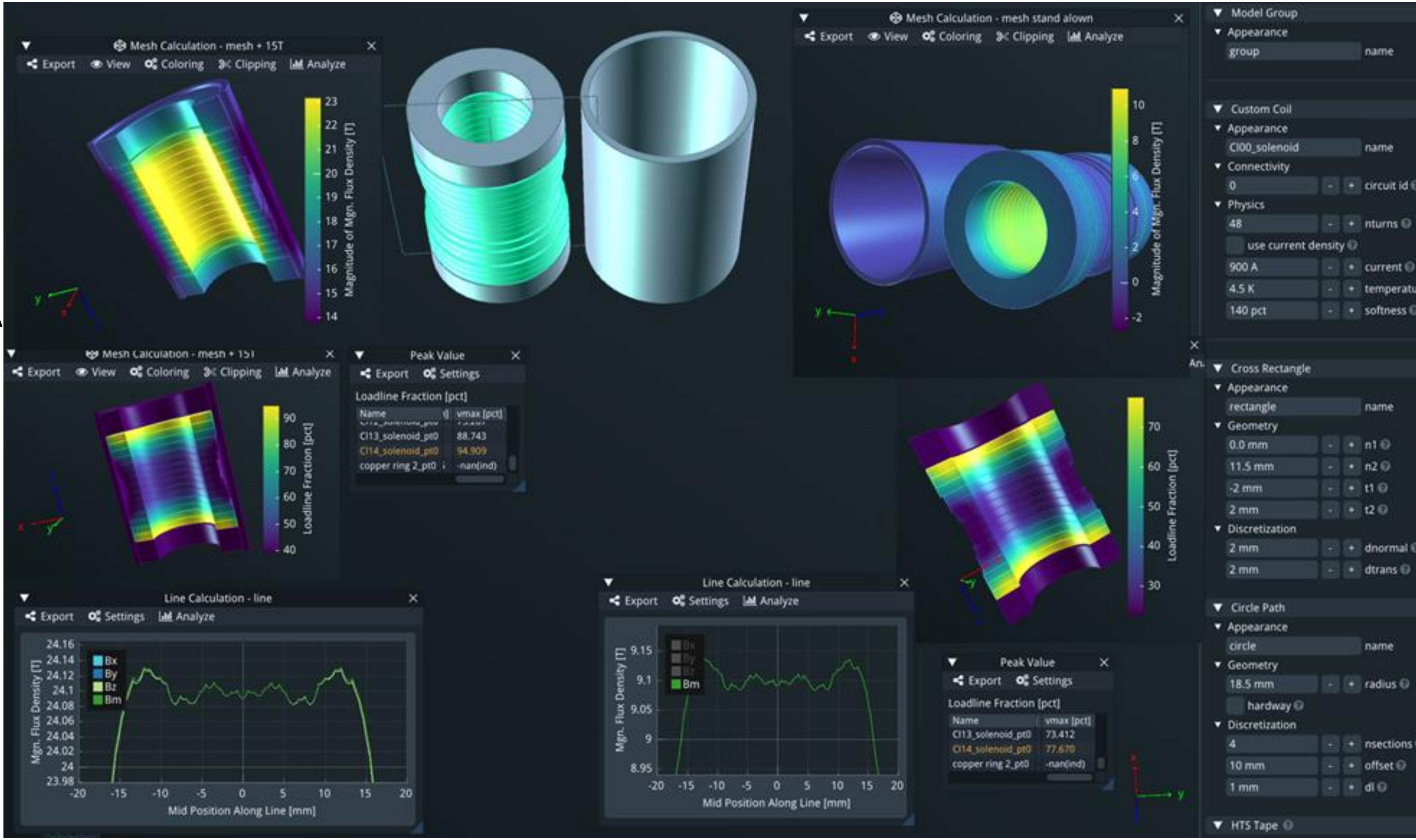
High performance
Fujikura tape 4.5K

Boost coil standalone
8.1T peak 77%ss 900A
10 T peak 100%ss 1100A

In 15 Tesla background
22.9T peak 95%ss 900A



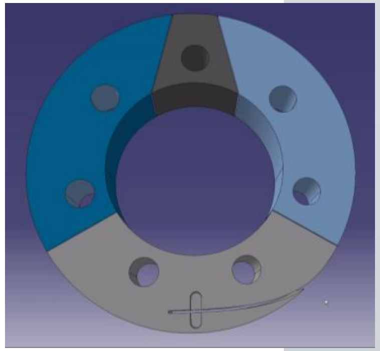
Constant inner diameter design

Joints alternate from inner to outer radii.

Viewed from top, Coils alternate between being wound clock-wise to anti-clock-wise.

We can increase the good field length by adding coils

Central section has Copper rings joints / spacers.



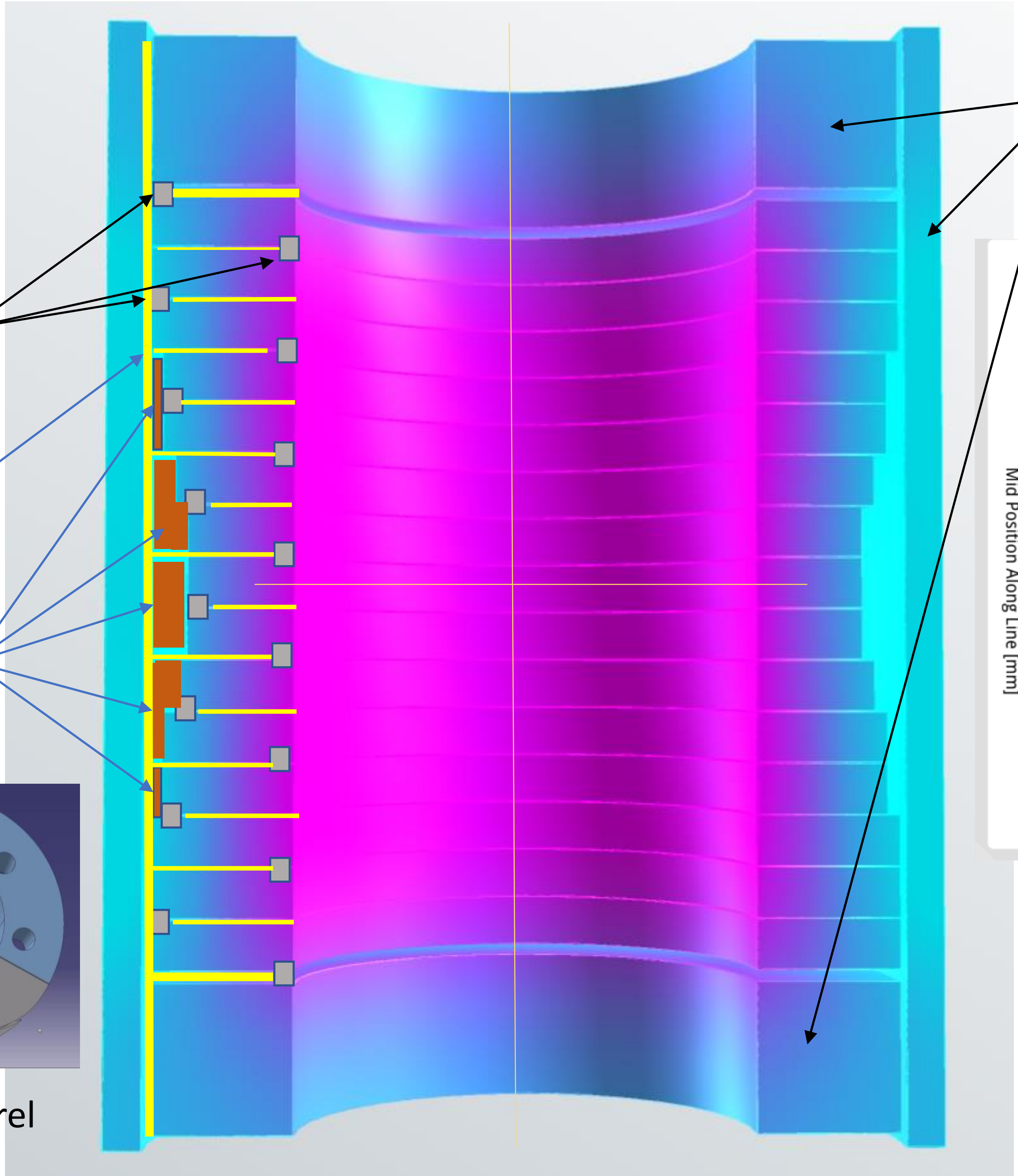
Collapsible central winding mandrel

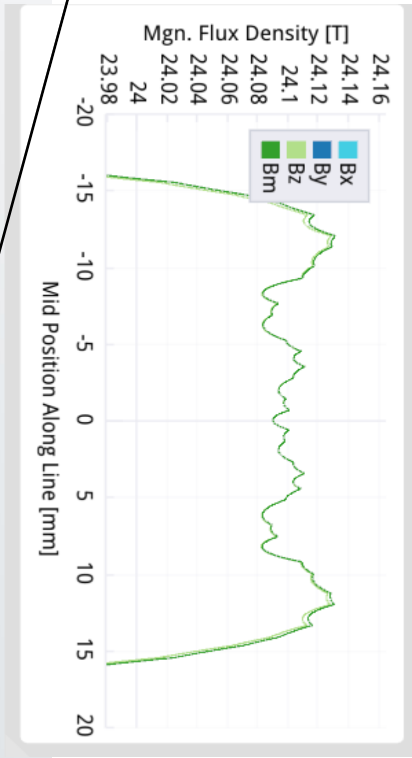
Edge joints

Insulation

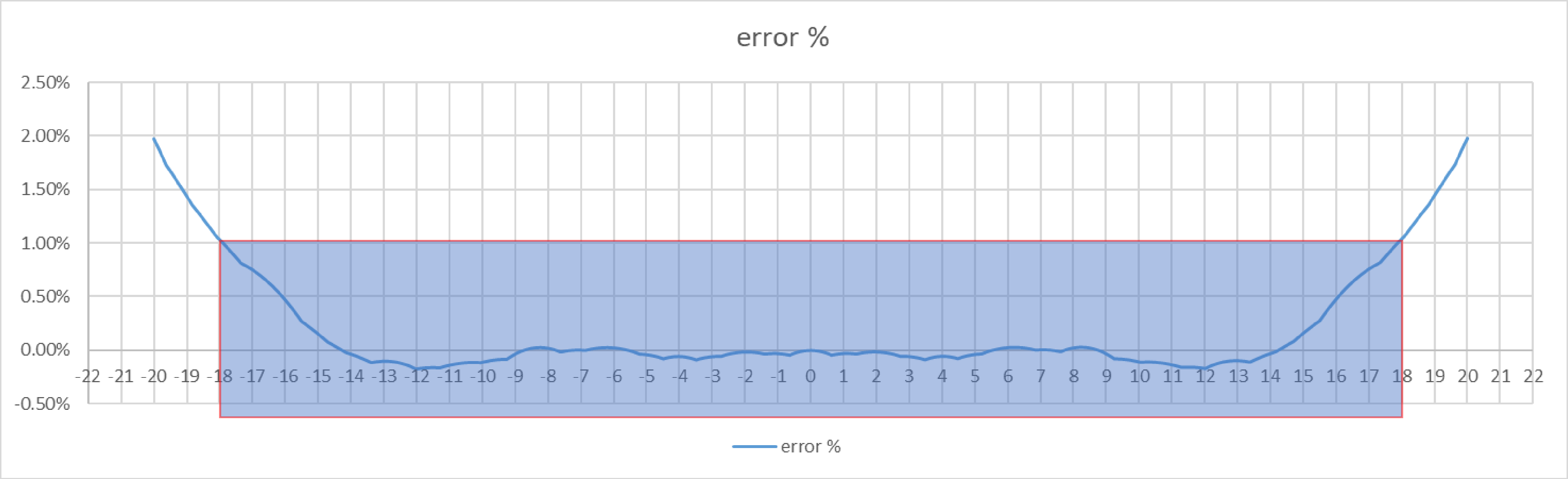
Copper Ring joints

Inductive shields



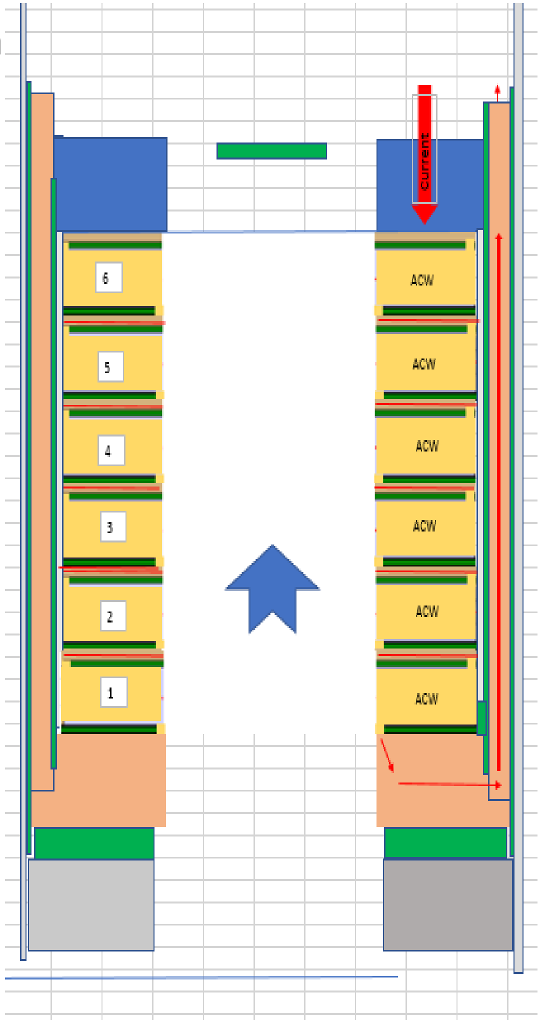


Field variation over sample volume



Magnet System overview

Top joint copper ring current injection

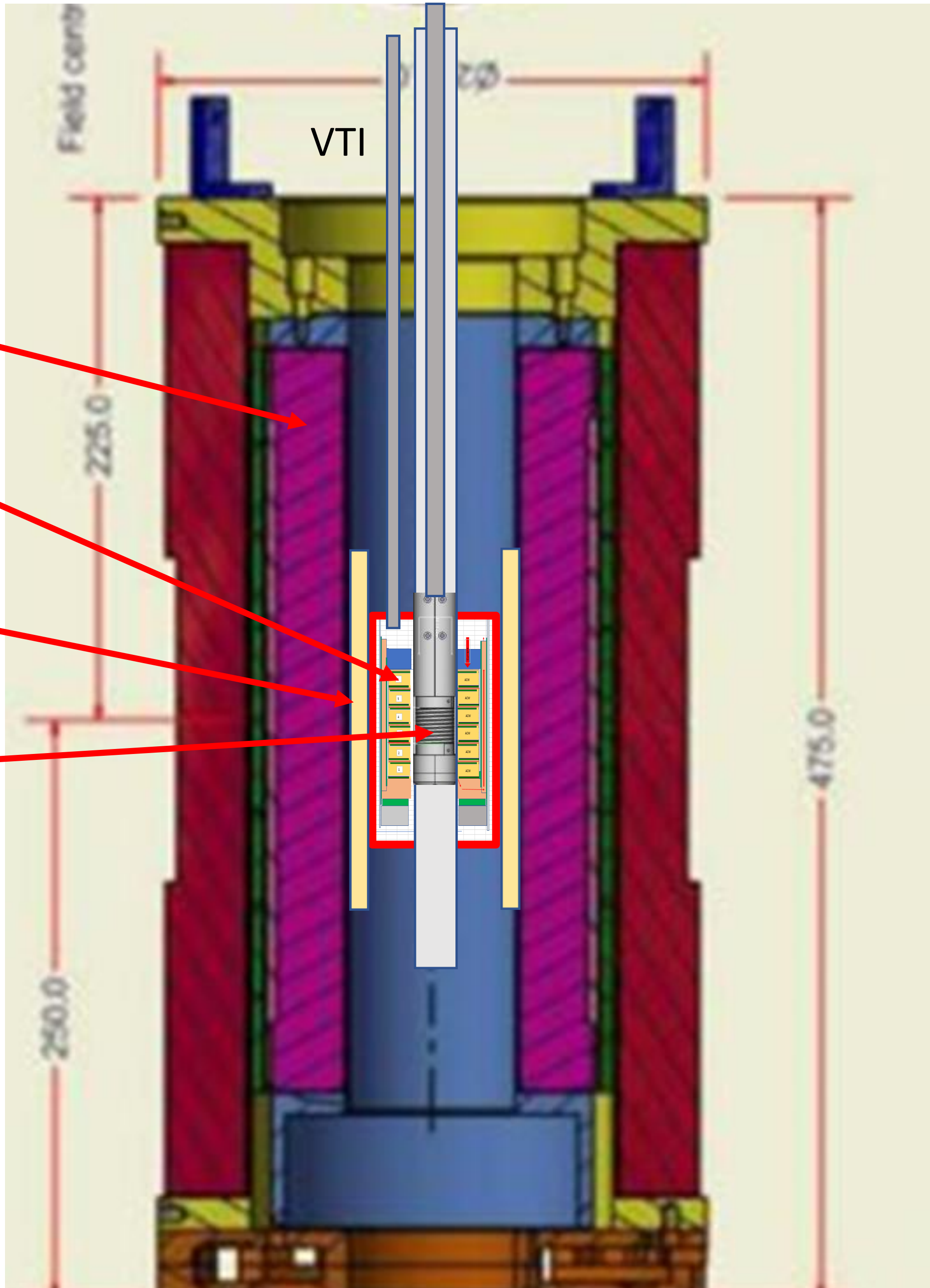


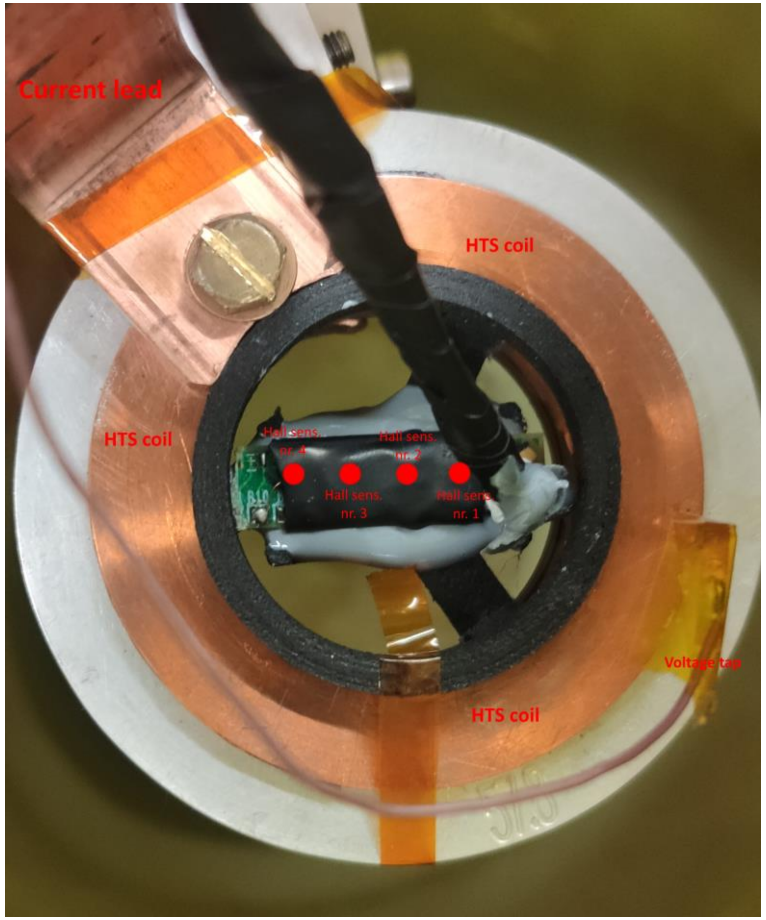
15 T Magnet

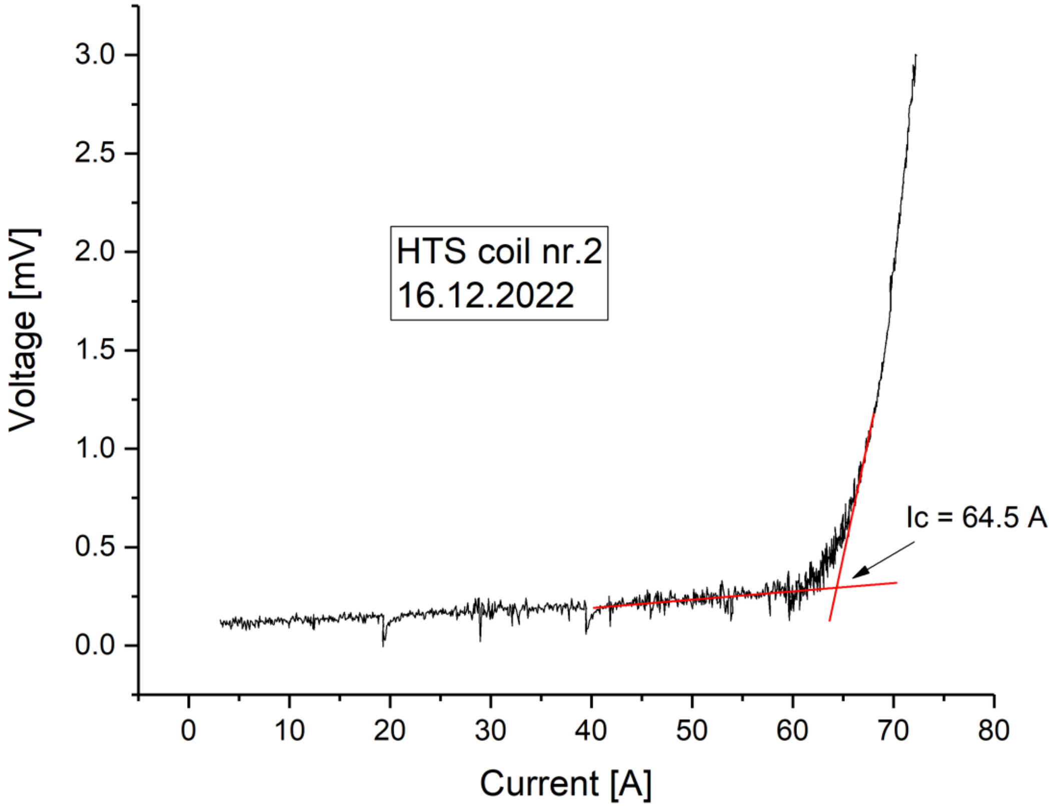
HTS Magnet insert

Inductive shield ?

Sample holder




Current lead
HTS coil
HTS coil
Hall sens. nr. 4
Hall sens. nr. 2
Hall sens. nr. 3
Hall sens. nr. 1
Voltage tap
HTS coil


HTS coil nr.2
16.12.2022
Ic = 64.5 A
Voltage [mV]
Current [A]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
10
20
30
40
50
60
70
80

Constant inner diameter design

Joints alternate from inner to outer radii.

Viewed from top, Coils alternate between being wound clock-wise to anti-clock-wise.

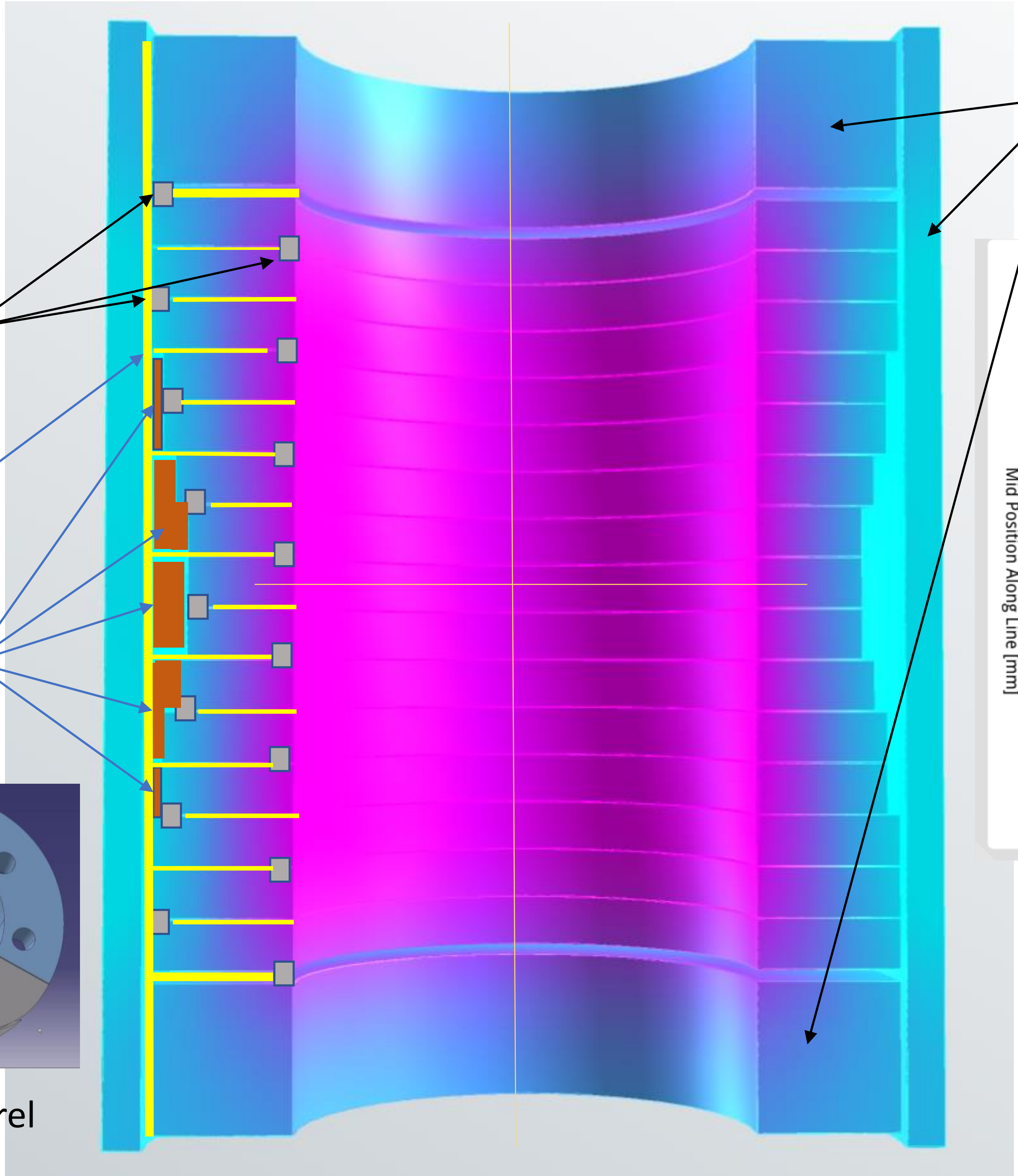
We can increase the good field length by adding coils

Central section has Copper rings joints / spacers.

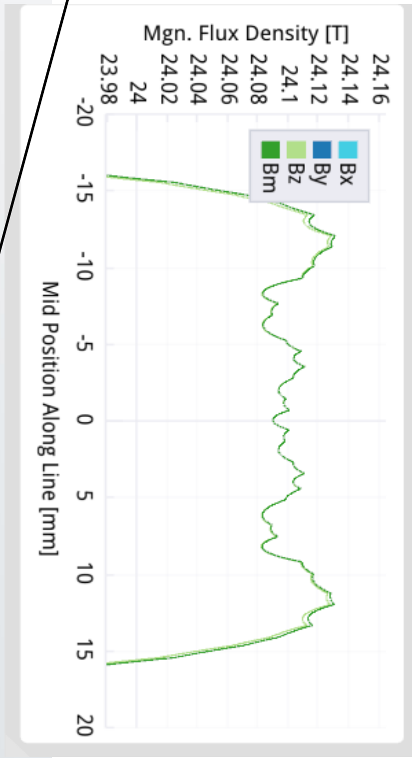
Edge joints

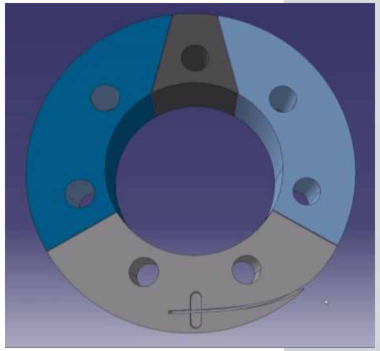
Insulation

Copper Ring joints

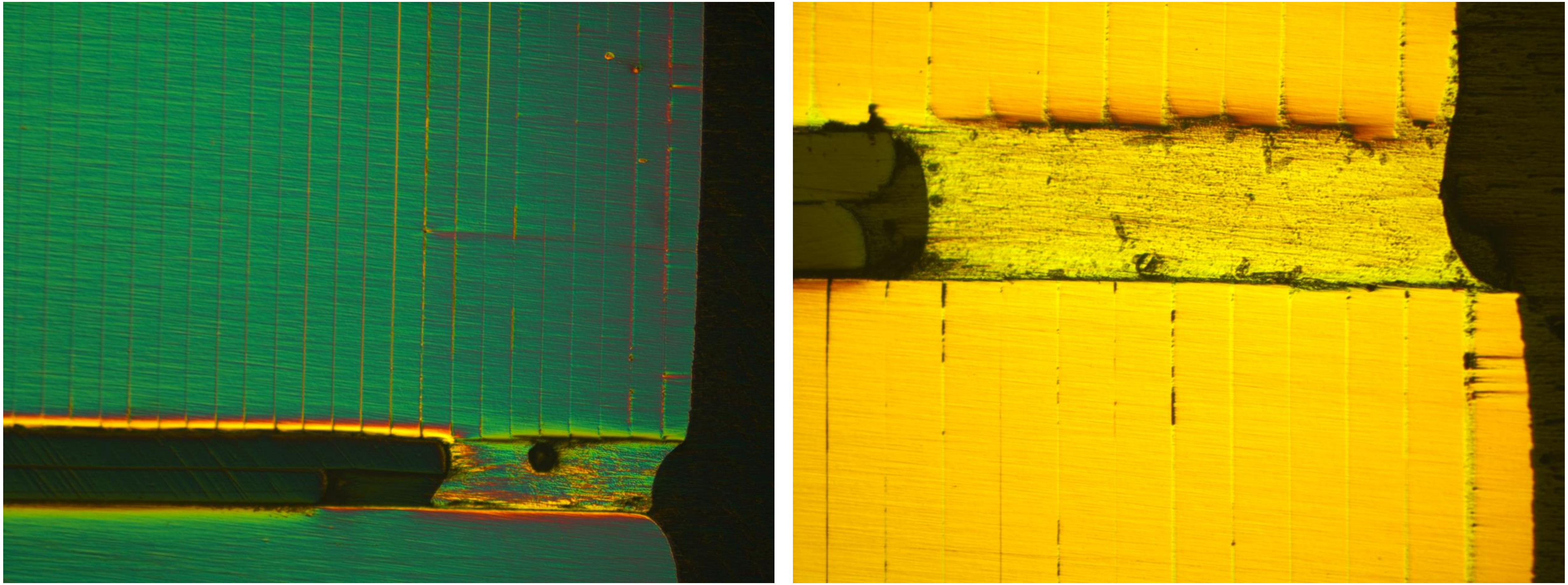


Inductive shields





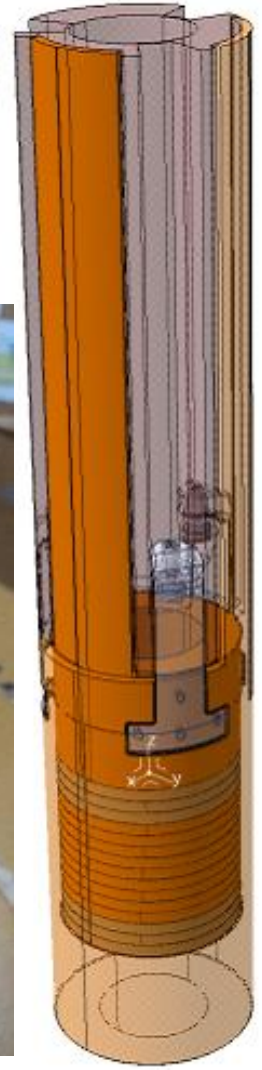
Collapsible central winding mandrel



Description of the results: T1-D2

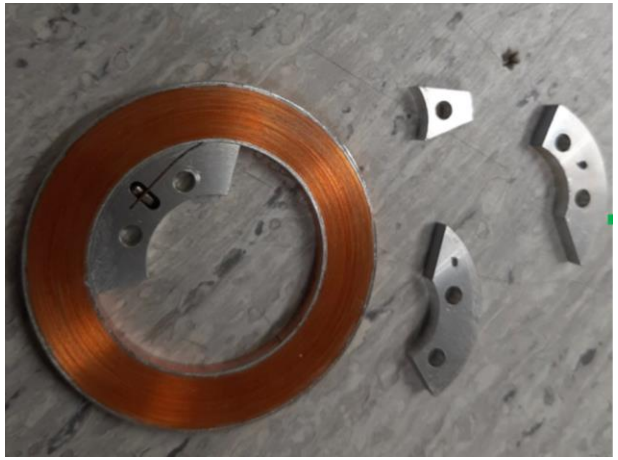
- Mechanical design completed
- 3D printed mock-up fabricated, assembly sequence validated
- All parts in production
- 3D printed 316L parts delivered





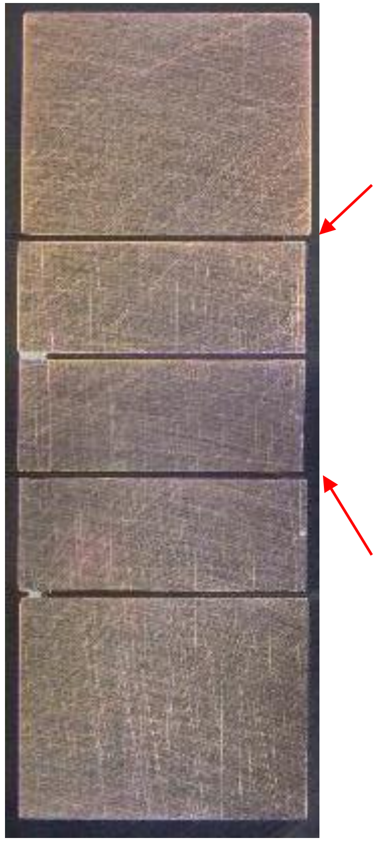
Description of the results: T1-D3

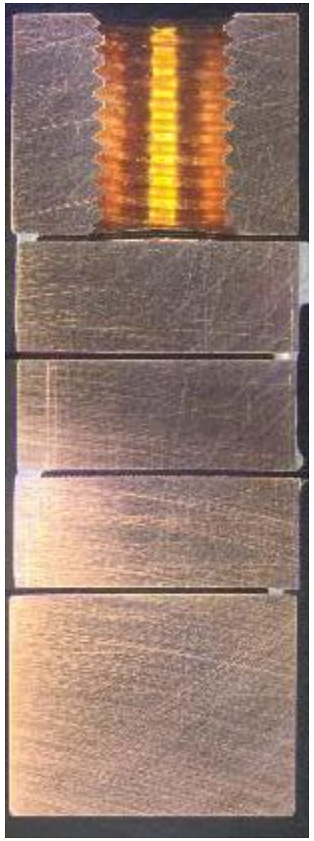
- Collapsible mandrel design, fabricated & validated
- Tooling ready for winding
- First & last turn soldered for mech. support



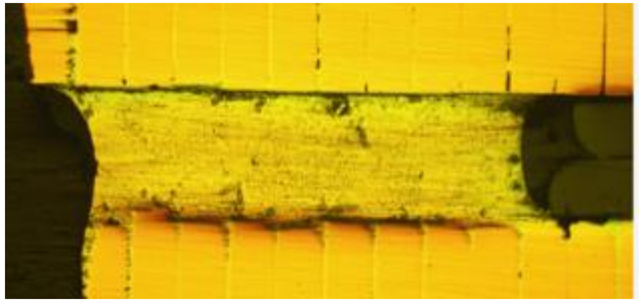
Description of the results: T1-D4

- Kapton disks with cut-outs for edge joints as tooling
  - Inner edge joints often with voids, difficult to fill reliably with solder
  - Double pancakes could be an alternative to eliminate inner joints

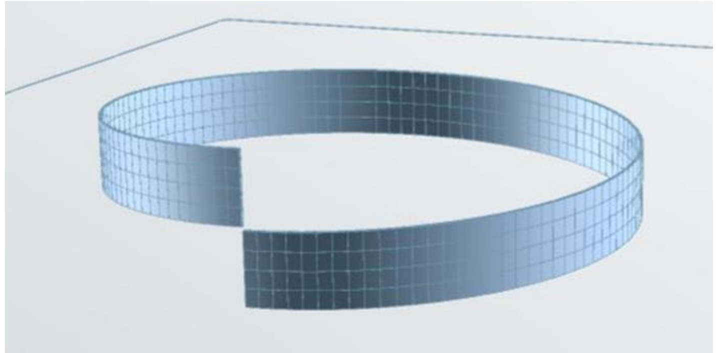




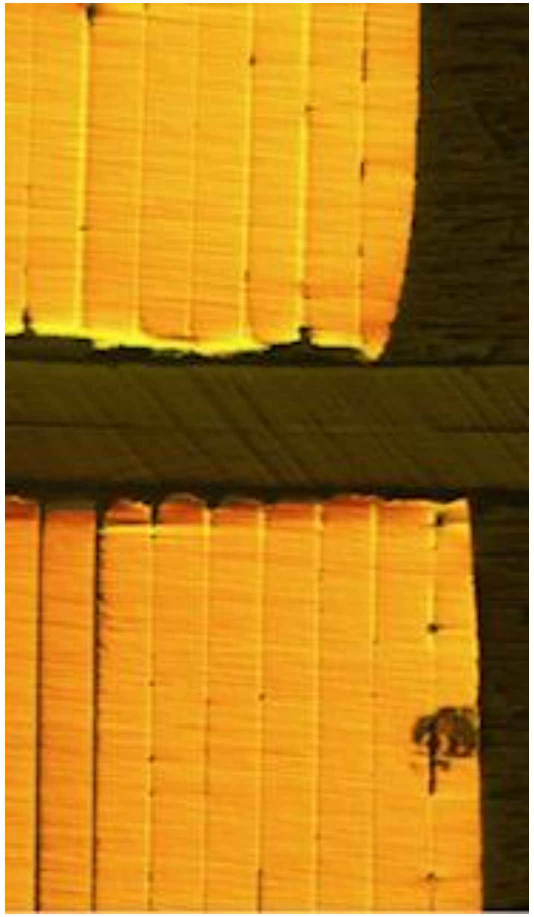
Test Copper coil with edge joints



Outer joint



Inner layer jump

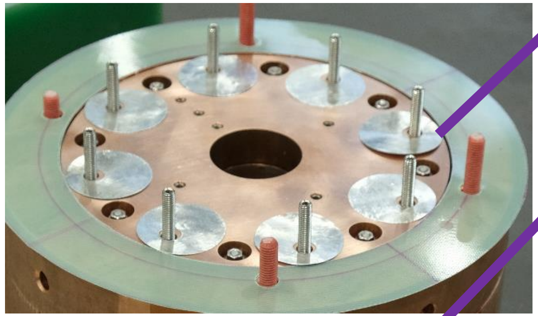


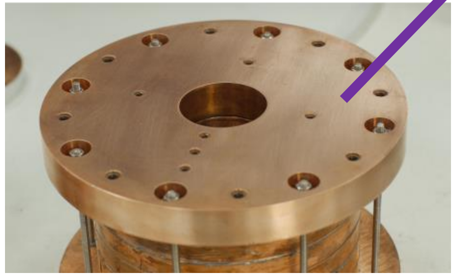
Outer and inner coil
insulation with no joint

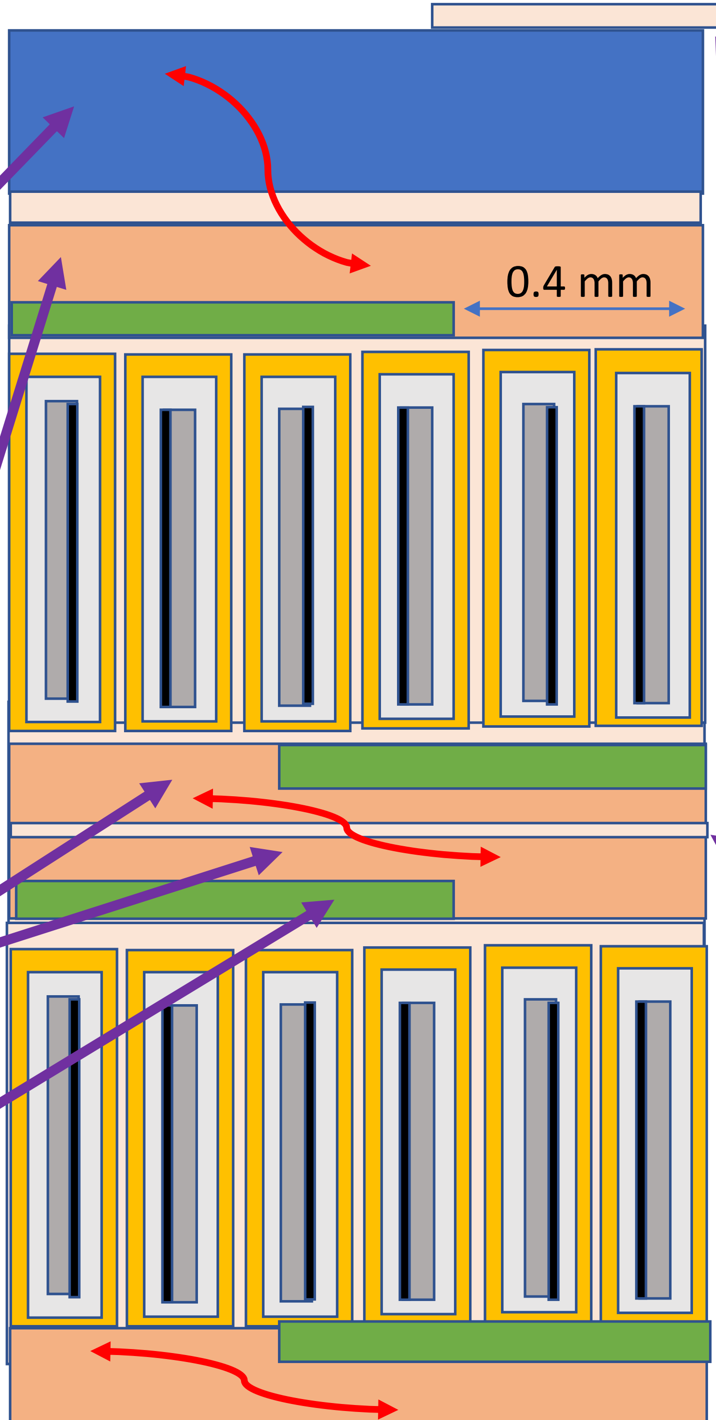
Description of the results: T1-D5

- Tooling to assemble multiple (double) pancakes into solenoid field booster
- Al tube as inductive shield and mech. support

Coil Layout & Edge Joint

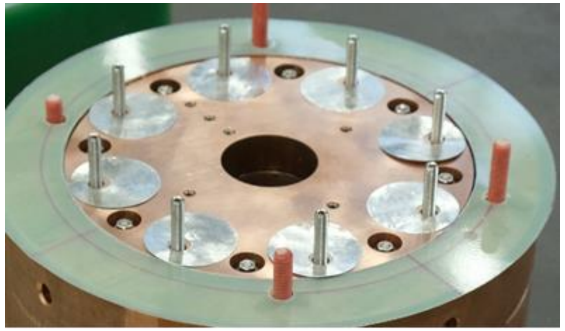


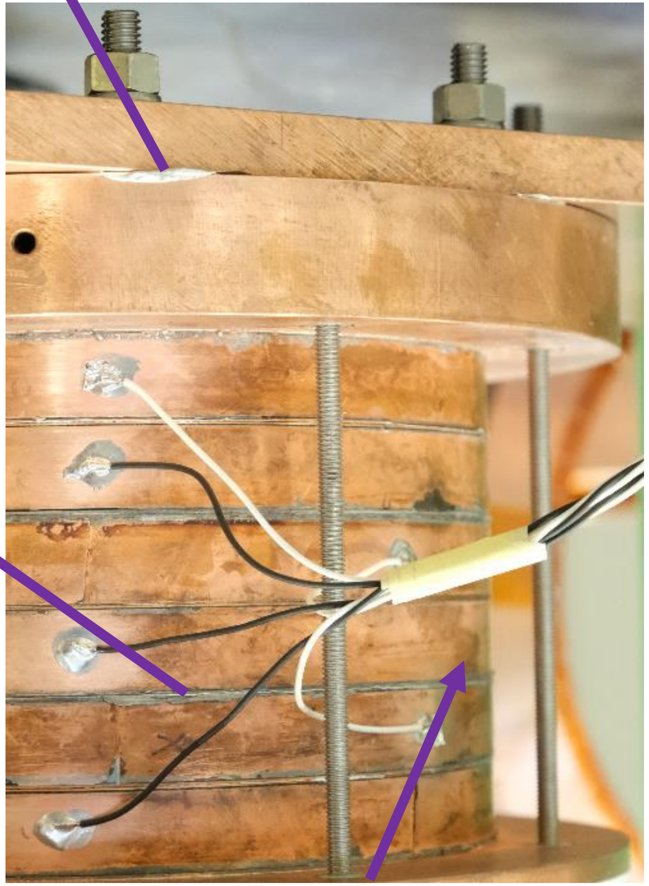




Copper coil joint plate 0.5mm thk

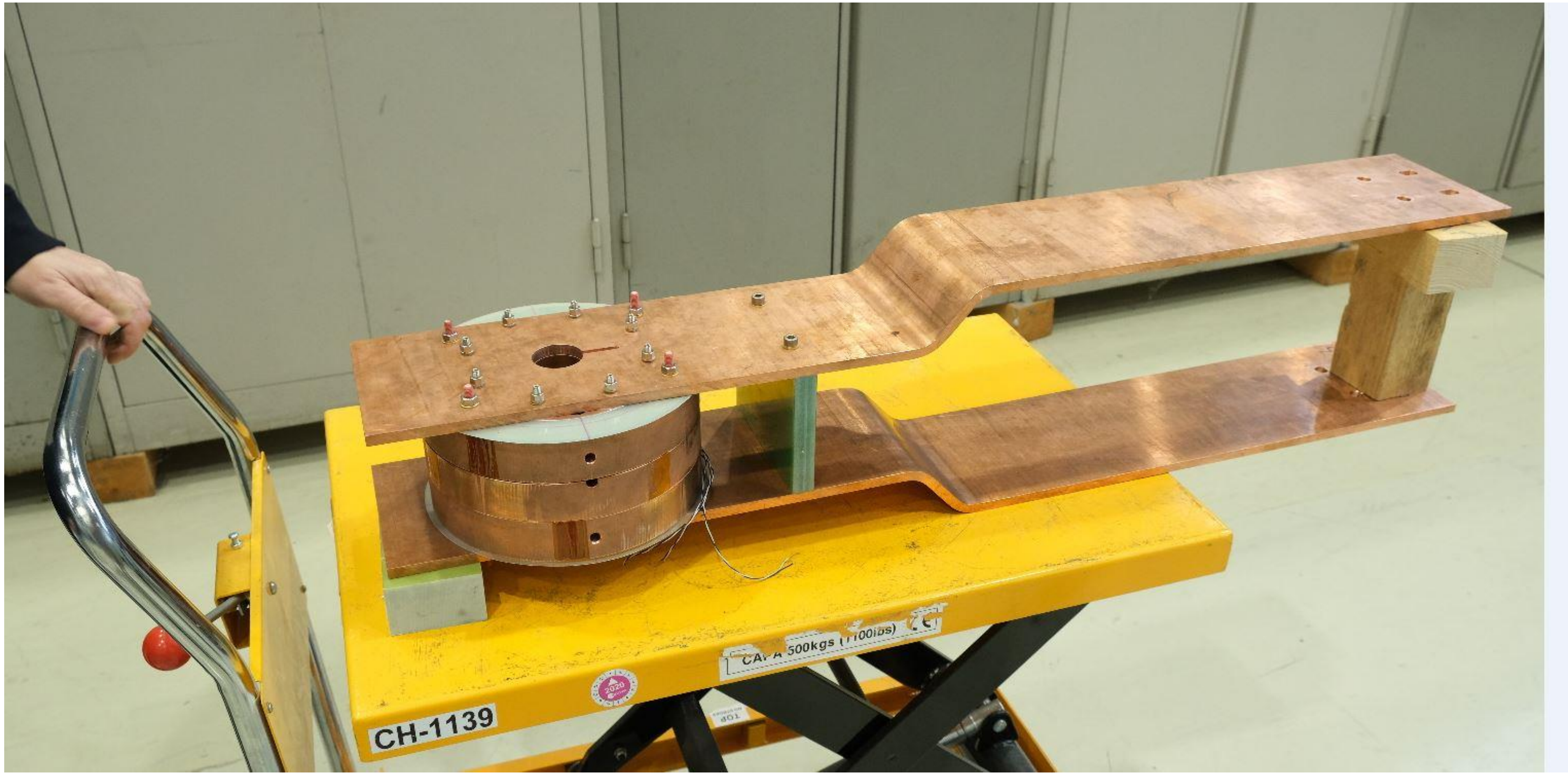
with 0.125 mm undercut for kapton insulation.





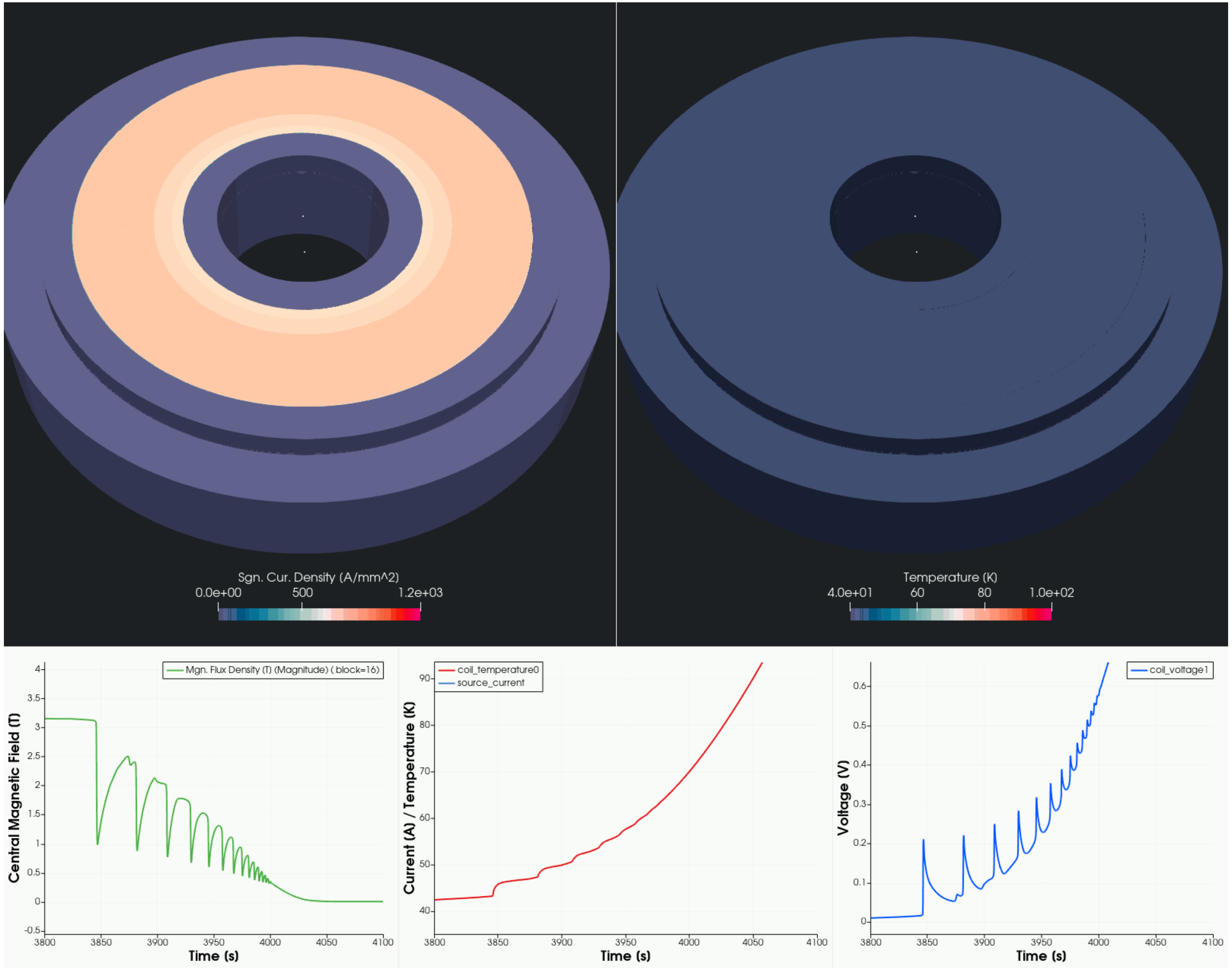
PSI and TokamakEnergy

26 T hts coil , Copper busbars clamped with Indium compression joints test at CERN Nov 2019



HTS Quench

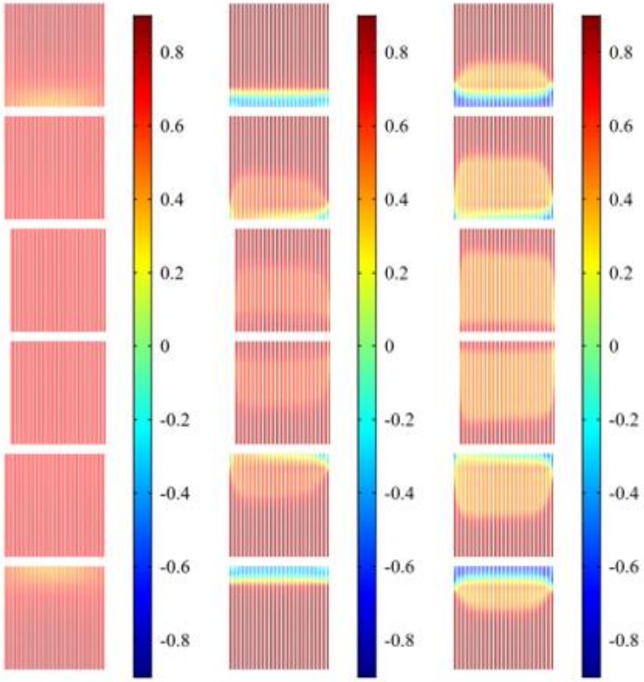
HTS quench in simple coil, we see the evolution of field, temperature, current density, voltage maps, during quench.

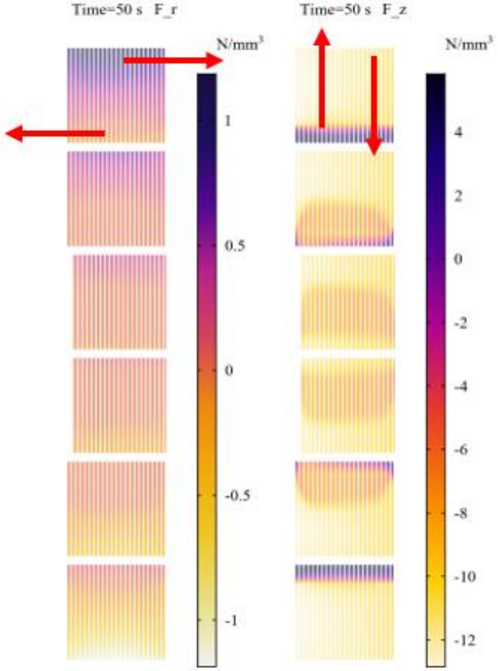


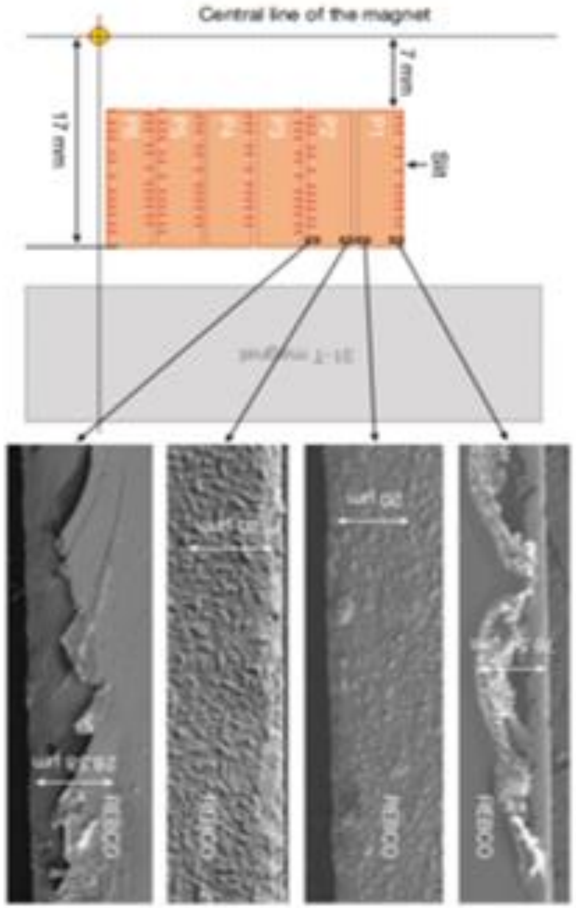
[DIPOLE HTS MAGNETS AT CERN | G. Kirby | 978 updates | 2 publications | Research Project (researchgate.net)]

Thanks to LittleBeast engineering for the modelling
Mar 31 2021

Screening currents





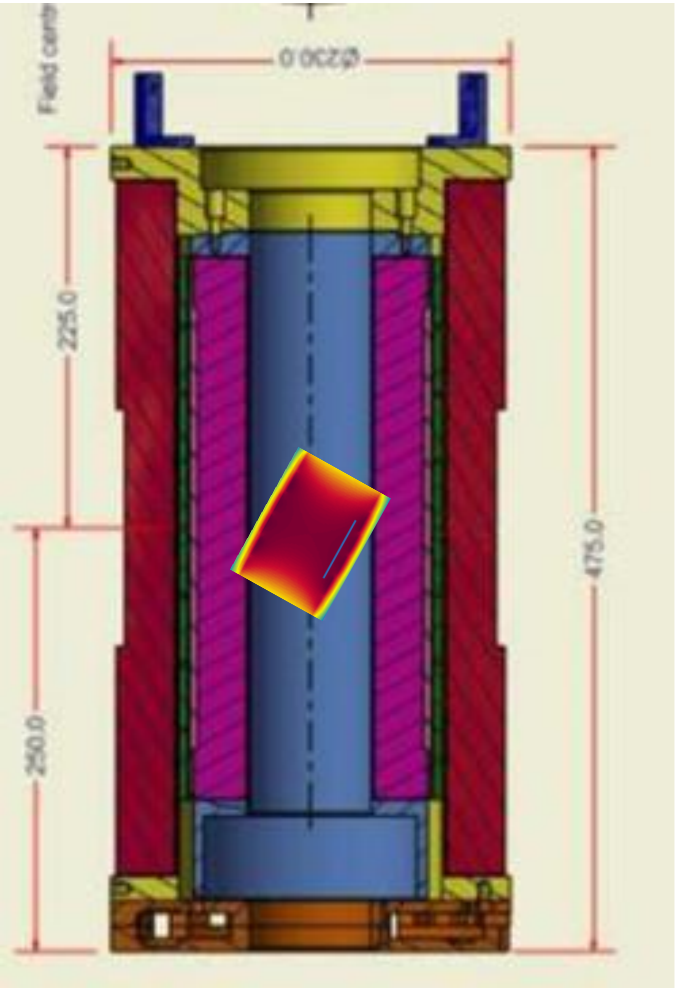


9 Results : Lorentz forces distribution in the coil

The Lorentz forces distribution is shown for the case of high-quality cable (1kA critical current, 25 n-value), and it is calculated for t=50s after the current plateau. From left to right: radial and vertical component. The arrows represent the main direction of the forces for the upper pancake.

Misalignment 5 mRad

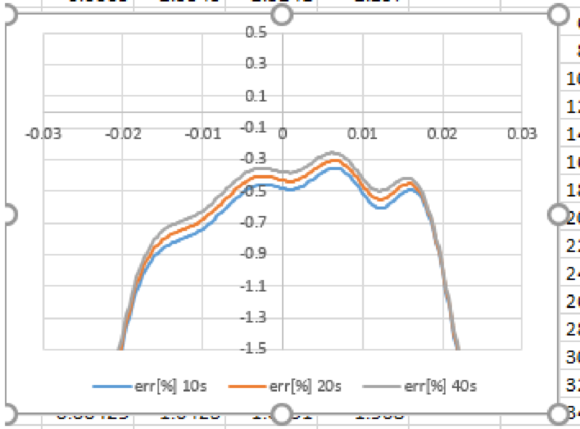
We looked at misalignment and the effect of screening currents and decay times.



Source
Background field ramp time 10s
Current ramp, rise time 10s, started 5s after field plateau (15s absolute time)
Results given in time after current plateau

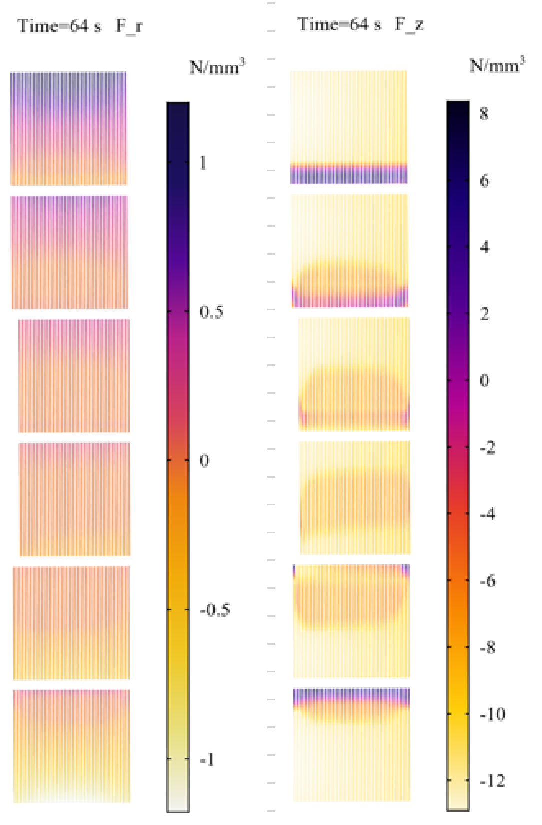
r 16[mm]
Ic =1 [kA]
n=25
err = 5 mrad coil rotation

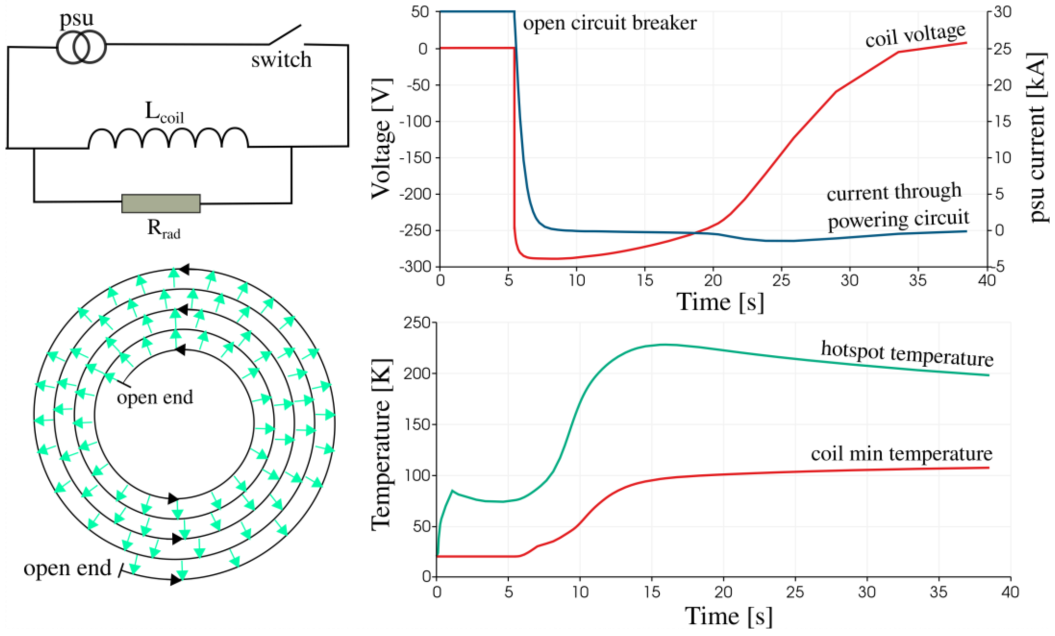
	t=10[s]	**t=20[s]**	**t=40[s]**
x [m]	err[%] 10s	err[%] 20s	err[%] 40s
0	-2.4154	-2.3907	-2.3695
0.00025	-2.3846	-2.3572	-2.333
0.0005	-2.3543	-2.3241	-2.297
[illegible]	[illegible]	[illegible]	[illegible]
0.0045	-1.581	-1.5441	-1.5073
0.00475	-1.5203	-1.4836	-1.447
0.005	-1.46	-1.4236	-1.3872
0.00525	-1.4064	-1.3695	-1.3327
0.0055	-1.3533	-1.316	-1.2787
0.00575	-1.3009	-1.263	-1.2254
0.006	-1.2493	-1.2109	-1.1728
0.00625	-1.2084	-1.1689	-1.1296
0.0065	-1.168	-1.1274	-1.087
0.00675	-1.1282	-1.0864	-1.045
0.007	-1.0893	-1.0464	-1.0038
0.00725	-1.0611	-1.0168	-0.9727
0.0075	-1.0333	-0.9876	-0.9421
0.00775	-1.0061	-0.959	-0.9121
0.008	-0.9797	-0.9313	-0.883
0.00825	-0.9612	-0.9116	-0.862

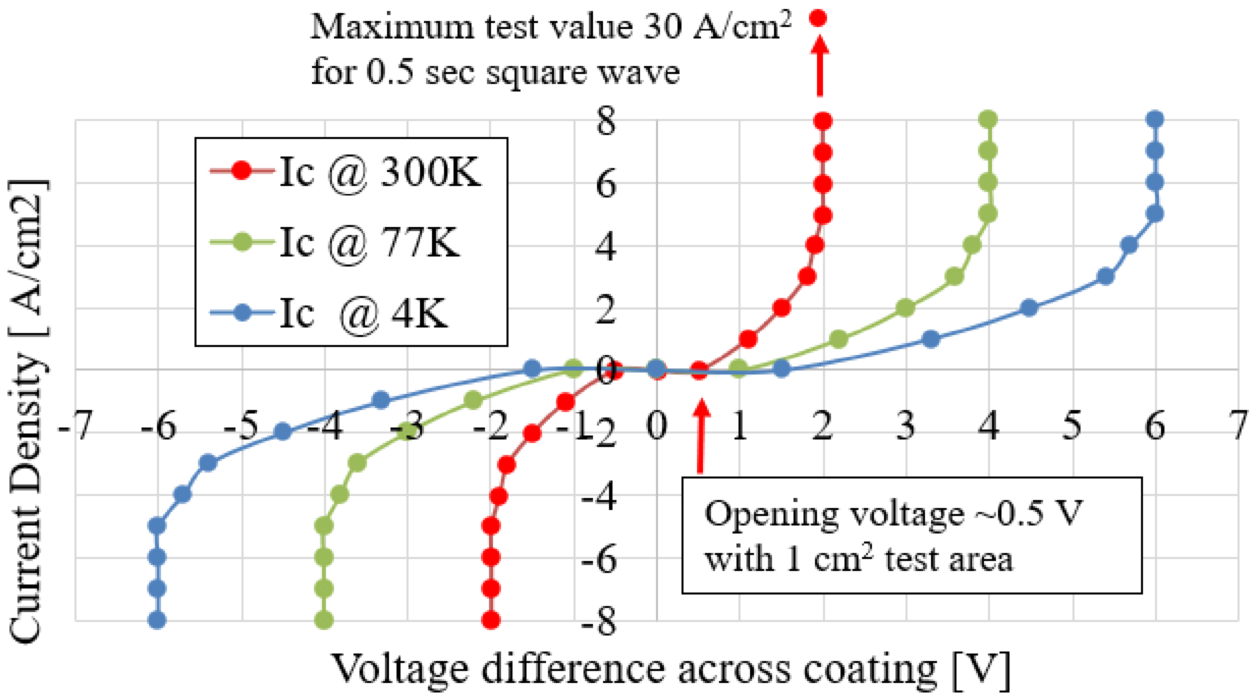


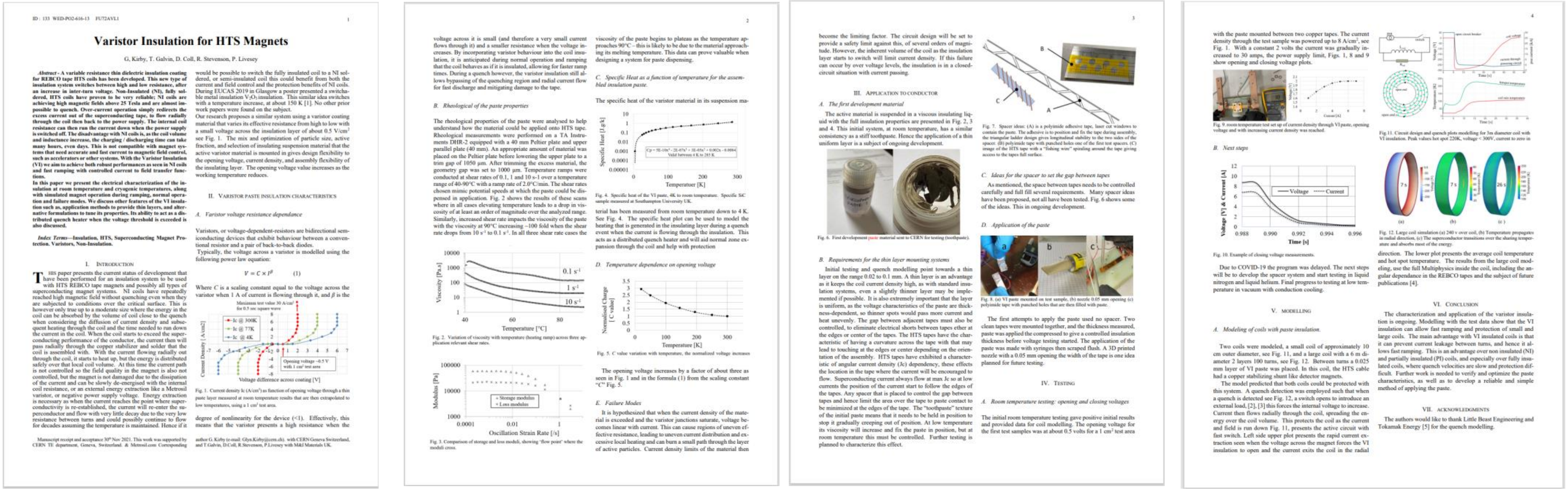
Max Lorentz Force in coil
Ic =1 [kA]
n=25

Time (s)	sqrt((J_phi*B_z)^2+(-J_phi*B_r)^2) (N/mm^3)
0	0.00E+00
2	2.05
4	5.2988
6	7.1282
8	10.557
10	15.255
12	10.918
14	11.517
16	13.178
18	16.175
20	17.089
22	19.139
24	17.817
26	53.188
28	34.056
30	29.451
32	20.08
34	13.767
36	13.652
38	13.556
40	13.474
42	13.404
44	13.339
46	13.279
48	13.225
50	13.174
52	13.128
54	13.084
56	13.044
58	13.007
60	12.974
62	12.945
64	12.918

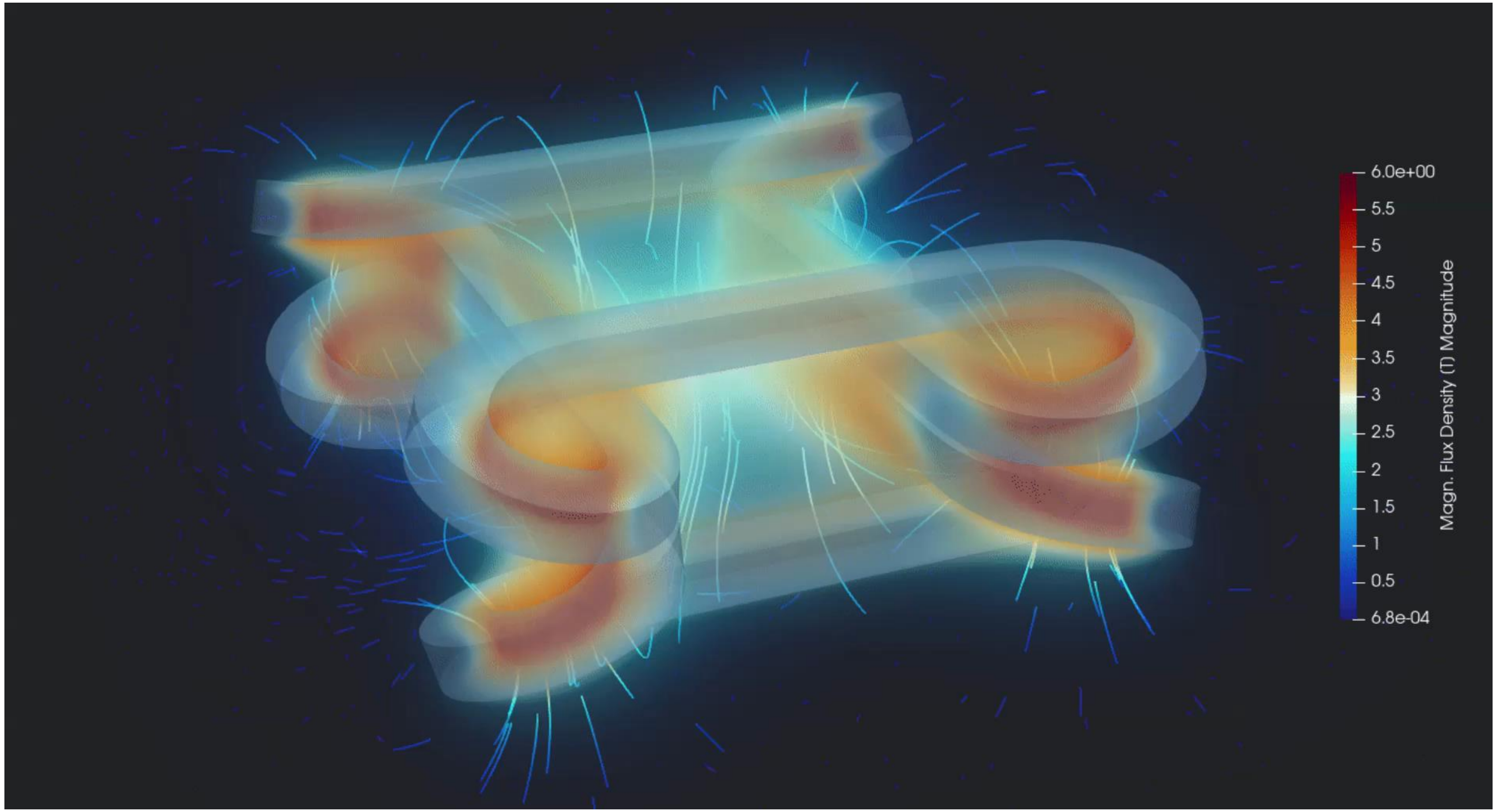



psu
switch
L_{coil}
R_{rad}
open end
open end
open circuit breaker
coil voltage
current through
powering circuit
Voltage [V]
psu current [kA]
Time [s]
hotspot temperature
coil min temperature
Temperature [K]
Time [s]


Maximum test value 30 A/cm²
for 0.5 sec square wave
Ic @ 300K
Ic @ 77K
Ic @ 4K
Opening voltage ~0.5 V
with 1 cm² test area
Current Density [A/cm2]
Voltage difference across coating [V]


ID : 133 WED-PO2-616-13 FU72AVL1
Varistor Insulation for HTS Magnets
G. Kirby, T. Galvin, D. Coll, R. Stevenson, P. Livesey

Cloverleaf


6.0e+00
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
6.8e-04
Magn. Flux Density (T) Magnitude

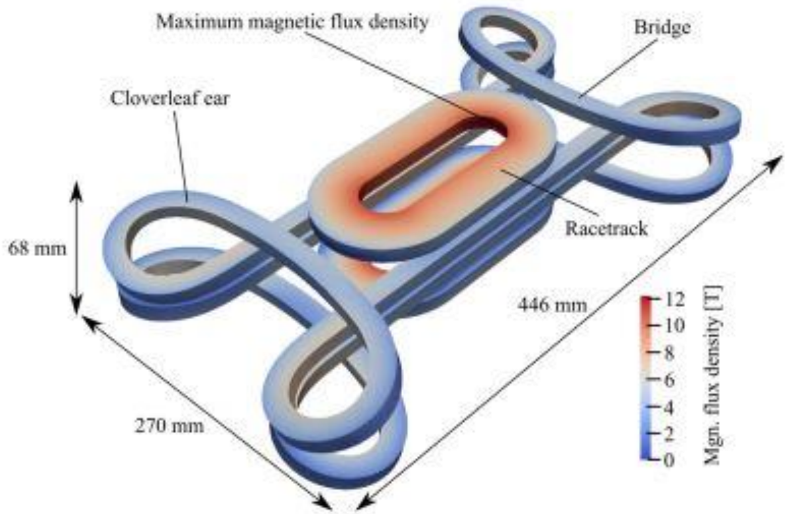


Fig. 1. Overview of the coil-layout of the short demonstrator magnet. The magnet consists of two poles, with each a cloverleaf coil and a racetrack coil. The colors on the coil indicate the magnetic flux density present on the conductor surface for a current of 2 kA. In this case, the maximum field is reached at the inside of the coil-end of the racetrack and has a magnitude of 12.2 T.

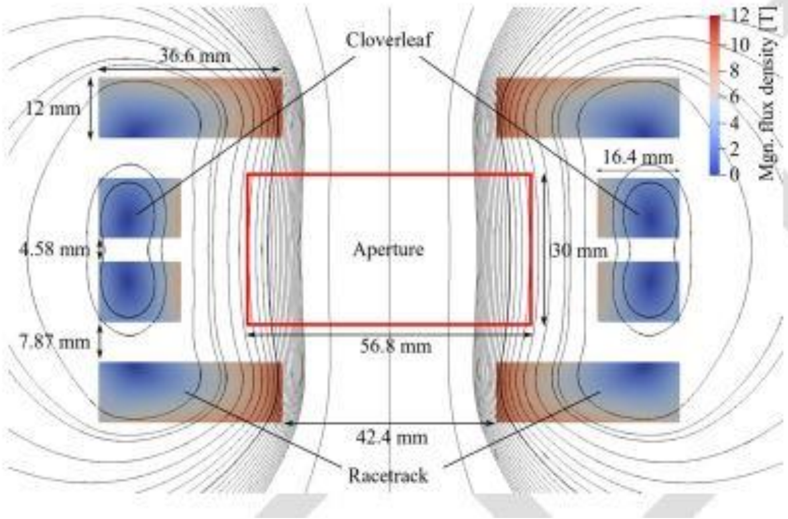


TABLE I
MAGNET PARAMETERS

Parameter	Value	Parameter	Value
Center field	9.4 T	Length cable/tape per cloverleaf	143/286 m
Maximum field on conductor	12.2 T	Length cable/tape per racetrack	80/160 m
Current	2000 A	Total tape length	894 m
Tape thick-ness/width	0.1/12 mm	Number of cable turns cloverleaf	82
Number of tapes in cable	2	Number of cable turns racetrack	183

[9]. This can lead to better current sharing between the tapes in the case of a quench, which can improve the stability of the coils. There is no insulation in-between the tapes.

On the inside and outside surfaces of the *Re*BCO coil windings, 2 mm thick copper tape windings are present. These layers serve as a stabilizer as well as current entry and exits point along the first and the last turn of the coil windings. In Table I, the most relevant coil parameters are listed.

B. Coil-End Design

The top and bottom coils of the cloverleaf-racetrack magnet are simple racetrack coils and the center coils are in cloverleaf configuration (see Fig. 1). The cloverleaf coils allow the conductor to go over the particle beam pipe. The cloverleaf configuration was first proposed by Gupta *et al.* in 2003 as a design for high field accelerator magnets using "React &

needed to prevent conductor movement. The casing is made out

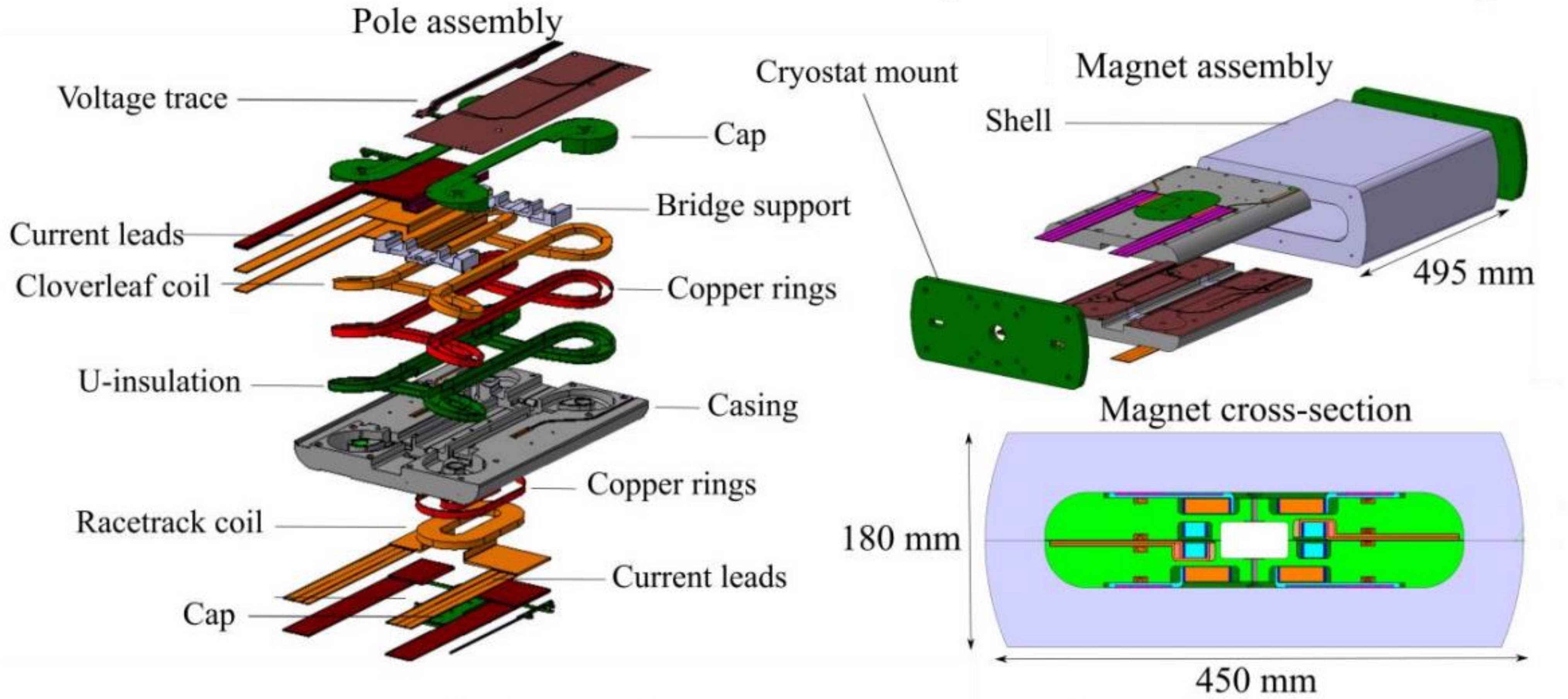
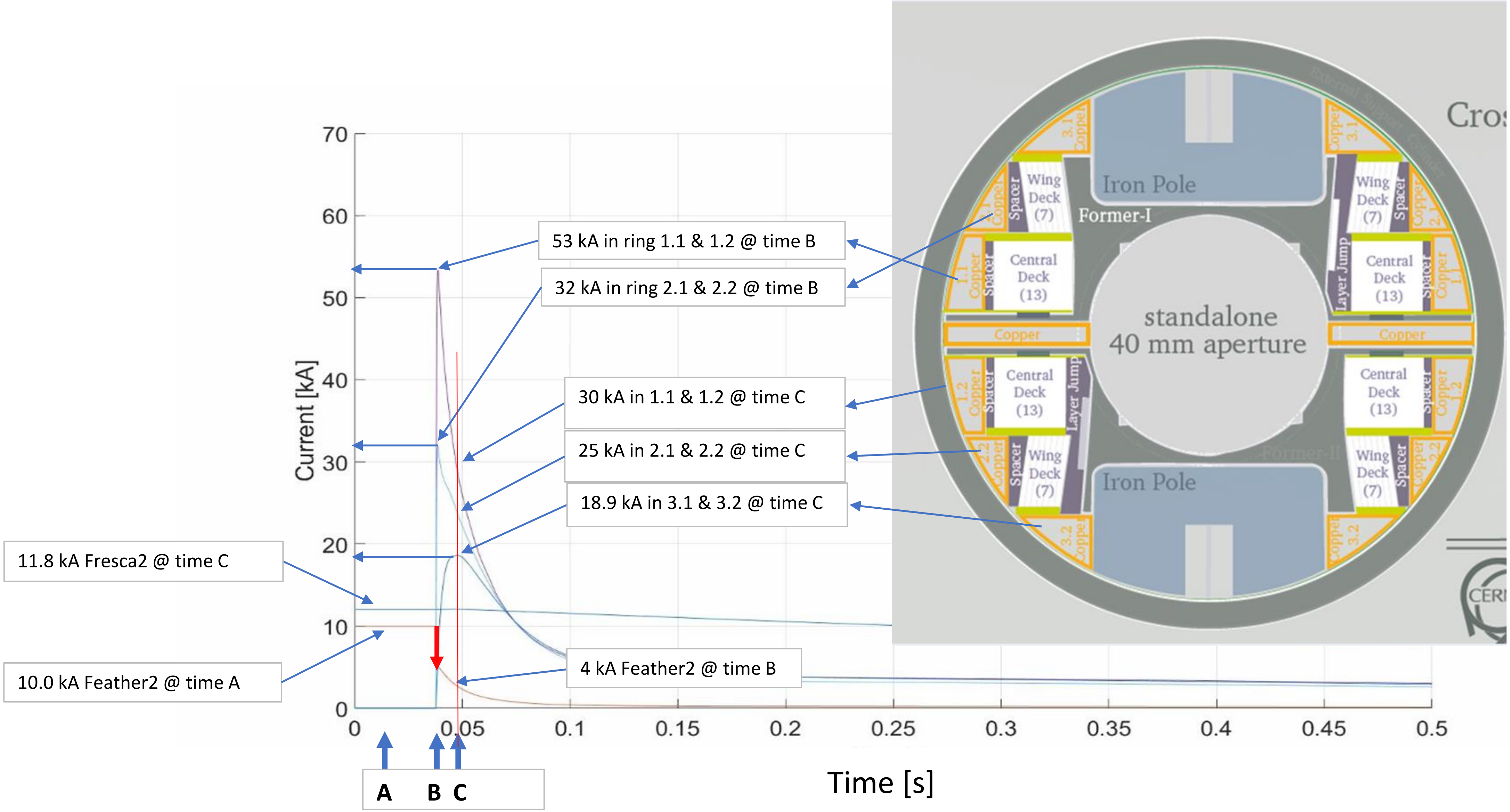


Fig. 4 Overview of the magnet assembly. On the left the individual components of a magnet pole are shown. On the right the magnet assembly and a cross-section along the mid-plane of the magnet are shown.

END

Induction of high currents



V-I measurements in coil 2.3

The degradation is visible from VI 2 to VI 3 (after the many extractions in Fresca2) and from VI 4 to VI 5 (after the magnetic measurements to 2 kA in Fresca, 4 kA in Feather).

Also, initial degradation from the standalone test to the first VI performed in this test campaign is visible