Step IV & VI: Local Flux Return

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Outline

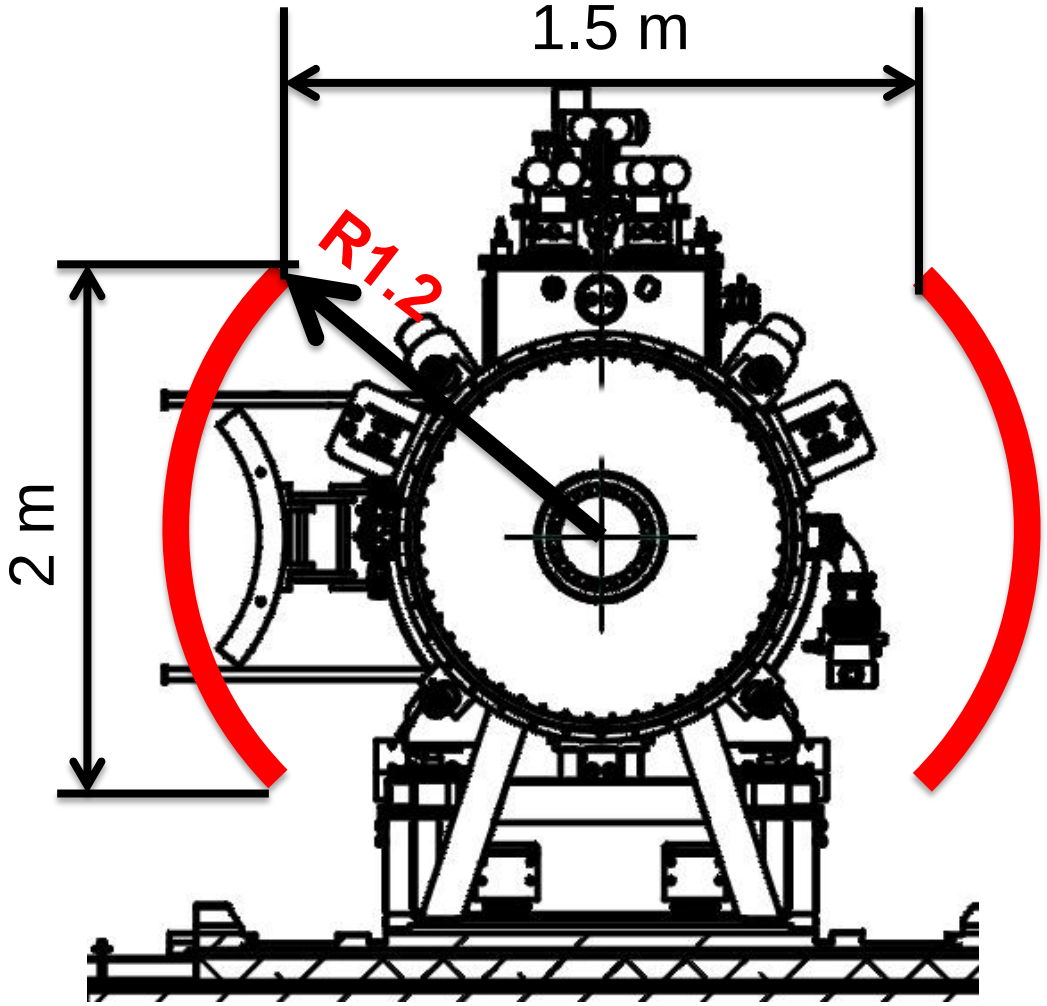
- Introduction and Concept
- Shielding efficiency
- Extension to Step VI
- Effect on beam
- Forces

Local Flux Return

- Explore shielding options
  - Initially only for Step IV, but should also work for Step VI (or upgradable)
- What has been done so far?
  - general concept
  - performance Step IV&VI (all cases)
  - effect of shielding on field of MICE
  - individual components
    - walls, Q9, floor, …
- However, there are many things which have not been done so far…

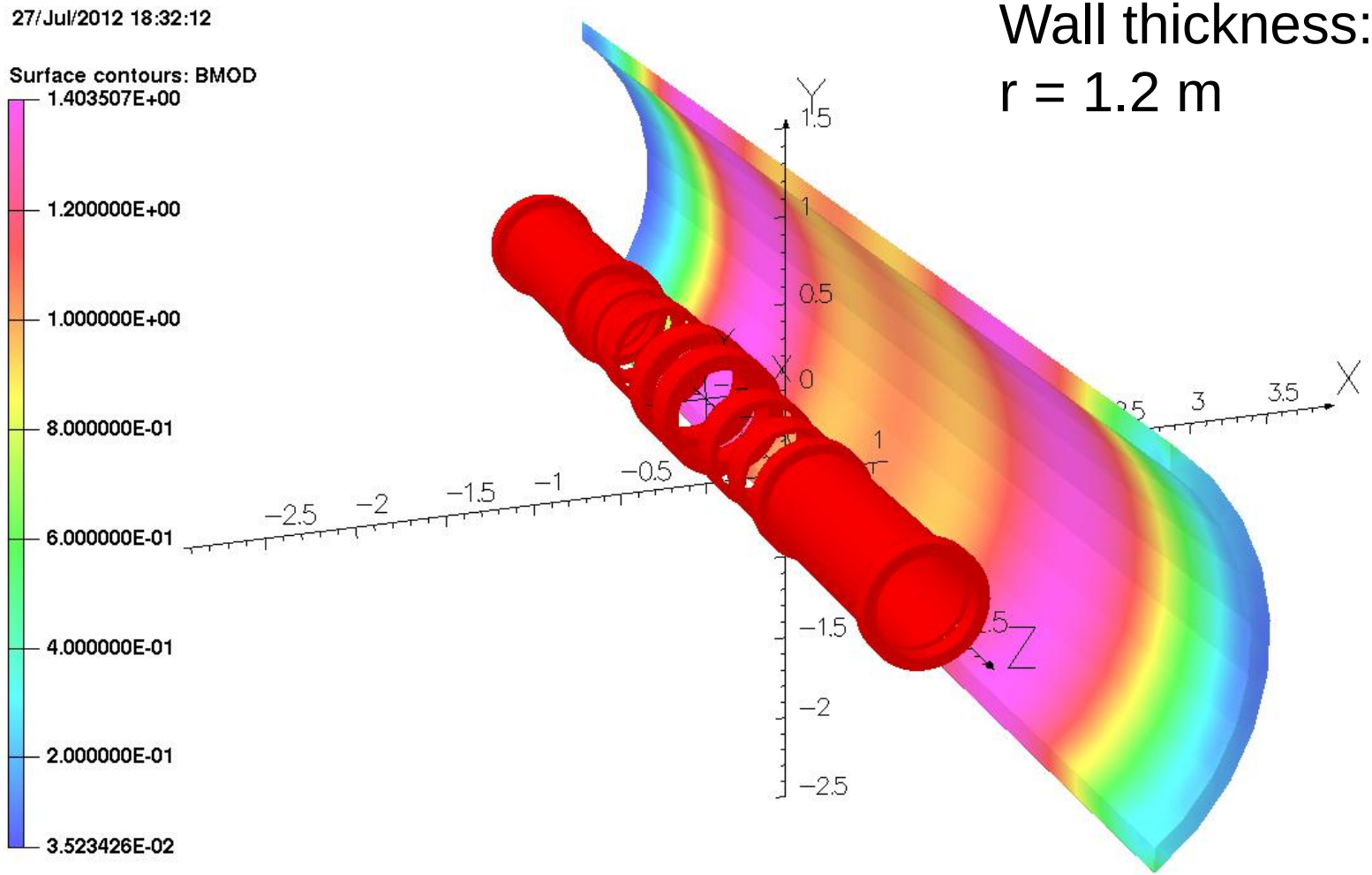
Concept

- To get good shielding horizontally: need continuous steel in azimuthal direction
- Geometry
  - Tube of radius 1.2 m
  - wall thickness 10 cm
  - azimuthally -50..50°
  - weight: 30t



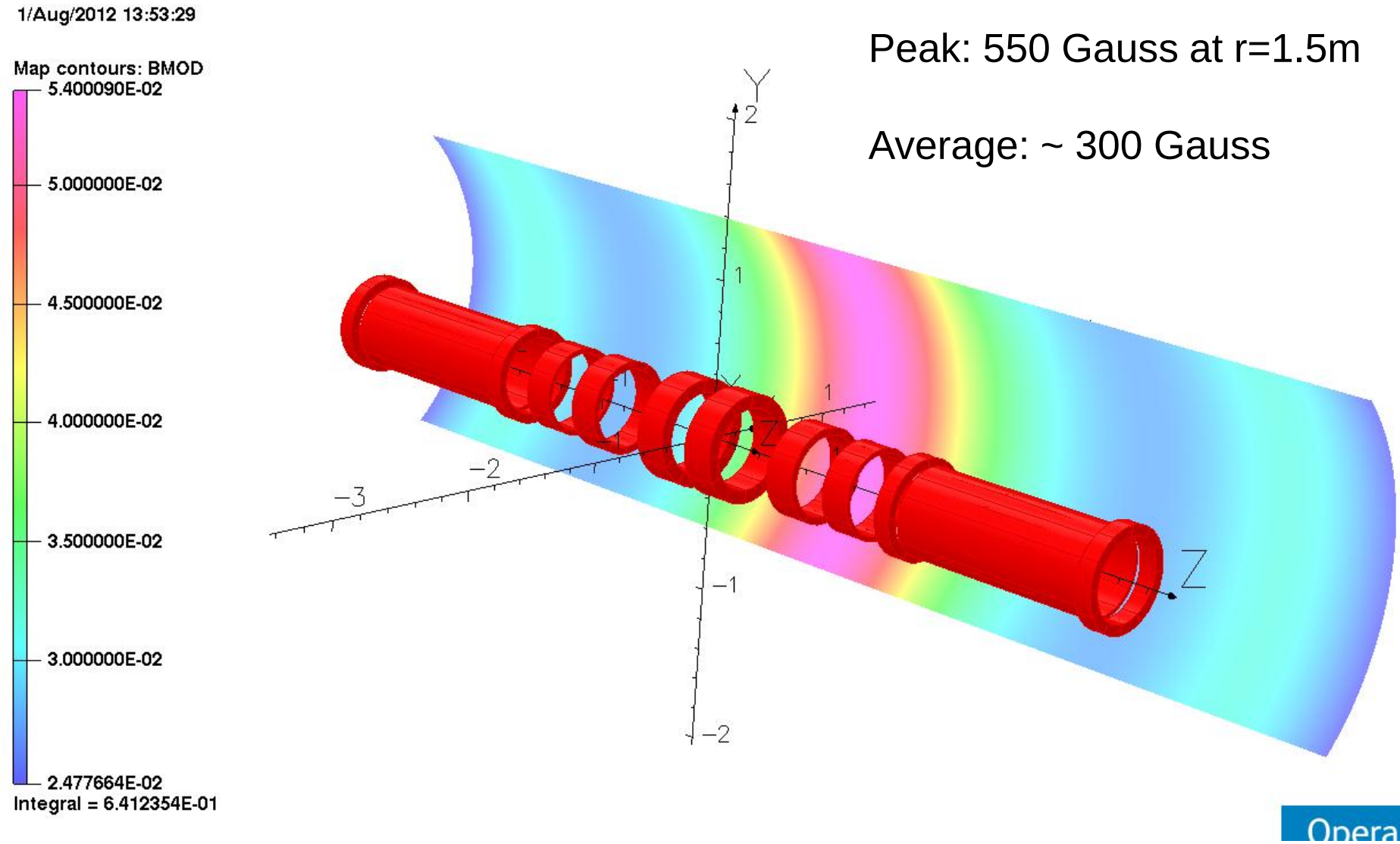
(Note: not to scale)

Magnetization In Shield



Wall thickness: 10 cm
r = 1.2 m

Initial Situation



Shielding Efficiency

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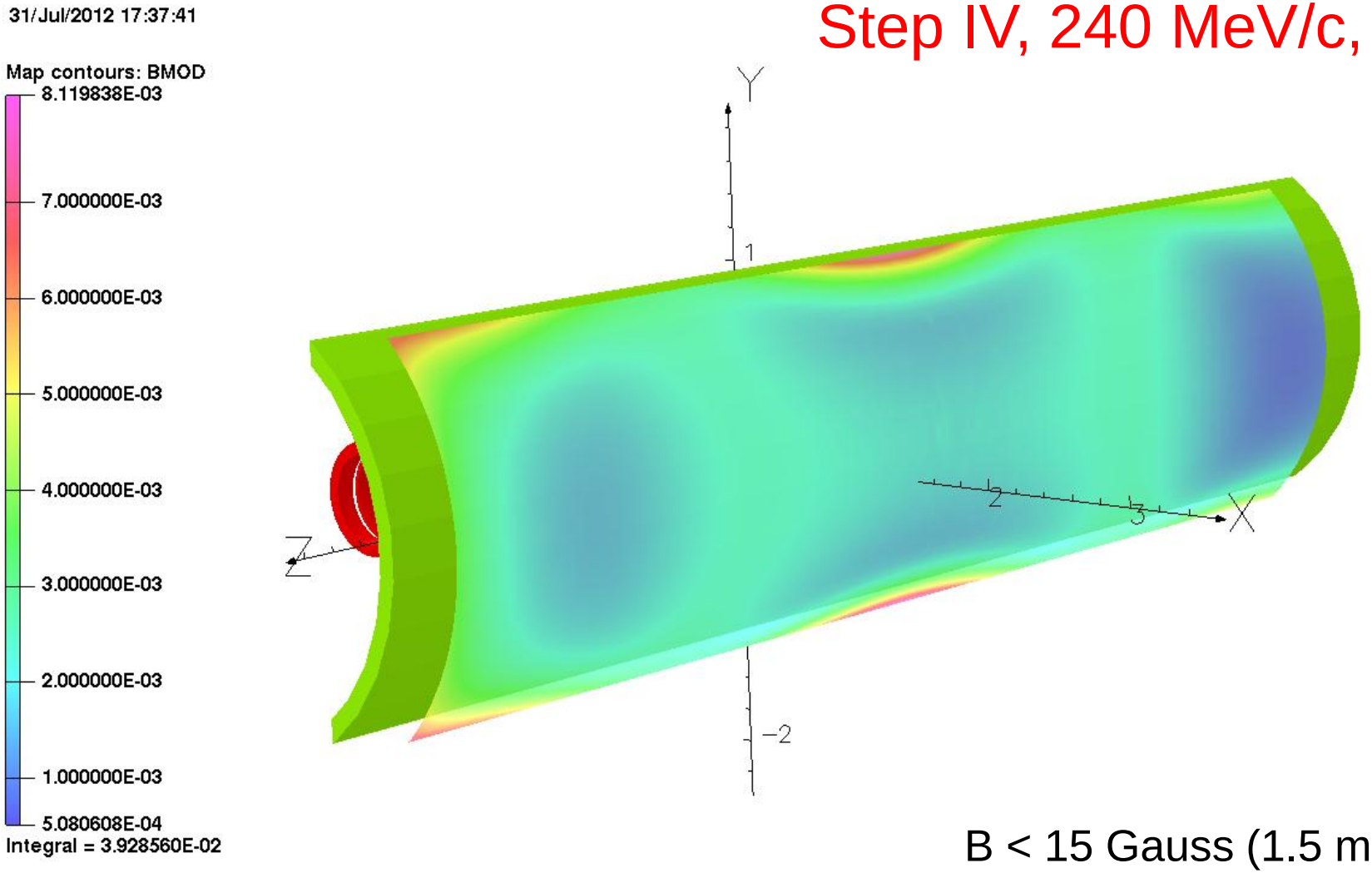
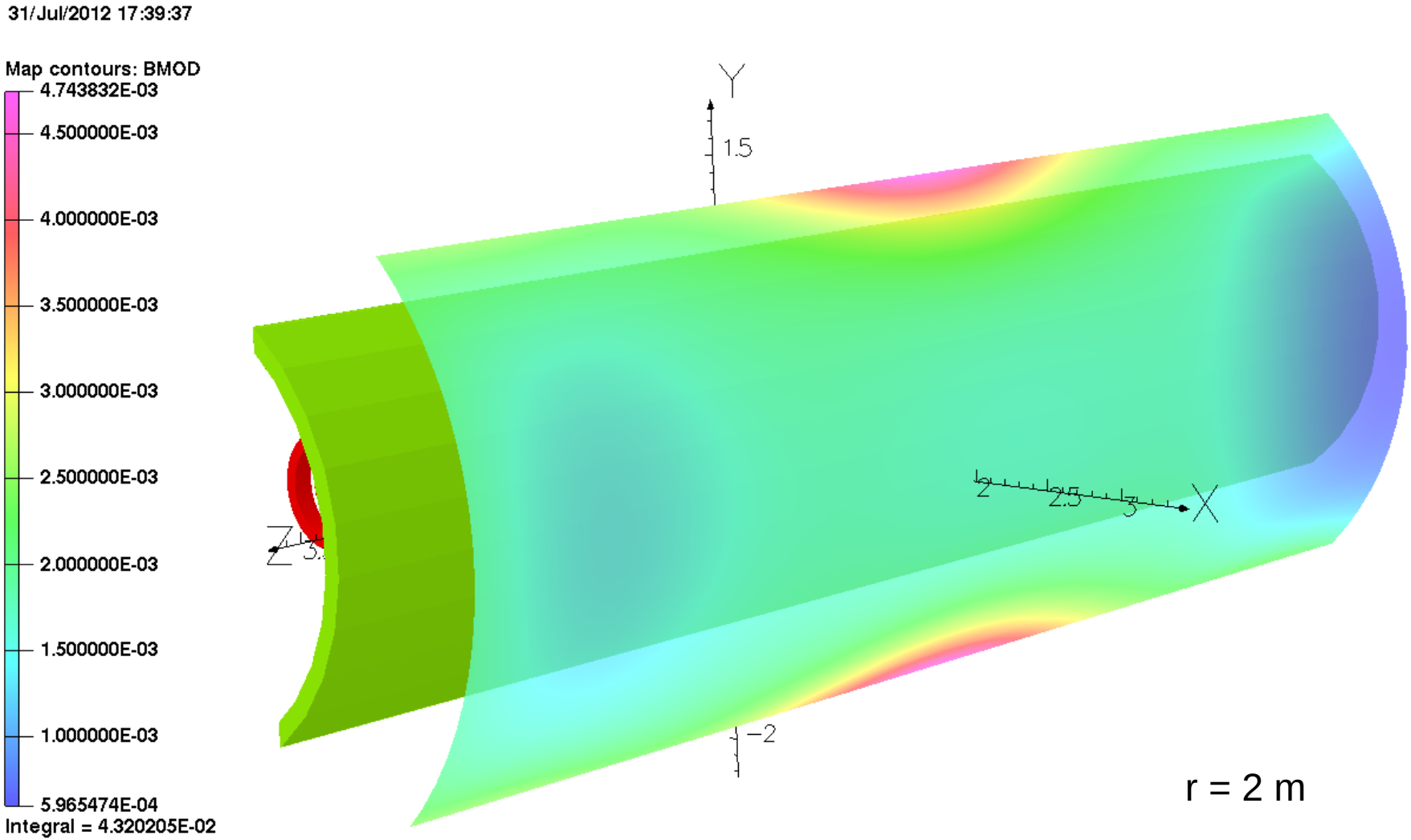


Step IV, 240 MeV/c, flip

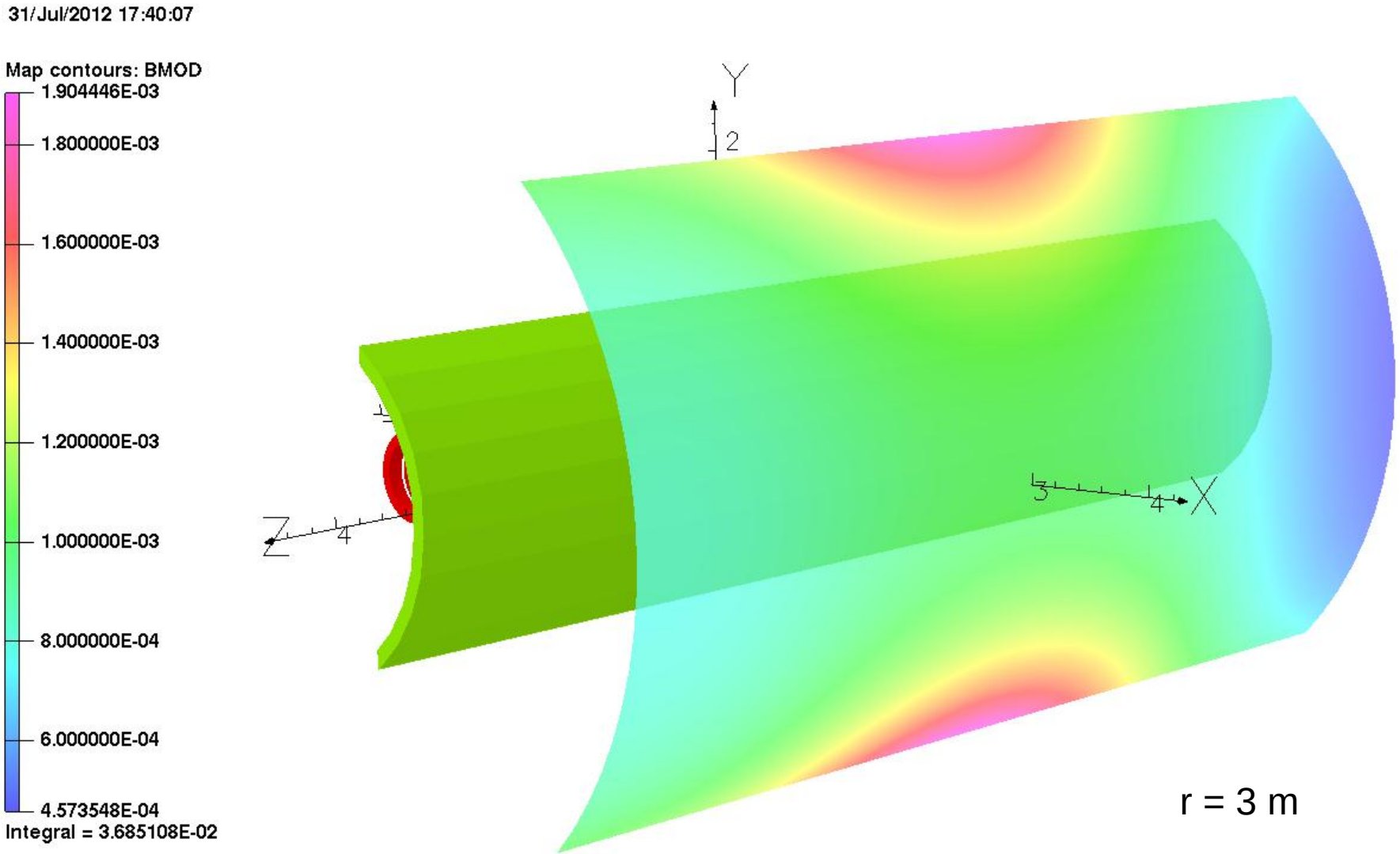
B < 15 Gauss (1.5 mT)

r = 1.5 m

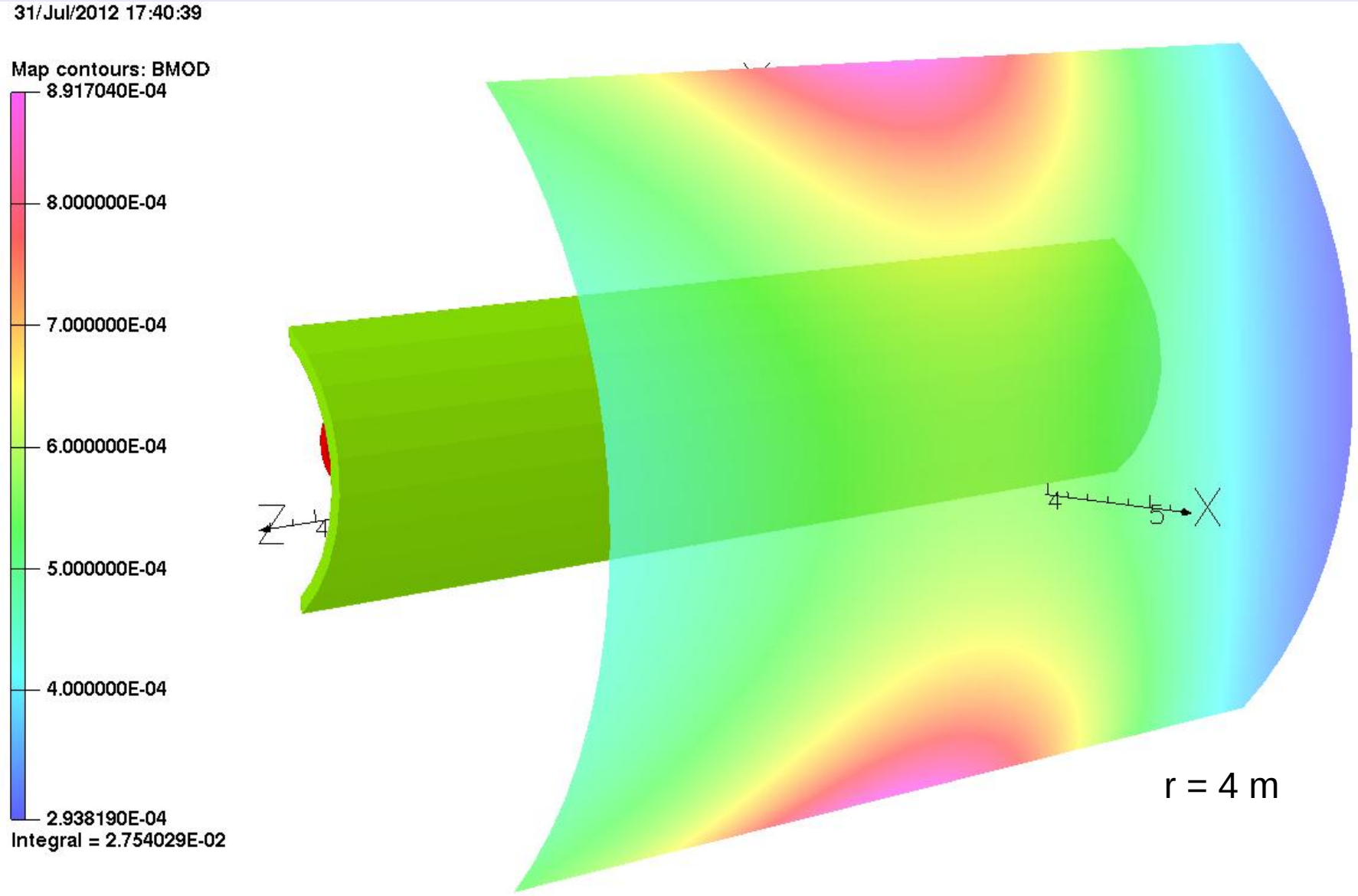
Development of Fringe Field



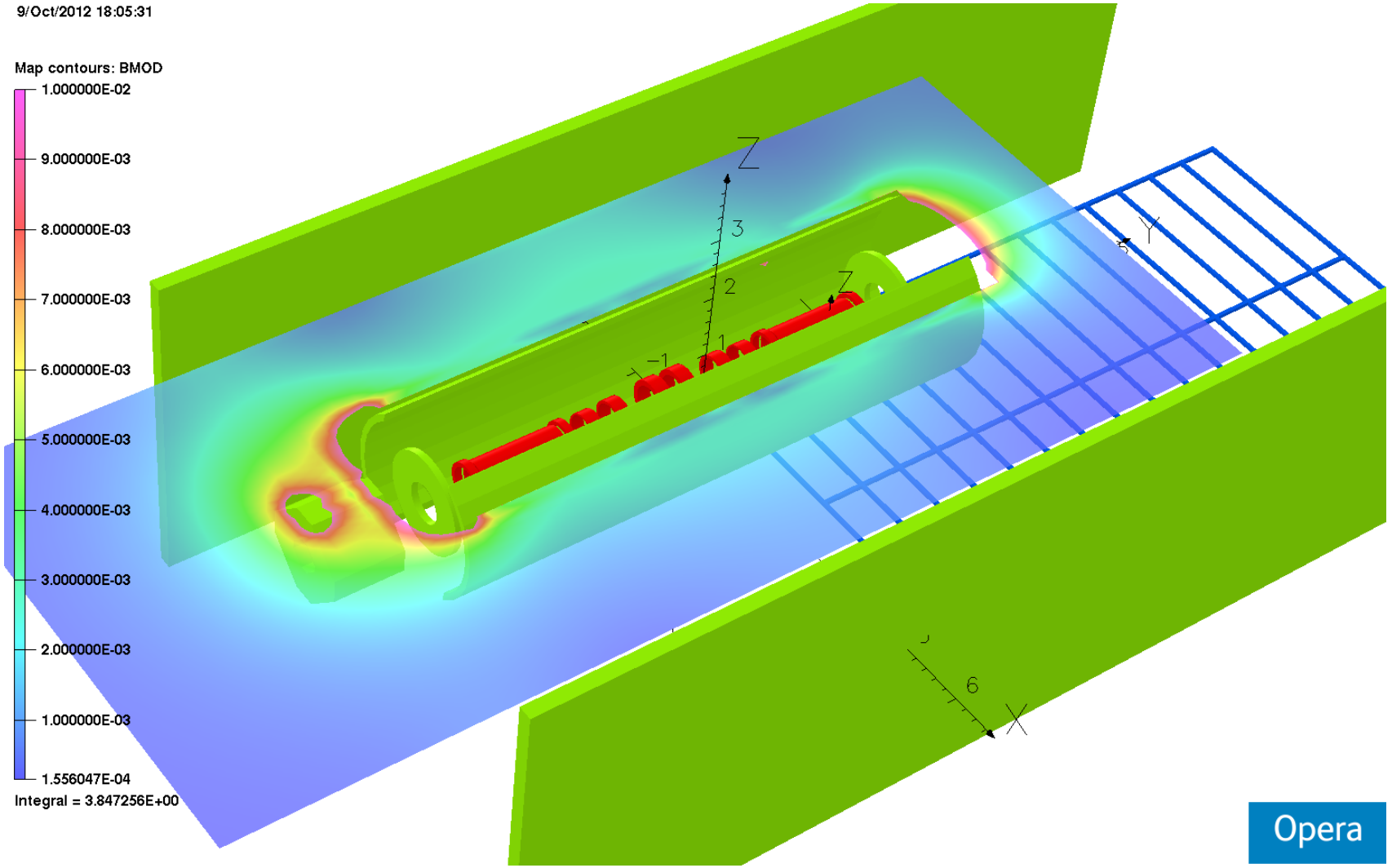
Development of Fringe Field



Development of Fringe Field



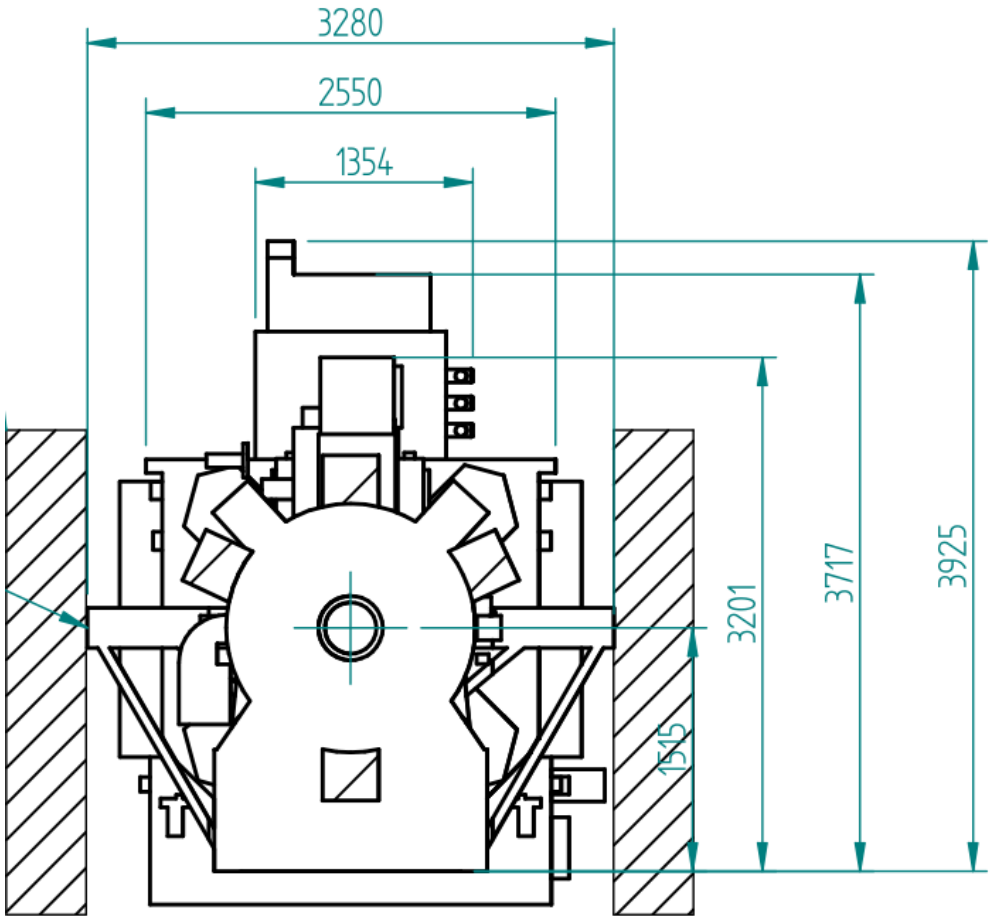
Fringe Field



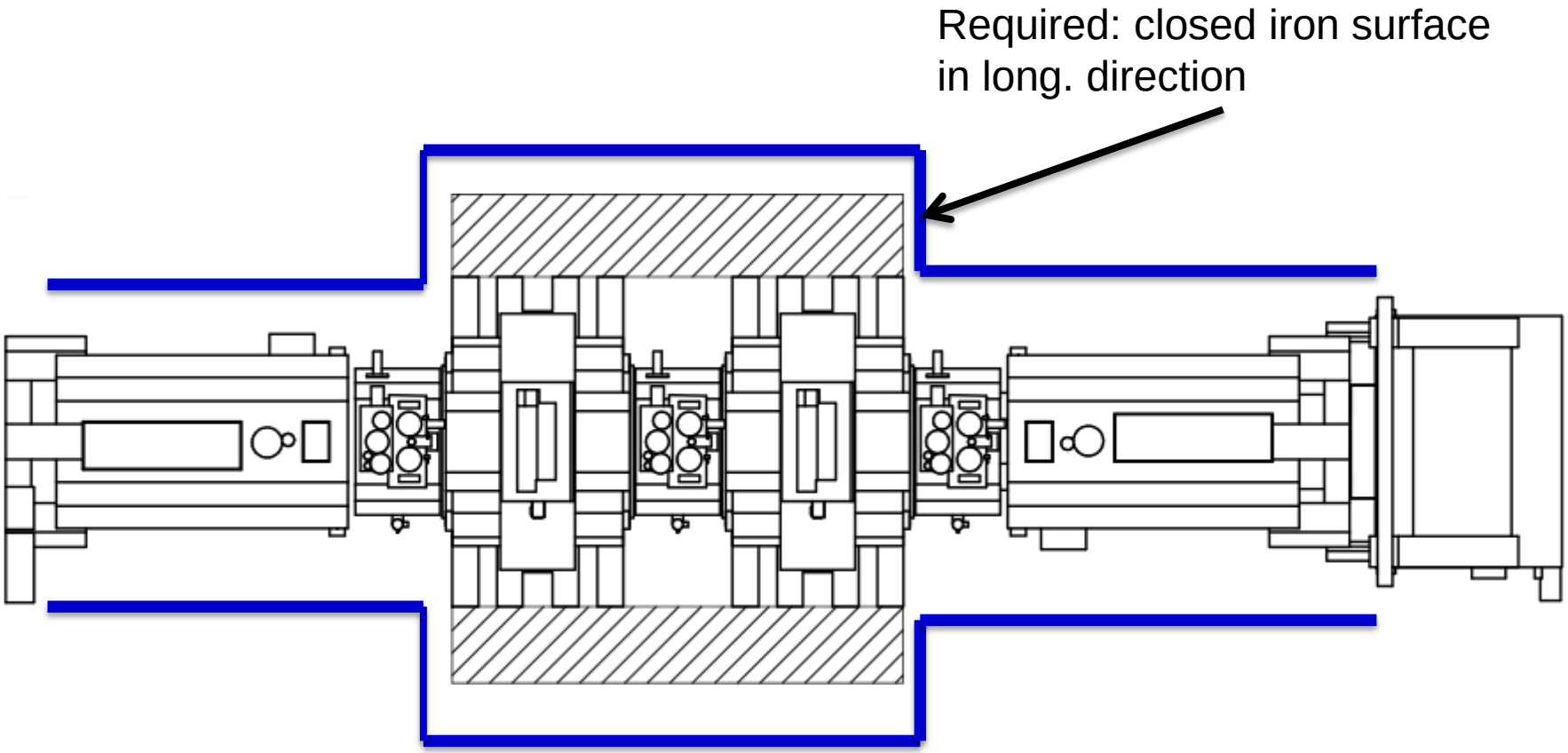
Vertical Position: 0.75m

Options for Extension Step VI

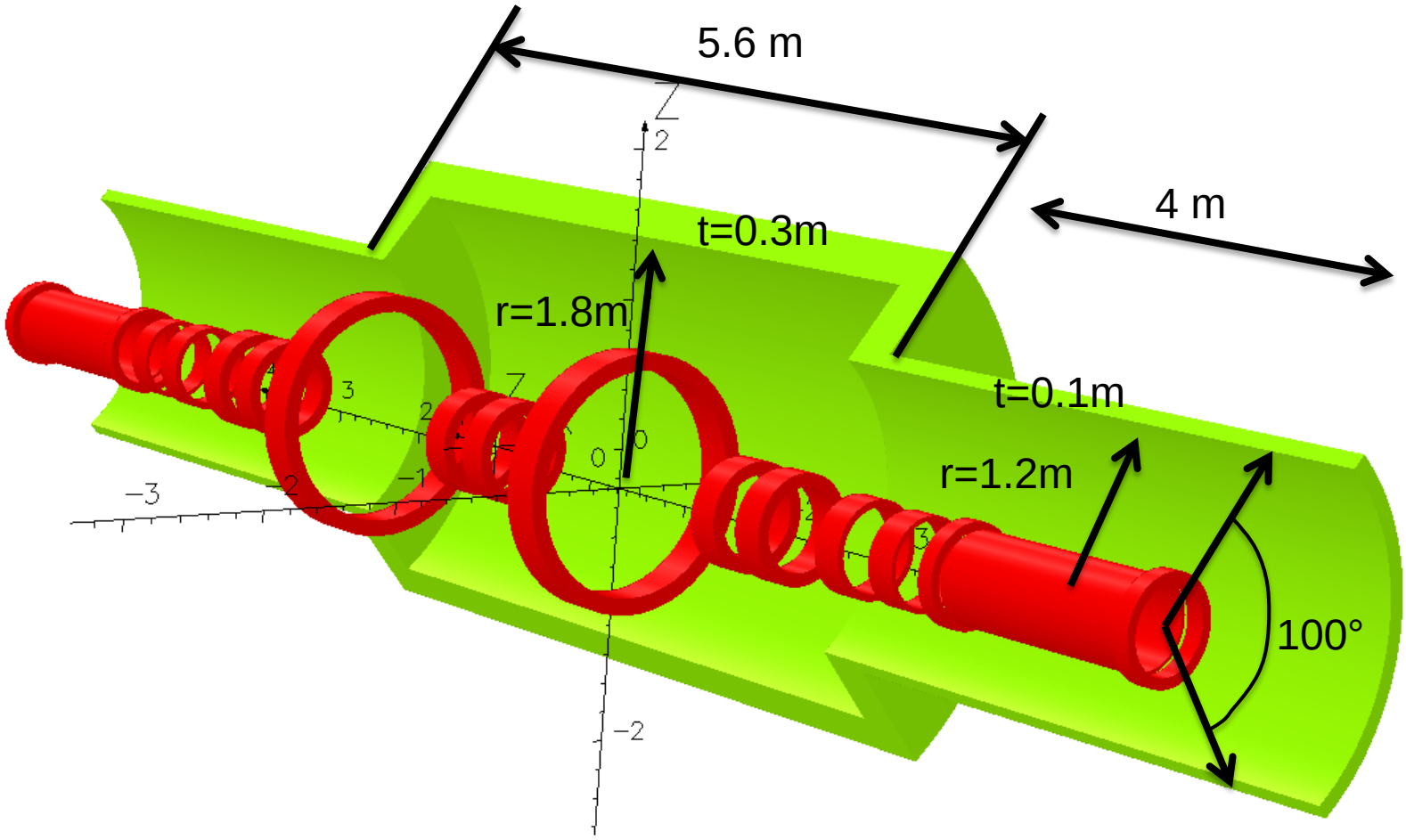
- MICE Step VI: significantly larger in diameter
  - Coupling coils
  - RF waveguides
- Adaption of scheme possible?
- Ideally:
  - single scheme for both scenarios
  - Or: possibility of modification



Extension to Step VI

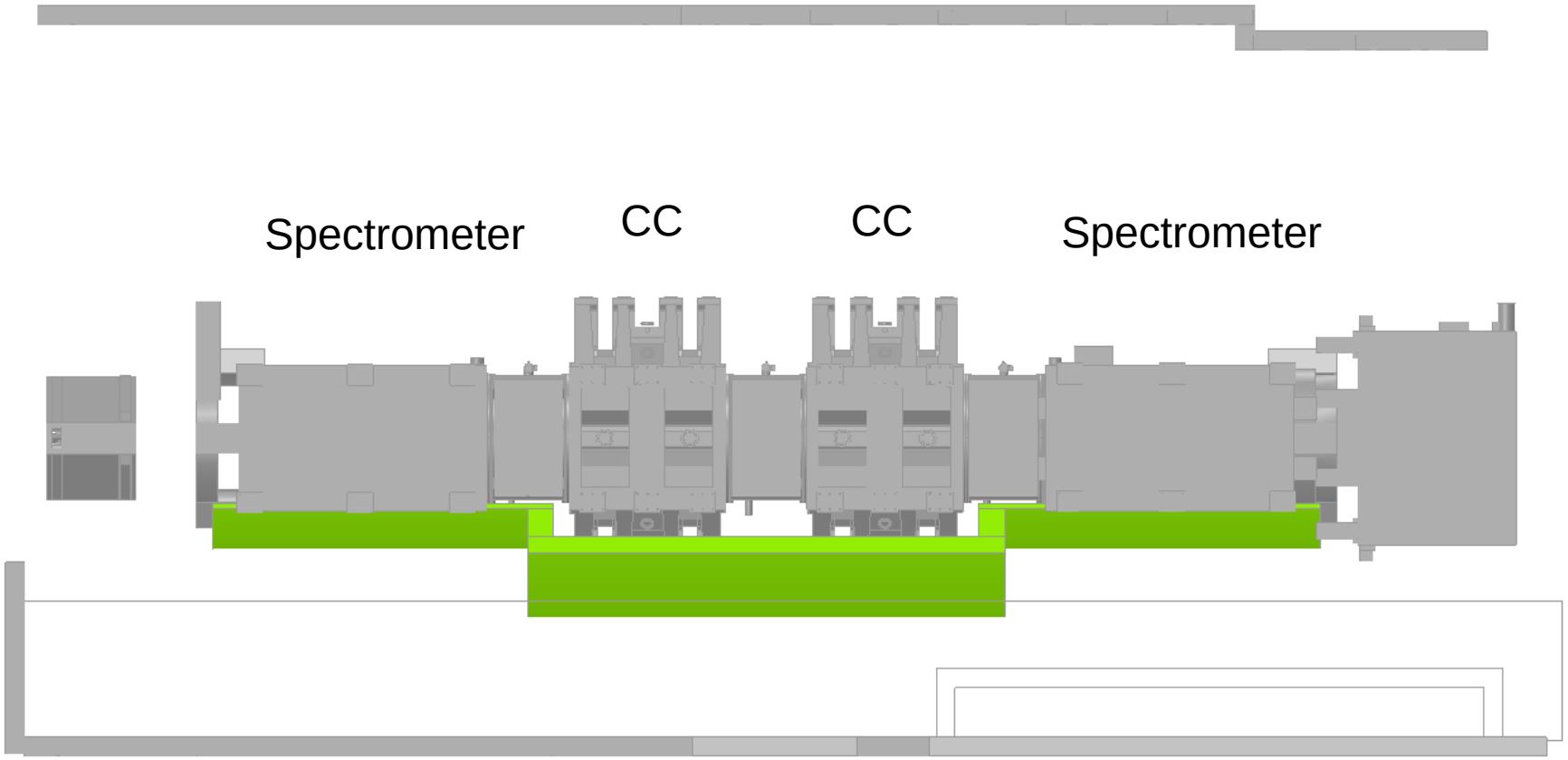


Geometry

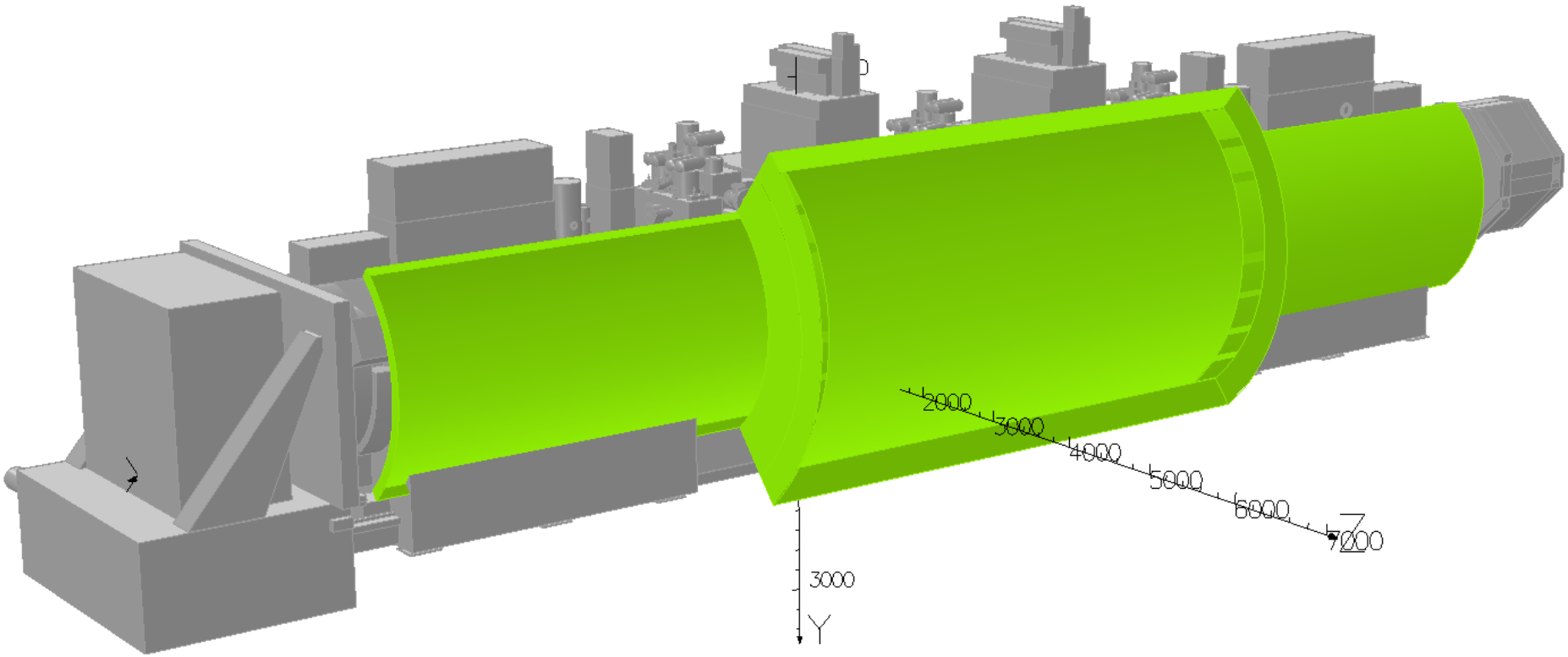


Weight: 130t
(both halfs)

Geometry

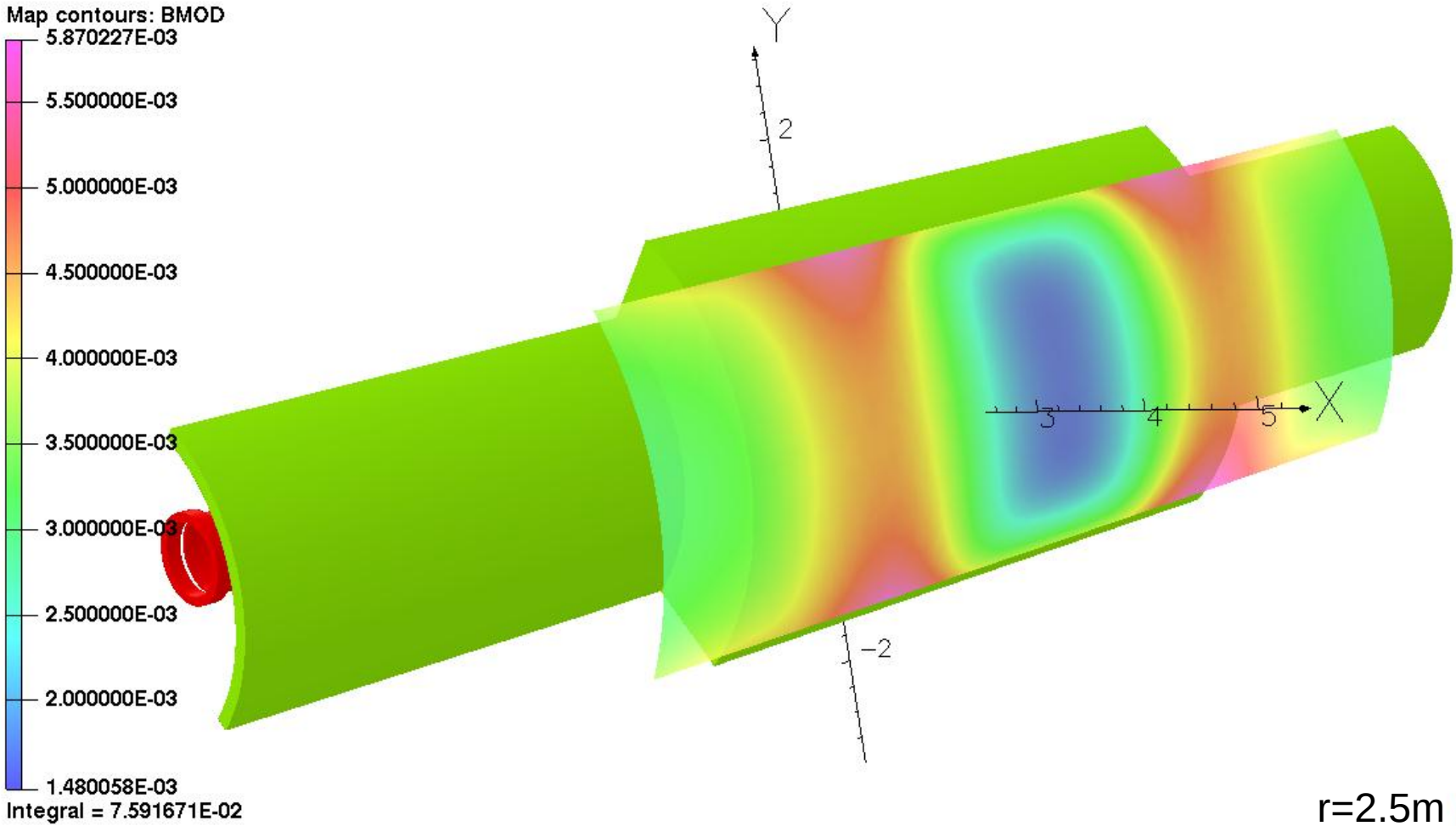


Geometry



Outside faces removed

200 MeV Flip Mode

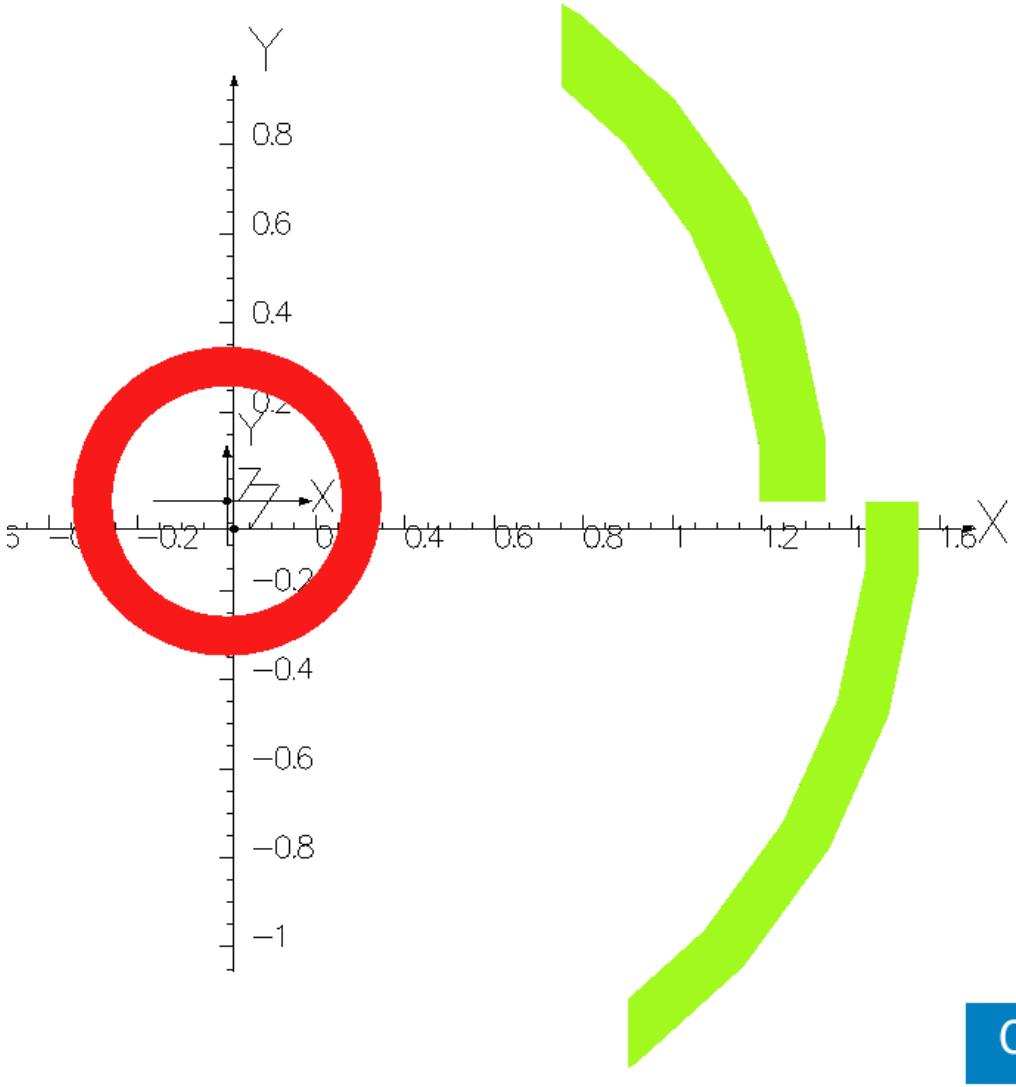


r=2.5m

Peak: 5.8 mT
Average: 3 mT?

MICE Step VI – Option 2

- Gap in radial direction
  - still continuous flux return path in longitudinal direction
- Shield at different radii
  - azimuthal angles must match
  - overlap seems not necessary
- Allows feed-in/out of tracker wiring?



MICE Step VI – Option 2

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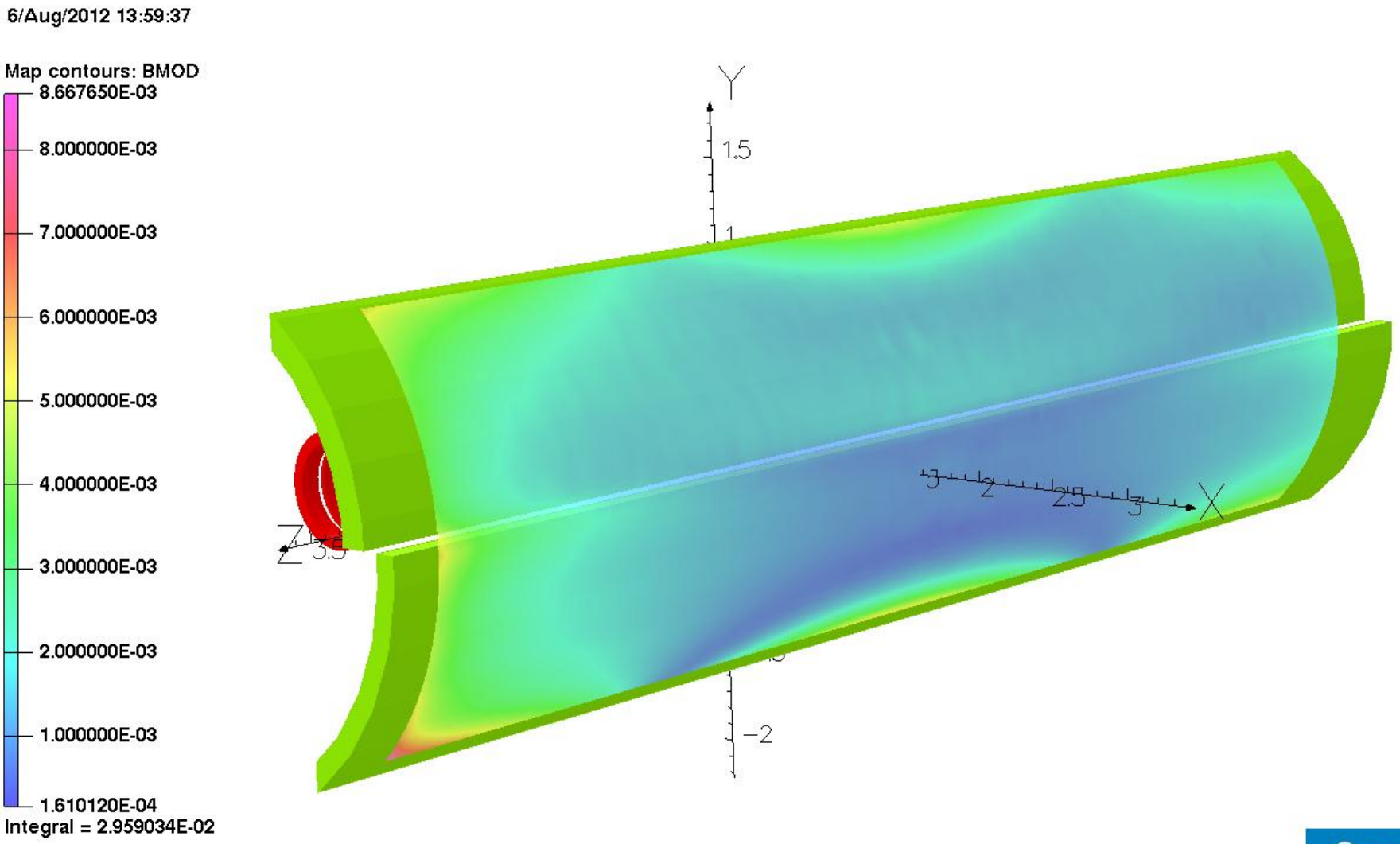
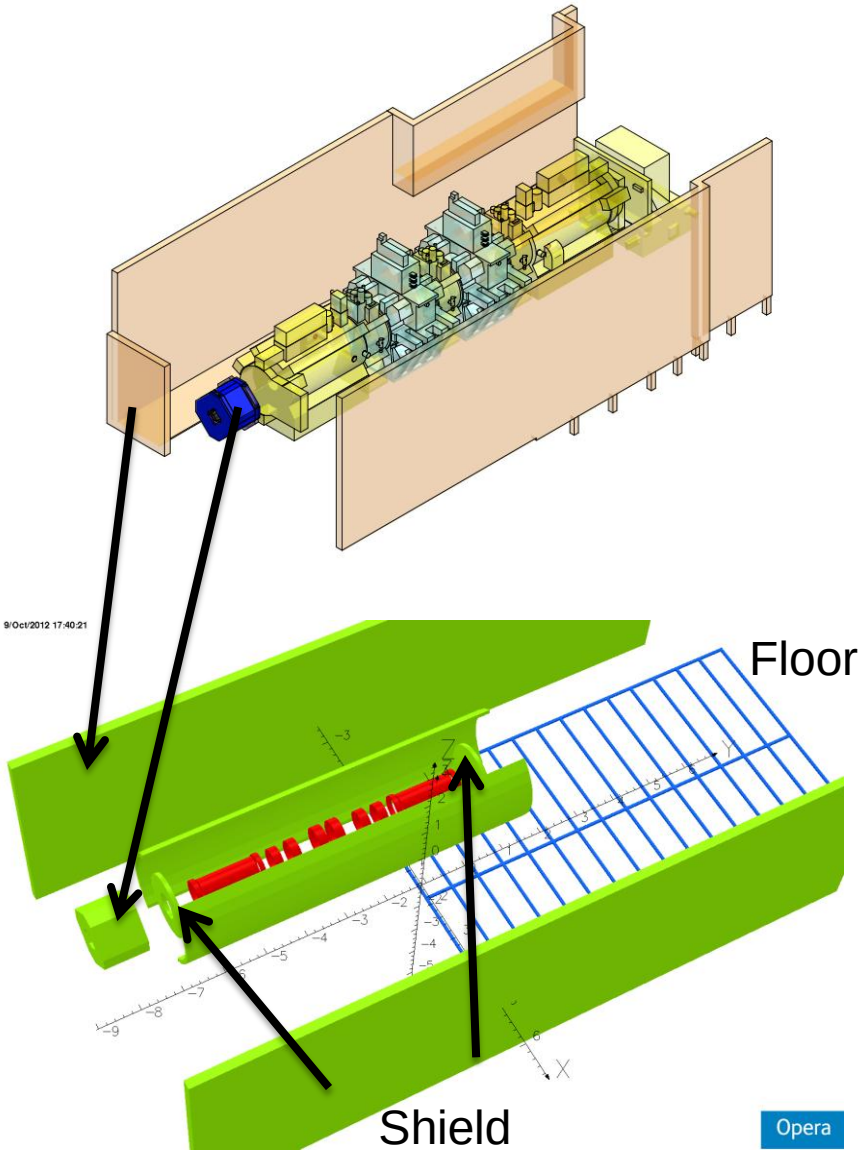
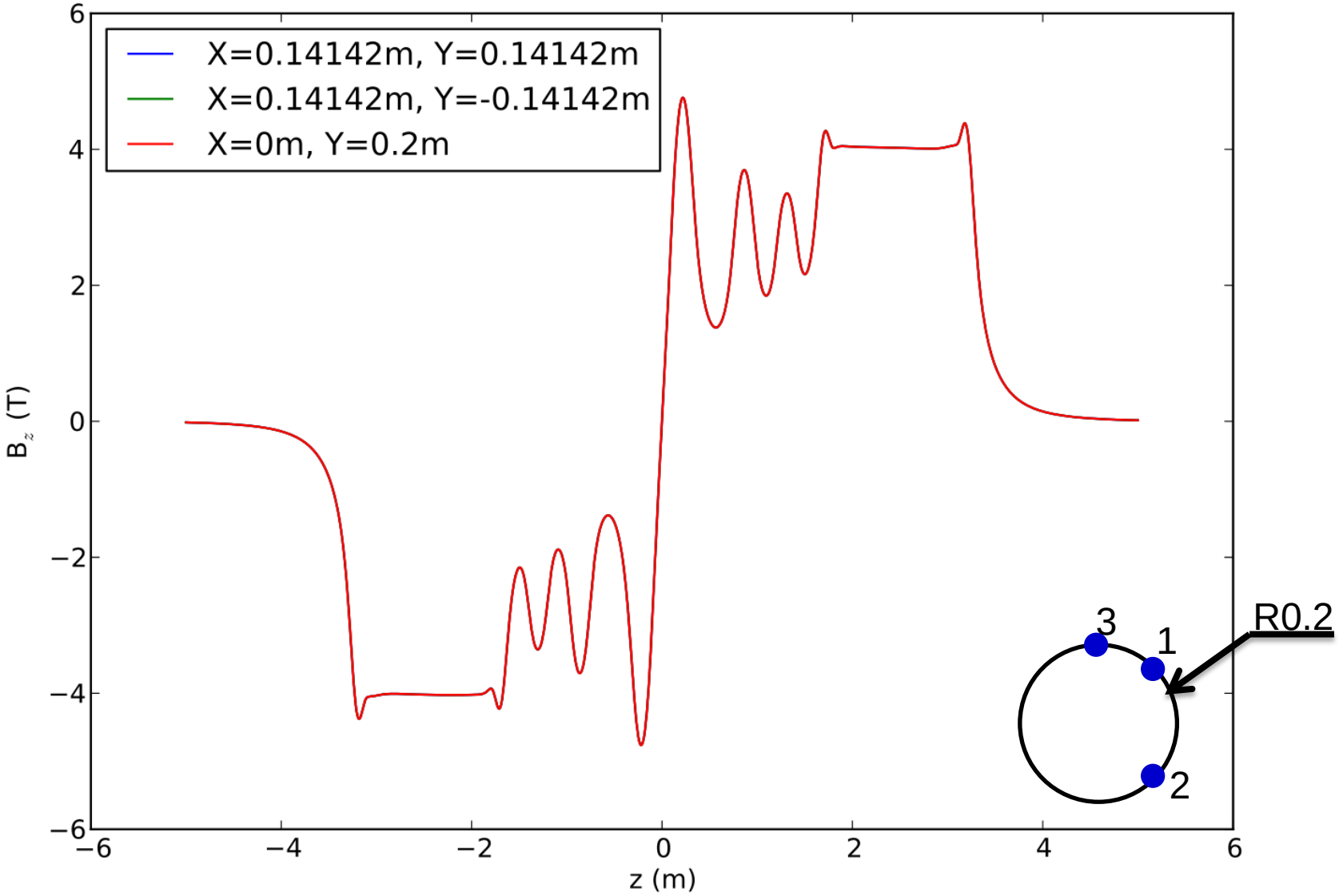


Additional Iron Structures

- Additions:
  - ‘Virostek’ shields
  - TOF cage
  - Quad Q9 (simplified)
  - Floor
- Field reductions due to shield
  - Q9: 63 to 36 mT
  - Walls: 150 mT to 12 mT



Effect on Field in Channel



Variation of B_z

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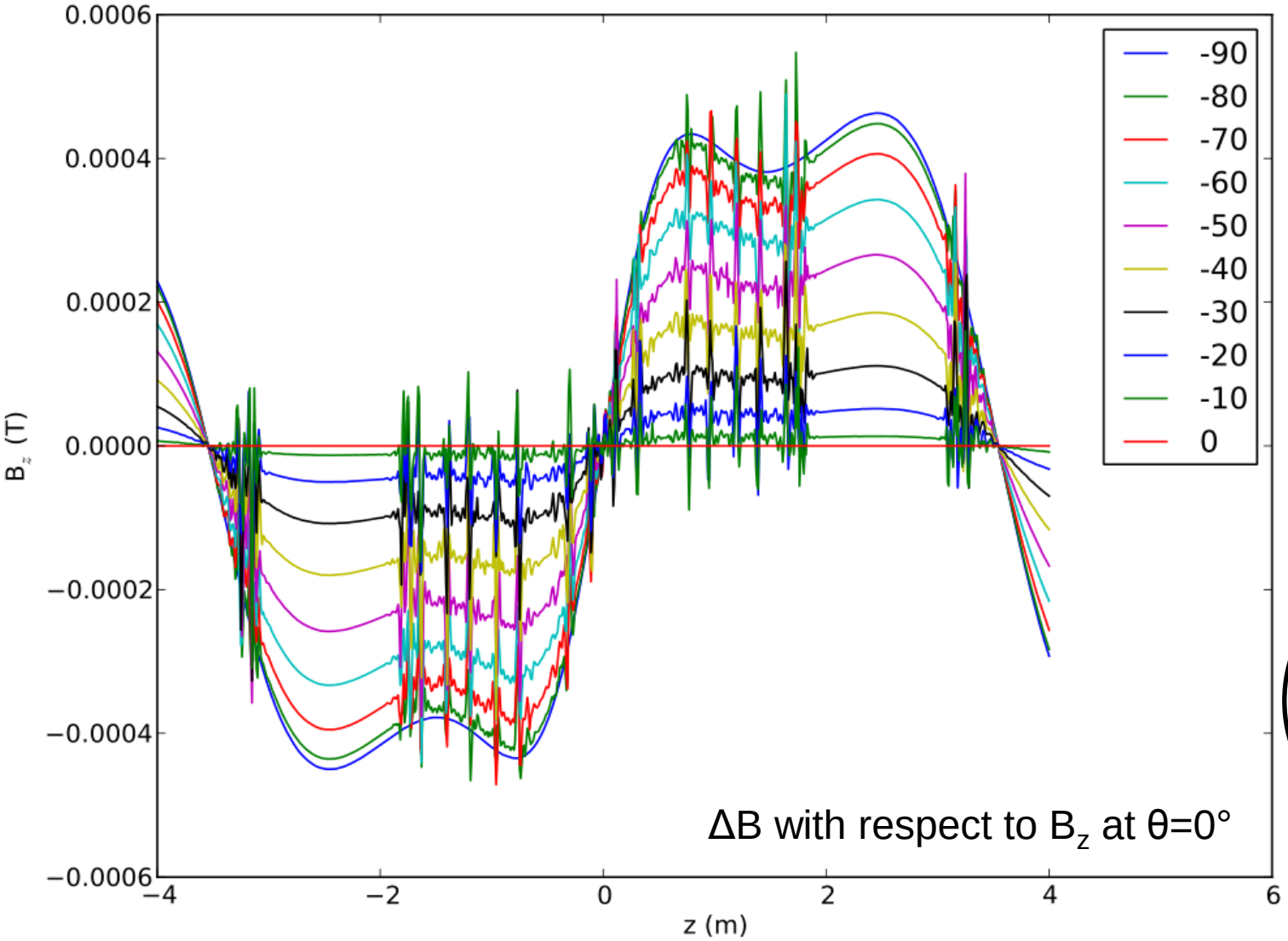
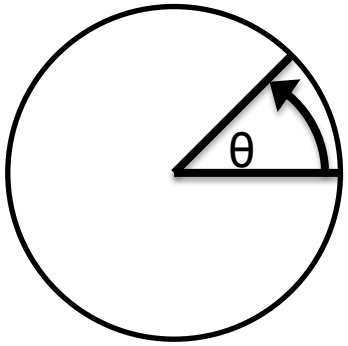
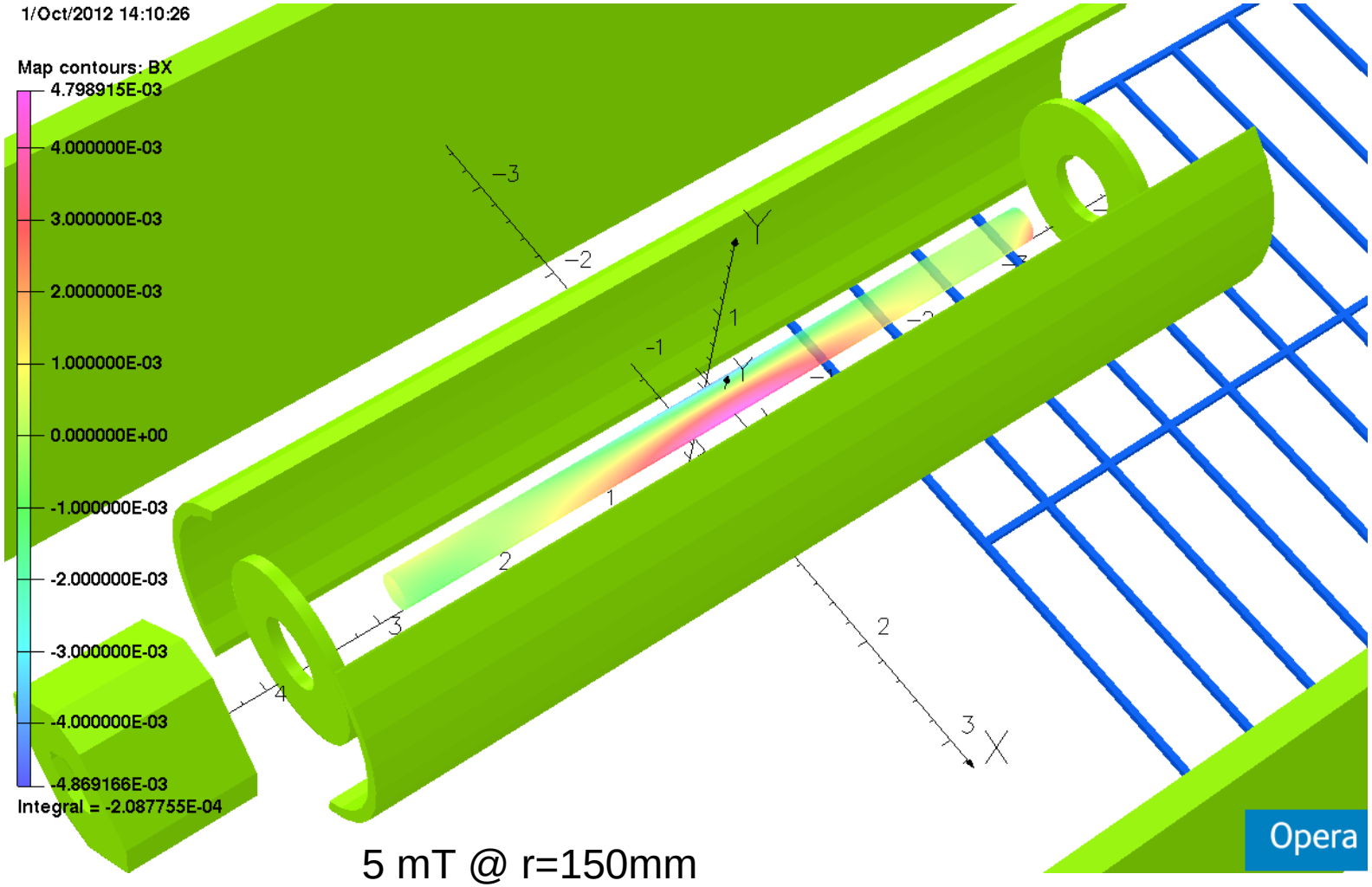




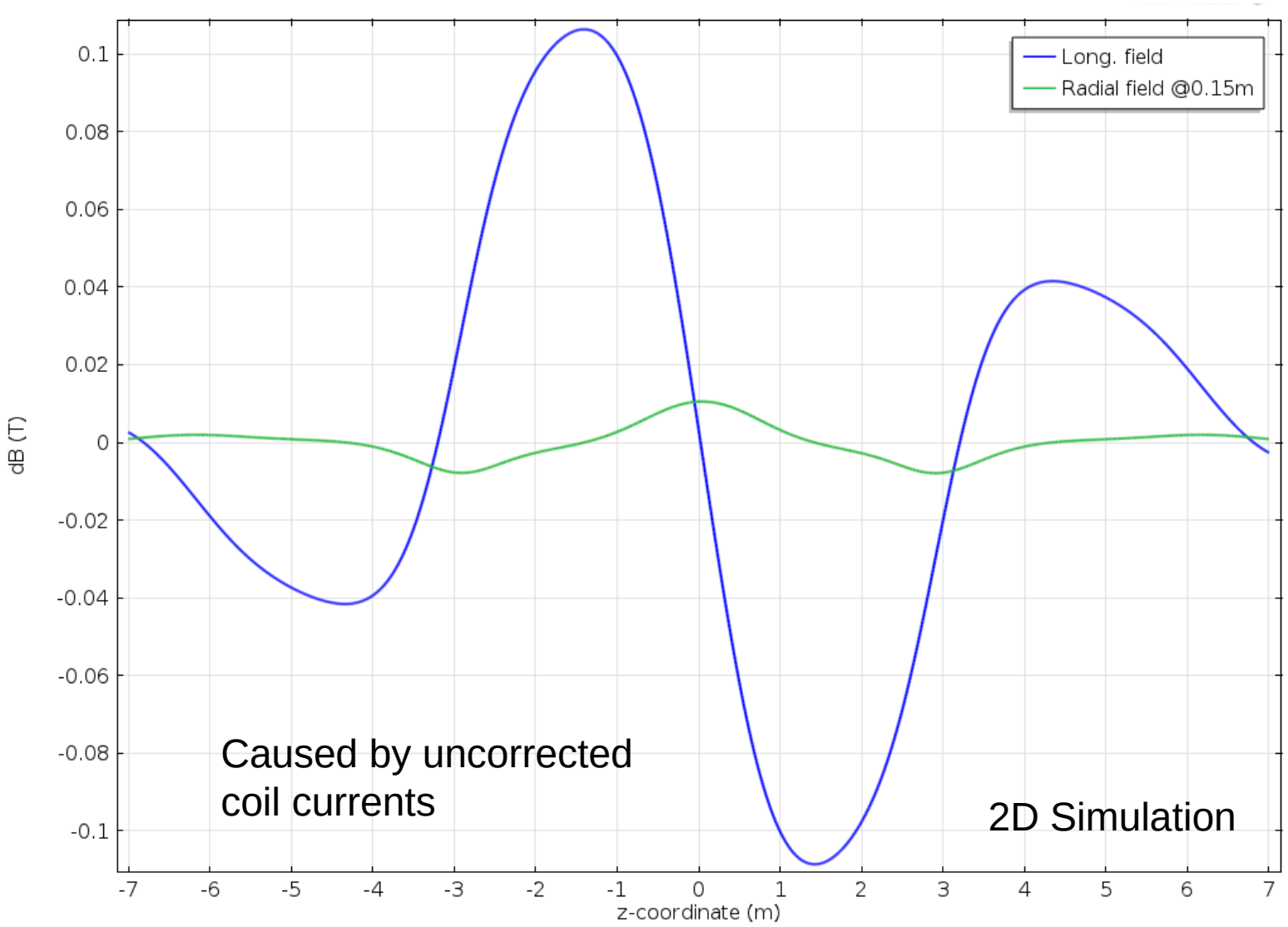
Unwanted Multipole Components



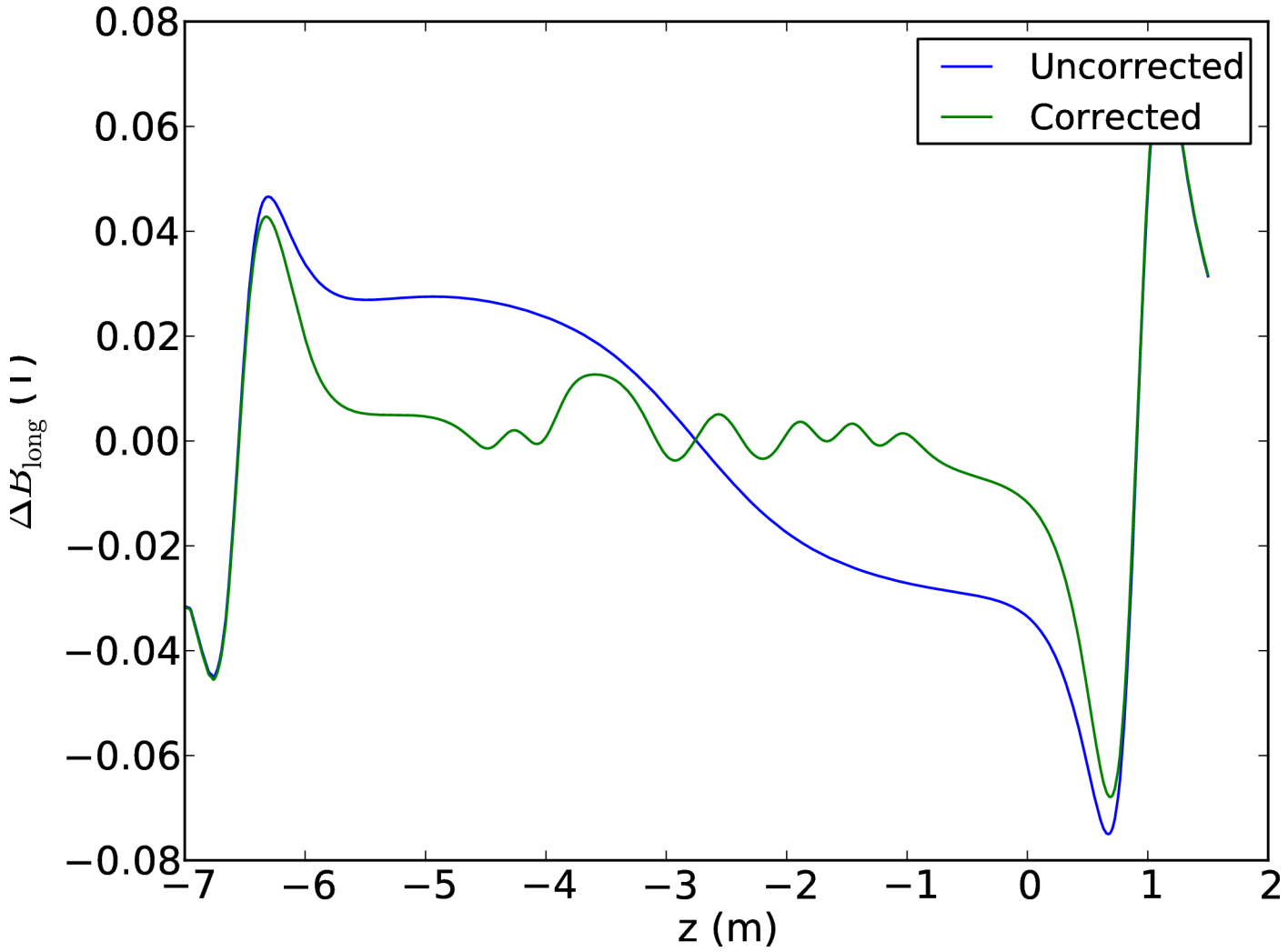
5 mT @ r=150mm

Additional hor. field introduced by shield

Unwanted Multipole Components



3D Field Correction



Forces

- Forces on shield under quench conditions
  - Normal operation: no longitudinal force on proposed shield
  - Cases studied: Step IV
    - 1. one tracker solenoid switched off
    - 2. one focusing coil switched off
- Coil forces
- Forces evaluated in Opera/VectorFields
  - Maxwell stress tensor
  - (virtual work gives identical results within simulation accuracy)
  - Field evaluation: Mesh = nodal, coil = integral

Forces on Shield

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	Hor. Force [kN]	Long. Force [N]
200 MeV Flip One tracker inactive	-13.6	73
200 MeV Sol One tracker inactive	-9.3	70
200 MeV One FC inactive	-30	-8
Reference 200 MeV Flip	-30	-158
Reference 200 MeV Solenoid	-13	-143

Coil Forces Step VI

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	No Iron	Iron	Change
FC1	-3367202	-3410424	1.012836
CC	-203400	-379805	1.867281
FC2	3235323	3294357	1.018247
FC3	-3281620	-3339131	1.017525
Match 1	-190322	-199323	1.047294
Match 2	-49992	-51374	1.027644
End1	-851298	-850645	0.999233
Spect. Sol	-29037	-14438	0.497228
End2	1400771	1407749	1.004982

Force in Newton

Radial Field CC

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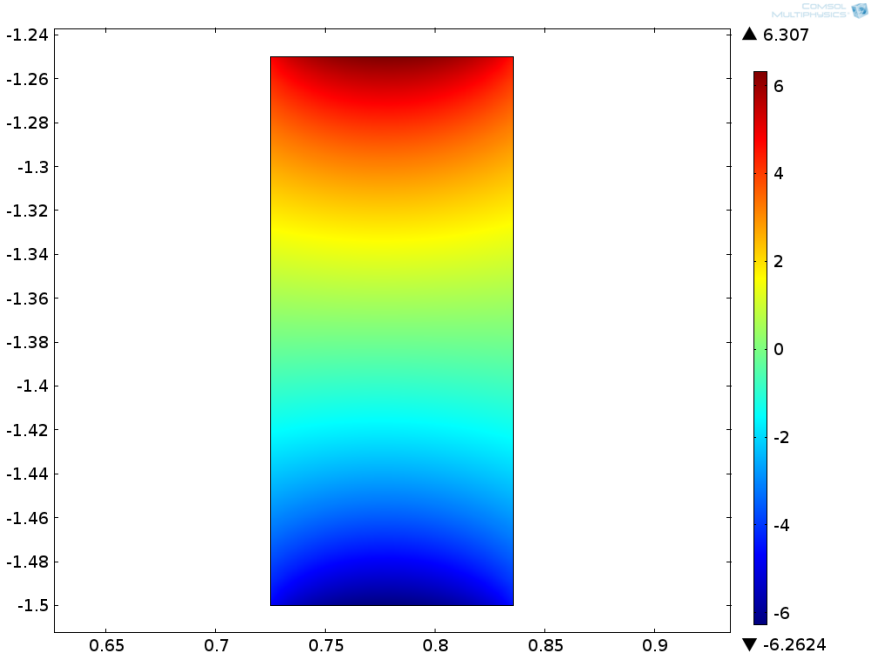
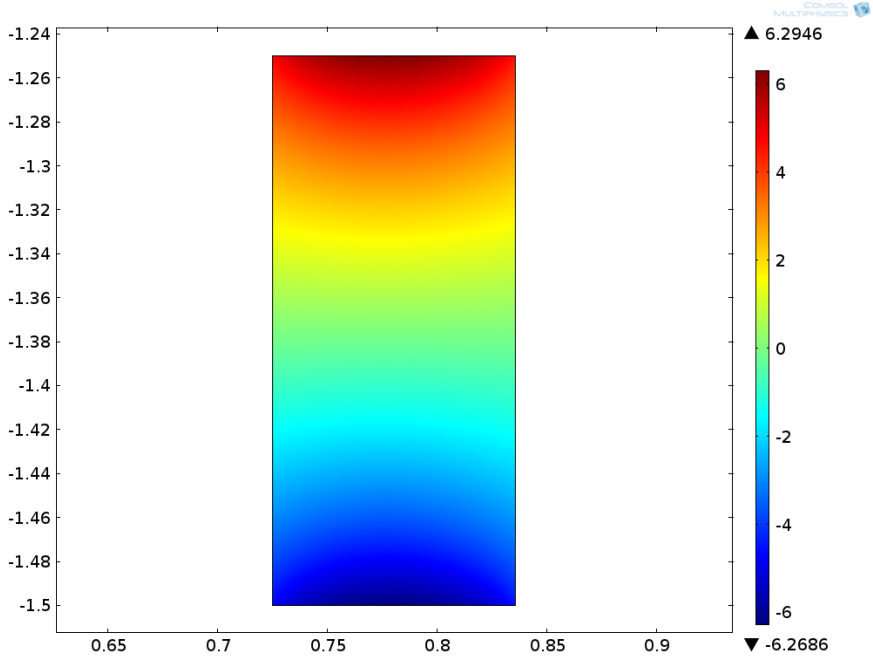
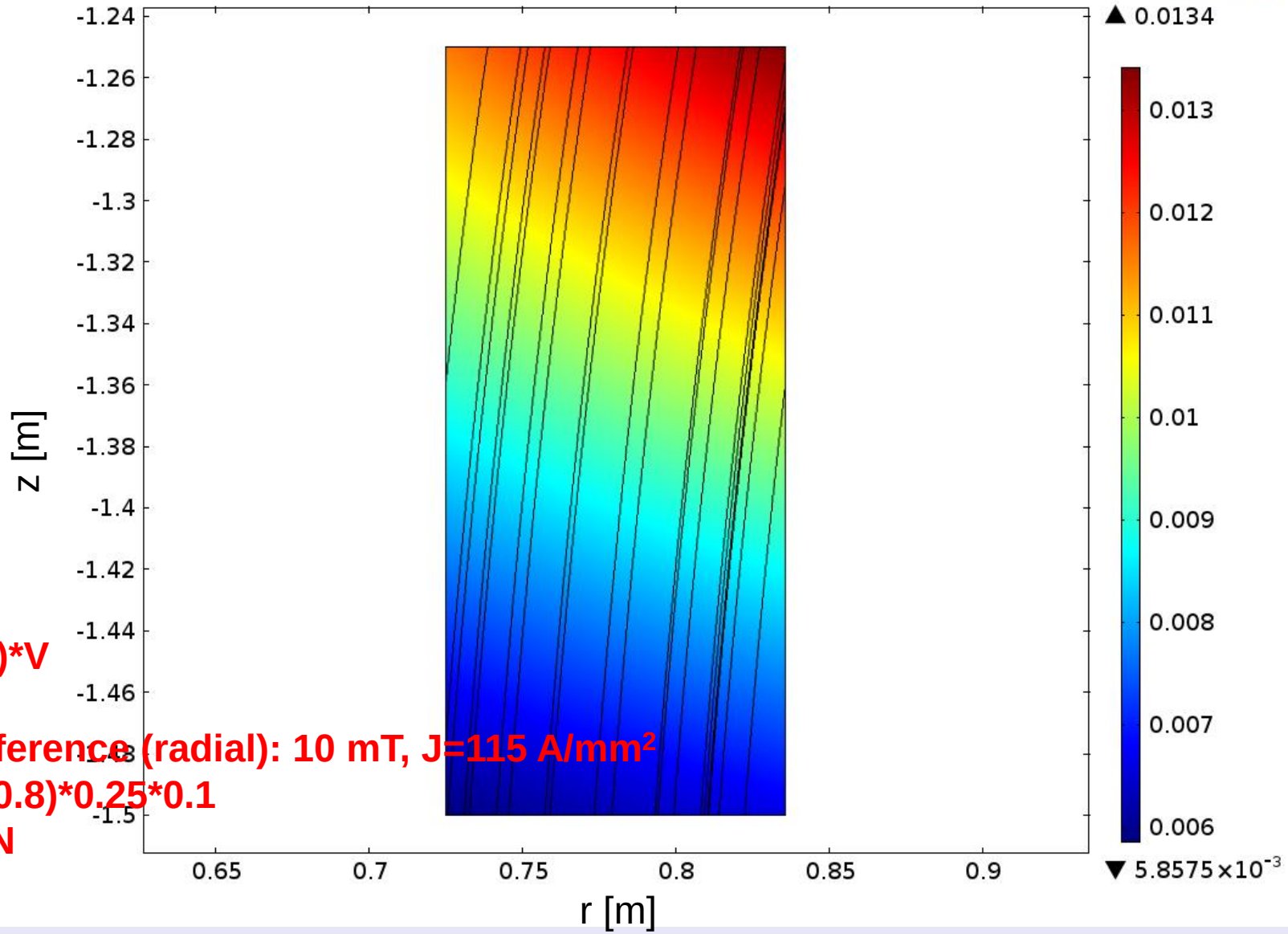
Iron



No Iron



Radial Field CC

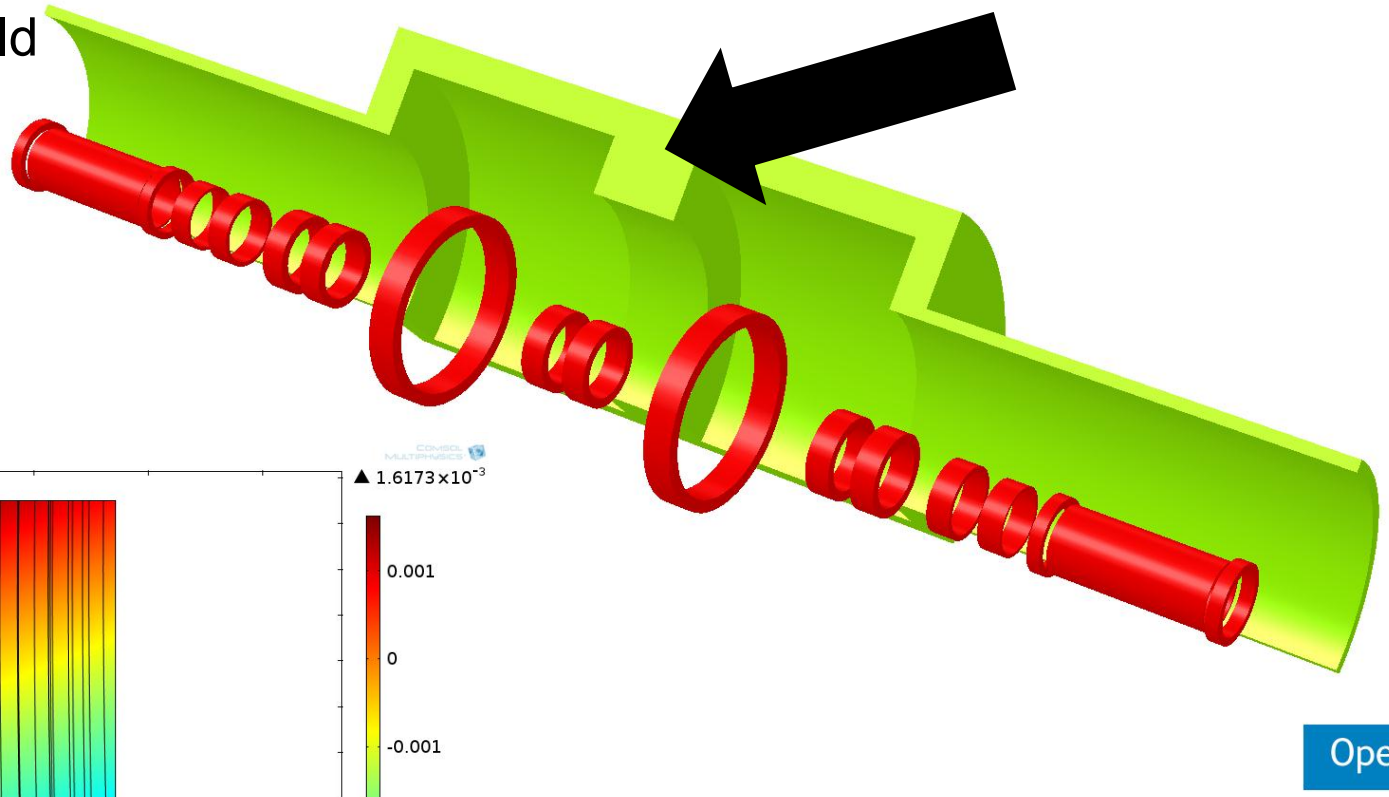


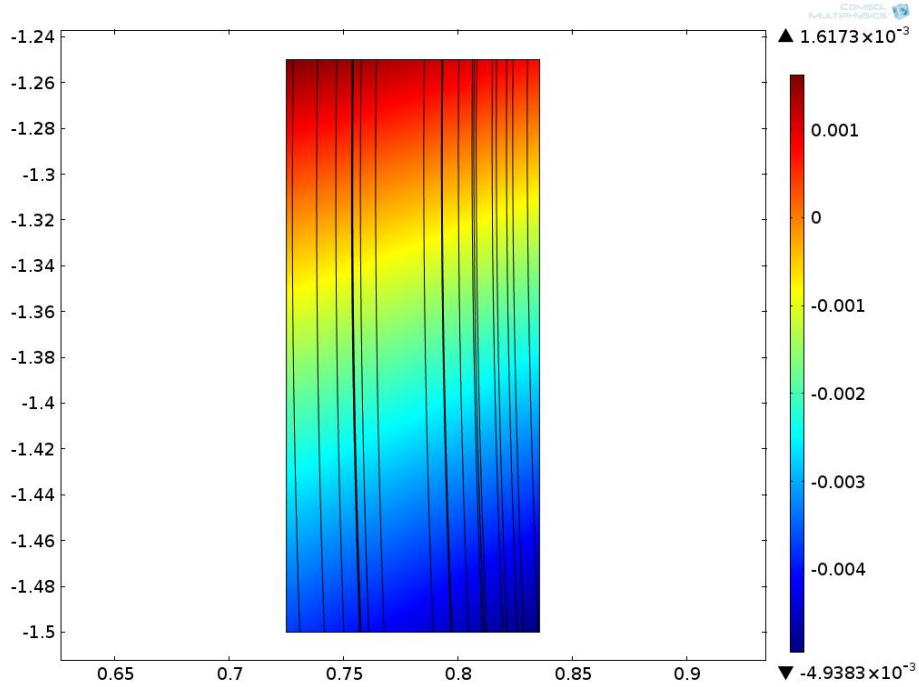
F = (JxB)*V

Field difference (radial): 10 mT, J=115 A/mm^2
V=(2*pi*0.8)*0.25*0.1
F=140 kN

Step VI Force on CC

Add ‘nose’ to shield

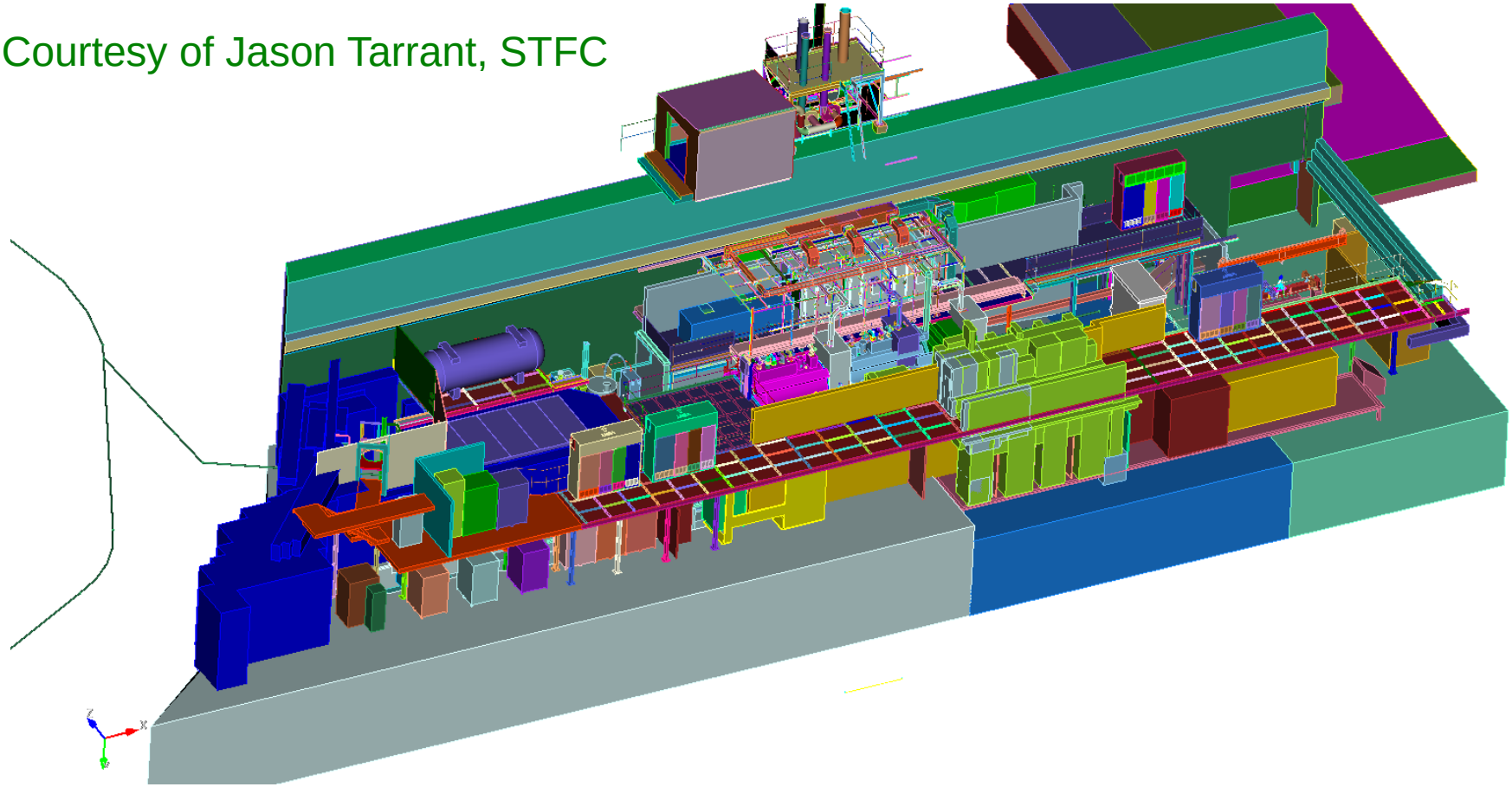




Force (Opera 3D):
198 kN (97% of TRD)

Engineering

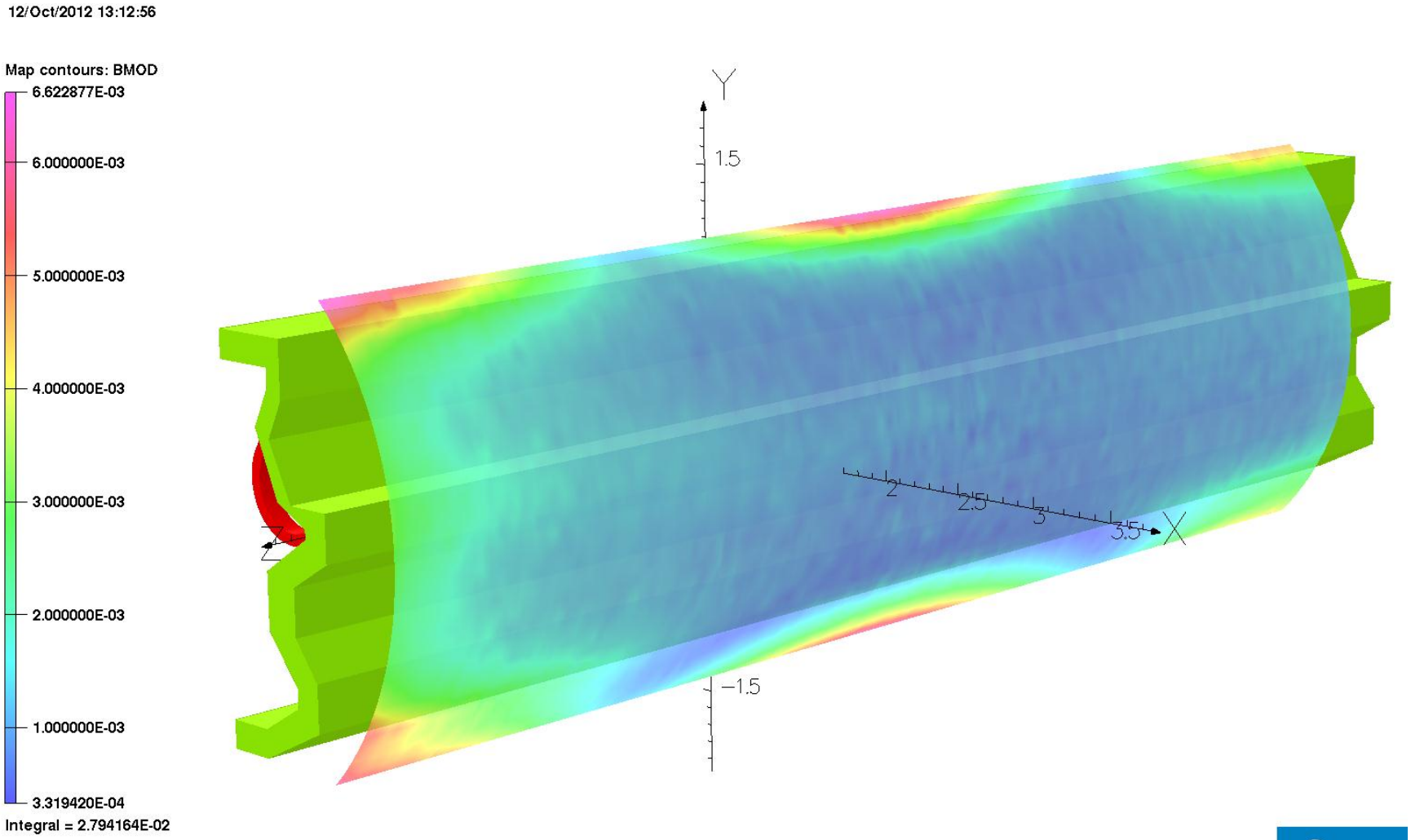
Courtesy of Jason Tarrant, STFC



BNL engineering effort to look into practical design and manufacturing
Present estimate: Full design 1st week January

Procurement: 4 months

Geometric Freedom



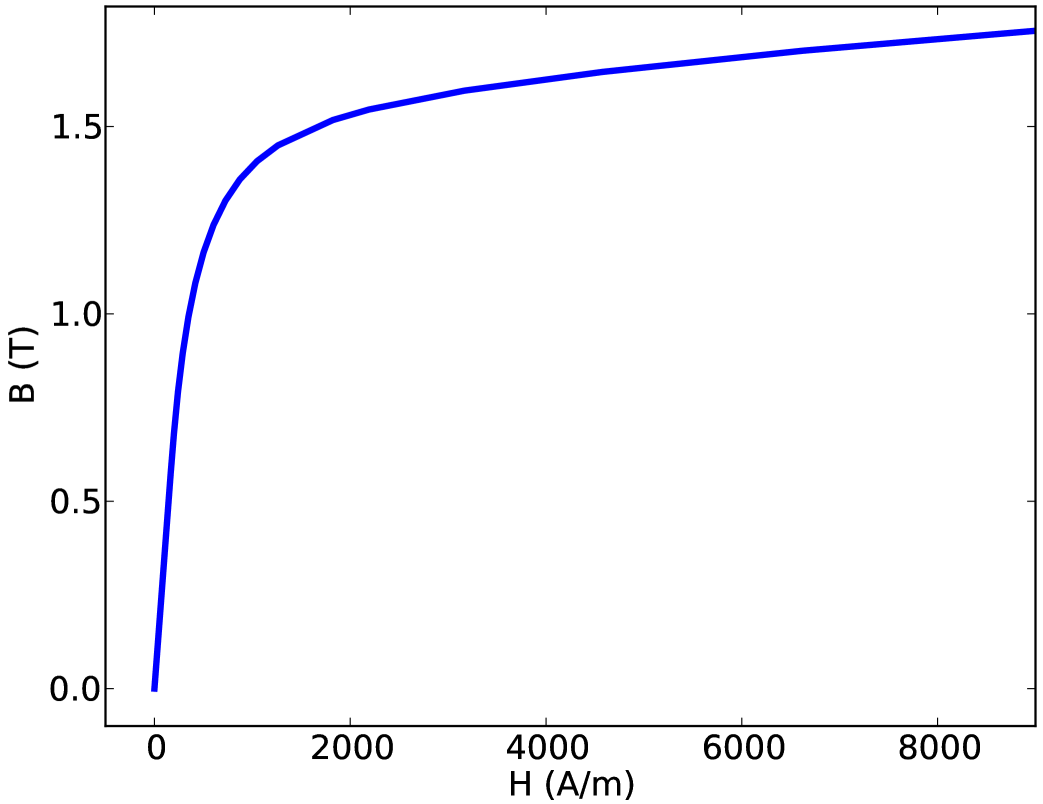
Conclusion

- Conceptual design of local flux return
  - reduces stray field in hall significantly (factor 30)
  - shield: about 30t of iron (130t for Step VI)
  - force on shield manageable
- Effect on beam
- Effect on other iron structures in hall
  - Q9, floor, walls
- Extension to Step VI possible
  - includes solution for natural breaks in shield for wire feed-in/out
- Engineering

Additional Slides

Simulation Details

- Finite element simulations
  - Opera from VectorFields/Cobham
  - Comsol Multiphysics
- Iron
  - AISI 1010 steel
  - BH curve: Opera/VF
- (Benchmarking)



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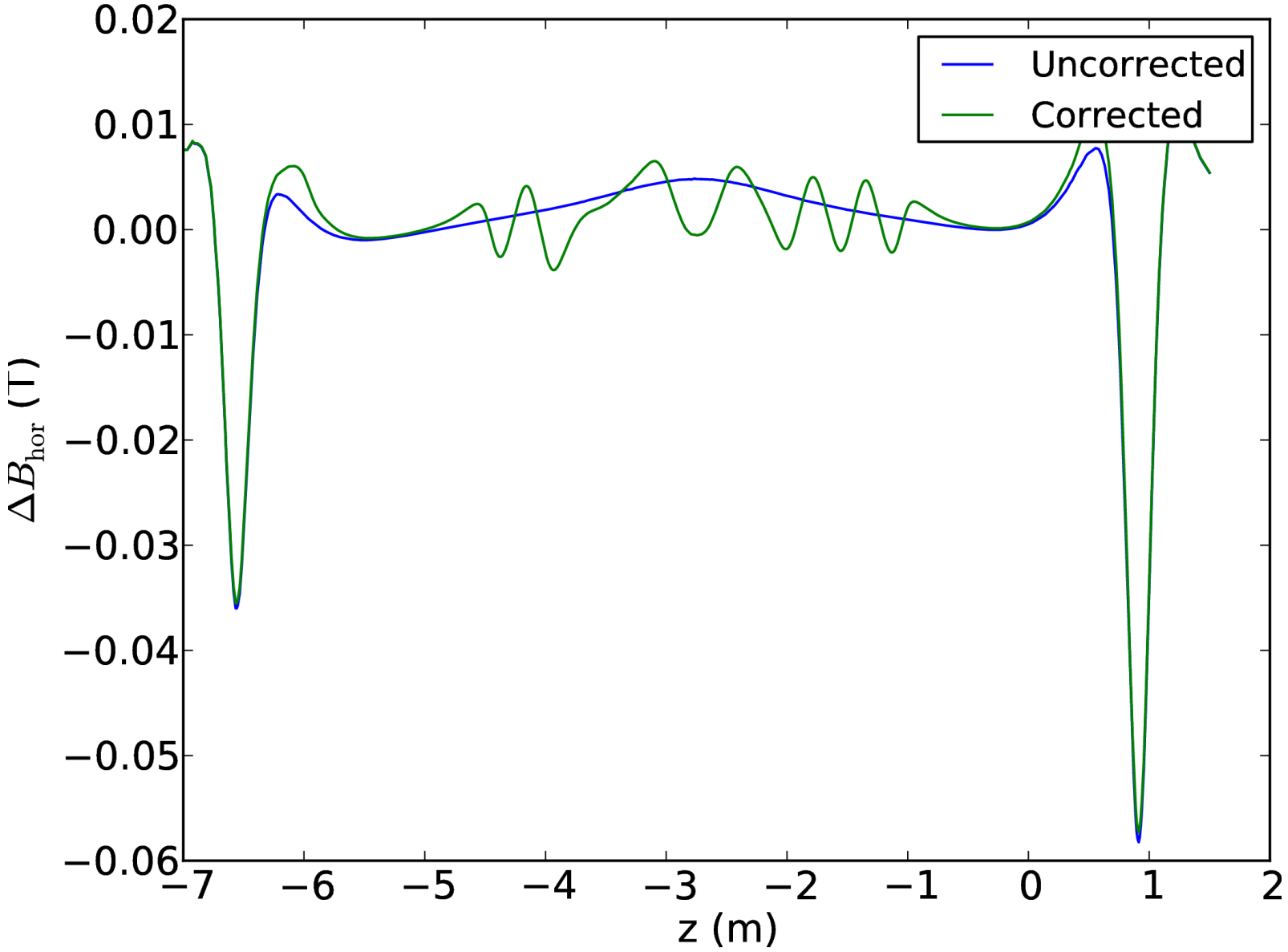

Quad Q9

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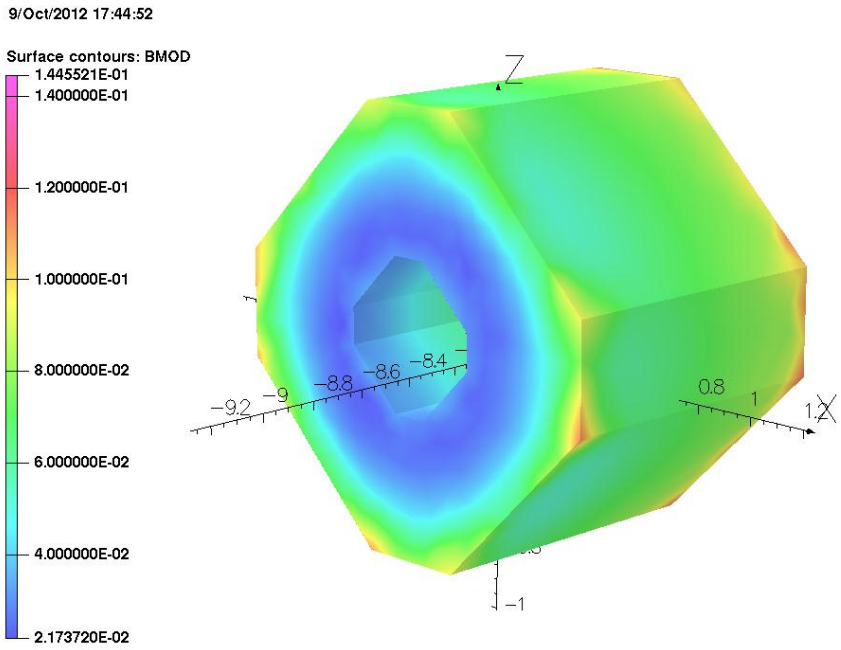
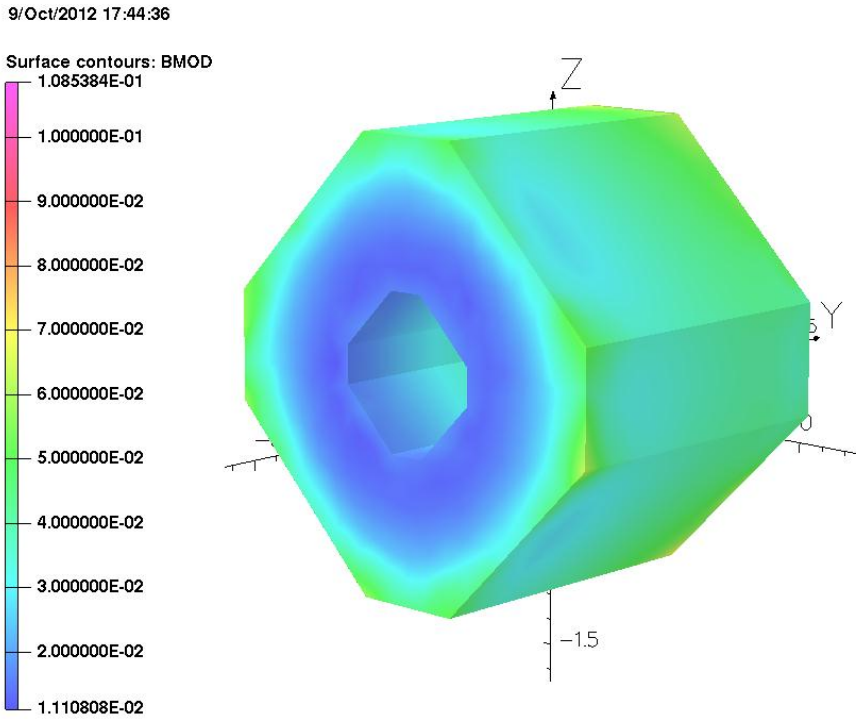
No Shield: 62mT

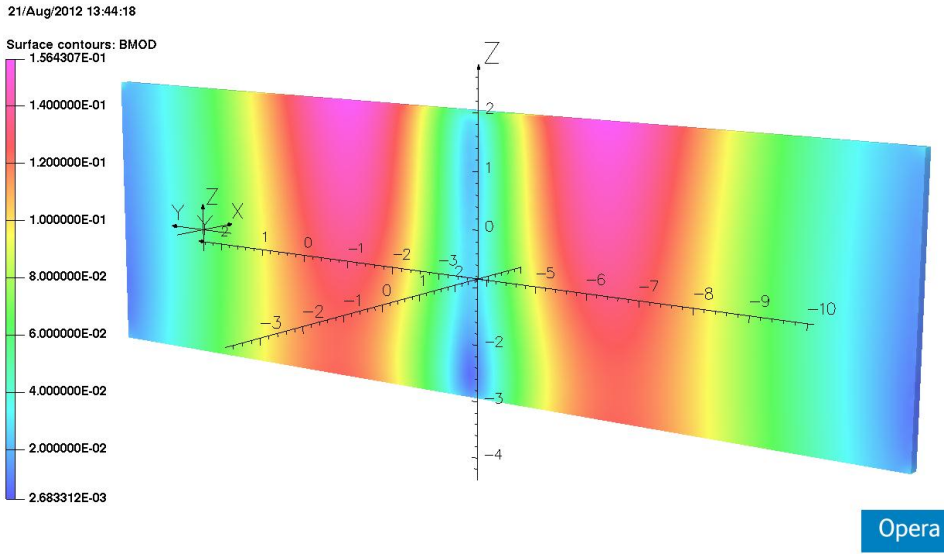


Shield: 36 mT (average)

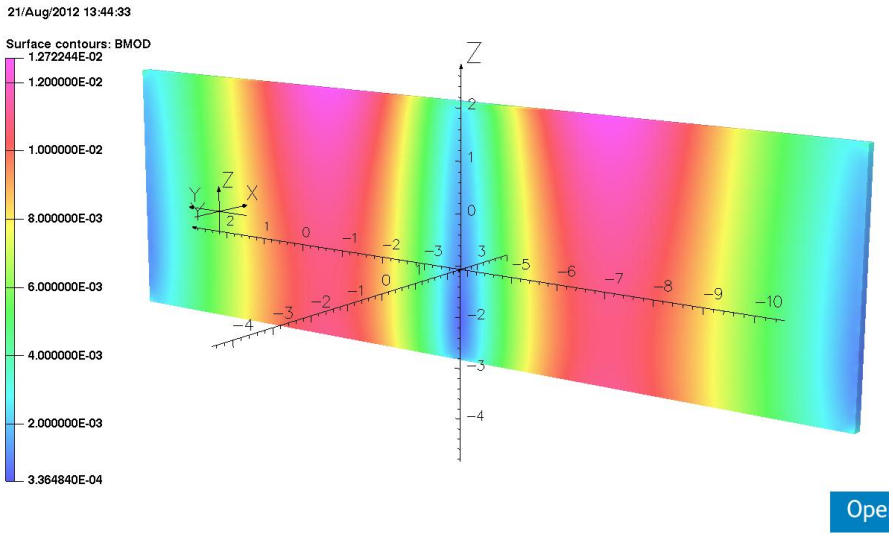


Walls

No Shield: 150 mT (peak)



Shield: 12 mT (peak)



Reduction of factor 10+