Yoke Optimization of B1pF

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Background

- Full size yoke for B1pF doesn't fit in the BNL vertical test facility. Therefore, an inner iron yoke was suggested for warm/low field measurements.
- Various mechanical and cryogenic requirements puts a challenge on the magnetic design of the inner yoke, particularly because of the limited radial width possible.
- Febin Kurian has been working on this design for some time and has performed a good systematic studies (reference: several presentations from Febin, latest - last week to SMD/Mechanical engineer group led by M. Anerella)

B1pF-2D-Yoke Optimization

Febin Kurian

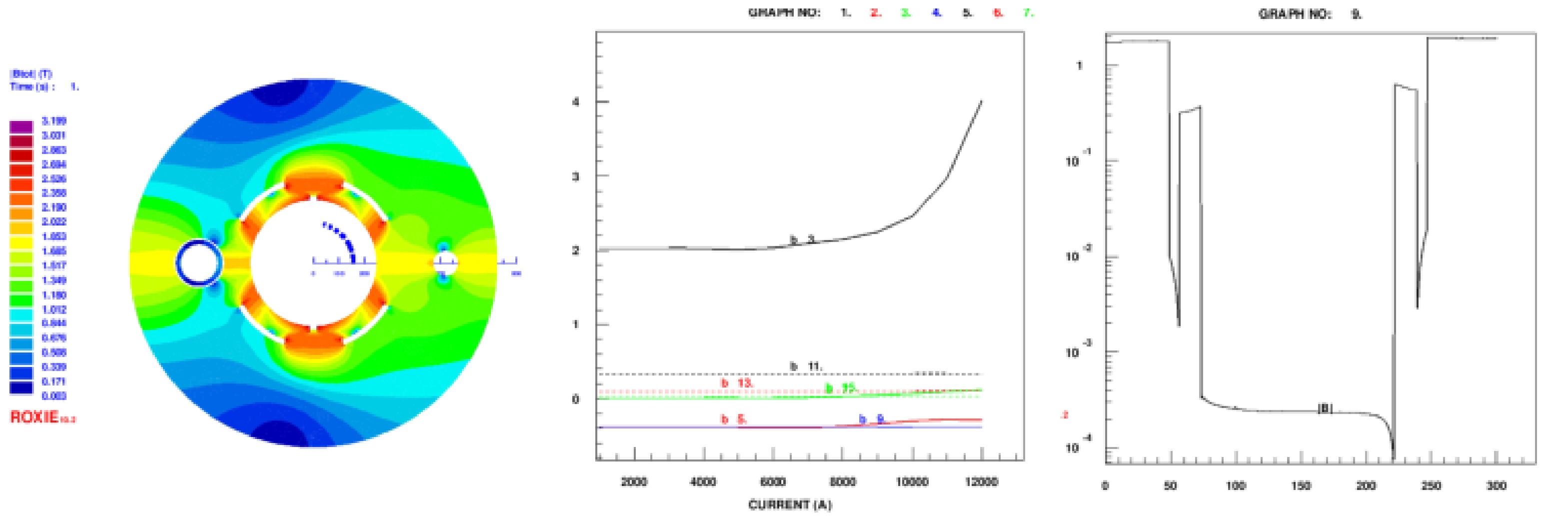
SMD-BNL

- This presentation provides update on the B1PF yoke design in Febin's absence.
- Apart from optimizing the magnetic design of the yoke to facilitate various mechanical engineering functions, this presentation also include some new developments.

Challenges for Inner Yoke (2d)

Case 10572:

Slide Courtesy
Febin Kurian



@ 12kA, angles of cut are 30&70 degree, gap between 320&345 mm

1/30/2023 EIC-B1pF

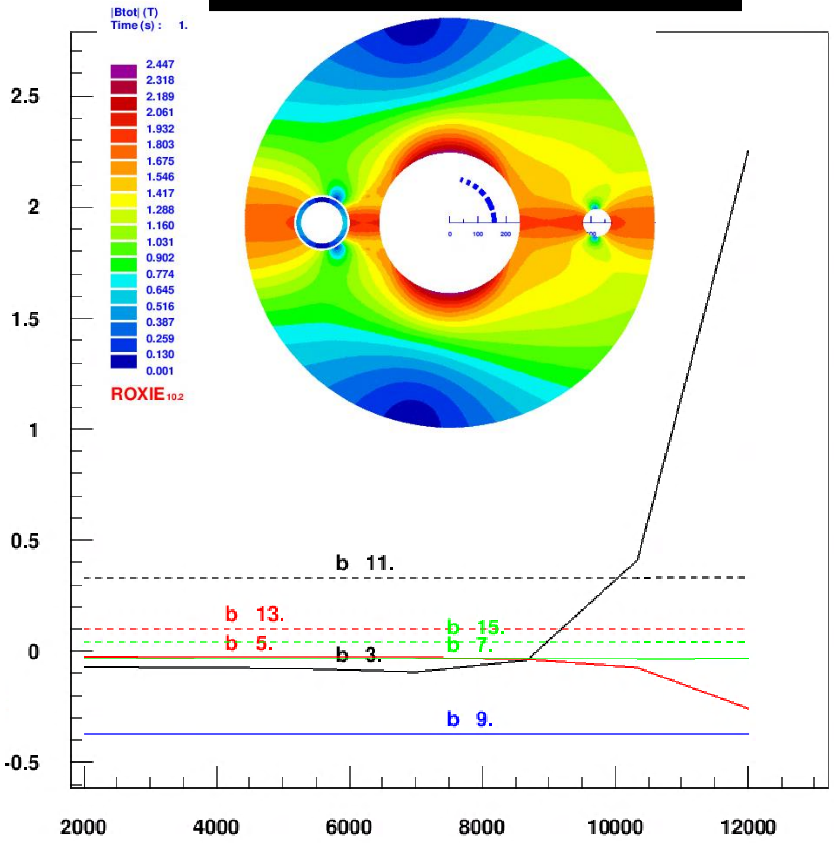
- Inner Yoke id: 500 mm
- Inner Yoke od: 26” (~660 mm) or 27” (~686 mm)
- 26” i.d. allows testing in two Dewars; one Dewar allows ~1.9 K

- Need large cutout at pole (keys) 19 mm to 30 mm
- Also need large cutout for end structure (21 sq inch or more)
- Would also like space for 1.9 K plumbing (2” dia hole)

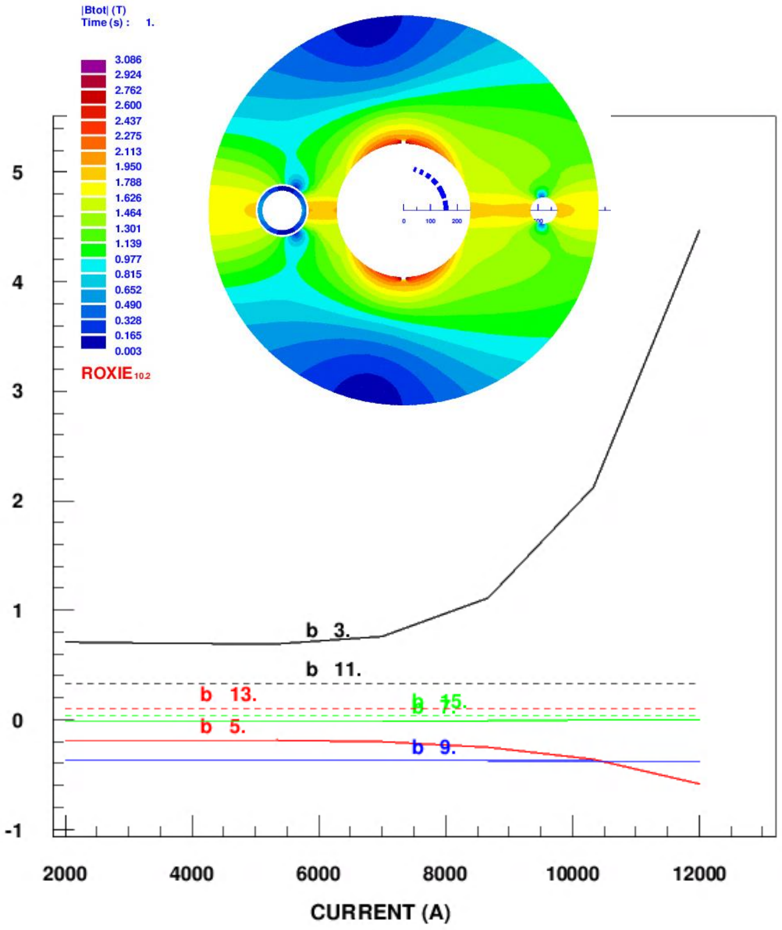
Above requirements pose challenges in obtaining good field quality, as Febin pointed out

Key at Pole – both low field b_3 and high field b_3 (iron saturation) become issue

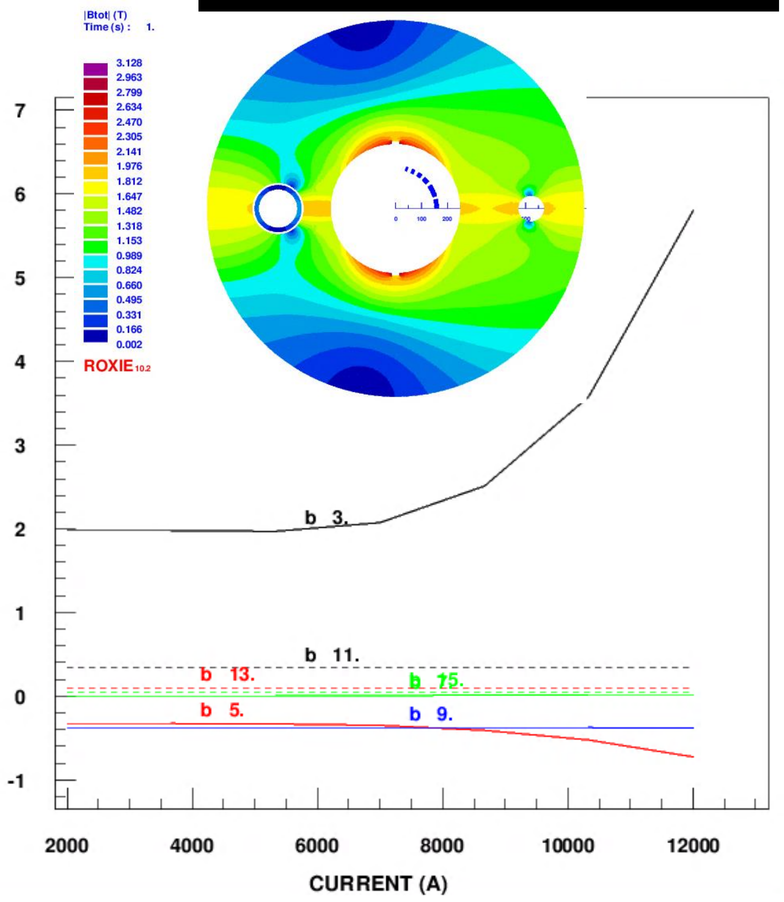
Circular Iron
b_3 (low field): ~0
b3 (high field): ~2.3



Notch (~19 mm wide)
b_3 (low field): 0.7
b3 (high field): 4.5



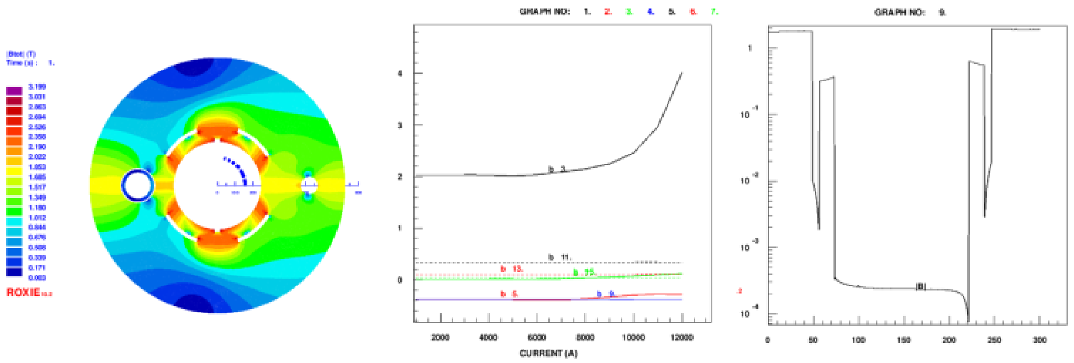
Notch (~30 mm wide)
b_3 (low field): ~2
b3 (high field): 5.8



Space for Large Cutout for Bar/Rod for End Structure

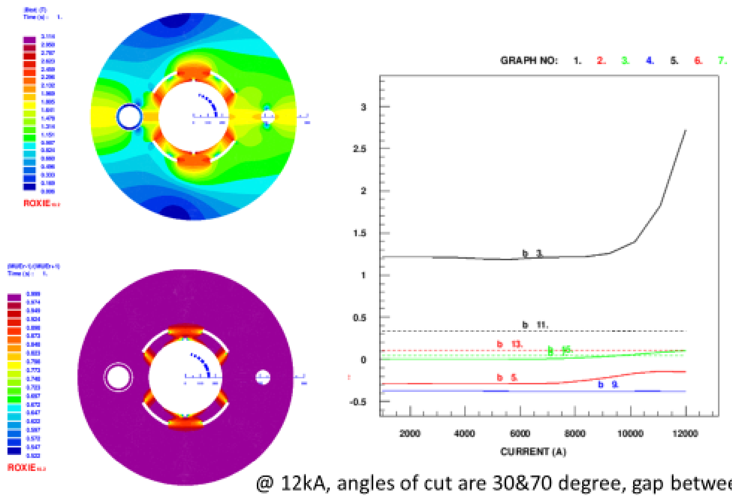
All slide: courtesy Febin Kurian

Case 10572:



@ 12kA, angles of cut are 30&70 degree, gap between 320&345 mm

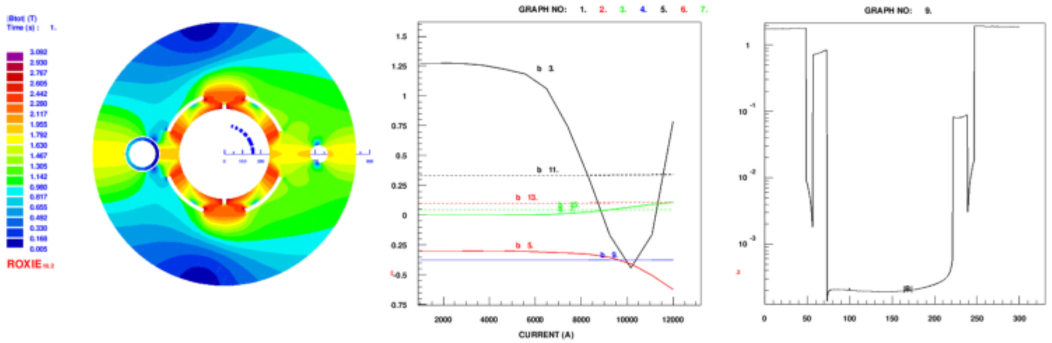
Case 107:



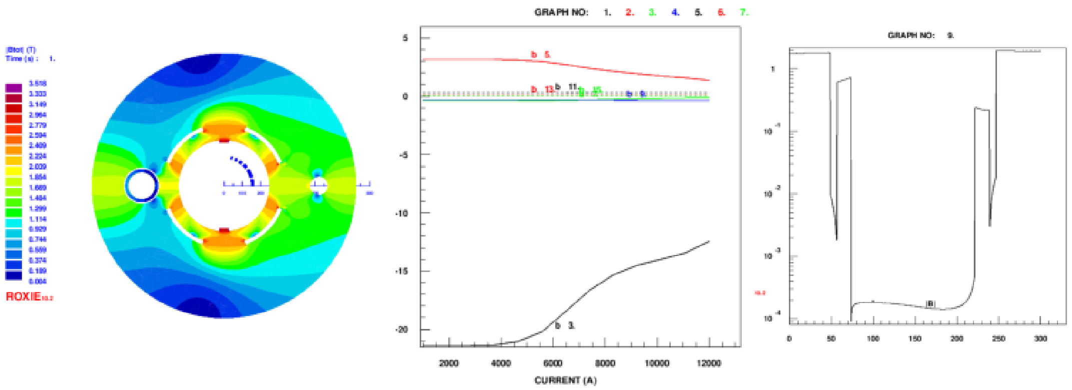
@ 12kA, angles of cut are 30&70 degree, gap between 320&345 mm
Key way: width =12.7 mm, depth=12.7

b_3 and b_3 saturation an issue. Space for cutout not enough

Case 112

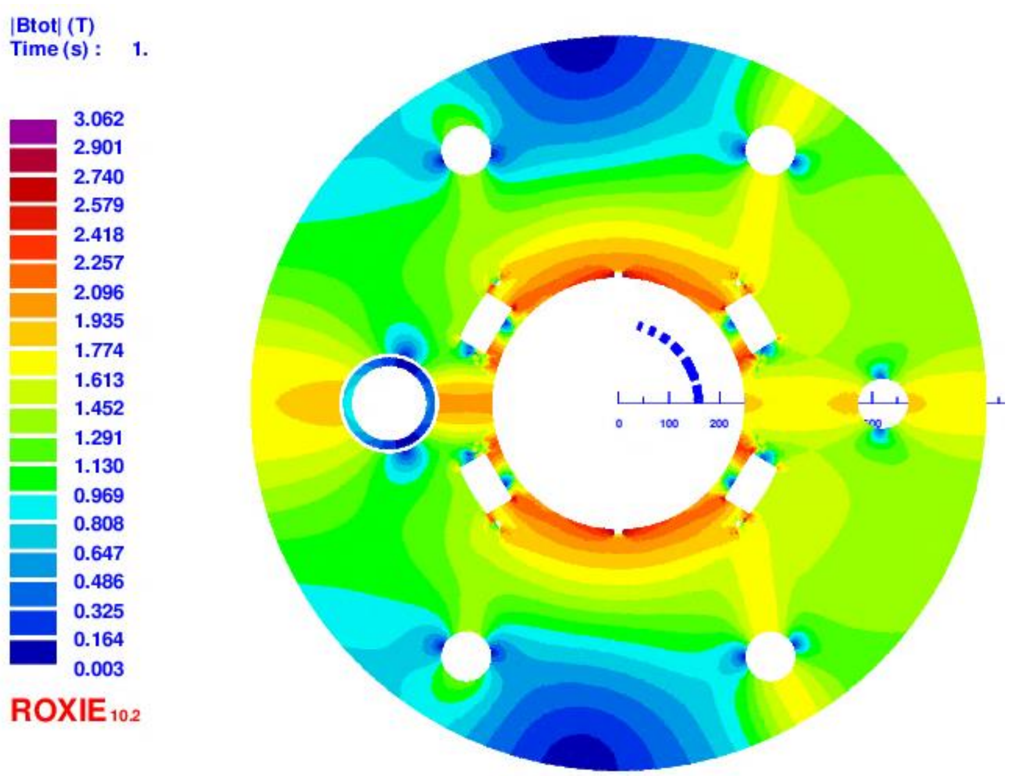


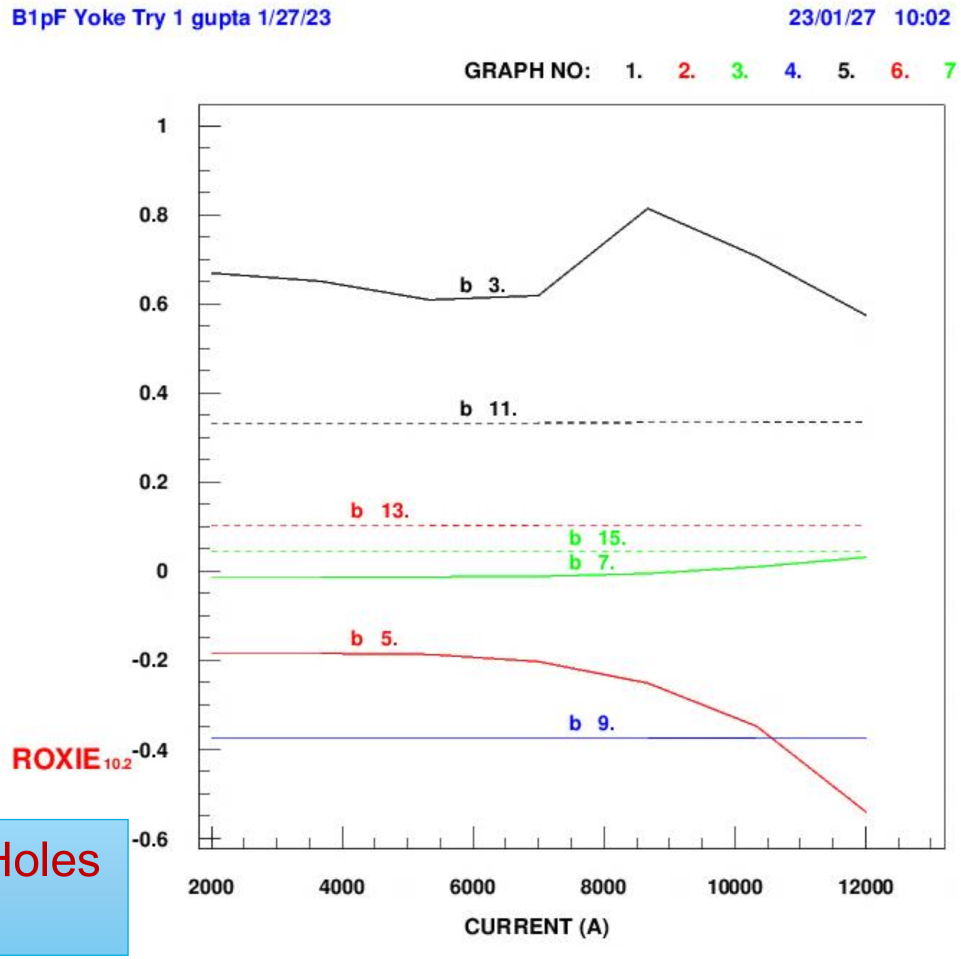
Case 113



Solution: Major Relocation/Optimization in the Cutout

Brings significant improvements : both b_3 and b_3 saturation become small (< 1 unit). The area of cutout is about 2X of what was required





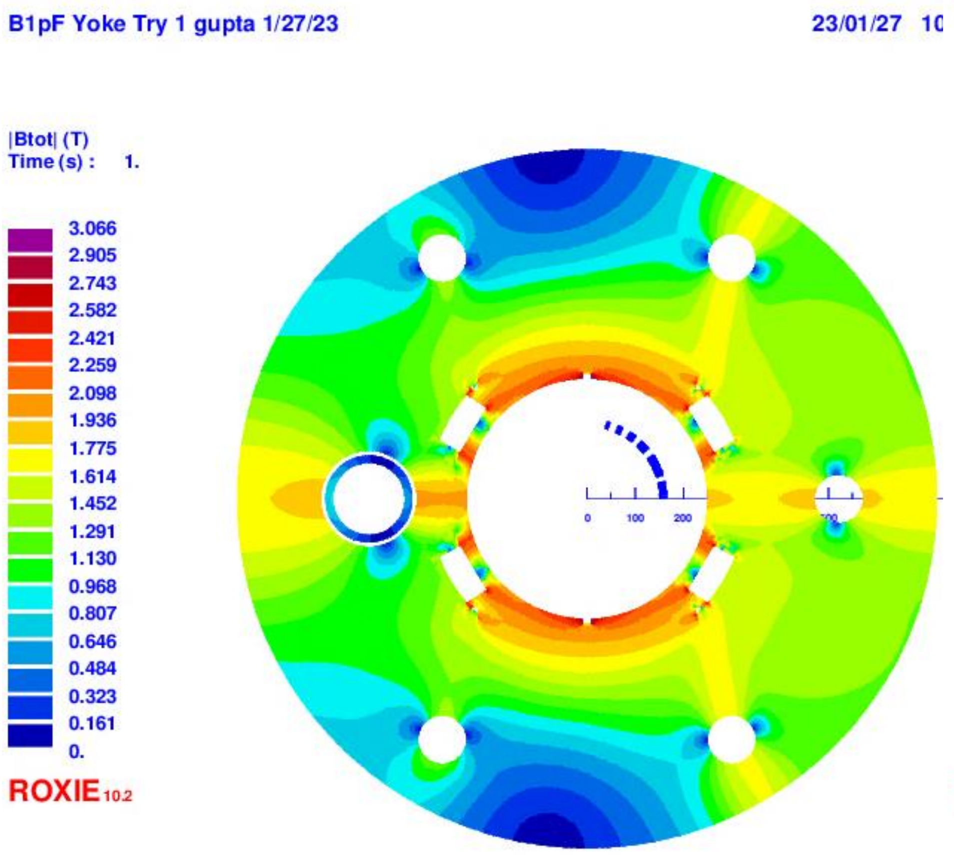
Inner yoke od: 27”
Notch width: 19 mm

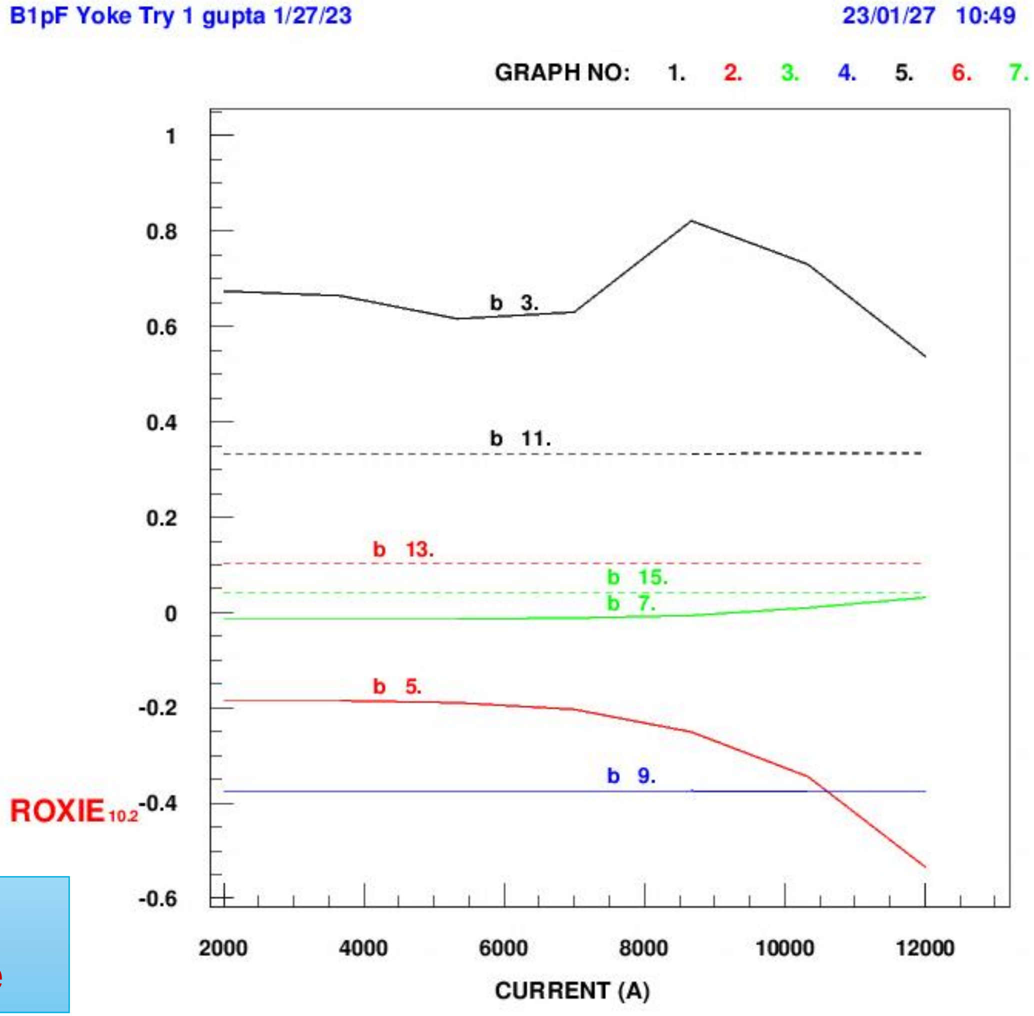
Request#1: Reduce inner yoke od to 26”

Design includes four 4” Helium Holes and 0.5”+ notches at 45 degree

Harmonics Remain Good for 26” od Inner Yoke

The area of cutout is still about 1.5X of what was required (21”), and both b_3 and b_3 saturation remain small (< 1 unit).





Inner yoke od: 26”
Notch width: 19 mm

Request#2:
Increase notch width to 30 mm

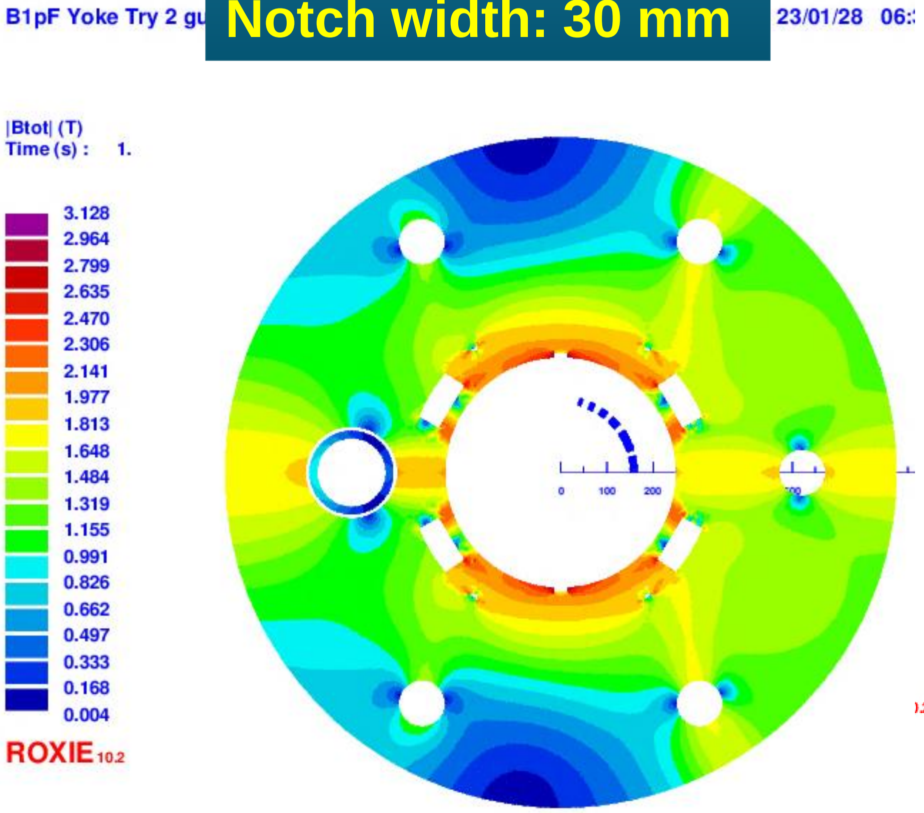
For 4” Helium Holes and 0.5”+ notches at 45 degree

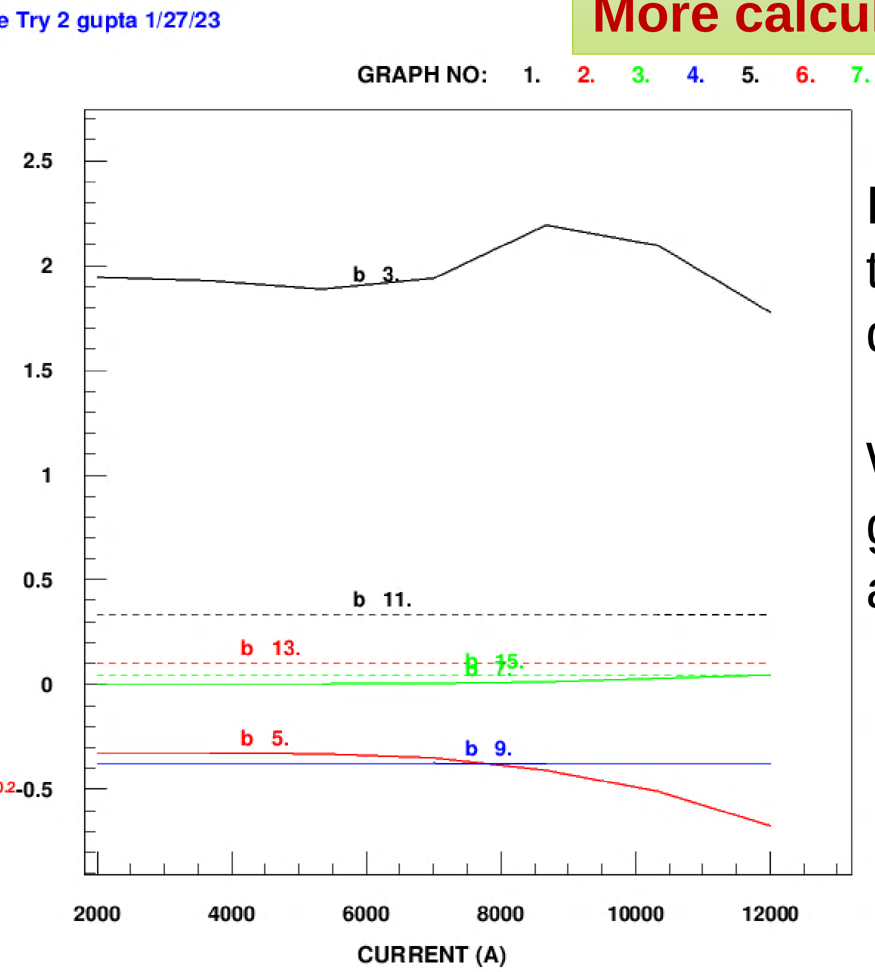
Cutouts in Inner Yoke reoptimized for Saturation Control

Re-optimization of cutout able to keep b_3 saturation small (< 1 unit).
Geometric (low field) b3 becomes large ~2 units due to larger key

Inner yoke od: 26”
Notch width: 30 mm

More calculations in the next slide





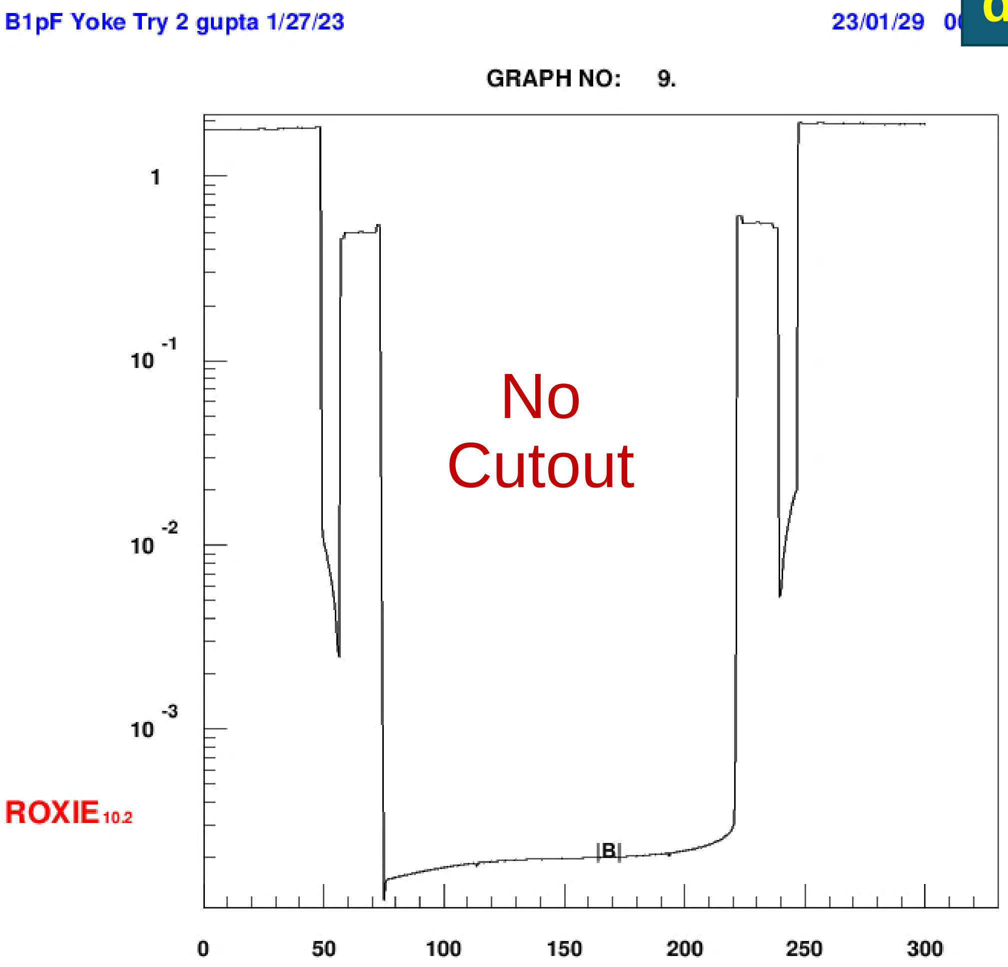
Low field (geometric) b_3 is typically minimized in coil design.

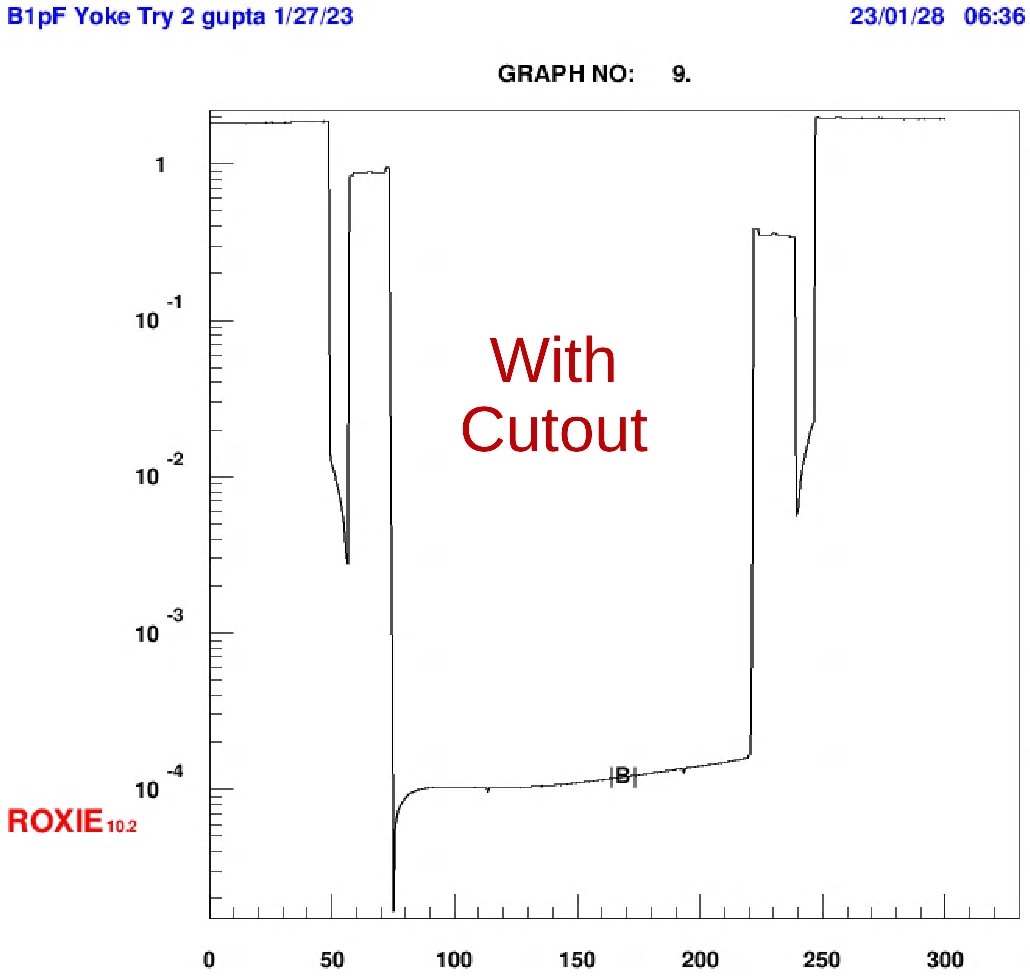
We have large midplane gaps and pole shims to accommodate such errors.

Area of bars is still 1.5 X of what was originally required

Field in e-Beam Hole for Optimized Inner Yoke

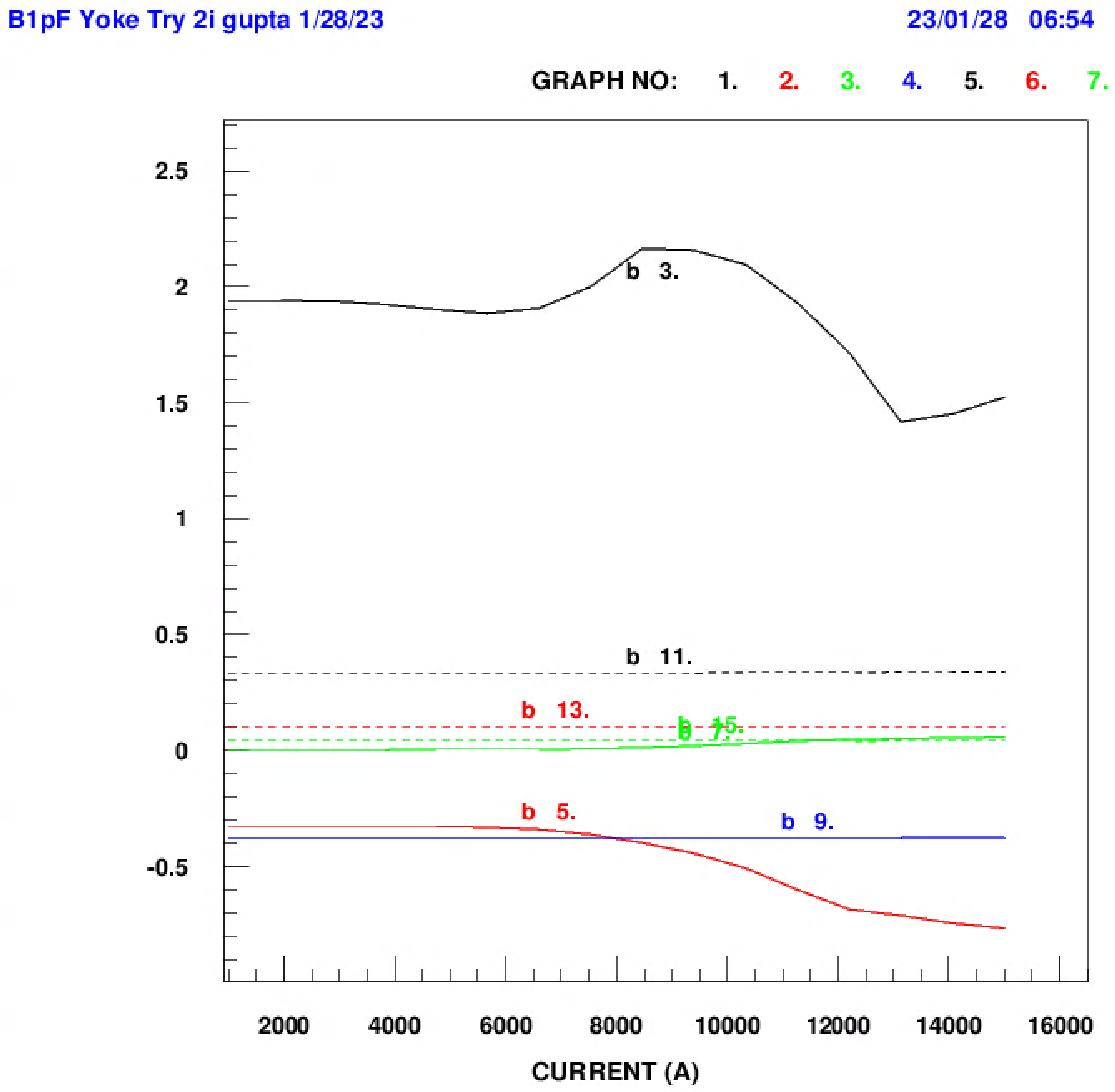
Cutout at appropriate place reduce field in the hole for electron in addition to reducing saturation. Same as done in the case of Q2pF yoke optimization.





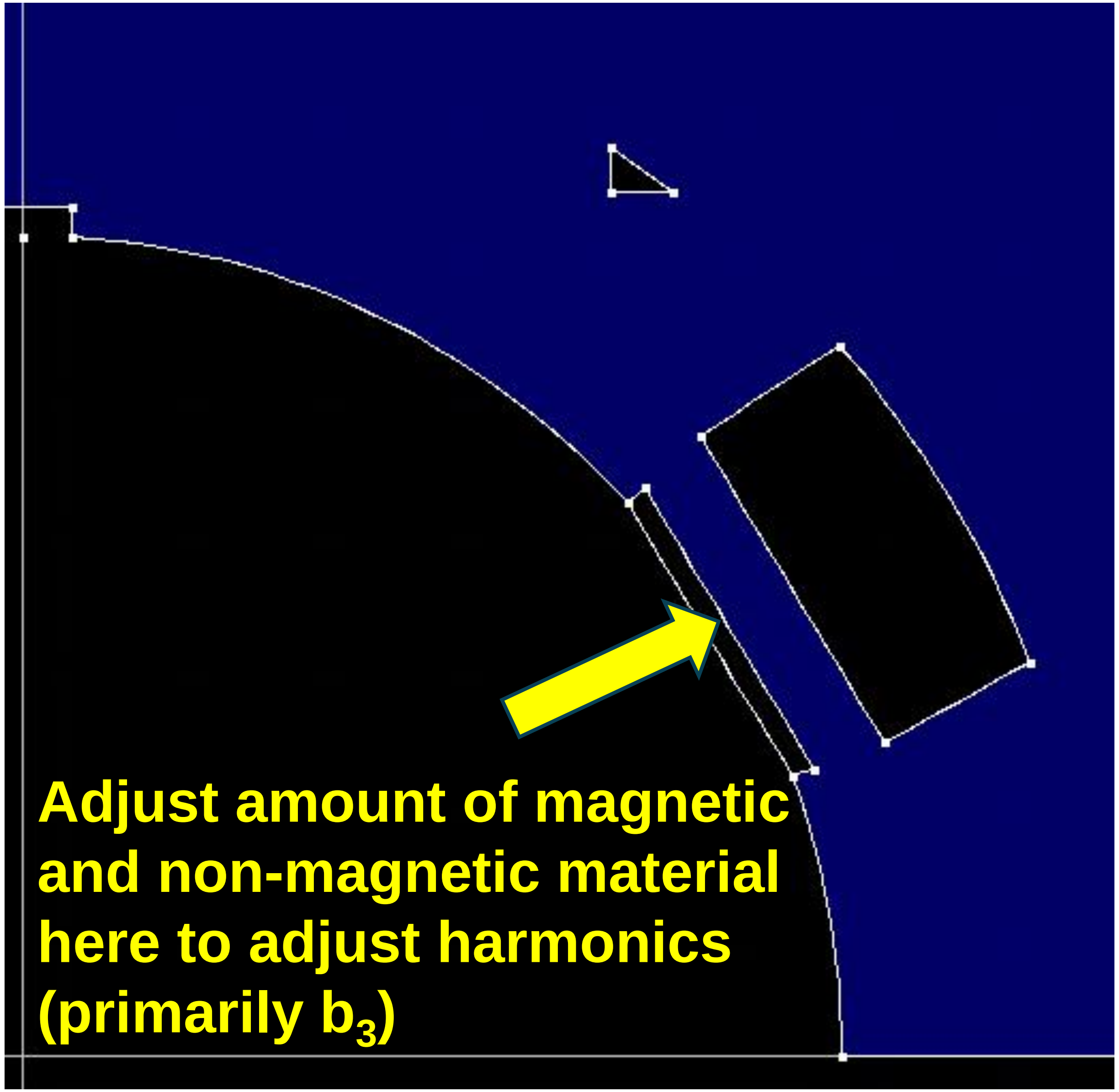
Saturation-induced harmonics beyond design (12 kA)

Change in all harmonics beyond 12 kA remains <1 unit



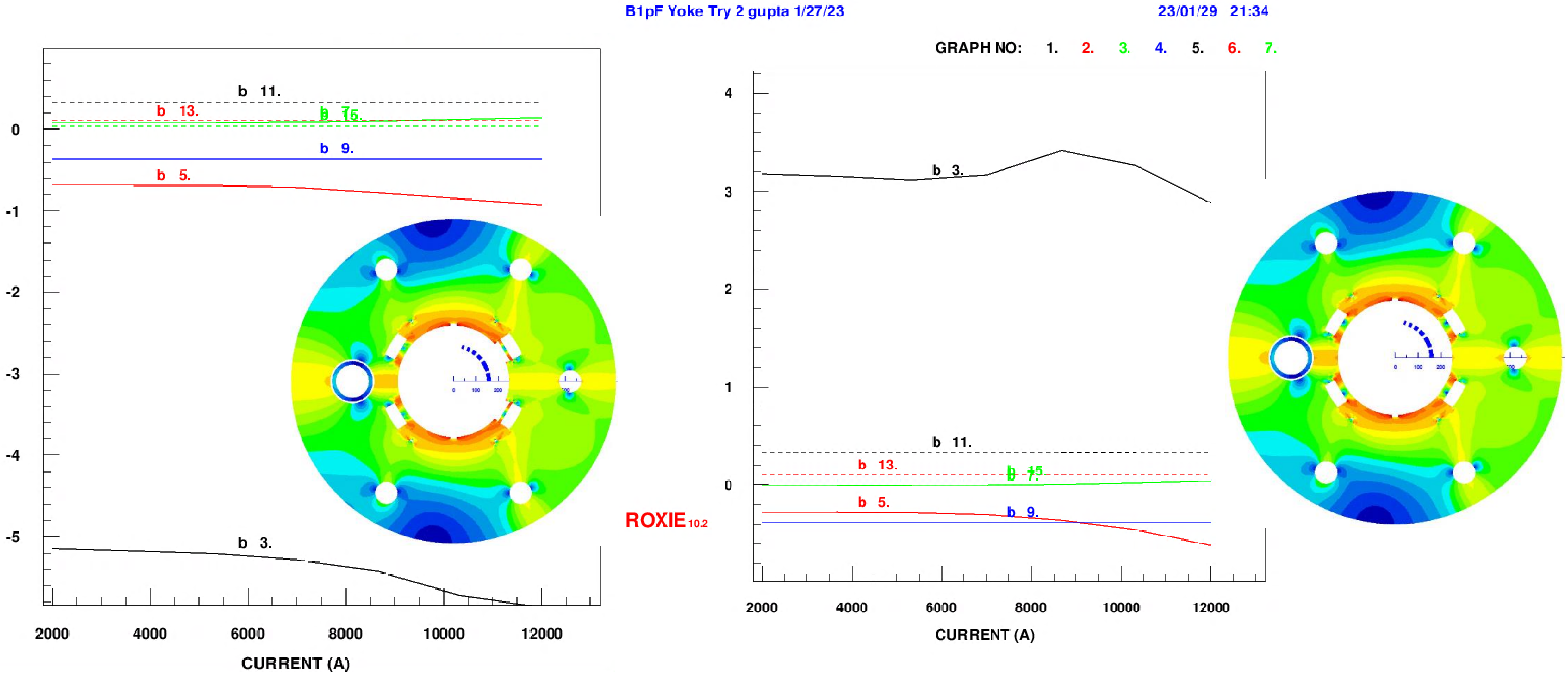
Tuning Field Harmonics after Construction (tuning shims)

- Tuning shims were used in RHIC 13 cm quad to adjust harmonics after construction.
- We can design the magnet to use it here as well.
- The place indicated is the good place for b_3

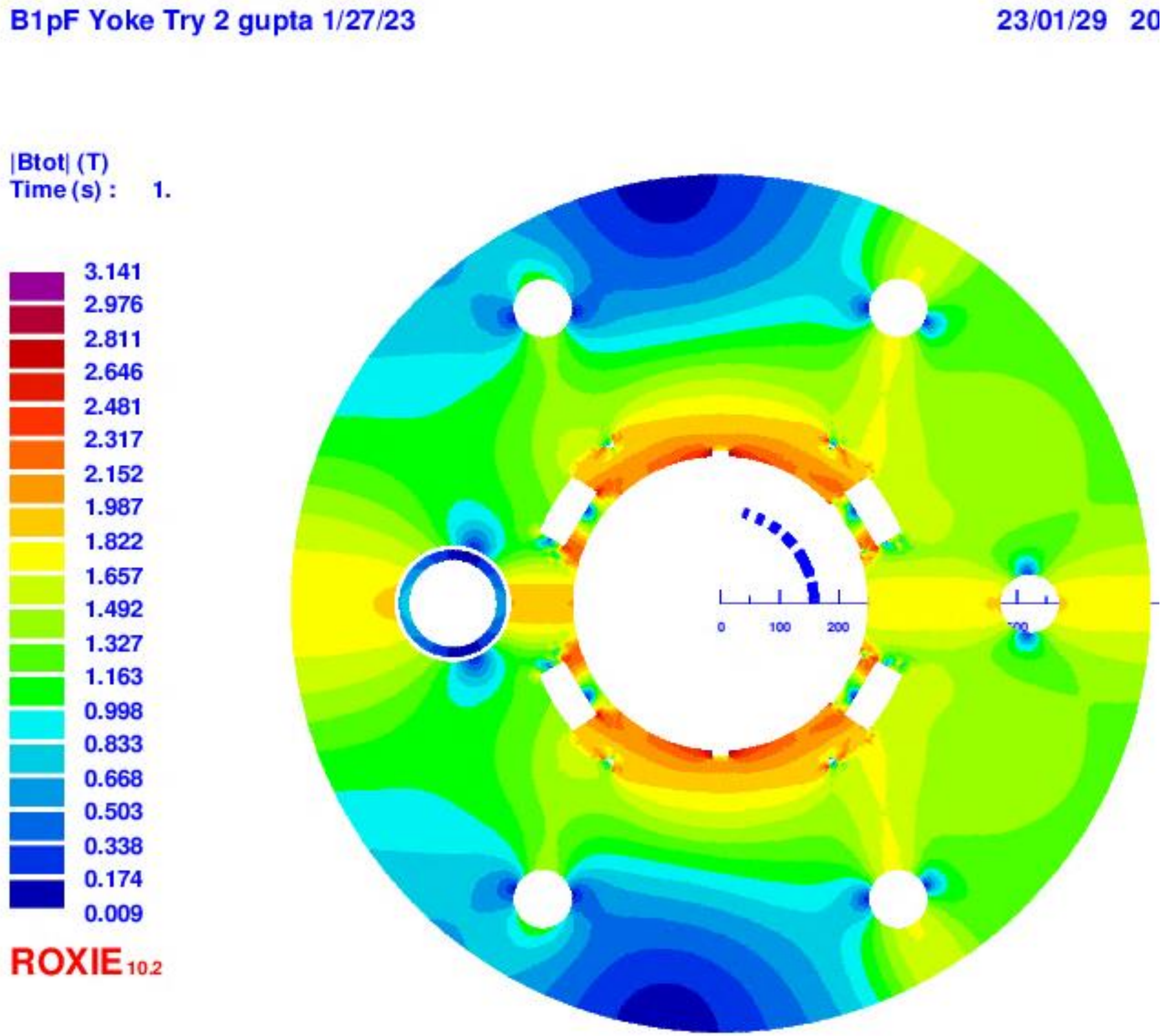


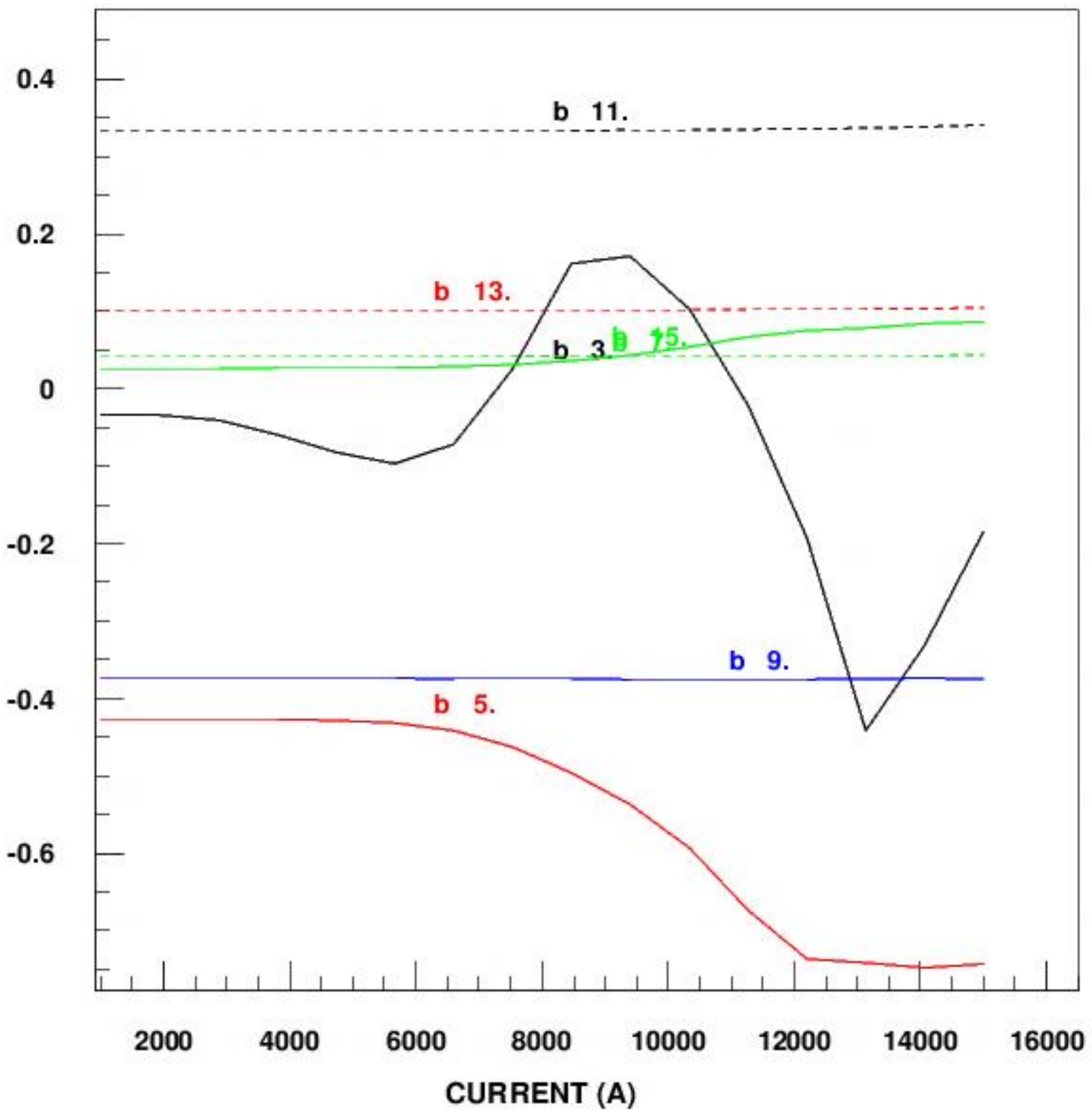
Tuning Field Harmonics after Construction (tuning shims)

- **Significant b_3 tuning (from over 3 units to under -5 units (> 8 units)**



Baseline Tuning Shims (Harmonic due to keys compensated)





Summary and Next Step

- It seems that a good magnetic design has been developed to satisfy the unusual and somewhat demanding mechanical requirement on the inner yoke B1pF.
- Large keys at the pole and large cutout in a relatively thin (small radial width) inner yoke have been accommodate while obtaining good field quality.
- Field harmonics as a function of current remain low, as well as the field in the hole for electron.
- Tuning shim design developed to adjust harmonics after construction (same as in RHIC 13 cm quadrupole).
- Next step #1: adjusting (tuning) saturation-induced b3 after construction. Initial calculations are encouraging and will be presented next.
- Next step #2: accommodating space in the inner yoke with 26” od to accomodating 2 K testing.