MBHSP104 - Stress analysis – Focus on mid-plane stresses

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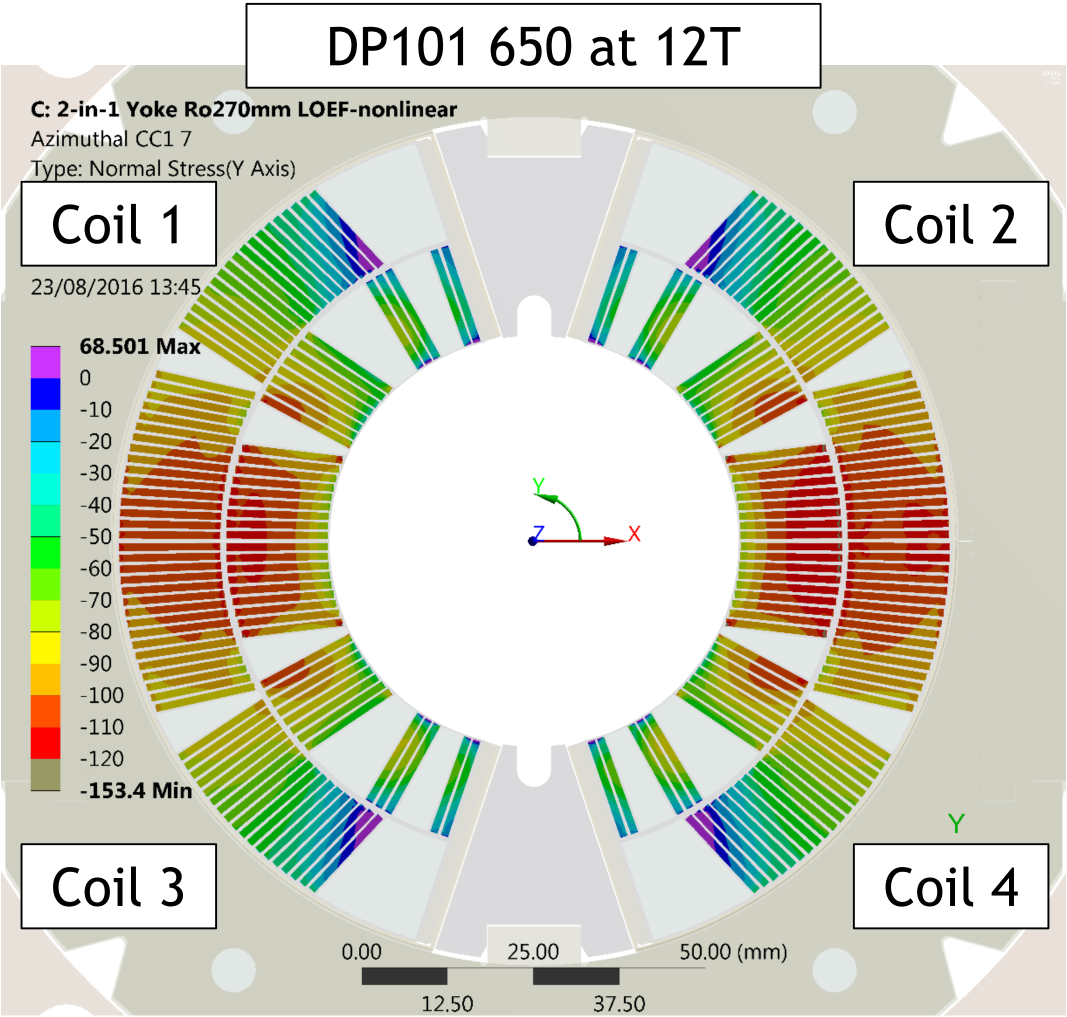
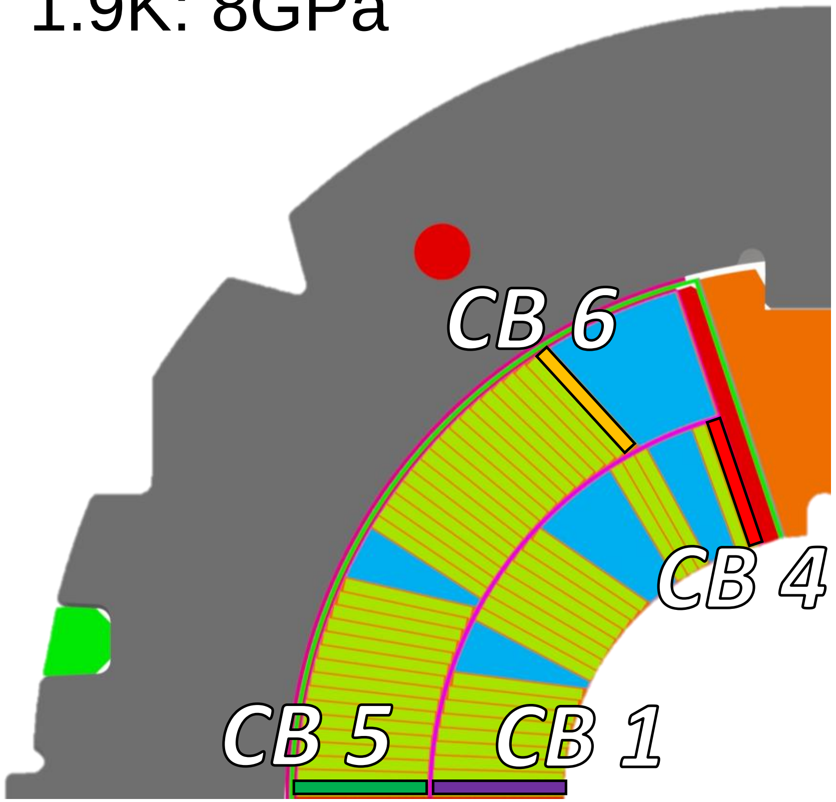
SP104 –midplane mechanics

- The stress on the collars and the bullet gauges had been discussed in the previous debriefing
- Bullet gauges behave very similar to previous models
- Strain Gauges on the collars show 25% more stress in the collared coil

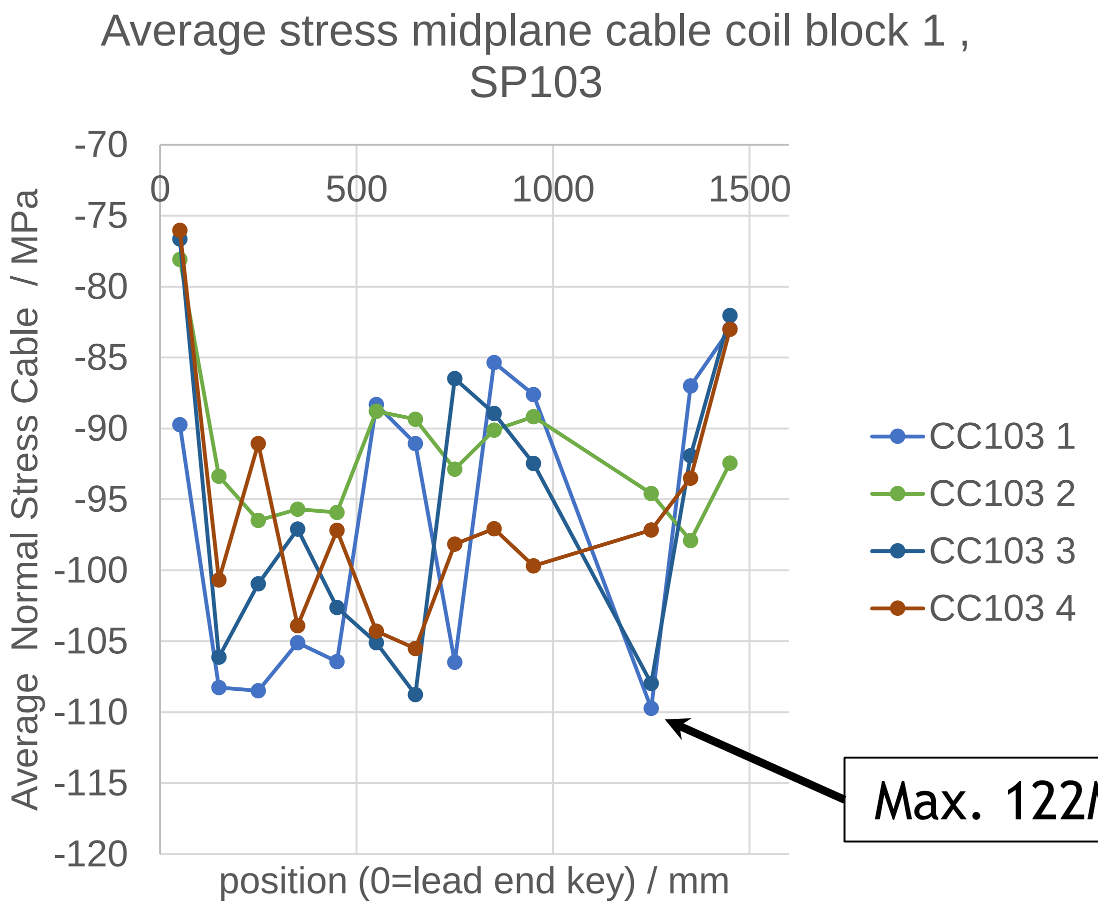
Midplane stresses



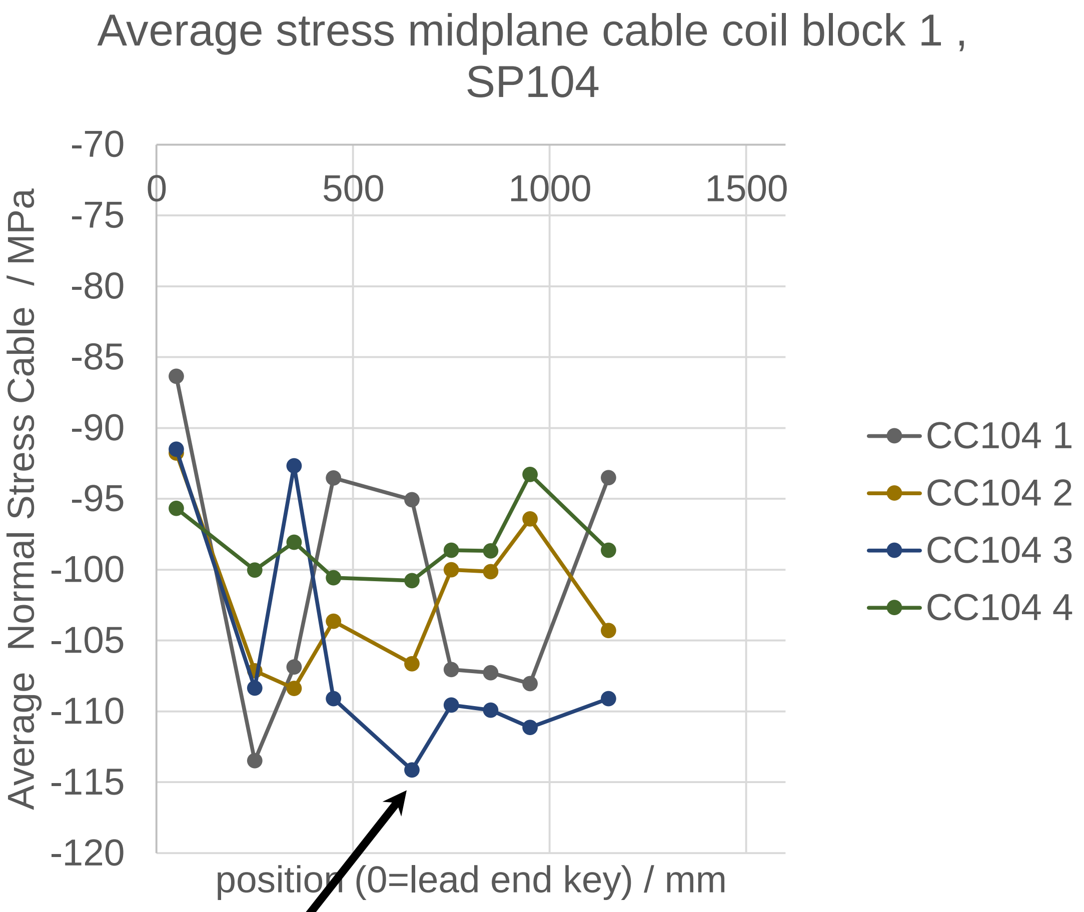
- Stresses will be shown as an average over one full cable
- Cable RT: 129GPa; 1.9K: 104GPa [2]
- Insulation RT: 6GPa; 1.9K: 8GPa



Midplane stresses at 12T / average over midplane cable CB1

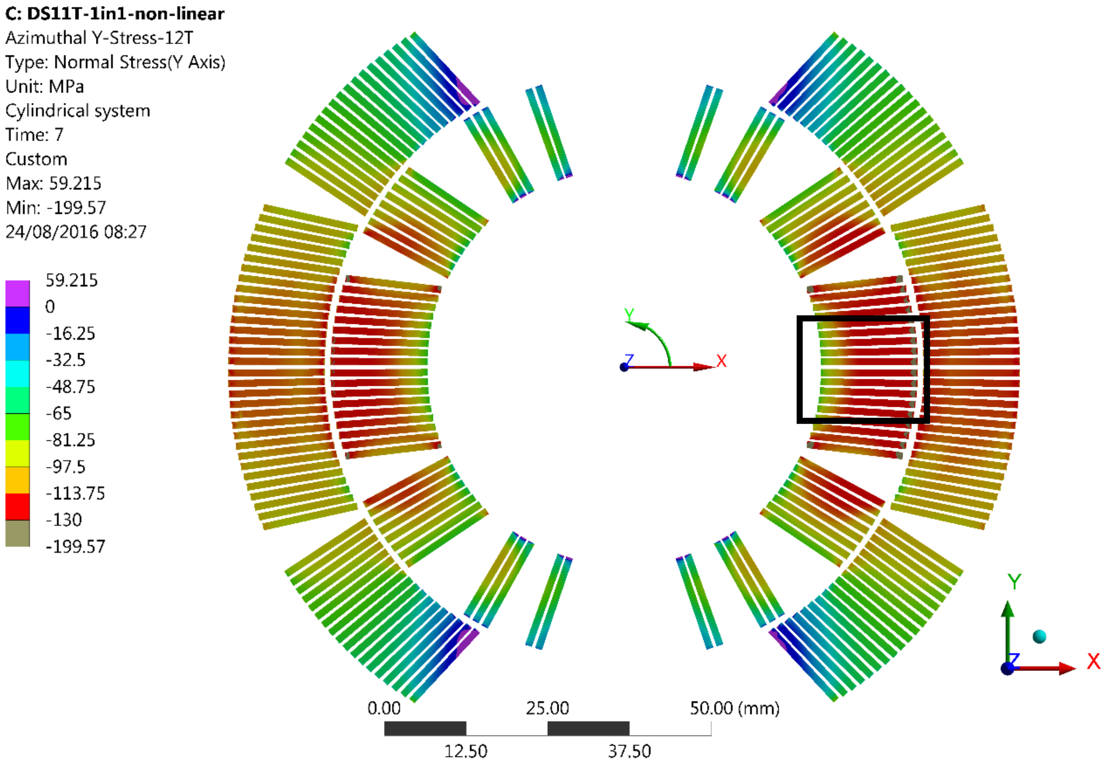


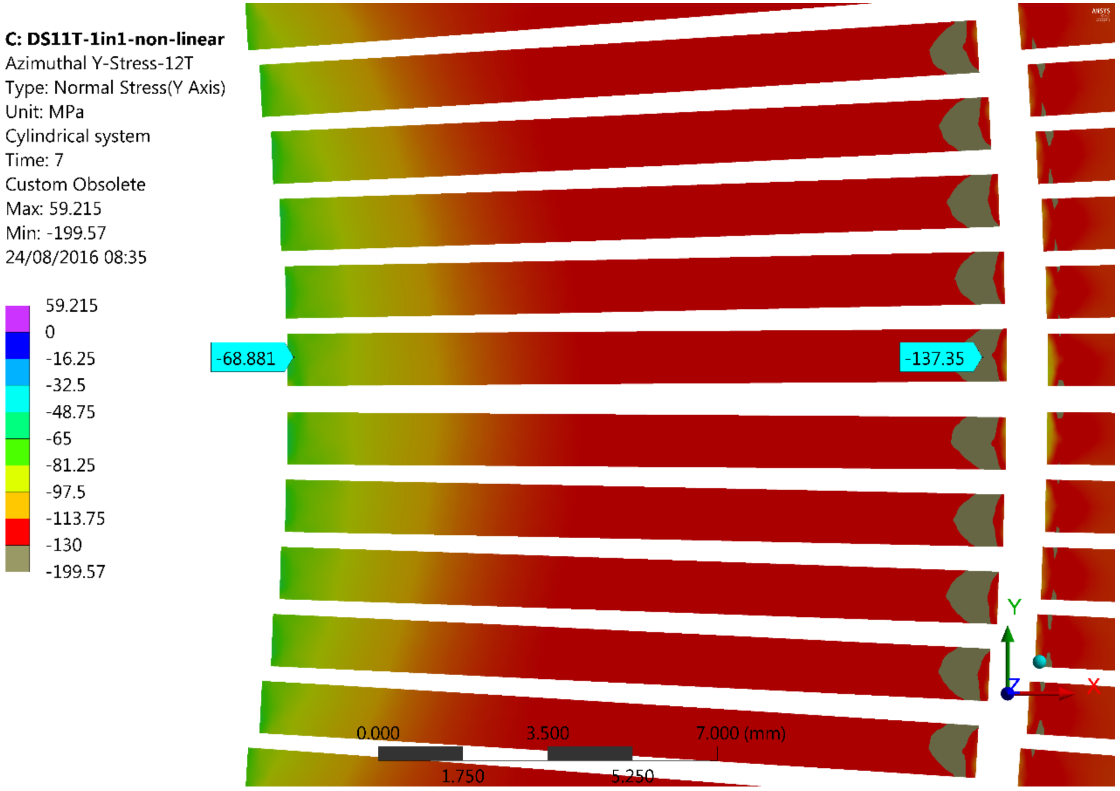
Max. 122MPa



Max. 137MPa

SP104 z=650mm at 12T





Applying the scaling law from Bernardo

$$I_1 = \varepsilon_1 + \varepsilon_2 + \varepsilon_3$$

$$J_2 = \frac{1}{6}[(\varepsilon_1 - \varepsilon_2)^2 + (\varepsilon_2 - \varepsilon_3)^2 + (\varepsilon_3 - \varepsilon_1)^2]$$

$$s(\boldsymbol{\varepsilon}) = \frac{e^{-C_1 \frac{J_2+3}{J_2+1} J_2} + e^{-C_1 \frac{I_1^2+3}{I_1^2+1} I_1^2}}{2}$$

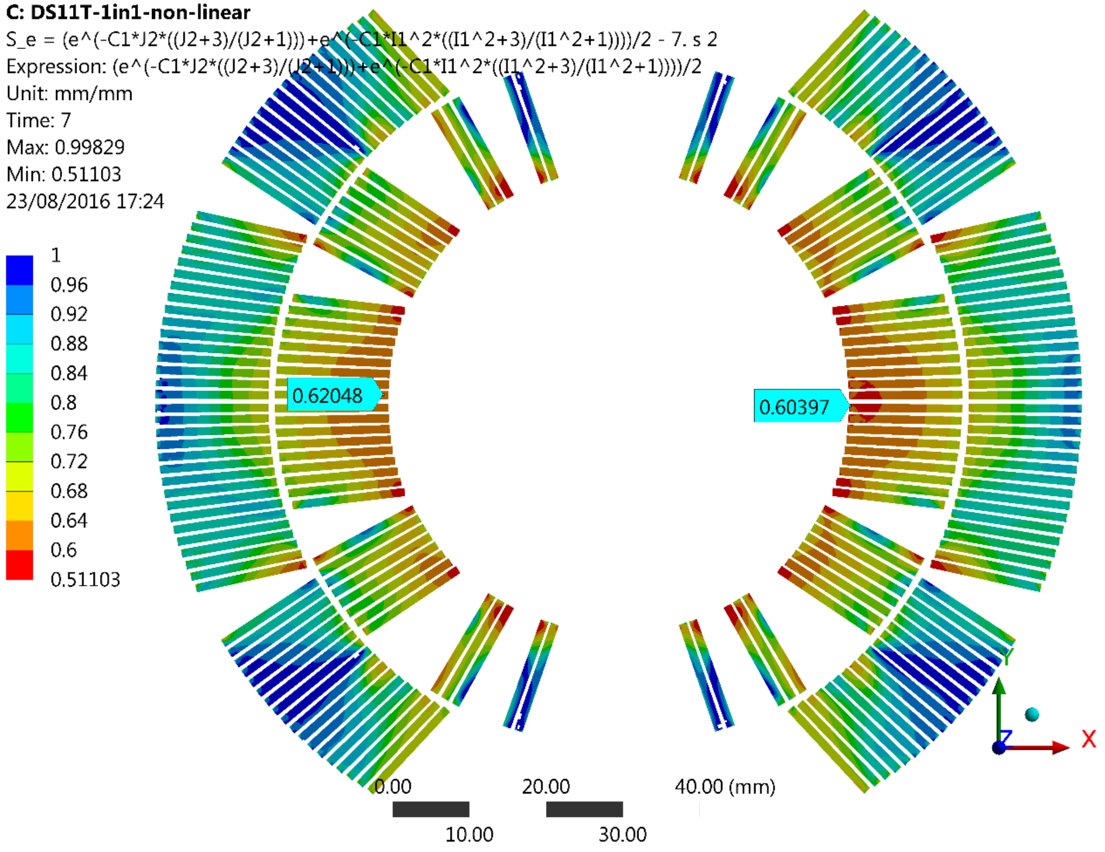
$$s(\varepsilon) \equiv \frac{B_{c2}(0, \varepsilon)}{B_{c2}(0, 0)}$$

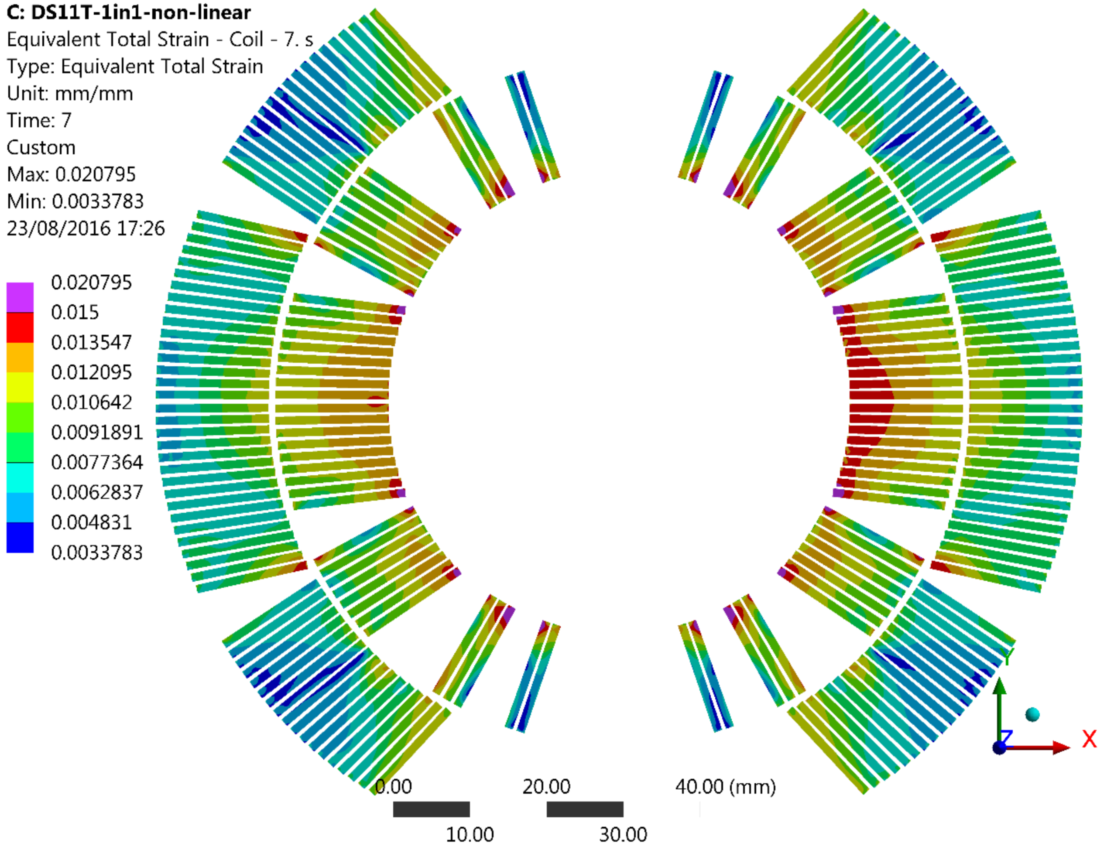
Assumption:

$C_1 = 0.875$

From: *An exponential scaling law for the strain dependence of the Nb 3 Sn critical current density,* B Bordini and P Alknes and L Bottura and L Rossi and D Valentinis, Superconductor Science and Technology 2013

SP104 z=650mm at 12T

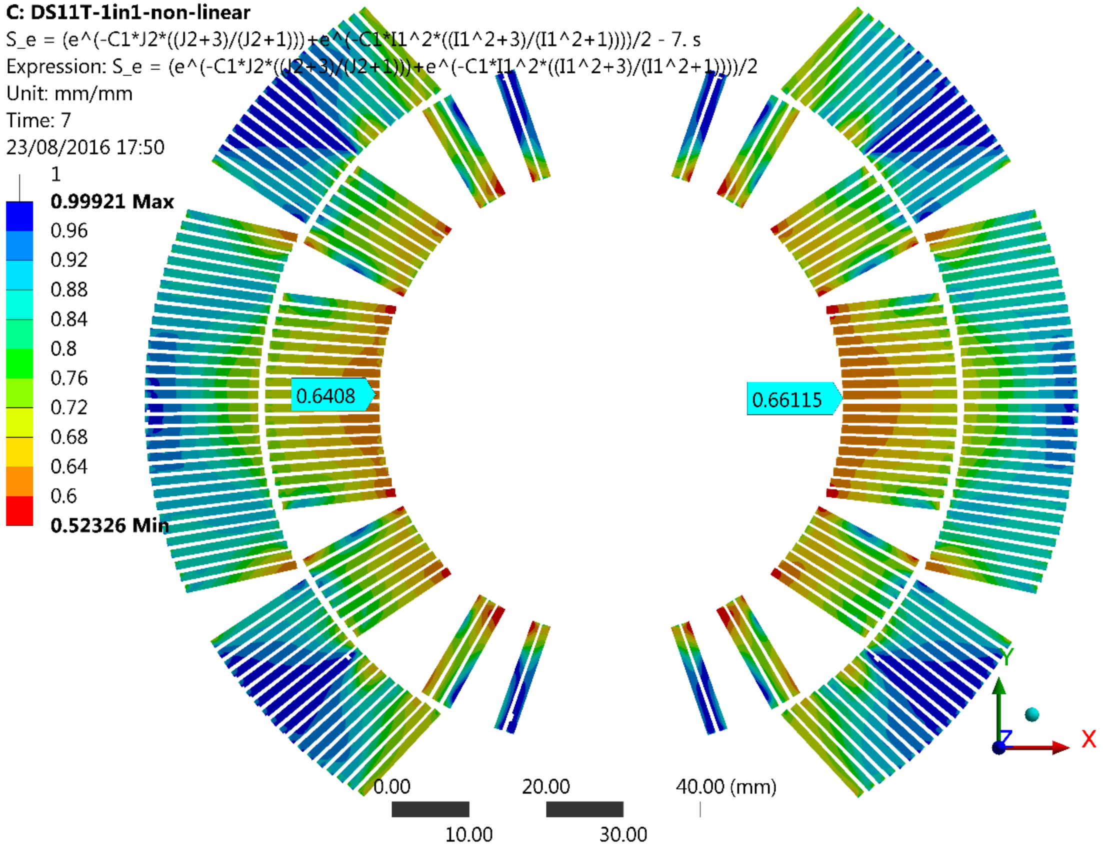




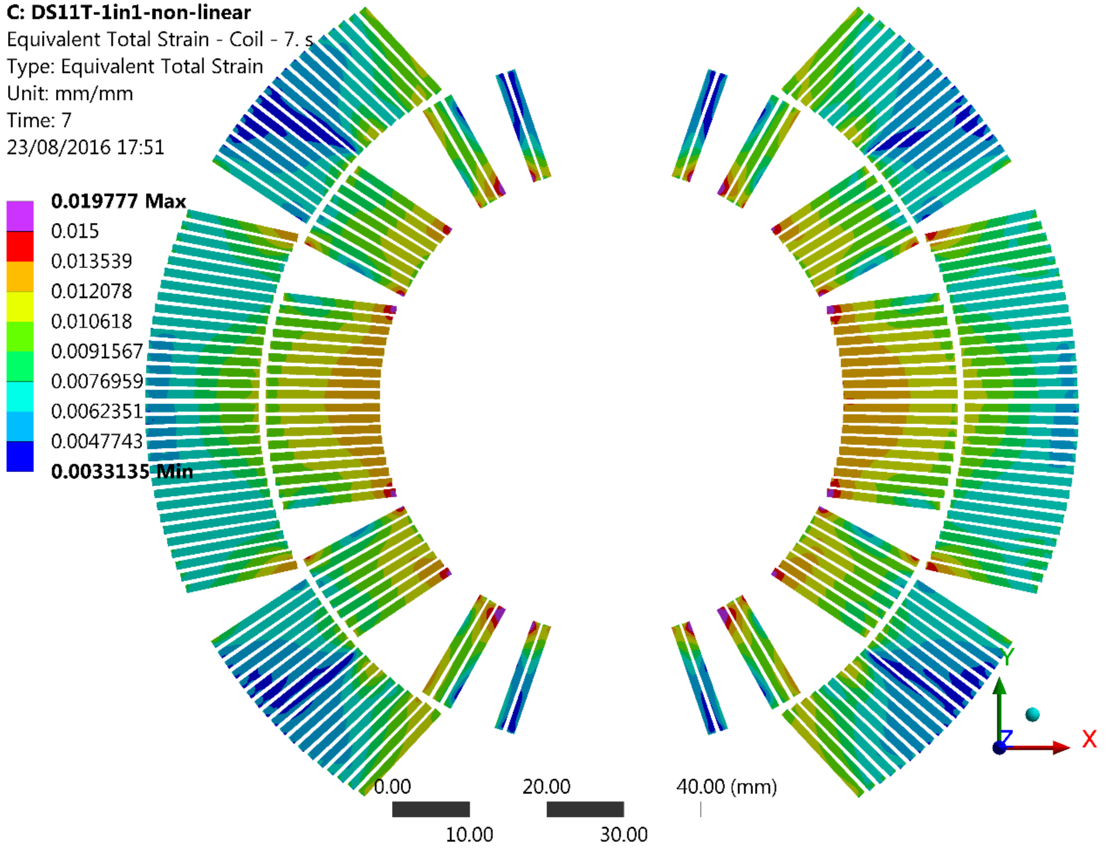
$s(\varepsilon)$

Equivalent Total Strain

SP103 z=650mm at 12T

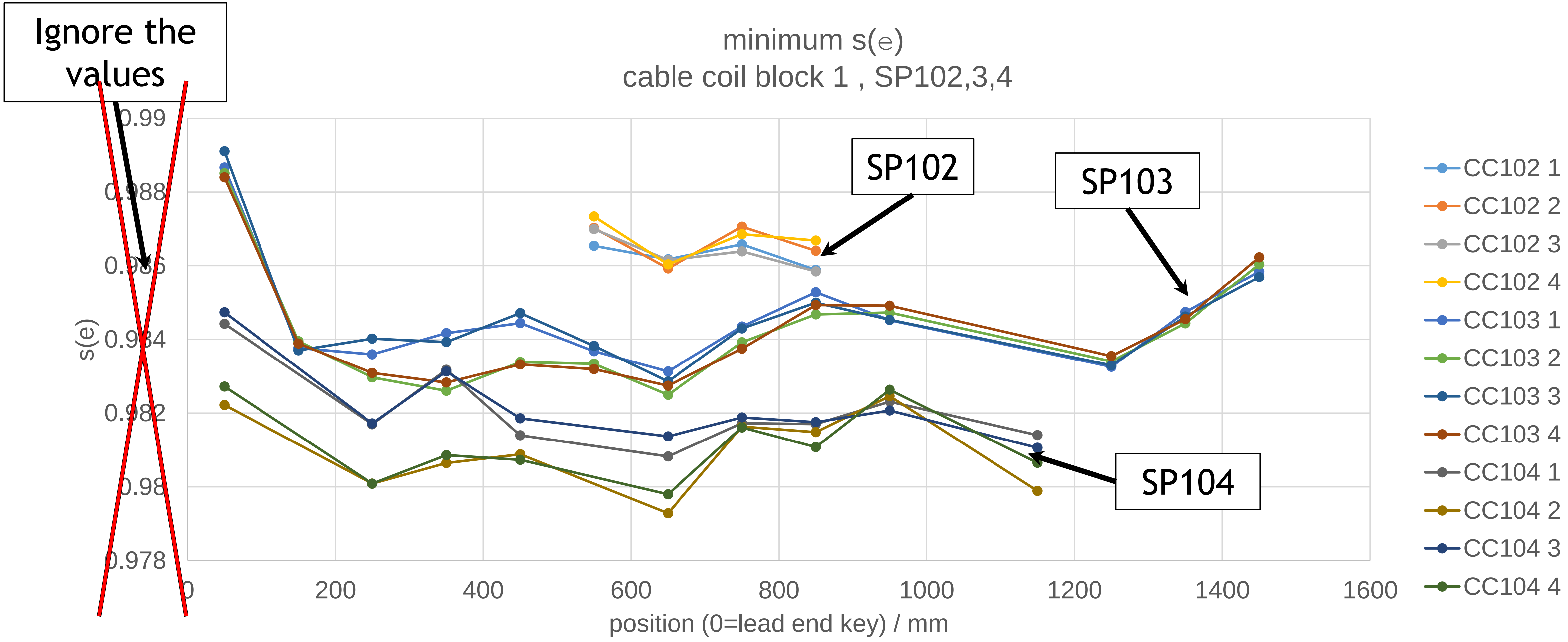


$s(\varepsilon)$



Equivalent Total Strain

Scaling law on midplane cable – plot only qualitative



Comparing SP103 and SP104

- The Maximum s(ϵ) for SP103 is **0.64** at the midplane
- For SP104 it is **0.6**
- Applying the scaling law to a full magnet model is a rather new method
- The cable is modeled as a smeared property of Nb3Sn and Copper, material data is based on [2]
  Elastic Anisotropy in Multifilament Nb3Sn Superconducting Wires

C. Scheuerlein, B. Fedelich, P. Alknes, G. Arnau, R. Bjoerstad, and B. Bordini

CERN

Stress in collars after test

- SP102 = -*111MPa*
- SP103 = -*116MPa*
- SP104 = -*165MPa*

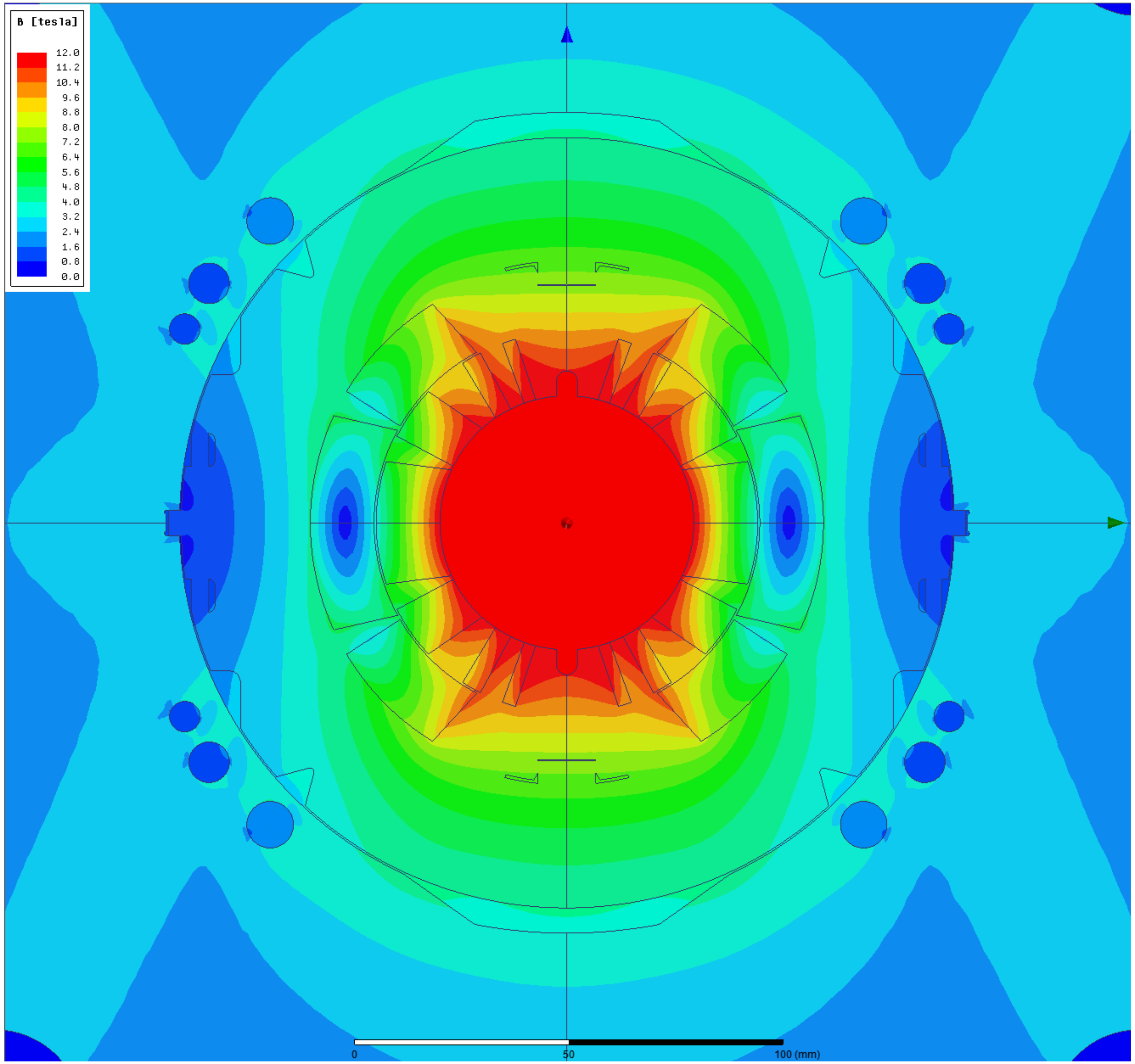
- Also after the cold-test SP104 is the model with the most pre-stress in the collar

[1] material

Table 2.2. Properties of the different spring materials and of a typical Nb_3Sn wire.

Material	Thermal expansion 293–4 K (%)	Young's modulus at 4 K [293 K] (GPa)	Poisson's ratio at 4 K [293 K]	Elastic limit at 4 K [293 K] (%)
Titanium -4Al-6V	−0.174[a]	130[b] [110]	[0.31][b]	1.3[c] [1.0][d]
Copper-beryllium (TH04)	−0.317[a]	132 [119][c]	[0.27][b]	1.0 [0.9][c]
Brass (C27200)	−0.370[e]	[105][f]	[0.34][f]	[0.4][f]
Stainless steel 316L	−0.300[a]	208[a] [193[f]]	0.28 [0.29][g]	[0.1][f]
Nb_3Sn wire	−0.28[g,h]	25–100[g,i]	—	~0 [~0][g]
Copper	−0.334[g]	137 [128][g]	[0.31][f]	0.04 [0.02][g]
Nb_3Sn	−0.16[j]	100 [135][g]	0.4[j]	—

[a] Reference[55]. Stainless steel data is for type 316.
[b] Reference[56]. Cryogenic data for Ti-6Al-4V at 20 K.
[c] Reference[19].
[d] Reference[42].
[e] Reference[57]. 70/30 Brass (C26000).
[f] Reference[58].
[g] Reference[59]. Stainless steel data is for type 316LN.
[h] Reference[60]. Vacuumschmelze bronze-route wire.
[i] Reference[61]. A range of tangent modulus values are shown for the Nb_3Sn wire (which behaves plastically). Similar at 293 and 7 K.
[j] Reference[22].



1in1 12.8kA

- [1] Critical current measurements of TFMC-LMI and CSMC-VAC Nb3Sn—measurements, FEA corrections and the scaling law parameterisation
  - DMJ Taylor, P Foley, HJ Niu and DP Hampshire
- [2] Elastic Anisotropy in Multifilament Nb3Sn Superconducting Wires
  - C. Scheuerlein, B. Fedelich, P. Alknes, G. Arnau, R. Bjoerstad, and B. Bordini