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Software Model Verification

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Comparison: Opera vs. COMSOL

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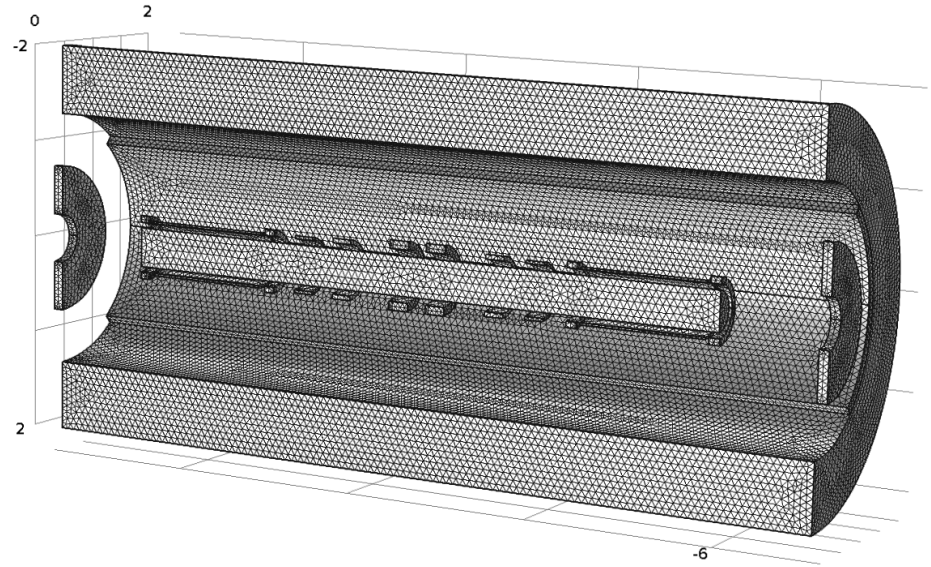
- Comparing FEA codes: usually not a good idea
  - Opera might be an exception…
- Opera 3D: solves for magnetic scalar potential
  - Field intensity $H=H_m+H_s$ (H_m: reduced potential)

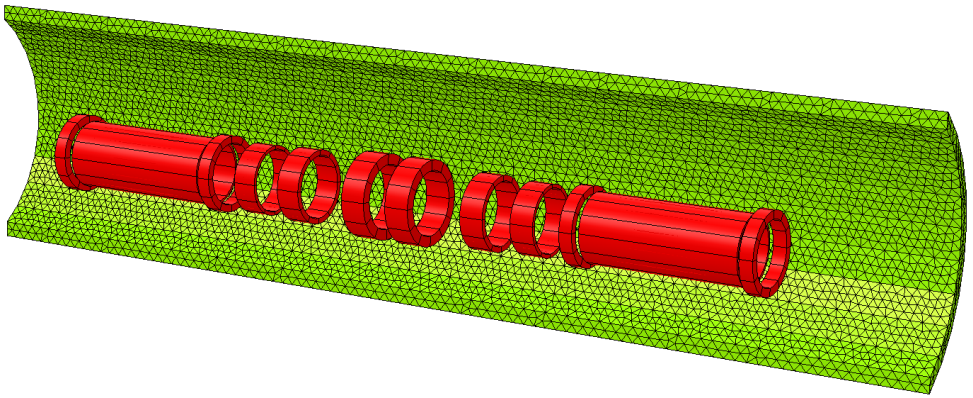
$$\nabla\mu\nabla\phi-\nabla\mu(\int_{\Omega_J}\frac{J\times R}{|R^3|}d\Omega_J)=0$$

  - Advantage: only scalar Φ unknown, reduces variables in finite element model
  - Potential errors if H_m and H_s are quite different
  - Solution: introduce total magnetic scalar potential (no current in magnetic materials): $H=-\nabla\Psi$
- COMSOL: $\nabla\times(\mu^{-1}\nabla\times A)=J$

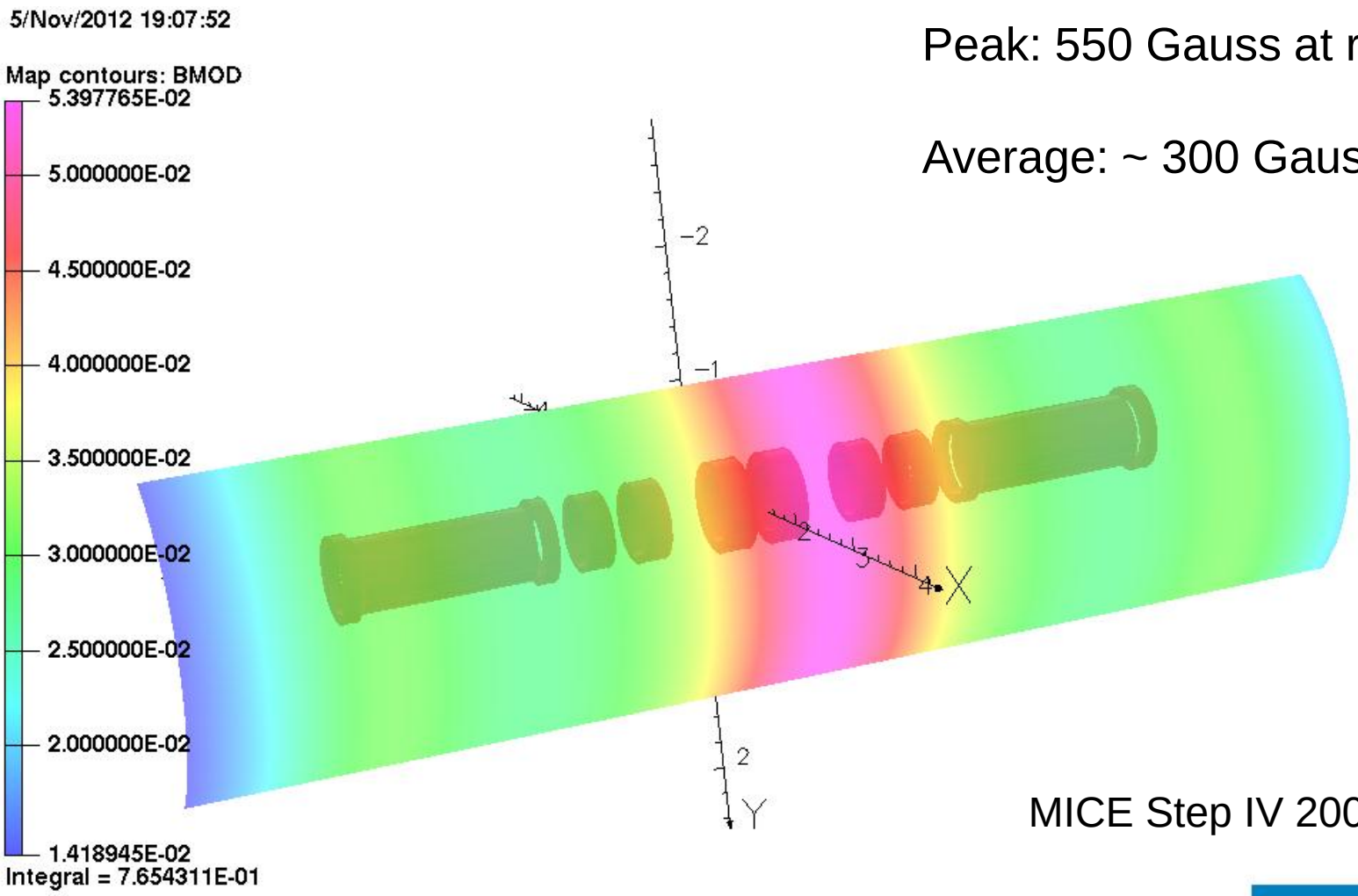
Simulation Details

- Identical geometry
  - MICE Step IV
- Identical coil configuration
  - 200 MeV, flip mode
- Identical material properties
  - AISI 1010 (VF)





No Iron - Opera



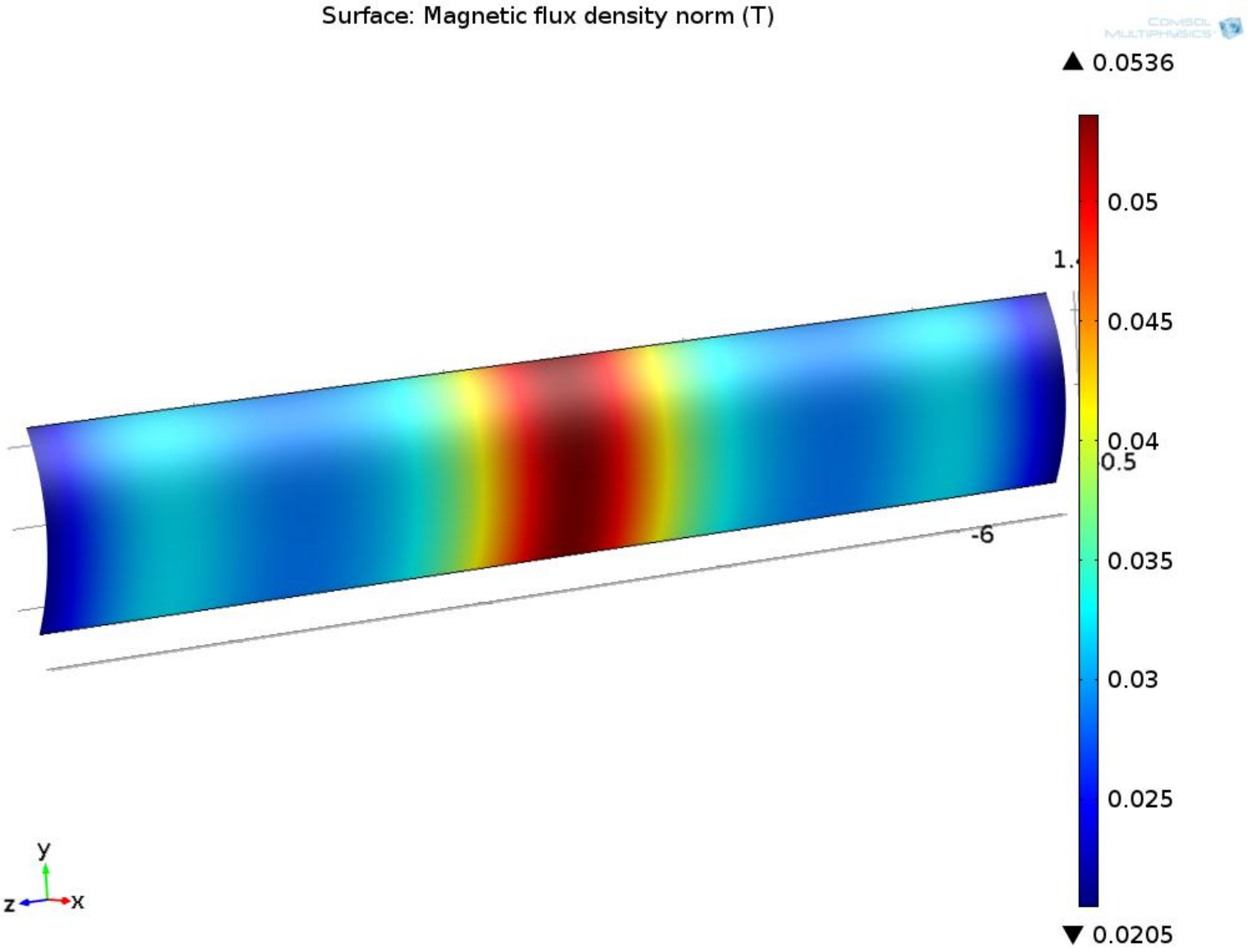
Peak: 550 Gauss at r=1.5m

Average: ~ 300 Gauss

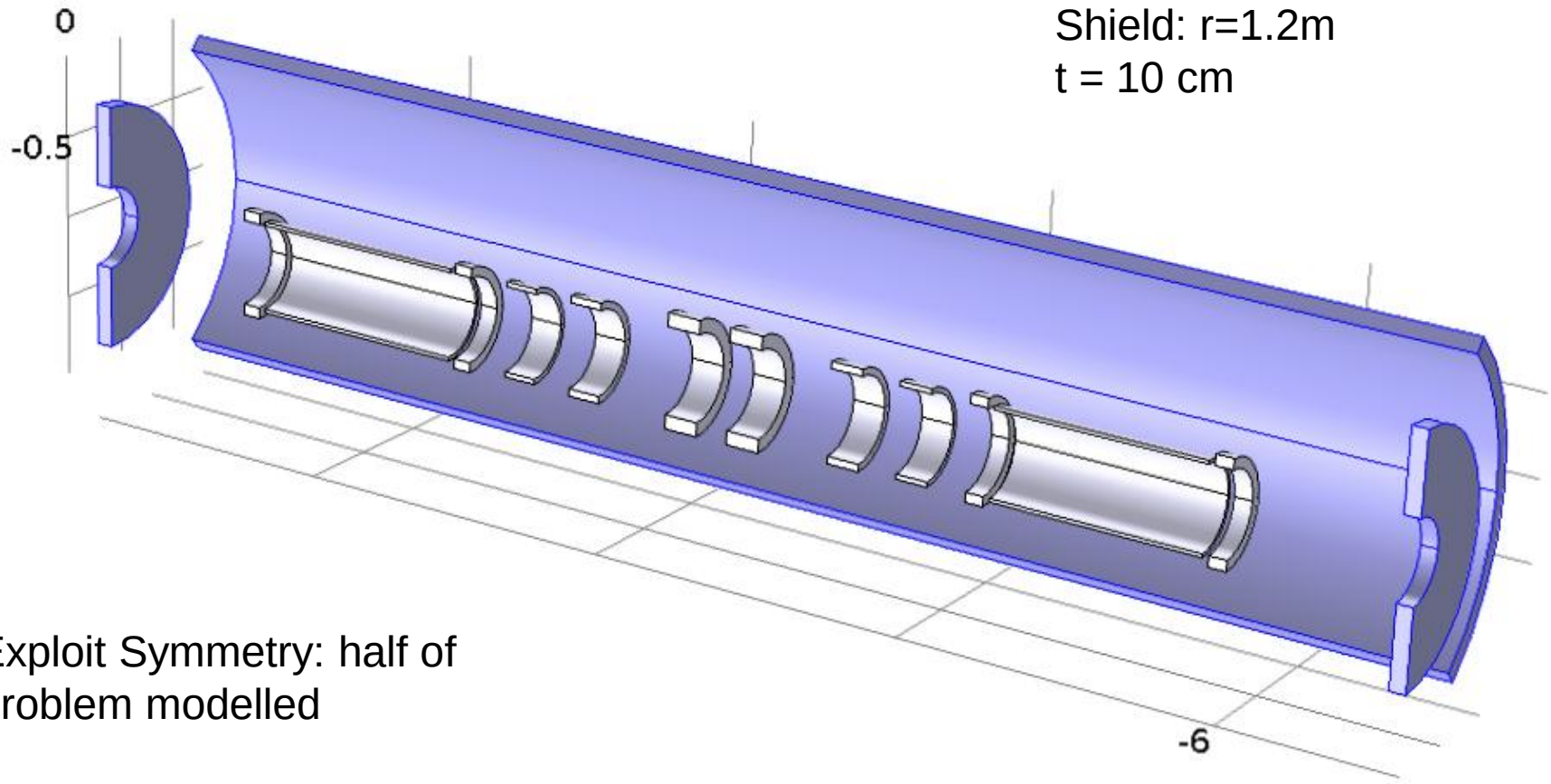
MICE Step IV 200 MeV Flip

Opera

No Iron - Comsol



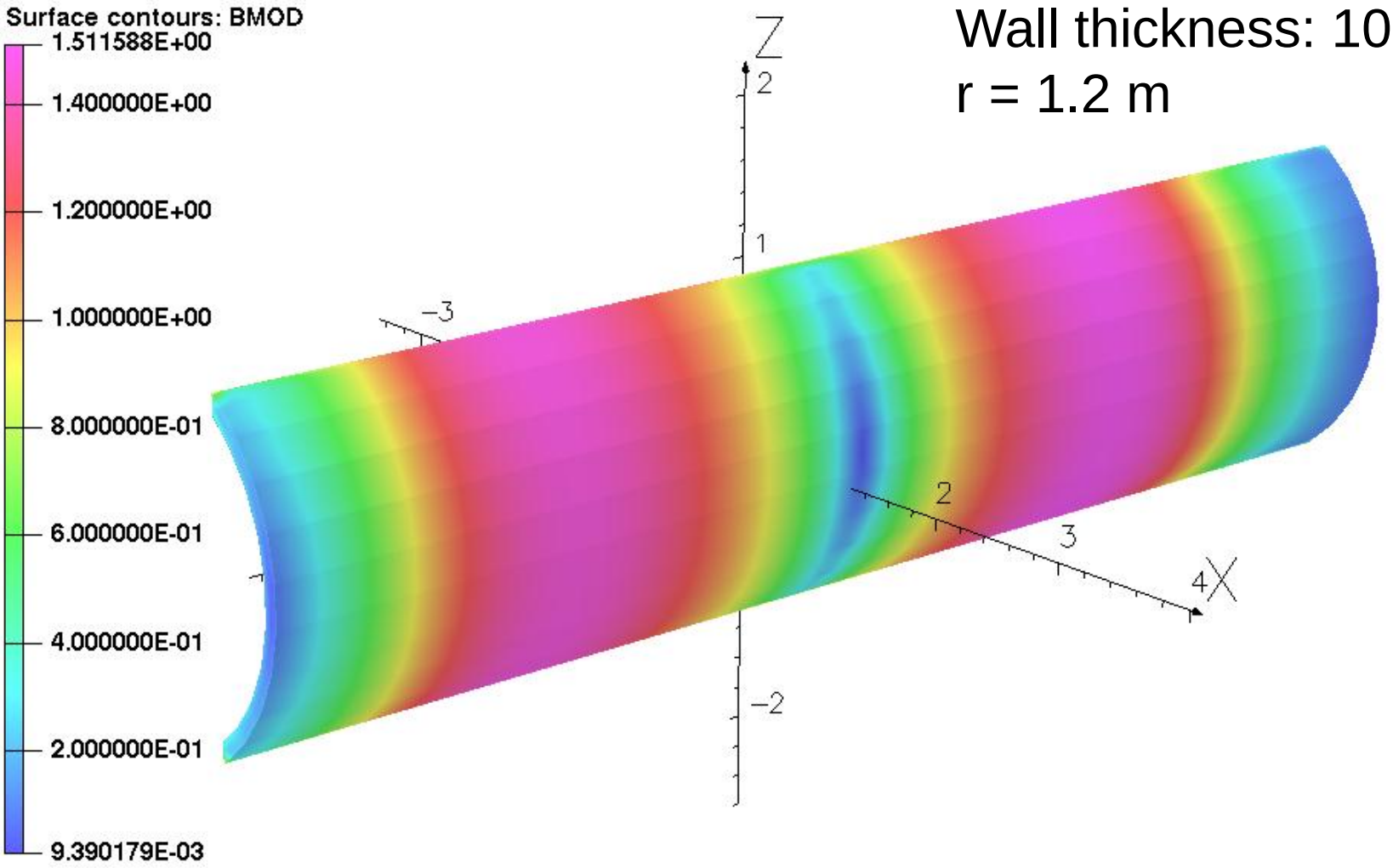
COMSOL Geometry



Shield: r=1.2m
t = 10 cm

Exploit Symmetry: half of problem modelled

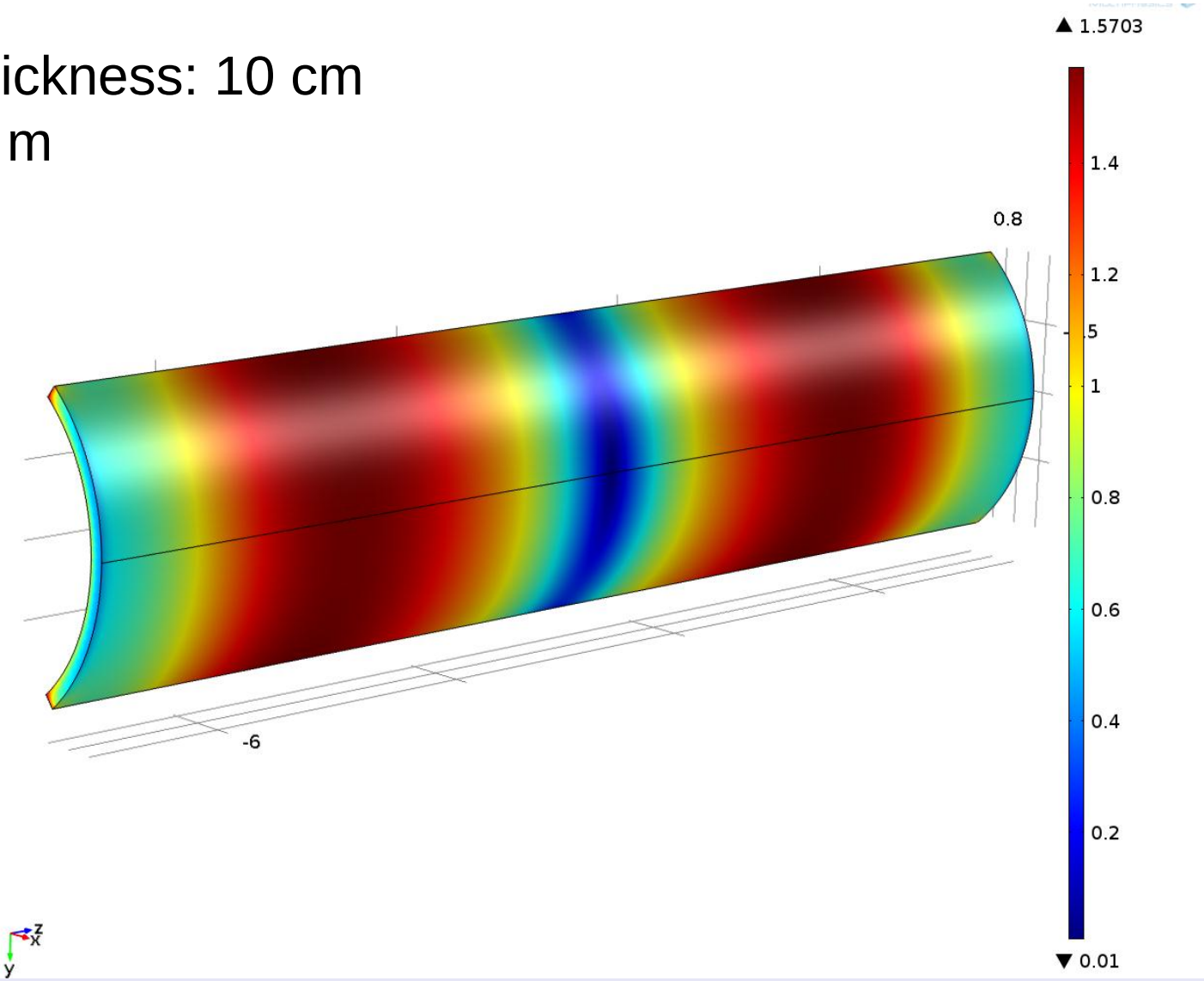
Magnetization In Shield - Opera



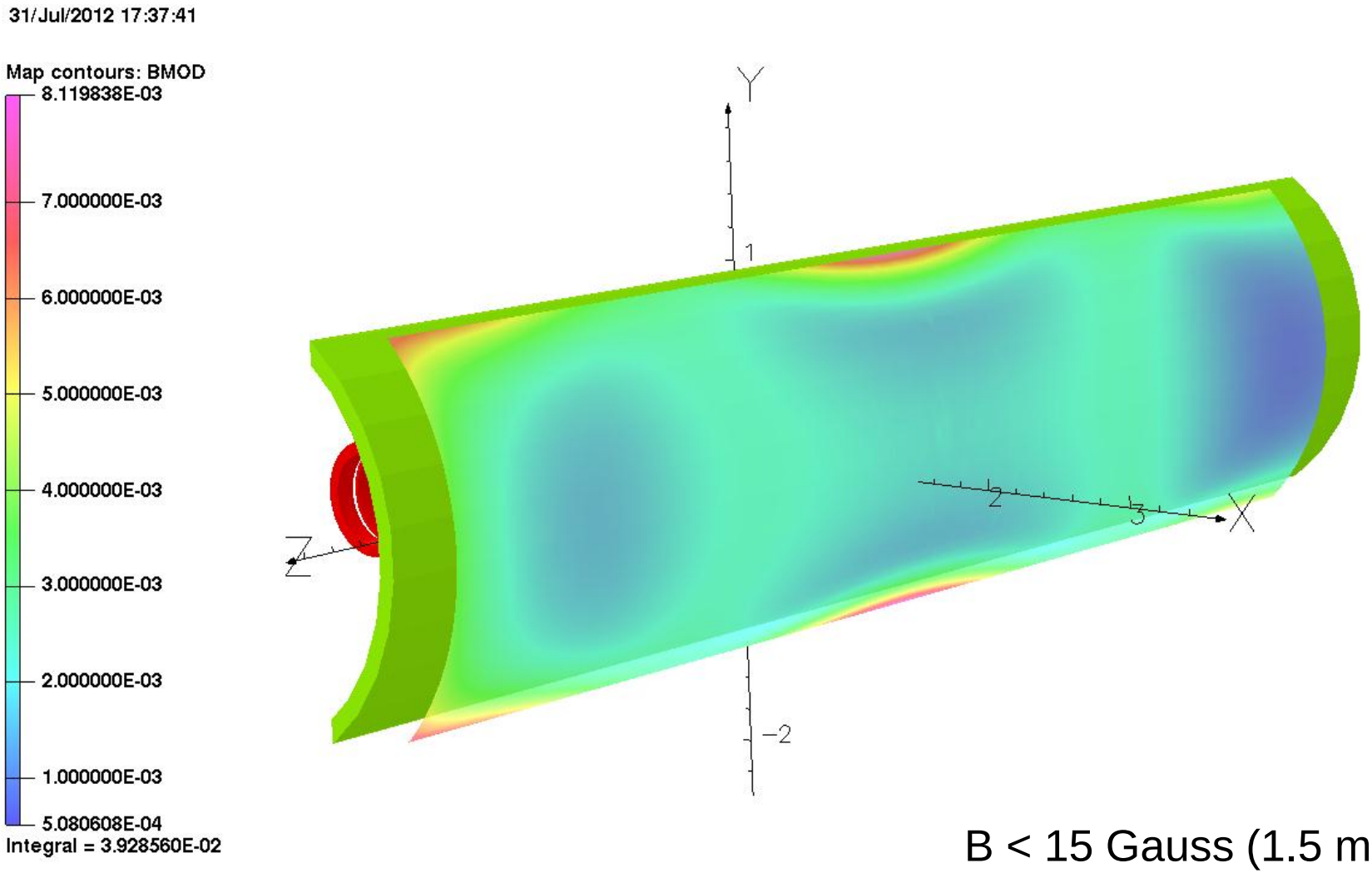
Wall thickness: 10 cm
r = 1.2 m

Magnetization In Shield - COMSOL

Wall thickness: 10 cm
r = 1.2 m



Shielding Efficiency - Opera



B < 15 Gauss (1.5 mT)

r = 1.5 m

Shielding Efficiency COMSOL

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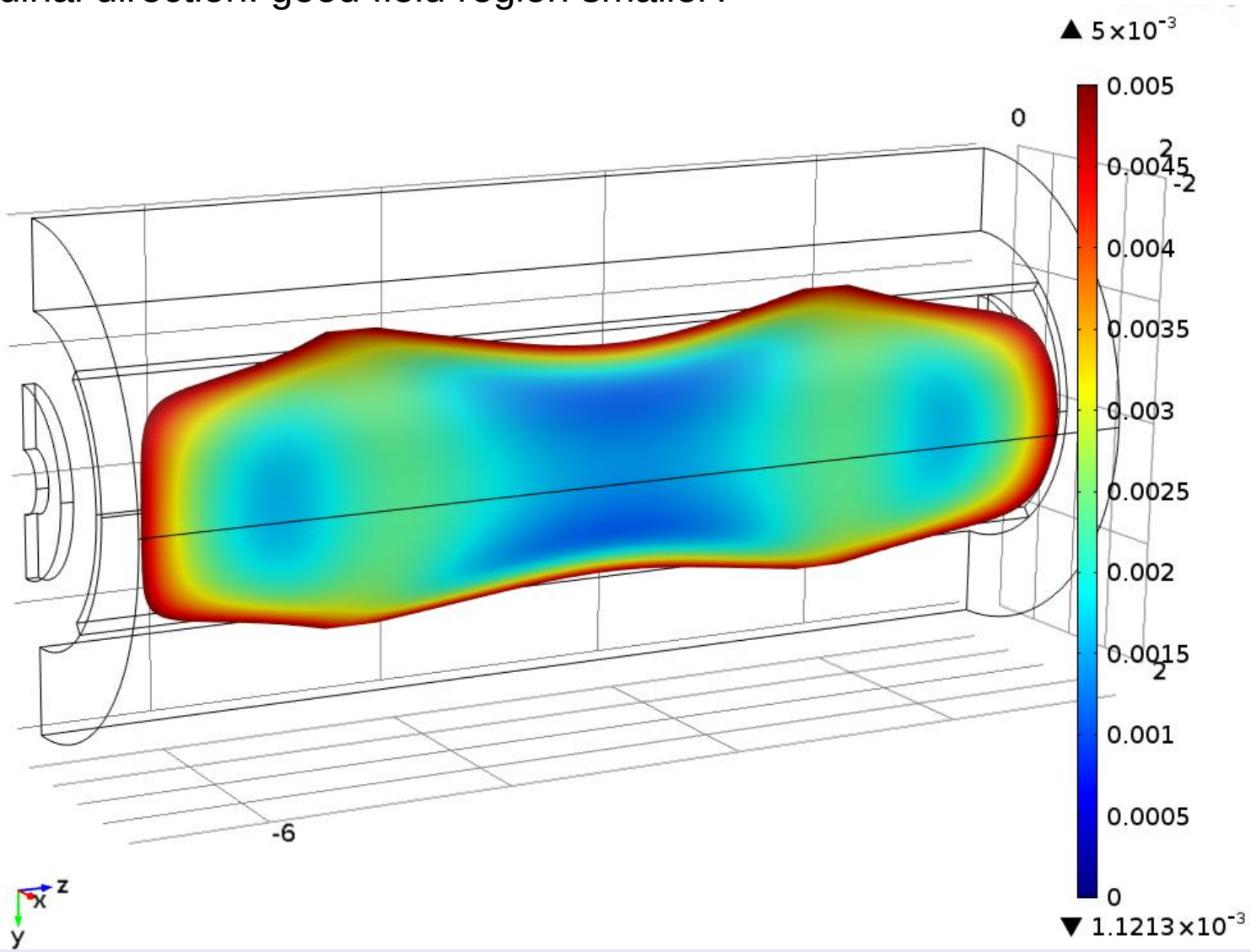
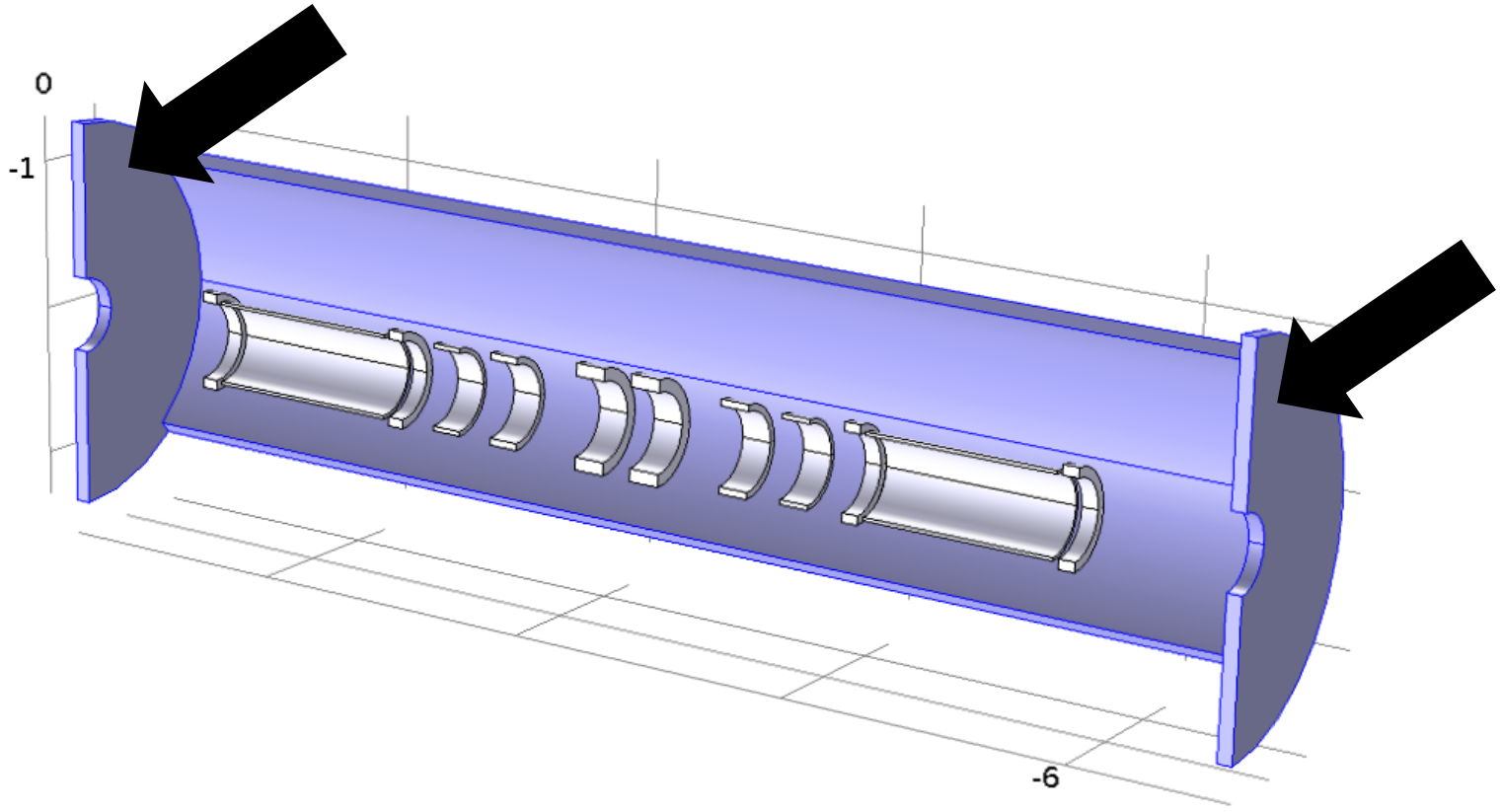
Longitudinal direction: good field region smaller?



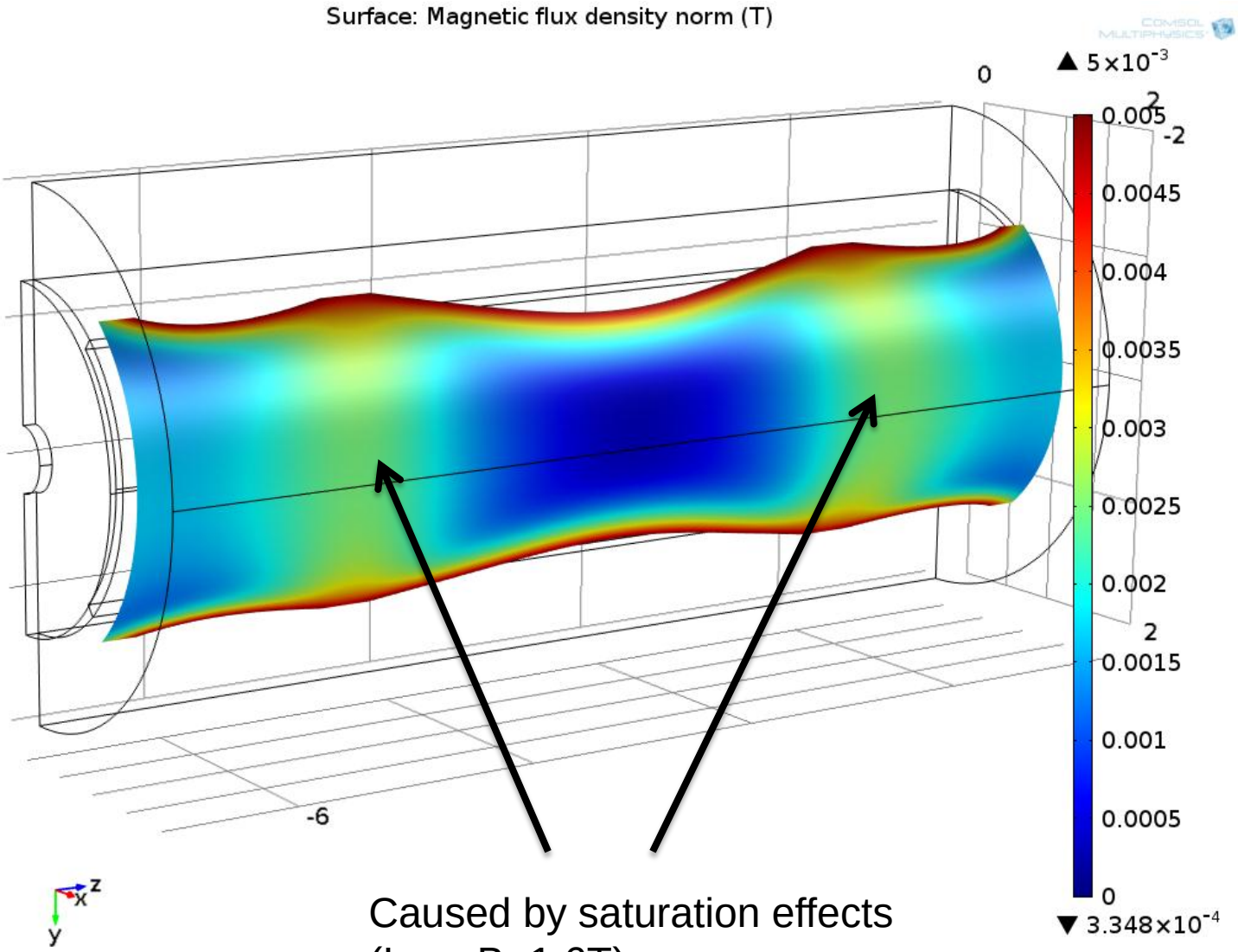
Geometry 2



Caused by flux leakage between shield and Virostek plate?

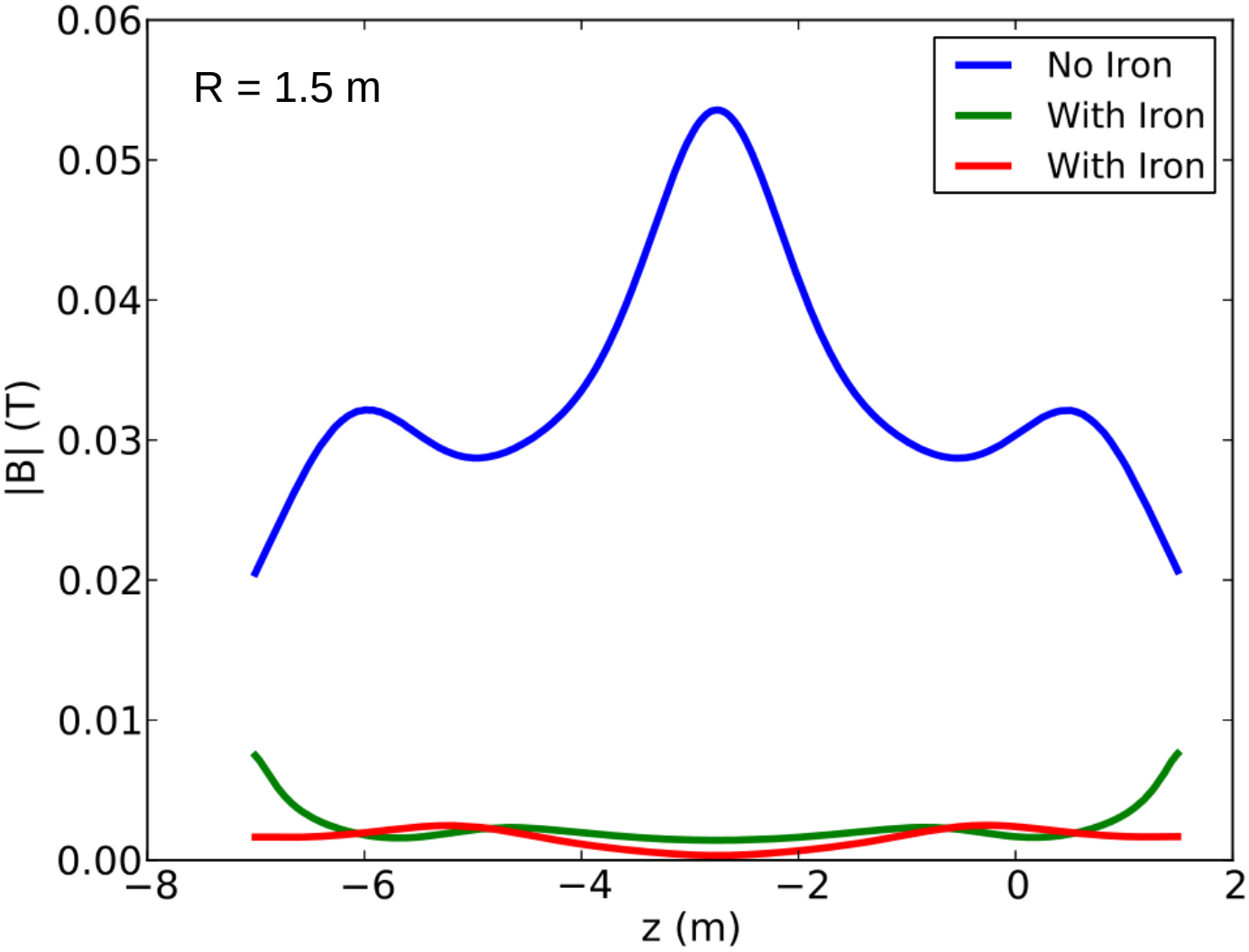
Idea from Alain Blondel: connect Virostek plate and shield

Shielding Efficiency COMSOL



Caused by saturation effects
(Iron: B~1.6T)

Comparison COMSOL



Summary

- MICE Step IV, 200 MeV flip mode
  - Comparison between COMSOL and Opera 3D
  - Different implementation
  - Performance
    - Opera: 4GB RAM / 45 min (single core)
    - COMSOL: 40GB RAM / 45 min (12 cores)
- In general good agreement
  - Major improvement on initial situation
  - Comparable shielding efficiency
- Differences
  - Good field region can be extended by connecting shield and Virostek plate
  - Simulations seem to indicate that shield could be thicker