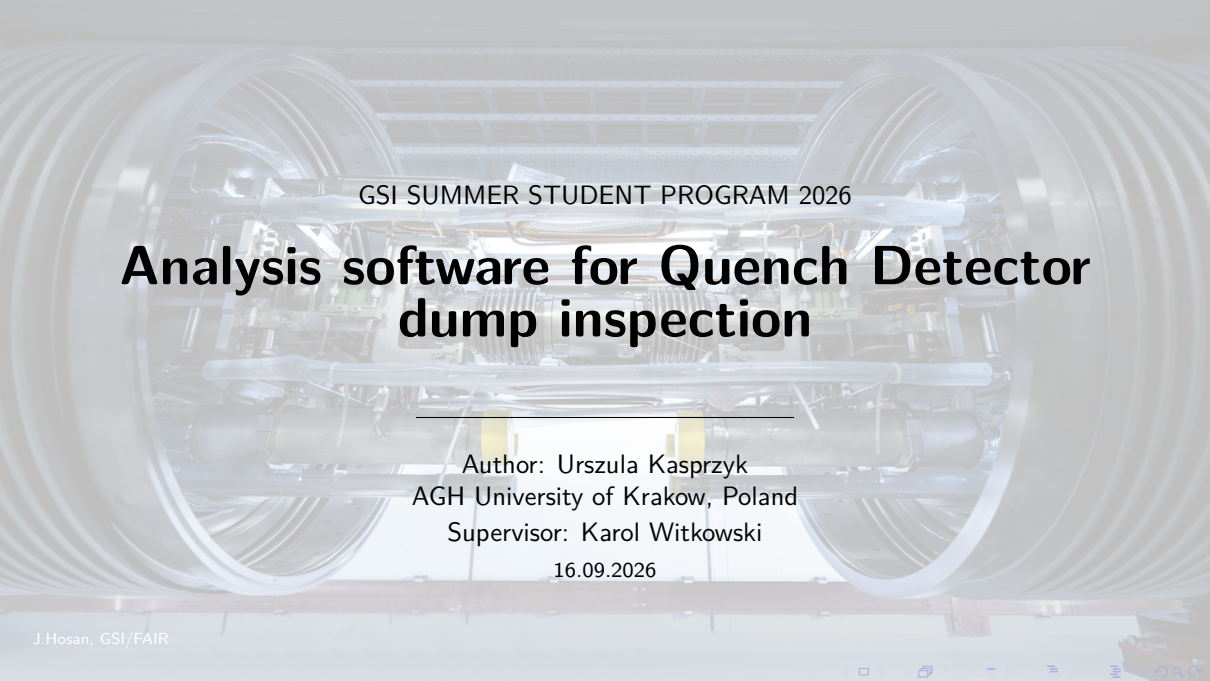




GSi SUMMER STUDENT PROGRAM 2026

Analysis software for Quench Detector dump inspection

Author: Urszula Kasprzyk
AGH University of Krakow, Poland
Supervisor: Karol Witkowski

16.09.2026

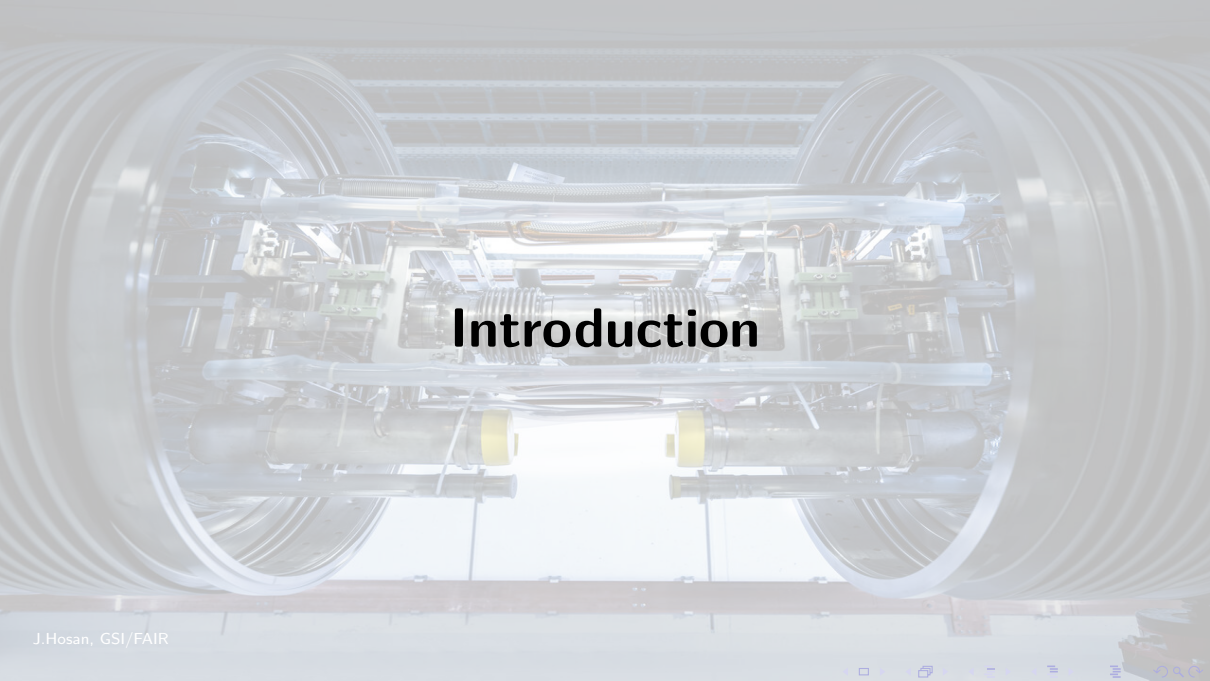
Table of contents

- 🐱 Goal of the project
- 🐱 Introduction
 - 🐱 Superconductivity
 - 🐱 Quench
 - 🐱 Quench detection system
- 🐱 Application improvement
 - 🐱 Example of quench dump
- 🐱 Summary

Goal of the project

Increase **efficiency of data analysis** from quench detection system dumps

Developing software and implementing **new functionalities** facilitating user experience



Introduction

Accelerator magnets

Primary function in the beamline

Dipole magnets

Quadrupole magnets

Higher-order magnets, multipoles

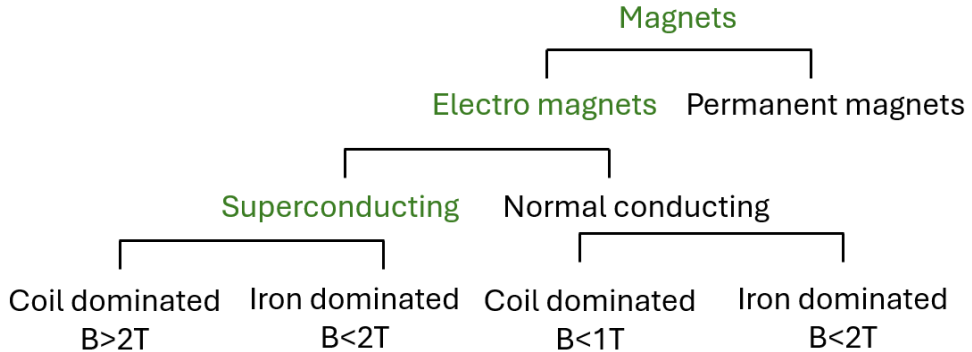
Technological and thermodynamic perspective

Warm (Resistive)

Limited by Joule heating, resistive power losses

Cold

Able to reach much higher fields than warm magnets



Superconductivity

State in with material has two essential features

- zero electrical resistance,
- Meissner effect.

This properties allow superconductor to deal with the current without the **energy loss**, making them ideal material for generation of **strong and stable magnetic field**.

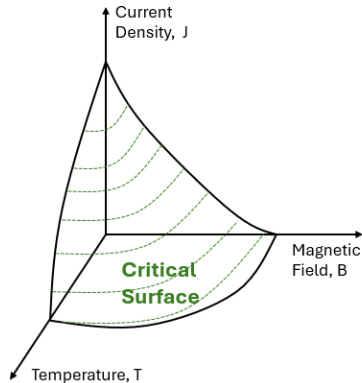


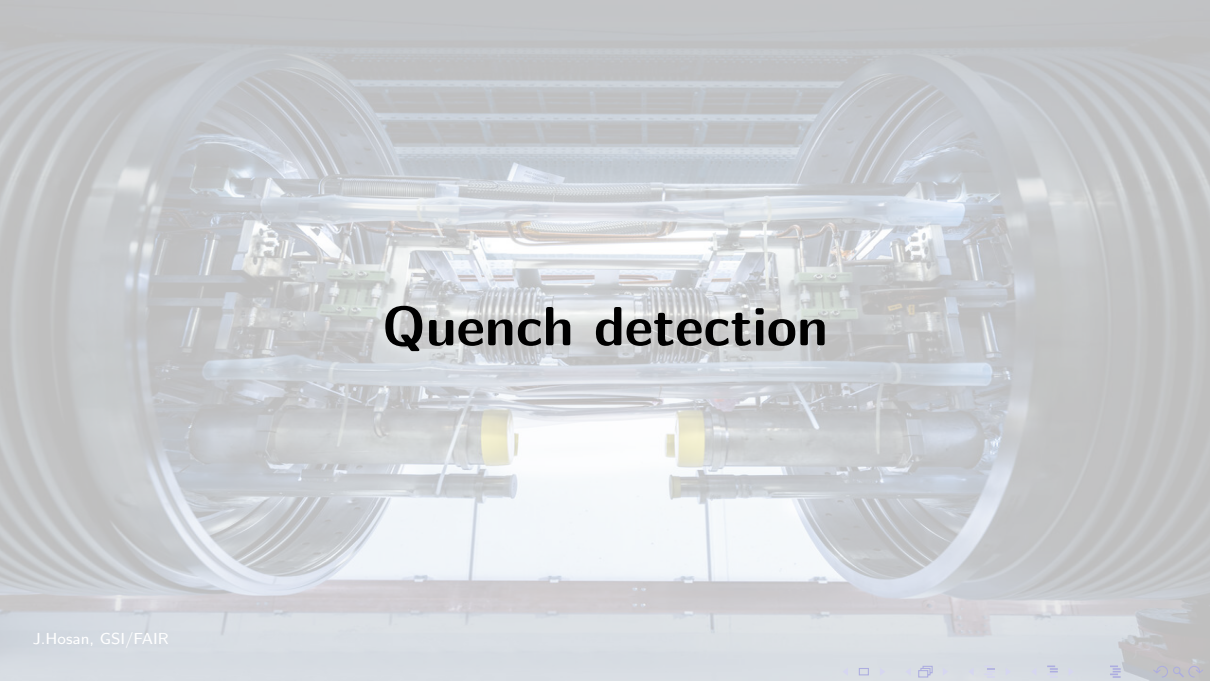
Figure: Critical temperature, current density, and magnetic field boundary separating superconducting and normal conducting states

Quench

Sudden transition of a superconducting material to its normal (resistive) state.

In consequence to occurrence of the quench

- 🐱 Superconductor **lose its zero-resistance property** → **heat is generated**,
- 🐱 any malfunction of magnet can **lead to beam loss and cause further damage**,
- 🐱 superconductivity involves the use of liquid helium, which evaporates into a gas at higher temperatures, entailing the **risk of an explosion**.



Quench detection

Quench detection system

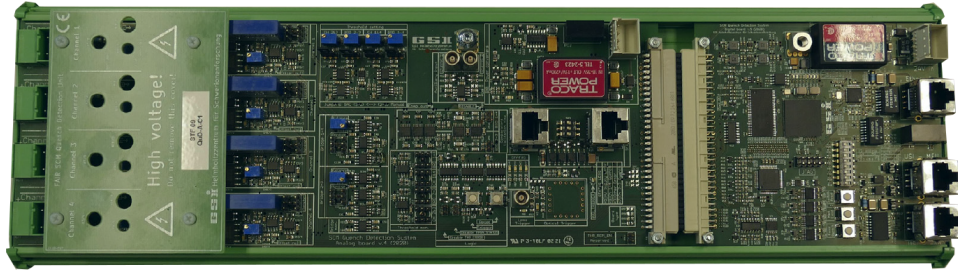


Figure: General view of the Quench Detection Unit: QuD-A board to the left and QuD-D board to the right [1].

At the FAIR facility the **voltage-based** measurement method will be use for the quench detection.

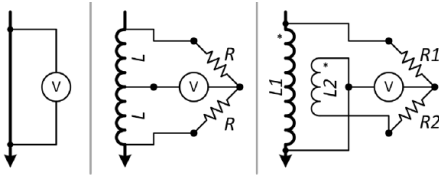


Figure: Three basic methods of quench signal pickup: direct measurement (left), bridge (middle) and mutual inductance detector (right) [1]

Depending on type of monitored component and its characteristic we can choose different approaches:

- 🐱 Direct monitoring
- 🐱 Bridge method
- 🐱 MID

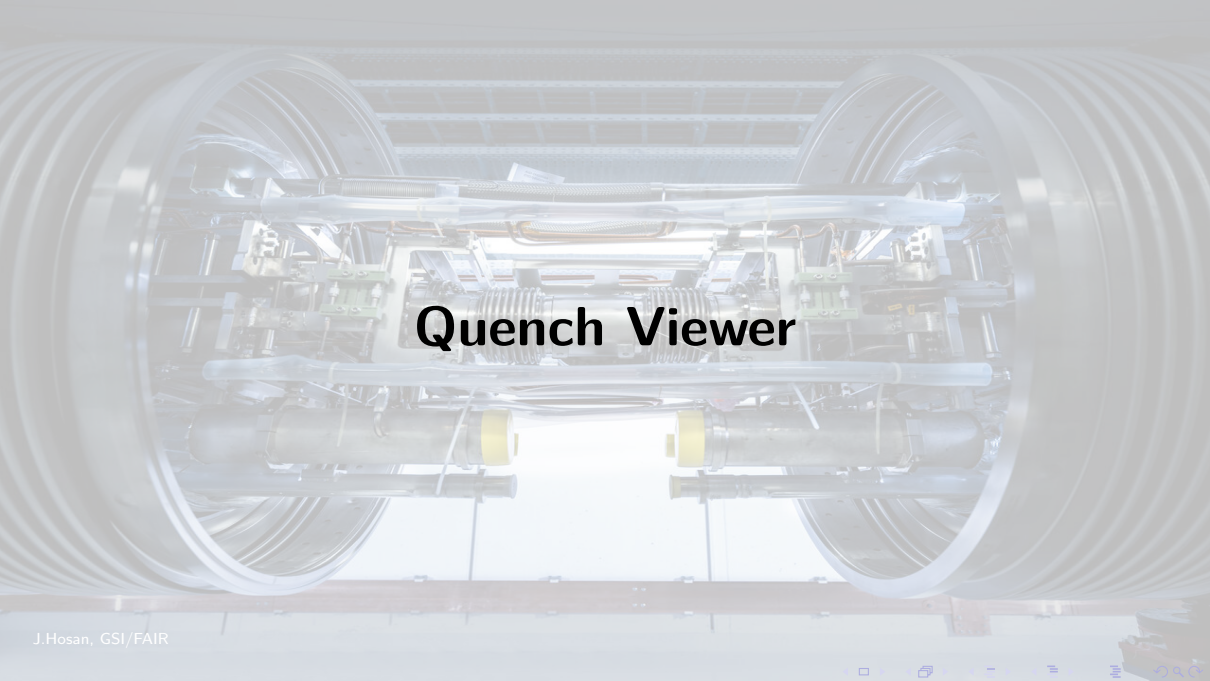
Why do we need a quench detection system?

Safety

- 🐱 Any magnet malfunction can lead to **beam loss and cause further damage** in the accelerator
- 🐱 Evaporated liquid helium (that occurs through the release of heat) entails **risk of an explosion**

Quench training

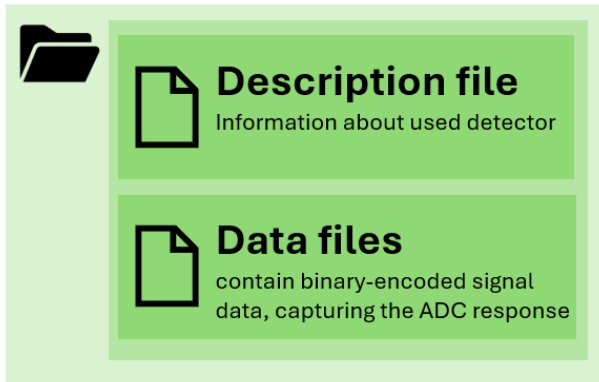
- 🐱 Enables magnets to be **operated in the nominal conditions**, without further premature quenching

A photograph of a complex scientific instrument, likely a particle detector, viewed through a circular opening. The instrument features a central cylindrical component with a ribbed texture, surrounded by various mechanical parts, including green and yellow components. The entire assembly is mounted on a metal frame. The text "Quench Viewer" is overlaid in the center.

Quench Viewer

Quench data structure

Each quench event is stored as the director containing multiple data files. Different **detector setups and configurations require different amount of files**



Application improvement

Architecture

🐱 Moving calculations from Python dictionaries to a vectorized pandas DataFrame lead to a **performance boost**

🐱 Replacing dynamic, row-by-row Python loops with optimized low-level operations, with use of **fast C-code**

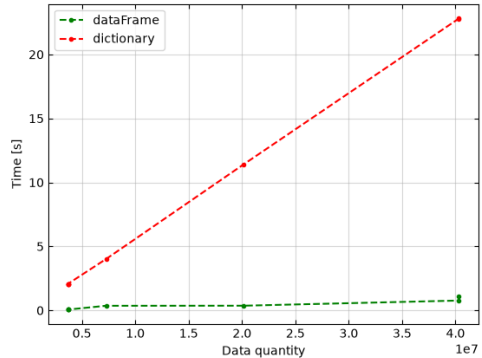
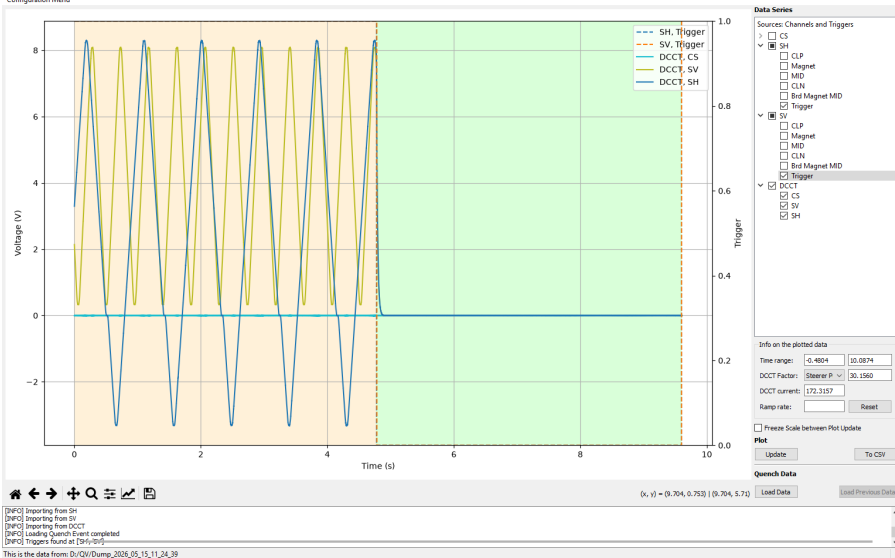


Figure: Change in speed performance in case of data quantity

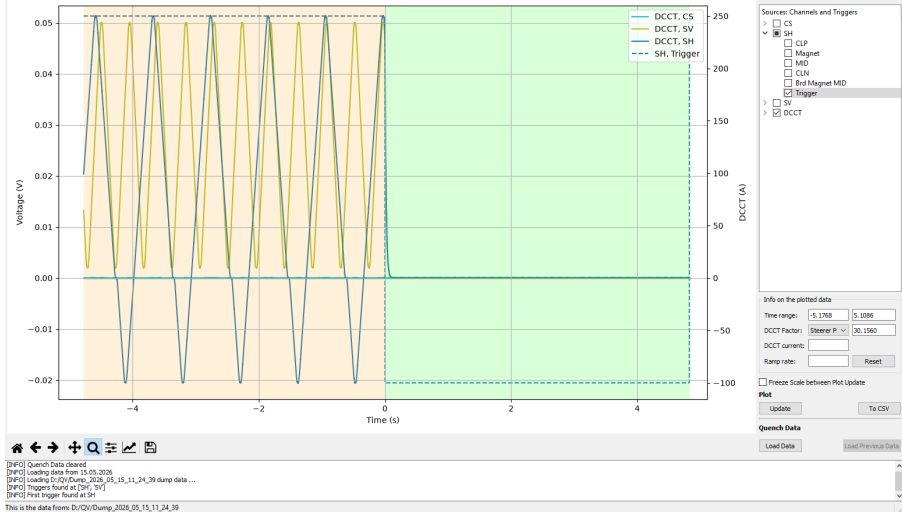
D:/QV/Dump_2026_05_15_11_24_39

Configuration Menu



D:/QV/Dump_2026_05_15_11_24_39

Configuration Menu



Functionalities

User experience

- 🐱 Get First Trigger
- 🐱 On DCCT Factor Change
- 🐱 Dump to CSV

Automatization

- 🐱 Load DCCT Factor
- 🐱 Detector Configuration Search

User experience

- 🐱 **Get First Trigger** - Search data for the occurrence of the first trigger
- 🐱 **On DCCT Factor Change** - Scale the Y-axis from voltage to current using the selected converter's DCCT factor
- 🐱 **Dump to CSV** - Save currently displayed signal series into a CSV file

Automatization

- 🐱 Load DCCT Factor
- 🐱 Detector Configuration Search

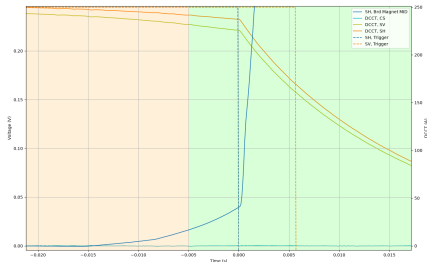
User experience

- 🐱 Get First Trigger
- 🐱 On DCCT Factor Change
- 🐱 Dump to CSV

Automatization

- 🐱 **Load DCCT Factor** - Automatically extract current parameters basing on the dump file name
- 🐱 **Detector Configuration Search** - Automatically locate and load the matching detector configuration file

Quench example



- Detectors **SV** and **SH** were powered by **alternating current**
- **Trigger** occurred on both detectors
- **First recorded trigger**, suggests that **detector SH quenched**, closer examination of the plot confirms this occurrence

Figure: Quench event example representing data from dump number
Dump_2026_05_15_11_24_39

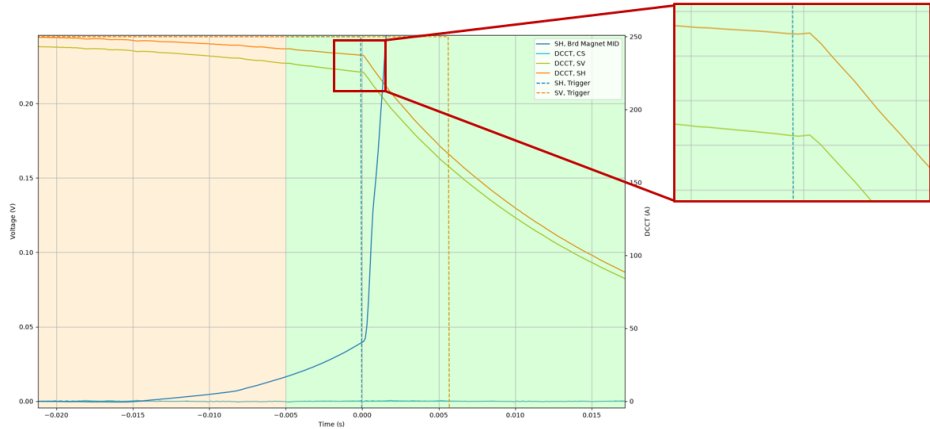


Figure: Zoom of the response speed of the quench detection system

Summary

Let's **highlight** the following key outcomes:

Critical System Role

Quench detection system is essential for protecting the beamline structure and reduce the risks associated with rapid liquid helium evaporation → explosion

Application Upgrade

Performance Optimization

Summary

Let's highlight the following key outcomes:

Critical System Role

Application Upgrade

The quench analysis application was upgraded to provide a more intuitive workflow for evaluating detector data. New functionalities were implemented to enable easier interpretation and a clearer view of the dump data

Performance Optimization

Summary

Let's highlight the following key outcomes:

Critical System Role

Application Upgrade

Performance Optimization

The use of Pandas DataFrames and NumPy improved the core computational pipeline, resulting in faster and more efficient data processing

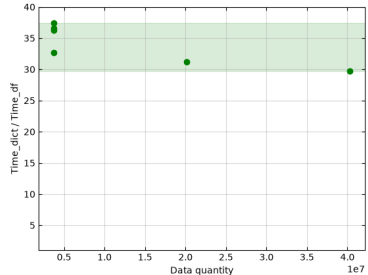


Figure: Fraction of dictionary and DataFrame time, representing the speed boost

Plan for the future

Final Week Tasks

Introduction of Decoder class:

- 🐱 Handles reading and interpreting data on the specific decoder
- 🐱 Opens up the possibility to analyse data dumps from other detector setups

Already done

The current version of the application handles two implemented decoder for two individual detector setup. That gives the opportunity for the further improvements and opens the program for new type of the data.

Conclusions

The outcome of this project is a **functional application** featuring refactored computational logic and essential from the user's perspective new functionalities.

- 🐱 Updated application **operates on an improved calculation engine powered by C-optimized data structures**
 - 🐱 for the data storing dictionaries were exchanged with dataFrames
 - 🐱 calculation were moved from basic loops to operation with NumPy arrays
- 🐱 Key operational features were implemented

Overall, these improvements **boost execution speed, usability, and data interpretability** for future users.

References

-  M. Dziewiecki, W. Freisleben, V. Raginel, P. Szwangruber, A. Wiest, K. Witkowski, Ch. Mueller, and B. Karadeniz, “Quench detection electronics for FAIR.”
-  S. Sanfilippo, “Superconducting Accelerator Magnets.”
-  S. Sanfilippo, “Conventional Accelerator Magnets.”
-  “Meissner effect”, https://en.wikipedia.org/wiki/Meissner_effect



Thank you for the attention!

Questions are welcome

Meissner effect

The **Meissner effect** is the expulsion of magnetic flux from a material when it enters the superconducting state. This phenomenon demonstrates that superconductivity is more than simply perfect electrical conductivity.

Shortly: It is expulsion of the magnetic field from its interior of the superconductor.

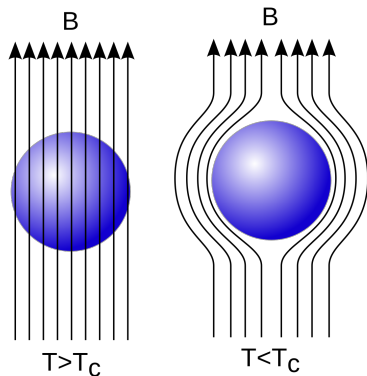


Figure: Meissner effect [4]

Dumps examples

