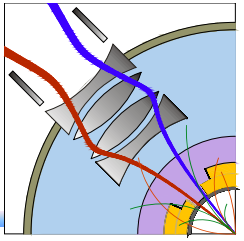


Magnets for the phase I LHC upgrade

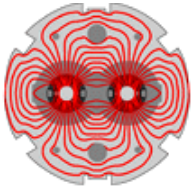
P. FESSIA

WITH THE CONTRIBUTION OF

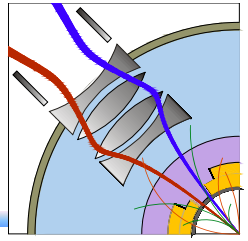
F. BORGNOLUTTI
F. CERUTTI
M. KARPPINEN
R. OSTOIJC
H. PRIN
F. REGIS
E. TODESCO
D. TOMMASINI
E. WILDNER

AND OF ALL THE SLHC-IR UPGRADE PHASE I PROJECT TEAM AND LIUWG TEAM

This project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under the Grant Agreement nº212114



Summary



- Guidelines
- Heat deposition
- Insulation
- Magnetic design: exploring the parameter space
- Mechanical feasibility study
- Correctors preliminary study
- Collaboration and brief planning

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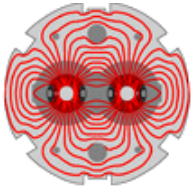
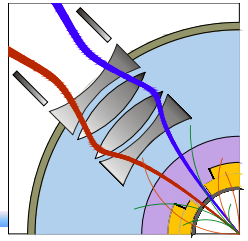


Guide-lines for magnet development



- Tunnel compatibility
  - Cryogenic load
  - Transport
  - Interfaces and interferences
- Cost reduction: max use of available material
  - SC cable: LHC dipole cables
  - Collar material: Nippon Steel YUS 130 (thickness 3 mm)
  - Yoke material: Cockerill steel (thickness 5.8 mm)
- Max use of available LHC experience
- Max use of existing tooling
  - Cold mass diameter
  - Cryostating system
  - Interconnection main tooling

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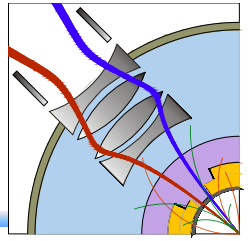
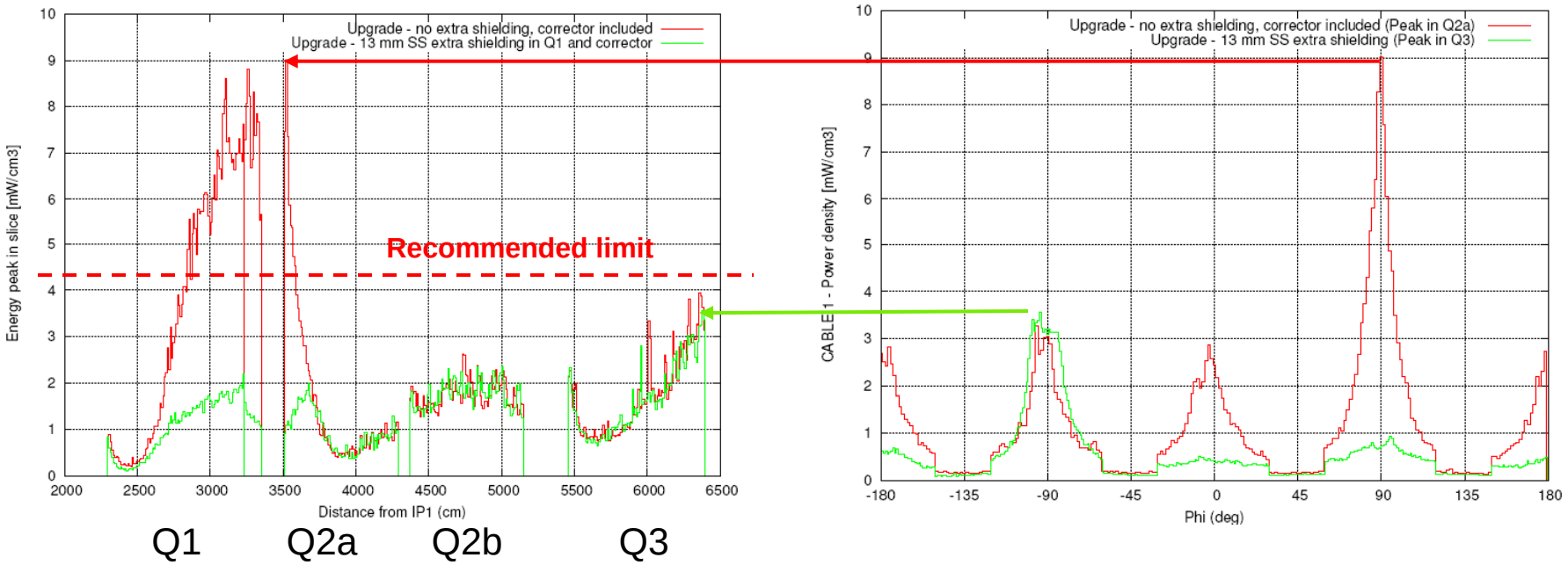
The new inner triplet deposited heat peaks in the coils

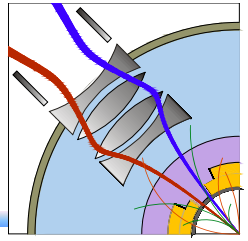




Peak energy deposition in each longitudinal bin, with and without proposed shielding

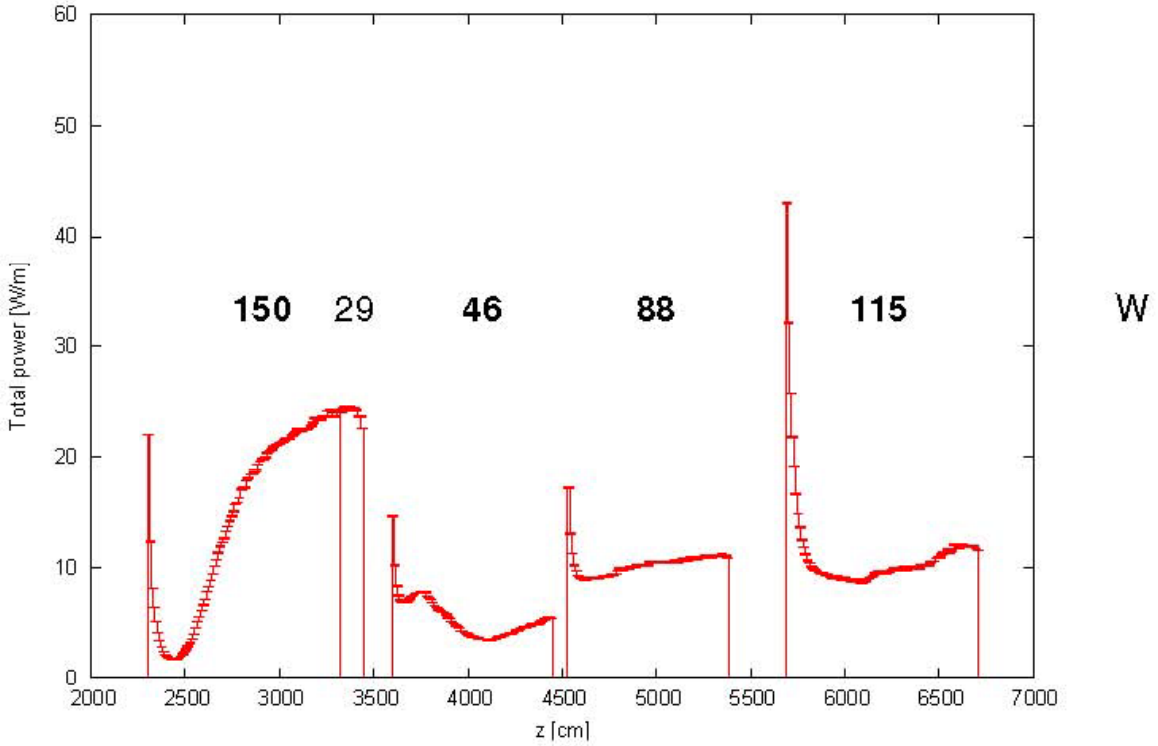
Azimuthal distribution at the longitudinal position of the peak, with and without proposed shielding

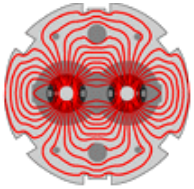
Total power



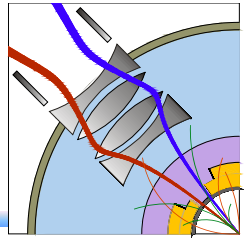
Total power for the shielded configuration of the updated layout [I]

longitudinal distribution





Power inventory in magnets



	Q1 [W]	Q2a[W]	Q2b[W]	Q3[W]
Beam Screen	14	5	10	14
Shielding	56	-	-	-
Cold bore	7	6	12	16
1st cable mid-plane	17	11	23	25
Collars	21	10	18	25
Iron Yoke	24	10	15	22
Total power/unit	94 [150]	46	88	115
Average power linear density in magnet	*9.2 [W/m]*	*5.4[W/m]*	*10.3[W/m]*	*11.2[W/m]*

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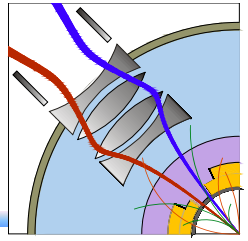
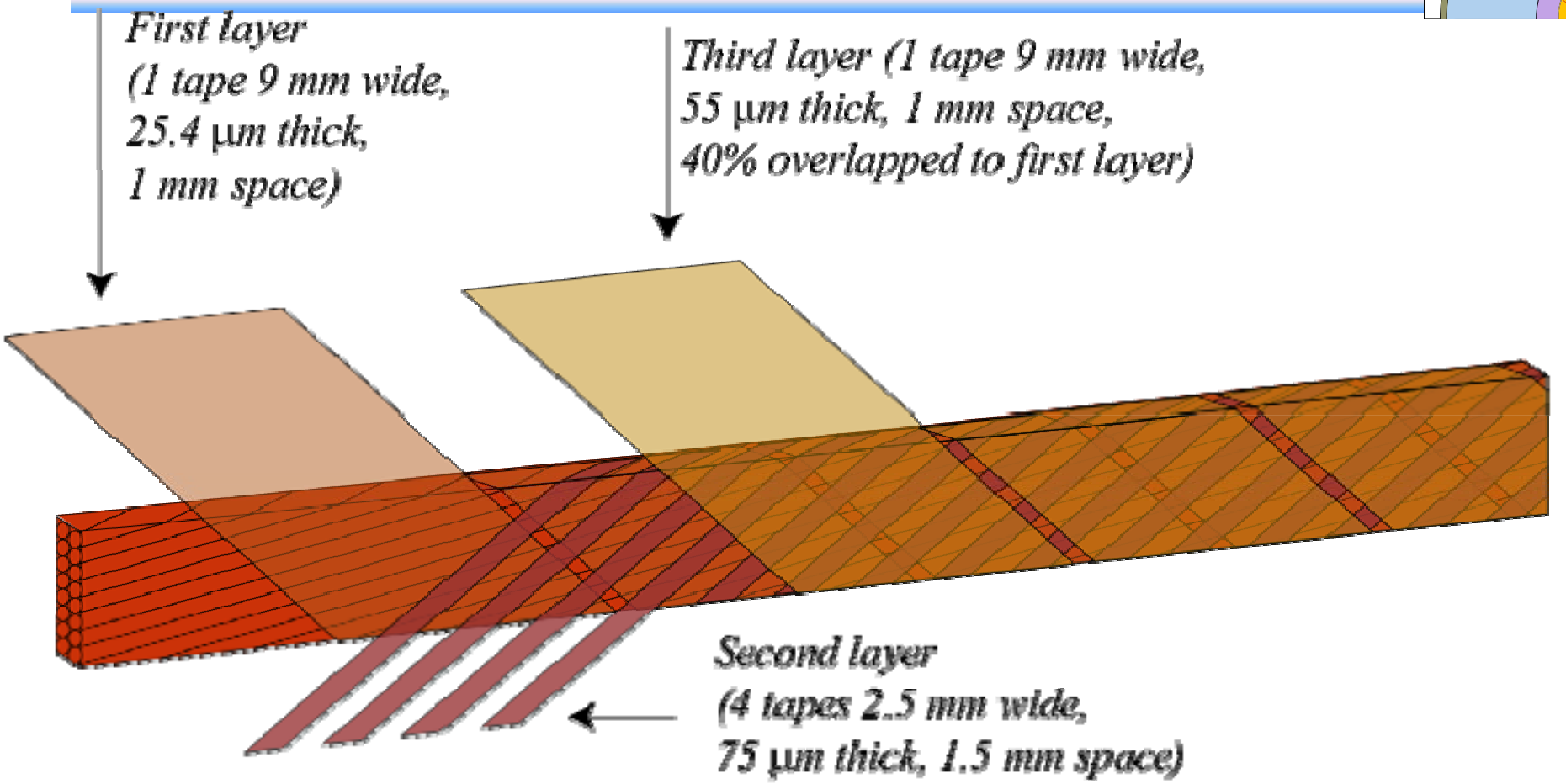
A step further: increasing heat transfer





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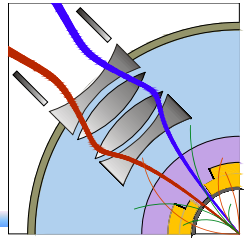
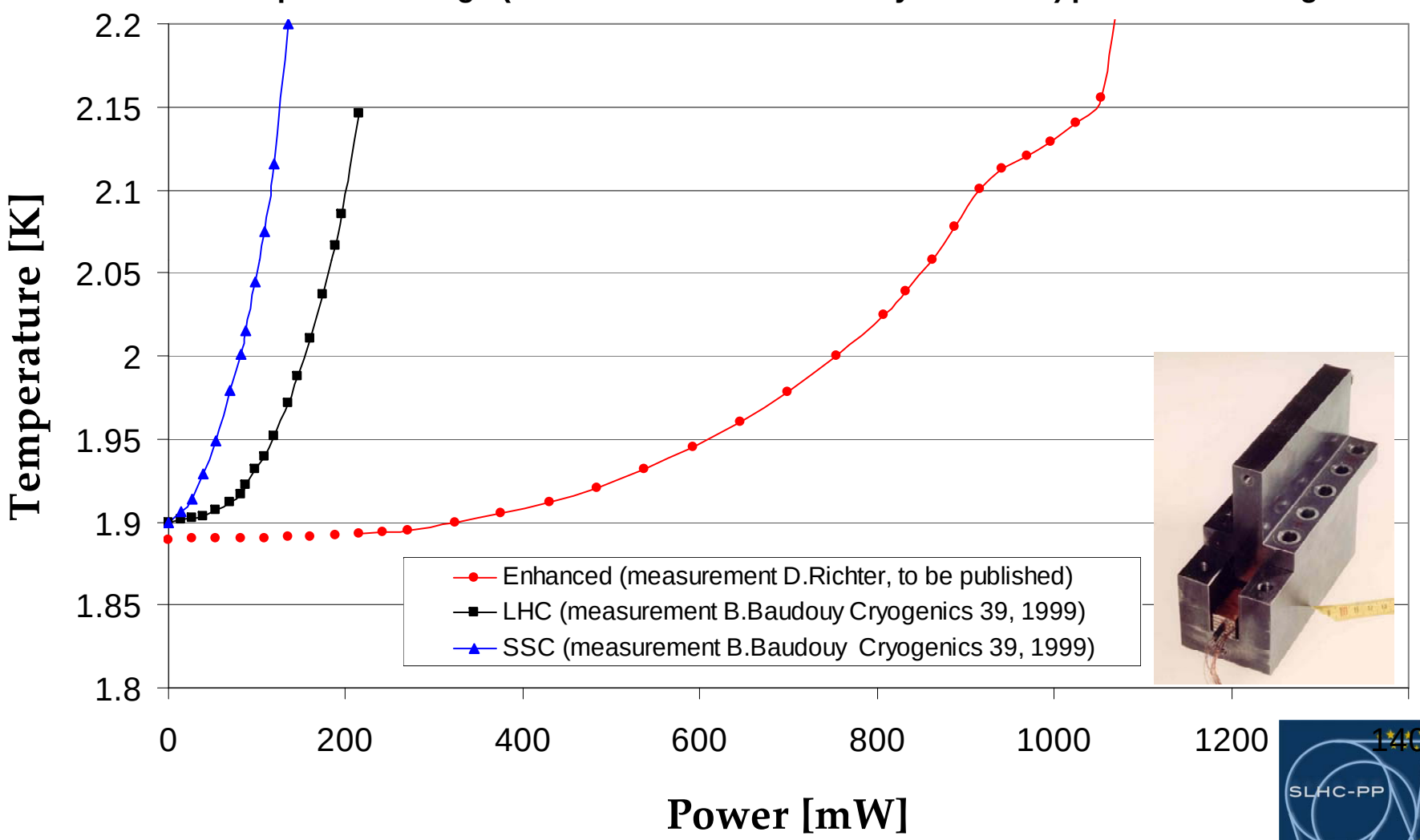
Preliminary measurements





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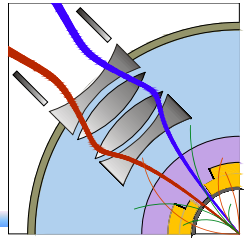
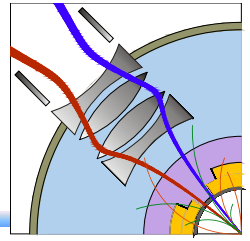
Full qualification undergoing



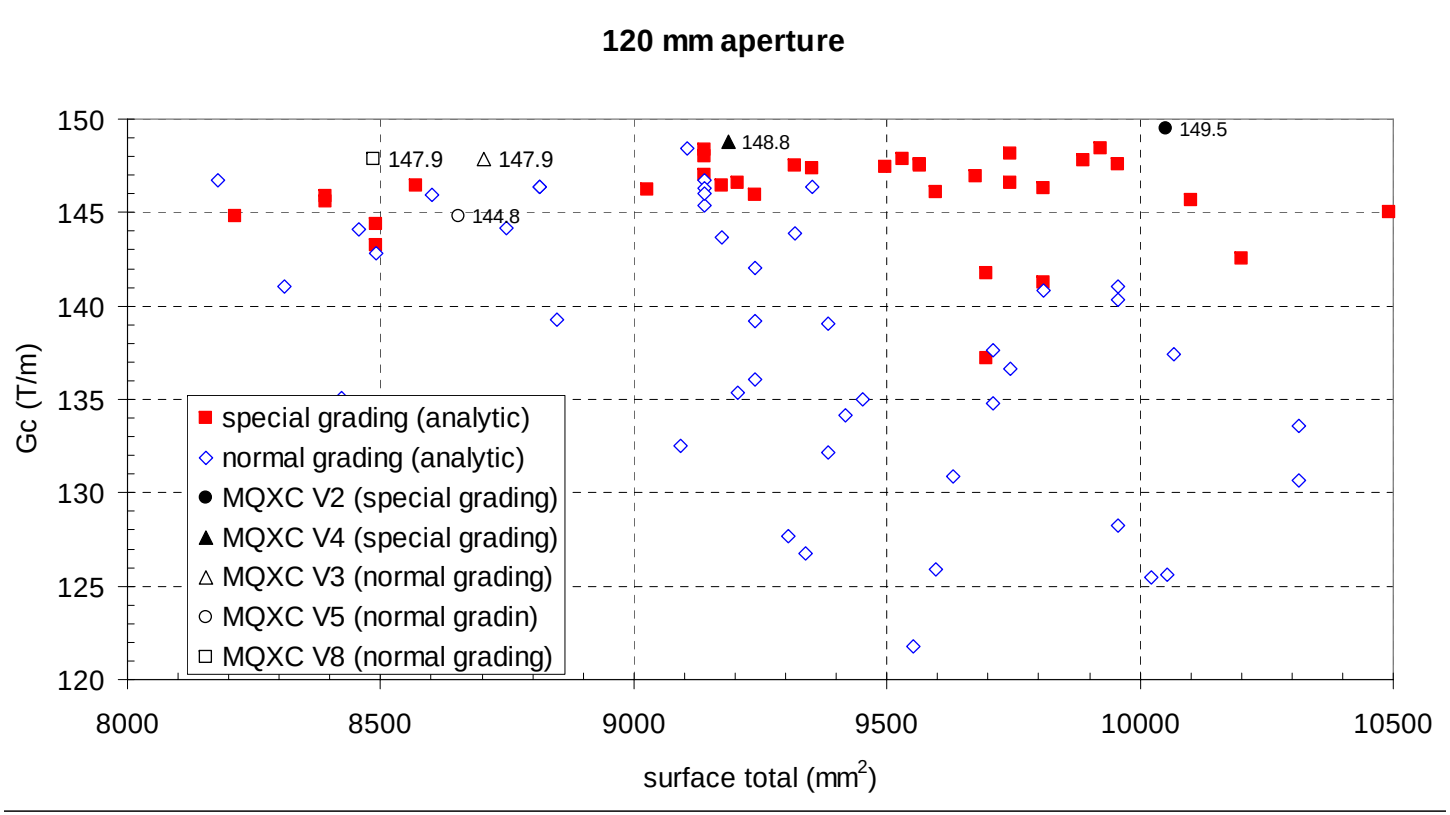
Intermediate tape 50 and 75 µm thickness, 3 mm wide

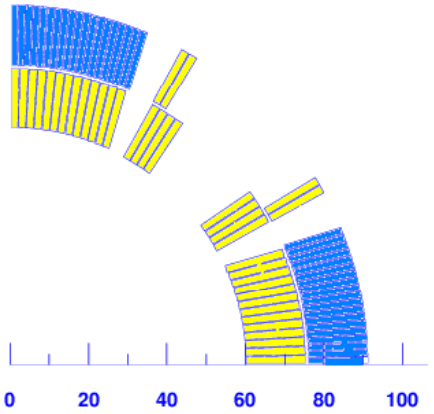
- Electrical insulation
  - 10 stacks
  - Pole winding (inner layer LHC dipole) before and after curing
- Mechanical
  - E-modulus
  - E-modulus vs. curing pressure
- Heat transfer

Magnetic design 1st results : 120 mm aperture

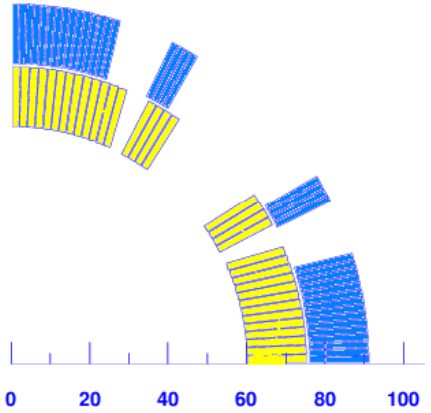


- Short sample gradient VS total coil area (no iron)

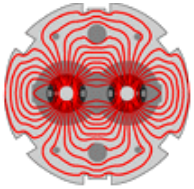




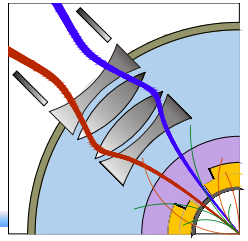
Special grading



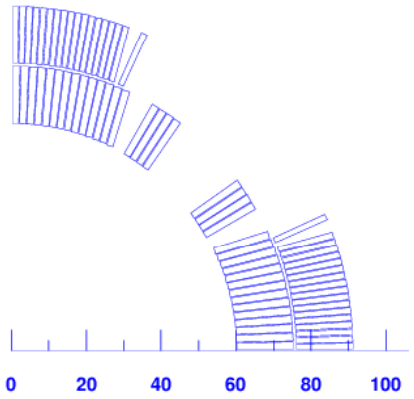
Normal grading



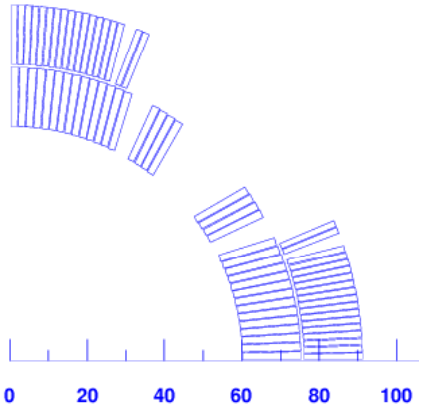
Examples of 120 mm aperture cross sections I



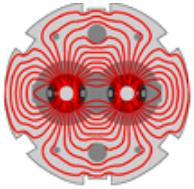
"Normal Grading" cases



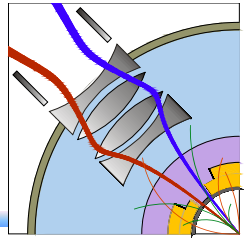
- Critical Gradient: 147.9 T/m
- Field quality:
  - b_6 = -0.35 units
  - b_{10} = 0.32 units
- Nb turn of cable 01/coil: 18
- Nb turn of cable 02/coil: 18
- Sample short gradient with iron (collar thickness of 37 mm) : 152.8 T/m (~+3.2%)



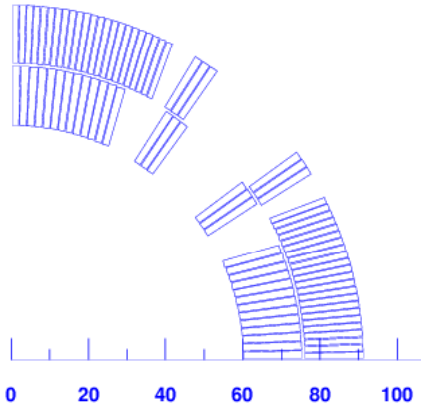
- Critical Gradient: 147.9 T/m
- Field quality:
  - b_6 = -0.06 units
  - b_{10} = 0.04 units
- Nb turn of cable 01/coil: 18
- Nb turn of cable 02/coil: 17
- Short sample gradient with iron (collar thickness of 37 mm) : 152.1 T/m (~+2.8%)



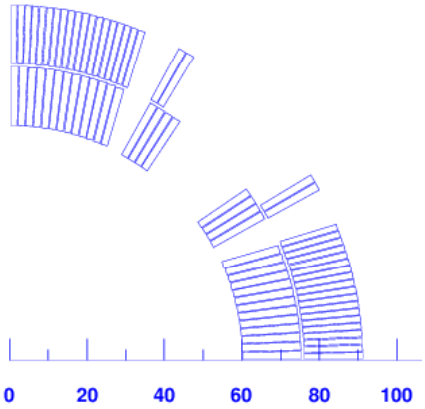
Examples of 120 mm aperture cross sections II



"Special Grading" cases



- Critical Gradient: 149.5 T/m
- Field quality:
  - b_6 = 0.37 units
  - b_{10} = -0.77 units
- Nb turn of cable 01/coil: 19
- Nb turn of cable 02/coil: 23
- SS Gradient with iron (collar thickness of 37mm) : 152.9 T/m (~+2.3%)



- Critical Gradient: 148.8 T/m
- Field quality:
  - b_6 = -0.07 units
  - b_{10} = 0.03 units
- Nb turn of cable 01/coil: 19
- Nb turn of cable 02/coil: 19
- SS Gradient with iron (collar thickness of 37mm) : 152.8 T/m (~+2.6%)

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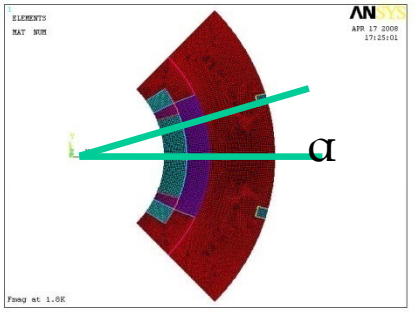
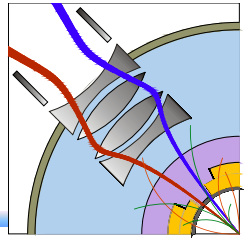
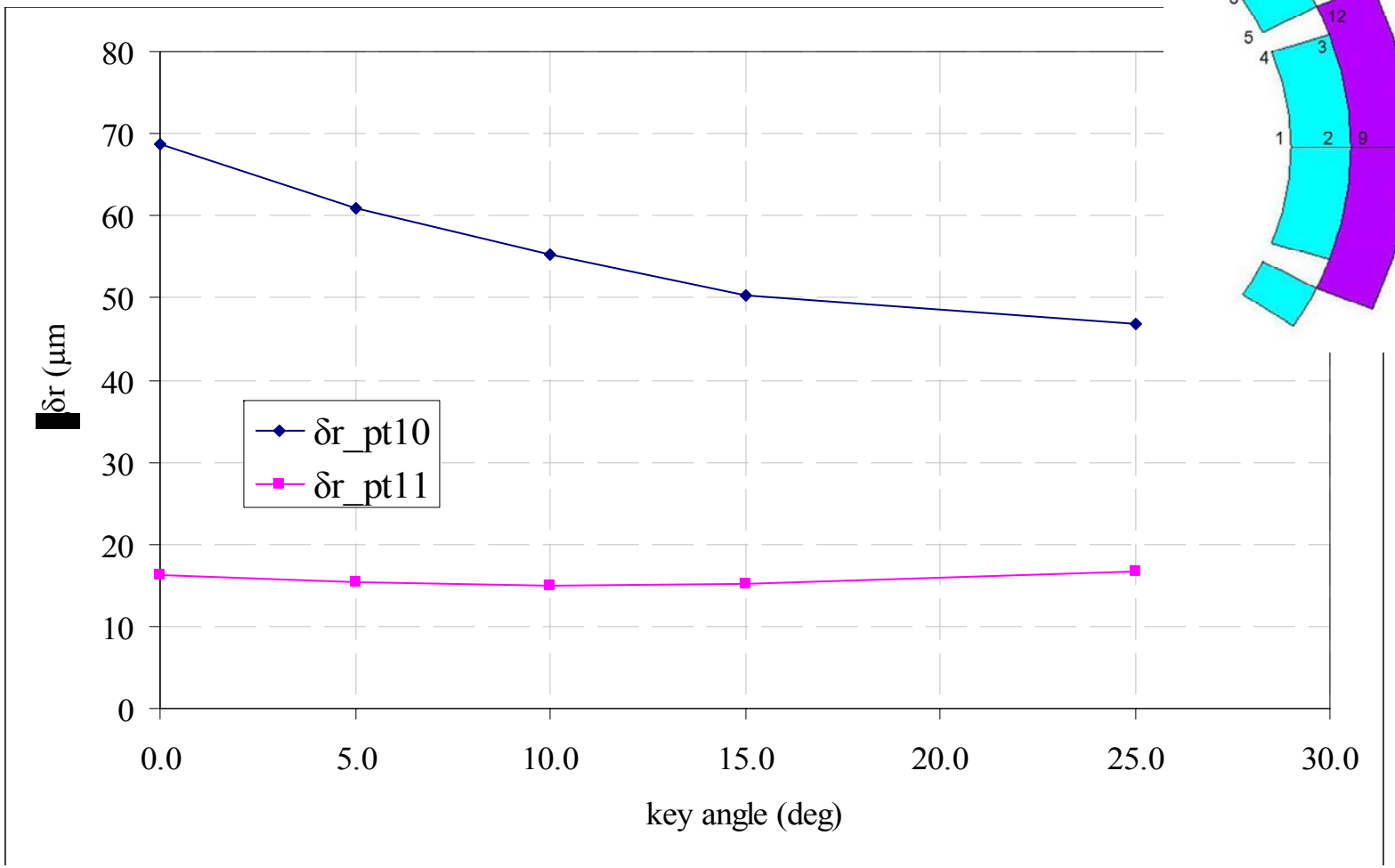
Key position





- Coil radial displacement in function of the angular distance between keys



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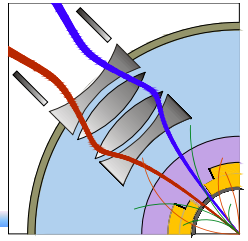
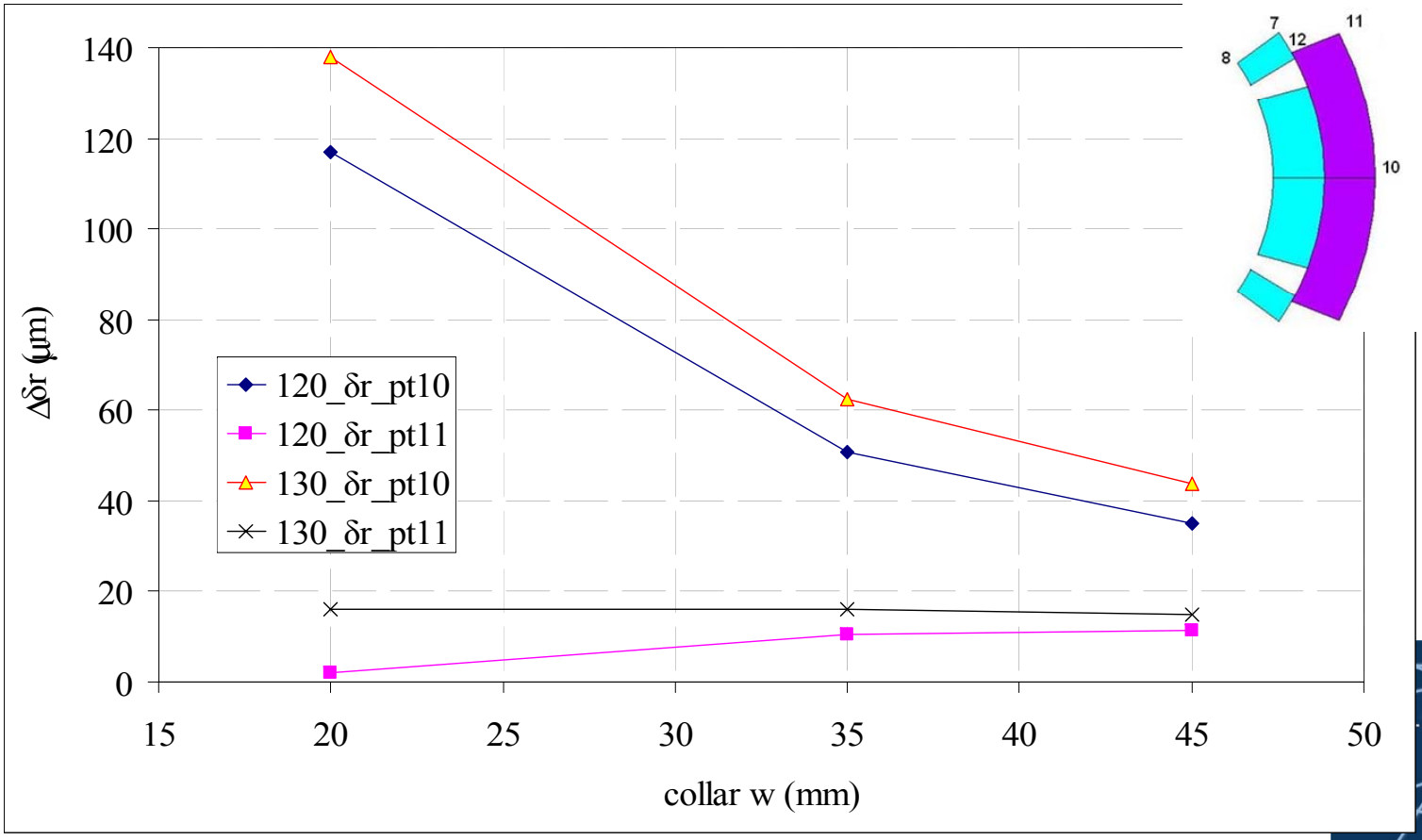
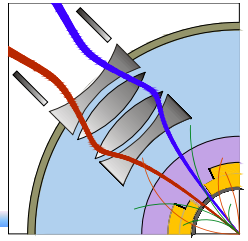
Deformations



- $\Delta\delta r = \delta r_{mag} - \delta r_{CD}$



Next steps



- Magnetic design
  - Re-evaluation using parameters of available and selected cable
  - Further layer jump and heads consideration
  - Harmonic sensitivity analysis
- Mechanical design
  - Detailed 2D analysis and optimization
  - Tolerance analysis
  - 3D mechanical analysis

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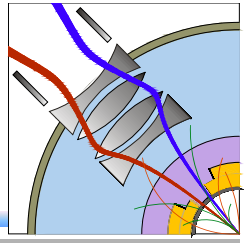
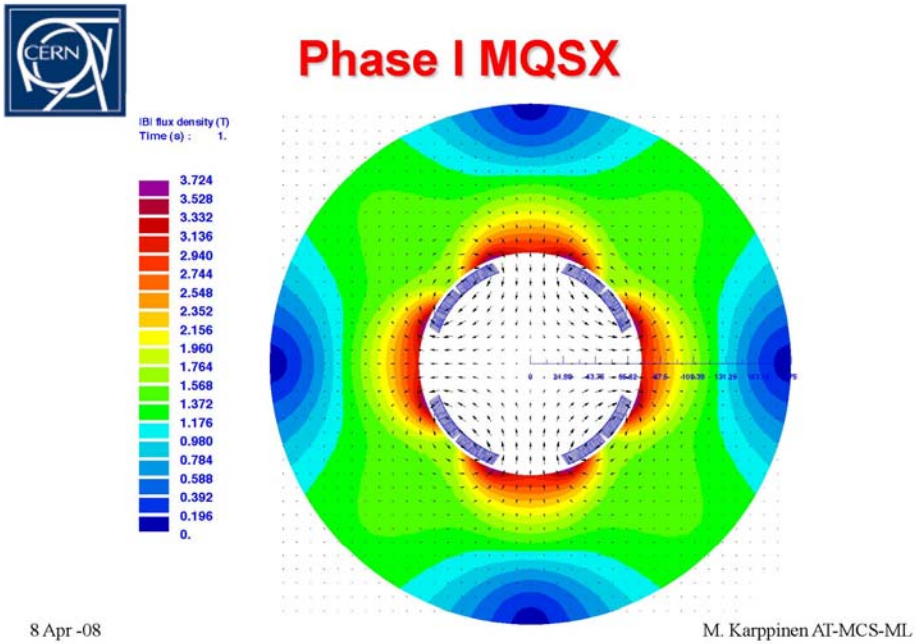
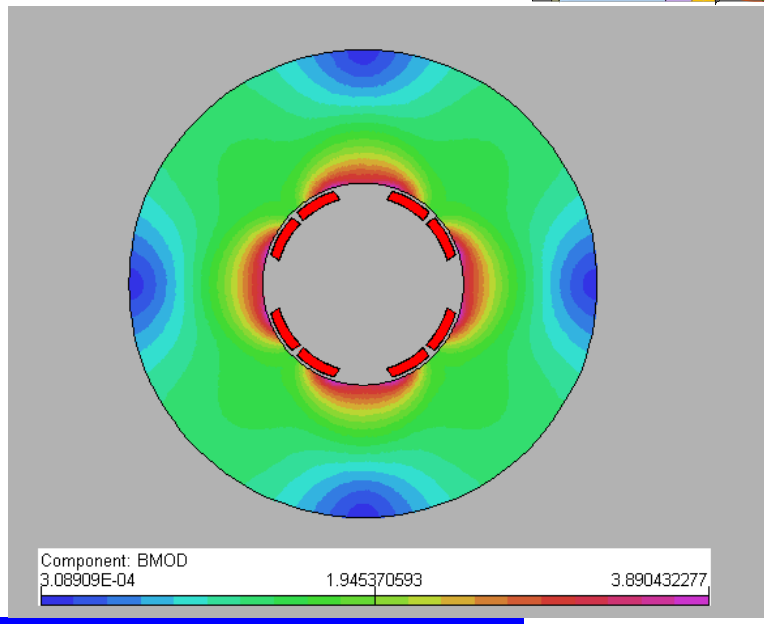
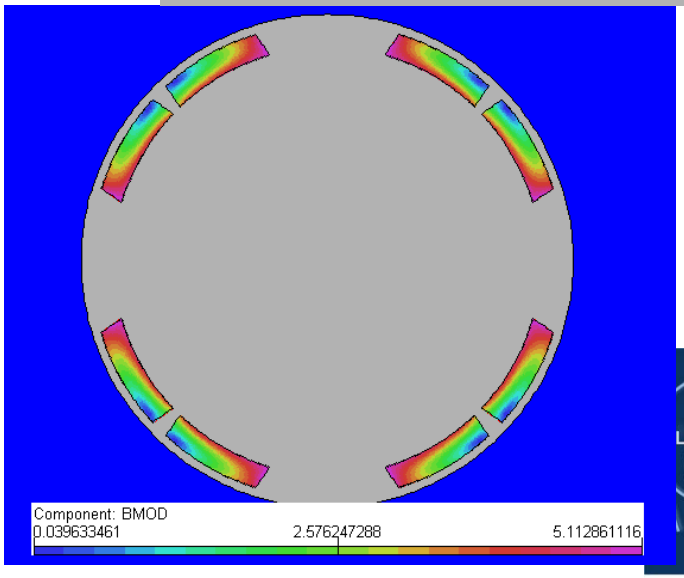
Correctors: ex MQSX









RAL results courtesy of James Rochford

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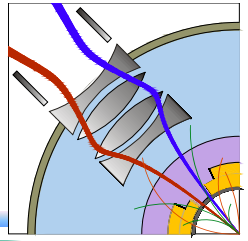
A joint R&D and construction effort



CEA-Saclay France

CIEMAT Spain

STFC U.K.

CNRS-IN2P3 France

EU-FP 7 SLHC-PP program WP6

Integrated project team CERN-CEA-CNRS

LHC IR upgrade phase I

France

Special contribution

US collaboration

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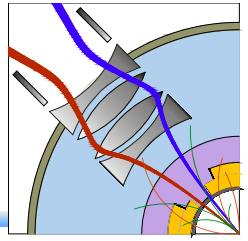
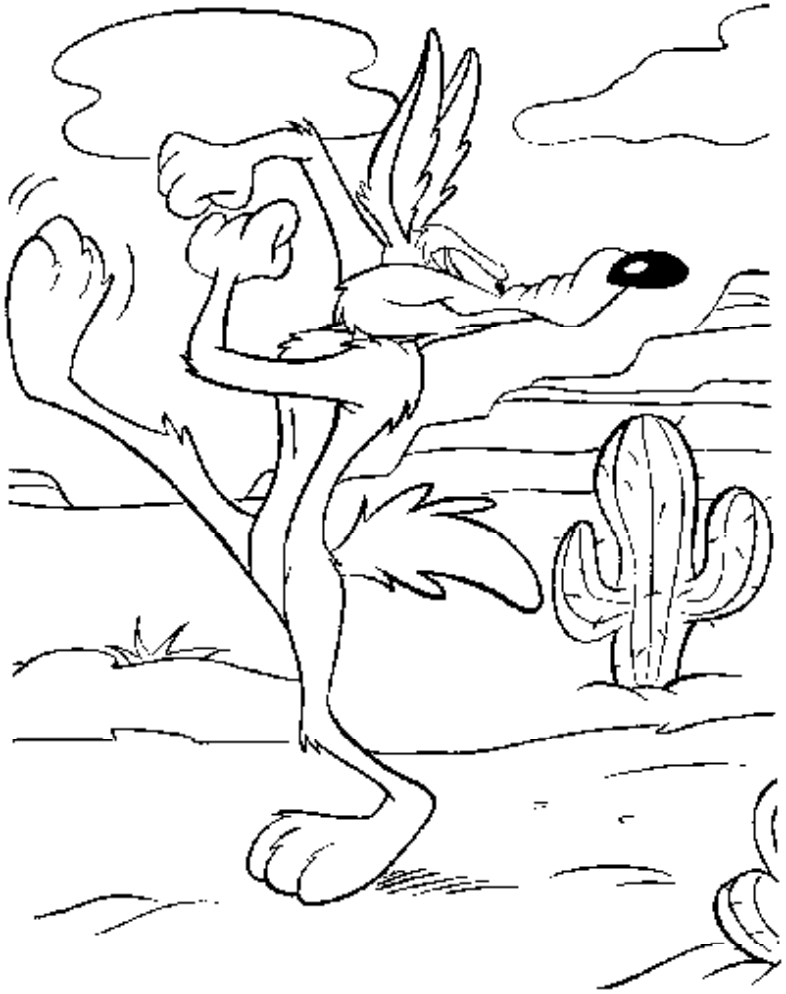
Magnet program planning



Phase	Task	Start	Completion
Model	Tooling installation	01/02/2008	01/02/2009
	Models construction	01/09/2008	01/07/2009
Prototype	Prototype and series tooling installation	01/02/2008	01/01/2010
	Prototypes construction	01/10/2009	01/09/2010
Series	Series production	01/10/2010	01/06/2012 Date of completion or delivery of last quadrupole. Production sequence optimized for installation and construction
Procurement	Specifications and invitation to tender for prototype and series components	01/02/2009	01/09/2009
	Delivery of components	01/10/2009	31/12/2011

And now it is time to run …



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