Magnetic and Mechanical Design of Large Aperture HTS Superconducting Dipole for the Muon Collider Accelerator Ring

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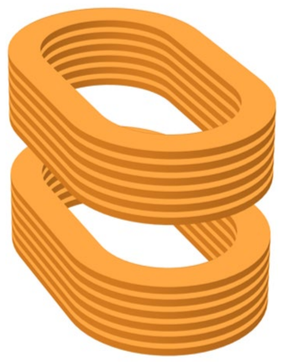
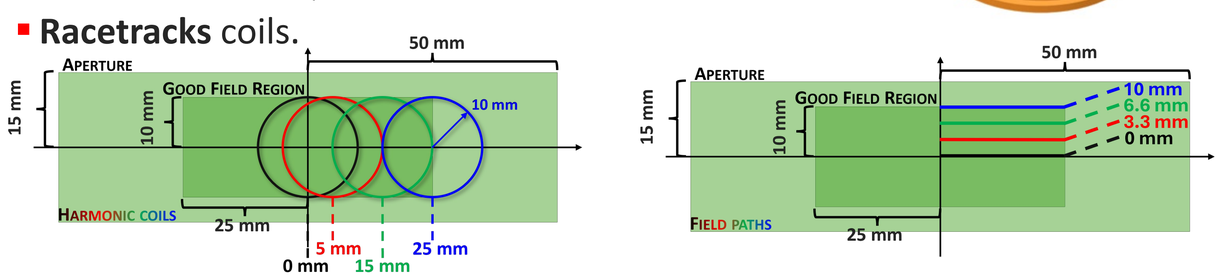
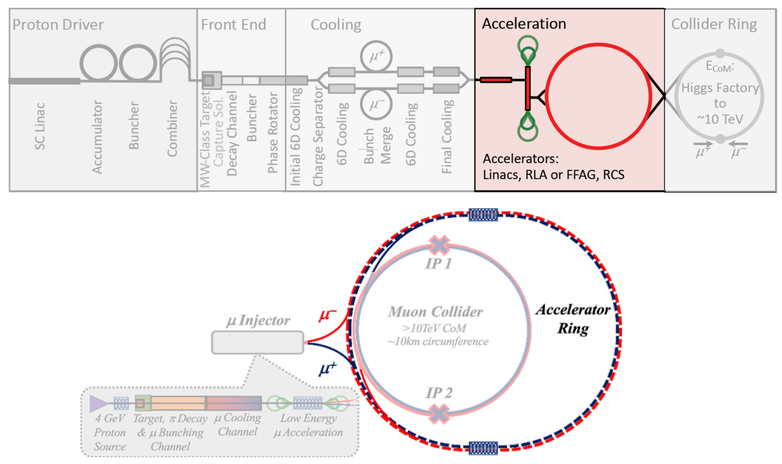
Main requirements of the dipole:

- Large rectangular aperture (w x h): **100 x 30 *mm***;
- Rectangular good field region (**GFR**) **50 x 20 *mm***;
- **Open midplane configuration**;
- **10 *T*** in the centre of the aperture;
- Magnetic field harmonics ≤ **10 units** in the GFR;
- Magnetic field homogeneity ≤ **1 %** in the GFR;
- Operating temperature: **20 *K***;
- Margin in temperature ≥ **2.5** K;
- **HTS REBCO** cable;
- **Racetracks** coils.





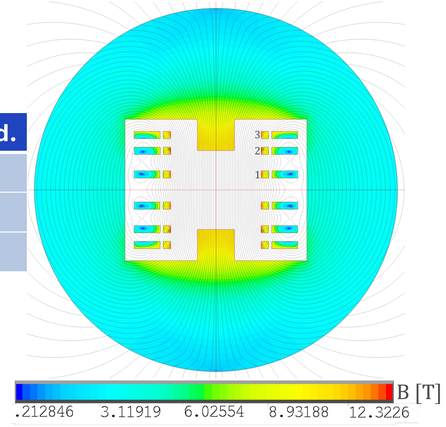
The Muon Collider complex



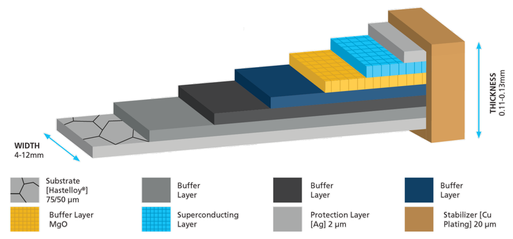
Magnetic design

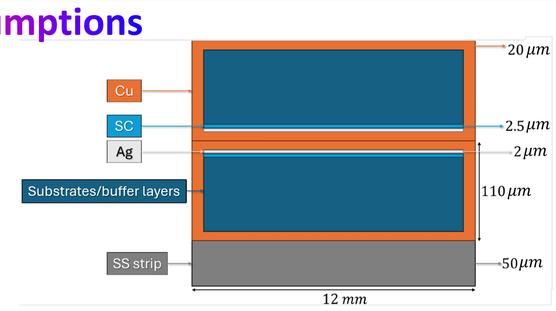
I [A]	$J\left[\frac{A}{mm^2}\right]$	B_0 [T]	B_p [T]	T_{op} [K]	Margin [K]	Cost $\left[\frac{k€}{m}\right]$
2381.13	734.92	10.00	12.32	20	>2.5	196.24

# racetrack	# cond. left	# cond. right	# tot. cond.
1	47	158	205
2	45	160	205
3	46	159	205



Cable assumptions

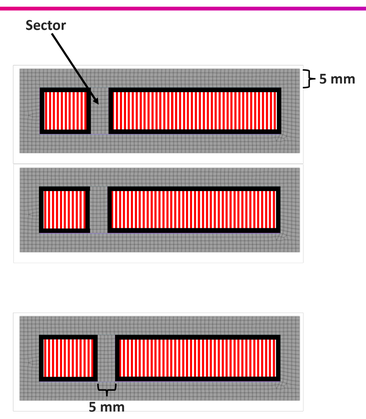




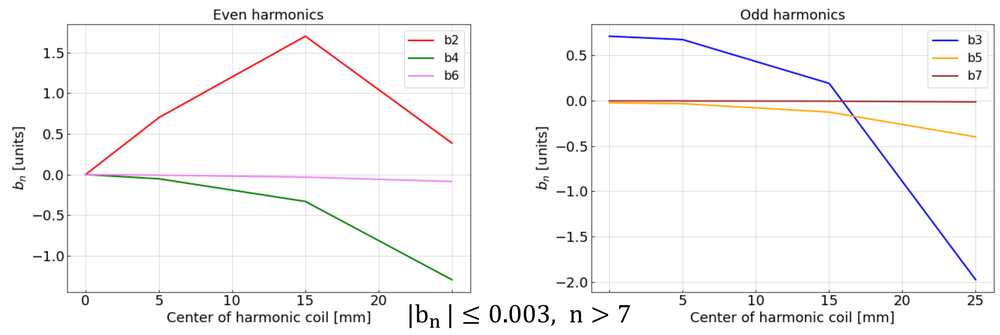
$A_{tot} = 3.24\ mm^2 \quad A_{SC} = 0.0598\ mm^2 \quad A_{Cu} = 0.9656\ mm^2$

Mechanical assumptions:

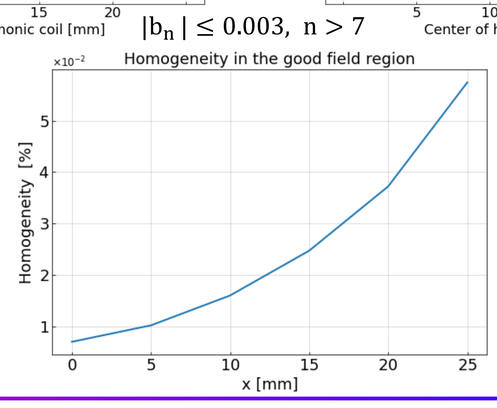
- Infinitely **rigid** mechanical structure;
- **Homogenous** material for racetracks: $E = 150.3\ GPa, \nu = 0.3$;
- **Maximum horizontal stress** 400 *MPa* and **maximum vertical stress** 100 *MPa;*
- **Frictionless** system;
- Use of the **sectors** to reduce stress.



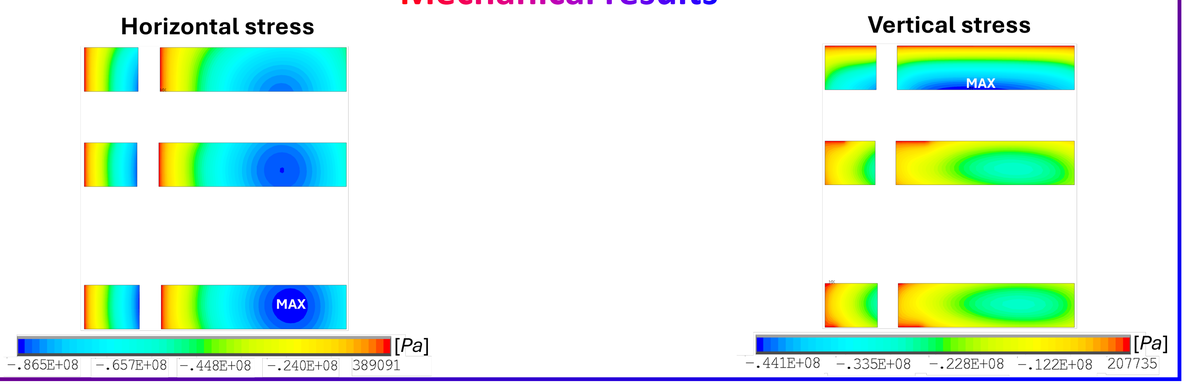
Magnetic results



$|b_n| \leq 0.003,\ n > 7$



Mechanical results



Cost

$Cost_{TOT} = (\sum A_x \rho_x C_x) + 20\,\frac{k€}{m}$ → Assembly

$\rho = density\left[\frac{kg}{m^3}\right]$ | $A = area\ [m^2]$ | $C = cost\ density\left[\frac{k€}{kg}\right]$

$\rho_{cond} = 8000\,\frac{kg}{m^3}$ $\quad C_{cond} = 2500\,\frac{€}{kg}$

$\rho_{iron} = 7800\,\frac{kg}{m^3}$ $\quad C_{iron} = 8\,\frac{€}{kg}$

$\rho_{SS} = 7800\,\frac{kg}{m^3}$ $\quad C_{SS} = 10\,\frac{€}{kg}$

Cost	
Conductor [k€/m]	159.41
Iron yoke [k€/m]	13.65
Mechanical structure [k€/m]	3.18
Assembly [k€/m]	20.00
Total cost [k€/m]	196.24

Magnetization

Using **T-A formulation**, it is possible to make a model that simulates the **charging phase** of the magnet.

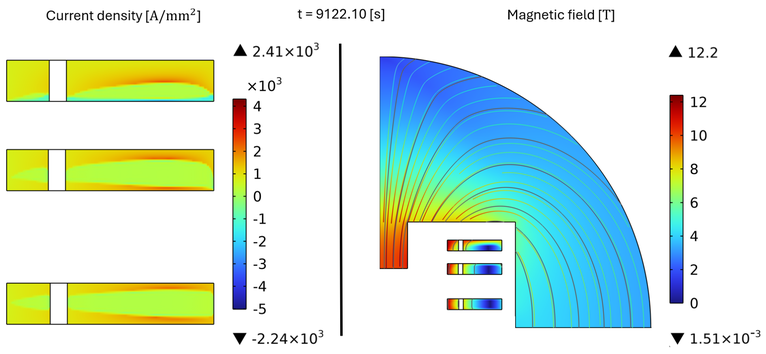
Assumption:

$$\begin{cases} J_x = 0 \\ J_y = 0 \end{cases} \quad \begin{cases} T_y = 0 \\ T_z = 0 \end{cases}$$

$q_{tot} = 49.35\ \frac{kJ}{m}$

$q_{peak} = 878.85\ \frac{W}{m}$

The charging phase is characterized by a slope of **20** $\frac{A}{s}$ until the peak current of $I_{max} = 2399.48\ A$ and the current stays **constant** for $9000\ s$



Magnetization of the cable causes a **different current distribution** that generates a different magnetic field map

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