Elettra Sincrotrone Trieste

Elettra
Sincrotrone
Trieste

Magnets for Elettra 2.0

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Outline

- ✓ ***Introduction***
- ✓ ***The "very last" magnets layout***
- ✓ ***Quadrupole design***
- ✓ ***Sextupole design***
- ✓ ***Bending design***
- ✓ ***Layout and 3D girder***
- ✓ ***Conclusions***

Introduction

In the last period, the Elettra 2.0 optics has changed many times!

From the magnets' point of view, these are the "last" main parameters and topologies:

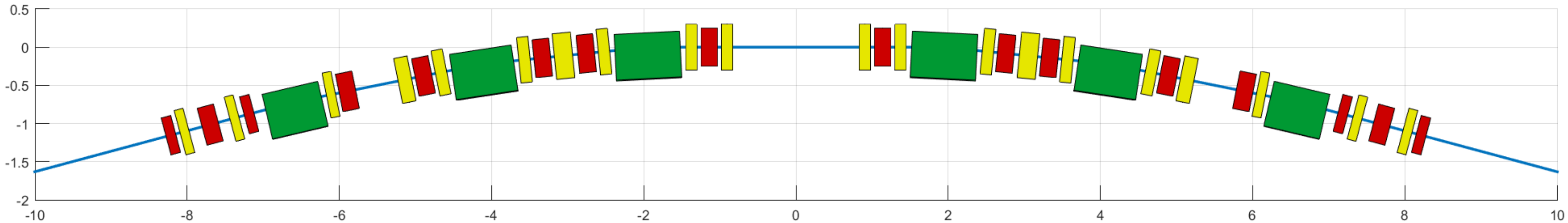
- The vacuum chamber will be circular with an external diameter of 25 mm (internal 23 mm)
- The magnets will have bore diameter (⌀) ≥ 26 mm.
- The magnets could be made by solid steel

(the full energy injection not require procedures of ramping or fast ramping)

- All the quadrupoles, sextupoles and correctors will be excited by individual Power Supplies.
- All the magnets will have coils cooled by air.
- The vacuum chamber will include BPM and Pumps tapers.

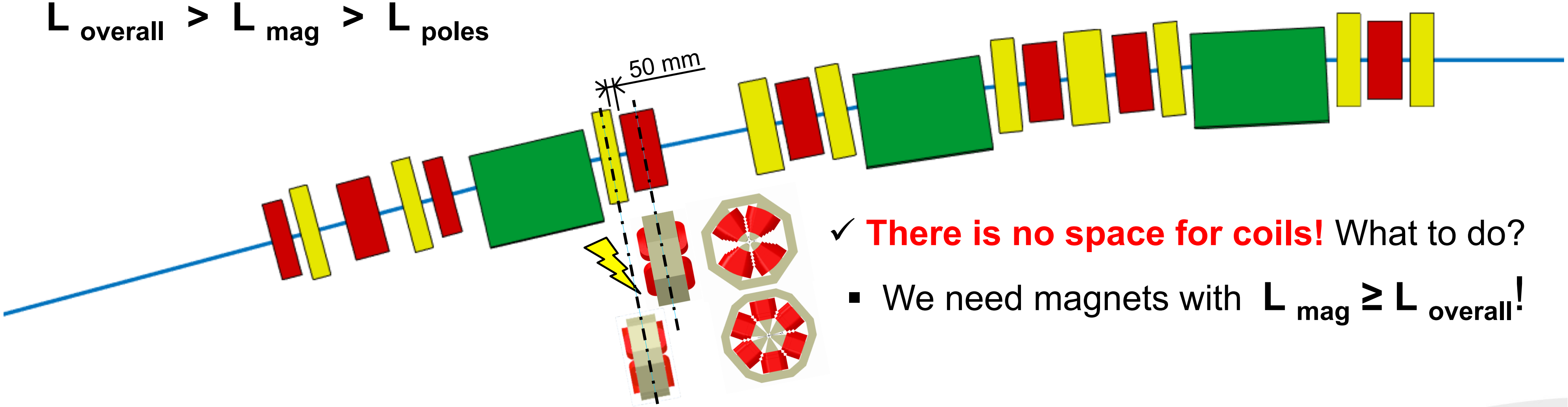
The very last magnets layout

Elettra 2.0 magnets layout has very short drifts between the magnetic lengths *(L_{mag})* !



Since the iron dominated electromagnets have, generally, the L_{mag} bigger than the iron length (L_{poles}) and, due to the coils, the overall length ($L_{overall}$) is bigger than the L_{mag}…

$L_{overall} > L_{mag} > L_{poles}$



✓ **There is no space for coils!** What to do?

- We need magnets with $L_{mag} \geq L_{overall}$!

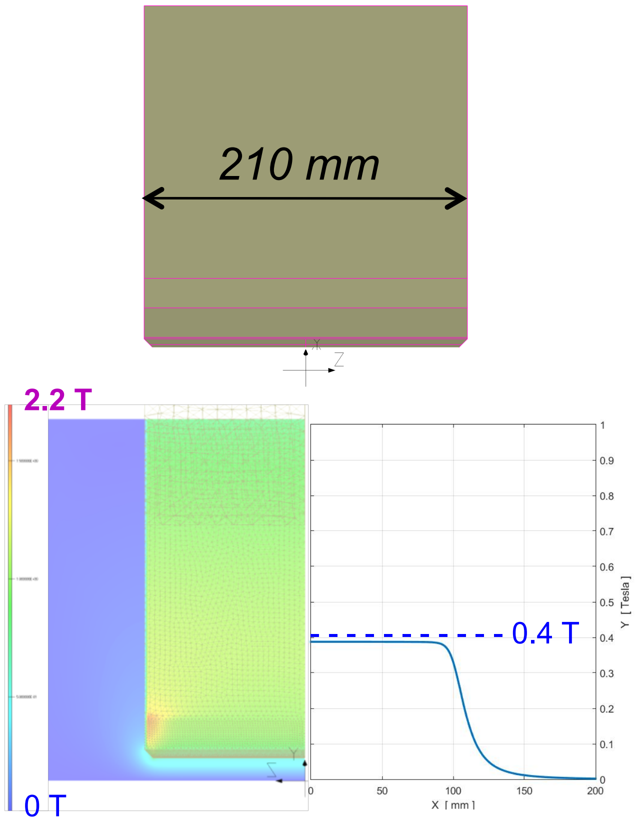
✓ How to design these magnets?

- The magnets **must have the coils longitudinally inside the pole ends**!

Quadrupole design: ●◎◎◎◎◎◎◎◎◎

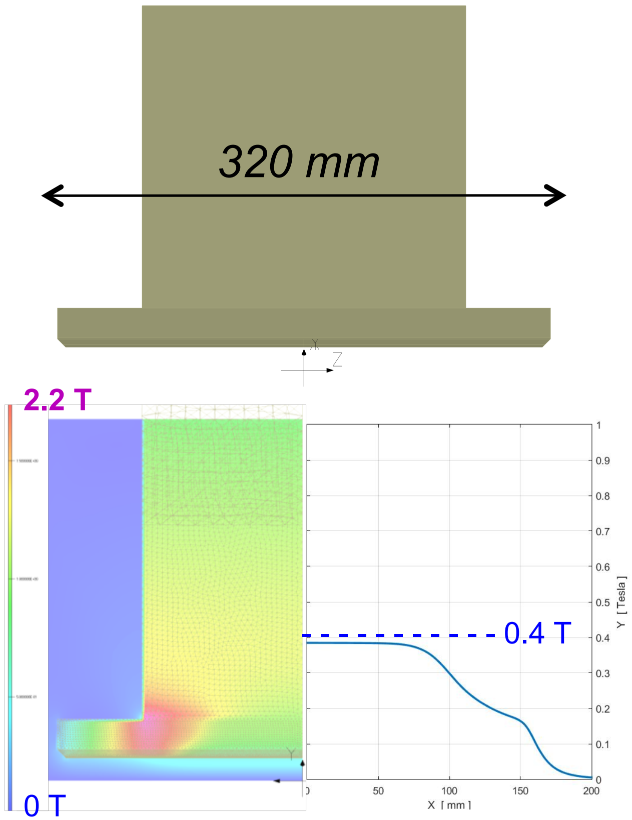
- First study: *pole length **extension** and overall length **reduction**.*

Original



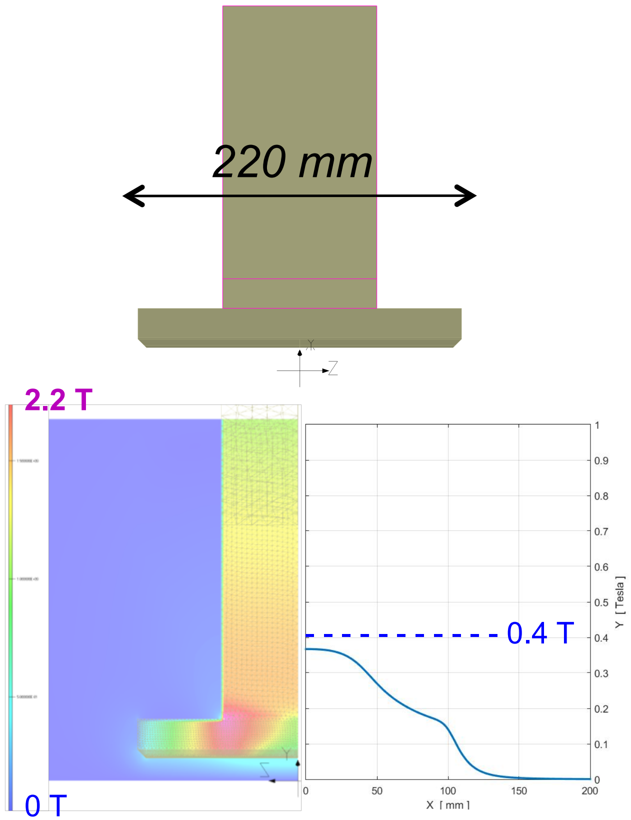
Gint = 8.7 T
G0 = 0.039 T/m
Lmag = 223 mm

L_{pole} extension



*Gint = **10.2 T***
G0 = 0.038 T/m
*Lmag = **265** mm*

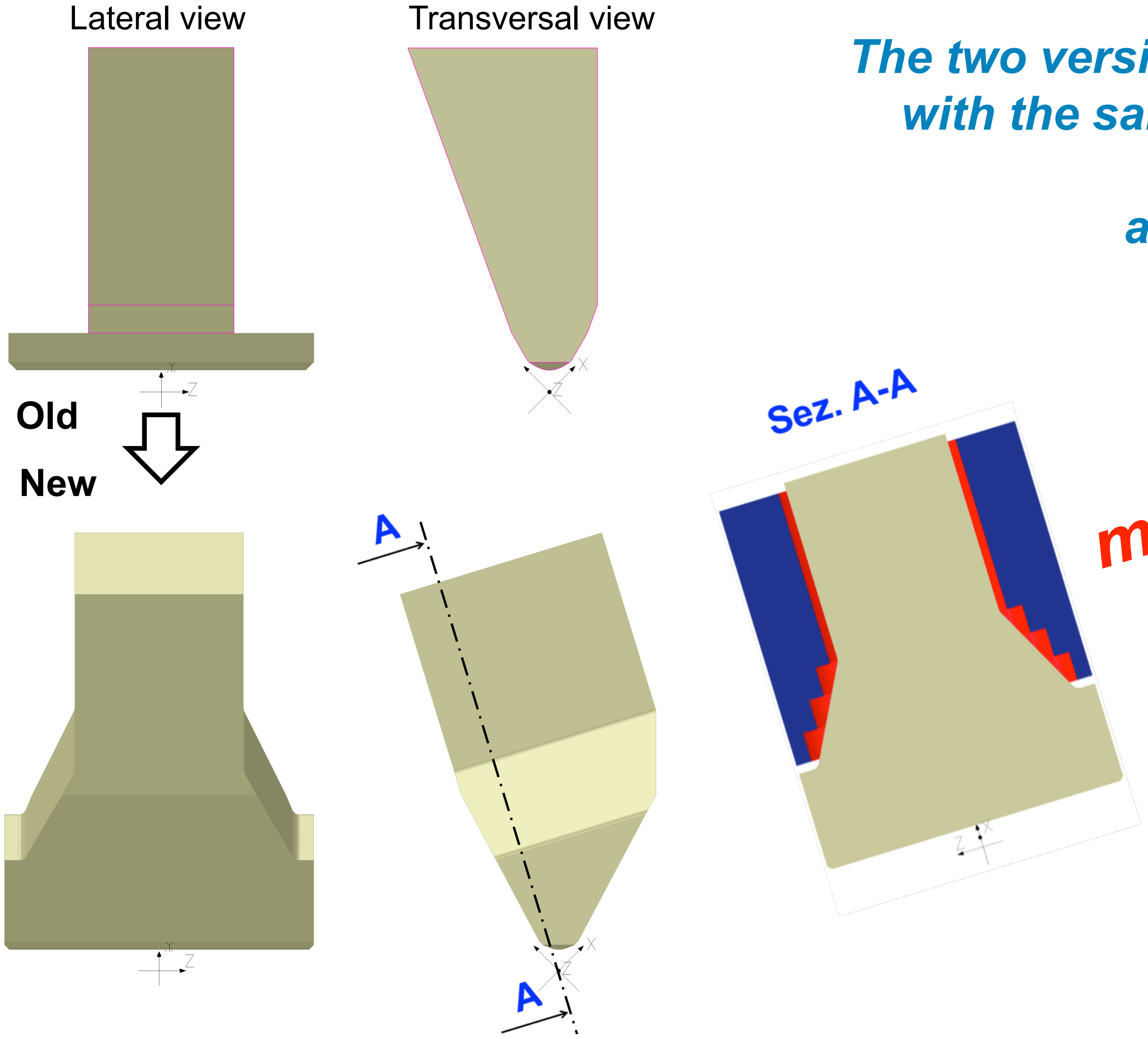
$L_{overall}$ reduction



Gint = 5.8 T
G0 = 0.037 T/m
Lmag = 158 mm

Quadrupole design: ●●◎◎◎◎◎◎◎◎

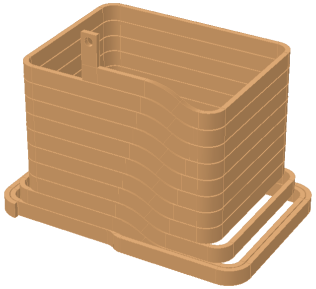
- Second study, *new **coil** and **pole shaping** for a better longitudinal matching*



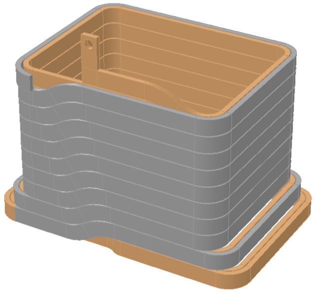
The two versions have been compared with the same conductor (20x4 mm), number of turns (60) and current values (0-90A)

Coil winding more complicated, but feasible!

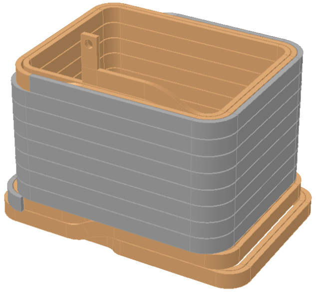
Extra - Coil winding



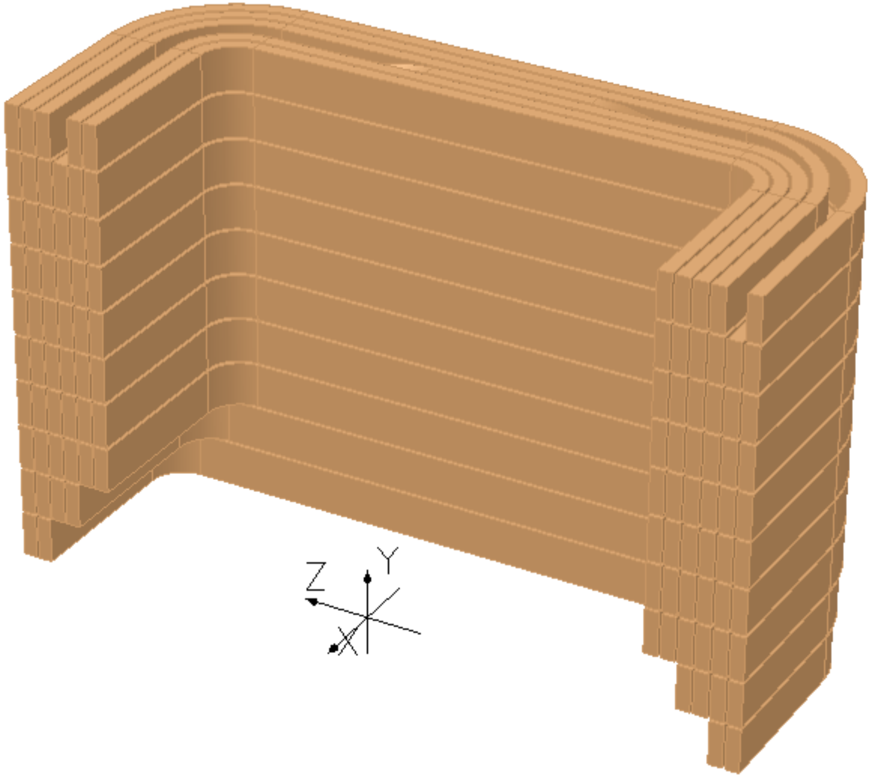
Layer 1

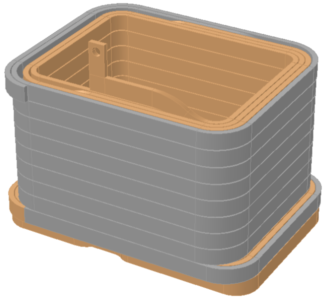


Layer 2

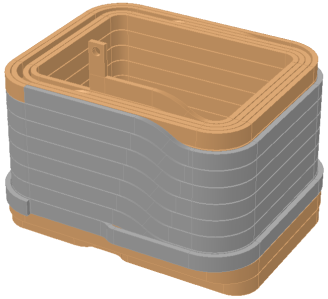


Layer 3

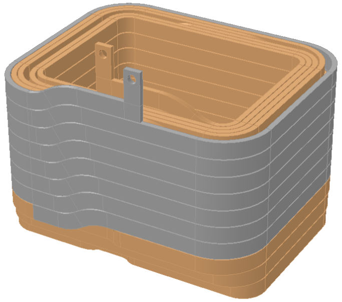




Layer 4



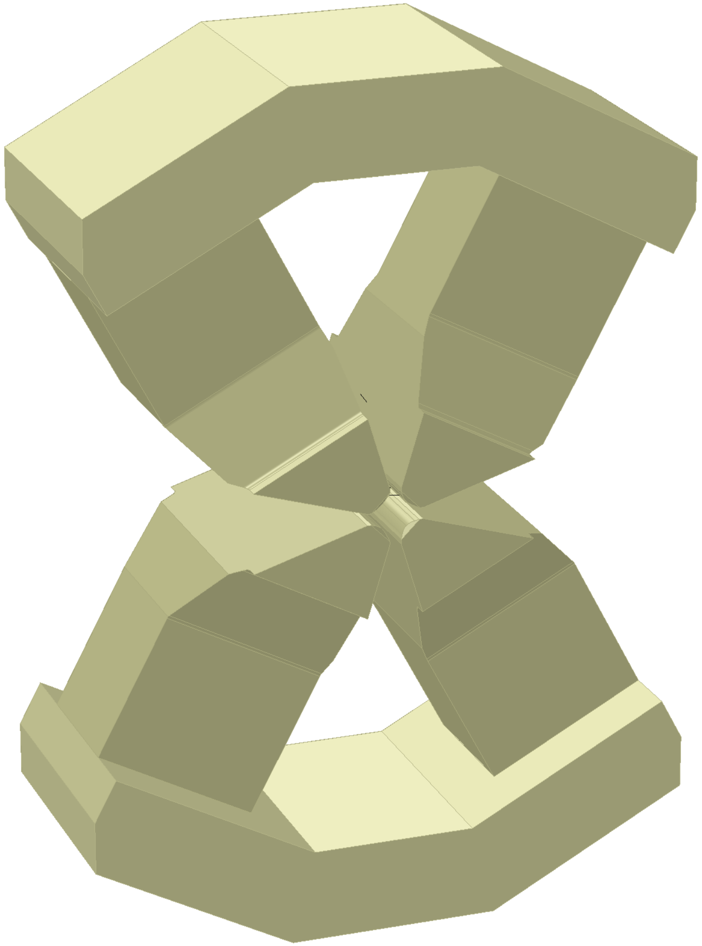
Layer 5



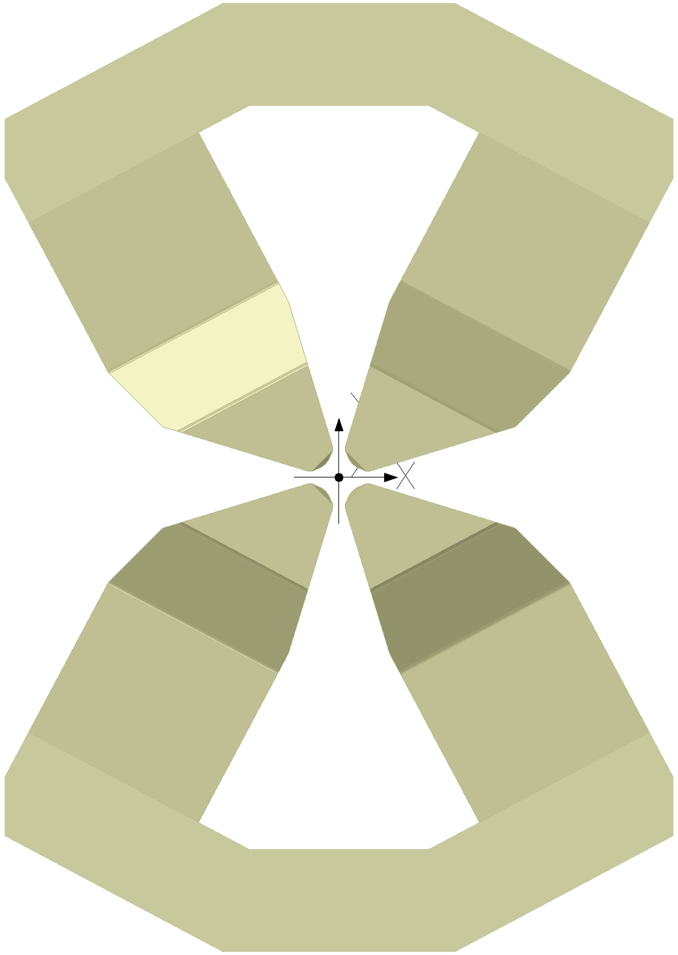
Layer 6

Conductor: 5x16 mm
Pole length: 260 mm
Turns: 53 (54-1)

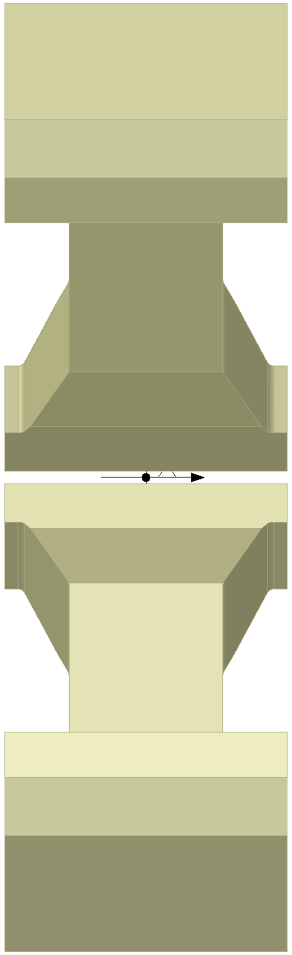
Quadrupole design: ●●●◎◎◎◎◎◎◎



View On XYZ

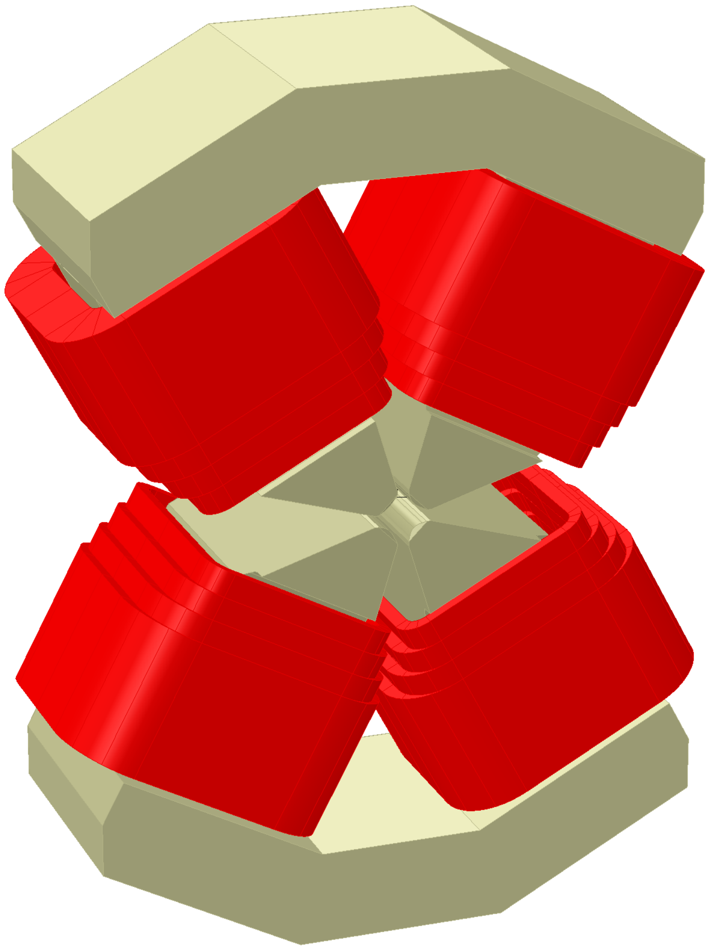


Orto On Z

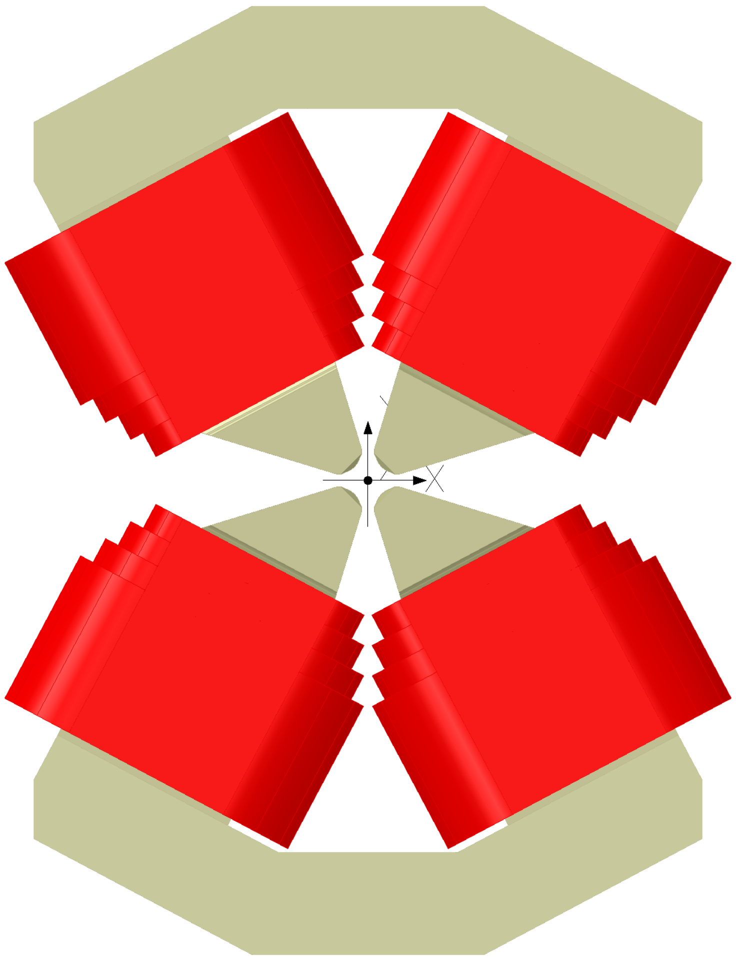


Orto On X

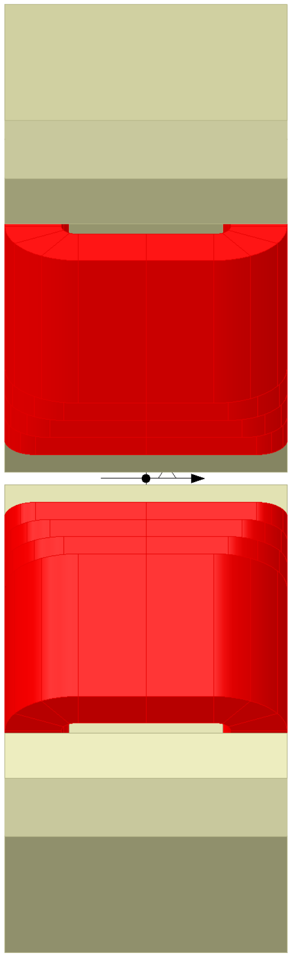
Quadrupole design: ●●●●◎◎◎◎◎◎



View On XYZ



Orto On Z

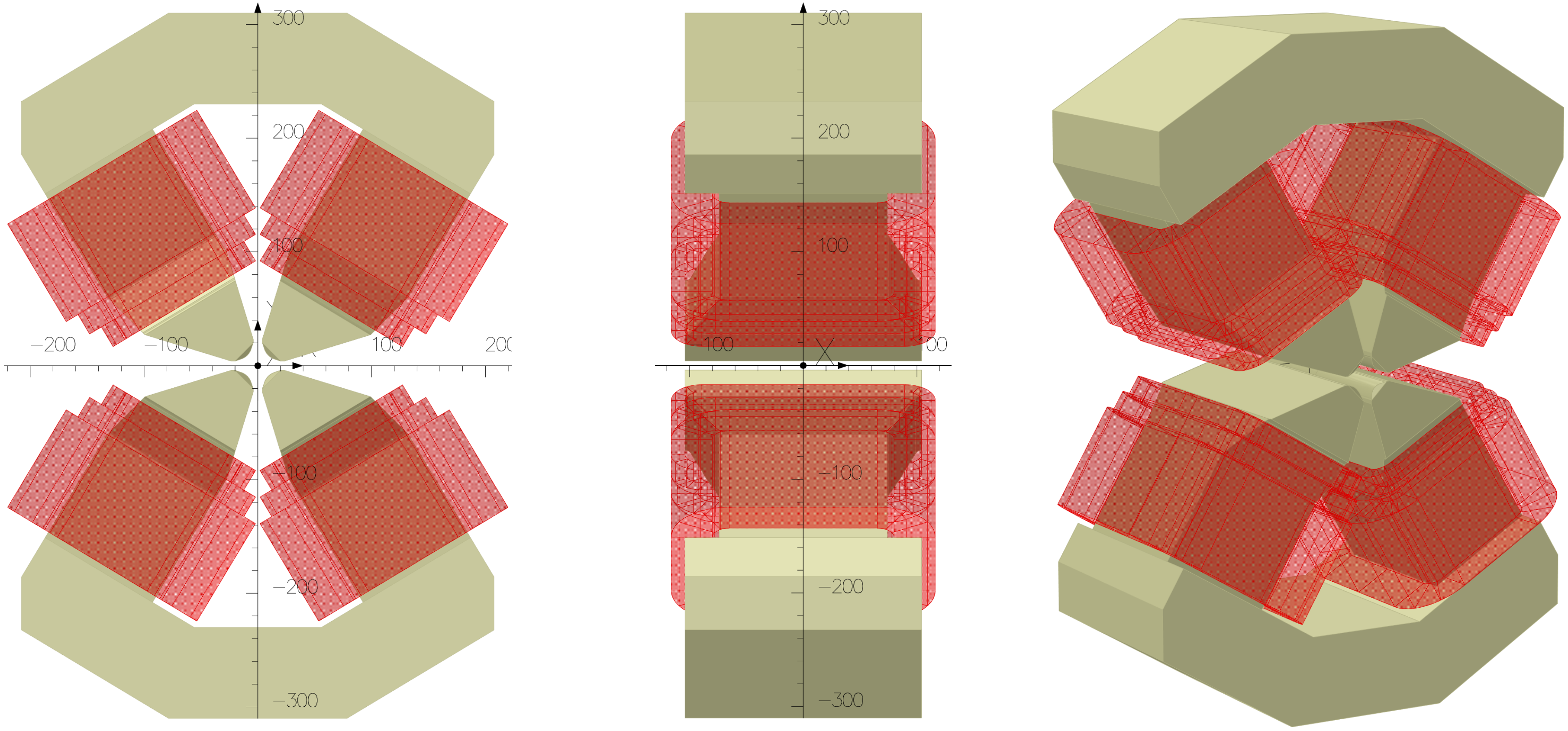


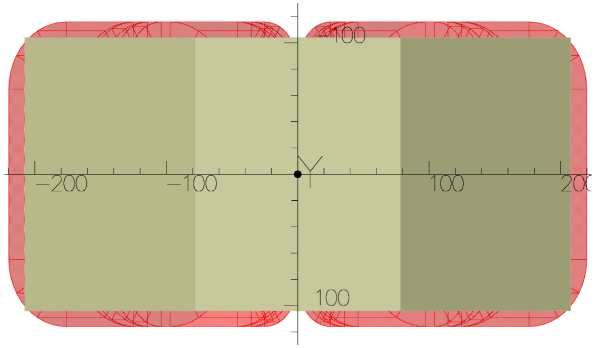
Orto On X

Quadrupole design: ●●●●●◎◎◎◎◎

Quadrupoles:		Q1	Q2	Q33a	Q33b	Q333a	Q333b	Q4_1	Q4	unit
Parameters:										
Beam Energy	En	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	GeV
Magnetic Lenght	L_{Mag}	130	220	130	220	220	220	220	220	mm
Maximum Strengt	$\lvert K_{max}\rvert$	3	5,825	0,45	6,2	6,78	6,492	5,78	6,22	$1/m^2$
Maximum Integrated Strengt	KL_{Max}	0,39	1,28	0,06	1,36	1,49	1,43	1,27	1,37	1/m
Maximum Gradien	G_{Int}	20,00	38,83	3,00	41,33	45,20	43,28	38,53	41,47	T/m
Maximum Integrated Gradien	GL_{Int}	2,60	8,54	0,39	9,09	9,94	9,52	8,48	9,12	T
Overall length	Z_{Tot}	140	230	140	230	230	230	230	230	mm
Bore diameter	Ø	26	26	26	26	26	26	26	26	mm
Field at pole tip radius	B_{Pole}	0,260	0,505	0,039	0,537	0,588	0,563	0,501	0,539	T
Current·Turns (per Pole) + 4,0 %	$N_{Tot}\cdot I_{Coil}$	1399	2716	210	2891	3161	3027	2695	2900	A·Turns
Turns per pole	N_{Tot}	52	72	28	72	72	72	72	72	Turns
Number of turns for each layer	NL_1	14	14	16	14	14	14	14	14	#
	NL_2	14	14	12	14	14	14	14	14	#
	NL_3	12	12	0	12	12	12	12	12	#
	NL_4	12	12	0	12	12	12	12	12	#
	NL_5	0	10	0	10	10	10	10	10	#
	NL_6	0	10	0	10	10	10	10	10	#
Coils current at defined Int. Grad	I_c	27,0	37,8	7,5	40,2	44,0	42,1	37,5	40,3	A
Conductor cross section widt	W_{Cu}	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	mm
Conductor cross section heigt	H_{Cu}	9,00	9,00	9,00	9,00	9,00	9,00	9,00	9,00	mm
Conductor cross section dia bore	$Ø_{Cu}$	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	mm
Conductor cross section smoot	r_{Cu}	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	mm
Conductor cross section area	A_{Cu}	44,99	44,99	44,99	44,99	44,99	44,99	44,99	44,99	mm^2
Conductor current density = I_c / A_{Cu}	ρ_{Cu}	0,60	0,84	0,17	0,89	0,98	0,94	0,83	0,90	A/mm^2
Single Coil conductor lengt	L_{Coil}	21,6	42,8	10,8	42,8	42,8	42,8	42,8	42,8	m
Single Coil electric resistance at T_{ave}	R_{Coil}	8,36	16,48	4,14	16,48	16,48	16,48	16,48	16,48	mΩ
Single Coil voltage drop at T_{ave}	V_{Coil}	0,23	0,62	0,03	0,66	0,73	0,69	0,62	0,66	V
Overall Lengt	L_{Tot}	114,0	210,0	94,0	210,0	210,0	210,0	210,0	210,0	mm
MAX Power Supply current = I_c + 0 %	I_{PS}	27,0	37,8	7,5	40,2	44,0	42,1	37,5	40,3	A
Magnet Power at I_{PS} and T_{ave}	P_{Mag}	25,0	95,0	1,0	107,0	128,0	117,0	93,0	108,0	W

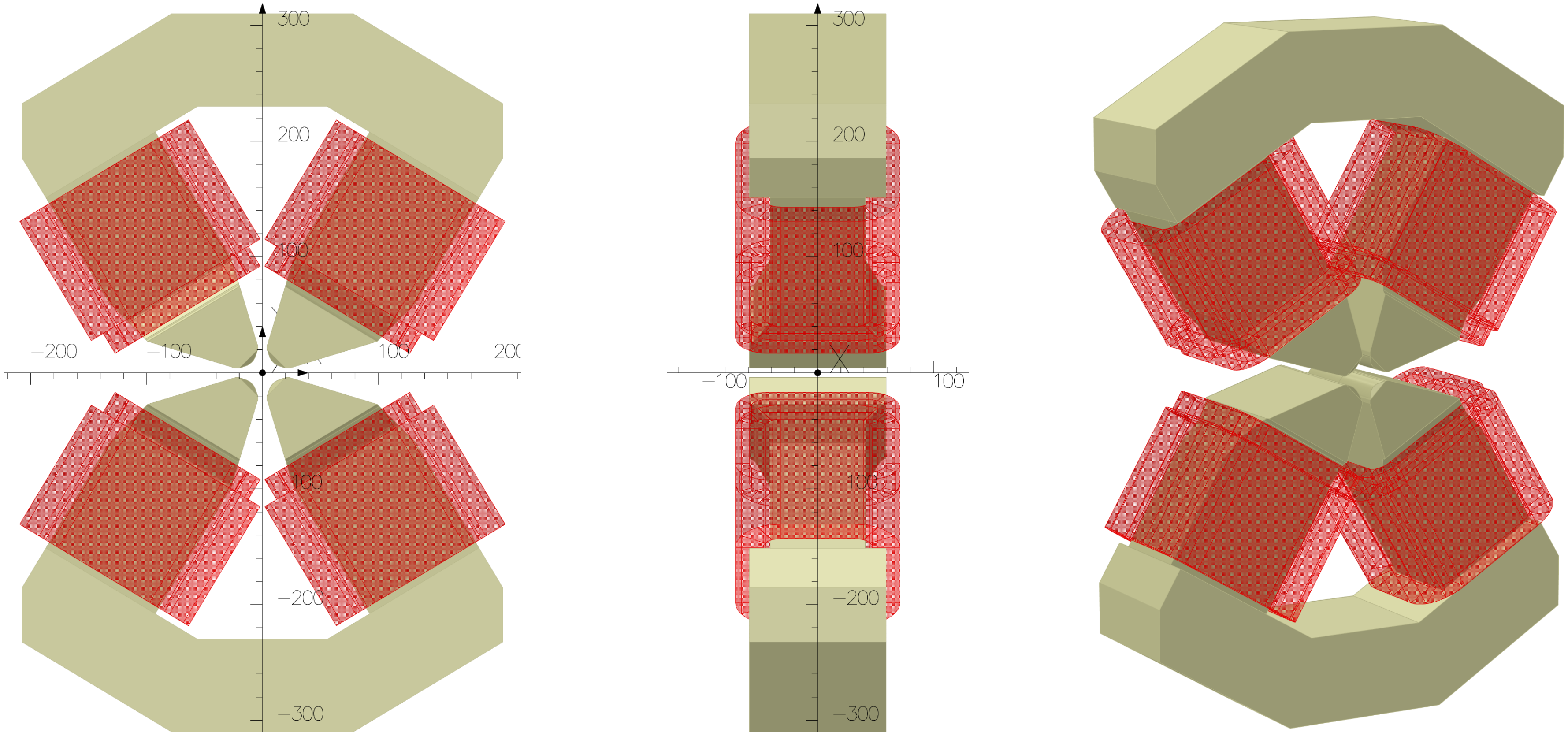
Quadrupole design: ●●●●●●◎◎◎◎

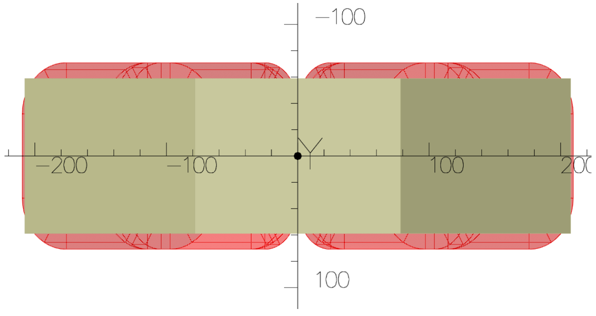




Elettra 2.0 Big Quad

Quadrupole design: ●●●●●●●◎◎◎

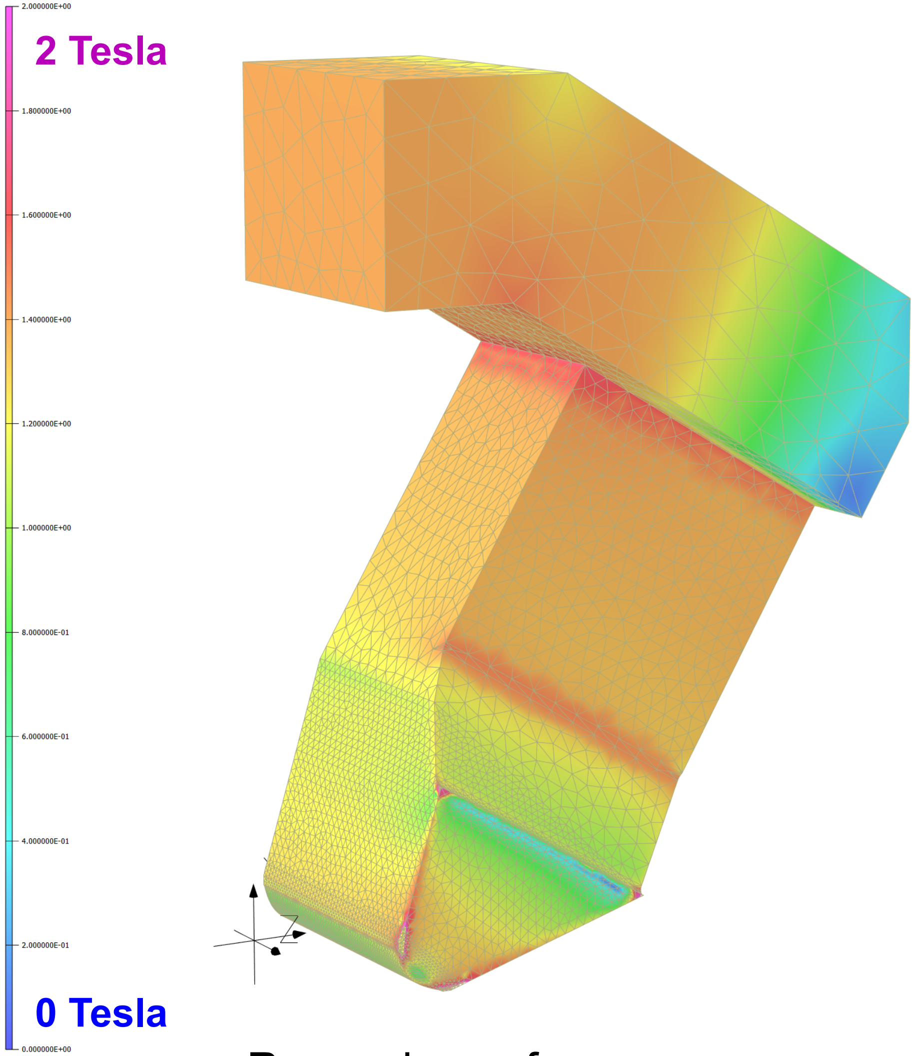




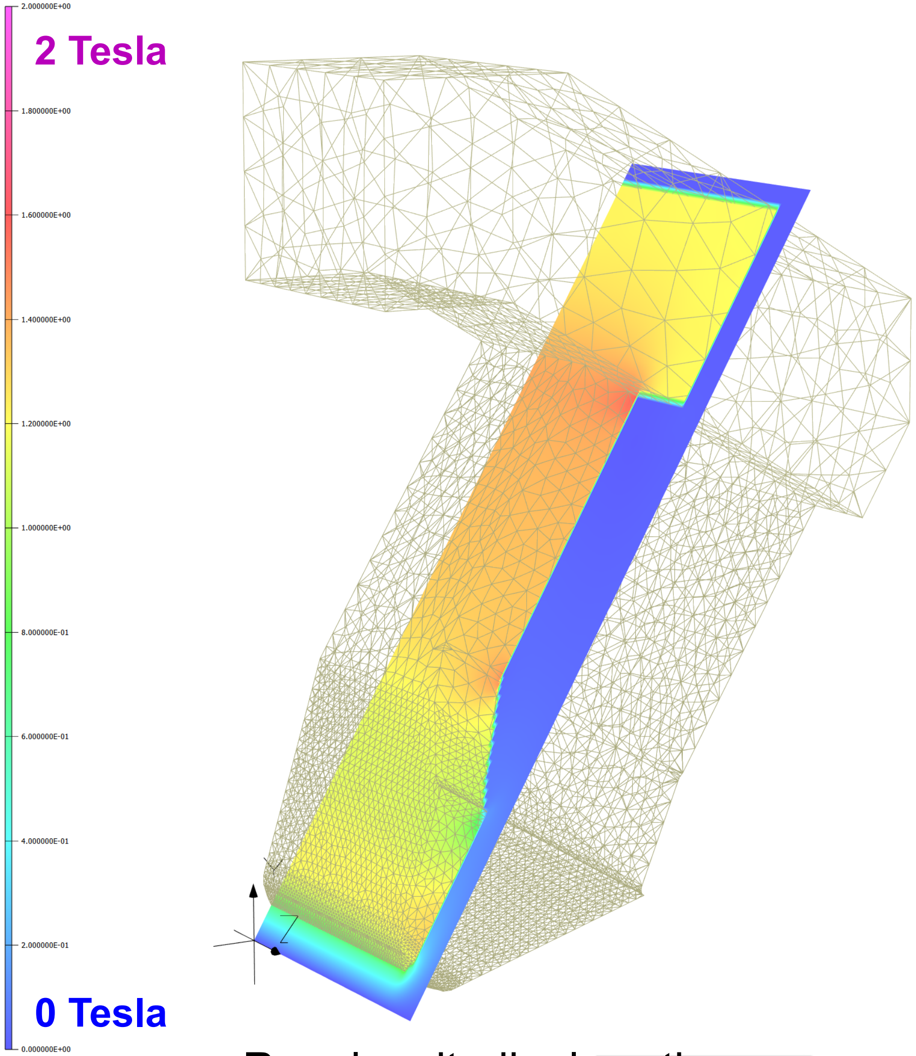
Elettra 2.0 Small Quad

Quadrupole design: ●●●●●●●●◎◎

Elettra 2.0 Big Quad at 50 A



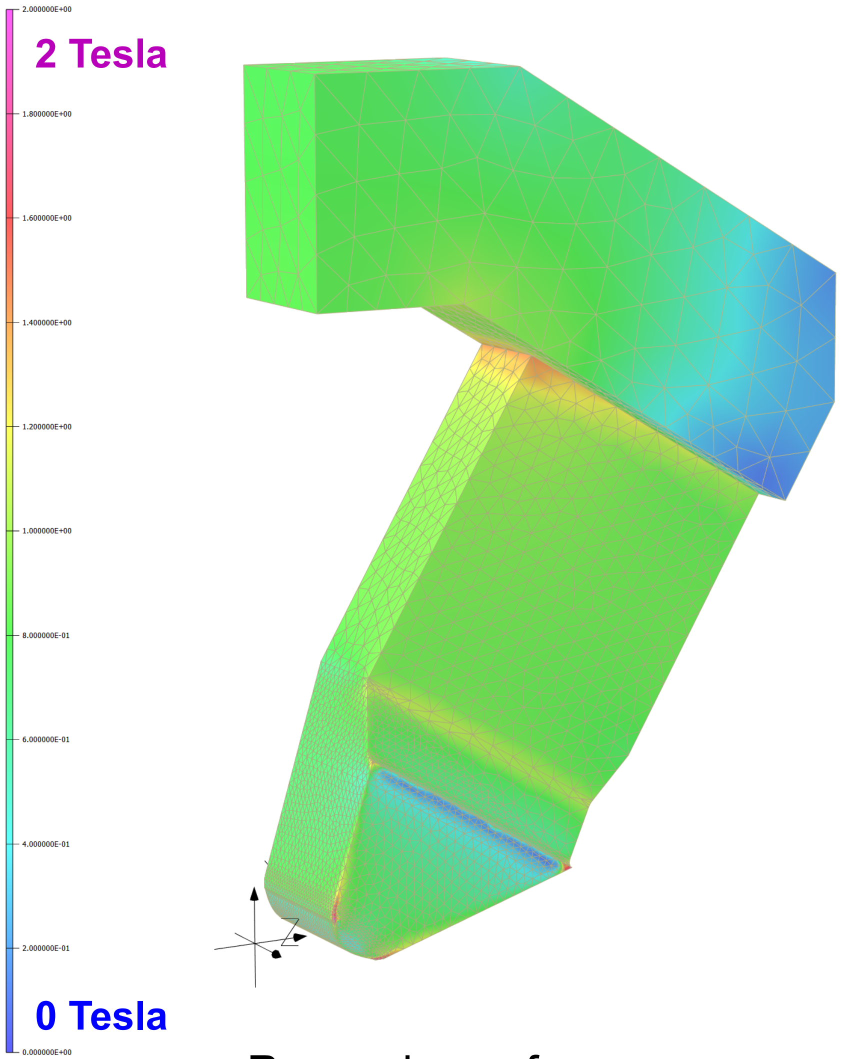
B on yoke surface



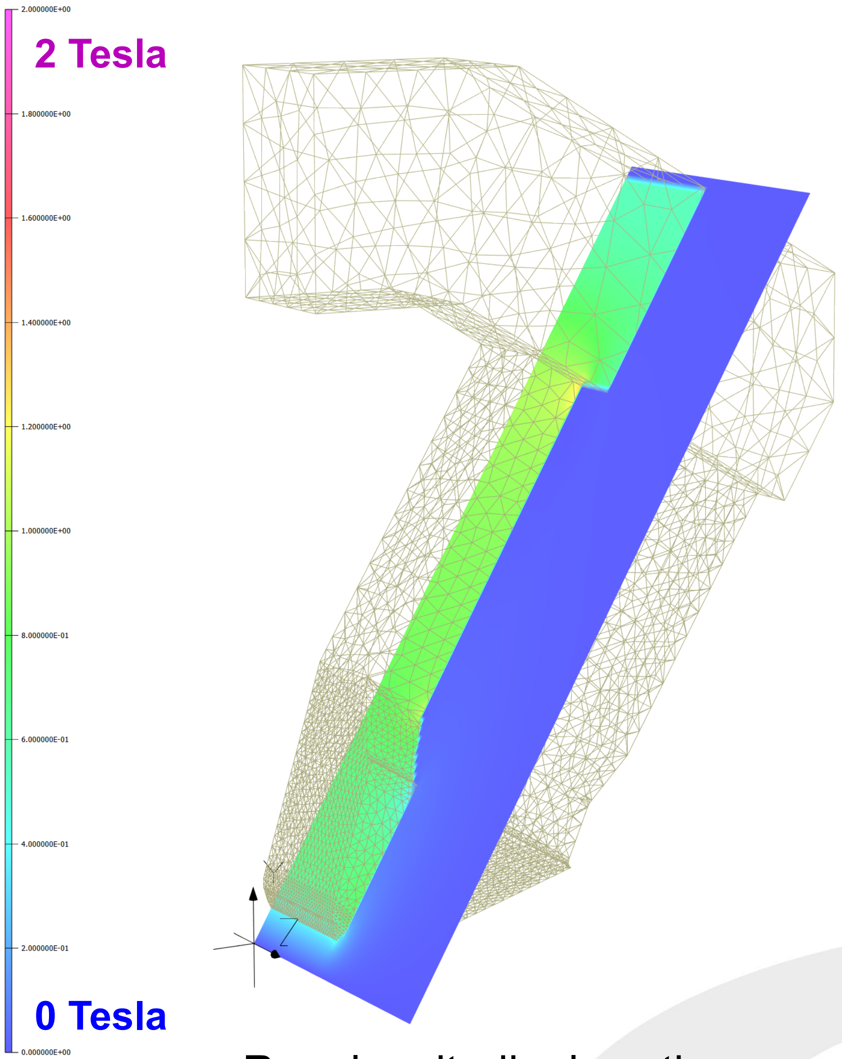
B on longitudinal section

Quadrupole design: ●●●●●●●●●◎

Elettra 2.0 Small Quad at 50 A



B on yoke surface



B on longitudinal section

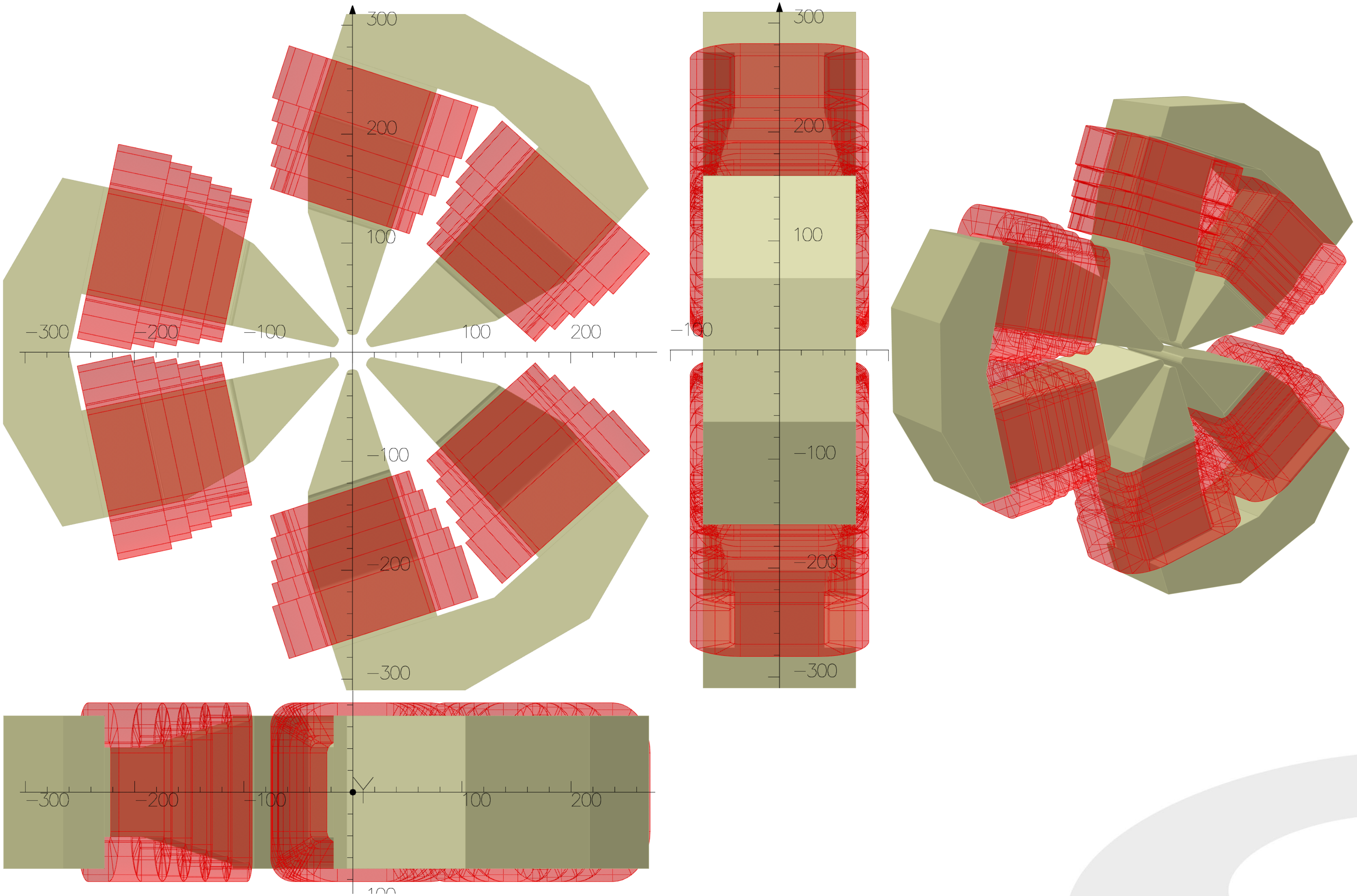
Quadrupole design: ●●●●●●●●●●

Quadrupoles:		Q3T5	Q3T5	Q3T5	Q10T9	Q10T9	Q10T9	unit
Parameters:								
Beam Energy	**En**	2,00	2,00	2,00	2,00	2,00	2,00	GeV
Magnetic Lenght	L_{Mag}	132	131	131	222	221	221	mm
Maximum Strengt	$\lvert K_{max}\rvert$	0,8	3	4,03	1,53	6,78	7,4	1/m^2
Maximum Integrated Strengt	KL_{Max}	0,11	0,39	0,53	0,34	1,50	1,64	1/m
Maximum Gradien	G_{Int}	5,33	20,00	26,87	10,20	45,20	49,33	T/m
Maximum Integrated Gradier	GL_{Int}	0,70	2,62	3,52	2,26	10,00	10,92	T
Iron saturation	**Sat**	0,00	0,04	-0,01	0,00	-3,39	-3,39	%
Overall lengt	Z_{Tot}	150	150	150	240	240	240	mm
Bore diameter	Ø	26	26	26	26	26	26	mm
Field at pole tip radiu	B_{Pole}	0,069	0,260	0,349	0,133	0,588	0,641	T
Efficiency and saturation	η	5,000	5,000	5,000	5,000	8,600	8,600	%
Current·Turns (per Pole) + 0,0 %	$N_{Tot}\cdot I_{Coil}$	377	1413	1897	721	3301	3603	A·Turns
Turns per pole	N_{Tot}	38	38	38	72	72	72	Turns
Coils current at defined Int. Grad	I_c	10,0	37,2	50,0	10,0	45,8	50,0	A
Conductor current density = I_c / A_{Cu}	ρ_{Cu}	0,22	0,83	1,11	0,22	1,02	1,11	A/mm^2
Single Coil electric resistance at T_{ave}	R_{Coil}	6,48	6,48	6,48	17,84	17,84	17,84	mΩ
Single Coil voltage drop at T_{ave}	V_{Coil}	0,06	0,24	0,32	0,18	0,82	0,89	V
Overall Lengt	L_{Tot}	142,0	142,0	142,0	232,0	232,0	232,0	mm
MAX Power Supply current = I_c + 0 %	I_{PS}	10,0	37,2	50,0	10,1	45,9	50,1	A
Magnet Power at I_{PS} and T_{ave}	P_{Mag}	3,0	36,0	65,0	8,0	151,0	180,0	W

Sextupole design: ●◎◎◎◎◎

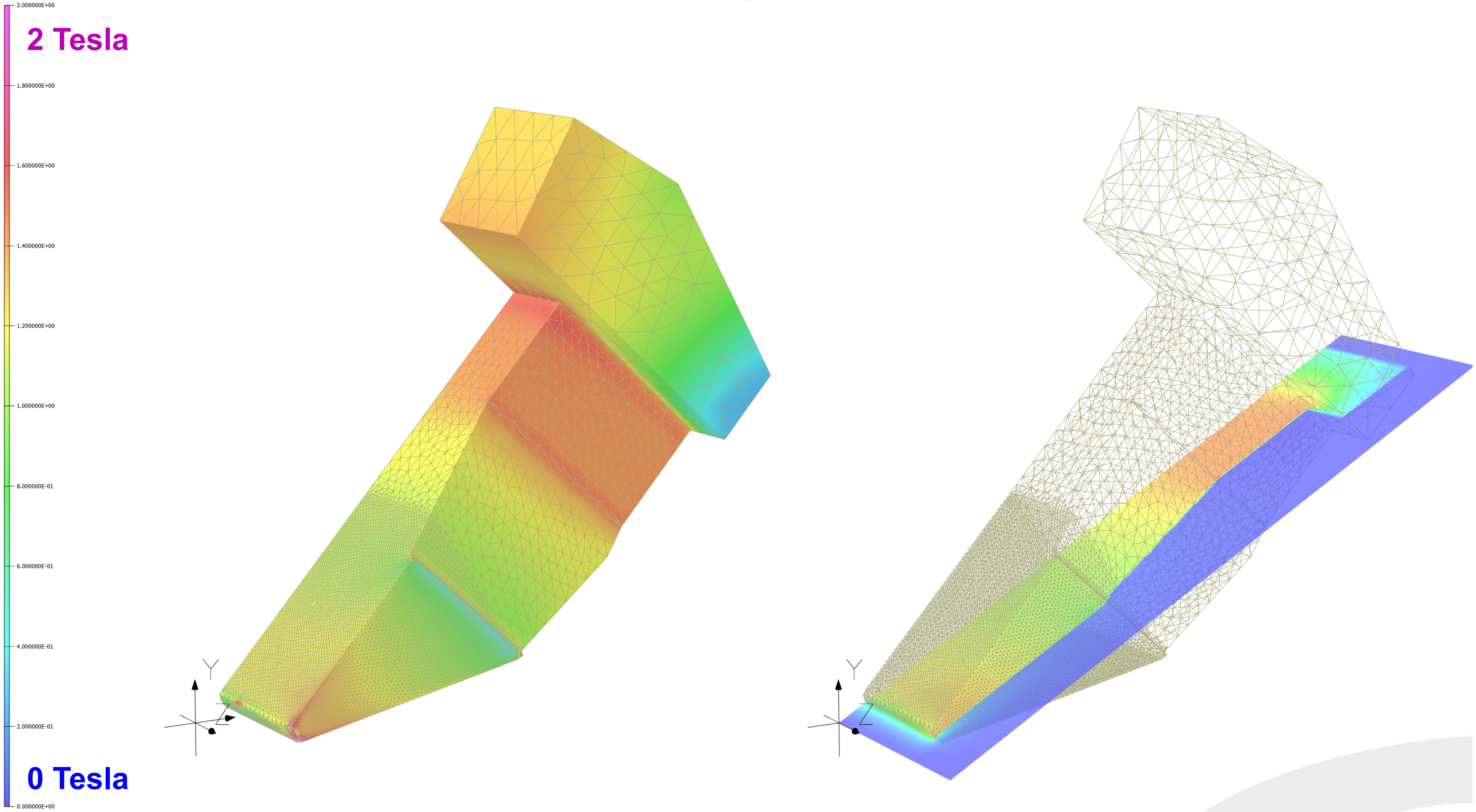
Sextupoles:		sd	sdL	sde	sd0	sfmsL	sfis	sf	sexp	unit
Parameters:										
Beam Energy	En	2,20	2,20	2,20	2,20	2,20	2,20	2,20	2,20	GeV
Magnetic Lenght	L_{Mag}	150	150	150	120	180	240	150	120	mm
Maximum Strengt	M	254,67	253,34	253,33	33,34	265,56	260	253,34	45	$1/m^3$
Maximum Integrated Strengt	ML_{Mag}	38,20	38,00	38,00	4,00	47,80	62,40	38,00	76	$1/m^2$
Maximum Differential Gradier	B''	3735,16	3715,65	3715,51	488,99	3894,88	3813,33	3715,65	660,00	T/m^2
Maximum Integrated Differential Gradier	$B''L_{Mag}$	560,27	557,35	557,33	58,68	701,08	915,20	557,35	79,20	T/m
Overall lengt	Z_{Tot}	170	170	170	140	200	260	170	140	mm
Bore diameter	Ø	32	32	32	32	32	32	32	32	mm
Field at pole tip radius	B_{Pole}	0,478	0,476	0,476	0,063	0,499	0,488	0,476	0,084	T
Current·Turns (per Pole) + 20 %	$N_{Tot}\cdot I_{Coil}$	2435	2423	2423	319	2540	2486	2423	431	A·Turns
Turns per pole	N_{Tot}	58	58	58	26	58	58	58	26	Turns
Number of turns for each layer	NL_1	13	13	13	13	13	13	13	13	#
	NL_2	13	13	13	13	13	13	13	13	#
	NL_3	11	11	11	0	11	11	11	0	#
	NL_4	9	9	9	0	9	9	9	0	#
	NL_5	7	7	7	0	7	7	7	0	#
	NL_6	5	5	5	0	5	5	5	0	#
Coils current at defined Int. Grad	I_c	42,0	41,8	41,8	12,3	43,8	42,9	41,8	16,6	A
Conductor cross section widt	W_{Cu}	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	mm
Conductor cross section heigt	H_{Cu}	9,00	9,00	9,00	9,00	9,00	9,00	9,00	9,00	mm
Conductor cross section dia bore	$Ø_{Cu}$	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	mm
Conductor cross section smoot	r_{Cu}	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	mm
Conductor cross section area	A_{Cu}	44,991	44,991	44,991	44,991	44,991	44,991	44,991	44,991	mm^2
Conductor current density $=I_c$ / A_{Cu}	ρ_{Cu}	0,93	0,93	0,93	0,27	0,97	0,95	0,93	0,37	A / mm^2
Single Coil conductor lengt	L_{Coil}	26,7	26,7	26,7	10,0	31,3	38,3	26,7	10,5	m
Single Coil electric resistance at T_{ave}	R_{Coil}	10,29	10,29	10,29	3,85	12,08	14,76	10,29	4,05	mΩ
Single Coil voltage drop at T_{ave}	V_{Coil}	0,43	0,43	0,43	0,05	0,53	0,63	0,43	0,07	V
Overall Lengt	L_{Tot}	154,0	154,0	154,0	106,0	194,0	254,0	154,0	106,0	mm
MAX Power Supply current $=I_c$ + 0 %	I_{PS}	42,0	41,8	41,8	12,3	43,8	42,9	41,8	16,6	A
Magnet Power at I_{PS} and T_{ave}	P_{Mag}	109,0	108,0	108,0	4,0	140,0	163,0	108,0	7,0	W

Sextupole design: ●●◎◎◎◎



Sextupole design: ●●●◎◎◎

Elettra 2.0 sextupole sdl at 50 A

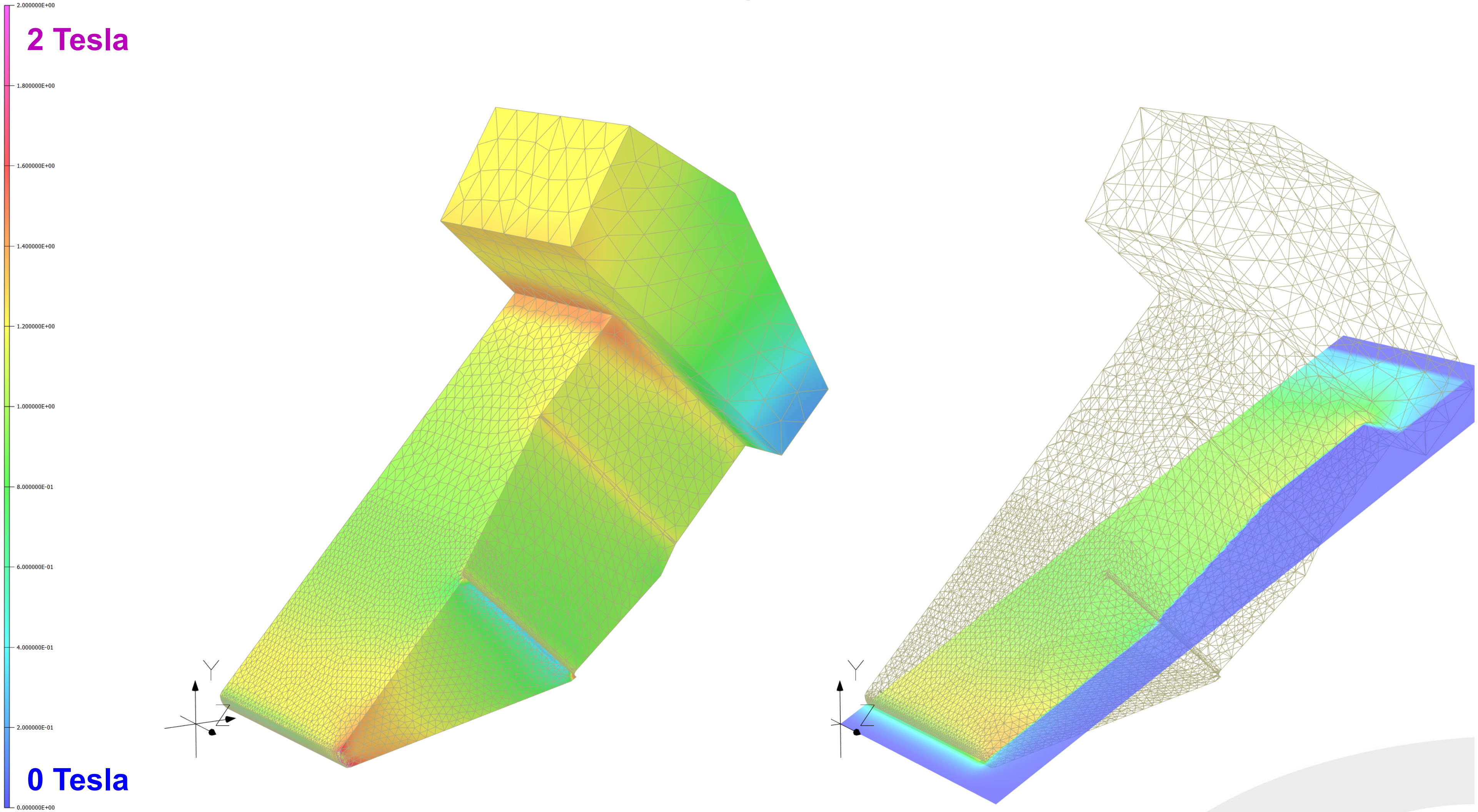


B on yoke surface

B on longitudinal section

Sextupole design: ●●●◎◎◎

Elettra 2.0 sextupole sfis at 50 A



B on yoke surface

B on longitudinal section

Sextupole design: ●◎◎◎◎◎

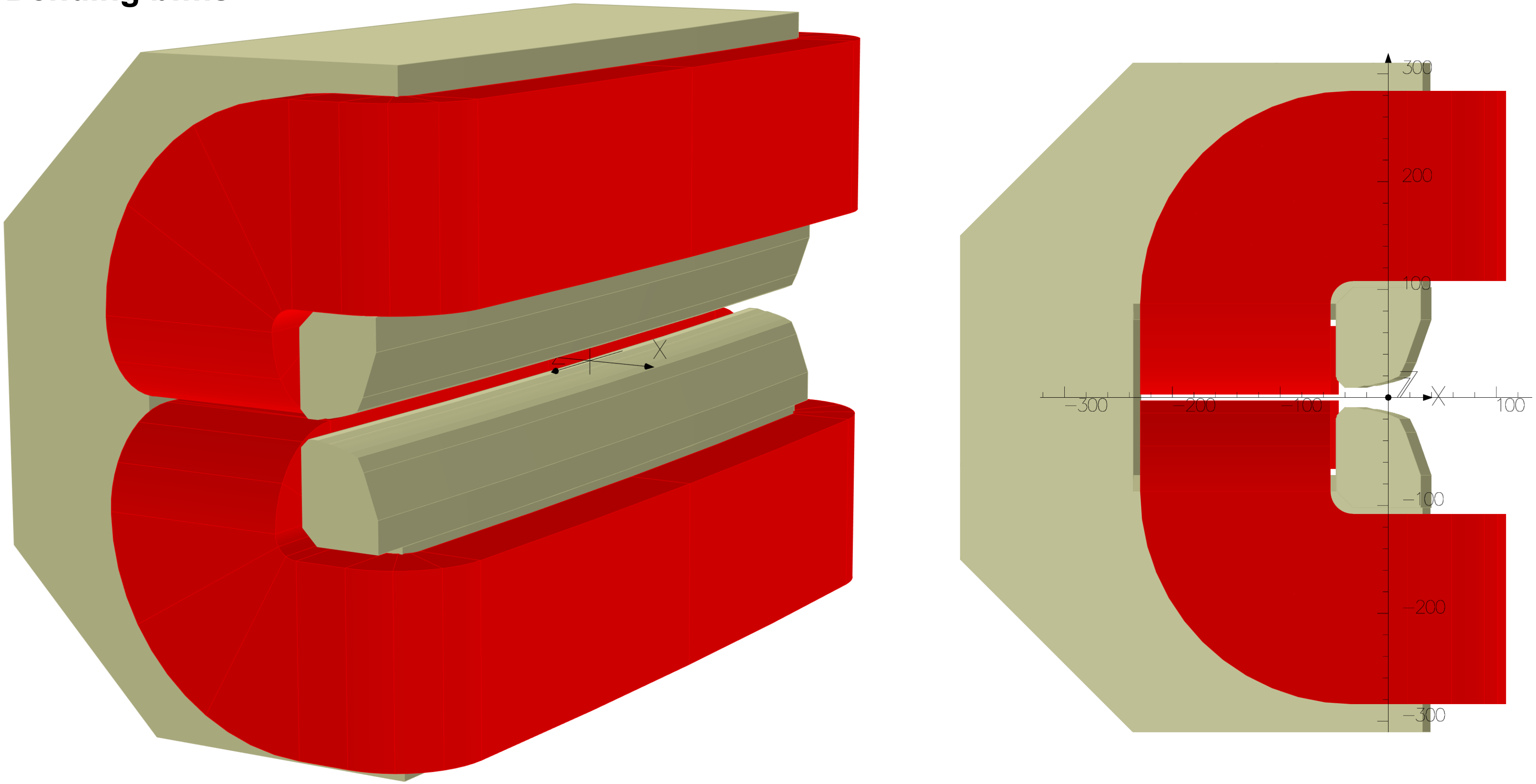
Sextupoles:		sdL	sdL	sdL	unit
Parameters:					
Beam Energy	**En**	2,00	2,00	2,00	GeV
Magnetic Lenght	L_{Mag}	151	151	151	mm
Maximum Strength	**M**	67,1	264	320	$1/m^3$
Maximum Integrated Strengt	ML_{Mag}	10,13	39,86	48,32	$1/m^2$
Maximum Differential Gradier	**B"**	894,67	3520,00	4266,67	T/m^2
Maximum Integrated Differential Gradier	$B''L_{Mag}$	135,09	531,52	644,27	T/m
Overall length	Z_{Tot}	170	170	170	mm
Bore diameter	**Ø**	32	32	32	mm
Field at pole tip radius	B_{Pole}	0,115	0,451	0,546	T
Efficency	**η**	84,0	82,5	80,0	%
Iron saturation	**Sat**	0,0	-1,7	-4,7	%
Current·Turns (per Pole) + 0 %	$N_{Tot} \cdot I_{Coil}$	579	2318	2898	A·Turns
Turns per pole	N_{Tot}	58	58	58	Turns
Coils current at defined Int. Grad	I_c	10,0	40,0	50,0	A
Conductor current density = I_c / A_{Cu}	ρ_{Cu}	0,22	0,89	1,11	A / mm^2
Single Coil conductor length	L_{Coil}	27,4	27,4	27,4	m
Single Coil electric resistance at T_{ave}	R_{Coil}	10,54	10,54	10,54	mΩ
Single Coil voltage drop at T_{ave}	V_{Coil}	0,11	0,42	0,53	V
Overall Length	L_{Tot}	164,0	164,0	164,0	mm
MAX Power Supply current = I_c + 0 %	I_{PS}	10,0	40,0	50,0	A
Magnet Power at I_{PS} and T_{ave}	P_{Mag}	7,0	102,0	159,0	W

Bending design: ●◎

DD-Bend Parameters:				***bf1***	***bf***	***bfms***	**unit**
# of Dipoles			**N**	***24***	***24***	***24***	
Curvature angle	**0**		**α**	**6,28E-02**	**1,01E-01**	**9,77E-02**	**rad**
	1			**3,60**	**5,80**	**5,60**	**º**
Beam energy of reference			**E0**	**2,000**	**2,000**	**2,000**	**GeV/c**
Integrated magnetic field at E_0			IY_0	**0,4189**	**0,6749**	**0,6516**	**T·m**
Magnetic arc length			L_{mag}	**750**	**860**	**820**	**mm**
Magnetic field at magnet centre at E_0			BY_0	**0,5585**	**0,7847**	**0,7946**	**T**
Curvature radius			**R**	**11937**	**8496**	**8390**	**mm**
Nominal gap			**Gap**	**26**	**26**	**26**	**mm**
Expected total length			Z_{Tot}	**1200**	**1200**	**1200**	**mm**
Combined quadrupole strength			**K**	**-1,87**	**-1,96**	**-2,14**	**m^{-2}**
Combined quadrupole gradien			**B'**	**-12,5**	**-13,1**	**-14,2**	**T/m**
Good field region			**R**	**10**	**10**	**10**	**mm**
Magnetic field at R			B_R	**0,68**	**0,92**	**0,94**	**T**
Minimum Gap at R			G_R	**18,0**	**16,2**	**16,7**	**mm**
Iron Saturation			**n**	**2,0**	**2,0**	**2,0**	**%**
Current·Turns +	**0**	%	NI_c	11790	16570	16770	**A·Turns**
Turns tot			N_{Tot}	**280**	**400**	**400**	**Turns**
Coils current			I_{Coil}	**42,2**	**41,5**	**42,0**	**A**
Conductor cross section width			W_{Cu}	**7,0**	**7,0**	**7,0**	
Conductor cross section heigth			H_{Cu}	**7,0**	**7,0**	**7,0**	**mm**
Conductor cross section area			A_{Cu}	**48,142**	**48,142**	**48,142**	**mm^2**
Conductor current density = I_c / A_{Cu}			ρ_{Cu}	**0,88**	**0,86**	**0,87**	**A / mm^2**
Coil conductor length (**single or total**)[1]			LG_{Cu}	**448,8**	**718,7**	**741,7**	**m**
Coil electric resistance at T_{ave} (**single or total**)[1]			R_{Mag}	**187,00**	**303,00**	**294,00**	**mΩ**
Coil voltage drop at T_{ave} (**single or total**)[1]			V_{Mag}	**7,89**	**12,57**	**12,35**	**V**
Overall Length			L_{Tot}	**870,0**	**1002,0**	**972,0**	**mm**
MAX Power Supply current = I_c +	**0**	%	I_{PS}	**43,0**	**42,0**	**42,0**	**A**
Magnet Power at I_{PS} and T_{ave}			P_{Coil}	**346,0**	**535,0**	**519,0**	**W**

Bending design: ●●

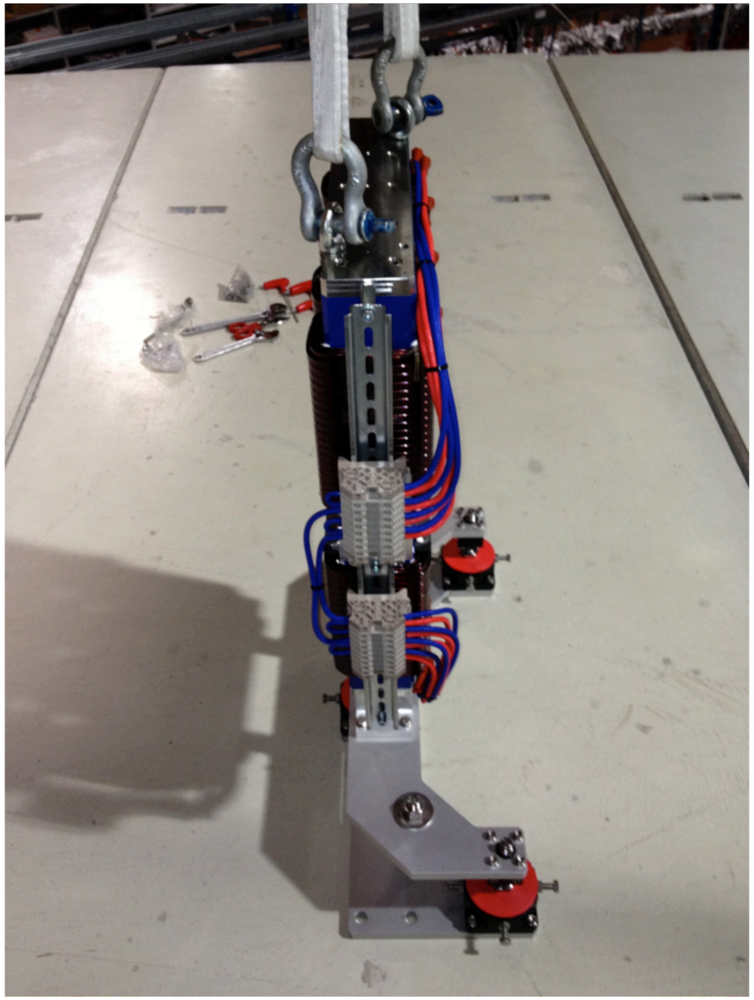
Bending bfms



- ✓ *All the Elettra 2.0 bendings are very similar*
- ✓ *Also in this case the short drift between bending and sextupole required the longitudinally extension of the pole terminations*

Layout and 3D girder: ●◎◎◎◎

Similary to Elettra, also Elettra 2.0 will have quad and sext with the yoke made by separated parts.



Past experiences…

1. Elettra Quadrupoles and Sextupoles:

The support of the yoke separated parts by two plates on the sides was not sufficient. The force between the poles had required additional parts in order to increase the structure stiffness.

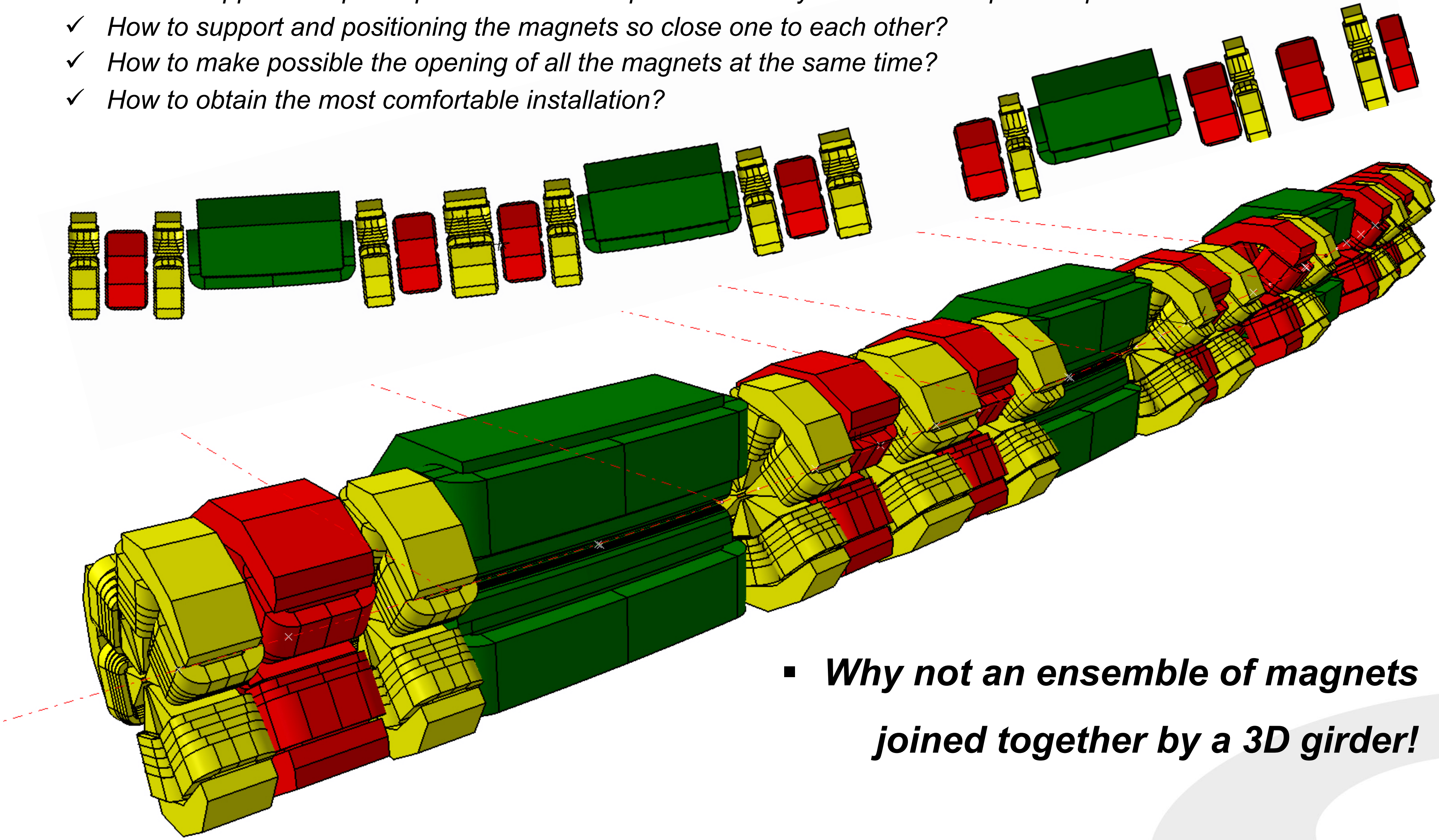
2. Elettra’s 8th corrector:

Due to the overall thin and tall geometry, the support based only on a plate on bottom was not sufficient. In order to eliminate the possible vertical vibrations we added a supplementary fixing on top!

Layout and 3D girder: ●●◎◎◎◎

<u>Questions coming from the layout requirements</u>:

- ✓ *How to support the quadrupole and the sextupoles with the yoke made of separated parts?*
- ✓ *How to support and positioning the magnets so close one to each other?*
- ✓ *How to make possible the opening of all the magnets at the same time?*
- ✓ *How to obtain the most comfortable installation?*



- ***Why not an ensemble of magnets joined together by a 3D girder!***

Layout and 3D girder: ●●●◎◎

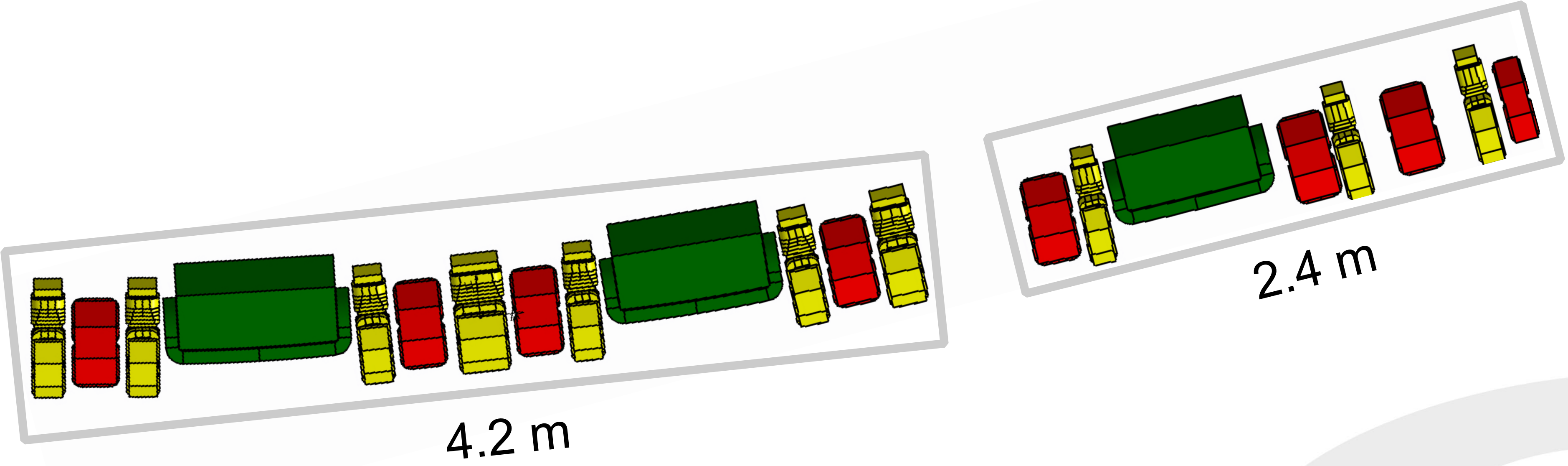
The idea is to design two 3D girders:

For each one, the structure will be done by two separable parts, upper and lower parts:

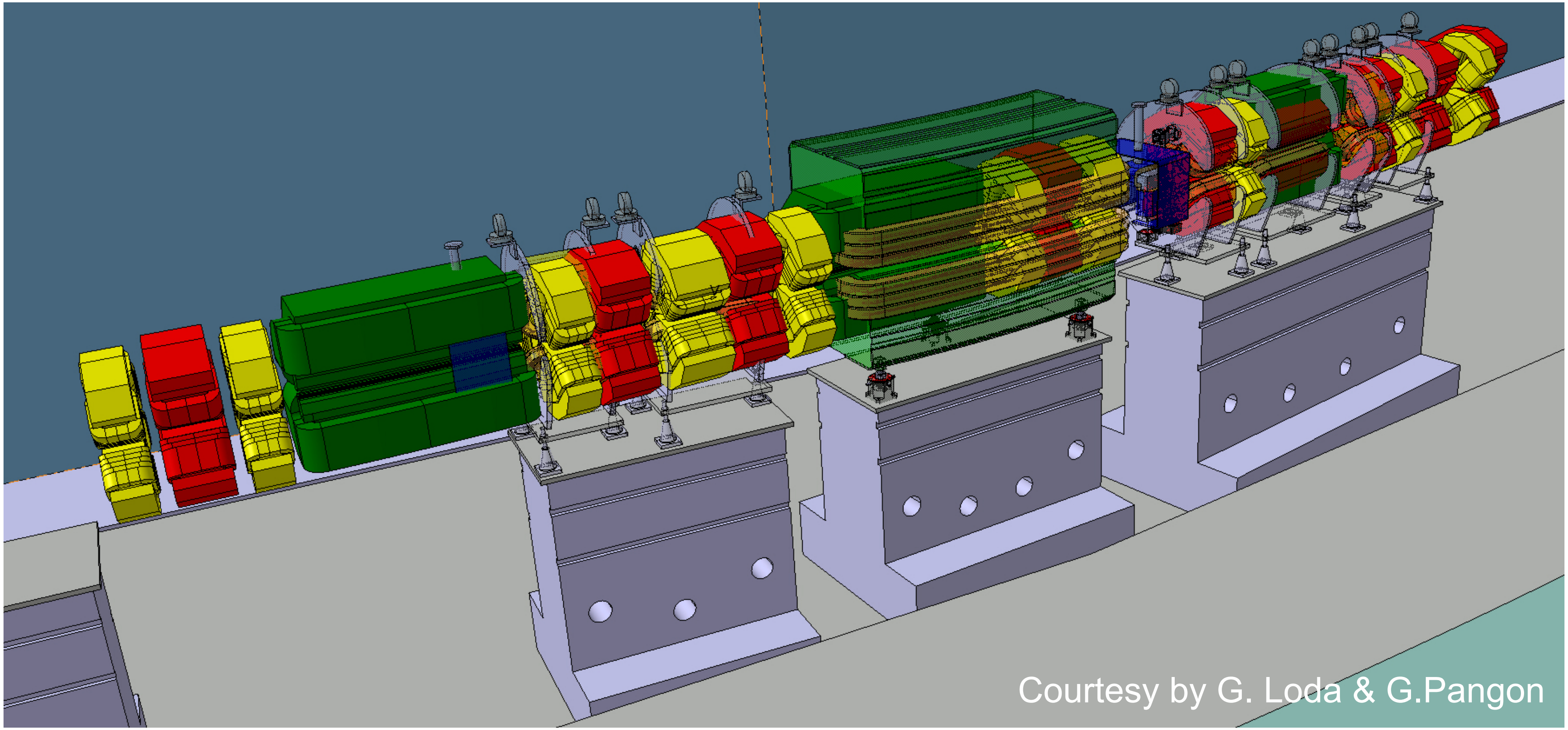
1. The lower part will support the whole bending, the quadrupoles 1/2 and the sextupoles 2/3
2. The upper part will support the quadrupoles 1/2 and the sextupoles 1/3.

The two 3D girder parts will be symmetric but not equal.

🟩 Bending 🟥 Quadrupole 🟨 Sextupole ⬜ Girder



Layout and 3D girder: ●●●●◎



Courtesy by G. Loda & G.Pangon

Elettra and Elettra 2.0 layouts comparison:

- ✓ All the new magnets will have the same overall height (620 mm)
- ✓ The smaller 3D girder will be placed on only one of the present basement
- ✓ The bigger 3D girder will need a bridge between two/three of the present basements

Conclusions

- ○ **The quadrupoles and the sextupole with the overall L_{mag} are feasible and efficient.**
- ○ **Also the bending can be cooled by air**
- ○ **The 3D girder ensemble of magnets can resolve the layout issues**

Next works…

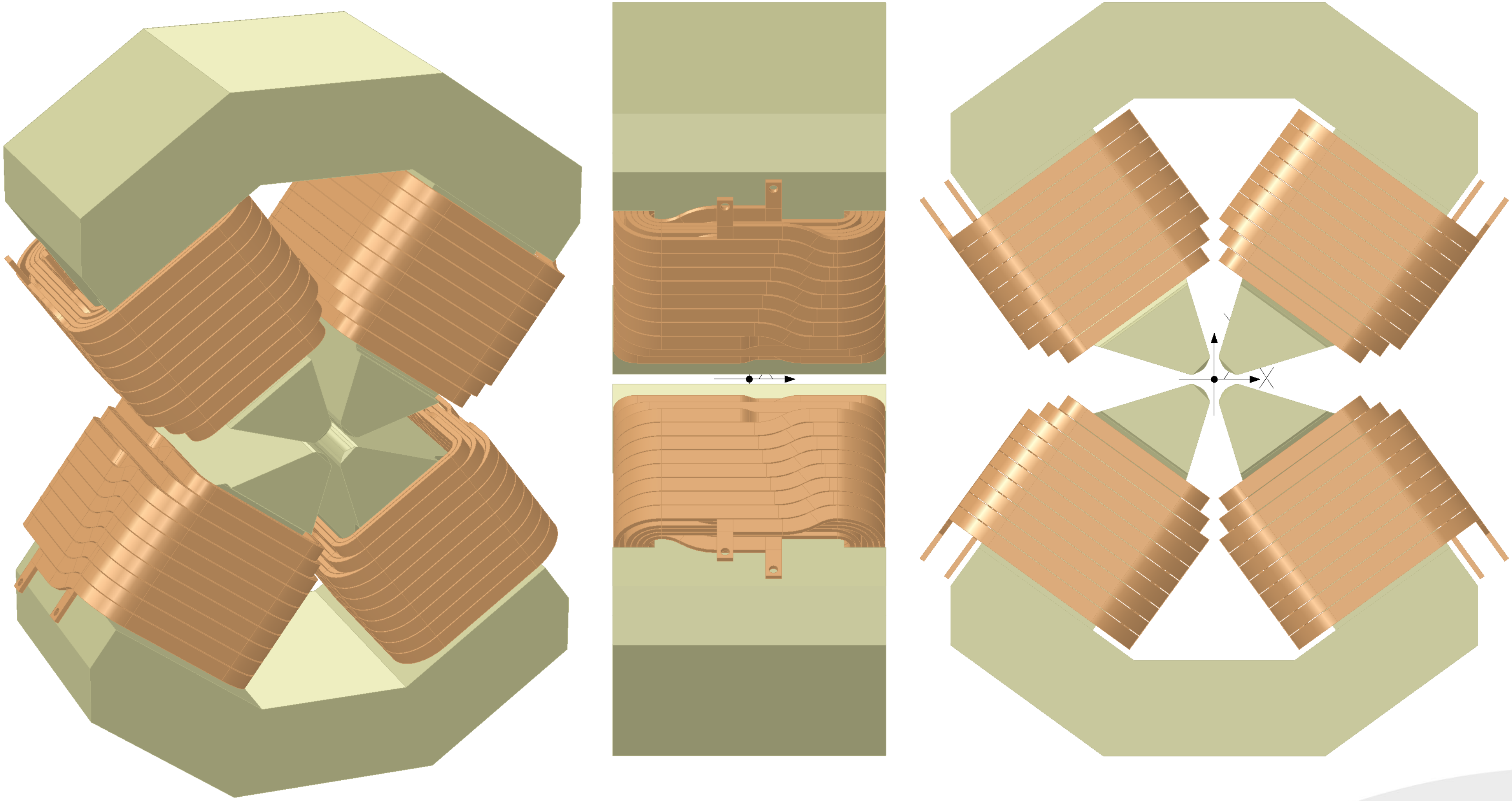
- ▪ **Magnets pole profile optimizations**
- ▪ **Study and check of cross-talk between the magnets (due the very short drifts)**
- ▪ **Realization of a quadrupole Q10T9 prototype**
- ▪ **Development of the 3D girder supporting and interfacing**
- ▪ **Design of the vacuum chamber parts**

Elettra
Sincrotrone
Trieste

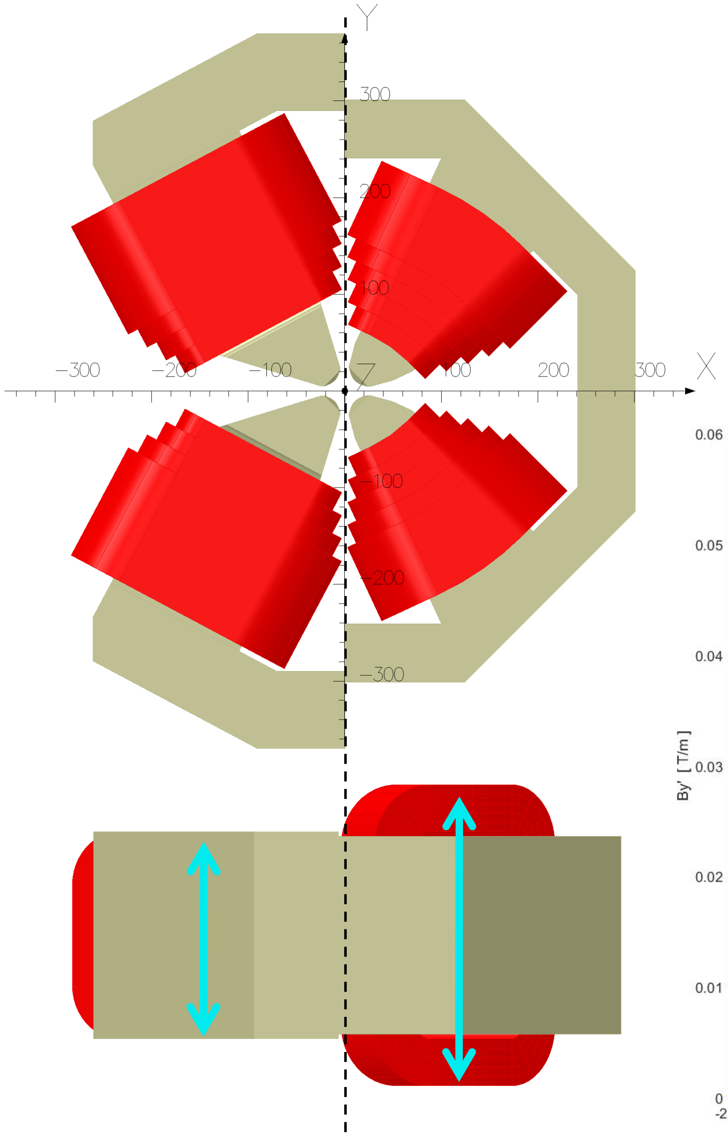
Thank You!

www.elettra.eu

Extra: yoke parts & windings



Quadrupole design: ●●●●◎◎



New ¦ Old

New *Vs Old*

Overall dimensions:

Length: **220** Vs 320 mm

Height: **740** Vs 600 mm

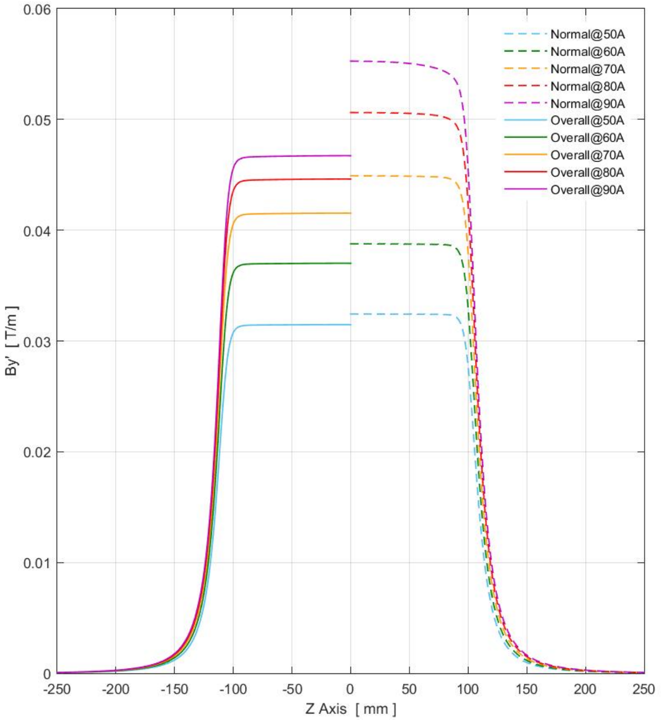
Width: **580** Vs 600 mm

Performances:

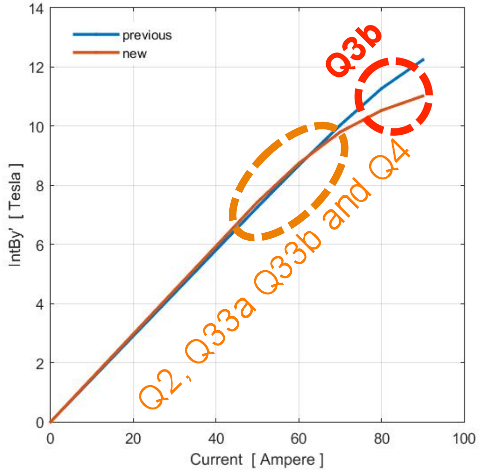
Gradient at 90 A: **46.7** Vs 55.3 T/m

Int.Grad at 90 A: **11.02** Vs 12.24 T

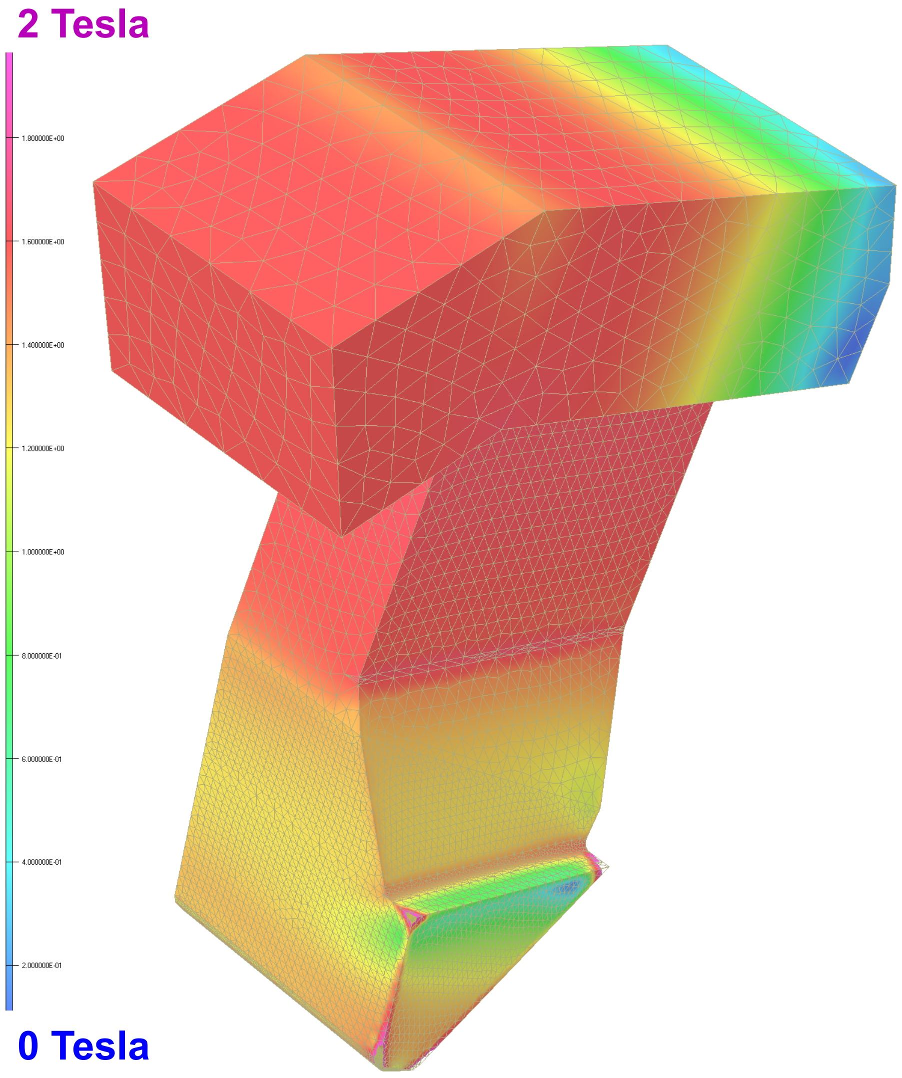
Saturation at 90 A: **17.6** Vs 6.3 %



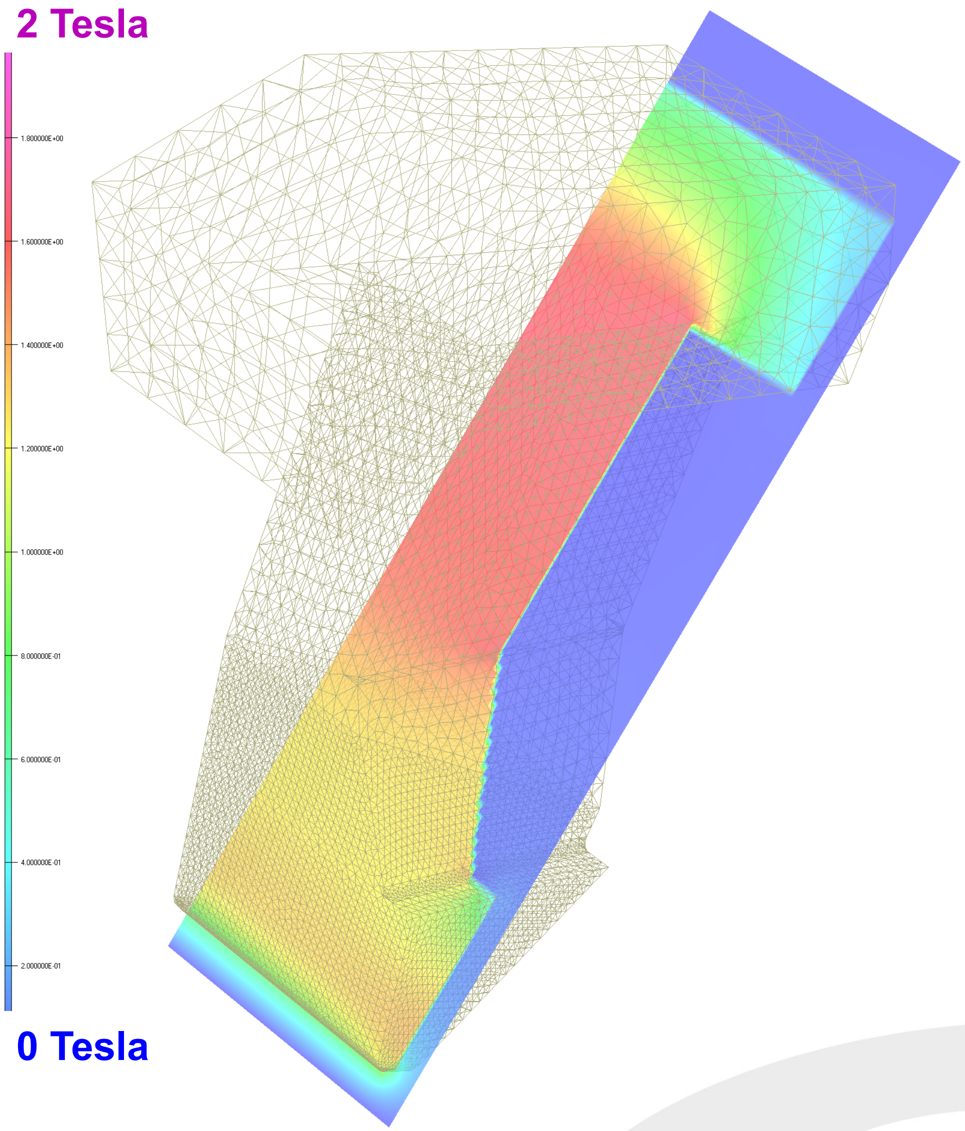
B’ on Z range = [-250 250] mm



Quadrupole design: ●●●●●◎



B on yoke surface

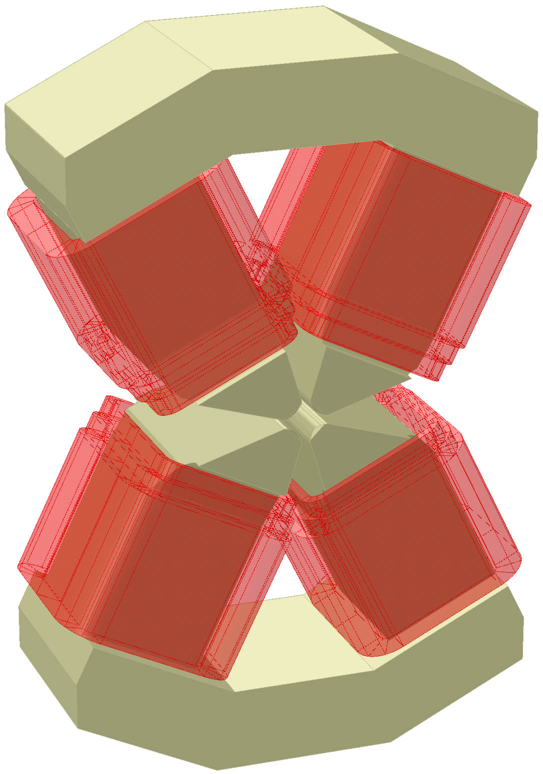


B on longitudinal section

Quadrupole design: ●●●●●●

Two of the Elettra 2.0 quad families could be:

E2Q10T5

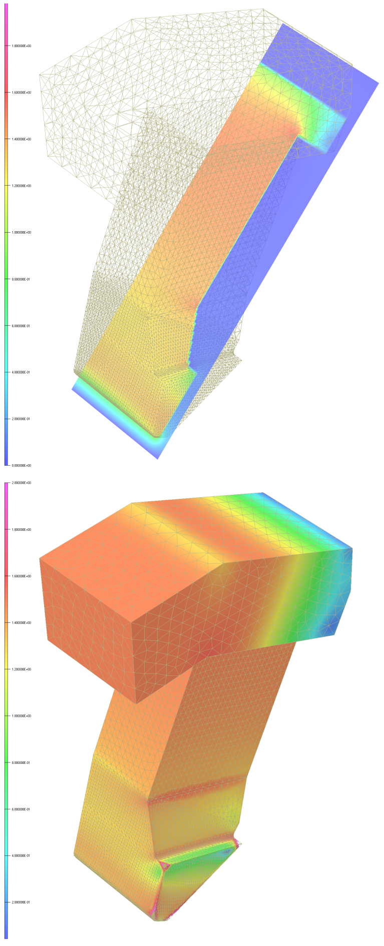


Turns: **54**

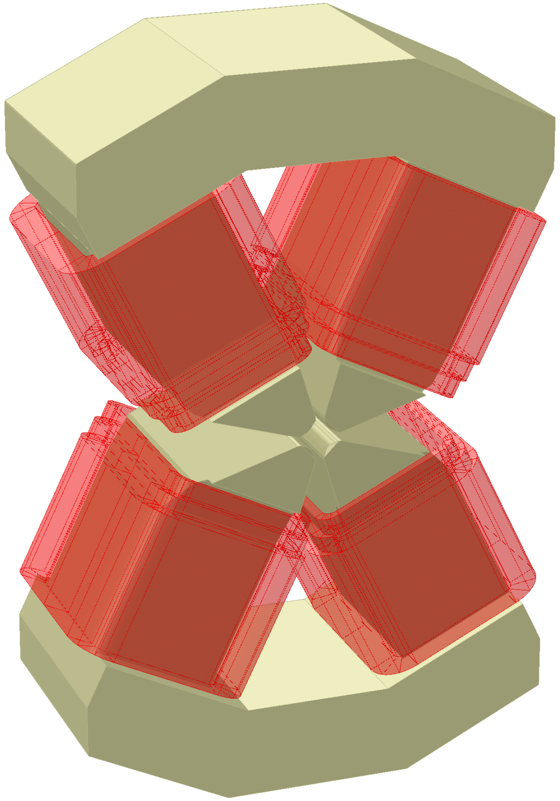
L_{overall} = **220** mm

Int.Grad at 90 A: **11.3** Tesla

Saturation at 90A: **7.3** %



E2Q12T5

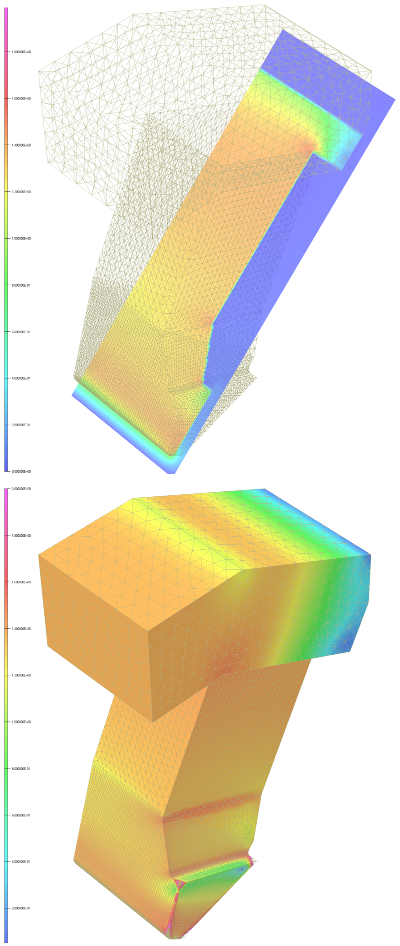


Turns: **54**

L_{overall} = **260** mm

Int.Grad at 90 A: **13.7** Tesla

Saturation at 90A: **4.5** %



Design and optimization

The magnets designs started from pre-designed models
and use the software:

Opera Tosca3D (finite element magnetostatic simulations)

modeFRONTIER (optimizations)

Matlab (post processing and particle tracking)

Very fast Tosca3D simulations

(low definition mesh, single lamination ~ 2.5D)

are done in parallel of all the pre-design excel sheets

to check the feasibility

Design and optimization

In the Quadrupoles, the pole geometry has been defined by the formula:

$$Y = (X^2+R^2)^{½}, \text{ for } 0 \leq |X| \leq X_0$$

$$Y = (X^2+R^2)^{½} - K\cdot((|X|-X_0) / (½\cdot W-X_0))^{\mathbf{N}}, \text{ for } X_0 \leq |X| \leq ½\cdot W$$

where:

R = bore radius [mm]
W = pole width [mm]
K = pole edges addition [mm]
N = order ≥ 2
and

$$X_0 = ½\cdot W - N\cdot K / (1/(1+(R / (½\cdot W))^2)^{½} - \tan(\text{alpha}))$$

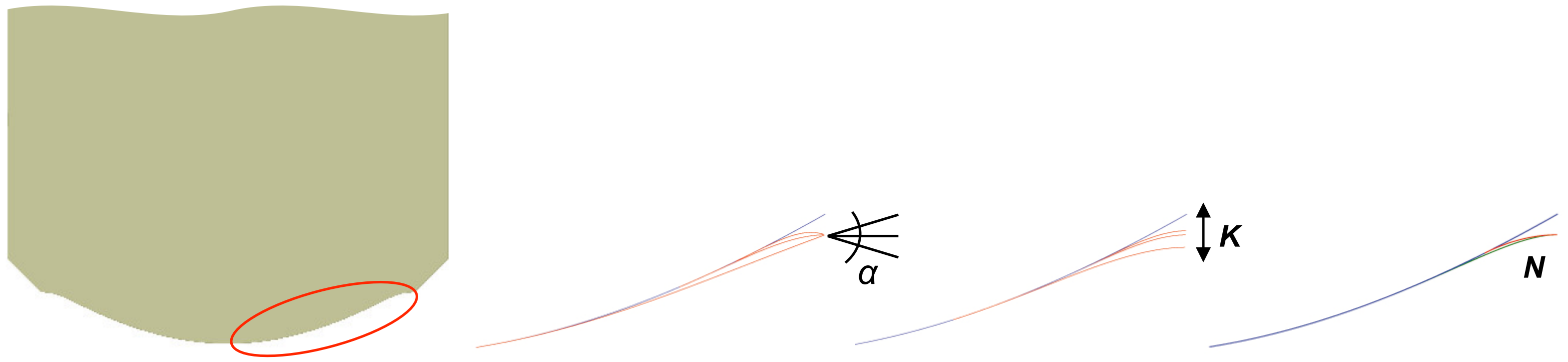
where:

alpha = tangent angle of the pole edges addiction [rad]

The goals are to use these equations in order to minimize 8-pole (asymmetric model), 12-pole and the 20-pole components.

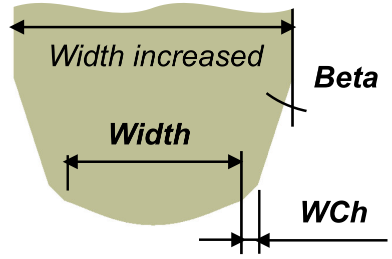
Design and optimization

Examples of the poles geometry as a function of: *Alpha*, *K* *and* *N*

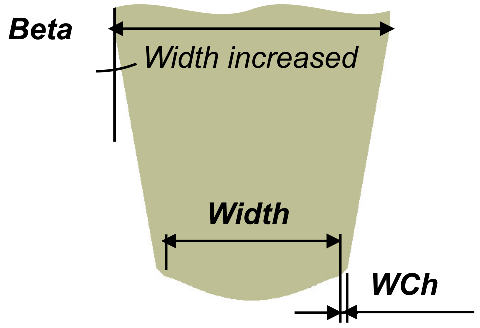


Other parameters in the real geometry are: *WCh* and *Beta*

eg 1:



eg 2:



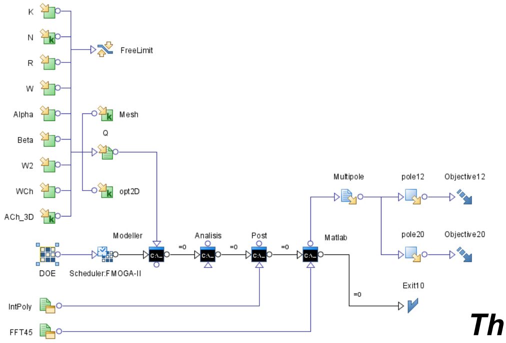
The pole have chamfers to minimize the field intensity

In some quadrupoles, the pole width is increased inside the coil

} *Minimize the iron saturation*

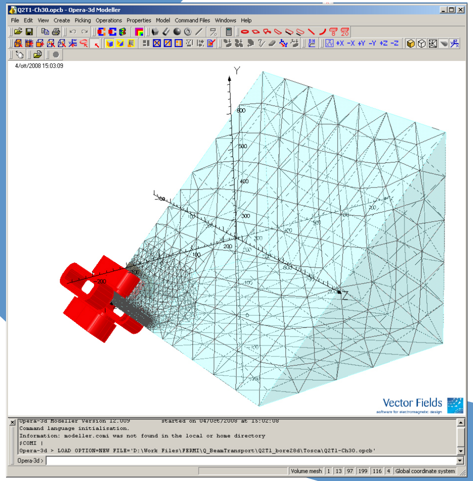
Design and optimization

The parameters (*W,K,N,Alpha,Wch,Beta*) optimization will use ***Esteco* modeFRONTIER**



The MathWorks MATLAB

VF TOSCA



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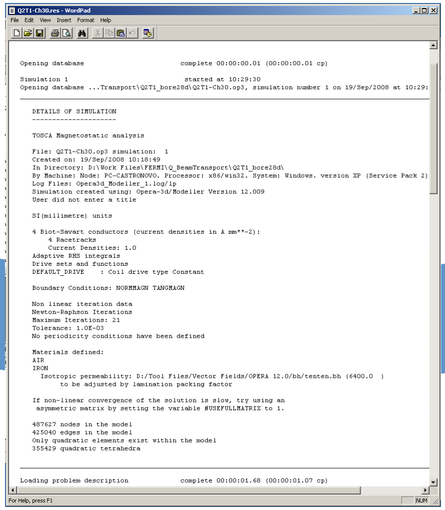
Opera-3d Modeller Version 12.009        started on 04/Oct/2008 at 15:02:08
Command language initialisation.
Information: modeller.comi was not found in the local or home directory
$COMI |
Opera-3d > LOAD OPTION=NEW FILE='D:\Work Files\FERMI\Q_BeamTransport\Q2T1_bore28d\Tosca\Q2T1-Ch30.opcb'
```

VF Modeller



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Opening database                        complete 00:00:00.01 (00:00:00.01 cp)

Simulation 1                             started at 10:29:30
Opening database ...Transport\Q2T1_bore28d\Q2T1-Ch30.op3, simulation number 1 on 19/Sep/2008 at 10:29:
________________________________________________________________________________

   DETAILS OF SIMULATION
   ---------------------

   TOSCA Magnetostatic analysis

   File: Q2T1-Ch30.op3 simulation:  1
   Created on: 19/Sep/2008 10:18:49
   In Directory: D:\Work Files\FERMI\Q_BeamTransport\Q2T1_bore28d\
   By Machine: Node: PC-CASTRONOVO. Processor: x86/win32. System: Windows. version XP (Service Pack 2)
   Log Files: Opera3d_Modeller_1.log/lp
   Simulation created using: Opera-3d/Modeller Version 12.009
   User did not enter a title

   SI(millimetre) units

   4 Biot-Savart conductors (current densities in A mm**-2):
       4 Racetracks
       Current Densities: 1.0
   Adaptive RHS integrals
   Drive sets and functions
   DEFAULT_DRIVE    : Coil drive type Constant

   Boundary Conditions: NORMMAGN TANGMAGN

   Non linear iteration data
   Newton-Raphson Iterations
   Maximum Iterations: 21
   Tolerance: 1.0E-03
   No periodicity conditions have been defined

   Materials defined:
   AIR
   IRON
     Isotropic permeability: D:/Tool Files/Vector Fields/OPERA 12.0/bh/tenten.bh (6400.0  )
          to be adjusted by lamination packing factor

   If non-linear convergence of the solution is slow, try using an
    asymmetric matrix by setting the variable #USEFULLMATRIX to 1.

   487627 nodes in the model
   425040 edges in the model
   Only quadratic elements exist within the model
   355429 quadratic tetrahedra

________________________________________________________________________________

Loading problem description              complete 00:00:01.68 (00:00:01.07 cp)
```

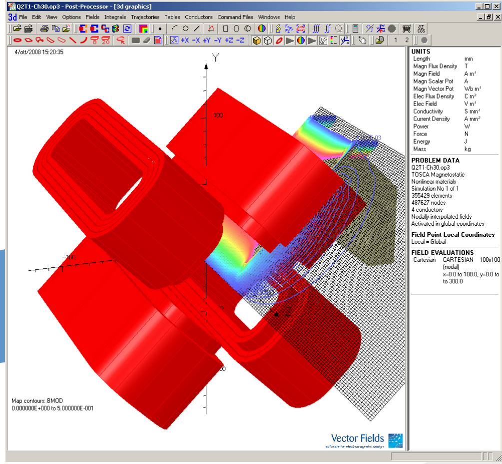

Map contours: BMOD
0.000000E+000 to 5.000000E-001

UNITS

Length	mm
Magn Flux Density	T
Magn Field	A m⁻¹
Magn Scalar Pot	A
Magn Vector Pot	Wb m⁻¹
Elec Flux Density	C m⁻²
Elec Field	V m⁻¹
Conductivity	S mm⁻¹
Current Density	A mm⁻²
Power	W
Force	N
Energy	J
Mass	kg

PROBLEM DATA
Q2T1-Ch30.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
355429 elements
487627 nodes
4 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates
Local = Global

FIELD EVALUATIONS
Cartesian CARTESIAN 100x100 (nodal)
x=0.0 to 100.0, y=0.0 to
to 300.0

VF Post-Processor

Elettra
Sincrotrone
Trieste

Design and optimization