Intelliquench status

Duc -- Fermilab

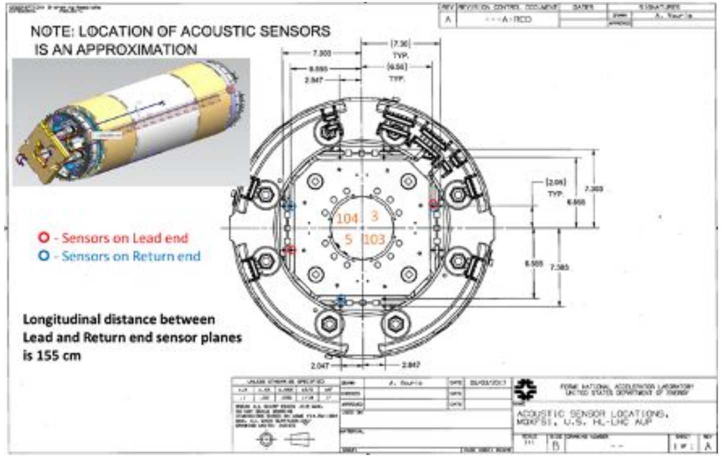
Outline

1. Setup & acoustic signals.
2. Rolling windows & statistical features.
3. Auto-encoder & online-learning process.
4. Results
5. Future studies

1. Setup & acoustic signals

MQXFS1

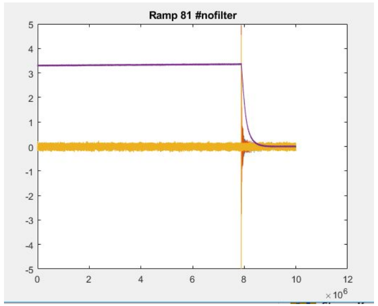
- **100kHz** sample rate.
- **5 acoustic sensors** attached to two sides on magnet.



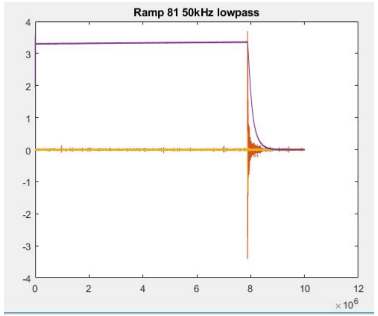
"15T"

- **1MHz** sample rate.
  - Applied a 50kHz **low-pass filter** & d**own sampled** to 100kHz.
- Only **two sensors** on both sides of the magnet.

No filter

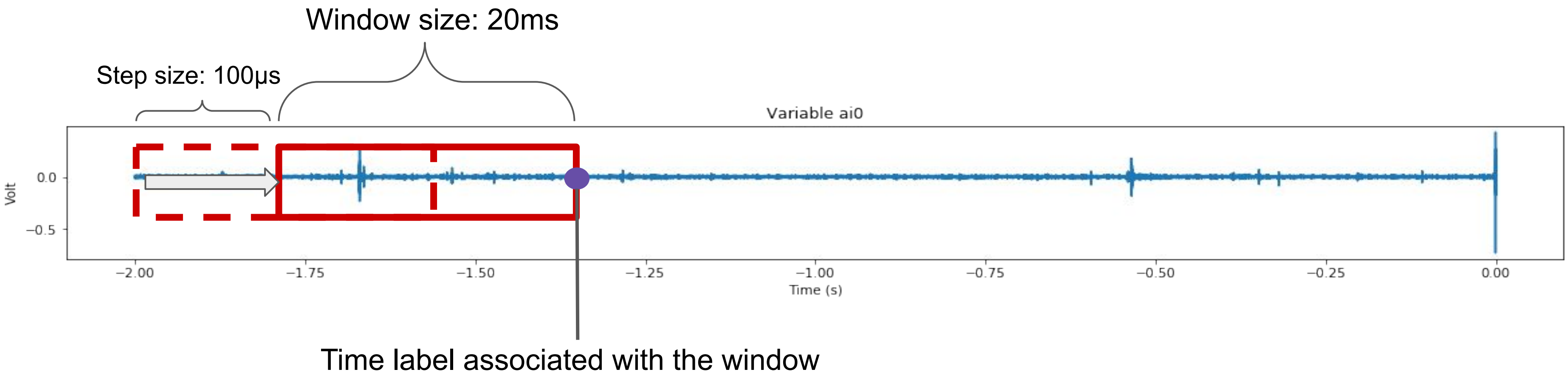


Low pass



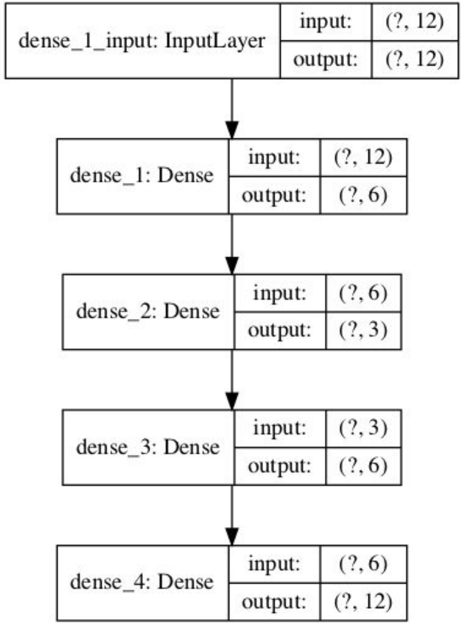
Rolling window & statistical features

- 2 features are calculated in each window for each sensor: **standard deviations** & **mean of the amplitudes.**
- After that, features across sensors are also multiplied together to give some more emphasis on consistent signals.

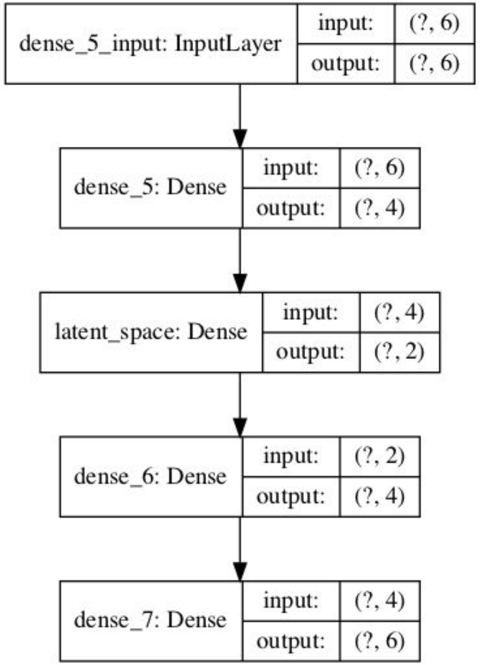


DNN auto encoder architecture

- **Mqxfs1**

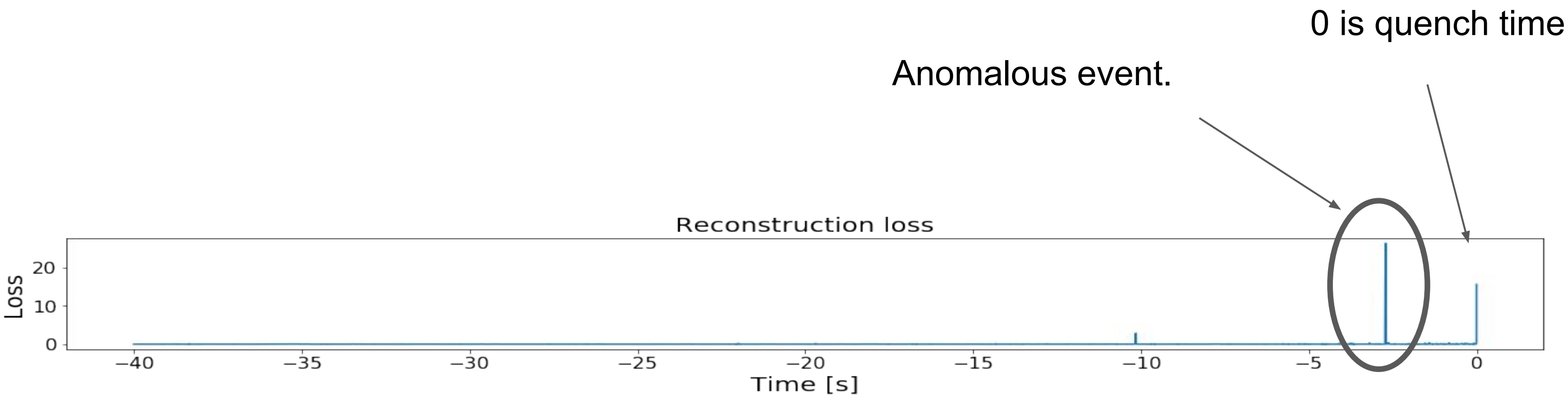


- **15T**

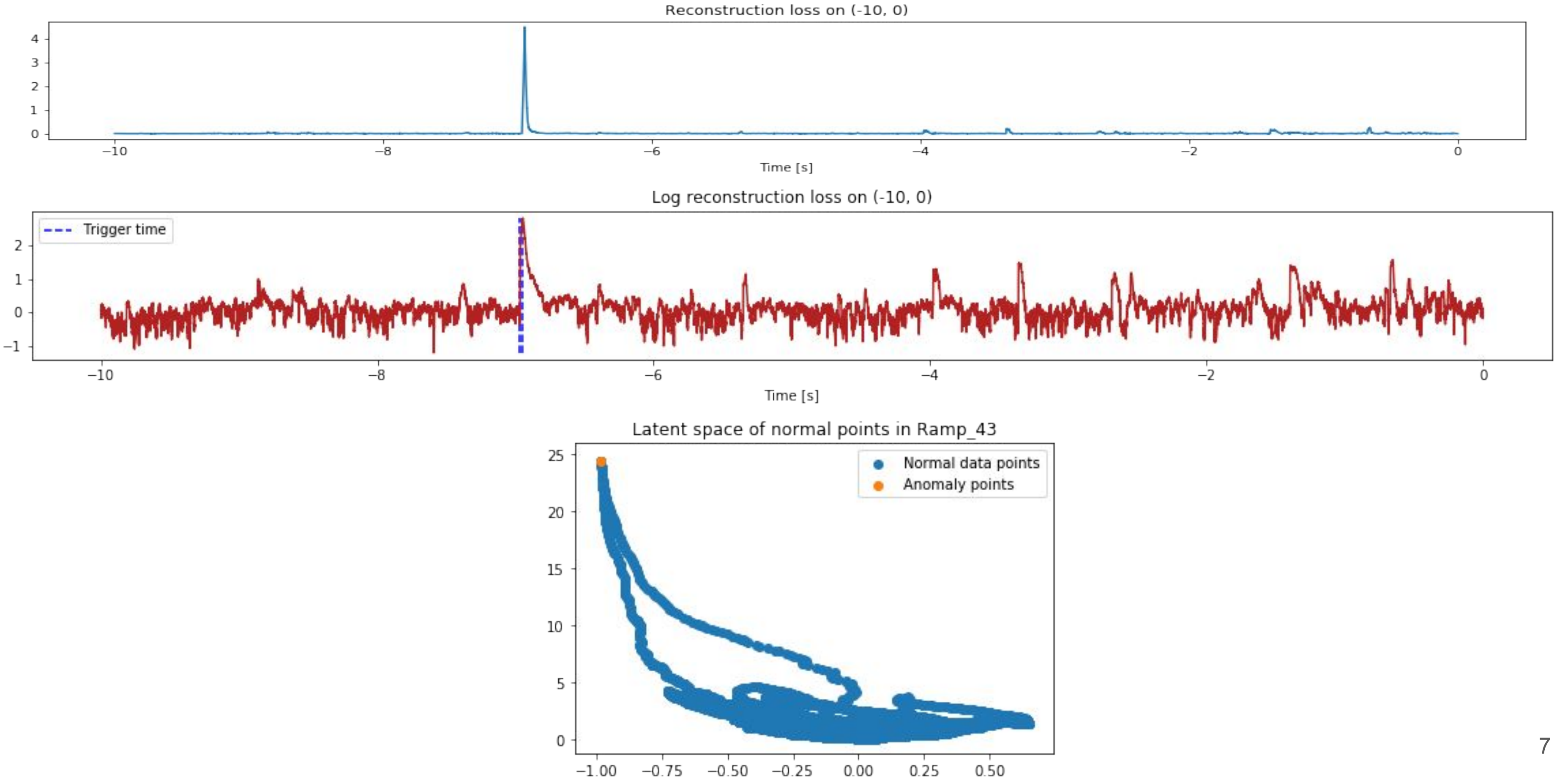


Note: all inputs are scaled to between (0,1) when training, same transformation is applied on testing data.

Anomaly visualization

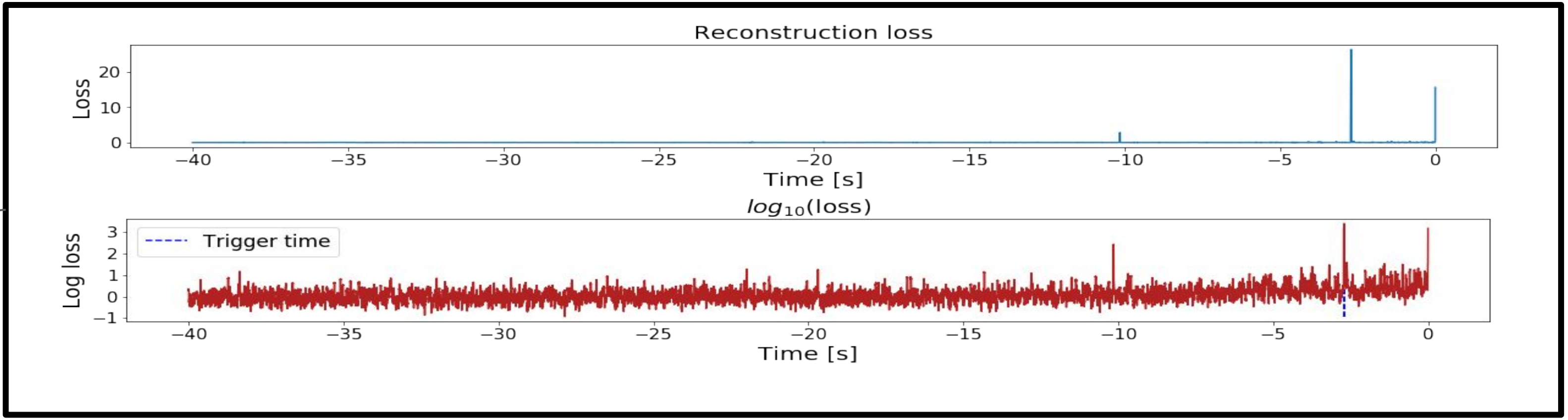


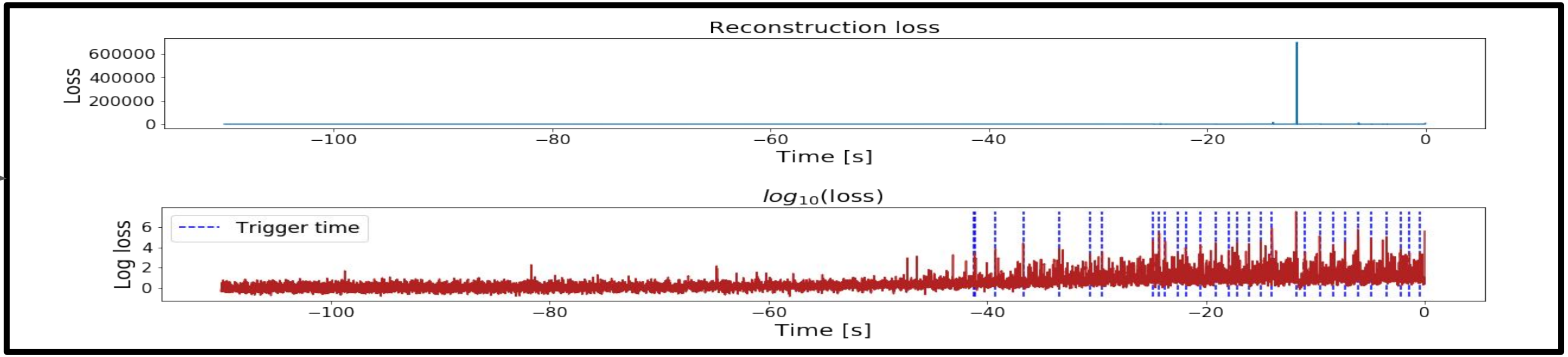
Latent space



Problem with “static learning”

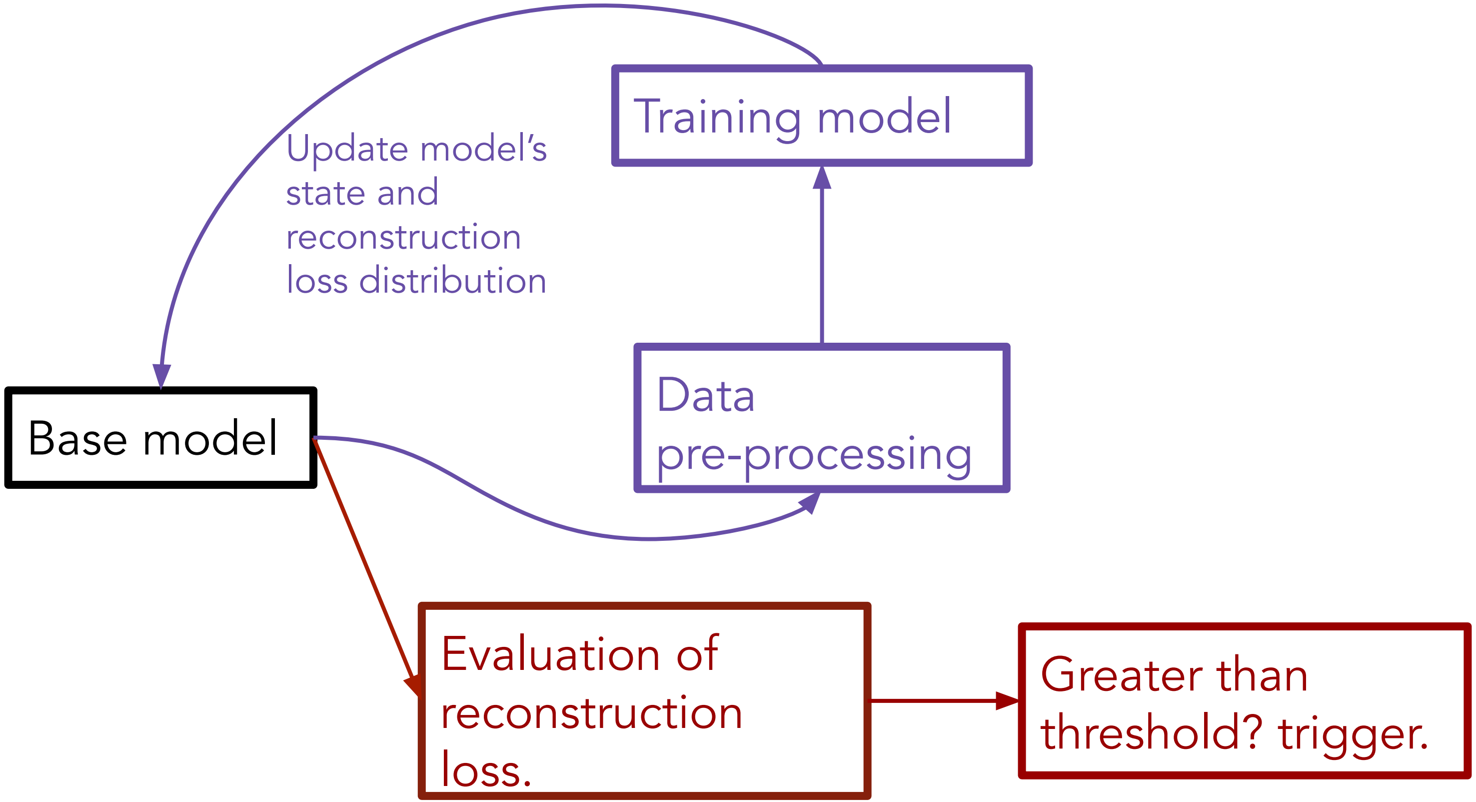
A threshold on one ramp doesn’t work with the other





Dynamic learning

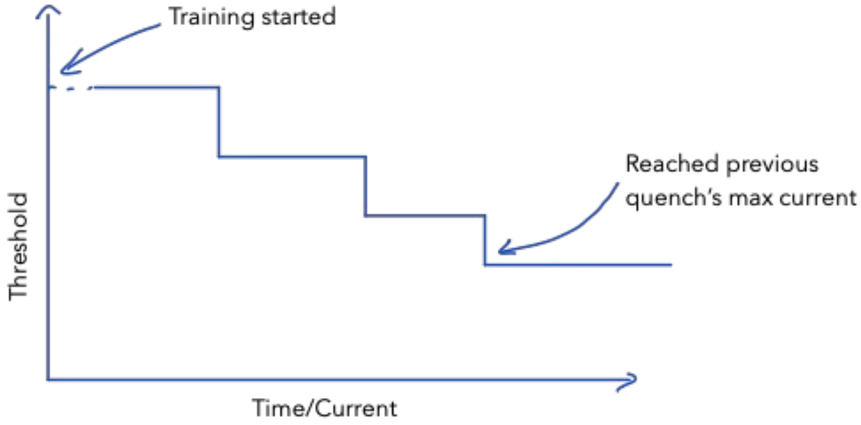
For each 10-second section



Dynamic threshold

2 motivations:

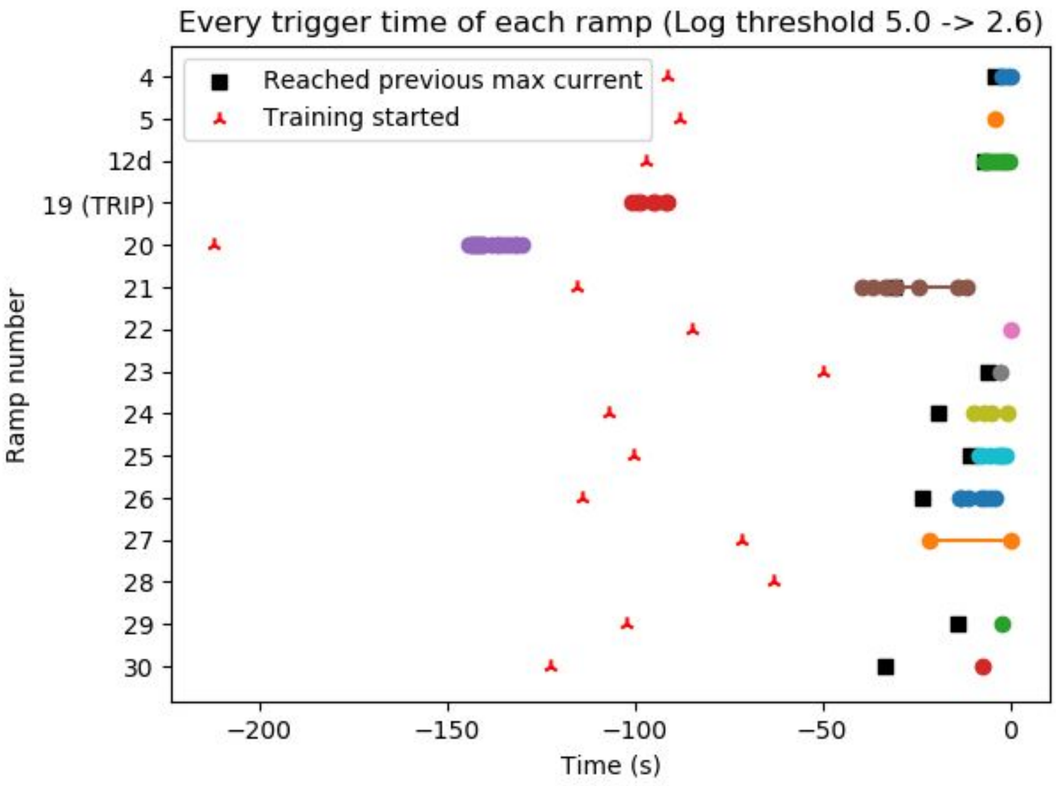
- Intuitively, more energy will be required to quench the magnet at lower current ->anomalous events at lower current will be less important.
- Prevent false positive early on, since if we train on a very quiet section then a small blip can make the reconstruction loss blow up.



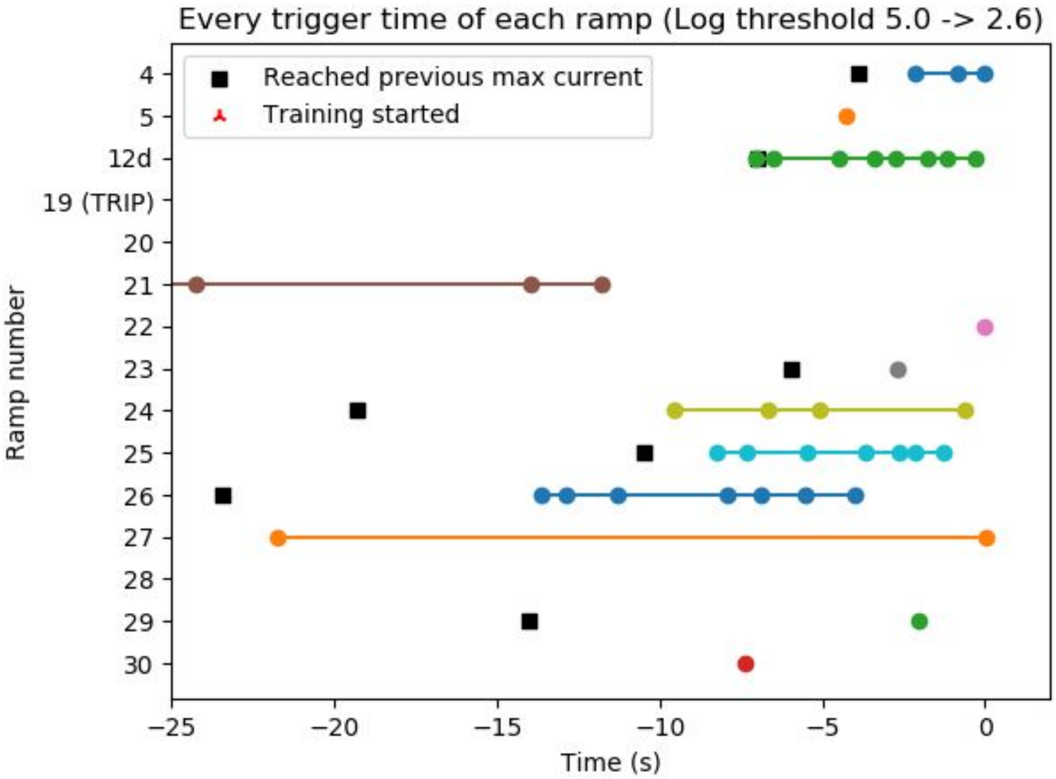
Procedure

- **Objective:** define a set procedure, and use it on unseen data to see what happens.
- Started the algorithm (dynamic learning & thresholding) when reached **9/10 max current** of previous ramp.
  - We’re just operating under a magnet training conditions.
  - The quench in the next ramp usually would not drop very significantly in this context.

Try procedure on Mqxfs1

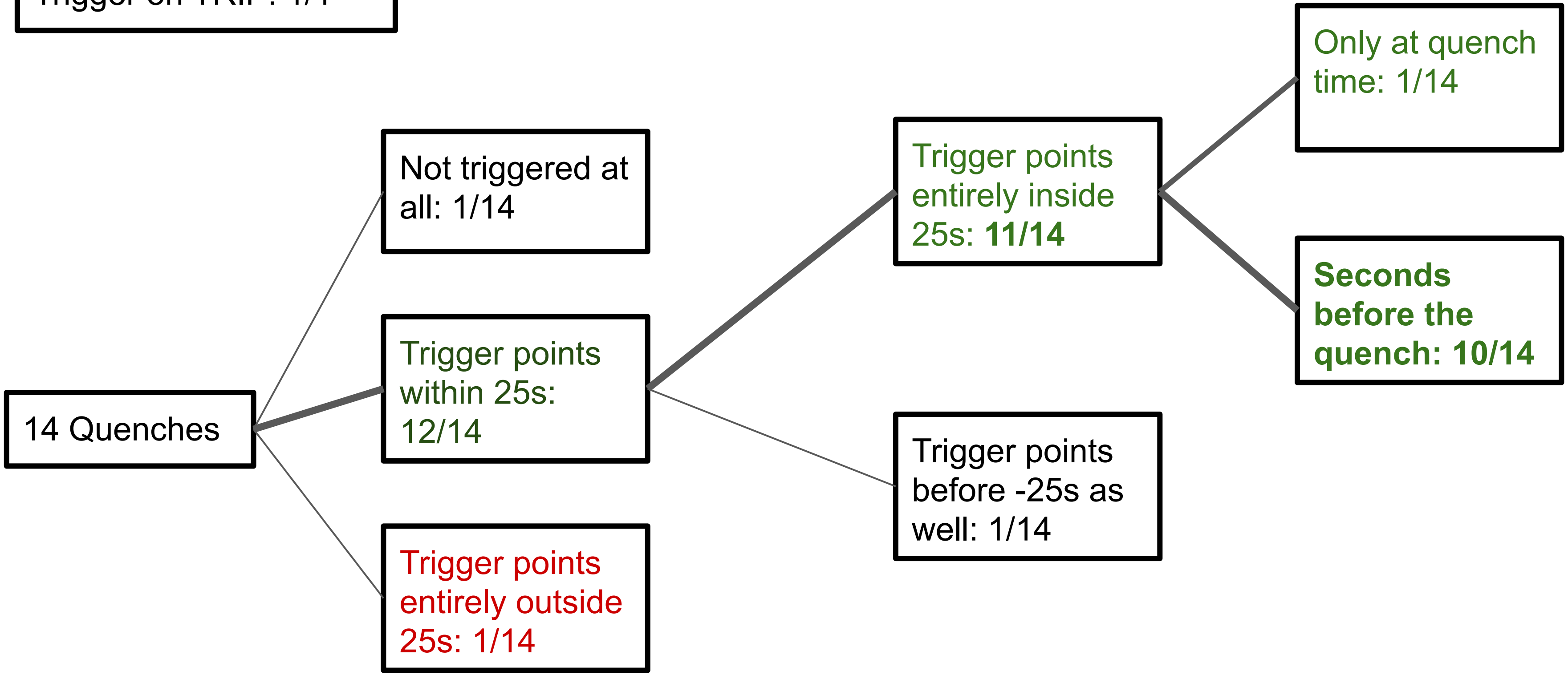


Mqfsx1d -- zoomed in (-25,0)

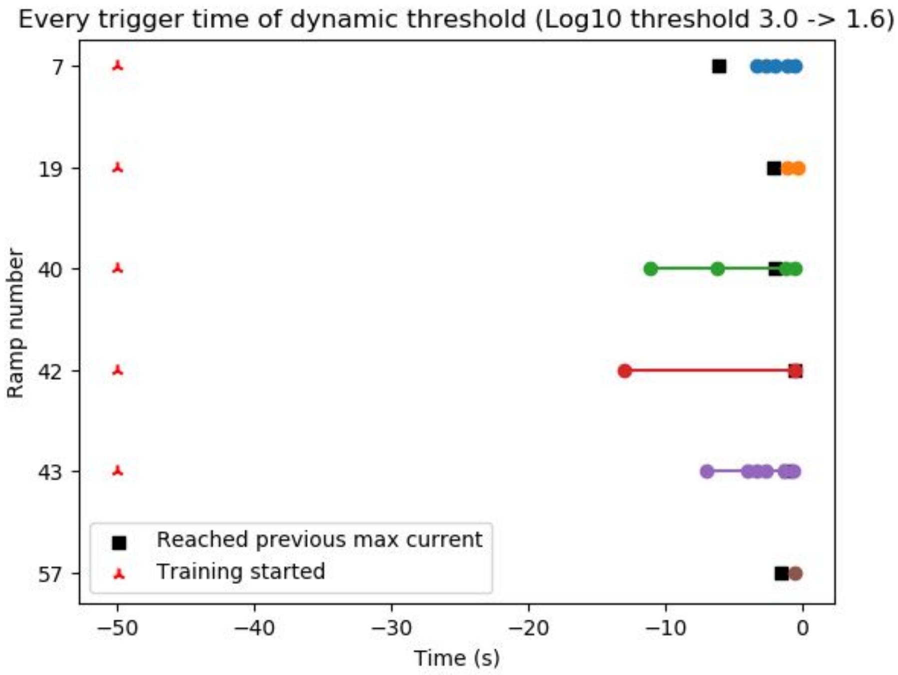


Summary

Trigger on TRIP: 1/1

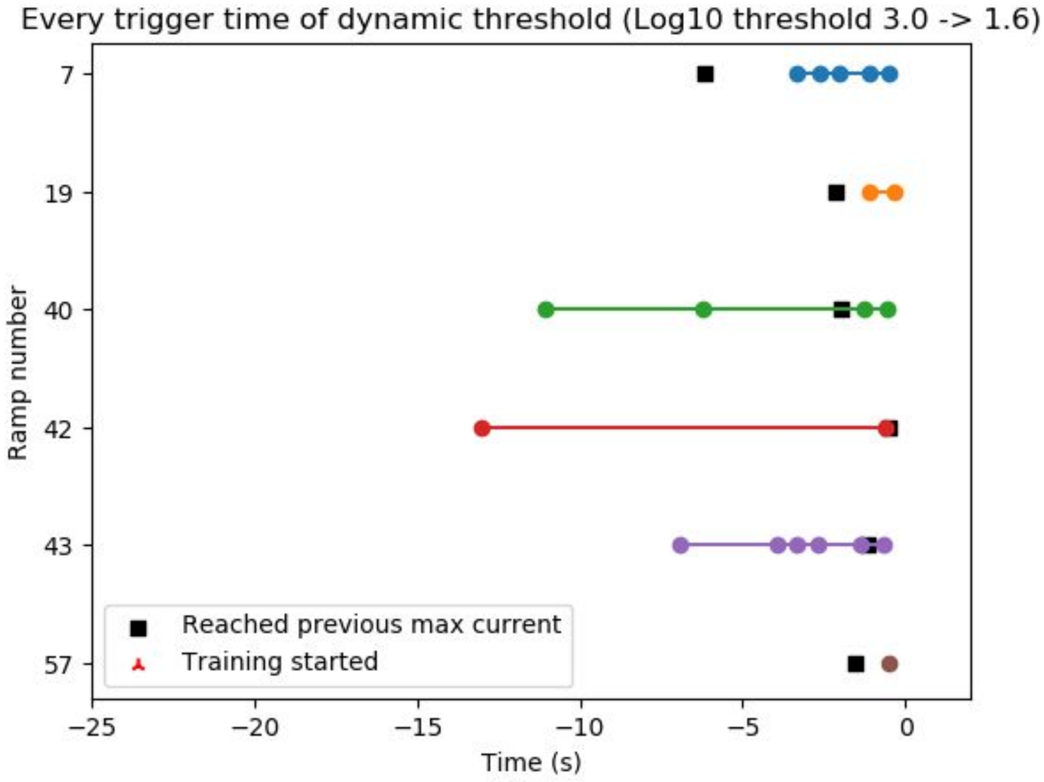


Try procedure on 6 randomly picked ramps in 15T



Fit thresholds on these 6 ramps, and then see how it performs on every other ramps.

15T - zoomed in (-15,0)



Conclusions

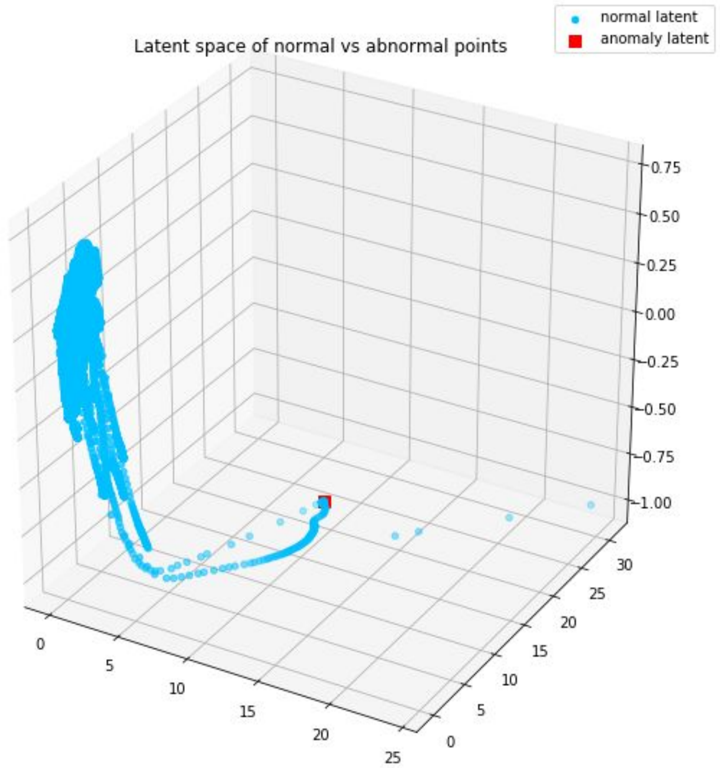
- We investigated DNNs for anomaly detections in acoustic data of 2 magnets: “Mqxfs1” & “15T”, and found anomalous events near the quench.
- We design a realistic incremental-learning workflow for real-time processing of acoustic data.
- We will be verify the procedure on new data & study the detected events.
- Data analysis tools & processing software in Python are also available.
- We’ll also explore the latent space both for unsupervised classification & real-time monitoring.

Future studies

1. Study & understand the detected anomaly points, and its relationship with the quench.
    a. One interesting thing to do is to investigate the latent space & its relationship with the inputs.
2. Improve data taking process & create a clean and structured data set.
3. Fancier models (Conv1D, RNN,...) & applications (modelling of magnet's acoustic response).

Back-ups

Latent space in Mqfsx1d (more inputs)



Performance on first few ramps in 15T