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

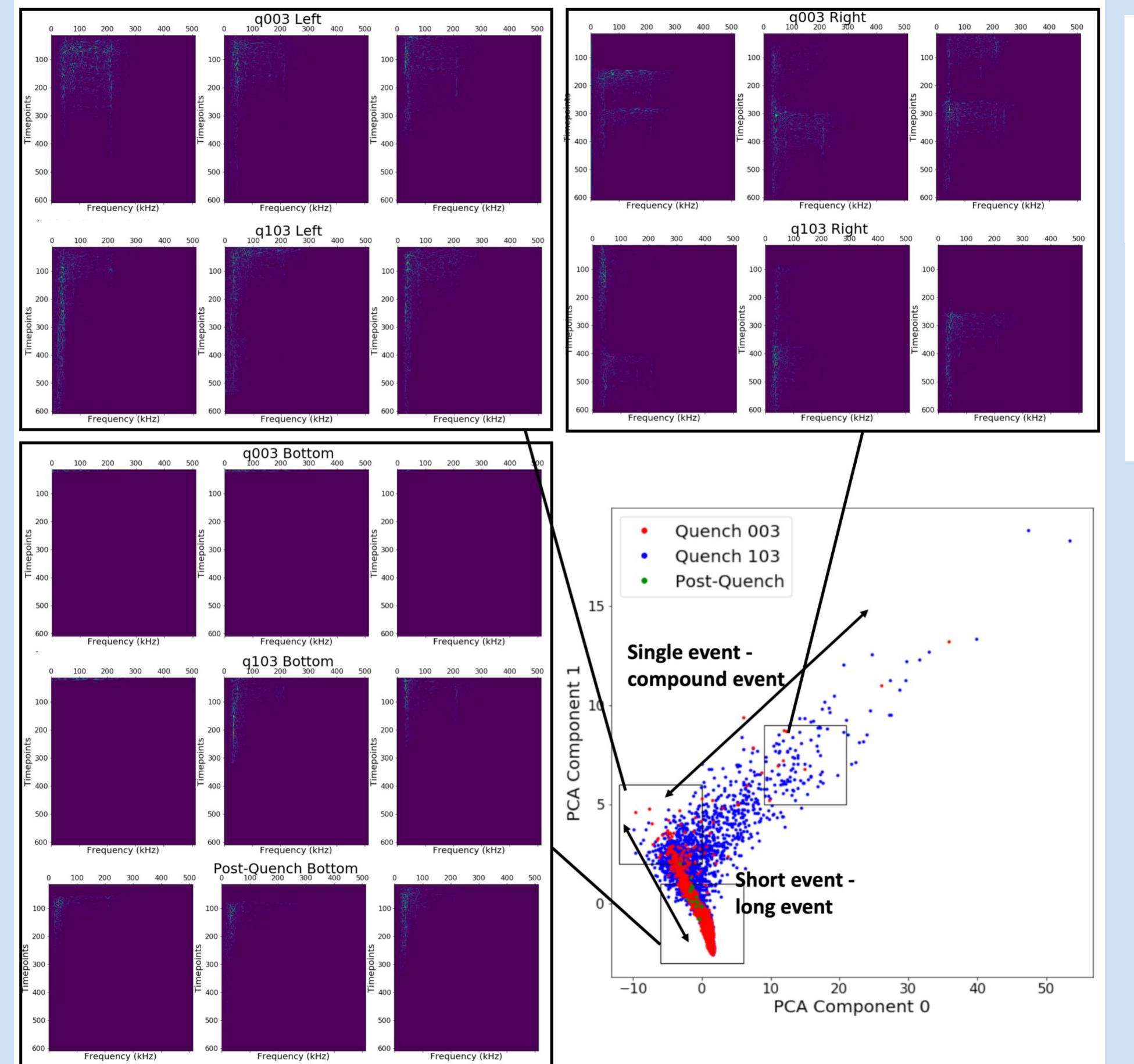
- This is an unsupervised problem
- Data are spectrograms from acoustic recordings (frequency vs time) at sample rate of 1 MHz
- Spectrograms are treated like images (may or may not be good assumption)
- Data were not normalized, but network used batch normalization in every layer
- Examing data from early training quench (q003), late training quench (q103), and post-quench (pq)
- 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

/conv2d-autoencoder

 Notebooks and analysis at <u>https://github.com/lastephey/magnet-notebooks/tree/master</u>

PCA in autoencoder latent space

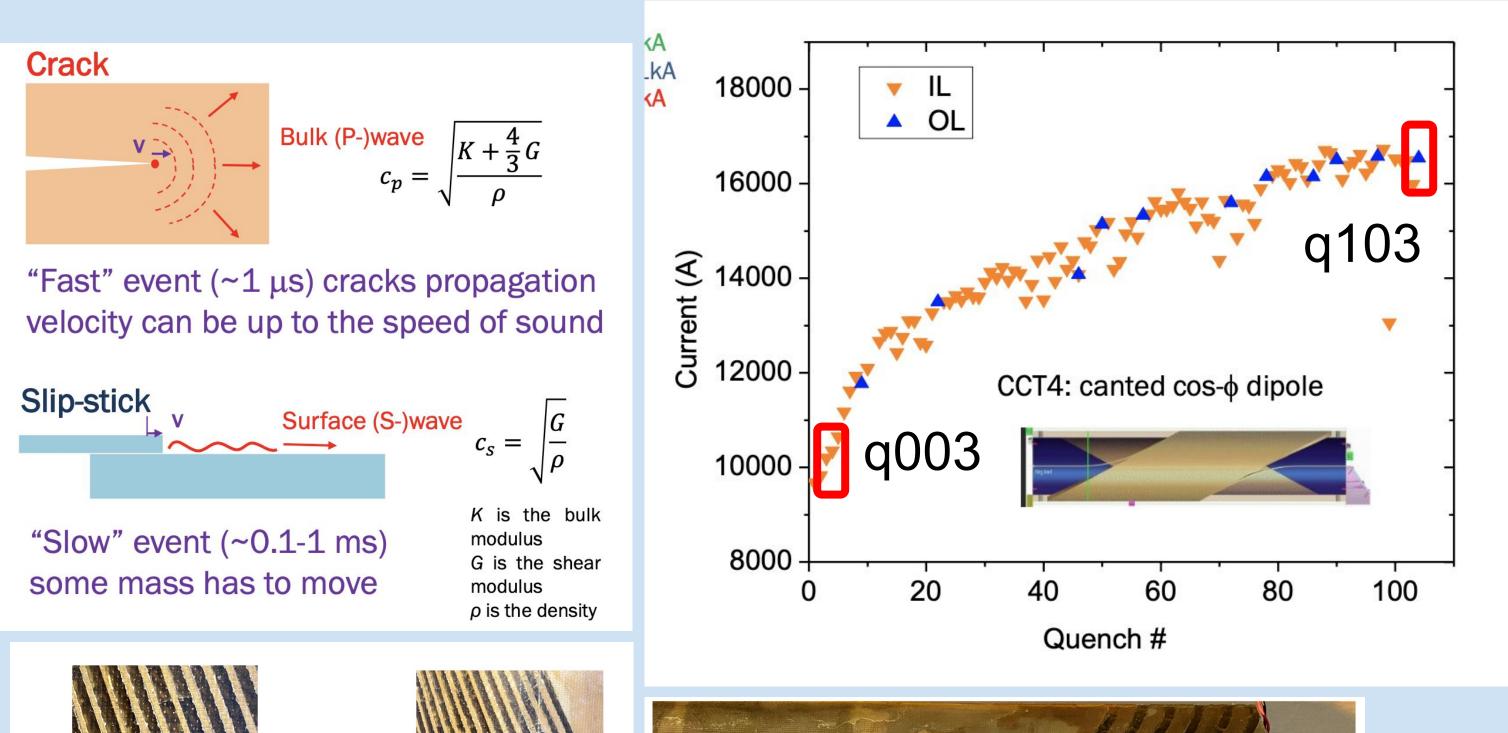
- Used PCA to reduce 8-dimensional latent space into 2 most significant PCA components, plotting 0th and 1st component
- No clear boundary between clusters
- The 0th PCA component appears to represent single or compound events and the 1st PCA component appears to represent the duration of the event

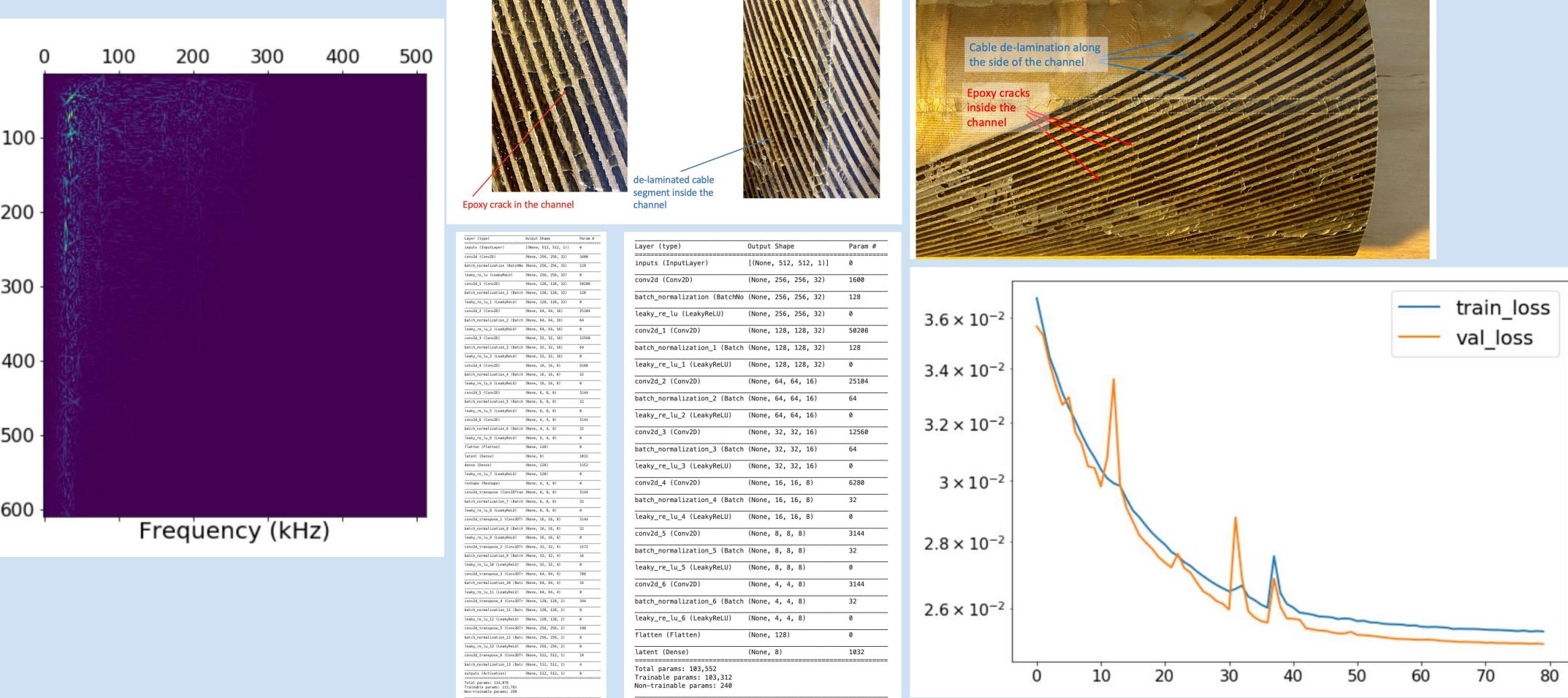


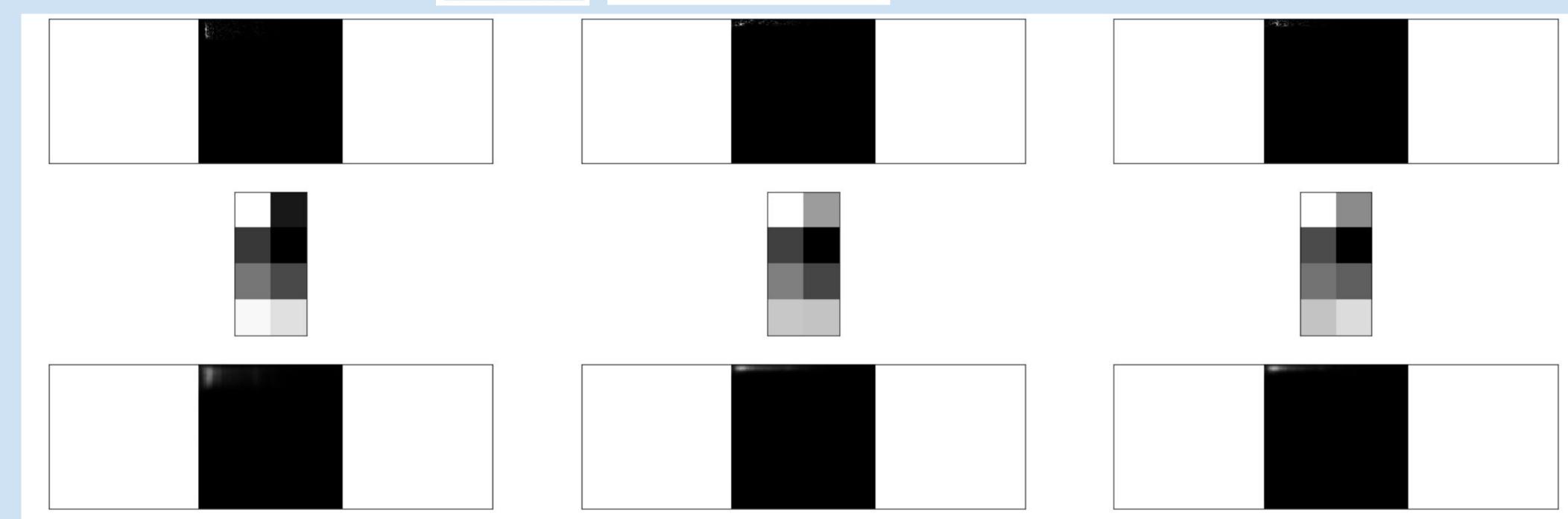




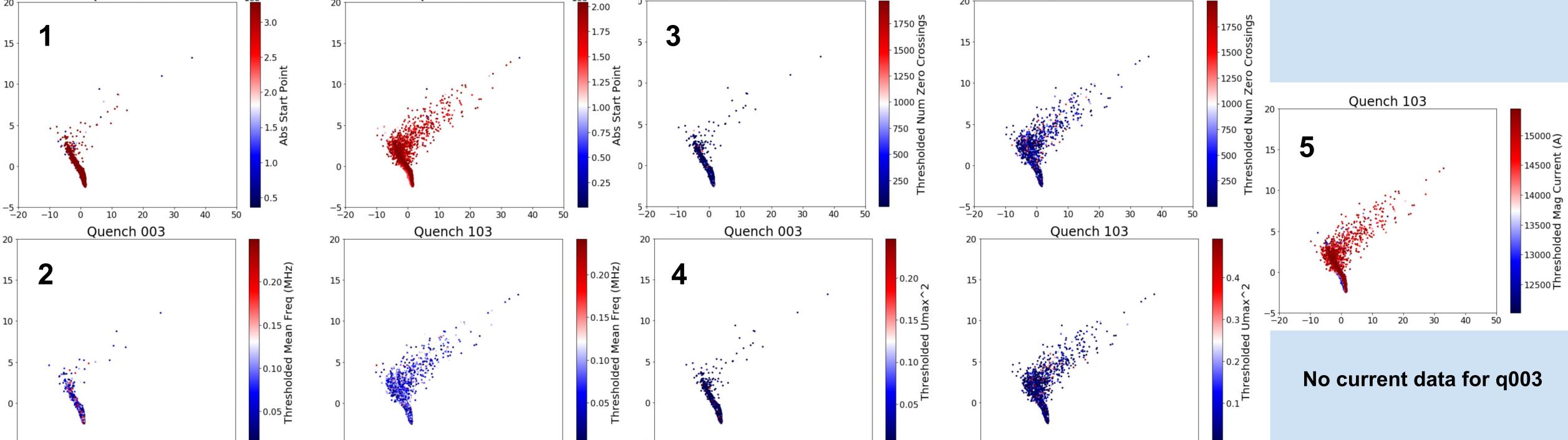








- The early quench (q003) included both short and long events but few compound events
- The late quench (q103) included long, short, and a greater number of compound events
- The post-quench data were closer to the short duration events and did not fall in the compound event region
- Based on results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



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