EUROfusion

Building a parsimonious disruption mitigation trigger

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Building a parsimonious disruption mitigation trigger

- Objective for 2022
  - Matlab code applied to JET data
  - Decision making capabilities after each discharge analysis to decide on retrain needs
    - Missed alarms and false alarms
- Parsimonious
  - Use of a minimal number of assumptions, steps or conjectures
  - Adaptive predictor from scratch
- Mitigation
  - Alarms: the closer to the disruption the better
- Software characteristics
  - Straightforward real-time implementation
    - Any real-time environment
  - Easy and fast retraining to be carried out between discharges

Remarks

- Constraint
  - Restricted number of diagnostics in the beginning of operation
- The mode lock signal shows good prediction capabilities
  - Signal increases when
    - The rotation of an MHD mode slows down and can be locked
    - The MHD mode amplitude grows
  - Signal decreases when
    - The MHD mode amplitude drops
    - The MHD mode unlocks and the rotation speeds up
- High amplitudes in the ML do not necessarily identify a disruptive behaviour
  - Smooth variations between consecutive samples are typical of non-disruptive conditions
- Small amplitudes in the ML do not necessarily identify a non-disruptive behaviour
  - Sudden variations between consecutive samples are typical of disruptive conditions
- Predictor parameter space
  - Two-dimensional space whose points are the amplitudes of consecutive samples

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Method

- An important difference with previous adaptive predictors from scratch is the objective of not to need a first disruption to start the training

- In a first phase, the predictor only needs non-disruptive discharges and can detect a first disruption by means of anomaly detection

- After the first detected disruption, disruptive and non-disruptive information can be used

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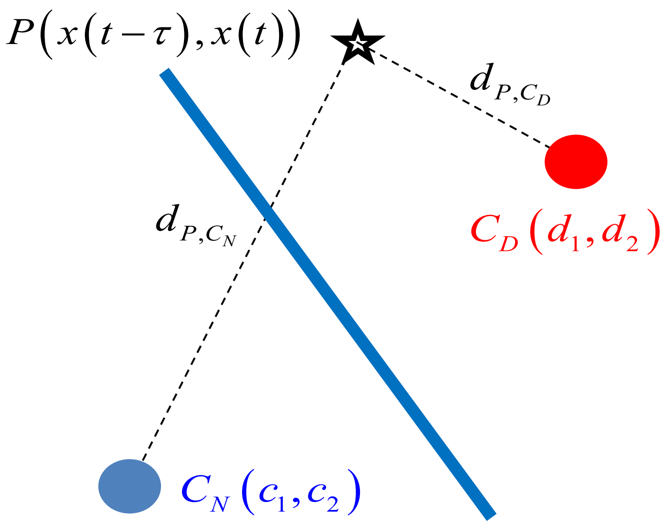
Method

- Using anomaly detection with non-disruptive discharges to predict a first disruption
  - The predictor has to learn from non-disruptive discharges how a non-disruptive behaviour is
- After the first disruption, two centroids (disruptive and non-disruptive) summarise the disruptive and non-disruptive behaviours



Linear frontier

$$x\left(t\right)=-\frac{d_1-c_1}{d_2-c_2}x(t-\tau)+\frac{d_1^2+d_2^2-c_1^2-c_2^2}{2\left(d_2-c_2\right)}$$

- After missed alarms or false alarms, the centroids can be re-computed (predictor retraining) and, therefore, the two centroids condense in two points all the past history about disruptive and non-disruptive behaviours

Database

- JET C-wall data with Ip >= 2 MA
- 1886 discharges in the range 65988 – 73126
  - 124 disruptive shots
  - 1762 non-disruptive shots

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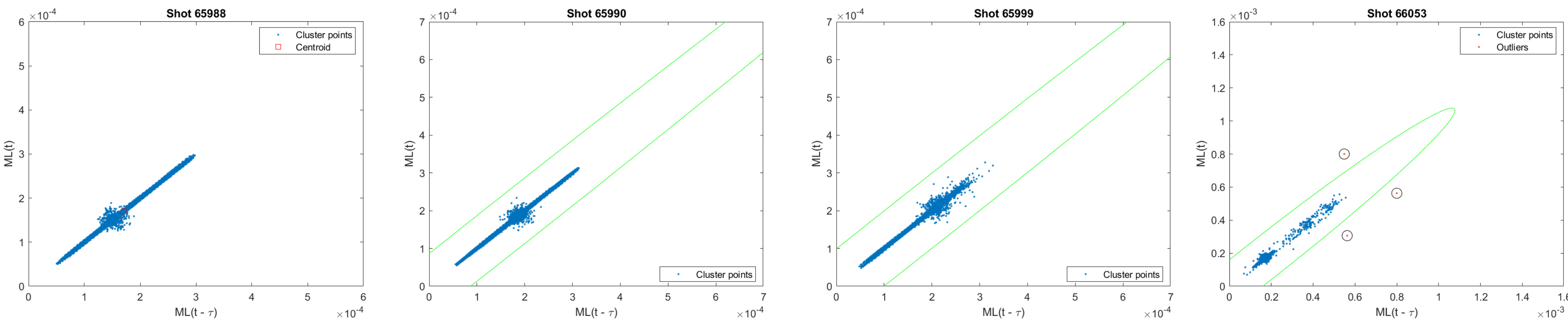
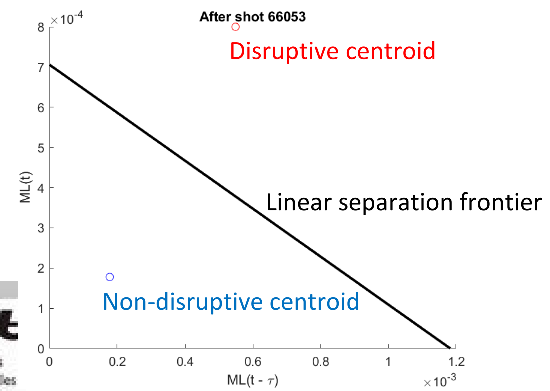
Anomaly detection to recognise a first disruptive behaviour

- In the two-dimensional parameter space, non-disruptive behaviours show a compact cluster of points
- A point ‘***far enough***’ from the cluster identifies a disruptive behaviour
- To take into account the data covariance, the Mahalanobis distance is used
  - Isocontours are ellipses





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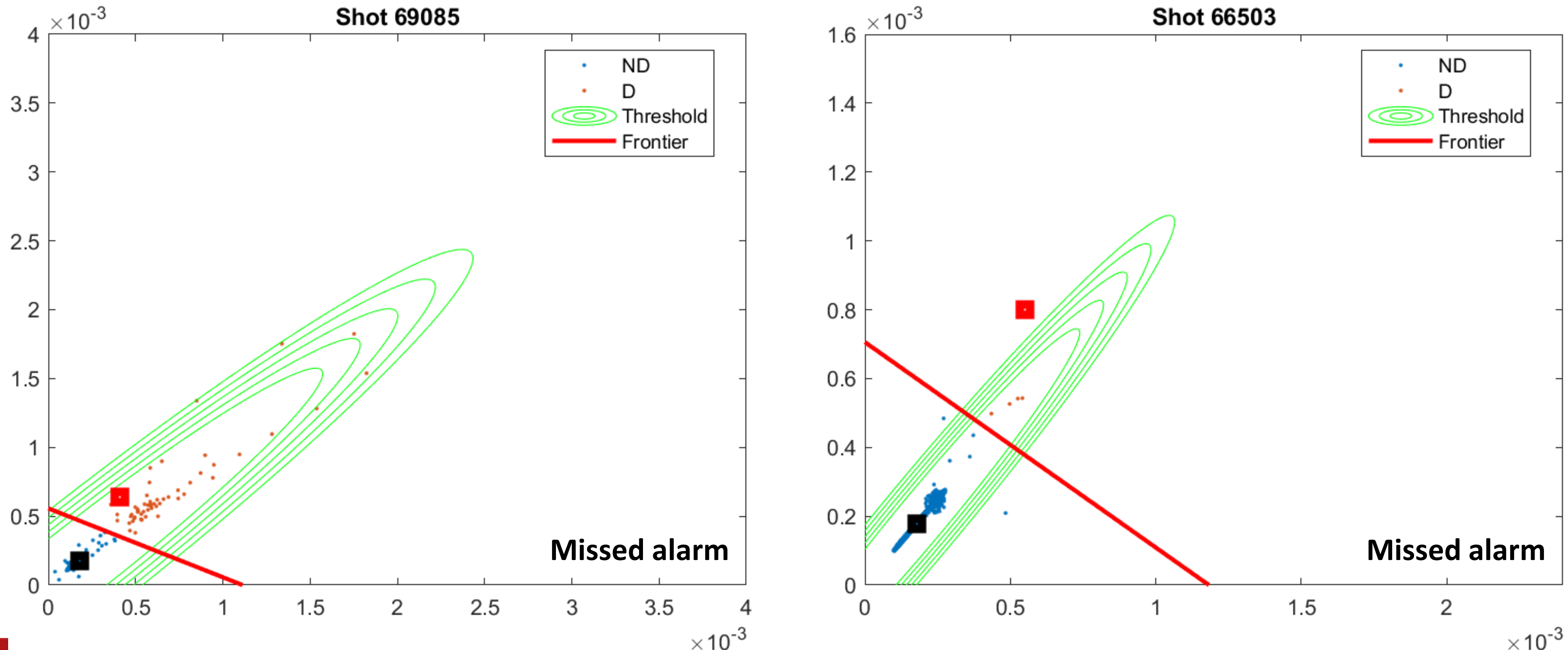
Adaptive prediction

- Two parameters can be optimised
  - Mahalanobis distance threshold to recognise disruptive behaviours when points are in the disruptive zone
  - Re-computation of centroids with information of past discharges



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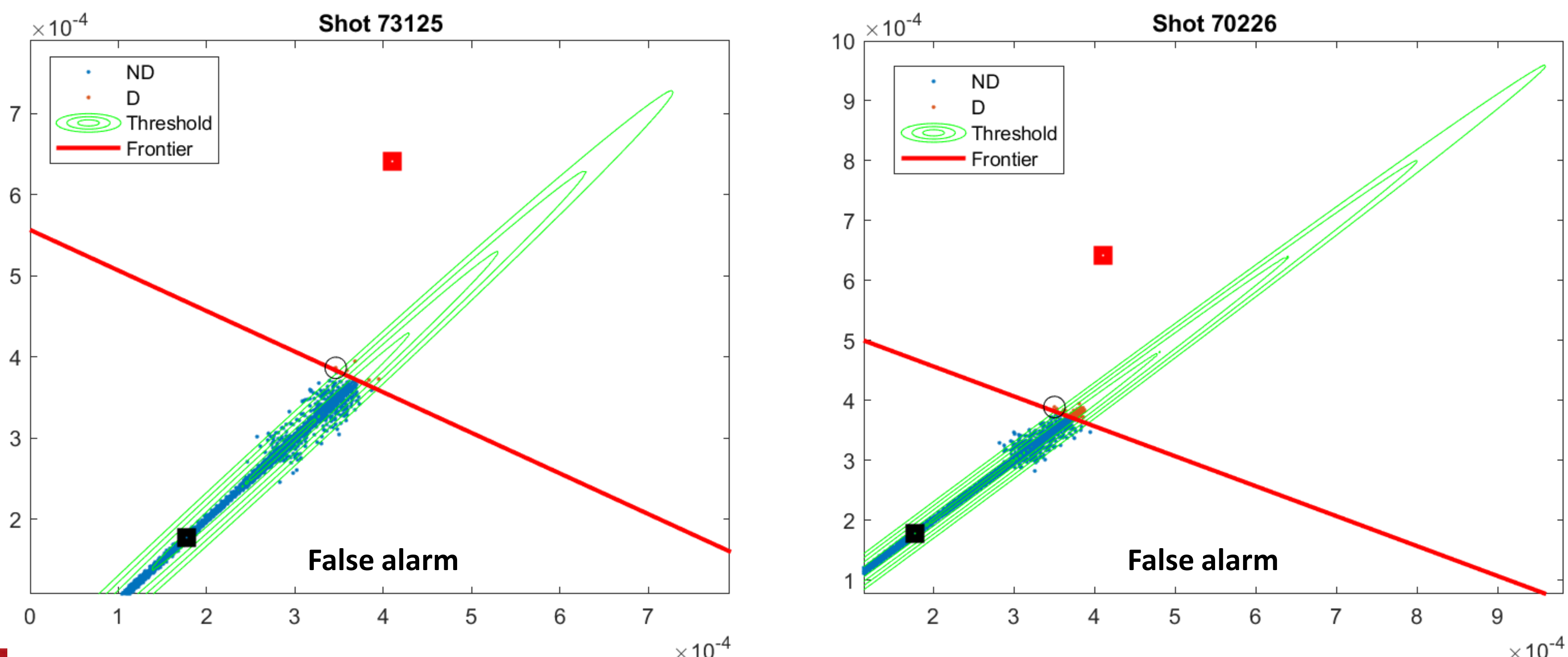

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Adaptive prediction

- Parameter optimisation applies to posterior discharges after the optimisation process

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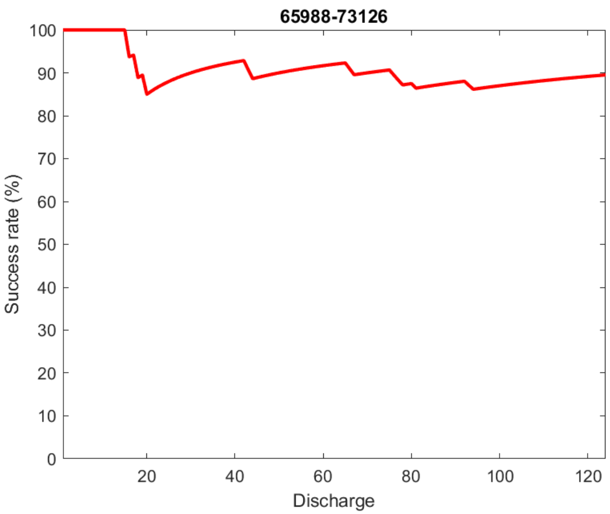
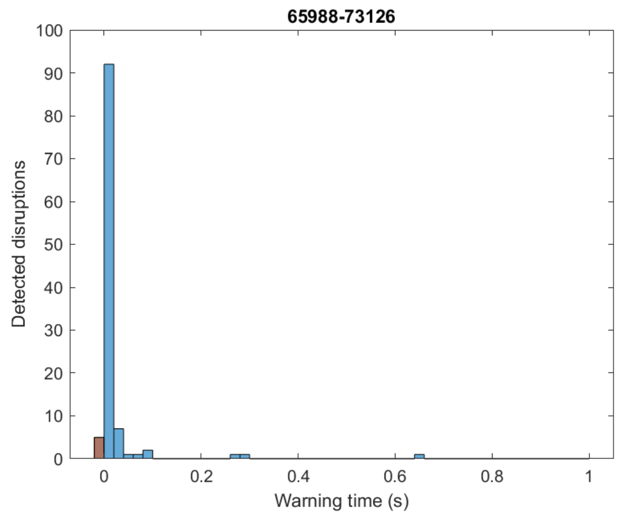
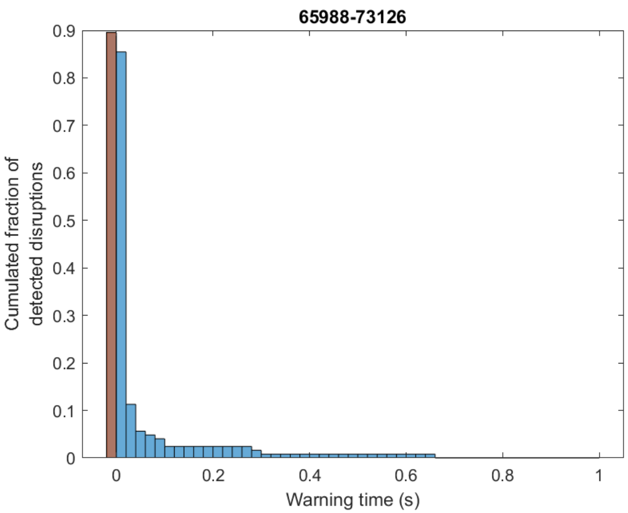
Results (1/3)

- No retraining after the first computation of centroids

Case	Success rate (%)	False alarms (%)
1	89.52 (111/124)	0 (0/1762)



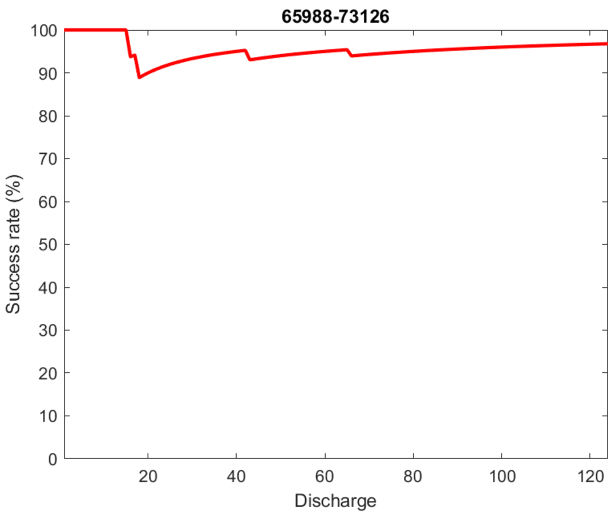


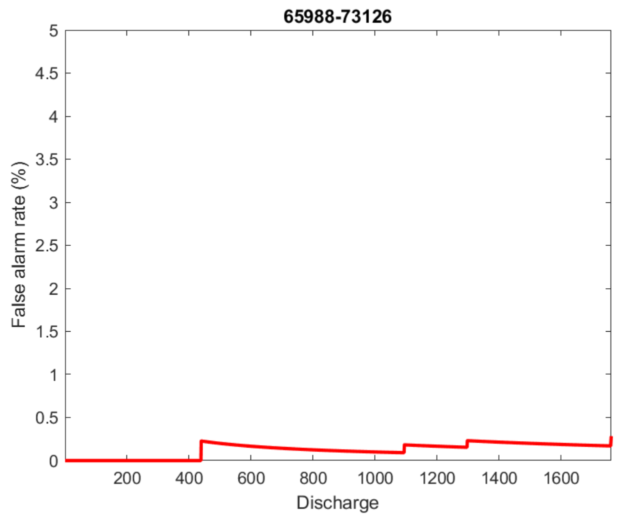


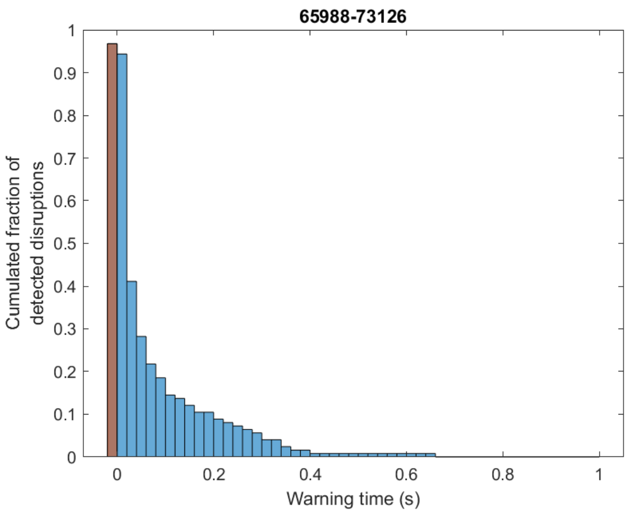
Results (2/3)

- Adaptive training after missed alarms and false alarms

Case	Success rate (%)	False alarms (%)
1	89.52 (111/124)	0 (0/1762)
2	**96.77 (120/124)**	**0.28 (5/1762)**







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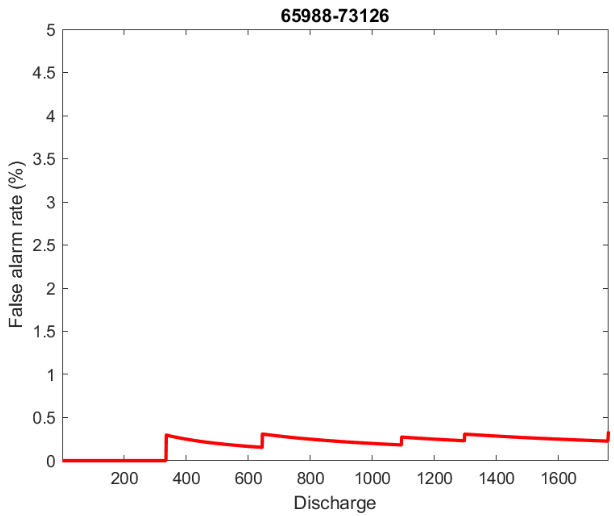
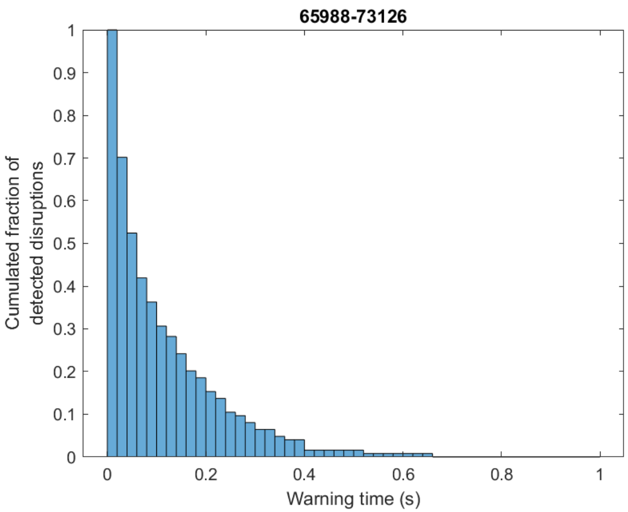
Results (3/3)

- Application of the optimised predictor (case 2) to the whole dataset

Case	Success rate (%)	False alarms (%)
1	89.52 (111/124)	0 (0/1762)
2	96.77 (120/124)	0.28 (5/1762)
3	**100 (124/124)**	**0.34 (6/1762)**





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Summary

- Conclusions
  - Straightforward and flexible method that only requires the ML signal and very simple computations
    - Real-time capabilities
  - Good results with JET C-wall data

- Conferences and publications
  - 2nd TM on Plasma Disruptions and their mitigation
  - NF/PPCF