Maurice Duval
Marc-Hervé Stodel
SPIRAL2/GANIL

HRS dipoles

Optical specifications

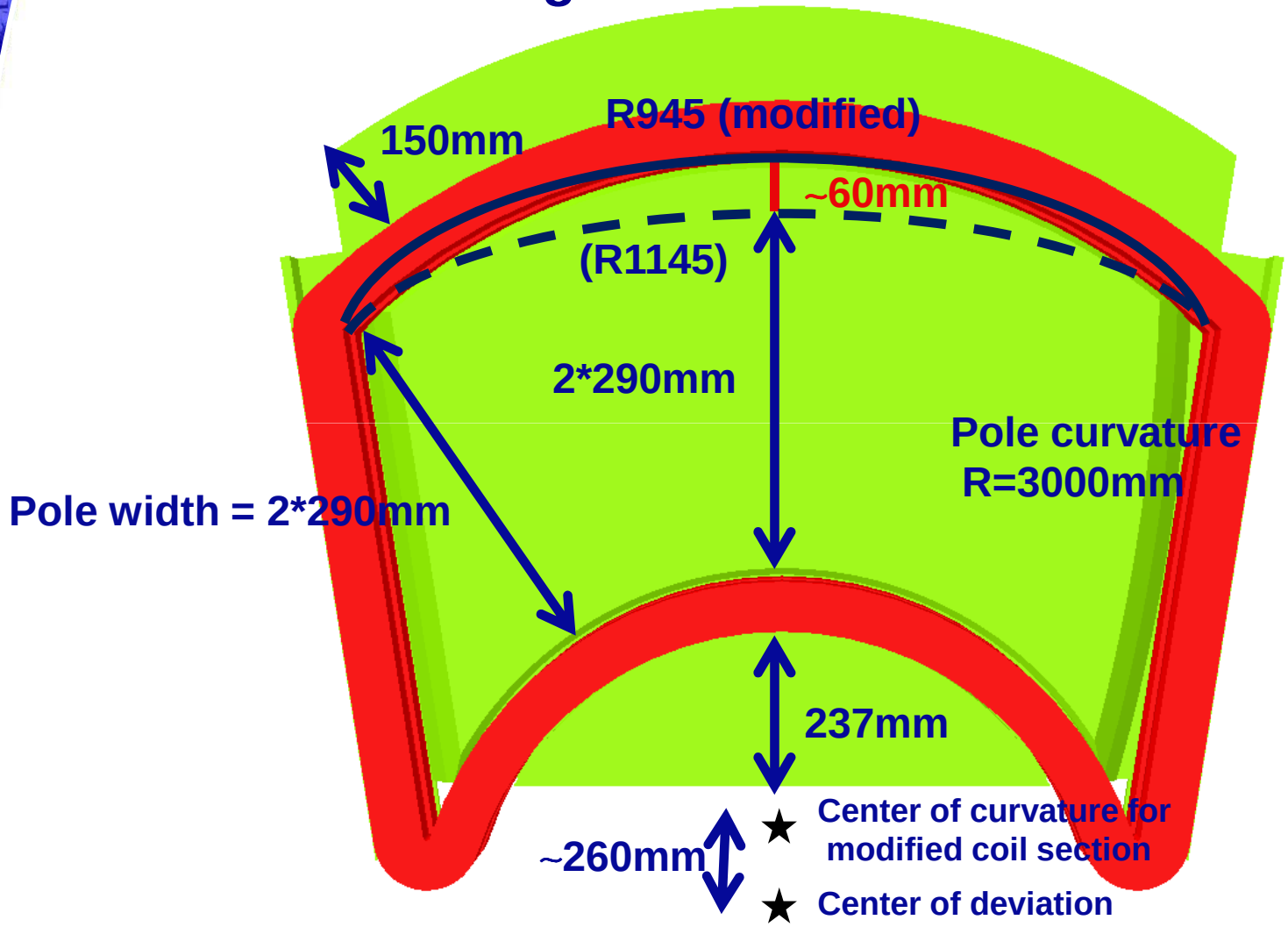
- Bending radius = 850mm
- Deviation = 90 °
- Input and output face angles = 36 °
- Bmin = 1000 Gauss
- Bmax = 5500 Gauss for 1+ (7500 Gauss for S3 low energy branch, to be confirmed)
- Gap = 70mm
- Good field region
  - = +/-150mm (homogeneity 1 to 2 .10^{e}-5 @ Bmax)
  - =+/-200mm (goal: 1.10^{e}-4 @ Bmax)
- Correction 2nd (according to results given by optical simulation codes : Zgoubi, Transport)

Overall Magnet design / Geometry (1/5)

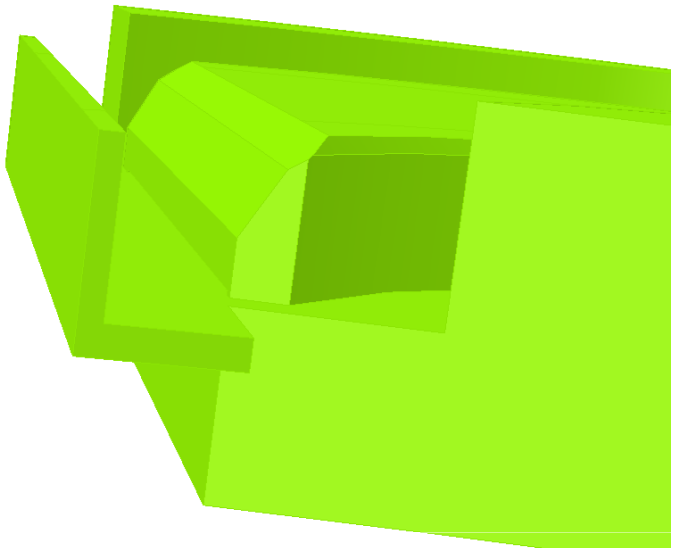
- The best homogeneity in the central zone is achieved using different techniques :
  - Large pole (2*290mm)
  - Lateral chamfer 10*10mm
  - Special curvature on the external part of the coil
  - Intermediate gap of 8mm
  - Shim in the intermediate gap
  - Asymmetrical shims
- The magnetic length (central trajectory) is adjusted with double chamfers and the small “plate coils” (to compensate the length varying with the field intensity)
- Asymmetric pole curvature (R=3000mm)
- Mirror plates

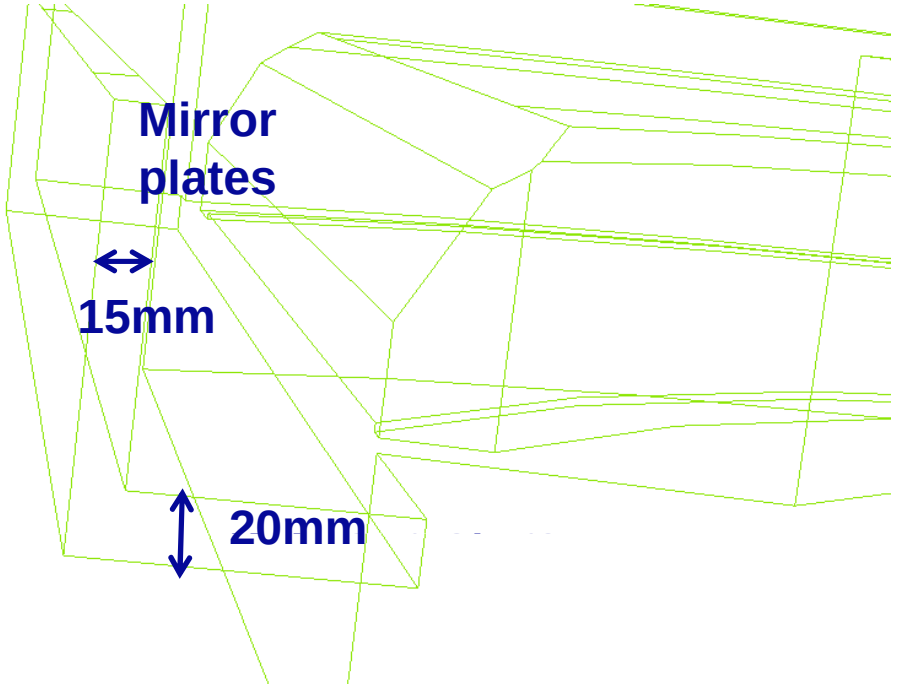
Overall Magnet design / Geometry (2/5)

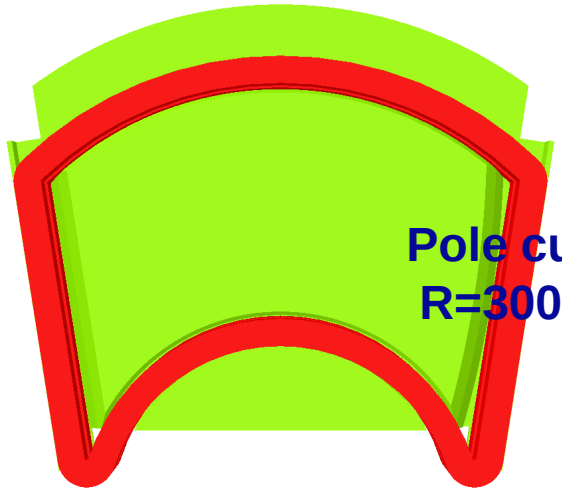
Pole enlarged in the central zone

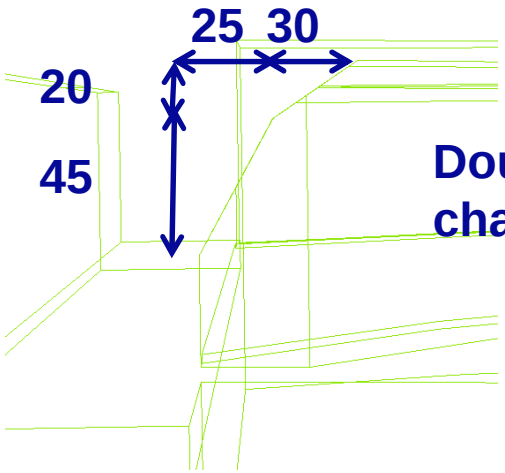


Overall Magnet design / Geometry (3/5)

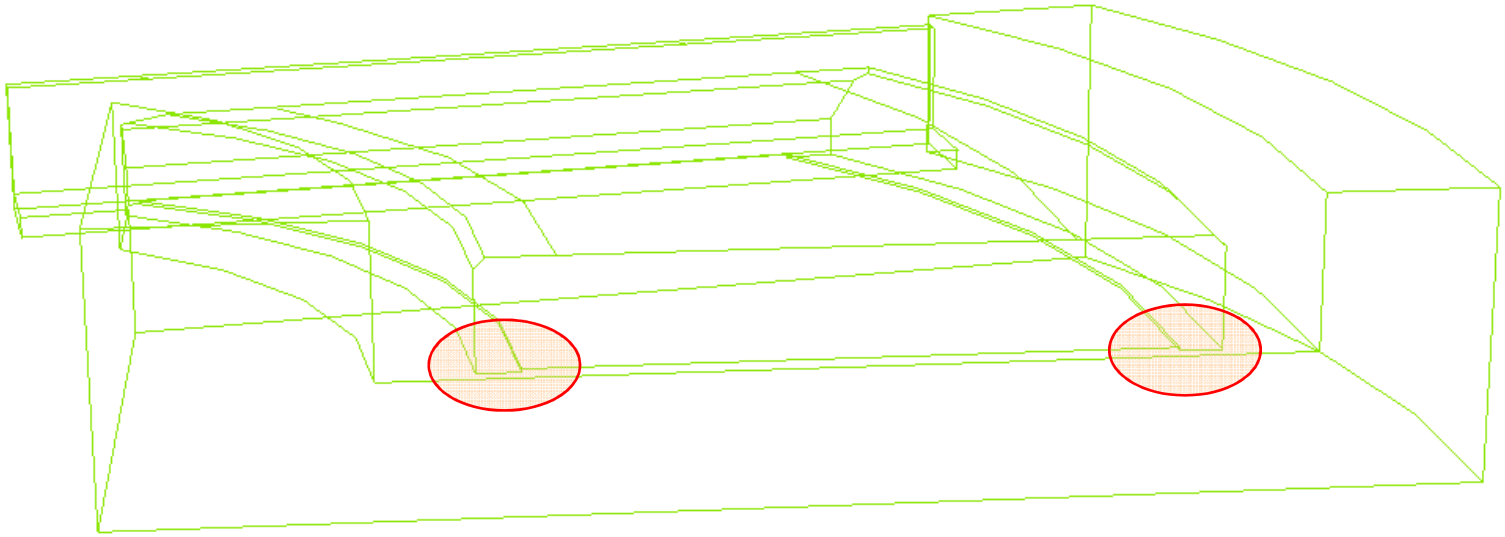




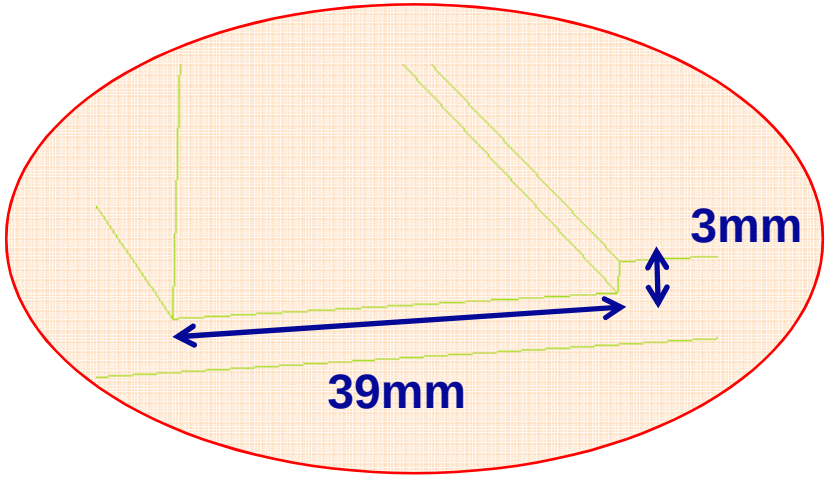


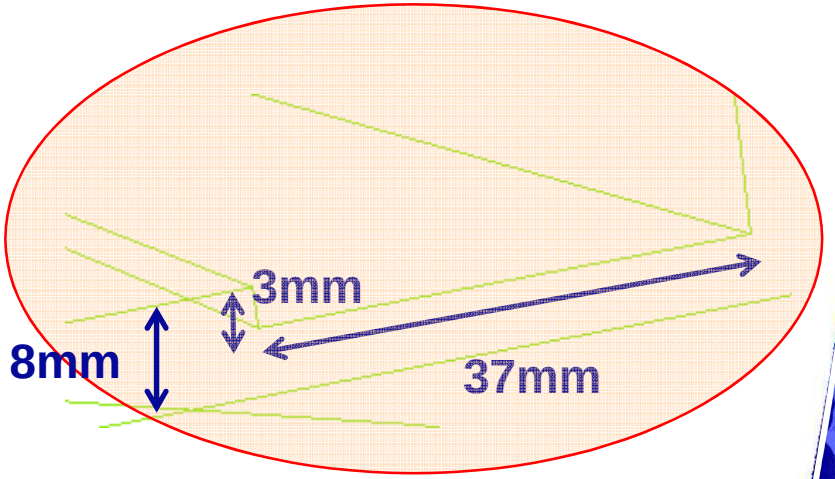


Overall Magnet design / Geometry (4/5)



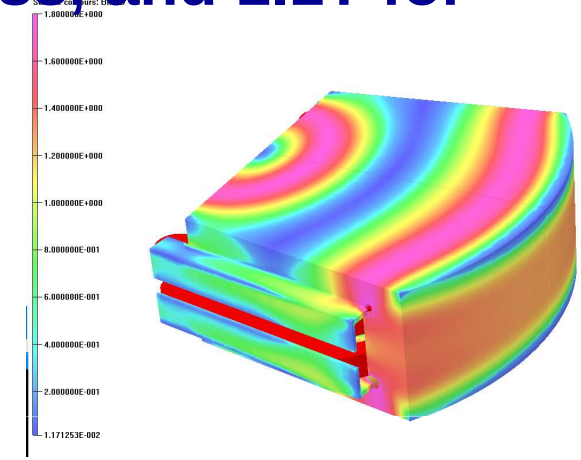
shims



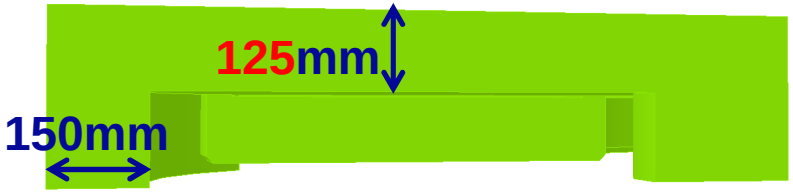


Overall Magnet design / Geometry (5/5)

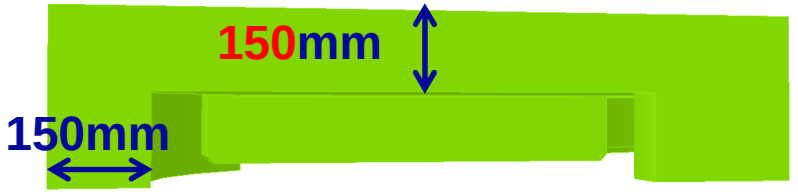
Yokes are balanced, with peak induction at about 1.5 T for 7500 Gauss, and 1.1T for 5500 Gauss



The section is 125mm of iron (external yoke) for 5500 Gauss and should be increased to 150mm for 7500 Gauss



5500 Gauss

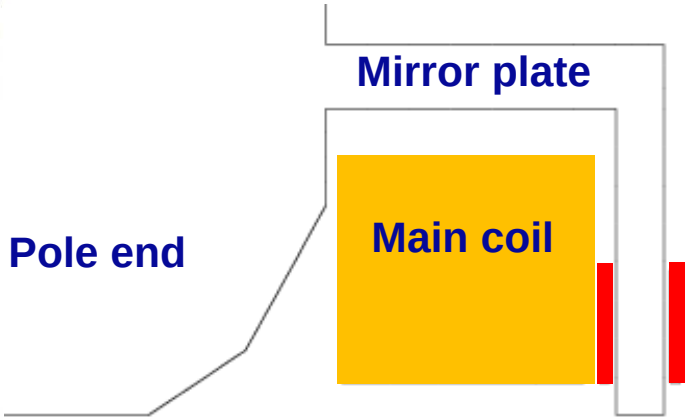


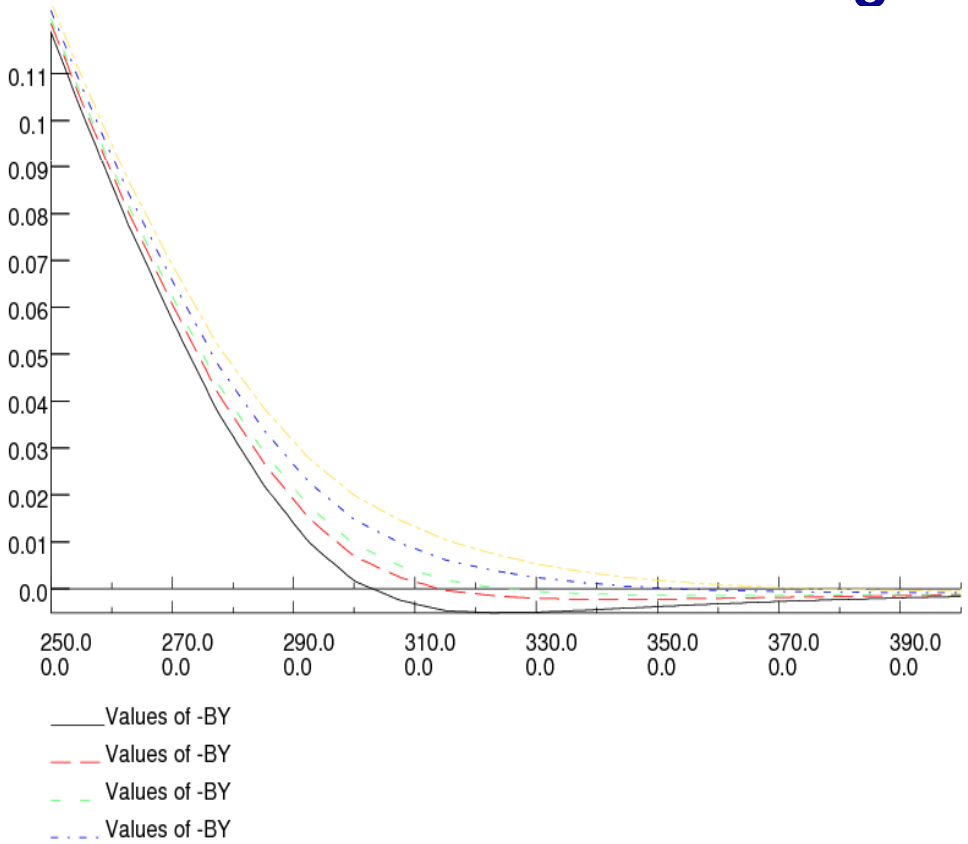
7500 Gauss

Plate coils

Usually, the magnetic length will decrease as the field get stronger.

The idea is to correct these small variations with a tiny coil placed around the mirror plate. It is a kind of electrical shimming.



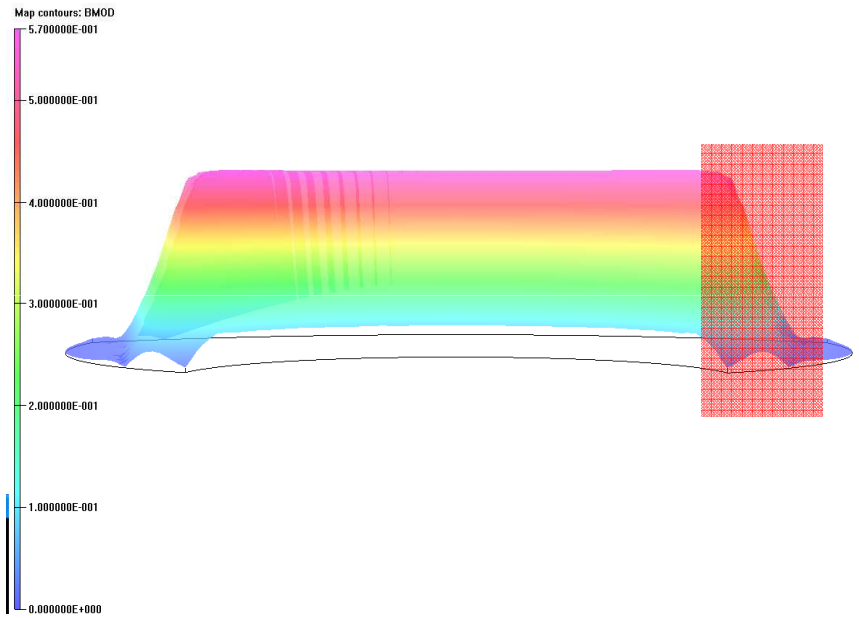


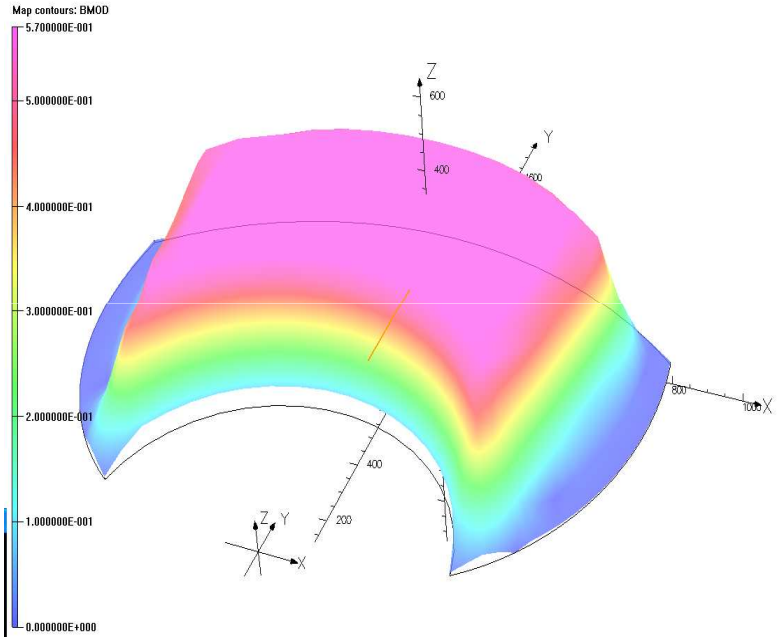
Overall Magnet design / Coils

	Base version	Optional
Bmax	**5500 gauss**	**7500 Gauss**
NI %loss due to saturation	20000A.turns 3.8%	28000 A.turns 15.4% 10.3% (with iron 150mm)
Coil section / average turn length	97mm*75mm 4.5m	116mm*75mm 4.5m
Number of turns Number of circuits	80 5	96 6
Power supply	250A/70V/17.5kW	295A /97V/29kW
Temp. rise Water flow	17 degrees 15 l/min	23 degrees 18 l/min

Performances / transverse @ +/-150mm

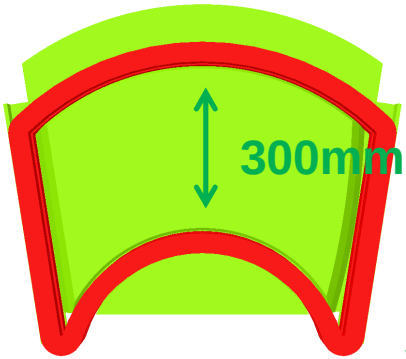
- **Reminder : the hard edge model versus the reality**



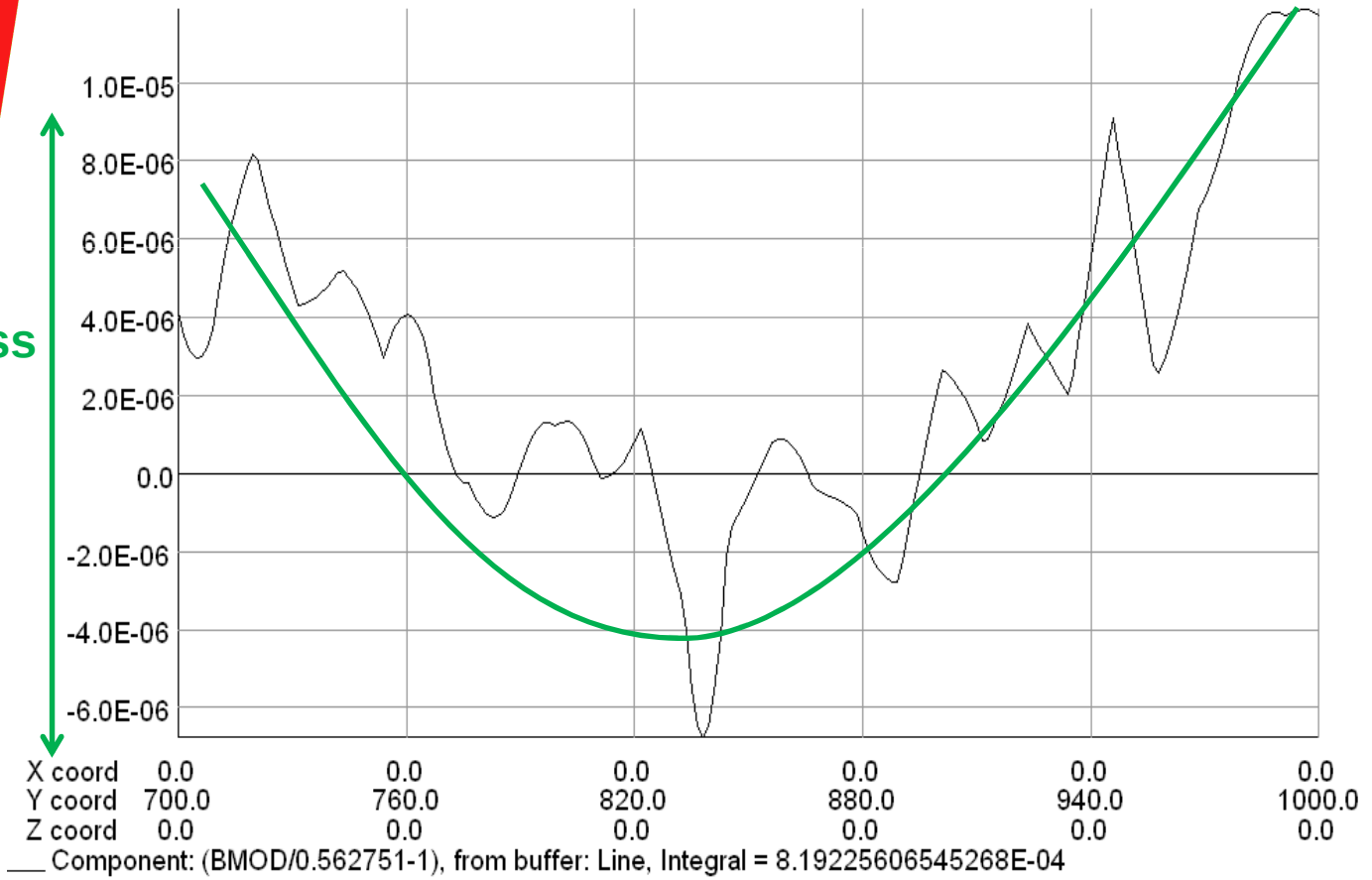


Performances / transverse @ +/-150mm

- Homogeneity 1.6 10^{e}-5 ☺

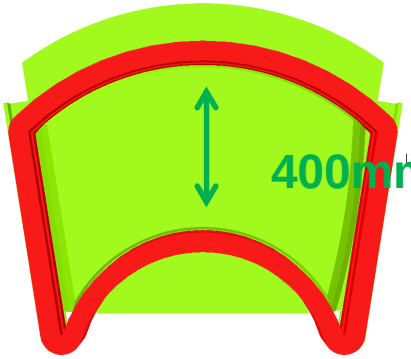


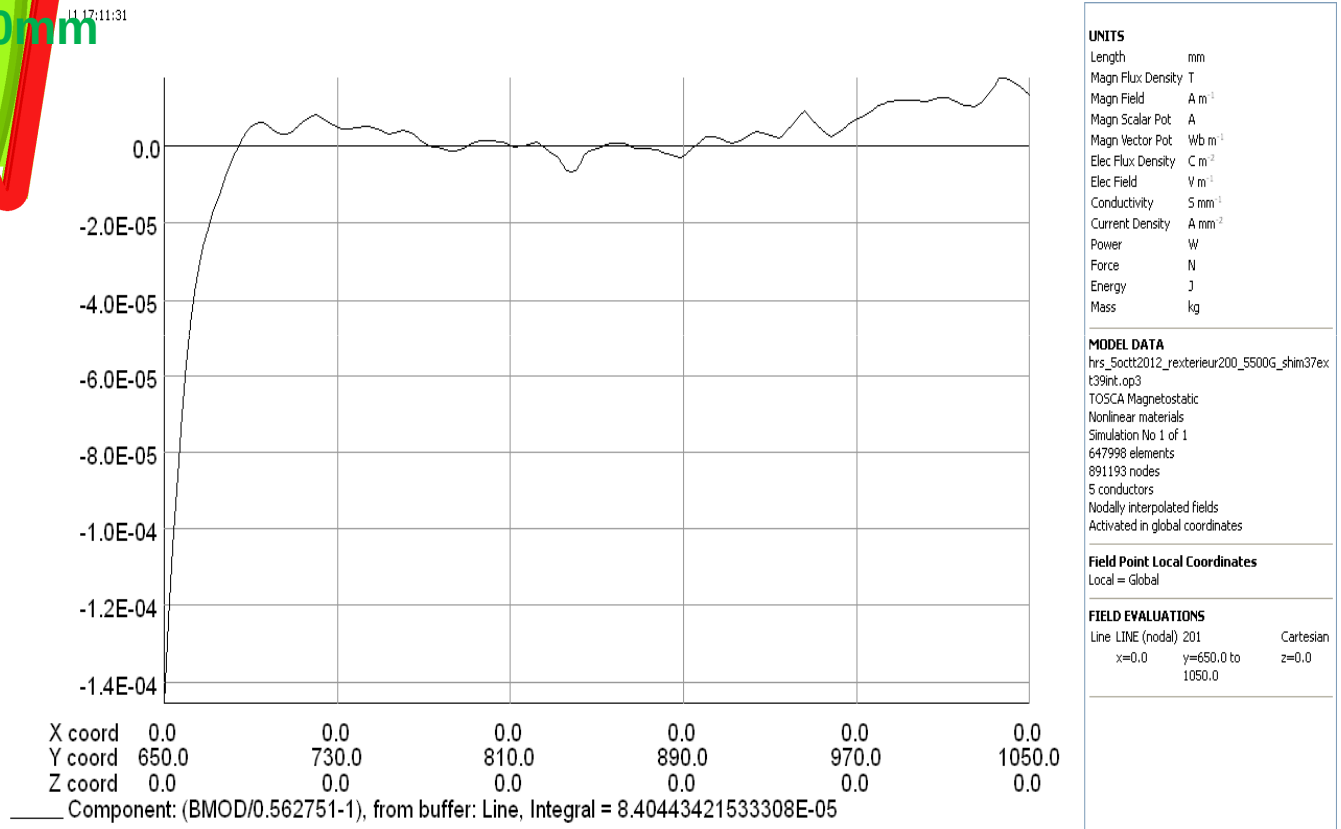
0.09 Gauss !!!



Performances / transverse @ +/-200mm

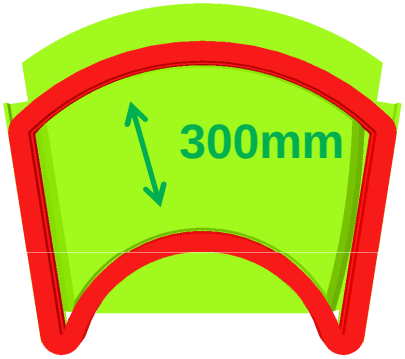
- **Homogeneity around 1.10^{e}-4**

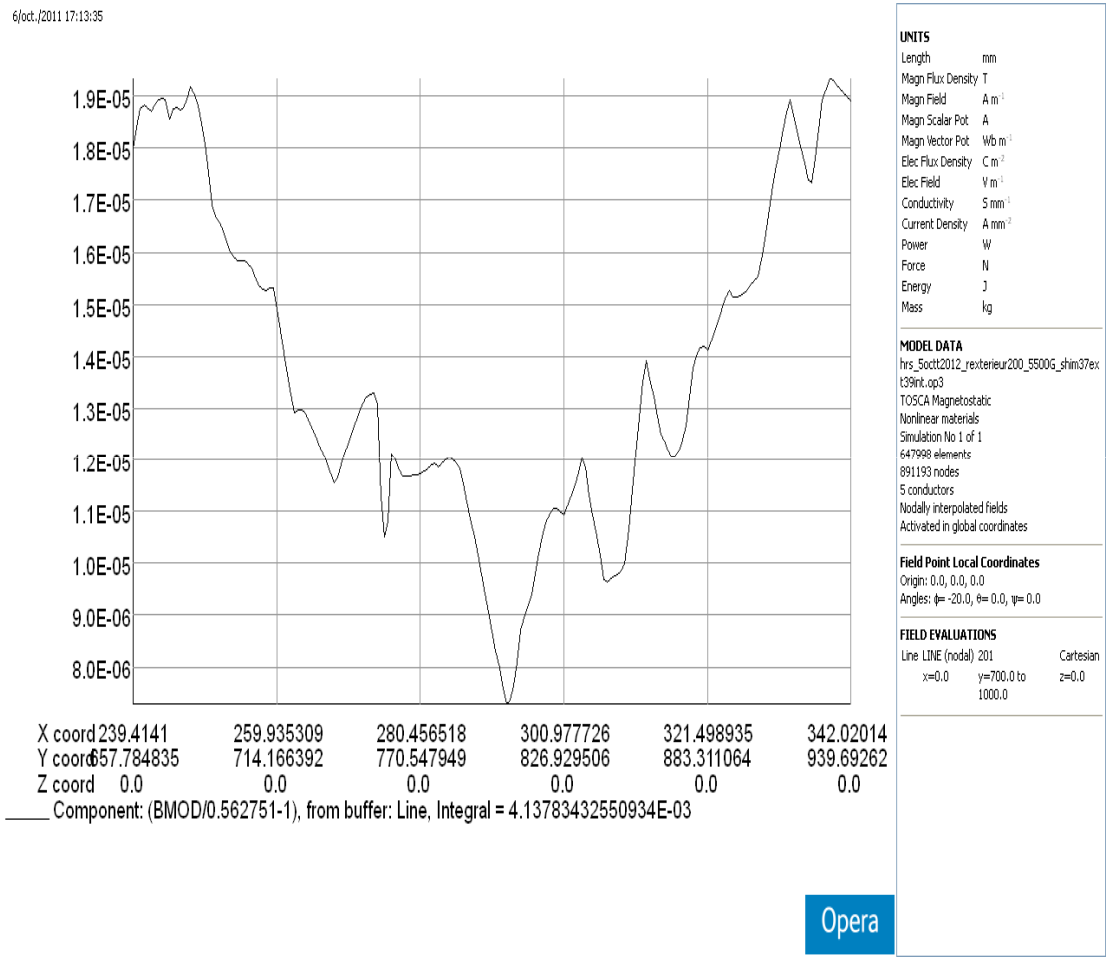




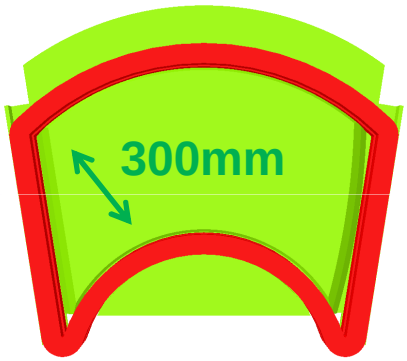
Performances / transverse @ 20°

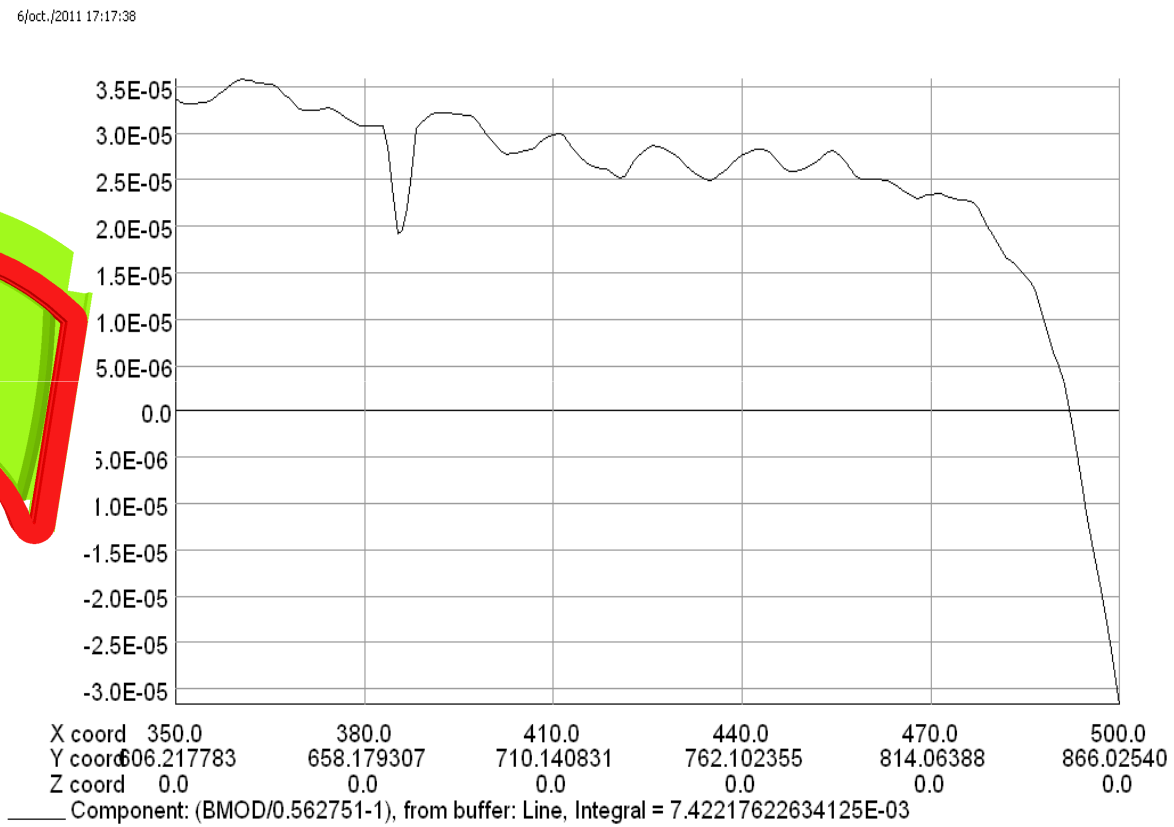
- **Still good**





Performances / transverse @ 30°





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

MODEL DATA

hrs_5octt2012_rexterieur200_5500G_shim37ext39int.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
647998 elements
891193 nodes
5 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates

Origin: 0.0, 0.0, 0.0
Angles: ϕ= -30.0, θ= 0.0, ψ= 0.0

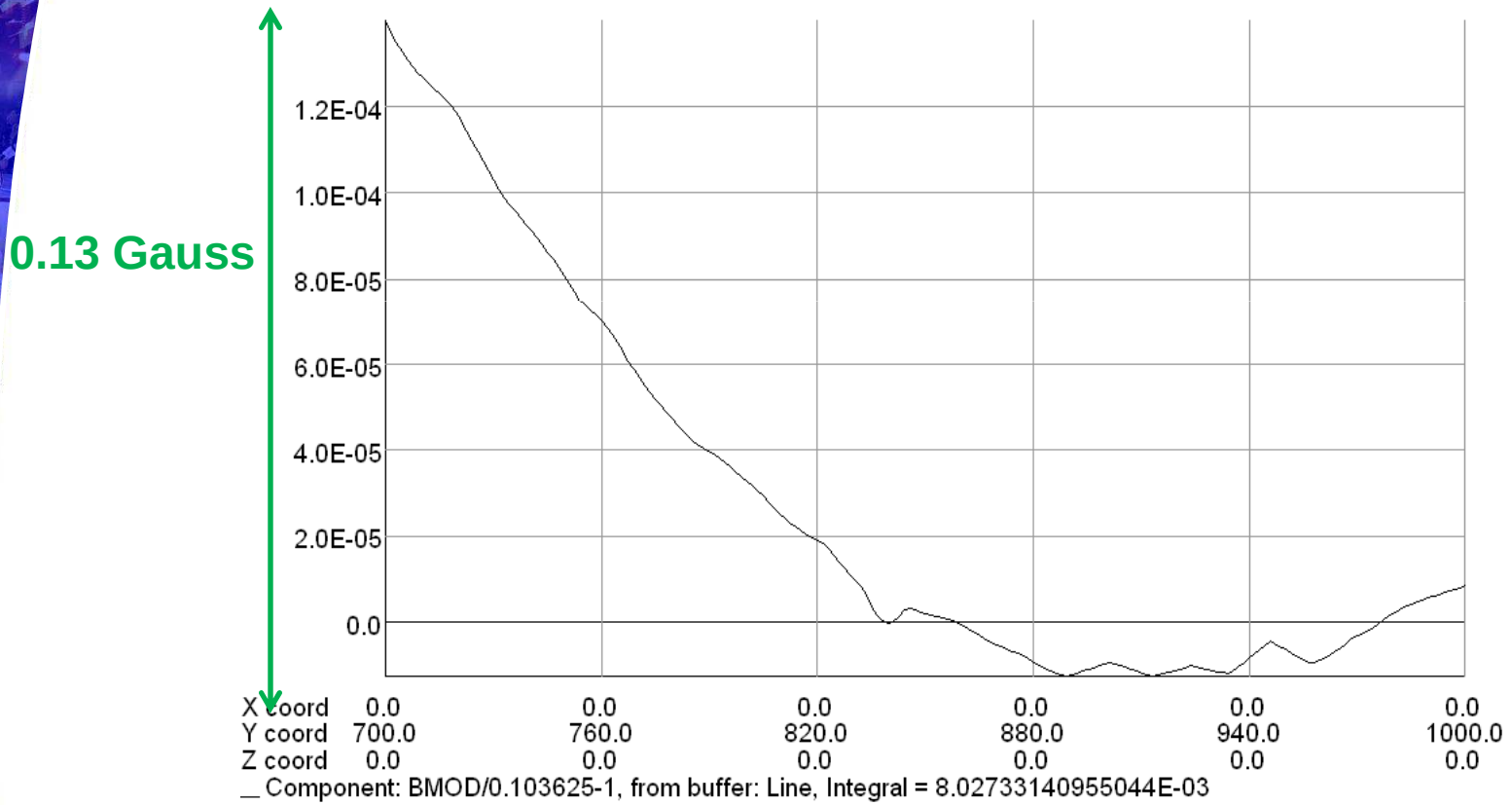
FIELD EVALUATIONS

Line	LINE (nodal)	201	Cartesian
	x=-3.5527E-14 to 0.0	y=700.0 to 1000.0	z=0.0

Opera

Performances@ 1000 Gauss

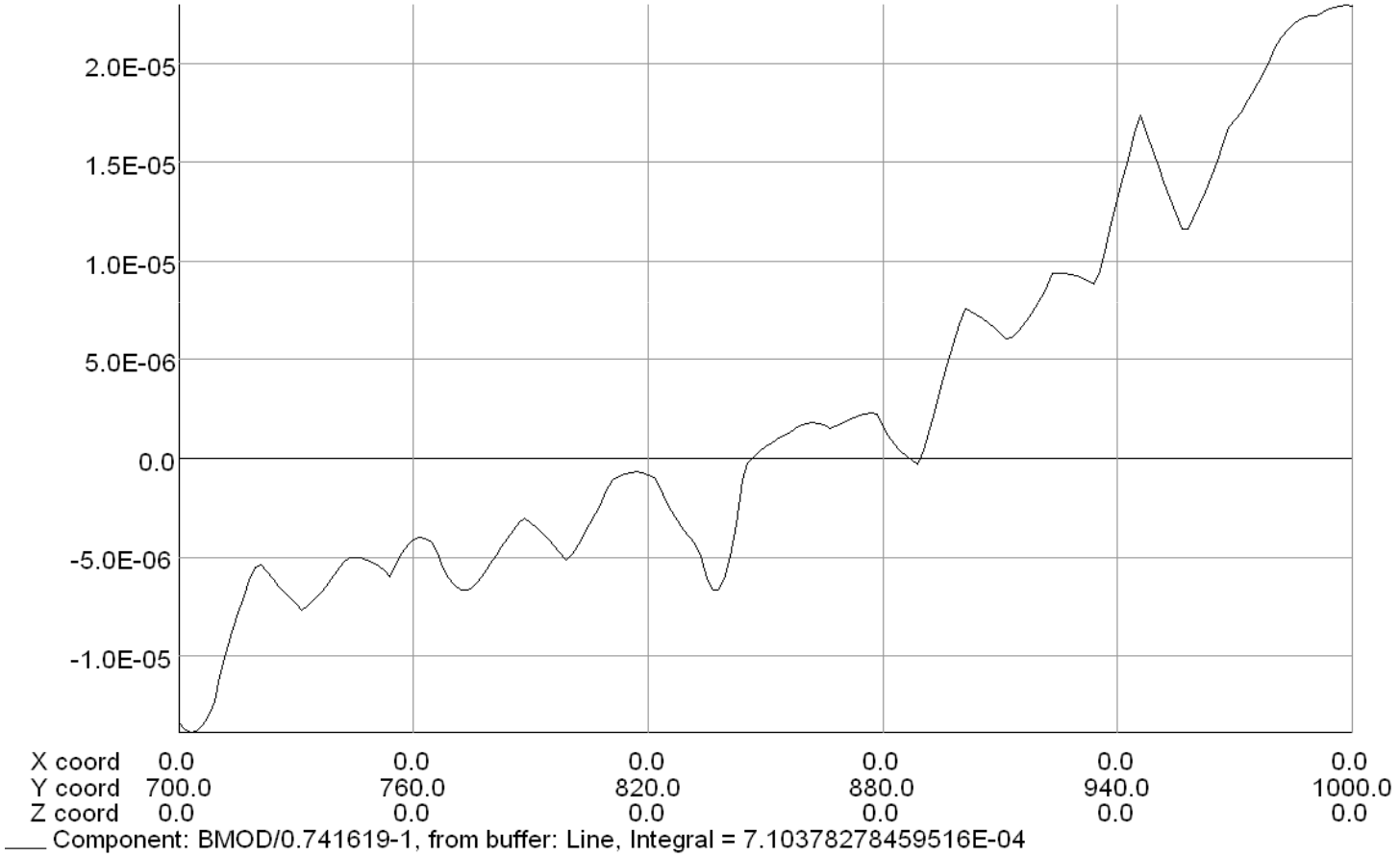
- **Homogeneity 1.3 10^{e}-4 however, in term of absolute value, this is already small.**



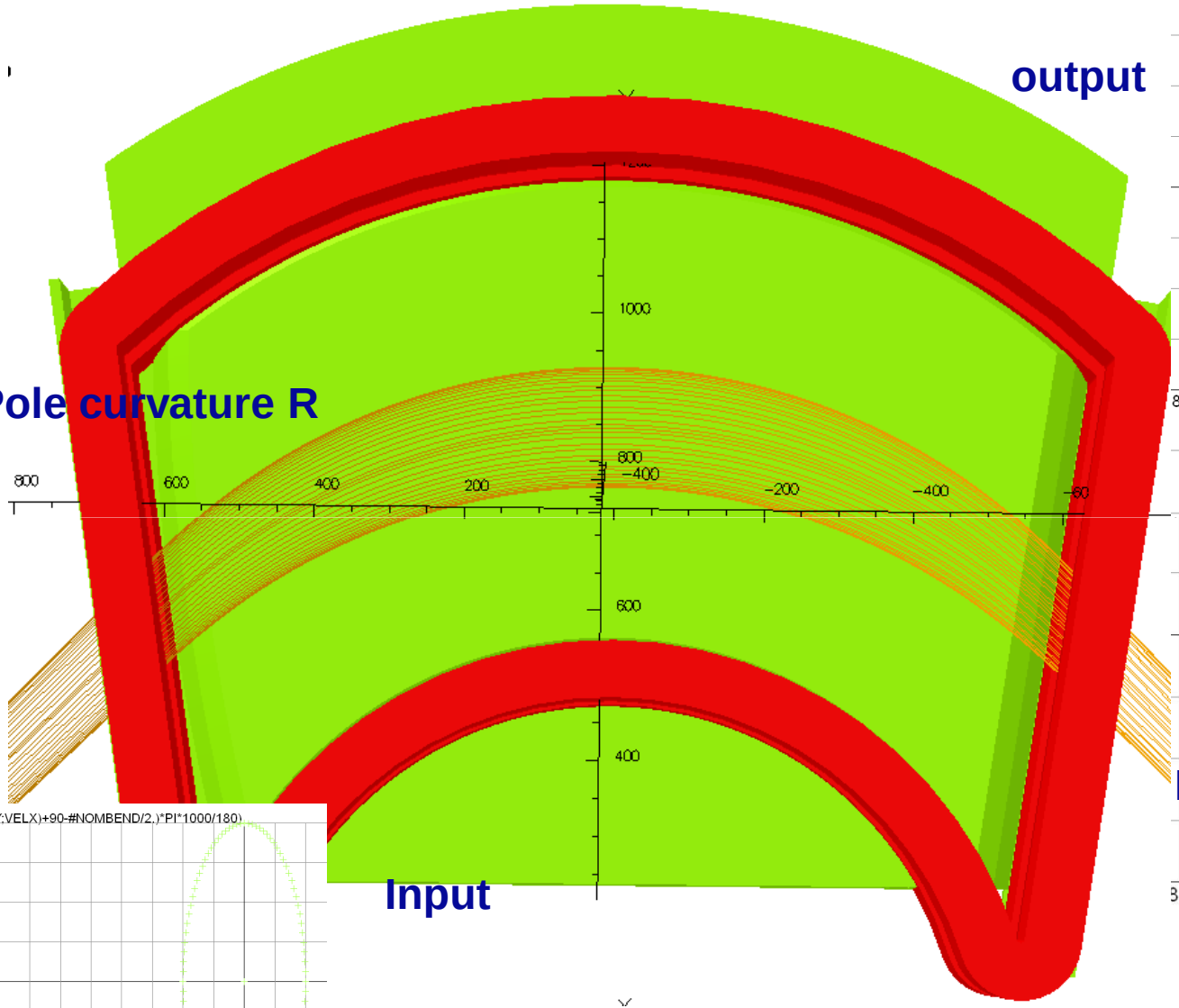
Performances @ 7500 Gauss, optional version

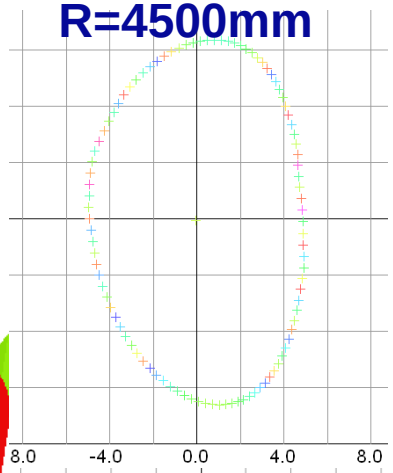
- **Iron section increased to 150mm,**

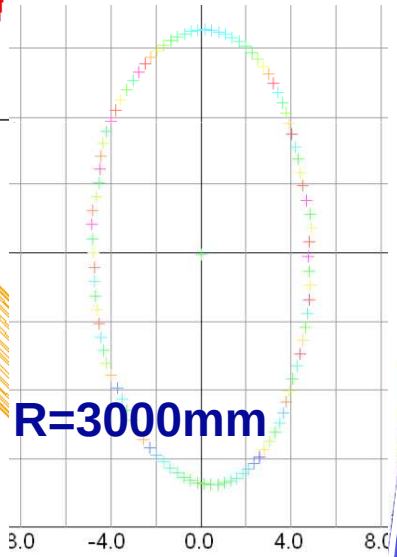
Homogeneity 3.10e-5

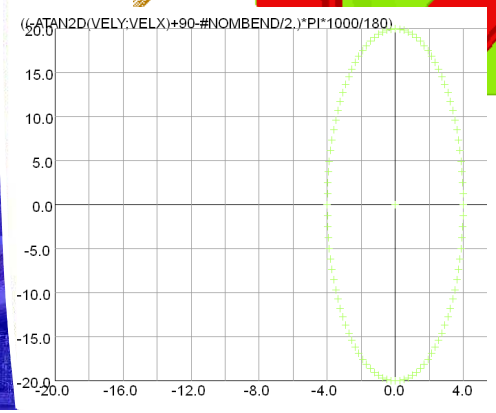


2nd order correction





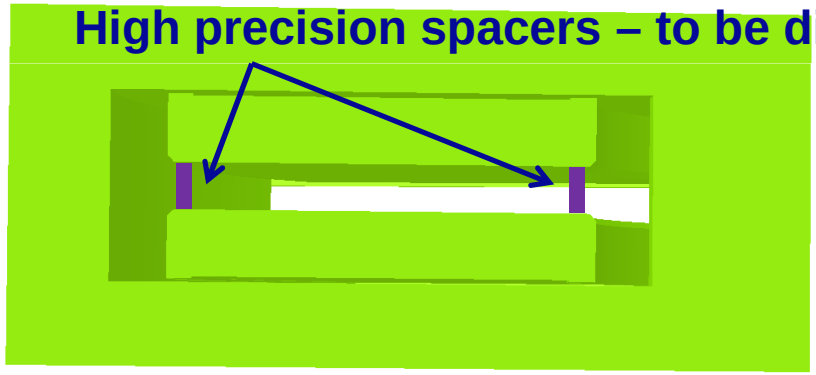




Opera

Tolerances / Fabrication

- Best achievable mechanical tolerance = 2/100^{e} mm => on a 70mm gap, this represents a default of B of 1.6 Gauss (@5500 Gauss) or 3.10^{e}-4 in homogeneity
- Fabrication : floating poles method



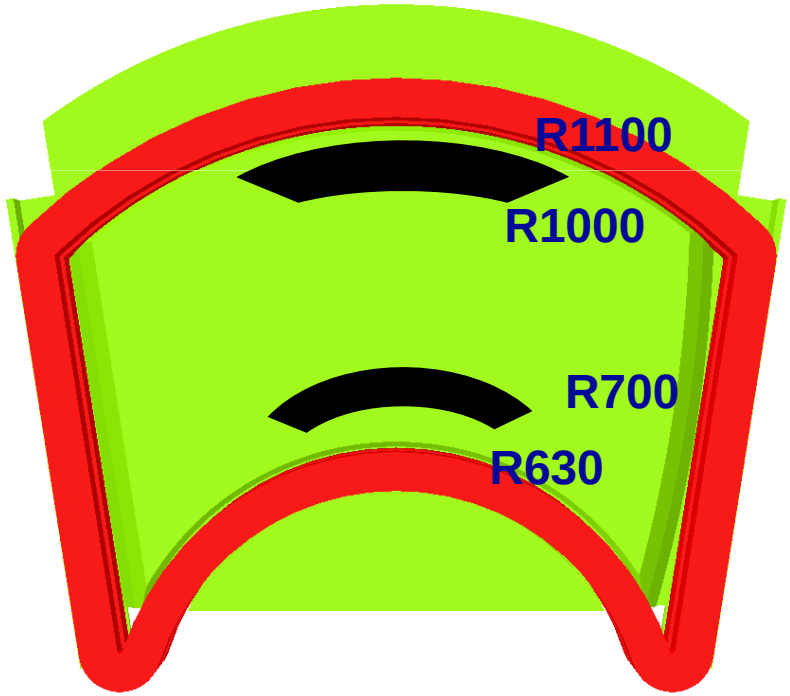
- Other mechanical values (chamfers, shim) have “less” influence, but some options are to be considered (removable pole ends,…)

RMN

- **Based on current version of NMR probes (Metrolab 1080), the required probes are :**

Probe ranges[Tesla]	Required field homogeneity[ppm/cm]
R = 2 1H from 0.11 to 0.26	1200
R = 3 1H from 0.17 to 0.52	1200
R = 4 1H from 0.35 to 1.05	1500

Possible zones for the NMR probes



Cost / planning

- Cost comparable with other dipoles of the same weight (5 tons).
  Complexity/precision plays probably a minor role.
- planning :
  - Mechanical integration : ???
  - Drawing & technical specifications: around 2 weeks
  - Call for tender : around 10 weeks to get a contract signed
  - Realization: 12 to 16 months from the kickoff meeting.

On going / Open ends

- (Optics validation)
- Unified specification with S^3
- Elaborate on the “plate coils” : type of conductor, size, current.
- Power supply (-ies) : 1 or 2, correction coils
- Vacuum chamber, shape, material (non-magnetic material like aluminum looks mandatory)
- Mechanical integration / drawings