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Improvement of design and manufacturing of a 90° dipole for hadrontherapy gantry

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Magnet Design Workshop – PAC – June 2007

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Imrpovement of design and manufacturing of a 90° dipole for hadrontherapy gantry

Part 1 – Magnet in its context

Part 2 - Starting point – HICAT 90° Magnet Design

(magnet made by SIGMAPHI for GSI in 2001)

Part 3 - 2D and 3D Magnetic computations

A. 3D Model - Construction and Validation

B. Improvement of the initial design

C. Manufacturing tolerances effects

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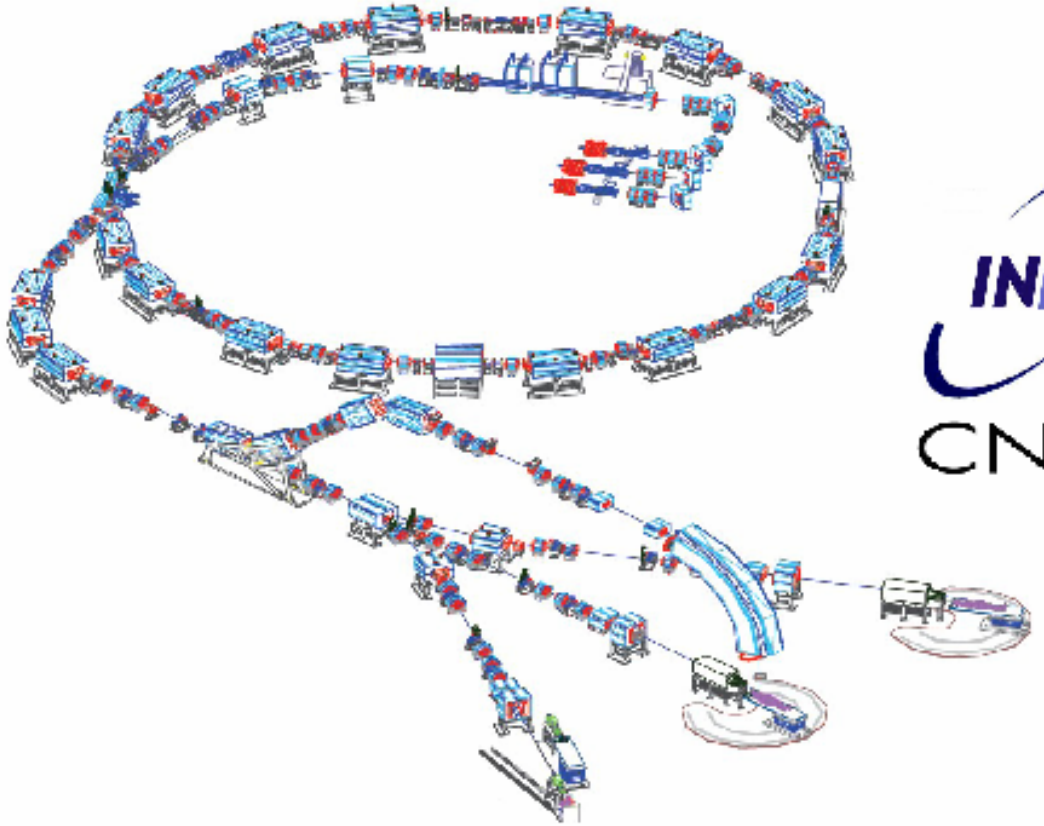
Part 1 – Magnet in its context

CNAO hadrontherapy facility (Pavia - Italy)

$^{12}C^{6+}$ up to
400 MeV/u

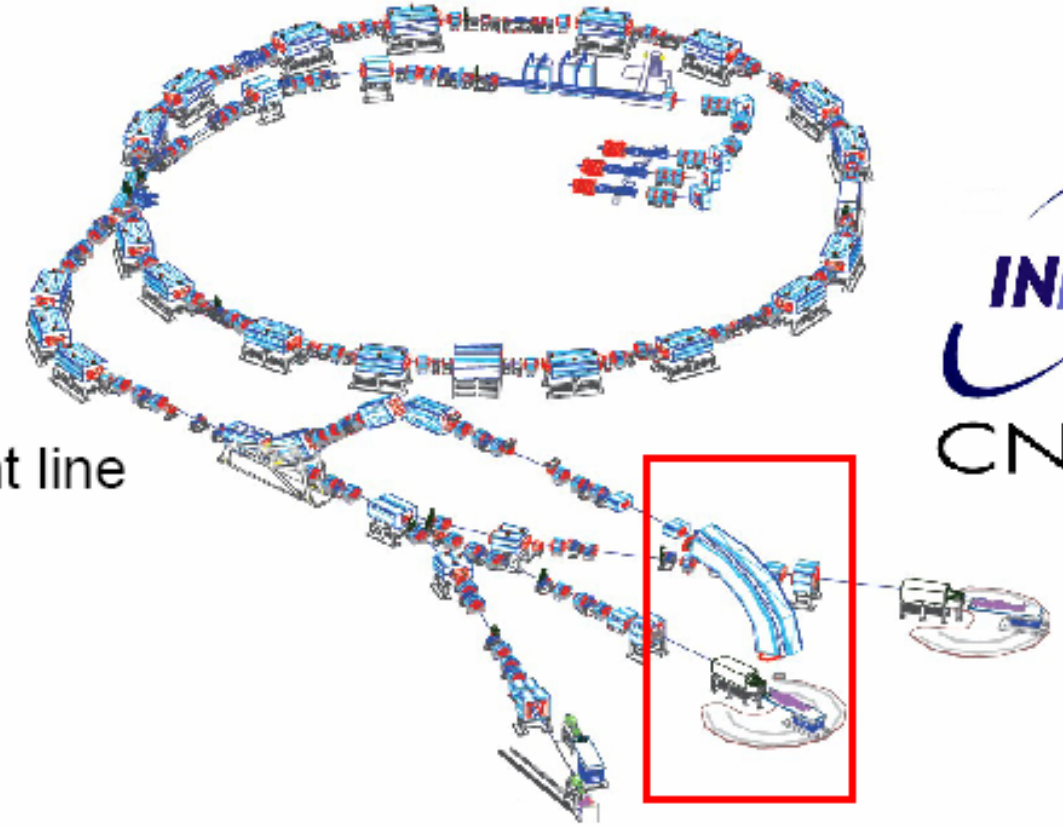


Part 1 – Magnet in its context

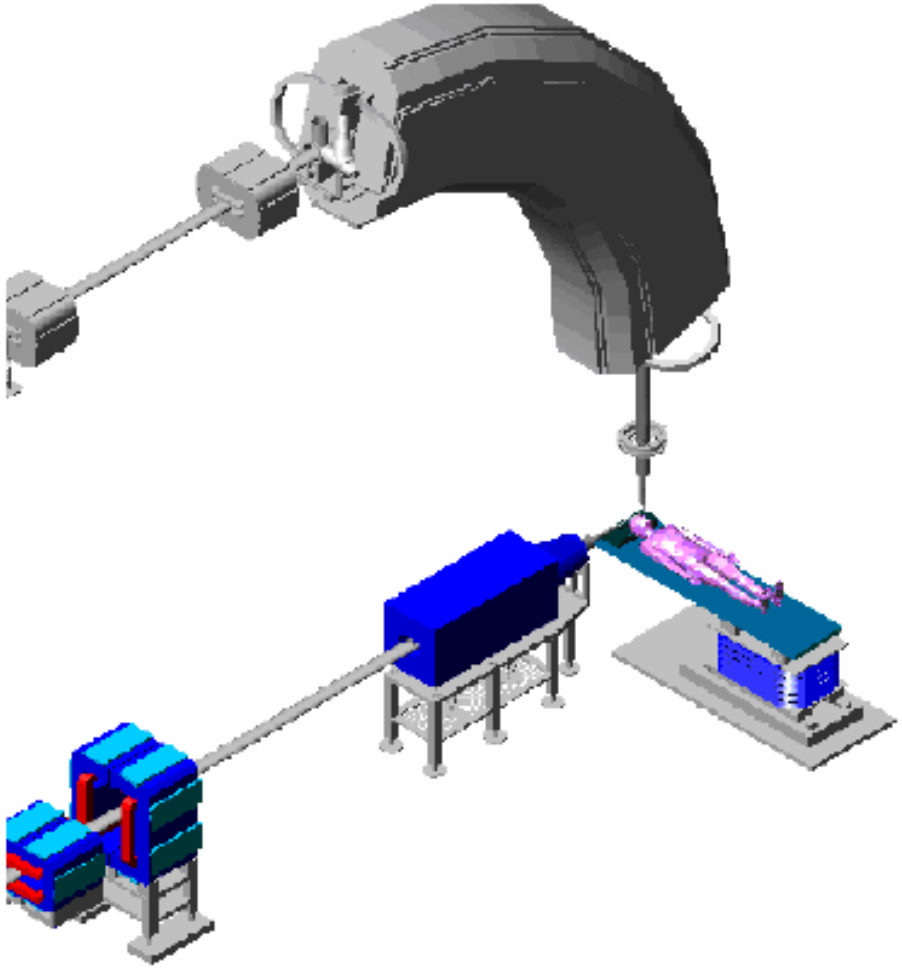
CNAO hadrontherapy facility (Pavia - Italy)

$^{12}C^{6+}$ up to
400 MeV/u

3 horizontal +
1 vertical treatment line

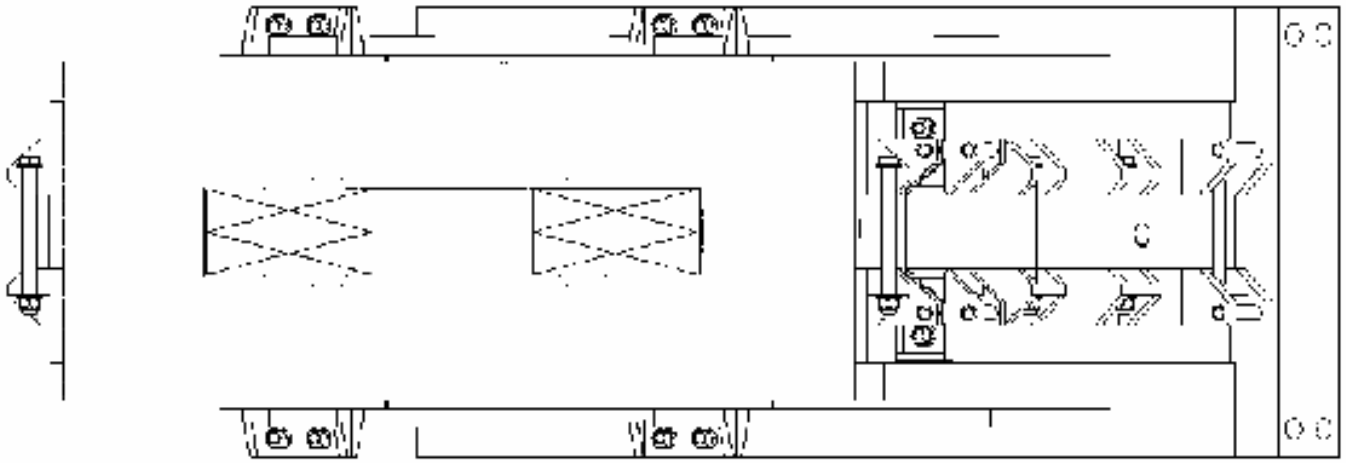


Part 1 – Magnet in its context



Part 2 – Starting point – HICAT 90° Gantry Dipole Magnet

Designed at GSI by A. Kalimov, B. Langenbeck, C.Muhle *et al*



GSI design : window frame magnet. Use of slots to inprove field quality

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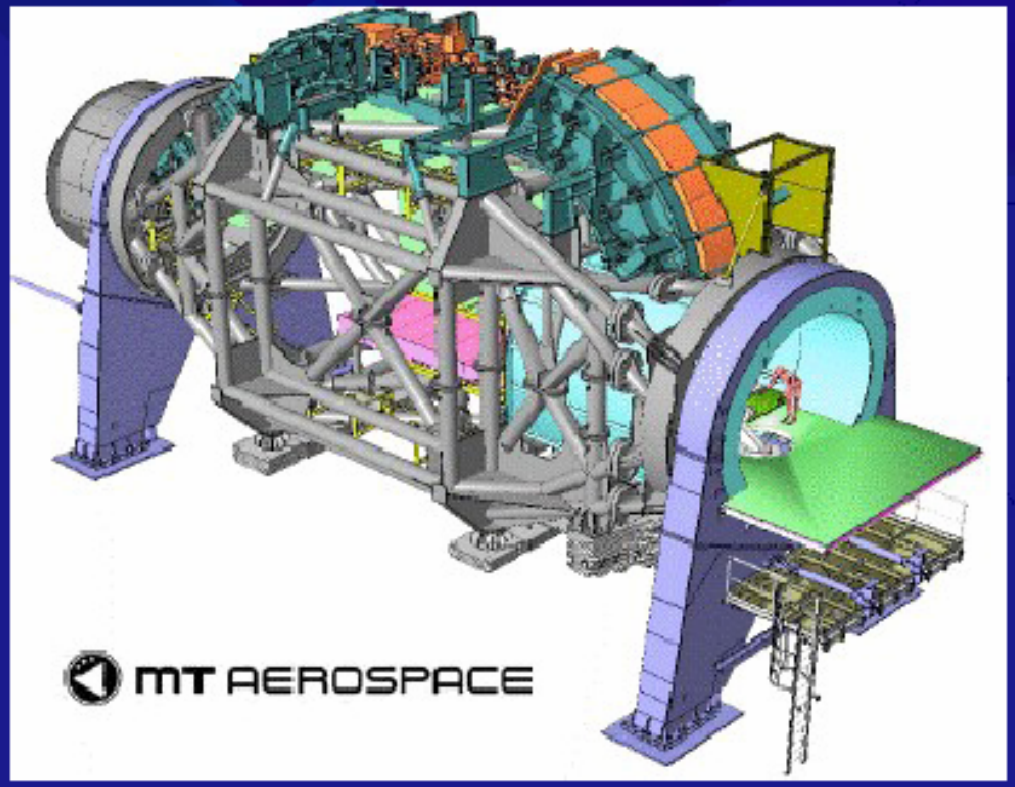
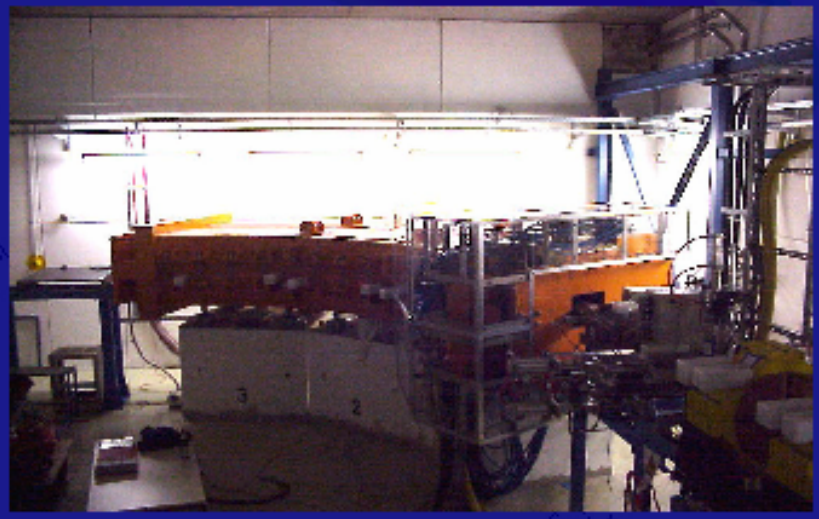
Part 2 – Starting point – HICAT 90° Gantry Dipole Magnet

Magnet manufactured by SIGMAPHI in 2001



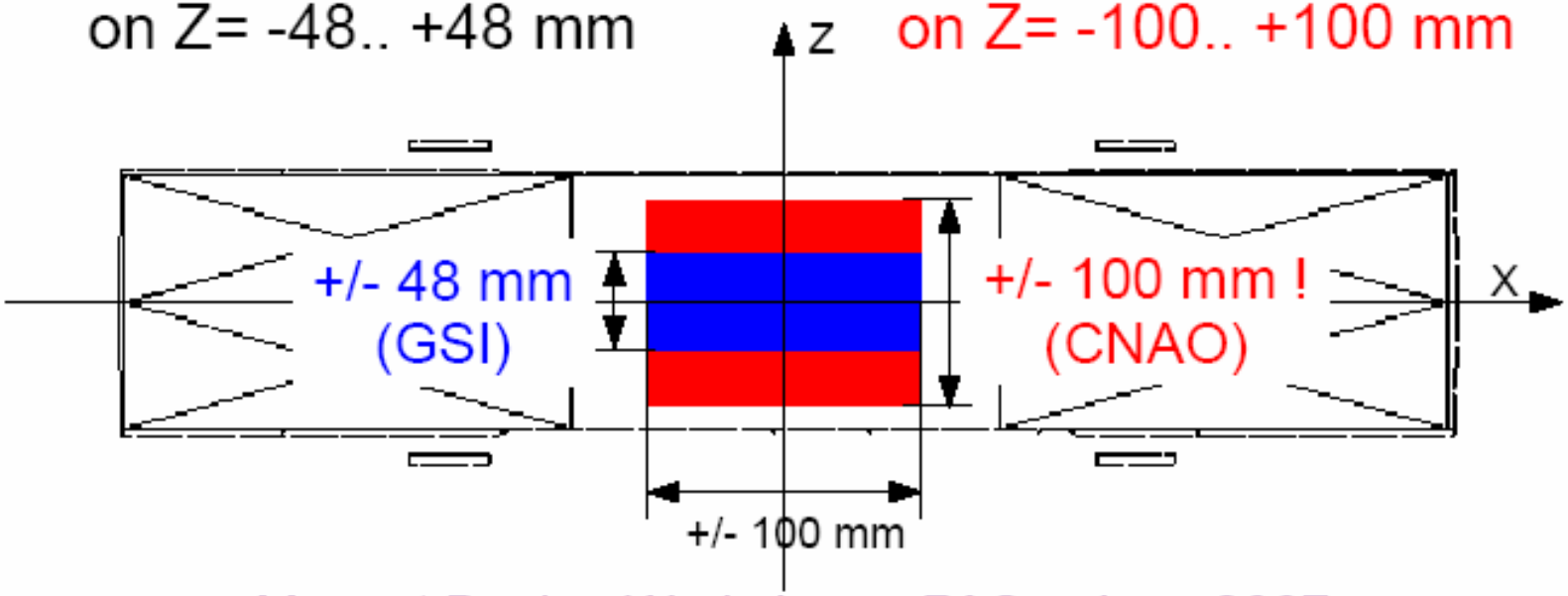
→ 75 tonnes dipole
→ Maximum field of 1.74 T
→ Hight integral field homogeneity required



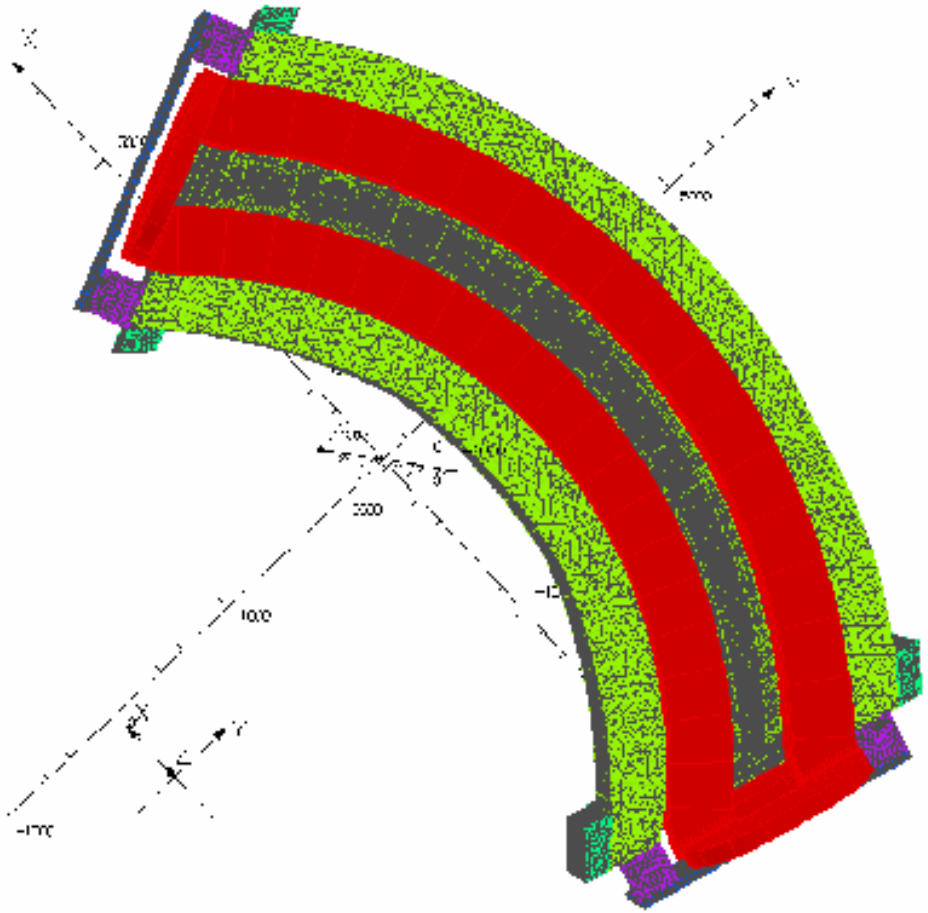
Part 2 – Starting point – HICAT 90° Magnet Design

Specifications on integral field relative homogenity

HICAT (2001)	CNAO (2006)
$+ 4.10^{-4}$ on Z= -48.. +48 mm	$+/- 2.10^{-4}$ on Z= -100.. +100 mm



Part 3 - 2D and 3D Magnetic computations

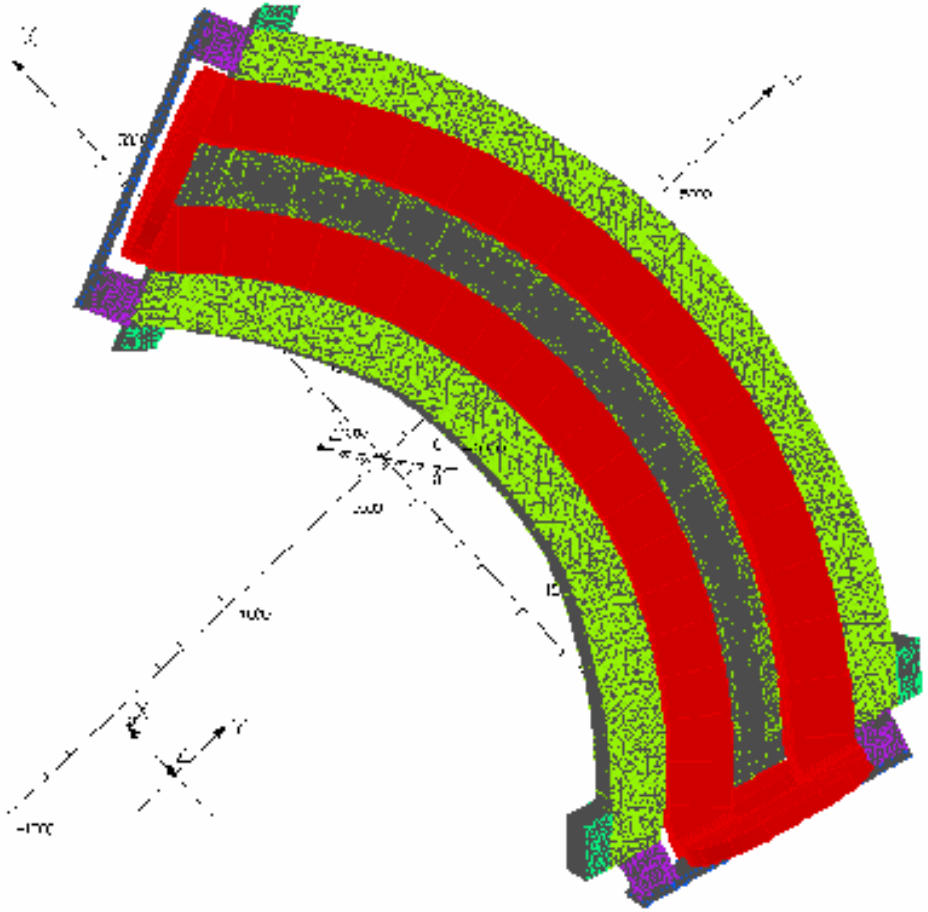


Using GSI-HICAT Design

Opera (TOSCA) 2D and 3D models implementation

Use of command files (.comi) : Model construction is reproducible and very fast

Part 3 - 2D and 3D Magnetic computations



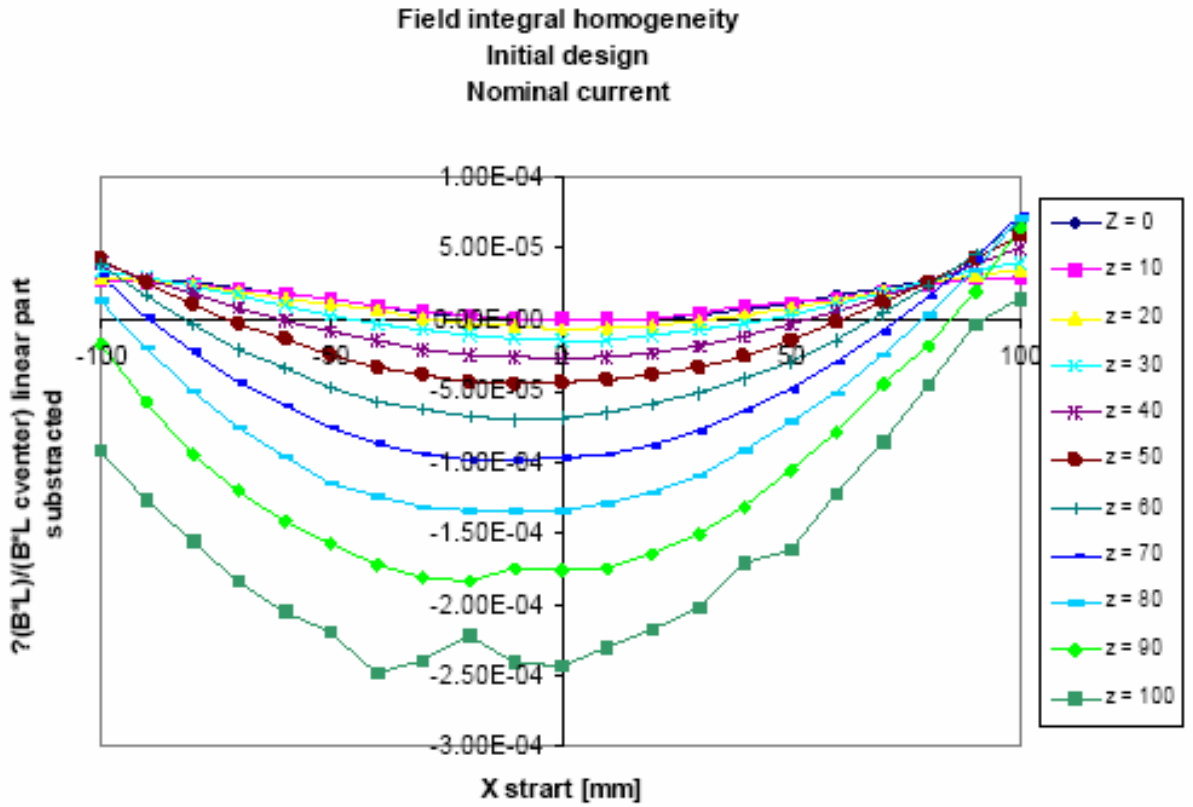
Models validation :

Mesh size decreased down to the optimum (invarience of field distrubution with mesh size reduction)

Excellent agreement between 2D and 3D computation in tne magnet center

Confrontation with GSI measurements

Part 3 - 2D and 3D Magnetic computations



Relative homogeneity
-2.5 / +1.10^{-4}

Integral homogeneity calculated with Opera 3D on GSI-HICAT design
B_0 = 1.74T at different vertical positions (Z=-100.. 100 mm). Linear part subtracted

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Part 3 - Improvement of the initial design

GSI-HICAT design – Already very well optimized design !

(1) Automatized 2D calculation algorism to improve the 2D design
No significant improvement reached → Initial design kept

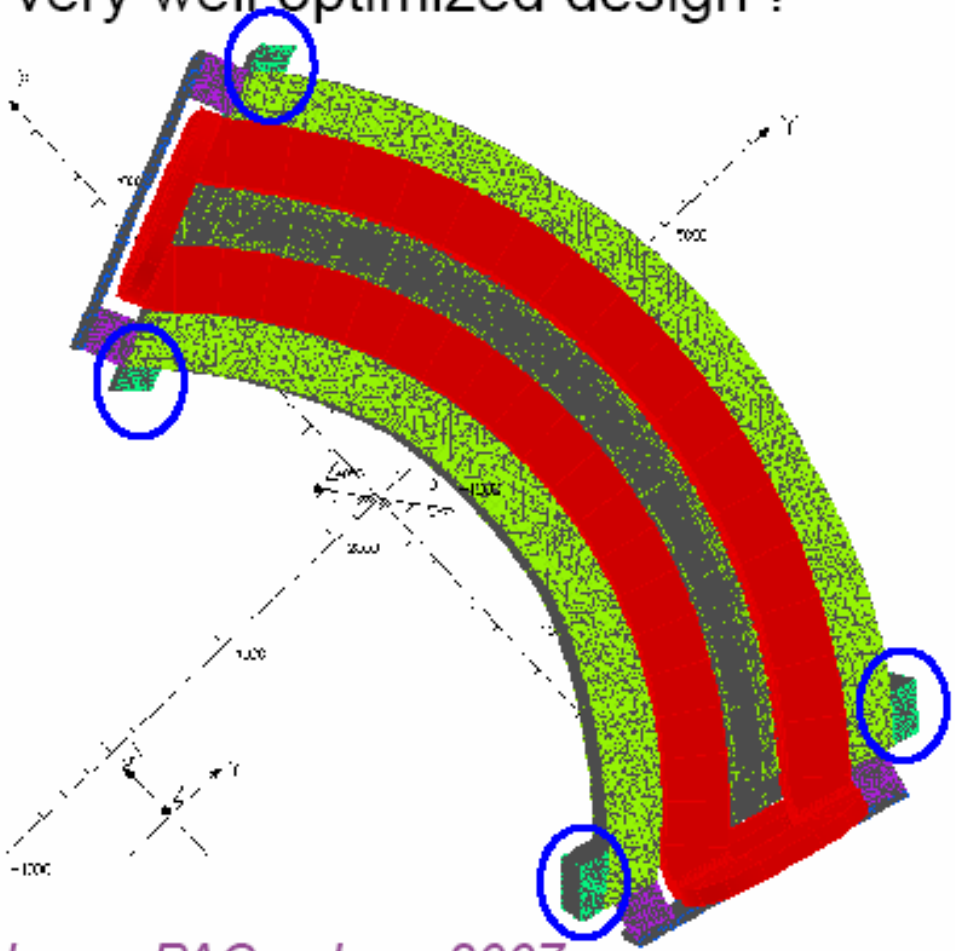
(2) No improvement reached on Rogowski profile

but...

Part 3 - Improvement of the initial design

GSI-HICAT design – Already very well optimized design !

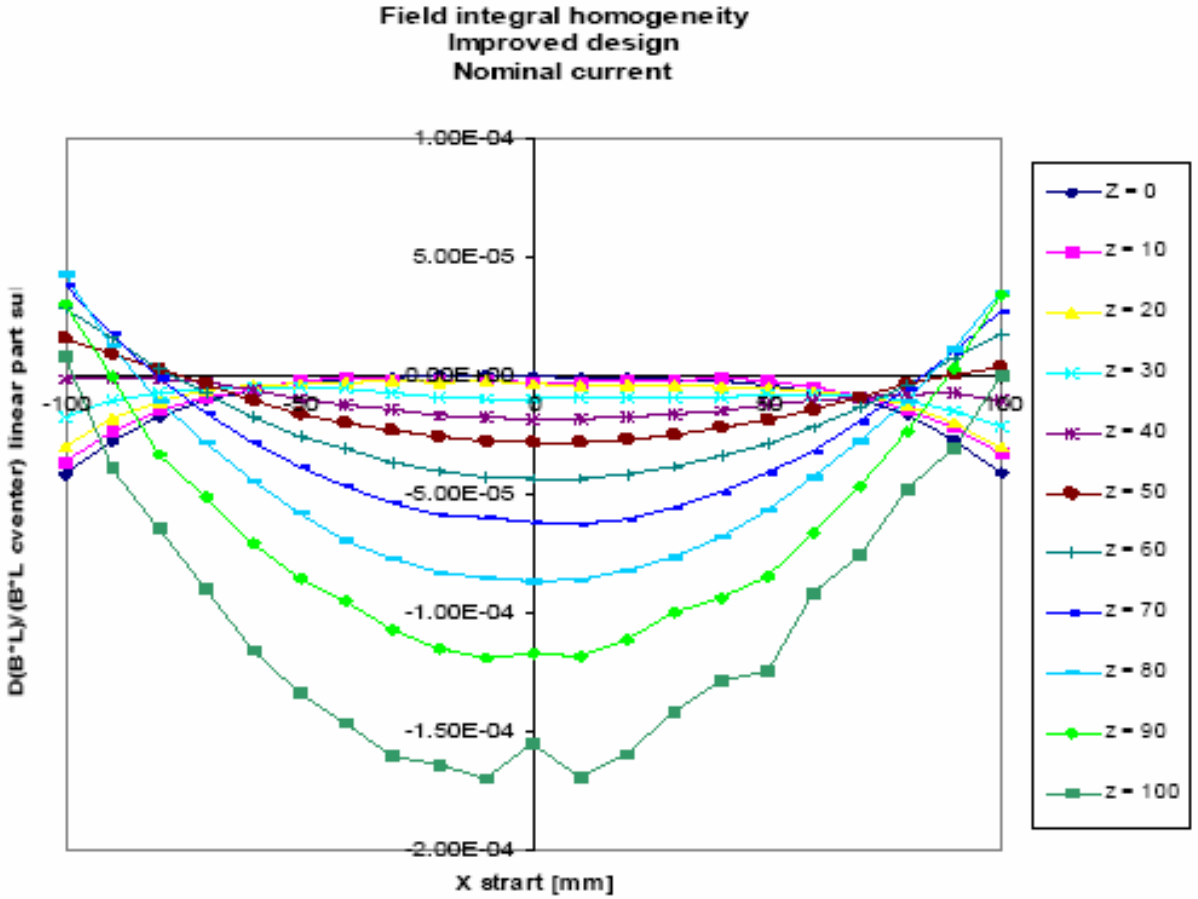
(3) Edge angle dependance with curent slightly improved (20% less) playing on « collar » size



Part 3 - Improvement of the initial design

GSI-HICAT design – Already very well optimized design !

(4) Integral field homogeneity increased playing on field clamps shape and size



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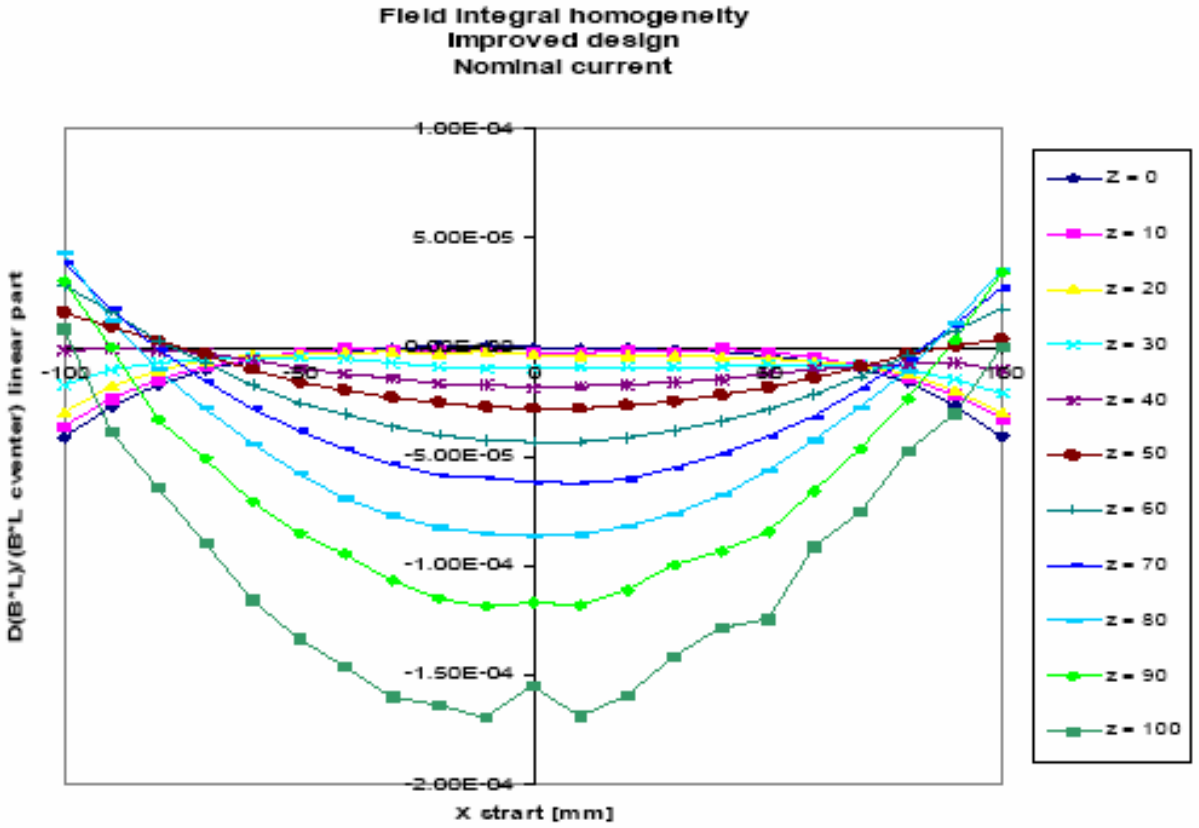

Relative homogeneity
$-2.5.10^{-}$ / $+1.10^{-4}$

Relative homogeneity
$-1.7.10^{-4}$ / $+4.10^{-5}$

Integral homogeneity calculated with Opera 3D on GSI-HICAT design

B_0 = 1.74T at different vertical positions (Z=-100.. 100 mm). Linear part subtracted

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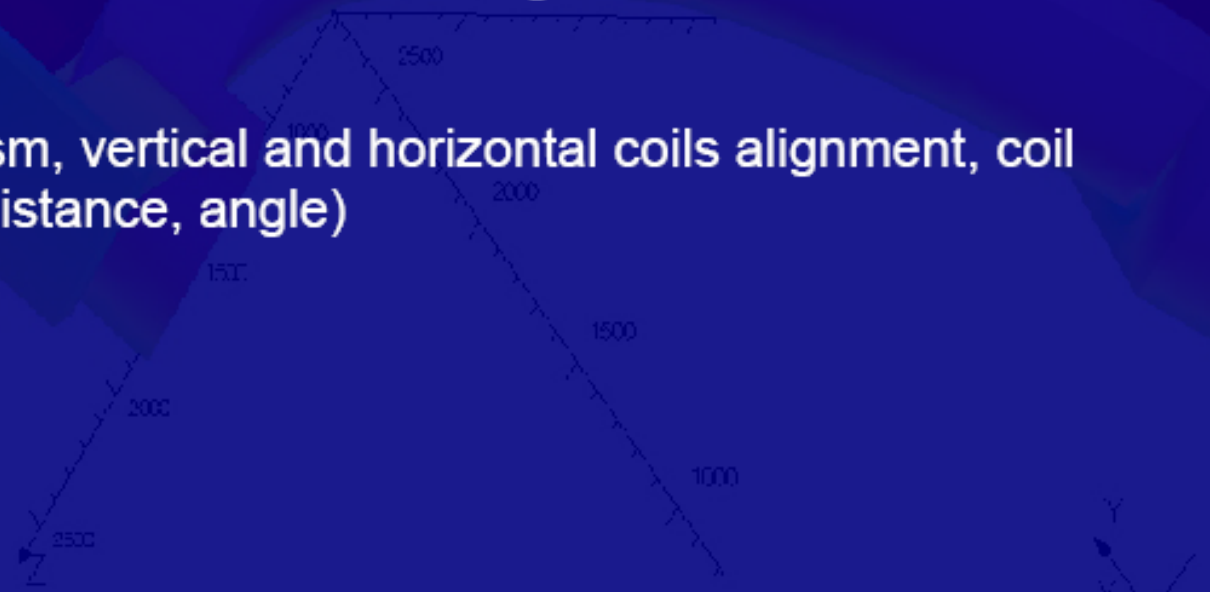
Part 3 - Manufacturing tolerances effects

Improvement of fabrication process might be guide by a good understanding of fabrication tolerences effects

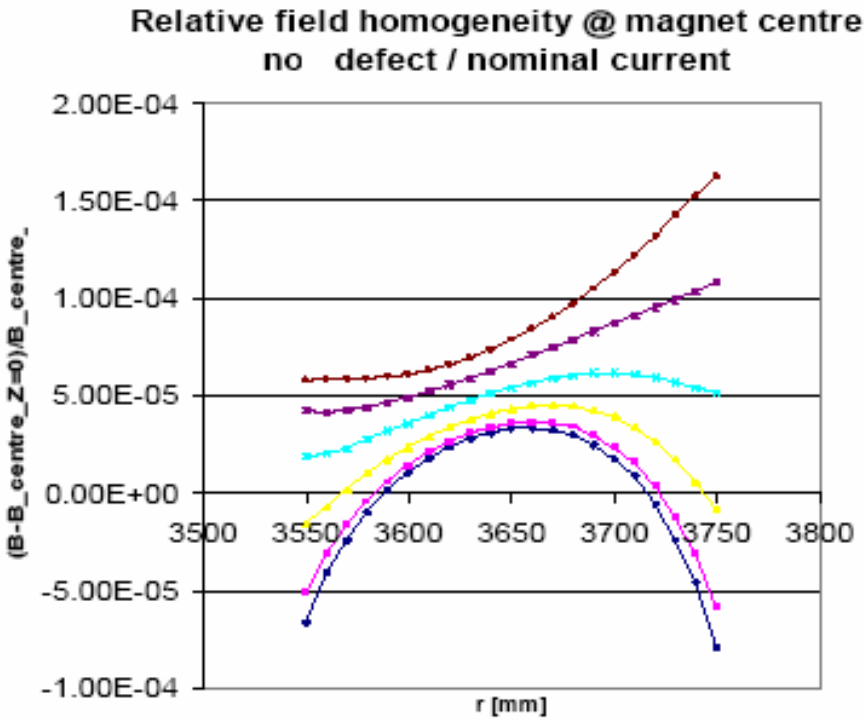
Several typical deffects tested through 2D and 3D calculations

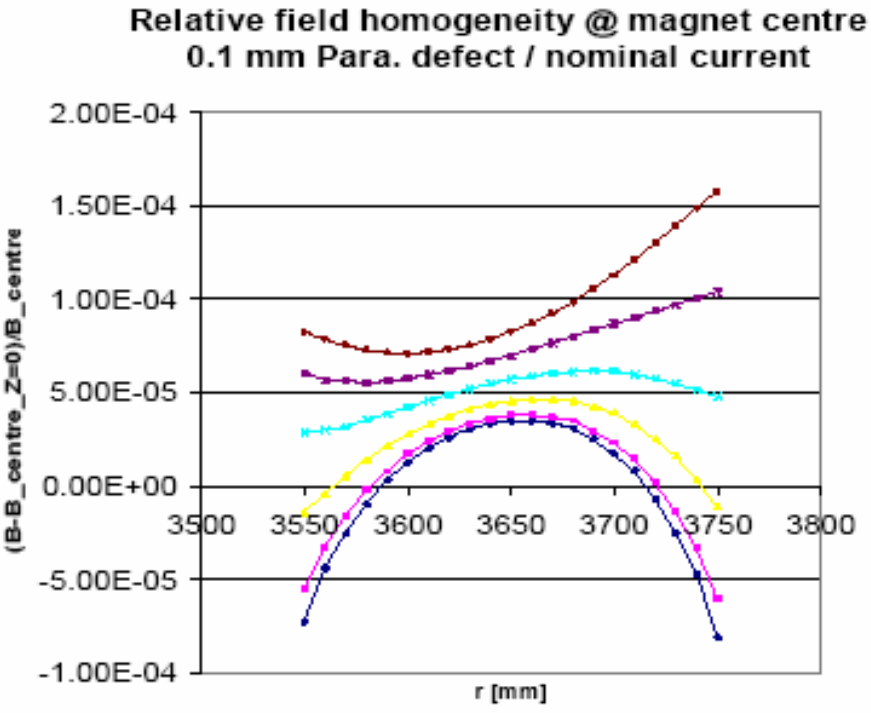
Gap parallelism, vertical and horizontal coils alignment, coil extremities (distance, angle)



Part 3 - Manufacturing tolerances effects

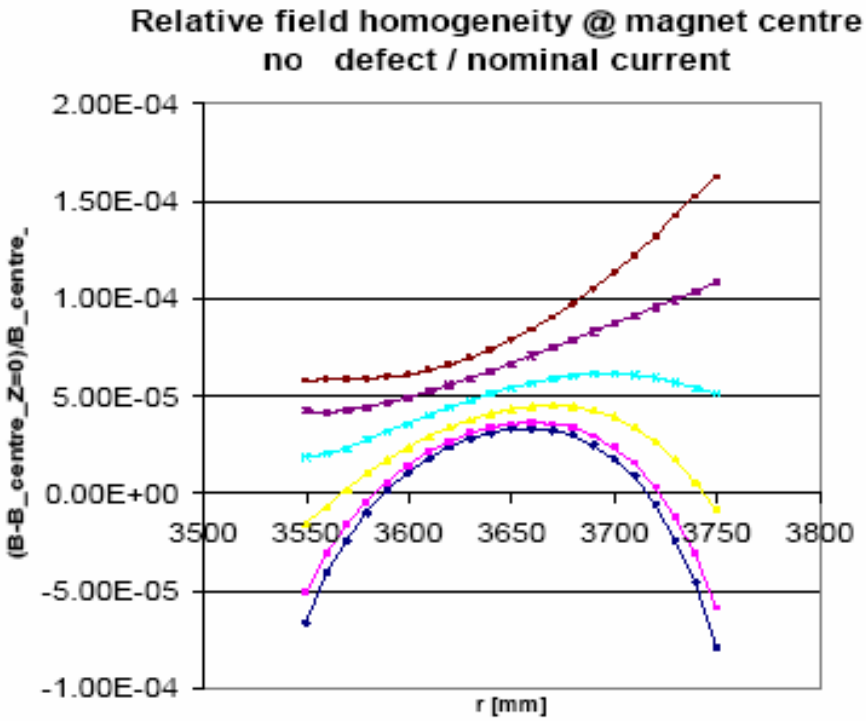
Parallelism defect

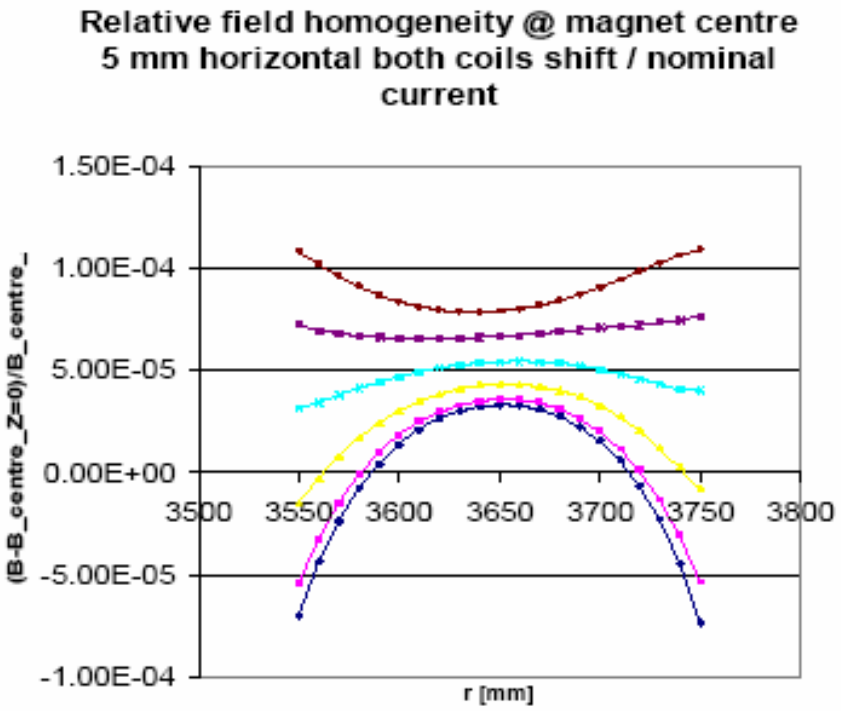




Part 3 - Manufacturing tolerances effects

Coil miss-alignment – significant effect of symetry break!





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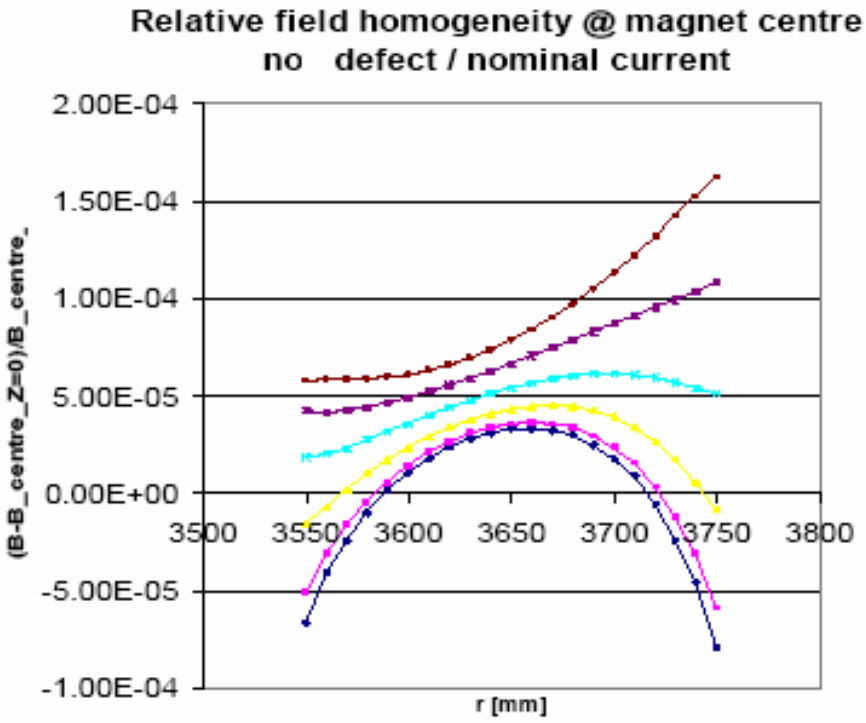

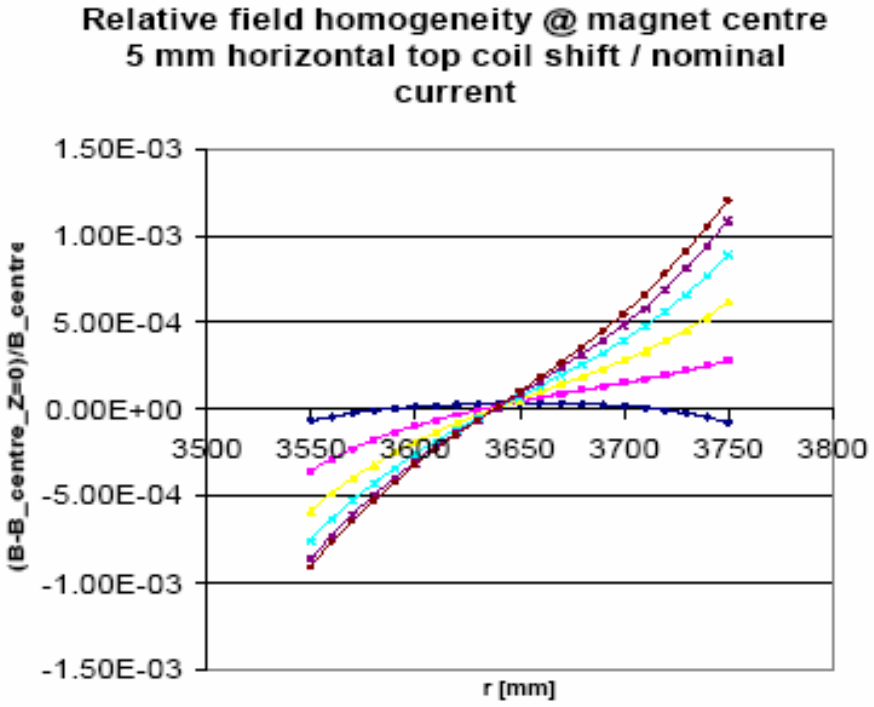

Conclusion

- GSI design slightly improved

- Effects are small, fabrication tolerences are strict enough to reach the specification

- A special attention has to be payed to coils up and down symetry

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Thank you for your attention

References :

[1] G. Moritz, *et al.* « Geometric and Magnetic Measurements of the Gantry Dipole for HICAT Medical Accelerator », 2B-p03