Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Revised Q2pF Cross-section with updated turn-to-turn spacing

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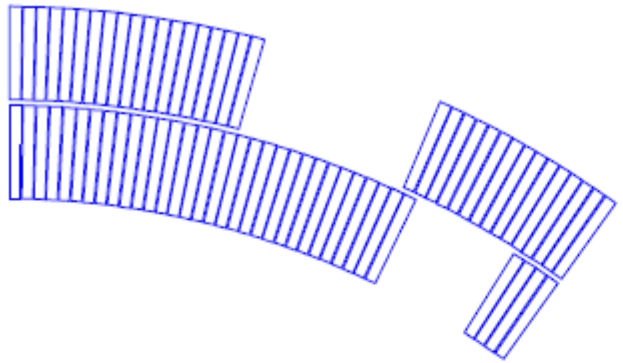
Updated Cross-section

- **Cross-section needs to be updated to accommodate a significant change in turn-to-turn spacing (0.0965 mm instead of 0.12 mm)**
- **Since the inner layer has 35 turns and the outer 34 turns, means a decrease of over 0.8 mm in each layer. This is a large change compared to the typical acceptable tolerances of 50 μm (2 mils).**
- **Such a large change test the flexibility of the design.**
- **Initial results show that it can be accommodated.**

Revised X-section with Symmetric Wedges

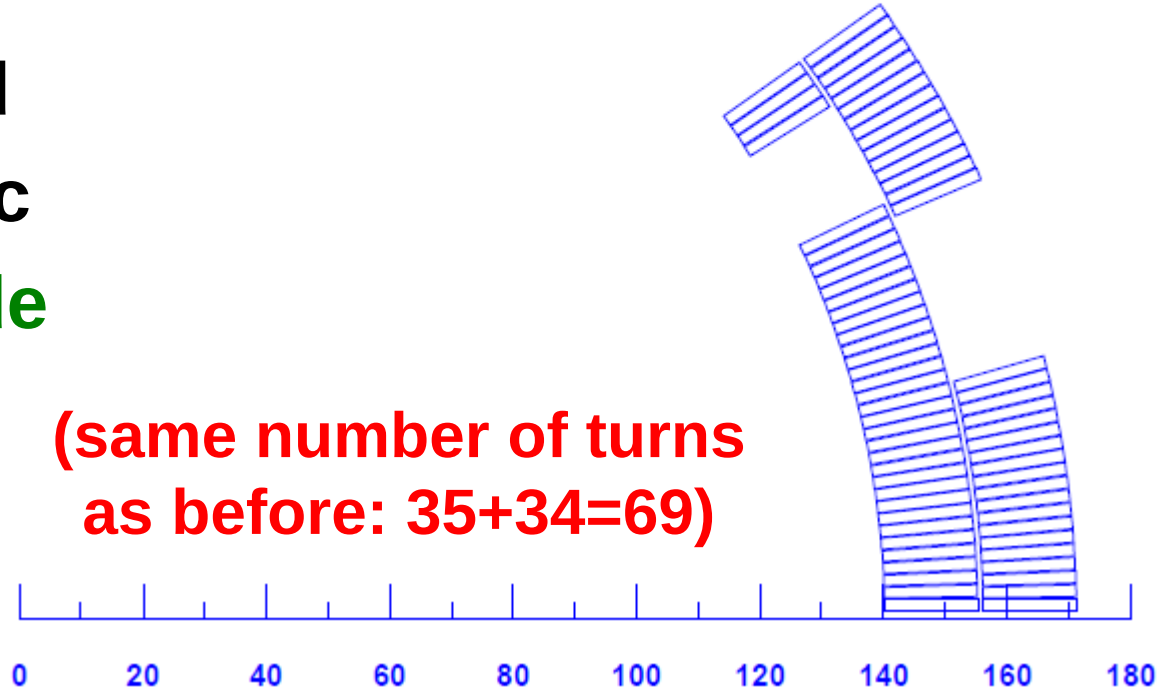


Looks good mechanically

- **Uses EIC Quad Cable**
- **Field Quality Optimized**
- **Peak field Optimized**
- **Poles of Outer and Inner aligned**
- **Wedges made exactly symmetric**
- **Collaring process should provide a good pre-stress**

(note: wedge shape at poles)

(same as before)



(same number of turns as before: 35+34=69)

Comparison with the Previous Design

Previous Design

5	ALLPOLYIL	0.15	0.12	POLYIMID MB INNER

Block Data 2D

No	Type	NCab	R	ϕ	α	Current	Cable name	N1	N2	I
1	Cos	31	140	0.54	0	-8500	EICLHCQ2K	2	20	0
2	Cos	4	140	31.179	25.196	-8500	EICLHCQ2K	2	20	0
3	Cos	21	156	0.54	0	-8500	EICLHCQ2K	2	20	0
4	Cos	13	156	17	30	-8500	EICLHCQ2K	2	20	0

Previous value of insulation

No	X1	Xu	Xs	String	Act	Block
1	3	9	6.44	PHIRS	2	2
2	6	12	10.34	PHIRS	2	4
3	0	0	0	ALPHRS	2	2
4	0	0	0	ALPHRS	2	4

New Design

2	EICQ2INS	0.15	0.0965	EICQ2PF insulation

Block Data 2D

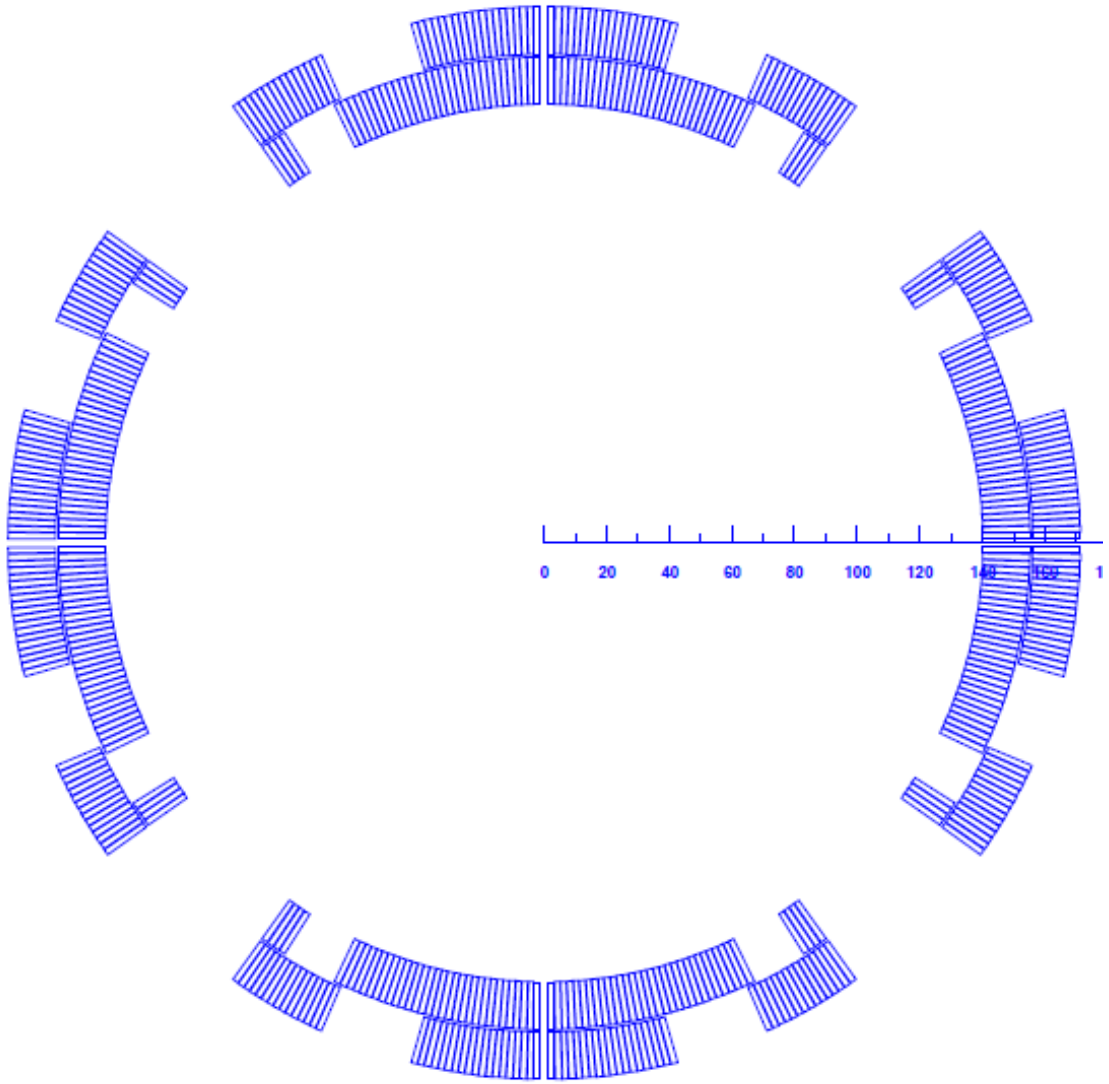
No	Type	NCab	X	Y	α	Current	Cable name	N1	N2	I
1	Cos	31	140	0.5	0	1000	EICQ2PF	2	20	0
2	Cos	4	140	32.2986	32.0511	1000	EICQ2PF	2	20	0
3	Cos	19	156	0.46	0	1000	EICQ2PF	2	20	0
4	Cos	15	156	24.6366	23.0593	1000	EICQ2PF	2	20	0

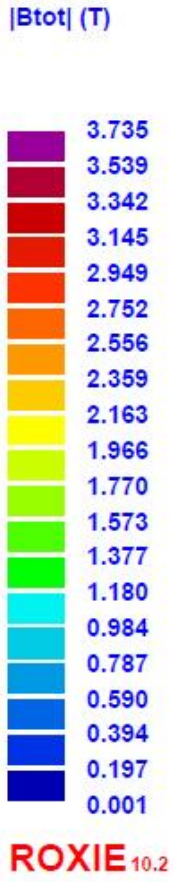
New value of insulation

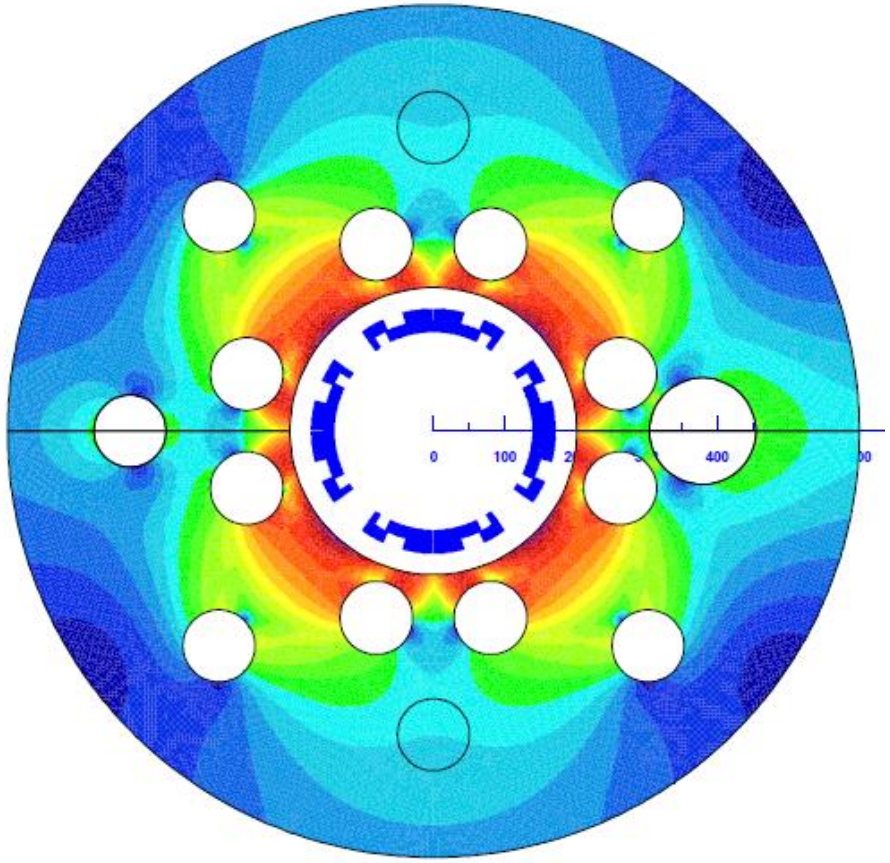
Optimization algorithm : 1 Extrem

No	X1	Xu	Xs	String	Act	N/a
1	0.5	1.3	0.5	PHI	2	1
2	0.45	1.3	0.46	PHI	2	3
3	2	9	6.6685	PHIRS	2	2
4	2	12	10.3535	PHIRS	2	4
5	0	0	0	ALPHRS	2	2
6	0	0	0	ALPHRS	2	4

Cross-section (ROXIE)







- **Symmetric wedges**

Comparison with the Previous Design (Field Harmonics)

Previous Design

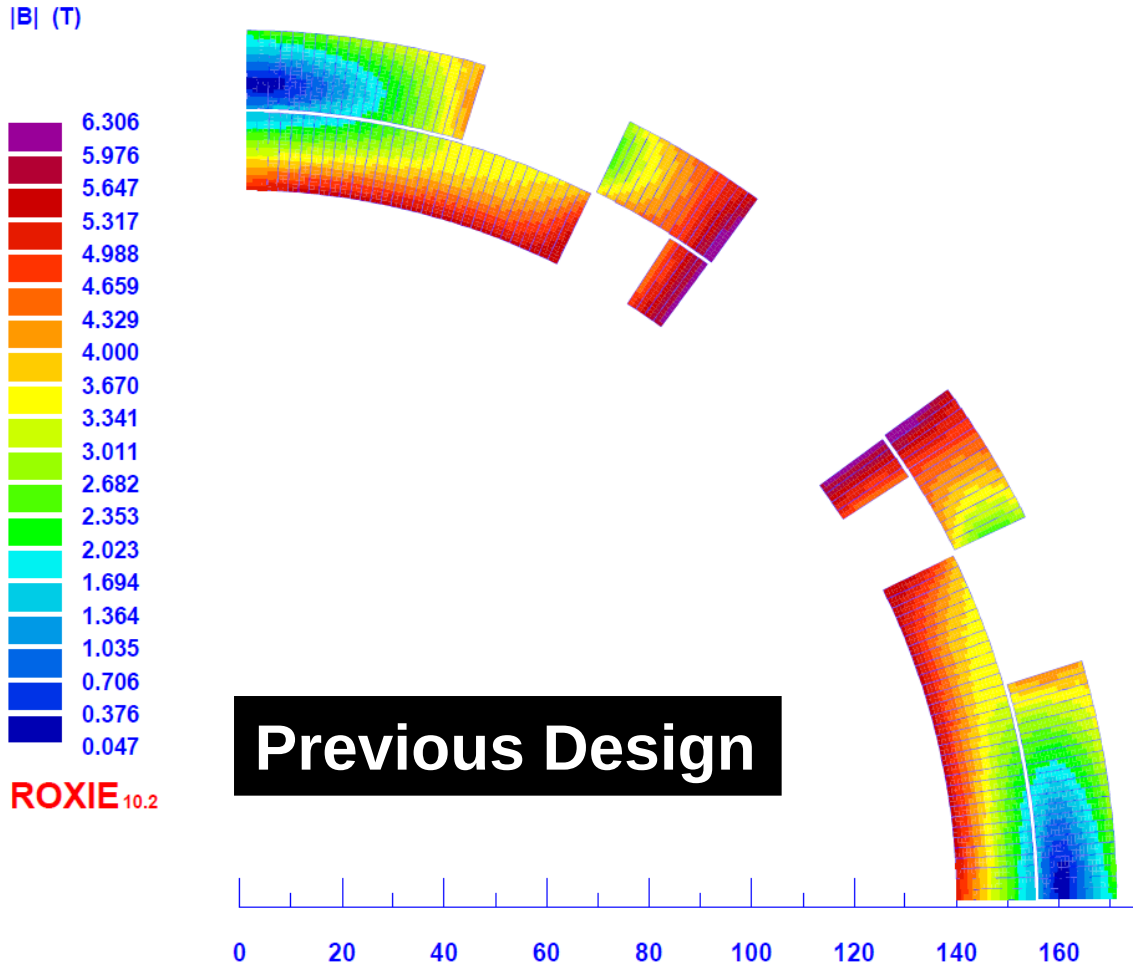
```
HARMONIC ANALYSIS NUMBER ..............................          1
MAIN HARMONIC .........................................          2
REFERENCE RADIUS (mm) .................................       83.0000
X-POSITION OF THE HARMONIC COIL (mm) ..................        0.0000
Y-POSITION OF THE HARMONIC COIL (mm) ..................        0.0000
MEASUREMENT TYPE ......................... ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ......................   0.6776E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) ........................................     3.147502
MAGNET STRENGTH (T/(m^(n-1)) ..........................     37.9217

NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:      -0.14254  b 2:  10000.00000  b 3:       0.00250
b 4:      -0.01577  b 5:      0.02641  b 6:      -0.10295
b 7:      -0.00201  b 8:     -0.00094  b 9:       0.00065
b10:      -0.40774  b11:     -0.00011  b12:       0.00000
b13:      -0.00002  b14:     -0.46484  b15:       0.00000
b16:      -0.00000  b17:     -0.00000  b18:       0.00550
```

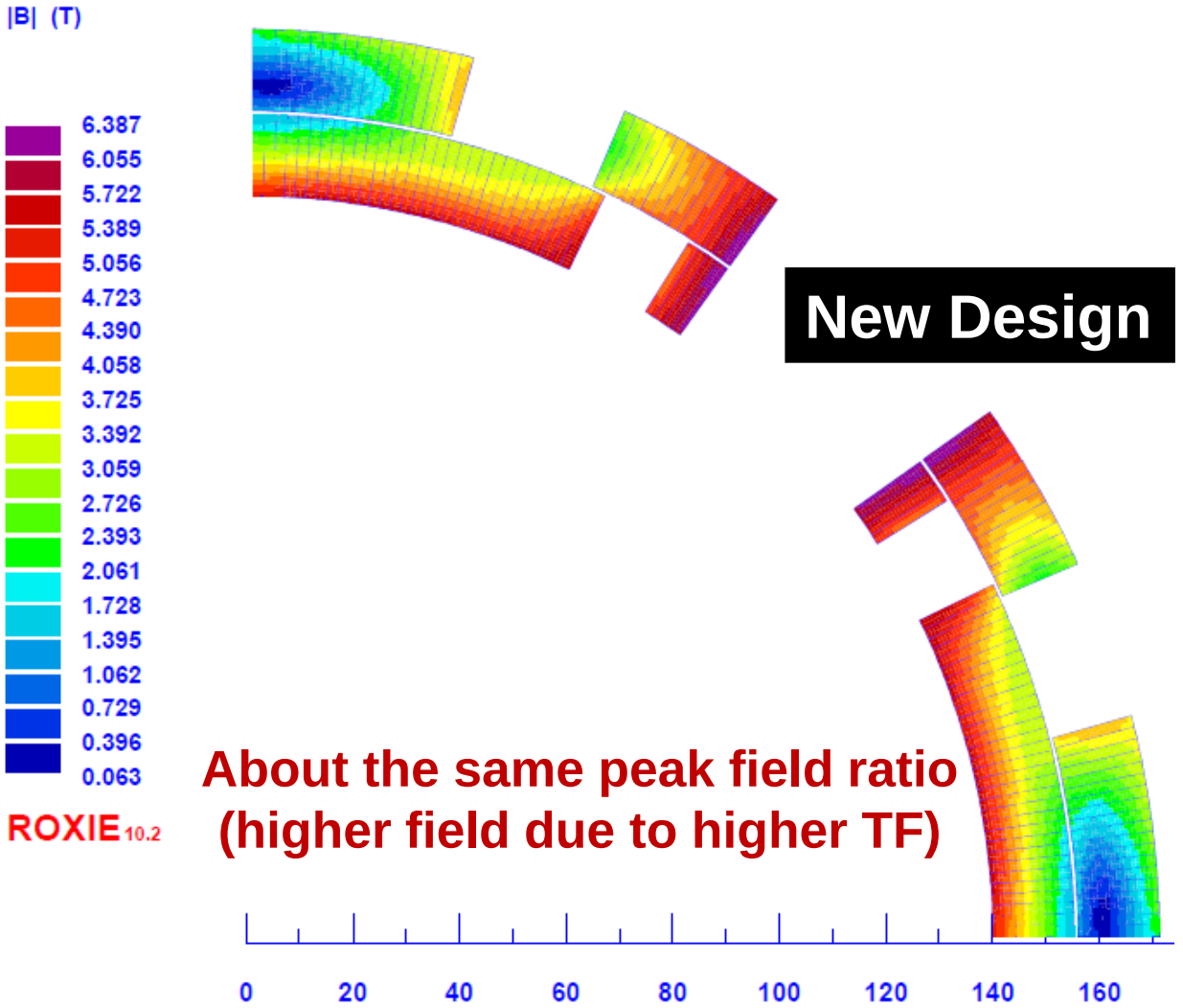
New Design

```
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 ......................   0.9964E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) ........................................     3.176139
MAGNET STRENGTH (T/(m^(n-1)) ..........................     38.2667

NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:      -0.30804  b 2:  10000.00000  b 3:       0.06621
b 4:      -0.02748  b 5:     -0.02339  b 6:       0.21543
b 7:      -0.00139  b 8:     -0.00180  b 9:      -0.00012
b10:       0.03688  b11:     -0.00009  b12:      -0.00000
b13:       0.00001  b14:     -0.29429  b15:       0.00000
b16:       0.00000  b17:      0.00000  b18:      -0.00151
```

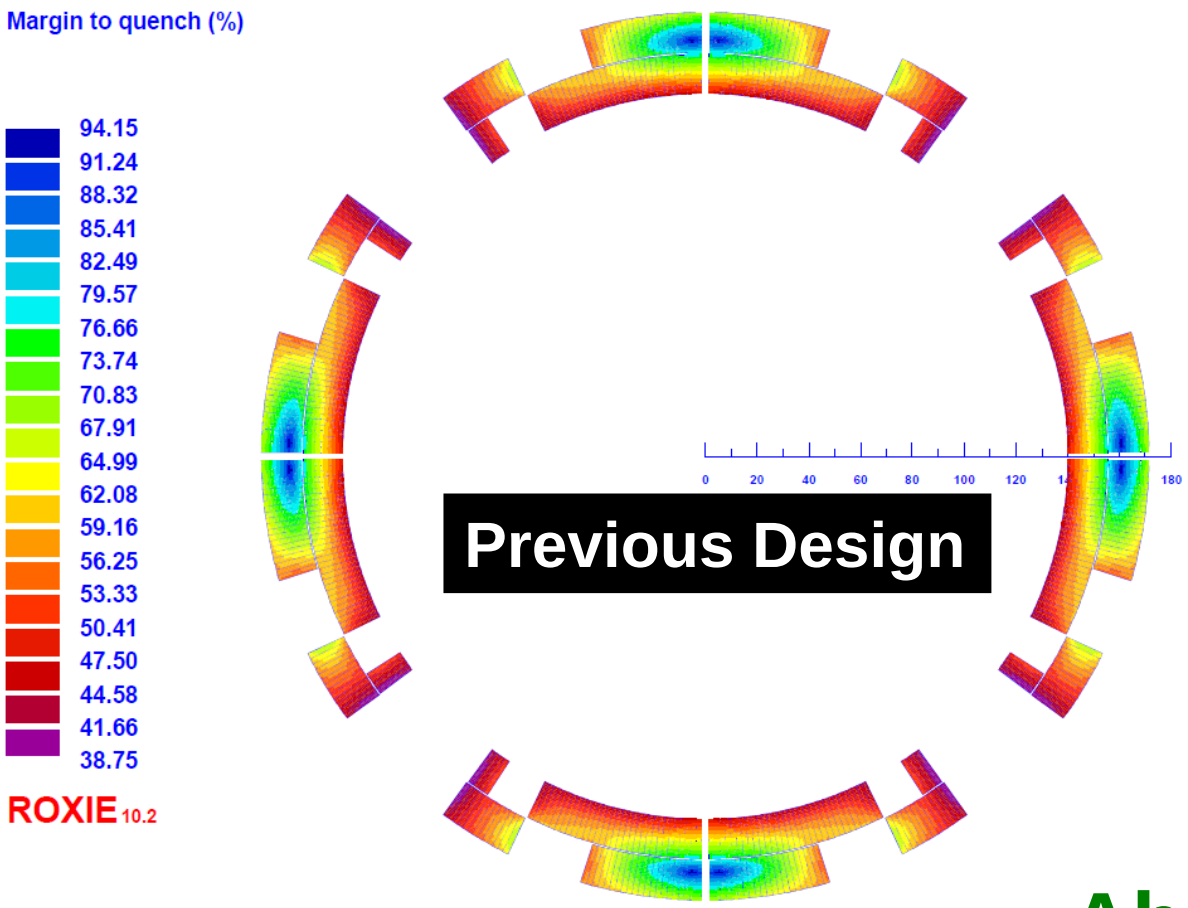
- ~1% higher transfer function
- better field quality (see b10 and b14)

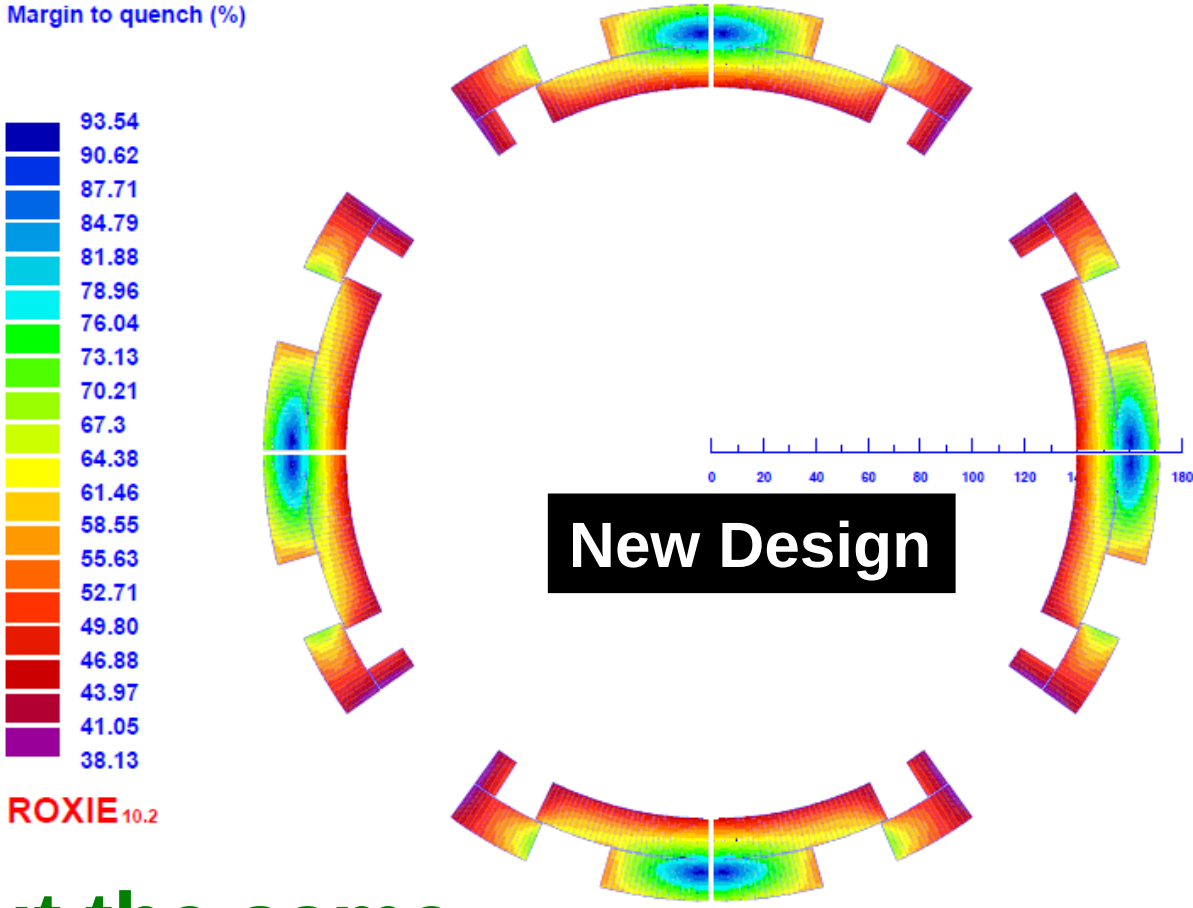
Comparison with the Previous Design (Peak Fields at 8500 A)





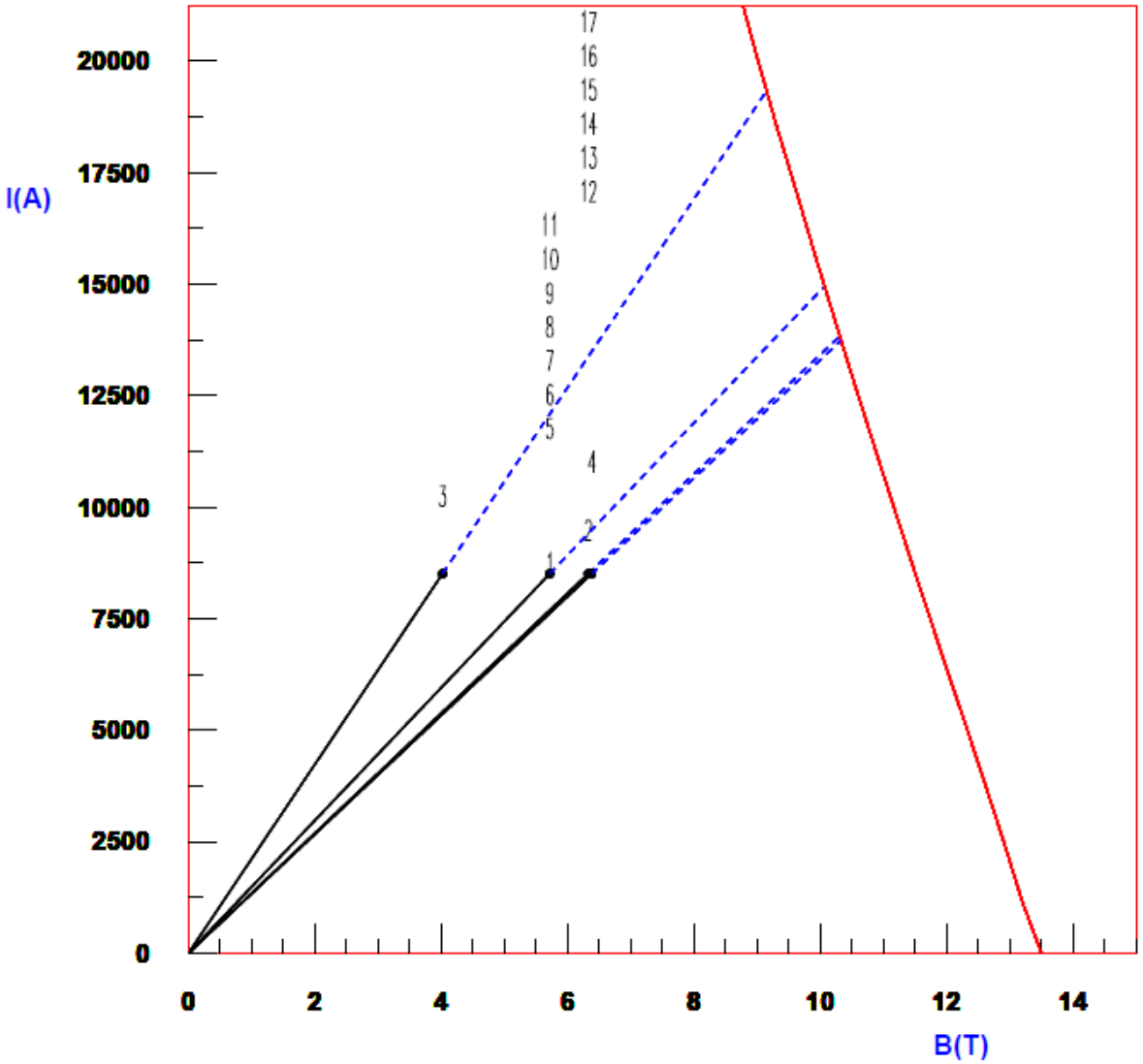
Comparison with the Previous Design (Quench Margin)

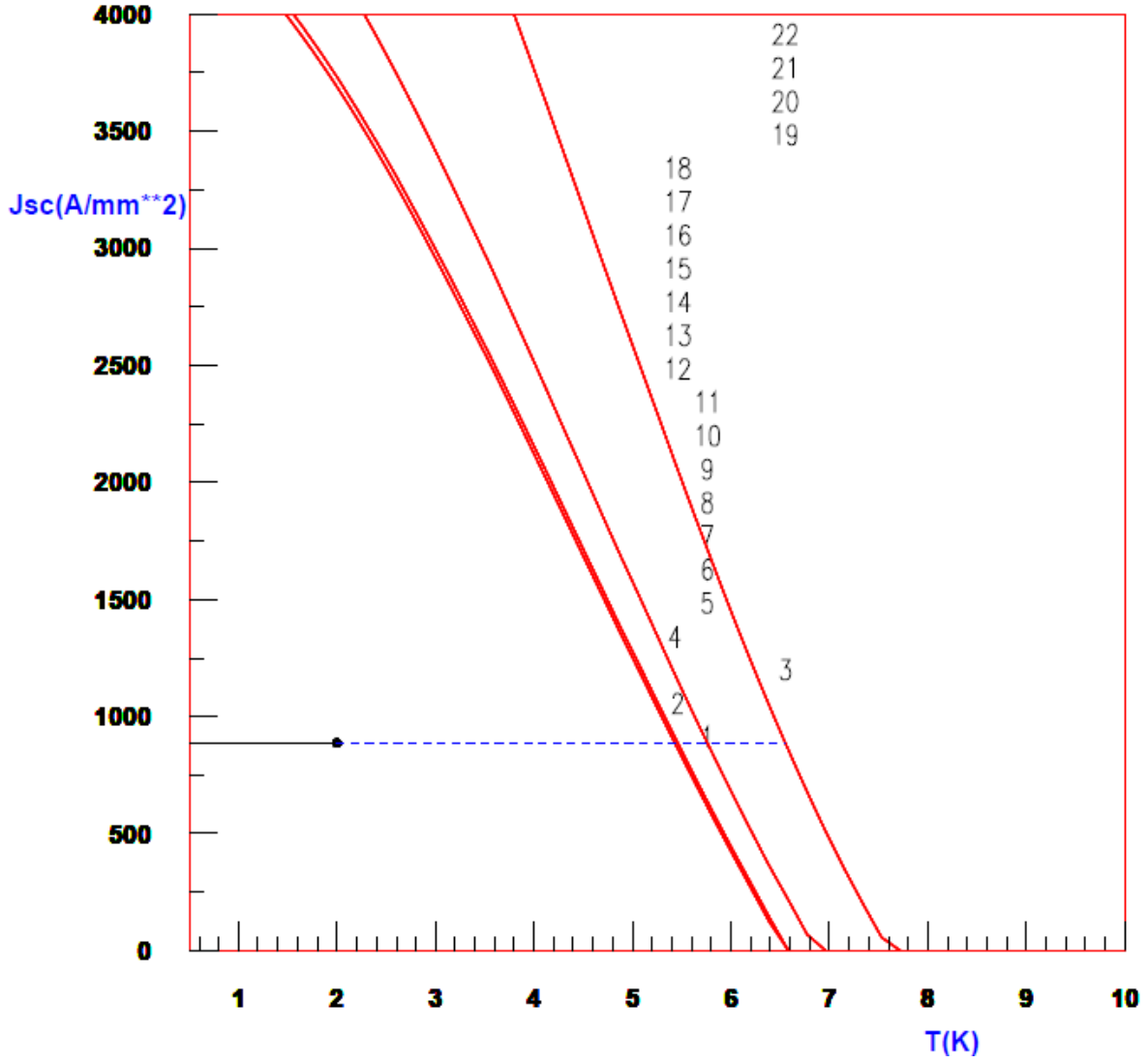




About the same

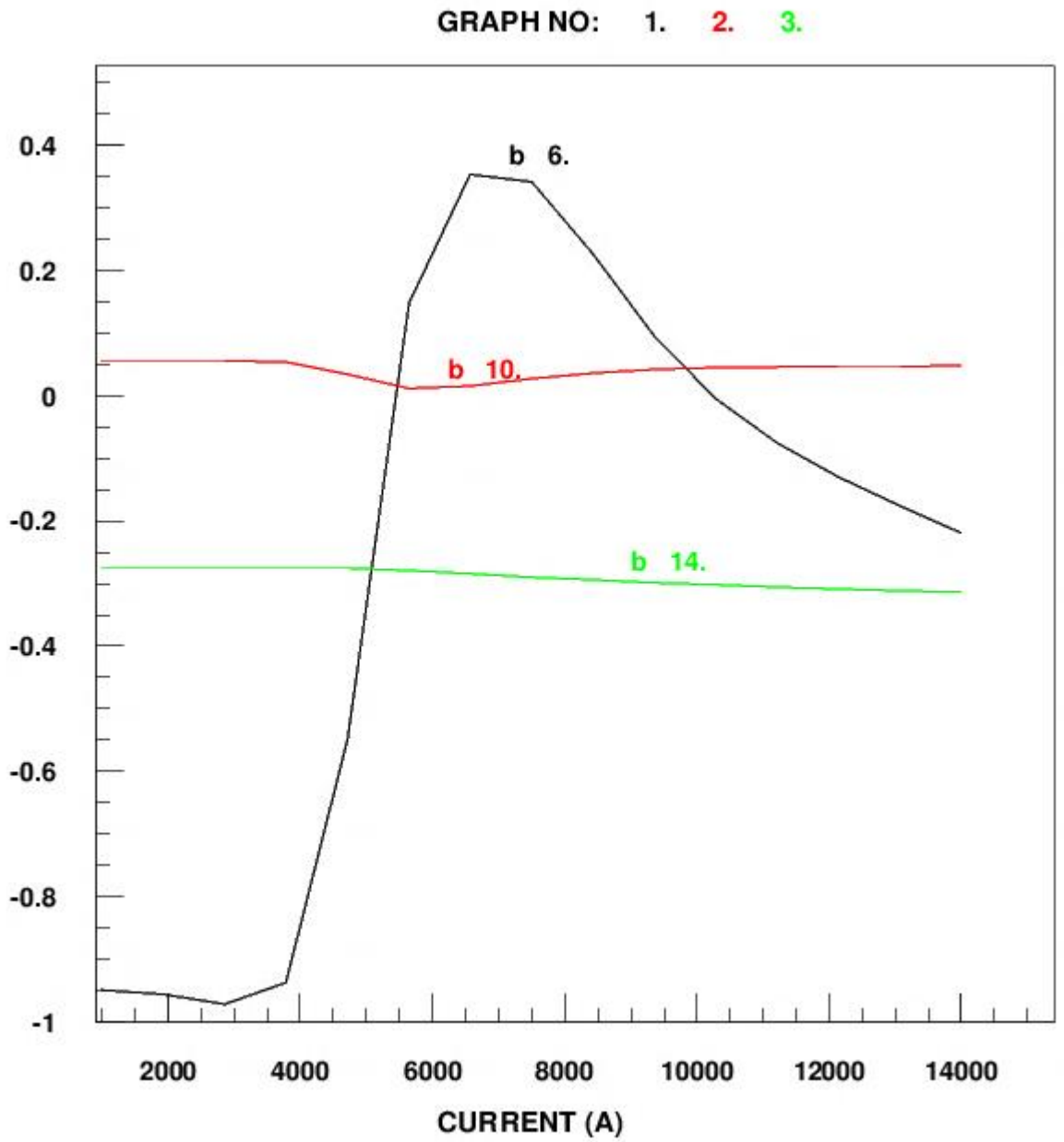
Field and Temperature Margins





Saturation-induced Harmonics

Looks ok (within 1 unit)
Can be optimized more



Summary

- Change in turn-to-turn spacing in the 2-d design could be quickly absorbed in the revised cross-section
- New design has about the similar performance as before - a little higher transfer function and a little better field quality (lower b6 and b10 harmonics)
- Since the detailed engineering design has not yet started, this update should not bring any appreciable delay in the overall schedule
- 3d end design has to be re-optimized for peak field and 3-d field harmonics (estimate about 2 weeks for both return and lead ends).
- This was a good test run for the ability to absorb surprises (hopefully not too many will come in future but always be ready for them)