Q2pF Studies for 4K Option

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BROOKHAVEN NATIONAL LABORATORY
a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

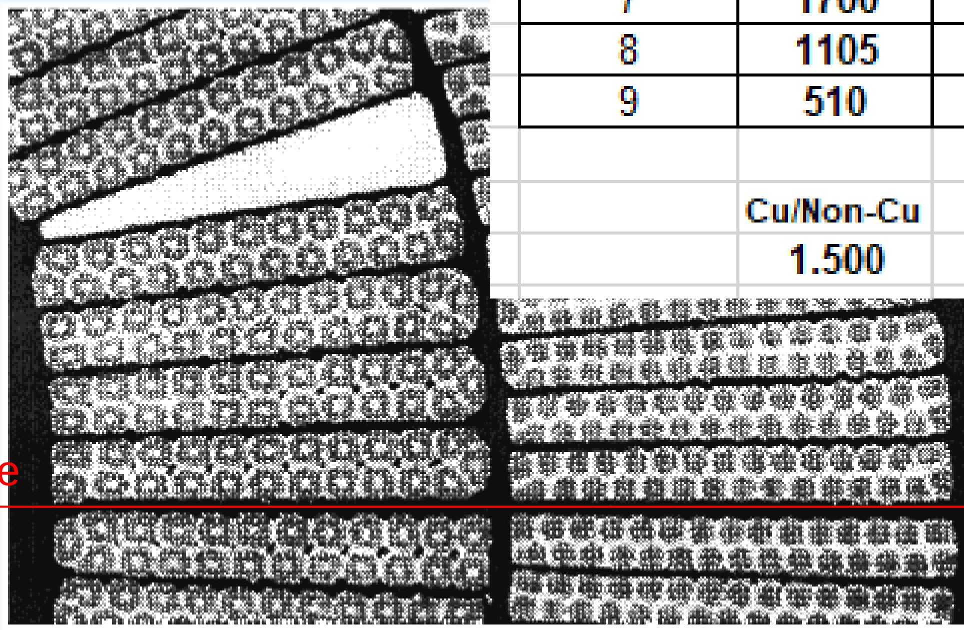
Overview

- Case studies to understand the magnet. Several cases examined. Only the case of 4.2 K will be presented in some details.
- Strand/wire used: dia =1.065 mm, Cu/Sc =1.6 (may be lower?)
- Cables considered: 19.7 mm wide (including insulation) with 36 strands (used in the design) and LHC inner with 28 strand
- Current density calculations are based on the cables made from strand with fill factor, insulation, degradation (while compacting and keystoning, etc.) - same as done in designing other magnets
- Coils examined: Single layer (1.8K) and double layer (for 4.2K?)
- Peak field (margin), field quality and field in the electron beam region optimized. Note: this is not the final design but almost good enough (almost ok for CDR) to see that a solution exist.
- Design gradient 41 T/m (is it reduced?)

Cable Current Density

Cable current density from strand includes fill factor, insulation (plus degradation)

Inner wire and cable parameters (generic)					
Non-Cu(%)	40	Cable Area	20.34	Strands(#)	30
B(T)	Jc (A/mm2)	Jw(A/mm2)	Iwire(A)	Icable(A)	*Joverall*
1	**7393**	*2957*	*1516*	45489	***2236***
2	**5164**	*2066*	*1059*	31774	***1562***
3	**4151**	*1660*	*851*	25541	***1256***
4	**3457**	*1383*	*709*	21271	***1046***
5	**2861**	*1144*	*587*	17603	***865***
6	**2289**	*916*	*469*	14084	***692***
7	**1700**	*680*	*349*	10460	***514***
8	**1105**	*442*	*227*	6799	***334***
9	**510**	*204*	*105*	3138	***154***
					Insulated
	Cu/Non-Cu				
	1.500				



midplane

Jsc(5T,4K) = 2861 A/mm^2 becomes Jw=1144 A/mm^2 and Jo = 865 A/mm^2 even before the degradation

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Cables in ROXIE (in RHIC/SSC, we used PAR2DOPT and PARENDOPT)

Strand

No	Name	diam.	cu/sc	RRR	Tref	Bref	Jc@BrTr	dJc/dB	Comment
[illegible]	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

No	Name	height	width_i	width_o	ns	transp.	degrd	Comment
1	EIC3642	19.4	1.773	2.027	36	115	3	EIC 36 STRAND @4.2K
1	EIC3618	19.4	1.773	2.027	36	115	3	EIC 36 STRAND @1.8K
2	EICLHC01	15.1	1.786	2.014	28	115	5	LHC CABLE KEYSTOR FOR EIC 4.2K
2	CABLE01	15.1	1.736	2.064	28	115	5	MB INNER LAYER,STR01
3	CABLE02	15.1	1.362	1.598	36	100	5	MB OUTER LAYER,STR01
4	CABLE04	8.8	0.78	0.91	36	66	5	MQM STR05

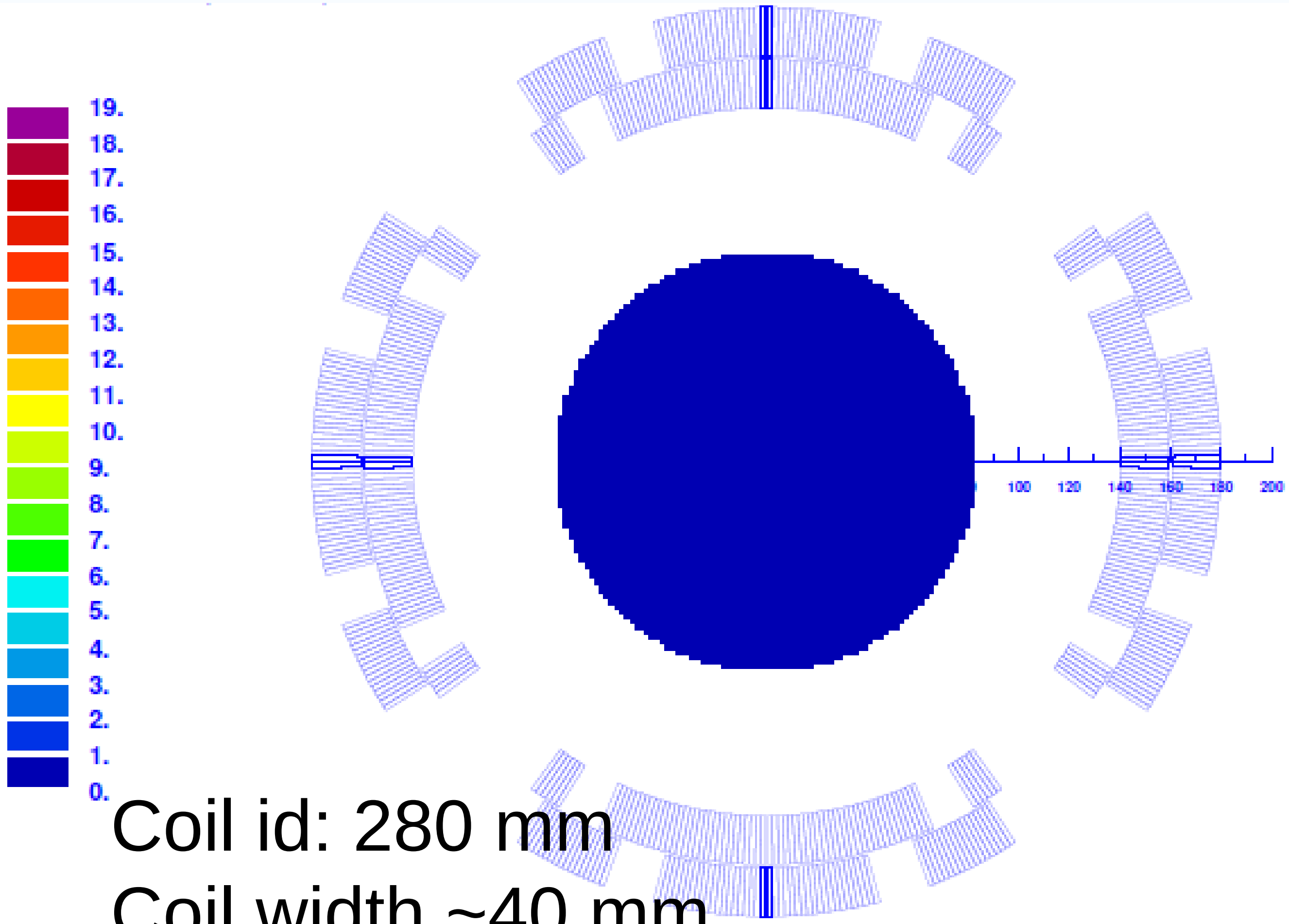
Cable Definition

No	Name	Cable Geom.	Strand	Filament	Insul	Trans	Quench Mat.	T_o	Comment
1	LHCIN42K	EICLHC01	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	4.2	LHC INNER FOR EIC @4.2K
1	YELLONIN	CABLE01	STR01	NBTII	ALLPOLYIL	TRANS1	NONE	1.9	V6-1 DESIGN DIPOLE INNER
2	YELLONOU	CABLE02	STR02	NBTIO	ALLPOLYOL	TRANS1	NONE	1.9	V6-1 DESIGN DIPOLE OUTER
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	20MMCABLE	20MMCABLE	STR01	NBTII	ALLPOLYIL	NONE	NONE	4.2	20mm cable eRHIC
38	20MMCAB18	20MMCABLE	STR01	NBTII	ALLPOLYIL	NONE	NONE	1.8	20mm cable eRHIC at 1.8K
39	20MMCBNOK	20MMCBNOK	STR01	NBTII	INSHQ_2	NONE	NONE	4.2	20mm cable eRHIC
40	20MMCAB2	20MMCAB2	STR01	NBTII	INSHQ_2	NONE	NONE	4.2	20mm cable-2
41	EIC3618	EIC3618	STREIC1	NBTII	ALLPOLYIL	NONE	NONE	1.8	EIC CABLE 36 STRAND, 1.8K
42	EIC3642	EIC3642	STREIC1	NBTII	ALLPOLYIL	NONE	NONE	4.2	EIC CABLE 36 STRAND, 1.8K

Cable used in calculation: Strand dia =1.065 mm, Cu/Sc =1.6, width 19.4 mm (bare) with 36 strands

Coil – 2 Layers, 73 turns/pole (36-strand cable, 2 wedges)

Design gradient 41 T/m @ I = ~9kA
(earlier single layer design required ~20 kA@1.8K)



Coil id: 280 mm
Coil width ~40 mm

Using 2 varieties of cables may give a little higher margin.
But may not be worth it for just one magnet.

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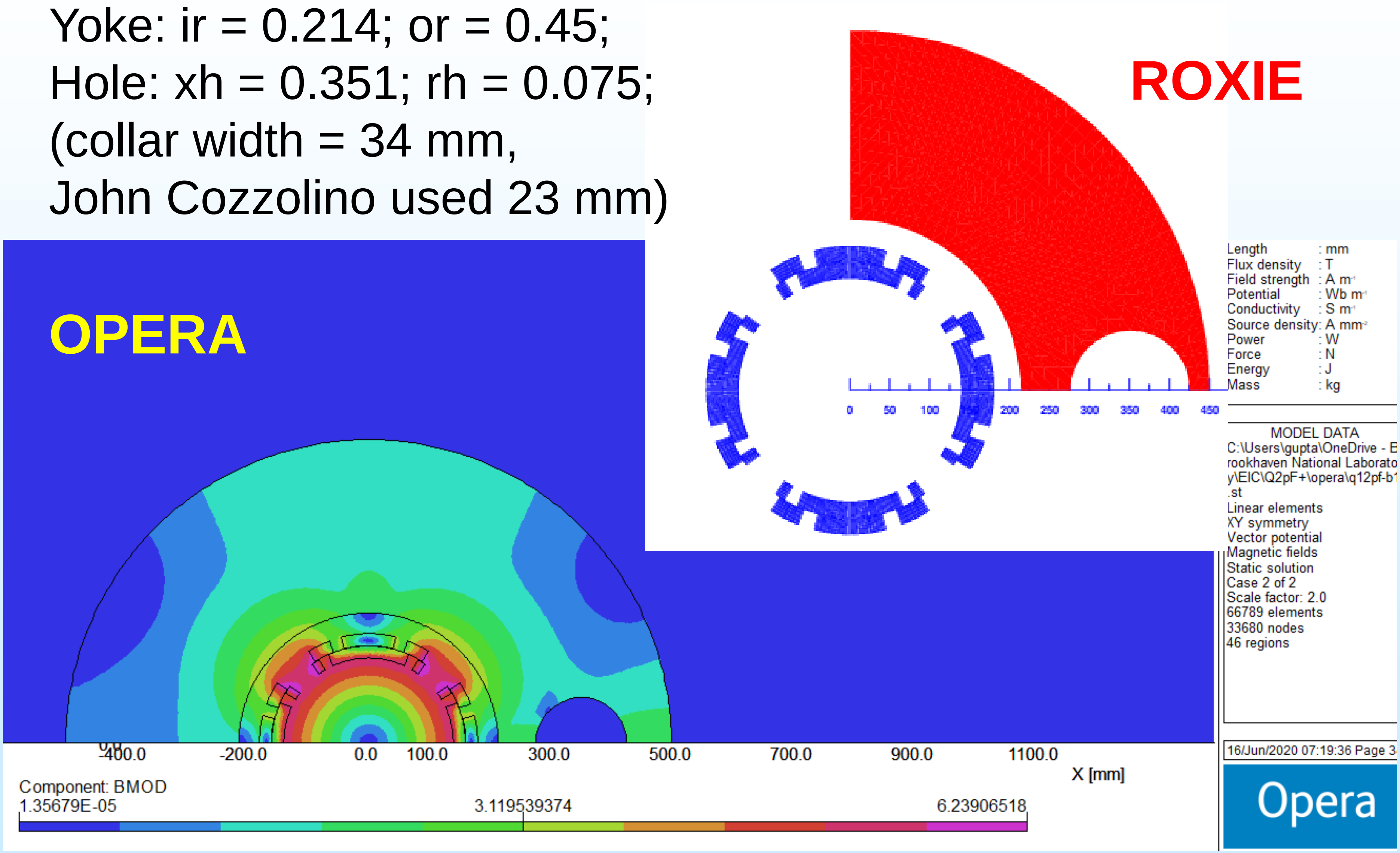
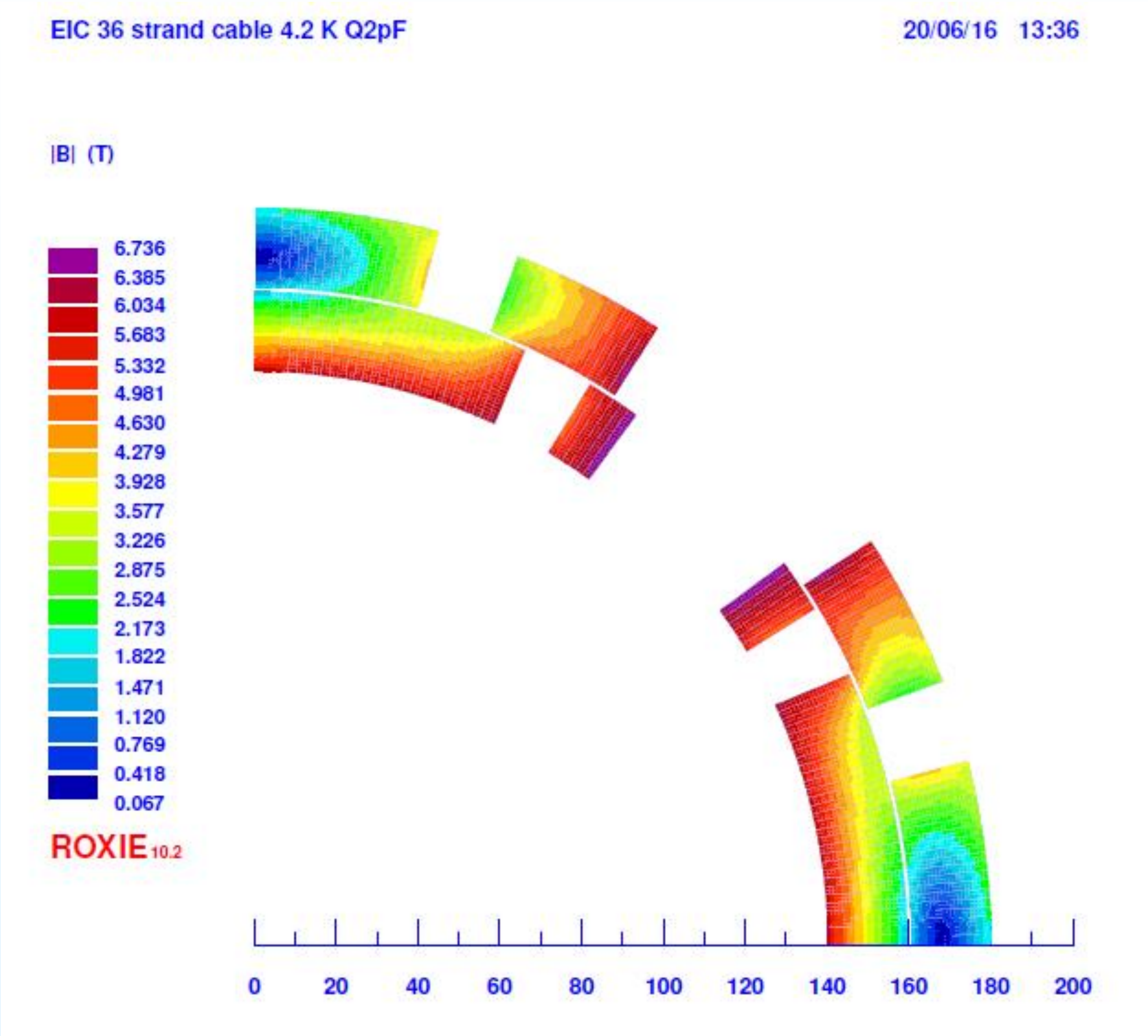
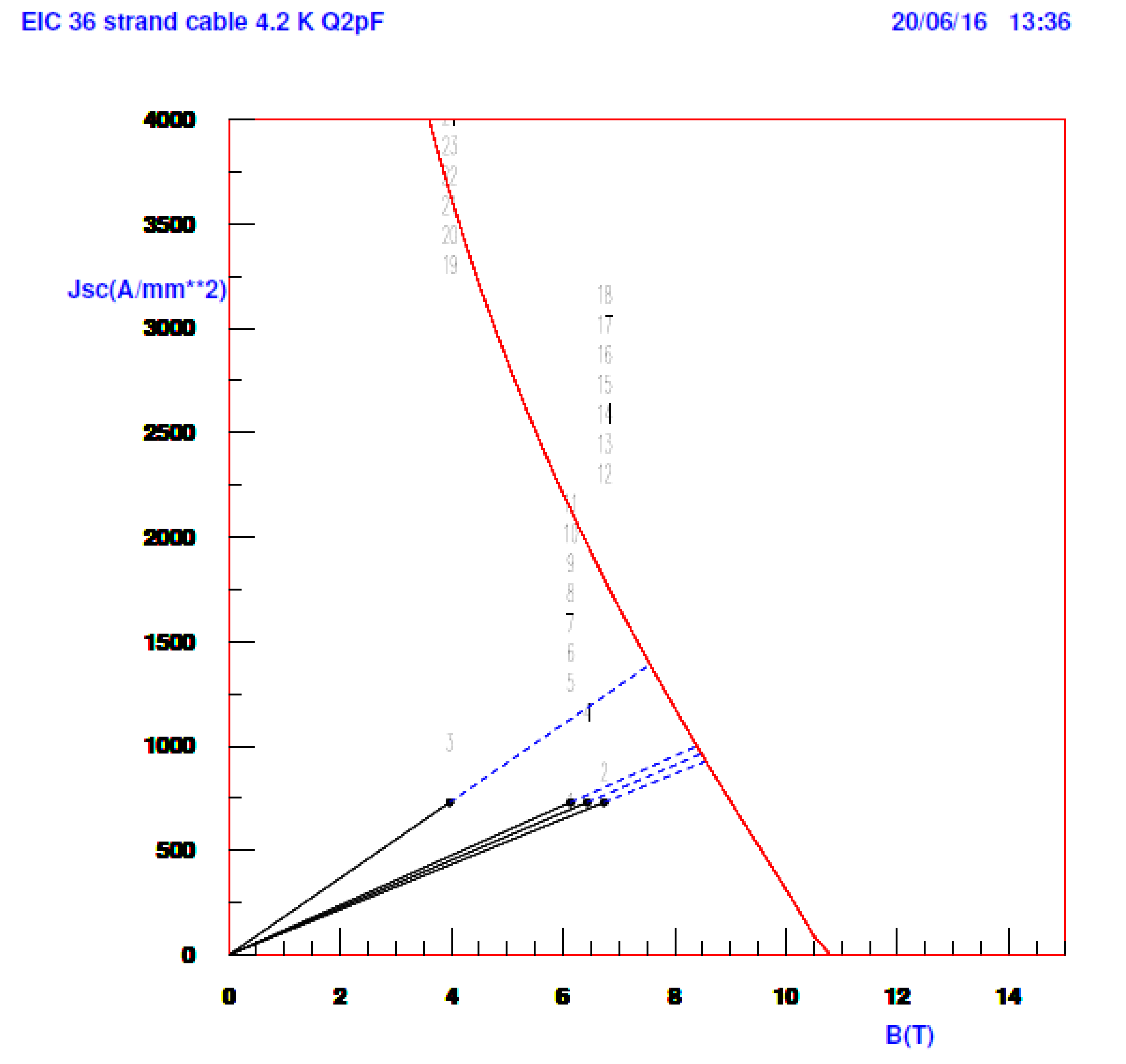
Iron – Initial Design

Yoke: ir = 0.214; or = 0.45;
Hole: xh = 0.351; rh = 0.075;
(collar width = 34 mm,
John Cozzolino used 23 mm)

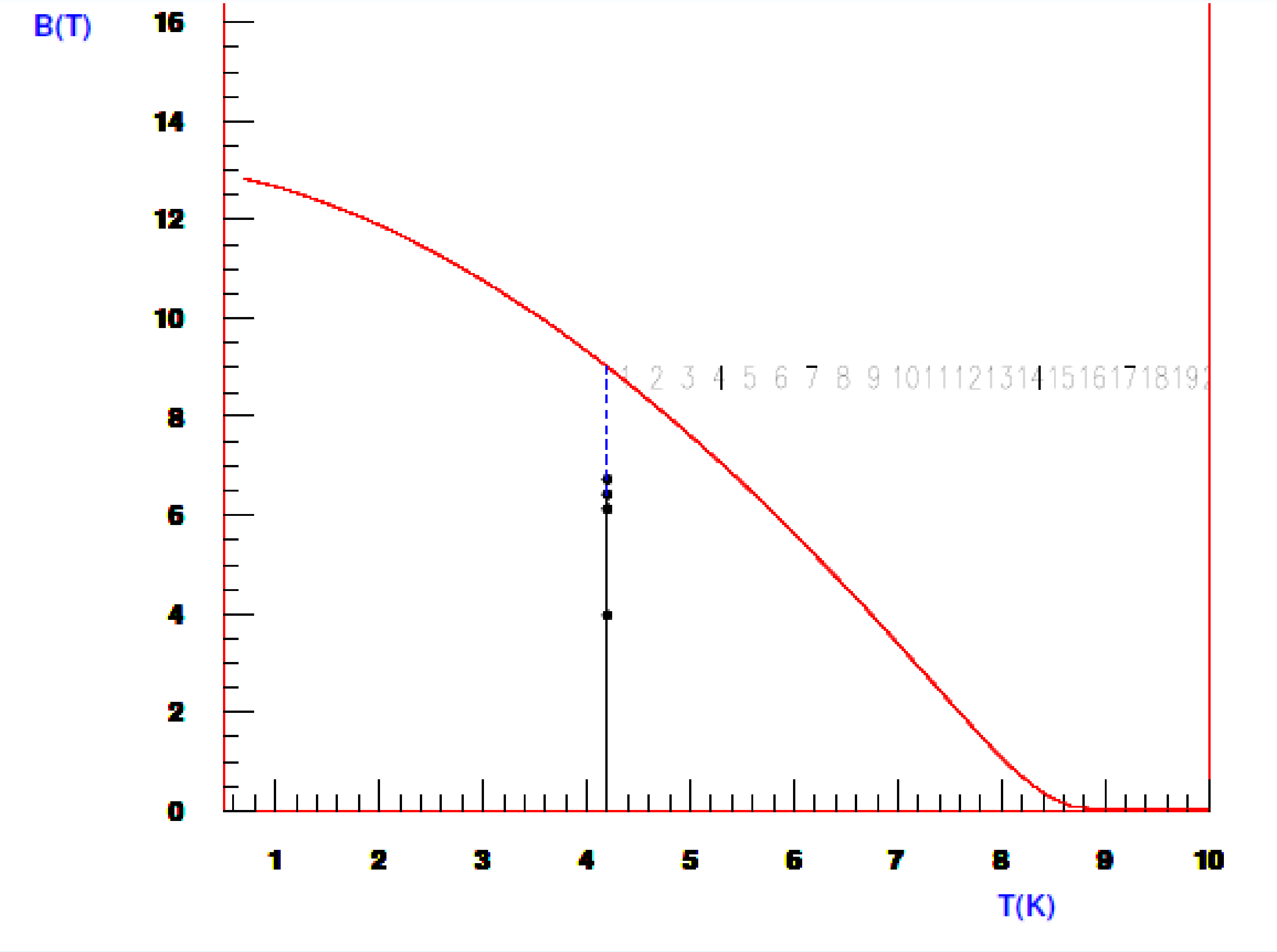



EIC 36 strand cable 4.2 K Q2pF
20/06/16 13:36
|B| (T)
6.736
6.385
6.034
5.683
5.332
4.981
4.630
4.279
3.928
3.577
3.226
2.875
2.524
2.173
1.822
1.471
1.120
0.769
0.418
0.067
ROXIE 10.2
0
20
40
60
80
100
120
140
160
180
200



Field Margin ~28% over 41 T/m at 4.2K

Temperature Margin Over Different Blocks



Field Quality (10^{-4}) Can be optimized more

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HARMONIC ANALYSIS NUMBER ...........................          1
MAIN HARMONIC ......................................          2
REFERENCE RADIUS (mm) ..............................    83.0000
X-POSITION OF THE HARMONIC COIL (mm) ...............     0.0000
Y-POSITION OF THE HARMONIC COIL (mm) ...............     0.0000
MEASUREMENT TYPE ........................ ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ...................  0.2495E-03
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) .....................................   3.437028
MAGNET STRENGTH (T/(m^(n-1)) .......................    41.4100

NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:       0.00000  b 2:  10000.00000  b 3:       0.00000
b 4:      -0.87800  b 5:     -0.00000  b 6:       0.25498
b 7:      -0.00000  b 8:     -0.00616  b 9:       0.00000
b10:       0.00008  b11:     -0.00000  b12:       0.00082
b13:      -0.00000  b14:     -0.23677  b15:       0.00000
b16:       0.00003  b17:     -0.00000  b18:       0.00087
b19:       0.00000  b20:     -0.00000  b
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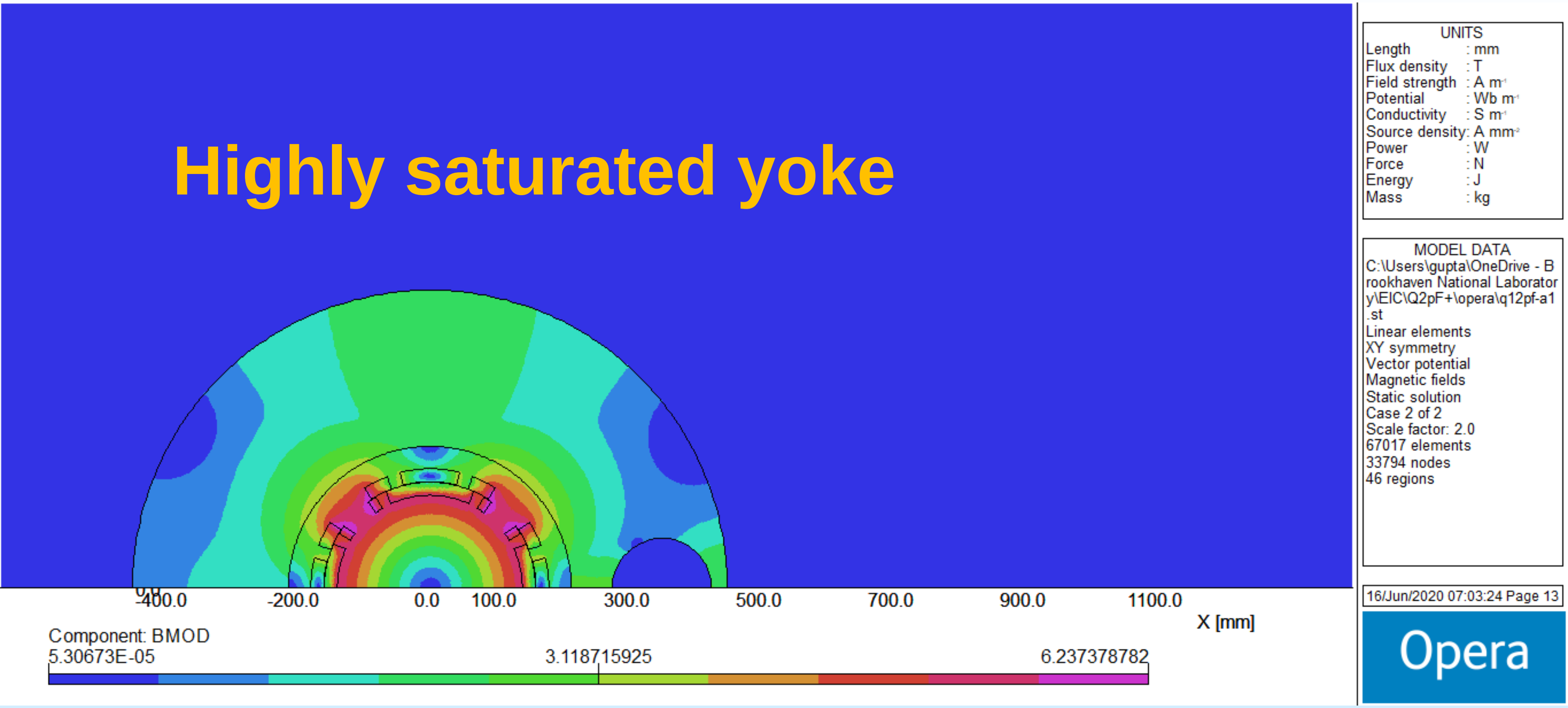
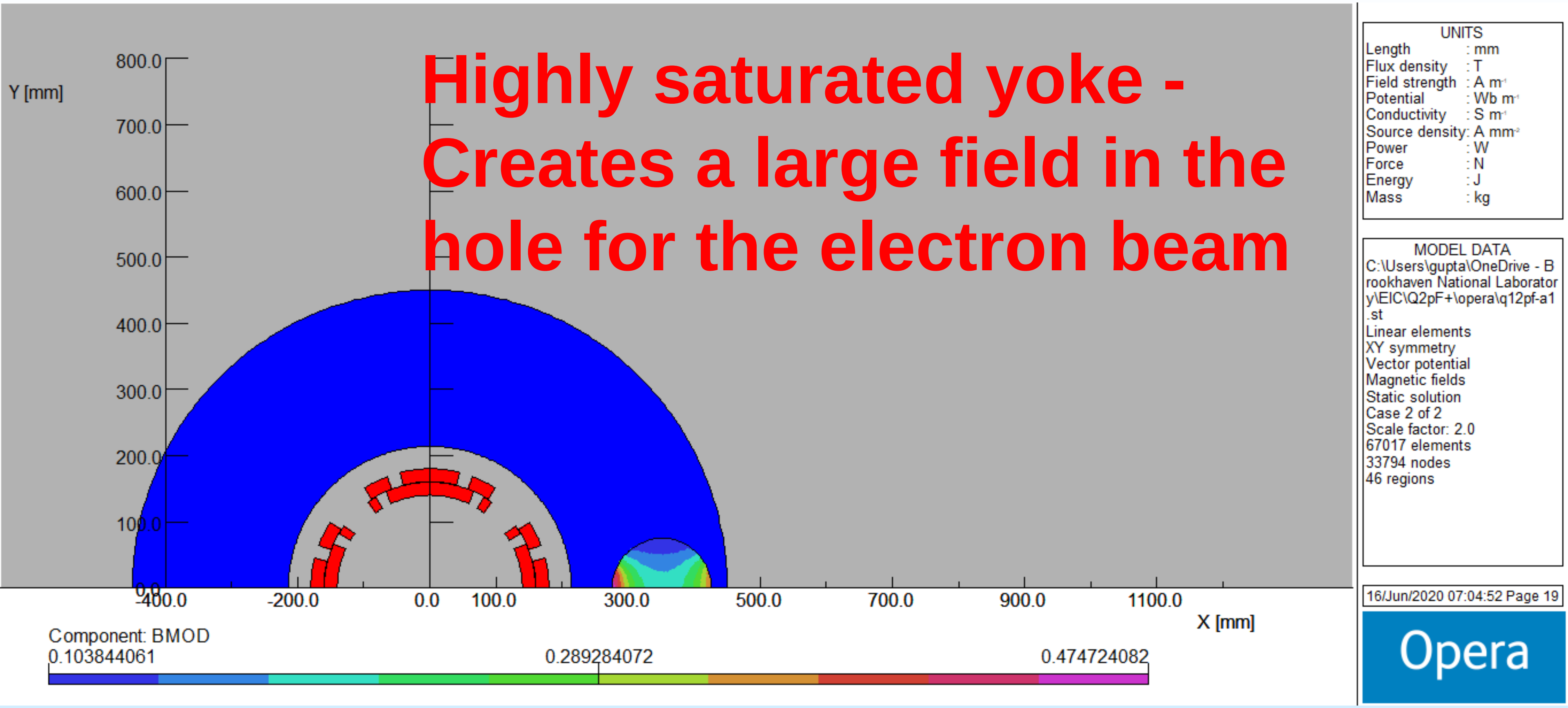
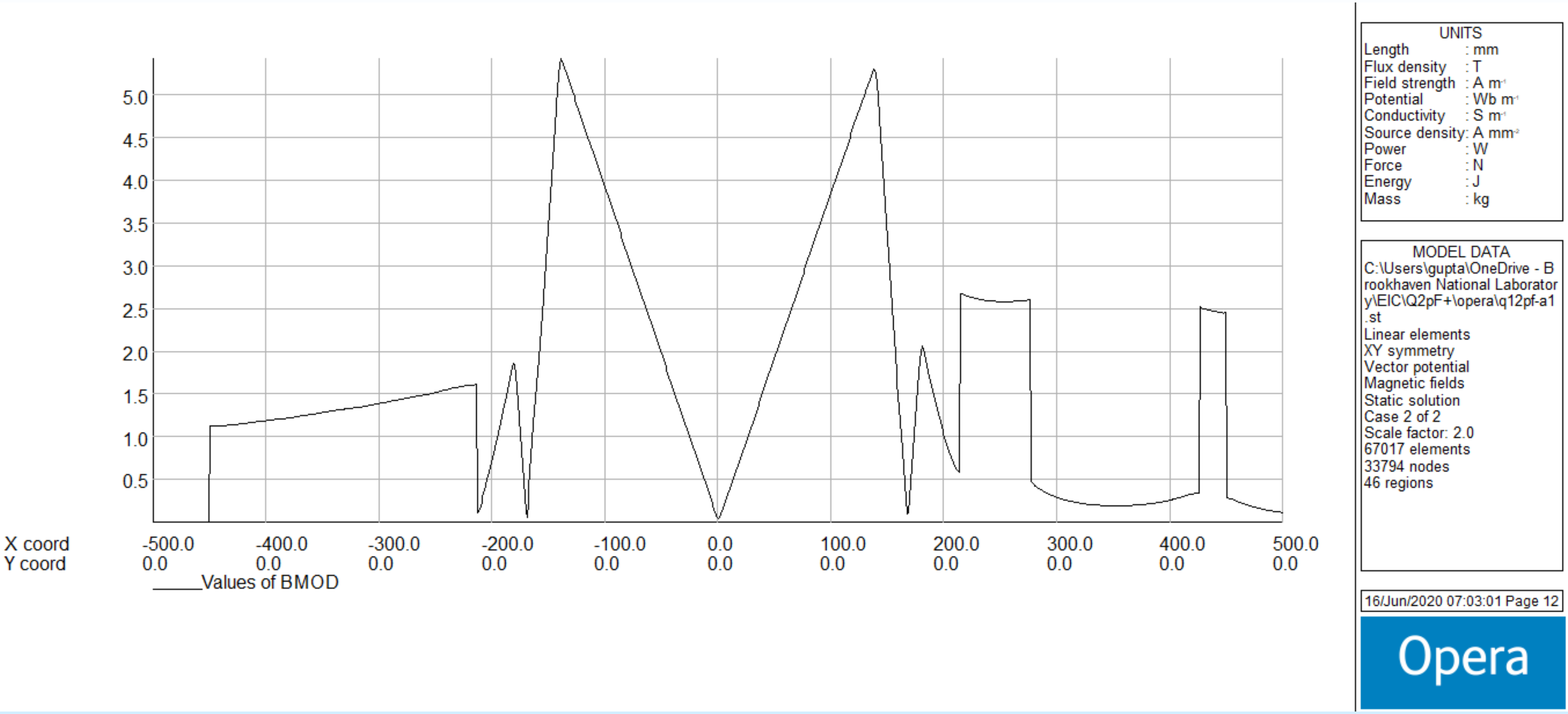
Field in the electron beam region
Yoke outer radius = 450 mm



Field in the electron beam region
Yoke outer radius = 450 mm



Field in the electron beam region Yoke outer radius = 450 mm



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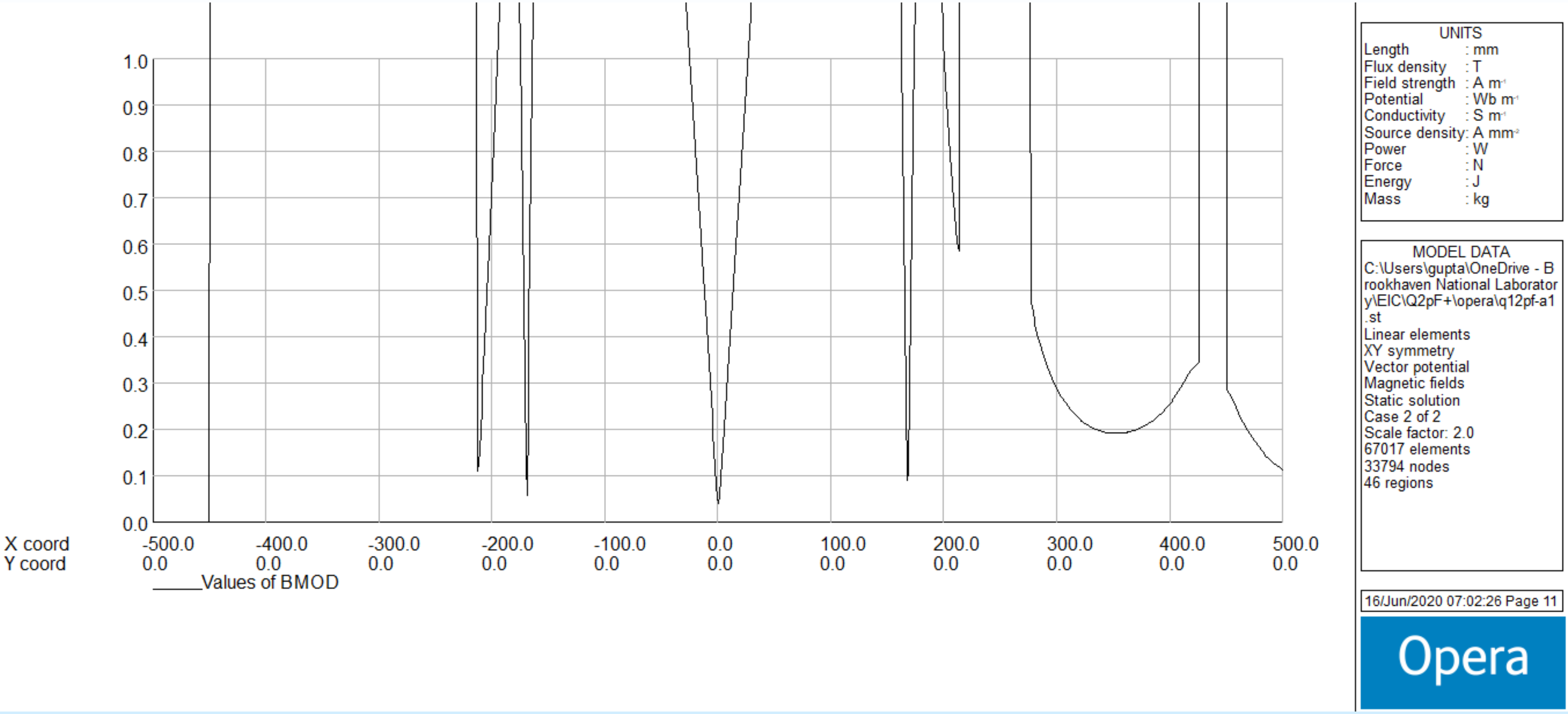
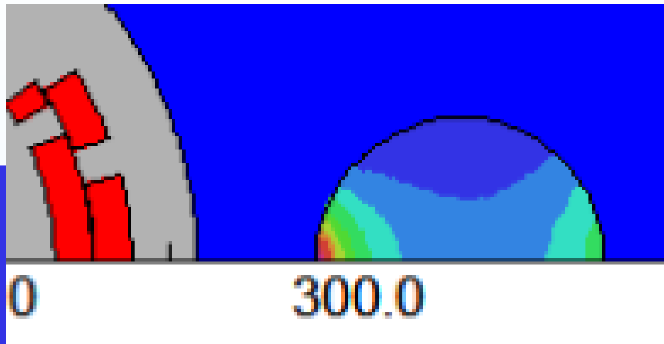
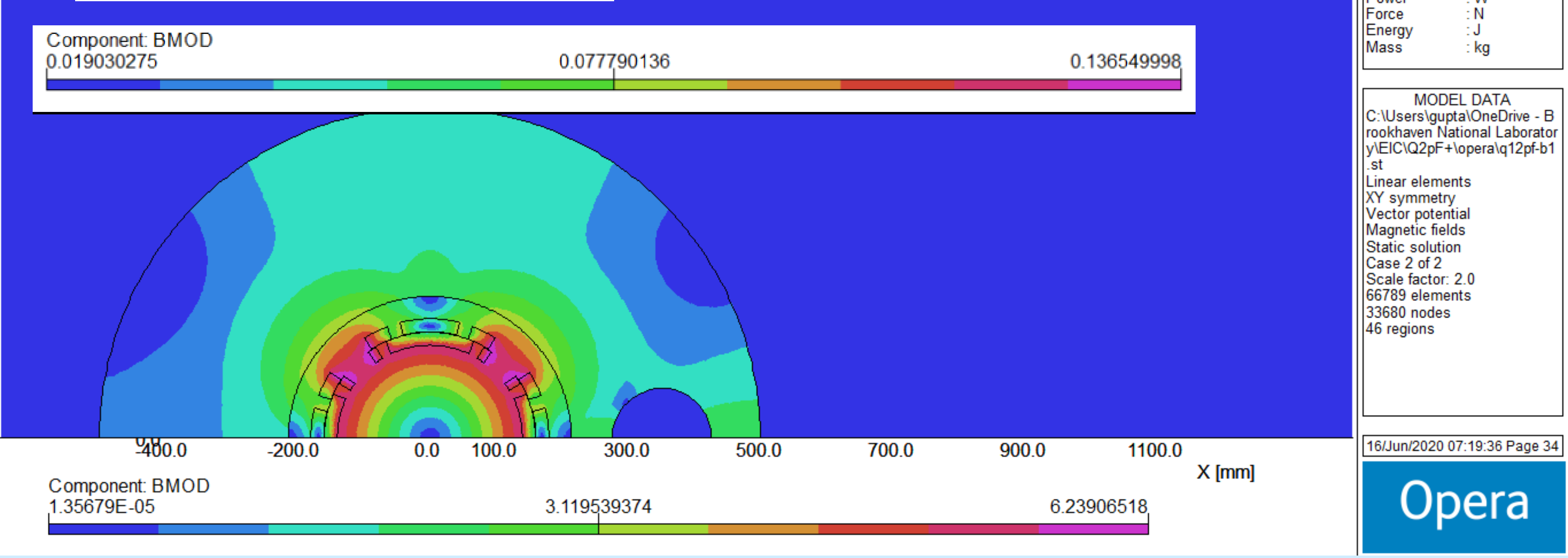


Field in the electron beam region Yoke outer radius = 500 mm



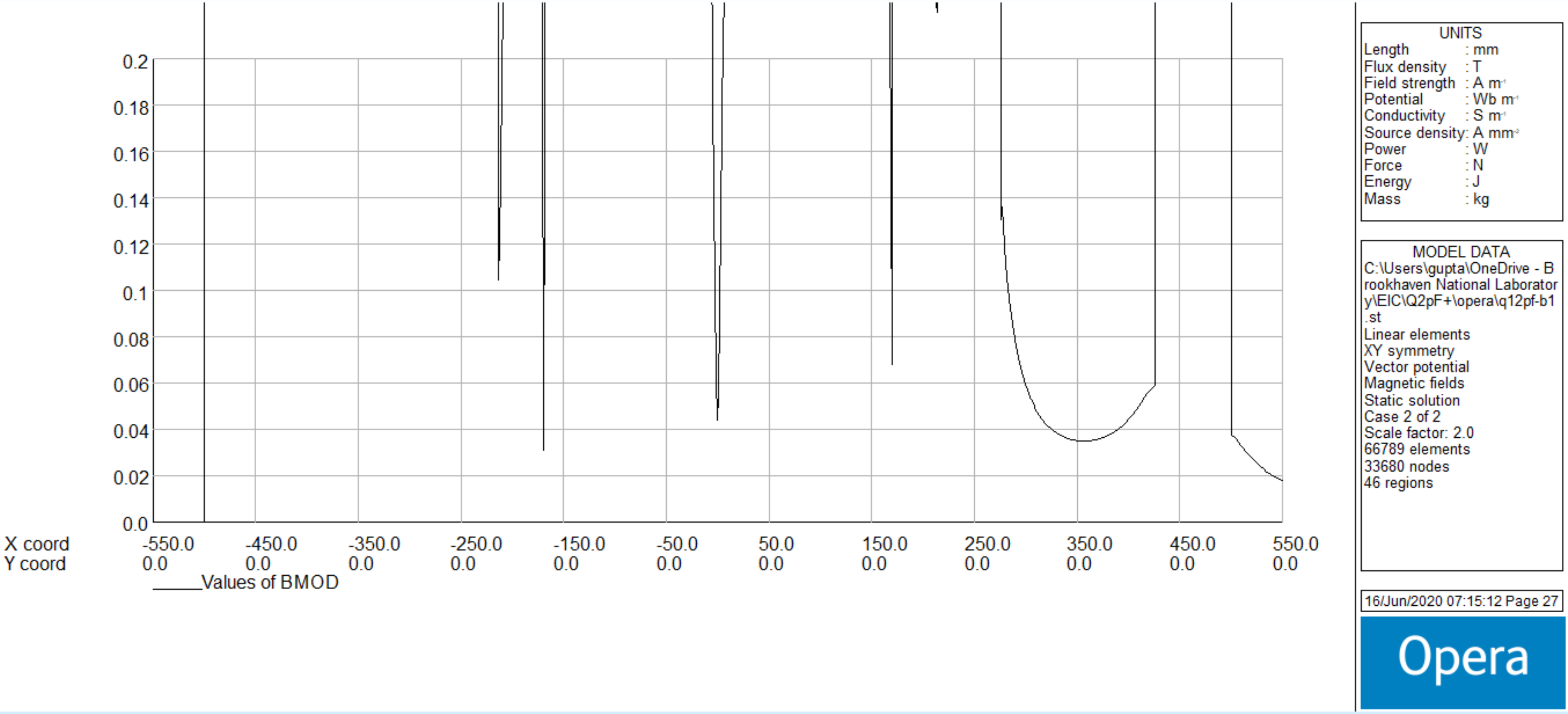
Significant field



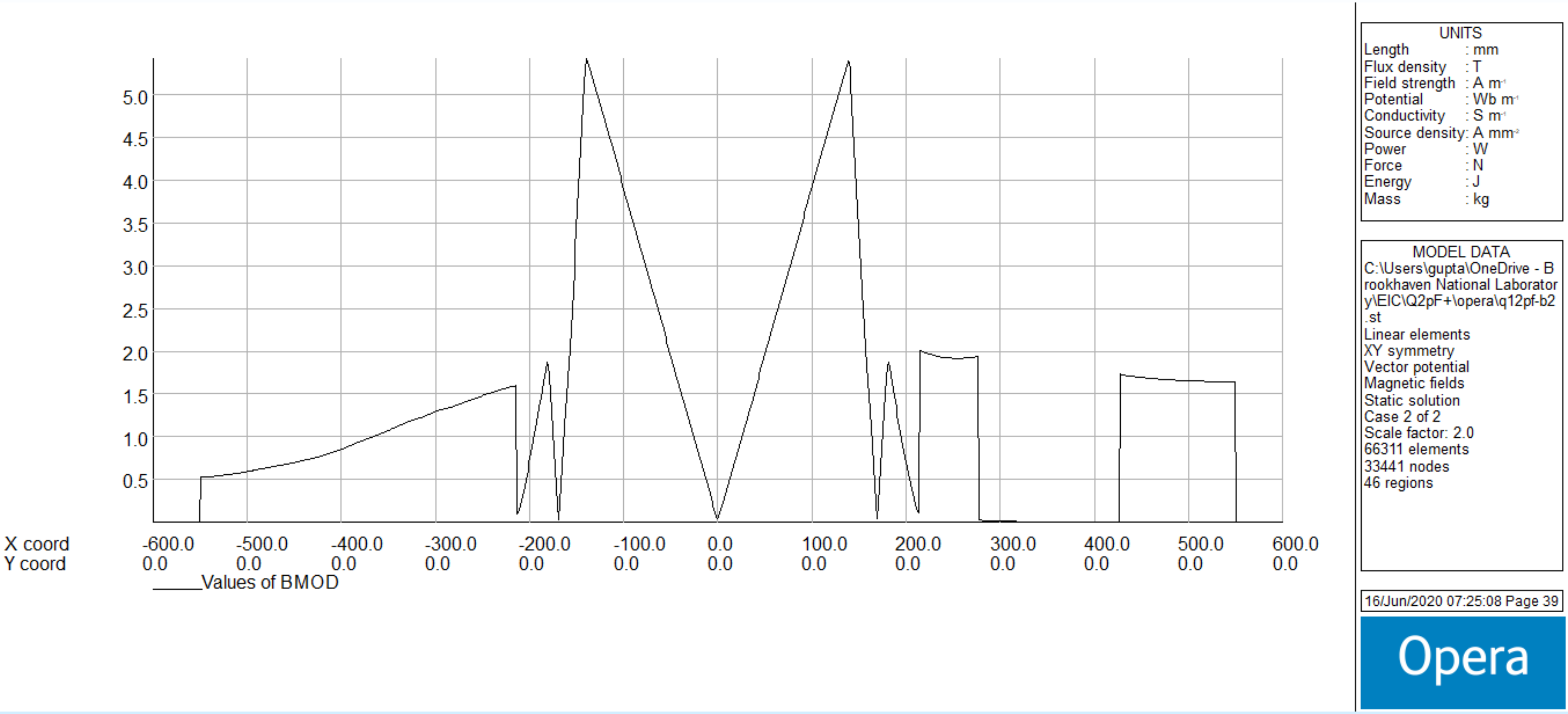
Extra layer reduced the space for the flux return and increased the field the electron beam region.

Field in the electron beam region can be reduced by increasing the yoke size

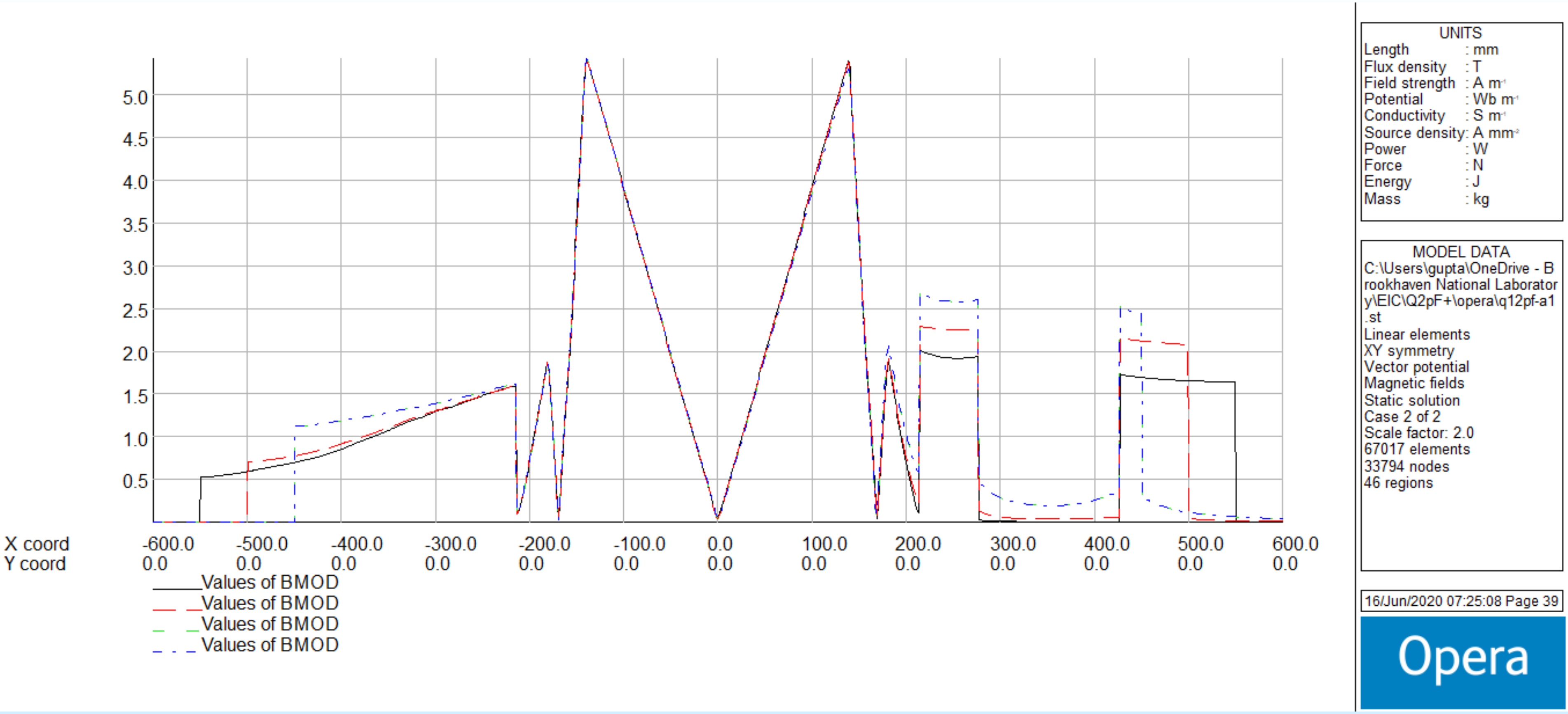
Field in the electron beam region Yoke outer radius = 500 mm



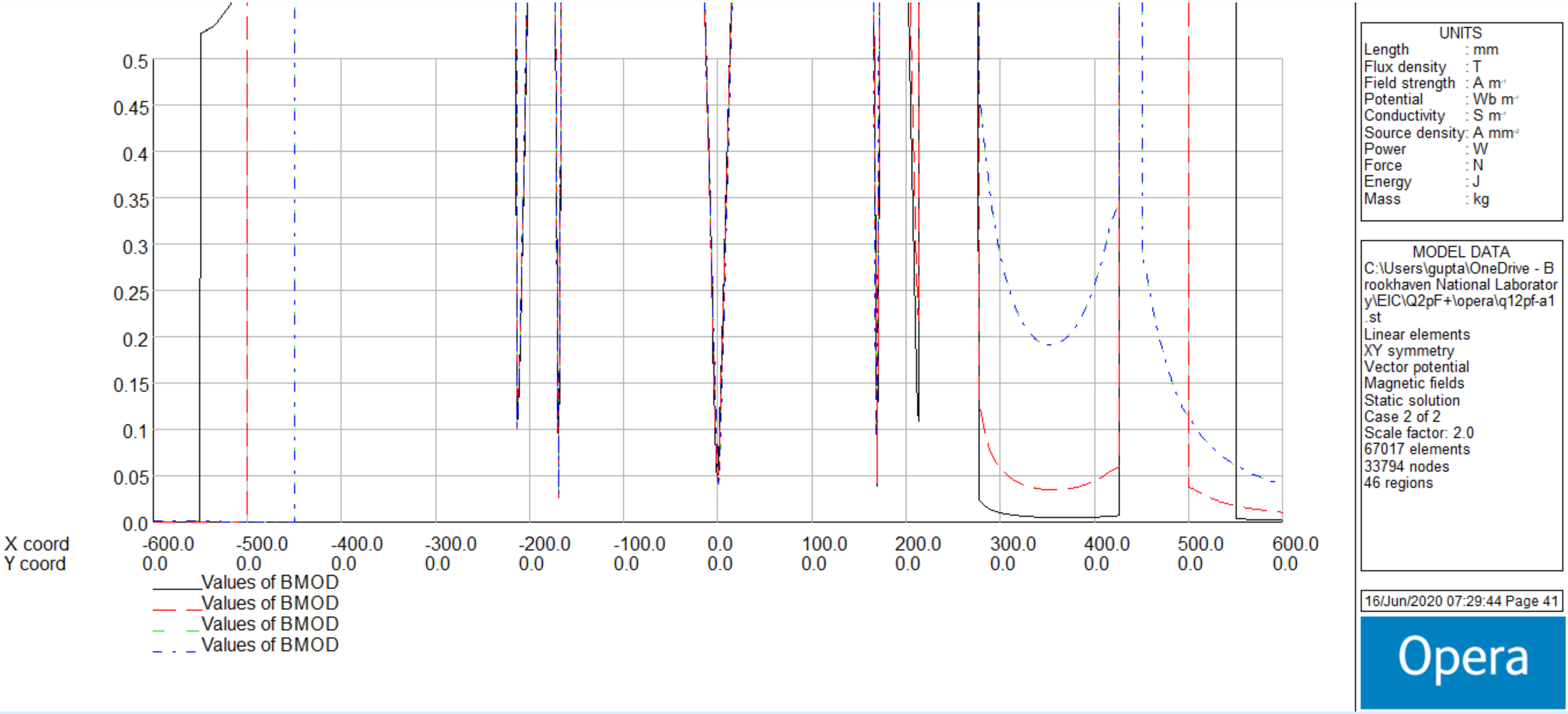
Field in the electron beam region Yoke outer radius = 550 mm



Comparison of yoke od



Comparison of yoke od



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