Investigation of multipole components in MCBRD

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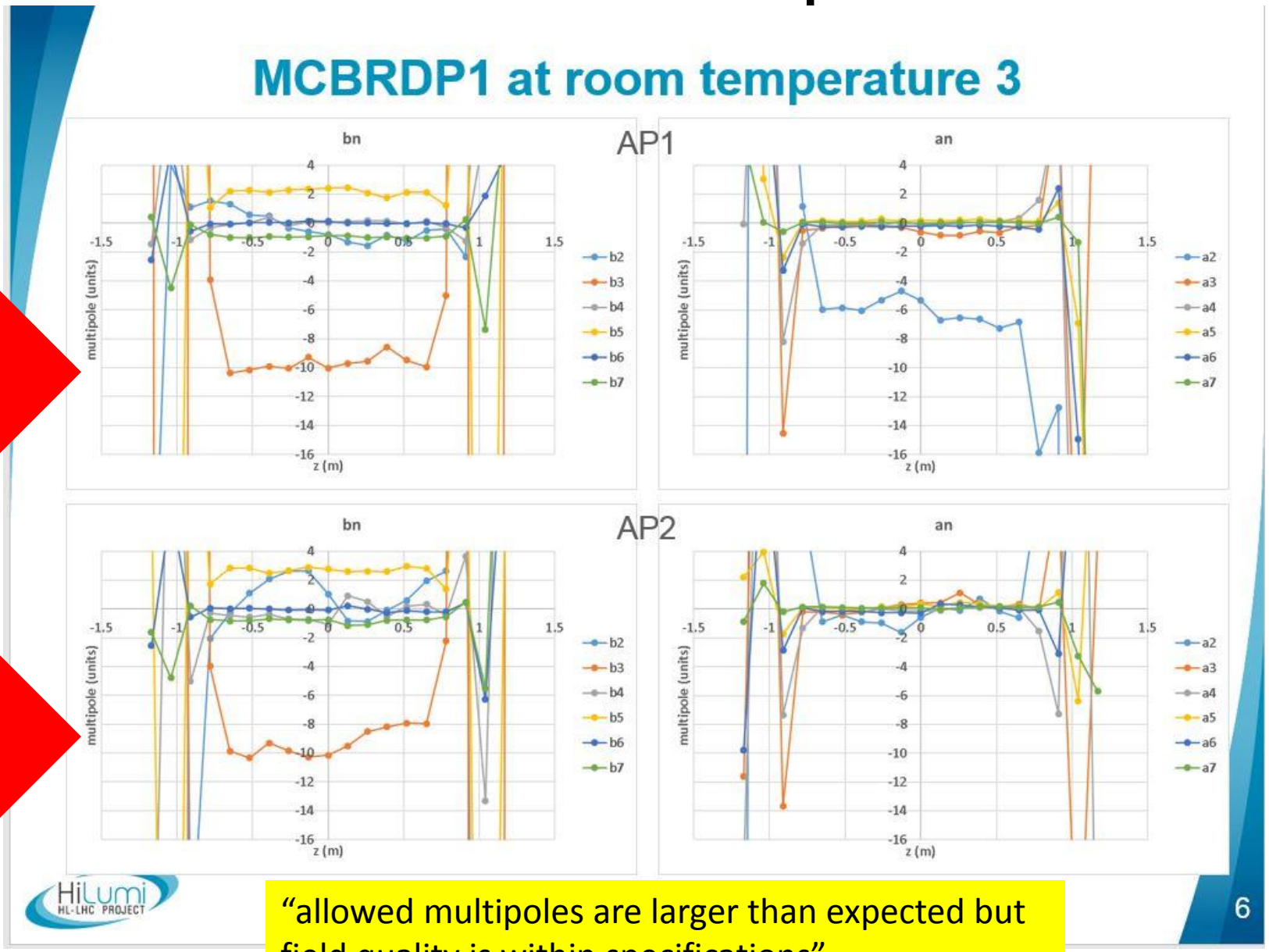
18/9/2018

The issue

- When measuring the field quality at warm of MCBRD, a large component of B3 was seen
- The measurement was confirmed by two methods, so I will assume it is real
- Although this component is still within specification, it would be nice to understand why it is there

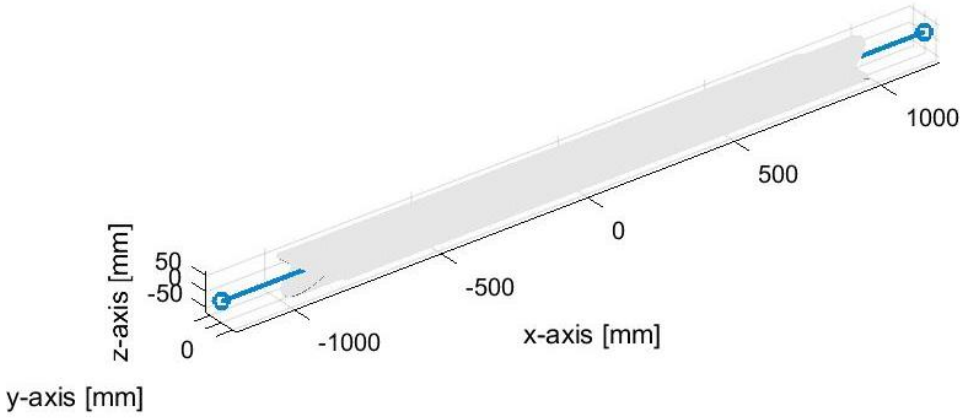
Effect seen at both apertures



"allowed multipoles are larger than expected but field quality is within specifications"

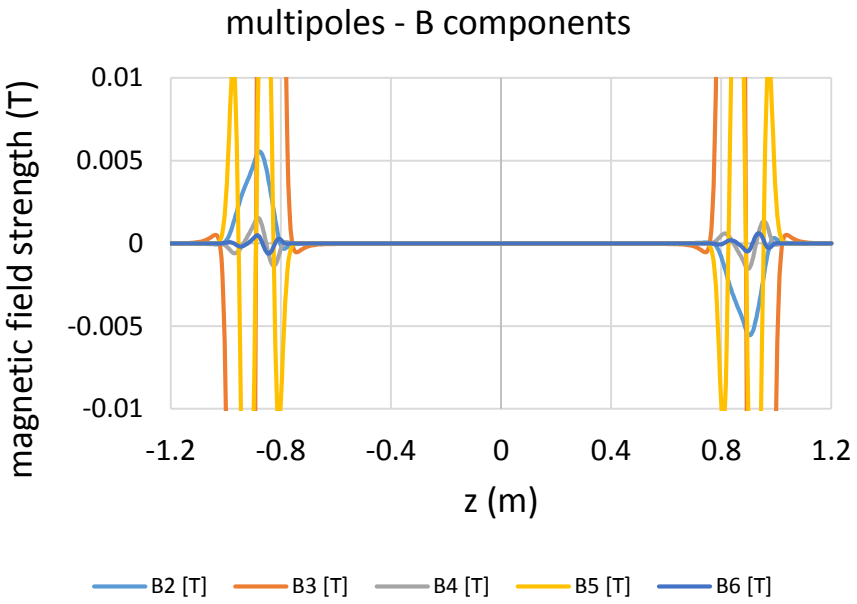
…but first, look at the ideal case

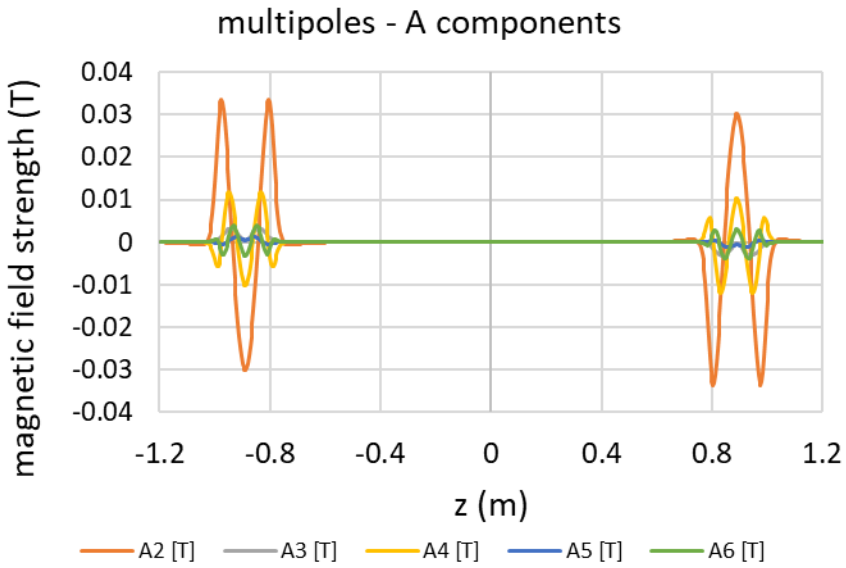
- CCT design: it has the virtue of excellent field quality
- How does the field look like?



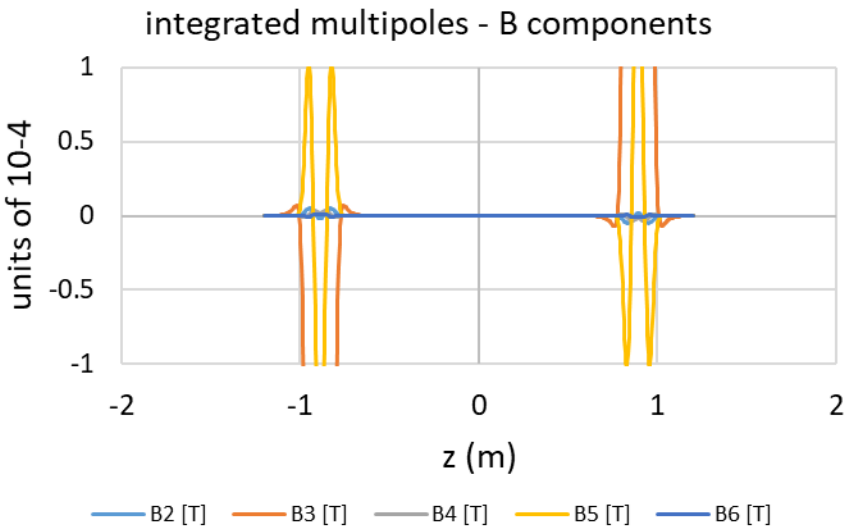
Field quality with ideal positioning of both coils

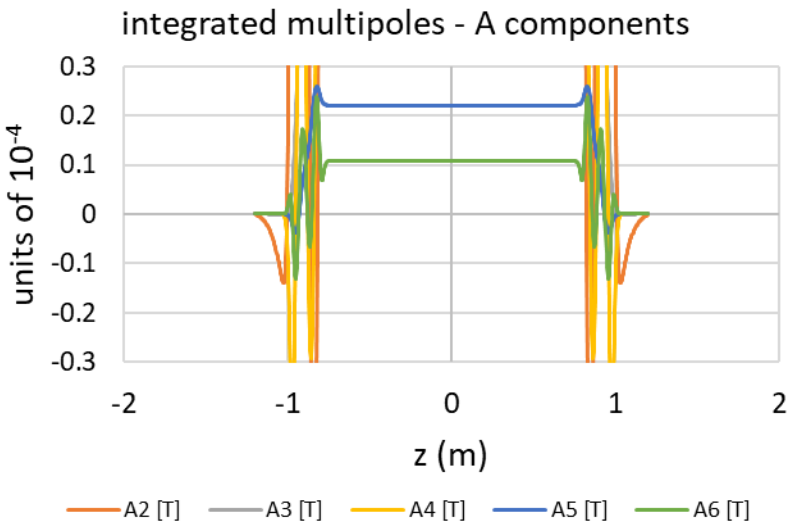
- Small effects at the edges that cancel out when integrating





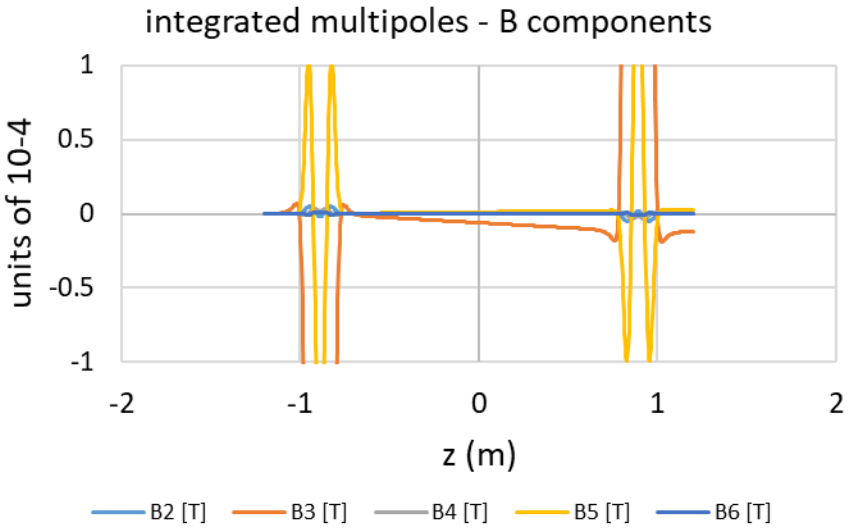
And if we integrate…

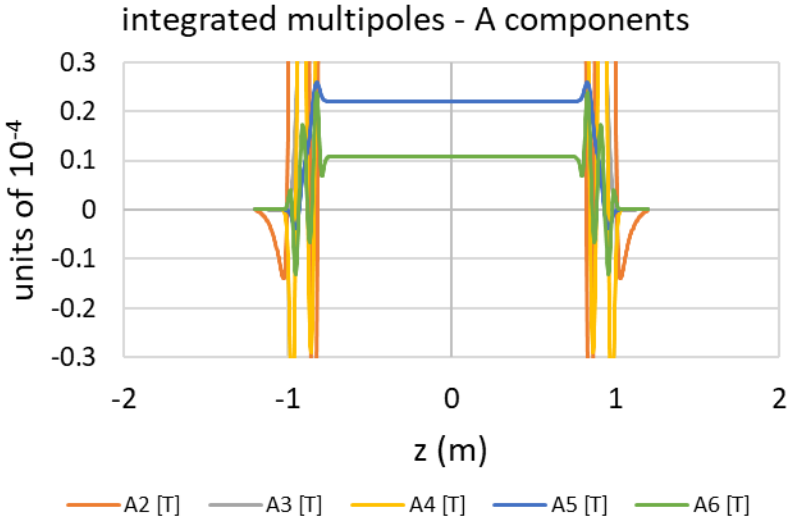




- This is for infinitely thin wires

Now, the into account the fact that the cable is 2mm wide



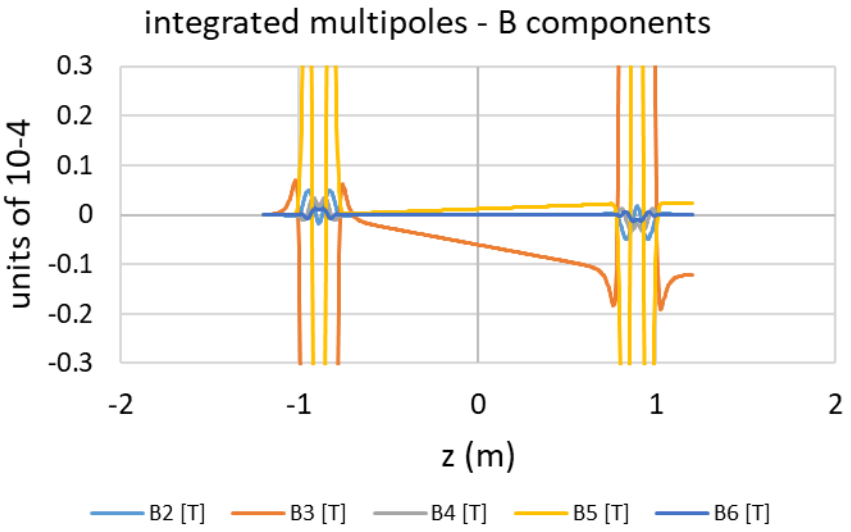


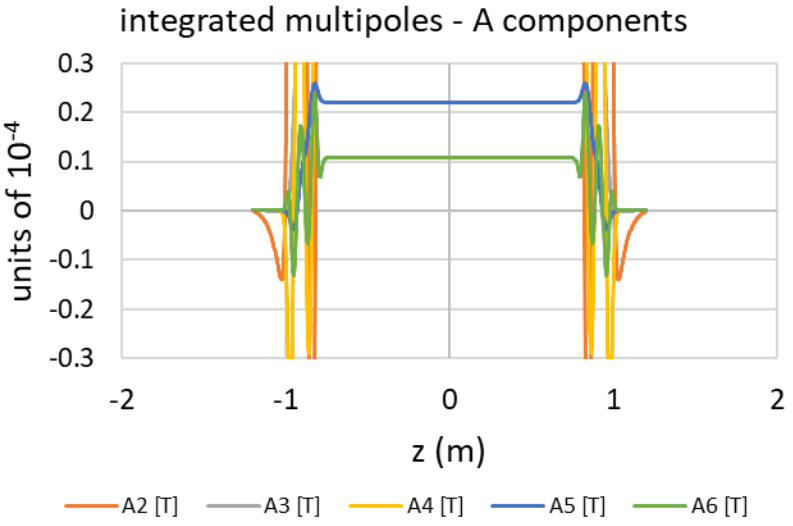
- This introduces a minute B3 component

Now, calculate the effect of misalignment

- Translation in x, y, z of the inner wrt the outer coil
- Rotation wrt all angles
- Simplifications: No iron, no cross talk, standalone magnet in air

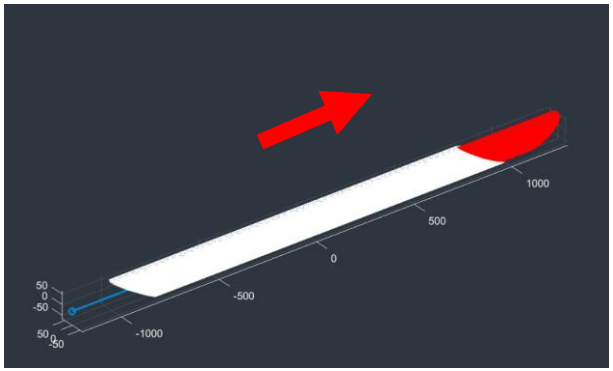
Reference

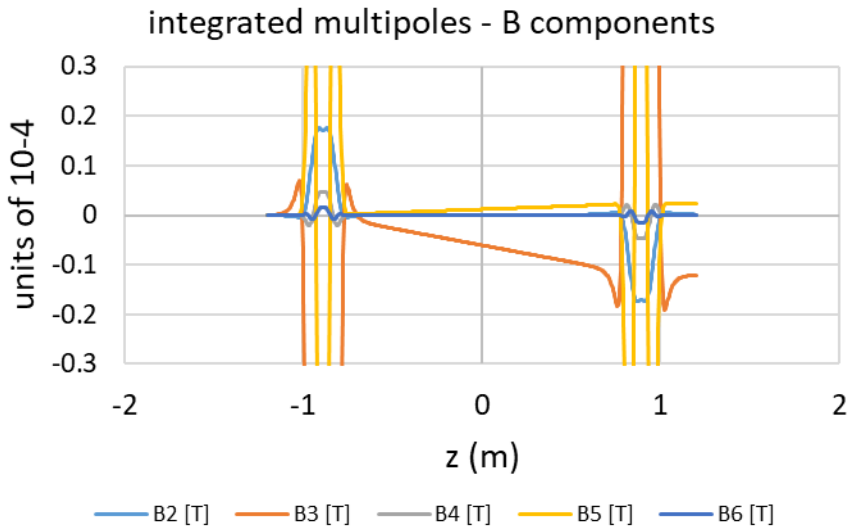

integrated multipoles - B components
units of 10-4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-2
-1
0
1
2
z (m)
B2 [T]
B3 [T]
B4 [T]
B5 [T]
B6 [T]

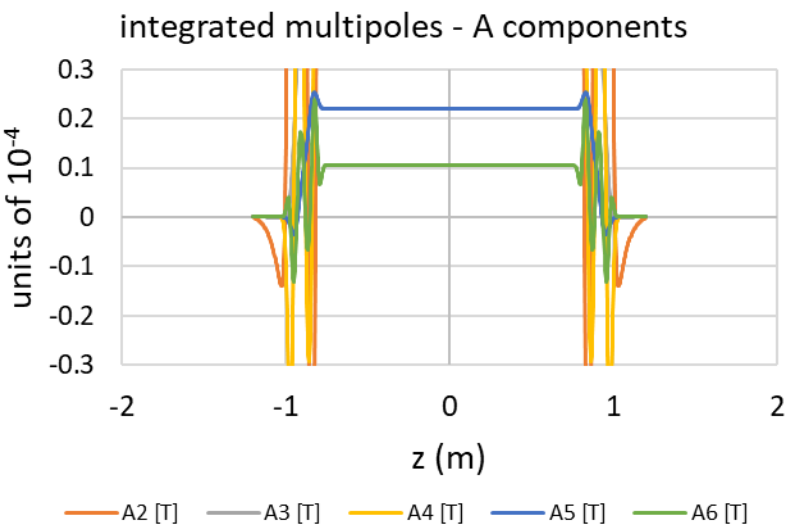

integrated multipoles - A components
units of 10-4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-2
-1
0
1
2
z (m)
A2 [T]
A3 [T]
A4 [T]
A5 [T]
A6 [T]

Misalignment along the beam

- By 3mm – no effect

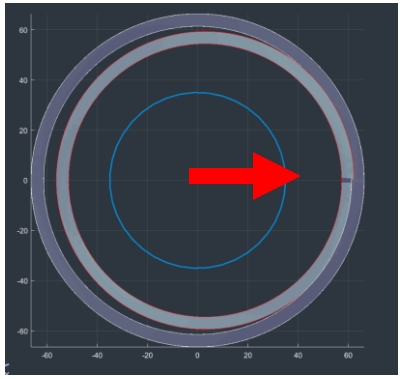


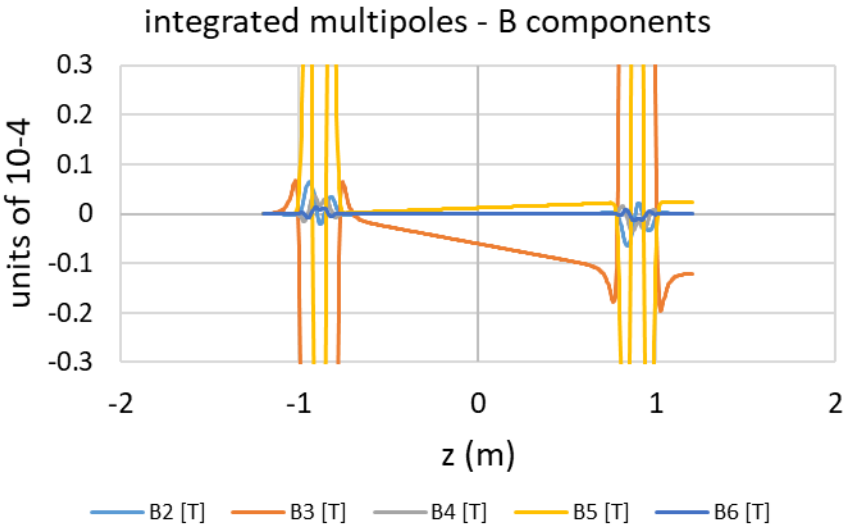


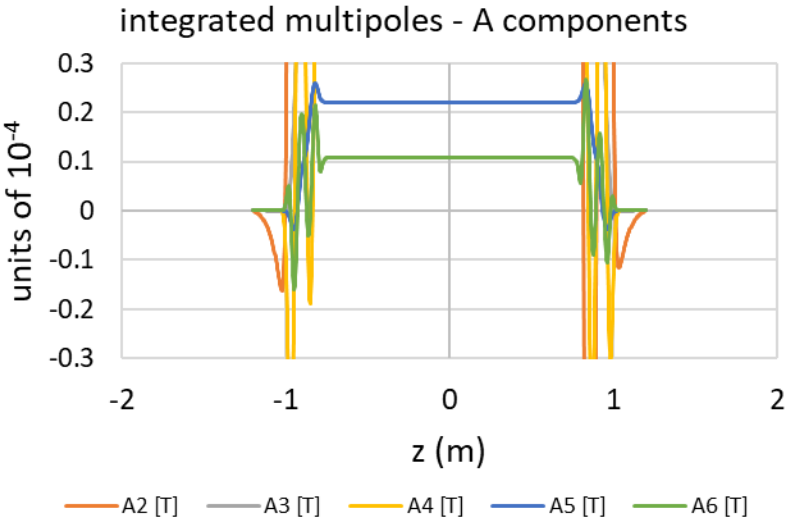


Misalignment horizontally

- By 200um – no effect

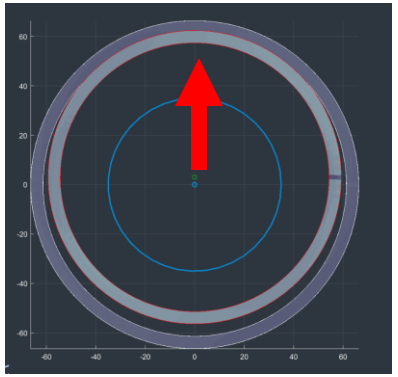


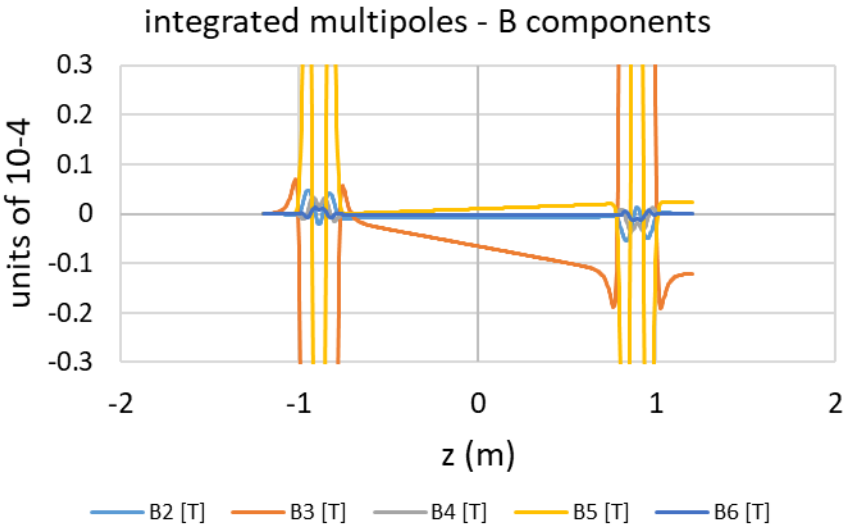


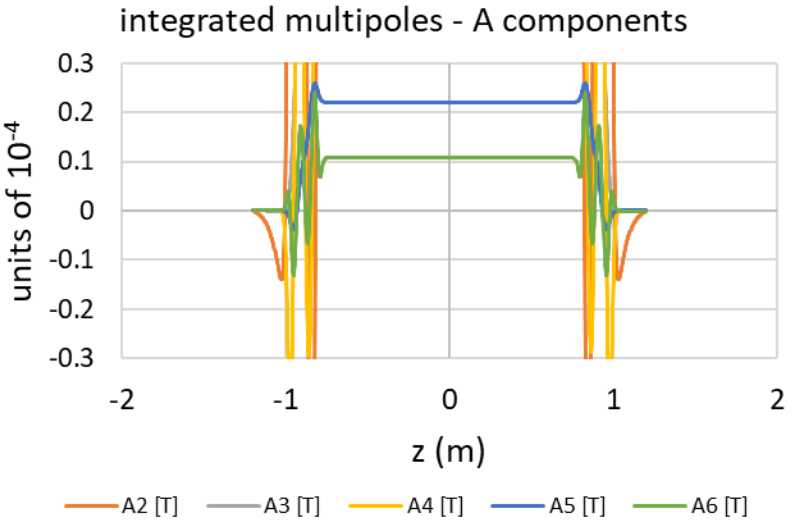


Misalignment vertically

- By 200um – no effect

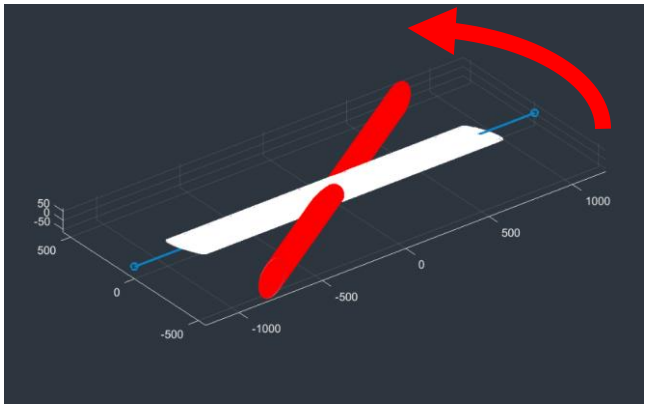


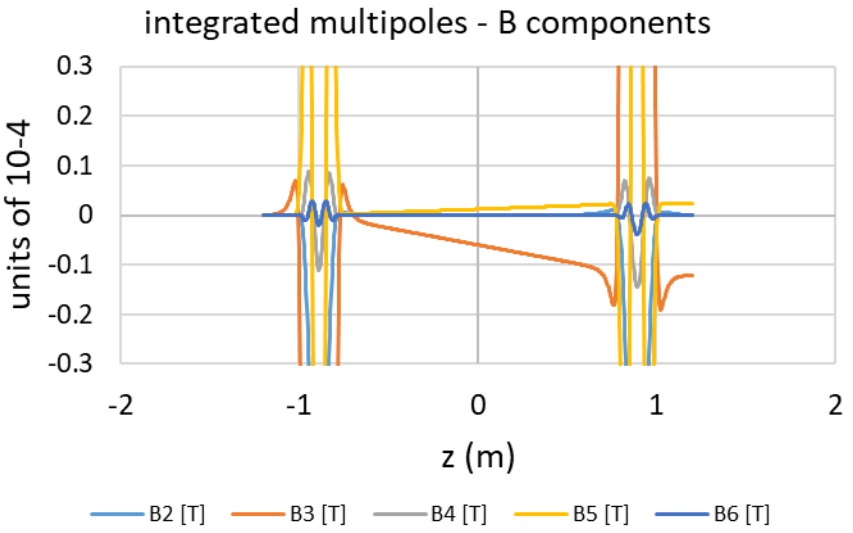


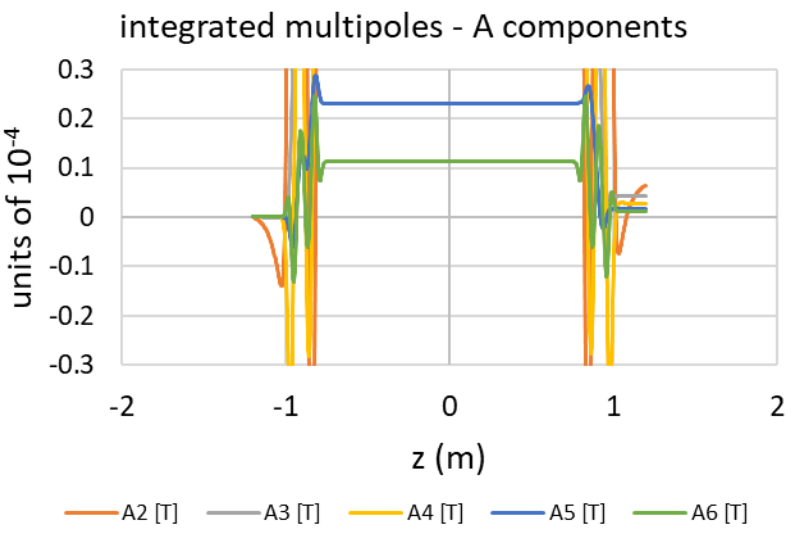


Twist horizontally

- By 1mrad – no effect

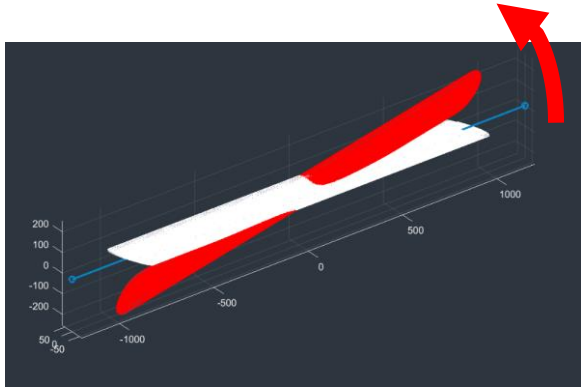


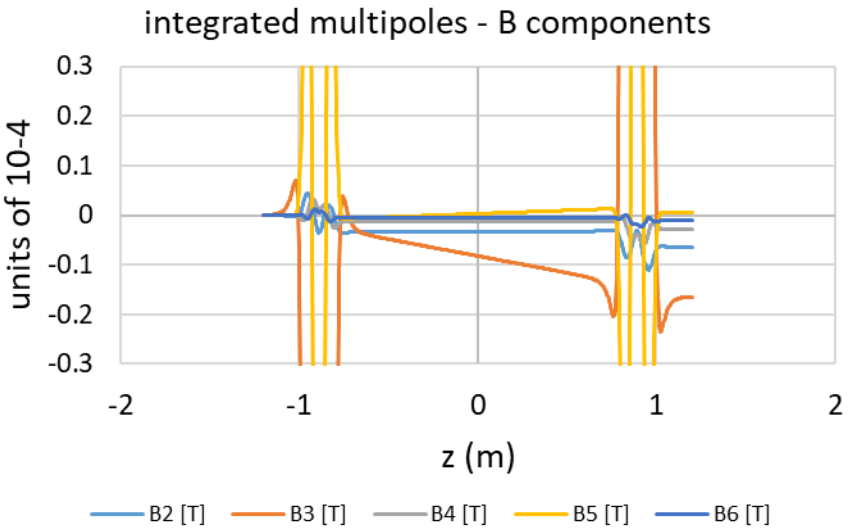


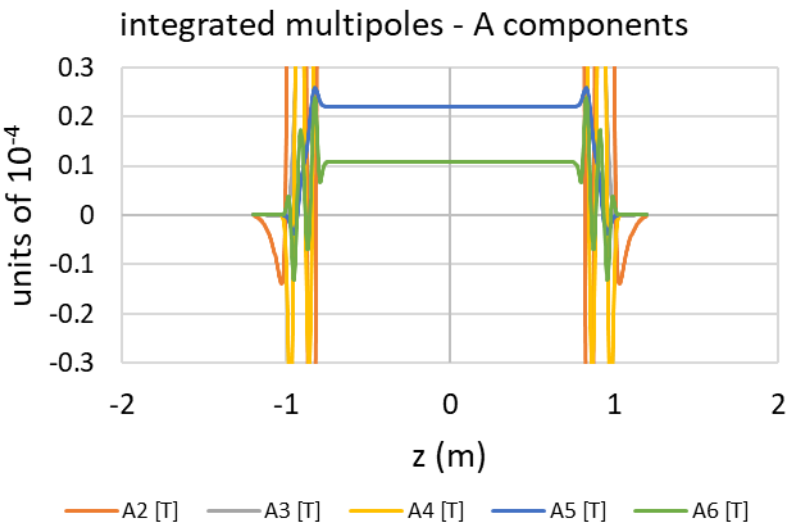


Twist vertically

- By 1mrad – no effect

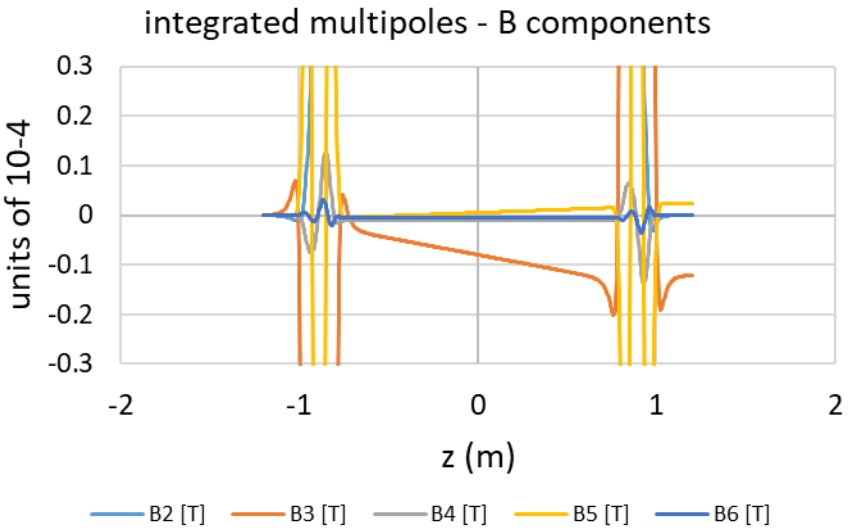


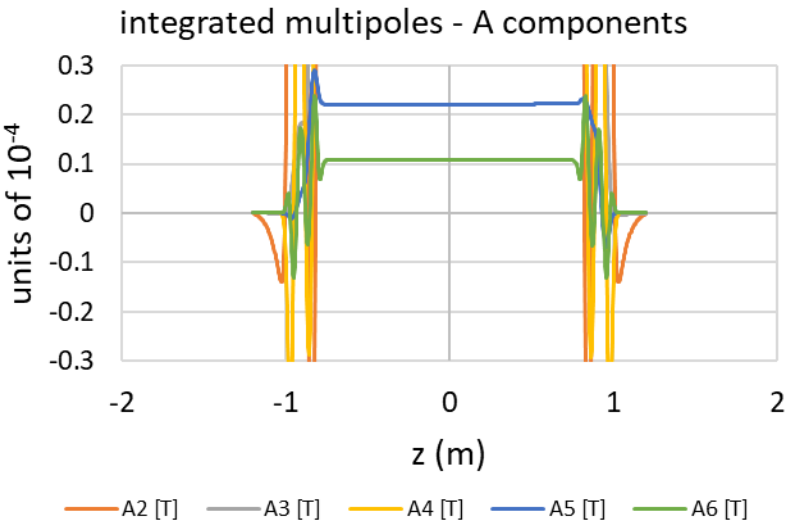




Rotate along beam

- By 10mrad – no effect





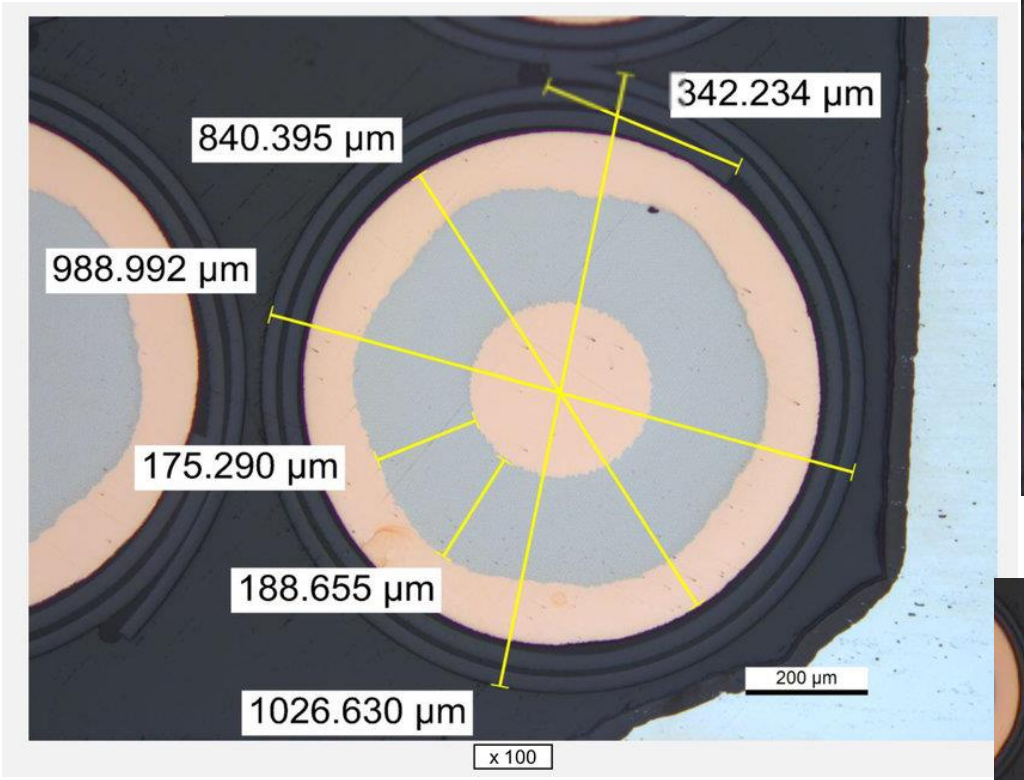
recap

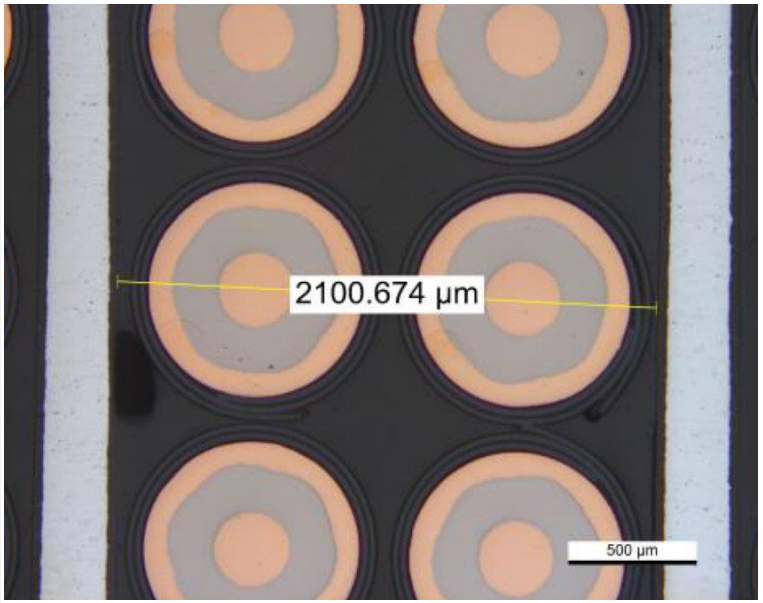
- The CCT design is very forgiving when it comes to mechanical tolerances (when we talk about the integral of the multipoles)
- So where does the 10 unit B3 component come from?

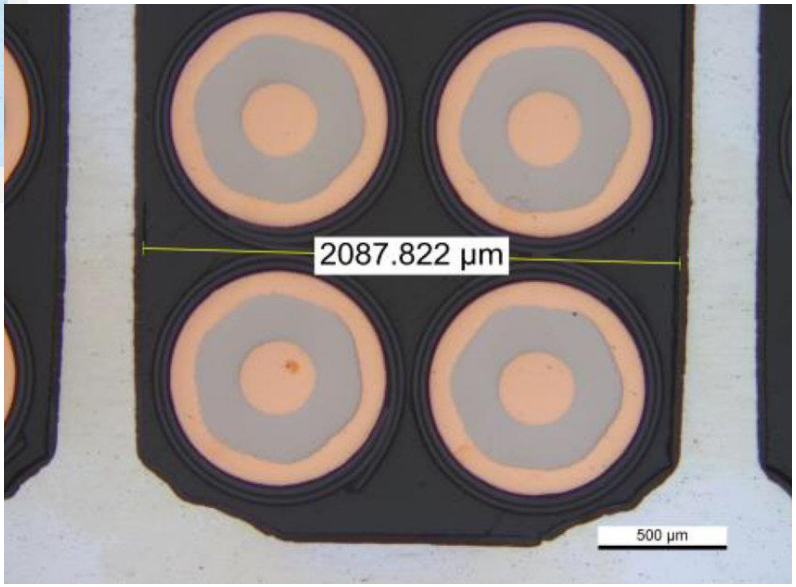
Possible culprits:

- Some error creeping in from the electrical design till the manufacturing process
  - I was unable to test this
- I will offer one more possible explanation…

Groove size vs cable size

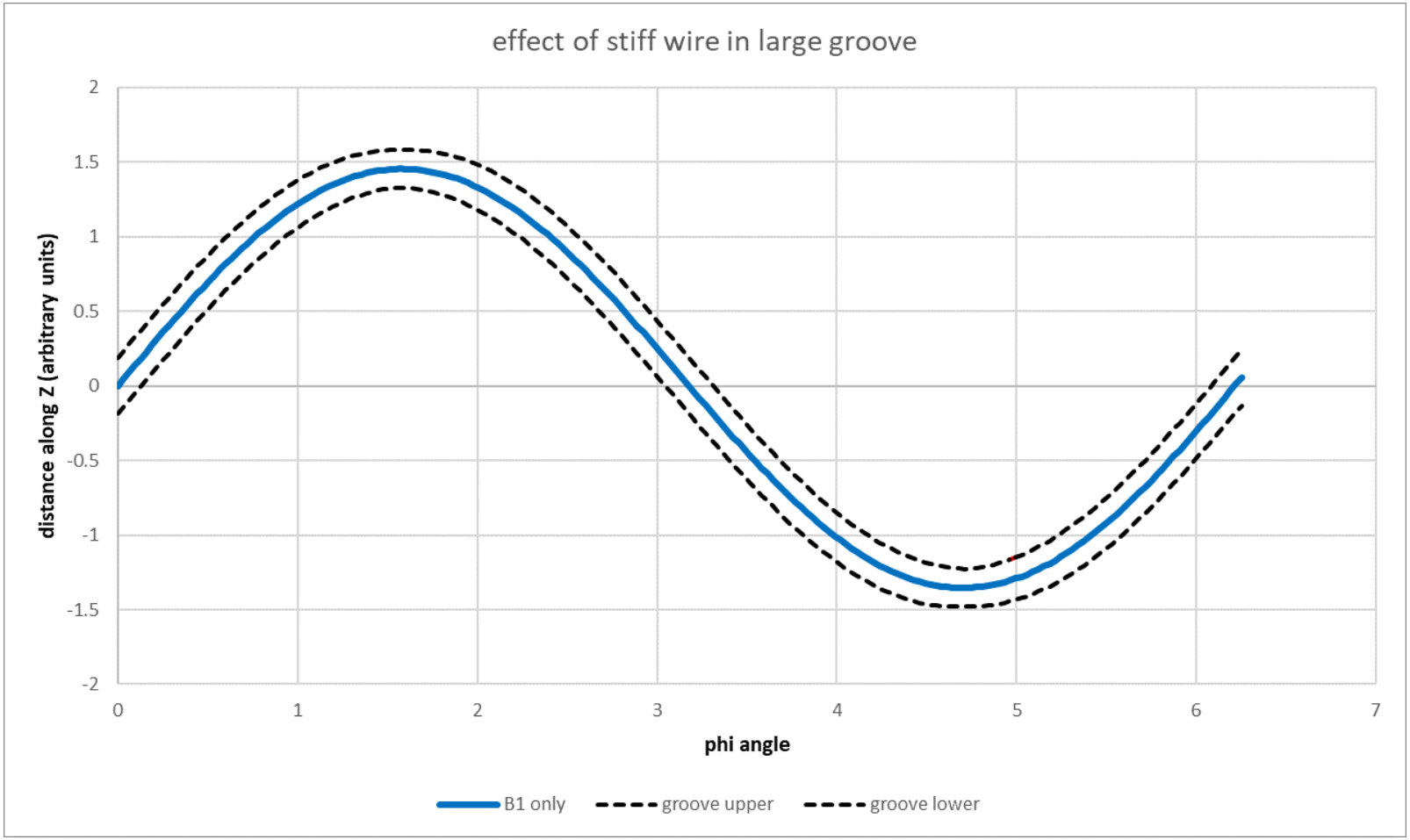




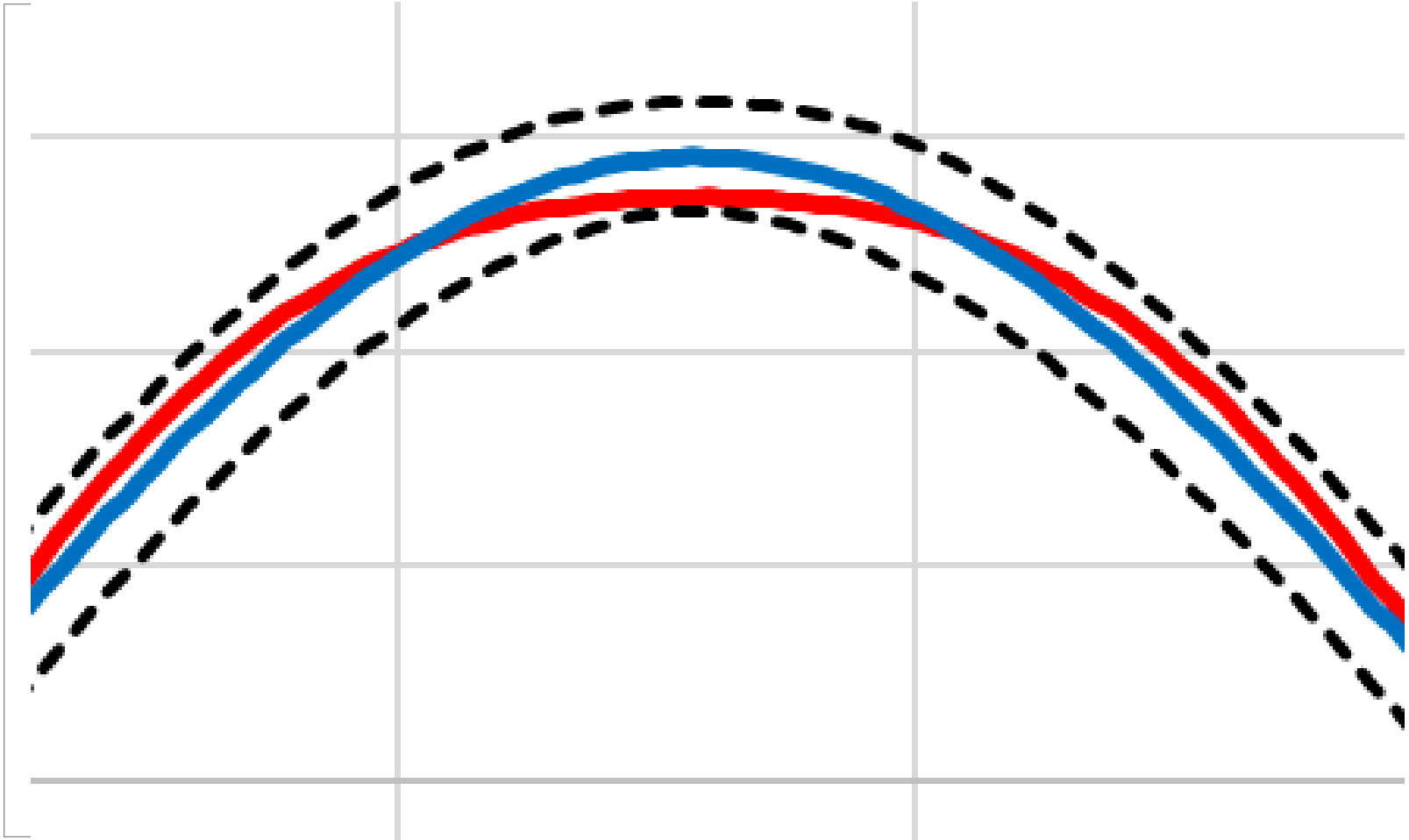


2100 µm vs 2 × 990 µm: there is an empty space of ±60 µm

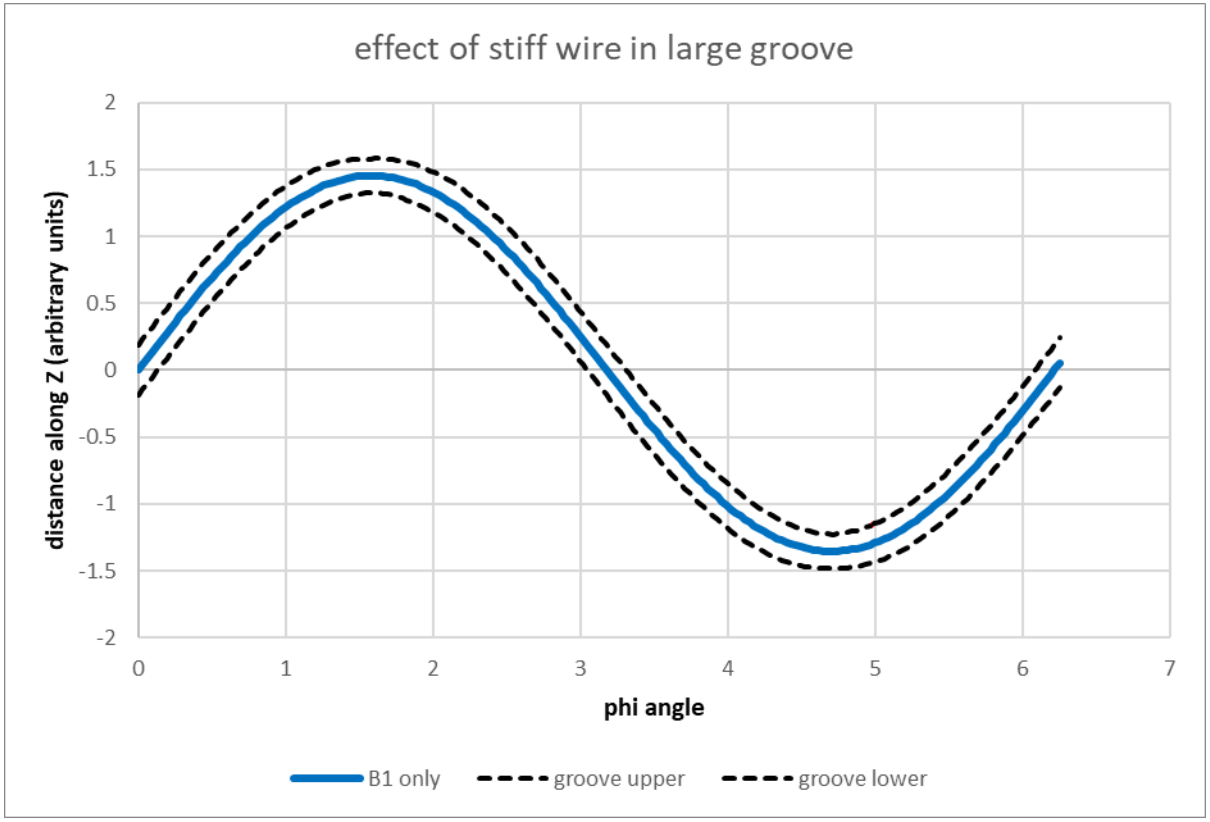
Slot around ideal position – B1 (dipole) case



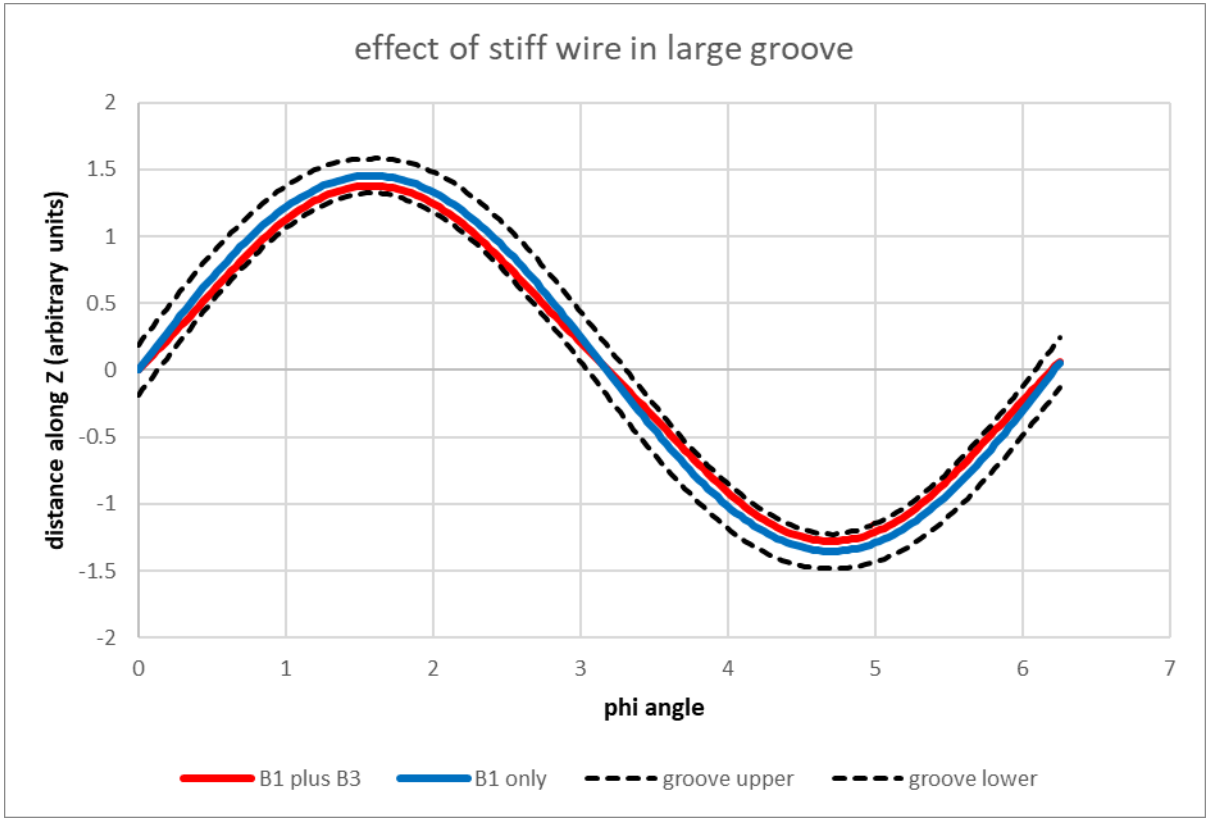
Positioning of a stiff wire in a larger groove



…or is it like this



…or is it like this

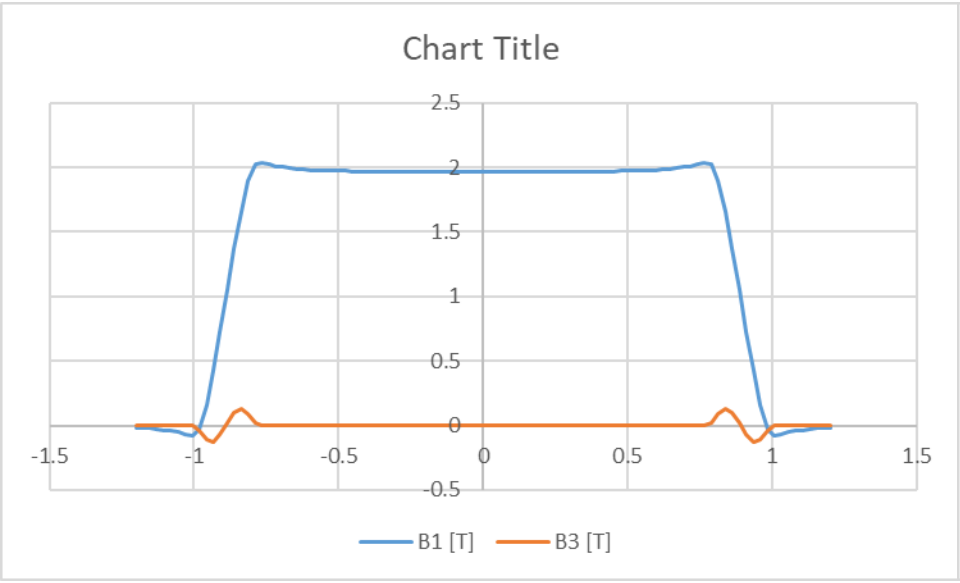


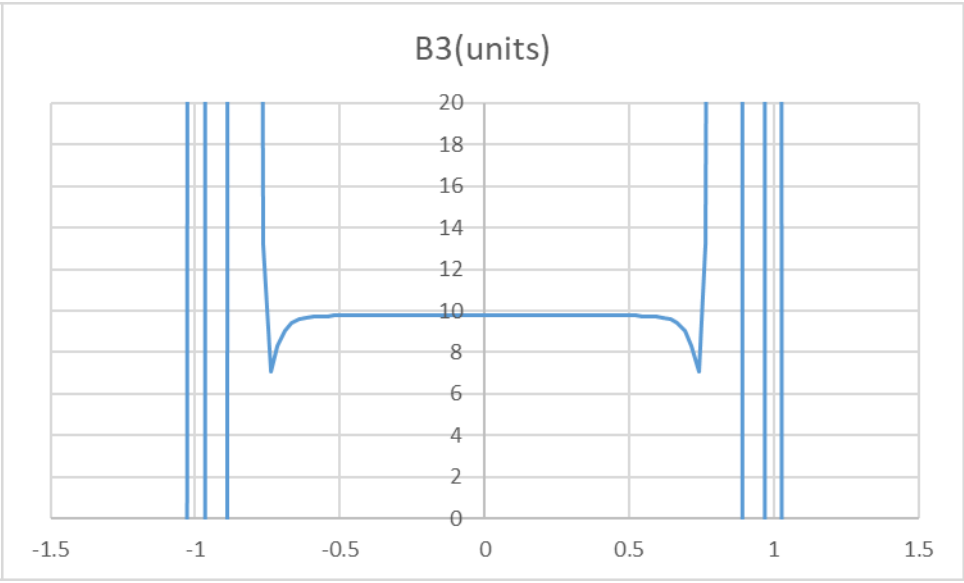
What does this have to do with B3?

- Actually, I have cheated. I do not (yet) have the a model for the position of a stiff wire inside a groove. What you saw in the previous slides is the addition of a B3 component to the existing B1 component
- In the first plot, a B3 component of the same sign as the B1 component was added
- In the second plot, a B3 and B5 component of the opposite sign were added
- In both cases, the result is that around the bend the wire sits in the lowest allowed region of the groove
- Question is: how many microns of wiggle do we need to get 10 units of B3?
- Use Jeroen's field program

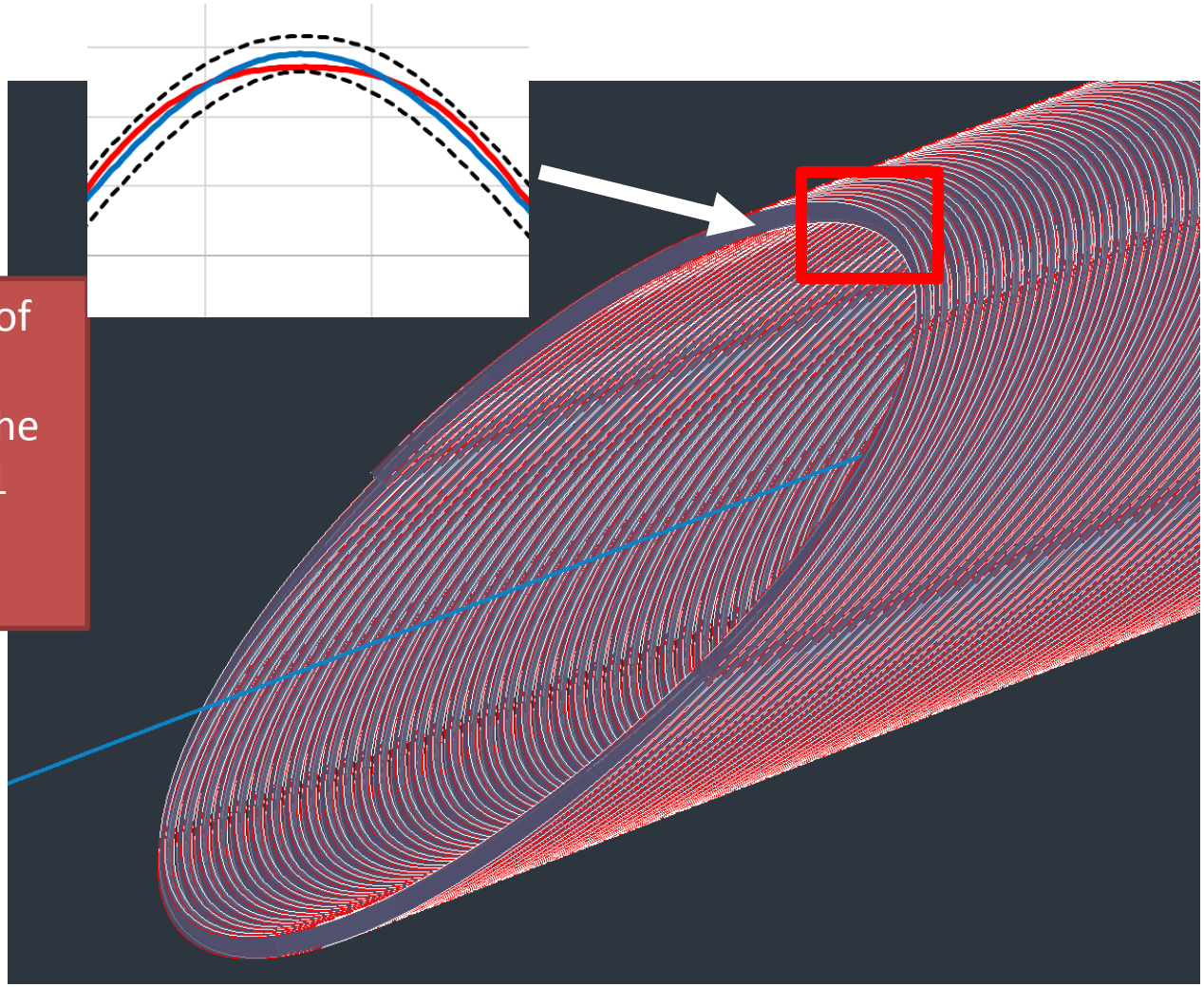
Model used

- Inner radius of inner cable: 54.35; cable size 2X5mm; outer cable inner radius: 61.35
- Strength of B1: maximum (60 degrees)
- Strength of B3: 1/200th of maximum (0.3 degrees)

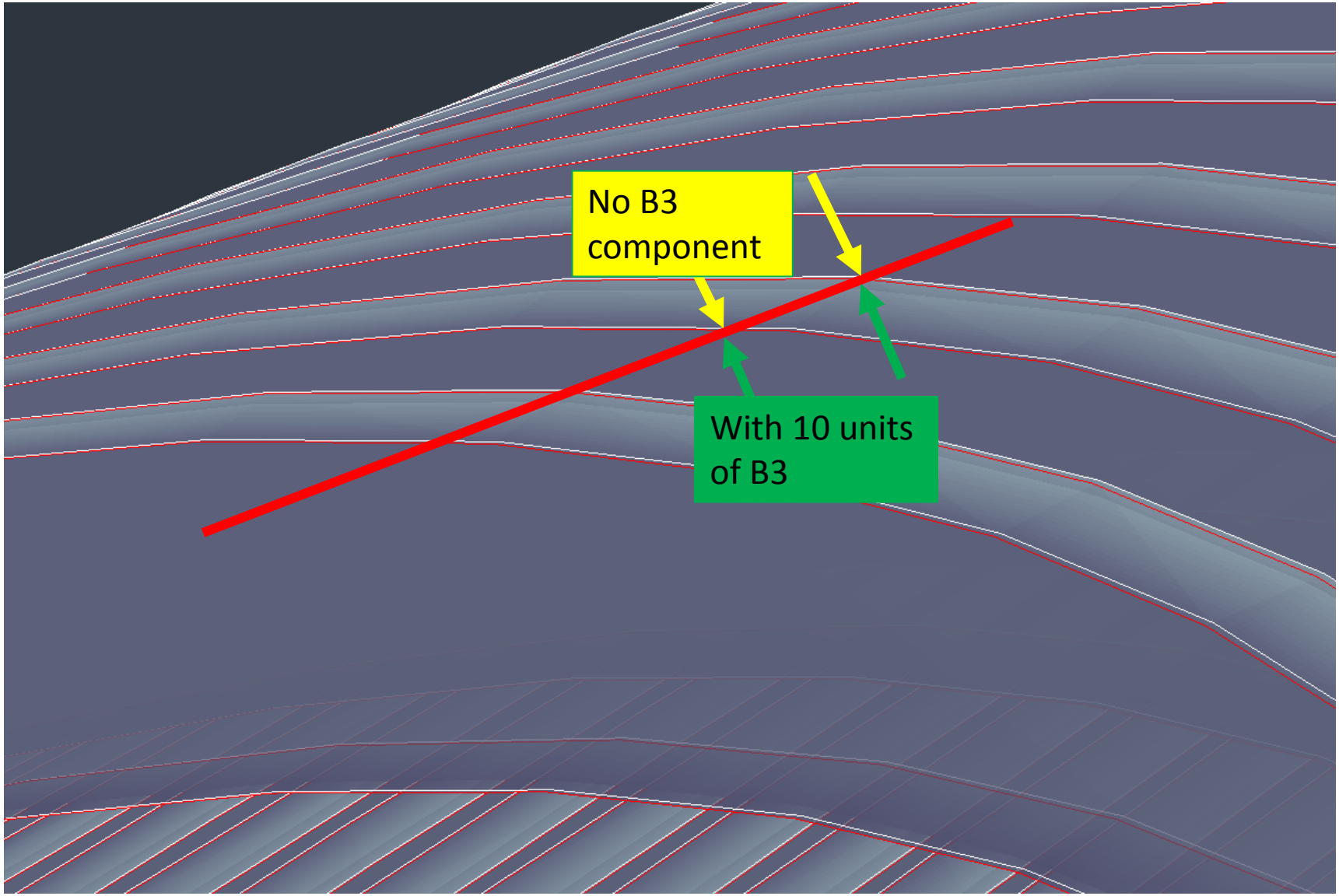


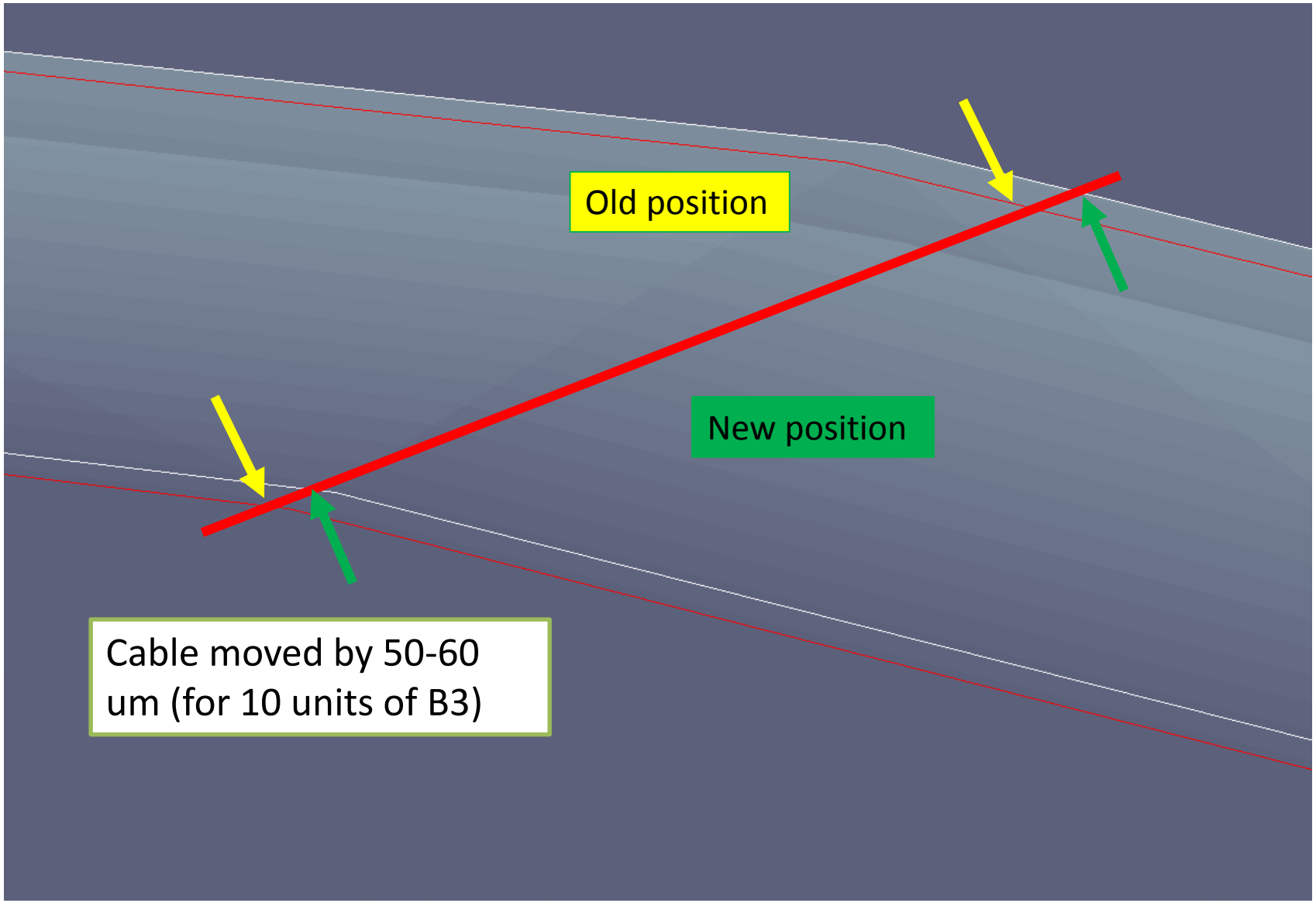


Effect on position of cable



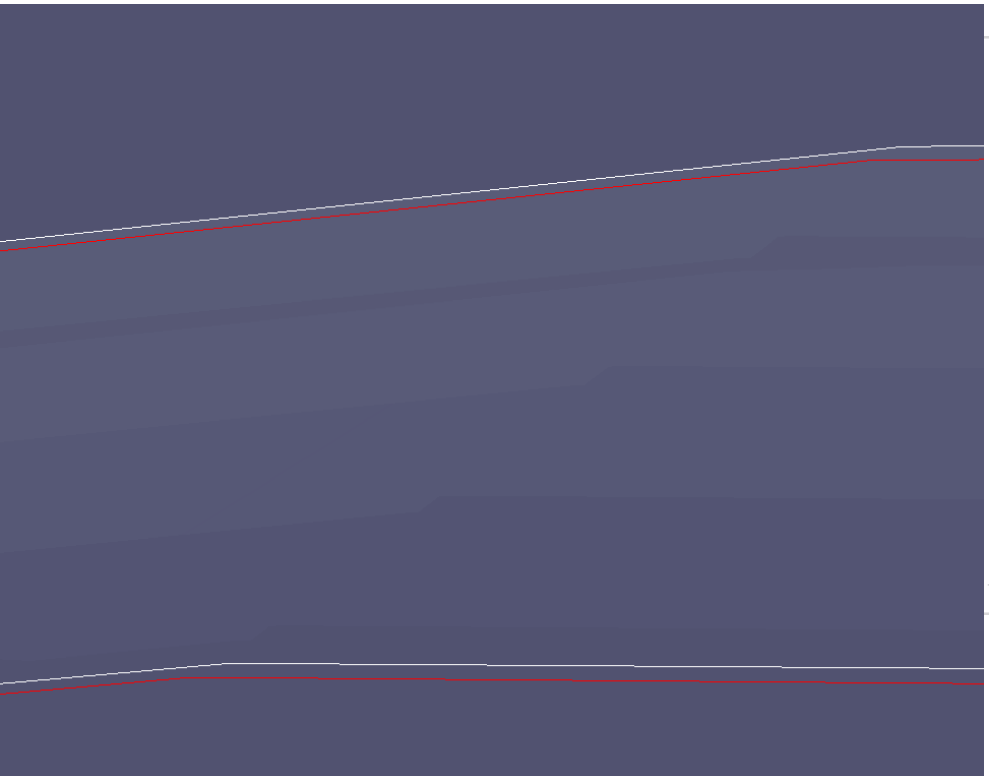
Superposition of two coils: one with only B1, the second with B1 and B3 compomennts


No B3 component
With 10 units of B3

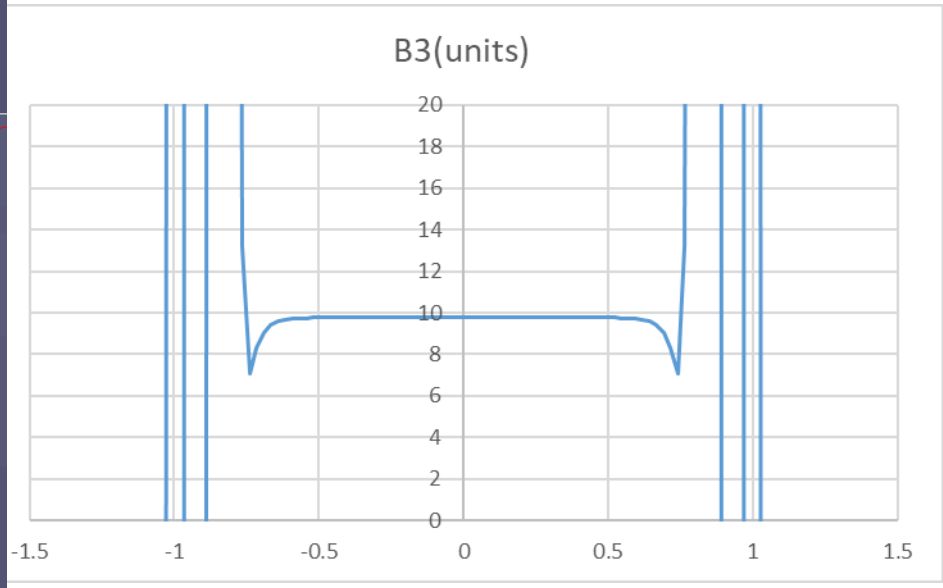

Old position
New position
Cable moved by 50-60 um (for 10 units of B3)

Max. displacement of cable and B3 component

50 um movement

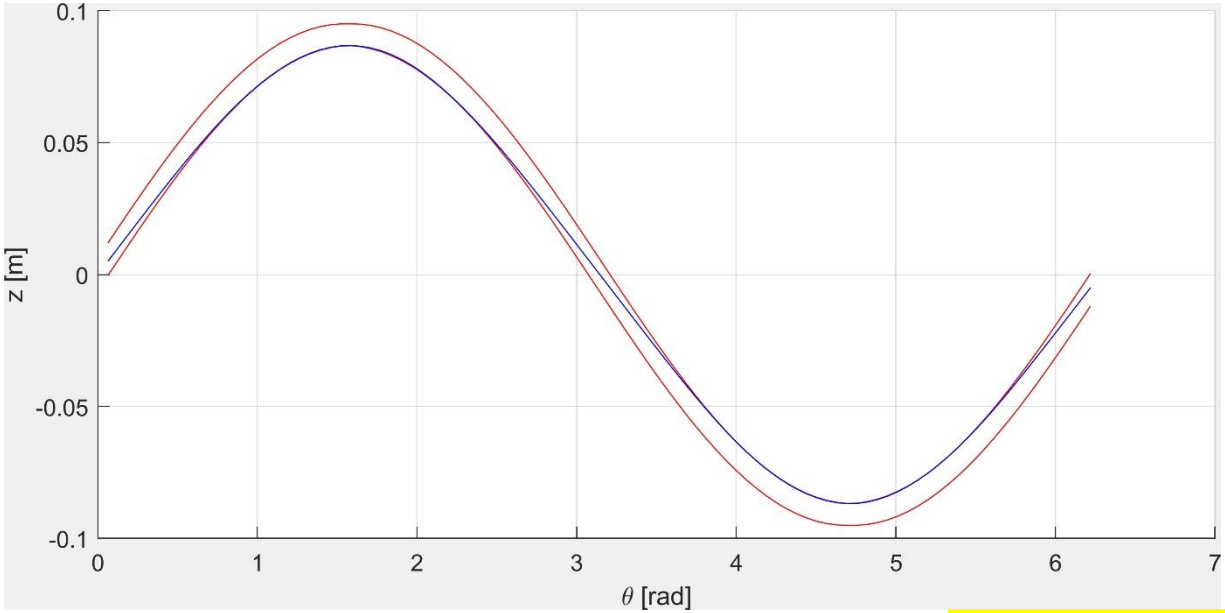


10 units of B3



Model of a stiff wire in a groove

- Work just started… modeling of the wire inside the groove, minimizing the potential energy of the wire
- Following is a sneak preview of this work (that even gives the correct strength of B3 (10 units in a groove of 2.1 mm where the wire width is 2X1mm)



Jeroen van Nugteren

Possible mitigation strategies

- Introduce a -10 units of B3 component
- Tighter fitting cable in slot
- Tension during winding ?? – this still has a few question marks until we understand the model well.

What about the 6 units of A2 found in one of the two apertures?

- Best theory is that one of the apertures is not centered wrt to the iron yoke, but I have not tested it

Conclusions

- I found a possible explanation for the large B3 component: it could be the combination of a stiff wire and a larger groove than the cable dimensions
- The numbers match: B3 component magnitude is what is expected by the size of the groove (2100um) and he size of the cables (2X990um)

End