Using an autoencoder to study events during superconducting magnet training

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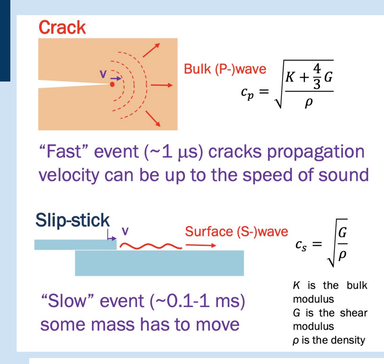
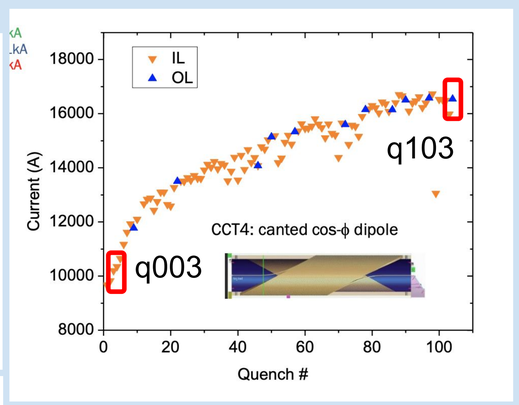
Goal: understand magnet training process

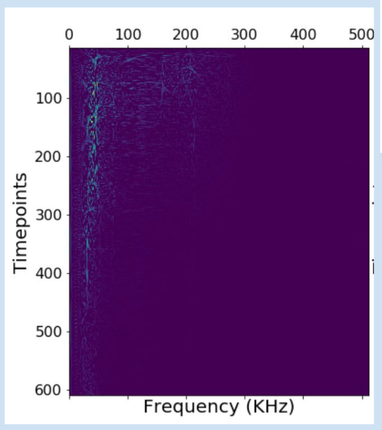
- Superconducting magnets require an expensive and lengthy training procedure to reach the operational design current
- Physics is not well-understood
- Goal: see if it is possible to identify physics using acoustic events generated in the training process

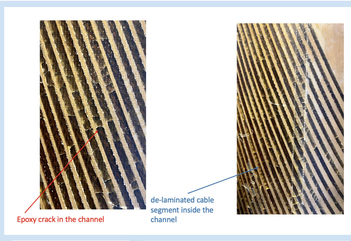


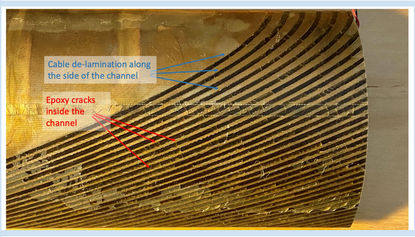


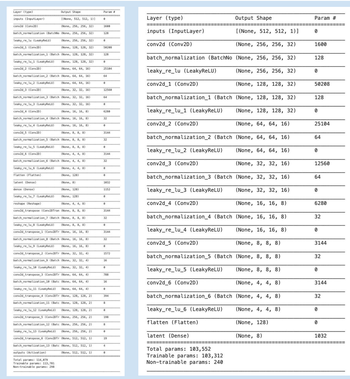
Methods- autoencoder + PCA

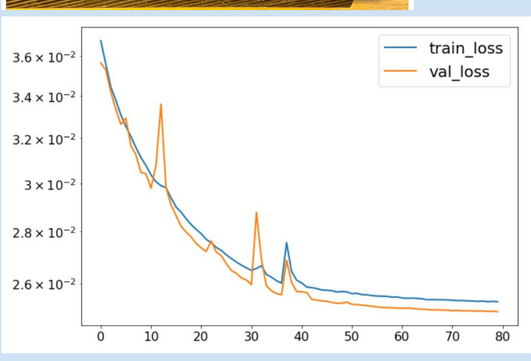
- This is an unsupervised problem
- Data are spectrograms from acoustic recordings (frequency vs time) at sample rate of 1 MHz
- Spectrograms are treated like images (may or may not be good assumption)
- Data were not normalized, but network used batch normalization in every layer
- Examing data from early training quench (003), late training quench (103), and post-quench
- Use autoencoder to look for clusters in the data
- Used 14 layer autoencoder (symmetrical 7 layer encoder + 7 layer decoder)
- Encoded 8-dimensional latent space
- Used binary cross-entropy loss
- Notebooks and analysis at https://github.com/lastephey/magnet-notebooks/tree/master/conv2d-autoencoder

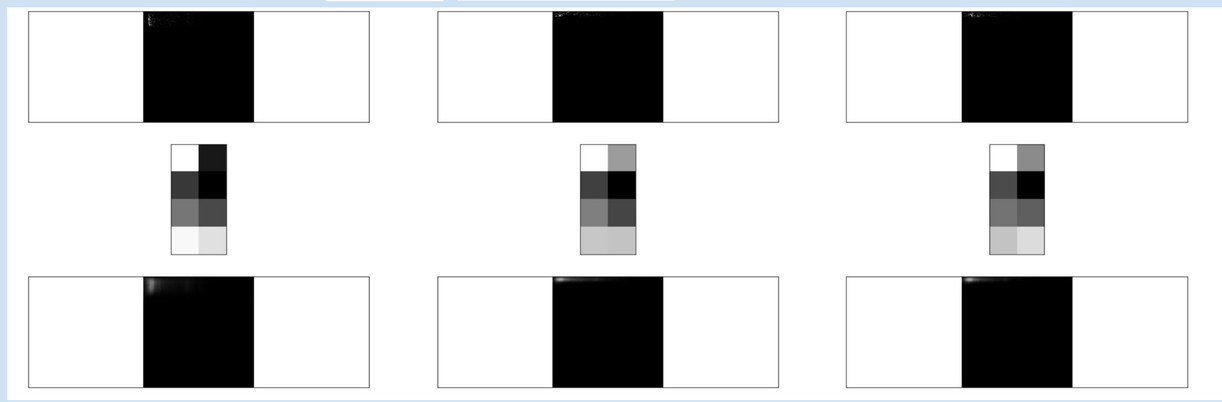






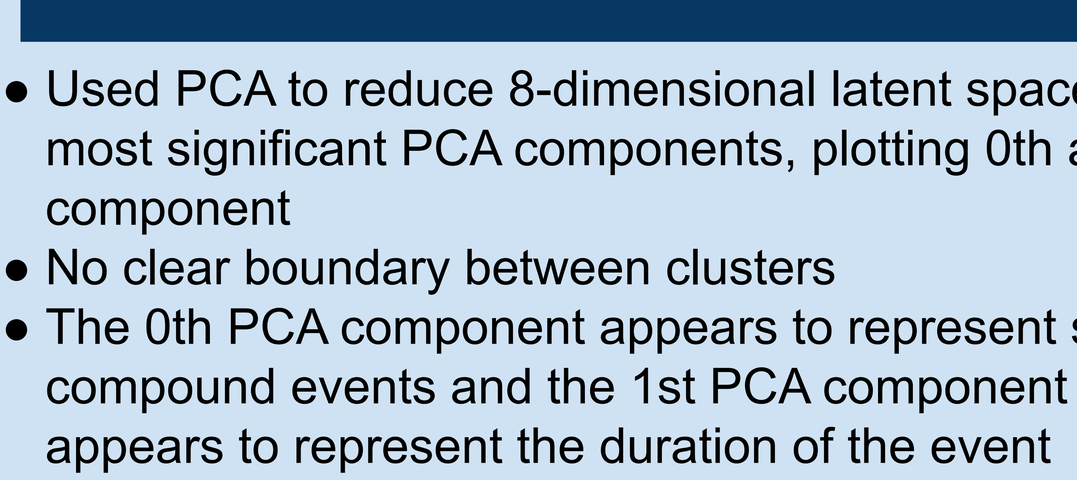






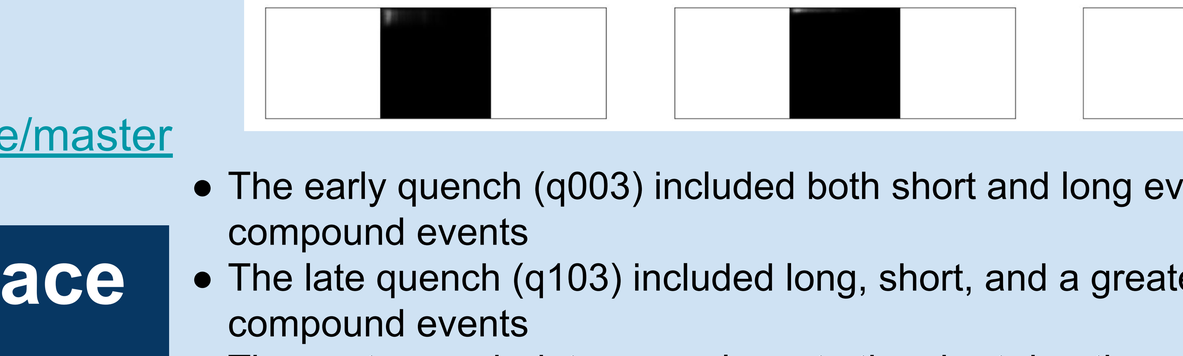
PCA in autoencoder latent space

- Used PCA to reduce 8-dimensional latent space into 2 most significant PCA components, plotting 0th and 1st component
- No clear boundary between clusters
- The 0th PCA component appears to represent single or compound events and the 1st PCA component appears to represent the duration of the event



- The early quench (q003) included both short and long events but few compound events
- The late quench (q103) included long, short, and a greater number of compound events
- The post-quench data were closer to the short duration events and did not fall in the compound event region
- Based on results from additional processing for q003 and q103:

1. Events late in training concentrated in the single event region
2. High frequency events appeared in all regions
3. Events with many zero crossings appeared in the longer, compound event region
4. Events with higher energy (Umax^2) appeared at left side of PCA space
5. Events at high current (near end of training quench) lie in short, single events region (no current data for q003)



No current data for q003

Summary and future work

- 2d convolutional autoencoder compressing data into 8-dimensional space + PCA does appear to learn salient features of spectrograms, particularly the length of the event and number of events
- Consider using semi-supervised techniques, designing experiments to yield supervised/labled results
- Examine data from additional magnets