PETRA IV PMQ Magnet development

Patrick N’Gotta, Markus Tischer,

on behalf of the DESY ID group

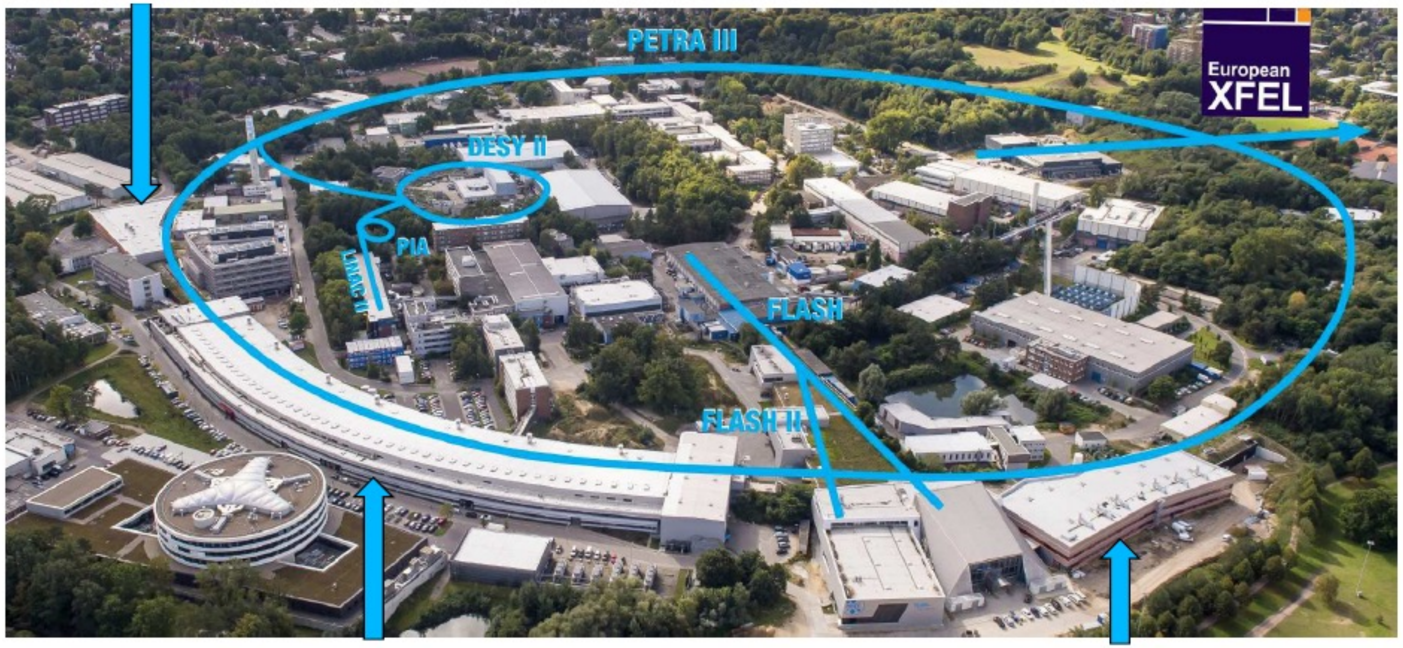
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

IPAC21

DESY.

PETRA IV Accelerator Upgrade

Ada Yonath Hall
Extension Hall East



Max von Laue Hall

Paul P. Ewald Hall
Extension Hall North

Parameter	PETRA III
Energy [GeV]	6
Circumference [m]	2304
Emittance (hor./vert.) [mm]	1.3/ 0.013
Total current [mA]	100

Courtesy of R. Bartolini

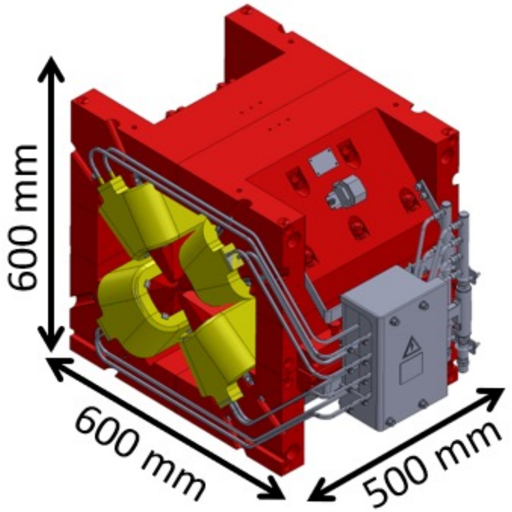
PETRA IV project:

replacing PIII with an ultra low emittance ring (20 pm) adding a new Experimental Halls in two more octants

ESRF PMQ Design Evolution

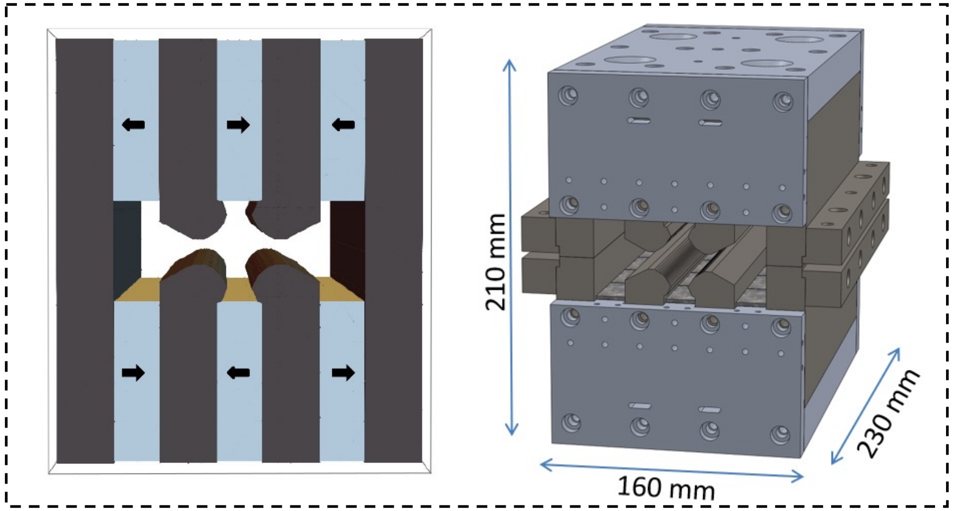
Specification for Petra IV PMQ

- Gradient: 120 T/m
- Bore Radius: 11 mm
- GFR: +-6 mm
- DG/G0: 5.10^-4
- Length: 0.169 m
- Vertical gap: 8.8mm

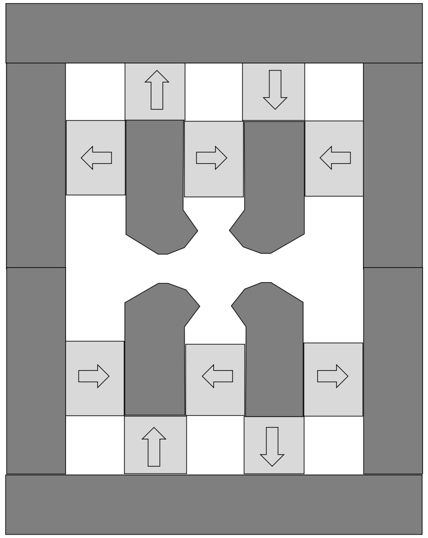


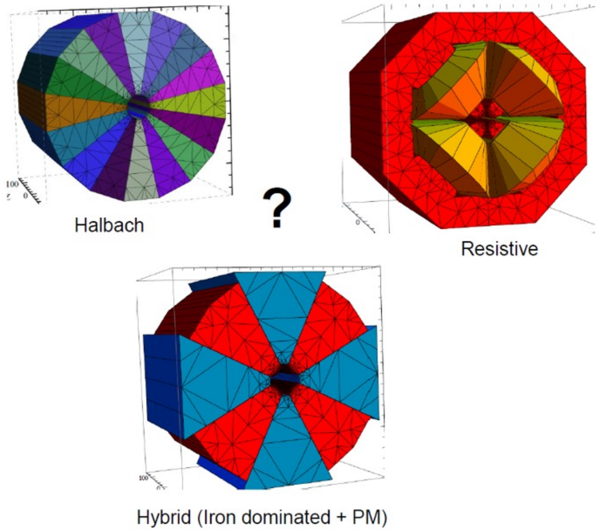
1 Ton

ESRF-EBS electromagnet

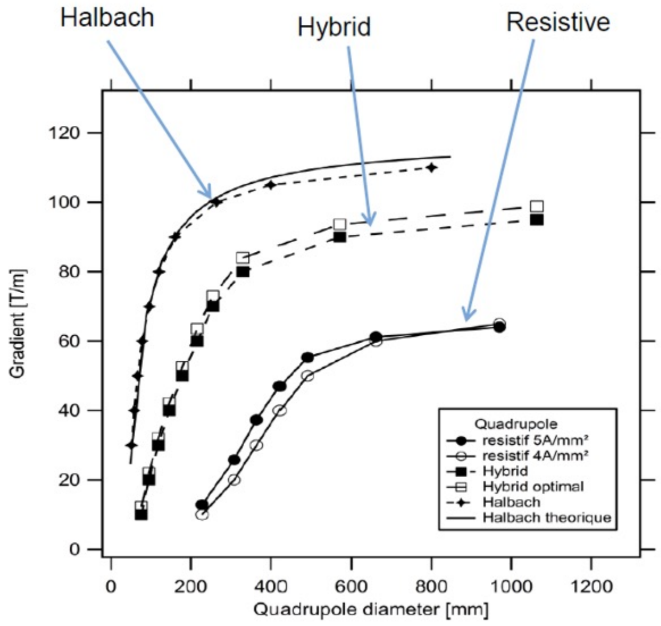


50kg



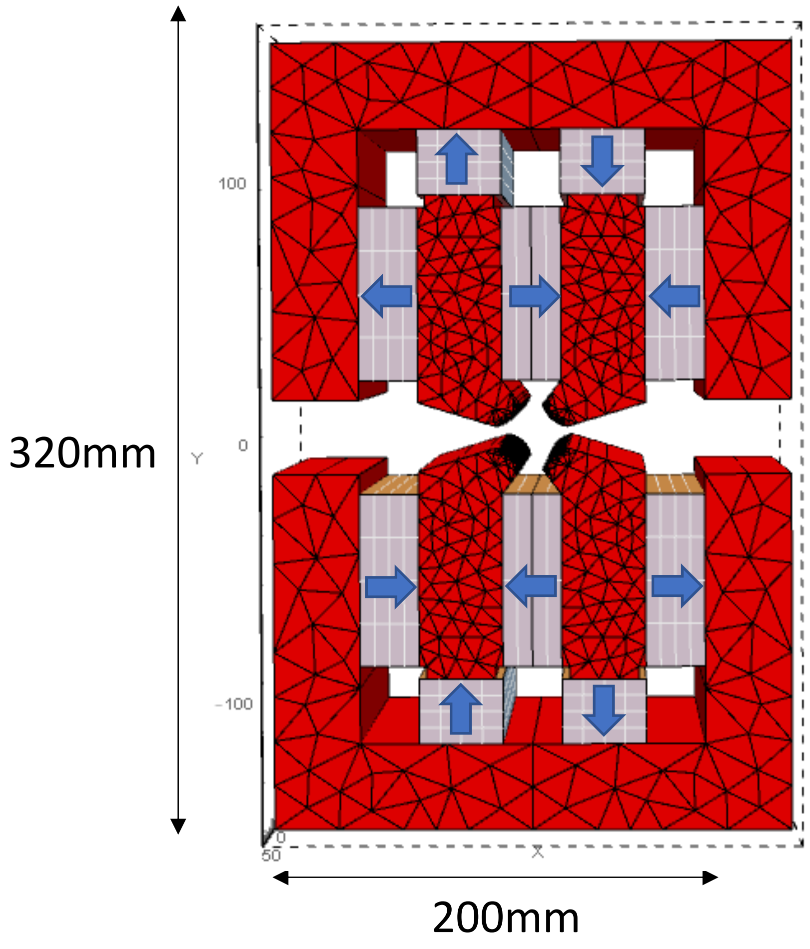


Magnet Performance Comparison

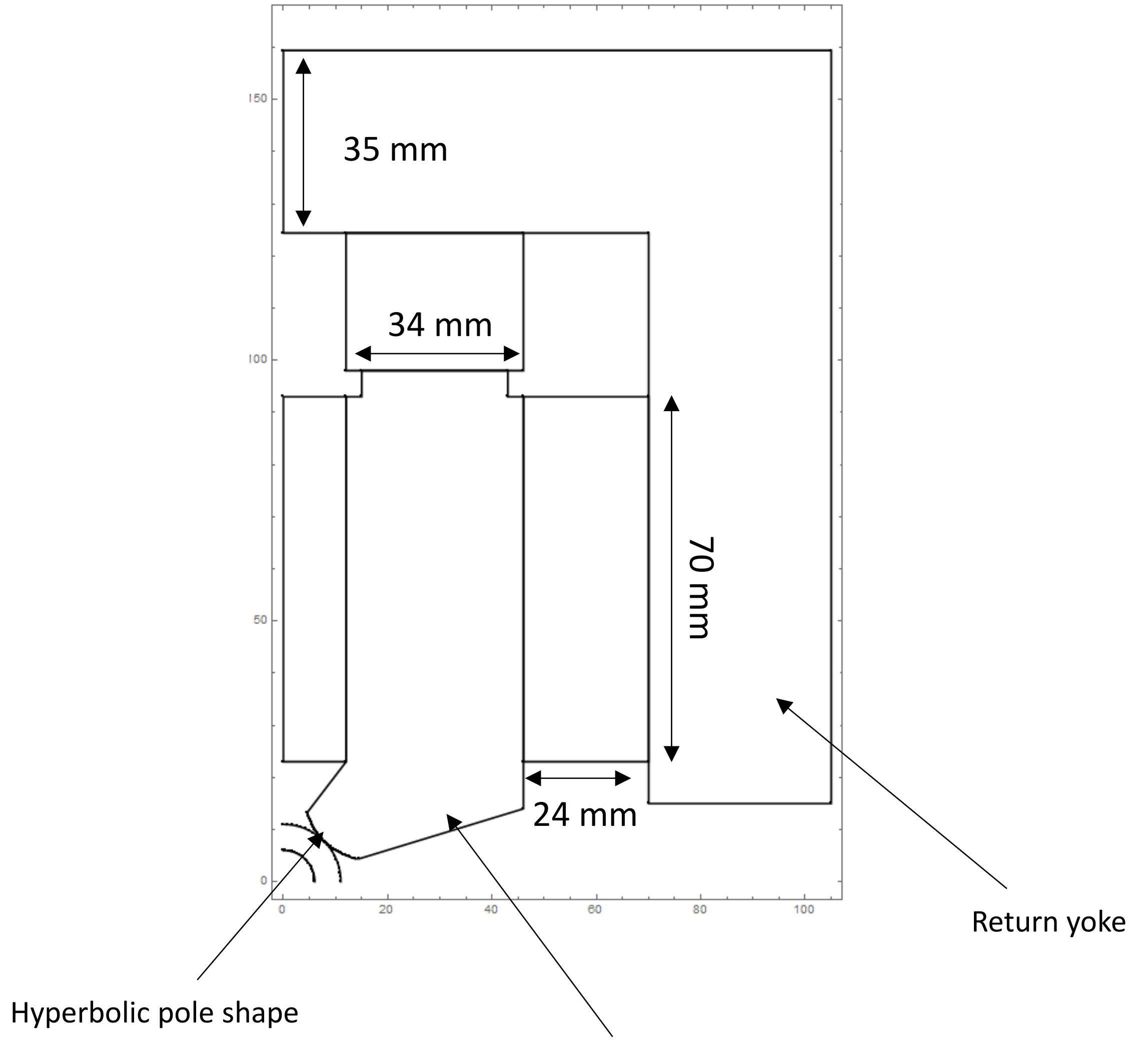


Gradient vs Transverse diameter

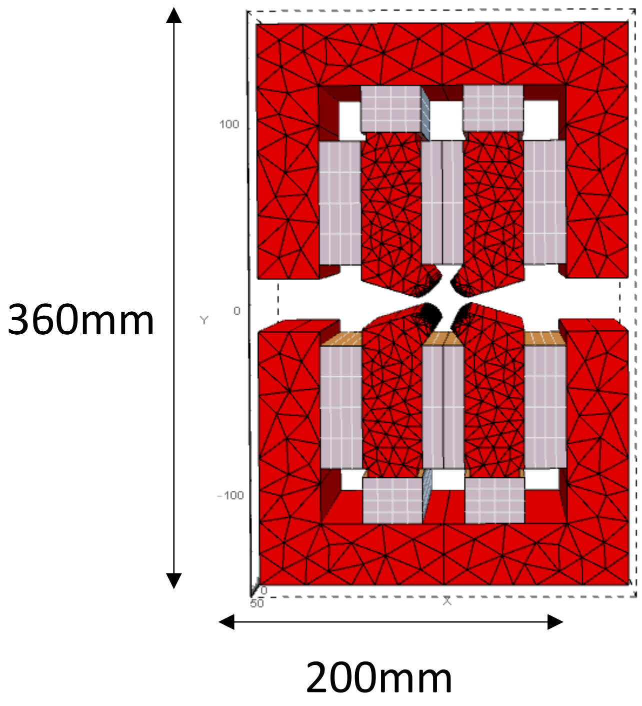
Preliminary Design



Radia model

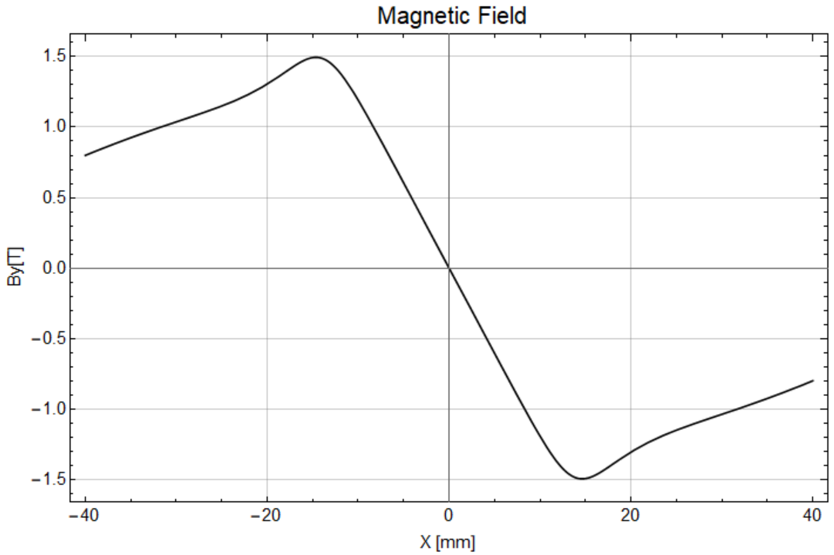


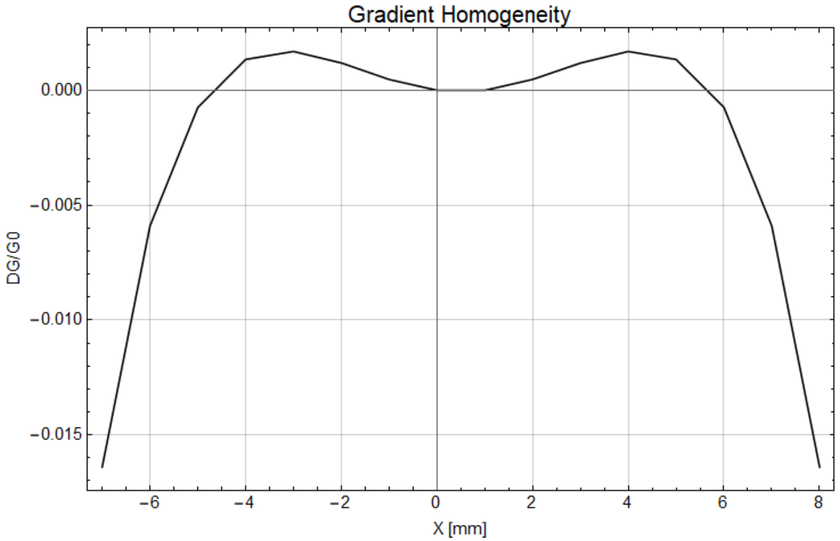
First Results (2D Study)

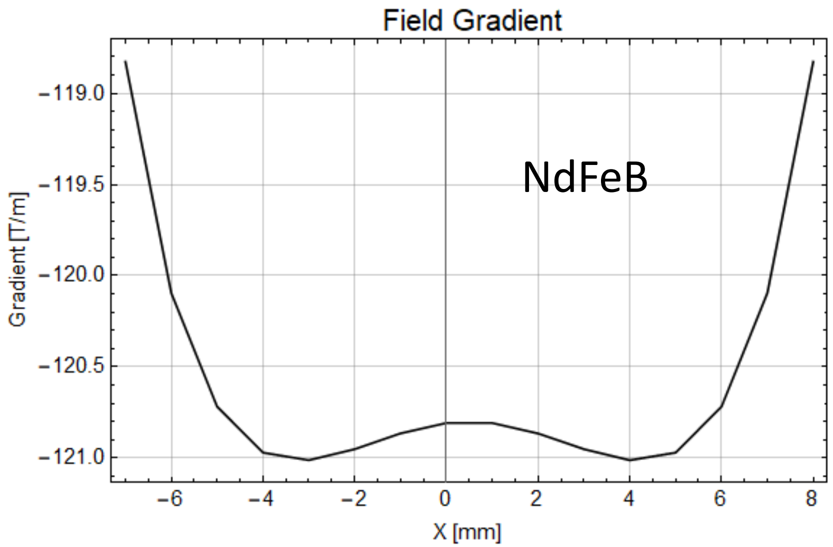


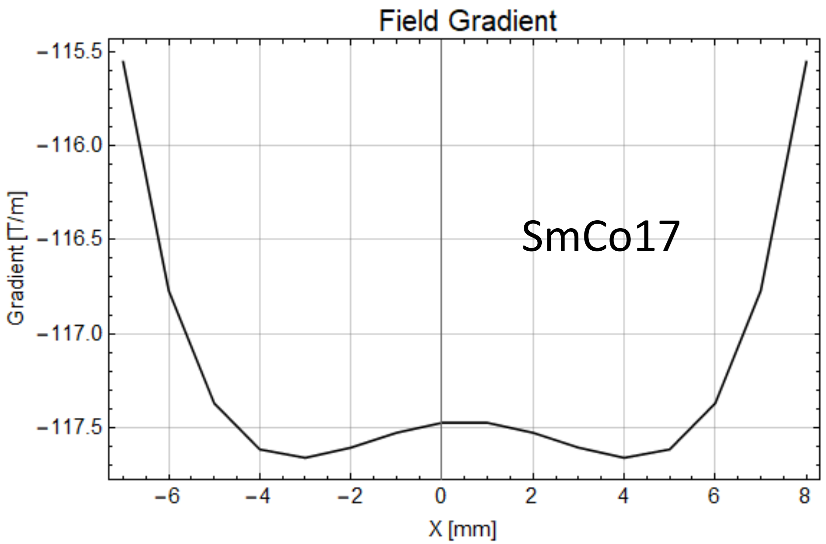
- Gradient: 120.8 T/m
- PM: NdFeB Br=1.25T
- Iron ARMCO

- Gradient: 117.5 T/m
- PM:SmCo17 Br=1.1T
- Iron ARMCO





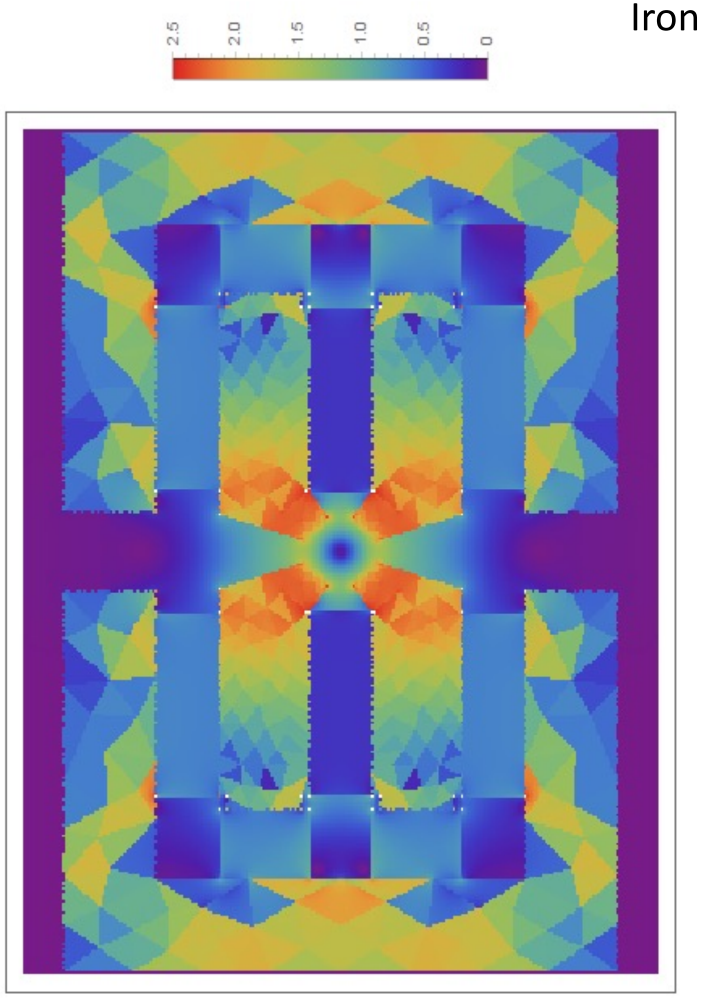


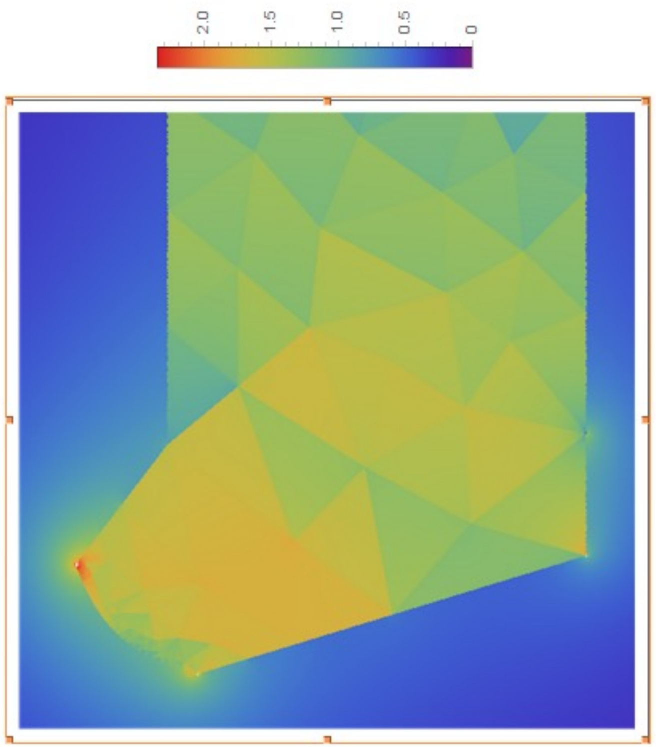


- Few T/m for NdFeB to SmCo17 PM (negligible)
- <u>Use of SmCo17 for radiation damage resistance and temperature stability</u>

Field Map

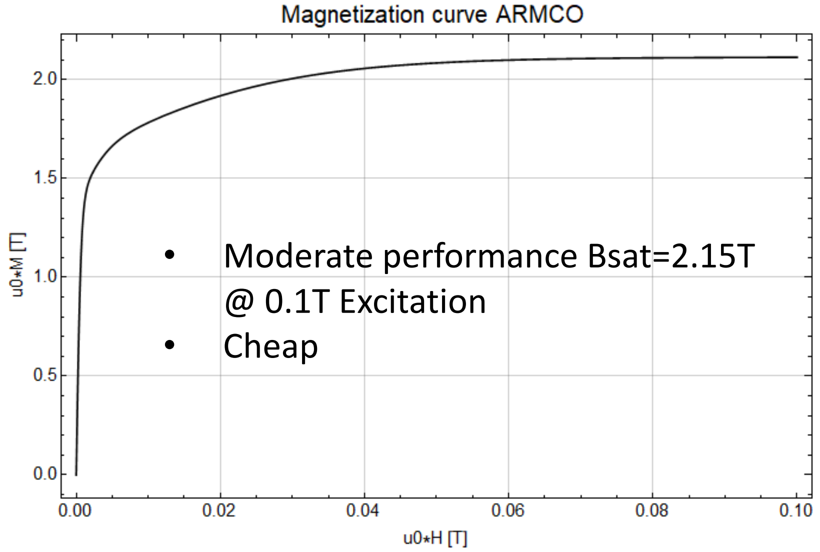
Iron ARMCO (XC06)

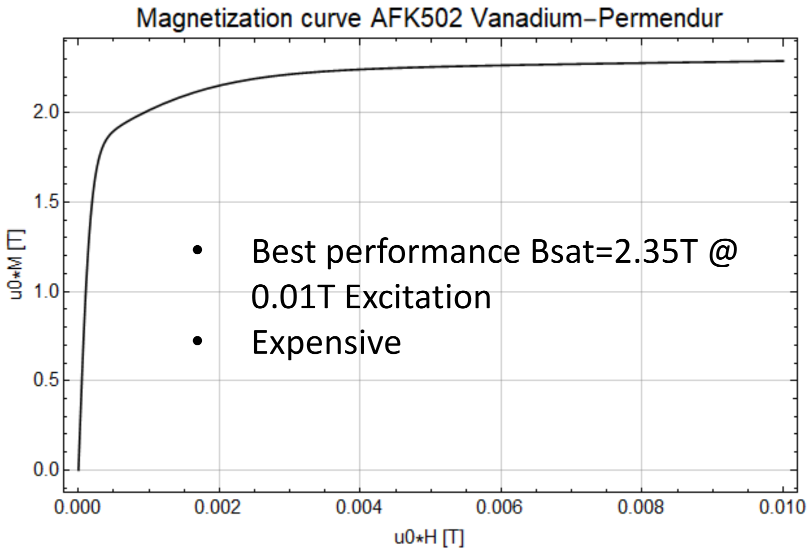




10 T/m Gradient gain using Vanadium Permendur Pole material (Vacoflux)

Ferromagnetic Materials performance

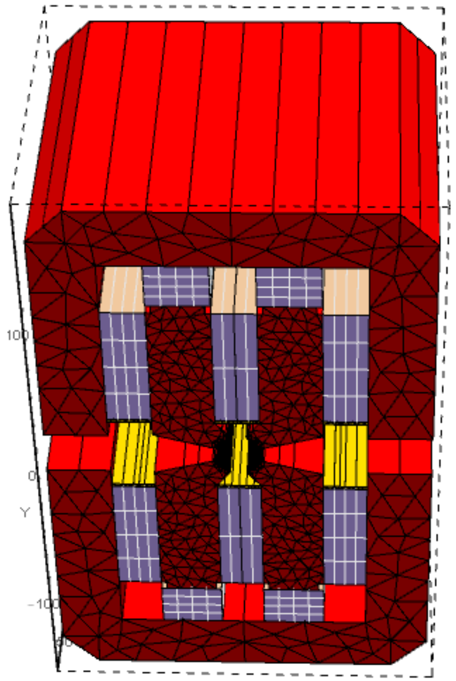




2D Vs 3D comparison

- Magnet Length: Lmag=0.169m
- R0=8mm (measurement radius)

2D (one bloc magnet)



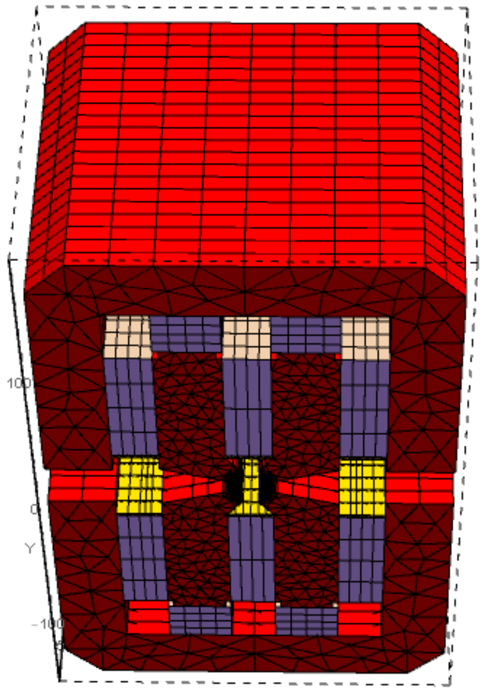
Integrated Harmonics (Ibn)

1	0
2	-0.161107
3	0
4	-0.0000437159
5	0
6	0.00200275
7	0
8	0.000022528
9	0
10	0.00033606
11	0
12	-4.99854×10^{-6}
13	0
14	7.72461×10^{-7}
15	0

3D (Longitudinal segmentation)

Integrated Harmonics (Ibn)

1	0
2	-0.158252
3	0
4	-0.0000681149
5	0
6	0.00195929
7	0
8	0.000046454
9	0
10	0.000304869
11	0
12	-6.22196×10^{-6}
13	0
14	2.57323×10^{-6}
15	0



IG0=Ib2/r0 → IG0=0.161/0.008= 20 T (Integrated Gradient)

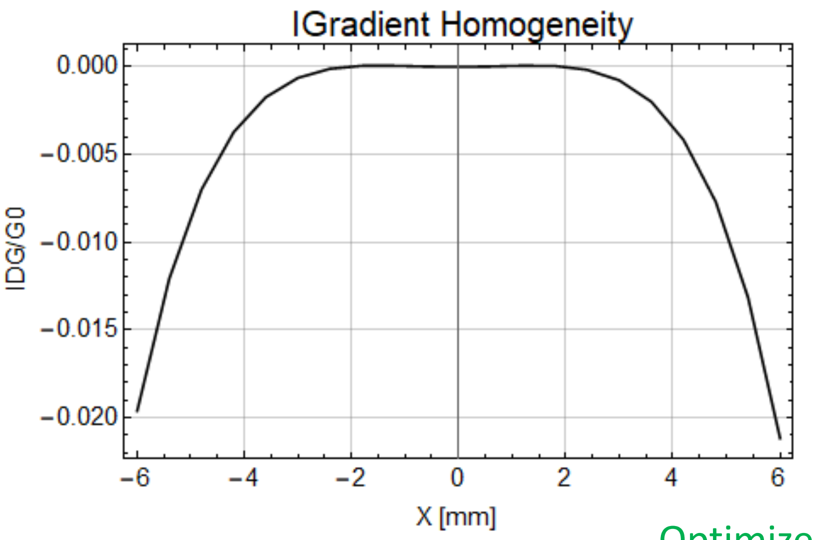
G0=IG0/Lmag → G0=20/0.169= 118 T/m

No Large difference for harmonics.
optimization can be done in 2D

Preliminary Shape optimization

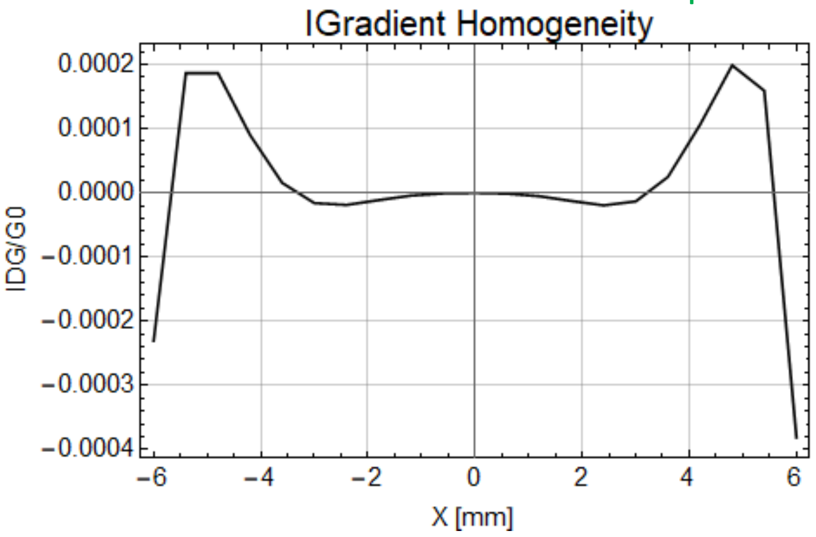
- Objective: DG/G0: 5.10^-4, GFR: 6mm
- Constraint: Limit Gradient reduction
- Constraint: Vertical Gap

Initial

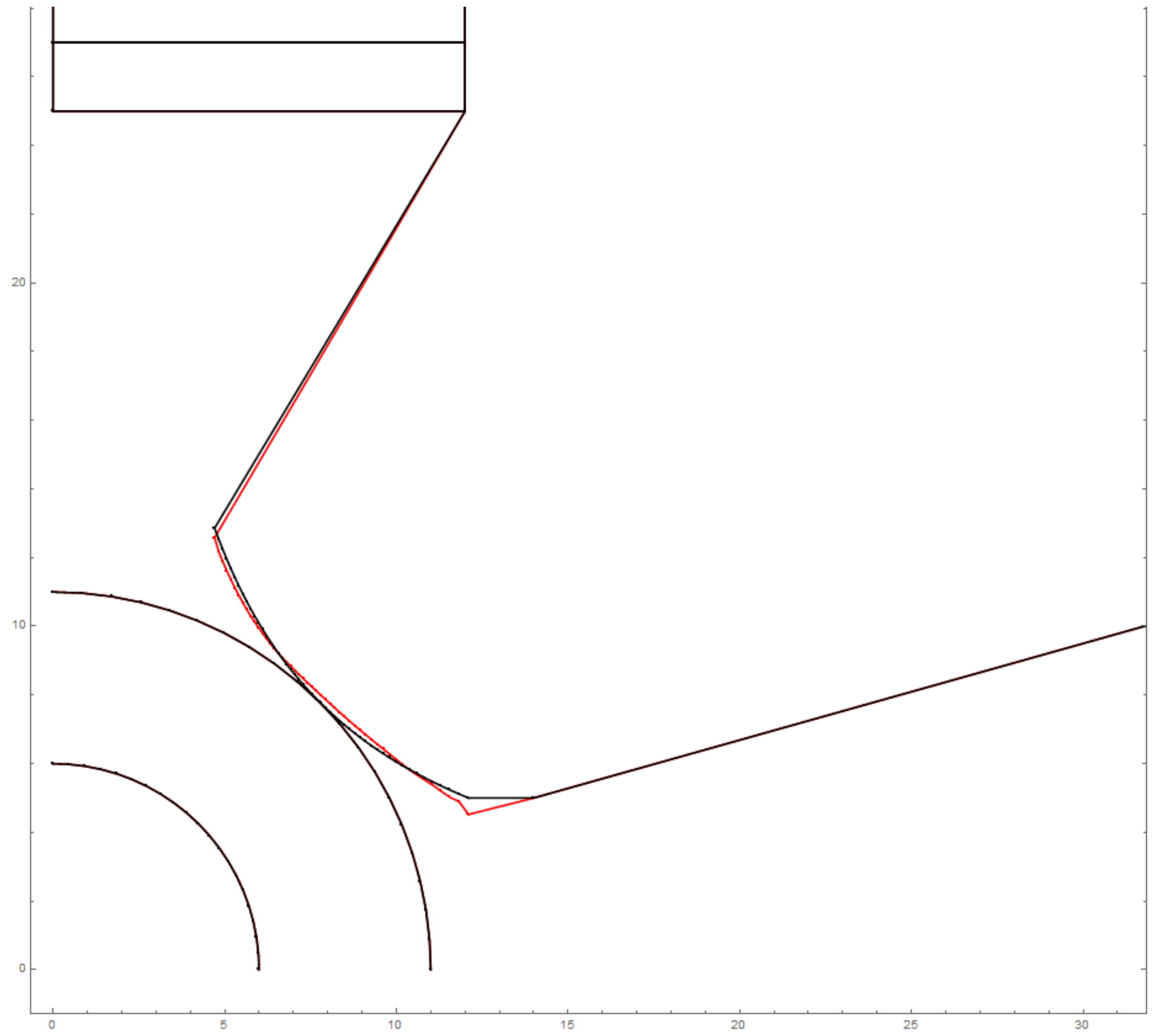


1	0
2	-0.121781
3	0
4	-0.000105196
5	0
6	0.000521578
7	0
8	-7.51985×10^{-6}
9	0
10	0.0000272883
11	0
12	-3.40837×10^{-7}
13	0
14	-2.08368×10^{-8}
15	0

Optimized



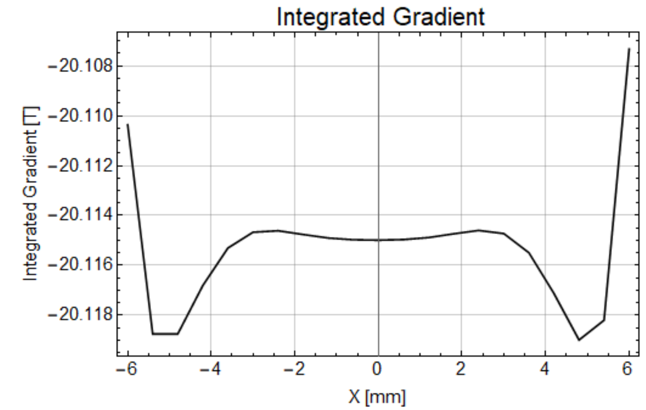
1	0
2	-0.12069
3	0
4	3.61714×10^{-6}
5	0
6	0.000022098
7	0
8	-0.0000905823
9	0
10	0.0000577879
11	0
12	3.4331×10^{-6}
13	0
14	-6.64846×10^{-7}
15	0

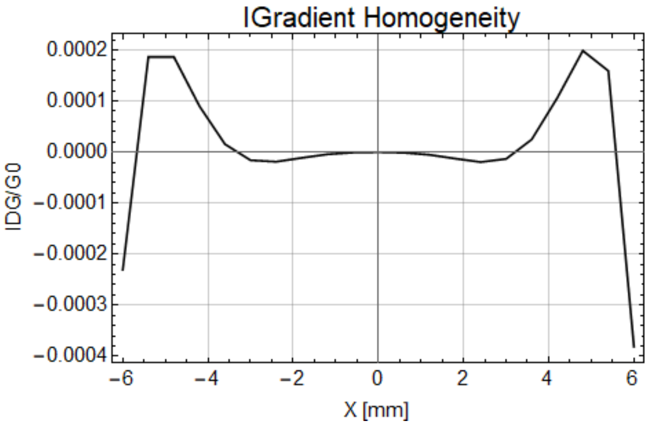


- DG/G0< 5.10^-4 within GFR: 6mm
- G=118 T/m
- Vgap= 4.5mm

Preliminary Shape optimization

2D



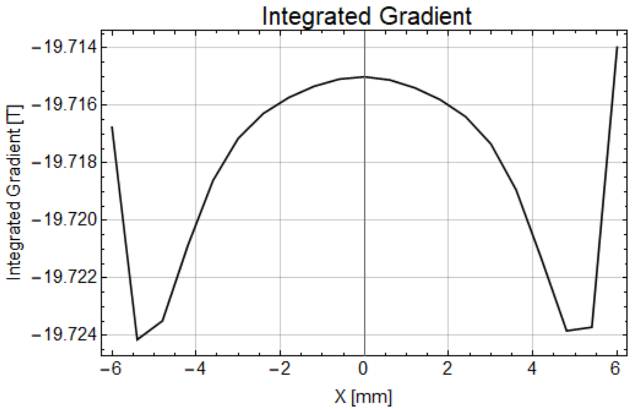


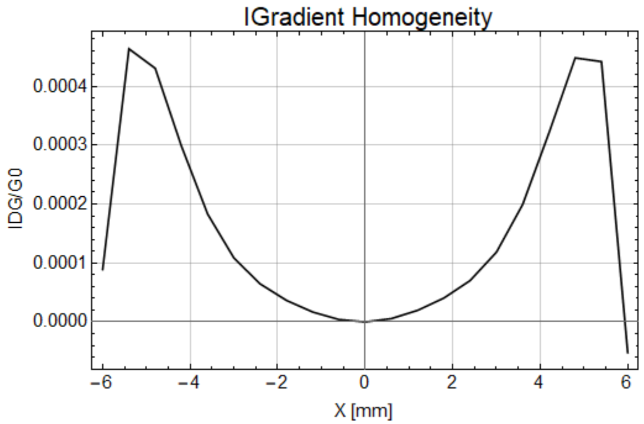
1	0
2	-0.12069
3	0
4	3.61714×10^{-6}
5	0
6	0.000022098
7	0
8	-0.0000905823
9	0
10	0.0000577879
11	0
12	3.4331×10^{-6}
13	0
14	-6.64846×10^{-7}
15	0

Sqrt[∑bn²]

0.000109798

3D

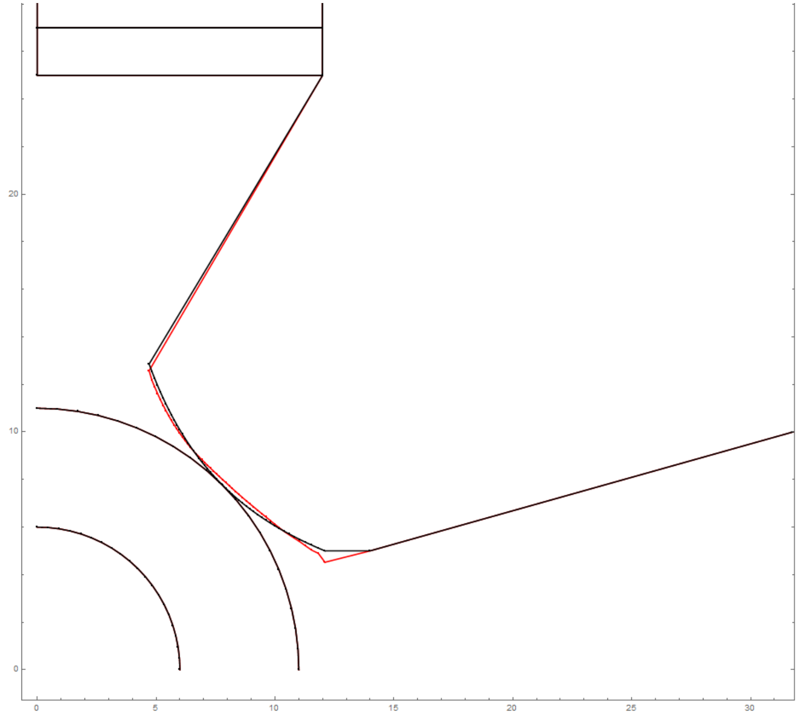




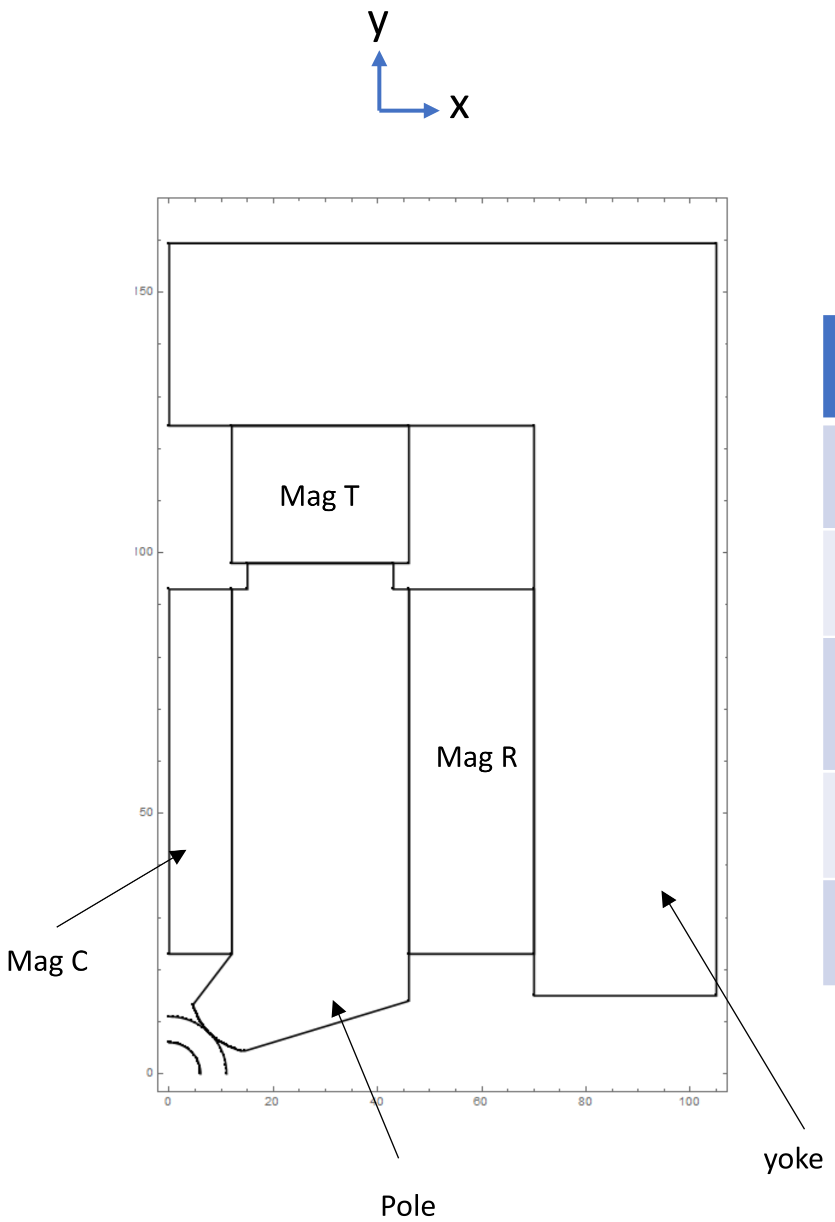
1	0
2	-0.11829
3	0
4	-0.0000194957
5	0
6	0.000027151
7	0
8	-0.0000839002
9	0
10	0.0000533205
11	0
12	3.13098×10^{-6}
13	0
14	-5.34749×10^{-7}
15	0

Sqrt[∑bn²]

0.000104927



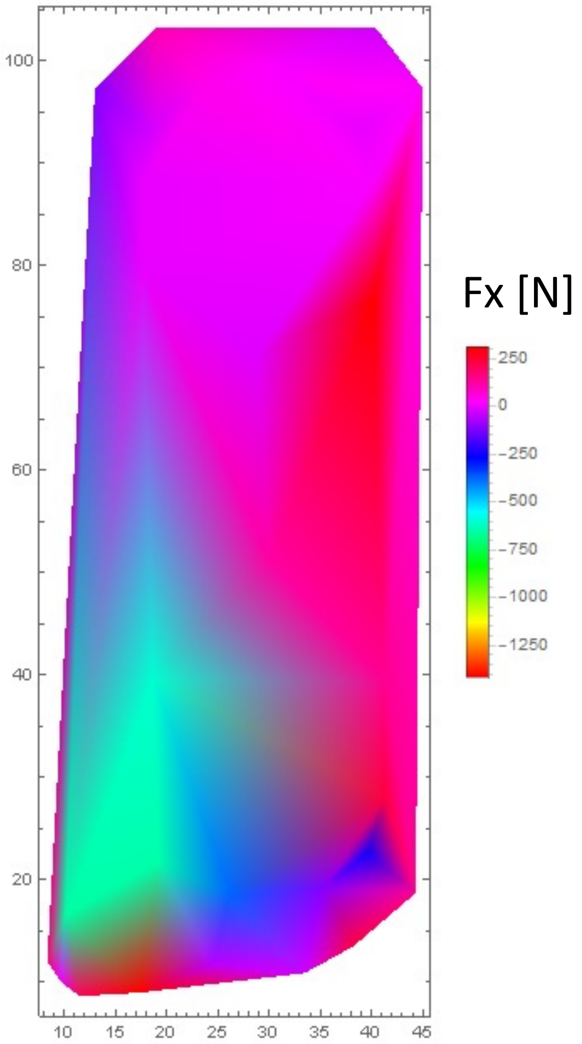
Force Computation



¼ of the Magnet

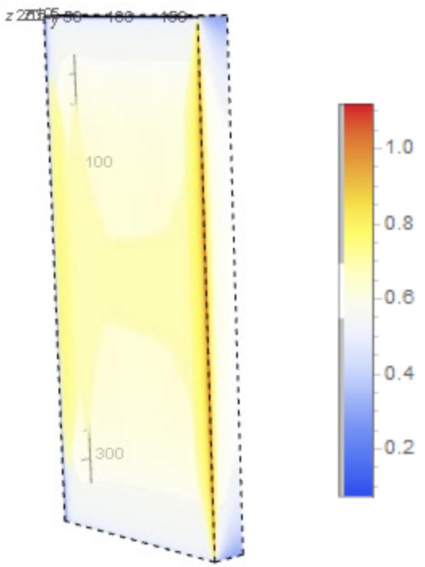
Name	Fx [N]	Fy [N]
Mag C	-594	-91
Mag R	551	59
Mag T	35	1240
Yoke	-300	-602
Pole	-1505	675

Pole Force (Fx) distribution (Deformation)



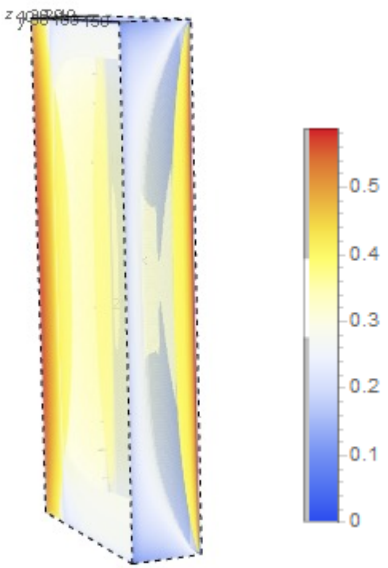
Permanent Magnet demagnetization

Mag C



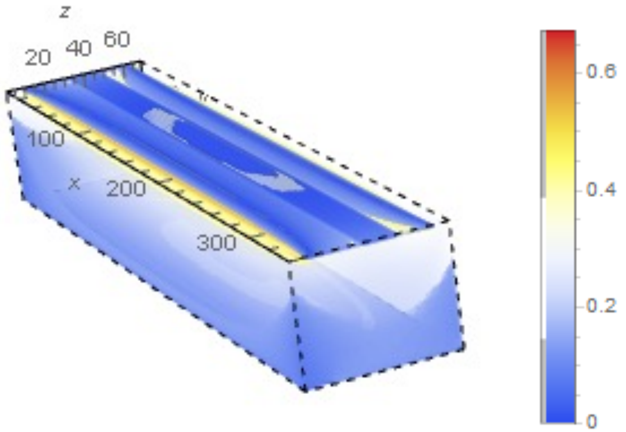
Hd Max = ~ 892 kA/m

Mag R



Hd Max = ~ 470 kA/m

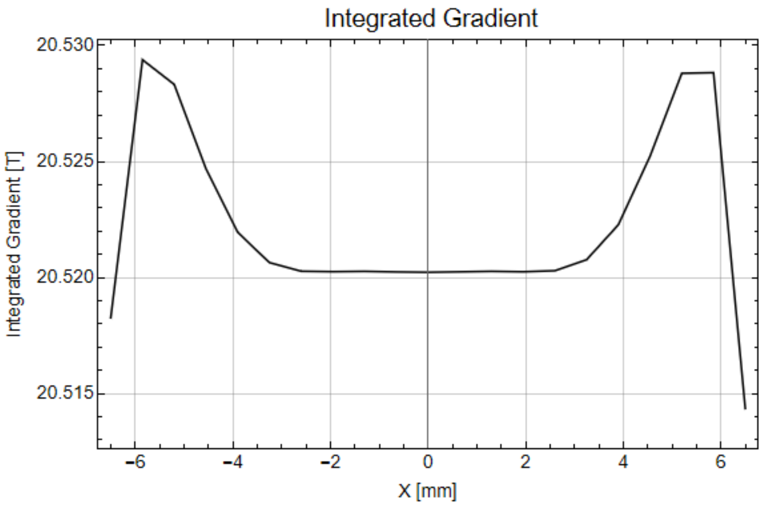
Mag T

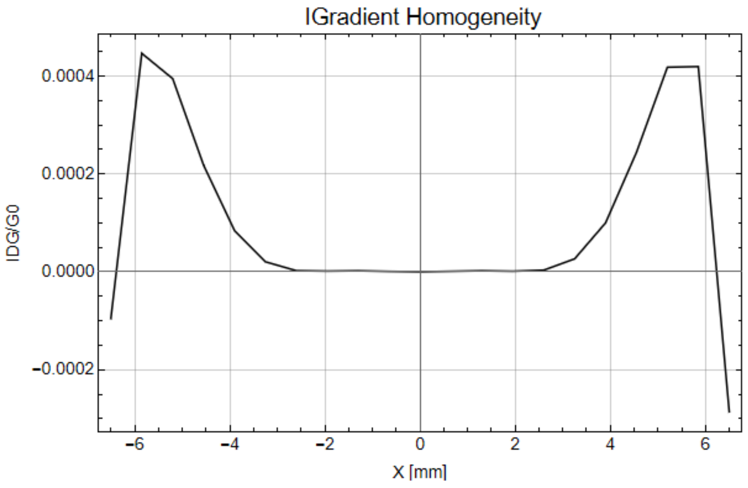


Hd Max = ~ 536 kA/m

Shape optimization Update

- Objective: DG/G0: 5.10^-4, GFR: 6.5mm
- Constraint: Limit Gradient reduction
- Constraint: Vertical Gap





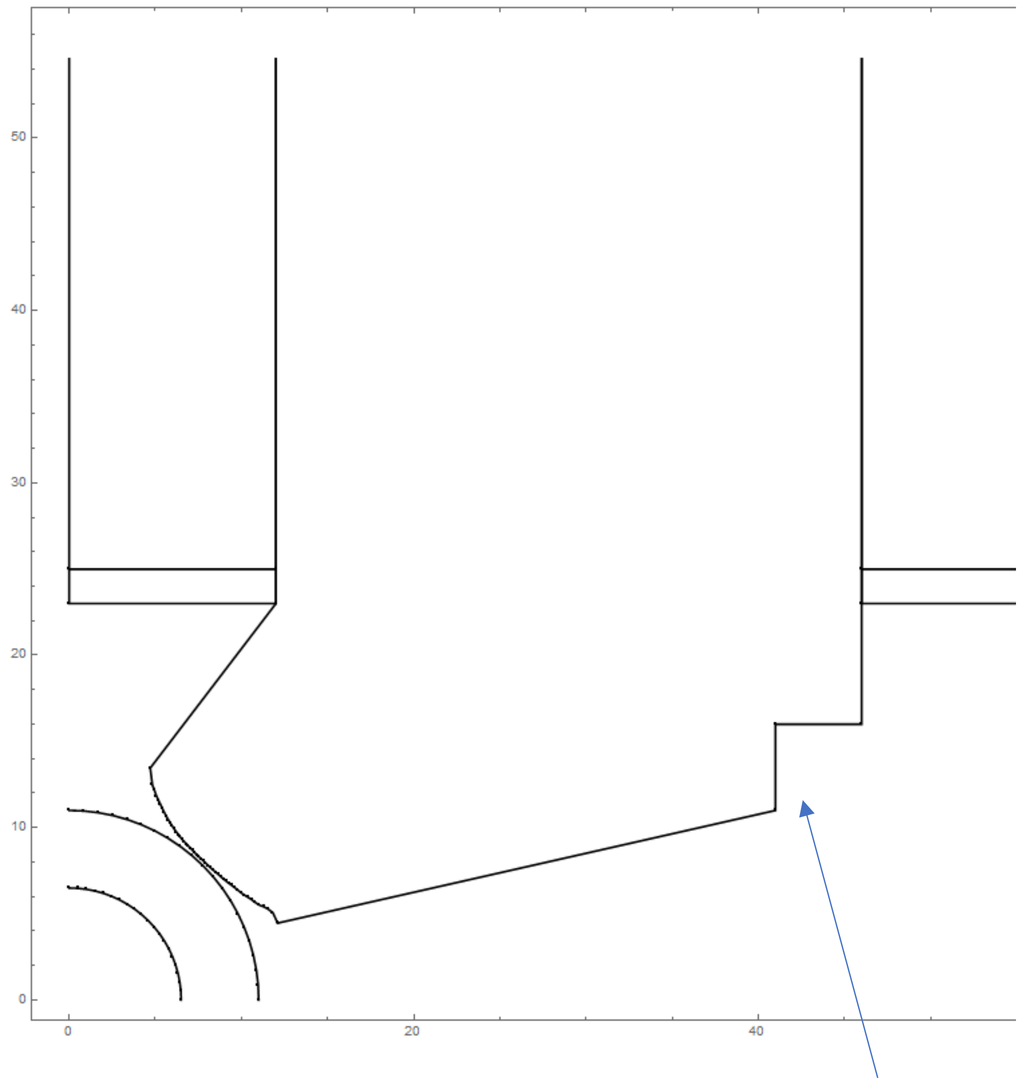
G= 121.4 T/m

Harmonics

1	0	0
2	0.133381	1.
3	0	0
4	4.72937×10^{-6}	0.0000354575
5	0	0
6	-0.0000464137	-0.000347977
7	0	0
8	0.000161125	0.001208
9	0	0
10	-0.000100488	-0.00075339
11	0	0
12	-4.22257×10^{-6}	-0.0000316577
13	0	0
14	1.69307×10^{-6}	0.0000126935
15	0	0

Sqrt[∑bn²]

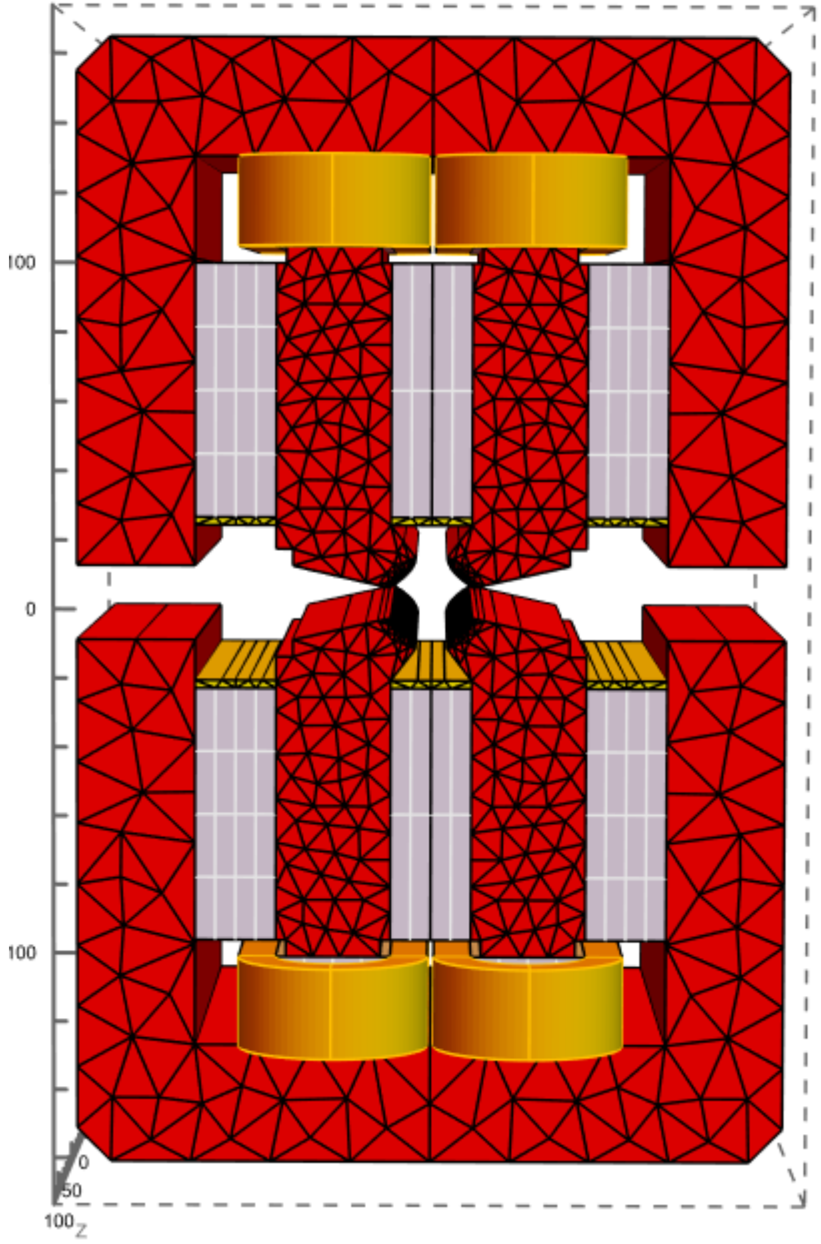
1.9x10^-4

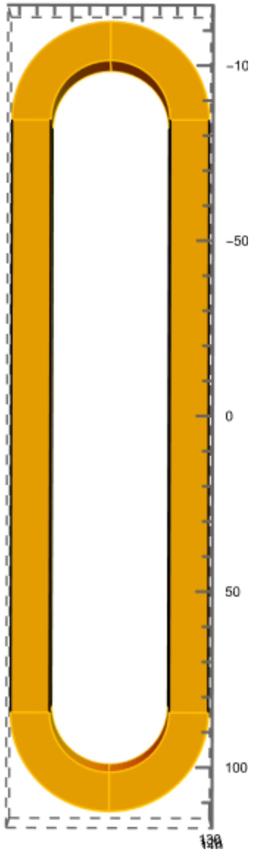


Vertical Gap: 8.8mm

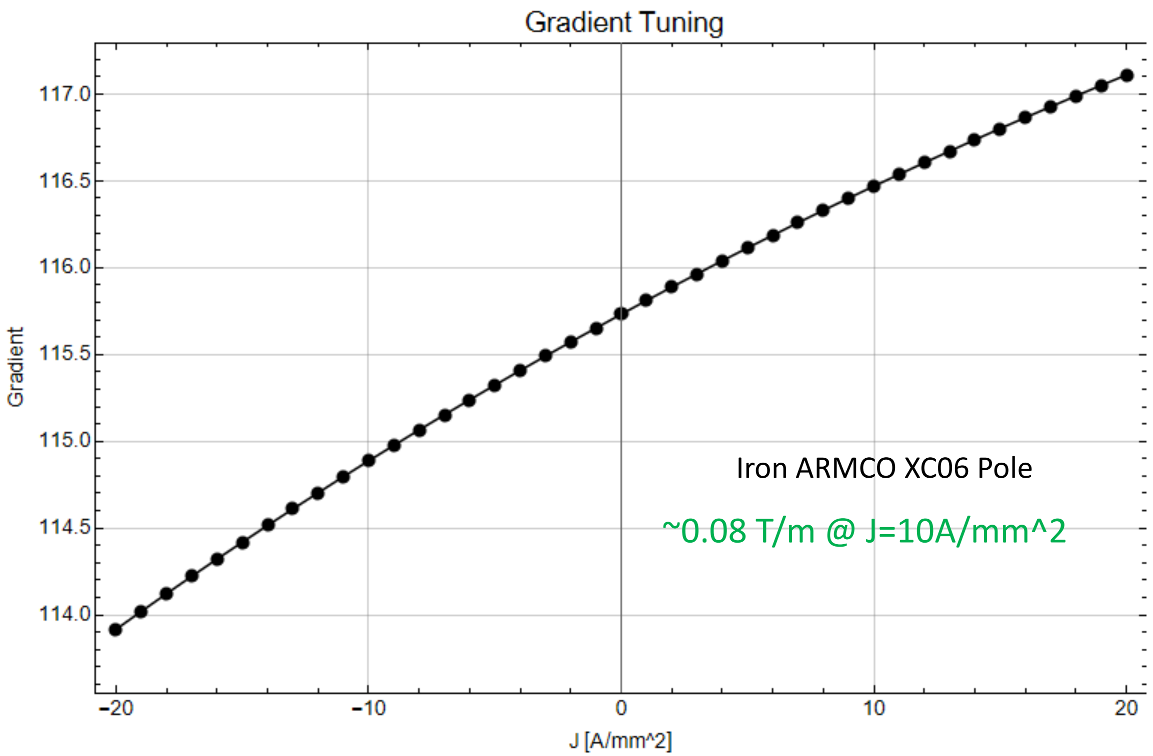
Cutout for Pole positioning

Gradient Tuning



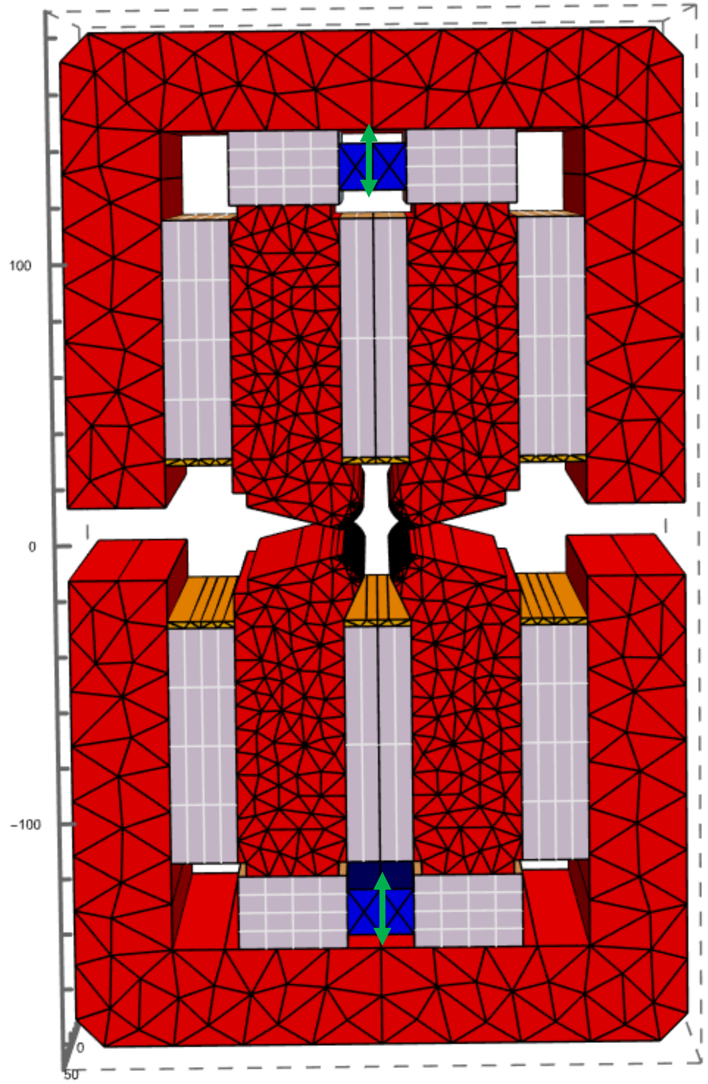


Tuning Coil

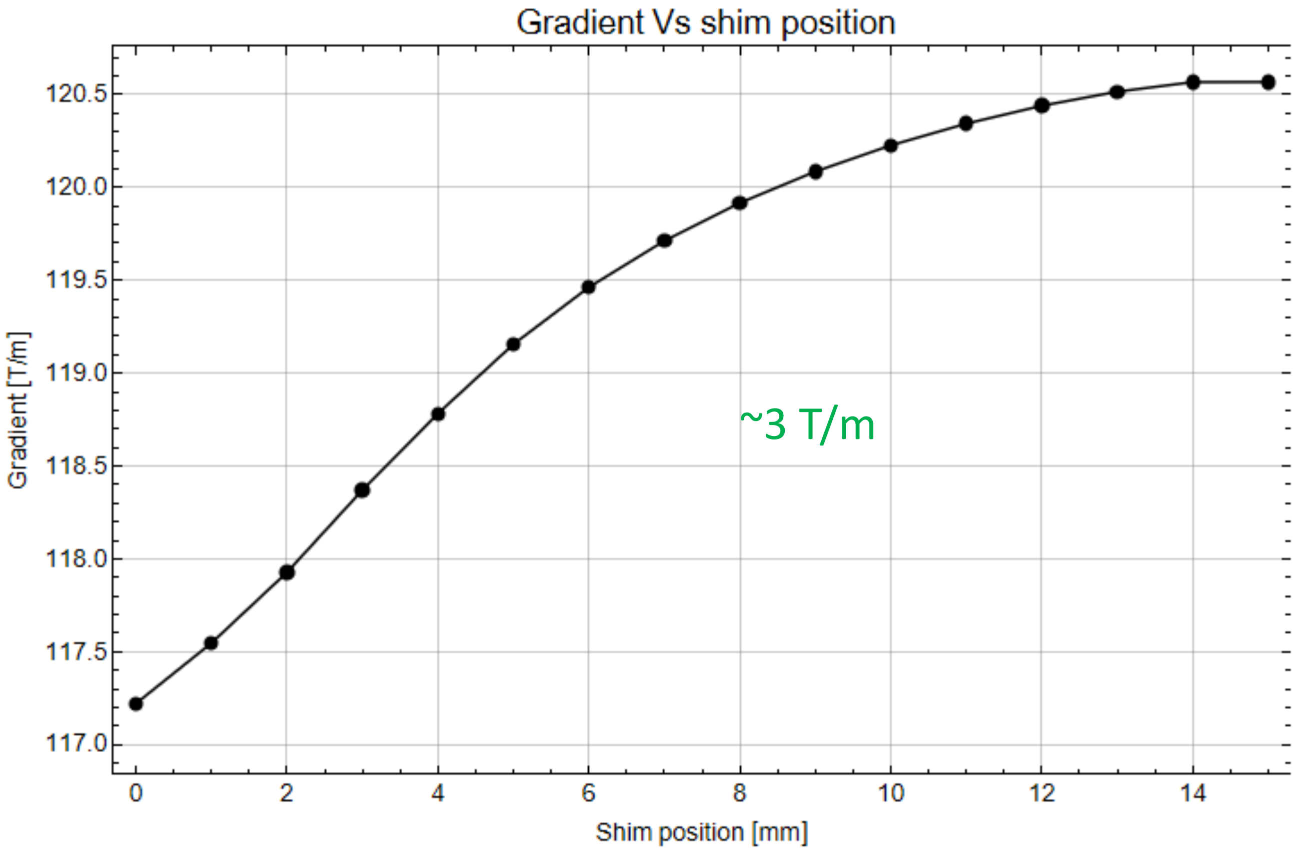


Tuning with top Permanent Magnet

Gradient Tuning

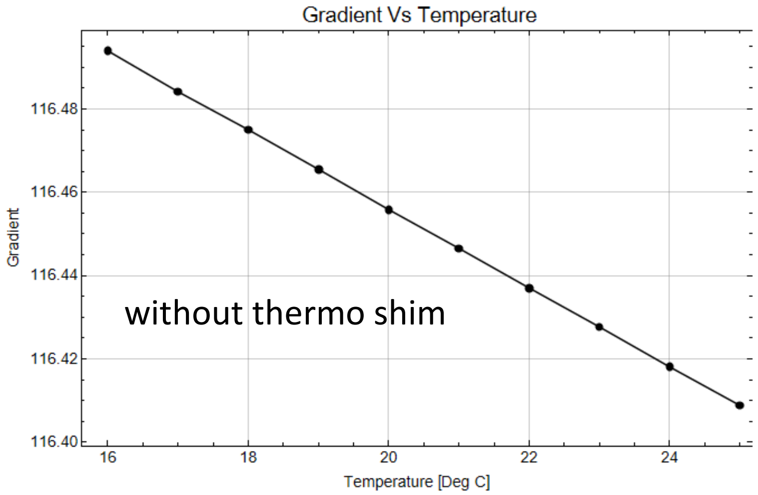


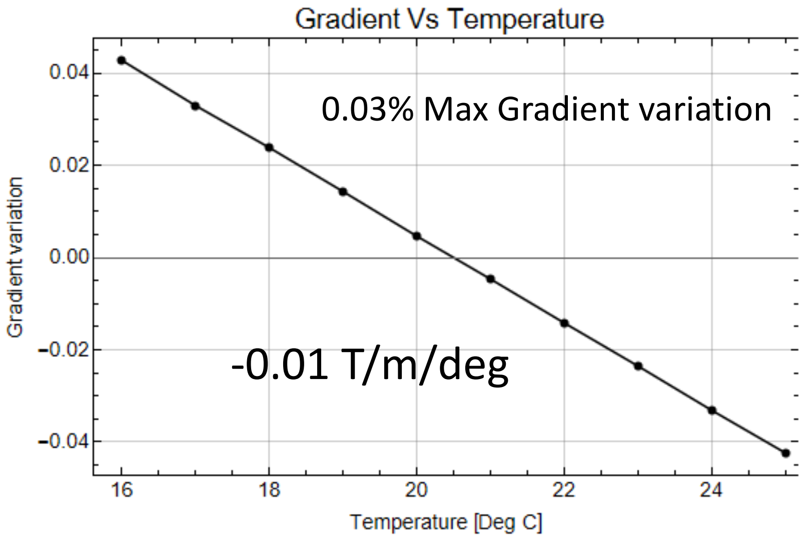
Moving Iron shim



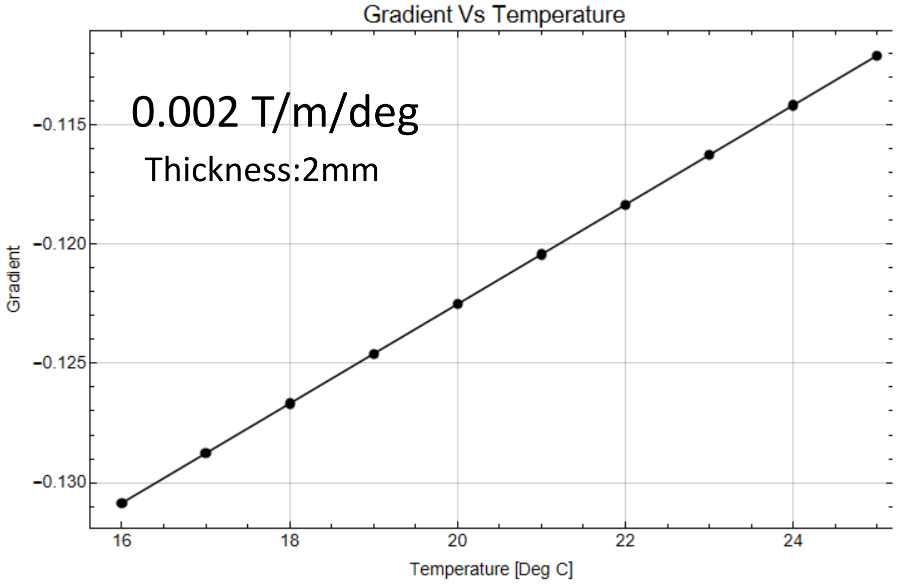
Temperature Compensation

- Temperature coefficient PM SmCo17: -0.033 %/deg
- Temperature coefficient thermo shim: -1.7 %/deg
- Thermal shim Thickness: 2mm

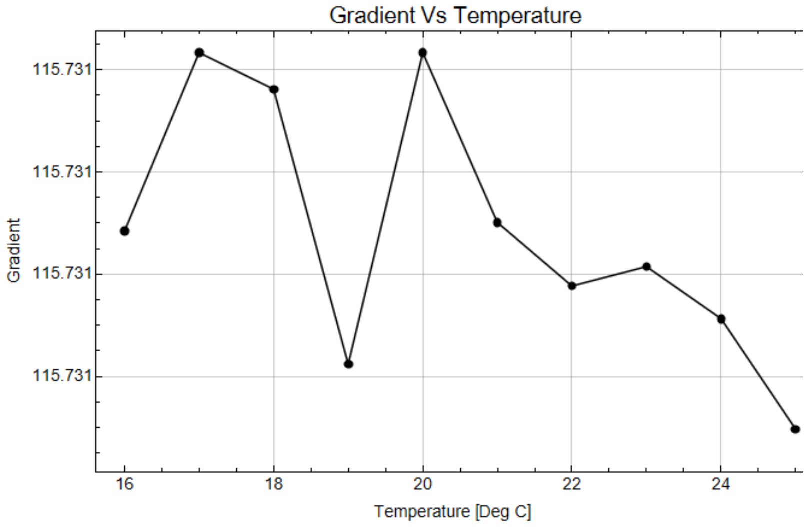


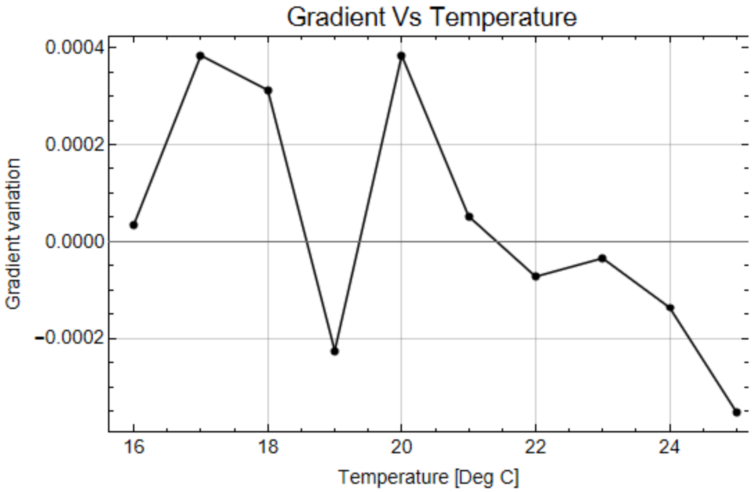


thermo shim Contribution



Compensated (thickness*1.18)





Next Work

- Sensitivity Study
- Correction strategy
- Mechanical Design
- Prototype…