Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

Intelliquench – Real Time detection of magnet quenches in superconducting radio frequency magnets.

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SIST Project Introduction

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U.S. MAGNET DEVELOPMENT PROGRAM

Outline

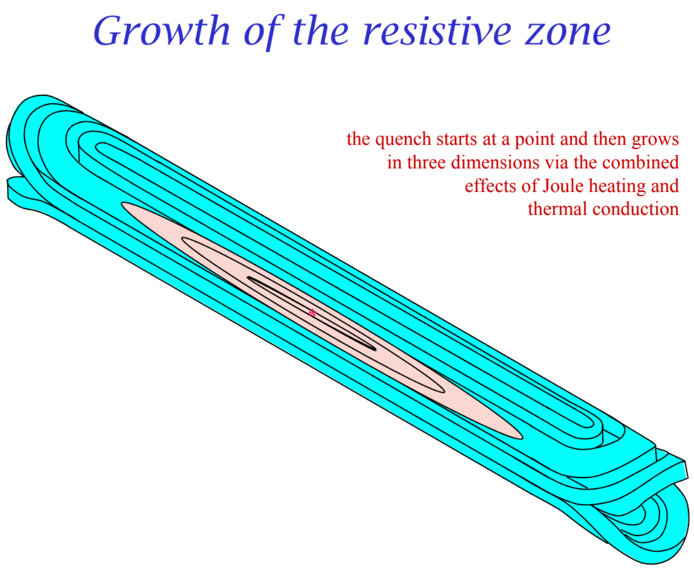
1. What are magnet quenches?
2. Consequences of magnet quenches.
3. Acoustic sensors (small microphones).
4. Deep Neural Network for monitoring acoustic signals to detect quenches.
5. Summary & Outlook

Magnet quenches

- Superconducting accelerator magnets must operate at **very low temperatures** to maintain superconductivity (**no resistance**).

- Due to several reasons (mechanical errors, conductor motion, …), a **specific spot** in the magnet **heats up.**

- This causes the magnet to become **resistive**, and with **huge amount of current** pumping through, it can be catastrophic.

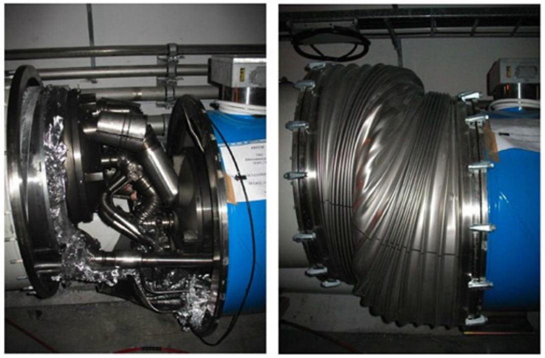


Wilson et al. Superconducting magnets for accelerators.

r/CatastrophicFailure

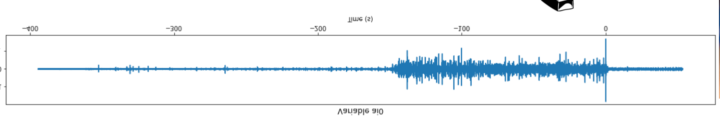
In **2008**, magnet quench occurred in **100 magnets at the LHC at CERN**, leading to a loss of approximately **six tonnes** of liquid helium.

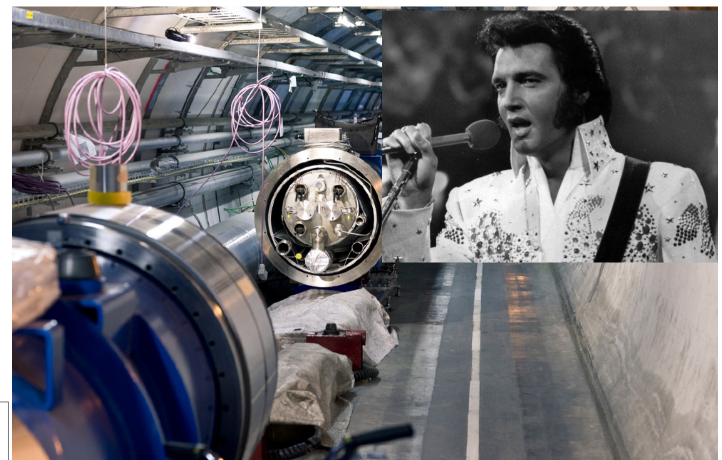
The escaping vapour expanded with **explosive force**, damaging a total of 53 superconducting magnets (each costs **several millions dollar**.)



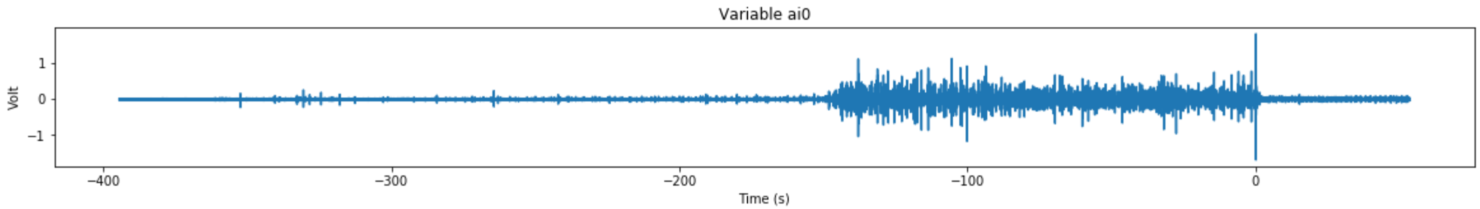
Acoustic sensors

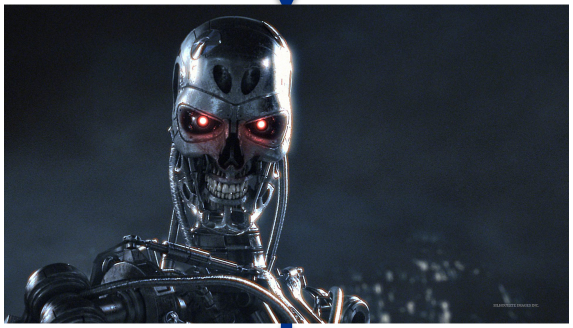
- We placed **5 tiny microphones** around the magnet to detect **abnormal sound signatures**.





Deep Neural Network to detect anomaly in the signal.





Deep Neural Network

Abnormal sound signals?

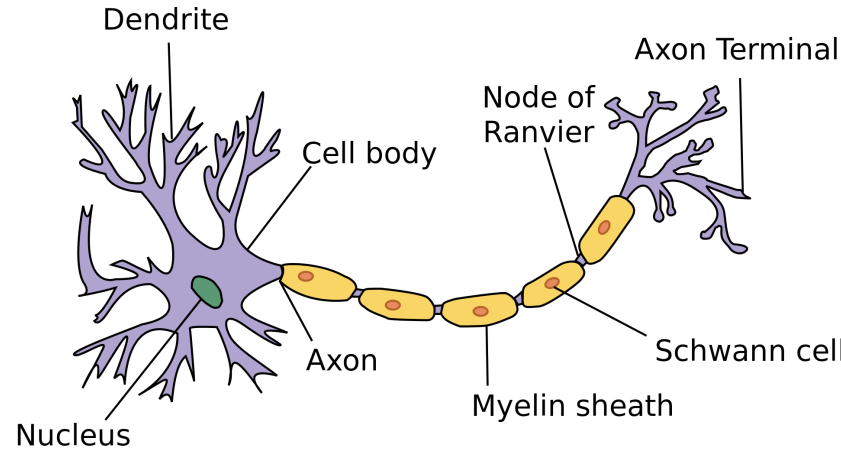
Summary & Outlook

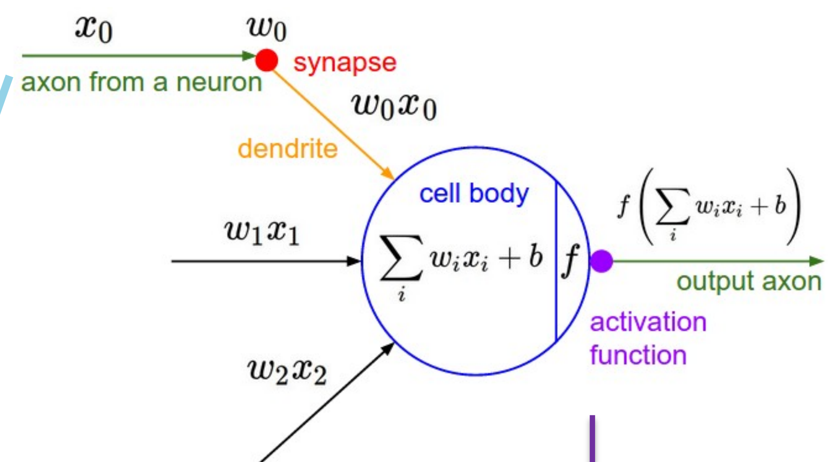
1. Magnet quenches **are expensive**.
2. We are using Deep Neural Network to **detect anomaly sound signals**, which hopefully enable us **to predict the quench**.

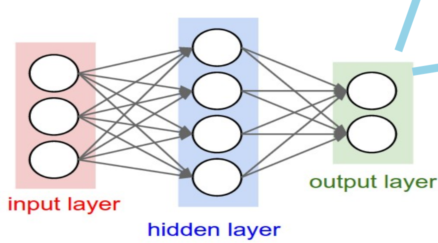
Back-ups

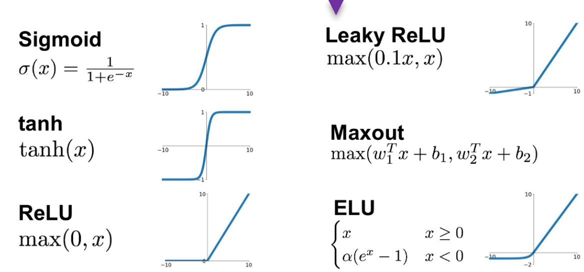
Deep Neural Networks

- Fully connected architecture
- Each **input** multiplied by a **weight**.
- **Weighted values** are summed, **Bias** is added.
- Non-linear **activation function** is applied
- Trained by varying the **parameters** to minimize a loss function (quantifies how many mistakes the network makes)









DNN Auto-encoder