Preliminary mechanical design of the large aperture HTS superconducting dipoles for the accelerator ring of the Muon Collider

T. Maiello[1,4,5], L. Alfonso[1], L. Balconi[2,6], A. Bersani[1], L. Bottura[4], B. Caiffi[1], S. Fabbri[4], S. Farinon[1], A. Gagno[1,5], F. Levi[1], F. Mariani[2,6], S. Mariotto[2,3], D. Novelli[1,6], A. Pampaloni[1], D. Rinaldoni[4], C. Santini[2], S. Sorti[2,3], M. Statera[2], G. Vernassa[2]

[1] INFN – Genova, [2] INFN LASA – Milano, [3] University of Milan, [4] CERN, [5] Università degli Studi di Genova, [6] Sapienza Università di Roma

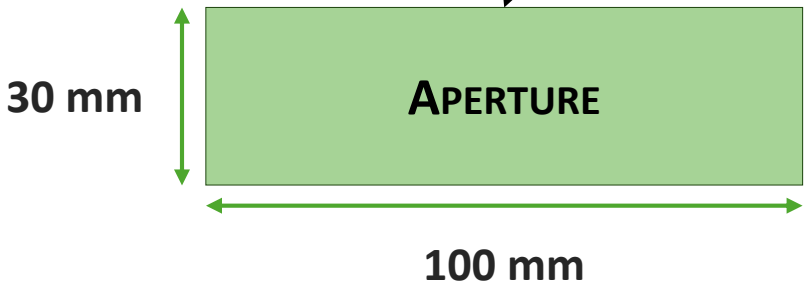
REQUIREMENTS FOR THE SC DIPOLES

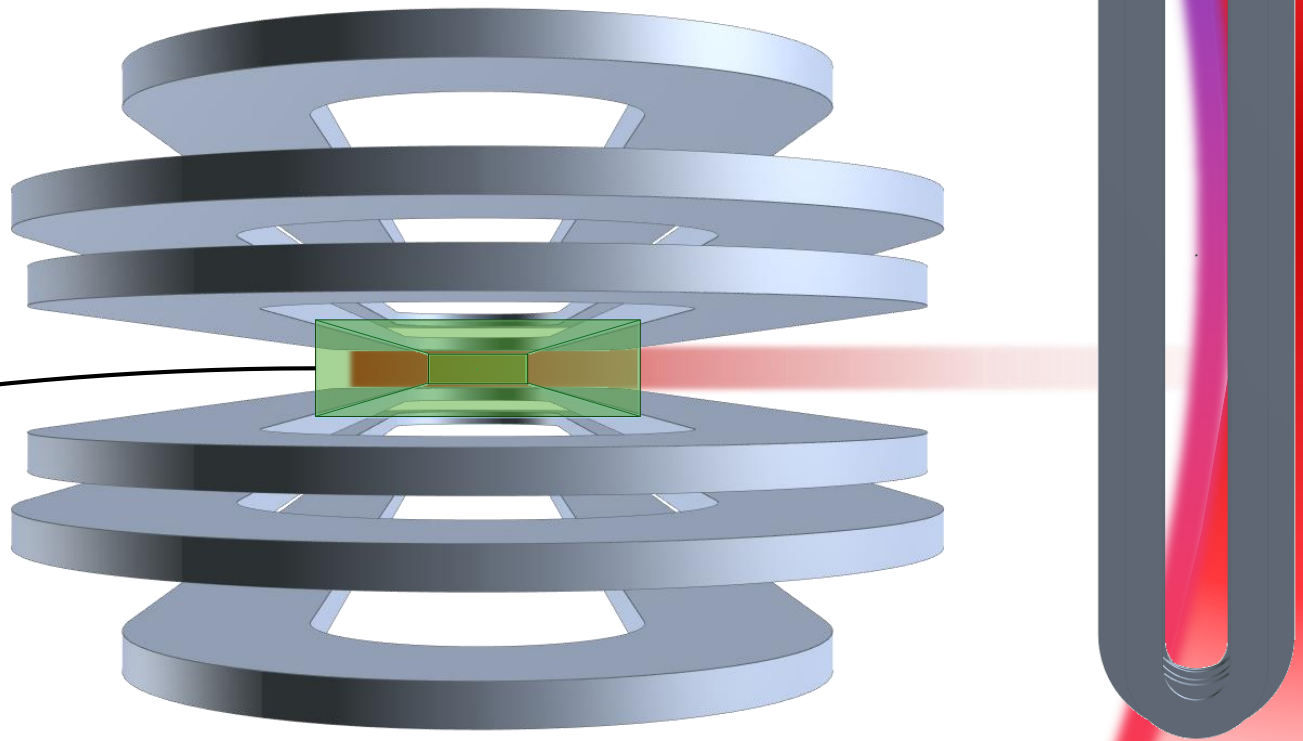
Main characteristics:

- **Open midplane** dipole to avoid deposition of the **radiation** from muon decay
- **10 T** of central field
- Rectangular aperture of **100 mm x 30 mm**

Proposed solution:

Magnet design based on **metal insulated HTS racetracks**



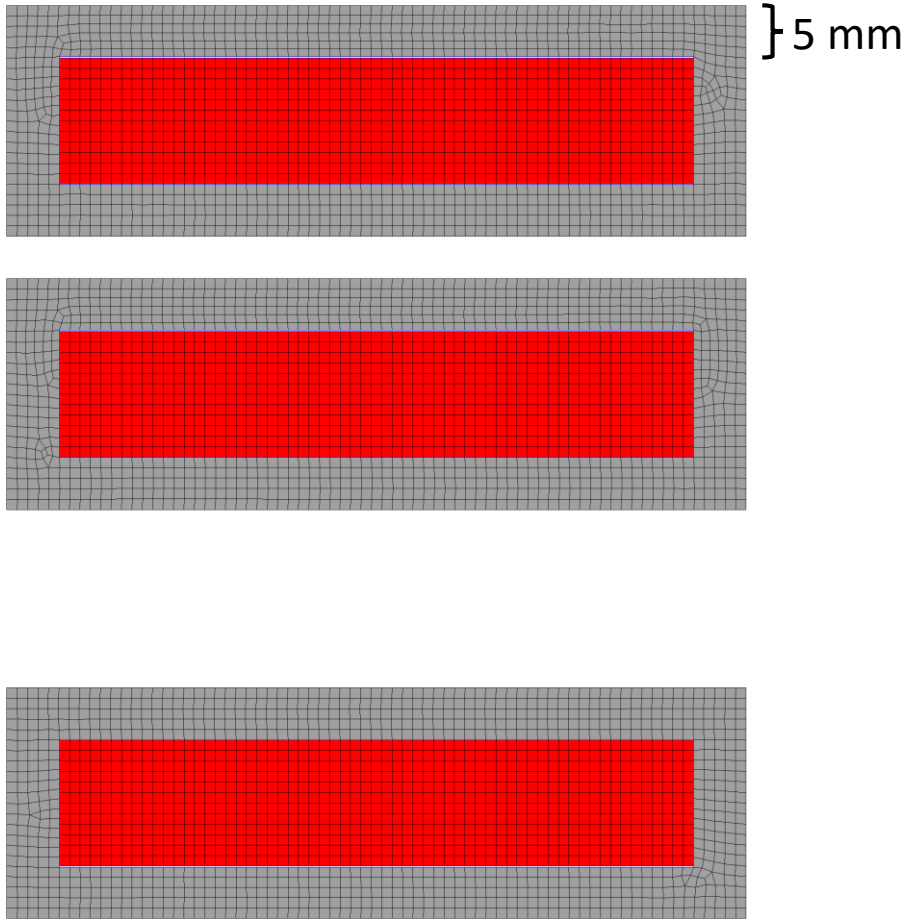


MECHANICAL PERFORMANCE

Lorentz forces effect evaluation:

This very simple model has the aim of **evaluate** the **stress** associated to the **Lorentz forces**, **not** for the **dimensioning** of the mechanical structure.

- Infinitely **rigid** structure.
- **Homogenous** material for racetracks:
  - $E = 150\ GPa$ [1]
  - $\nu = 0.3$
- **Frictionless** system.



[1] Value taken from "Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T" https://iopscience.iop.org/article/10.1088/0953-2048/28/4/045011

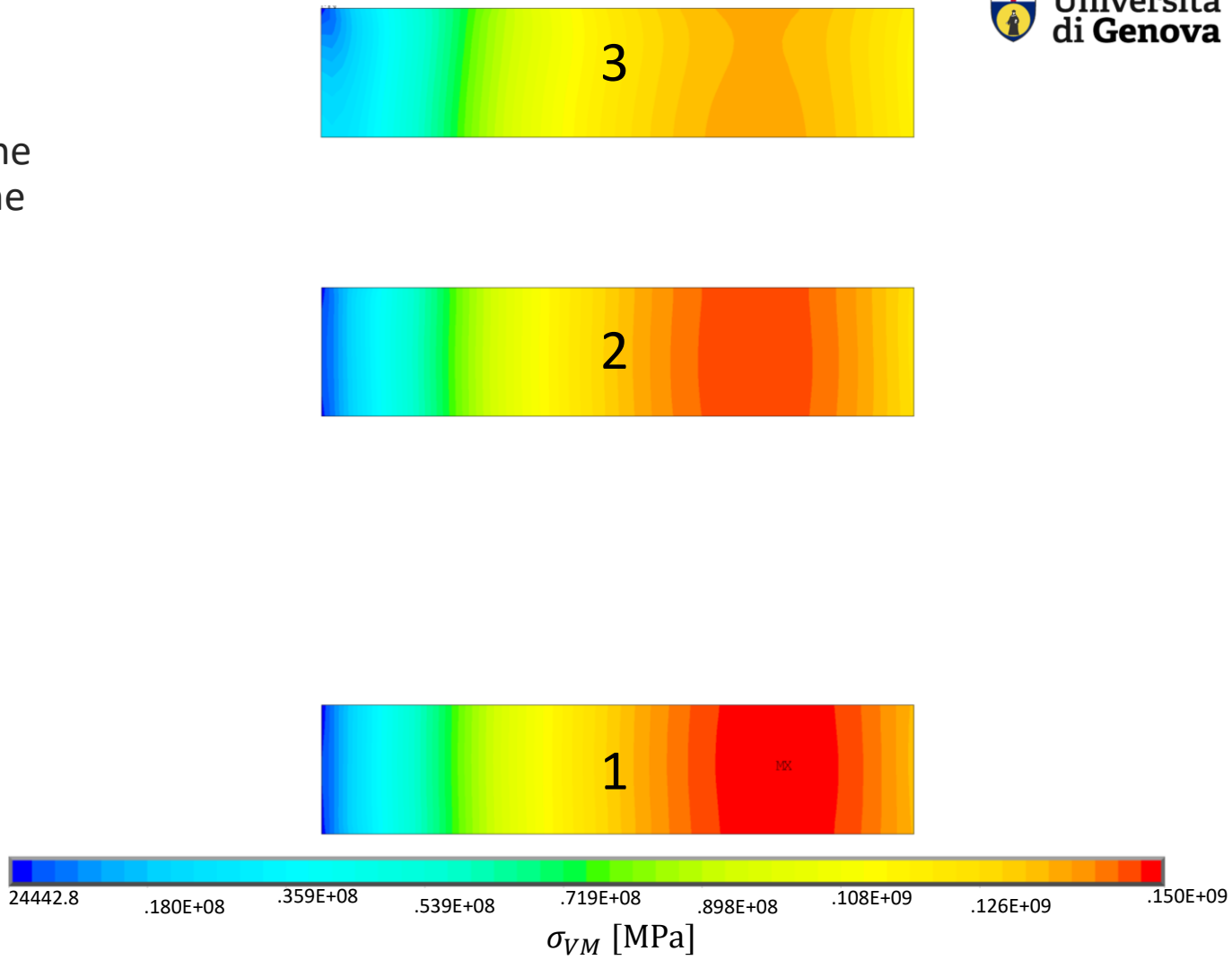
MECHANICAL PERFORMANCE

Lorentz forces effect evaluation:

This very simple model has the aim of **evaluate** the **stress** associated to the **Lorentz forces**, **not** for the **dimensioning** of the mechanical structure.

- Infinitely **rigid** structure.
- **Homogenous** material for racetracks:
  - $E = 150\ GPa$ [1]
  - $\nu = 0.3$
- **Frictionless** system.

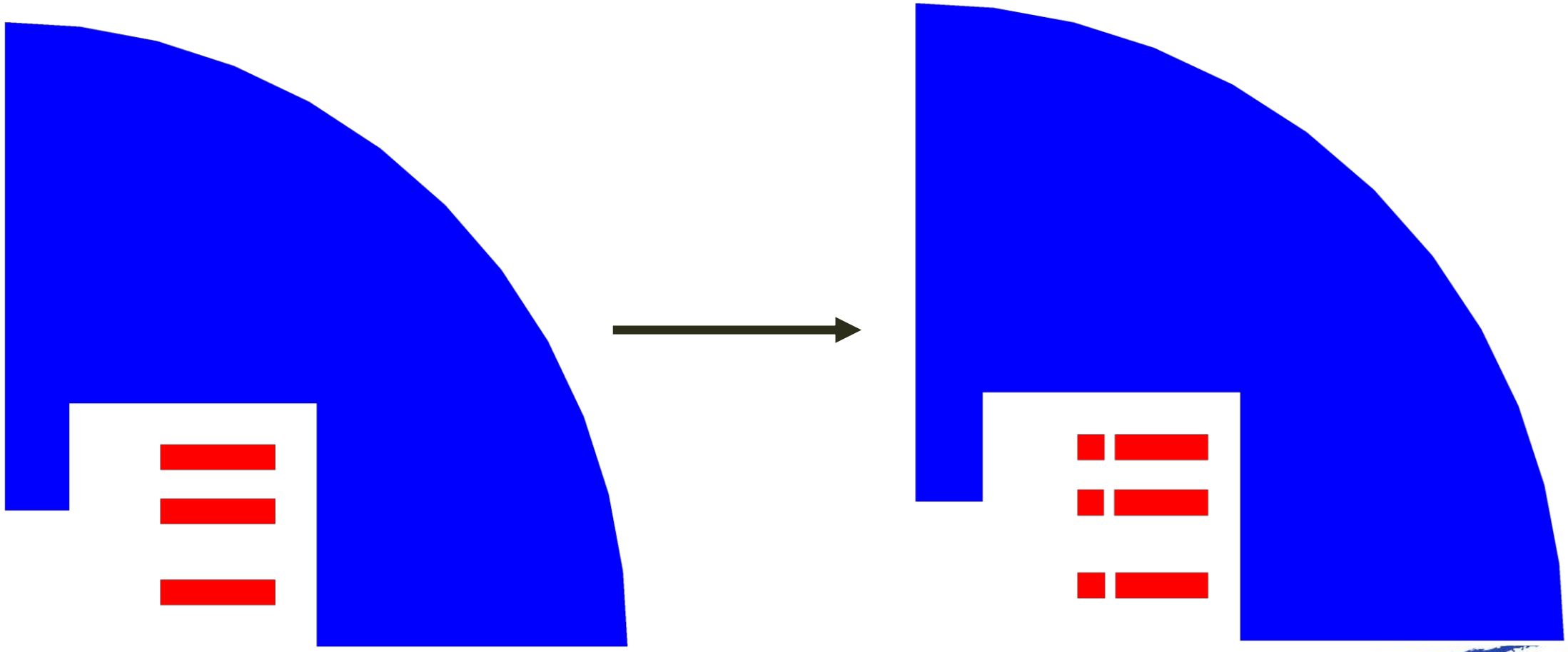
Racetrack	F_x [kN/m]	F_y [kN/m]	Peak σ_{VM} [MPa]
1	1793	140	150
2	1670	-407	146
3	1546	-2151	137
tot	5009	-2418	/



[1] Value taken from "Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T" https://iopscience.iop.org/article/10.1088/0953-2048/28/4/045011

STRESS MANAGEMENT STRATEGY

A **5 mm vertical sector** splitting the racetracks into two was inserted to reduce the stress. The position of each sector is the result of an optimization study.



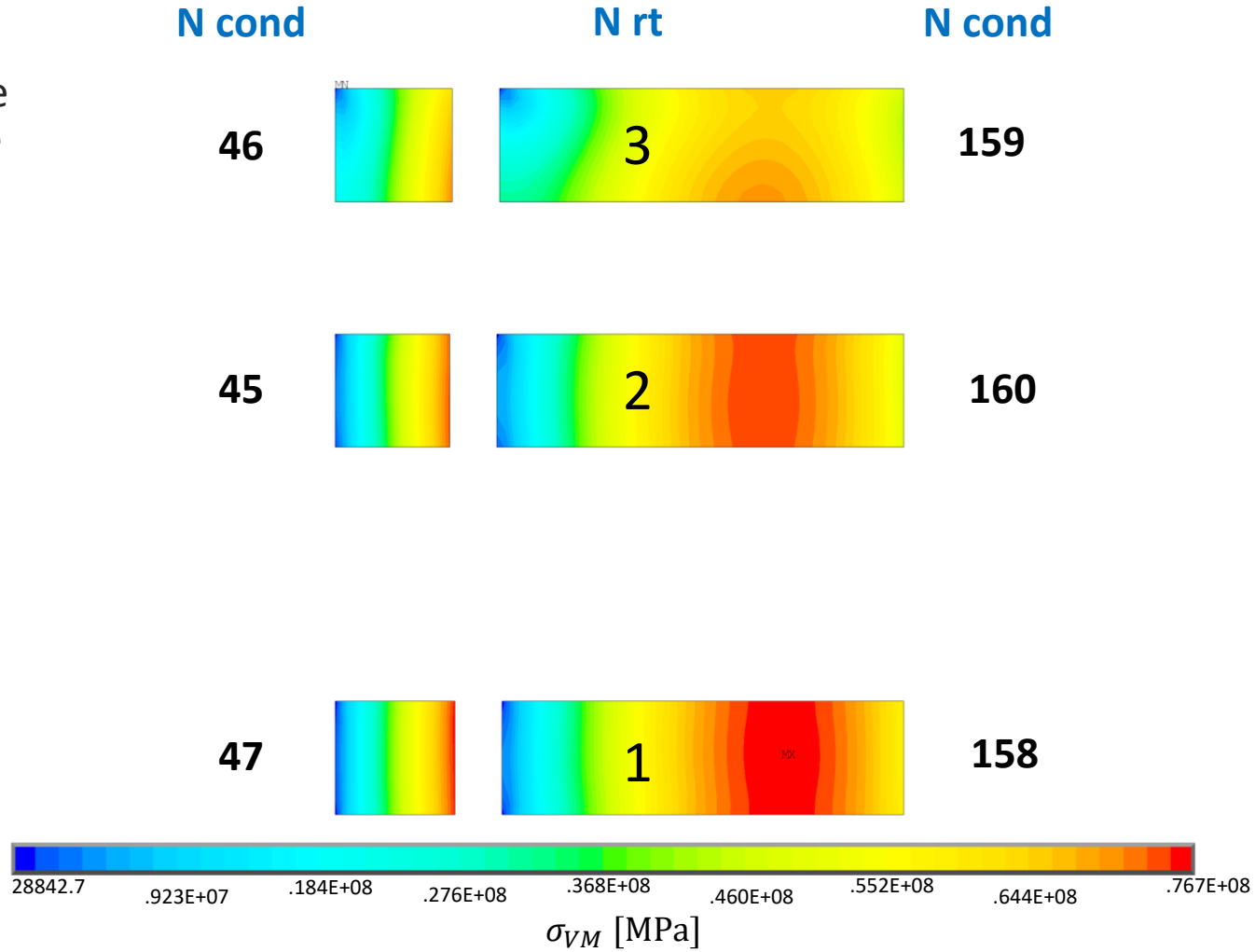
3 ALIGNED

Lorentz forces effect evaluation:

This very simple model has the aim of **evaluate** the **stress** associated to the **Lorentz forces**, **not** for the **dimensioning** of the mechanical structure.

- Infinitely **rigid** structure.
- **Homogenous** material for racetracks:
  - $E = 150\ GPa$ [1]
  - $\nu = 0.3$
- **Frictionless** system.

Racetrack	F_x [kN/m]		F_y [kN/m]		Peak σ_{VM} [MPa]	
1	1019	799	24	95	76	77
2	993	698	-93	-378	74	75
3	927	632	-418	-1797	72	71
tot	5068		-2567		/	

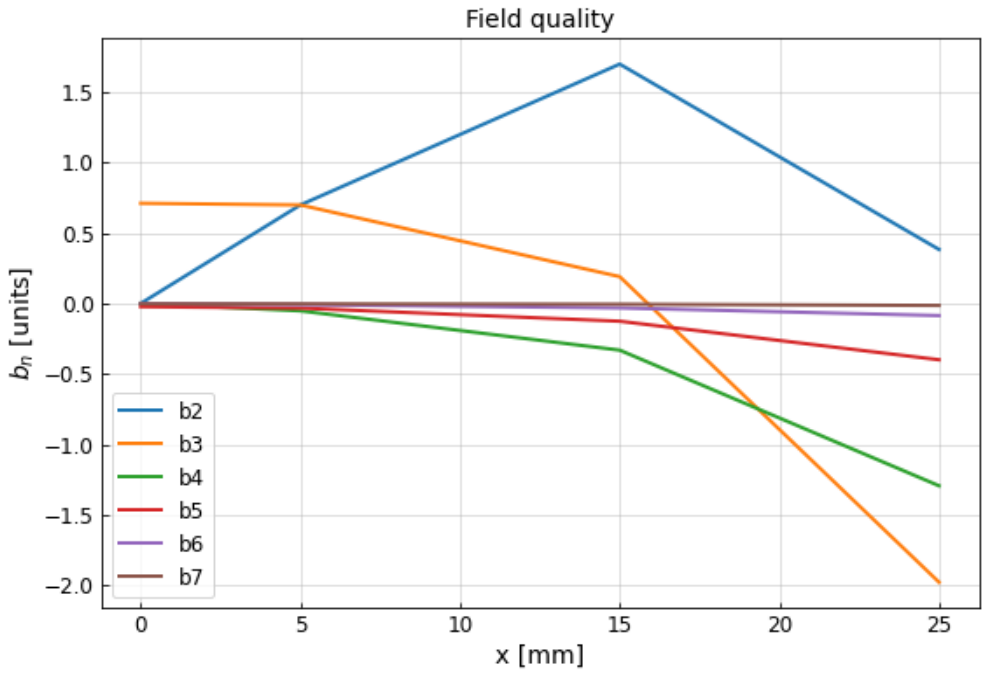


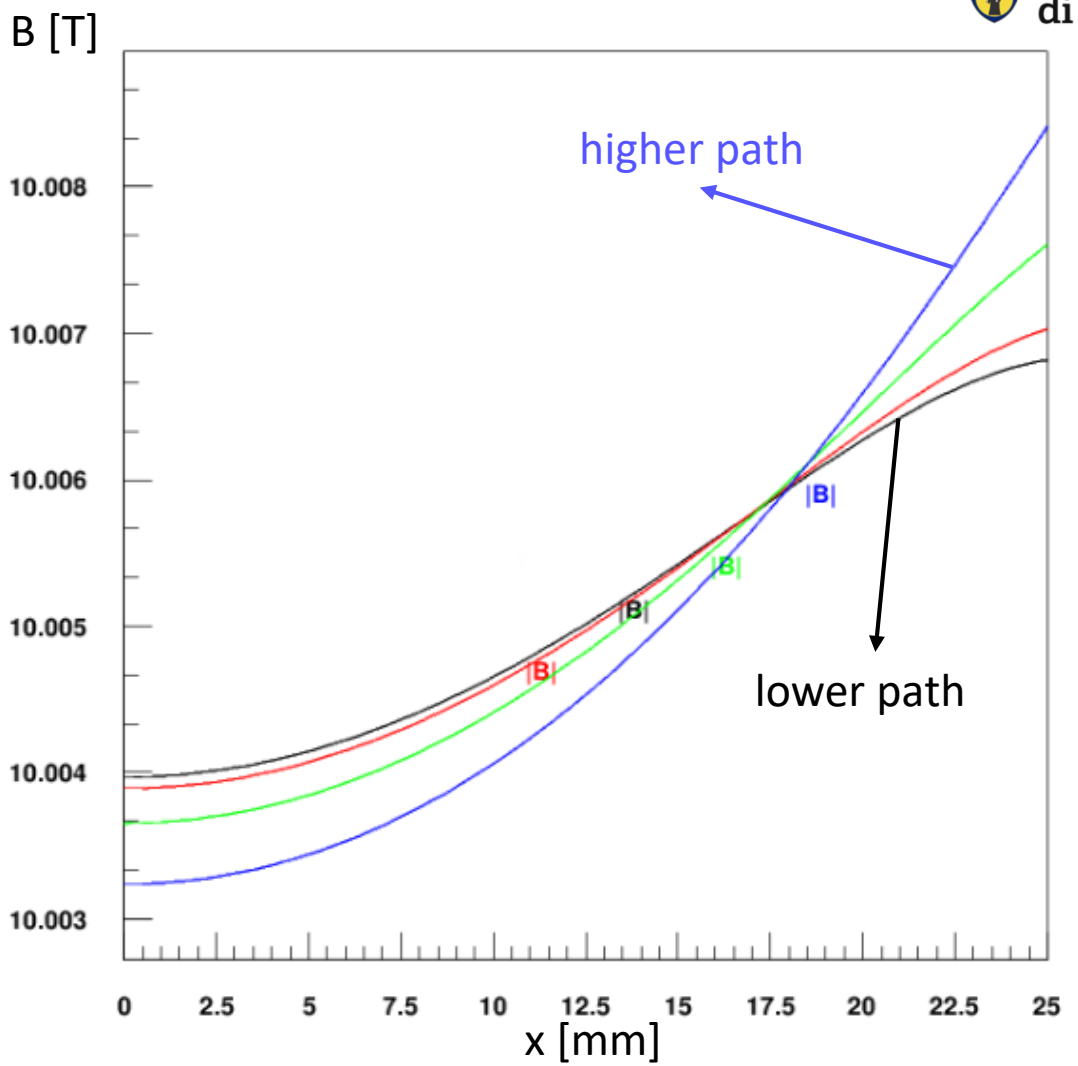
[1] Value taken from "Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T" https://iopscience.iop.org/article/10.1088/0953-2048/28/4/045011

3 ALIGNED

The new field **homogeneity** at x = 25 mm is about **0.058%.**

I [A]	J_{eng} [A/mm²]	B_0 [T]	B_p [T]	B_p/B_0
2380.91	734.85	10.00	12.32	1.23
+2.0%	+2.0%	/	-1.4%	-1.4%





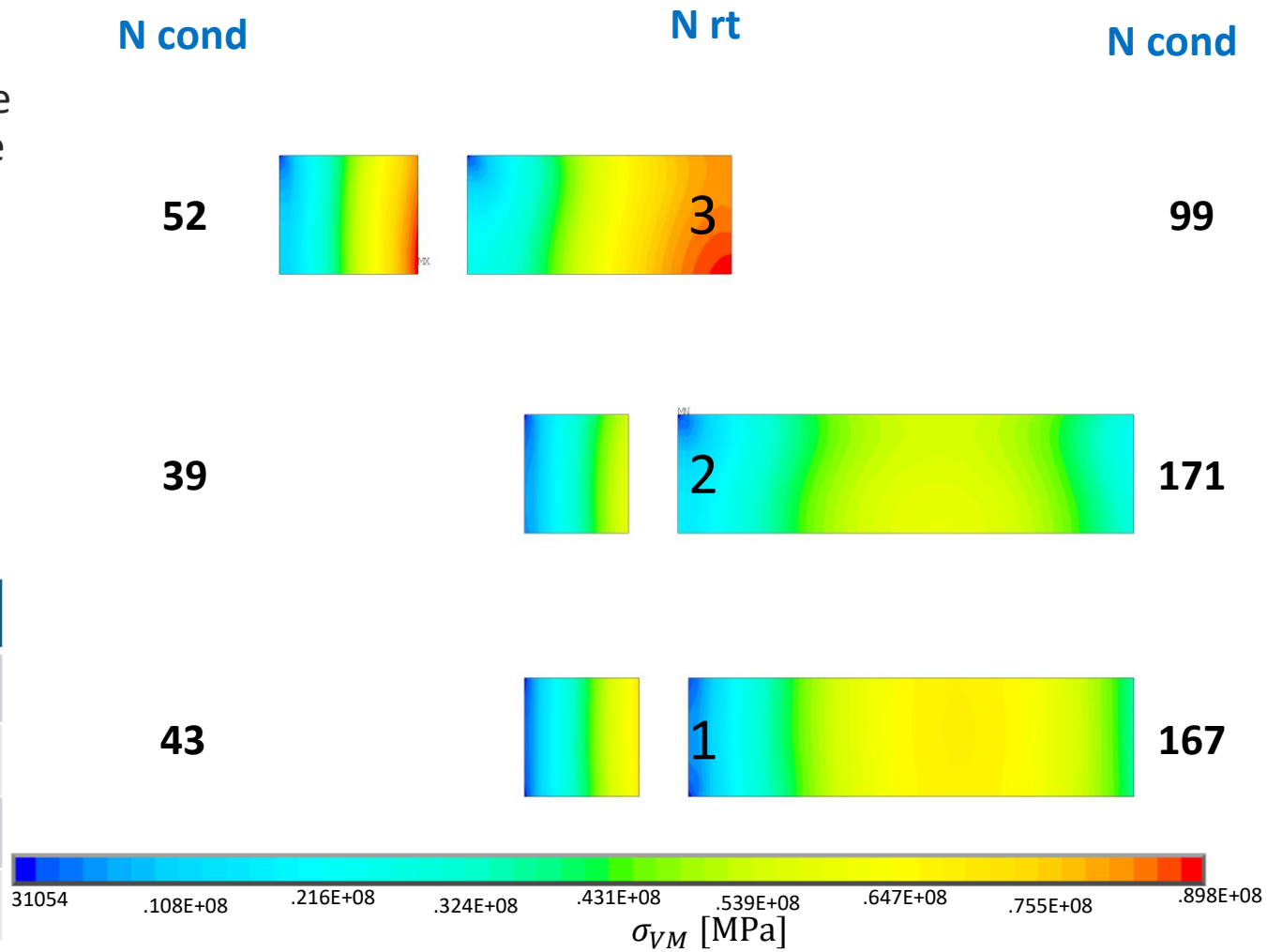
2 ALIGNED

Lorentz forces effect evaluation:

This very simple model has the aim of **evaluate** the **stress** associated to the **Lorentz forces**, **not** for the **dimensioning** of the mechanical structure.

- Infinitely **rigid** structure.
- **Homogenous** material for racetracks:
  - $E = 150\ GPa$ [1]
  - $\nu = 0.3$
- **Frictionless** system.

Racetrack	F_x [kN/m]		F_y [kN/m]		Peak σ_{VM} [MPa]	
1	949	524	53	142	71	70
2	798	338	-144	-1525	61	61
3	1169	1140	-323	-1081	90	89
tot	4918		-2878		/	

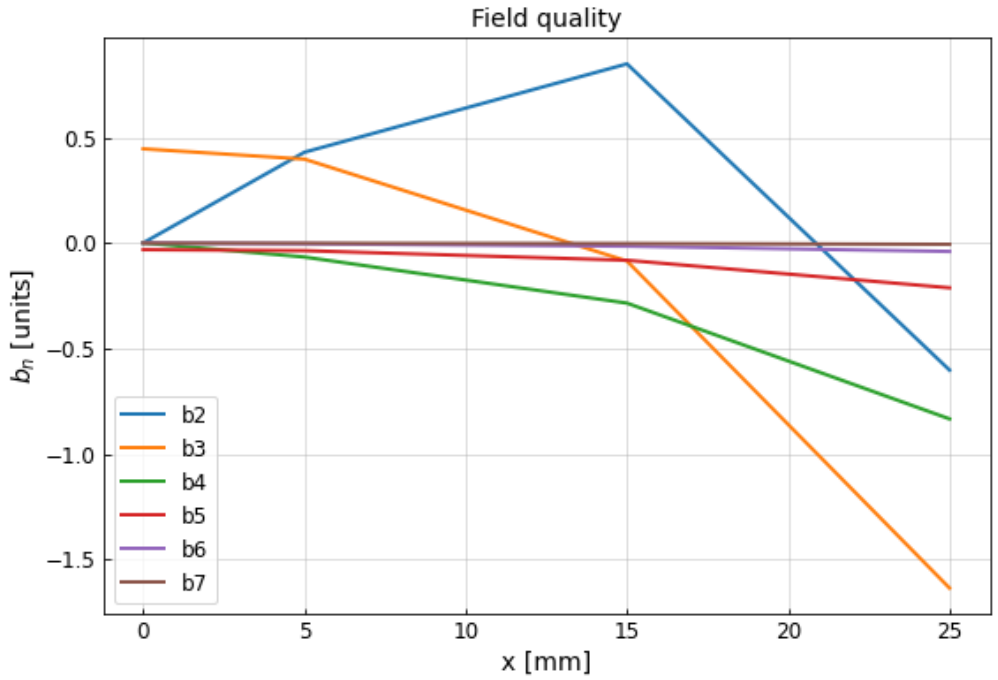


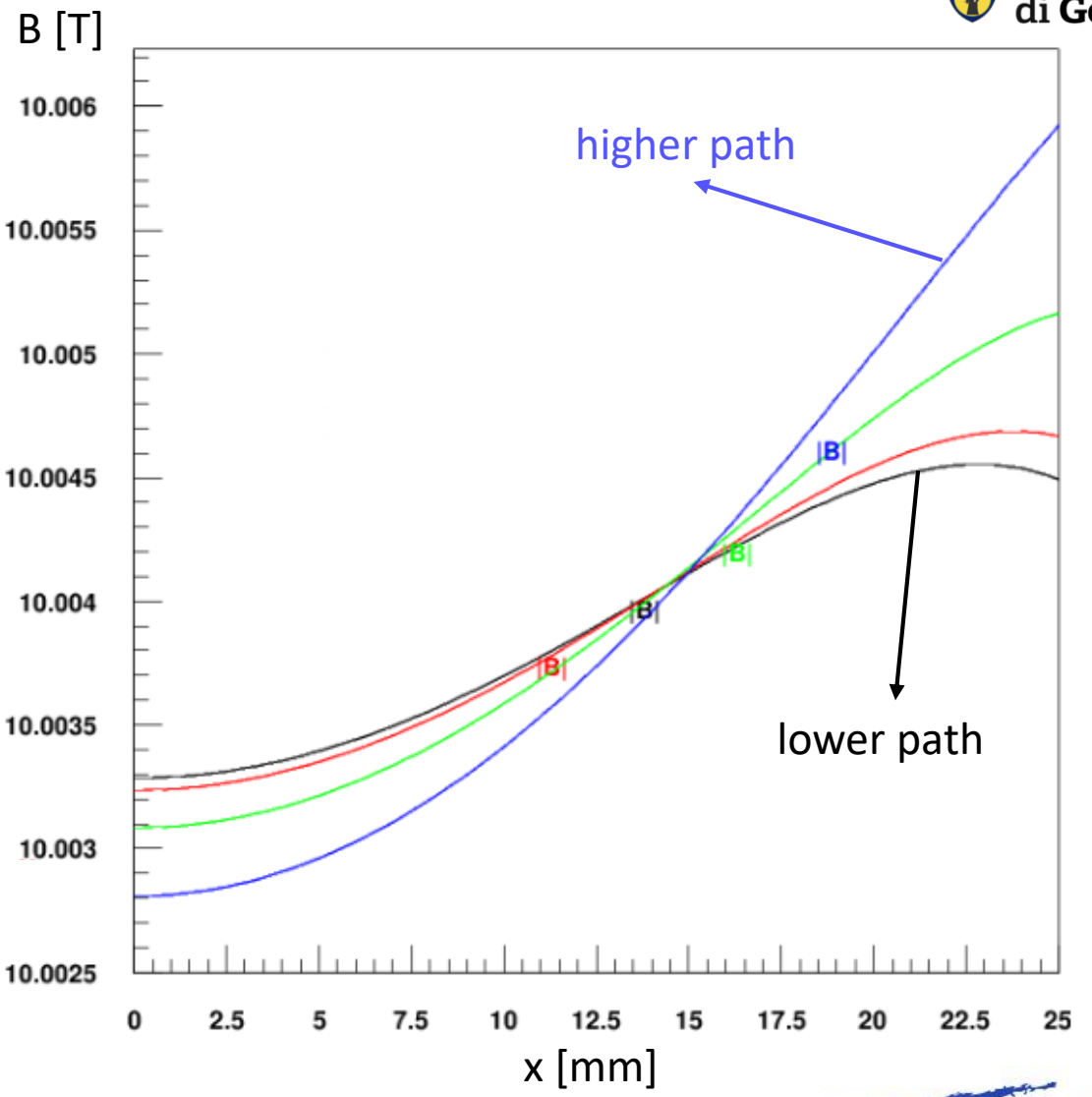
[1] Value taken from "Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T" https://iopscience.iop.org/article/10.1088/0953-2048/28/4/045011

2 ALIGNED

The new field **homogeneity** at x = 25 mm is about **0.036%.**

I [A]	J_{eng} [A/mm²]	B_0 [T]	B_p [T]	B_p/B_0
2441.72	753.62	10.00	12.36	1.23
+2.1%	+2.1%	/	-1.4%	-1.4%





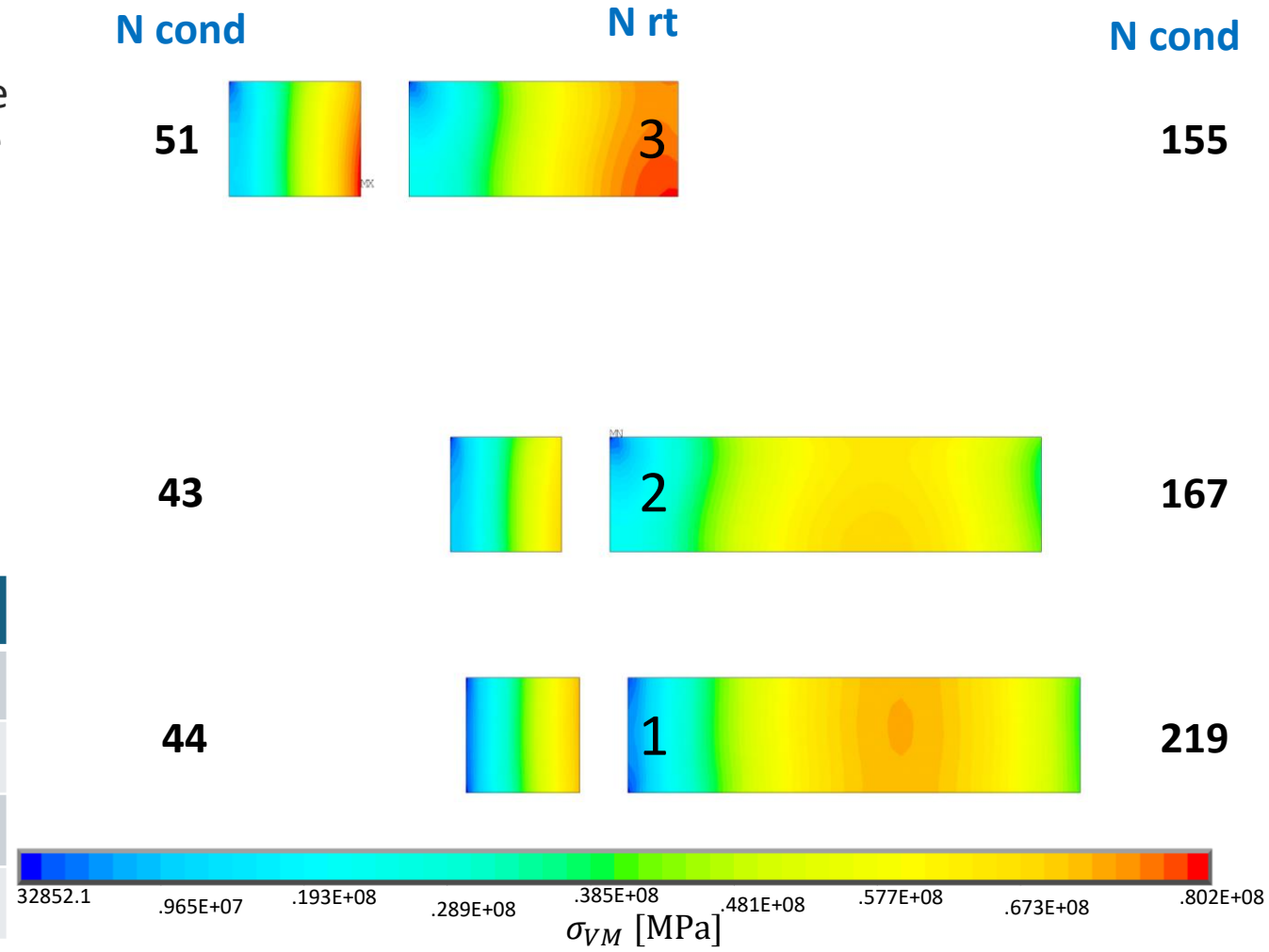
0 ALIGNED

Lorentz forces effect evaluation:

This very simple model has the aim of **evaluate** the **stress** associated to the **Lorentz forces**, **not** for the **dimensioning** of the mechanical structure.

- Infinitely **rigid** structure.
- **Homogenous** material for racetracks:
  - $E = 150\ GPa$ [1]
  - $\nu = 0.3$
- **Frictionless** system.

Racetrack	F_x [kN/m]		F_y [kN/m]		Peak σ_{VM} [MPa]	
1	961	532	48	107	72	72
2	893	529	-209	-1547	69	69
3	1044	1013	-290	-942	80	79
tot	4972		-2833		/	

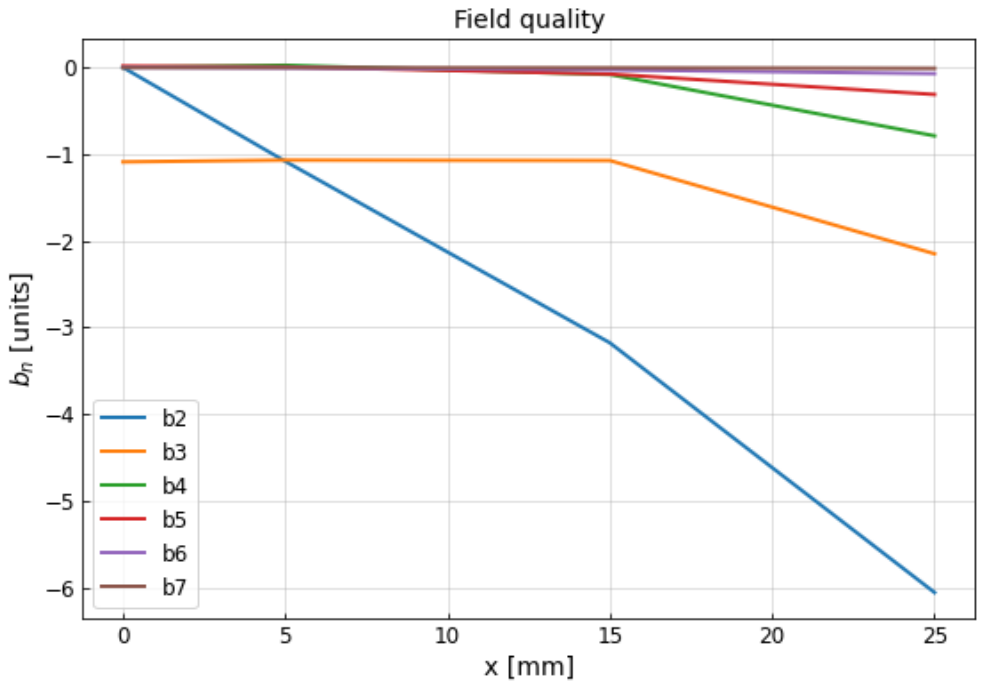


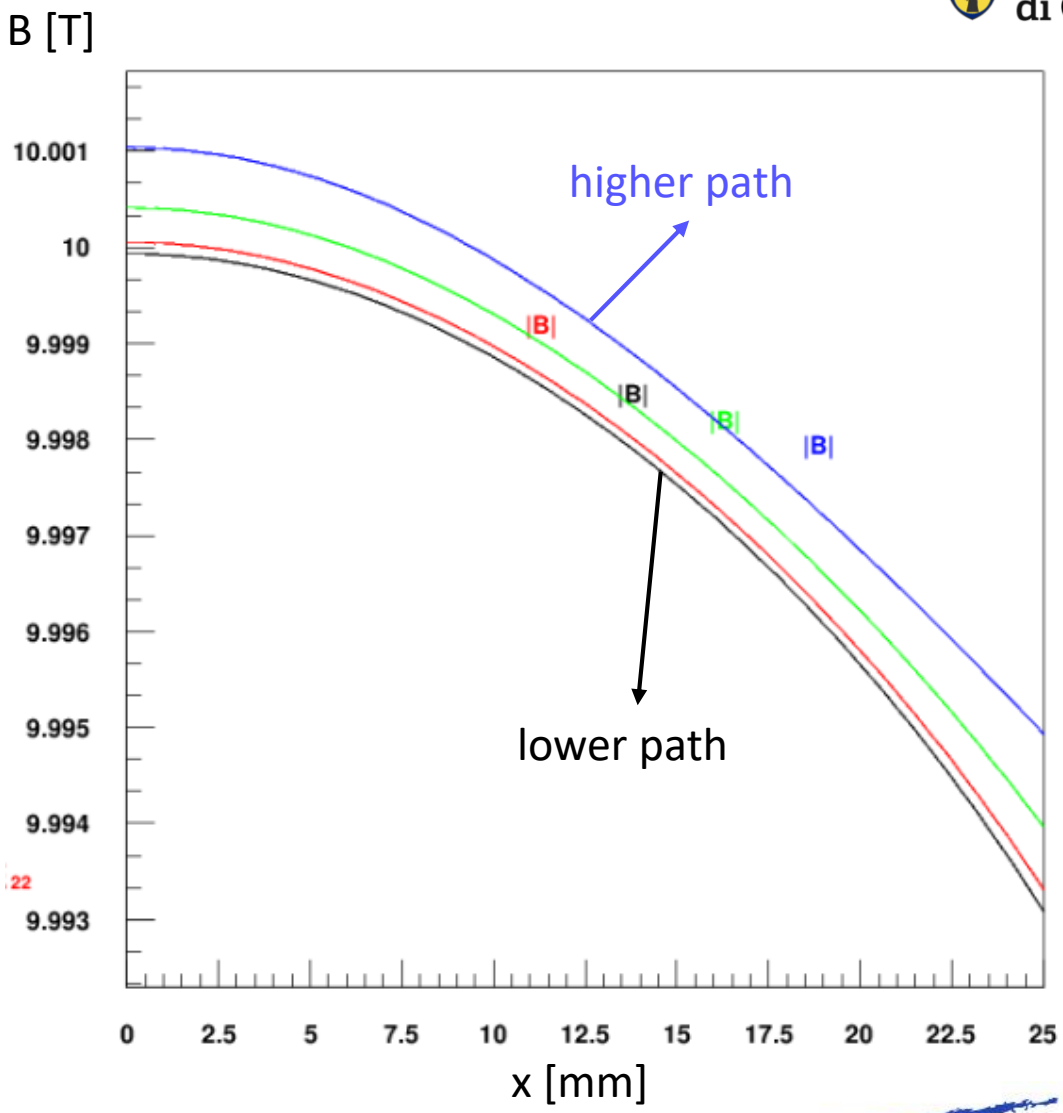
[1] Value taken from "Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T" https://iopscience.iop.org/article/10.1088/0953-2048/28/4/045011

0 ALIGNED

The new field **homogeneity** at x = 25 mm is about **0.030%.**

I [A]	J_{eng} [A/mm²]	B_0 [T]	B_p [T]	B_p/B_0
2395.09	739.22	10.00	12.20	1.22
+2.0%	+2.0%	/	-1.0%	-1.0%



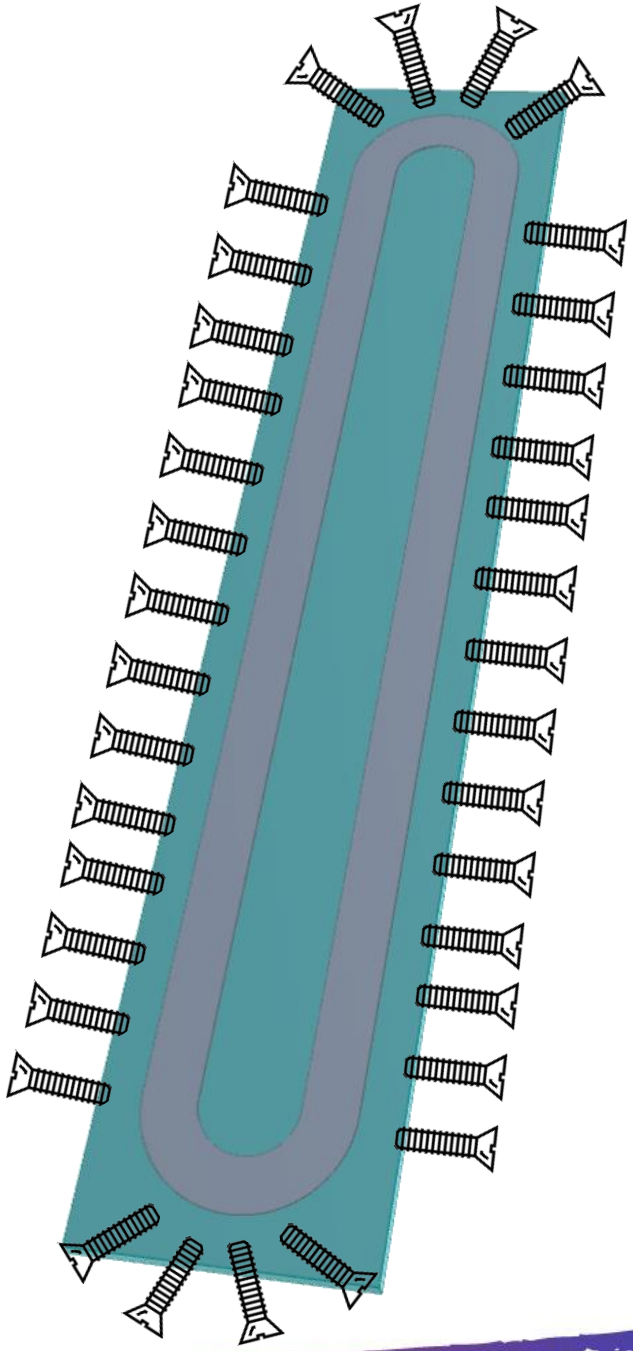


Thanks for your attention

T. Maiello[1,4,5], L. Alfonso[1], L. Balconi[2,6], A. Bersani[1], L. Bottura[4], B. Caiffi[1], S. Fabbri[4], S. Farinon[1], A. Gagno[1,5], F. Levi[1], F. Mariani[2,6], S. Mariotto[2,3], D. Novelli[1,6], A. Pampaloni[1], D. Rinaldoni[4], C. Santini[2], S. Sorti[2,3], M. Statera[2], G. Vernassa[2]

[1] INFN – Genova, [2] INFN LASA – Milano, [3] University of Milan, [4] CERN, [5] Università degli Studi di Genova, [6] Sapienza Università di Roma

CASE

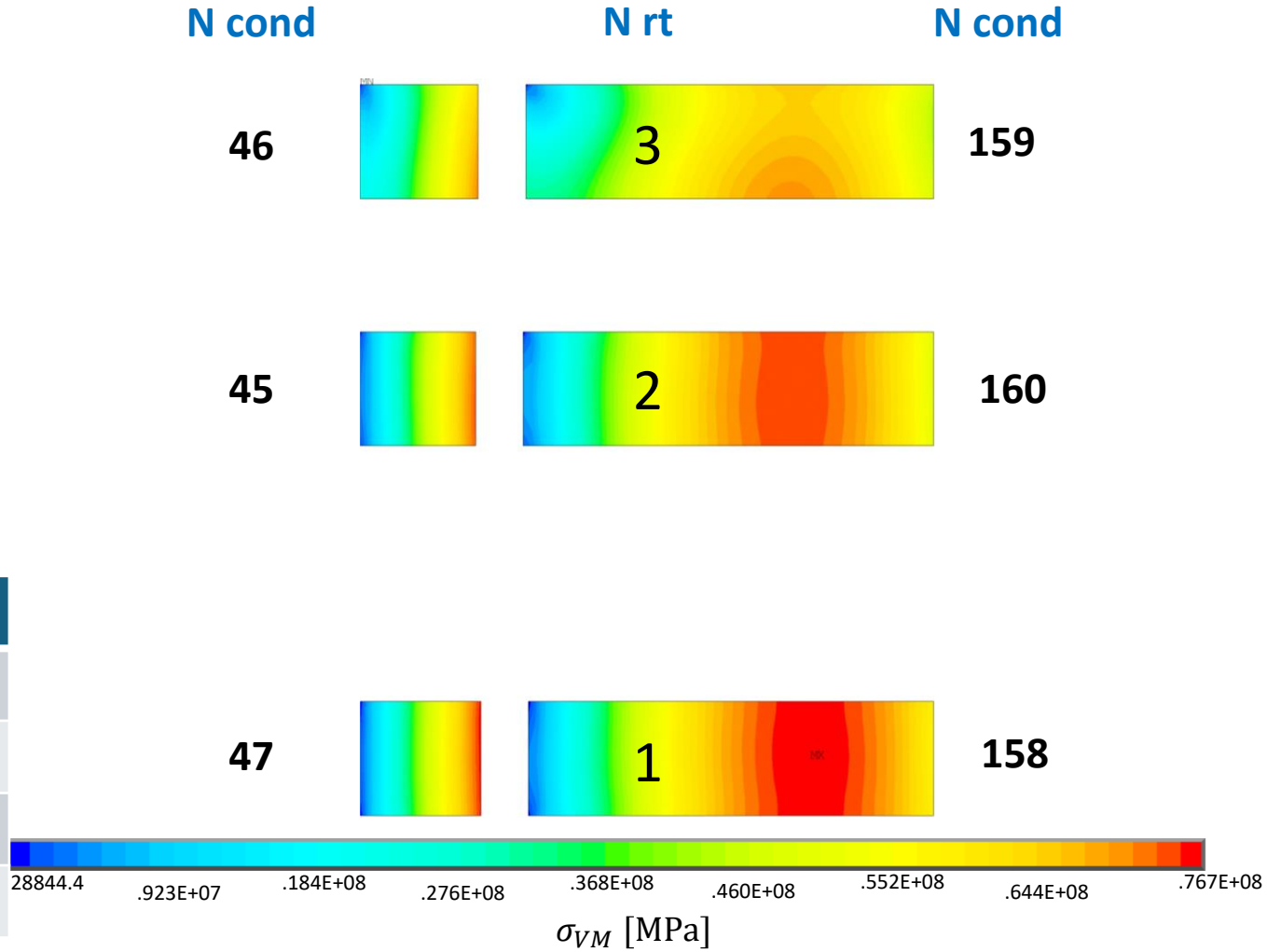


Very preliminary mechanical concept:

- SS both inside and outside of the racetrack.
- Threads to convey the preload from outside.

3 ALIGNED

To get an idea of what happens to the mechanics using $E = 174\ GPa$ a test was done and the variation of the values is so small that with the precision shown in the tables the numbers do not change



Racetrack	F_x [kN/m]		F_y [kN/m]		Peak σ_{VM} [MPa]	
1	1019	799	24	95	76	77
2	993	698	-93	-378	74	75
3	927	632	-418	-1797	72	71
tot	5068		-2567		/	

[1] Value taken from "Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T" https://iopscience.iop.org/article/10.1088/0953-2048/28/4/045011