

MATLAB EXPO 2018

Controllo open-loop e closed-loop
di attività epilettica *in vitro*
attraverso matrici di microelettrodi

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Istituto Italiano di Tecnologia





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ROBOTICS

NANOMATERIALS

**COMPUTATIONAL
SCIENCES**

LIFETECH*



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TECNOLOGIA

LIFETECH*



ISTITUTO ITALIANO
DI TECNOLOGIA

Neuroningegneria

Neuroprotesi

NINE lab

Neural Interfaces and NEurorehabilitation

Elettrofisiologia di reti neuronali

in vitro: colture neuronali

ex vivo: tessuto cerebrale

in vivo: EEG

Neurofisiopatologia

epilessia

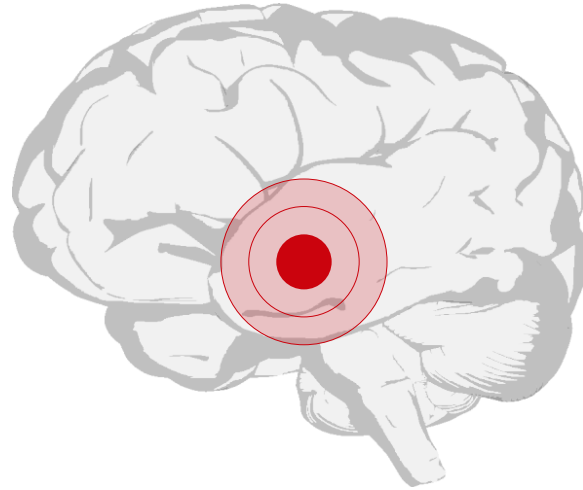
ictus

Neurofarmacologia

Outline

- **Epilessia, modelli *in vitro* e razionale sperimentale**
- **Registrazione di attività epilettica *in vitro* con matrici di microelettrodi (MEA)**
- **Controllo dell'attività epilettica *in vitro* (1): OPEN-LOOP**
- **Controllo dell'attività epilettica *in vitro* (2): CLOSED-LOOP**

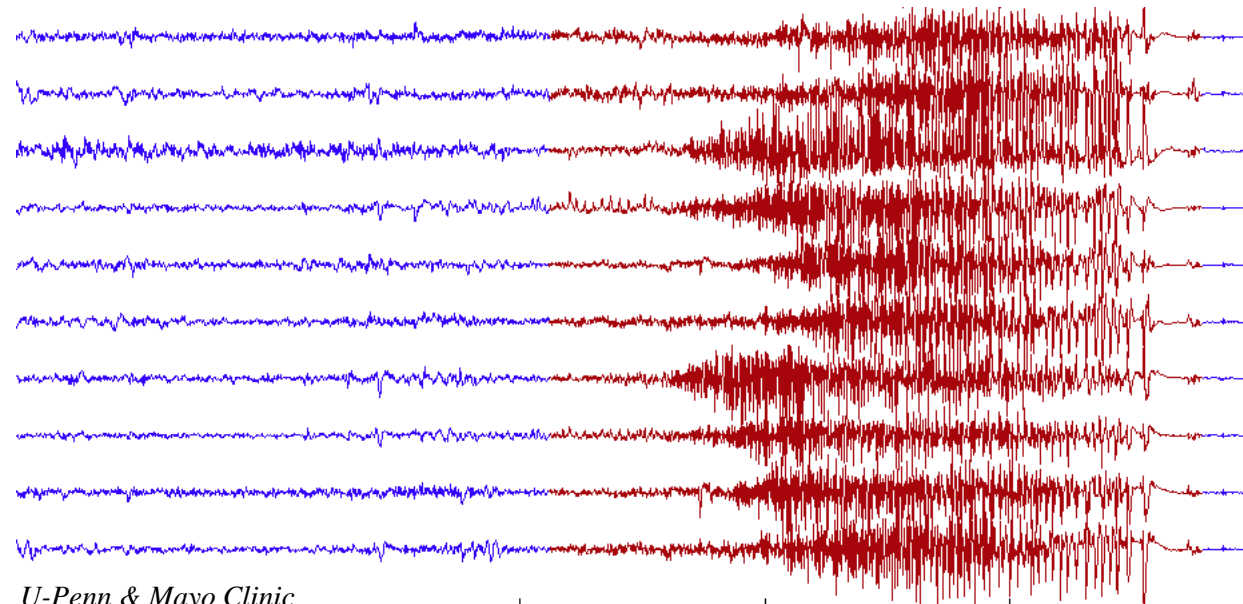
Epilessia e modelli *in vitro*



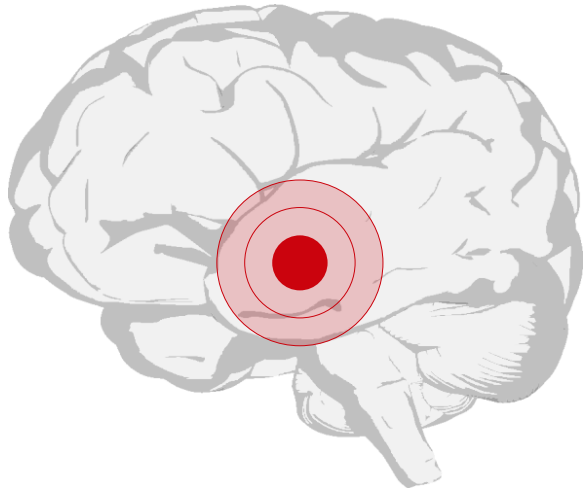
Attività cerebrale abnorme, sincrona ed improvvisa

Crisi epilettiche spontanee ricorrenti

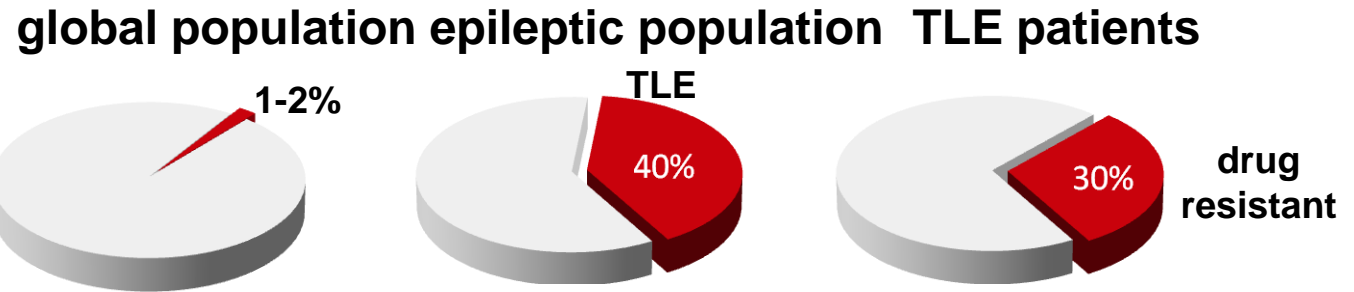
Sintomi sensoriali e/o motori



Epilessia e modelli *in vitro*



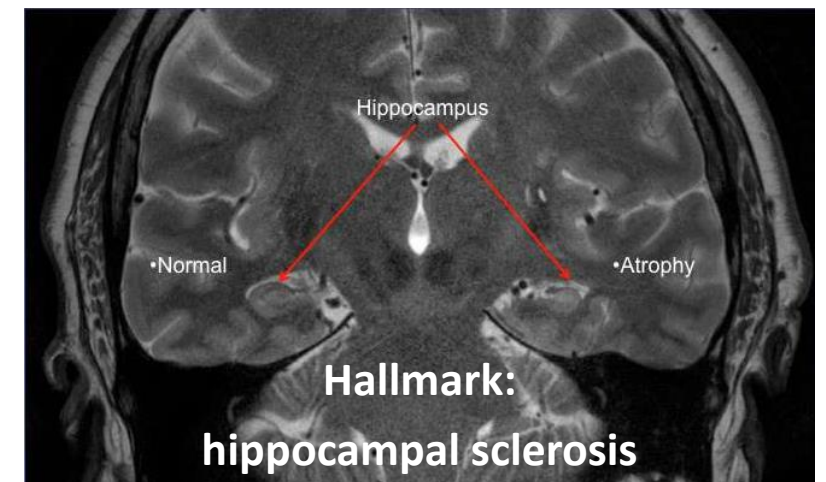
Epilessia del Lobo Temporale (*Temporal Lobe Epilepsy* – TLE)



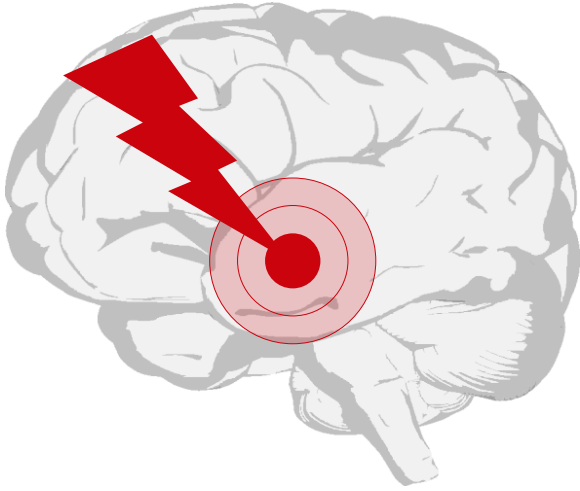
IL MECCANISMO ESATTO AD OGGI È SCONOSCIUTO



IPPOCAMPO → KEY PLAYER



EPILESSIA E MODELLI *IN VITRO*



Epilessia del Lobo Temporale (*Temporal Lobe Epilepsy – TLE*)

QUALI INTERVENTI TERAPEUTICI?

Farmaci anti-epilettici

Neurochirurgia

Deep-Brain Stimulation (DBS)

Modelli *in vitro* di TLE

Tessuto nervoso (*fettina*)

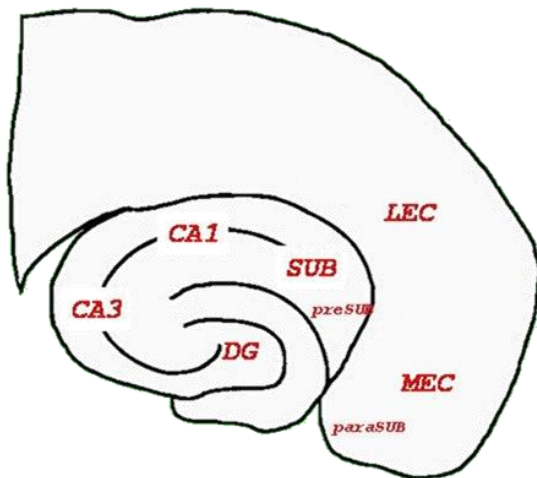
- strutture anatomiche & circuiti neuronali fondamentali

Trattamento farmacologico & disconnessione anatomica

- aumento di attività neuronale
- ipereccitabilità

Registrazioni elettrofisiologiche

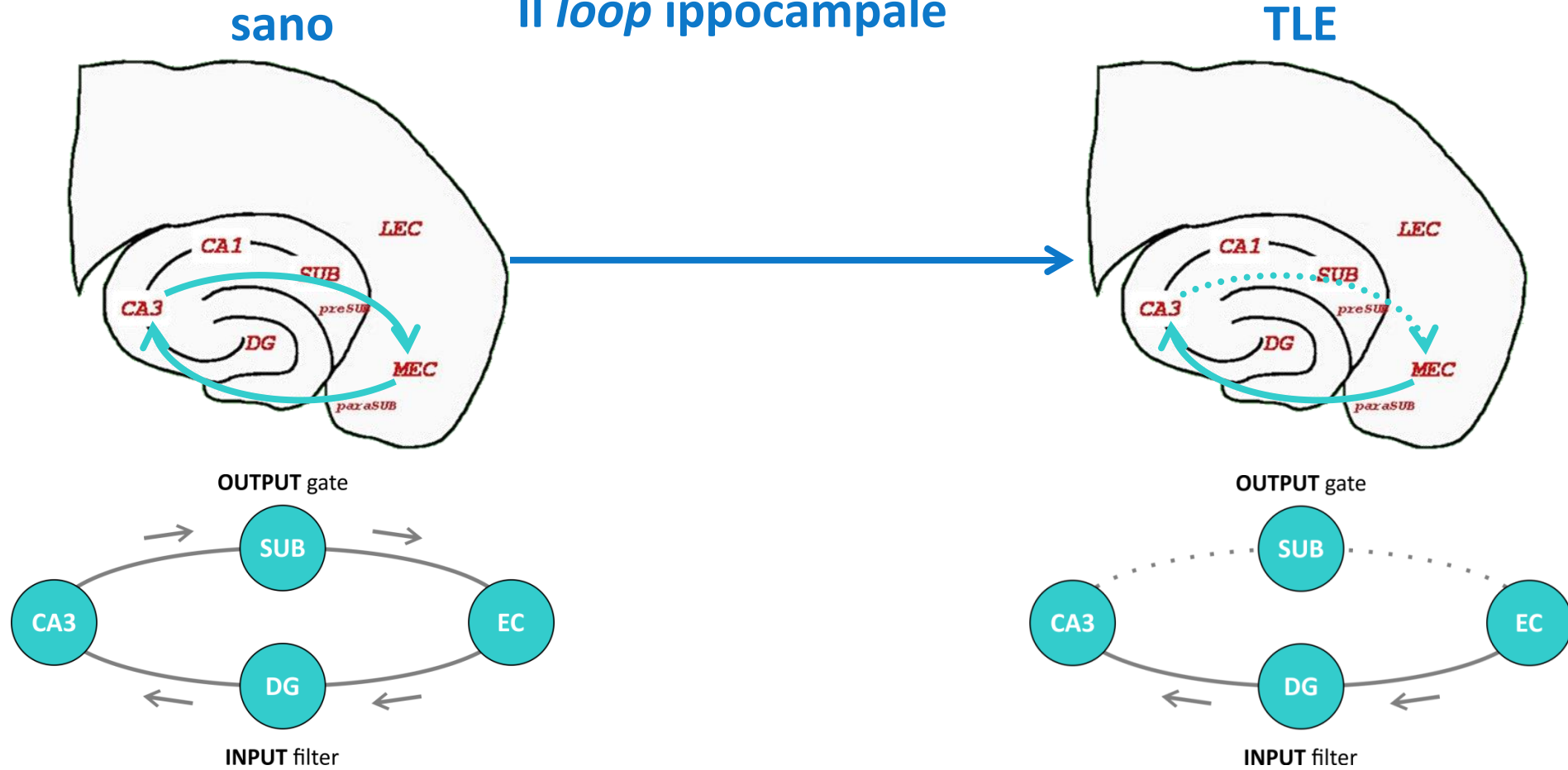
- potenziali di campo (attività di network)
- pattern elettrico simile ad EEG di paziente TLE



Epilessia e modelli *in vitro*

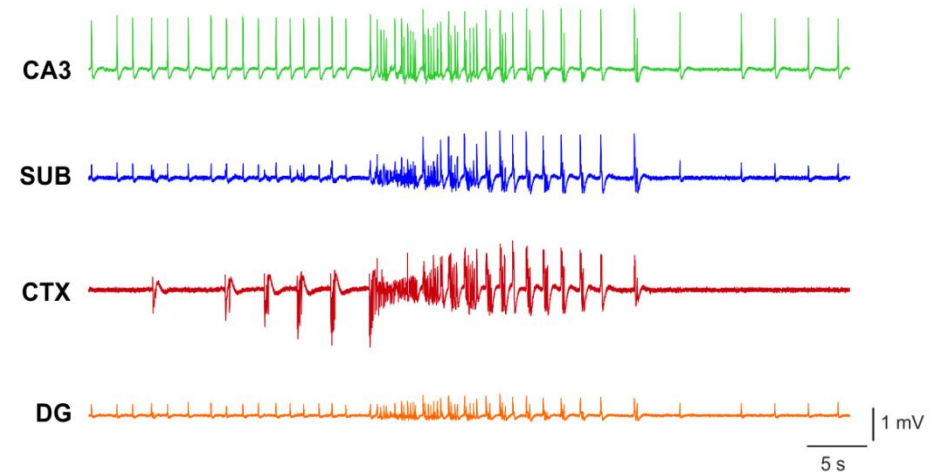
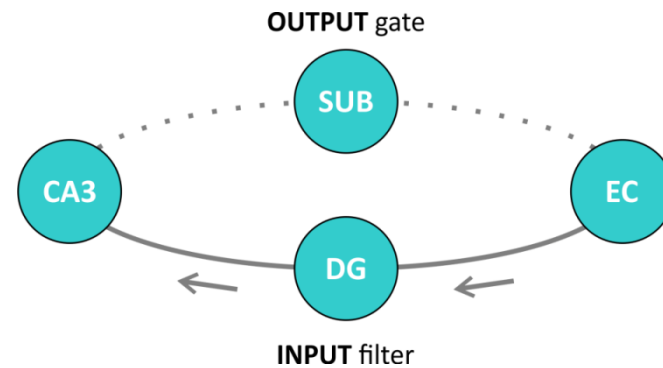
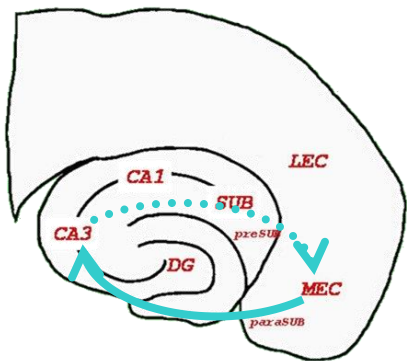
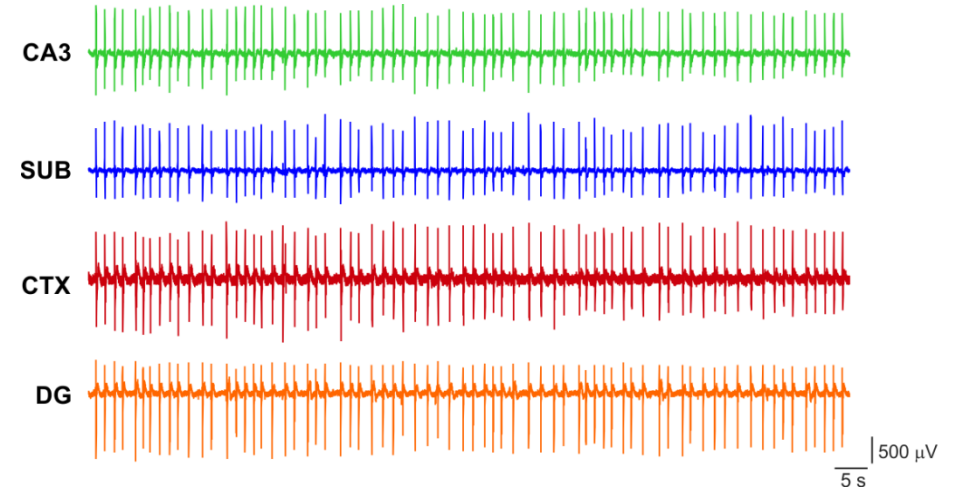
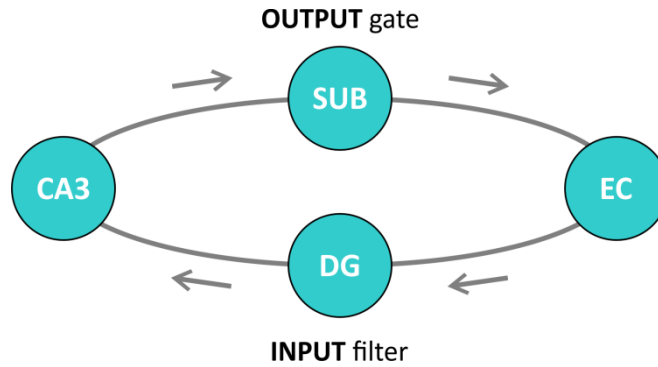
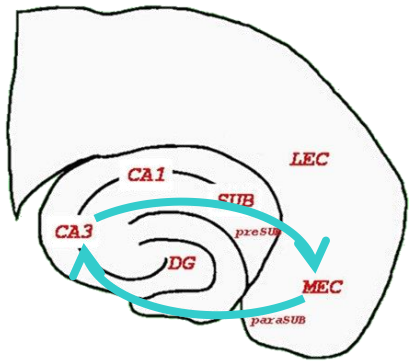
Modelli *in vitro* di TLE

Il *loop* ippocampale

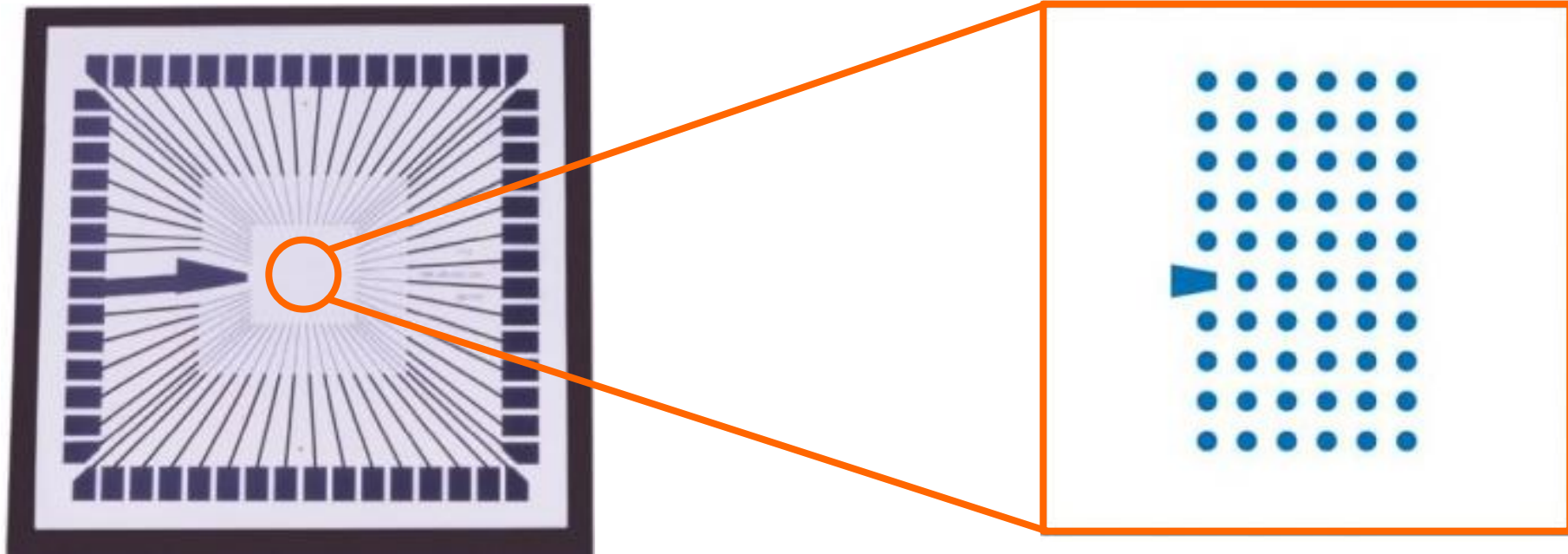


Epilessia e modelli *in vitro*

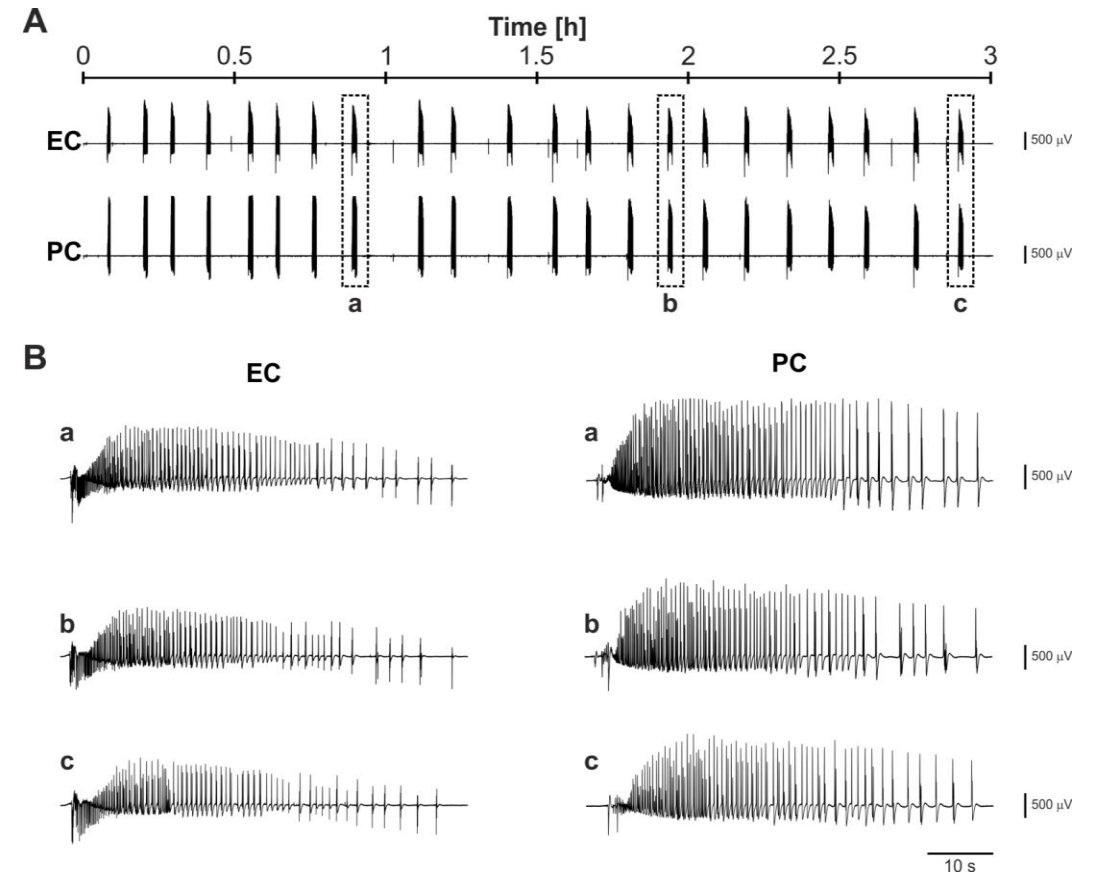
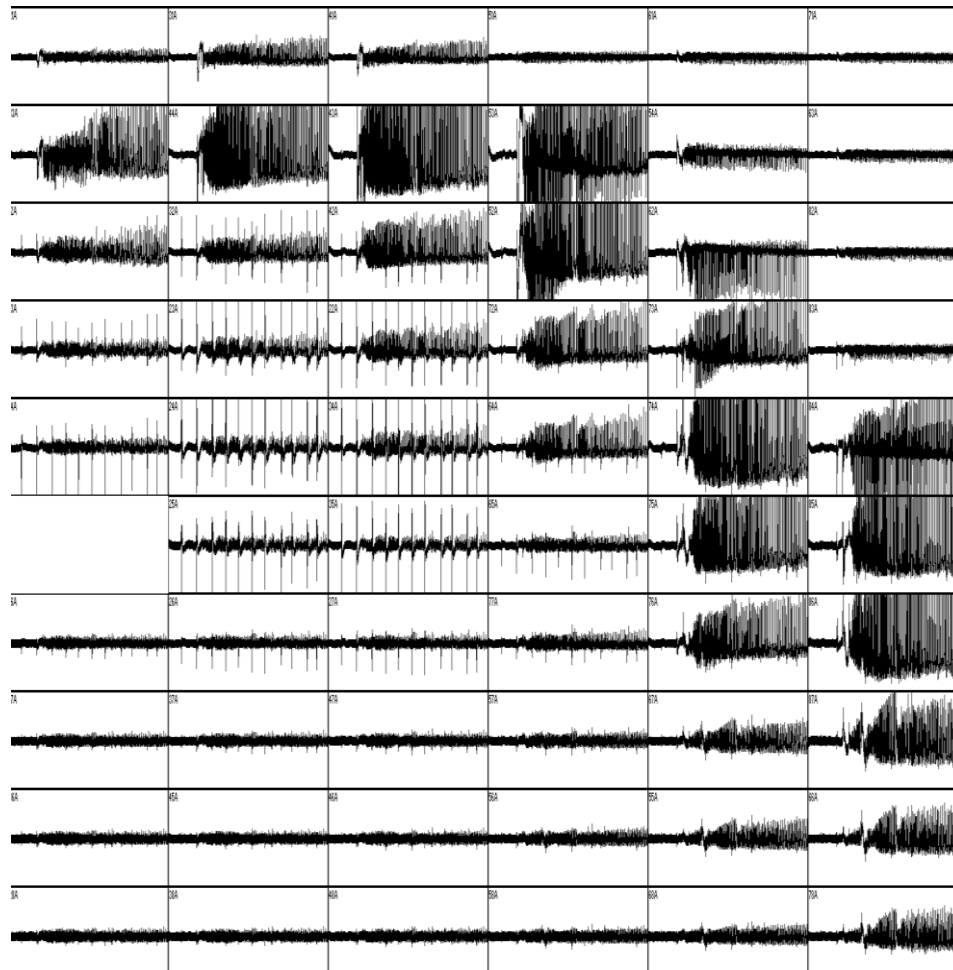
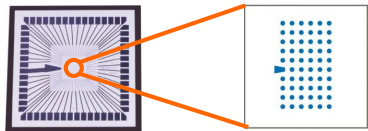
Modelli *in vitro* di TLE



Registrazione di attività epilettica con matrici di microelettrodi (MEA)

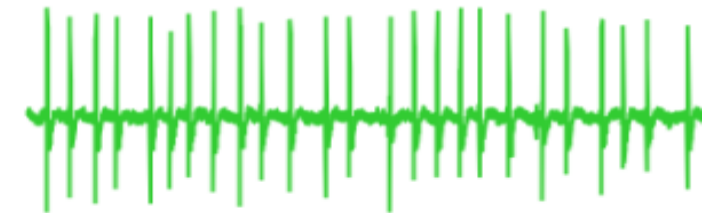
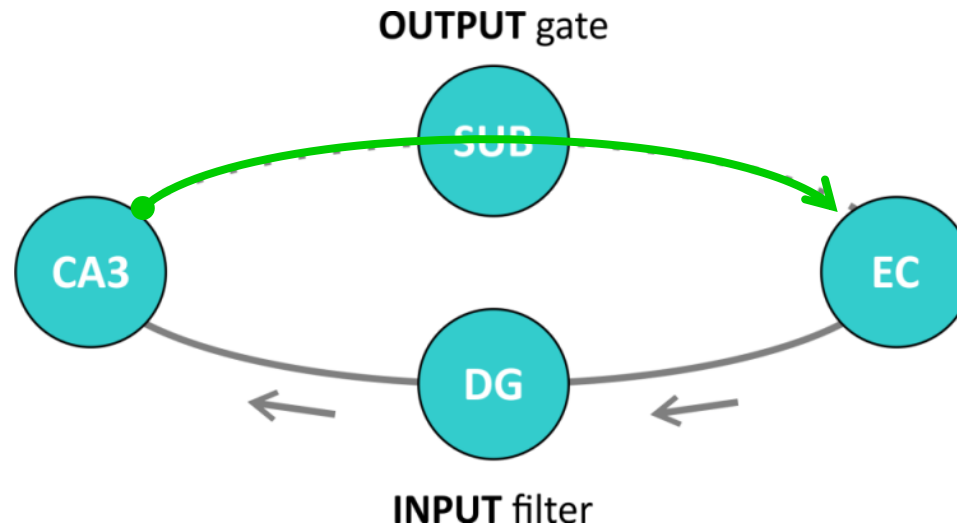
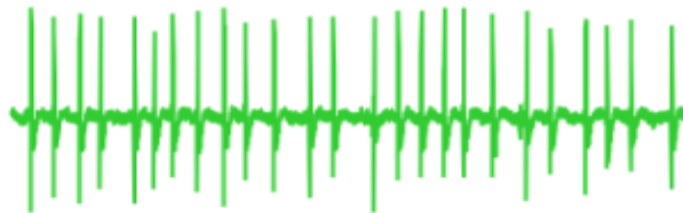
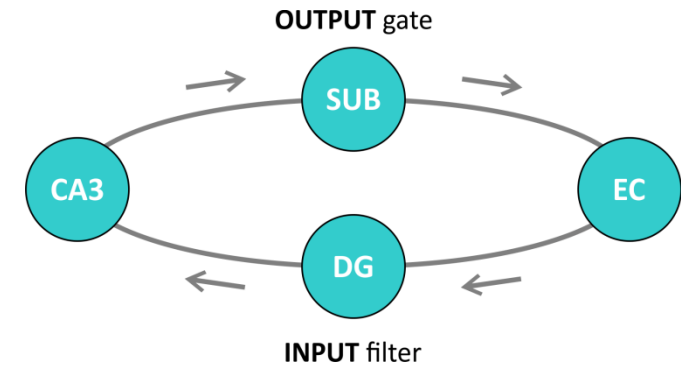
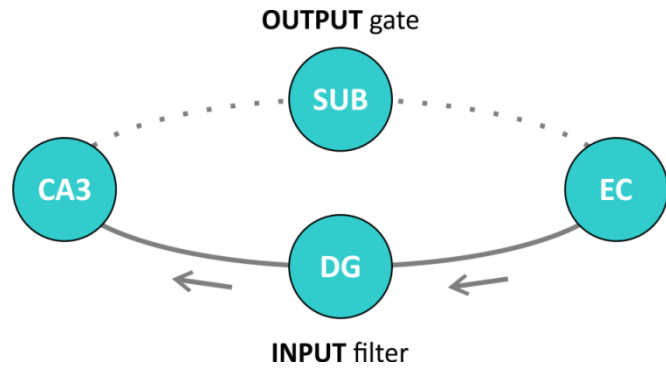


Registrazione di attività epilettica con matrici di microelettrodi (MEA)



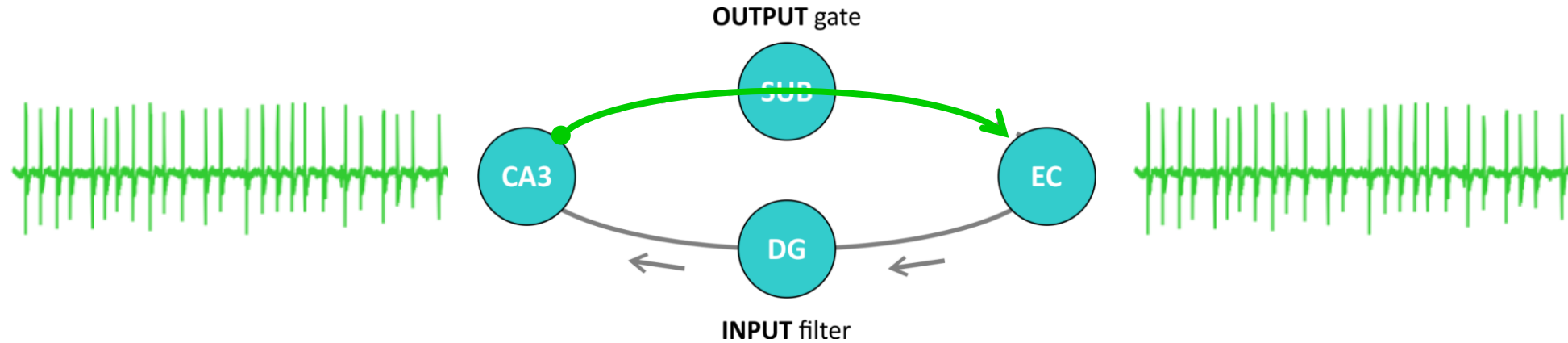
Controllo dell'attività epilettica *in vitro*

Razionale sperimentale



Controllo dell'attività epilettica *in vitro*

Strategia sperimentale



SIMULAZIONE DEL PATTERN



Neuromodulazione *open-loop*

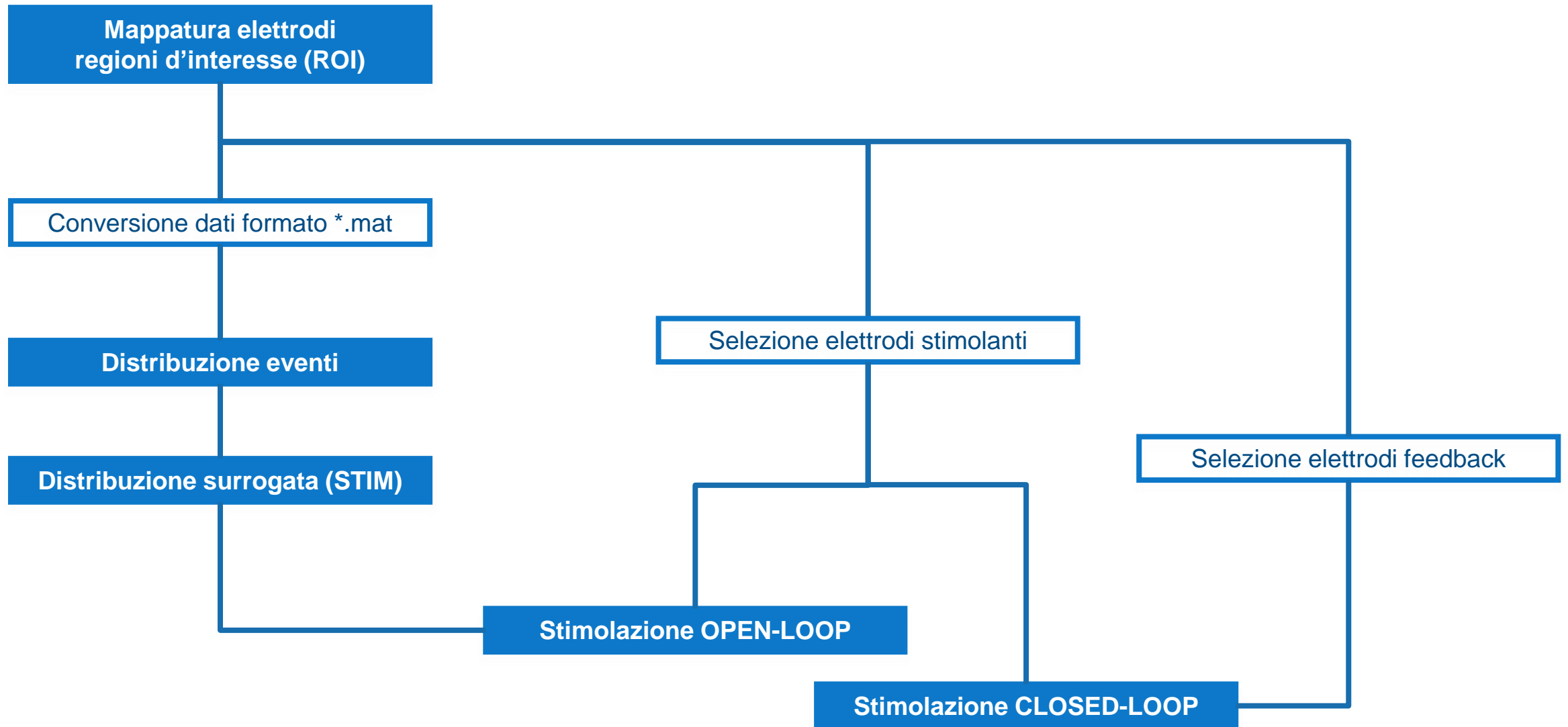
RICONNESSIONE FUNZIONALE



Neuromodulazione *closed-loop*

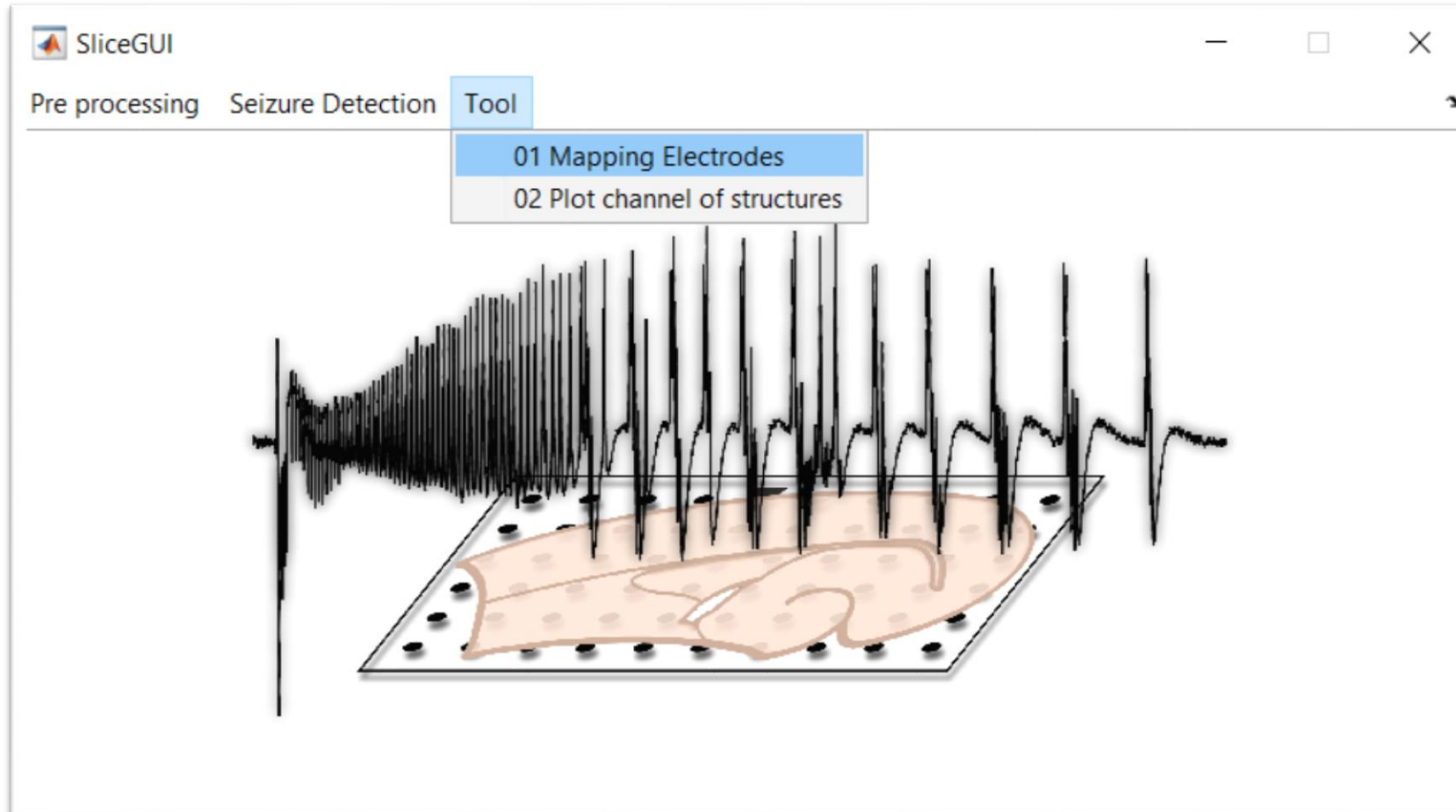
struttura target

Controllo dell'attività epilettica *in vitro*



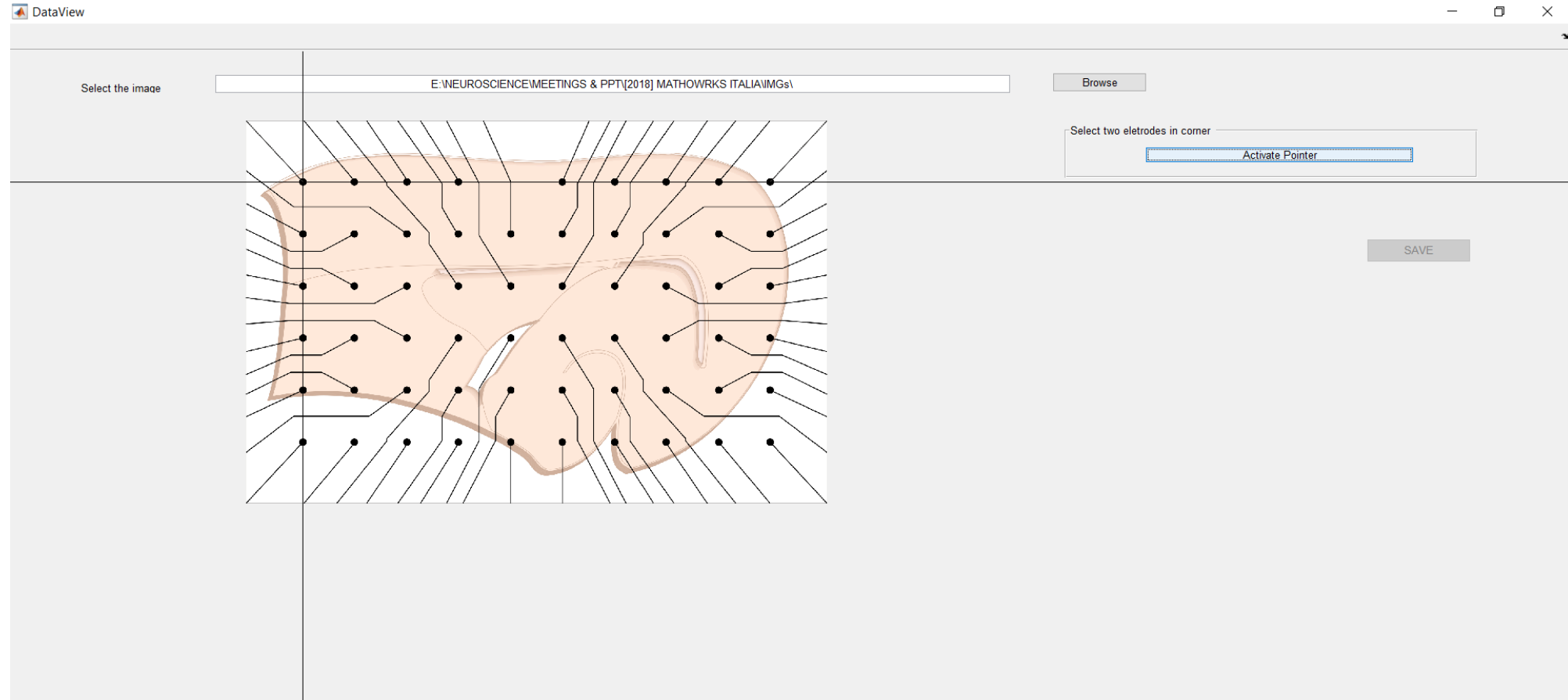
Controllo dell'attività epilettica *in vitro*

Mappatura degli elettrodi rispetto alle regioni d'interesse (ROI)



Controllo dell'attività epilettica *in vitro*

Mappatura degli elettrodi rispetto alle regioni d'interesse (ROI)



Controllo dell'attività epilettica *in vitro*

Mappatura degli elettrodi rispetto alle regioni d'interesse (ROI)

Select the image: E:\MATLAB-EXPO-2018\slice_on_MEA.png

Select two electrodes in corner: Activate Pointer

Horizontal

Default Structures Enter Structures SAVE

Labelling

| | | |
|-----|-------|--------|
| CA3 | | Cancel |
| EC | | Cancel |
| PC | | Cancel |
| SUB | 42 52 | Cancel |

| | | | | | | | | |
|----|----|----|----|----|----|----|----|----|
| 28 | 36 | 17 | 16 | 14 | 13 | 12 | 33 | 21 |
| 38 | 45 | 37 | 26 | 25 | 24 | 23 | 32 | 44 |
| 48 | 46 | 47 | 27 | 35 | 34 | 22 | 42 | 43 |
| 58 | 56 | 57 | 77 | 65 | 64 | 72 | 52 | 53 |
| 68 | 55 | 67 | 76 | 75 | 74 | 73 | 62 | 54 |
| 78 | 66 | 87 | 86 | 85 | 84 | 83 | 82 | 63 |
| | | | | | | | | 71 |

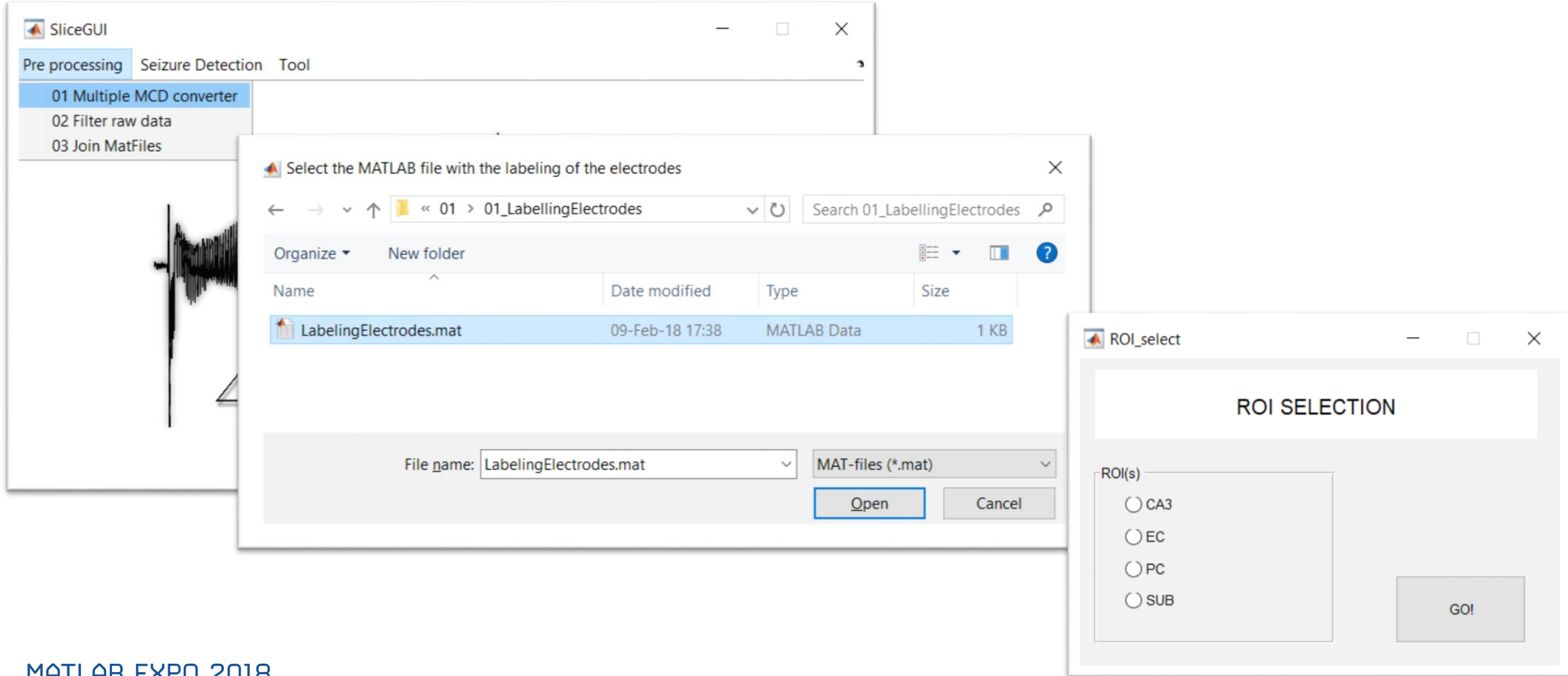
Selezione elettrodo/i

Selezione:

- tipo sezione
- ROI

Controllo dell'attività epilettica *in vitro*

Conversione dei dati in formato *.mat



The image shows the SliceGUI software interface with three overlapping windows:

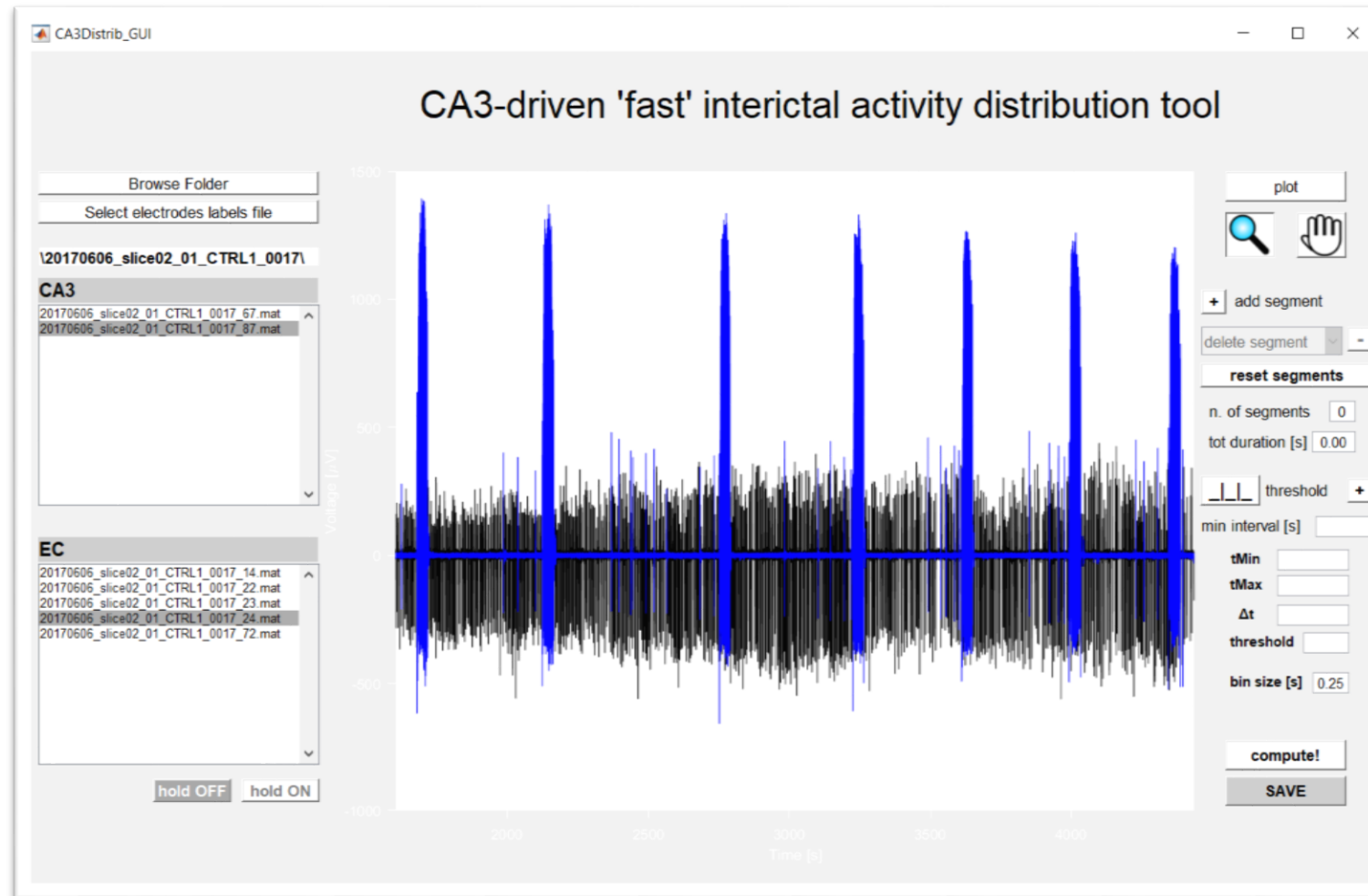
- SliceGUI (Background):** Shows a menu with 'Pre processing', 'Seizure Detection', and 'Tool'. Under 'Pre processing', there are three options: '01 Multiple MCD converter' (highlighted), '02 Filter raw data', and '03 Join MatFiles'. A waveform plot is visible on the left.
- Select the MATLAB file with the labeling of the electrodes (Middle):** A file selection dialog showing the path '01 > 01_LabelingElectrodes'. It contains a table with the following data:

| Name | Date modified | Type | Size |
|------------------------|-----------------|-------------|------|
| LabelingElectrodes.mat | 09-Feb-18 17:38 | MATLAB Data | 1 KB |

 The 'File name' field is set to 'LabelingElectrodes.mat' and the file type is 'MAT-files (*.mat)'. 'Open' and 'Cancel' buttons are at the bottom.
- ROI_select (Right):** A dialog titled 'ROI SELECTION' with a 'ROI(s)' label and a list of radio buttons: CA3, EC, PC, and SUB. A 'GO!' button is located at the bottom right.

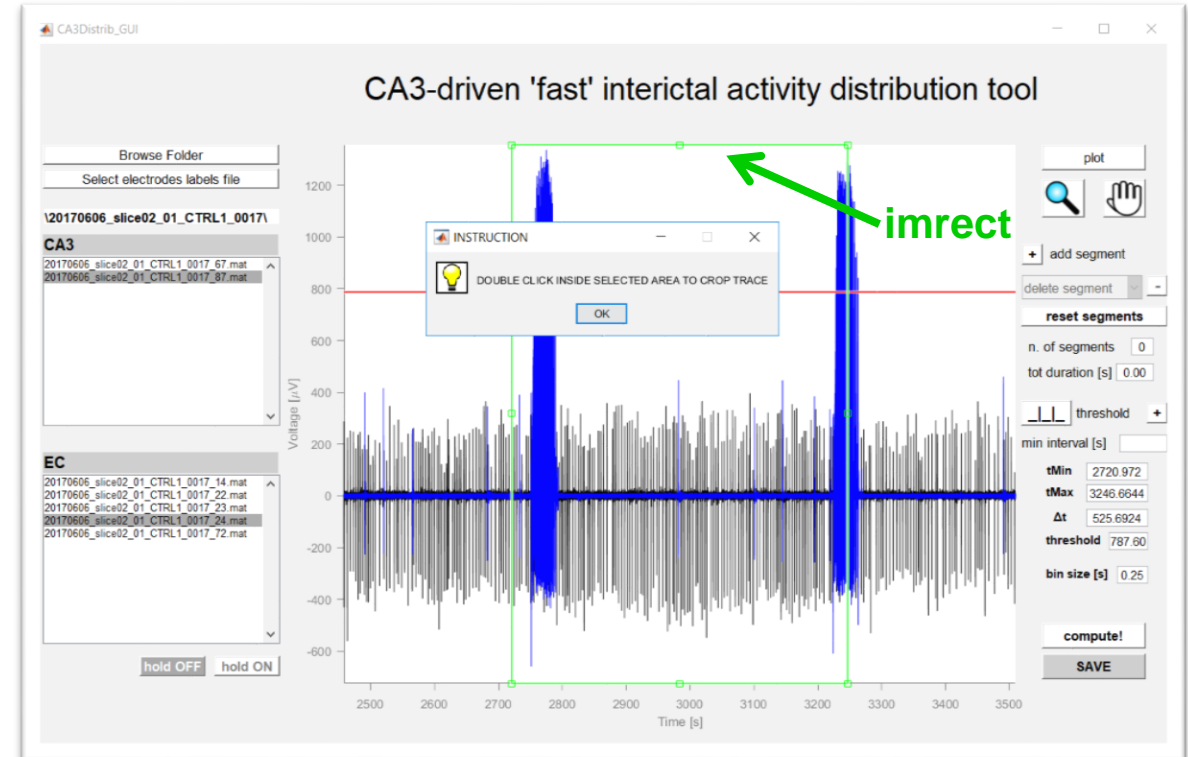
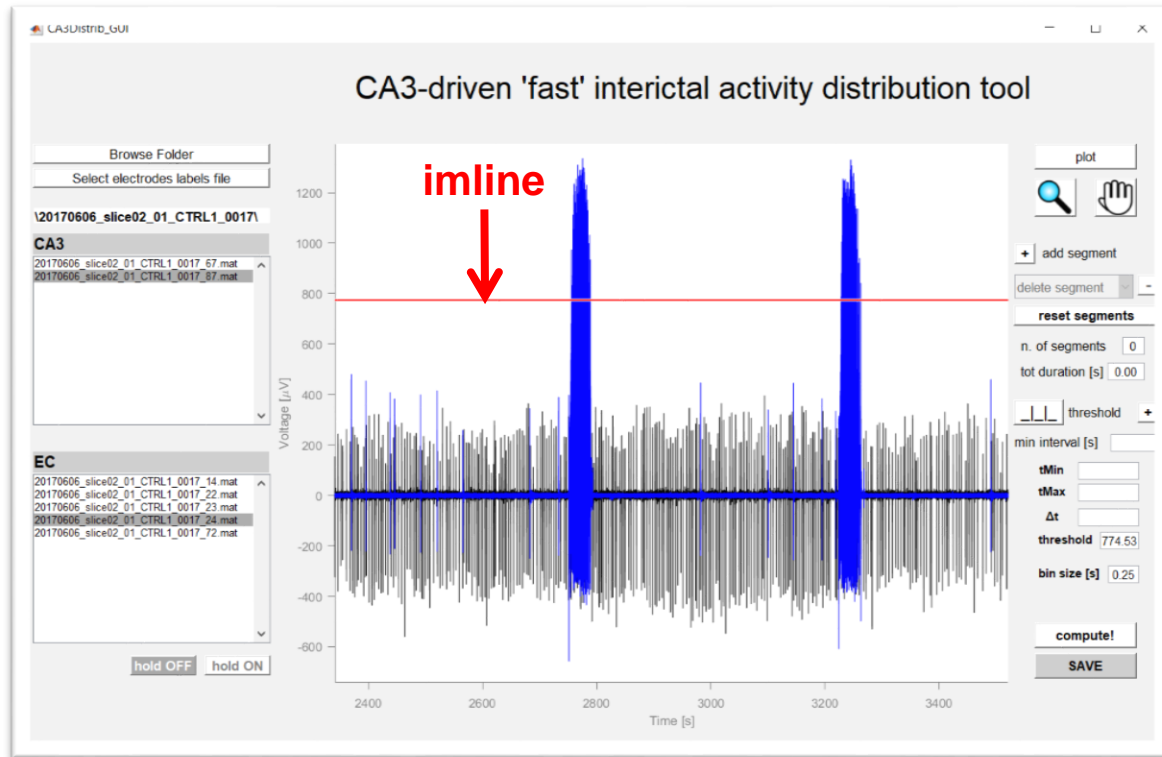
Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali → distribuzione eventi



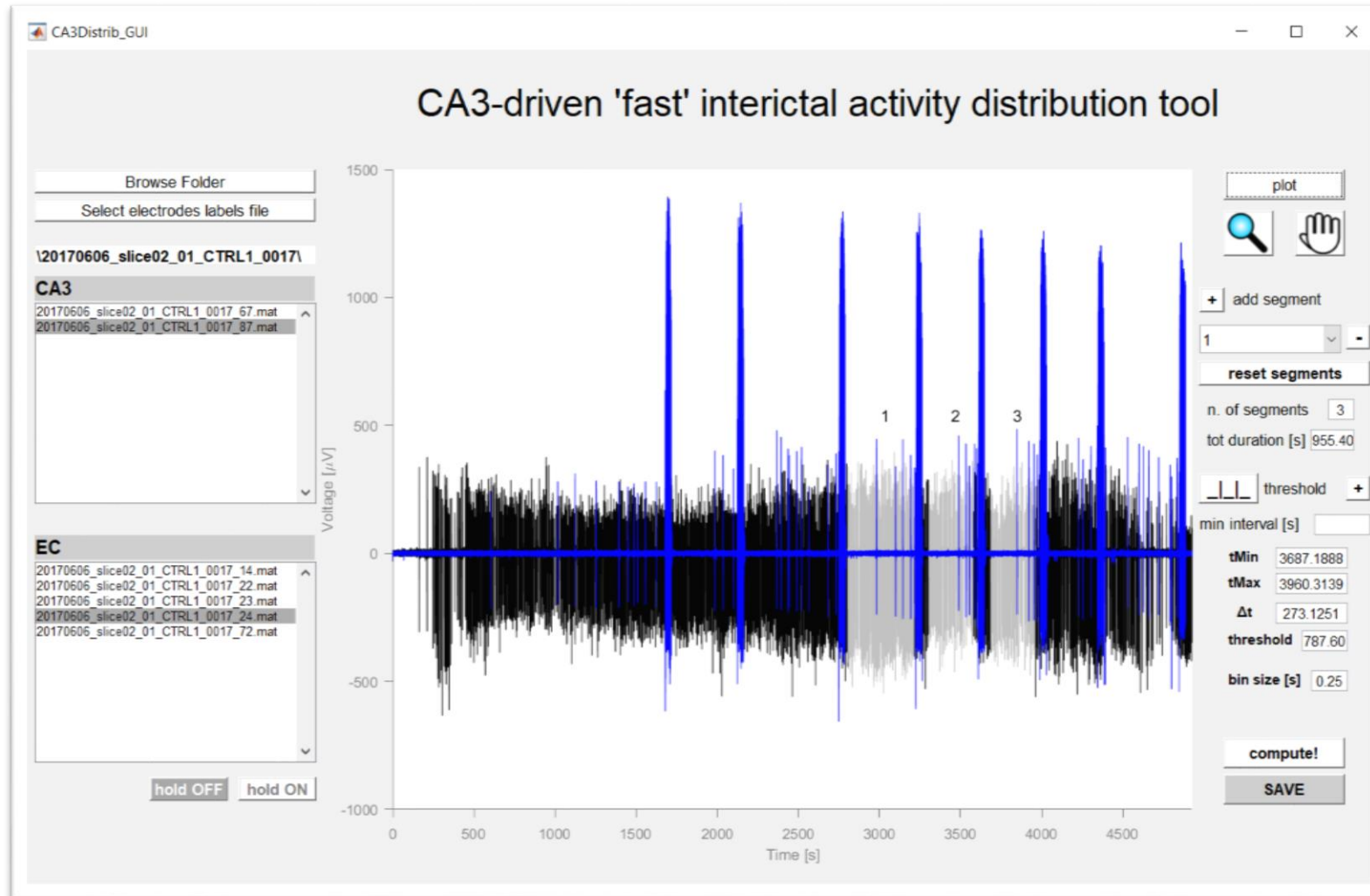
Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali → distribuzione eventi



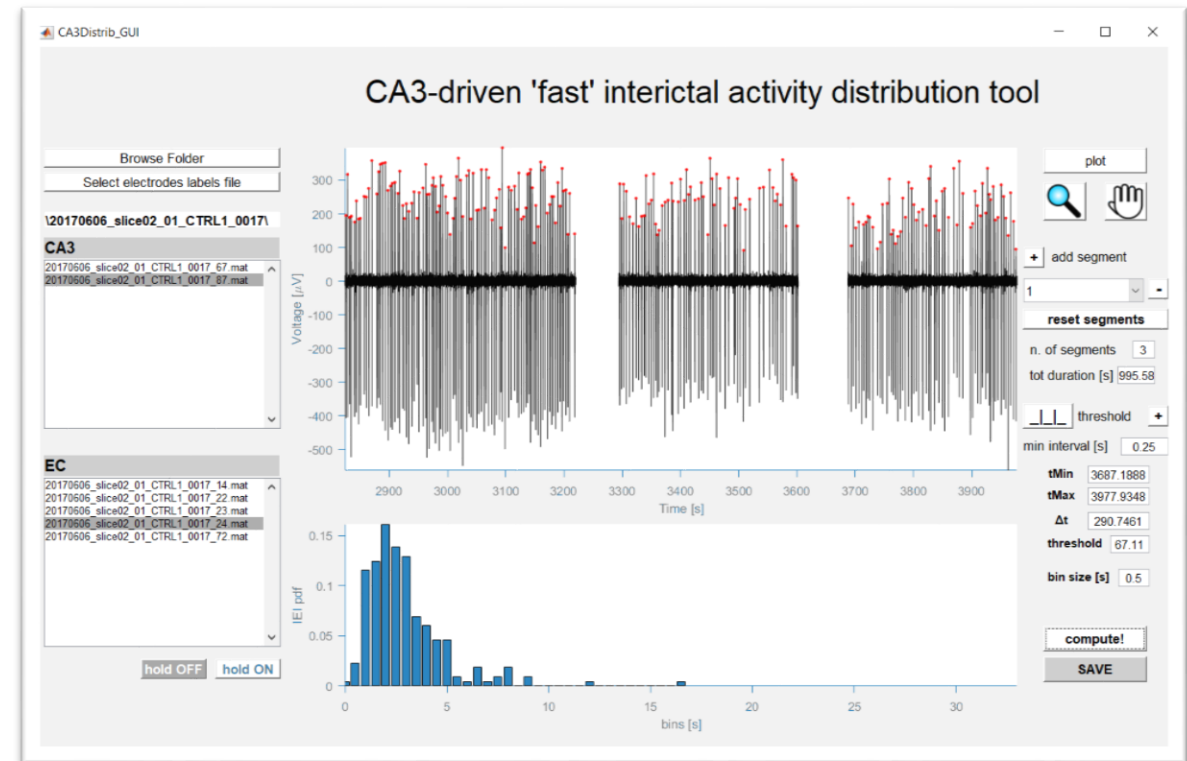
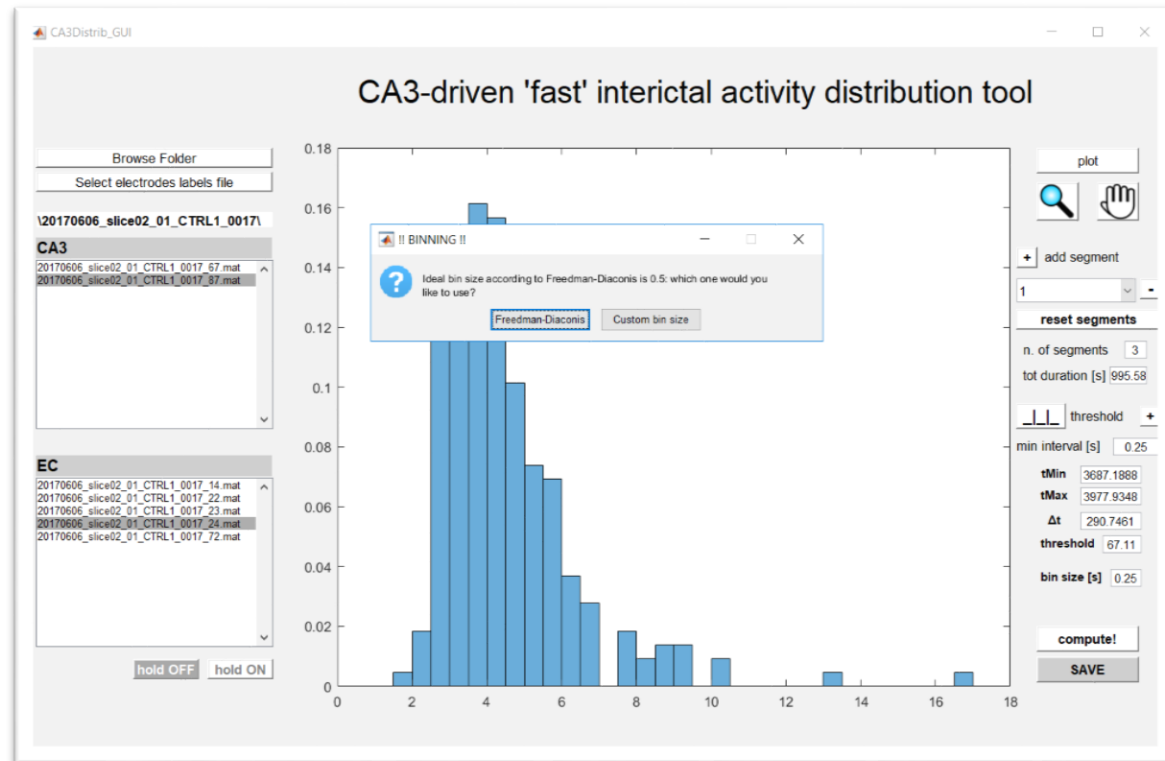
Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali → distribuzione eventi



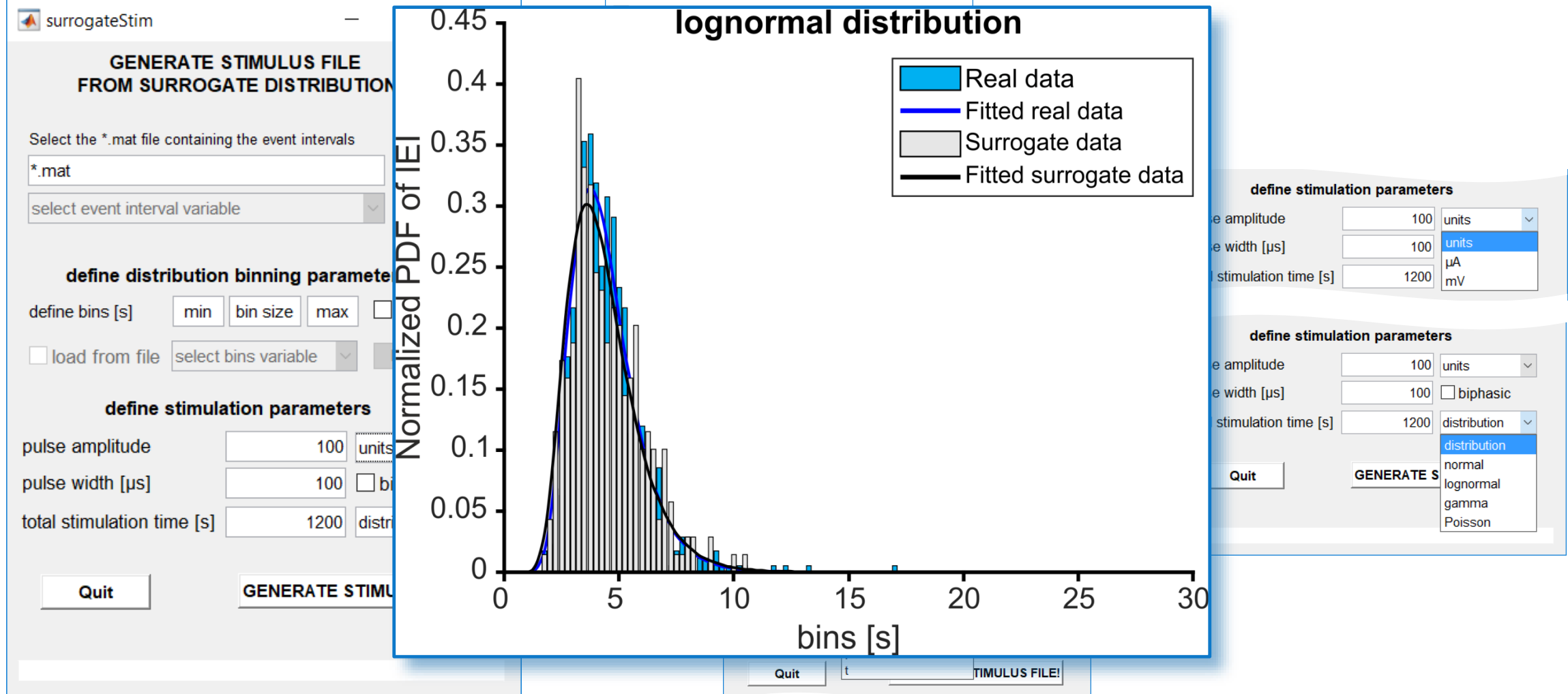
Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali → distribuzione eventi



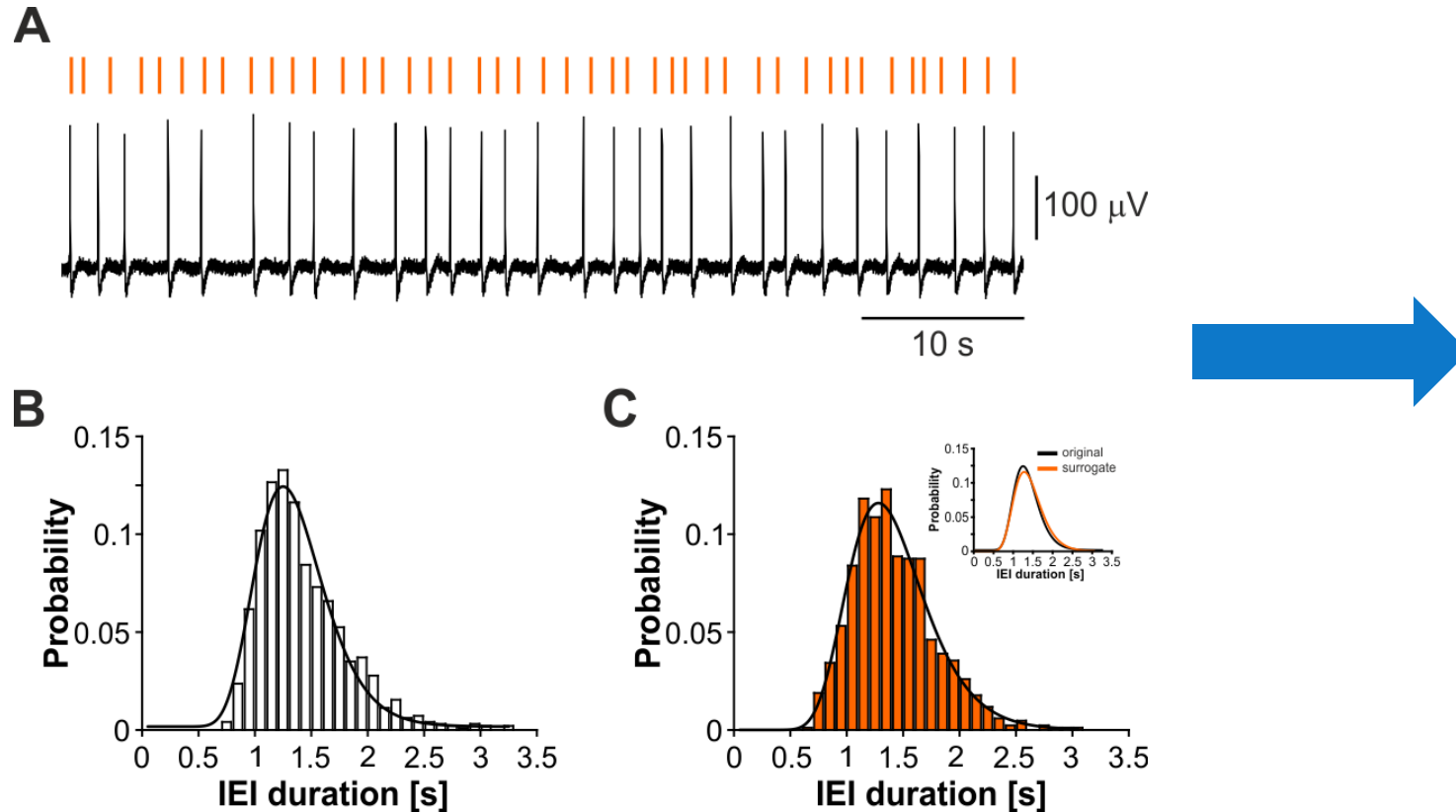
Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali



Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali



Esportazione serie di
pulsu in ASCII file
STIM.txt

Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali

MC_Stimulus II - [MC_Stim1]

File Edit STG Batch Signal View Window Settings

- New Ctrl+N
- Open... Ctrl+O
- Close
- Save Ctrl+S
- Save As...
- Import ASCII File...
- Export ASCII File...
- Print... Ctrl+P
- Print Preview
- Print Setup...

MC_Stimulus II - [20170606_slice02_STIM_CA3distrib.txt]

File Edit STG Batch Signal View Window Settings Help

STG: Connect Programmed: Sweep: Voltage Range: Current Range:

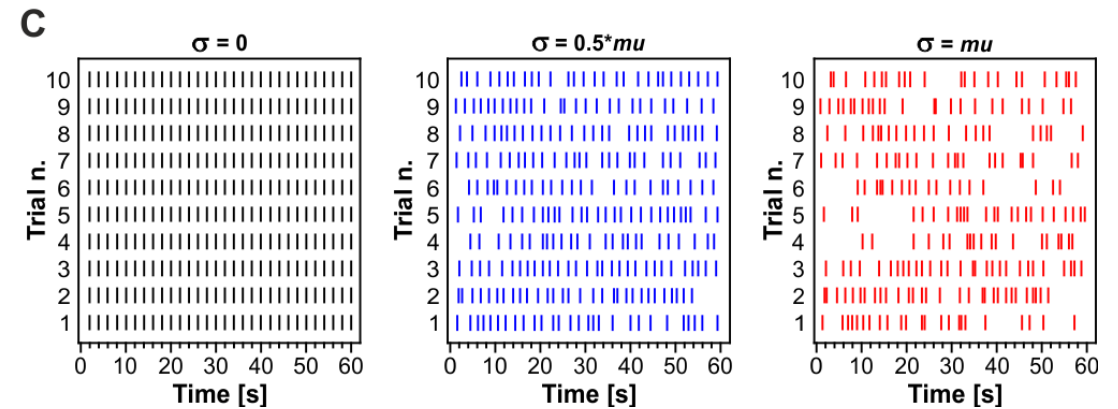
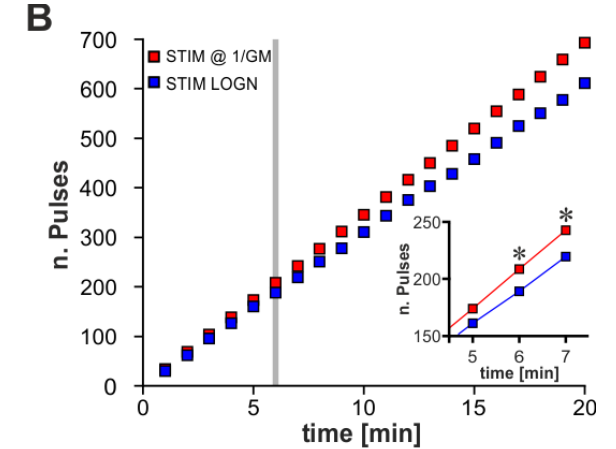
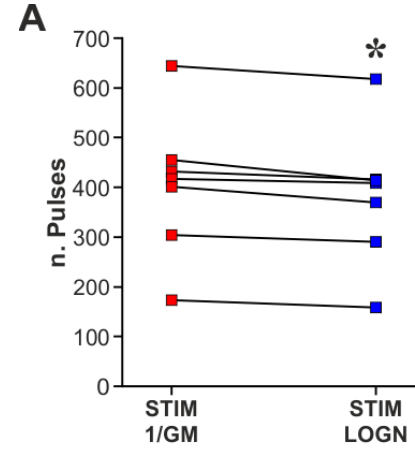
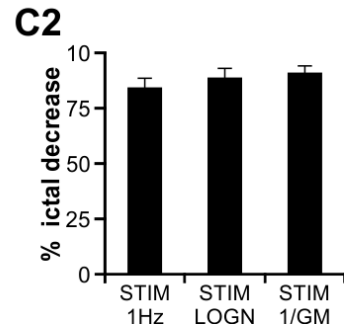
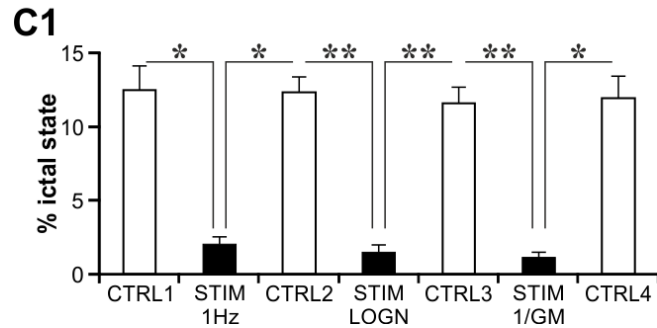
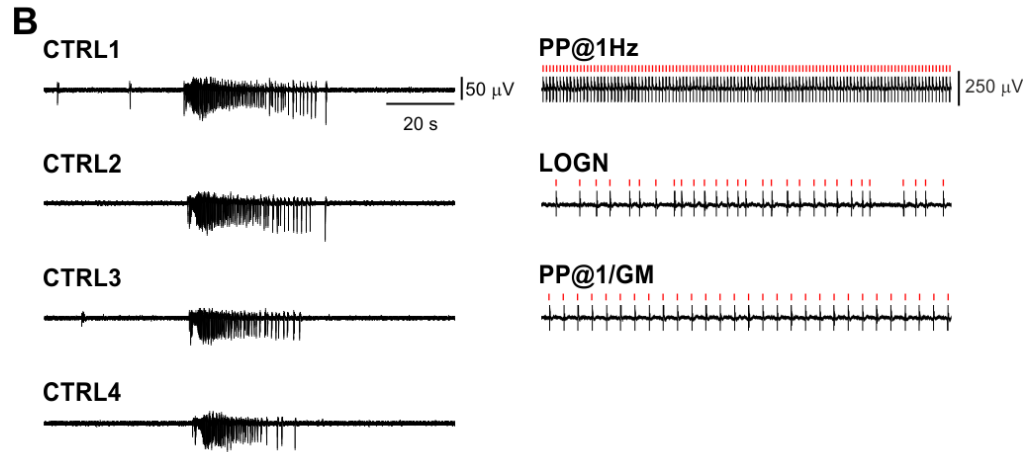
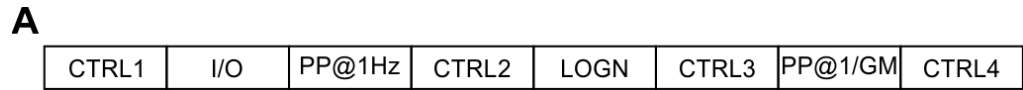
Channel: 1 Last Download: Cont. Mode: On Off Output Mode: Voltage Current Download Channel: 1 2 3 4 5 6 7 8 Download Sync: 1 2 3 4 5 6 7 8 Comment:

| | Pulse | valu | Uni | time | Unit | valu | Uni | time | Unit | valu | Uni | time | Unit | Row r | Group |
|----|-------------|------|-----|------|------|------|-----|------|------|------|-----|------|------|-------|-------|
| 1 | rectangular | 250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 2 | rectangular | -250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 3 | rectangular | 0 | µA | 5661 | µs | | µA | | µs | | µA | | µs | | |
| 4 | rectangular | 250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 5 | rectangular | -250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 6 | rectangular | 0 | µA | 2798 | µs | | µA | | µs | | µA | | µs | | |
| 7 | rectangular | 250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 8 | rectangular | -250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 9 | rectangular | 0 | µA | 6961 | µs | | µA | | µs | | µA | | µs | | |
| 10 | rectangular | 250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 11 | rectangular | -250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 12 | rectangular | 0 | µA | 5529 | µs | | µA | | µs | | µA | | µs | | |
| 13 | rectangular | 250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 14 | rectangular | -250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |
| 15 | rectangular | 0 | µA | 7753 | µs | | µA | | µs | | µA | | µs | | |
| 16 | rectangular | 250 | µA | 100 | µs | | µA | | µs | | µA | | µs | | |

Ready STG: NUM

Controllo dell'attività epilettica *in vitro*

(1) OPEN-LOOP → emulazione di pattern neuronali

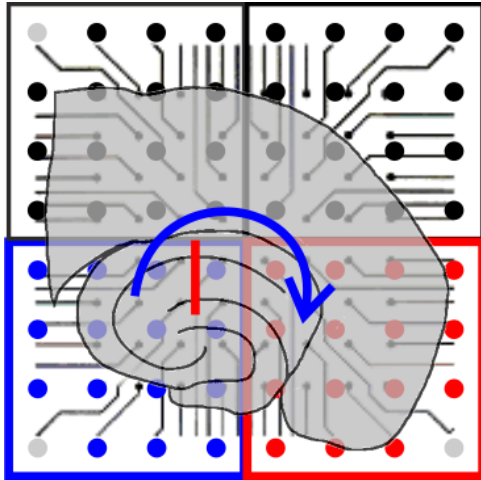


Controllo dell'attività epilettica *in vitro*

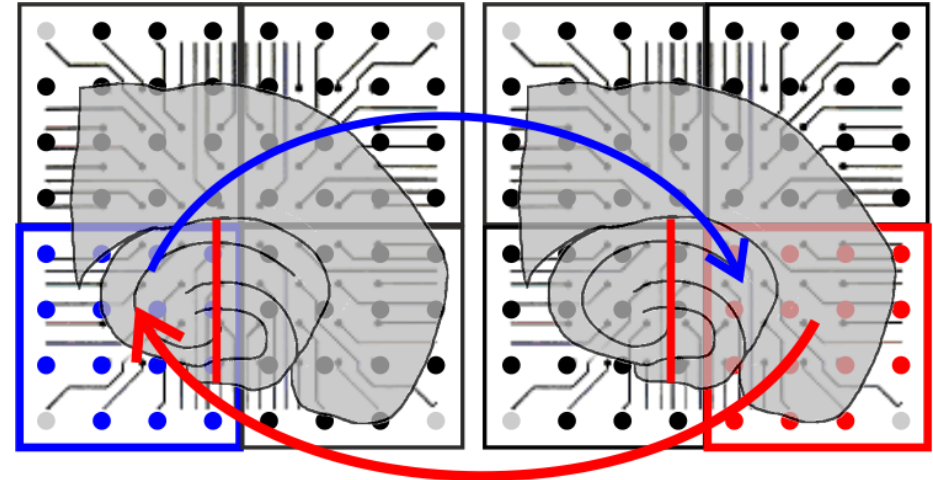
(2) CLOSED-LOOP → ponti elettronici

Simulink environment

Ponte UNIDIREZIONALE



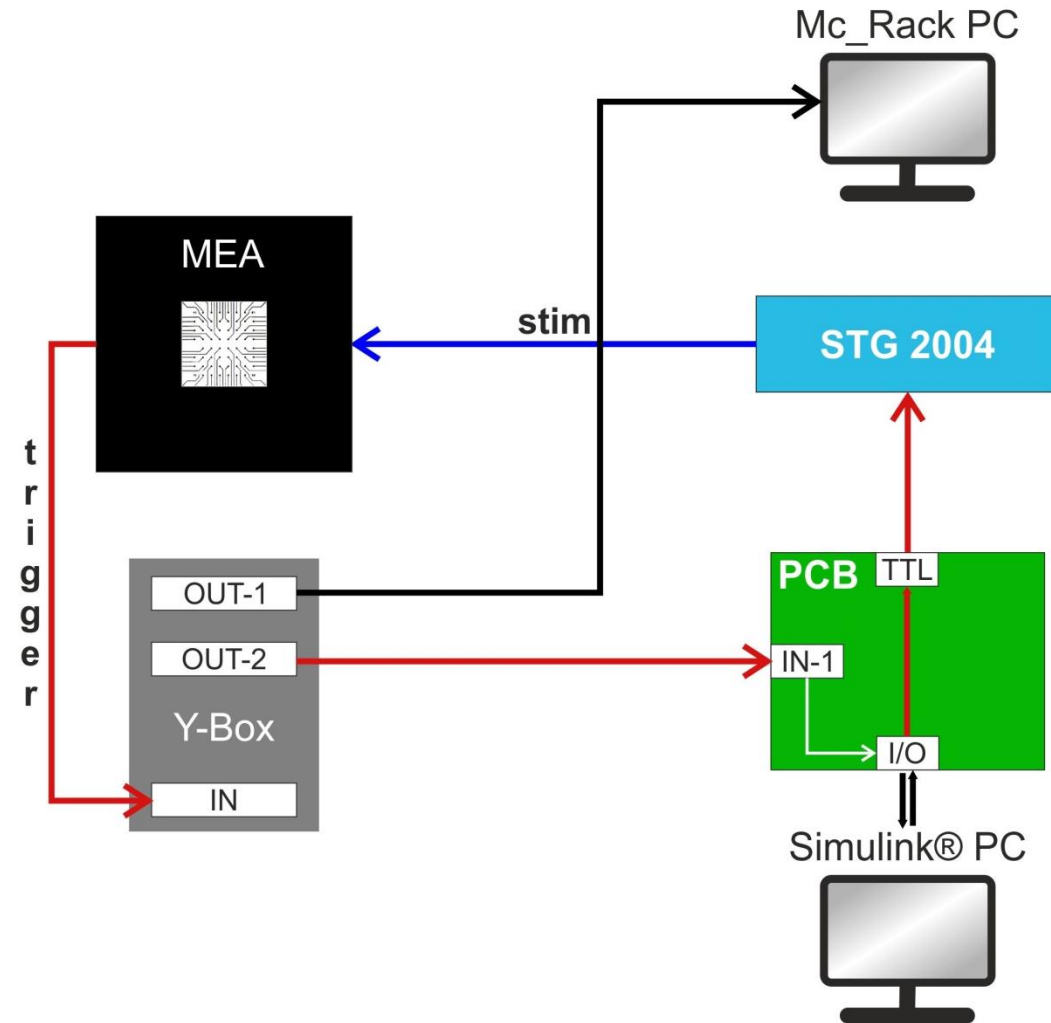
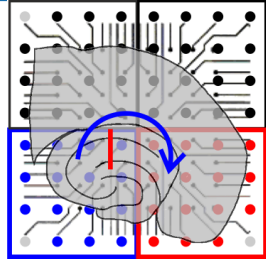
Ponte BIDIREZIONALE



Controllo dell'attività epilettica *in vitro*

(2) CLOSED-LOOP → ponti elettronici

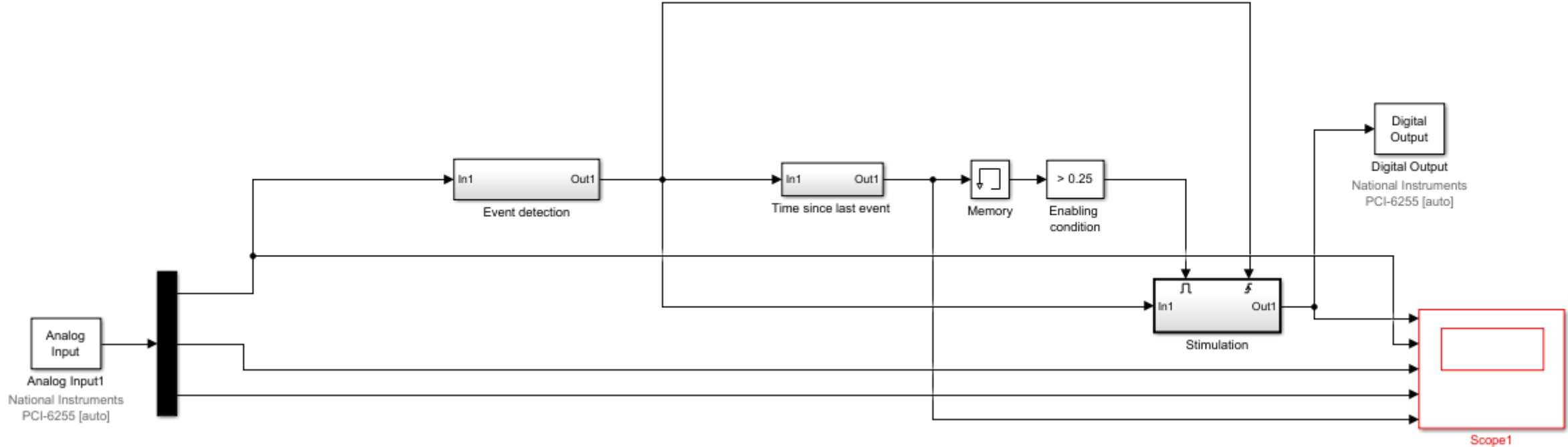
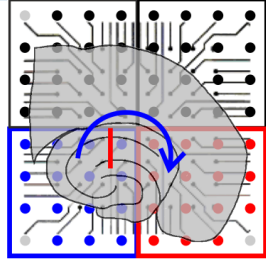
Ponte UNIDIREZIONALE



Controllo dell'attività epilettica *in vitro*

(2) CLOSED-LOOP → ponti elettronici

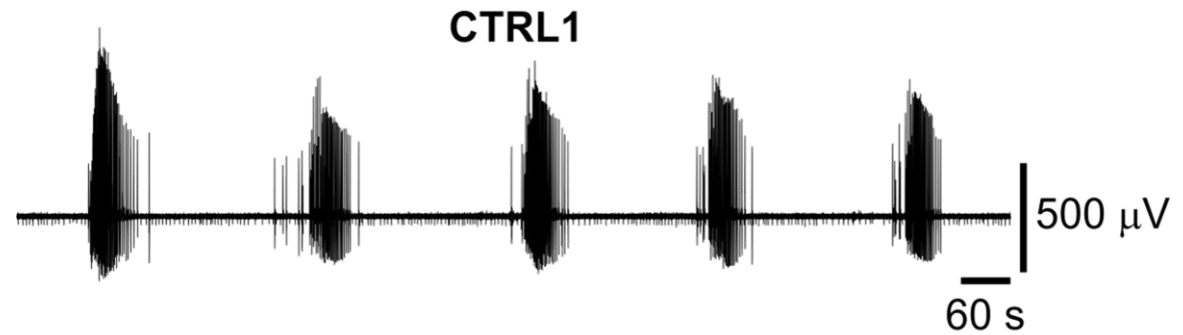
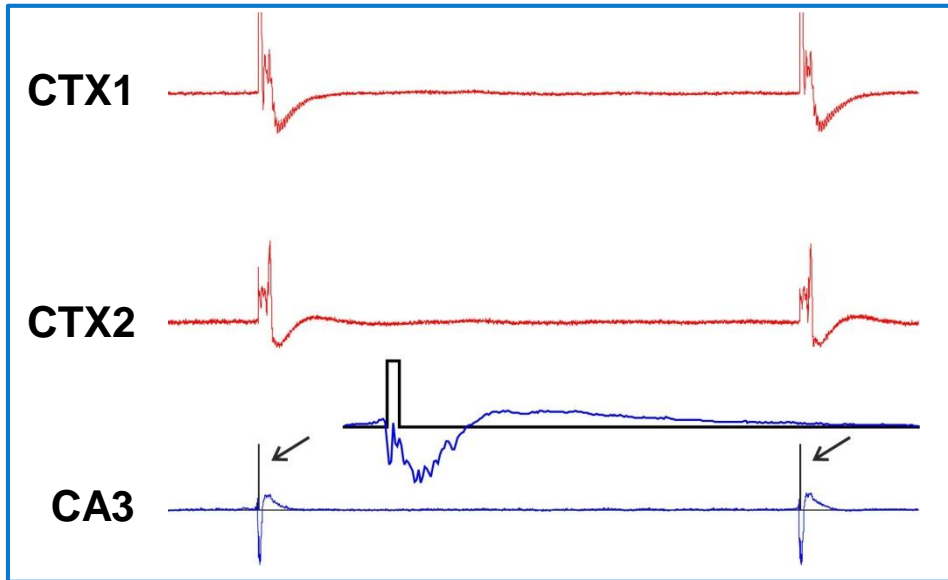
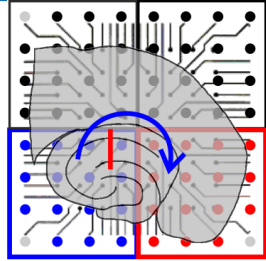
Ponte UNIDIREZIONALE



Controllo dell'attività epilettica *in vitro*

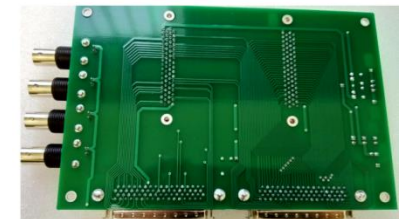
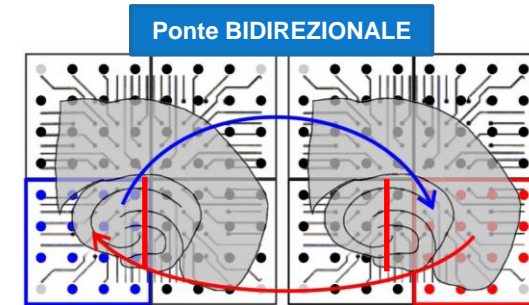
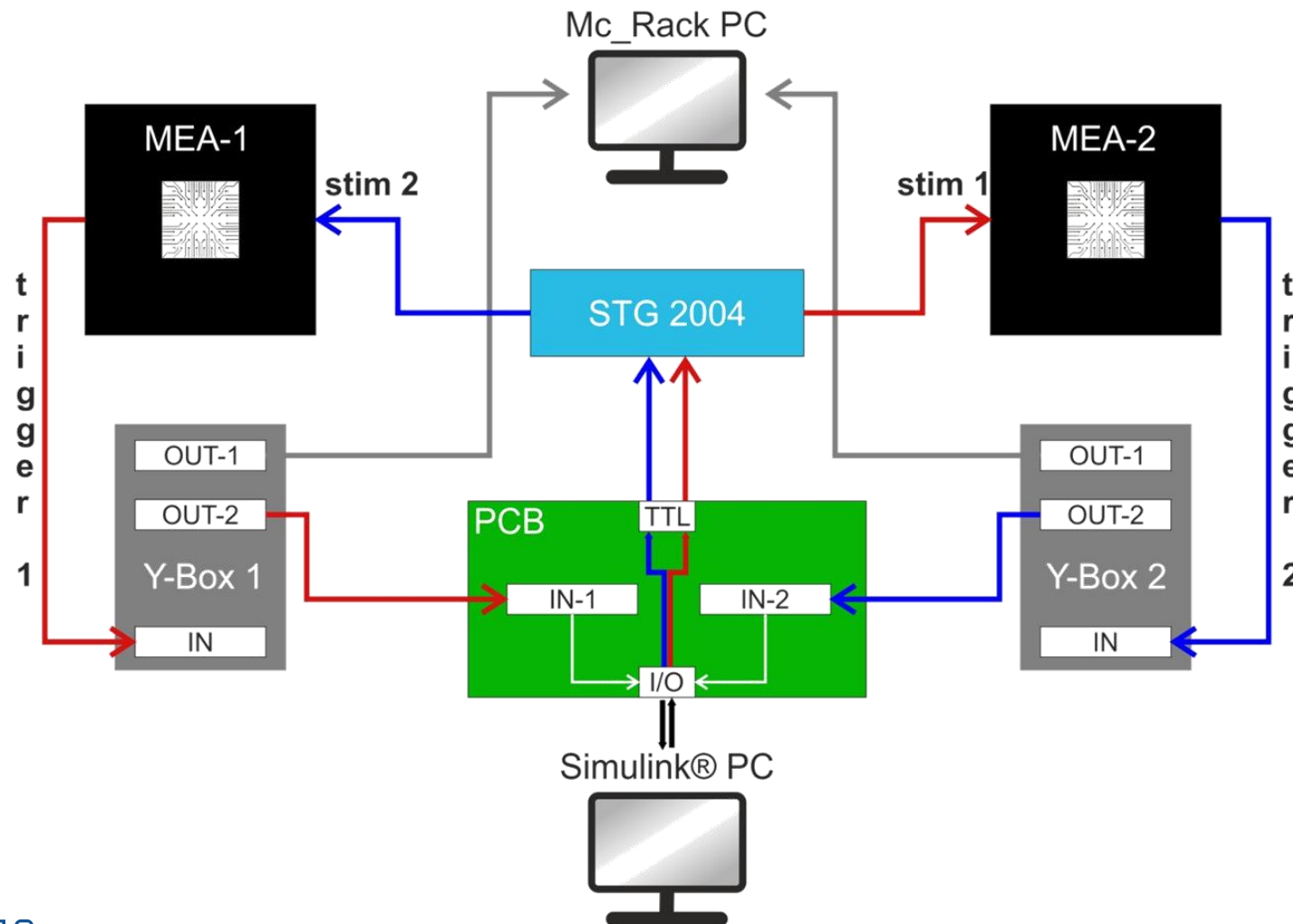
(2) CLOSED-LOOP → ponti elettronici

Ponte UNIDIREZIONALE



Controllo dell'attività epilettica *in vitro*

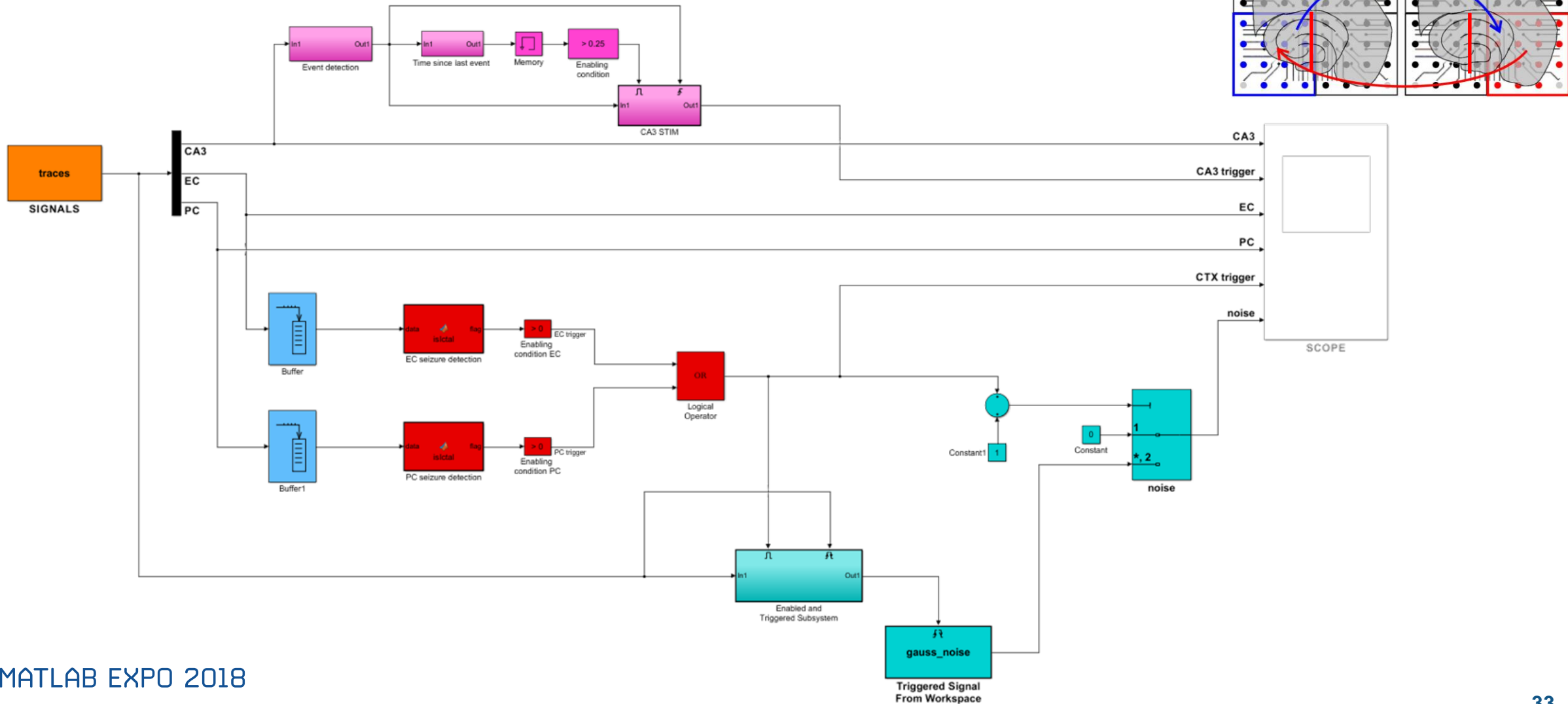
(2) CLOSED-LOOP → ponti elettronici



custom PCB

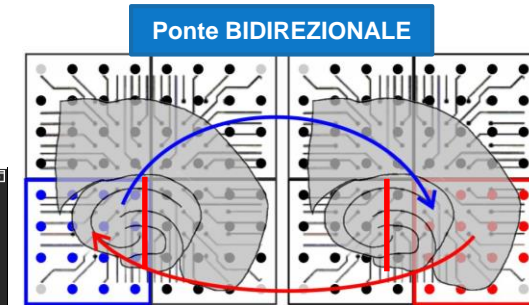
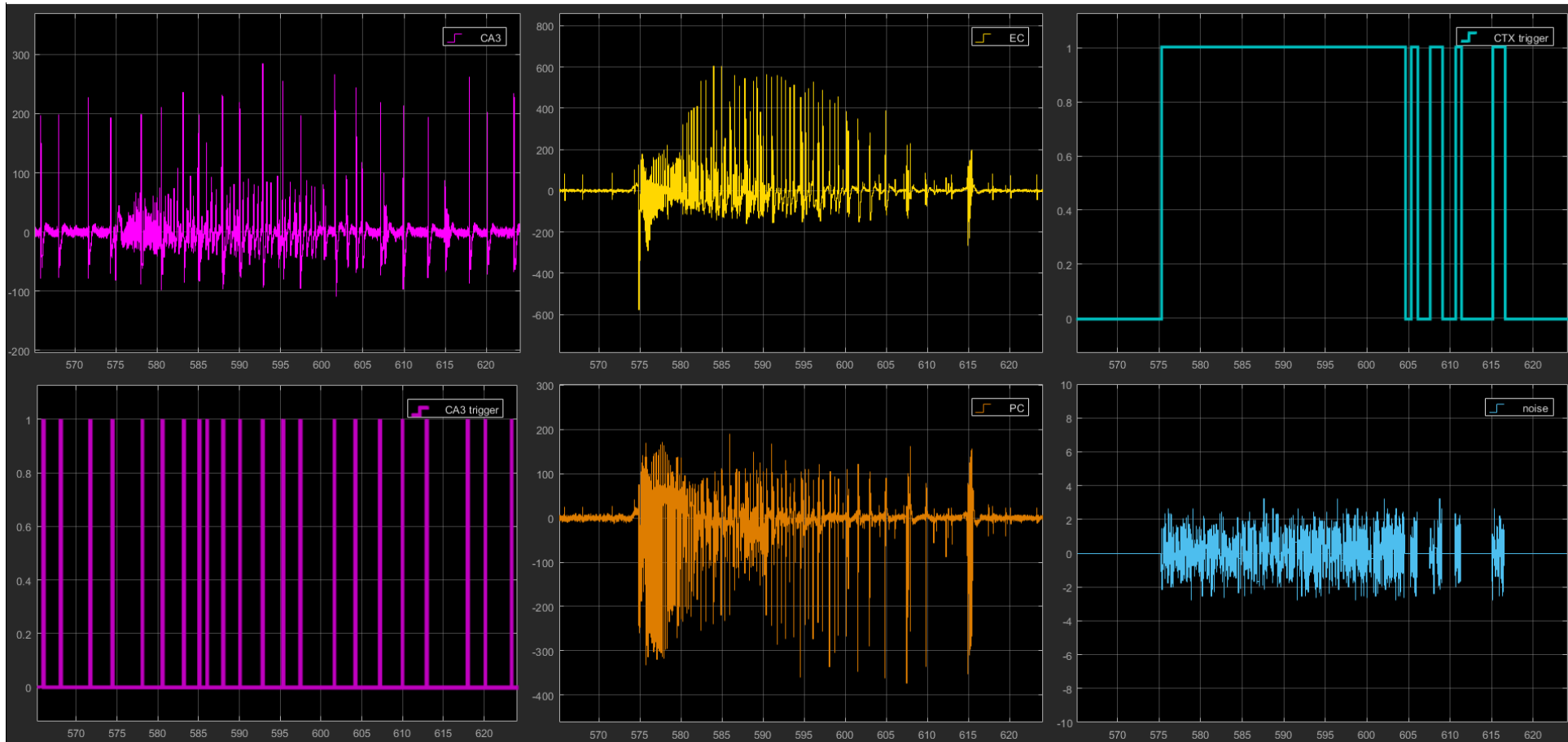
Controllo dell'attività epilettica *in vitro*

(2) CLOSED-LOOP → ponti elettronici



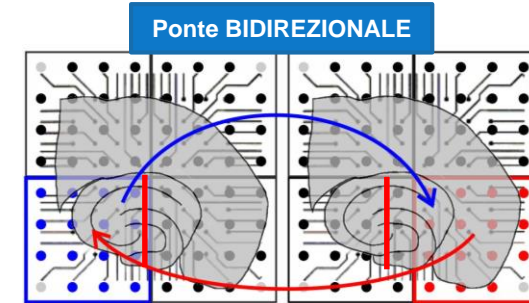
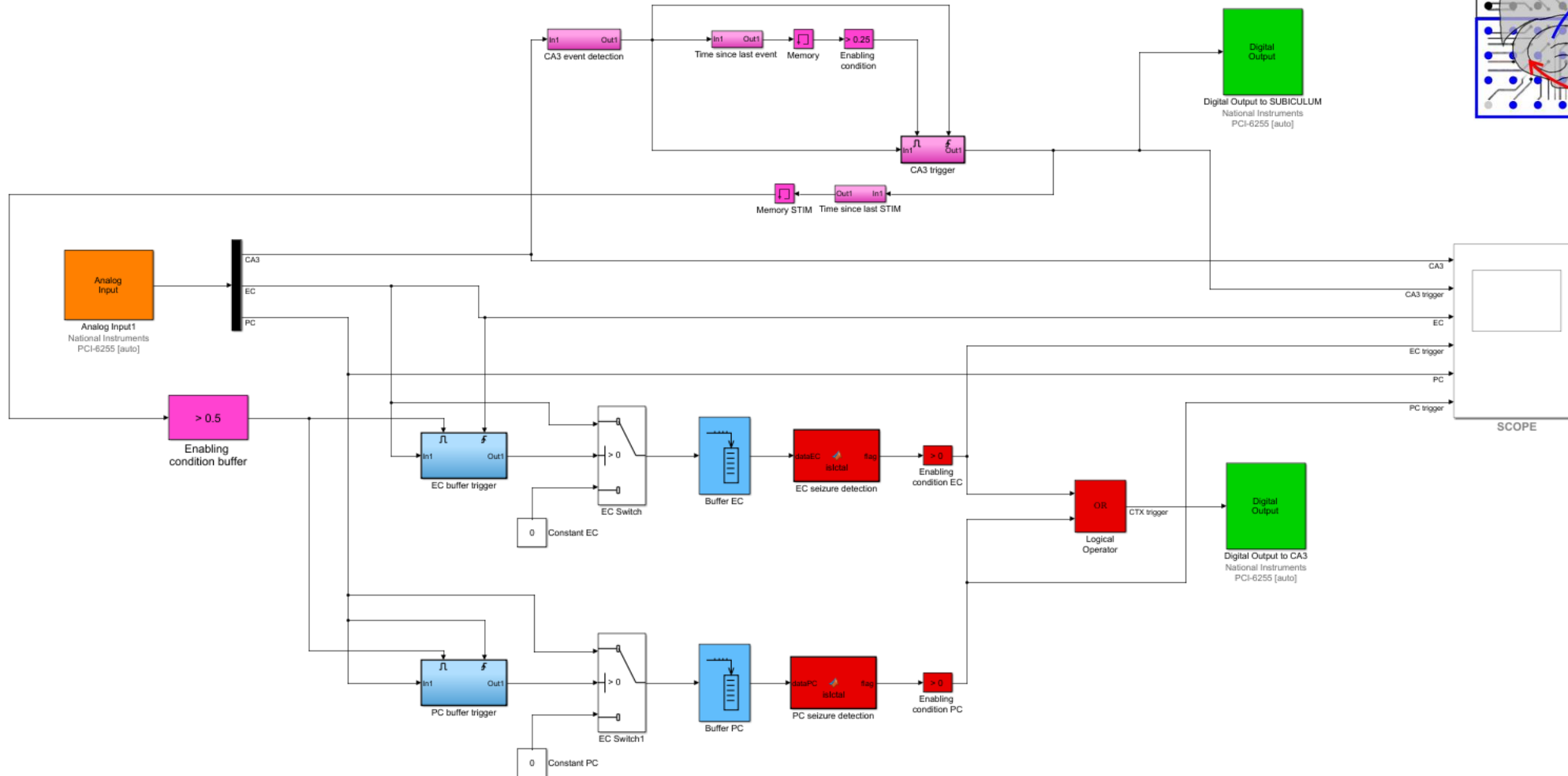
Controllo dell'attività epilettica *in vitro*

(2) CLOSED-LOOP → ponti elettronici



Controllo dell'attività epilettica *in vitro*

(2) CLOSED-LOOP → ponti elettronici



work in progress...

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