

# Impact of Larger Collar and Tie Rods Holes in Q2pF Yoke

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Superconducting Magnet Division

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**BROOKHAVEN**  
NATIONAL LABORATORY

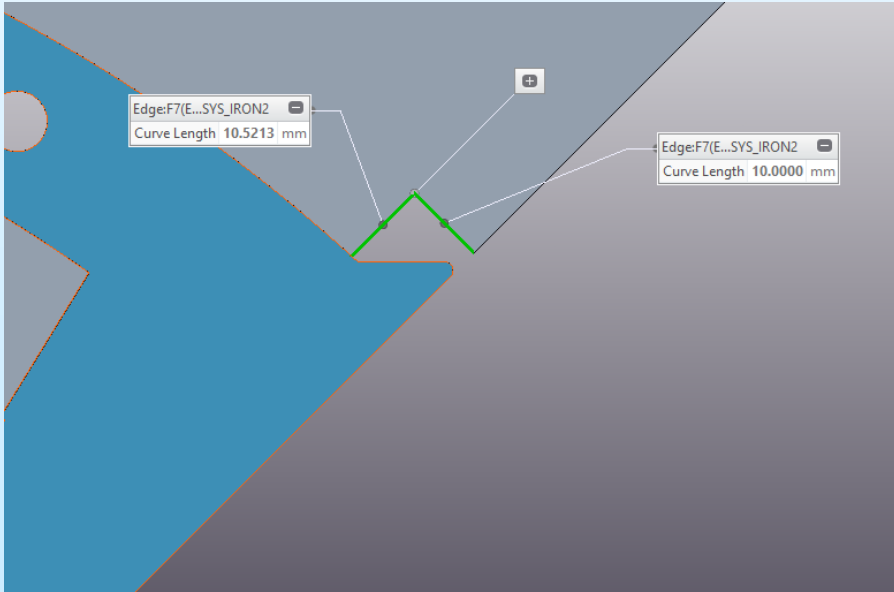
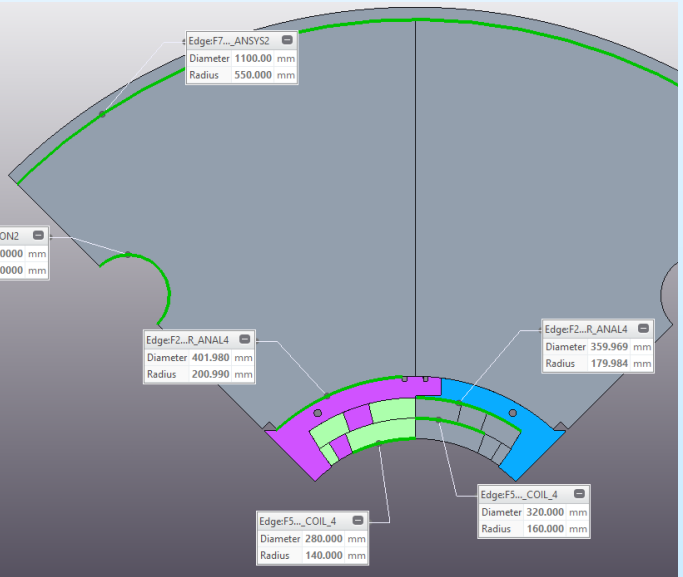
*a passion for discovery*

 Office of  
Science  
U.S. DEPARTMENT OF ENERGY



# Overview

- Q2pF mechanical design would benefit from wider collar. This will, however, reduce the transfer function and the quench field.
- **Impact of increasing collar thickness on the loss in transfer function and loss in quench margin evaluated to see if this is ok.**
- **There are other changes in the yoke – notch at yoke inner radius and holes for tie rods. These will have impact on field quality. Impact evaluated on the field harmonics.**



# Iron Yoke - June 2020 Design

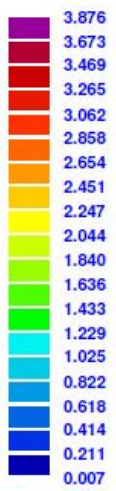
**Collar width = 20 mm**  
Yoke:  $r_i = 201$  mm;  $r_o = 550$  mm  
Hole @  $x = 366.8$  mm to  $423$  mm  
Radius of e-beam hole =  $75$  mm  
Current for 36 T/m:  $7510$  A

EIC 36 strand cable 4.2 K Q2pF

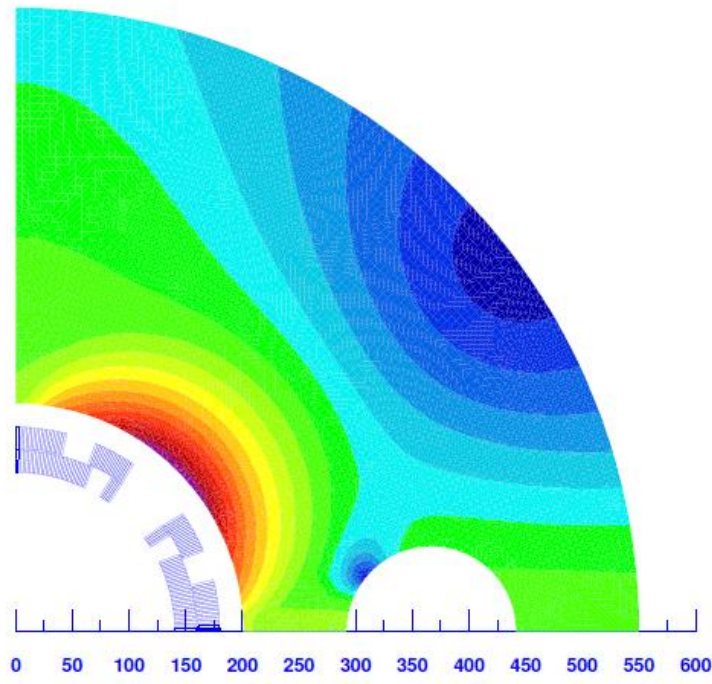
20/06/22 17:35

**ROXIE**

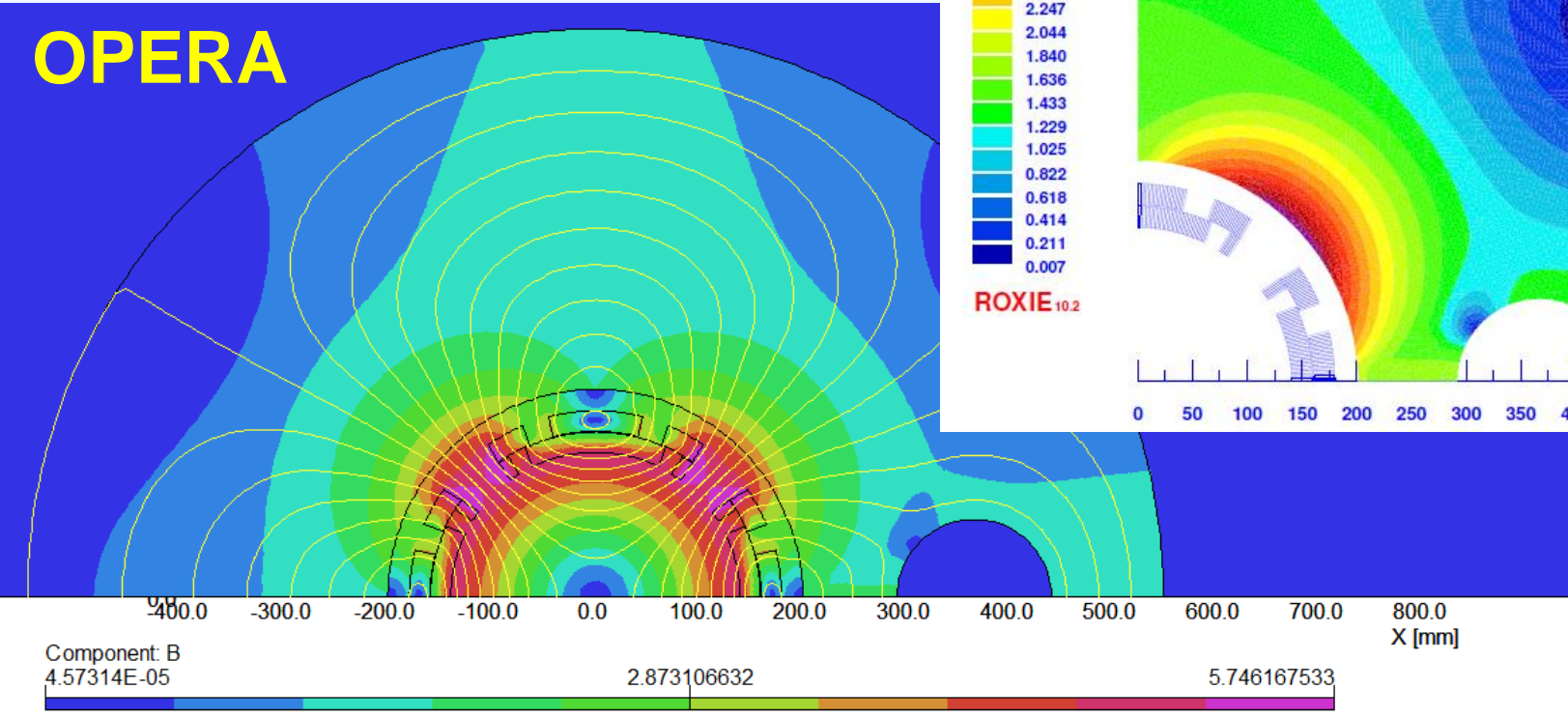
|B| flux density (T)



ROXIE<sub>10.2</sub>



**OPERA**



31404 nodes  
46 regions

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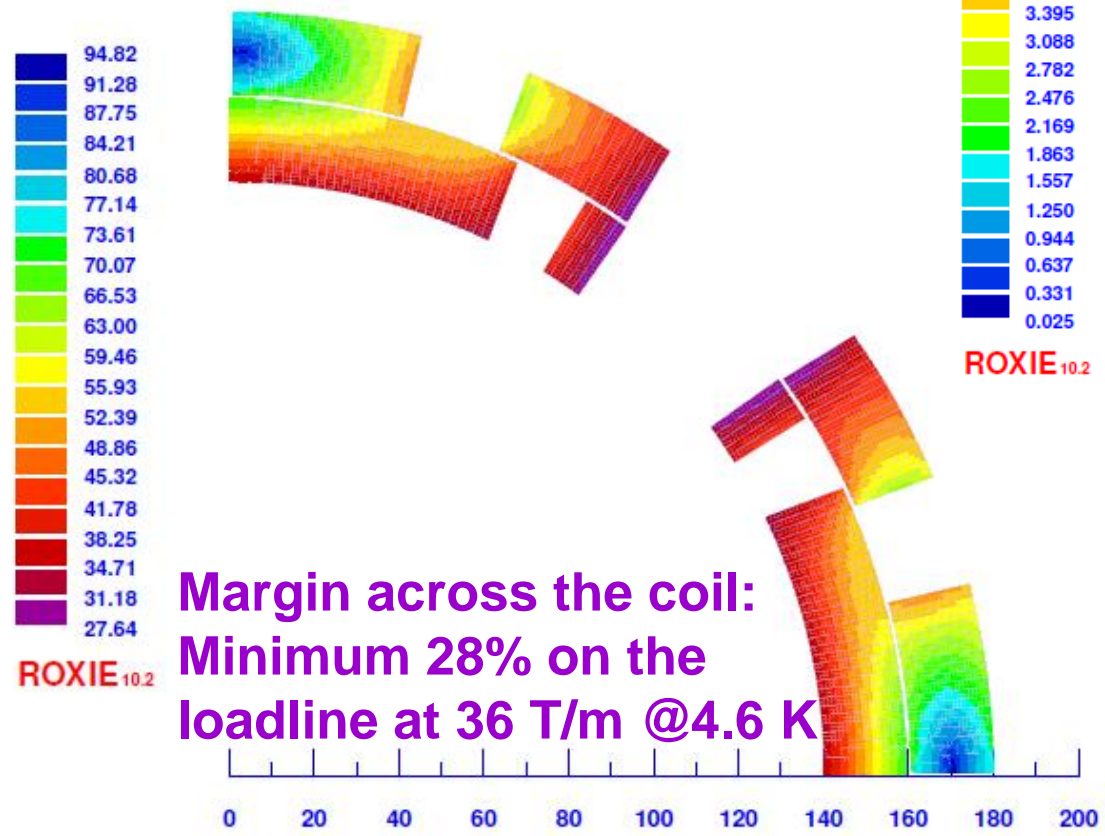
**Opera**

# Original Design Field Margin at 4.6 K

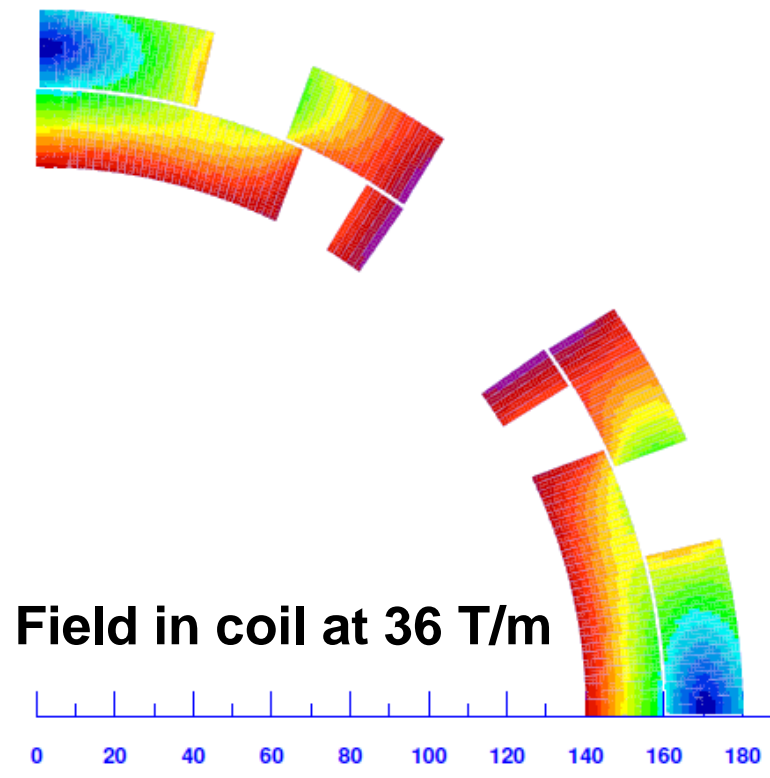
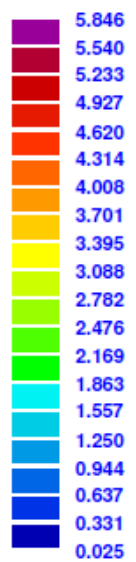
Superconducting  
Magnet Division

- Current for 36 T/m: 7.51 kA
- Peak Field: 5.85 Tesla
- Margin at 4.6 K: 28%

Margin to quench (%)



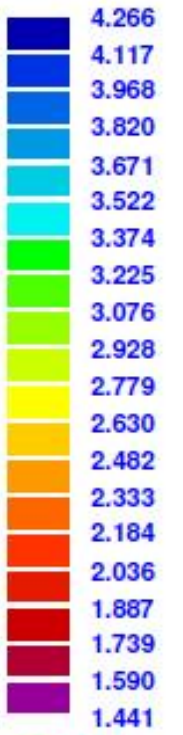
|B| (T)



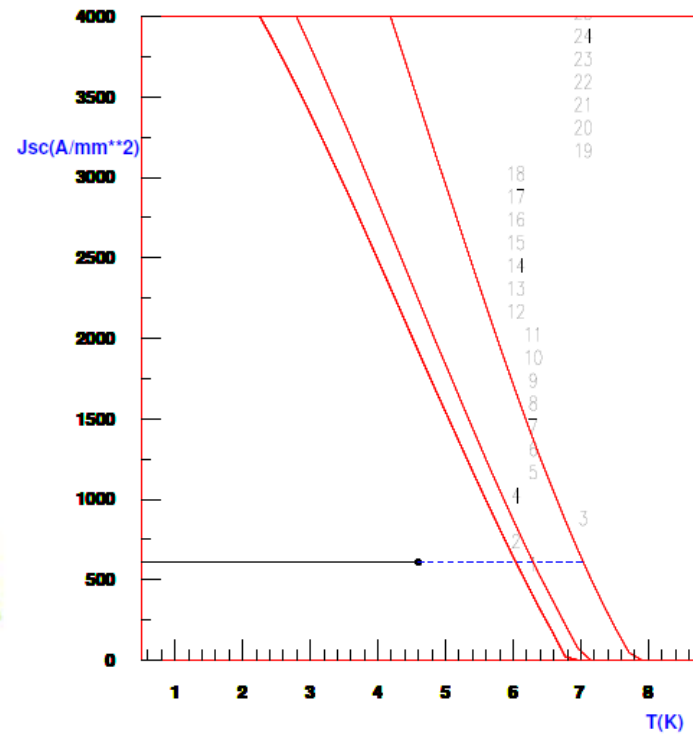
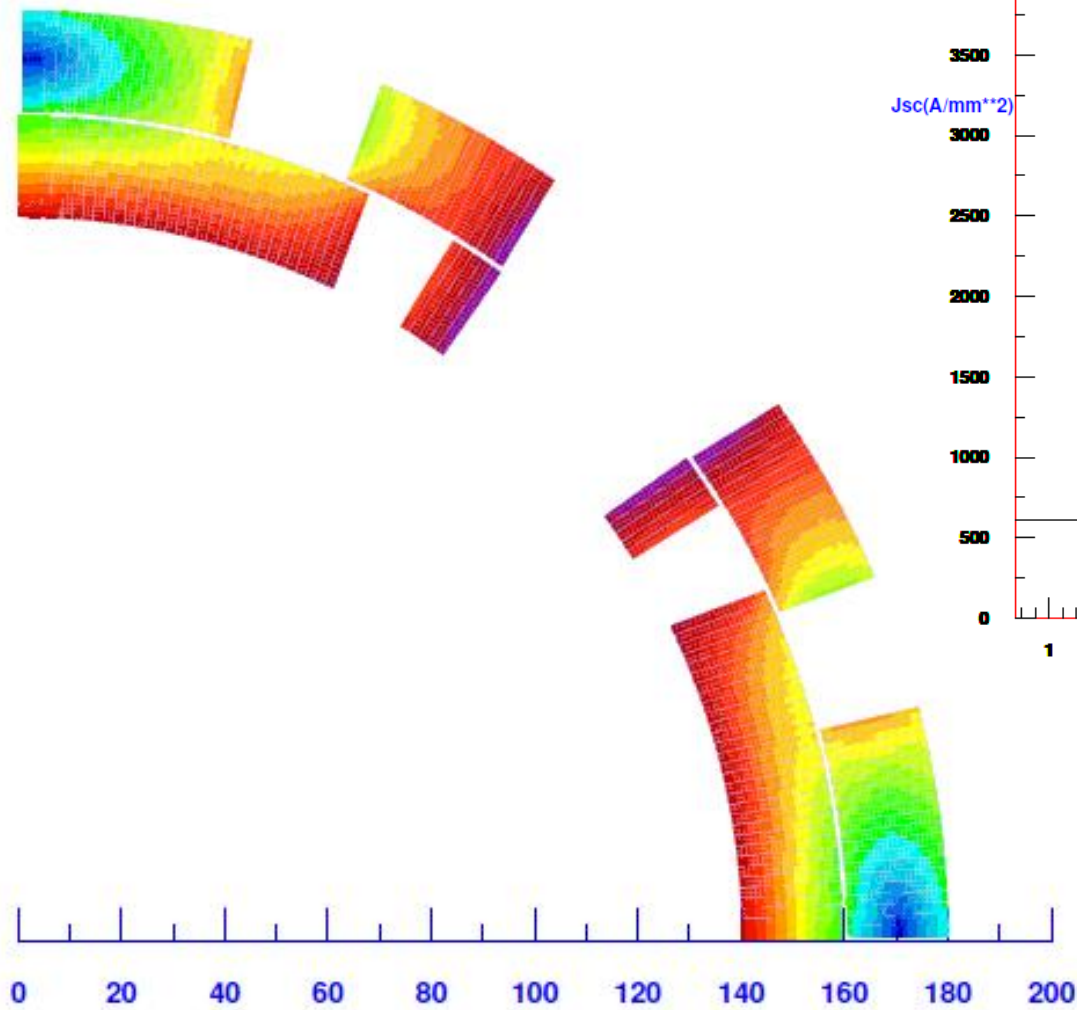
**Computed margin  
at 4.2 K : 32%**

# Temperature Margin Over Different Blocks at 4.6 K

Temperature margin (at Jop,Bop,Top)(K)

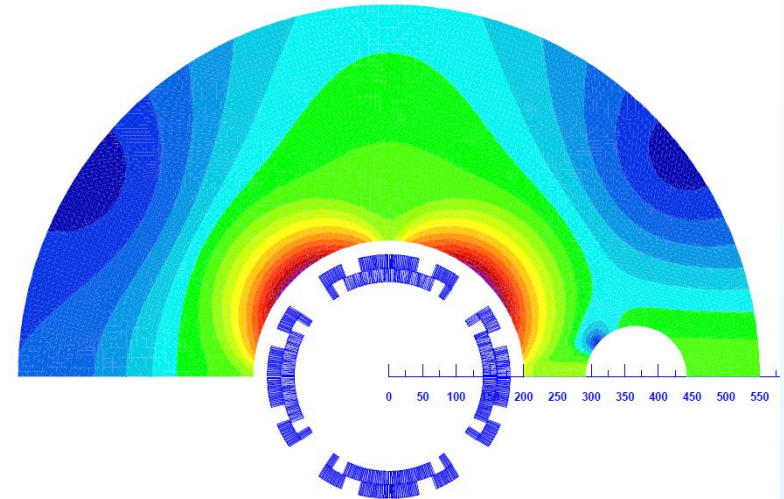


ROXIE<sub>10.2</sub>



# Field Harmonics in Q2pF (6/20 model)

**Field quality in 6/20 design**  
(collar width ~20 mm, no  
holes for tie rod, no notch)  
(all harmonics <1 unit)



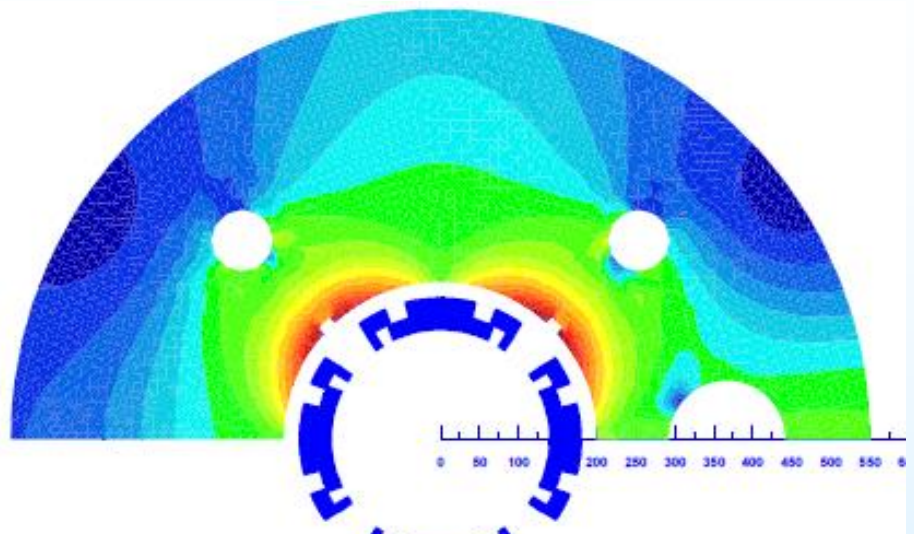
```
REFERENCE RADIUS (mm) ..... 83.
MAGNET STRENGTH (T/(m^(n-1))) ..... 36.0373
```

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

**Yoke modified for tie rods and notch**  
(New model : May 2021)

**Harmonics with the same coil**  
(collar width ~20 mm, holes in yoke for tie rods and notch)



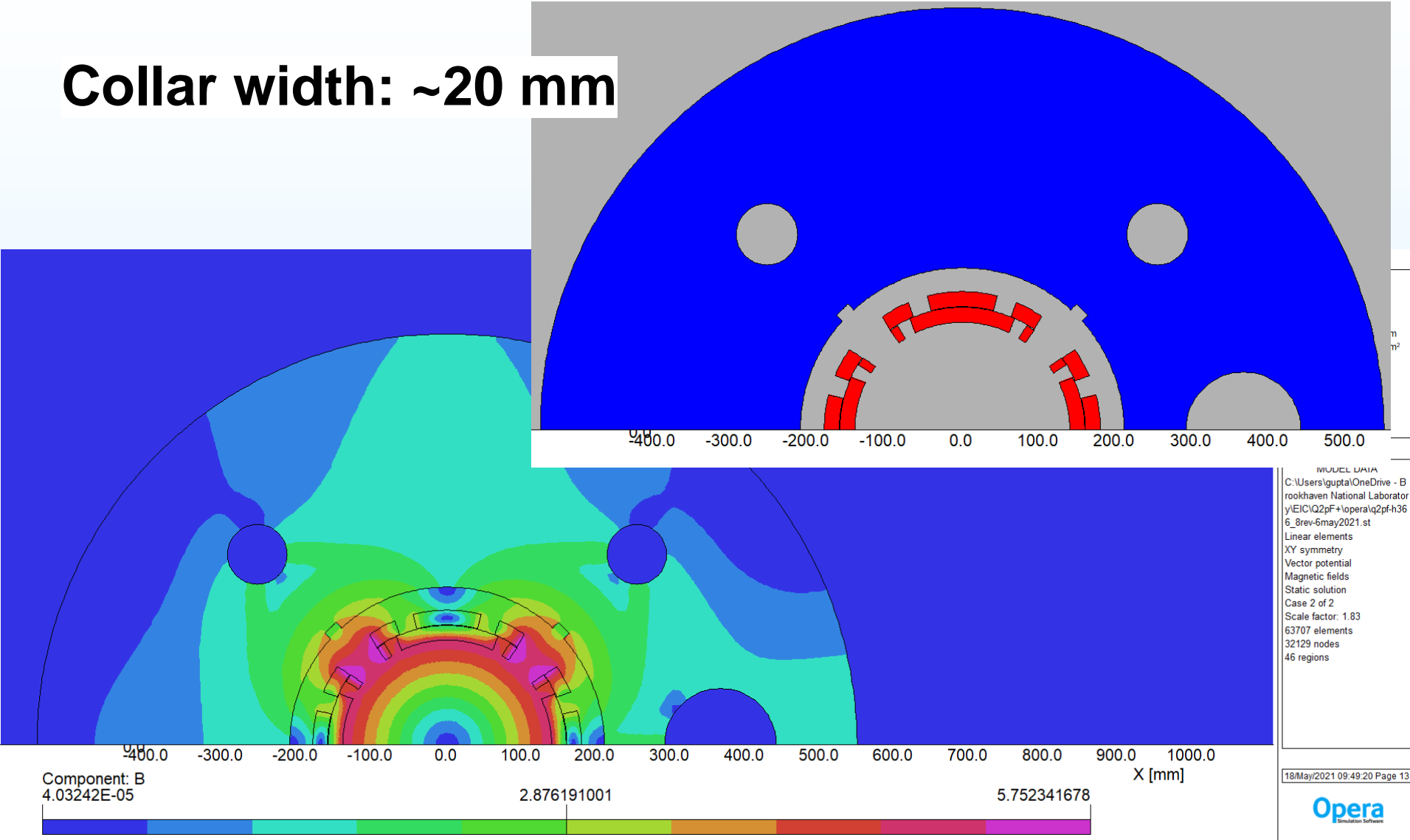
```
MAIN FIELD (T) ..... 2.988146
MAGNET STRENGTH (T/ (m^ (n-1)) ..... 36.0018
```

NORMAL RELATIVE MULTIPOLES (1.D-4) :

b 1:	-1.50352	b 2:	10000.00000	b 3:	-0.18195
b 4:	0.75848	b 5:	-0.03335	b 6:	1.31550 ←
b 7:	-0.00667	b 8:	0.01562	b 9:	-0.00100
b10:	0.55171	b11:	-0.00020	b12:	0.00024
b13:	-0.00003	b14:	-0.22307	b15:	-0.00000
b16:	0.00000	b17:	-0.00000	b18:	0.01231

**Yoke modified for tie rods and notch**  
**OPERA Model (May 2021)**

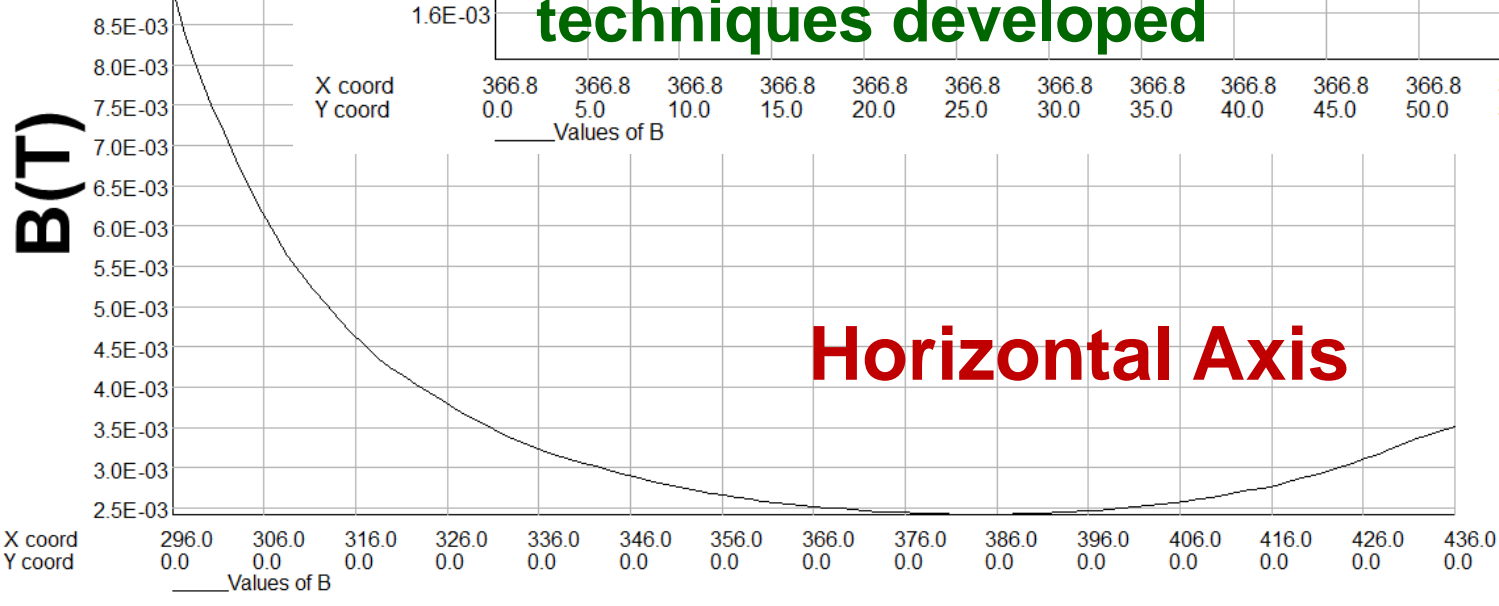
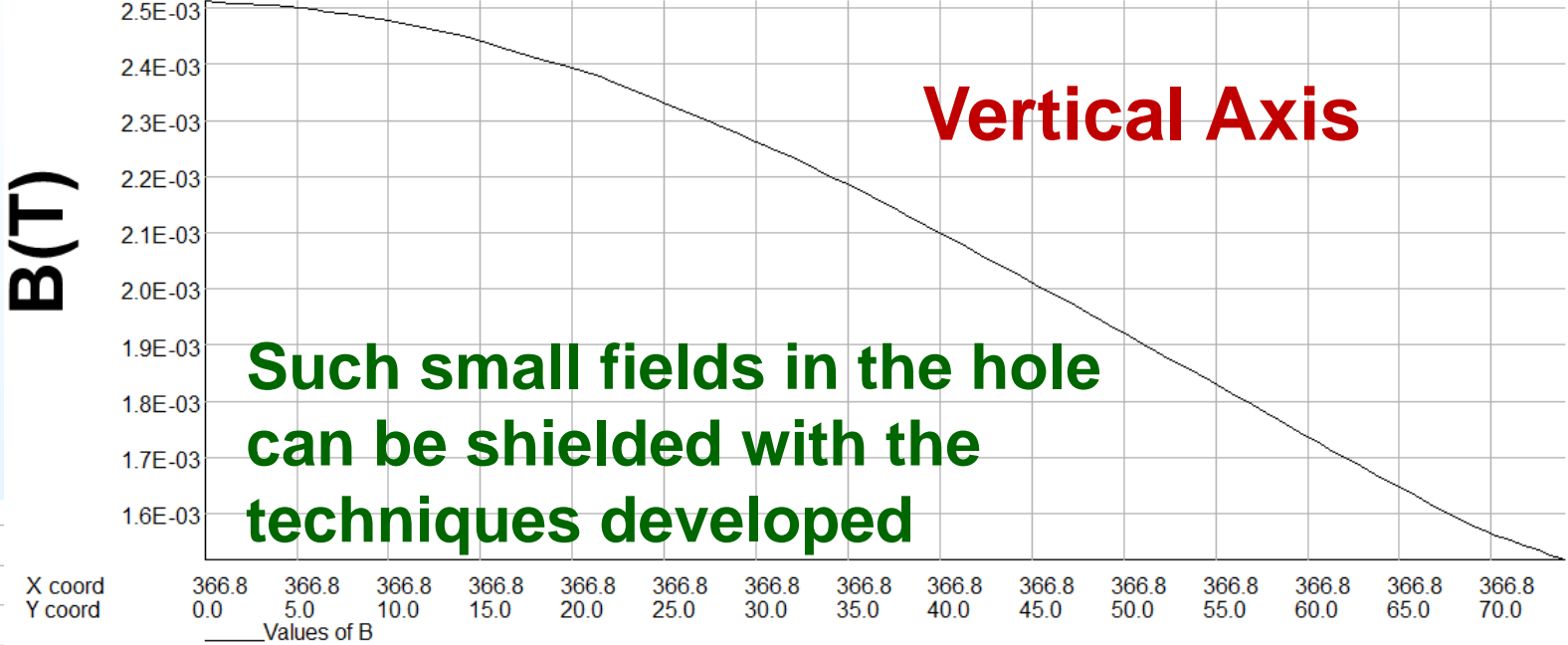
**Collar width: ~20 mm**





Field in the electron beam region (6/20)  
 Yoke OR = 550 mm, Hole@366.8 mm

June 2020 Design

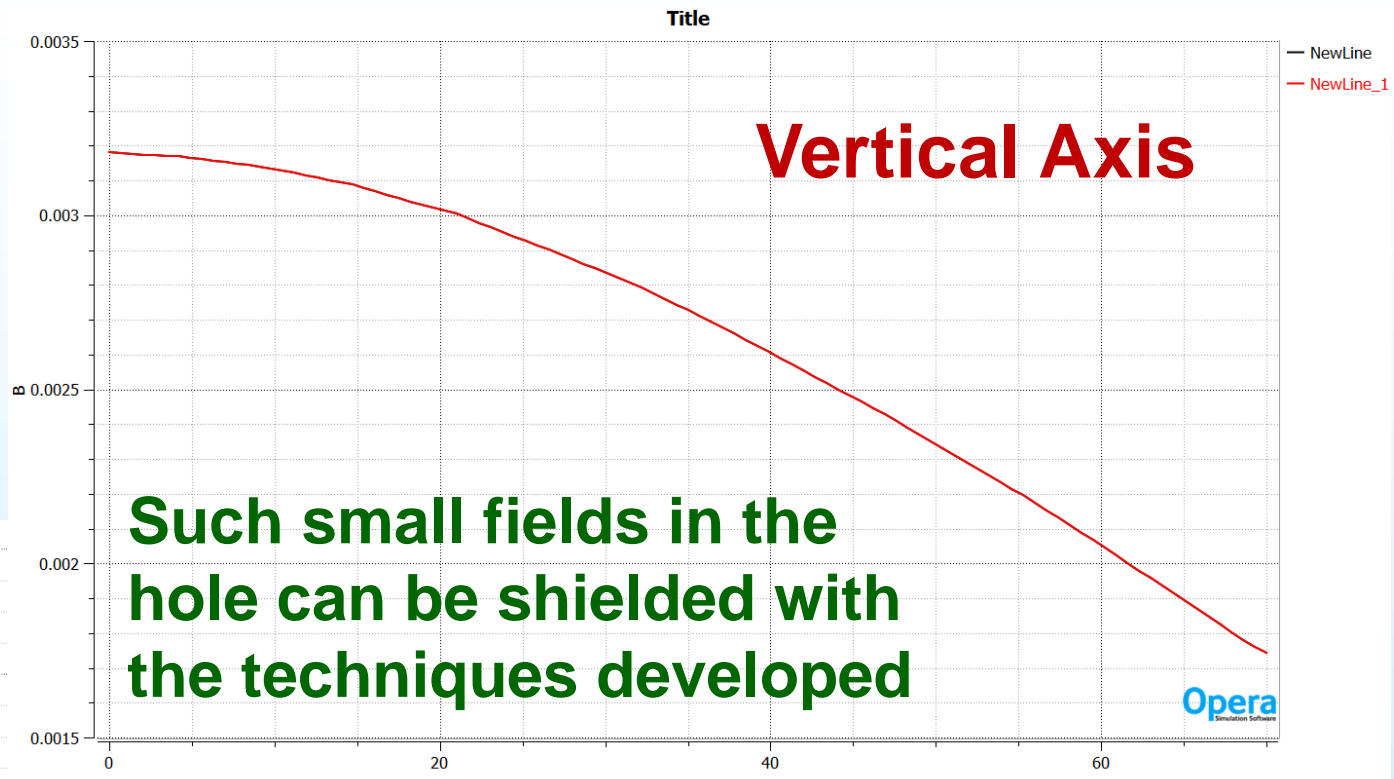


**MODEL DATA**  
 C:\Users\gupta\OneDrive - Brookhaven National Laboratory\EIC\Q2pF+lopera\q2pf-06-23-2020.st  
 Linear elements  
 XY symmetry  
 Vector potential  
 Magnetic fields  
 Static solution  
 Case 2 of 2  
 Scale factor: 1.77  
 62257 elements  
 31404 nodes  
 46 regions

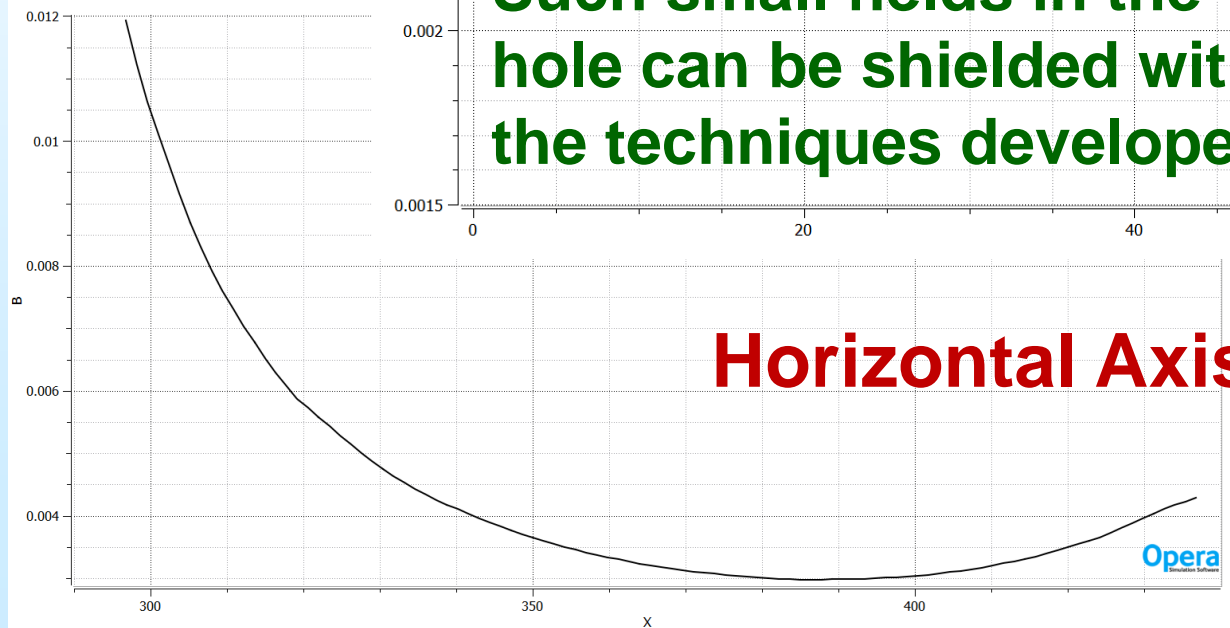
**Field in the electron beam region (6/20)**  
**Yoke OR = 550 mm, Hole@366.8 mm**

May 2021 Design

**B(T)**

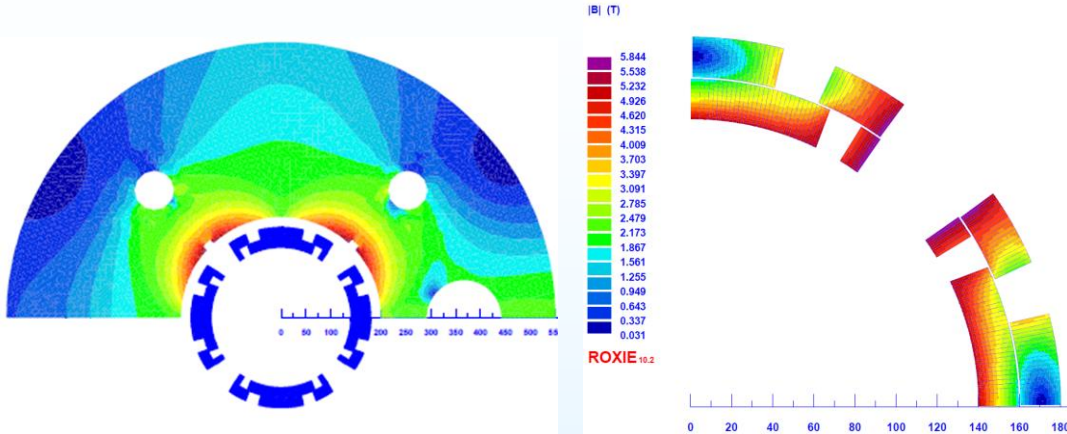


**B(T)**



# Yoke modified for tie rods and notch Coil modified for field quality (5/21)

**Harmonics with the iterated coil**  
(collar width ~20 mm, holes in yoke for tie rods and notch)  
(all harmonics now <1 unit, b1, a small dipole component at high field; it will go away once symmetric holes are put)



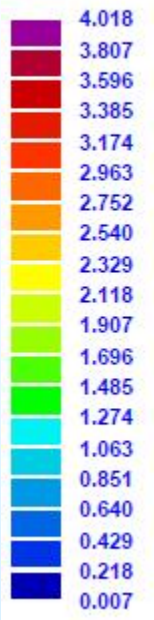
MAIN FIELD (T)	.....	2.998451
MAGNET STRENGTH (T/(m^(n-1)))	.....	36.1259
NORMAL RELATIVE MULTIPOLES (1.D-4):		
b 1:	-1.51276	b 2: 10000.00000
b 4:	0.75723	b 5: -0.03405
b 7:	-0.00667	b 8: 0.01549
b10:	-0.00006	b11: -0.00020
b13:	-0.00003	b14: -0.11884
b16:	0.00000	b17: -0.00000
		b 3: -0.18261
		b 6: -0.00006
		b 9: -0.00101
		b12: 0.00023
		b15: -0.00000
		b18: 0.00175



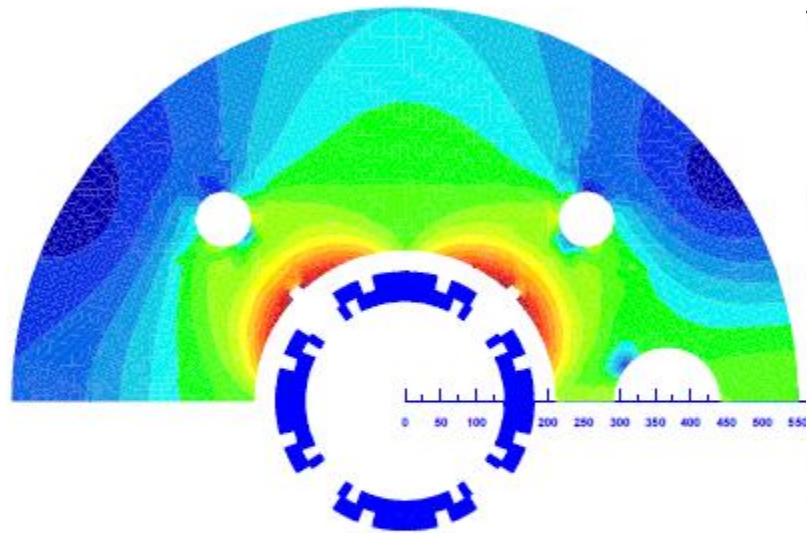
# Evaluation of the Impact of Increasing the Collar Width

# New Iron Yoke: May 2021 Design

|Btot| (T)



ROXIE<sub>10.2</sub>

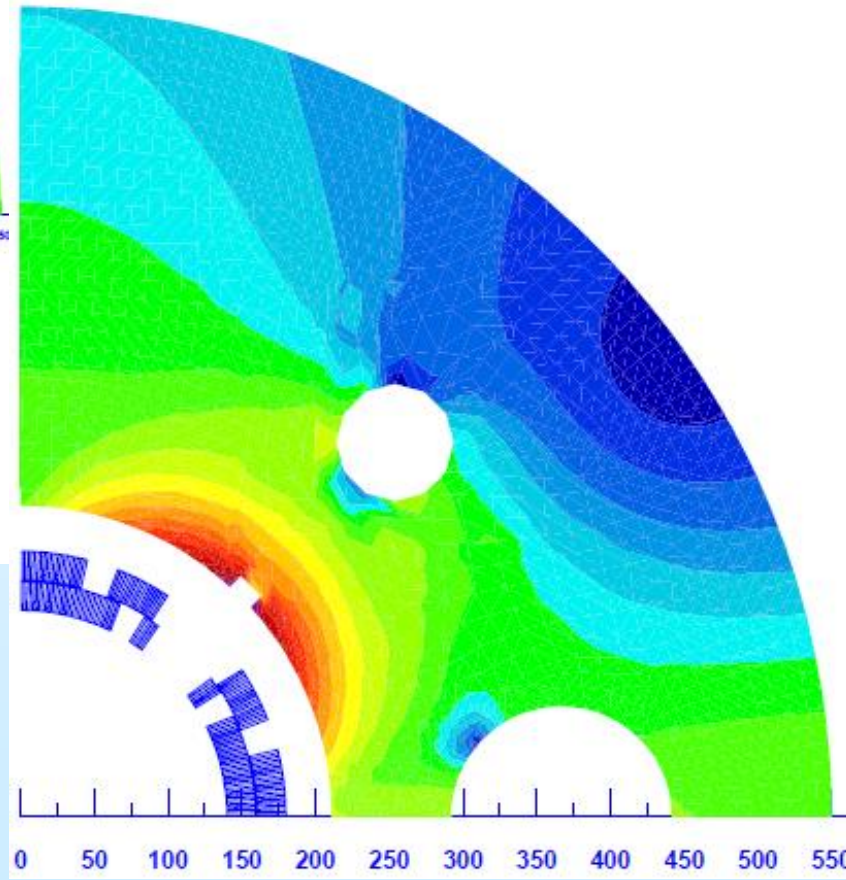


=211mm tie rod field quality

21/05/18 0

**ROXIE**

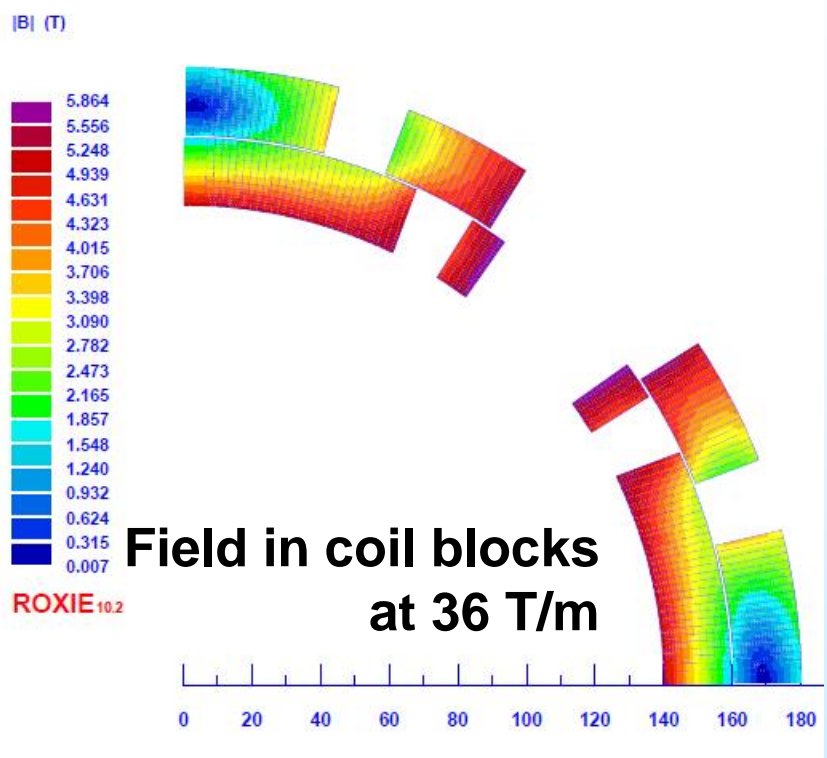
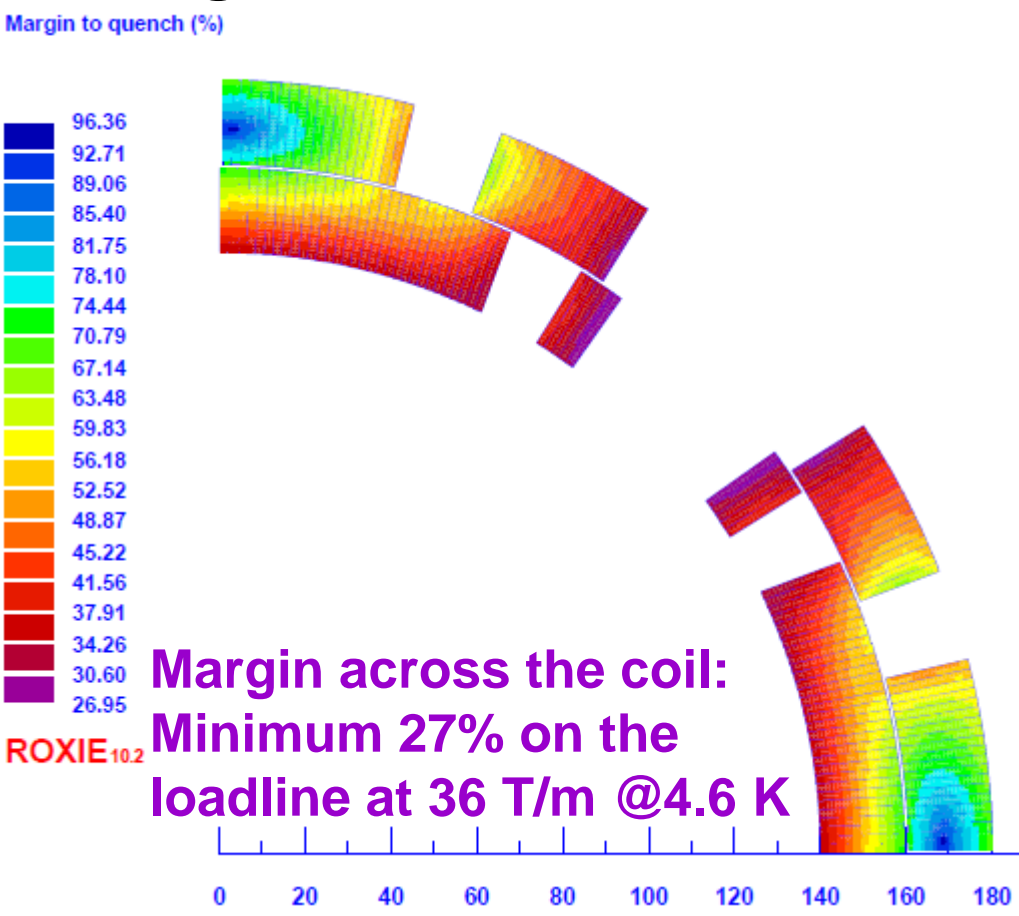
Yoke:  $r_i = 211$  mm  
 Yoke  $r_o = 550$  mm  
 Holes in yoke for tie rods  
 Notch at yoke inner radius  
 ➤ Collar width: ~30 mm  
 36 T/m at 7.78 kA



# New Design: Collar 30 mm (May 2021) Field Margin at 4.6 K

- Current for 36 T/m: 7.78 kA
- Peak Field: 5.85 Tesla
- Margin at 4.6 K: 27%

EIC Q2pF 4.6 K  $i_r=211\text{mA}$   $i_c$  field quality 21/05/18



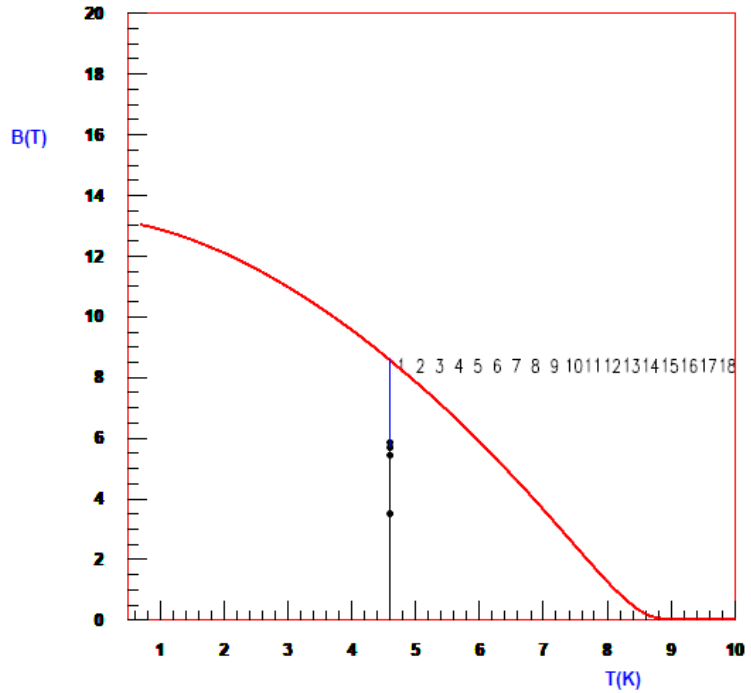
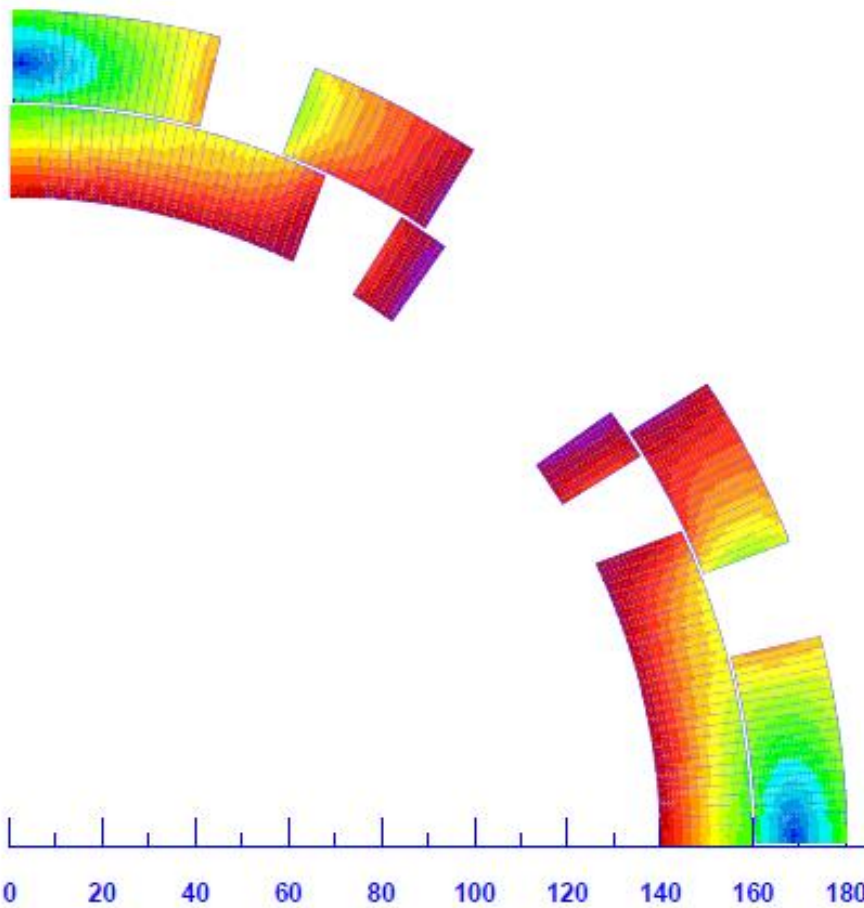
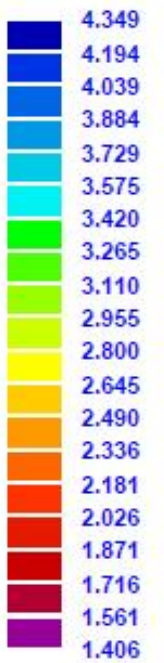
**Reduction in margin: ~1%  
from increase in collar width  
by 10 mm (this should be ok)**

# Temperature Margin (5/21) Over Different Blocks at 4.6 K

EIC Q2pF 4.6 K ir=211mm rdc field quality

21/05/18 09:26

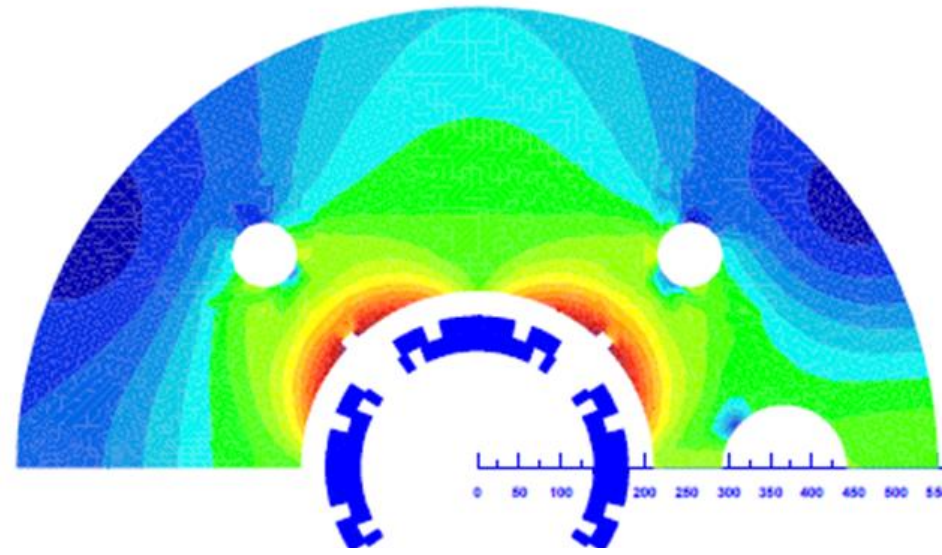
Temperature margin (at Jop,Bop,Top)(K)



**Reduction in temperature margin: 0.035 K from the increase in collar width (this should be ok)**

**Yoke modified for tie rods and notch**  
(New model : May 2021)

**Harmonics with the same coil**  
(collar width ~30 mm, holes in yoke for tie rods and notch)  
Margin is ok but the field quality is no longer good.  
➤ This can be easily fixed by iterating the coil x-section



```
MAIN FIELD (T) ..... 2.988434
MAGNET STRENGTH (T/(m^(n-1))) ..... 36.0052
```

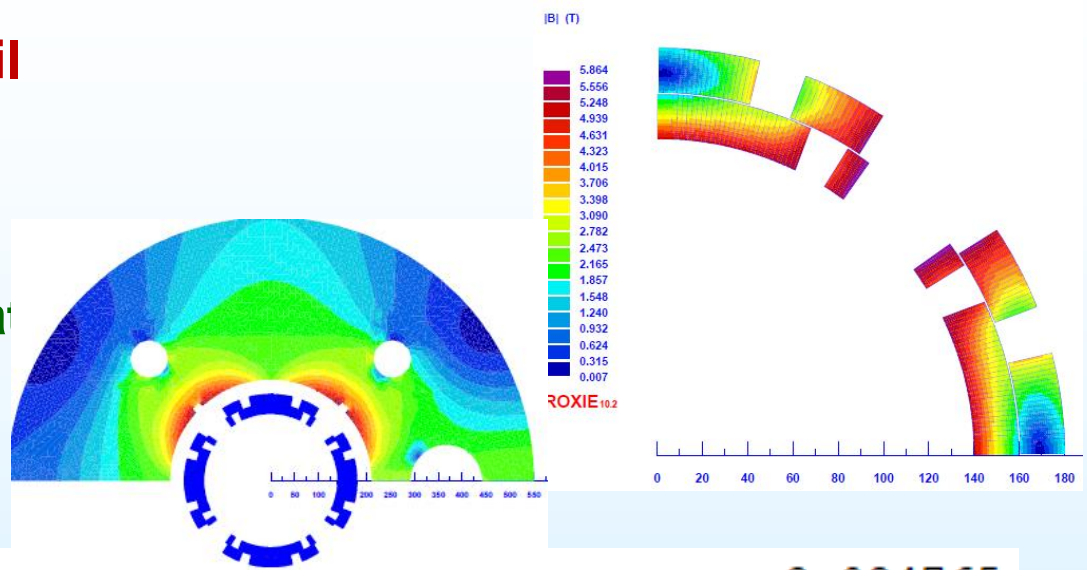
NORMAL RELATIVE MULTIPOLES (1.D-4) :

b 1:	-1.70511	b 2:	10000.00000	b 3:	-0.20627
b 4:	0.57776	b 5:	-0.03999	b 6:	-3.28511 ←
b 7:	-0.00686	b 8:	0.00904	b 9:	-0.00097
b10:	0.50566	b11:	-0.00016	b12:	0.00005
b13:	-0.00002	b14:	-0.23322	b15:	-0.00000
b16:	0.00000	b17:	-0.00000	b18:	0.01276



# Yoke modified for tie rods and notch Coil modified for field quality (5/21)

**Harmonics with the iterated coil**  
 (collar width ~30 mm, holes in yoke for tie rods and notch)  
 (harmonics now <1 unit,  
 b1, a small dipole component at high field; it will go away once symmetric holes are put)



MAIN FIELD (T) ..... 3.024765  
 MAGNET STRENGTH (T/ (m<sup>(n-1)</sup>)) ..... 36.4429

NORMAL RELATIVE MULTIPOLES (1.D-4) :

b 1:	-1.71120	b 2:	10000.00000	b 3:	-0.19220	
b 4:	0.56687	b 5:	-0.04316	b 6:	-0.00006	←
b 7:	-0.00699	b 8:	0.00857	b 9:	-0.00103	
b10:	-1.10539	b11:	-0.00017	b12:	0.00004	
b13:	-0.00003	b14:	-0.16055	b15:	-0.00000	
b16:	0.00000	b17:	-0.00000	b18:	0.01564	

# Other cases

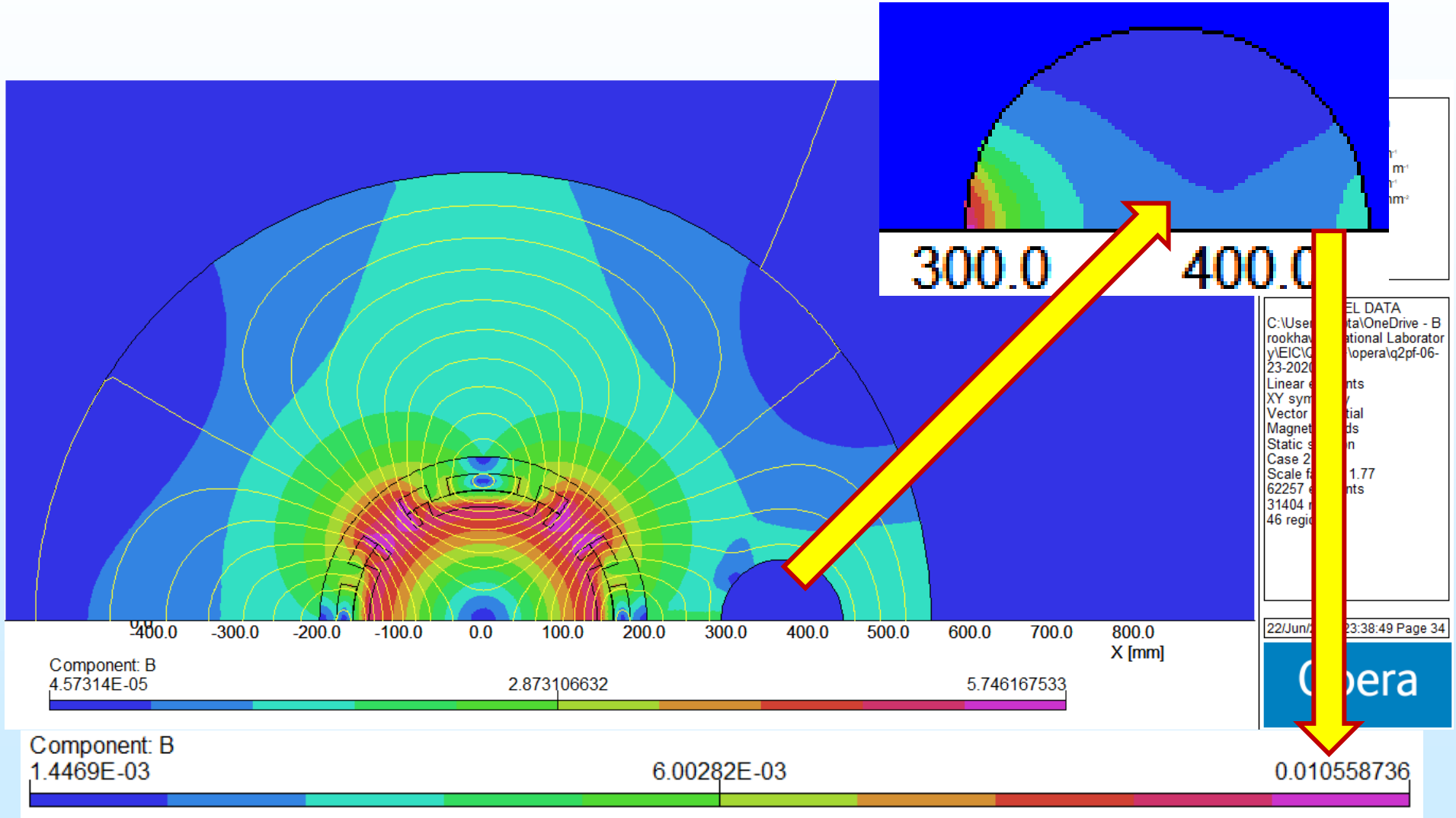
Also examined cases for the collar width of

~25 mm and 40 mm  
(not presented here)

# Summary

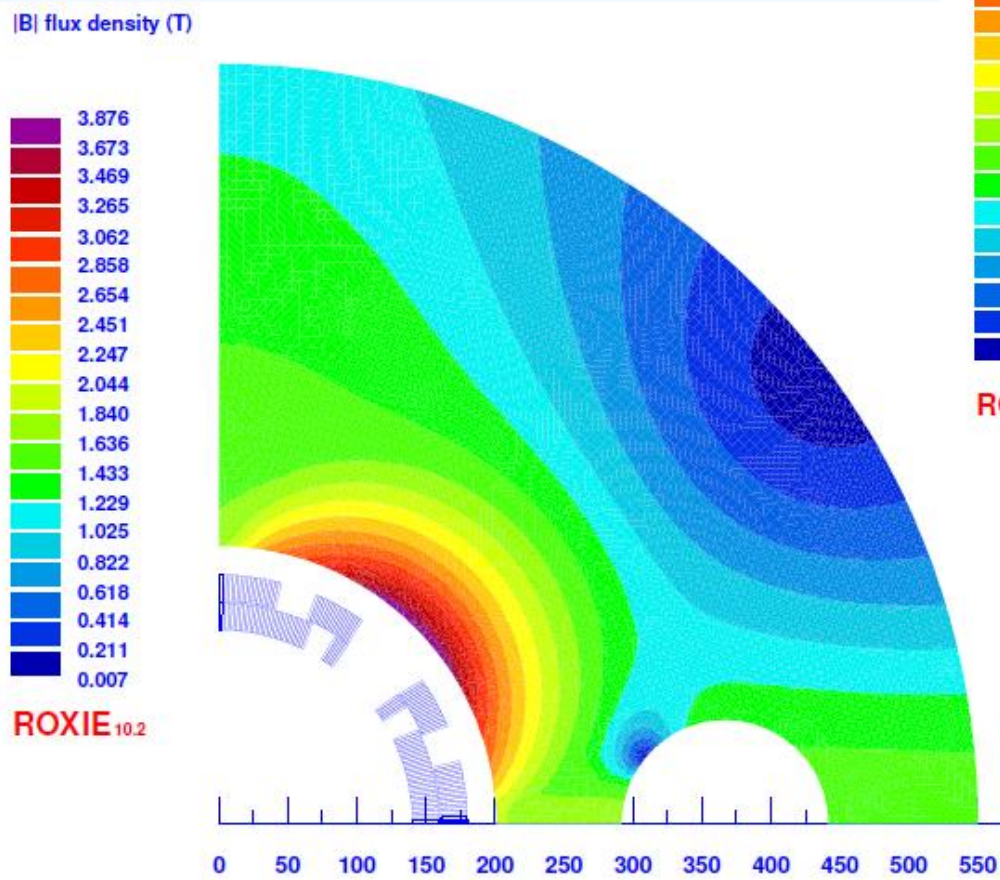
- **Impact of increasing collar thickness on the field margin evaluated. This should be acceptable.**
- **Other changes in the yoke, like notch at the yoke inner radius and holes in the yoke for tie rods also evaluated for the impact on field harmonics. There is a significant (not large) change in field harmonics due to these changes.**
- **An iteration in coil cross-section can take care of that.**
- **Additional holes in yoke will be needed to keep low unallowed harmonics. Field in the hole for path of e-beam can be kept low.**
- **These changes in the coil and yoke design should not have any appreciable impact on the structure analysis of the magnet.**
- **However, the final iteration, including the end design, should be carried out after the magnet parameters are fixed.**
- **Detailed engineering design should be carried out after that.**

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



# Hole Positions in the 2-d Yoke

@x=366.8 mm



@x=423 mm

