

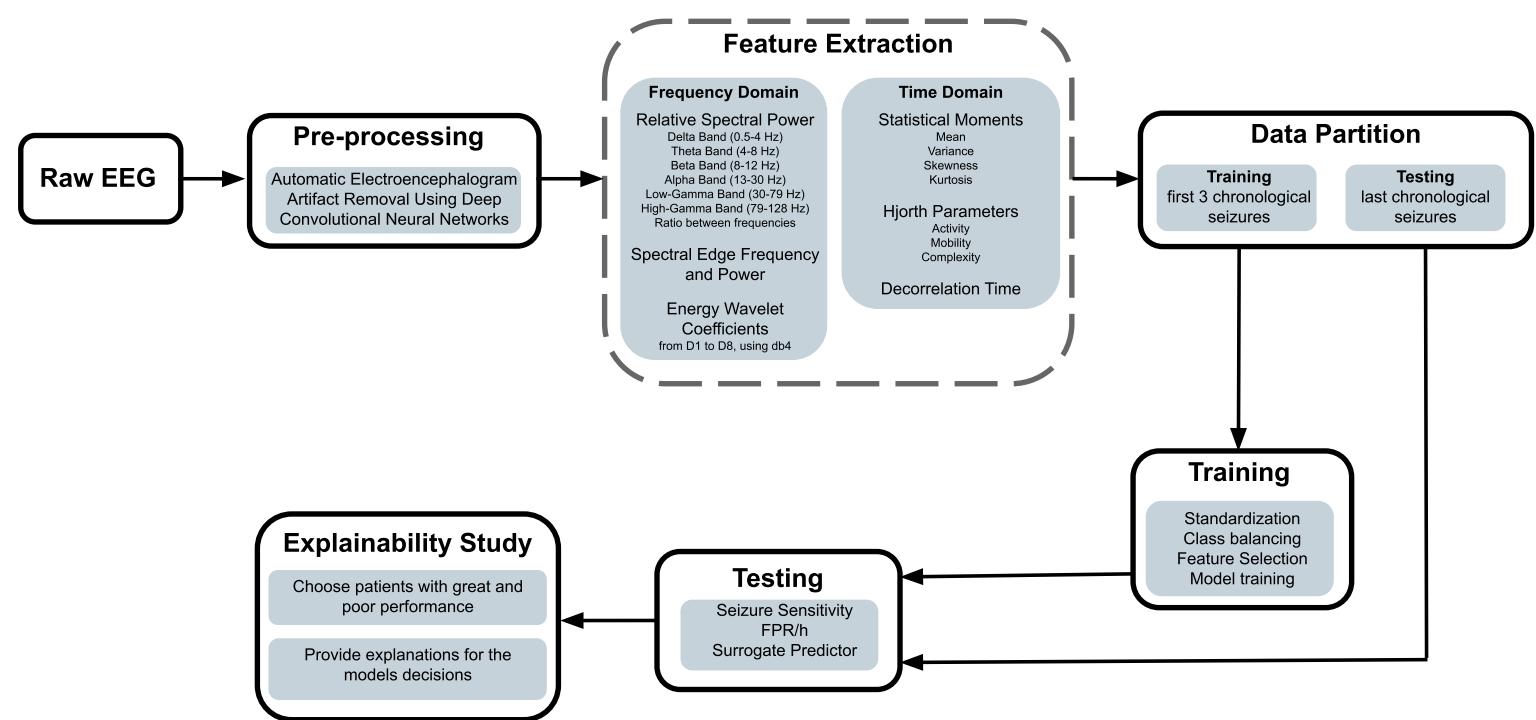
Interview Data Scientists

Motivation

- Current state-of-the-art methods for electroencephalogram seizure prediction use Machine Learning (ML). However, as they deal with multidimensionality, they may create black boxes where clinicians may not have sufficient trust to use them for high-risk decisions.
- Also, existing explainability methods are designed for single model decisions, where seizure prediction concerns a time-series problem that performs sliding window analysis and classification.
- This work studies which explanations may be provided about the models to increase trust in their decisions.

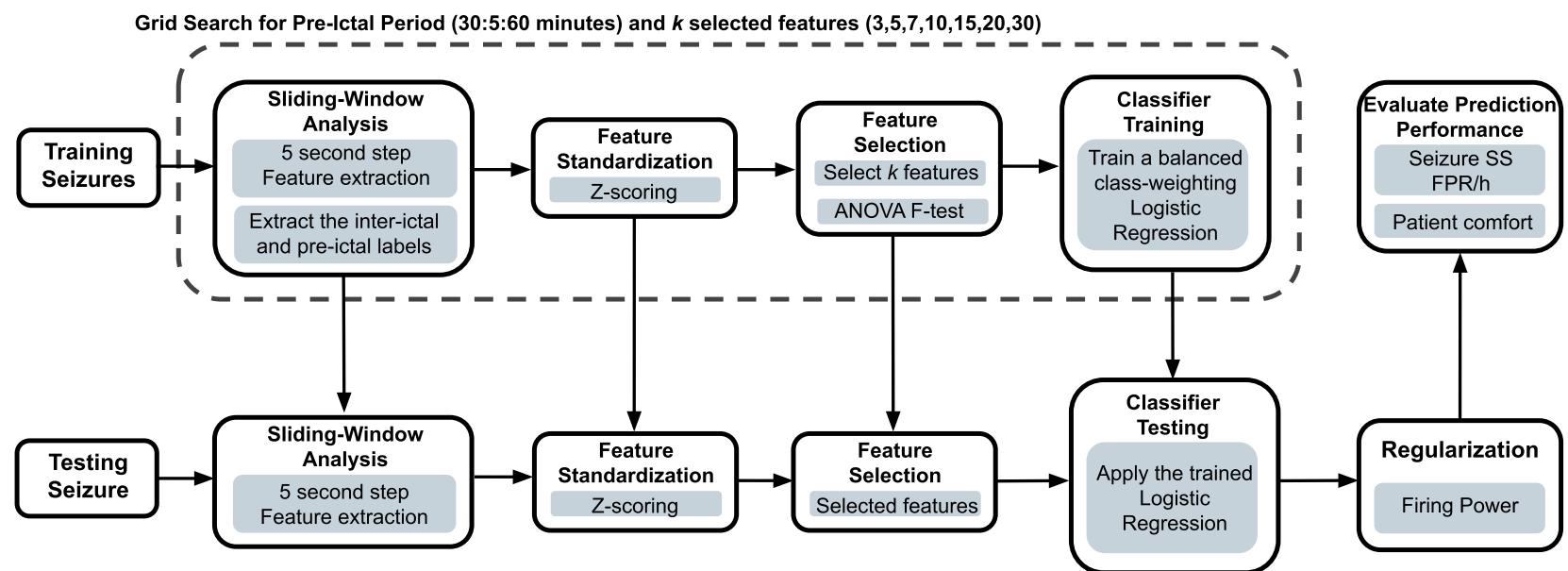
General Methodology

- 40 Patients from EPILEPSIAE in pre-surgical monitoring
 - 104 tested seizures and 2055 hours of data
- 3 methodologies
- This figure presents the pipeline for each patient



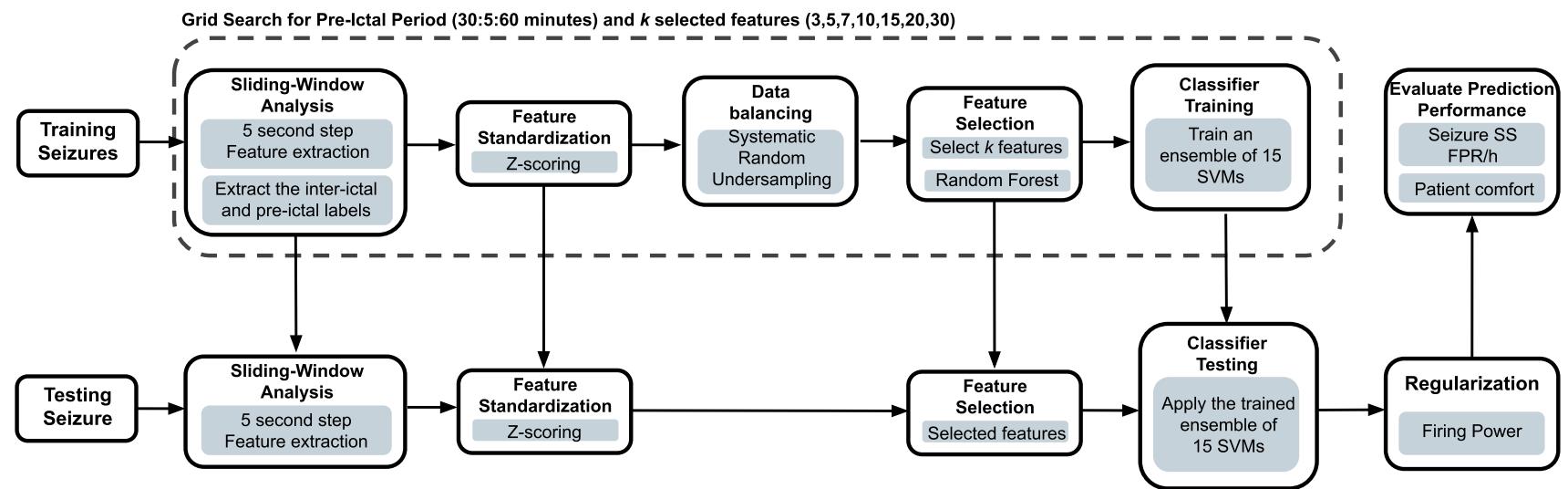
Methodology A - Logistic Regression

- Pre-Ictal Period and number of features obtained by grid search
- Feature selection: filter method (best k features)
- Data balancing: class-weighted classifier
- Model: Logistic Regression



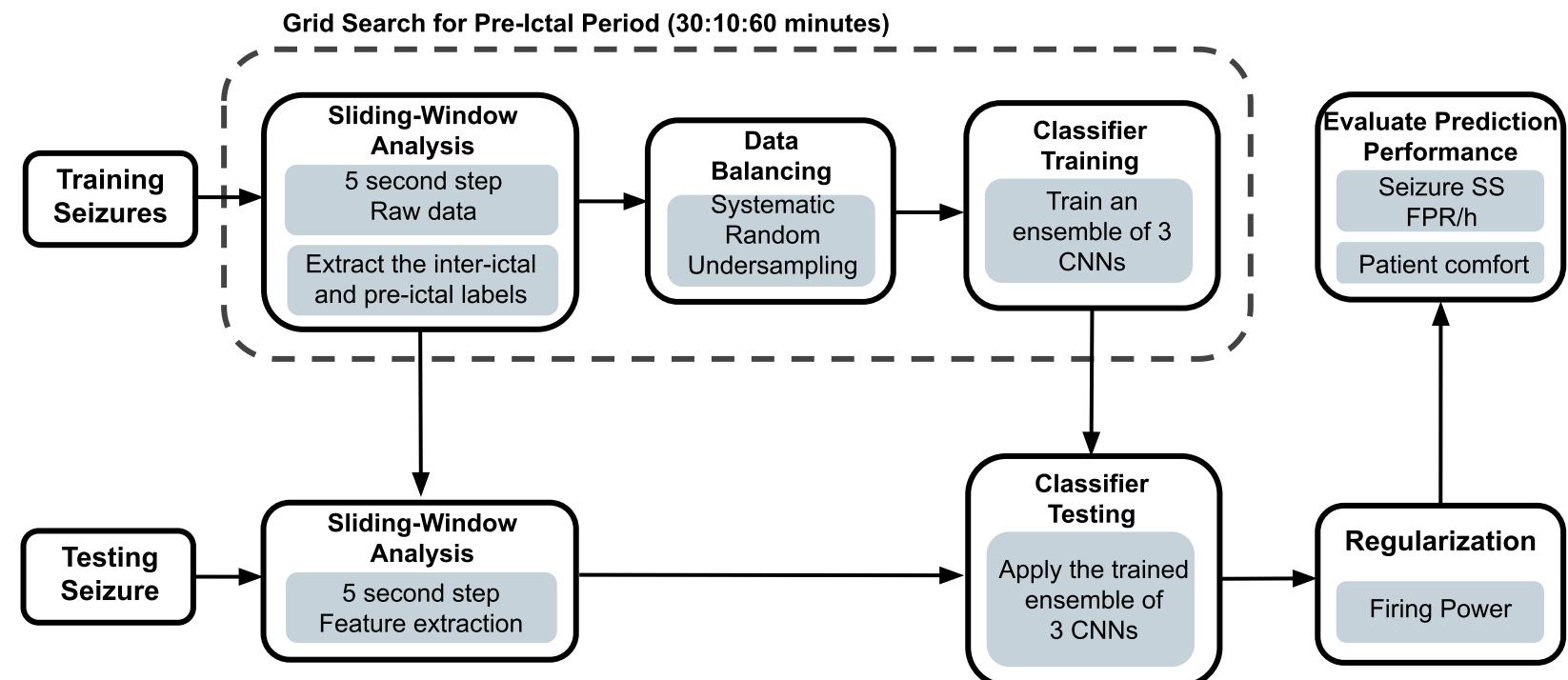
Methodology B - Ensemble of 15 SVMs

- Pre-Ictal Period and number of features obtained by grid search
- Feature selection: Random Forest where we select the best k features
- Data balancing: systematic random undersampling
- Model: Ensemble of 15 SVMs



Methodology C - Ensemble of 3 CNNs

- Pre-Ictal Period obtained by grid search
- No feature selection, uses raw data
- Data balancing: systematic random undersampling
- Model: Ensemble of 3 CNNs



Methodology A-Results

- Mean SS: 0.13
- Mean FPR: 0.40
- Validated Patients: 12.5% (5)

Patient	Pre-ictal Period (minutes)	Features	SS	FPR/h	Validated	Patient	Pre-ictal Period (minutes)	Features	SS	FPR/h	Validated
30802	60	5	0.20	0.40	0	75202	35	30	0.00	0.04	0
402	60	20	0.00	0.00	0	80702	50	30	0.33	0.28	1
8902	35	7	1.00	0.11	1	85202	30	20	0.00	0.11	0
11002	30	7	0.00	0.78	0	93402	30	3	1.00	0.50	1
16202	30	30	0.00	0.03	0	94402	55	30	0.00	0.80	0
21902	50	10	0.00	0.00	0	95202	35	15	0.00	0.37	0
23902	55	15	0.50	1.35	0	96002	35	3	0.25	0.69	0
26102	60	30	0.00	0.00	0	98102	35	20	0.00	0.13	0
32702	30	7	0.50	0.06	1	98202	35	30	0.00	0.02	0
45402	35	20	0.00	0.71	0	101702	60	30	0.00	0.71	0
46702	40	20	0.00	0.00	0	102202	60	3	0.00	0.05	0
50802	30	10	0.00	0.28	0	104602	45	30	0.00	0.40	0
52302	55	30	0.00	1.01	0	109502	40	20	0.00	2.32	0
53402	50	20	0.00	0.32	0	110602	50	10	0.50	0.32	1
55202	55	3	0.20	0.55	0	112802	30	3	0.33	0.75	0
56402	30	10	0.00	0.53	0	113902	55	30	0.00	0.06	0
58602	30	3	0.00	0.54	0	114702	45	30	0.00	0.00	0
59102	45	30	0.50	1.05	0	114902	35	10	0.00	0.00	0
60002	45	7	0.00	0.13	0	123902	35	3	0.00	0.00	0
64702	50	3	0.00	0.56	0	93902	55	5	0.00	0.13	0

Methodology B-Results

- Mean SS: 0.17
- Mean FPR: 0.87
- Validated Patients: 17.5% (7)

Patient	Pre-ictal Period (minutes)	Features	SS	FPR/h	Validated	Patient	Pre-ictal Period (minutes)	Features	SS	FPR/h	Validated
30802	60	5	0.40	0.38	0	75202	20	30	0.00	0.11	0
402	60	30	0.00	0.00	0	80702	45	30	0.33	0.44	1
8902	30	30	0.00	0.27	0	85202	60	7	0.50	0.52	1
11002	30	10	0.00	3.93	0	93402	30	7	0.50	0.77	0
16202	30	20	0.00	0.07	0	94402	30	15	0.00	1.29	0
21902	45	15	0.00	0.28	0	95202	45	30	0.00	0.12	0
23902	55	10	0.00	1.34	0	96002	55	20	0.00	1.52	0
26102	60	30	0.00	0.10	0	98102	60	15	1.00	0.14	1
32702	30	20	0.00	0.12	0	98202	30	30	0.00	4.14	0
45402	30	15	0.00	1.13	0	101702	30	7	0.50	1.56	0
46702	60	30	0.00	0.00	0	102202	60	5	0.00	0.39	0
50802	30	30	0.00	0.17	0	104602	55	3	0.50	1.49	0
52302	60	3	0.00	1.13	0	109502	60	7	0.00	0.65	0
53402	60	3	1.00	0.22	1	110602	45	10	0.50	0.70	1
55202	30	15	0.20	1.11	0	112802	45	3	0.00	3.01	0
56402	30	15	0.00	3.83	0	113902	60	3	0.67	1.44	0
58602	30	3	0.00	0.00	0	114702	45	5	0.00	0.04	0
59102	60	15	0.00	0.52	0	114902	30	3	0.25	0.21	1
60002	30	30	0.33	0.67	1	123902	30	3	0.00	0.00	0
64702	50	3	0.00	1.02	0	93902	45	3	0.00	0.13	0

Methodology C-Results

- Mean SS: 0,04
- Mean FPR: 0,18
- Validated Patients: 7,5% (3)

Patient	Pre-Ictal Period (minutes)	SS	FPR/h	Validated	Patient	Pre-Ictal Period (minutes)	SS	FPR/h	Validated
30802	30	0,20	0,48	0	75202	30	0,00	0,16	0
402	60	0,00	0,00	0	80702	40	0,00	0,21	0
8902	60	0,50	0,00	1	85202	30	0,50	0,37	1
11002	60	0,00	0,00	0	93402	30	0,00	0,57	0
16202	60	0,25	0,08	1	94402	40	0,00	0,04	0
21902	60	0,00	0,00	0	95202	30	0,00	0,08	0
23902	30	0,00	1,65	0	96002	60	0,00	0,00	0
26102	30	0,00	0,10	0	98102	40	0,00	0,00	0
32702	50	0,00	0,00	0	98202	50	0,00	1,30	0
45402	40	0,00	0,00	0	101702	30	0,00	0,10	0
46702	30	0,00	0,10	0	102202	60	0,00	0,00	0
50802	40	0,00	0,10	0	104602	40	0,00	0,08	0
52302	60	0,00	0,00	0	109502	30	0,00	0,00	0
53402	50	0,00	0,09	0	110602	50	0,00	0,00	0
55202	60	0,00	0,07	0	112802	50	0,00	0,00	0
56402	40	0,00	0,11	0	113902	30	0,00	0,11	0
58602	40	0,00	0,05	0	114702	50	0,00	0,04	0
59102	50	0,00	0,40	0	114902	30	0,00	0,07	0
60002	50	0,00	0,20	0	123902	30	0,00	0,00	0
64702	40	0,00	0,34	0	93902				

Methodology A-Selected Patients

- Patient 8902
 - Good SS and good FPR/h
- Patient 101702
 - Bad SS and bad FPR/h
- Patient 93402
 - Good SS but bad FPR/h
- Patient 402
 - Never raised an alarm

Patient	Pre-Ictal Period (minutes)	Features	SS	FPR/h	Validated	Patient	Pre-Ictal Period (minutes)	Features	SS	FPR/h	Validated
30802	60	5	0.20	0.40	0	75202	35	30	0.00	0.04	0
402	60	20	0.00	0.00	0	80702	50	30	0.33	0.28	1
8902	35	7	1.00	0.11	1	85202	30	20	0.00	0.11	0
11002	30	7	0.00	0.78	0	93402	30	3	1.00	0.50	1
16202	30	30	0.00	0.03	0	94402	55	30	0.00	0.80	0
21902	50	10	0.00	0.00	0	95202	35	15	0.00	0.37	0
23902	55	15	0.50	1.35	0	96002	35	3	0.25	0.69	0
26102	60	30	0.00	0.00	0	98102	35	20	0.00	0.13	0
32702	30	7	0.50	0.06	1	98202	35	30	0.00	0.02	0
45402	35	20	0.00	0.71	0	101702	60	30	0.00	0.71	0
46702	40	20	0.00	0.00	0	102202	60	3	0.00	0.05	0
50802	30	10	0.00	0.28	0	104602	45	30	0.00	0.40	0
52302	55	30	0.00	1.01	0	109502	40	20	0.00	2.32	0
53402	50	20	0.00	0.32	0	110602	50	10	0.50	0.32	1
55202	55	3	0.20	0.55	0	112802	30	3	0.33	0.75	0
56402	30	10	0.00	0.53	0	113902	55	30	0.00	0.06	0
58602	30	3	0.00	0.54	0	114702	45	30	0.00	0.00	0
59102	45	30	0.50	1.05	0	114902	35	10	0.00	0.00	0
60002	45	7	0.00	0.13	0	123902	35	3	0.00	0.00	0
64702	50	3	0.00	0.56	0	93902	55	5	0.00	0.13	0

Patient 8902 – Overall performance

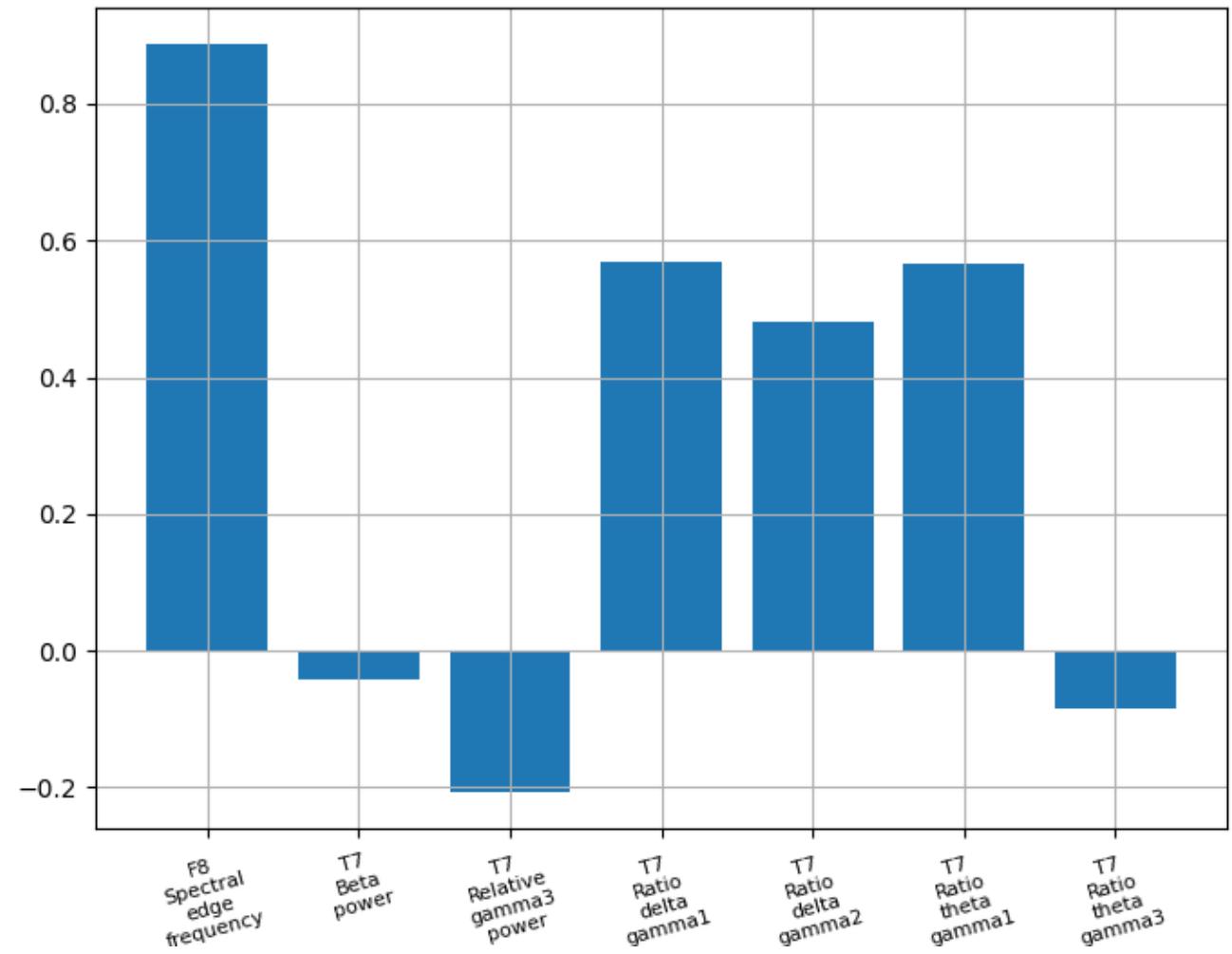
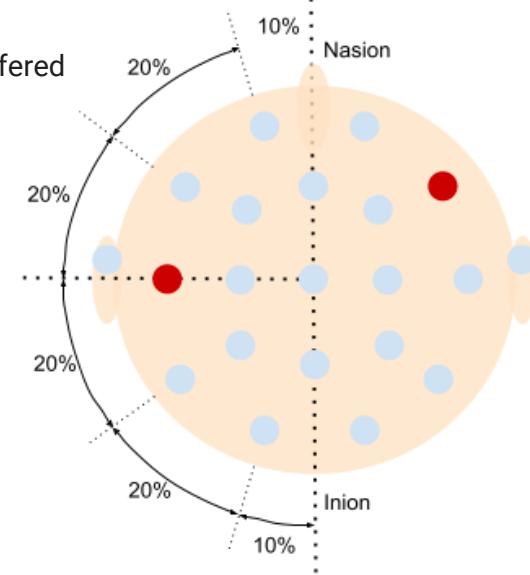
- SS:100%, FPR/h=0.11
- Above chance
- Logistic Regression with 7 features
- All seizures during the night.
Sleep related?
- Surgery decision: not offered
- Focus localization=tpl
Temporal polar left

	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 00:51:14	Unclassified	Rhythmic alpha waves	Awake
	Day 1 00:03:23	FOIA	Rhythmic beta waves	Awake
	Day 1 06:37:05	FOIA	Rhythmic alpha waves	Awake
Testing Seizures	Day 2 01:35:56	FOIA	Amplitude depression	Awake
	Day 2 06:10:26	FOIA	Rhythmic alpha waves	Awake

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Seizure 4 Day 2 01:35:56	Yes	1	≈17
	Seizure 5 Day 2 06:10:26	Yes	1	≈4

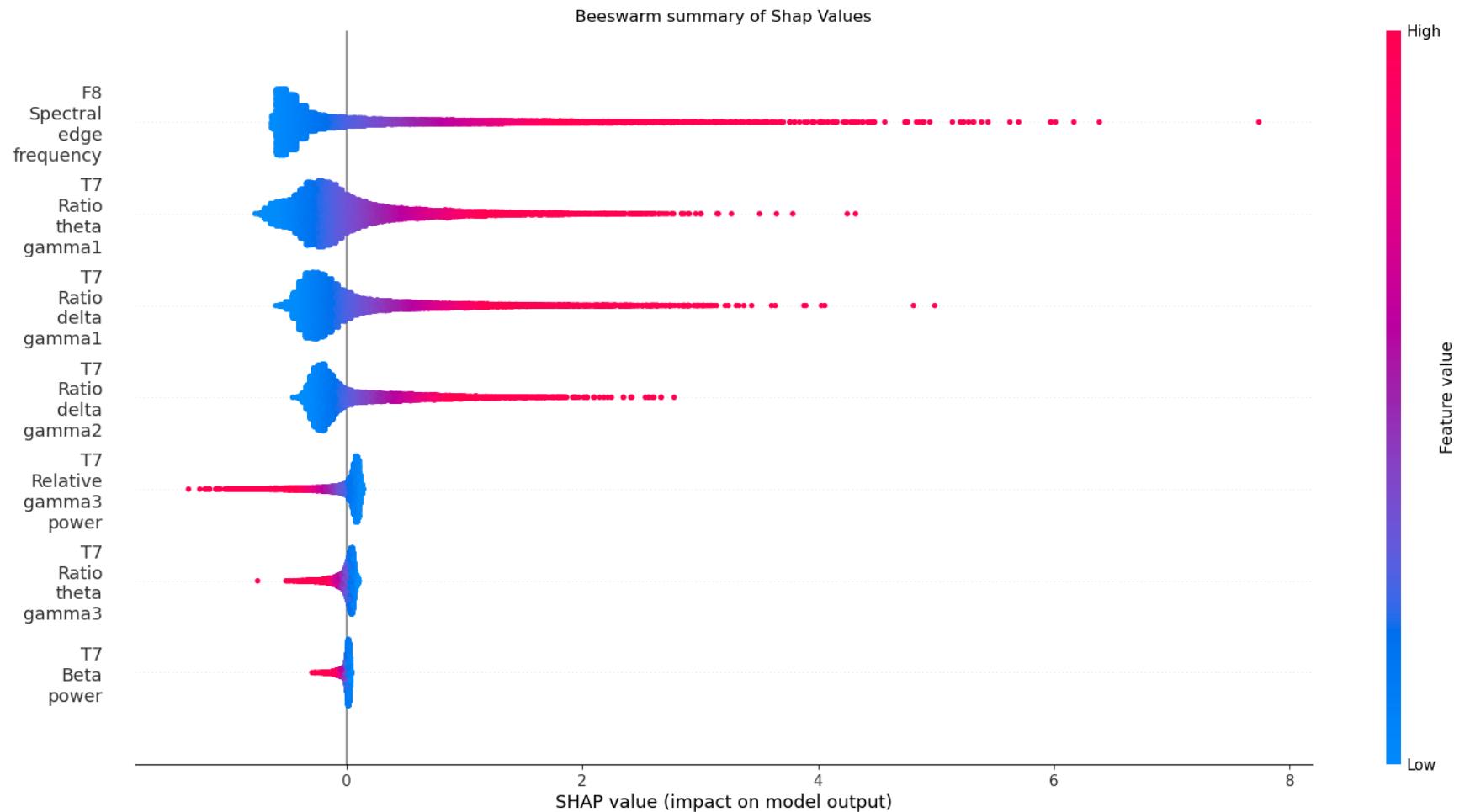
Patient 8902 – Analysing regression coefficients

- What can we say about these features?
- Ratios between gamma bands
- Strong influence of the gamma bands
- Electrodes: F8 and T7
- Surgery decision: not offered
- Focus localization= tpl
Temporal polar left



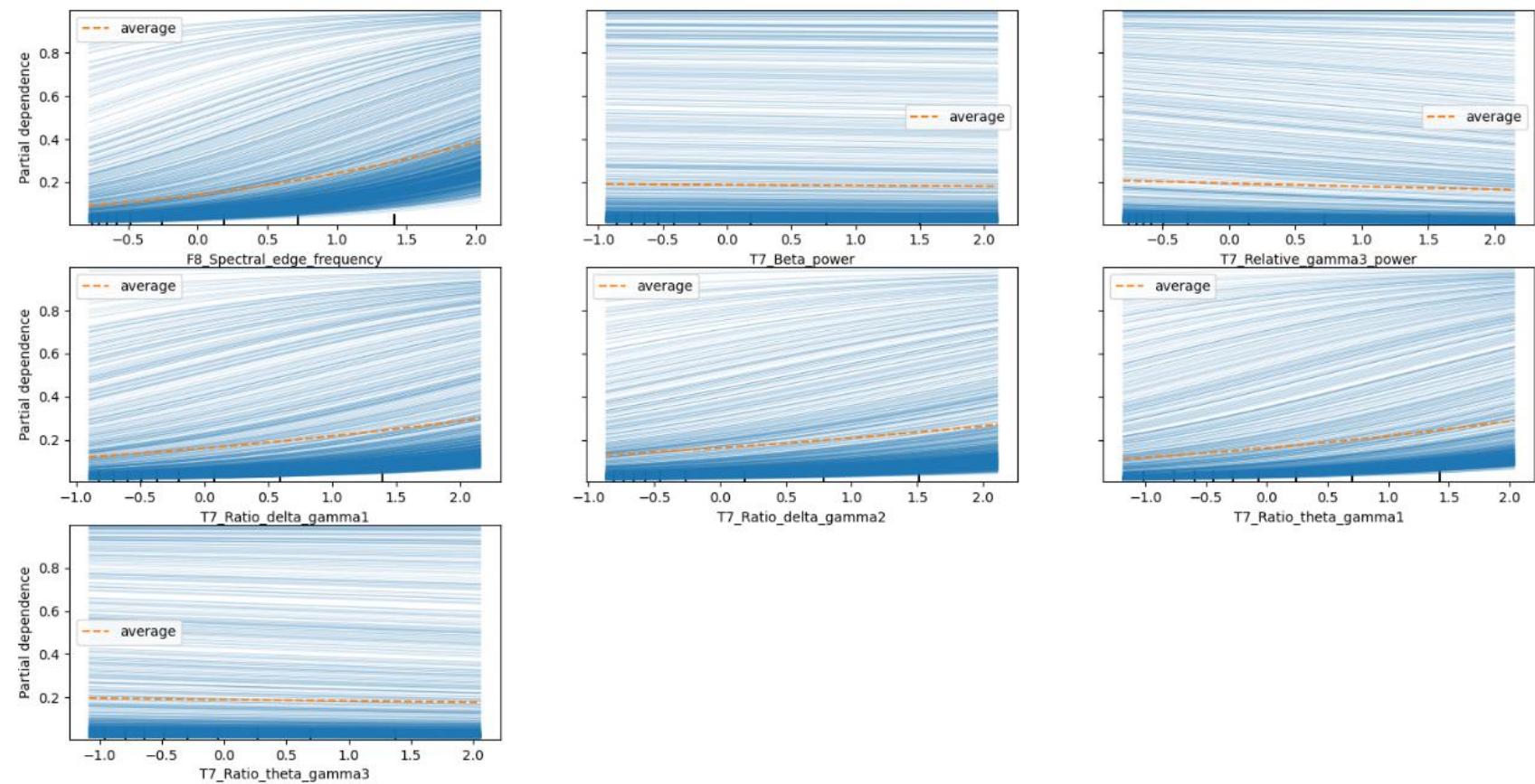
Patient 8902 – A beeswarm summary of Shap Values

- Colours: feature value
- X-axis: impact on classification



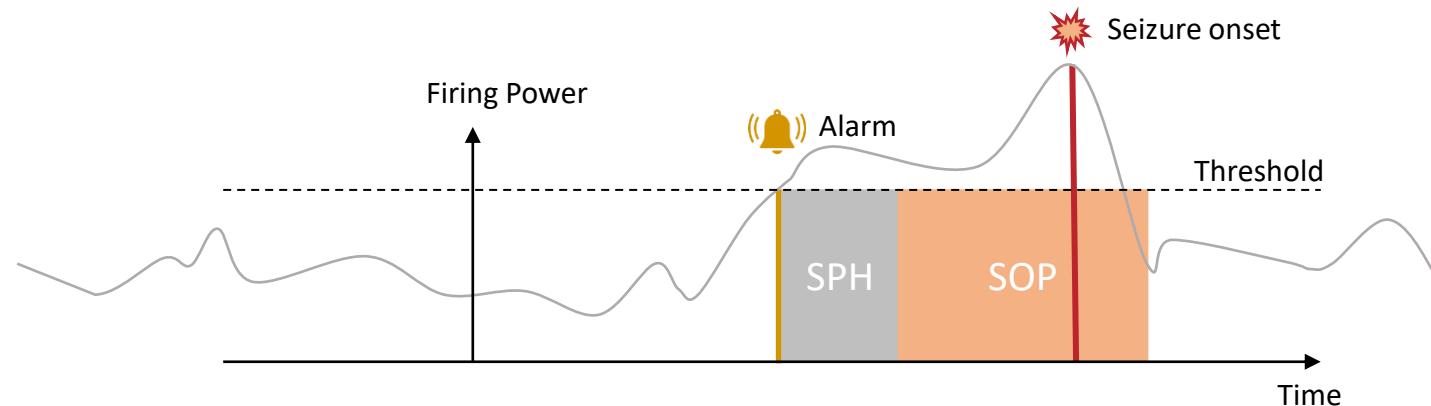
Patient 8902 – Partial dependence plots

- How each feature “behaves” towards the label: interictal/preictal (0/1)
- Sign and module of slope



Patient 8902 – Calibration plots

- This is a mixture of a scatter plot with a calibration plot
- On x-axis: feature value
- On y-axis: Firing Power value
- Colours (labels):
 - Blue: interictal
 - Orange: preictal
- This plot shows:
 - how well a feature may “calibrate” the model
 - how the model behaves according to each feature value



On the left: true labels

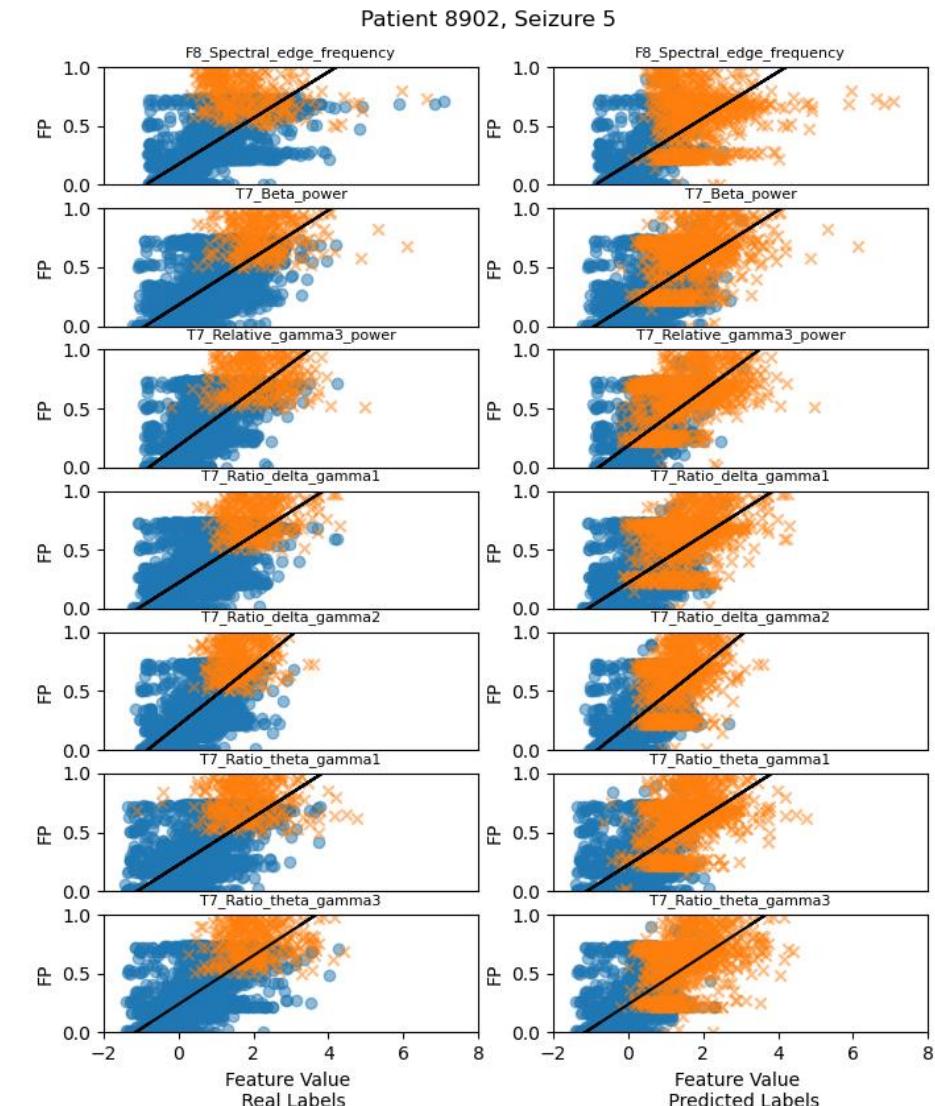
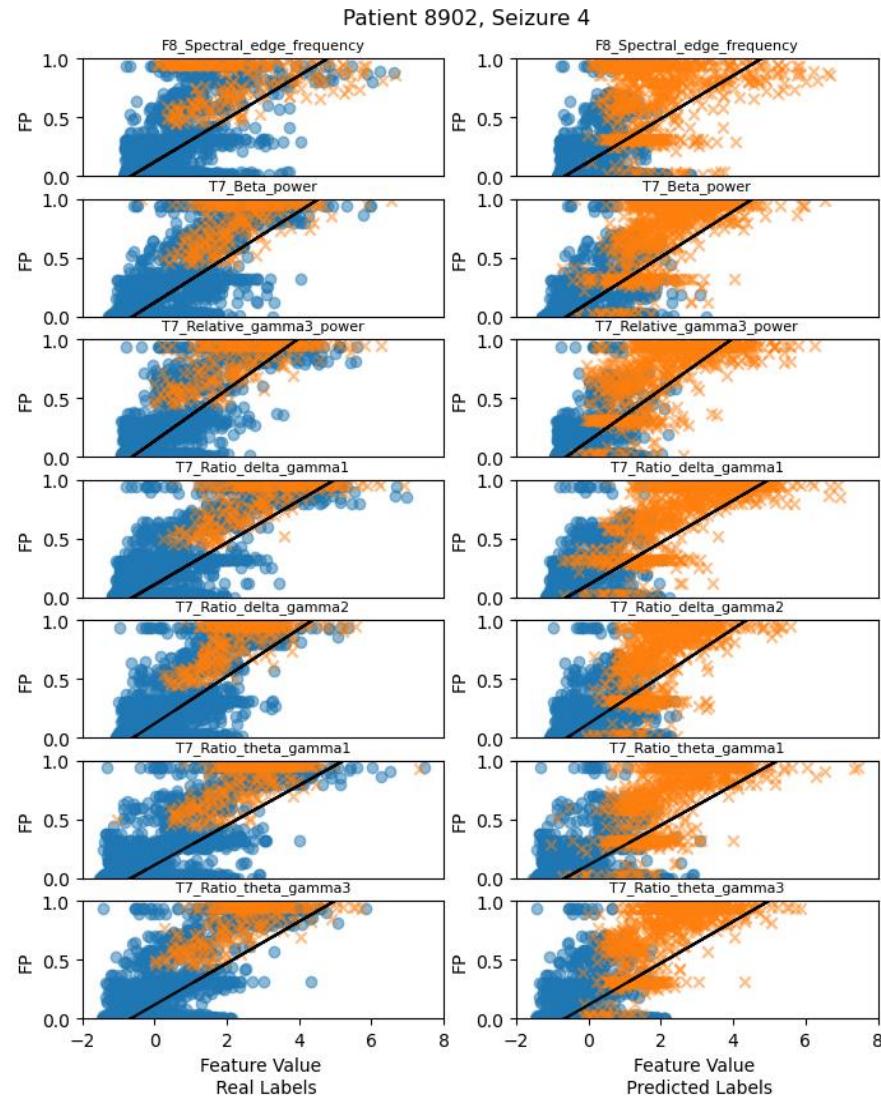
On the right: predicted labels

Patient 8902 – Calibration plots

- This is a mixture of a scatter plot with a calibration plot
- On x-axis: feature value
- On y-axis: Firing Power value
- Colours (labels):
 - Blue: interictal
 - Orange: preictal
- This plot shows:
 - how well a feature may “calibrate” the model
 - how the model behaves according to each feature value

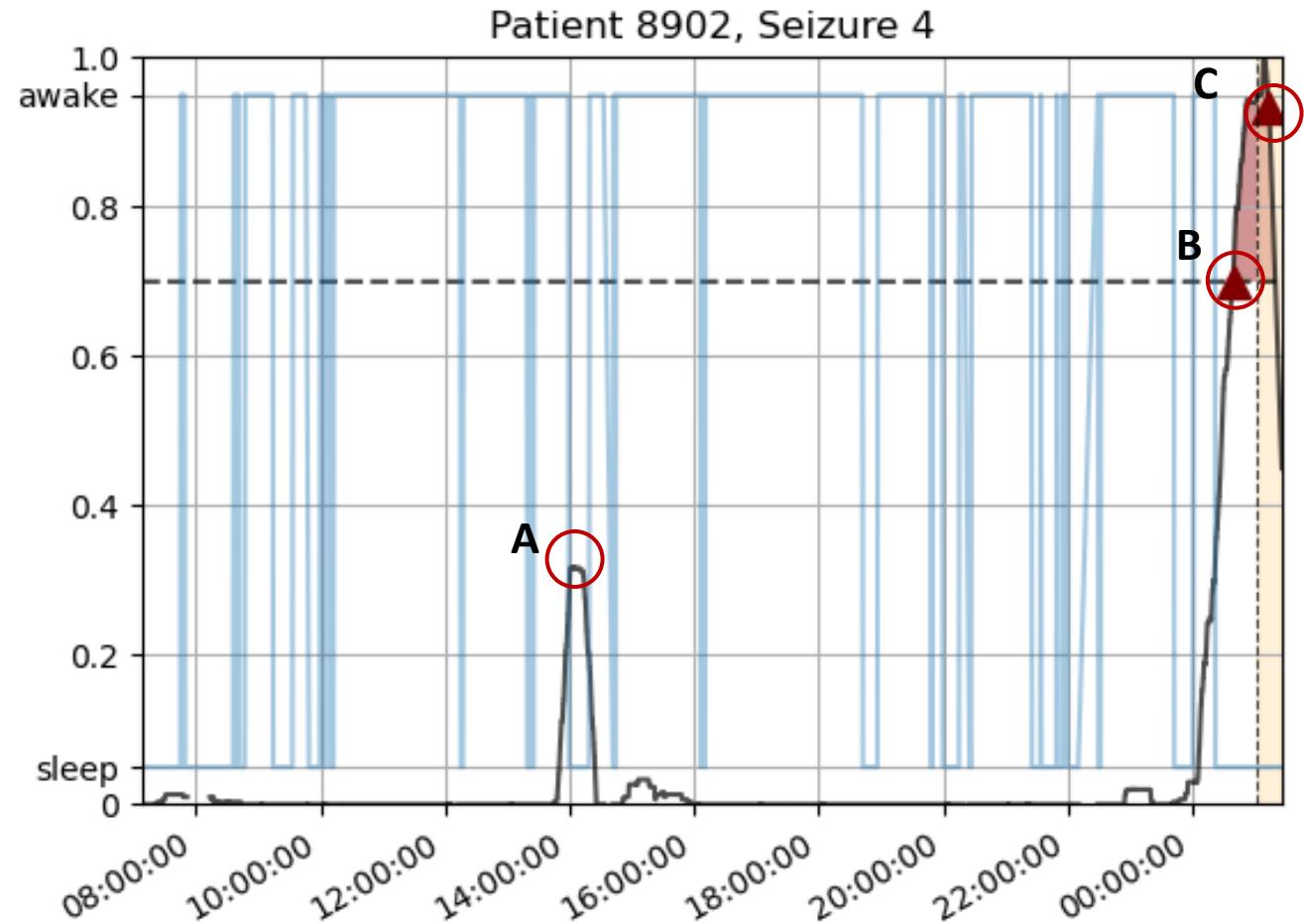
On the left: true labels

On the right: predicted labels



Patient 8902 – Over time

- Point A (14h00):
 - Firing Power=0.35
 - But did not raise an alarm. Regularization dealt good!
 - Why this peak? Lunch, sleepiness?
- Point B (00h00):
 - A false alarm, but close to the seizure
 - Firing Power increased until reaching Preictal period
 - It missed the seizure, but is it truly a “false” alarm?
- Point A (01h00):
 - True alarm
 - But interestingly, the Firing Power curve is already going down

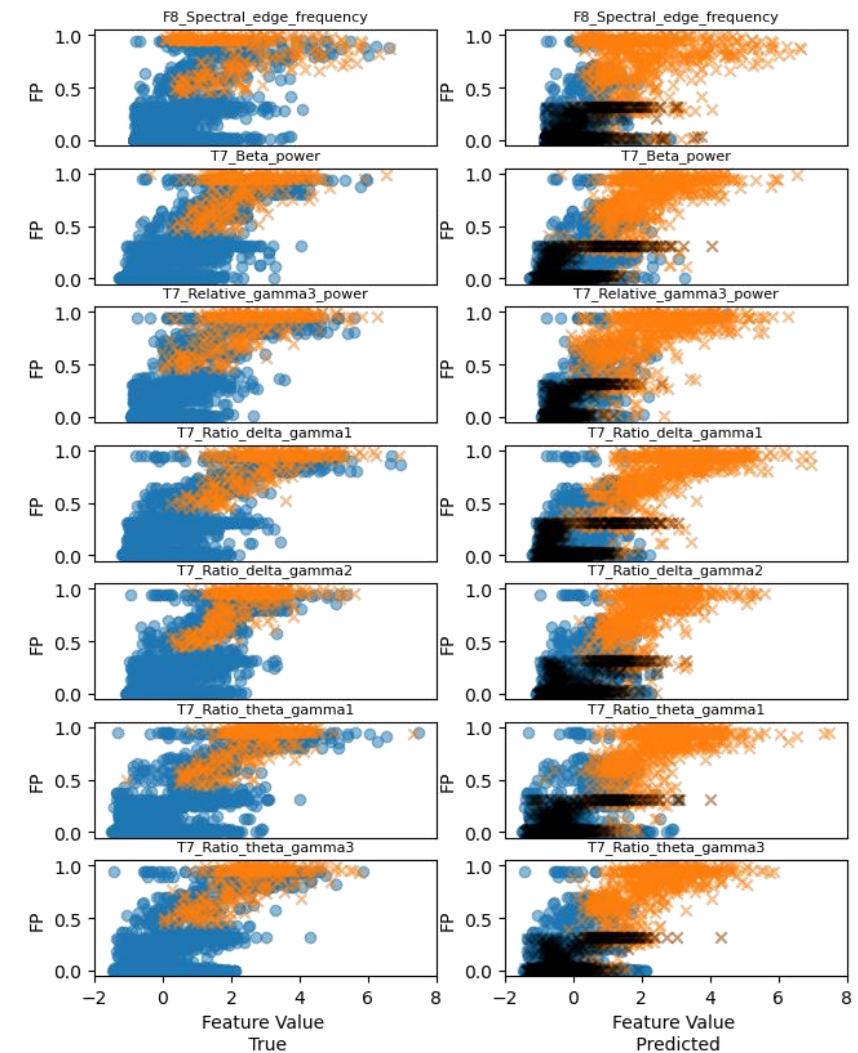
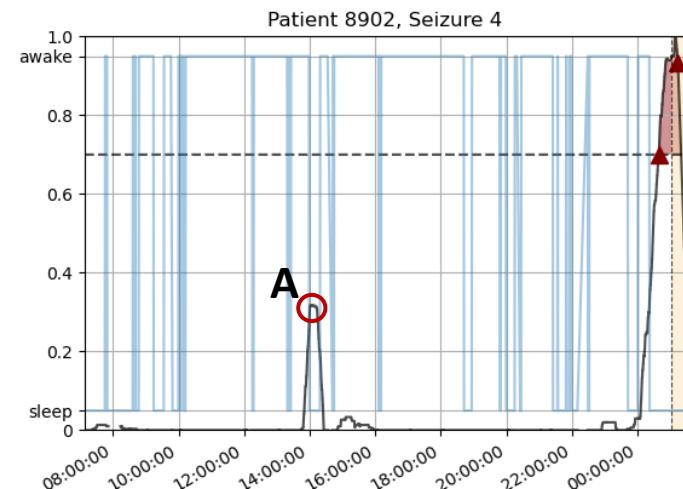


Patient 8902 – Peak A (14h00)

Patient 8902, Seizure 4
1st Peak at 14h00

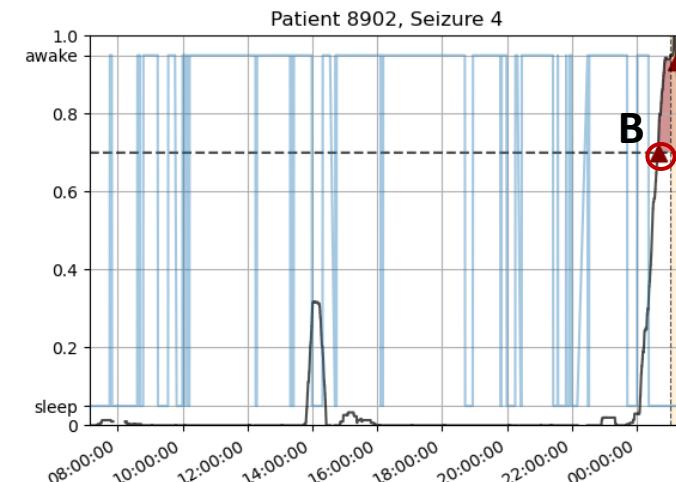
- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
- Three top features
- No interactions studied
- 14h: Eating? Nap?

- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - T7_Beta_power: $0.13+/-0.13$
 - T7_Ratio_theta_gamma3: $-0.73+/-0.73$
 - T7_Relative_gamma3_power: $-1.12+/-1.12$

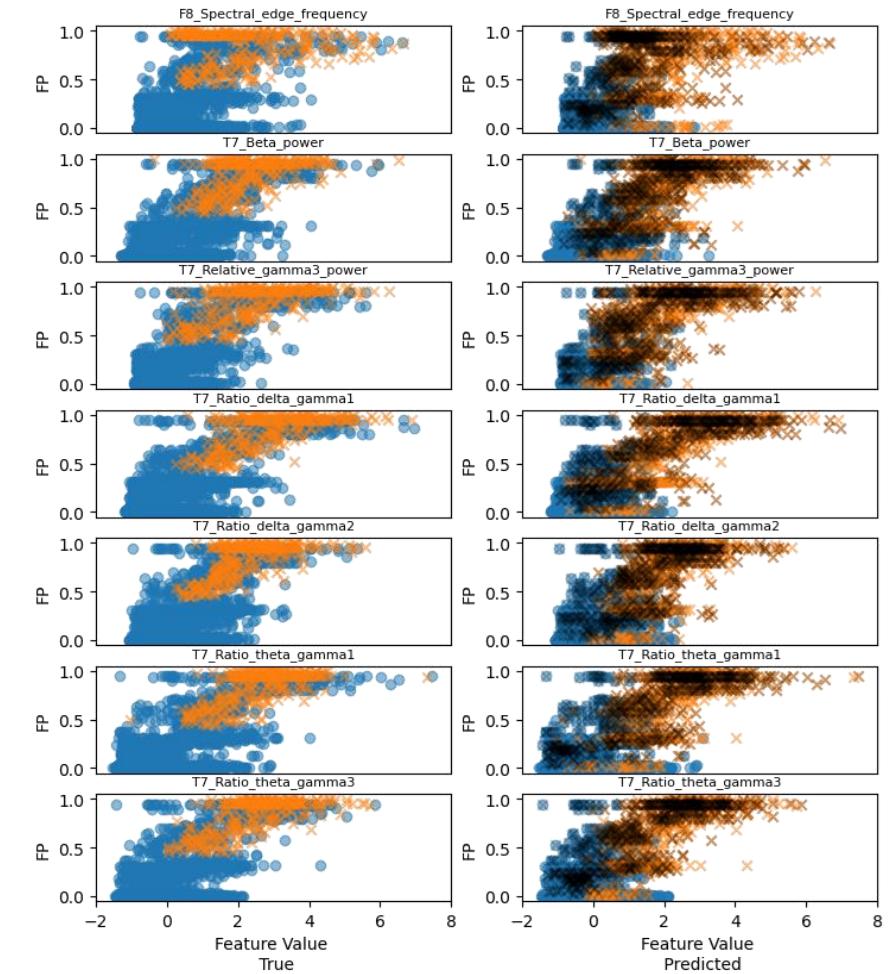


Patient 8902 – Peak B (00h00)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 00h: Sleeping?

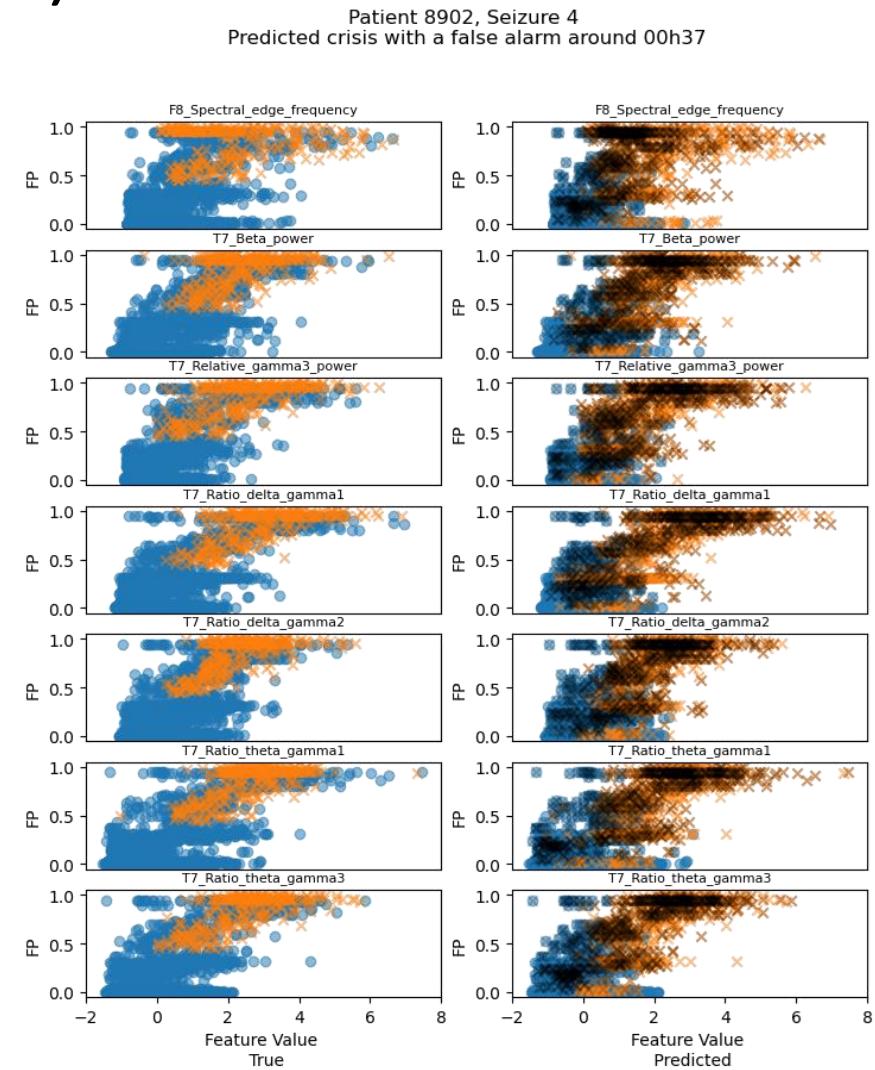
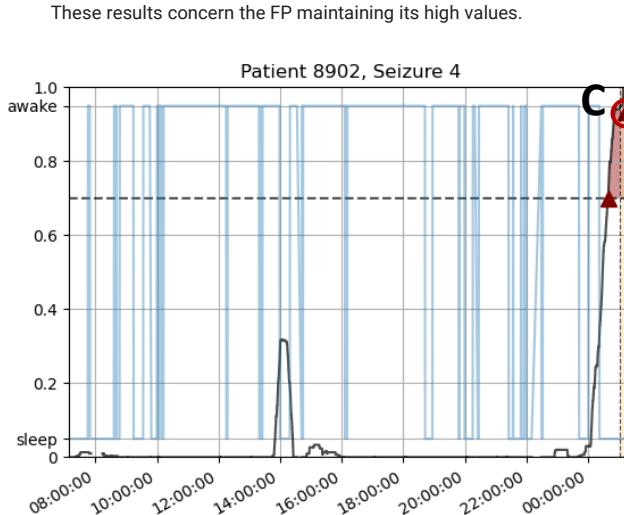


Patient 8902, Seizure 4
Predicted crisis with a false alarm around 00h37



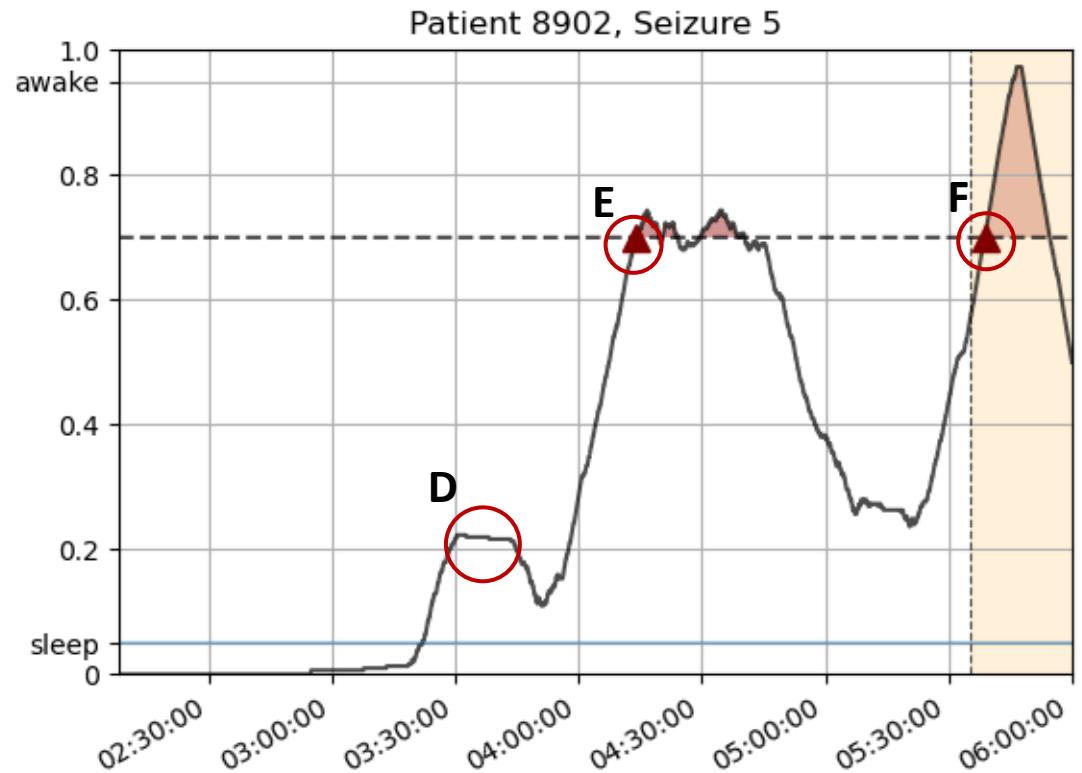
Patient 8902 – Peak C (01h00)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 01h: Sleeping?
- Despite being a true alarm, Firing Power was already decreasing
- Counterfactual explanations:
 - For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - F8_Spectral_edge_frequency: -5.03+/-5.03
 - T7_Ratio_theta_gamma1: -6.84+/-6.84
 - T7_Ratio_delta_gamma1: -6.84+/-6.84



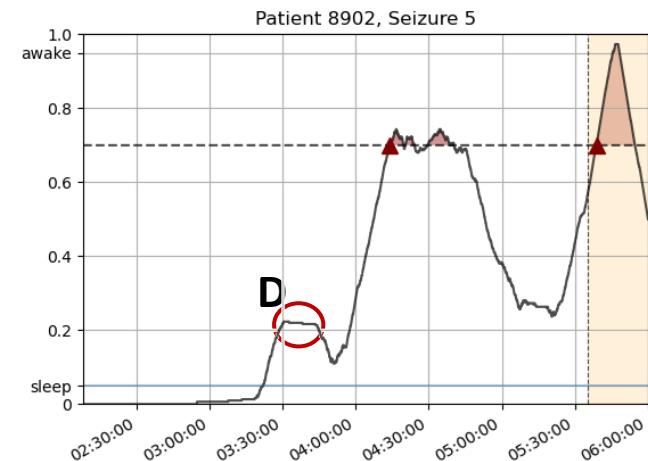
Patient 8902 – Over time

- Point D (03h30):
 - Firing Power=0.21
 - But did not raise an alarm. Regularization dealt good!
 - Why this peak, sleepiness?
- Point E (04h15):
 - A false alarm, and then FP goes down
 - May it be a seizure susceptibility?
 - Is it related to sleep?
- Point F (05h40):
 - True alarm
 - The FP is rising until it reaches a peak.

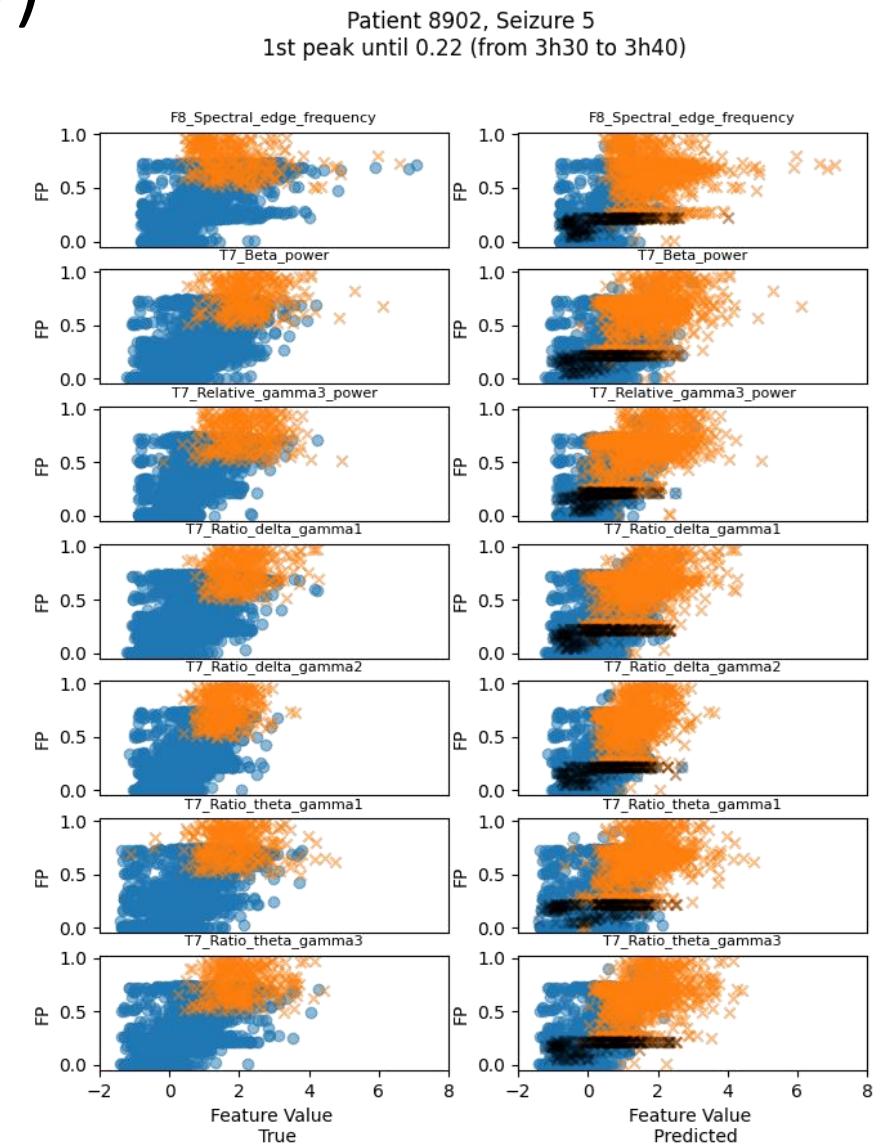


Patient 8902 – Peak D (03h30)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 03h30: Related to a sleep state transition? Sleep perturbation?

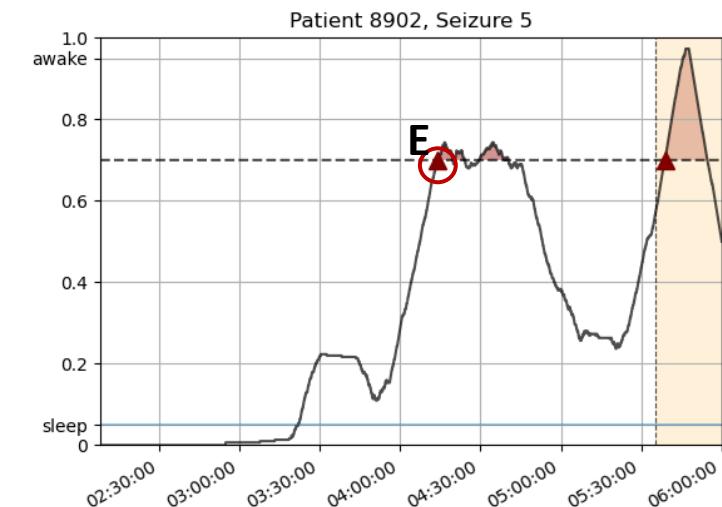


- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - T7_Ratio_theta_gamma3: $-0.15+/-0.15$
 - T7_Beta_power: $0.17+/-0.17$
 - T7_Relative_gamma3_power: $-1.31+/-1.31$

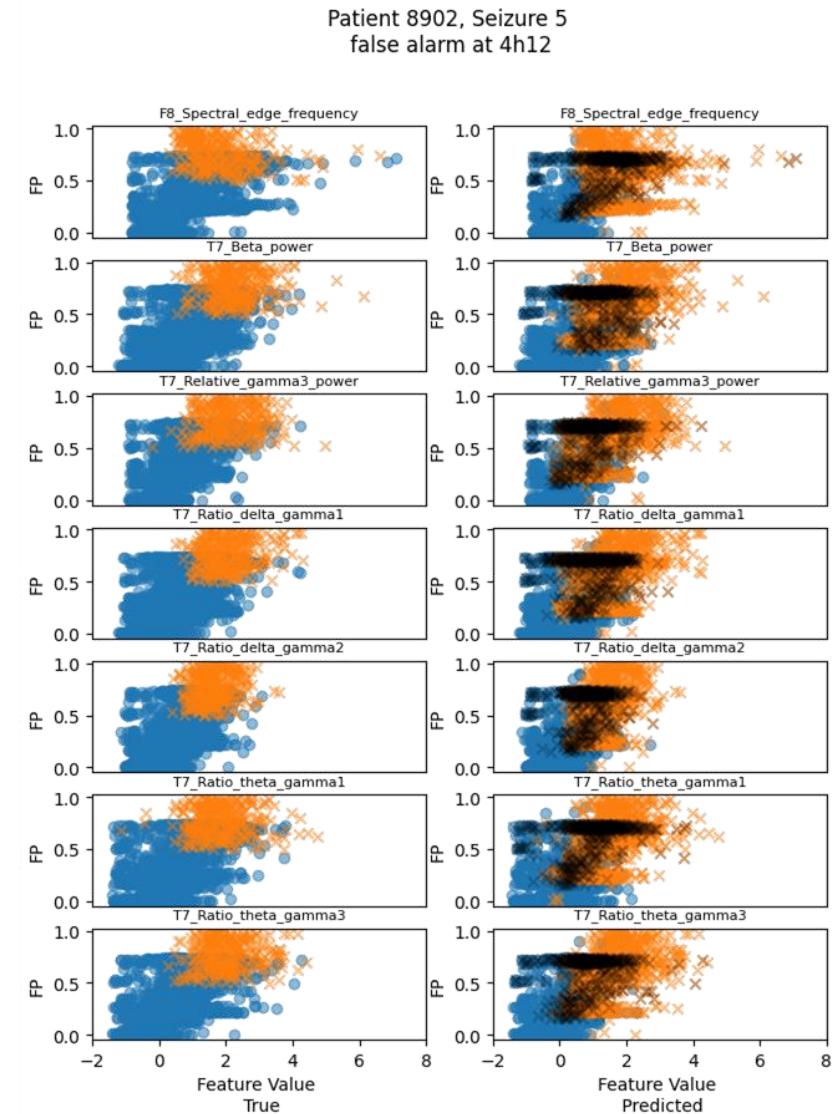


Patient 8902 – Peak E (04h15)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
- Three top features
- No interactions studied
- 04h15: Related to a sleep state transition? Sleep perturbation?

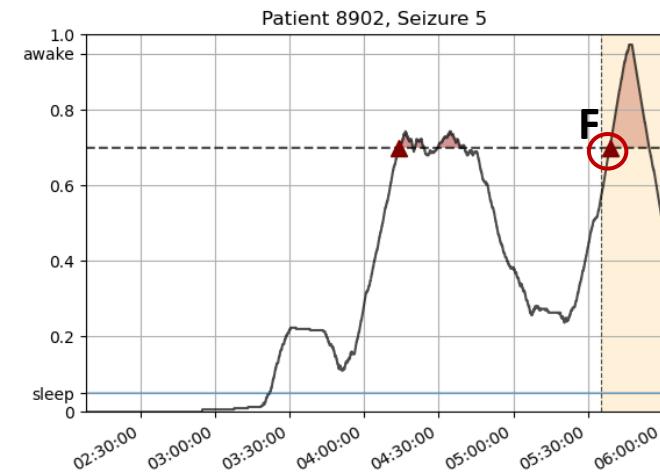


- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - F8_Spectral_edge_frequency: -0.14+/-0.14
 - T7_Ratio_delta_gamma1: -0.2+/-0.2
 - T7_Ratio_theta_gamma1: -0.2+/-0.2

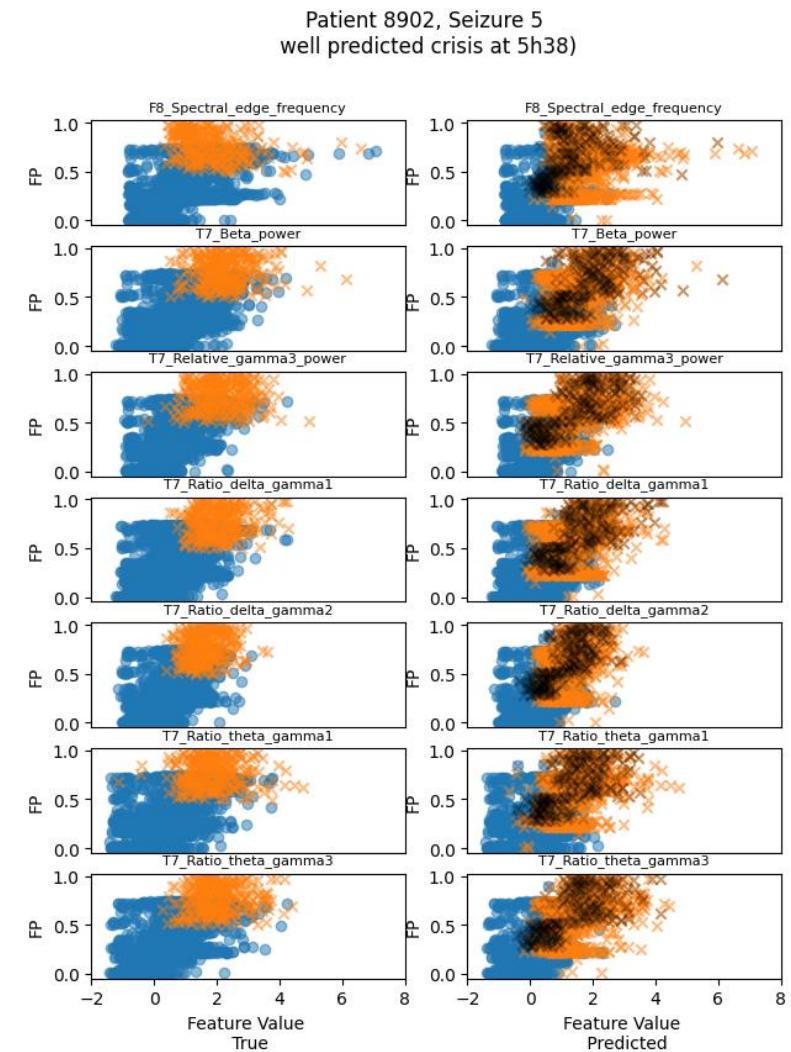


Patient 8902 – Peak F (05h40)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 05h40: Related to a sleep state transition? Sleep perturbation?



- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - T7_Ratio_theta_gamma3: $-0.37+/-0.37$
 - T7_Relative_gamma3_power: $0.46+/-0.46$
 - F8_Spectral_edge_frequency: $-0.53+/-0.53$



Patient 101702 – Overall performance

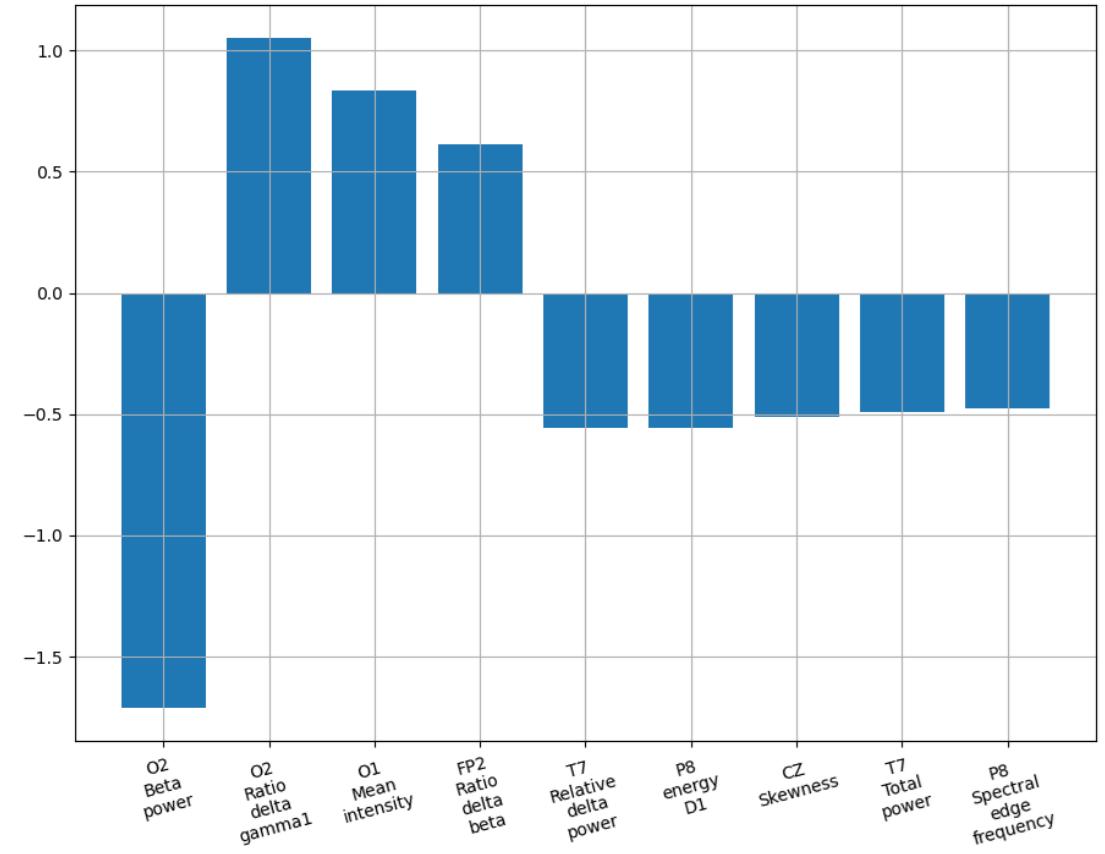
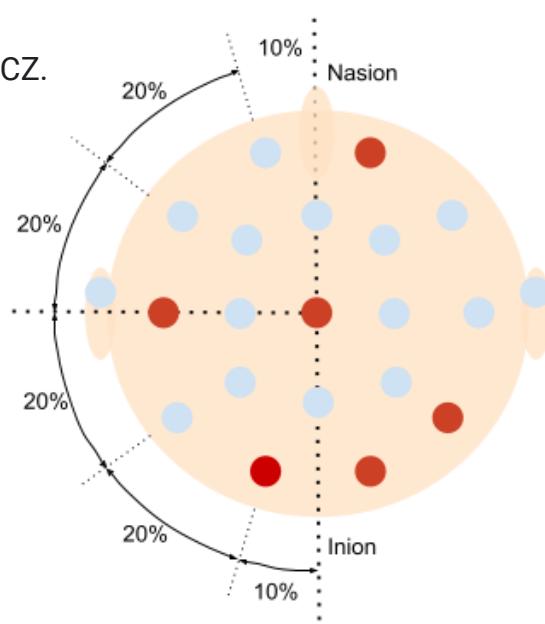
- SS:0%, FPR/h=0.71
- Not above chance and FPR/h too high
- Logistic Regression with 30 features
- Surgery decision: not offered
- Focus localization=t-r, t-l
Temporal right and left

	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 08:35:40	FOIA	Rhythmic theta waves	Awake
	Day 0 13:29:53	FOIA	Rhythmic theta waves	Awake
	Day 0 20:33:06	FOIA	Rhythmic theta waves	Awake
Testing Seizures	Day 1 08:35:22	FOIA	Repetitive spiking	Non-REM II
	Day 1 21:26:01	FOIA	Repetitive spiking	Awake

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Day 1 08:35:22	No	0	≈10
	Day 1 21:26:01	No	9	≈12

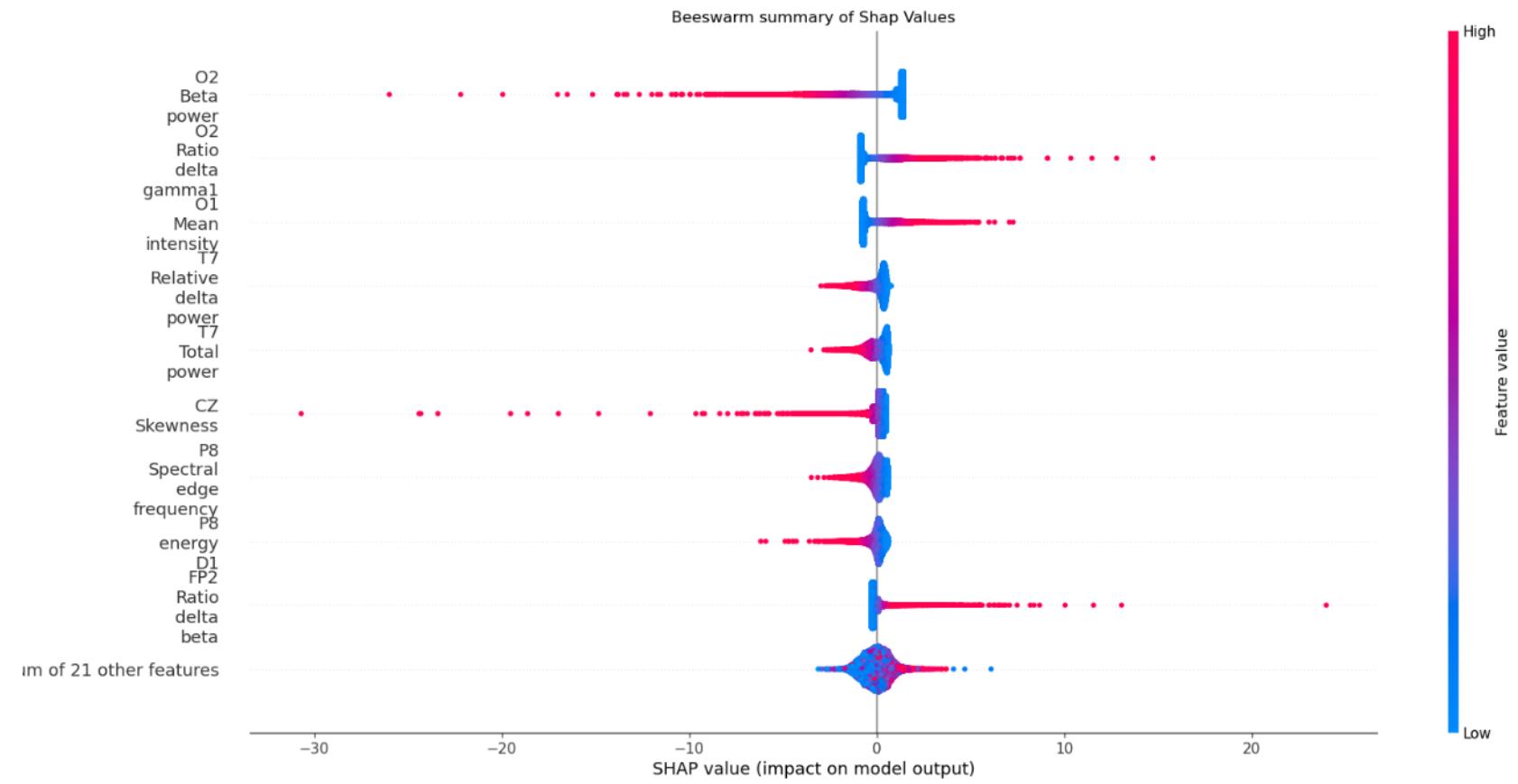
Patient 101702 – Analysing regression coefficients

- What can we say about these features?
- Ratio between bands
- Influence of the gamma bands
- Electrodes: O2, O1, FP2, T7, P8, CZ.
 - Do these electrodes make sense?



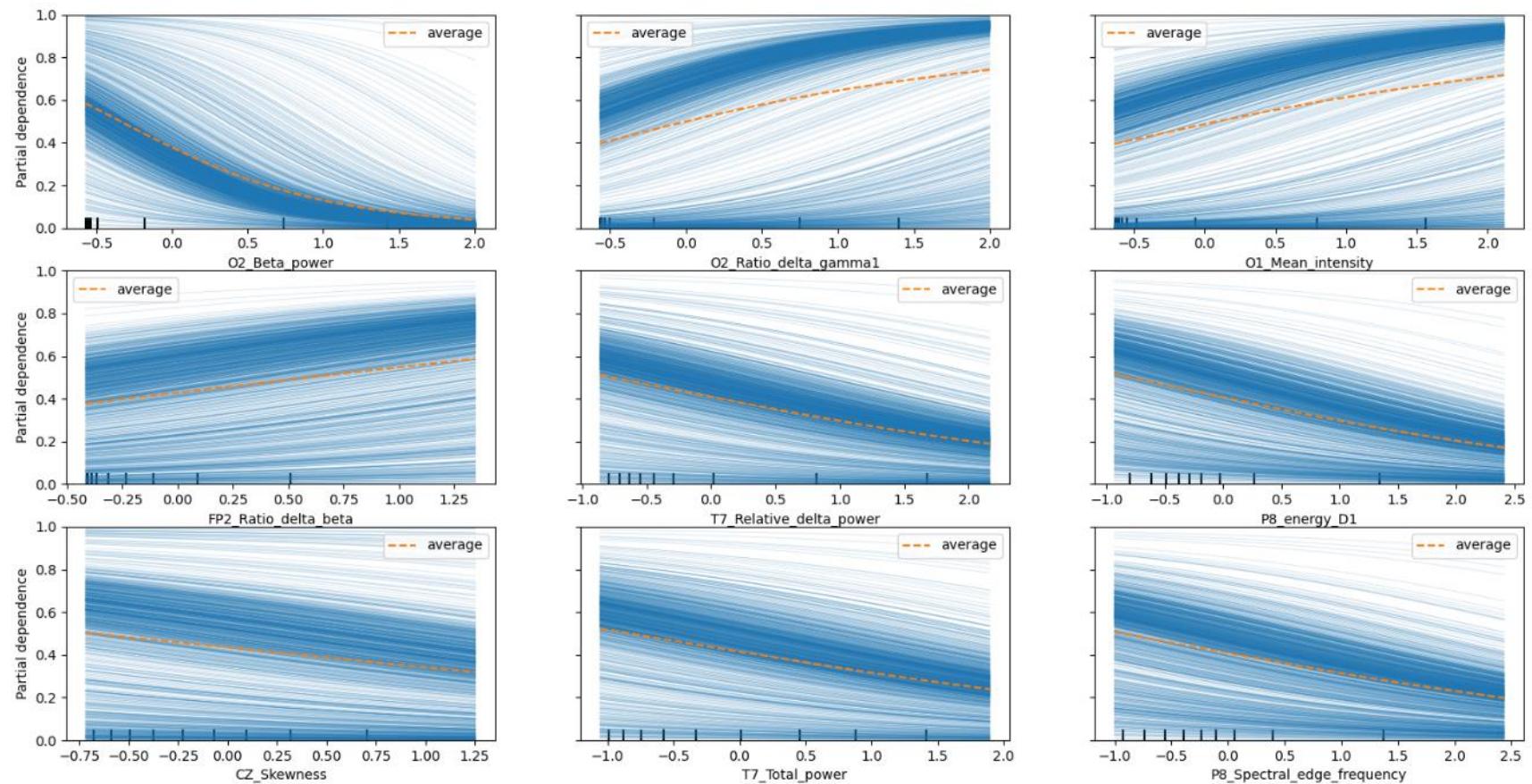
Patient 101702 – A beeswarm summary of Shap Values

- Colours: feature value
- X-axis: impact on classification



Patient 101702 – Partial dependence plots

- How each feature “behaves” towards the label: interictal/preictal (0/1)
- Sign and module of slope



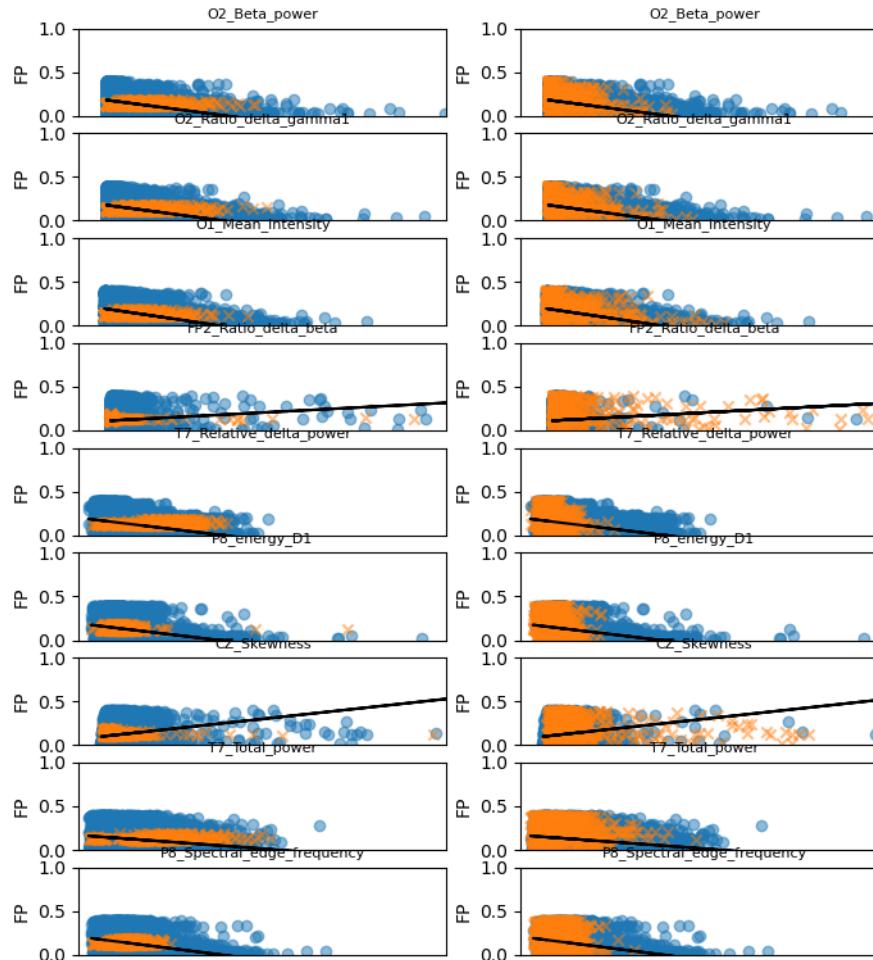
Patient 101702 – Calibration plots

- This is a mixture of a scatter plot with a calibration plot
- On x-axis: feature value
- On y-axis: Firing Power value
- Colours (labels):
 - Blue: interictal
 - Orange: preictal
- This plot shows:
 - how well a feature may “calibrate” the model
 - how the model behaves according to each feature value

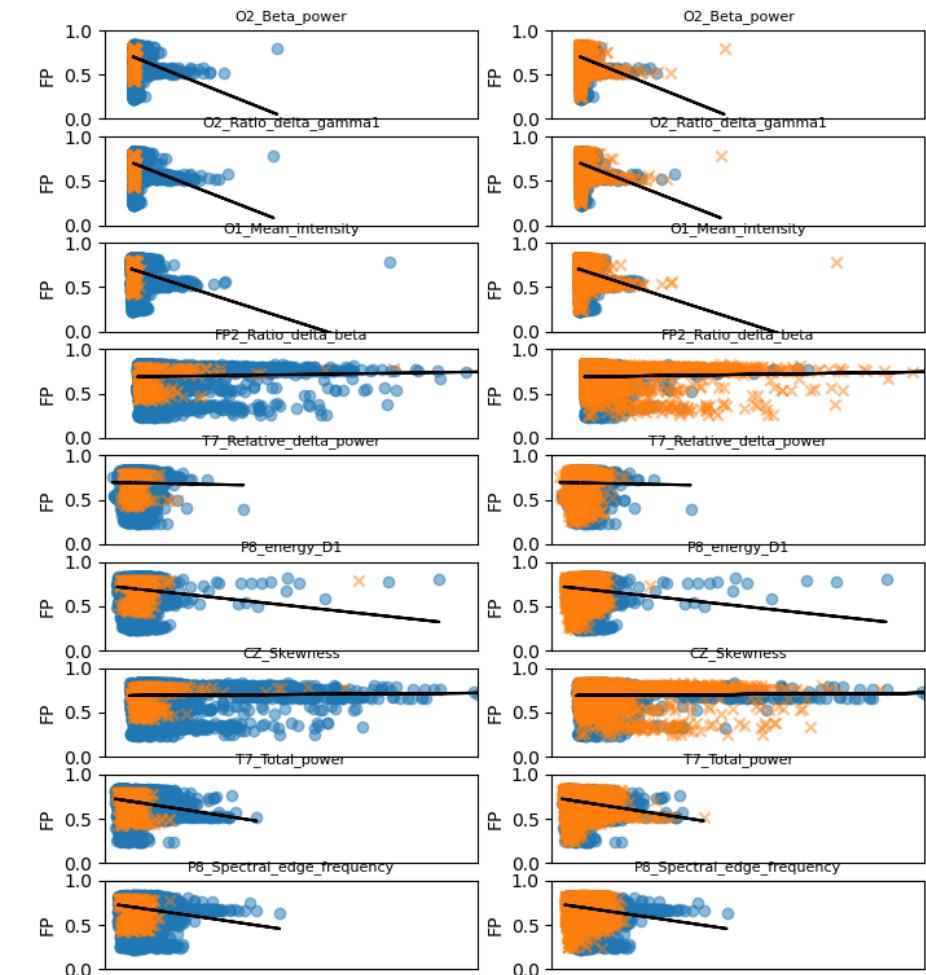
On the left: true labels

On the right: predicted labels

Patient 101702, Seizure 4

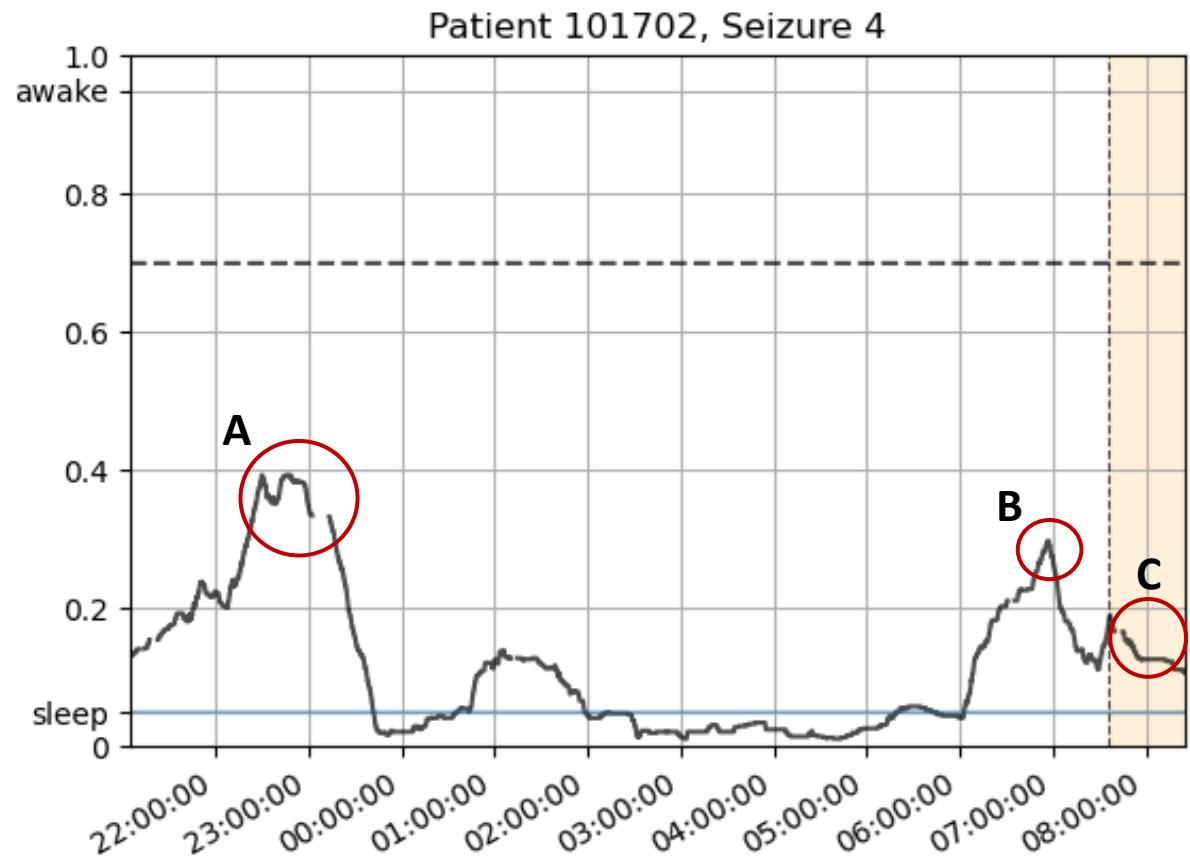


Patient 101702, Seizure 5



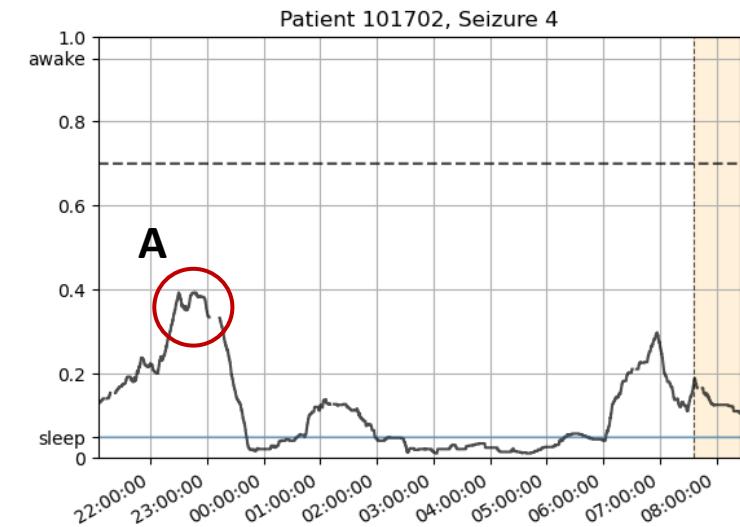
Patient 101702 – Over time

- Point A (22h00-23h00):
 - Firing Power=0.40
 - But did not raise an alarm. Regularization dealt good!
 - Why this peak? Sleepiness?
- Point B (07h00):
 - A peak that did not lead to seizure, but close to the seizure
 - Was it related to waking-up? Food? But it made sense to have this peak, right?
- Point C (08h30):
 - Why did it miss the seizure?

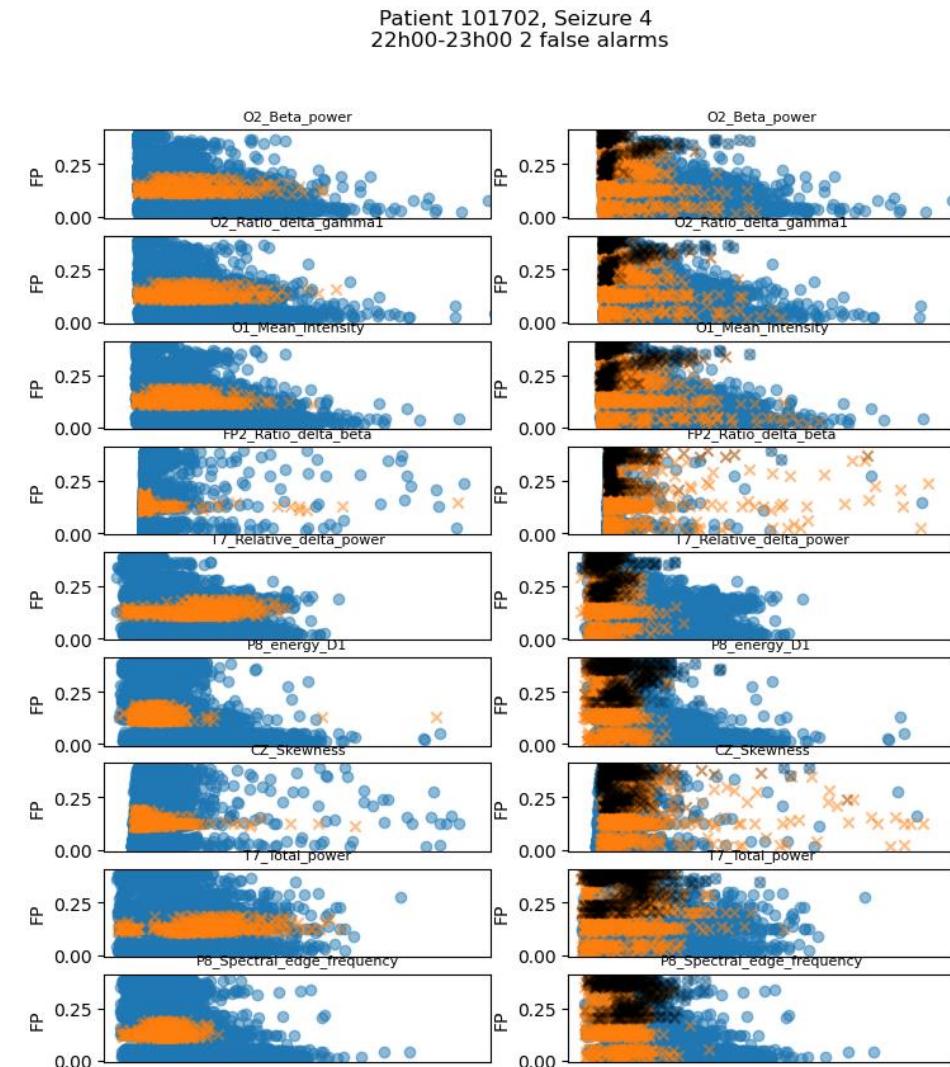


Patient 101702 – Peak A (22h30)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 22h30-23h00: Sleeping?

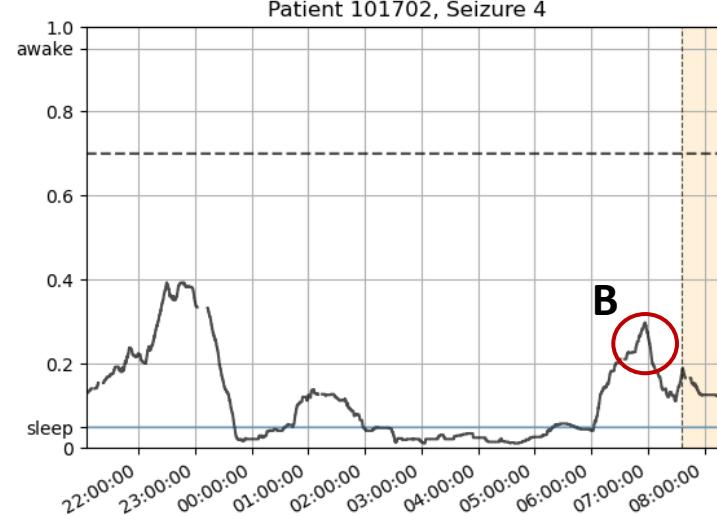


- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - O1_Ratio_theta_gamma3: $-0.18+/-0.18$
 - O2_Beta_power: $-0.21+/-0.21$
 - O2_Ratio_delta_gamma1: $0.34+/-0.34$



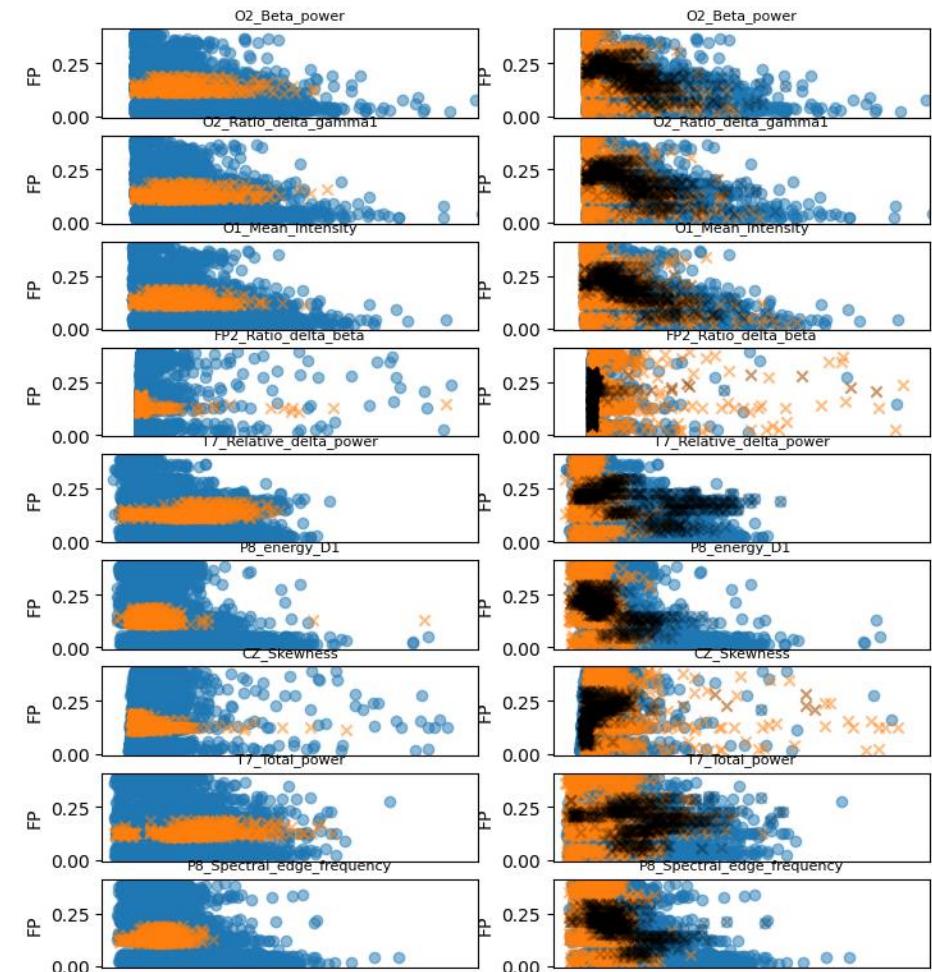
Patient 101702 – Peak B (07h00)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 14h: Eating? Nap?



- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - T8_Ratio_delta_theta: $-0.2+/-0.2$
 - PZ_Relative_gamma4_power: $-0.26+/-0.26$
 - O1_Ratio_theta_gamma3: $-0.57+/-0.57$

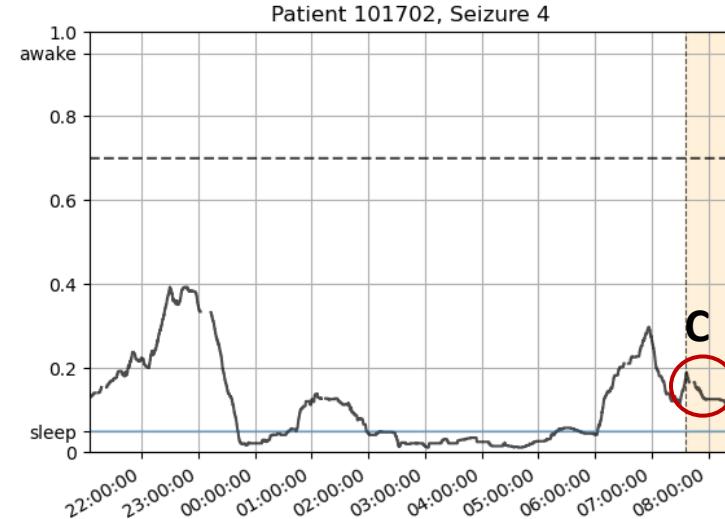
Patient 101702, Seizure 4
small peak around 7h00



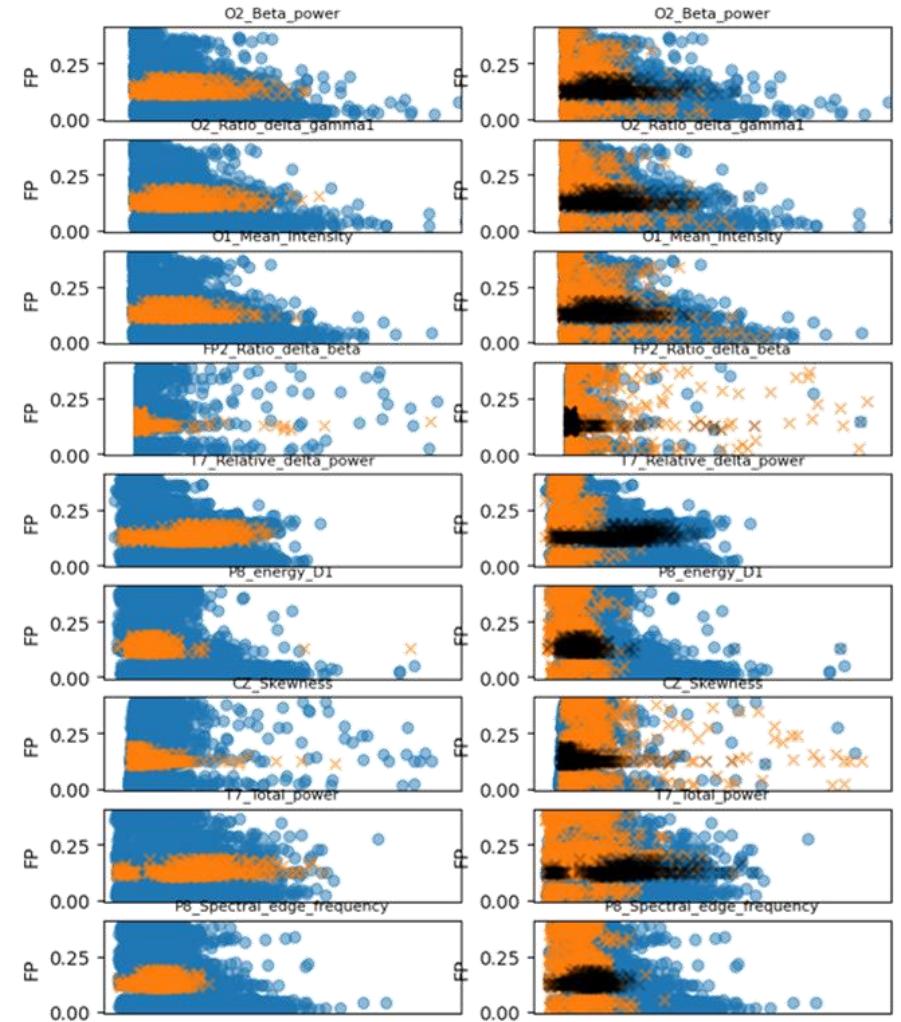
Patient 101702 – Peak C (08h00)

Patient 101702, Seizure 4
missed seizure

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 08h: Awaking? Breakfast?

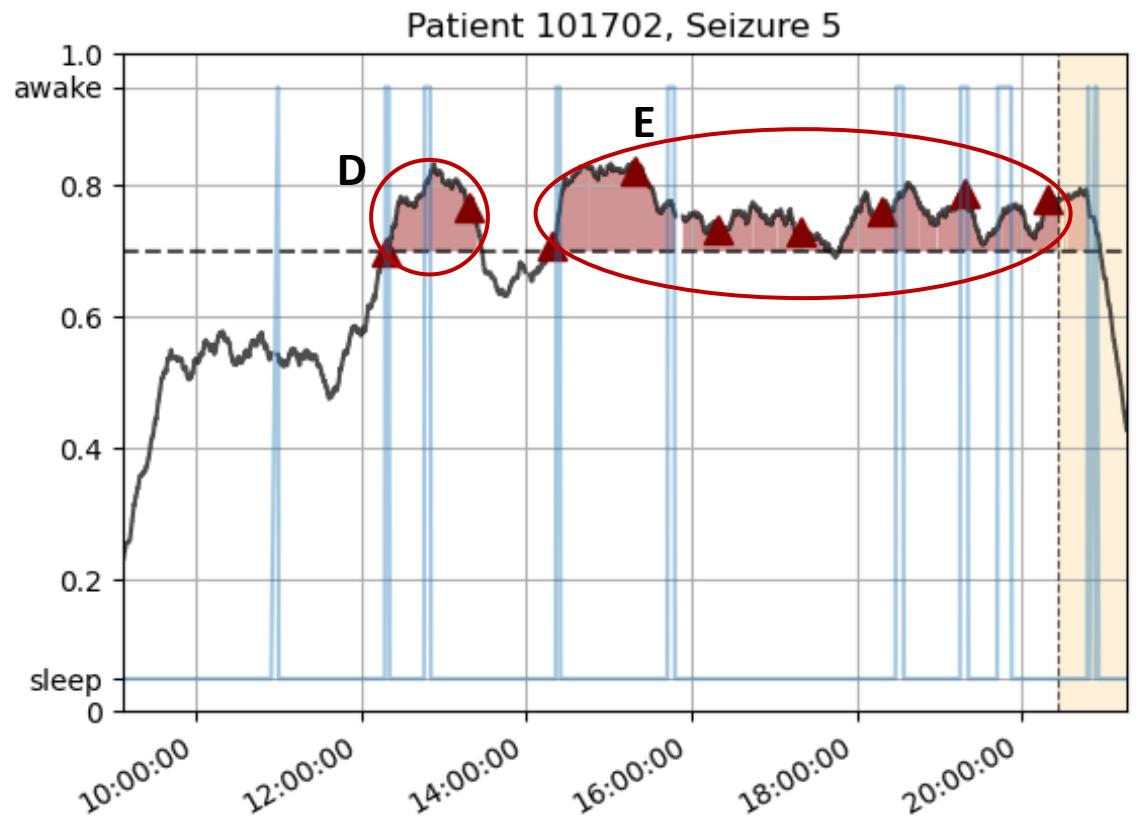


- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - O2_Beta_power: -0.63+/-0.63
 - T8_Alpha_peak_frequency: 0.66+/-0.66
 - PZ_Relative_gamma4_power: 0.86+/-0.86



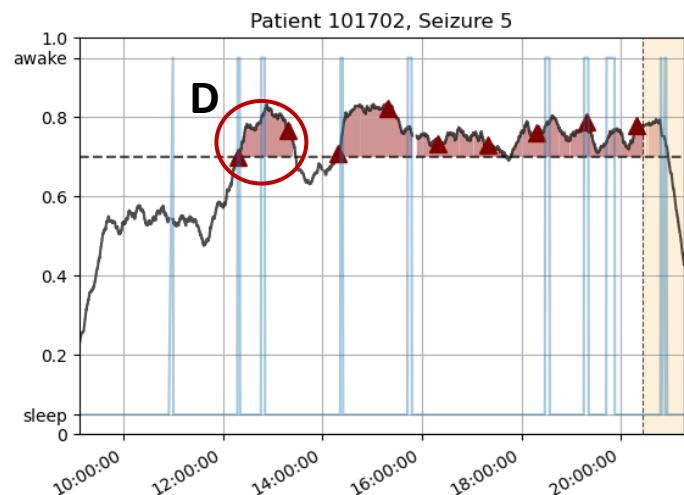
Patient 101702 – Over time

- Point D (12h00-14h00):
 - Two false alarms
 - Lunch? Nap?
- Point E (14h00-20h40):
 - Several false-alarms. Firing Power always up, until it goes down in the pre-ictal period
 - Was it related to what? It is such a long period

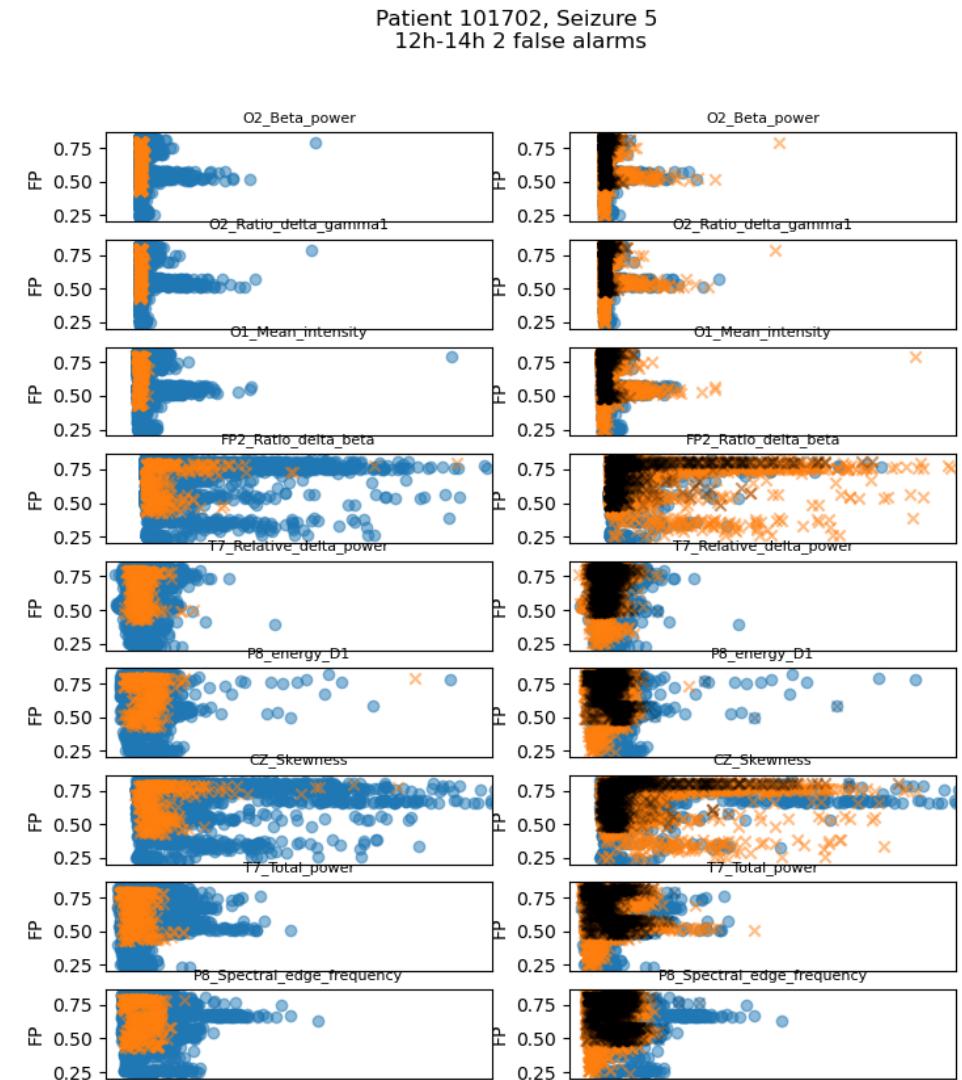


Patient 101702 – Peak D (12h00-14h00)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 12h-14: Lunch? Nap?

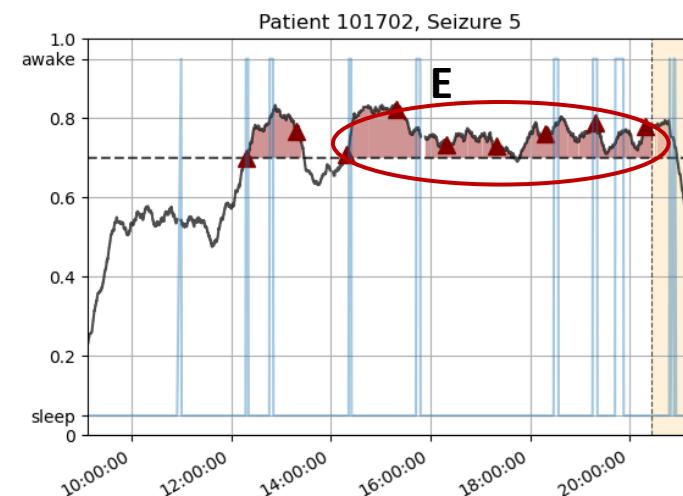


- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - O2_Beta_power: $0.14+/-0.14$
 - O2_Ratio_delta_gamma1: $-0.23+/-0.23$
 - O1_Mean_intensity: $-0.28+/-0.28$

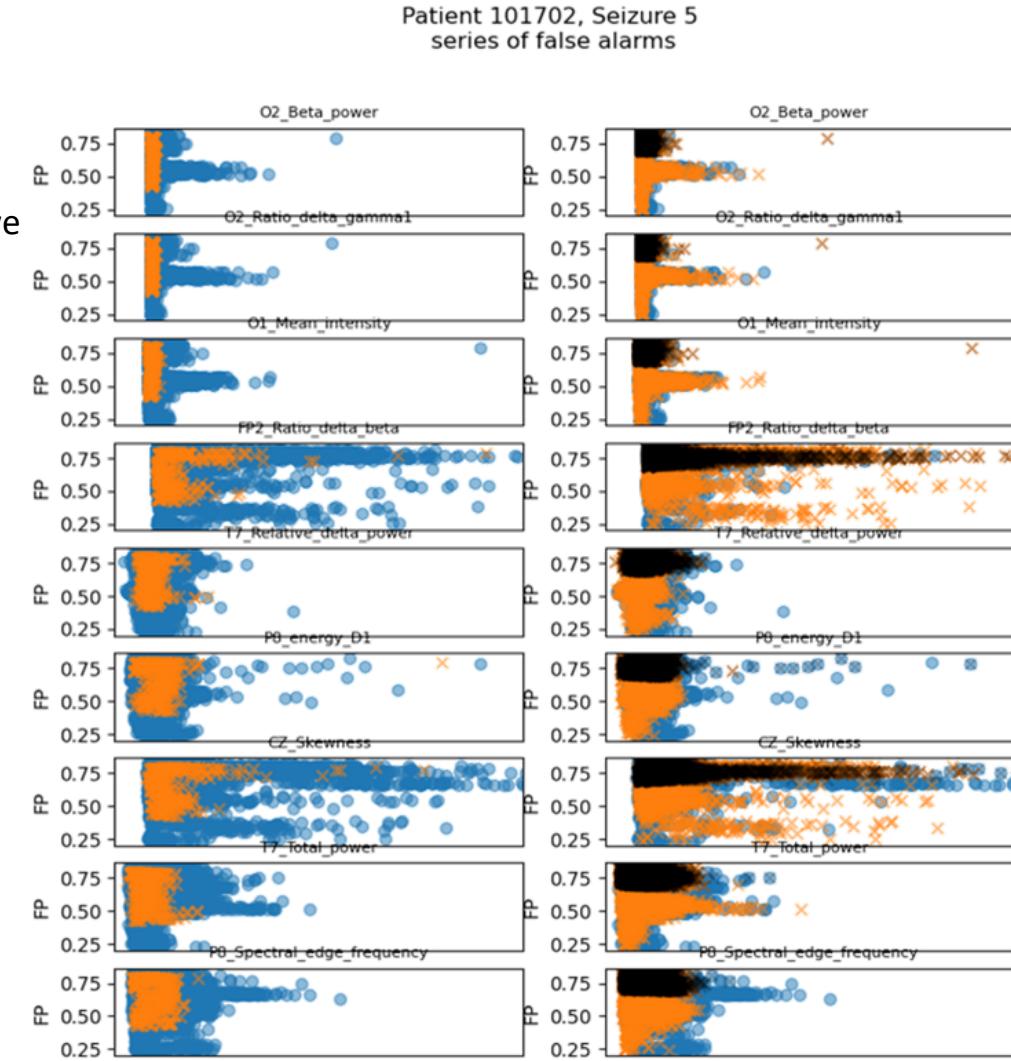


Patient 101702 – Peaks E (14h20-20h40)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- What did it happen?



- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - O2_Beta_power: $0.13+/-0.13$
 - O2_Ratio_delta_gamma1: $-0.21+/-0.21$
 - T8_Ratio_delta_theta: $0.21+/-0.21$



Patient 93402 – Overall performance

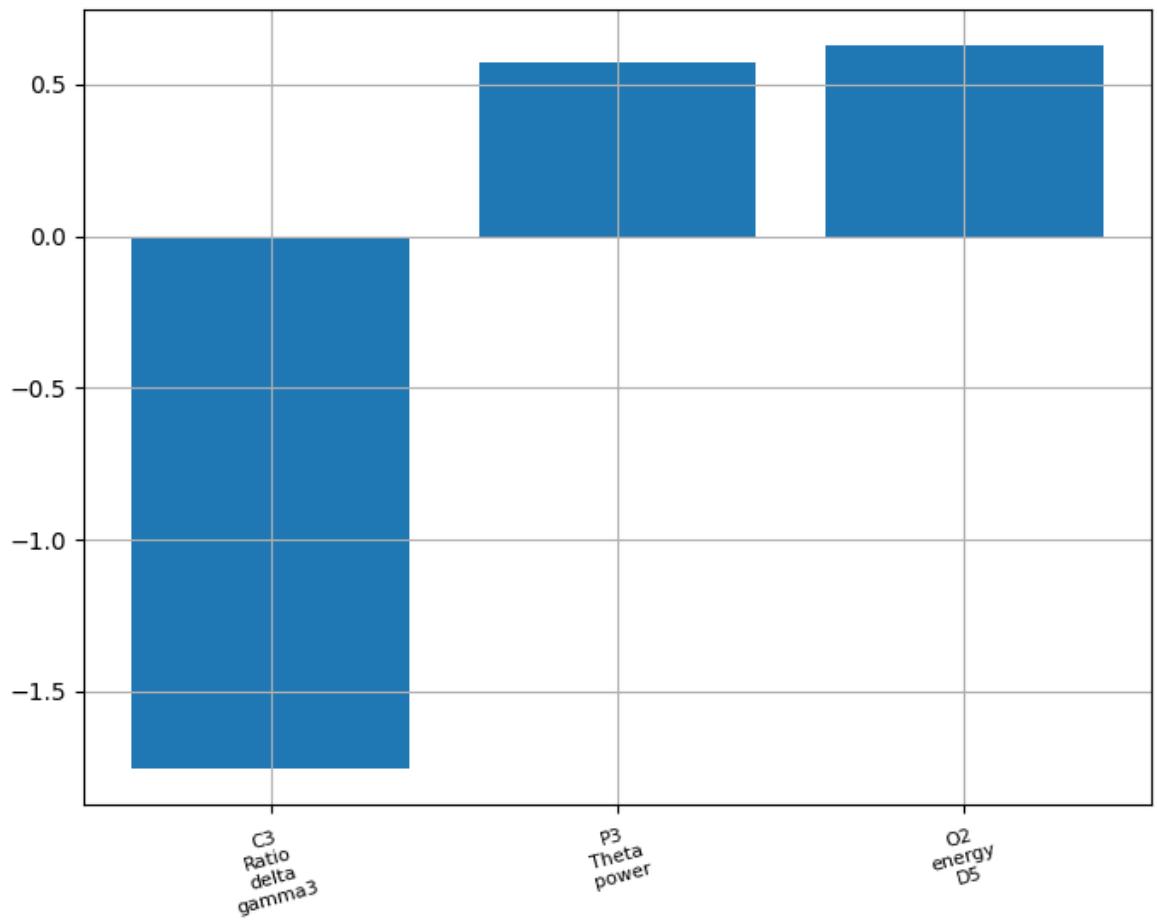
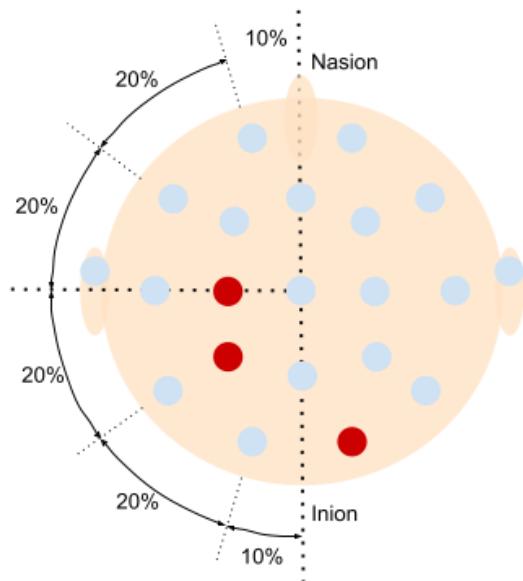
- SS:100%, FPR/h=0.50
- Above chance but FPR/h too high
- Logistic Regression with 3 features
- Surgery decision: not offered
- Focus localization= tpl
Temporal polar left

	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 22:17:50	FBTC	Rhythmic theta waves	Non-REM II
	Day 1 10:21:34	FOIA	Rhythmic theta waves	Non-REM II
	Day 1 23:20:24	FOIA	Rhythmic theta waves	Non-REM II
Testing Seizures	Day 4 00:59:09	Unclassified	Rhythmic theta waves	Non-REM II
	Day 4 06:26:26	Unclassified	Rhythmic theta waves	Non-REM II

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Seizure 4 Day 4 00:59:09	Yes	15	≈49
	Seizure 5 Day 4 06:26:26	Yes	6	≈5

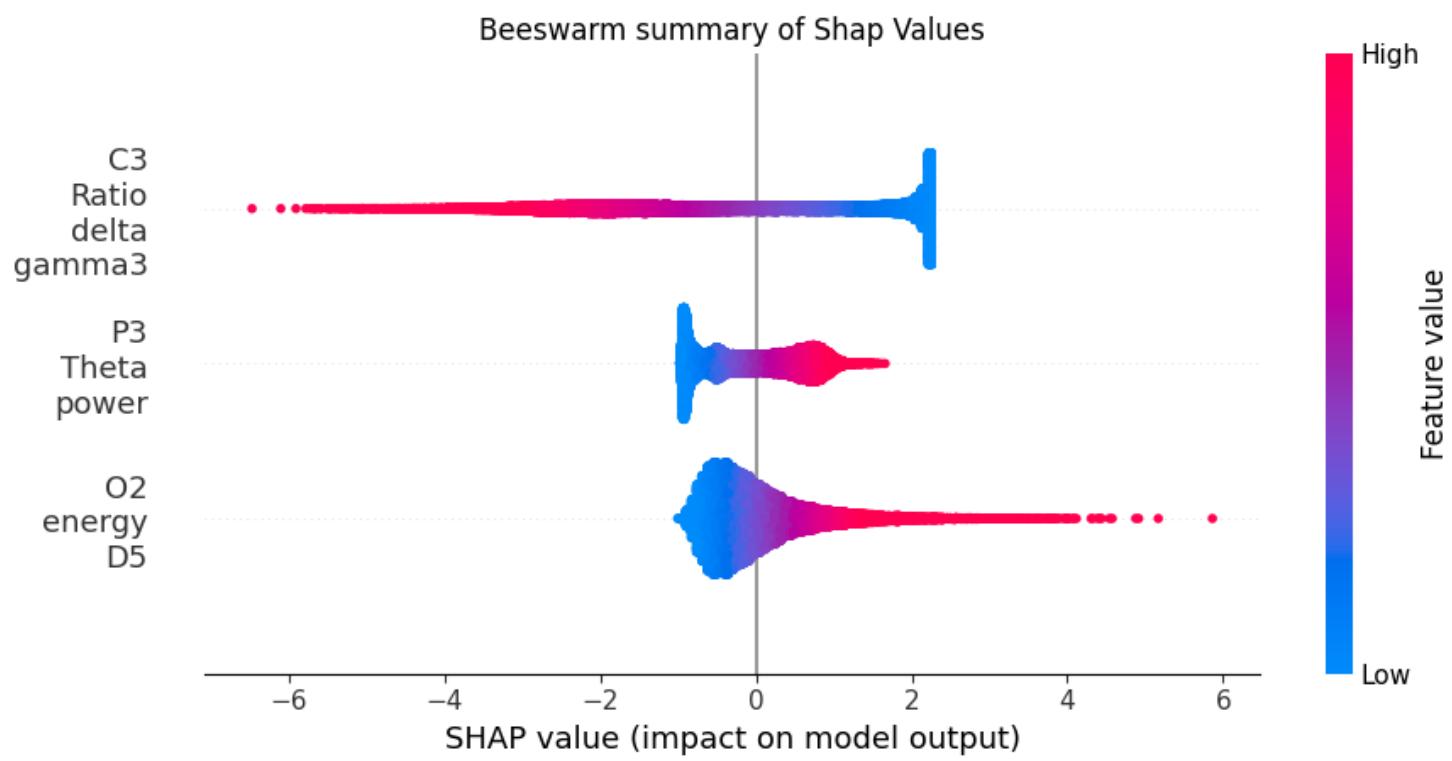
Patient 93402 – Analysing regression coefficients

- What can we say about these features?
- Theta band power, which makes a lot of sense
- Influence of the gamma bands
- Electrodes: C3 , P3, and O2.
 - C3 and P3 make sense. Near focus



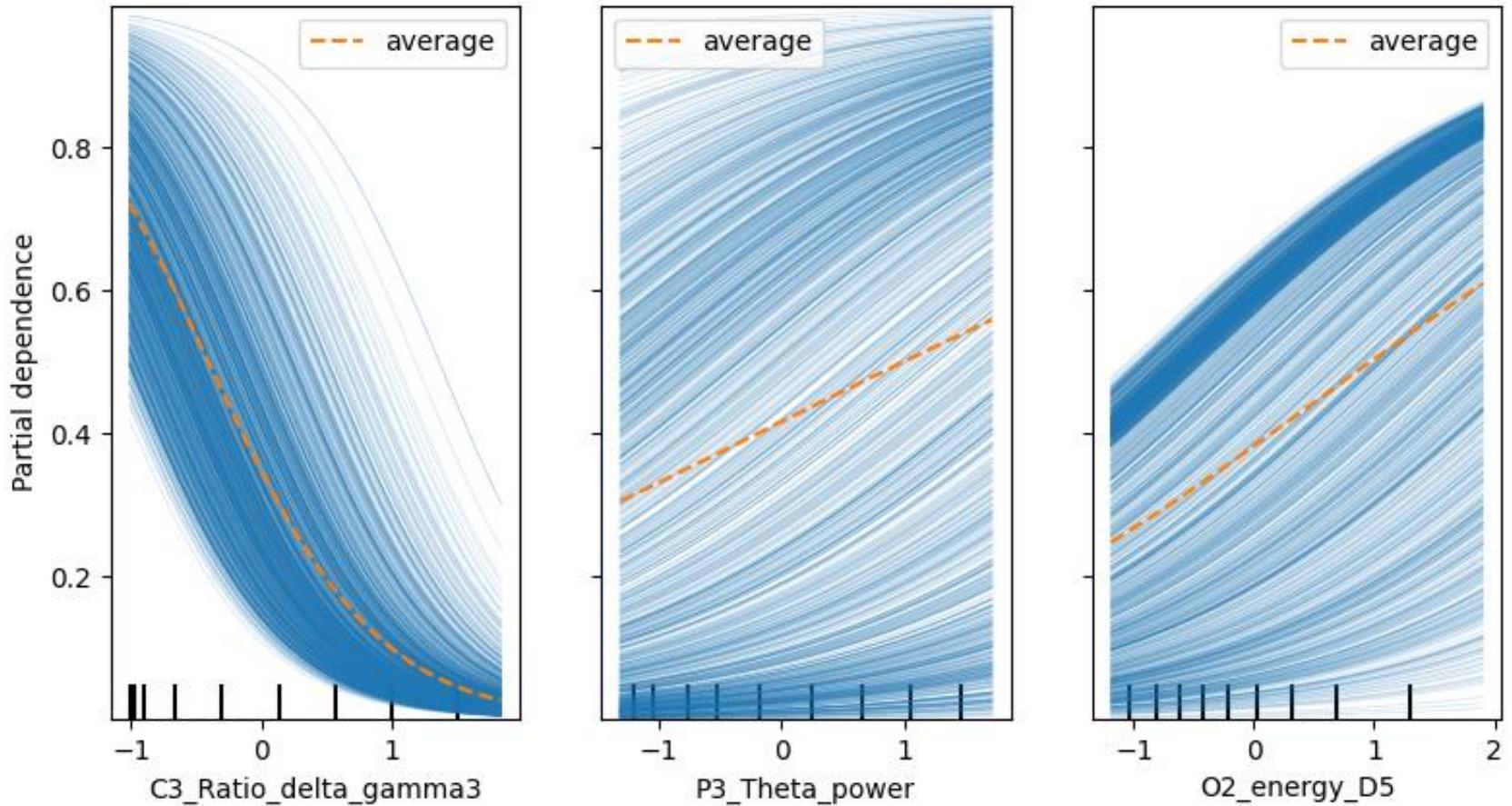
Patient 93402 – A beeswarm summary of Shap Values

- Colours: feature value
- X-axis: impact on classification



Patient 93402 – Partial dependence plots

- How each feature “behaves” towards the label: interictal/preictal (0/1)
- Sign and module of slope

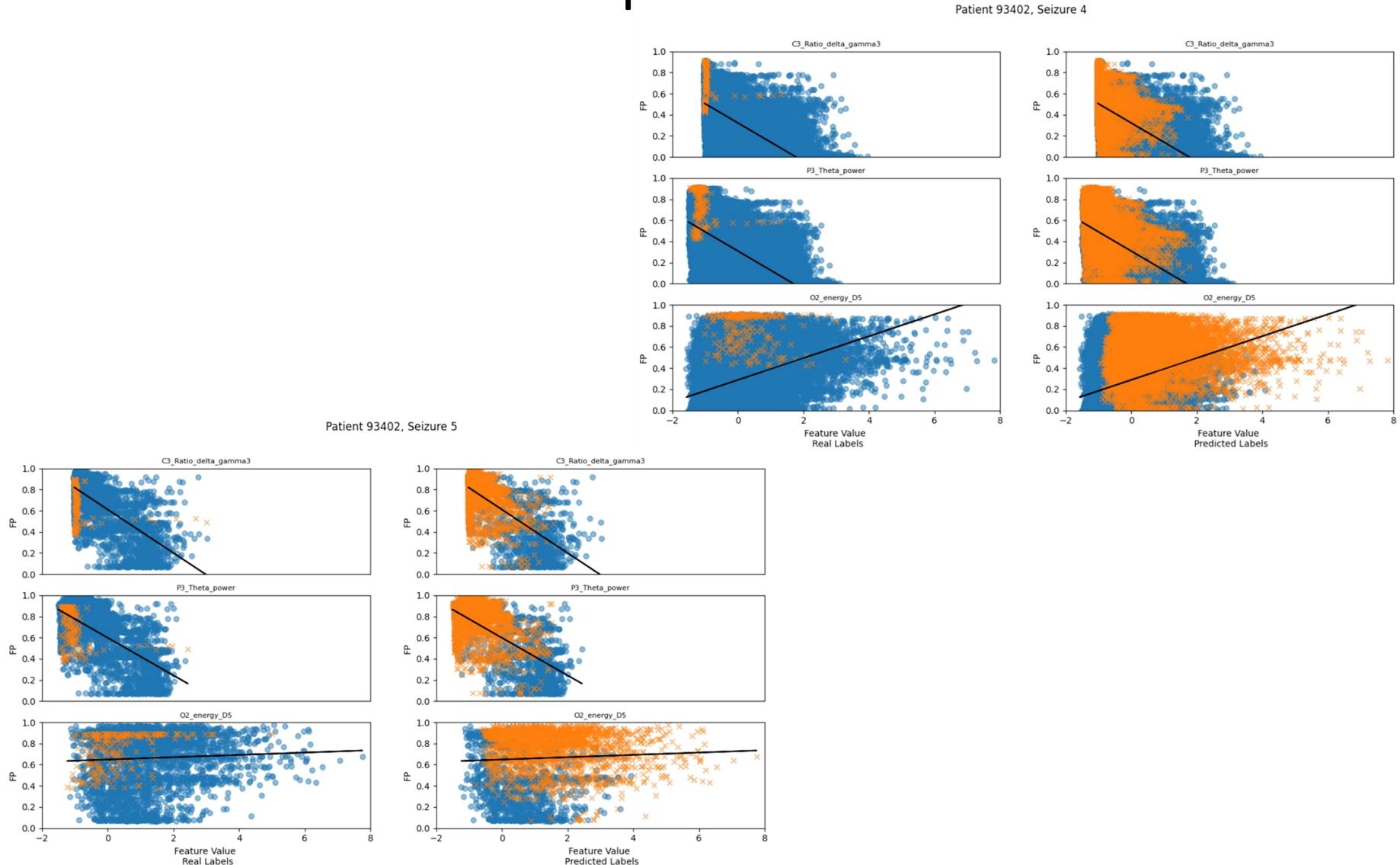


Patient 93402 – Calibration plots

- This is a mixture of a scatter plot with a calibration plot
- On x-axis: feature value
- On y-axis: Firing Power value
- Colours (labels):
 - Blue: interictal
 - Orange: preictal
- This plot shows:
 - how well a feature may “calibrate” the model
 - how the model behaves according to each feature value

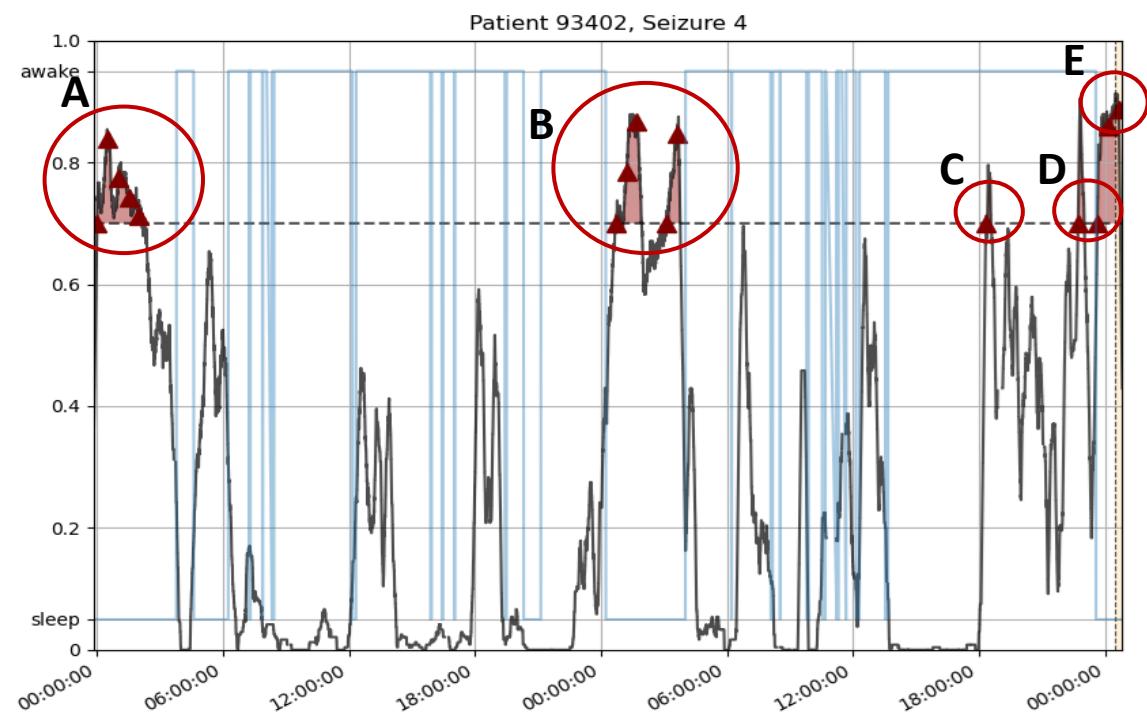
On the left: true labels

On the right: predicted labels



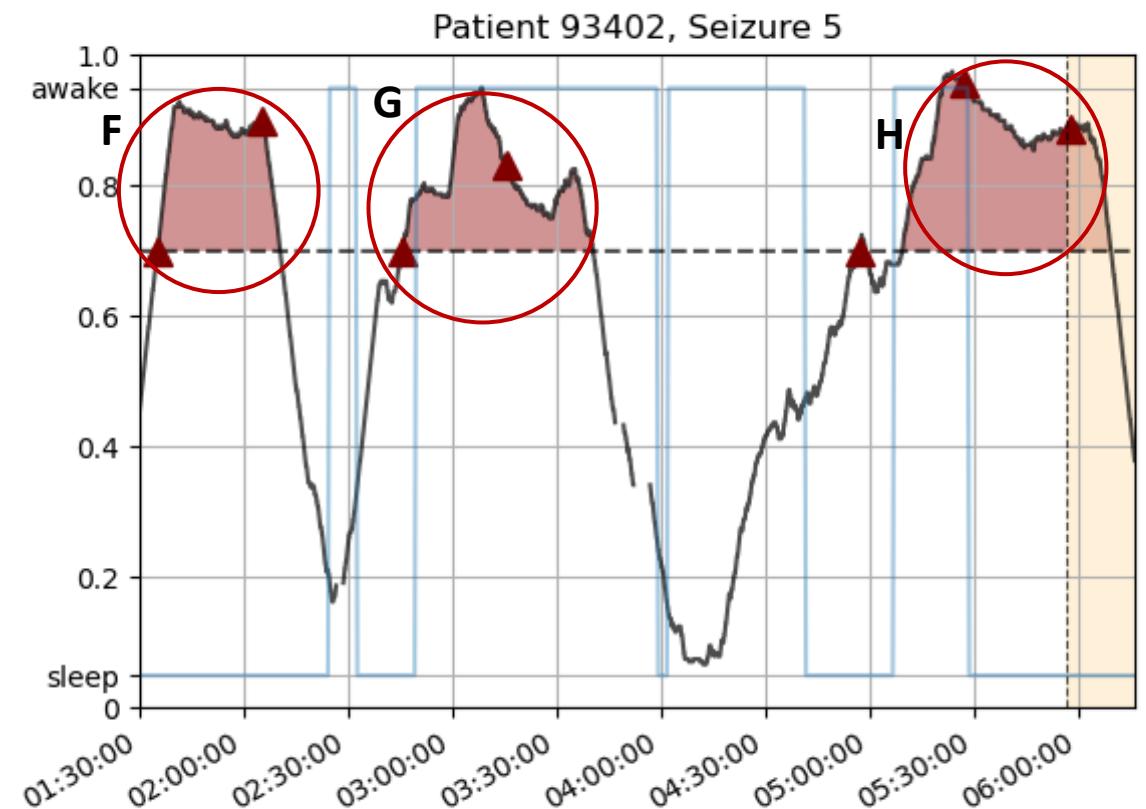
Patient 93402 – Over time

- Cluster A (00h00-03h00):
 - A series of false alarms
- Cluster B (00h00-06h00):
 - A series of false alarms
 - In the previous day, there is a cluster from 00h00-03h00 and then a peak that almost reaches an alarm near 06h00
- Point C (18h00):
 - False alarm
 - In the previous day, there is also a peak near 18h00
- Point D (18h00):
 - Two false alarms near 22h
- Point E (00h00):
 - A false alarm, followed by a correct one
 - The Firing Power from the false alarm was already increasing and it falls after the True alarm
- Circadian cycles influence? Sleep stages?
- Seizure susceptibility?



Patient 93402 – Over time

- Cluster A (00h00-03h00):
 - A series of false alarms
- Cluster B (00h00-06h00):
 - A series of false alarms
 - In the previous day, there is a cluster from 00h00-03h00 and then a peak that almost reaches an alarm near 06h00
- Point C (18h00):
 - False alarm
 - In the previous day, there is also a peak near 18h00
- Point D (18h00):
 - Two false alarms near 22h
- Point E (00h00):
 - A false alarm, followed by a correct one
 - The Firing Power from the false alarm was already increasing and it falls after the True alarm
- Circadian cycles influence? Sleep stages?
- Seizure susceptibility?



Patient 402 – Overall performance

- SS:0%, FPR/h=0.00
- No single alarm was raised
- Logistic Regression with 20 features

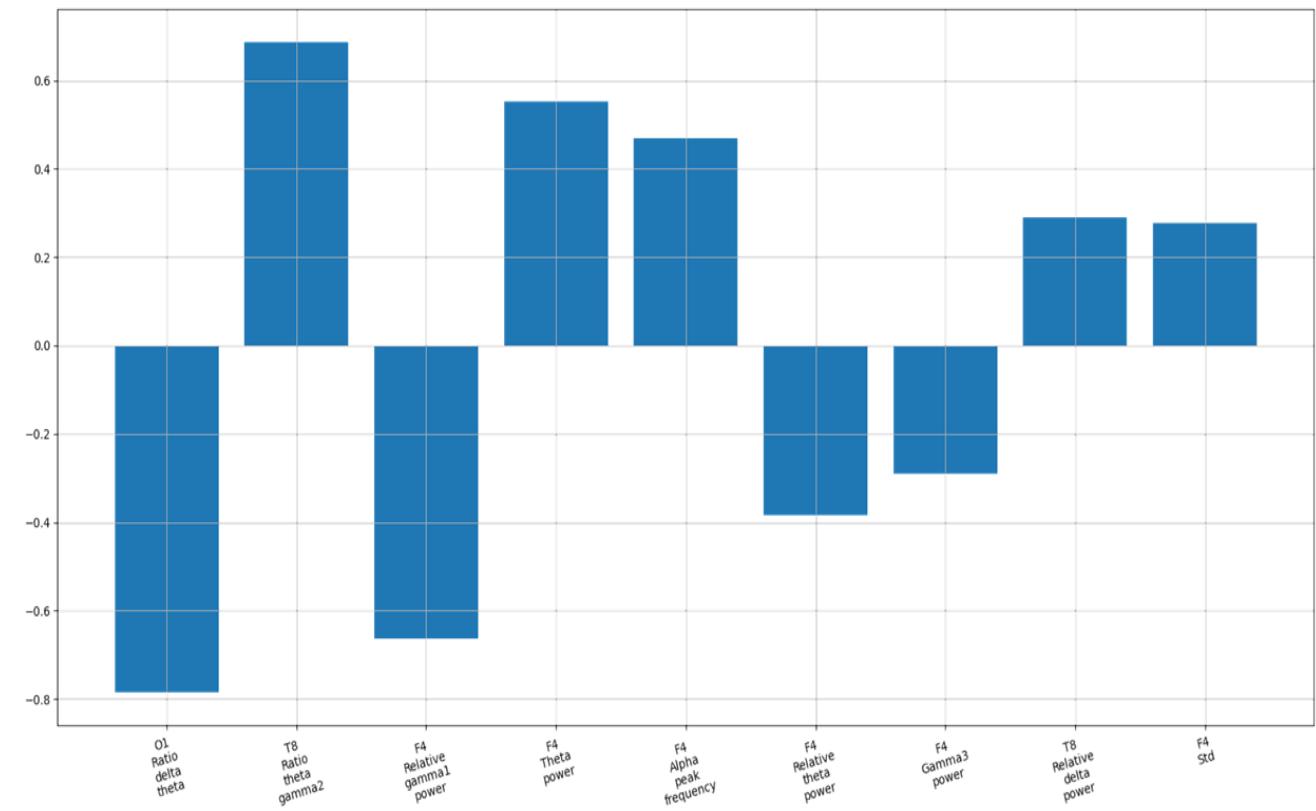
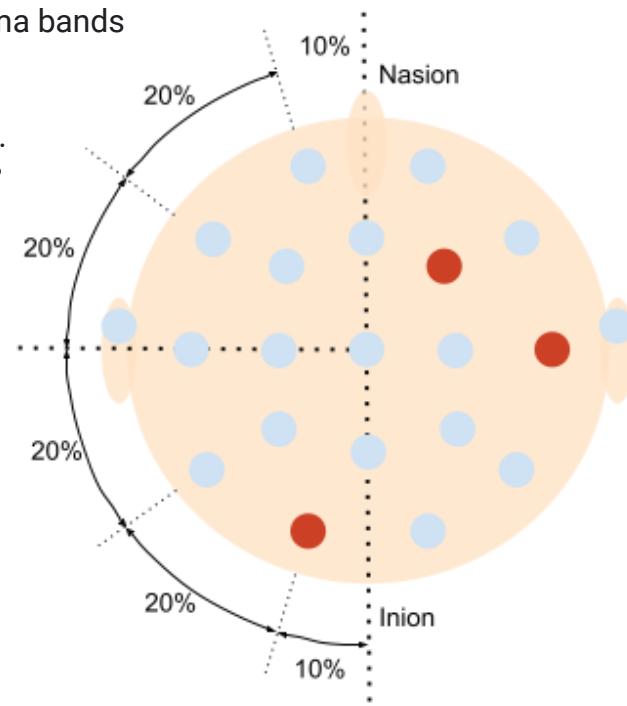
	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 23:45:26	FOIA	Rhythmic theta waves	Awake
	Day 2 22:27:34	FBTC	Rhythmic theta waves	Awake
	Day 3 03:13:30	FOIA	Rhythmic theta waves	Awake
Testing Seizures	Day 3 09:53:21	FBTC	Rhythmic theta waves	Awake
	Day 4 09:57:27	FOIA	Rhythmic theta waves	Awake

- Surgery decision: invasive
- Focus localization= t-r, t-l
Temporal right, temporal left

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Day 3 09:53:21	No	0	≈6
	Day 4 09:57:27	No	0	≈24

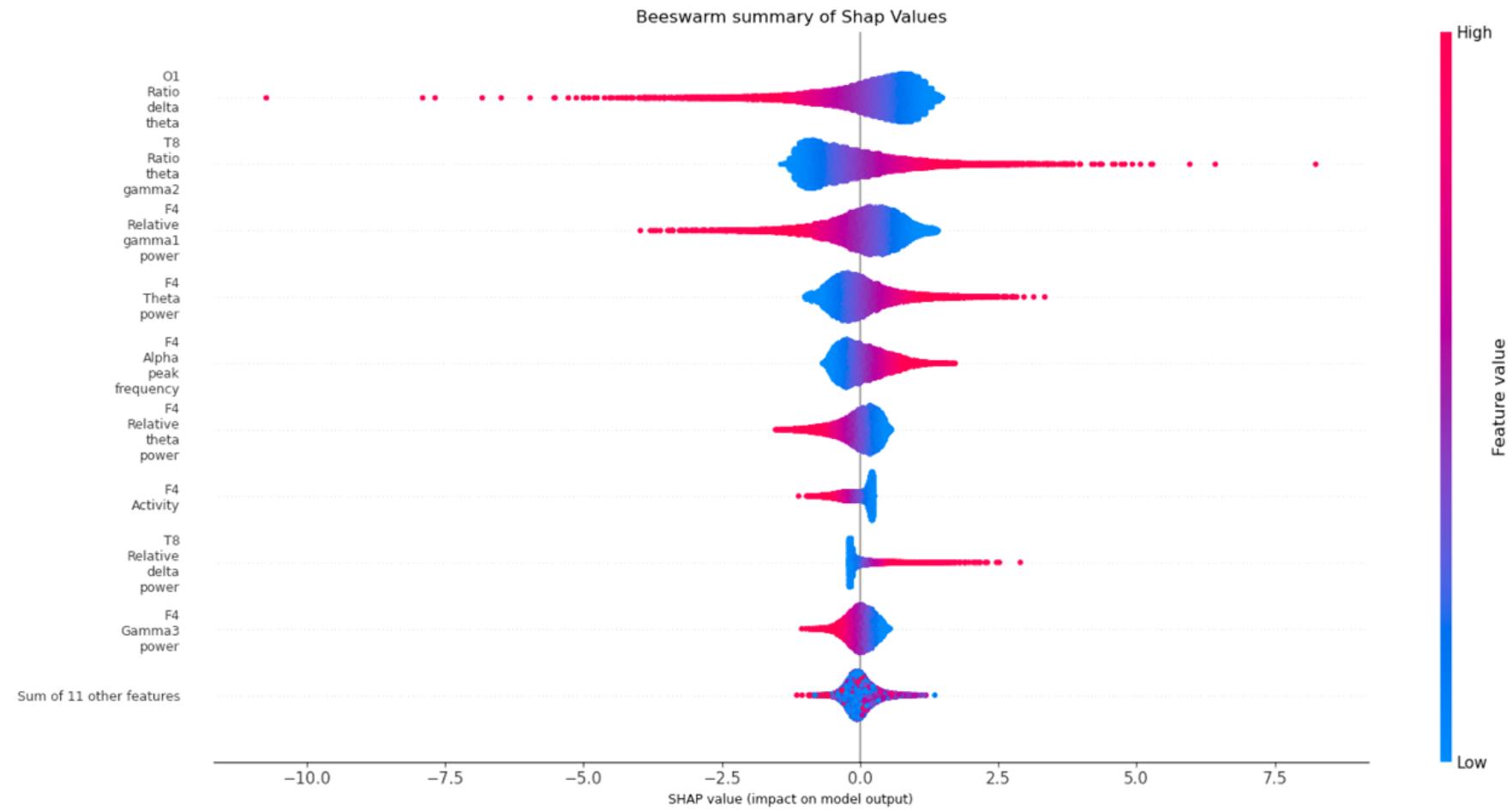
Patient 402 – Analysing regression coefficients

- What can we say about these features?
- Different gama bands, kurtosis, activity, energy
- Influence of the gamma bands
- Electrodes: F3 and F4.
 - Do these make sense?



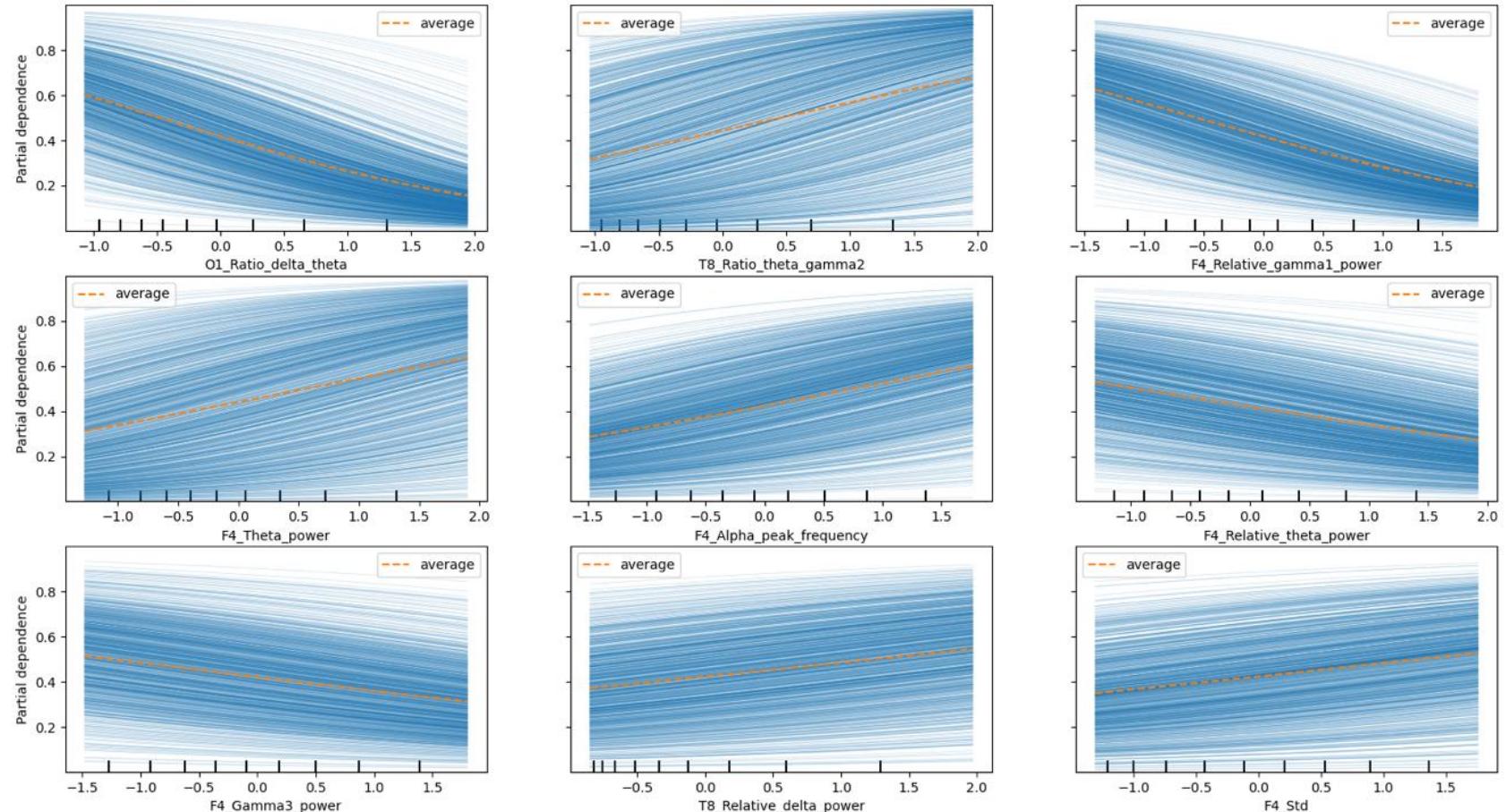
Patient 402 – A beeswarm summary of Shap Values

- Colours: feature value
- X-axis: impact on classification



Patient 402 – Partial dependence plots

- How each feature “behaves” towards the label: interictal/preictal (0/1)
- Sign and module of slope



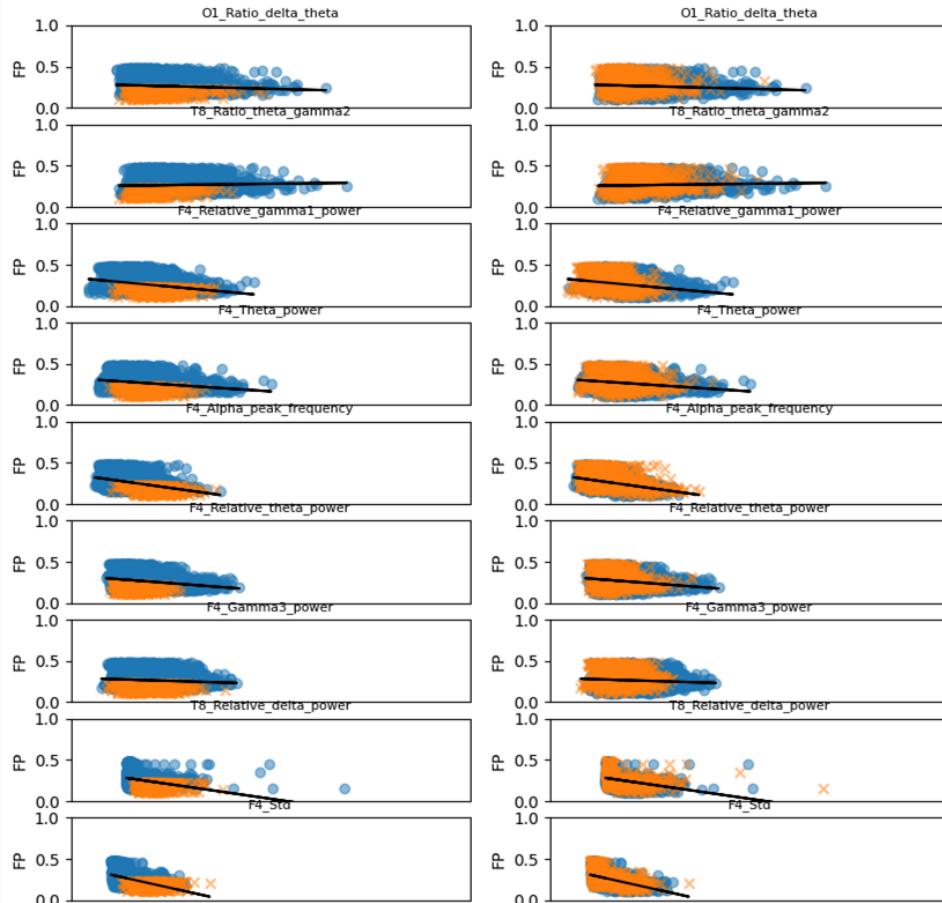
Patient 402 – Calibration plots

- This is a mixture of a scatter plot with a calibration plot
- On x-axis: feature value
- On y-axis: Firing Power value
- Colours (labels):
 - Blue: interictal
 - Orange: preictal
- This plot shows:
 - how well a feature may “calibrate” the model
 - how the model behaves according to each feature value

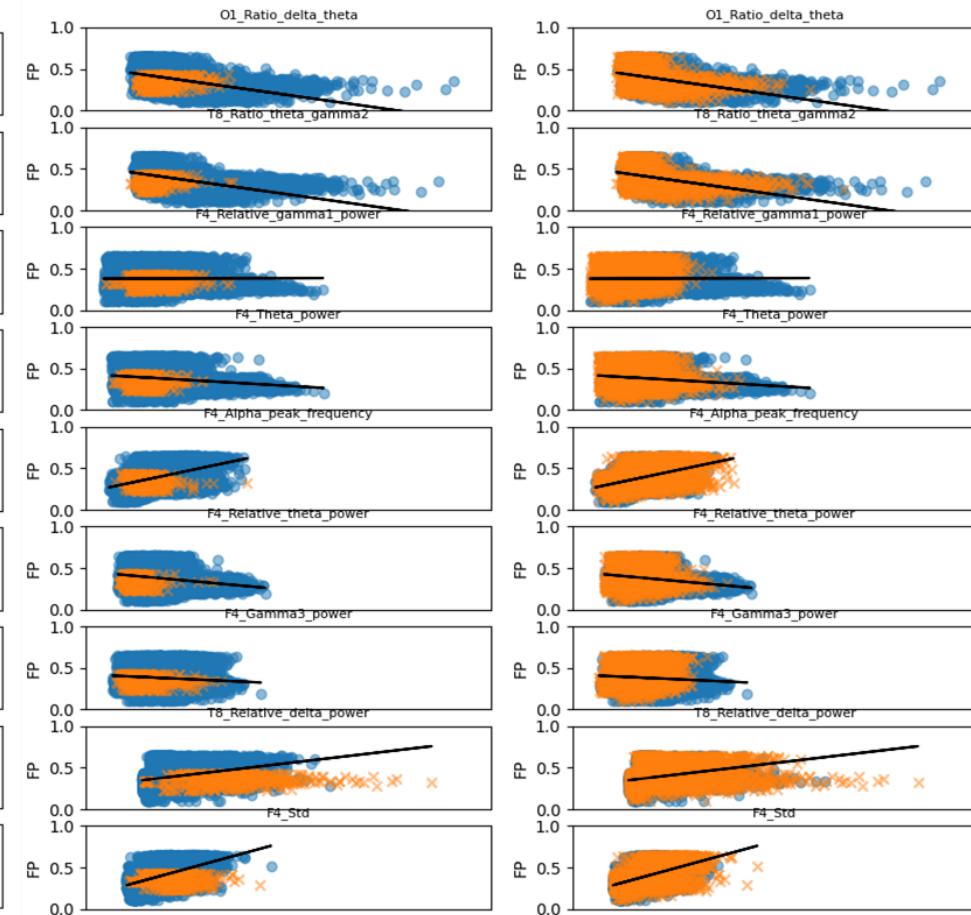
On the left: true labels

On the right: predicted labels

Patient 402, Seizure 4

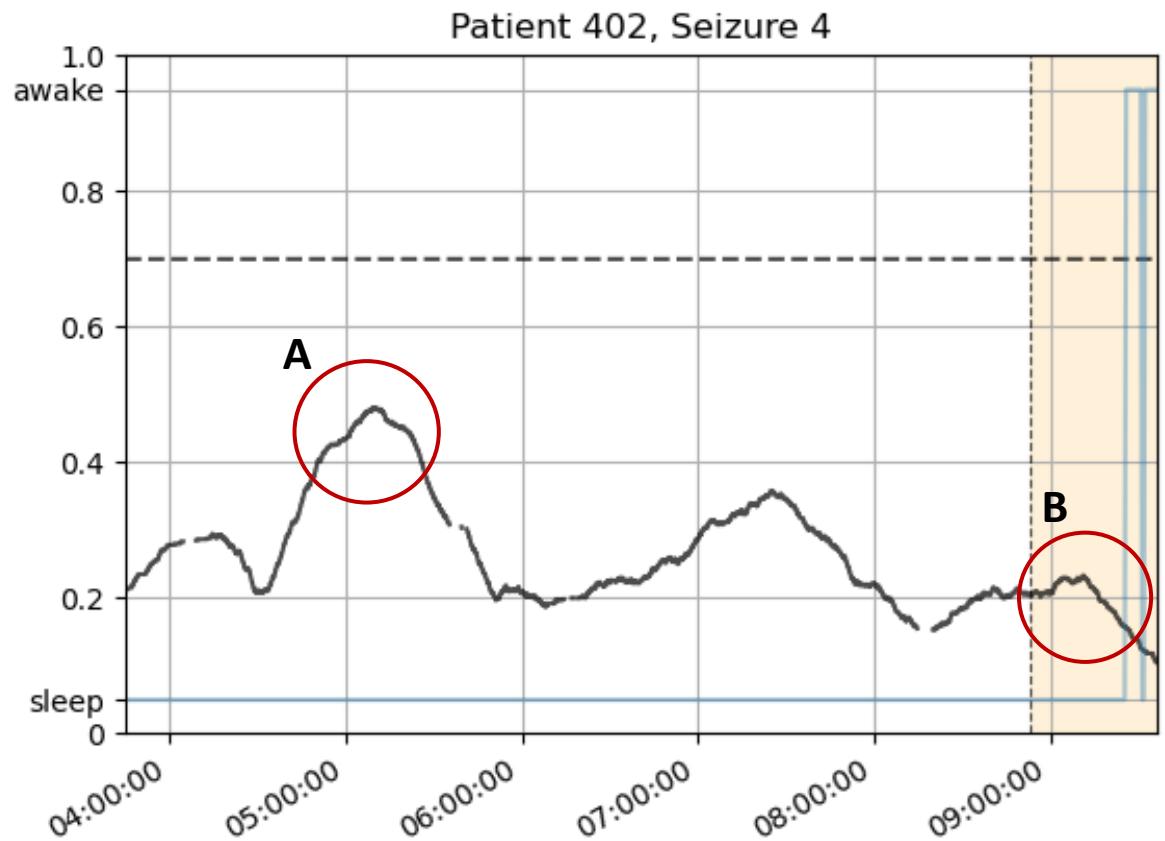


Patient 402, Seizure 5



Patient 402 – Over time

- Cluster A (04h30-05h12):
 - A peak of 0.47, sleep?
- Cluster B (09h00):
 - Did not predict the seizure

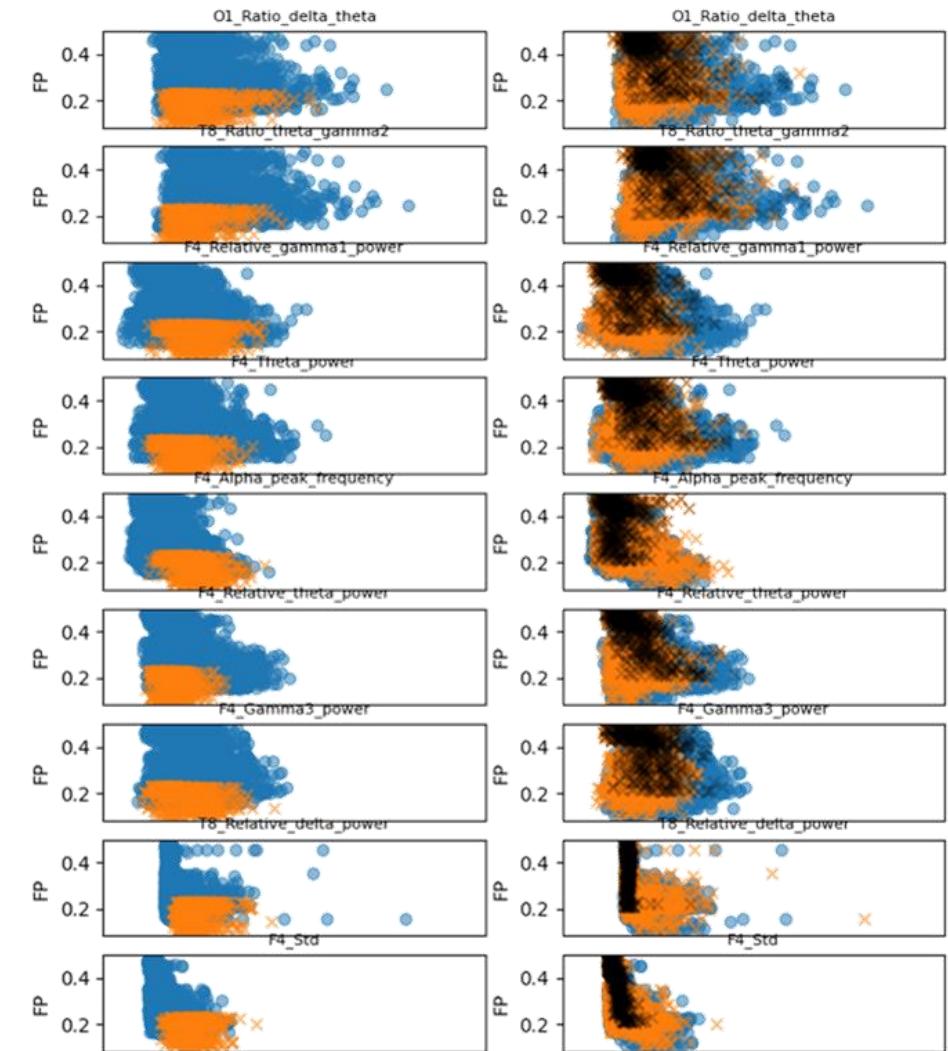
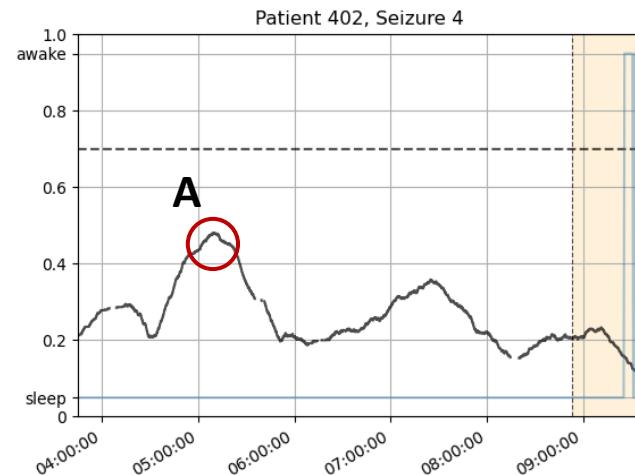


Patient 402 – Peak A (04h30)

Patient 402, Seizure 5
1st peak roughly 5 am

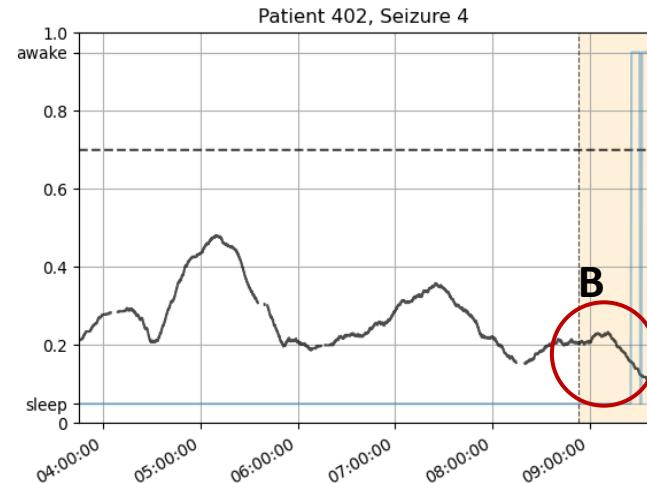
- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
- 4h30-5h12: sleeping?

- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - C3_Gamma1_power: $0.1+/-0.1$
 - T8_Gamma2_power: $-0.14+/-0.14$
 - O1_Ratio_delta_theta: $-0.17+/-0.17$

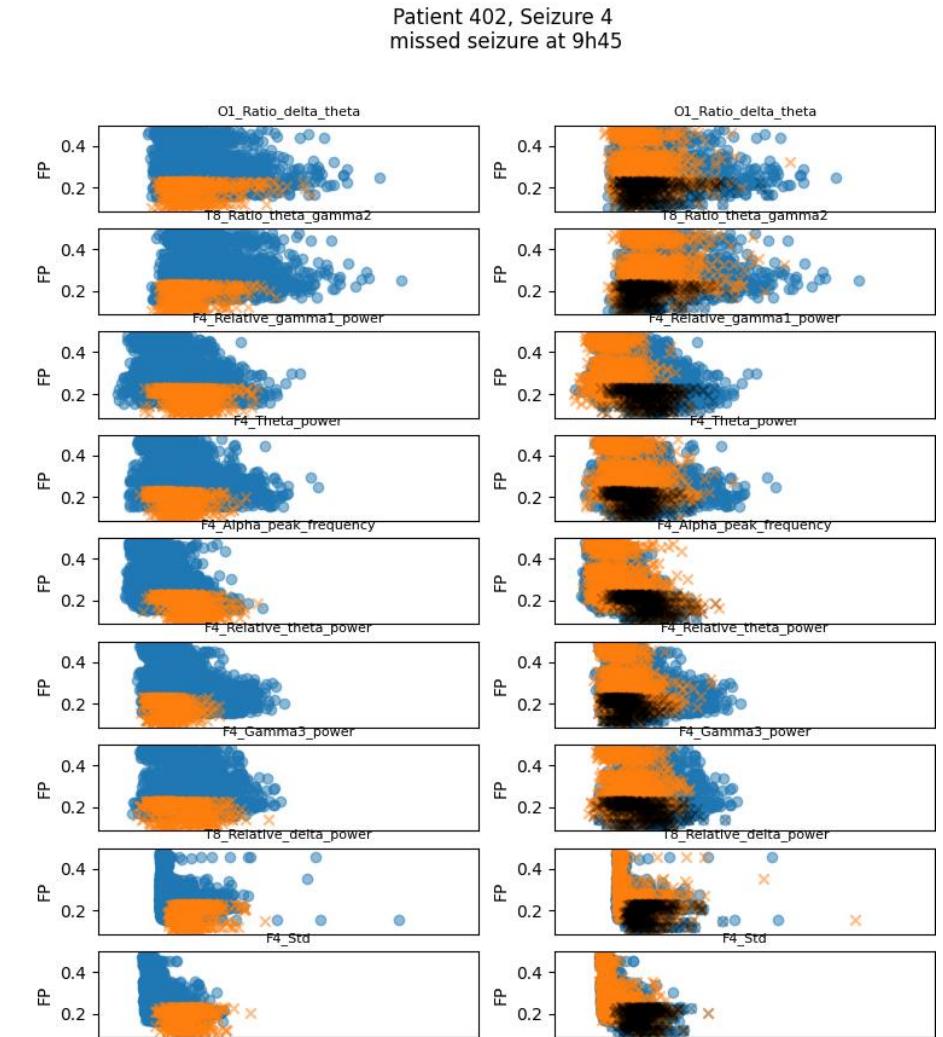


Patient 402 – Peak B (09h45)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 09h00-09h45: sleeping?

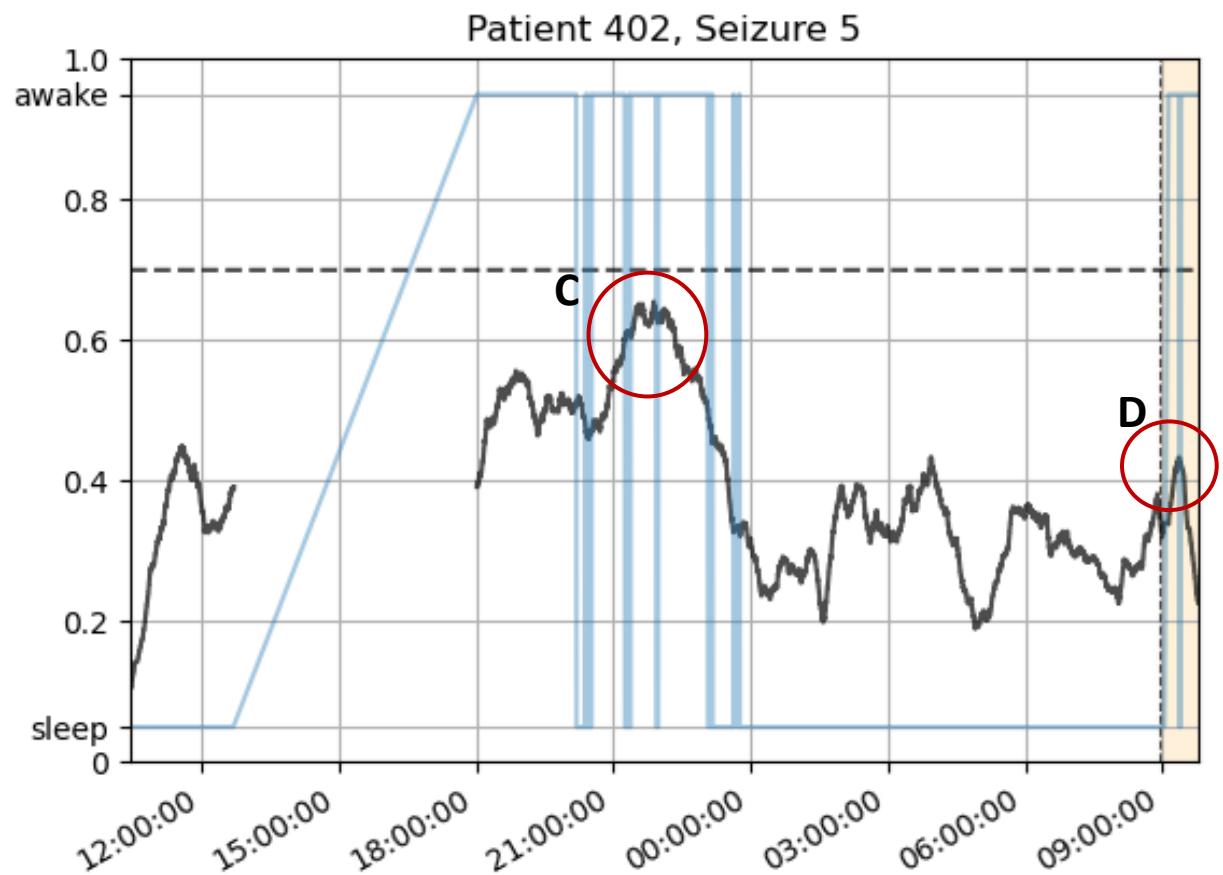


- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - F4_Kurtosis: $0.46+/-0.46$
 - O1_Ratio_delta_theta: $-0.67+/-0.67$
 - T8_Ratio_theta_gamma2: $0.76+/-0.76$



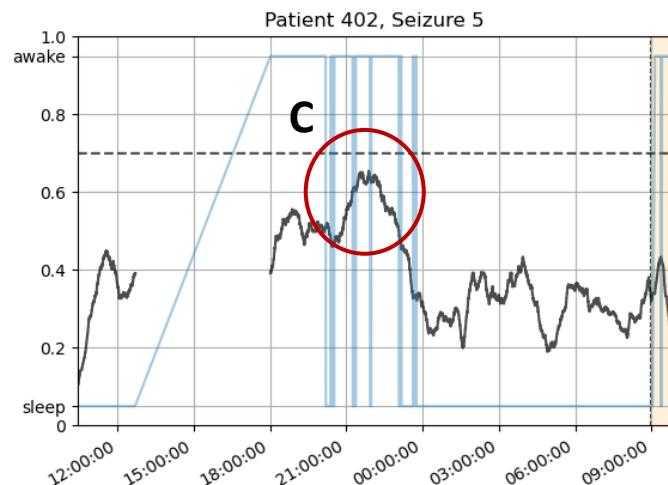
Patient 402 – Over time

- Cluster A (21h00-00h00):
 - A peak of 0.66, sleep?
- Cluster D (09h00):
 - Again, at the same time, a seizure occurred but it was not predicted

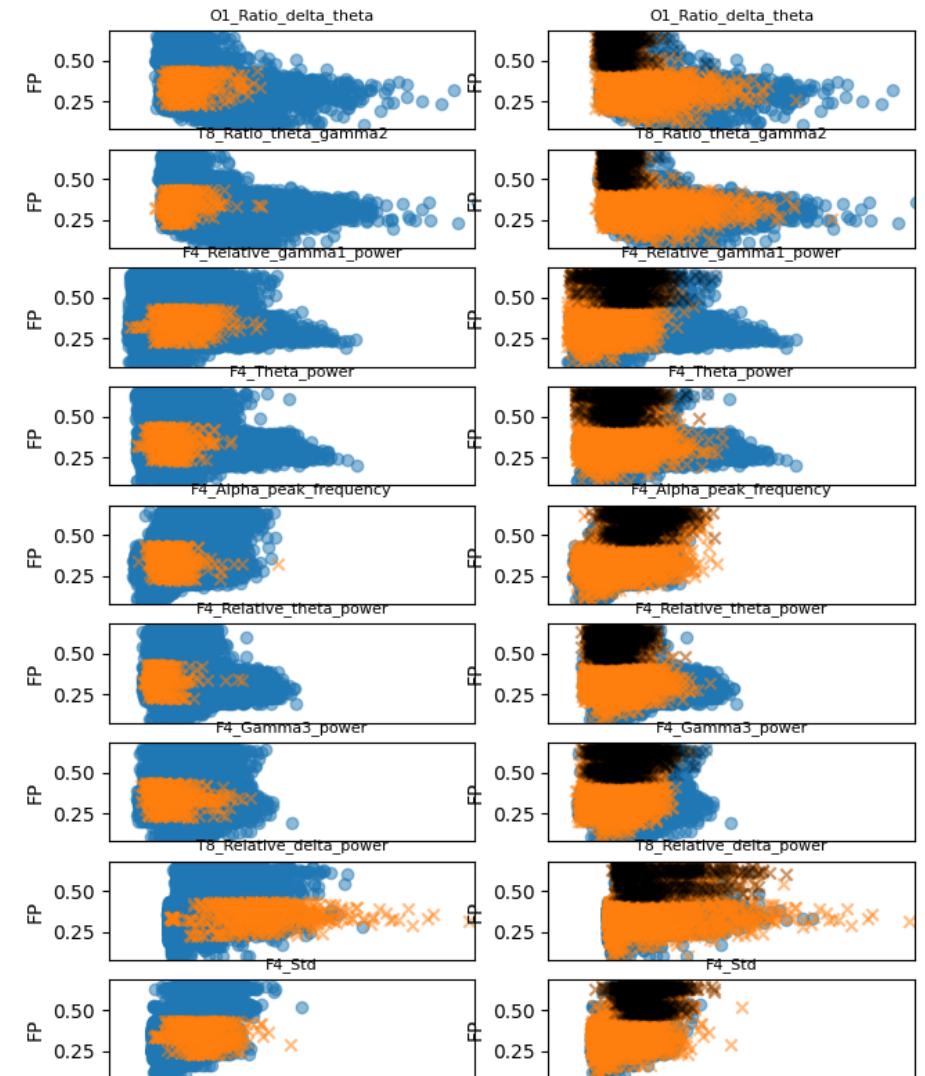


Patient 402 – Peak C (21h00)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
 - Three top features
 - No interactions studied
- 20h44-22h17: sleeping?
- Counterfactual explanations:
 - For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - F4_Kurtosis: $0.03+/-0.03$
 - O1_Ratio_delta_theta: $0.17+/-0.17$
 - T8_Ratio_theta_gamma2: $-0.19+/-0.19$



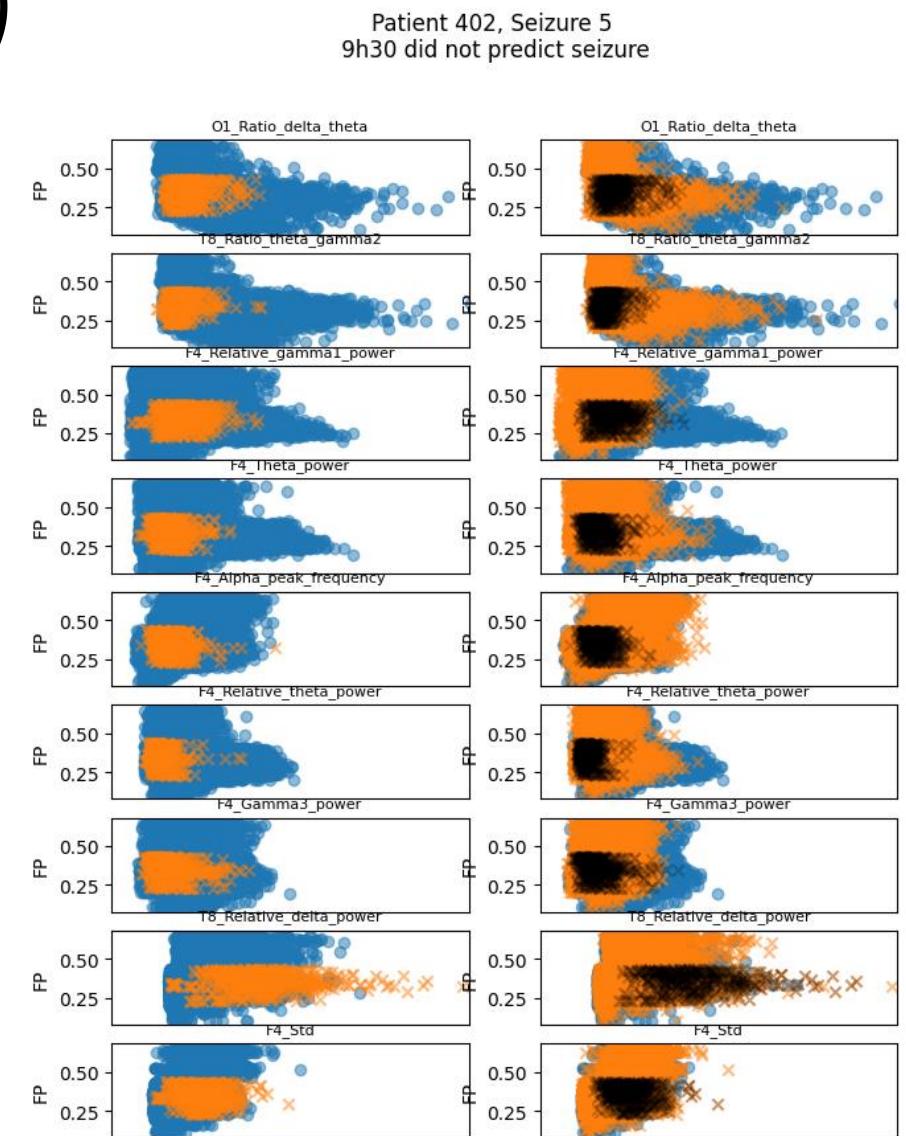
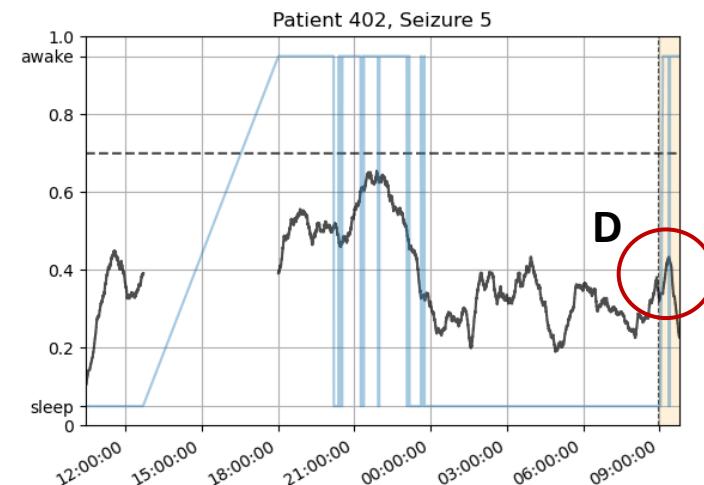
Patient 402, Seizure 4
21h30 almost false alarm



Patient 402 – Peak C (09h30)

- Scatter/calibration plot
 - Black: the predicted samples
- Counterfactual explanations
- 09h: sleeping?

- Counterfactual explanations:
- For the prediction to be different (no peak), we would have to change the following features (top 3 by order of importance):
 - O1_Ratio_delta_theta: -0.16+/-0.16
 - T8_Ratio_theta_gamma2: 0.18+/-0.18
 - F4_Relative_gamma1_power: -0.19+/-0.19

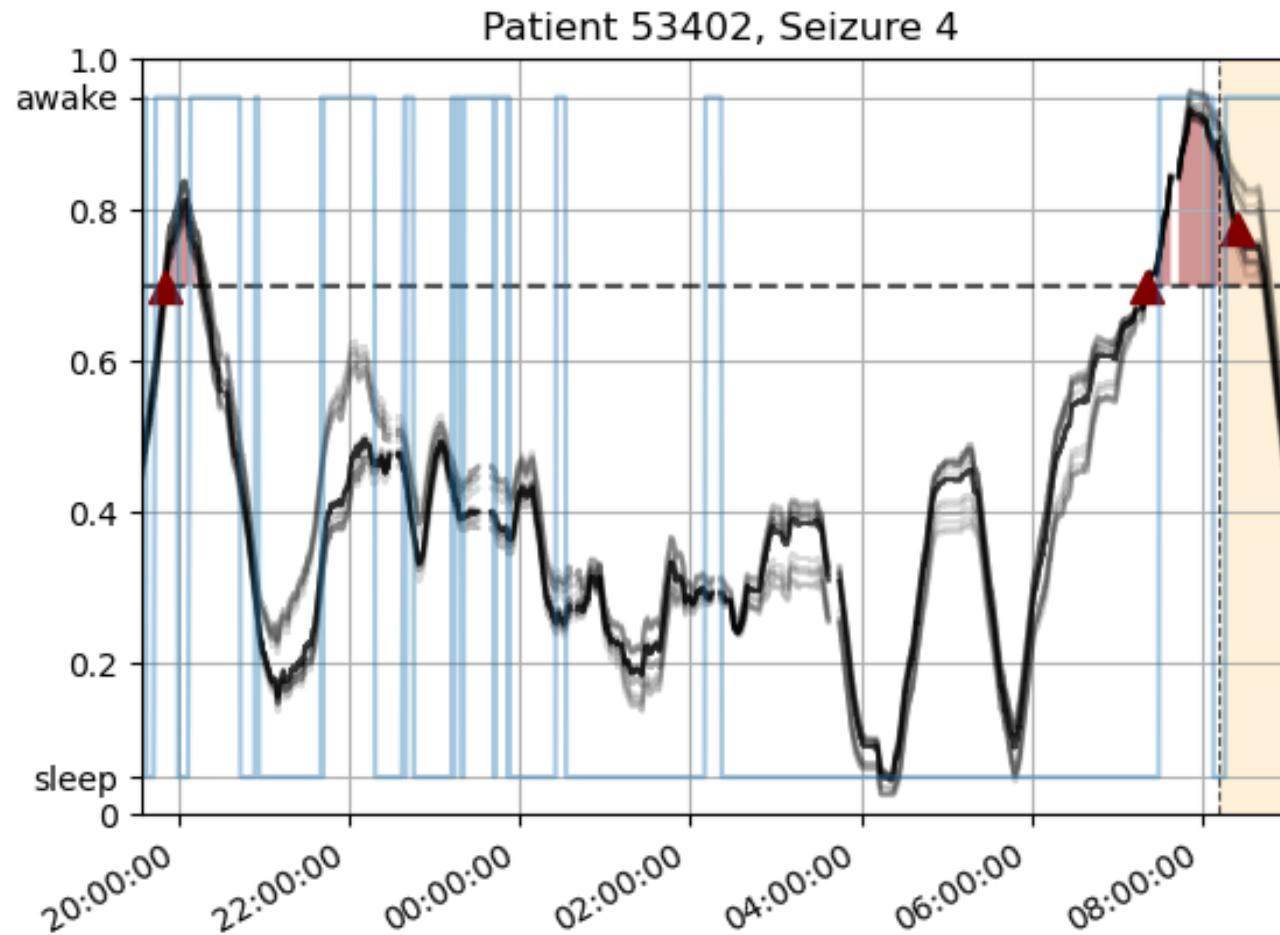


Methodology B-Selected Patients

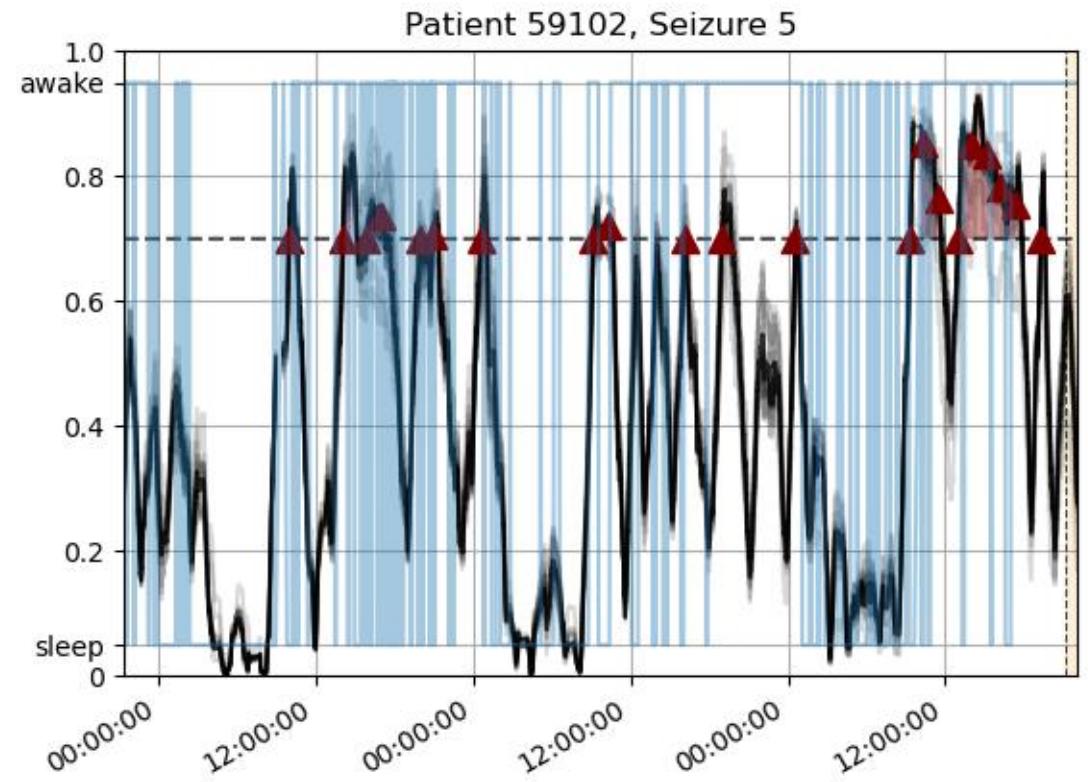
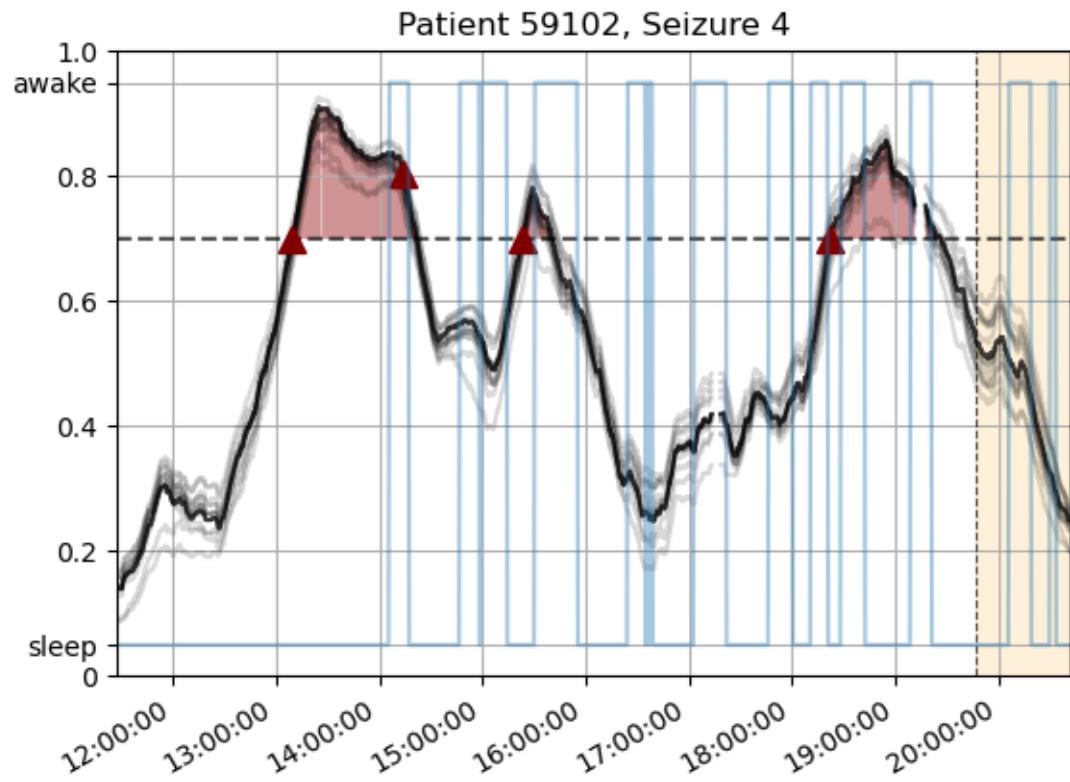
- Patient 53402
 - Good SS and good FPR/h
- Patient 59102
 - Bad SS and bad FPR/h
- Patient 46702
 - Never raised an alarm

Patient	Pre-Ictal Period (minutes)	Features	SS	FPR/h	Validated	Patient	Pre-Ictal Period (minutes)	Features	SS	FPR/h	Validated
30802	60	5	0.40	0.38	0	75202	20	30	0.00	0.11	0
402	60	30	0.00	0.00	0	80702	45	30	0.33	0.44	1
8902	30	30	0.00	0.27	0	85202	60	7	0.50	0.52	1
11002	30	10	0.00	3.93	0	93402	30	7	0.50	0.77	0
16202	30	20	0.00	0.07	0	94402	30	15	0.00	1.29	0
21902	45	15	0.00	0.28	0	95202	45	30	0.00	0.12	0
23902	55	10	0.00	1.34	0	96002	55	20	0.00	1.52	0
26102	60	30	0.00	0.10	0	98102	60	15	1.00	0.14	1
32702	30	20	0.00	0.12	0	98202	30	30	0.00	4.14	0
45402	30	15	0.00	1.13	0	101702	30	7	0.50	1.56	0
46702	60	30	0.00	0.00	0	102202	60	5	0.00	0.39	0
50802	30	30	0.00	0.17	0	104602	55	3	0.50	1.49	0
52302	60	3	0.00	1.13	0	109502	60	7	0.00	0.65	0
53402	60	3	1.00	0.22	1	110602	45	10	0.50	0.70	1
55202	30	15	0.20	1.11	0	112802	45	3	0.00	3.01	0
56402	30	15	0.00	3.83	0	113902	60	3	0.67	1.44	0
58602	30	3	0.00	0.00	0	114702	45	5	0.00	0.04	0
59102	60	15	0.00	0.52	0	114902	30	3	0.25	0.21	1
60002	30	30	0.33	0.67	1	123902	30	3	0.00	0.00	0
64702	50	3	0.00	1.02	0	93902	45	3	0.00	0.13	0

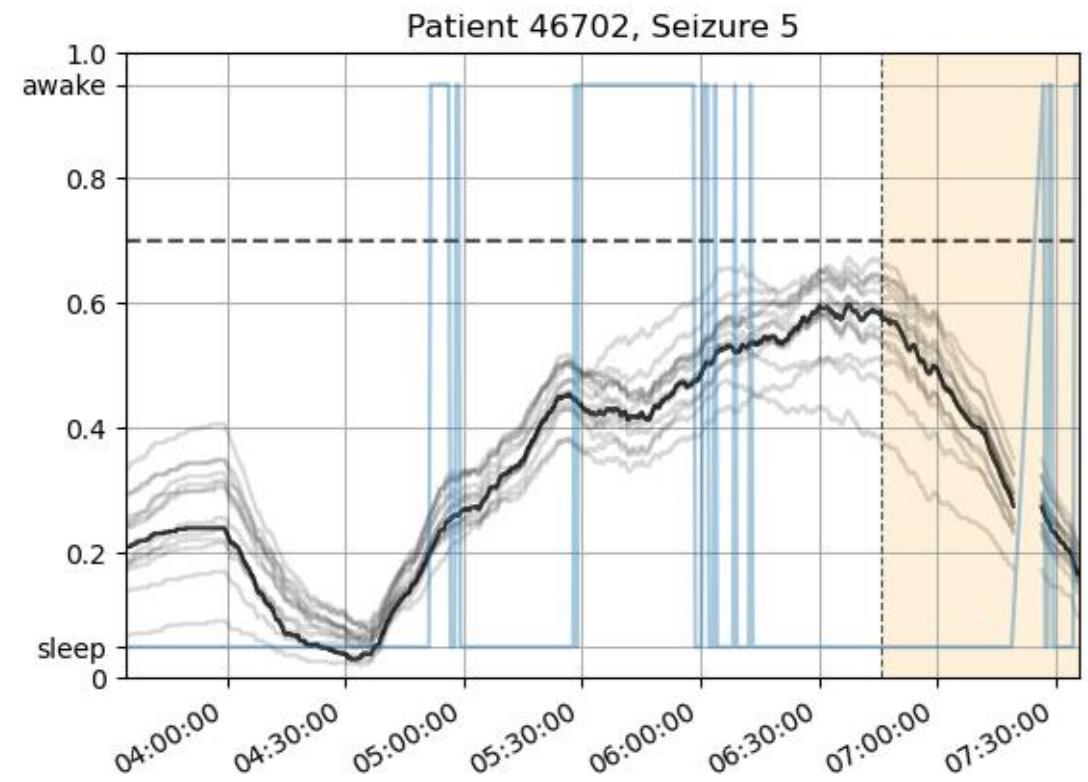
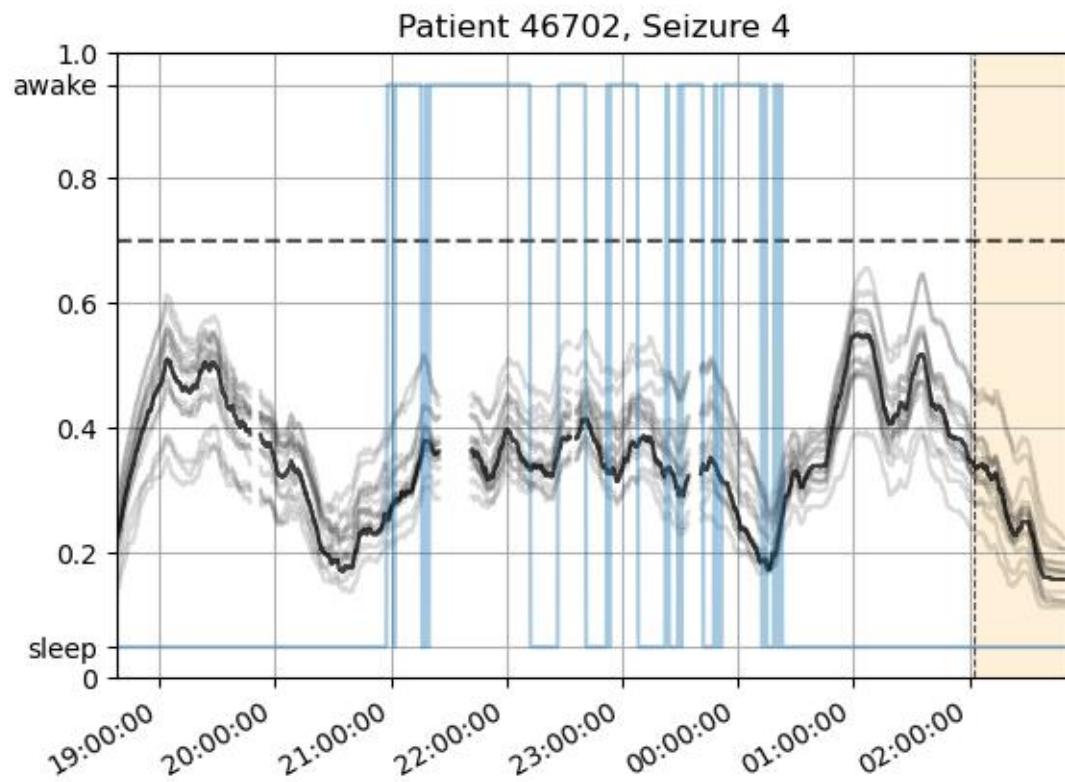
Patient 53402 – Over time



Patient 59102 – Over time



Patient 46702 – Over time



Methodology C - Results

- Patient 8902
 - Good SS and good FPR/h
- Patient 23902
 - Bad SS and bad FPR/h
- Patient 32702
 - Never raised an alarm

Patient	Pre-ictal Period (minutes)	SS	FPR/h	Validated	Patient	Pre-ictal Period (minutes)	SS	FPR/h	Validated
30802	30	0,20	0,48	0	75202	30	0,00	0,16	0
402	60	0,00	0,00	0	80702	40	0,00	0,21	0
8902	60	0,50	0,00	1	85202	30	0,50	0,37	1
11002	60	0,00	0,00	0	93402	30	0,00	0,57	0
16202	60	0,25	0,08	1	94402	40	0,00	0,04	0
21902	60	0,00	0,00	0	95202	30	0,00	0,08	0
23902	30	0,00	1,65	0	96002	60	0,00	0,00	0
26102	30	0,00	0,10	0	98102	40	0,00	0,00	0
32702	50	0,00	0,00	0	98202	50	0,00	1,30	0
45402	40	0,00	0,00	0	101702	30	0,00	0,10	0
46702	30	0,00	0,10	0	102202	60	0,00	0,00	0
50802	40	0,00	0,10	0	104602	40	0,00	0,08	0
52302	60	0,00	0,00	0	109502	30	0,00	0,00	0
53402	50	0,00	0,09	0	110602	50	0,00	0,00	0
55202	60	0,00	0,07	0	112802	50	0,00	0,00	0
56402	40	0,00	0,11	0	113902	30	0,00	0,11	0
58602	40	0,00	0,05	0	114702	50	0,00	0,04	0
59102	50	0,00	0,40	0	114902	30	0,00	0,07	0
60002	50	0,00	0,20	0	123902	30	0,00	0,00	0
64702	40	0,00	0,34	0	93902	45	0,00	0,00	0

Patient 8902 – Overall performance

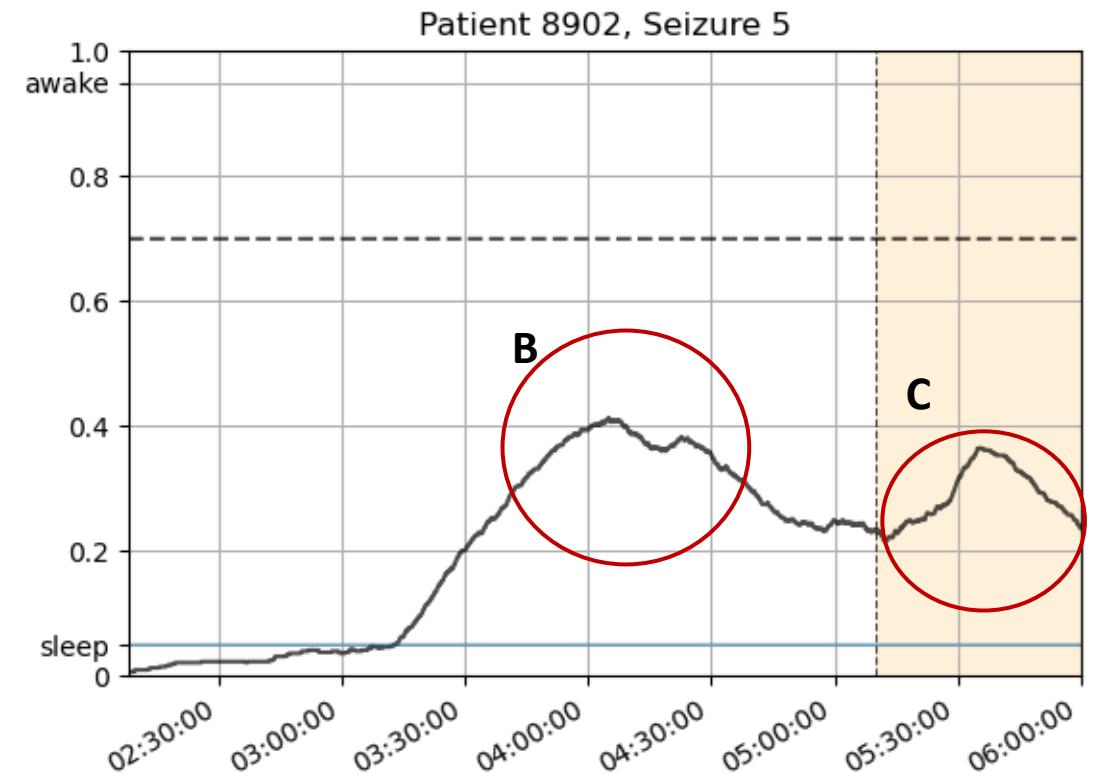
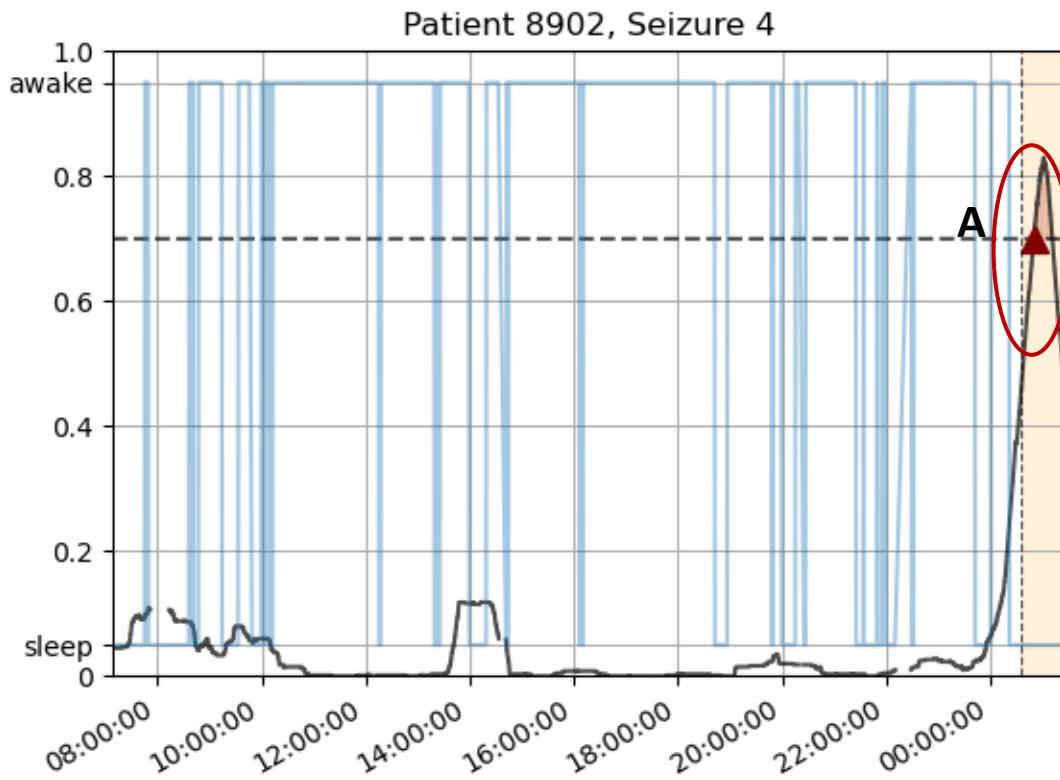
- SS:50%, FPR/h=0.00
- Above chance
- All seizures during the night.
Sleep related?

	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 00:51:14	Unclassified	Rhythmic alpha waves	Awake
	Day 1 00:03:23	FOIA	Rhythmic beta waves	Awake
	Day 1 06:37:05	FOIA	Rhythmic alpha waves	Awake
Testing Seizures	Day 2 01:35:56	FOIA	Amplitude depression	Awake
	Day 2 06:10:26	FOIA	Rhythmic alpha waves	Awake

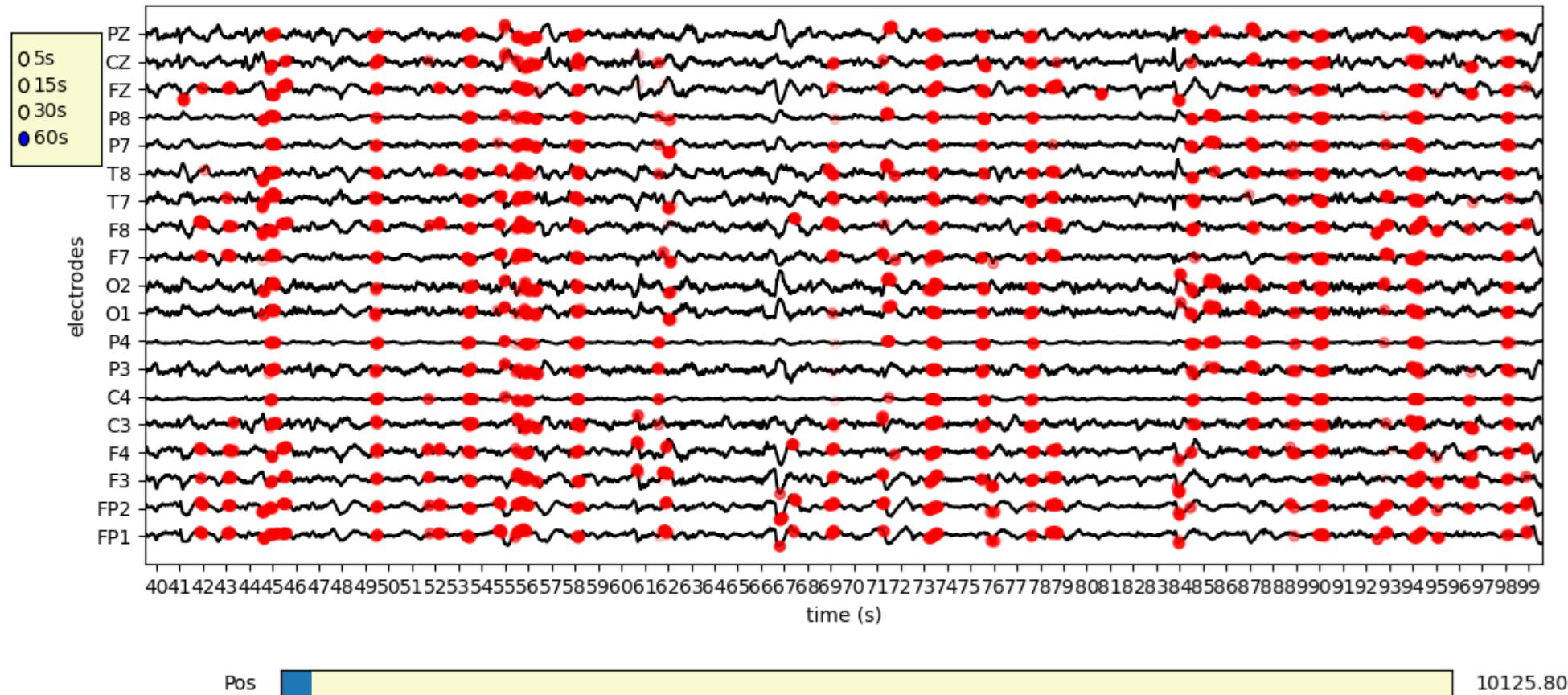
- Surgery decision: not offered
- Focus localization=tpl
Temporal polar left

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Seizure 4 Day 2 01:35:56	Yes	1	≈17
	Seizure 5 Day 2 06:10:26	Yes	1	≈4

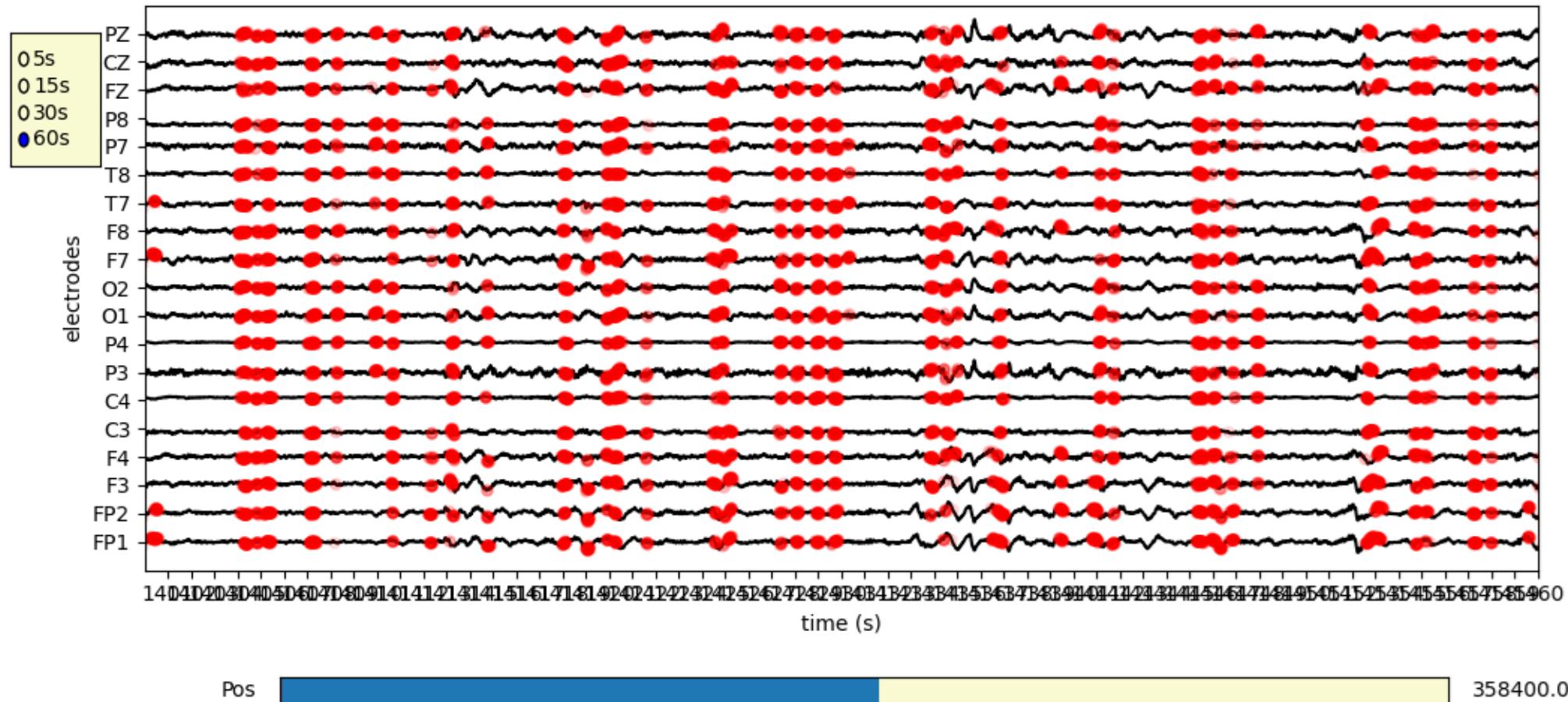
Patient 8902 – Over time



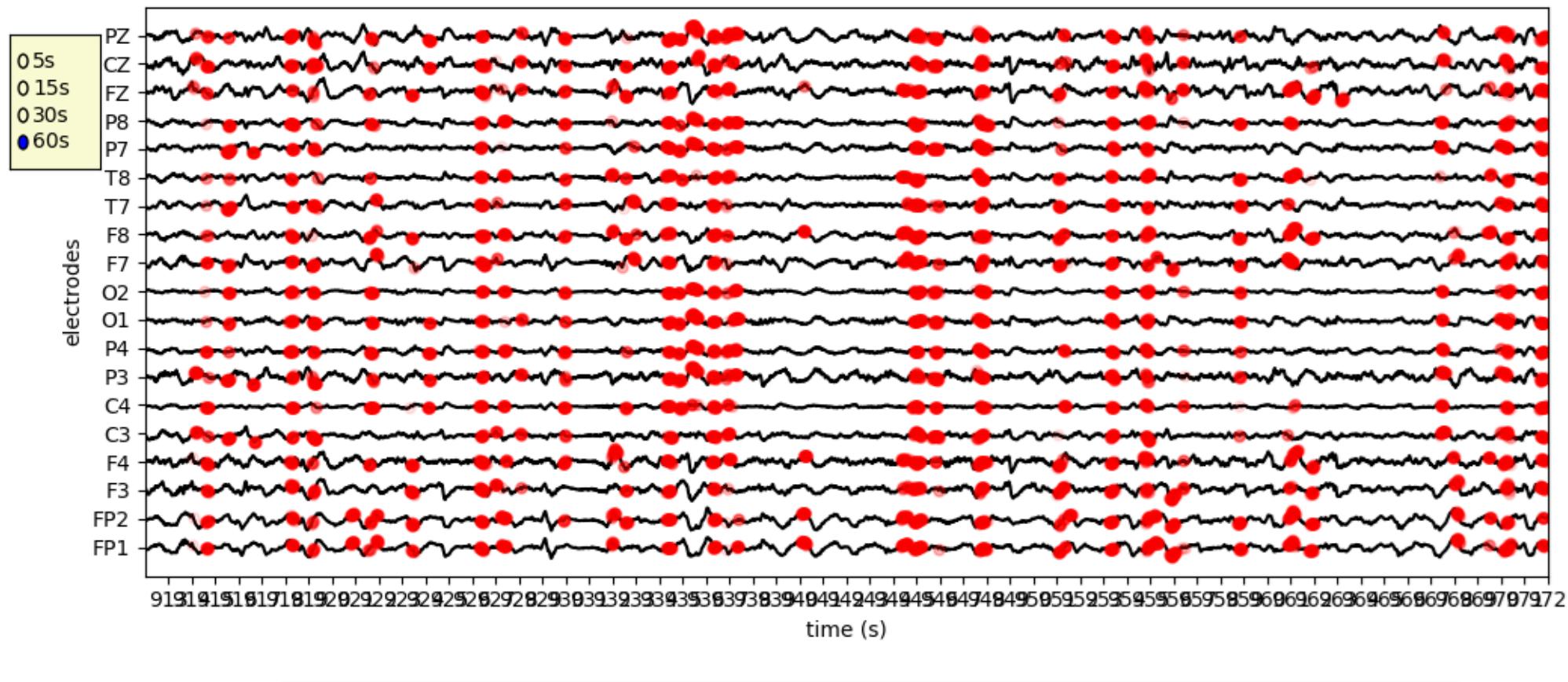
Patient 8902 – Point A



Patient 8902 – Point B



Patient 8902 – Point C



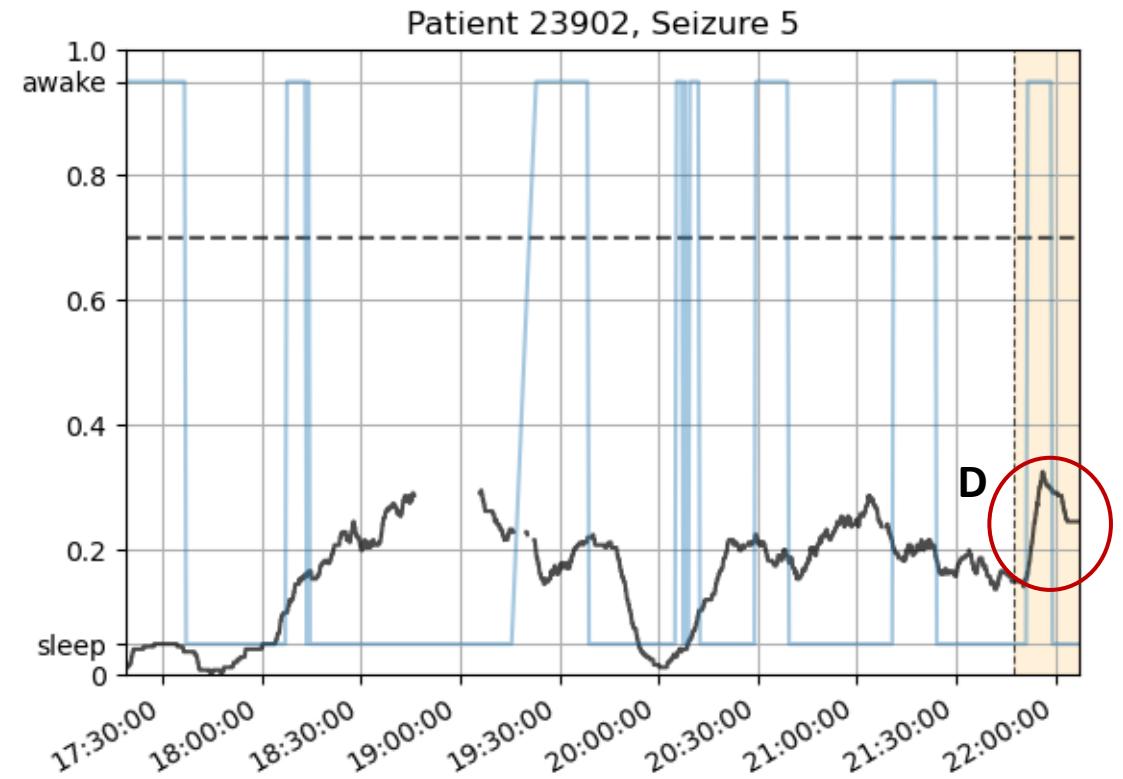
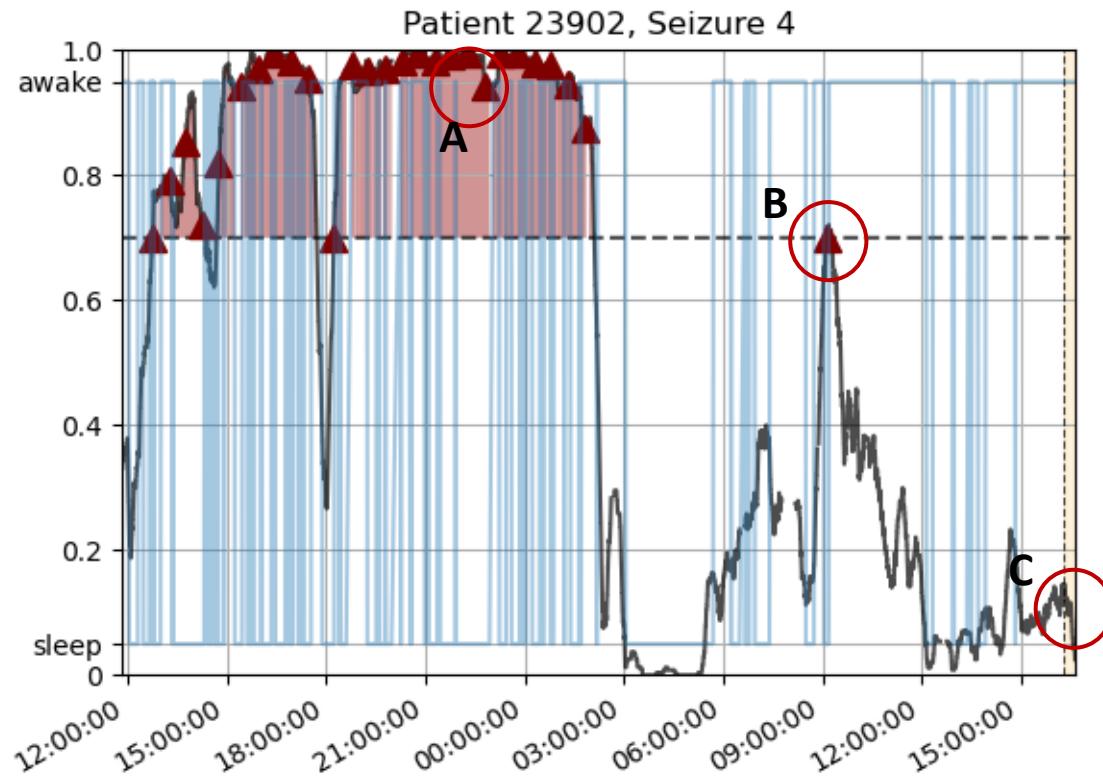
Patient 23902 – Overall performance

- SS:0%, FPR/h=1.65
- Not above chance
- Surgery decision: performed
- Focus localization=t-l
Temporal left

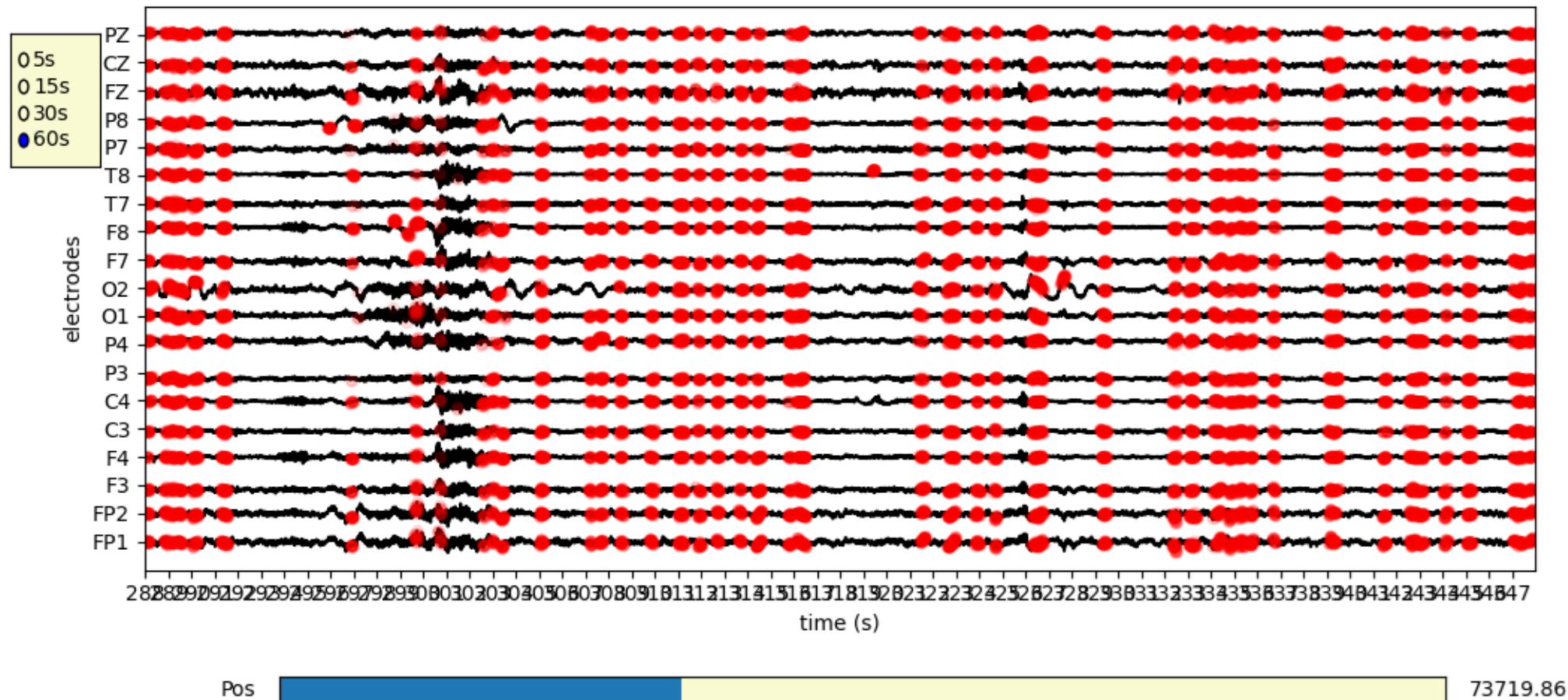
	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 10:18:13	FOA	Rhythmic theta waves	Awake
	Day 0 20:50:38	FOA	Rhythmic theta waves	Awake
	Day 2 11:18:12	FOA	Rhythmic theta waves	Awake
Testing Seizures	Day 3 16:48:02	FOA	Rhythmic delta waves	Awake
	Day 3 22:17:22	FOA	Rhythmic theta waves	Awake

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Seizure 4 Day 2 16:48:02	No	32	≈28
	Seizure 5 Day 2 22:17:22	No	0	≈5

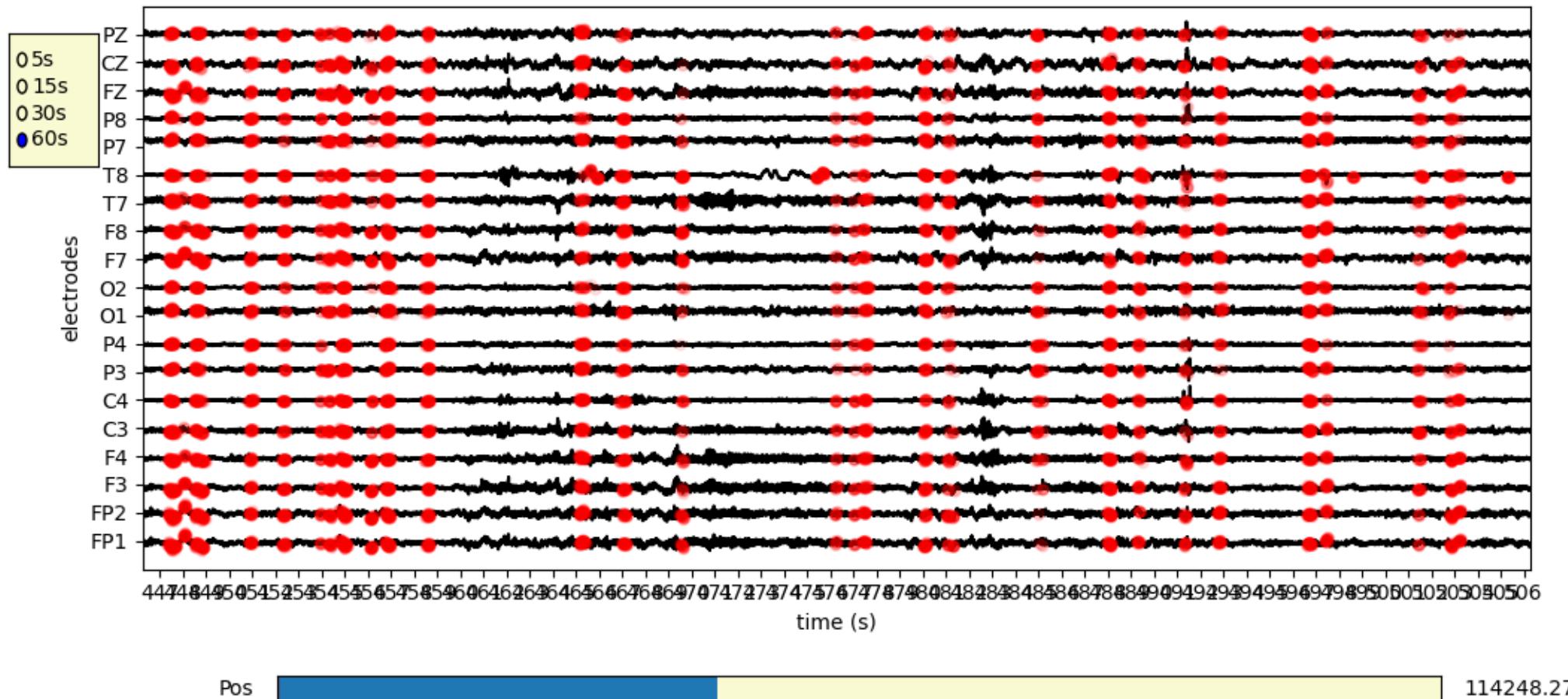
Patient 23902 – Over time



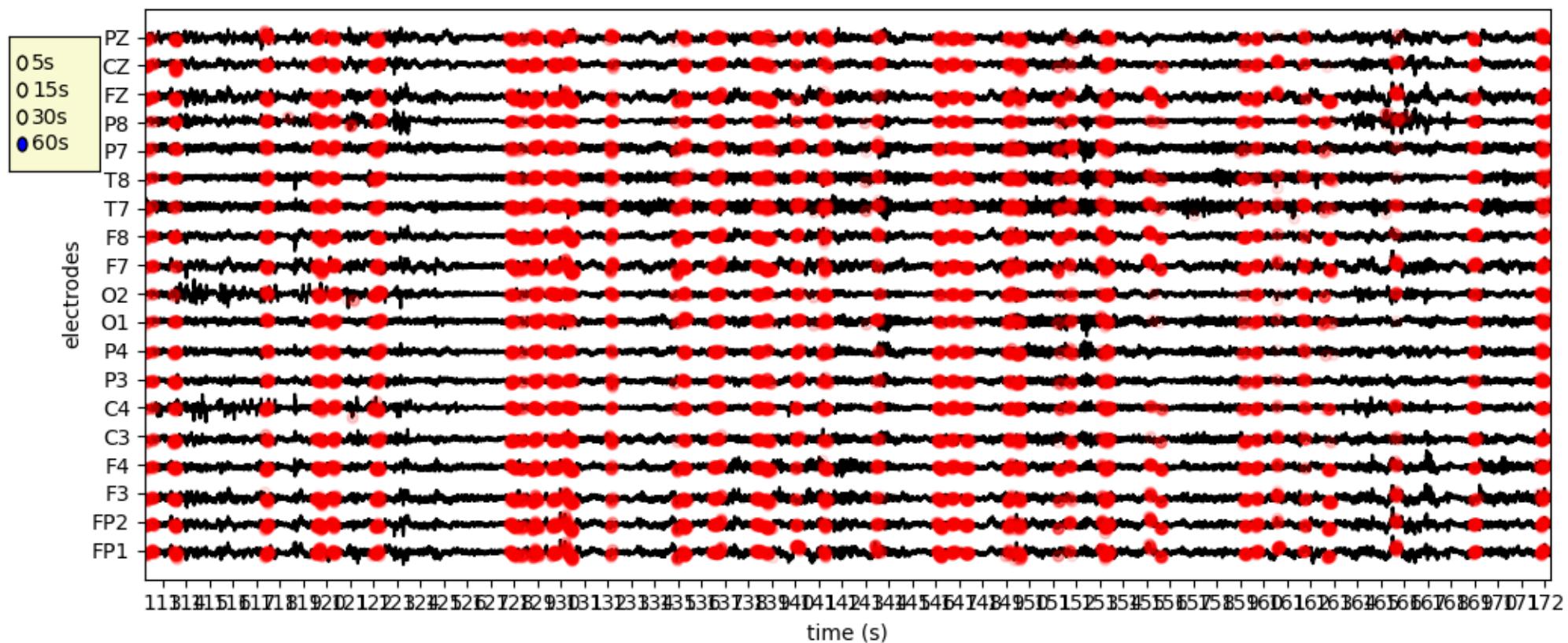
Patient 23902 – Point A



Patient 23902 – Point B



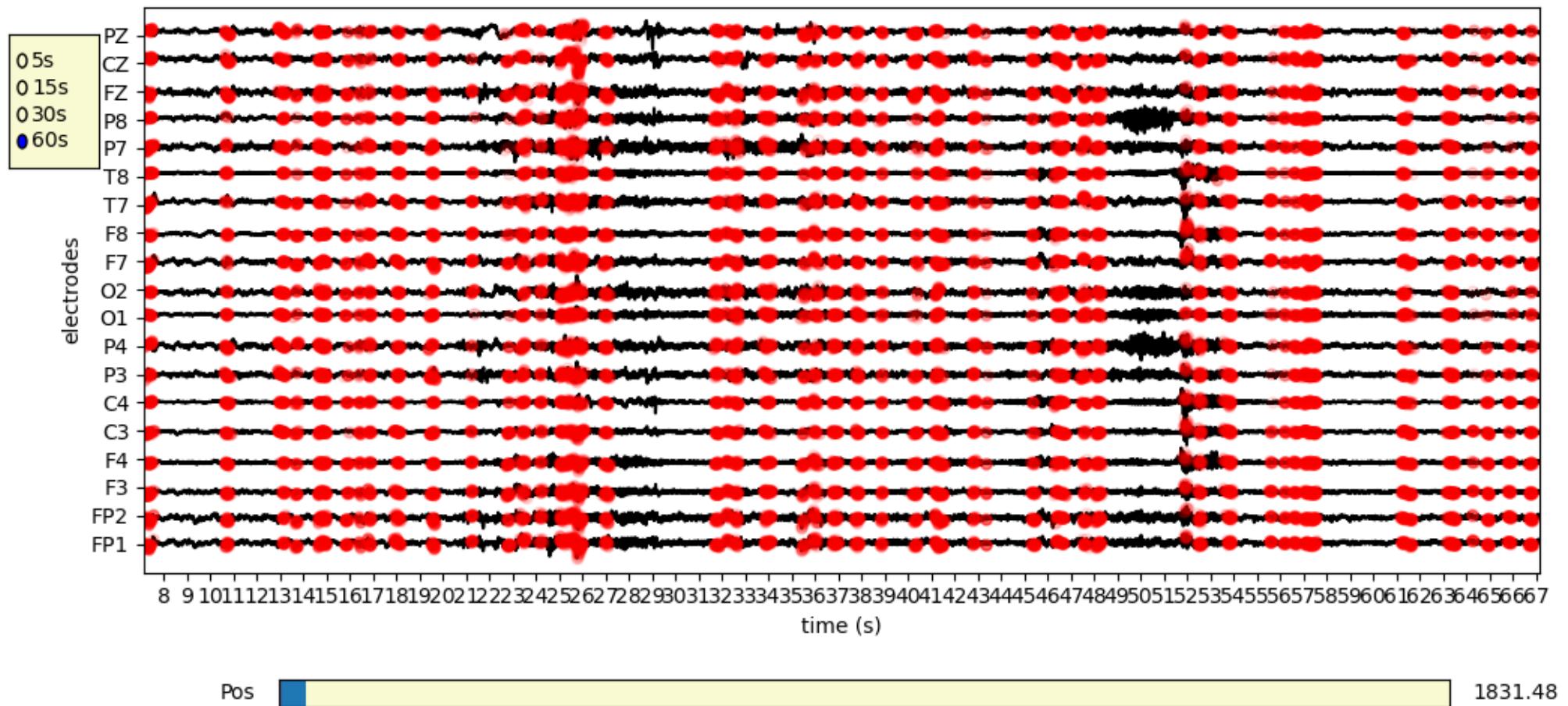
Patient 23902 – Point C



Pos

28734.45

Patient 23902 – Point D



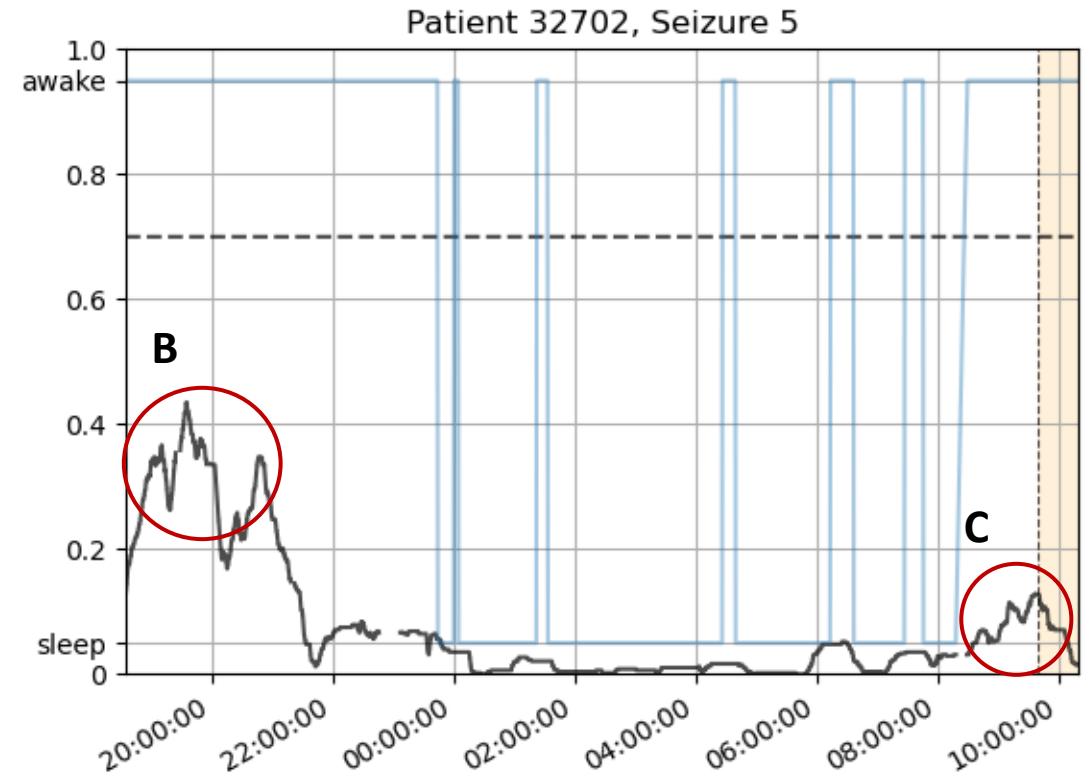
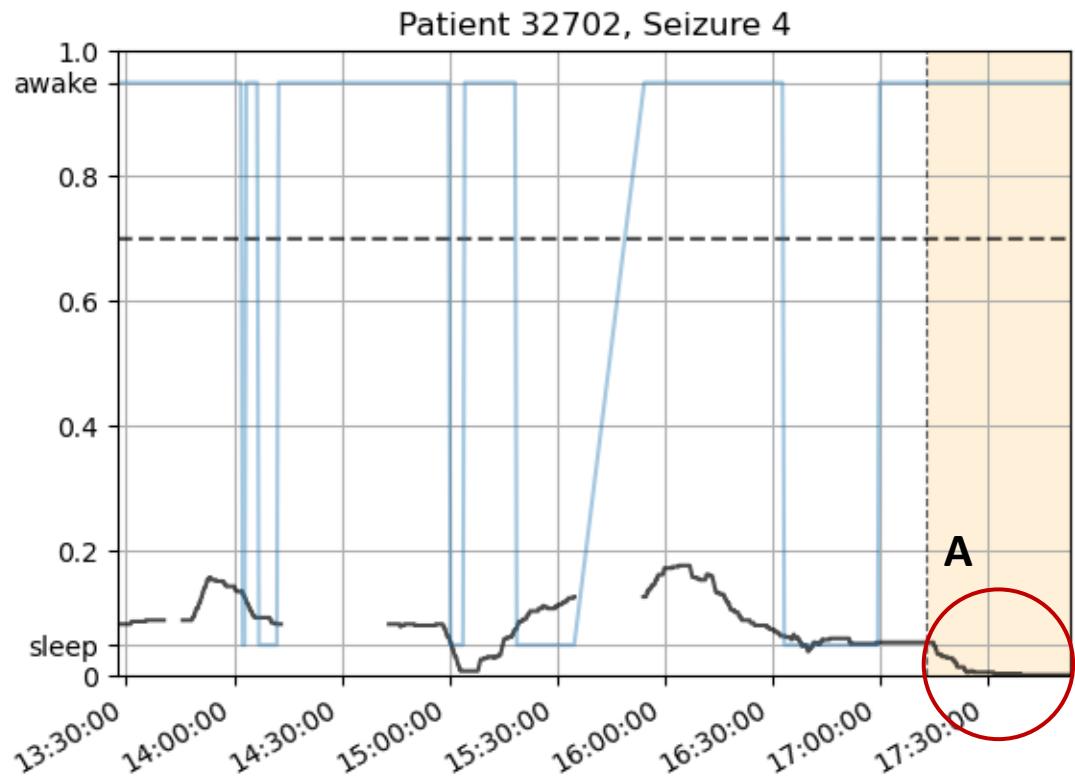
Patient 32702 – Overall performance

- SS:0%, FPR/h=0.00
- Not Above chance
- Surgery decision: not offered
- Focus localization=t-r, tpl
Temporal, none, right
Temporal, polar, left

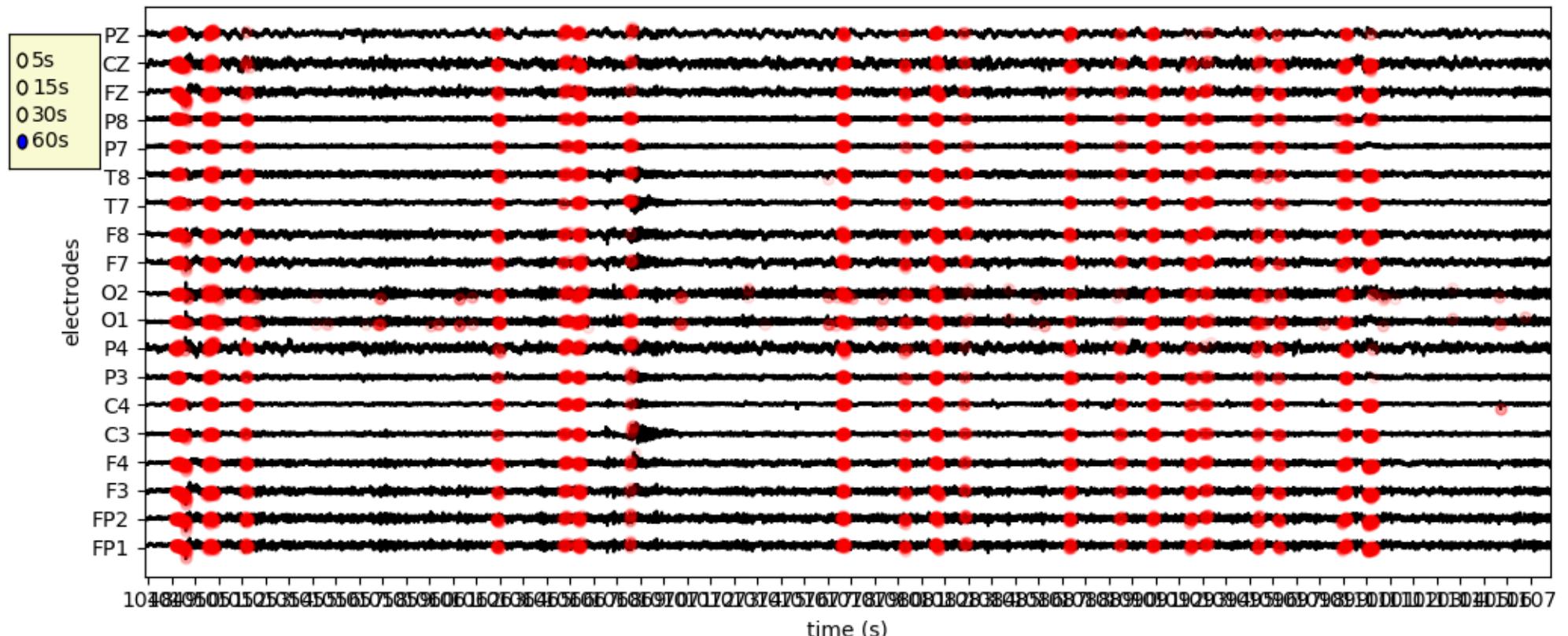
	Onset	Type	Pattern	Vigilance state at onset
Training Seizures	Day 0 09:25:28	FOIA	Rhythmic theta waves	Awake
	Day 1 11:22:47	FOIA	Rhythmic theta waves	Awake
	Day 2 11:13:13	FOIA	Rhythmic theta waves	Awake
Testing Seizures	Day 2 18:03:16	FOIA	Repetitive spiking	Awake
	Day 3 10:29:02	FOIA	Rhythmic alpha waves	Awake

	Onset	Predicted	#False Alarms	Hours of analysed data
Testing Seizures	Seizure 4 Day 2 18:03:16	No	0	≈5
	Seizure 5 Day 2 10:29:02	No	0	≈16

Patient 32702 – Over time



Patient 32702 – Point A

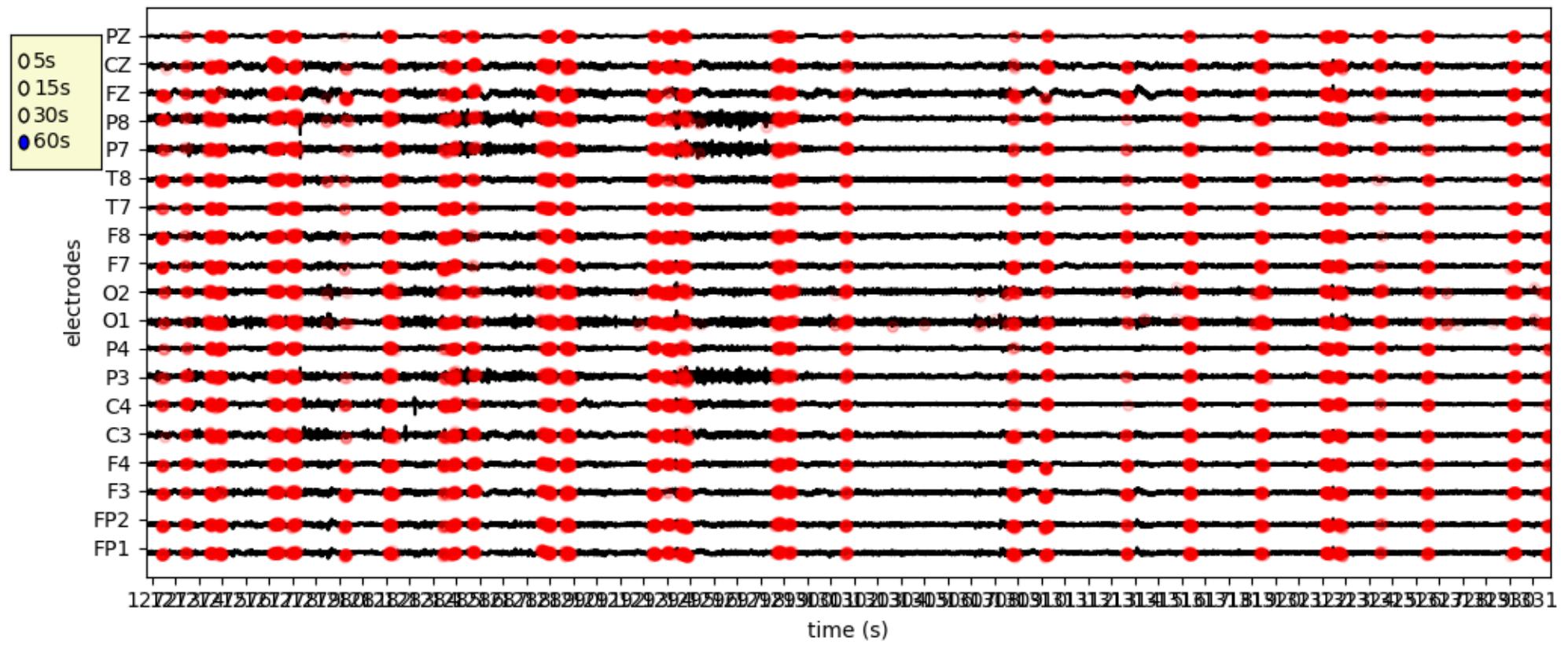


Pos



268248.67

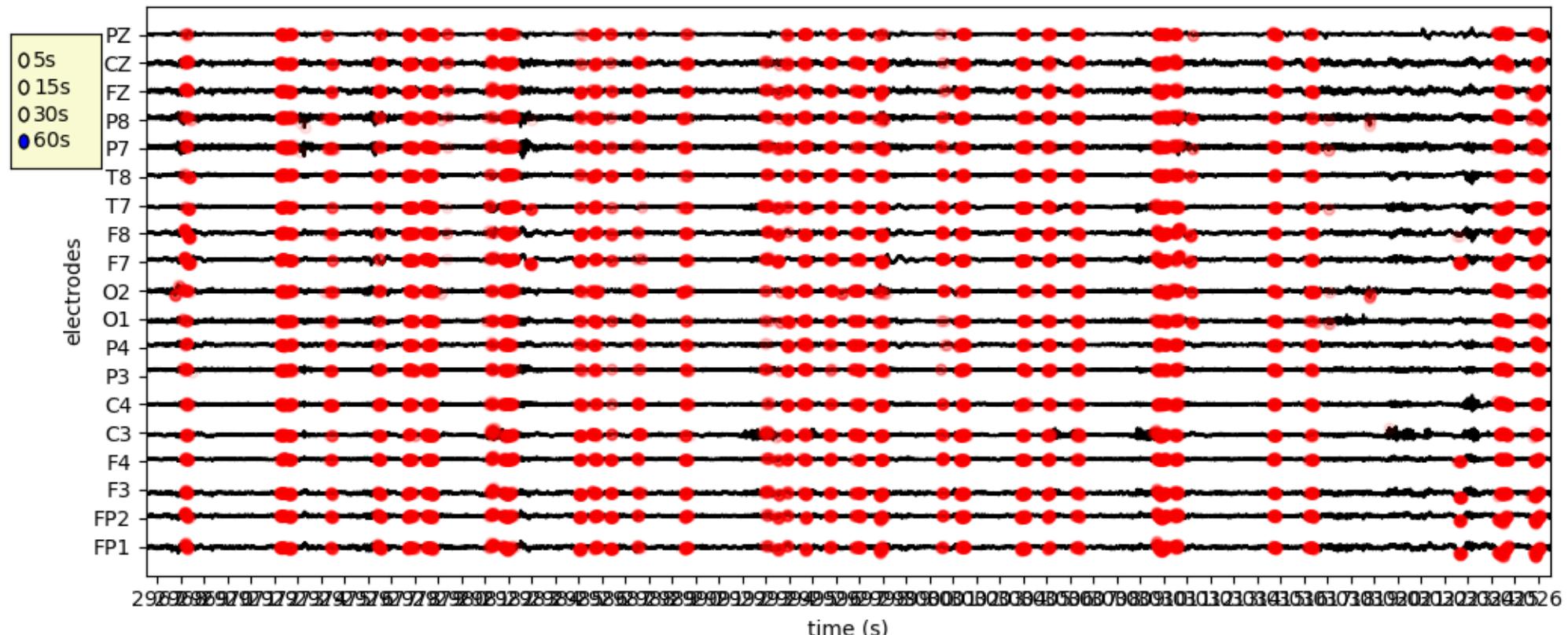
Patient 32702 – Point B



Pos

325572.98

Patient 32702 – Point C



Pos

759433.88