

Design and test of the HTS magnet of the robust and low maintenance magnetic billet heater “RoWaMag”

Sonja I. Schlachter¹, Andrej Kudymow¹, Ralph Lietzow¹, Mathias Noe¹, Anis Smara², Wolfgang Goor³, Stefan Kreuzer³

¹ Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

² THEVA Dünnschichttechnik GmbH, 85737 Ismaning, Germany

³ Bültmann GmbH, 58809 Neuenrade, Germany

Supported by:



Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

FKZ 03ET1651A-D

Background: High energy requirements in production of semi-finished metal products



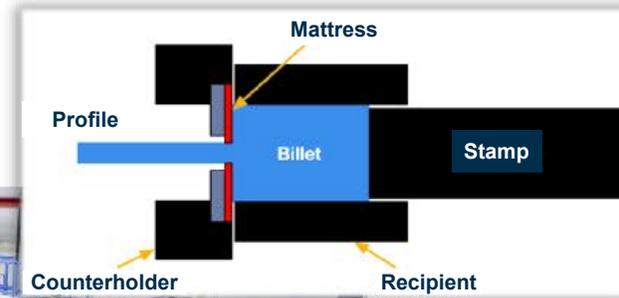
Metal-billet heating:

Aluminium: 500°C

Copper: 1000°C



Extrusion press

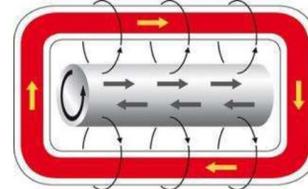
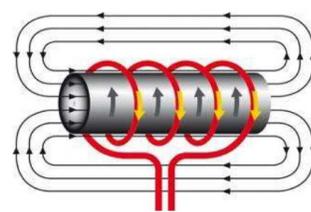


Aluminium Profile



How can energy consumption be reduced?

Comparison of Heating Concepts



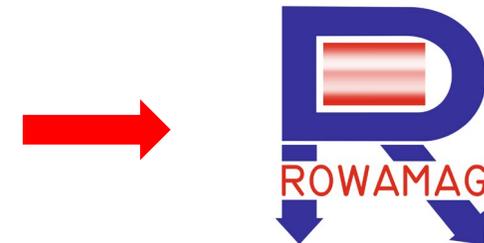
	Furnace with fossil fuels	Induktion heater	Magnet heater
Efficiency	20-40%	50-60%	70-80%
Temperature homogeneity	-	0	+
Heating duration	30-120 min.	few minutes	few minutes
Operating costs	+	-	0
Productivity	-	0	+

160 extrusion presses in Germany process **800,000 tons** of aluminium every year.

Heating up to 500°C requires thermal energy of around **97 GWh/year**.

Higher efficiency (50% → 70%) can save

- **55 GWh/year** el. energy or
- approx. **20,000 tons*** of CO₂



* corresponding to energy mix 2024 in Germany

Project partners:

- Karlsruhe Institute of Technology
- Theva Dünnschichttechnik
- Beck Maschinenfabrik GmbH
- Bültmann GmbH

Duration: 01.04.2019 - 30.06.2025

Funding: € 2,162,438
FKZ 03ET1651A-D

Supported by:

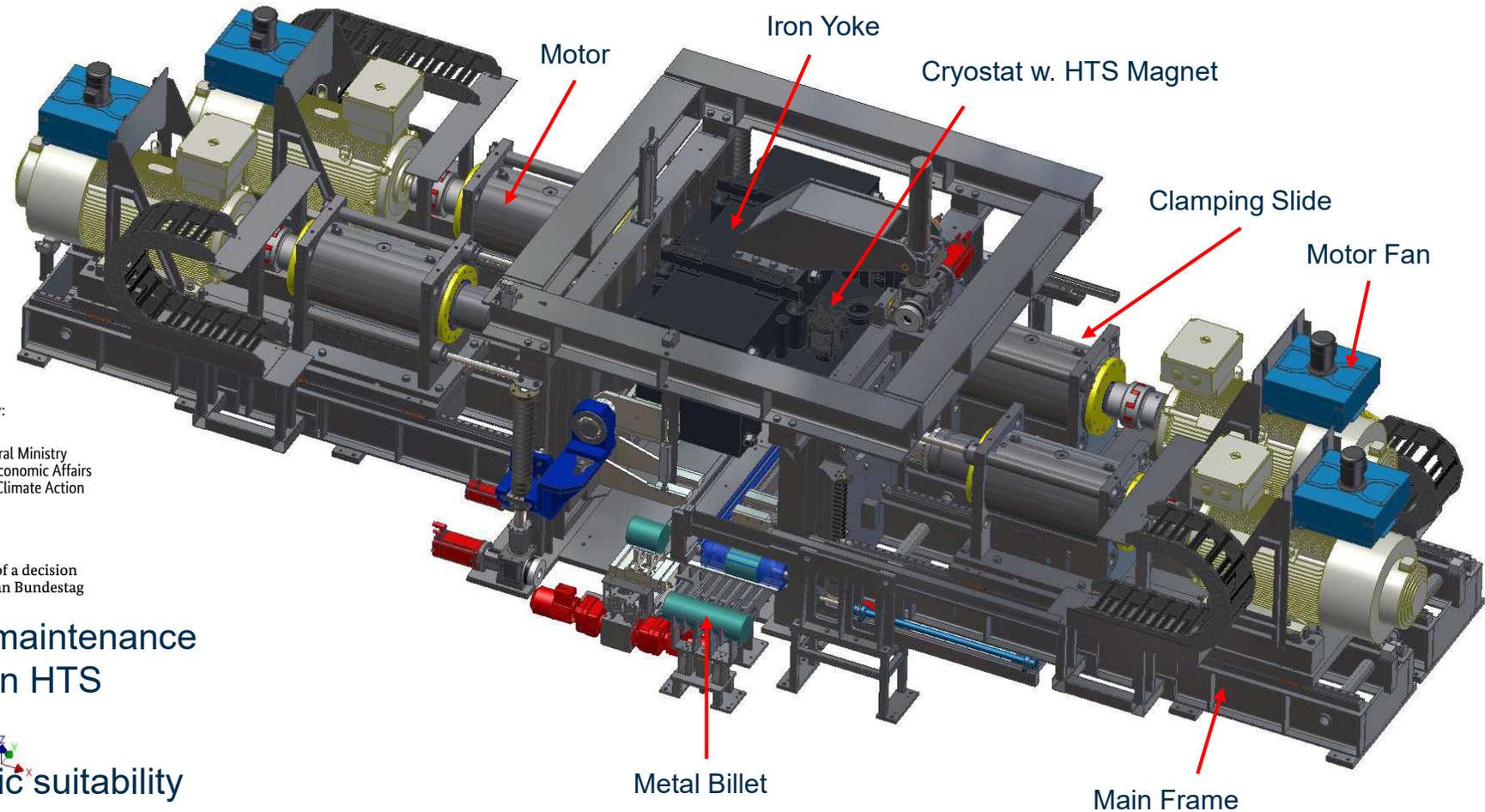


Federal Ministry
for Economic Affairs
and Climate Action

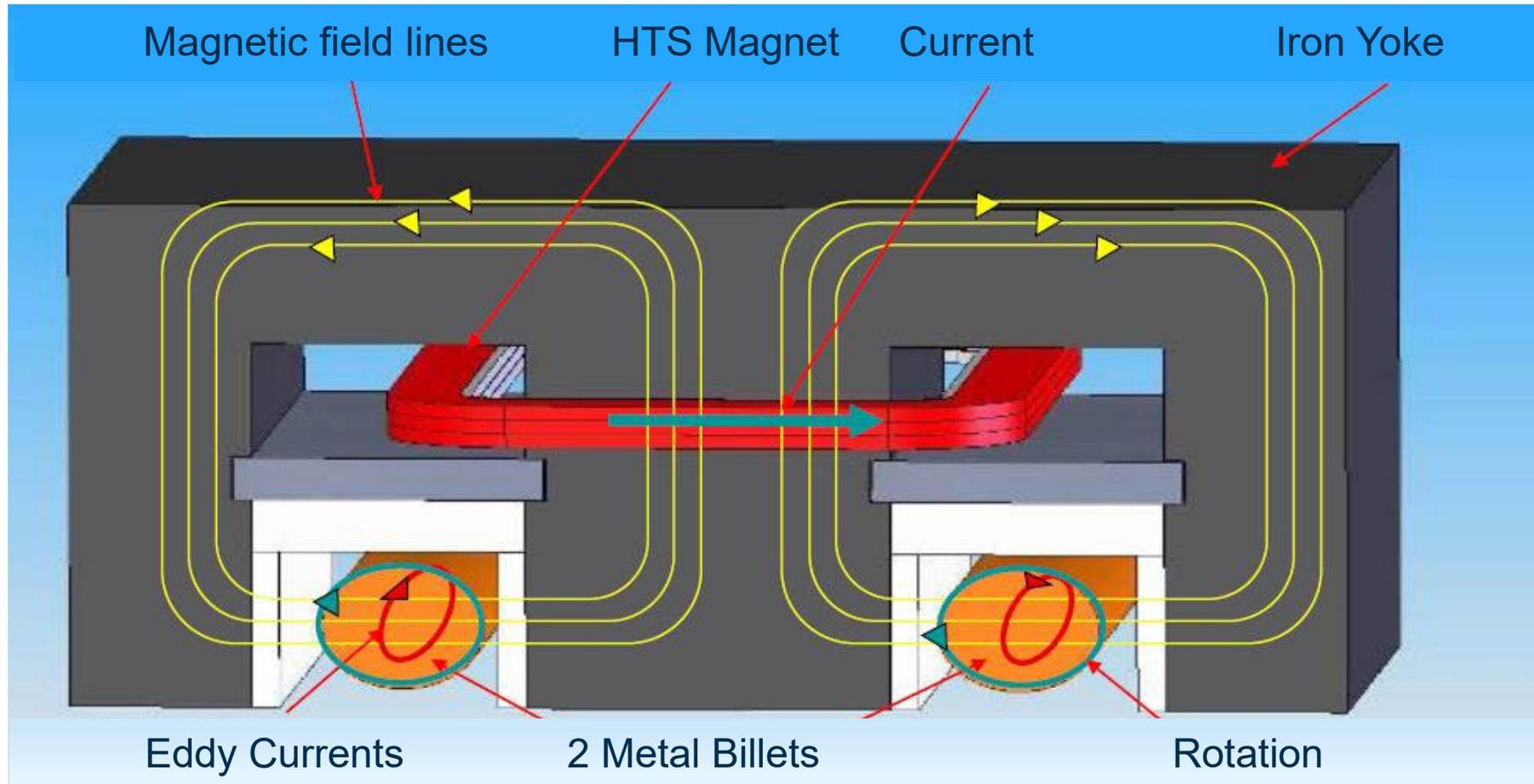
on the basis of a decision
by the German Bundestag

Project objectives:

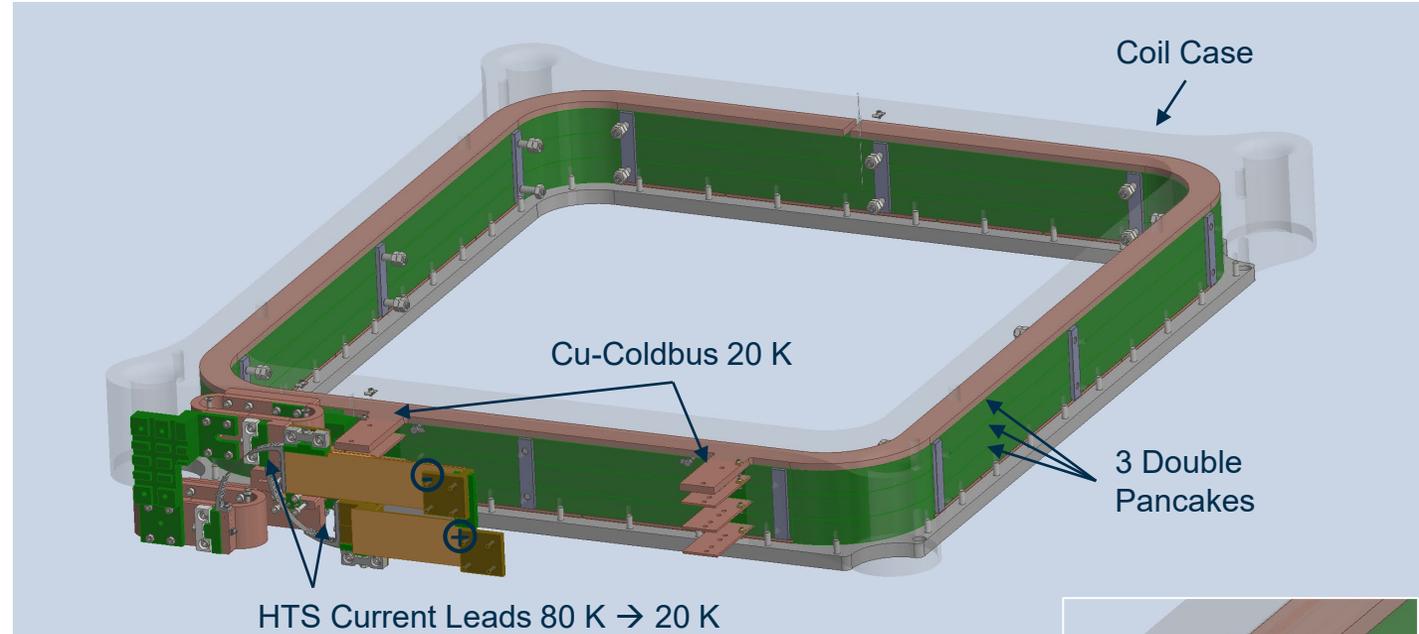
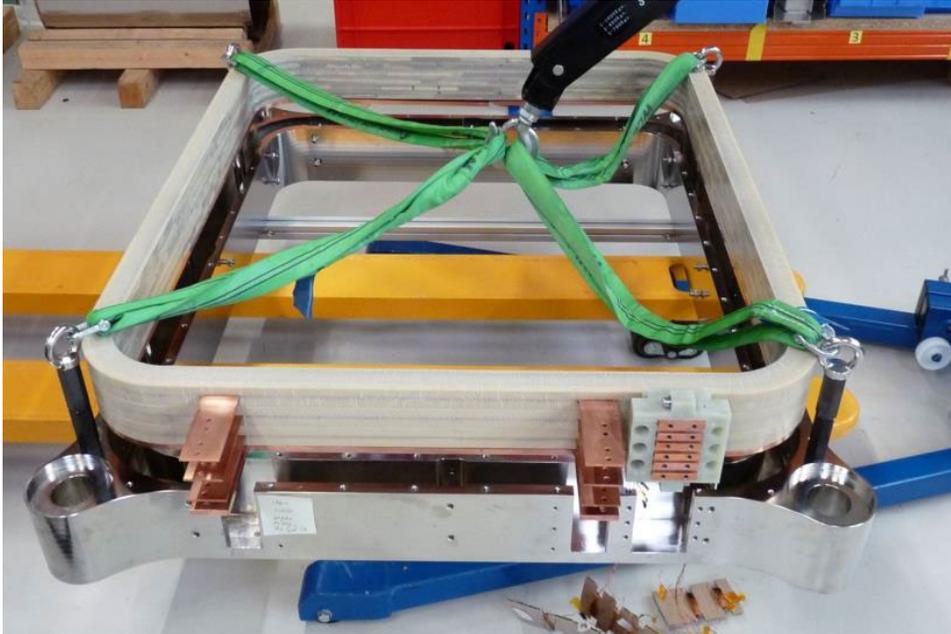
- Development of a robust and low-maintenance magnetic heater with 2nd generation HTS conductors
- Proof of the technical and economic suitability of the magnetic heater



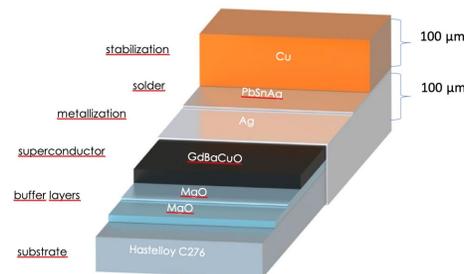
RoWaMag: Magnetic Billet Heating



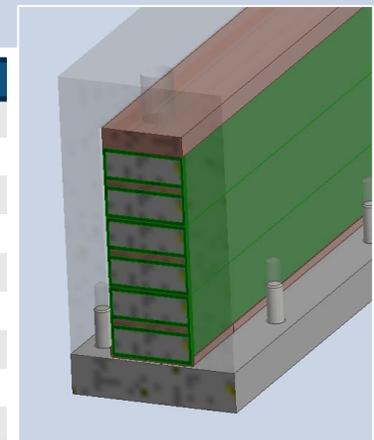
RoWaMag HTS-Magnet



HTS Tape	
Superconductor	GdBCO
Tape width	12 mm
Tape thickness	210 μm
Tape Length	3110 m

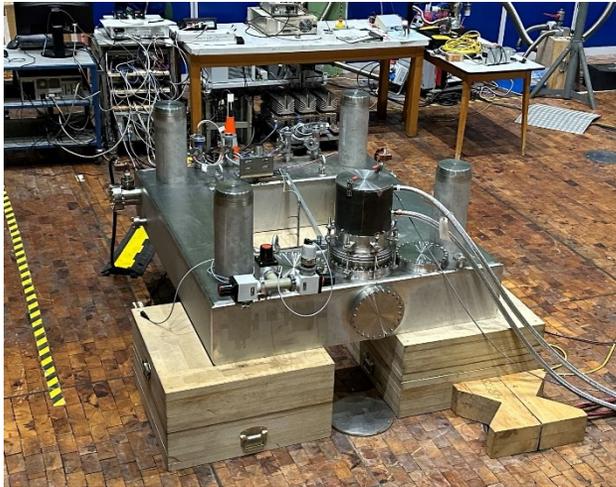


Magnet	
Winding number in single pancake	127
Coil number	3 Double-Pancakes (DPs)
Nominal current	505 A
Thickness of cold bus	3x 3 mm (1 / DP) + 10 mm (on top)
Insulation between windings	PEN-foil, thickness 18 μm
Coil potting compound	PU4110
DP height	35 mm
DP width	41 mm
Coil outer dimensions	1179 mm x 1041 mm



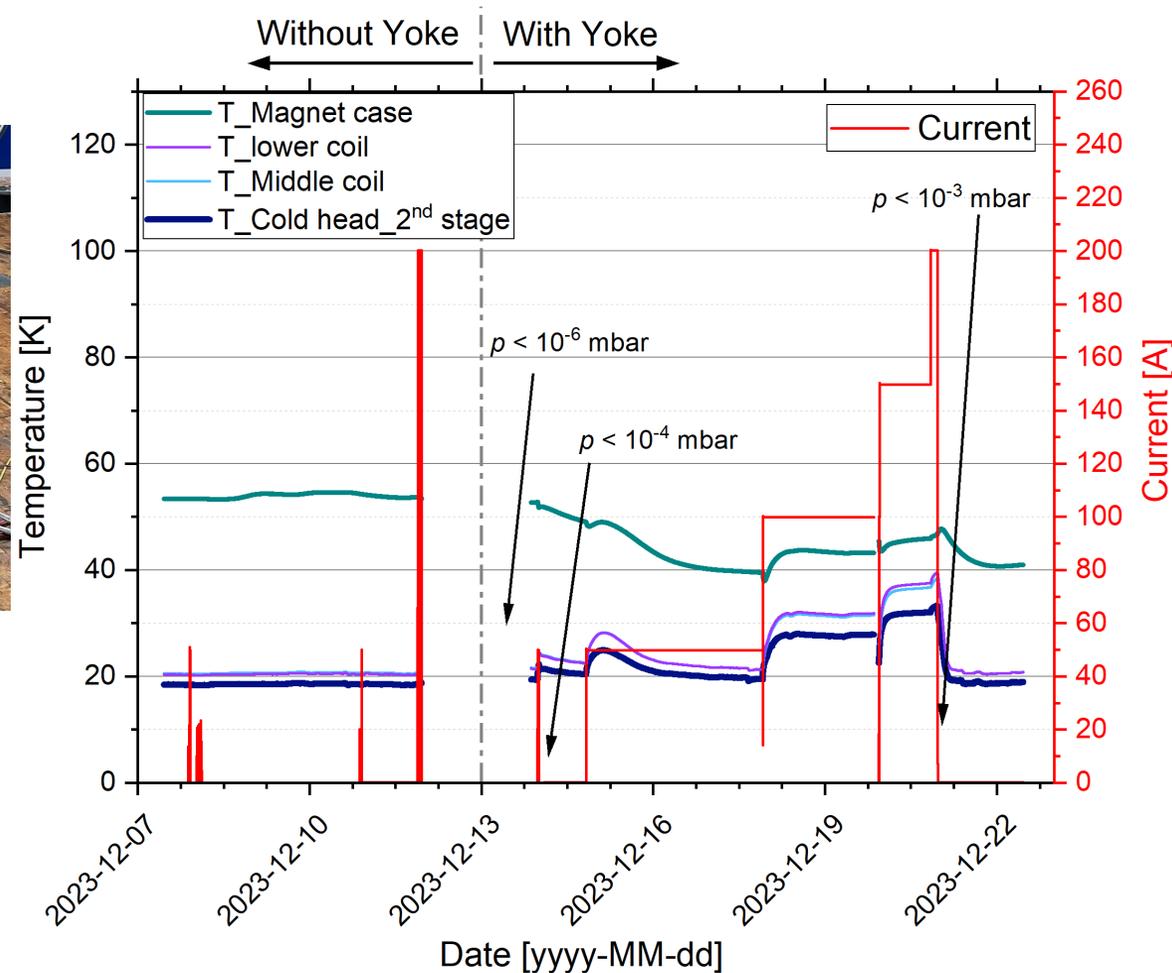
1st Magnet Test in 12/2023

Influence of Current and Yoke on Magnet Temperatures



Without Iron Yoke:

- Only small temperature changes with applied current.

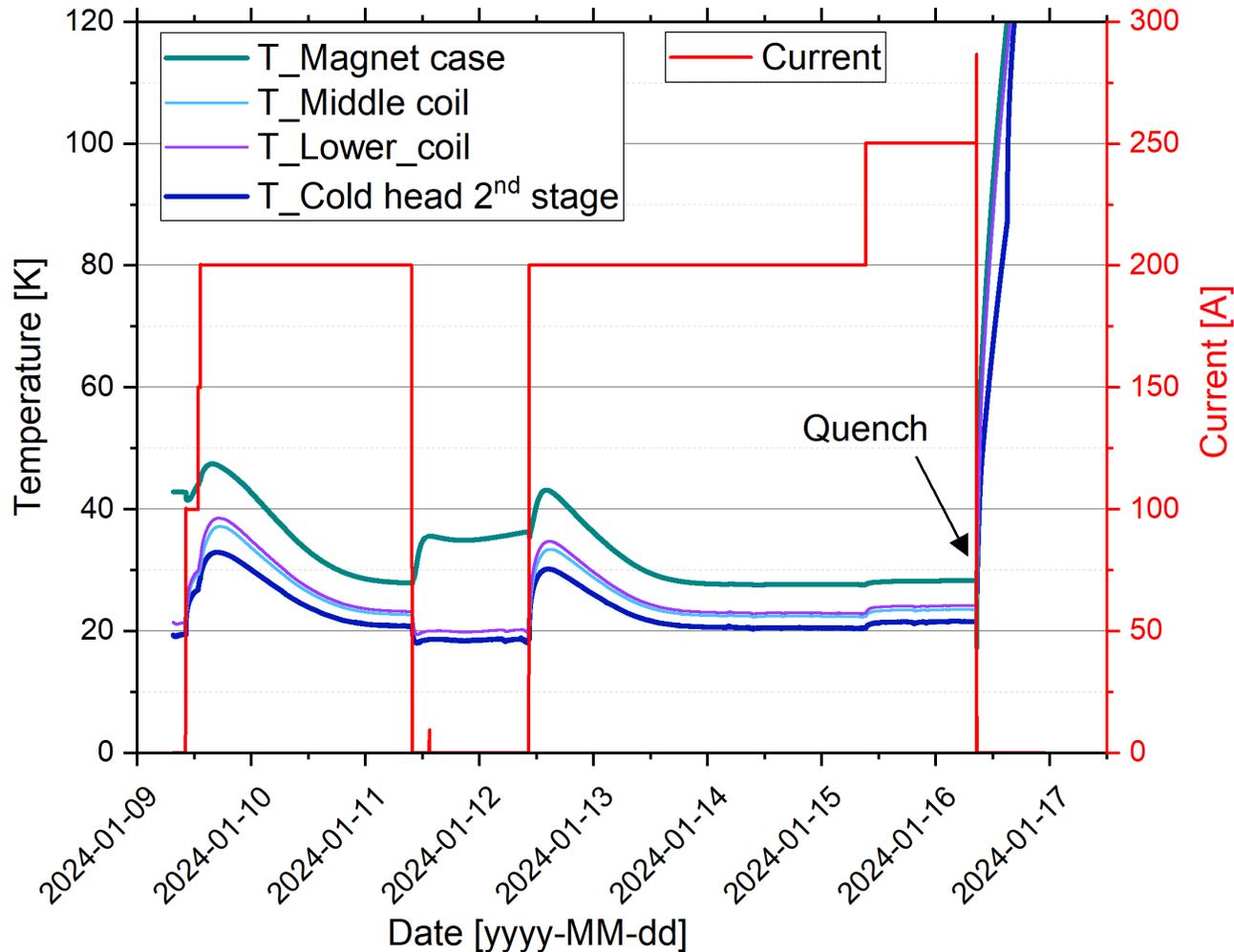


With Iron Yoke:

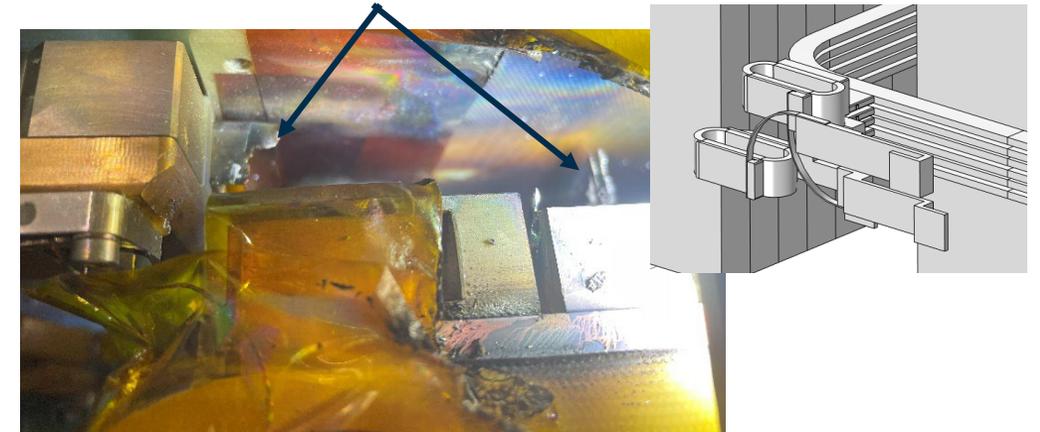
- Stronger thermal coupling of magnet and magnet case
- Large temperature changes with applied current
- Influence of pressure

Magnet Test continued in 01/2024

Test at higher currents



- Current up to 200 A stable for several days
- Strong temperature changes up to approx. 200 A
- 250 A stable, only small temperature changes
- Quench of current lead at approx. 280 A during current ramp from 250 A to 300 A
 - HTS current lead tape destroyed



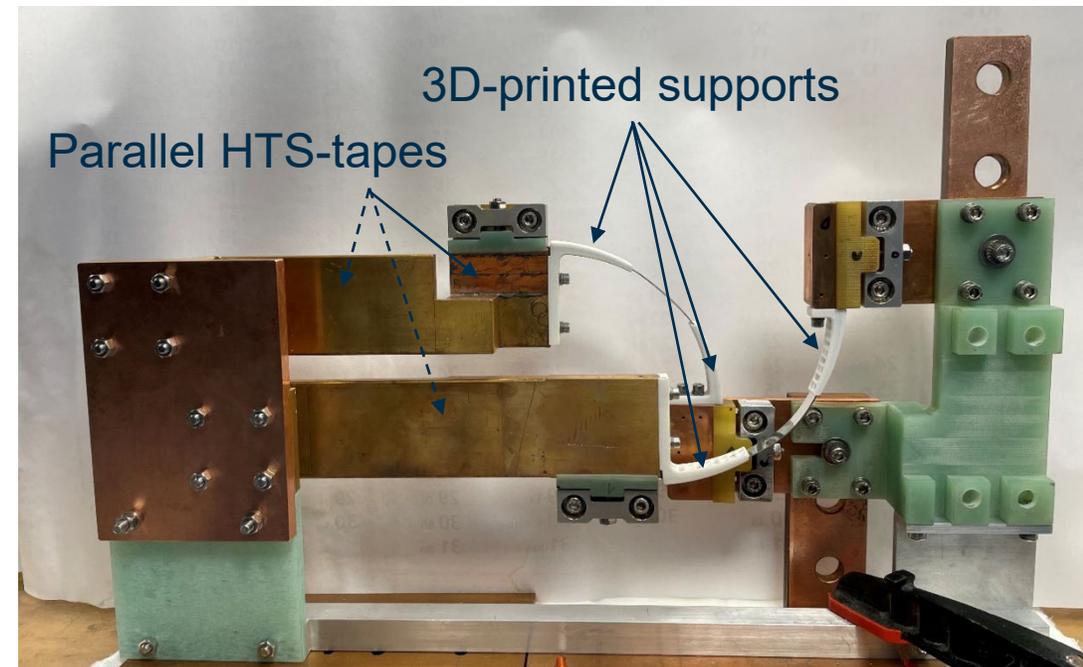
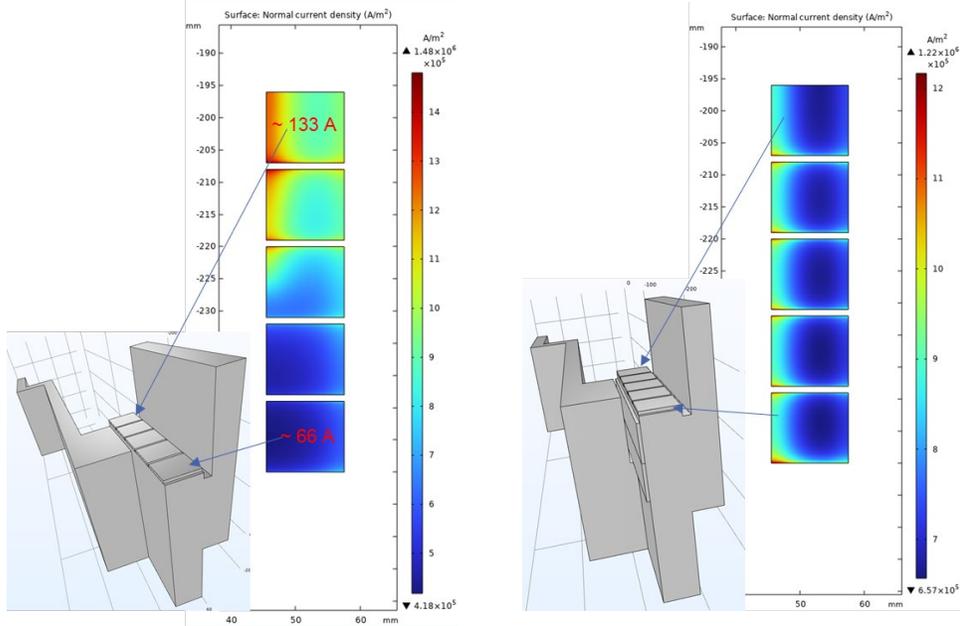
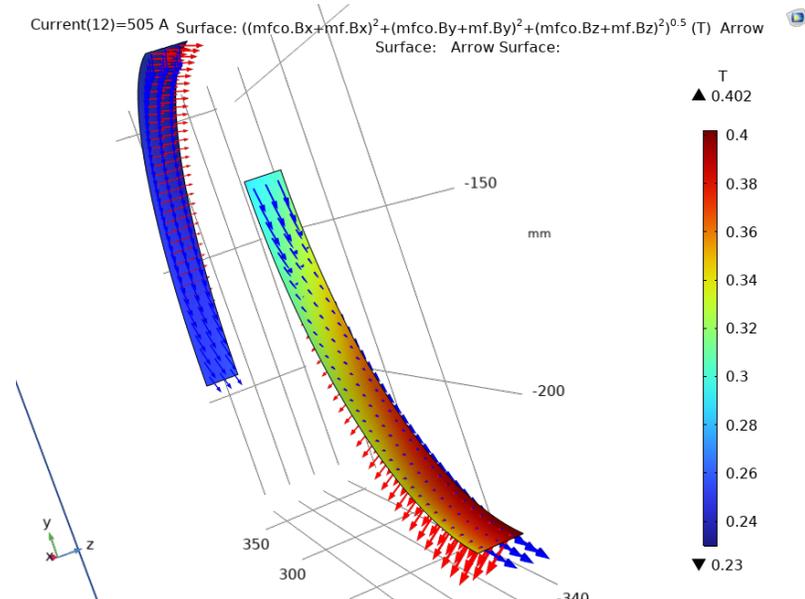
Warm end temperature at destroyed current lead ~ 75 K
Magnetic field at current leads caused

- I_c -reduction
- Lorentz forces

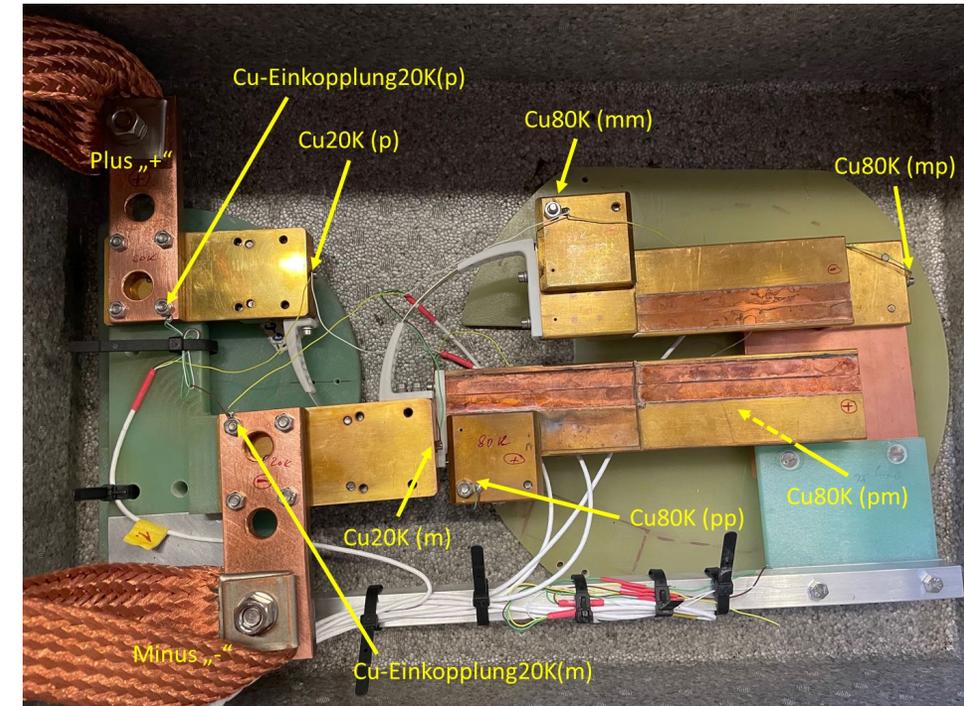
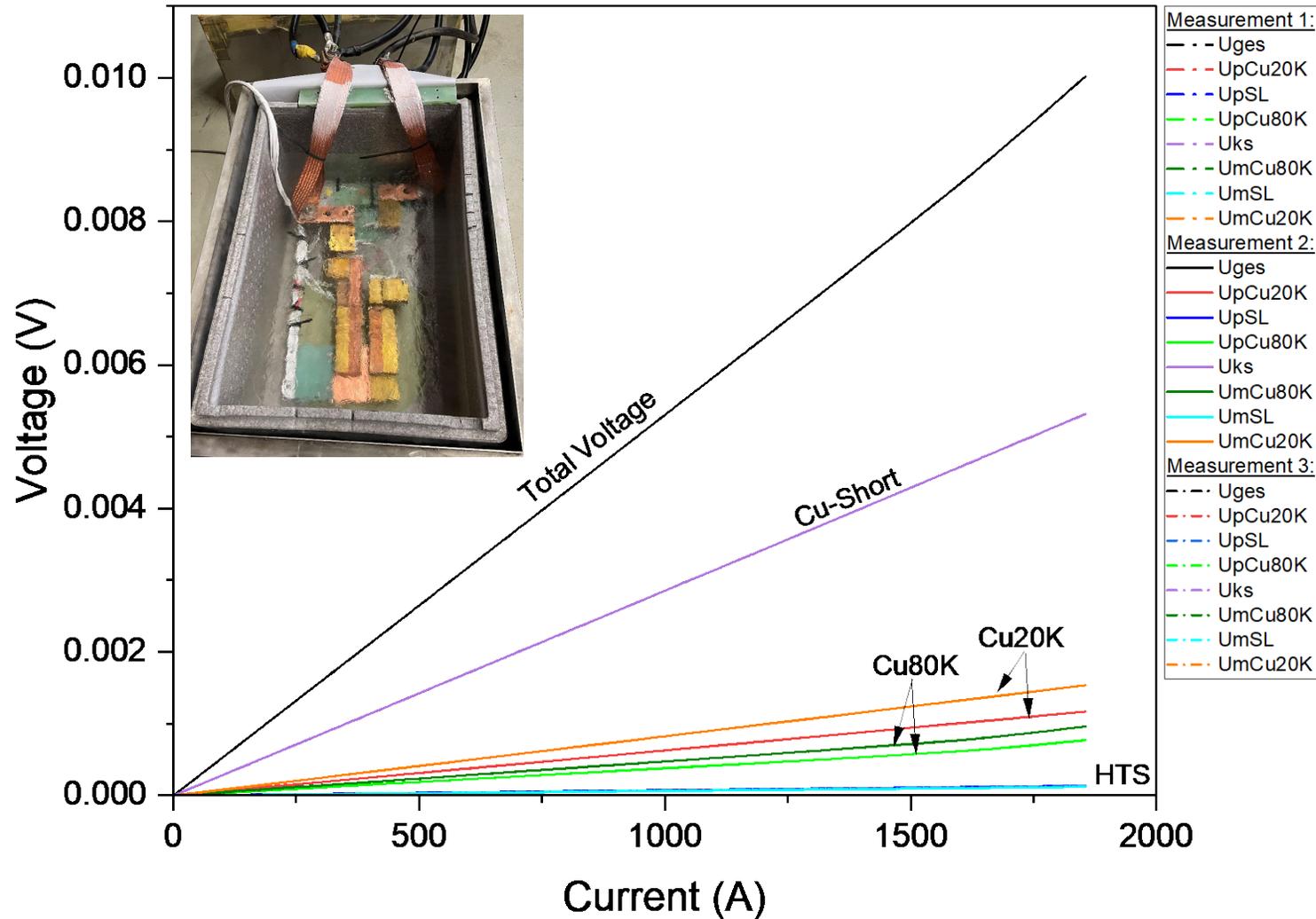
New Current Lead Design

FEM Simulations: $B_{\max} \sim 0.4$ T, Lorentz force $F_L \sim 0.7$ N/cm

- Single HTS tape replaced by stack of 5 HTS-tapes in each current lead
- 3D-printed supports against Lorentz forces
- Parallel tapes at warm Cu busbars
 - Homogeneous current injection
 - Reduction of Joule losses at warm end



Current Lead Test in LN₂



Reproducible data in 3 measurements:

- Test 1: $I \leq 311.5 \text{ A}$
- Test 2: $I \leq 1856 \text{ A}$
- Test 3: $I \leq 1856 \text{ A}$

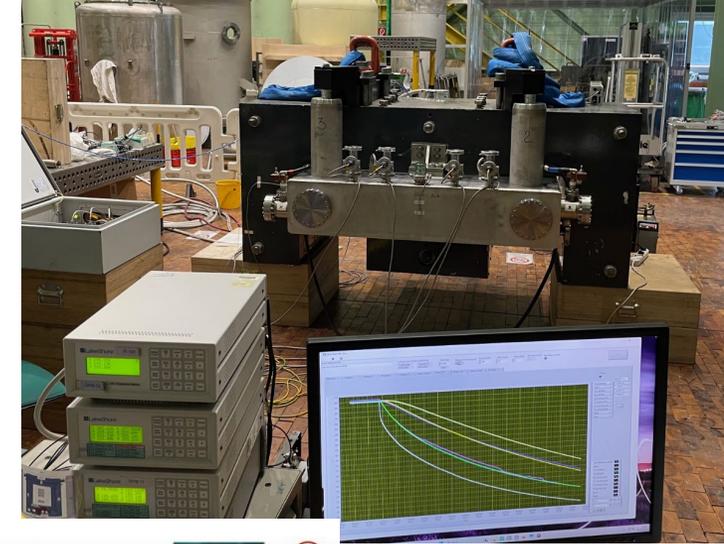
Magnet and Cryostat Assembly

- Redesign HTS current leads and cold bus ✓
- Assembly: current leads, magnet, thermal shield, cryostat ✓
- Data acquisition ✓
- Welding, pumping leakage tests ✓
- Cooling ✓



Summary

- Design of cryogenic system and vacuum vessel adapted to operating and maintenance conditions
- HTS magnet built and tested on REBCO basis
- Quench power supply due to insufficient design in terms of current carrying capacity and Lorentz forces
- Redesign of HTS power supply, assembly and testing completed
- Magnet assembly in cryostat completed



Outlook

- Magnet test → week 21-24/2025
- Transfer to Bültmann
- Installation in heater rack
- Functional test heating up various metal billets

