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Characterizing Acoustic Signals in the Buildup to a Magnet Quench

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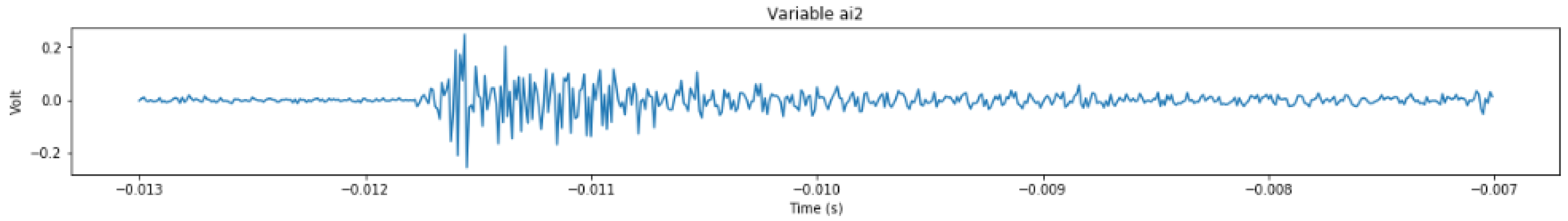
What is a magnet quench? Why do we care?

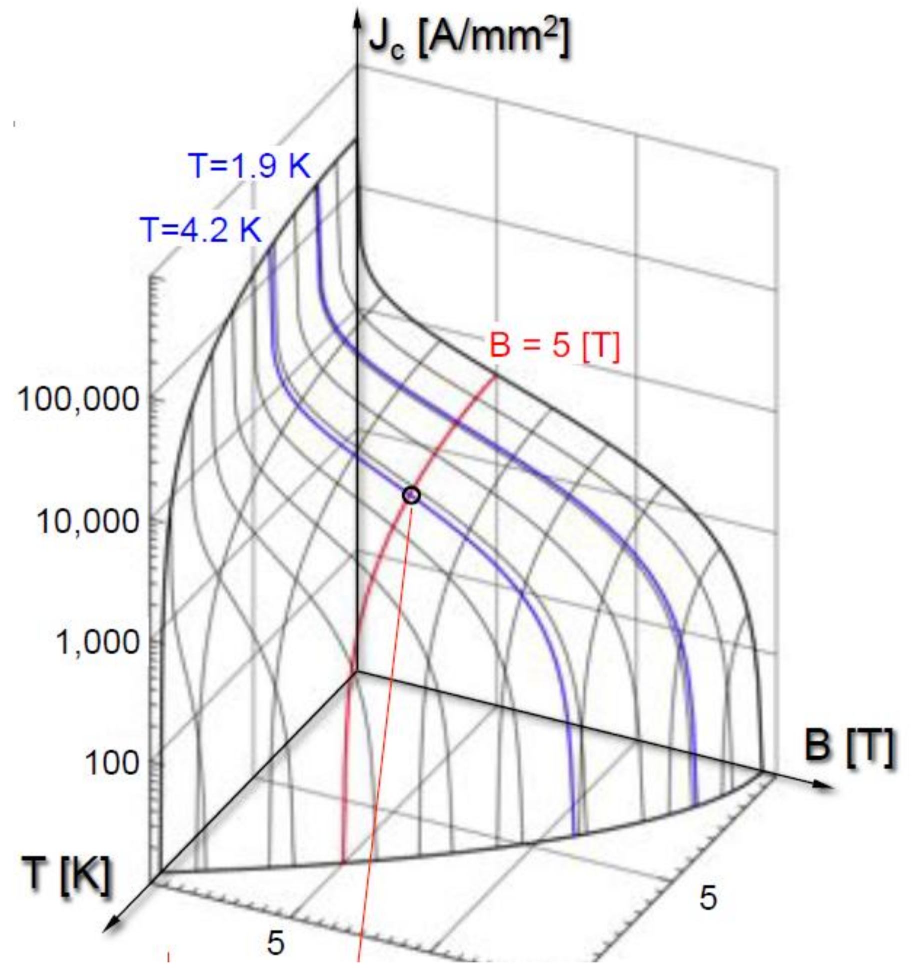
Superconducting magnets are needed to provide the powerful magnetic fields that direct particles on curved paths at the world's most powerful accelerators. Imperfections or natural limitations can cause the magnet to lose its superconductivity. The transition to a non-superconducting state is called a quench; it is quite costly, but its exact reasons are still poorly understood. Learning more about the buildup to a quench may help us improve our understanding of the drivers of superconducting magnet performance.

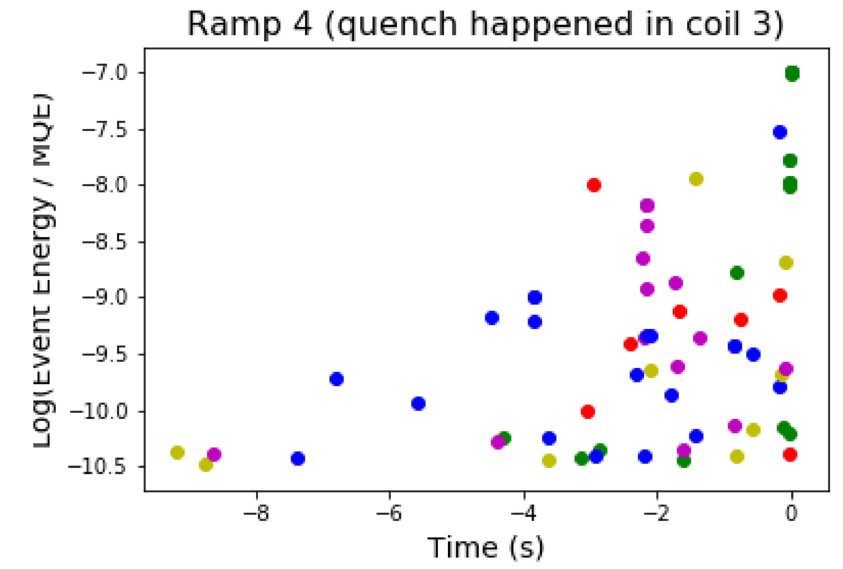
What can acoustic signals reveal about the buildup to a quench?

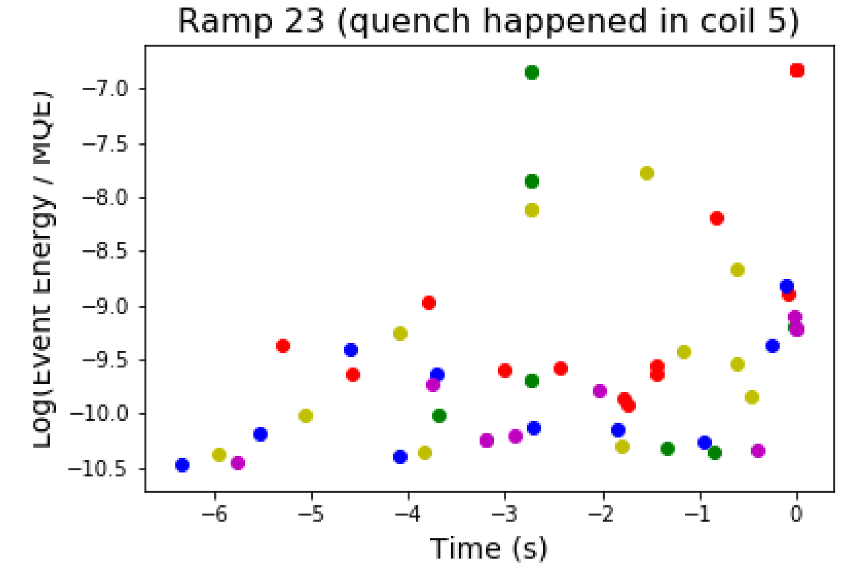


Sensors placed on the ends of the magnet (which is shaped like a long cylinder) frequently detect sound waves originating from within the magnet. An example of an acoustic event is shown above. These events are an important source of information regarding what is happening inside the magnet as it trains.

The minimum quench energy (MQE) is a theoretical construct that estimates the amount of energy needed to quench the magnet. The critical surface shown below is a key component used to compute MQE in a given situation. (Source: Martin Wilson, "Superconducting Magnets for Accelerators")

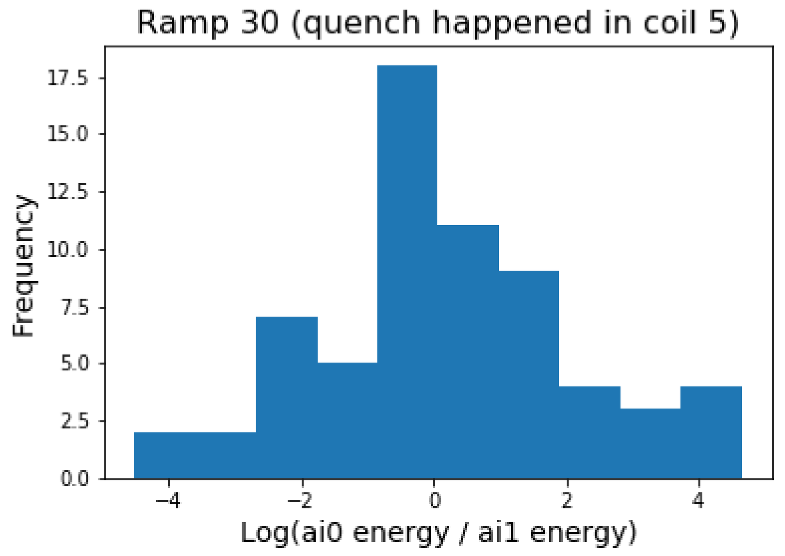


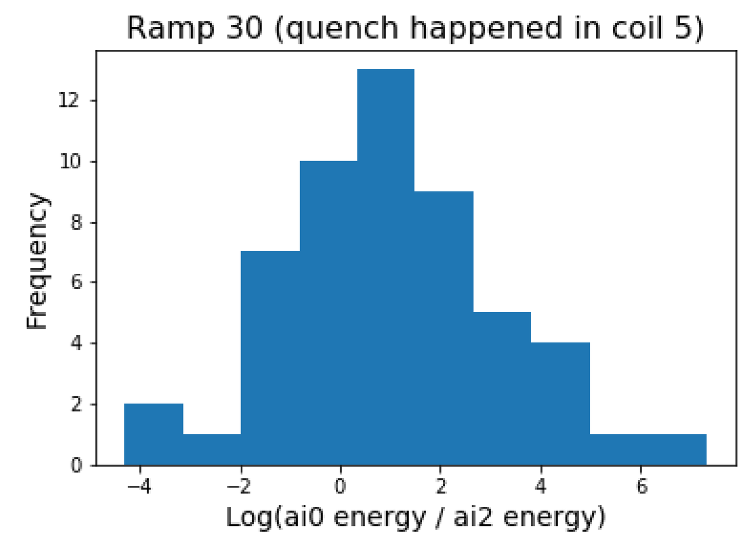




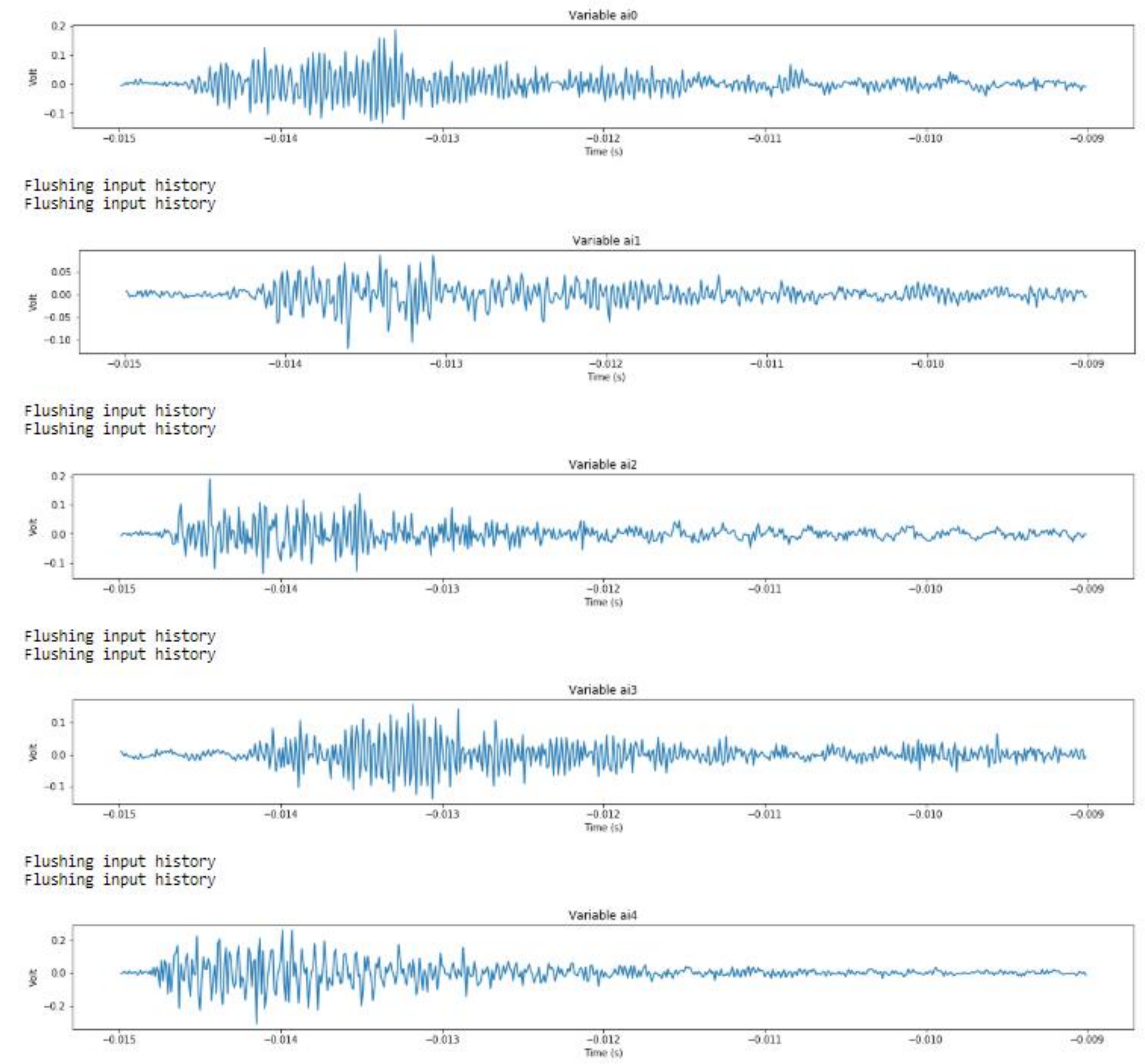
By comparing the "energies" of acoustic signatures with the MQE at the time at which they occurred, we can see how events tend to become stronger relative to the MQE as time passes. However, the nature and strength of this trend is very different for different cases leading to a quench, and there are often "outlier" events which are much stronger than one would expect for a given time. Why such events did not trigger the quench earlier remains unknown.

What are the limitations of the acoustic data? How do they restrict our ability to derive understanding from the signals?





If the event energy in a given sensor were a consistent function of the distance from the event origin to the sensor, then the distribution on the left (which compares two sensors on the same side of the magnet) should be much narrower than the one on the right (which compares two sensors on opposite sides of the magnet).



The acoustic events, even the ones we think we understand (such as those occurring just before a quench), show far more variability than previously thought in terms of their durations and their relative strengths in the different sensors. This makes it very difficult to develop a useful and consistent notion of the "strength" of an event.

This event shows up strangely early in ai0; given the locations of the sensors, it should show up in ai0, ai1, and ai3 at about the same time. This leads to fundamental concerns about the validity of the sensor data and what other sources might be contributing to these acoustic signals.

What are the logical next steps to further our knowledge?

A number of possible directions exist for future investigation. They include:

- Setting a real-time calibration source to improve quality of data
- Determining whether the generally increasing trend of acoustic "energy" relative to MQE can be turned into a quench prediction mechanism
- Developing more sophisticated techniques to estimate the origin location of an event

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