

Mechanical properties for FalconD 12T program

RD Line 4 fourth Forum meeting, - Modelling Tools,
Materials Protection and Cryogenics

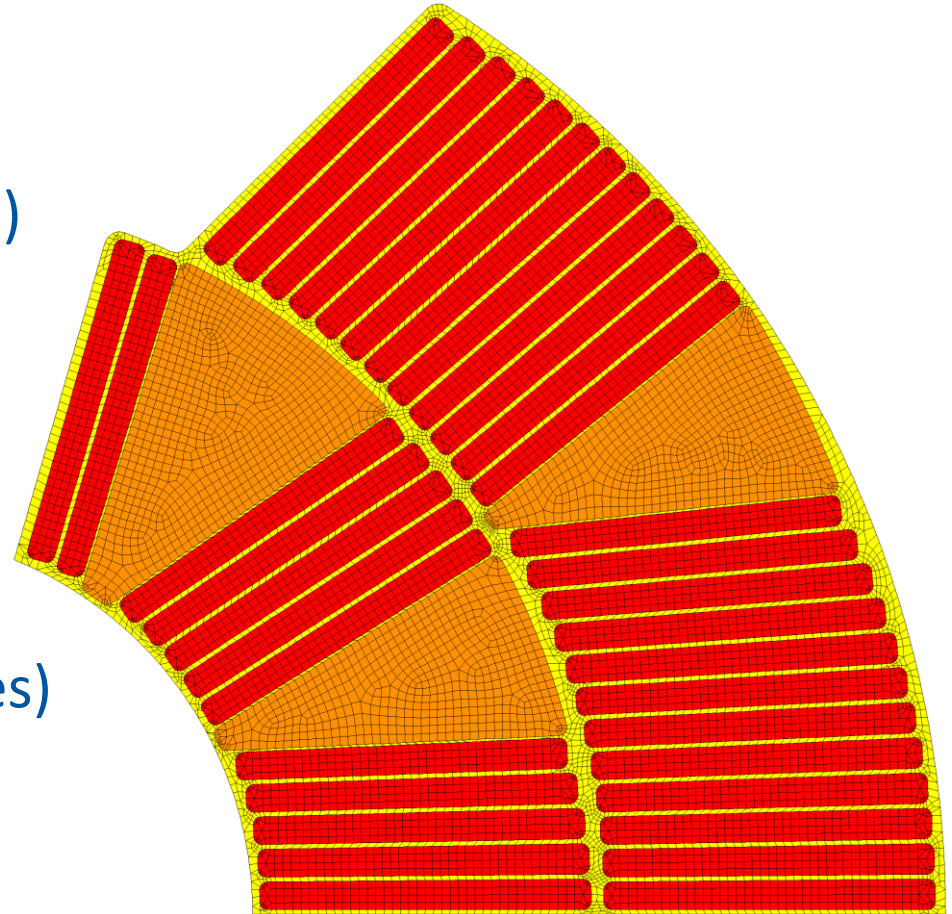
Authors: N. Sala on behalf of FalconD collaboration

Date: December 5th, 2023

ANSYS Mechanical model: mesh

~ 30 000 Plane183
(8-node quadrilateral elements)
w/ Plane stress
Esize = 2.5 mm

Intel(R) Core(TM)
i5-10400 CPU @ 2.90Ghz (6 cores)
Solution time ~ 7 min



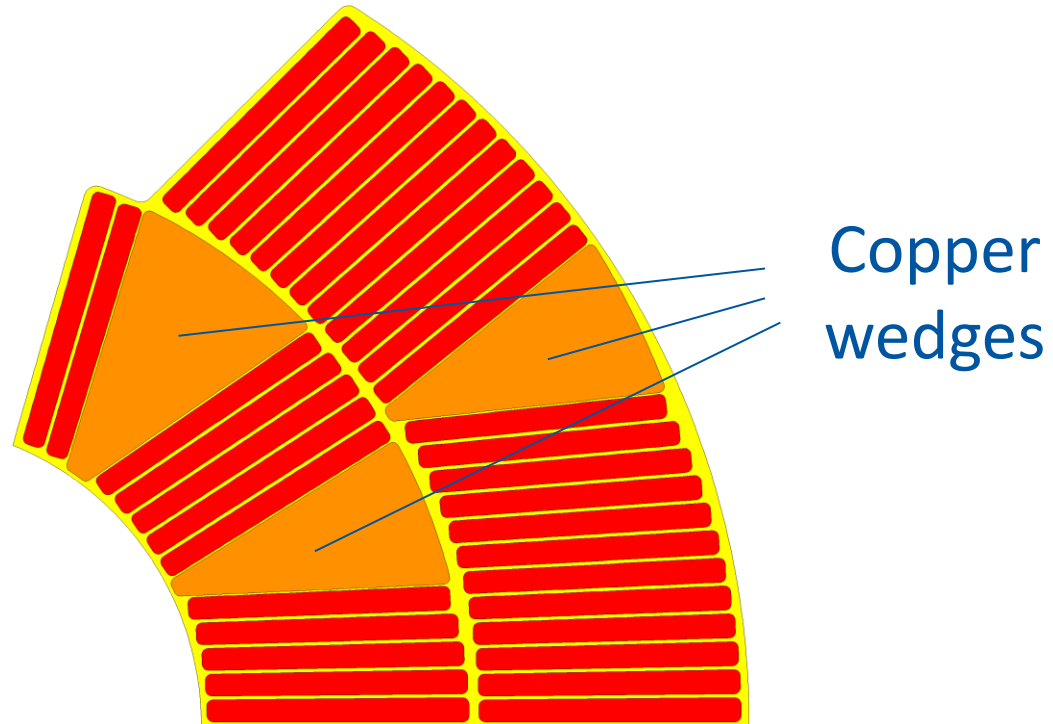
Coils physical properties*

Conductors & Insulation

$$\alpha_{rad} = 1.68 \text{ mm/m}$$

$$\alpha_{theta} = 3.8 \text{ mm/m}$$

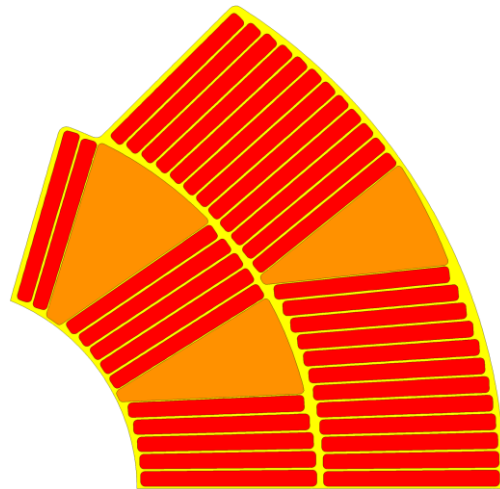
$$\alpha_z = 2.98 \text{ mm/m}$$



«Characterization of the thermal contraction of superconducting magnet coils for the High-Luminosity upgrade of the Large Hadron Collider (HL-LHC)» by S. Hoell (2022)

<https://cds.cern.ch/record/2845427?ln=en>

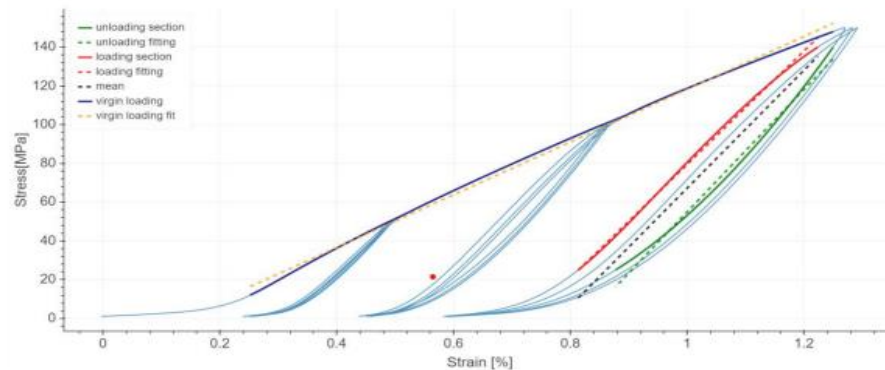
Coils mechanical properties*



Calculated Stiffness

- Virgin Loading:
14 ±2 GPa
- RT Loading/unloading phase:
31 ±3 GPa
- 77K Loading/unloading phase:
39 ±3 GPa

*«11T Cable Stacks Compression Tests at RT and 77K» by. O Sacristan (2019)



https://indico.cern.ch/event/850550/contributions/3574865/attachments/1914741/3165117/EDMS_2208499_11_T_Cablestacks_Tests2019v2.pdf

Coils mechanical properties*

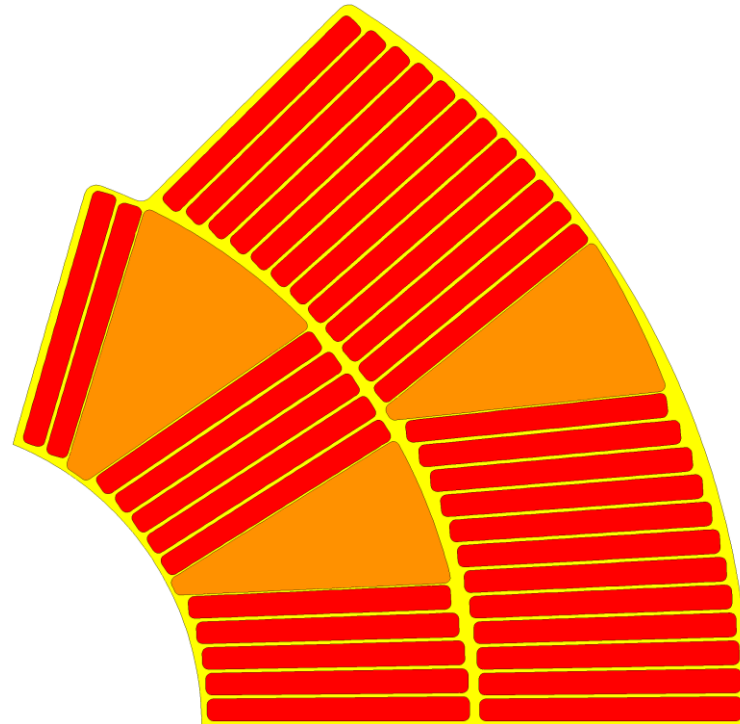
Conductors & Insulation

$$\sigma_{eqv} = \sigma_{VM}, \sigma_{theta}, \sigma_I$$

$$\sigma_{limit, R.T.} = 100 \text{ MPa} *$$

$$\sigma_{limit, 1.9K} = 120 \text{ MPa} *$$

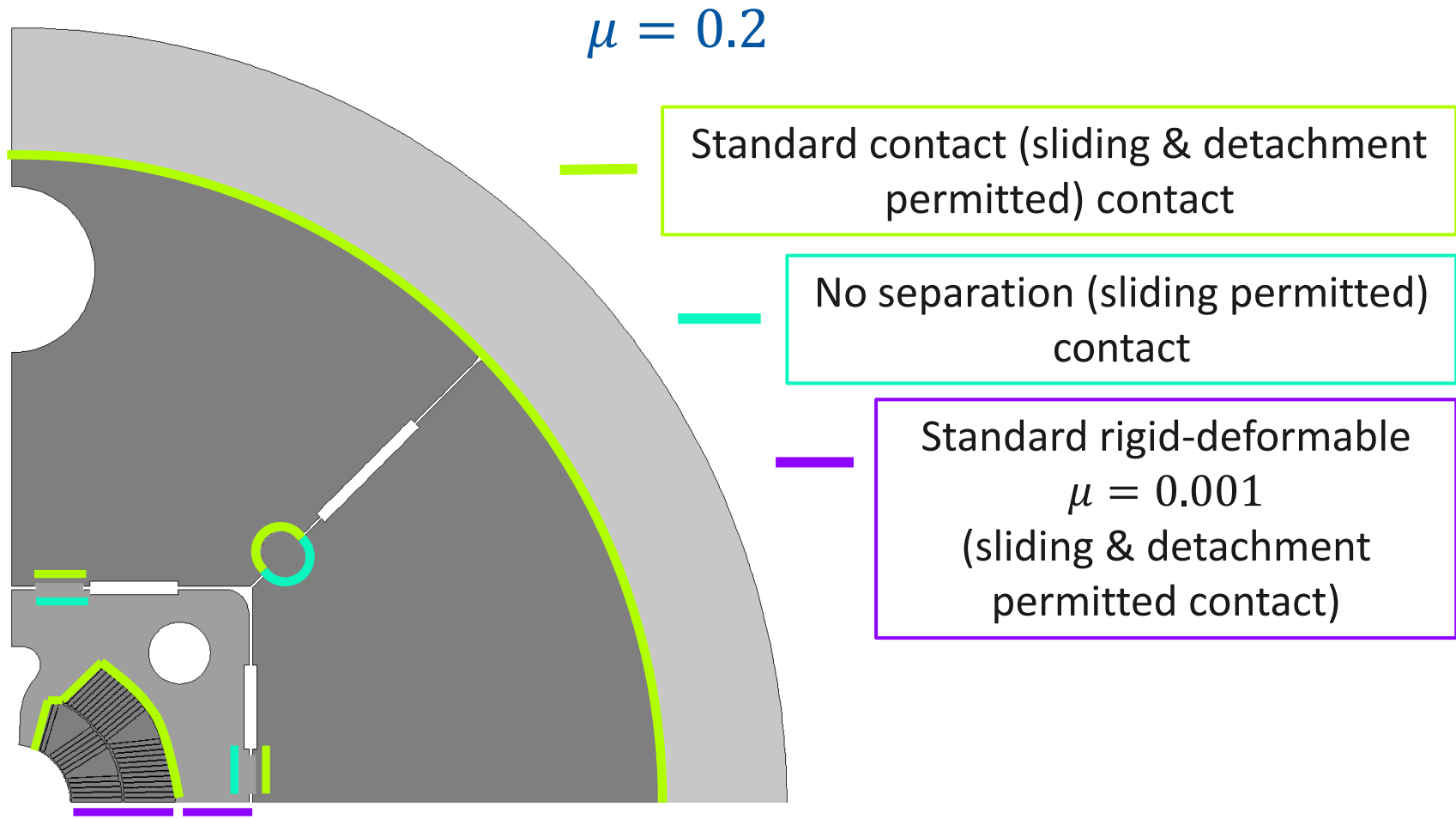
$$\sigma_{tensile} < 20 \text{ MPa} *$$



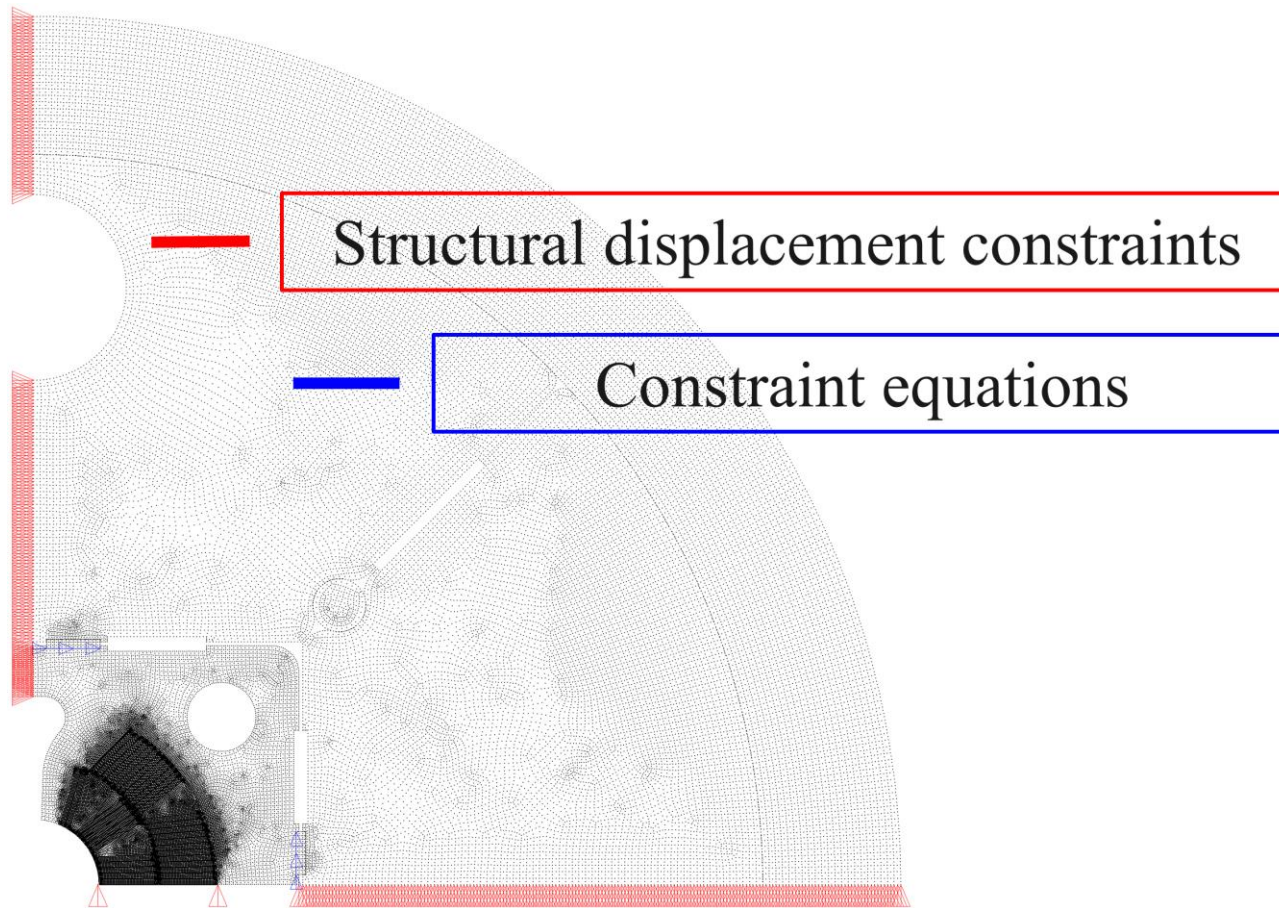
*«Mechanical structures for superconducting dipoles. Different configurations for different applications» by D. Perini (2022)

<https://indico.cern.ch/event/1192313/attachments/2549170/4390531/Seminar.pdf>

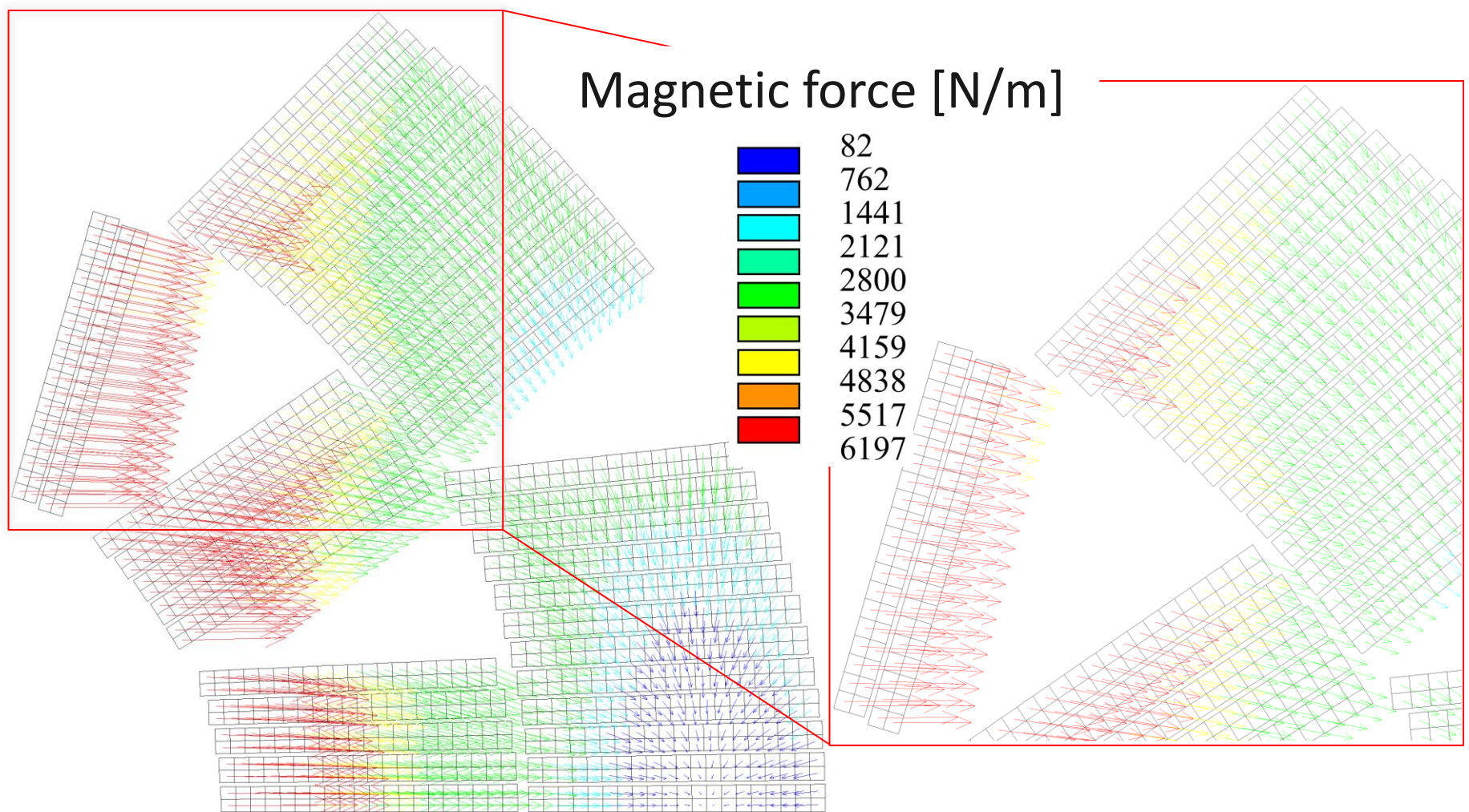
ANSYS Mechanical model: contacts



ANSYS Mechanical model: BCs



ANSYS Mechanical model: Lorentz forces



wedges properties



Material	Behaviour	E [GPa] @ R.T. (1.9K)	Stress limit [MPa] @R.T.	Stress limit [MPa] @1.9K	α [mm/m] R.T. → 1.9K
ODS Copper	ductile	110 (110)	270	340	3.37

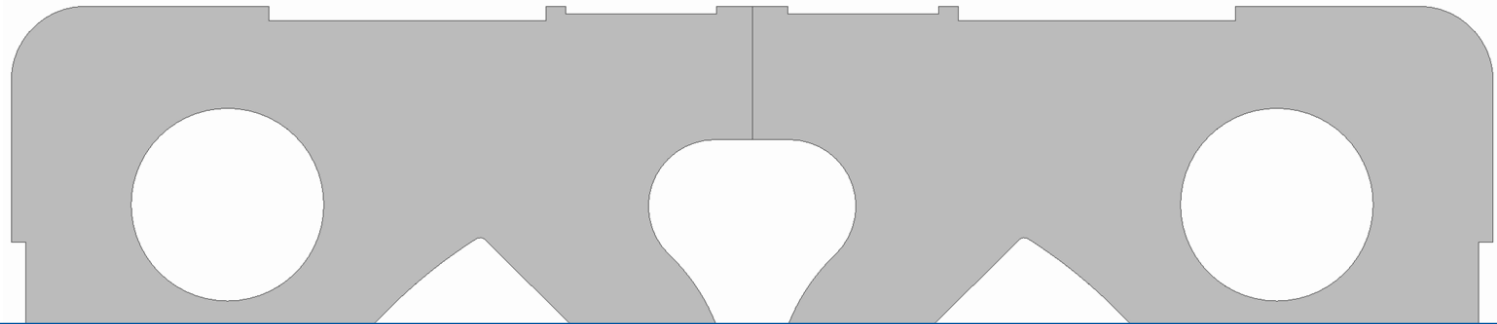
* «A Review of the Mechanical Properties of Materials Used in Nb3Sn Magnets for Particle Accelerators» by G. Vallone (2023)
DOI: 10.1109/TASC.2023.3248544

Keys properties

Material	Behaviour	E [GPa]	Stress limit [MPa]	Stress limit [MPa]	α [mm/m]
		@ R.T. (1.9K)	@R.T.	@1.9K	R.T. → 1.9K
SS316LN*	ductile	193 (210)	238	610	2.80
Kawa SS*	ductile	186 (204)	320	(?)	1.80
Nitronic 40*	ductile	225 (210)	682	1427	2.60

* «A Review of the Mechanical Properties of Materials Used in Nb3Sn Magnets for Particle Accelerators» by G. Vallone (2023)
DOI: 10.1109/TASC.2023.3248544

Pad properties



Material	Behaviour	E [GPa]	Stress limit [MPa]	Stress limit [MPa]	α [mm/m]
		@ R.T. (1.9K)	@R.T.	@1.9K	R.T. → 1.9K
SS316LN*	ductile	193 (210)	238	610	2.80
Nitronic 40*	ductile	225 (210)	682	1427	2.60

* «A Review of the Mechanical Properties of Materials Used in Nb3Sn Magnets for Particle Accelerators» by G. Vallone (2023)
DOI: 10.1109/TASC.2023.3248544

Iron properties

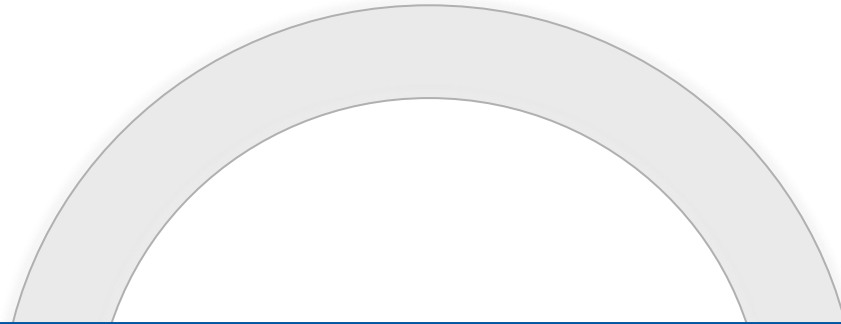
Fragile: $\sigma_l < 200 \text{ MPa}$ at 1.9K **

** «Review of Key-and-Bladder structures» by P. Ferracin (2016)

Material	Behaviour	E [GPa]	Stress limit [MPa]	Stress limit [MPa]	α [mm/m]
		@ R.T. (1.9K)	@R.T.	@1.9K	R.T. → 1.9K
ARMCO*	fragile	224 (213)	286	975	2.00
Magnetil*	fragile	200 (200)	249	723	2.00

* «A Review of the Mechanical Properties of Materials Used in Nb3Sn Magnets for Particle Accelerators» by G. Vallone (2023)
DOI: 10.1109/TASC.2023.3248544

Shell properties



Material	Behaviour	E [GPa]	Stress limit [MPa]	Stress limit [MPa]	α [mm/m]
		@ R.T. (1.9K)	@R.T.	@1.9K	R.T. → 1.9K
A7075*	fragile	72 (79)	480	490	4.20

* «A Review of the Mechanical Properties of Materials Used in Nb3Sn Magnets for Particle Accelerators» by G. Vallone (2023)
DOI: 10.1109/TASC.2023.3248544

ANSYS Mechanical model: properties*

Material	Behaviour	E [GPa]	Stress limit [MPa]	Stress limit [MPa]	α [mm/m]
		@ R.T. (1.9K)	@R.T.	@1.9K	R.T. → 1.9K
Conductors	fragile	31 (39)	100	120	3.80
Glidcop wedges	ductile	110 (110)	270	340	3.37
Fiberglass	-	-	-	-	-
SS316LN* pad	ductile	193 (210)	238	610	2.80
Kawa SS keys	ductile	186 (204)	320	(?)	1.80
Iron yoke*	fragile	204 (225)	250	720	2.00
Al7075* shell	fragile	72 (79)	480	490	4.20

* «A Review of the Mechanical Properties of Materials Used in Nb3Sn Magnets for Particle Accelerators» by G. Vallone (2023)
DOI: 10.1109/TASC.2023.3248544

Thanks for the attention