Summary of ILD Stray Field Calculations

LSWC 2014
Belgrade

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Outline

- Stray field requirements
- Initial calculations
- Recent calculations

  Motivation

  - Trying to reduce size of ILD yoke
  - Better understanding of uncertainties
- Conclusions

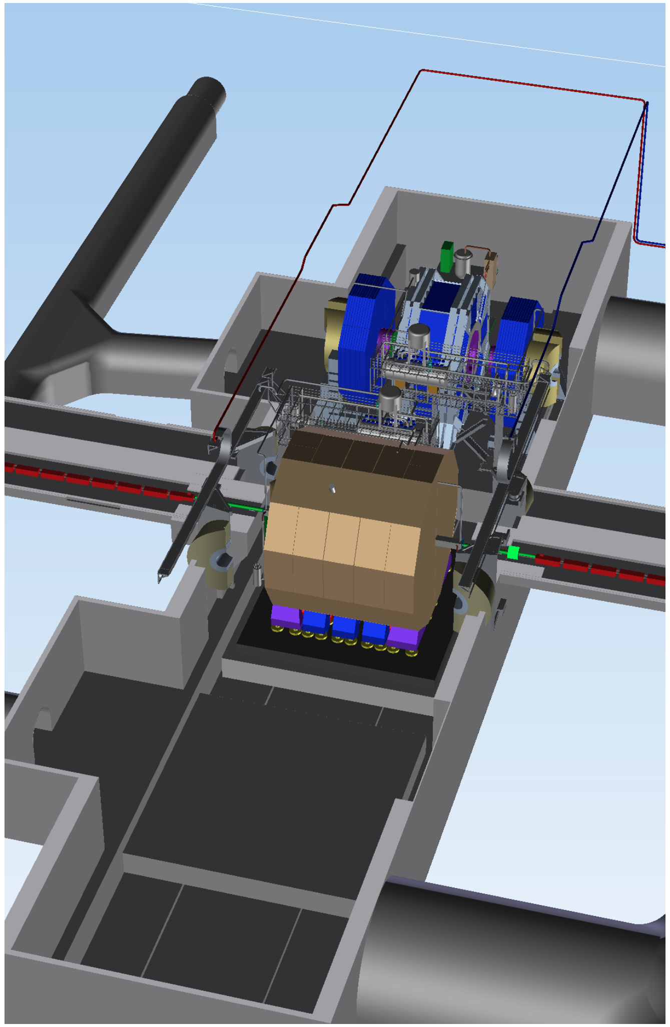
Main work done by:

- A.Petrov, M.Lemke, B.Krause (DESY)
- E. Bondarchuk, B. Kitaev, E. Vyrva (Efremov Insitute, St.Petersburg)

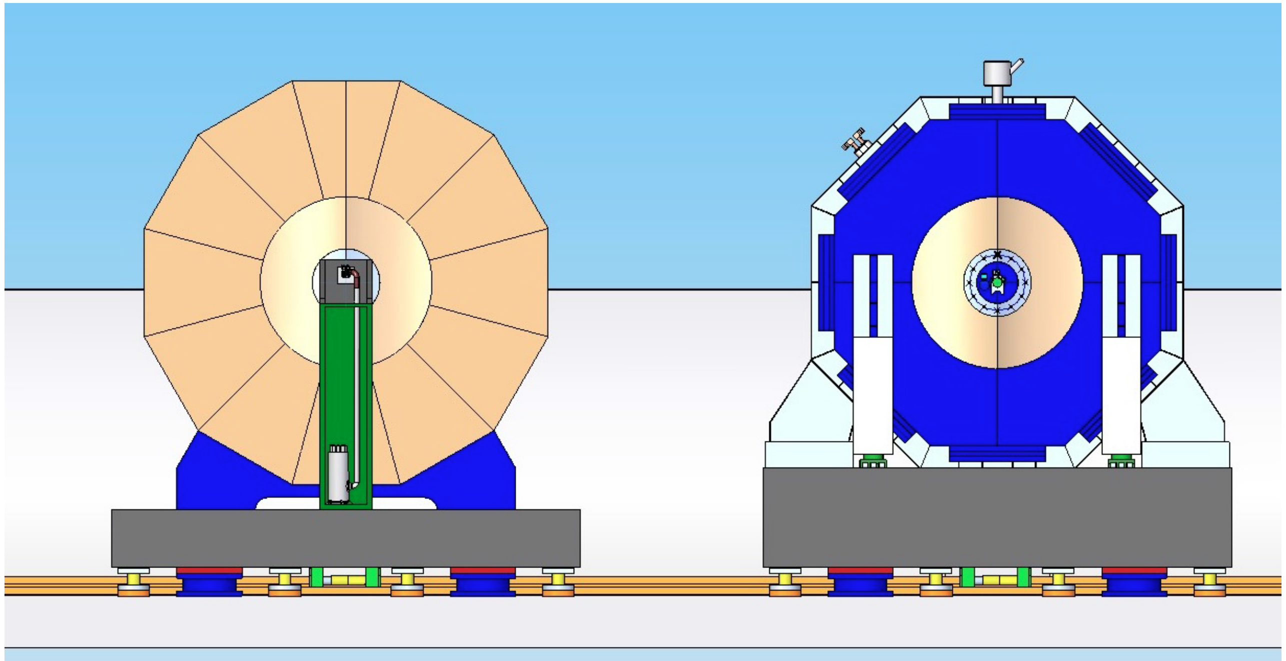
Some involvement:

- K.Büsser, K.Sinram, U.S.

Stray field requirements



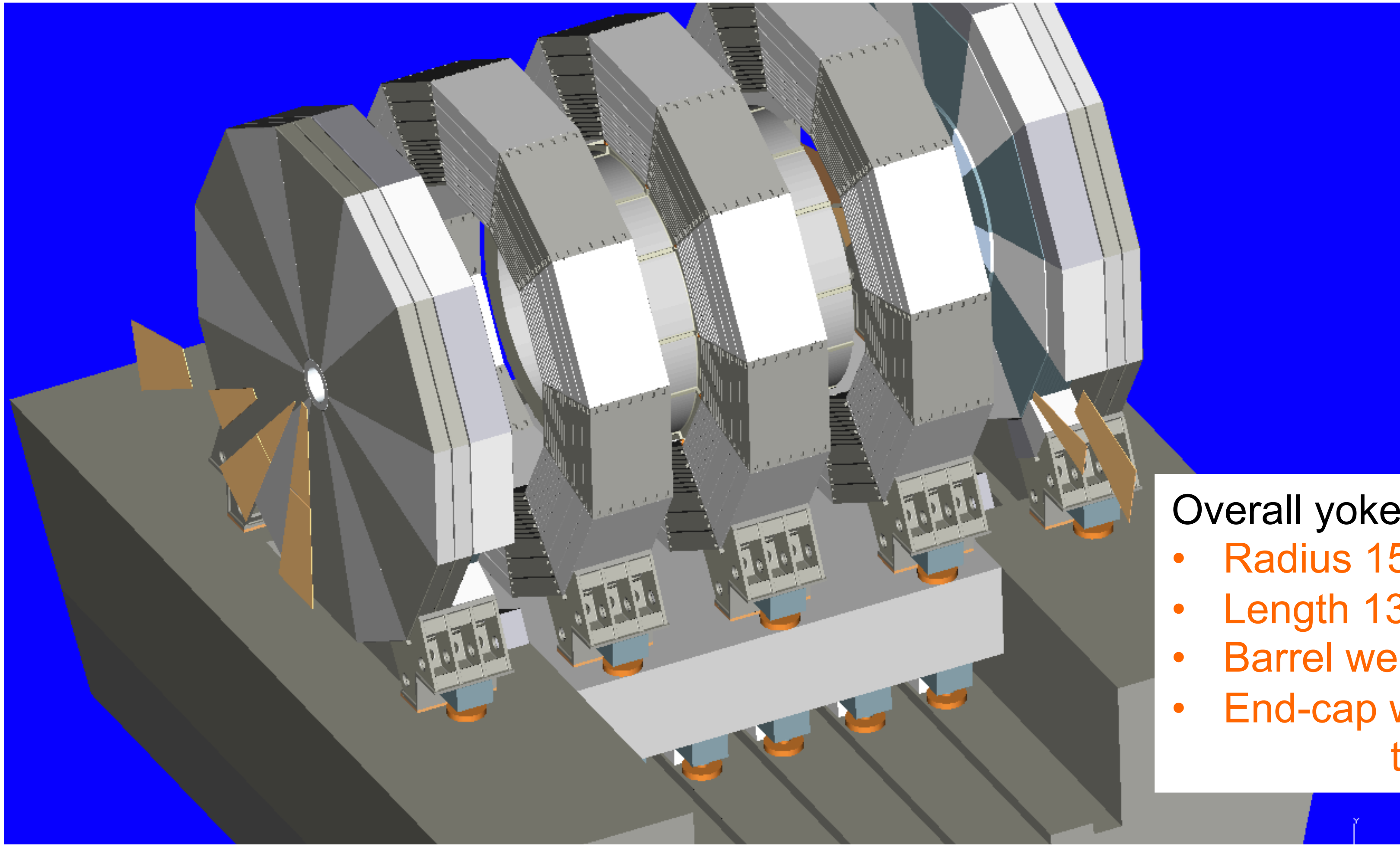
- Two detectors in one experimental hall, in beam and in park position
- Requirements on stray field
  - 50G in 15m radial distance from detector center based on CMS experience



Yoke Design Overview

Design based on CMS

- Large volume magnet (similar to CMS)
  - Field: 4T (maximum), 3.5T (nominal operation)

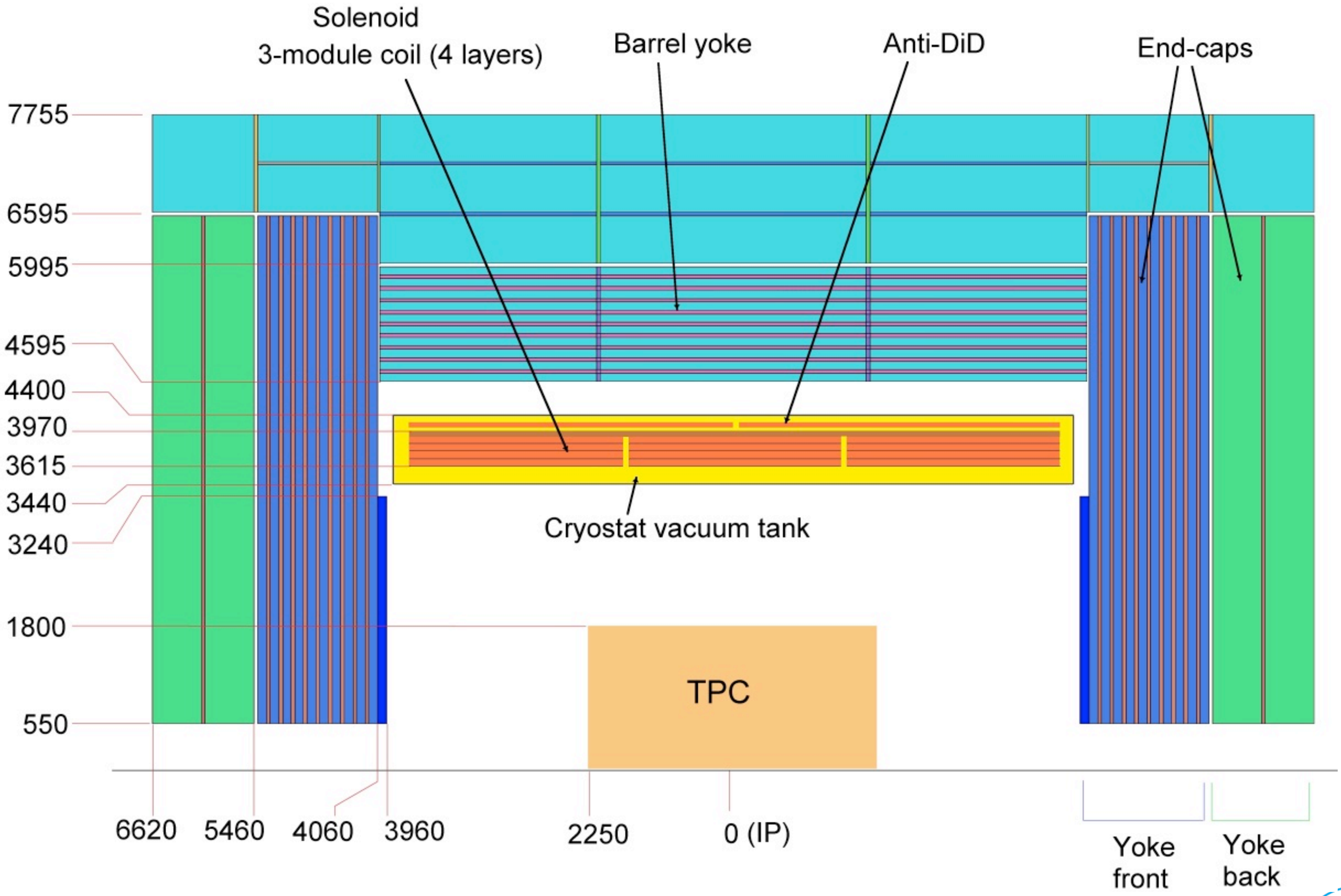


Overall yoke dimensions

- Radius 15.5m
- Length 13.2m
- Barrel weight 6900t
- End-cap weight 6500t

  total 13400t

Yoke Cross-Section Overview

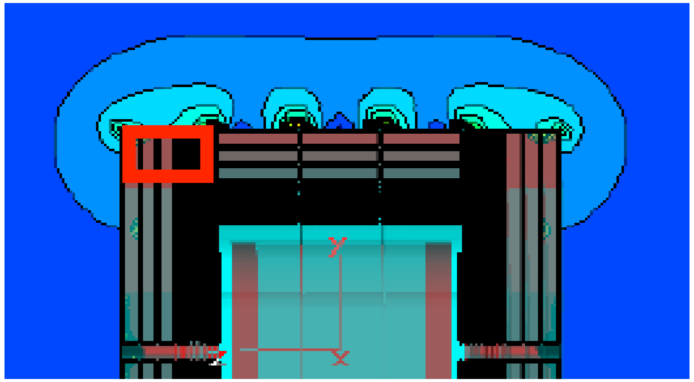


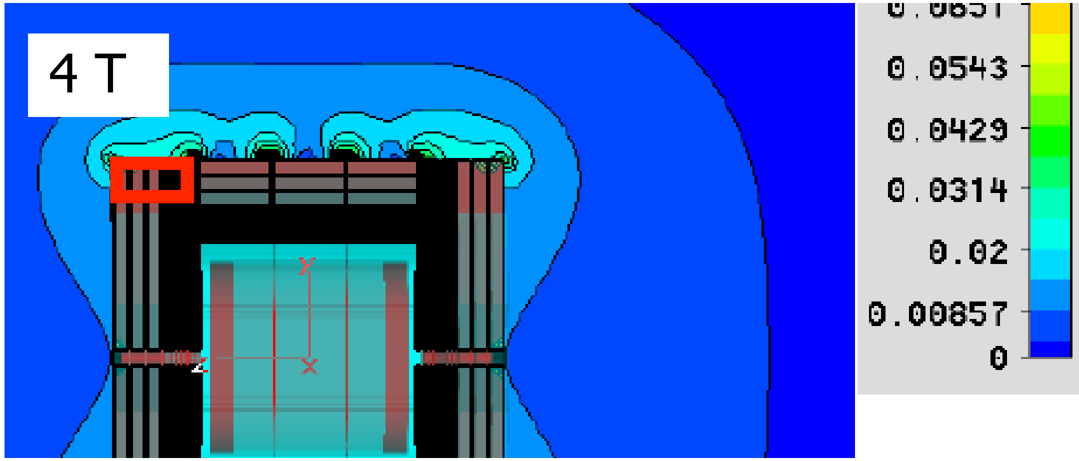
Stray Field Calculations

CST Studio 3D, A. Petrov, 2008

3.5 T

gaps filled

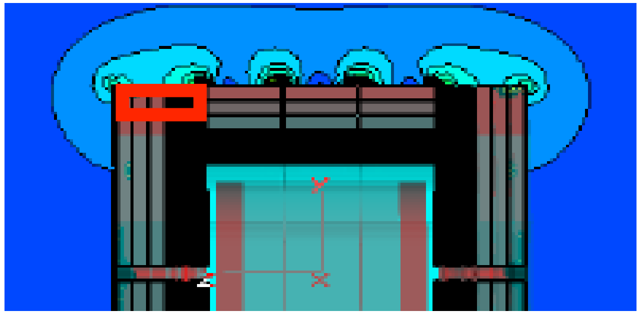




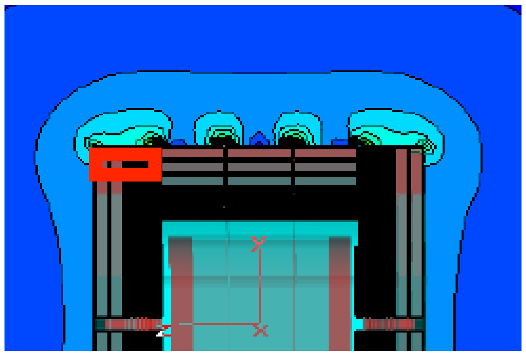
iron thickness 2.68/2.12m
total thickness 3.16/2.56m

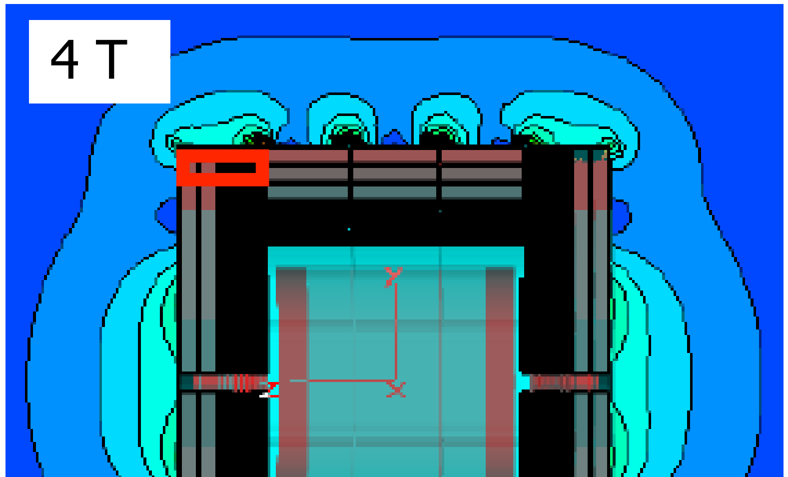
r_{out} = 7.655m, z = 6.605m

gaps partly filled



gaps partly filled, EC 2 plates





Stray Field Calculations

central field 3.5 T

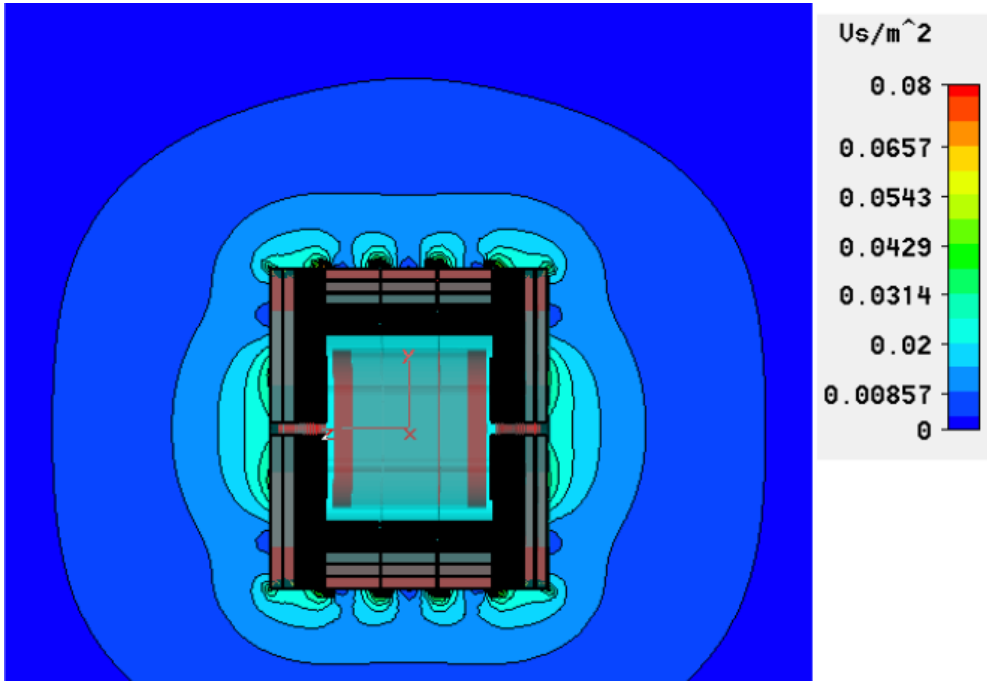
4 T

iron yoke	3 thick plates		3 thick plates EC filled		3 thick plates EC partly filled		3/2 thick plates EC partly filled		3/2 thick plates EC partly filled	
B (T)	3.6		3.6		3.6		3.6		4	
z (m)	0	5.4	0	5.4	0	5.4	0	5.4	0	5.4
B stray (G)	y (m)	y (m)	y (m)	y (m)	y (m)	y (m)	y (m)	y (m)	y (m)	y (m)
200	7.7	11.3	7.6	7.9	7.6	7.9	7.6	8.2	7.6	8.4
100	13.4	13.9	10	10.3	10	10.3	10	10.3	10.5	10.6
50							13.2	12.6	13.7	13.2
	d (m)	d (m)	d (m)	d (m)	d (m)	d (m)	d (m)	d (m)		
200	0	3.6	0	0.3	0	0.2	0	0.5	0	0.7
100	5.7	6.2	2.3	2.6	2.3	2.6	2.3	2.6	2.8	2.9
50							5.5	4.9	6	5.5

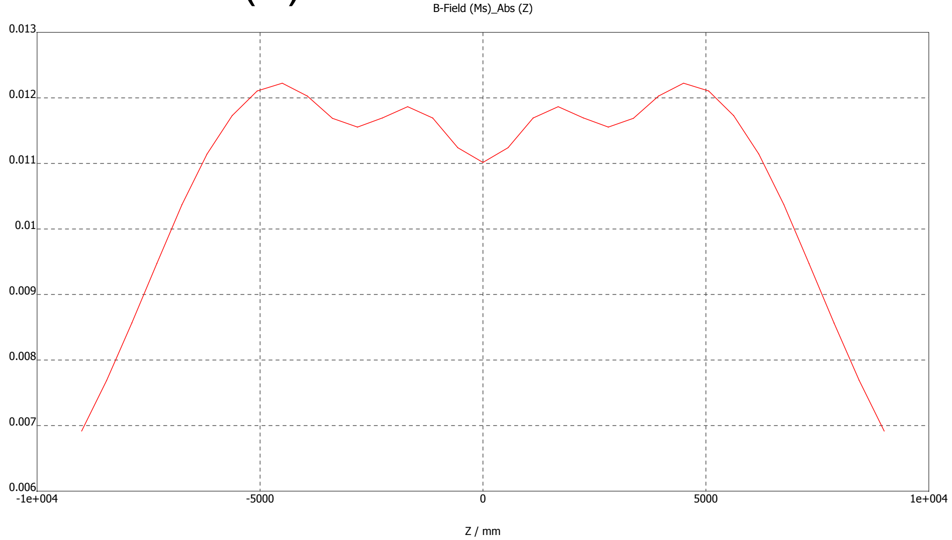
Stray field < 50G at 15m horizontal distance from beam line for 4 T.
Limit as discussed in Chicago MDI meeting.

Stray Field Calculations

CST Studio 3D, A. Petrov, 2008



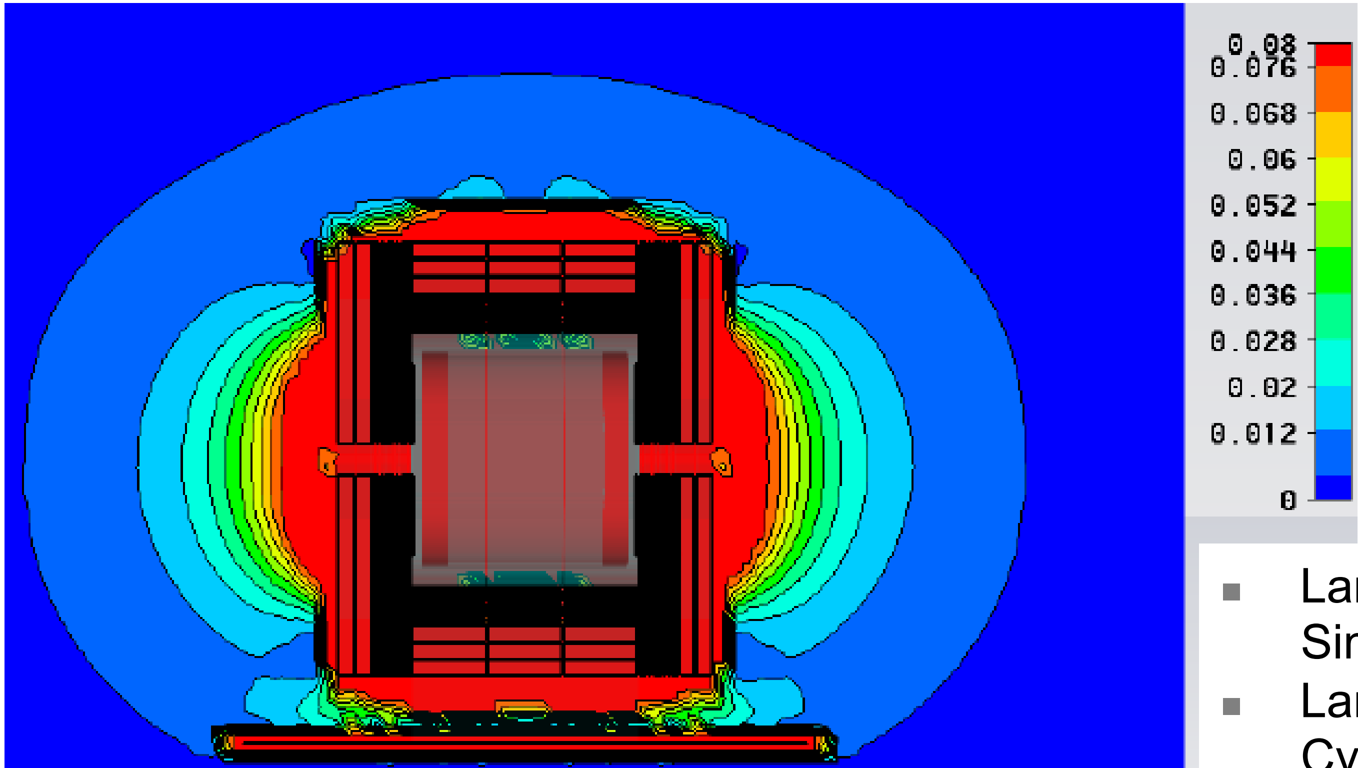
B (T) vs. z at r = 10m



B (T) vs. z at r = 15m

Stray Field with Floor Steel Plate

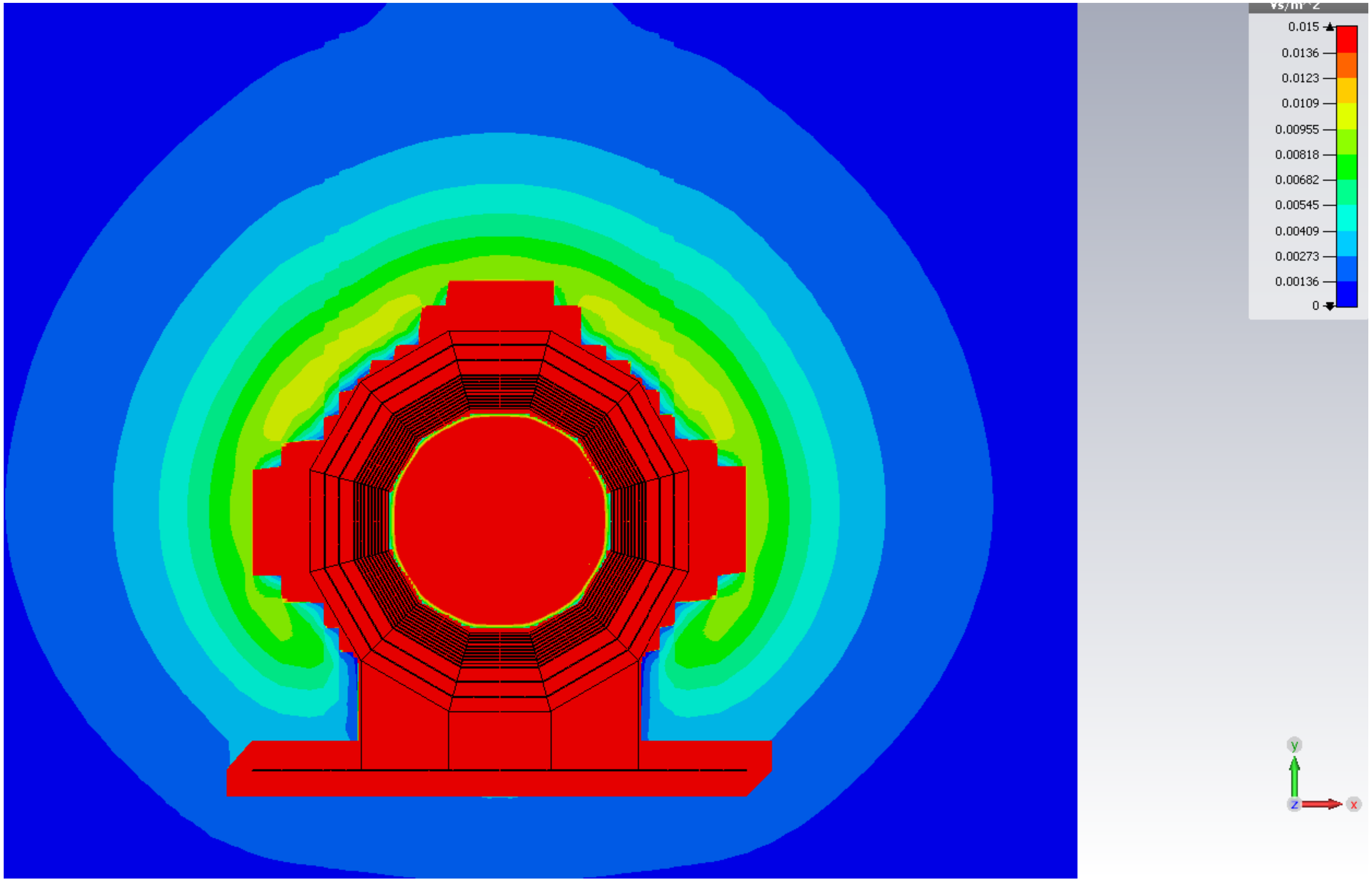
- Simplified iron support feet, 4 T field A. Petrov, 2009
- Floor with steel plate (20m x 20m 60mm thick)
- Increased end-cap hole to 1.1m diameter for rectangular support tube



- Large field in steel floor 1.6T
  Similar with non-magnetic feet
- Larger EC hole increases stray field in z
  Cylindrical support tube would be better

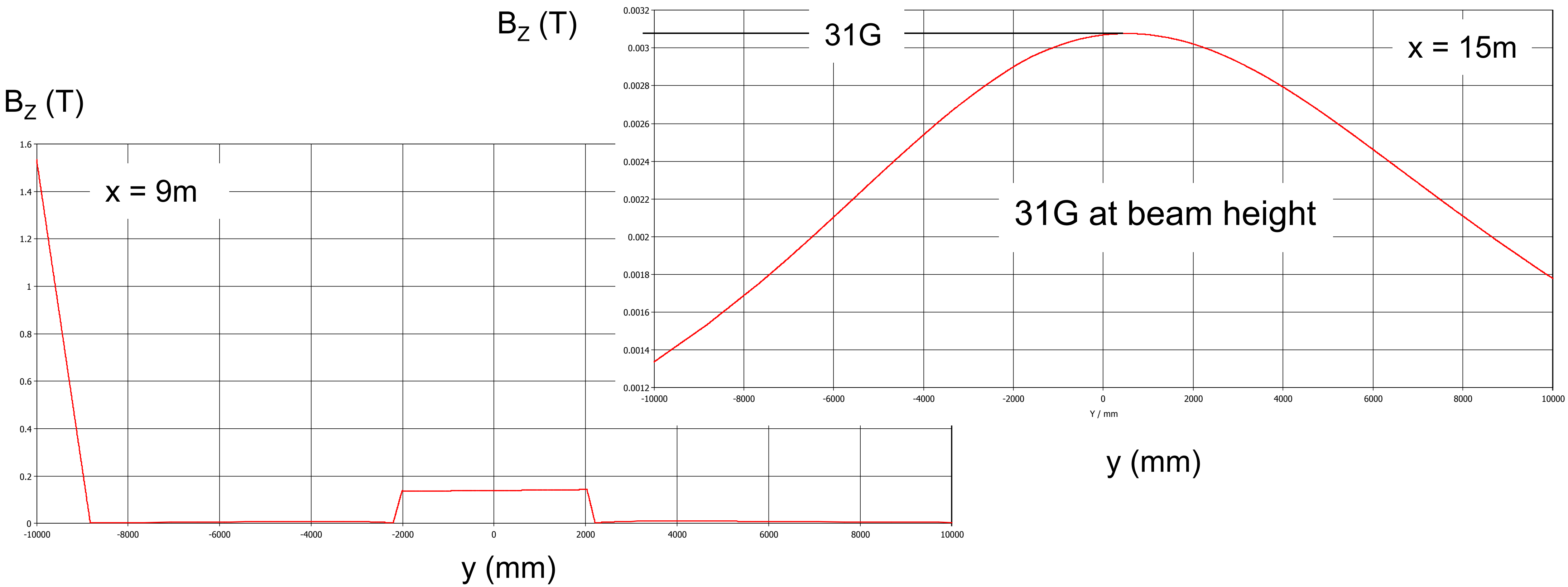
Stray Field with Floor Steel Plate

- Simplified iron support feet,   4 T field   A. Petrov, 2009
- Floor with steel plate (20m x 20m 60mm thick)



Stray Field with Floor Steel Plate

Field at z = 0, x = 9m (on platform) and 15m as function of y (-10 to 10m)



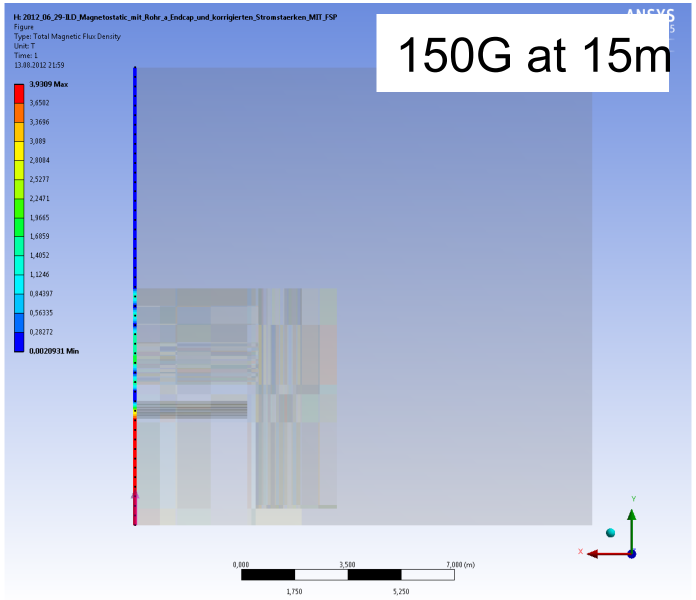
- Large field in steel floor, 1.6T
- Field obviously asymmetric
- Achieve <50G at 15m

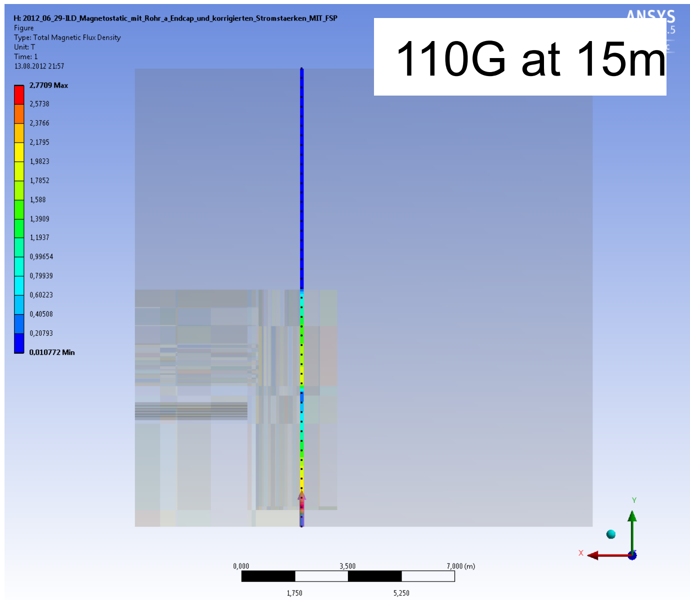
More Recent Field Calculations

M. Lemke 2012

Motivation

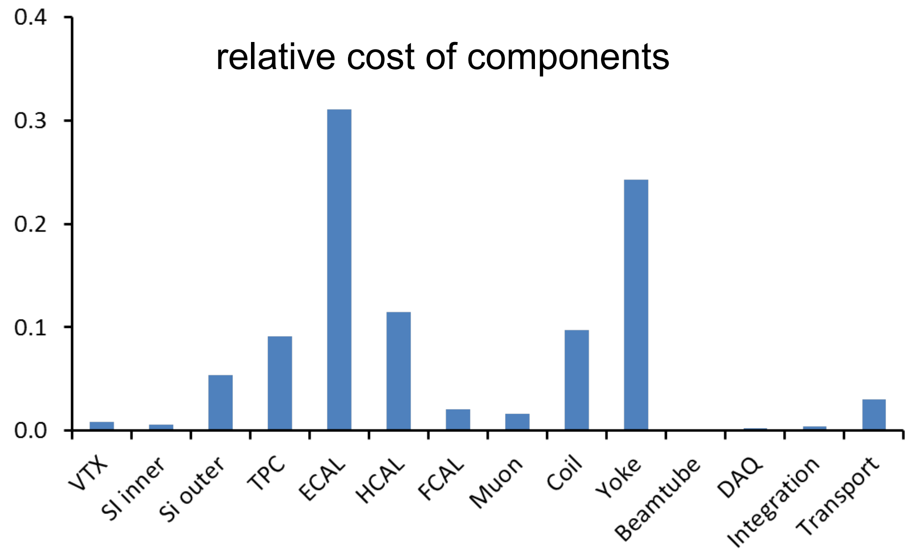
- FEM calculations of yoke deformation and stress due to magnetic forces using Ansys 3D code
- Used updated coil configuration (minor change)
- Looked at stray fields as well
- Quite a bit a higher: 150G
- Recently, checked calculations again. Found some issues. No conclusion yet. Work in progress.





Yoke Discussion

- Thickness and cost of yoke is determined by stray field requirements
- Reduce iron (cost saving)?
  - Coil Geometry (2nd large solenoid): No
  - Additional end cap coils (CLIC detector): No, power consumption too expensive
  - Add shielding iron at distance: No
  - Reduce iron thickness ???



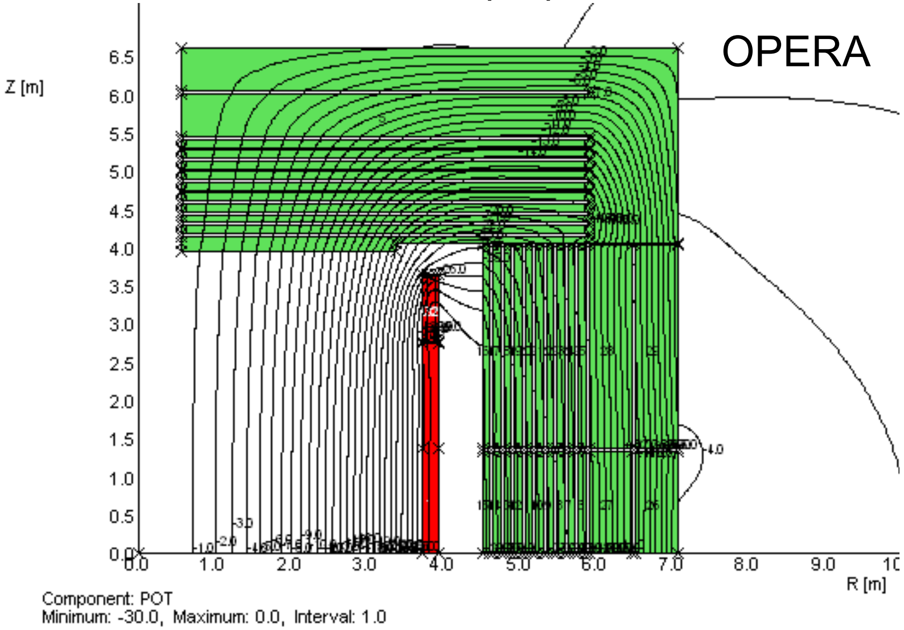
- Need good understanding of field calculations
  - Uncertainties and limits of FEM code
  - Different code, mesh size, mesh, …
- Realistic simulation/description of detector in real hall
  - Additional iron (infrastructure, services, scaffolding,…) ?
  - Platform/floor, hall walls, …

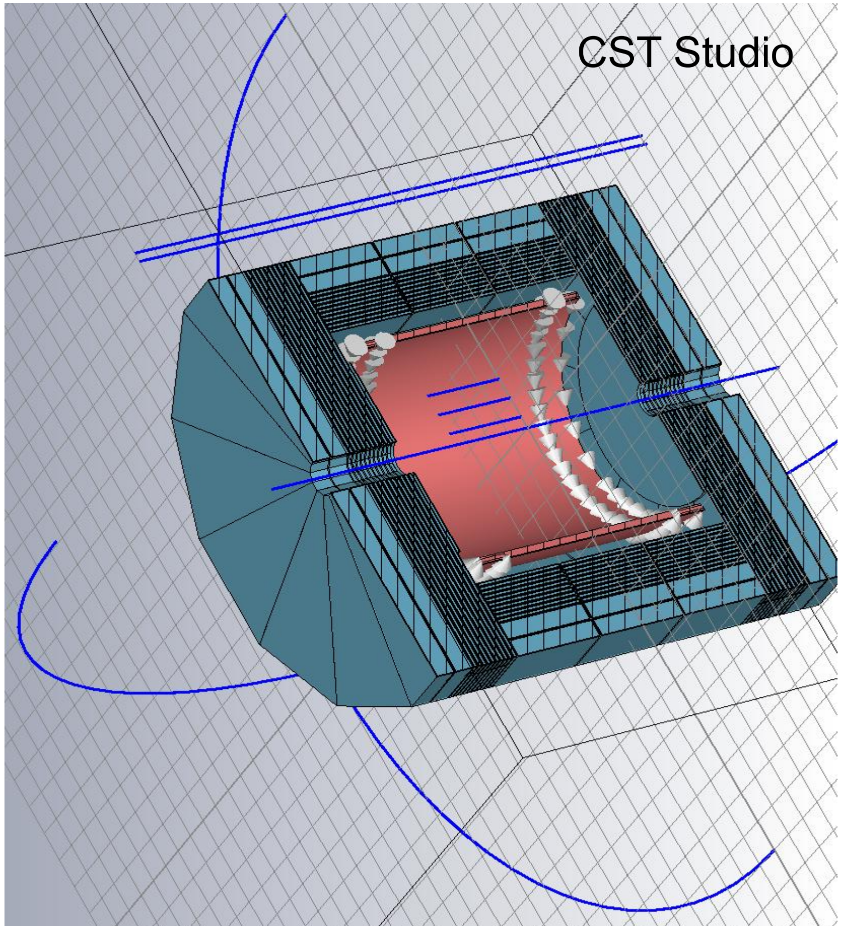
New Field Calculations

> Spring/summer 2014 study at Efremov Institute (St.Petersburg)
  - Motivation: field for reduced yoke, compare FEM codes

> Slightly reduced radius, 2 instead of 3 thick iron plates (60cm less in radius)

> Study dependence on FEM codes
  - ANSYS Maxwell 2D and 3D (x_V,y_V 30 - 40m)
  - OPERA 2D and 3D (x_V,y_V 30 - 40m)
  - CST EM Studio (x_V,y_V 17m, 4×10^7 knots)



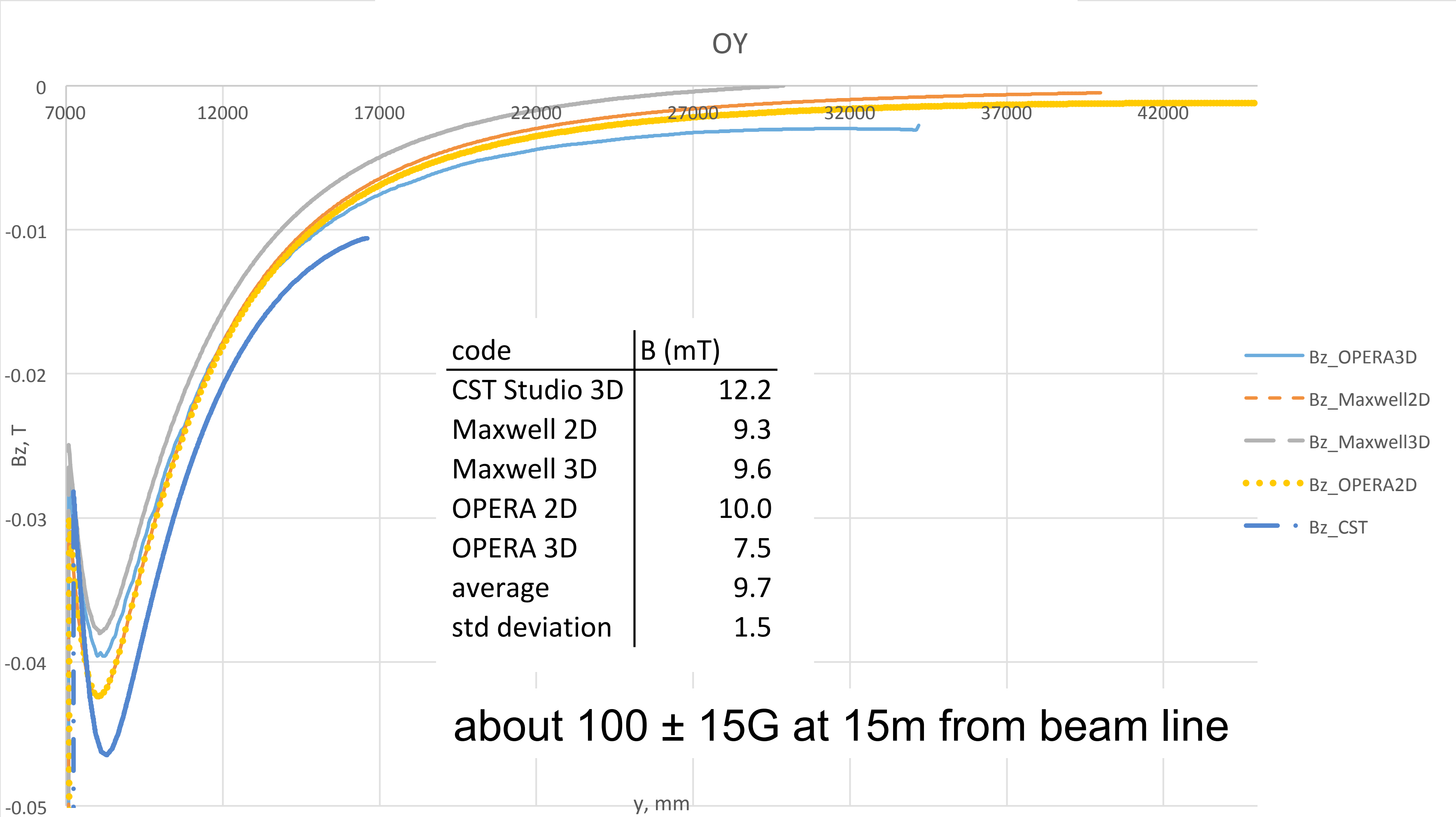


New Field Calculations: Reduced Radius

Comparison of different FEM codes

Efremov, 2014

B_z (T) as function of y for x=0, z=0



code	B (mT)
CST Studio 3D	12.2
Maxwell 2D	9.3
Maxwell 3D	9.6
OPERA 2D	10.0
OPERA 3D	7.5
average	9.7
std deviation	1.5

about 100 ± 15G at 15m from beam line

New Field Calculations: Reduced Radius

- CST EM Studio volume size x_V, y_V 17m, limited by memory
- Repeated simulation at DESY, varying volume size

CST Studio 3D

volume size r (m)	B (mT)
17 (Efremov)	12.2
30 (DESY)	9.9
40 (DESY)	10.8
60 (DESY)	8

all ~ 100G

Conclusions

Present design

> Achieved goal of < 50G at 15m distance from beam line for 4 T
  - Still have to understand ANSYS calculations

> Thickness and cost of yoke (and size of detector) determined by stray field requirements

> Important to close gaps as much as possible

> Preliminary study of influence of steel plate floor (platform)
  - Small change of field in air, large field in floor

→ Large size makes yoke very expensive, would like to reduce size

Smaller yoke

> Get 100G for slightly smaller barrel (60cm less in radius)

> Independent FEM calculations very consistent

However,

> At limit of FEM codes, required accuracy ~0.1% of max. field

> Need realistic description of hall
  - Steel in platform, wall, any other magnetic materials

> Avoid magnetic material between detectors

Proposal

> Stray field only important on one side of detector in operation
  - No major work on detector in operation (accept replacing some electronics,…)
  - Do not disturb work on detector in park position

Proposal

> No electronics and infrastructure (which requires maintenance) on side facing other detector
> Avoid magnetic material between detectors as much as possible
> Restricted access between detectors when magnet on
> Agree on increasing stray field to reasonable level