PAUL SCHERRER INSTITUT PSI

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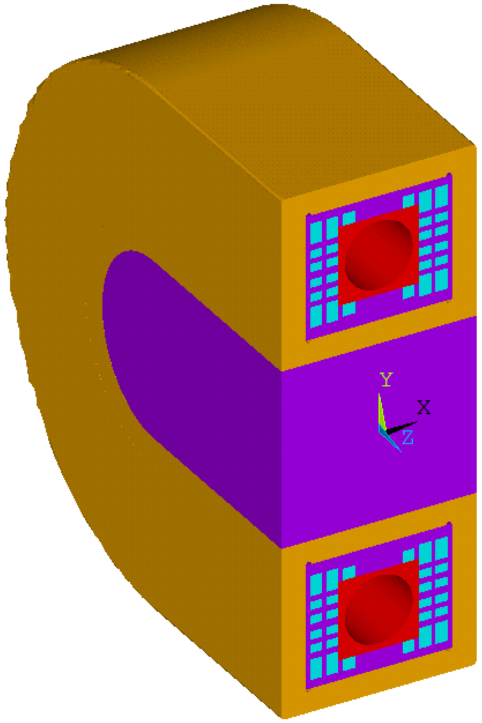
Status of PSI Nb_3Sn Subscale Stress-Managed Common Coils Magnet

1st joint common-coils meeting, June 2023

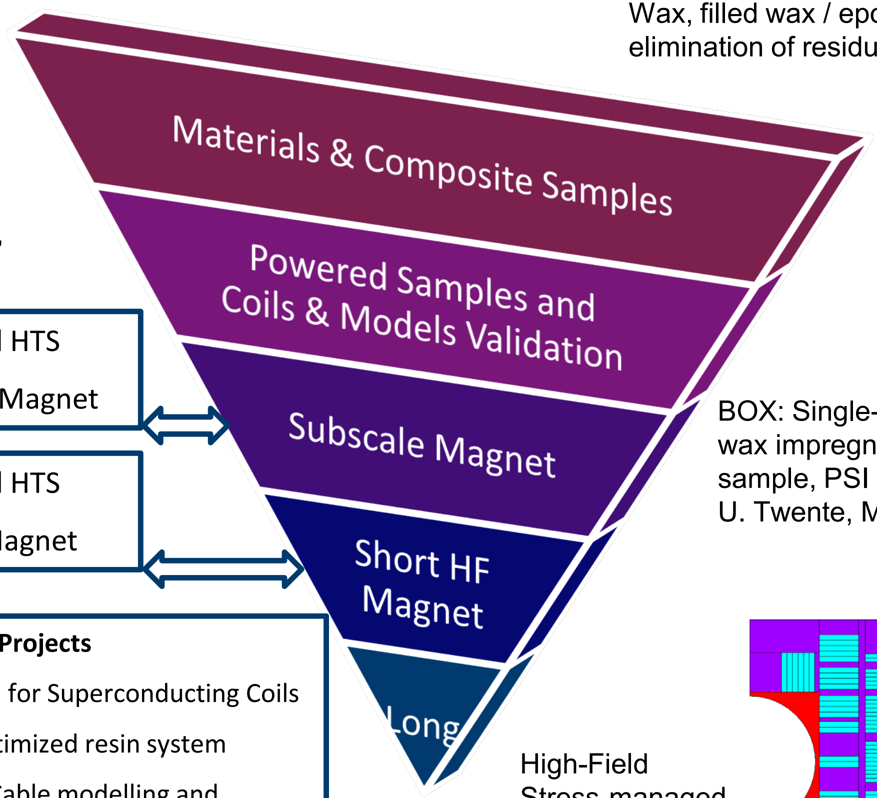
This work was performed under the auspices of and with support from the
Swiss Accelerator Research and Technology (CHART) program (www.chart.ch).

Overview

- LTS Roadmap
- Subscale Goals and Parameters
- Magnet Structure
- 2D Magnetic Design and Mechanical Analysis
- Common-coils as a first step
- Engineering Design Challenges
- Winding Trials



LTS & Hybrid Roadmap Outlook



D. Sotnikov,
H. Garcia

Hybrid HTS Subscale Magnet

Hybrid HTS Short Magnet

CHART Mag Projects

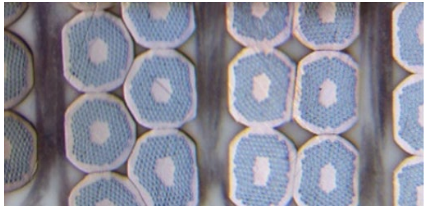
MagAM: AM for Superconducting Coils

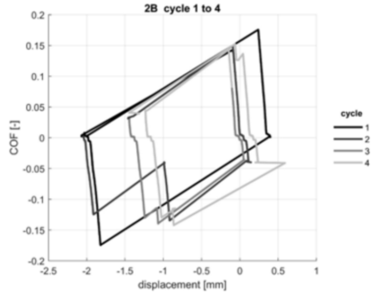
MagRes: Optimized resin system

MagComp: Cable modelling and caracterization

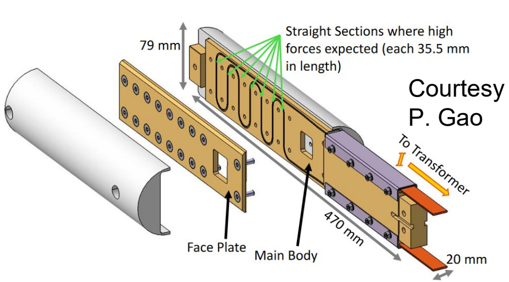
MagNum: Modelling & Optimization

Wax, filled wax / epoxy process development, HT elimination of residues and sliding interfaces, A. Brem

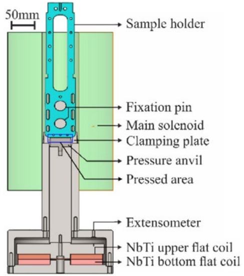




BOX: Single-turn wax impregnated sample, PSI & U. Twente, M. Daly

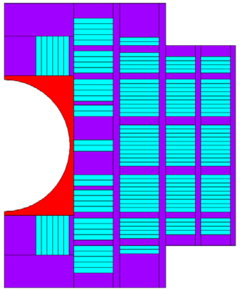


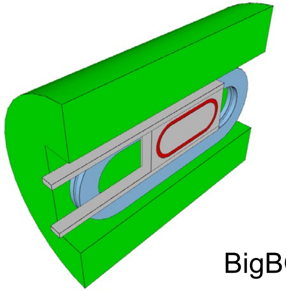
Courtesy P. Gao

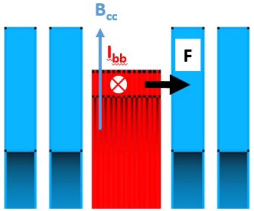


High-Field Stress-managed common coils

D. M. Araujo







BigBOX, PSI & MDP/BNL

Subscale Stress-managed Common-coils Goals and Parameters

- The subscale magnet serves as a platform for validating design and optimization tools, as well as manufacturing and assembly processes.

Cable & strand (LBNL Subscale CCT)		
Strand dia	0.6	mm
Number of strands	11	-
Bare dimensions	3.7 x 1.1	mm
Insulation thickness	0.155	mm
Cu/no-cu	1.17	

Goals		
Nominal Field B0	4 +	T
T operational	4.5	K
Max current	10.0	kA
Margin at Top and B_0	> 15	%

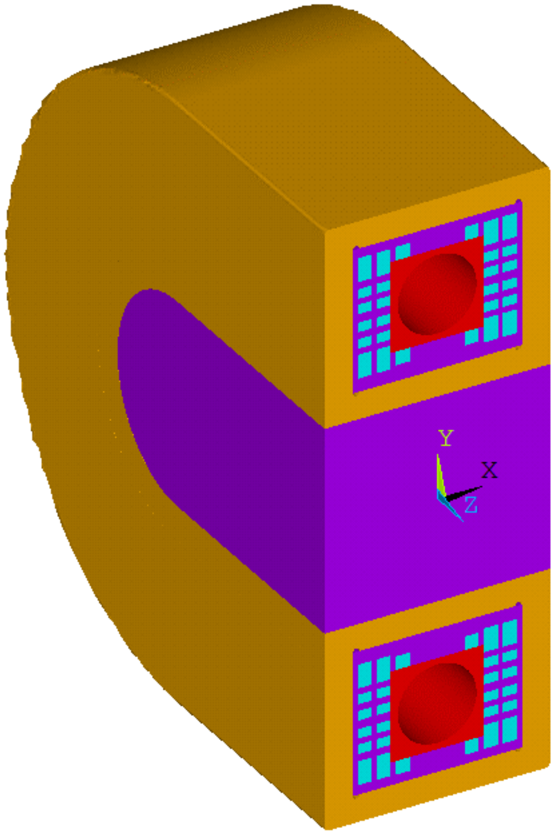
Dimensions		
Straight-Section	150	mm
Bore radius	22	
Intra-beam	120	
Total length	350	

Magnet Structure

- Return Side Representation

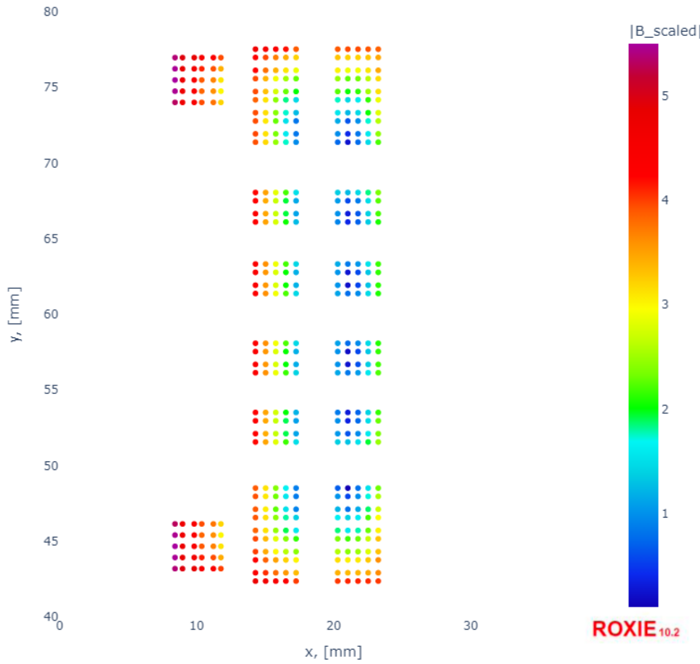
- Inner Common-coils
- Stress-Managed Structure
- Inner and outer coils
- Pole-coils
- Outer-collar
- Inner-collar
- Pole
- Filler

- Stress-Managed Structure, Collars, Pole and Filler made of Stainless-steel

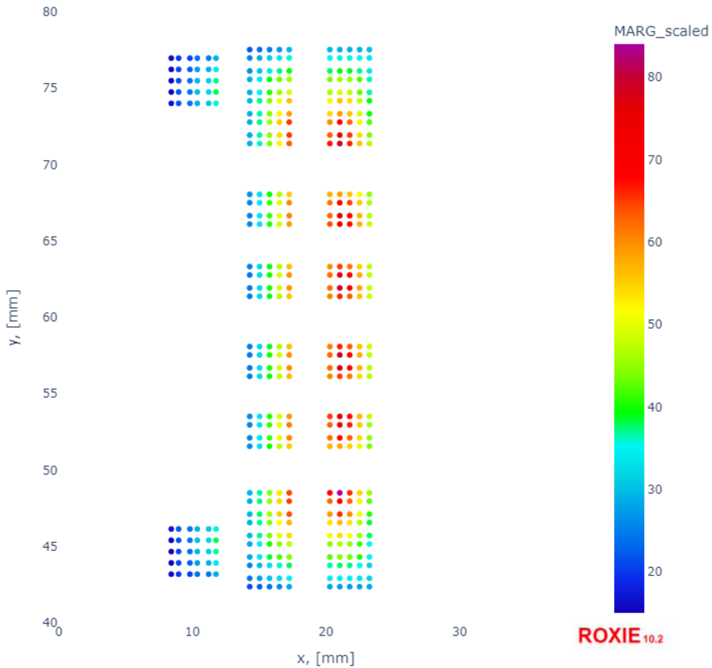


2D Magnetostatics: B_0 = 4.5 T, I = 7.1 kA

- Peak field on conductor: 5.49 T



- Margin at 4.5 K: 15 %



- Field Quality

Multi pole	Units
b3	-0.2
b5	-3.1
b7	3.8
b9	-1.
a2	0.9
a4	3.7
a6	-0.2
a8	0.0

This can still be improved

2D Mechanical Analysis

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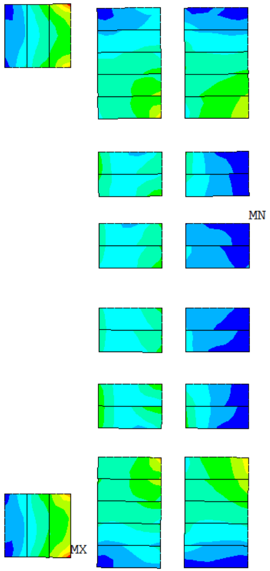
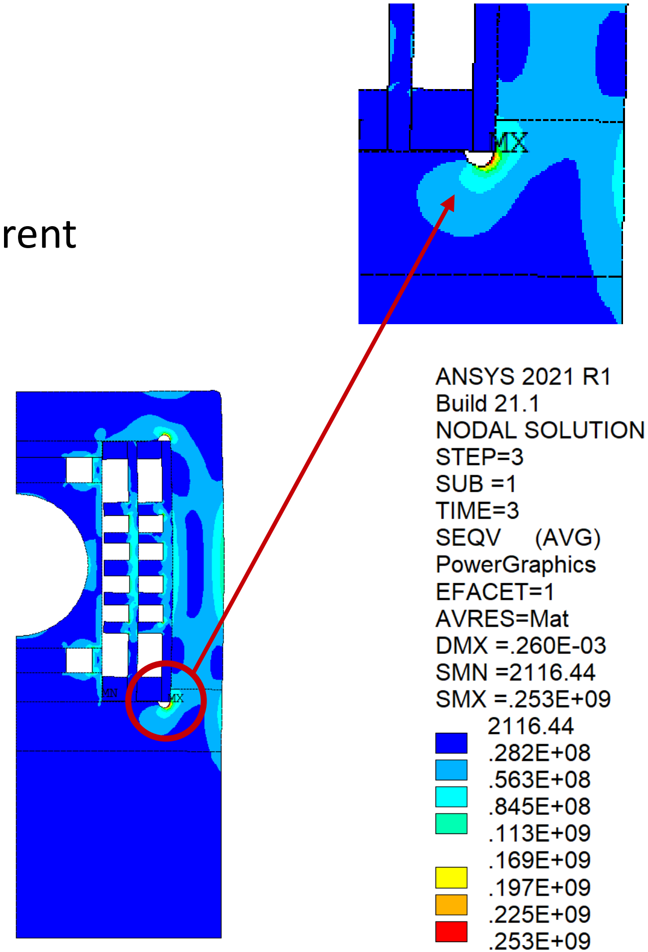
- The analysis was performed with short sample current
- Von Mises Stress on Coils and Structure



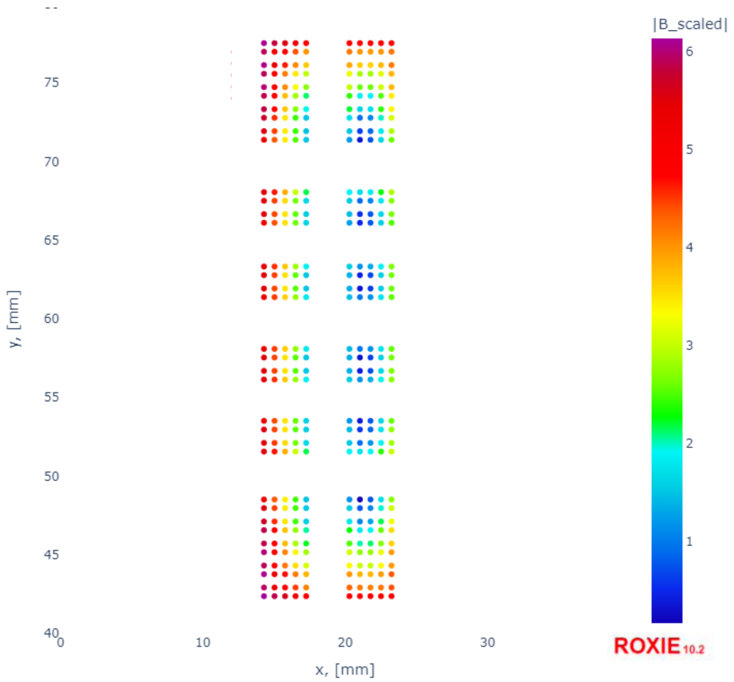


If we test only the common-coils

- For the first subscale test, we would like to power only the common coils.

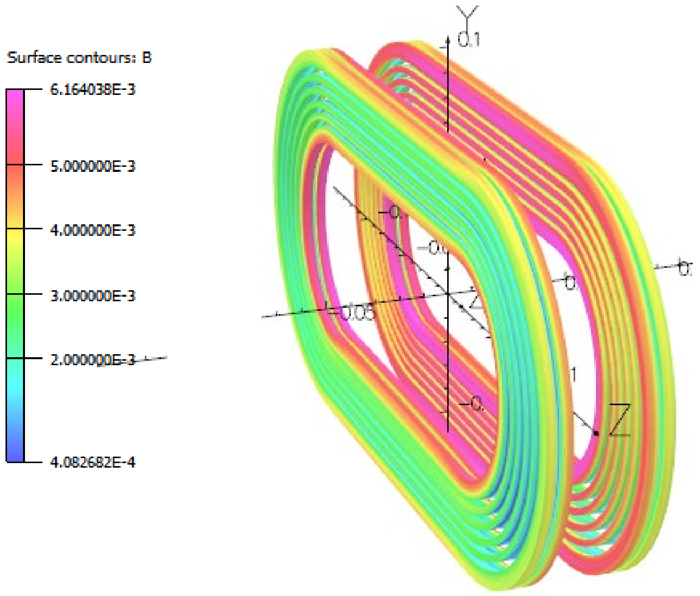
- In this case:
  - T_{op} = 4.5 K
  - B_0 = 5.1 T at short sample
  - I_{ss} = 8.9 kA
  - B_{peak} = 6.13 T

- Peak field on conductor: 6.13 T

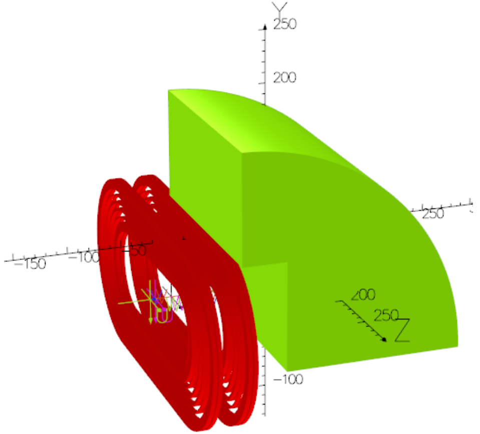


If we test only the common-coils: 3D

- Peak field on conductor: 6.16 T



- With the 3D model and at short sample:
  – T_{op} = 4.5 K
  – B_0 = 5.1 T at short sample
  – I_{ss} = 8.5 kA
  – With a iron yoke, the enhancement of field would be of about 0.5 T



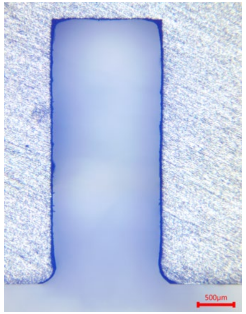
We are optimizing the ends to get good integral field quality

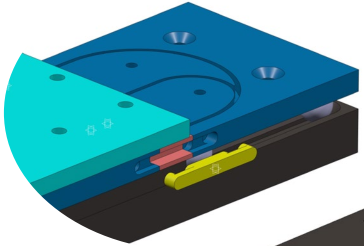
Engineering Design Challenges

- Coil / Stress-Managed Structure Insulation
- Winding methods for stress-managed structure
- Axially divides structure, gaps for heat treatment and closing gaps before impregnation
- Inter-layers Splices & Pole Coils Splices
- Instrumentation
- Vacuum bag impregnation with wax / filled-wax

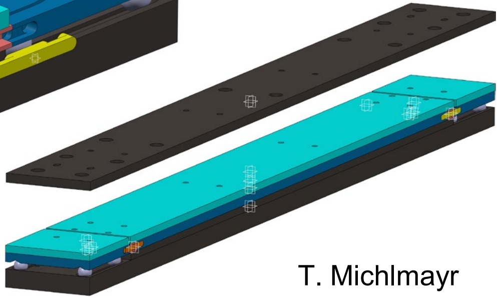
- Handling the coil into the SM structure through all manufacturing process
- Assembling structure

High temperature glass-ceramic coatings, A. Brem

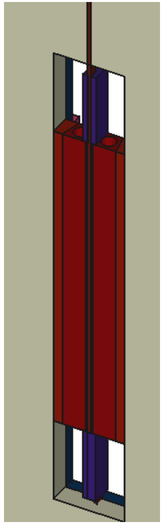




M. Daly



T. Michlmayr

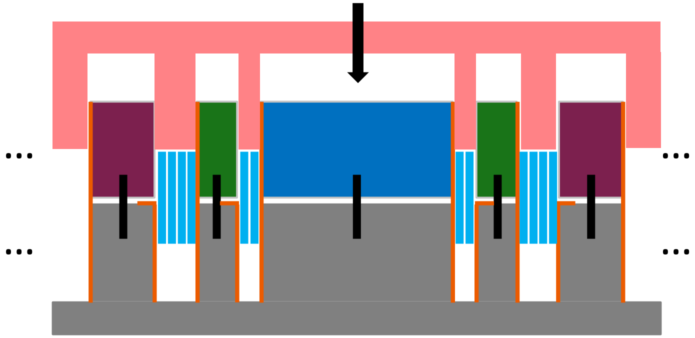


A. Brem, M. Colin, M. Daly

Winding Trials: Methods

- Removable pole and ribs
  - Solid spar where pole and ribs are assembled during the winding process

- Pushing coil into the solid structure

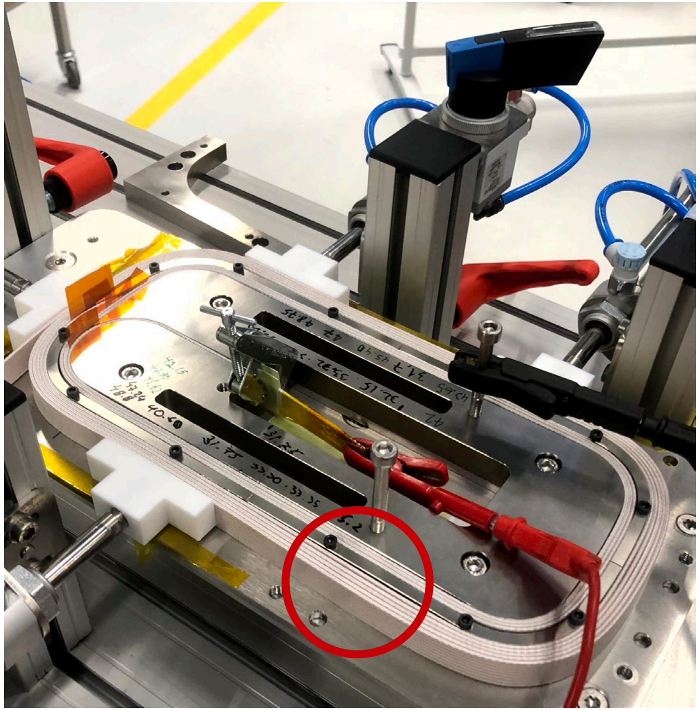


Central pole
First set of ribs
Second set of ribs
Connections
Spar
Conductor

Pusher
Kapton
Solid Structure

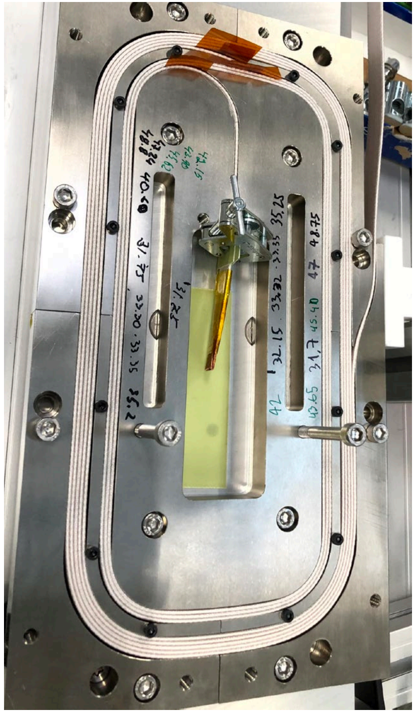
Winding Trials: First Method

- Winding the second block



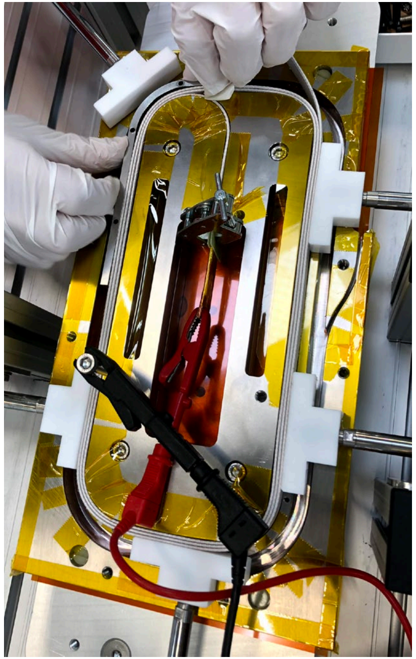
- Placing the outer rib

- After placing all ribs



Winding Trials: Second Method

- Placing the first rib set after 3 turns



- Placing the first rib after 3 turns

- Pushing the coil into the structure

Winding Trials: Improvements / comments

- **Split** the central pole to make the central lead winding easer
- Increasing the channel depth, since the coil was protruding
- Radius on the top part of the channel: the sharp edges could damage the cable and makes the coating process less effective.
- If the first method is used, we have to

find a way to better close the **gaps** between ribs parts

- Decreasing the **channel width,**

specially on the round corners where we measured a gap of up to 0.7 mm.