D2 STATUS

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- The cross talk compensation
- Optimised 2D design
- Coil end design
- Mechanical aspects
- Future Programs

The framework

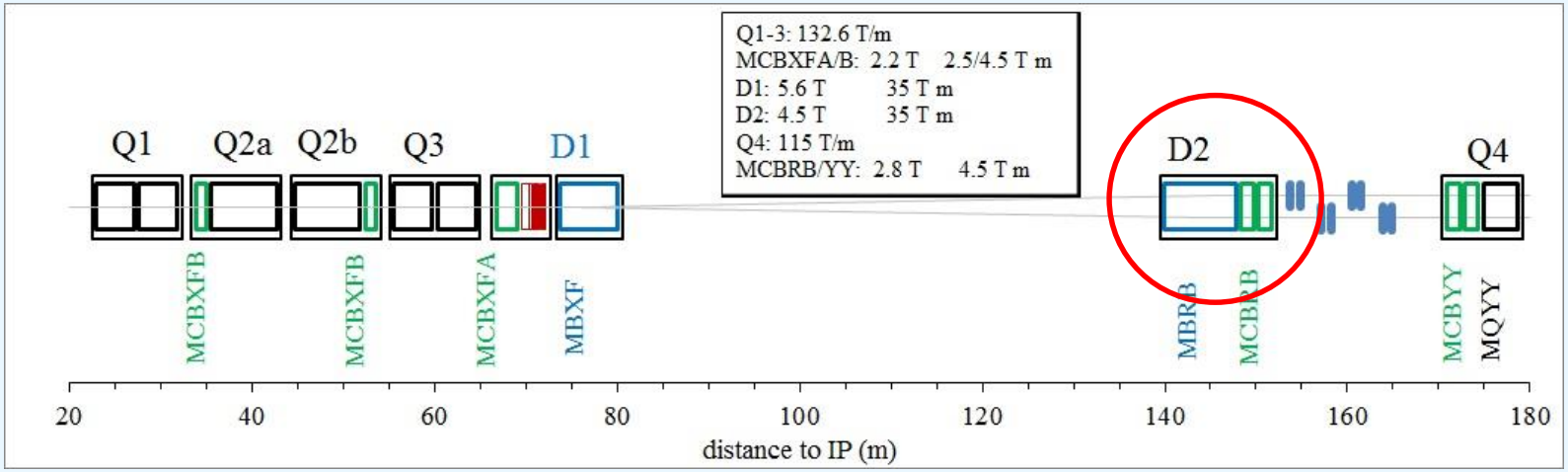
CERN-INFN Collaboration Agreement KE2291/TE/HL-LHC for R&D Activities Relating to High-Luminosity LHC (HL-LHC) Superconducting Magnets

MAGIX		
WP1	CORRAL	Design, construction and test of the five prototypes of the corrector magnets for the HL interaction regions of HiLUMI
WP2	PADS	2D & 3D engineering design of the D2 magnets
WP3	SCOW-2G	Development of HTS coil for application to detectors and accelerators
WP4	SAFFO	Low-loss SC development for application to AC magnets

MAGIX is a INFN-funded research project whose goal is to develop superconducting technologies for application to future accelerator magnets.
It includes four WP's, two of which are relevant to HL-LHC.

2014-2017

The D2 dipoles in HL-LHC (Requirements)

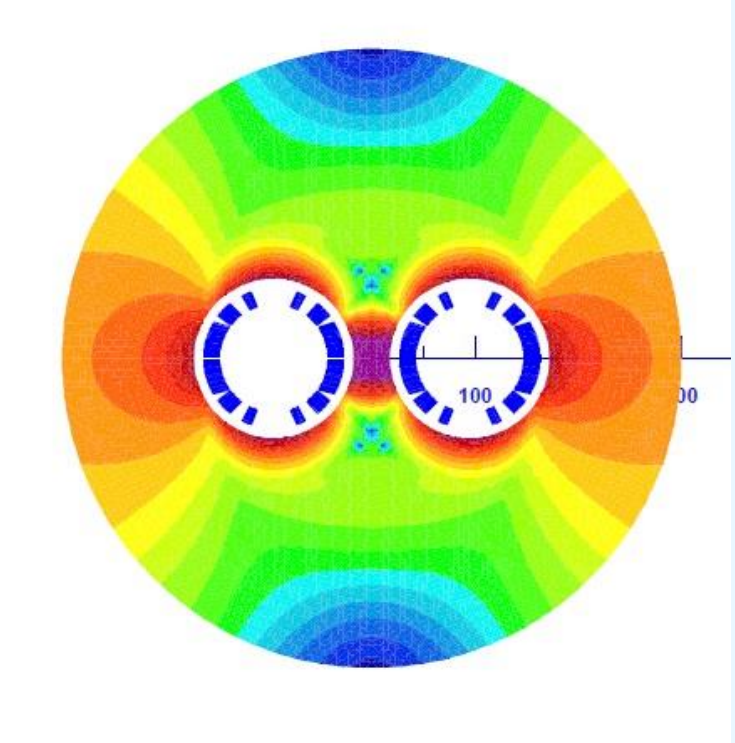


Characteristics	Unit	Value
Integrated magnetic field strength	Tm	35
Magnetic length	m	<10
Aperture	mm	105
Beam separation (cold)	mm	188
Operating temperature	K	1.9
Margin on the load line	%	35
Multipoles variation due to iron saturation		<10 unit

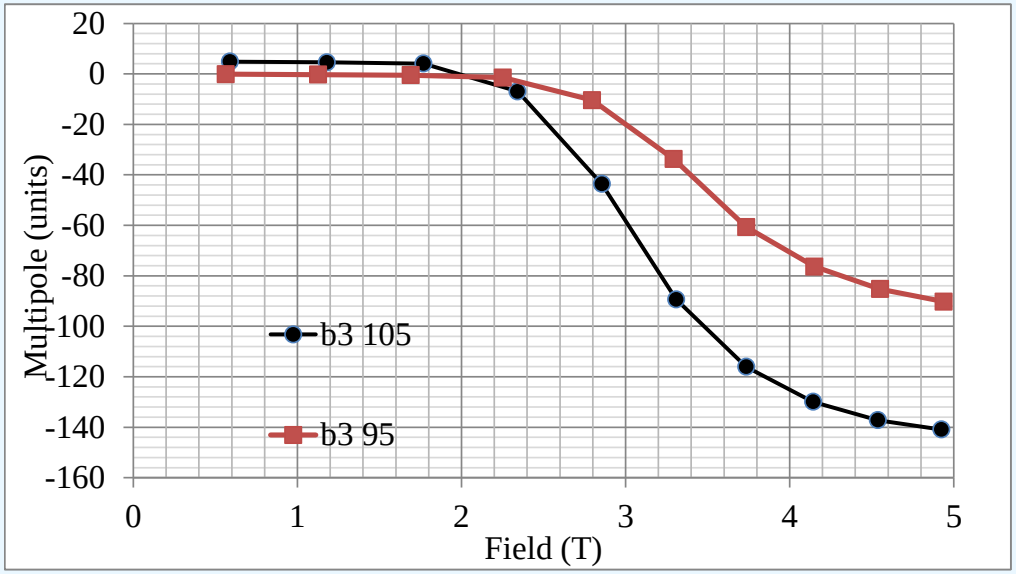
The basic problem of a D2 dipoles for HL-LHC

(slides from a preliminary study of E.Todesco)

- Aperture: 95 and 105 mm
- B Field from 3.5 to 5 T
- Coil width15 mm
- Collar thickness10 mm



The high magnetic field of the two coils sum-up in the center saturating the iron. A relevant magnetic **cross talk** takes place for B>2.1 T and high values unwanted multipole appear.



A strategy was developed!

In order to actively compensate the cross talk in a wide magnetic field range in the two apertures we developed a strategy based on three pillars:

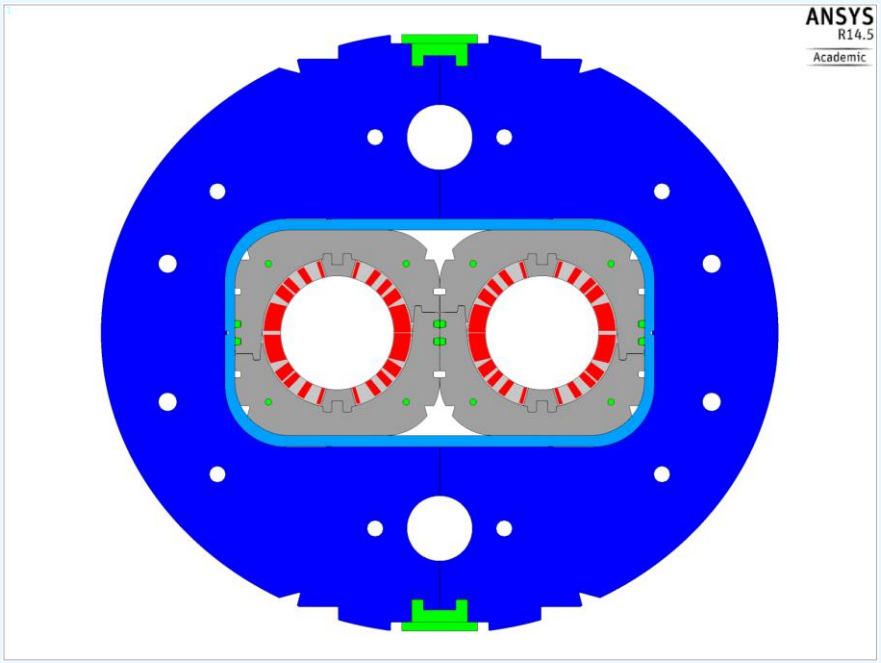
a) No iron is placed in between the coils, so limiting saturation effects (an idea developed at CERN);

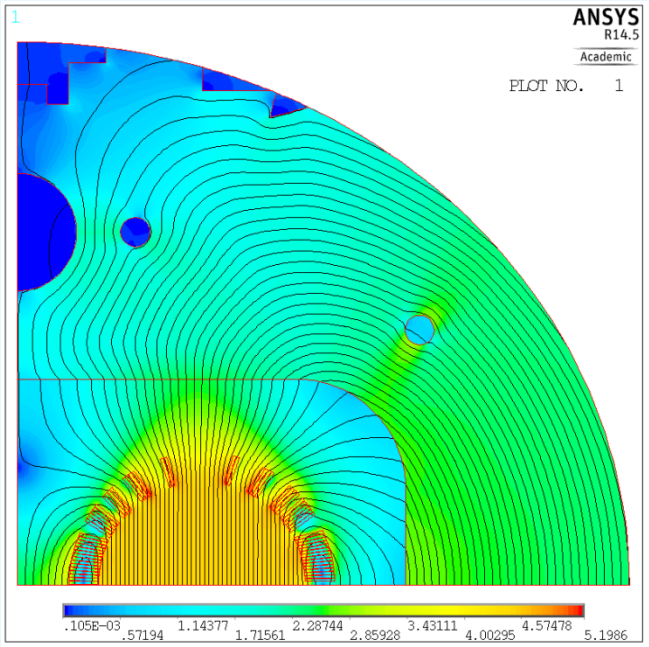
b) Each coil is asymmetric in a way to cancel the magnetic cross talk each other (an idea developed at Fermilab and LBNL)

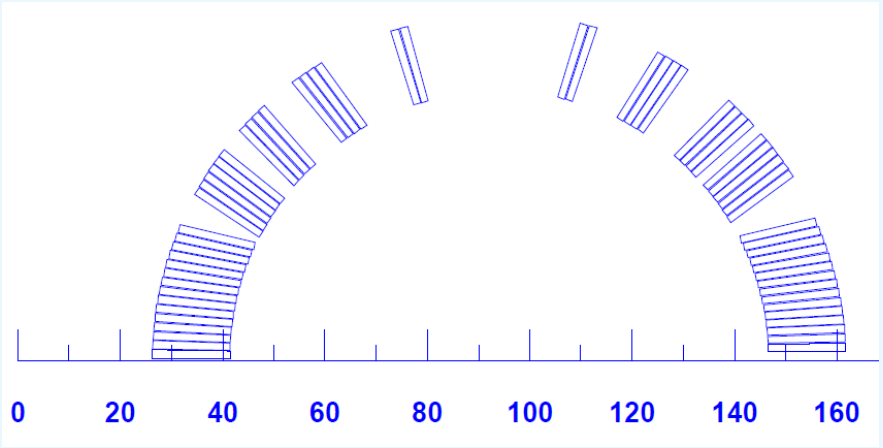
a) The yoke is suitably profiled for keeping constant the harmonic components (an idea developed at BNL)

Based on these concepts a 2D magnetic optimization was carried

A solution was found for the 2D Lay-out



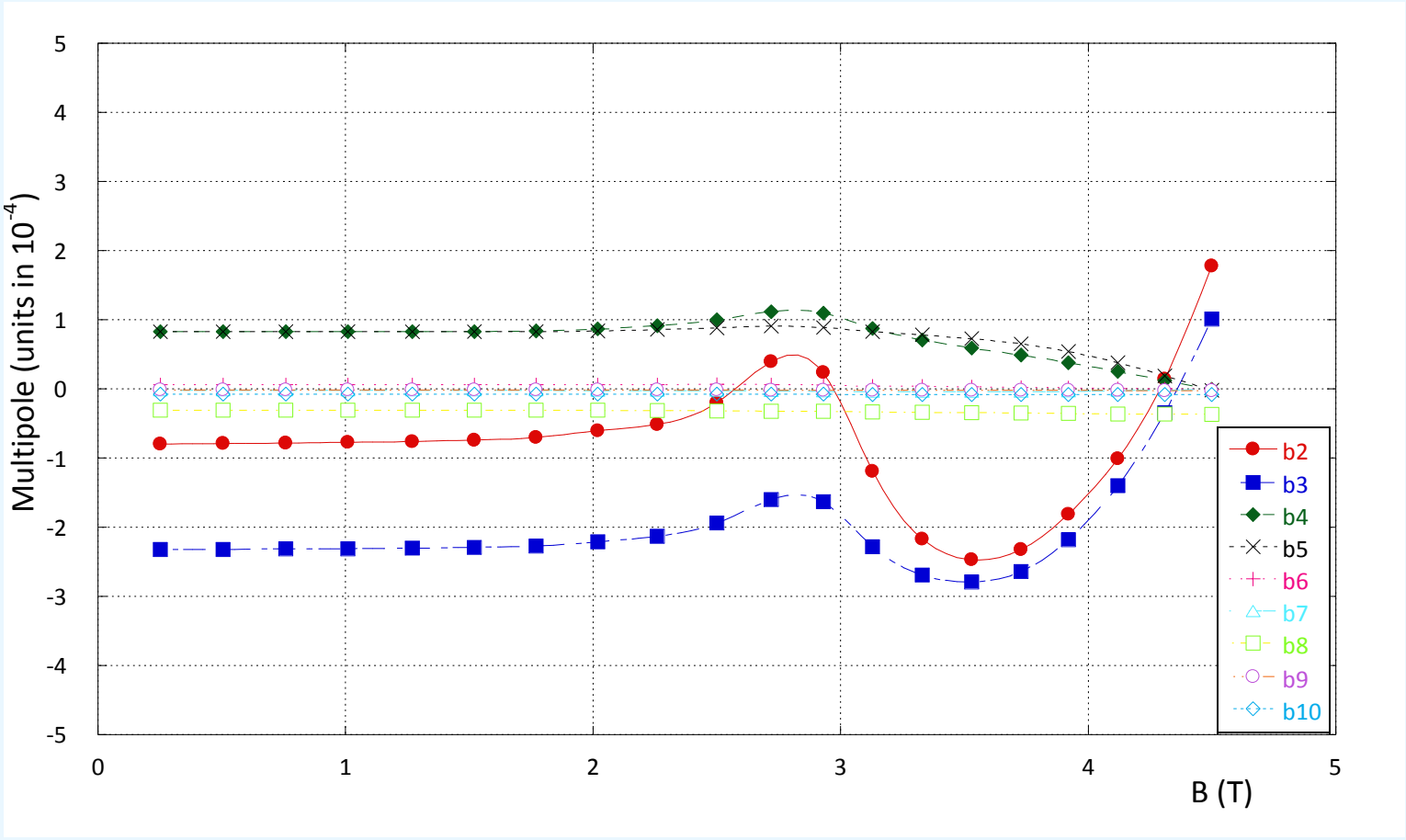




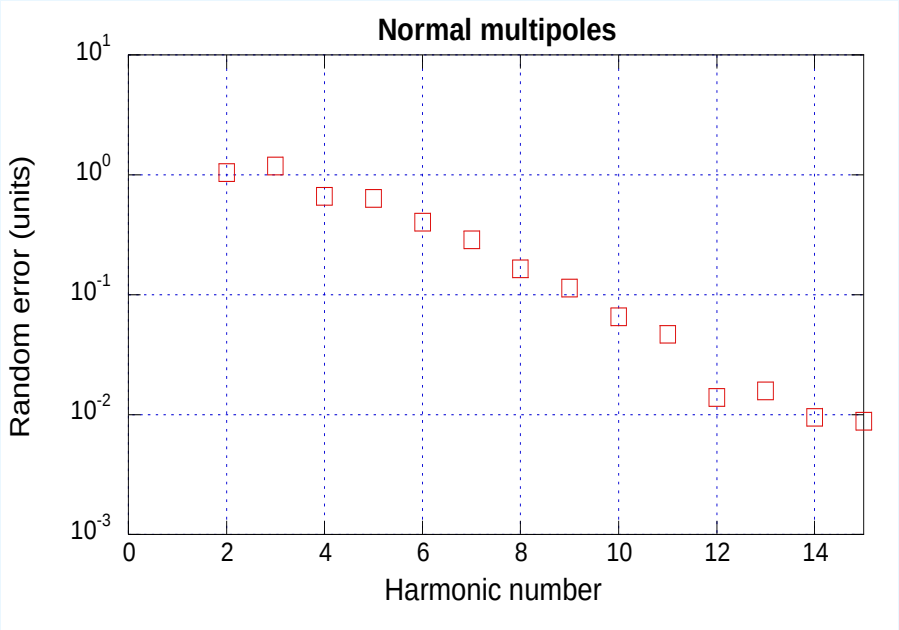
Characteristics	Units	Value
Aperture	mm	105
Distance between apertures	mm	188
Magnetic length	m	7.78
Bore field	T	4.5
Peak field	T	5.20
Current	kA	12.050
Temperature	K	1.9
Load line margin	(%)	35
Overall current density	A/mm^2	443
Stored energy per meter	MJ/m	0.2807

Field quality

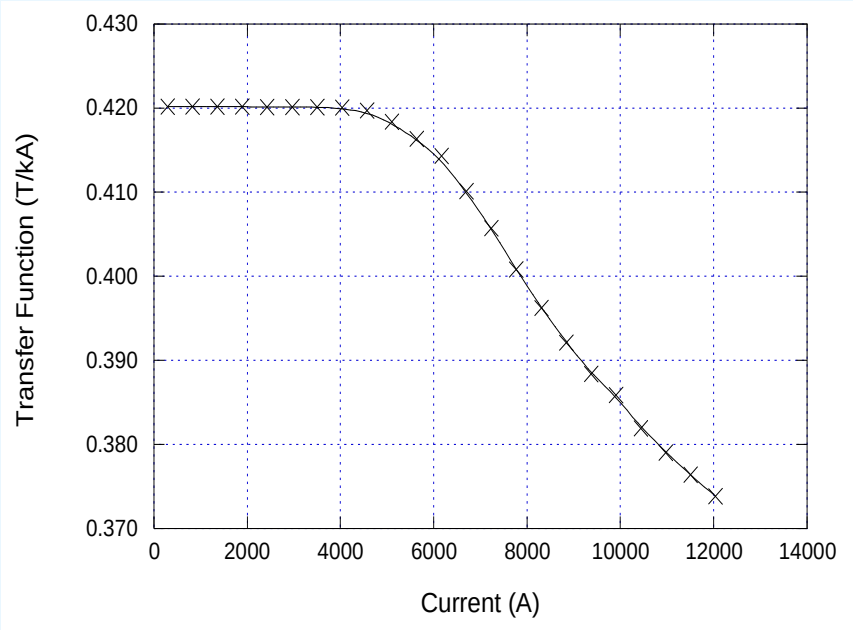
b2 and b3 optimised at a B field slightly lower than 4.5 T (4.3 T)



Random errors

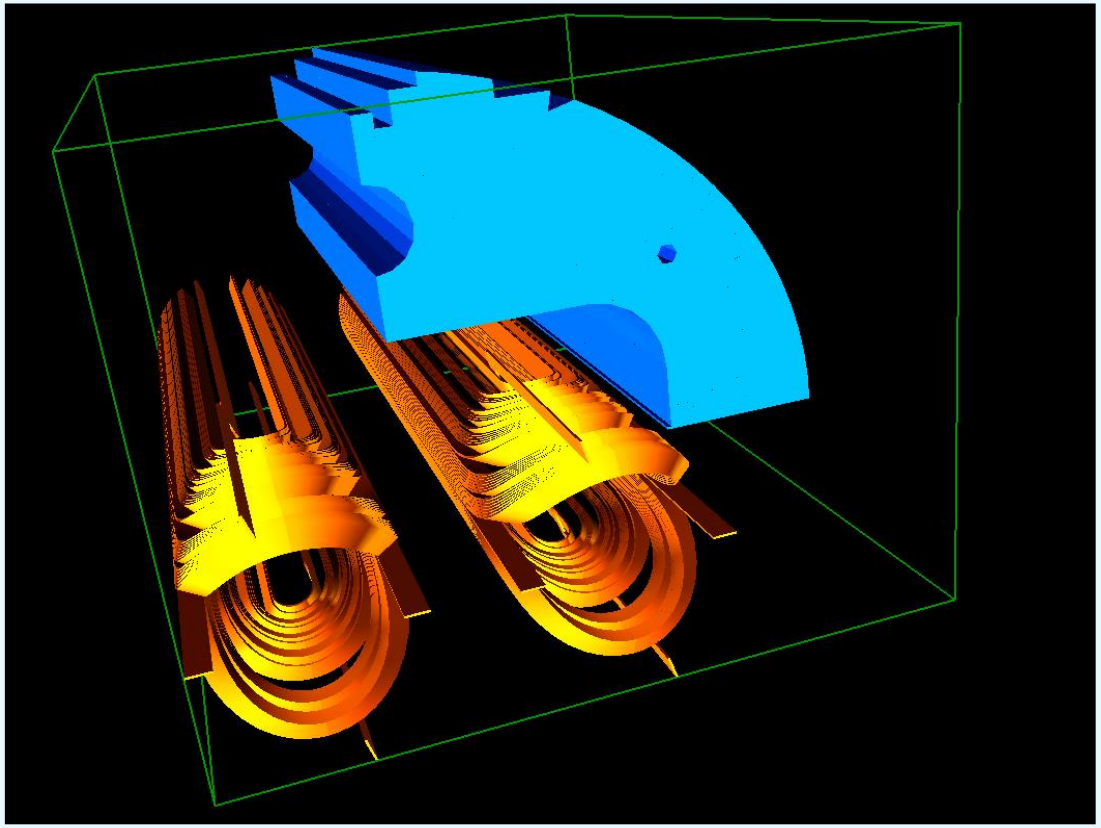


Transfer Function



40 µm displacement

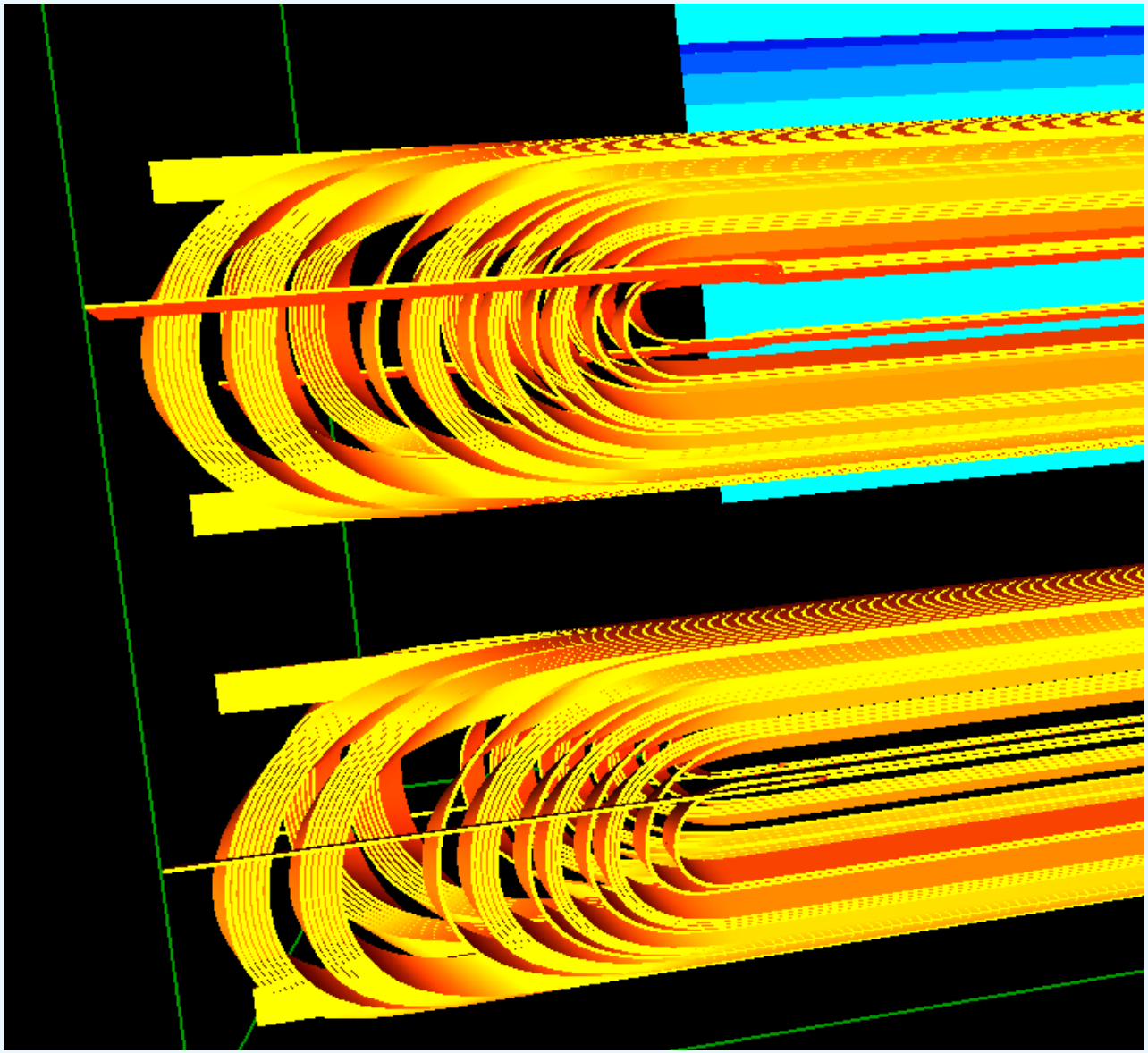
Coil ends were developed with the aim to optimise the lay-out and the integral field quality



Coil end with connections

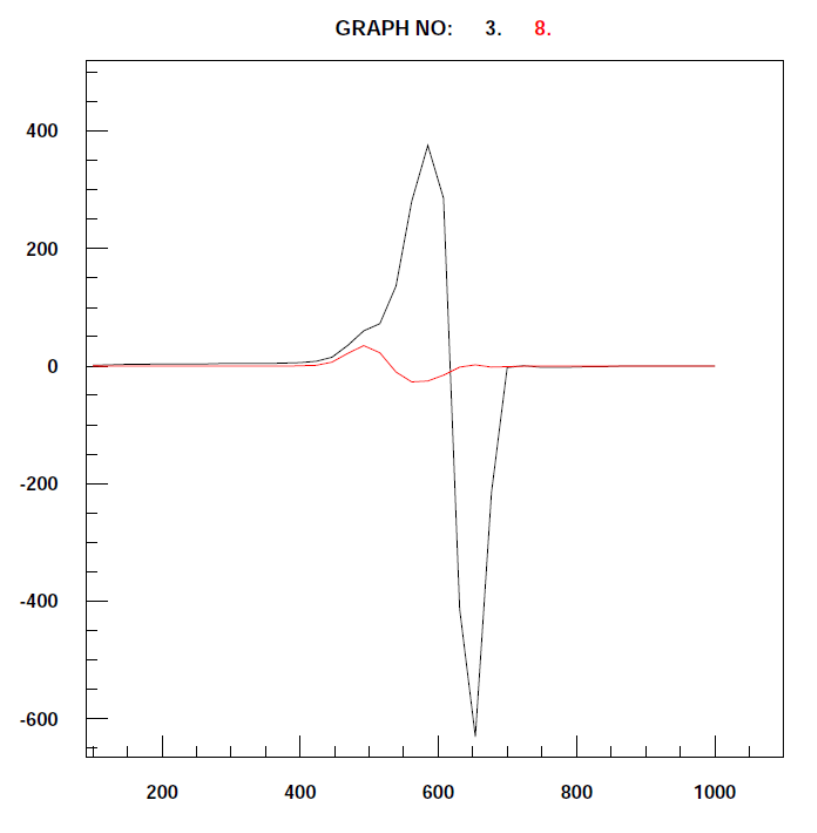
- All poles are wound clockwise
- The upper pole of the left coil when rotated around the axis of 180° is the lower pole of the right coil.
- Same for upper pole of the left coil and lower pole of the right coil.

Only two kinds of poles shall be built.

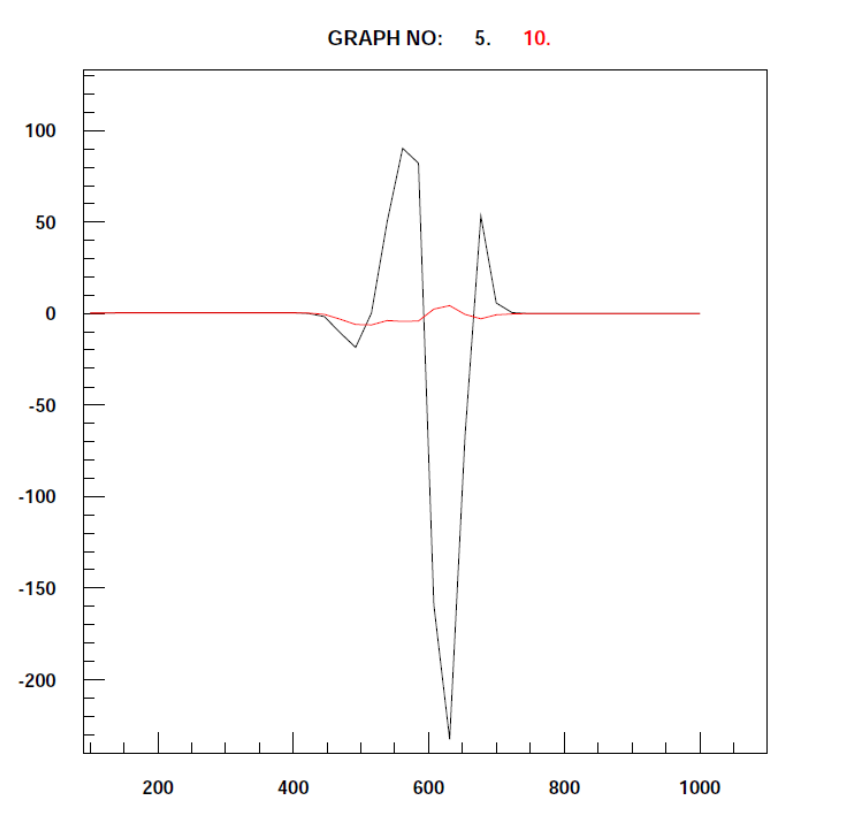


Odd field harmonics in coil end (with connections)

b3 (black) and a3 (red) components

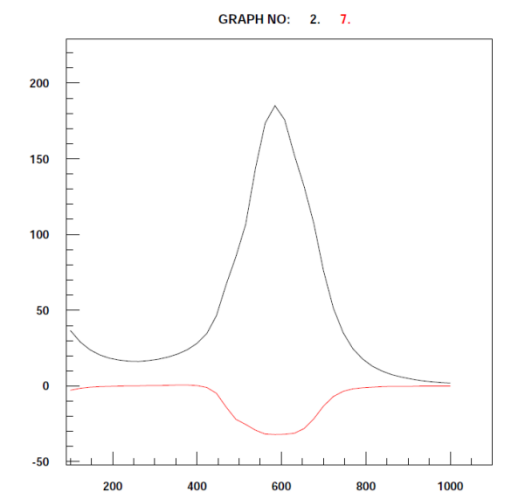


b5 (black) and a5 (red) components

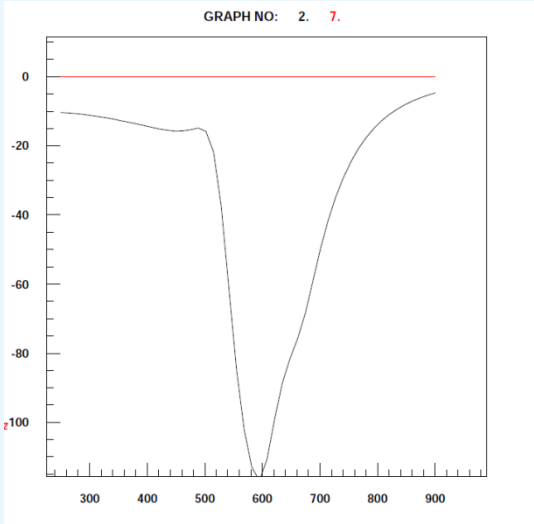


Even field harmonics in coil ends

b2 (black) and a2 (red) components

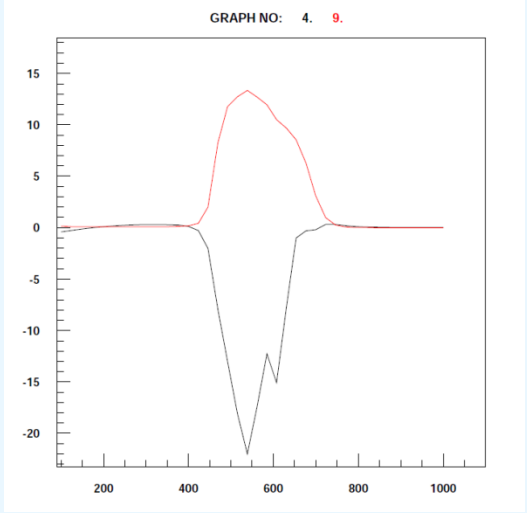


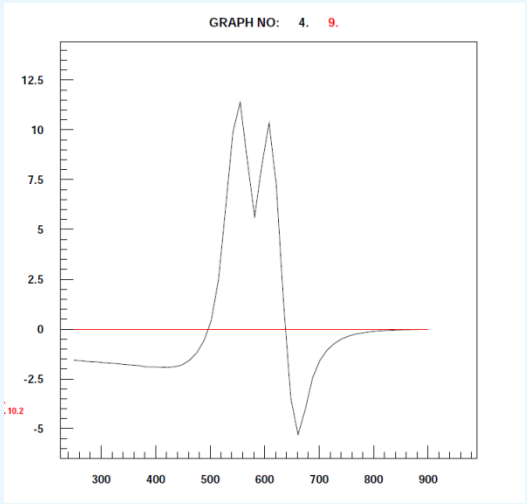
End with connections



End with no connections

b4 (black) and a4 (red) components



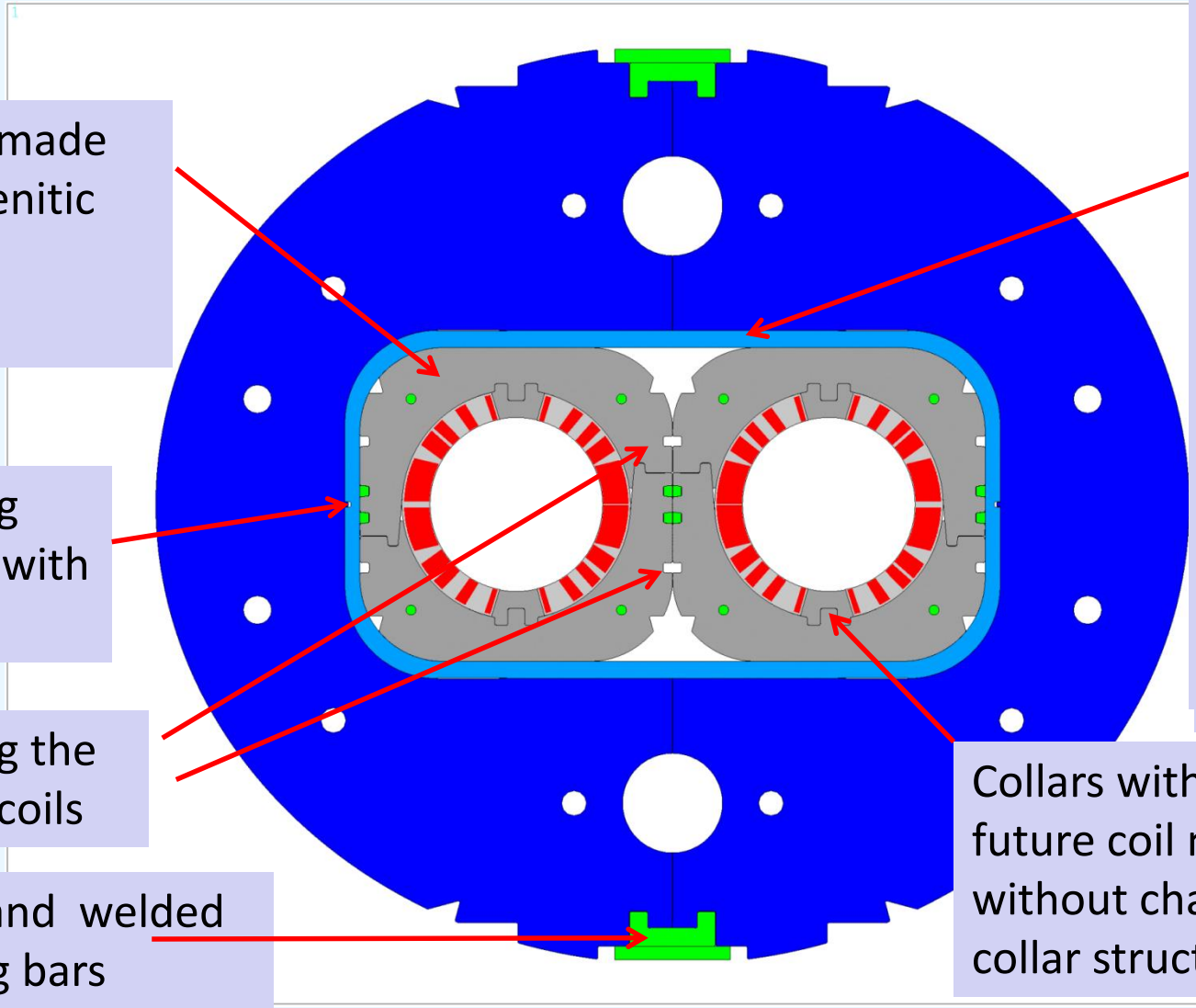


Integrated Field Quality

Recombination dipole D2 field quality version 2.0 - October 26 2015 - R_{ref}=35 mm

	Straigth part									Ends		Integral	
	Systematic					Uncertainty		Random					
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field	Conn. Side	Non conn. Side	Injection	High Field
2	-0.800	1.800	0.000	-0.800	1.000	0.200	0.100	0.200	0.100	94.000	-64.800	2.118	3.729
3	-2.400	3.000	-14.000	-16.400	0.600	0.727	0.300	0.727	0.300	2.500	0.200	-14.524	0.697
4	0.800	-0.400	0.000	0.800	0.400	0.126	0.040	0.126	0.040	-5.500	0.800	0.419	0.060
5	0.800	-0.400	-1.000	-0.200	0.400	0.365	-0.040	0.365	-0.040	-9.600	-6.700	-1.056	-0.518
6	0.000	0.000	0.000	0.000	0.000	0.060	0.060	0.060	0.060	-0.600	1.500	0.030	0.030
7	0.200	0.100	-0.700	-0.500	0.300	0.165	0.165	0.165	0.165	-4.000	-0.200	-0.699	0.018
8	0.000	0.000	0.000	0.000	0.000	0.027	0.027	0.027	0.027	-0.700	1.000	0.002	0.002
9	0.000	0.090	0.020	0.020	0.090	0.065	0.065	0.065	0.065	-2.700	-4.200	-0.331	-0.268
10	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008	-0.040	0.500	0.020	0.020
11	0.000	0.030	0.000	0.000	0.030	0.019	0.019	0.019	0.019	-2.500	-3.100	-0.288	-0.261
12	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003	-1.600	1.600	-0.026	-0.026
13	0.000	0.000	0.000	0.000	0.000	0.006	0.006	0.006	0.006	-1.900	-1.900	-0.199	-0.199
14	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	-0.090	0.800	0.030	0.030
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	-0.070	-0.700	-0.035	-0.035
Skew													
2	0.000	0.000	0.000	0.000	0.000	0.679	0.679	0.679	0.679	-14.500	0.000	-0.878	-0.878
3	0.000	0.000	0.000	0.000	0.000	0.282	0.282	0.282	0.282	0.500	0.000	0.030	0.030
4	0.000	0.000	0.000	0.000	0.000	0.444	0.444	0.444	0.444	5.500	0.000	0.333	0.333
5	0.000	0.000	0.000	0.000	0.000	0.152	0.152	0.152	0.152	-1.000	0.000	-0.061	-0.061
6	0.000	0.000	0.000	0.000	0.000	0.176	0.176	0.176	0.176	-1.400	0.000	-0.085	-0.085
7	0.000	0.000	0.000	0.000	0.000	0.057	0.057	0.057	0.057	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.061	0.061	0.061	0.061	0.200	0.000	0.012	0.012
9	0.000	0.000	0.000	0.000	0.000	0.020	0.020	0.020	0.020	0.200	0.000	0.012	0.012
10	0.000	0.000	0.000	0.000	0.000	0.025	0.025	0.025	0.025	-0.200	0.000	-0.012	-0.012
11	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.007	0.007	-0.100	0.000	-0.006	-0.006
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Magnetic length straight part					6.966			Mag. Len. Ends		0.471	0.343	Total length	7.78

Mechanical 2D baseline lay-out with a double collar option



Collars made of austenitic steel

Centering the core with iron

Centering the collared coils

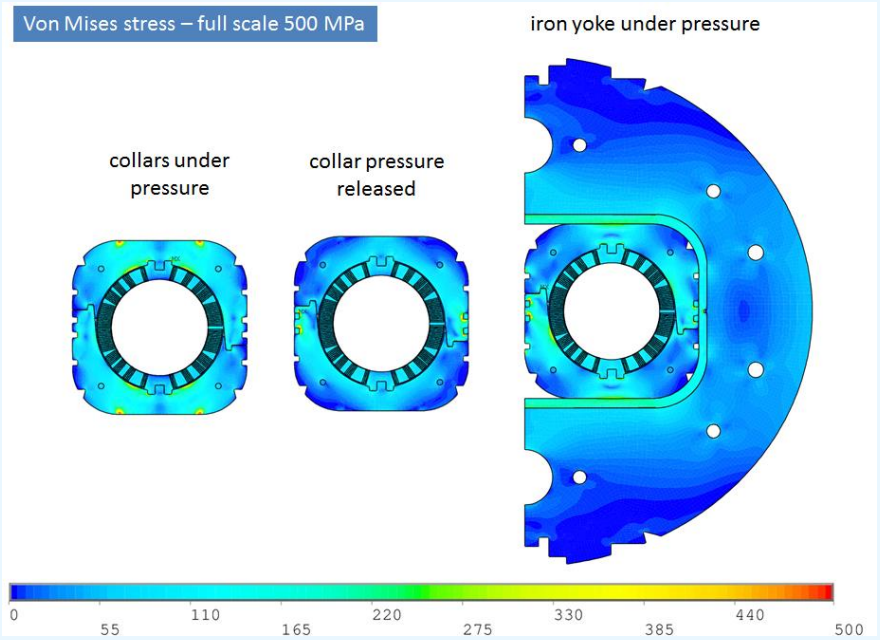
Clamps and welded stiffening bars

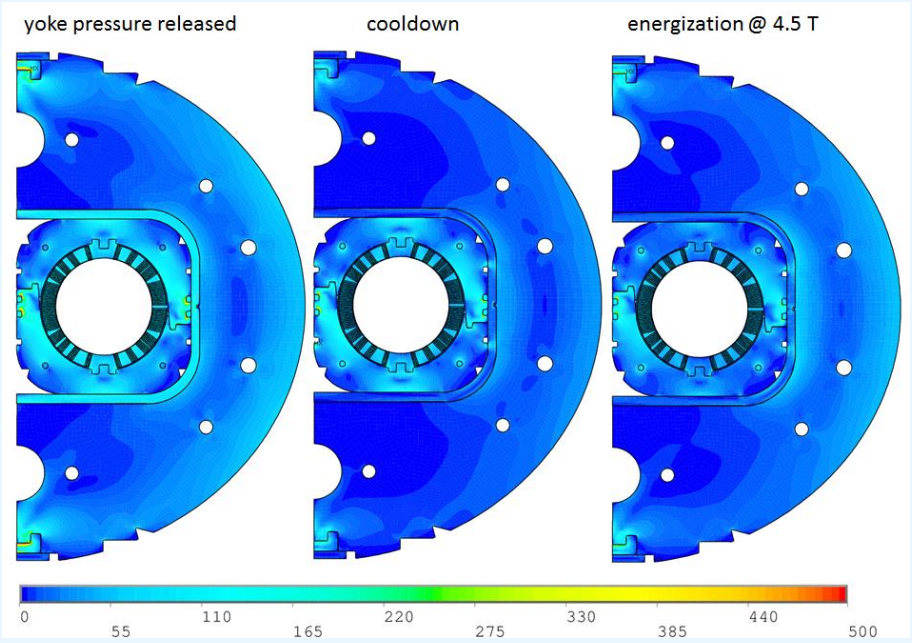
Alternatively

A stainless steel profile done in two pieces to be inserted onto the collared coils and welded

Collars with nose. It allows future coil modifications without changing the main collar structure

2D Mechanical FE Analysis following a historical approach

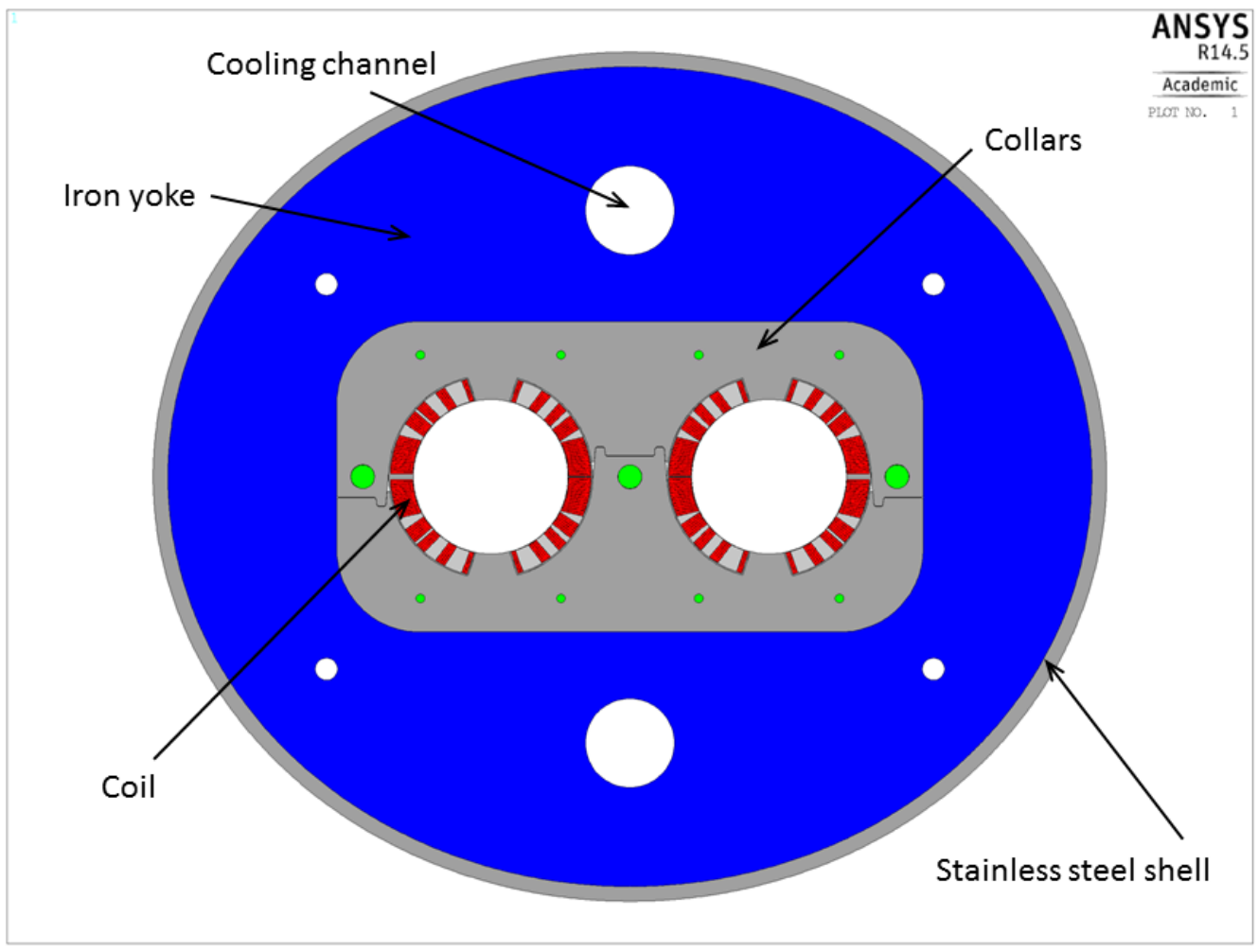




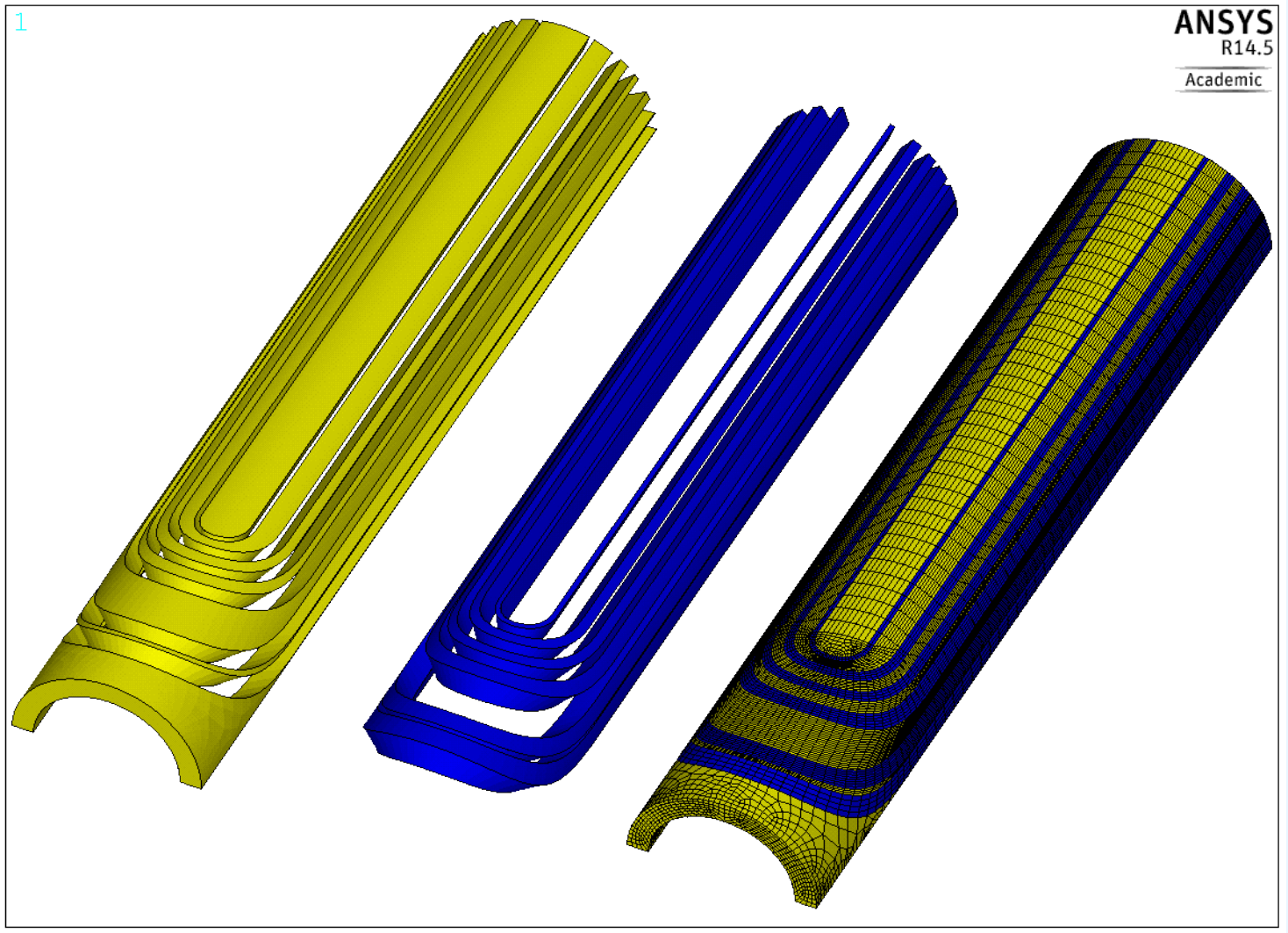
- The presentation of the mechanical analysis would require a dedicated talk. Here we stress only that the stress level at any stage of construction and operation is at an acceptable value.

- No show stoppers to the construction are coming from mechanics.

LAY-OUT 2 (Plan B)



3D Mechanics (mainly aimed at determining the axial pre-stress)



CONCLUDING REMARKS AND FUTURE ACTIVITIES

- At present time the 2D and 3D magnetic designs are almost finished as well as the 2D mechanical design.
- The 3D mechanical analysis aimed at suitably sizing the axial pre-stress is still under way.
- Quench analyses are proceeding as well.
- The studies performed till allowed launching a CERN market survey for the short model (1.5 m long) construction, with a call for tender that will be assigned before the end of 2015.
- The short model is expected to be ready within the end of 2016.
- The following steps will be the design, construction and test of a full length magnet (about 8 m) to be completed in 2018, in a way to be ready for the production in 2020-2021 of the four magnets to be installed in LHC plus one spare.