PAUL SCHERRER INSTITUT

PSI

CHART

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Status of PSI Nb_3Sn Subscale Stress-Managed Common Coils Magnet

2nd joint common-coils meeting, August 2023

This work was performed under the auspices of and with support from the Swiss Accelerator Research and Technology (CHART) program (www.chart.ch).

Overview

- Goals and Parameters
- 3D Coil ends optimization
  - 2D vs 3D field quality
  - 3D optimization
- Progress on the engineering design
- Ongoing trials and modelling
- Planning

Subscale Stress-managed Common-coils Goals and Parameters

- The subscale magnet serves as a platform for validating design and optimization tools, as well as manufacturing and assembly processes.

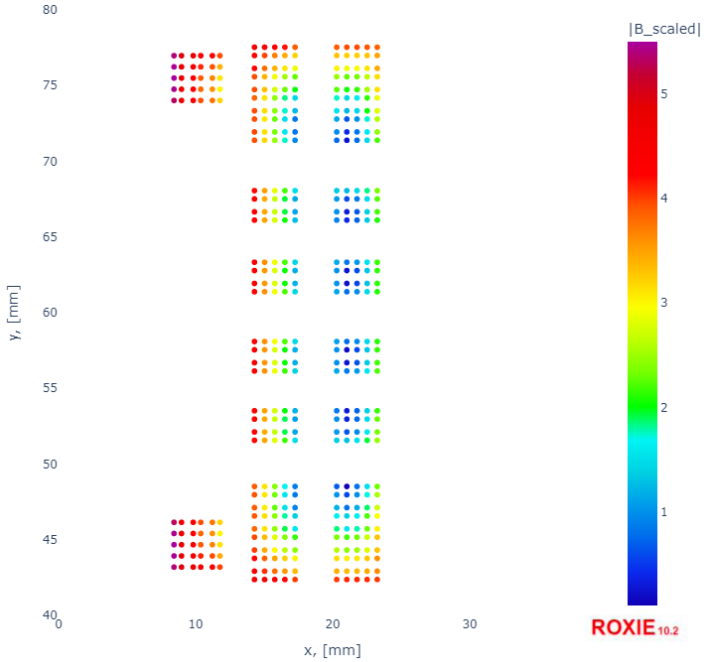
Cable & strand (LBNL Subscale CCT)		
Strand dia	0.6	mm
Number of strands	11	-
Bare dimensions	3.7 x 1.1	mm
Insulation thickness	0.155	mm
Cu/no-cu	1.17	

Goals		
Nominal Field B0	4 +	T
T operational	4.5	K
Max current	10.0	kA
Margin at Top and B_0	> 15	%

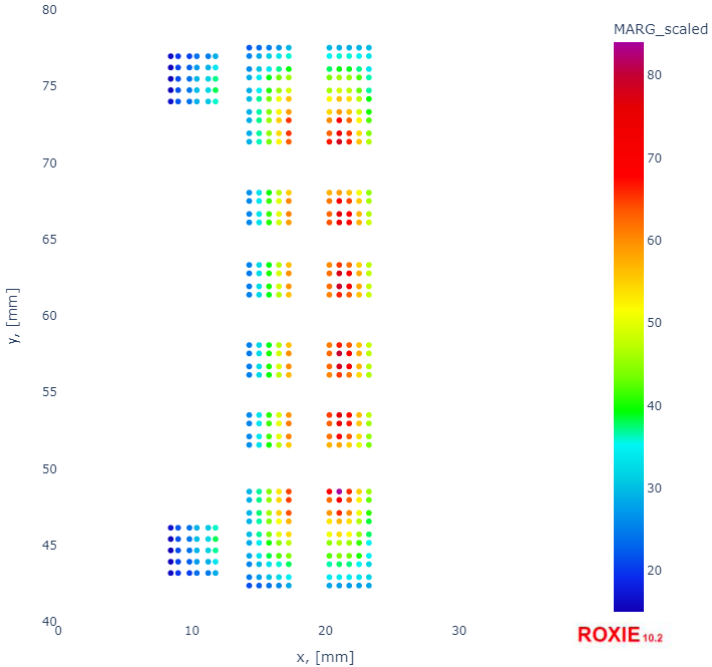
Dimensions		
Straight-Section	150	mm
Bore radius	22	
Intra-beam	120	
Total length	350	

2D Magnetostatics: B_0 = 4.5 T, I = 7.1 kA

- Peak field on conductor: 5.49 T



- Margin at 4.5 K: 15 %

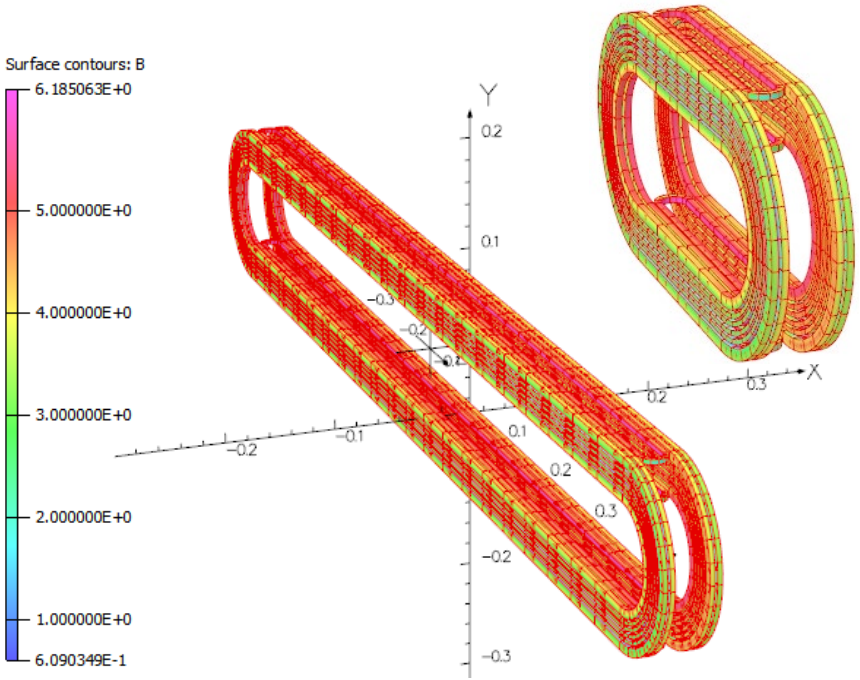


- Field Quality

Multi pole	Units
b3	-0.2
b5	-3.1
b7	3.8
b9	-1.
a2	0.9
a4	3.7
a6	-0.2
a8	0.0

3D Field Quality Computation

- 1 m and 150 mm long straight section

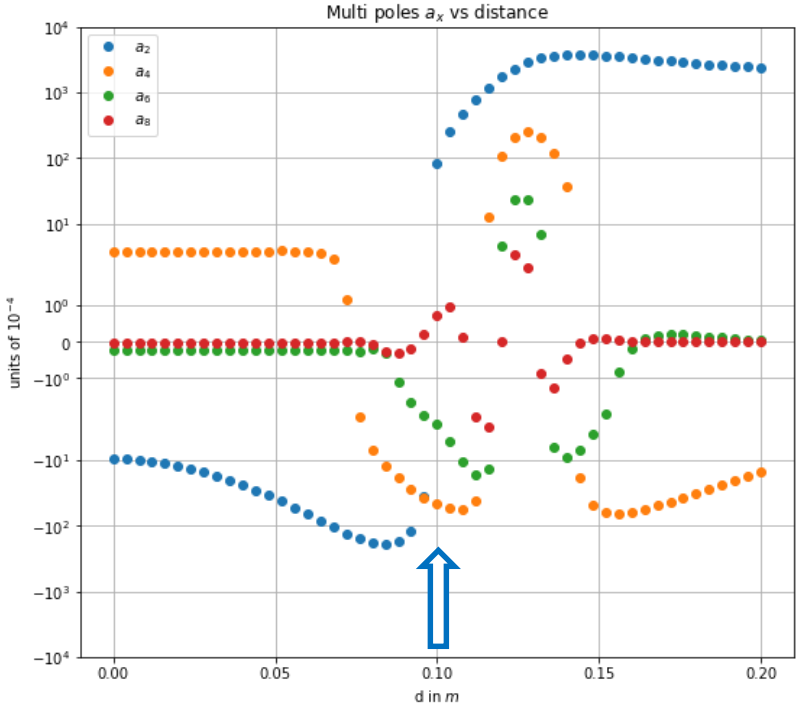


Multi-poles	Units			
-	2D	3D 1 m	3D 0.15 m	Integral
b3	-0.2	-0.62	-0.26	87.8
b5	-3.1	-3.34	-3.35	-1.2
b7	3.8	3.81	3.82	2.0
b9	-1.	-1.00	-1.00	-0.7
a2	0.9	0.89	-9.54	315.1
a4	3.7	3.71	3.72	5.67
a6	-0.2	-0.23	0.23	-0.8
a8	0.0	-0.01	-0.01	-0.1

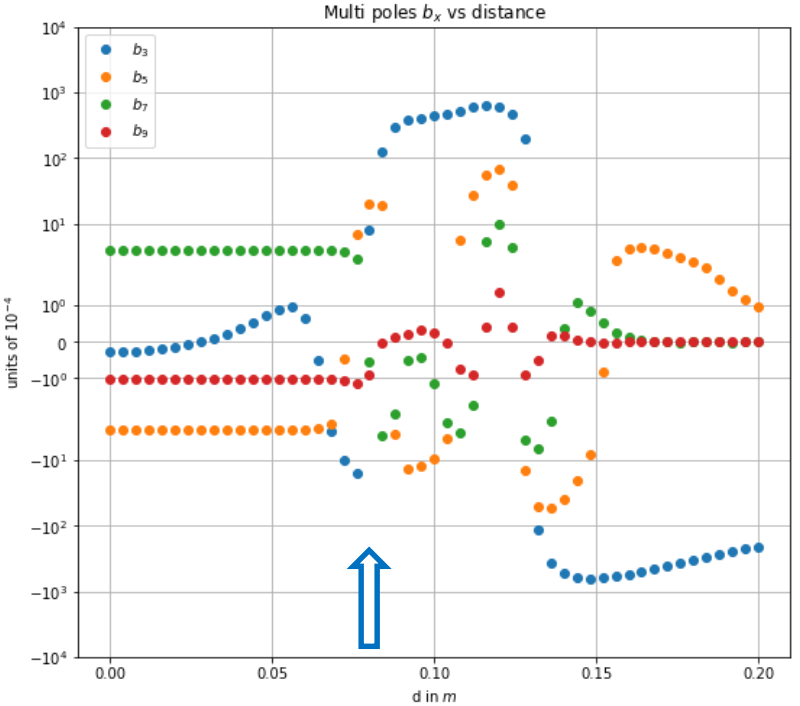
Cross-section

Needs optimization

Why does the sign of the integral change? 1/2

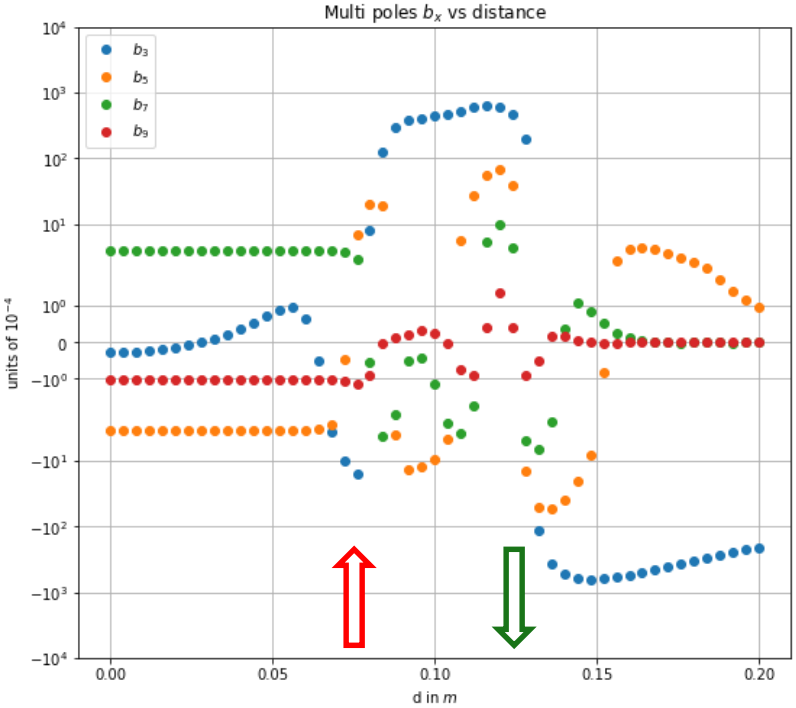


Integral a2 >> 0

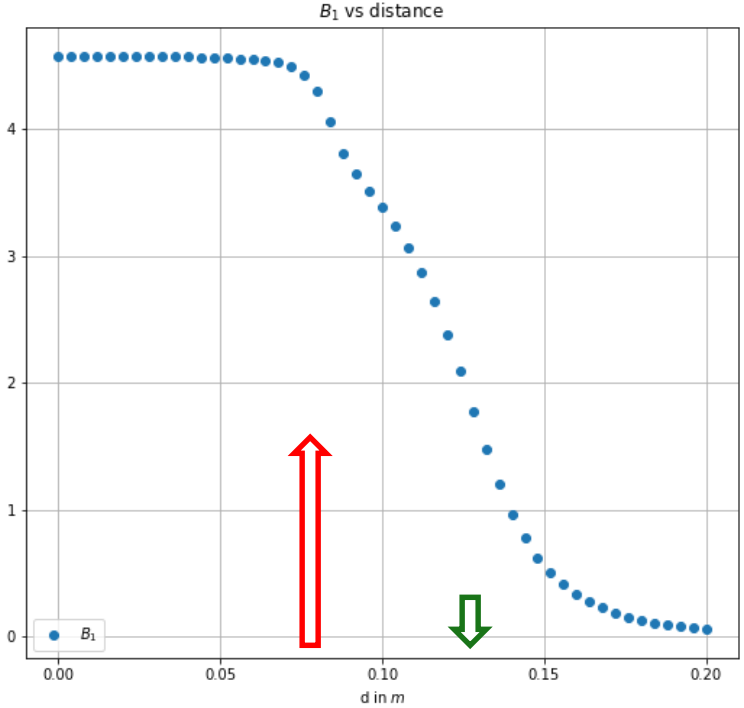


Integral b3 >> 0

Why does the sign of the integral change? 2/2

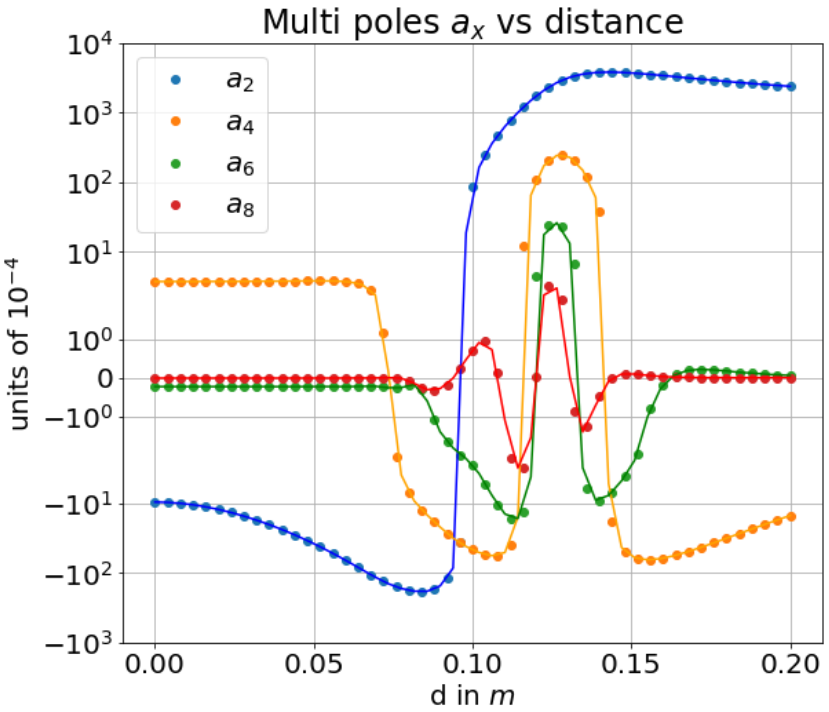


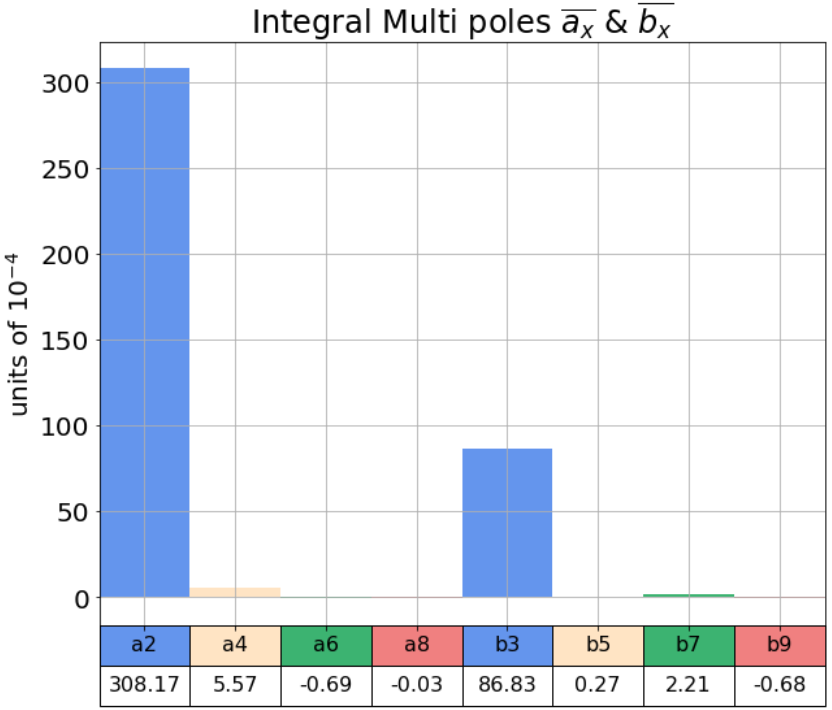
Integral b3 >> 0



big contribution vs small contribution

In order to optimize, how can we quickly calculate the integral?

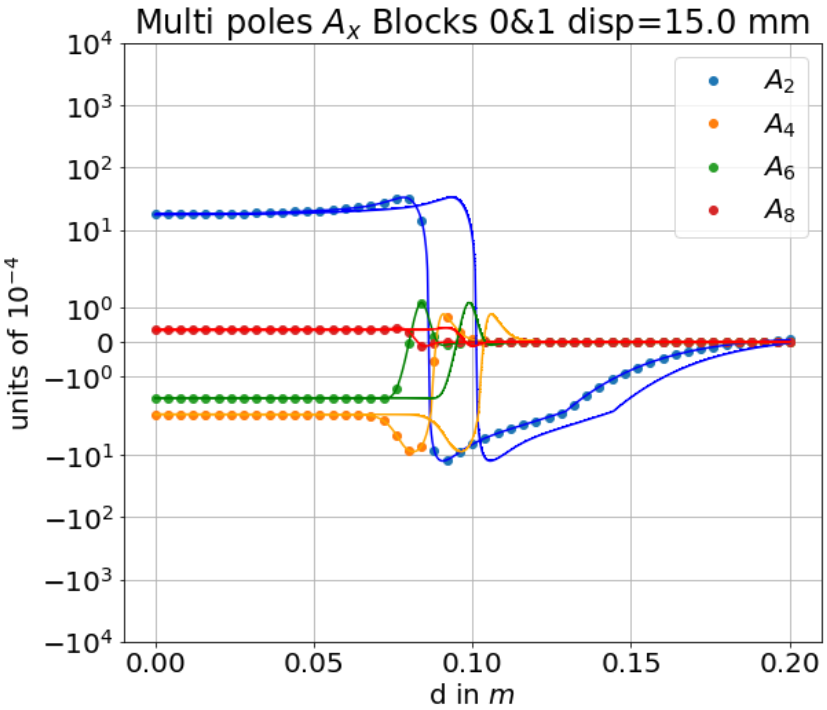


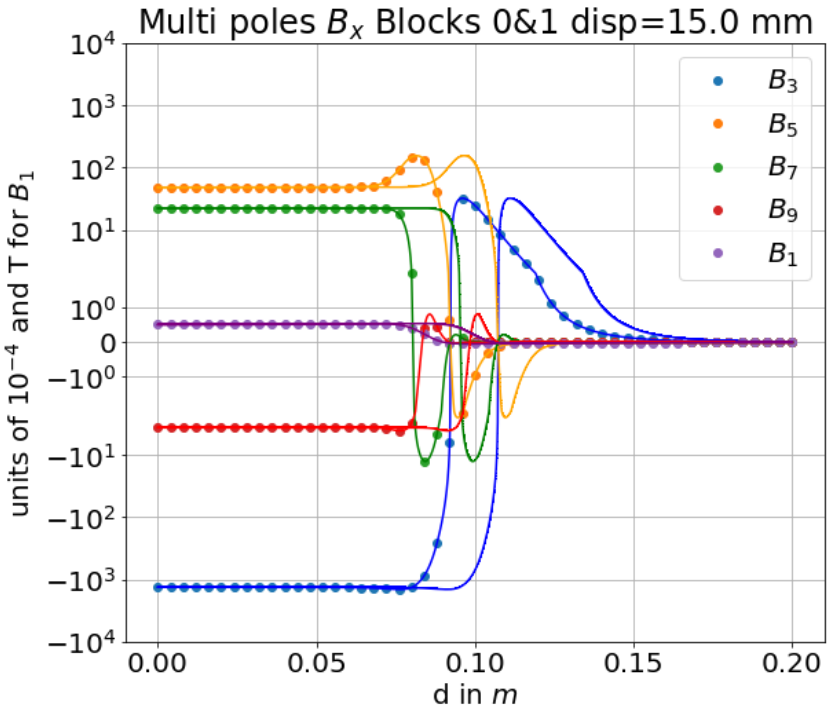


Cubic-spline interpolation

Integration over the interpolated function

Blocks' contribution and displacement

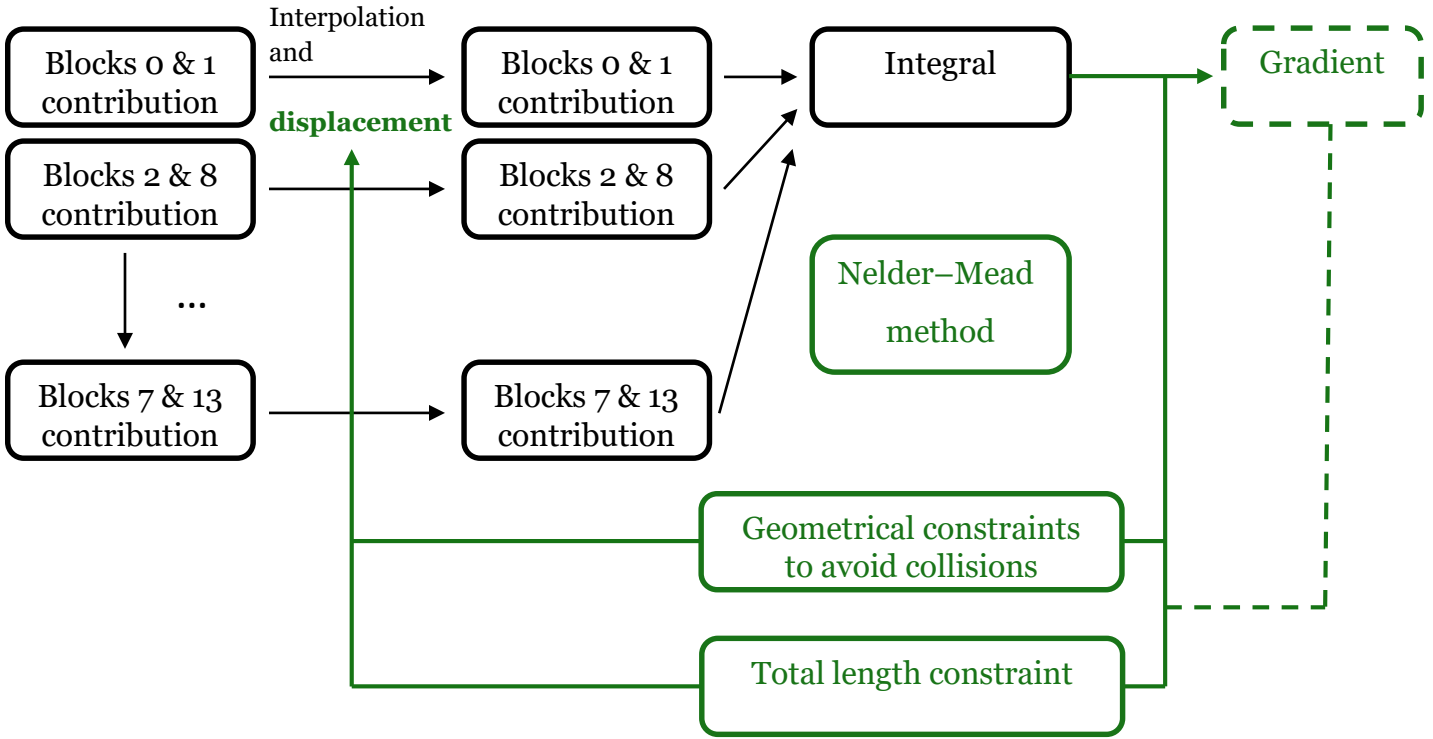




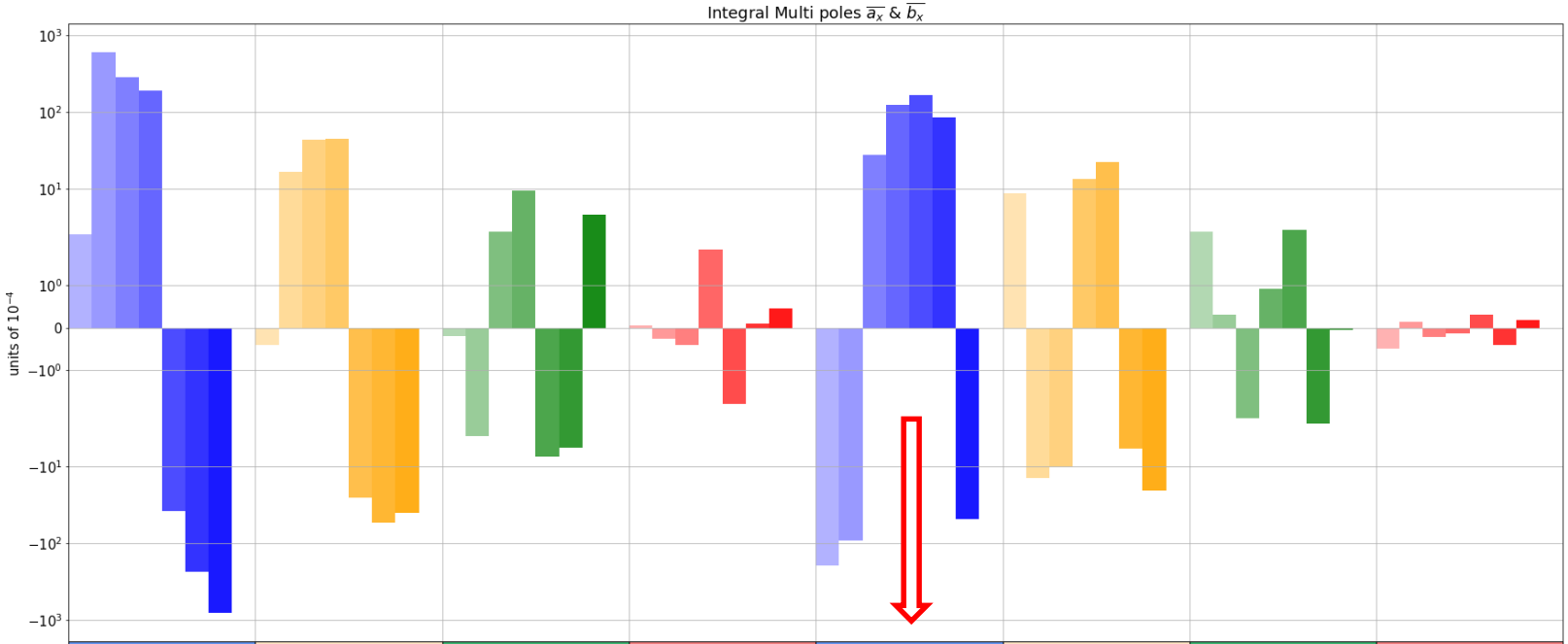
Cubic-spline interpolation and shift on the axial direction

B1 is also displaced to allow the integral computation

Optimization scheme

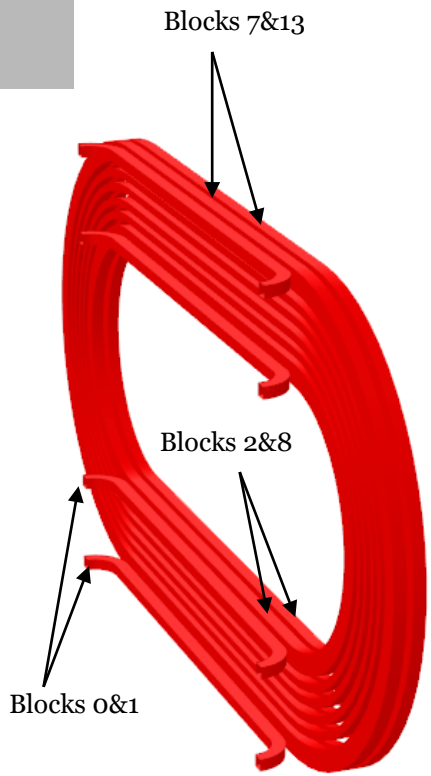


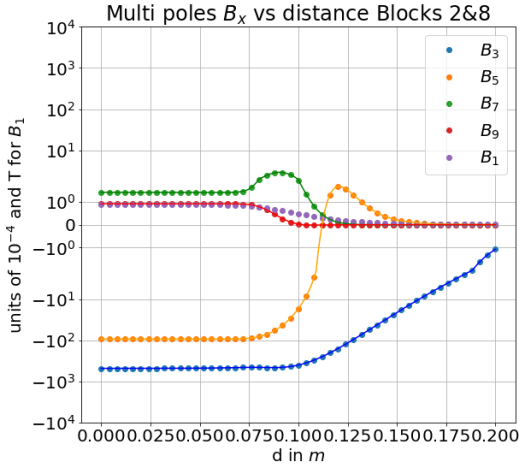
Result: sum of multi poles = 101.18

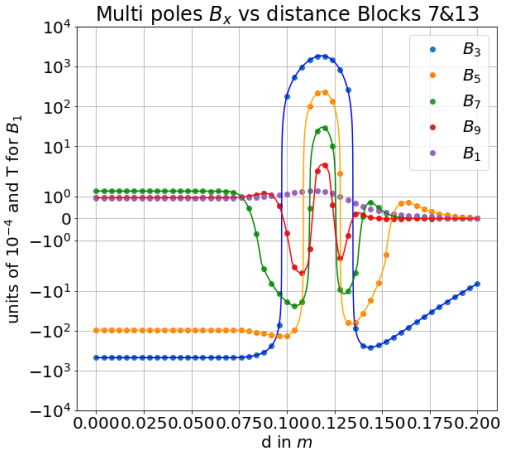


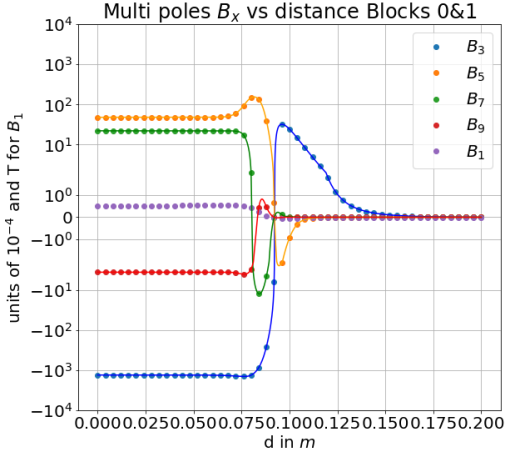
	$\overline{a_2}$ = -0.0	$\overline{a_4}$ = -14.2	$\overline{a_6}$ = -0.6	$\overline{a_8}$ = -0.0	$\overline{b_3}$ = 72.7	$\overline{b_5}$ = -5.6	$\overline{b_7}$ = 1.8	$\overline{b_9}$ = -0.6
Blocks 0 & 1	2.53	-0.42	-0.2	0.05	-193.56	8.88	2.78	-0.5
Blocks 2 & 8	609.39	16.65	-4.06	-0.26	-92.28	-14.25	0.31	0.14
Blocks 3 & 9	286.71	43.86	2.79	-0.4	28.09	-9.97	-2.36	-0.22
Blocks 4 & 10	193.77	45.2	9.45	1.84	125.53	13.39	0.91	-0.12
Blocks 5 & 11	-38.14	-25.53	-7.52	-1.79	166.16	22.74	2.96	0.3
Blocks 6 & 12	-237.78	-53.48	-5.63	0.1	86.82	-5.83	-2.77	-0.4
Blocks 7 & 13	-816.48	-40.49	4.6	0.46	-48.04	-20.61	-0.04	0.19

b3 example: blocks able to decrease it







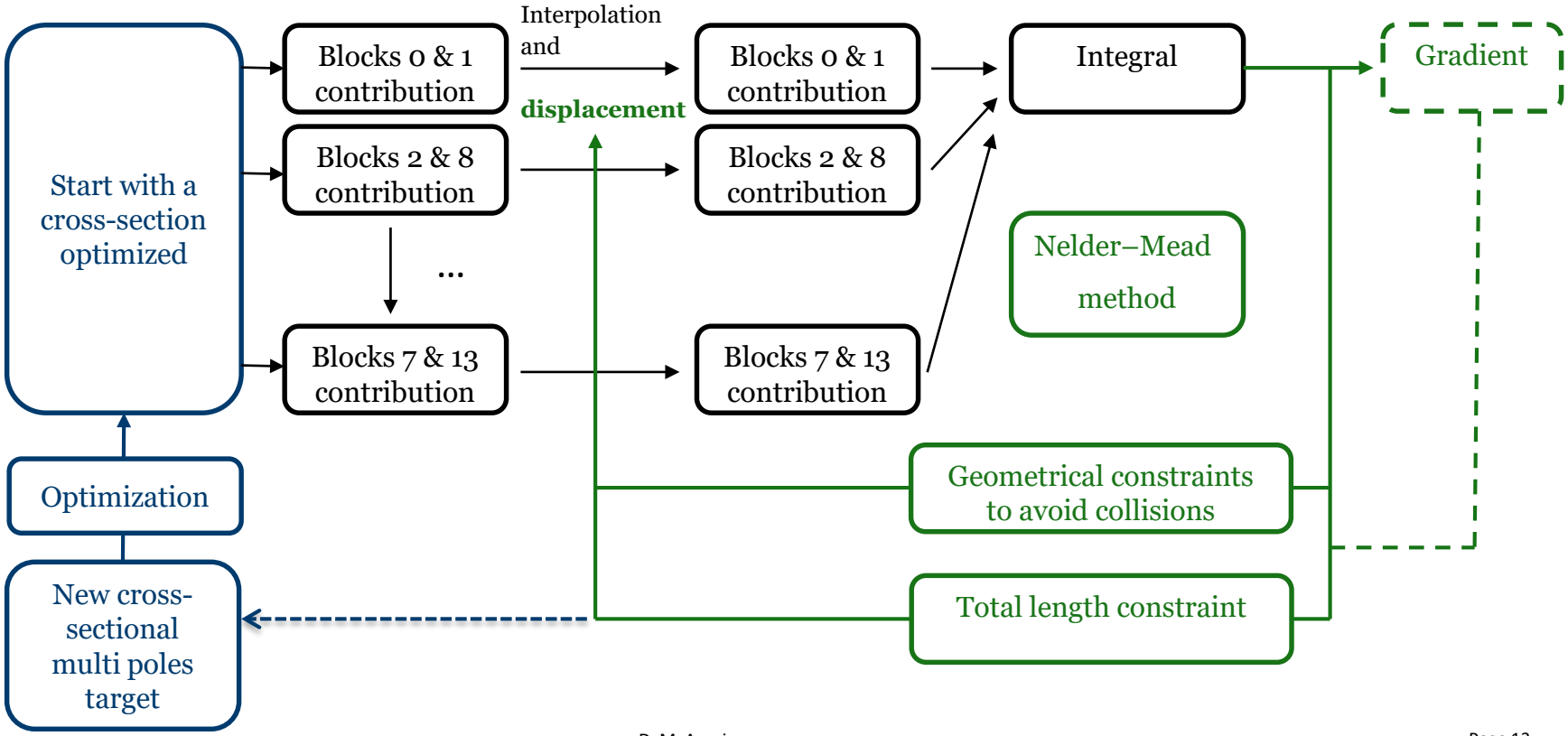


Blocks 2&8: increasing their length would shift the entirely coil pack

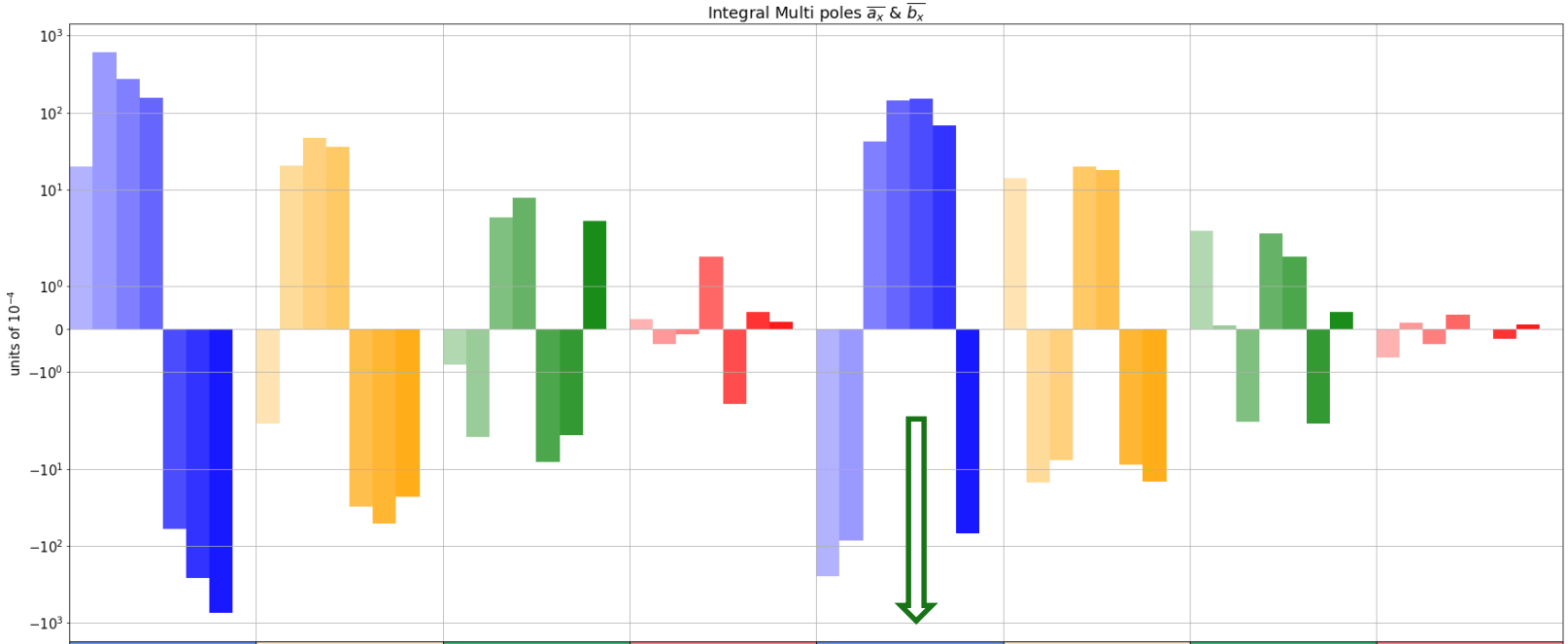
Blocks 0&1: increasing their length helps but they contribute little to B1

Blocks 7&13: increasing their length increases this block length but not the whole magnet

Optimization scheme 2

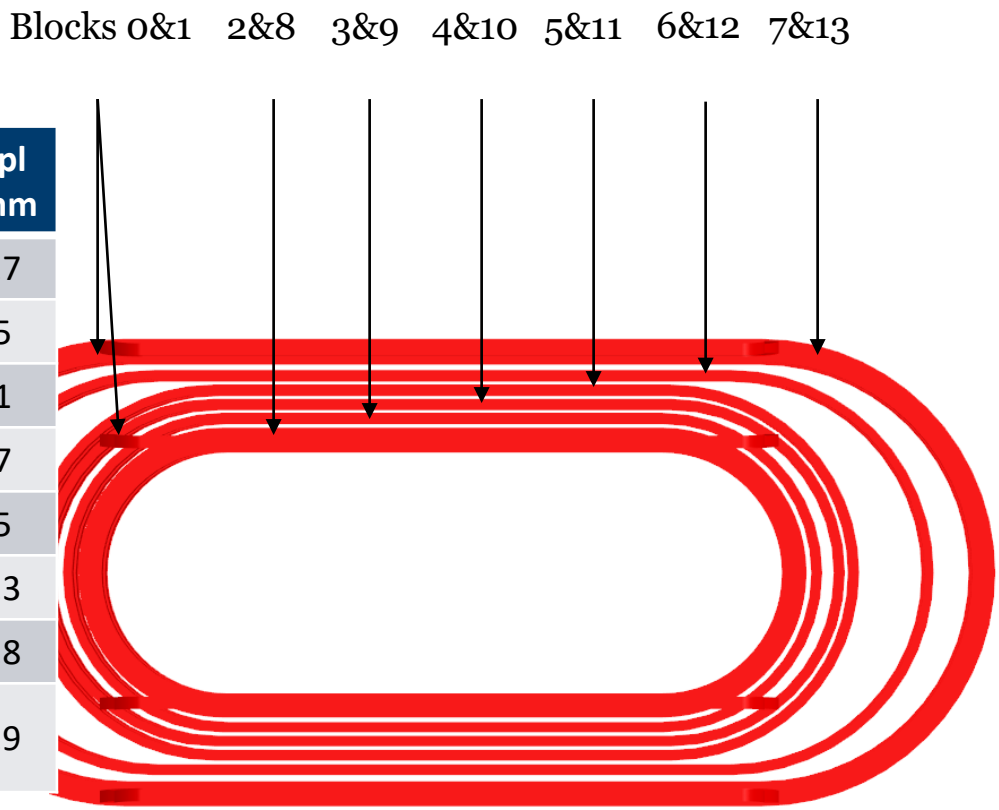


Result 2: sum of multi poles = 15.76



	$\overline{a_2}$ = -4.4	$\overline{a_4}$ = -3.7	$\overline{a_6}$ = -0.3	$\overline{a_8}$ = 0.3	$\overline{b_3}$ = 4.4	$\overline{b_5}$ = 5.3	$\overline{b_7}$ = 2.8	$\overline{b_9}$ = -0.6
Blocks 0 & 1	20.05	-2.58	-0.82	0.24	-244.76	13.95	2.96	-0.65
Blocks 2 & 8	607.79	20.41	-3.91	-0.34	-85.83	-15.15	0.1	0.14
Blocks 3 & 9	275.31	46.86	4.35	-0.12	42.38	-7.74	-2.49	-0.35
Blocks 4 & 10	157.47	35.97	7.88	1.7	144.6	19.78	2.72	0.33
Blocks 5 & 11	-60.04	-30.77	-8.15	-1.74	150.2	17.99	1.69	0.01
Blocks 6 & 12	-262.31	-50.69	-3.65	0.41	67.21	-8.95	-2.56	-0.23
Blocks 7 & 13	-742.69	-22.9	3.98	0.18	-69.4	-14.58	0.4	0.11

Optimized geometry



Blocks	Displ in mm
0 & 1	27.7
2 & 8	0.5
3 & 9	0.1
4 & 10	3.7
5 & 11	0.5
6 & 12	24.3
7 & 13	34.8
Total 2-13	63.9

Multi-poles	Units	
-	Cross-section	Integral
b3	0.6	4.3
b5	8.6	5.3
b7	4.2	2.8
b9	- 0.8	-0.6
a2	- 35.4	-3.2
a4	11.3	-3.7
a6	-1.0	-0.3
a8	0.2	-0.3

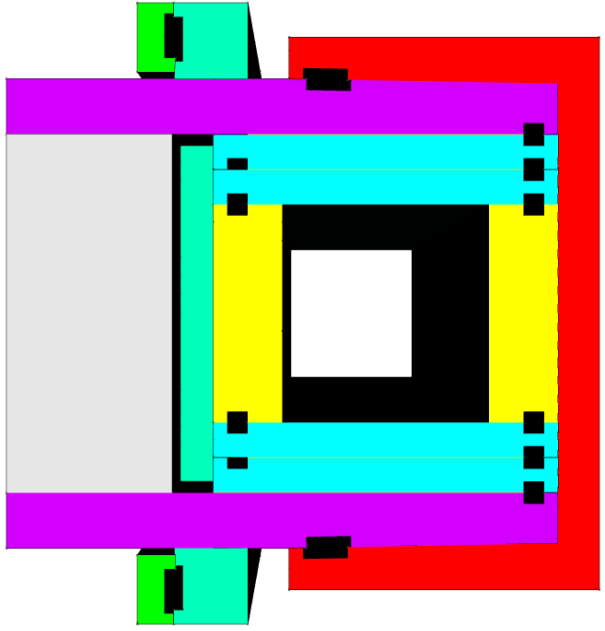
Optim 2

Progress on the engineering design

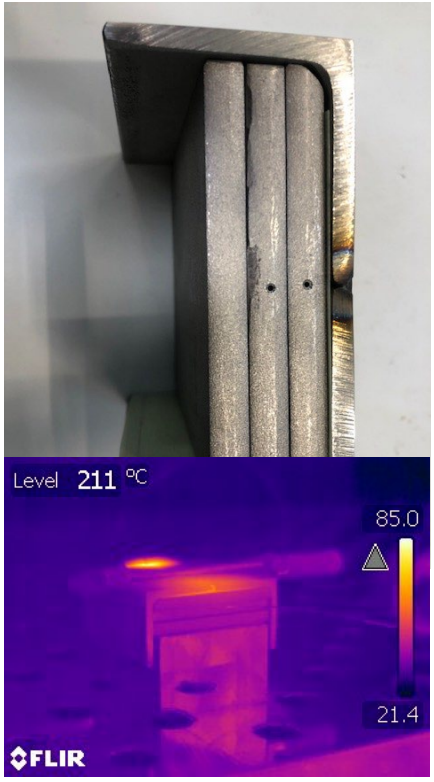
- T. Michlmayr

Ongoing magnet structure trials and modelling

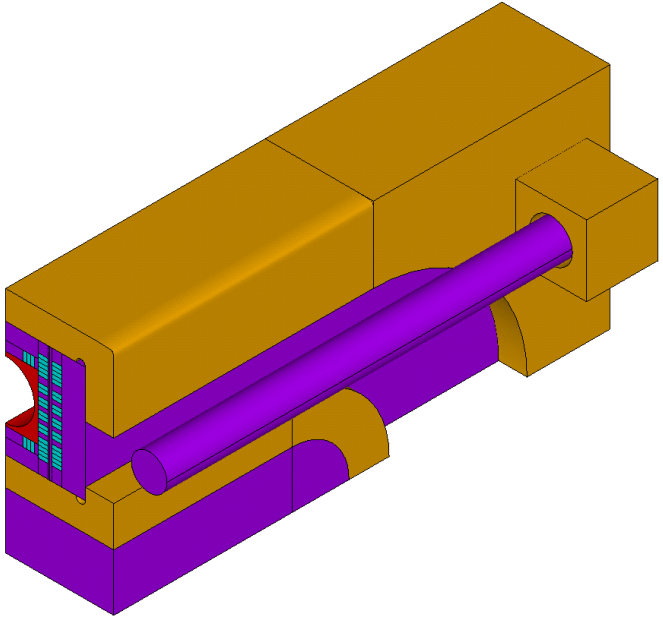
- Assembling



- Welding trials



- 3D mechanics



Planning: June 2023 version

Task	July					August				September				October					November				December				January					February			
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9
Engineering Design																																			
Procurement of Coil Components																																			
1st Coil Ceramic coating and winding																																			
1st Coil HT																																			
1st Coil Intrumentation																																			
2nd Coil Ceramic coating and winding																																			
2nd Coil HT																																			
2nd Coil Intrumentation																																			
1st and 2nd Coils splice and impregnation																																			
3rd Coil Ceramic coating and winding																																			
3rd Coil HT																																			
3rd Coil Intrumentation																																			
4th Coil Ceramic coating and winding																																			
4th Coil HT																																			
4th Coil Intrumentation																																			
3rd and 4th Coils splice and impregnation																																			
Coils Outer Splices																																			
Magnet Structure: intrumentation																																			
Magnet Structure: assembly with dummy Coils																																			
Magnet Assembly and Final Checks																																			
Shipment																																			
Jun-23				Thomas Holidays							MT 28							HF M			CAS				Break										