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SUPERCONDUCTING DETECTOR MAGNETS FOR FCC-EE

Superconducting solenoids for the IDEA and CLD Detector concepts

CONTENT OF THIS TALK

- Introduction: FCC-ee Detector magnets
- The superconducting solenoid for the CLD
- The superconducting solenoid for the IDEA
- 3D Quench studies on the IDEA magnet
- Summary

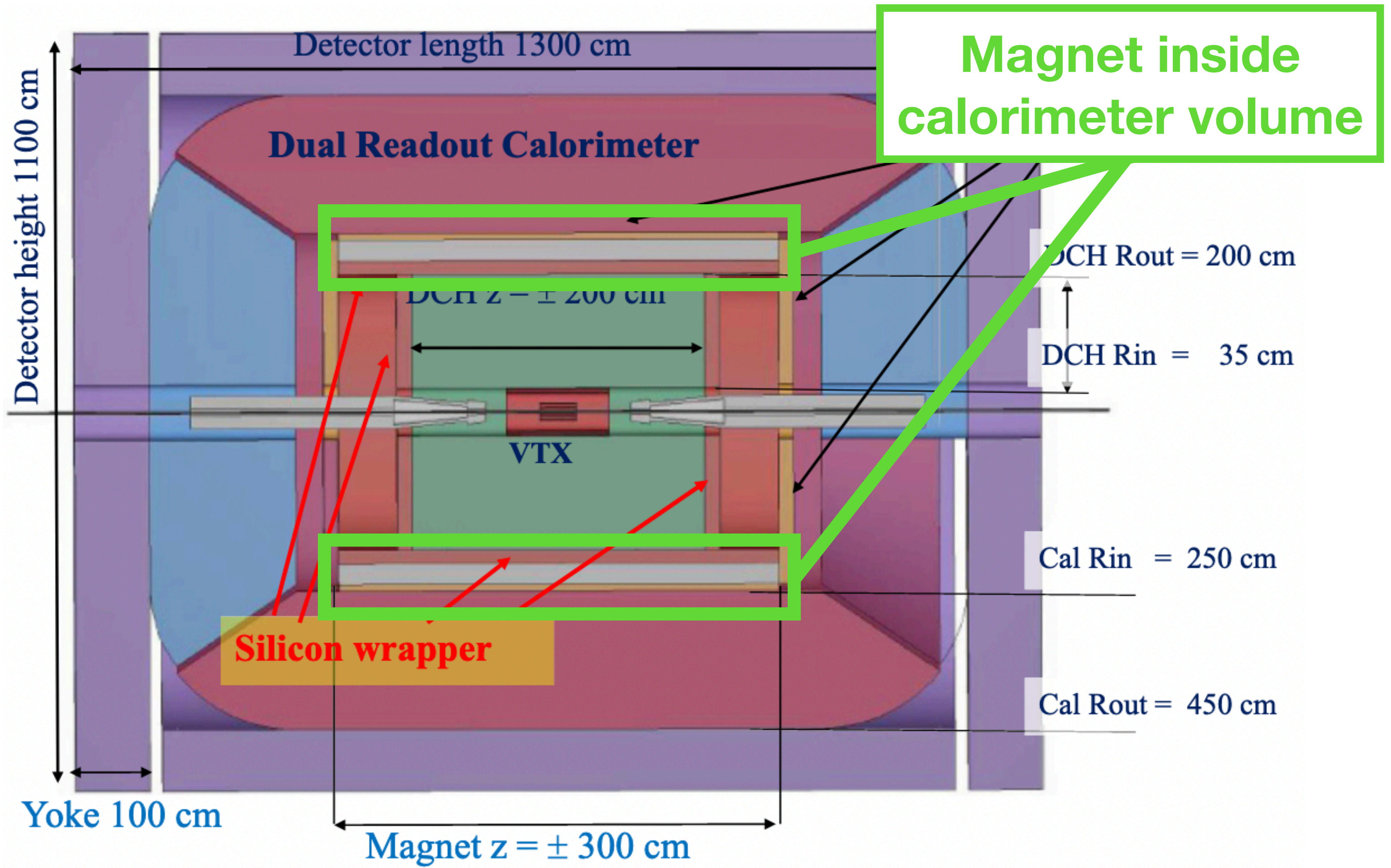
* Focus will be on the cold mass, the cryostat is being design in the context on WP4 @ CERN [7]

Introduction: FCC-ee Detector magnets

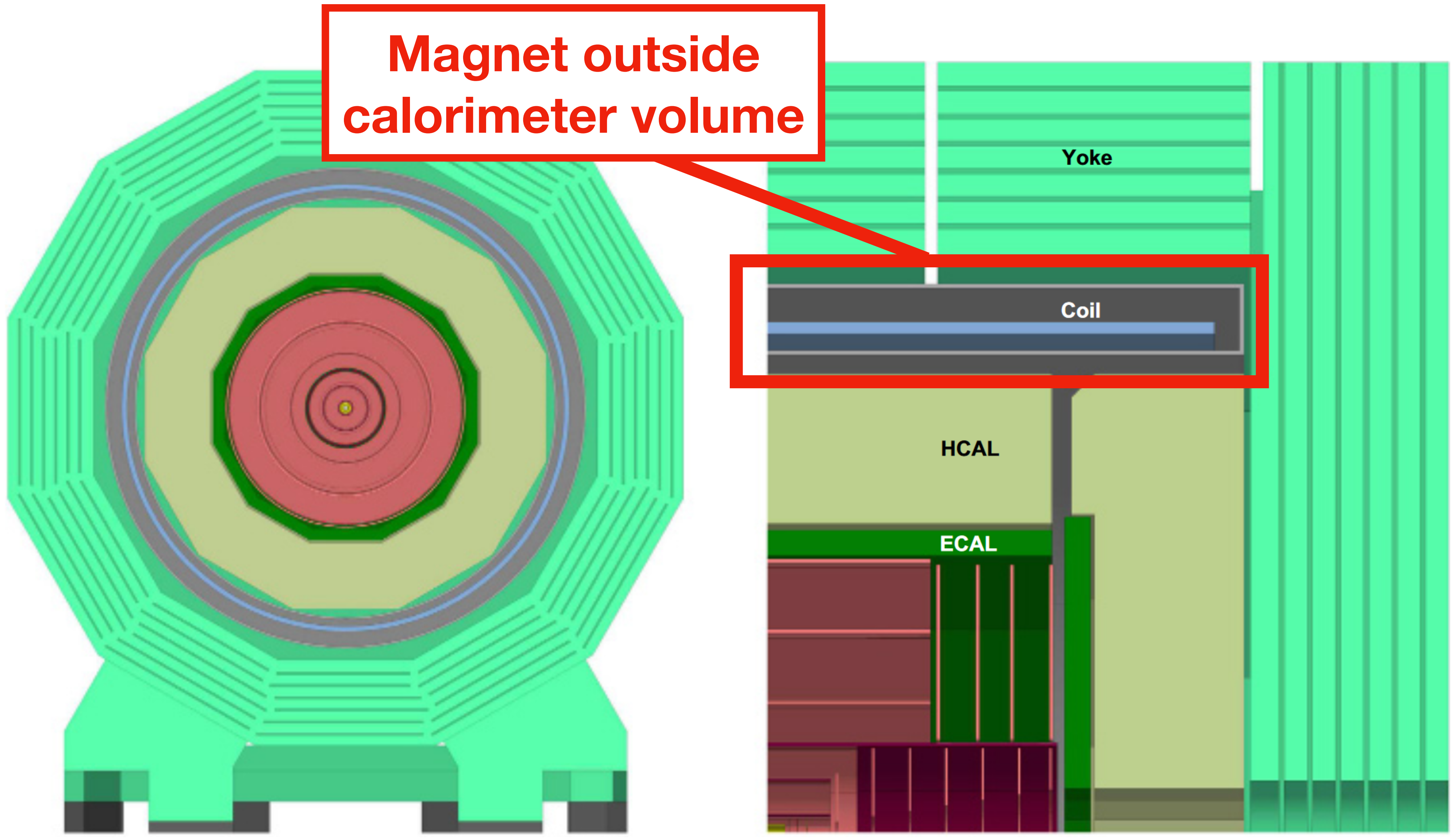
- Two detector designs are being studied for FCC-ee [1]
- **International Detector for Electron-positron Accelerators** (IDEA) and the **CLIC-Like Detector** (CLD)
- Both have superconducting solenoid with **B_{center} of 2 T**
- IDEA solenoid **inside,** CLD solenoid **outside** calorimeters

This talk: design and quench analysis of FCC-ee magnets

International Detector for Electron-positron Accelerators

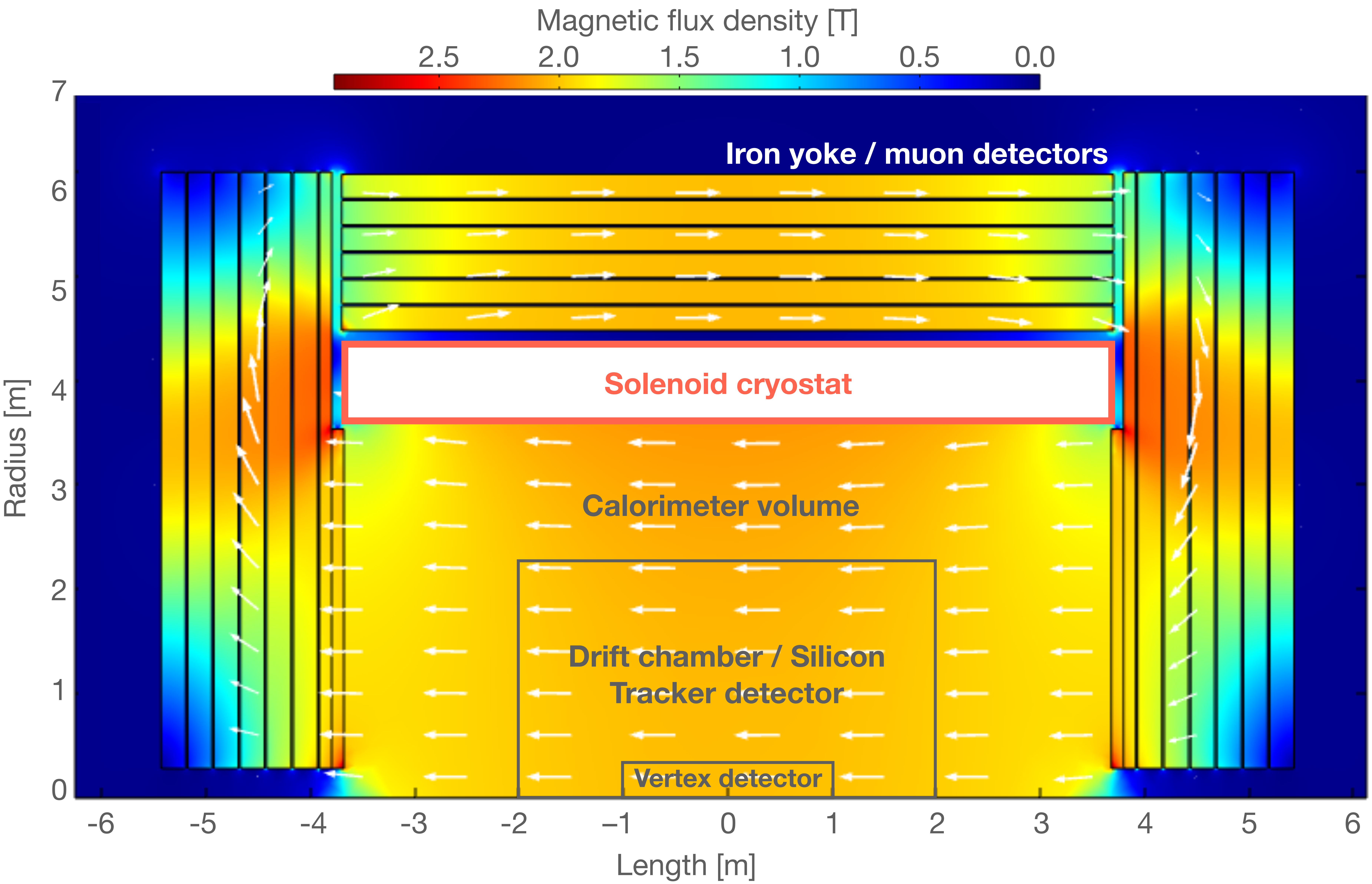


CLIC-Like Detector



The design of the **CLD** Detector Magnet

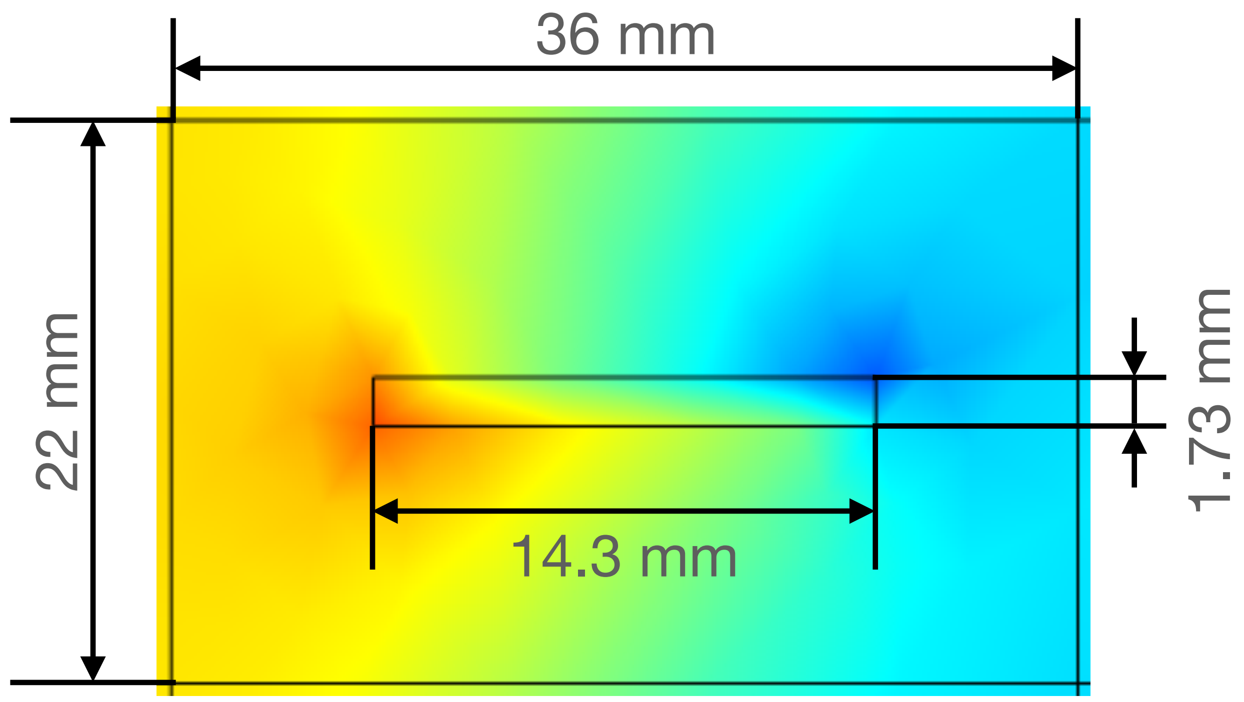
CLD Detector design



Solenoid outside HCal [1, 8]

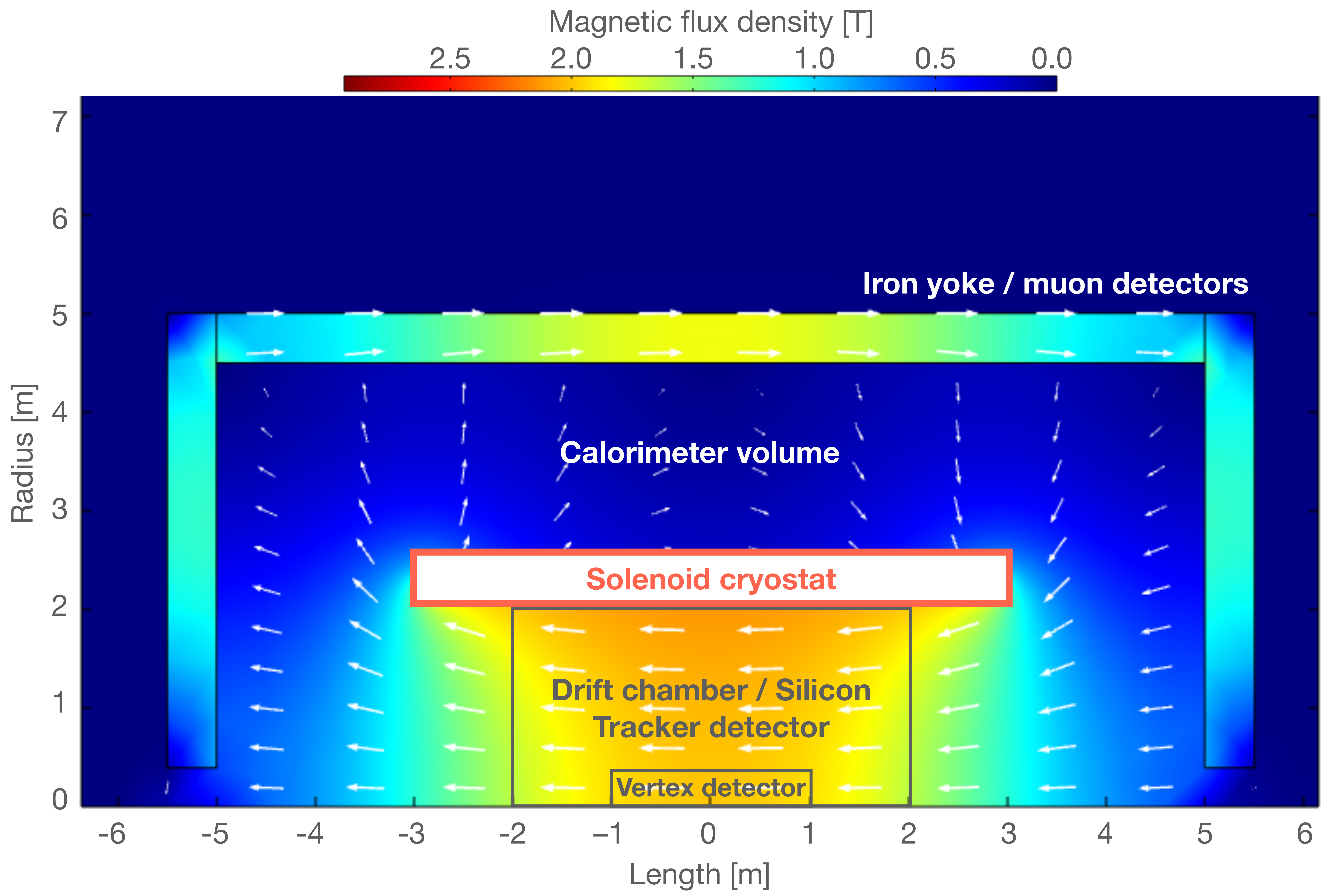
- Free bore diameter: **7.4 m**
- Central field: **2 T**
  - Operating current: **20 kA**
  - Operating temp.: **4.5 K**
  - Stored energy: **600 MJ**
- Aluminium stabilised **NbTi/Cu** conductor
- Two layers, 300 turns
- Support cylinder of **25 mm**

No showstoppers, CMS like [9]



The design of the **IDEA** Detector Magnet

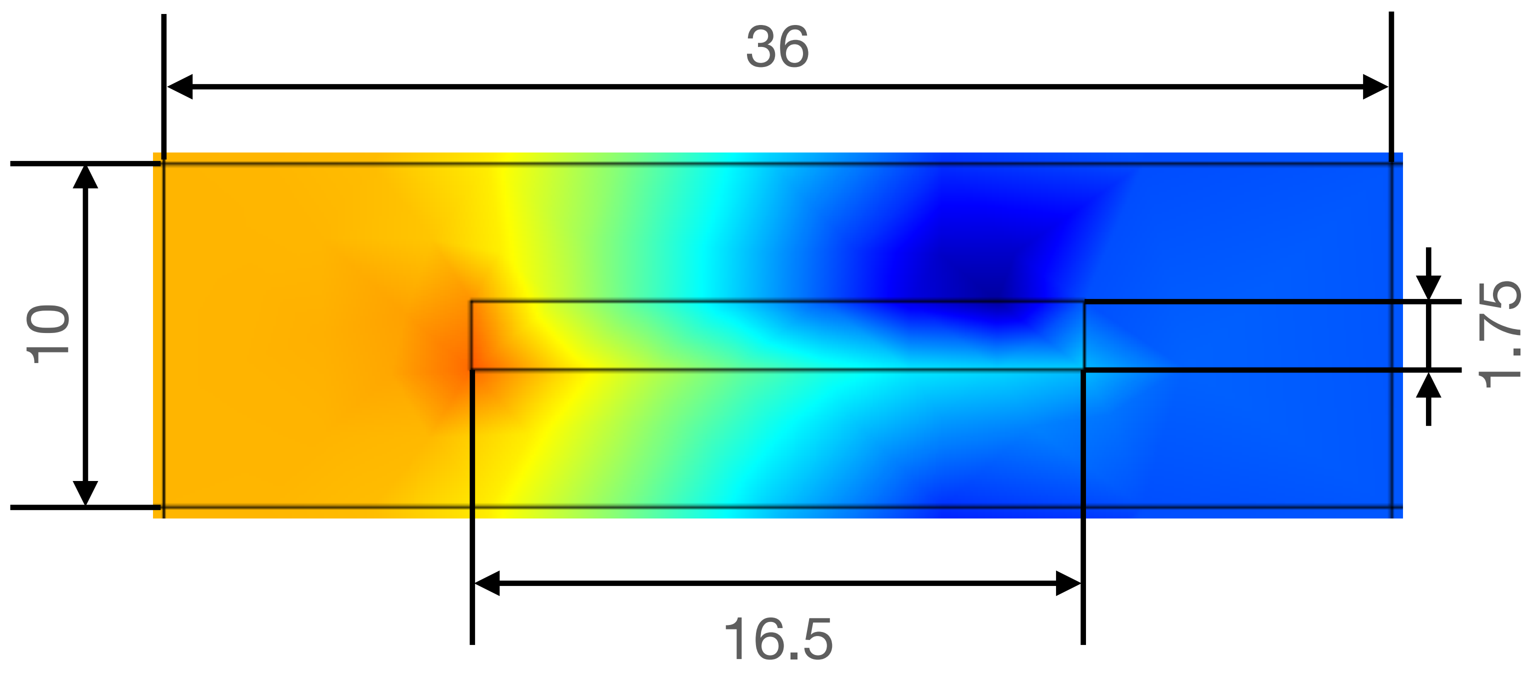
IDEA Detector design



Superconducting solenoid inside calorimeter [1]

- Need transparency: **1 > X_0**
- Free bore diameter: **4.2 m**
- Central field: **2 T**
  - Operating current: **20 kA**
  - Operating temp.: **4.5 K**
  - Stored energy: **170 MJ**
- Aluminium stabilised **NbTi/Cu** conductor
- One layer, 530 turns

Trade-off: high stored energy and mechanical stability vs. transparency



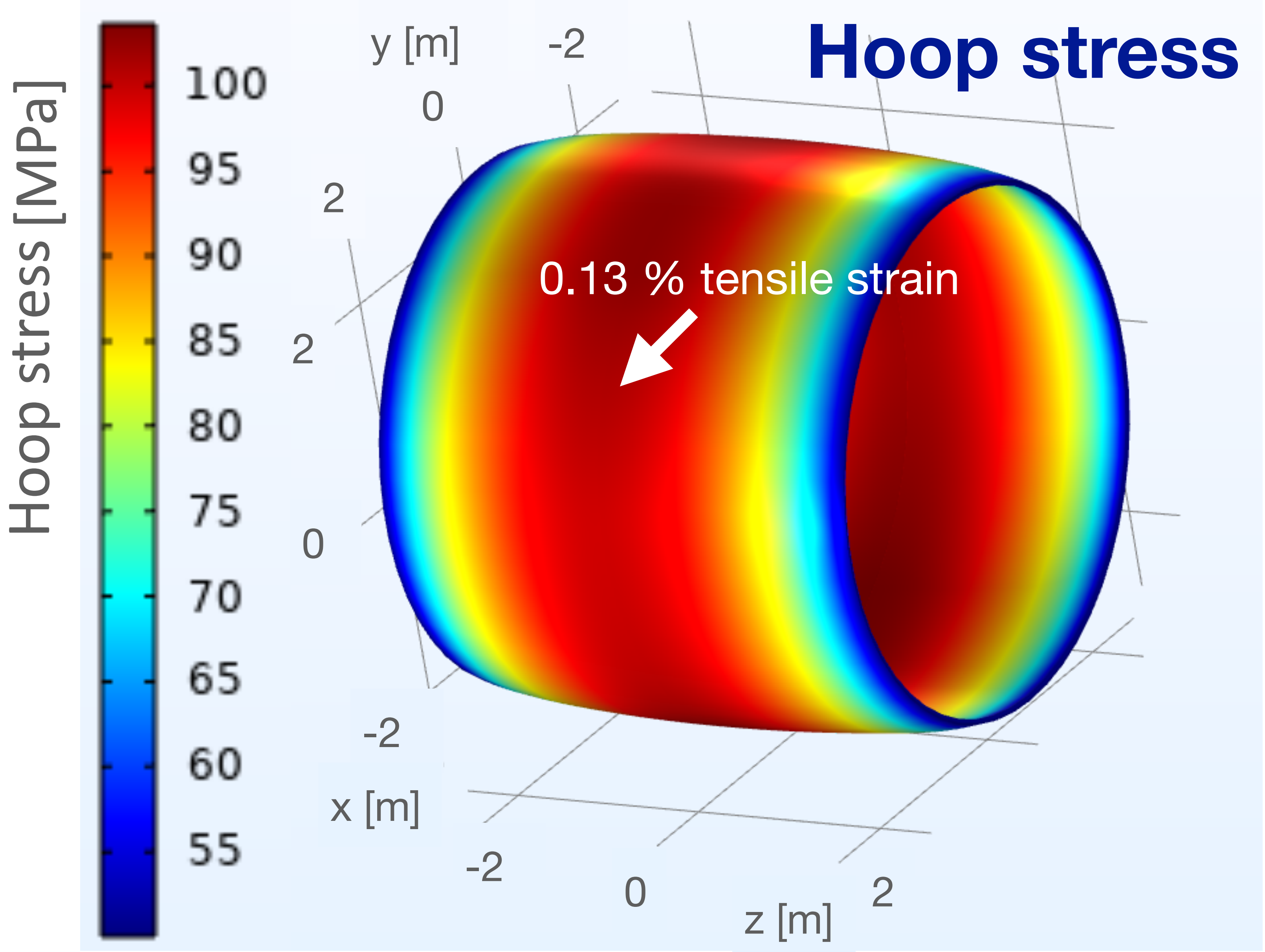
Mechanical support for the IDEA magnet

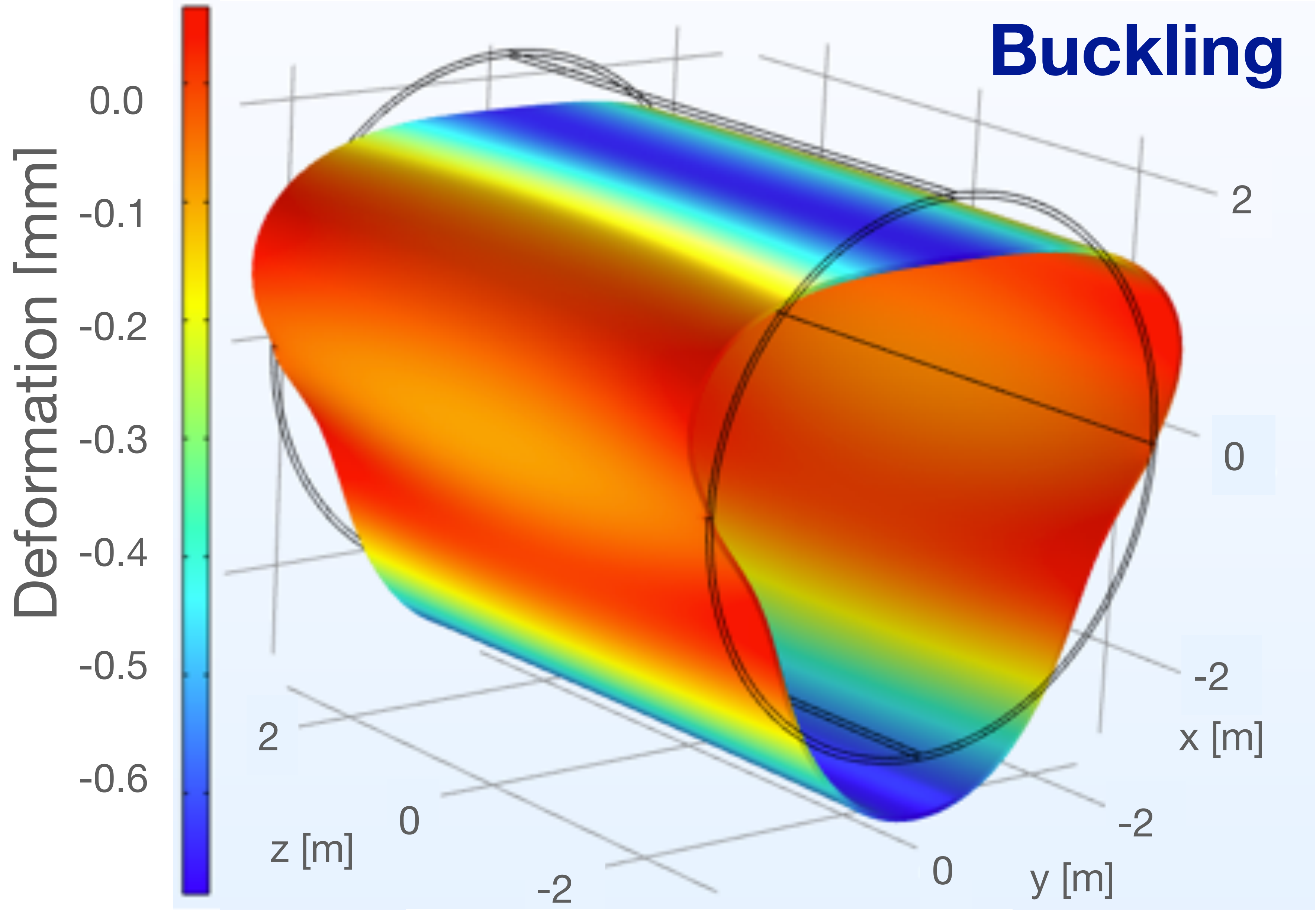
- Support cylinder with thickness of 12 mm
- Support cylinder material: aluminium 5083

Transparency of the cold mass: 0.76 X_0
Energy density: ~14 kJ/kg [2]

- First mechanical analysis is promising

	Conductor	Support	
Parameter	Value	Value	Unit
Material	Ni-doped aluminium	Aluminium 5083	
Yield strength	147 (with NbTi) [3]	209 @ 4.2 K [4]	MPa
Young's modulus	75 x 10^3	81 x 10^3	MPa



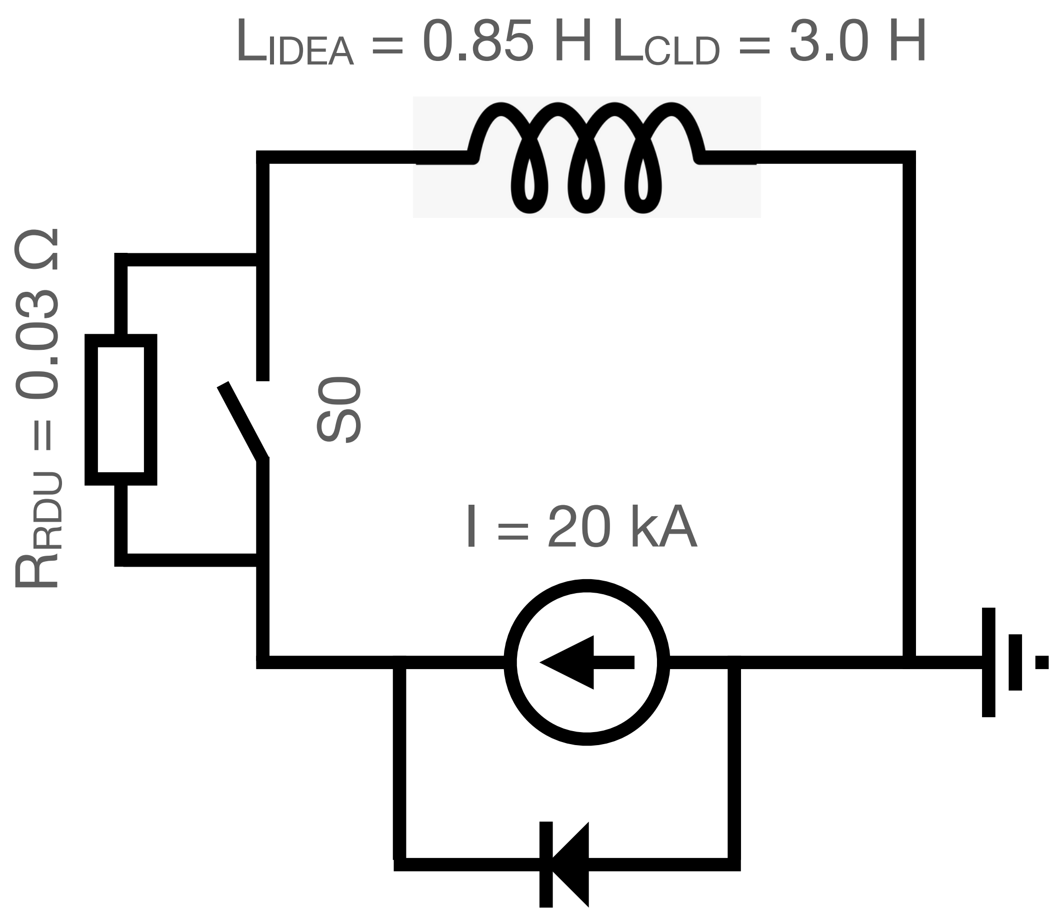


- Peak von Mises stress: **105 MPa**
- Peak tensile strain: **0.13 %**
- Peak shear stress: **0.5 MPa**
- Buckling of coil with simple **(pessimistic)** support, max. deformation: **0.7 mm**

3D quench simulation of **IDEA** Detector Magnet

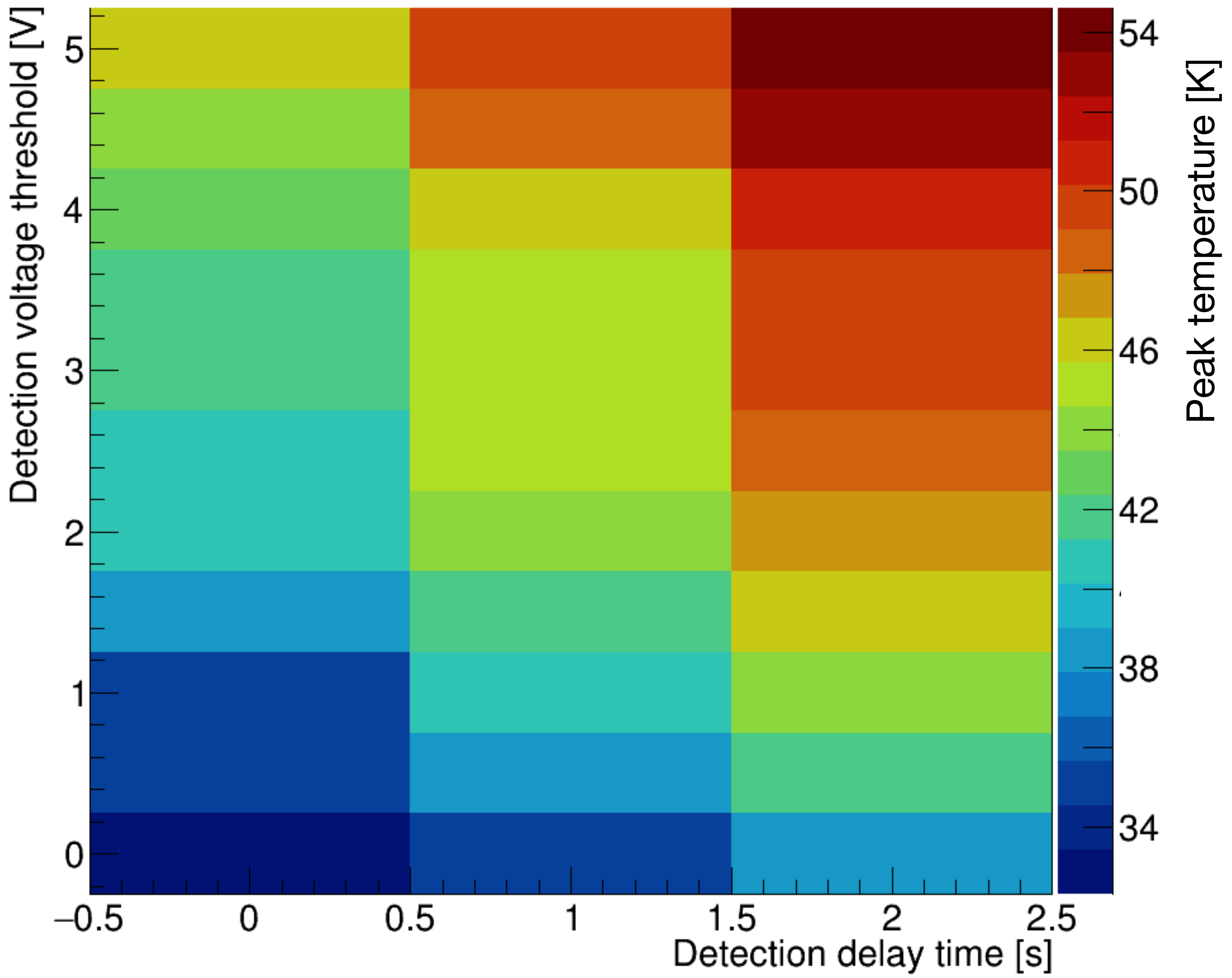
3D Quench simulations IDEA magnet

Quench protection



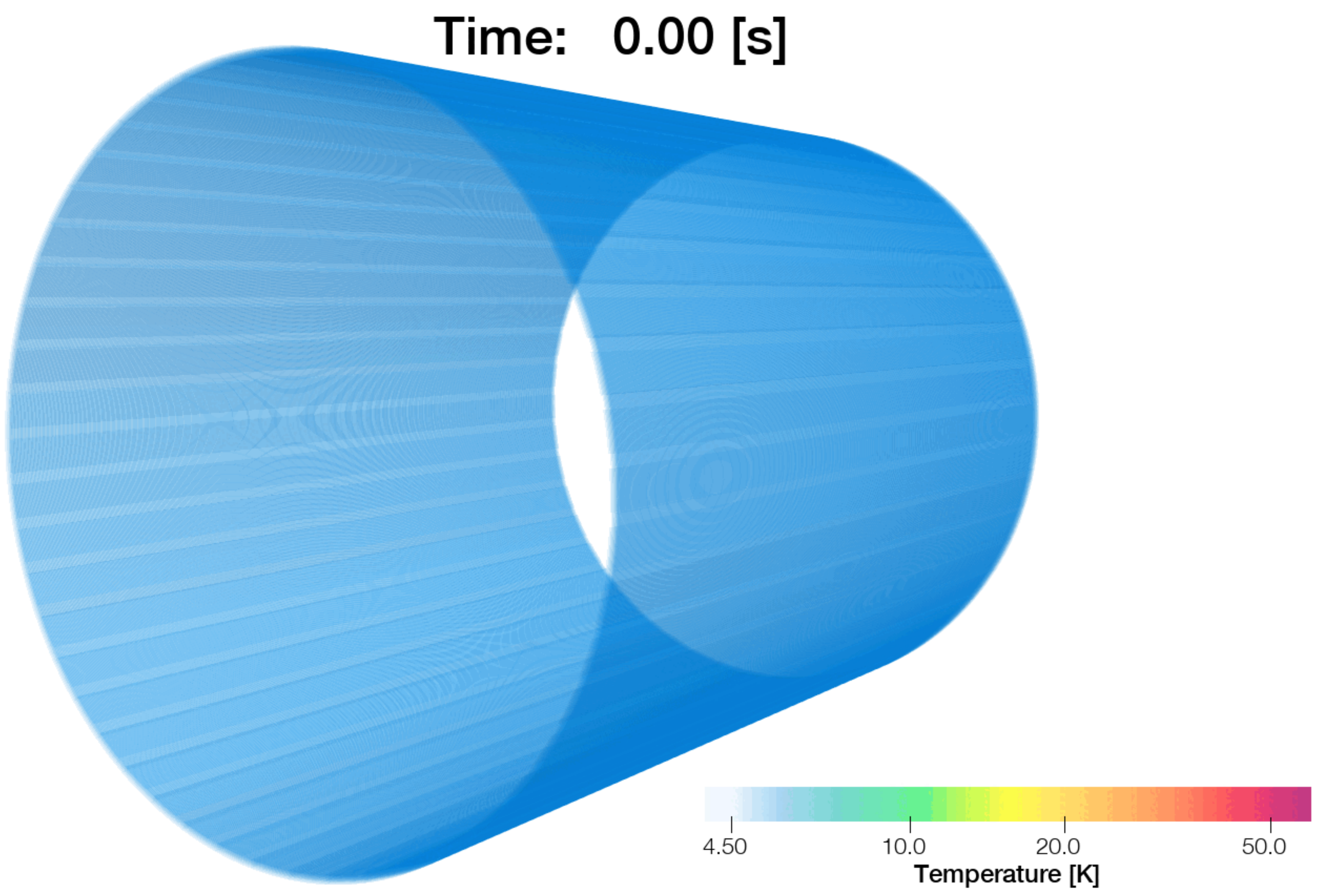
- **Quench** is sudden (local) loss of superconductivity, causes **heating due to resistive conductor**
- 3D thermo-electrical network software called **Raccoon2** based on the work described in [6]
- Validated with data measured at the ATLAS Central Solenoid [7]
- **First detection:** scan voltage threshold vs. delay

Choice for IDEA: threshold = 0.1V, delay = 1s, based on ATLAS CS experience

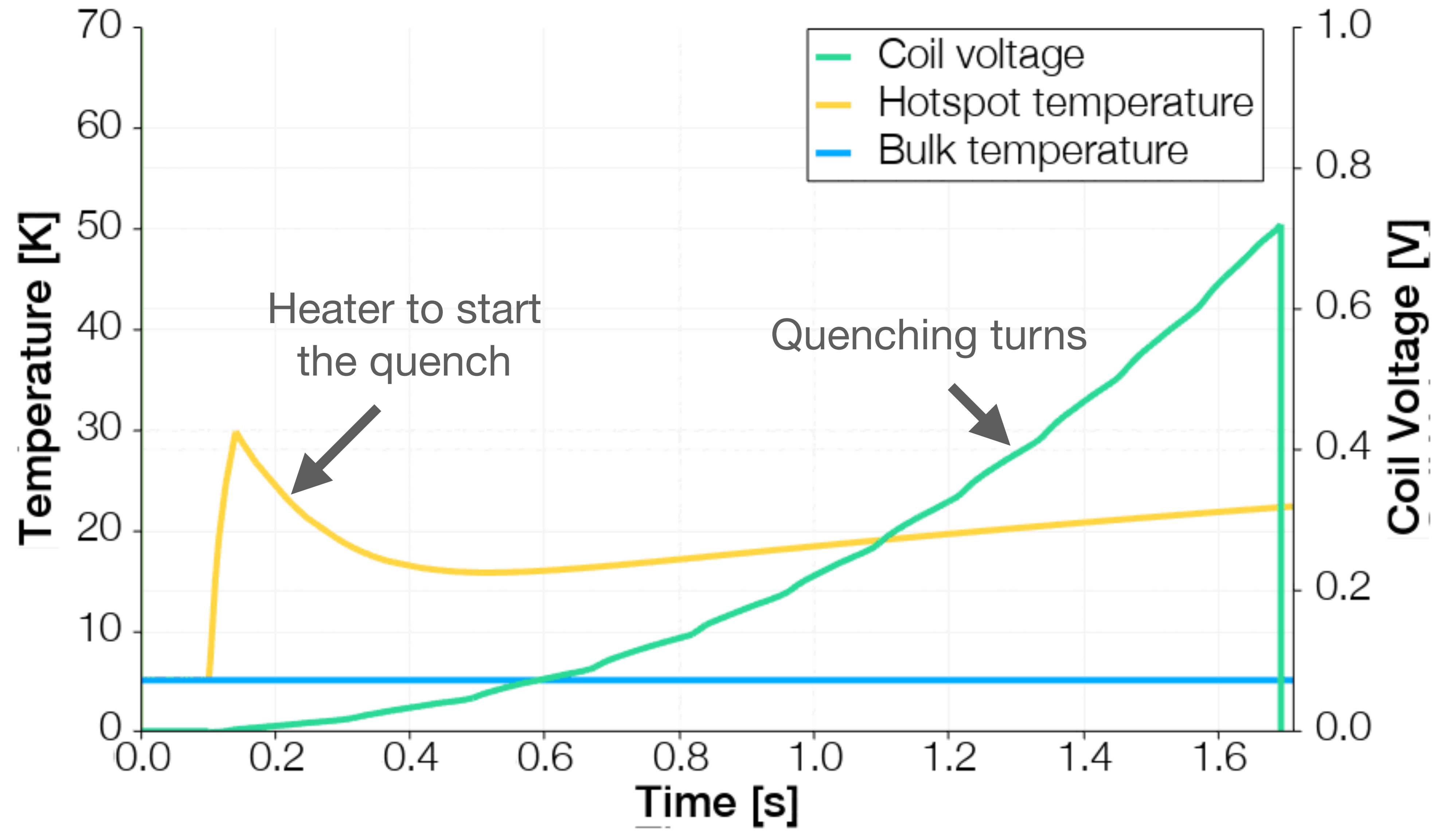


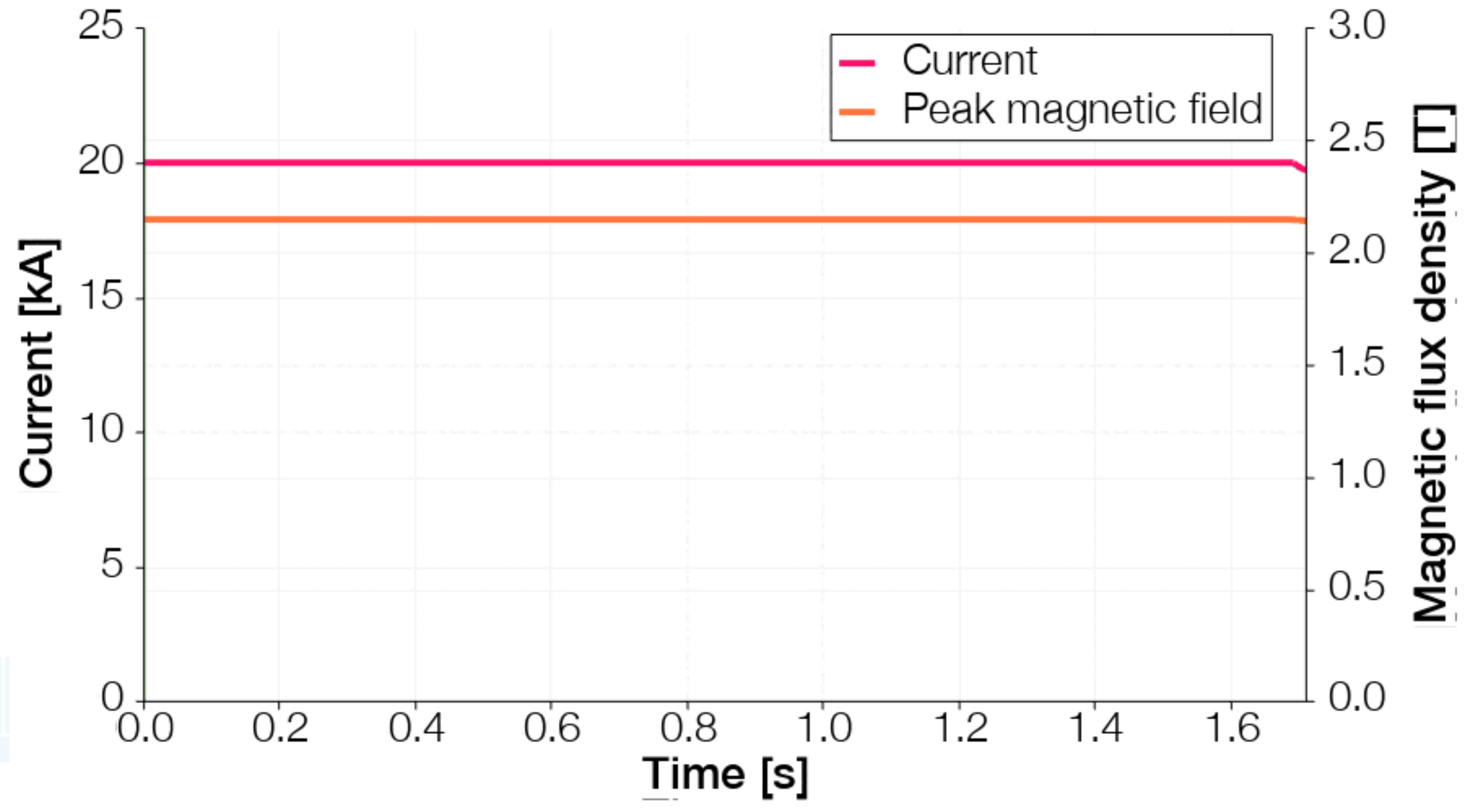
3D Quench simulations IDEA: RDU + QP strips

Initiating the quench



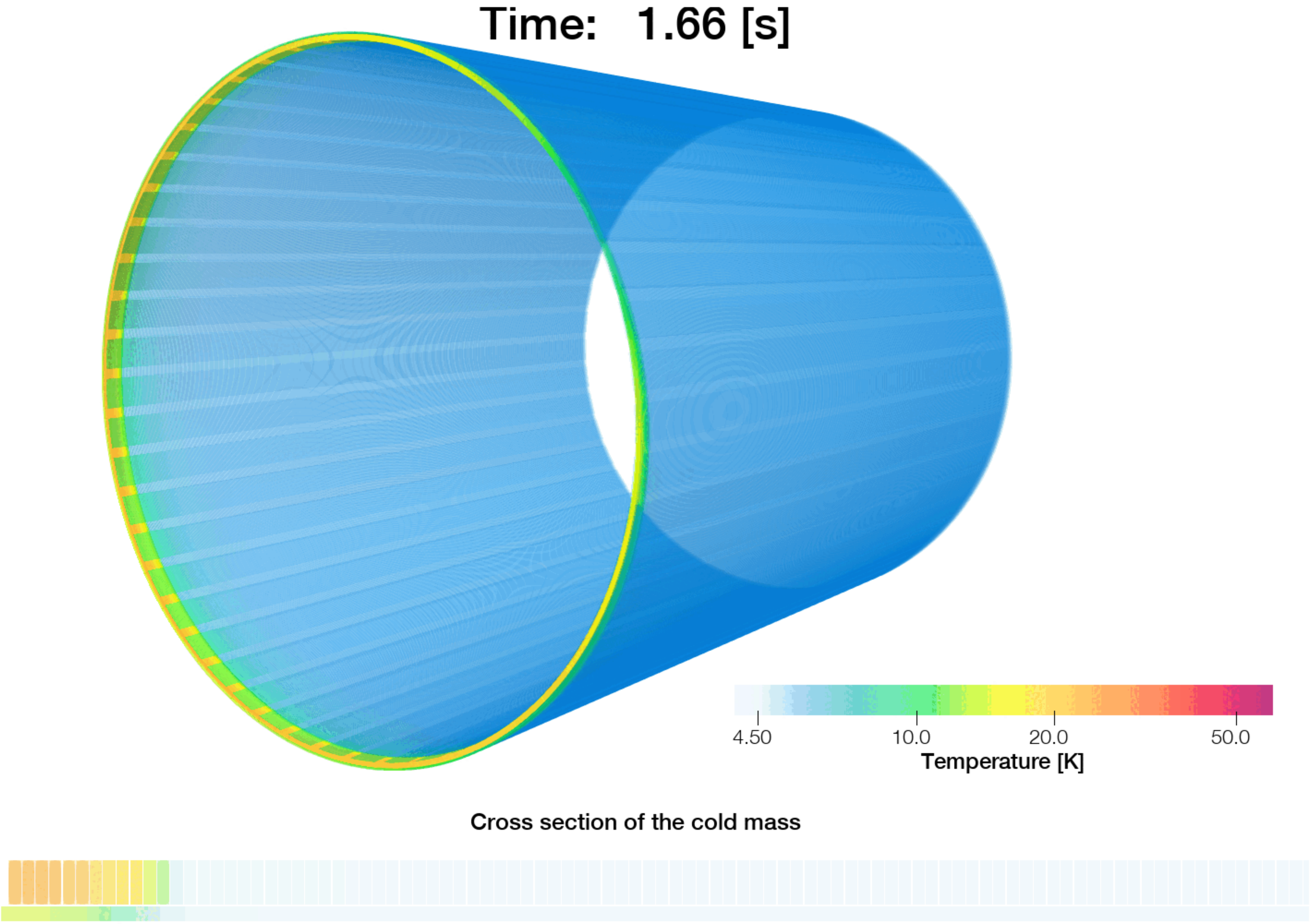
Cross section of the cold mass

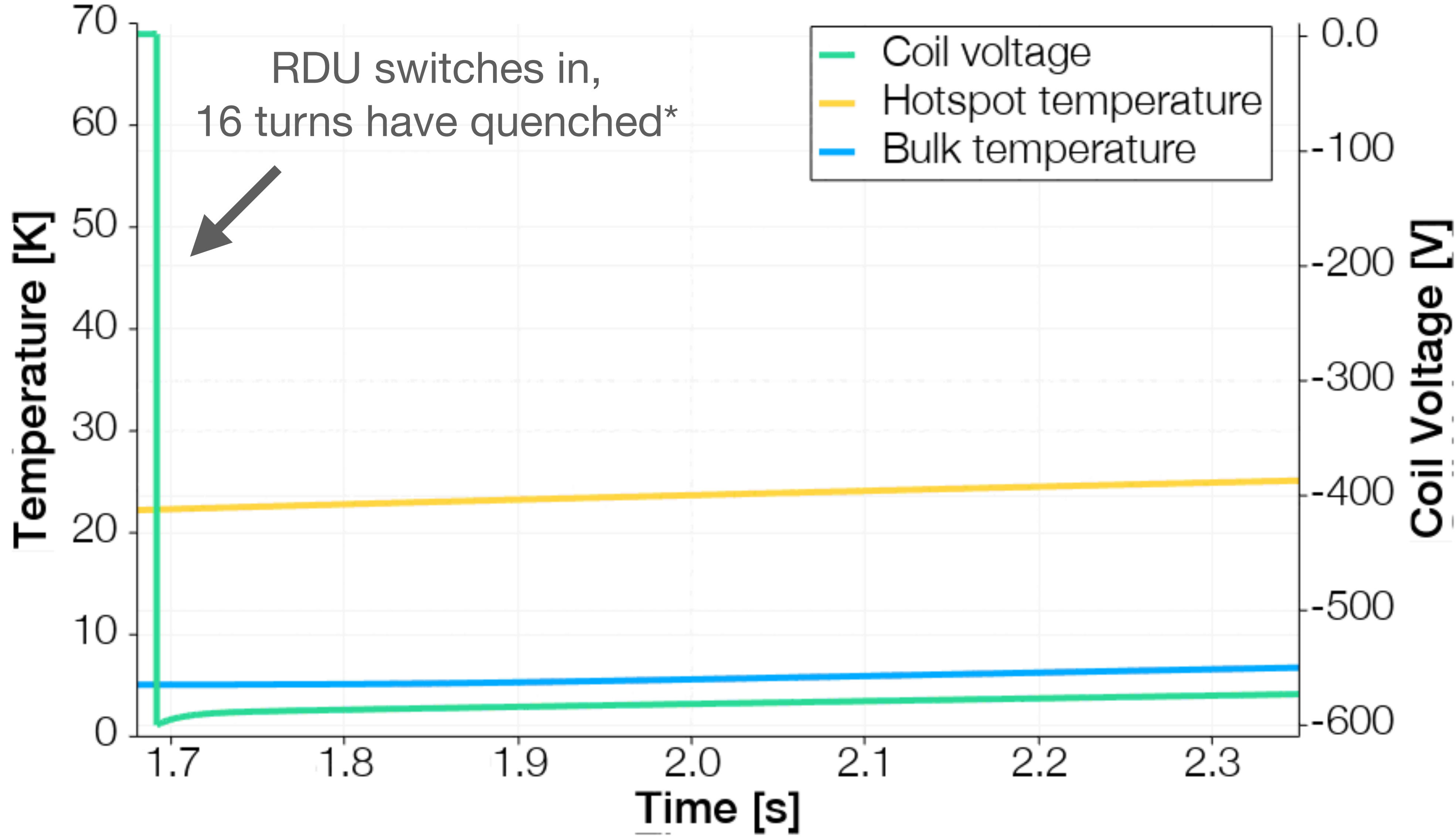


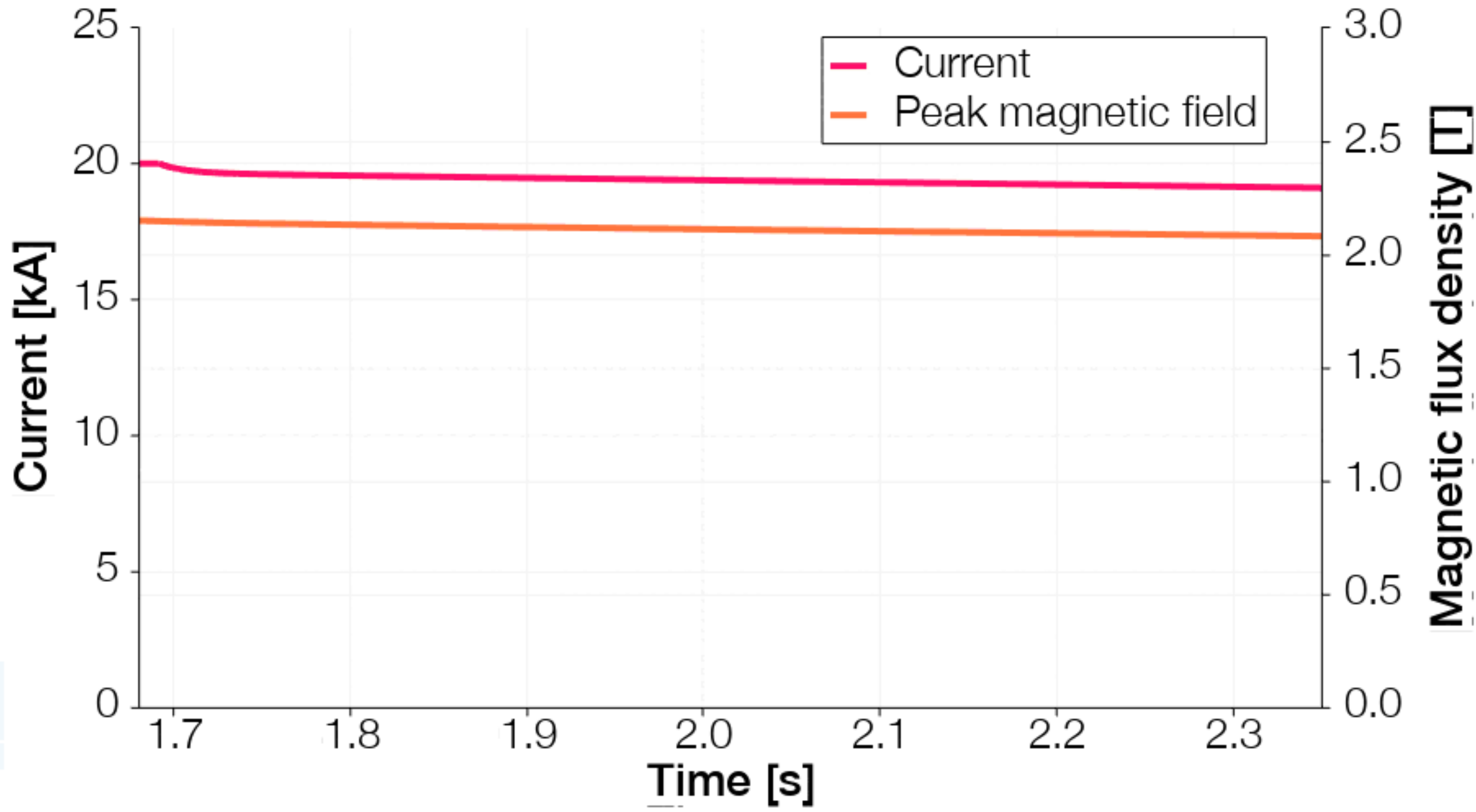


3D Quench simulations IDEA: RDU + QP strips

Switching in the extraction resistor



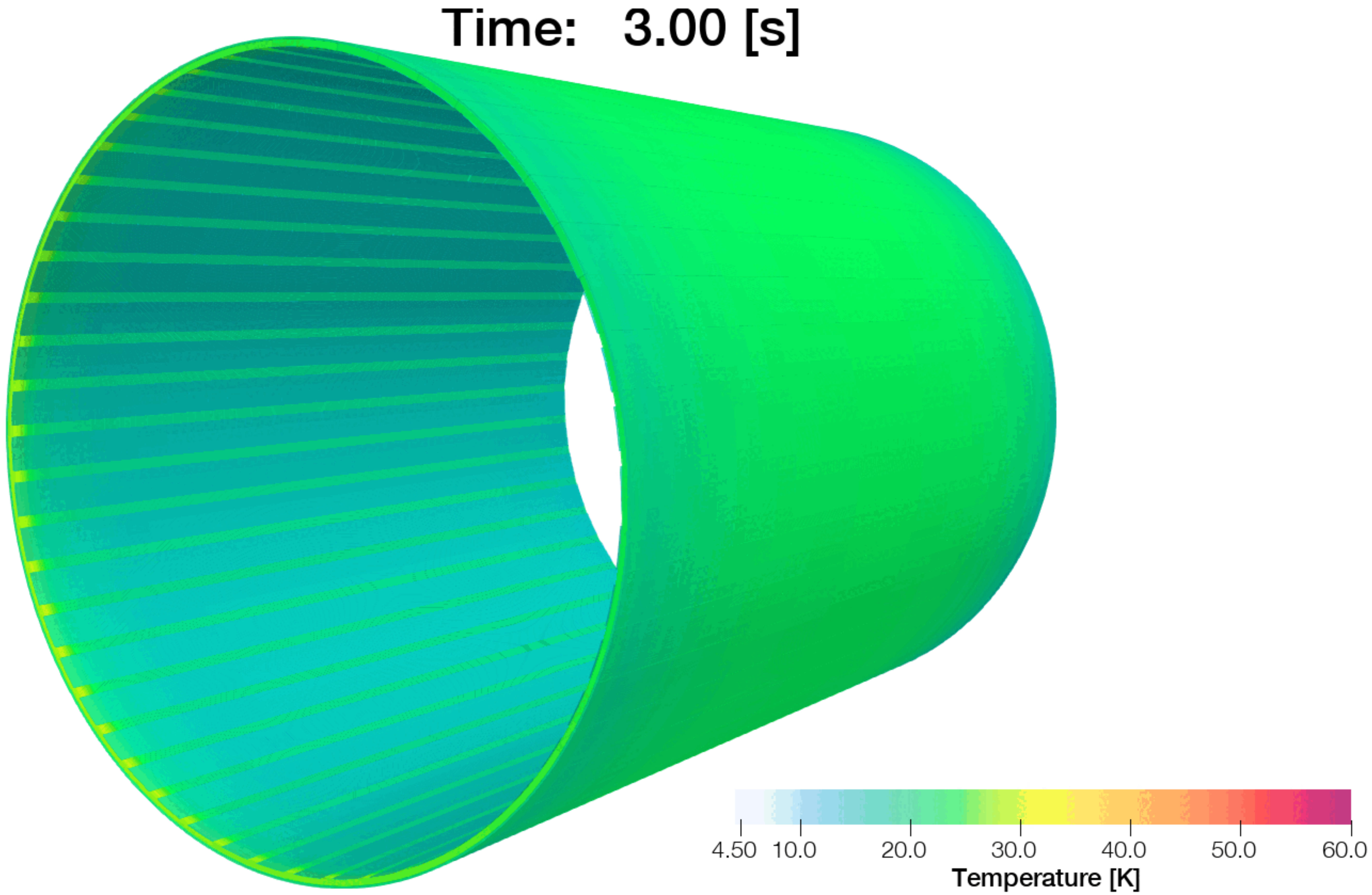




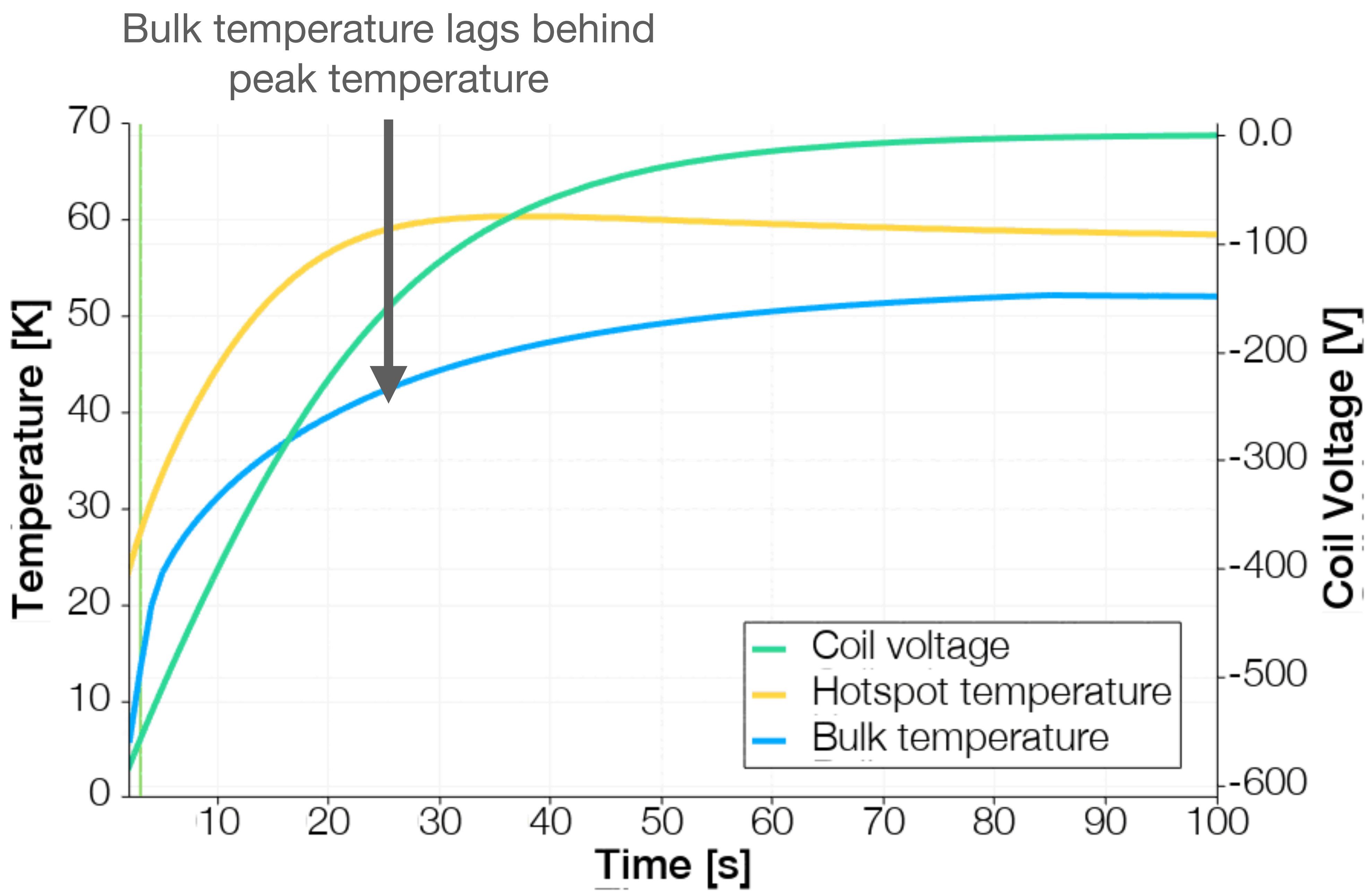
* With QP strips 16 turns quench before RDU, without strips 11 turns quench before RDU

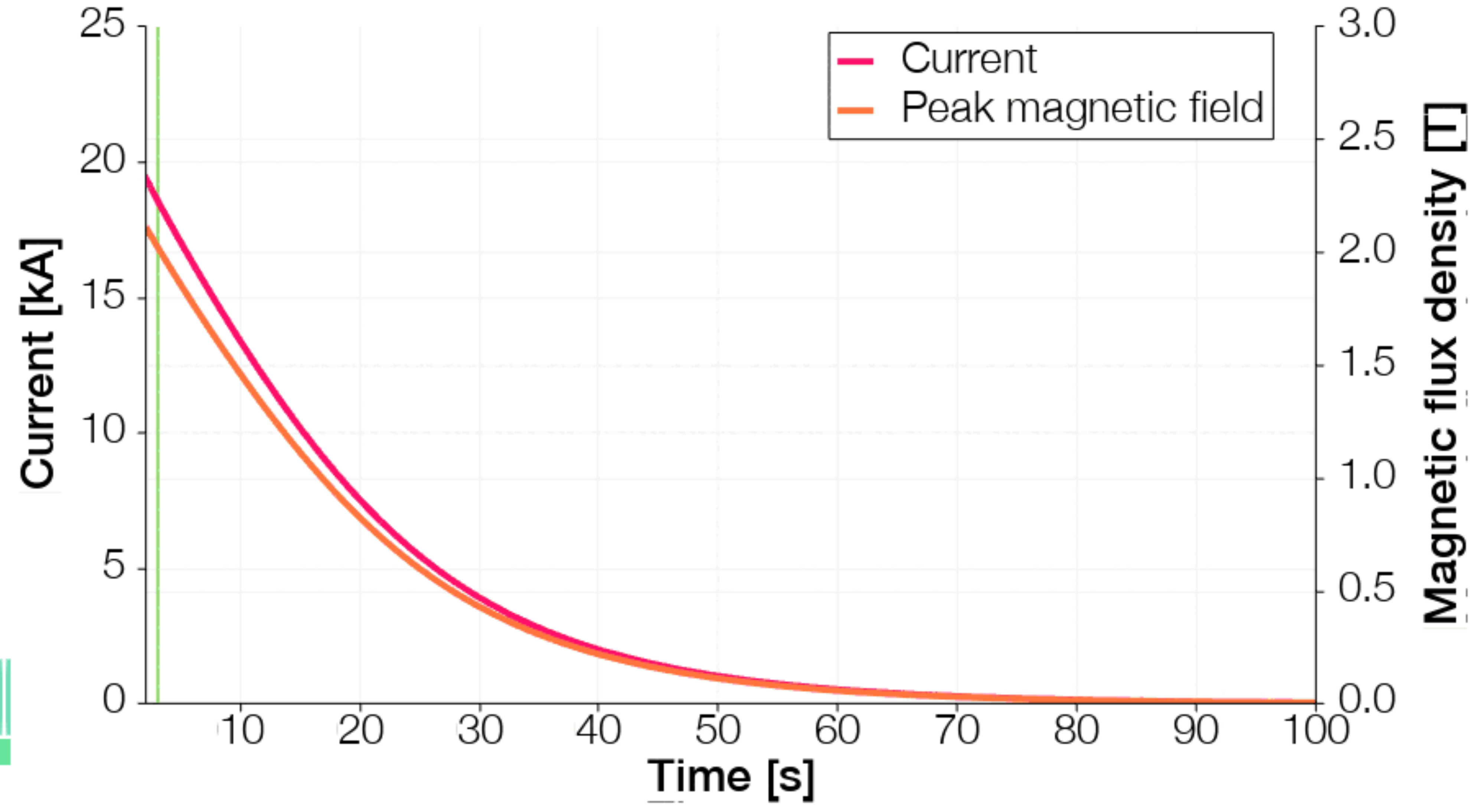
3D Quench simulations IDEA: RDU + QP strips

Extracting the energy from the magnet



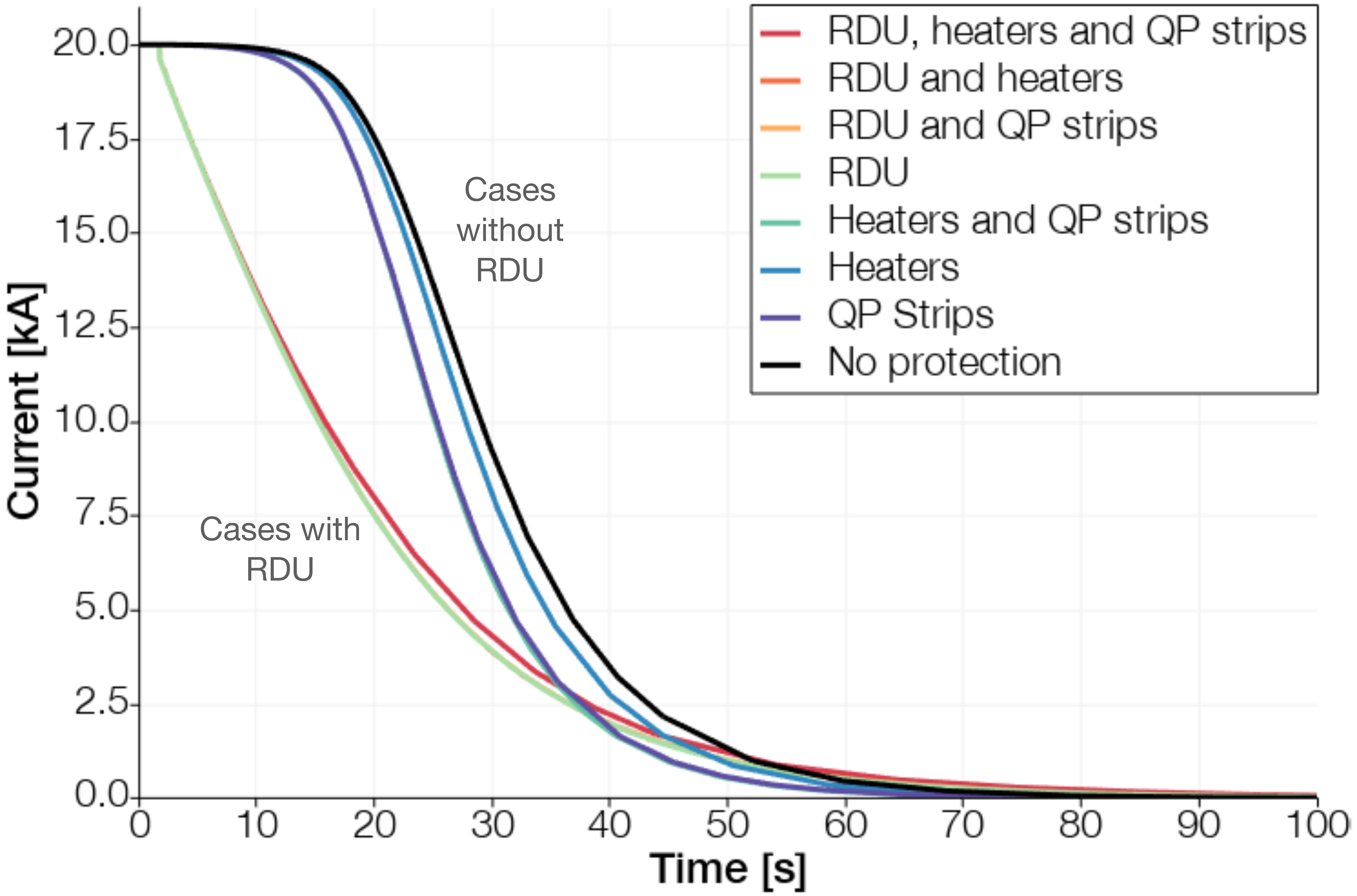
Cross section of the cold mass

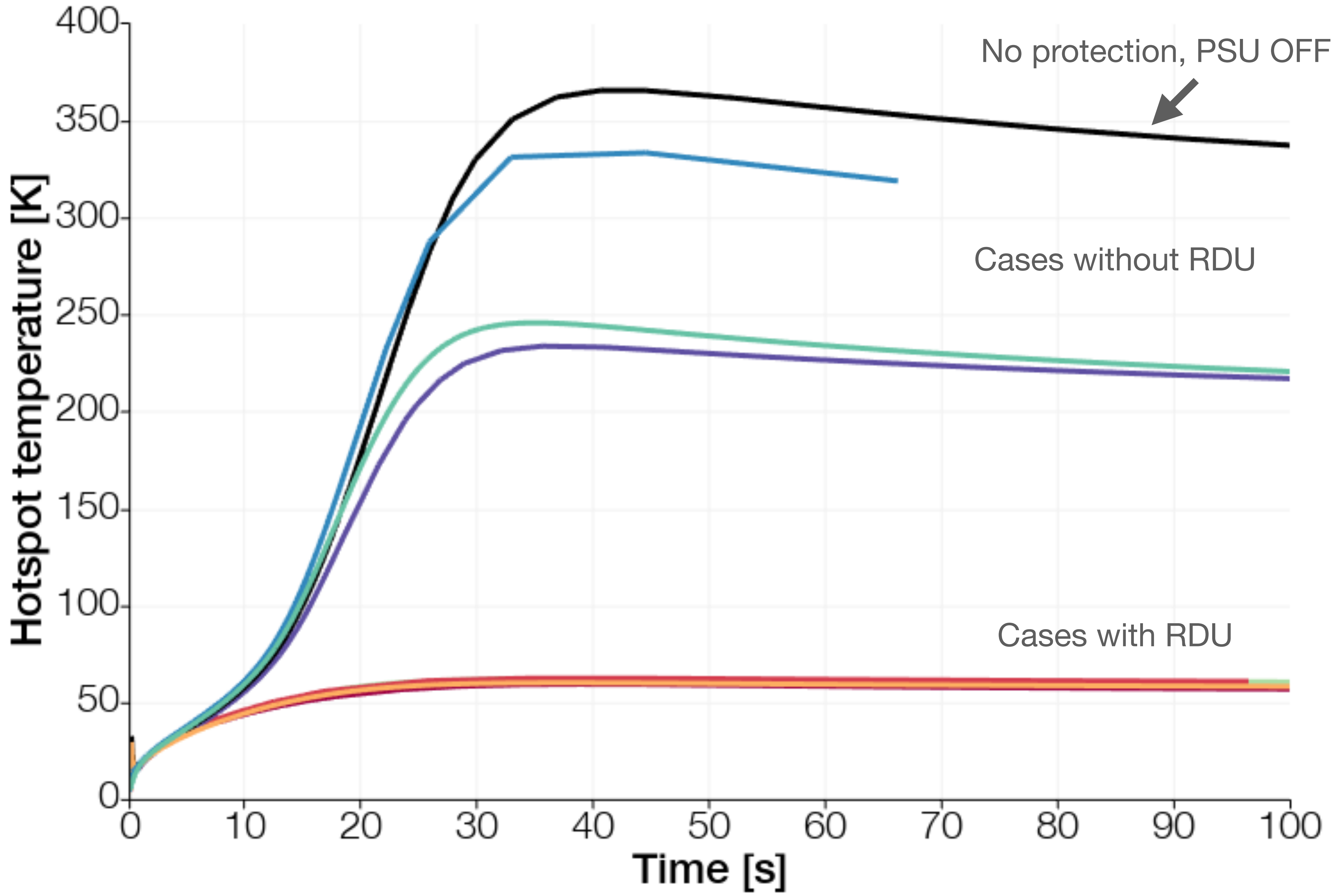




Other quench protection methods for IDEA

- Study difference between protection w/wo **RDU, five heaters** (P = 10 W, t = 5s) and 1 mm thick pure aluminium (RRR = 3000) **quench propagation strips** (QP) along the length of the solenoid
- QP strips have **positive effect** on the peak temperature. **With QP 16 turns** quench before protection, **without QP 11 turns** quench before protection.
- Heater power, QP strips dimensions, and no protection to be studied in more detail: **promising results**





Summary

Summary

- **Two detector designs** are being studied for the lepton Future Circular Collider
- Both the **IDEA and the CLD detector concept** include a superconducting solenoid design that would provide a 2 T magnetic field inside the detector
- These studies show **promising results** without immediate show stoppers, though the IDEA design presented is a **very challenging design,** matching the world-record energy density of the Bess Balloon Detector magnet [2]
- Both designs **would require extensive R&D** in the coming years to reach the goals set out in the FCC-ee Conceptual Design Report [1]
- More detailed quench protection, support structure, service lines, aluminium stabilised conductor availability, …

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