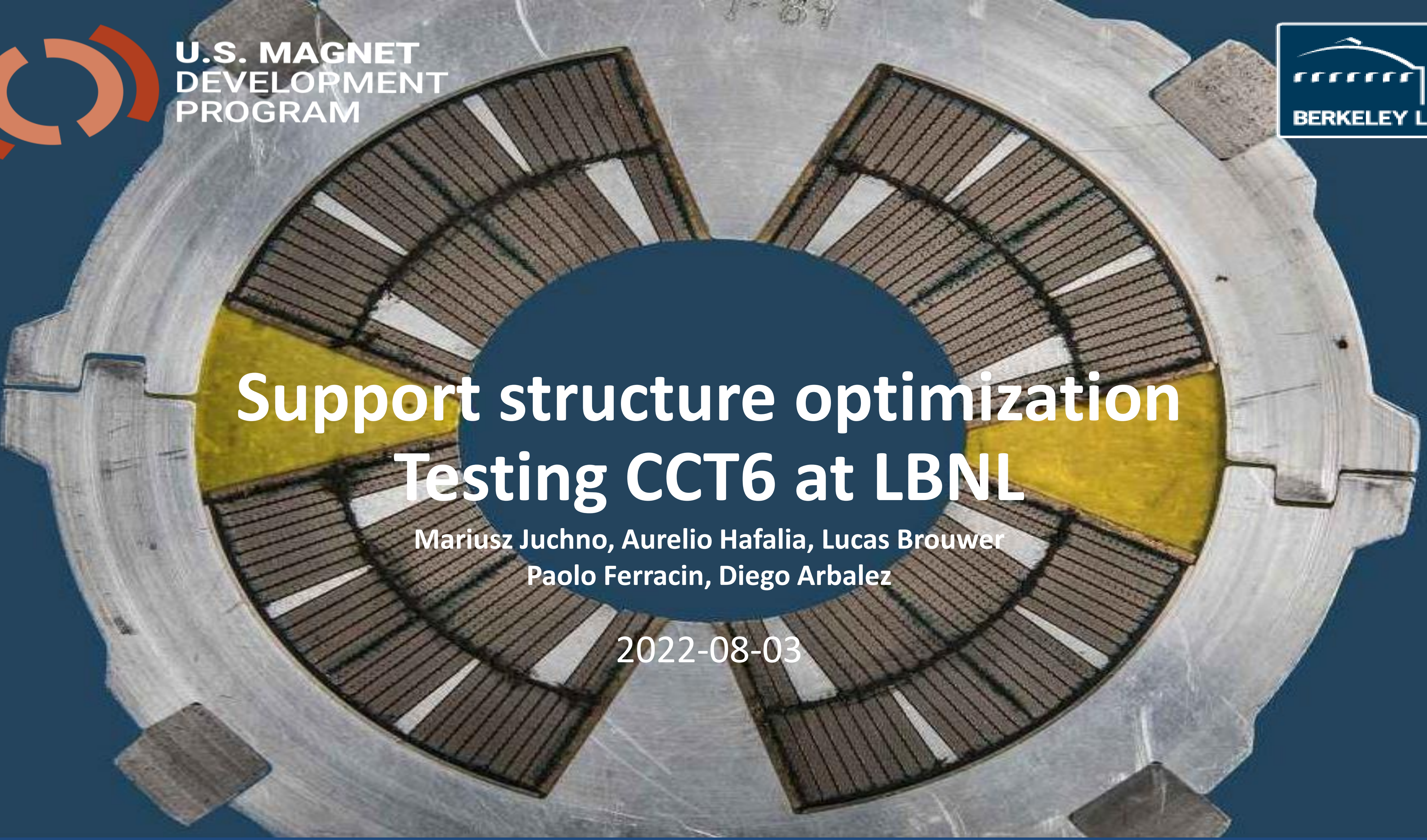
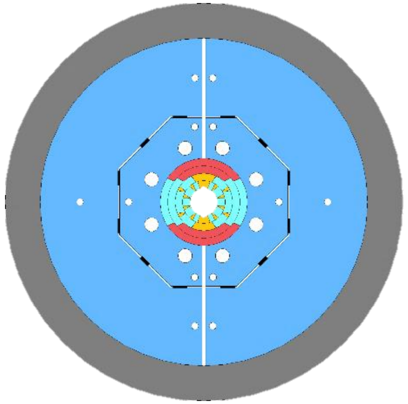


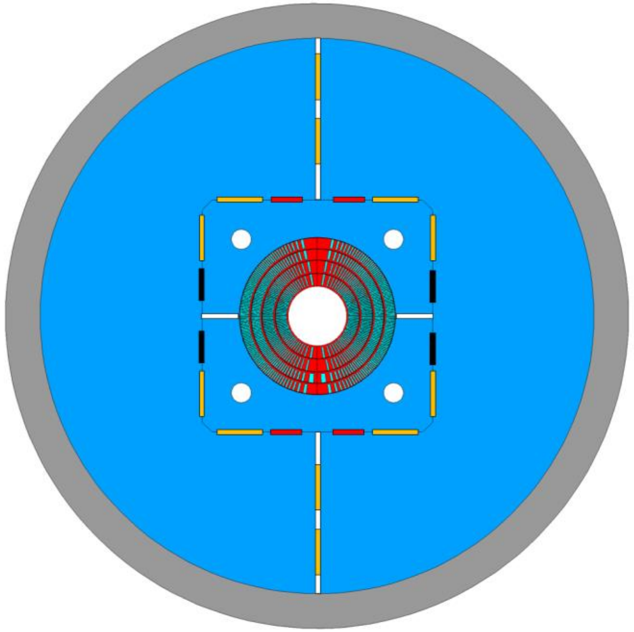
Support structure optimization
Testing CCT6 at LBNL

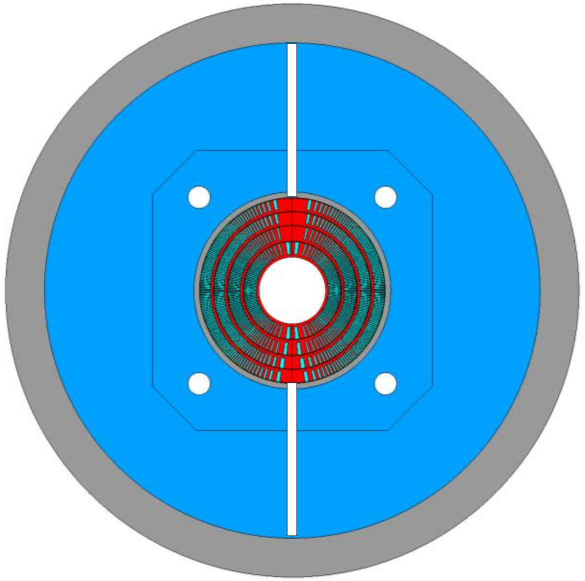
Mariusz Juchno, Aurelio Hafalia, Lucas Brouwer
Paolo Ferracin, Diego Arbalez

2022-08-03

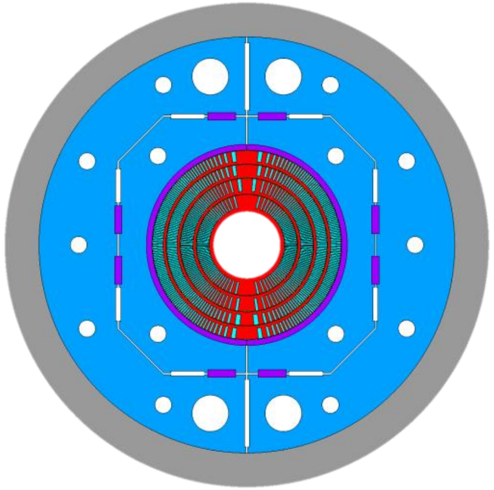
MDP structure design evolution for various goals/constraints







This presentation



750 mm OD
- CCT5/MDPCT
- Smaller FNAL cryostat (?)
- Octagonal pad due to limited space

1260 mm OD
- CCT6/SMCT/20T
- Existing LD1 shell
- Vertical split yoke, horizontal split pad due to high (fixed) cool-down pre-load

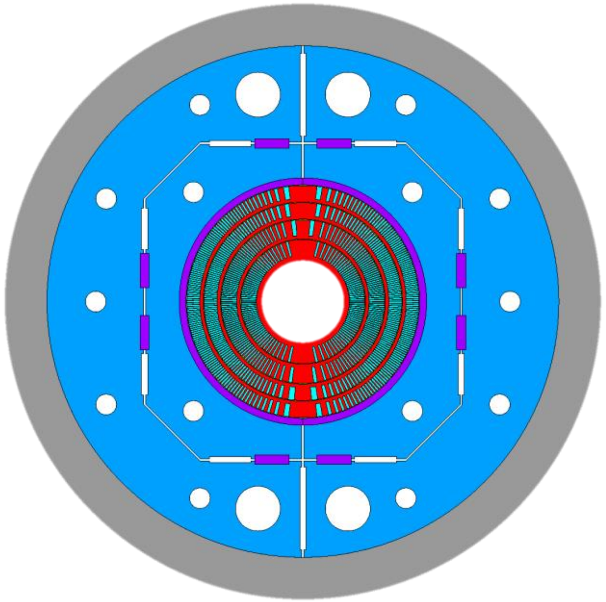
1030 mm OD
- CCT6/SMCT
- Current LBNL pit, new cryostat
- Vertical split yoke/pad thanks to smaller shell

860 mm OD
- CCT6/SMCT
- Current LBNL cryostat
- Optimized spar thickness and new mandrel material

CCT6 structure for current cryostat

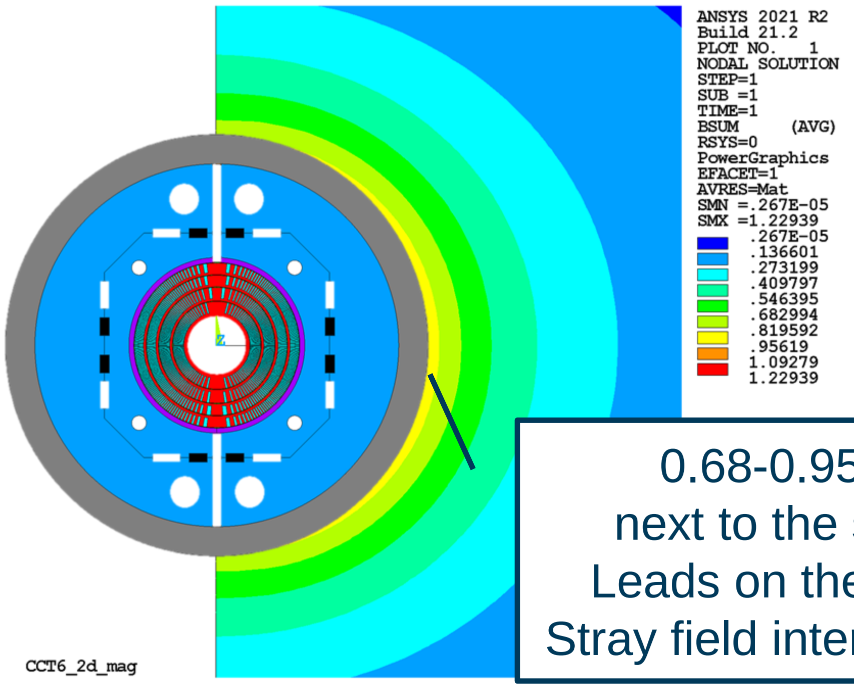
Structure designed around existing LD1 shell (already presented) shows satisfactory coil preload.

Smaller structure is designed take advantage of existing 36” cryostat.



- Aluminum shell
  - OD 860 mm, TH 60 mm
- Iron yoke/pad
  - Vertical split, pad ID 357.6 mm, only about 190 mm of iron radially
- Protective shell (split)
  - Stainless steel
- Aluminum bronze mandrel
  - Spar thickness 7-5-5-5 mm
  - C63000 instead of C95400
- Load keys
  - Horizontal 700um, Vertical 0um
- Bladder pressure
  - < 40MPa
- Features added (keys, slots, holes)
- Magnet supported from the yoke
- Leads at the top

Impact of reduced yoke OD



0.68-0.95 T
next to the shell
Leads on the top?
Stray field interaction?

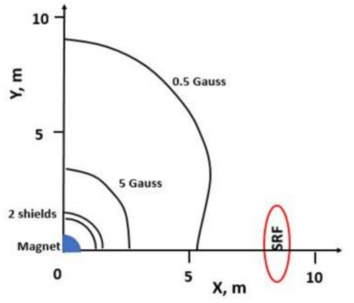


Fig. 3. Fringe field around shielded HFVMTF with magnet at center, producing at 15.3 T. The SRF mark shows the position of the closest SRF test stand.

- LBNL test facility
  - No known limitation on fringe field
- Fermilab test facility
  - 2x 1" shells made of AISI 1020 steel to protect SRF cavity test facility

- Mechanical analysis at 13.2 T
  - Current for 1260 mm OD structure
    - 11.8 kA
  - Current for 860 mm OD structure
    - 12.58 kA
  - About 6.6% increase due to reduced iron OD
    - Impact on current margins (1-2 %? TBD)

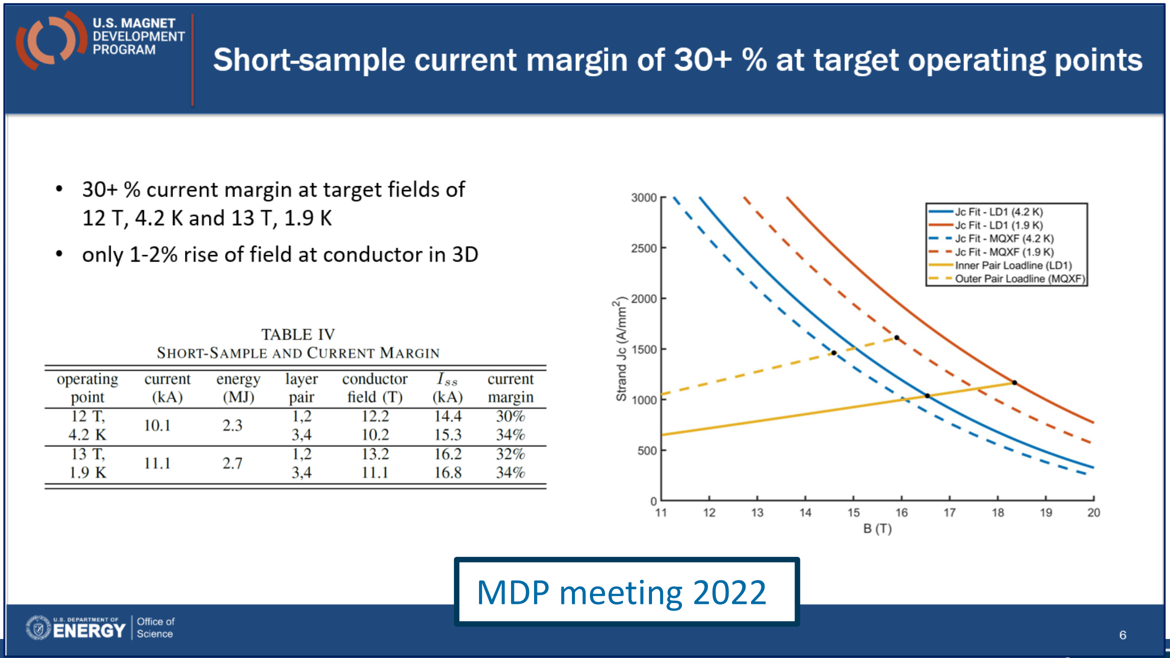


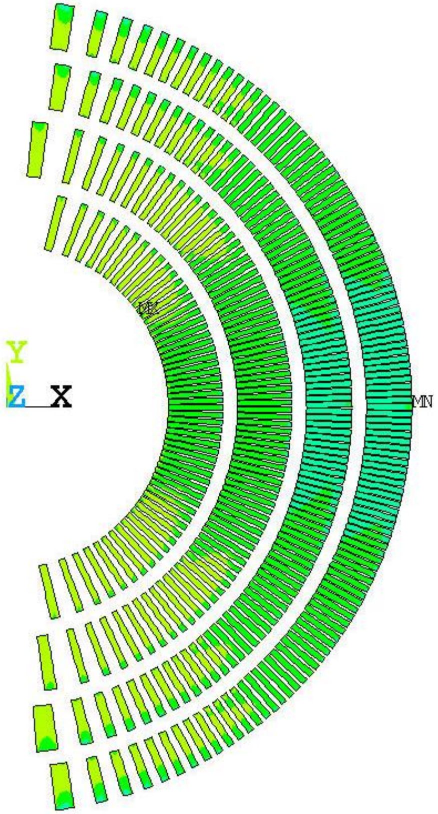
TABLE IV
SHORT-SAMPLE AND CURRENT MARGIN

operating point	current (kA)	energy (MJ)	layer pair	conductor field (T)	I_{ss} (kA)	current margin
12 T, 4.2 K	10.1	2.3	1,2	12.2	14.4	30%
			3,4	10.2	15.3	34%
13 T, 1.9 K	11.1	2.7	1,2	13.2	16.2	32%
			3,4	11.1	16.8	34%

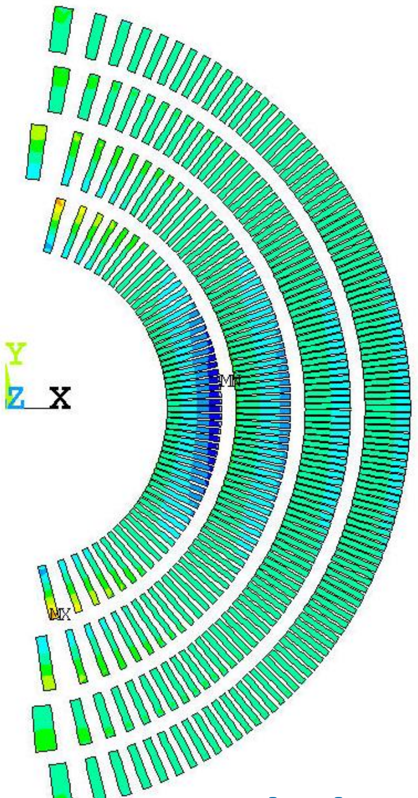
MDP meeting 2022

Conductor stress after cool-down

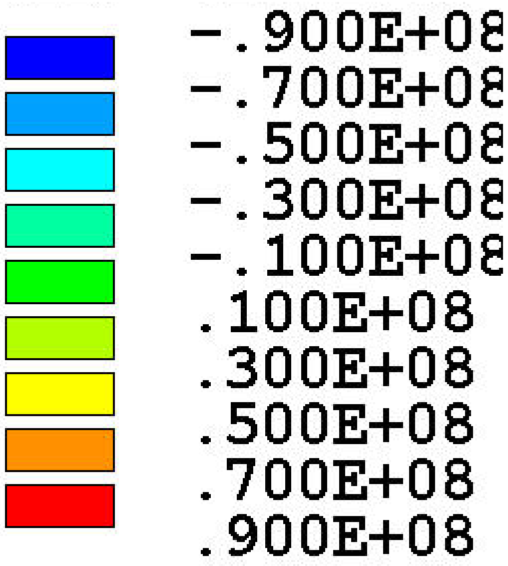
Bonded | **De-bonded**

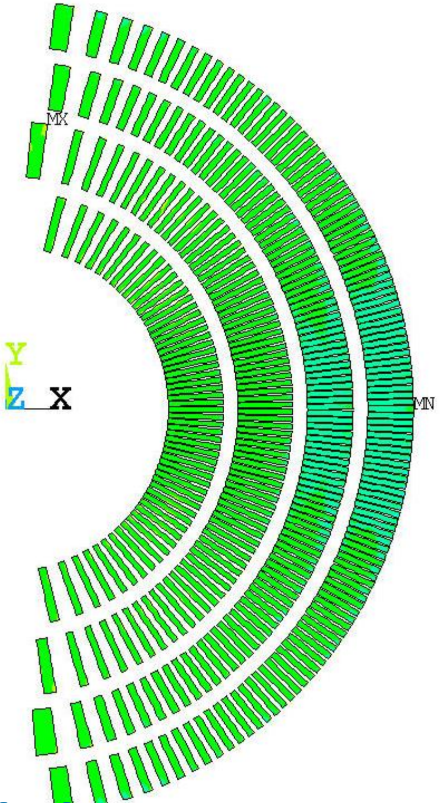


Radial < 30 MPa

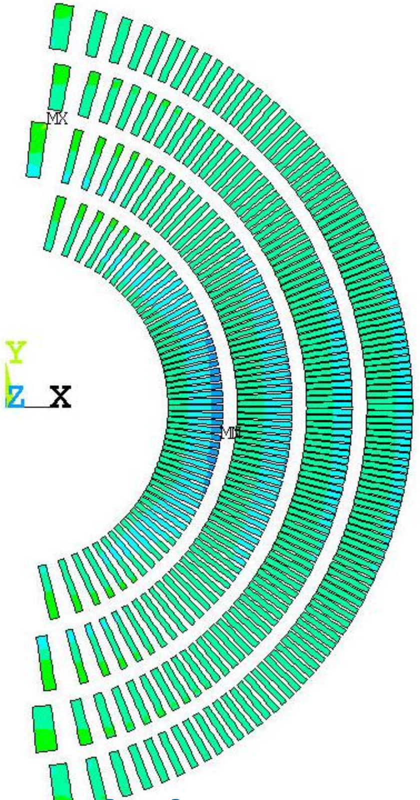


Azimuthal < 105 MPa





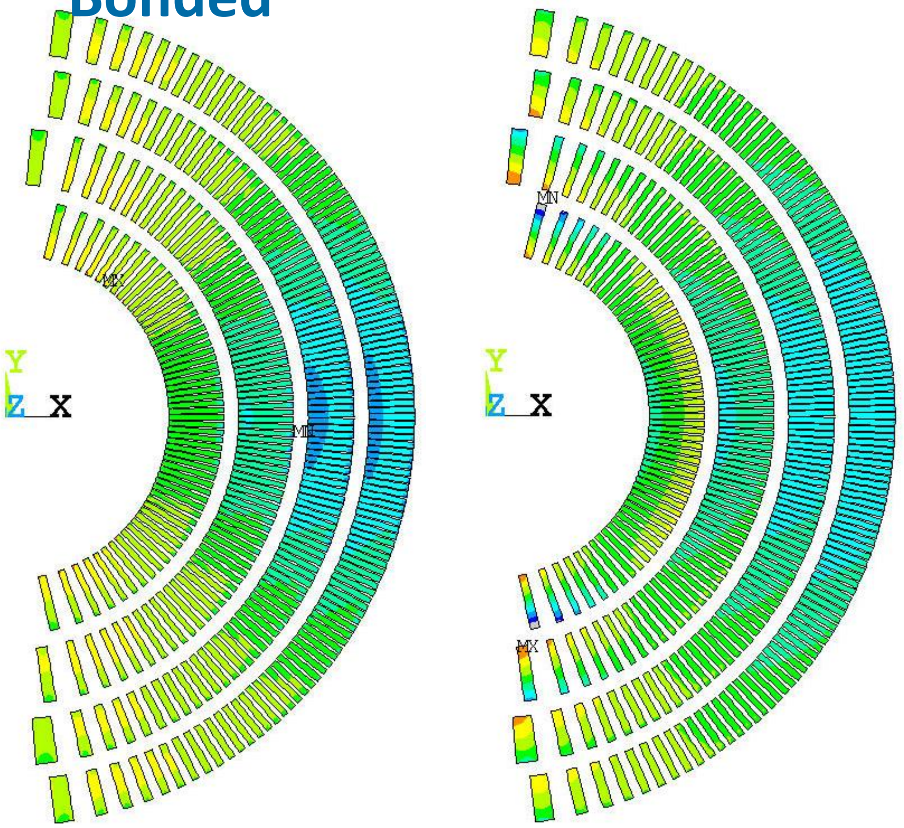
Radial < 30 MPa



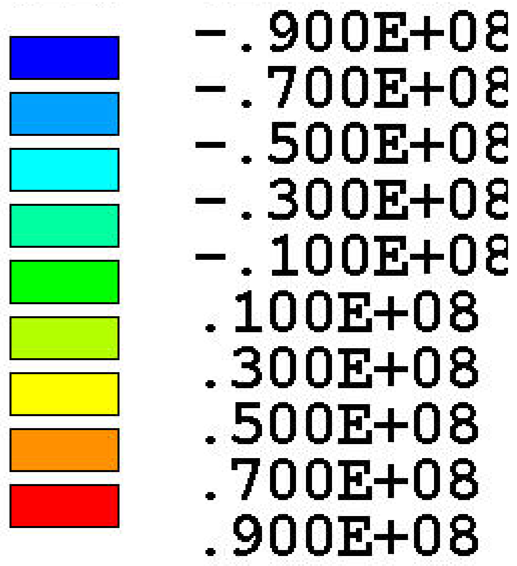
Azimuthal < 80 MPa

Conductor stress with magnetic forces at 13.2T

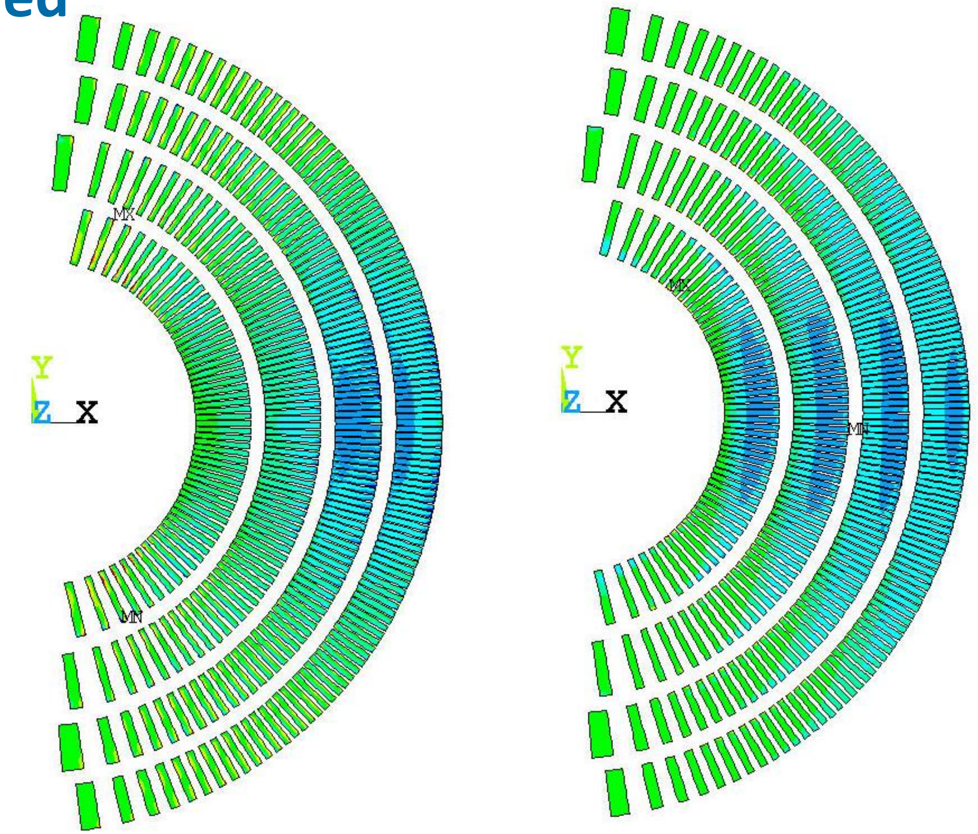
Bonded



Radial < 80 MPa **Azimuthal < 130 MPa**



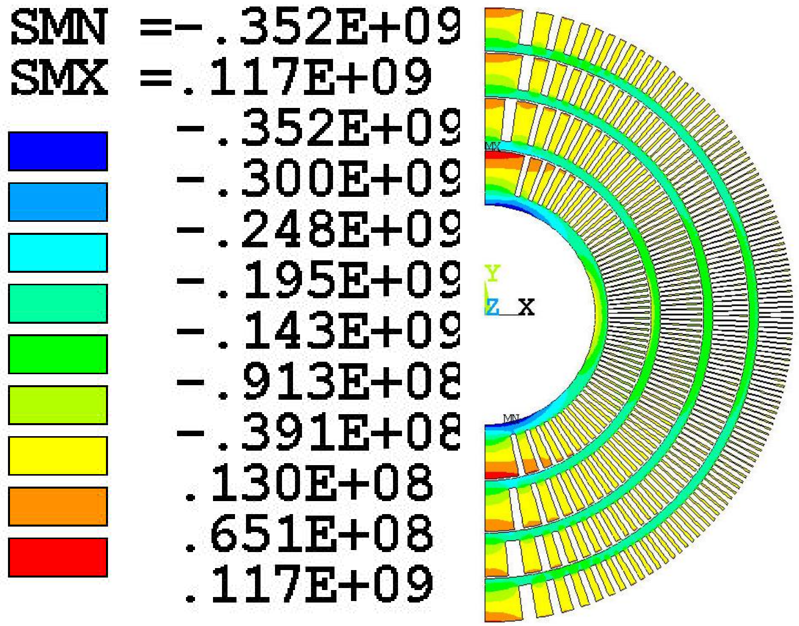
De-bonded



Radial < 80 MPa **Azimuthal < 80 MPa**

Mandrel Stress (azimuthal stress) <363MPa (C63000 Rp0.2 at 4.2K is 578.6 MPa)

Cool-down < 352 MPa



C63000

at RT as produced

Rm/Rp0,2/A: 857/612/12 MPa/MPa/%

at RT after a heat treatment at 670ºC for 48h.

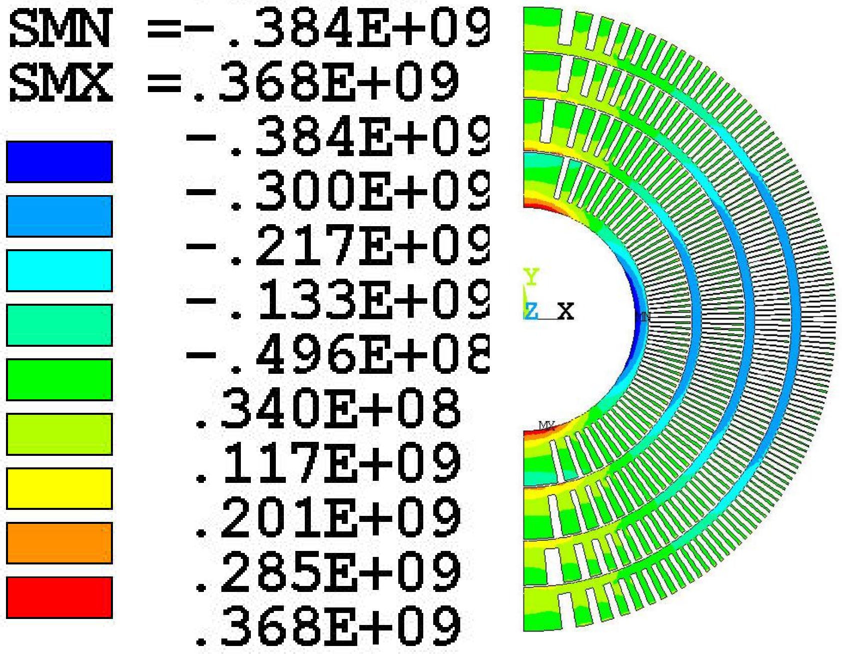
Rm/**Rp0,2**/A: 739/**390**/23 MPa/MPa/%

at 4.2 K after a heat treatment at 670ºC for 48h.

Rm/**Rp0,2**/A: 918/**578**/6 MPa/MPa/% and an elastic modulus of 133 GPa

Measurements of C63000 and C95400 are considered

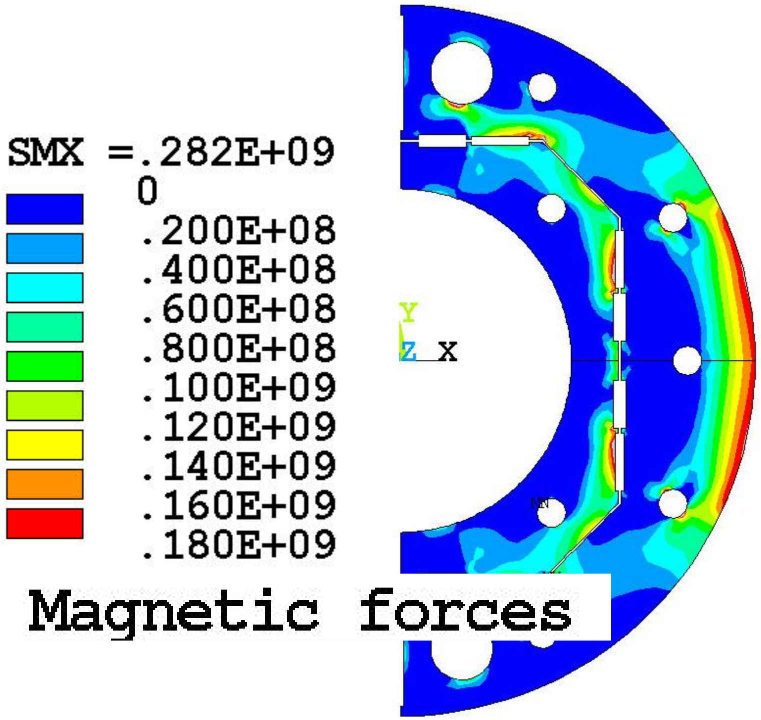
Magnetic forces < 384 MPa

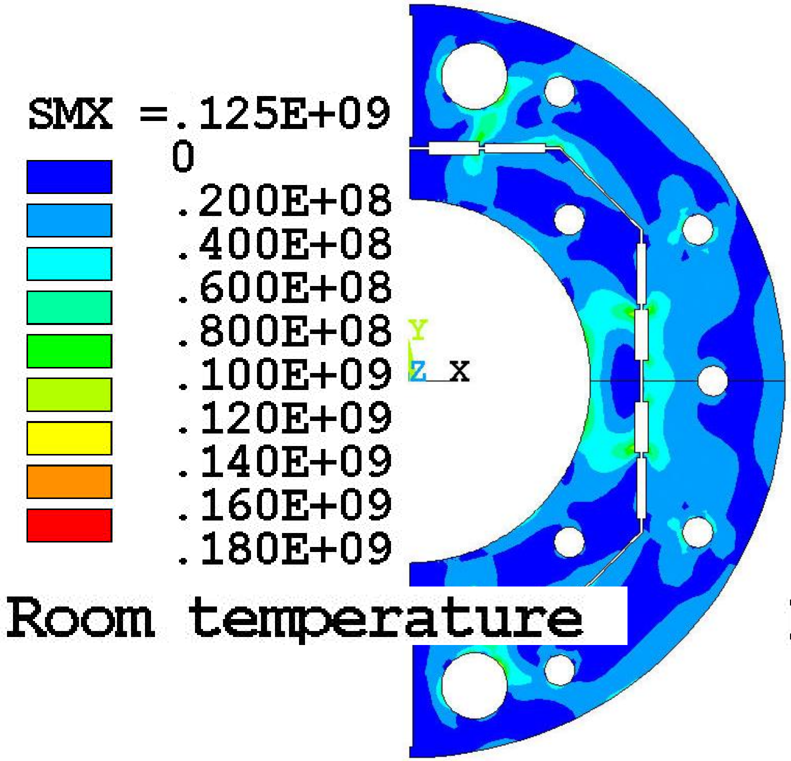


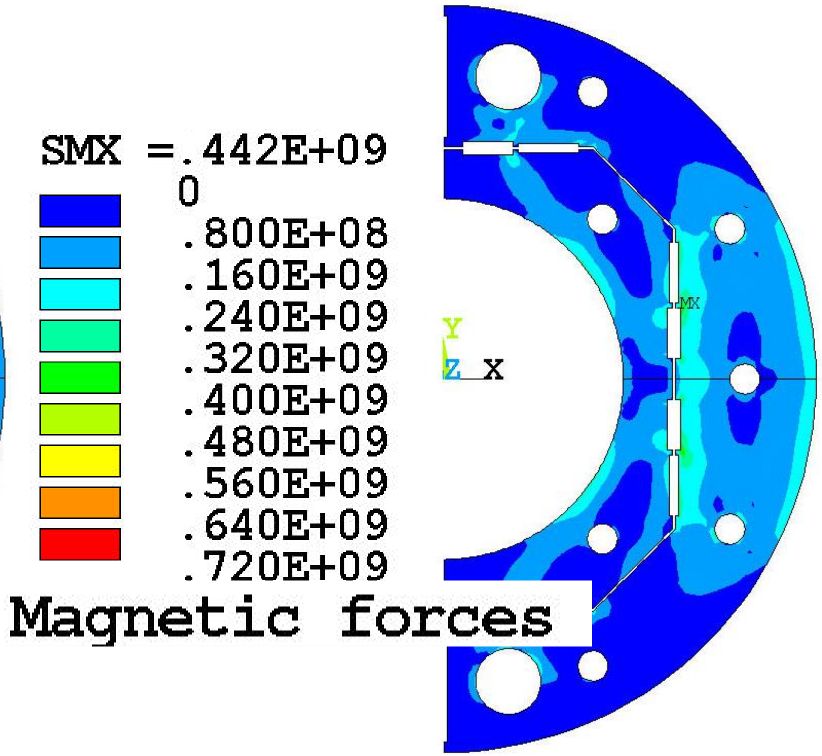
Iron yoke and pad

First principal stress

Von Mises stress

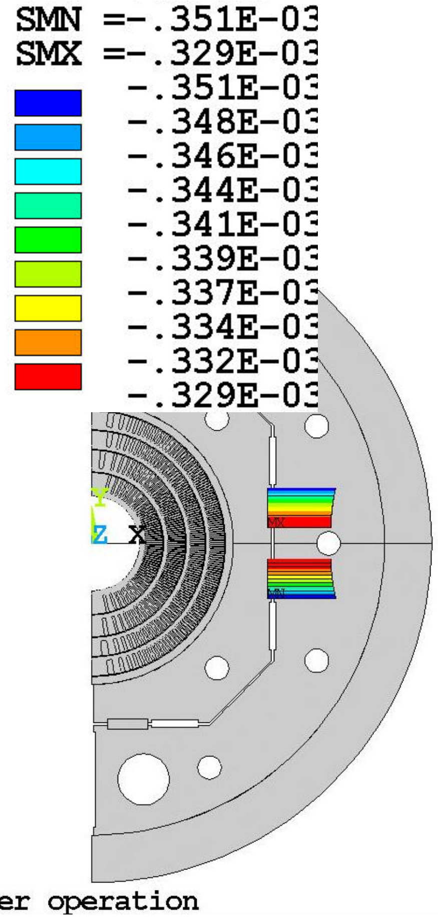


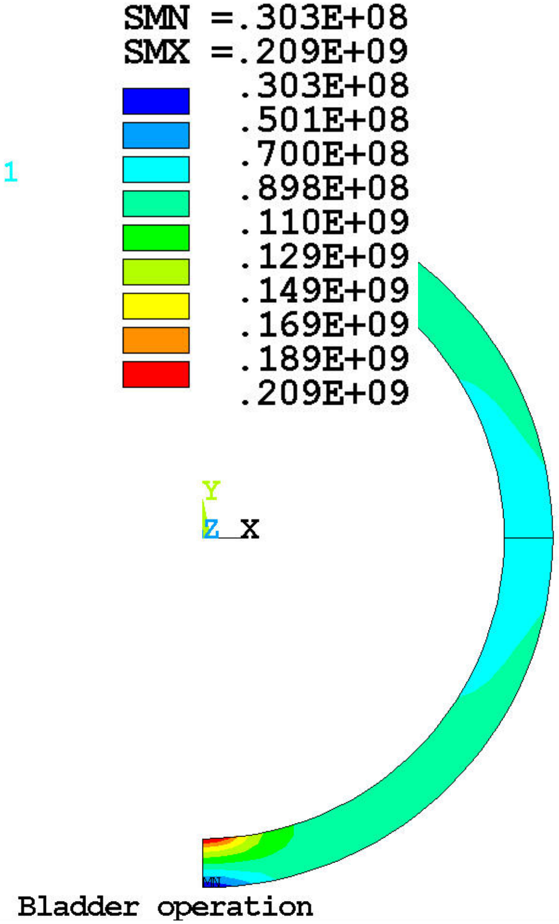


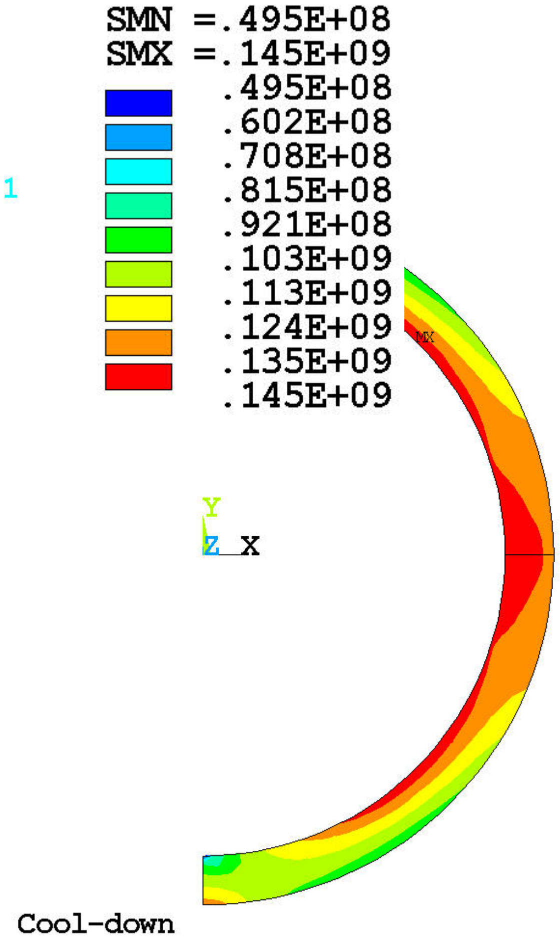


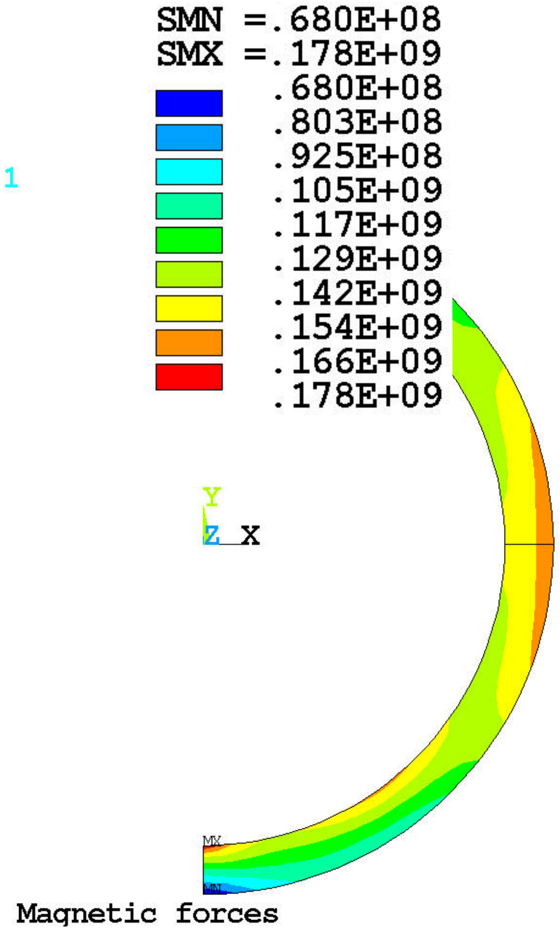
Azimuthal Shell Stress

Gap [m] at 40 MPa bladder pressure





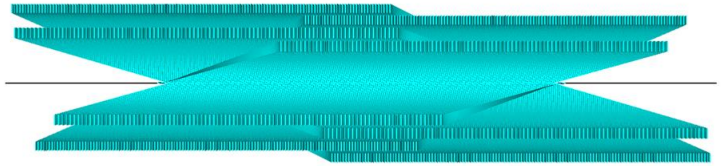




Work on the 3D model

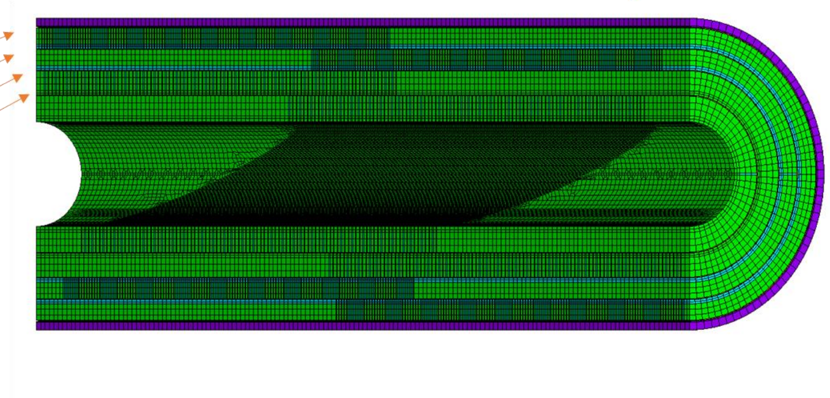
Full 3D model setup (coarse mesh)

- ~1 M elements
- everything is shared mesh (thus bonded) except shims
- 7-5-5-5 spar case



Artificially stiff shell to mimic "infinitely" stiff external structure

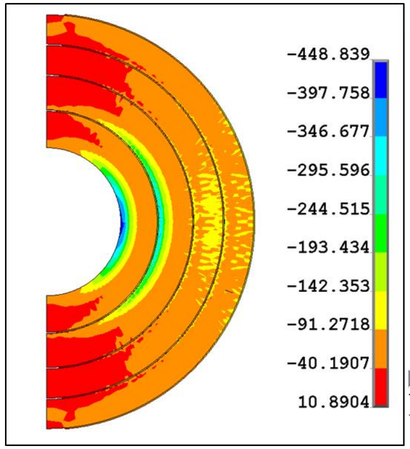
PLOT NO. 1

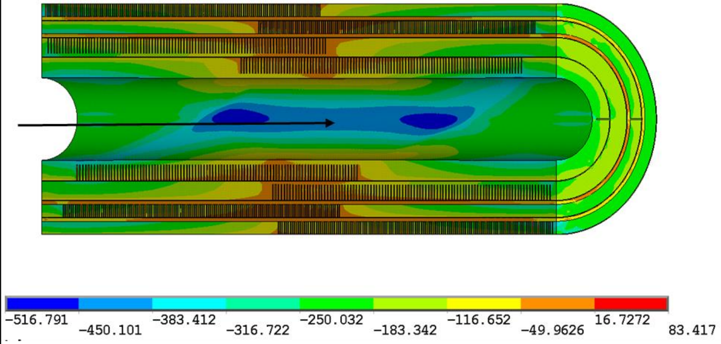


Assembly shims are +/- 85 deg

First steps:

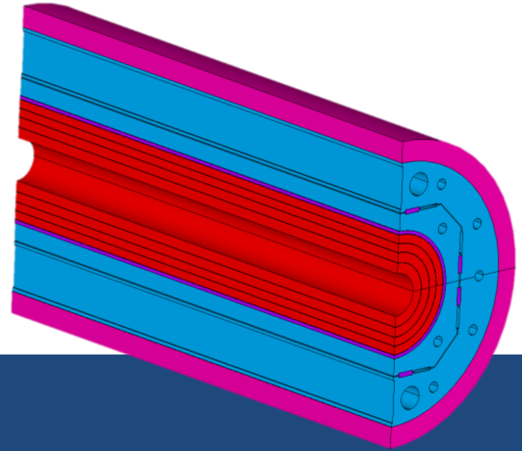
1. Model setup, convergence
2. 2D benchmark (rigid shell)





Next step:

1. Benchmark of the 3D structure model with dummy coils
2. Combining 3D CCT6 and 3D structure models

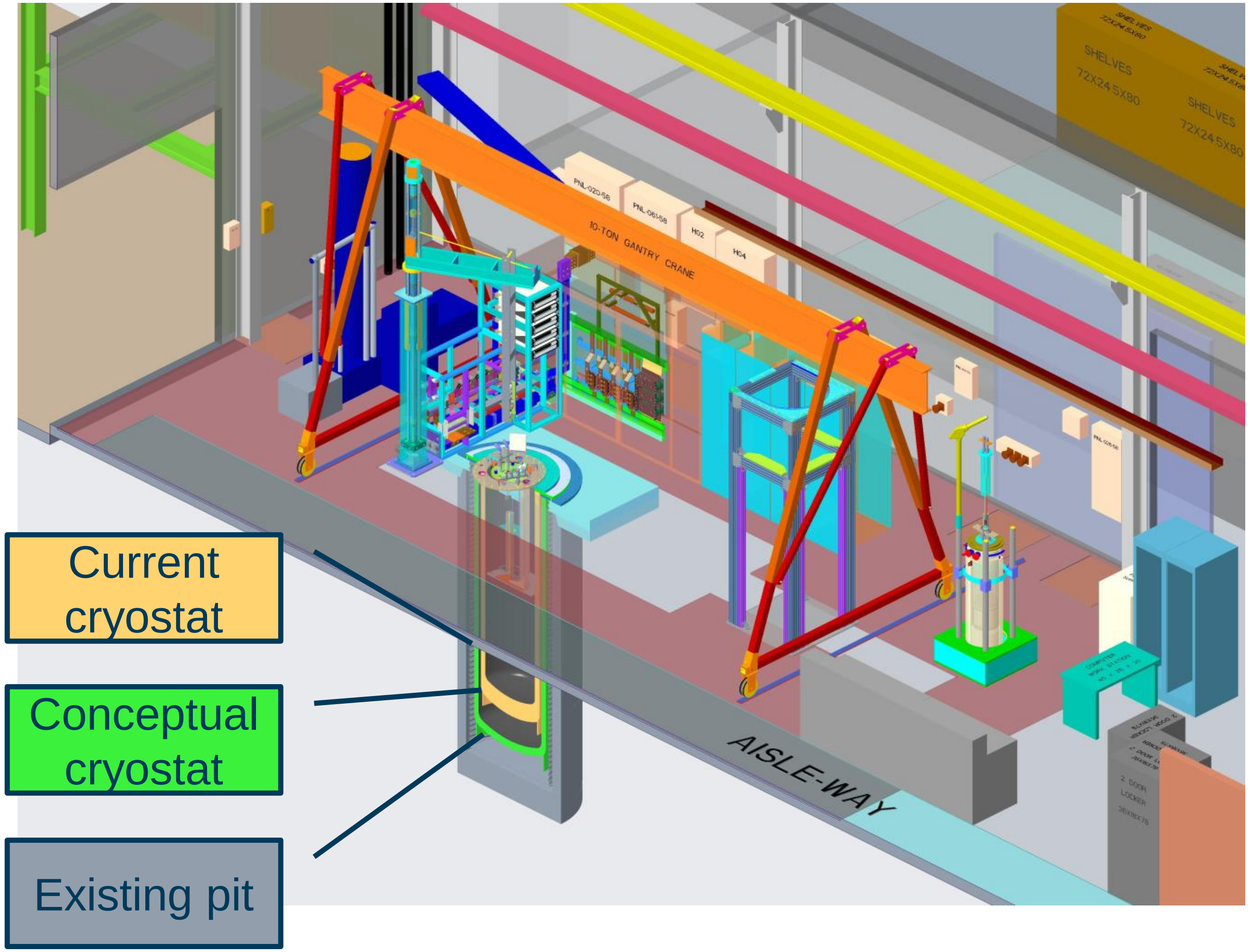


Conclusions

- 2D mechanical analysis of 860mm OD structure completed
  - Design takes advantage of existing 36” cryostat
  - Pre-load target was established. Coil stress in acceptable range.
  - Optimized spar thickness and new mandrel material allow to mitigate mandrel deformation/damage risk (AlBr properties measurements)
  - No show-stoppers in terms of support structure stress
- Next steps
  - Final setup of 3D model and analysis with CCT6 coil
  - Investigation of testing CCT6+BiCCT1/2 (already started, initially 2D)
  - Performing analysis with SMCT geometry (860 and 1260 mm OD shells)
  - Performing analysis with 20T tesla coils (1260 mm OD shell)

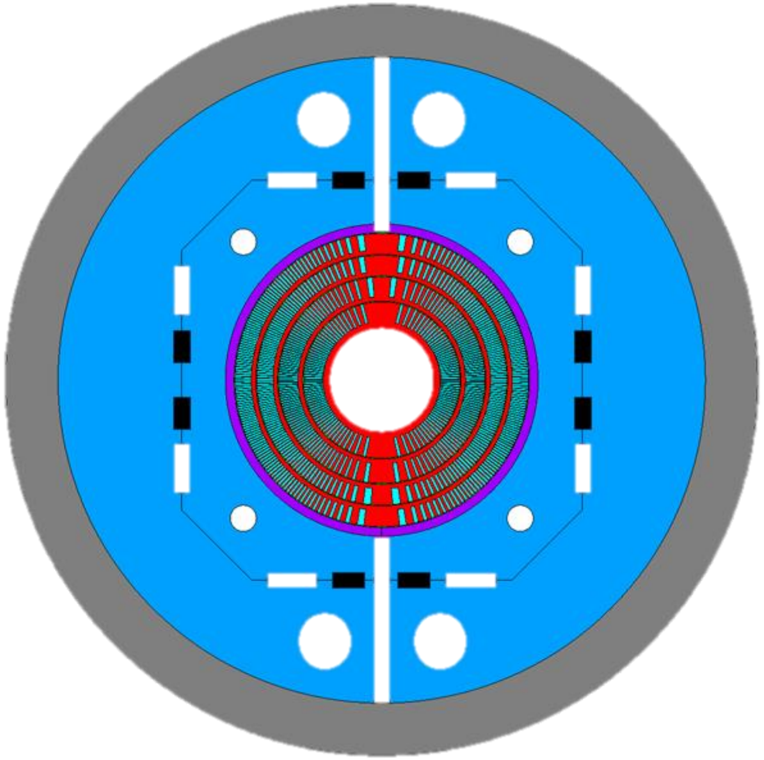
Backup

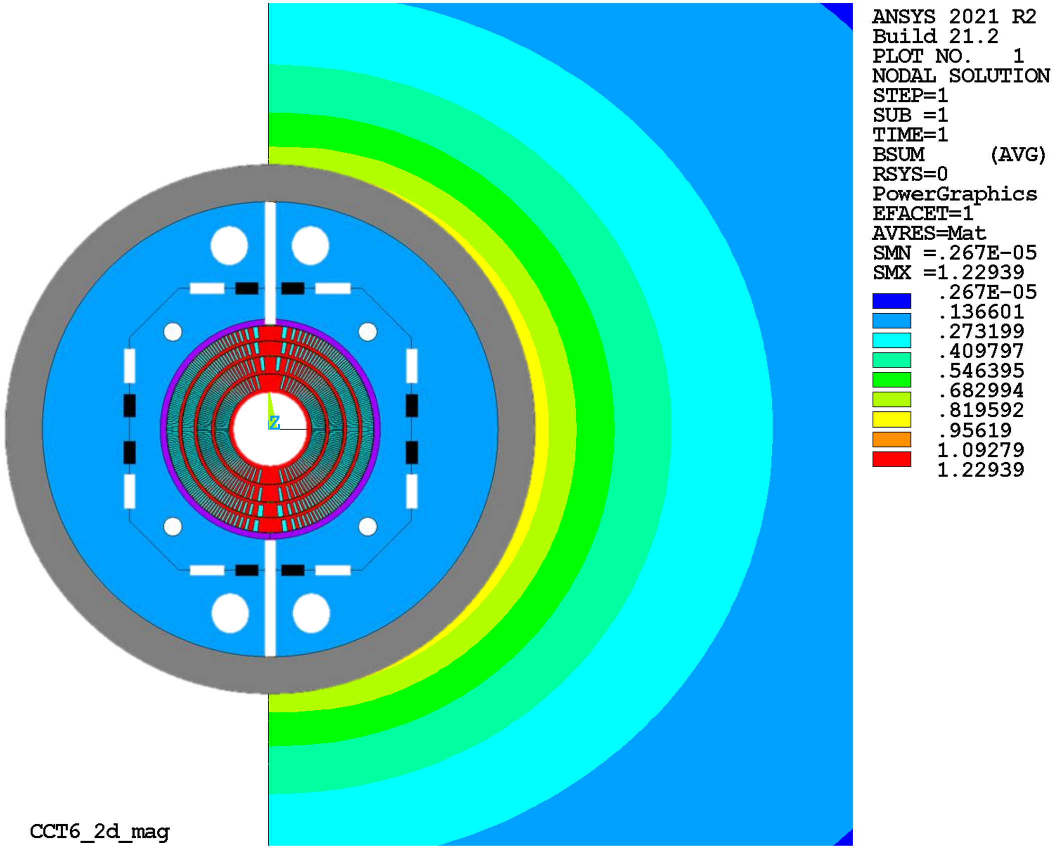
Testing facility in B58 not compatible with LD1 shell



Current facility

- Crane
  - ~10t or 20k lbs
  - Can be used up to 80% without riggers
  - Clearance below the crane 13ft 6in (4.115m)
- The pit
  - ID 53.7” (~1364 mm)
  - DEPTH 162.5” (4127.5 mm)
- The cryostat
  - OD 42“ (1066.8 mm)
  - ID 36” (914.4 mm)
  - DEPTH 138” (3505.2 mm)
  - Radial thickness 3”
- Max. magnet dimensions
  - OD 34” (860 mm)?
  - Radial separation 1” ?




ANSYS 2021 R2
Build 21.2
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
BSUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
SMN =.267E-05
SMX =1.22939
.267E-05
.136601
.273199
.409797
.546395
.682994
.819592
.95619
1.09279
1.22939
CCT6_2d_mag