Q2pF Design for 4K Option

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a passion for discovery

Overview

- Design studies completed for now for Q2pF. Several cases examined but only the chosen one will be presented.
- Operation at 4.2K/4.6K. Peak field (margin), field quality and field in the electron beam region optimized.
- The optimized design benefits from the feedback from the last meeting on the geometric, mechanical, magnetic design.
- Strand/wire used: dia =1.065 mm, Cu/Sc =1.6.
- Cable: 19.4 mm wide (19.7 with insulation) with 36 strands, min thickness: 1.788 mm, max thickness: 2.012 mm.
- We will "try" to use this cable (and RHIC dipole type cable) for all EIC magnets.
- Initial discussion on B1ApF and B0ApF.

Chosen Cable Design (ROXIE)

Strand

No	Name	diam.	cu/sc	RRR	Tref	Bref	Jc@BrTr	dJc/dB	Comment
3	STREIC1	1.065	1.6	70	1.9	10	1591	500.34	EIC BRUKER-CERN SCALED,7%DEGRA
1	STR01	1.065	1.6	70	1.9	10	1433.3	500.34	MB INNER
2	STR02	0.825	1.9	80	1.9	9	1953	550.03	MB OUTER, MQ

Cable Geometry

No	Name	height	width_i	width_o	ns	transp.	degrd	Comment
1	EIC3642A	19.4	1.788	2.012	36	115	3	EIC 36 STRAND @4.2K 2 Layers

Cable Definition

No	Name	Cable Geom.	Strand	Filament	Insul	Trans	Quench Mat.	T_o	Comment
42	EIC3618	EIC3618	STREIC1	NBTII	ALLPOLYIL	NONE	NONE	1.8	EIC CABLE 36 STRAND, 1.8K
43	EIC3642	EIC3642	STREIC1	NBTII	ALLPOLYIL	NONE	NONE	4.2	EIC CABLE 36 STRAND, 4.2K
44	EIC3642A	EIC3642A	STREIC1	NBTII	ALLPOLYIL	NONE	NONE	4.2	EIC CABLE 36 STRAND, 4.2K
45	EIC3642B	EIC3642A	STREIC1	NBTII	ALLPOLYIL	NONE	NONE	4.6	EIC CABLE 36 STRAND, 4.6K

Strand dia =1.065 mm; 36 strands in cable

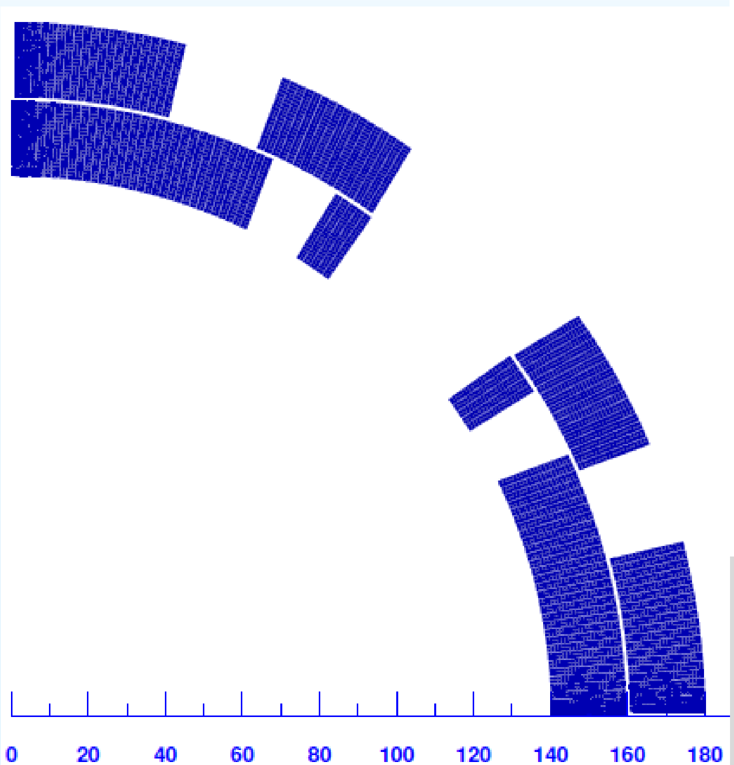
Cu/Sc =1.6, width 19.4 mm (bare)

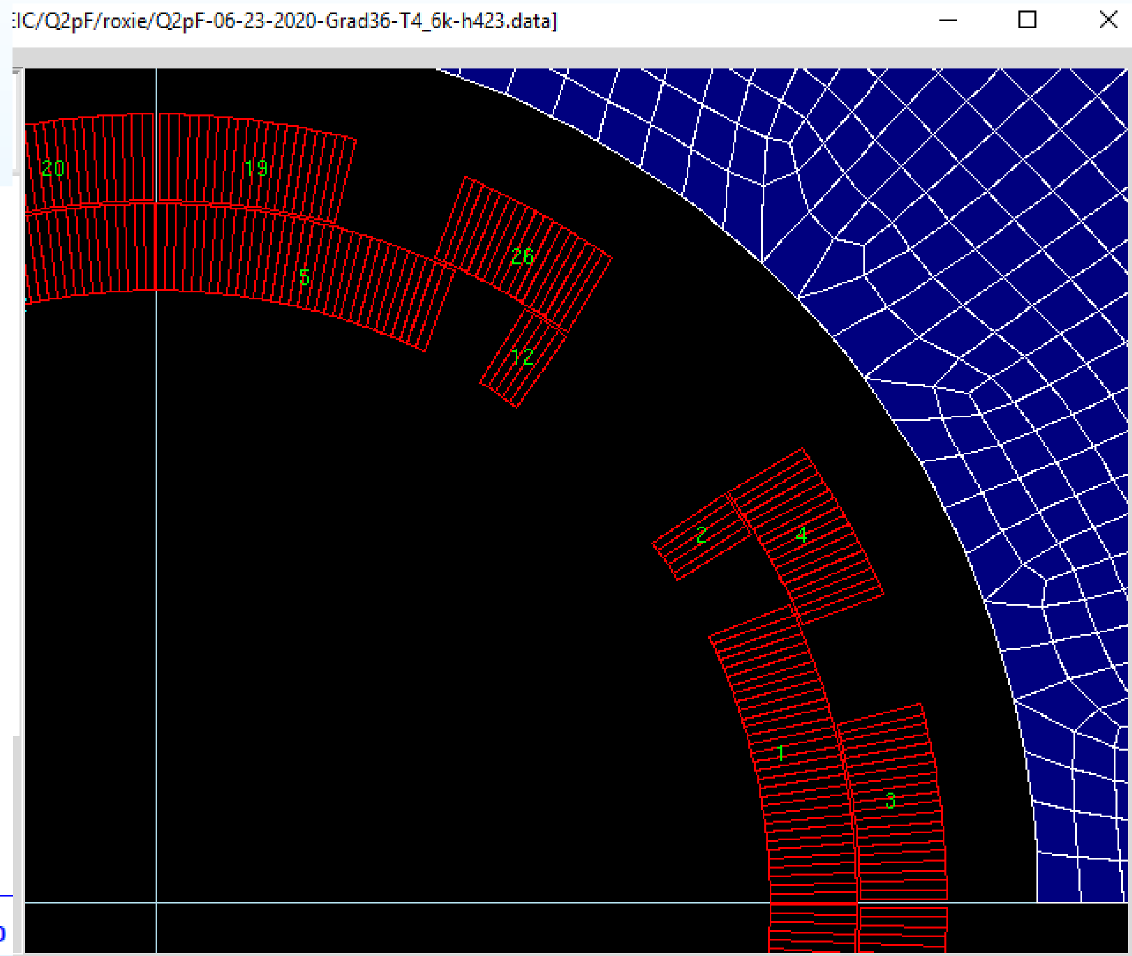
Operating Temperature: 4.2 K / 4.6 K

Coil 2 Layers, one wedge in each layer 73 turns/pole (36 inner, 37 outer)

- Poles of inner and outer layers aligned
- Coil poles have proper angles for collaring

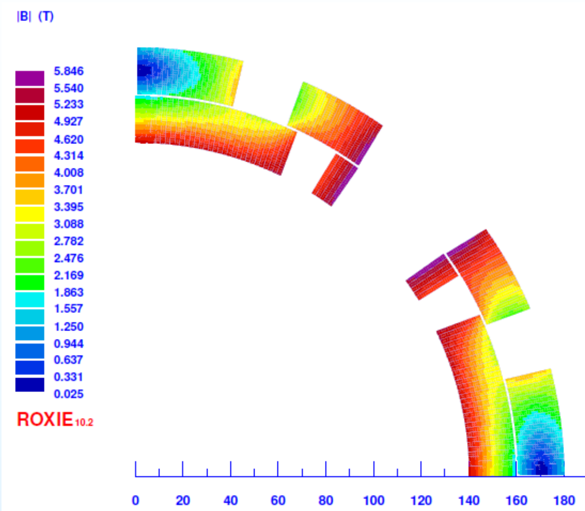
Coil radius: 140 mm





Field Harmonics in Q2pF

A good field quality can be obtained with the restriction of designing the cross-section for a good mechanical design
(all harmonics <1 unit)



REFERENCE RADIUS (mm) .... 83.

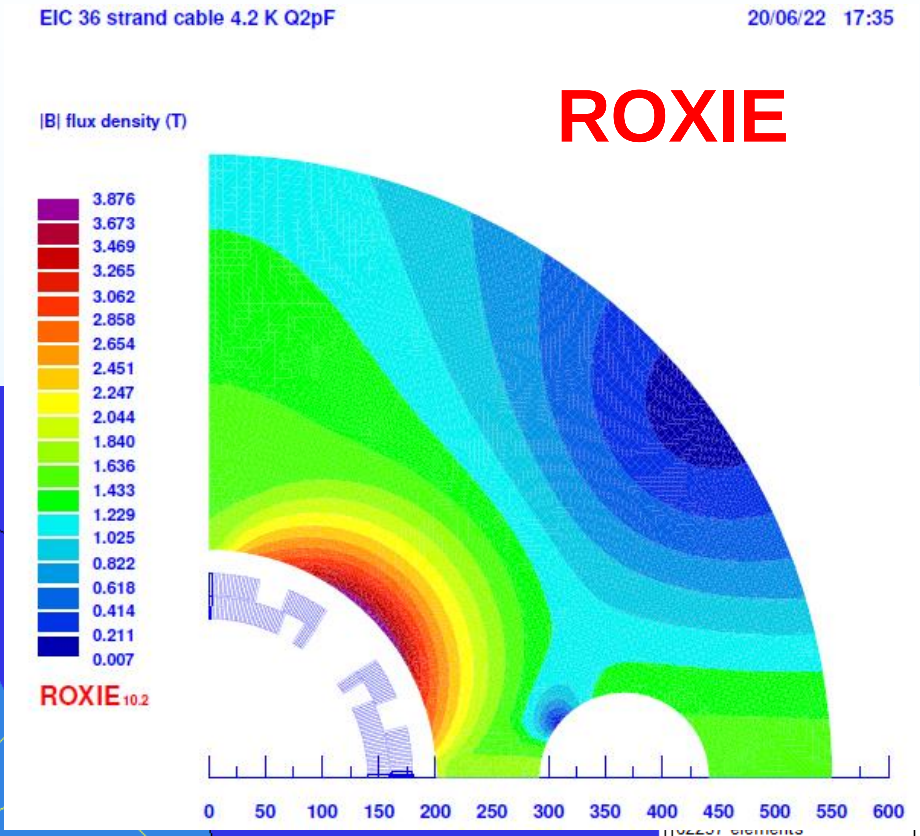
MAGNET STRENGTH (T/(m^(n-1)) 36.0373

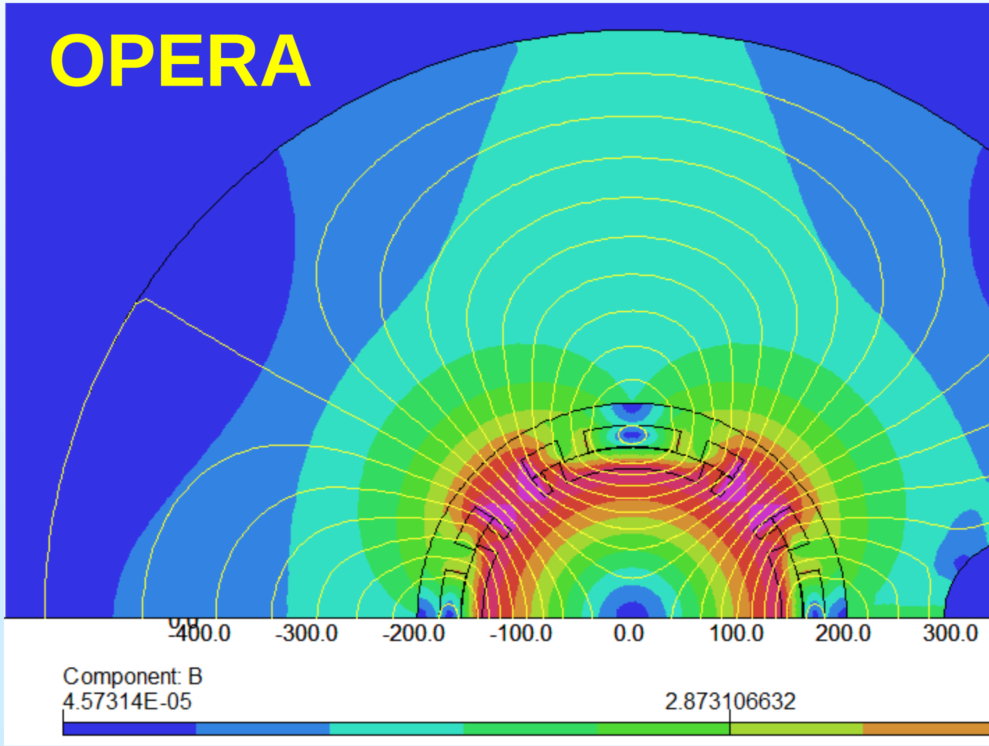
NORMAL RELATIVE MULTIPOLES (1.D-4):

b 1:	-0.00000	b 2:	10000.00000	b 3:	-0.00000
b 4:	-0.04348	b 5:	0.00000	b 6:	-0.36357
b 7:	0.00000	b 8:	-0.00184	b 9:	-0.00000
b10:	0.62176	b11:	-0.00000	b12:	-0.00007
b13:	0.00000	b14:	-0.22463	b15:	-0.00000
b16:	-0.00000	b17:	0.00000	b18:	0.01234

Iron Yoke – Current Design

Yoke: ir = 201 mm; or = 550 mm
Hole@ x = 366.8 mm to 423 mm
Radius of hole = 75 mm
Collar width = 20 mm for 36 T/m





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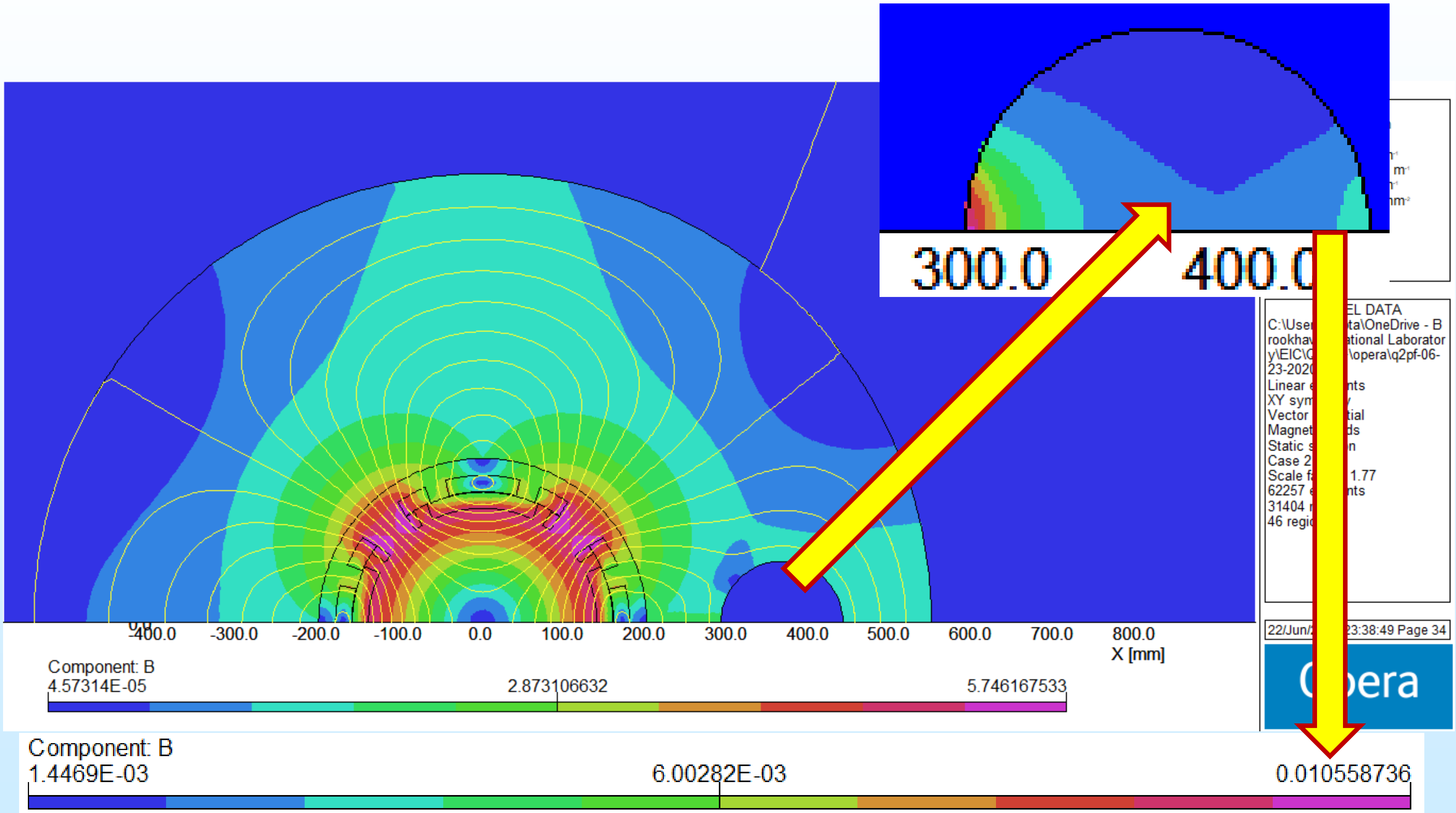
Field in the electron beam region (1)
Yoke OR = 550 mm, Hole@366.8 mm



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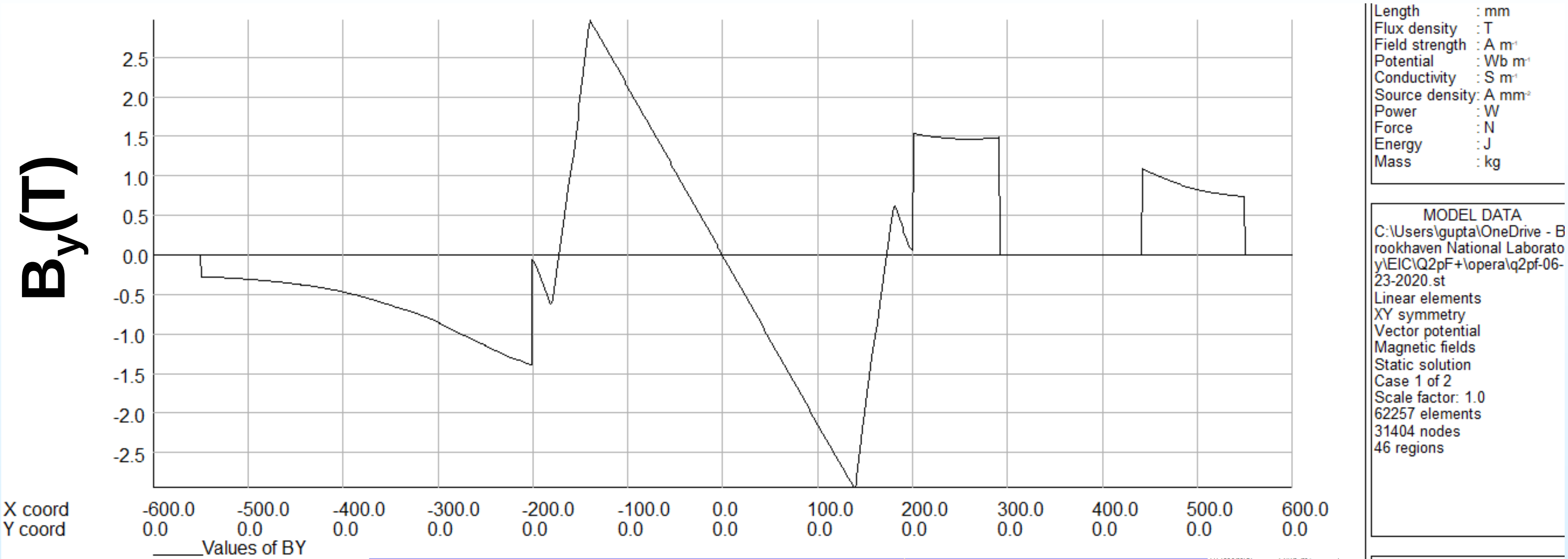
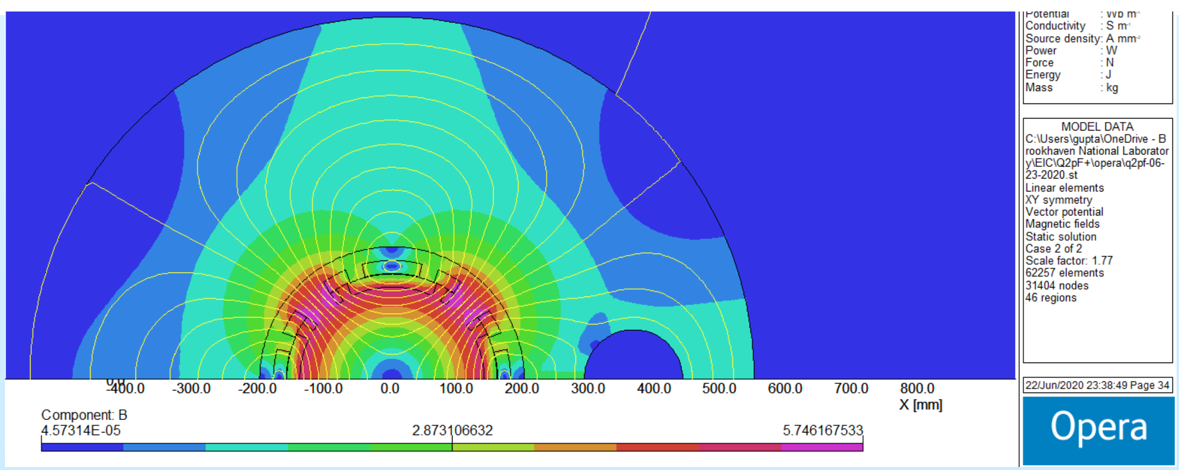
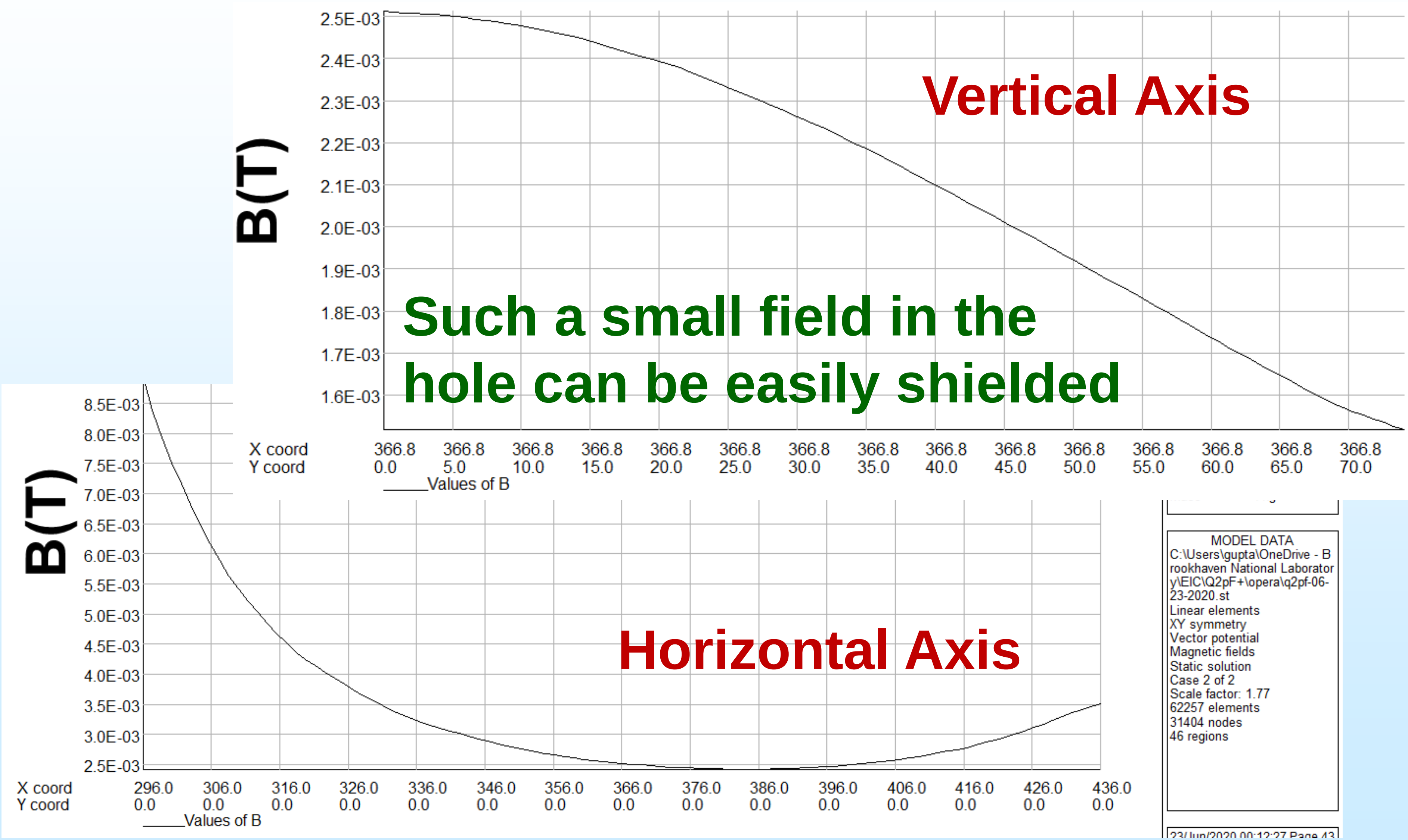
Field in the electron beam region (2)
Yoke OR = 550 mm, Hole@366.8 mm



B(T)



Field in the electron beam region (3)
Yoke OR = 550 mm, Hole@366.8 mm

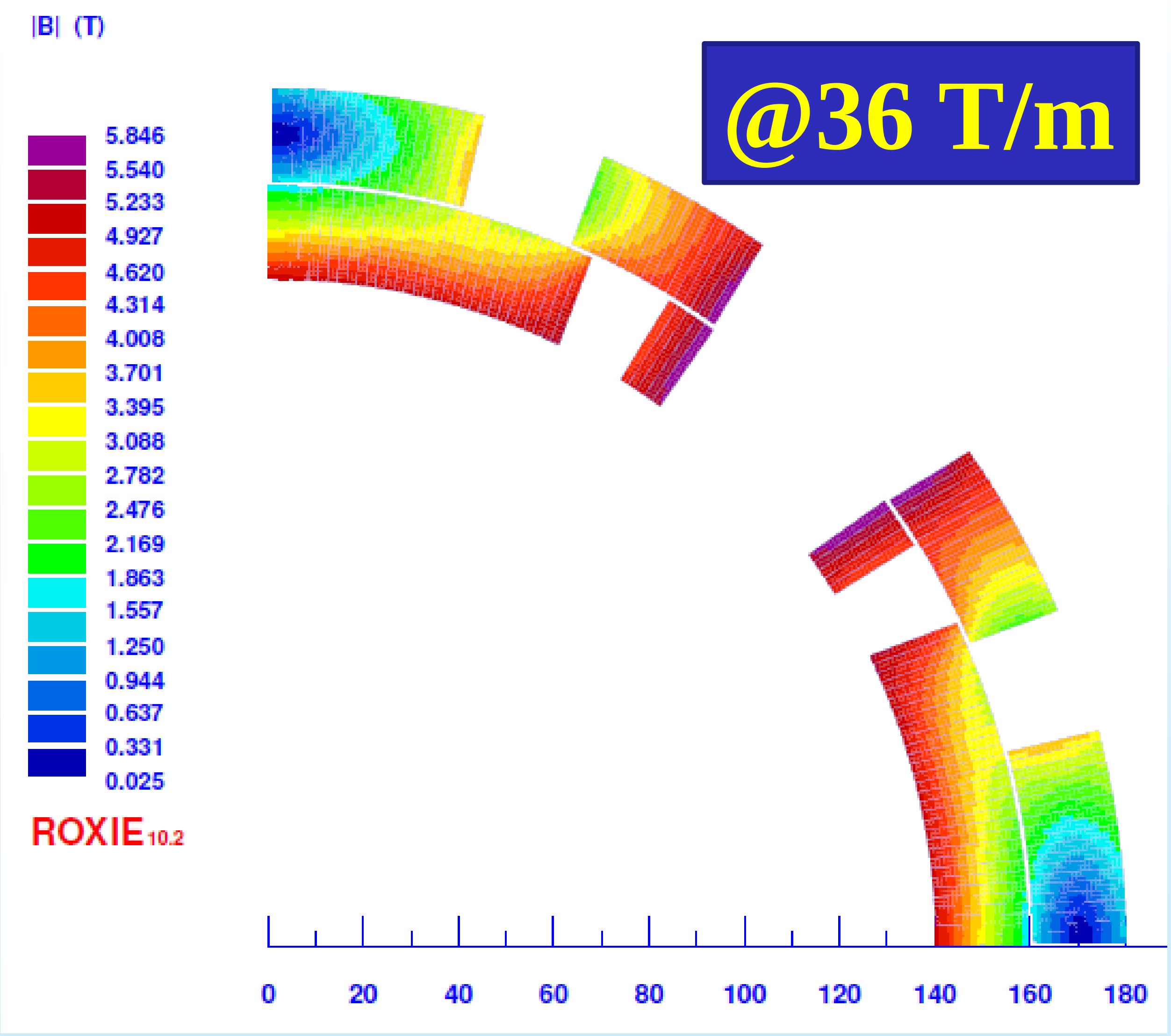


Minimization of Peak Field (optimization to increase margin)

Peak field on conductor: 5.85 T

Field Gradient X Coil radius = 36 T/m * 0.14 m = 5.04 T
Enhancement = 5.85/5.04=16%

Operating current: 7. 51 kA (lower current density for higher margin)



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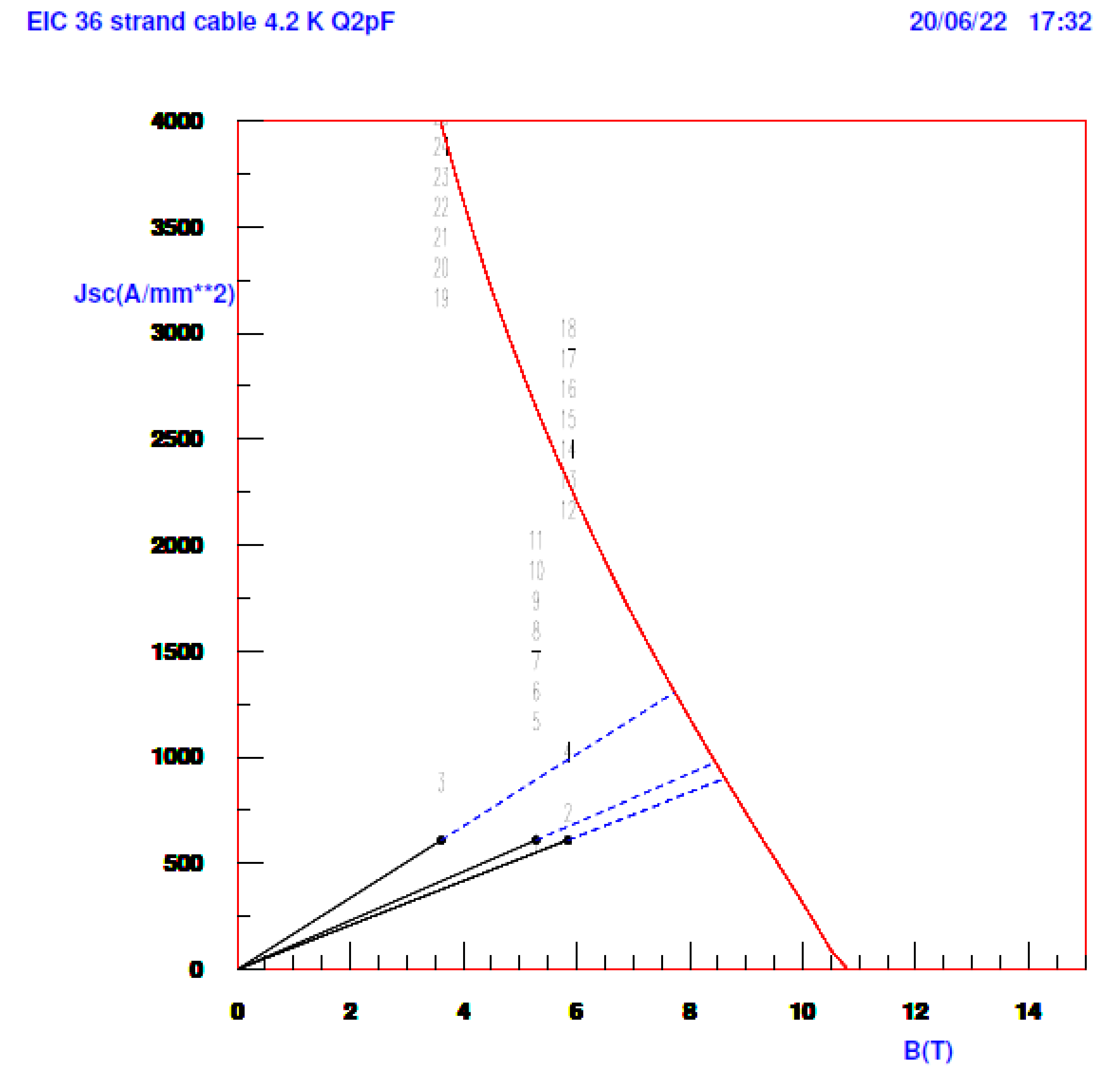
Field Margin at 4.2 K



Healthy Margin:
~47% over 36 T/m
at 4.2K
(68% on loadline)

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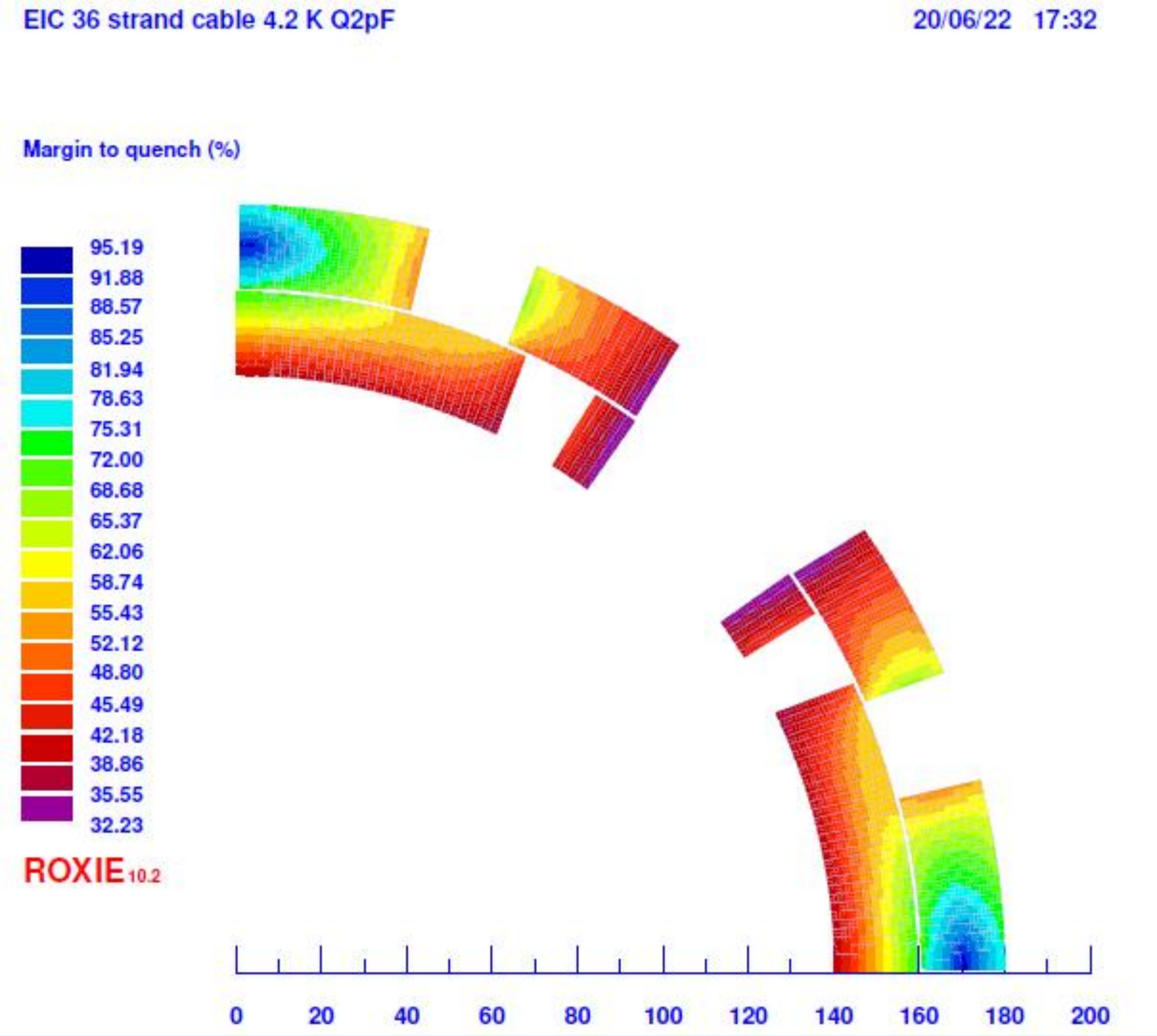
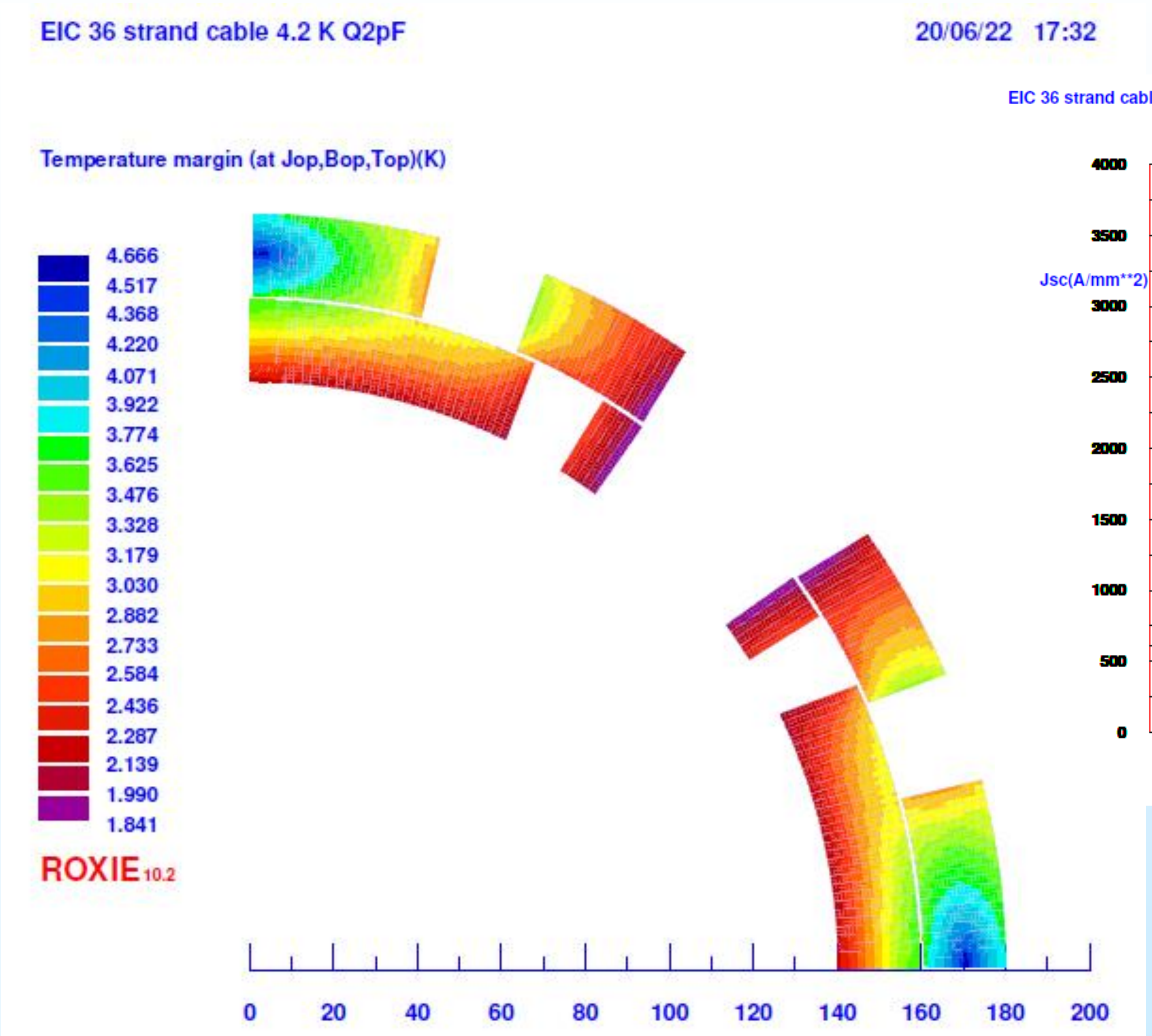
Field Margin at 4.2 K

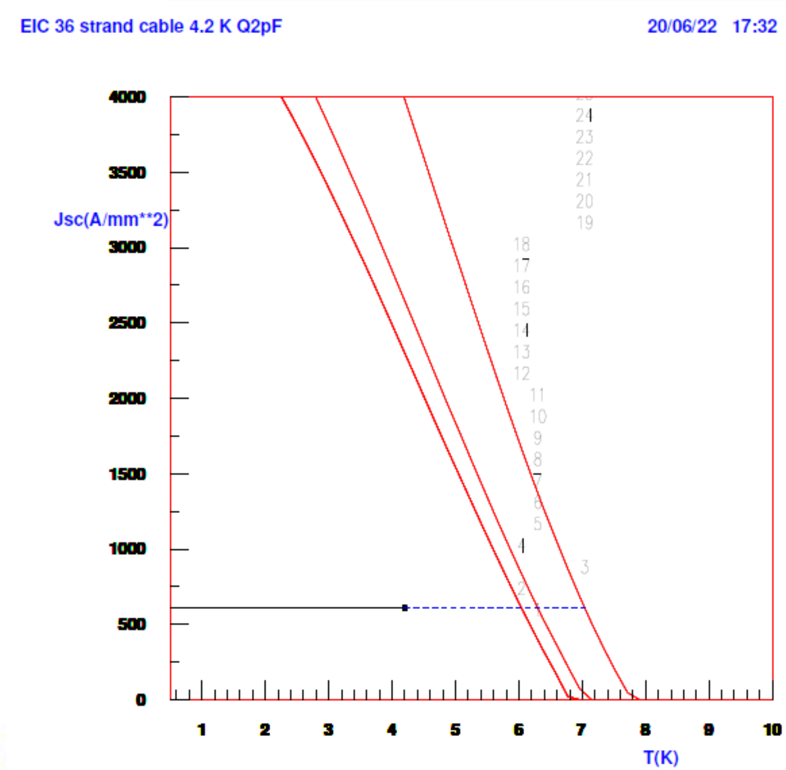


Margin across the coil: Minimum 32% on the loadline at 36 T/m at 4.2K

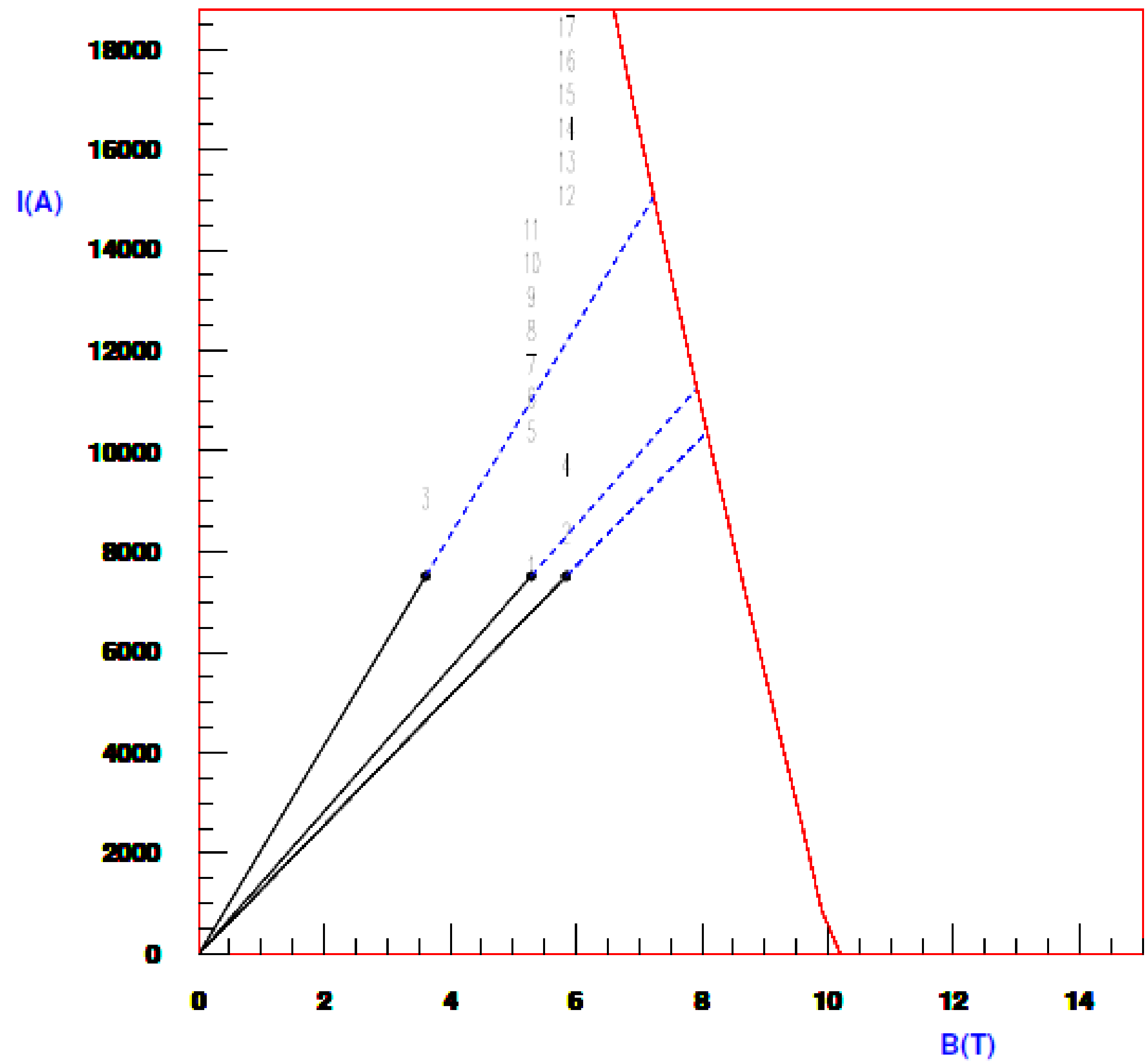
Healthy Margin:
~47% over 36 T/m at 4.2K
(68% on loadline)

Temperature Margin at 4.2 K Over Different Blocks



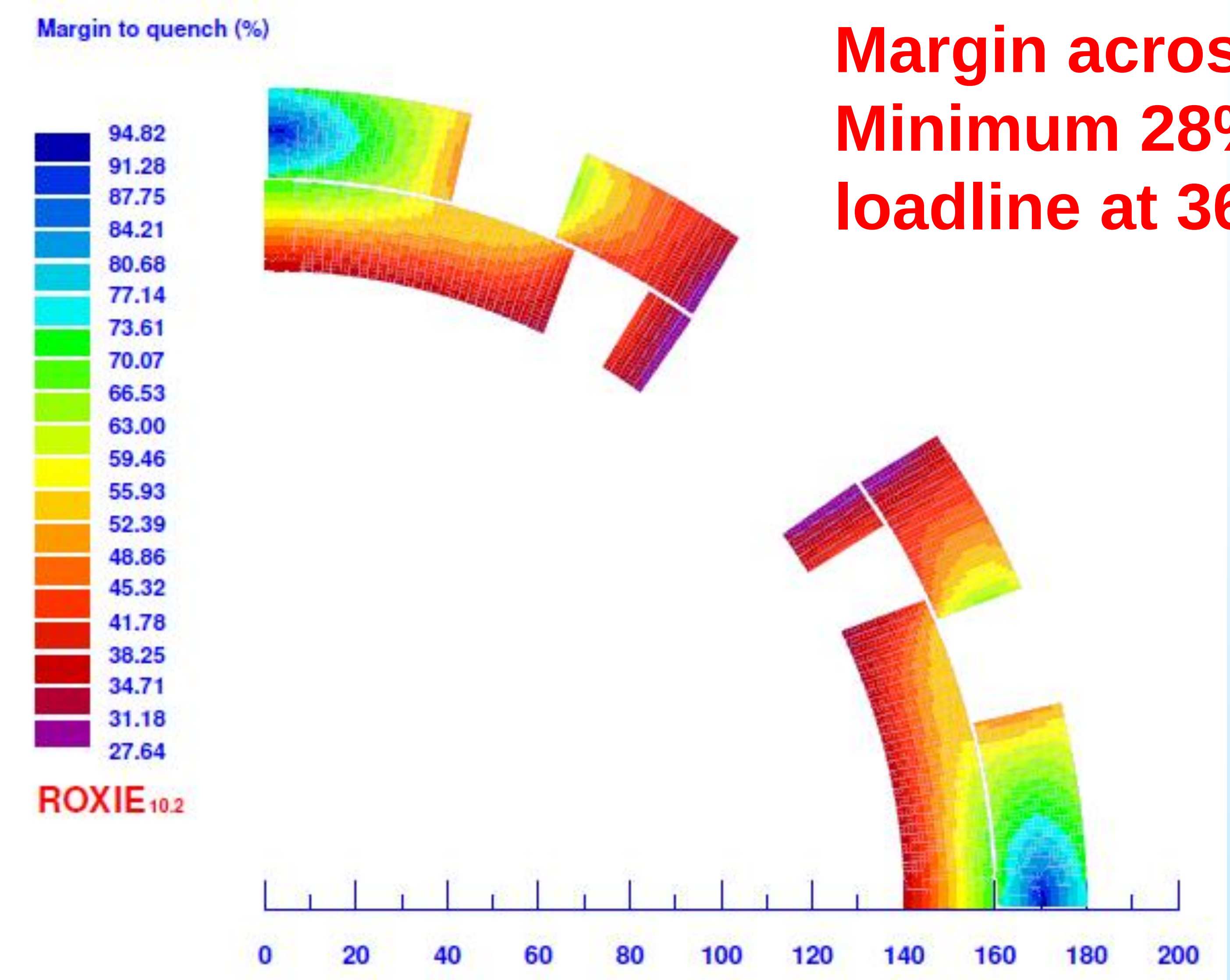


Field Margin at 4.6 K



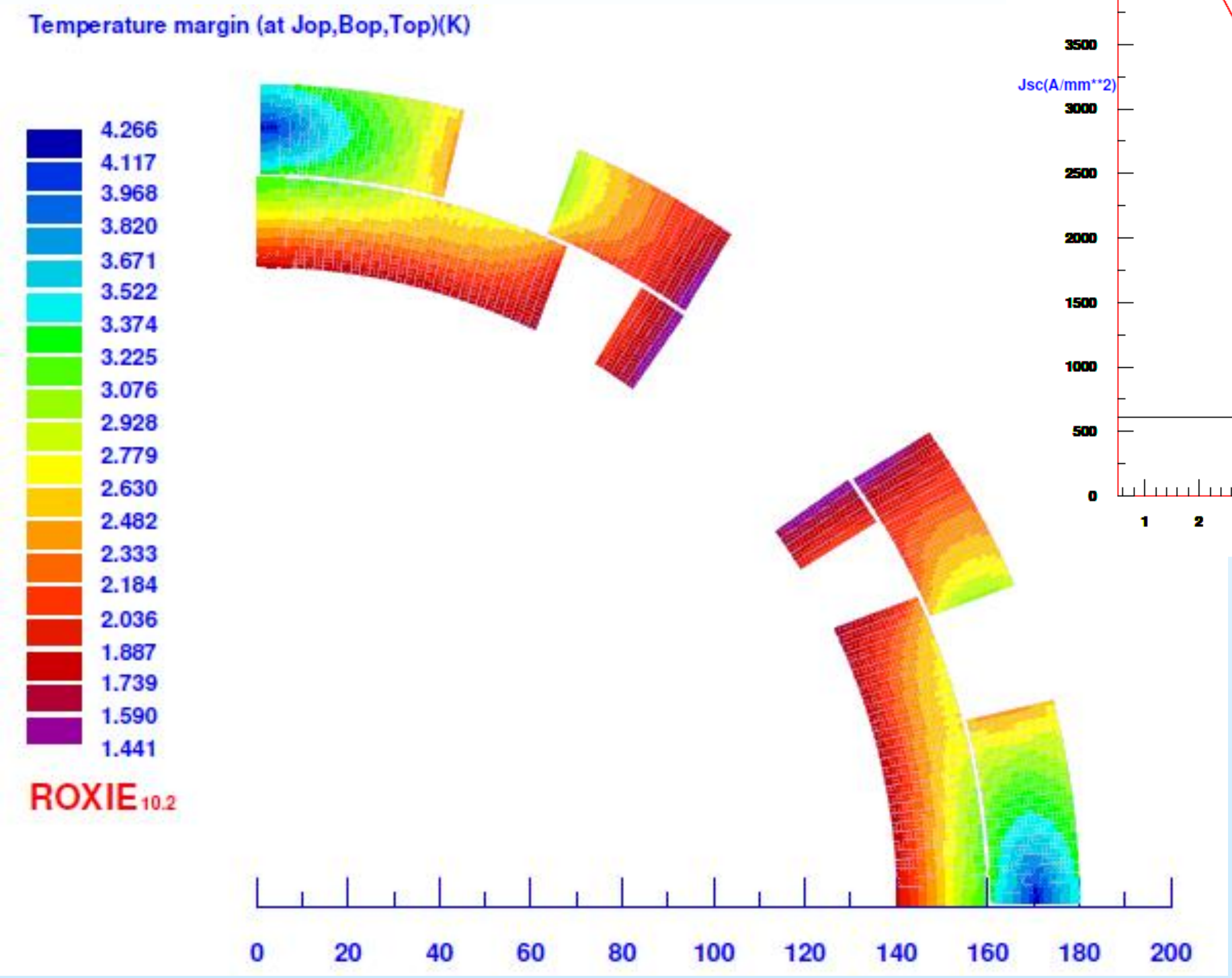
Healthy Margin:
~38% over 36 T/m
at 4.6K
(72% on loadline)

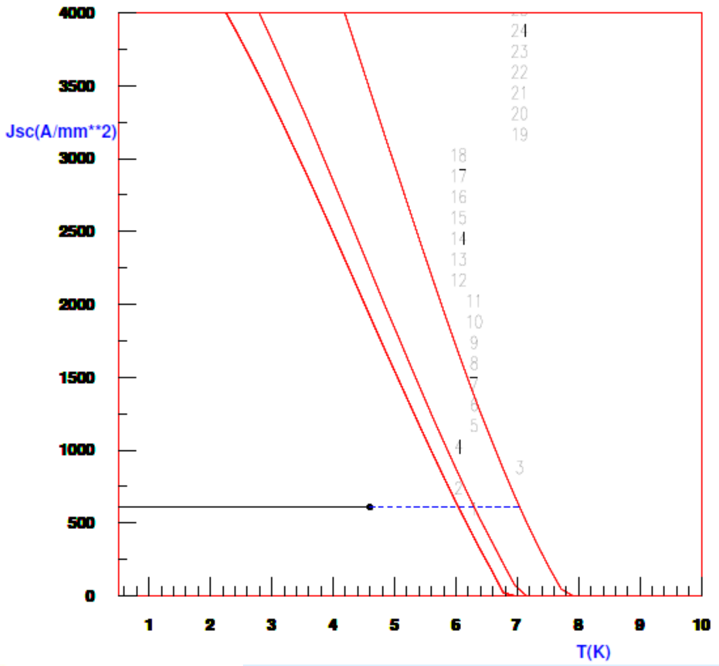
Field Margin at 4.6 K



Margin across the coil: Minimum 28% on the loadline at 36 T/m @4.6 K

Temperature Margin at 4.6 K Over Different Blocks





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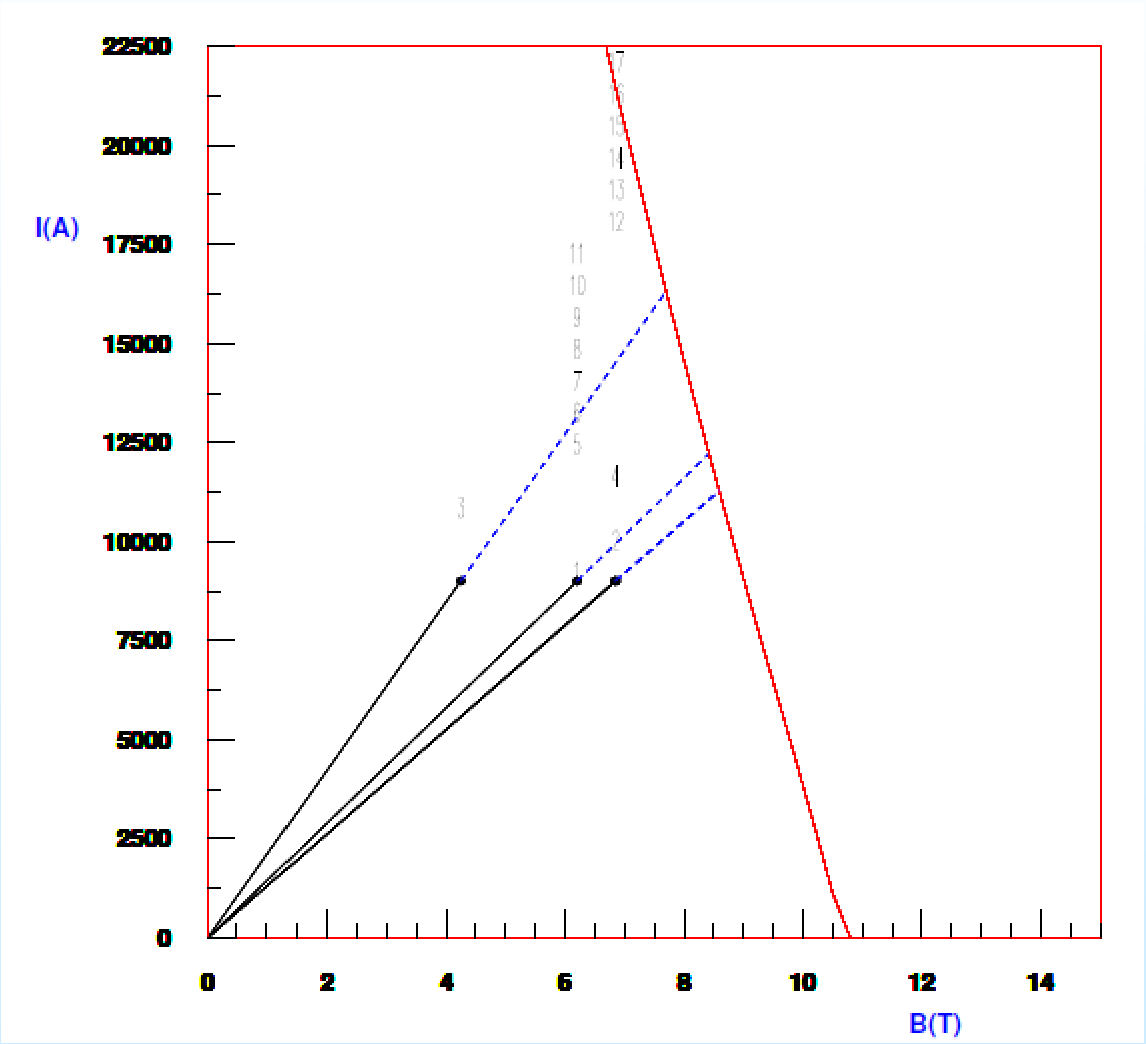
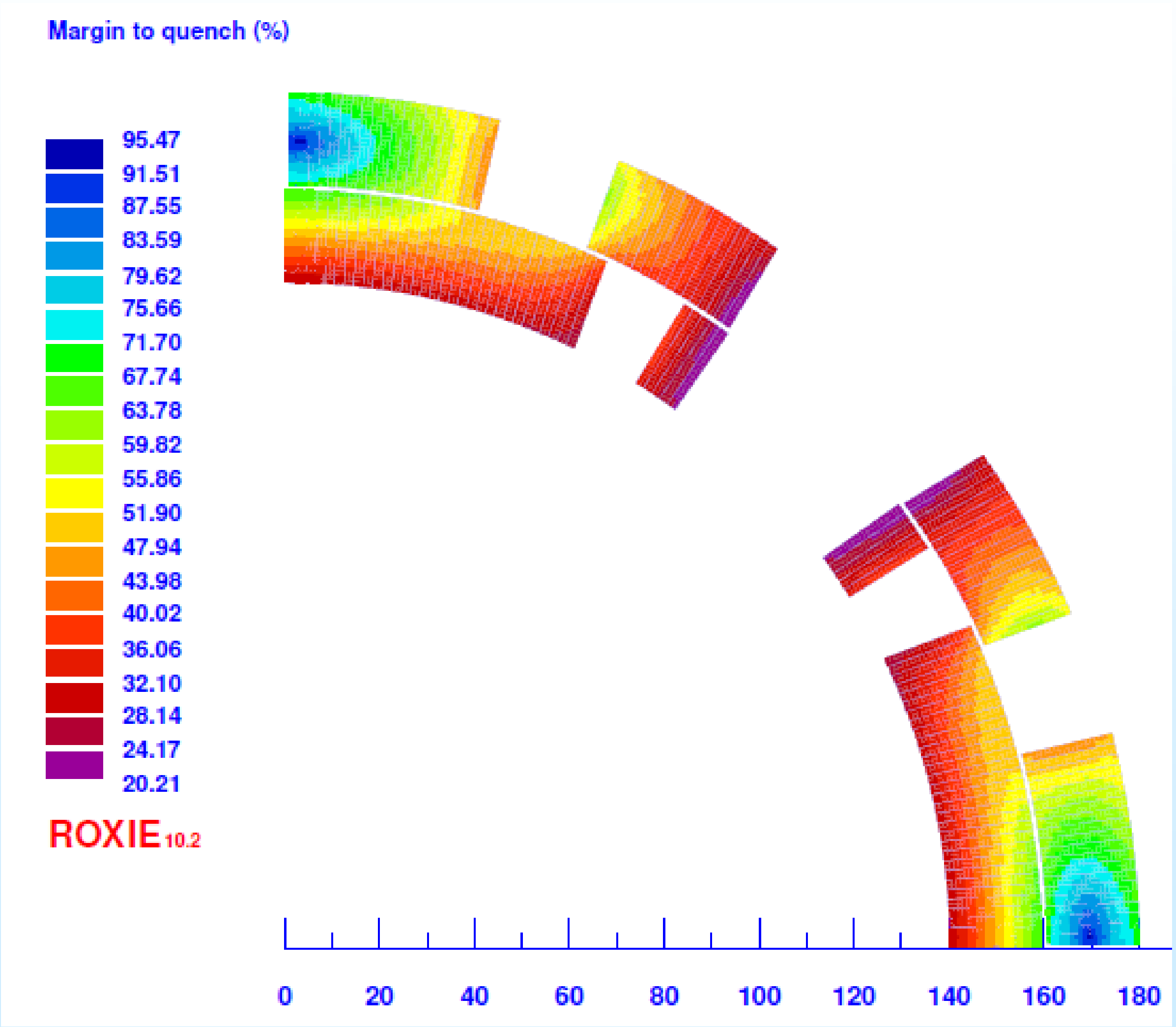
Field Margin at 4.2 K over 41 T/m



Significant Margin: ~25% over 41 T/m at 4.2K (9 kA) (80% on loadline)

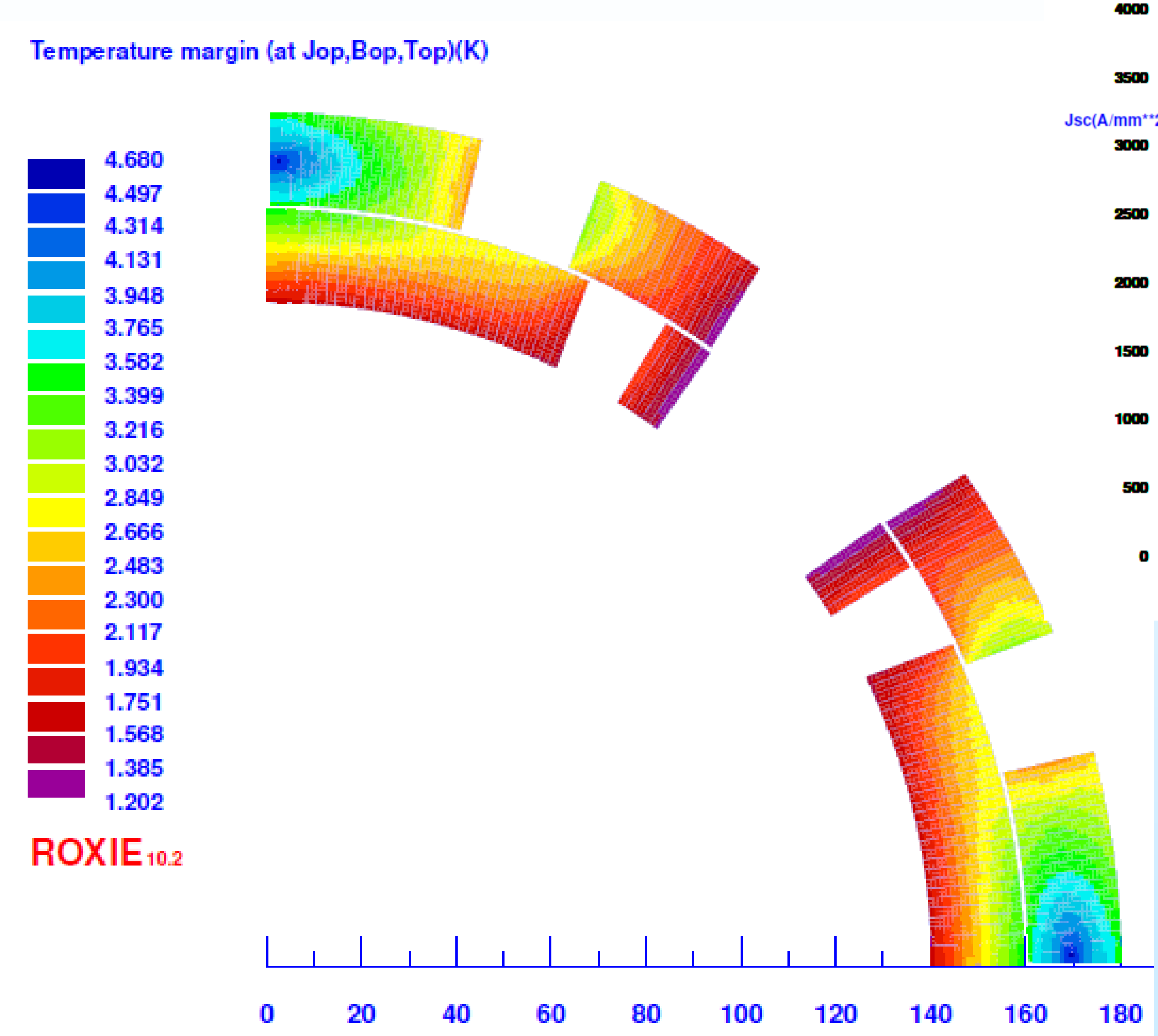
Field Margin over 41 T/m @4.2 K

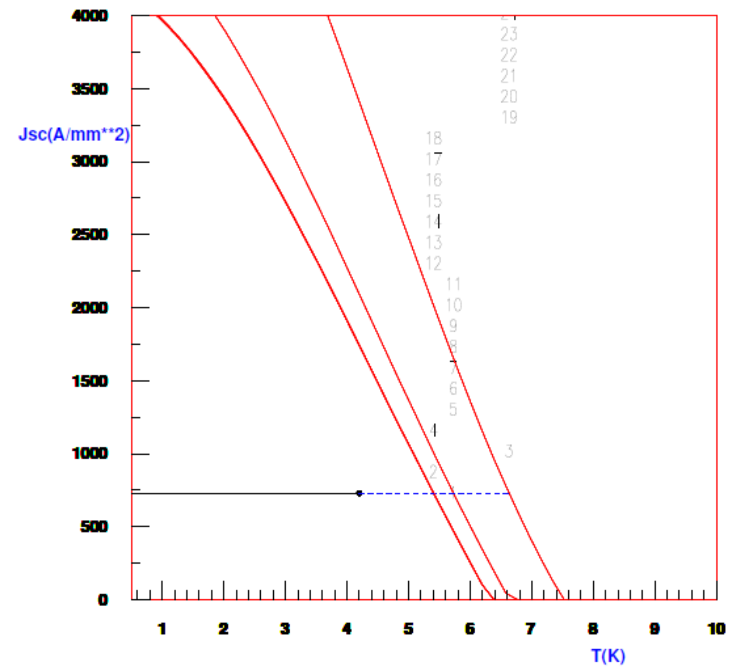


Margin across the coil: Minimum 20% on the loadline at 41 T/m at 4.2K

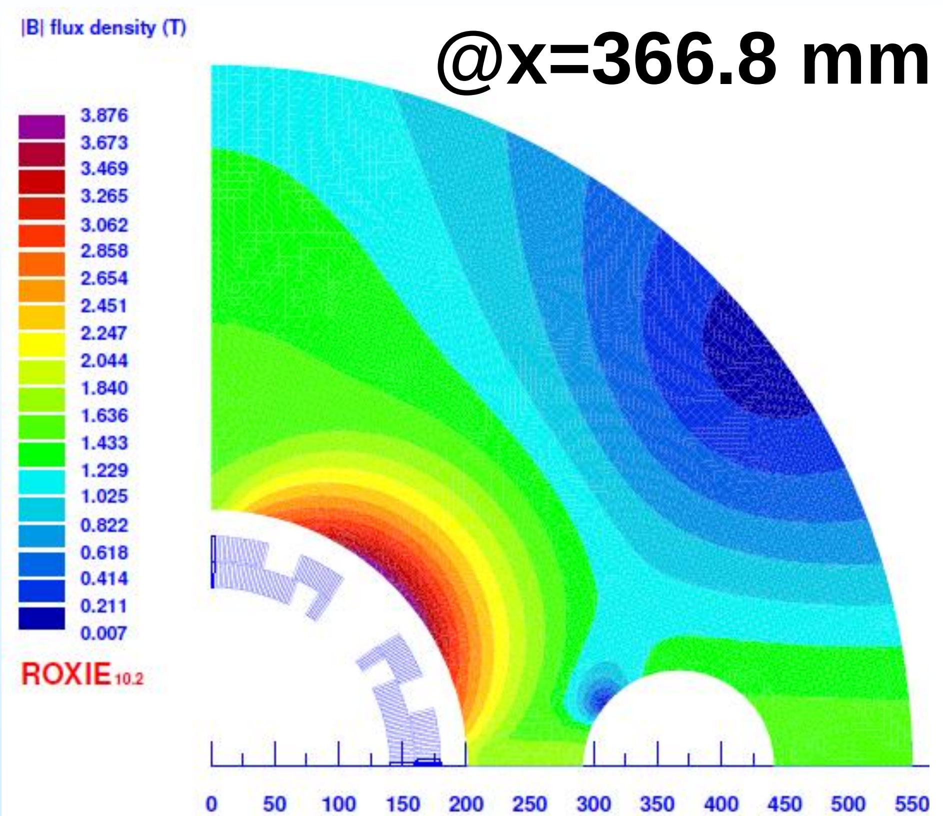
A Reasonable Margin: ~25% over 41 T/m at 4.2K (80% on loadline)

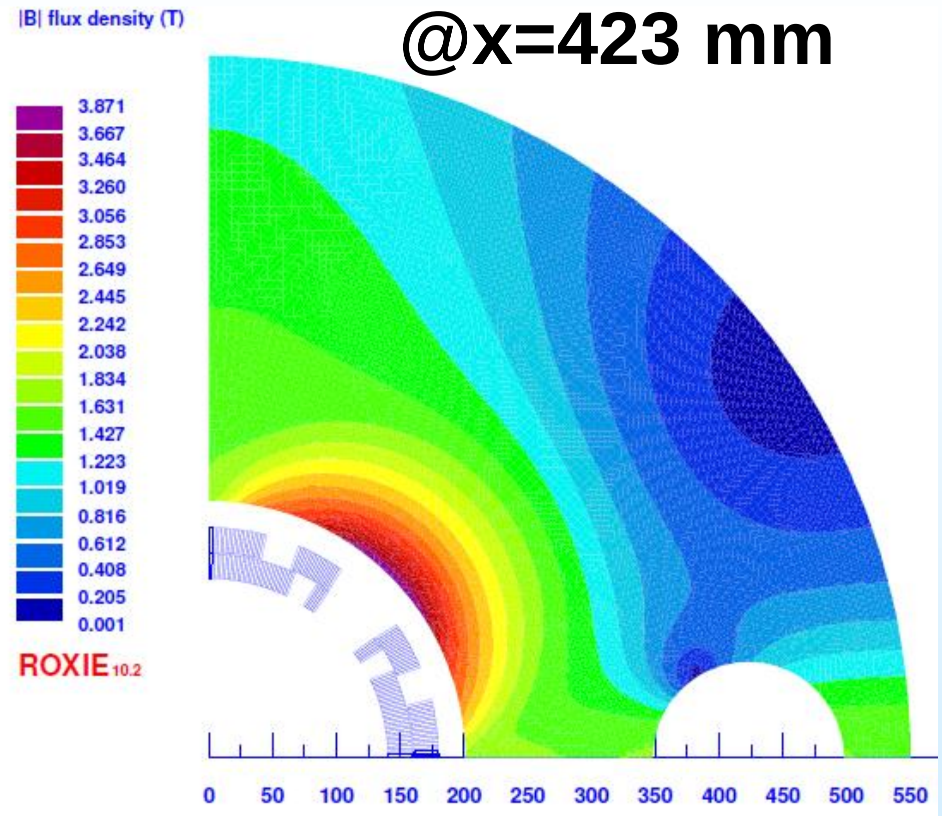
Temperature Margin over 41 T/m at 4.2 K Over Different Blocks





Two Positions of Holes in the Yoke





A total of five sets of files. 4.2 K and 4.6 K for two hole positions. Also one case at 41 T/m for completeness.

Other Magnets

Progress on other magnets should be rapid now. Most overall issues are settled and things are automated.

As per our recent discussion, I would now move to Q1B and then Q1A and then other cable magnets.

It is very important that all restrictions and all wishes are communicated completely and clearly ASAP.

Some thoughts on B0ApF and B1ApF based on a quick overall survey of cable magnets.

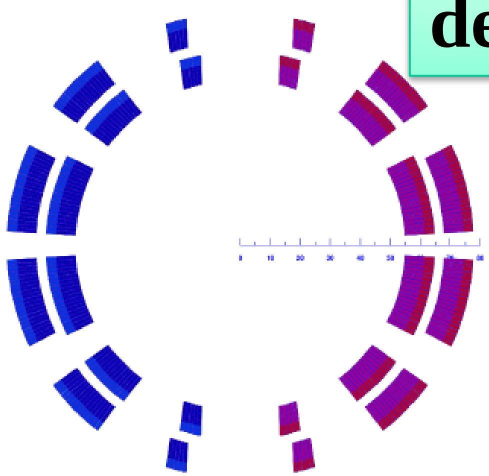
B0APF

Table 6.3: Parameters of the B0APF magnet.

Parameter	Value
Magnetic length [m]	0.6
Maximum dipole field [T]	3.3
Aperture [m]	0.09
Required field quality	1×10^{-4}
Physical length [m]	0.6
Physical width [m]	0.16
Physical height [m]	0.16
Superconductor type	NbTi
Conductor [mm^2]	RHIC cable, 9.73×1.2679
Current density [A/mm^2]	421
Cu:Sc ratio	2
Temperature [K]	4.2
Peak field wire [T]	4.36
Magnetic energy [J]	264000
Ampere turns [A·t]	343200
Number of turns	78
Current [A]	4400
Inductance [H]	0.027273
Margin loadline [%]	30

What can be the coil aperture? Try to make it 10 cm, then one can use the already developed design and tooling of single layer D0 magnet. Such a debate can save significant time and budget.

(a) Geometry



(b) Current density in A/mm^2

and current density of B0APF corrector dipole at th

Why a 2-layer design for 3.3T?

We should be able to get a solution in a single layer design!!!

B1APF

Table 6.10: Parameters of the B1APF Dipole Magnet.

Parameter	Value
Magnetic length [m]	1.5
Maximum dipole field [T]	2.7
Aperture front [m]	0.3360
Aperture rear [m]	0.3360
Design field quality	1×10^{-4}
Physical length [m]	1.6
Physical width [m]	0.41
Physical height [m]	0.41
Superconductor type	NbTi
Conductor	Cable 20x2mm^2
Current density [A/mm^2]	148
Cu:Sc ratio	1.3
Temperature [K]	4.2
Peak field wire [T]	3.5
Magnetic energy [MJ]	0.717
Ampere turns [MA·t]	1.16
Number of turns	154
Current [A]	7670
Inductance [H]	0.024376
Margin loadline [%]	60

- **Dipole field is only 2.7 T**

(compare this to RHIC dipole, 3.45 T with good margin).

We should be able to get a solution with the RHIC cable and "*should not*" have to use the more difficult wider cable (in dipole, the cable width is independent of magnet aperture).

Magnet has a large aperture. There may be a significant loss of pre-stress on cooldown in a typical design with steel/stainless steel collars.

Candidate for Aluminum?