THOMX Ring status magnets

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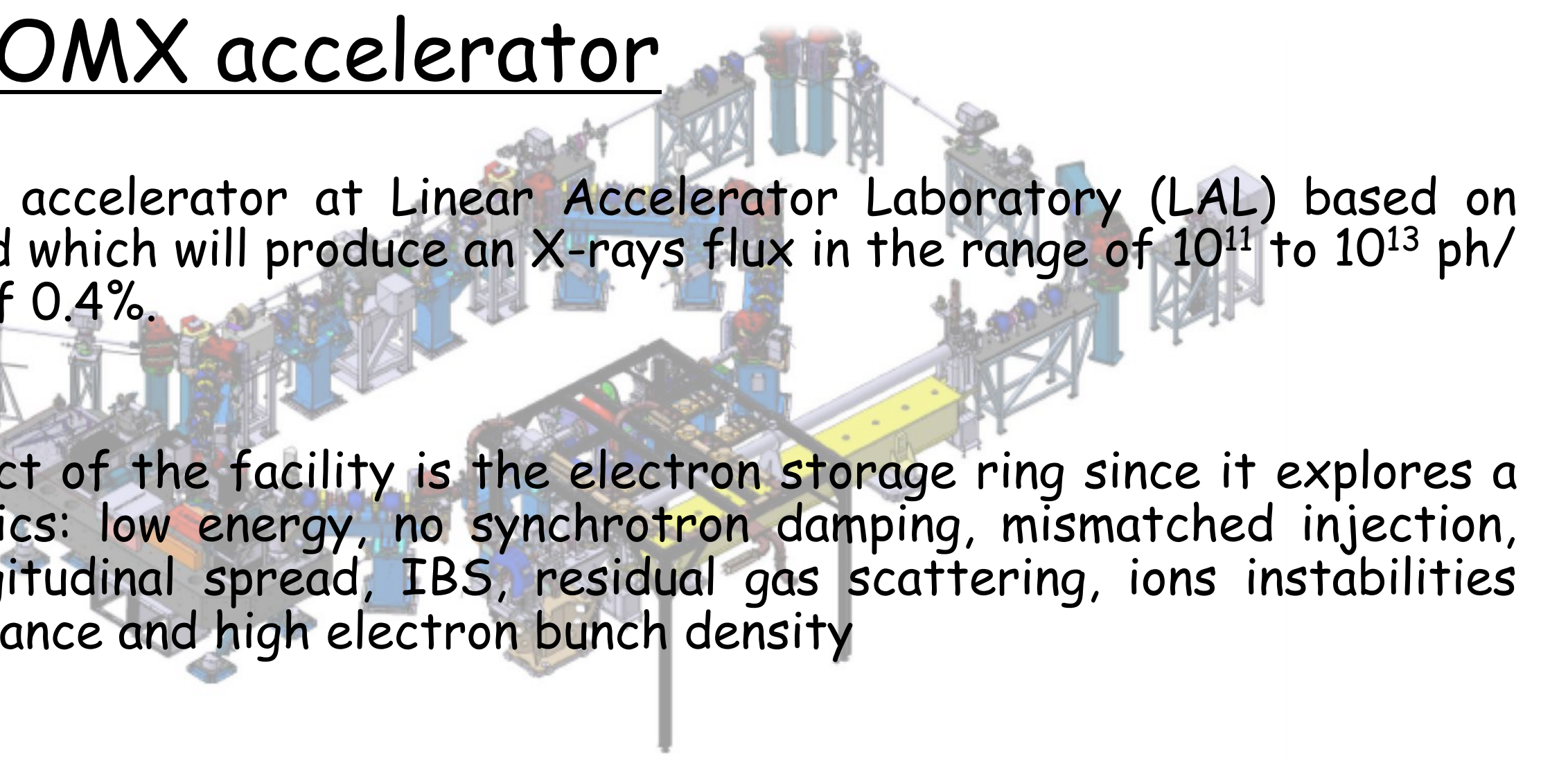
Introduction: THOMX accelerator



✓THOMX facility is a new accelerator at Linear Accelerator Laboratory (LAL) based on Compton effect radiation and which will produce an X-rays flux in the range of 10^{11} to 10^{13} ph/s with an energy resolution of 0.4%.

✓The most challenging aspect of the facility is the electron storage ring since it explores a new domain of beam dynamics: low energy, no synchrotron damping, mismatched injection, Compton recoil induced longitudinal spread, IBS, residual gas scattering, ions instabilities together with the ring impedance and high electron bunch density

Ring lattice

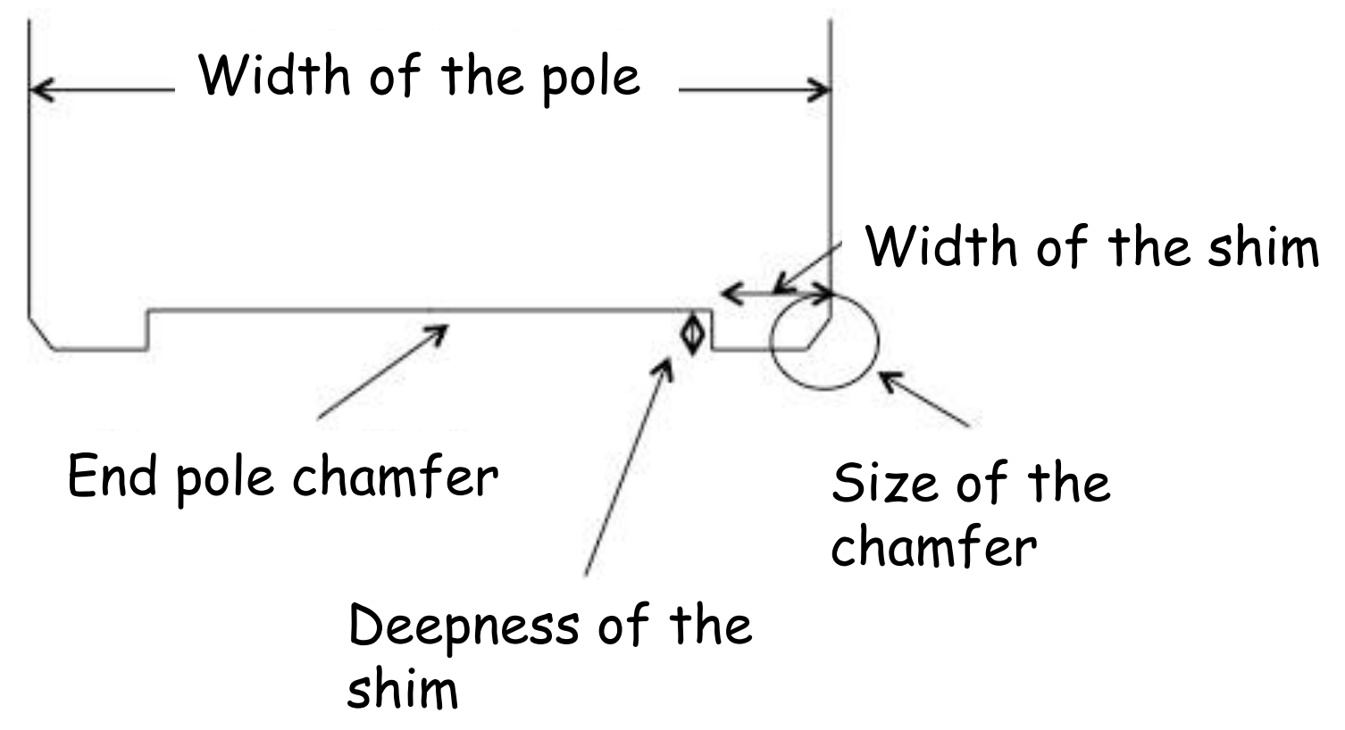
✓The storage ring has a circumference of 18 meters and consists of 44 magnetic elements, including

- 8 C-shaped bending magnets
- 24 quadrupoles,
- 12 sextupoles containing 12 two-plane correctors

Item	Dipole	Quadrupole	Sextupole
Quantity	8	24	12
Yoke length (mm)	276.5 R=353mm	140	60
Field strength	0.7 T	5 T/m	40T/m^2
Aperture (mm)	42	41	44
Overall dimensions (cm^3)	35*40*40	19*19*18	19*19*18
Good field region (mm)	+/- 20	+/- 20	+/- 20

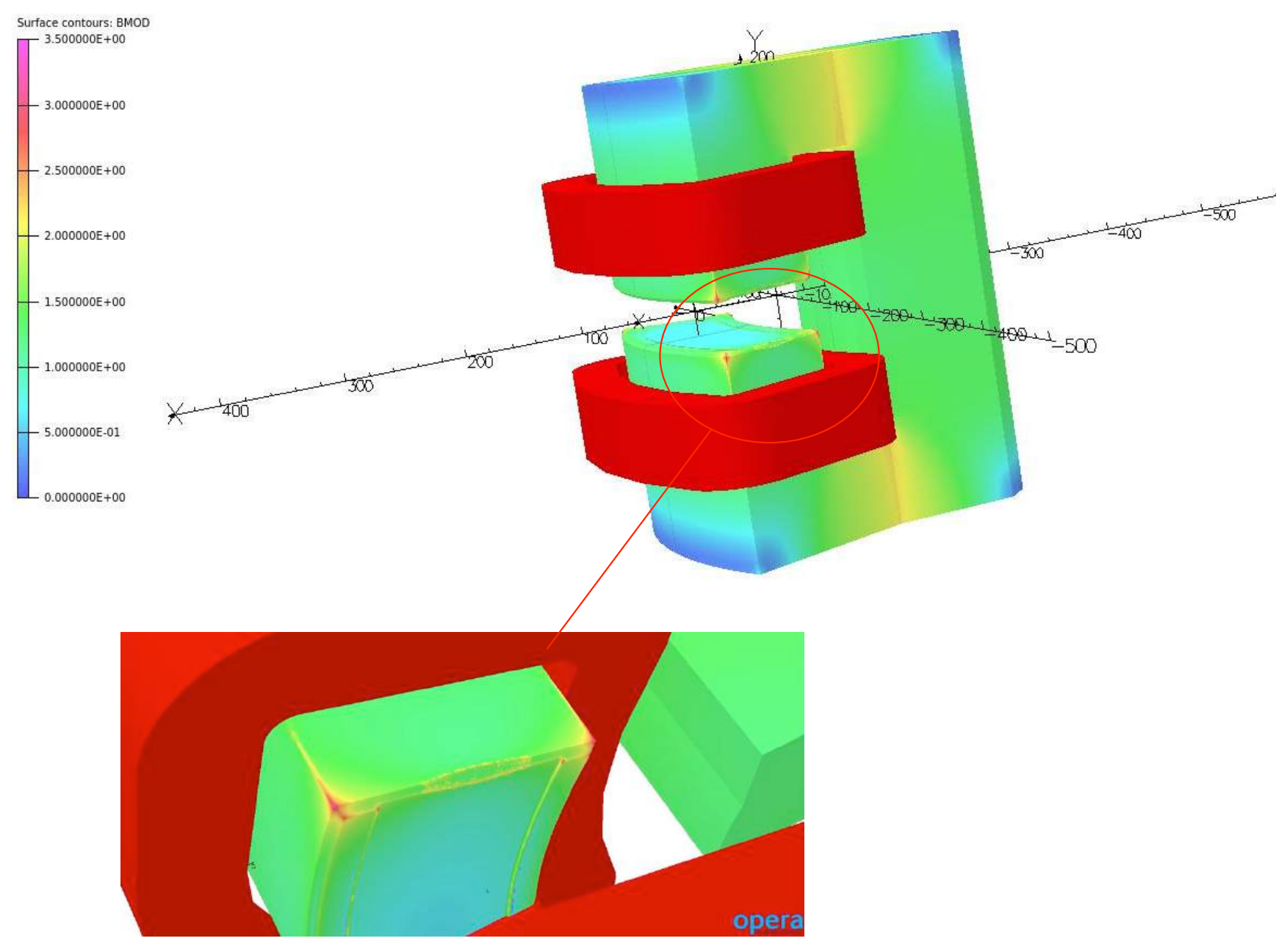
DIPOLE

✓Parameters of optimization



A special endeavour has been done for the design of poles, in particular, for the deepness and width of the entrance/output chamfer design. It has been optimized to maintain the magnetic face with an angle of 22.5 ° both at the entrance and the exit for radial trajectory between +/20mm and to limit its error.

✓ Design 3D - OPERA/TOSCA



✓Results of analysis simulations with MatLab

The multipole components of the dipole has been extracted from the field expansion :

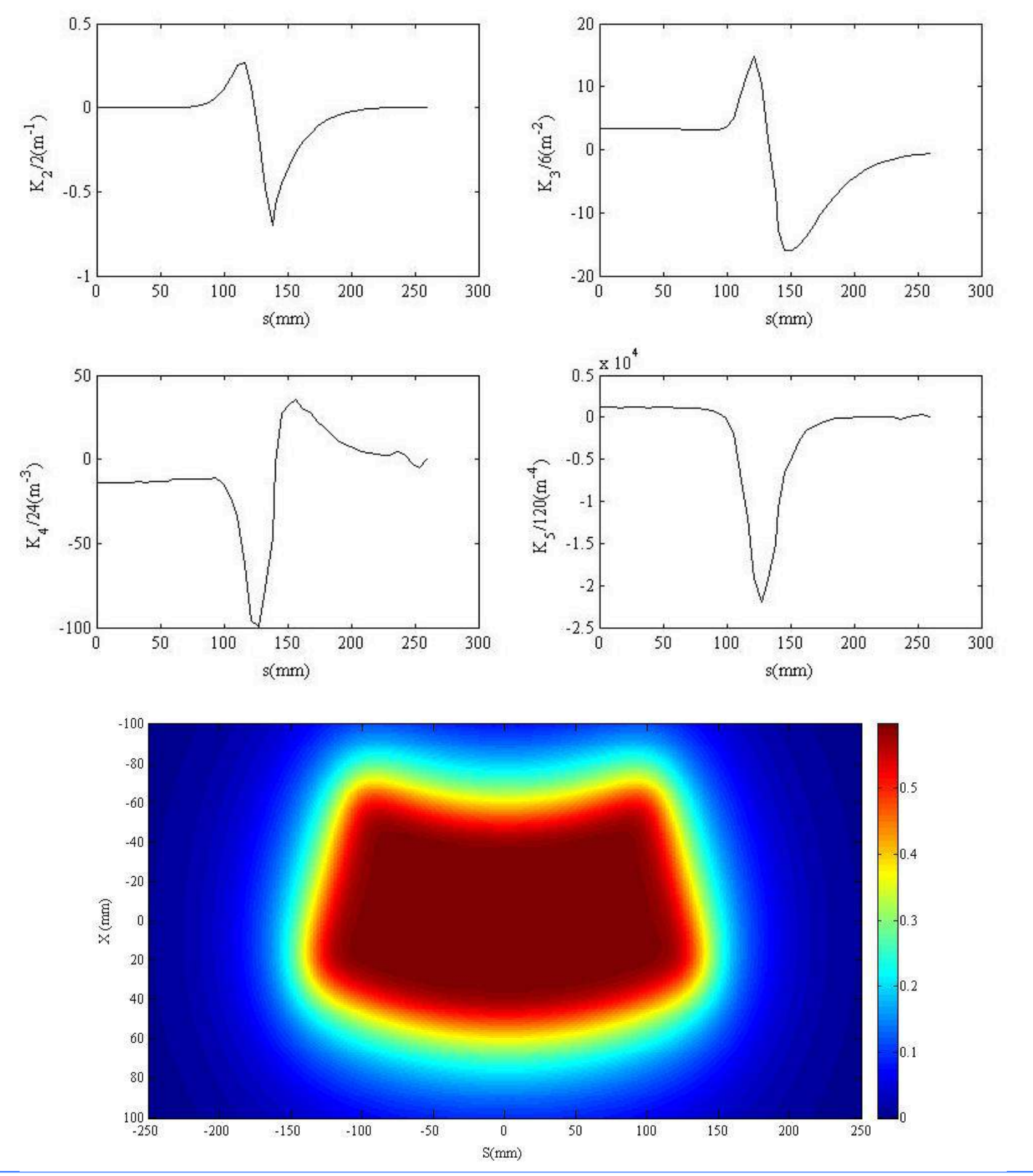
$$B_y(x).L = B_0.\rho.\left(\frac{L}{\rho}+\frac{B_1.x^1.L}{B_0.\rho}+\frac{B_2.x^2.L}{B_0.\rho}+\cdots+\frac{B_n.x^n.L}{B_0.\rho}\right)$$

From this equation, the relative field error at a distance x in terms of mutipole components can be expressed by :

$$\frac{\Delta B_y(x).L}{B_0.L} = \rho.\left(K_1x+\frac{K_2}{2}x^2+\cdots+\frac{K_n}{n!}x^n\right)$$

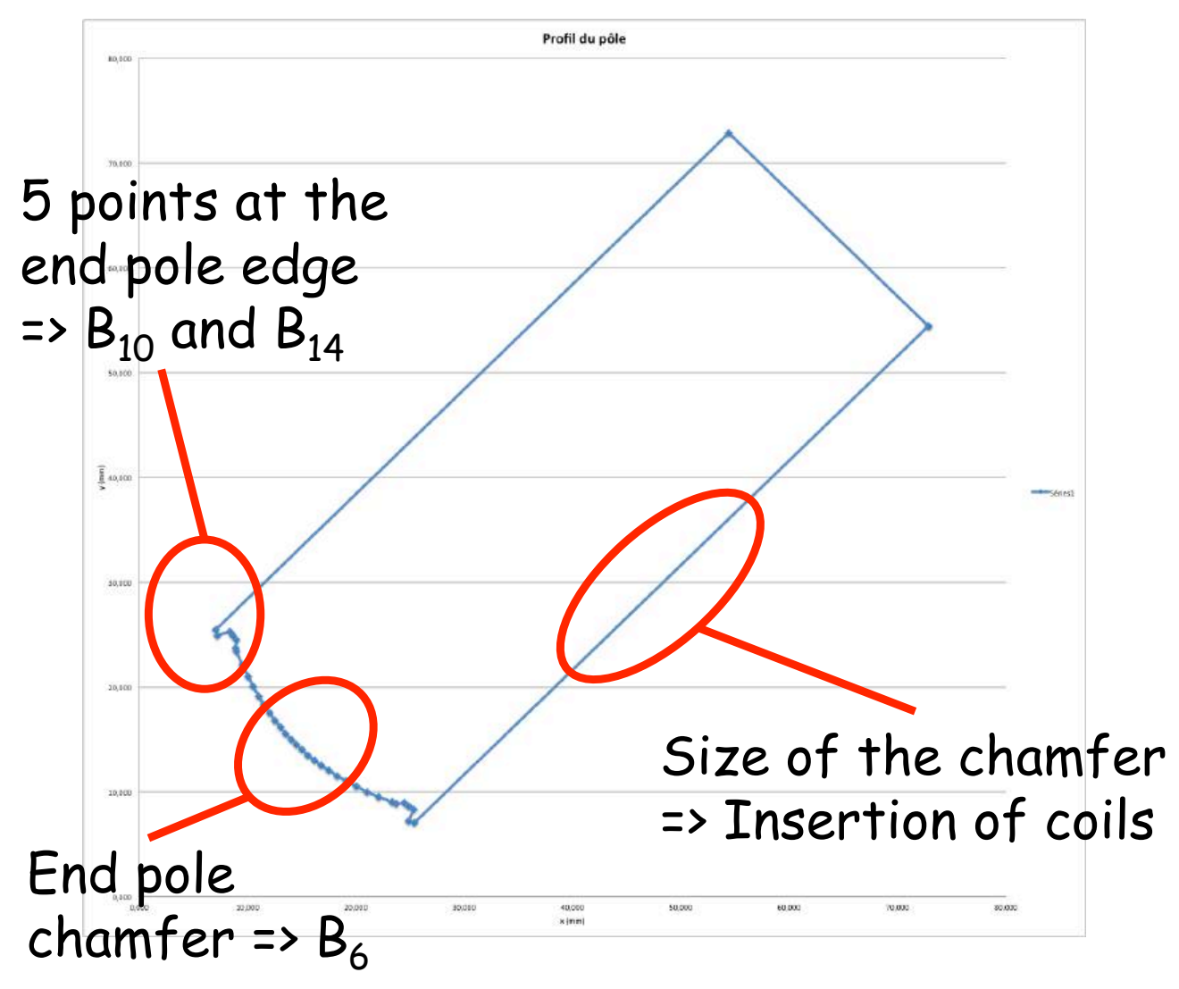
So, the relationship between relative field error at a specific distance x0 and the corresponding multipole is :

$$\left(\frac{\Delta B}{B}\right)_{n,x_0} = \rho.\frac{K_n}{n!}x_0^n$$



QUADRUPOLE

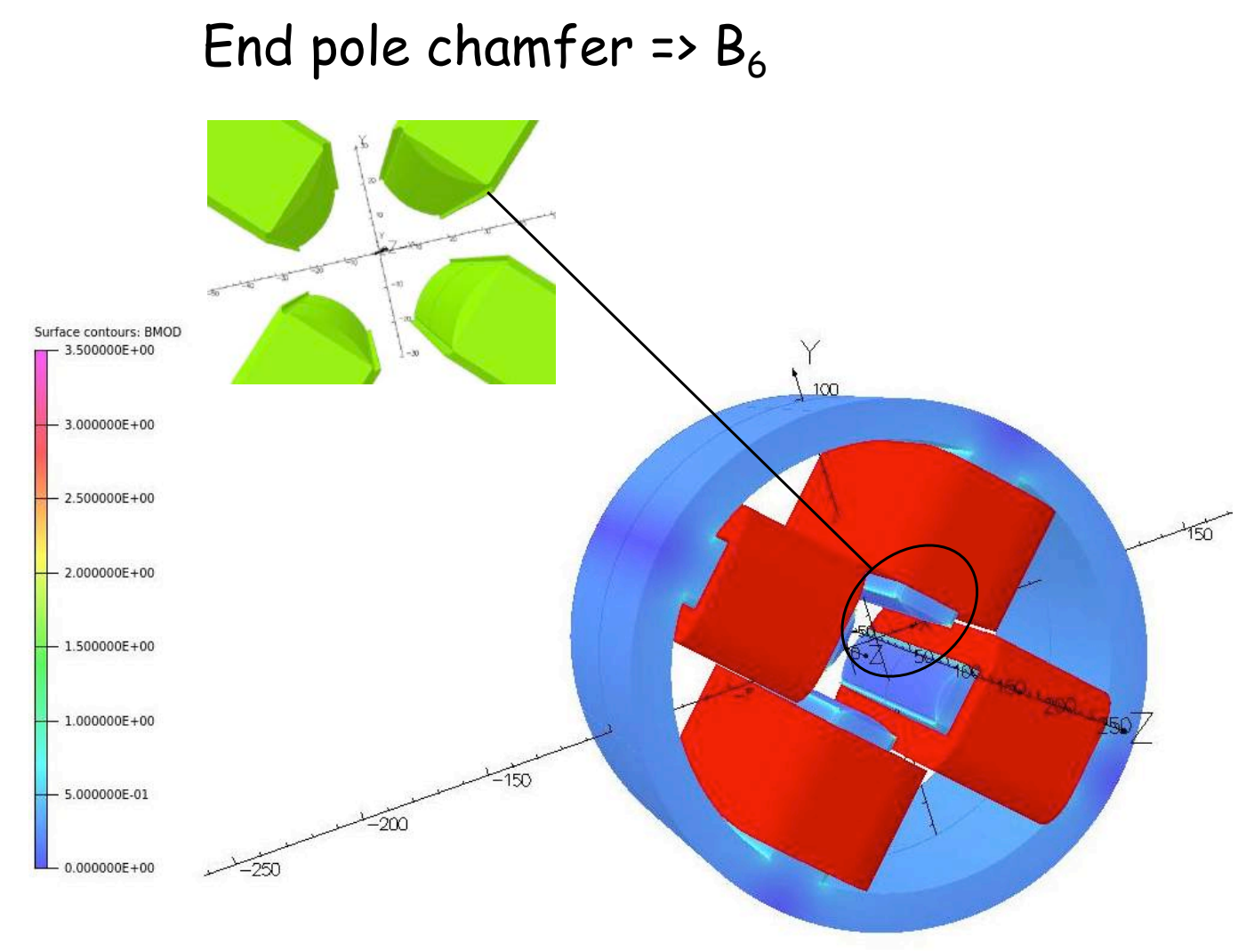
✓Parameters of optimization



A special endeavour has also been done to optimize the profile and the end chamfer, leading to achieve very small multipolar components, and to keep a large dynamic aperture, as well as a large injection efficiency and beam lifetime.

The 5 points at the end of pole edge have been optimized with the module optimizer from OPERA.

✓ Design 3D - OPERA/TOSCA

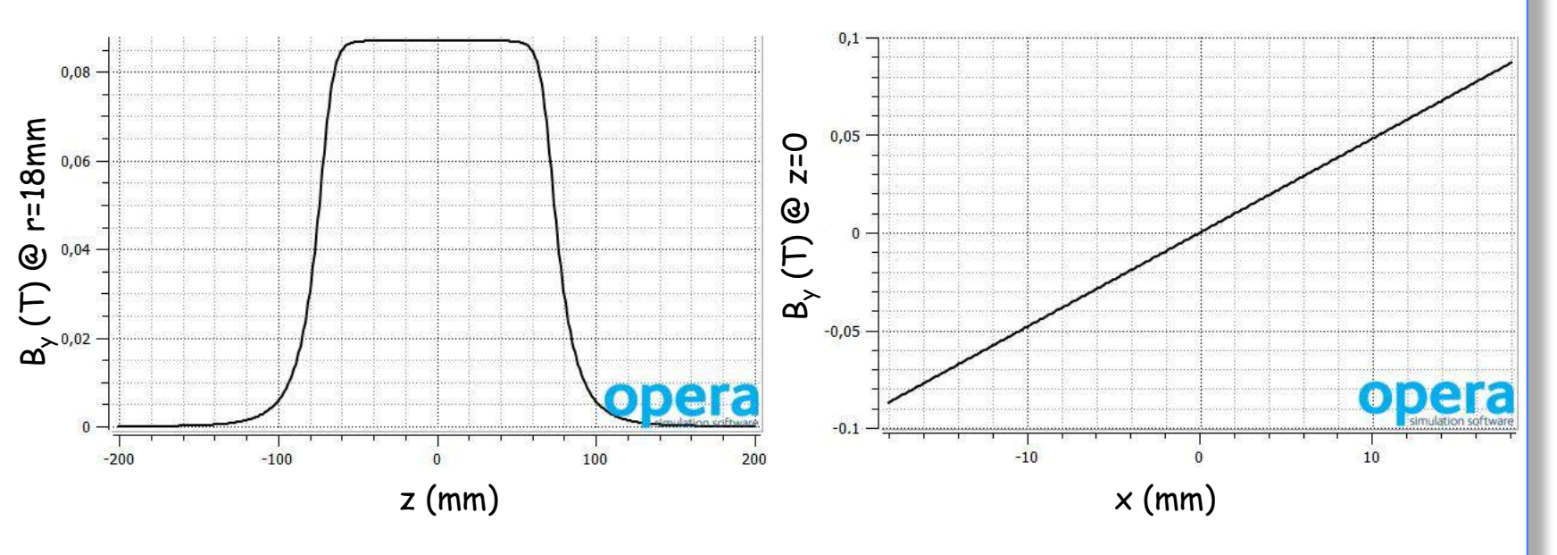


OPERA 3D/TOSCA was used to estimate the field integrated along the magnet trajectory and individual multipole components were evaluated by Fourier analysis on a cylinder.

✓Results of analysis simulations with OPERA

Harmonic Contents B_n/B_2 (1.10^{-4})	End pole chamfer 0*0mm	End pole chamfer 1*1mm	End pole chamfer 2.6*2.6mm
B_6	-34	-21	2
B_{10}	1	-4.5	-6.4
B_{14}	-10	-8.2	-9

The lateral chamfer has been set at 2*2mm in order to facilitate the insertion of the coil around the pole and to minimize harmonic contents.



B_y(z=0) = 0.0869 T @ r=18mm
Integral = 13.6702 mT.m
L_{mag} = 157.16 mm

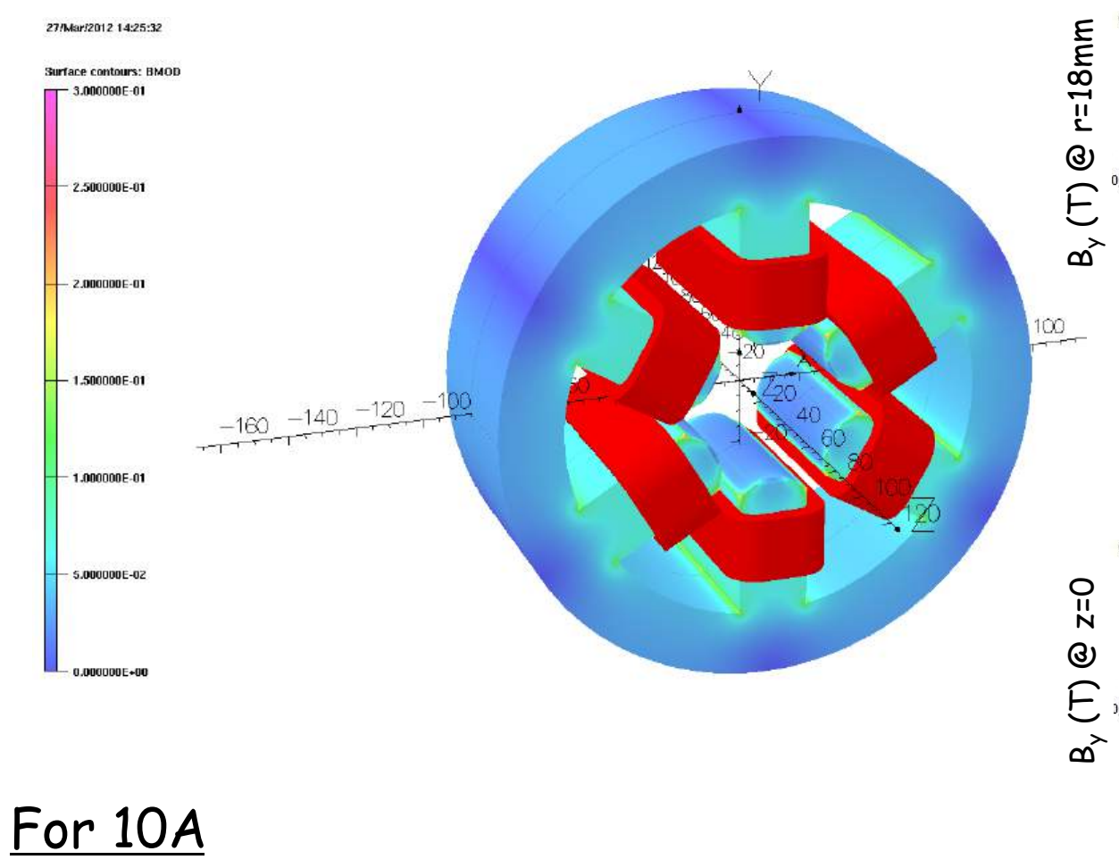
SEXTUPOLE & Dipolar correctors

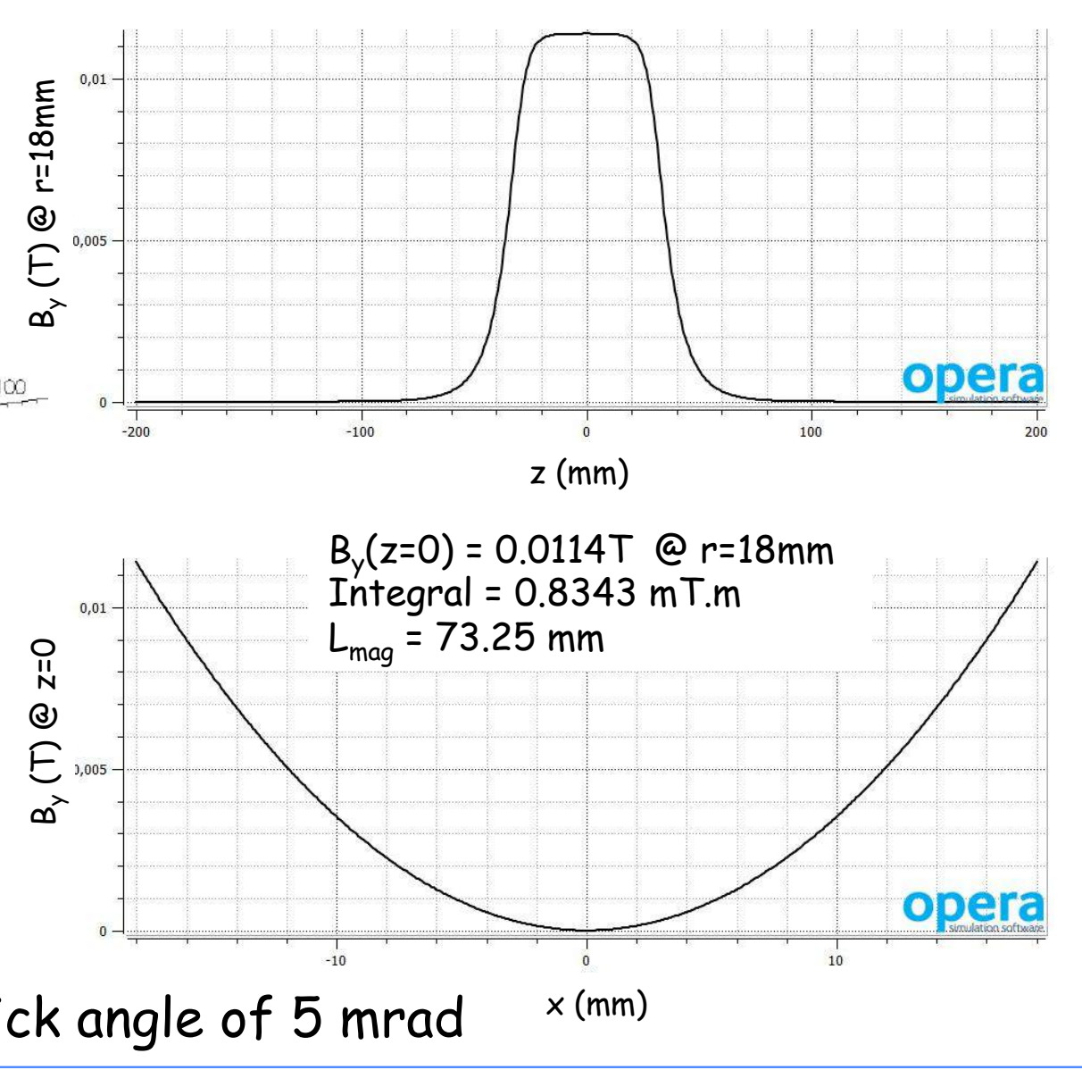
✓Parameters of optimization

The pole shape of the sextupole has been done by fitting the pole end chamfer and by applying the ideal pole shape equation :

$$3x^2y - y^3 = \pm R^3$$

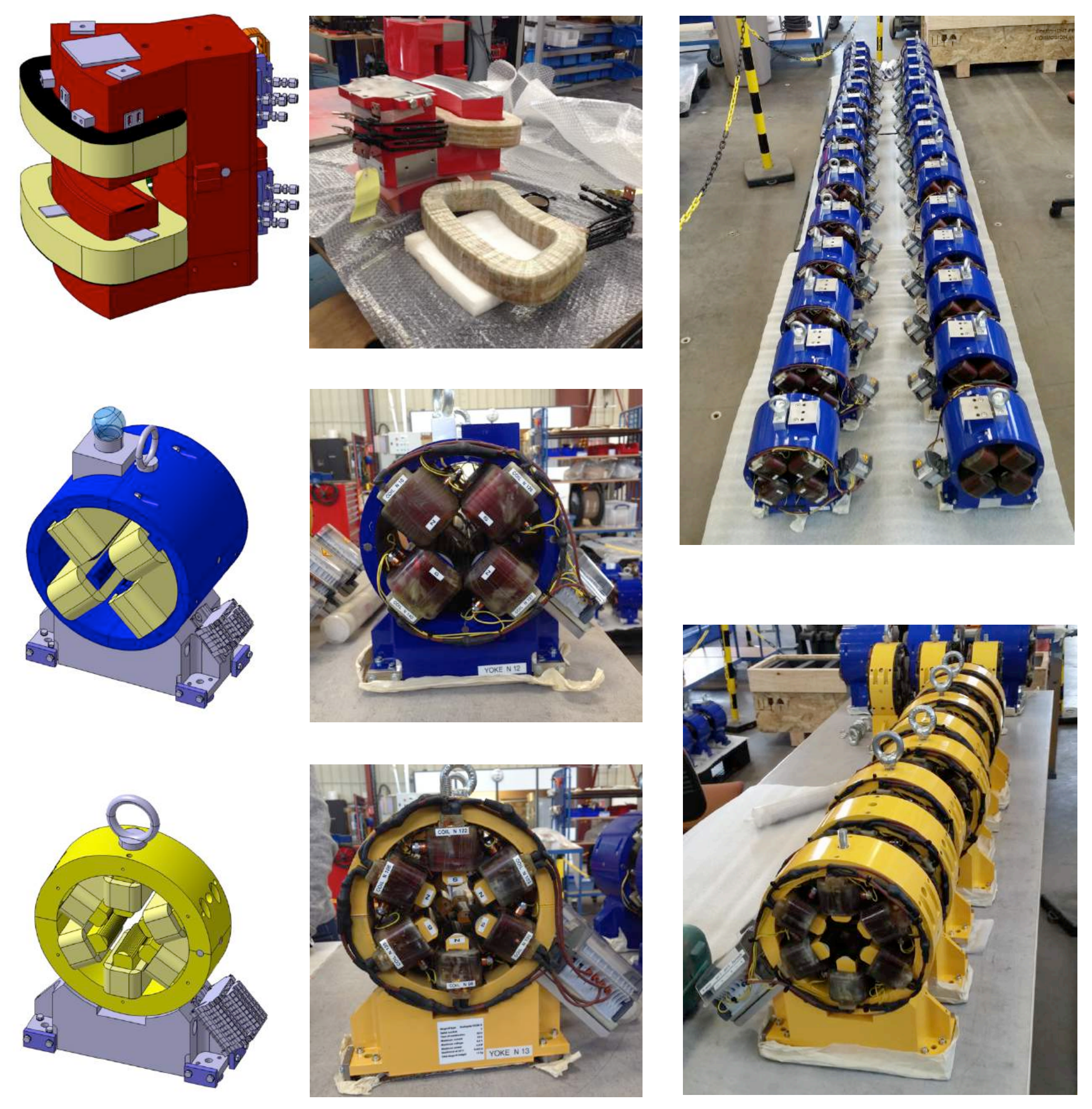
Harmonic Contents B_n/B_3 (1.10^{-4})	Values
B_9	-9.7
B_{15}	6.7
B_{21}	9.1





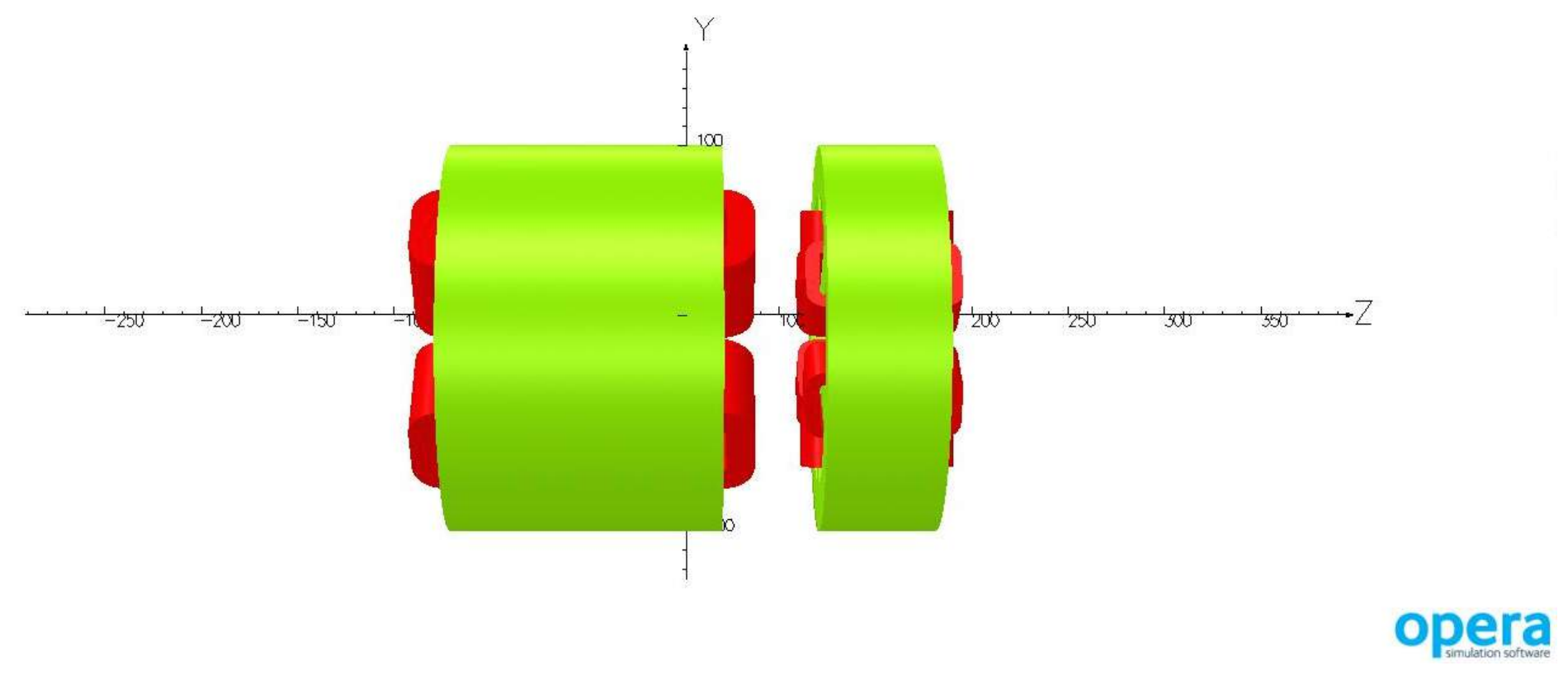
B_y(z=0) = 0.0114T @ r=18mm
Integral = 0.8343 mT.m
L_{mag} = 73.25 mm

<u>For 10A</u>
Horizontal corrector : B_1 = 8.7 10^{-4} T
Vertical corrector : A_1 = 8.1 10^{-4} T so a kick angle of 5 mrad



CROSS-TALK
QUADRUPOLE - SEXTUPOLE

A drawback from the compact lattice is the fringe field mixing between quadrupoles and sextupoles, in particular in the arc region where sextupole yoke are located as close as 50 mm from quadrupole yoke.



Simulations of the sextupole effect on quadrupole and inversely have been done to estimate the impact.

Results of three cases for quadrupole are summarized in the tables below:
- *Case 1: the quadrupole magnet is alone in the space*
- *Case 2: the quadrupole and the sextupole are in the space and only quadrupole magnet is powered*
- *Case 3: Both magnets are powered*

Harmonic contents B_n/B_2 (1.10^{-4}) at Rref = 18mm	Quadrupole alone	Quad ON Sextu OFF	Quad ON Sextu ON
B_6	2.4	2.36	2.36
B_{10}	-6.5	-6.45	-6.45
B_{14}	-9.2	-9.19	-9.19

Results of three cases for sextupole:
- *Case 1: the sextupole magnet is alone in the space*
- *Case 2: the quadrupole and the sextupole are in the space and only sextupole magnet is powered*
- *Case 3: Both magnets are powered*

Harmonic contents B_n/B_3 (1.10^{-4})	Sextupole alone	Quad OFF Sextu ON	Quad ON Sextu ON
B_9	-13	-13.12	-12.95
B_{15}	-4	-4.05	-4.07
B_{21}	-0.22	-0.22	-0.18

Cross-talk simulations have shown that sextupole doesn't affect quadrupole and vice-versa, whatever the configuration, for an inter-distance of 50mm.

Conclusion

Design and manufacturing are done for all THOMX accelerator magnets.
Magnetic measurements are on going :
- At ALBA for quadrupoles and dipoles. Dipoles are measured by by a 3D method Hall probes and quadrupoles by a rotating coil bench
- At LAL for sextupoles by the stretched wire technique, method developed by ESRF
- At SOLEIL for one of each kind of magnets.

All magnets should be installed on girders at the end of this year for a commissioning in 2017.

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