HFM

High Field Magnets

Update on Common Coil activities at CIEMAT

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High field magnet program at CIEMAT

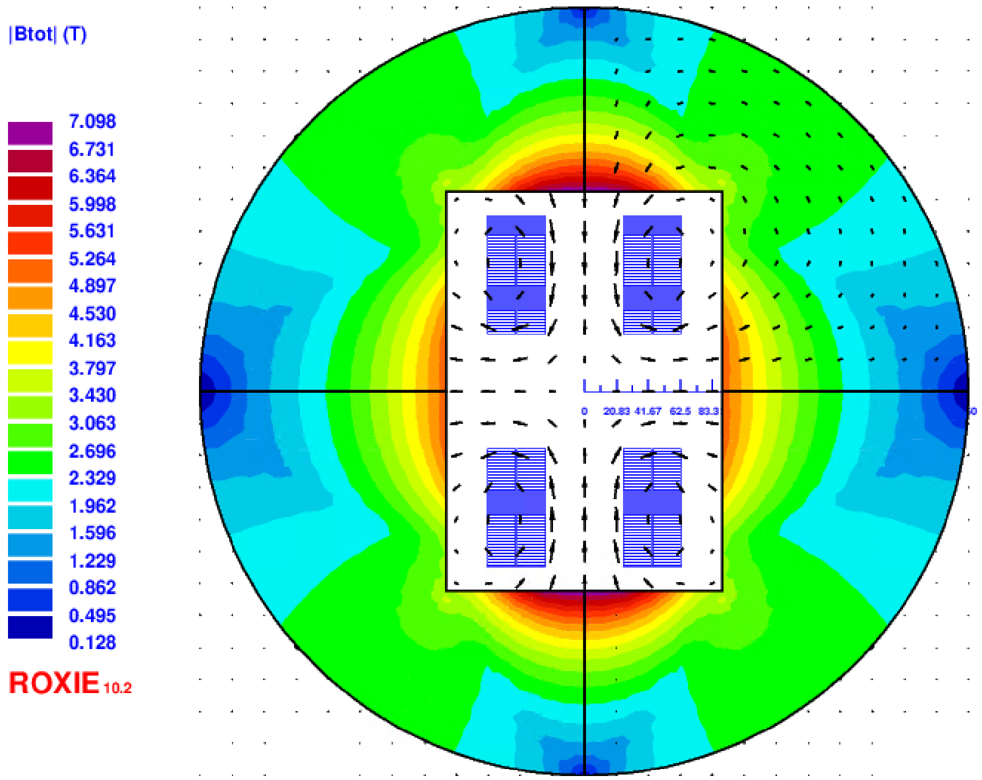
- Initial constraints for the research on high field magnets at CIEMAT:
  - Some delay in starting the activity due to the workload driven by MCBXF magnets.
  - The new laboratory will not be fully operational till Spring 2024.

- Our proposal is based on the following steps:
  1. Model magnet using RMC coils in common coil configuration (ISAAC Investigating Superconducting Assembly to Address Common coil mechanics).
  2. Research on fabrication techniques: react-and-wind coils.
  3. Prototype of a high field magnet in common coil configuration.

	HIGH FIELD SC MAGNET MODELS FOR FCC	2022				2023				2024				2025				2026				2027			
UM-IO-1.1	Provision of building and services	■	■	■	■	■																			
UM-IO-1.2	Set-up and commissioning of laboratory				■	■	■	■	■	■															
UM-IO-2.1	Production of tooling and structure for ERMC and RMM					■	■	■	■	■	■														
UM-IO-2.2	Production of practice coils						■	■	■	■	■	■	■												
UM-IO-3.1	High field demonstrator: detailed design								■	■	■	■	■	■	■										
UM-IO-3.2	High field demonstrator: design and procurement of the tooling												■	■	■	■	■								
UM-IO-3.3	High field demonstrator: manufacturing of the coils															■	■	■	■						
UM-IO-3.4	High field demonstrator: magnets assembly and participation to cold tests & analysis																			■	■				

Magnetic design: Goals & constrains

- Main goal: learn for the 14T model, mostly mechanics
  - Provide 14T in the aperture (100% load required)
  - Decrease F_y: Low vertical preload goal (free horizontal movement, without friction)
  - Mechanics & assembly as easy as possible

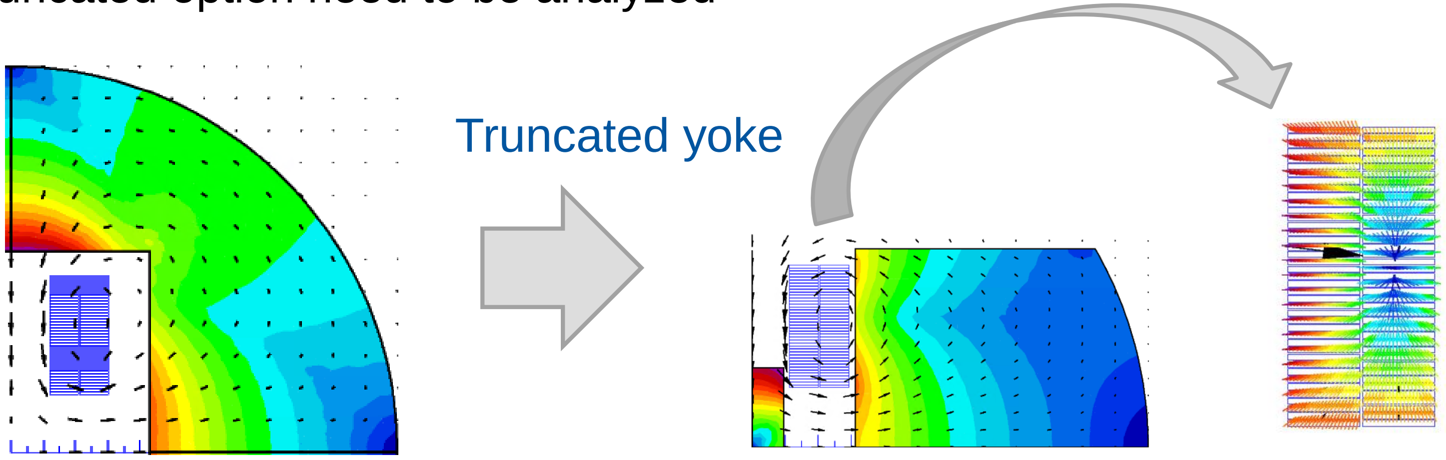


Initial base case

Design ID	2D_V0_80	Units
Aperture	50	mm
Intra-beam dist.	152	mm
I_nom	16	kA
Yoke inner X	90	mm
Yoke inner Y	130	mm
Yoke outer diam.	500	mm
B	10.25	T
Peak field	11.68	T
Load	80.2	%
Stored energy	855	kJ/m
Static Self Induct.	6.68	mH/m
L*I	106.86	HA/m
Stray field (20 mm)	0.29	T
Sum Fx Q1	4.19	MN/m
Sum Fy Q1	1.54	MN/m
Total F	4.47	MN/m

Magnetic design: Decreasing F_y

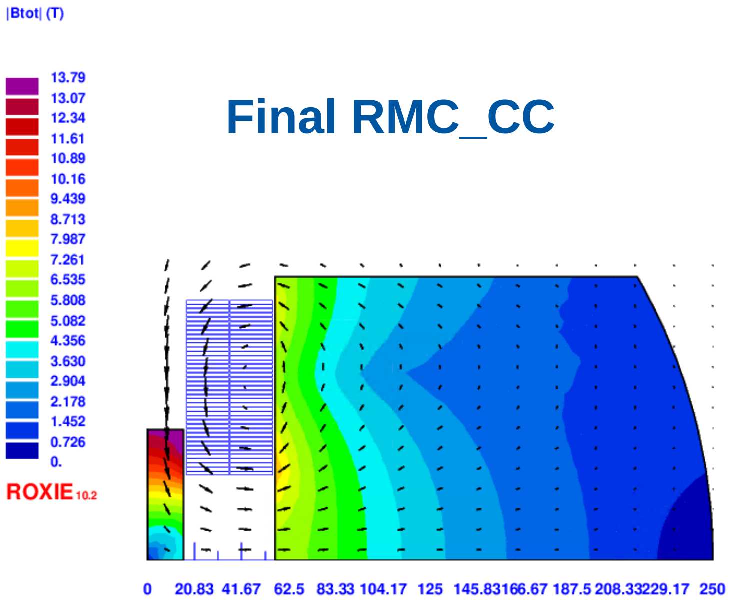
- Vertical EM forces inside the coil need to be as balanced as possible
- Yoke is used to pull the field lines in the desired direction
- Yoke is truncated above the coil to provide good horizontal support
- Middle yoke helps to decrease F_y significantly
- Mechanics of this truncated option need to be analyzed



Units	MN/m	MN/m	MN/m	N/A
Design ID	Total F	Sum Fx Q1	Sum Fy Q1	Ratio Fy/Fx
2D_V0_80: **Base case**	4.4673466	4.19413	**1.53833**	0.366781669
2D_V5_wo_MY: **Truncated iron without middle yoke**	4.325538645	4.279708	**0.628**	0.146738983
2D_V5_MY20x50: **Truncated iron + middle yoke**	4.205129335	4.17877	**0.4701**	0.112497218

Magnetic design to provide 14T

- Aperture decreased from 50 mm to 34 mm
- Yoke very close to the coil (only 1.2 mm away)
- Intra-beam distance tuned to decreased a2
- Middle yoke has a strong influence despite its assembly could be not straightforward
- Protection is possible using a dump resistor according to first simulations: R_{dump} = 45 mΩ yields a hotspot temperature of 286K and 900V voltage



Design ID	Block	Final RMC_CC	CC	CC*	Units
Aperture	74	34	74	74	mm
Intra-beam dist.	-	150	152	252	mm
I_nom	14486	19083	21353	20460	A
Yoke outer radius	246	250	246	246	mm
B	14	14	11.3	11.96	T
Peak field	16.16	14.8	14.27	14.51	T
Peak Field/B	1.154	1.0571	1.263	1.213	-
Load	99.99	99.99	100.27	100.36	%
Stored energy	1752	1038	1701	1733	kJ/m
Static Self Induct.	16.7	5.7	7.46	8.28	mH/m
L*I	242	109	159	169	HA/m
Stray field (20 mm)	1.188	0.44	0.65	1.56	T
Sum Fx Q1	5.1	6.636	5.79	6.53	MN/m
Sum Fy Q1	-4.3	0.474	3.02	0.73	MN/m

Magnetic design: field quality vs coil position

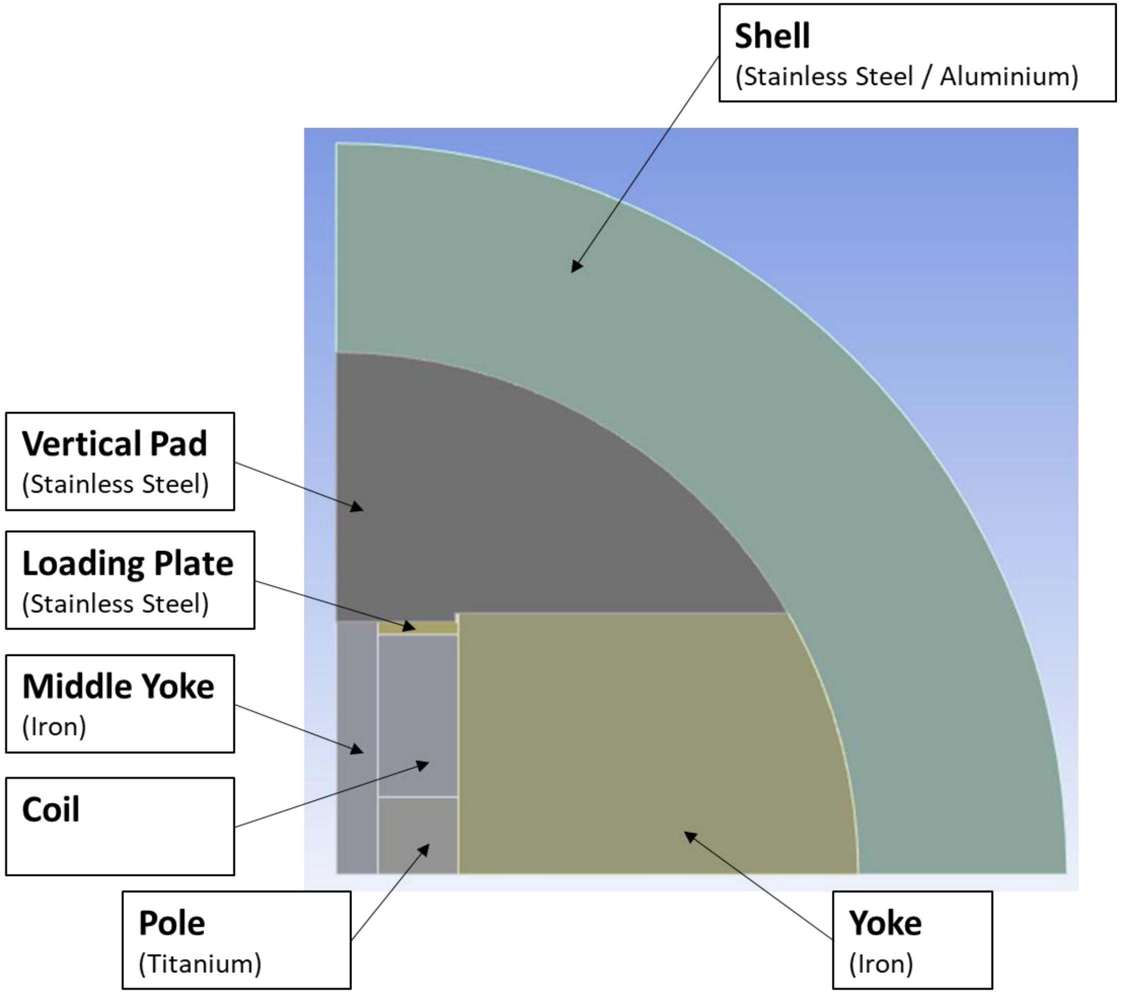
- 14T Magnet aperture: 34 mm
- Horizontal displacement 0.5mm => decrease field 1% aprox and multipoles variation below 0.5 units

mm	T	units	units	units	units	units	units	units	units	%
Displ. X	**Aperture field**	**b3**	**b5**	**b7**	**b9**	**a2**	**a4**	**a6**	**a8**	**% B**
0	13.999139	297.12975	0.74637	2.18884	-0.52826	3.02079	-25.65207	-1.53509	1.44829	**0**
0.5	13.863671	297.03506	1.08324	2.19718	-0.53572	1.49924	-25.94459	-1.55069	1.46195	**-0.96768808**
1	13.729701	296.82646	1.42133	2.20147	-0.5382	-0.00928	-26.23901	-1.56249	1.47012	**-1.92467551**
1.5	13.597258	296.50431	1.75736	2.20814	-0.54216	-1.50665	-26.53531	-1.57543	1.4797	**-2.87075512**

Mechanical design (I)

First mechanical simulations:

- Parts in contact (without prestress) at room temperature
- Stainless Steel vertical pad
- Cooling (from 295.15K to 1.9K)
- Electromagnetic Forces

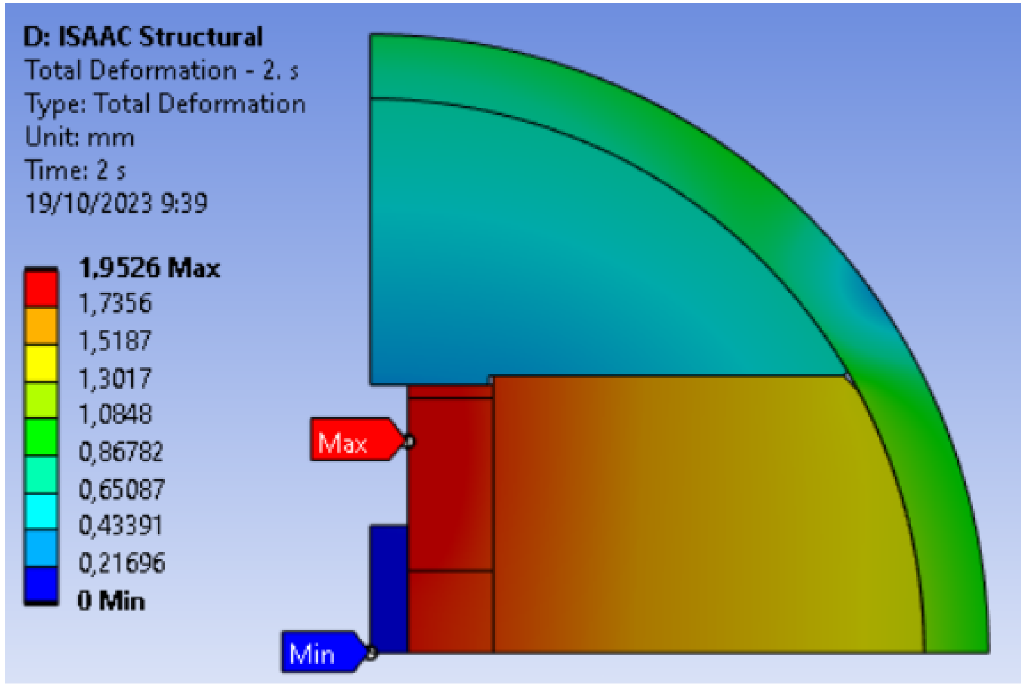


Mechanical design (I)

- Aluminium Shell similar to SMC CERN block configuration
  - Outer yoke radius: 250 mm
  - Shell thickness: 29 mm

Goal: Coil displacement below 1mm (after cooling) in order to:

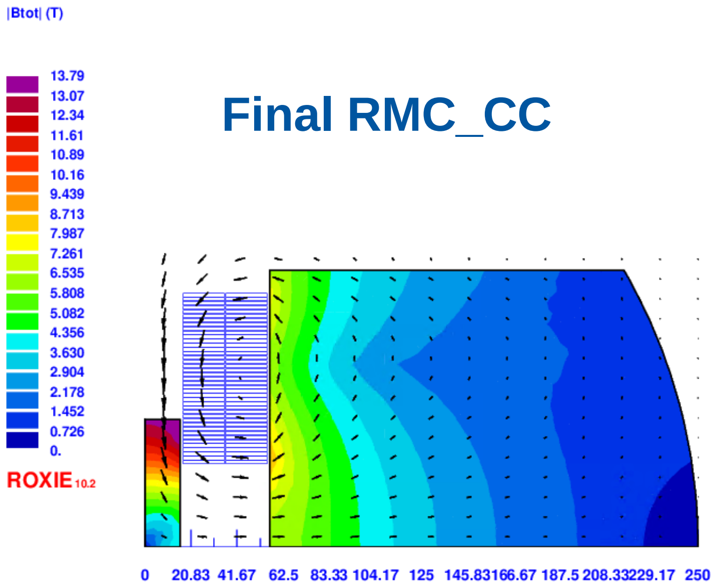
- Reduce the possibility of sudden coil movements
- Aperture field over 13.7T

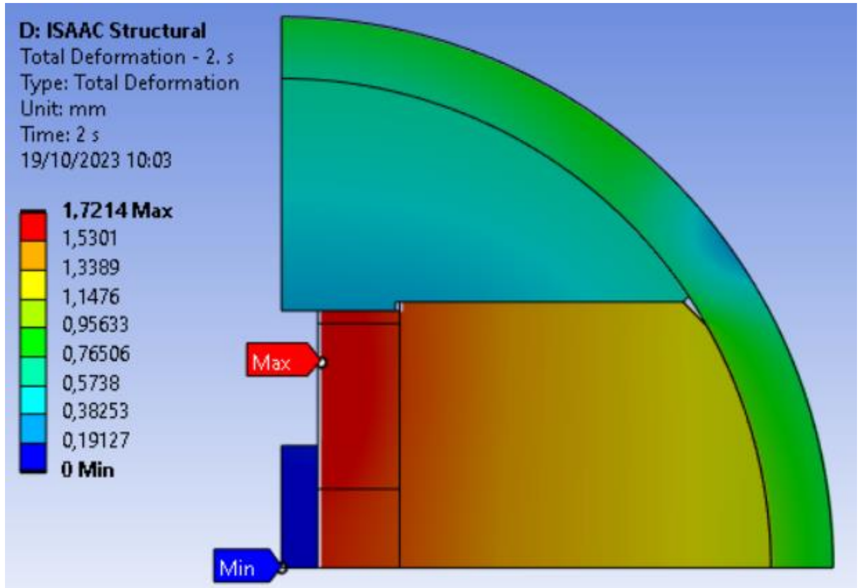


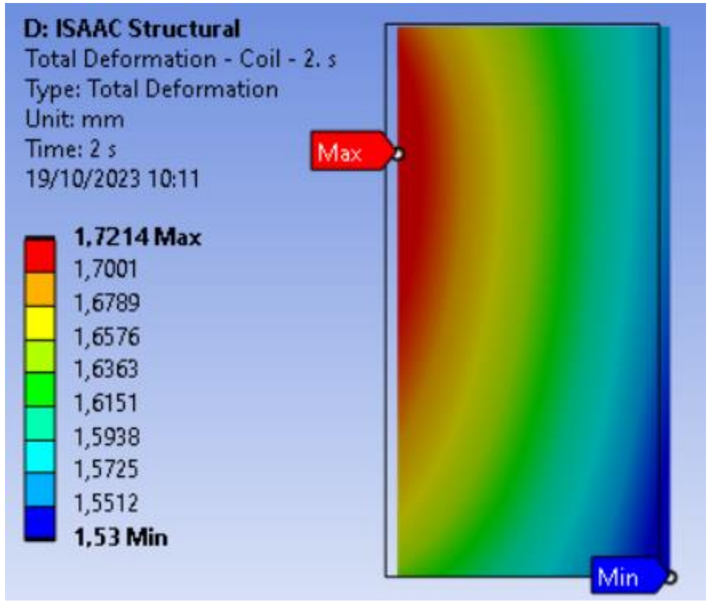
Mechanical design (III)

- Aluminium Shell inner radius from 250mm to 230mm:
  - Very similar magnetic field (14T => 13.98T)
  - Coil displacement reduced (1,95mm => 1,72mm)

	R230	R250		Dif.
Peak field B	14,553	14,559	T	-0,04%
B (aperture)	13,980	14,000	T	-0,14%







Conclusions

- The new laboratory building is finished. Procurement of equipment is ongoing.
- Magnetic & Mechanical design of a 14T CC magnet using existing RMC-QXF coils (ISAAC):
  - F_y decreased: analysis of free horizontal movement of the coils without friction
  - Analysis of magnetic field sensitivity vs. coil position
  - Mechanical structure design ongoing (shell materials, dimensions...). Minimize coil horizontal displacement (less than 1mm)