Concepts for 20 T dipoles

SnowMass Preparation 21-2-2013

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We want a new 20T Dipole

- Higher energies to find new fundamental physics
- So we can improve our understanding of the universe we live in

- However development of such a magnet will take some time
- Therefore we need to start thinking now
  - Many ideas 'floating' around
  - Many new technologies such as HTS

- Assignment: make first steps within context EUCARD I/II

(Wallpapers NASA)

Development Plan

- Started November 2012 in the framework of PhD
  - Work far from complete
- Compare all (or most relevant) designs/layouts
- Boundaries
  - Iron influence
    - With – gain 2 T for single aperture
    - Without – B distribution modified
    - Active shielding?
  - Conductor
    - Existing performance
    - Future extrapolated performance -> to prospect ultimate possibilities
  - Field quality
    - Not too much focus on field quality yet. Because winding pack is thick, it can be corrected for later.

Making a Fair Comparison

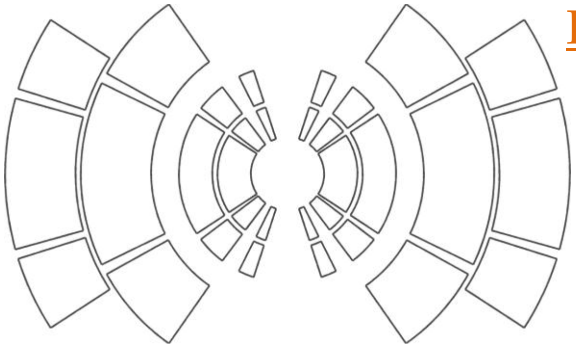
- All designs/layouts must follow same set of rules
  - 20 T operating field
  - same critical surfaces for conductor
  - same operating points (80%Ic)
  - same operating temperature (1.9 K)
  - same free bore (40 mm)
  - same assumptions on how to deal with forces
  - same shielding/iron

- Compare in terms of
  - Forces and stresses in coil
  - Amount of conductor
  - Feasibility

- Need to watch out to compare also to some designs of different groups.

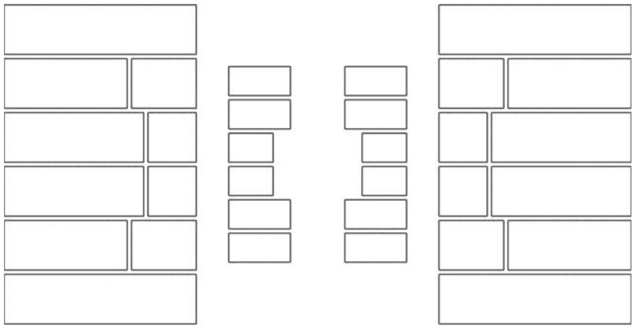
Design Options

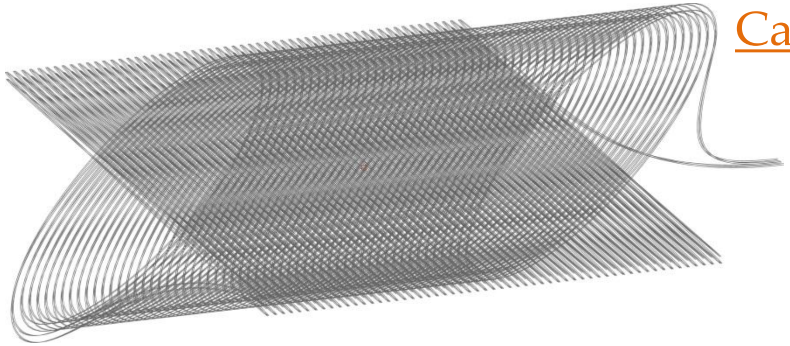
- Configuration per Layer
  - Cos-Theta
  - Block
  - Canted Cos-Theta
  - Perhaps other



Full Cos-Theta

Full Block





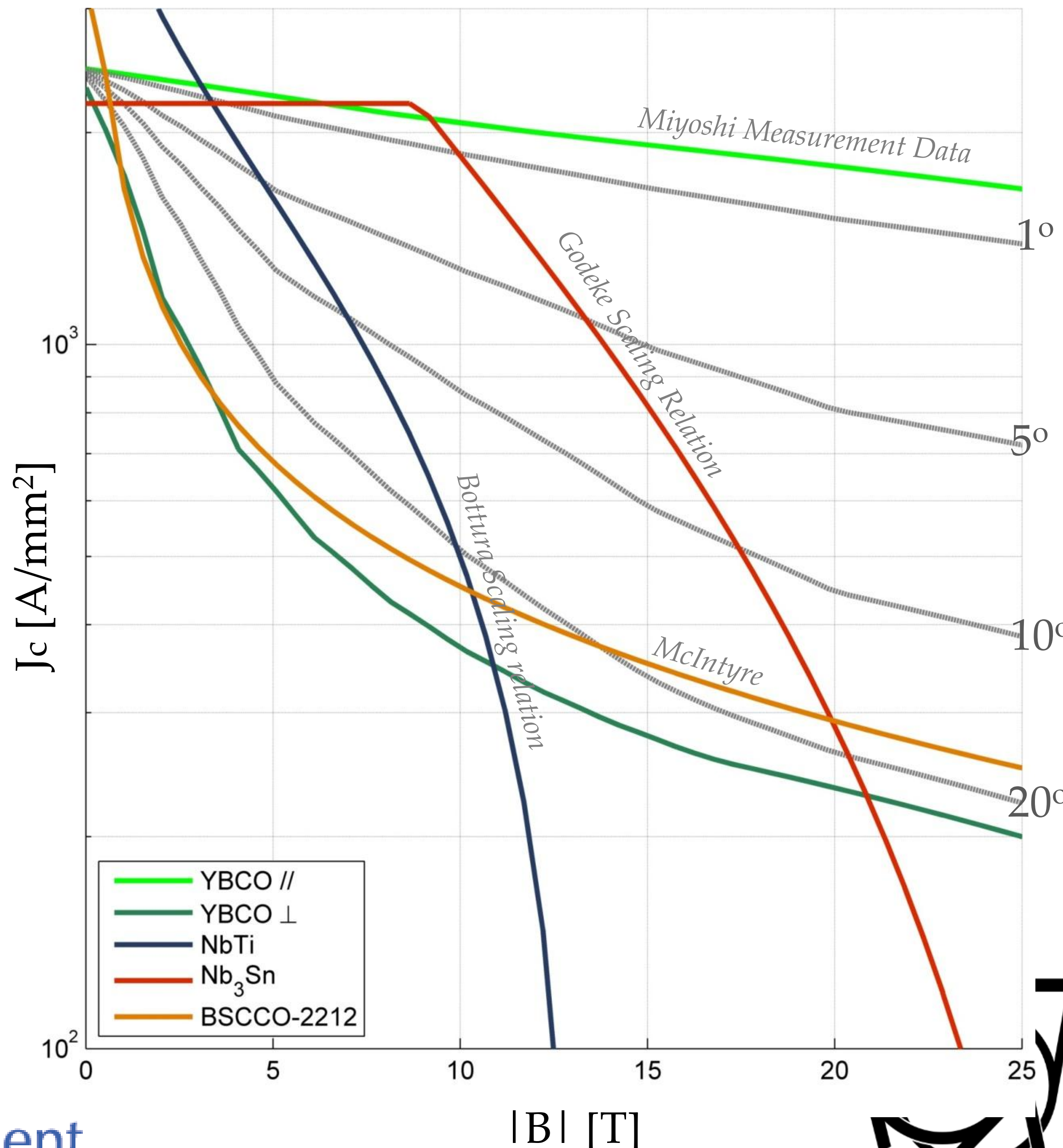
Canted Cosine Theta (CCT)

Design Options

- Conductor per Layer
  - NbTi
  - Nb3Sn
  - YBCO (fieldangle)
  - BSCCO (stresses)

- Cables
  - Rutherford
  - Roebel
  - Cork
  - Other?

- One or multiple power supplies?



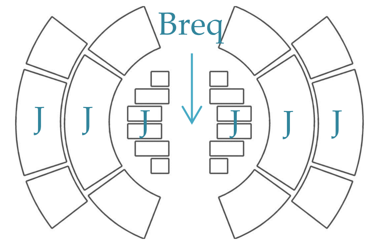
Pocket Sized Coil Optimizer

- New iterative 2D magnet optimization tool

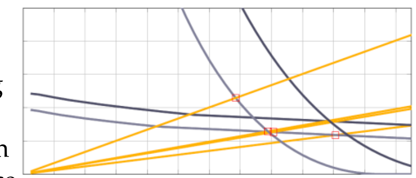
Start

Load input coils

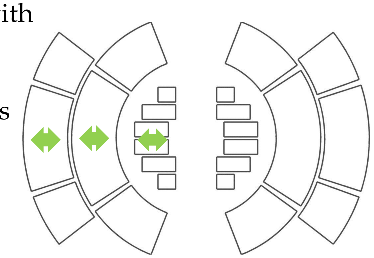
Set current to match field contribution



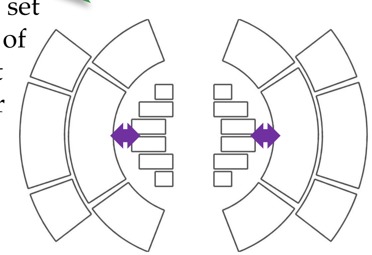
Calculate Engineering Current Density from critical surface



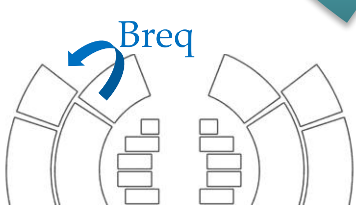
Scale Layer thickness with J/Je, set nesting conditions



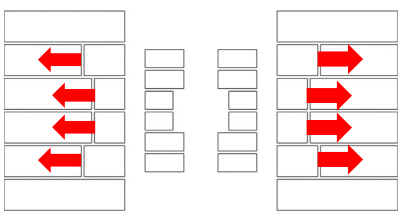
Calculate Forces and set thickness of support cylinder



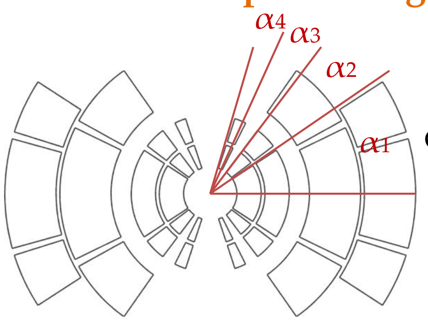
Redistribute Breq over layers that have been set to equal width



Optimize block coil structure with moving walls



Optimize field quality by adjusting predefined variables



Change less than 0.001%

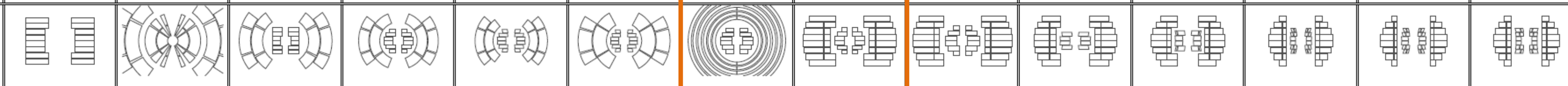
no

yes

Convergence Reached (:

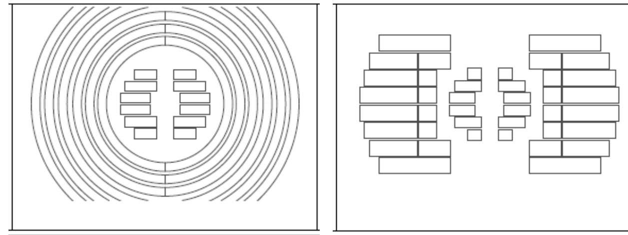
Post processing

Pocket Sized Coil Optimizer

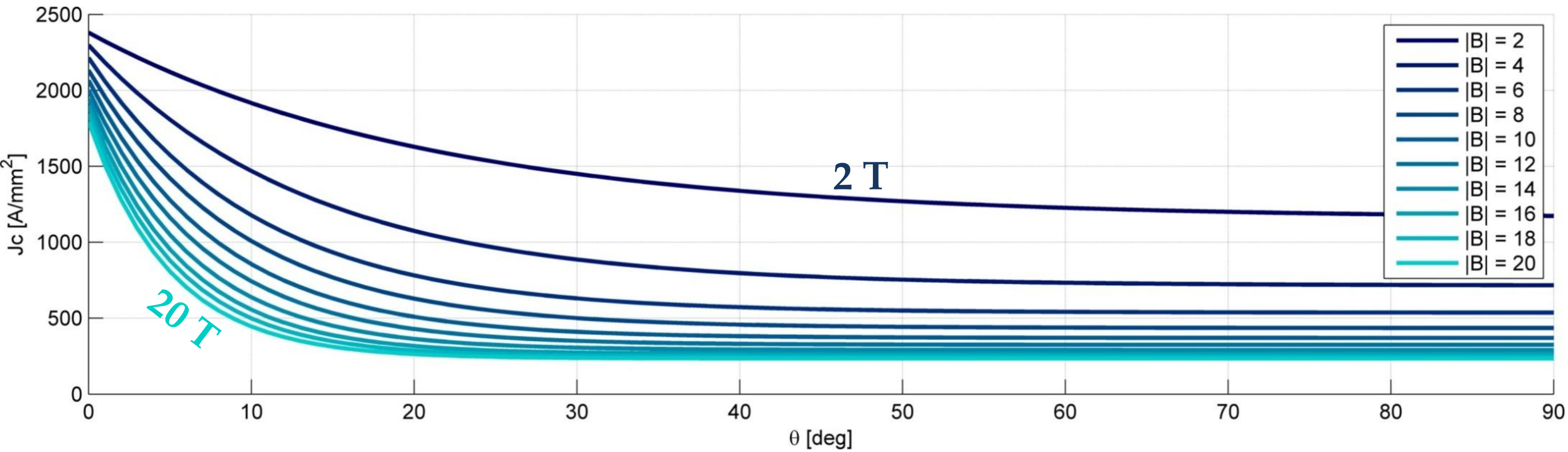
name	Fresca2	Ct2Ct1	Bl2Ct1	Bl2Ct2	Bl2Ct3	Bl2Ct4	Bl2Hc1
layout							
YBCO	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	6.00 [T] 23052.9 [mm^2] 102.71 [MPa]	6.00 [T] 7204.5 [mm^2] 154.39 [MPa]	6.00 [T] 5515.0 [mm^2] 164.43 [MPa]	7.00 [T] 4704.0 [mm^2] 188.18 [MPa]	7.00 [T] 4264.7 [mm^2] 186.03 [MPa]	7.00 [T] 7318.8 [mm^2] 181.26 [MPa]
BSCCO	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]
Nb3Sn	11.03 [T] 29640.8 [mm^2] 88.94 [MPa]	14.00 [T] 57257.3 [mm^2] 244.69 [MPa]	14.00 [T] 36621.4 [mm^2] 222.93 [MPa]	14.00 [T] 31536.9 [mm^2] 207.23 [MPa]	13.00 [T] 22930.6 [mm^2] 214.66 [MPa]	8.29 [T] 22456.1 [mm^2] 167.62 [MPa]	13.00 [T] 22908.4 [mm^2] 380.20 [MPa]
NbTi	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	4.71 [T] 17892.8 [mm^2] 69.77 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]
Rin Rout1 Rout2	58.24 [mm] 166.18 [mm] 137.72 [mm]	21.00 [mm] 246.45 [mm] 246.45 [mm]	21.00 [mm] 184.78 [mm] 184.78 [mm]	21.00 [mm] 158.47 [mm] 158.47 [mm]	21.00 [mm] 144.20 [mm] 144.20 [mm]	21.00 [mm] 182.99 [mm] 182.99 [mm]	21.00 [mm] 194.00 [mm] 194.00 [mm]
Estored	0.66 [MJ/m]	4.56 [MJ/m]	2.28 [MJ/m]	1.64 [MJ/m]	1.31 [MJ/m]	1.30 [MJ/m]	3.30 [MJ/m]

name	Bl2Bl1	Bl2Bl2	Bl2Bl5	Bl2Bl7	Bl2Bl8	Bl2Bl4	Bl2Bl6
layout							
YBCO	6.00 [T] 6025.7 [mm^2] 160.02 [MPa]	7.00 [T] 8783.3 [mm^2] 172.02 [MPa]	7.00 [T] 4843.2 [mm^2] 206.90 [MPa]	7.00 [T] 4691.8 [mm^2] 184.10 [MPa]	7.00 [T] 3399.1 [mm^2] 148.67 [MPa]	8.00 [T] 4132.2 [mm^2] 169.83 [MPa]	7.00 [T] 4570.5 [mm^2] 169.30 [MPa]
BSCCO	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]
Nb3Sn	7.00 [T] 18558.2 [mm^2] 147.02 [MPa]	6.50 [T] 16250.3 [mm^2] 138.03 [MPa]	7.00 [T] 15472.6 [mm^2] 123.39 [MPa]	6.00 [T] 13331.4 [mm^2] 119.02 [MPa]	6.00 [T] 6899.1 [mm^2] 63.16 [MPa]	5.50 [T] 5790.7 [mm^2] 55.32 [MPa]	7.00 [T] 8195.7 [mm^2] 68.33 [MPa]
NbTi	7.00 [T] 21157.7 [mm^2] 158.97 [MPa]	6.50 [T] 21719.4 [mm^2] 139.47 [MPa]	6.00 [T] 15244.7 [mm^2] 136.95 [MPa]	7.00 [T] 14460.2 [mm^2] 138.28 [MPa]	7.00 [T] 12197.8 [mm^2] 76.46 [MPa]	6.50 [T] 11623.5 [mm^2] 63.08 [MPa]	6.00 [T] 11065.0 [mm^2] 79.33 [MPa]
Rin Rout1 Rout2	21.00 [mm] 188.52 [mm] 188.52 [mm]	21.00 [mm] 199.22 [mm] 199.22 [mm]	21.00 [mm] 166.86 [mm] 166.86 [mm]	21.00 [mm] 148.39 [mm] 148.39 [mm]	21.00 [mm] 130.92 [mm] 130.92 [mm]	21.00 [mm] 133.78 [mm] 133.78 [mm]	21.00 [mm] 132.92 [mm] 132.92 [mm]
Estored	1.88 [MJ/m]	2.07 [MJ/m]	1.51 [MJ/m]	1.22 [MJ/m]	0.97 [MJ/m]	0.99 [MJ/m]	1.01 [MJ/m]

- Provides playground to create many coil designs (following the rules) for comparison
- At present we have studied YBCO insert, single aperture only to test the code
- Ultimate goal is to create comparative tables with many design options for dual aperture
- Already provided us with some ideas …

Bl2Hc1	Bl2Bl1
	
7.00 [T] 7318.8 [mm^2] 181.26 [MPa]	6.00 [T] 6025.7 [mm^2] 160.02 [MPa]
0.00 [T] 0.0 [mm^2] 0.00 [MPa]	0.00 [T] 0.0 [mm^2] 0.00 [MPa]
13.00 [T] 22908.4 [mm^2] [MPa]	7.00 [T] 18558.2 [mm^2] 147.02 [MPa]
0.00 [T] 0.0 [mm^2] 0.00 [MPa]	7.00 [T] 21157.7 [mm^2] 158.97 [MPa]
21.00 [mm] 194.00 [mm] 194.00 [mm]	21.00 [mm] 188.52 [mm] 188.52 [mm]
3.30 [MJ/m]	1.88 [MJ/m]

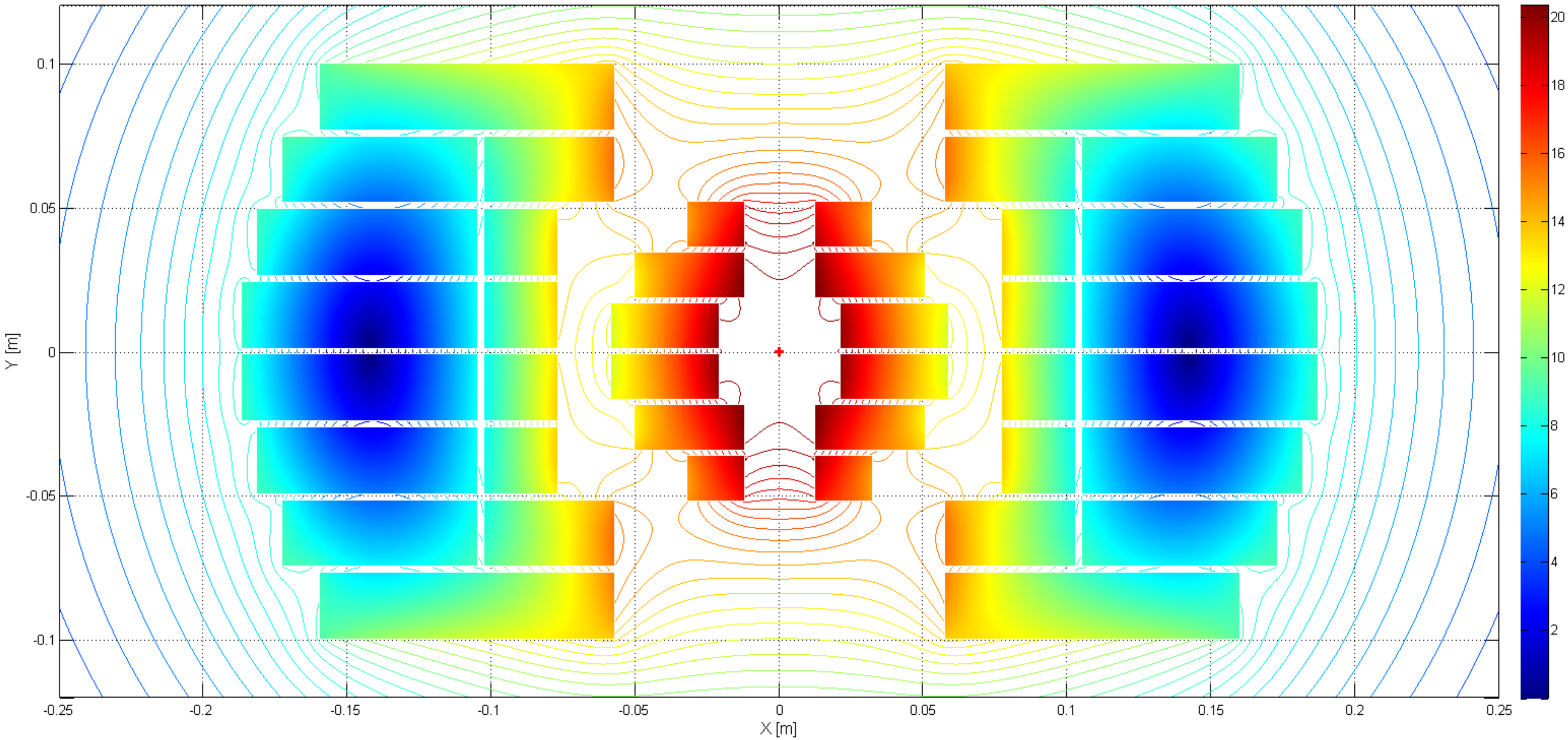
Idea 1 – Angle optimization for YBCO



- The critical current of YBCO tapes/cables is highly dependent on the incident angle of the magnetic field
- Effect becomes stronger at higher fields
- Because of this for presently available YBCO, only designs with good field angle inside the insert turn out to be feasible

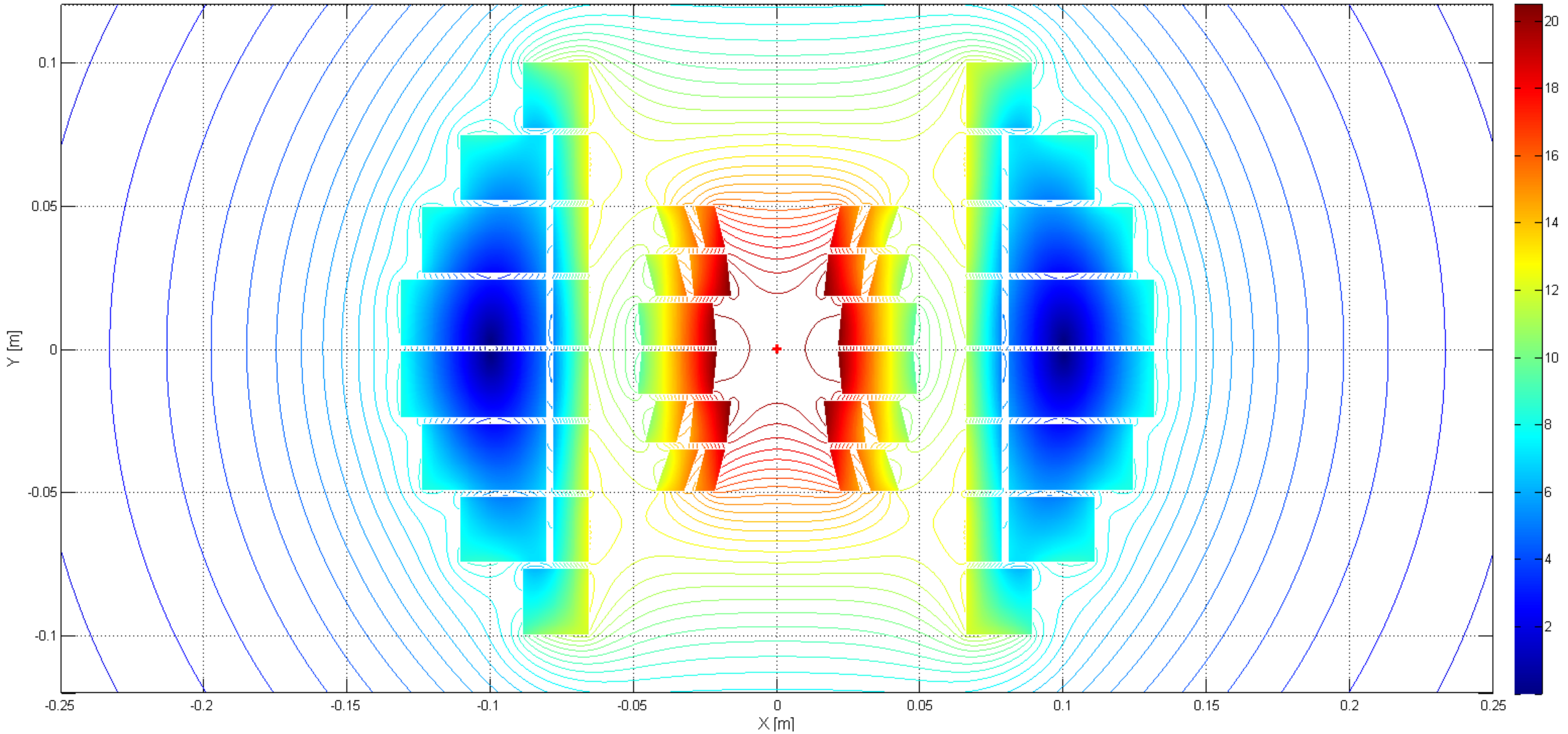
Idea 1 – angular optimization

- For example - Normal Block Coil



Idea 1 – angular optimization

- Insert: Crystalized Block Coil // Sharded Block Coil
- How to make the ends? (Need 3D model)



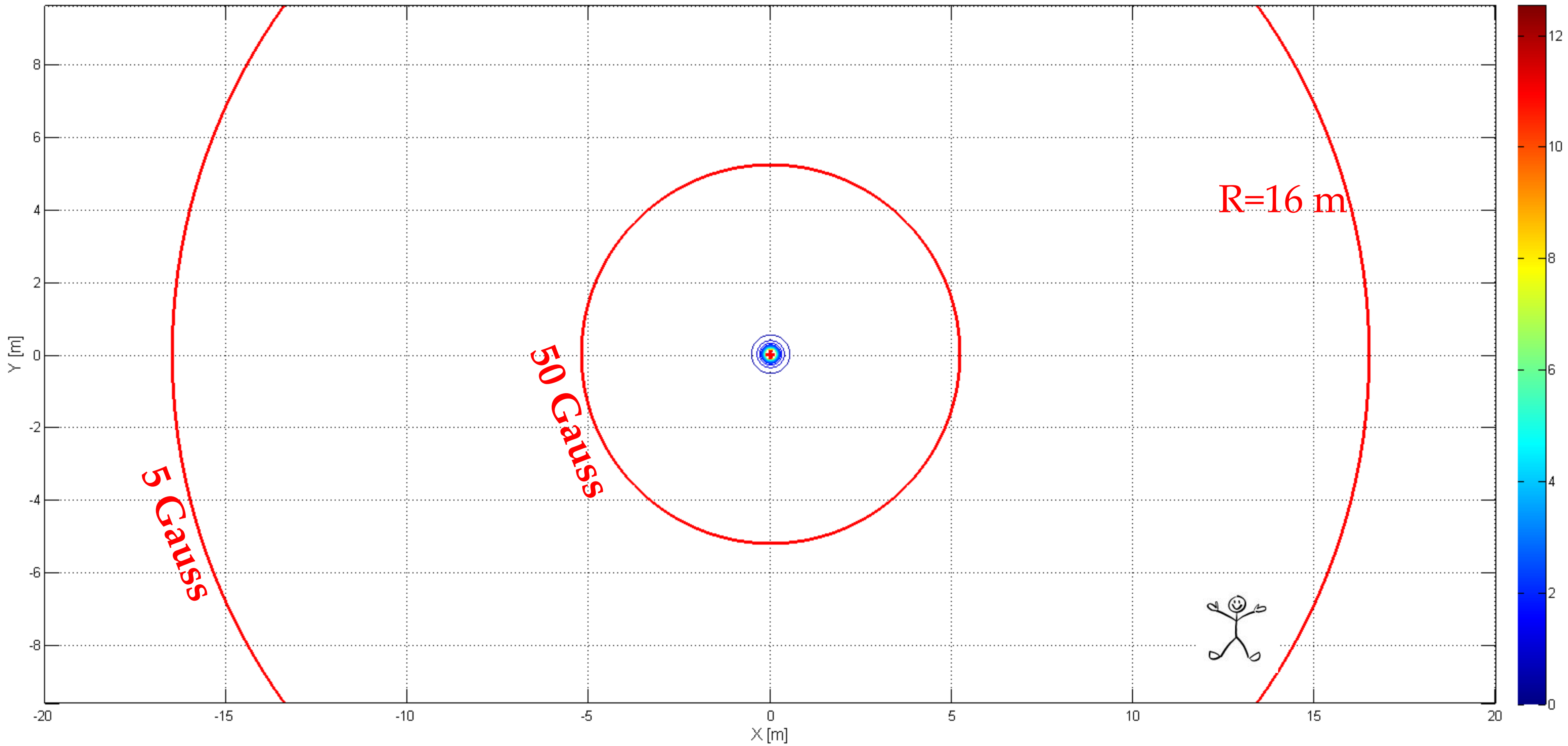
Idea 2 - Active Shielding

- 20 T magnet would require massive iron yoke
- Therefore it was decided to look also at active shield coils
  - Less weight
  - More compact

- However
  - Instead of gaining field you lose field
  - There is something called Blooming Field Effect

Idea 2 - Active Shielding

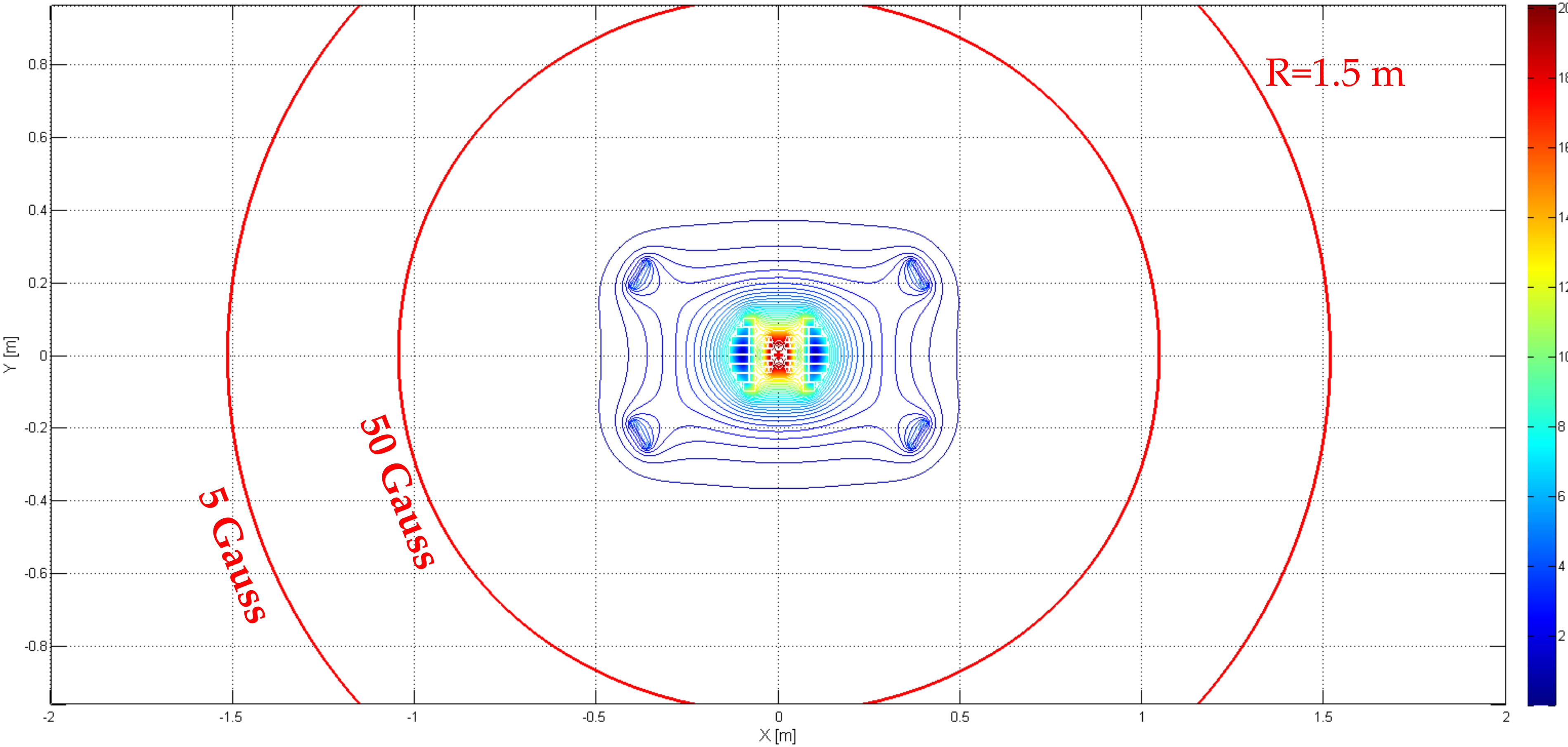
- Single aperture – no shield



Note that for the dual aperture case, the result is different (this is an exercise)

Idea 2 - Active Shielding

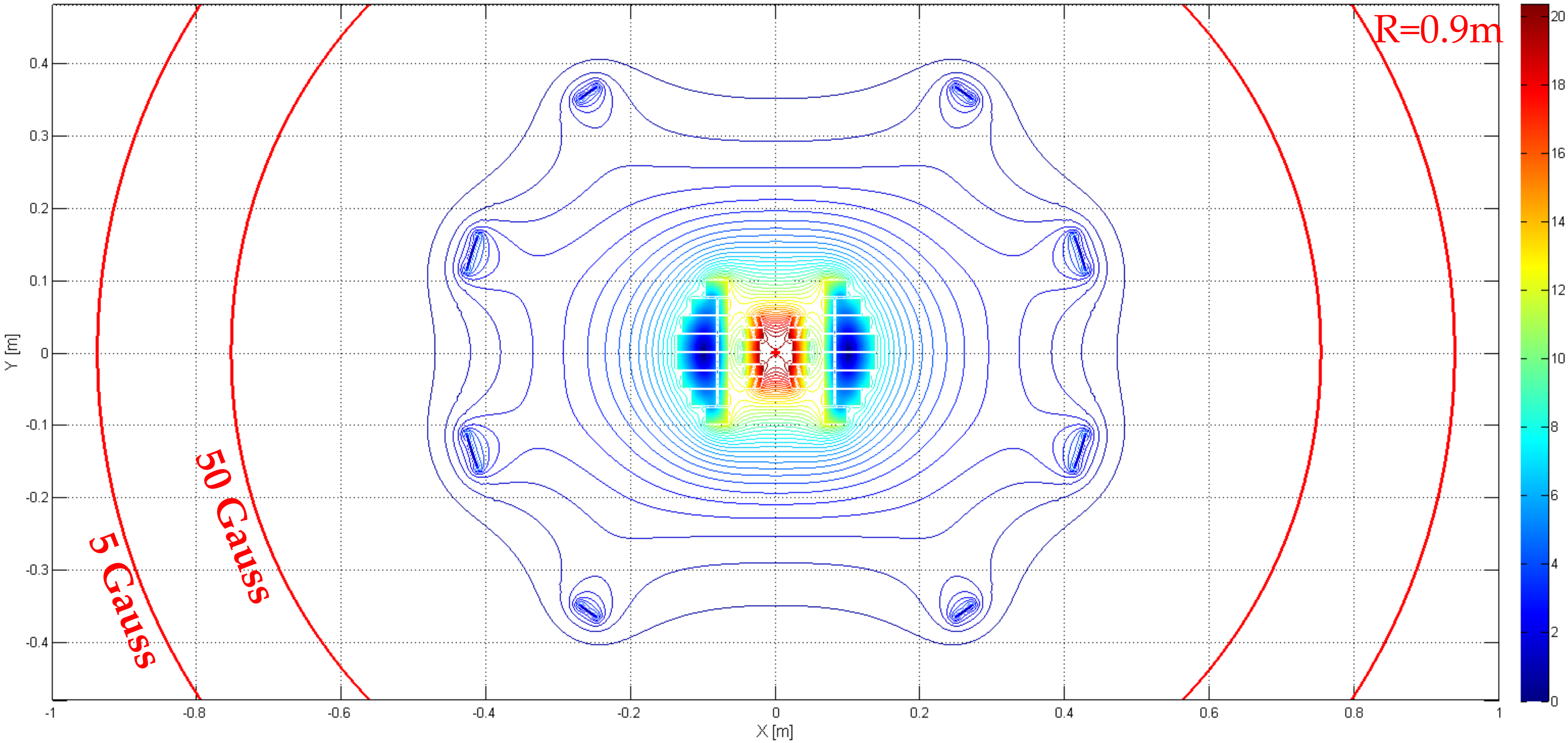
- Single aperture – 1 shield block



- Requires approximately 10-15% extra conductor

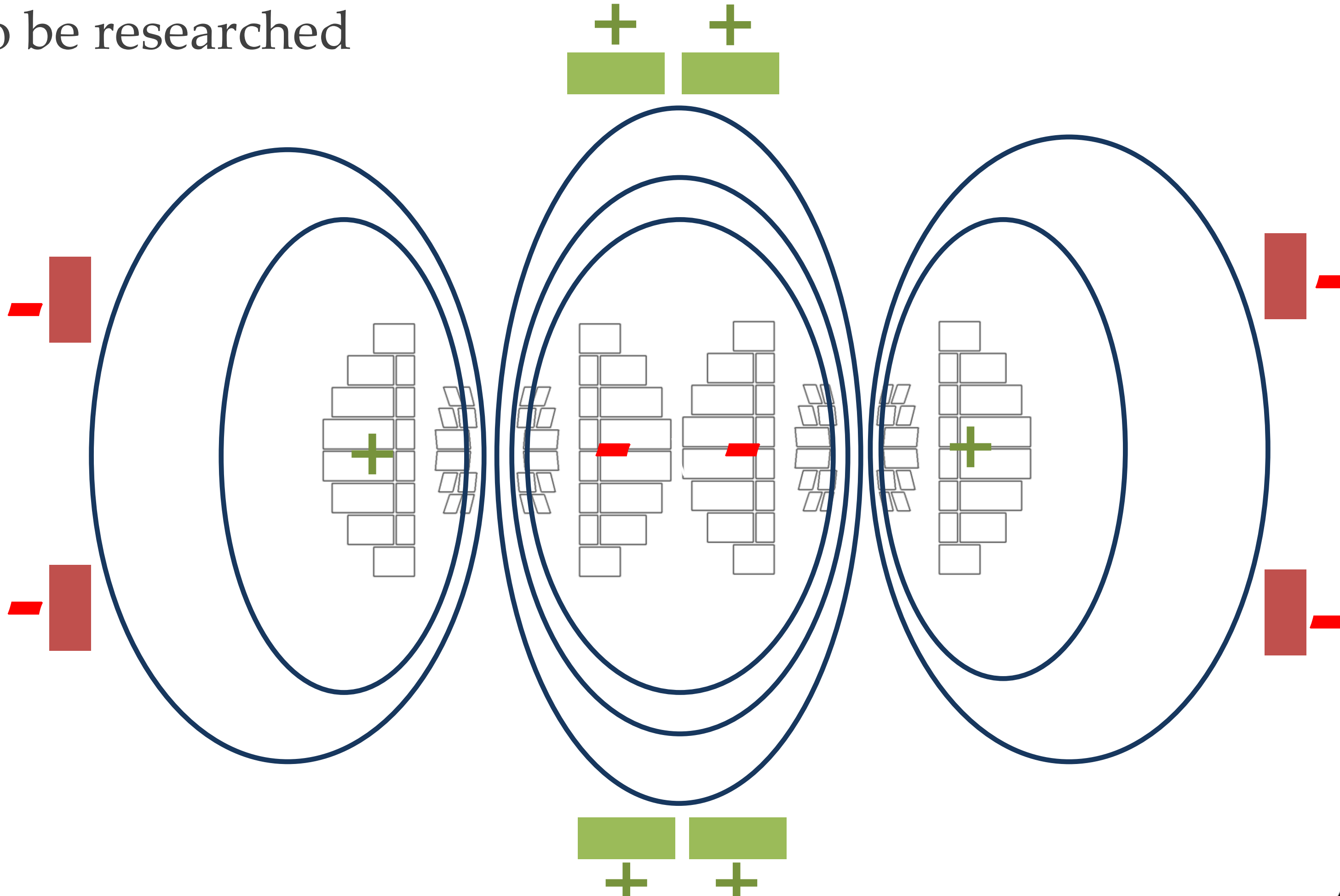
Idea 2 - Active Shielding

- Single aperture – 2 shield blocks



Idea 2 – Dual aperture active shield?

- Dual aperture gives quadrupole stray field
- Artistic impression of possible shield layout
- Yet to be researched



Yet to be done

- Two-in-One aperture (and its shielding)
- Iron including saturation
- Coil ends in 3D models
- Designs with BSCCO
- Mechanics
- Quench Behaviour

Thank you for your kind attention

PSCO – Simply Nesting Layers

- Types of layers
  - Sector (cosine theta, helical, …)
  - Block (block coil)
- Nesting conditions (in/out)
  - wallin
  - wallout
  - radiusin
  - radiusout
  - radiuscen
  - beampipe
  - beampipe_sqe
  - beampipe_sqo
  - moving