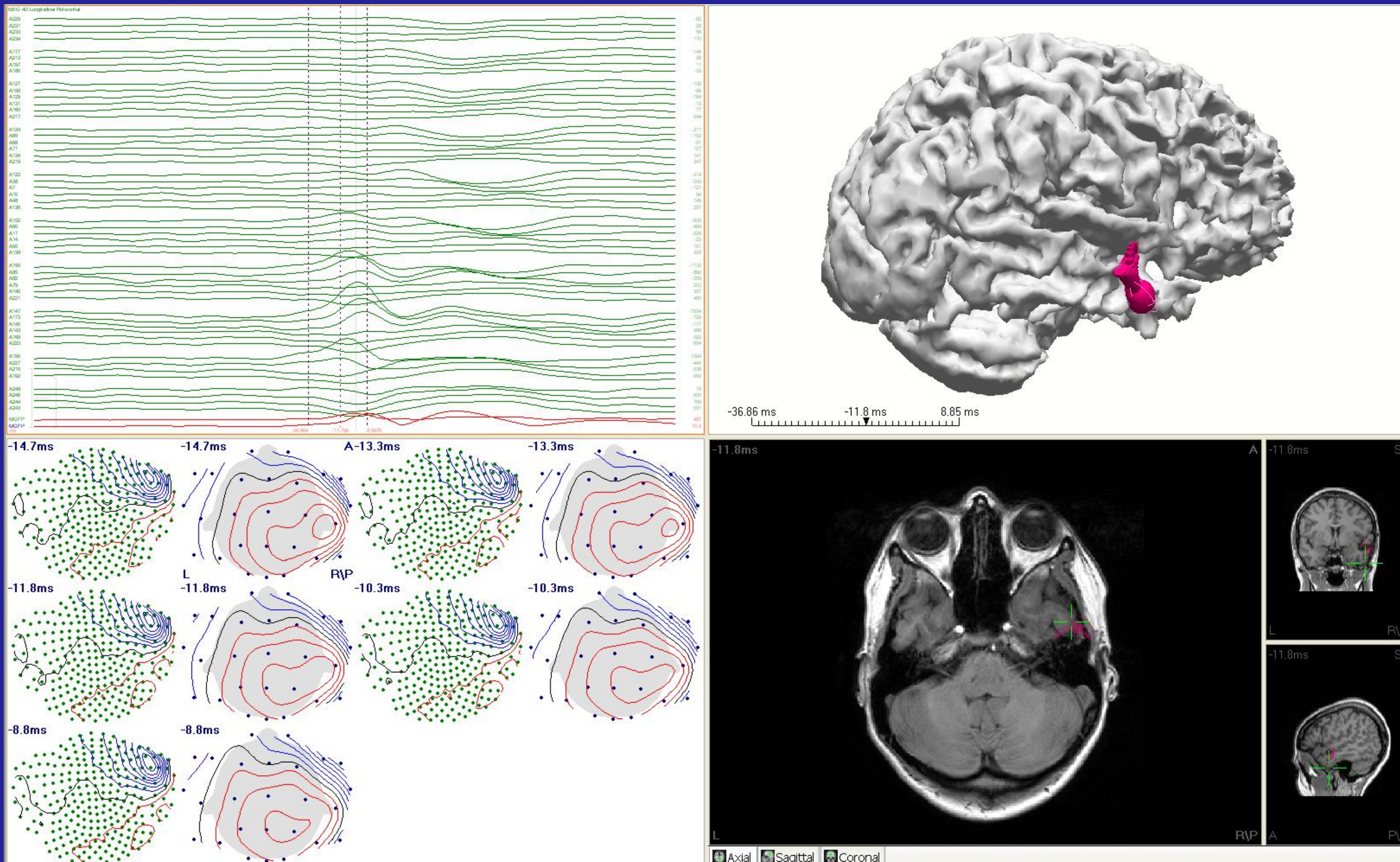
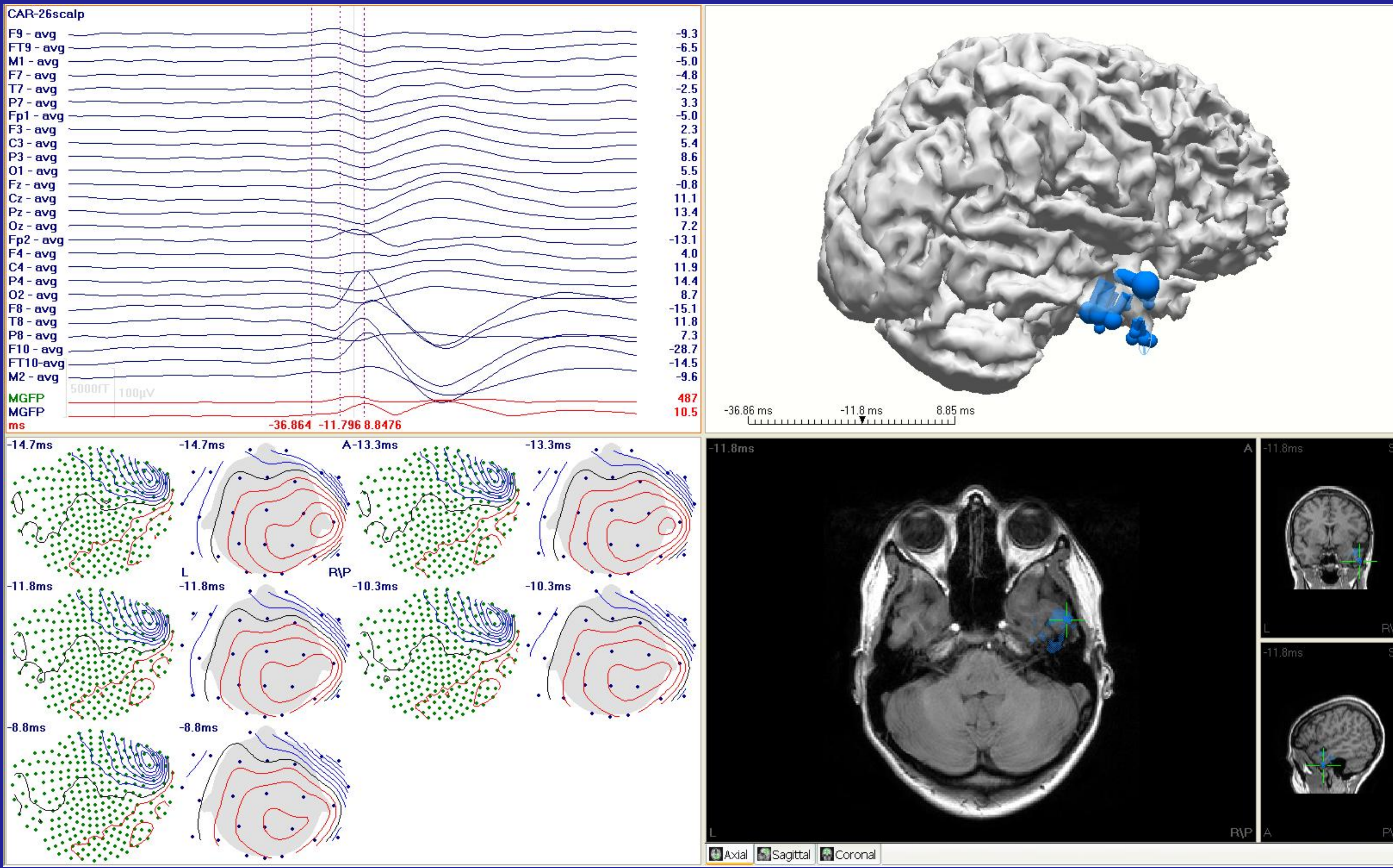
-5.9ms
S
A
P\
Axial
Sagittal
Coronal



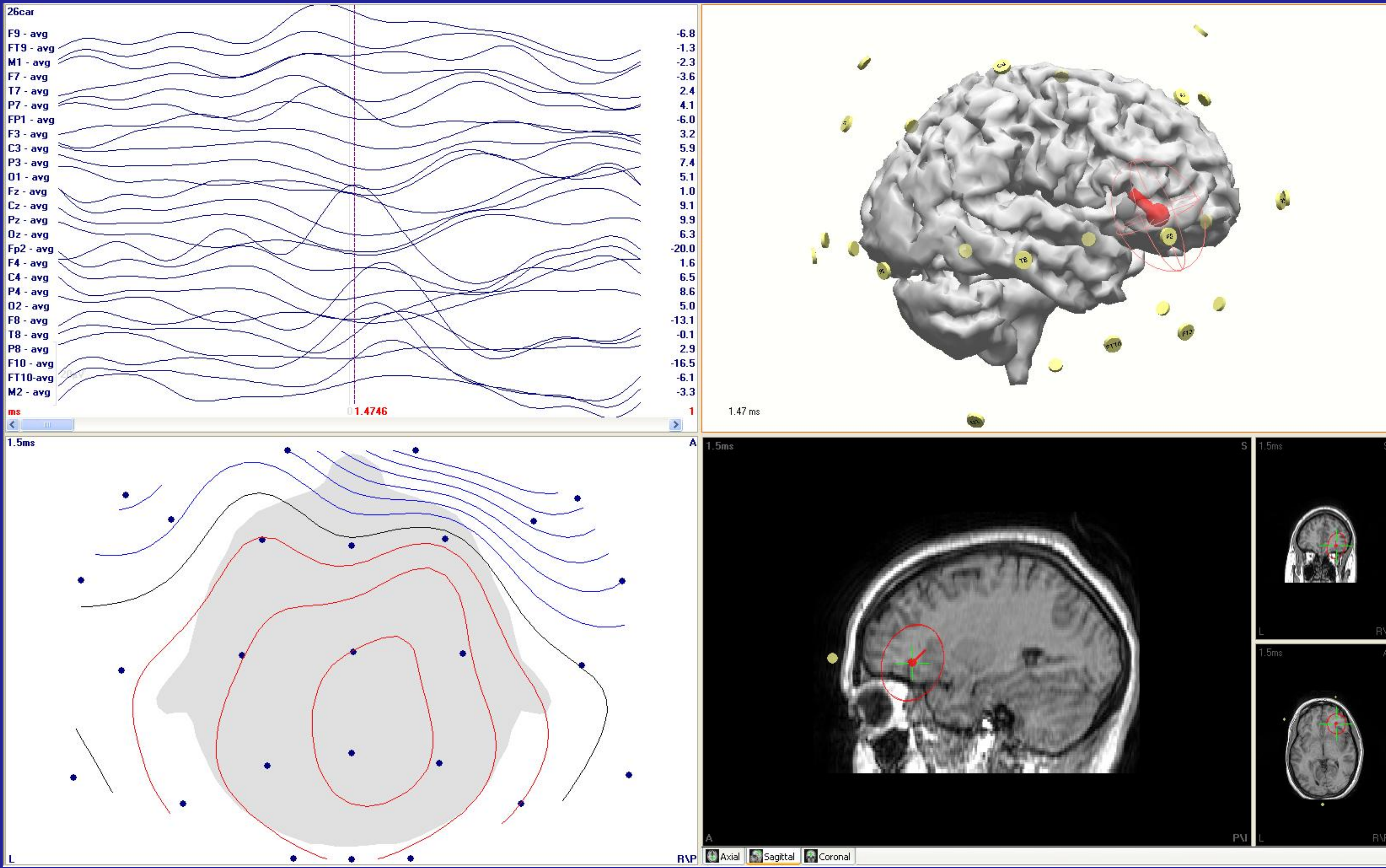
-36.86 ms
-11.8 ms
8.85 ms
-14.7ms
-14.7ms
A-13.3ms
-13.3ms
L
R\P
-11.8ms
-11.8ms
-10.3ms
-10.3ms
-8.8ms
-8.8ms
-11.8ms
A
L
R\P
-11.8ms
S
L
R\I
-11.8ms
S
A
P\I
Axial
Sagittal
Coronal


CAR-26scalp
F9 - avg
FT9 - avg
M1 - avg
F7 - avg
T7 - avg
P7 - avg
Fp1 - avg
F3 - avg
C3 - avg
P3 - avg
O1 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
Fp2 - avg
F4 - avg
C4 - avg
P4 - avg
O2 - avg
F8 - avg
T8 - avg
P8 - avg
F10 - avg
FT10-avg
M2 - avg
MGFP
MGFP
ms
5000fT
100µV
-9.3
-6.5
-5.0
-4.8
-2.5
3.3
-5.0
2.3
5.4
8.6
5.5
-0.8
11.1
13.4
7.2
-13.1
4.0
11.9
14.4
8.7
-15.1
11.8
7.3
-28.7
-14.5
-9.6
487
10.5
-36.864 -11.796 8.8476
-36.86 ms
-11.8 ms
8.85 ms
-14.7ms
-14.7ms
A-13.3ms
-13.3ms
L
R\P
-11.8ms
-11.8ms
-10.3ms
-10.3ms
-8.8ms
-8.8ms
-11.8ms
A
L
R\P
-11.8ms
S
L
R\
-11.8ms
S
A
P\
Axial
Sagittal
Coronal

MEG vs. EEG

Some patients (10-15%) have EEG spikes, but no accompanying MEG spikes

Usually these EEG spikes are purely radial, but not always


26car
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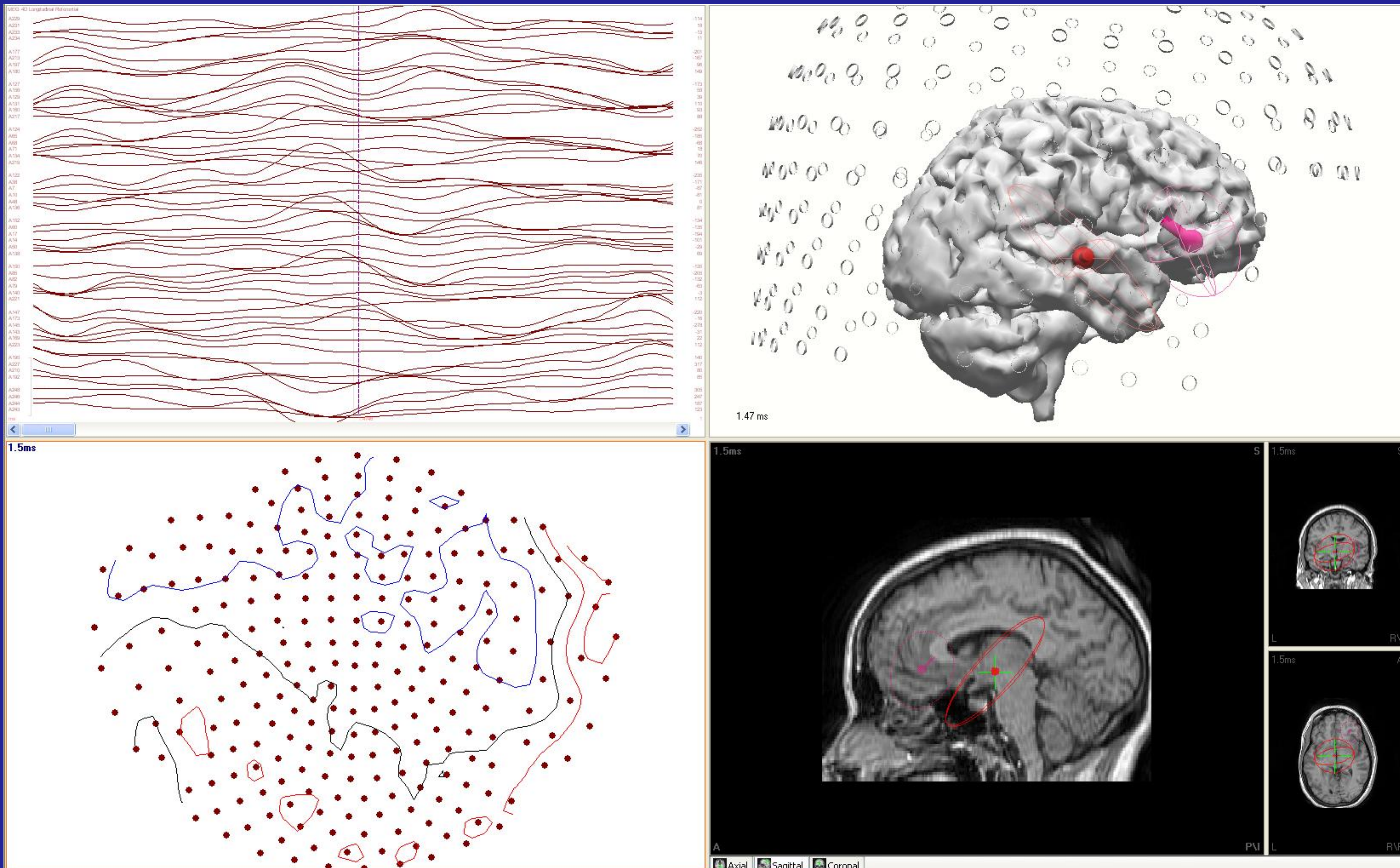
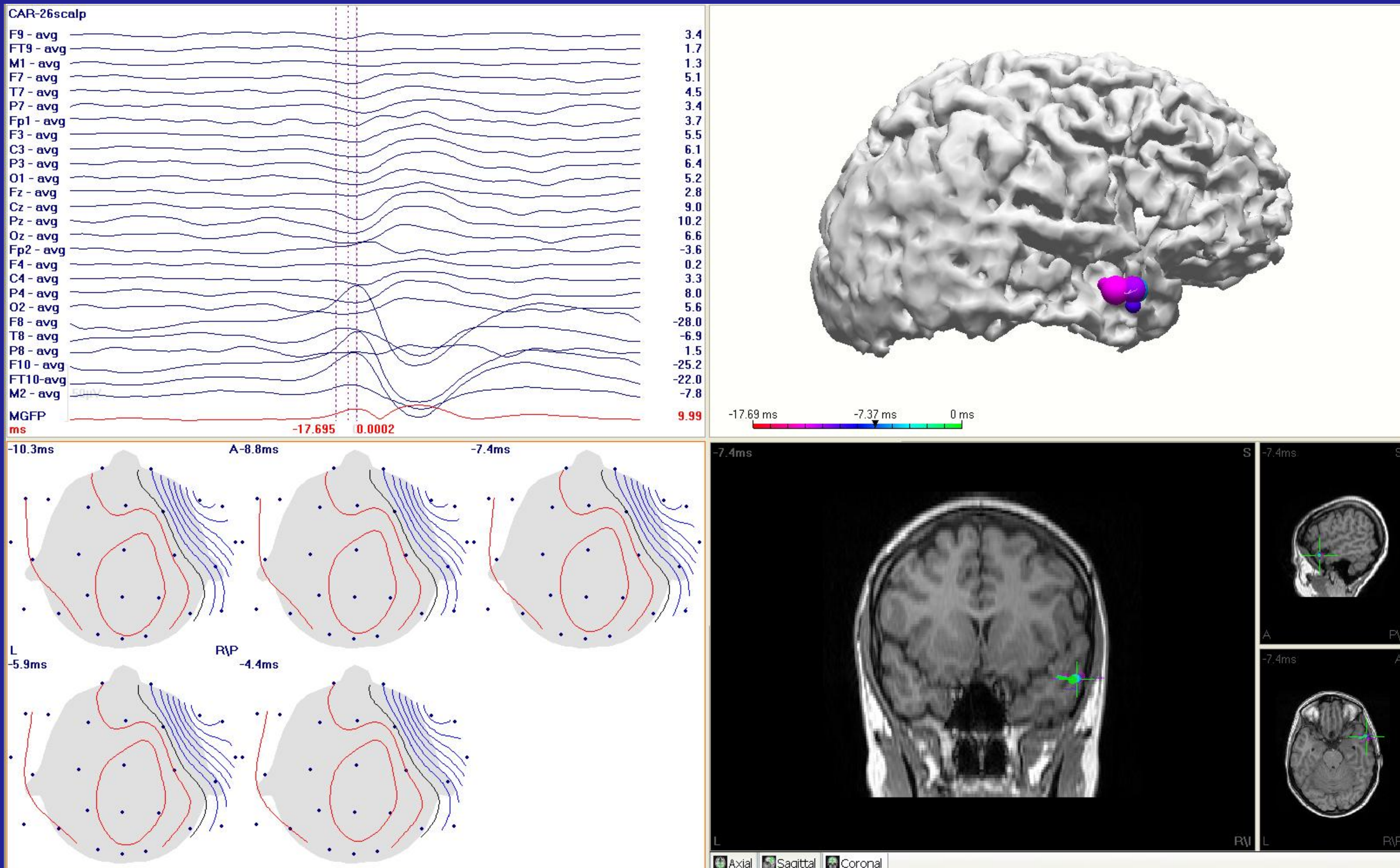
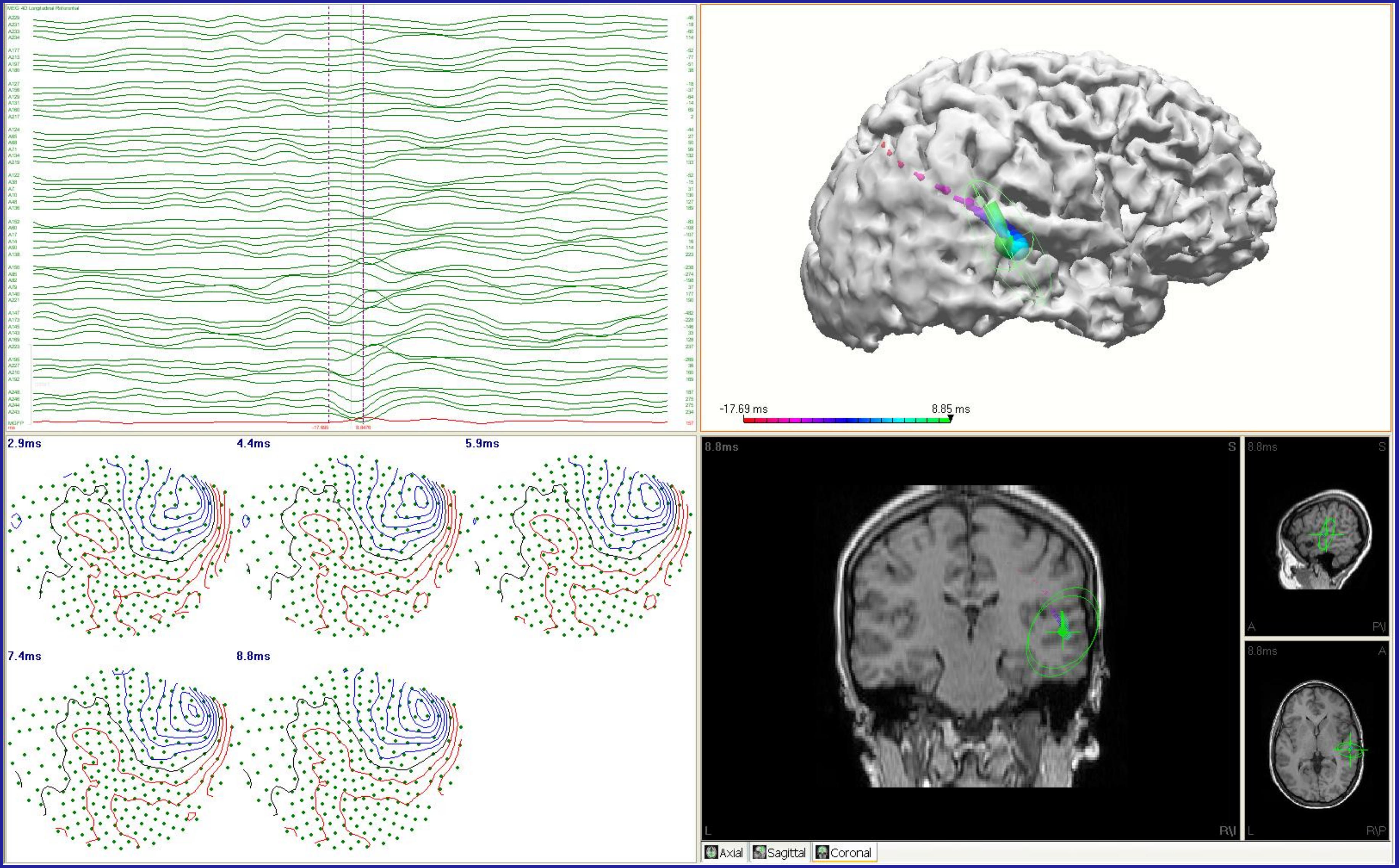
M1 - avg
F7 - avg
T7 - avg
P7 - avg
FP1 - avg
F3 - avg
C3 - avg
P3 - avg
O1 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
Fp2 - avg
F4 - avg
C4 - avg
P4 - avg
O2 - avg
F8 - avg
T8 - avg
P8 - avg
F10 - avg
FT10-avg
M2 - avg
-6.8
-1.3
-2.3
-3.6
2.4
4.1
-6.0
3.2
5.9
7.4
5.1
1.0
9.1
9.9
6.3
-20.0
1.6
6.5
8.6
5.0
-13.1
-0.1
2.9
-16.5
-6.1
-3.3
ms
1.4746
1
1.47 ms
1.5ms
A
L
R\P
1.5ms
S
A
P\I
1.5ms
S
L
R\I
1.5ms
A
L
R\P
Axial
Sagittal
Coronal



1.47 ms
1.5ms
1.5ms
S
A
P\I
1.5ms
S
L
R\I
1.5ms
A
L
R\P
Axial
Sagittal
Coronal


CAR-26scalp
F9 - avg 3.4
FT9 - avg 1.7
M1 - avg 1.3
F7 - avg 5.1
T7 - avg 4.5
P7 - avg 3.4
Fp1 - avg 3.7
F3 - avg 5.5
C3 - avg 6.1
P3 - avg 6.4
O1 - avg 5.2
Fz - avg 2.8
Cz - avg 9.0
Pz - avg 10.2
Oz - avg 6.6
Fp2 - avg -3.6
F4 - avg 0.2
C4 - avg 3.3
P4 - avg 8.0
O2 - avg 5.6
F8 - avg -28.0
T8 - avg -6.9
P8 - avg 1.5
F10 - avg -25.2
FT10-avg -22.0
M2 - avg -7.8
MGFP 9.99
ms -17.695 0.0002
-17.69 ms
-7.37 ms
0 ms
-10.3ms
A-8.8ms
-7.4ms
L
R\P
-5.9ms
-4.4ms
-7.4ms
S
L
R\I
A
P\I
Axial
Sagittal
Coronal

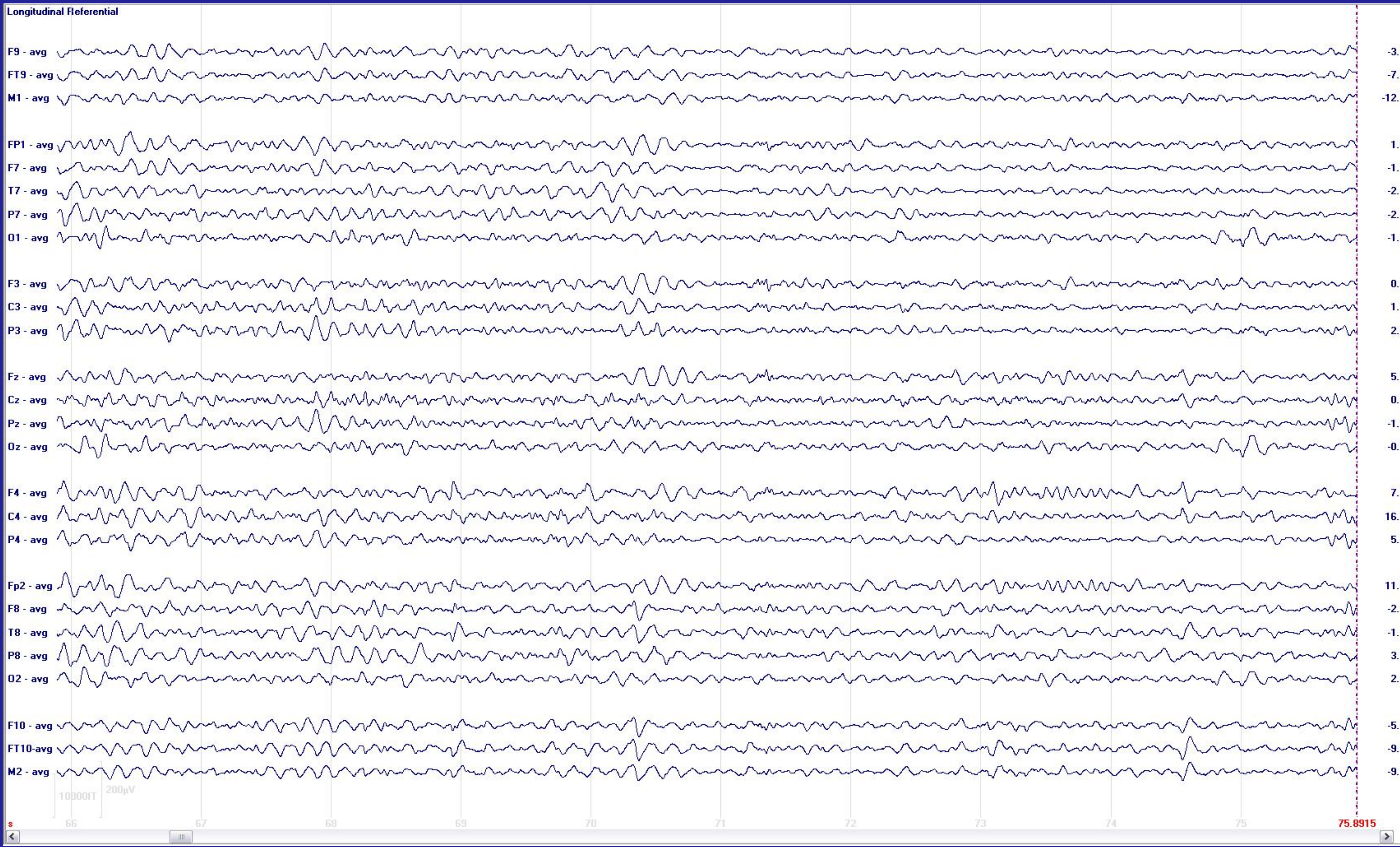

-17.69 ms
8.85 ms
2.9ms
4.4ms
5.9ms
7.4ms
8.8ms
8.8ms
S
L
R\I
A
P\I
R\P
Axial
Sagittal
Coronal

MEG vs. EEG

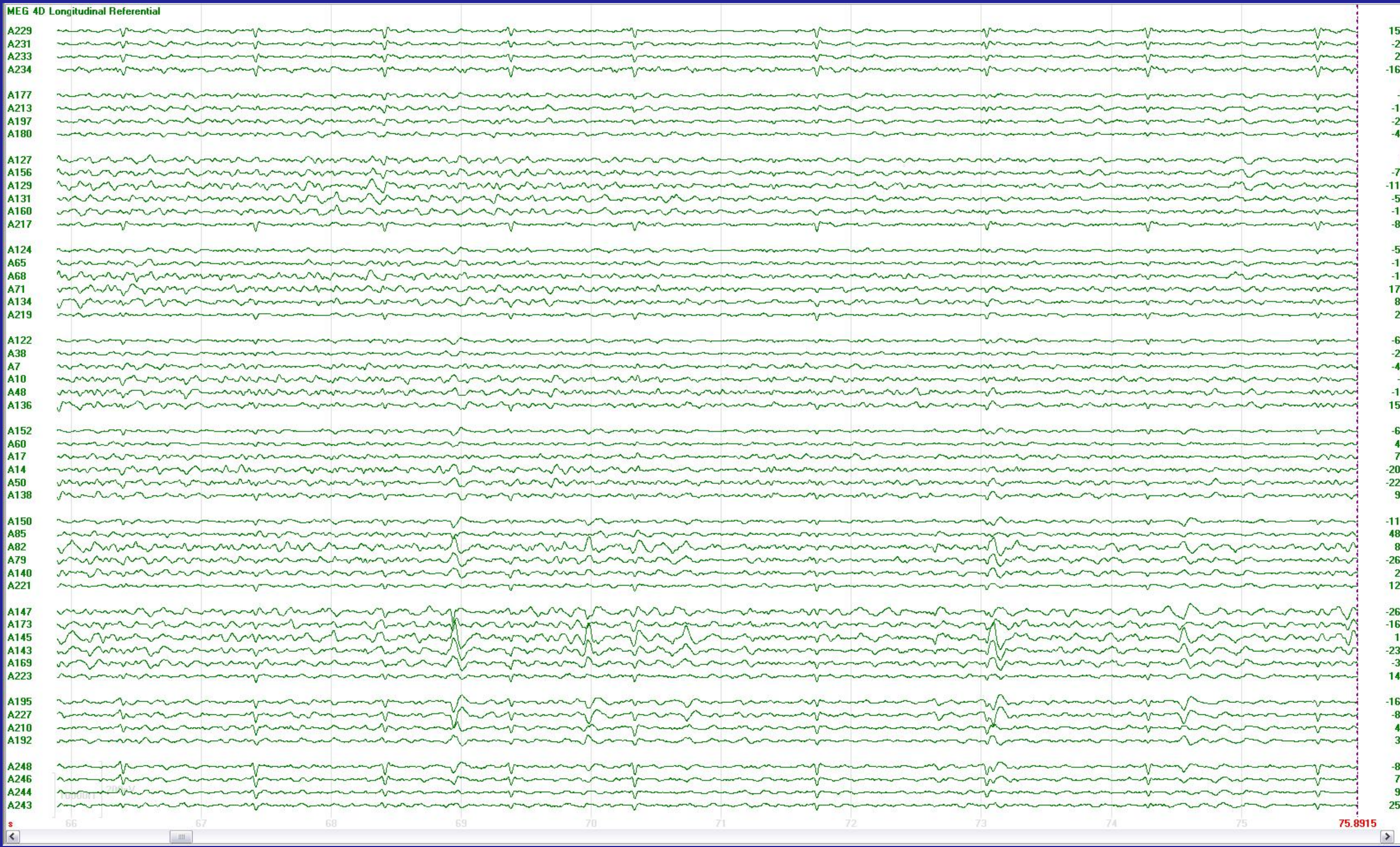
A few patients (<10%) have MEG spikes, but no accompanying EEG spikes

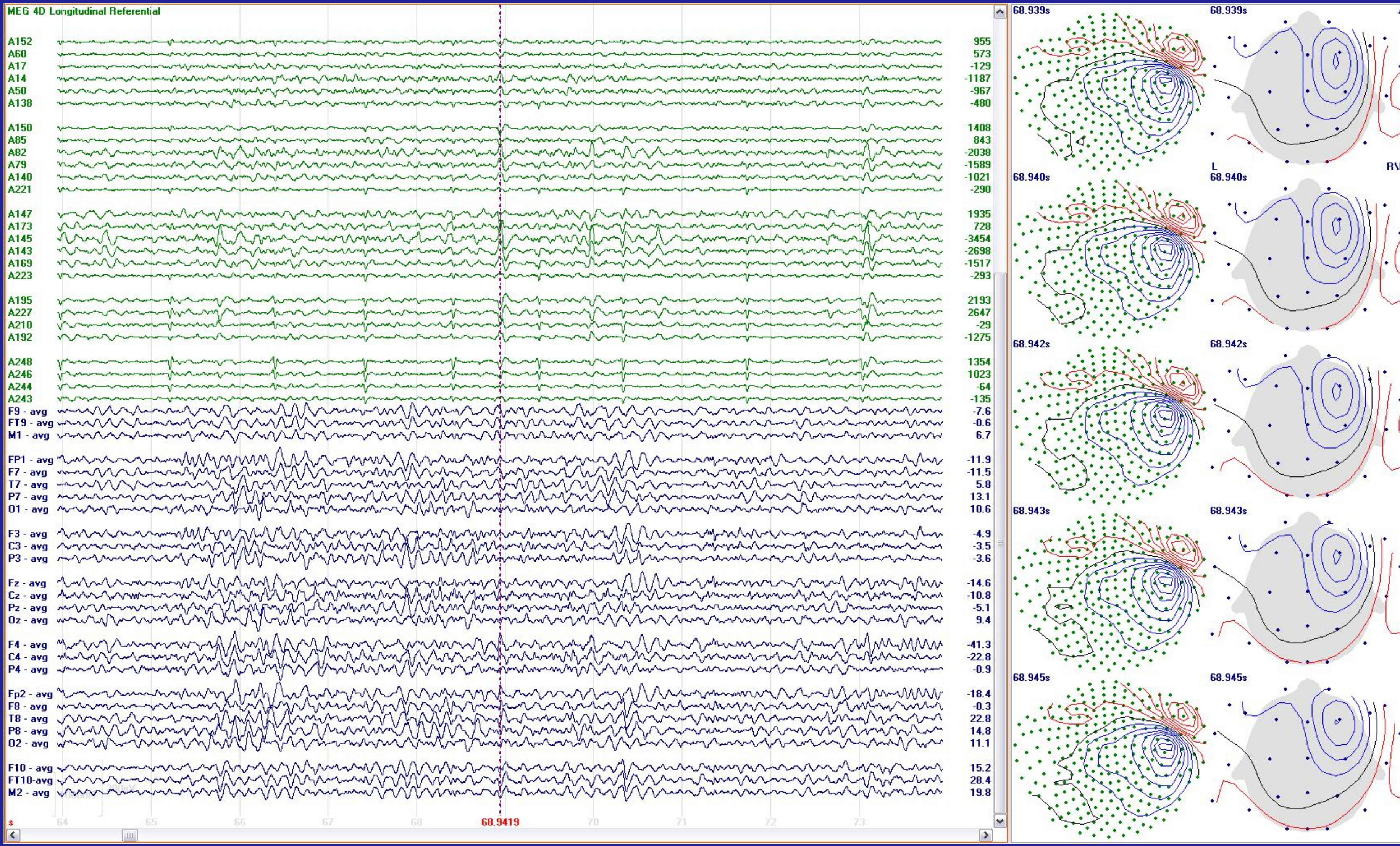
Some appear to be “benign variants”

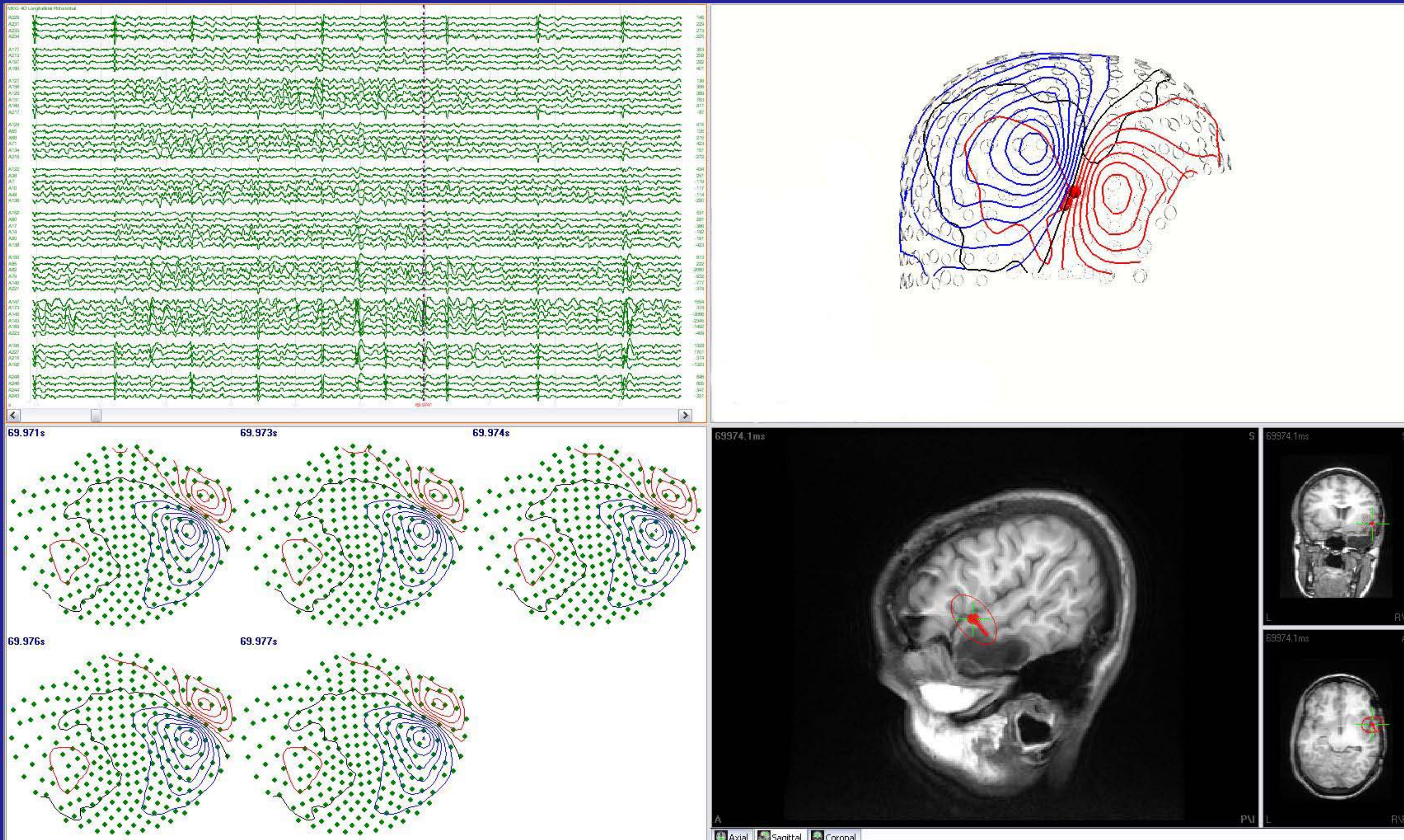
Mid-posterior, superior, vertical temporal dipoles, in particular, may be benign



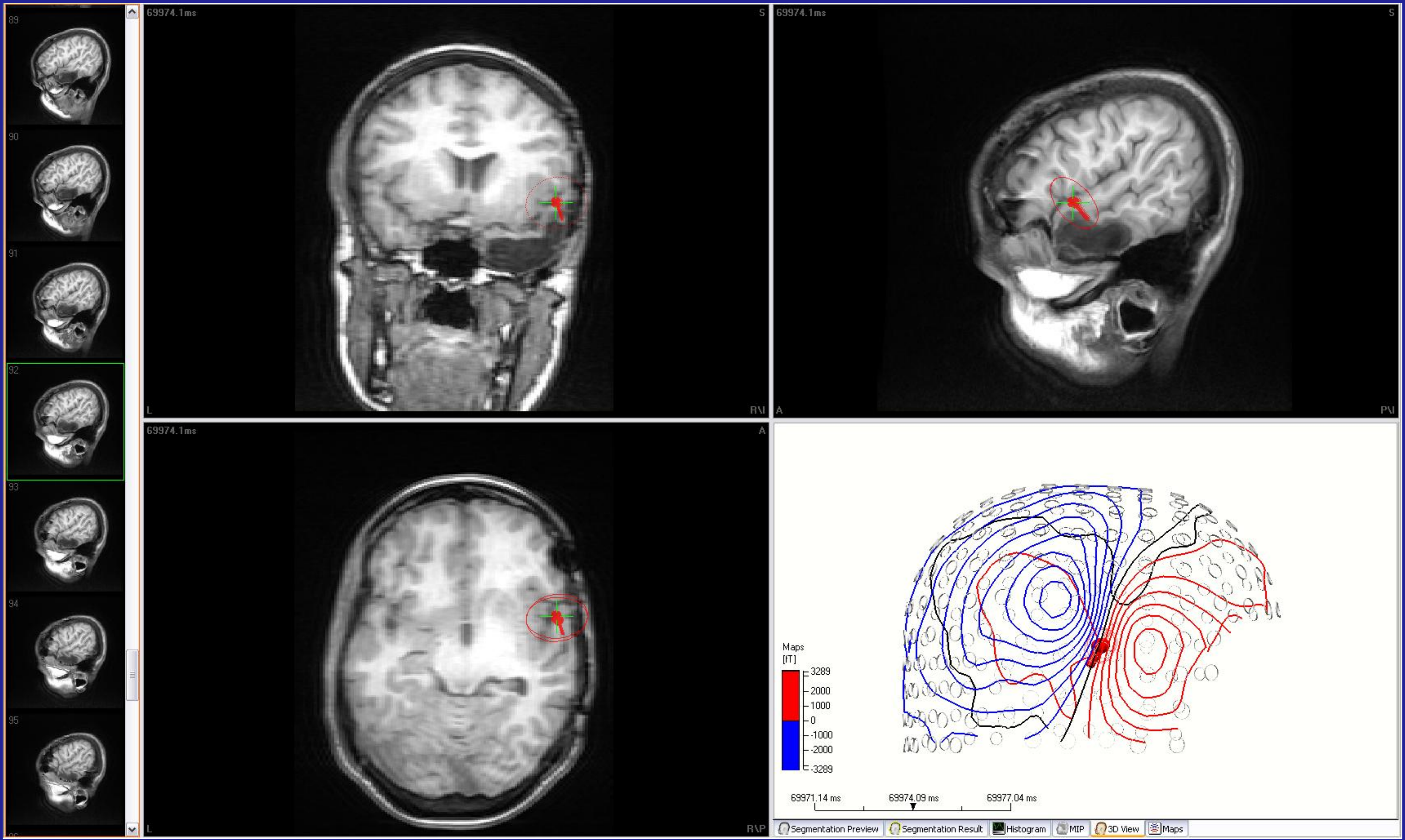
Longitudinal Referential
F9 - avg -3.3
FT9 - avg -7.4
M1 - avg -12.1
FP1 - avg 1.5
F7 - avg -1.7
T7 - avg -2.1
P7 - avg -2.9
O1 - avg -1.2
F3 - avg 0.6
C3 - avg 1.5
P3 - avg 2.7
Fz - avg 5.3
Cz - avg 0.3
Pz - avg -1.2
Oz - avg -0.9
F4 - avg 7.7
C4 - avg 16.5
P4 - avg 5.8
Fp2 - avg 11.5
F8 - avg -2.1
T8 - avg -1.1
P8 - avg 3.8
O2 - avg 2.4
F10 - avg -5.2
FT10-avg -9.4
M2 - avg -9.1
10000fT
200µV
s
66
67
68
69
70
71
72
73
74
75
75.8915


MEG 4D Longitudinal Referential
A229 159
A231 -25
A233 29
A234 -161
A177 -2
A213 -12
A197 -23
A180 -45
A127 1
A156 -75
A129 -118
A131 -55
A160 -10
A217 -86
A124 -57
A65 -18
A68 -12
A71 175
A134 83
A219 21
A122 -65
A38 -26
A7 -41
A10 -2
A48 -12
A136 159
A152 -66
A60 44
A17 78
A14 -200
A50 -224
A138 97
A150 -118
A85 480
A82 89
A79 -264
A140 23
A221 123
A147 -262
A173 -161
A145 17
A143 -233
A169 -34
A223 143
A195 -169
A227 -89
A210 42
A192 32
A248 -88
A246 77
A244 90
A243 253
s
66
67
68
69
70
71
72
73
74
75
75.8915

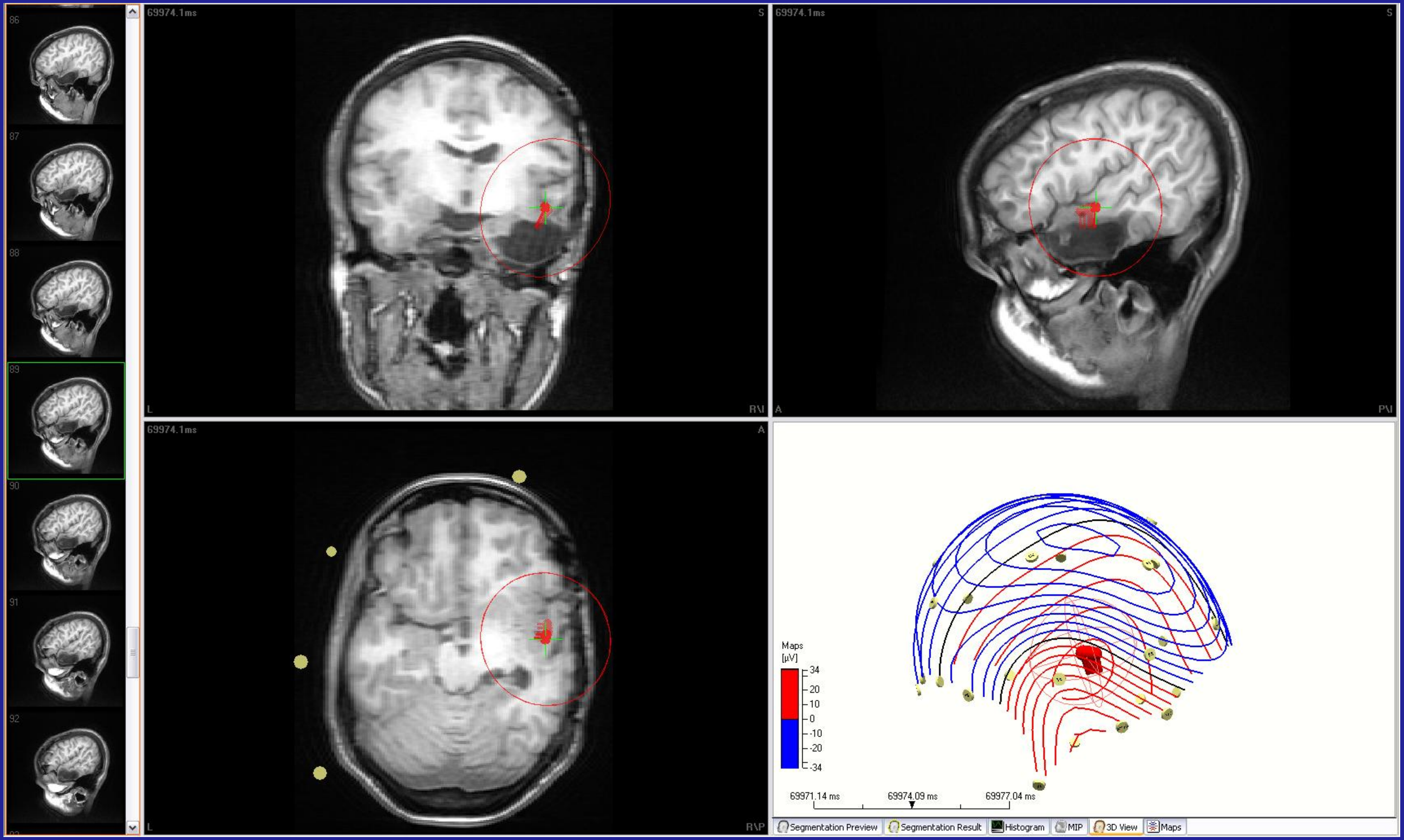

MEG 4D Longitudinal Referential
A152
A60
A17
A14
A50
A138
A150
A85
A82
A79
A140
A221
A147
A173
A145
A143
A169
A223
A195
A227
A210
A192
A248
A246
A244
A243
F9 - avg
FT9 - avg
M1 - avg
FP1 - avg
F7 - avg
T7 - avg
P7 - avg
O1 - avg
F3 - avg
C3 - avg
P3 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
F4 - avg
C4 - avg
P4 - avg
Fp2 - avg
F8 - avg
T8 - avg
P8 - avg
O2 - avg
F10 - avg
FT10-avg
M2 - avg
68.9419
68.939s
68.940s
68.942s
68.943s
68.945s
A
L
R\P

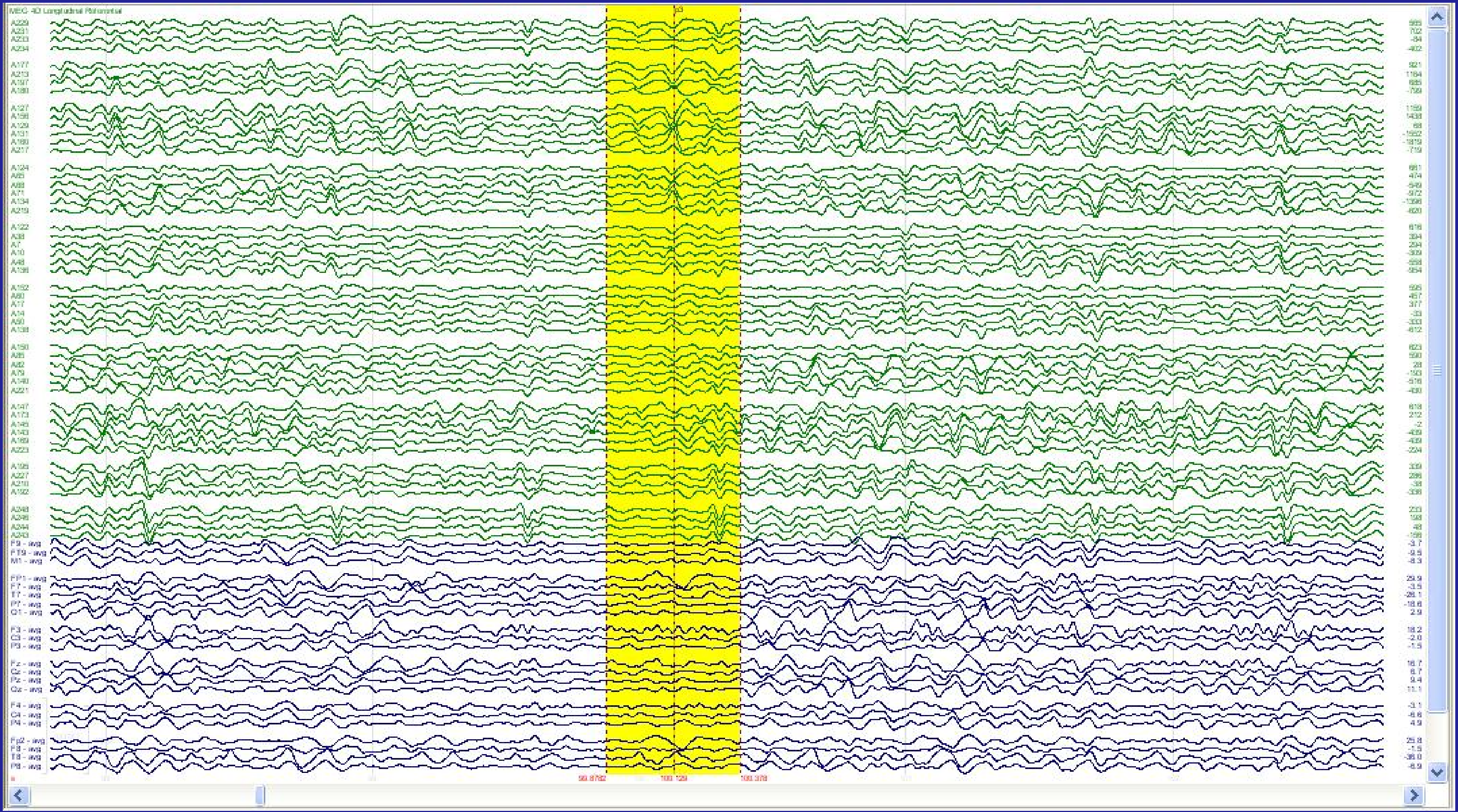


69.971s
69.973s
69.974s
69.976s
69.977s
69974.1ms
69974.1ms
69974.1ms
Axial
Sagittal
Coronal

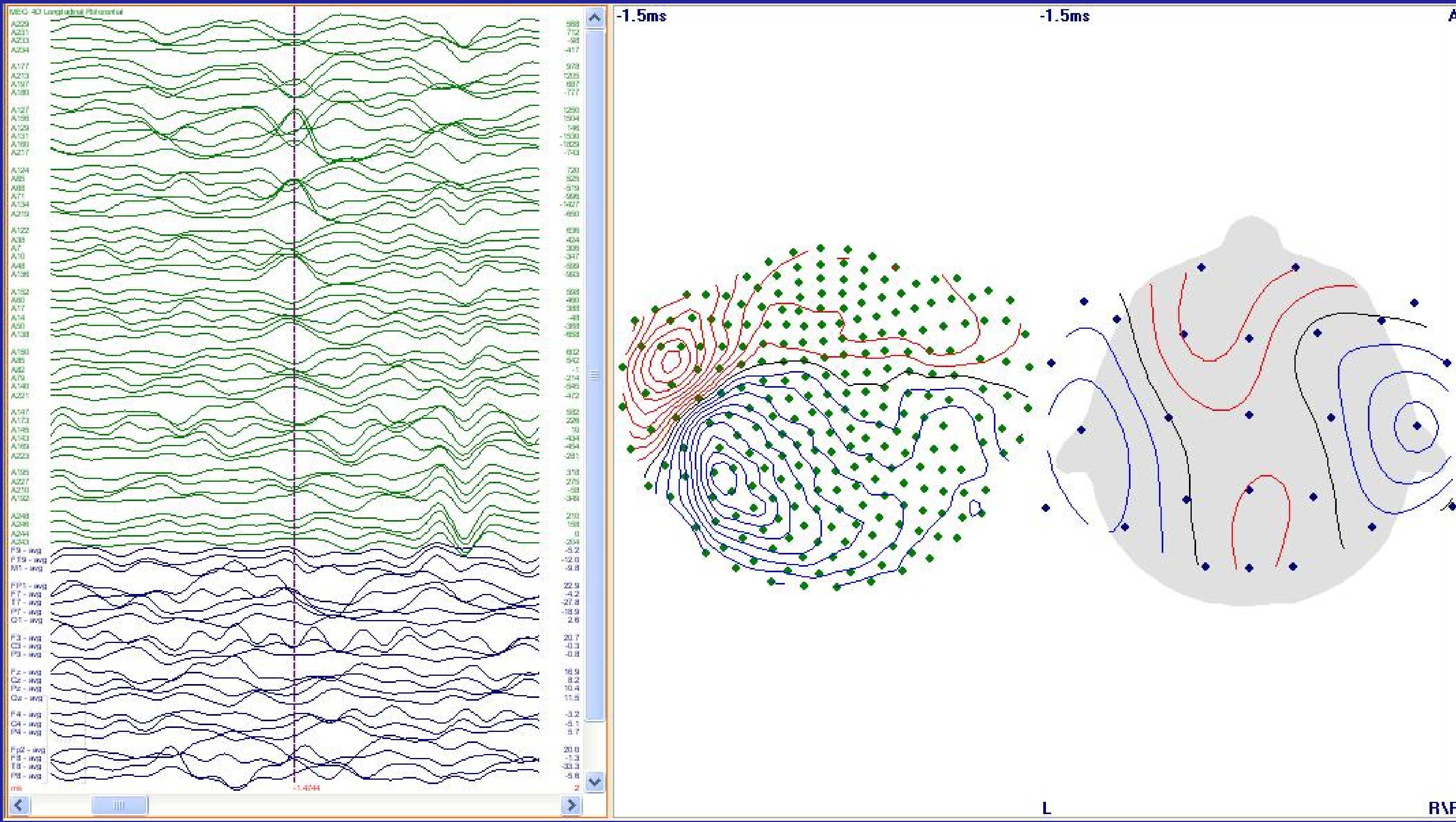


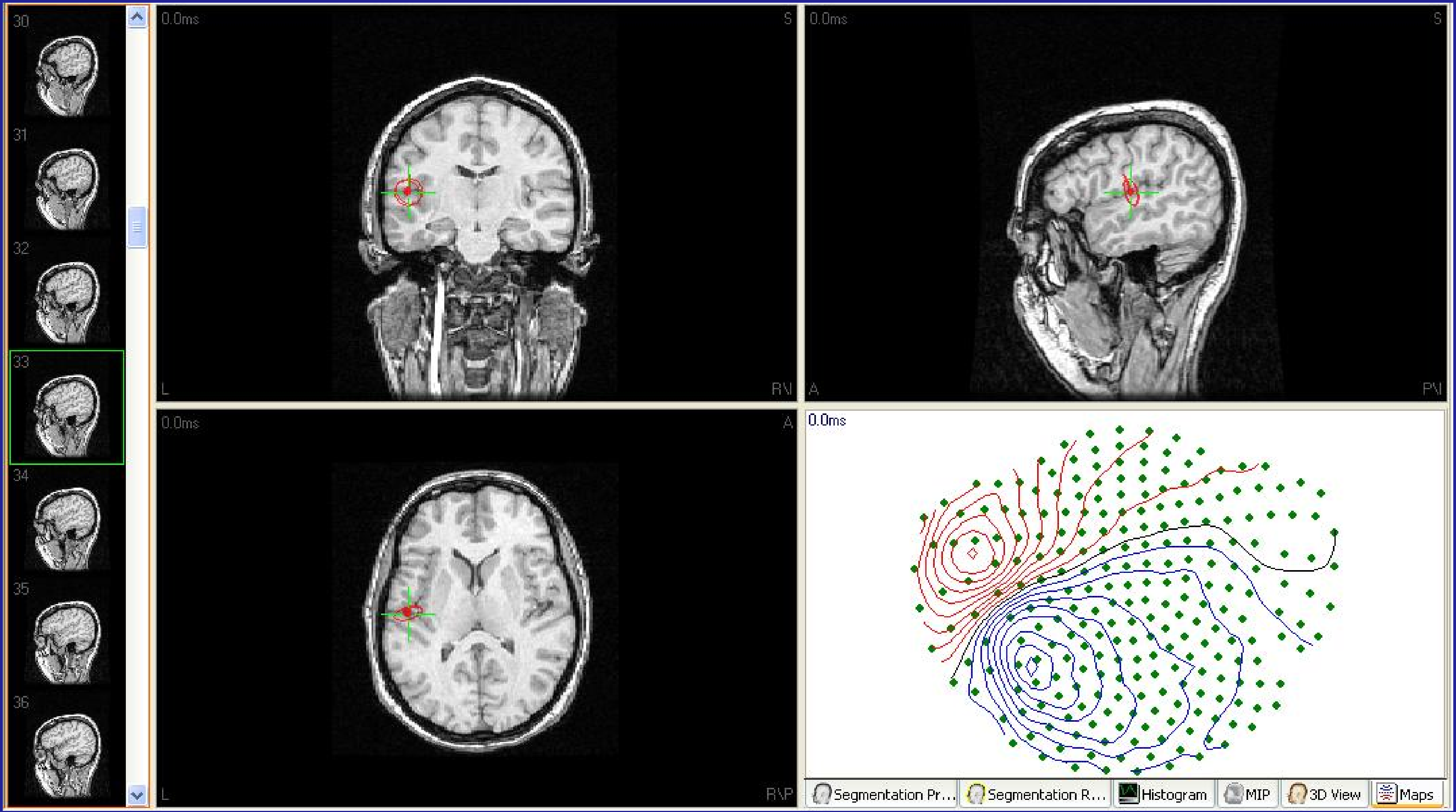
69974.1ms
S
L
R\I
A
P\I
Maps
[fT]
3289
2000
1000
0
-1000
-2000
-3289
69971.14 ms
69974.09 ms
69977.04 ms
Segmentation Preview
Segmentation Result
Histogram
MIP
3D View
Maps

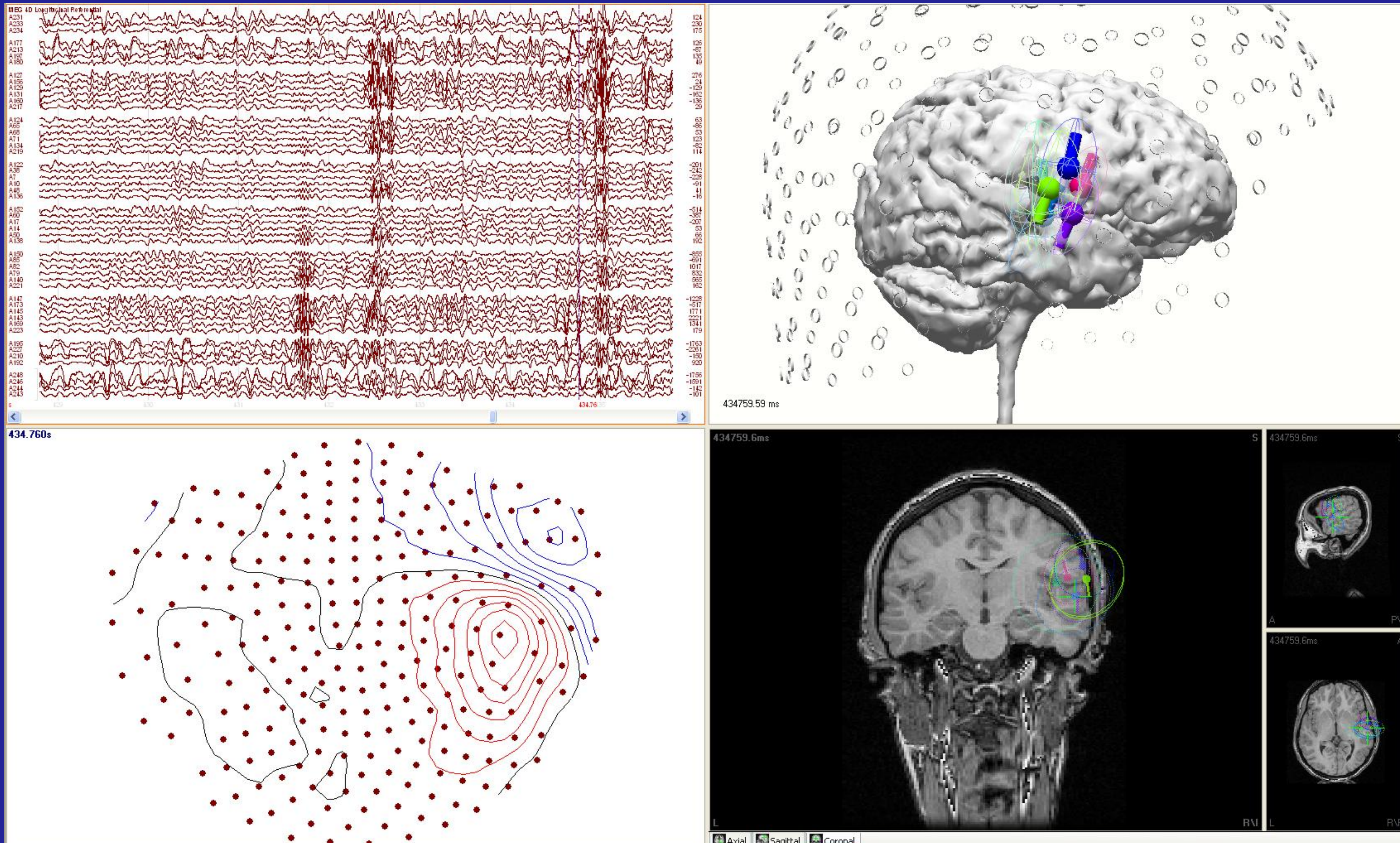

69974.1ms
Maps
[µV]
34
20
10
0
-10
-20
-34
69971.14 ms
69974.09 ms
69977.04 ms
Segmentation Preview
Segmentation Result
Histogram
MIP
3D View
Maps

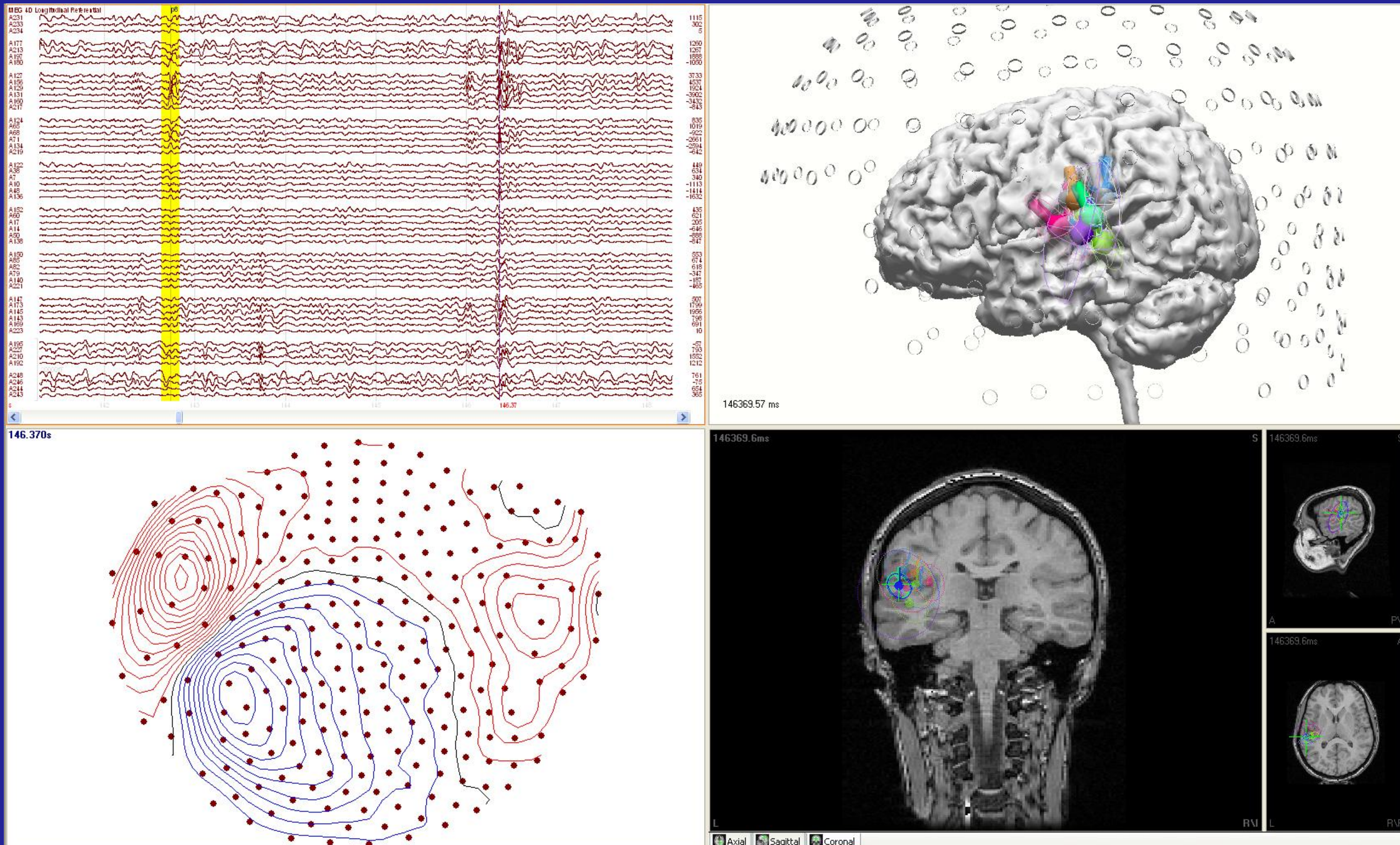


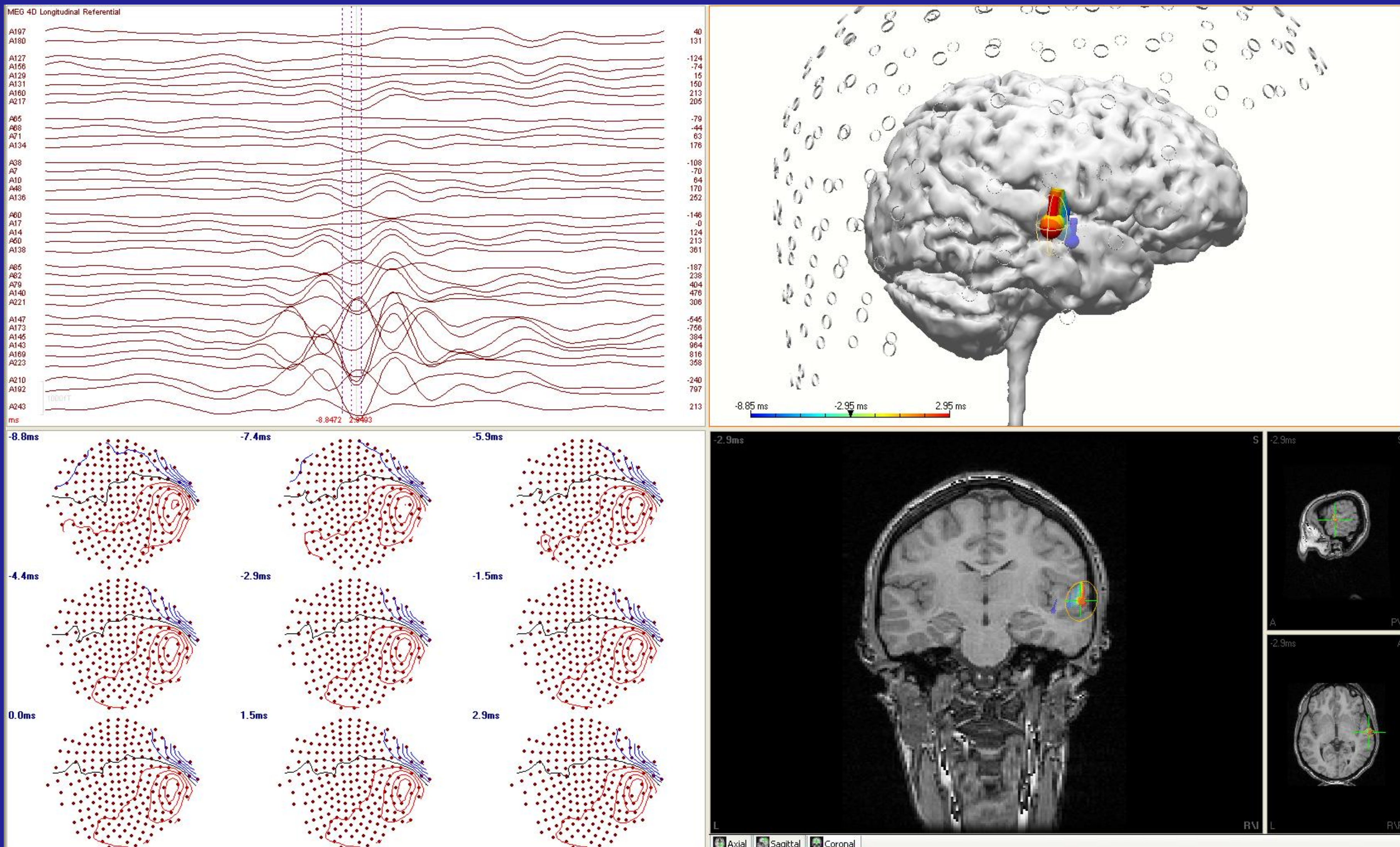
F3 - avg
C3 - avg
P3 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
F4 - avg
C4 - avg
P4 - avg

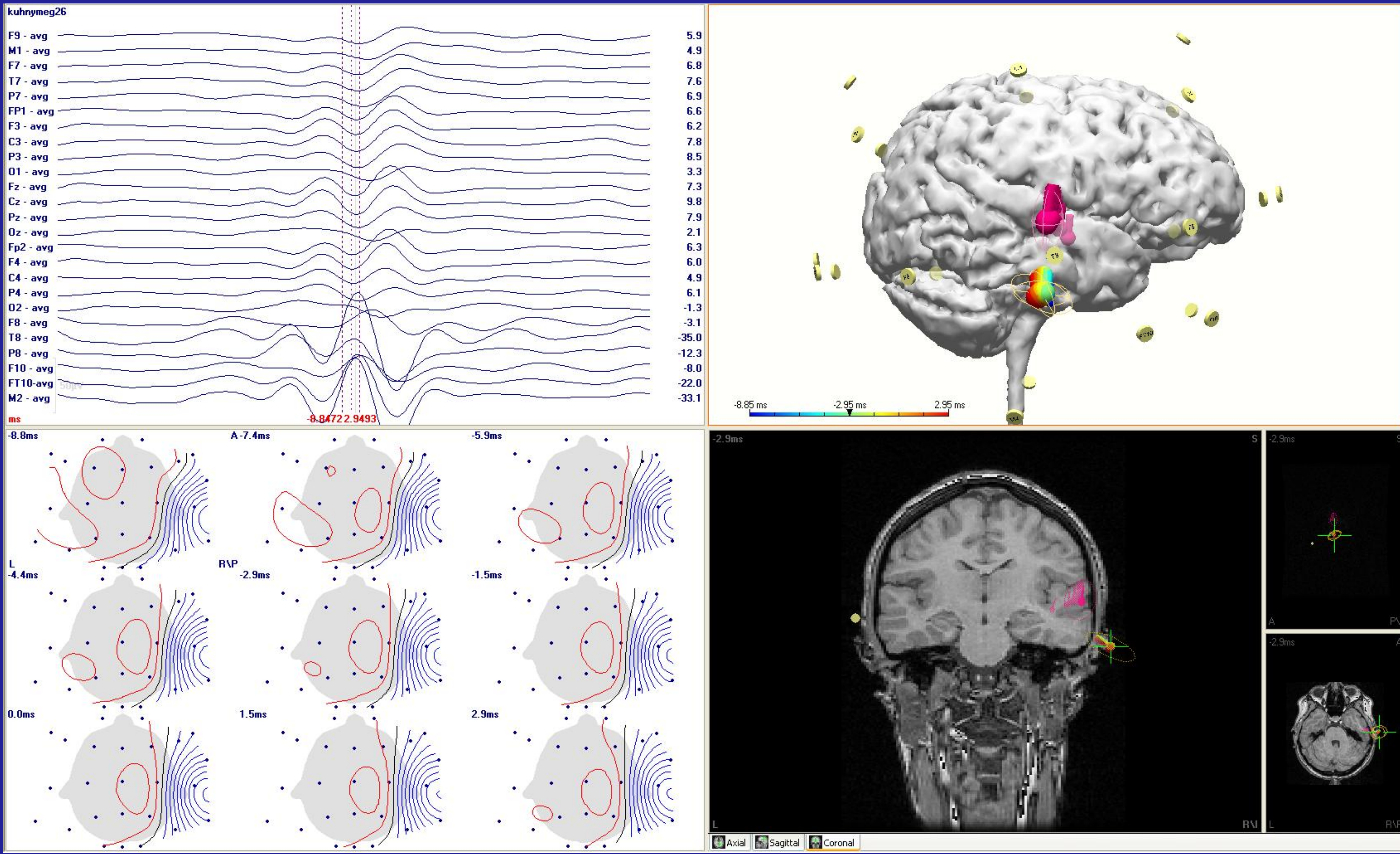

-1.5ms
-1.5ms
A
L
R\P


30
31
32
33
34
35
36
0.0ms
S
L
R\I
0.0ms
S
A
P\I
0.0ms
A
L
R\P
0.0ms
Segmentation Pr...
Segmentation R...
Histogram
MIP
3D View
Maps


434759.59 ms
434.760s
434759.6ms
434759.6ms
434759.6ms
Axial
Sagittal
Coronal


146369.57 ms
146.370s
146369.6ms
Axial
Sagittal
Coronal

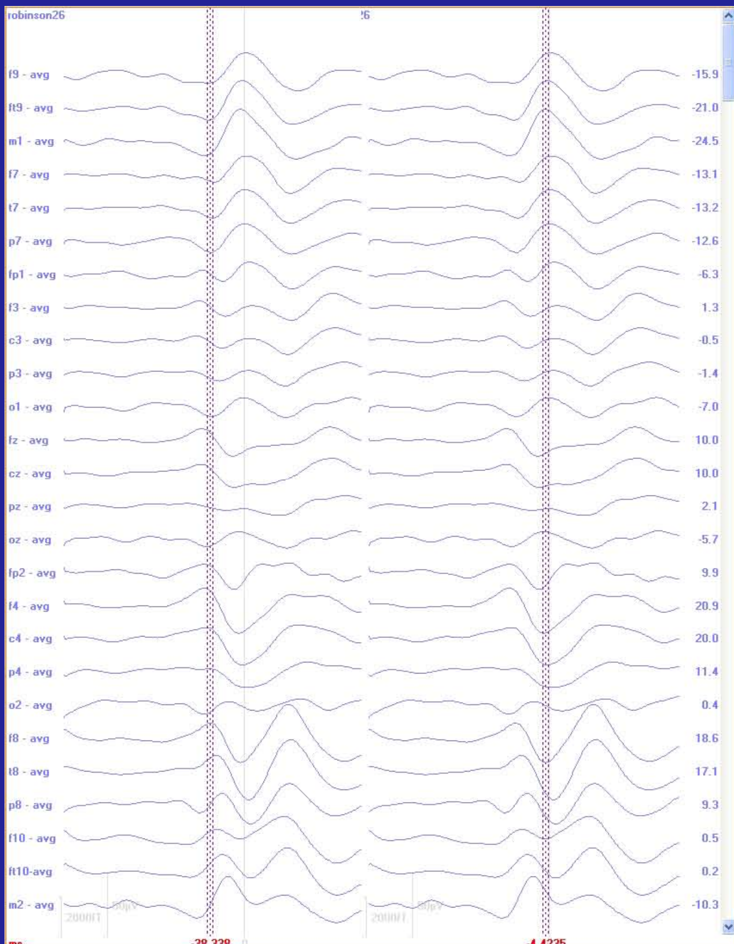
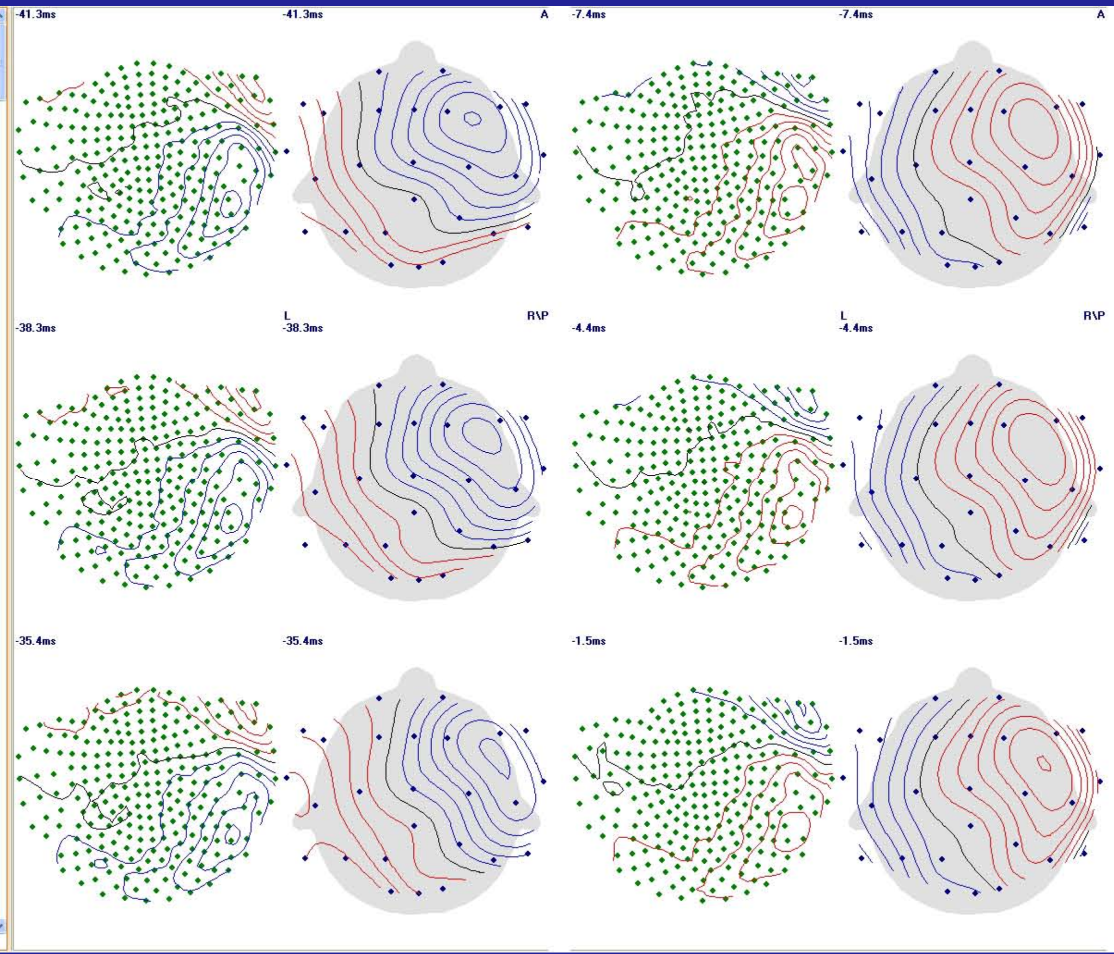

MEG 4D Longitudinal Referential
-8.8472
2.9493
-8.85 ms
-2.95 ms
2.95 ms
-8.8ms
-7.4ms
-5.9ms
-4.4ms
-2.9ms
-1.5ms
0.0ms
1.5ms
2.9ms
Axial
Sagittal
Coronal

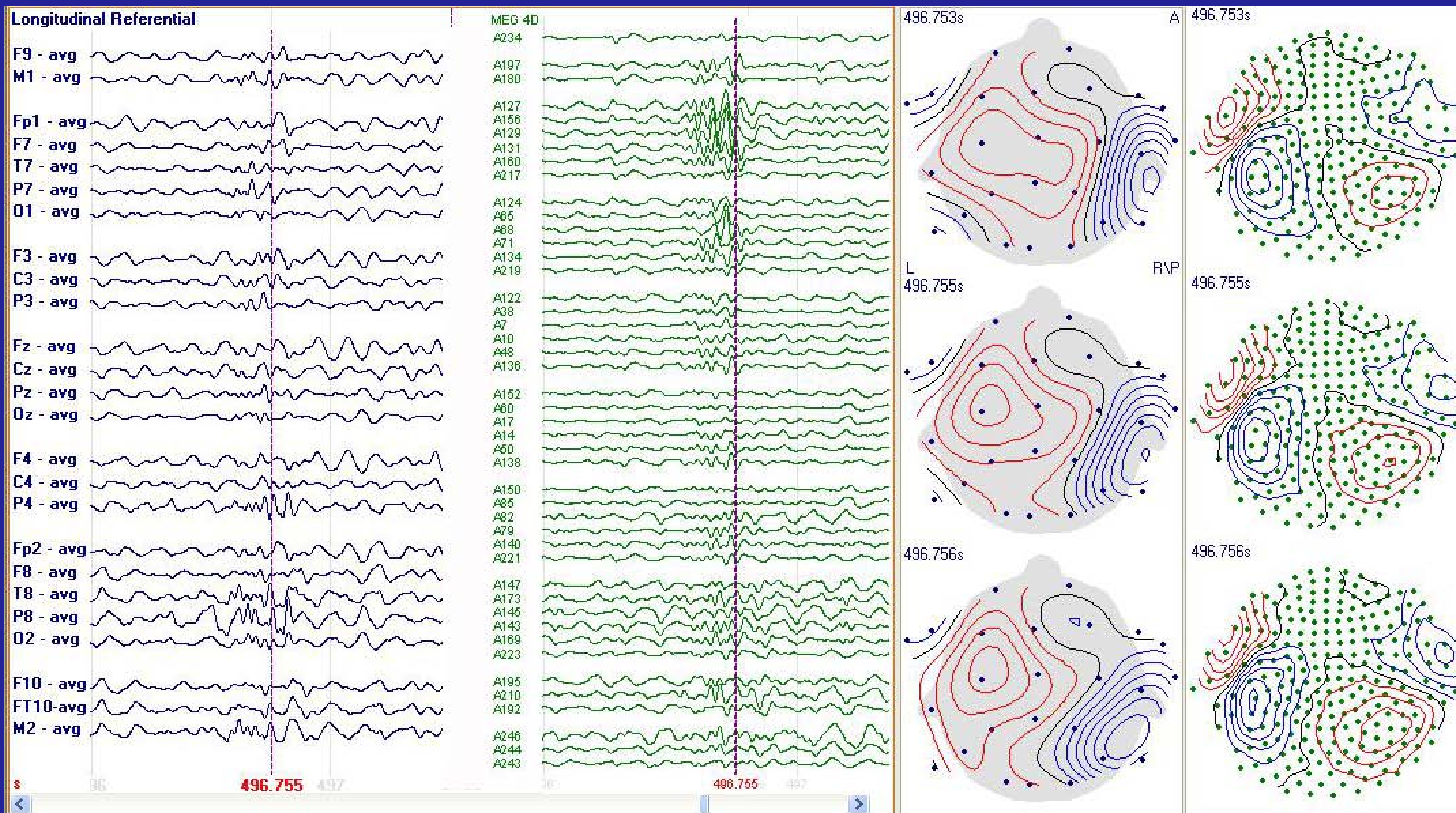

kuhnymeg26
F9 - avg
M1 - avg
F7 - avg
T7 - avg
P7 - avg
FP1 - avg
F3 - avg
C3 - avg
P3 - avg
O1 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
Fp2 - avg
F4 - avg
C4 - avg
P4 - avg
O2 - avg
F8 - avg
T8 - avg
P8 - avg
F10 - avg
FT10-avg
M2 - avg
5.9
4.9
6.8
7.6
6.9
6.6
6.2
7.8
8.5
3.3
7.3
9.8
7.9
2.1
6.3
6.0
4.9
6.1
-1.3
-3.1
-35.0
-12.3
-8.0
-22.0
-33.1
ms
-8.8472 2.9493
-8.85 ms
-2.95 ms
2.95 ms
-8.8ms
A -7.4ms
-5.9ms
L
R\P
-4.4ms
-2.9ms
-1.5ms
0.0ms
1.5ms
2.9ms
-2.9ms
S
L
R\I
-2.9ms
S
A
P\I
-2.9ms
A
L
R\P
Axial
Sagittal
Coronal

MEG vs. EEG

MEG resolves the ambiguity of laterality vs. bilaterality better than EEG

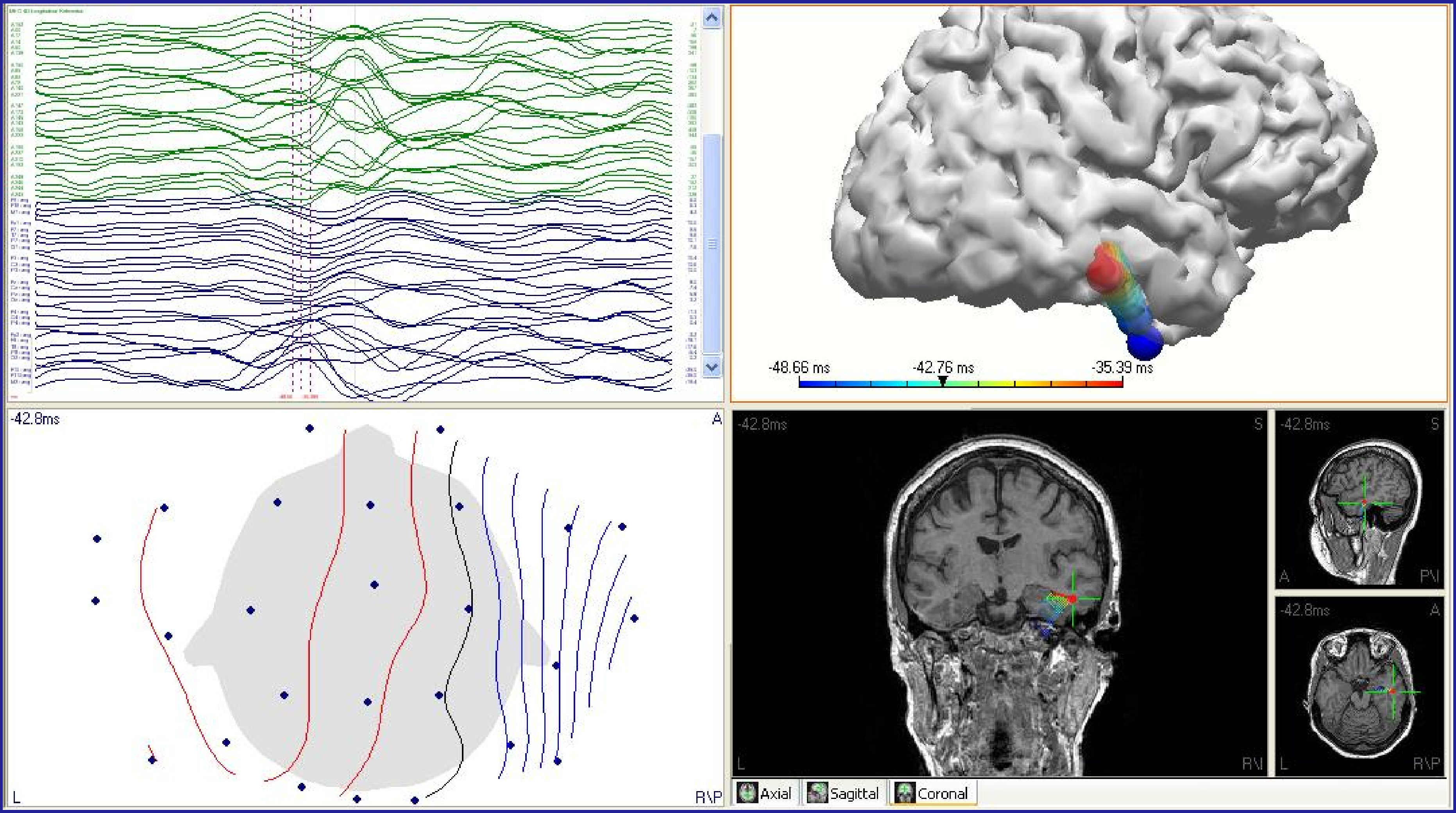
EEG more influenced by far field activity and breach effects

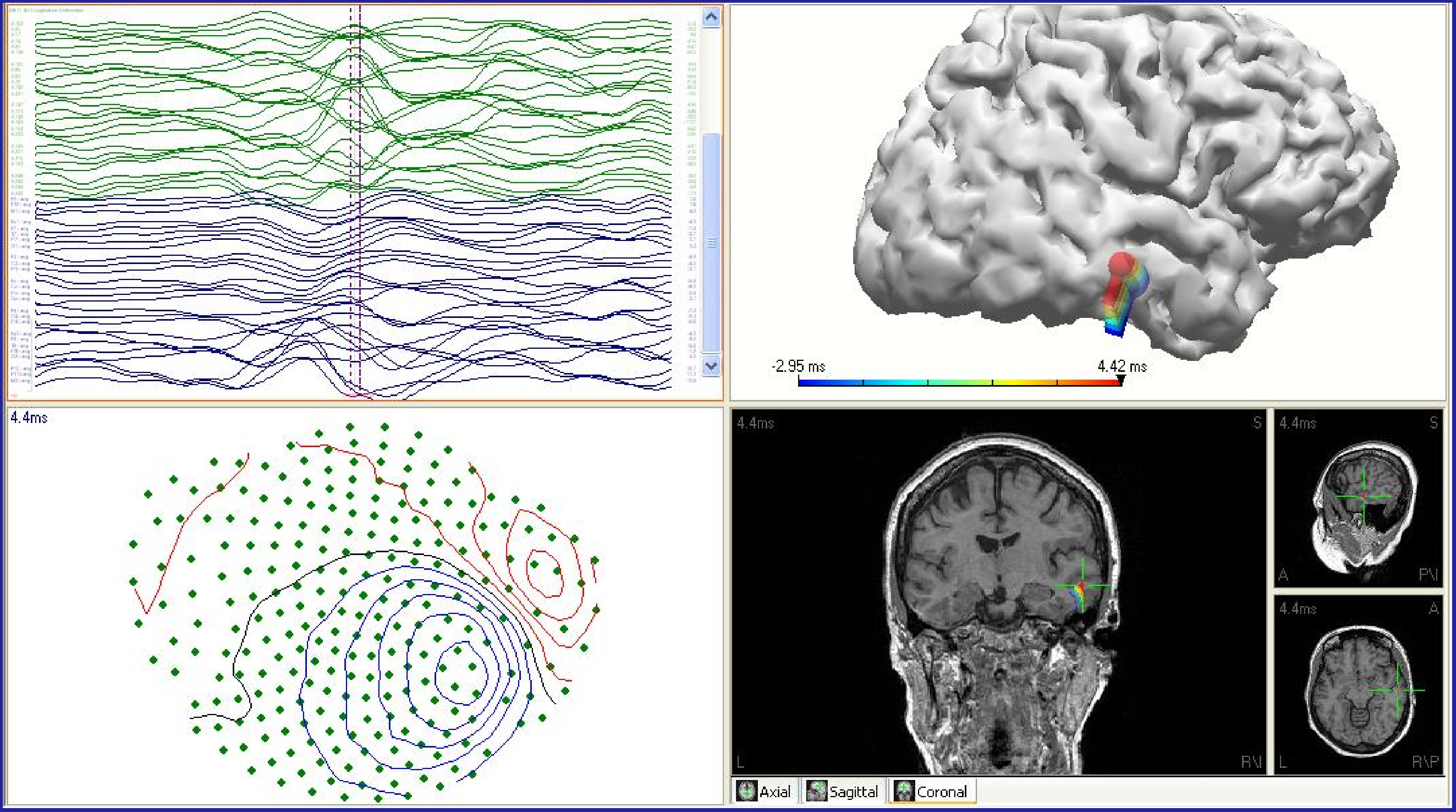

robinson26
f9 - avg
ft9 - avg
m1 - avg
f7 - avg
t7 - avg
p7 - avg
fp1 - avg
f3 - avg
c3 - avg
p3 - avg
o1 - avg
fz - avg
cz - avg
pz - avg
oz - avg
fp2 - avg
f4 - avg
c4 - avg
p4 - avg
o2 - avg
f8 - avg
t8 - avg
p8 - avg
f10 - avg
ft10-avg
m2 - avg
-15.9
-21.0
-24.5
-13.1
-13.2
-12.6
-6.3
1.3
-0.5
-1.4
-7.0
10.0
10.0
2.1
-5.7
9.9
20.9
20.0
11.4
0.4
18.6
17.1
9.3
0.5
0.2
-10.3
ms
-38.338
0
-4.4235

-41.3ms
-41.3ms
A
-7.4ms
-7.4ms
A
L
R\P
L
R\P
-38.3ms
-38.3ms
-4.4ms
-4.4ms
-35.4ms
-35.4ms
-1.5ms
-1.5ms

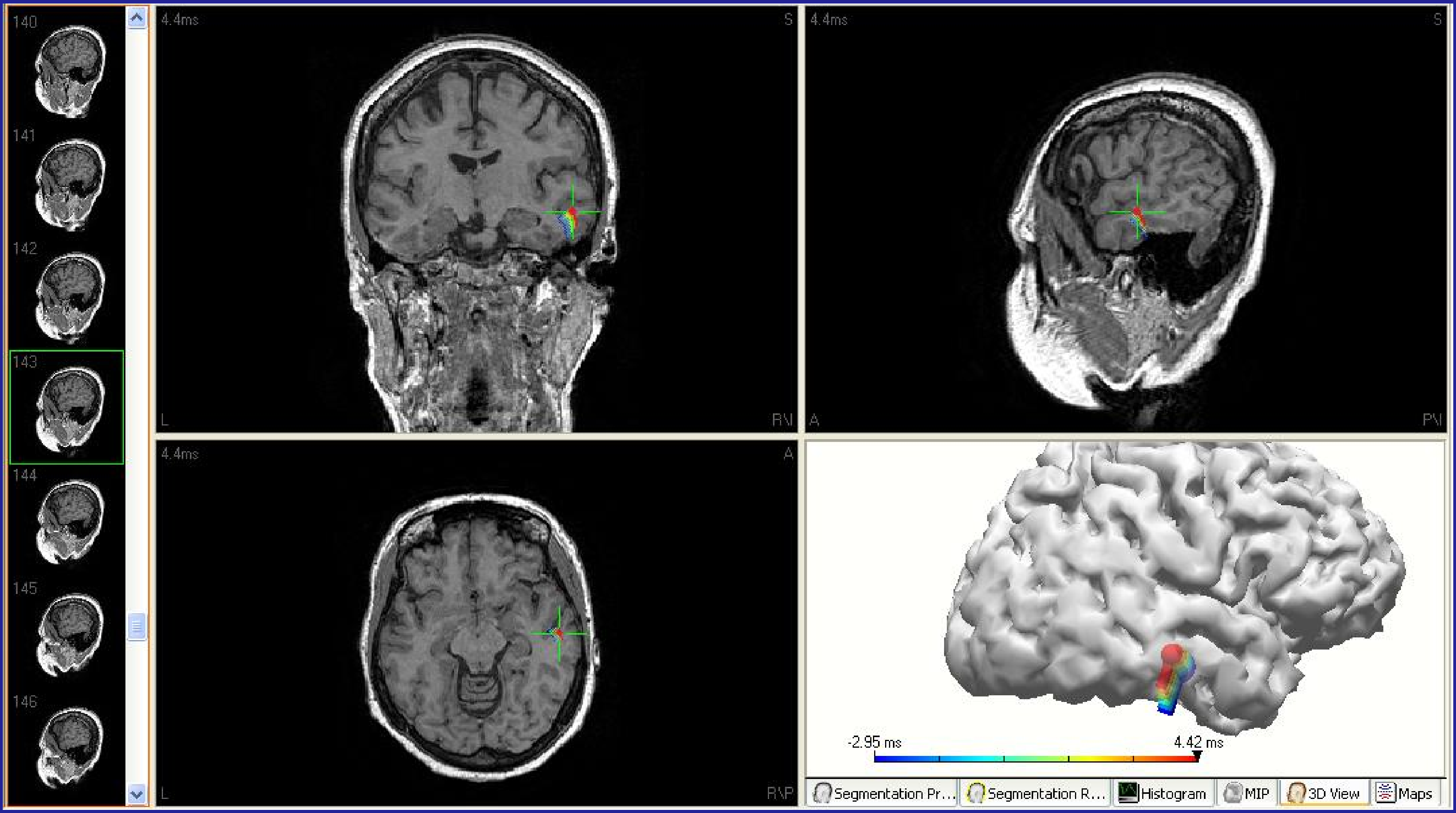

Longitudinal Referential
F9 - avg
M1 - avg
Fp1 - avg
F7 - avg
T7 - avg
P7 - avg
O1 - avg
F3 - avg
C3 - avg
P3 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
F4 - avg
C4 - avg
P4 - avg
Fp2 - avg
F8 - avg
T8 - avg
P8 - avg
O2 - avg
F10 - avg
FT10-avg
M2 - avg
496.755
MEG 4D
A234
A197
A180
A127
A156
A129
A131
A160
A217
A124
A65
A68
A71
A134
A219
A122
A38
A7
A10
A48
A136
A152
A60
A17
A14
A50
A138
A150
A85
A82
A79
A140
A221
A147
A173
A145
A143
A169
A223
A195
A210
A192
A246
A244
A243
496.755
496.753s
A
L
R\P
496.755s
496.756s
496.753s
496.755s
496.756s

MEG vs EEG

Because MEG can lag, as well as lead, EEG, both are needed to define propagation fully


-48.66 ms
-42.76 ms
-35.39 ms
-42.8ms
A
L
R\P
-42.8ms
S
L
R\I
-42.8ms
S
A
P\I
-42.8ms
A
L
R\P
Axial
Sagittal
Coronal

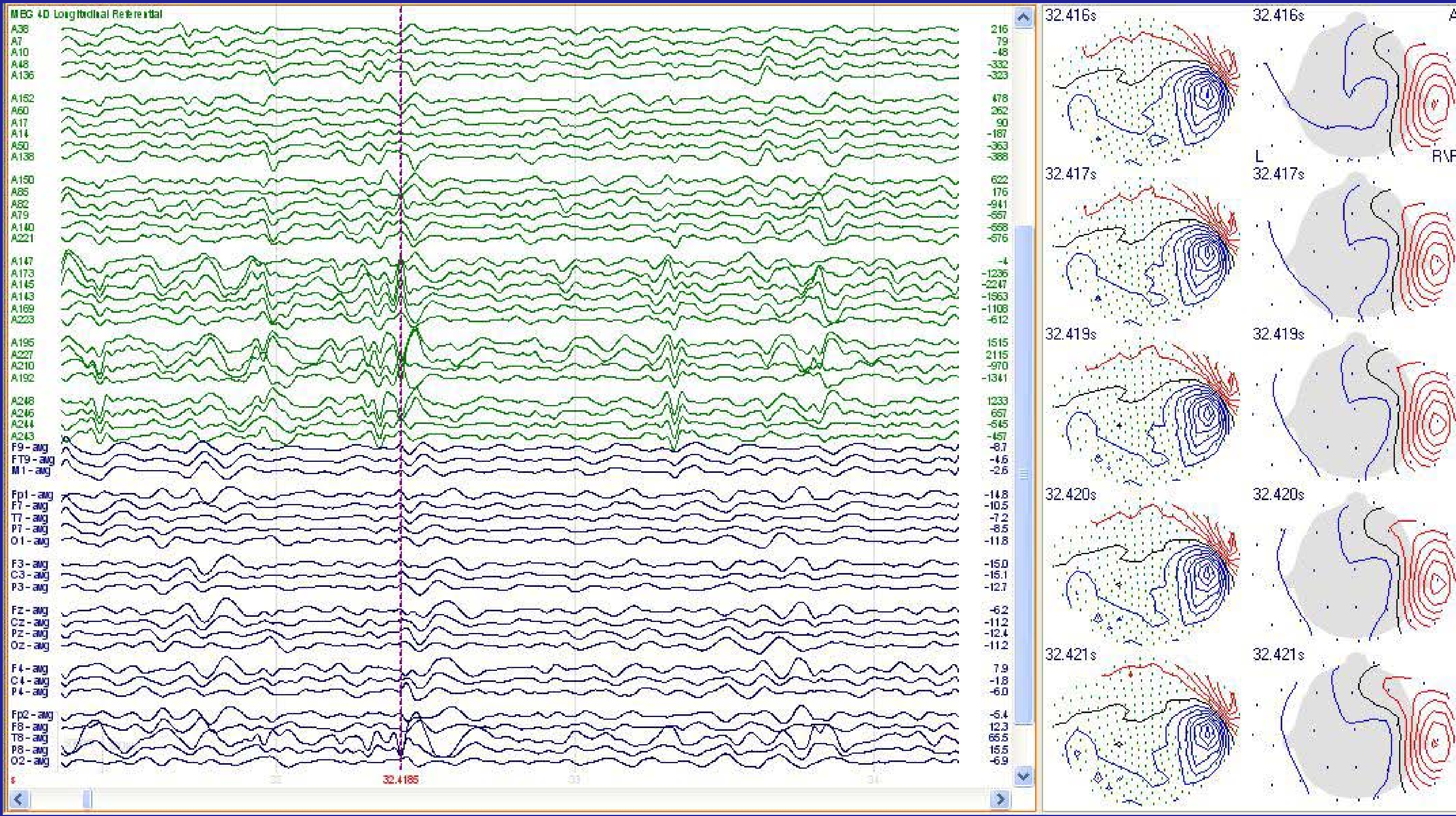

-2.95 ms
4.42 ms
4.4ms
4.4ms
S
L
R\I
4.4ms
S
A
P\I
4.4ms
A
L
R\P
Axial
Sagittal
Coronal

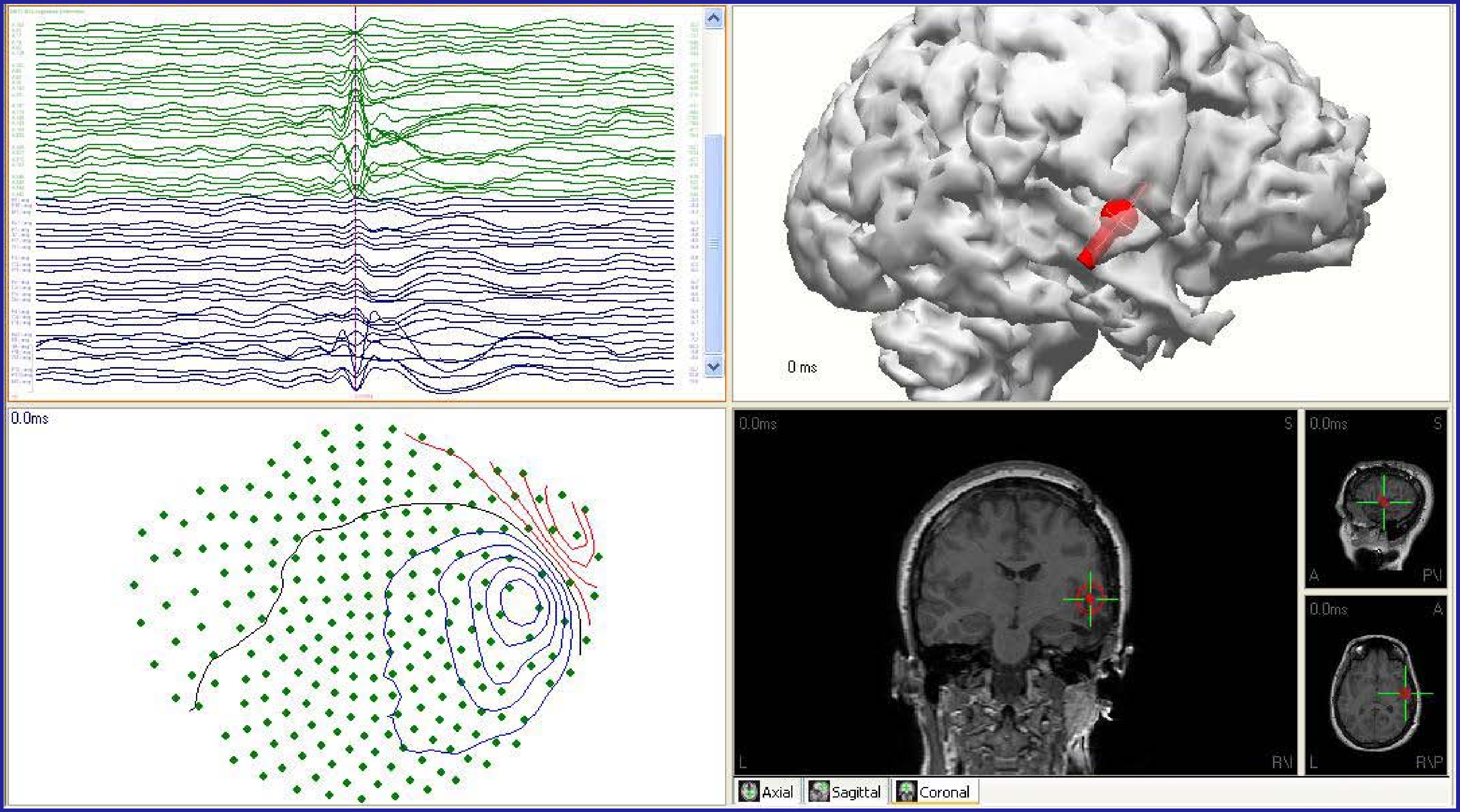


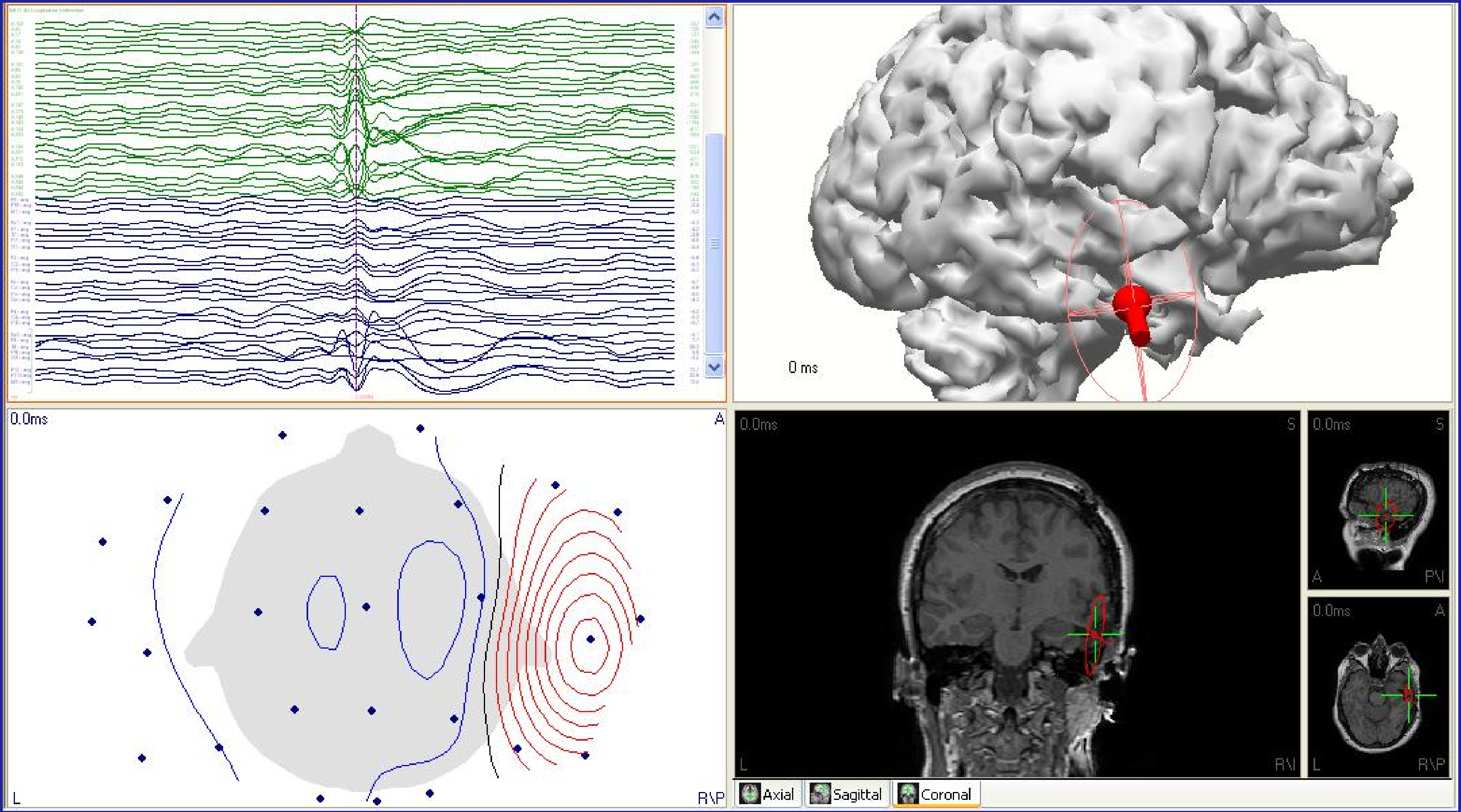
140
141
142
143
144
145
146
4.4ms
S
L
R\I
A
P\I
R\P
-2.95 ms
4.42 ms
Segmentation Pr...
Segmentation R...
Histogram
MIP
3D View
Maps

EEG/MEG Dipole Interpretation

- EEG dipole localization is sub-lobar
- EEG dipole orientation identifies cortical patch within that region and represents all orientational components
- MEG dipole localization can be nearly gyrus/sulcus specific
- MEG dipole orientation is restricted to the tangential component


MEG 4D Longitudinal Referential
A38
A7
A10
A48
A136
A152
A60
A17
A14
A50
A138
A150
A85
A82
A79
A140
A221
A147
A173
A145
A143
A169
A223
A195
A227
A210
A192
A248
A246
A244
A243
F9 - avg
FT9 - avg
M1 - avg
Fp1 - avg
F7 - avg
T7 - avg
P7 - avg
O1 - avg
F3 - avg
C3 - avg
P3 - avg
Fz - avg
Cz - avg
Pz - avg
Oz - avg
F4 - avg
C4 - avg
P4 - avg
Fp2 - avg
F8 - avg
T8 - avg
P8 - avg
O2 - avg
32.4186
32.416s
32.417s
32.419s
32.420s
32.421s
A
L
R\P


0 ms
0.0ms
0.0ms
S
L
R\I
0.0ms
S
A
P\I
0.0ms
A
L
R\P
Axial
Sagittal
Coronal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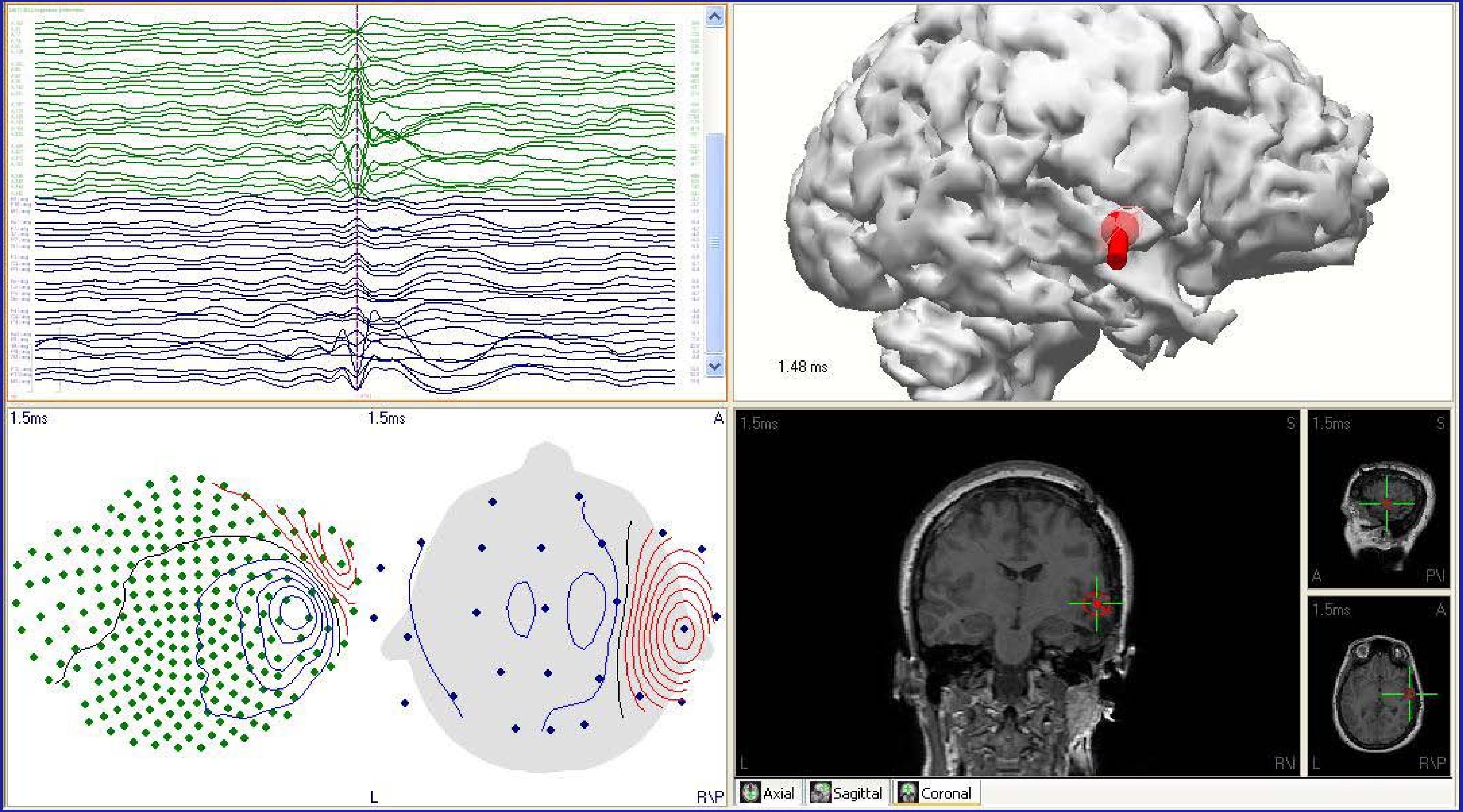
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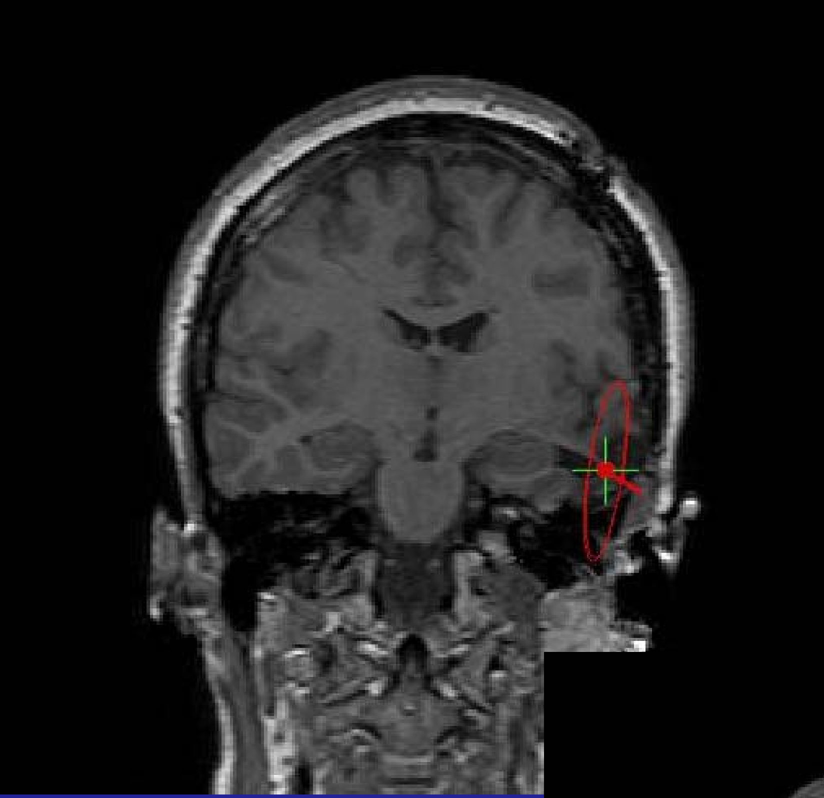

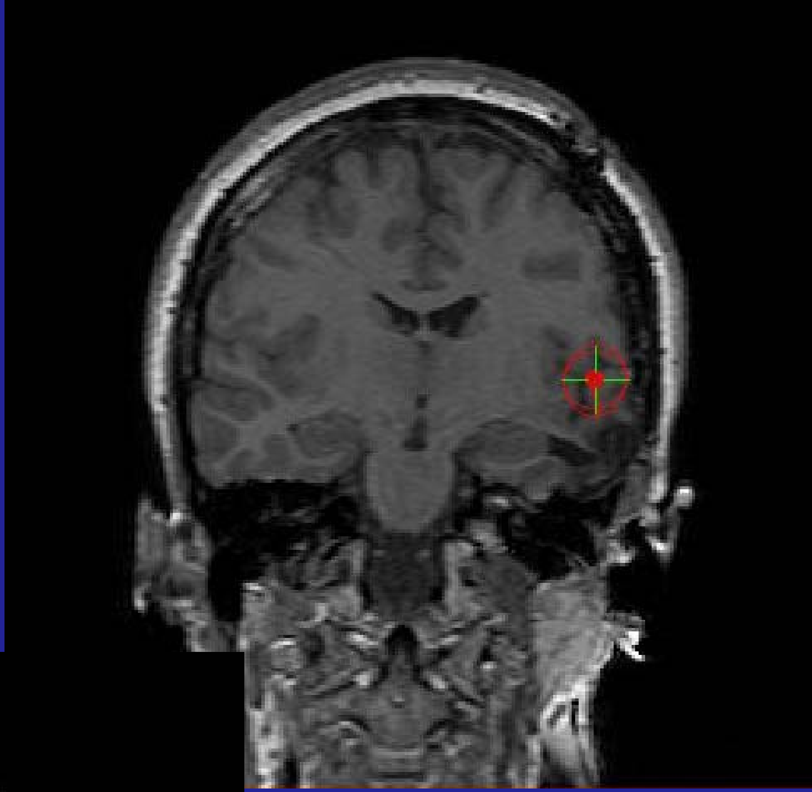

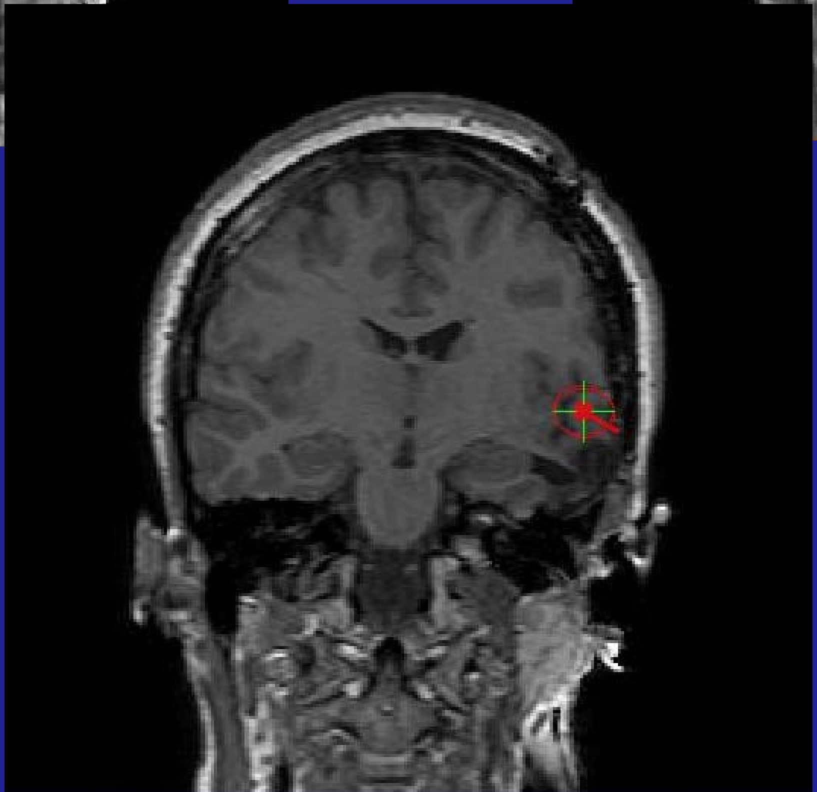

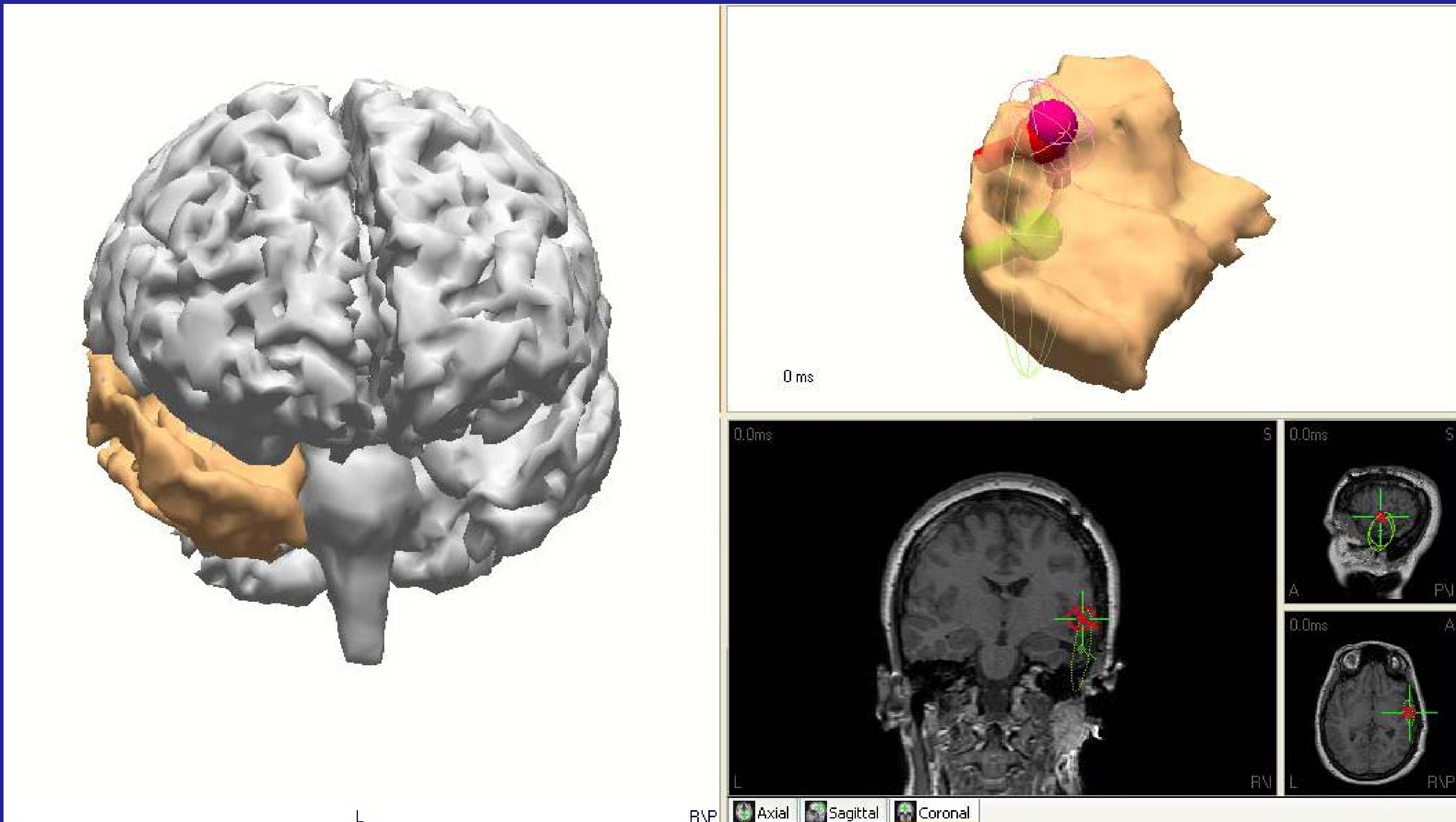
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Bottom Line Comparison

MEG sees a window of brain activity with more sensitivity and clarity than EEG

Localization of that activity with source models is more accurate than with EEG

EEG sees a more complete picture of brain activity but less clearly than MEG

Localization with EEG source models is less precise, but orientation information is more complete than MEG

Conclusions

MEG and EEG strengths are complementary!

Source modeling of both MEG and EEG improves the characterization of spike and seizure sources and subsequent propagation

Clinical epilepsy evaluations should whenever possible include source models of both data