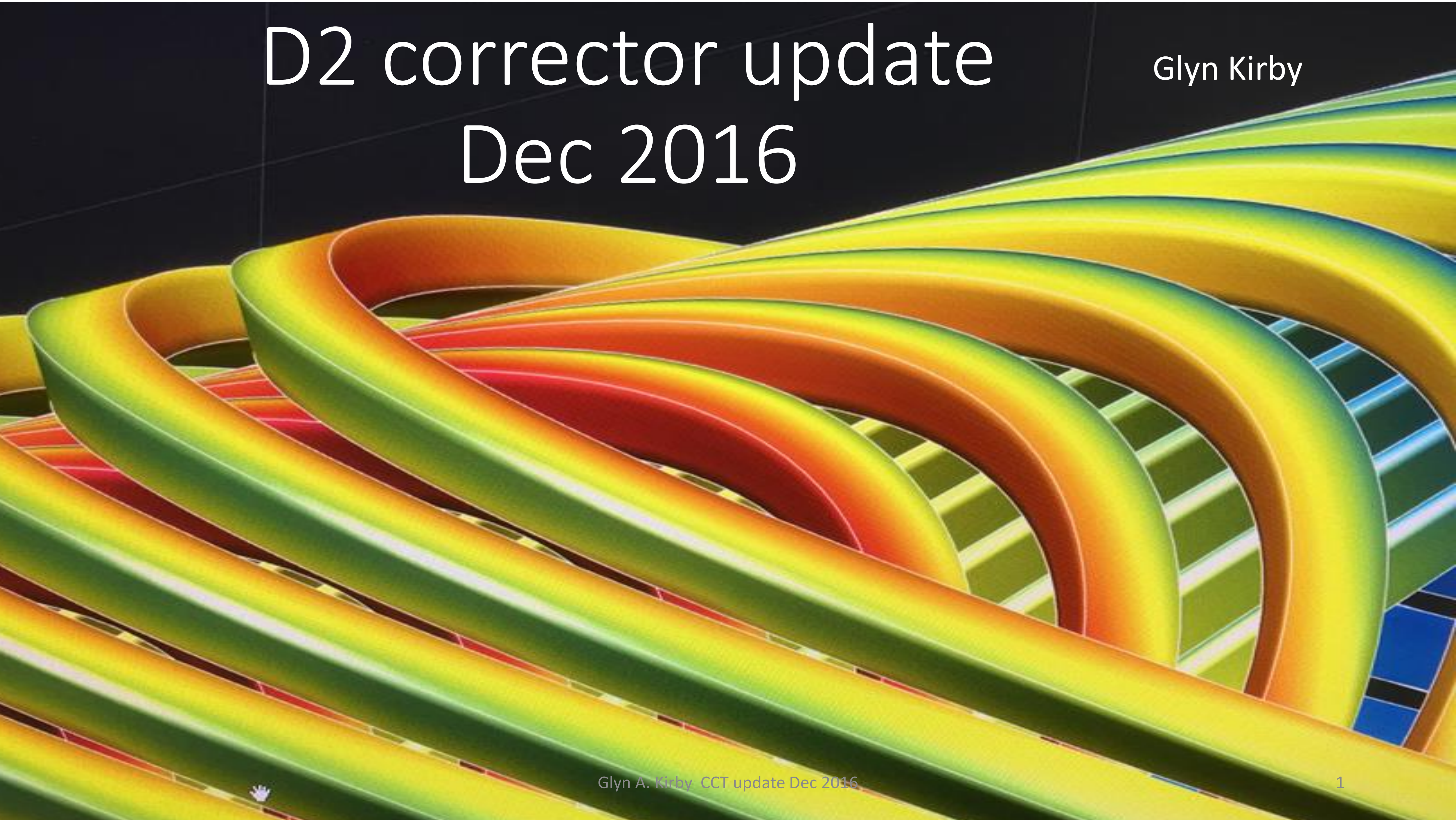
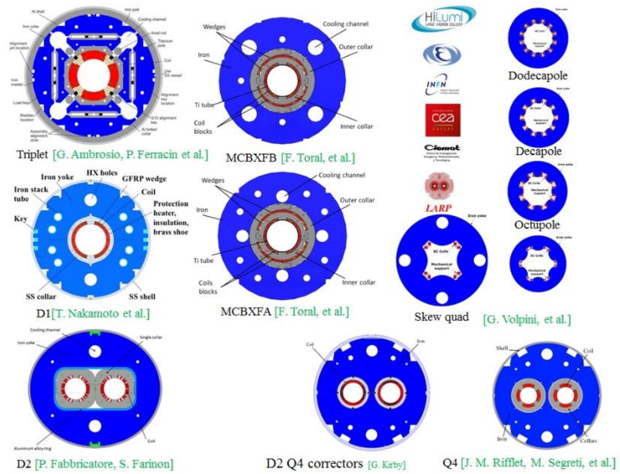


D2 corrector update Dec 2016

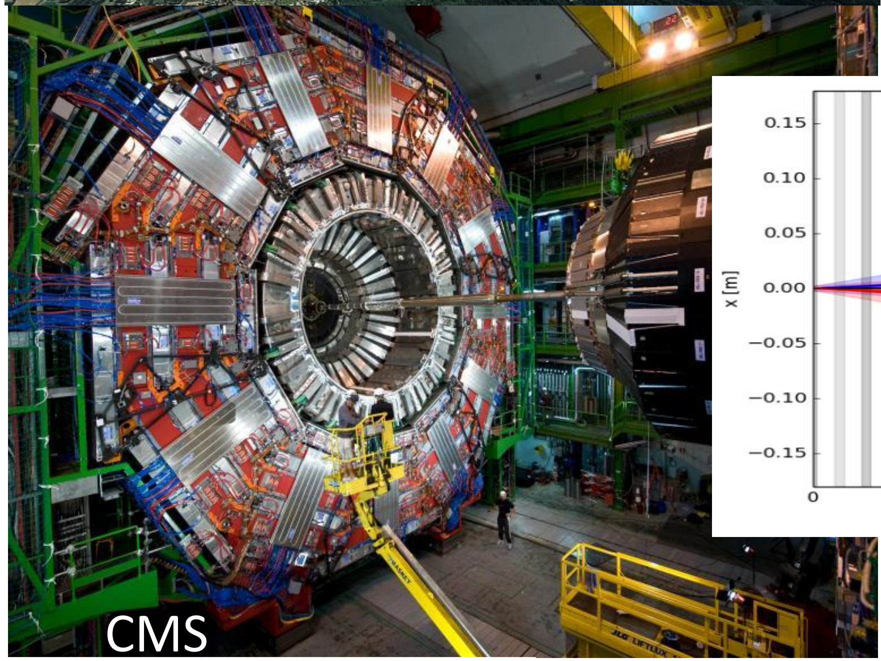
Glyn Kirby

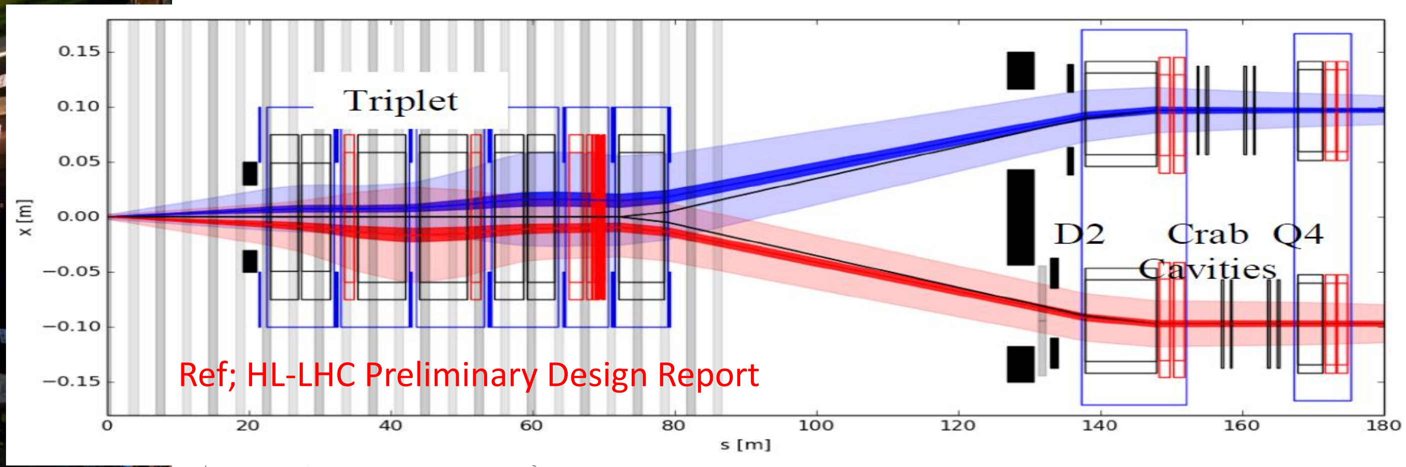
What is “High Luminosity LHC”

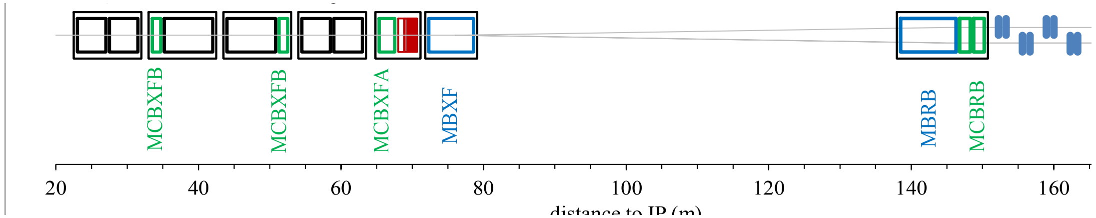
Goal of Hi-Lumi LHC increase Luminosity by factor ~10
In CMS and ALTAS
Installation Due 2024 - 2026



Upgrade Magnet Set







Short model 0.5 meter design reminder

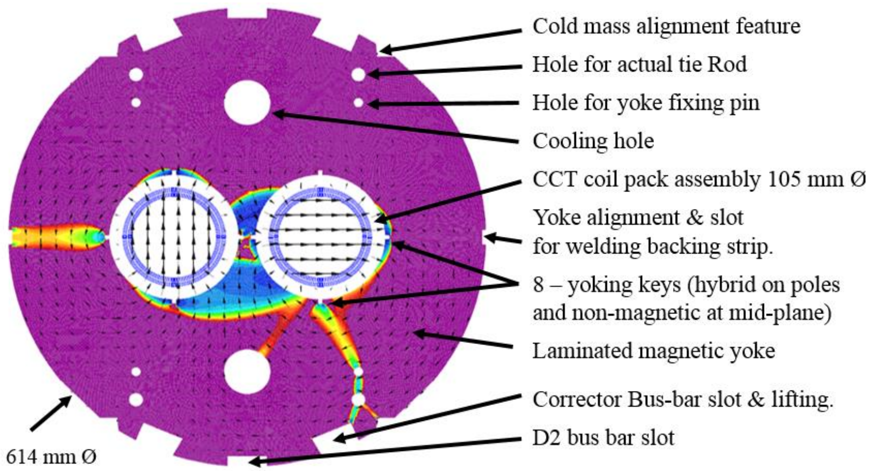
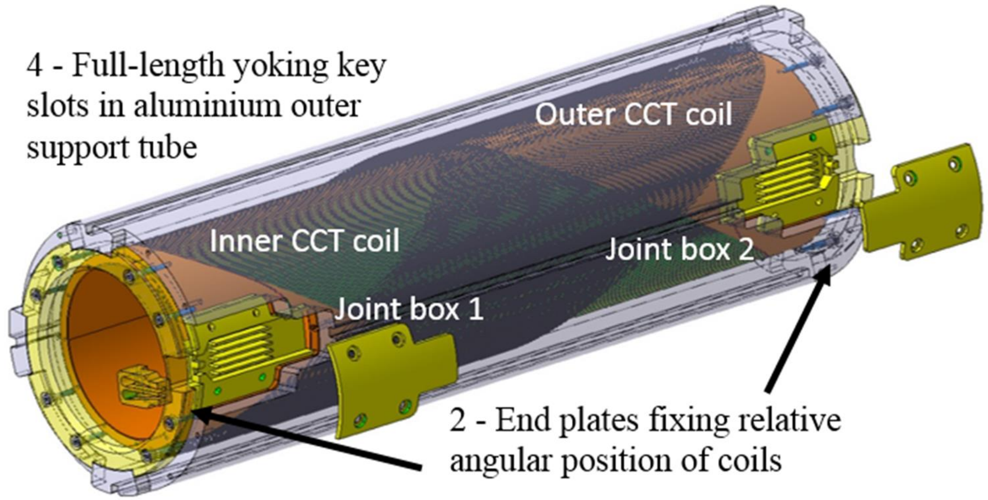
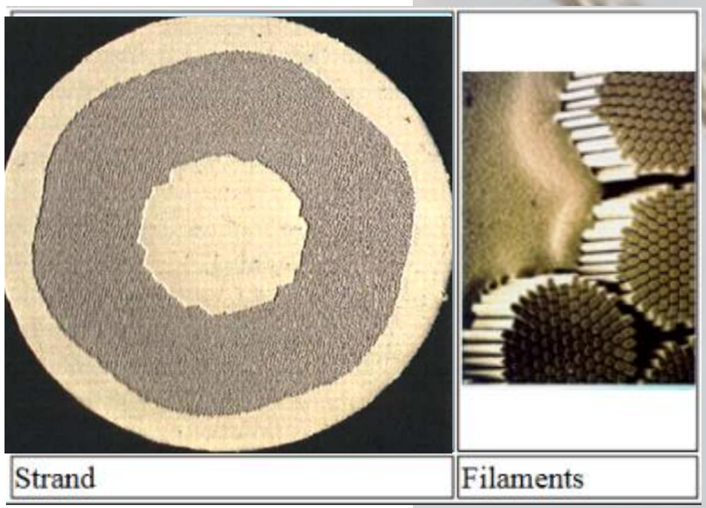


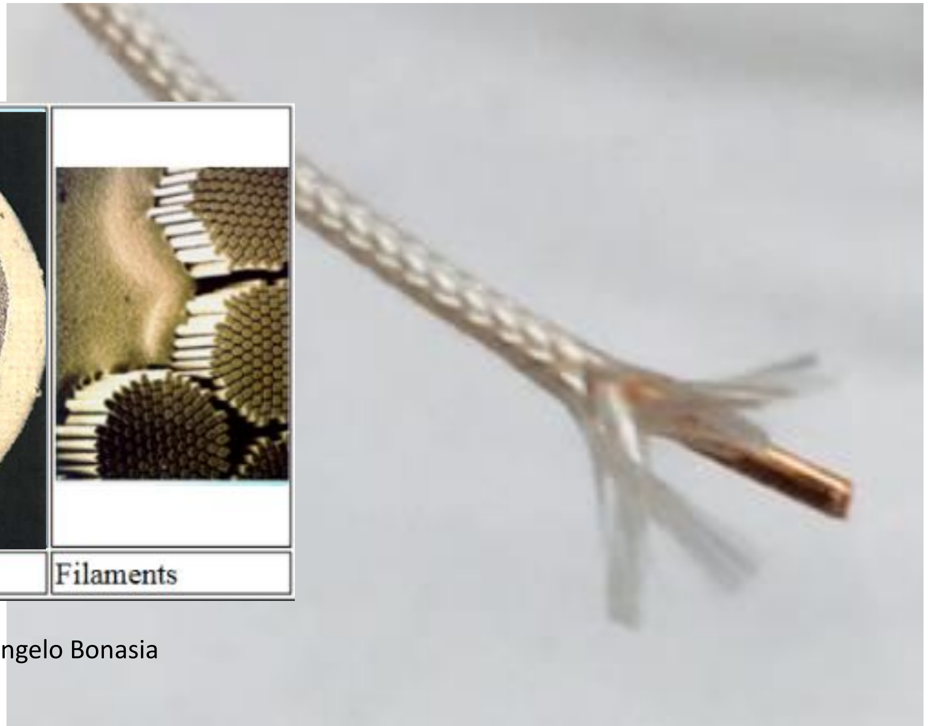
Image of Cross section is as full length magnet

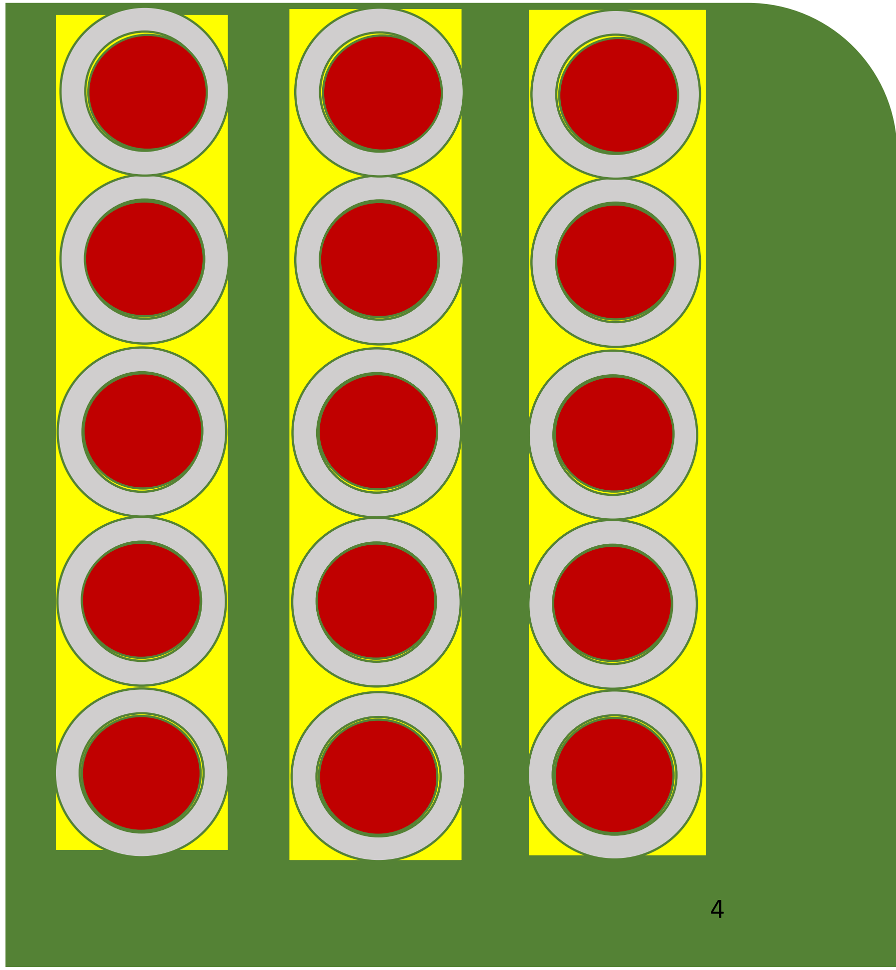


Short model 0.5m

LHC dipole Nb-Ti wire 0.825 dia   1.9:1 Cu:Sc with PVA or PEI enamel coating, then S2 Class 0.05mm thick sleeve, Resin Impregnated

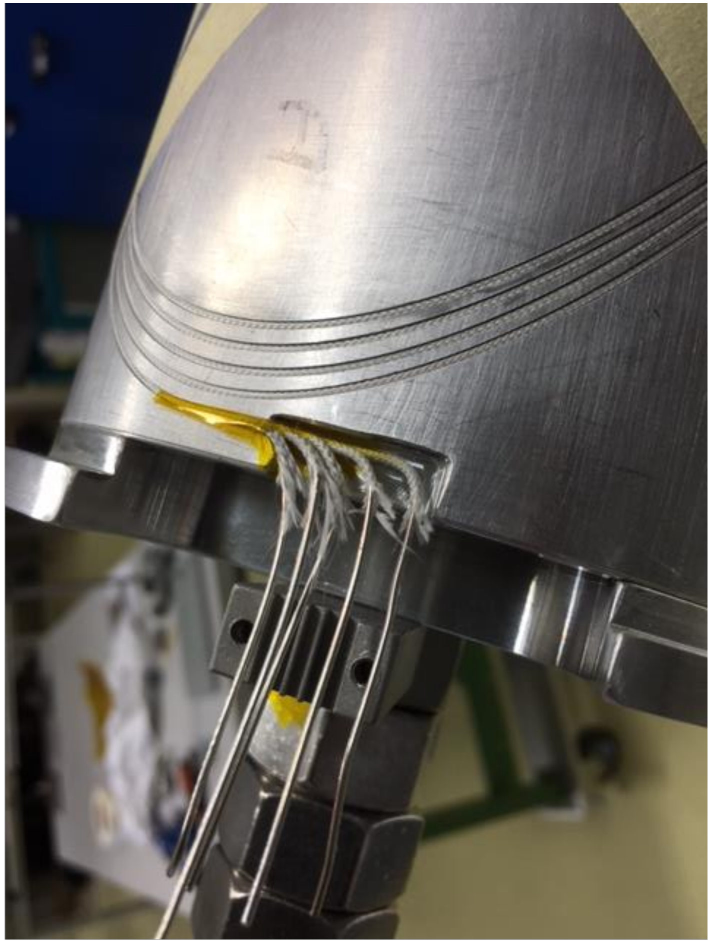


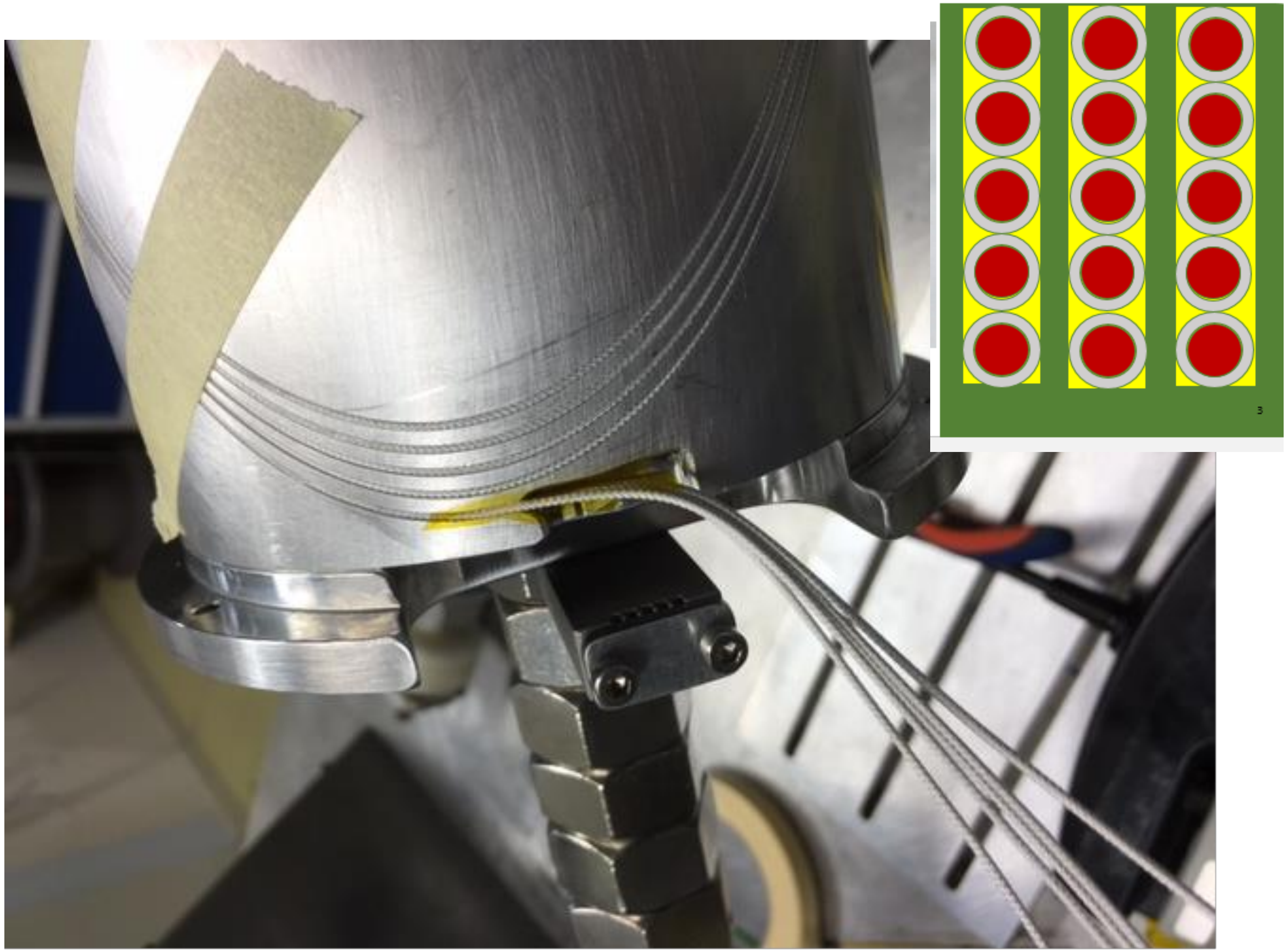




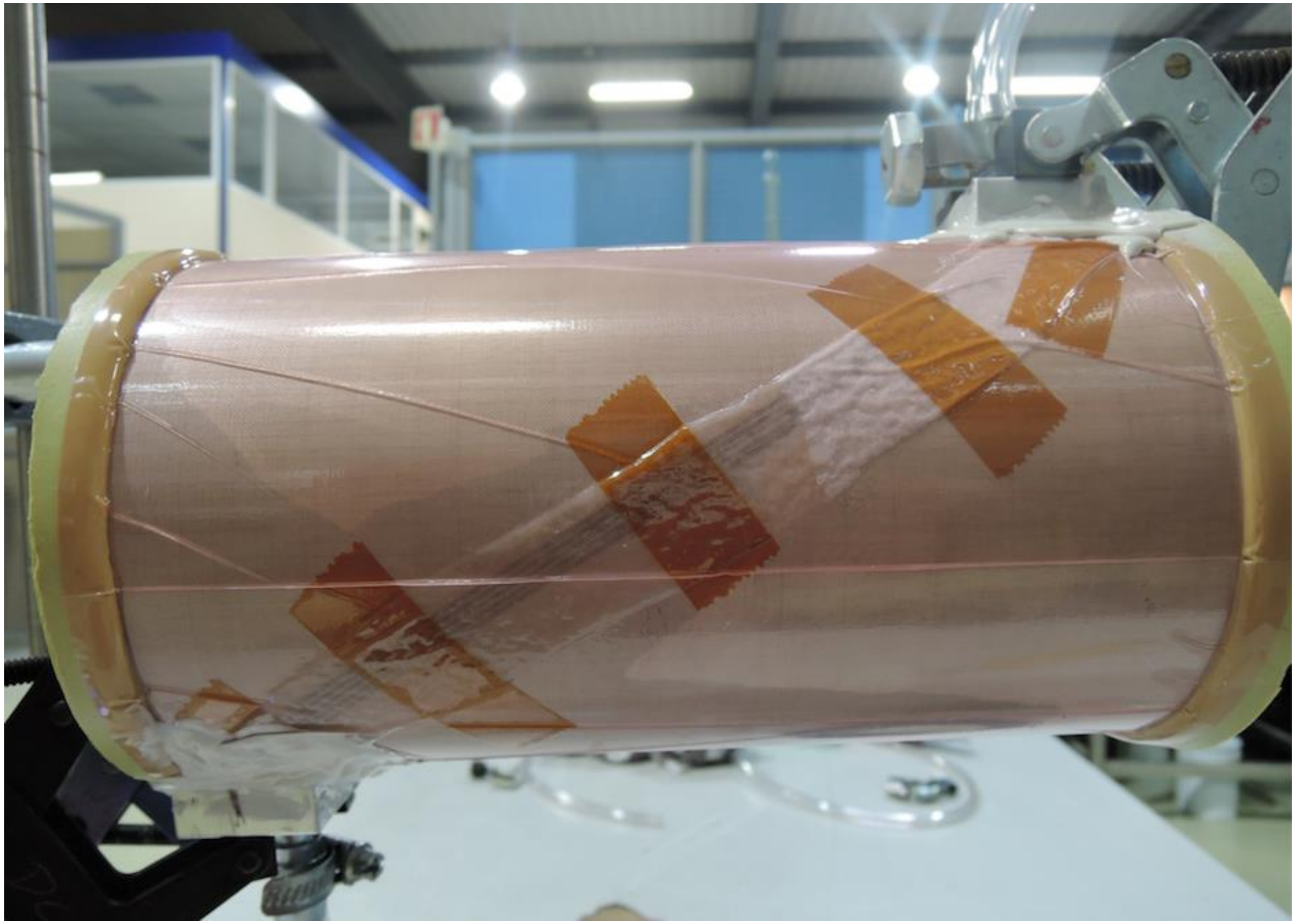
Courtesy of : Amalia Ballarino & Angelo Bonasia
Conductor section & CERN

Winding in 927 of 1mm x 5mm deep test

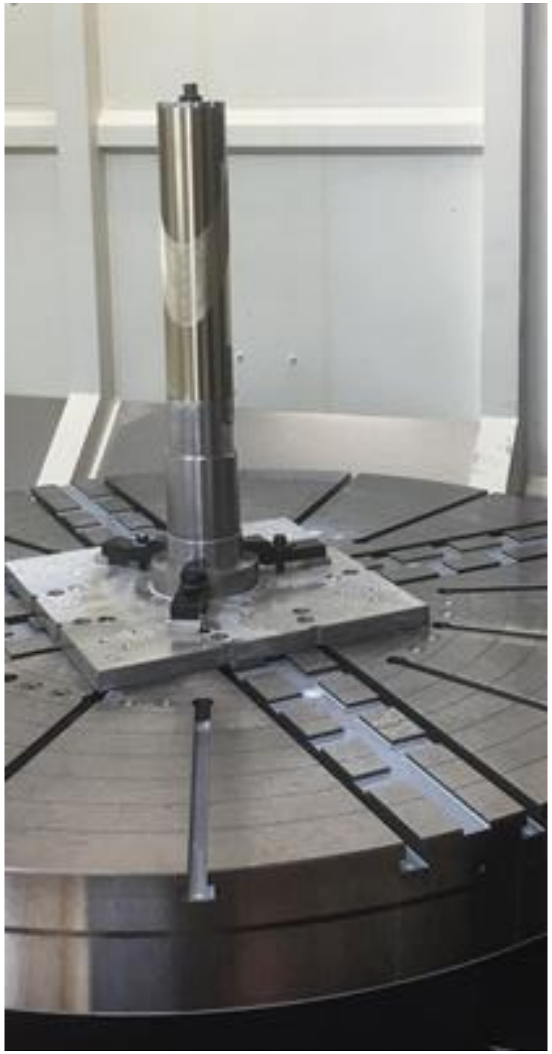




1mm x 5 mm deep winding test.
Tight to get glass insulated wire into slot without damaging the insulation but was achieved!
Former has some sharp edges. That will need removing on next models.



0.5m model m/c

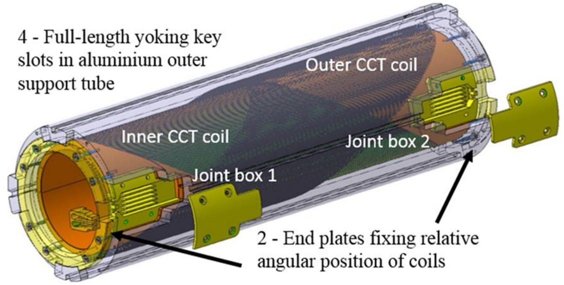


Problem tool damaged

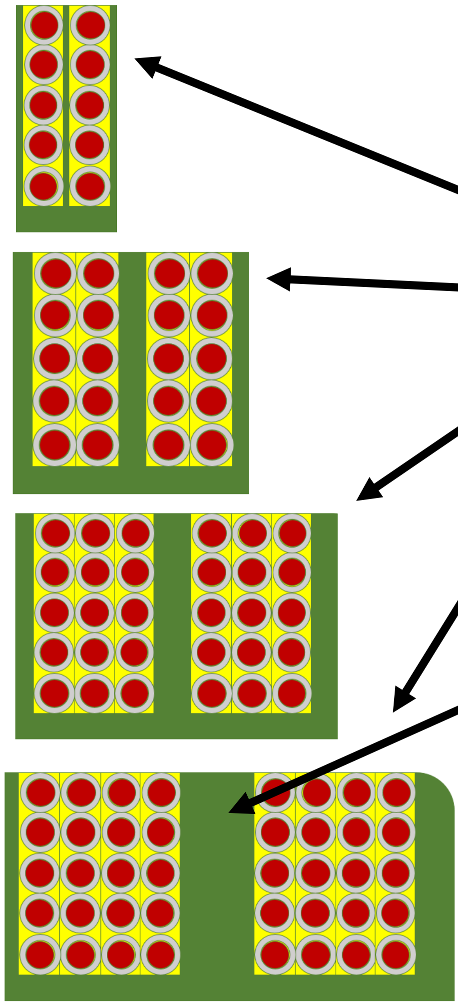
1mm dia cutting tool
35000 rpm

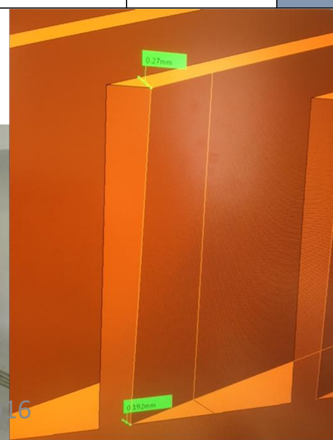
When we moved to the full 0.5m long short model the tool broke! Long story.

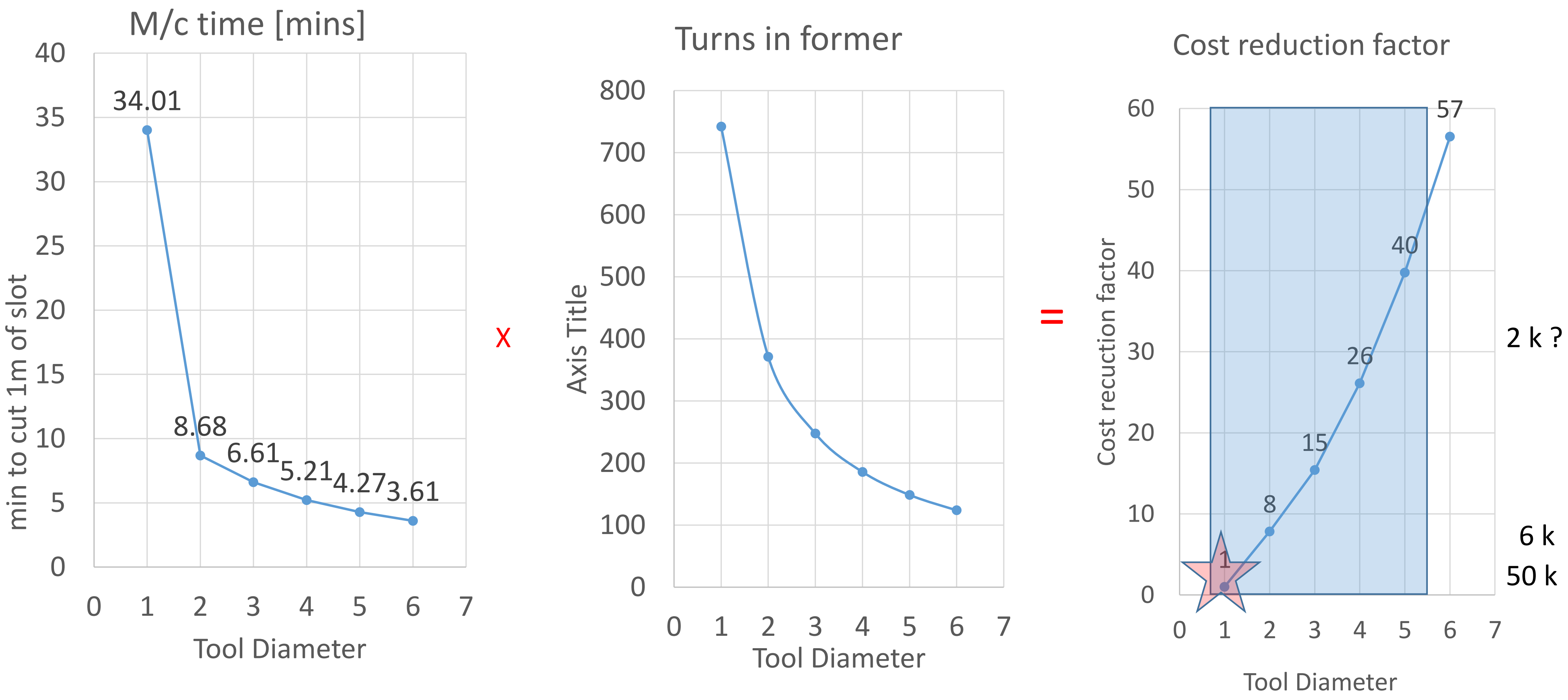
Cost Reduction Improvement Idea's



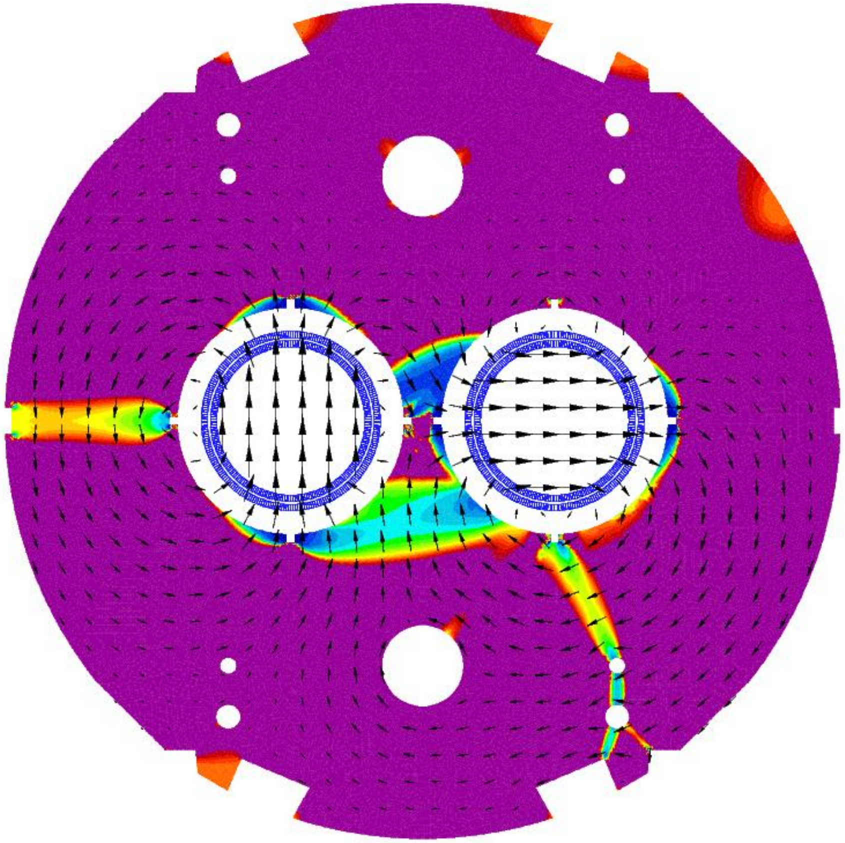
Slot and tool Ø	turns in former	Wires in each slot	Former min wall thickness [mm]	Former wall thickness at poles [mm]	Joints total	lead end # joints	retrun end # joints
1	742	5	0.3	1.6	8	3	5
2	371	10	0.6	3.2	18	8	10
3	248	15	0.9	4.8	28	13	15
4	186	20	1.2	6.4	38	18	20
5	149	25	1.5	8	48	23	25
6	124	30	1.8	9.6	58	28	30

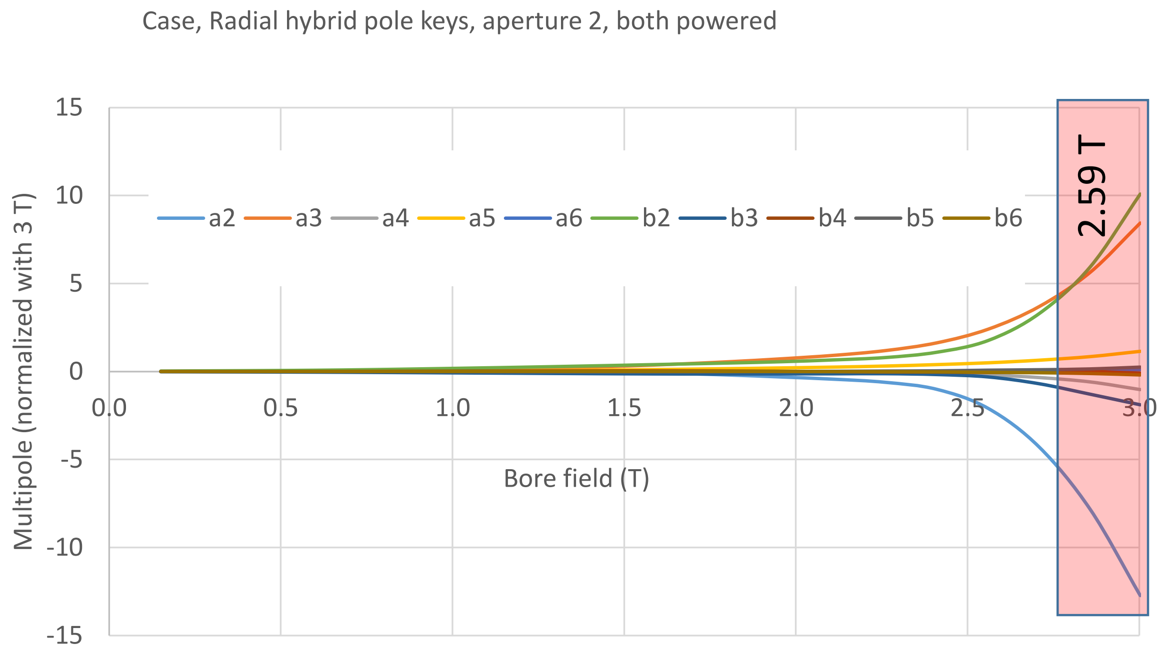





M/c time [mins]
min to cut 1m of slot
0
5
10
15
20
25
30
35
40
34.01
8.68
6.61
5.21
4.27
3.61
0 1 2 3 4 5 6 7
Tool Diameter
x
Turns in former
Axis Title
0
100
200
300
400
500
600
700
800
0 1 2 3 4 5 6 7
Tool Diameter
=
Cost reduction factor
Cost recuction factor
0
10
20
30
40
50
60
1
8
15
26
40
57
0 1 2 3 4 5 6 7
Tool Diameter
2 k ?
6 k
50 k

Magnetic Field Optimization

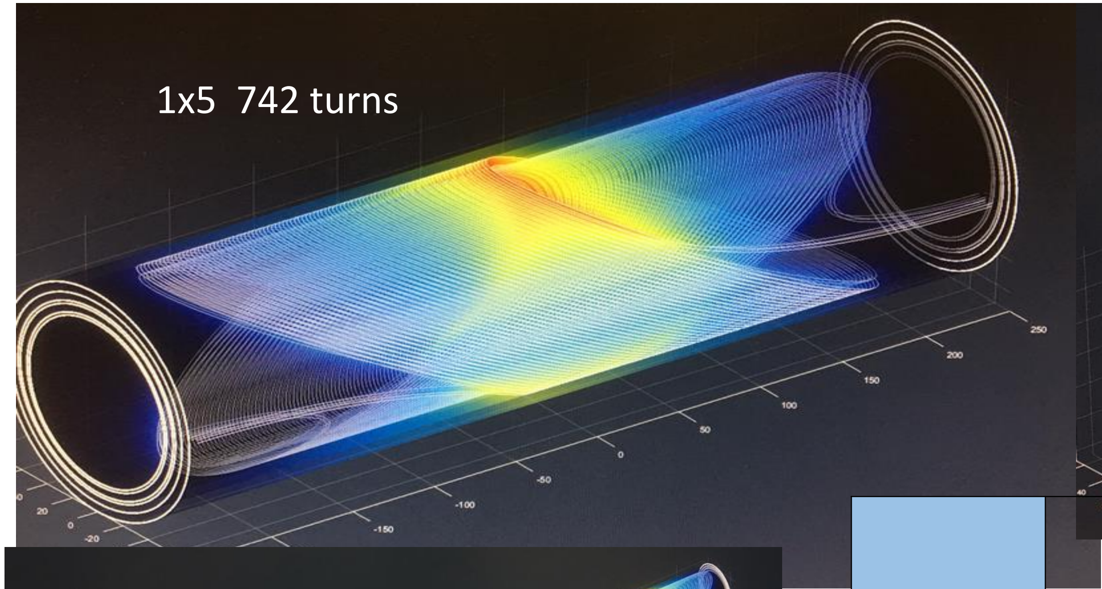


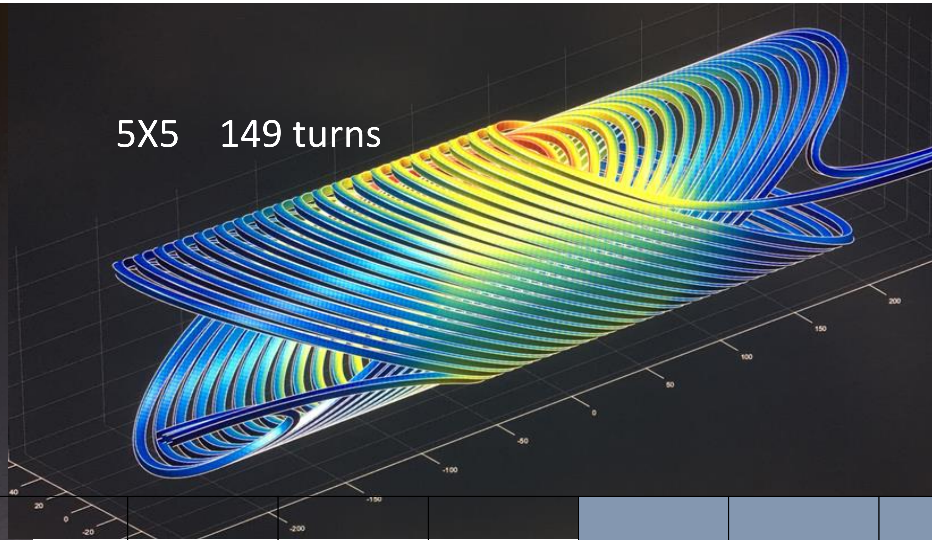


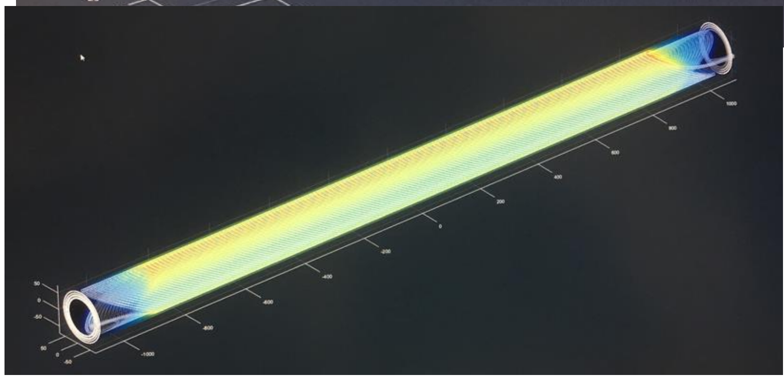
More complicated than one plot,

Example of one configuration Presenting harmonic solution due to high field in the adjacent aperture

- To achieve 5 Tm field integral with less than 10 units we first determine the maximum field in one aperture that will not pollute the field quality in the adjacent aperture.







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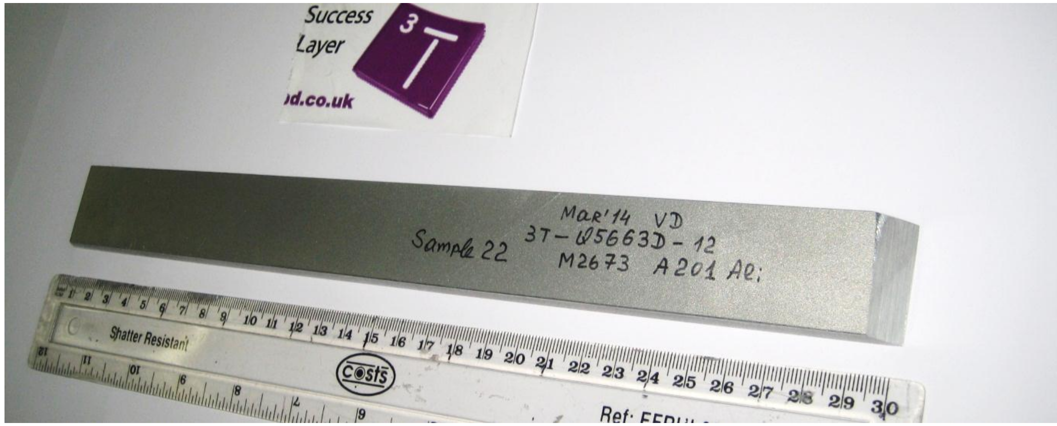
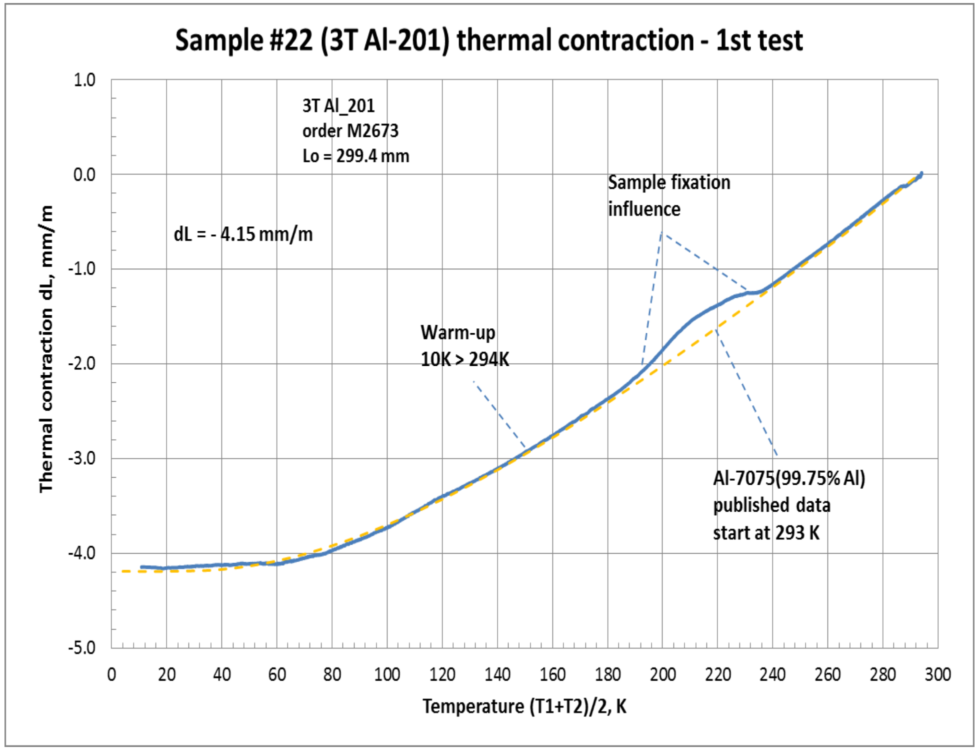
4	186	20	1.2	6.4	38	18	20
5	149	25	1.5	8	48	23	25
6	124	30	1.8	9.6	58	28	30

Former Thermal contraction !!! 1930mm
Aluminium -4.19 mm/m 8.0 mm
Alu Brass -3.24 mm/m 6.24 mm
std barass -3.83 mm/m (0.283%) 7.4 mm
Nb-Ti wire 2.97 mm/m **5.73 mm**

First 3T sample #22 thermal contraction test at CERN, Bdg.927, 30.04.14

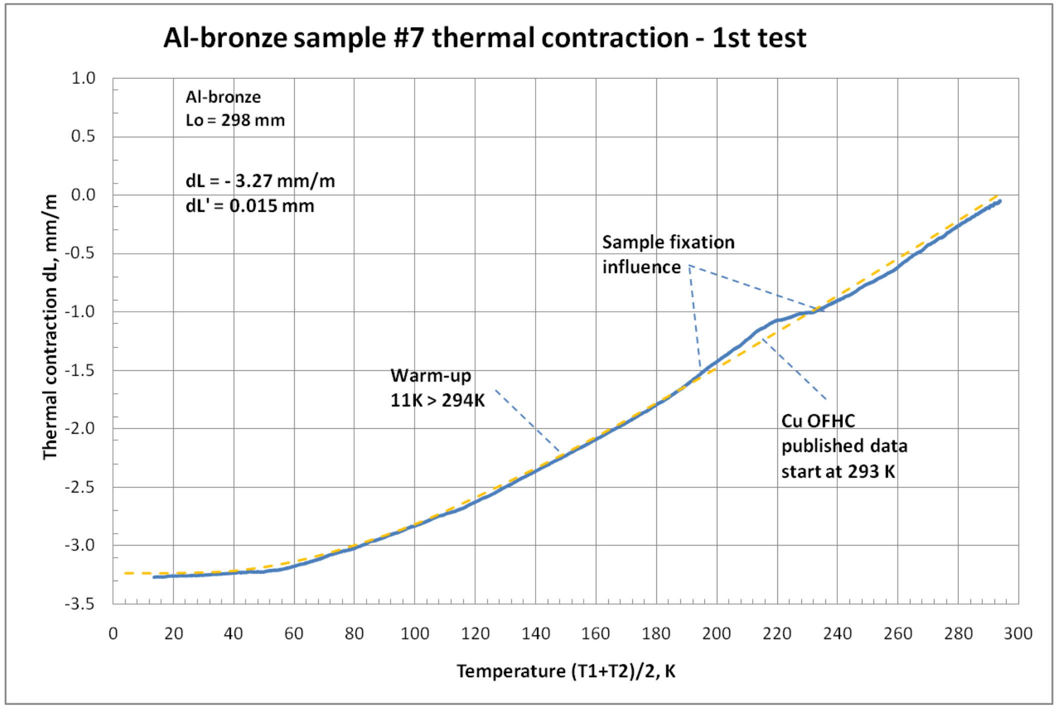
1. Al sample (A-201 Ali) – 3T order Q5663D-12 (M2673).
2. Cooling in the temperature range 294K > 10K.
3. Result: thermal contraction dL/L = - 4.15 mm/m (- 0.415%) is very close to reference material Al-7075 dL/L = - 4.19 mm/m (- 0.419%).

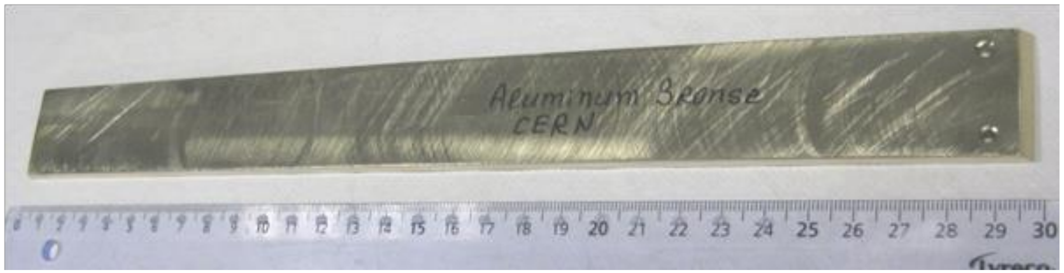




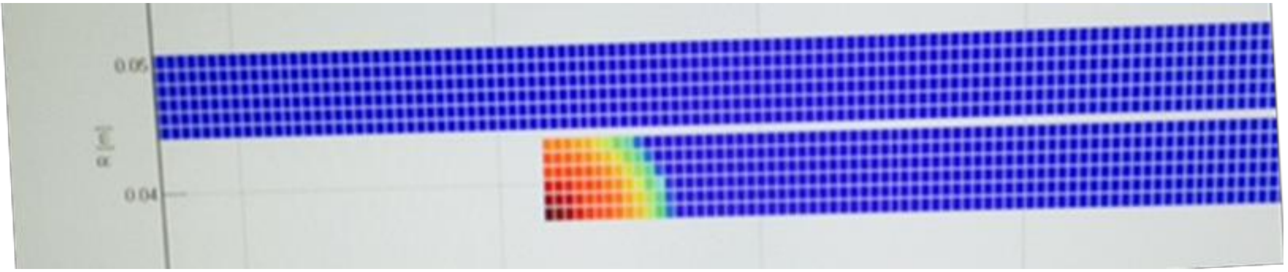
Al-bronze sample thermal contraction test at CERN, Bdg.927, 15-16.08.16

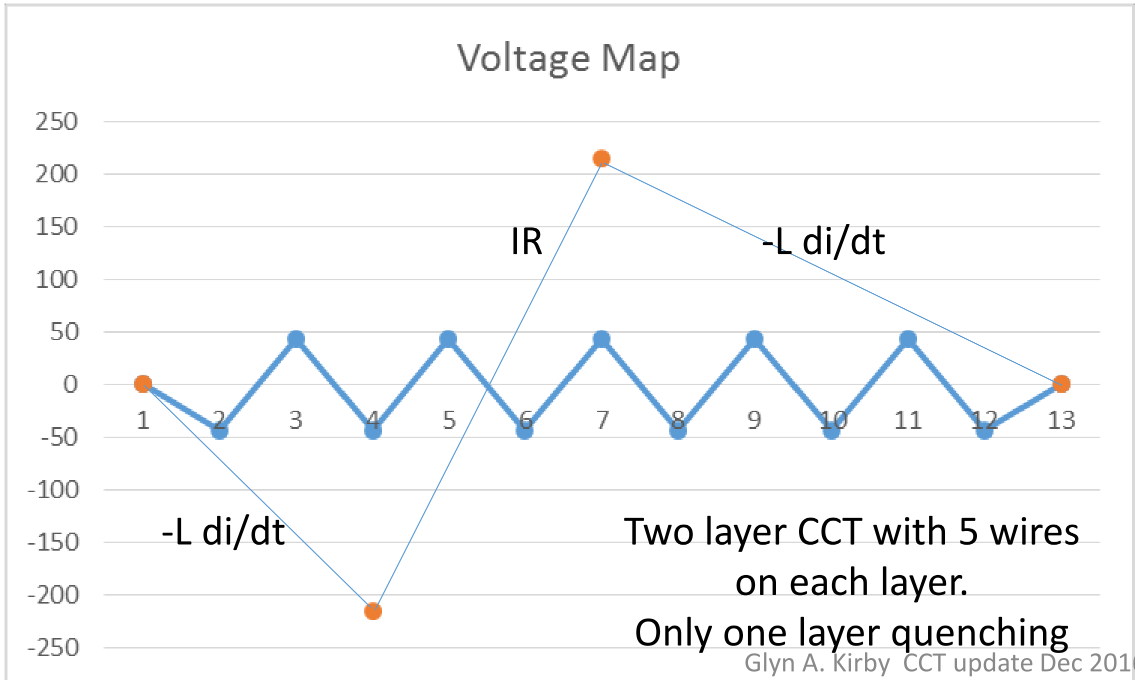
1. Al-bronze (Cu-81%,Al-10%,Ni-5%,Fe-4%) sample, Lo = 298.6 mm.
2. First cooling in the temperature range 296K > 11K.
3. Result: thermal contraction dL/L = - 3.27 mm/m (- 0.327 %) - the closest reference material is Cu OFHC dL/L = - 3.24 mm/m (- 0.324 %).

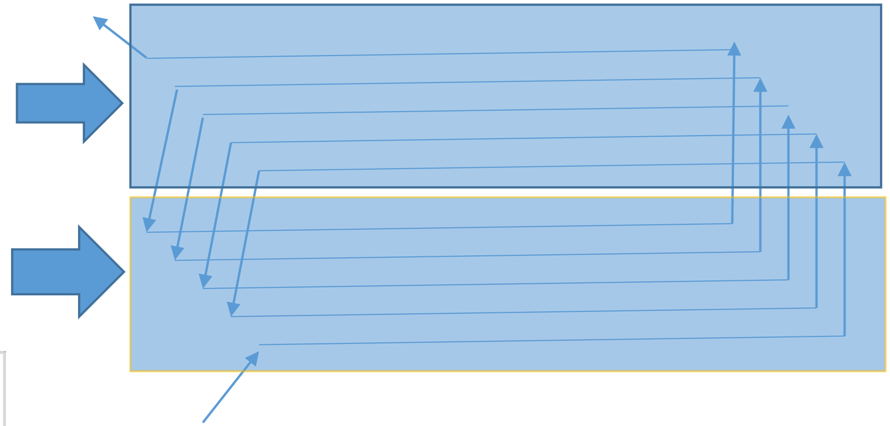




Voltage Map, an overview



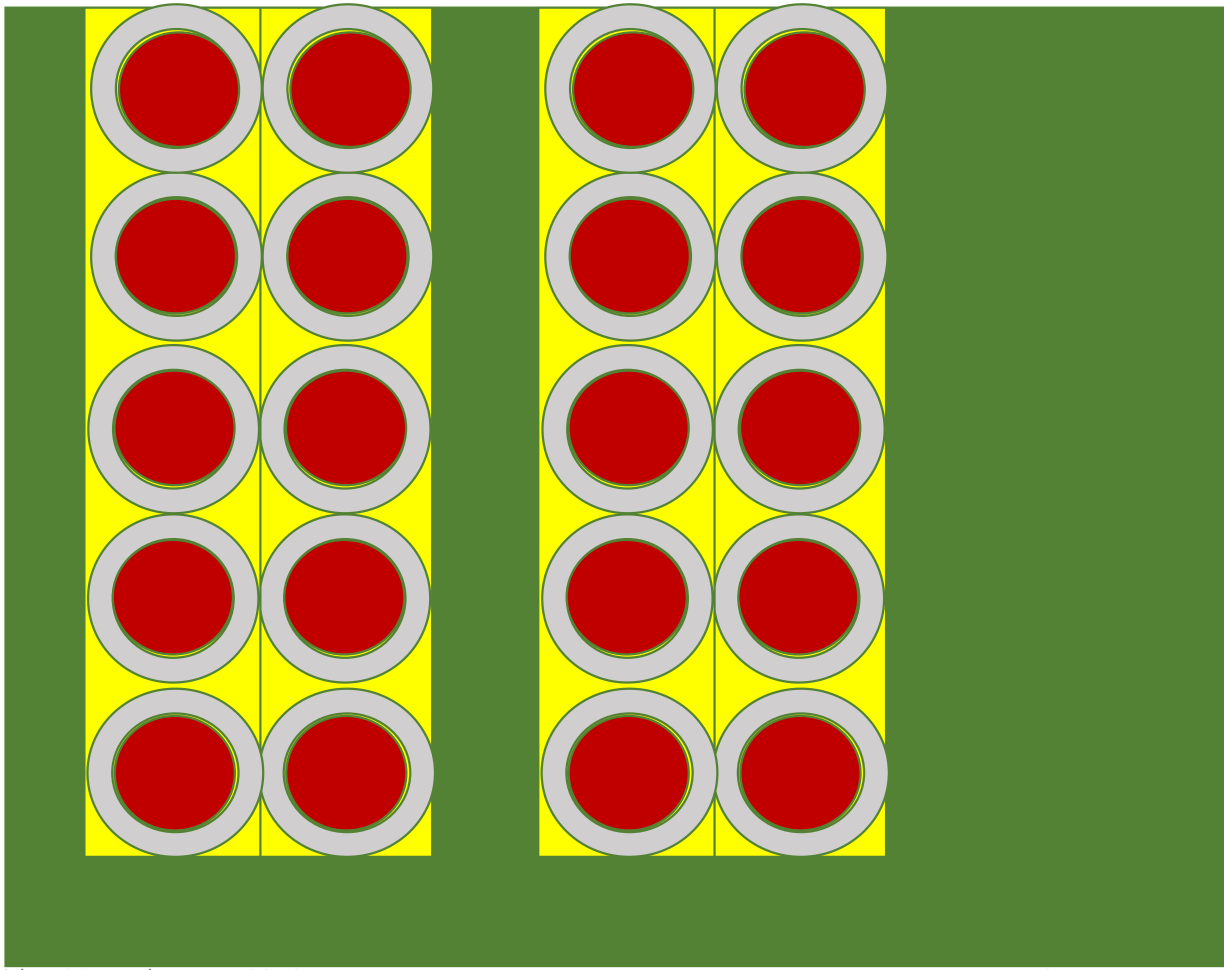




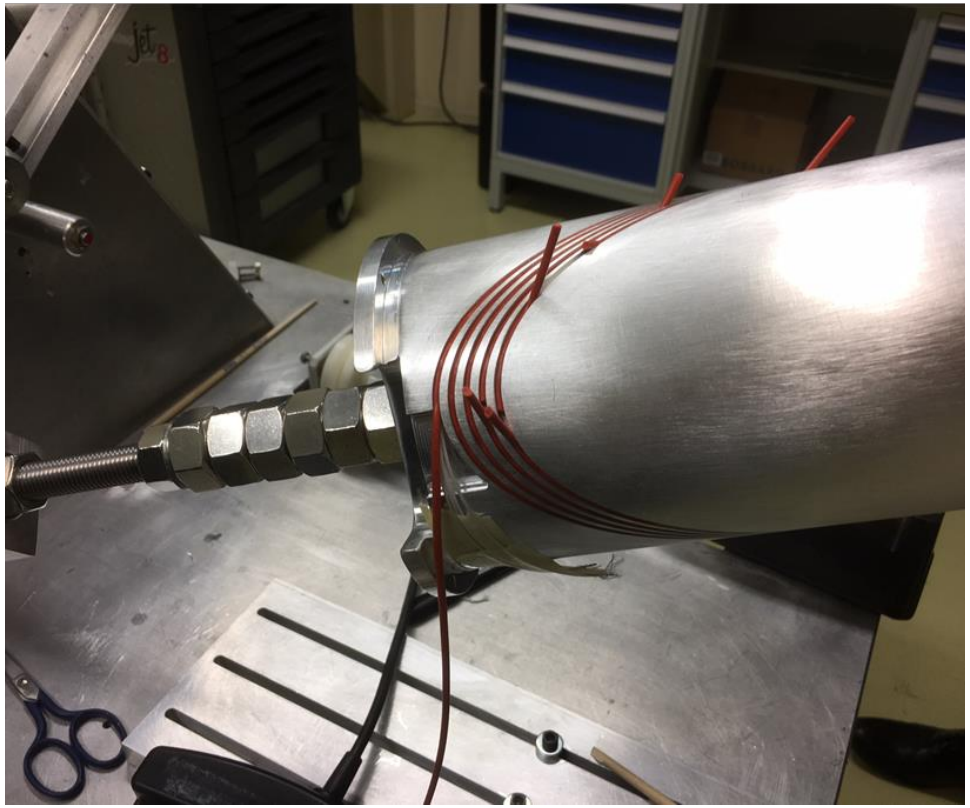
This is for the 1 x5 design

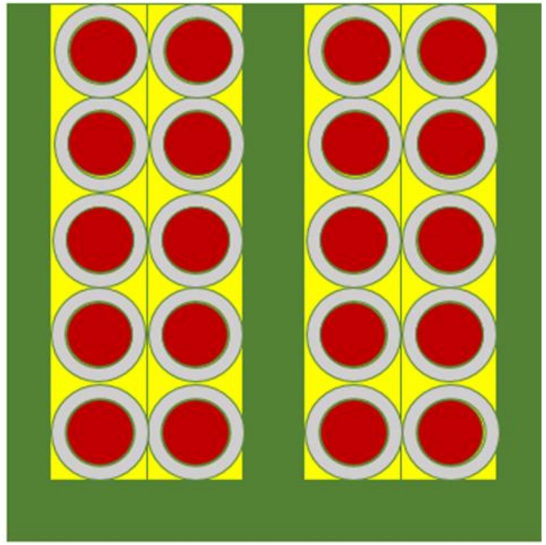
With more joints the voltage is spread.

New test former with 2mm x 5 mm slot

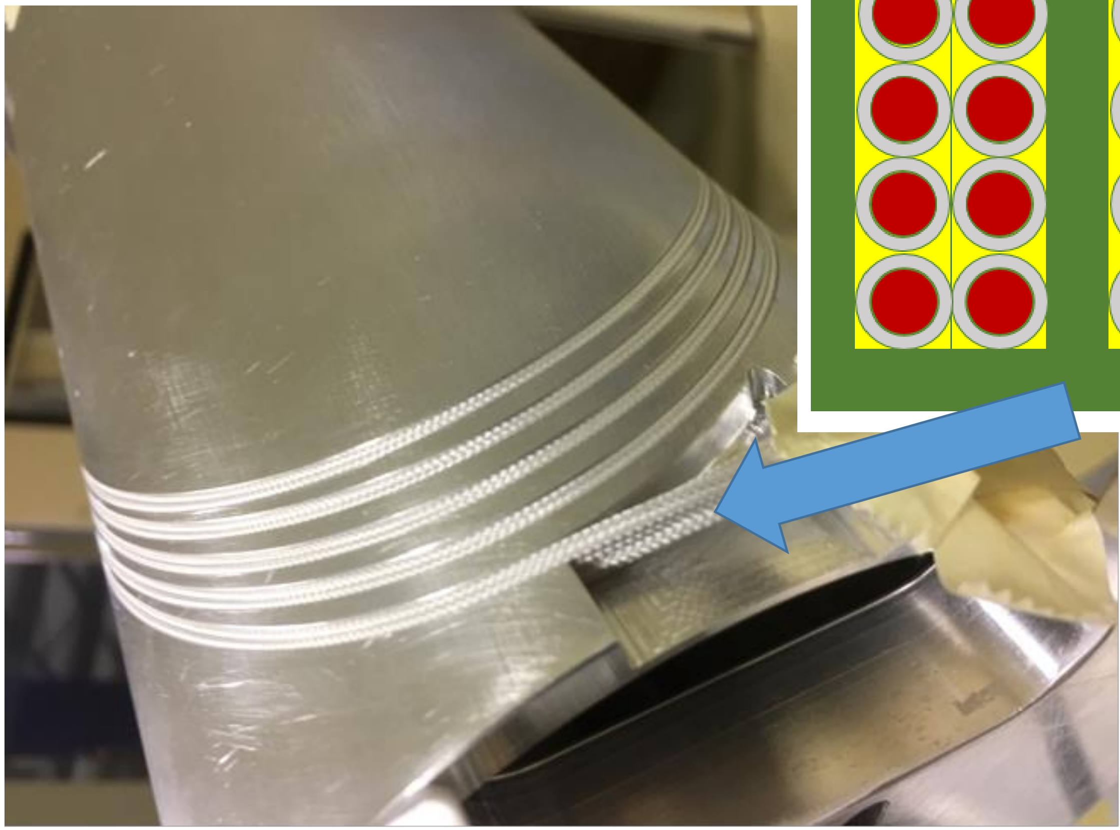


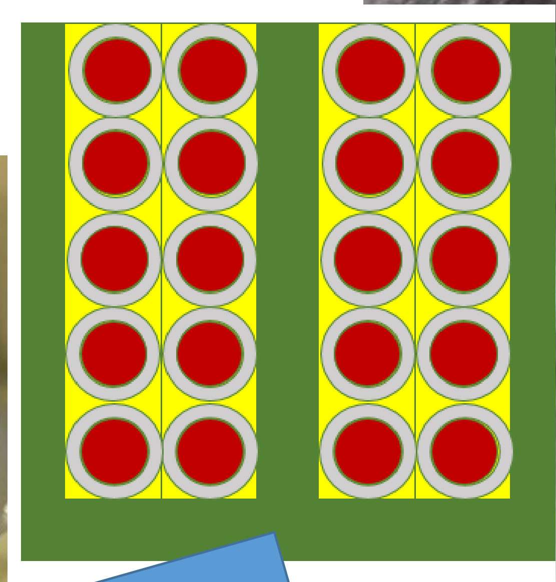
2 mm x 5 mm slot with 10 wires coil Winding was successful

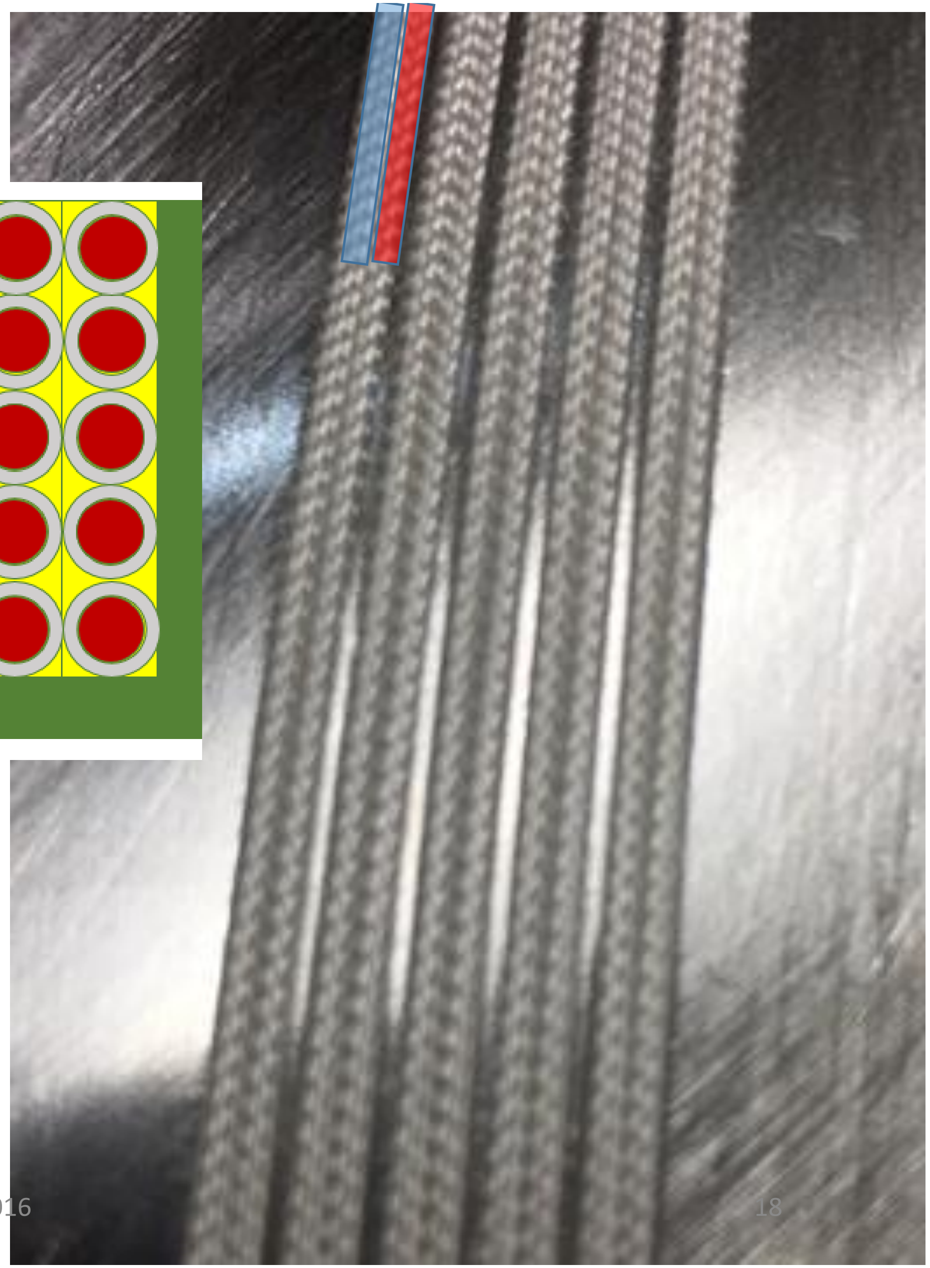




2 wide x 5 deep turns







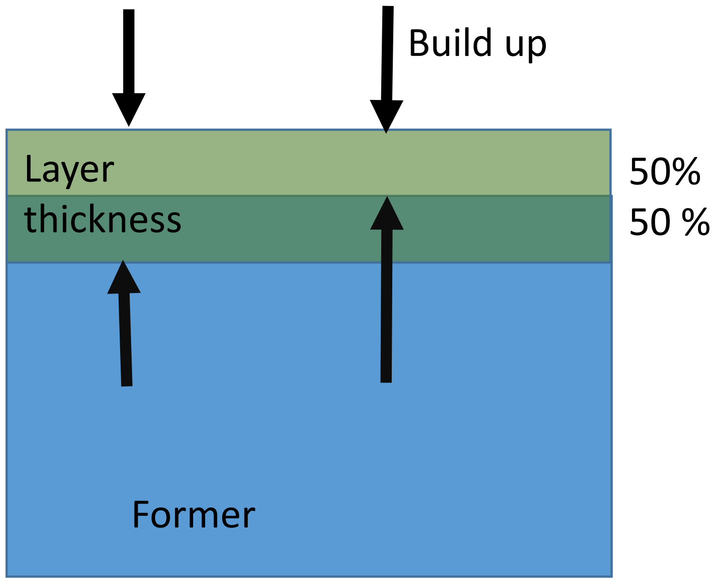
Magnet Insulation

- Glass sleeve impregnated with CTD 101K or CTD 422 !   Tests = < 2kV
- Enamel coating in wire, we are still looking for company to coat our old lhc wire , three companies contacted waiting for reply = 700 V
- Aluminium 6000 Former coating Anodizing 60 um to 80 um up to 4000 V

- Tutn to turn = 2kV to 3kV
- Coil to former = 2 - 3kV,   (with Anodized former 6 - 7 kV with coating.

Hard Anodizing on aluminium for electrical insulation and radiation hardness!

Layer build up 0.04mm
2000 to 4000 v

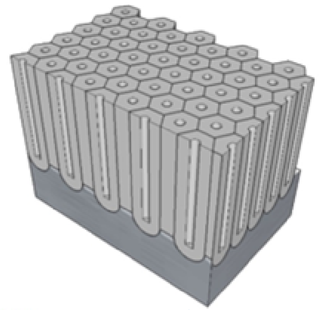


The Anodic Layer

Ever wondered why anodizing dyes so well? It has to do with the microscopic structure of the anodizing layer.

The oxide or "anodic" layer formed in the anodizing process consists of microscopic hexagonal oxide columns with holes or "pores" which extend nearly the entire length of each column. It is these pores which hold the dye

The anodic layer is extremely hard- usually between 60-70 Rockwell C. The layer is also an excellent insulator, with a .002"hardcoat layer having a breakdown voltage of 1500-2000 volts.



The characteristic hexagonal structure of anodizing (hypothetically about 40,000x magnification). Note the hexagonal oxide columns have been sliced through to show the structure. An actual layer would be much thicker, with the height of the columns 200 or more times higher than their diameter.

Material Hardness v UTS

Fig.1 Variation of Vickers micro hardness (H_V) with aging time for various aluminum alloys.

Fig.2 Variation of 12% true proof stress with aging time for various aluminum alloys.

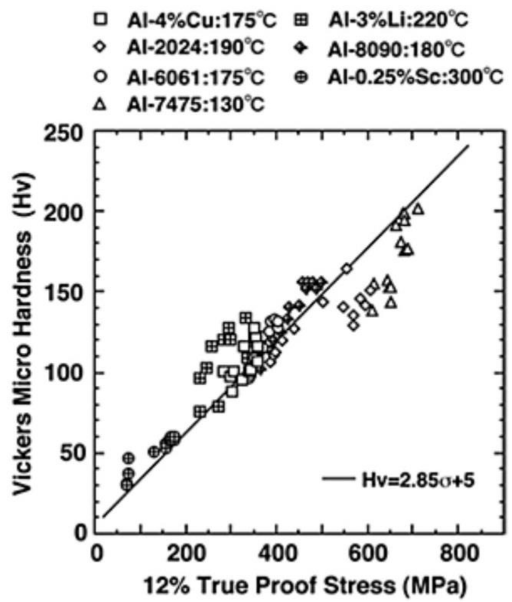
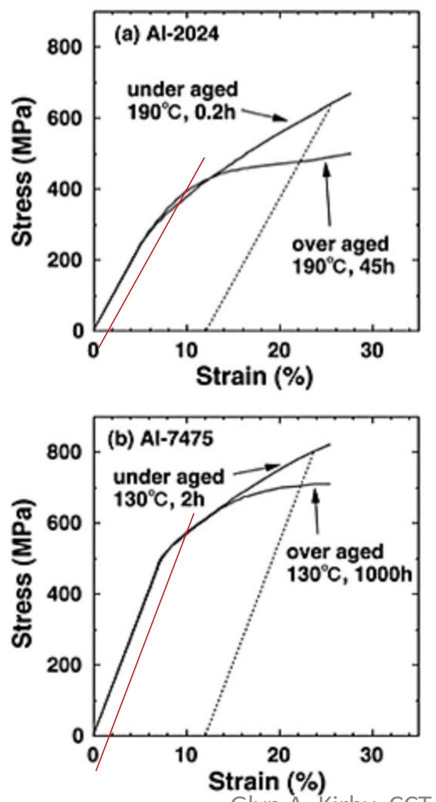


Fig.3 Relationship between Vickers micro hardness (H_V) and 12% true proof stress for various aluminum alloys.



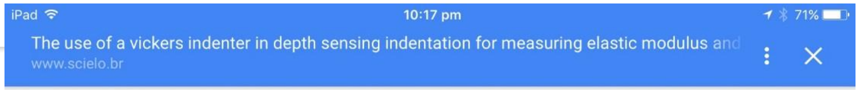
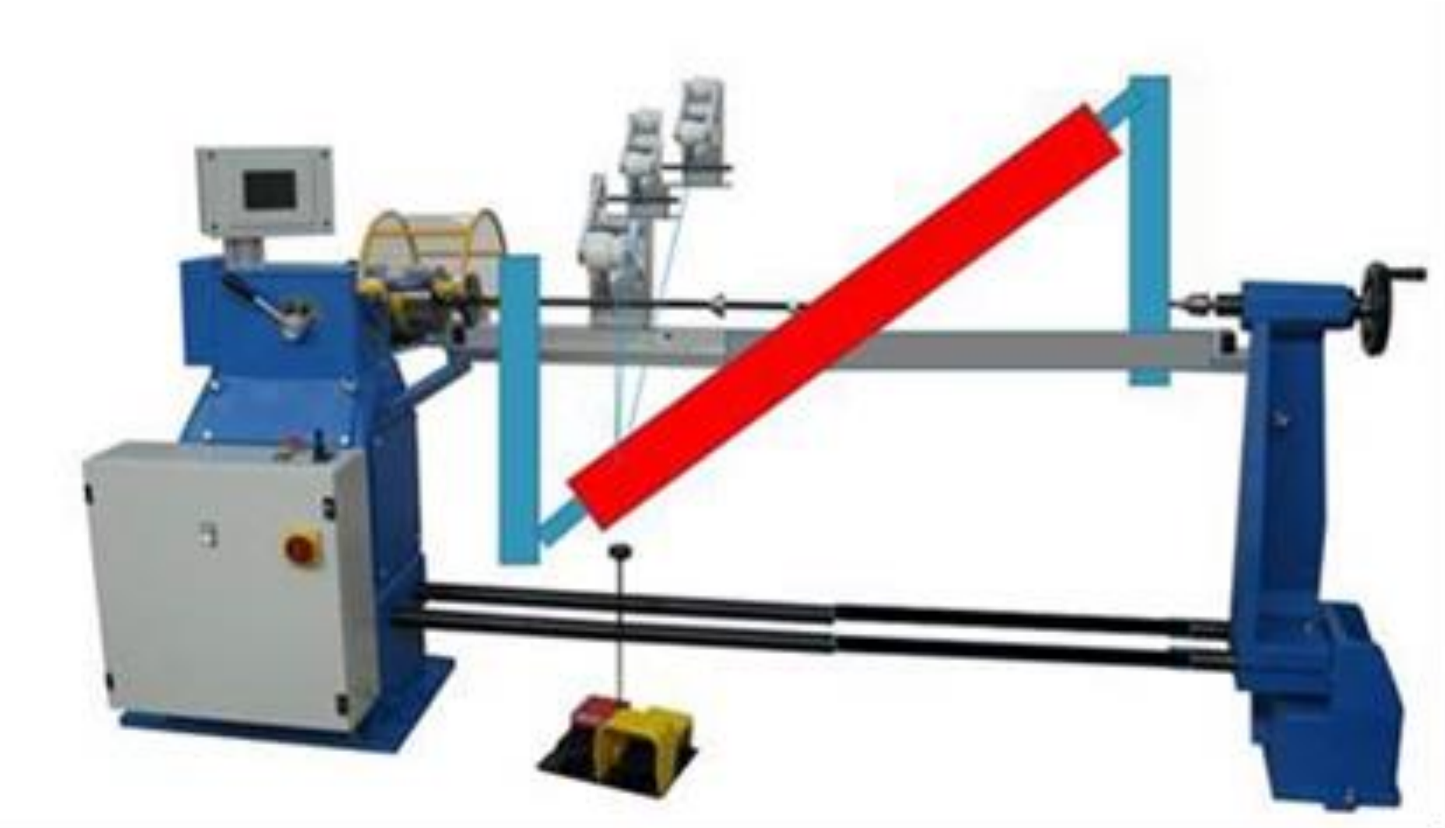


Table 6. Hardness Vickers determined experimentally using different loading, for materials of different elastic-plastic behaviors.

Material	Hardness Vickers, kgf/mm²	Load, mN
5.0 µm TiN coating	2421 ± 119	30
Al_2O_3 (99.8%)	2005 ± 50	1000
	1947 ± 81	500
	2028 ± 135	50
300 µm WC-12%Co coating	1399 ± 167	50
	1455 ± 90	100
AISI D2 tool steel	650 ± 59	250
Soda-lime glass	550 ± 0 2	50
AISI H13 tool steel	485 ± 17	50
	481 ± 9	500
Co-25%Cr	398 ± 35	100
	403 ± 35	500
316 stainless steel	228 ± 7	750
Au (99.98%)	217 ± 11	10
Au-12%Pt	194 ± 14	100
Aluminum	35 ± 4	750

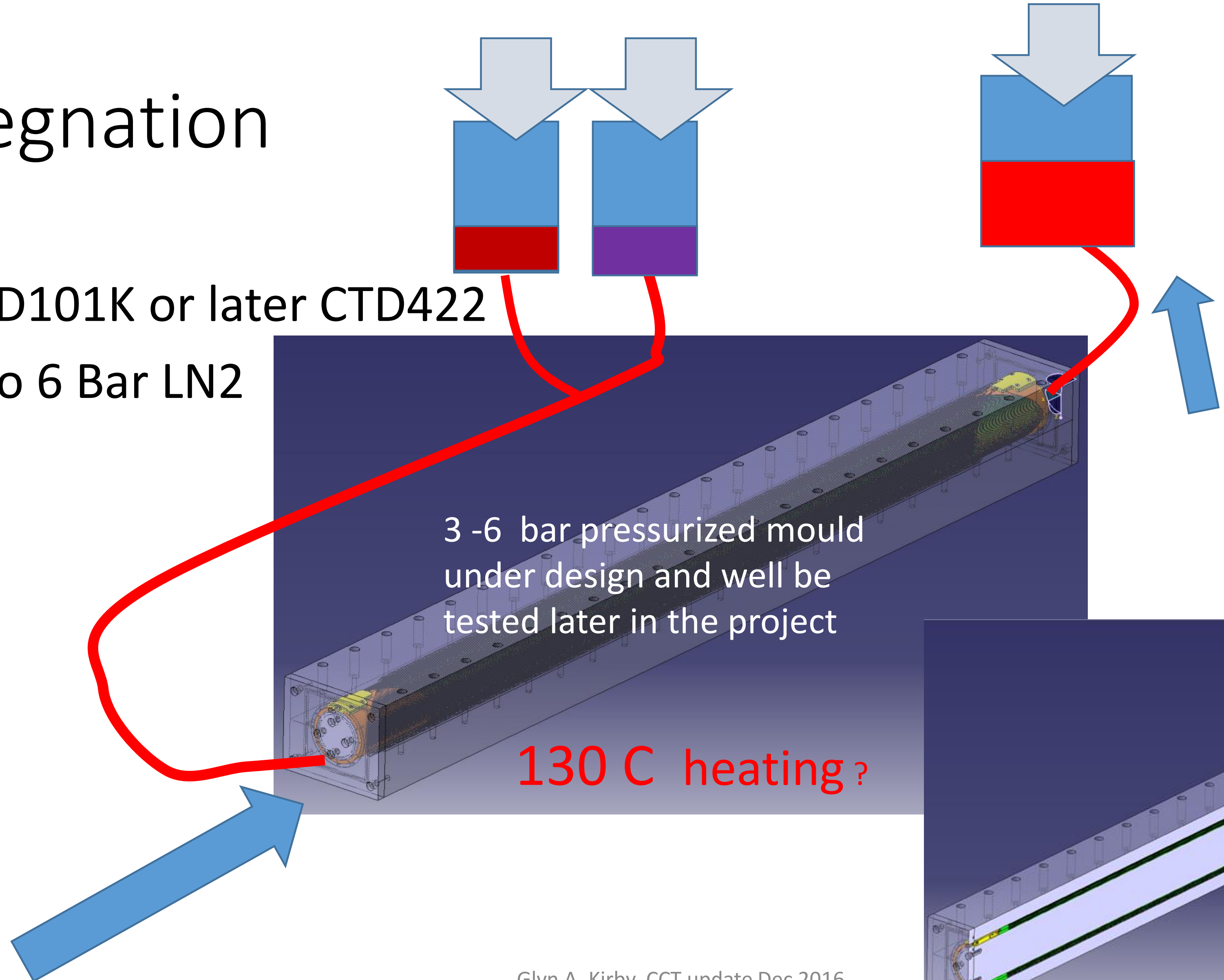
New coil winding M/c search visit this week

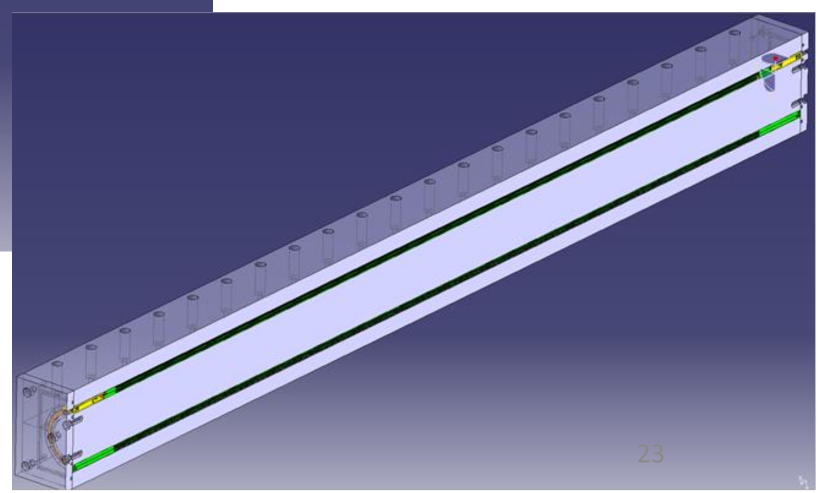


http://www.whitelegg.com/products/wire-forming

Impregnation

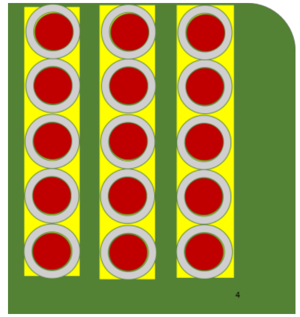
- CTD101K or later CTD422
- 3 to 6 Bar LN2



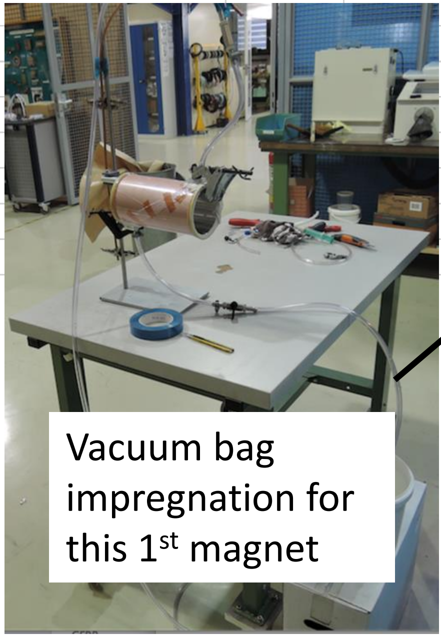


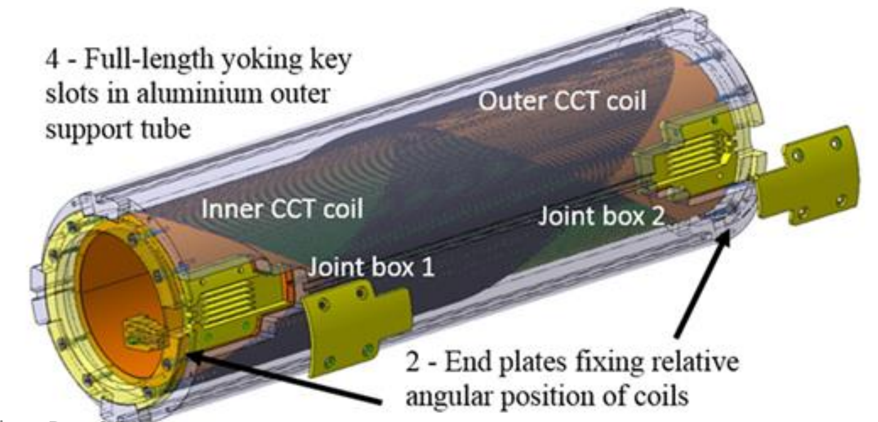
Test Planning 1st model

1mm x 5mm design



				jan				Feb					
			Xmas	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10
Machining inner tube													
Machining outer tube													
Winding 0.5m inner former													
Winding 0.5mouter former													
jointing													
yoke assembly													
Cold test !									CCT Cold test				





Project Summary

- The D2 orbit Corrector (CCT) magnetic design is now fixed in terms of:
  - Conductor type (using LHC dipole outer strand wire Nb-Ti 0.825mm dia 1.9:1 Cu/Sc)
  - Coil geometry ,Number of turns of conductor, coil length.
- Machining Tests have led to the need to change from a single wire in a machined slot to a 2 wire in one slot design this does not change the magnet length.
  - Winding tests were successful and this is the new base line design.
  - This also had a significant reduction in the machining cost ~ factor 8.
  - Moving to wider and wider slots with many wires in each slot is a possibility however at the complexity of more joints. Which for this design is not easy!
  - The wider slot with 2 wires also gives larger stronger walls between slots and a tougher component.
- Insulation systems
  - Wire Insulation. We are testing a Polyimide coating on the strand then with a glass sleeve impregnated with CTD101K to give extra insulation and mechanical support.
  - The CCT coil former material selection is under review.
    - Initially : Aluminium Bronze was selected, for its free machining , thermal contraction , and heat extraction. but the is not a low cost option and is difficult to electrically insulate. During quench will extract some energy from the coil, not essential but help a little.
    - Aluminium 6000 series: can be hard Anodized giving ~ 4kV insulation! , is less expensive, and easy to machine. Testing of the anodized electrical insulation has started, and will extract energy during quench.
    - A third interesting option is : a GRP with radiation hard resign cyanate ester blend, insulating material, bonding of the glass sleeve would be very good to the GRP former. (for consideration, not for now) the drawings would not change only the material.
- The 1mm wide slot test coil is being machined and will be wound in January if the machining is successful.
- Full length material is in stock at CERN , 3m long Aluminium bars, we are now investigating the machining of the full length 2.2m design with the 2mm wide slot. And testing the new joint box with its 10 joint design.
- We are looking for a company that can insulate the wire. Waiting for offers!
- Cold testing of the first coil planned early in 2017.