Q4 update

M. Segreti, H. Felice, J.M. Rifflet, E. Todesco

MAGNETIC DESIGN USING MQM CABLE

- Magnetic design optimized at the nominal current in the two apertures
- Harmonics are calculated at the reference radius (2/3 of the aperture radius)
- Magnet integrated strength = 440 T
- Margin on the load line = at least 20 %
- Cable used= MQM insulated with its classical insulation (0.08 mm thick after curing & collaring). Main characteristics of MQM cable are listed below

Cable characteristics	Width (mm)	Min thick (mm)	Max thick (mm)	Nb strands	Transp (mm)	Degrad (%)	Fil
	8.8	0.78	0.91	36	66	5	NbTi
Strand characteristics	Diam (mm)	Cu/sc	RRR	Tr (K)	Br (T)	Jc @ BrTr	dJc/dB
	0.48	1.75	80	1.9	5	2872	600

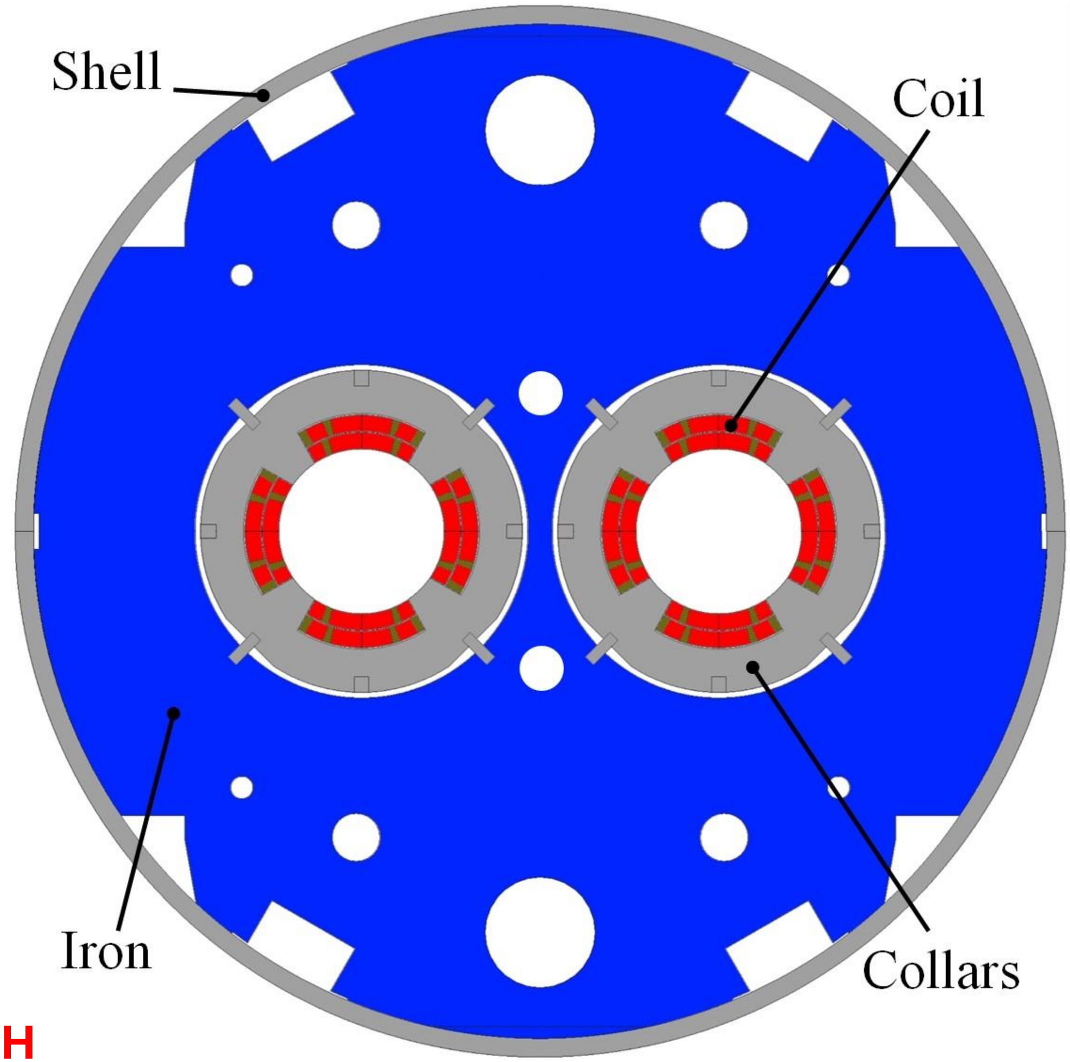
MAGNETIC DESIGN USING MQM CABLE

2 layers of MQM cable
Inner blocks: 17 + 8 turns
Outer blocks: 16 +10 turns

Aperture = 90 mm (as before)

Integrated gradient = 440 T
Magnetic length = 3.67 m
Nominal gradient = 120 T/m

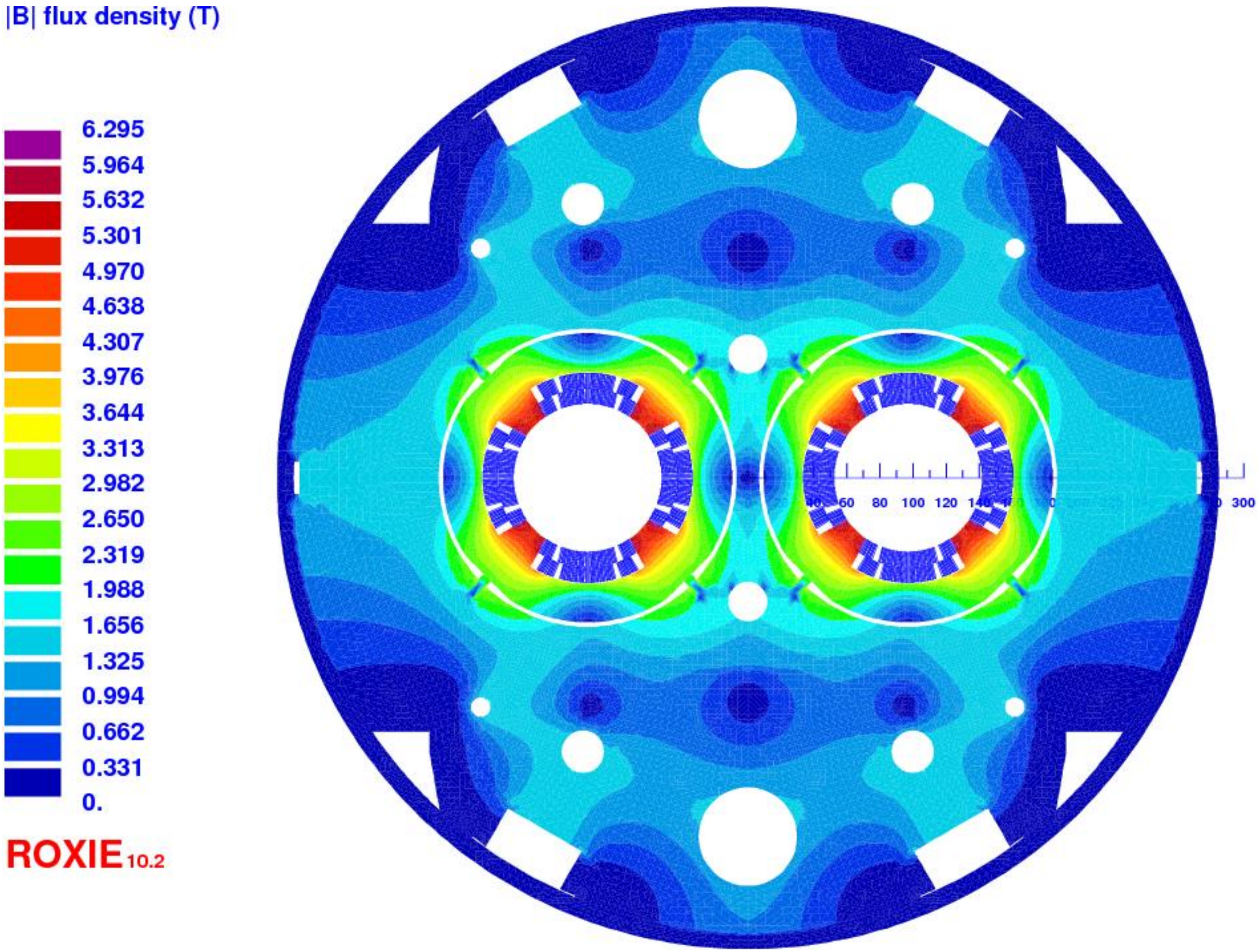
Loadline margin = 20 %
Temperature = 1.9 K
Nominal current = 4590 A
Stored energy = 0.81 MJ
Differential inductance = 2 × 37.5 mH



MAGNETIC DESIGN USING MQM CABLE

Calculation with collars (assuming a relative permeability of 1.0025)

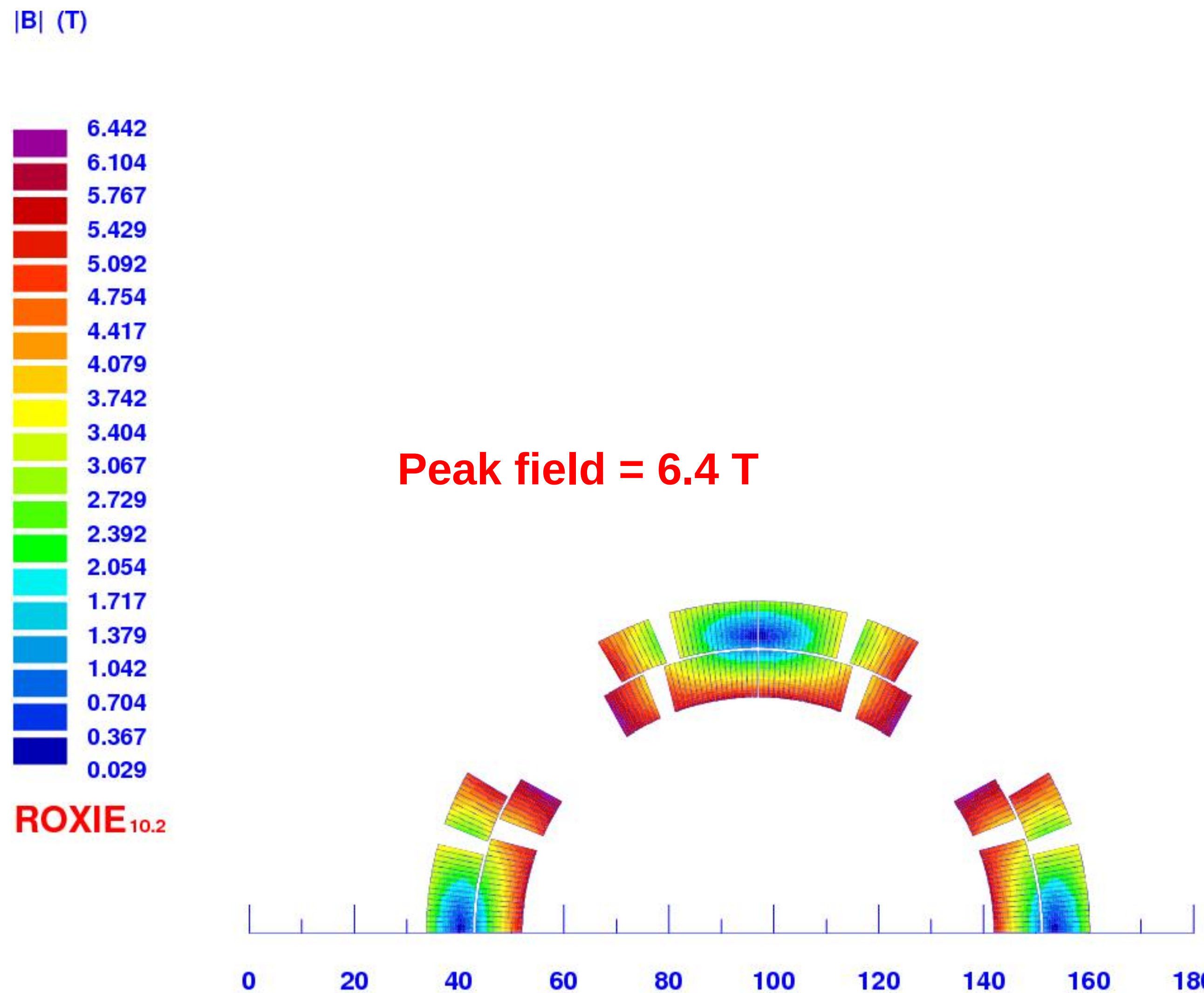
Re-optimized cross-section to minimize impact of collars on b6



MAGNETIC DESIGN USING MQM CABLE

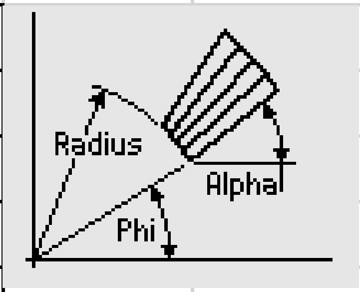
Calculation with collars (assuming a relative permeability of 1.0025)

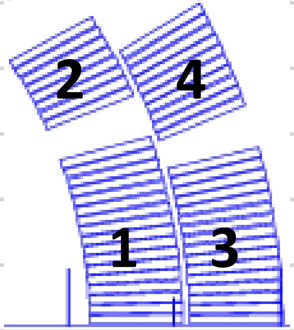
At 4590 A, collars increase the peak field on conductor by about 0.12 T



With collars + iron yoke + shell

Blocks	Ncab	R (mm)	φ (Deg)	α (Deg)
1	17	45	0.1590	0.0000
2	8	45	24.3201	21.7291
3	16	54.46	0.1320	0.0000
4	10	54.46	18.6833	22.6004



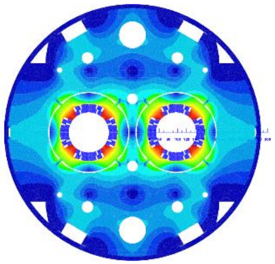


0 % unbalanced regime

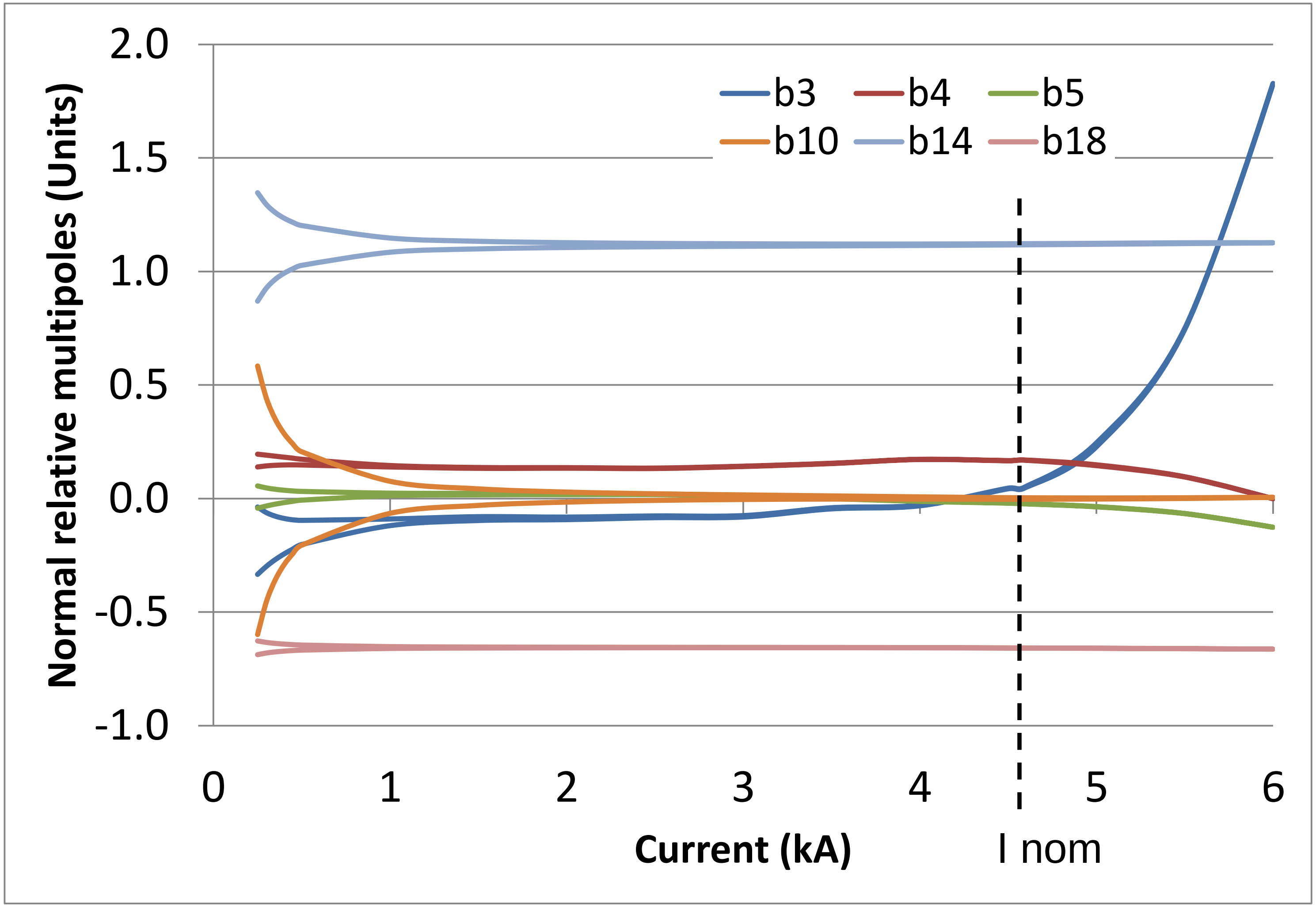
Current (A)	Gradient (T/m)	b3	b4	b5	b6	b10	b14	b18
4590	120	-0.05	0.17	0.02	0.00	0.00	**1.12**	-0.66

Current (A)	Gradient (T/m)	b3	b4	b5	b6	b10	b14	b18
4590	120	0.05	0.17	-0.02	0.00	0.00	**1.12**	-0.66

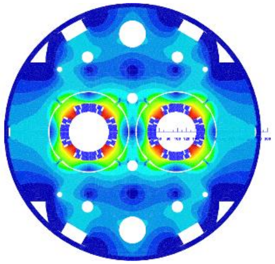
FIELD QUALITY
TRANSIENT FROM 250 A TO 6 KA



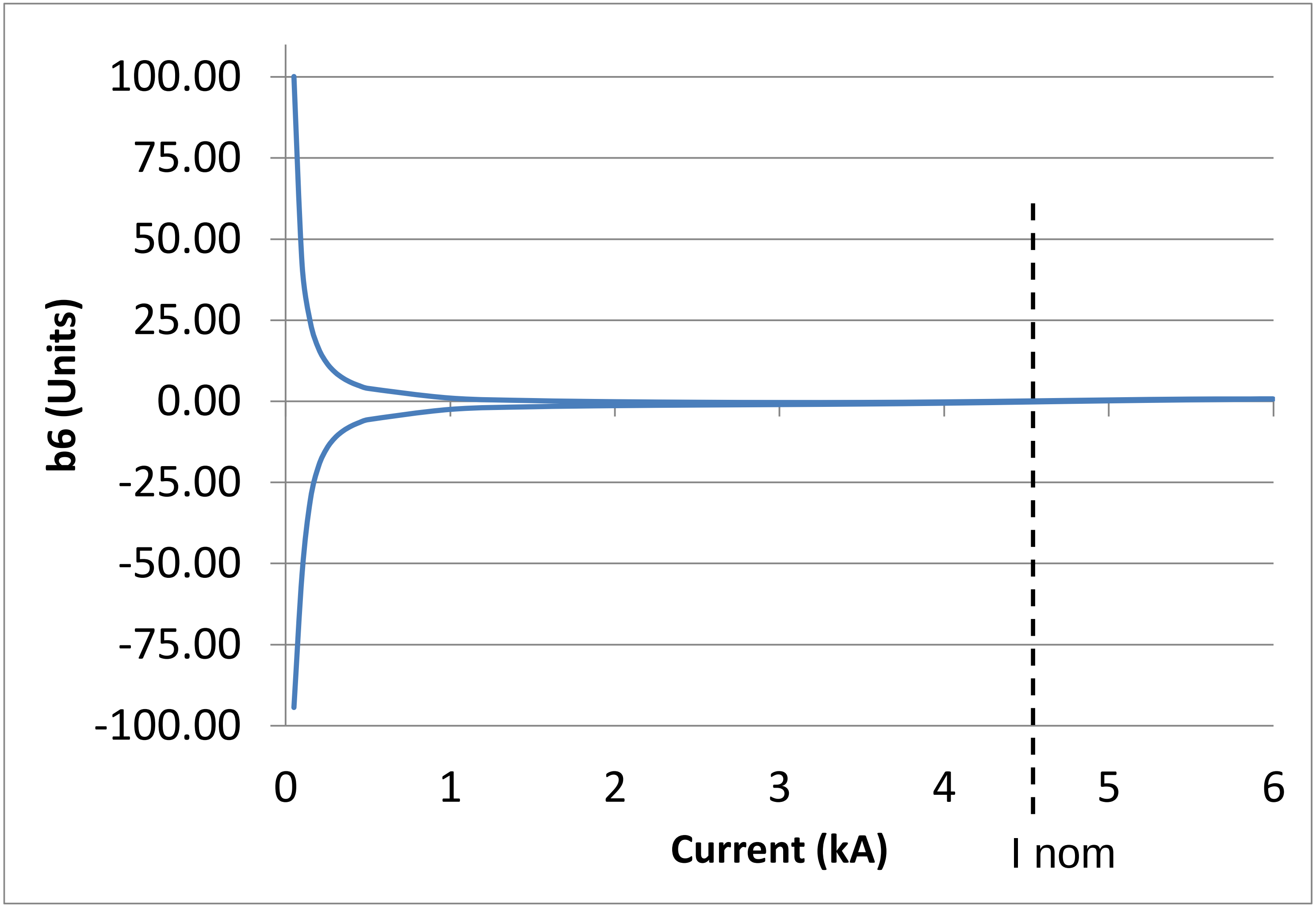
Evolution of normal relative multipoles with the current (cable eddy currents taken into account)



FIELD QUALITY
TRANSIENT FROM 50 A TO 6 KA

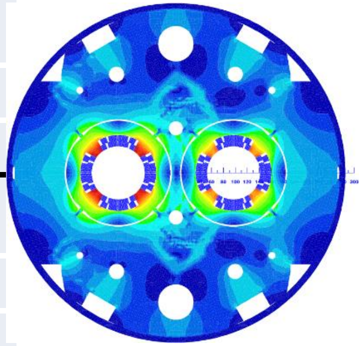


Evolution of b6 with the current (cable eddy currents taken into account)

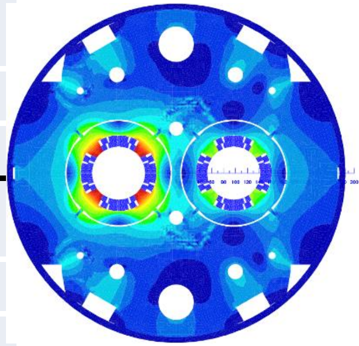


Unbalanced regime

20 % unbalanced regime								
Current	Gradient							
(A)	(T/m)	b3	b4	b5	b6	b10	b14	b18
4590	120	-0.57	0.09	-0.04	-0.01	0.00	**1.12**	-0.66
Current	Gradient							
(A)	(T/m)	b3	b4	b5	b6	b10	b14	b18
3672	96	-0.09	0.19	0.01	-0.53	0.00	**1.12**	-0.66

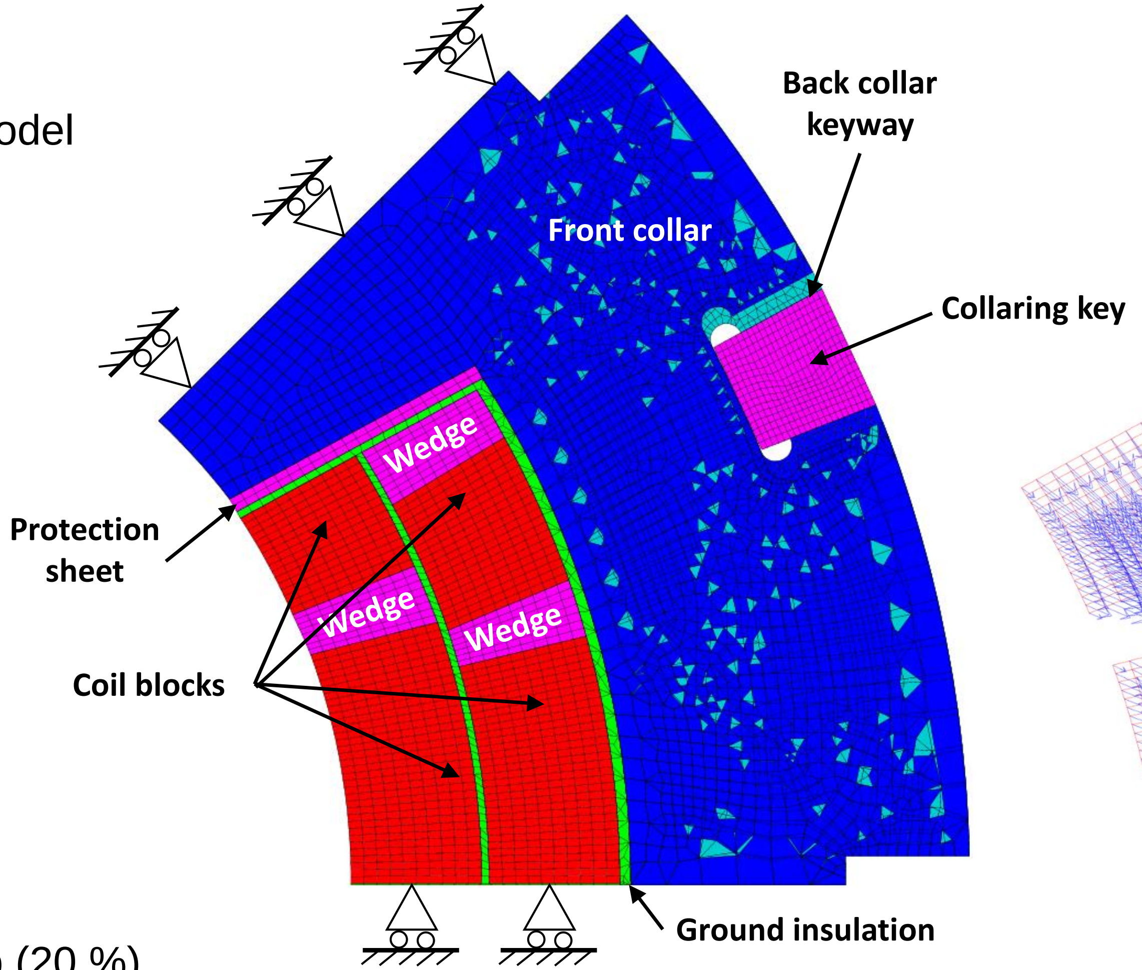


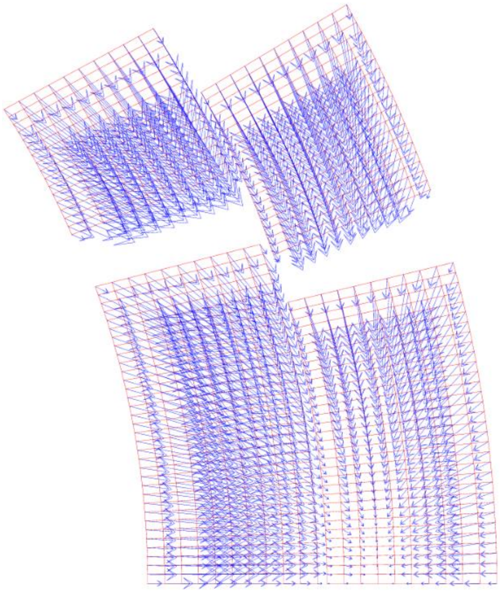
50 % unbalanced regime								
Current	Gradient							
(A)	(T/m)	b3	b4	b5	b6	b10	b14	b18
4590	120	-0.55	0.11	-0.03	0.00	0.00	**1.12**	-0.66
Current	Gradient							
(A)	(T/m)	b3	b4	b5	b6	b10	b14	b18
2295	60	-0.36	0.32	-0.02	-0.70	0.01	**1.12**	-0.66



MECHANICAL STUDY

Mechanical model
CAST3M





Fx = 0.47 MN/m

Fy = - 0.63 MN/m

Simulation :

- Collaring (key)
- Insulation creep (20 %)
- Cooling
- Energisation at 110 % of I_{nom} → Magnetic forces are computed at each coil node

Thermomechanical properties of materials

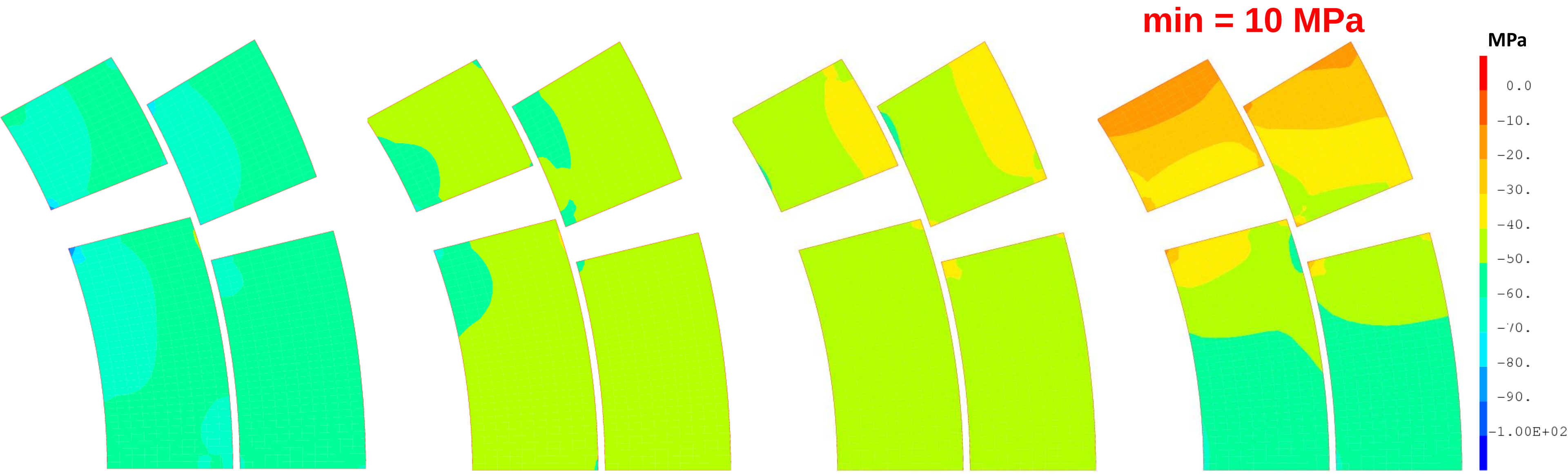
Materials / *Componants*	Temp. (K)	Elastic Modulus E (GPa)	Yield Strength (MPa)	Ultimate Strength (MPa)	Integrated Thermal Shrinkage α (mm/m)
yus 130 S Nippon Steel	300	190	445	795	
Collars	2	210	1023	1595	2.4
316L Stainless Steel	300	205	275	596	
Keys	2	210	666	1570	2.9
Copper	300	136			
Angular wedges	2	136			3.3
Kapton Foils	300	2.5			
inter-layer & inter-pole insulations	2	4			6.0
insulated NbTi conductor blocks	300	**5.6 ***			
Coils with MQM cable	2	**7.84 ***			**5.0 ***

*** For MQM insulated conductor, it is assumed that: $E_{2K} = 1.4 \times E_{300K}$ and $\alpha = 5.0$ mm/m (see in red)**

Thanks to Julio for his data on MQM magnet!

20 % loss of pre-stress is assumed after collaring due to insulation creep

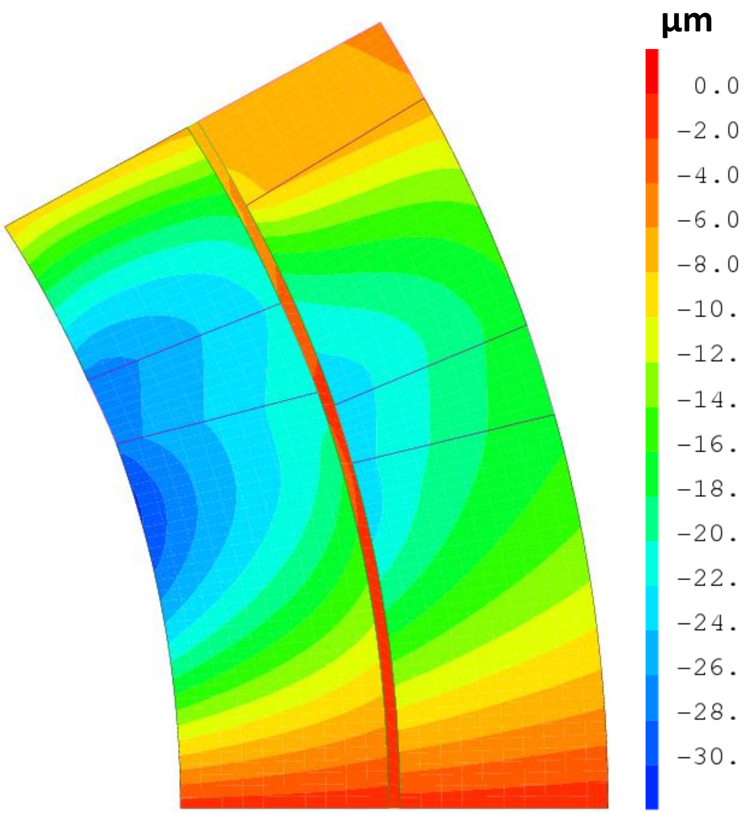
MECHANICAL STUDY



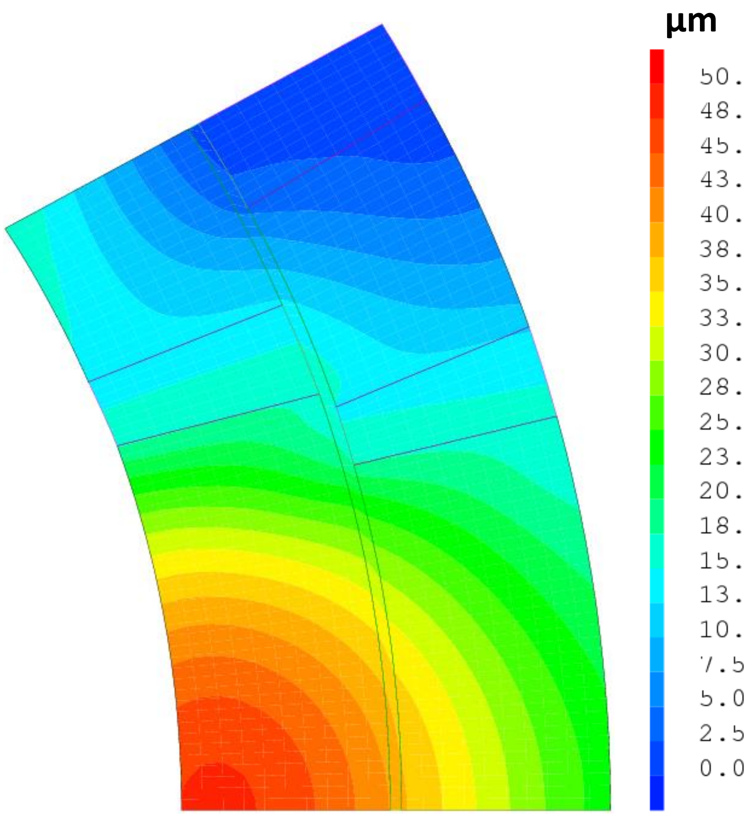
After collaring | After creep | After cooling | At 110 % of nominal current

Azimuthal stress distribution in coil at each main step

MECHANICAL STUDY



Azimuthal displacement

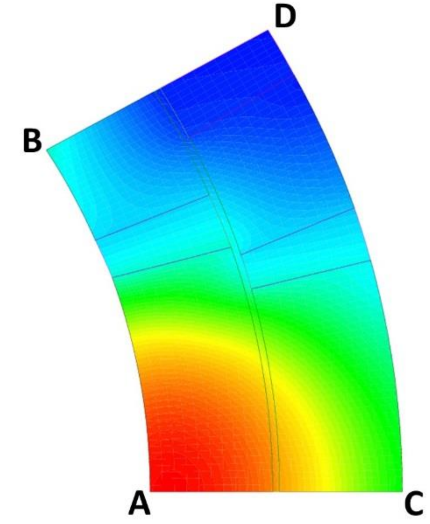


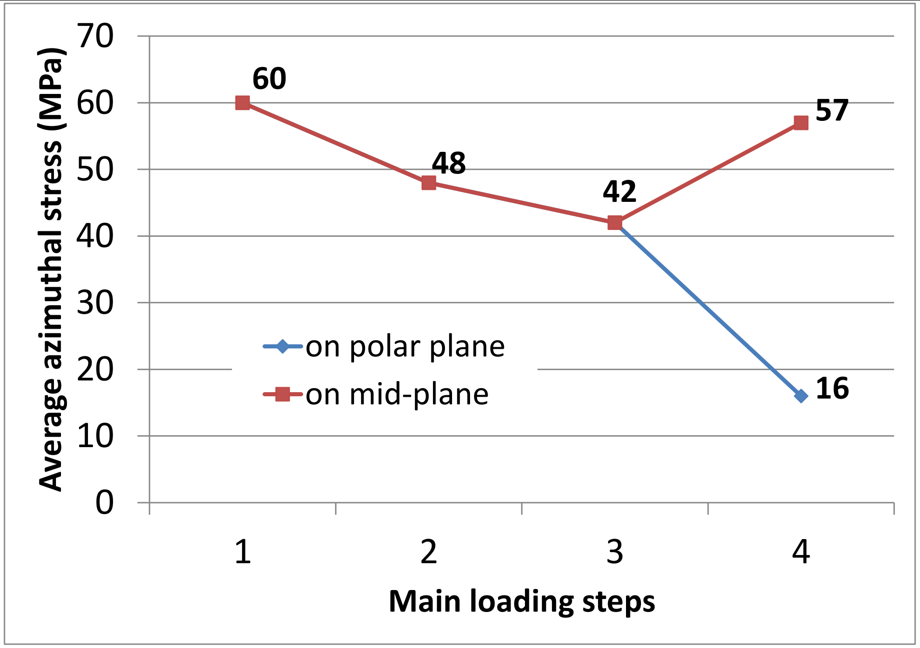
Radial displacement

Displacement in coil due to magnetic forces

MECHANICAL STUDY

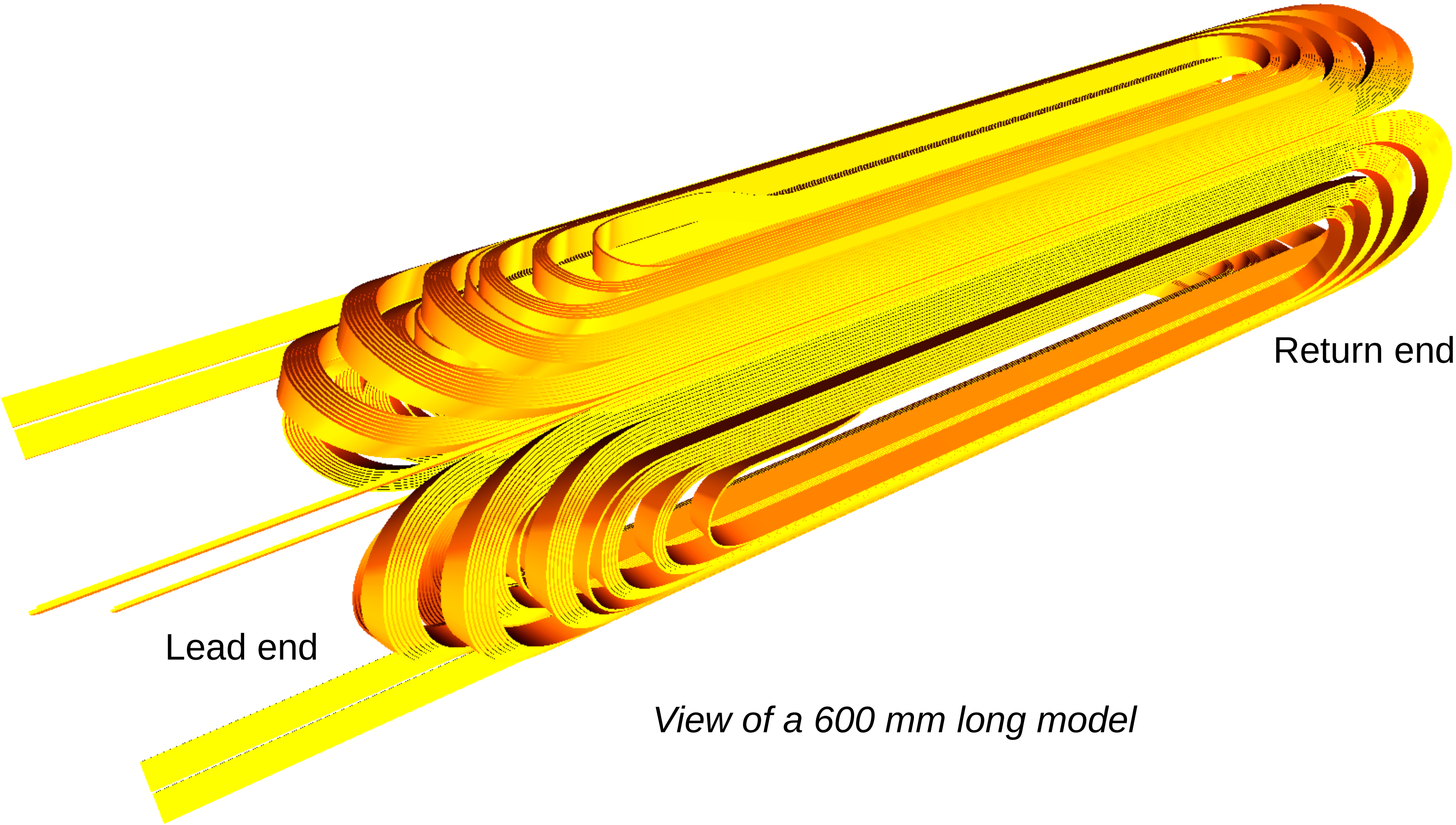
Q4 with MQM cable	Collaring	Creep (20%)	Cool down	Energization
Azimuthal stress in coil (MPa)				
Max	-94	-77	-52	-63
Average	-60	-48	-42	-43
Min on polar plan				**-10**
Average on polar plan				-16
Coil radial displacement due to Lorentz forces (µm)				
Point A				48
Point B				18
Point C				23
Point D				2





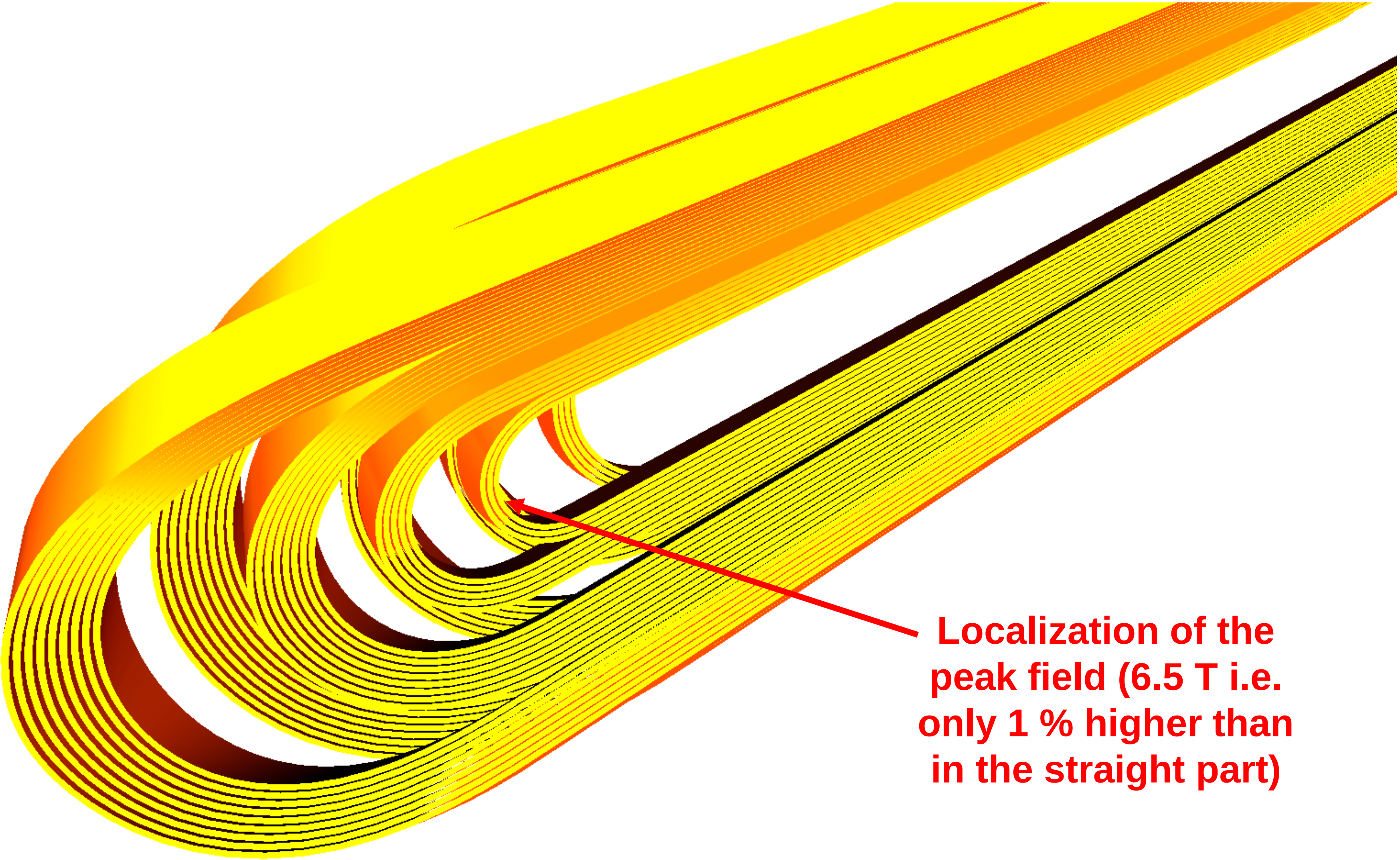
The self-standing collar solution as mechanical structure is validated

COIL ENDS



View of a 600 mm long model

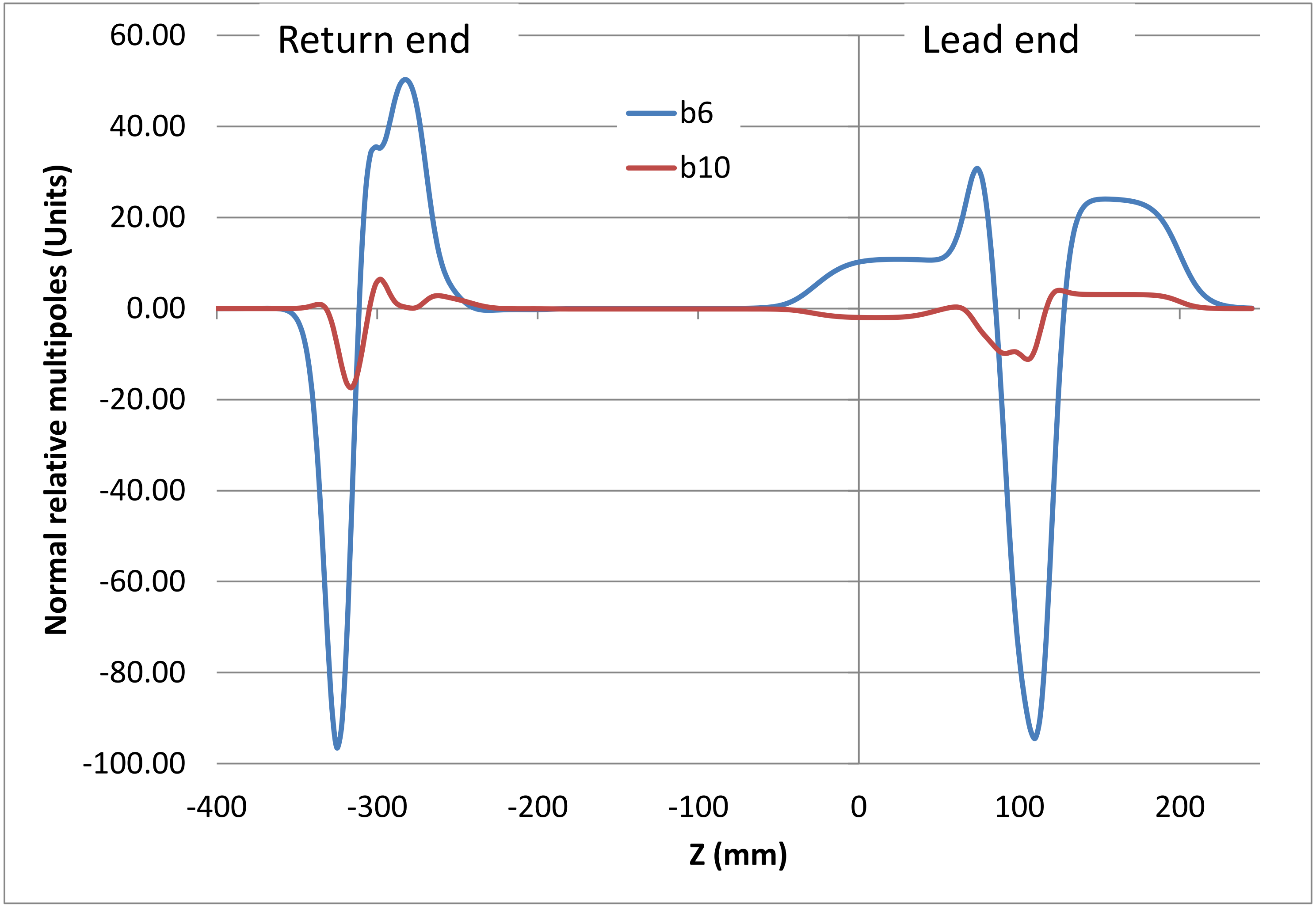
COIL ENDS



Localization of the peak field (6.5 T i.e. only 1 % higher than in the straight part)

COIL ENDS

Integrated b6 has been minimized

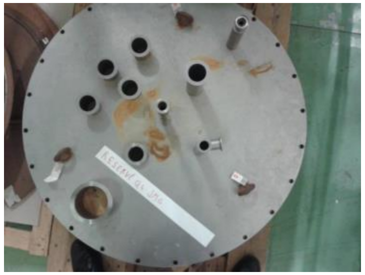


COST ESTIMATE FOR THE SHORT MODEL TEST AT CEA

- Ongoing effort with Jean-Marc Gheller and Denis Bouziat to establish a cost estimate of the test of the single aperture short model at CEA-Saclay

Mechanical

- Cost estimate based on the **recovery/modification** of existing components
    - Top plate
    - 6 kA current leads
    - Current leads insert

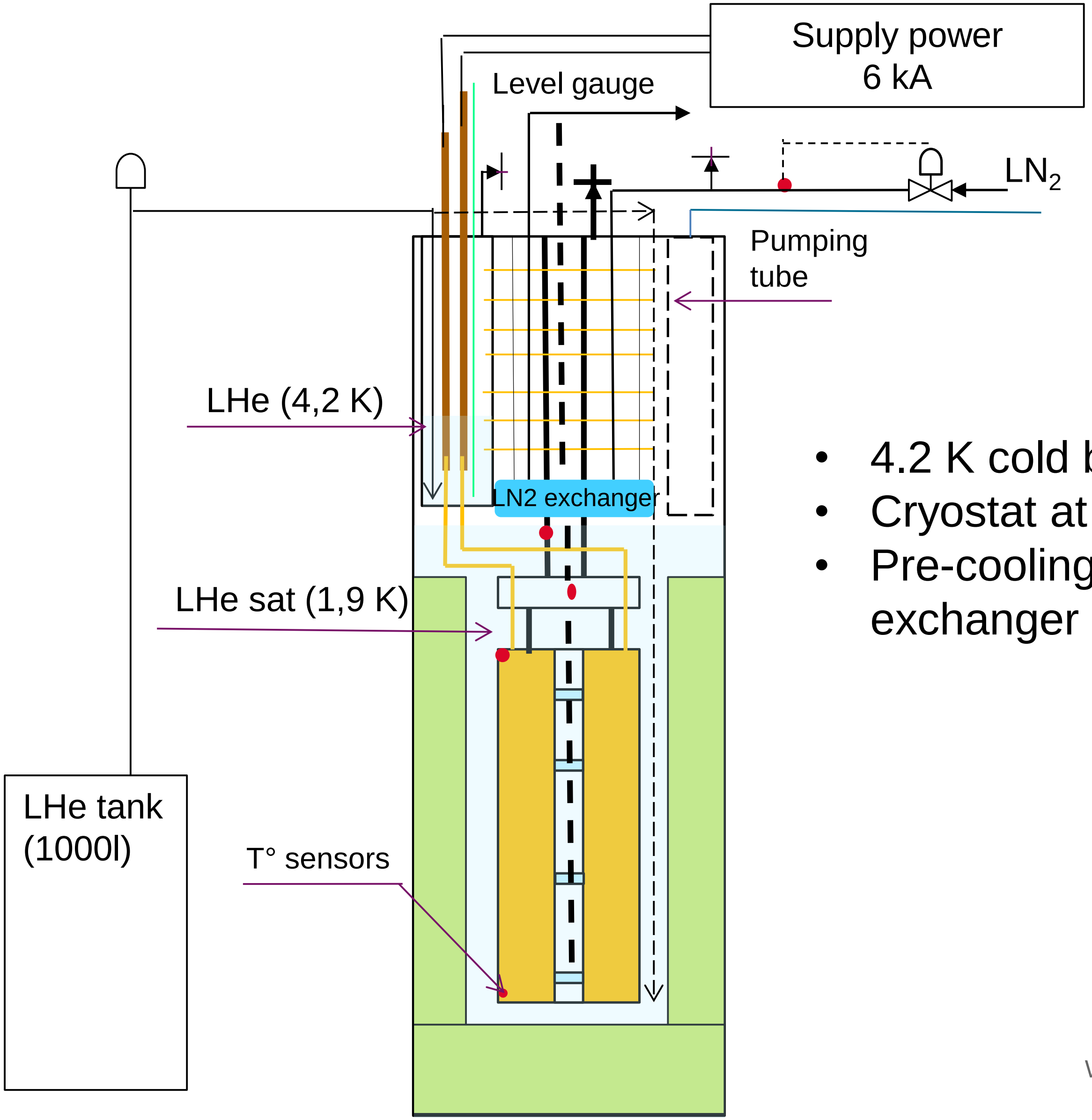


- Ongoing CAD modeling to assess the required effort to perform:
    - The modification of the top plate
    - The integration of the current leads
    - The addition of a safety valve
    - The addition of a central port for magnetic measurements (performed by CERN)
        - A flange ISO K DN100 is presently considered => to be discussed with CERN
- Limited space on the top plate requires some optimization

DAQ and Magnet Protection

- Assessment of available equipment is ongoing

MAGNET IN CRYOSTAT



- 4.2 K cold box for the current leads
- Cryostat at 1.9 K (23 mbar)
- Pre-cooling obtained by LN_2 heat exchanger

PROPOSAL FOR NEW MILESTONES AND DELIVERABLES FOR SHORT MODEL

N°	Description	Steering committee 04/09/2015	As of 25/11/2015 Starts in/ Completed in
2.1	Complete design of the single aperture magnet short model	**July 2016**	**Aug 2015 /July 2016**
2.2	Winding and polymerization of short coil 0	**December 2016**	**Sept/Dec 2016**
2.3	Completion of all coils (1 set + 2 spares in total?)	**July 2017**	**Jan / April 2017 (~12 weeks)**
2.4	Single aperture magnet short model assembly (instrumentation + collaring + yoking)	**September 2017**	**March/June* 2017**
~~2.5~~ ?	~~Assembly procedure end of cold mass (quad + correctors)~~ Test of short model	**December 2017**	**July / Oct 2017**

*preliminary assumption

Thanks for your attention