



## Tools for convulsive seizures and interictal spikes detection

Daniel Diaz-Arce, Anis Ghouma, Pierre Guetschel, Théodore Papadopoulo,  
Massimo Mantegazza, Fabrice Duprat

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Daniel Diaz-Arce<sup>a</sup>, Anis Ghouma<sup>a</sup>, Pierre Guetschel<sup>ab</sup>, Théodore Papadopoulou<sup>ab</sup>, Massimo Mantegazza<sup>acd</sup>, & Fabrice Duprat<sup>acd</sup>

<sup>a</sup> Université Côte d'Azur, Valbonne-Sophia Antipolis, France

<sup>c</sup> CNRS UMR7275, Institute of Molecular and Cellular Pharmacology (IPMC), Valbonne, France

<sup>b</sup> Inria, Valbonne-Sophia Antipolis, France

<sup>d</sup> Inserm, Valbonne-Sophia Antipolis, France

## 1 Introduction

Epilepsy is a very invalidating and common disorder, and the use of rodent models of epilepsy to test new anti-epileptic treatments is of great interest. The ability to detect epileptic seizures in these models with automated or semi-automated methods is still a major challenge.

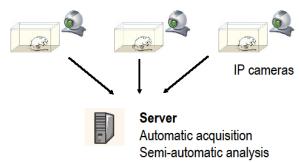
We have developed two new computer-based tools using Python language that,

- 1) enable the noninvasive semi-automated detection of convulsive seizures from videos,
- 2) enable the automatic detection of interictal spikes from Electrocorticogram recordings (ECoG).

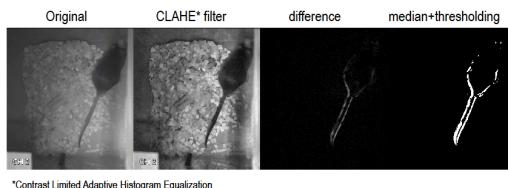
## 2 Detecting convulsive seizures from videos

Convulsive seizures are very serious phenotypic manifestations occurring in severe forms of epilepsy, they appear as clonic or tonic-clonic seizures with wild jumping. Our method is based on motion and its power spectral analysis calculated from video recording of freely moving mice. It helps the user to easily spot convulsive seizures within hundreds of hours of video recordings.

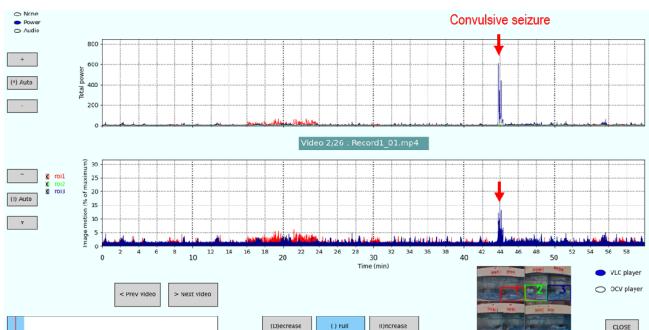
## 3 Non-invasive video-recording



## 4 Semi-automated analysis: image motion calculation



## 5 Display of image motion and its spectral power



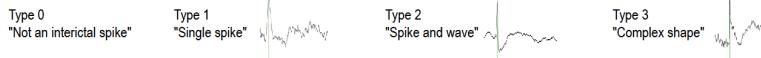
The main advantages of our method are 1) its noninvasiveness, the animals can be recorded in normal cages with minor modifications, 2) the high speed of the analysis with a good accuracy (88,8% accuracy in comparison to full video visual inspection, 93,2% accuracy in comparison to ECoG analysis), 3) the ability to acquire and analyze a very large number of files, thus long video lasting recordings, 4) the easy to use graphical interfaces, and 5) its cost-effectiveness

## 6 Detecting interictal spikes from ECoG signal using AI

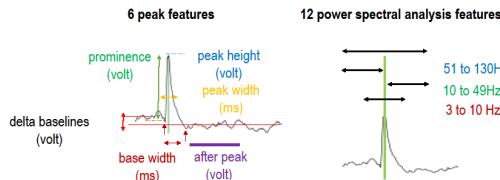
Interictal spikes is a typical feature of ECoG recordings and they are overrepresented in epileptic animals. The spikes are very short peaks (few tens of ms) and hence hard to spot within days of recordings. We have used a random forest classifier trained with 7000 manually classified peaks and using 18 peaks features to automatically classify thousands of peaks over long periods of acquisition.

## 7 Defining spikes shapes and features to train a classifier

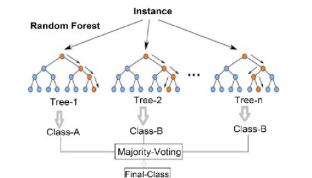
### Spikes shapes



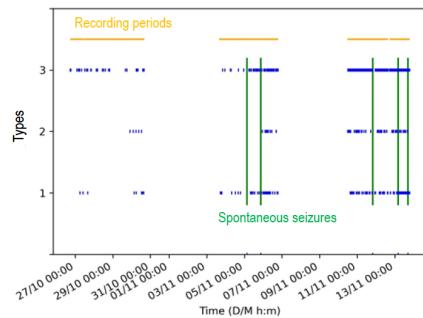
### Spikes features



### Training of a random forest classifier

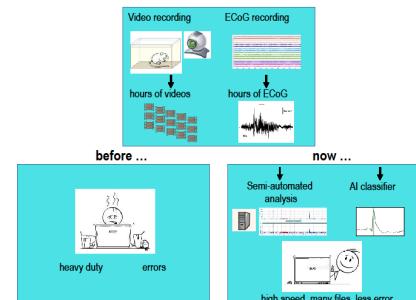


## 8 Using the classifier



When comparing the classifier results with manually classified spikes we obtained more than 80% accuracy

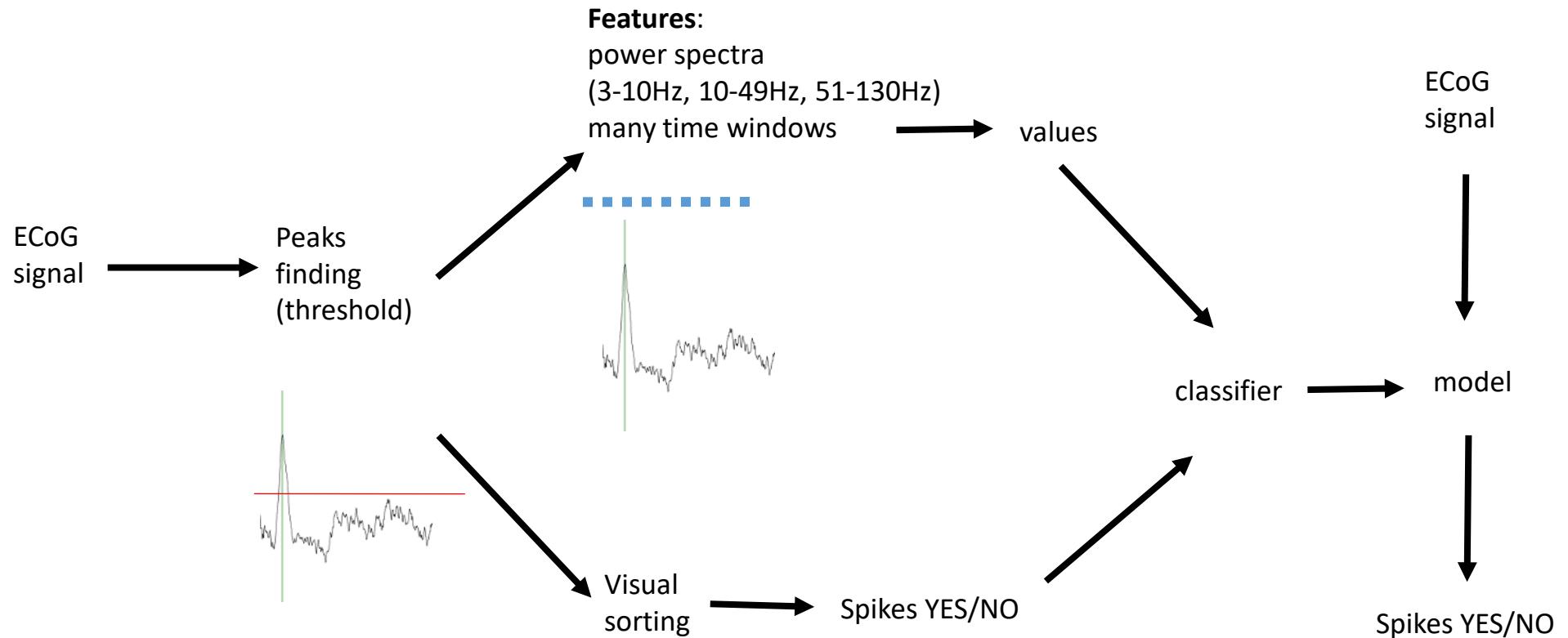
## 9 Conclusion

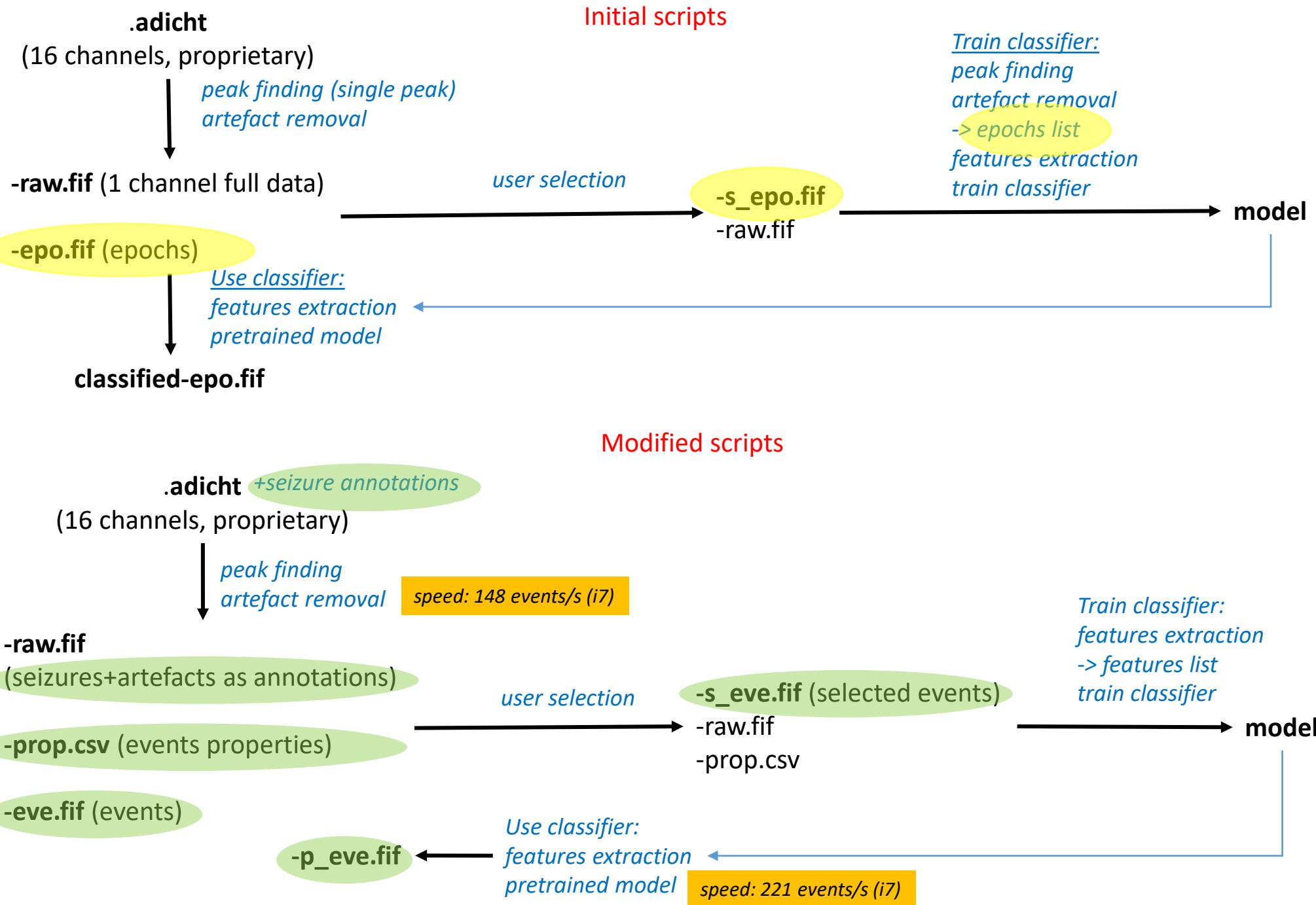


These new tools enable the analysis of hundreds of hours of video and ECoG recordings and give way to higher throughput analysis of our mice epileptic models.

# Classifier for Interictal spikes search

Initial scripts Pierre Guetschel, Théo Papadopoulo INRIA

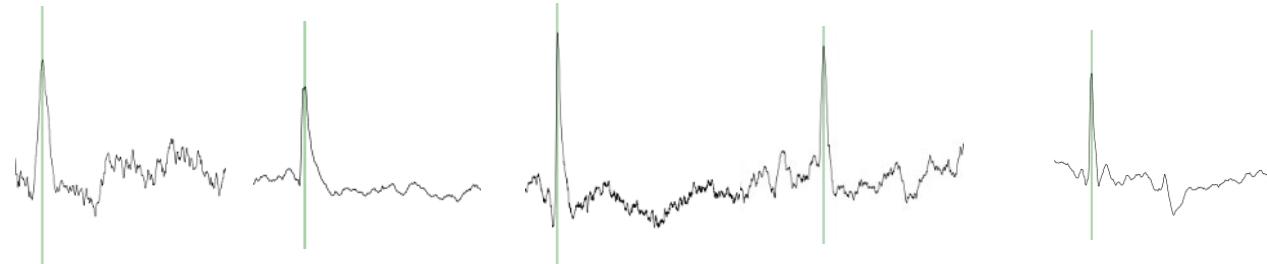




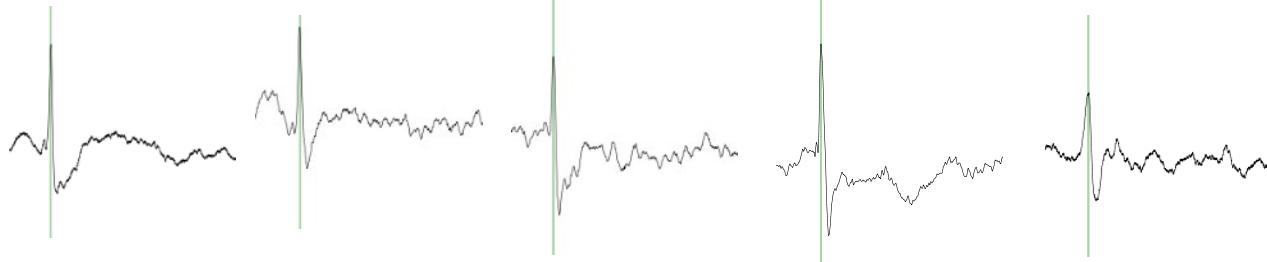
# Redefining spikes types

**Type 0 = not an interictal spike**

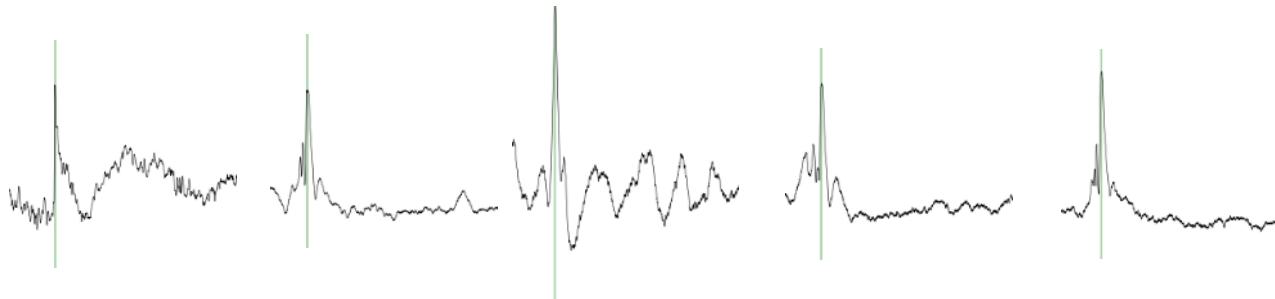
**Type 1**  
"single spike"



**Type 2**  
"spike and wave"  
"SWA"



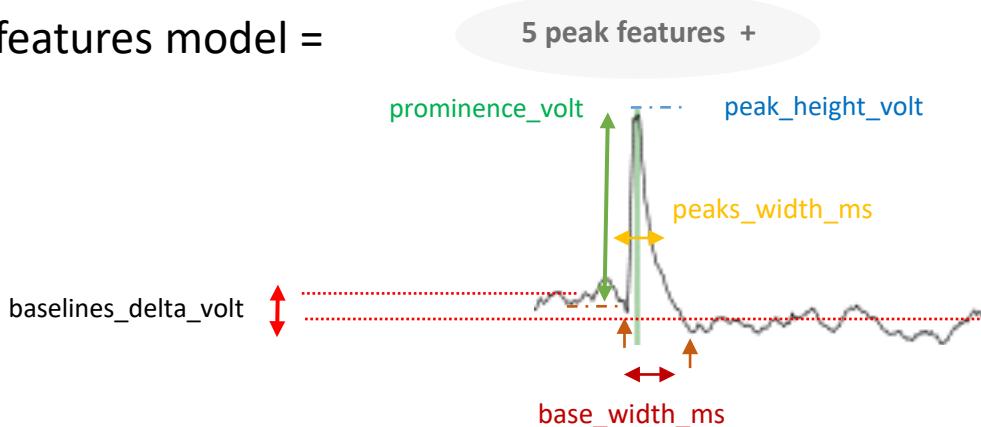
**Type 3**  
"others"



## Modified scripts

# Refining features

13 features model =



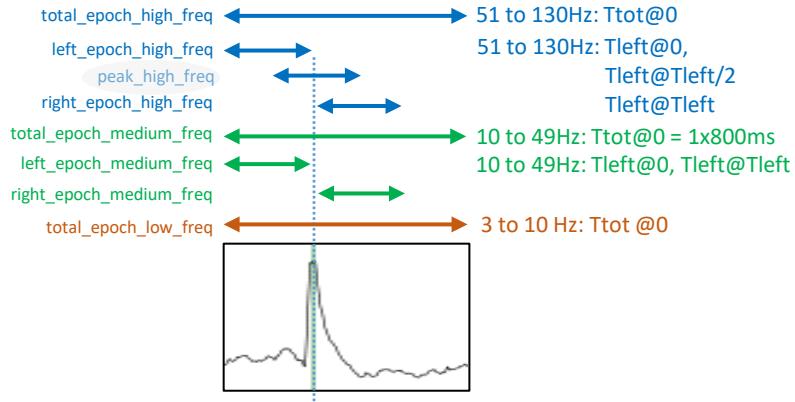
18 features model =

+ 1 peak feature



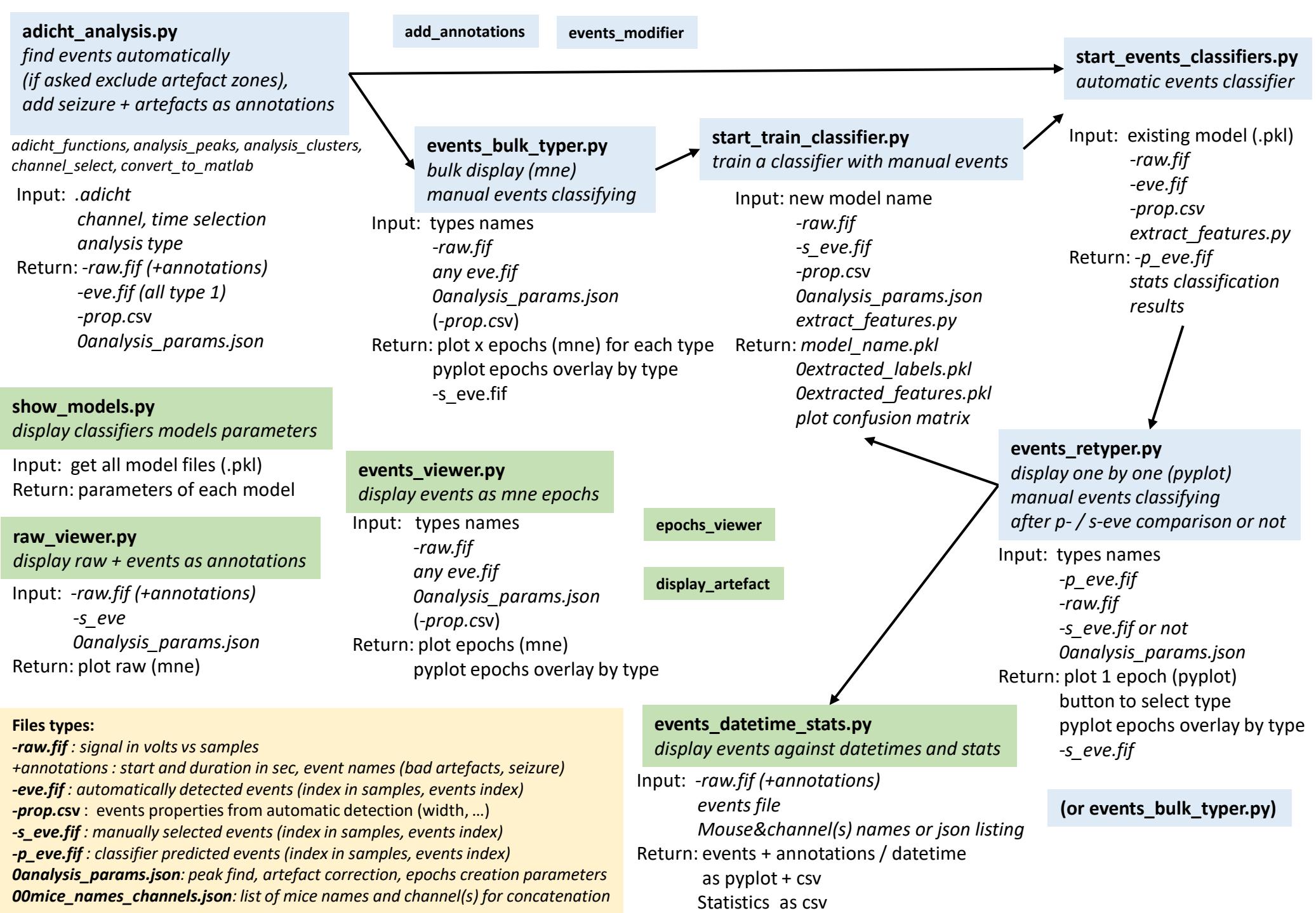
8 features model (peak centered)

8 power spectral analysis optimised features



+ last 5 spectral features





# Testing of various features

All trained with 5635 events and tested with 627

Model name	Nb of features	True type 0 events	True type 1 events	True type 2 events	True type 3 events	Total accuracy (%)
<b>ef8 : Peak centered</b>	<b>8</b>	43/63 68,3%	83/165 50,3%	73/105 69,5%	186/294 63,3%	61,4
<b>ef13 : Peak and surrounding optimised</b>	<b>13</b>	37/58 63,8%	84/164 51,2%	73/106 68,9%	210/299 70,2	64,4
<b>ef18 : Peak and surrounding, all frequencies, afterpeak</b>	<b>18</b>	45/63 71,4%	95/165 57,6%	84/105 80%	246/294 83,7%	75

## ef8

Features	Importances
peaks_widths_ms	0.17
peak_low_freq	0.14
peak_medium_freq	0.13
bases_widths_ms	0.13
peak_high_freq	0.12
prominences_volt	0.11
peaks_heights_volt	0.1
baselines_delta_volt	0.09

## ef13

Features	Importances
left_epoch_high_freq	0.12
peaks_widths_ms	0.11
peak_high_freq	0.09
total_epoch_medium_freq	0.08
left_epoch_medium_freq	0.08
prominences_volt	0.08
right_epoch_high_freq	0.07
total_epoch_low_freq	0.07
total_epoch_high_freq	0.07
bases_widths_ms	0.06
peaks_heights_volt	0.06
baselines_delta_volt	0.06
right_epoch_medium_freq	0.05

## ef18

Features	Importances
afterpeak_volt	0.18
peaks_widths_ms	0.08
left_epoch_high_freq	0.08
peak_low_freq	0.07
peak_medium_freq	0.07
total_epoch_medium_freq	0.05
left_epoch_medium_freq	0.05
prominences_volt	0.05
right_epoch_high_freq	0.05
peak_high_freq	0.05
total_epoch_high_freq	0.04
right_epoch_low_freq	0.04
peaks_heights_volt	0.03
left_epoch_low_freq	0.03
total_epoch_low_freq	0.03
baselines_delta_volt	0.03
bases_widths_ms	0.03
right_epoch_medium_freq	0.03

# Hyperparameters optimization

split random state=range(1, 100, 5), RF classifier random state=range(1, 200, 5):

Bests: accuracy 83,1% : split random\_state=21, RF classifier random\_state =101

Worse: accuracy 73,2% : split random\_state =26, RF classifier random\_state =116

NEUROMOD STUDENT : random search, grid search, Bayesian optimization, ... ?

**n\_estimators int, default=100** The number of trees in the forest.

**max\_features {"auto", "sqrt", "log2"}, int or float, default="auto"** The number of features to consider when looking for the best split

**max\_depth int, default=None** The maximum depth of the tree

**min\_samples\_split int or float, default=2** The minimum number of samples required to split an internal node

**min\_samples\_leaf int or float, default=1** The minimum number of samples required to be at a leaf node.

**criterion{"gini", "entropy"}, default="gini"** The function to measure the quality of a split

**bootstrap, bool, default=True** Whether bootstrap samples are used when building trees. If False, the whole dataset is used to build each tree.

**min\_weight\_fraction\_leaf, float, default=0.0** The minimum weighted fraction of the sum total of weights (of all the input samples) required to be at a leaf node.

**max\_leaf\_nodes, int, default=None** Grow trees with max\_leaf\_nodes in best-first fashion. Best nodes are defined as relative reduction in impurity

**min\_impurity\_decrease, float, default=0.0** A node will be split if this split induces a decrease of the impurity greater than or equal to this value.

**oob\_score bool, default=False** Whether to use out-of-bag samples to estimate the generalization score. Only available if bootstrap=True.

**random\_state, int, RandomState instance or None, default=None** Controls both the randomness of the bootstrapping of the samples used when building trees and the sampling of the features to consider when looking for the best split at each node (if max\_features < n\_features)

**warm\_start bool, default=False** When set to True, reuse the solution of the previous call to fit and add more estimators to the ensemble, otherwise, just fit a whole new forest.

**ccp\_alpha, non-negative float, default=0.0** Complexity parameter used for Minimal Cost-Complexity Pruning.

**max\_samples, int or float, default=None** If bootstrap is True, the number of samples to draw from X to train each base estimator.

## ADICHT & RAW.FIF FILES ANALYSIS

Select adicht

```
<210924.adicht> 744_Ch1_1a_ECoG_red (ch1) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 788_Ch3_1b_ECoG_red (ch3) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 789_Ch5_2a_red (ch5) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 789_Ch6_2_black (ch6) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 790_Ch7_2b_red (ch7) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 790_Ch8_2b_black (ch8) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 828_Ch9_3a_red (ch9) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 828_Ch10_3a_black (ch10) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 829_Ch11_3b_red (ch11) starting at 24/09/21 16:40:30 for 66h 47min 55s
<210924.adicht> 829_Ch12_3b_black (ch12) starting at 24/09/21 16:40:30 for 66h 47min 55s
```

Select raw

Reset selection lists

Options  Save raw file  Save epo file  Save 2 channels  Artefact correction  Single peaks  Start analysis

Events viewer

Quit

## Adicht analysis

IMPORTING <210924.adicht> file

SELECT CHANNEL(S) AND ONE BLOCK  Block1 File end time:

Channel	Block start time:	File end time:
All channels	24/09/21 16:40:29	27/09/21 11:28:25
#1 744_Ch1_1a_ECoG_red	2nd channel	66h 47min 56s (2.0kHz)
#2 744_Ch2_1a_EMG_yellow_green	2nd channel	66h 47min 56s (2.0kHz)
#3 788_Ch3_1b_ECoG_red	2nd channel	66h 47min 56s (2.0kHz)
#4 788_Ch4_1b_EMG_yellow_green	2nd channel	66h 47min 56s (2.0kHz)
#5 789_Ch5_2a_red	2nd channel	66h 47min 56s (2.0kHz)
#6 789_Ch6_2_black	2nd channel	66h 47min 56s (2.0kHz)
#7 790_Ch7_2b_red	2nd channel	66h 47min 56s (2.0kHz)
#8 790_Ch8_2b_black	2nd channel	66h 47min 56s (2.0kHz)
#9 828_Ch9_3a_red	2nd channel	66h 47min 56s (2.0kHz)
#10 828_Ch10_3a_black	2nd channel	66h 47min 56s (2.0kHz)
#11 829_Ch11_3b_red	2nd channel	66h 47min 56s (2.0kHz)
#12 829_Ch12_3b_black	2nd channel	66h 47min 56s (2.0kHz)
#13 827_Ch13_4a_red	2nd channel	66h 47min 56s (2.0kHz)
#14 827_Ch14_4a_black	2nd channel	66h 47min 56s (2.0kHz)
#15 830_Ch15_4b_red	2nd channel	66h 47min 56s (2.0kHz)
#16 830_Ch16_4b_black	2nd channel	66h 47min 56s (2.0kHz)

DEFINE TIME WINDOW TO ANALYSE (WITHIN SELECTED BLOCK)

Choose start datetime (dd/mm/yy hh:mm:ss): 24/09/21 16:41:00  OR use file start datetime

Choose duration (hh:mm): 24:00  OR up to end of block  Save selection

## Train classifier

Select new model name & events files, classifier is trained

Model name (\_ , letters and digits only) ?

default\_model

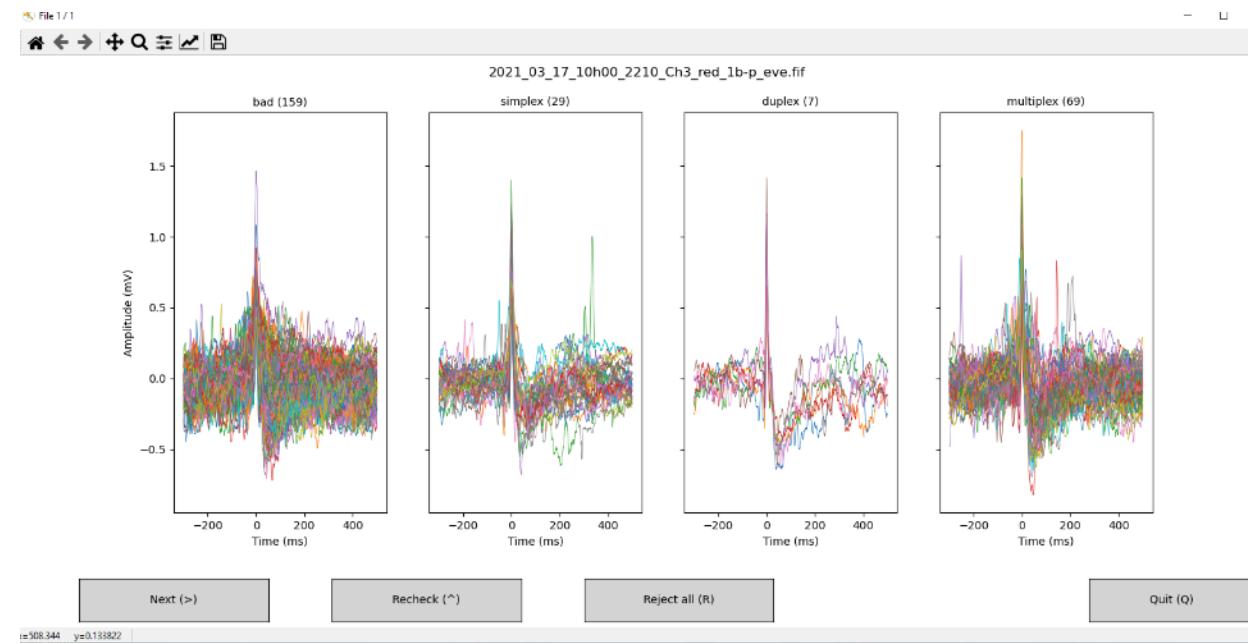
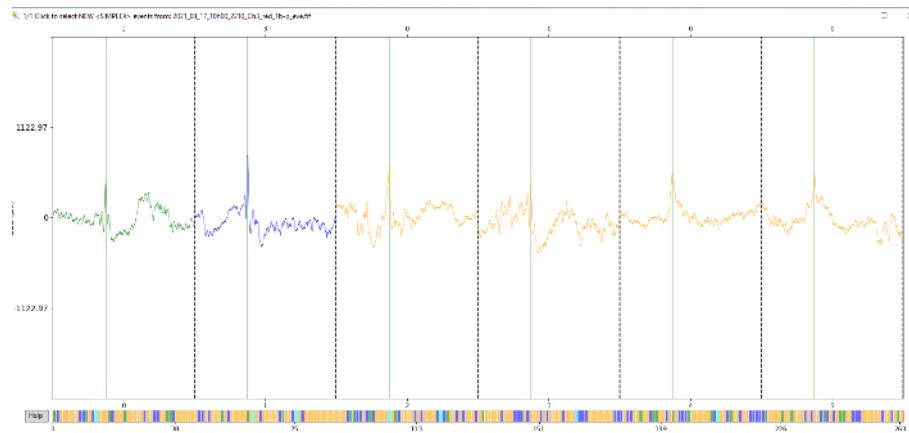
overwrite

Select s\_eve files, and start

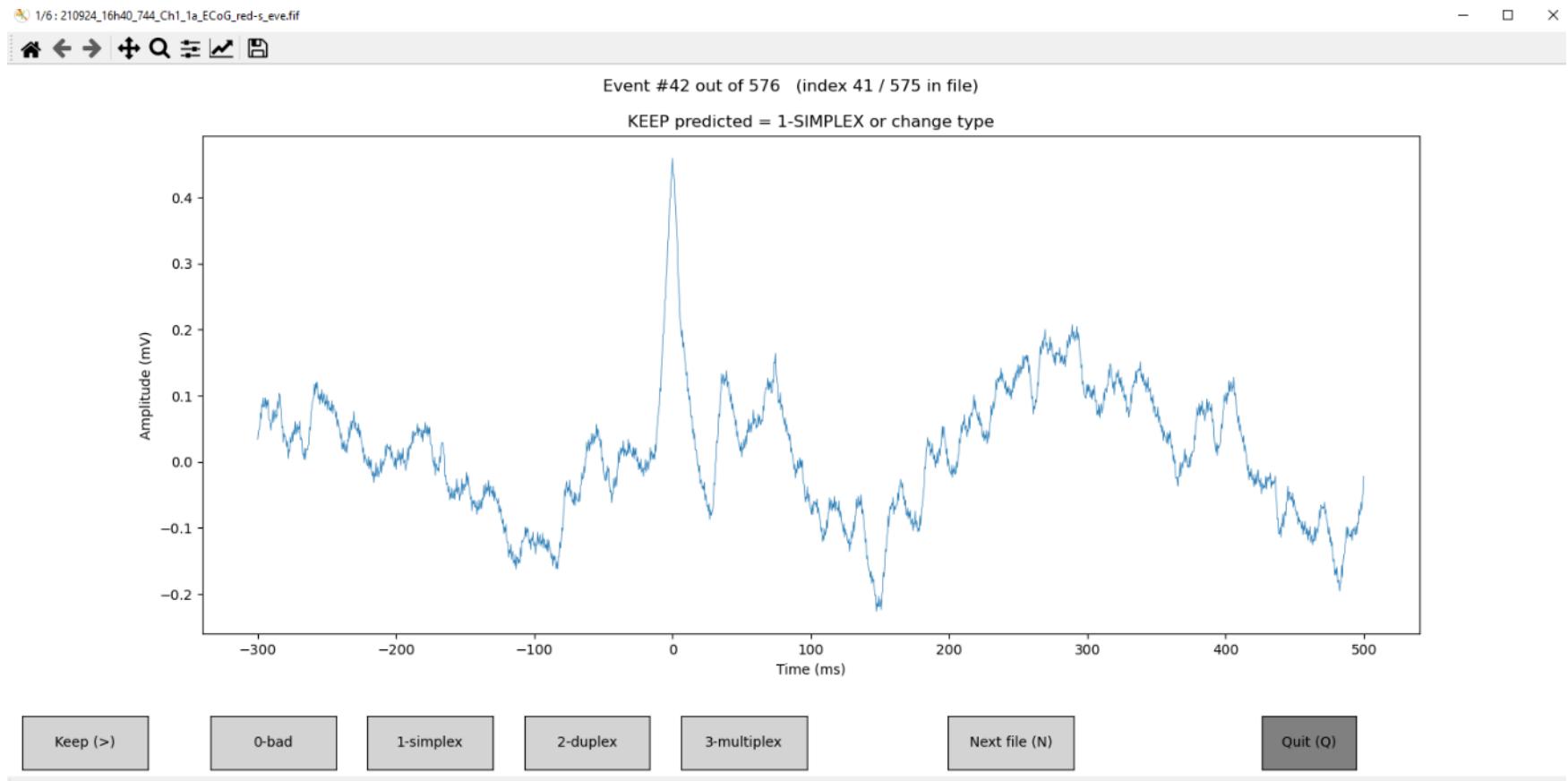
exit

Classifier model is saved to pkl file.

# Events bulk typer



# Events typer



## Events classifier

Events classifier

```
>>> 49 / 53 : 210928b_11h47_827_Ch14_4a_black-raw.fif
Extracting features and making prediction...
208 predicted events saved to p_eve.fif

>>> 50 / 53 : 210928b_11h47_828_Ch9_3a_red-raw.fif
Extracting features and making prediction...
1012 predicted events saved to p_eve.fif

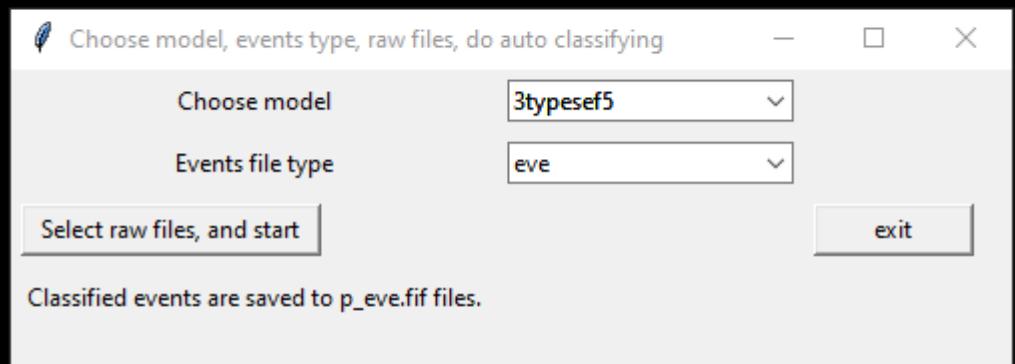
>>> 51 / 53 : 210928b_11h47_828_Ch10_3a_black-raw.fif
Extracting features and making prediction...
1679 predicted events saved to p_eve.fif

>>> 52 / 53 : 210928b_11h47_829_Ch11_3b_red-raw.fif
Extracting features and making prediction...
4220 predicted events saved to p_eve.fif

>>> 53 / 53 : 210928b_11h47_829_Ch12_3b_black-raw.fif
Extracting features and making prediction...
1807 predicted events saved to p_eve.fif

Classification results for 165478 events:

Type      Count
-----  -----
false     140612
simplex   22789
duplex     8
multiplex 2069
```

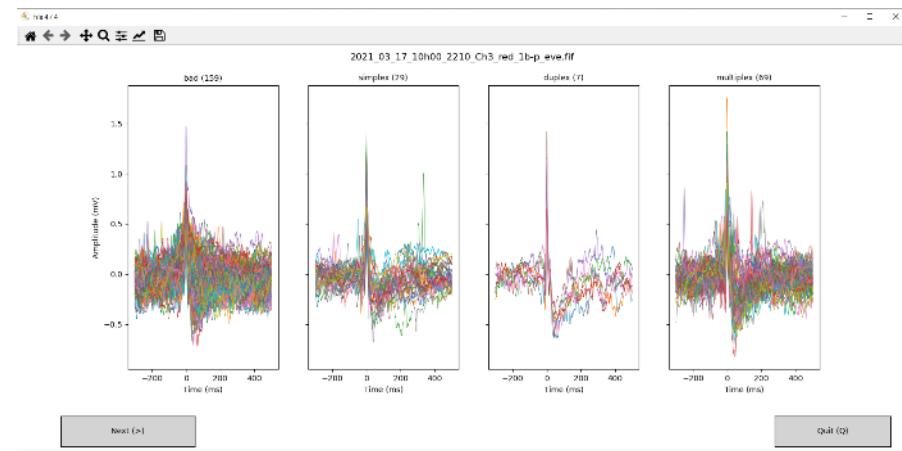
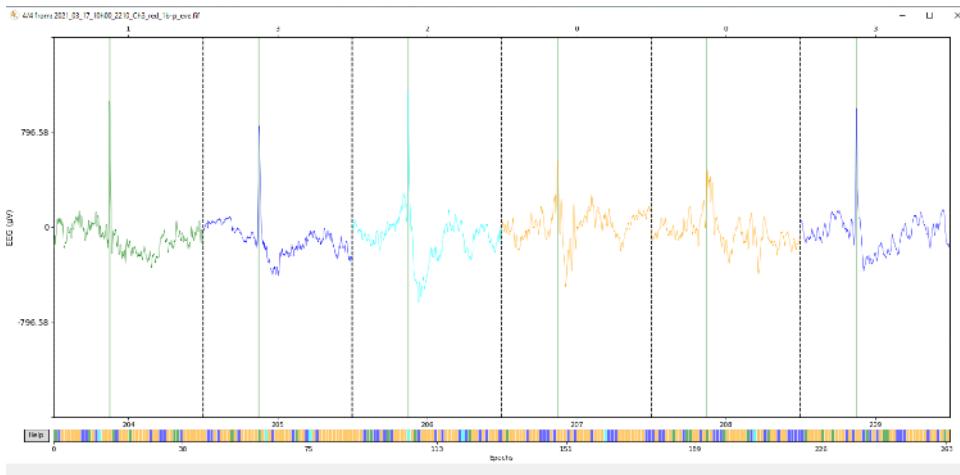
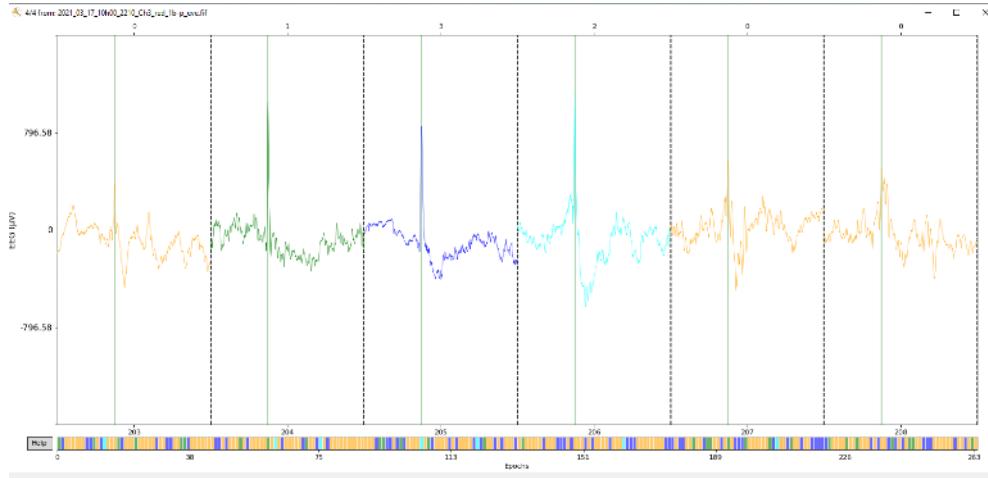


14 channels of 6811 minutes analysed in 19 min = 4915x

```
#### MODEL 3typesef5.pkl ####

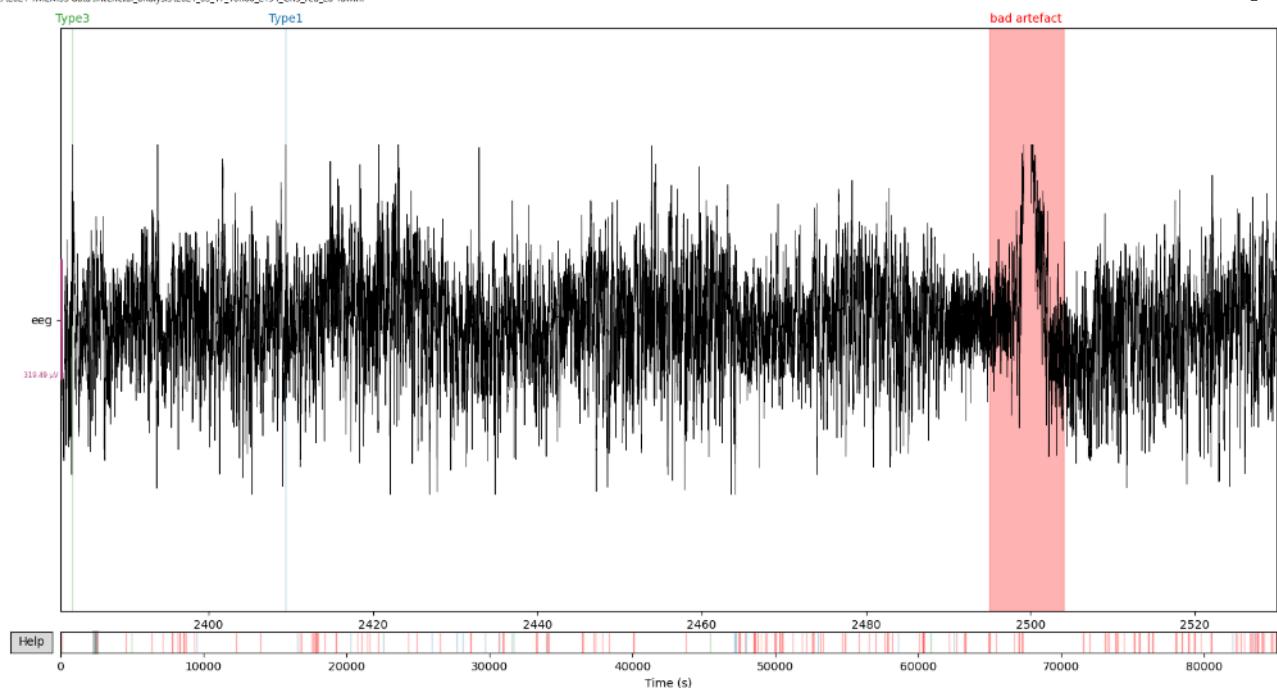
>> find_peaks_args : {'height': [0.001, 0.003], 'threshold': [0, 4], 'prominence': 0.0005, 'wlen': 600, 'width': [10, 200], 'rel_height': 0.5, 'distance': 600}
>> find_artefacts_args : {'t_window': 3, 'max_ratio': 3, 'artefact_radius': 3.0, 'min_length': 20.0, 'online': True, 'preheat': 20.0, 'stride': 0.2}
>> extract_features_args : {'use_total_spectrum': True, 'use_left_spectrum': True, 'use_peak_spectrum': True, 'use_right_spectrum': True, 'use_peak_prop': True, 'freq_ranges': ((3.0, 10.0), (10.0, 49.0), (51.0, 130.0)), 'epoch_durations': (0.3, 0.5)}
>> clf : RandomForestClassifier(criterion='entropy', n_jobs=4, random_state=42)
>> tmin : -0.3
>> tmax : 0.5
>> sfreq : 2000.0
>> raw_file 88:
>> spike_reference_file 88:
>> features_names 18:
['total_epoch_low_freq', 'total_epoch_medium_freq', 'total_epoch_high_freq', 'left_epoch_low_freq', 'left_epoch_medium_freq', 'left_epoch_high_freq', 'peak_low_freq', 'peak_medium_freq', 'peak_high_freq', 'right_epoch_low_freq', 'right_epoch_medium_freq', 'right_epoch_high_freq', ' prominences_volt', 'peaks_heights_volt', 'peaks_widths_ms', 'bases_widths_ms', 'baselines_delta_volt', 'afterpeak_volt']
-----
Features                      Importances
afterpeak_volt                0.18
peaks_widths_ms                0.08
left_epoch_high_freq            0.08
peak_low_freq                  0.07
peak_medium_freq                0.07
total_epoch_medium_freq         0.05
left_epoch_medium_freq          0.05
prominences_volt                0.05
right_epoch_high_freq           0.05
peak_high_freq                  0.05
total_epoch_high_freq           0.04
right_epoch_low_freq             0.04
peaks_heights_volt              0.03
left_epoch_low_freq              0.03
total_epoch_low_freq             0.03
baselines_delta_volt            0.03
bases_widths_ms                 0.03
right_epoch_medium_freq          0.03
```

# Events viewer



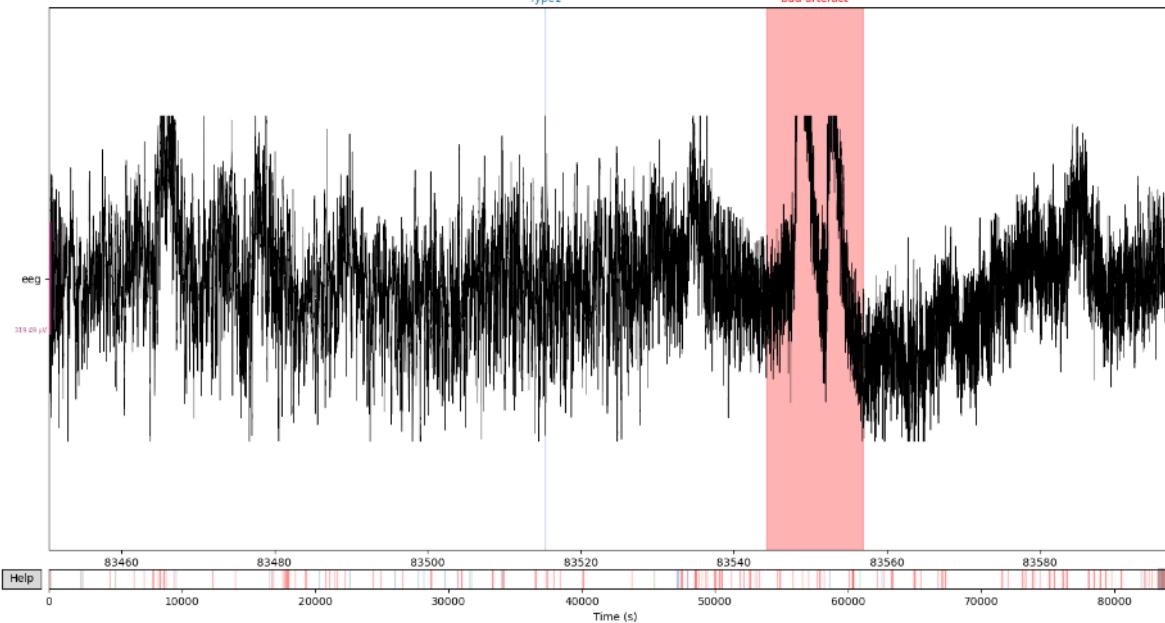
# Raw viewer

E:\2021 TMEM33 data\interictal\_analysis\2021\_03\_17\_10h00\_2194\_Ch5\_red\_2a.raw.tif



E:\2021 TMEM33 data\interictal\_analysis\2021\_03\_17\_10h00\_2194\_Ch5\_red\_2a.raw.tif

Type1 bad artifact



Select infos and files for one mouse or json file with many mice infos

- □ ×

Events datetime stats

Corresponding events file type to use

p\_eve

Plot each file

Plot mouse&channels concatenated events

OPTION 1) SELECT A BATCH OF RAW FILES OR DIRECTORY, AND ONE MOUSE & CHANNELS NAMES

Mouse name

2358

autofocus all files in directory \*

Channel name

Ch4

compulsory for autofocus

or

optionnal

or

optionnal

Select directory (\*) or raw files, and Start

Save stats & Exit

OPTION 2) SELECT JSON FILE CONTAINING MOUSE & CHANNELS NAMES (raw/eve files in the same directory)

Select json, Save stats & Exit

.csv file

B	C	D	E	F	G	H	I	J
mouse_name	channel_name1	nb_files	duration_sec	nb_seizures	nb_type0	nb_type1	nb_type2	nb_type3
2210	Ch3	5	428261	0	748	198	19	327
2210	Ch4	5	428261	0	725	180	13	293
2245	Ch7	5	428261	0	749	23	0	28
2245	Ch8	5	428261	0	1887	31	1	26
2354	Ch11	3	257525	0	43	25	1	27
2354	Ch12	3	257525	0	309	36	0	29
2356	Ch15	5	428261	0	1209	151	0	90
2356	Ch16							
2358	Ch3	6	581477	1	899	59	1	31
2358	Ch4	7	673552	1	1384	273	1	85
2363	Ch7	7	673552	0	1917	47	4	164
2363	Ch8	7	673552	0	1842	70	4	481
2364	Ch11	7	673552	2	2421	649	0	78
2364	Ch12	7	673552	2	2678	356	0	71
2357	Ch13	7	673552	0	6443	27	0	105
2357	Ch14	7	673552	0	7617	24	0	150
2193	Ch1	4	340848	0	44	4	0	7
2193	Ch2	4	343376	0	113	12	0	5
2194	Ch5	5	428261	0	2387	124	2	49
2194	Ch6	5	428261	0	2395	226	3	69
2195	Ch9	4	340848	0	447	15	0	14
2195	Ch10	4	344939	0	469	9	0	3
2196	Ch13	5	428261	0	6452	49	0	26
2196	Ch14	5	428261	0	4437	38	0	20
2319	Ch1	7	673552	0	4167	88	3	75
2319	Ch2	7	673552	0	2201	60	0	75

← .json file

```
1 {"serie": "TMEM33",  
2 "infos": []  
3 ["2193", "Ch1", "Ch7", "Ch11"],  
4 ["2193", "Ch2", "Ch8", "Ch12"],  
5 ["2210", "Ch3", "", ""],  
6 ["2210", "Ch4", "", ""],  
7 ["2194", "Ch5", "", ""],  
8 ["2194", "Ch6", "", ""],  
9 ["2245", "Ch7", "", ""],  
10 ["2245", "Ch8", "", ""]]
```

Values for 2358\_Ch4, from 7 p\_eve files

.jpg file

