



DESIGN STUDY OF THE MECHANICAL STRUCTURE OF THE SIS300 SUPERCONDUCTING DIPOLES

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DISCORAP Review, November 12th 2008



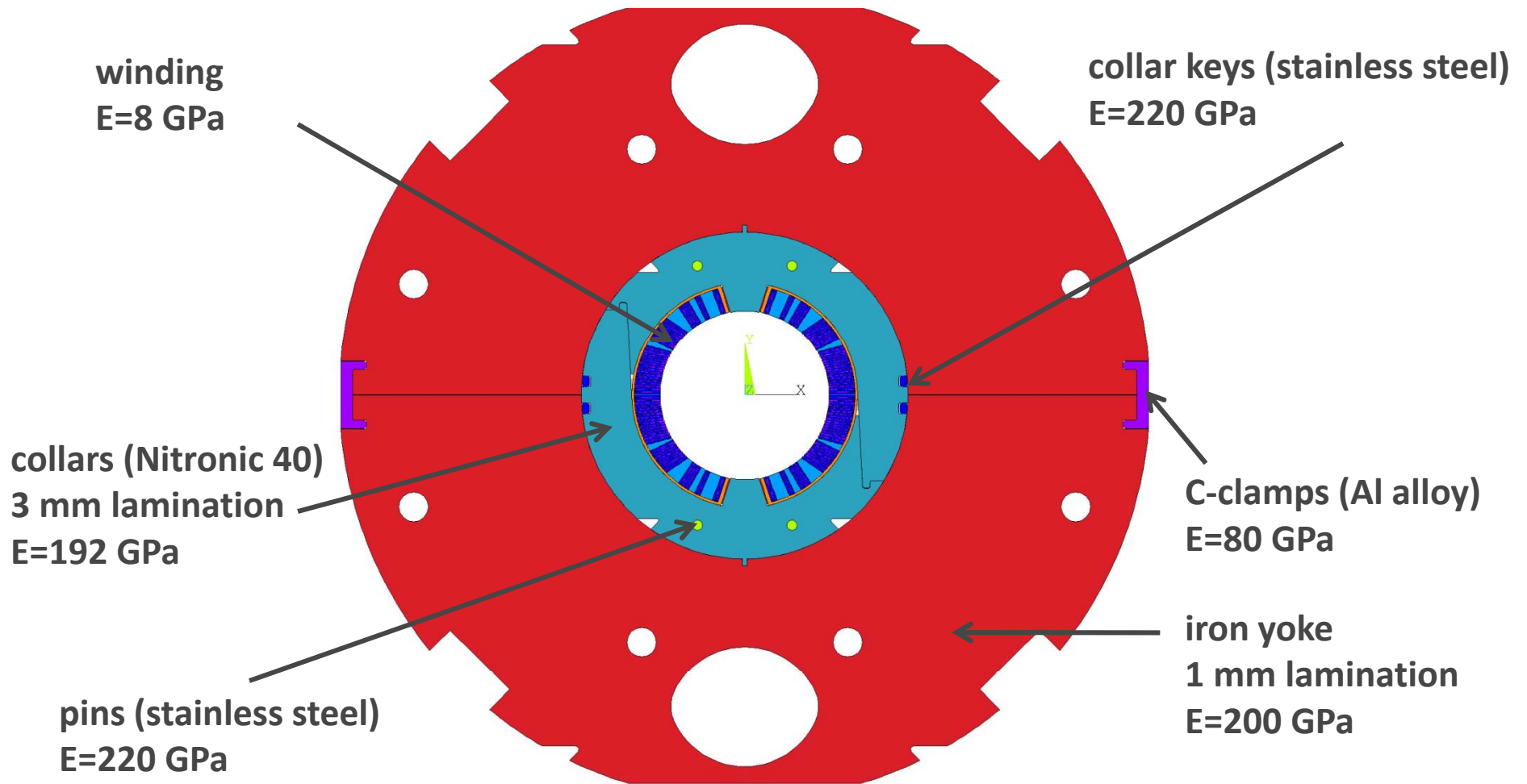
Outline

- 2D mechanical analysis
- Mechanical tests on conductors
- Preliminary 3D mechanical analysis



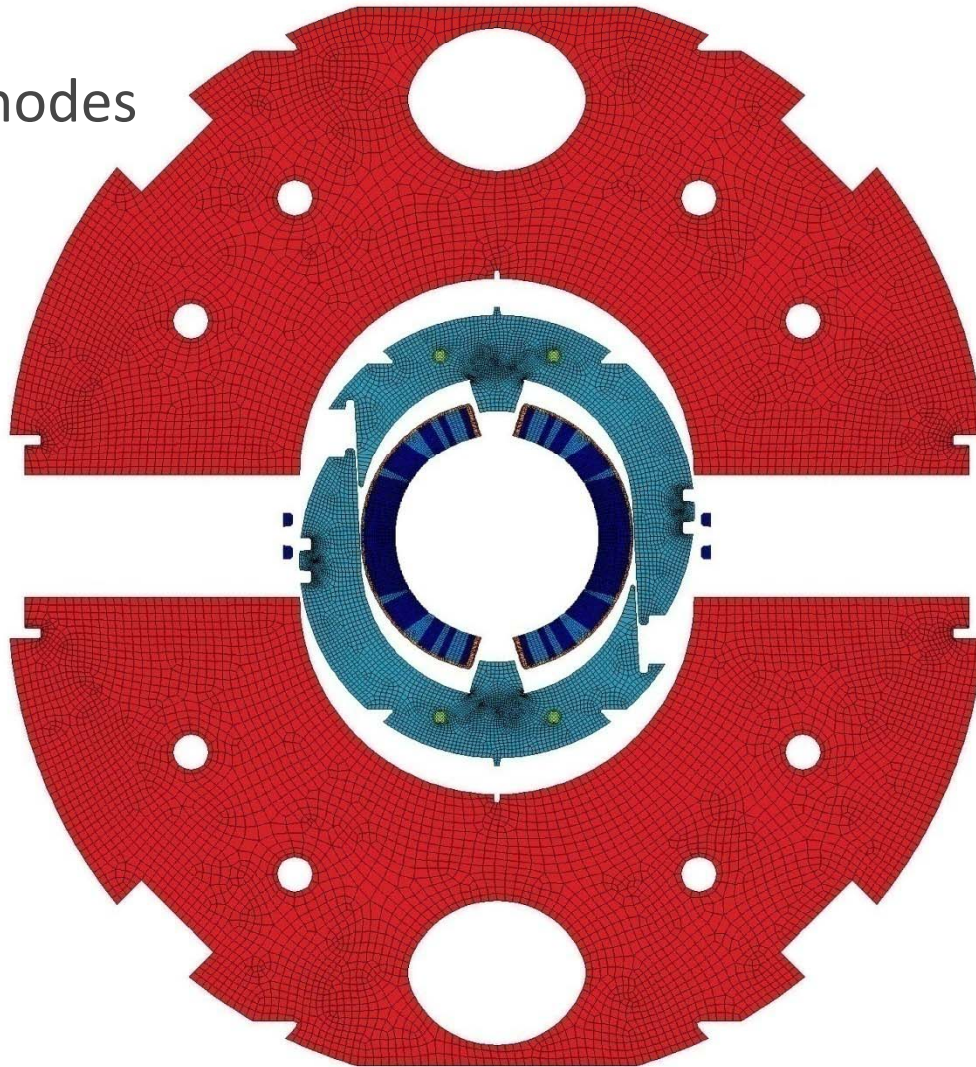
2D mechanical analysis

SIS300 dipole mechanical structure



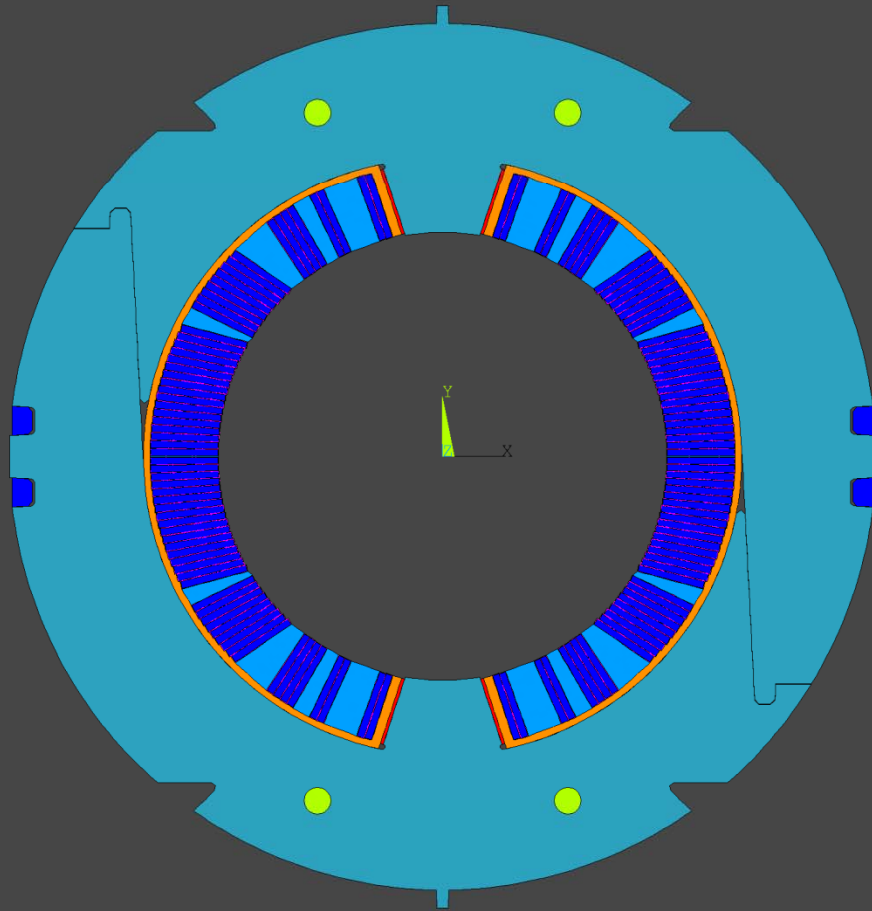
2D finite element model

110'500 nodes



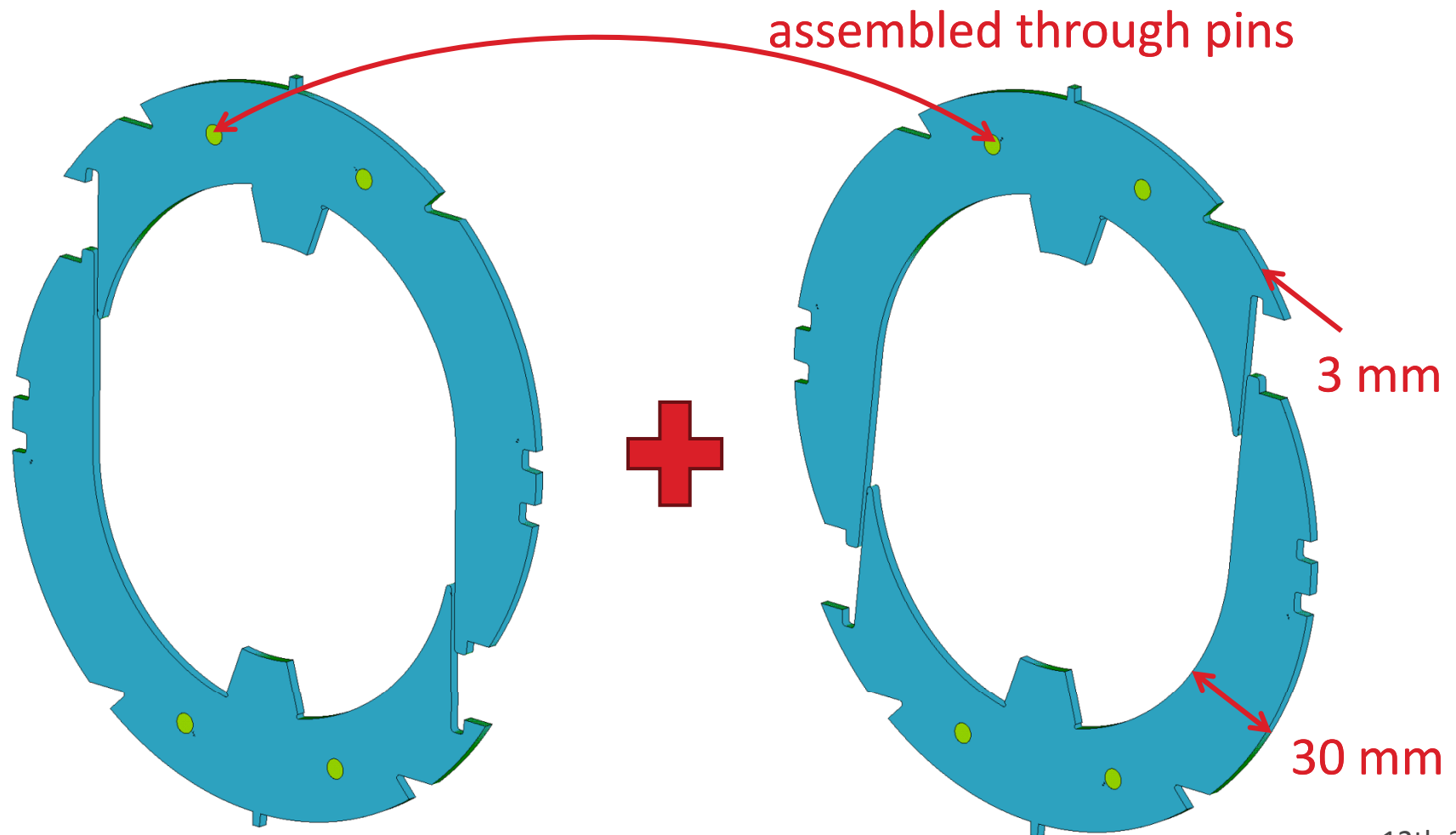
4 load-steps:

1. collaring
2. iron yoke assembly
3. cool-down
4. energization

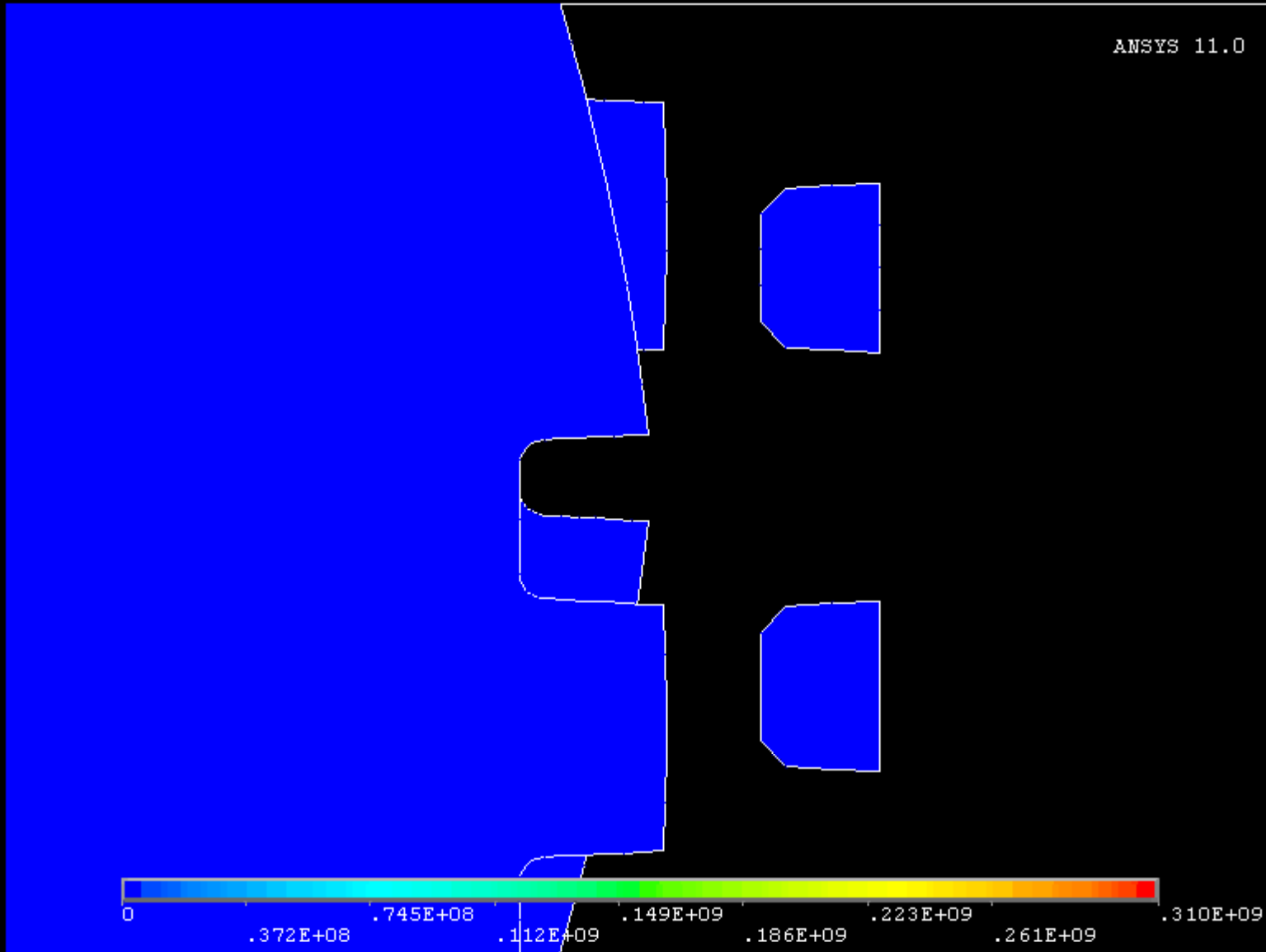


Collaring

collars assembly

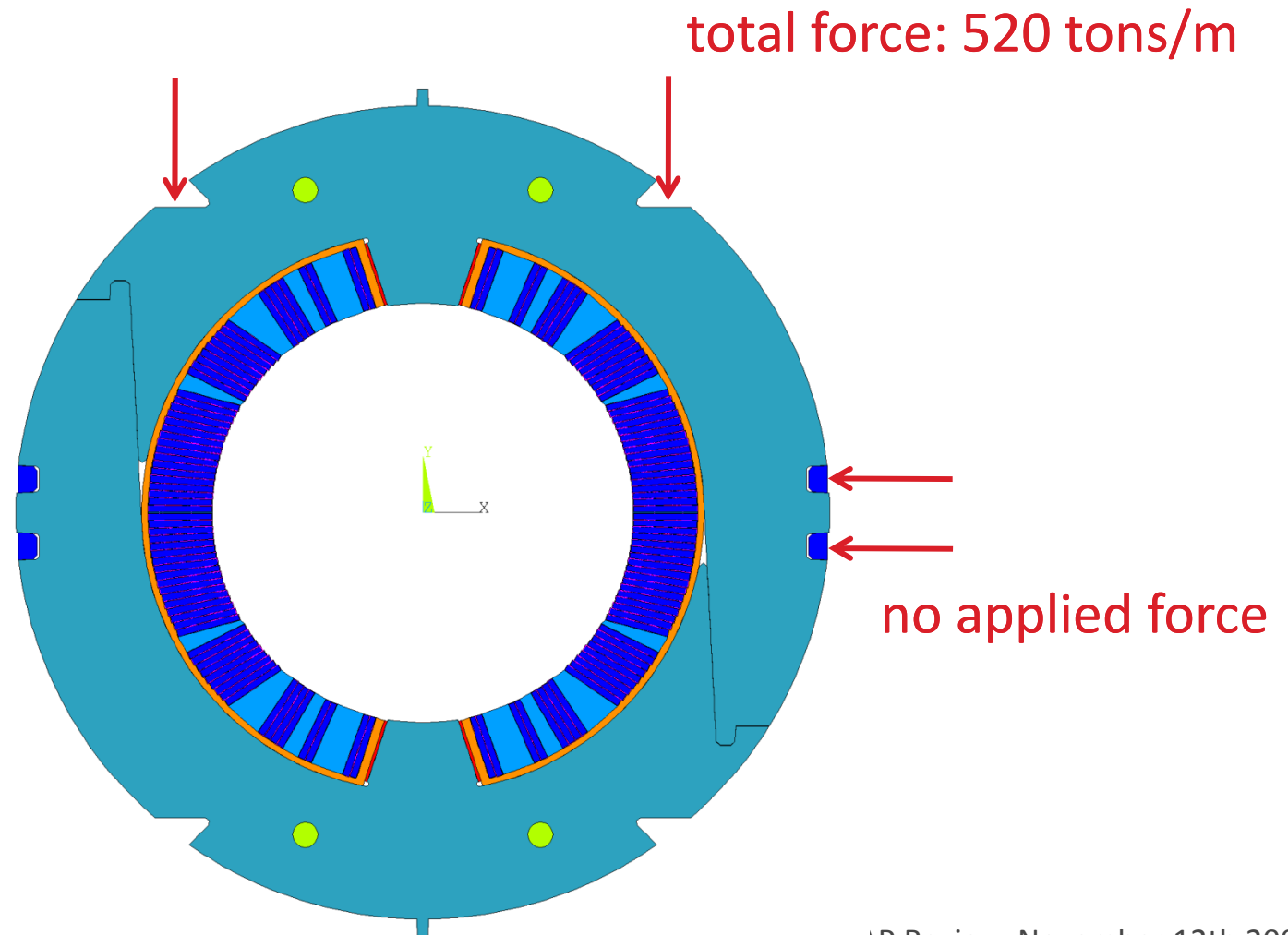


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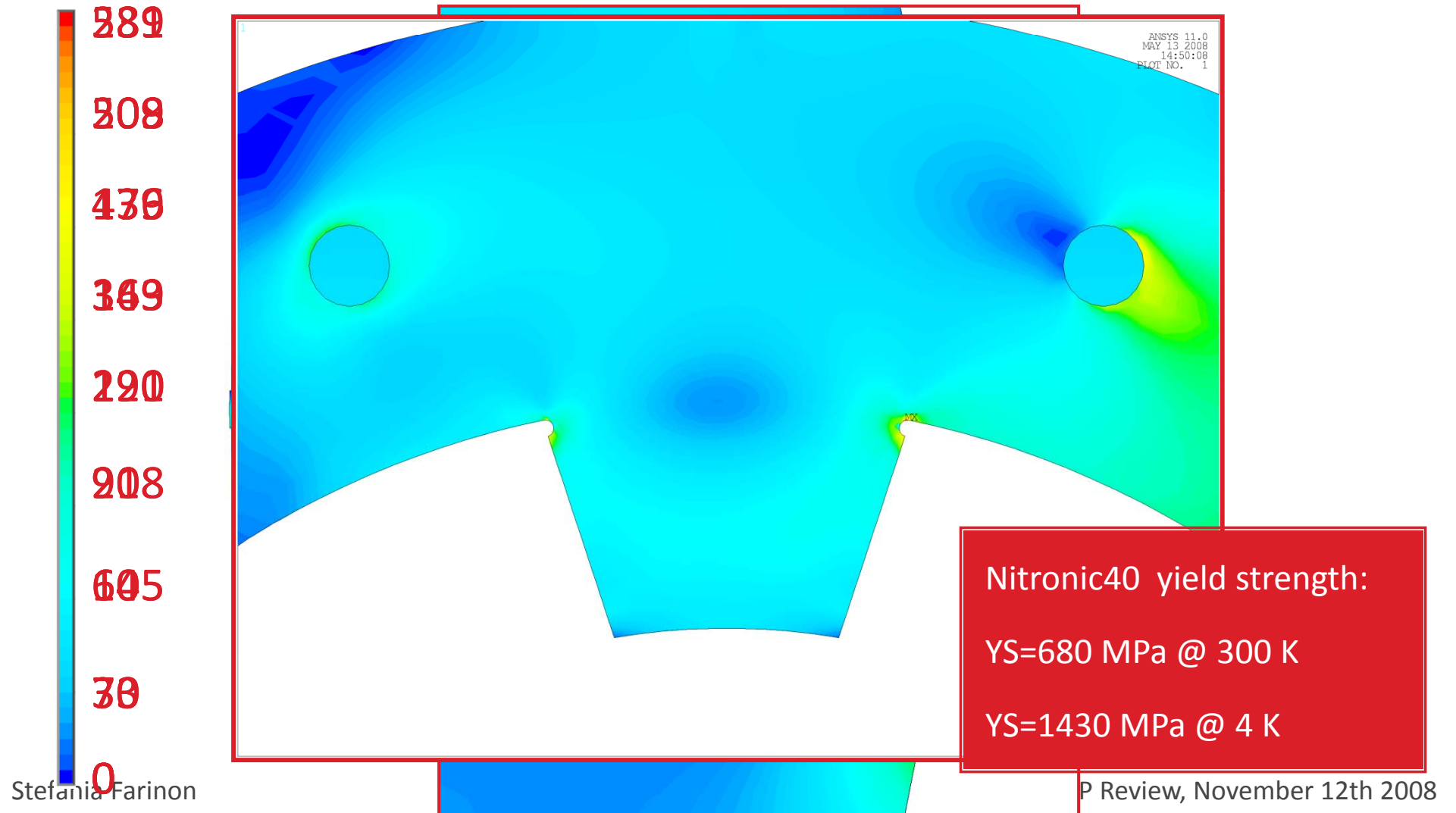


collaring operation



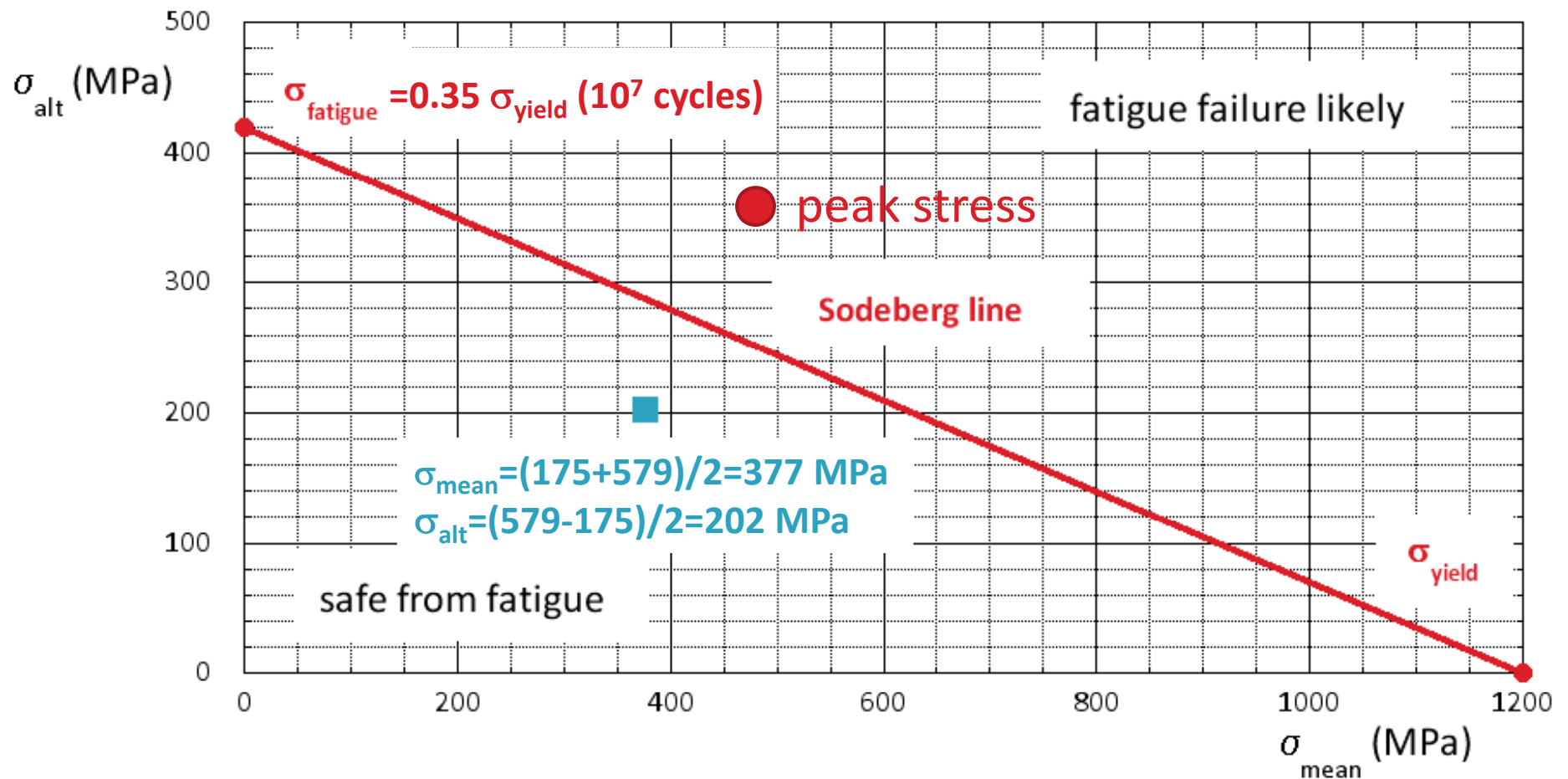


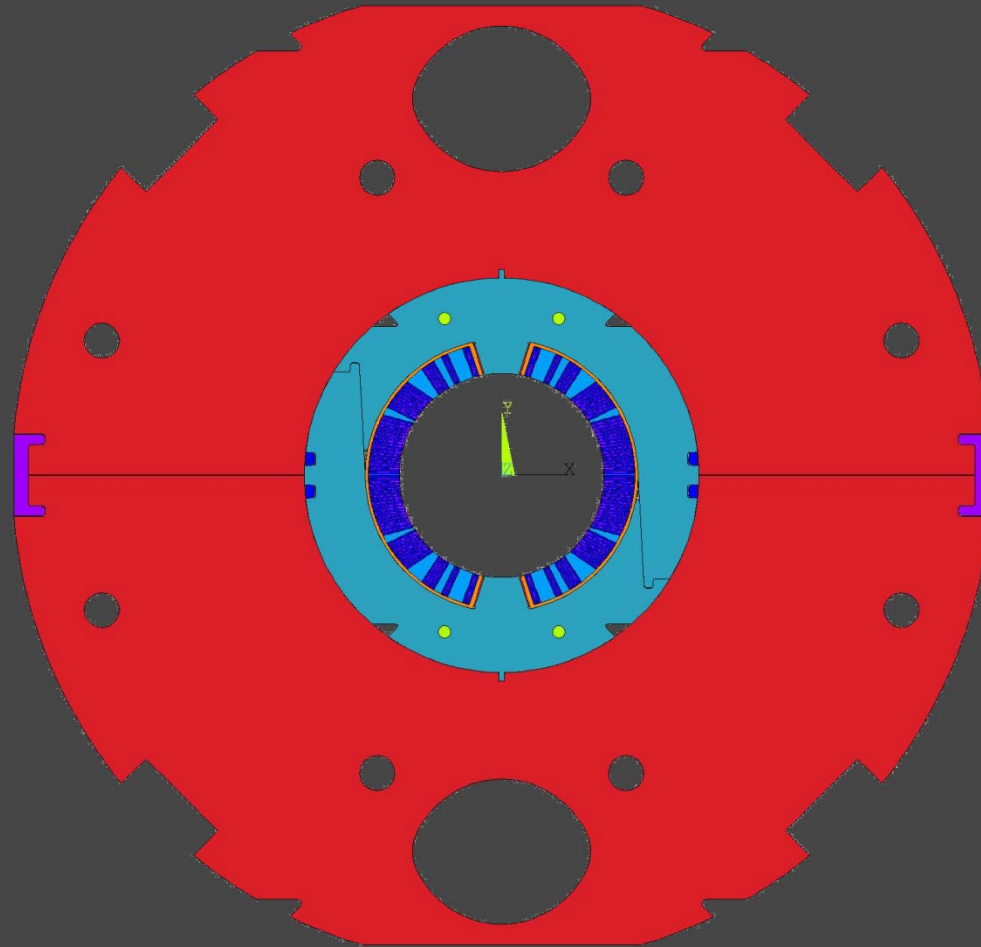
Von Mises stress after collaring (MPa)





cool-down and energization of collared-only windings (without iron)





Iron yoke assembly



iron yoke constraints

The goal is a side containment to collars.

We should:

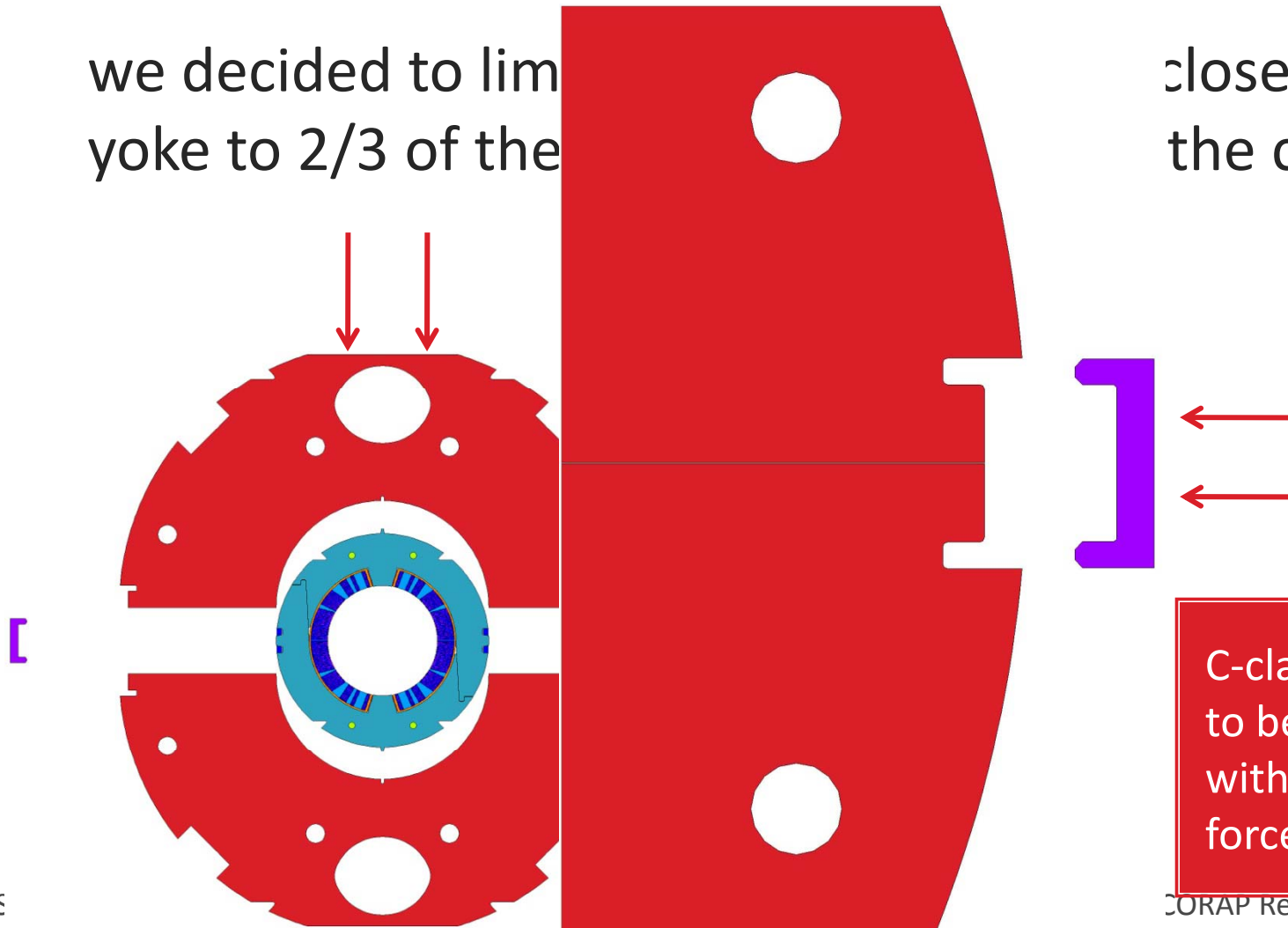
- avoid making a second collaring operation on the winding



force to close the iron yoke

we decided to limit the force to close the iron yoke to 2/3 of the

close the iron yoke by heating the collars:



C-clamps are heated to be inserted without any applied force



iron yoke constraints

The goal is a side containment to collars.

We should:

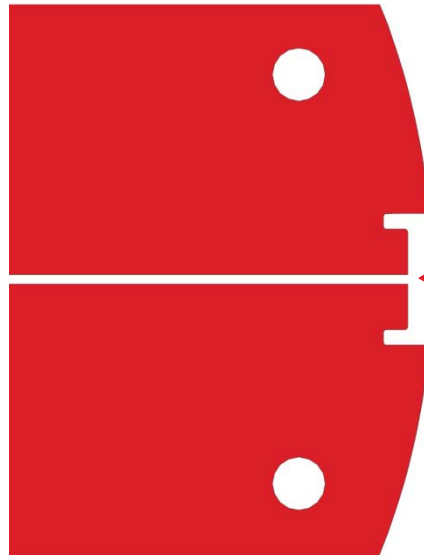
- avoid making a second collaring operation on the winding
- take into account the effect of the different thermal contractions of stainless steel and iron



effect of differential thermal contractions

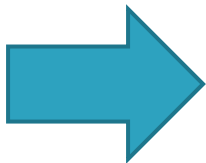
$$(\alpha_{\text{iron}} \sim 1.8 \cdot 10^{-3}, \alpha_{\text{Nitronic40}} \sim 2.4 \cdot 10^{-3})$$

- we apply a pre-stress to the collared coils through the iron yoke:



80 μm are removed from the midplane

- C-clamps are made of Al-alloy ($\alpha_{\text{Al alloy}} \sim 4.3 \cdot 10^{-3}$)



they keep closed the iron yoke



iron yoke constraints

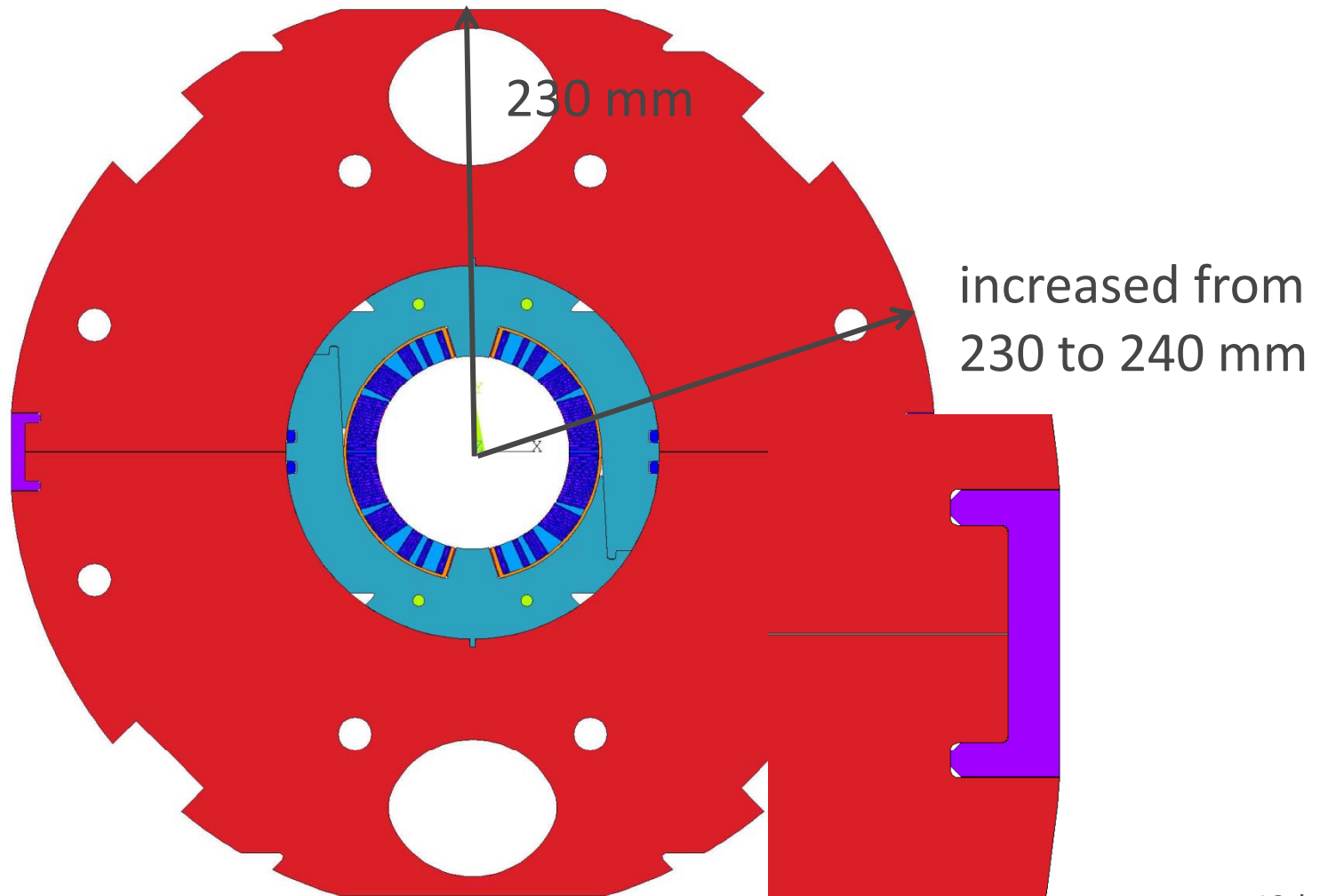
The goal is a side containment to collars.

We should:

- avoid making a second collaring operation on the winding
- take into account the effect of the different thermal contraction of iron and stainless steel
- limit the fringe field increase

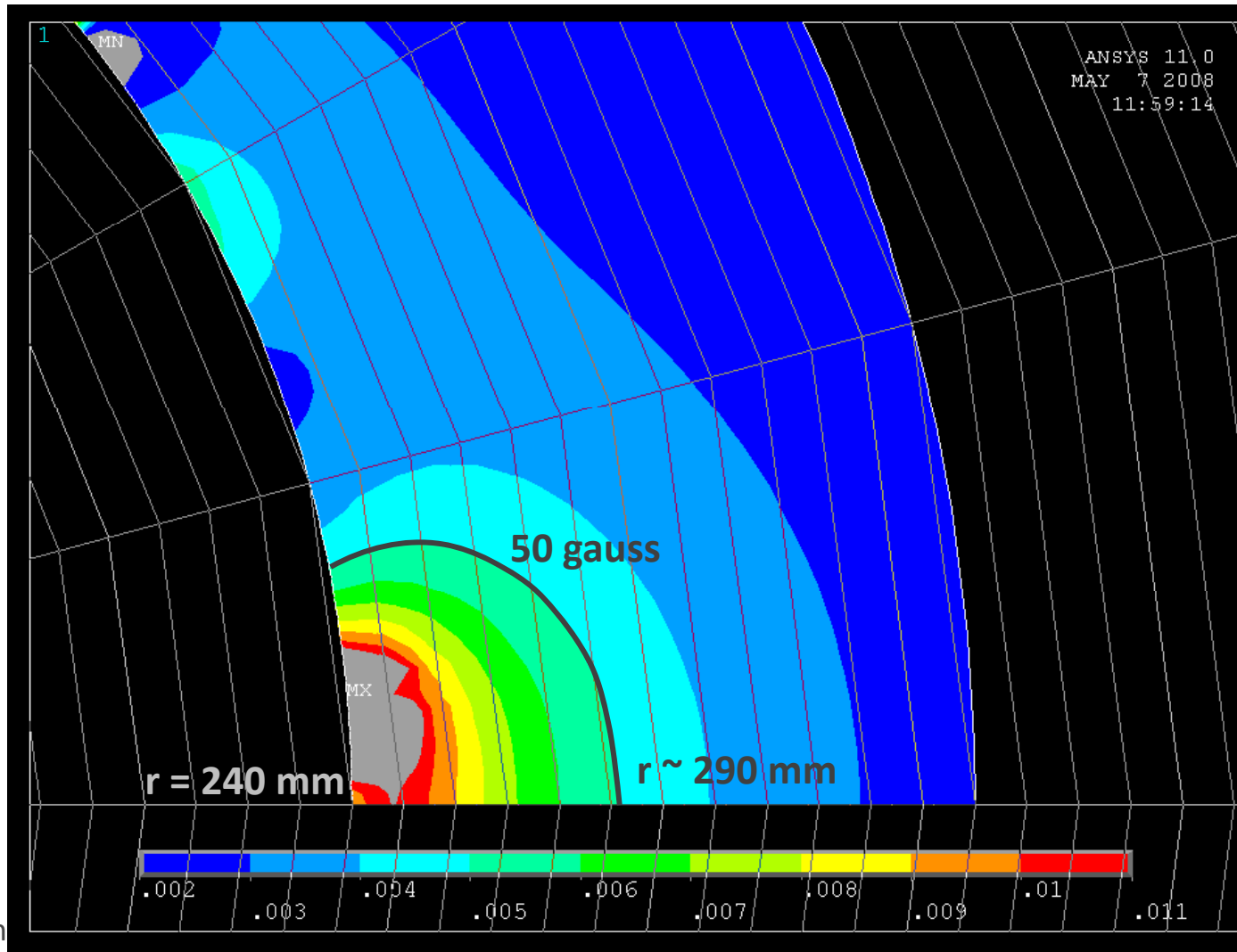


fringe field

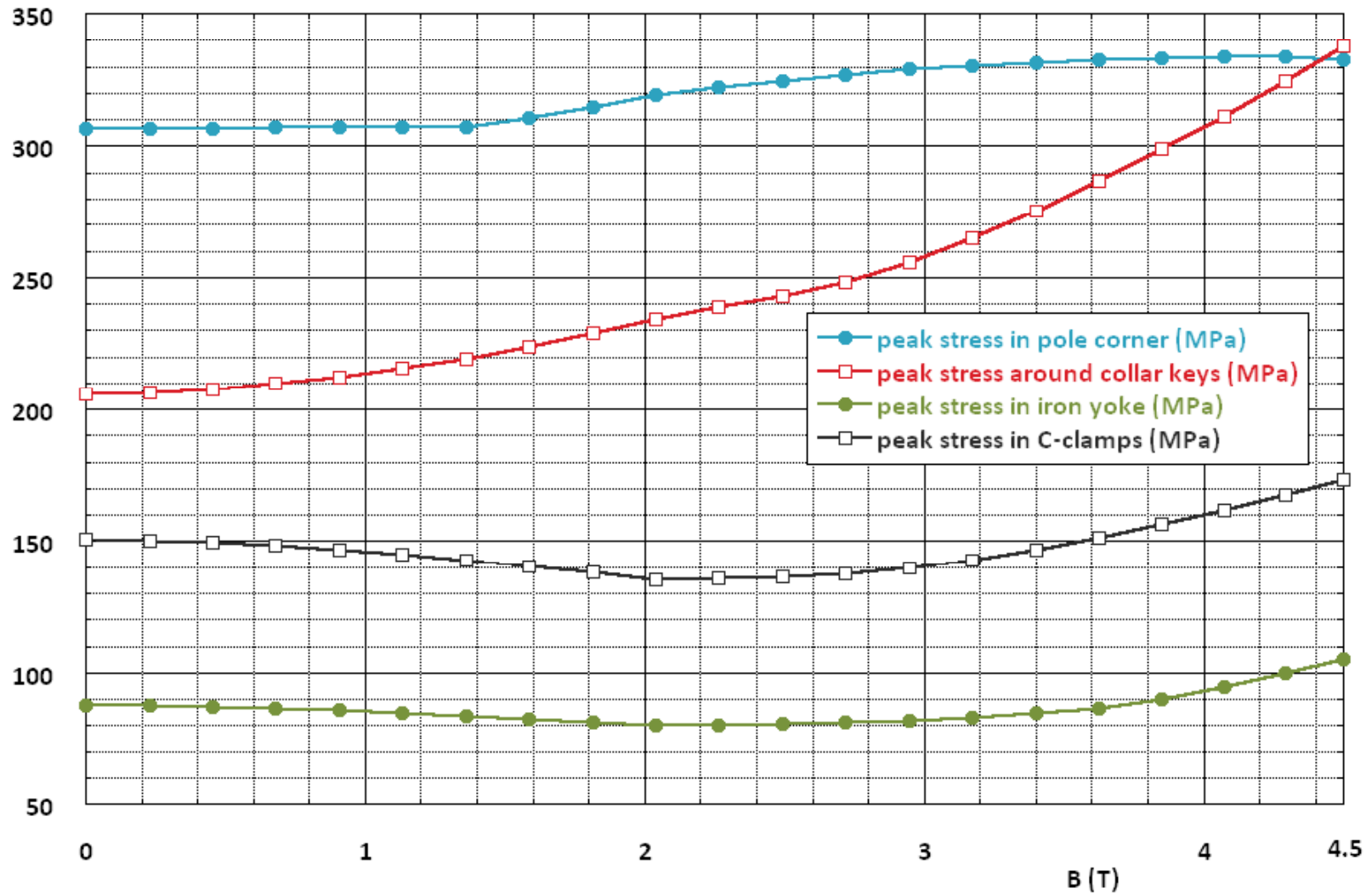




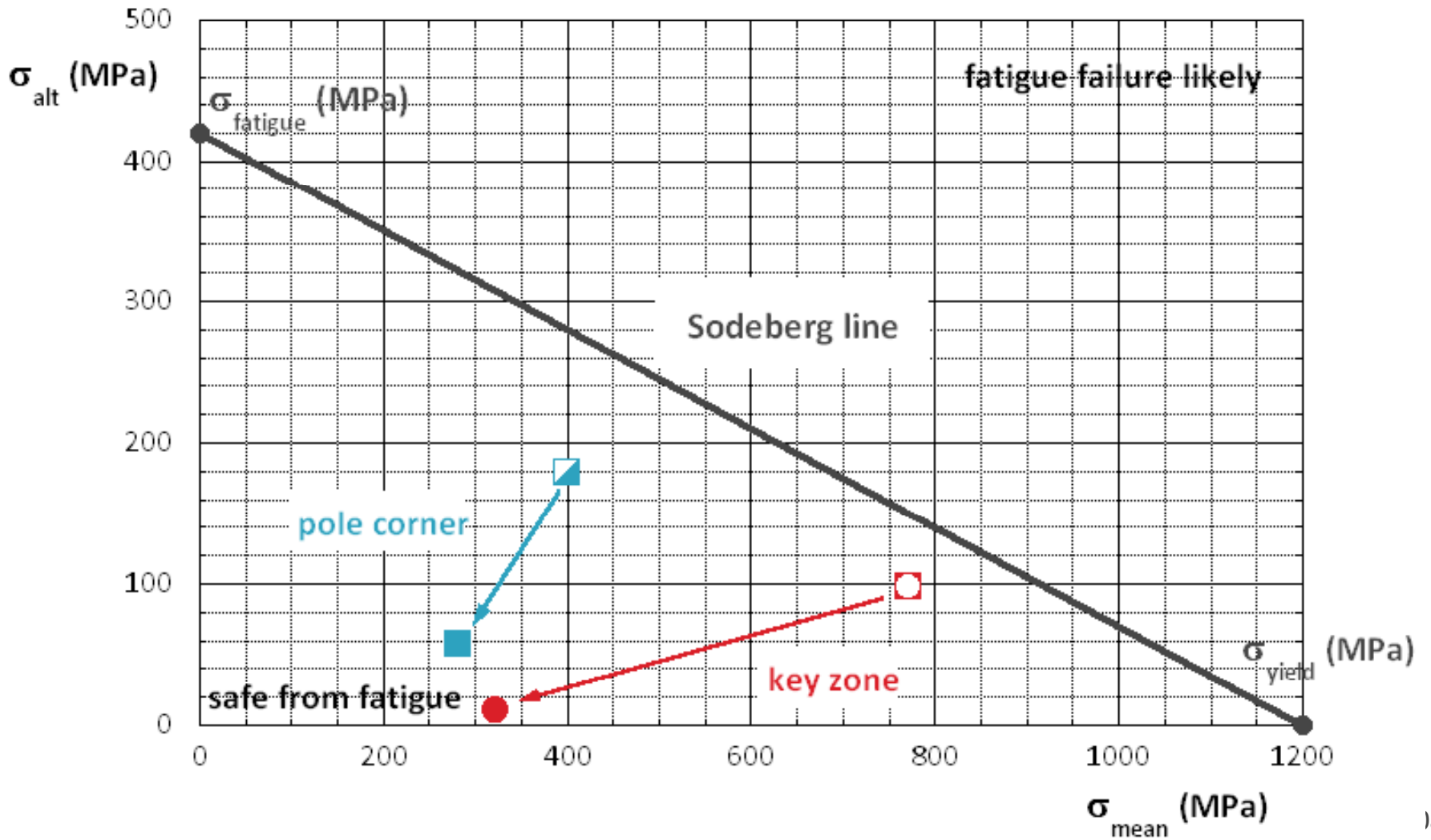
fringe field



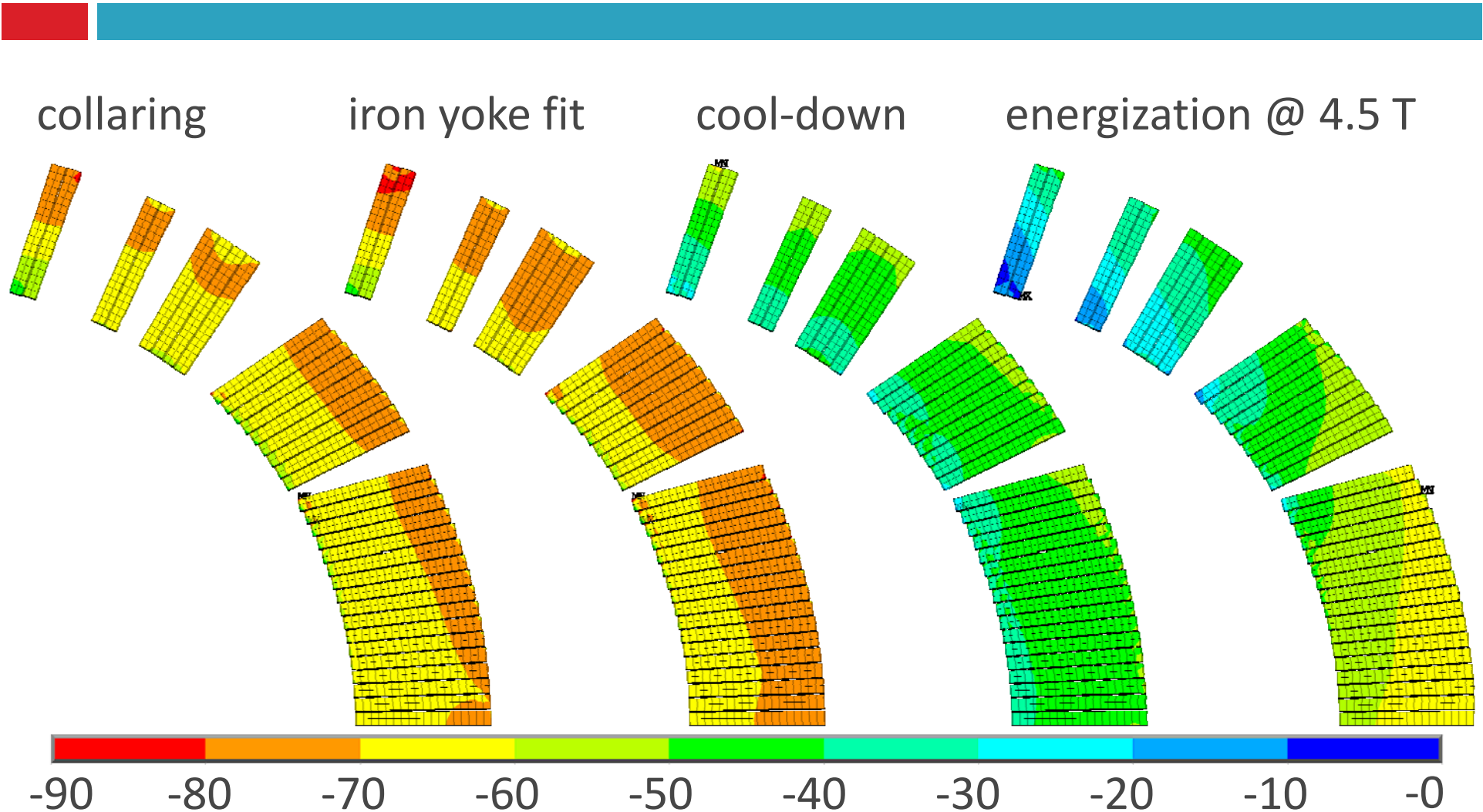
peak Von Mises stress (MPa)



fatigue limit in the range 0-4.5 T



Azimuthal stress in the winding (MPa)



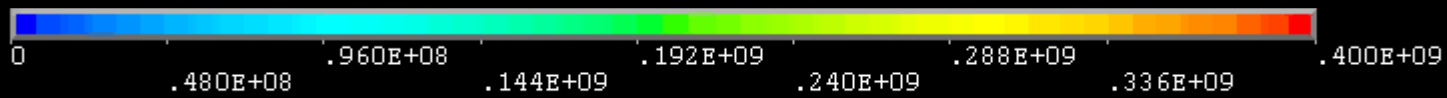
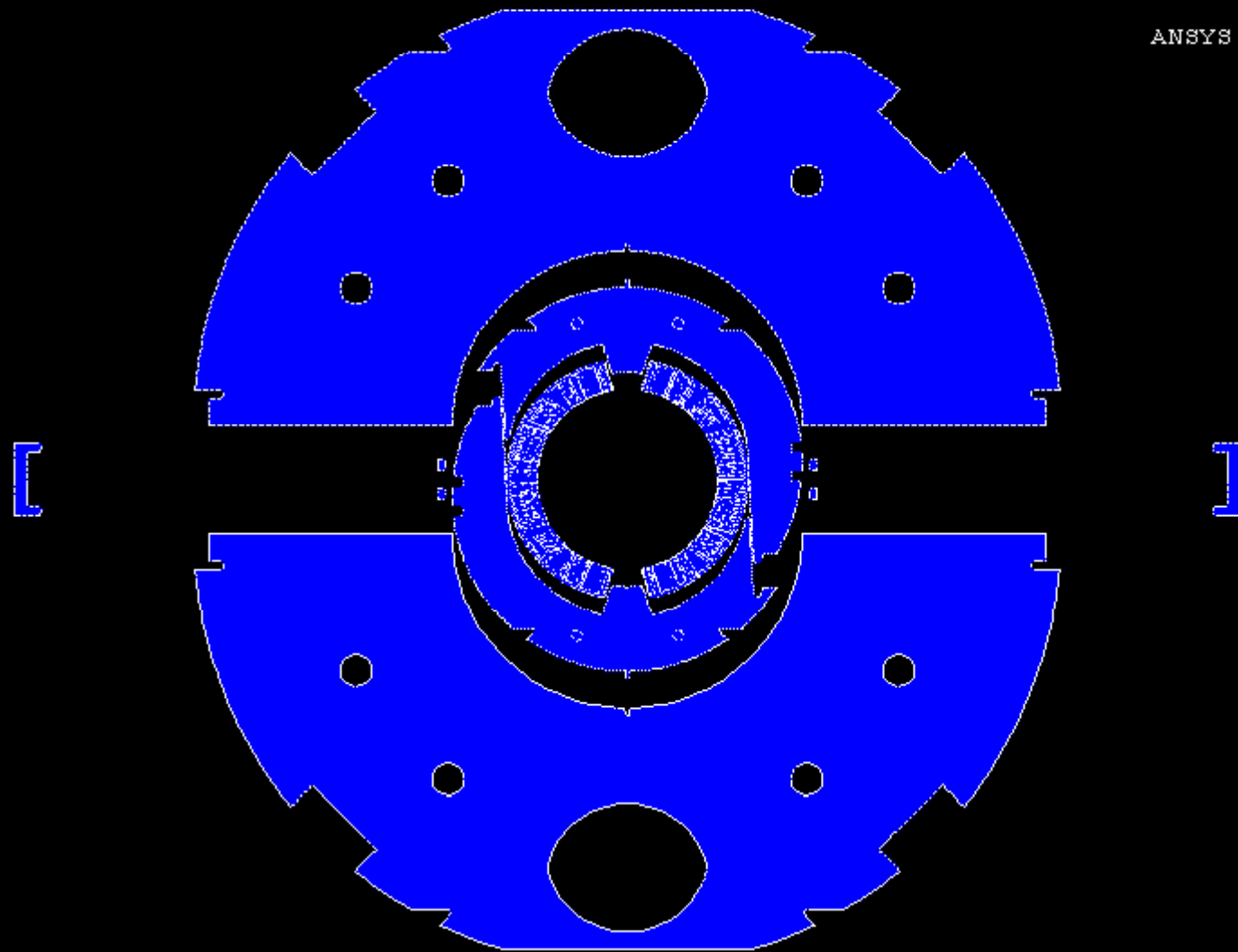


Azimuthal stress in the winding (MPa)

	COLLARING	IRON YOKE FIT	COOL-DOWN	ENERGIZATION @ 4.5 T
average azimuthal stress in the winding (MPa)	-68	-70	-44	-48
minimum azimuthal stress of last turn (MPa)	-39	-41	-29	-7

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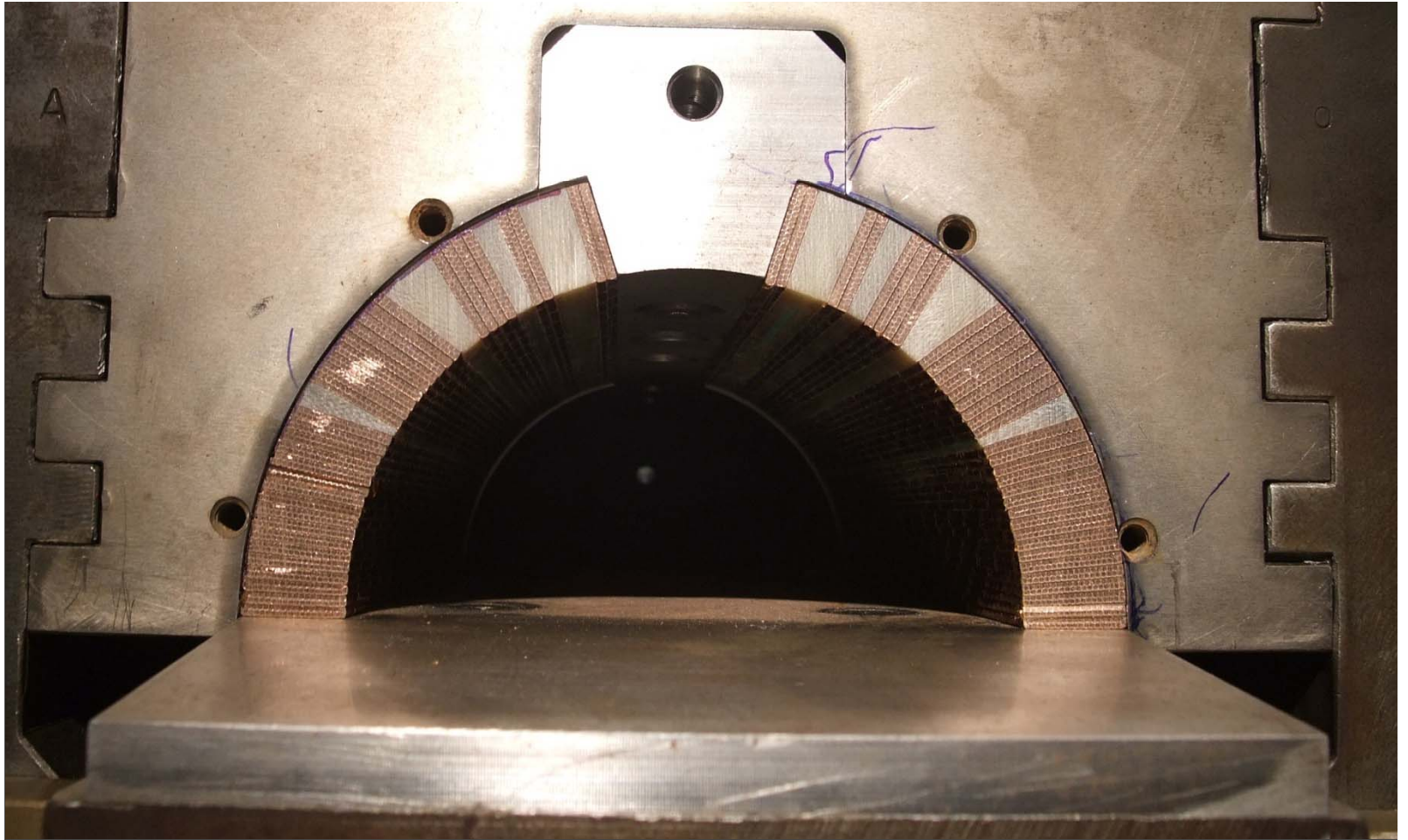


Conclusions

- The mechanical design requires necessarily both the collars and the iron yoke to limit the stresses
- The peak stresses (MPa) are:

	collars	keys	iron yoke	C-clamps
T=4 K, B=0 T	307	102	92	151
T=4 K, B=4.5 T	338	92	111	175

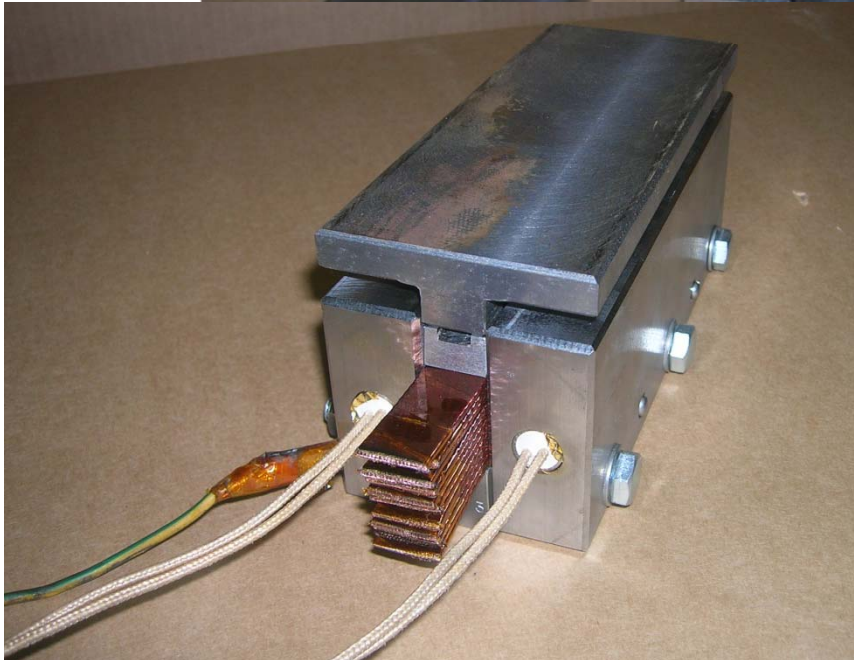
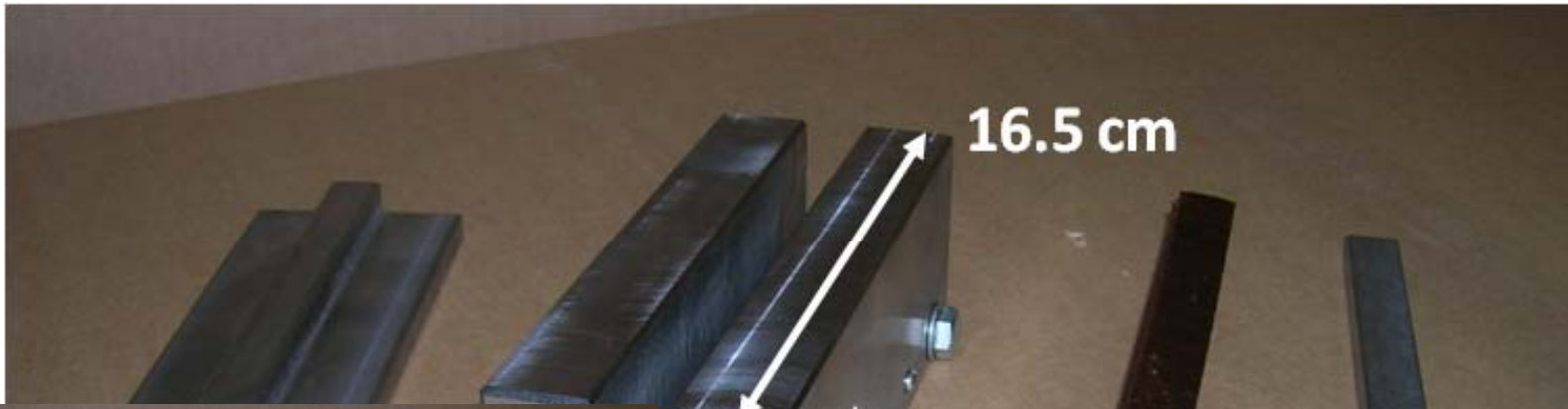
- The fatigue behaviour is especially critical in this project. The largest stress variation in the collar is 116 MPa, well within the limit of the Sodeberg diagram for 10 millions cycles



Mechanical tests

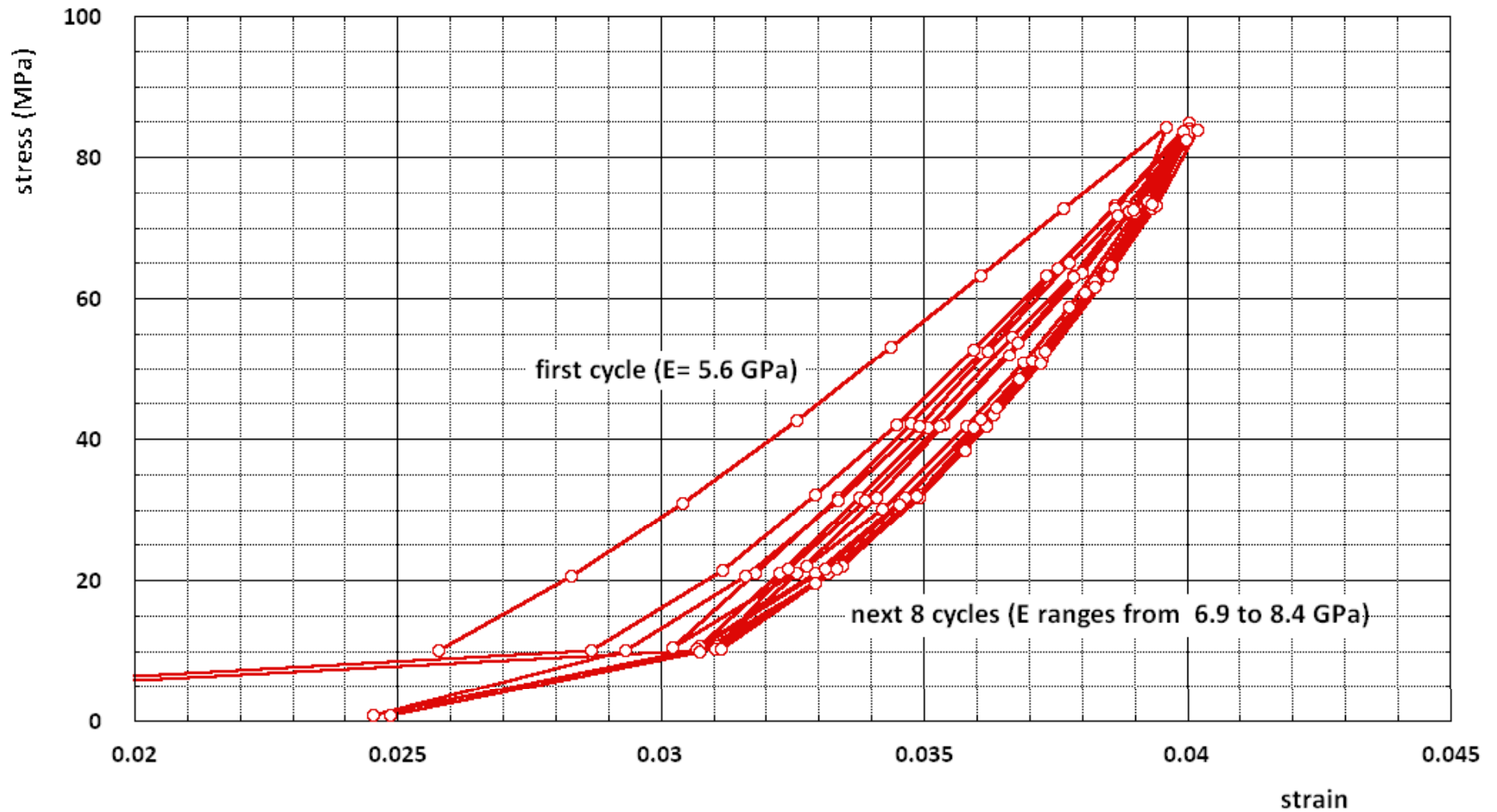


Stacking tests



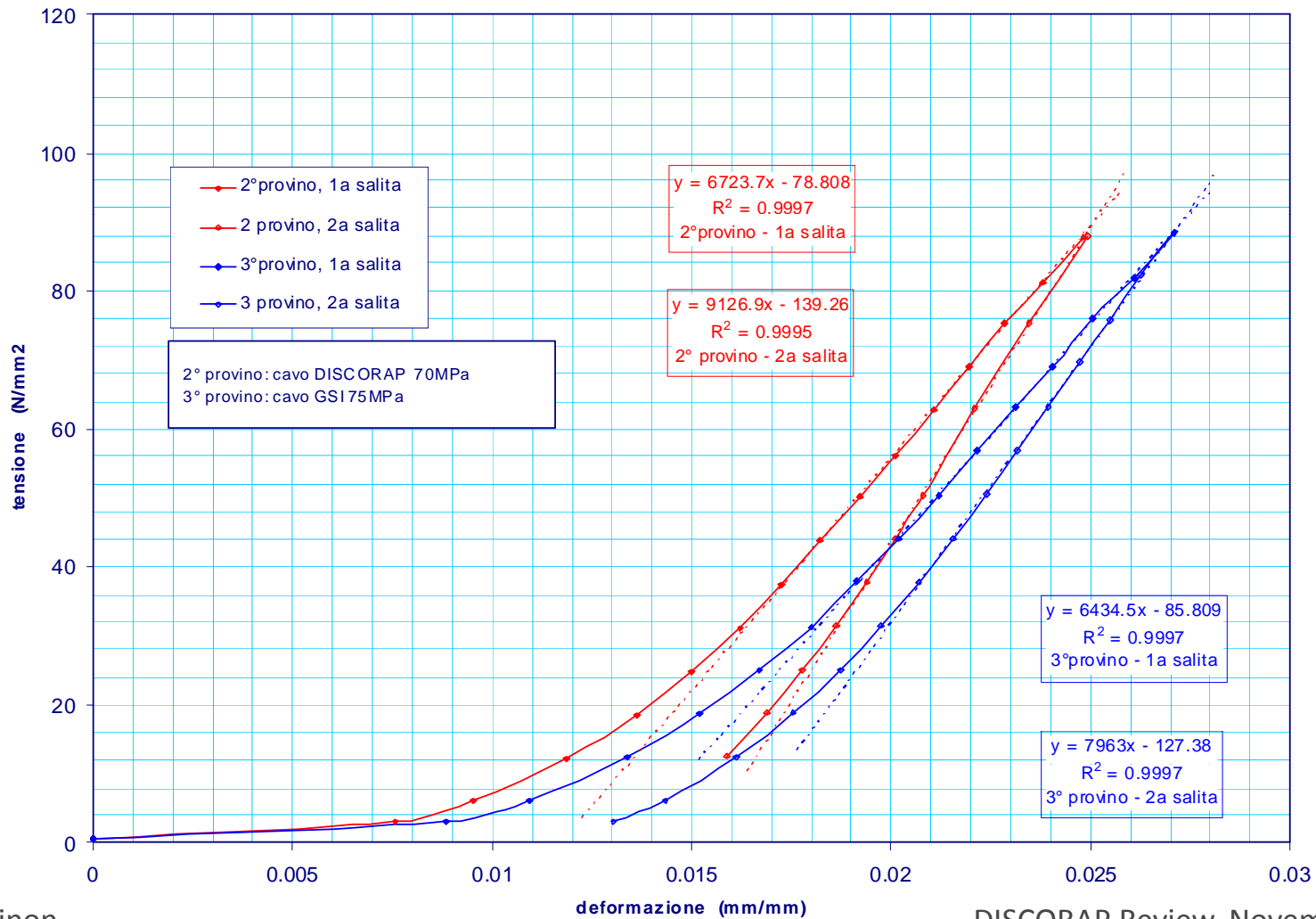


Typical measurement in ASG



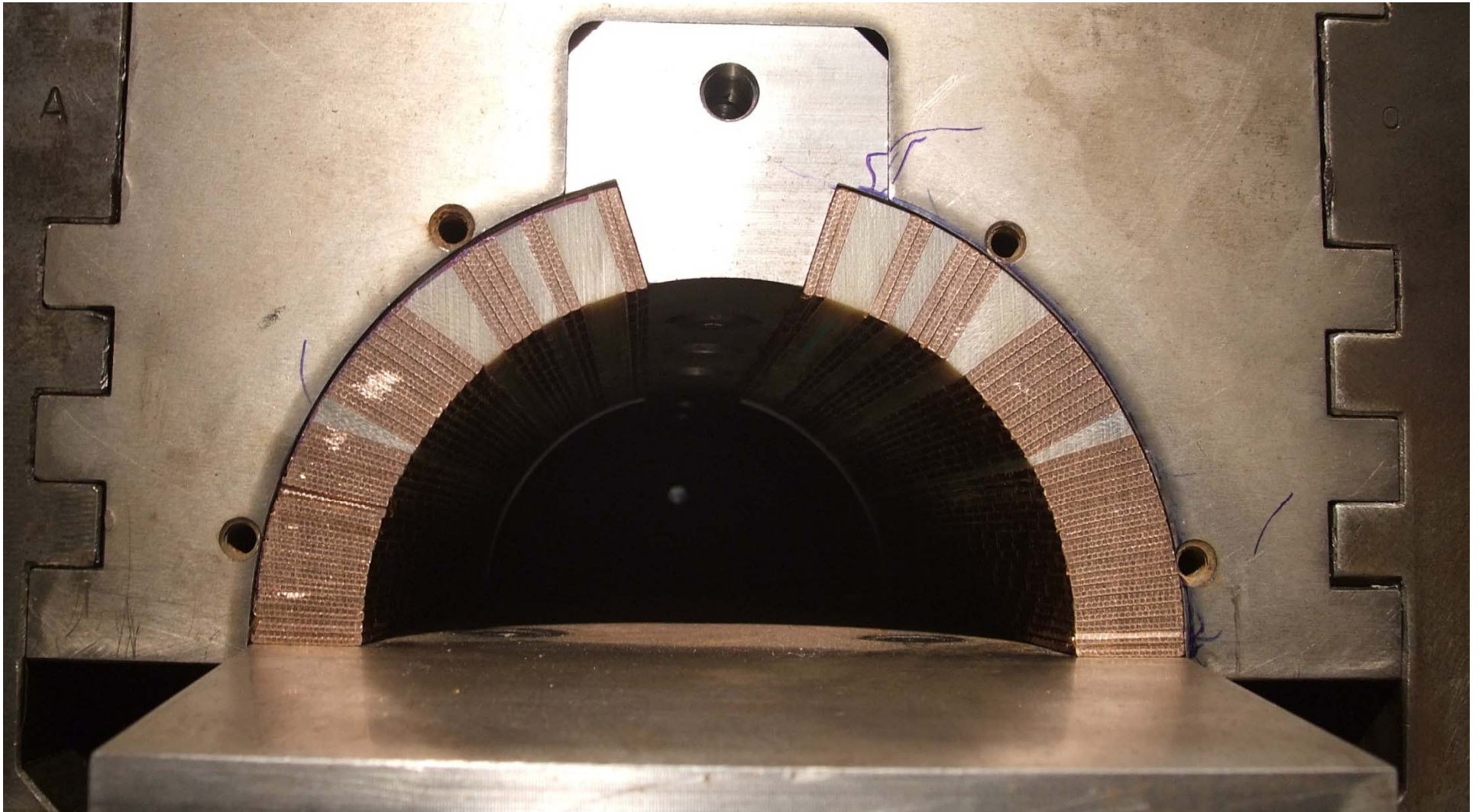


Typical measurement at LASA



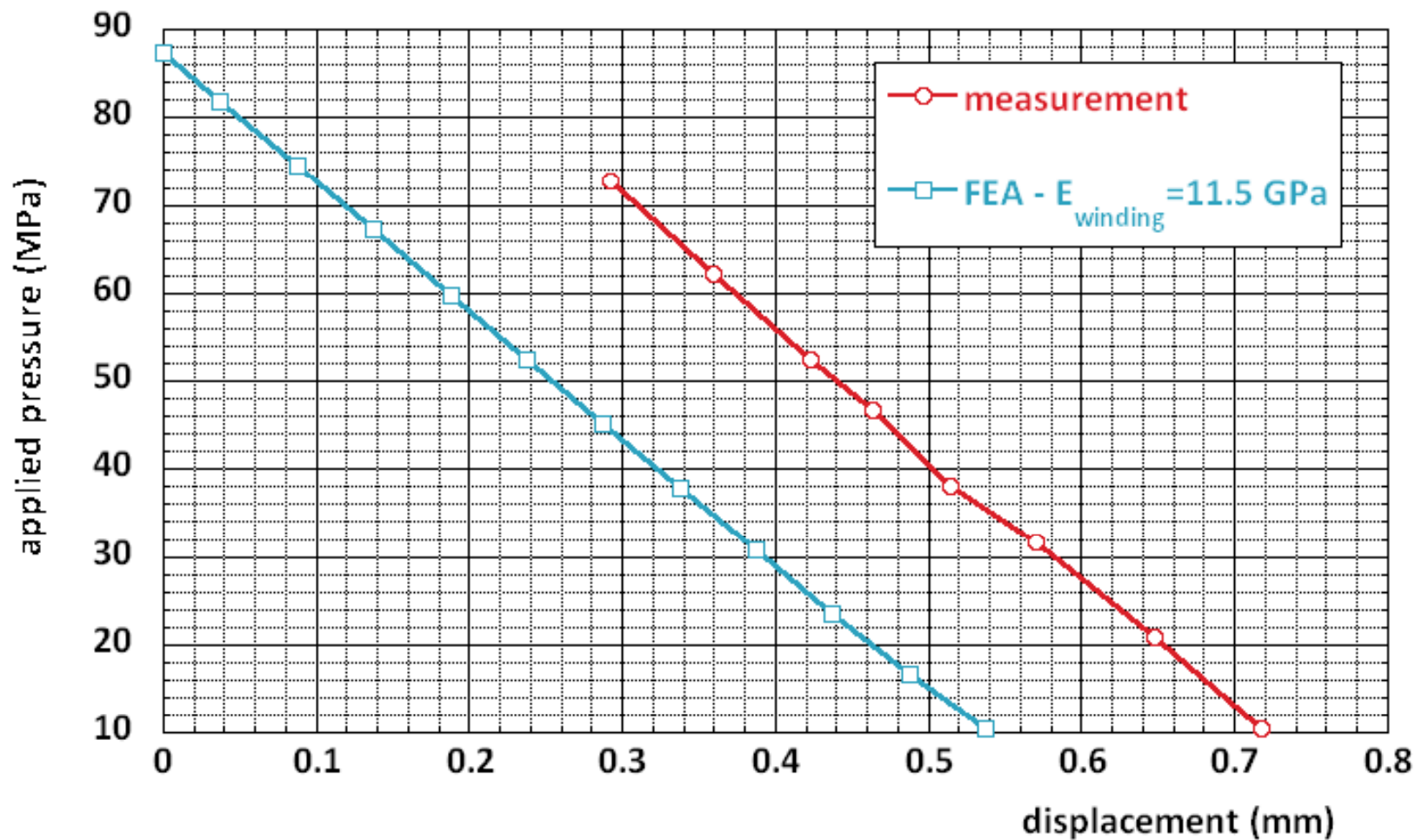


Arc piled tests



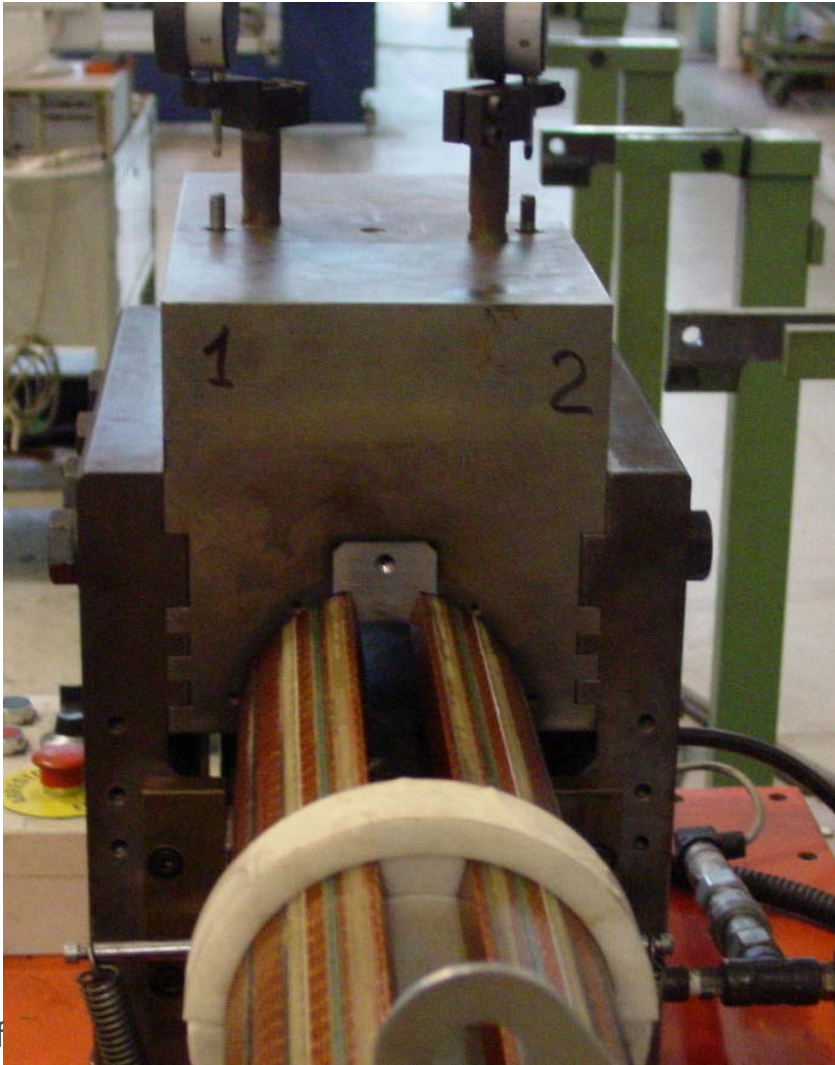


Arc-piled sample (in the FE model $E=11.5$ GPa)





Complete dipole

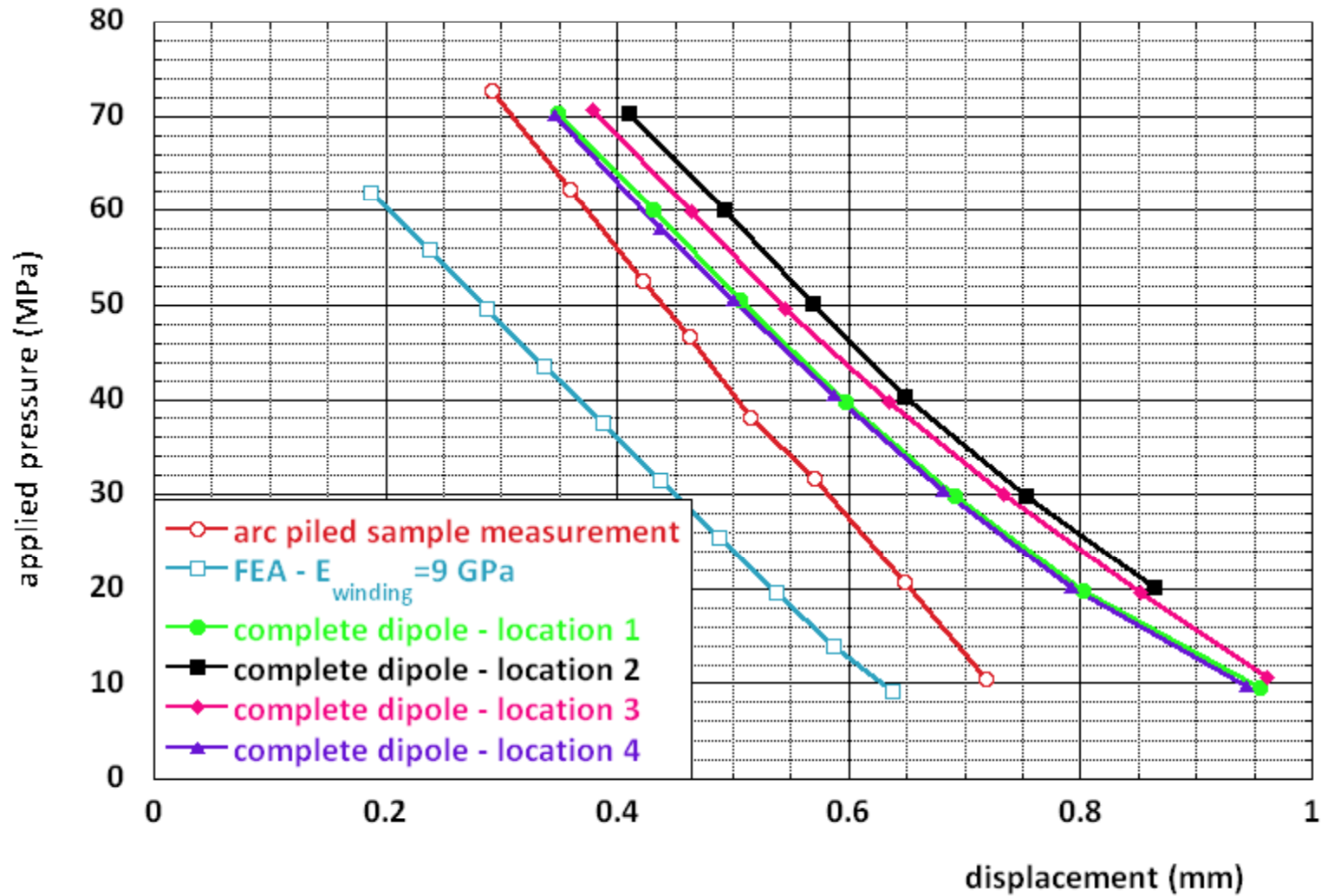


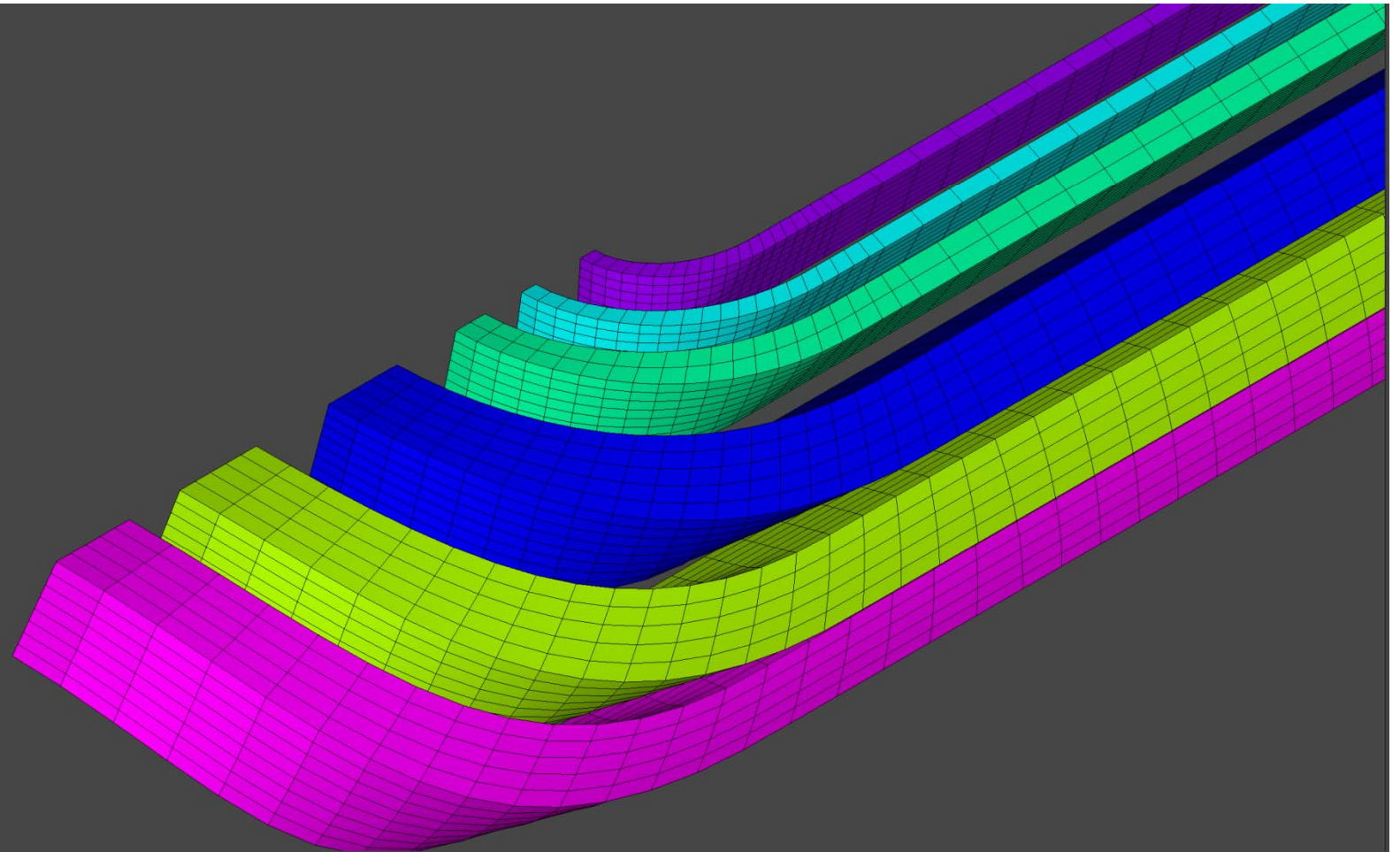
Step





Complete dipole (in the FE model $E=9$ GPa)

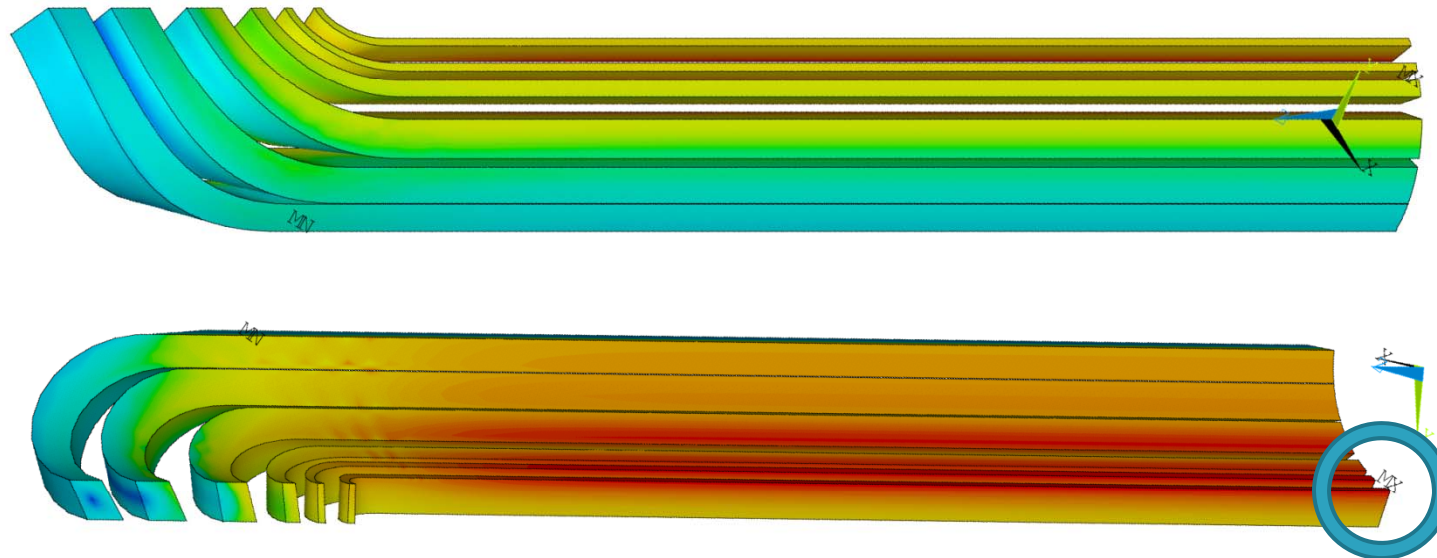




3D mechanical analysis



First step: electromagnetic model



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Blue	.012154
Light Blue	.550273
Cyan	1.088
Green	1.627
Yellow-Green	2.165
Yellow	2.703
Orange	3.241
Red-Orange	3.779
Red	4.317
Dark Red	4.855



Lorentz forces

Straight section	Fx (MN/m)	Fy (MN/m)	Fz (MN/m)
3D	+0.678	-0.300	0
2D	+0.684	-0.301	0

Coil ends	Fx (kN)	Fy (kN)	Fz (kN)
3D total	+53.815	-29.324	+23.322
Block #1a	+ 7.2	- 3.6	+ 1.2
Block #1b	+14.0	-11.3	+ 7.2
Block #2	+17.6	-10.1	+ 8.8
Block #3	+ 7.9	- 2.8	+ 3.5
Block #4	+ 3.9	- 1.0	+ 1.6
Block #5	+ 3.1	- 0.5	+ 1.0



Second step: mechanical analysis

ELEMENTS
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