SSS assembly – new parameters

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New parameters for 91km ring

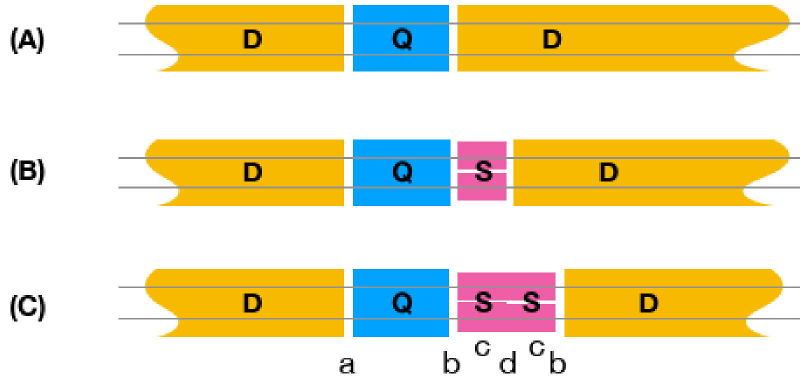
Following a redesign of the optics for the new layout by Katsunobu, there are small changes in the parameters:

- Now length of quad is 2.9m (from 3.2m). Quads should not be shorter, due to SR issues
- Strength of quads is 11.84 T/m at tt (was 10T/m)
- Length of sextupoles is 1.5m. Sextupoles can be made stronger and shorter at will.
- Strength of sextupoles is 812 T/m^2 at tt.

cf: Katsunobu’ s presentation

Changes in the spacings & lengths

FUTURE CIRCULAR COLLIDER



Label	Description	Length (m)	CDR (m)
a	• between quad and dipole, on the opposite side of sext. • usable for dipole correctors	0.3	0.3
b	• between quad and sext, dipole and sext	0.2	0.3
c	• sext thickness	1.5	1.4
d	• between sexts	0.15	0.1

- Need technical advices on the spacing and field profile of each magnet to finalize.
- Also for other sections.

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If I presume that quad length is 2.9m, then SSS lengths are (including distances from dipoles)

- Type C: .3+2.9+.2+1.5+.15+1.5+.2=6.75m
- Type B: .3+2.9+.2+1.5+.2=5.1m
- Type A: .3+2.9+.3=3.5m

If total half-cell length is 26.1, then the difference in bending radius between type A and type C cells is 12%.

The strategy

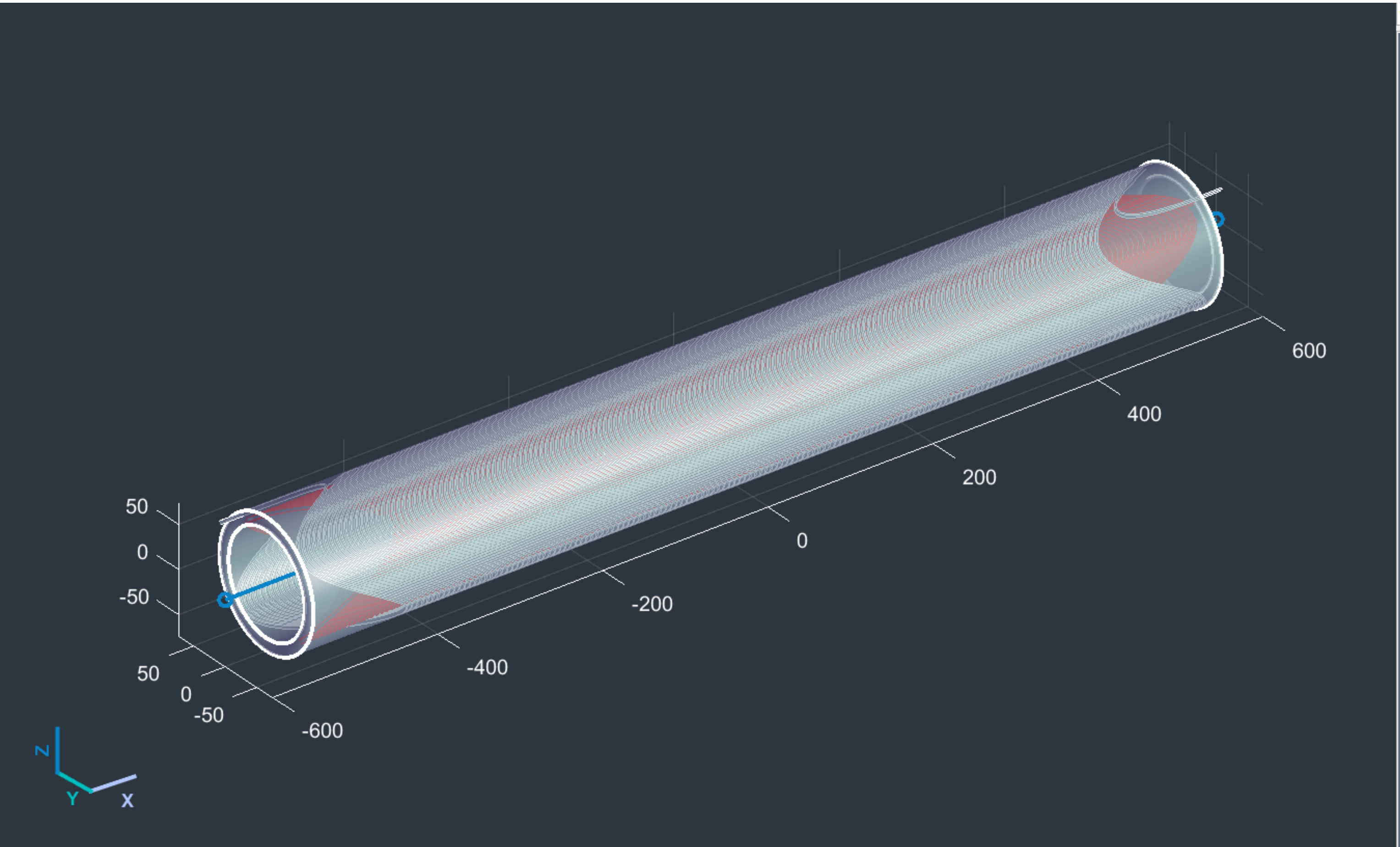
- I have re-visited the question of packaging the SSSs. My original idea was to split the unit internally in two.
- This results in ~1.5m long objects, but there is only one interface between units, leading to a rather efficient design.
- However, ~1.5m long objects are difficult to manufacture and assemble, leading to extra costs
- I decided to move my baseline design to a three-unit design with ~1m-long objects, much cheaper and a bit less performant.
- We can always move at a later stage to a two unit design

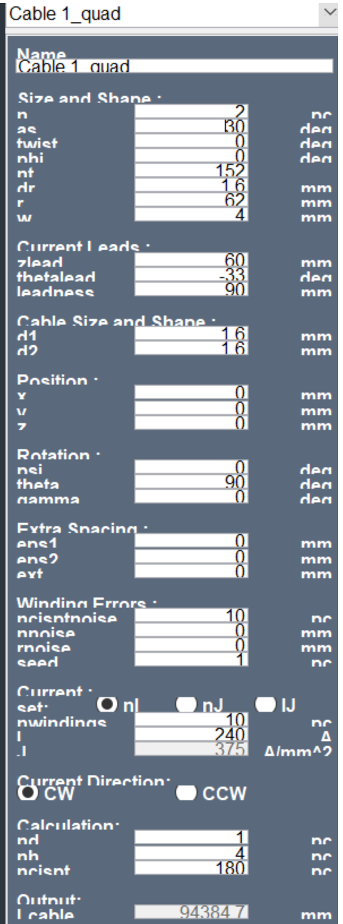
Packaging

- Strategy is to split the components into three units.
- Sextupoles will be made stronger and shorter with a physical size of 900mm.
- Three correctors are needed, 200mm each, which will fit next to the sextupole
- Quads with physical size 1100mm have a magnetic length of 974mm, which is o.k. (longer than the requested 967mm)
- Distance between units: 50mm
- Total length of SSS: 25+1100+50+1100+50+1100+25=3450mm
- Total length of cryostat: 3500mm

Quad

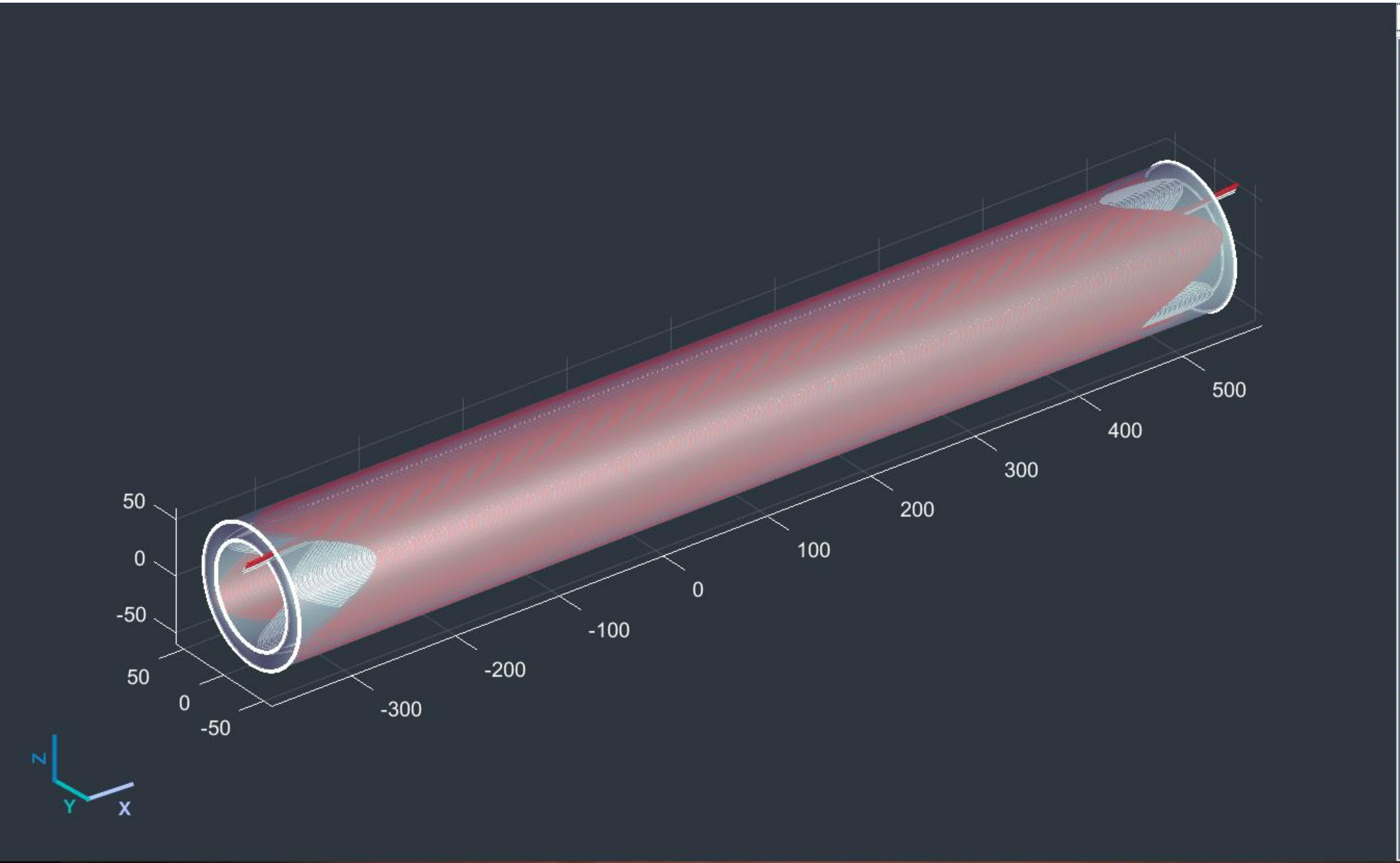
- Specs are 2.9m long, 12T/m
- Divide by 3: magnetic length per quad: 967mm
- Physical length of each quad in this design: 1100mm, leading to a magnetic length of 2X487=974mm. This is larger than 967mm, which is correct.
- Gradient: 12T/m with 10*240A tapes

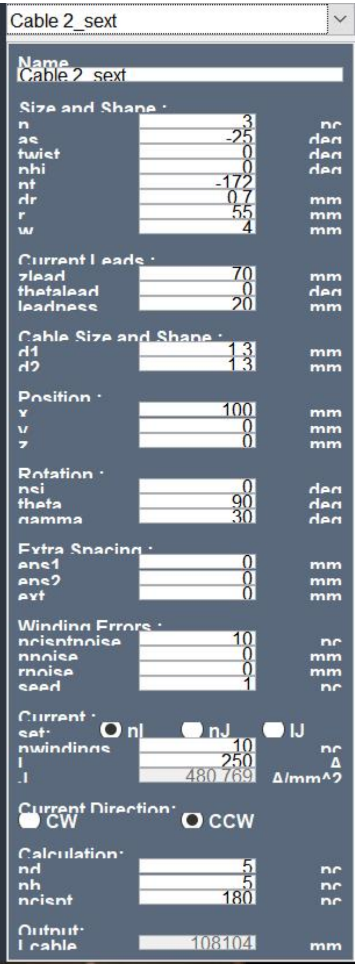




sextupole

- Specs are 1.5m (two units) and 812T/m2
- I have modified that to 1000T/m2 and magnetic length 814mm × 3 (physical size 900mm × 3)
- Pitch is 2mm between windings, number of turns 172 per unit (3 units)
- Current: 250A per tape for a stack of 10 tapes





Correctors

- Three correctors are needed:
  - Skew quad
  - Dipole (horizontal)
  - Dipole (vertical)
- We assume that the correctors will be asked to correct for 300um deviation and 300urad rotation. Typical values of these corrections are 100um/100urad

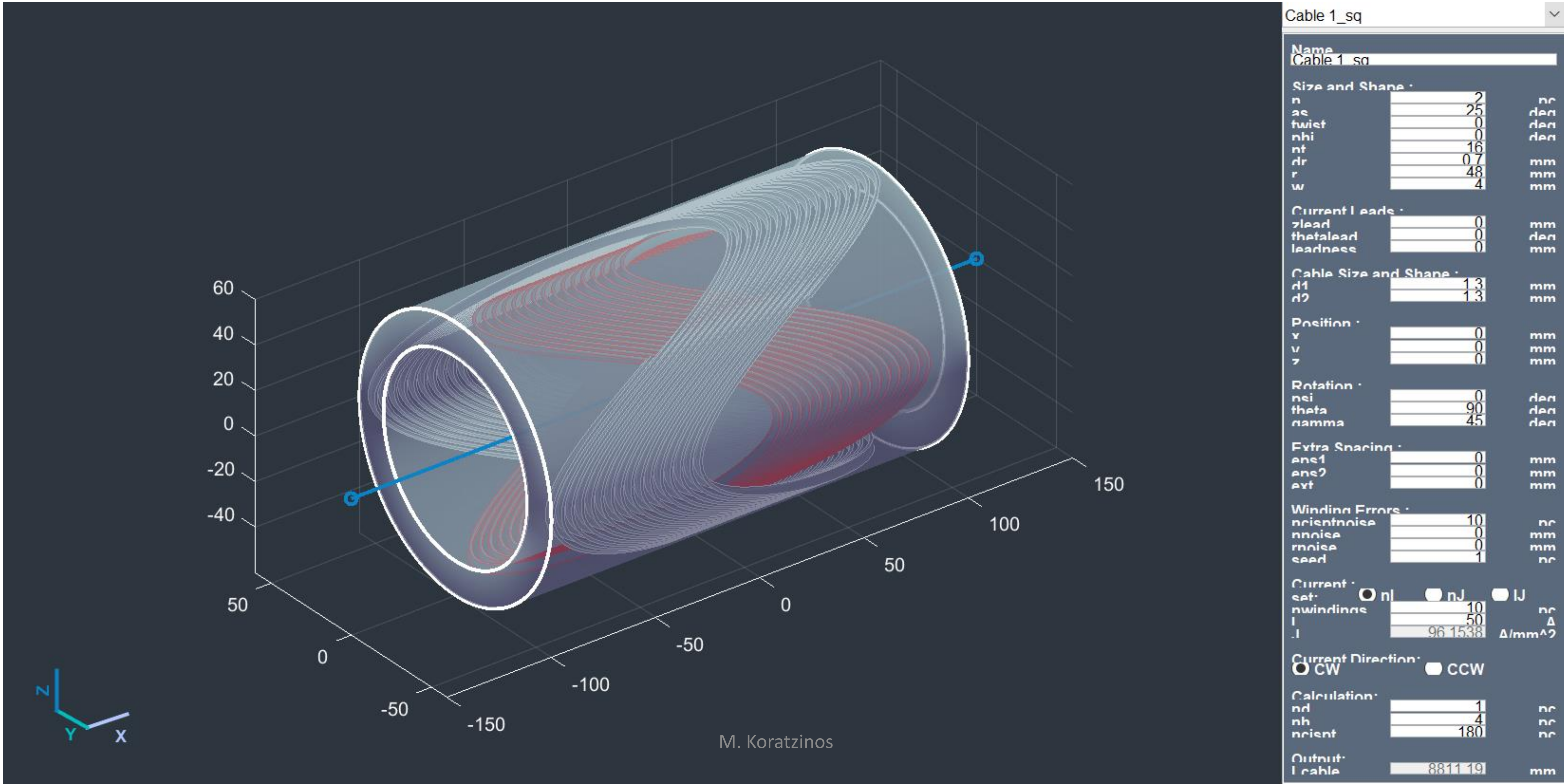
Skew quad corrector

- The strongest corrector.
- According to Katsunobu, Skew quad strength should be

B' = (2 * 12T/m * 3e-4 (rad) *2.9 m + 807 T/m^2 * 3e-4 (m) * 1.5 m) / Lc

- First term: quadrupole roll, second term: sextupole misalignment; Second term dominates
- Total gradient should be 1.9T/m for a magnet with magnetic length of 200mm. In reality, the *physical* length is 200mm, so the skew quad has a max. strength of 4T/m
- Current 50A, 10 tapes

Skew quad



60
40
20
0
-20
-40
50
0
-50
-150
-100
-50
0
50
100
150
Z
Y
X
Cable 1_sq
Name
Cable 1_sq
Size and Shape :
n 2 nc
as 25 deg
twist 0 deg
phi 0 deg
nt 16
dr 0.7 mm
r 48 mm
w 4 mm
Current Leads :
zlead 0 mm
thetalead 0 deg
leadness 0 mm
Cable Size and Shape :
d1 1.3 mm
d2 1.3 mm
Position :
x 0 mm
y 0 mm
z 0 mm
Rotation :
psi 0 deg
theta 90 deg
gamma 45 deg
Extra Spacing :
eps1 0 mm
eps2 0 mm
ext 0 mm
Winding Errors :
ncisptnoise 10 nc
nnoise 0 mm
rnoise 0 mm
seed 1 nc
Current :
set: nI nJ IJ
nwindings 10 nc
I 50 A
J 96.1538 A/mm^2
Current Direction:
CW CCW
Calculation:
nd 1 nc
nh 4 nc
ncispt 180 nc
Output:
Lcable 8811.19 mm

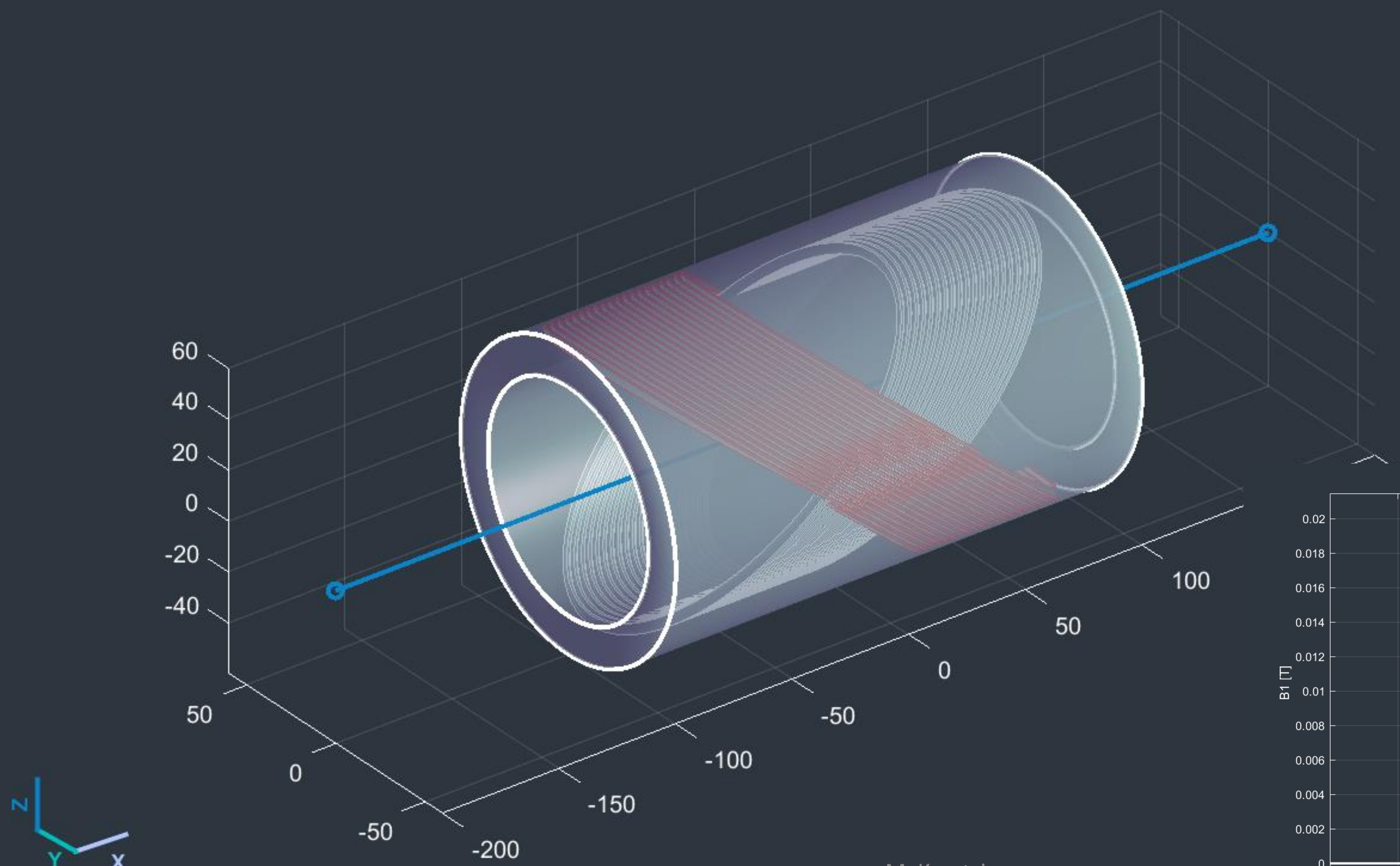
Dipole correctors

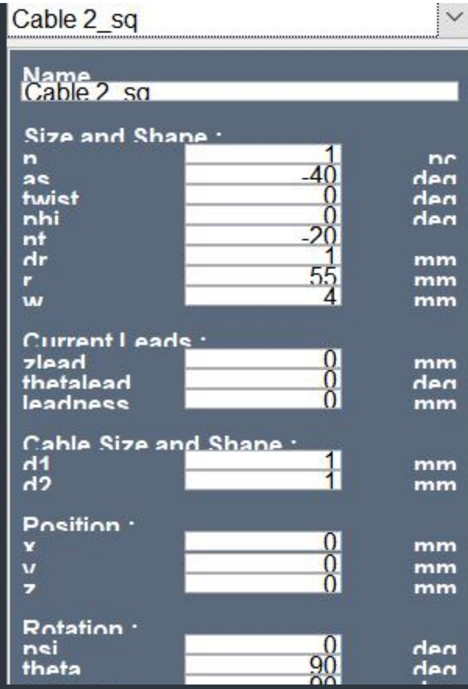
- Physical length 200mm, I=25A, Bdl along a line 10mm from the centre= 0.004Tm
- According to Katsunobu Skew quad strength should be:

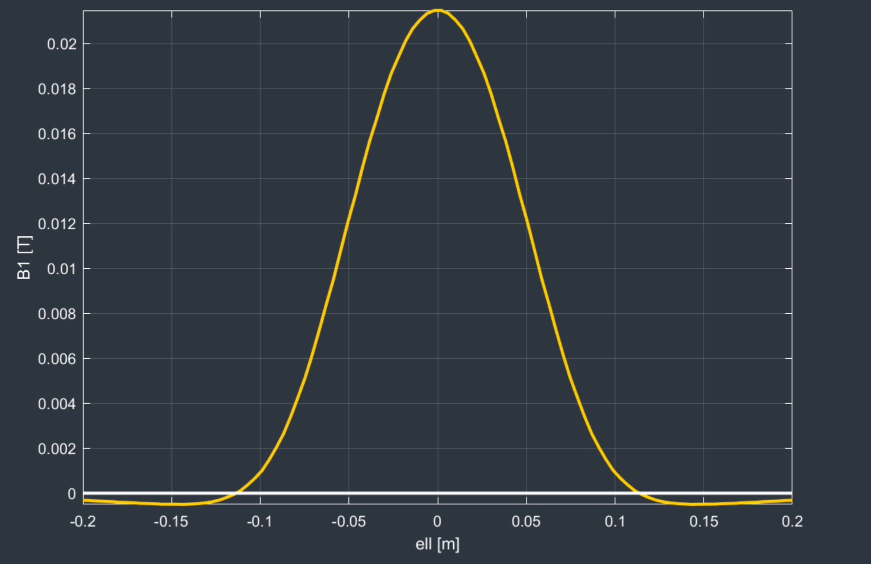
  B = 12 T/m * 3e-4 m * 2.9 m / Lc,

  where Lc is the length of the magnet
- Strength is therefore 0.01T for a magnetic length of 10cm and a physical length of 20cm
- Number of tapes: 3; current: 25A

Dipole corrector







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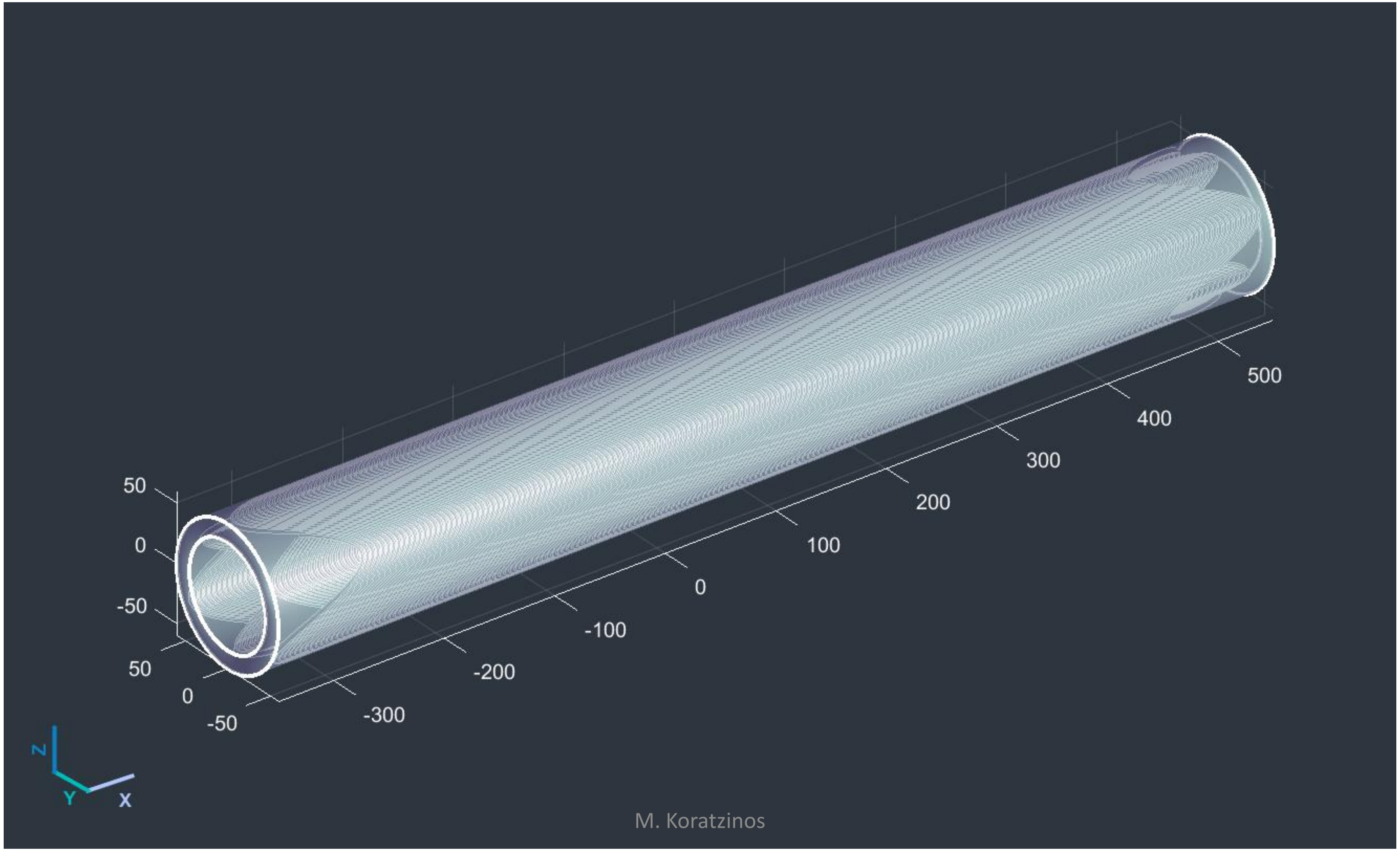
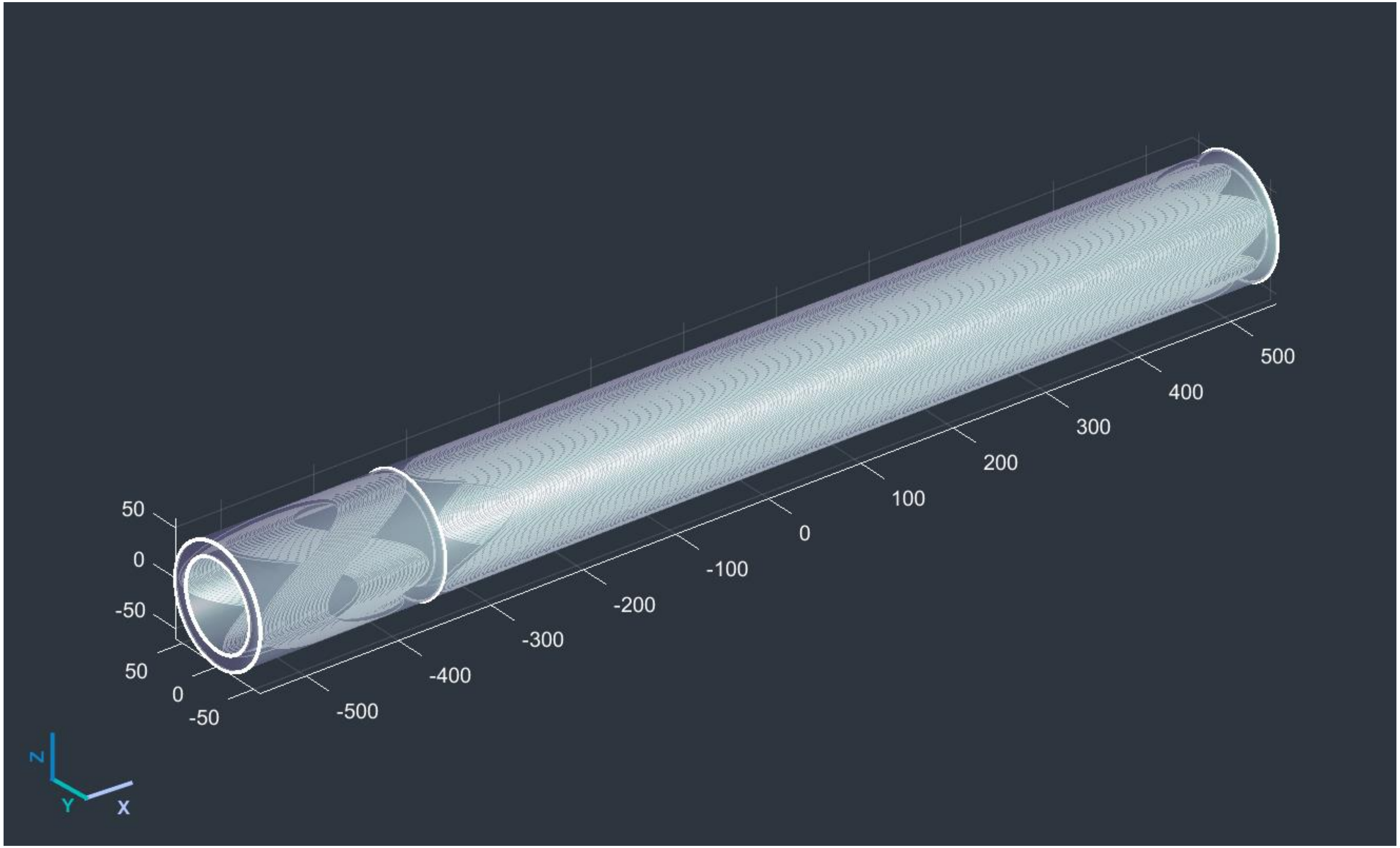
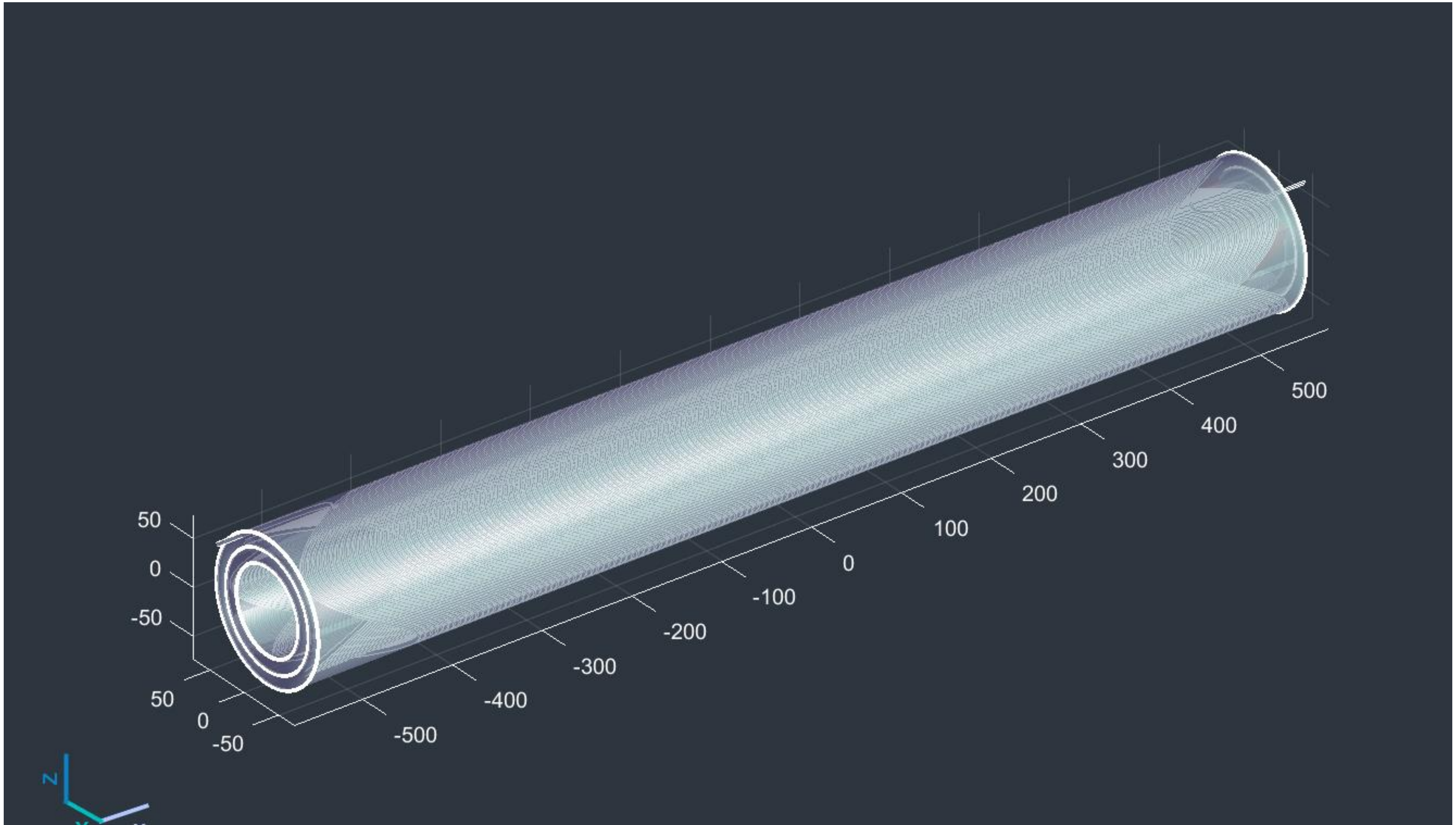
Assembly: sextupole



The assembly – inner layers: sext+corrector



The assembly – plus outer layers (quad)



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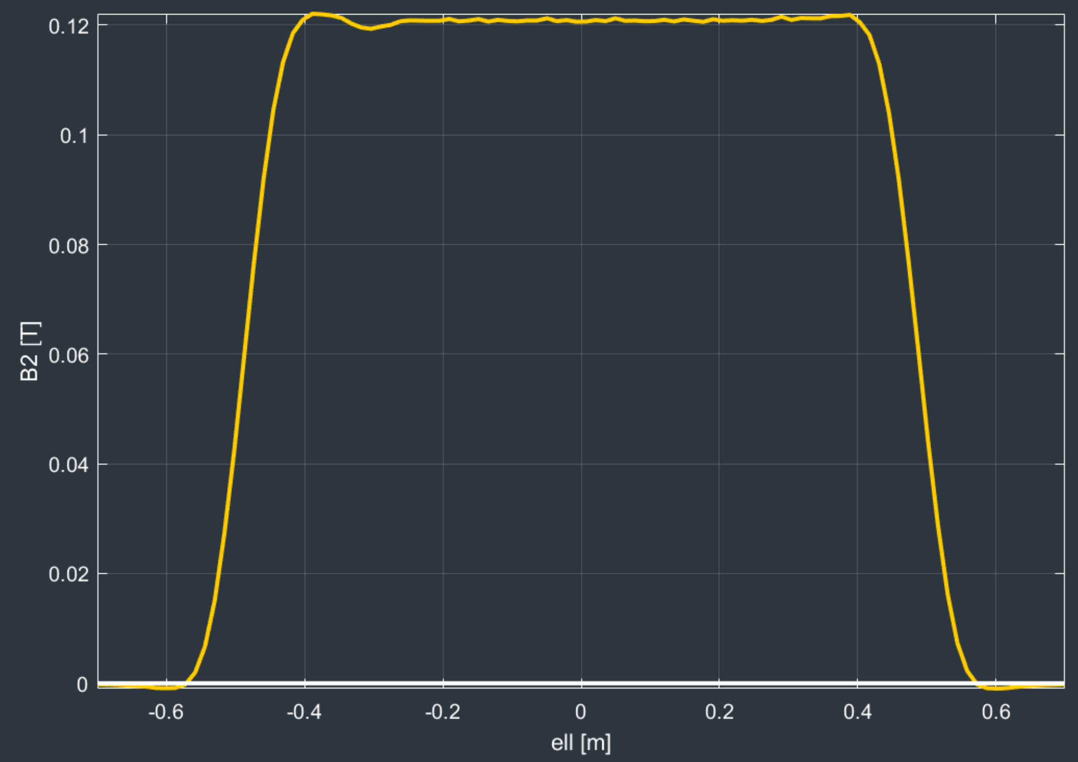
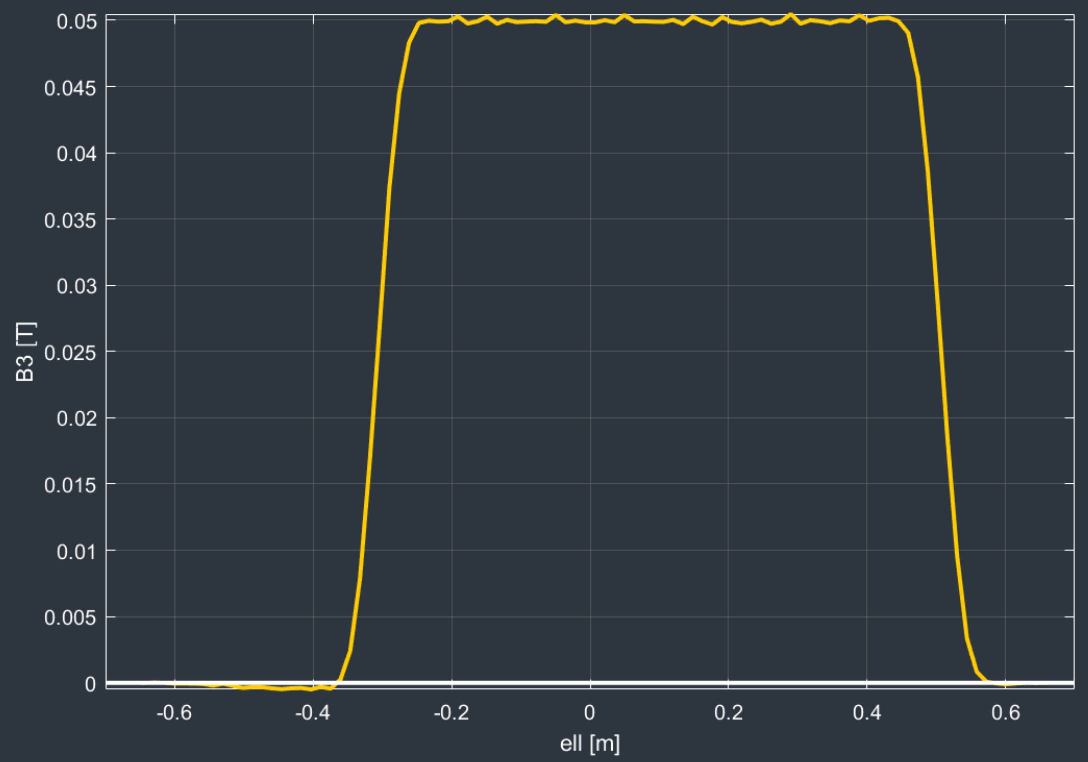
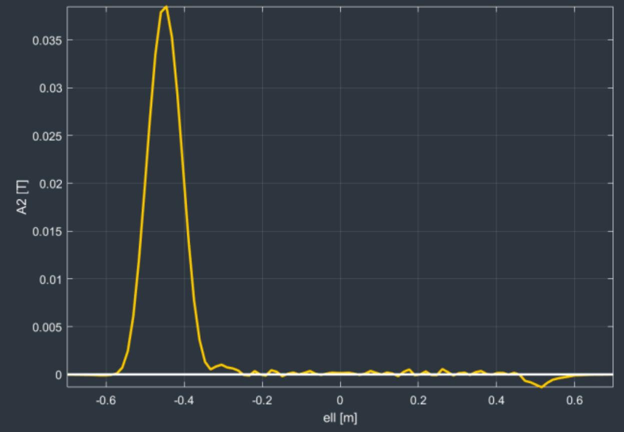
Strengths at 10mm radius







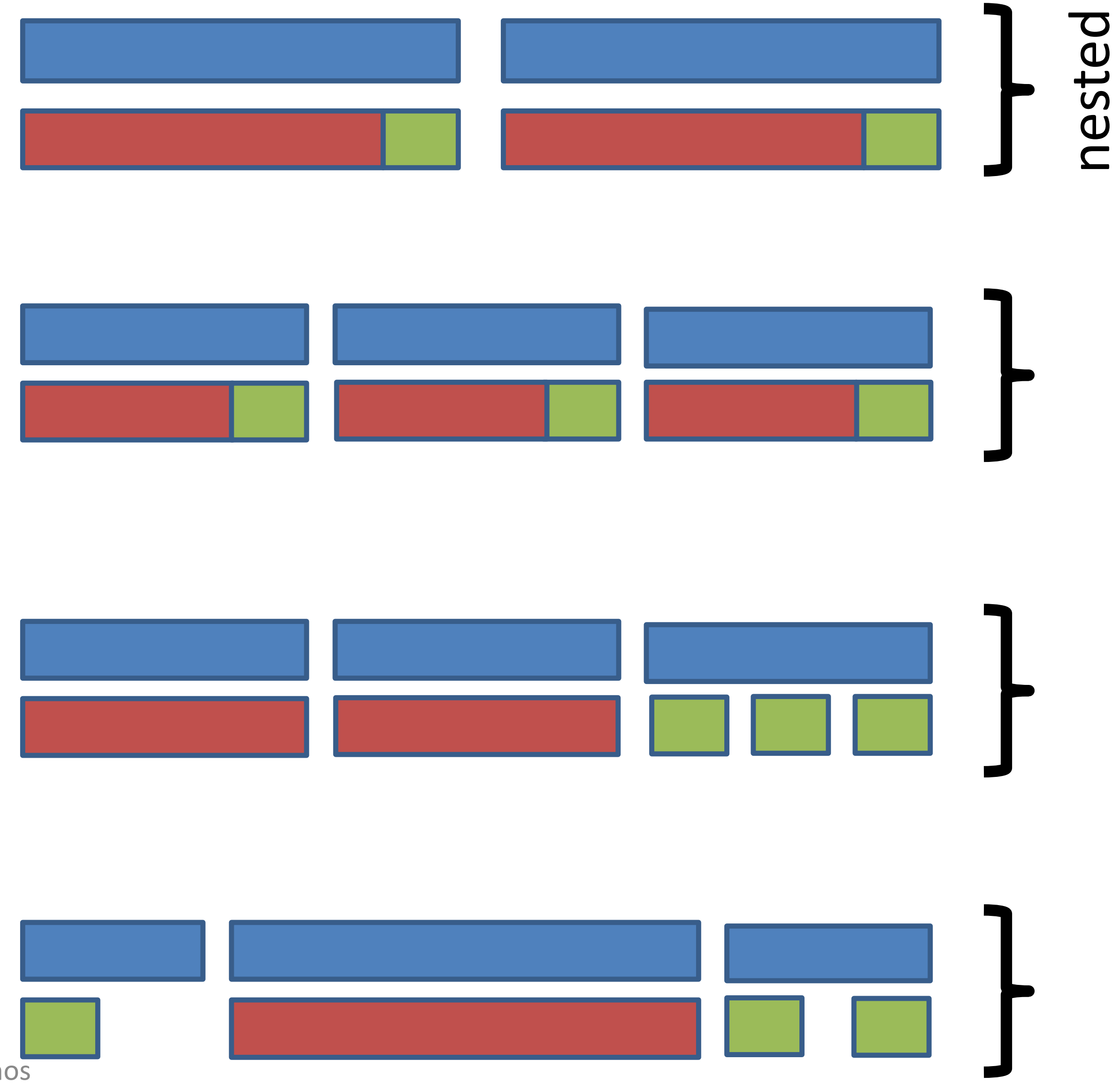
Discussion: sextupole length

- I have increased the strength of the sextupole magnets by ~20%
- However, this has not resulted in a magnetic length which is 20% smaller, due to the presence of correctors dispersed between sextupoles
- If I was to increase the strength by another 20%, then I could fit the sextupoles in only two of the three units, resulting in a magnetic length of ~2m instead of ~3m in the baseline design
- I could make that modification at a later stage.

Summary

Quad, sext, correctors

- Old
- New
- Future possibility 1
- Future possibility 2

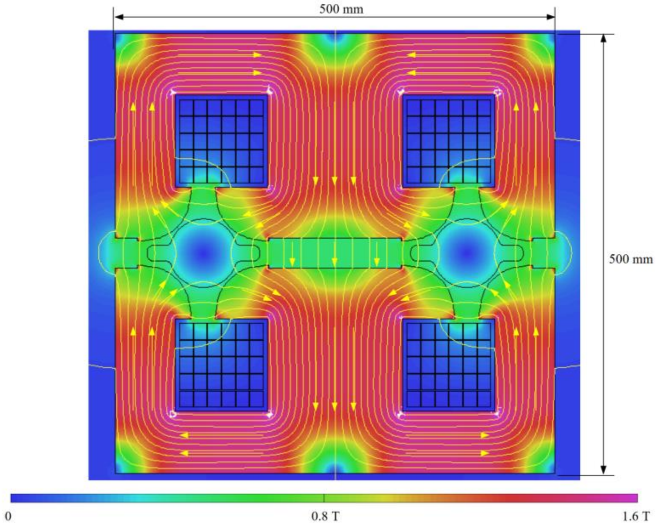


Extra slides

CDR: a reminder: Arc quads

Table 3.2: Parameters of the main quadrupole magnets.

Maximum gradient	T/m	10.0
Magnetic length	m	3.1
Number of twin units per ring		2900
Aperture diameter	mm	84
Radius for good field region	mm	10
Field quality in GFR (not counting dip. term)	10^{-4}	≈ 1
Maximum operating current	A	474
Maximum current density	A/mm^2	2.1
Number of turns		2×30
Resistance per twin magnet	mΩ	33.3
Inductance per twin magnet	mH	81
Maximum power per twin magnet	kW	7.4
Maximum power, 2900 units (with 5% cable losses)	MW	22.6
Iron mass per magnet	kg	4400
Copper mass per magnet (two coils)	kg	820



- 3.1 m long (cannot be shorter due to SR)
- 2900 double aperture units
- **Power consumption 23MW**

CDR: Arc sextupoles

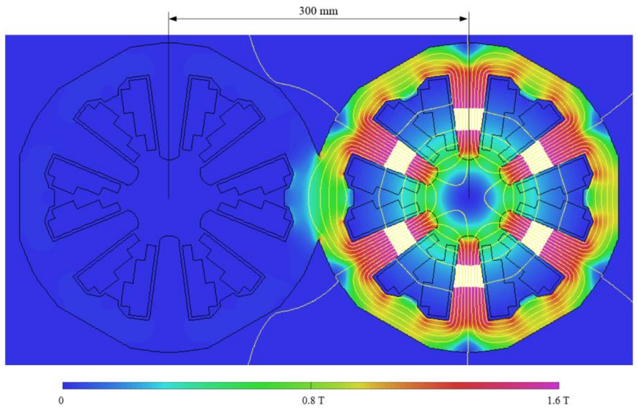


Table 3.3: Parameters of the main sextupole magnets.

Maximum strength, B''	T/m^2	807.0
Magnetic length	m	1.4
Number of units per ring		208×4=832 (Z, W) 292×8=2336 (H, $t\bar{t}$)
Number of families per ring		208 (Z, W) 292 (H, $t\bar{t}$)
Aperture diameter	mm	76
Radius for good field region (GFR)	mm	10
Field quality in GFR	10^{-4}	≈1
Ampere turns	A	6270
Current density	A/mm^2	7.8
Maximum power per single magnet at 182.5 GeV	kW	15.5
Average power per single magnet at 182.5 GeV	kW	4.4
Total power at 182.5 GeV (4672 units)	MW	20.5

- (832+2336)*2= 6336 units
- Power consumption **21MW**
- Aperture of 76mm does not fit in the CDR beam pipe…
- Therefore, power estimate most probably underestimated
- No prototype constructed yet

CDR: The optics cell

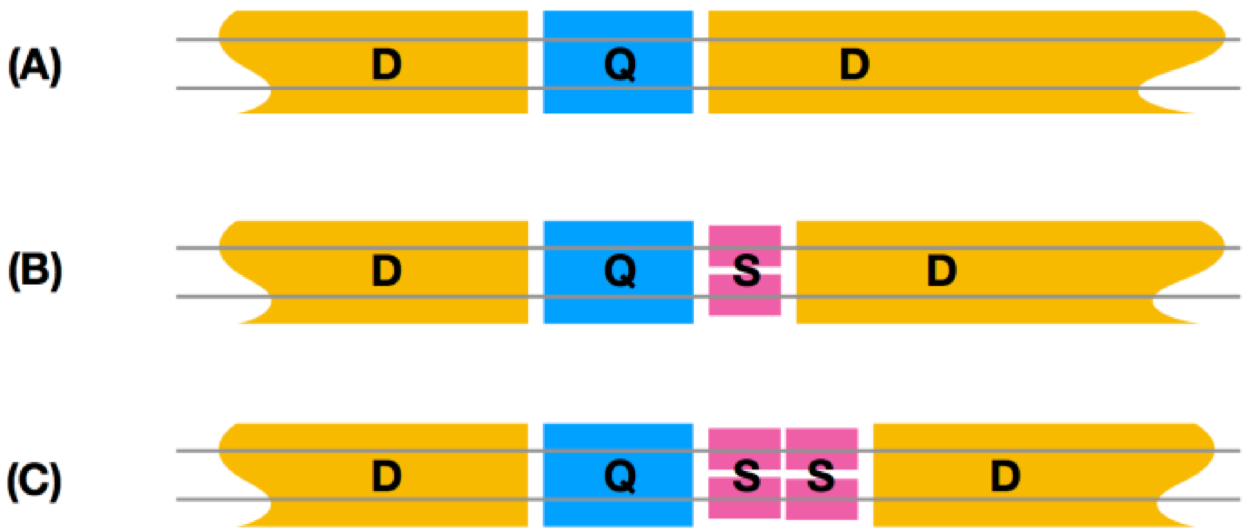


Figure 2.5: Three magnet arrangements around a quadrupole. D: twin-aperture dipole, Q: twin-aperture quadrupole. S: single-aperture sextupole. (A) no sextupole, (B) single aperture, singlet sextupole only for $60^\circ/60^\circ$, (C) single aperture, doublet sextupole for either $60^\circ/60^\circ$ or $90^\circ/90^\circ$. In case (C) for $60^\circ/60^\circ$, only the part of the doublet next to the quadrupole is powered. As a result, three dipole lengths are needed to maintain a constant distance between quadrupoles.

- Three families of dipoles
- If we can embed the sextupoles in the quads, only a single dipole size will be needed

Lengths (m)			
Dipole	quad	sext	units
21.2	**3.2**	**3.2**	**1152**
22.7	**3.2**	**1.5**	**492**
24.4	**3.2**	**0**	**1256**

Half cell length: 27.9 m