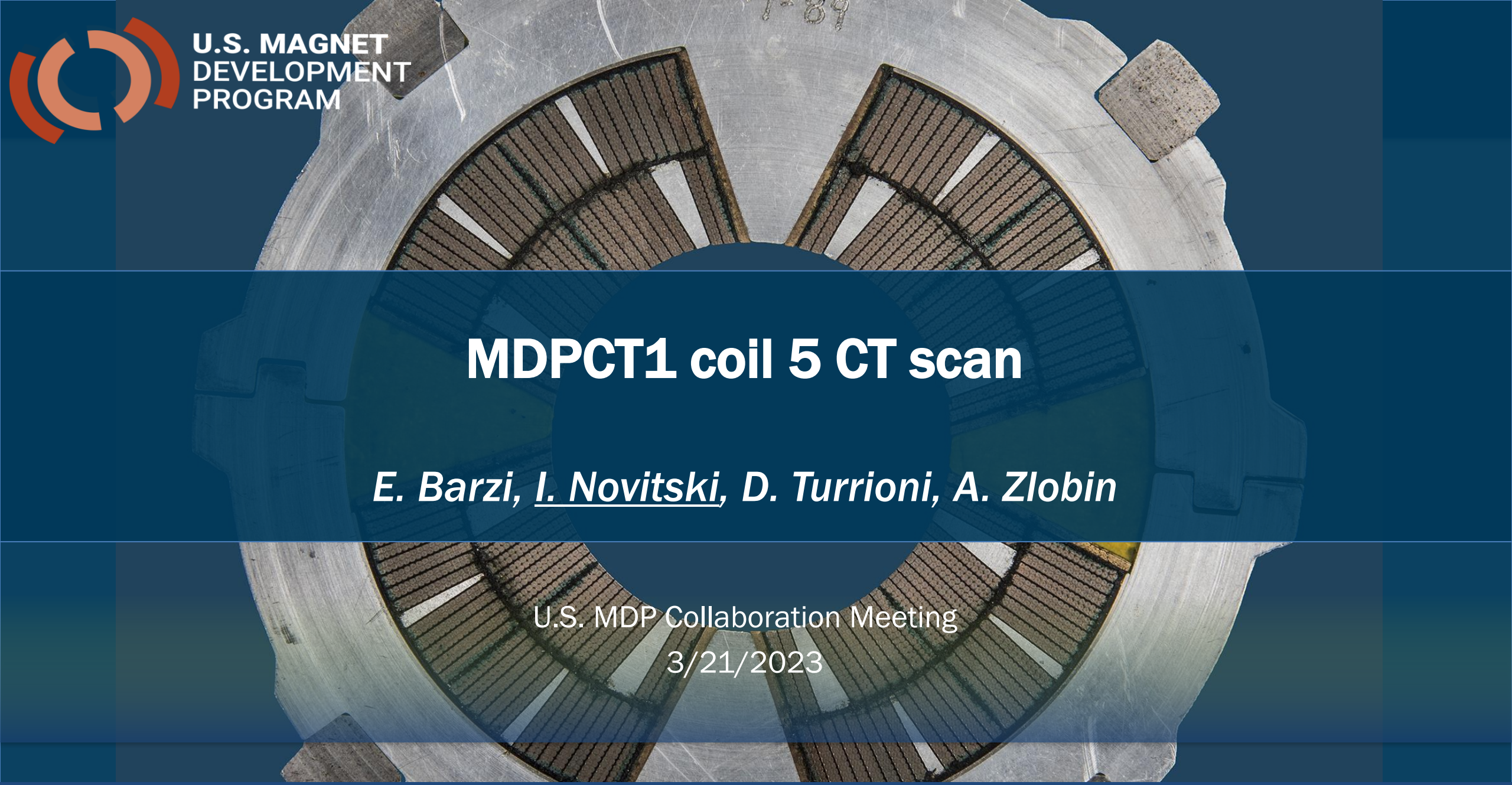


U.S. MAGNET DEVELOPMENT PROGRAM

MDPCT1 coil 5 CT scan

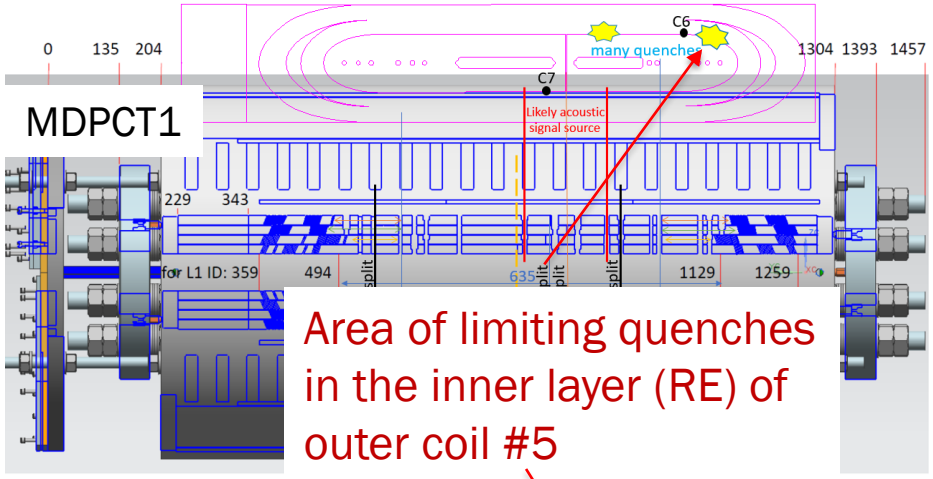
E. Barzi, I. Novitski, D. Turrioni, A. Zlobin

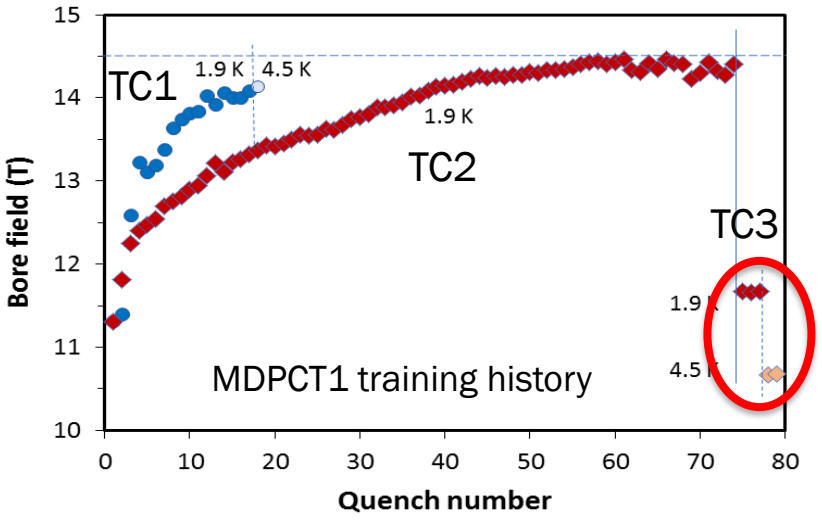
U.S. MDP Collaboration Meeting

3/21/2023

Introduction - Dipole magnet MDPCT1

- Magnet test data – location of the limiting quenches
- CT scan of 3 areas of interest by Diondo
- First observations
  - coil LE
  - coil straight section
  - coil RE
  - "low-density" area on RE pole turns
- Summary





Coil #5 Return End ID view

After curing | After reaction | Before impregnation | After impregnation | After cold test

CT scan by "Diondo" of 3 areas of interest motivated by CERN work with 11T coil

diondo
x-ray systems and services

CT System Specifications

X-Ray Source.....3 / 6 / 9 [MeV]

Detector:
Flat Panel Detector.....3.000 x 3.000 px, 140 [µm]
Line Detector.....px, 200 [µm]

Scan Volume, maximum
Ø 700 x 1000 H [mm] with Flat Panel Detector
Ø 1000 x 1000 H [mm] with LDA

Focus-Detector-Distance..... Variable to 4000 [mm]

Sample Weight.....200 [kg]

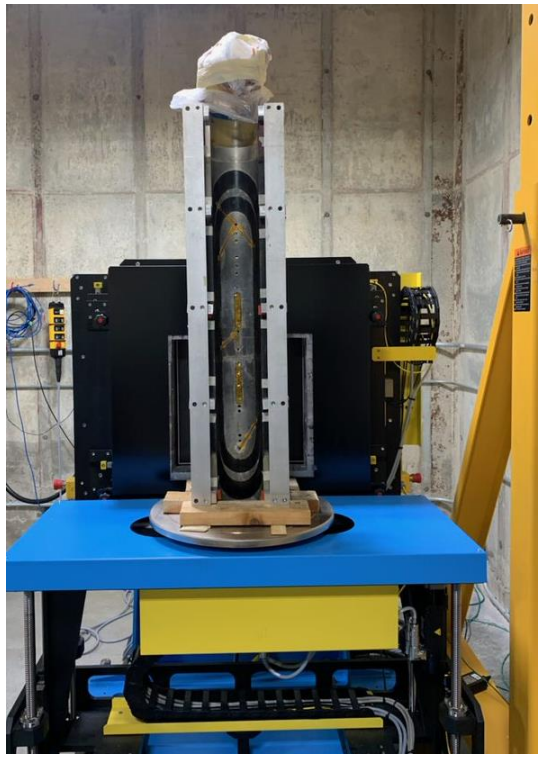
System Dimensions.....L 5.900 x B 1.500 x H 2.900 [mm]

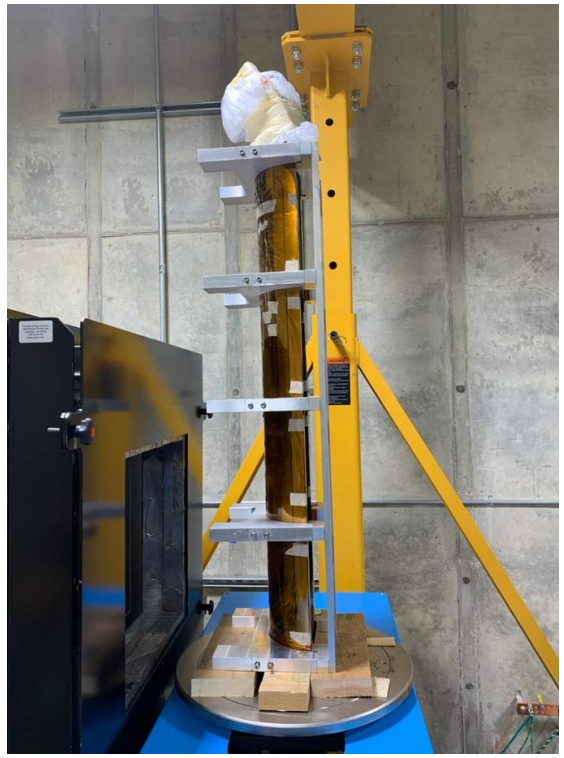
System Weight .....17 [t]

diControl Features
DR-Function, di Scatter, Scan Enhancement, Multiline CT, Daily Check, Health Monitor, Helix CT, Batch Mode, Offset CT, Limited Angle CT

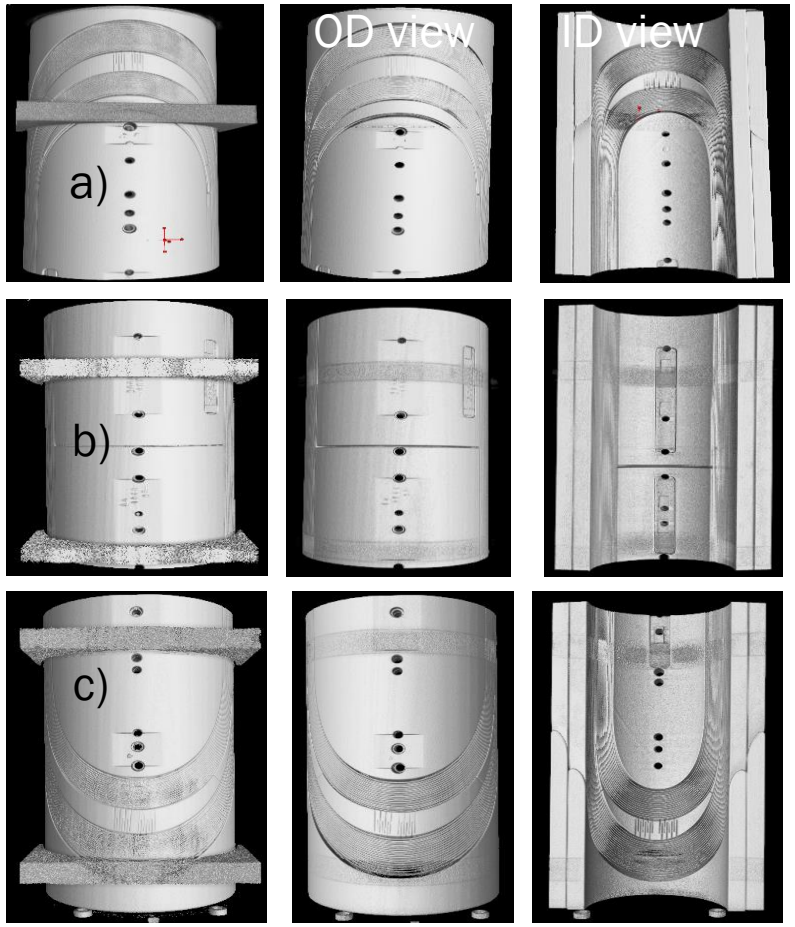
Manipulation..... granite based, 6 / 7 axes

Optional customized features are available upon request.





Coil set up on the scanned platform, two side views

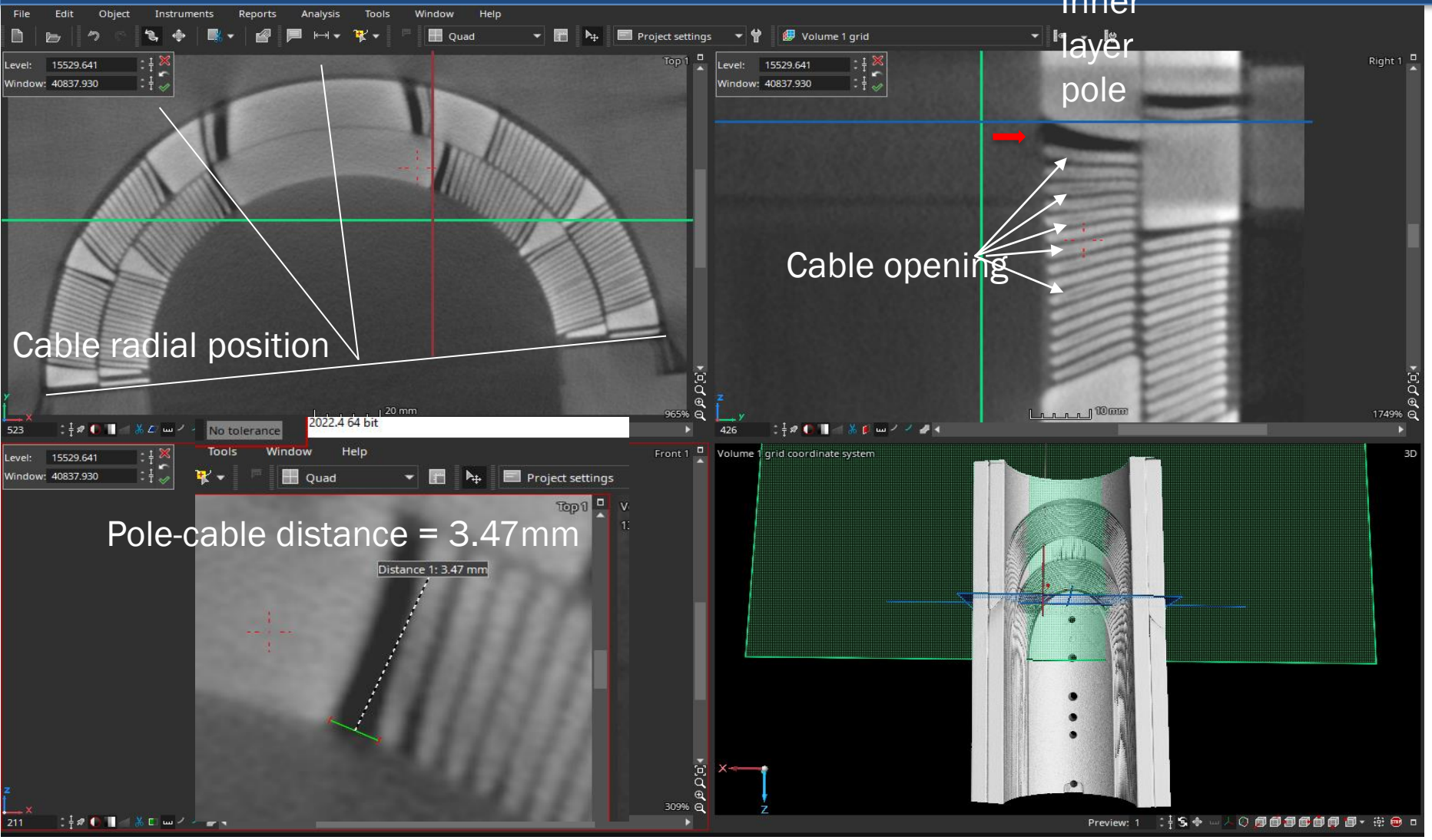


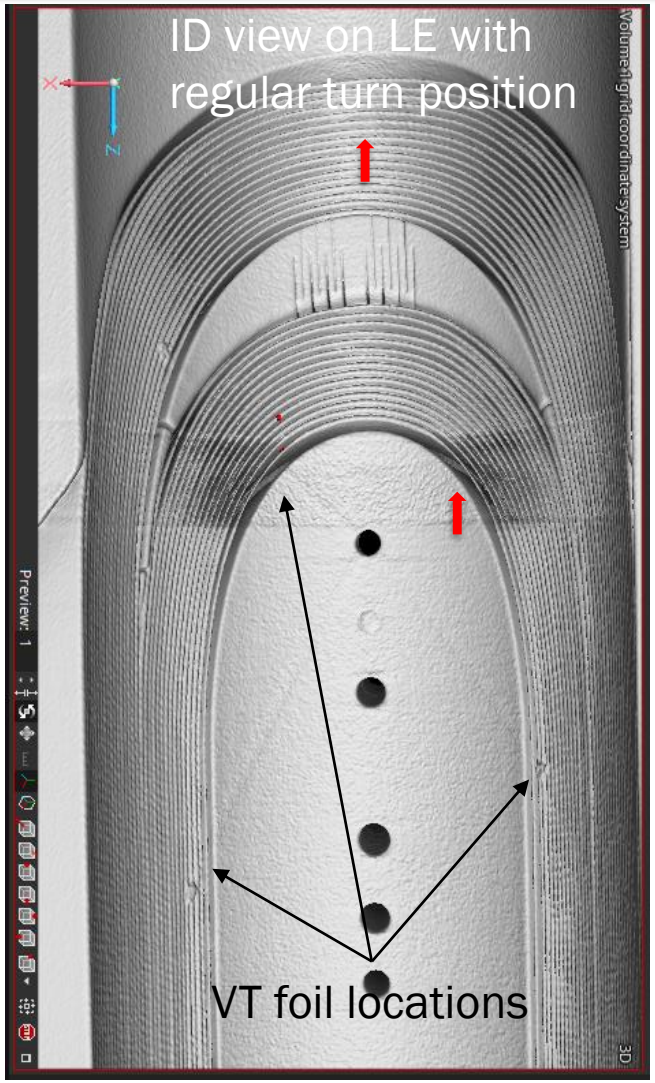
3 areas of interest:
a) LE, b) Straight Section and c) RE.

- 6 or 9 MeV High-power Linear Accelerator/ Flat Panel CT-system to view 0.4 - 0.5 mm porosity and cracks.
- The material, thickness, shape of the crack and geometry of the coil contribute to the resolution.

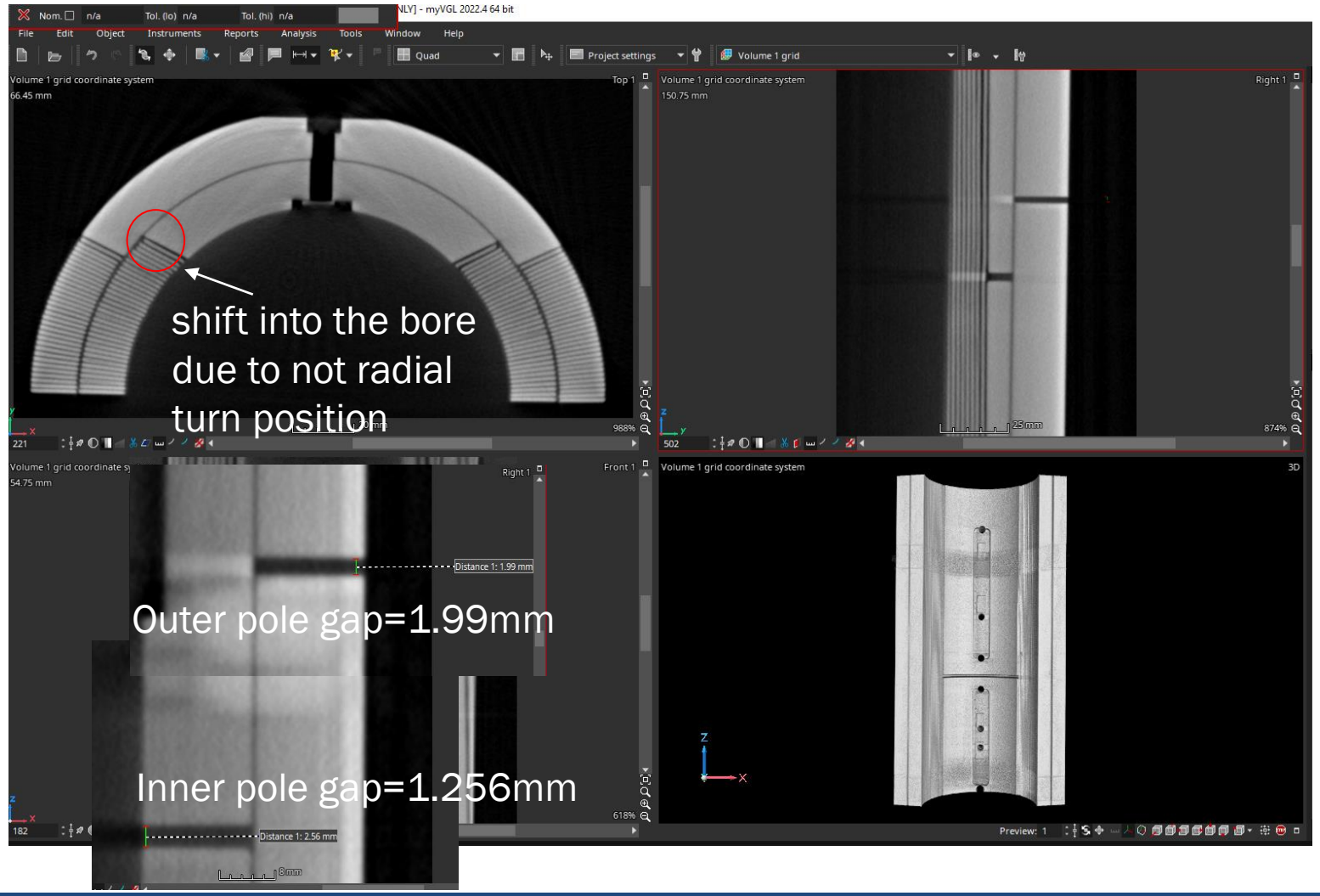
U.S. MAGNET DEVELOPMENT PROGRAM

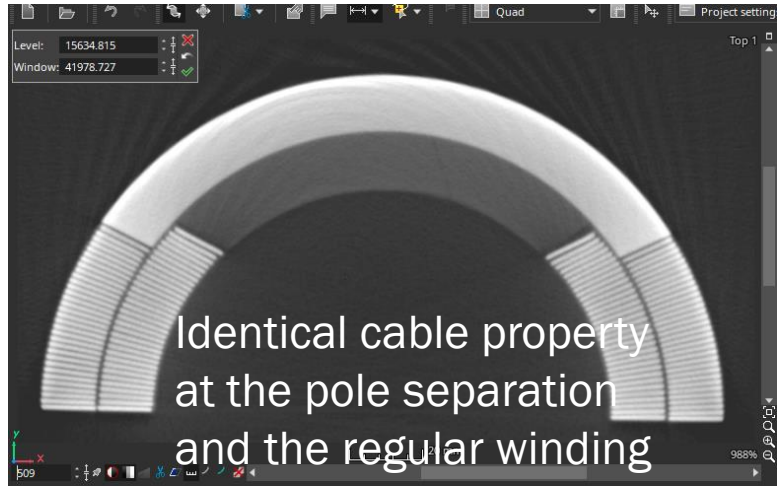
Coil LE winding quality



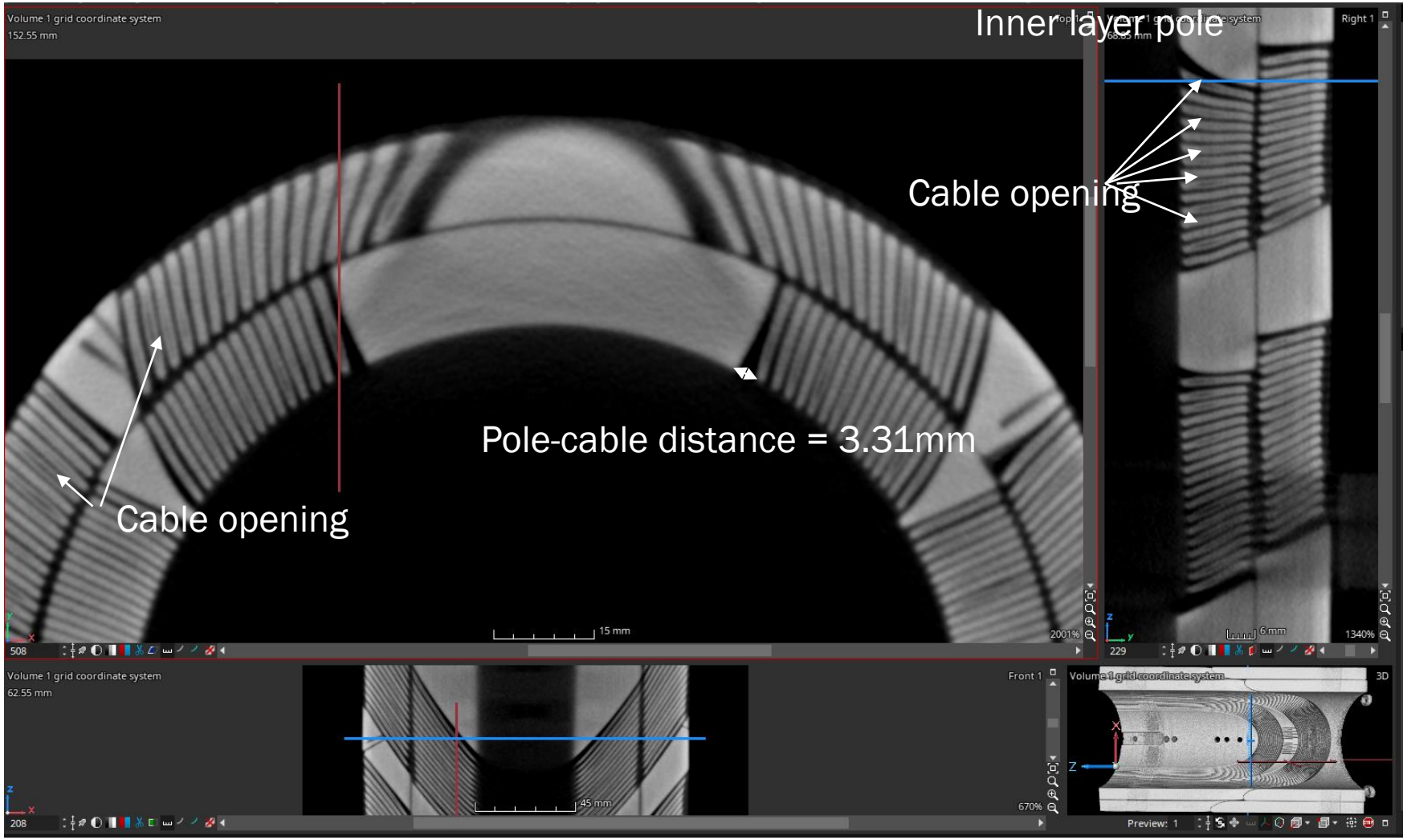


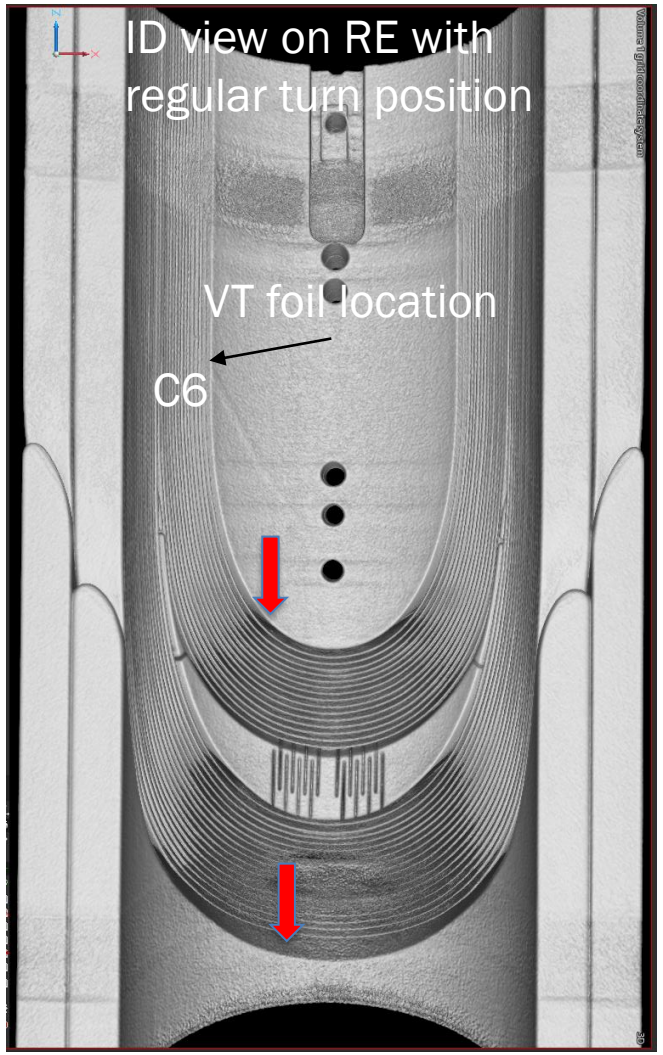
Straight section winding quality



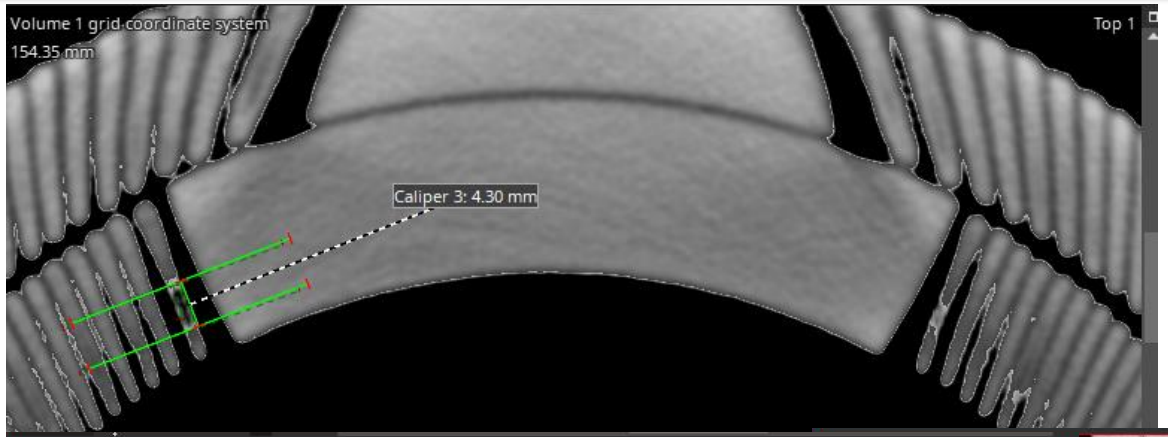


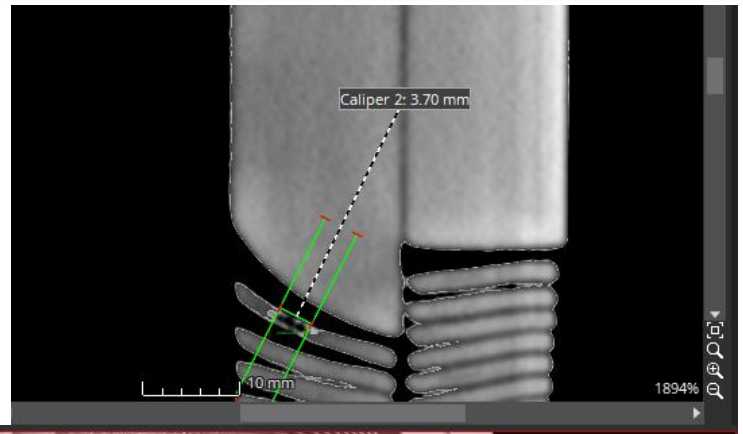
Coil RE winding quality

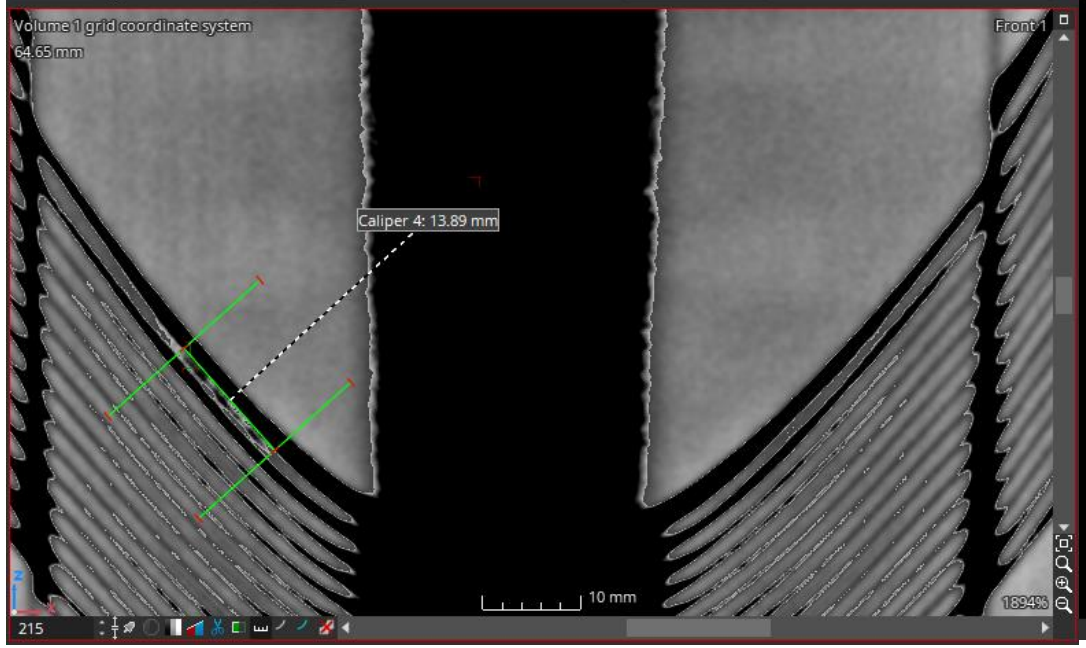


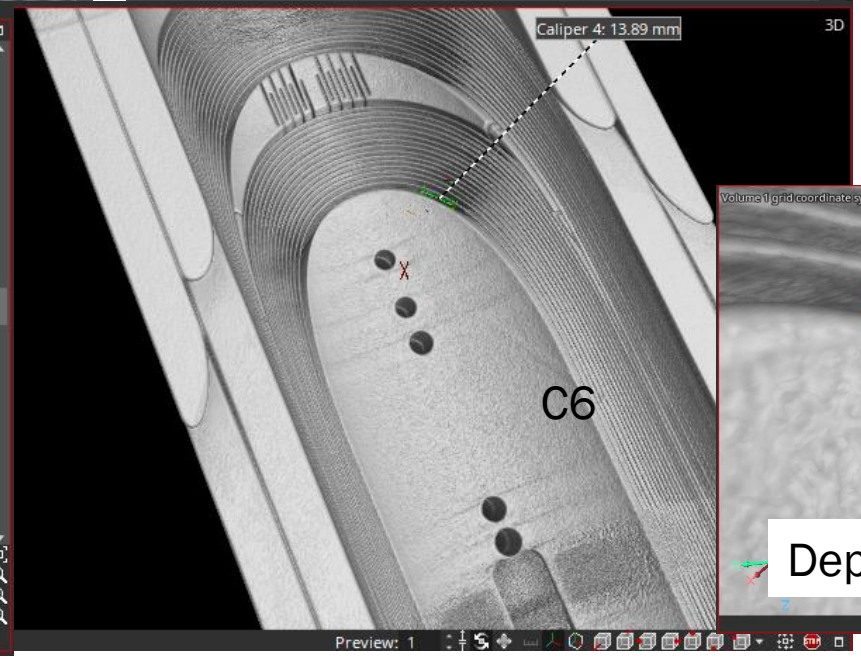


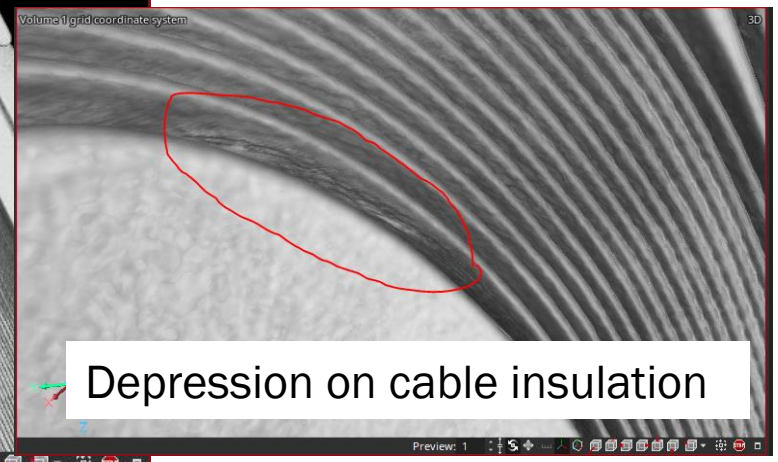
"Low-density area" on RE pole turn









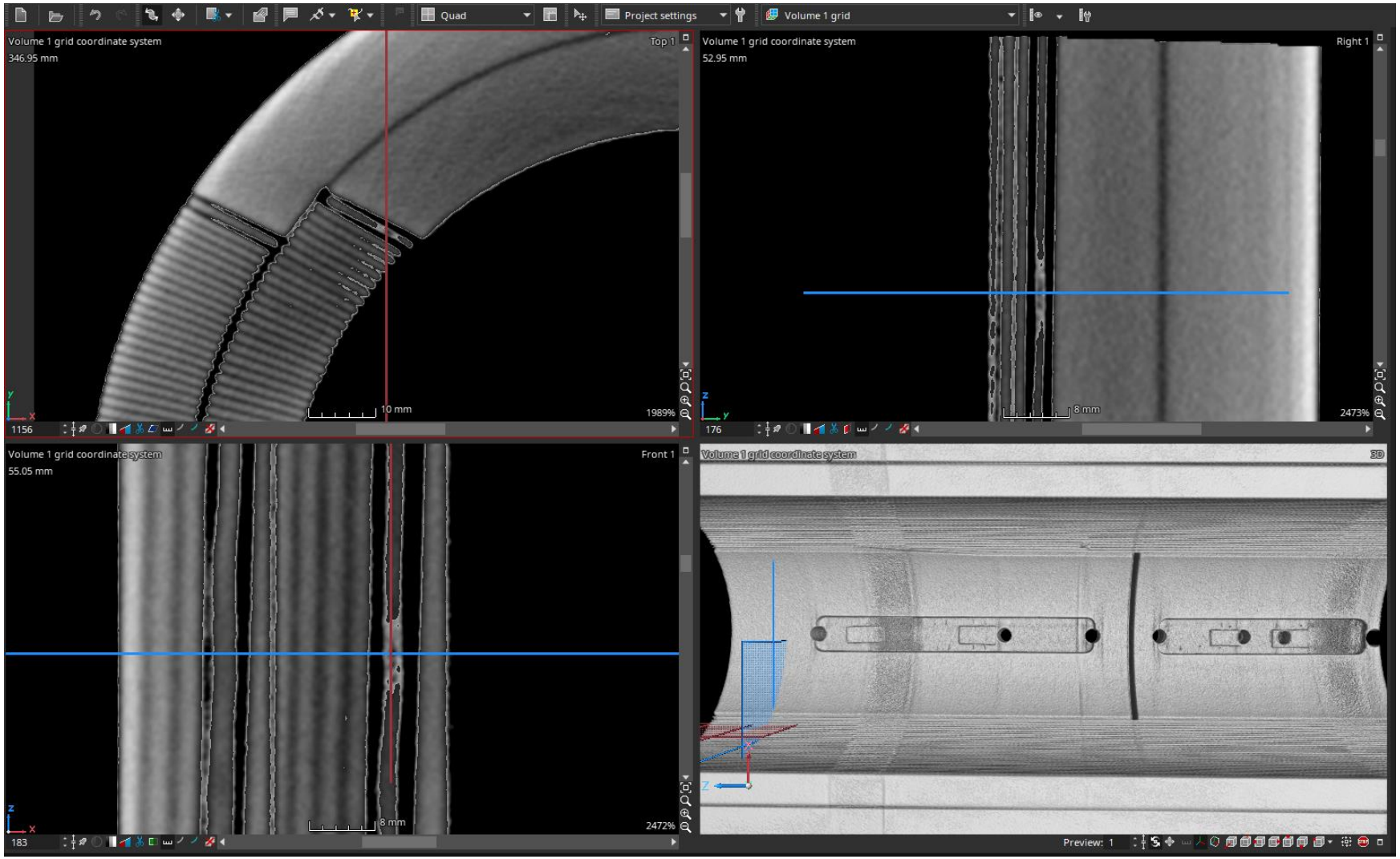


Depression on cable insulation

Observations:

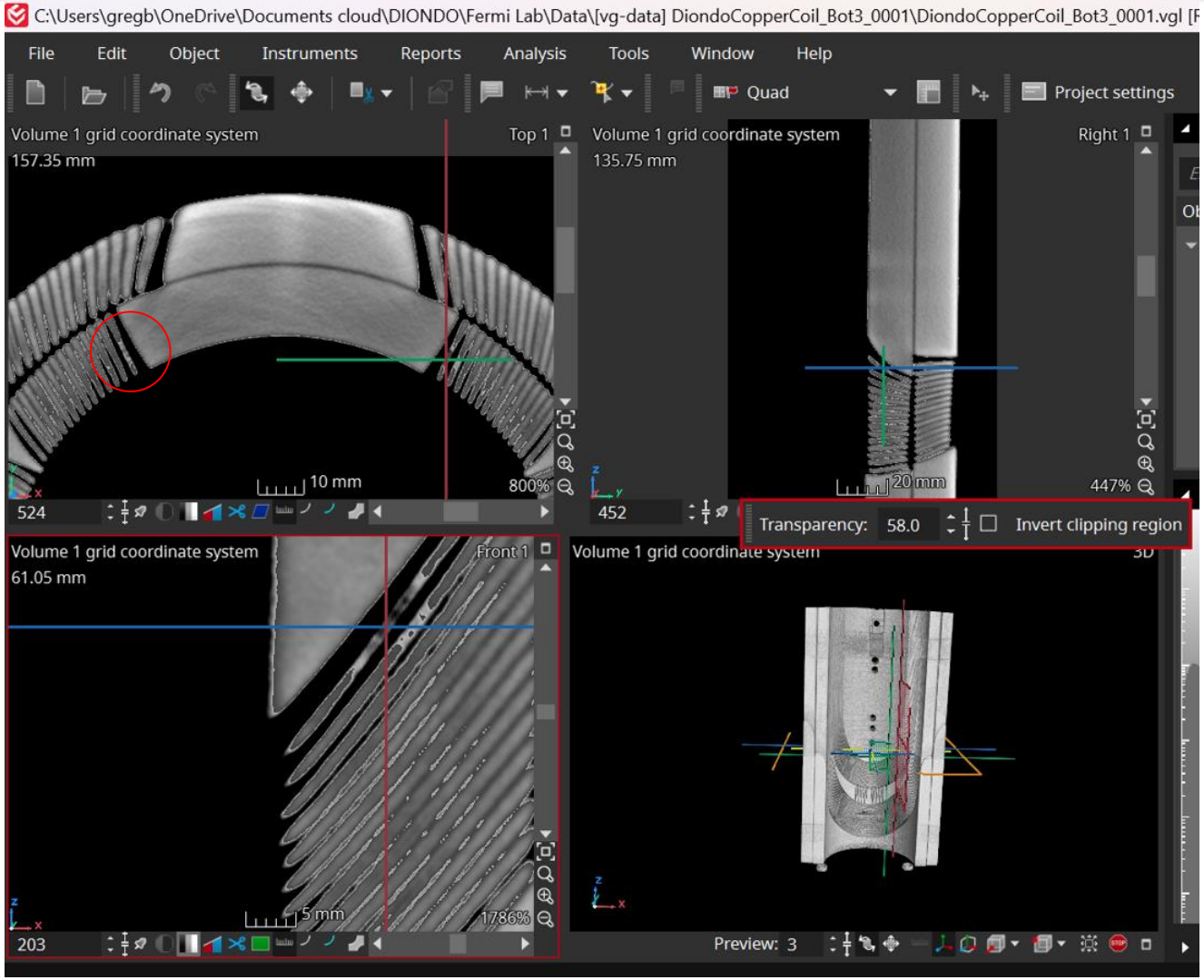
- "low-density area" size ~4.3mm x 3.7mm x 14mm
- Two symmetrical spots
- Not on the cable edge
- Depression of cable insulation on one side
- Correlates with the limited quench location

“Gray area” in the straight section pole turn



- Similar, smaller spot can be seen on the pole turn in the coil straight section near the LE
- Not on the cable edge

Comments from Diondo experts



FNAL question:

In some areas along the coil ends, we see spots in pole cable cross-section on both sides (marked in the pictures). Could be interpreted as a cable properties change or it's just a software problem?

Diondo comments:

- In our opinion, it appears that the wire is stretched or smashed so the density is less. In the color and opacity mode the window and level is changed so that the contrast is much higher and it shows the surface changes.
- Also, if we manually change the window and level of the exploded area we can see changes in density. The copper strand resistance may increase with a stretching fatigue and will turn into a crack over time with heat and flexing.
- To characterize this image as a failure the part would usually be dissected which has many difficulties because the surfaces are disturbed. I included a microscopic cross section of a copper wire from a capacitor that was vibrating slightly on a PCB just to show how the wire can split and begin to overheat and eventually break.
- I don't know if this helps but it is a good bet that the strands in question may be damaged.

We plan to use this coil

Summary

- MDPCT1b coil #5 was scanned by Diondo using High-power Linear Accelerator/ Flat Panel CT-system
- CT scan allows continuous analysis of the coil structure, including internal inaccessible areas
- First result of the coil 5 analysis shows a regular coil winding w/o visible parts defects
- Cable strand separations at the ends pointed to a soft coil structure for axial loading
  - need better and more rigid end design
- Cable pole turn position is not optimal in the straight section and in both ends
  - require coil design optimization: to provide radial pole turn position in the outer coils by introducing wedges in the coil straight section and improvements of coil-end parts interface
- Cable property change, “low-density area”, observed in the RE, correlates with the limited quench location at TC3
- A similar but less noticeable defect is also observed in the straight section
- The new SMCT coil structure addresses all the mentioned coil design changes