Human Brain Project EBRAINS

SGA3 RP1 Review

March 2022

Showcase 2 – Improving epilepsy surgery with the Virtual BigBrain

WP 1

WP 1

Showcase 2: Improving epilepsy surgery with the Virtual BigBrain

Objective: Develop a more precise estimation of the epileptogenic zone in drug resistant epilepsy patients.

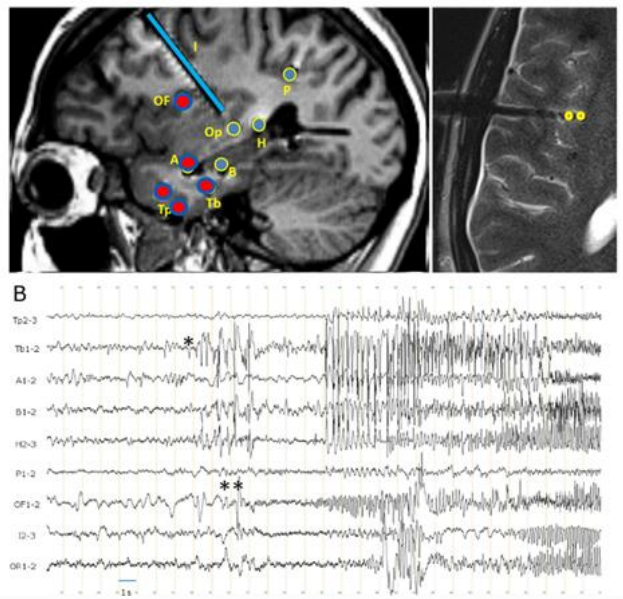
Motivation: Drug resistant focal epilepsies are severe diseases (1% of the world population, high morbidity and mortality). Epilepsy surgery is the only potential curative treatment and consists in the removal of the most epileptogenic brain regions. Failures (complete or partial) exist in about 40% of all patients (particularly in extra temporal lobe epilepsy).

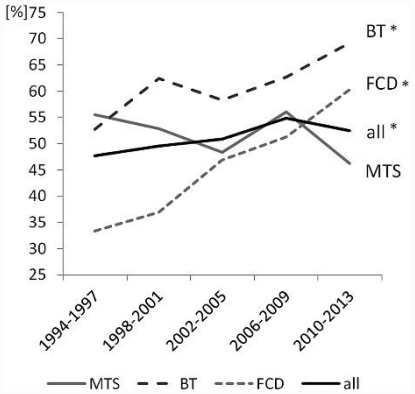
M21 D1.2: DEMO2 of Showcase 2

Only on EBRAINS: Simulation with EBRAINS Simulation services, models to be constrained with EBRAINS Data and Atlas services.

Outputs: Workflow in EBRAINS implementing high-resolution brain simulation.

Applications: Clinical neuroscience.





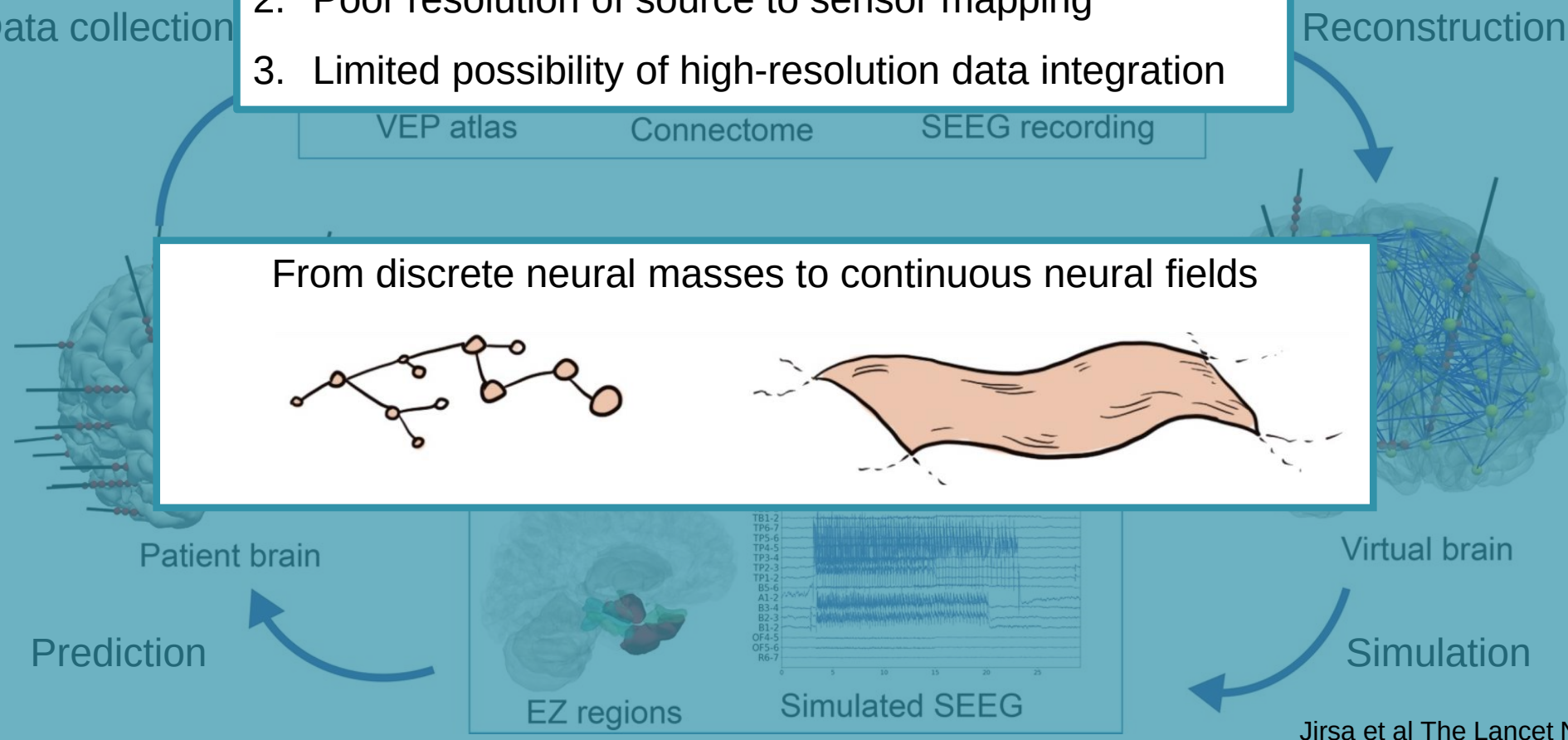
% of seizure freedom after surgery *Cloppenborg et al, 2017*

WP 1

Showcase 2: Estimation of the EZ – State of the art

Challenges

1. Limited spectrum of possible seizure dynamics
2. Poor resolution of source to sensor mapping
3. Limited possibility of high-resolution data integration



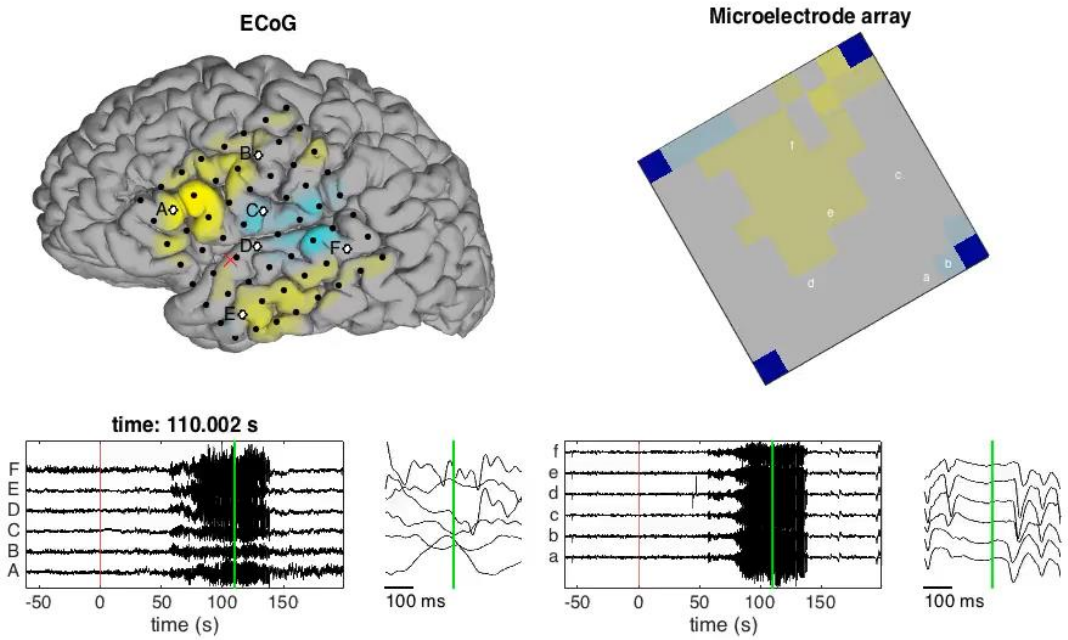
Jirsa et al The Lancet Neurology (in revision)

WP 1

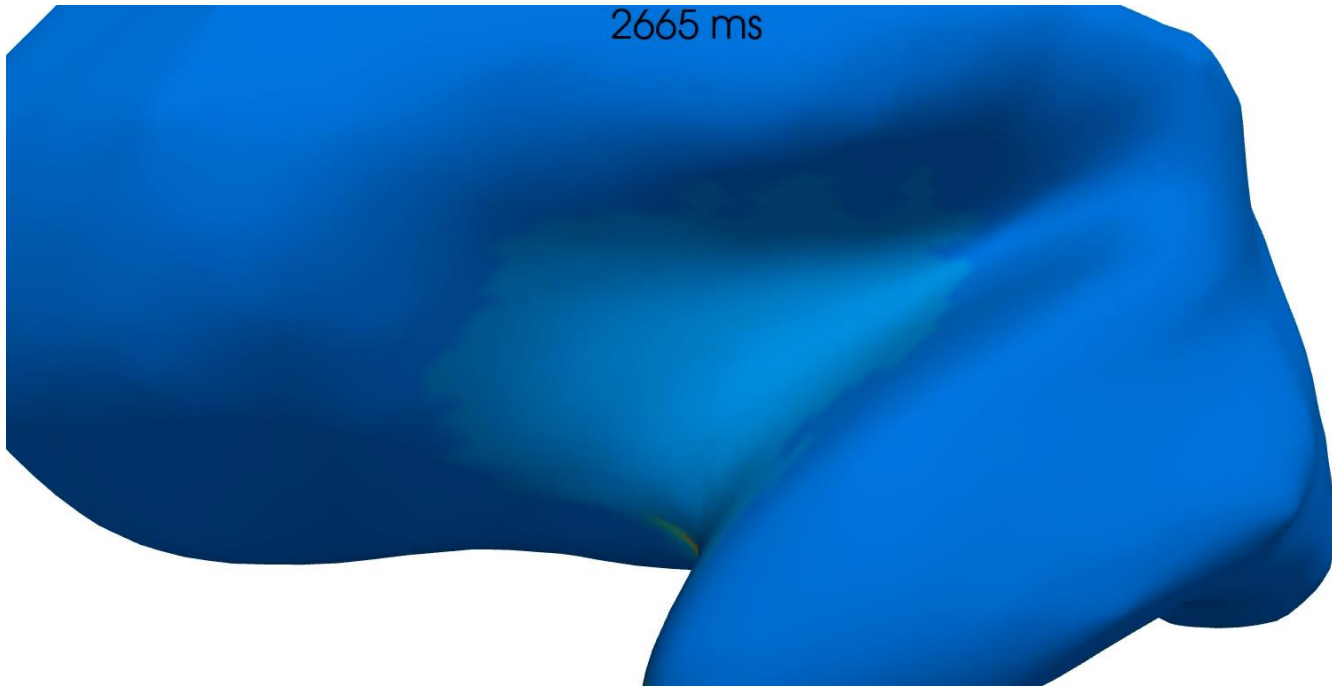
Showcase 2: Why neural fields in epilepsy ?

Improved representation of spatio-temporal seizure dynamics.

Real patient epilepsy



Simulated epilepsy

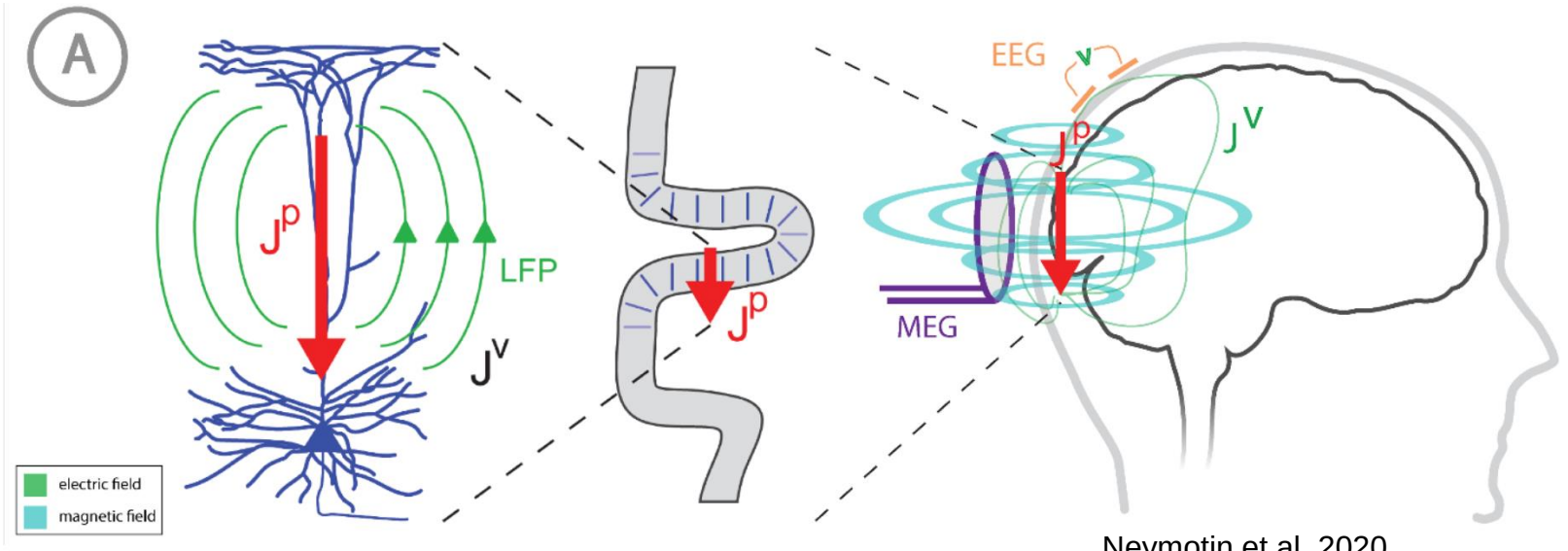


Martinet et al. 2016

WP 1

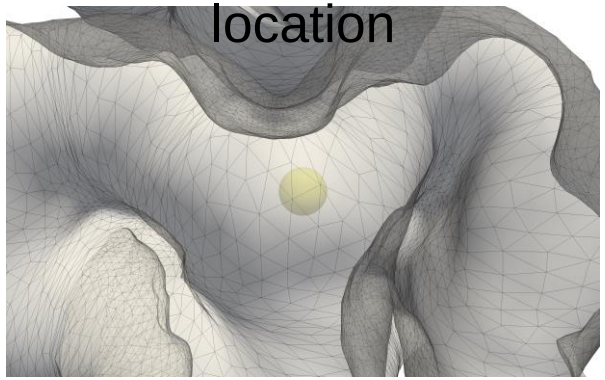
Showcase 2: Why neural fields in epilepsy ?

Orientation and distance of the electrical source matters, for an accurate source to sensor mapping.



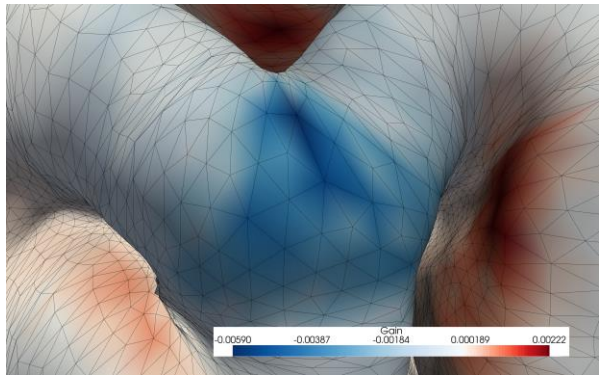
Neymotin et al. 2020

SEEG location



Dipole orientation

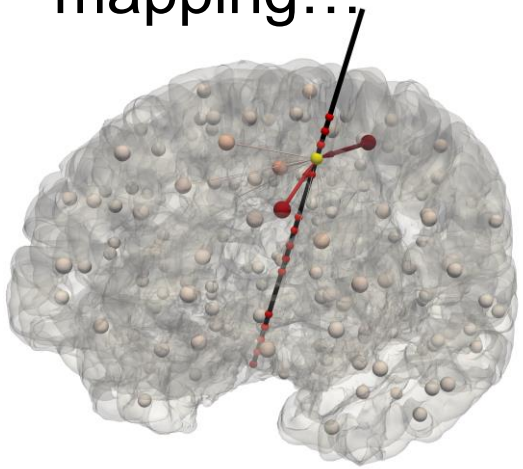
Source to sensor mapping

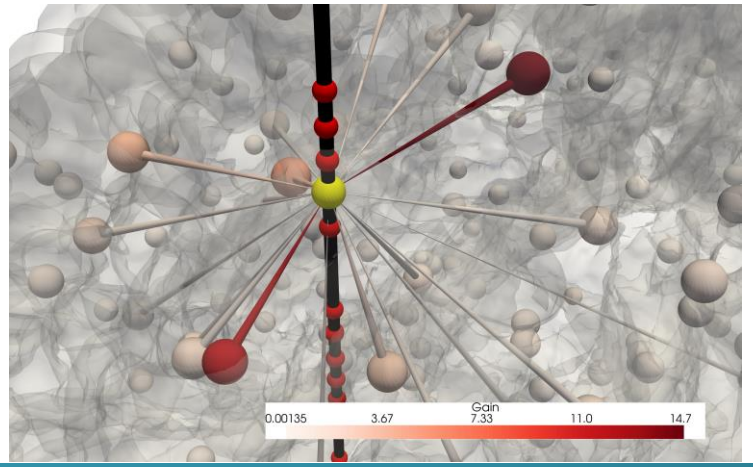


WP 1

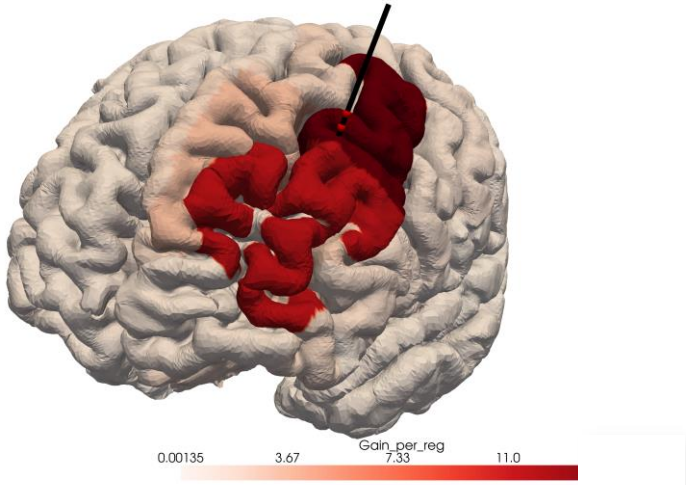
Showcase 2: Why neural fields in epilepsy ?

Current source to sensor mapping…

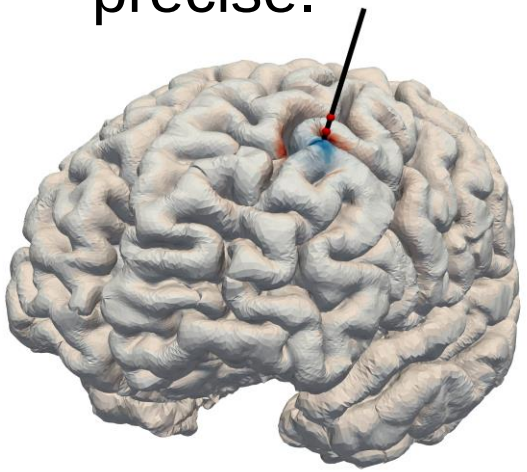


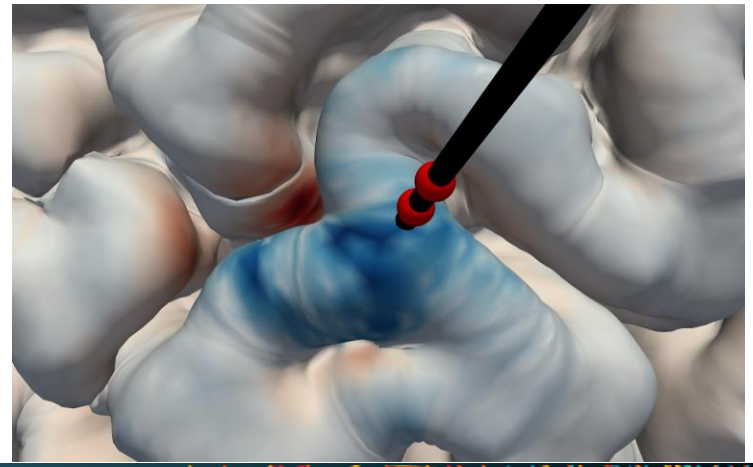


… and its representation on the surface, when actually…



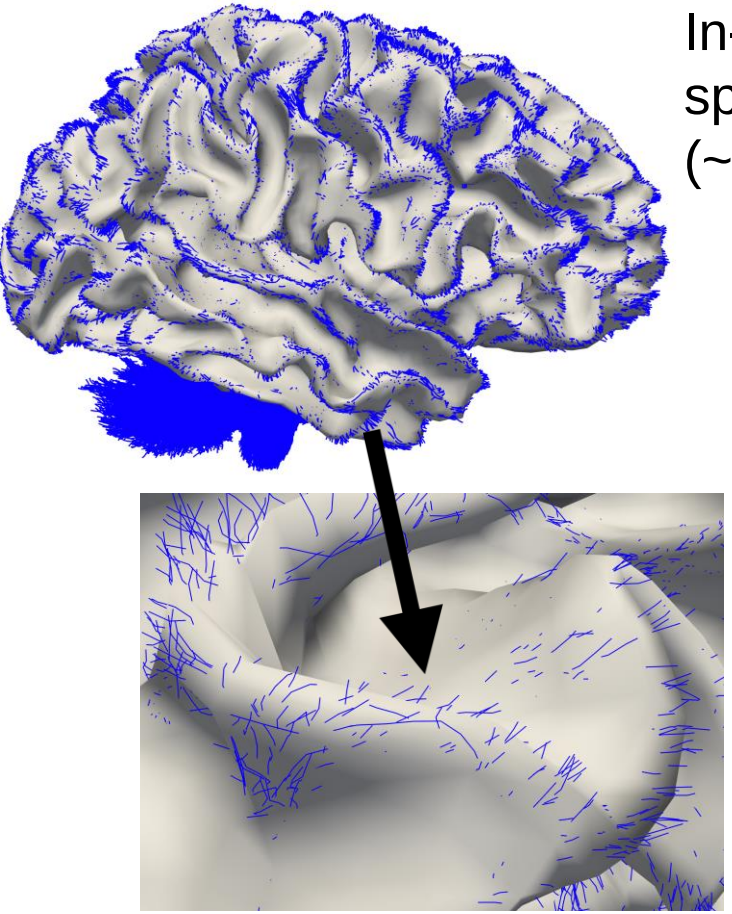
… neural fields are more precise.



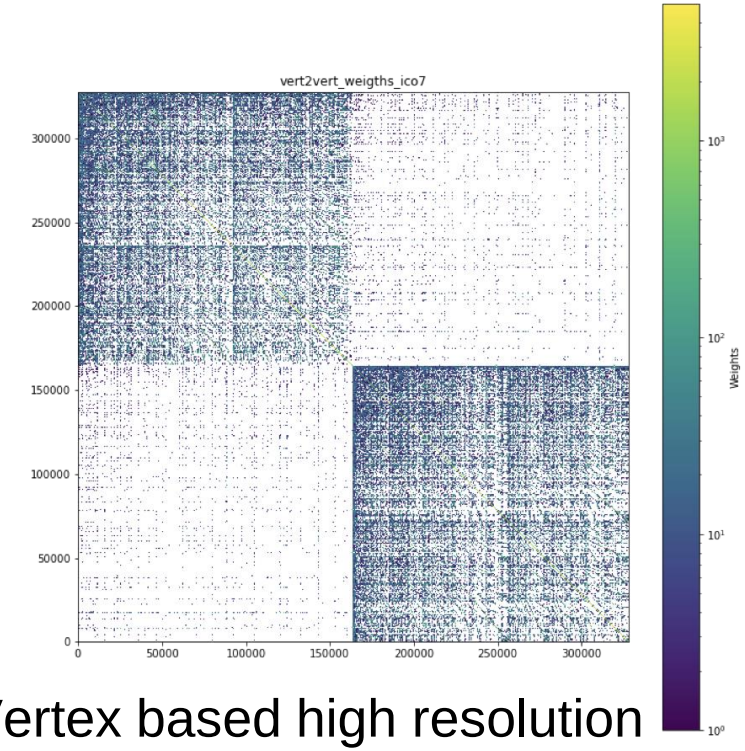


WP 1 Showcase 2: Why neural fields in epilepsy ?

Integration of high-resolution data

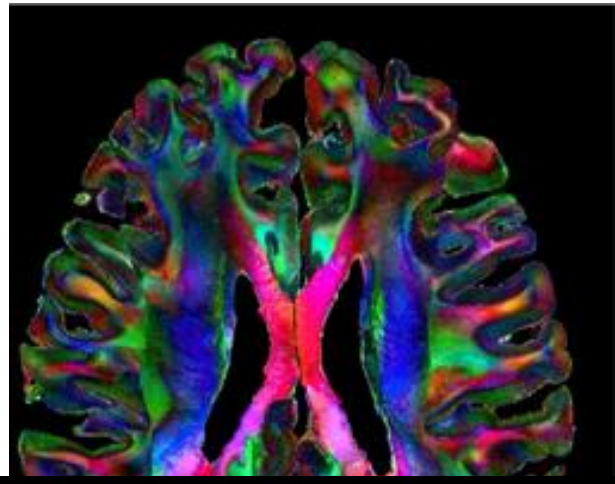


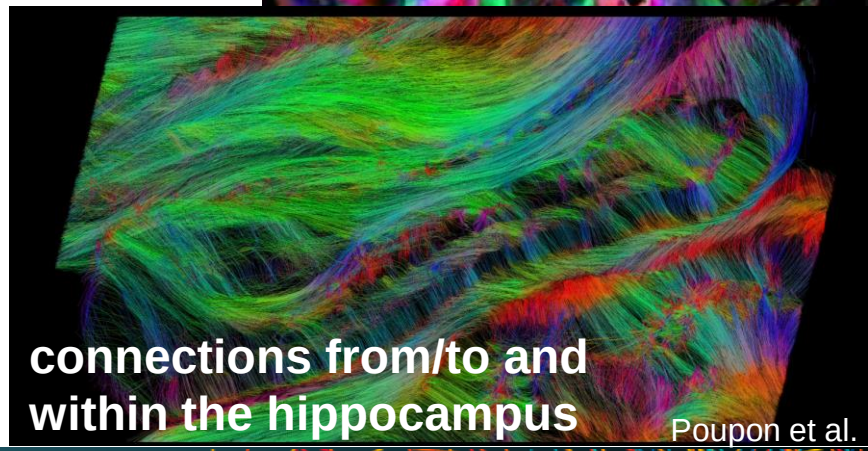
In-vivo patient specific imaging (~2mm³)



Vertex based high resolution connectome is atlas independent

CHENONCEAU post-mortem high-resolution (200 µm) imaging





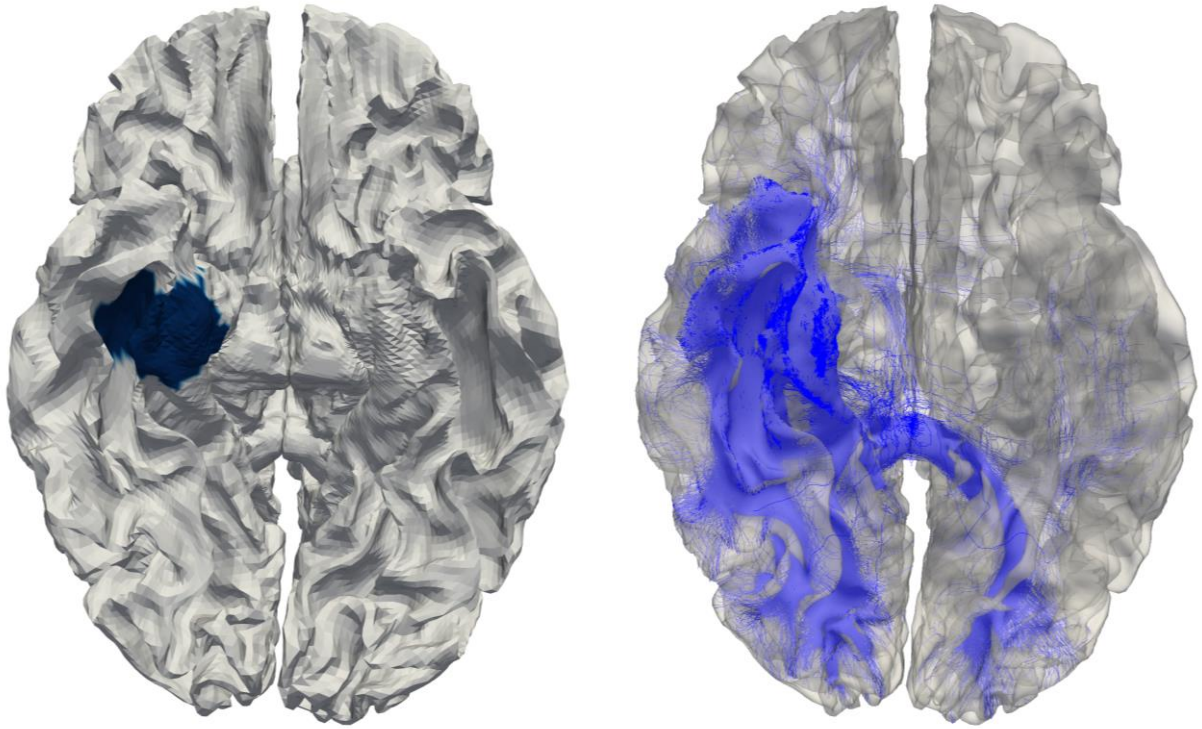
connections from/to and within the hippocampus

Poupon et al.

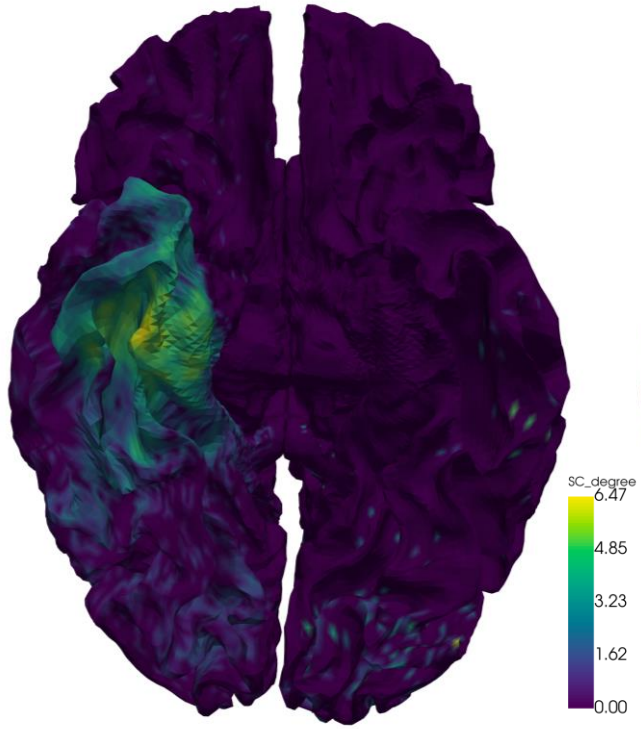
WP 1

Showcase 2: High resolution connectome

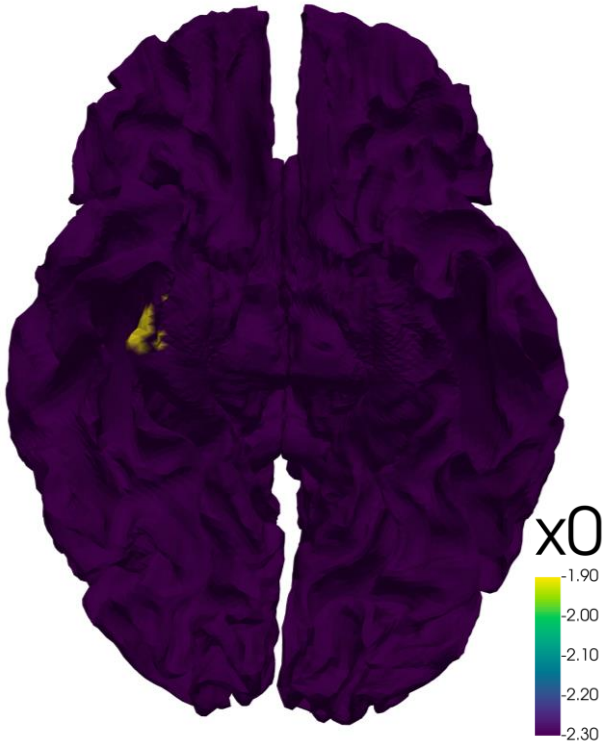
Fibres of the rhinal cortex

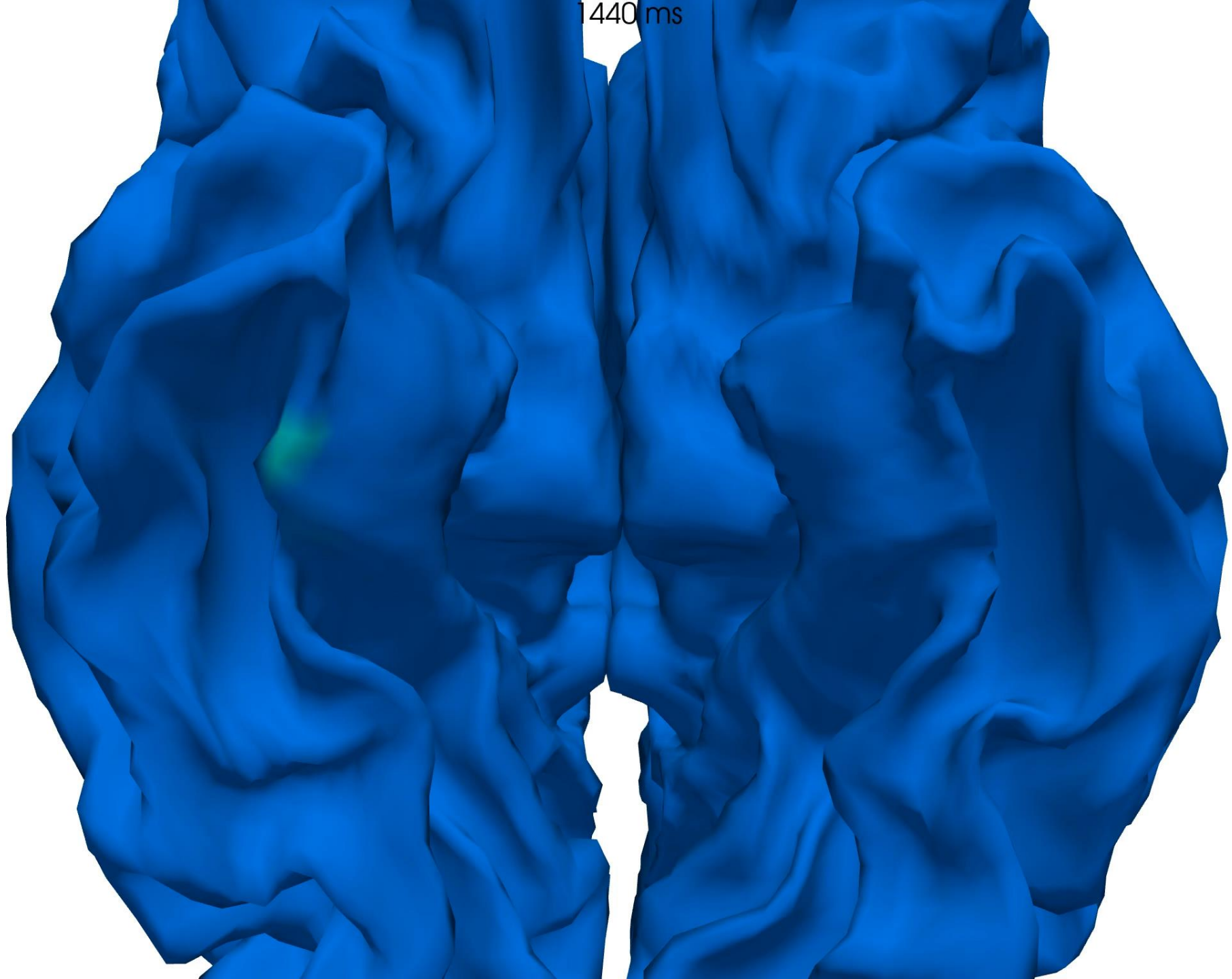


Vertex connectivity strength



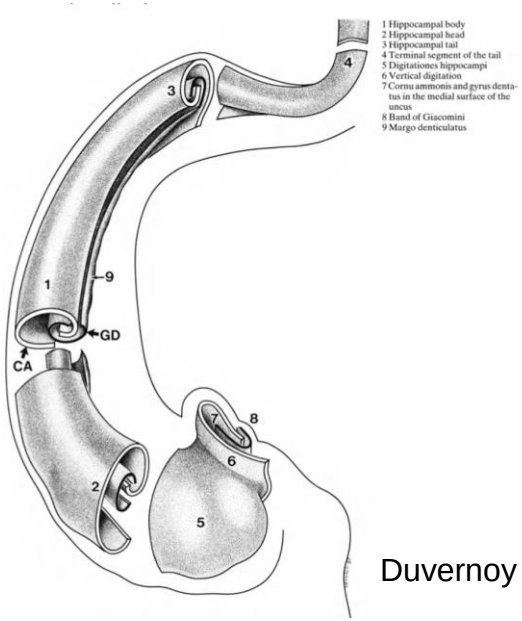
EZ




1440 ms

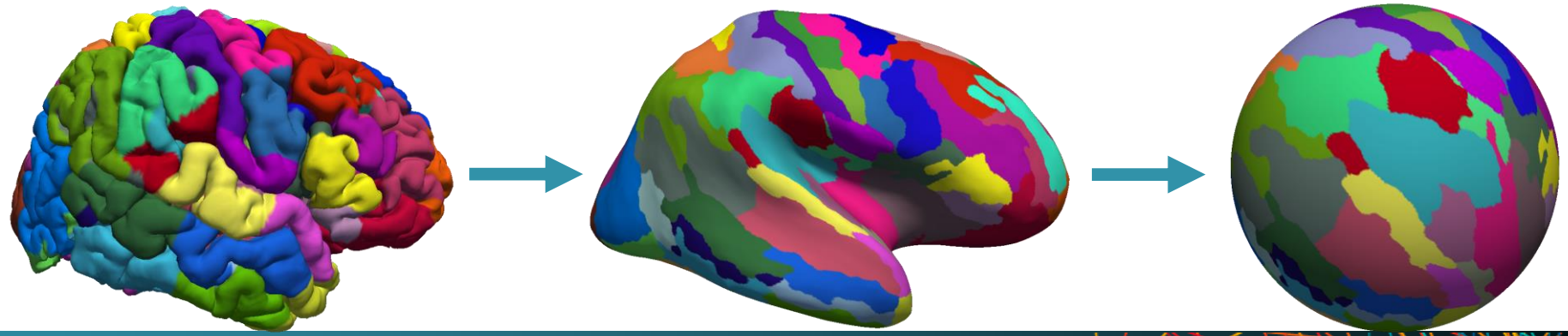
WP 1 Showcase 2: High resolution virtual BigBrain

Neural field of the hippocampus



Duvernoy 1988

Inflation for better visualisation



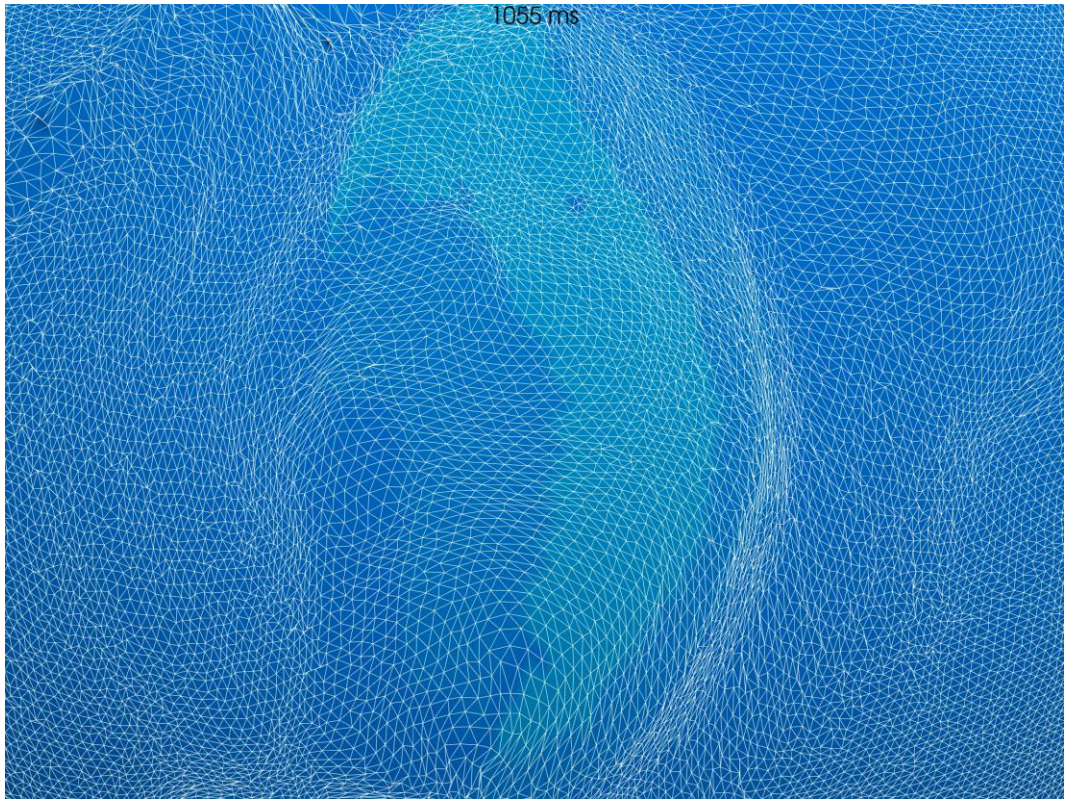
WP 1

Showcase 2: High resolution virtual BigBrain

Improved representation of the hippocampal subfields with pathomechanistic relevance.

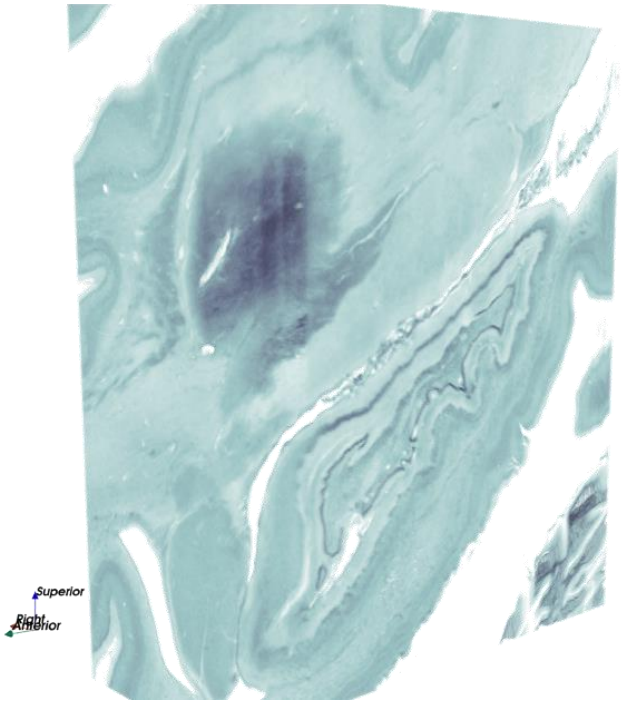
Hippocampus on the inflated sphere

- CA4
- CA3
- CA1
- Subiculum
- Presubiculum
- Parasubiculum
- Rhinal cortex
- Parahippocampal cortex
- Hippocampus tail

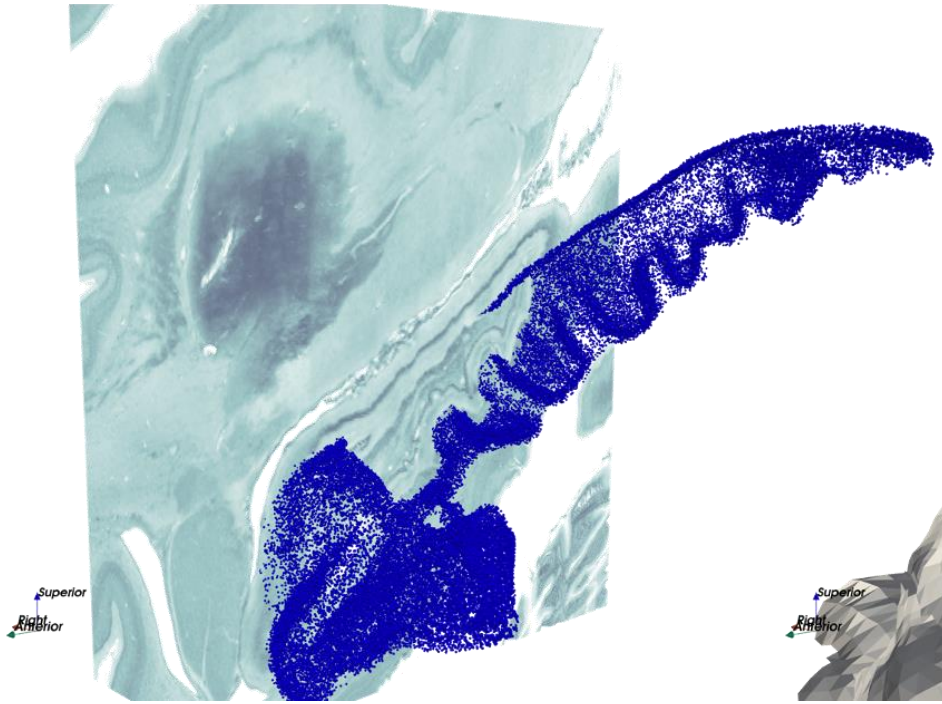


WP 1 Showcase 2: TVB-NEST Co-simulation

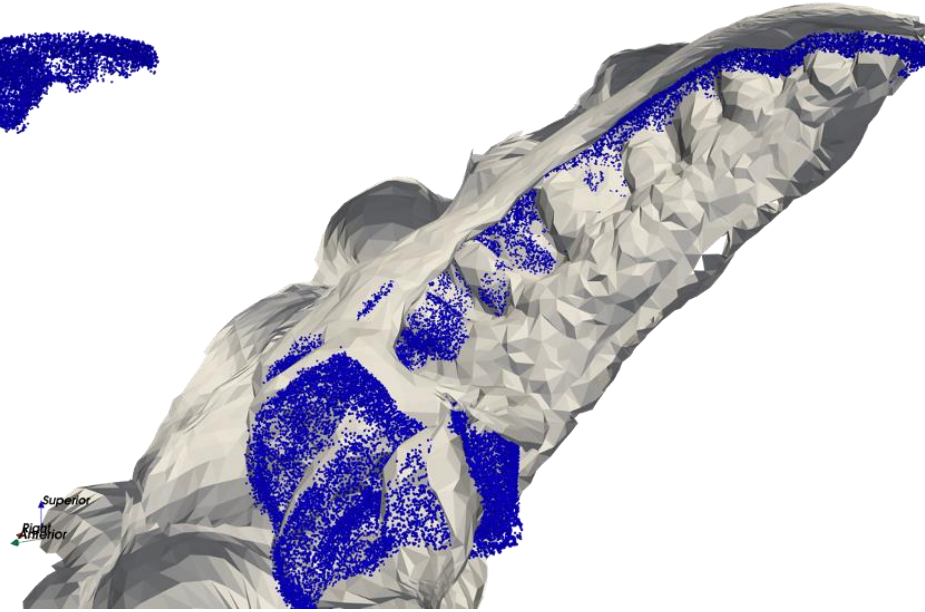
From annotated microscopic BigBrain data …



… to placement of NEST spiking neural networks in CA1…



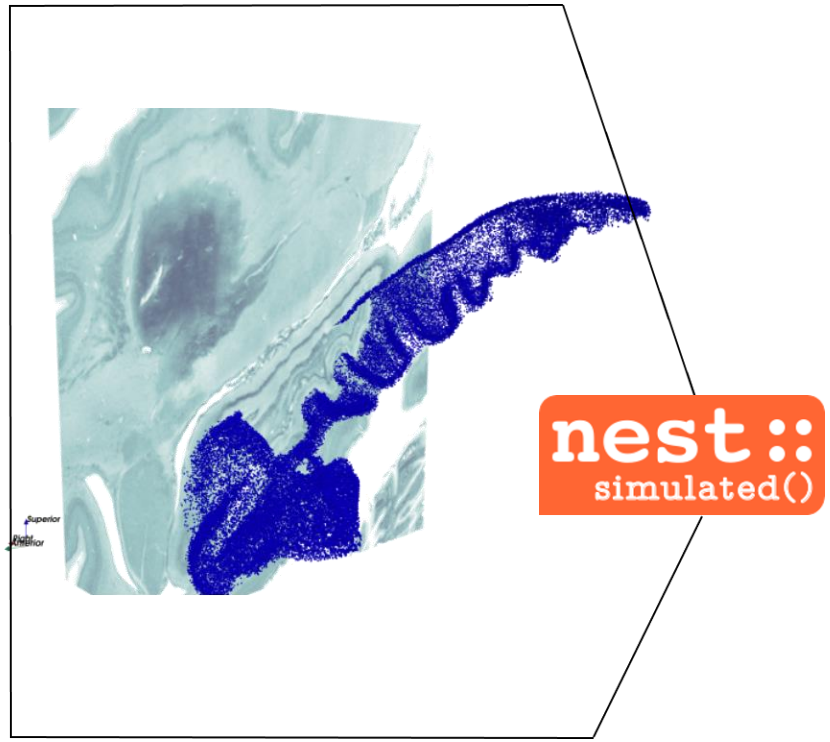
… to a connection of spiking neurons to points on the neural field of TVB.



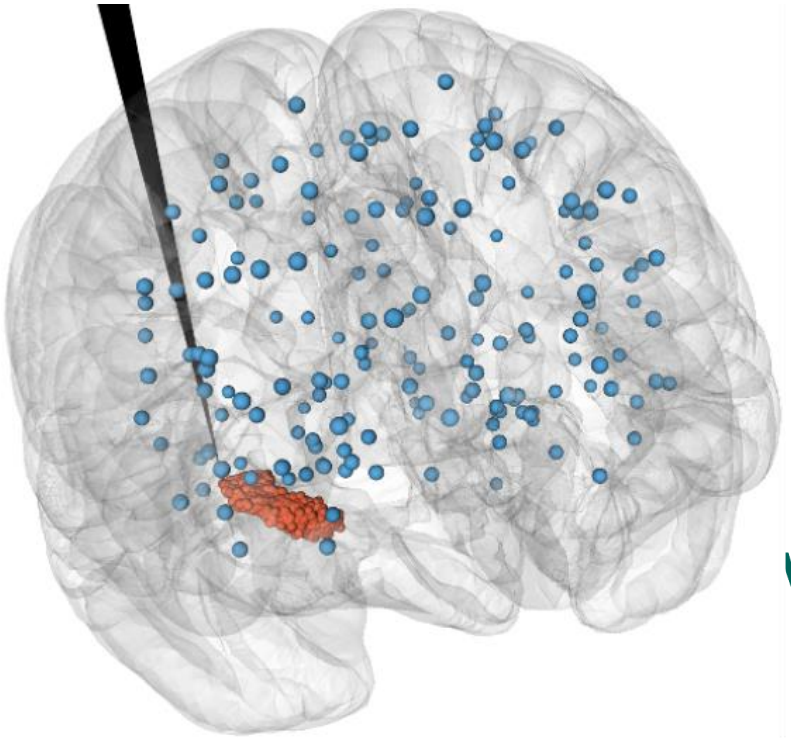
Dekraker et al. 2020
Amunts et al. 2013

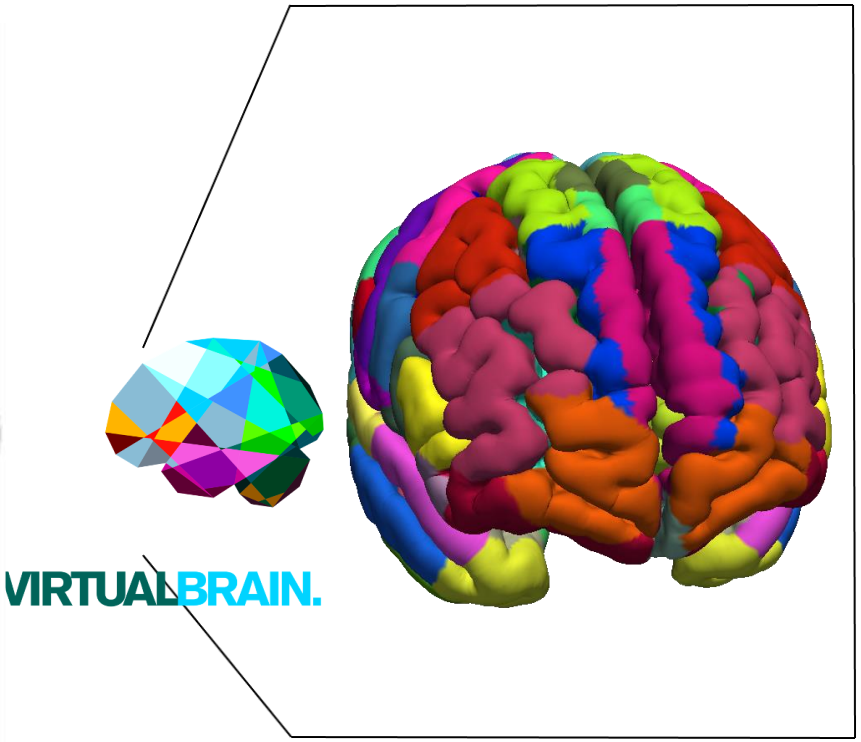
WP 1 Showcase 2: TVB-NEST Co-simulation

Allows the implementation of hypothesised epilepsy pathomechanism on the microscale and spatio-temporal seizure dynamics on the macroscale.



nest :: simulated()





VIRTUALBRAIN.

Step1_setup_... (auto-U : 3) - Ju

https://lab.ch.ebrains.eu/user/triebjp/lab/workspaces/auto-U/tree/shared/SGA3 D1.2 Showcase 2/co_simulation/notebook/Step1_setup_cosimulation.ipynb

133 %

Débuter avec Firefox

Autres marque-pages

File Edit View Run Kernel Git Tabs Settings Help

Mem: 430 / 2048 MB

Filter files by name

/ ··· / co_simulation / notebook /

Name	Last Modified
data	6 days ago
helper_fun...	21 hours ago
long_simul...	4 days ago
long_simul...	4 days ago
simulation_1	6 days ago
Step1_set...	26 minutes ago
Step2_run...	15 minutes ago
Step3_vis...	25 minutes ago

Step1_setup_cosimulation.i | Step2_run_cosimulation.ip | Step3_visualisation.ipynb

Code git Python 3 (ipykernel)

[1]:
```
%%capture
!pip install pyunicore --upgrade
!pip install tqdm
!pip install tvb-data
```

[2]:
```
%pylab inline
```

```
Populating the interactive namespace from numpy and matplotlib
```

[3]:
```
%%capture
import os
import sys
import numpy as np
numpy.set_printoptions(linewidth=150)

sys.path.append(os.getcwd())
from helper_functions.get_url import get_file, get_url, get_list_file
from helper_functions.run_cosimulation import Co_simulation_hippocampus_TVB
from helper_functions.plot_data import plot_CA1, plot_connectome_weight, plot_connectome_tracklength, brain_surface, get_cortext
```

Token for the authentification

[4]:
```
bearer_token = clb_oauth.get_token()
```

Run jobs for setup the environment for the co-simulation :

- The first job makes the folder and download the data from the bucket and the scripts and parameters files from the wiki (transfert_file)
- The second job creates the parameters files for the simulations and visualizations and also create the configuration file for BSB (Brain Scaffold Builder) for the simulation of CA1 network

[5]:
```
# setup the cosimulation on the cluster (2 jobs)
cosimulation = Co_simulation_hippocampus_TVB(token=bearer_token, path_local=os.getcwd()+'/simulation_1/', host='DAINT-CSCS', pro
cosimulation.run_set_up()
```

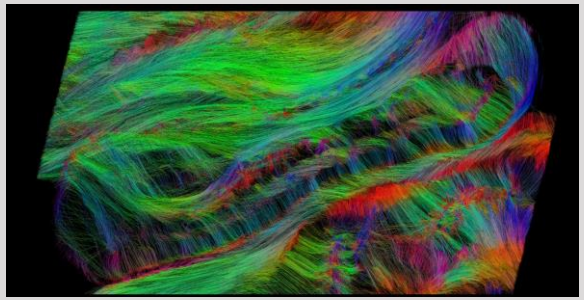
Simple 1 0 Python 3 (ipykernel) | Idle Mode: Command Ln 1, Col 1 Step1_setup_cosimulation.ipynb

WP 1 Showcase 2 : Implementation

Brain data

EBRAINS Human Brain Atlas

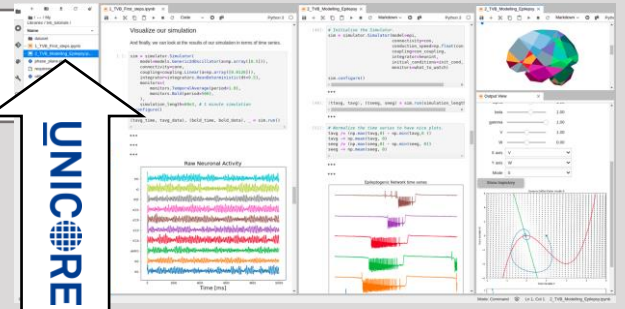
Interactive computing



Atlas services
Knowledge Graph
High resolution imaging data

Modeling

EBRAINS Collaboratory



UNICORE

Personalization & data fusio

EBRAINS Simulation services

FENIX RI High Performance Computing

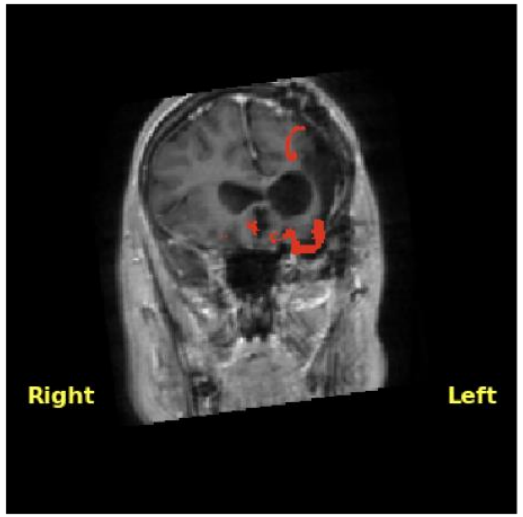
Sensitive Data (WIP) HDC HealthDataCloud HIP

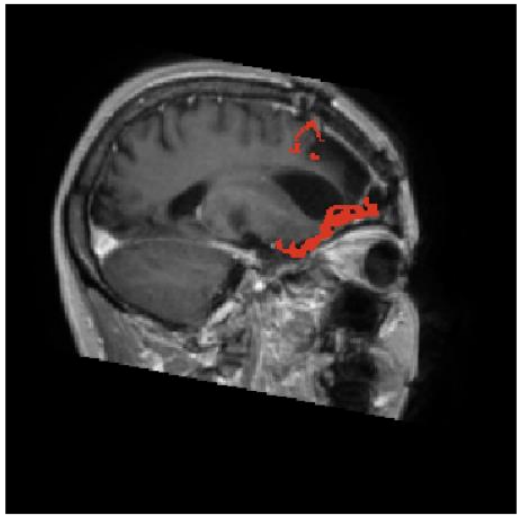
WP 1

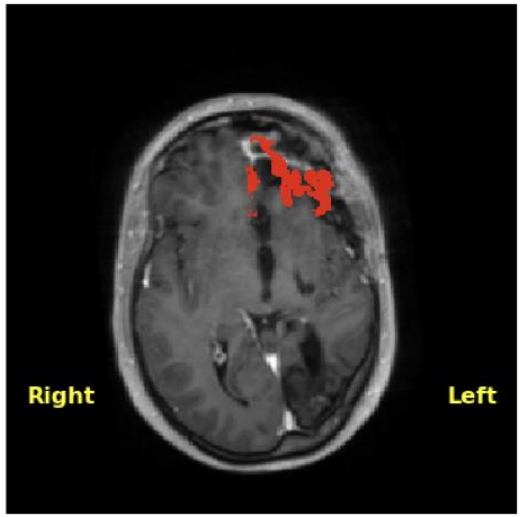
Showcase 2: Inference – State of the art

Good overlap with resection in seizure-free patients

Less overlap with resection in non-seizure-free patients







WP 1

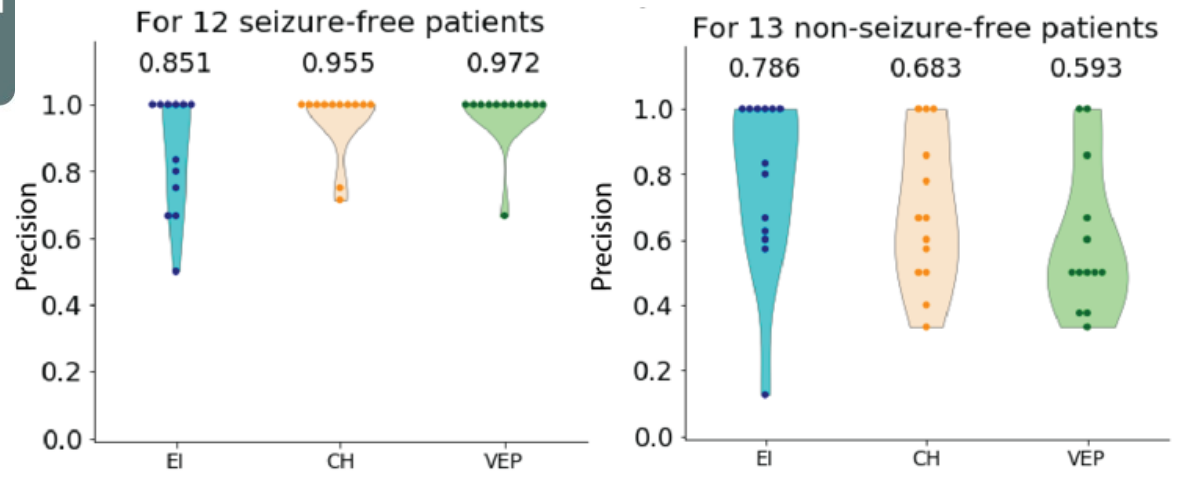
Showcase 2 : Estimation of the EZ – State of the art

Clinical trial EPINOV ongoing in France (13 epilepsy centers, 400 prospective patients in total)

epinov

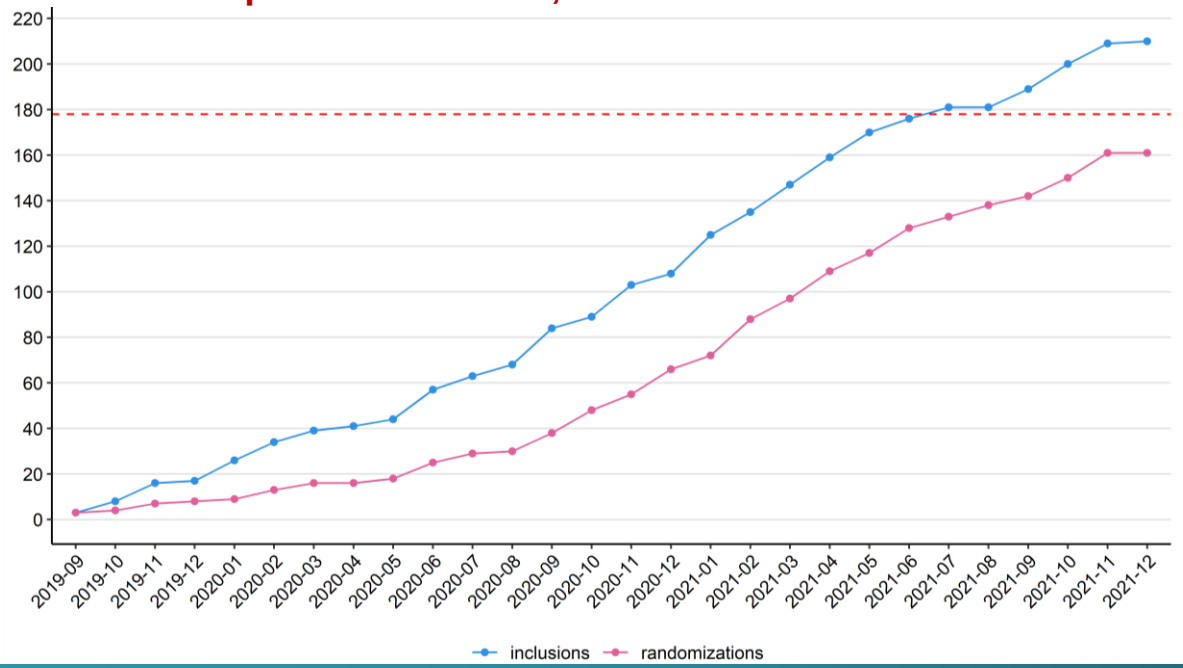
UN PROJET RHU

State of the art applied to a cohort of epilepsy patients retrospectively.



Patient inclusion

12/2021: 210 patients included, data of 161 have been randomized



Human Brain Project EBRAINS

Thank you