Slotted Corrector Designs for Superconducting Solenoid for e-lens

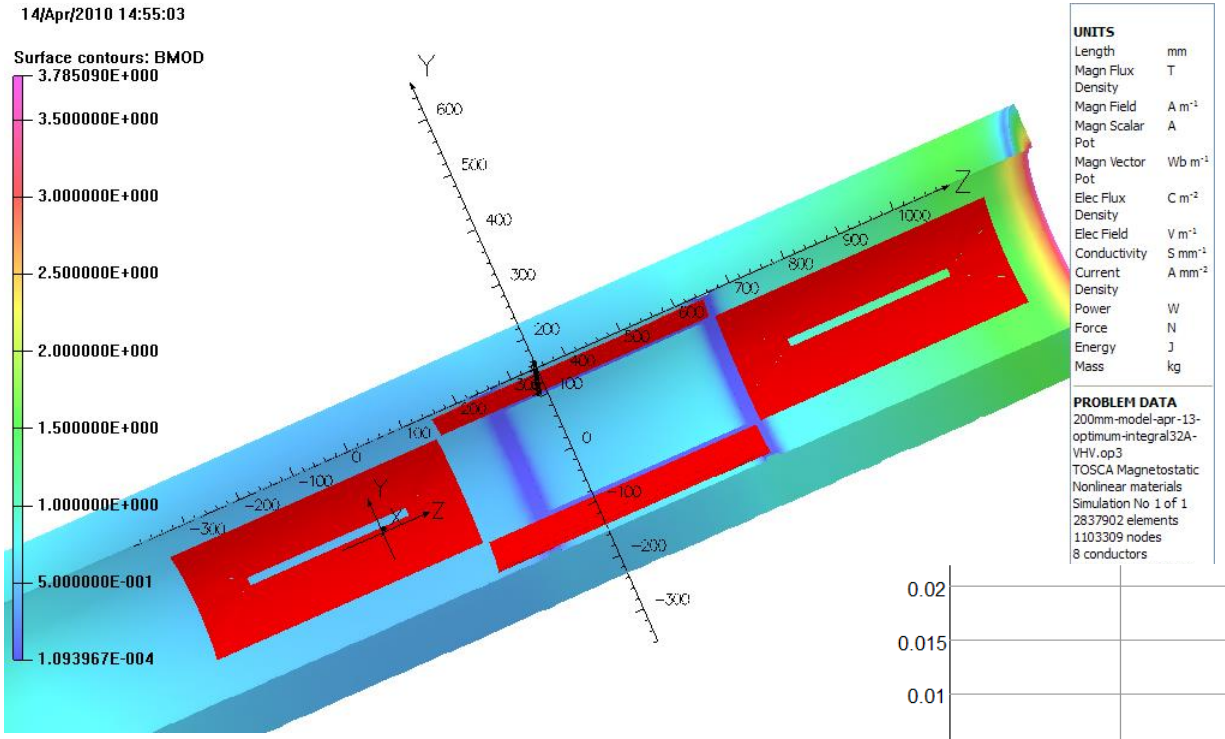
Ramesh Gupta

June 7, 2010

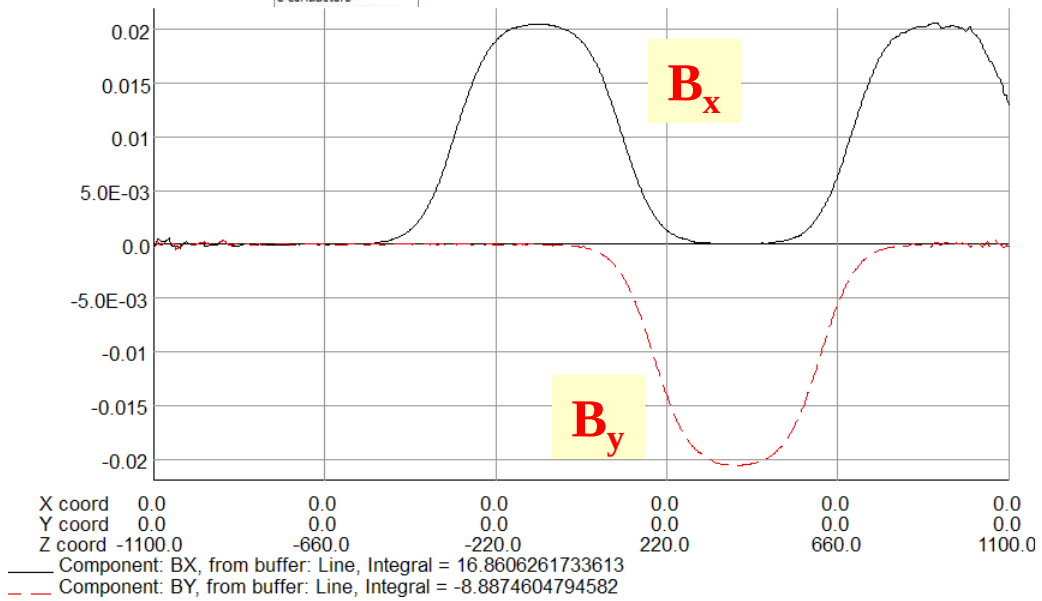
Design Considerations for e-lens correctors

- Short correctors must create a dipole field of 0.02 T and long correctors 0.006+ T (both horizontal and vertical)
- Should have low operating current to minimize heat load (more important for tests when RHIC cryo-system is not on)
- Should have a minimum layers to minimize schedule and cost
- Slotted design is preferred over the direct wind for schedule and cost reasons
- After a very brief overview, details of the design will be discussed

Optimum Integral Design for e-lens Correctors in Series

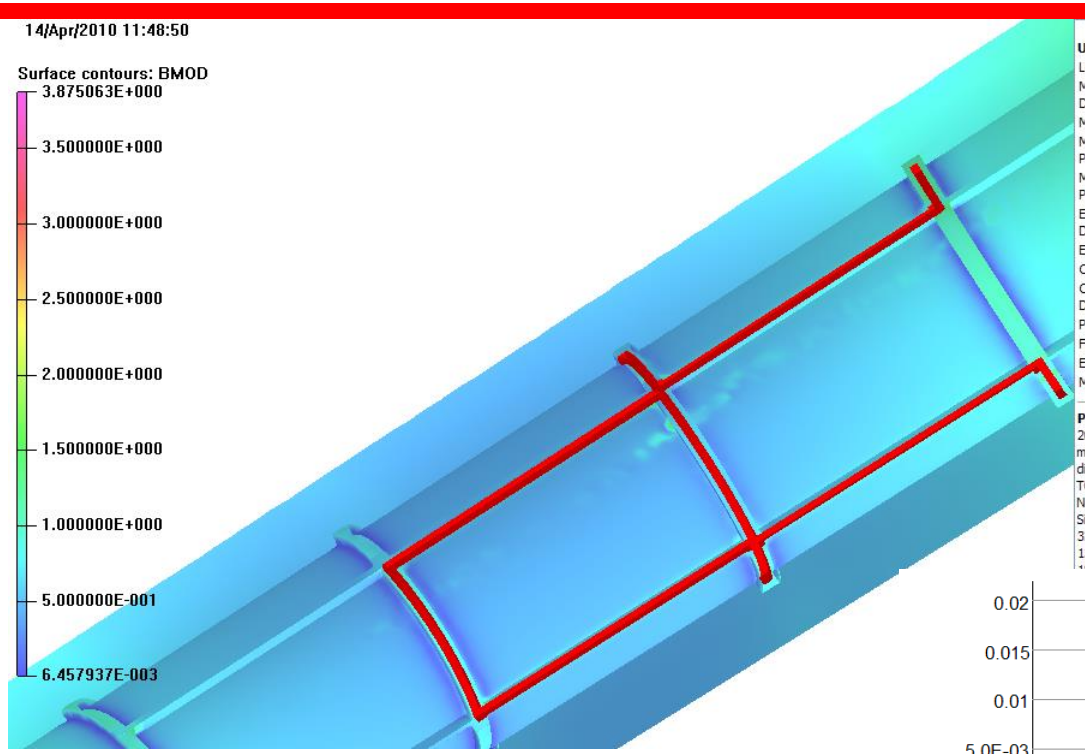


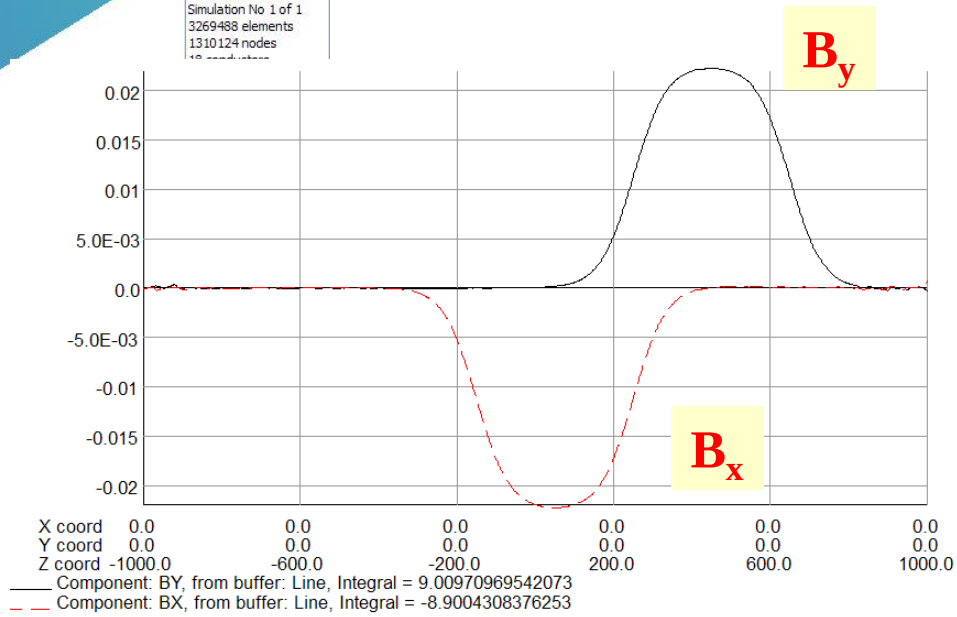
Powered alternately at full horizontal or full vertical field



Works well.
Little cross-talk, etc. for transverse field in other direction.

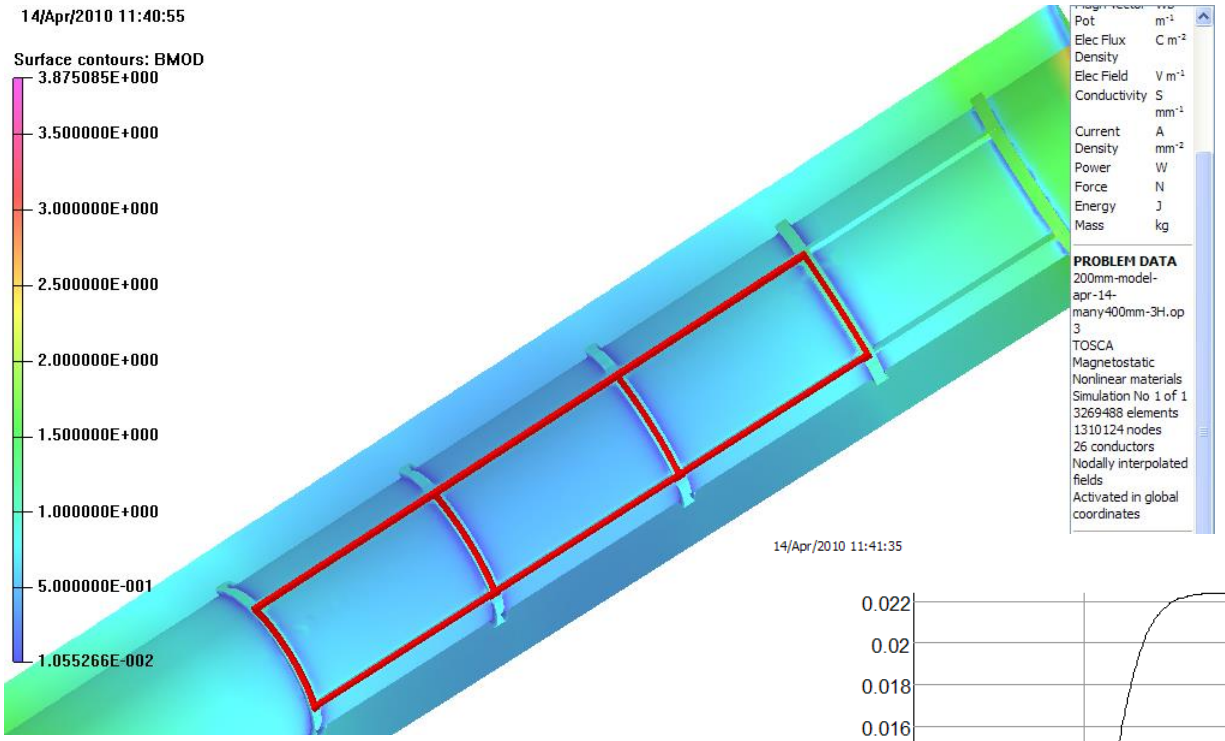
Vertical and Horizontal Corrector Powered (next to each other)

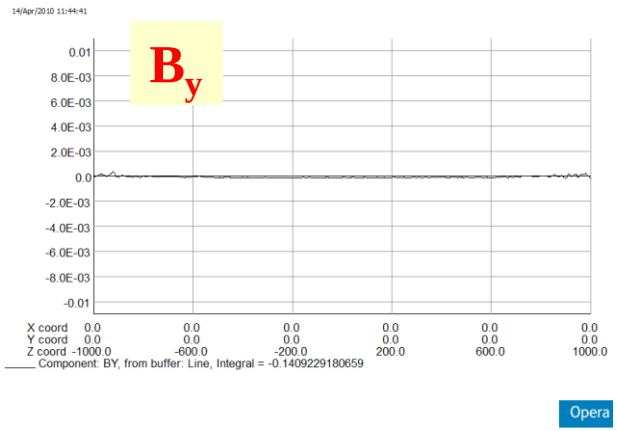




Works well

Three Horizontal Correctors at Full Strength





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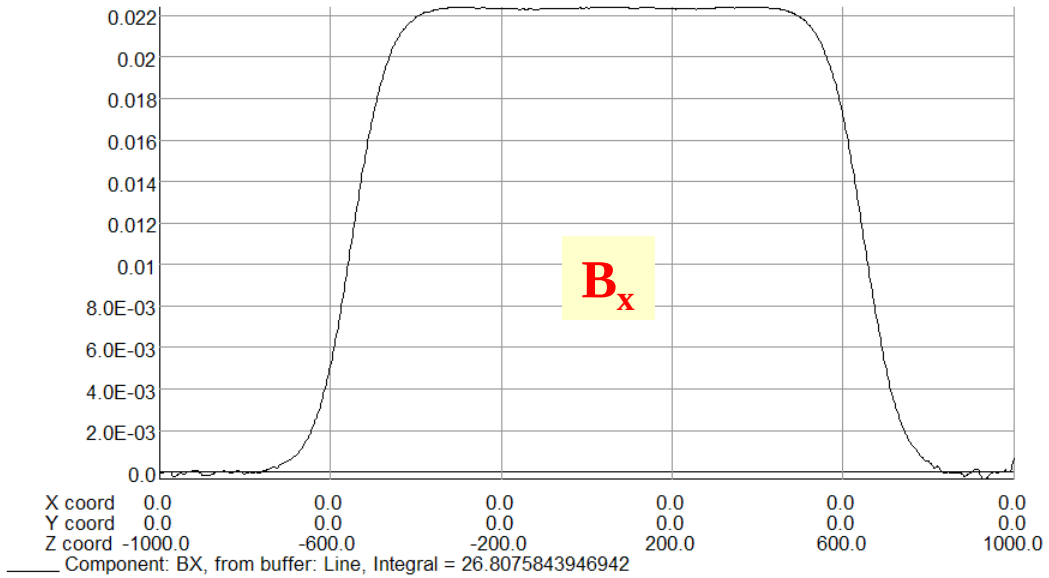
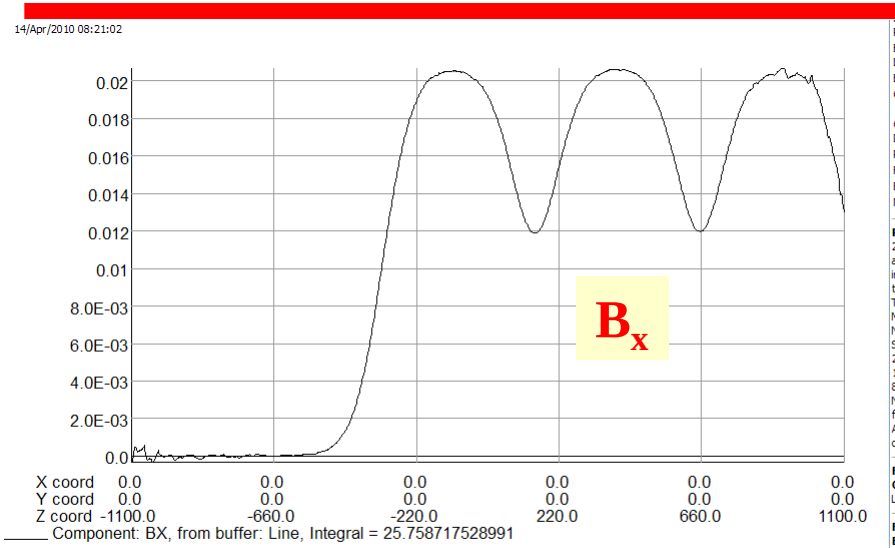
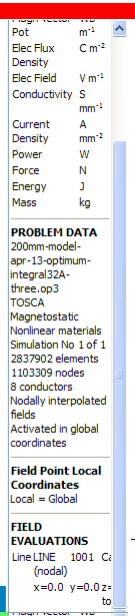


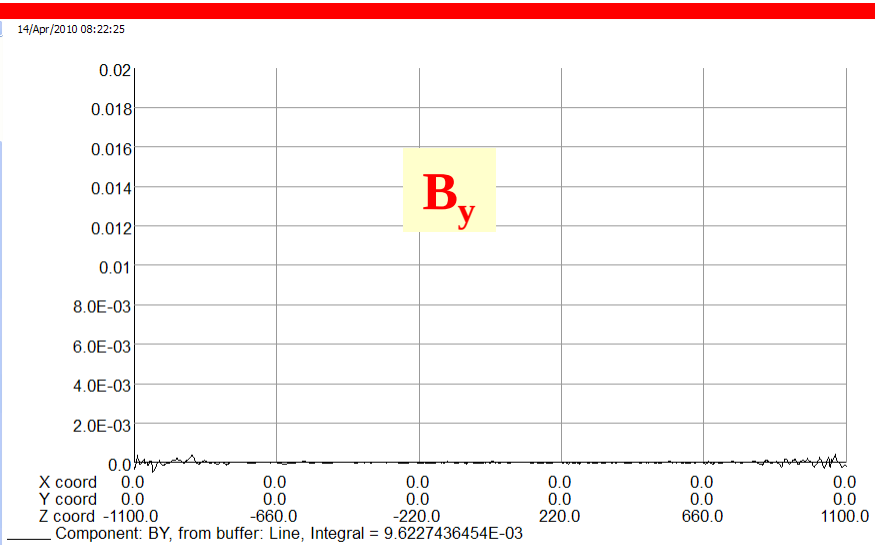
Works really well – even better than optimum integral design (field is very flat in this case).

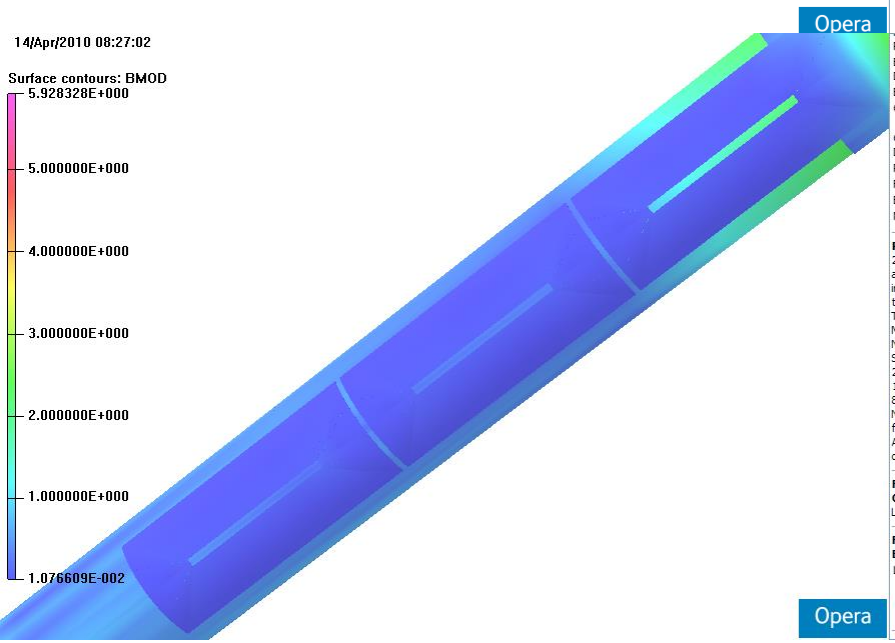
Compare in next slide

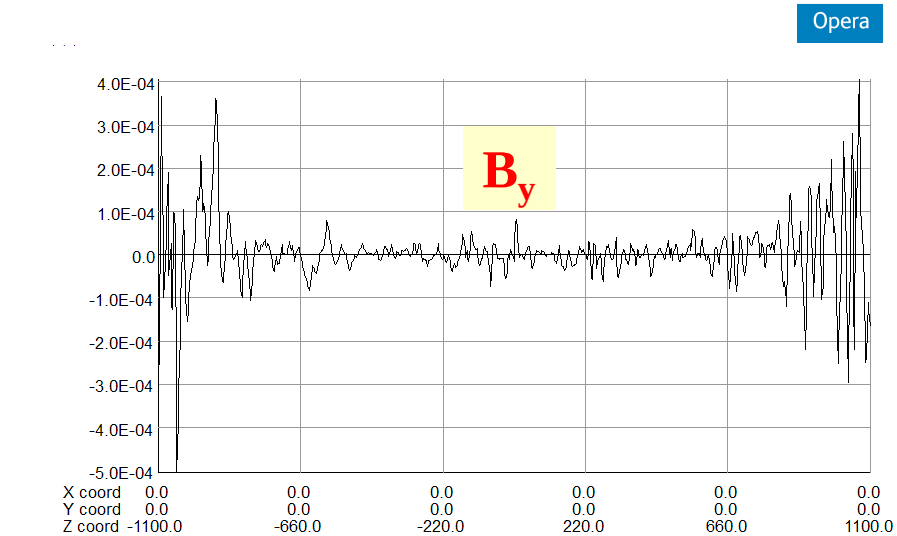
Compare with the
Optimum Integral Design for e-lens Correctors in Series











Ramesh Gupta, April 14, 2010

all dimensions are in mm unless noted

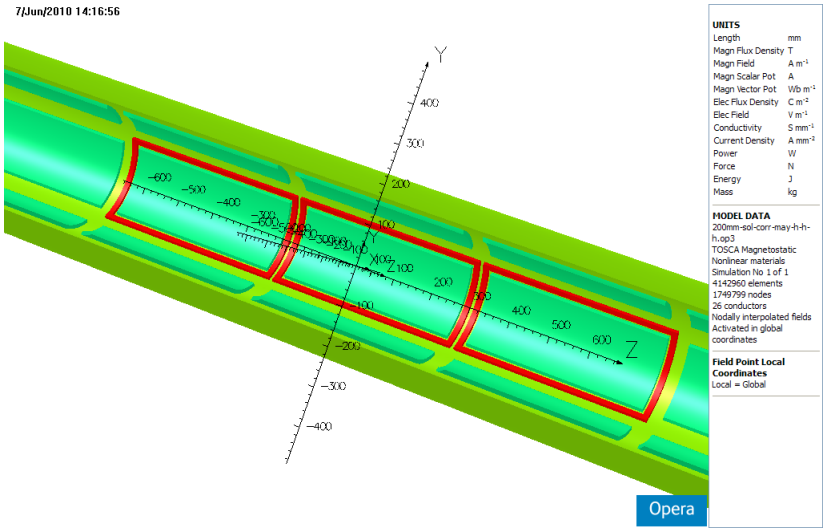
support tube ID	300	
support tube OD / coil ID	304	
circumference	955	
# of windings	1504	.635 mm (.025 inch) wire spacing
		assumes horizontal and vertical coils are on
		the same layer, 100% fill, i.e. each block is1/8
max. # of windings per block	188	of circumference
block width	12.7	
windings per layer	20	
# of layers	4	
final # of windings per block	80	
block height	3	
block insulator - pushers	3	
over-wrap after last layer	1.30	per A. Marone
total block height	7.30	
corrector assembly OD	318.59	
yoke ID	324.6	

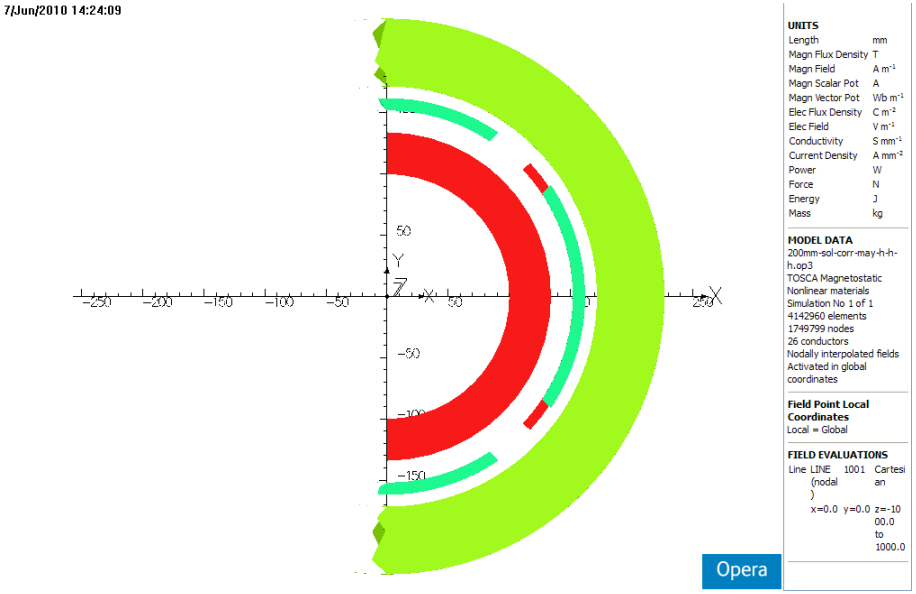
conductor length per 0.5m coil (2 blocks)	160	length in meters
total length of 10 coils	1600	length in meters
conductor length per 2.5m coil (2 blocks)	800	length in meters
total length of 2 coils	1600	length in meters
Total conductor length, ONE MAGNET	3200	length in meters

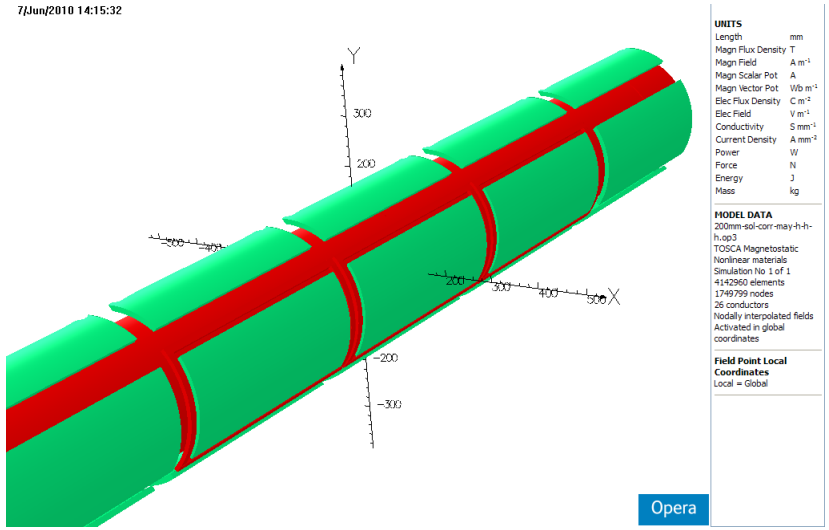
Item	Dimension (mm) thickness	inner diameter	outer diameter
inner cryostat (assumes 60mm aperture)	3	148	154
radial insulating space	5	154	164
Heat shield	4	164	172
radial insulating space	4	172	180
helium vessel / support tube	10	180	200
solenoid, 26 layers	37	200	274
G-10 buildup (max., tapered)	10	274	294
support shell (max., tapered)	5	294	304
assembly clearance (min., at max. taper)	1	304	306
corrector tube wall (to bottom of grooves)	2	306	310
corrector layers (4) + overwrap	7.3	310	324.6
helium space	3	324.6	330.6
yoke	61.7	330.6	454
assembly clearance thickness	1.5	454	457
helium vessel	19	457	495
insulation thickness	24	495	543
heat shield	3	543	549
insulation thickness	24	549	597
cryostat	6.35	597	610

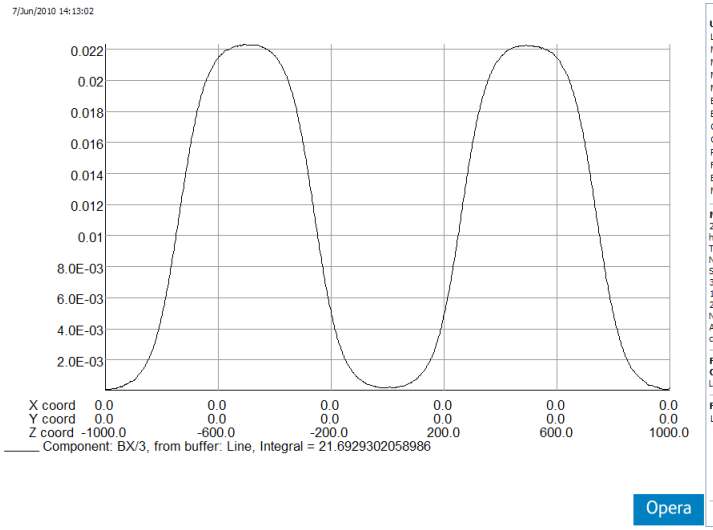
Iron Pole or NOT

- Iron pole is not connected to the yoke.
- It is small, it is expensive (machining), it saturates and the benefit is not clear
- Therefore, it is removed from the final design. Only slot in the tube for conductor.





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0.02
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0.016
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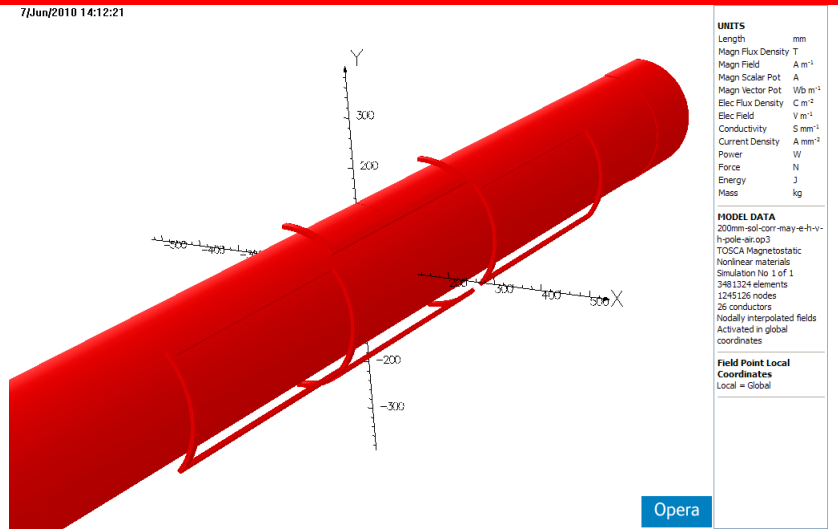
4.0E-03
2.0E-03
X coord 0.0 0.0 0.0 0.0 0.0 0.0
Y coord 0.0 0.0 0.0 0.0 0.0 0.0
Z coord -1000.0 -600.0 -200.0 200.0 600.0 1000.0
Component: BX/3, from buffer: Line, Integral = 21.6929302058986
Opera
UNITS
Length mm
Magn Flux Density T
Magn Field A m-1
Magn Scalar Pot A
Magn Vector Pot Wb m-1
Elec Flux 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
200mm-sol-corr-may-e-h-v-h-pole-air.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
3481324 elements
1245126 nodes
26 conductors
Nodally interpolated fields
Activated in global coordinates
Field Point Local Coordinates
Local = Global
FIELD EVALUATIONS
Line LINE 1001 (nodal) Cartesian
x=0.0 y=0.0 z=-1000.0 to 1000.0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Opera
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
200mm-sol-corr-may-e-h-v-h-pole-air.op3
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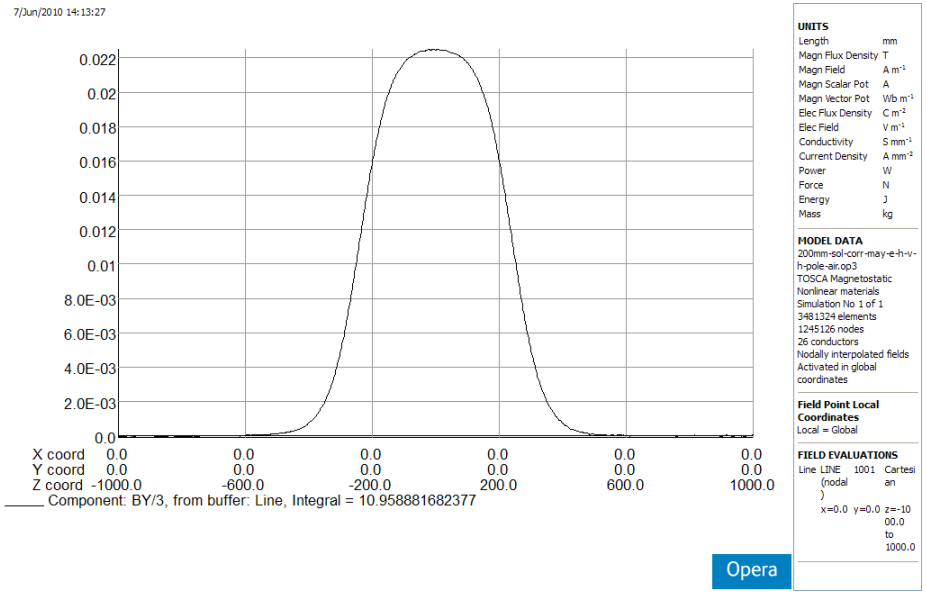
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0.0
X coord 0.0 0.0 0.0 0.0 0.0 0.0
Y coord 0.0 0.0 0.0 0.0 0.0 0.0
Z coord -1000.0 -600.0 -200.0 200.0 600.0 1000.0
Component: BY/3, from buffer: Line, Integral = 10.958881682377
Opera
UNITS
Length mm
Magn Flux Density T
Magn Field A m-1
Magn Scalar 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
200mm-sol-corr-may-e-h-v-h-pole-air.op3
TOSCA Magnetostatic
Nonlinear materials
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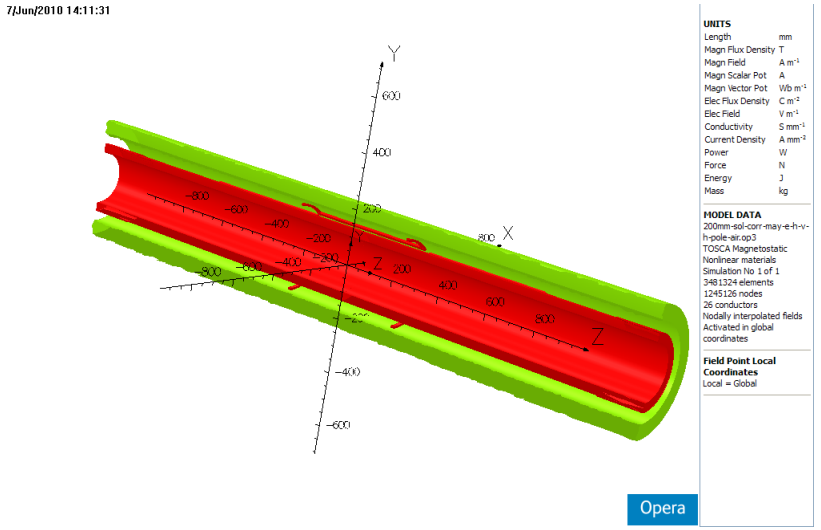
Line LINE 1001 (nodal) Cartesian
x=0.0 y=0.0 z=-1000.0 to 1000.0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X
Z
-400
-600
Opera
UNITS
Length mm
Magn Flux Density T
Magn Field A m-1
Magn Scalar Pot A
Magn Vector Pot Wb m-1
Elec Flux Density C m-2
Elec Field V m-1
Conductivity S mm-1
Current Density A mm-2
Power W
Force N
Energy J
Mass kg
MODEL DATA
200mm-sol-corr-may-e-h-v-h-pole-air.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
3481324 elements
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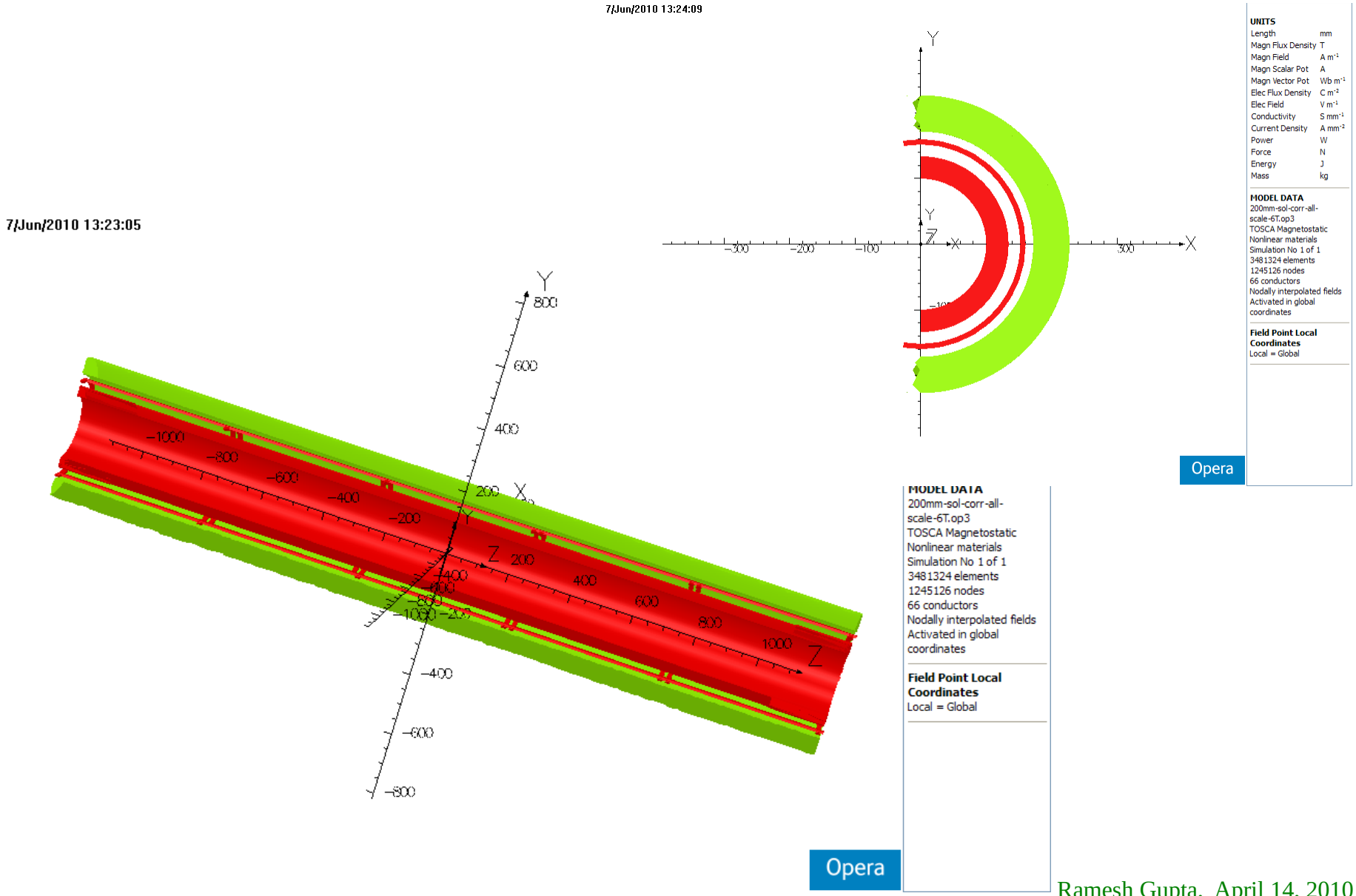
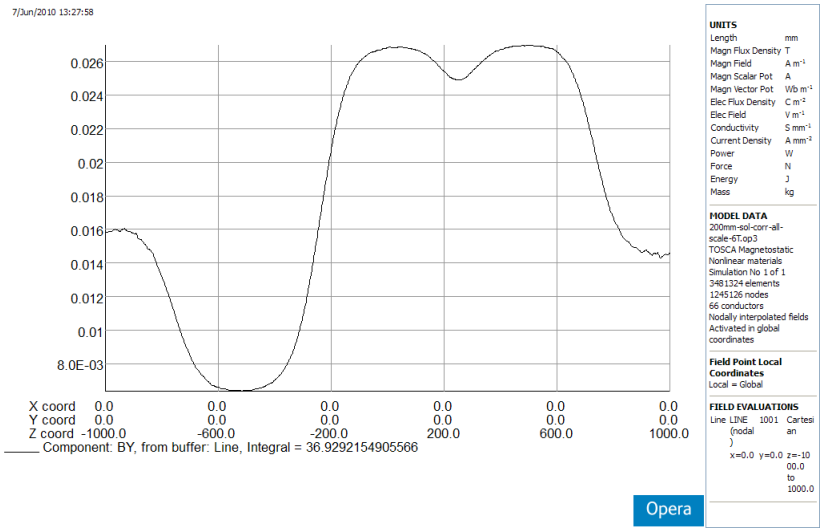
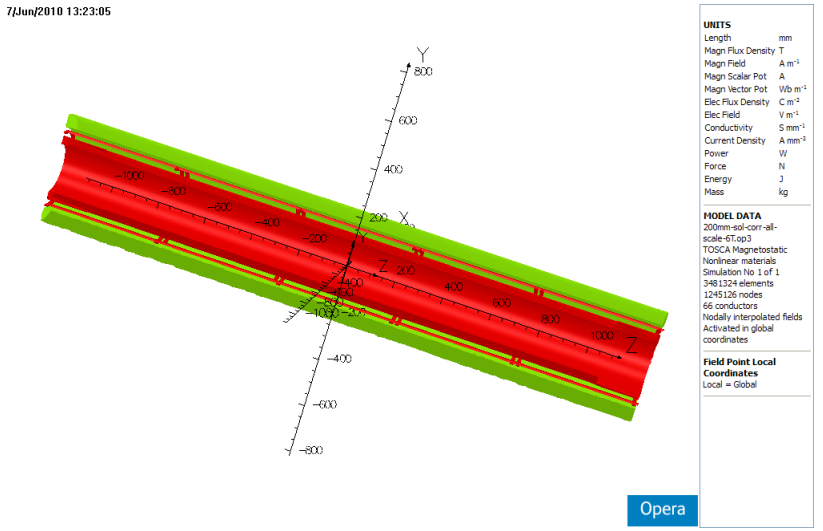
26 conductors
Nodally interpolated fields
Activated in global coordinates
Field Point Local Coordinates
Local = Global

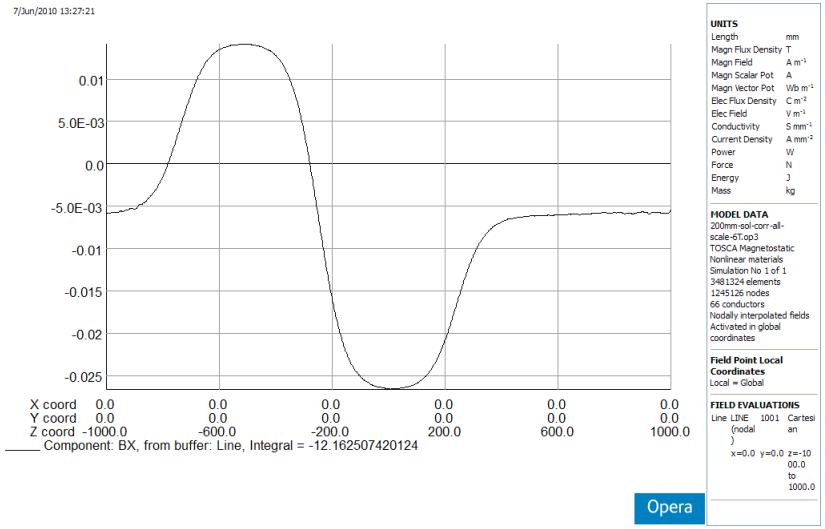
Model with Short and Long correctors

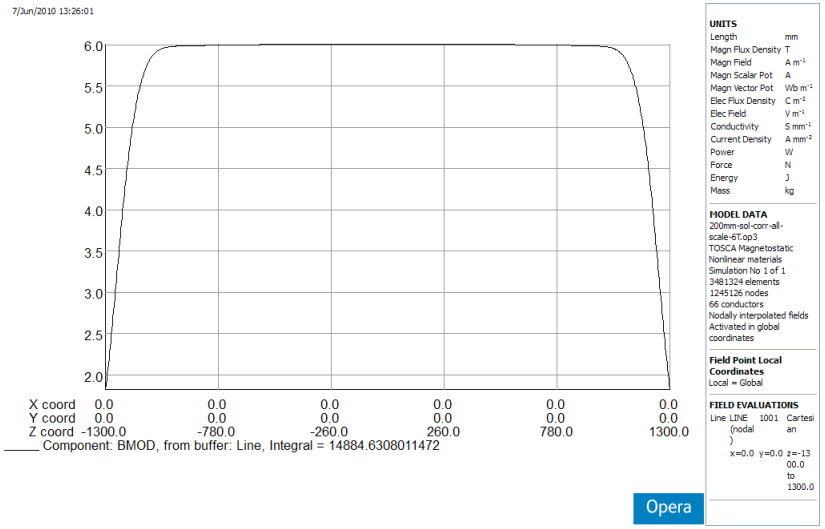


Field with Short and Long correctors



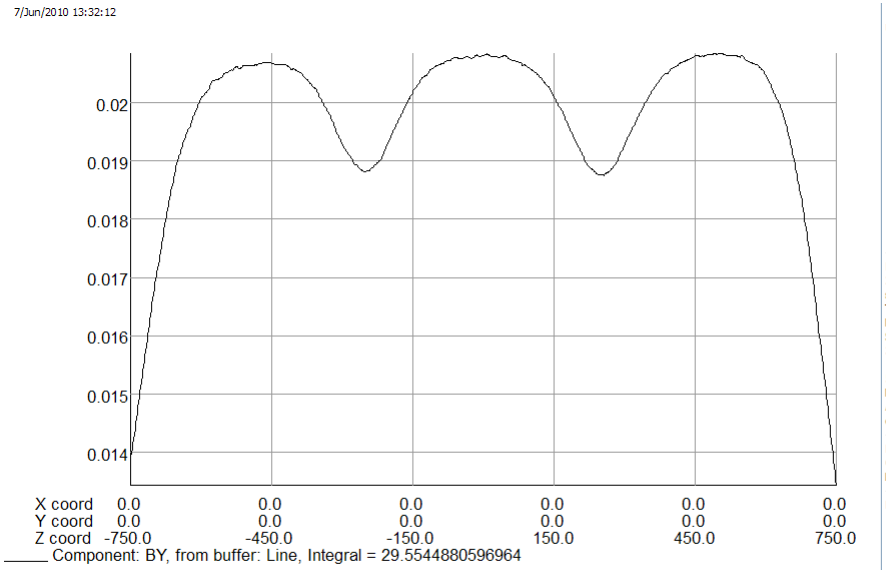


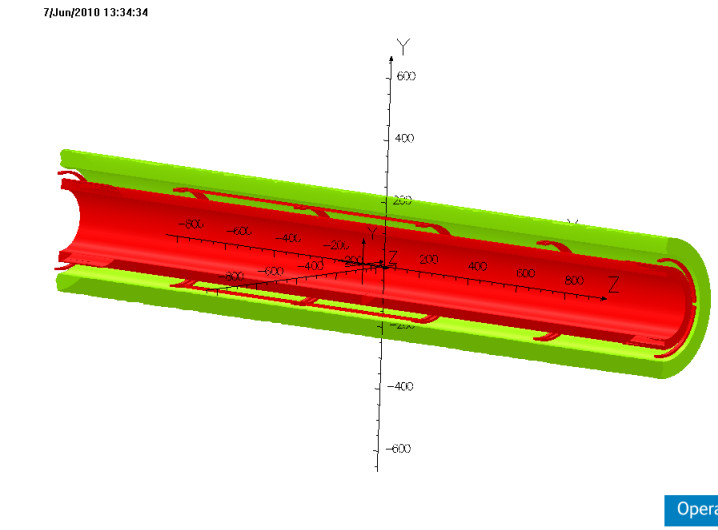


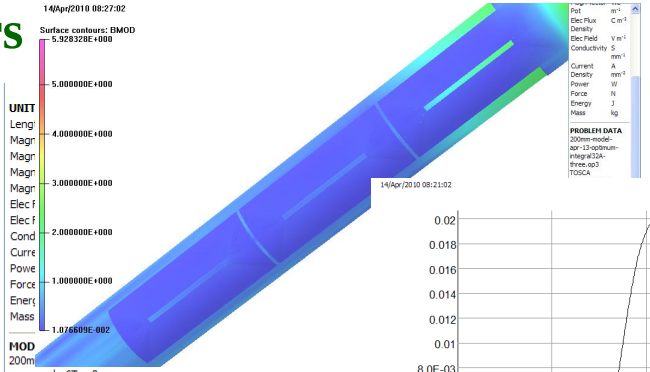


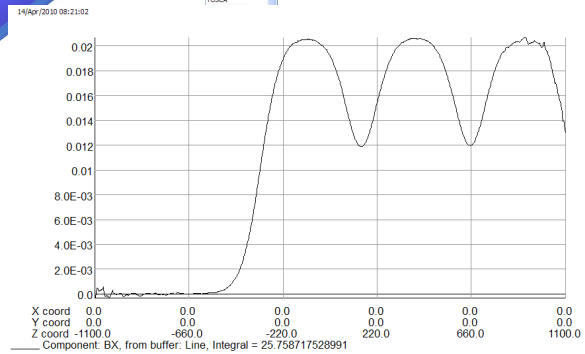
Comparison of Field between Optimum Integral Design and Block Design

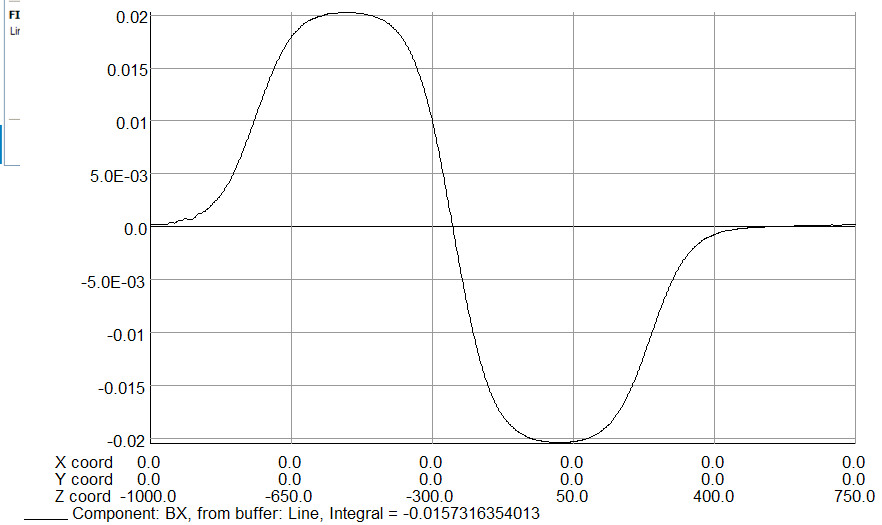
Field with Short and Long correctors

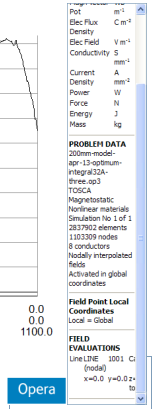










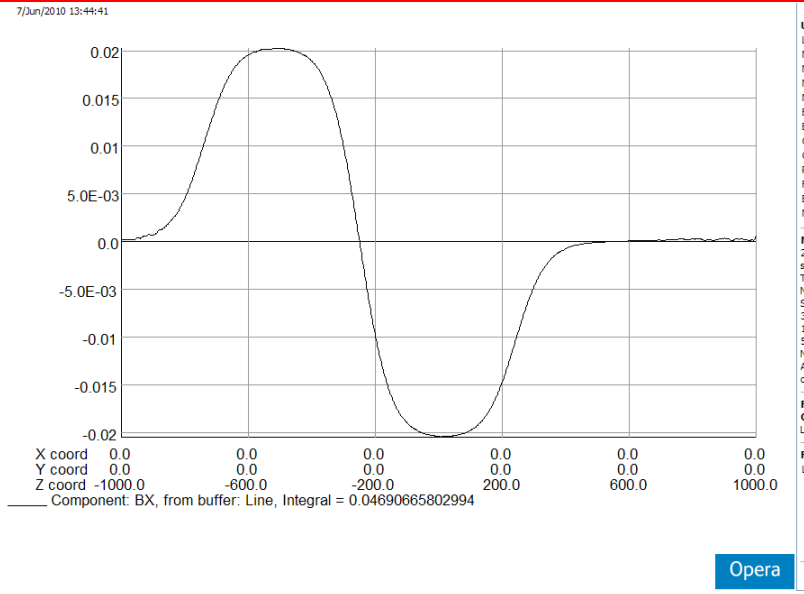


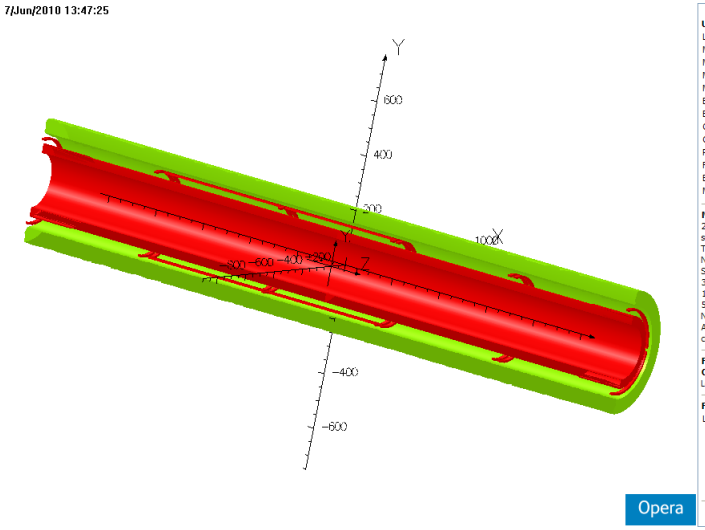
Case for separate short and long correctors (1)

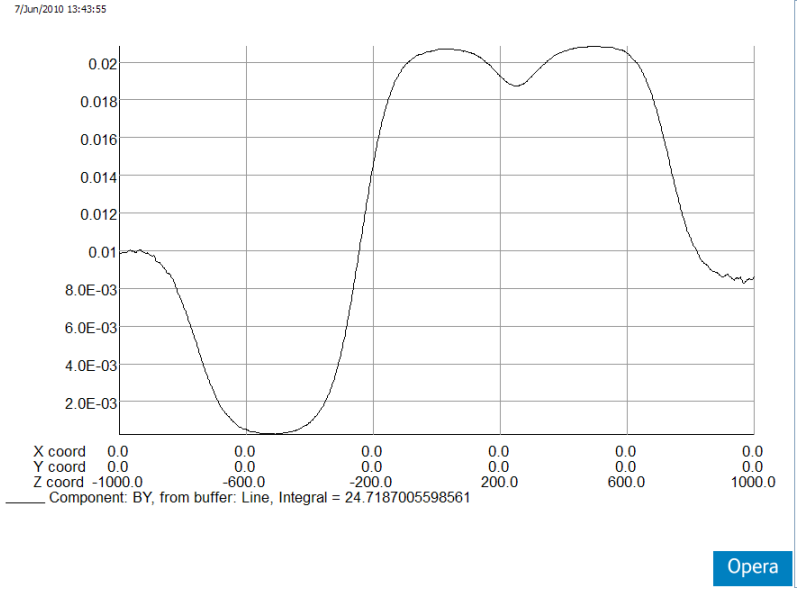
- **Main solenoid will operate from 3 T to 6 T**
- **Correctors (both short and long) must correct for the position error at each field**
- **Since the iron saturation is significant at 6 T, current will not scale linearly.**
- **Remember, each short corrector, will in general have a different value.**
- **Therefore, a simple scaling of current in corrector with solenoid field (3 T to 6 T) would create some error.**
- **The error could increase when the correcting field from the long corrector is added.**
- **Next few slides will examine this problem.**

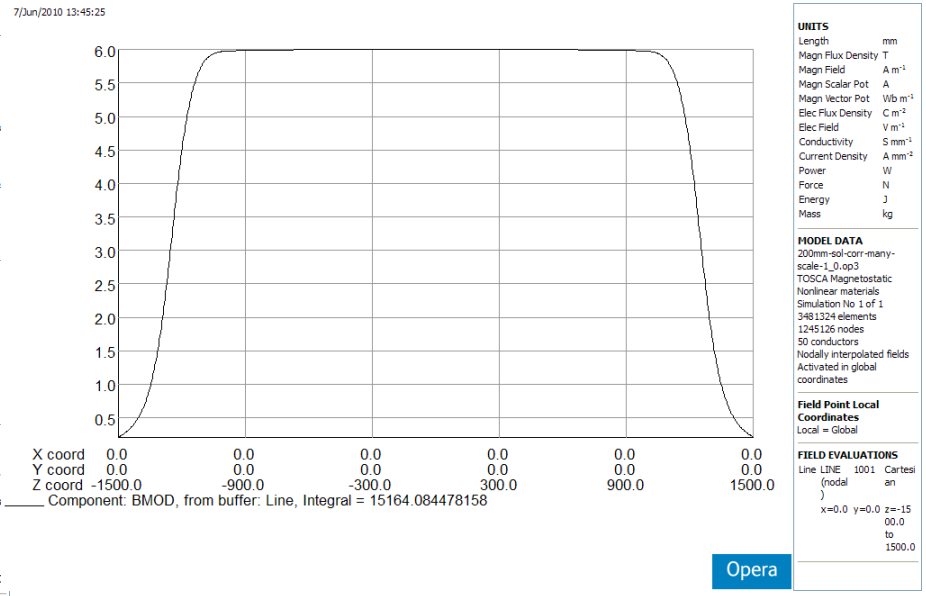
- **Compare this for the case of building separate long correctors and the benefit we had hoped for (set short corrector and forget it).**

Case for separate short and long correctors (2)
(Correction at 6 T)

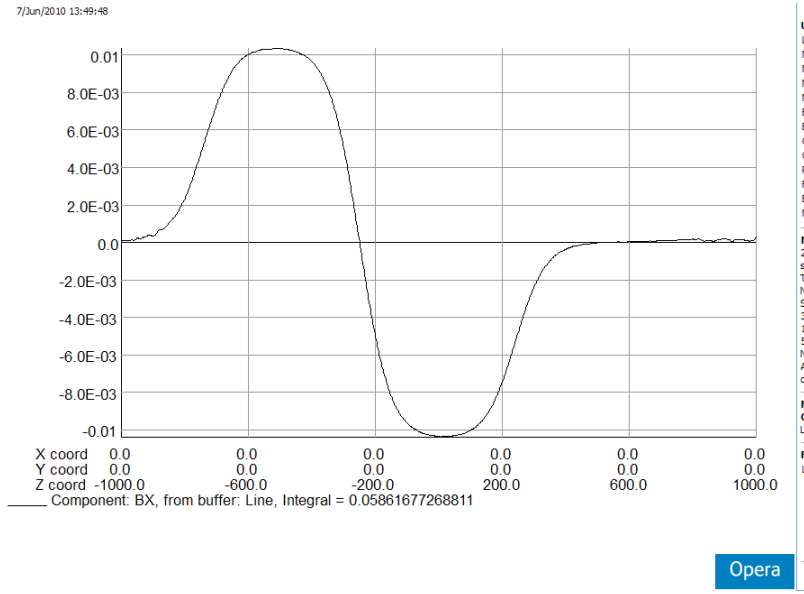


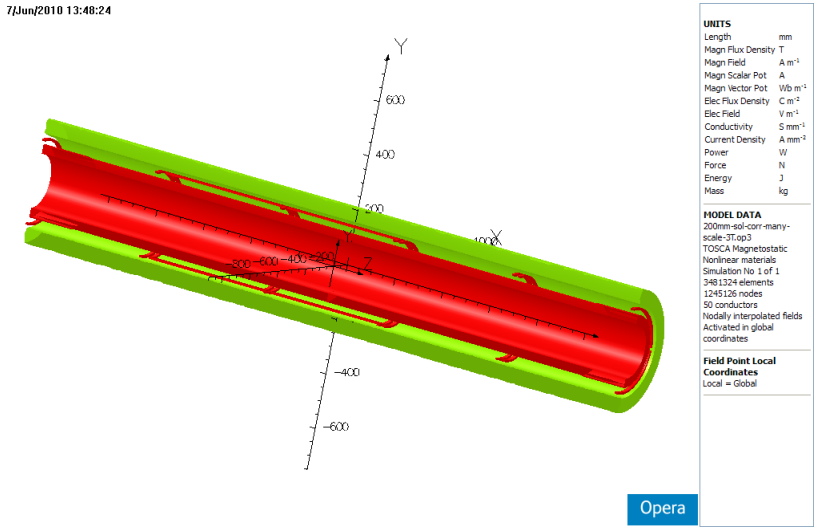


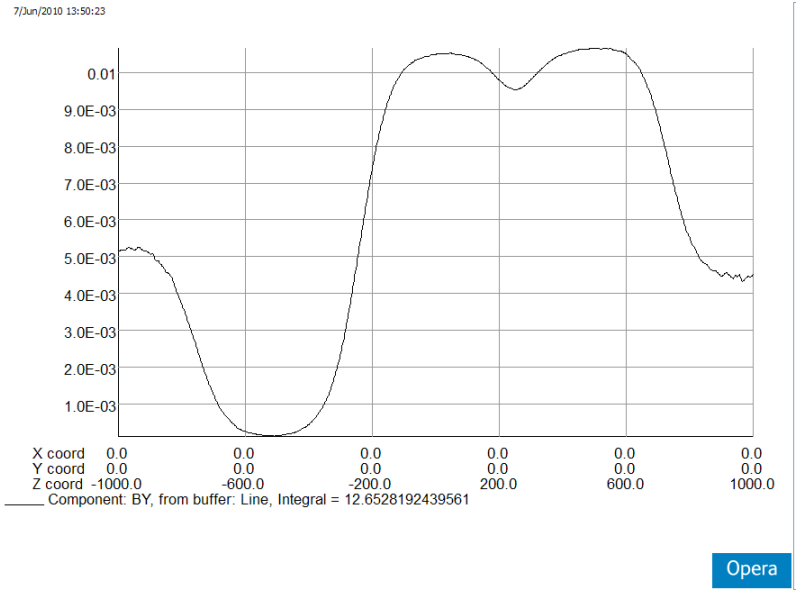


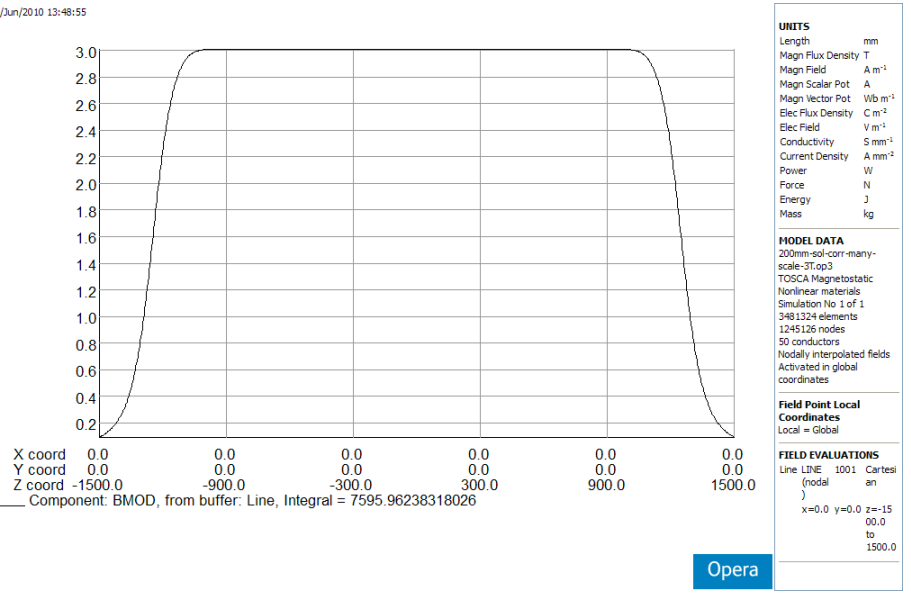


Case for separate short and long correctors (2)
(Correction at 3 T)

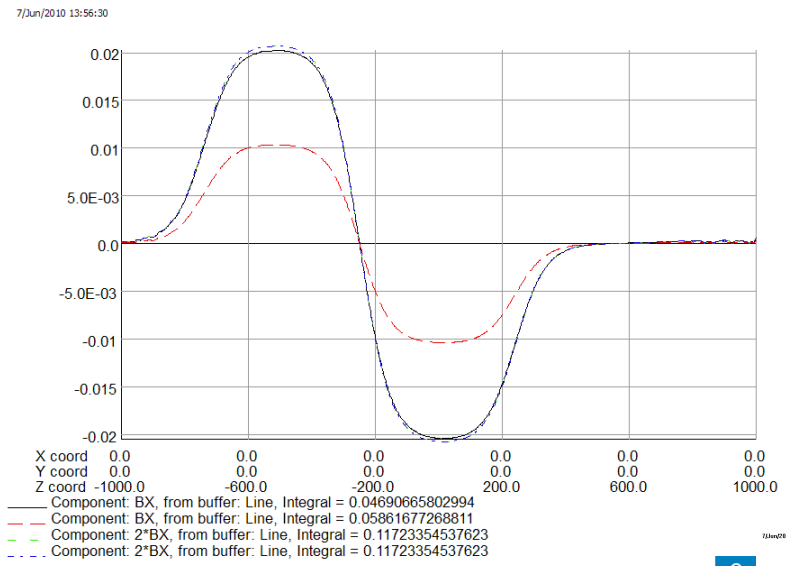


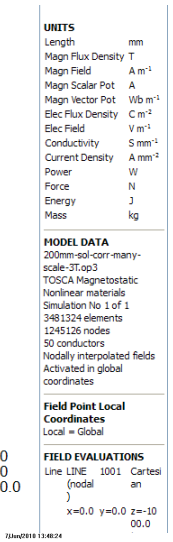


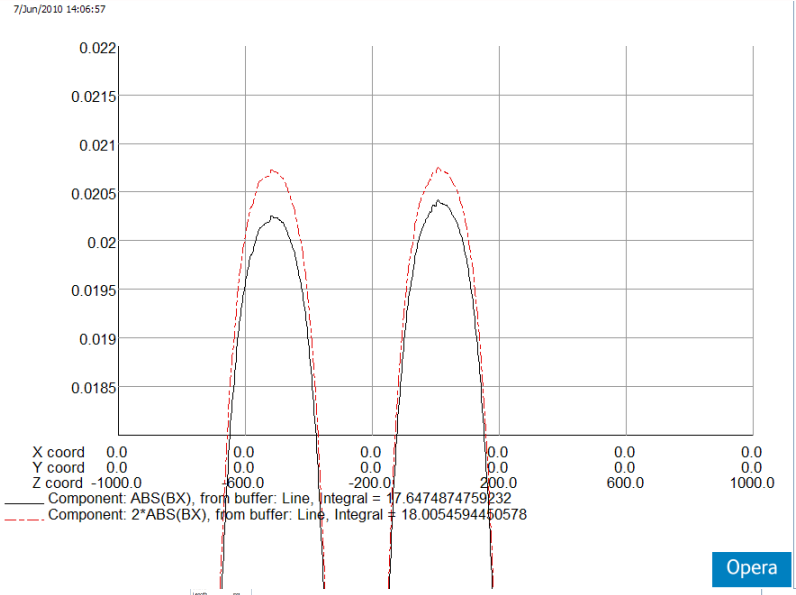


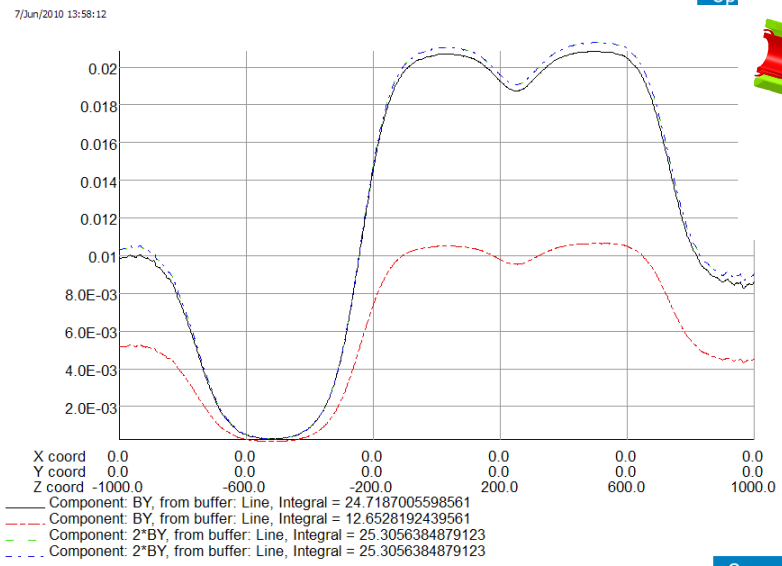


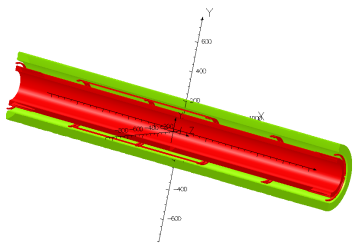
Influence of Iron Saturation (short corrector needs to be adjusted)

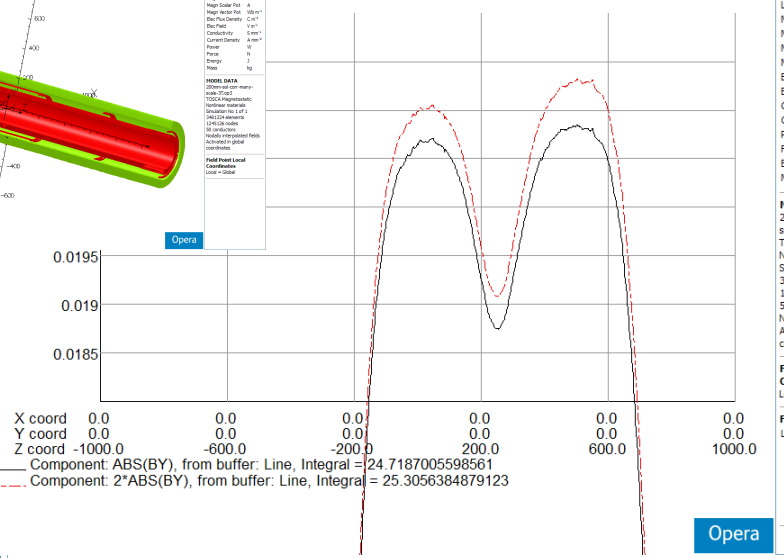












Ramesh Gupta, April 14, 2010

Summary

- **Slot design of correctors seems to be working well .**
- **Iron pole is eliminated (as it does not give much benefit). Removing it saves cost with practically no penalty.**
- **Short corrector may be sufficient. Having separate long and short correcrtor do not de-couple the task. Simple computer algorithm should allow short correctors (with slightly increased amp-turns) to serve for both.**