



U.S. MAGNET  
DEVELOPMENT  
PROGRAM

# Status of the 15T Cos-theta MDPCT1 post-mortem – lessons learned

*Alexander Zlobin  
for the MDP Team*

*Presentation to the MDP TAC*

*October 1, 2021*





U.S. MAGNET DEVELOPMENT PROGRAM

Preliminary Feedback from  
MDP Technical Advisory Committee

March 5, 2021

G. Apollinari (FNAL), A. Lankford (UCI; Chair), J. Minervini (MIT),  
M. Palmer (BNL), D. Tommasini (CERN), A. Yamamoto (KEK/CERN)

ENERGY

## Findings

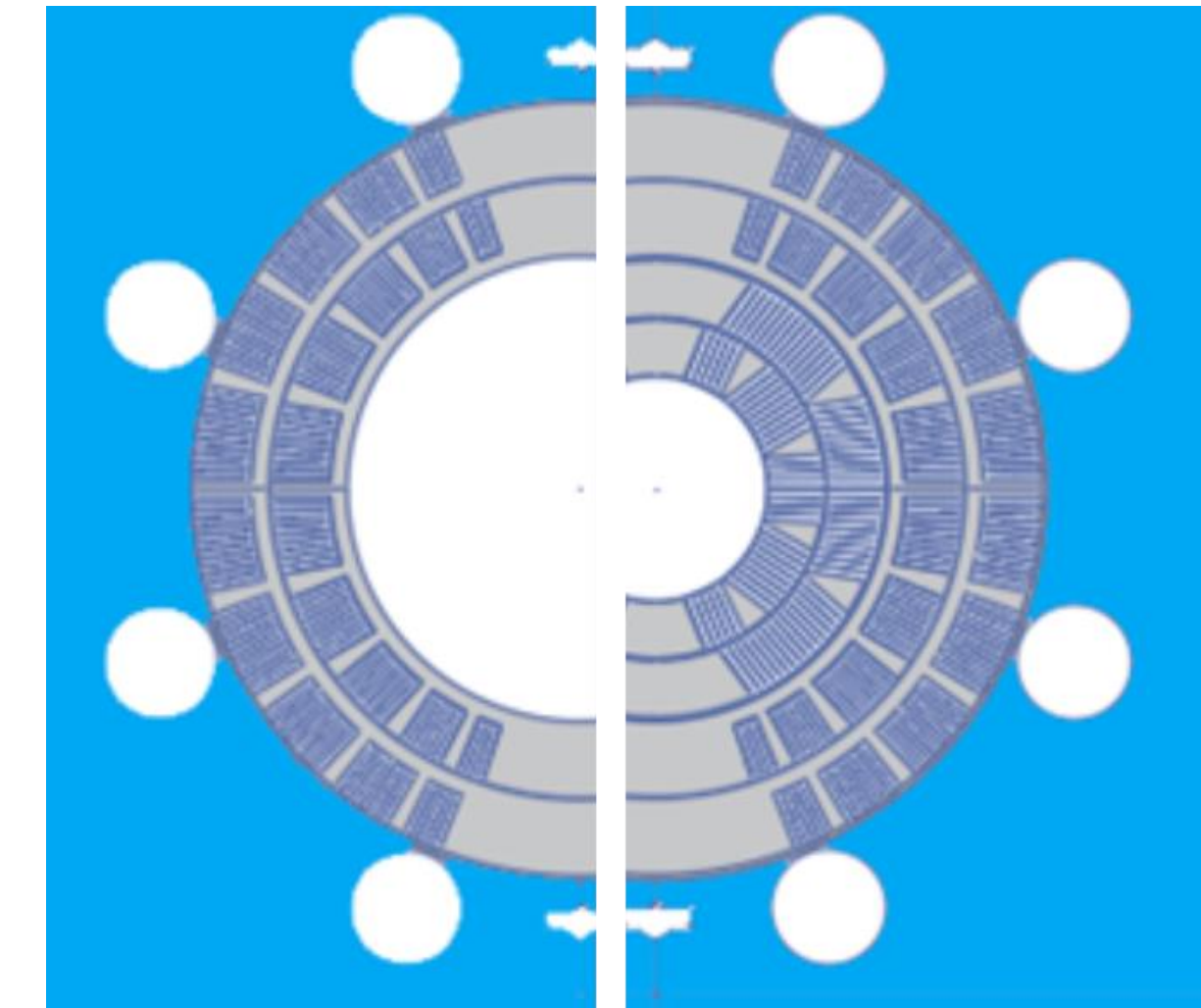
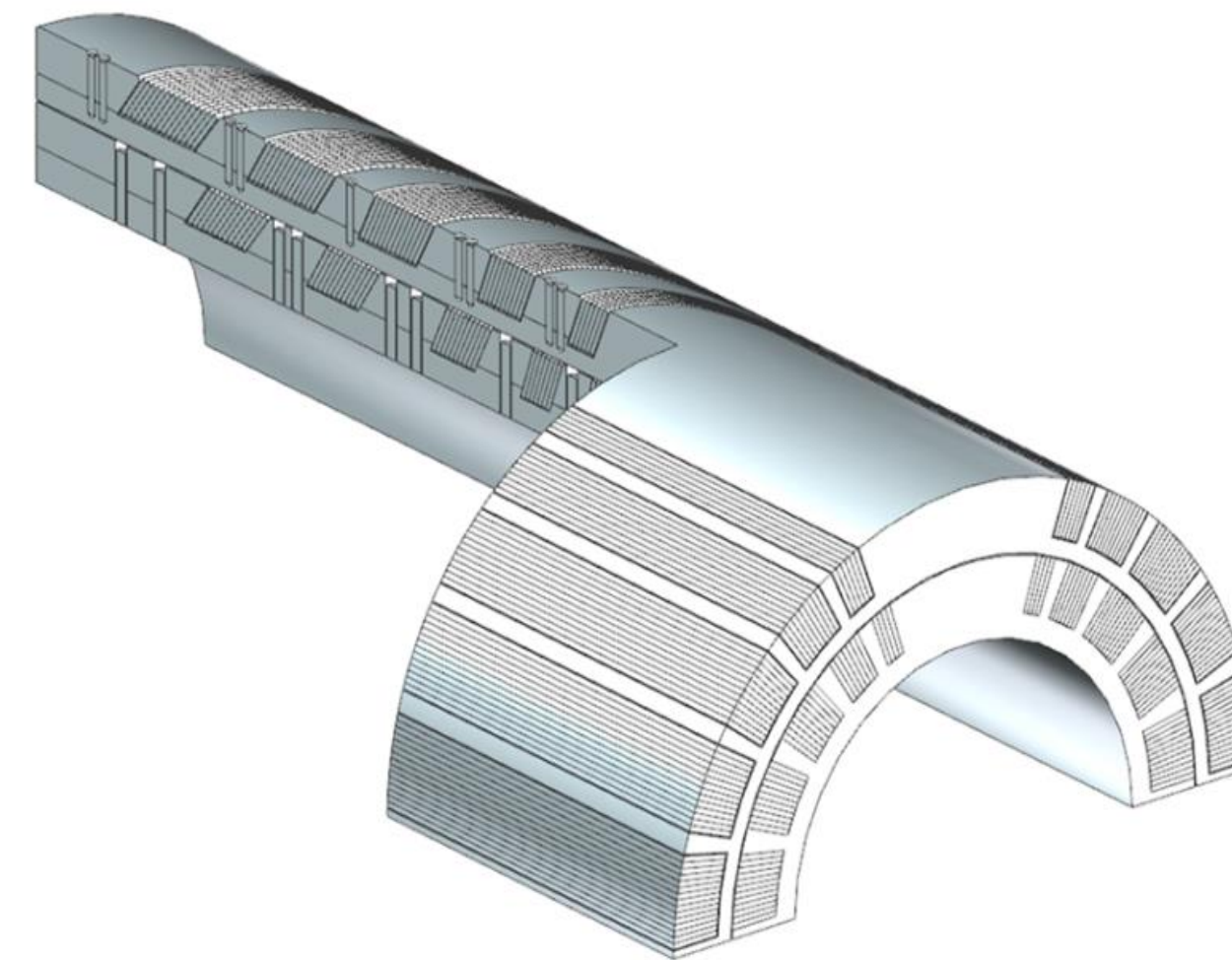
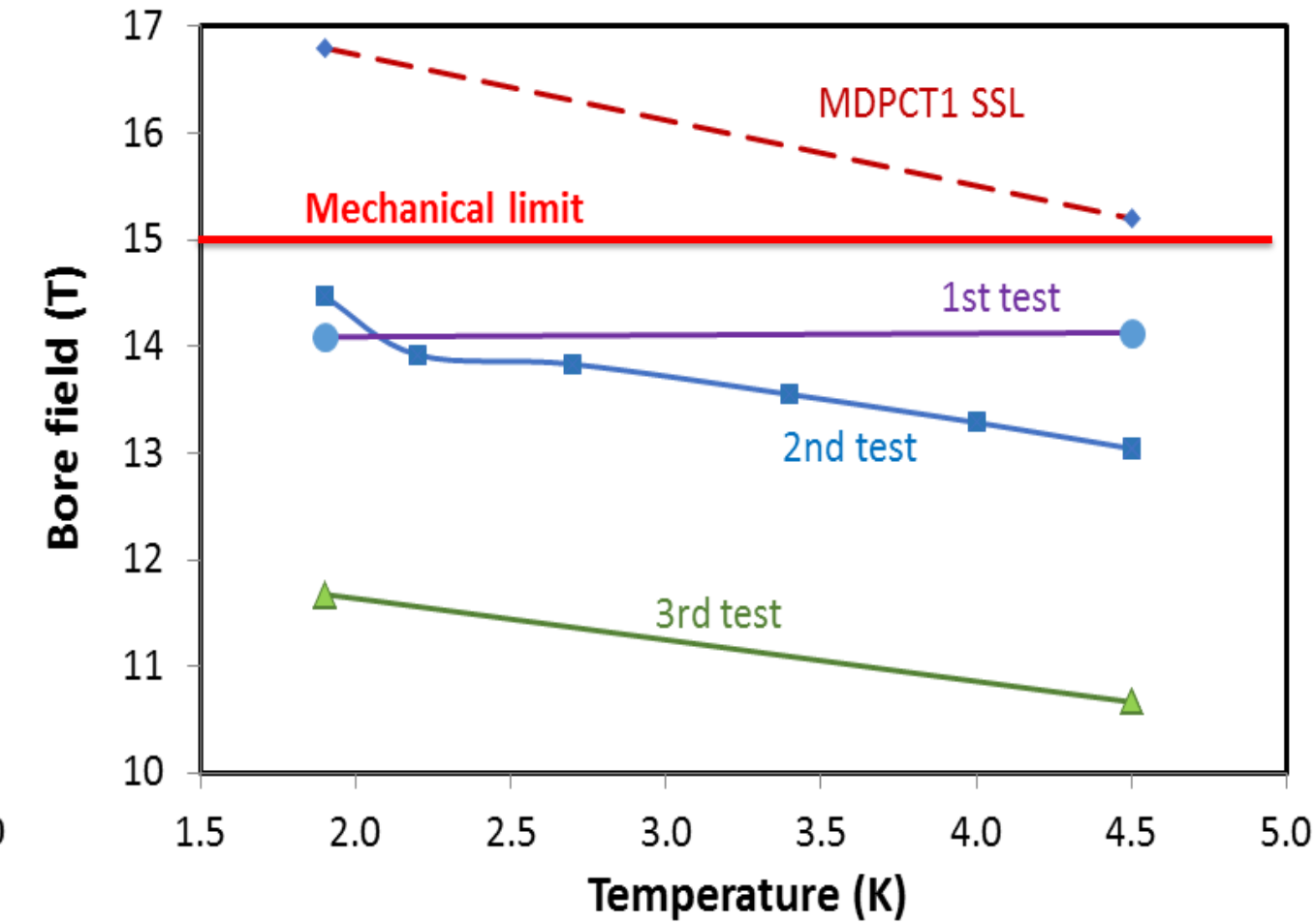
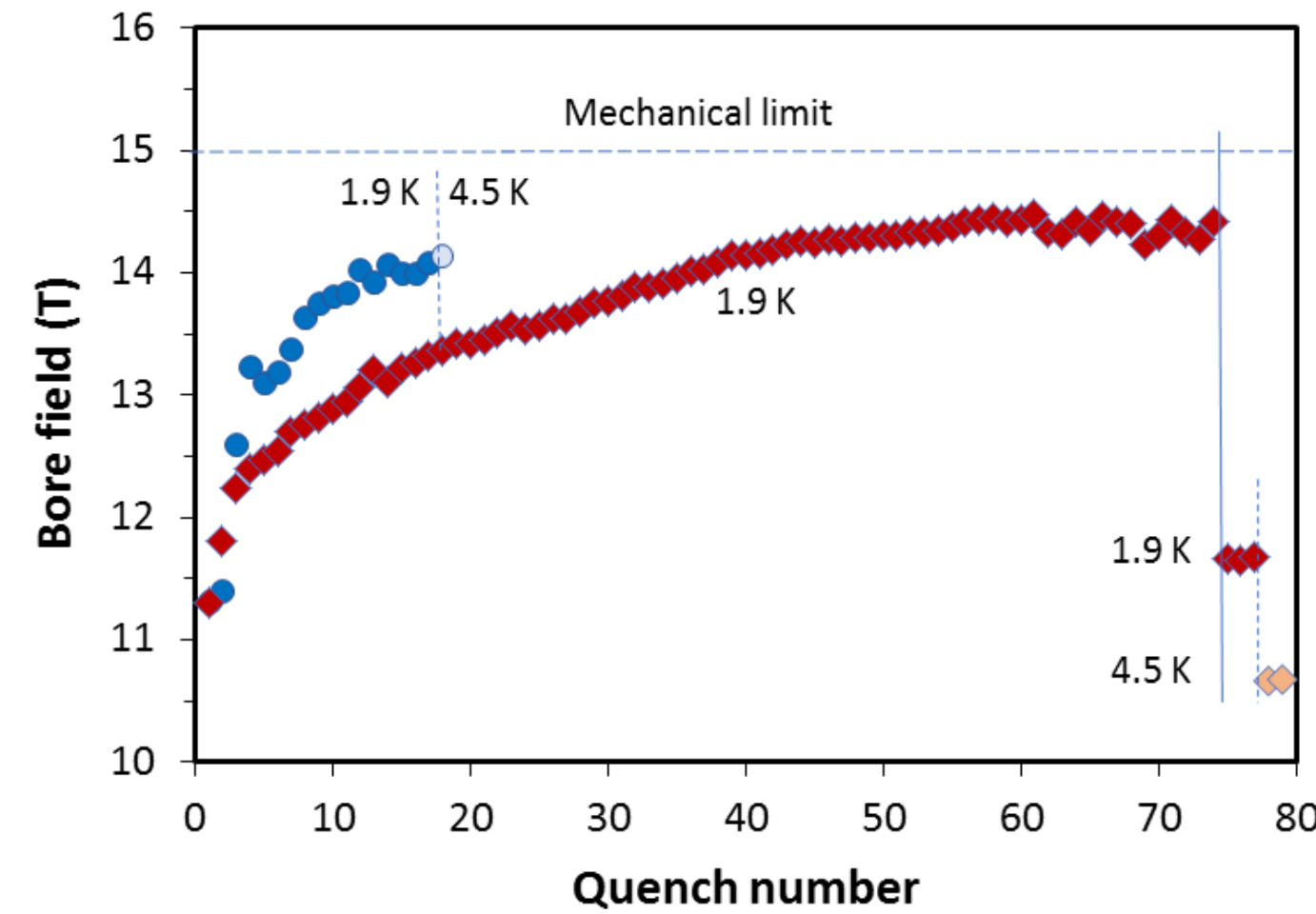
- ....
- **Second test of MDPCT1 (June 2020) showed record field (14.6 T), limited by considerable (18%) conductor degradation of OLs.**
- ...

## Comments

- ...
- **The results of the MDPCT1 emphasize the importance of introducing stress management features in high field Nb<sub>3</sub>Sn magnets.**
- ...

## Recommendations

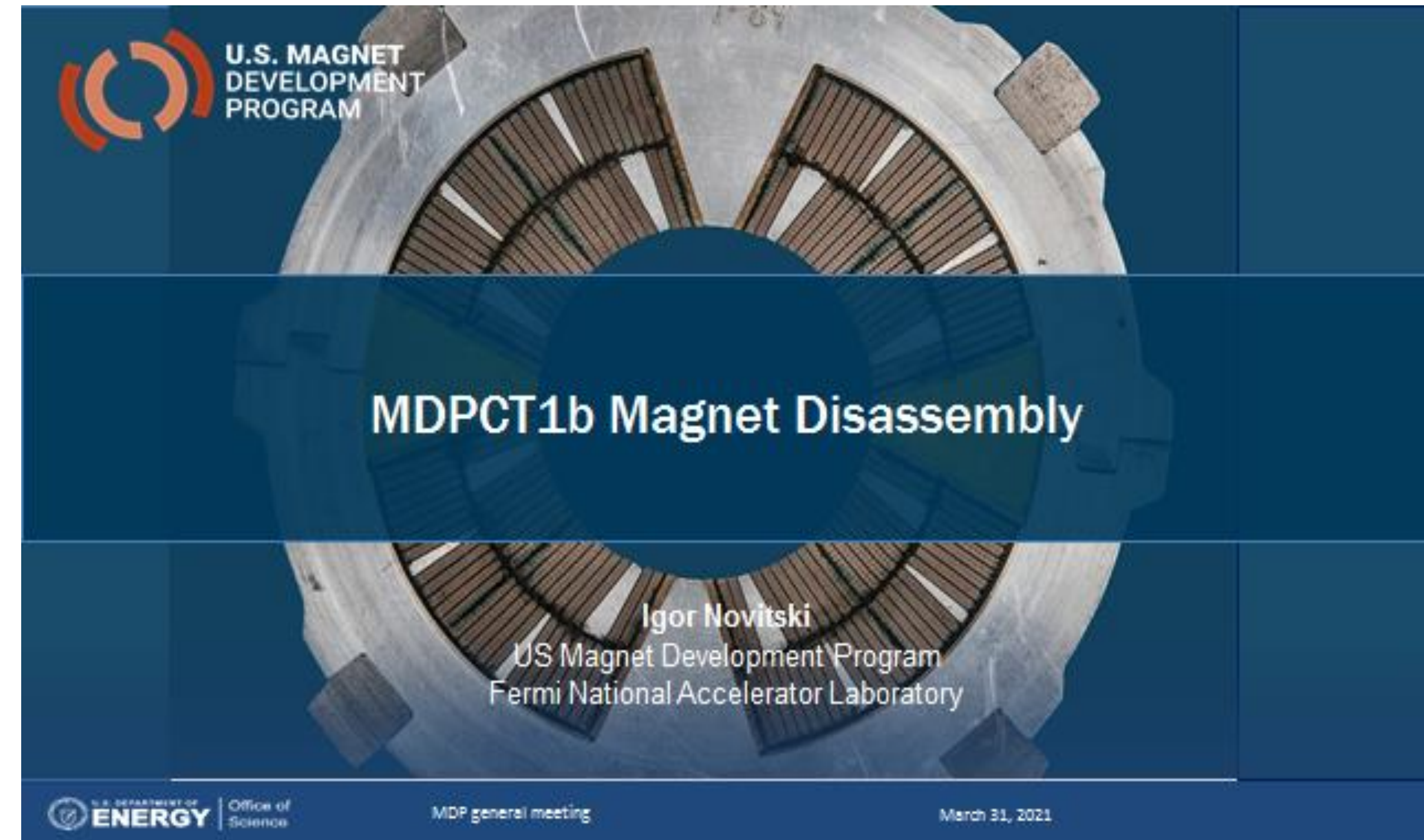
- 1) ...
- 2) **For the post-mortem analysis of the MDPCT1 degraded coils look for synergies with the methods applied for the 11 T post-mortem.**
- 3) ...







- MDPCT1b disassembly completed in March 2021
  - ✓ details summarized by Igor Novitski
- All structural elements (stainless steel skin, iron laminations, aluminum clamps, end plates, axial rods) have been inspected
  - ✓ no visual damage found
- Coil block axial and radial shimming has been checked and found consistent with the assembly plan
- Surfaces of outer coils 4&5 and inner coils 2&3 have been inspected
  - ✓ separation of end pole turns from poles is seen on the inner surface of both outer coils





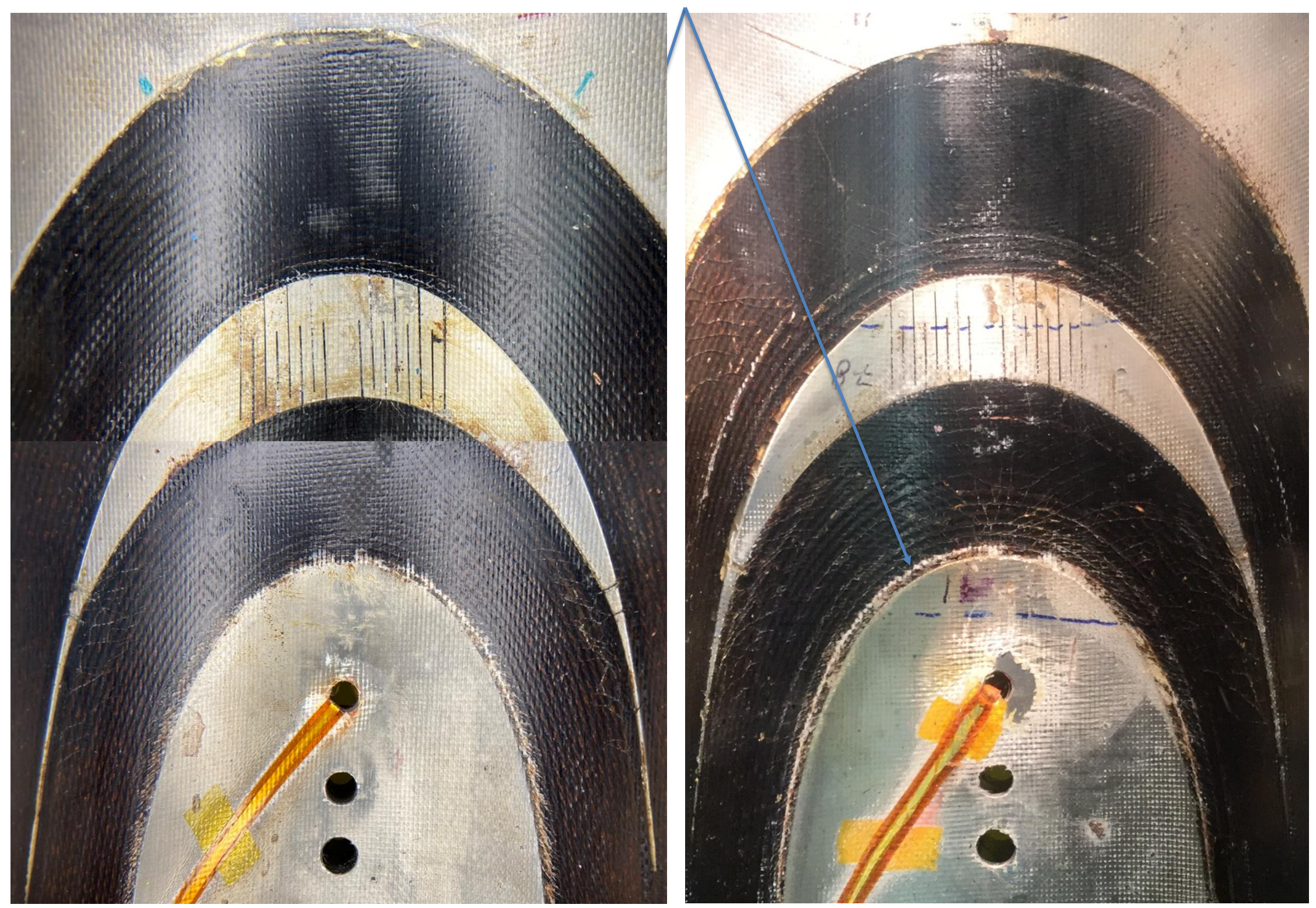


# Inner Layer view of coils 4&5 RE/LE after test 2

Coil 4

Pole turn separation

Coil 5

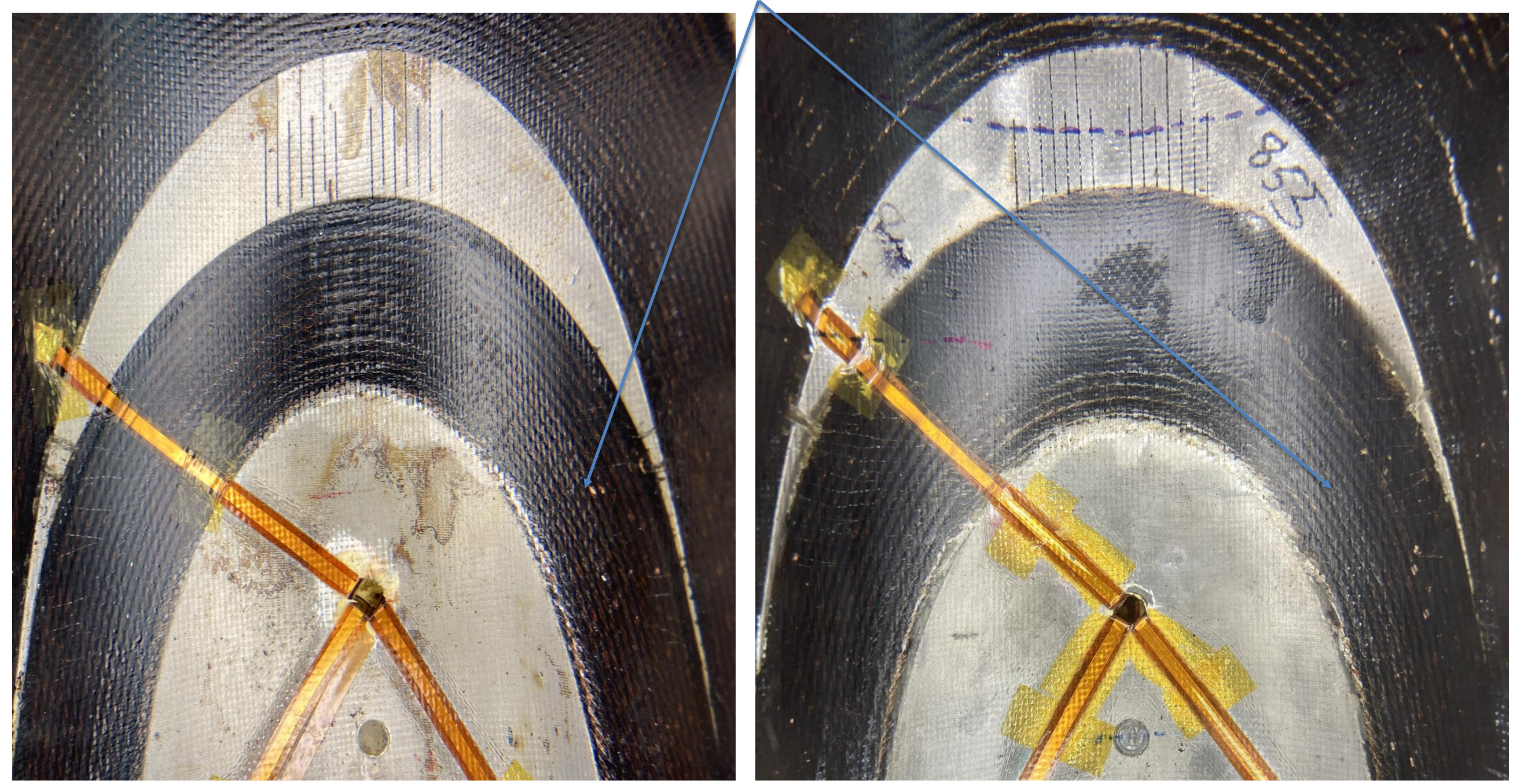


RE

Coil 4

Pole turn epoxy cracking

Coil 5



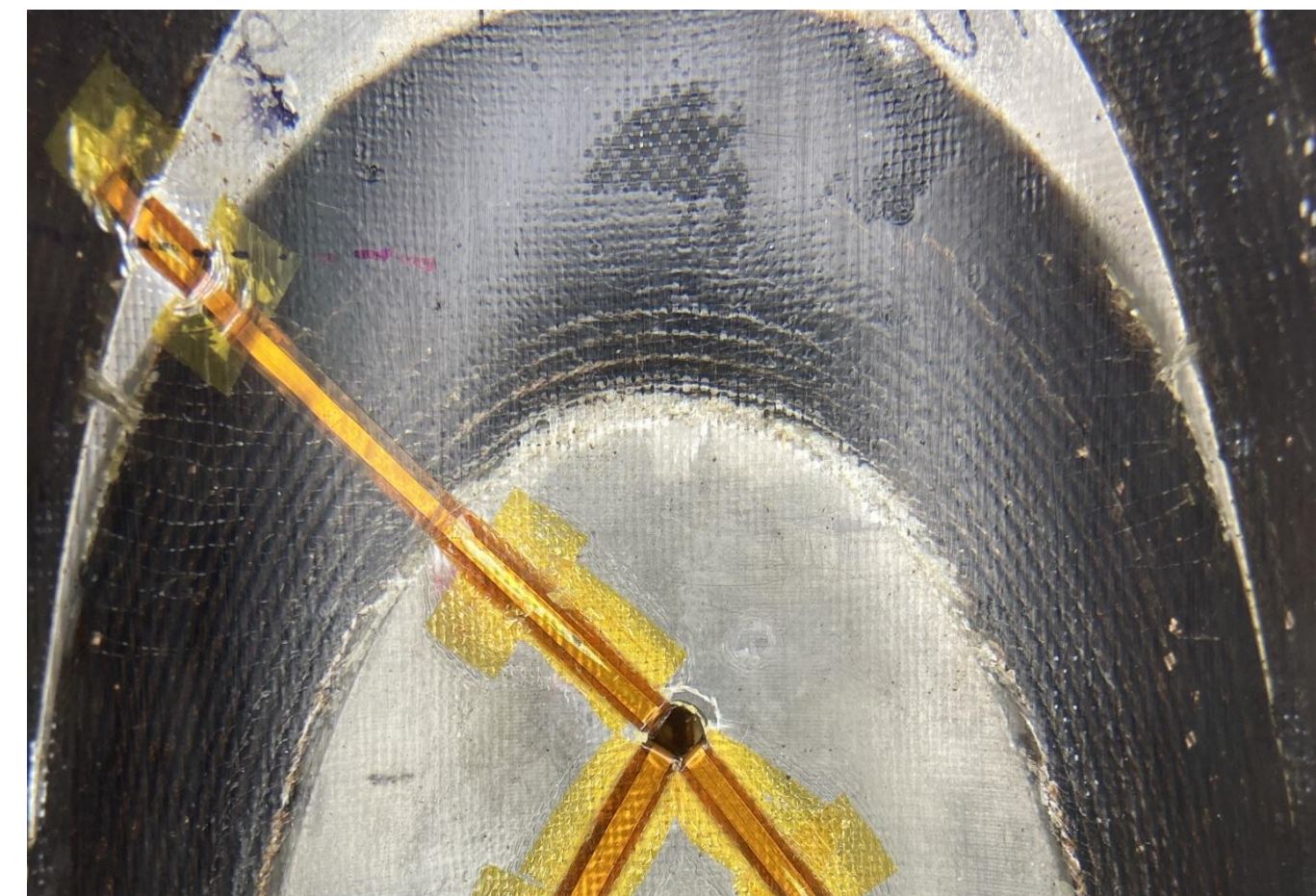
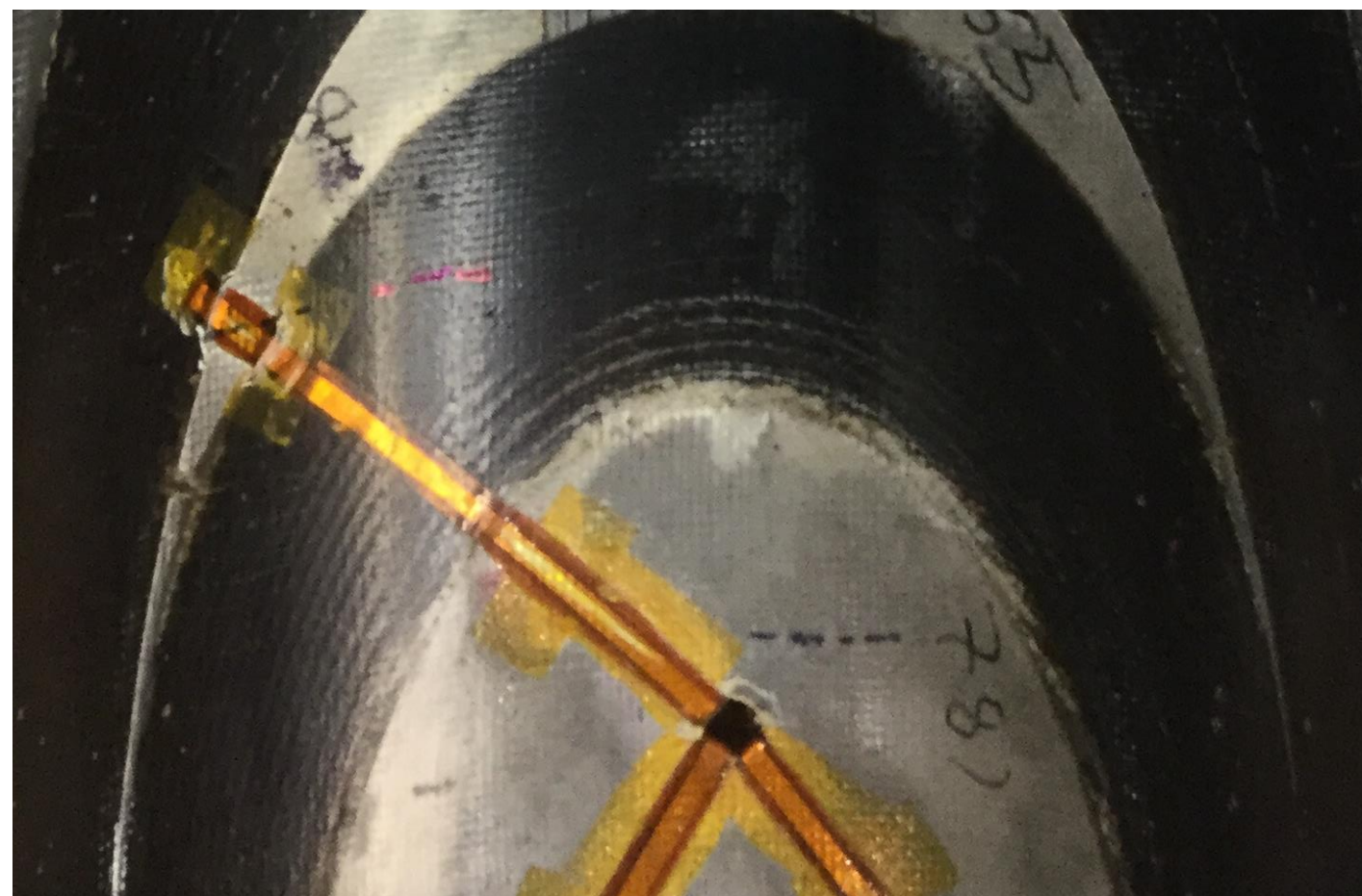
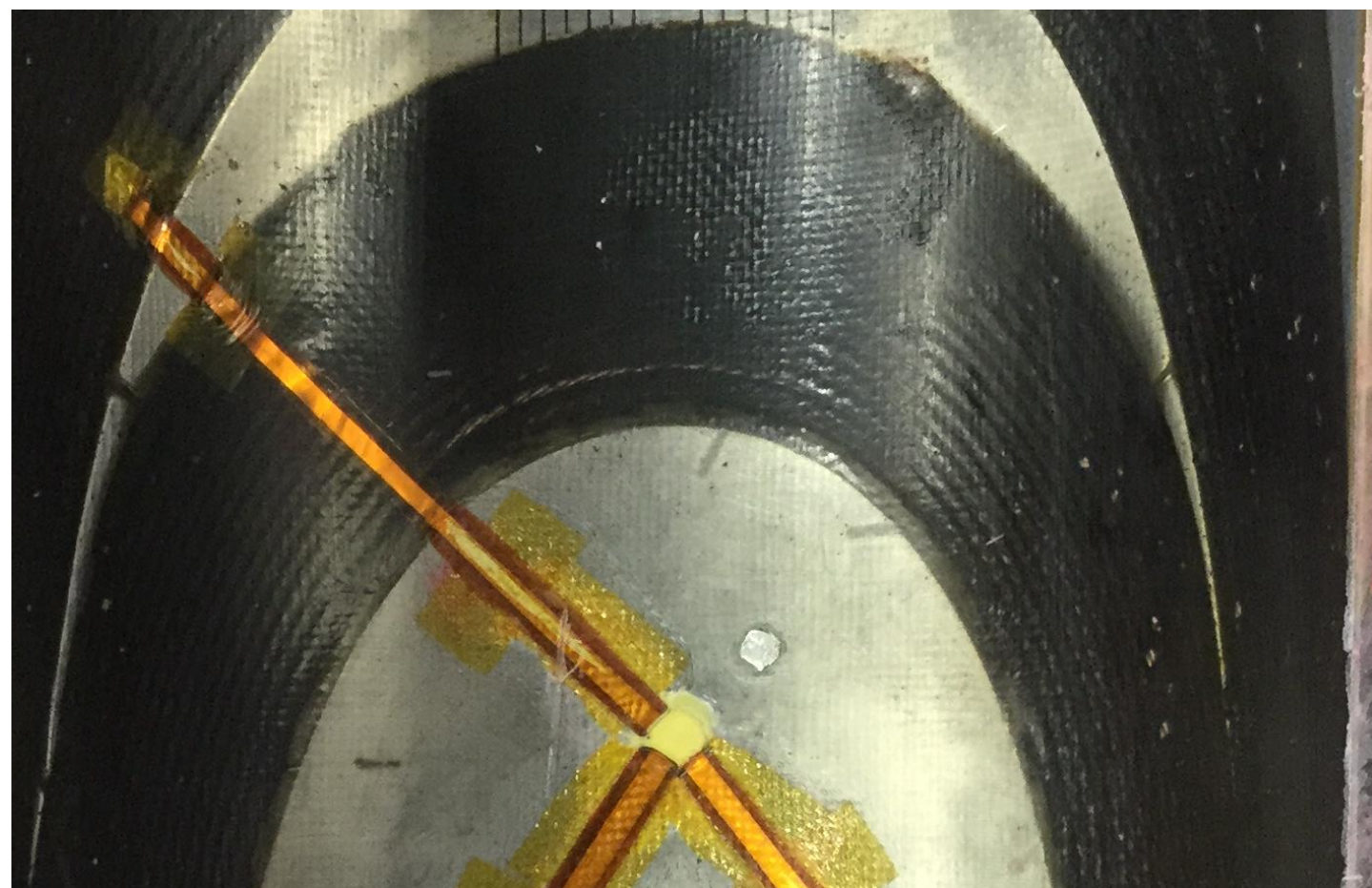
LE





# Inner Layer LE/RE view of coil 5

Lead End

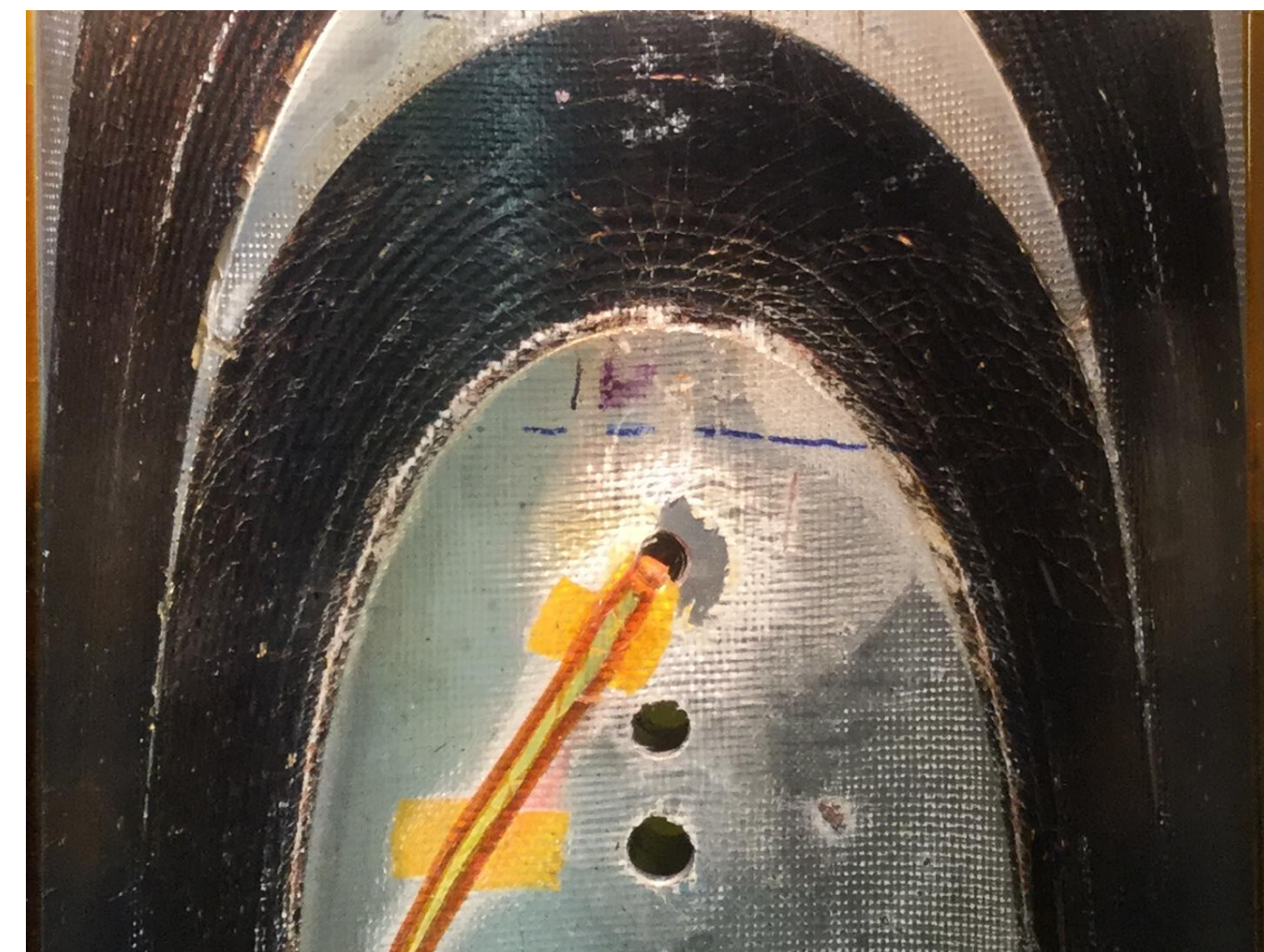


Before test

After test 1

After test 2

Return End







# Inner Layer RE view of coil 5 at different stages

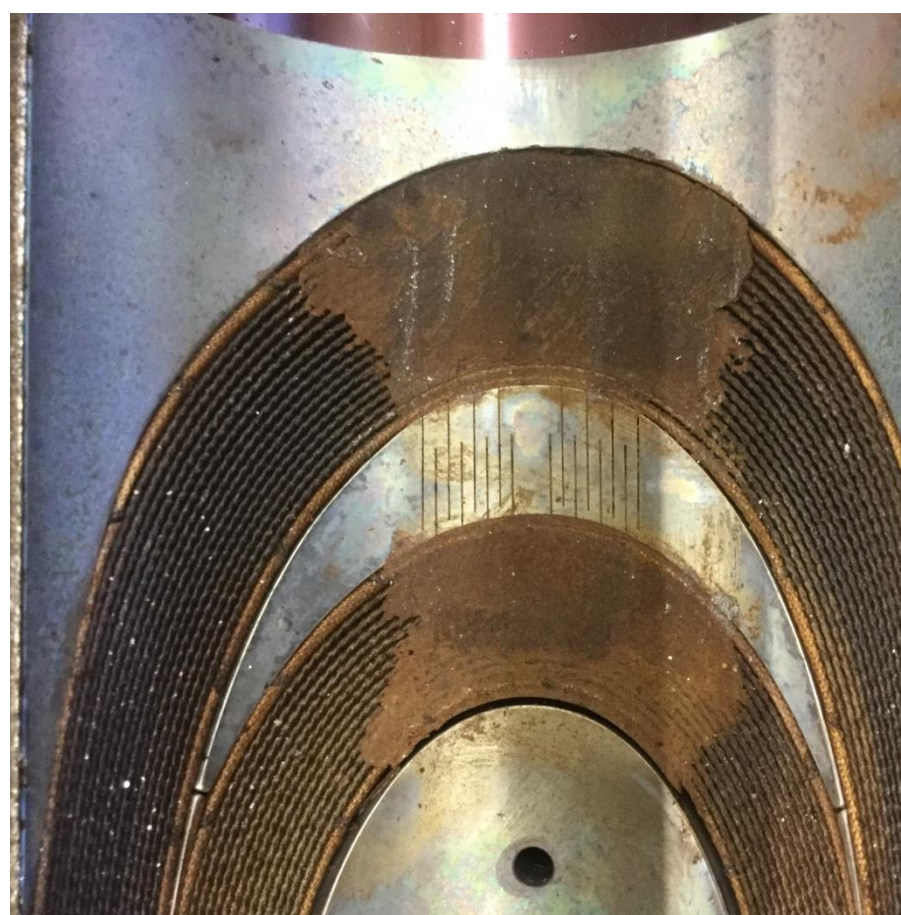
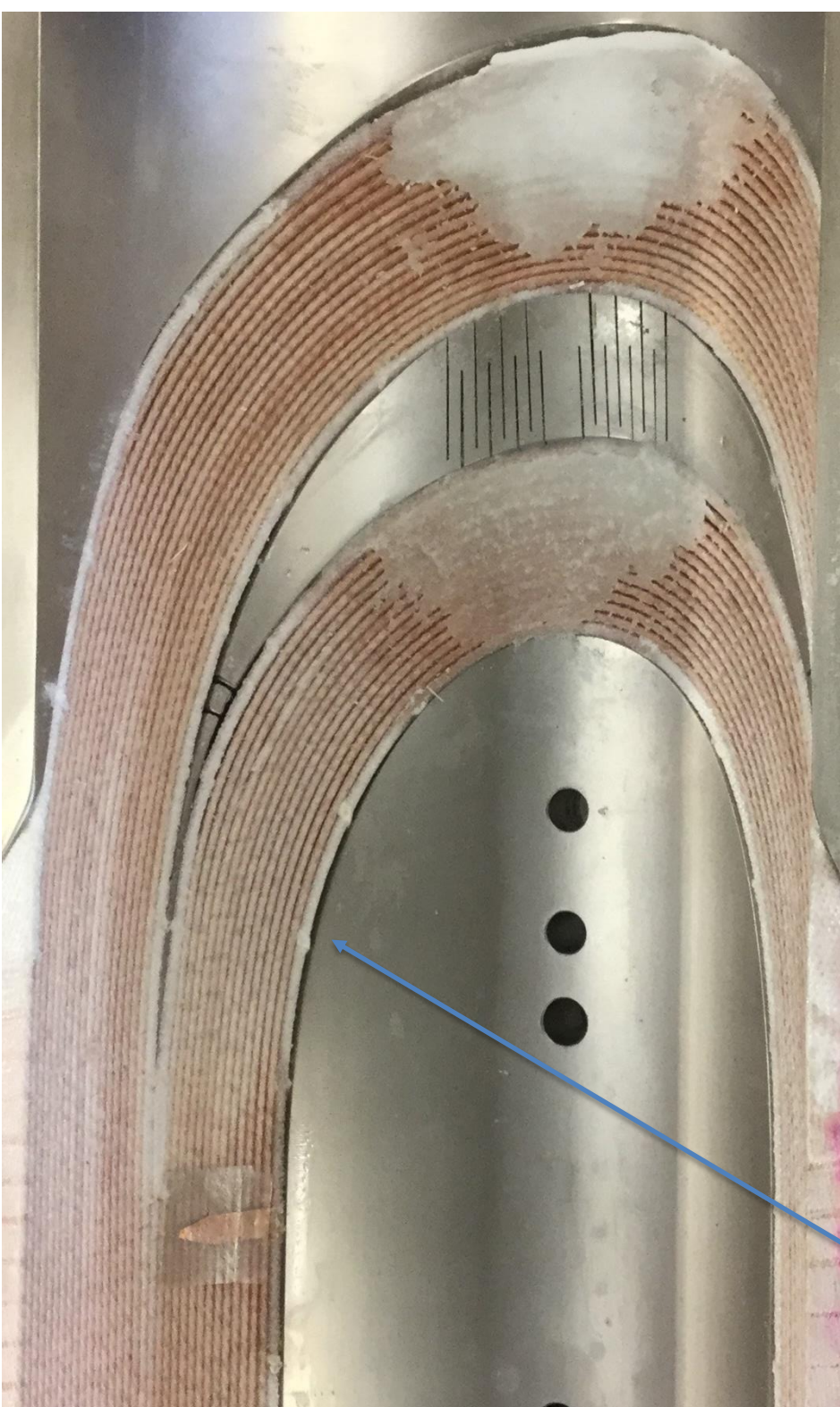
After curing

After reaction

Before impregnation

After impregnation

After cold test



glass filler

pole turn, extra insulation

Inner layer was wound/cured/rewound

No clear evidence why coil 5 limits magnet performance.



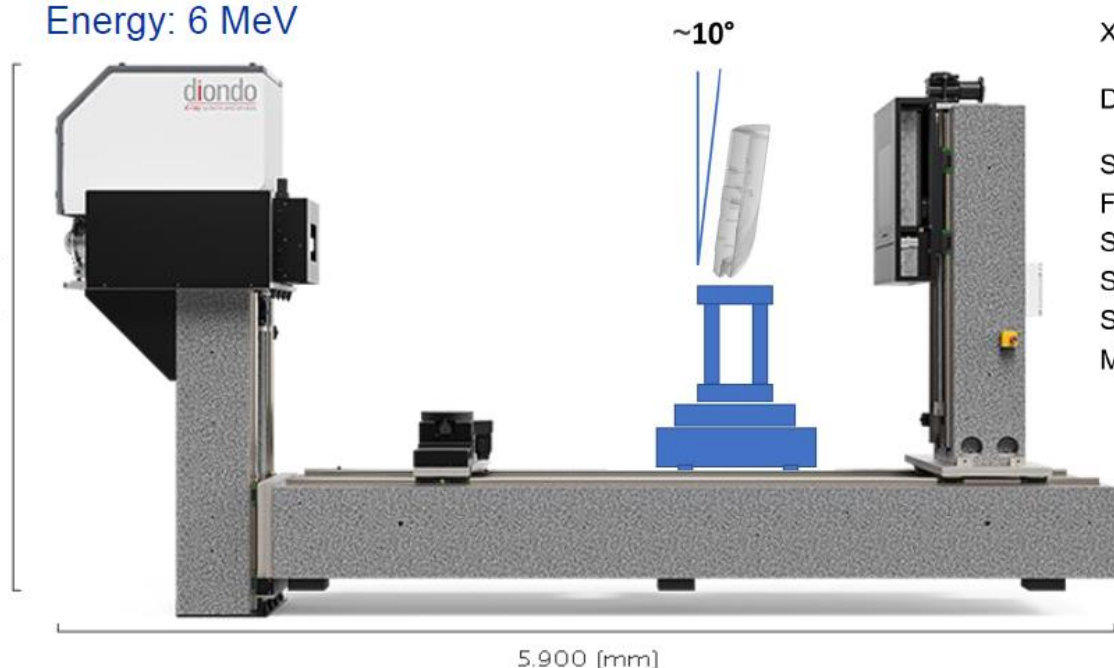


# Next step: coil 5 nondestructive CT scan

## Global High Energy X-ray Computed Tomography

6 MeV LINAC tomography - TEC-Eurolab Modena /IT

Resolution: 120  $\mu\text{m}$   
Spot size: 2 mm  
Energy: 6 MeV



X-Ray Source

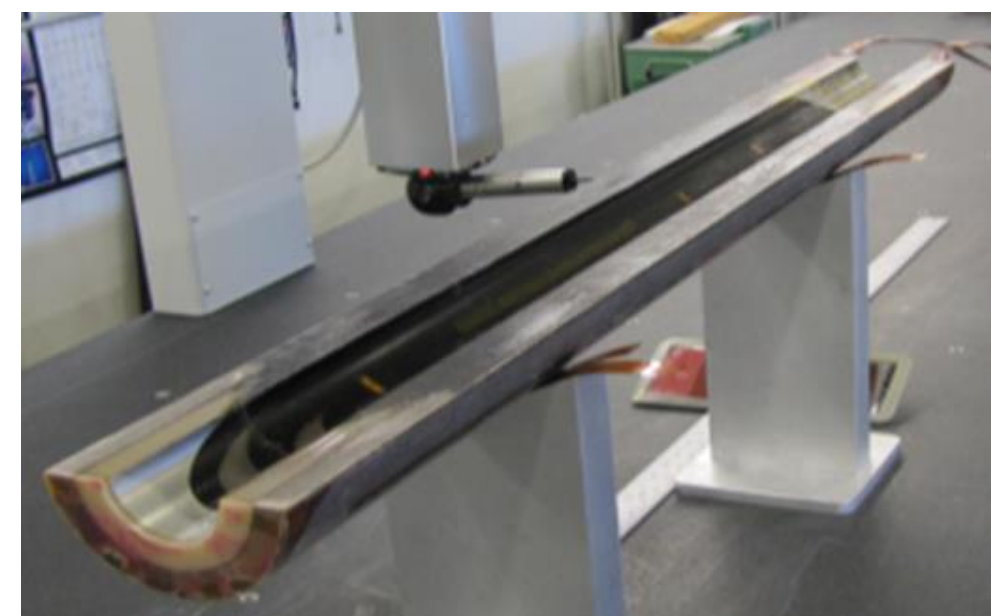
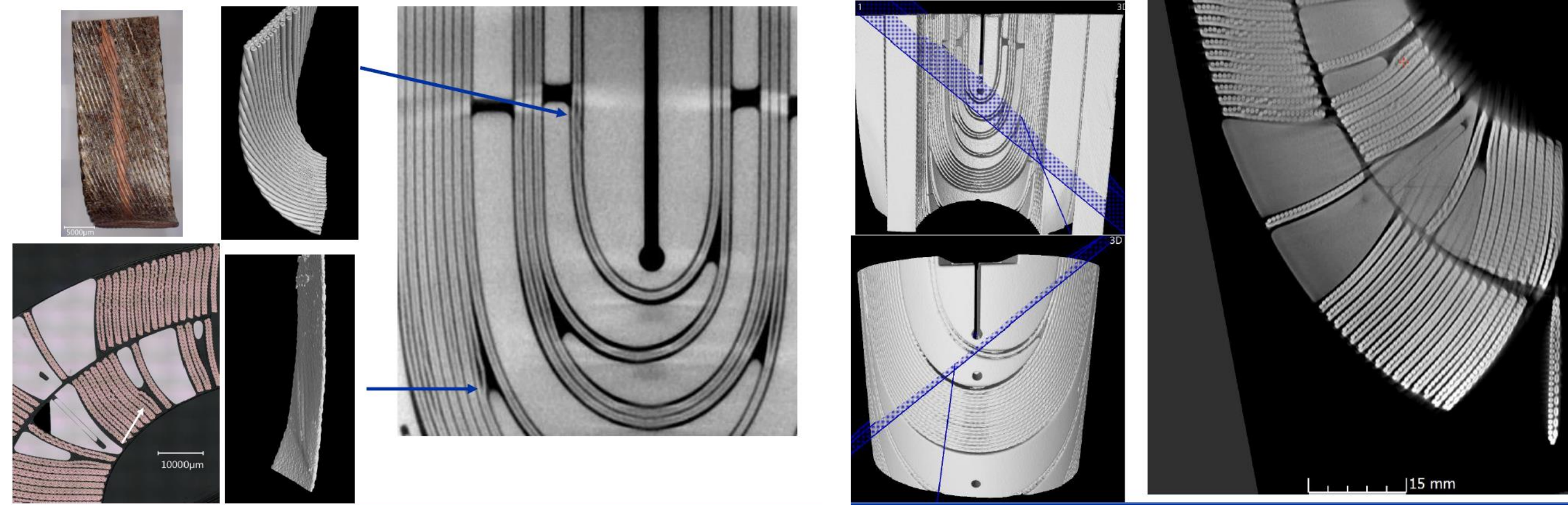
Detector

Scan Volume, maximum  
Focus-Detector-Distance  
Sample Weight  
System Dimensions  
System Weight  
Manipulation

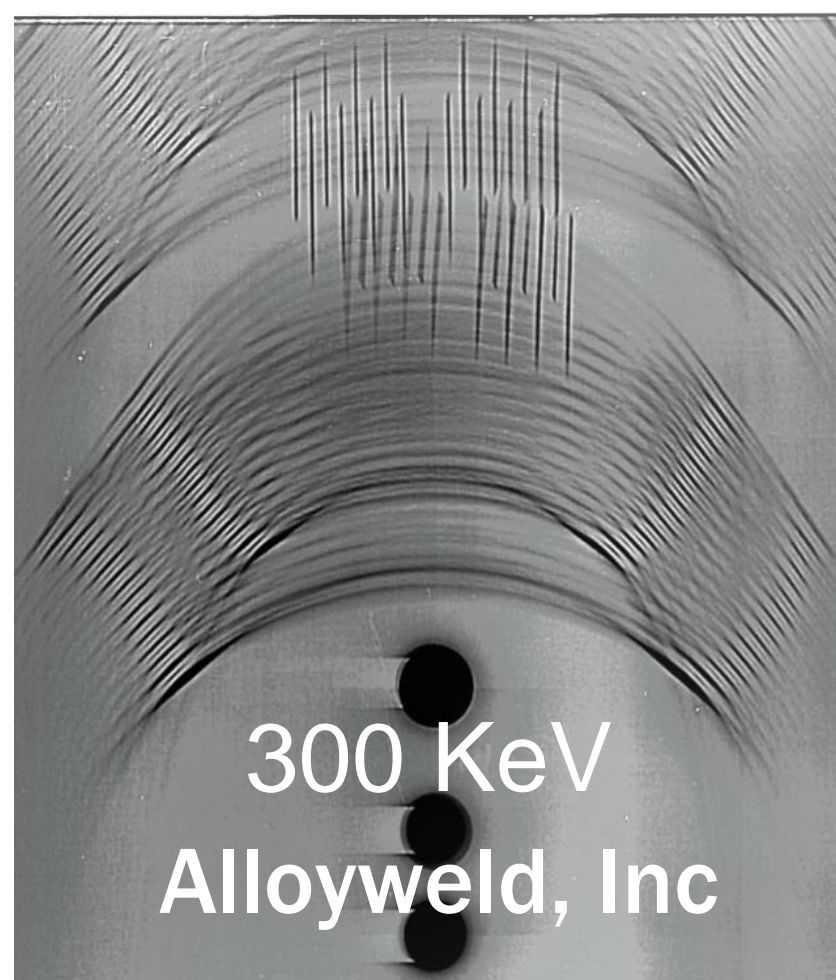
3 / 6 / 9 [MeV]

Flat Panel Detector  
3.000 x 3.000 px, 140  $\mu\text{m}$   
 $\varnothing$  700 x 1000 H [mm]  
4000 [mm]  
200 [kg]  
L 5.900 x B 1.500 x H 2.900 [mm]  
17 [t]  
granite based, 6 / 7 axes,

## CERN 11T coil pictures at 6 MeV

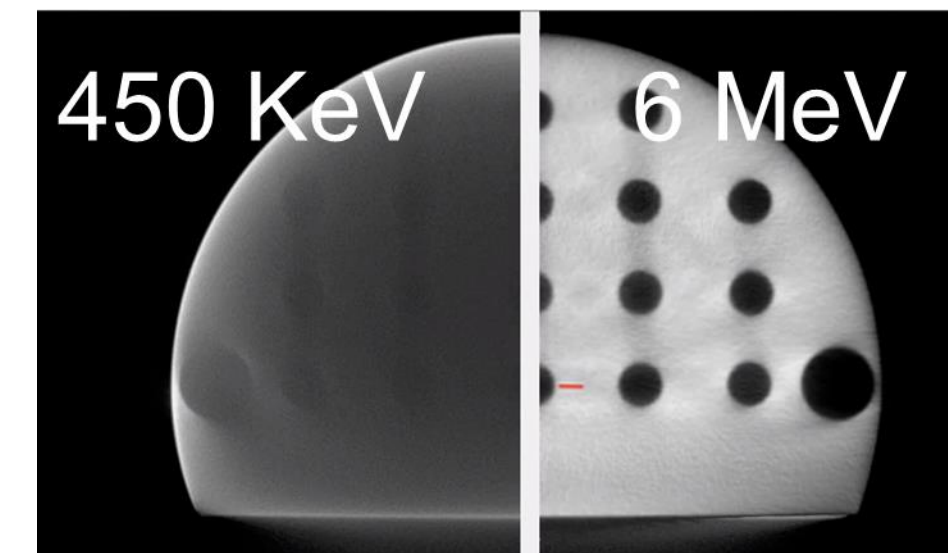


Nondestructive test  
Coil length – 1080 mm  
Coil width – 120 mm



300 KeV  
Alloyweld, Inc

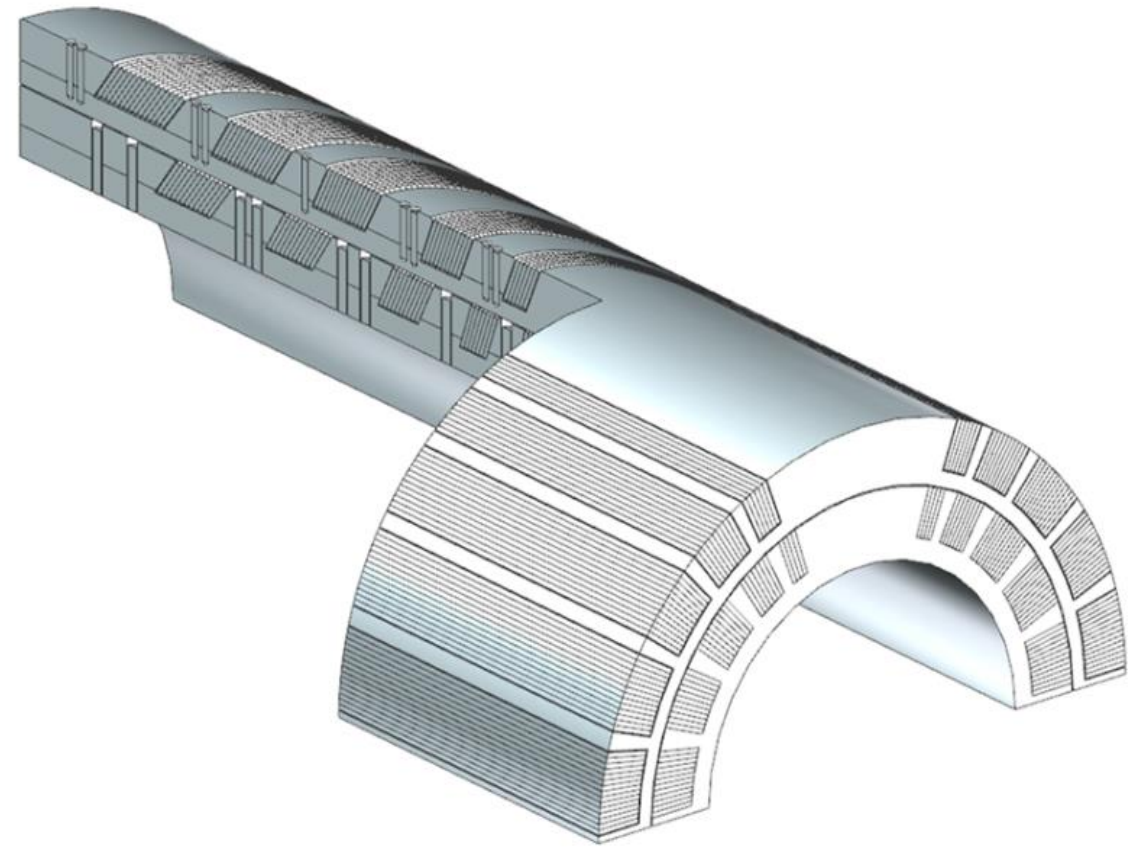
- The company headquarter in Hattingen (Germany) and office in Las Vegas (USA)
- Standard and customized industrial CT systems with a wide range of X-ray sources and digital imaging detectors
- Time ~ 2 weeks
- Extended scan cost 2.9k\$
- Transportation cost ~ 2.3k\$





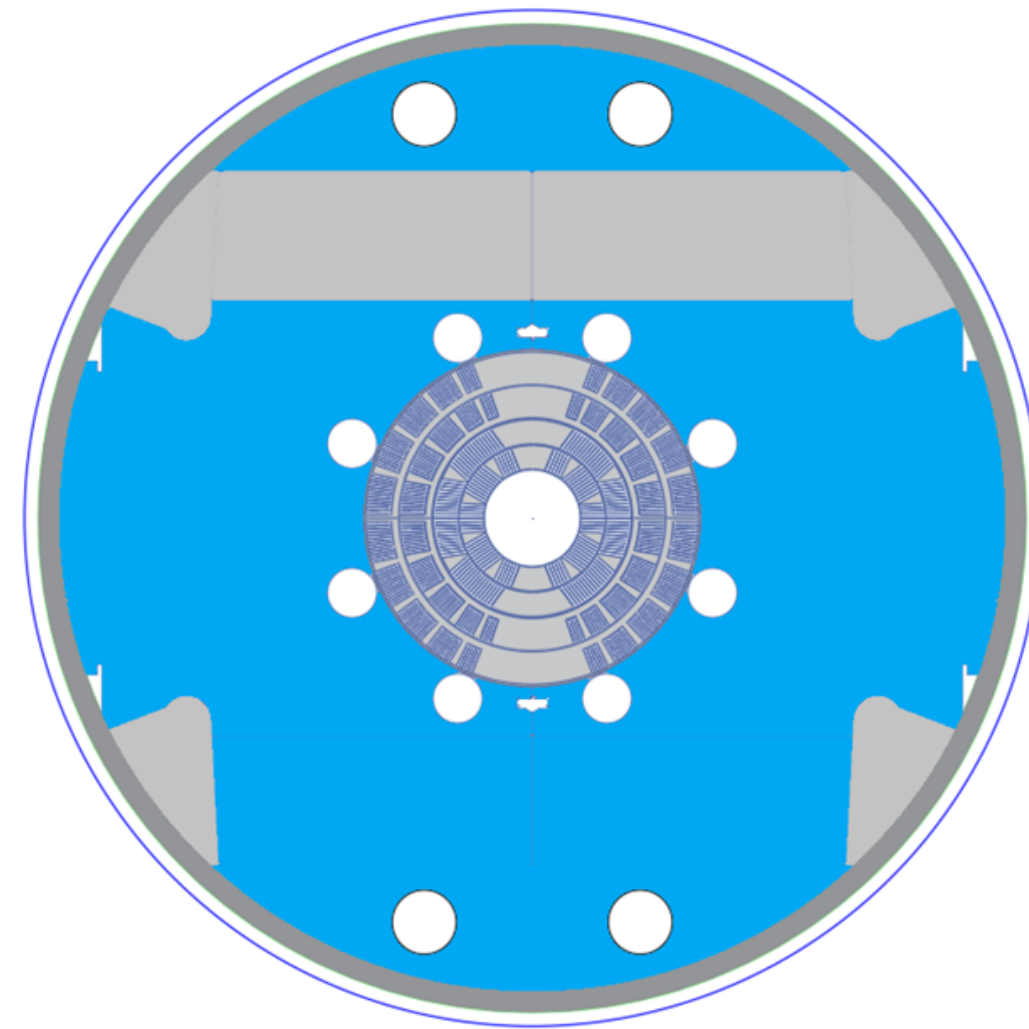


# End support in SMCT coil & MDPCT structure improvements

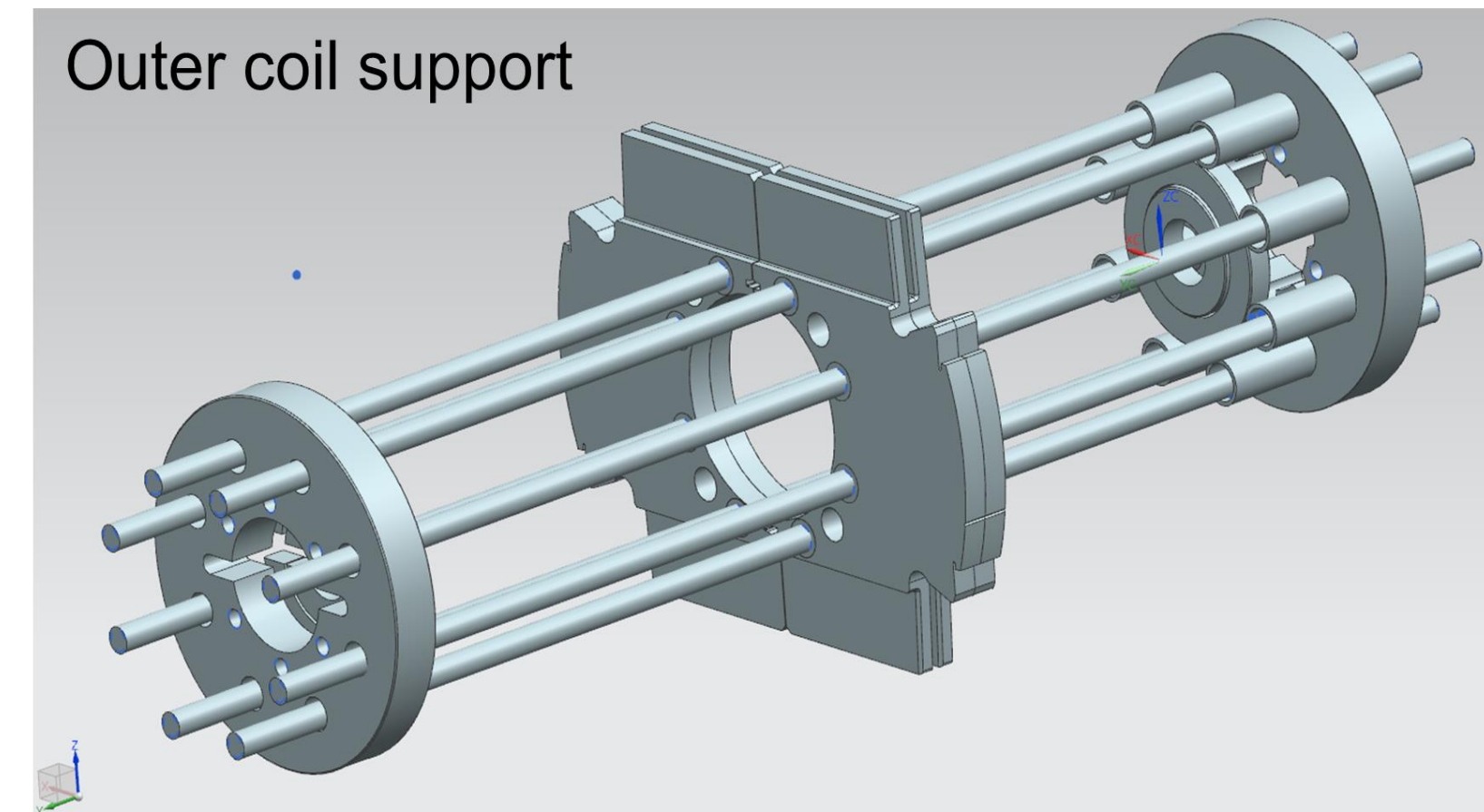
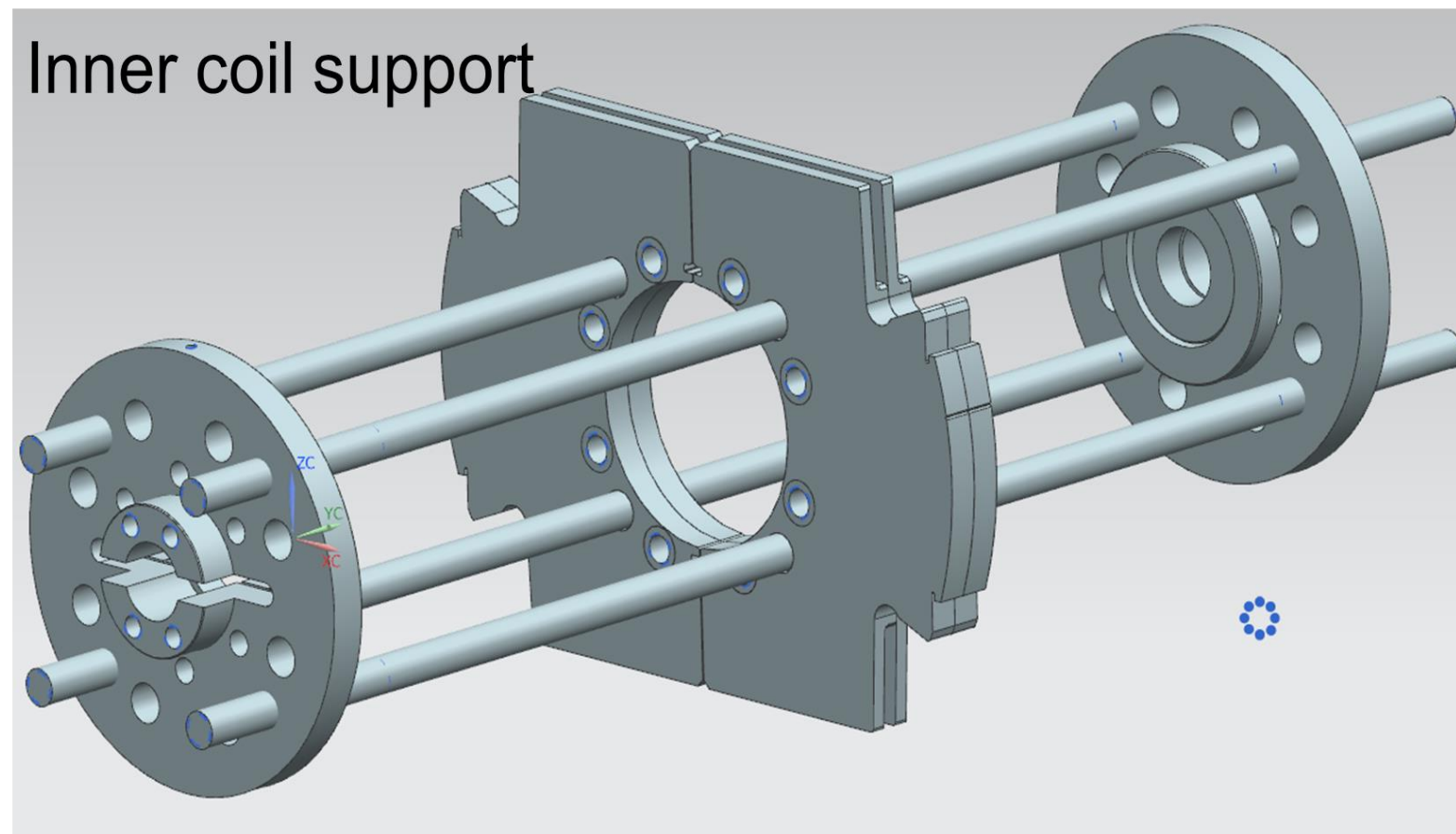


SM structure improves turn azimuthal and axial support

- 3D end analysis
- coil tests



- MDPCT structure will be used to test 4-layer magnets with SMCT and regular coils to achieve the fields up to 17 T
- Axial support system reinforcement
  - 4 new rods for inner coil
  - 6 rods old rods for outer SMCT coil
- SMCT coil rod anchoring
- End thermal contraction control for SMCT coil







- Disassembly and coil visual inspection is complete
- Next steps
  - end mechanical analysis of coil 5 and SMCT coil
  - CT test of coil 5 ends and later the first SMCT coil
- MDPCT structure will be used to test 4-layer high field magnets with SMCT coils
  - coil end support structure design has been improved based on the lessons learned from MDPCT1 tests and data analysis