

EuroCirCol

Status of block design mechanics

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CEA

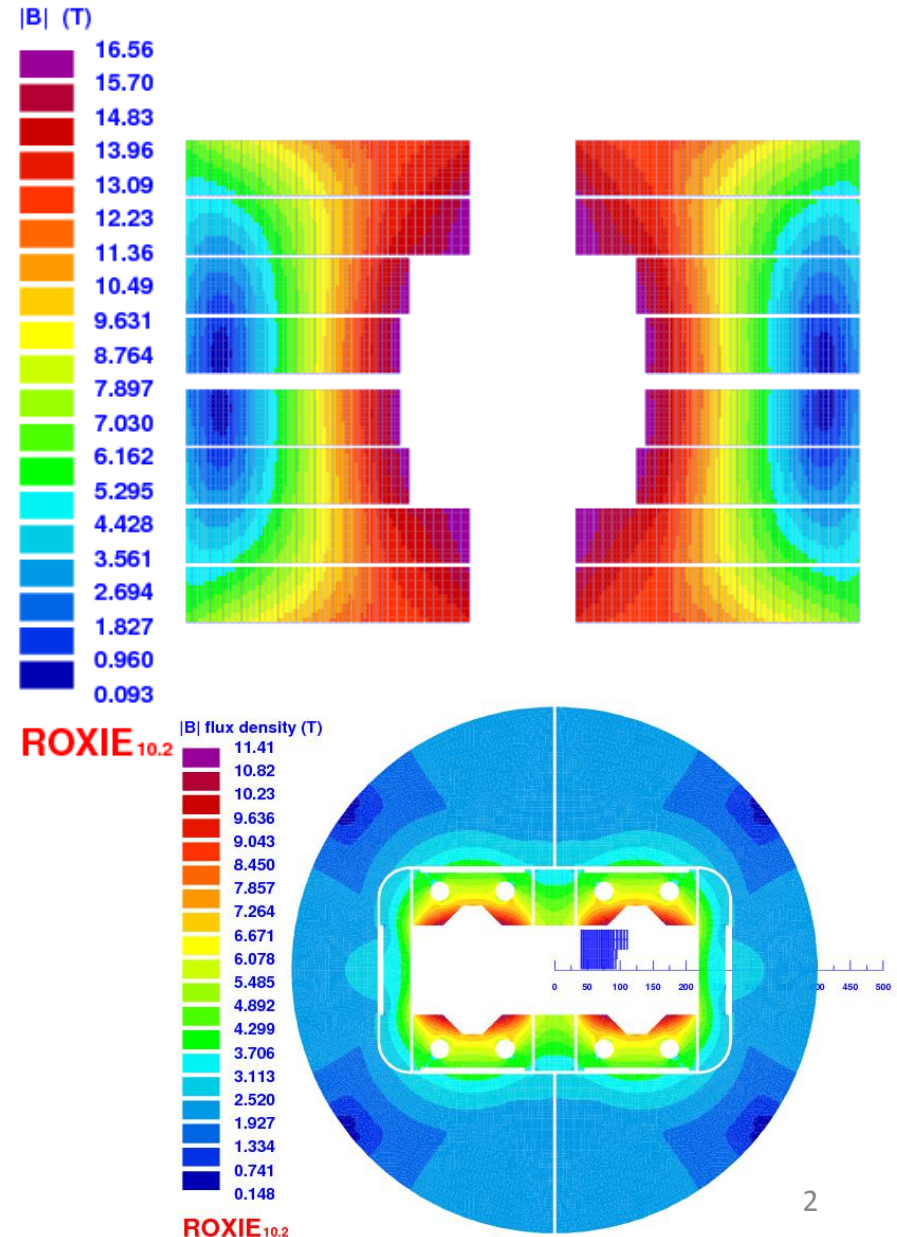
Cern, 12 May 2016

Reminder of the block magnet

- Two cables
 - HF cable: $\Phi = 1.1$ mm, 24 strands
13.85 mm x 2 mm
 - LF cable $\Phi = 0.7$ mm, 37 strands
13.85 mm x 1.25 mm

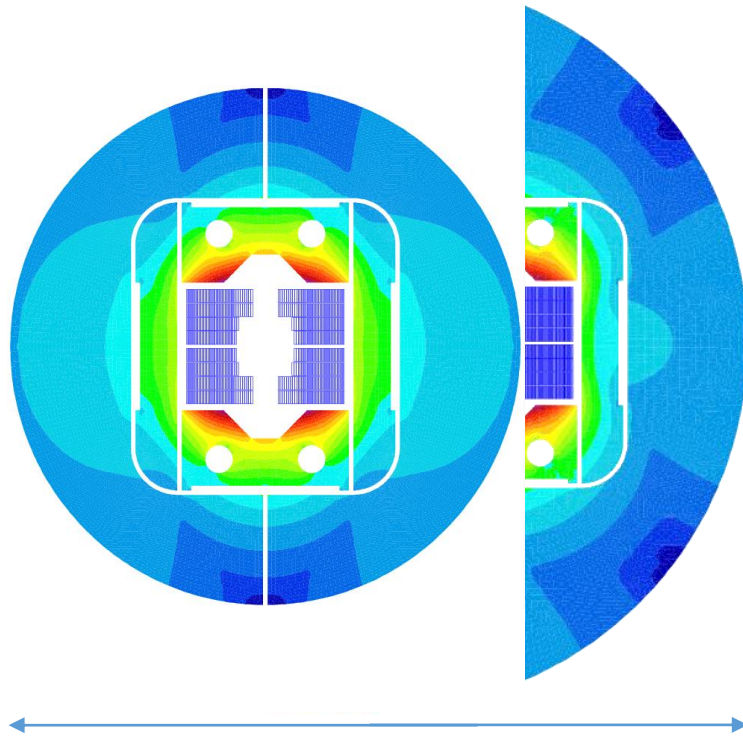
Quantity	Value	Unit
I_{nom}	8470	A
B_{peak}	16.56	T
LL margin	9.3	%
Inductance diff. (2 ap)	88.19	mH/m
Stored energy (2 ap)	3340	kJ/m
Conductor area (2 ap)	190*	cm ²
F_x (per ½-coil)	8817	kN/m
F_y (per ½-coil)	-3703	kN/m
Hotspot	310	K

*10800 tons



Mechanical specifications

- Single Aperture (SA) configuration: $\Phi_{\text{yoke}} = 800 - 250 = 550 \text{ mm}$



Baseline :

- Investigation at **16.8 T** central field (**105%** of nominal current)
- Mechanical structure must withstand 18 T
- Coil maximum stress
 - @ 4.2 K: 200 MPa
 - @ 300 K: 150 MPa

Mechanical specifications

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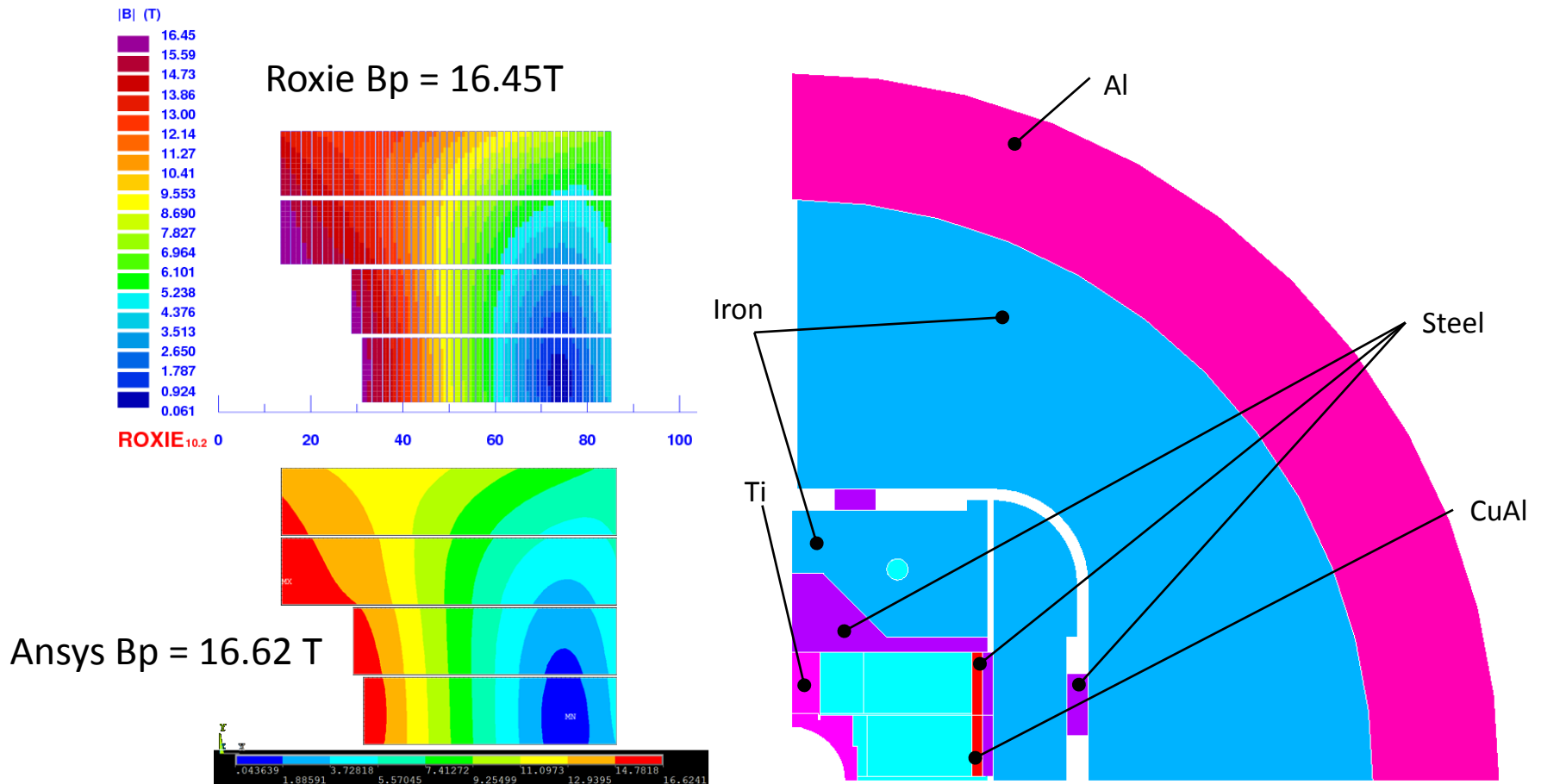
Material	$R_{p0.2}$ [MPa]	
	293 K	4.3 K
Al 7075	480	690
SS 316 LN	286	930
NITRONIC 40	353	1240
MAGNETIL	180	723
Ti 6Al 4V	827	1654

Material	E [GPa]		pr	$(L_{4.3K} / L_{293K}) / L_{293K}$
	293 K	4.3 K		
Coil	EX = 44 EY = 52 GXY = 21	EX = 44 EY = 52 GXY = 21	0.3	X = 3.36e-3 Y = 3.08e-3
StSt	193	210	0.28	2.84e-3
Iron	213	224	0.28	1.97e-3
Aluminum	70	79	0.34	4.2e-3
Titanium	130	130	0.3	1.74e-3
Nitronic 40	210	225	0.28	2.6e-3

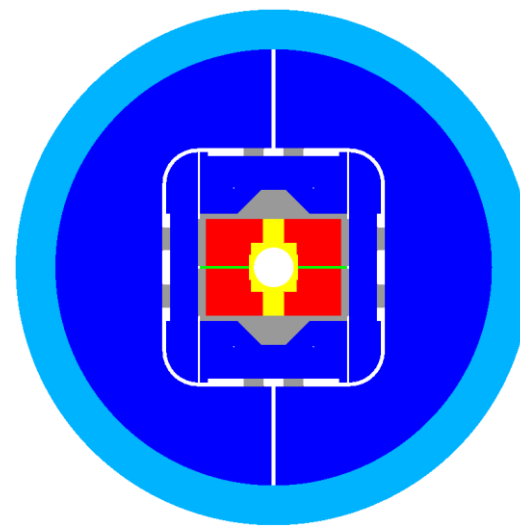
Iron @ 4.2 K stress < 200 MPa in tension (brittle) ?

Lorentz forces

- Comparison Roxie @ 16 T central field (Ansys + Cast3m)



Assembly steps



Assembly steps

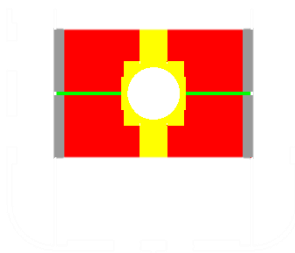


Pole

Ti6Al4V



Assembly steps



Pole

Ti6Al4V



Windings

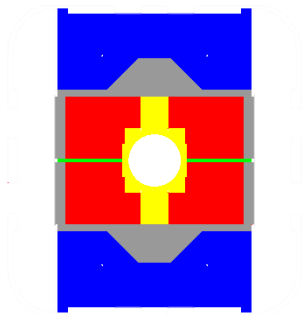
Nb₃Sn



Pad

StSt

Assembly steps



Pole

Ti6Al4V



Windings

Nb₃Sn



Pad

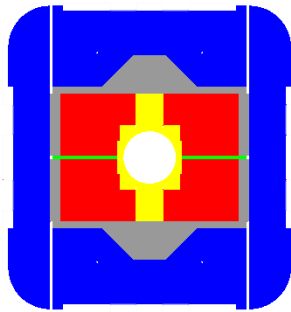
StSt



Pad

Iron

Assembly steps



Pole

Ti6Al4V



Windings

Nb₃Sn



Pad

StSt

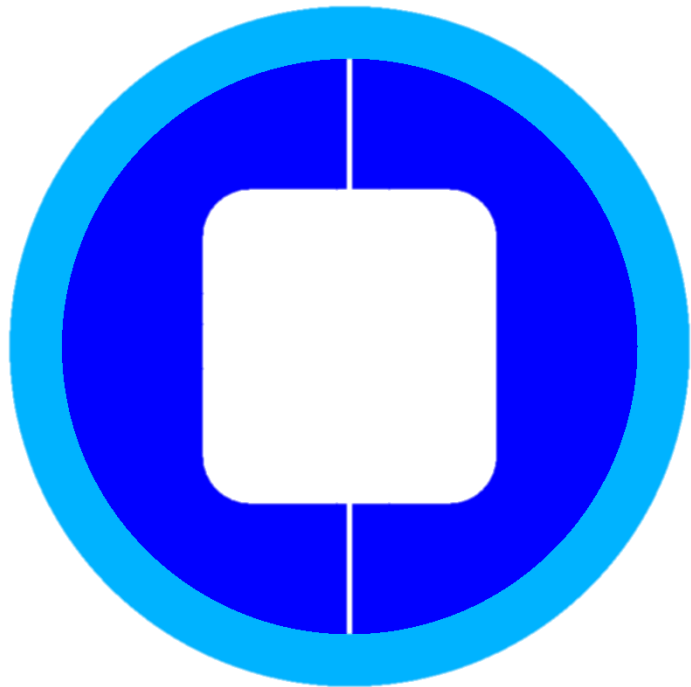


Pad

Iron

-> Coil pack

Assembly steps



Yoke

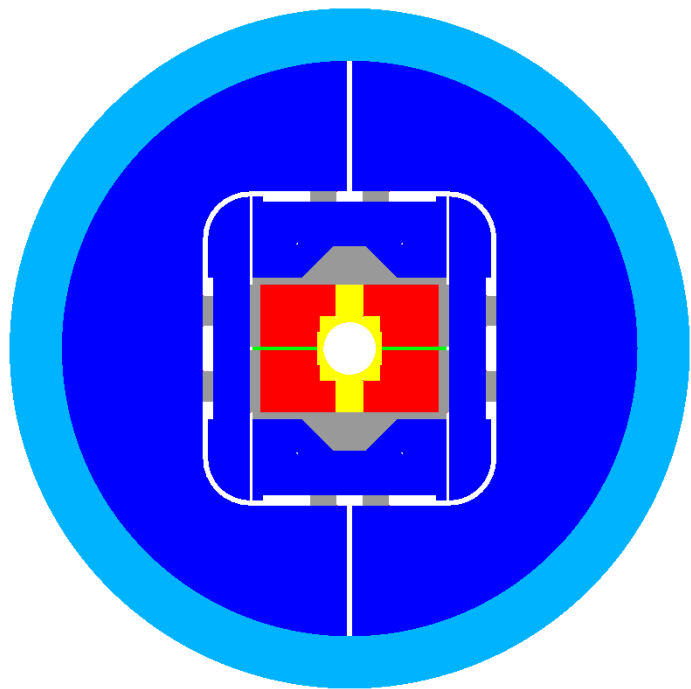
Iron



Shell

Aluminium

Assembly steps



Pole

Ti6Al4V



Bobines

Nb₃Sn



Pad

StSt



Pad + Yoke

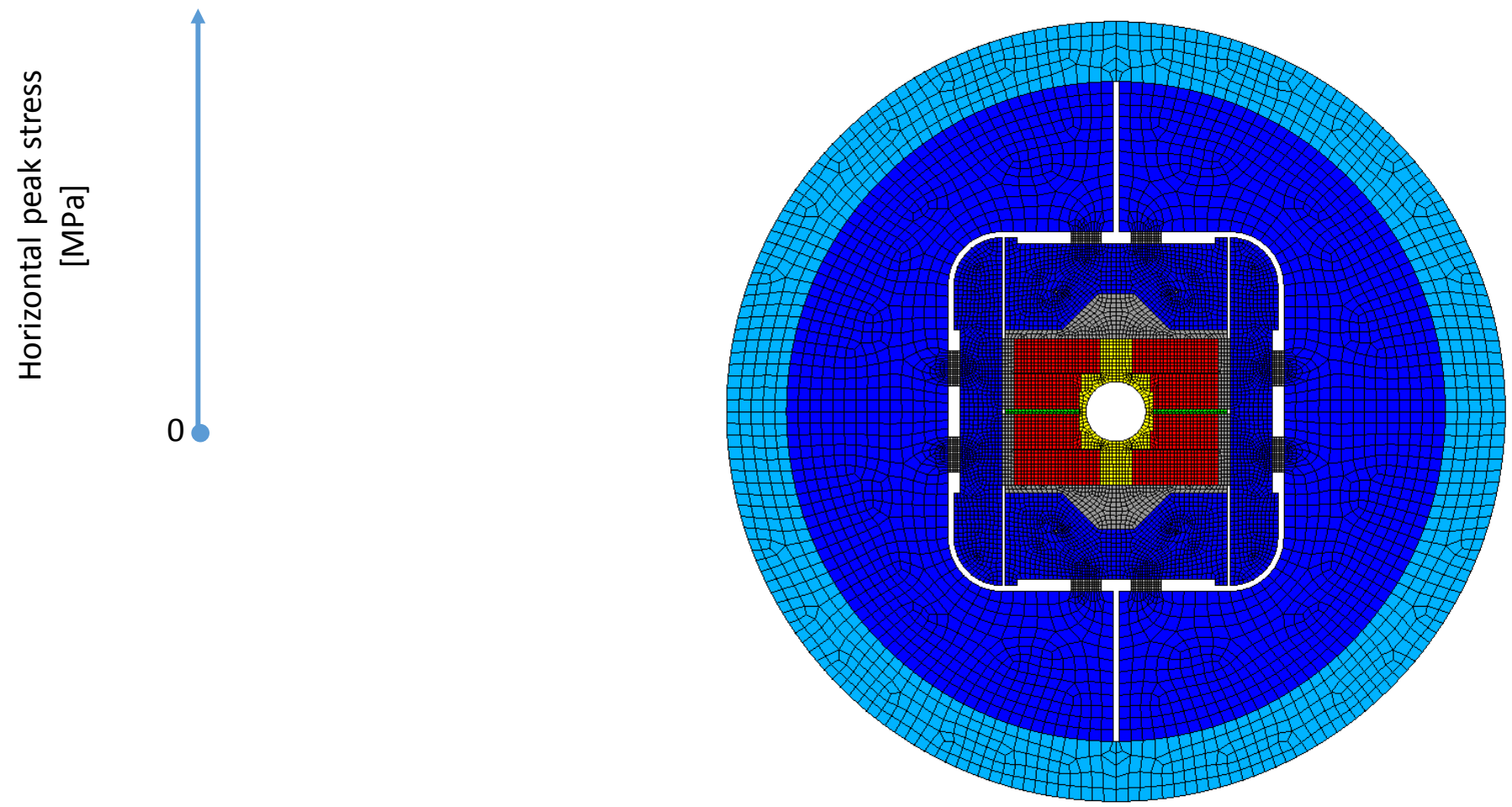
Iron



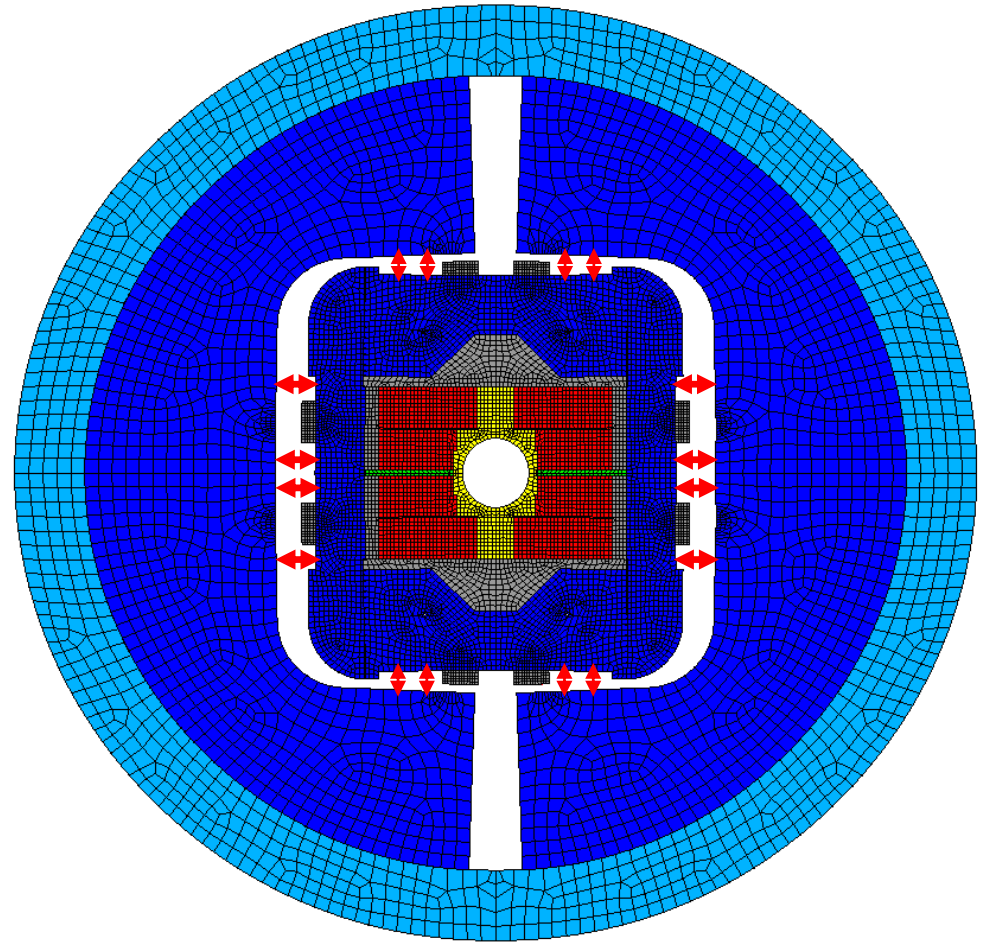
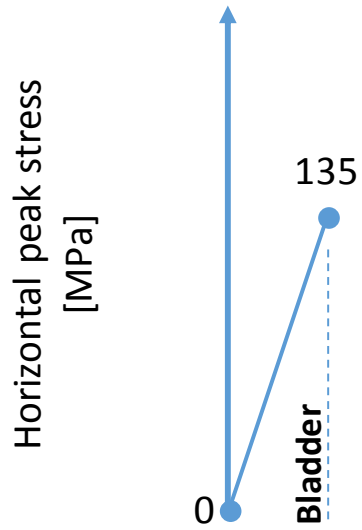
Shell

Aluminium

Magnet *at ease*

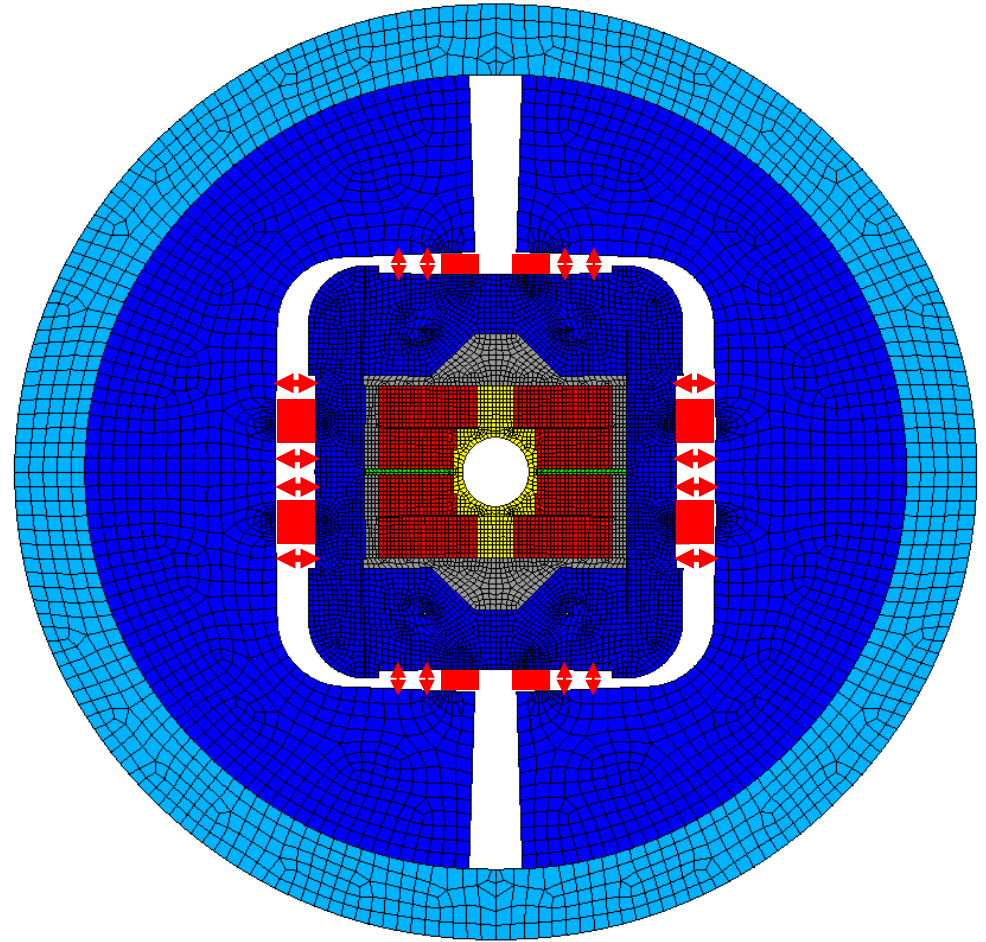
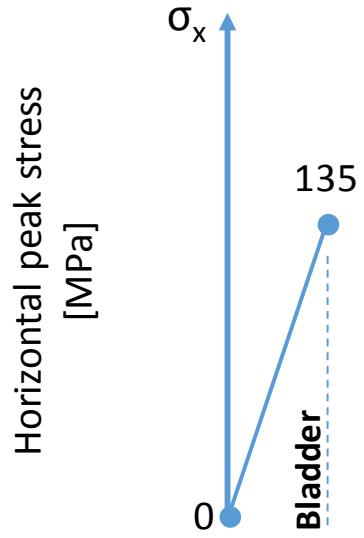


Bladder inflation

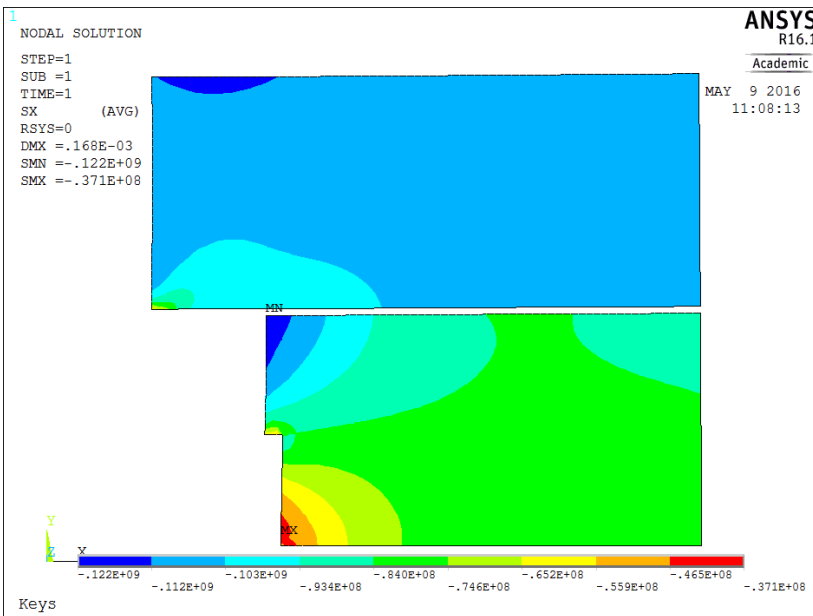
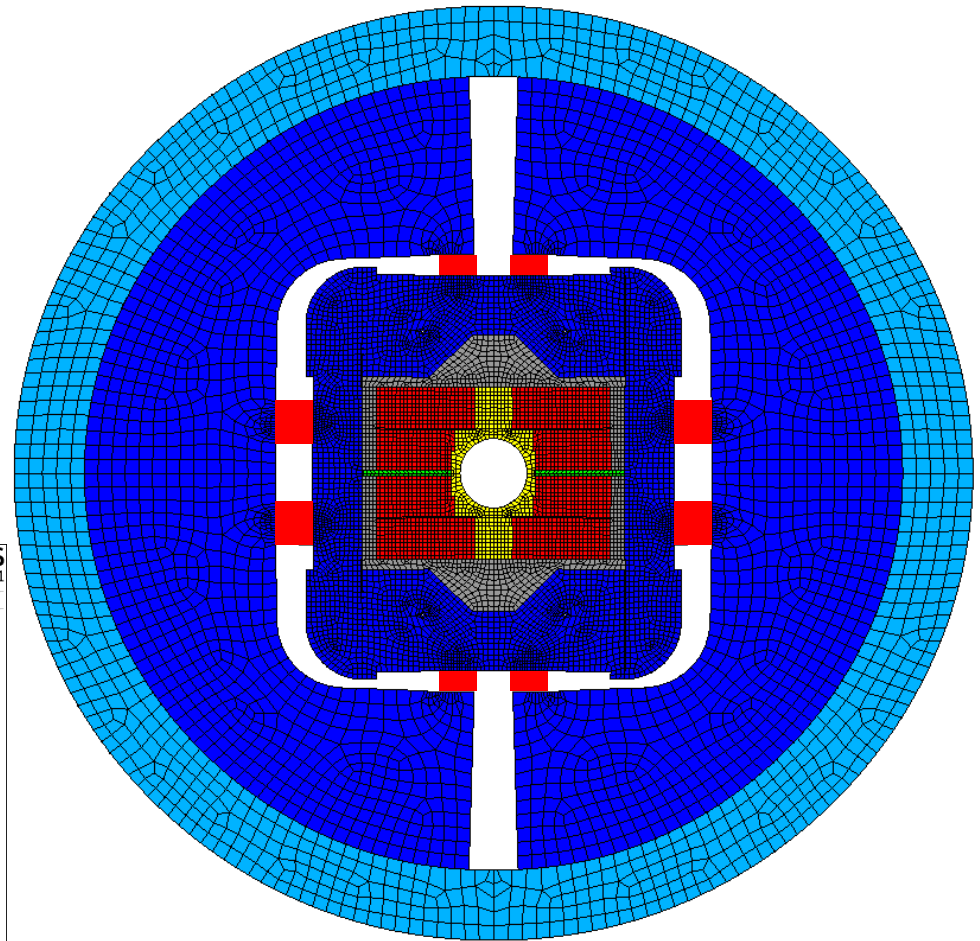
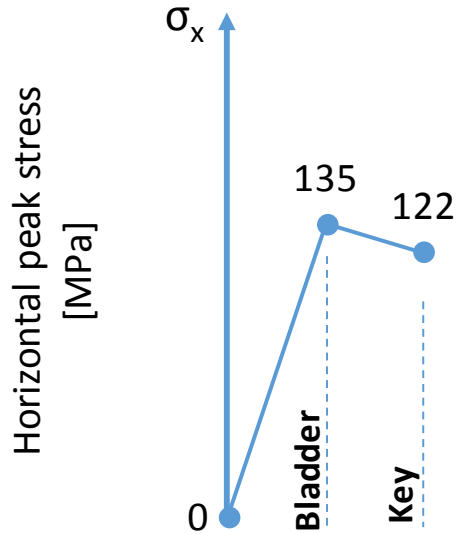


Not simulated so far,
estimated only

Key insertion



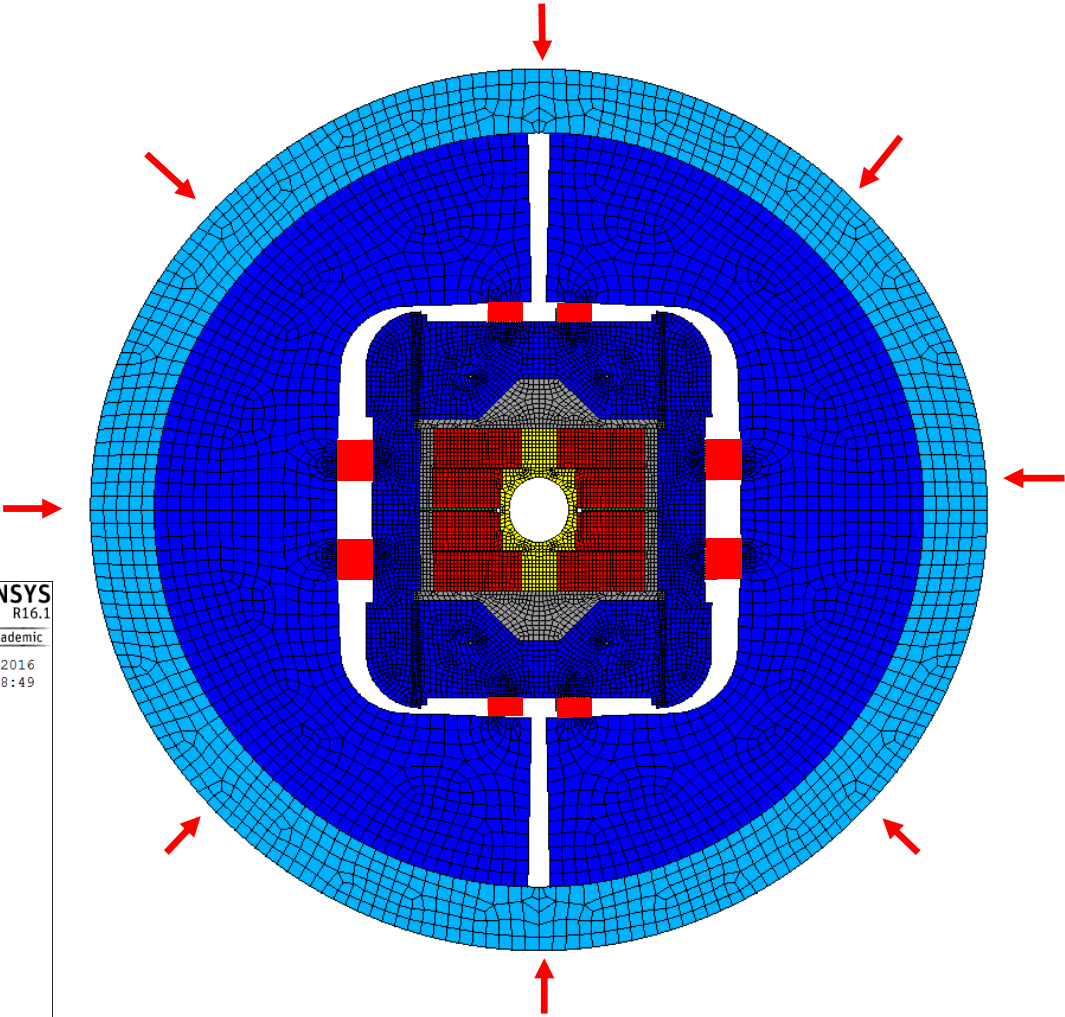
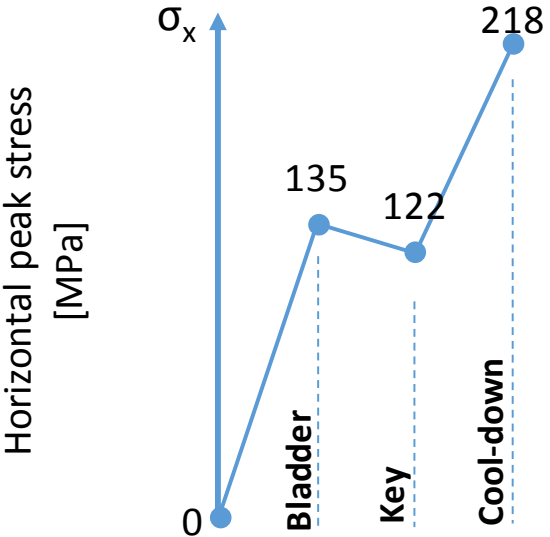
Spring back



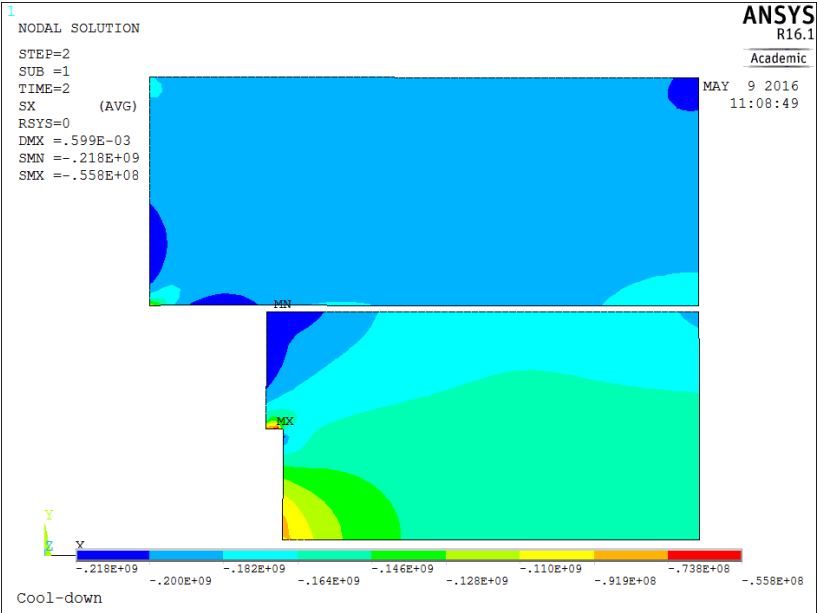
scale: -122 MPa to -37 MPa

- ↓ Horizontal key: nominal + 150 μm
- ← Vertical key: nominal + 1050 μm

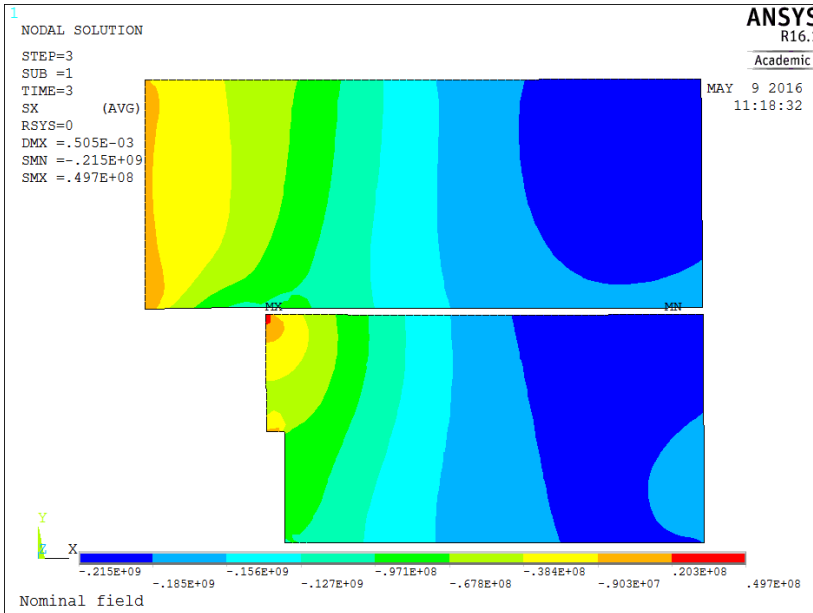
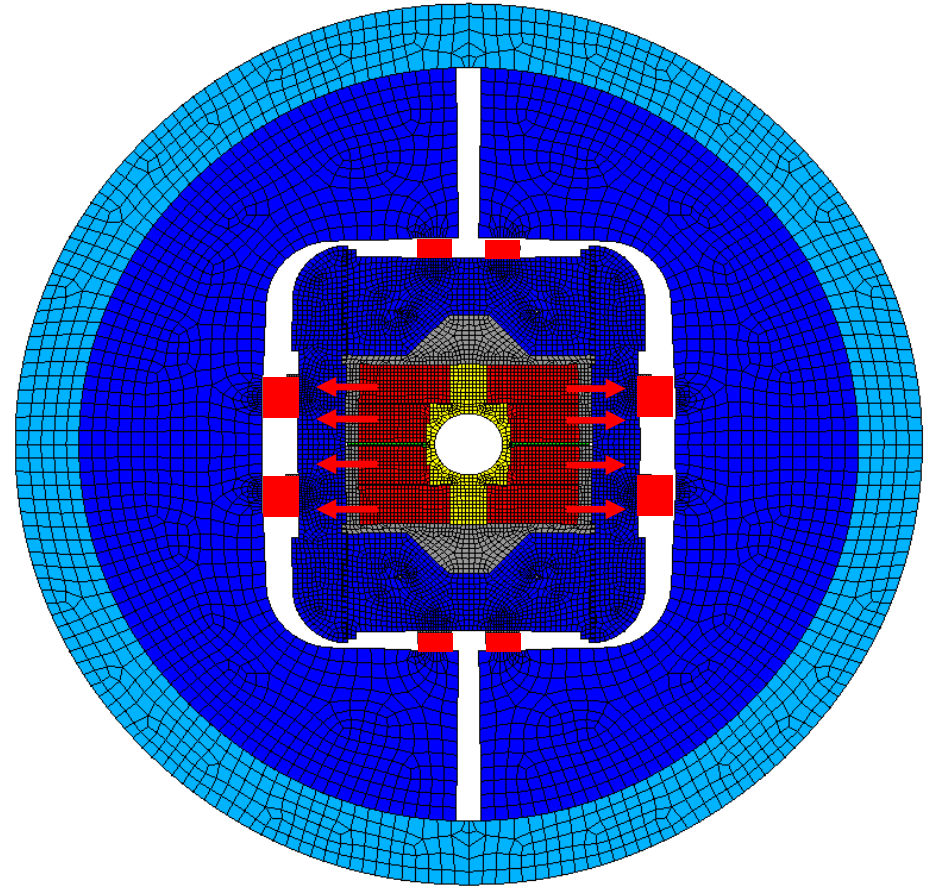
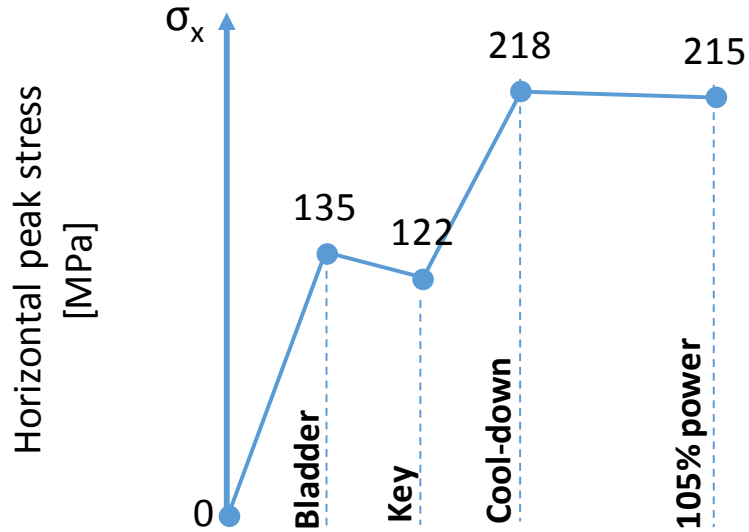
Cool-down



Shell thickness: 50 mm

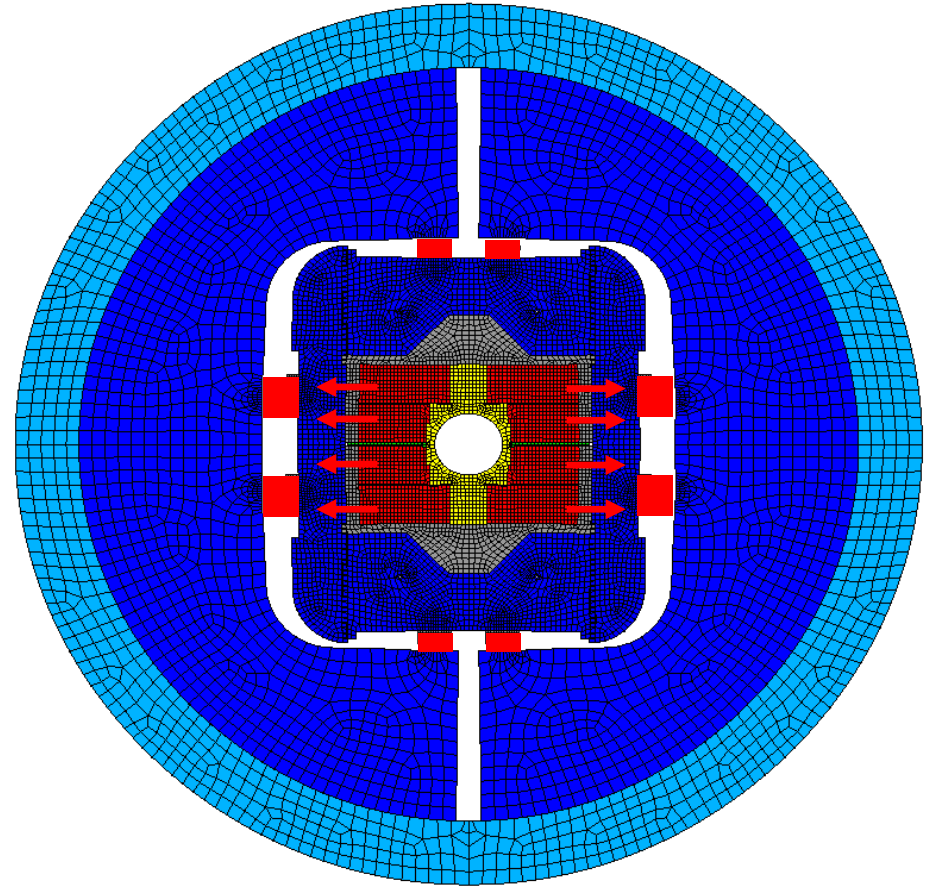
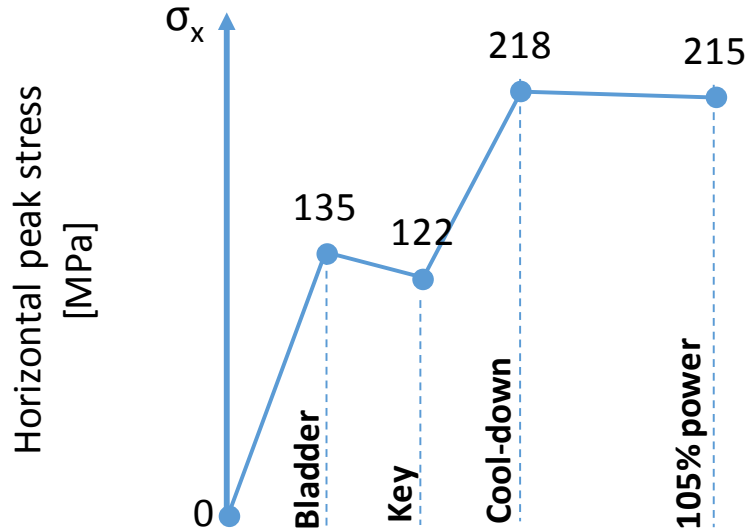


Powering to 105% (16.8 T)



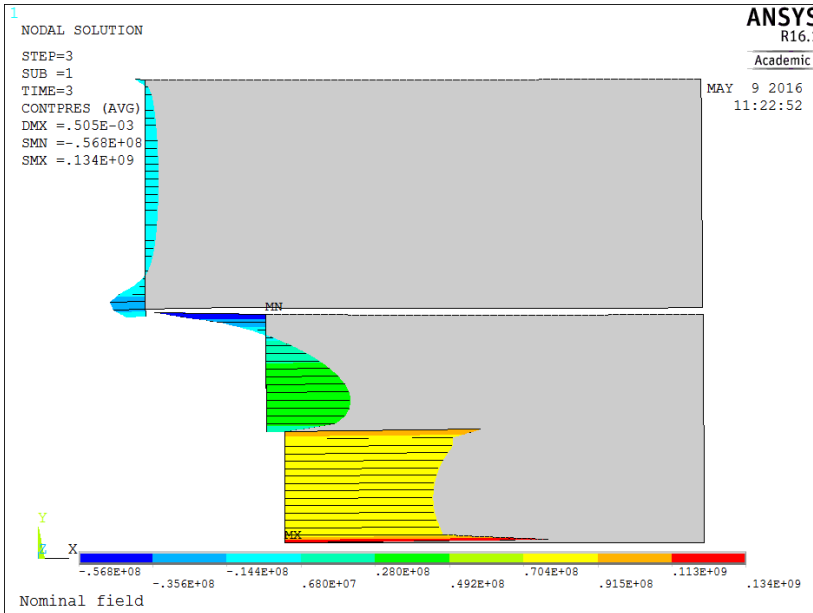
scale: -215 MPa to +50 MPa

Contact coil-pole at 105 % (16.8T)



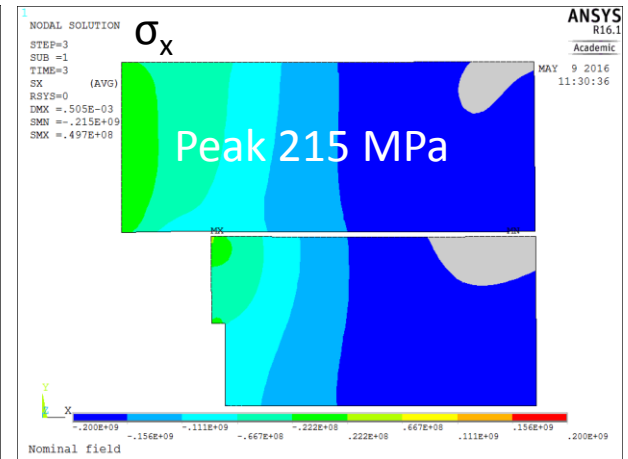
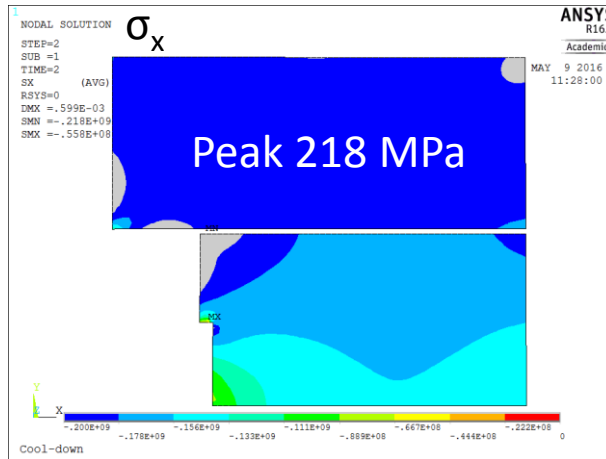
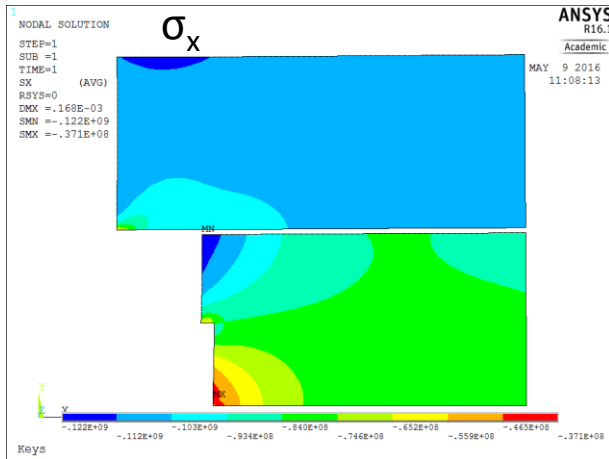
16.8 T

Contact: 2 MPa in the middle of the cable



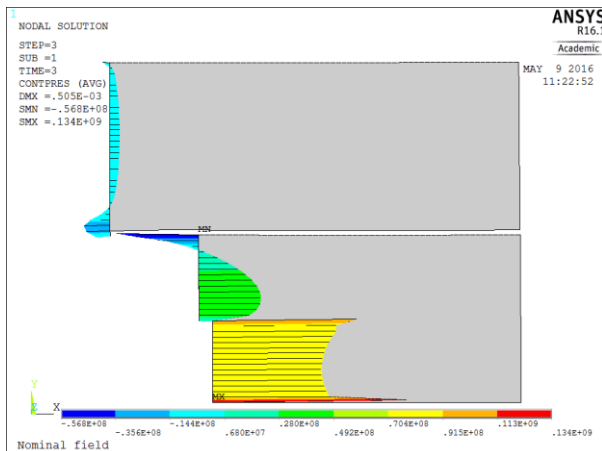
Summary for windings + contact

- Key (bladder tbc)
- Cool-down
- Powering 105%

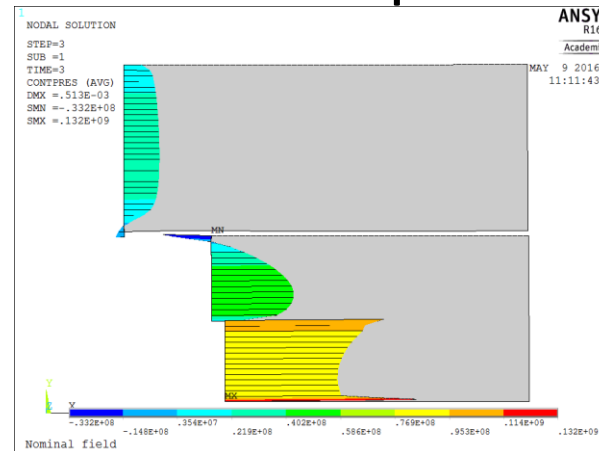


- Contact coil-pole 105%

- Contact coil-pole 100%



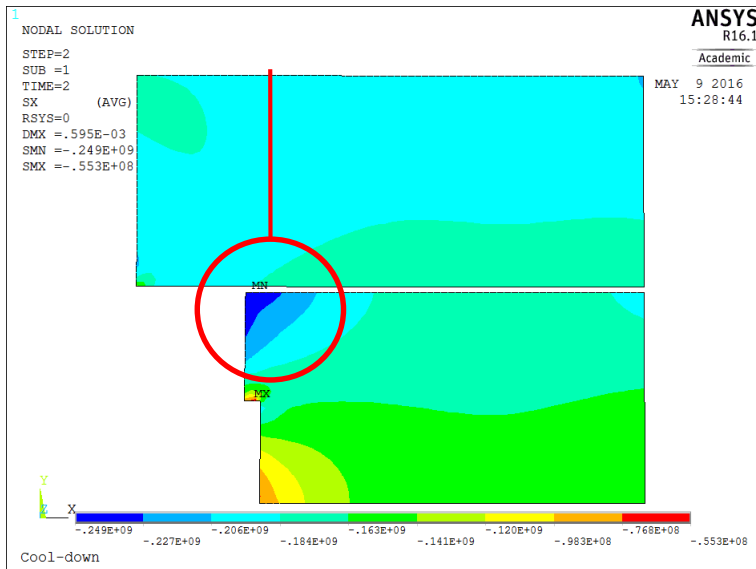
scale: -57 MPa to +134 MPa



scale: -34 MPa to +132 MPa

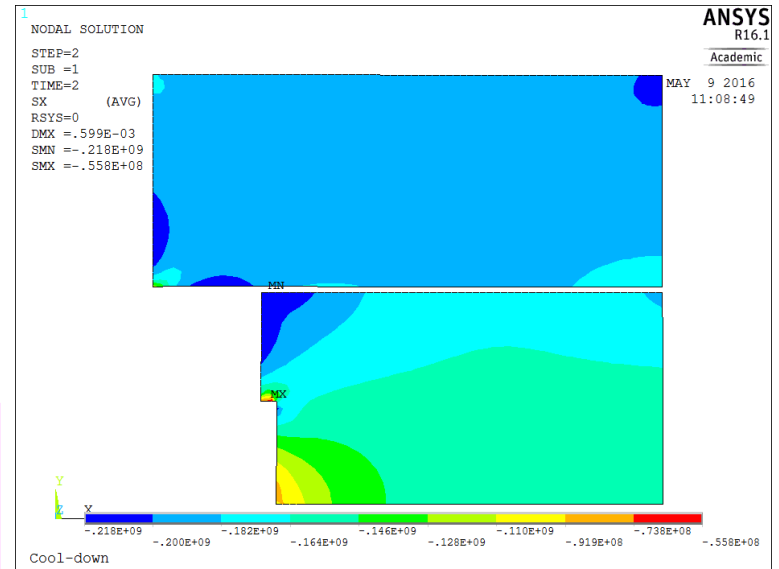
Pole slit

- Initial pole
 - 249 MPa at cold



Cool-down step: 4.2 K, 0 T

- Pole with slit
 - 218 MPa at cold

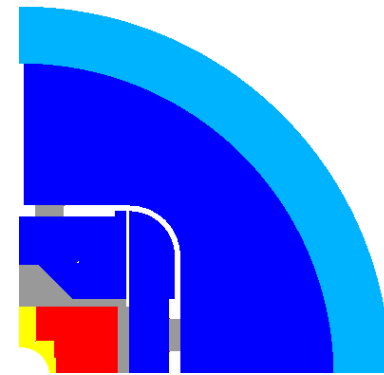


Cool-down step: 4.2 K, 0 T

← pole slit to make the pole flexible and avoid too high peak stress in the coil

Mechanical structure (18 T)

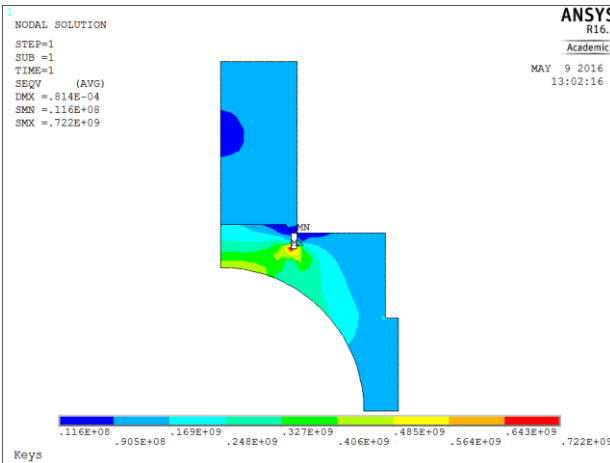
von Mises stress



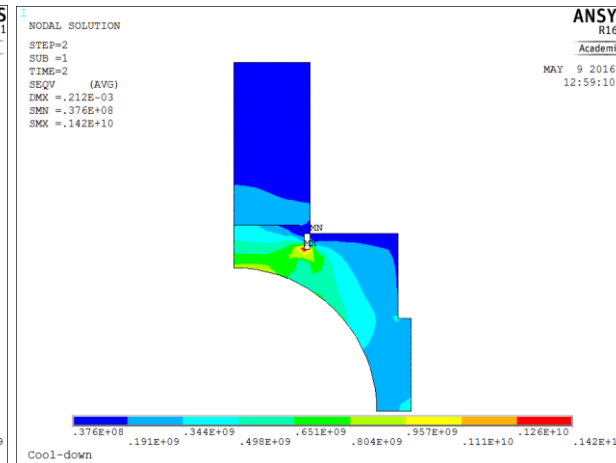
Key in

Cool-down

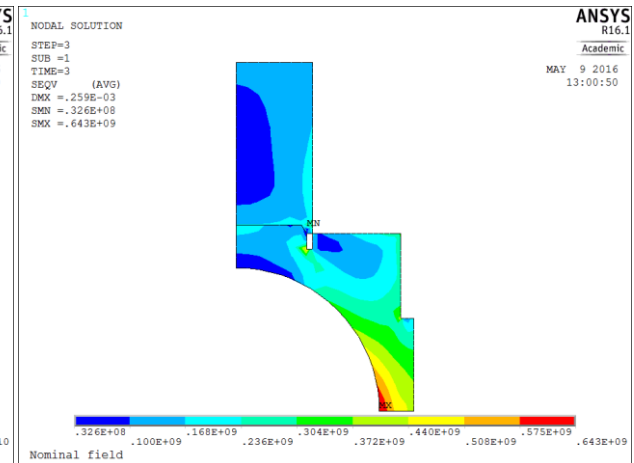
18 T



17 MPa to 722 MPa



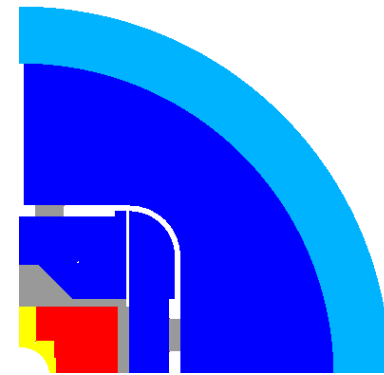
38 MPa to 1420 MPa



33 MPa to 643 MPa

Material	$R_{p0.2}$ [MPa]	
	293 K	4.3 K
Ti 6Al 4V	827	1654

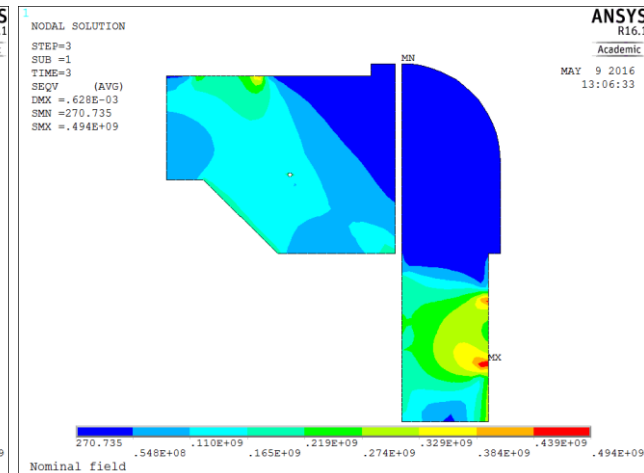
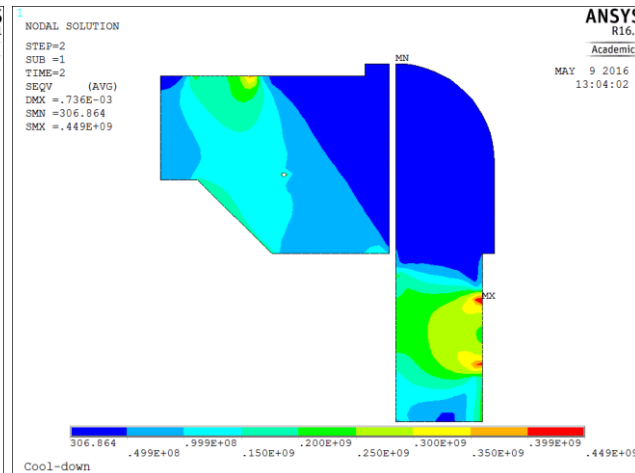
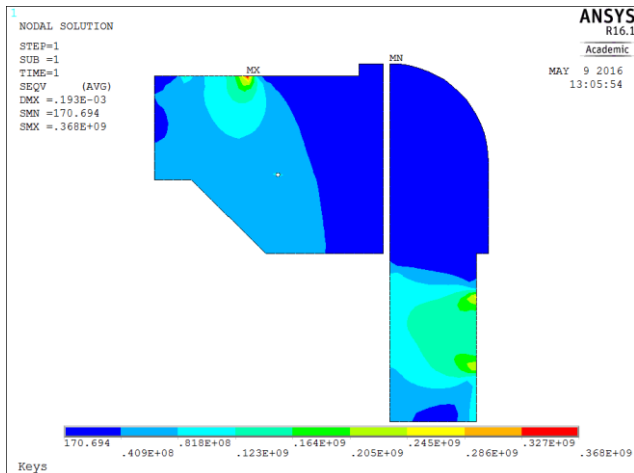
Mechanical structure (18 T)



Key in

Cool-down

18 T



0 MPa to 368 MPa

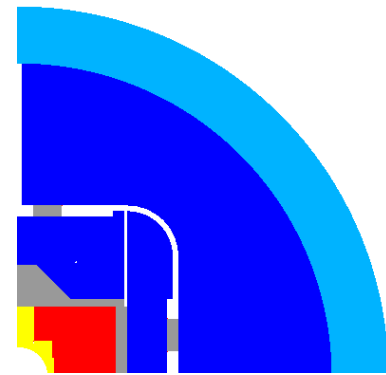
0 MPa to 450 MPa

0 MPa to 494 MPa

Material	$R_{p0.2}$ [MPa]	
	293 K	4.3 K
Magnetil	180	723

Iron @ 4.2 K stress < 200 MPa in tension (brittle) ?

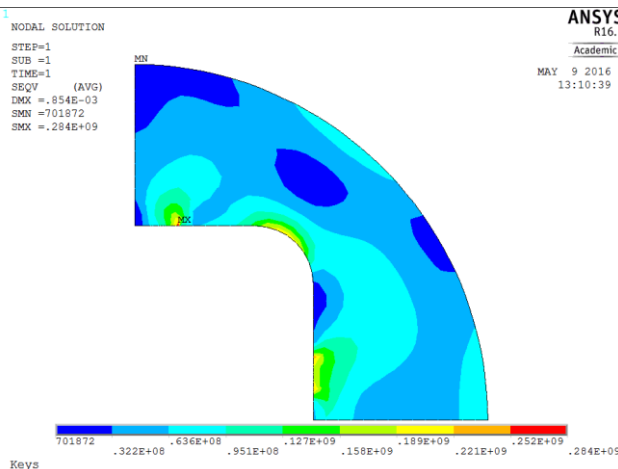
Mechanical structure (18 T)



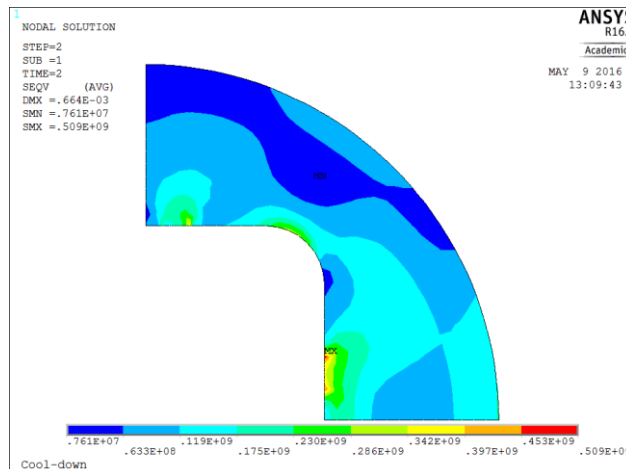
Key in

Cool-down

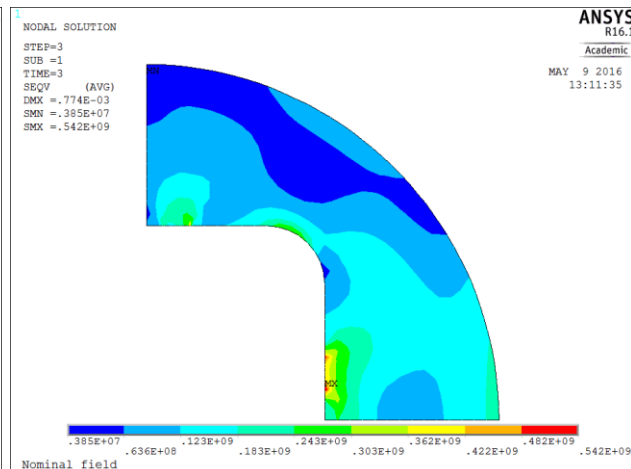
18 T



0 MPa to 284 MPa



0 MPa to 509 MPa

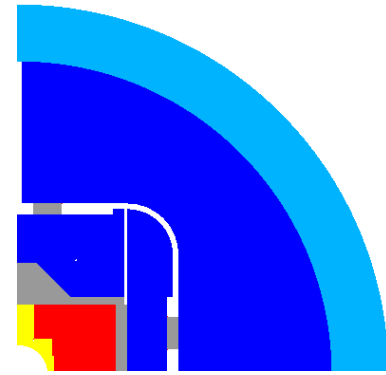


0 MPa to 542 MPa

Material	$R_{p0.2}$ [MPa]	
	293 K	4.3 K
Magnetil	180	723

Iron @ 4.2 K stress < 200 MPa in tension (brittle) « SSC », investigation on going at Cern

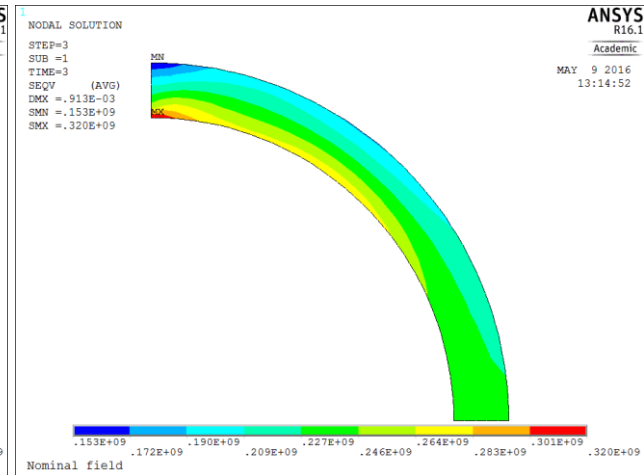
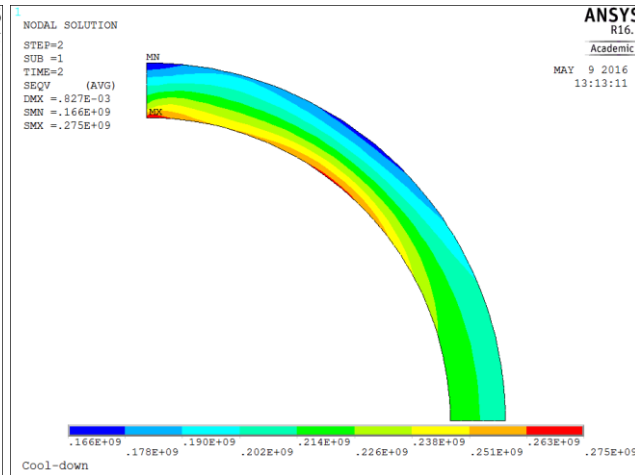
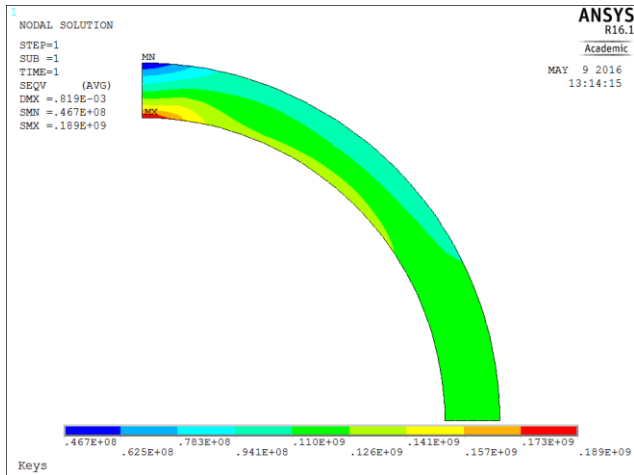
Mechanical structure (18 T)



Key in

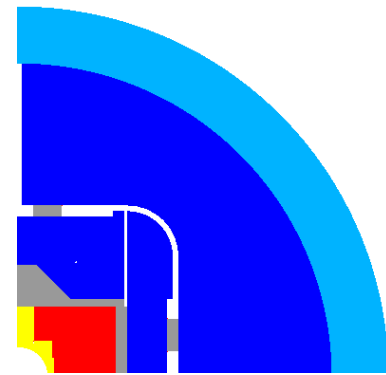
Cool-down

18 T



Material	$R_{p0.2}$ [MPa]	
	293 K	4.3 K
Al 7075	480	690

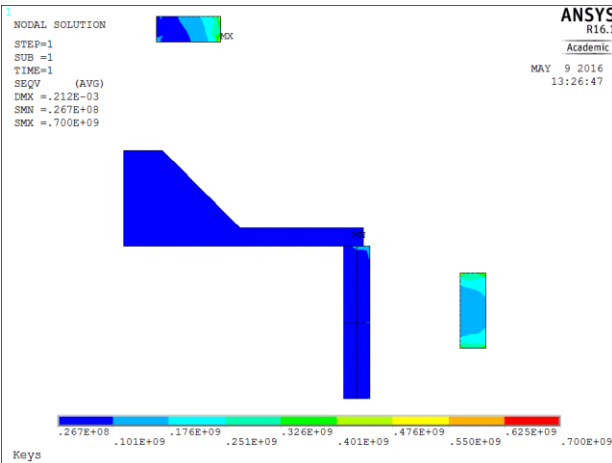
Mechanical structure (18 T)



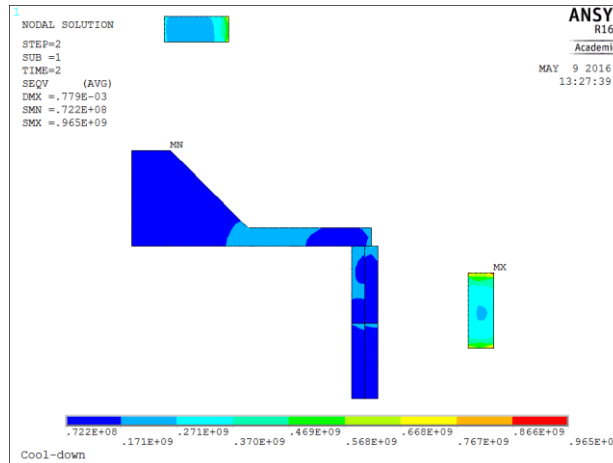
Key in

Cool-down

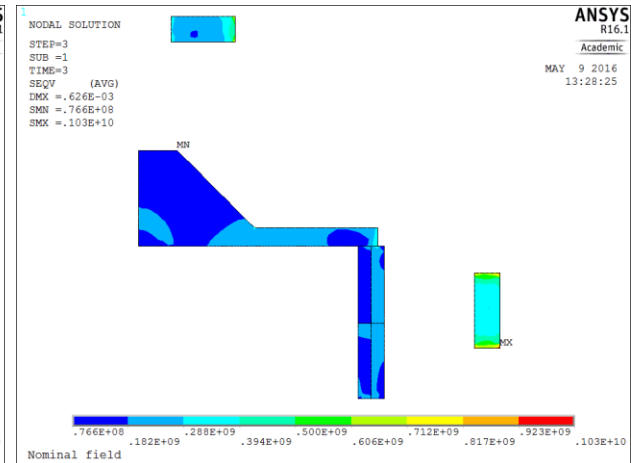
18 T



0 MPa to 700 MPa

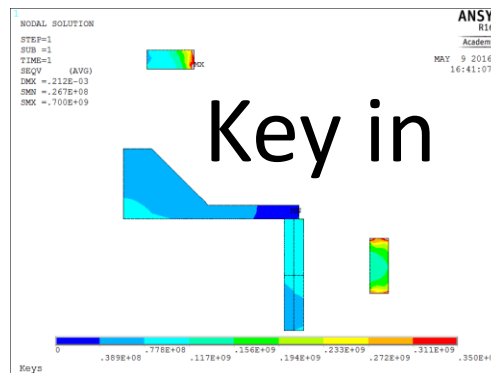


0 MPa to 965 MPa

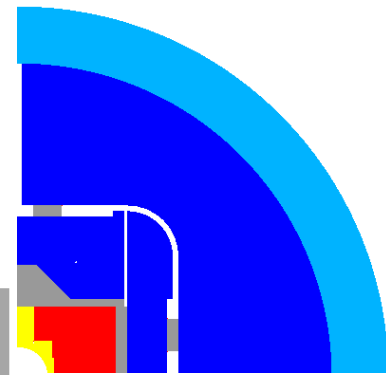


0 MPa to 1030 MPa

Material	$R_{p0.2}$ [MPa]	
	293 K	4.3 K
SS 316 LN	286	930
NITRONIC 40	353	1240



Peak stress in the structure



Von Mises max [MPa]	Material	Key in	Cool-down	105% power
Pole	Ti6Al4V	722	1420	643
Pads	Iron	368	450	494
Pads	SS 316 LN	121	298	386
Key	Nitronic40®	760	965	1030
Yoke	Iron	284	504	542
Shell	AL 7075	189	275	301

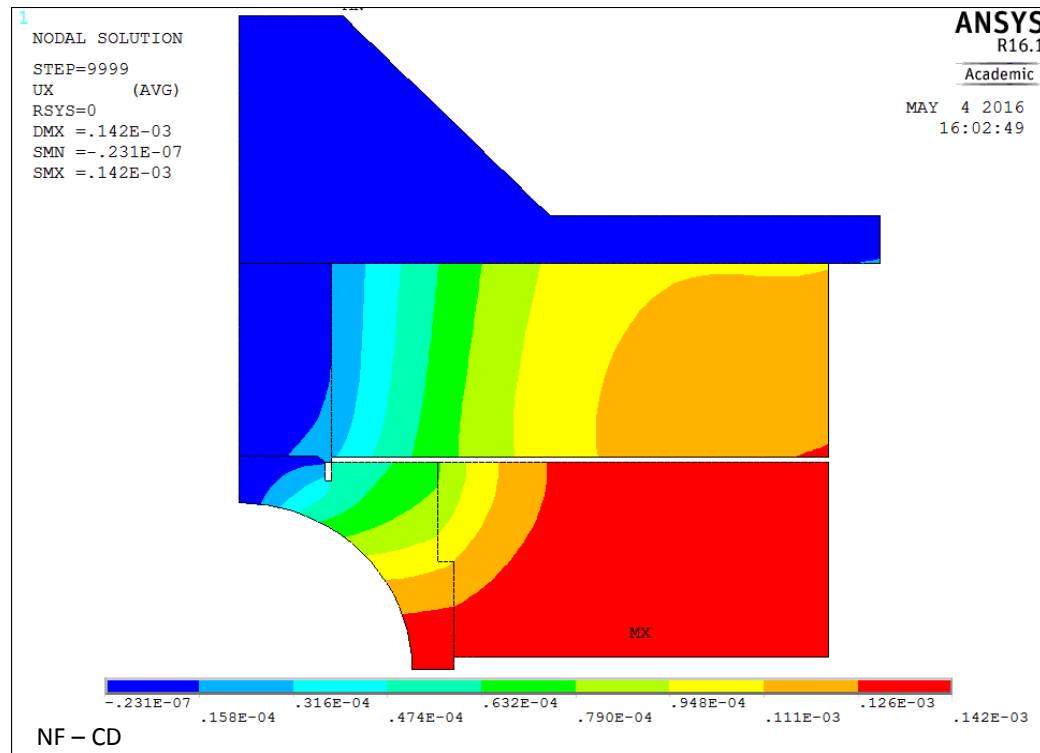
Material	R _{p0.2} [MPa]	
	293 K	4.3 K
Al 7075	480	690
SS 316 LN	286	930
NITRONIC 40	353	1240
MAGNETIL (IRON)	180	723
Ti 6Al 4V	827	1654

Summary – single aperture

- Bladder&key pre-stress method
- Windings:
 - Peak stress values up to 220 MPa
 - Good contact up to nominal (100% powering)
 - Contact degraded at 105% (still acceptable?)
- Mechanical structure:
 - Shell, pole in the yield stress limit
 - Iron parts in tension need deeper investigation (200 MPa or more?) and better shaping

Extra

- Relative x-displacement between CD and NF



Contact at 18 T

