Q1ApF Coil and Q1BpF Iron plus Q1BpF Coil Redesign for 4K Operation

Ramesh Gupta

Superconducting Magnet Division

July 14, 2020

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science U.S. DEPARTMENT OF ENERGY

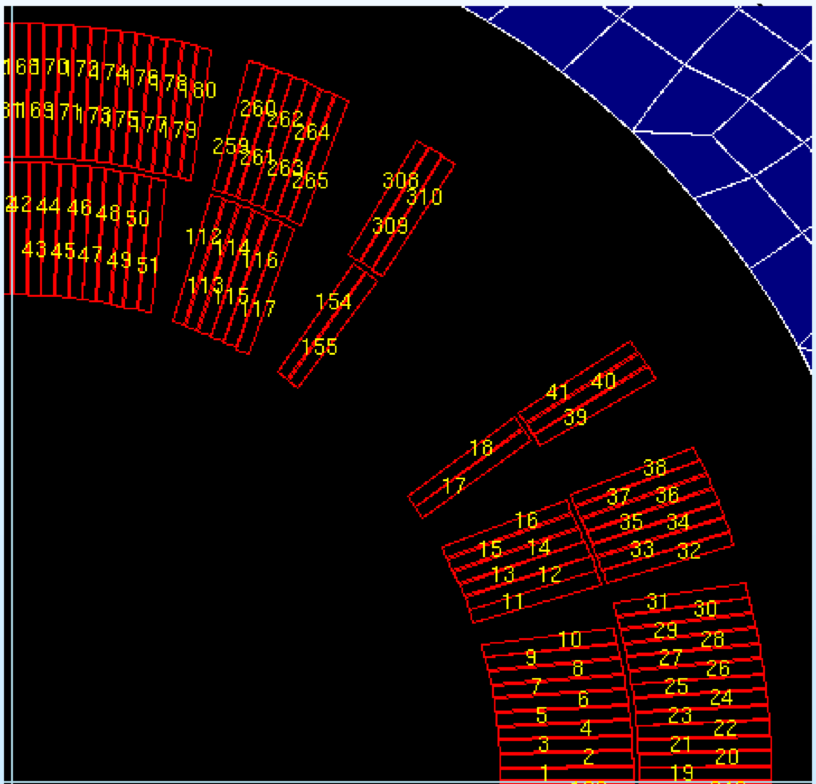
Overview

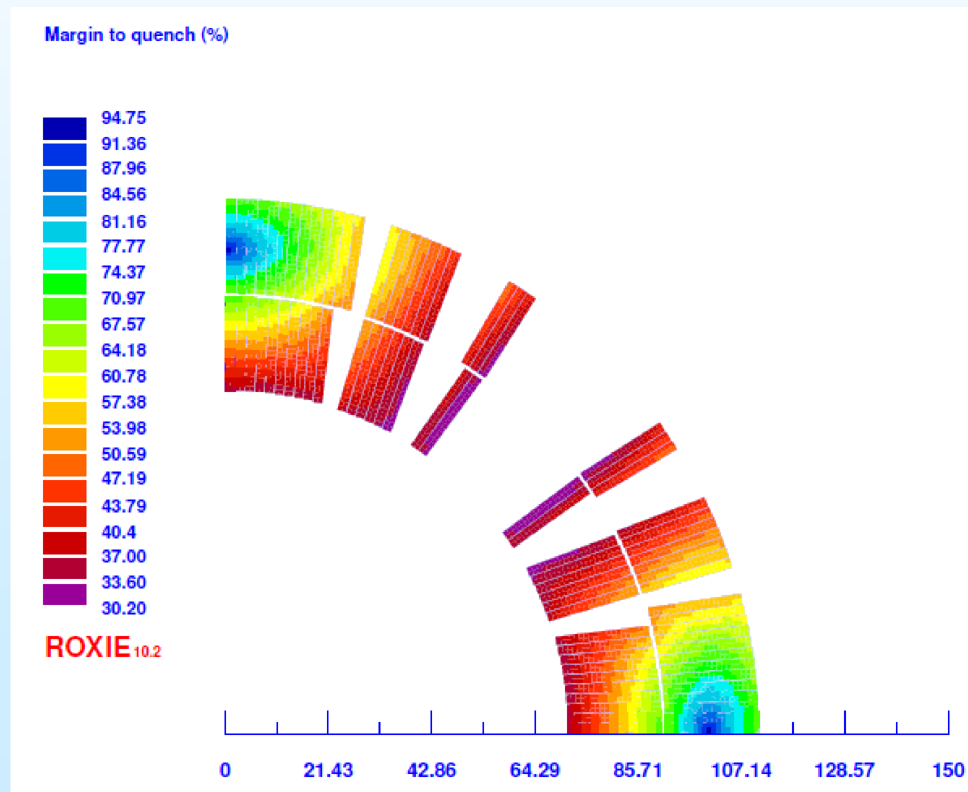
- Design studies of Q1ApF coil for a possible 4.2 K operation.
- Q1BpF yoke optimization to reduce field in electron beam region.
- Q1BpF coil redesign to increase margin for 4.2 K operation
- Several cases examined; only one each of above will be presented.
- In all cases, peak field (margin), field quality and field in the electron beam region are being optimized together.
- The design consider several fronts - geometric, mechanical, magnetic design. Anis will continue on further optimization.
- Strand/wire used: dia =1.065 mm, Cu/Sc =1.3 and 1.6.
- Use this cable (and RHIC dipole type cable) for all EIC magnets.
- Some thoughts on system optimization

Q1ApF Coil 2 Layers, Four wedges 41 turns/pole (18 inner, 23 outer)

- **Poles of inner and outer layers aligned**
- **Coil poles have proper angles for collaring**
- **Two wedges in each layer to deal with keystone**

Coil radius: 71 mm (Q1B had 93 and Q2B had 140

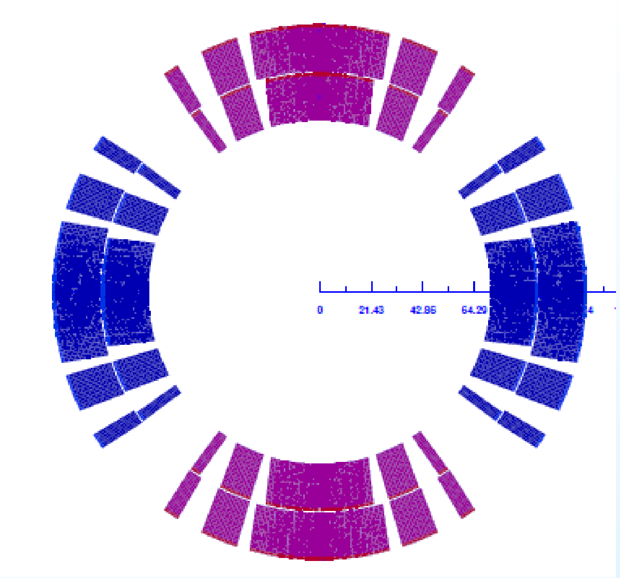




Field Harmonics in Q1BpF

A reasonably good field quality is obtained with a good mechanical design (coil radius 71 mm)

(all harmonics <1 unit)



Gradient 72.6 T/m at ~9.3 kA

REFERENCE RADIUS (mm) 36.0

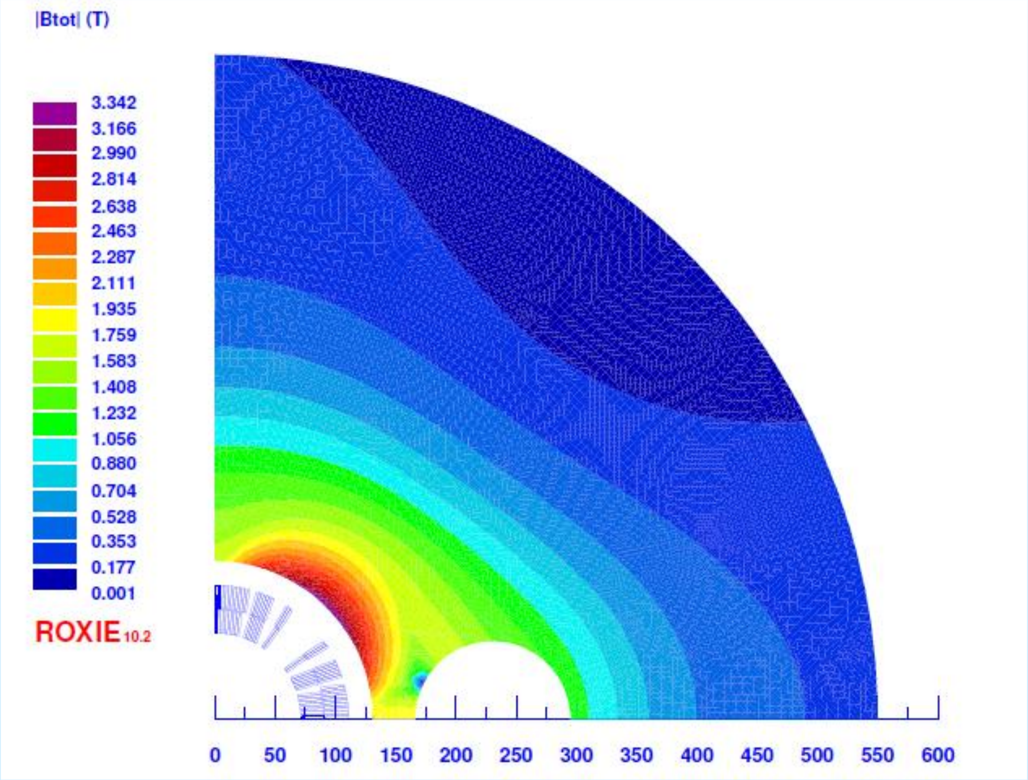
MAGNET STRENGTH (T/(m^(n-1)) 72.6821

NORMAL RELATIVE MULTIPOLES (1.D-4):

b 1:	-0.77119	b 2:	10000.00000	b 3:	-0.17439
b 4:	-0.03551	b 5:	-0.01107	b 6:	-0.18329
b 7:	-0.00119	b 8:	-0.00028	b 9:	-0.00008
b10:	0.17361	b11:	-0.00001	b12:	-0.00000
b13:	-0.00000	b14:	0.04157	b15:	-0.00000
b16:	-0.00000	b17:	0.00000	b18:	-0.00097
b19:	-0.00000	b20:	-0.00000	b	

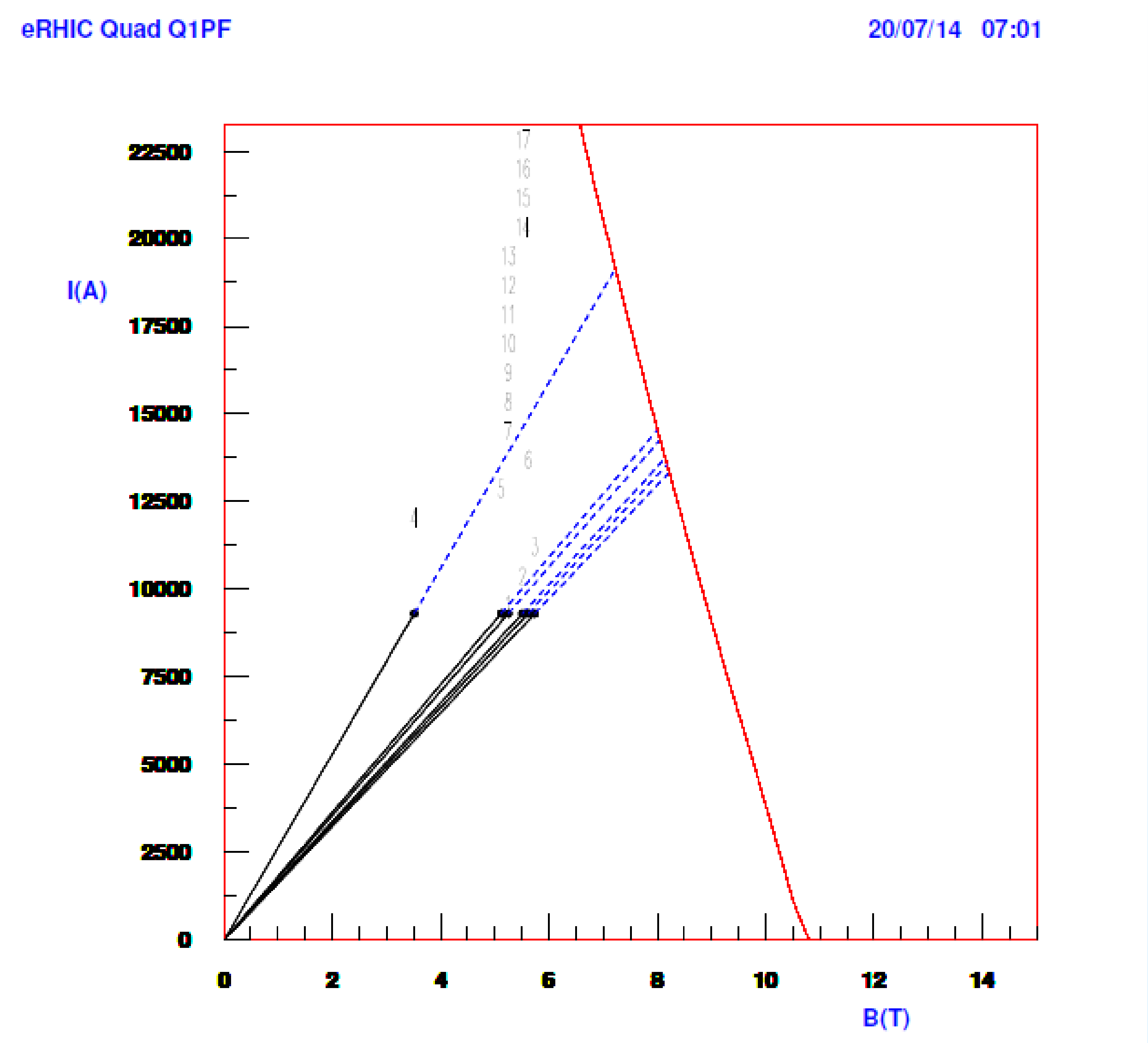
Iron Yoke – Initial Design

Yoke: ir = ~131 mm; or = 550 mm (or 500 mm)
Hole@ x = 230.5 mm to 259 mm
Radius of hole = 44.6 & 58.4 mm (+20 mm for electron beam)
Collar width = ~20 mm



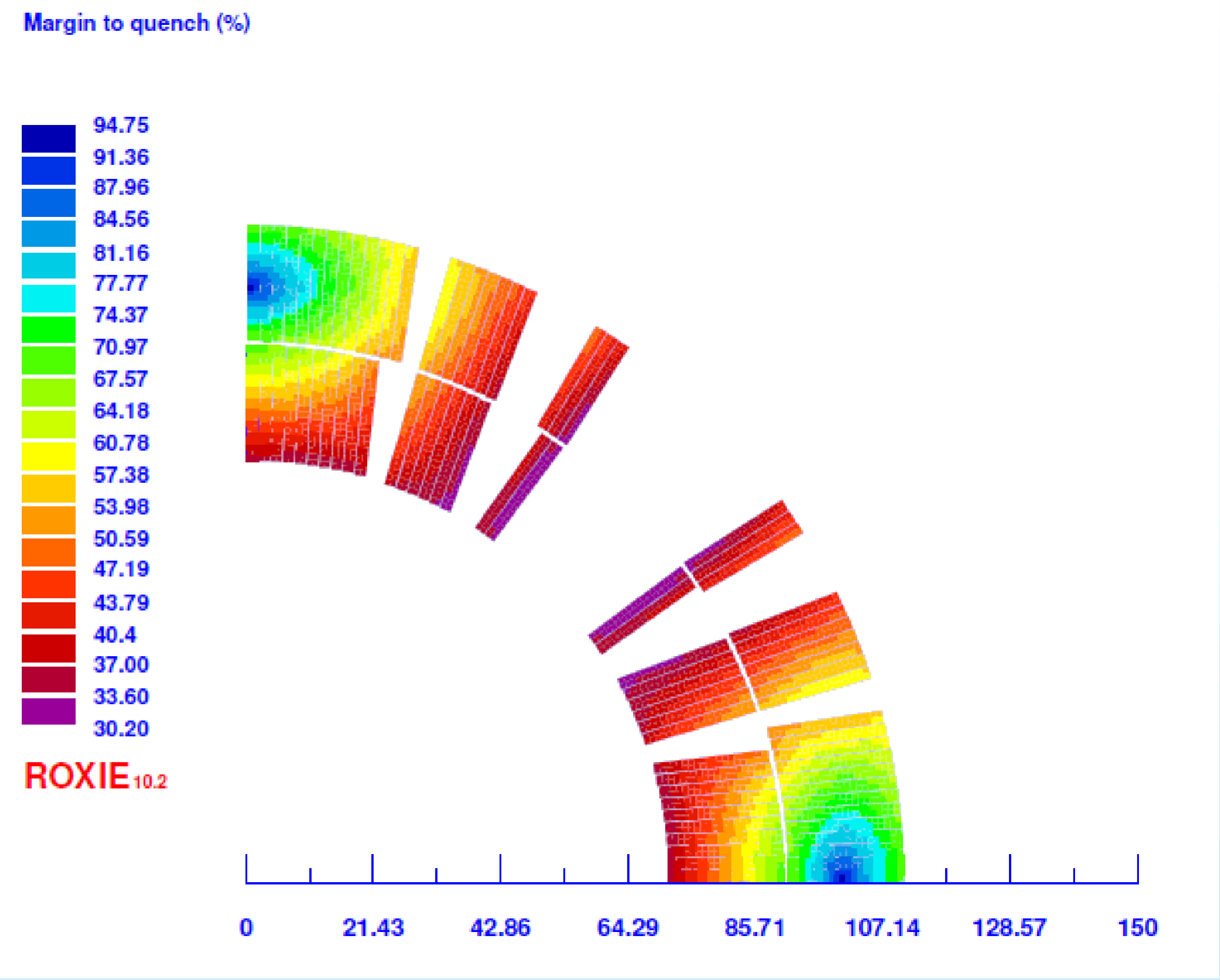
ROXIE

Field Margin at 4.2 K

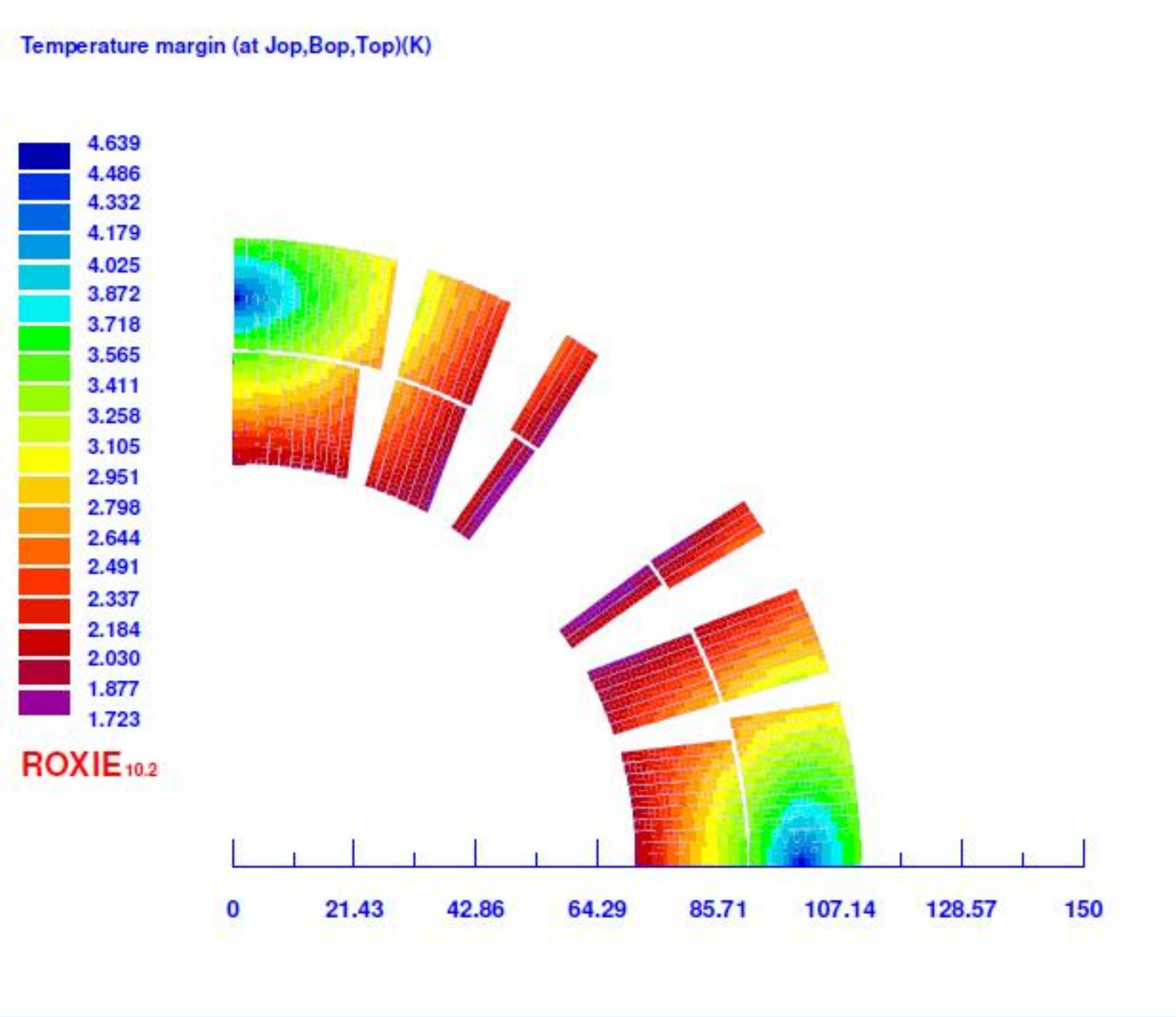


Very Good Margin

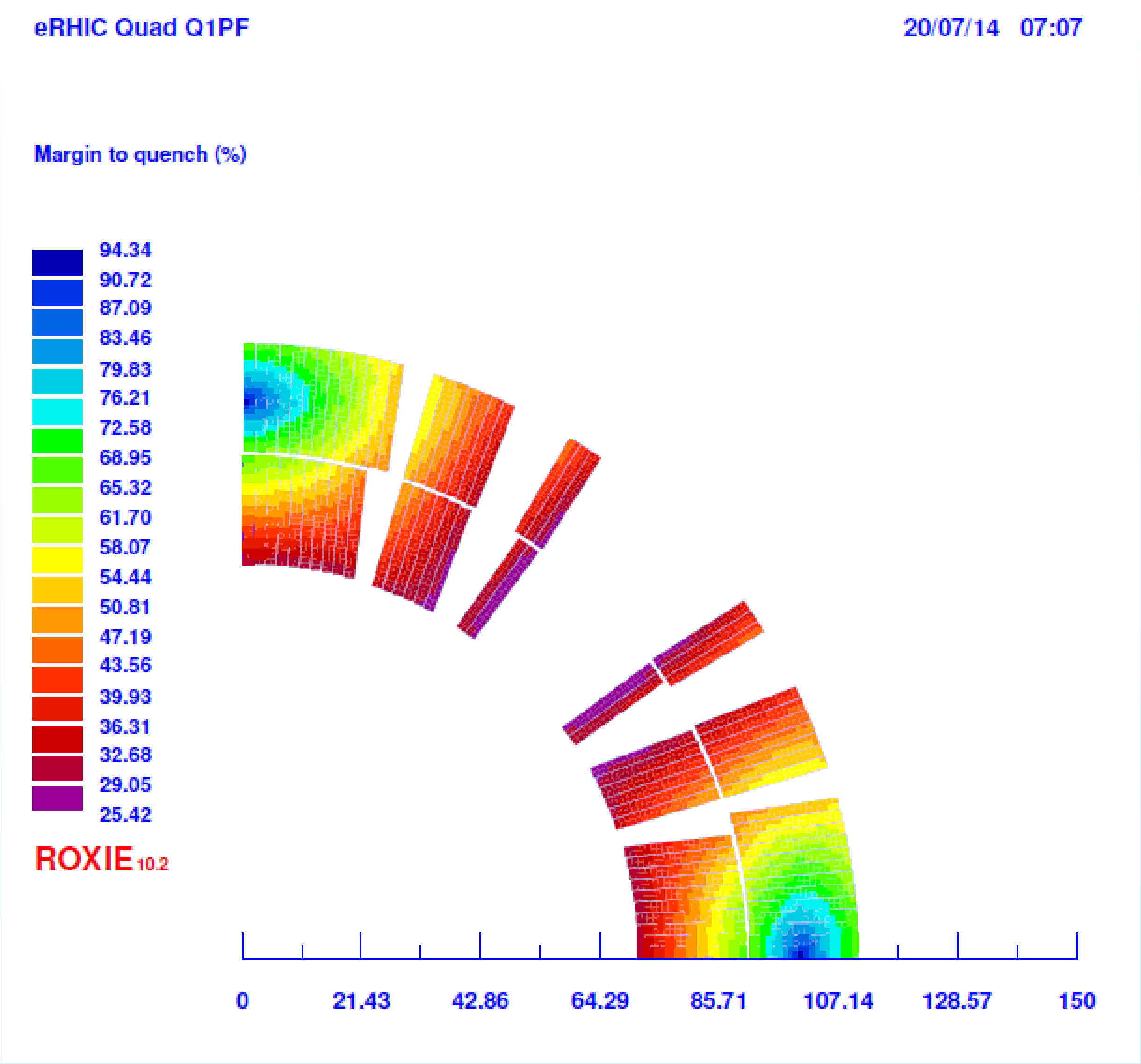
Field Margin at 4.2 K



Temperature Margin at 4.2 K Over Different Blocks



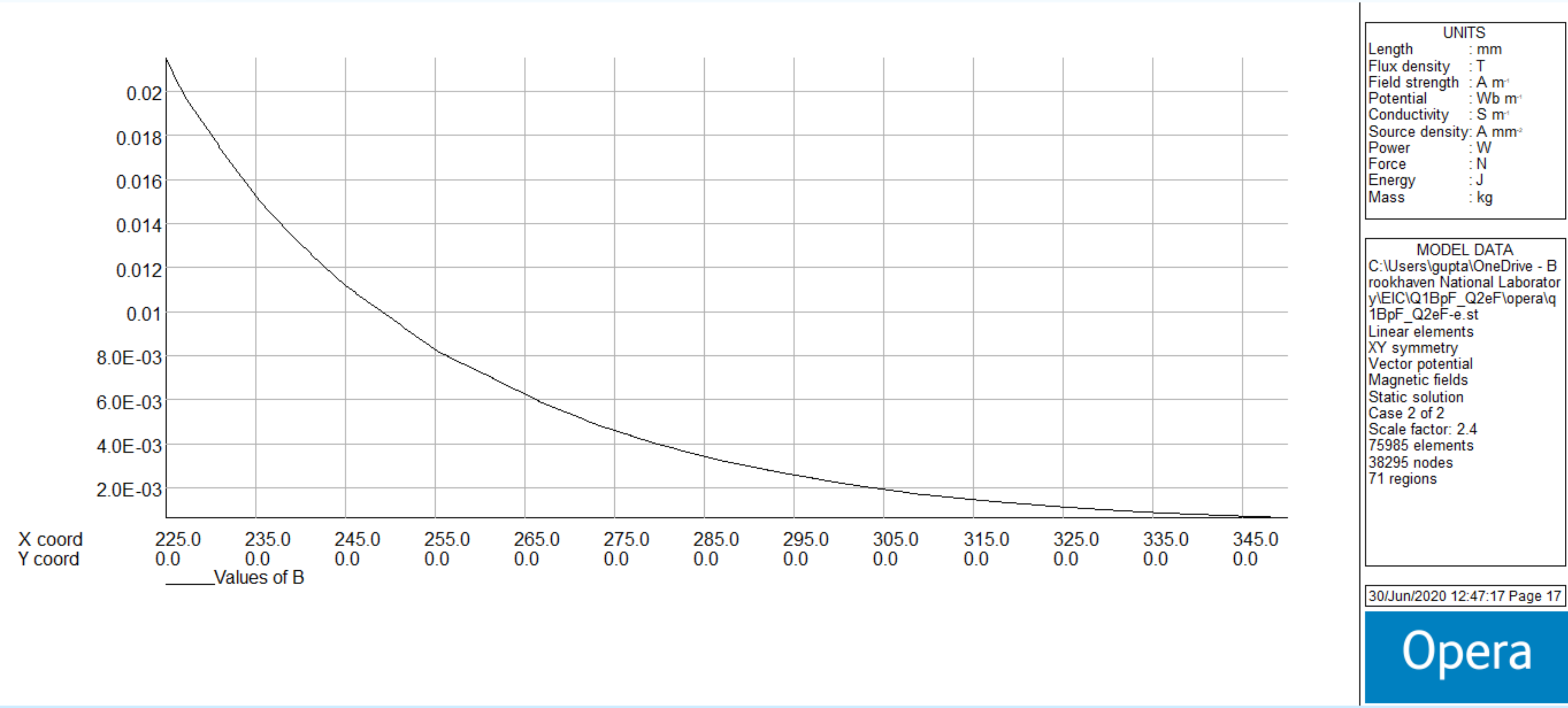
Field Margin at 4.6 K, Cu/Sc =1.6



Iron Optimization to Reduce Field in the electron Beam Region

Field in the electron beam region
Yoke OR = 550 mm, Hole@288.3 mm

Shown a couple week ago (6/30/2020)
Field in electron Beam Region 0.02 T

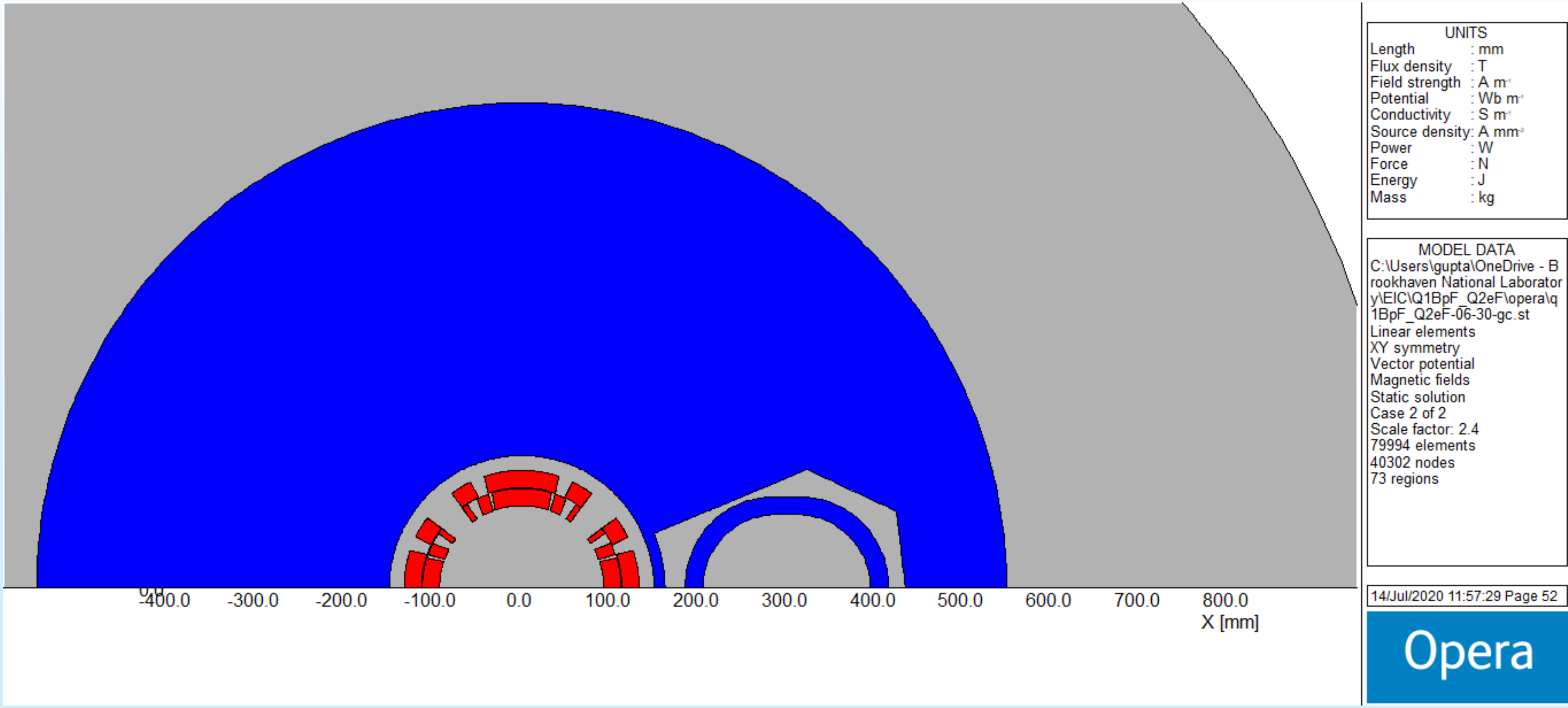


Several techniques from the first principle examined.

Only a couple of cases shown

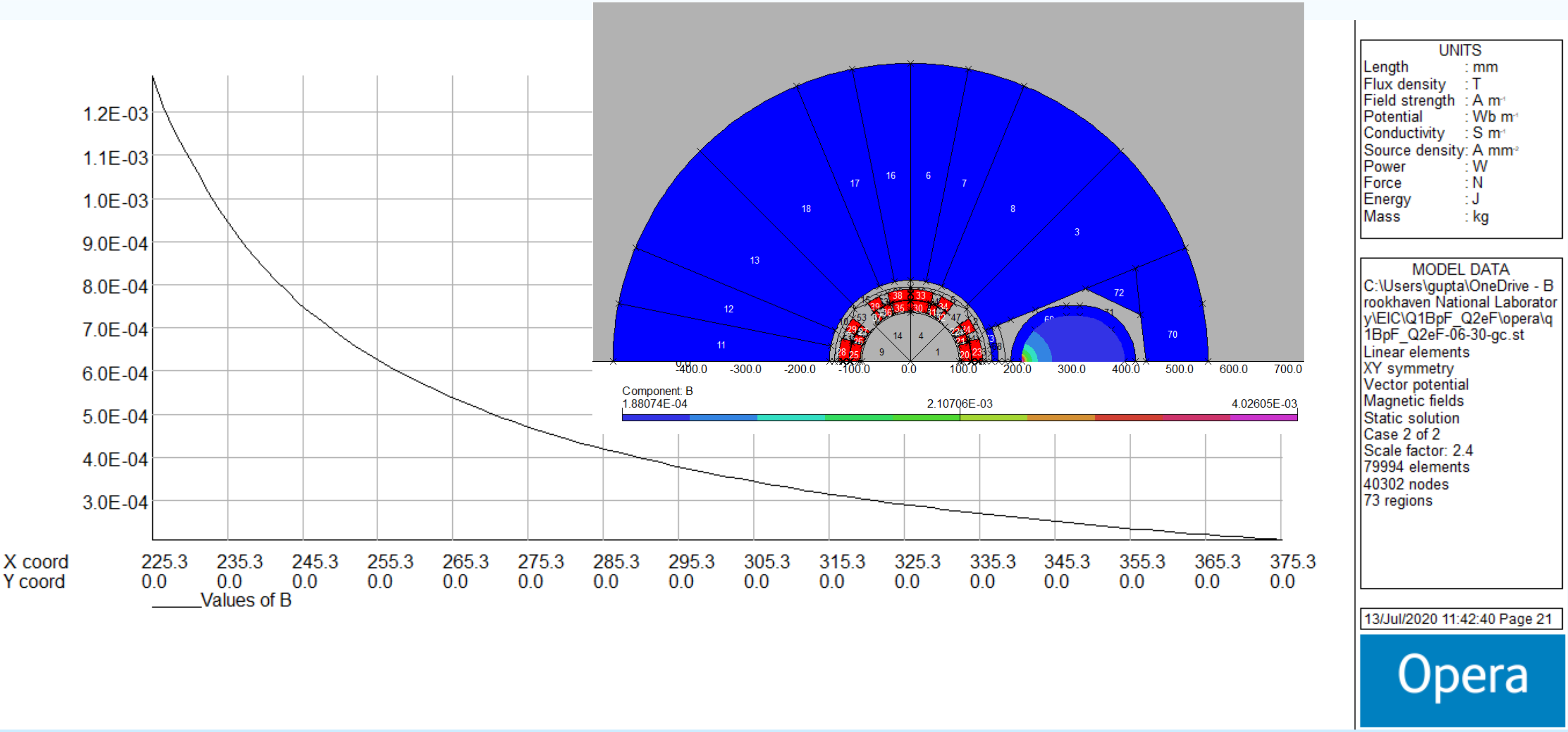
Technique: Guide flux away from electron beam region

Provide circular shielding for electron and ion beam

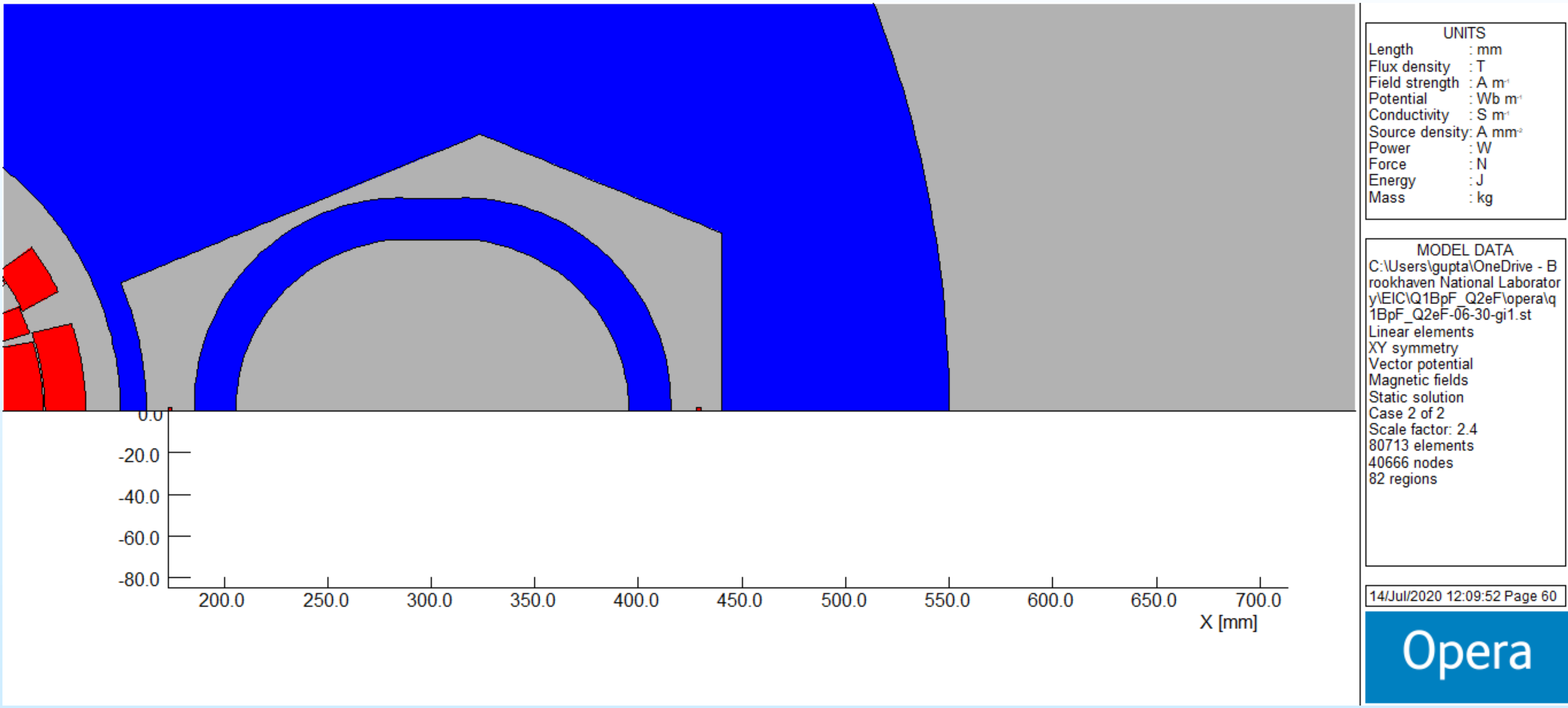


Over an order of magnitude reduction in field

This field can be shield with mu-metal, etc.



Further Reduction

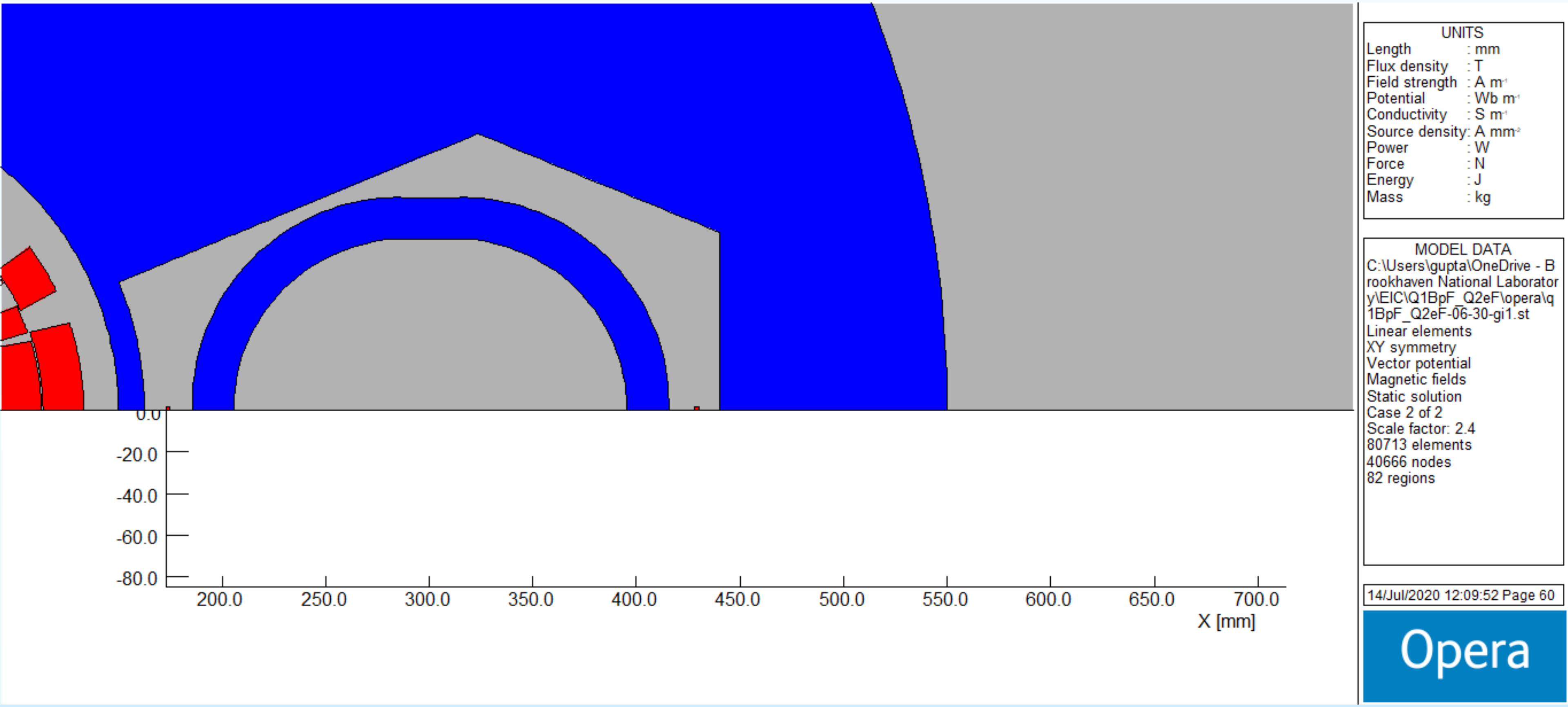


BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division

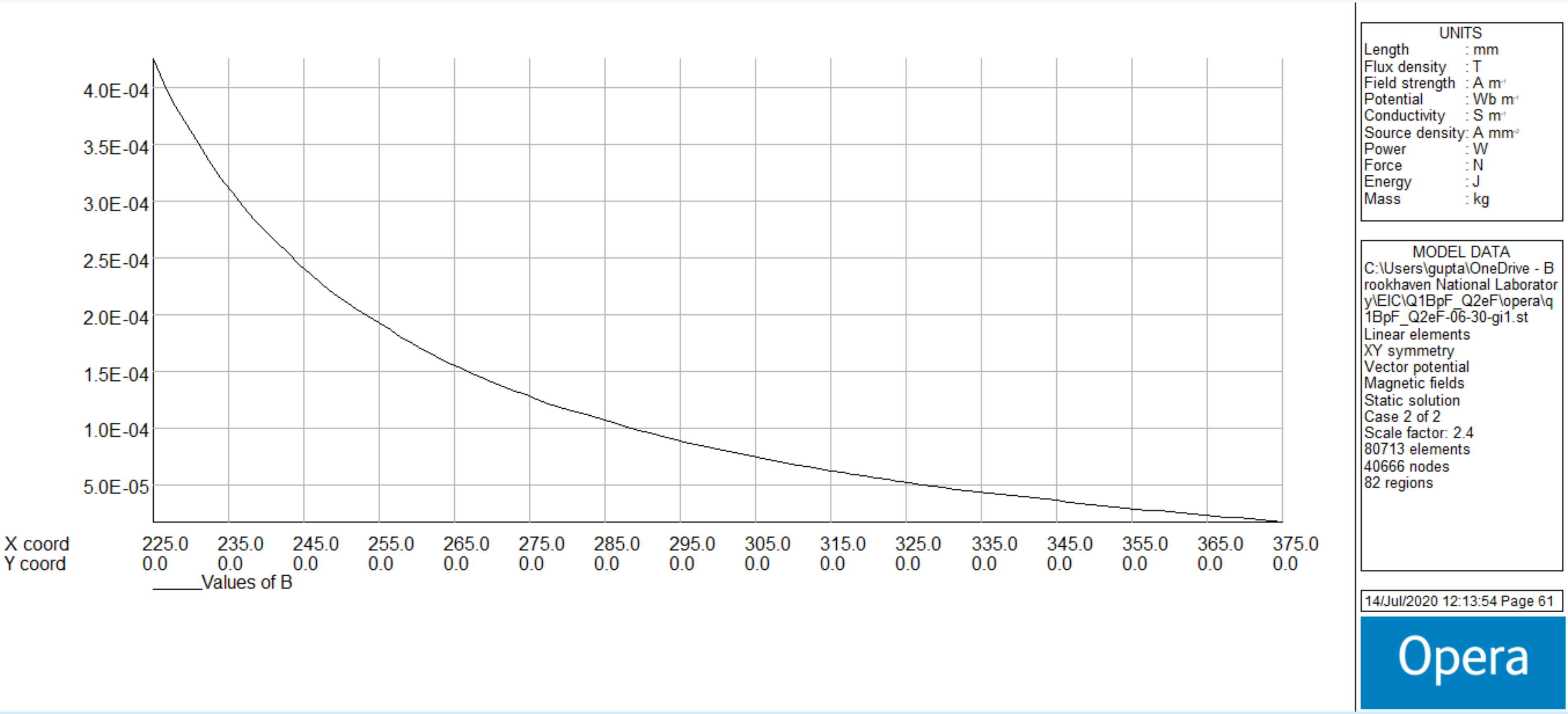
Shielding

Tiny current on the two side of circular yoke over e-beam (still shielding for electron and ion beam)



Two order of magnitude reduction

Tiny current on the two side of circular yoke over e-beam gives a solution (still shielding for electron and ion beam)

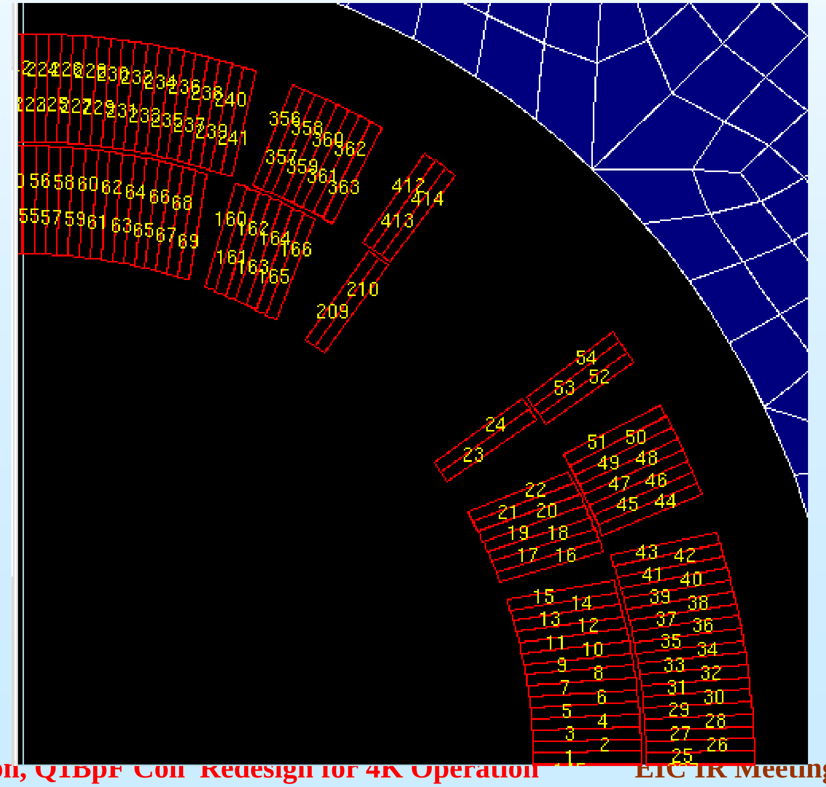


Redesign of Q1B to increase margin

New Q1BpF Coil 2 Layers, 4 Wedges 54 turns/pole (24 inner, 30 outer)

- **Poles of inner and outer layers aligned**
- **Coil poles have proper angles for collaring**
- **Two wedges in each layer to deal with keystone**

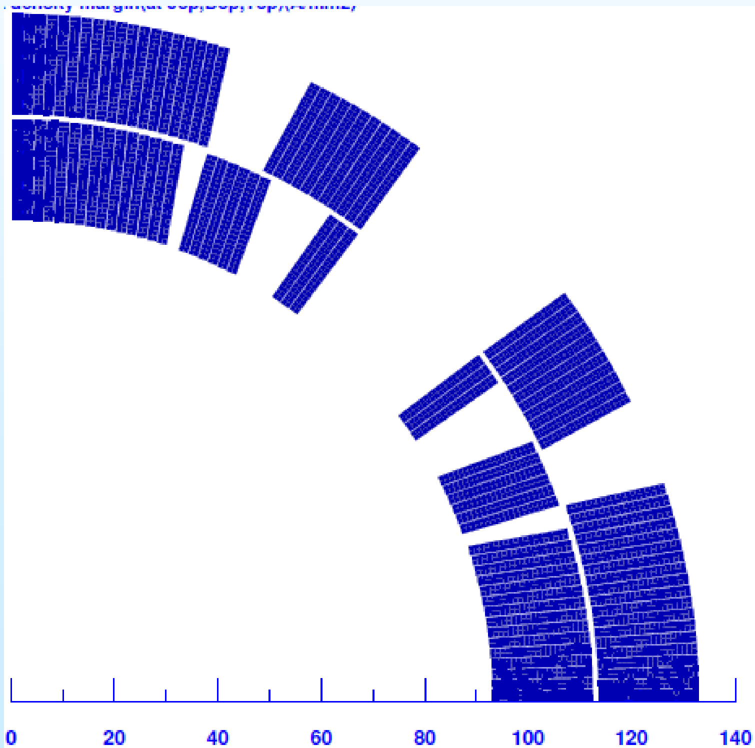
Coil radius: 93 mm (Q1A has 7a and Q2B has 140 mm)

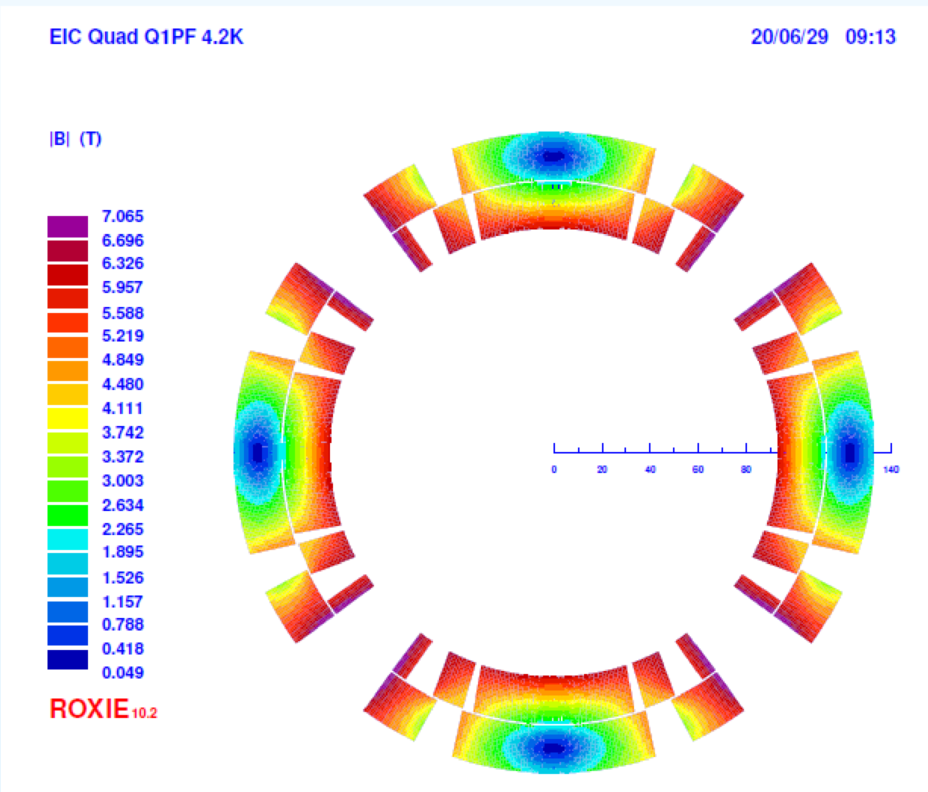


Coil 2 Layers, Three wedges (2+1) 54 turns/pole (24 inner, 30 outer)

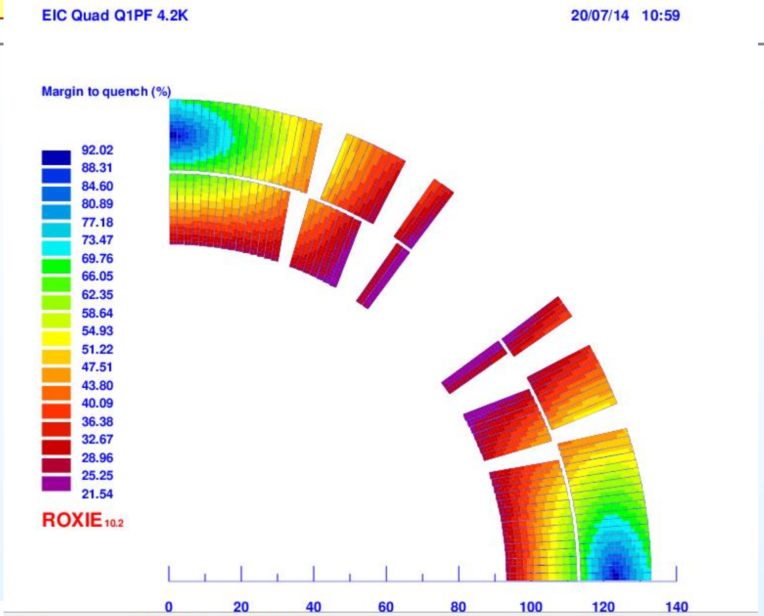
- **Poles of inner and outer layers aligned**
- **Coil poles have proper angles for collaring**
- **Two wedges in the inner to deal with keystone**

Coil radius: 93 mm (Q2B had 140 mm)





Field Harmonics in Q1BpF



A reasonably good field quality is obtained with a good mechanical design (coil radius 93 mm)

(all harmonics <1 unit)

REFERENCE RADIUS (mm) . 36 ..

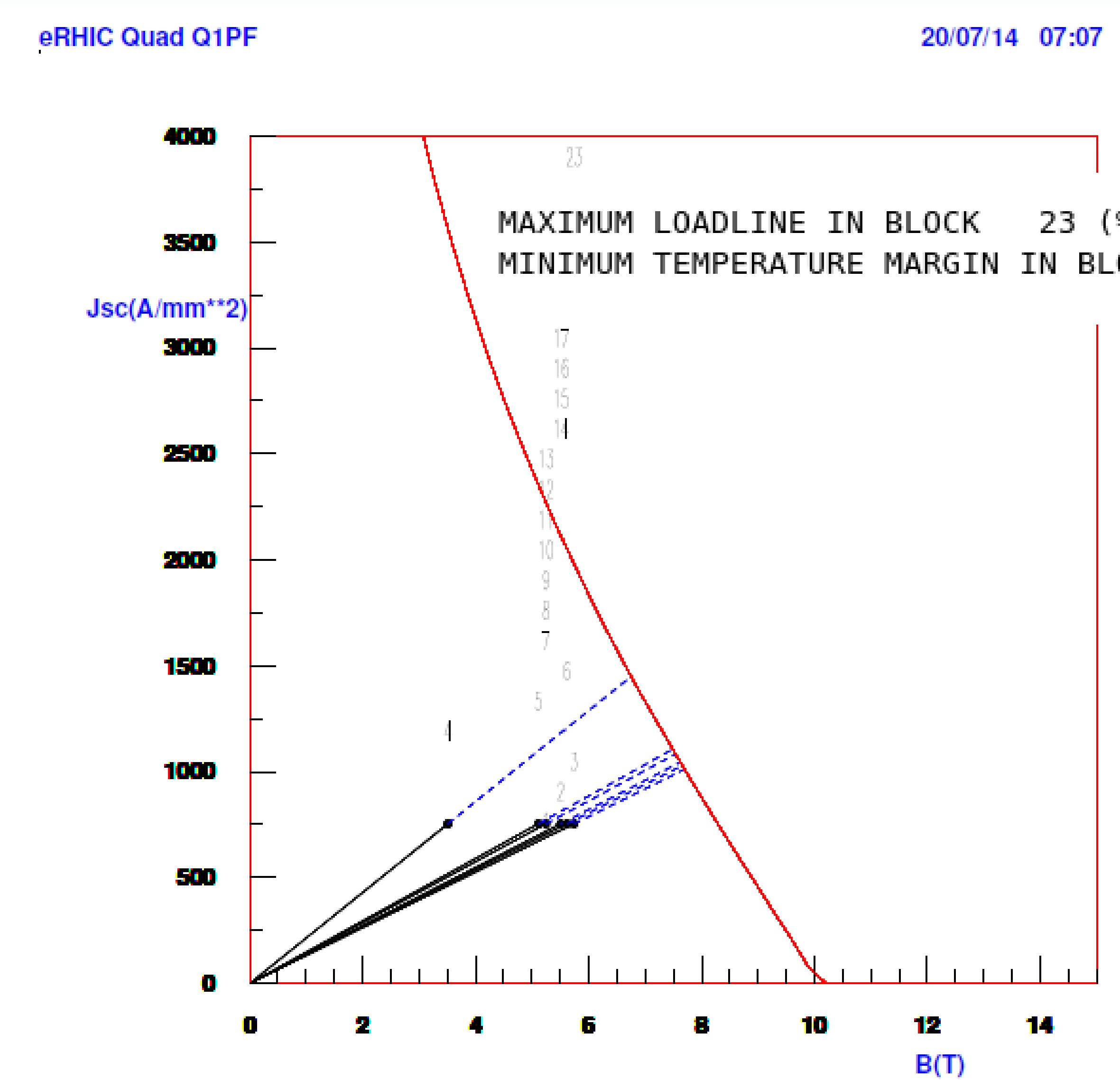
MAGNET STRENGTH (T/(m^(n-1)) 66.3340

NORMAL RELATIVE MULTIPOLES (1.D-4):

b 1:	-4.01552	b 2:	10000.00000	b 3:	-0.42580
b 4:	-0.08594	b 5:	-0.02245	b 6:	-0.37287
b 7:	-0.00156	b 8:	-0.00035	b 9:	-0.00008
b10:	-0.03587	b11:	-0.00001	b12:	-0.00000
b13:	-0.00000	b14:	0.00119	b15:	-0.00000
b16:	0.00000	b17:	-0.00000	b18:	-0.00002

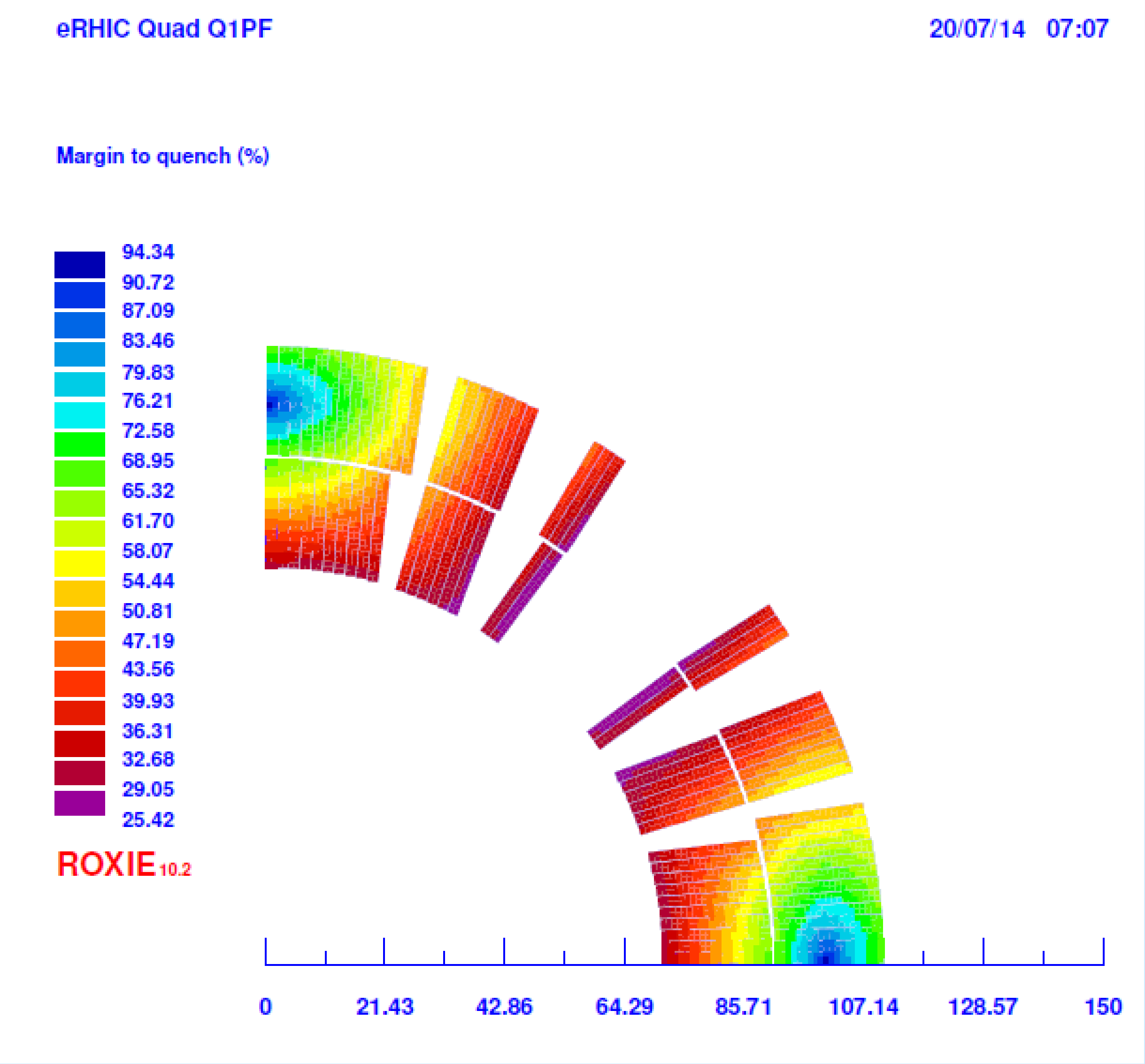
Gradient 66.2 T/m at ~9.8 kA

Field Margin at 4.2 K
Cu/Sc = 1.3

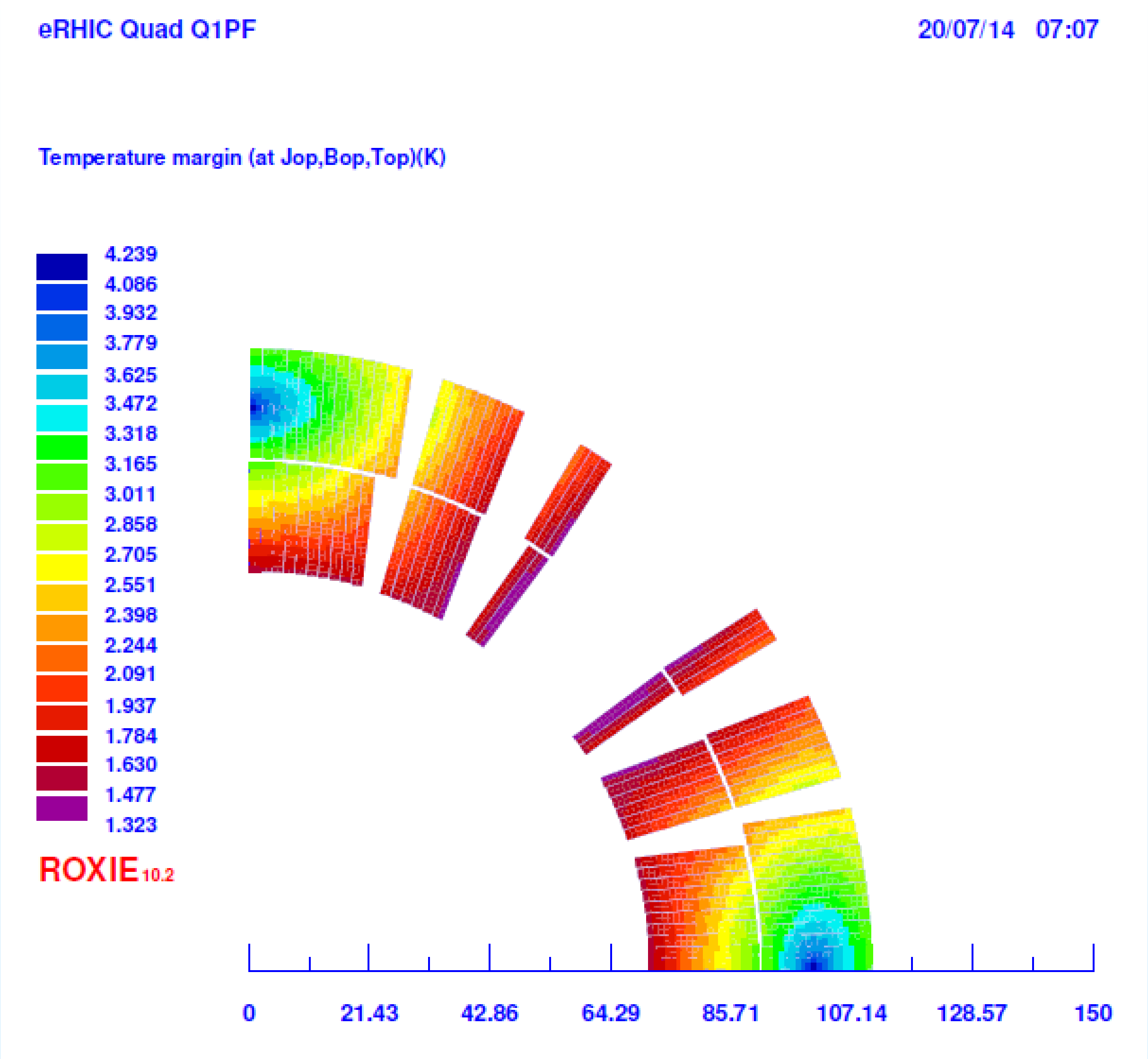



```
MAXIMUM LOADLINE IN BLOCK   23 (%) .................     78.4529
MINIMUM TEMPERATURE MARGIN IN BLOCK   23 (T) .......      1.2764
```

Field Margin at 4.2 K



Temperature Margin at 4.2 K Over Different Blocks



Discussion

- **Good results for 4.2 K option**
- **Q1A and Q1B have the same polarity**
- **Q1A has much bigger margin than Q1B (though new Q1B is in acceptable range)**
- **Re-optimize optics for either increasing length of Q1B (reduce length of Q1A) or increasing design gradient of Q1A and reducing that of Q1B**

- **Next task – Q1A iron**