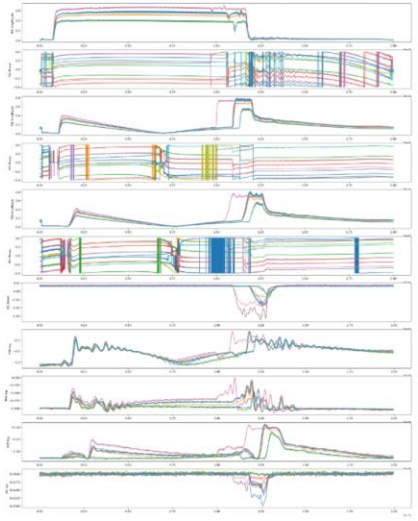
Problem

RF cavities experience occasional breakdowns which damage equipment and cause loss of beam time.
Detection and prediction of breakdown events is therefore critical.

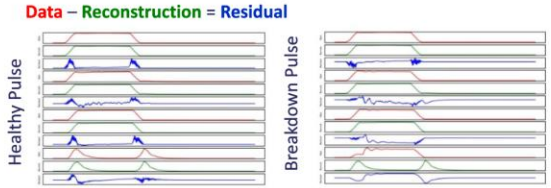
Existing RF breakdown detection systems rely on masking and perform poorly.

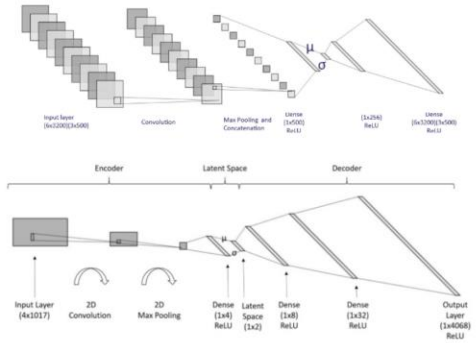
We have recorded phase and amplitude traces from multiple points in the RF system, and seek to apply machine learning to detect, and hopefully predict, breakdowns.



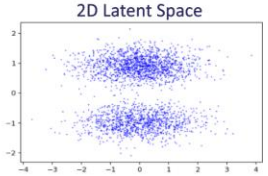
Solution

We constructed a beta convolutional variational autoencoder (βCVAE) with RF conditioning data signal traces as inputs.
We train the autoencoder to reconstruct healthy (non-breakdown) traces, with all breakdown traces held back.
The per-channel reconstruction error and latent space vector of the autoencoder are then fed into a deep neural network-based classifier to detect breakdowns.





This method has the advantage of not requiring mitigation of the class imbalance.



Results

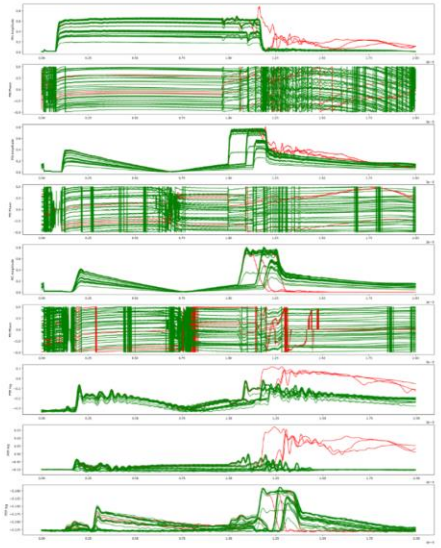
An almost perfect classifier demonstrated on both CLARA and CERN's XBOX2 test stand, with an exceptionally low false positive rate.

	Positive	Negative
True	95.8%	98.0%
False	4.2%	2.0%

CLARA Breakdown Detection

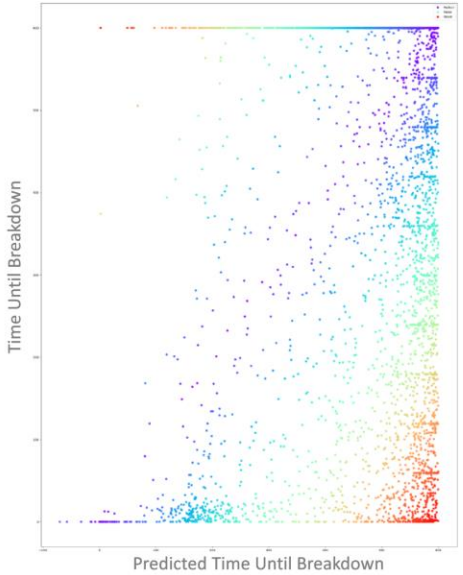
	Positive	Negative
True	97.9%	99.6%
False	2.1%	0.4%

CERN Breakdown Detection



Prediction

Training the network to instead predict time-until-breakdown resulting in overall poor accuracy. 73% prediction of time until breakdown within a 30 second window.
We believe this poor prediction performance is due to the low sampling frequency of the shot capture, with only one shot per minute being captured.



Future Work

- Collection of 100% of shot data for a new dataset to train prediction.
- Refining the anomaly detection system to achieve perfect classification of breakdowns.
- Deploying this detection and prediction system to CLARA for online ML-based breakdown monitoring.

Science and Technology Facilities Council

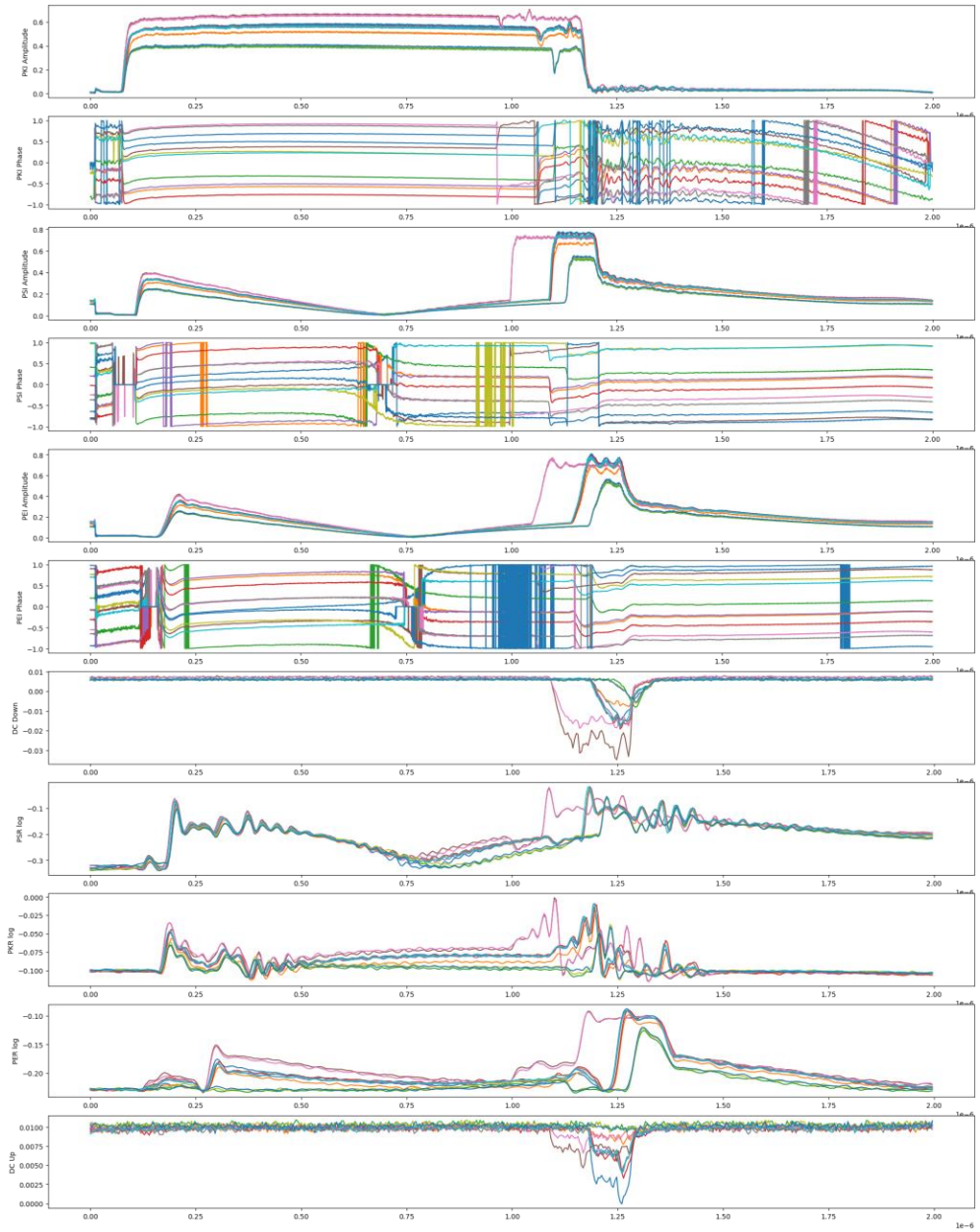
WEPV021 - Machine Learning for RF Breakdown Detection at CLARA

Problem

RF cavities experience occasional breakdowns which damage equipment and cause loss of beam time.
Detection and prediction of breakdown events is therefore critical.

Existing RF breakdown detection systems rely on masking and perform poorly.

We have recorded phase and amplitude traces from multiple points in the RF system, and seek to apply machine learning to detect, and hopefully predict, breakdowns.



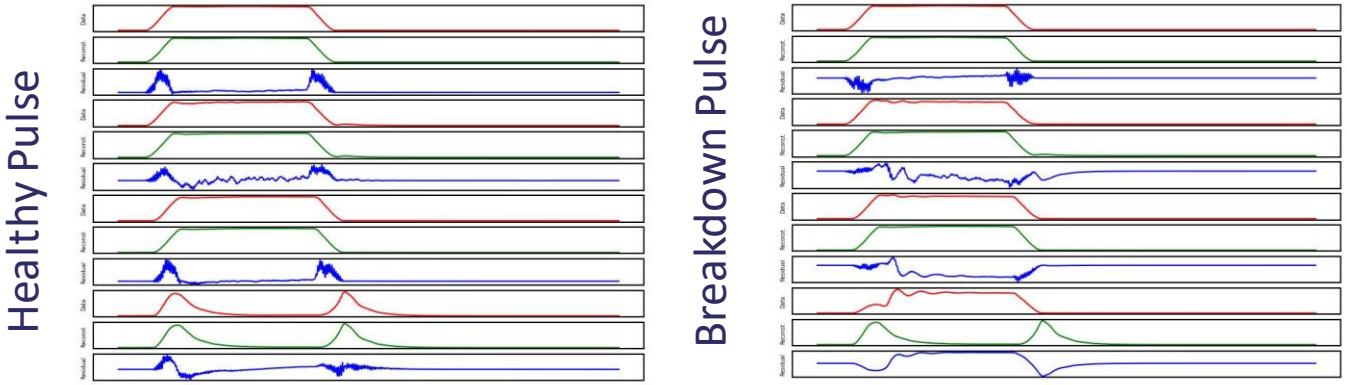
Science and Technology Facilities Council

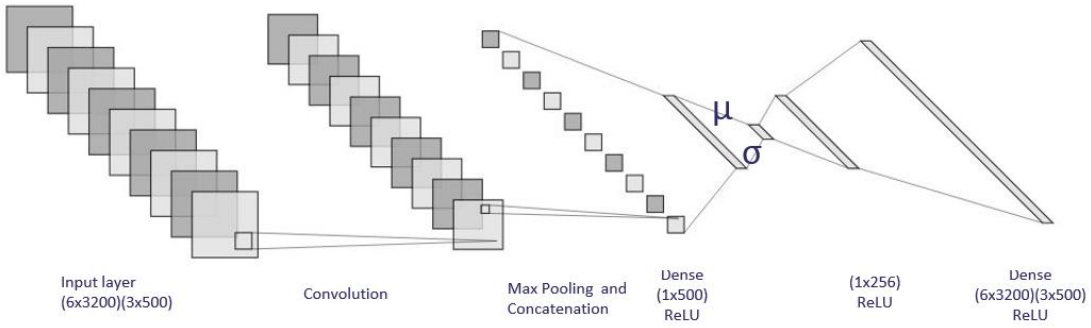
Solution

We constructed a beta convolutional variational autoencoder (βCVAE) with RF conditioning data signal traces as inputs. We train the autoencoder to reconstruct healthy (non-breakdown) traces, with all breakdown traces held back.
The per-channel reconstruction error and latent space vector of the autoencoder are then fed into a deep neural network-based classifier to detect breakdowns.

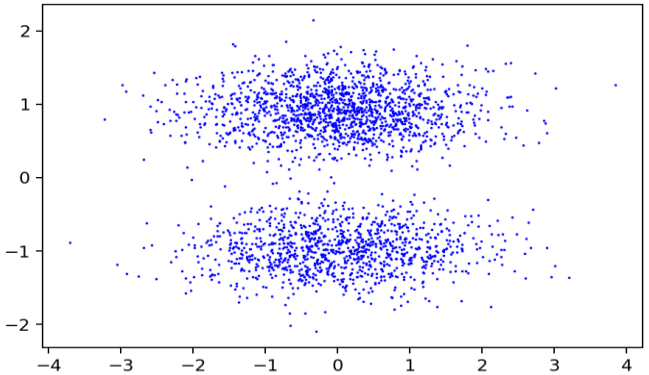
This method has the advantage of not requiring mitigation of the class imbalance.

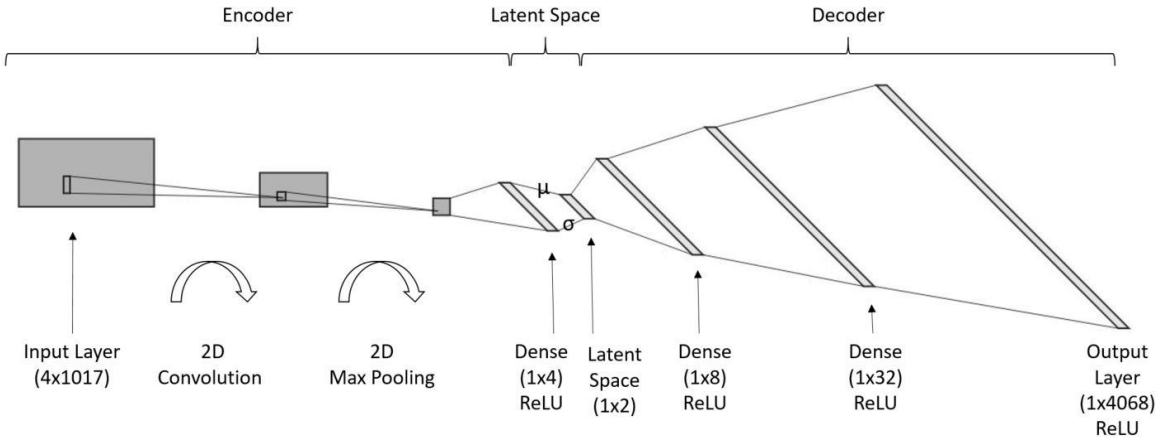
Data – Reconstruction = Residual





2D Latent Space





Science and Technology Facilities Council

Results

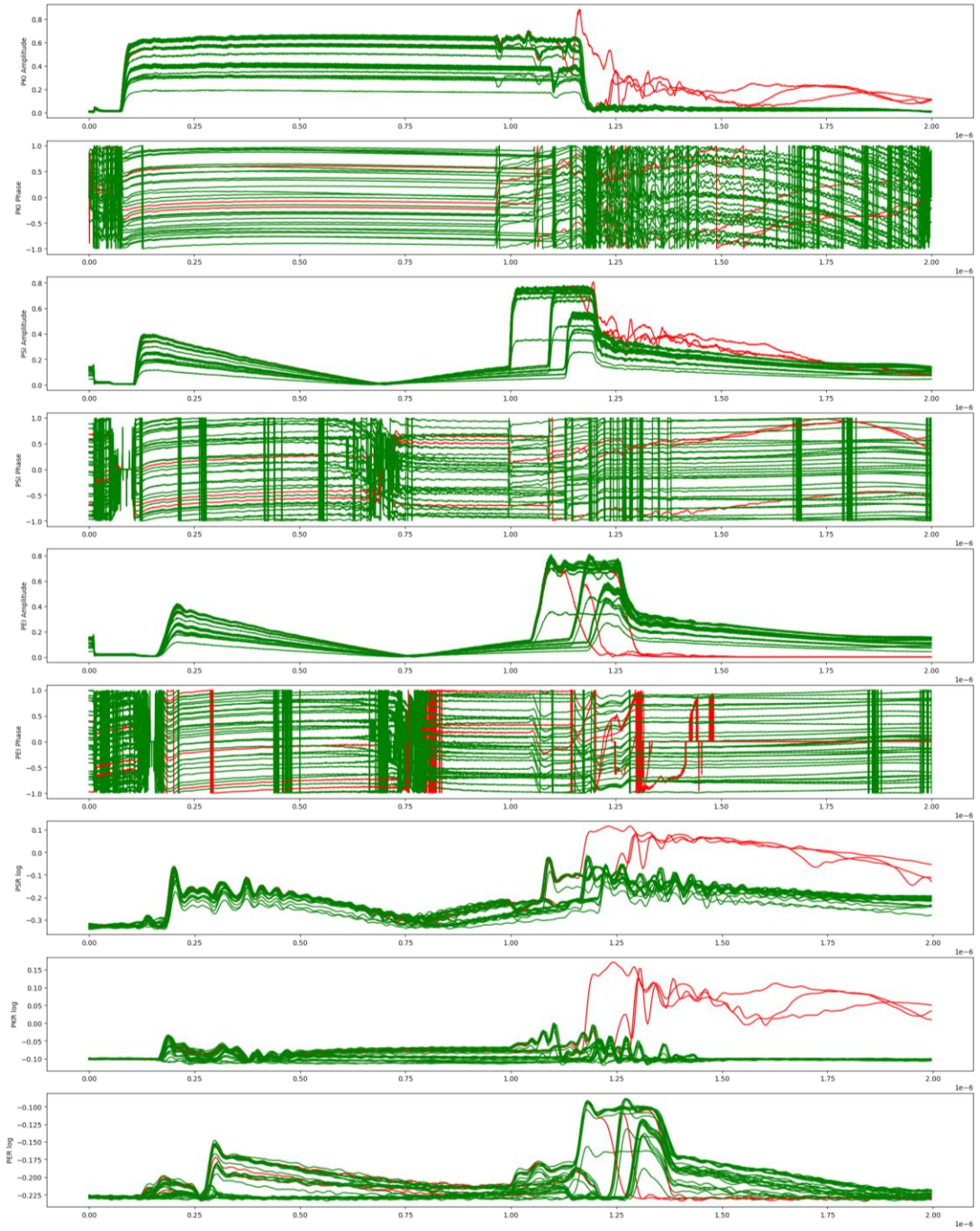
An almost perfect classifier demonstrated on both CLARA and CERN's XBOX2 test stand, with an exceptionally low false positive rate.

	Positive	Negative
True	95.8%	98.0%
False	4.2%	2.0%

CLARA Breakdown Detection

	Positive	Negative
True	97.9%	99.6%
False	2.1%	0.4%

CERN Breakdown Detection



Science and Technology Facilities Council

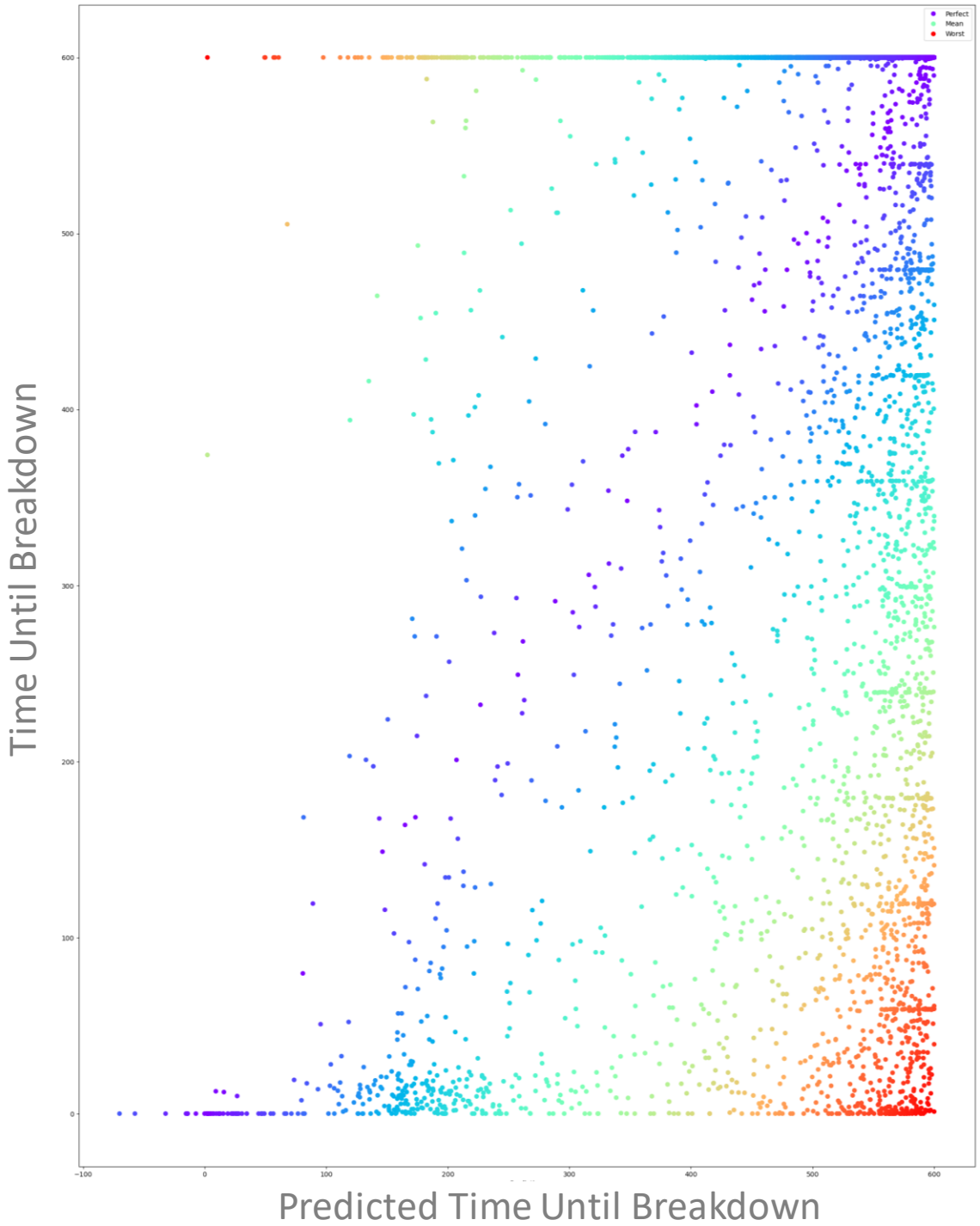
Prediction

Training the network to instead predict time-until-breakdown resulting in overall poor accuracy. 73% prediction of time until breakdown within a 30 second window.

We believe this poor prediction performance is due to the low sampling frequency of the shot capture, with only one shot per minute being captured.

Future Work

- Collection of 100% of shot data for a new dataset to train prediction.
- Refining the anomaly detection system to achieve perfect classification of breakdowns.
- Deploying this detection and prediction system to CLARA for online ML-based breakdown monitoring.



Science and Technology Facilities Council