

Cross-talk Control between Q1BpF & Q1eF (understanding & implementation of the novel solution)

Ramesh Gupta

Superconducting Magnet Division

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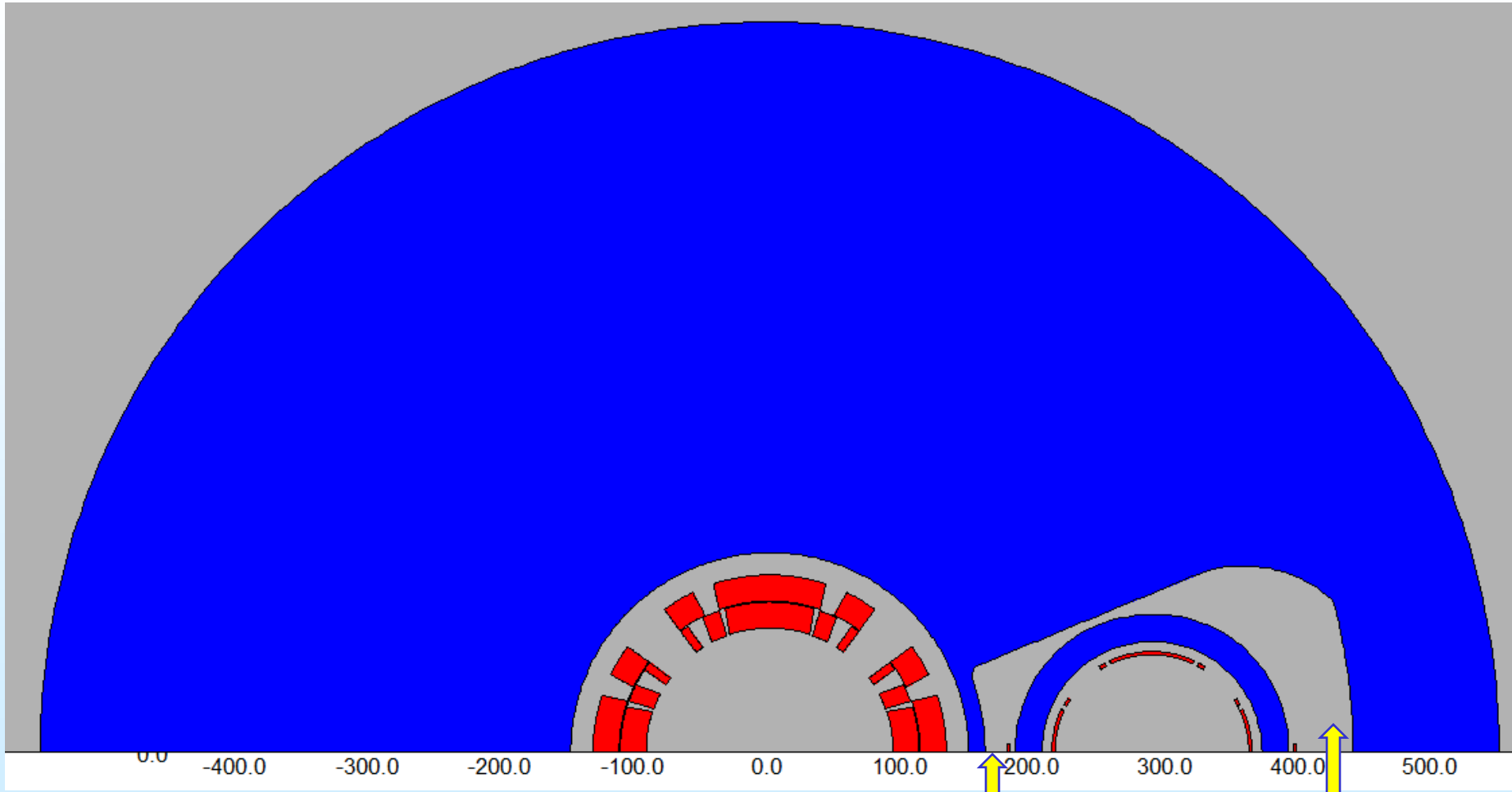
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Overview

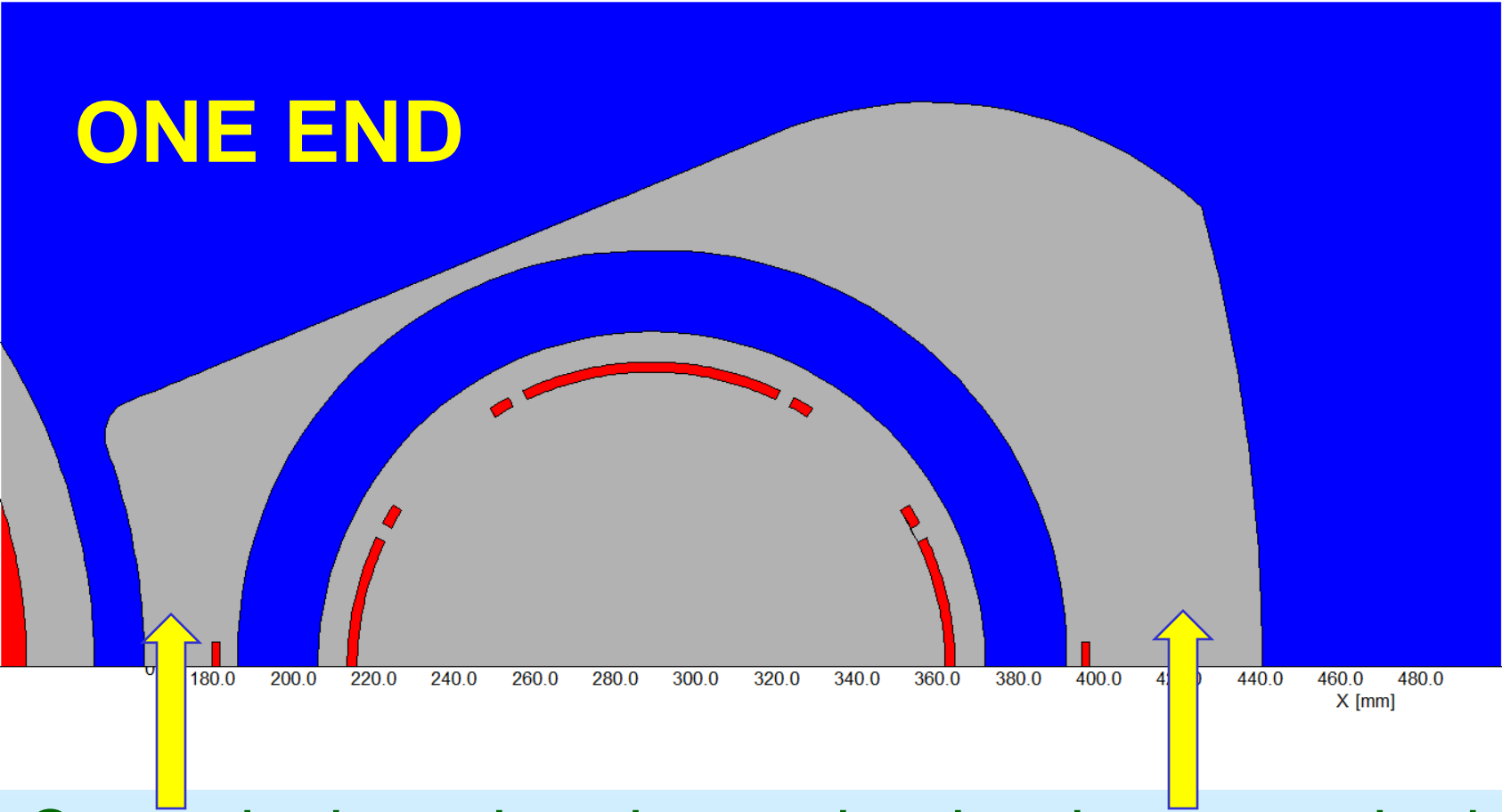
- This presentation explains the unique and novel strategy for reducing cross-talk between Q1BpF and Q1eF
- It tries to magnetically decouple the two quadrupoles by creating conditions so that magnetic shielding can work despite a high leakage field by reducing yoke saturation
- It uses correctors (a sort of) not to shape the field inside the quadrupoles directly but to keep field in the iron at the crucial places low enough so that it is able to shield
- The first defense against the cross talk is an air barrier and then the additional coils, as and if needed
- This presentation explains the approach and implementation so that it can be properly used

The Basic Model (1)



Cutout in the yoke where other hardware can be inserted

The Basic Model (2)



UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

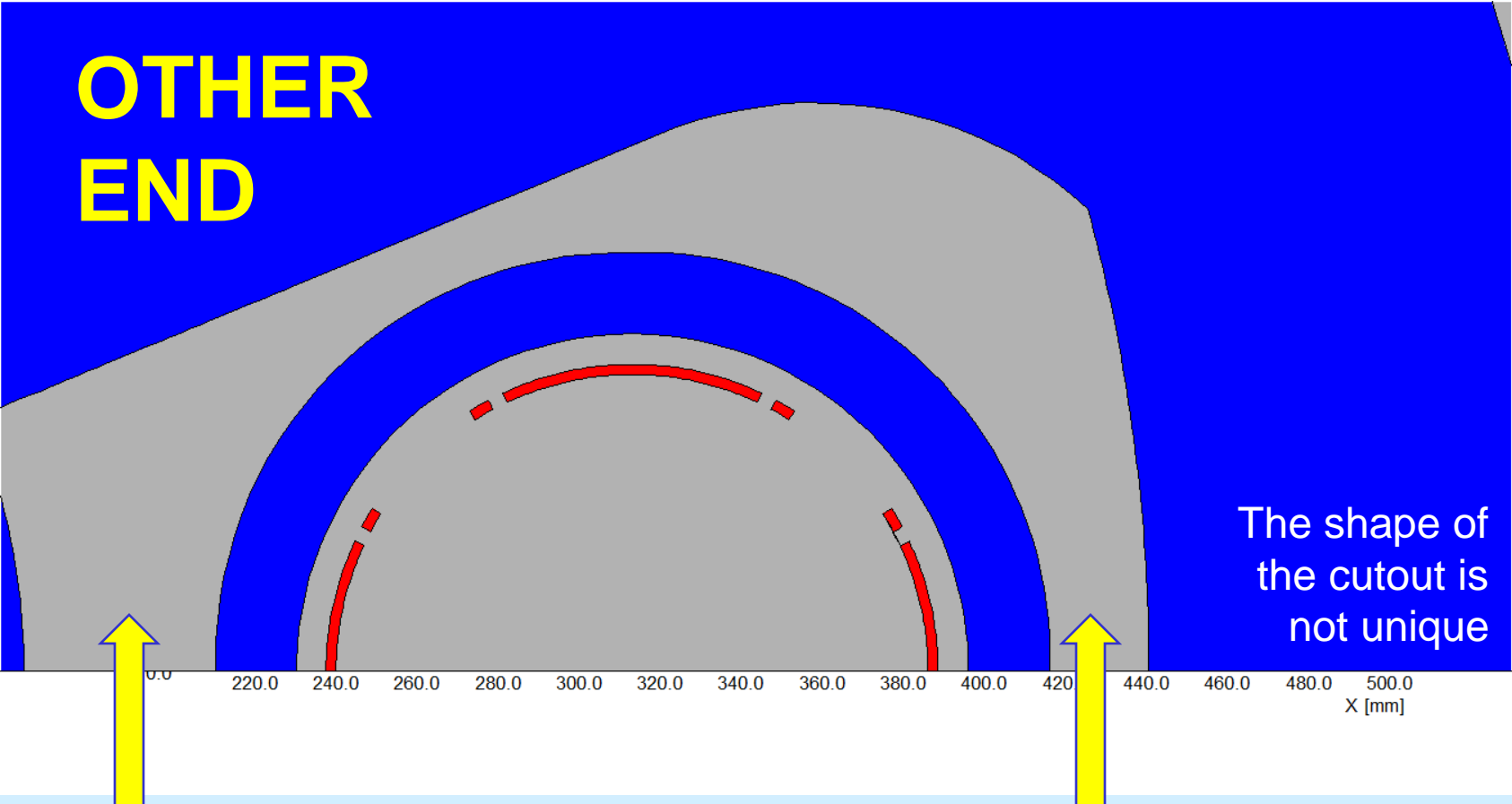
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 Linear elements
 XY symmetry
 Vector potential
 Magnetic fields
 Static solution
 Case 2 of 2
 Scale factor: 2.4
 93110 elements
 46919 nodes
 96 regions

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Cutout in the yoke where other hardware can be inserted
 (with rounded corners for the cutout)

The Basic Model (3)



UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

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Magnetic fields	
Static solution	
Case 2 of 2	
Scale factor: 2.4	
93212 elements	
46961 nodes	
96 regions	

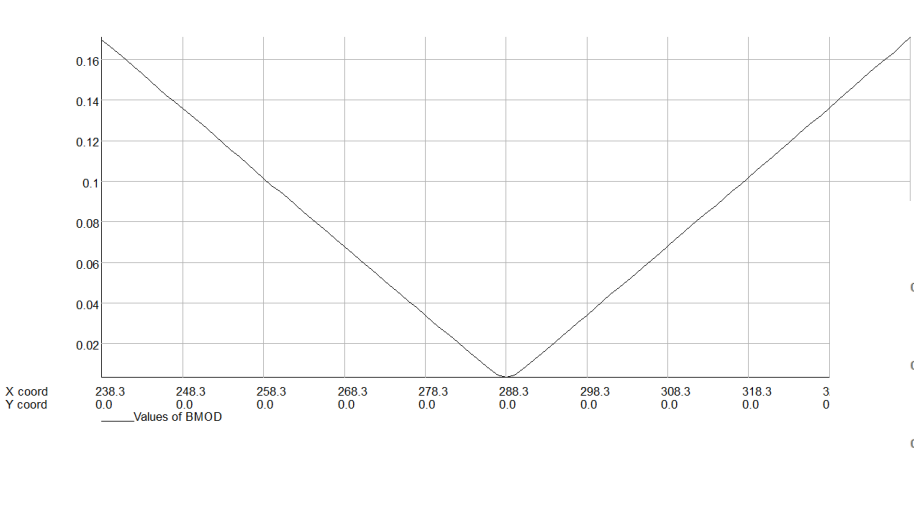
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Opera

Cutout in the yoke where other hardware can be inserted (with rounded corners for the cutout)

The Issue

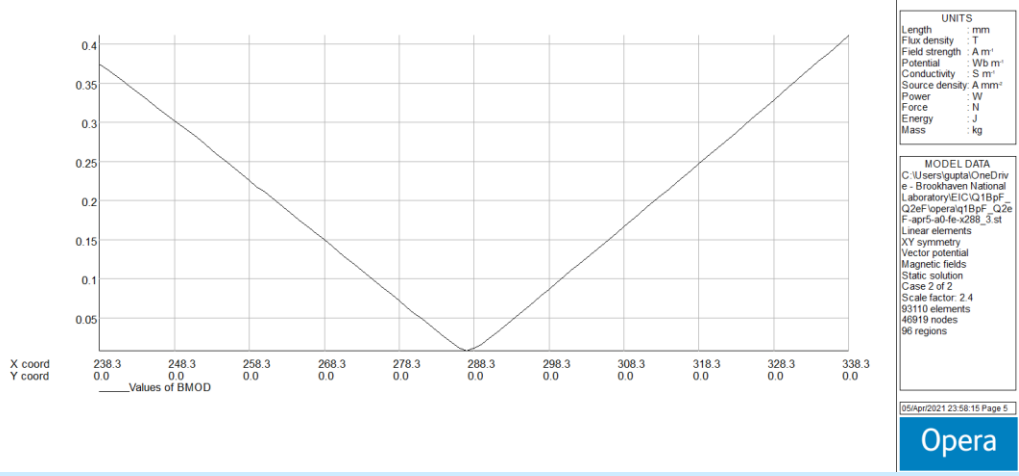
- Close proximity (leakage field) create cross-talk between Q1BpF and Q1eF and distort the field quality at high level of excitation
- It can be seen most prominently by looking at the magnitude of the field on the x-axis of Q1eF



UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻¹
Power	: W
Force	: N
Energy	: J
Mass	: kg

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(NOT symmetric at the design field)

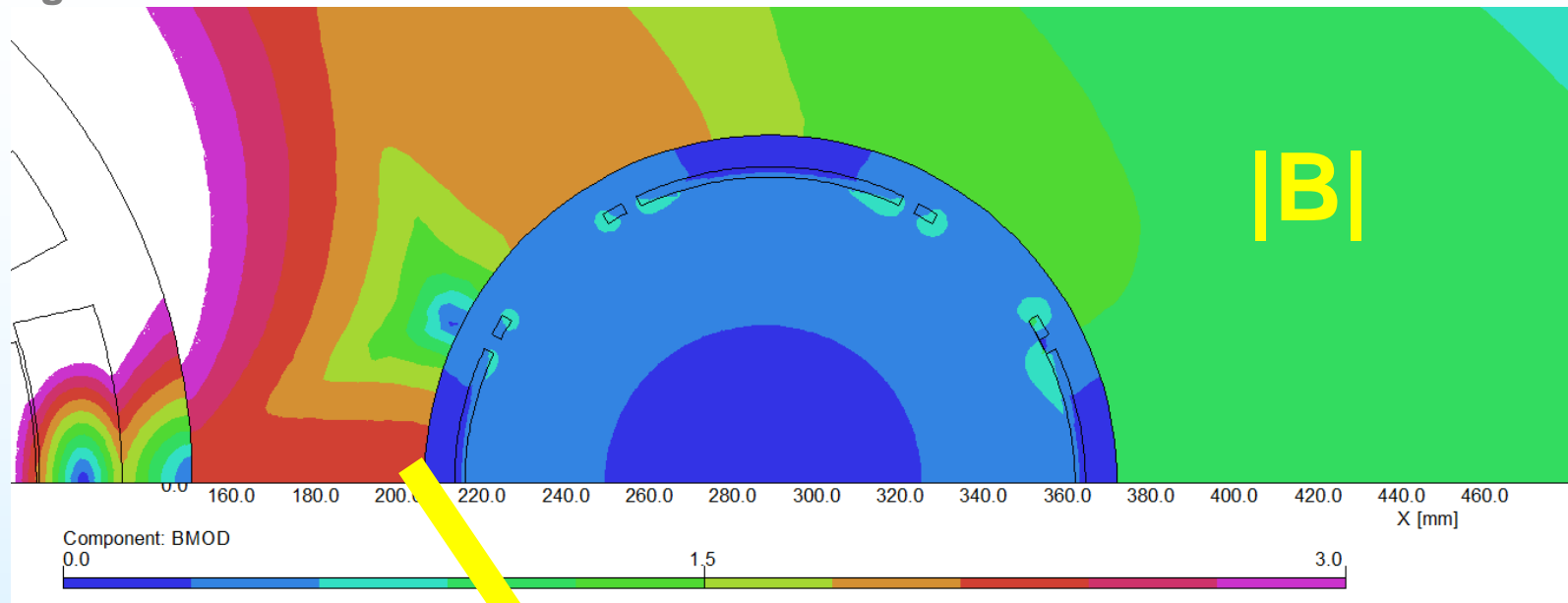


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Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻¹
Power	: W
Force	: N
Energy	: J
Mass	: kg

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Linear elements	
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96 regions	

(symmetric @40% of the design field)

Magnitude of the Field in the Yoke



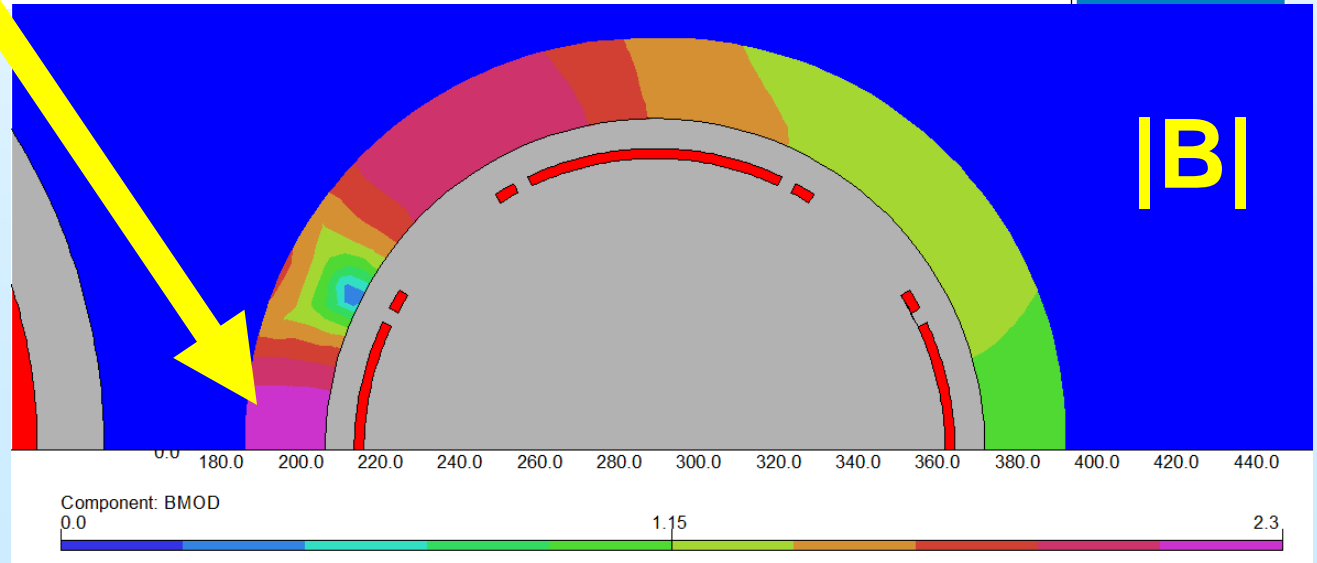
Mass : kg

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 Linear elements
 XY symmetry
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 Case 2 of 2
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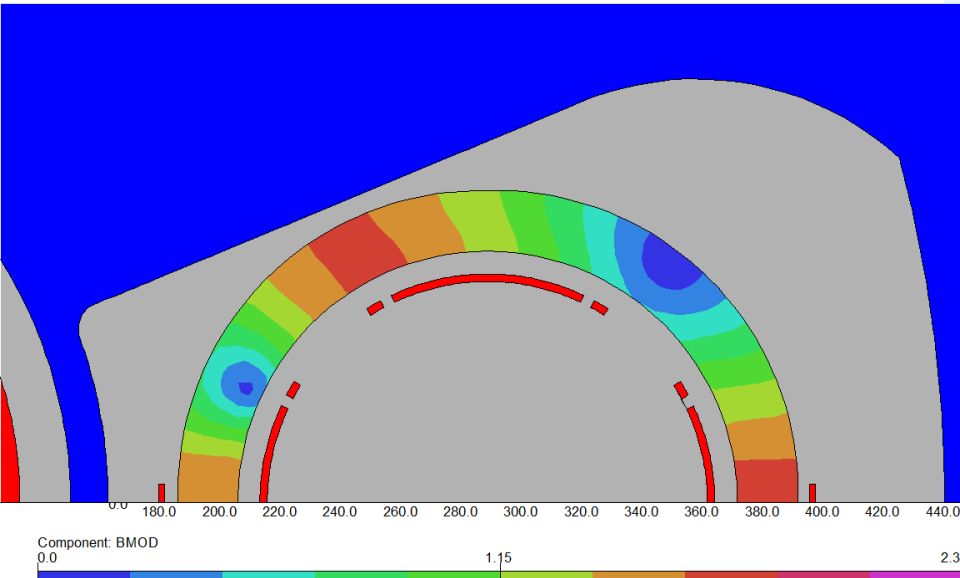
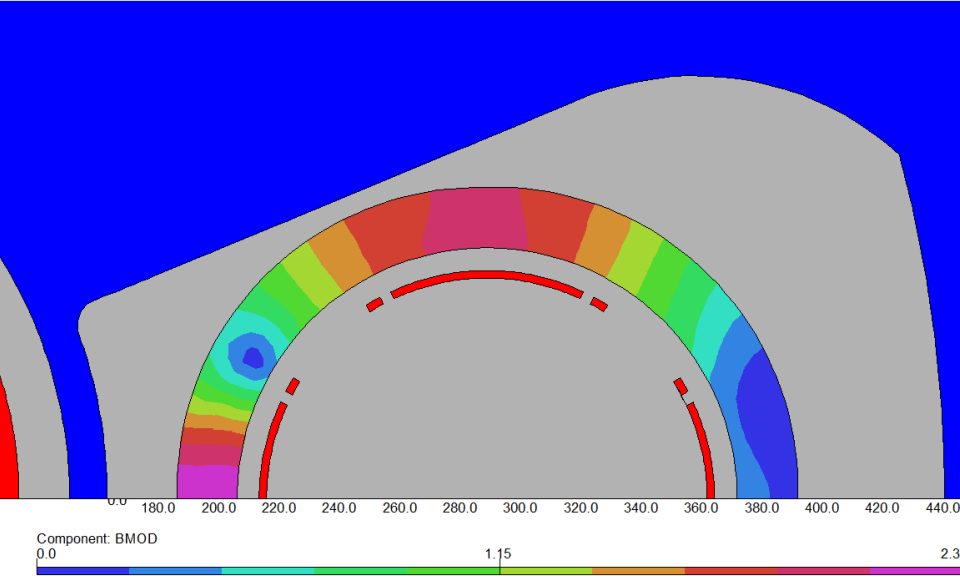
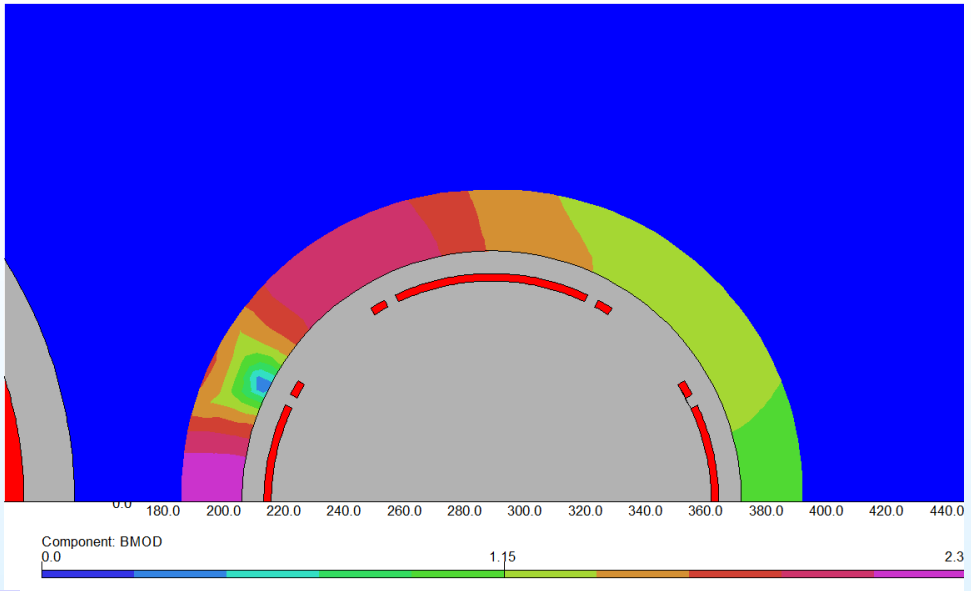
Opera

Large field (saturation) on the left side of the yoke of Q1eF



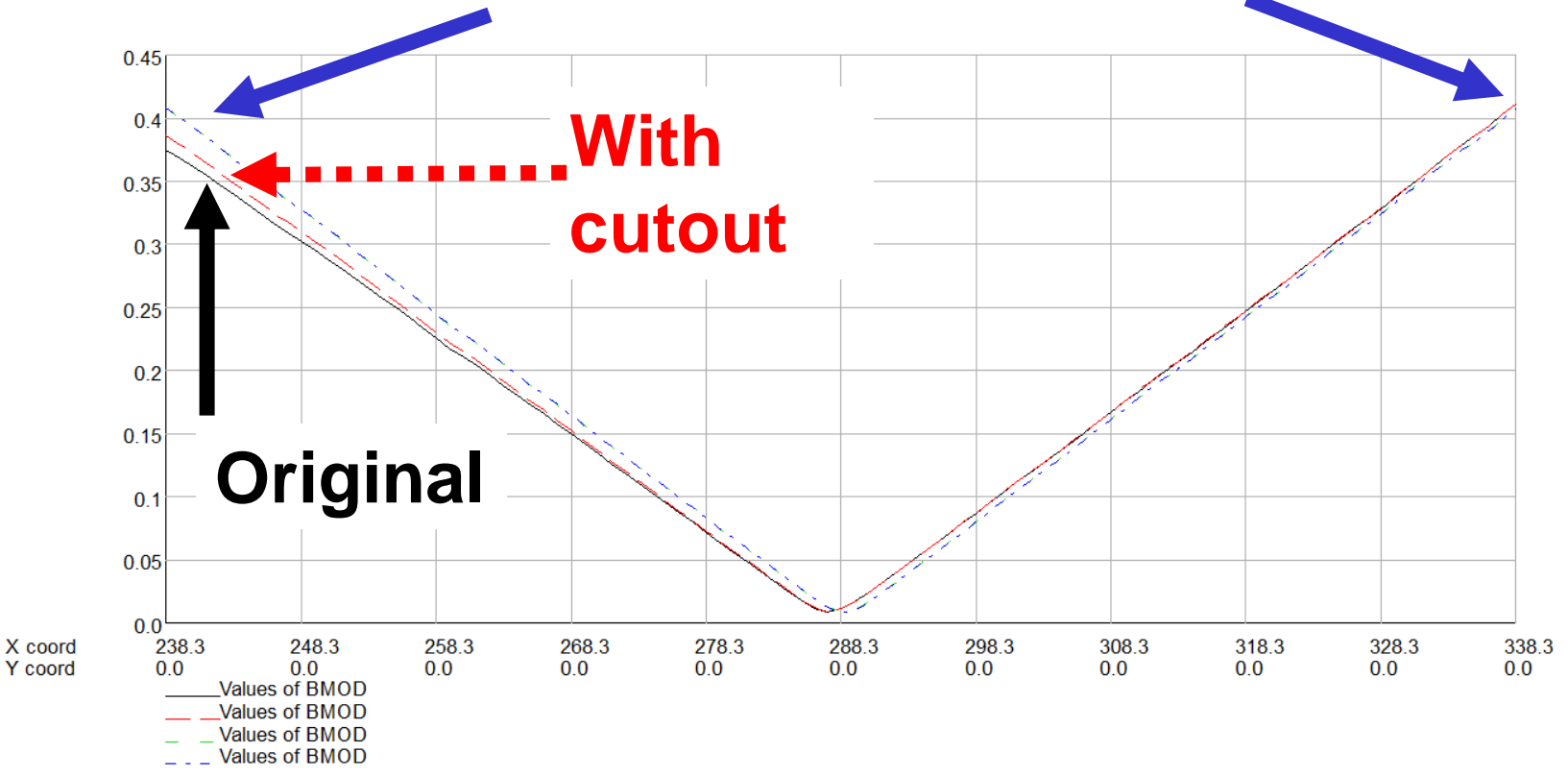
Development of the Design

1. Starting design: yoke between the two quad for maximum shielding
2. Cut out (to guide field lines away) and an iron ring around e-quad
3. Special corrector to reduce field in the iron ring (see reduction from ~2.3 Tesla max to ~1.6 Tesla. Yoke shielding works much better now



The Results: Compare the symmetry of the field on x-axis around the center

With cutout and corrector



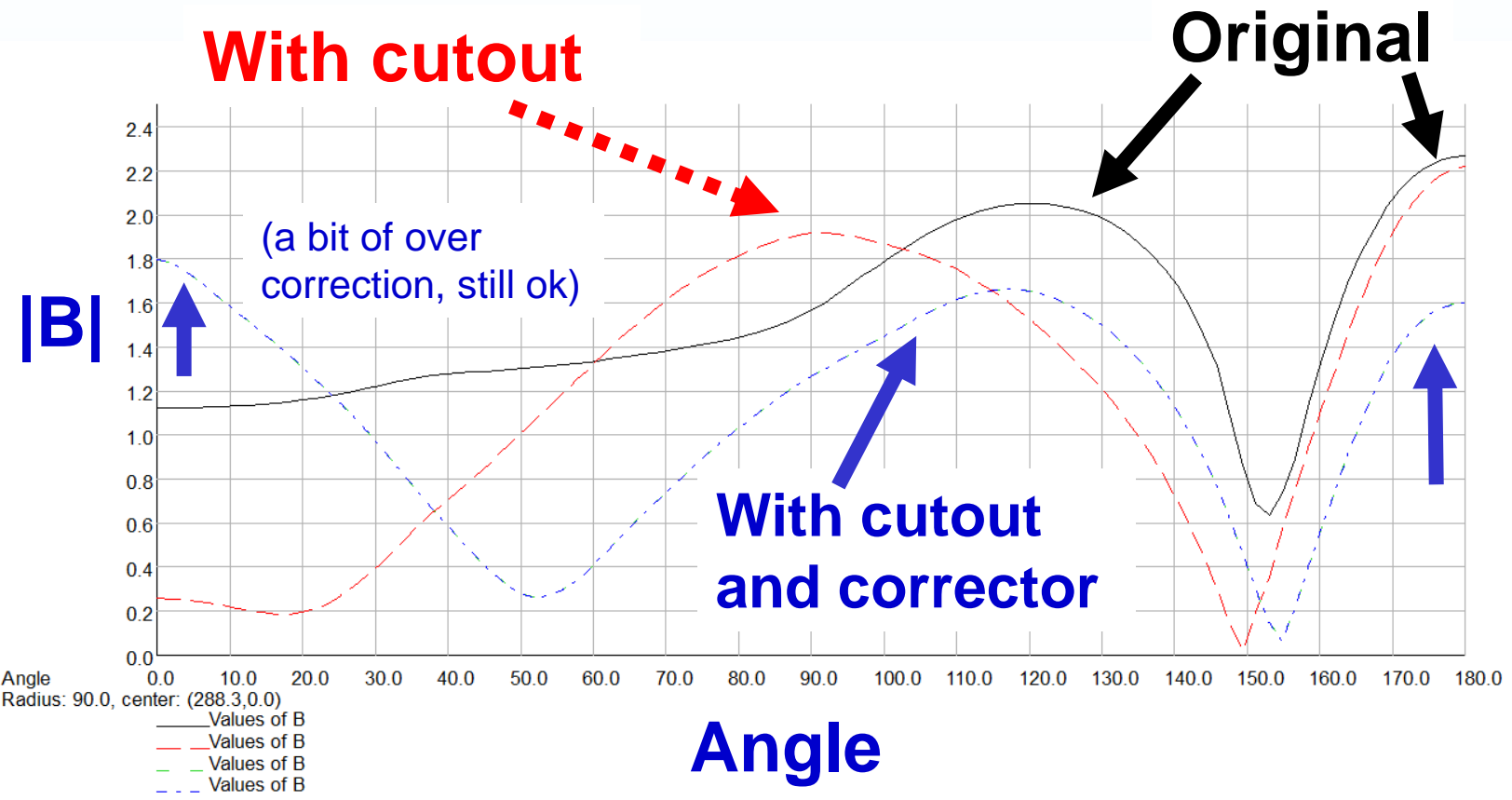
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Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

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Note: Symmetry with cutout and corrector

The real action is in reducing the maximum field in the iron around Q1eF



UNITS

Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

MODEL DATA

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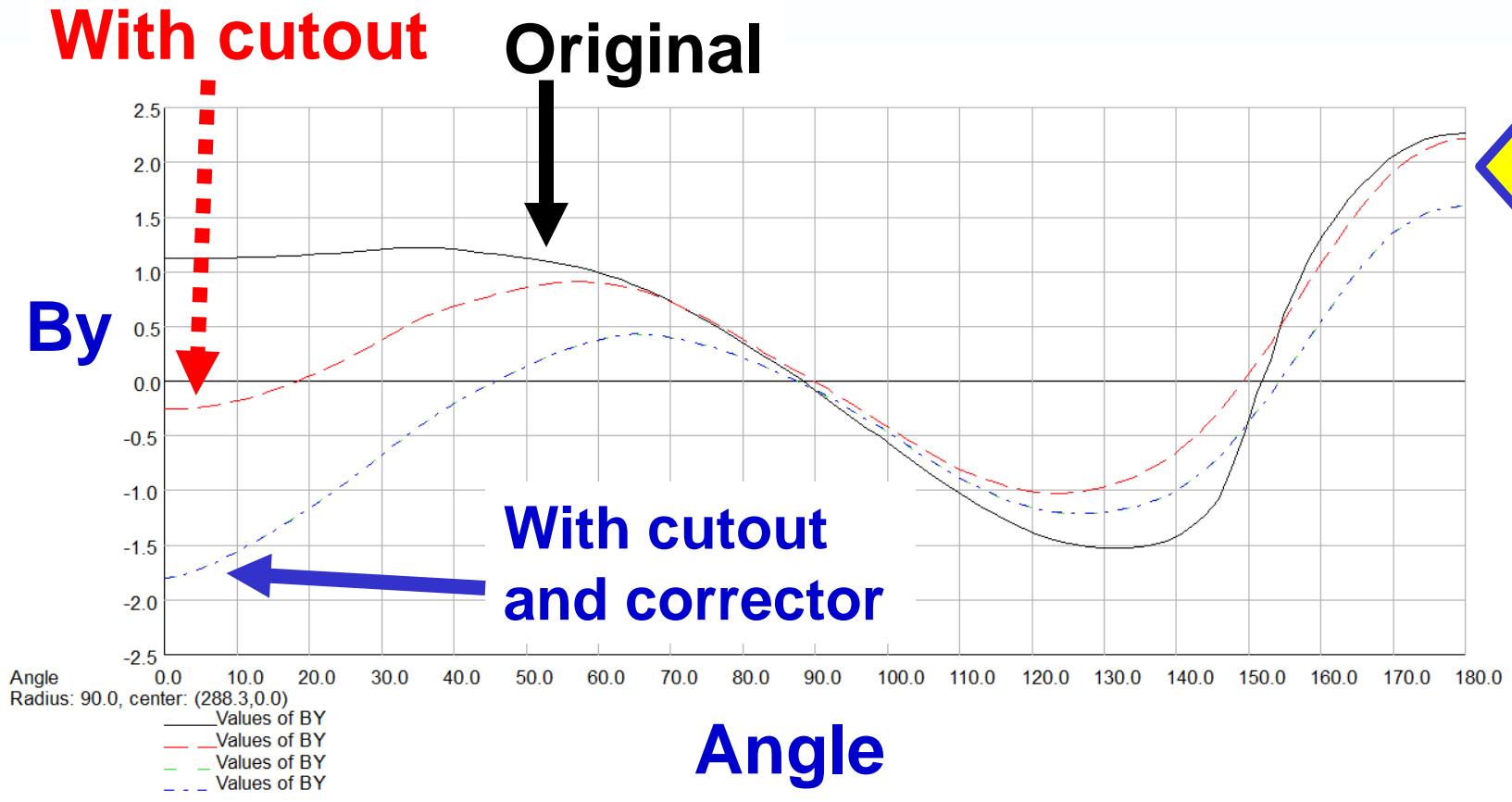
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Case 2 of 2
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Note: Reduction in the maximum field (2.2 T to 1.6 T) in the yoke at a radius of 90 mm

Even more dramatic is in reducing or shifting "By" in the iron around Q1eF



UNITS

Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

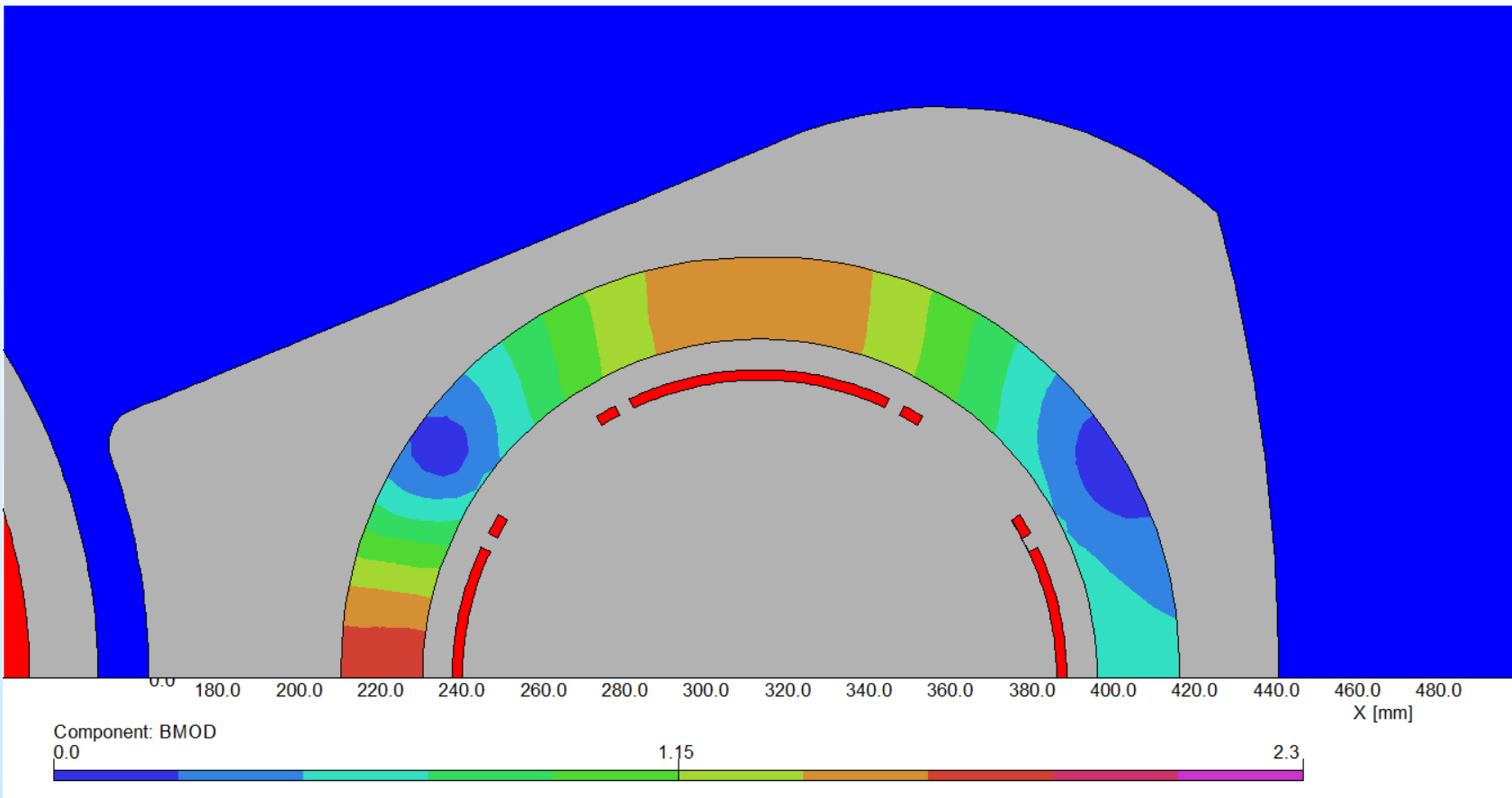
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 Linear elements
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Note: Change or Shift in By (angle=0 on right side)

Situation at the other end

Field in the yoke around Q1eF appears to be low enough (~ 1.8 T) that we may get by with just cutout



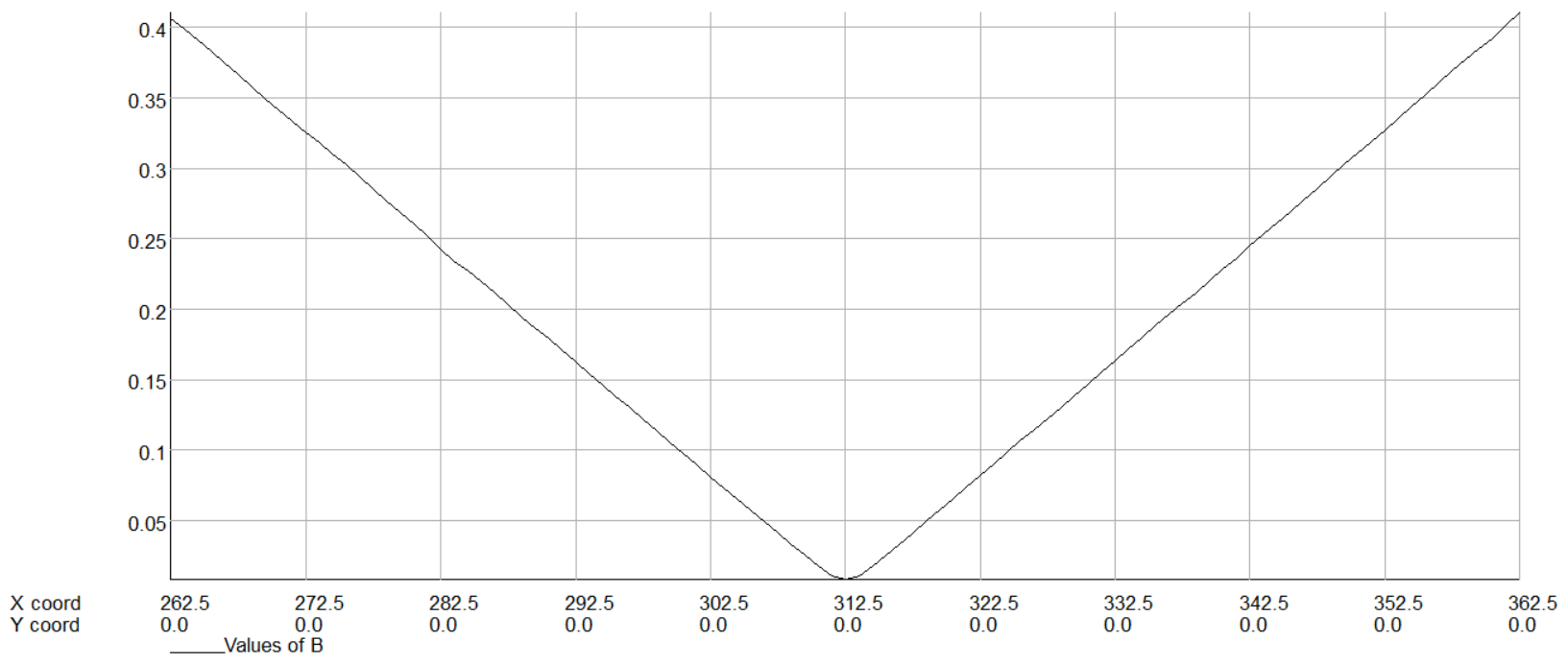
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Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

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XY symmetry	
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93212 elements	
46961 nodes	
96 regions	

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Situation at the other end



UNITS

Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

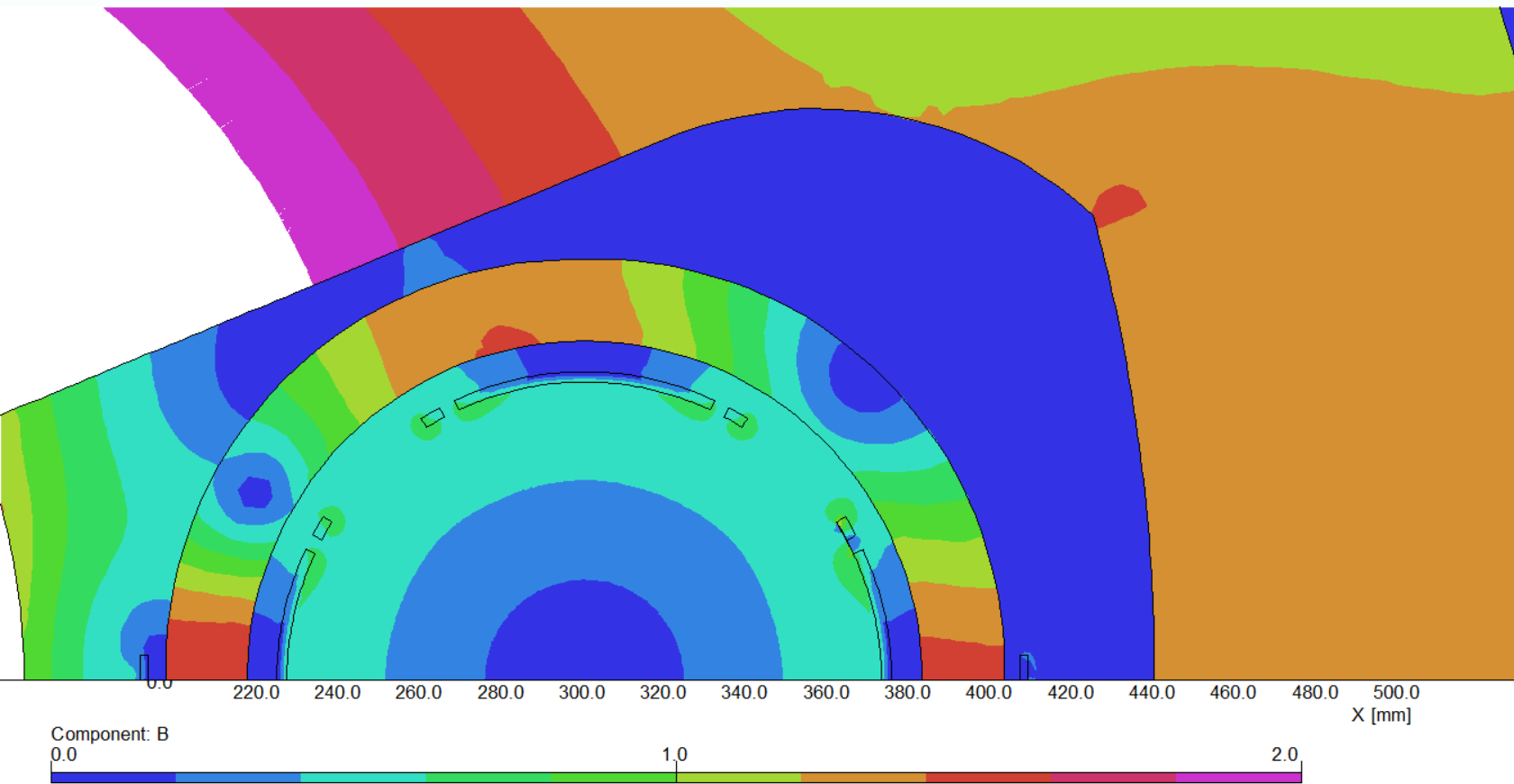
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 Linear elements
 XY symmetry
 Vector potential
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 Case 2 of 2
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 93212 elements
 46961 nodes
 96 regions

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Field on the x-axis is symmetric around the center (x0=312.5). We can get by with just with cutout in the yoke (no corrector needed)

Situation in the Middle



UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

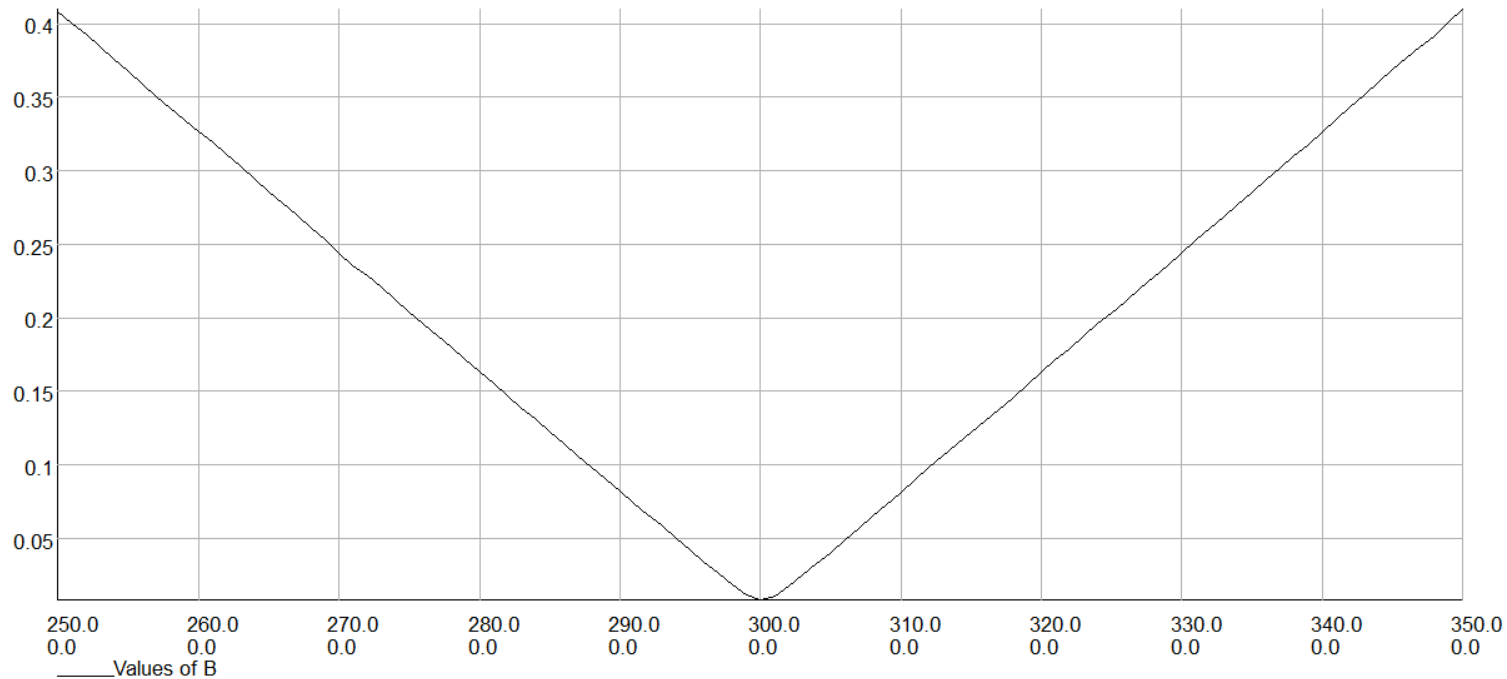
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 Linear elements
 XY symmetry
 Vector potential
 Magnetic fields
 Static solution
 Case 2 of 2
 Scale factor: 2.4
 93187 elements
 46951 nodes
 96 regions

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Field in the yoke around Q1eF with reduced strength of the corrector

Situation in the Middle



UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

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Vector potential	
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Static solution	
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Scale factor: 2.4	
93187 elements	
46951 nodes	
96 regions	

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Field on the x-axis is symmetric around the center (x0=300 mm) with cutout & reduced strength of corrector

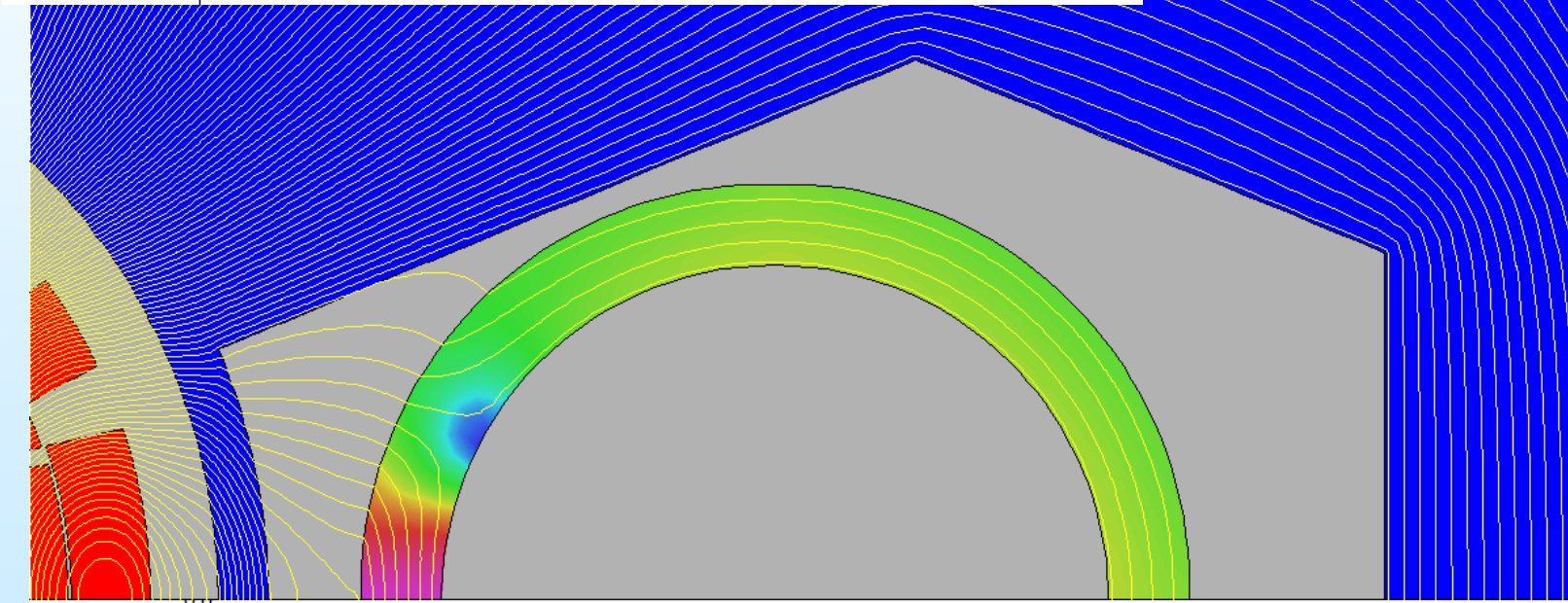
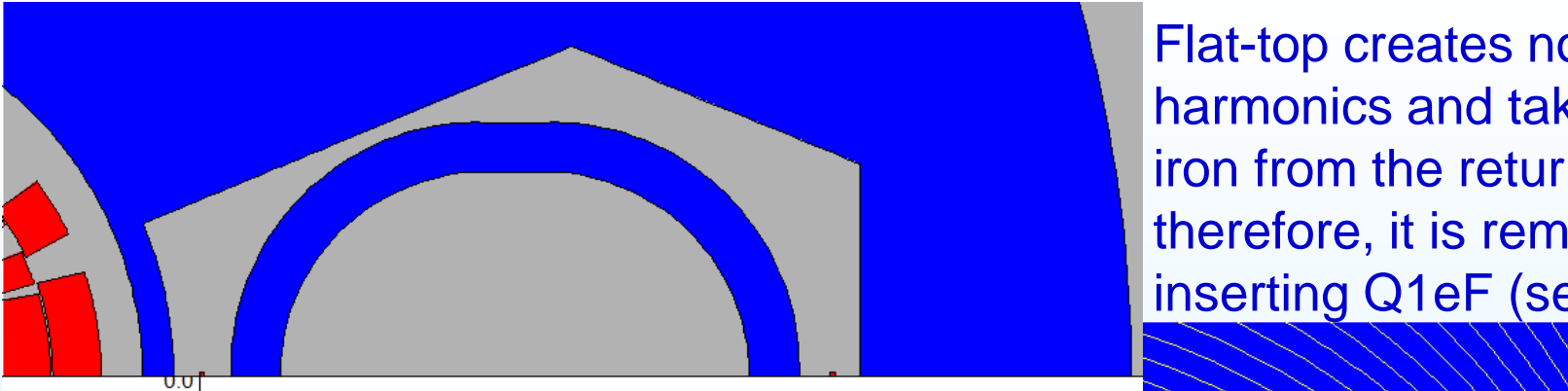
Summary

- **A novel technique is being developed to reduced cross-talk on tight space (cutout and controlling iron saturation with small additional coils).**
- **It is based on controlling the yoke saturation (experience from RHIC magnets - now standard around the world), where we reduced saturation from 40+ unit of sextupole to just a few units.**
- **The corrector strength (or number of turns) needs to be adjusted in going from the one end (maximum) to the other end (none).**

Backup Slides (from last year)

Q1BpF with Q1eF (need to remove flat-top)

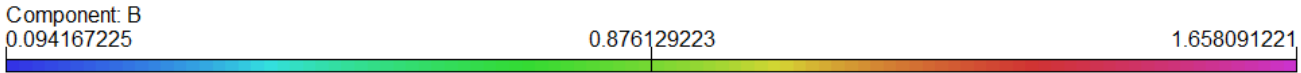
Flat-top creates non-allowed harmonics and takes away iron from the return yoke. therefore, it is removed for inserting Q1eF (see below)



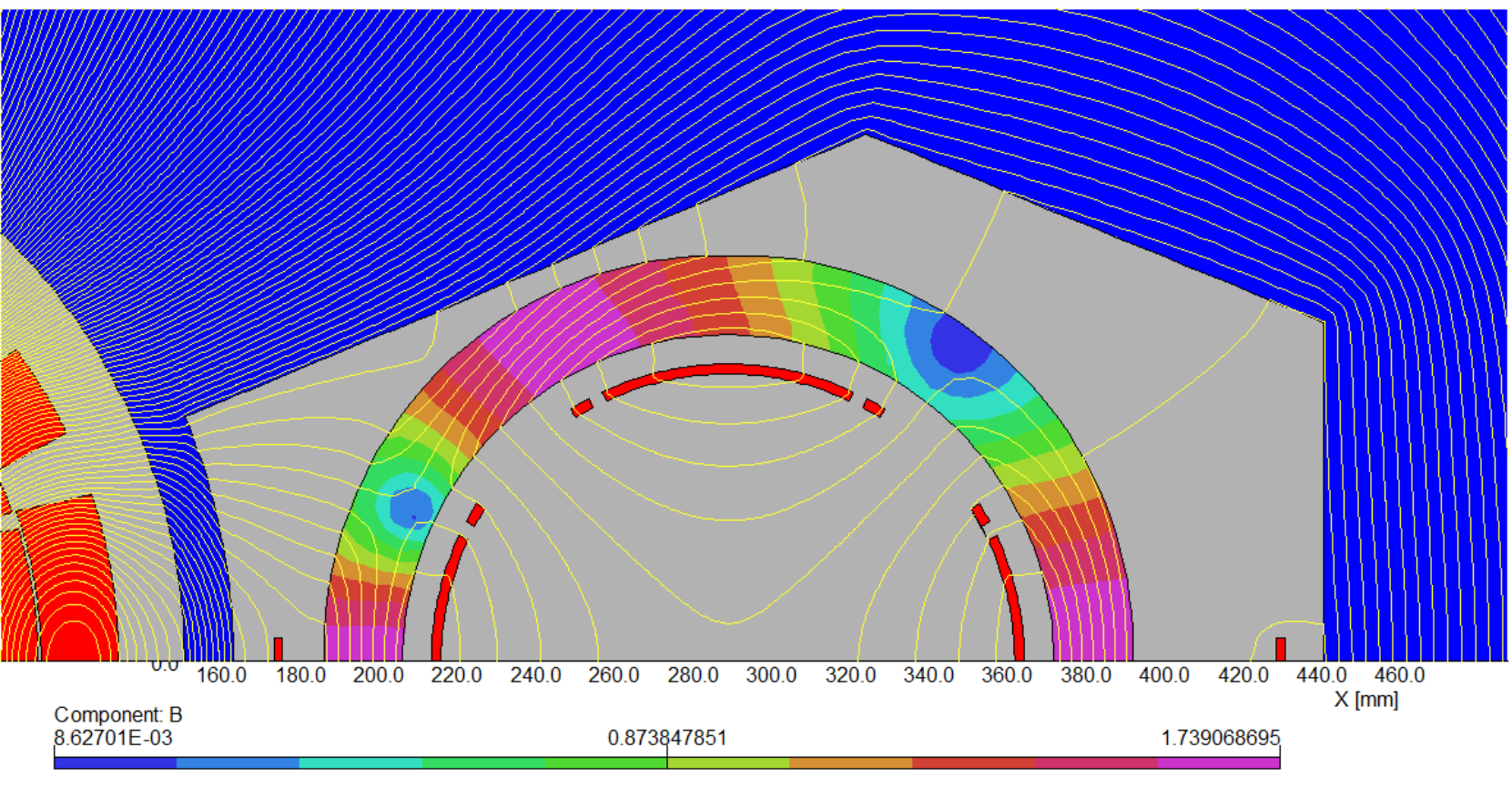
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Flux density	: T
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Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

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Vector potential	
Magnetic fields	
Static solution	
Case 2 of 2	
Scale factor: 2.4	
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46250 nodes	
96 regions	

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Q1BpF (Q1eF with opposite polarity AND stronger control coils)



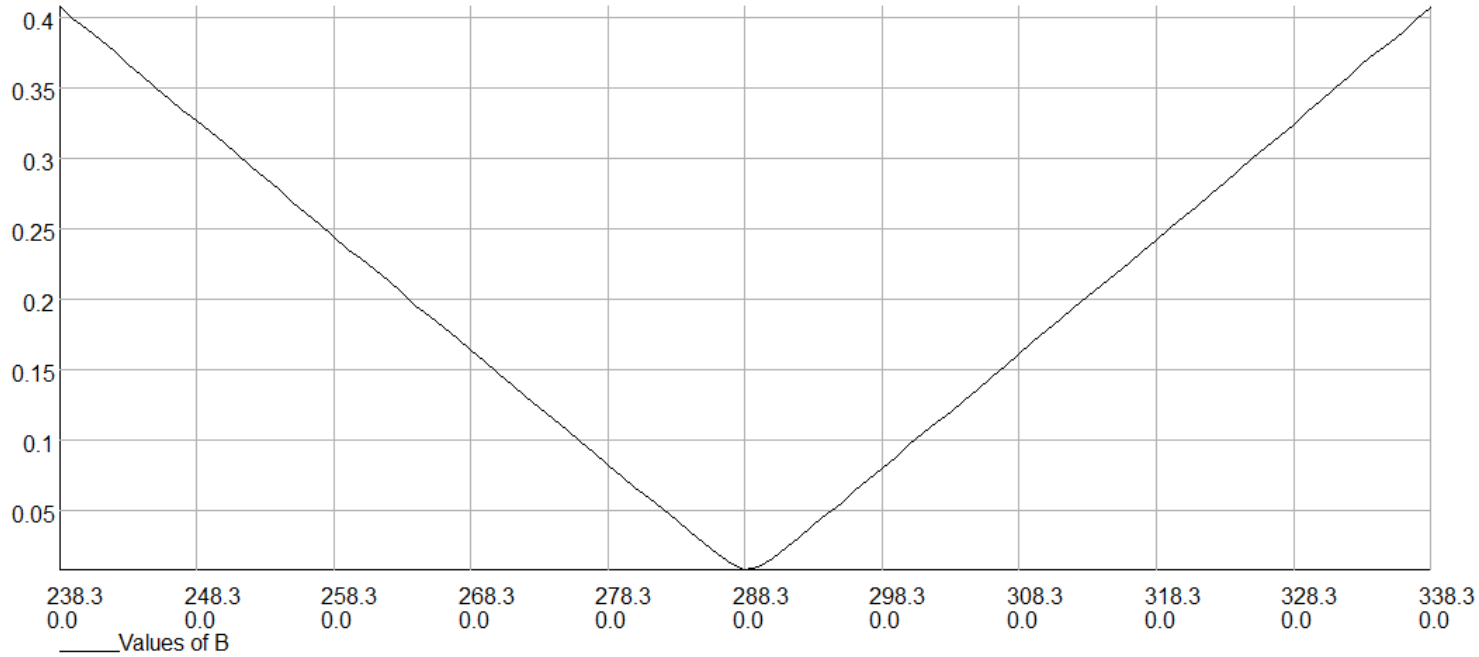
UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ⁻²
Power	: W
Force	: N
Energy	: J
Mass	: kg

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Linear elements	
XY symmetry	
Vector potential	
Magnetic fields	
Static solution	
Case 2 of 2	
Scale factor: 2.4	
91725 elements	
46218 nodes	
96 regions	



Looks better as the iron providing the shielding is less saturated (1.7 T rather than over 2 T)

Q1BpF (Q1eF with opposite polarity AND stronger control coils)



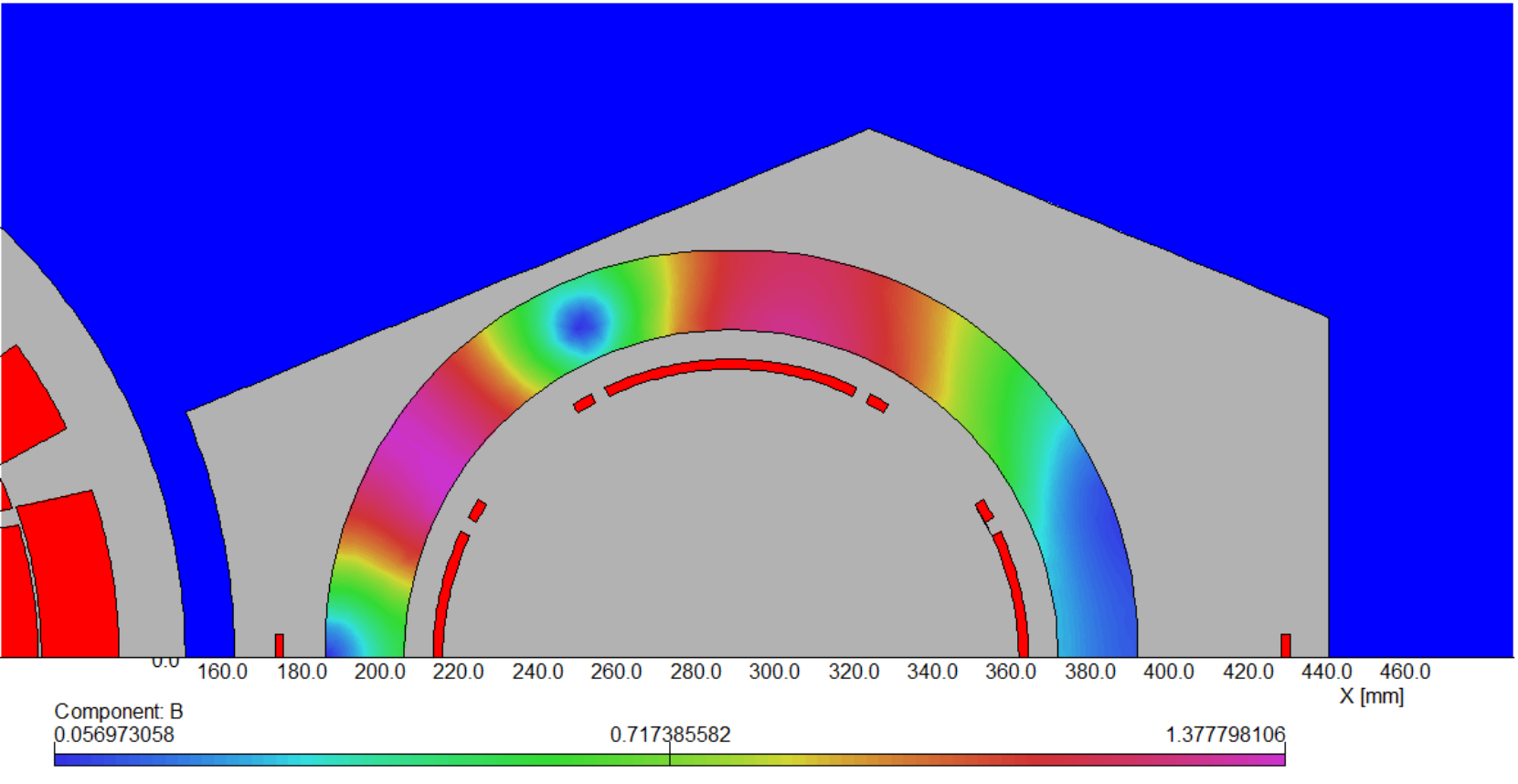
UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ³
Power	: W
Force	: N
Energy	: J
Mass	: kg

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 Linear elements
 XY symmetry
 Vector potential
 Magnetic fields
 Static solution
 Case 2 of 2
 Scale factor: 2.4
 91725 elements
 46218 nodes
 96 regions



Still looks good as gradient is symmetric around the center of Q1eF (x=288.3)

Q1BpF (Q1eF with good polarity AND stronger control coils)



UNITS	
Length	: mm
Flux density	: T
Field strength	: A m ⁻¹
Potential	: Wb m ⁻¹
Conductivity	: S m ⁻¹
Source density	: A mm ²
Power	: W
Force	: N
Energy	: J
Mass	: kg

MODEL DATA
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 Linear elements
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 Case 2 of 2
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 91725 elements
 46218 nodes
 96 regions

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Looks good as the iron providing the shielding is less saturated (1.3 T)