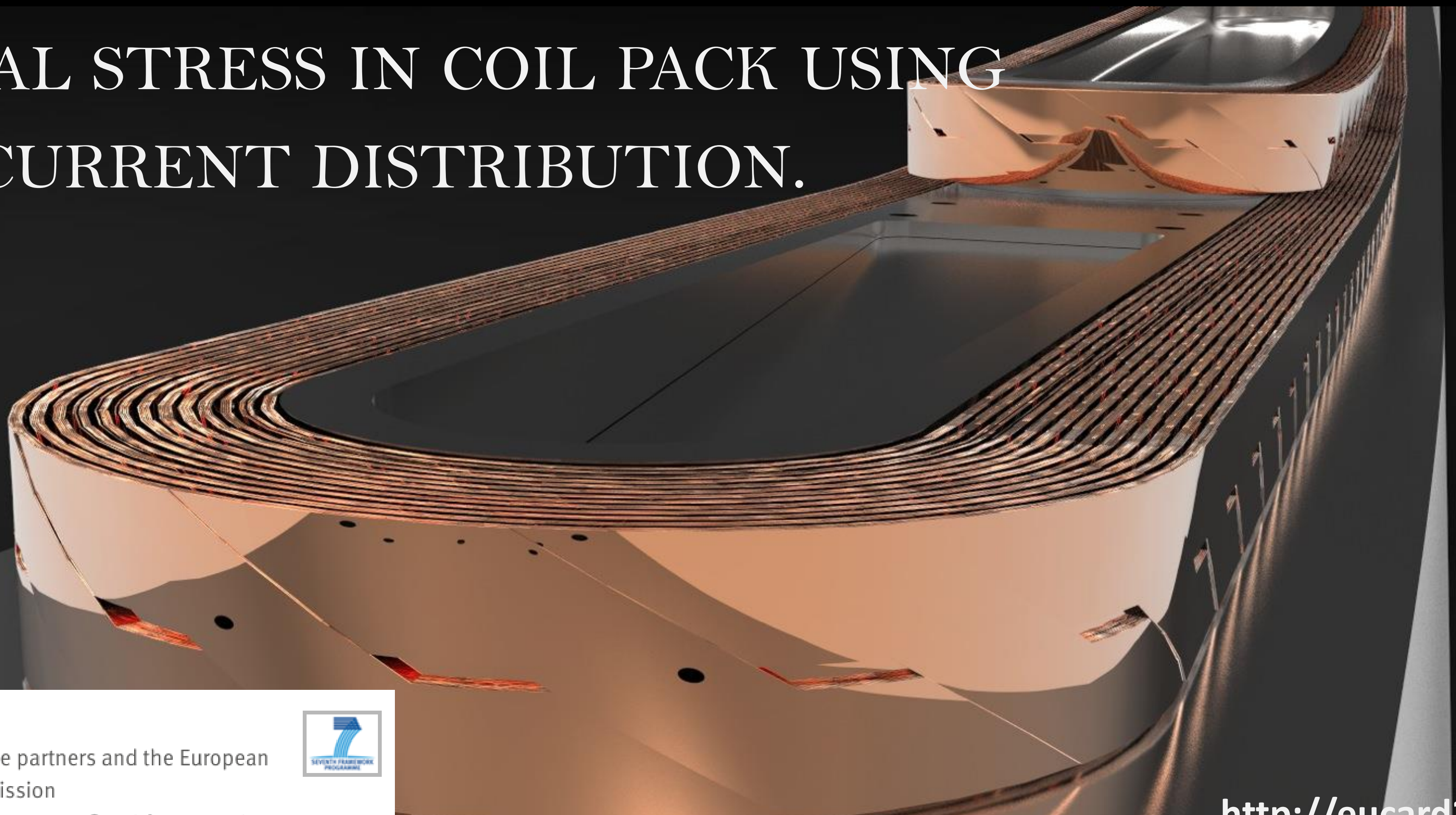
MECHANICAL STRESS IN COIL PACK USING DETAILED CURRENT DISTRIBUTION.



EuCARD-2 is co-funded by the partners and the European Commission
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J. Murtomäki, J. van Nugteren, G. Kirby, K. Broekens, H. Bajas, A. Ballarino, M. Bajko L. Bottura, M.Canale, L.Gentini, J. Mazet, J.C. Perez, F-O. Pincot, G. de Rijk, A. Rijllart, L. Rossi, (CERN), M.Durante, P. Fazilleau, C. Lorin (CEA) M. Marchevsky, (LBNL), W. Goldacker, A. Kario, (KIT) A.Usoskin, (Bruker)

http://eucard2.web.cern.ch/

TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

3.5. 2016

Talk Overview

- Non-homogenous current distribution in Feather M2 coil pack
- Mechanical modelling of the cable and importing forces into it due to current distribution

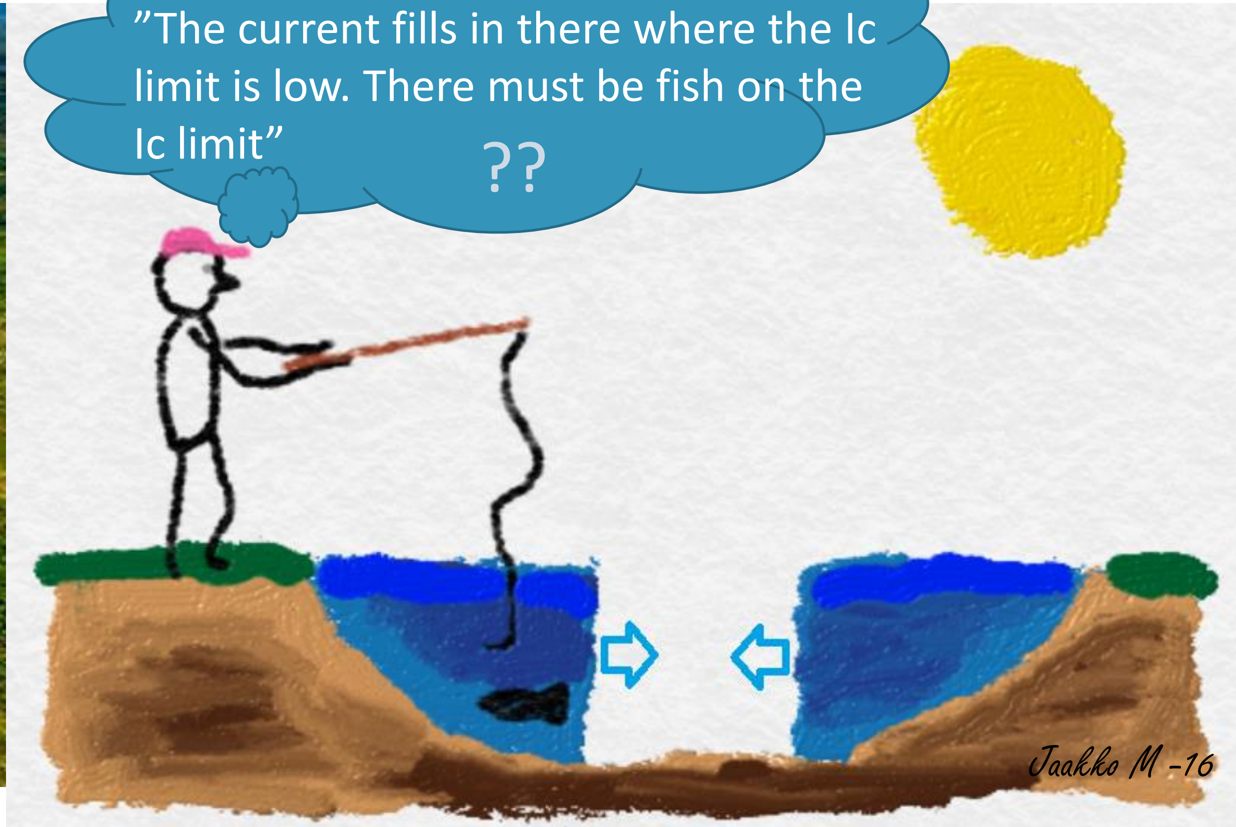
ReBCO Coated Conductor Tape

The HTS is special, current is not running flat in one continuum, but is filling in from the sides of the wide tape!

Standard river

”The current fills in there where the Ic limit is low. There must be fish on the Ic limit”

??

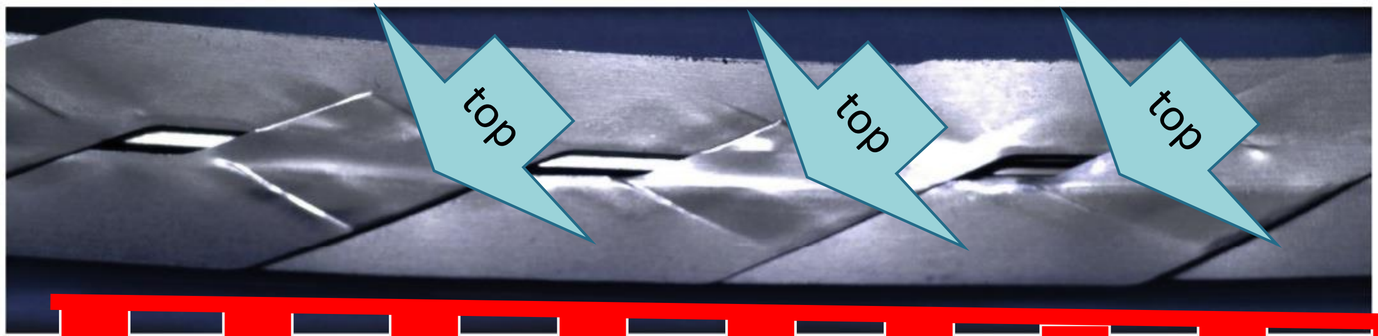


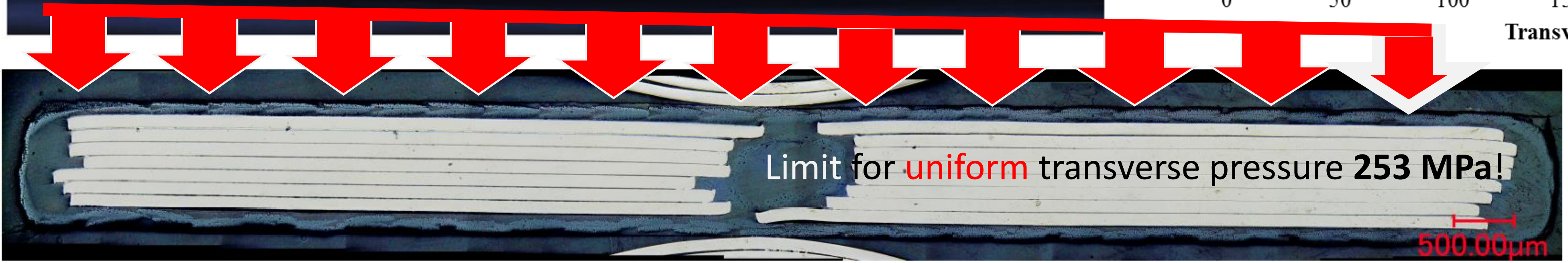
The cable is composed of HTS Rivers…

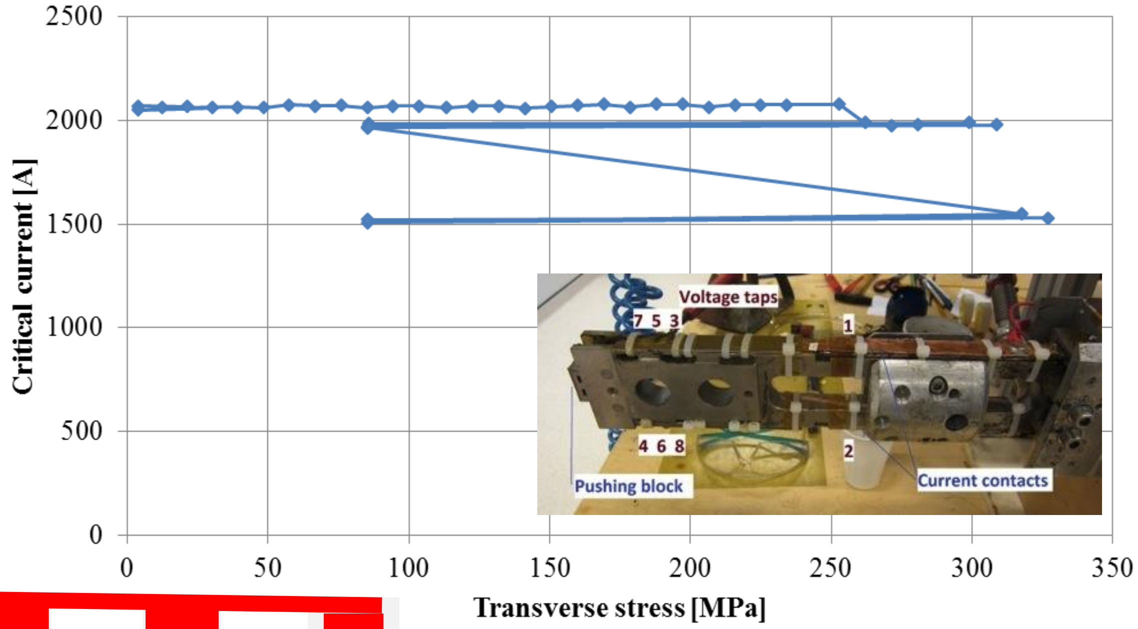
UNIVERSITY OF TWENTE.

IMPREGNATION

- Impregnation is obligatory
- With glass fiber sleeve insulation







TRANSVERSE PRESSURE DEPENDENCE OF THE CRITICAL CURRENT IN EPOXY IMPREGNATED REBCO ROEBEL CABLES

Simon Otten

MAGNETIC FIELD DIRECTION AND FORCES

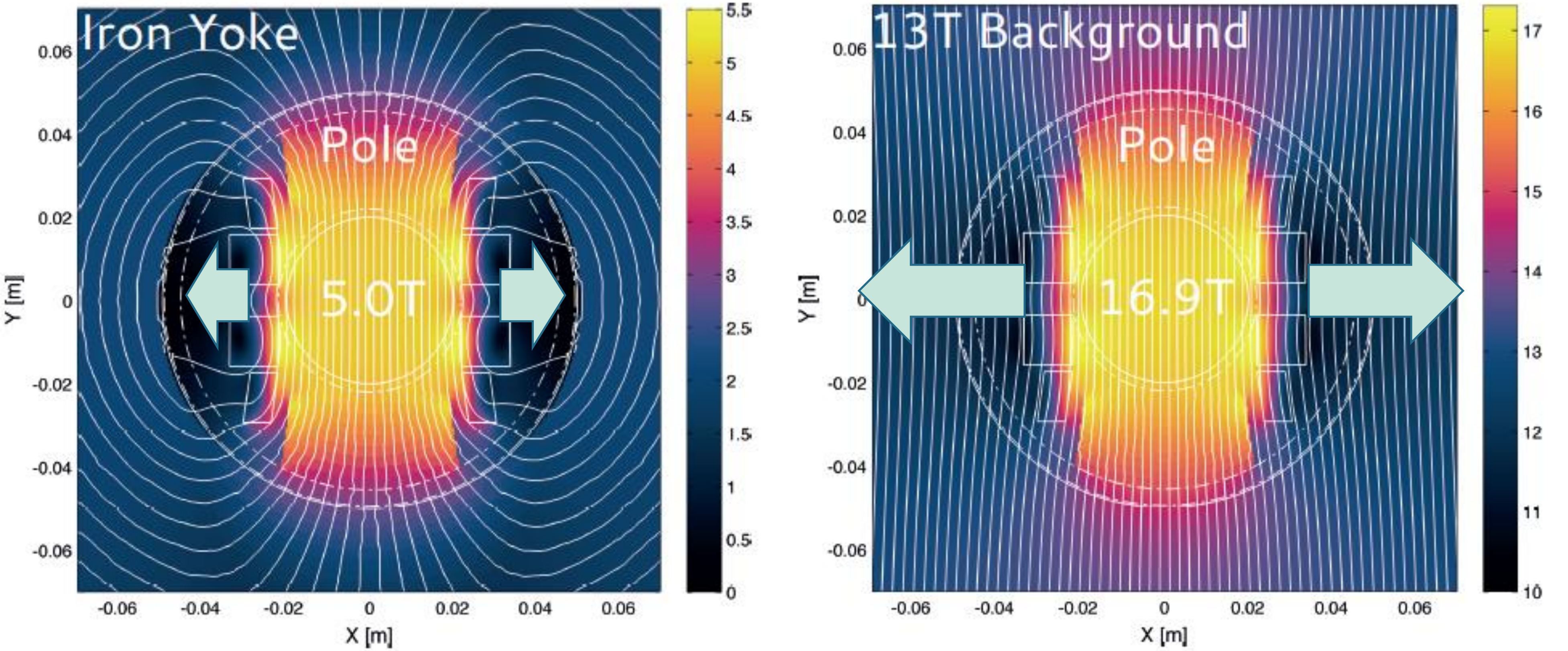
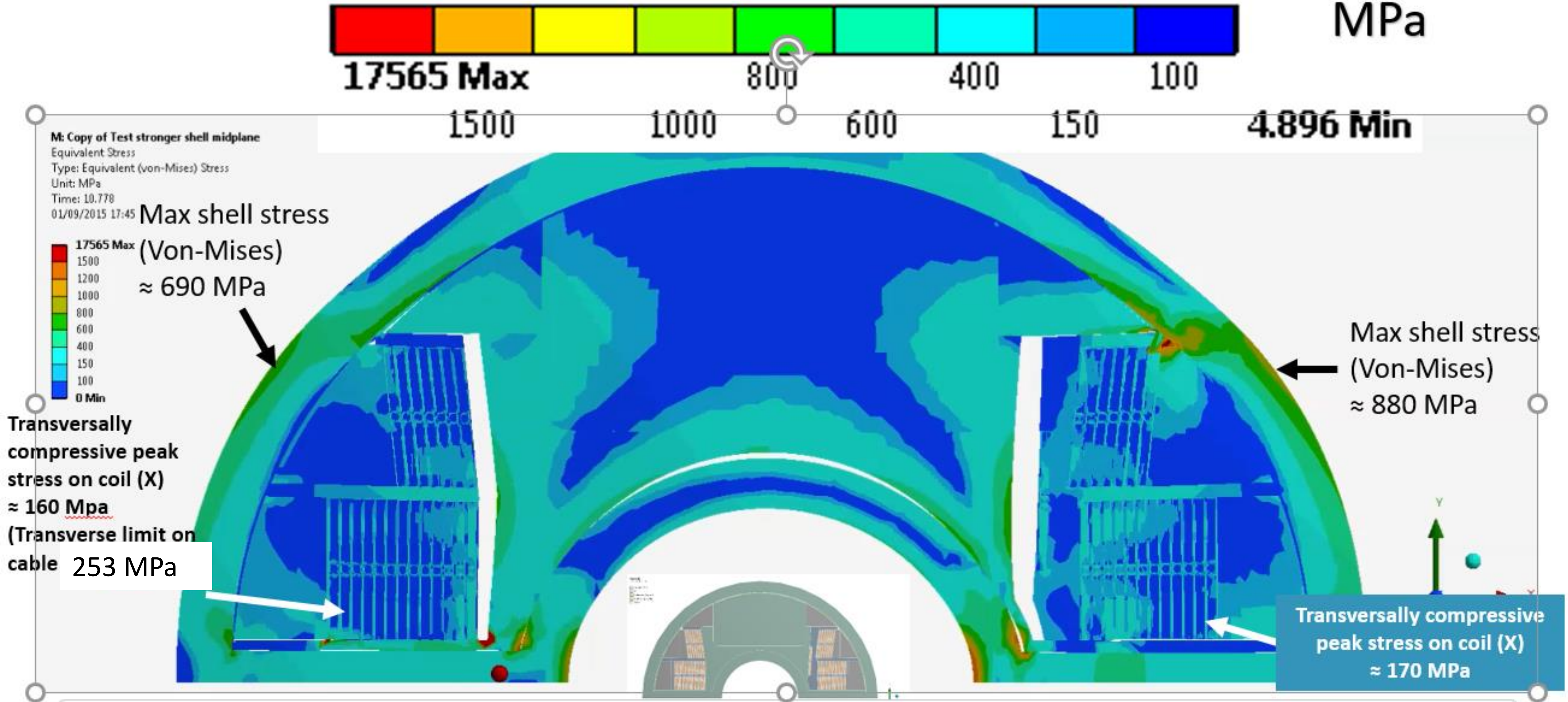


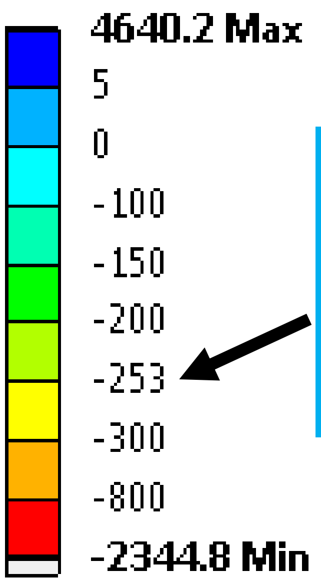
Figure 2.11: Calculated fieldlines for a 2D cross section of the Feather-M2 magnet. On the left side standalone in iron yoke and on the right side in a $13\ T$ background field.

FEATHER M2 2D Von-Mises plot, Cool down to powering 9kA + 15 T background field ≈ 20 T in the bore

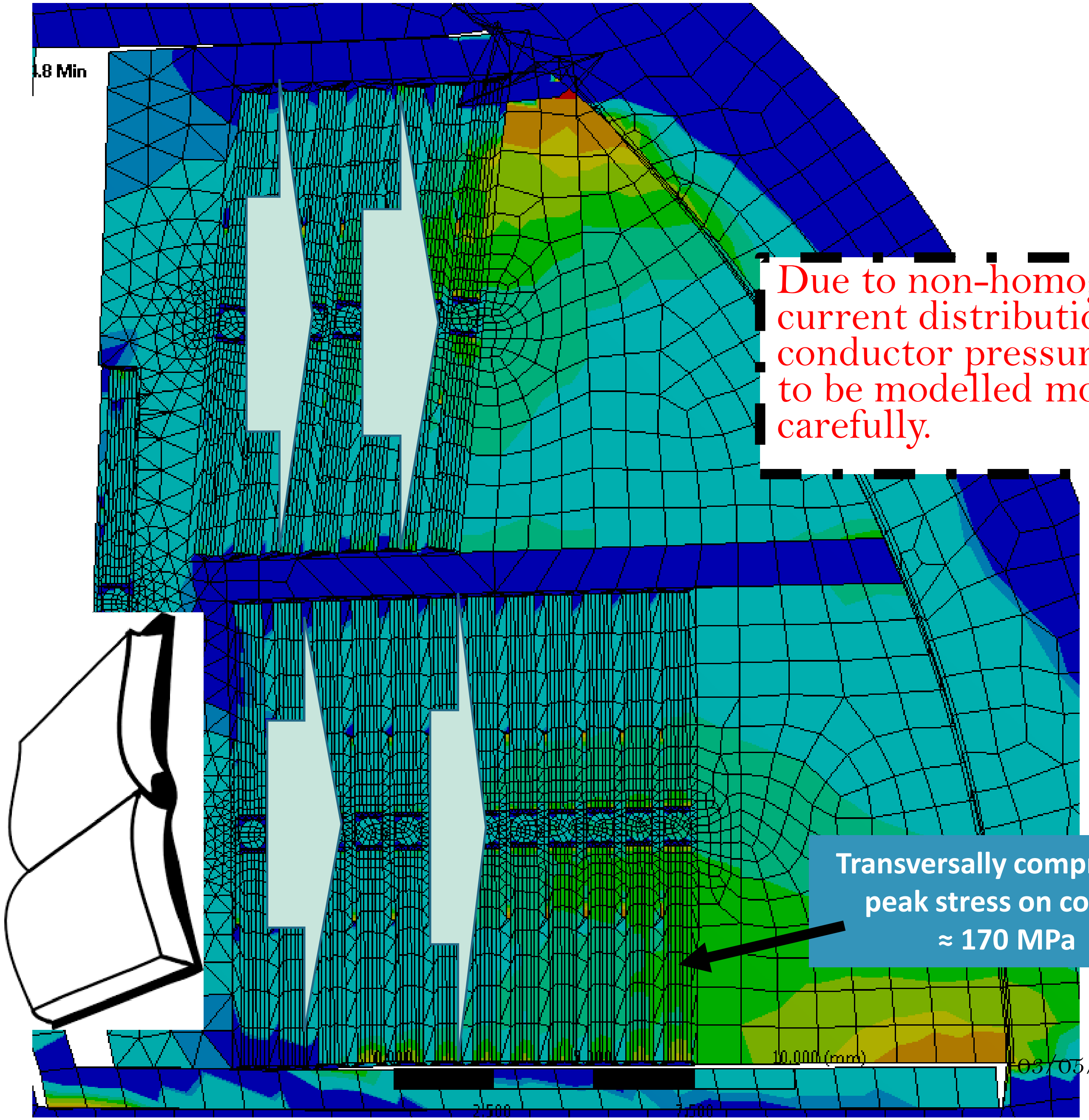
Assuming uniform current distribution over the cable



M: Copy of Test stronger shell midplane
Normal Stress 3
Type: Normal Stress(X Axis)
Unit: MPa
Global Coordinate System
Time: 11
01/09/2015 20:06



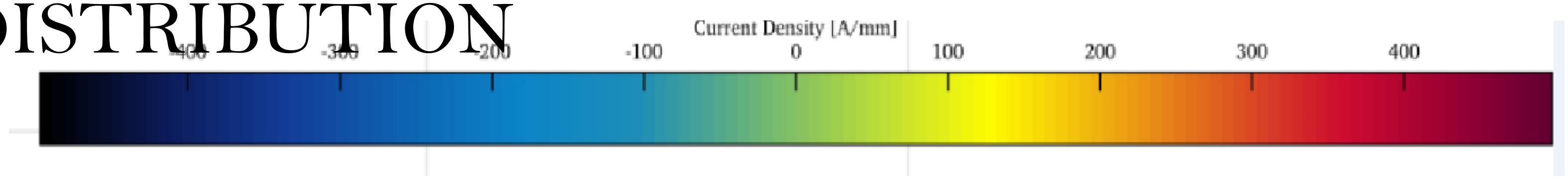
(REMEMBER: uniformly applied Transverse limit on cable 253 Mpa)

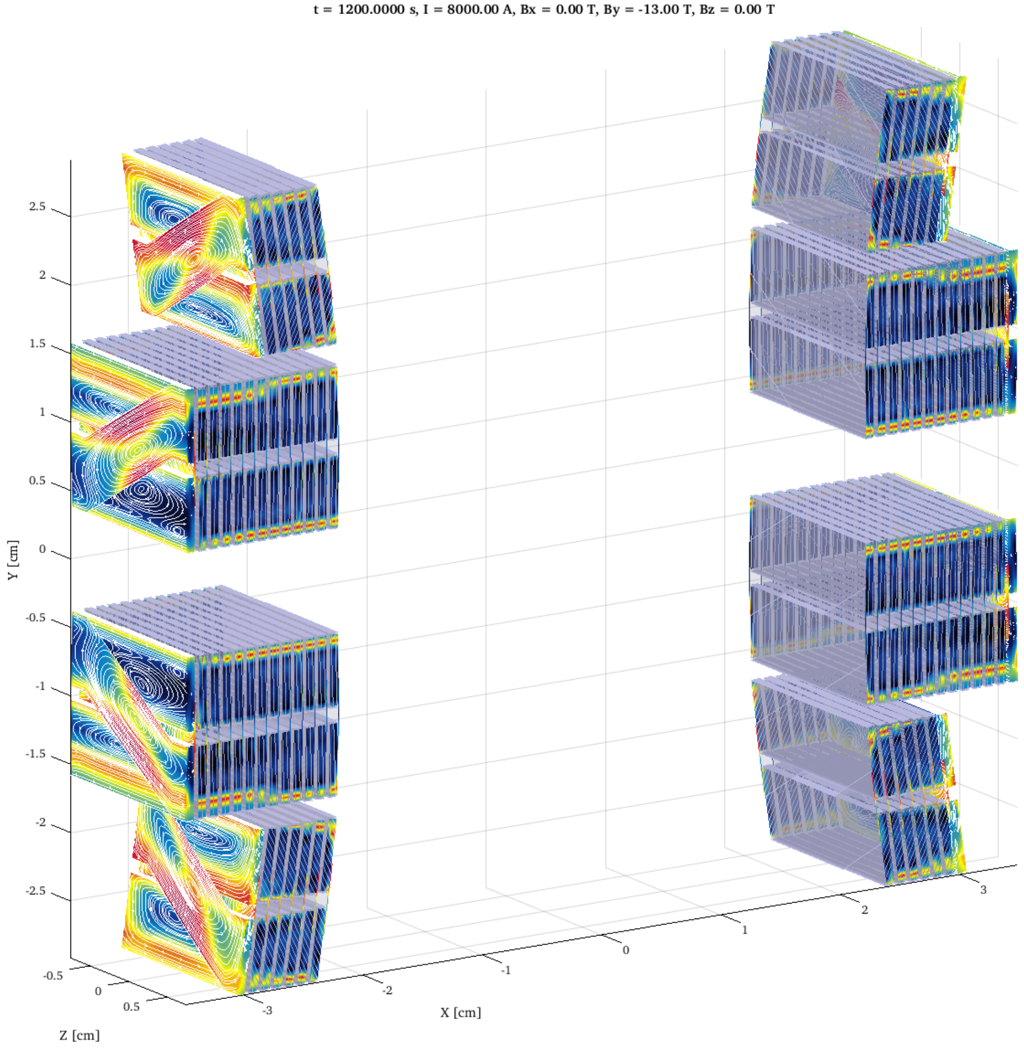


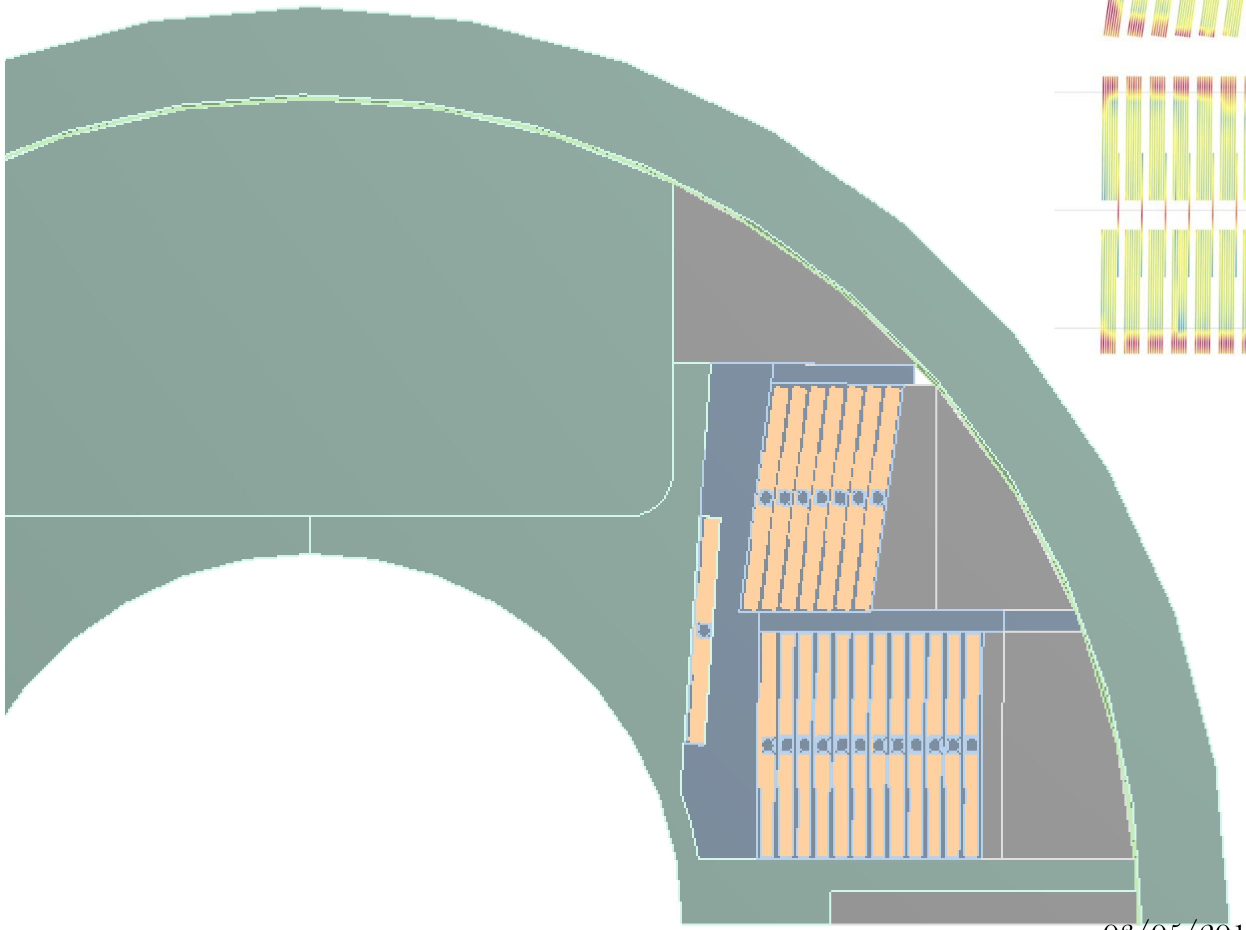
Due to non-homogenous current distribution, conductor pressure needs to be modelled more carefully.

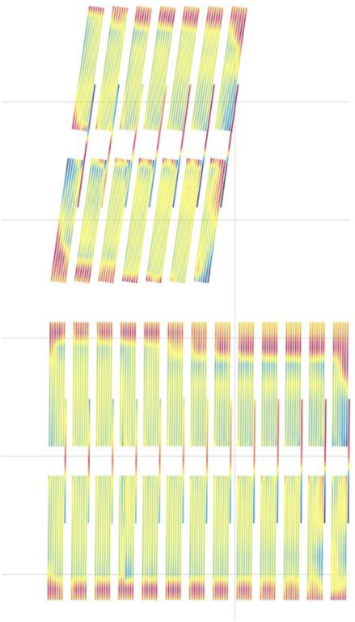
Transversally compressive peak stress on coil (X) ≈ 170 MPa

The mechanical analysis with non-homogenous current distribution









MODELING THE COIL PRESSURE

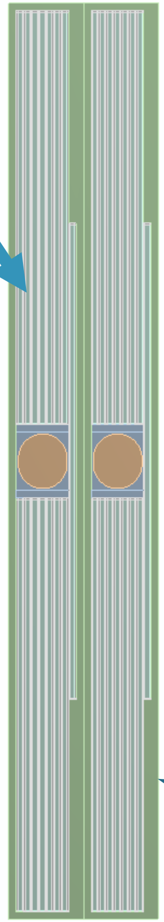
- We have a simplified approach to have a quick initial look at the pressure distribution in the most loaded turn 13 in Feather M2

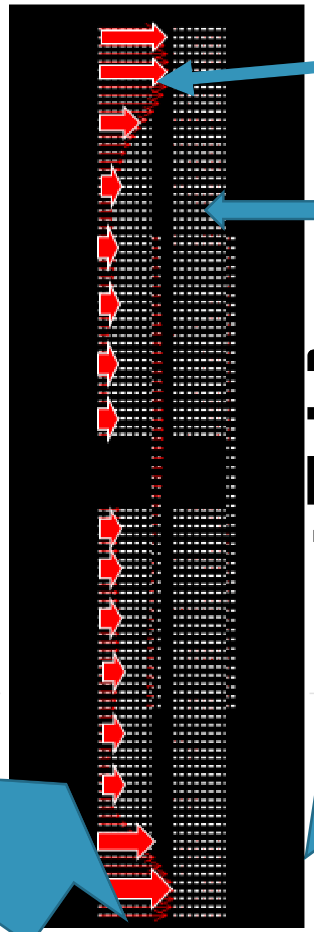
Ignore wing deck for now

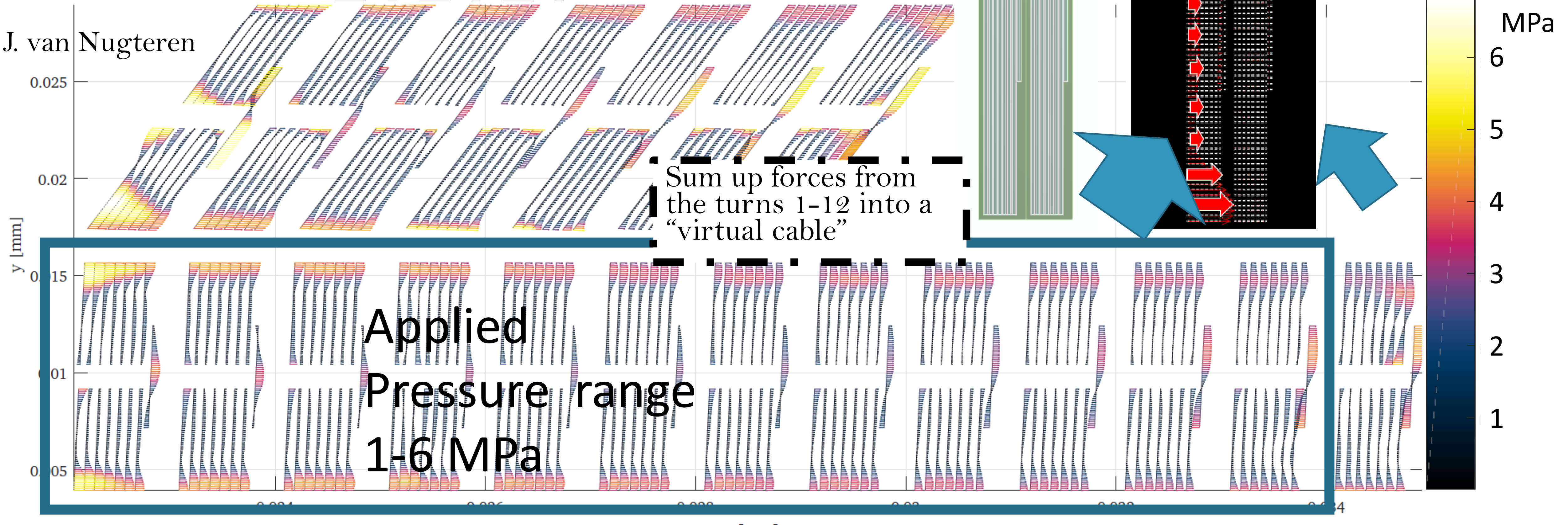
- build a structural two cable stack model, import forces

Take forces for the 13 turn

Sum up forces from the turns 1-12 into a "virtual cable"



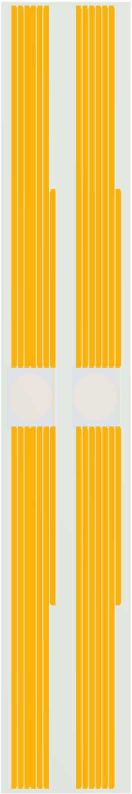




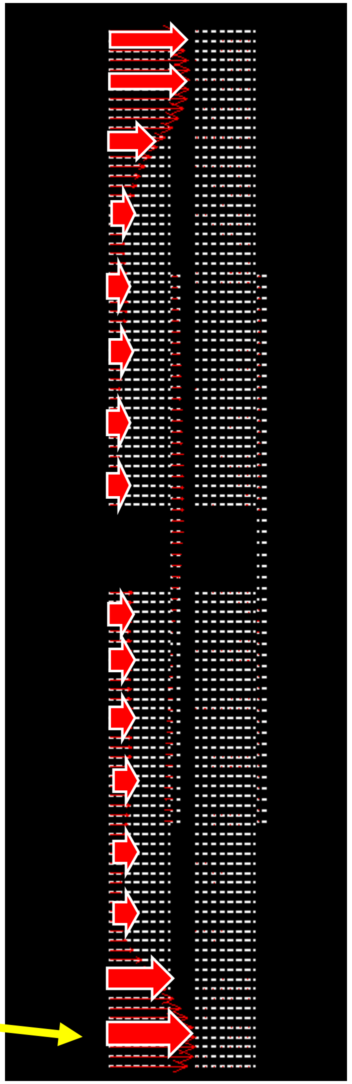
MODELING THE ROEBEL CONTACT

- Frictional sliding contacts assumed between tapes, realistic approach, since they are free to slide
- Increases stresses by 1/3 compared to fully glued tapes!

(REMEMBER: uniformly applied Transverse limit on cable 253 Mpa)

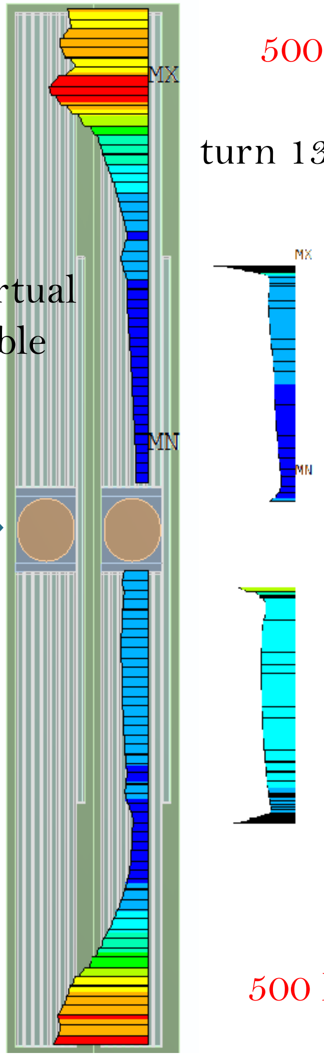


Applied pressure



Applied Peak 316 MPa

Resulting pressure distribution on turn 13



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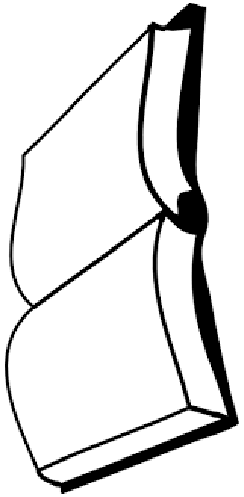
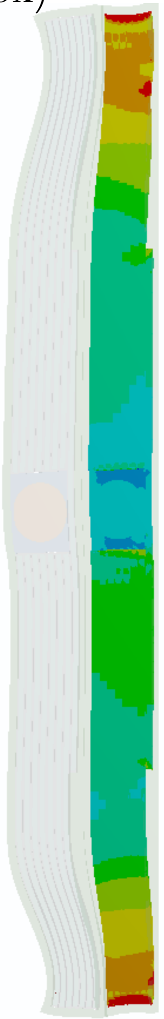
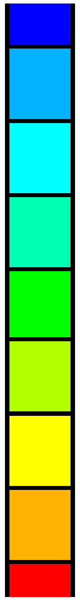


Horizontal Stress distribution Mpa (deformed shape magnified 16x)





Compressive

MPa

Conclusions

- The non-homogenous current distribution property for HTS was described
- The effect of non-homogenous transverse pressure need to be studied more carefully for the Feather M2 aligned block design
- The same for the cosinus-theta demonstrator as well!
- Maybe it is possible to do measurements as well with the existing set-up

Thank you!

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Back ups

Introduction to the EuCARD2 WP 10 project

- Racetrack wound around aperture by lifting the central decks; called " flared ends "

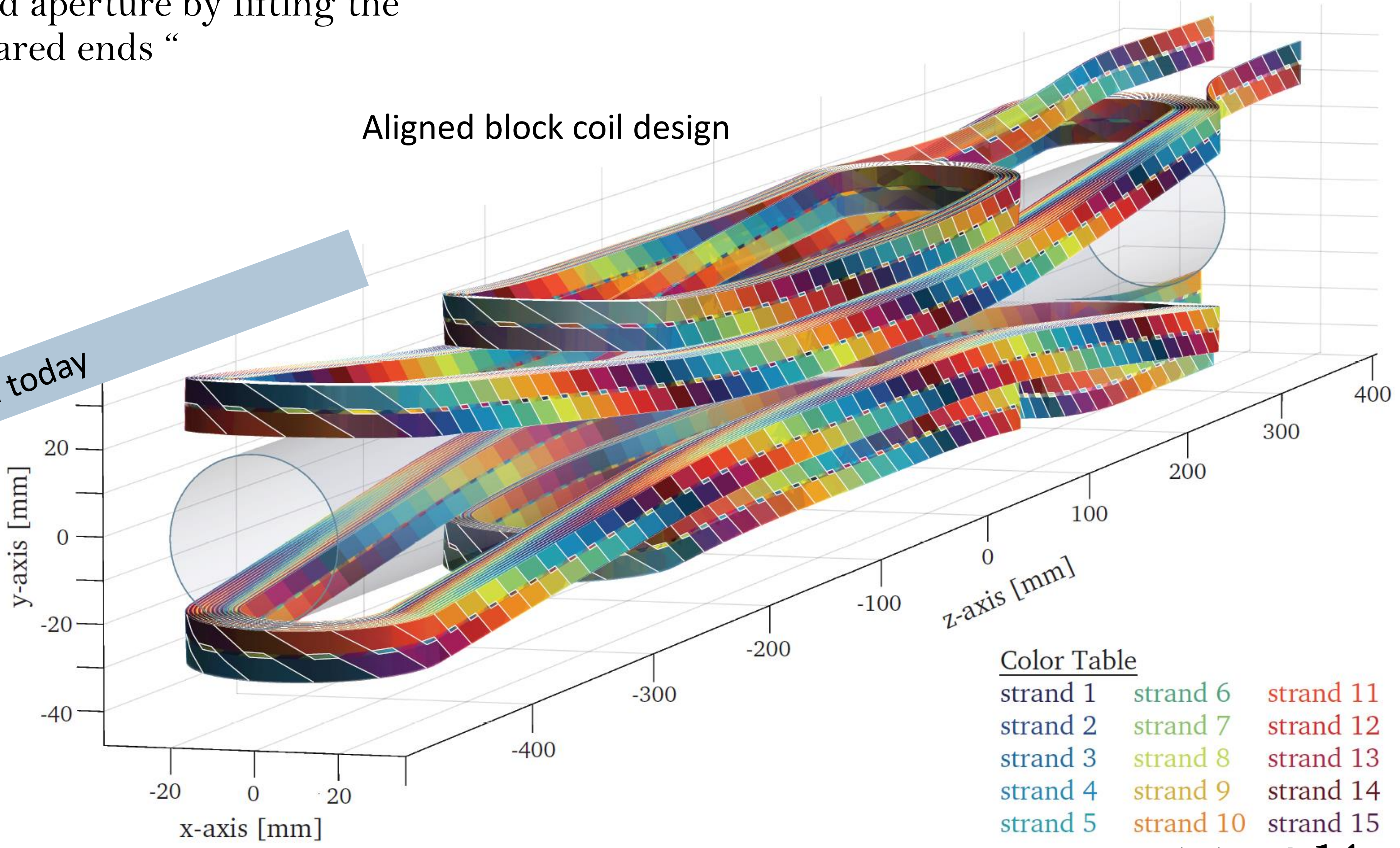
- EuCaRD2 Work package 10 Accelerator dipole
- 5 Tesla stand alone the workpackage requirement

(but we decided to go further for 17 Tesla in 13 Tesla background field)

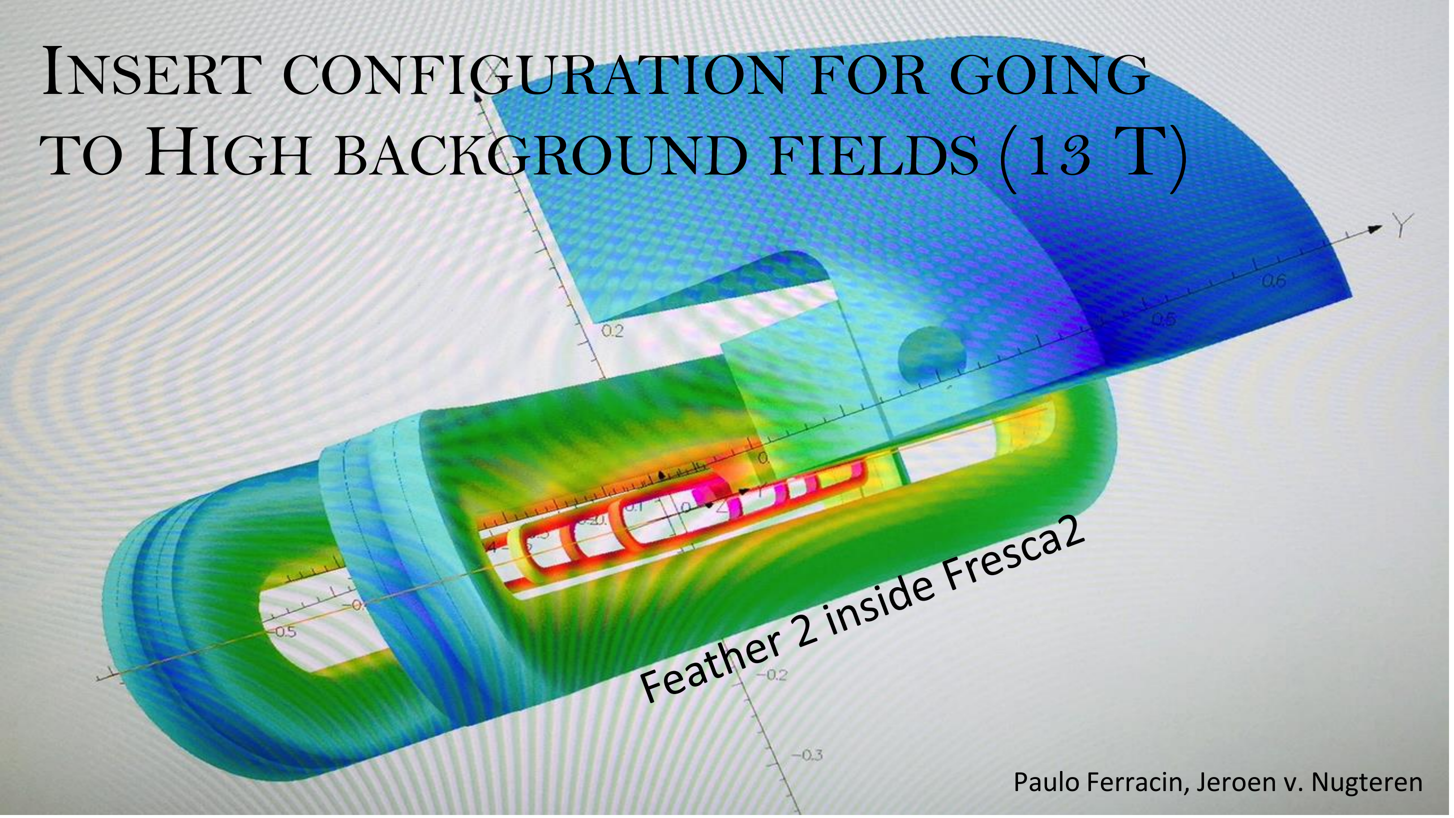
- 40 mm aperture
- 10 kA class cable
- @ 4.5K

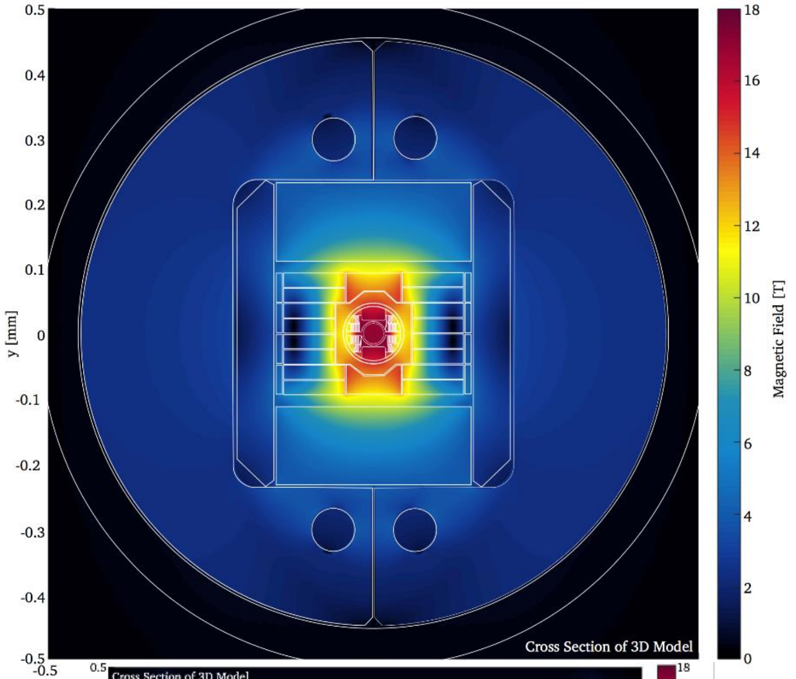
Already covered by Lucio Rossi today

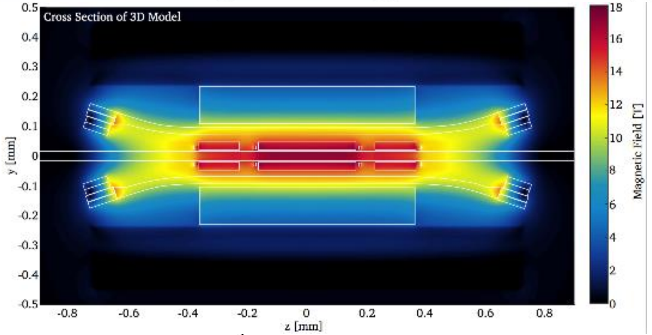
Aligned block coil design



Insert configuration for going to High background fields (13 T)

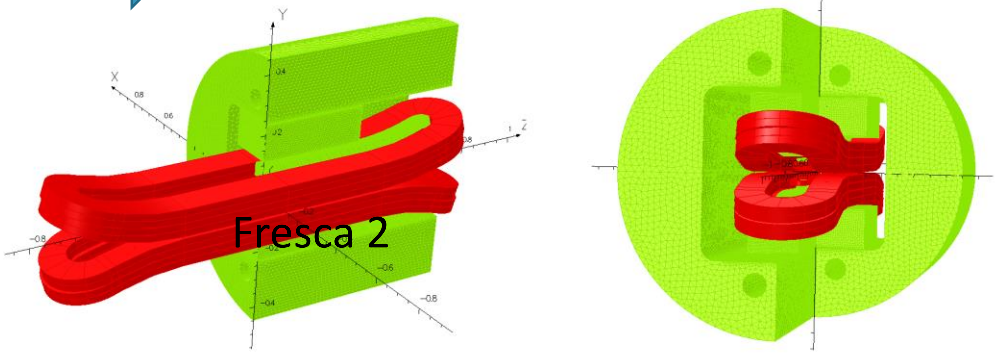


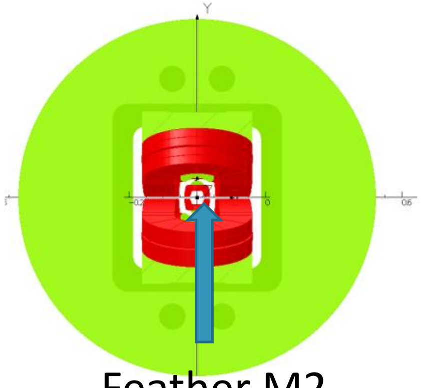


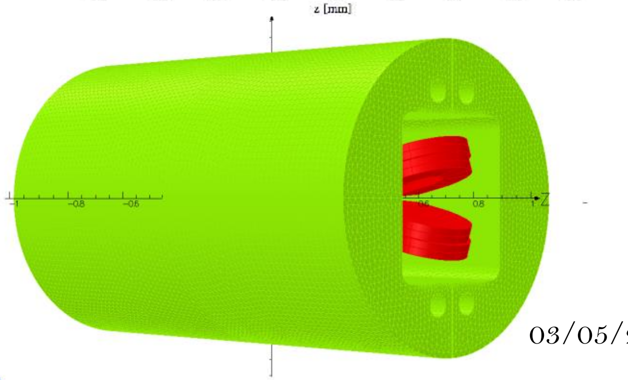


The main mechanical constraint is that the insert has to be mechanically self-supported and decoupled from the Fresca 2 outsert magnet.

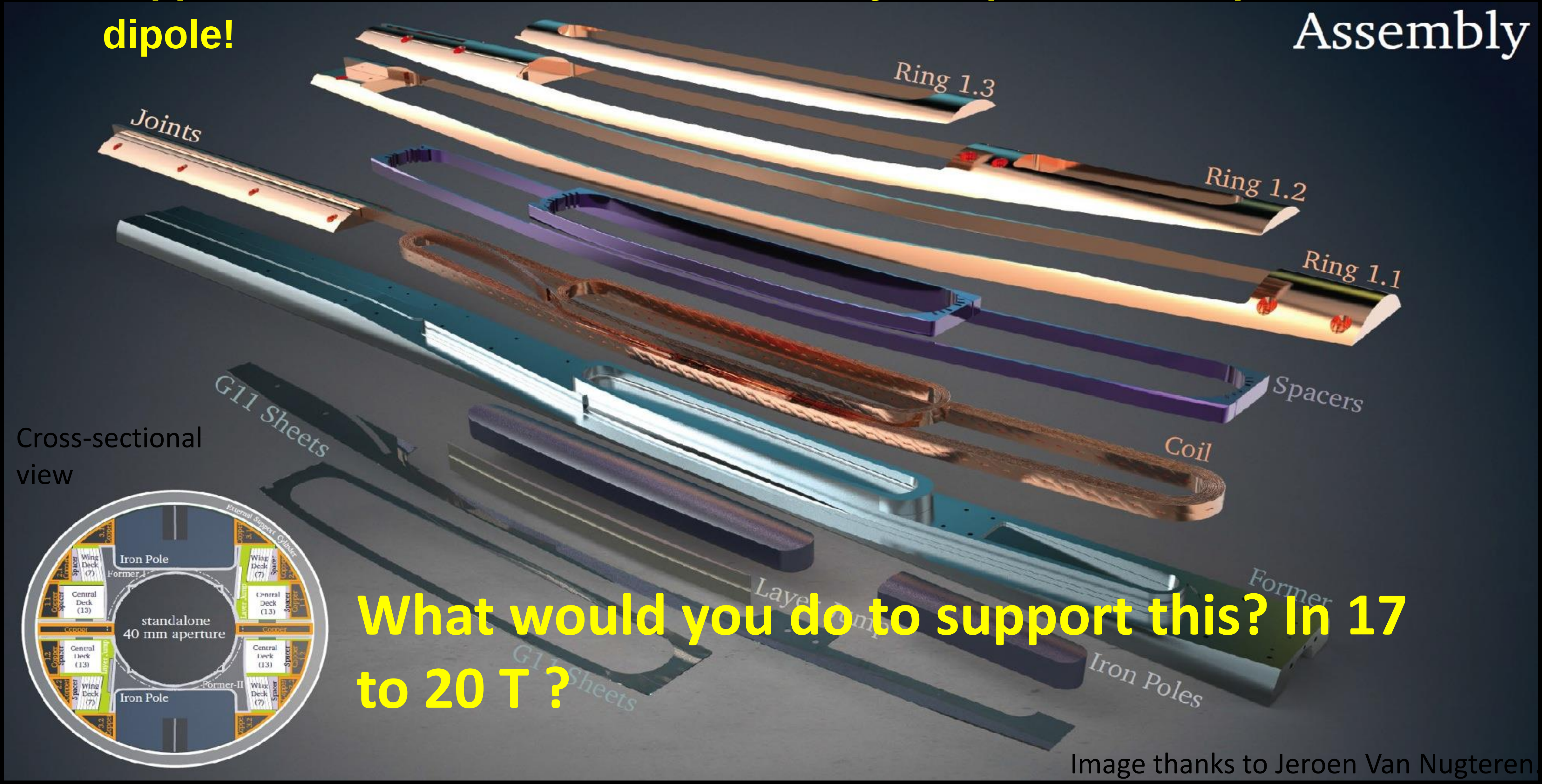
Main constraint for supports of the Feather!







In 17 T, electromagnetic forces are 253 t per one side of the magnet, supported in the 99 mm diameter magnet. (and 340 t/m) like LHC dipole!

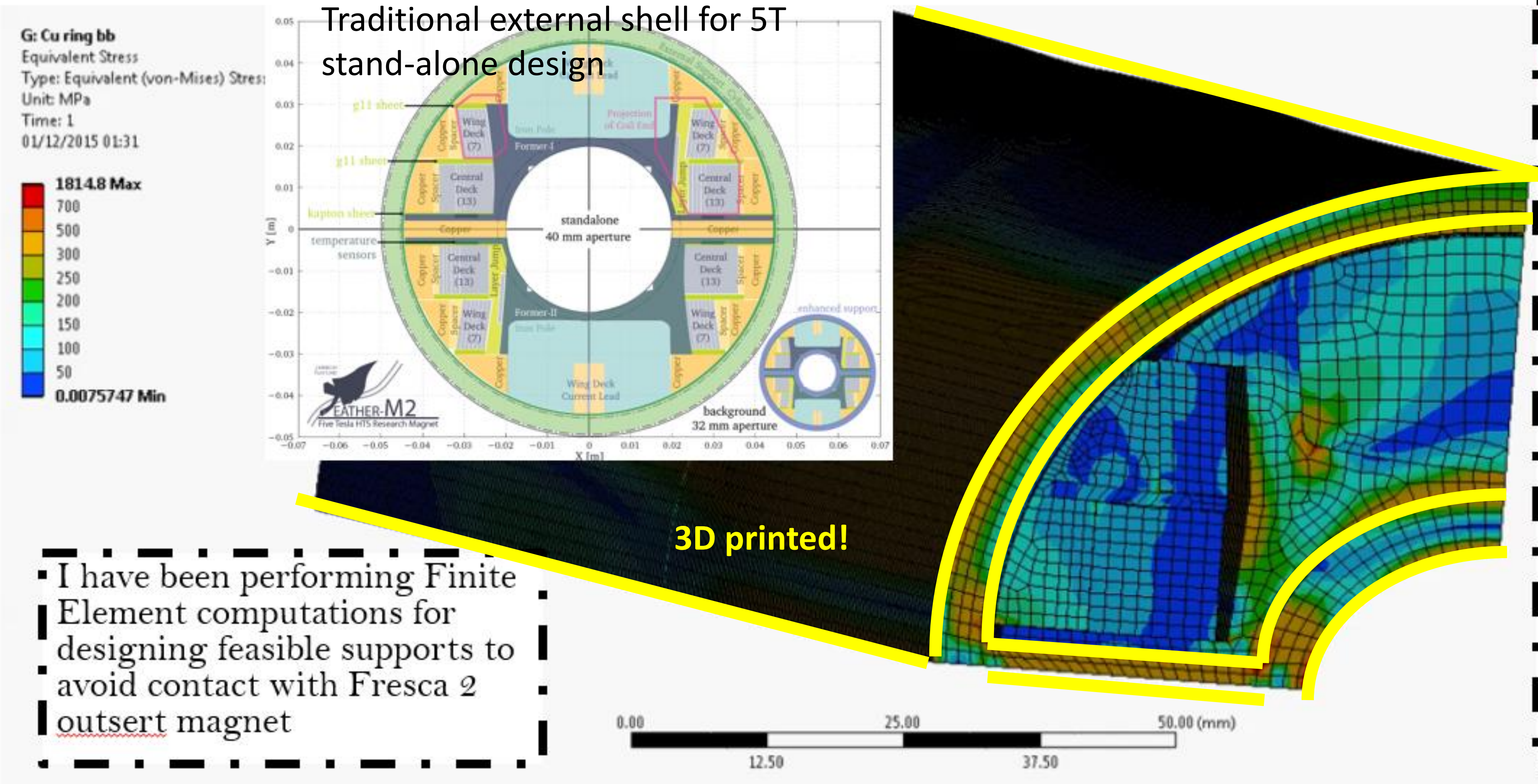


What would you do to support this? In 17 to 20 T ?

Image thanks to Jeroen Van Nugteren.

THE MECHANICAL ANALYSIS WITH HOMOGENOUS CURRENT DISTRIBUTION

Computed at 9kA + 12 T background field = 17 T



I have been performing Finite Element computations for designing feasible supports to avoid contact with Fresca 2 outsert magnet

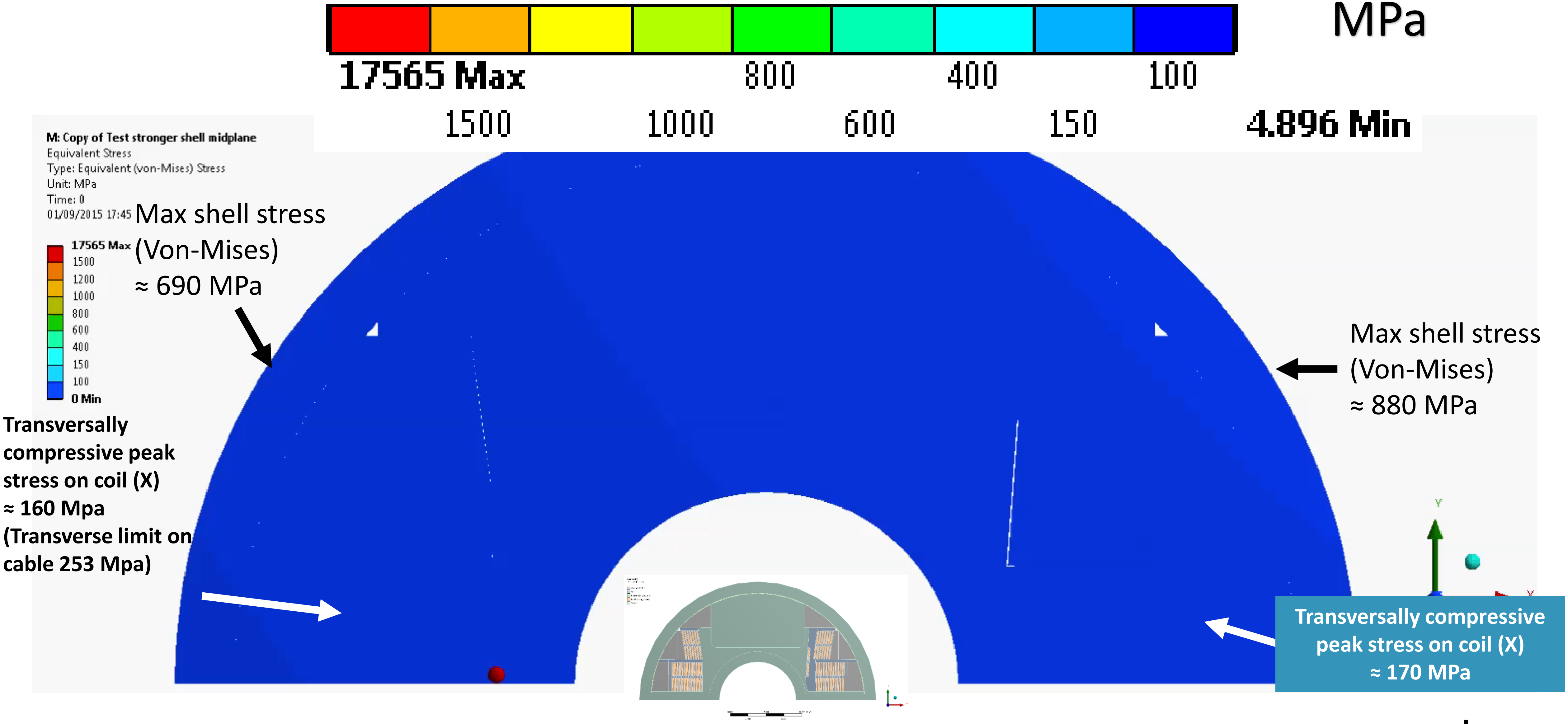
We cheated a little bit

The EuCARD-2 requirement is 40 mm aperture and 5T for 20T, we change the traditional external shell to a 3D printed integral support comprising of external and internal shell and mid-plane connection between the shells for extra support. But we trade off 4 mm radially from the aperture.

No pre-stress is applied to the dipole magnet design (compare LHC)! No shrinking shell concept

FEATHER M2 2D Von-Mises plot, Cool down to powering 9kA + 15 T background field ≈ 20 T in the bore

Assuming uniform current distribution over the cable



CLICK TO PLAY

Forces for quarter of a Coil

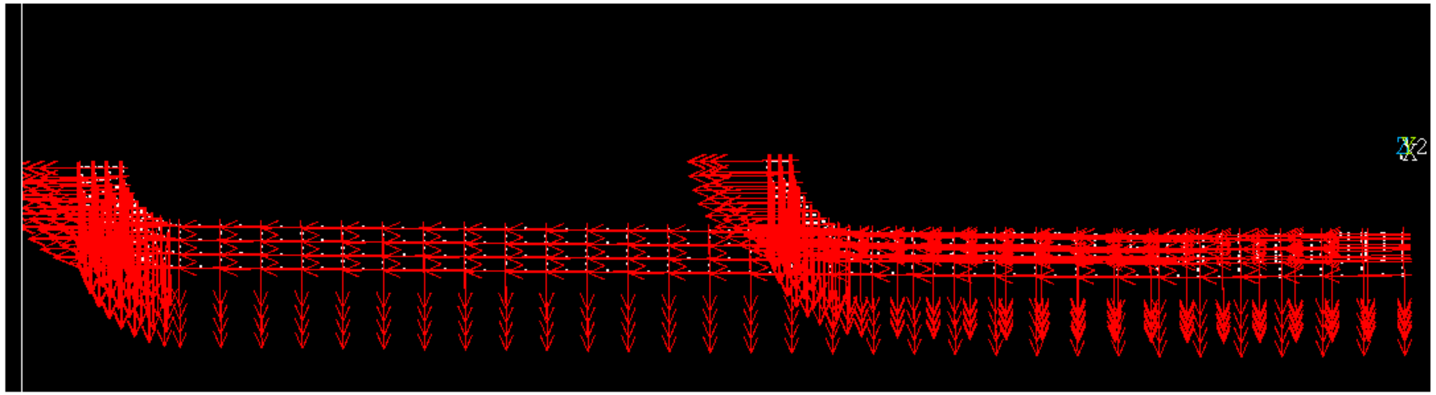
FX_tot (lateral) = 6.2015 *1.0e+05 N = 620 kN = 63 tonnes

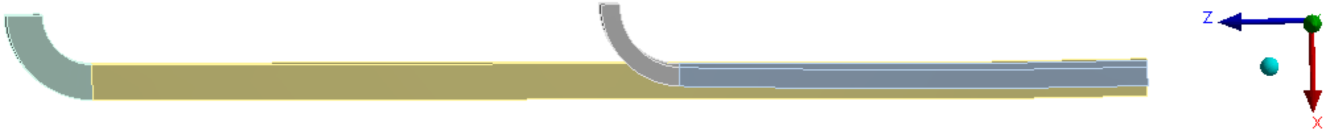
FY_tot (vertical)= -0.2281 *1.0e+05 N = -22 kN = -2 tonnes (poles attract each other)

17 T

FZ_tot (conductor axial)= 0.5778 *1.0e+05 N = 58 kN = 6 tonnes

Length 380 mm





In 17 T, This means 253 t per one side of the magnet, (and 340 t/m) like LHC!

Force transfer method by Attilio Milanese: A method to transfer distributed Lorentz forces in 3D to a finite element mechanical model
http://cds.cern.ch/record/1325572/files/OPERA_ANSYS_v2.pdf?version=2