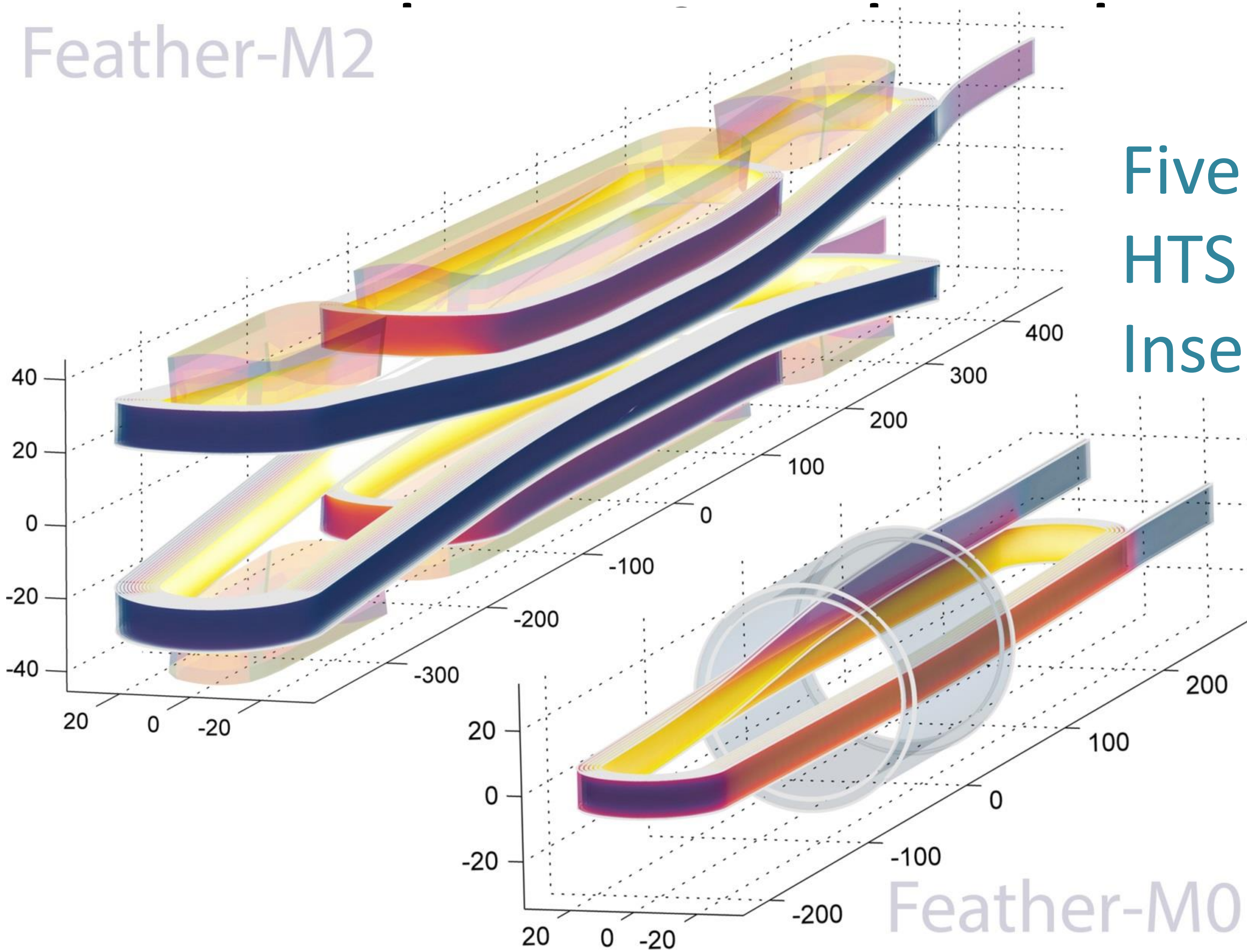
HTS Magnet Testing

Over view

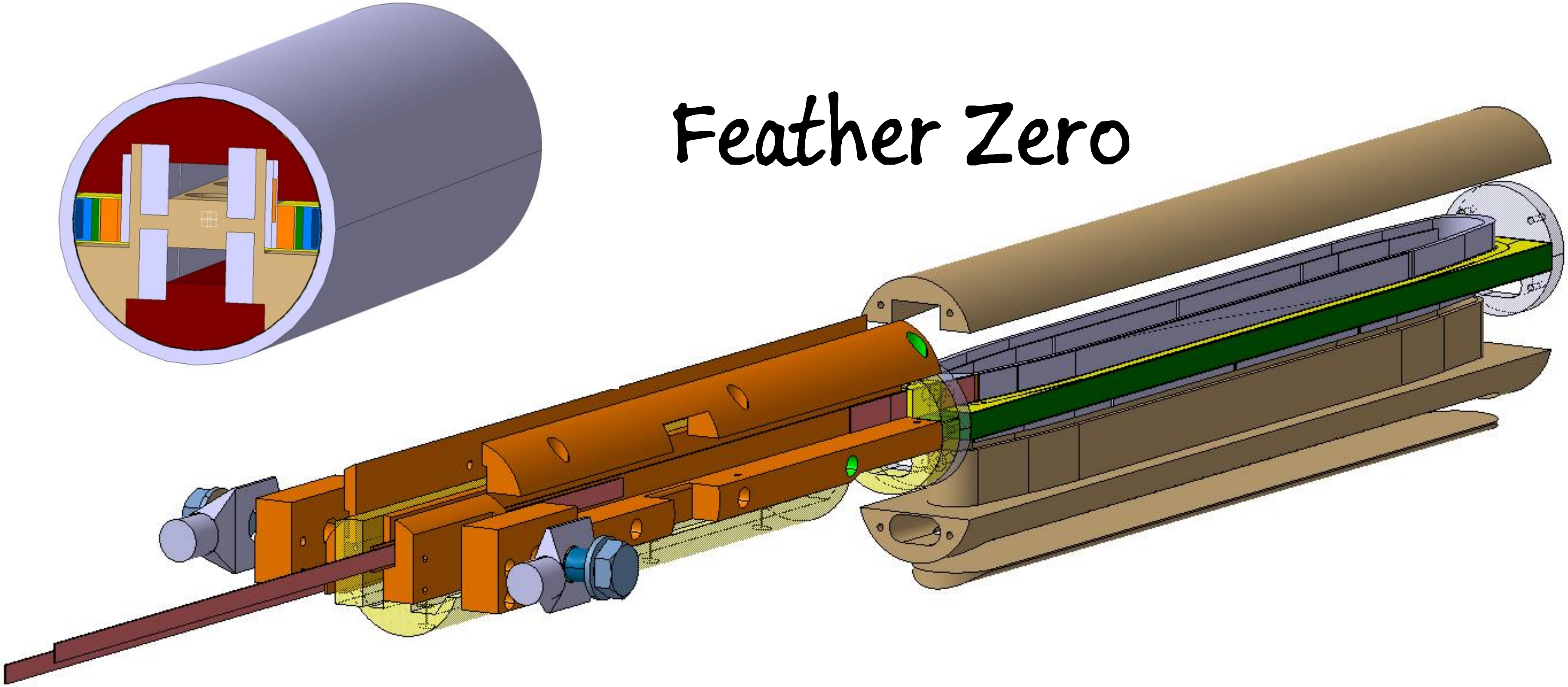
- Feather Zero & Two reminder
- High temperature margin
- Testing at high temperature 60K in gas.
- Magnetic field Harmonics.
- Magnet Quench calculations.
- Test requirements

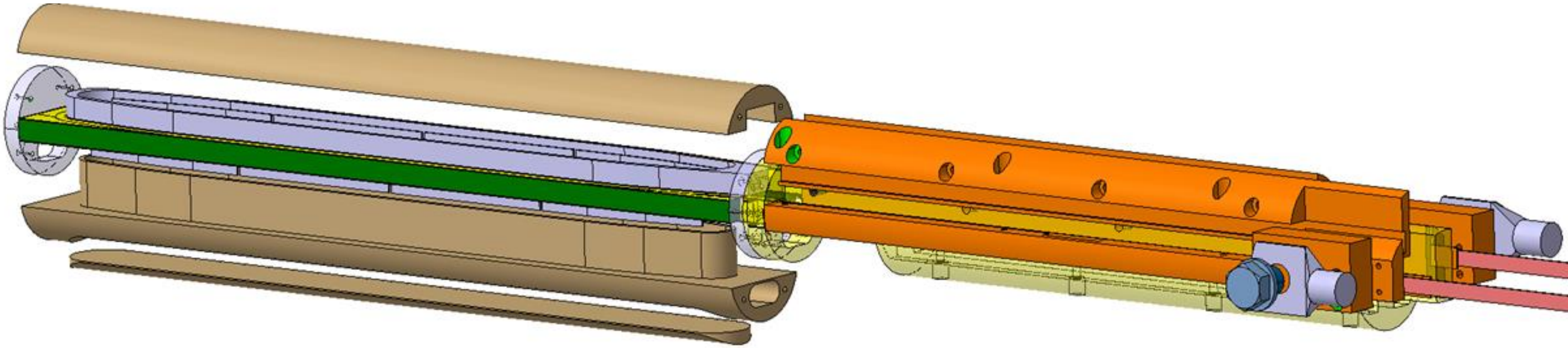
M2

Five Tesla
HTS Research
Insert-Magnet



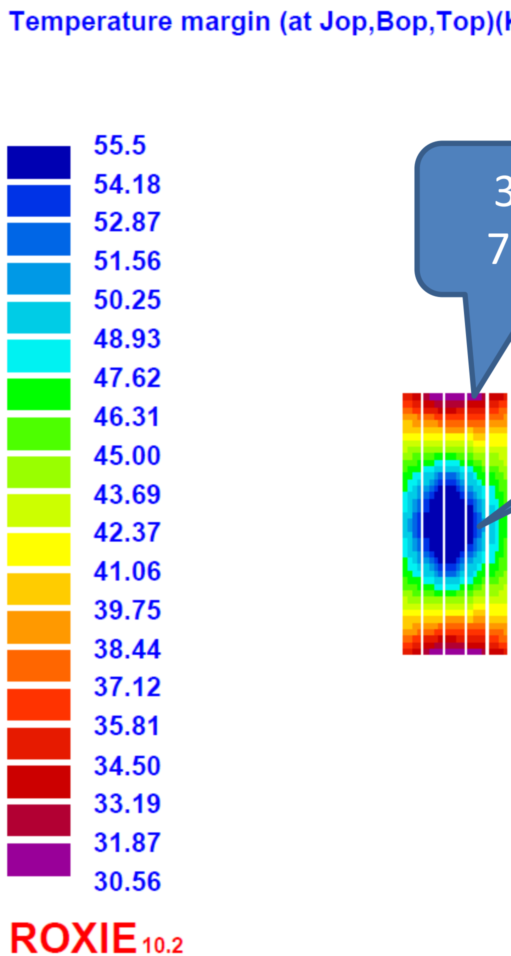
Feather Zero





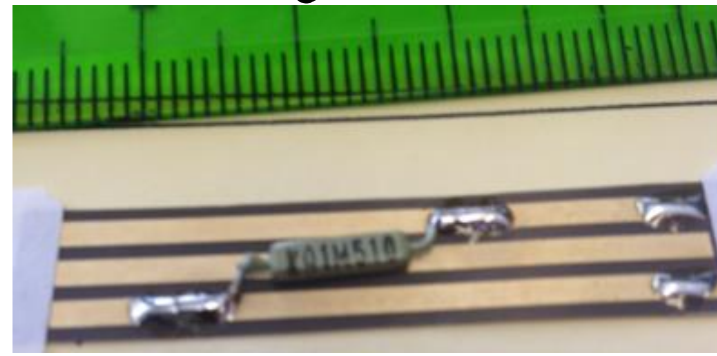
Feather Zero parts

10 kA Temperature margin

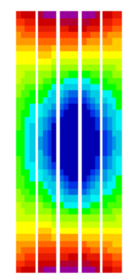


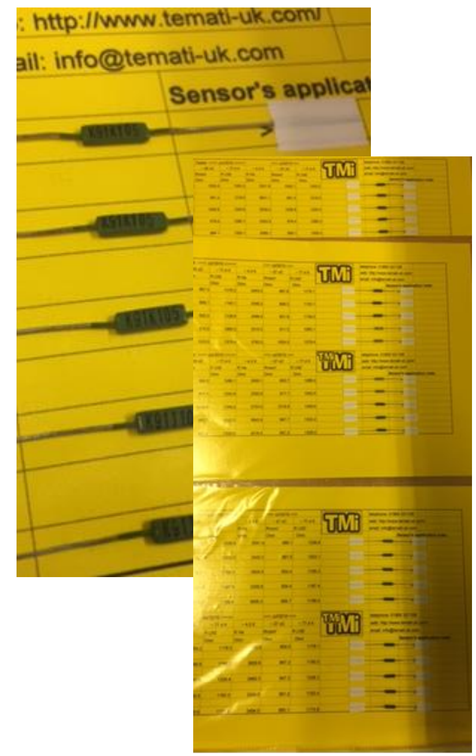
30.5 `K
70 % SS

55.5 K



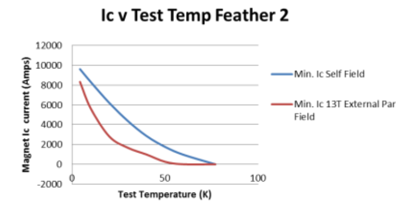
Temp. sensor CCS

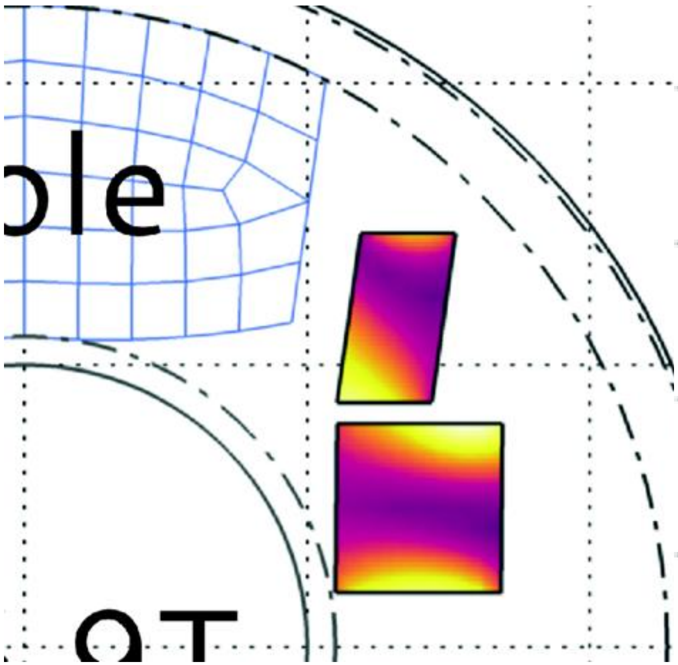


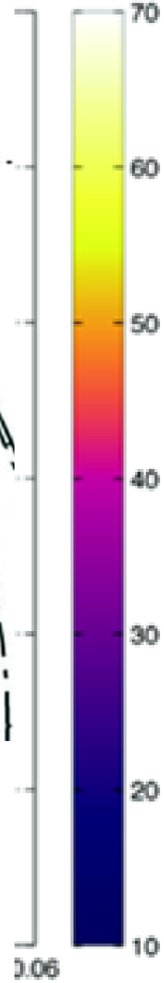


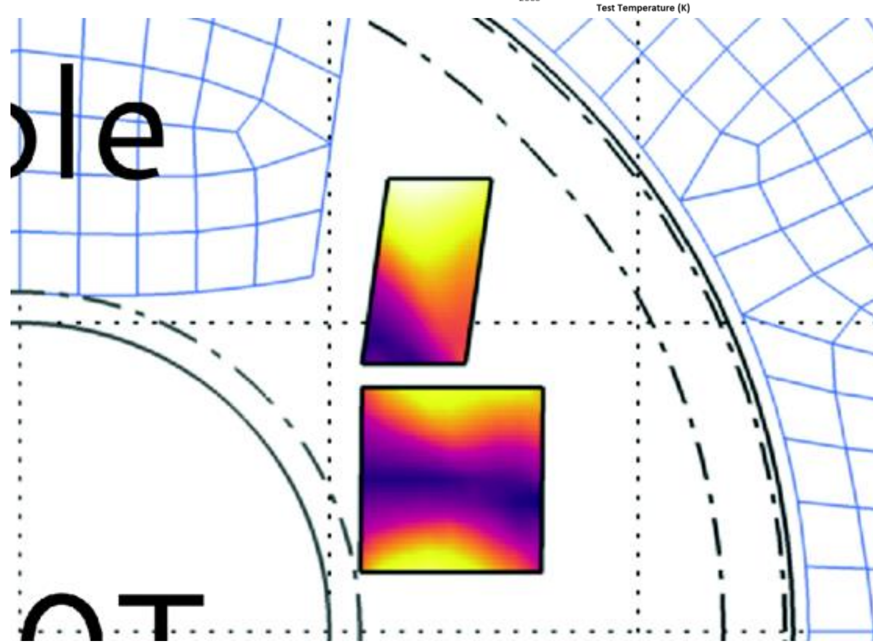
Large temperature margin can we use this for quench detection?

Position of short sample in coil



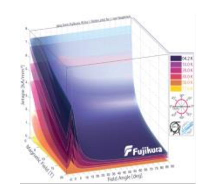




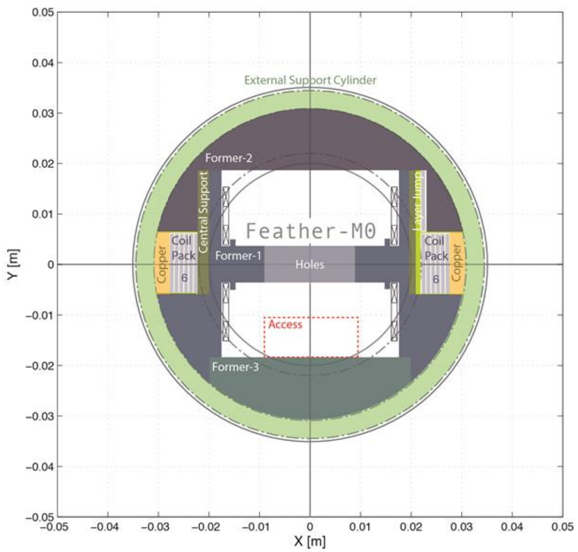


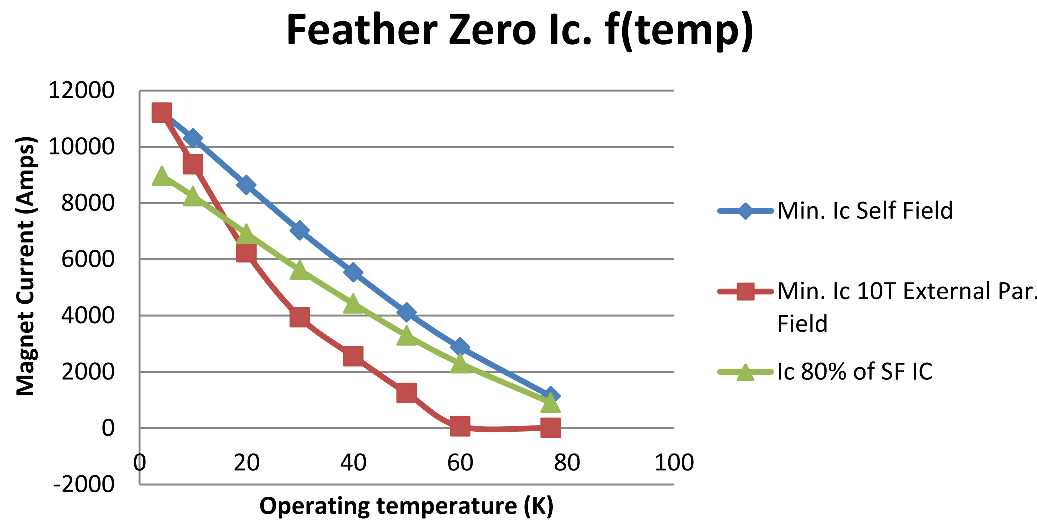
16.9 Tesla

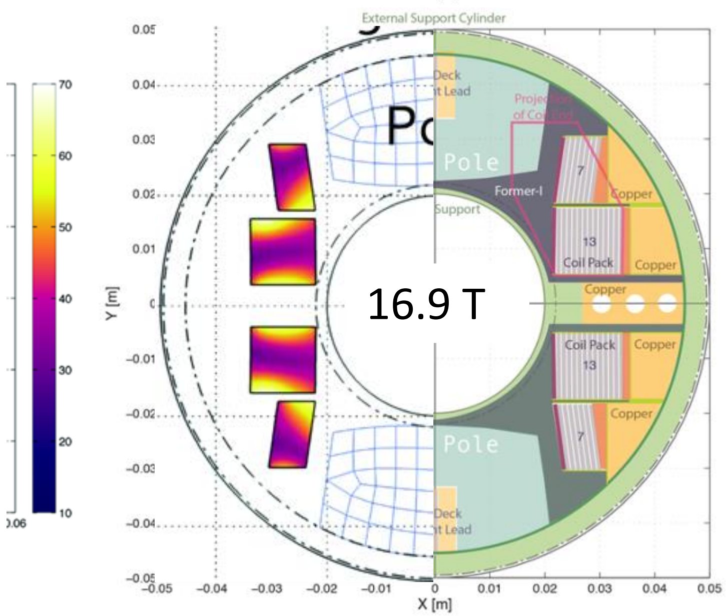
5.0 Tesla

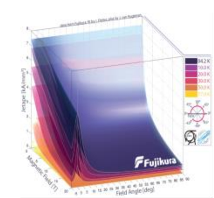


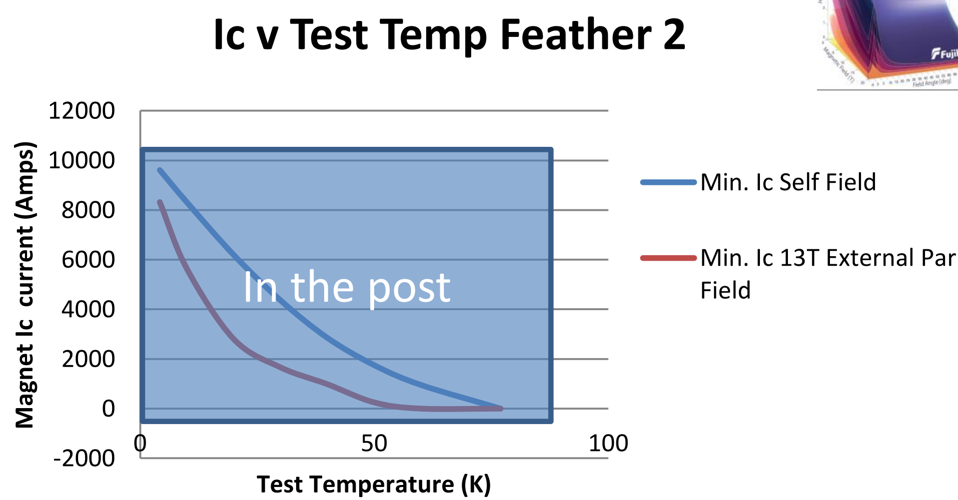
Ic v Test temperature



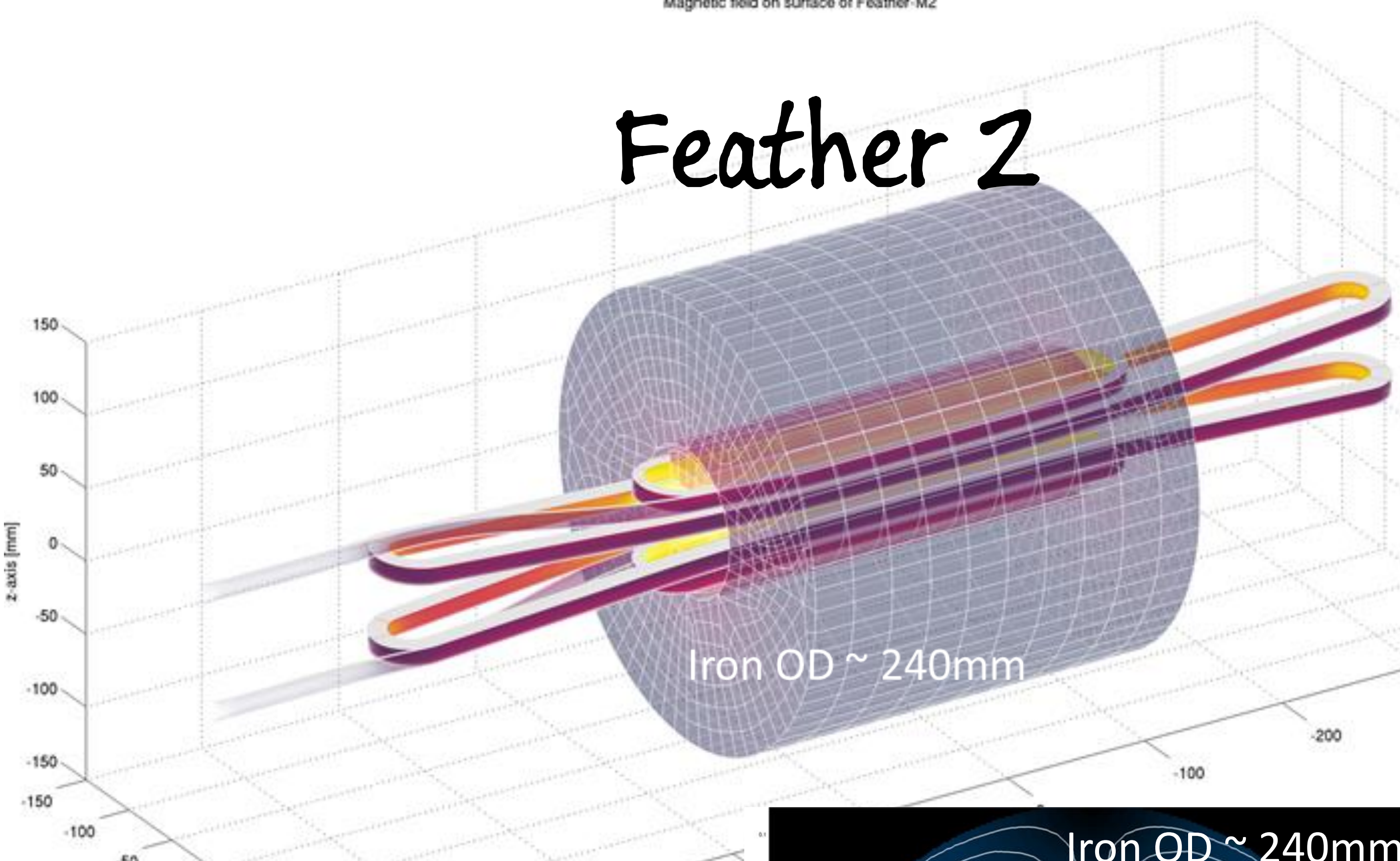




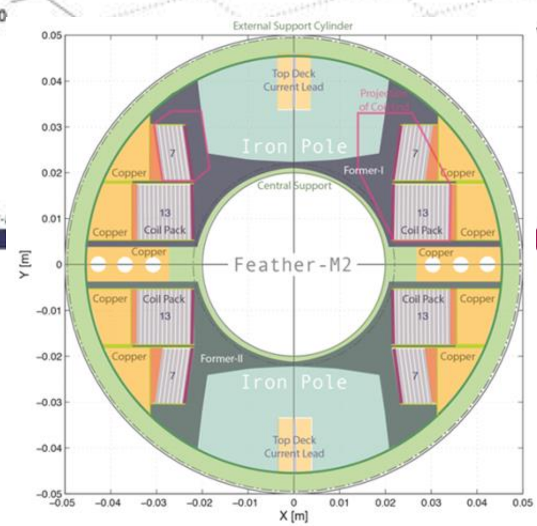




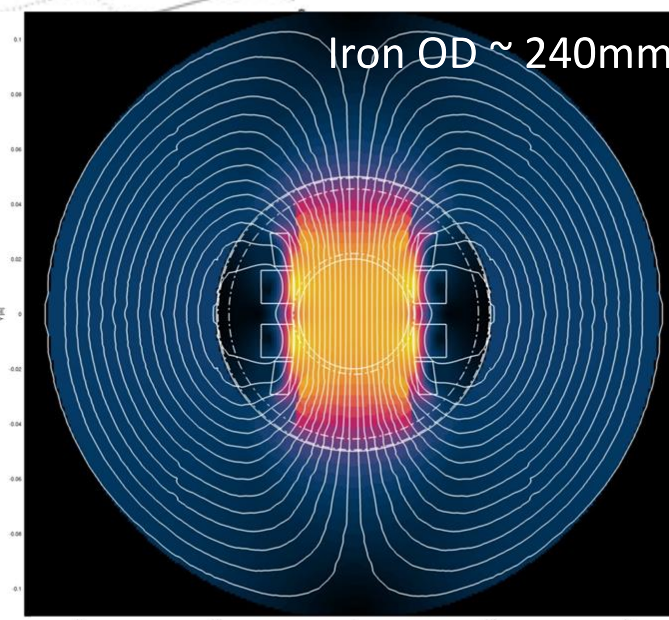
Feather 2



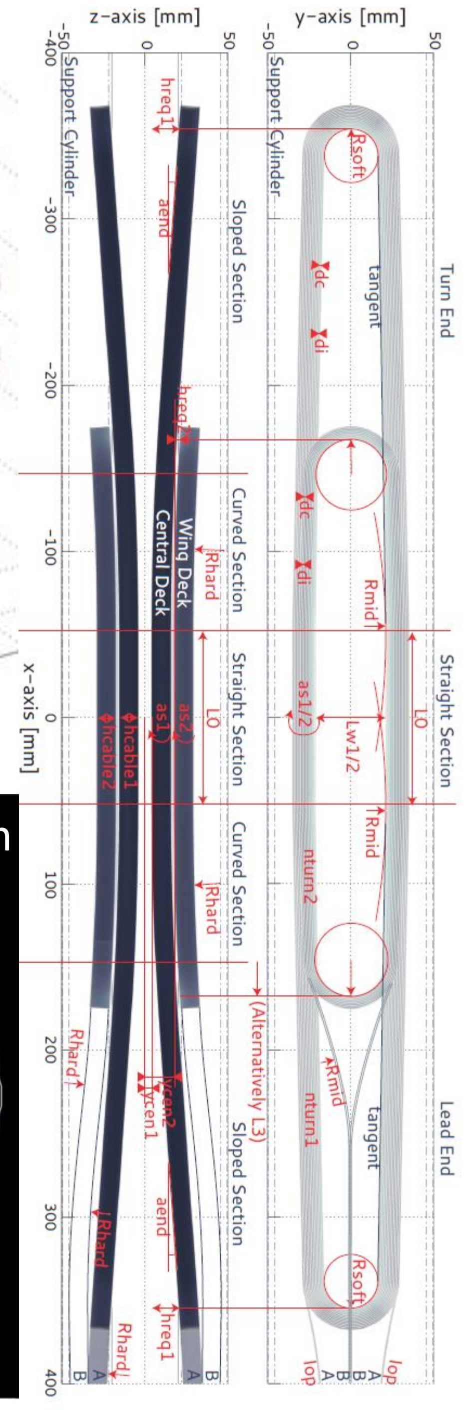
Magnetic field on surface of Feather-M2
Iron OD ~ 240mm
z-axis [mm]



External Support Cylinder
Top Deck Current Lead
Iron Pole
Copper
Coil Pack
Central Support
Former-I
Former-II
Feather-M2
X [m]
Y [m]



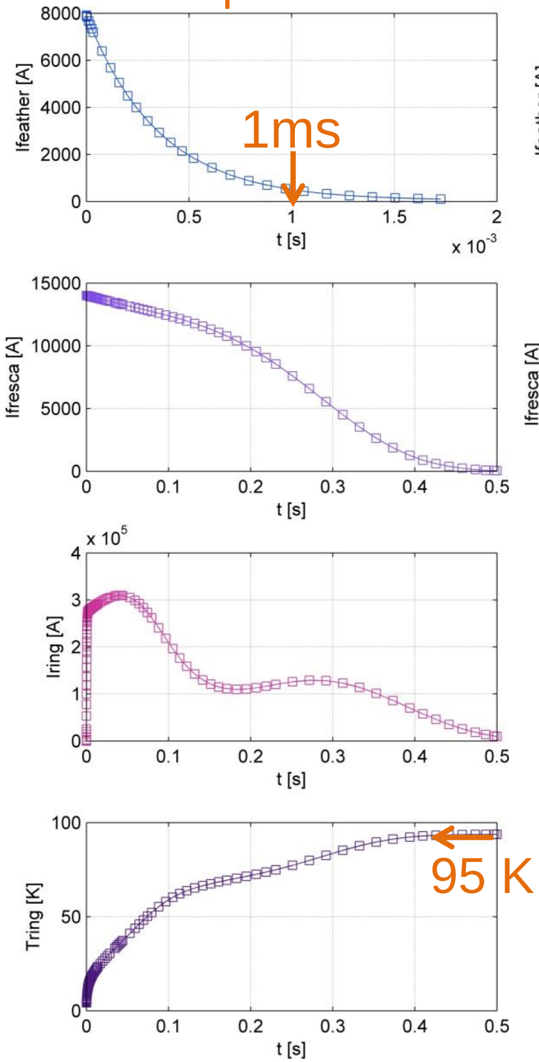
Iron OD ~ 240mm



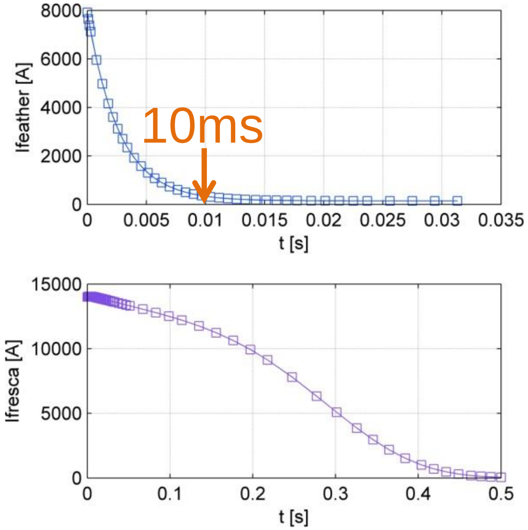
z-axis [mm]
y-axis [mm]
x-axis [mm]
Support Cylinder
Sloped Section
Curved Section
Straight Section
Turn End
Lead End
Wing Deck
Central Deck
tangent
(Alternatively L3)

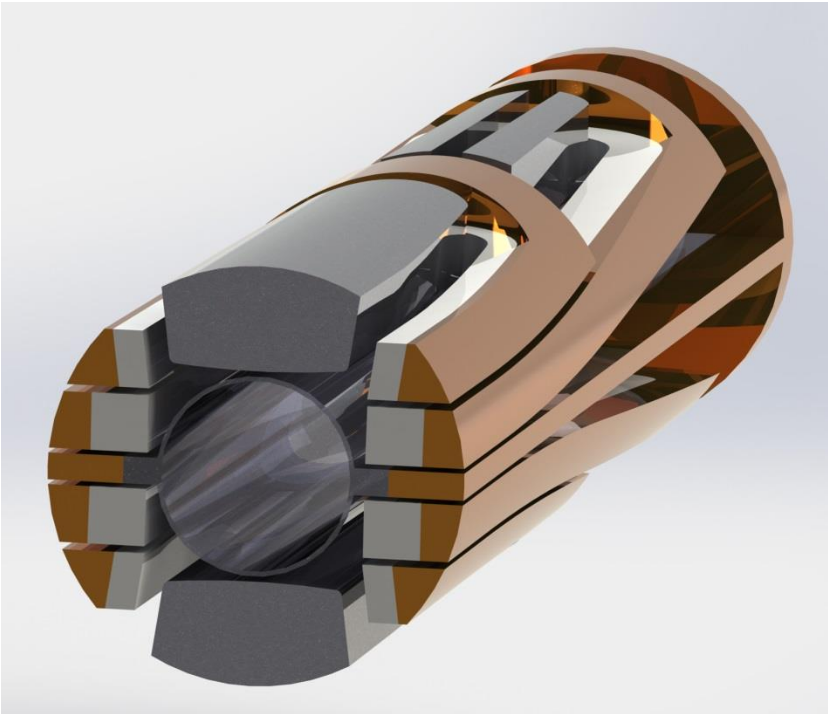
Quench Protection with Copper ICEE Loops

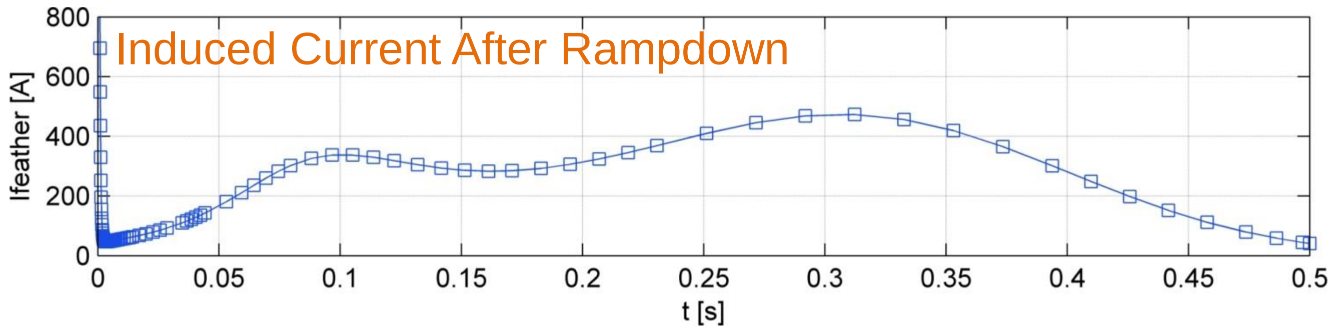
With Loops



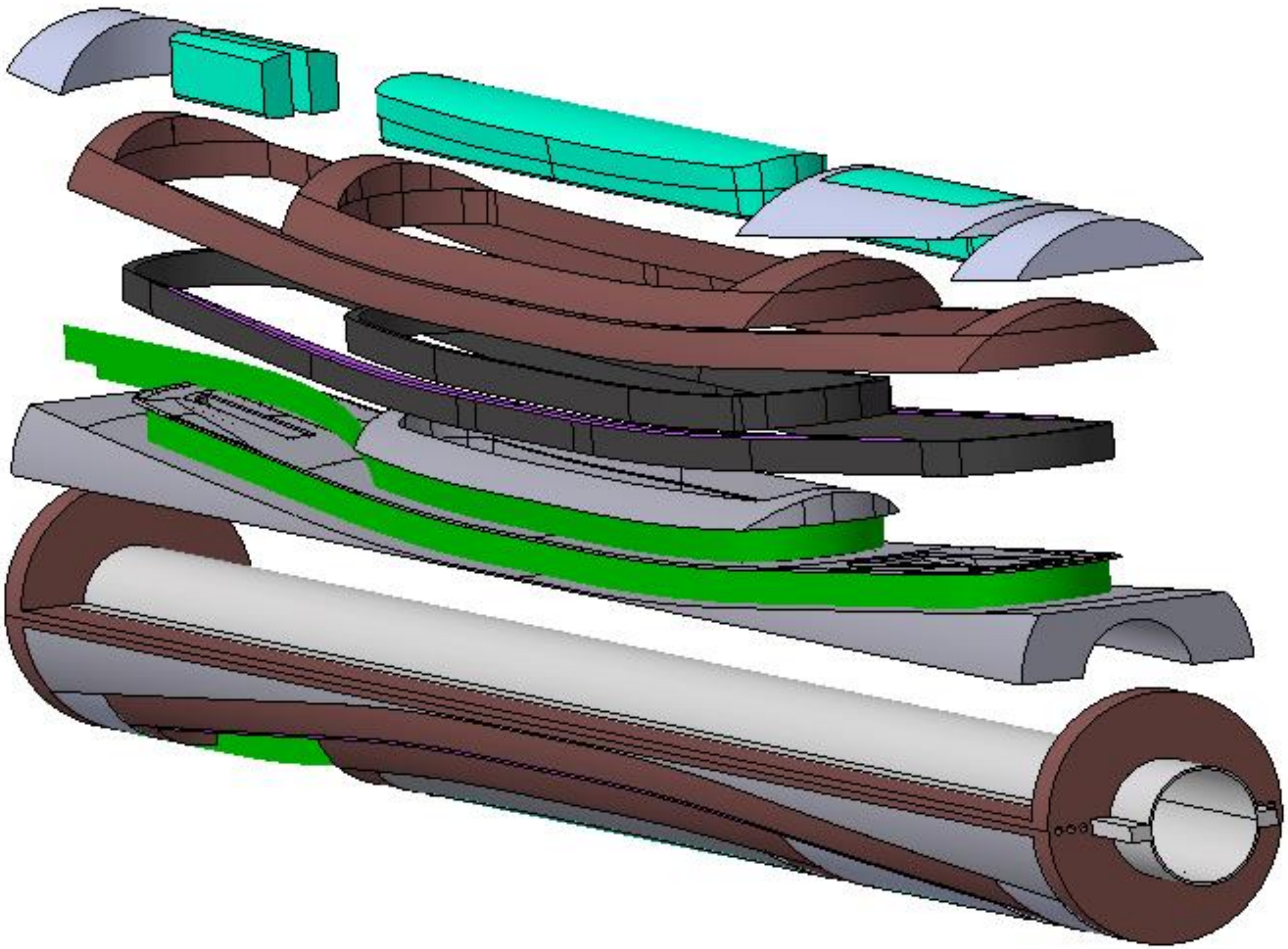
Without Loops



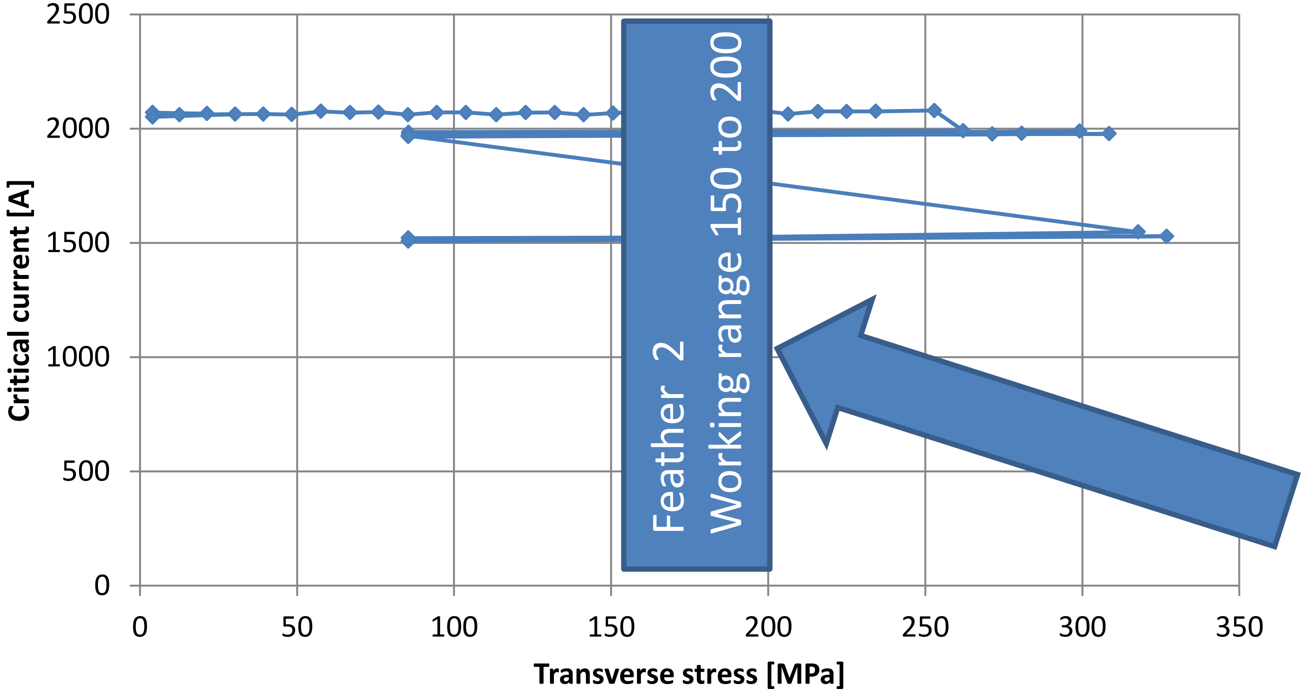




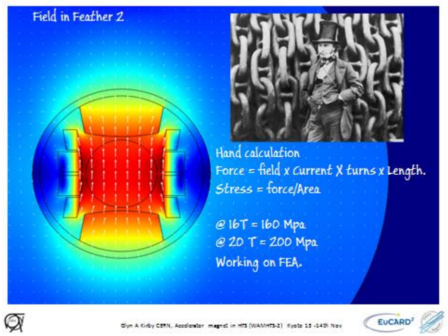
Review of Feather 2 components



I_c versus transverse stress



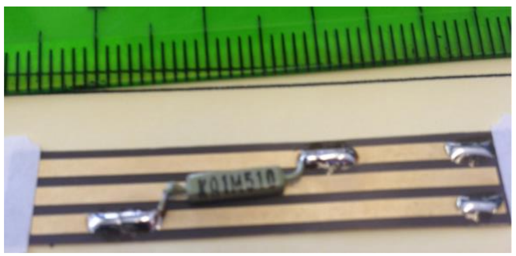
T = 4.2 K
B = 10.5 T



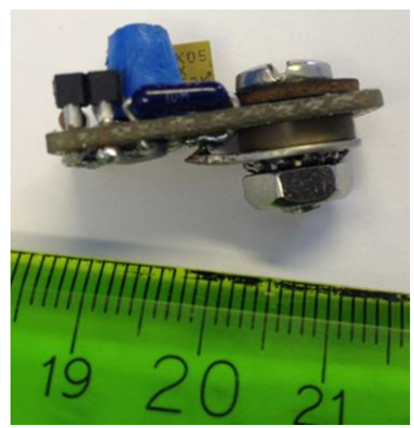
- No degradation up to 253 MPa
- Degradation at higher pressures is irreversible

Quench detection

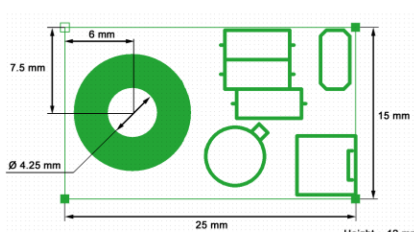
- Voltage taps (low current)
- Temperature sensors (high current)



- Pickup coils high current (Feather zero trial)

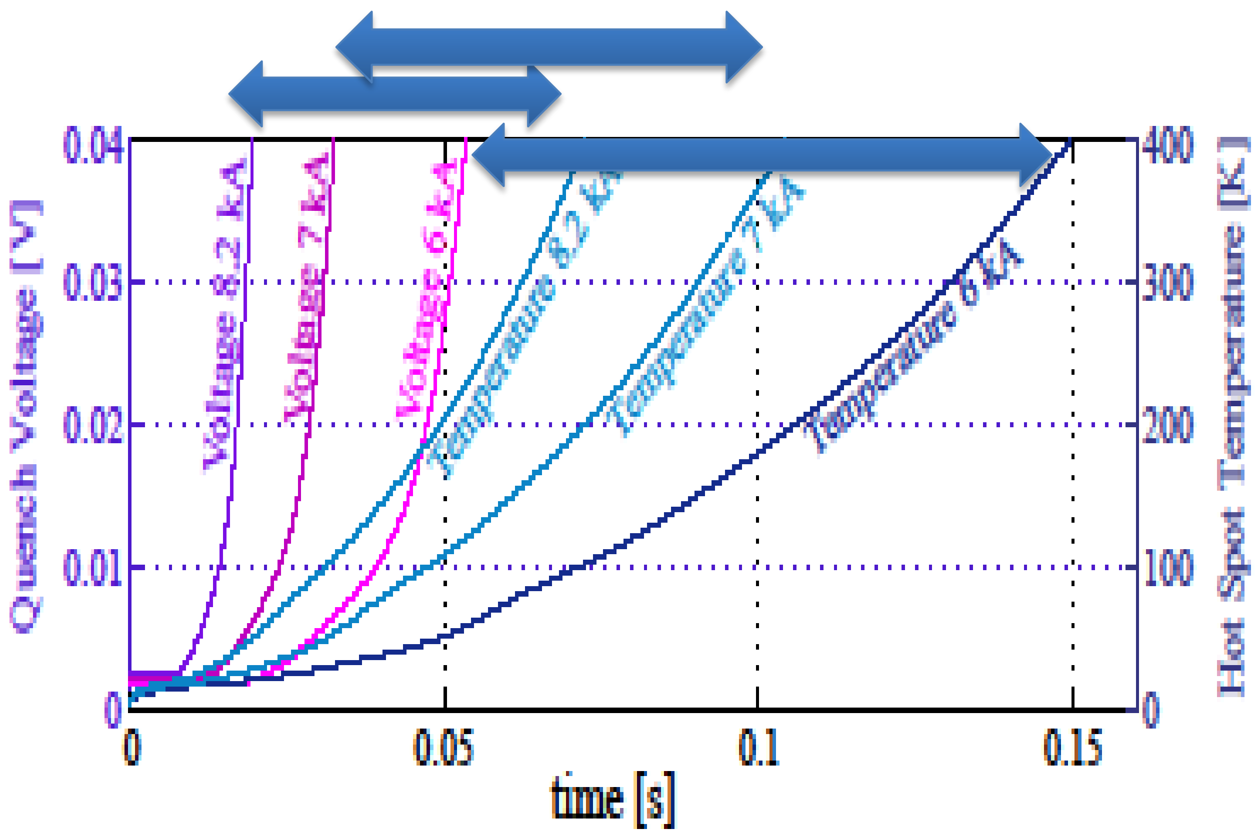


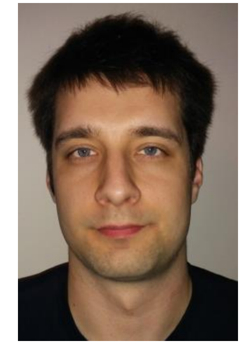
- Acoustics



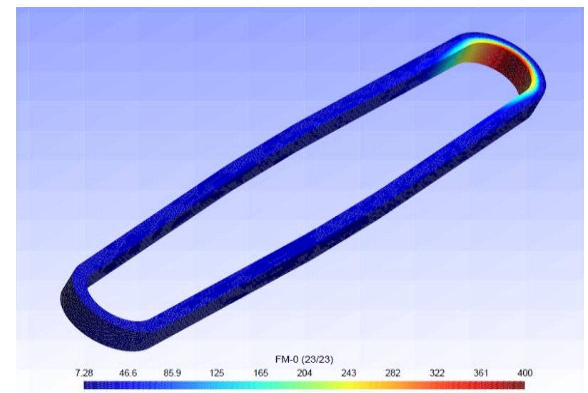
Thanks to Maxim Marchevsky at LBL

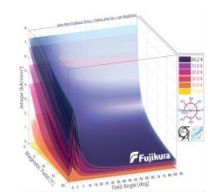
Feather-M0 Quench Behaviour 4.5K f(current)





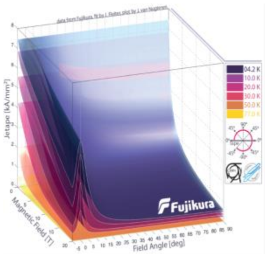
Erkki Härö





Finite Element Model using anisotropic thermal conductivities

Will we be able to see this in the cable ?

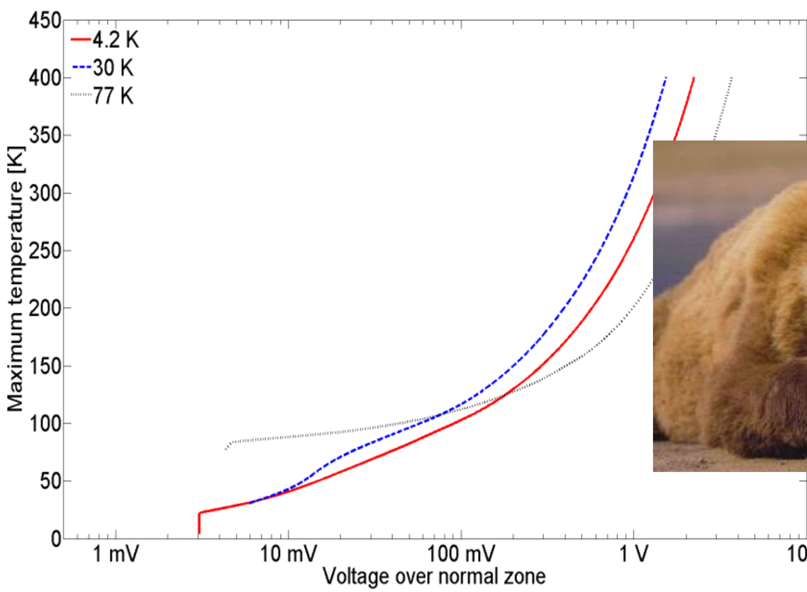


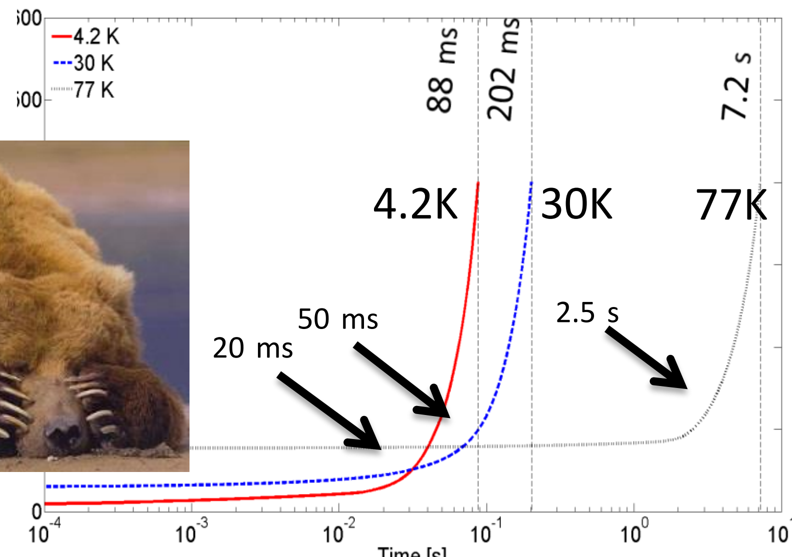
Feather M0 Quench Behaviour f(test temp)

Quench simulation results for Feather-M0 with different operation temperatures: 4.2 K, 30 K and 77 K.

Operation currents with 4.2 K, 30 K and 77 K were 8960 A, 5616 A and 904 A, respectively.

Operation current was chosen to be 80 % of the short sample Ic value.





If we can see it in the Roebel cable and coil

Non-Linear Current Sharing Model

- Current sharing refers to the current distribution between the matrix material and the superconductor provides Vnl(I)
- In the model three options are available:
  1. Pure power law (not useable for quench analysis because only valid below or just above Tcs)
  2. Linear transition between Tcs and Tc

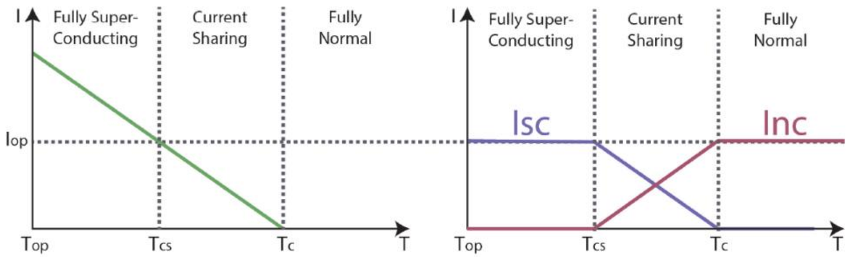
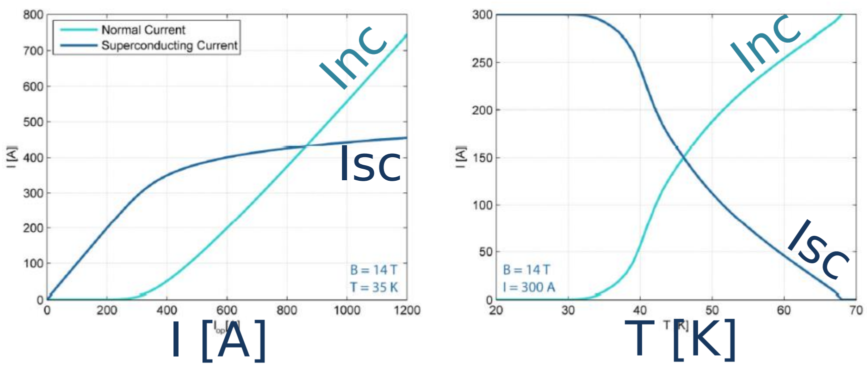
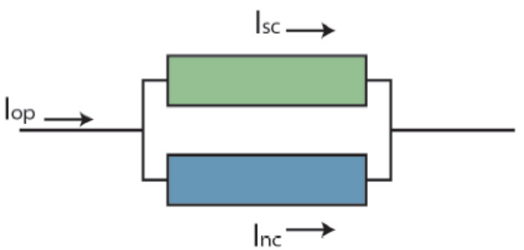


Figure 4.1: Schematic representation of current sharing in a practical superconductor (adapted from Bellis [35]).

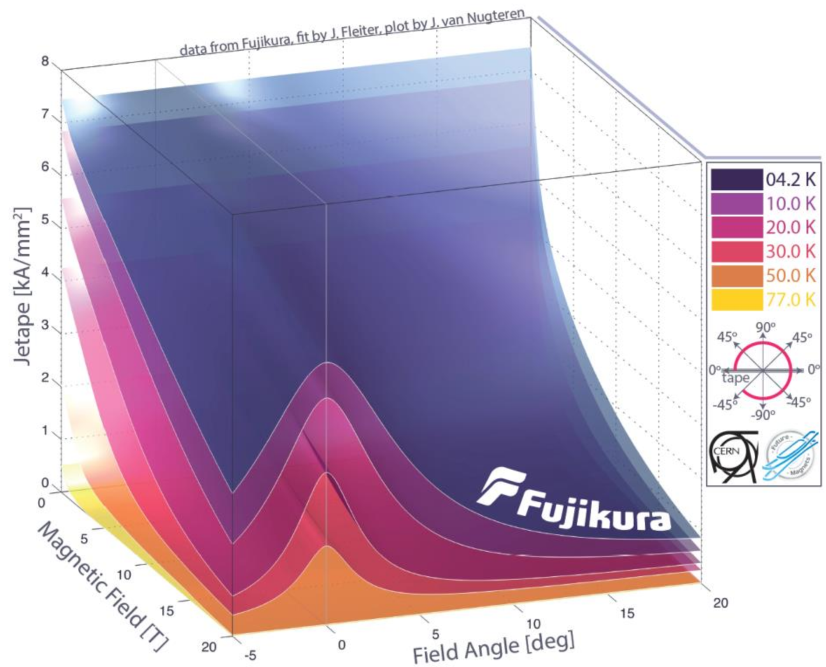
  3. Superconducting power law element in parallel with resistive (matrix) element (implicit equation)



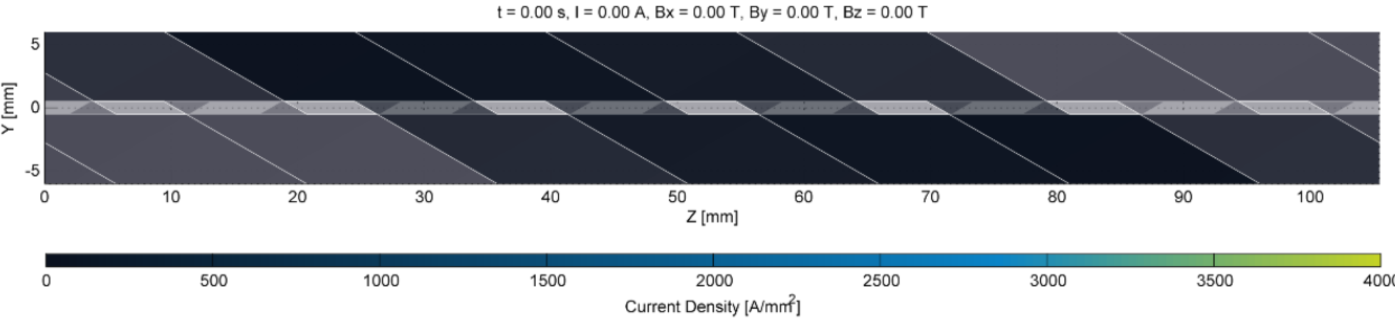
Current Sharing

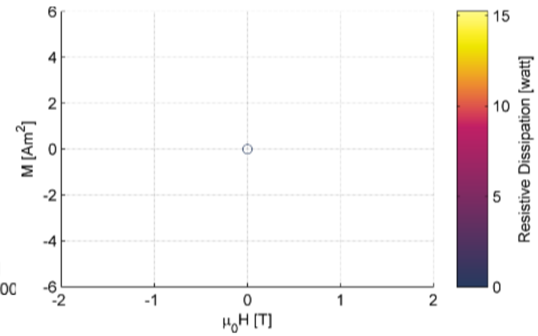


Angular Dependent Critical Current

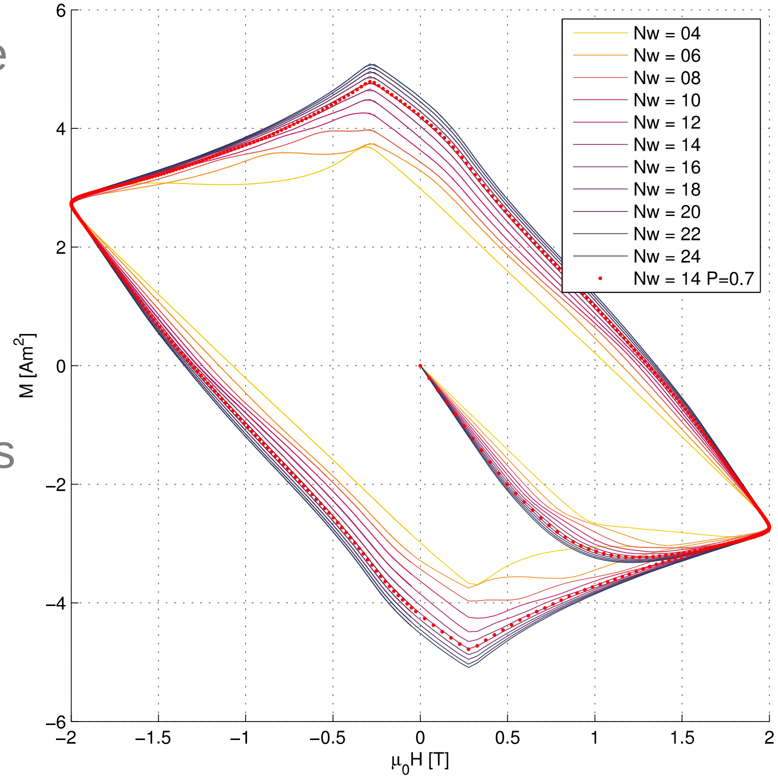


Magnetisation of Roebel Cable

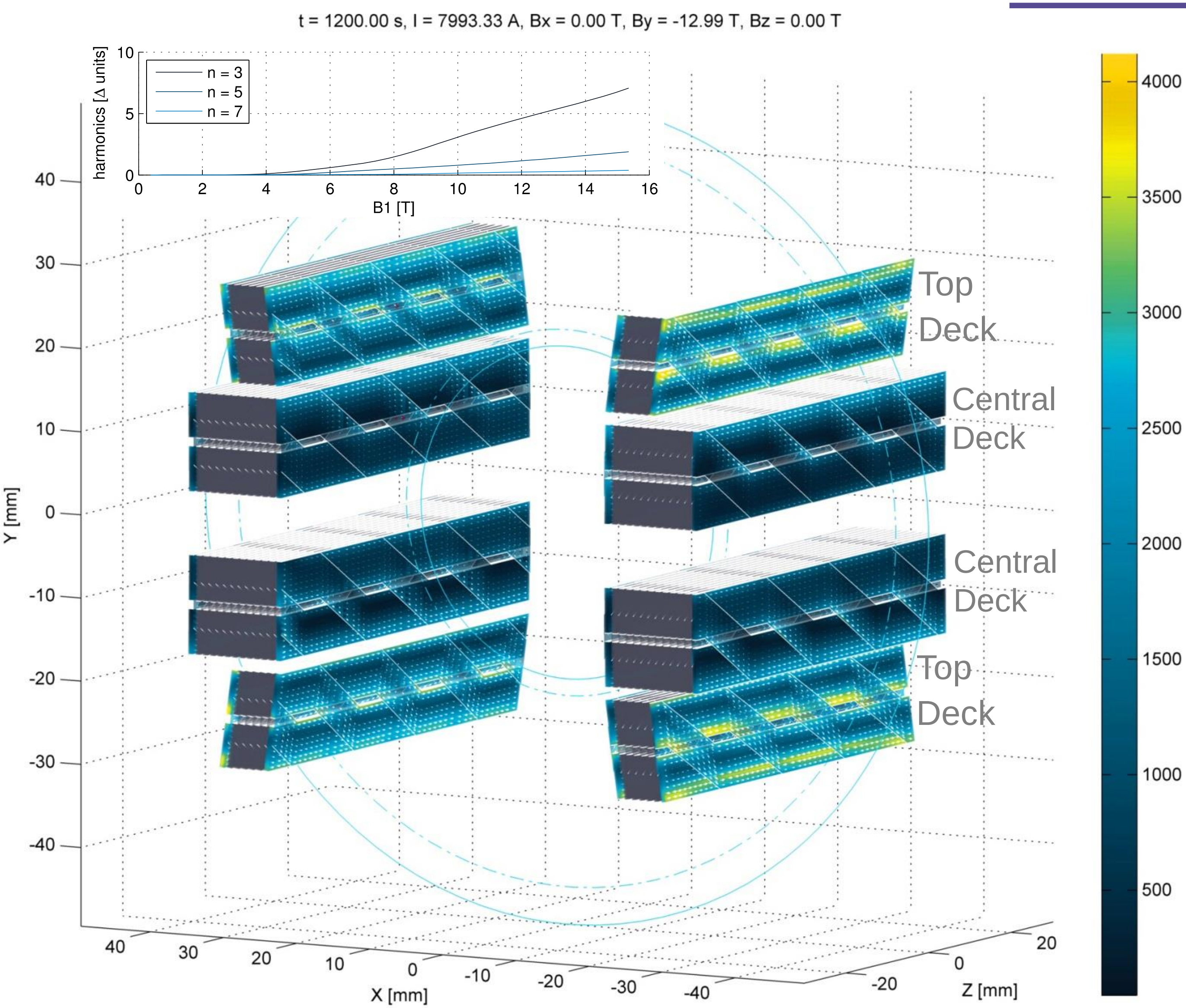




- The calculated magnetisation of a Roebel cable in -2 to 2 T sinusoidal applied field in the perpendicular direction
- Only hysteresis, almost no coupling currents observed
- Hysteresis curve as function of number of elements along width of tapes
- Studied the influence of the number of elements across the width of the tape (decided to use 14 or more)
- Measurement of hysteresis and AC-losses is on-going at the University of Twente



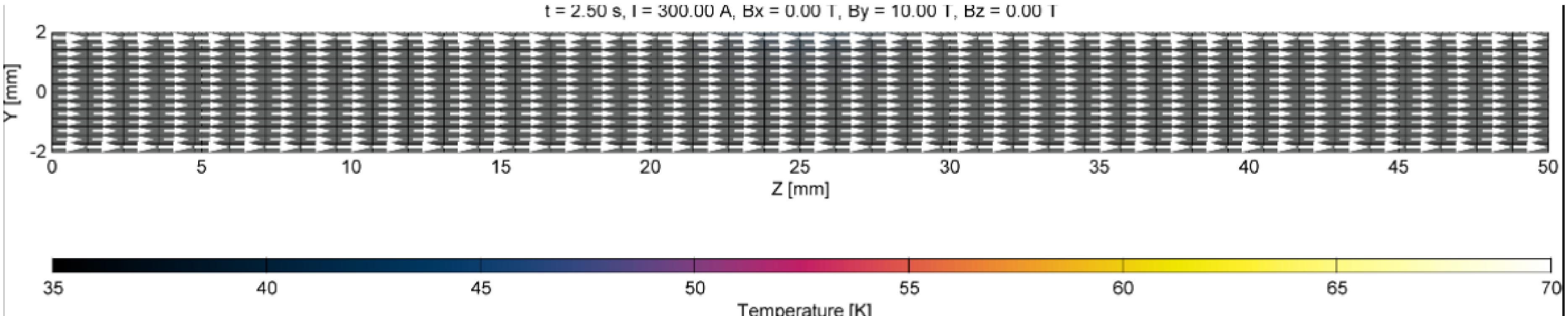
Feather–M2 Harmonics

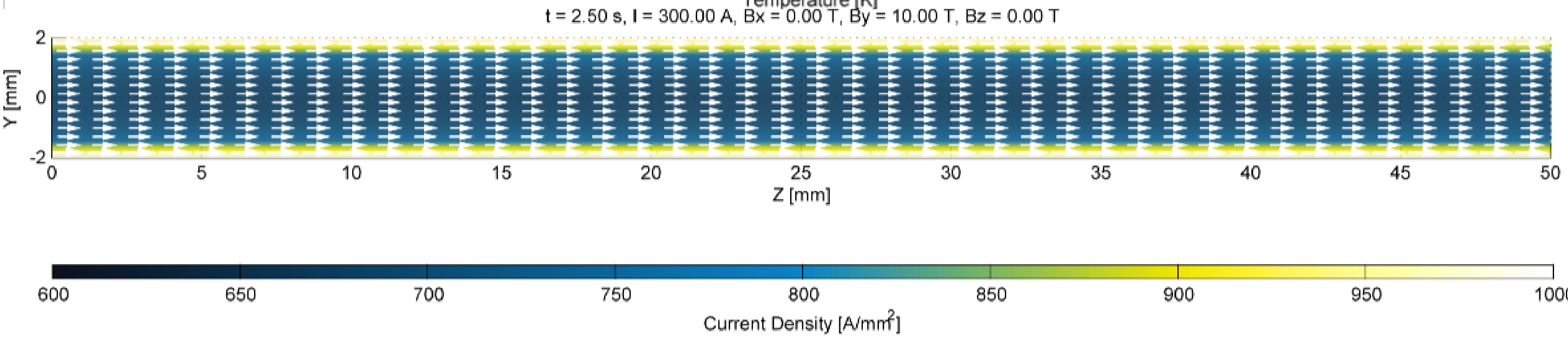


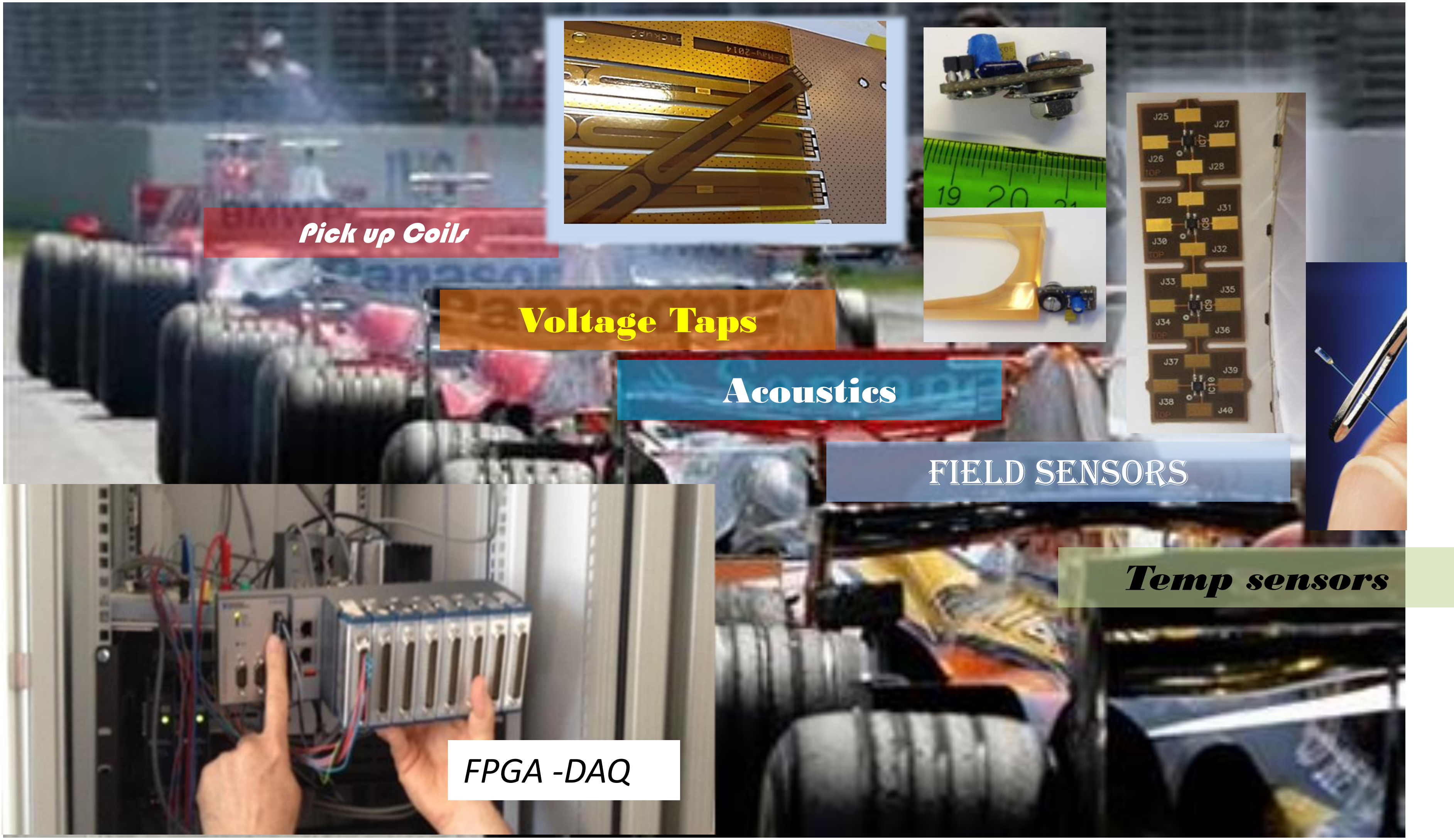
- Due to limitations of the BemFem no Iron pole (yet)
- Simultaneous ramp of Fresca2 and insert over 20 minutes (1200 s)
- Top deck generates more shielding currents due to field angle
- Harmonics at 2/3 aperture less than 10 units
- Keeping alignment during ramping could reduce the field error by a great deal

Validation of Thermal Model

- Comparison University of Twente normal zone propagation measurement data (master assignment JvN).
- As an example a quench at 35 K, 10 T parallel, 300 A in a 4 mm wide tape
- Quench was purposely initiated at edge of tape to show redistribution of current
- Propagation is, due to the redistribution of the current, much faster in width direction than longitudinal direction!







Pick up Coils
Voltage Taps
Acoustics
FIELD SENSORS
Temp sensors
FPGA -DAQ

Test station spec.

- Feather‘s Current ~10 kA
- Dump resistor.
- 10 kA semiconductor Fast switch 1 or 2 mS
- Variable test temperature ~80 to 4K in steps! (temp stability, current leads opp.,
- Instrumentation. (224 channel FBGA DAQ)
- Temp sensors, voltage taps, pick up coils.
- Feather 2 dynamic field measurements. 40mm
- Feather 2 in Iron yoke od ~ 240 mm
- Feather 0 in Iron yoke od ~ 120mm

HTS Quench DAQ

NI-CompactRIO

224 total

Received at CERN 14 March

30 cm

Processor:

667 MHz dual-core ARM
512 MB RAM
1 GB storage
NI Linux Real-Time OS

FPGA:

Xilinx Artix-7
2 M cells

7 modules: 16 differential analog inputs each
+/- 200 mV till +/- 10 V input range
16 bits
7.8 kS/s per channel

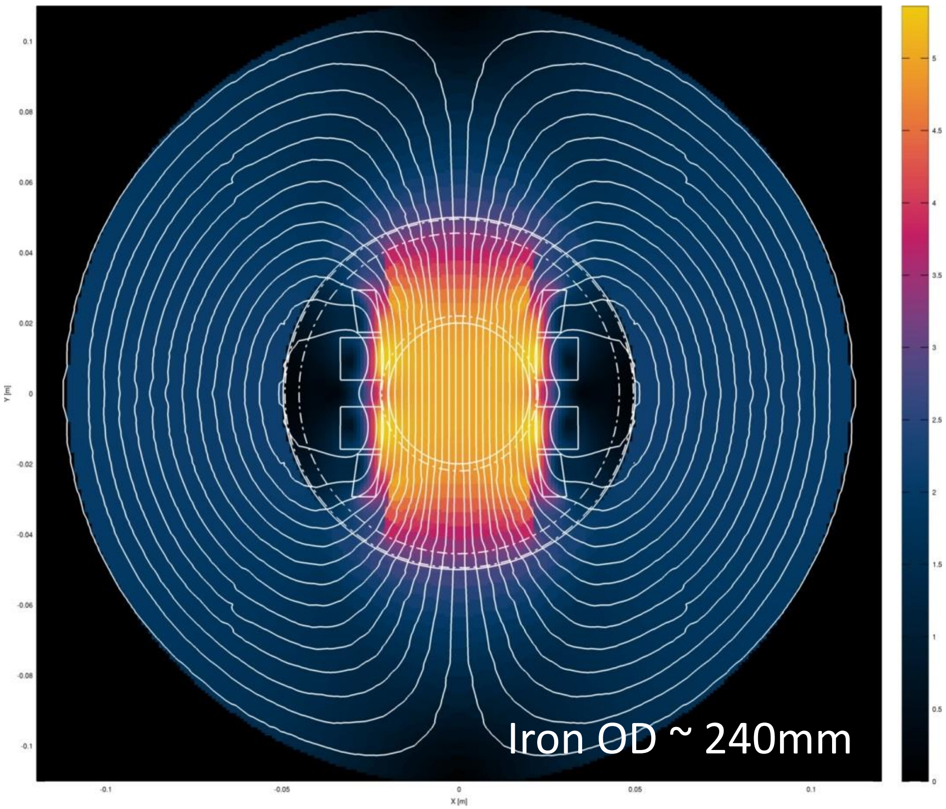
1 module: 32 digital outputs
5 V TTL
7 µs response time

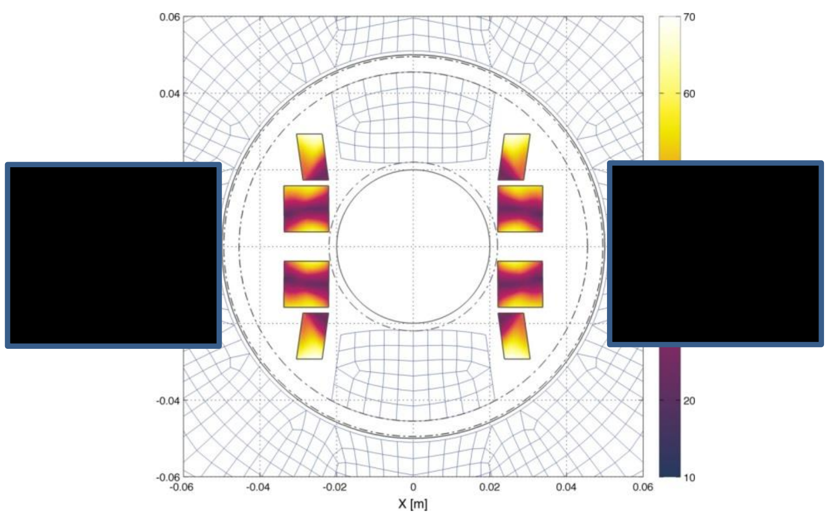
Also available: **high speed module**
4 differential analog inputs
16 bits
1 MS/s, simultaneous sampling

A similar system is used by the EL group to capture voltage transients on the electrical network caused by EDF switching, thunderstorms and internal load changes.

Cross section 5 T Stand alone

98 mm outer diameter, to be able to fit inside Fresca-2 without touching.
Standalone we may fit a simple magnetic yoke





This is one of the many possible designs we are Thinking about: Placing IRON yoke to Exaggerate the change in field angle to assess angular dependence

Possible test ideas after stand alone