

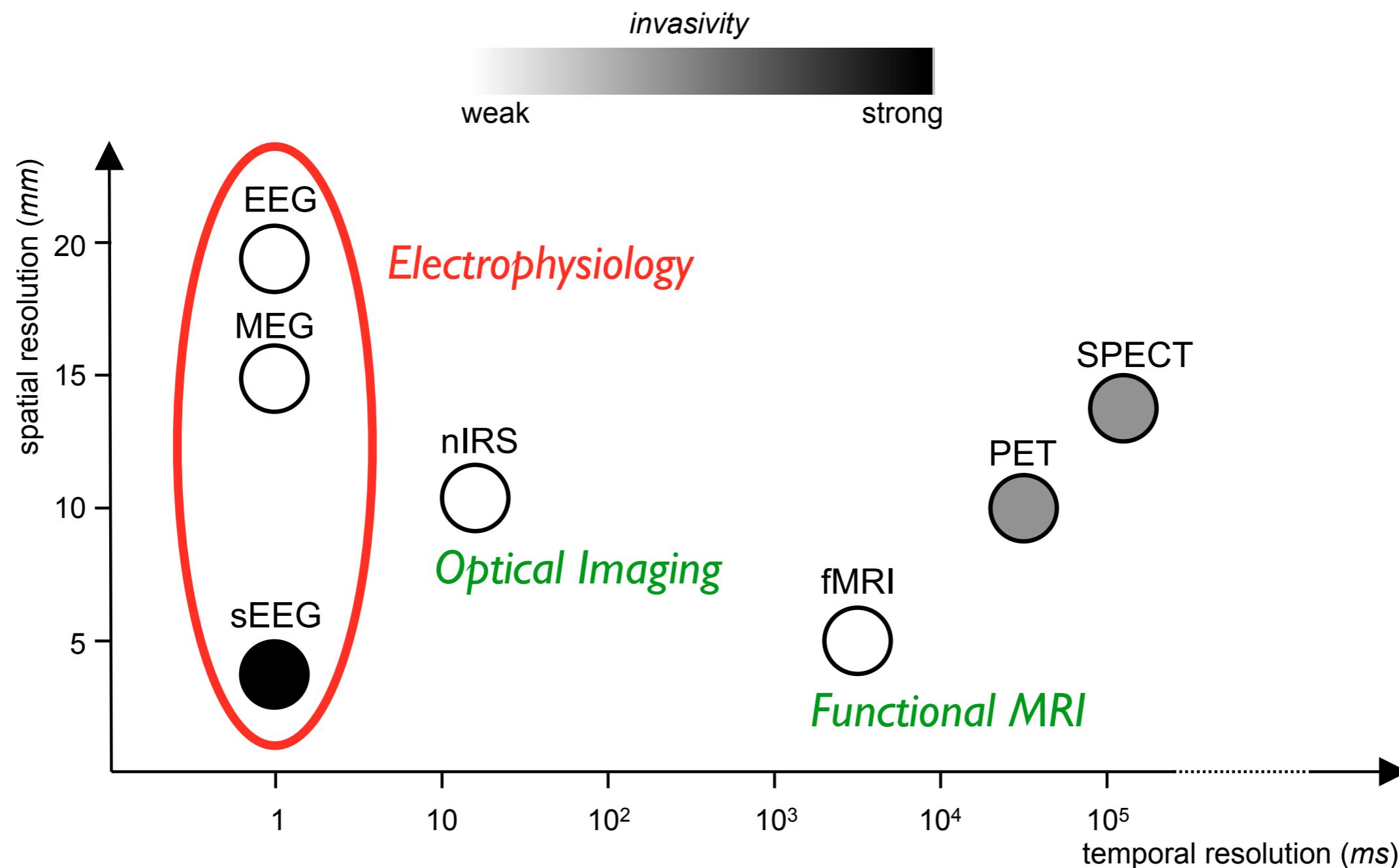
Functional Brain Imaging with MEG (Magnetoencephalography) and EEG (Electroencephalography)

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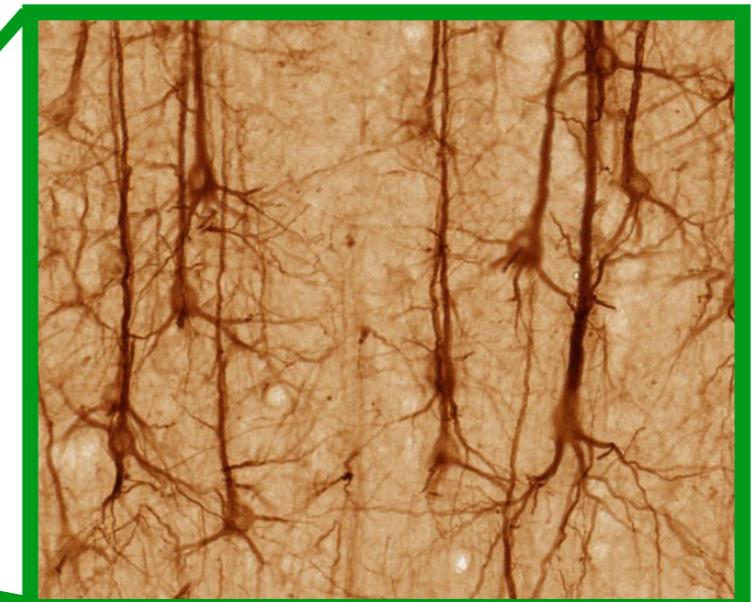
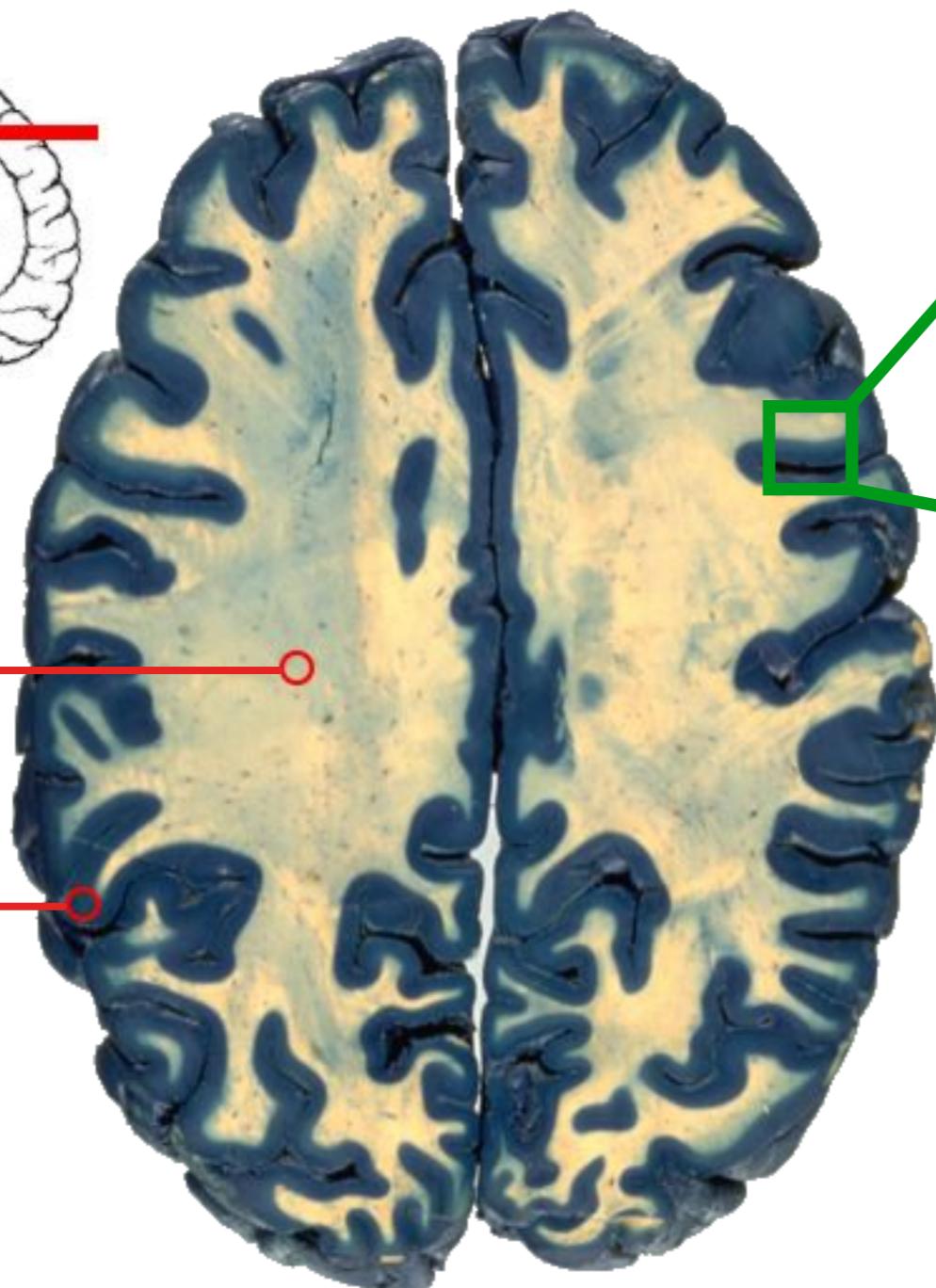
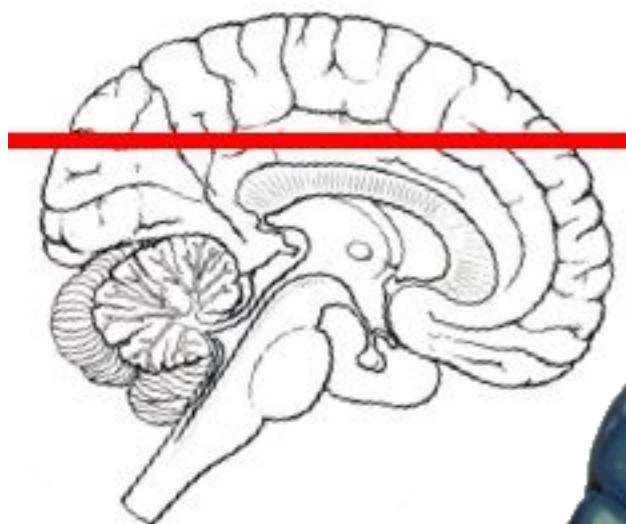
Functional neuroimaging landscape



Electrophysiology: Origin of the signals

Brain anatomy

Axial slice

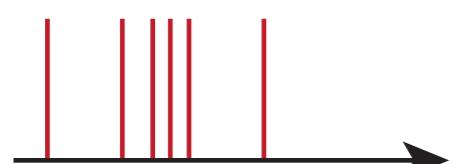


**Neurons
in the gray matter**

Source: dartmouth.edu

APs (action potentials) & PSPs (post-synaptic potentials)

Action Potentials



Axon

Synapse

Neuron body

Dendrite

PSP

1 ms

AP

100 mV

10 mV

10 ms

PSP

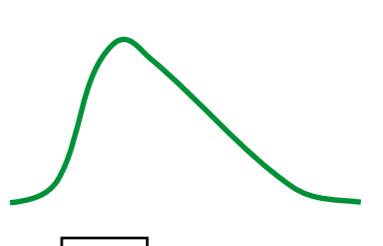
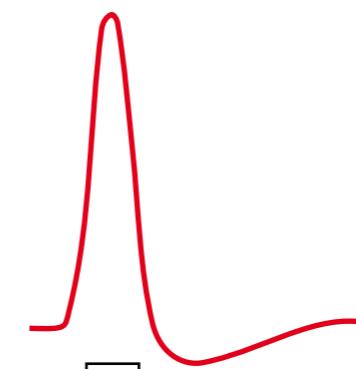
Action Potentials



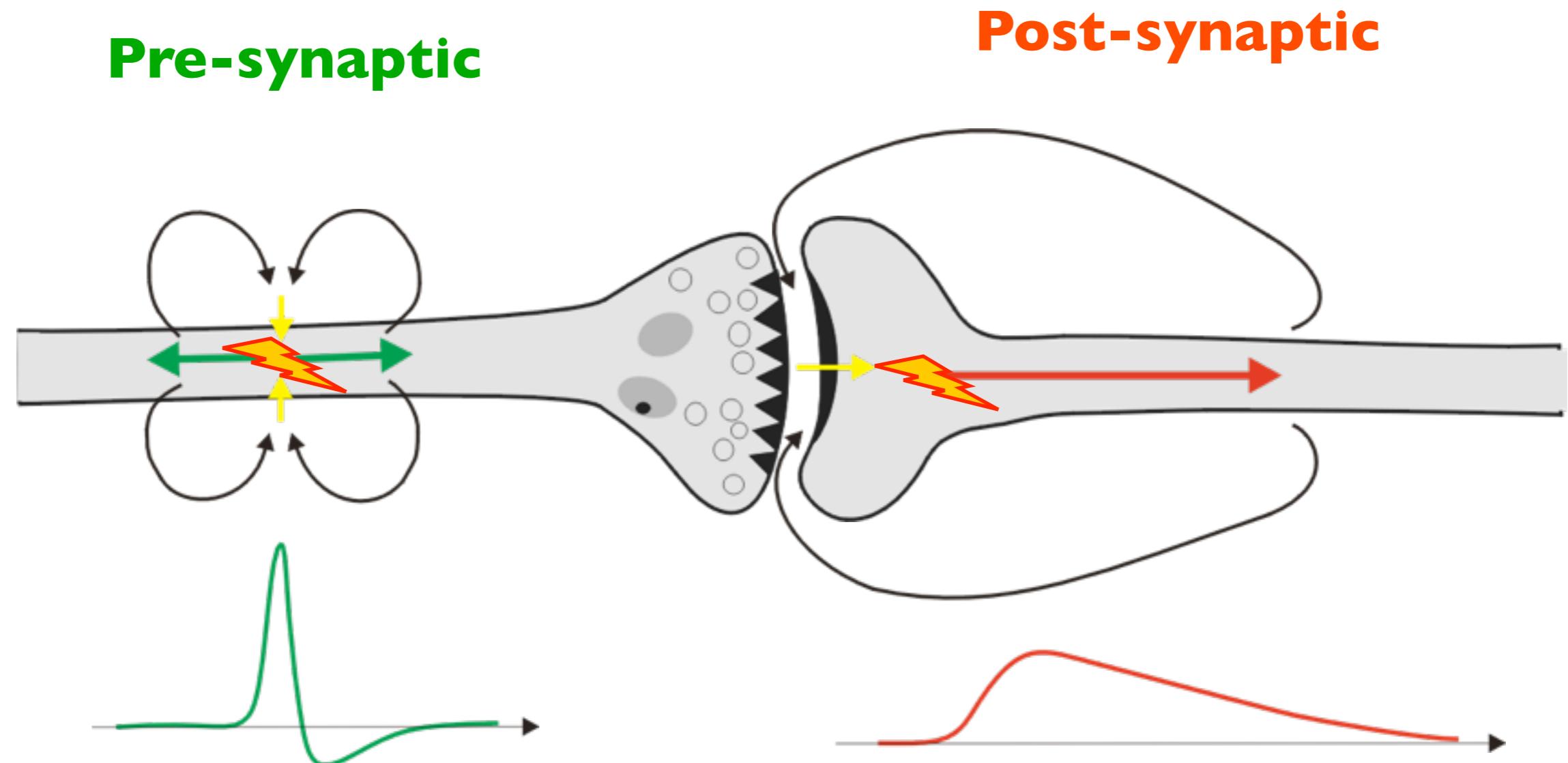
Axon

Spike initiation zone

Temporal dynamics



APs (action potentials) & PSPs (post-synaptic potentials)

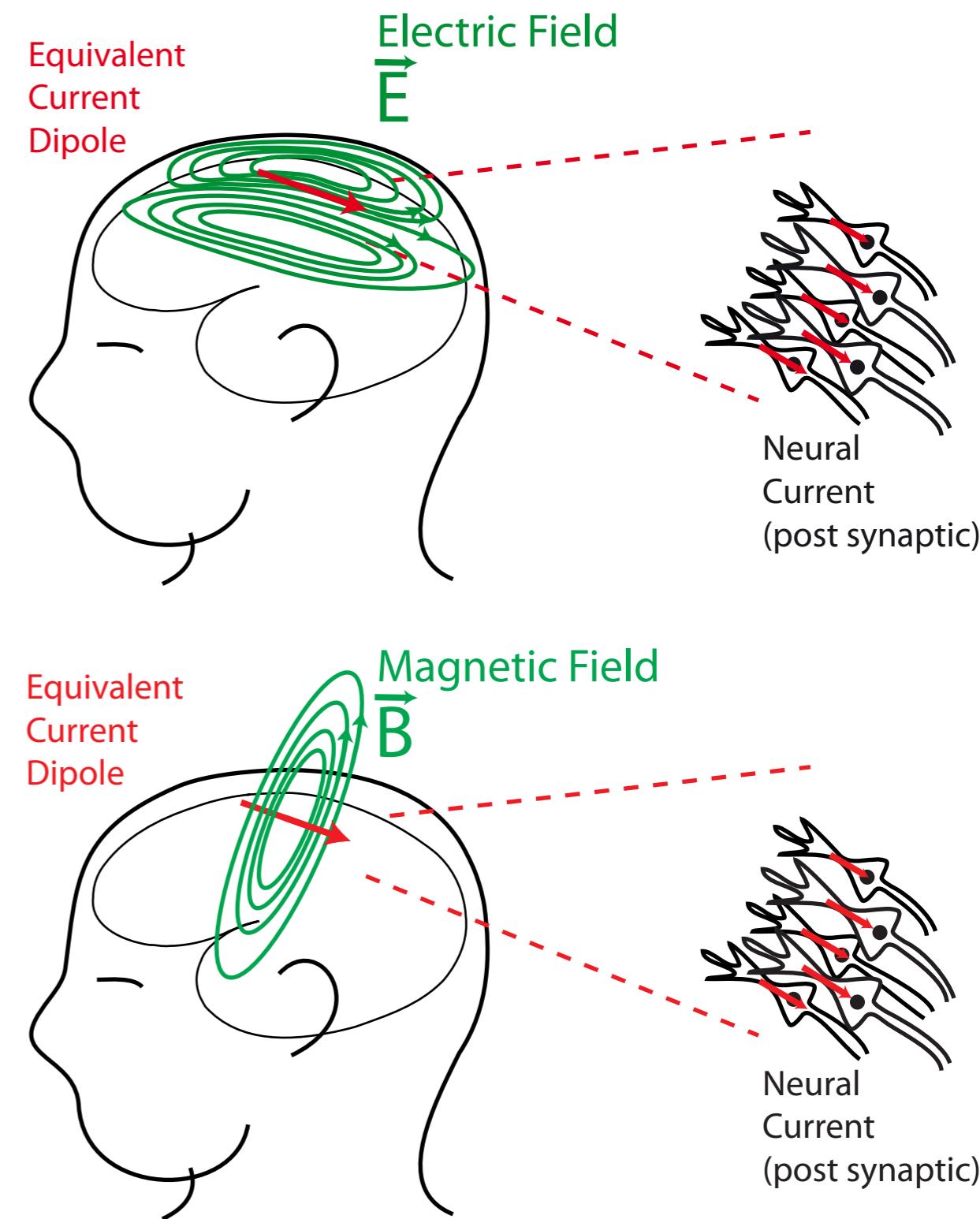
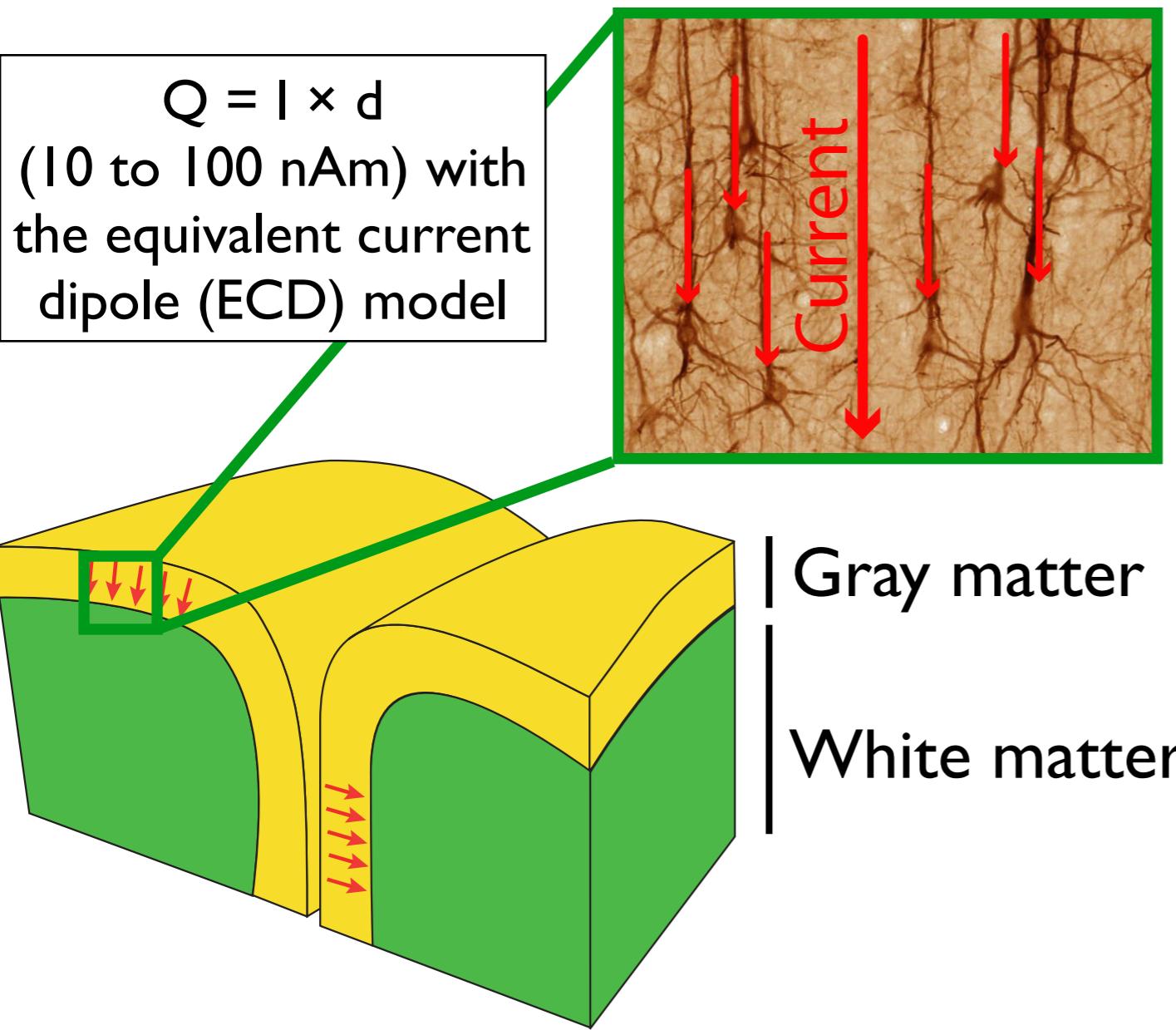


Action potentials:
fields diminish too rapidly to sum

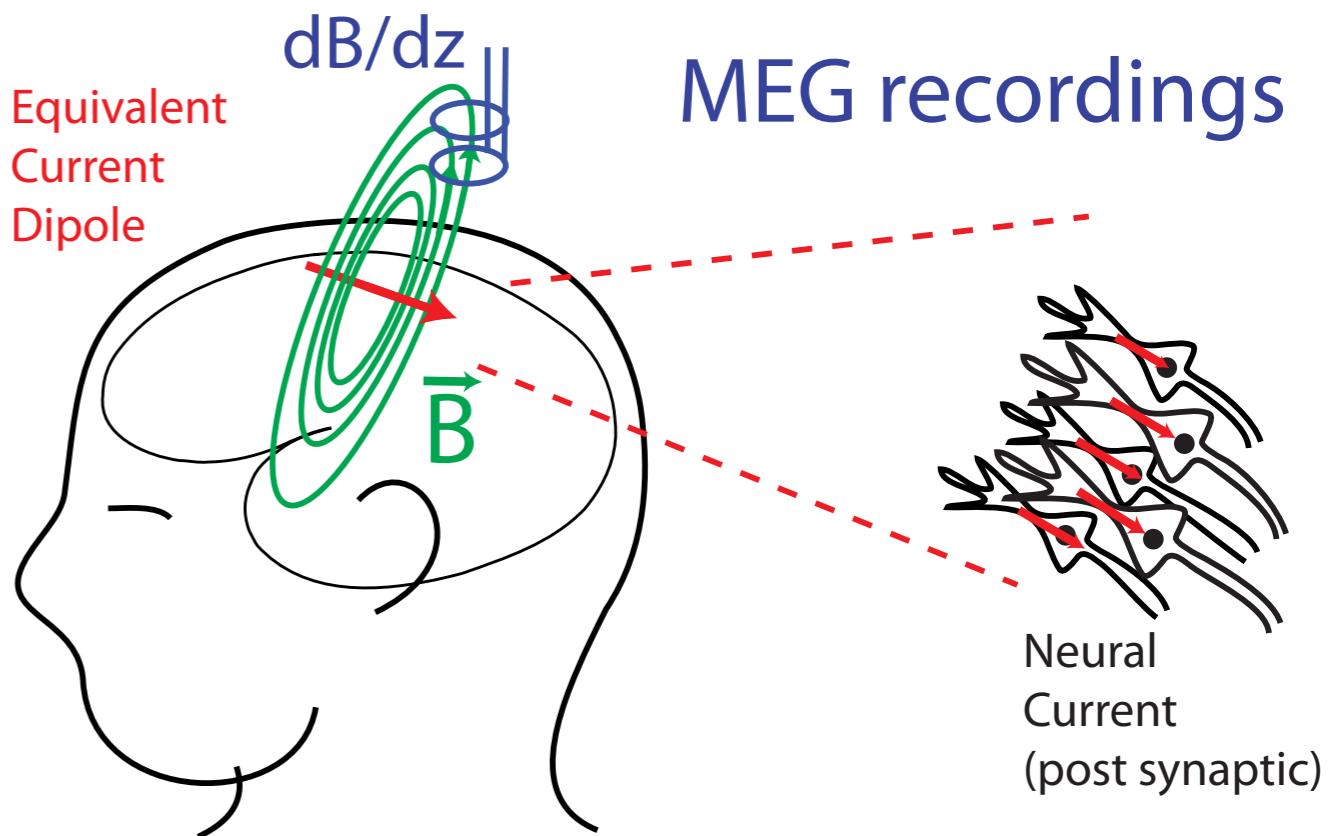
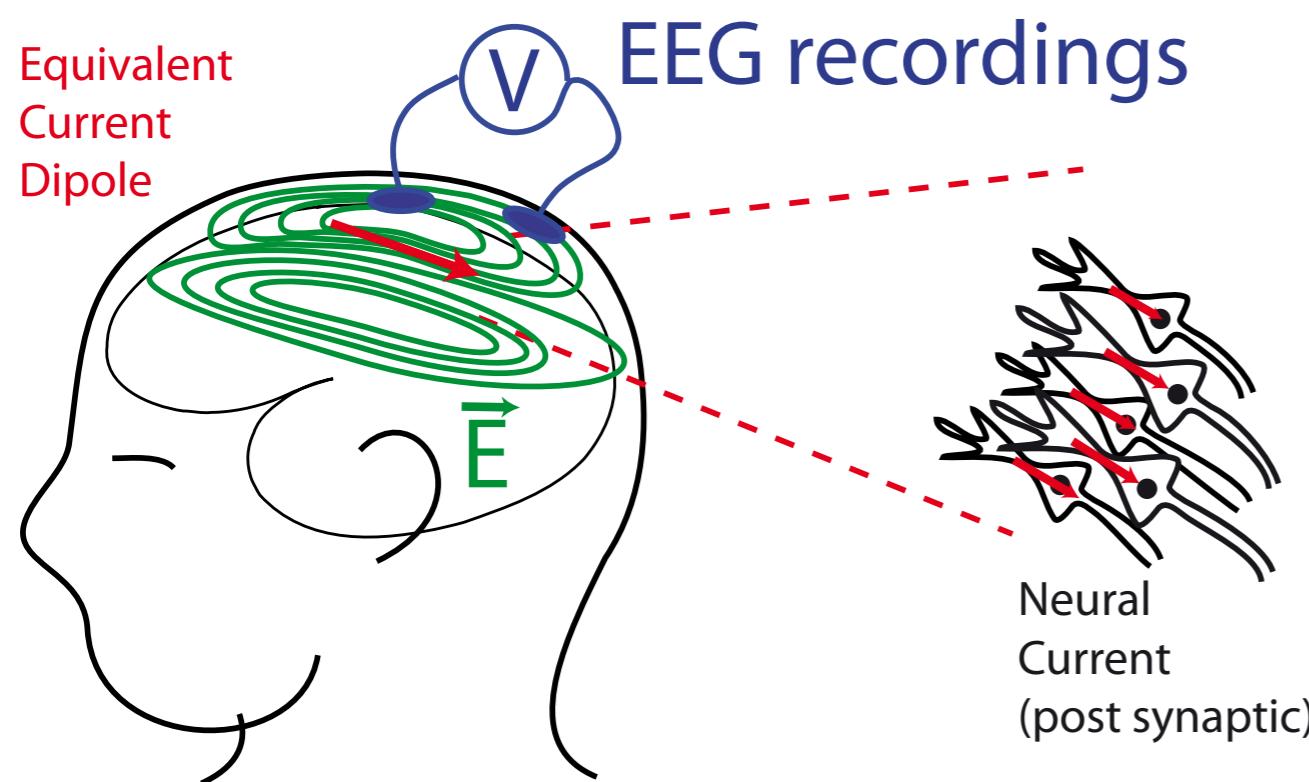
Postsynaptic currents:
fields diminish gradually

Neurons as current generators

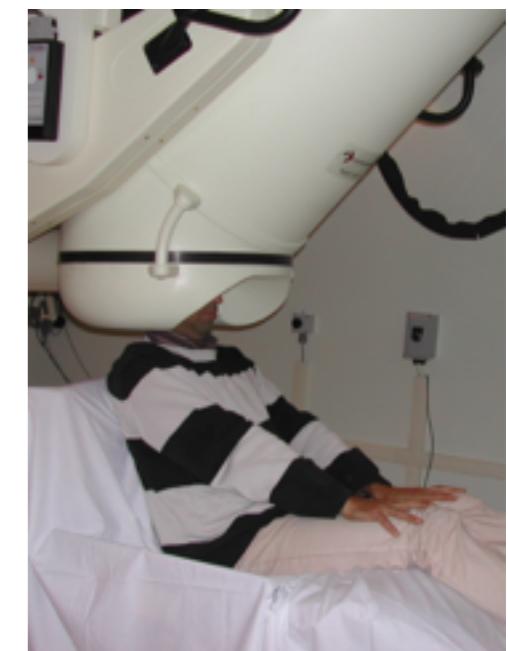
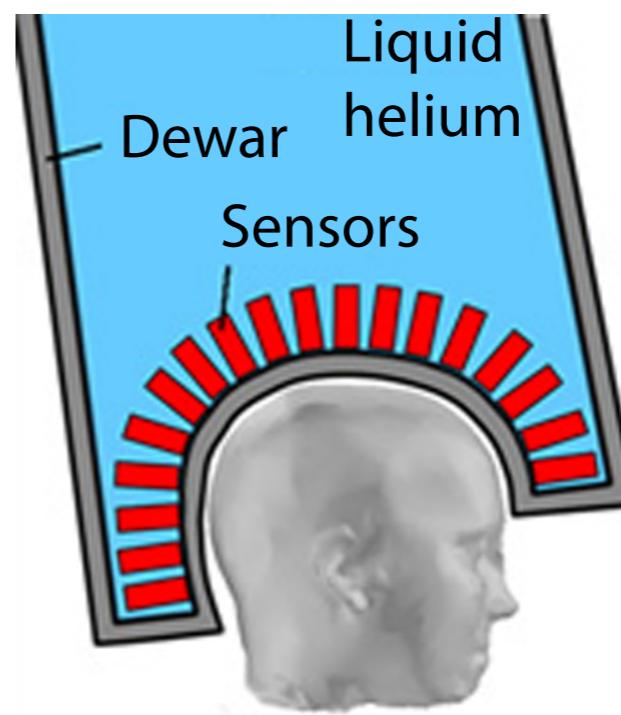
Large cortical pyramidal cells organized in macro-assemblies with their **dendrites** normally oriented to the local cortical surface



EEG & MEG systems

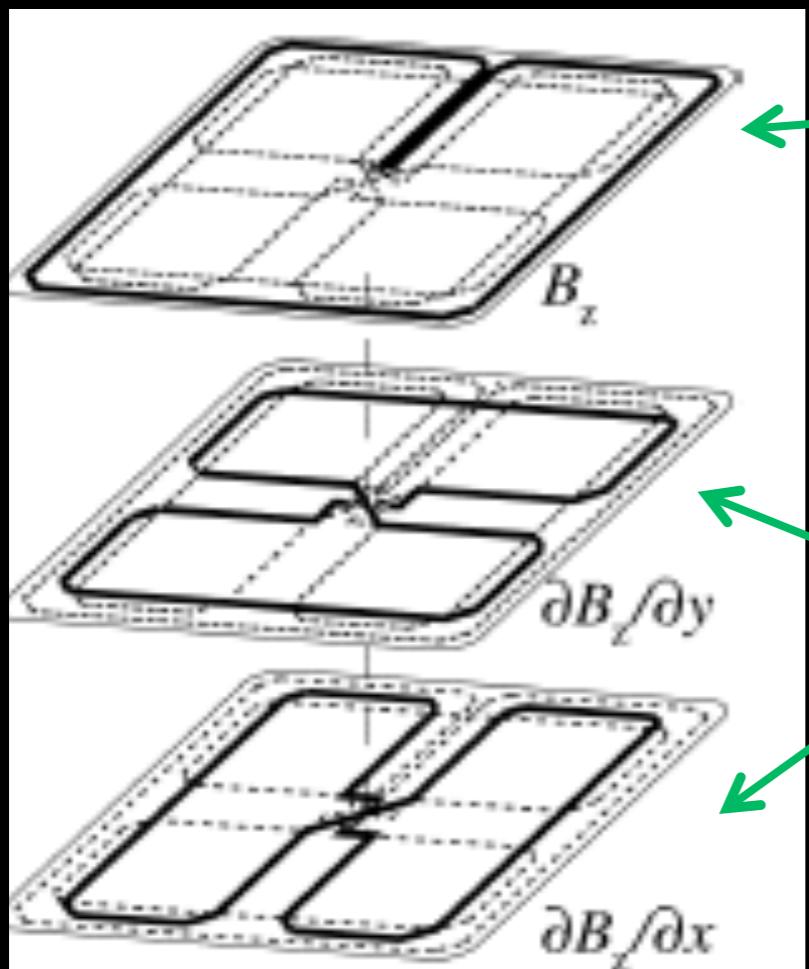


First EEG recordings in 1929 by H. Berger



Hôpital La Timone Marseille, France

MEG sensors



Magnetometer

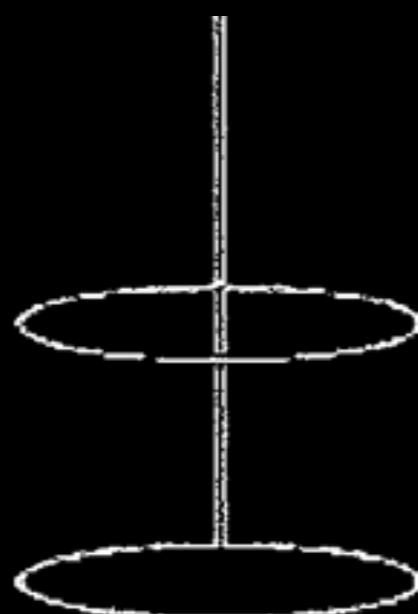
- General magnetic fields
- Very sensitive overall, noisy

Planar Gradiometer

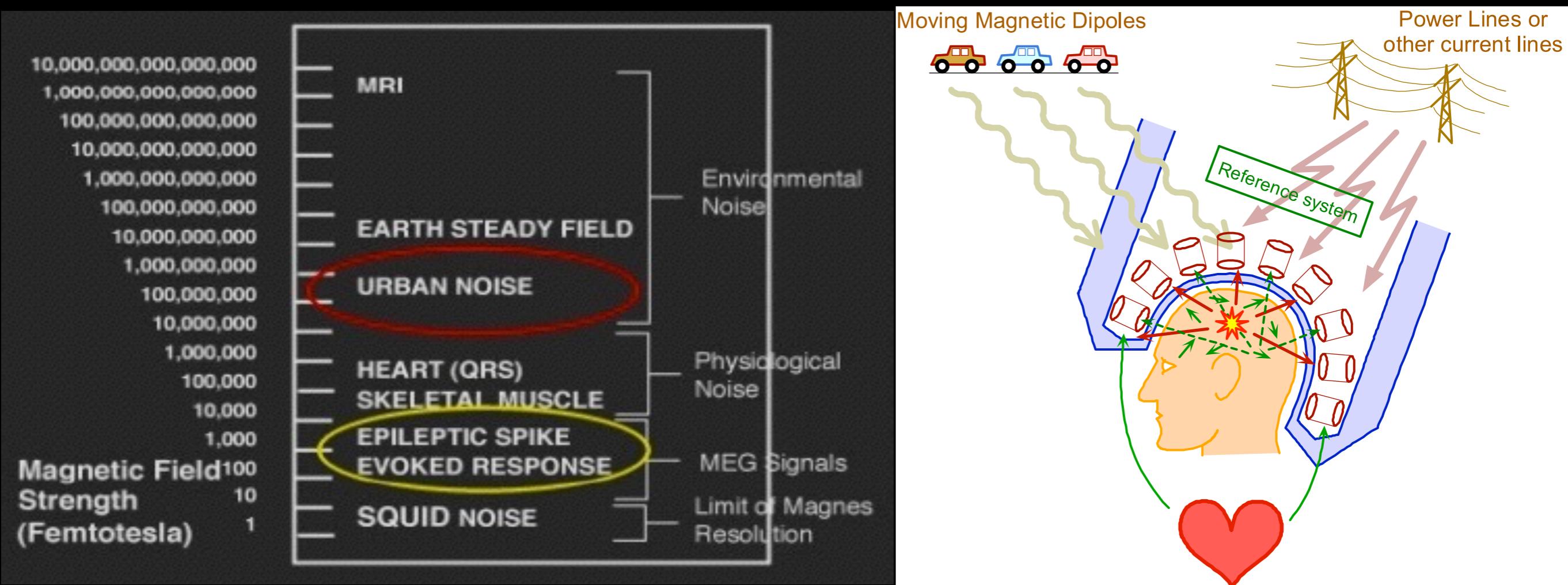
- Focal magnetic fields
- Most sensitive to fields directly underneath

Axial Gradiometer

- Focal magnetic fields
- Most sensitive to fields directly underneath it



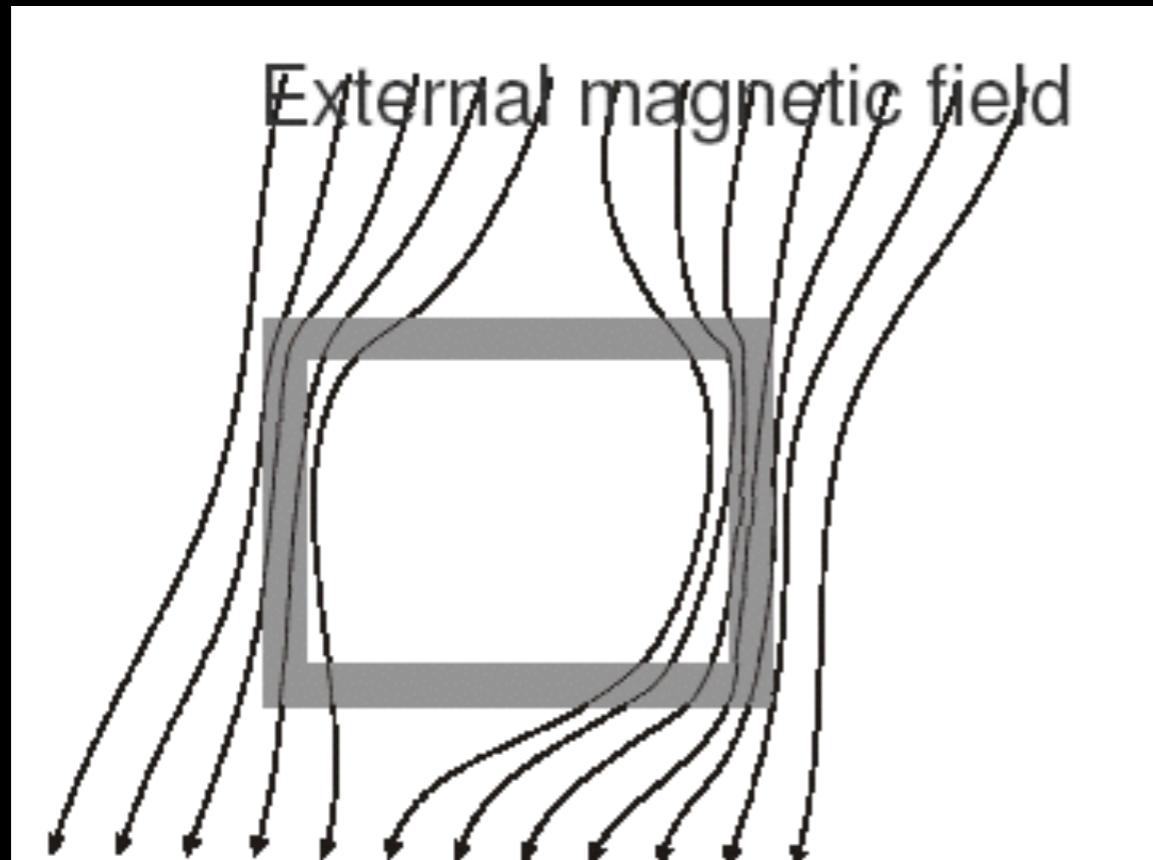
Magnetic shielding



Hence the importance of shielding...

Magnetic shielding

Magnetically Shielded Room (MSR)



3-ply μ -metal room



A machine (Neuromag vectorview)



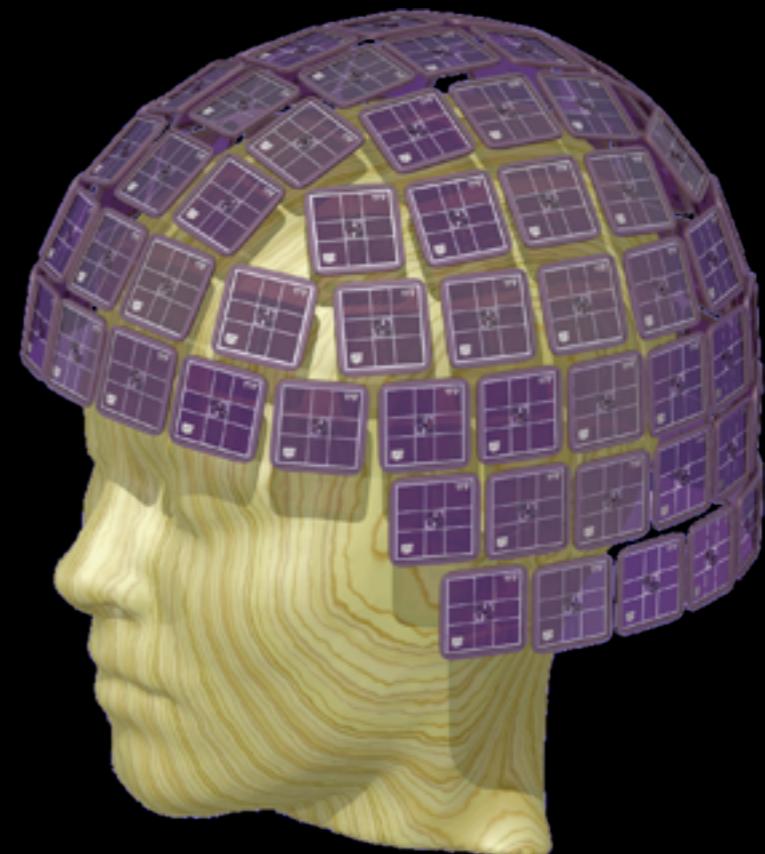
No Magnet

Quiet

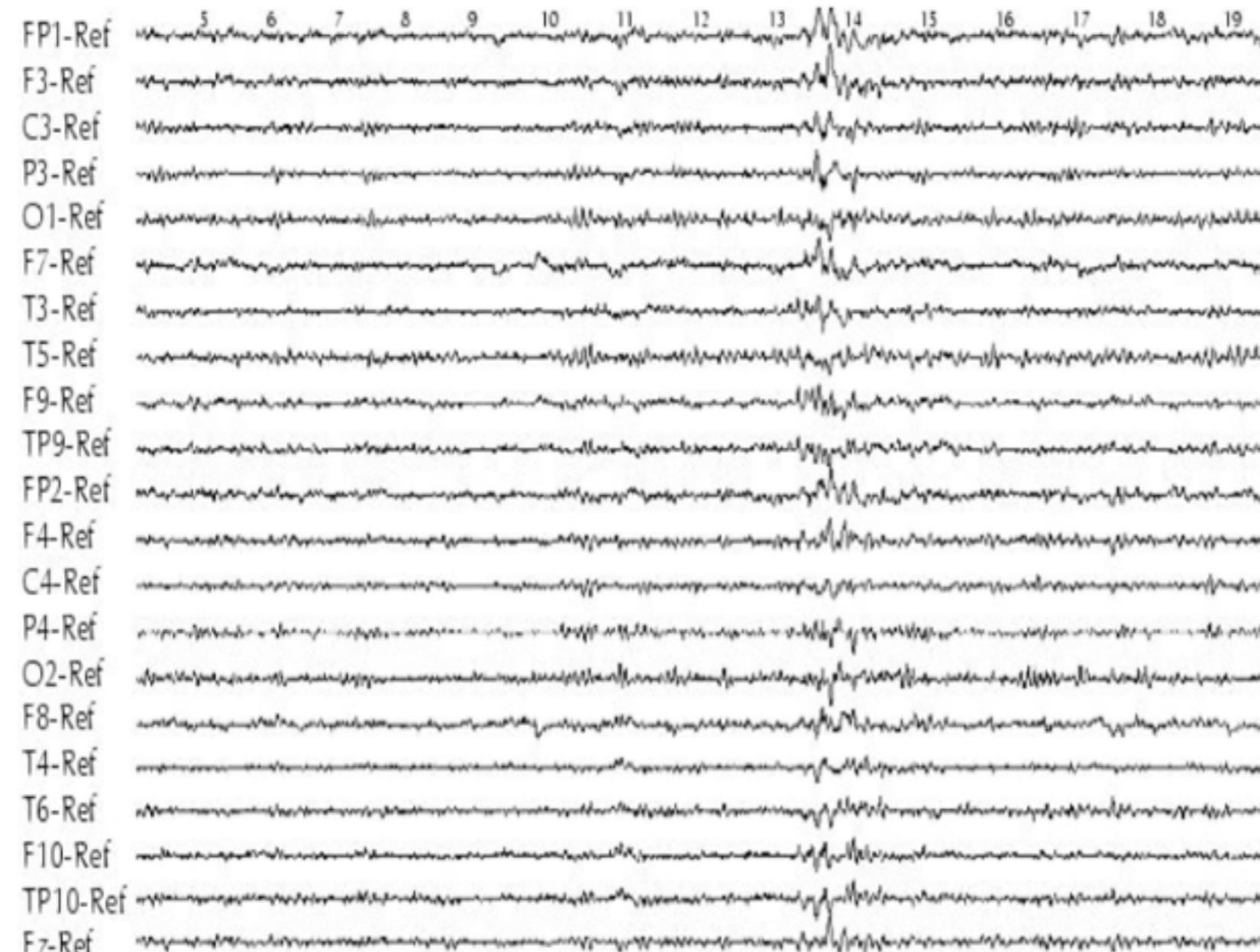
Machine makes no noise

Participant can sit or lay down

Can record 128 EEG
simultaneously



M/EEG Measurements



Sample EEG measurements

EEG :

- \approx 100 sensors

MEG :

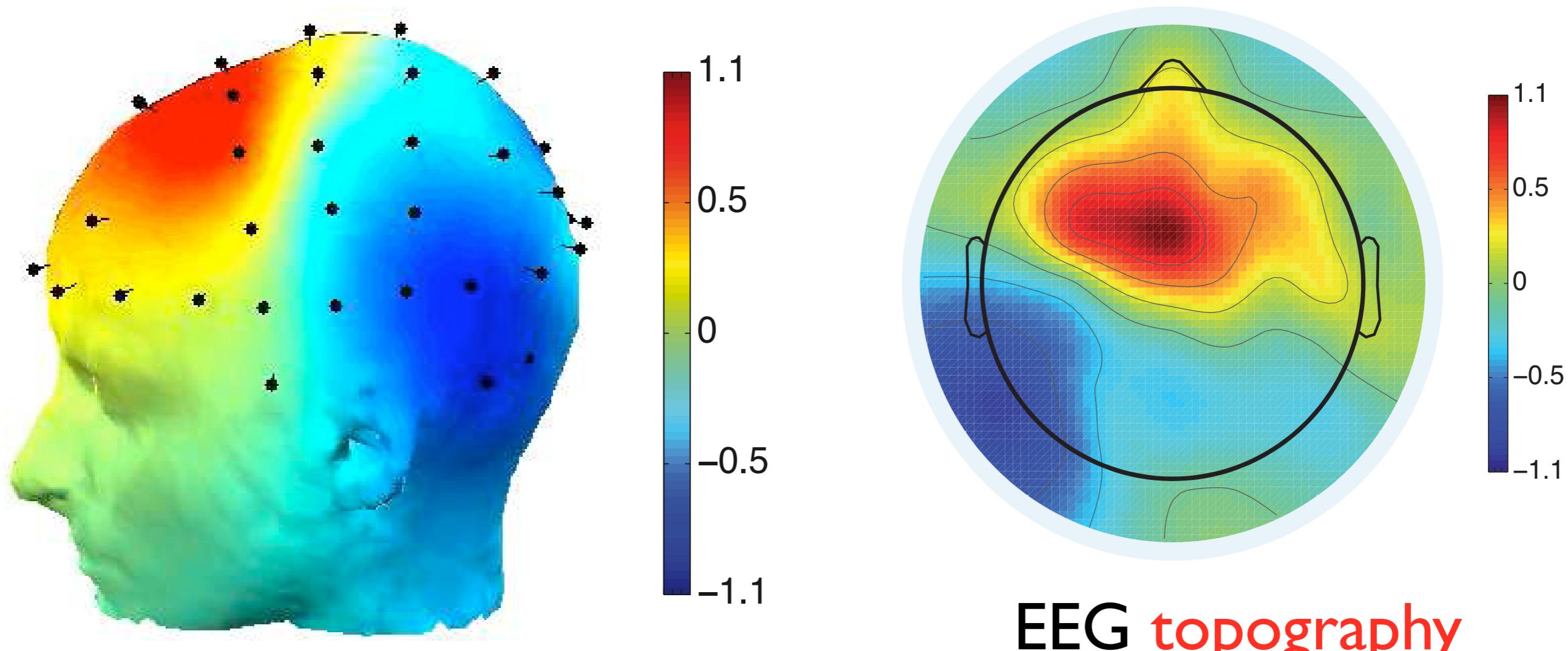
- \approx 150 to 300 sensors

Sampling between 250
and 1000 Hz

High temporal
resolution but what
about spatial
resolution?

M/EEG Measurements

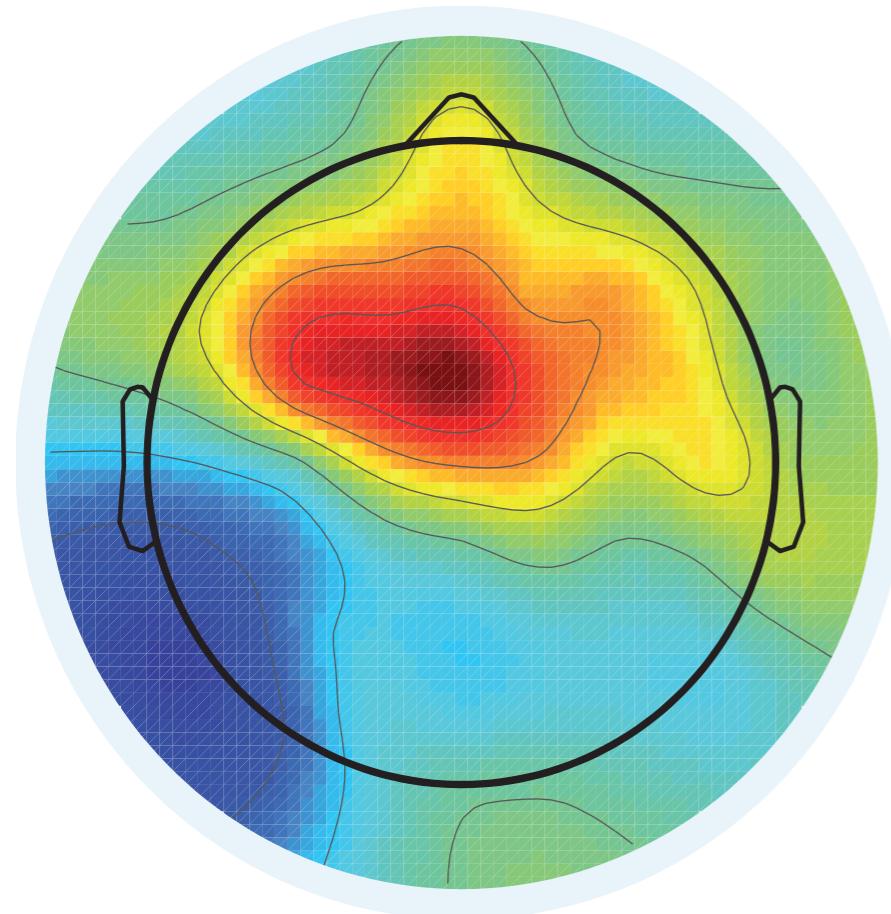
At each time instant EEG sensors measure a potential field



Remark: Such a smooth potential field confirms the presence of current generators within the head

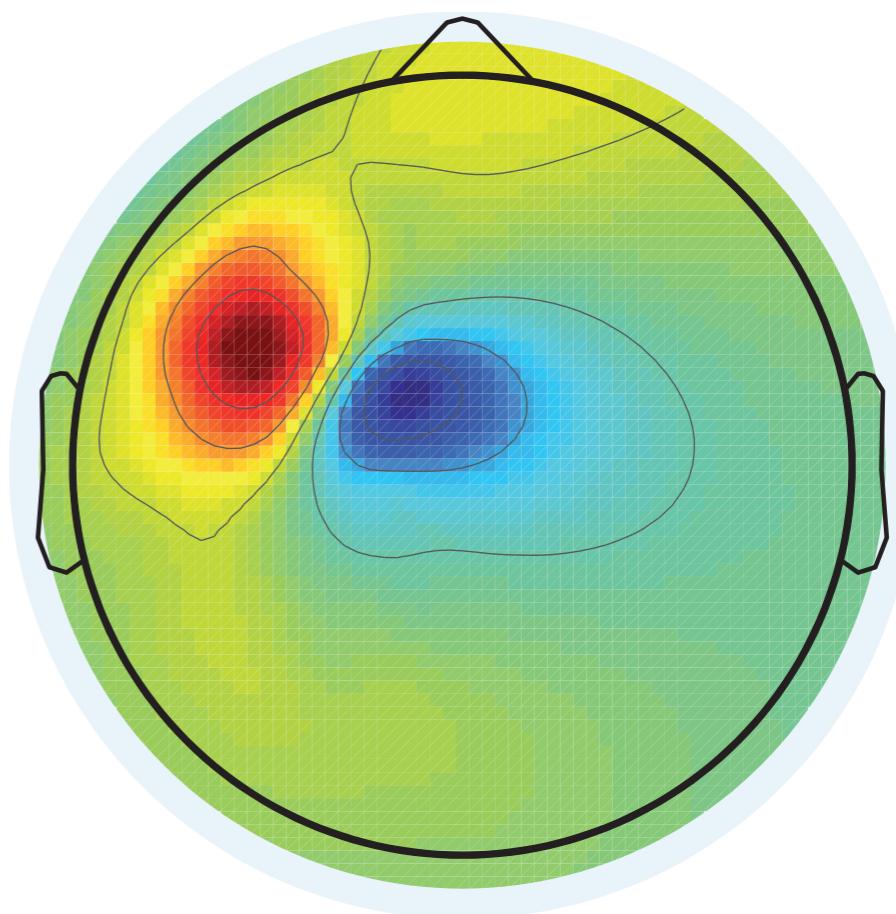
M/EEG Measurements

EEG topography



vs.

MEG topography



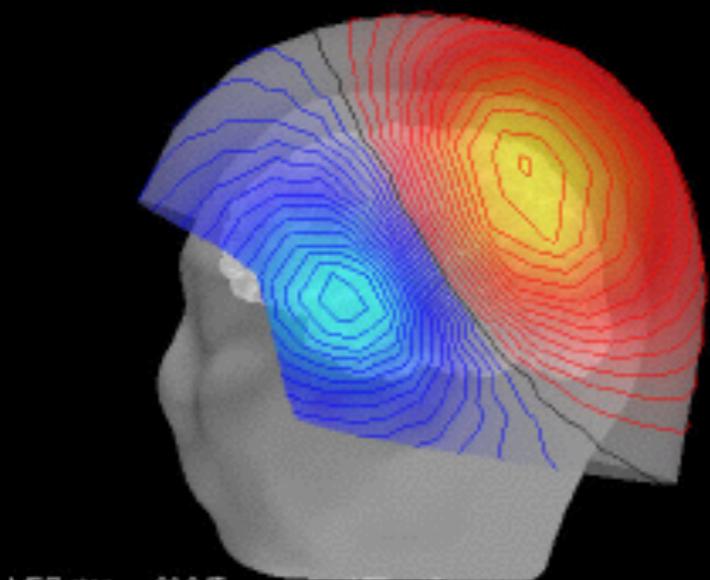
*CTF system with 151
axial gradiometers*

MEG topography exhibits also a dipolar field but MEG has a better spatial resolution

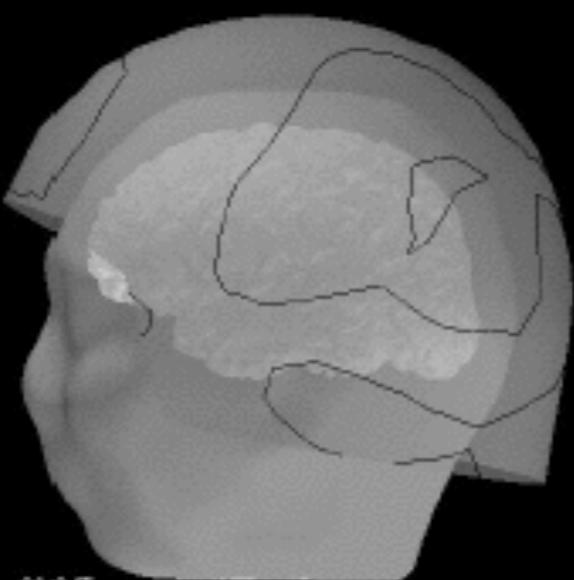
M/EEG Measurements

MEG

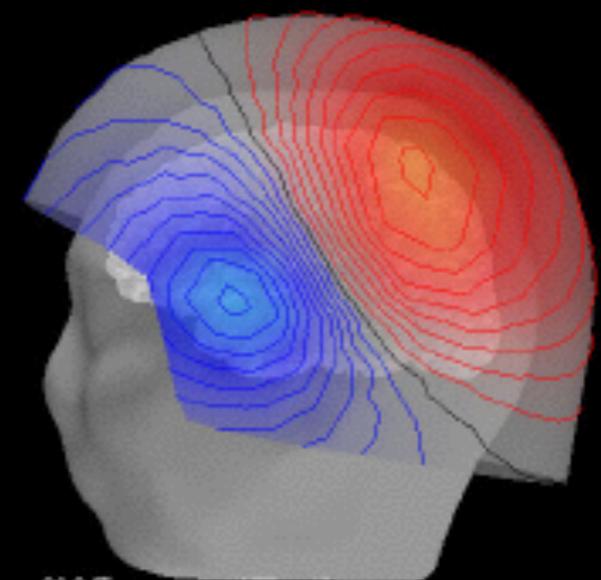
tangential



radial



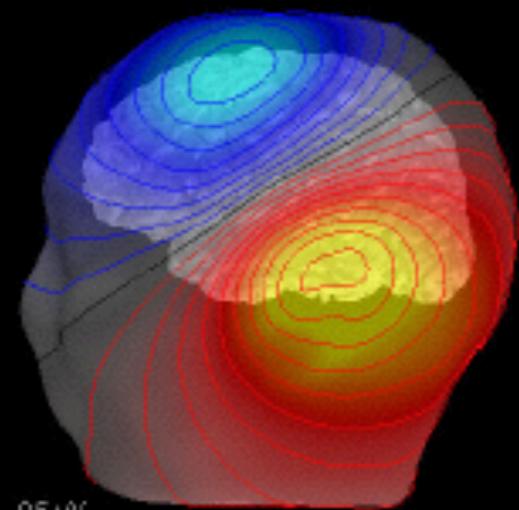
tilted



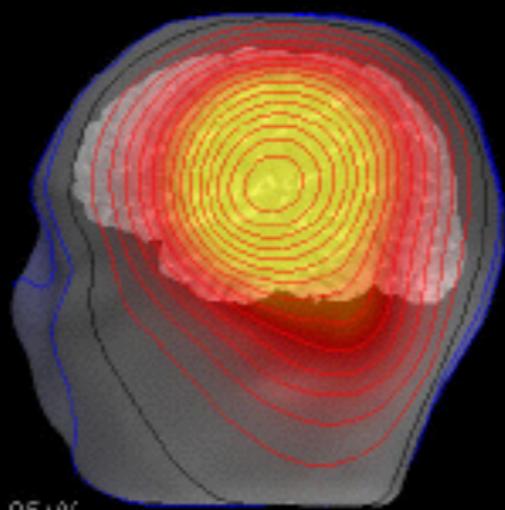
Courtesy of Prof. Matti Hämäläinen, Harvard

EEG

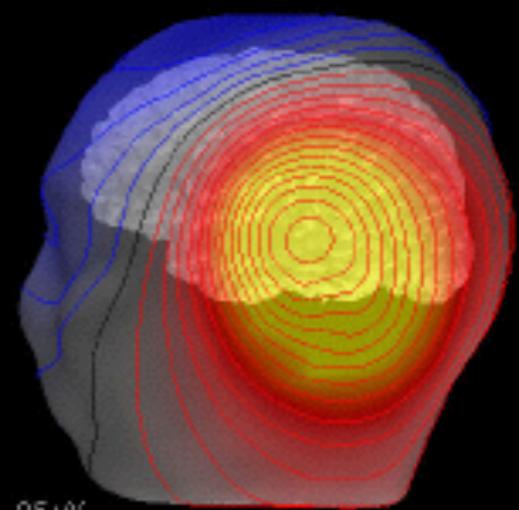
tangential



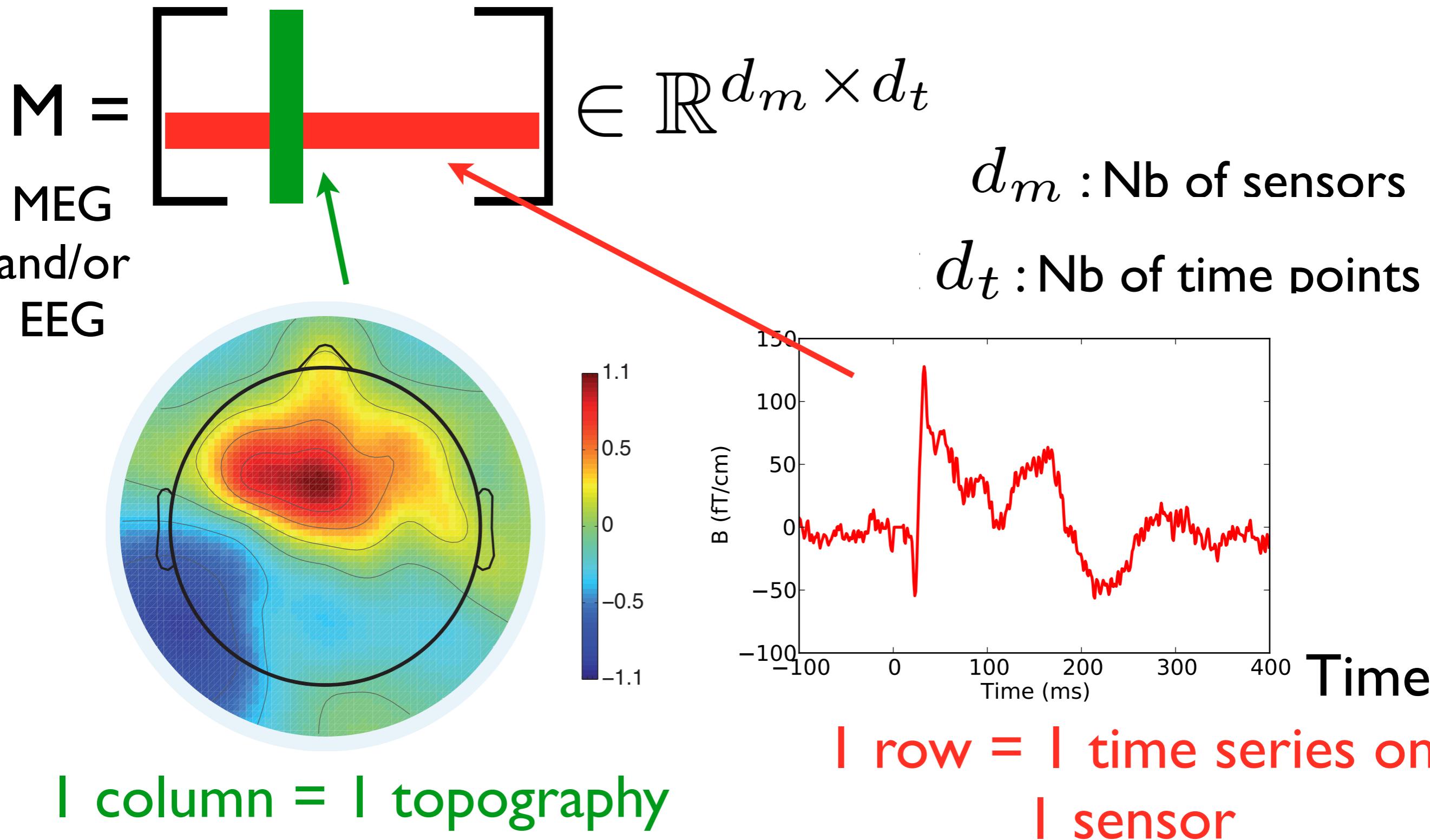
radial



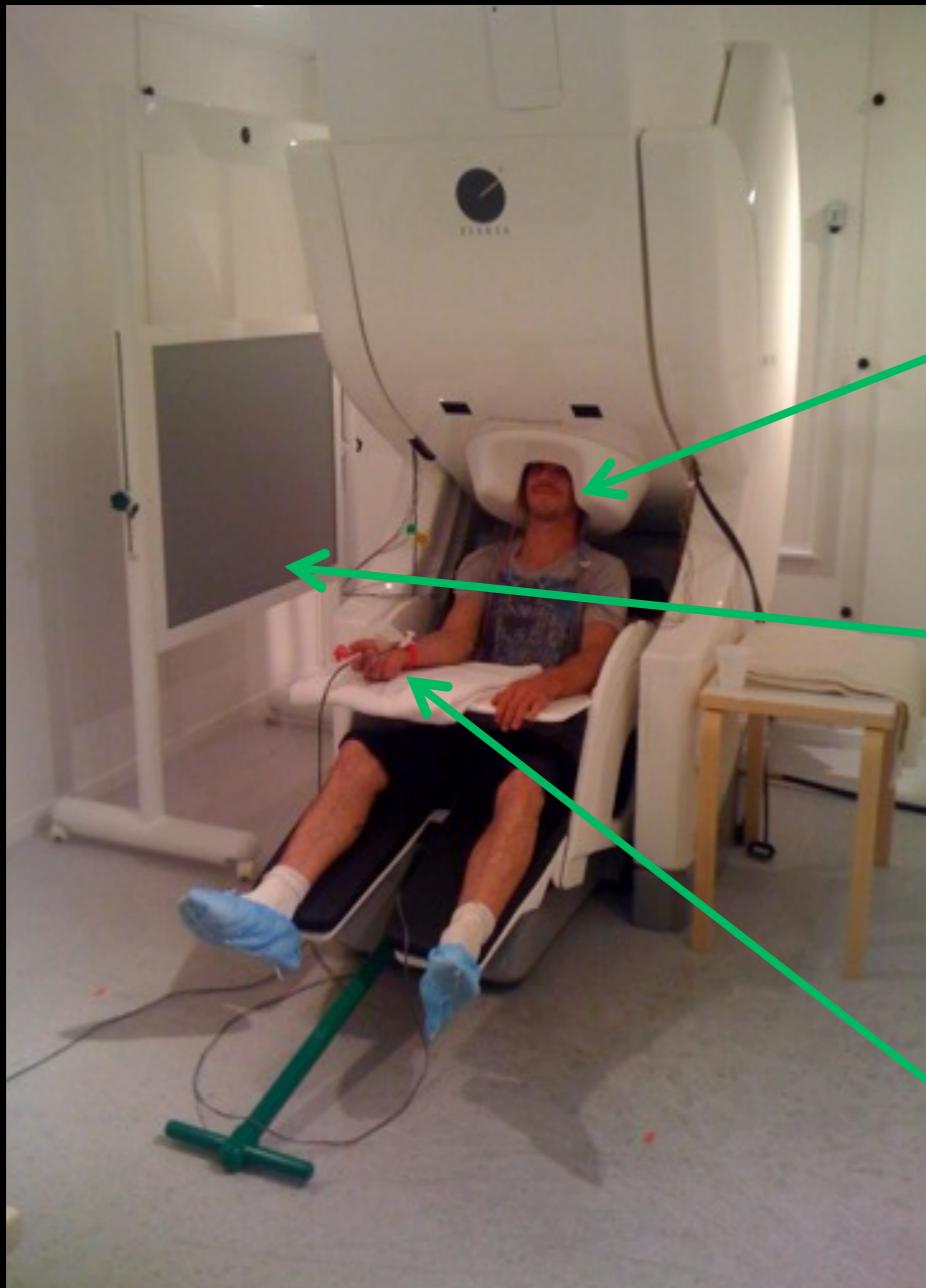
tilted



M/EEG Measurements: Notation



Data acquisition examples



Earphones

Presentation Screen
(moved to front!)

Electrical Stimulator

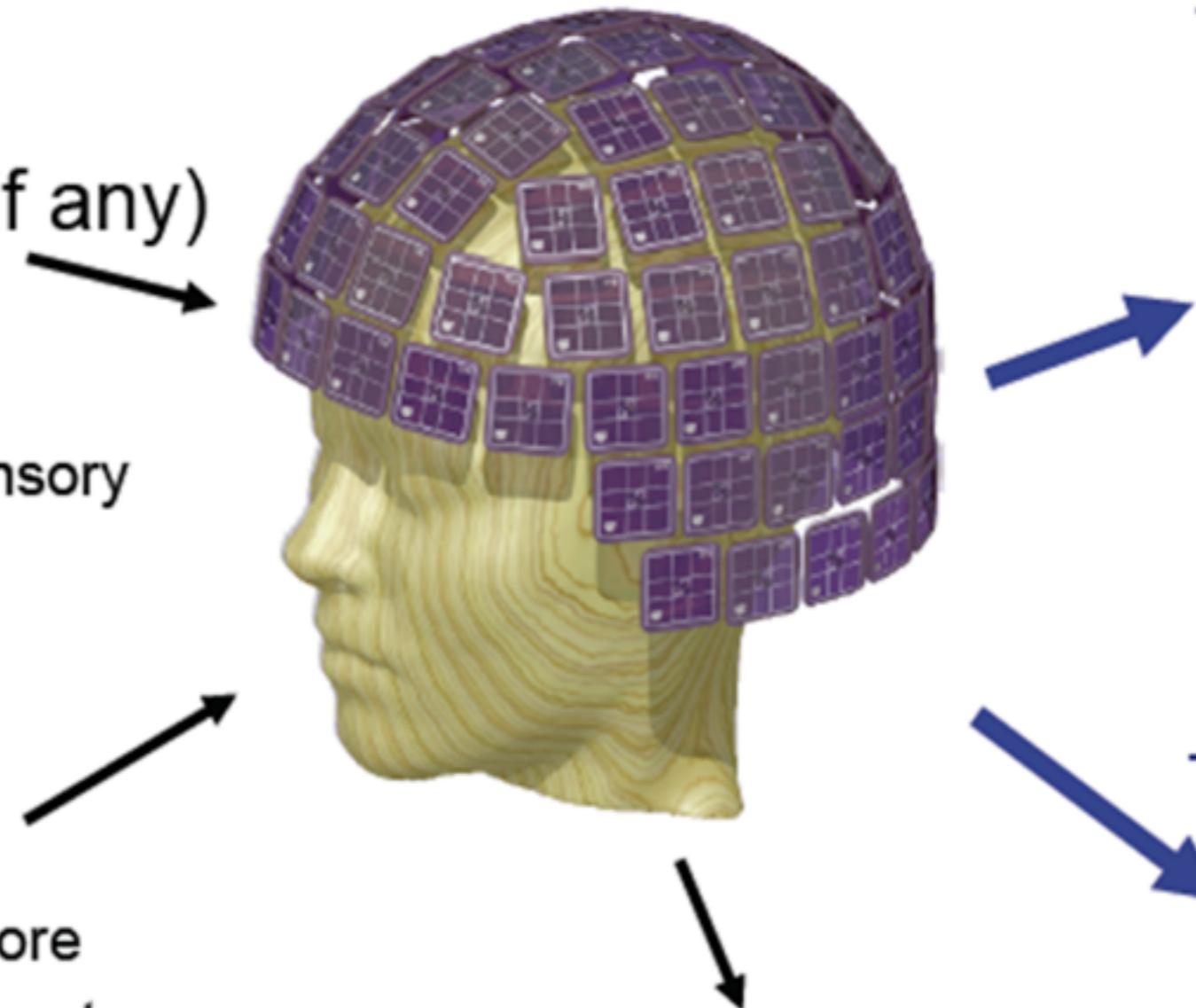
Also:
Button Pads
Button Gloves
Manual Tapper

Stimulus delivered
by E-Prime,
PsychToolBox, etc.

Data acquisition examples

Stimuli (if any)

- auditory
- visual
- somatosensory



Task

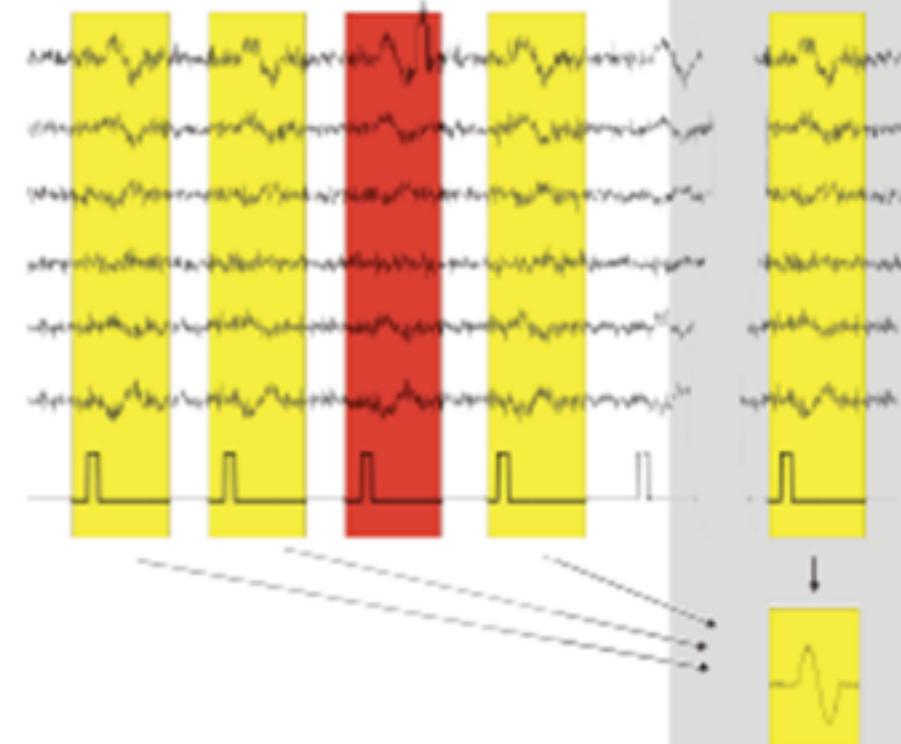
- attend/ignore
- detect + react

Behavioral responses

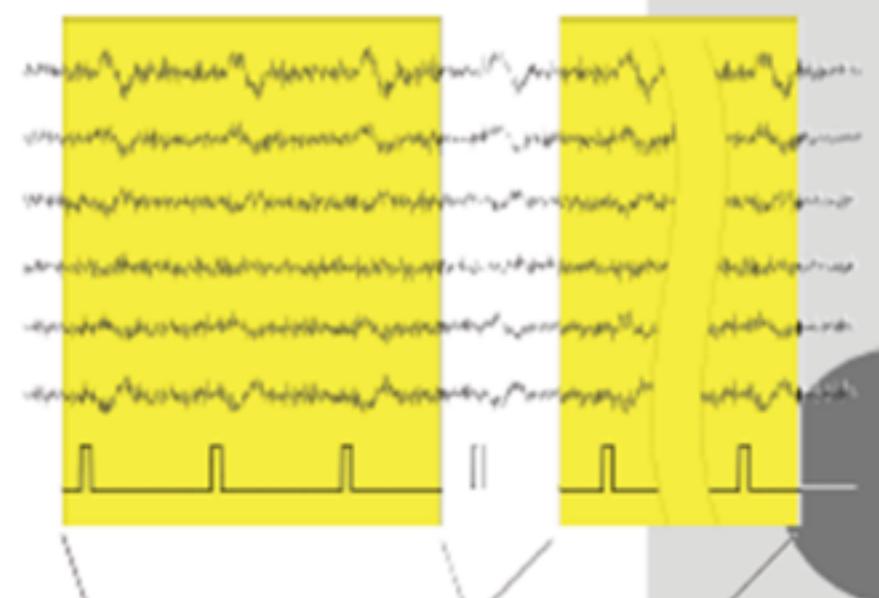
- limb/finger movement
- speech

MEG/EEG

- evoked responses

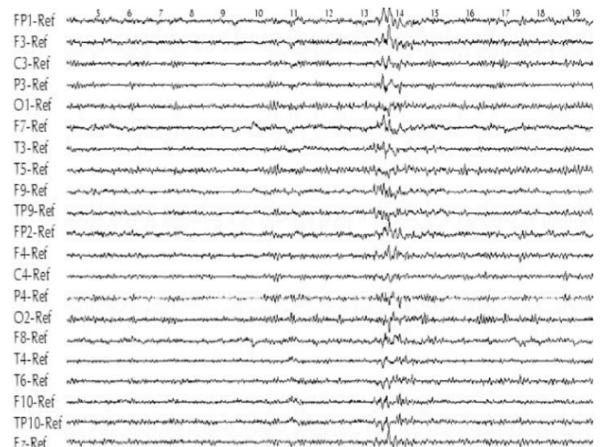


- spontaneous data

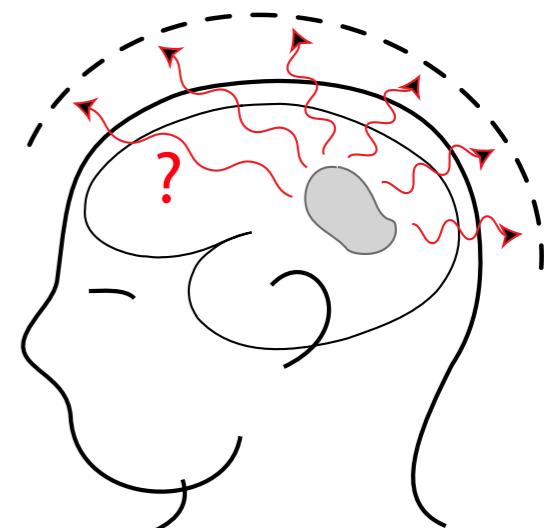


What are the challenges?

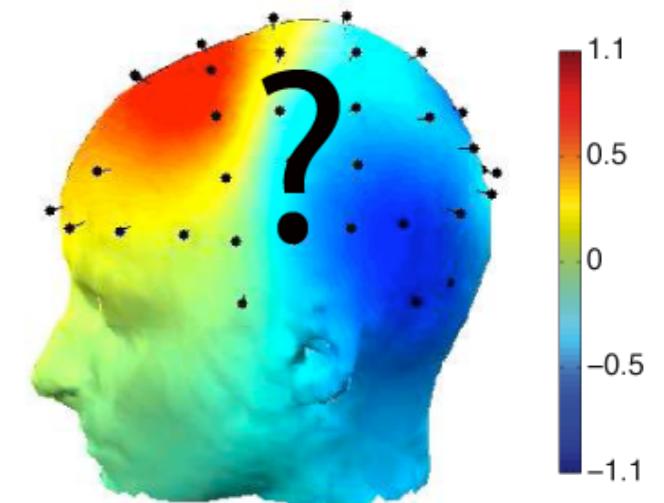
Signal Extraction:
Signal processing, Denoising, Artifact rejection, Single trial analysis.



Forward problem:
Maxwell Equations, Numerical solvers, Finite and Boundary Element Method (BEM & FEM), Image Segmentation and meshing for head modeling.

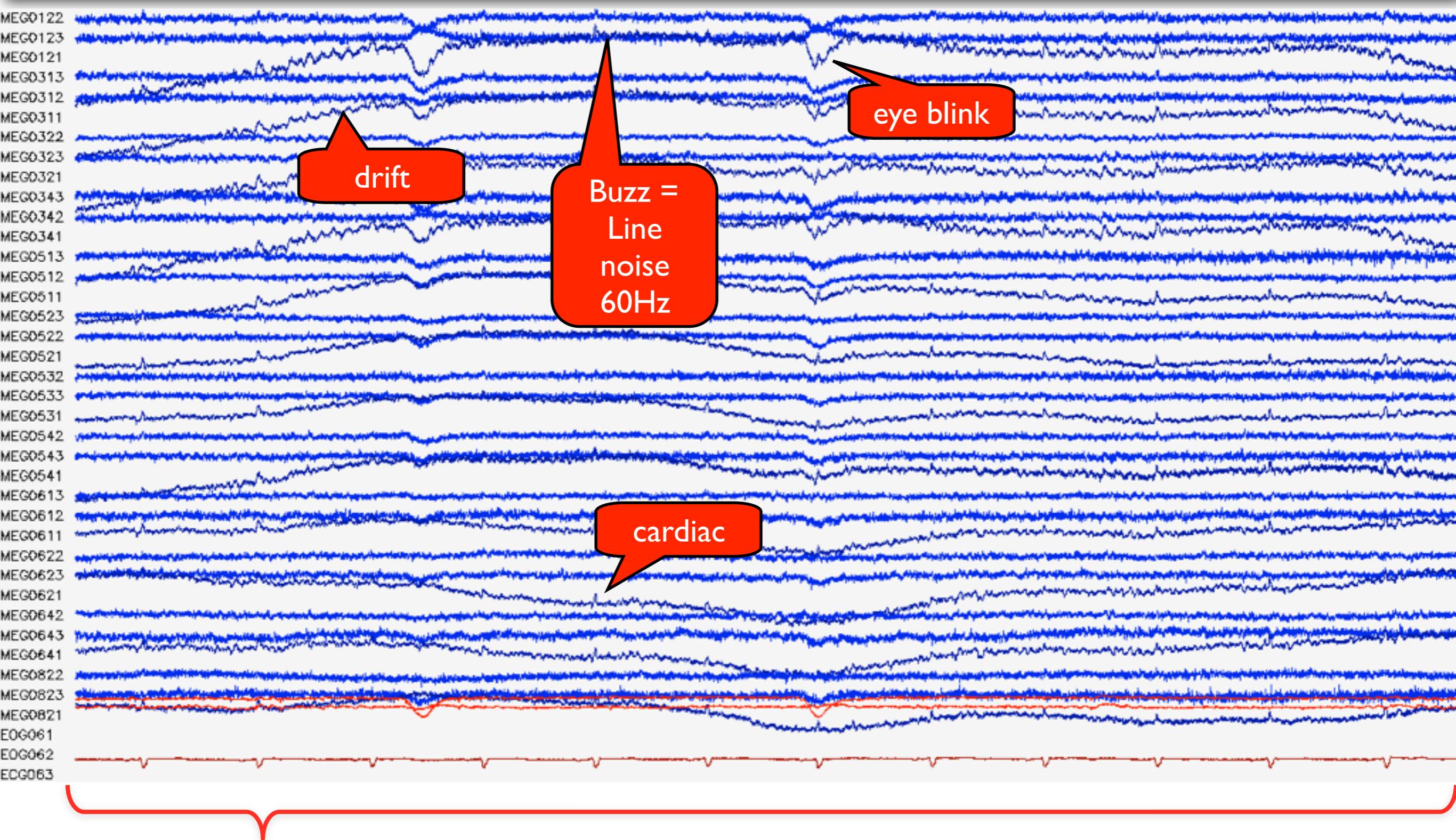


Inverse problem:
Deconvolution problem, Ill-posed problem, Requires efficient solvers to use different priors.



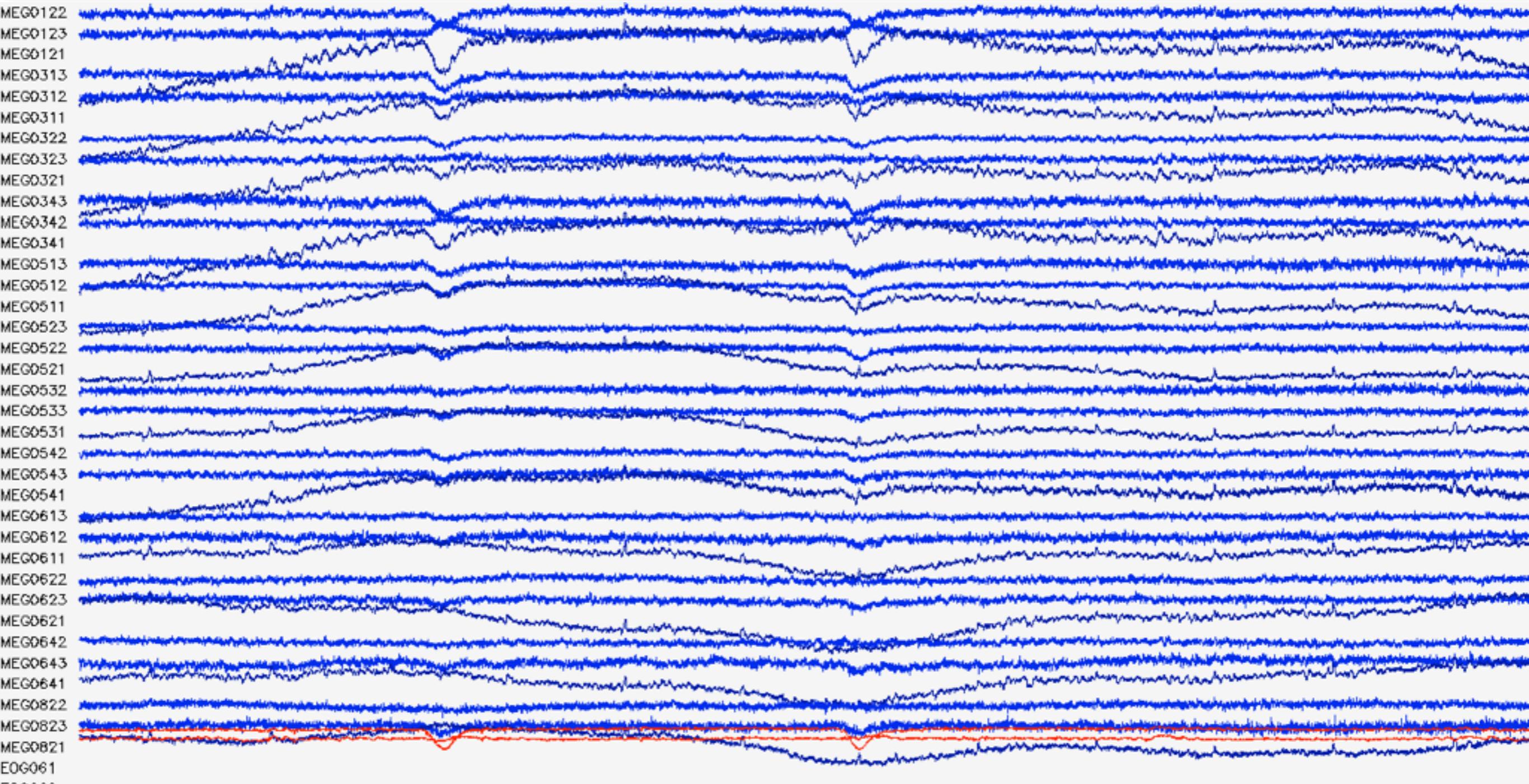
Preprocessing

Artifacts



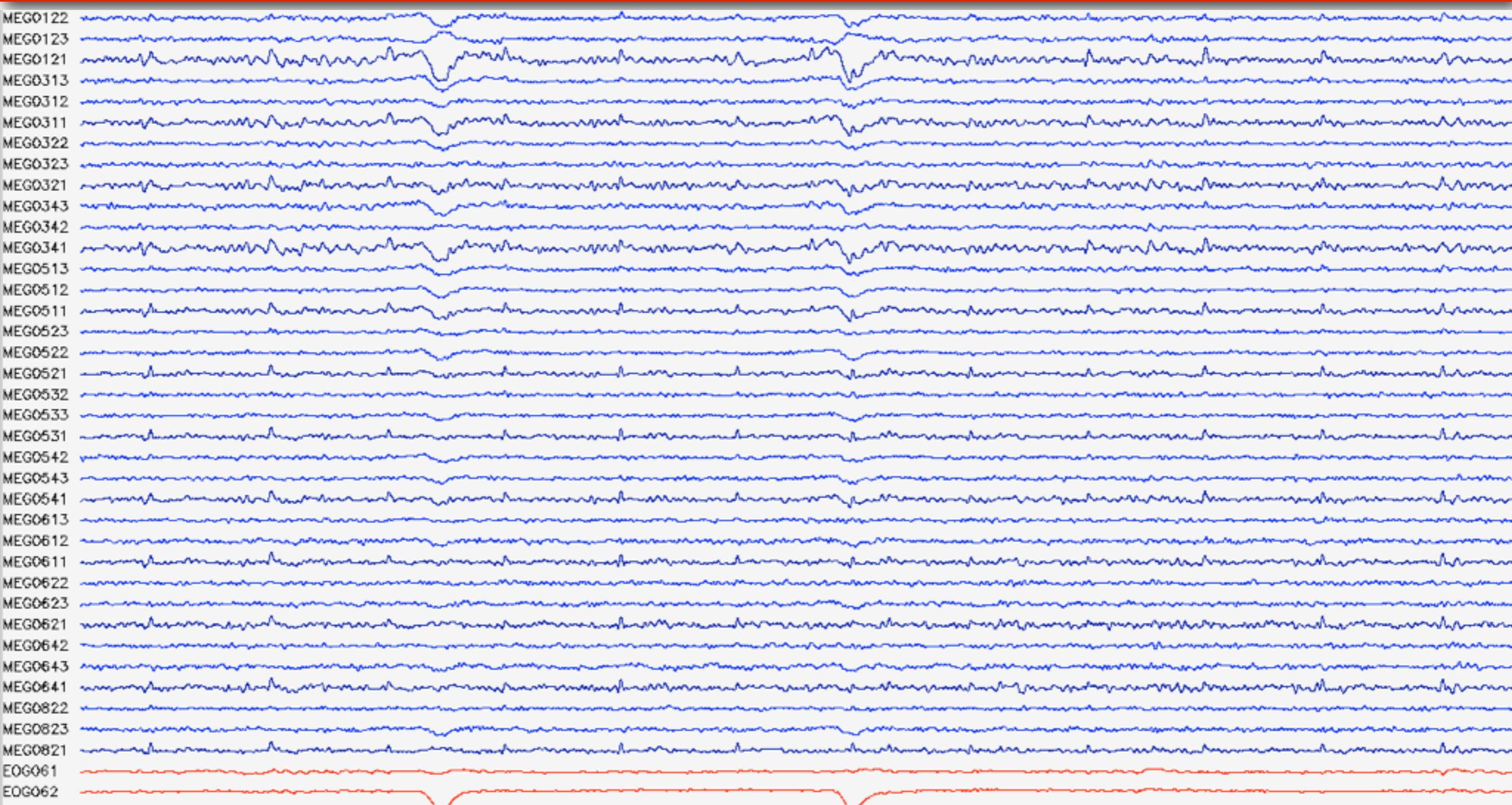
Time frame: 10 seconds

Raw continuous data



Time frame: 10 seconds

Filtered 1-40Hz

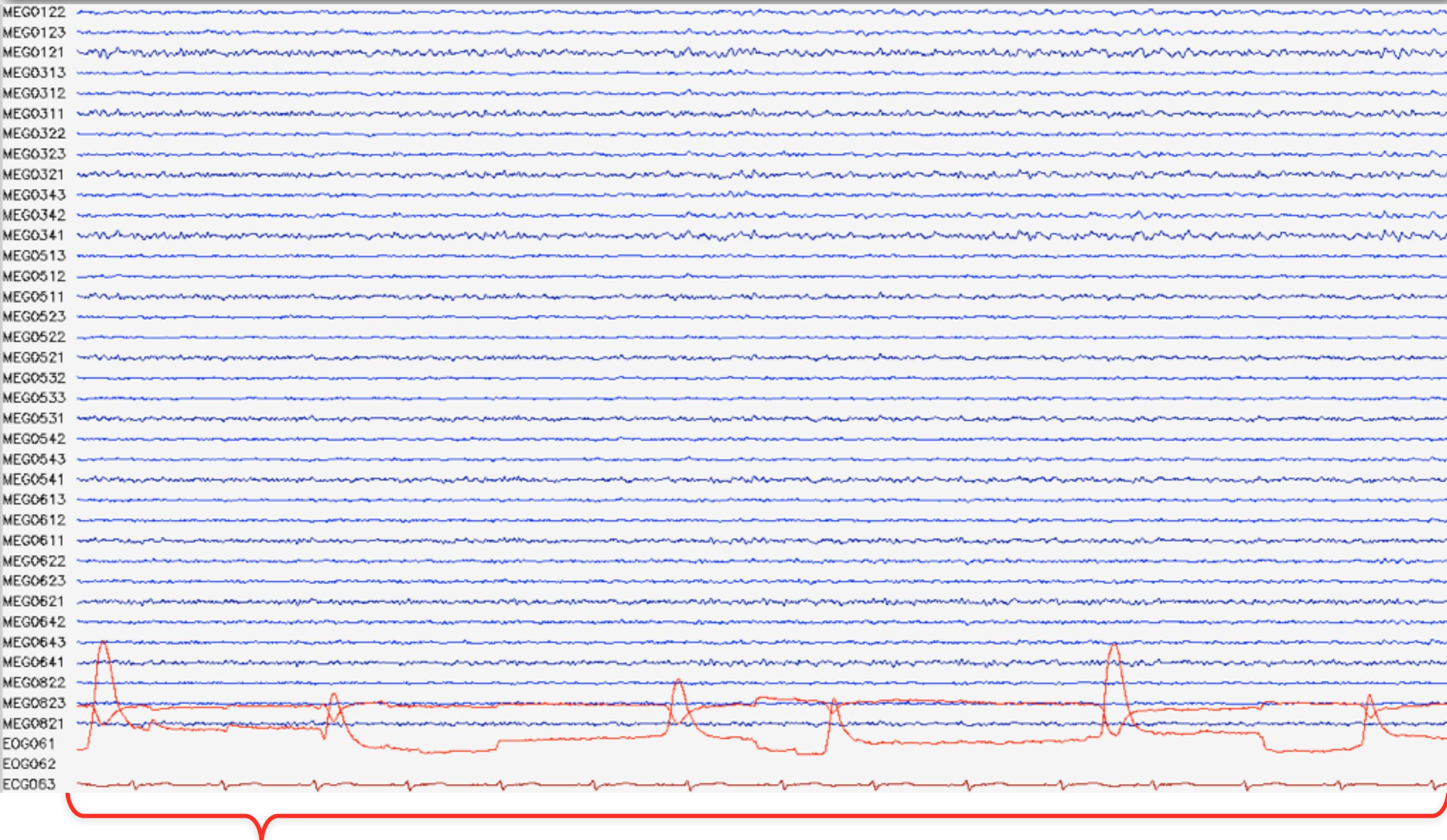


Time frame: 10 seconds

Artifact correction

- SSP - PCA correction
- Signal space projections
- Empty room correction
- Independent component analysis (ICA)
- ...

To get clean data...



Time frame: 10 seconds