Q2PF
EIC IR SC Magnet design Status

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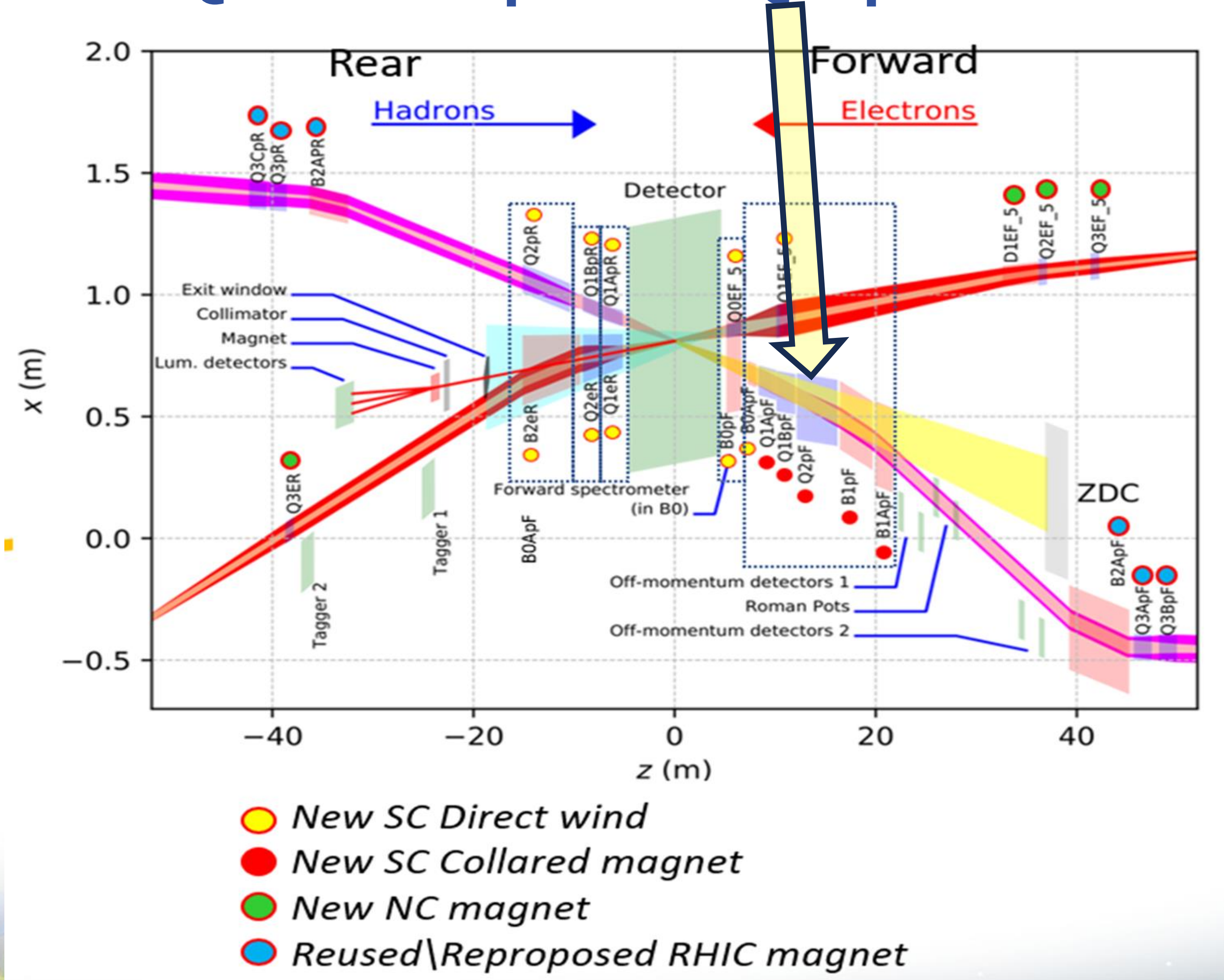
February 07, 2024

Electron-Ion Collider

EIC IR Quadrupole Q2pF



Requirements section

Requirements check list	Y/N/?
Are all the requirements needed to start the design process in place.	Y
Are the requirements understood.	Y
Has the L2(or deputy) reviewed the requirements and approved them.	?

Magnet Requirements

Magnet requirements		
The lattice version used to generate the requirements is	EIC-HSR-230421a Colliding	
The name of unique magnet is	Q2PF	
The number of magnets required are	1	
Additional notes	SC QUAD Q2PF	
The magnet design proposal is	New	**(N,REU,REW)**
The number of magnet functions shall be	1	
The field type shall be	Qu	(Di,Qu,Sx,Oc,De,Do,Sol,Ki,Hk,Vk)
The field direction shall be	na	(V,H,Z)
The field rotation shall be	No	(Norm, Skew)
The min coil inner rad shall be	113\-	m
The min gap shall be	na	m
The good field aperture drx required shall be	68.69	m
The good field aperture dry required shall be	17.69	m
The mag length shall be	<3.8	m
The slot length shall be	3.80	m
Field Reqs		
The dipole field B shall be	na	na
The grad field G shall be	39.74	T/m
The ramp rate shall be	na	T/s
The field stability shall be	TBD	T/s
Max multipole content		
The harmonic reference Radius and current shall be	Ir=TBD[A]\Rr=16[mm]	(mm,A)
The Field at the reference radius and current shall be	Bref=TBD	(T)
0th order of	na	(10^-4)
1st order of	-	(10^-4)
2nd order of	10000	(10^-4)
3rd order of	<1	(10^-4)
4th order of	<1	(10^-4)
5th order of	<1	(10^-4)
6th order of	<1	(10^-4)
7th order of	<1	(10^-4)
8th order of	<1	(10^-4)
9th order of	<1	(10^-4)
10th order of	<1	(10^-4)
11th order of	<1	(10^-4)
12th order of	<1	(10^-4)
13th order of	<1	(10^-4)
14th order of	<1	(10^-4)
15th order of	<1	(10^-4)
16th order of	<1	(10^-4)

Notes

Data through Jim Rochford from EIC SharePoint IR magnet folder

Max X talk multipole content		
The magnet shall be designed to limit Xtalk Requirements	N	(Y\N)
The xtalk shall be constrained as described ;	TBD	
The radial distance to X-talk location content shall be	TBD	mm
The Xtalk harmonic reference Radius and current shall be	TBD	(mm, A)
0th order of	TBD	T
1st order of	TBD	T
2nd order of	TBD	T
3rd order of	TBD	T
4th order of	TBD	T
5th order of	TBD	T
6th order of	TBD	T
7th order of	TBD	T
8th order of	TBD	T
9th order of	TBD	T
10th order of	TBD	T
11th order of	TBD	T
12th order of	TBD	T
13th order of	TBD	T
14th order of	TBD	T
15th order of	TBD	T
16th order of	TBD	T
Fringe field constraints		
The magnet design shall constrain the ext. fringe field	TBD	(Y\N)
The magnet shall be designed to meet the following fringe field requirments	TBD	

Preliminary EM design

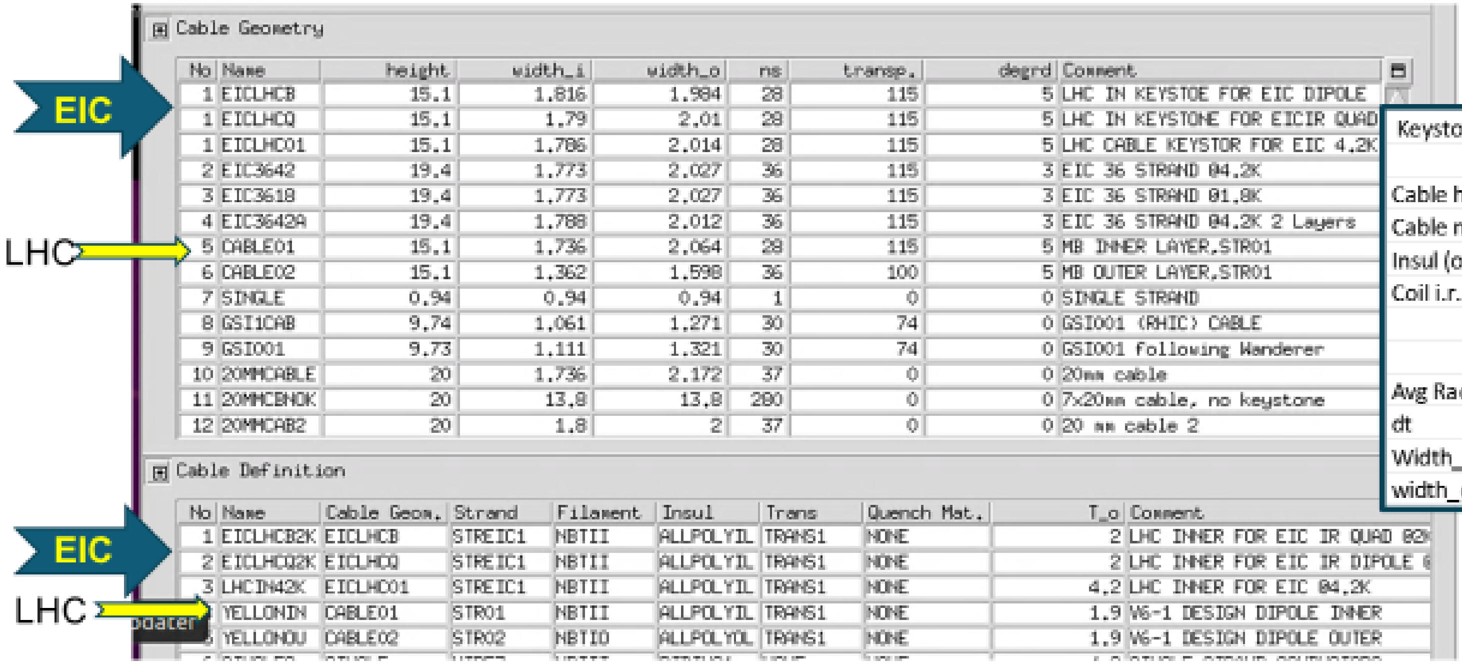
Comments/Questions:

1. Need to define and understand the difference between the preliminary design and the detailed design (next section)?
2. What is included in the preliminary and what in the detailed?
3. Should a preliminary design morph into a detailed design?

Preliminary EM design Section

Conceptual EM model check list	Y/N/?
Has an optimized 2D cross section been generated (collared mags only)	Y
Has the final 2d section been cross checked in a separate code (Roxie\VF\COMSOL, etc.)	Y(a)
Are the 2D model conductor properties different from the proposed production conductor.	N
Are the Iron properties assumed consistent with the proposed production Iron?	?
Is the conductor temperature assumed consistent with the proposed temperature needed.	Y
Are the Bore field and Harmonics consistent with requirements at all operating currents.	Y (2d)
Are the cross-talk requirements met for all operating currents	Y (b)
Are all the operating parameters (Bore field, Peak field , Stored energy, Iop, Jop, Operating margin, Inductance, etc) such that the magnet can reliably meet the requirements	Y
Has the magnet design information been recorded in the magnet spec in the requirements folder	N(c)
Are there issues with the analysis that you are concerned with	?
Y(a): Yes, but not the latest	
Y (b): Yes, but not fully checked/optimized for the latest 2-d and 3-d	
N (c): Latest design to be uploaded after the consistency check	

LHC Style Cable used in Quad & Dipole (based on full keystone for Q2pF and B1ApF)



Cable Geometry

No	Name	height	width_i	width_o	ns	transp.	degrd	Comment
1	EICLHCB	15.1	1.816	1.984	28	115	5	LHC IN KEYSTOE FOR EIC DIPOLE
1	EICLHCQ	15.1	1.79	2.01	28	115	5	LHC IN KEYSTONE FOR EICIR QUAD
1	EICLHC01	15.1	1.786	2.014	28	115	5	LHC CABLE KEYSTOR FOR EIC 4.2K
2	EIC3642	19.4	1.773	2.027	36	115	3	EIC 36 STRAND 04.2K
3	EIC3618	19.4	1.773	2.027	36	115	3	EIC 36 STRAND 01.8K
4	EIC3642A	19.4	1.788	2.012	36	115	3	EIC 36 STRAND 04.2K 2 Layers
5	CABLE01	15.1	1.736	2.064	28	115	5	MB INNER LAYER,STR01
6	CABLE02	15.1	1.362	1.598	36	100	5	MB OUTER LAYER,STR01
7	SINGLE	0.94	0.94	0.94	1	0	0	SINGLE STRAND
8	GSI1CAB	9.74	1.061	1.271	30	74	0	GSI001 (RHIC) CABLE
9	GSI001	9.73	1.111	1.321	30	74	0	GSI001 following Wanderer
10	20MMCABLE	20	1.736	2.172	37	0	0	20mm cable
11	20MMCBNOK	20	13.8	13.8	280	0	0	7x20mm cable, no keystone
12	20MMCAB2	20	1.8	2	37	0	0	20 mm cable 2

Cable Definition

No	Name	Cable Geom.	Strand	Filament	Insul	Trans	Quench Mat.	T_o	Comment
1	EICLHCB2K	EICLHCB	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	2	LHC INNER FOR EIC IR QUAD 02
2	EICLHCQ2K	EICLHCQ	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	2	LHC INNER FOR EIC IR DIPOLE
3	LHCIN42K	EICLHC01	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	4.2	LHC INNER FOR EIC 04.2K
[illegible]	YELLOWIN	CABLE01	STR01	NBTII	ALLPOLYIL	TRANS1	NONE	1.9	V6-1 DESIGN DIPOLE INNER
5	YELLOWOU	CABLE02	STR02	NBTIO	ALLPOLYOL	TRANS1	NONE	1.9	V6-1 DESIGN DIPOLE OUTER

Keystone angle for cable width << coil readius

	Q2pF	B1ApF
Cable height	15.1	15.1
Cable mid-thickness	1.9	1.9
Insul (one side)	0.12	0.12
Coil i.r.	140	185
Avg Rad	147.55	192.55
dt	0.2190	0.1678
Width_i	1.790	1.816
width_o	2.010	1.984

Note: Keystones are reduced for EIC

- **Q2pF cross-section designs with both cables examined.**
- **EICLHCQ2K cable has perfect keystone for Q2pF and is chosen here.**
- **Both cables are similar to the one used in LHC dipole inner layer, except for the keystone (choice made early on for easier availability)**

Q2pF Major EM Design Parameters (preliminary)

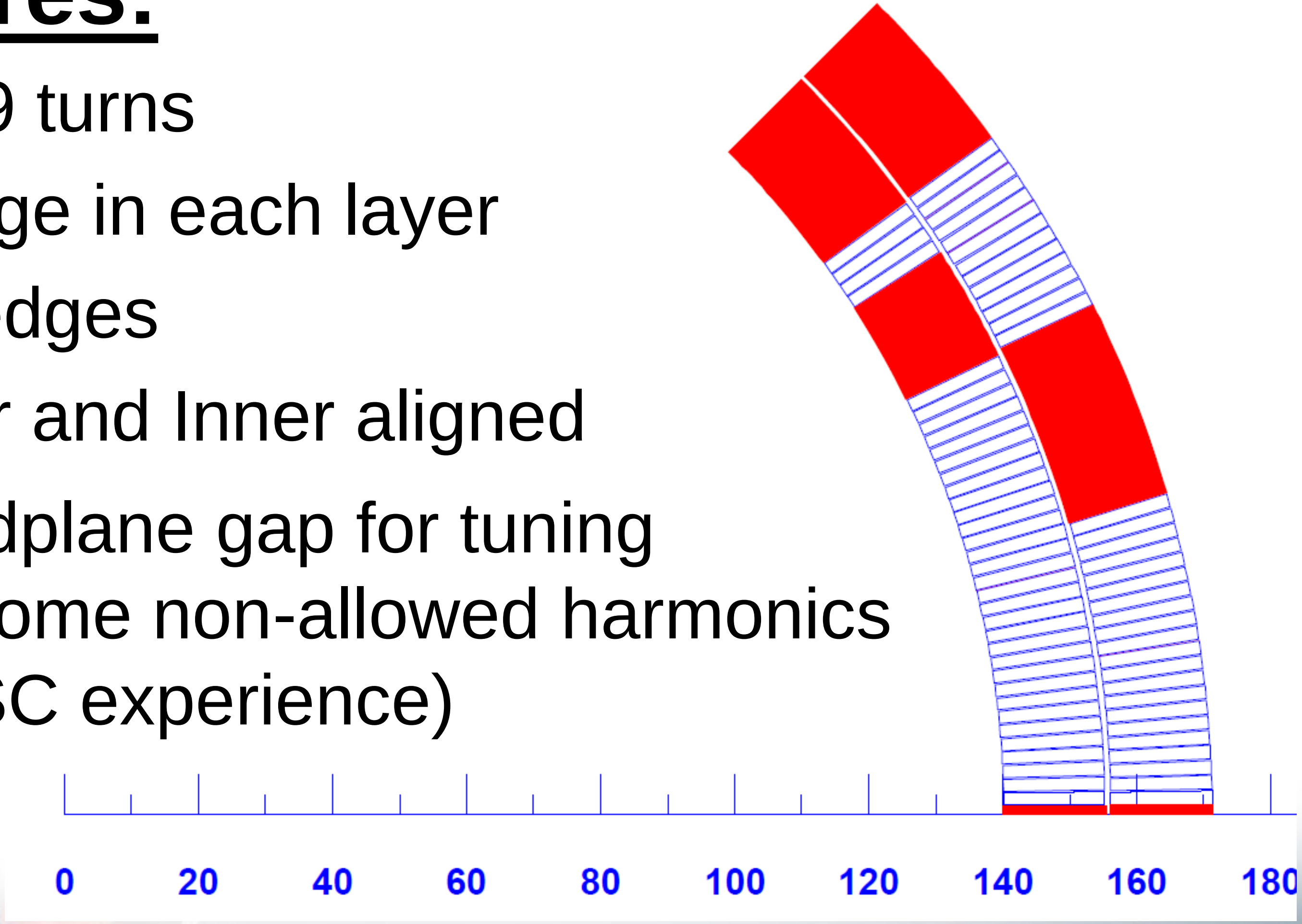
Magnet Name	**Q2pF (old)**	**Q2pF(12/20/2023)**	**for EIC IR**
(Original table created by Ramesh Gupta on 11/9/2022)			
Magnet type	Quadrupole		
Coil inner diameter	280		mm
Coil outer diameter	342.8		mm
Number of layers	Two		
Integrated gradient @design	133.55		T
Design gradient (@center of magnet)	38.22		T/m
Operating current @ design gradient	8500	8570	A
Magnetic length	3.494		meter
Coil length (last turn to last turn)	3.64		meter
Yoke length	3.72		meter
Total number of turns per coil	70	69	per octant
Number of turns in inner layer	34	35	per octant
Number of turns in outer layer	36	34	per octant
Cable required (whole magnet)	2		km

Superconductor	NbTi	
Cu/Sc Ratio (nominal)	1.6	
strand diameter (mm)	1.065	
Number of strands in cable	28	
Cable width, bare (mm)	15.1	mm
Cable mid-thickness, bare (mm)	1.9	mm
Cable insulation radial	0.15	mm
Cable insulation azimuthal	0.12	mm
Cable width insulated	15.4	mm
Cable mid-thickness, insulated	2.14	mm
Operating temperature (nominal)	2	K
Stored energy @design gradient	2.7	MJ
Inductance	75	mH
Quech current	13700	A
Quench gradient (@center, @13.7kA)	58.3	T/m
Peak field @design	6.4	T

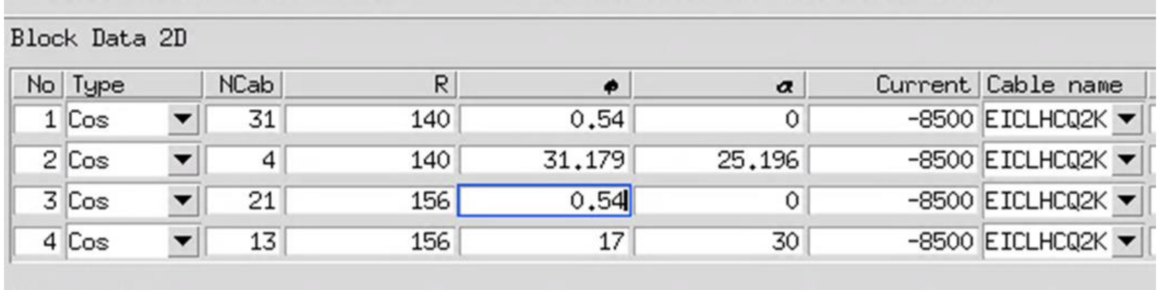
Q2pF Coil Cross-section

Main Features:

- Two layers, 69 turns
- Only one wedge in each layer
- Symmetric wedges
- Poles of Outer and Inner aligned
- Significant midplane gap for tuning allowed and some non-allowed harmonics (RHIC and SSC experience)

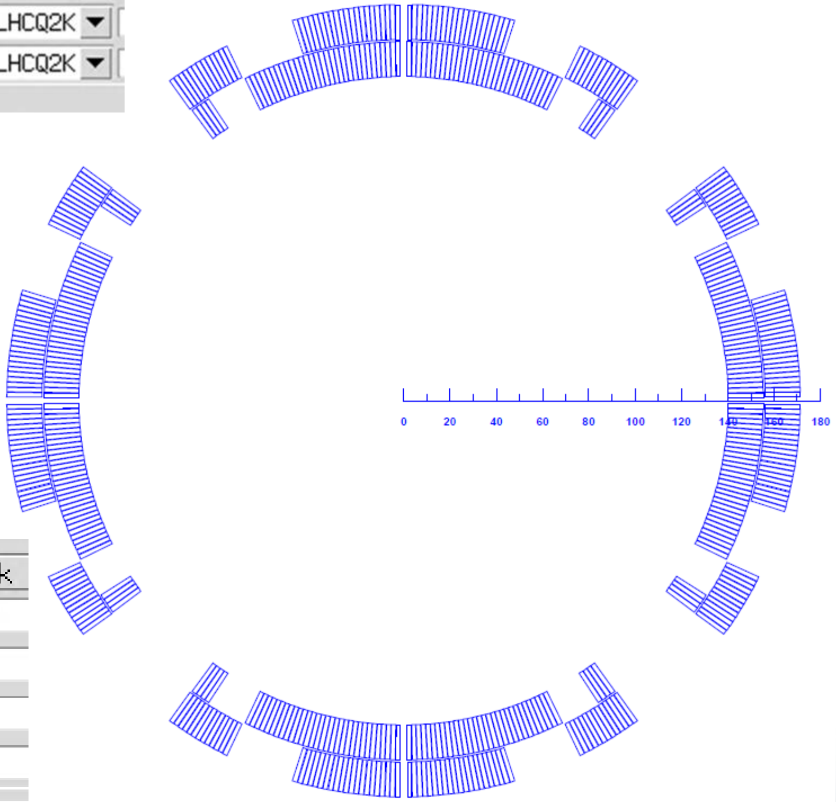


Coil Cross-section Details (ROXIE input)

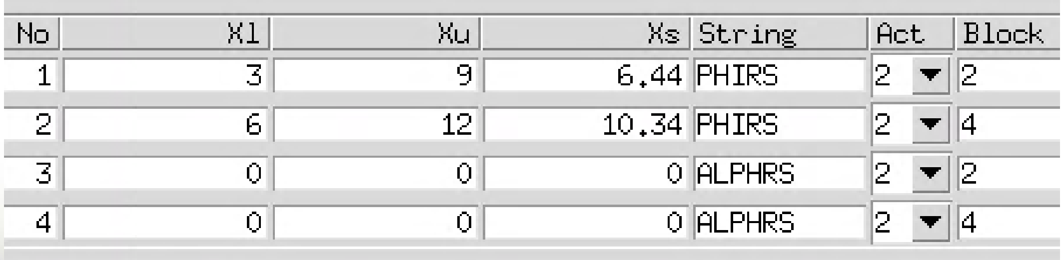


Block Data 2D

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

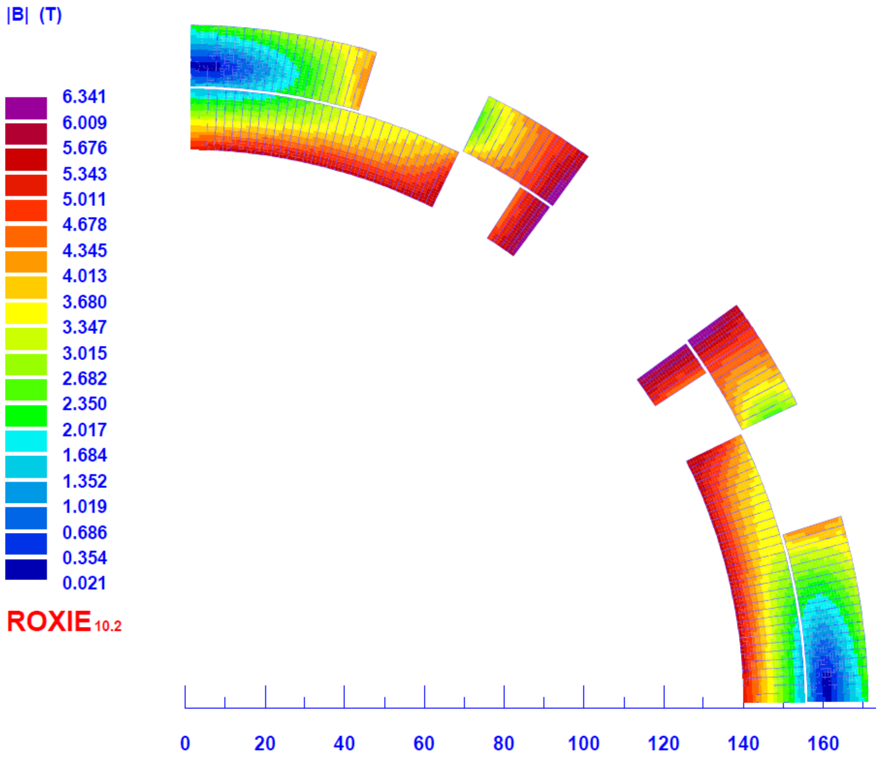


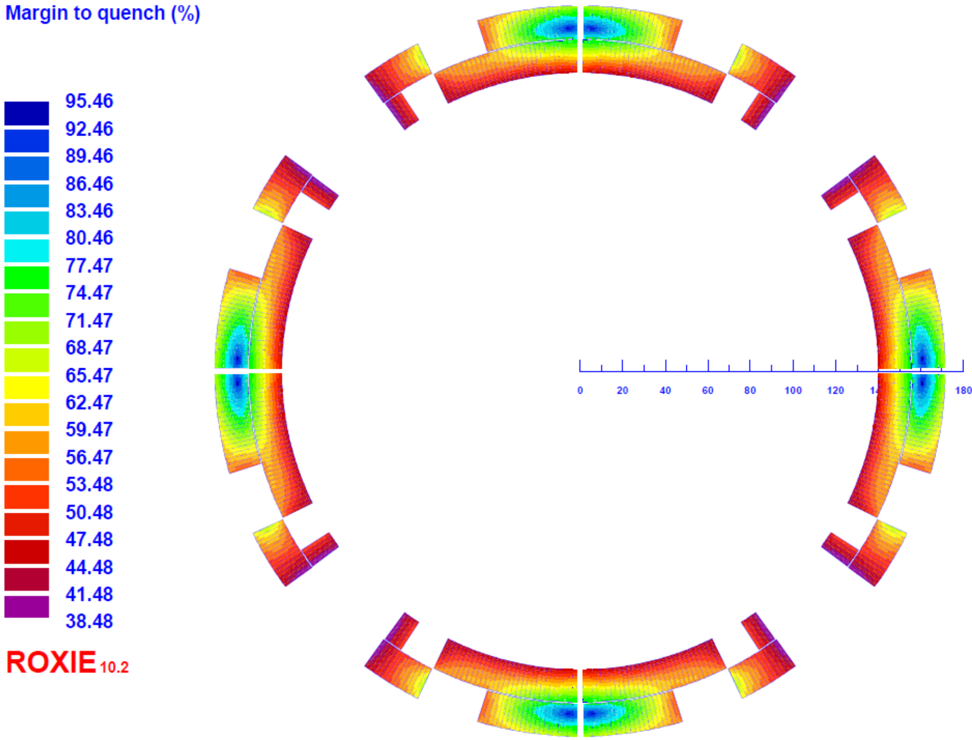
- **35 turns in inner and 34 in outer**
- **Symmetric wedges**



No	Xl	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

Peak Field and Margin





Field at coil midplane:

38.22 X 0.14 = 5.35 T

Peak field Enhancement: 18%

(max field over the midplane field)

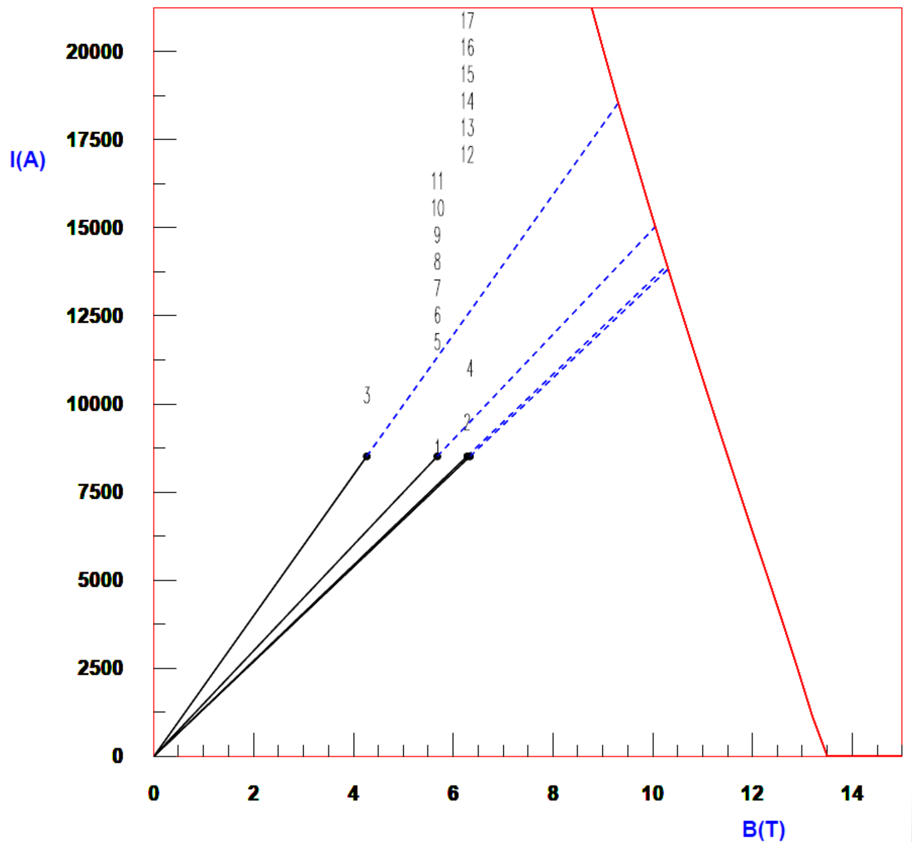
Margin on Load-line: 38%

Conventional definition: 56%

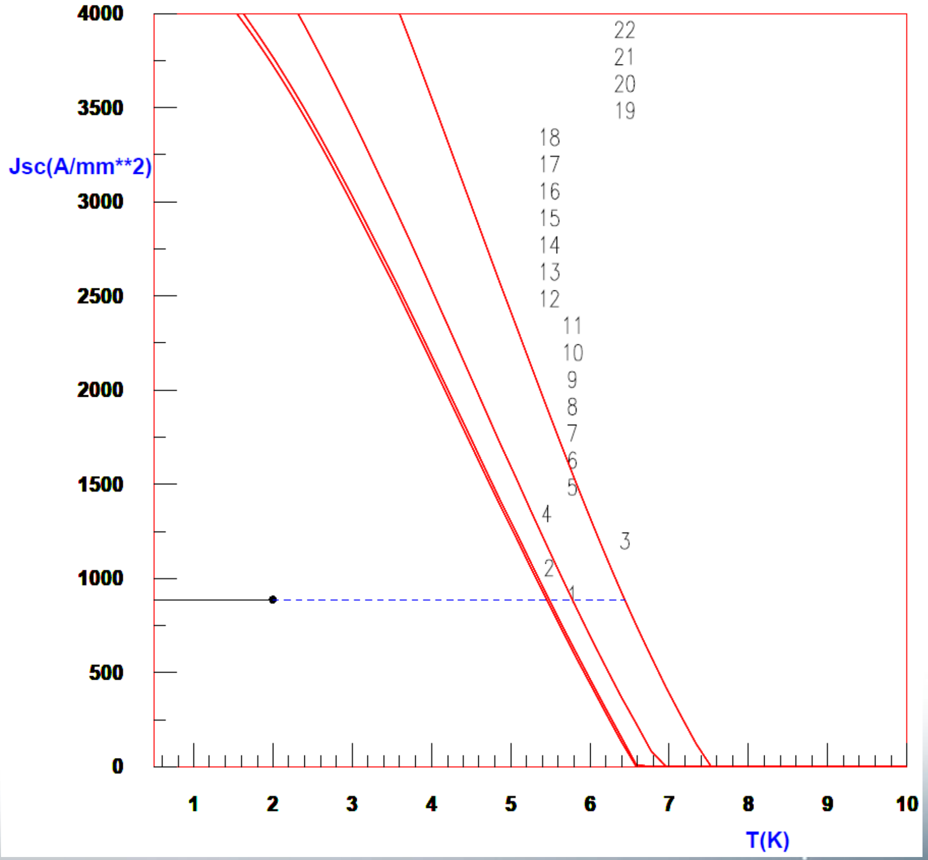
(short sample over design)

Quench Margins

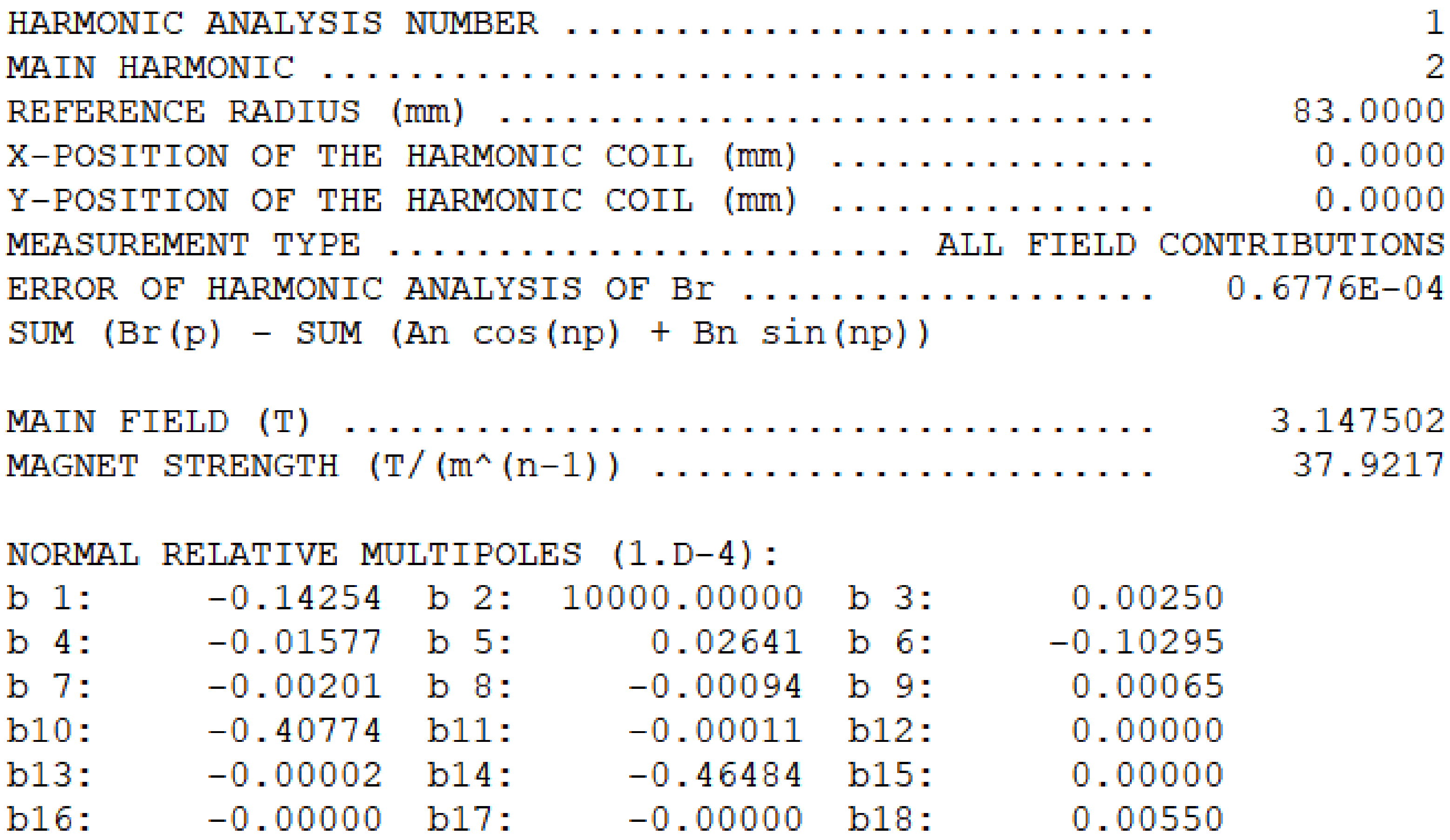
Field margins in various blocks



Temperature margins in various blocks



Field Harmonics at the Design Field



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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))

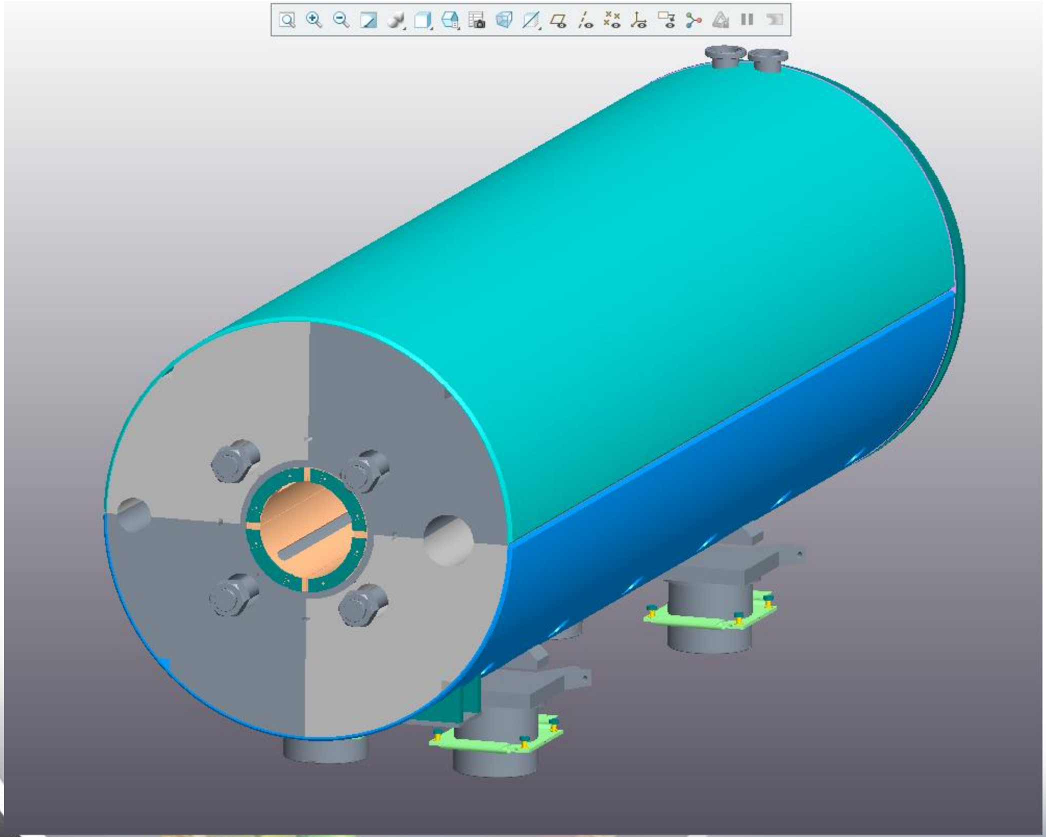
MAIN FIELD (T) ........................................   3.147502
MAGNET STRENGTH (T/(m^(n-1)) ..........................    37.9217

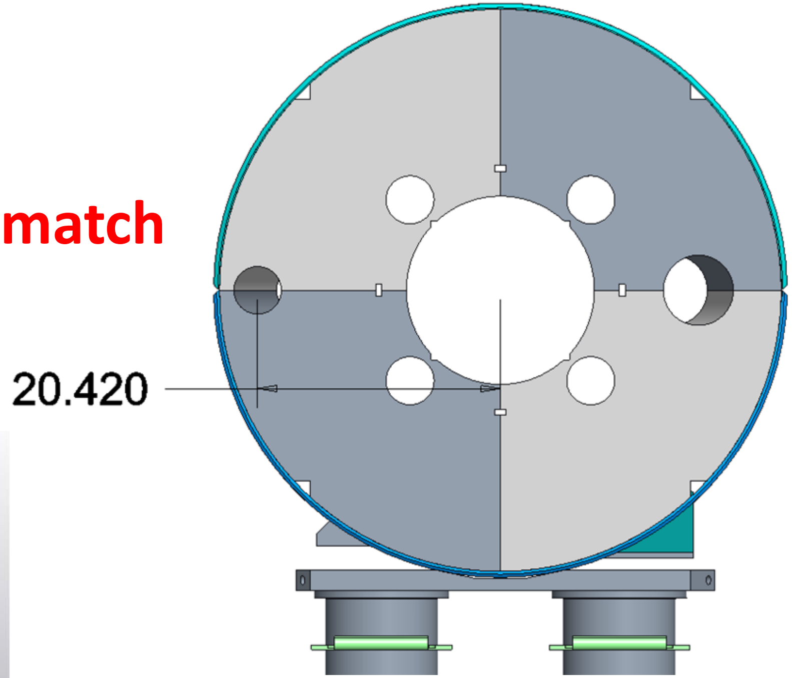
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:      -0.14254  b 2:  10000.00000  b 3:      0.00250
b 4:      -0.01577  b 5:      0.02641  b 6:     -0.10295
b 7:      -0.00201  b 8:     -0.00094  b 9:      0.00065
b10:      -0.40774  b11:     -0.00011  b12:      0.00000
b13:      -0.00002  b14:     -0.46484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

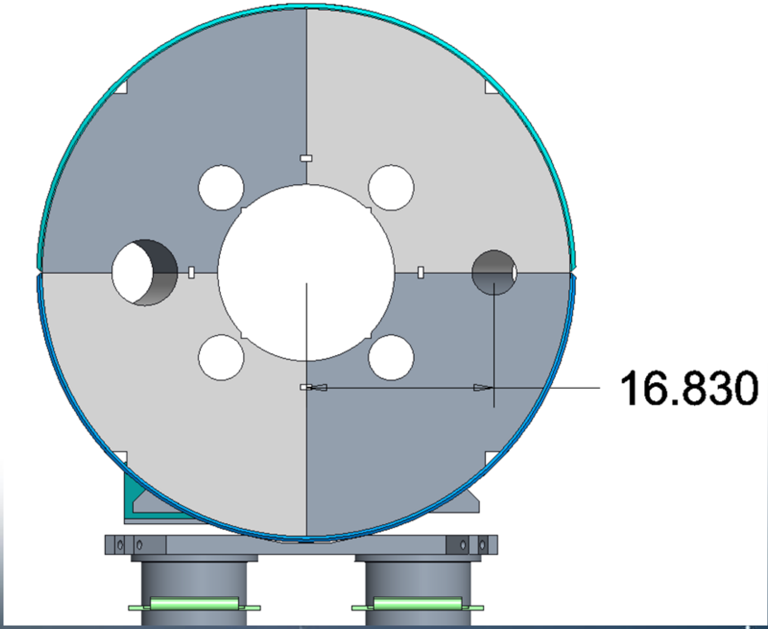
All harmonics < 1 unit

EM Yoke Design

Caution: Engineering drawings do not match to Mechanical and Magnetic designs



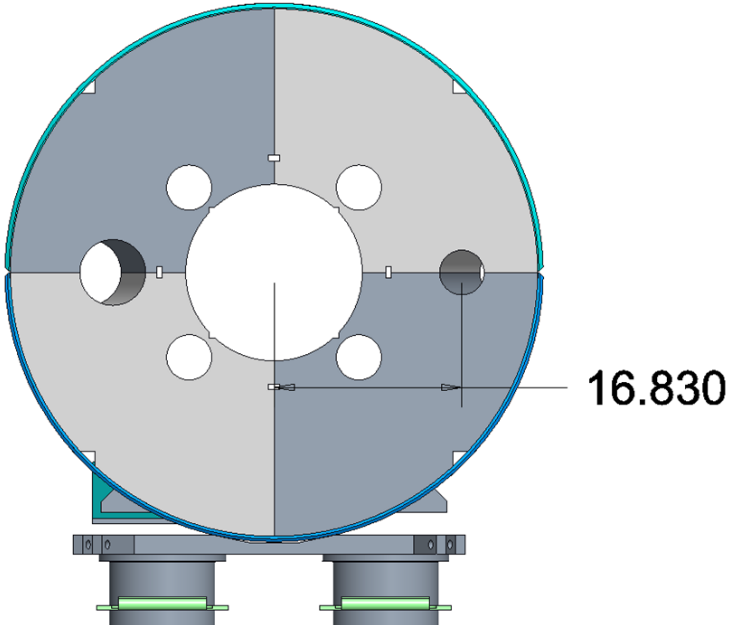




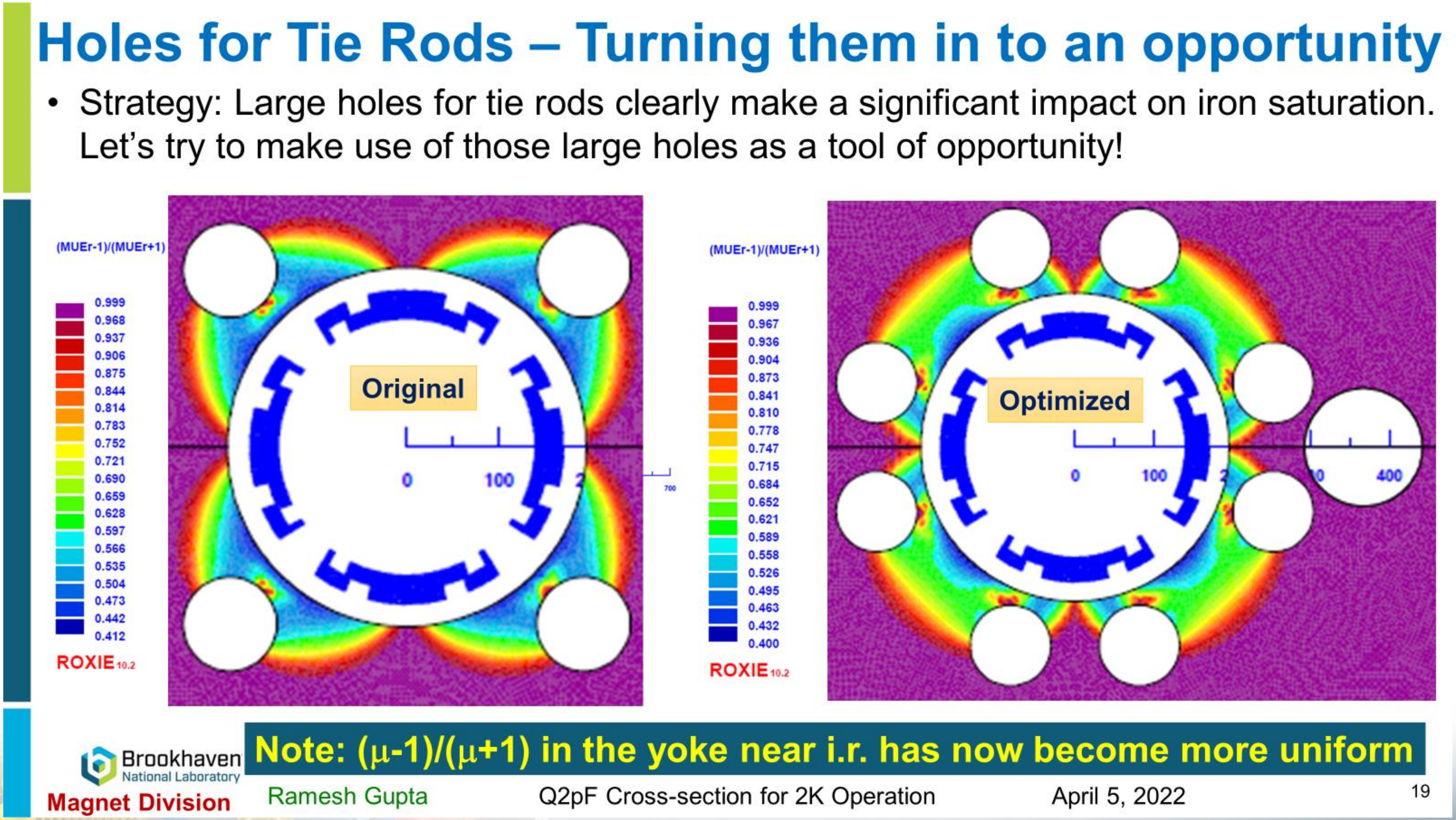
EM Yoke Design

Challenges in yoke magnetic design

- Non-linear yoke saturation.
    - Holes have been efficiently used in RHIC and follow-on magnetic designs to control saturation. However, in EIC IR magnets large holes or cutout (B1pF) are required too close to the yoke inner surface, which could create major problems.
- Field in the hole for the passage of electron beam



EM Yoke Optimization (1)



Holes for Tie Rods – Turning them in to an opportunity

- Strategy: Large holes for tie rods clearly make a significant impact on iron saturation. Let's try to make use of those large holes as a tool of opportunity!

Note: (μ-1)/(μ+1) in the yoke near i.r. has now become more uniform

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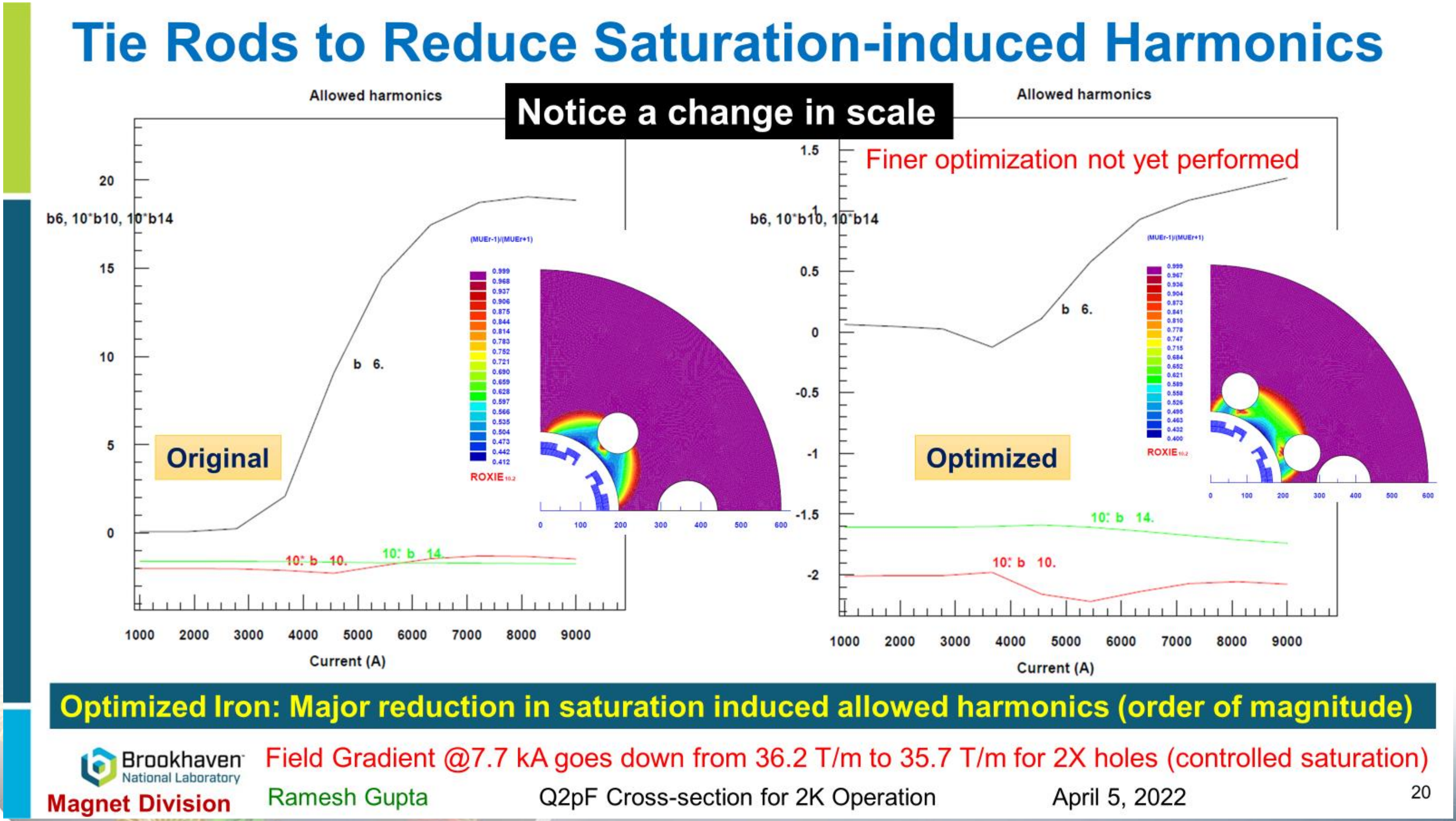
EM Yoke Optimization (2)



Tie Rods to Reduce Saturation-induced Harmonics

Notice a change in scale

Finer optimization not yet performed

Optimized Iron: Major reduction in saturation induced allowed harmonics (order of magnitude)

Field Gradient @7.7 kA goes down from 36.2 T/m to 35.7 T/m for 2X holes (controlled saturation)

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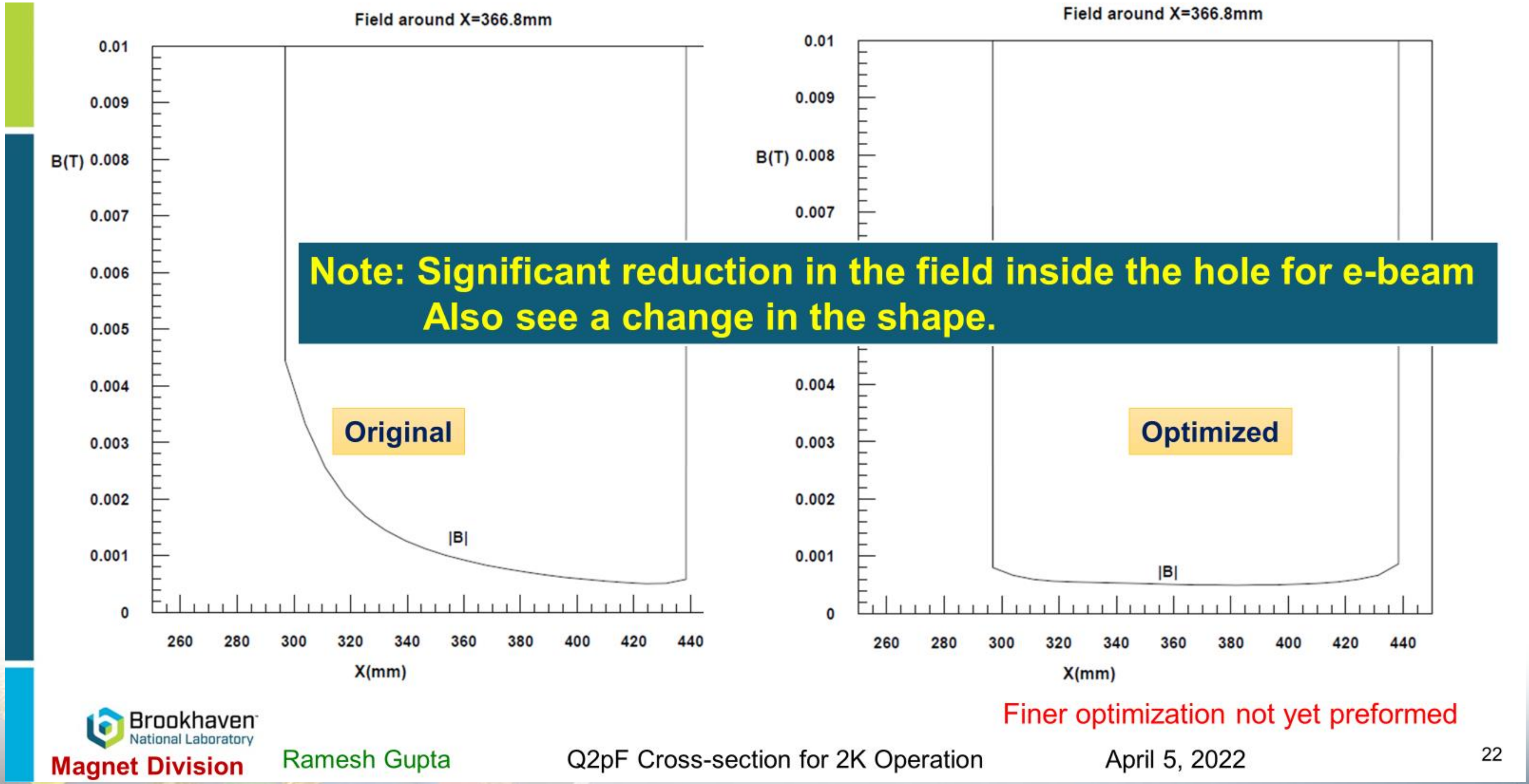
EM Yoke Optimization (3)

Optimized tie rod holes can divert field away from the electron beam hole



Note: Significant reduction in the field inside the hole for e-beam
Also see a change in the shape.

Original

Optimized

Finer optimization not yet preformed

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Q2pF Cross-section for 2K Operation

April 5, 2022

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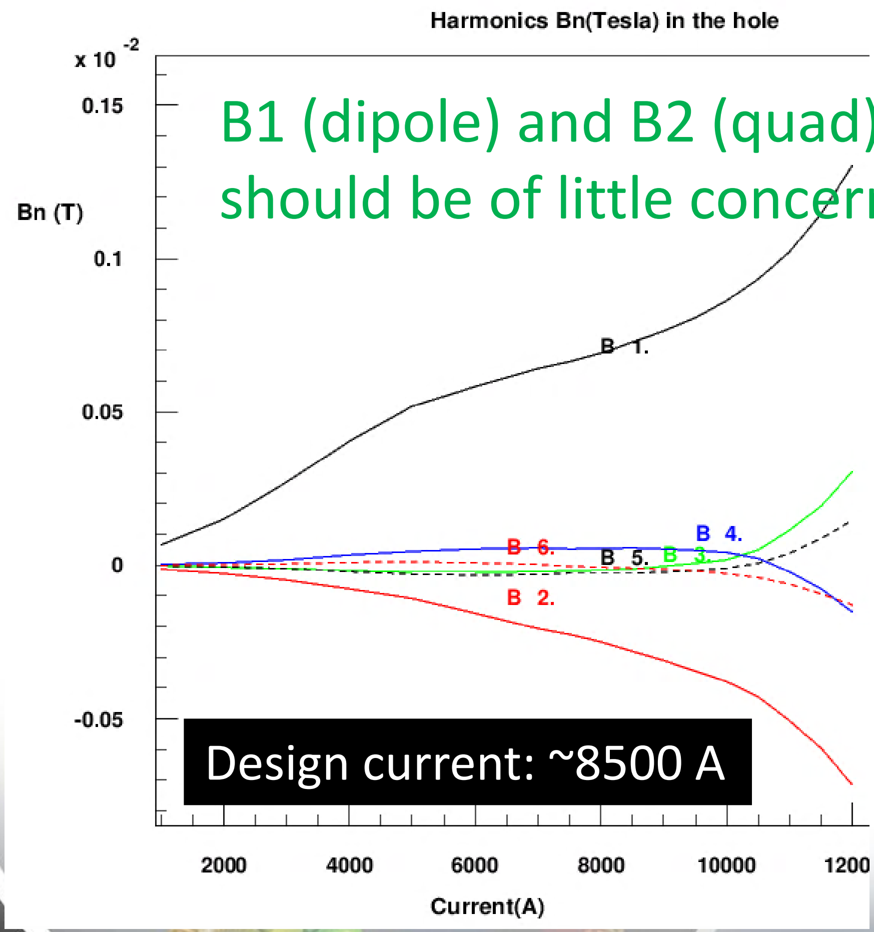
Evaluation of the impact of the fringe field on the electron beam from the nearby hadron magnets

- Current approach is to make the fringe field below the earth’s magnet field.
- Shouldn’t this be evaluated as the harmonic errors?
- Otherwise, we may be putting unnecessarily stringent requirements on the magnets and infrastructure cost.
- Suggestion: Study the beam dynamics impact of the computed error harmonics on the electron beam from the excitation of the nearby hadron magnet.

Cross-talk in the current design of Q2pF

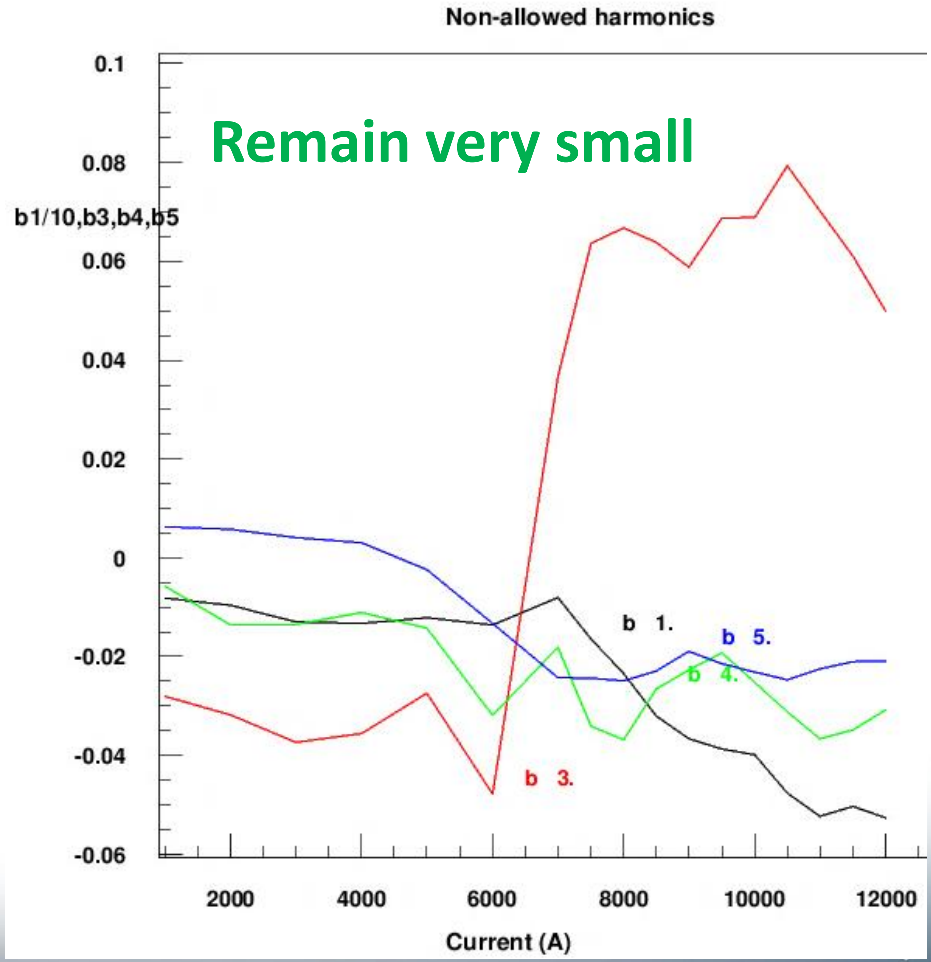
X-talk for e-beam
(harmonics are in Tesla.unit, not normalized)



B1 (dipole) and B2 (quad) should be of little concern

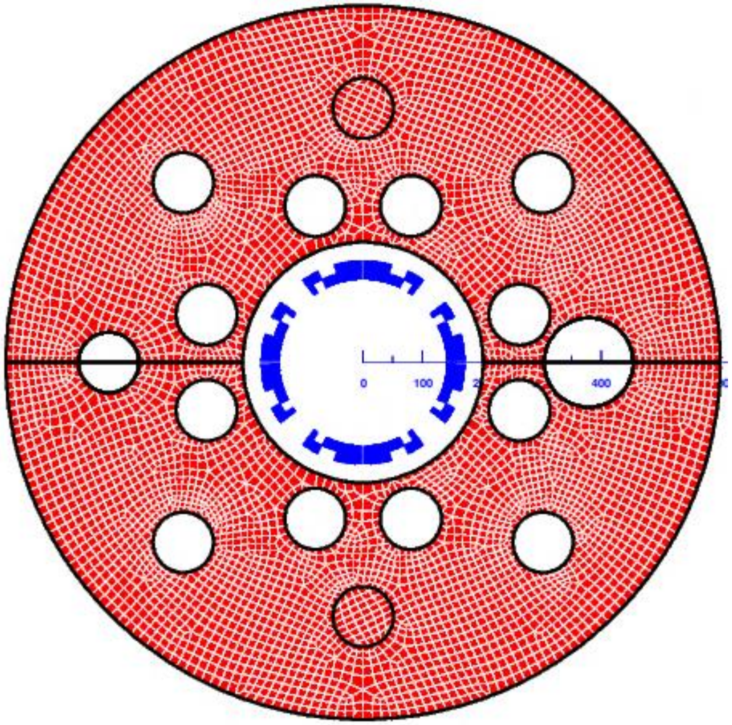
Design current: ~8500 A

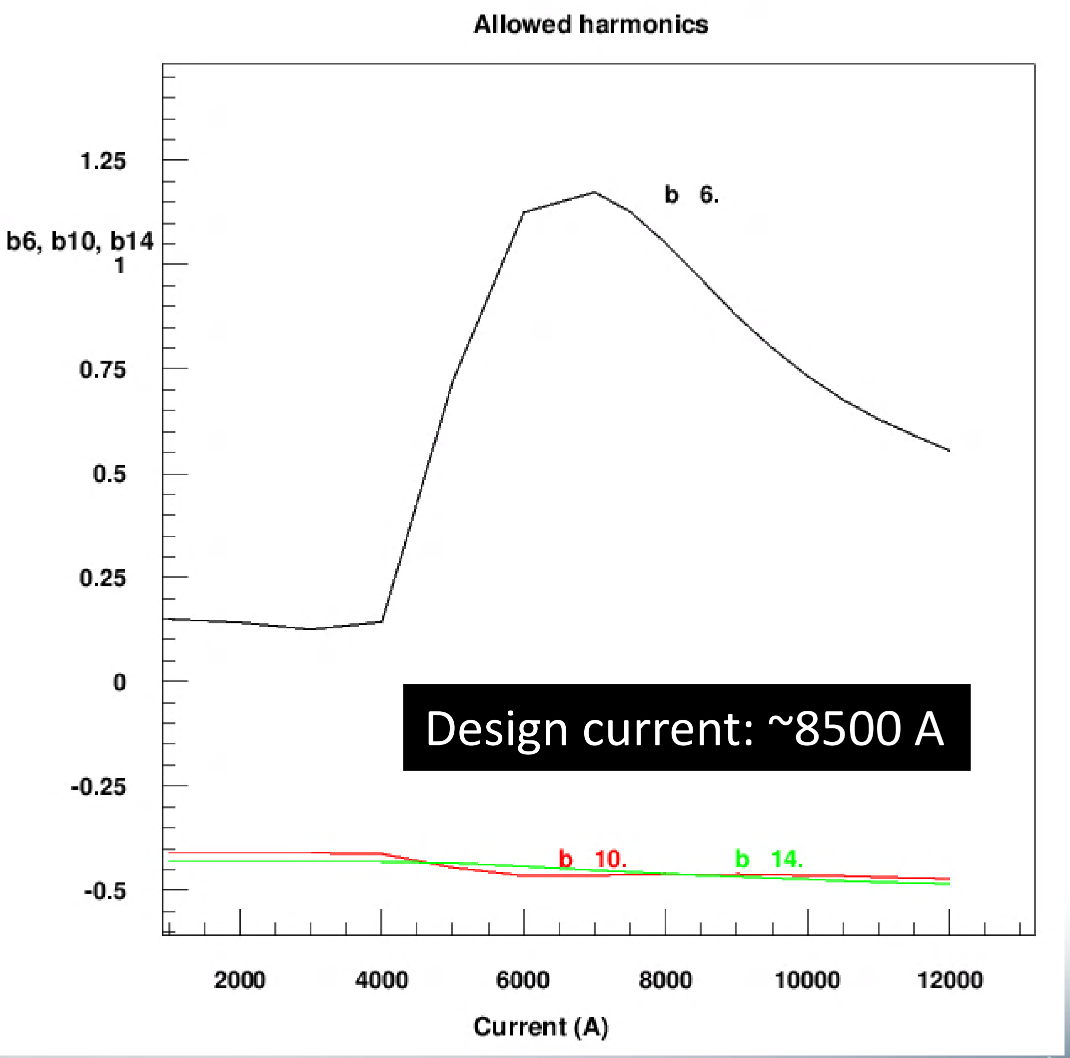
X-talk for hadron beam
(harmonics normalized to quad field)



Remain very small

Allowed harmonics in the current design

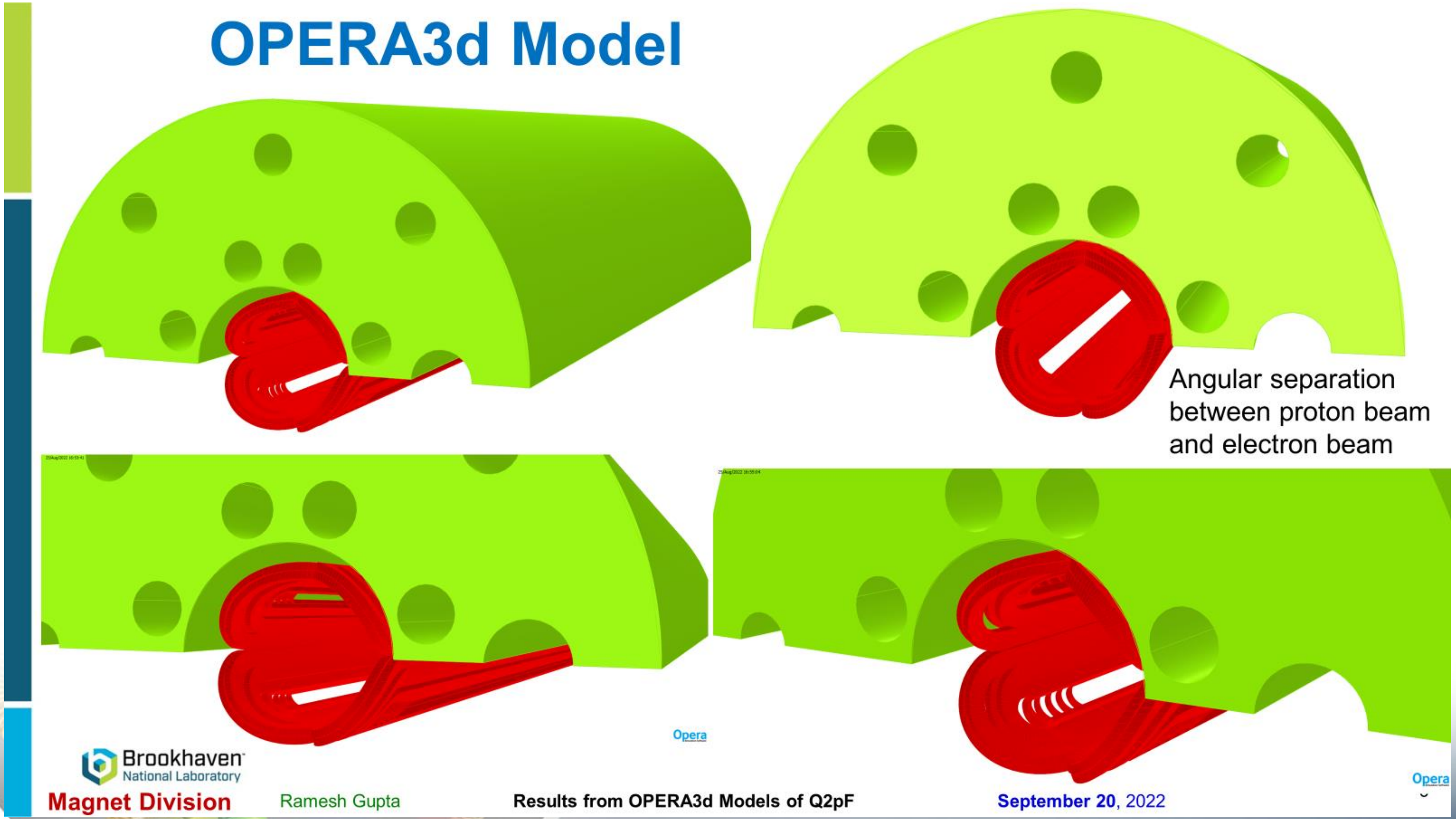




Design current: ~8500 A

- b6 has gone slightly above 1 unit, perhaps due to some update in the yoke X-section.
- Will be brought down to less than 1 unit in the next iteration

EM 3-d yoke (earlier coil ends but for yoke it shouldn't matter much)



OPERA3d Model

Angular separation between proton beam and electron beam

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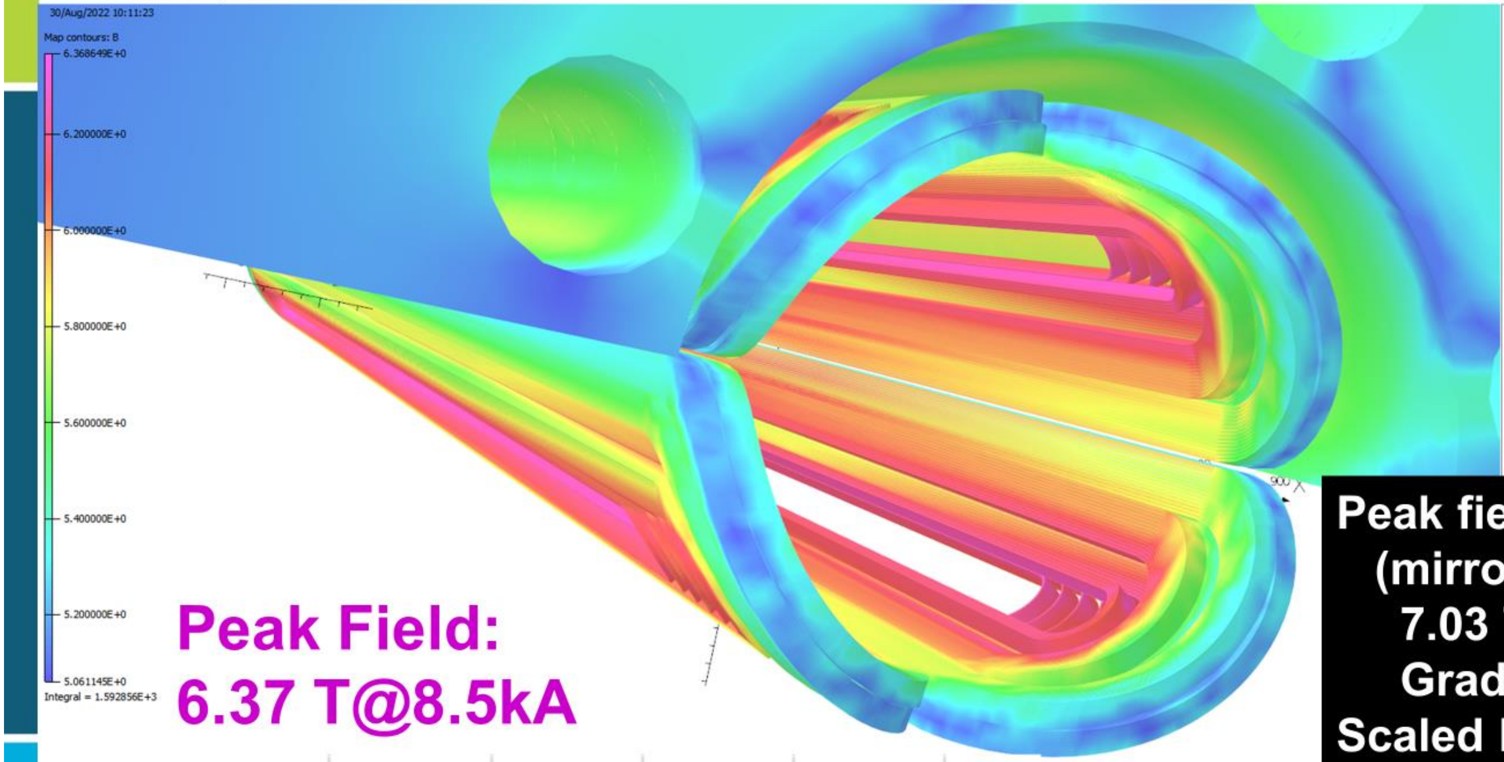
Magnet Division Ramesh Gupta **Results from OPERA3d Models of Q2pF** **September 20**, 2022

Calculation of Peak Field with OPERA3d (non-linear iron)

Integration method for the coil field to assure a reasonable accuracy



UNITS

Length	mm
Magn Flux Density	T
Magnetic Field	A/m
Magn Scalar Pot	A
Current Density	A/mm^2
Power	W
Force	N

MODEL DATA

q2pF-25aug2022-e.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 1 of 1
1395612 elements
992728 nodes
23520 conductors
Fields by integration
Activated in global coordinates
Reflection in ZX plane (Z+X fields=0)

Field Point Local Coordinates

Local = Global

FIELD EVALUATIONS

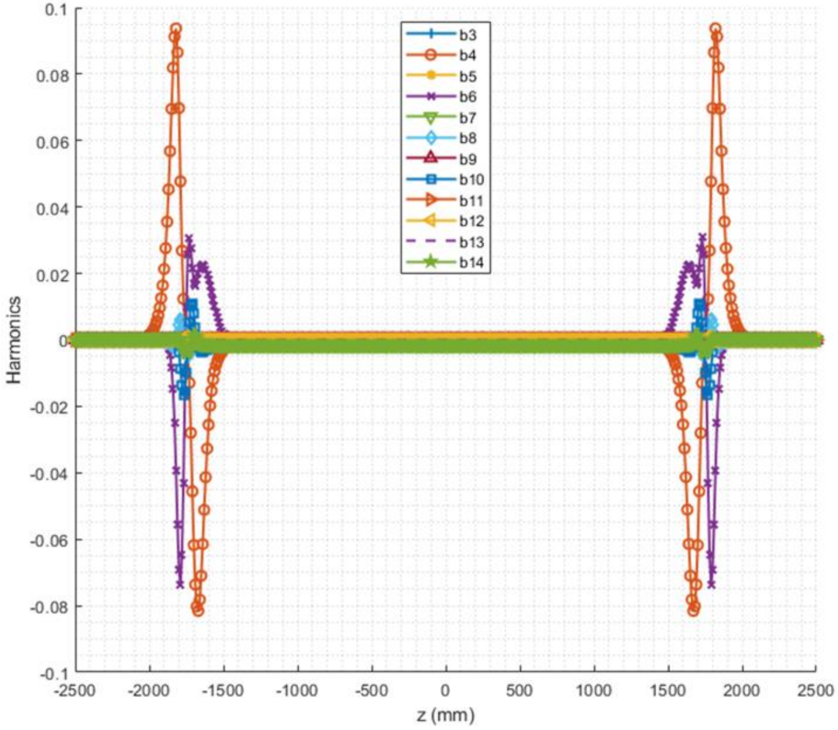
Line	LINE (nodal+inte)	101	Cartesian
	x=100.0	y=0.0	z=-2000.0 to 2000.0
Circle	CIRCLE (nodal+inte)	201	Cylindrical
	r=140.0	θ=0.0 to 360.0	z=0.0
Cartesian	CARTESIAN (nodal +inte)	100x100	Cartesian
	x=-200.0 to 200.0	y=-200.0 to 200.0	z=0.0
Polar	POLAR (nodal+inte)	100x25	Cylindrical

Peak Field:
6.37 T@8.5kA

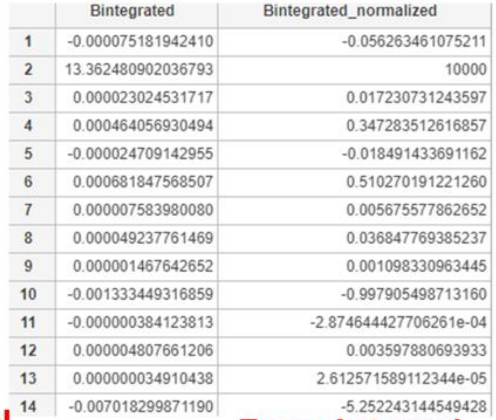
Peak field from ROXIE (mirror iron):
7.03 T @8.5 kA
Gradient: 41.8 T/m
Scaled Peak field:
6.42 T for 38.2 T/m

Gradient @ center	38.218	T/m

Field Harmonics Along the Axis from OPERA3d at 8.5 kA (R=100 mm)



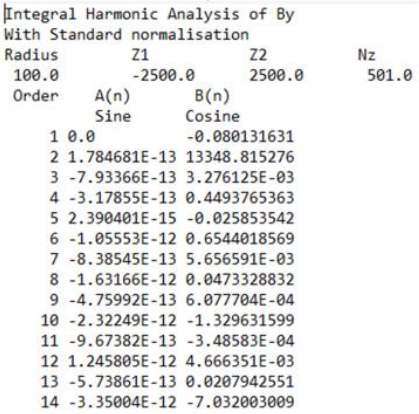
Tesla.Meter



	Bintegrated	Bintegrated_normalized
1	-0.000075181942410	-0.056263461075211
2	13.362480902036793	10000
3	0.000023024531717	0.017230731243597
4	0.000464056930494	0.347283512616857
5	-0.000024709142955	-0.018491433691162
6	0.000681847568507	0.510270191221260
7	0.000007583980080	0.005675577862652
8	0.000049237761469	0.036847769385237
9	0.000001467642652	0.001098330963445
10	-0.001333449316859	-0.997905498713160
11	-0.000000384123813	-2.874644427706261e-04
12	0.000004807661206	0.003597880693933
13	0.000000034910438	2.612571589112344e-05
14	-0.007018299871190	-5.252243144549428

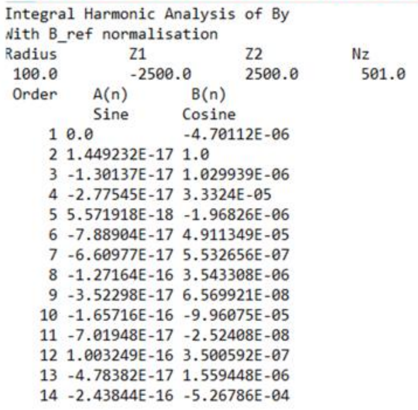
Prime Unit

From Integral in Tesla.mm



```
Integral Harmonic Analysis of By
With Standard normalisation
Radius        Z1           Z2          Nz
 100.0        -2500.0      2500.0       501.0
 Order    A(n)         B(n)
          Sine        Cosine
      1 0.0            -0.080131631
      2 1.784681E-13 13348.815276
      3 -7.93366E-13 3.276125E-03
      4 -3.17855E-13 0.4493765363
      5 2.390401E-15 -0.025853542
      6 -1.05553E-12 0.6544018569
      7 -8.38545E-13 5.656591E-03
      8 -1.63166E-12 0.0473328832
      9 -4.75992E-13 6.077704E-04
     10 -2.32249E-12 -1.329631599
     11 -9.67382E-13 -3.48583E-04
     12 1.245805E-12 4.666351E-03
     13 -5.73861E-13 0.0207942551
     14 -3.35004E-12 -7.032003009
```

From Integral Prime Unit Normalized to 1



```
Integral Harmonic Analysis of By
With B_ref normalisation
Radius        Z1           Z2          Nz
 100.0        -2500.0      2500.0       501.0
 Order    A(n)         B(n)
          Sine        Cosine
      1 0.0            -4.70112E-06
      2 1.449232E-17 1.0
      3 -1.30137E-17 1.029939E-06
      4 -2.77545E-17 3.3324E-05
      5 5.571918E-18 -1.96826E-06
      6 -7.88904E-17 4.911349E-05
      7 -6.60977E-17 5.532656E-07
      8 -1.27164E-16 3.543308E-06
      9 -3.52298E-17 6.569921E-08
     10 -1.65716E-16 -9.96075E-05
     11 -7.01948E-17 -2.52408E-08
     12 1.003249E-16 3.500592E-07
     13 -4.78382E-17 1.559448E-06
     14 -2.43844E-16 -5.26786E-04
```

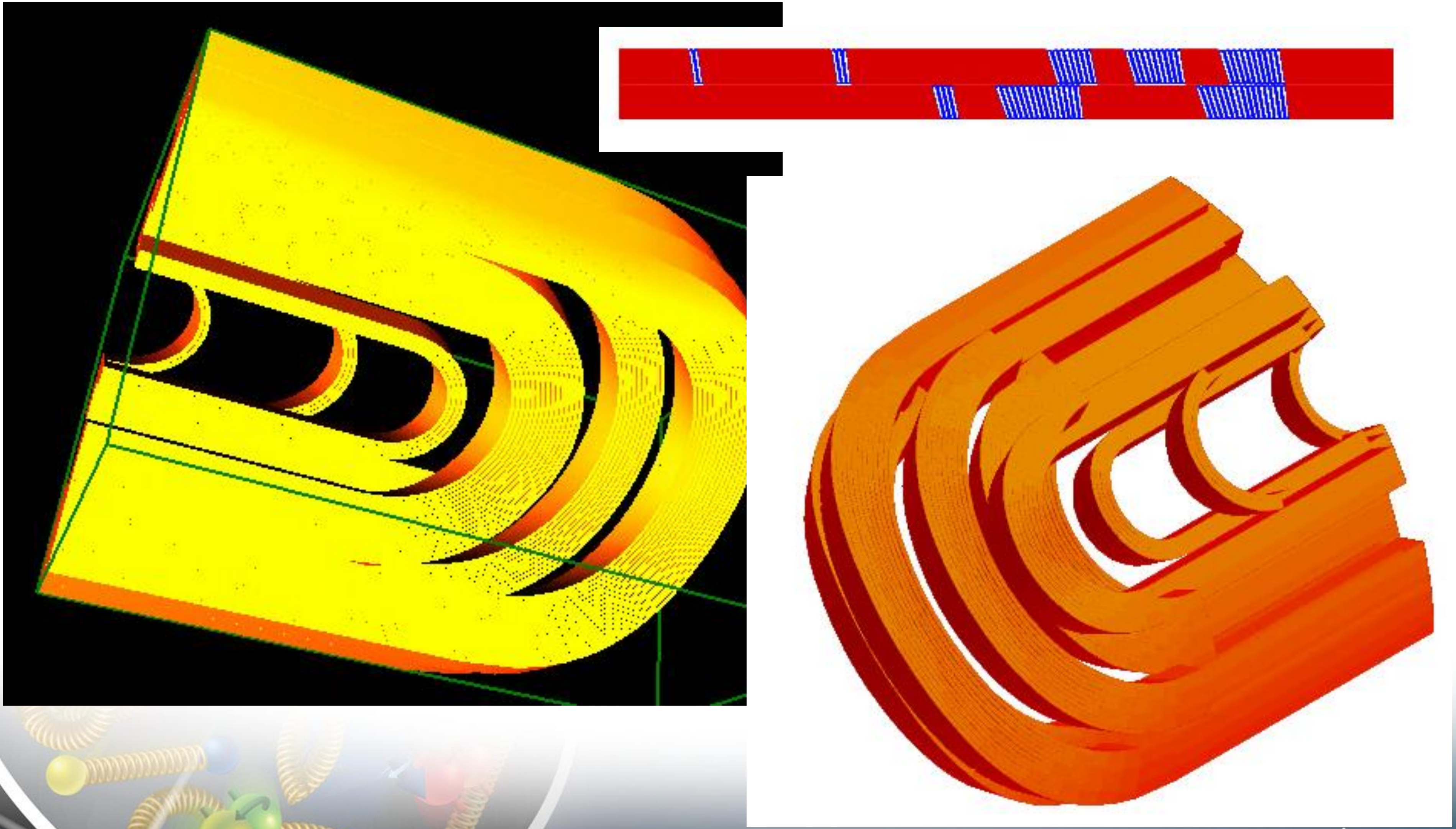
Coil End Winding Approach

- These magnets are much larger in aperture than any high field NbTi accelerator magnets ever built
- Therefore, the empirical criterion used in previous magnets may not be valid for winding the coil ends
- To overcome this uncertainty, a short cut experimental approach was devised. In this approach a single turn cable winding test will be carried out to determine the basis or figure of merit of optimization.
- Full winding is too expensive and would take too long.
- Cable from CERN was requested (same width but a slightly different stone). CERN delivered that cable early on.

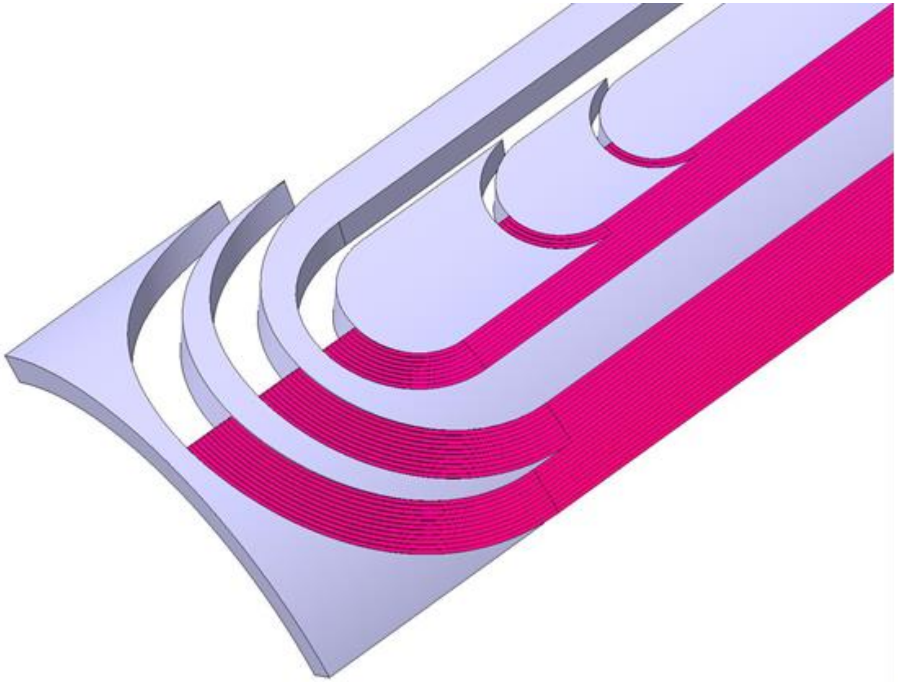
Strategy for Q2pF

- The exercise of using CERN cable in single turn winding test has been very useful.
- This basically meant that the ROXIE criterion (developed for small aperture magnet) has to be updated so much so that they can’t be used as such.
- Based on that, we completely ignored that path and determine the shape based on the single turn winding.
- This approach makes particularly more sense for Q2pF as we have significantly more time in the case of Q2pF.

Coil Ends (latest design of Return End)

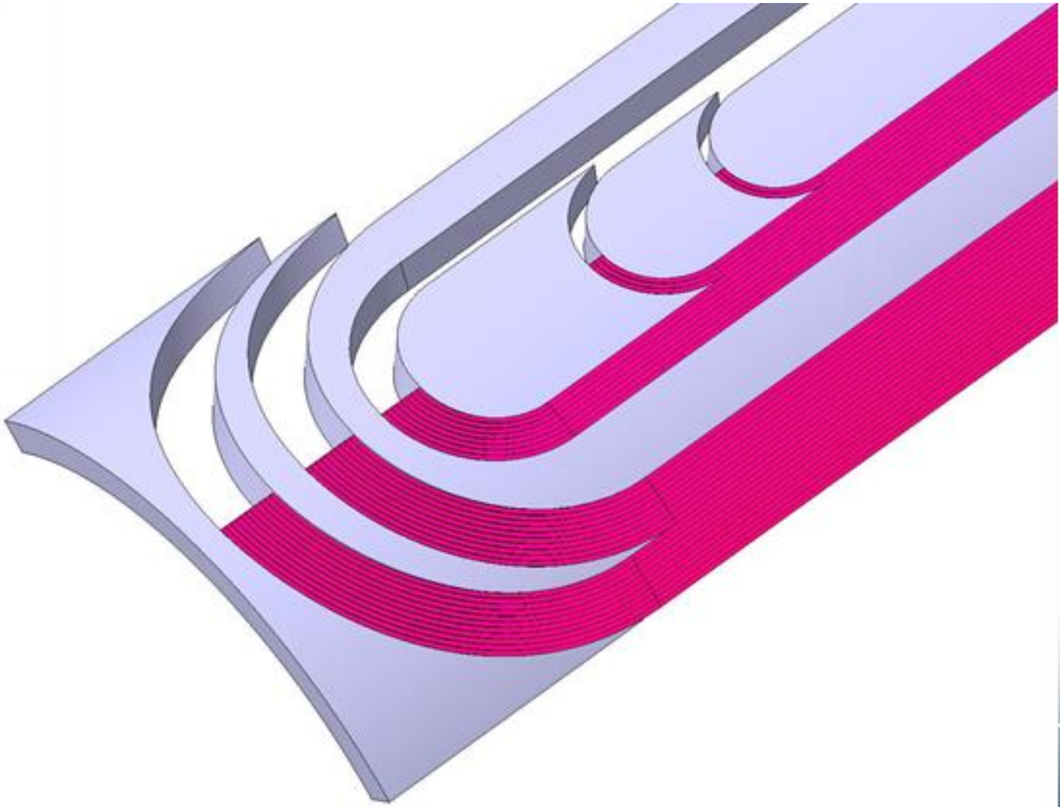


From Jesse (Via Sara and Holger)

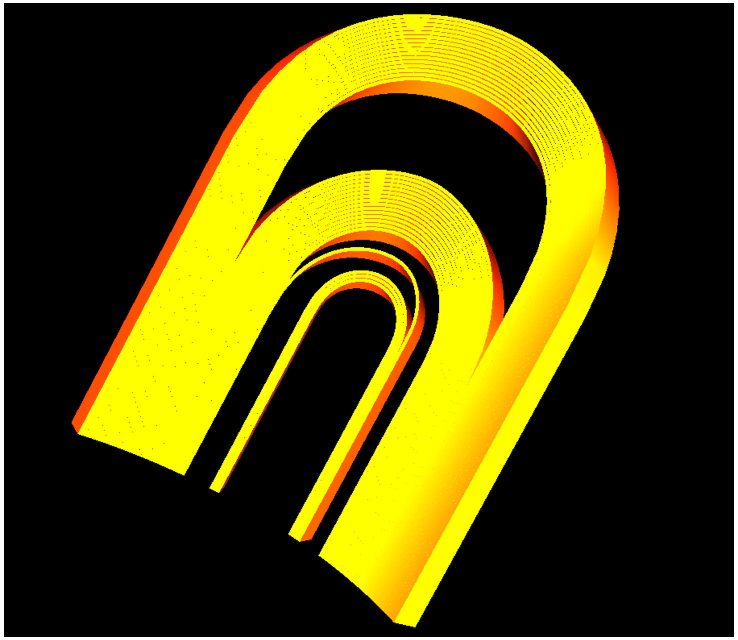


Inner

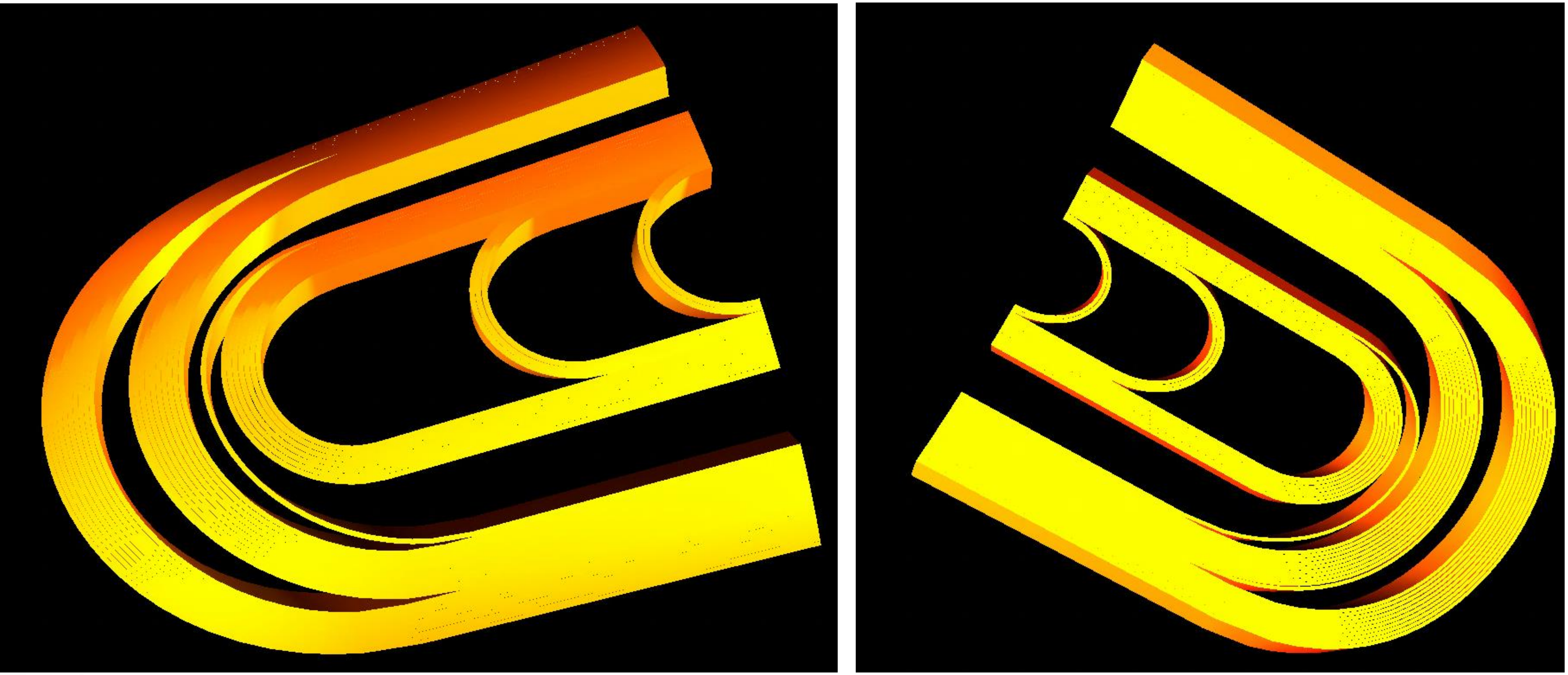
Outer



Coil Lead End Inner Layer (latest design)



Coil Lead End Outer Layer (latest design)



Preliminary EM design Summary

Magnet design information	Func 1		`
The magnet design info from	Hyperlink		
The magnet design intent is	New		
The magnet model name is	Q2PF		
The number of magnets required is	1		
General Magnet Spec			
Bagnetic length =	TBD	(m)	
Bore tube outer-dia =	TBD	(mm)	
Bore field (B or G) =	TBD	(T),(T/m),(T/m2)	
Field integral =	TBD	(T.m),(T),(T/m)	
Coil aperture IR or pole gap =	TBD	(mm)	
Ramp rate =	TBD	(T/s)	
Operating temperature =	TBD	(K)	
Total ampere turns =	TBD	(Aturns)	
Total number of num Layers =	TBD		
Layer function =	TBD		
This layer index =	TBD		
Number of turns per pole =	TBD		
Current =	TBD	(A)	
Inductance =	TBD	(H)	
Stored energy =	TBD	(MJ)	
Resistance =	TBD	(mOhm)	
Engineering current density =	TBD	(A/mm2)	
Power dissipation =	TBD	(W)	
Peak field in winding =	TBD	(T)	
Magnet bore Harmonics			
Analysis radius R_A Analysis current I_A =	TBD	(mm) (A)	
Field at I_A and R_A=	TBD	(T)	
Design harmonics allowed multipoles =	TBD	(10-4)	
Design harmonics nonallowed multipoles =	TBD	(10-4)	
Xtalk and fringe fields			
Xtalk Location (x,y,z) =	TBD	(mm,mm,mm)	
Xtalk analysis radius R_A, Analysis current I_A =	TBD	(mm) (A)	
Xtalk Field at I_A and R_A=	TBD	(T)	
Xtalk harmonics multipoles =	TBD	(10-4)	
Location of Fringe filed R or Location (x,y,z) =	TBD	(mm)	
Value of fringe field at target location =	TBD	(T)	
SC Cables, Strand's =			
Superconductor type used =	TBD		
Conductor\cable used =	TBD		
Cu:Sc ratio =	TBD		
Critical field of wire =	TBD	(T)	
Xsectional area of wire =	TBD	(mm2)	
Critical current of wire =	TBD	(A)	
Critical temperature =	TBD	(K)	
Operating margin =	TBD	%	

Issues & outstanding work needed

Add here as needed

Magnet heat load\Cooling			
Operational temp of magnet =	TBD	(K)	
Max operational temp of magnet =	TBD	(K)	
Nominal operating heat loads =	TBD	(W)	
Peak quench heat loads =	TBD	(W)	
Peak quench heat load duration =	TBD	(s)	
Coils			
Coil width in X (od or dx) =	TBD	(m)	
Coil height (od or dy) =	TBD	(m)	
Coil length dz =	TBD	(m)	
Mass of coils =	TBD	(Kg)	
Iron collar\Yoke			
Iron temp=	Cold	(Cold,Warm)	
Iron extent (od or dx) =	TBD	(m)	
Iron extent (od or dy) =	TBD	(m)	
Iron length dz =	TBD	(m)	
Yoke mass =	TBD	(Kg)	
Cold Mass			
Cold mass extent (od or dx) =	TBD	(m)	
Cold mass extent (od or dy) =	TBD	(m)	
Cold mass length dz =	TBD	(m)	
Coldmass mass =	TBD	(Kg)	
Fully Assembled insertion			
Complete magnet width dx =	TBD	(m)	
Complete magnet height =	TBD	(m)	
Complete magnet length dz =	TBD	(m)	
Full assembly mass =	TBD	(Kg)	

Detailed EM design

Detailed EM design Section (still being iterated)

Detailed EM model check list	**Y/N/?**
Has an optimized 3D model been generated to include the effect of end turn spacing.	Y
In winding terms is the 3D coil geometry considered realistic.	?
Is the 3D model output consistent with the 2D model output.	Y
Are the 3D model conductor properties different from the proposed production conductor.	N
Are the Iron properties assumed consistent with the proposed production Iron.	?
Is the conductor temperature assumed consistent with the proposed operating temperatures.	Y
Are the Integrated Bore field Harmonics consistent with requirements at all energies/field configurations.	?
Are the cross-talk requirements met for all all energies/field configurations.	Y*
Are the fringe field requirements met for all all energies/field configurations.	Y*
Are the more accurate estimates(Peak field, Inductance, integrated harmonics etc) added to the Magnet spec sheet.	N
Y*: Yes, based on the 2-d models; needs to verified with 3-d model	

Detailed EM design Summary

Magnet design information	Func 1		`
The magnet design info from	Hyperlink		
The magnet design intent is	New		
The magnet model name is	Q2PF		
The number of magnets required is	1		
General Magnet Spec			
Bagnetic length =	TBD	(m)	
Bore tube outer-dia =	TBD	(mm)	
Bore field (B or G) =	TBD	(T),(T/m),(T/m2)	
Field integral =	TBD	(T.m),(T),(T/m)	
Coil aperture IR or pole gap =	TBD	(mm)	
Ramp rate =	TBD	(T/s)	
Operating temperature =	TBD	(K)	
Total ampere turns =	TBD	(Aturns)	
Total number of num Layers =	TBD		
Layer function =	TBD		
This layer index =	TBD		
Number of turns per pole =	TBD		
Current =	TBD	(A)	
Inductance =	TBD	(H)	
Stored energy =	TBD	(MJ)	
Resistance =	TBD	(mOhm)	
Engineering current density =	TBD	(A/mm2)	
Power dissipation =	TBD	(W)	
Peak field in winding =	TBD	(T)	
Magnet bore Harmonics			
Analysis radius R_A Analysis current I_A =	TBD	(mm) (A)	
Field at I_A and R_A=	TBD	(T)	
Design harmonics allowed multipoles =	TBD	(10-4)	
Design harmonics nonallowed multipoles =	TBD	(10-4)	
Xtalk and fringe fields			
Xtalk Location (x,y,z) =	TBD	(mm,mm,mm)	
Xtalk analysis radius R_A, Analysis current I_A =	TBD	(mm) (A)	
Xtalk Field at I_A and R_A=	TBD	(T)	
Xtalk harmonics multipoles =	TBD	(10-4)	
Location of Fringe filed R or Location (x,y,z) =	TBD	(mm)	
Value of fringe field at target location =	TBD	(T)	
SC Cables, Strand's =			
Superconductor type used =	TBD		
Conductor\cable used =	TBD		
Cu:Sc ratio =	TBD		
Critical field of wire =	TBD	(T)	
Xsectional area of wire =	TBD	(mm2)	
Critical current of wire =	TBD	(A)	
Critical temperature =	TBD	(K)	
Operating margin =	TBD	%	

Issues & outstanding work needed

Add here as needed

Magnet heat load\Cooling			
Operational temp of magnet =	TBD	(K)	
Max operational temp of magnet =	TBD	(K)	
Nominal operating heat loads =	TBD	(W)	
Peak quench heat loads =	TBD	(W)	
Peak quench heat load duration =	TBD	(s)	
Coils			
Coil width in X (od or dx) =	TBD	(m)	
Coil height (od or dy) =	TBD	(m)	
Coil length dz =	TBD	(m)	
Mass of coils =	TBD	(Kg)	
Iron collar\Yoke			
Iron temp=	Cold	(Cold,Warm)	
Iron extent (od or dx) =	TBD	(m)	
Iron extent (od or dy) =	TBD	(m)	
Iron length dz =	TBD	(m)	
Yoke mass =	TBD	(Kg)	
Cold Mass			
Cold mass extent (od or dx) =	TBD	(m)	
Cold mass extent (od or dy) =	TBD	(m)	
Cold mass length dz =	TBD	(m)	
Coldmass mass =	TBD	(Kg)	
Fully Assembled insertion			
Complete magnet width dx =	TBD	(m)	
Complete magnet height =	TBD	(m)	
Complete magnet length dz =	TBD	(m)	
Full assembly mass =	TBD	(Kg)	

Mechanical & Thermal design

EM\Mechanical analysis details 1

EIC IR Magnet Q2pF Mechanical Structure Finite Element Analyses

John Cozzolino / Chris Runyan

Outline:

- 2-D Analyses
- 3-D Coil End Analysis
- End Plate – Axial Support Analyses

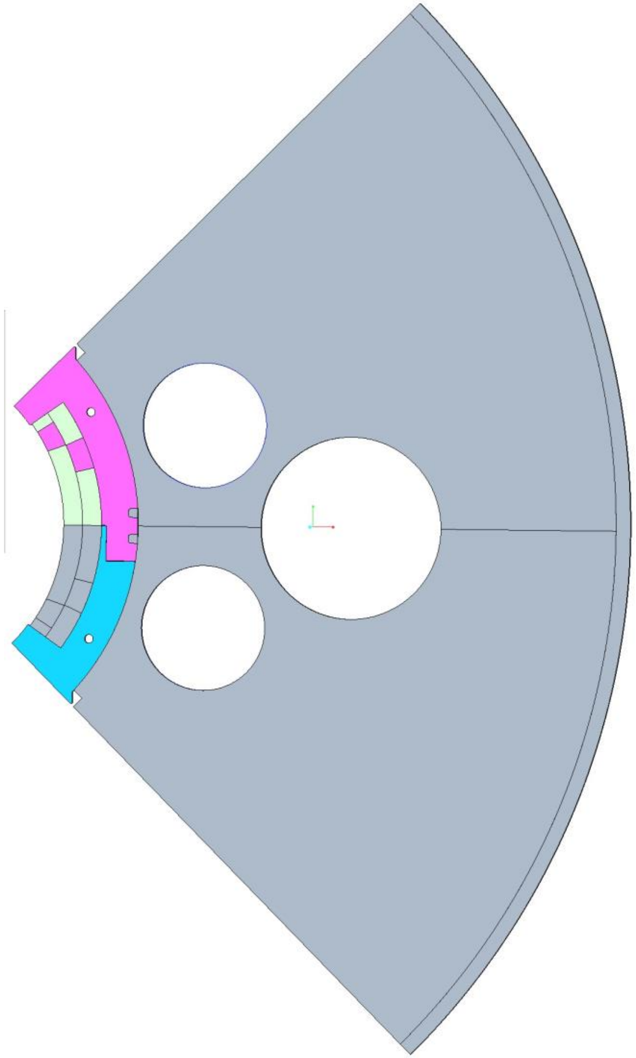
Note: this is a compilation of preliminary work performed in 2021; work will be reviewed shortly for consistency with the present design, repeated if necessary

Q2pF 2-D FEA

John Cozzolino

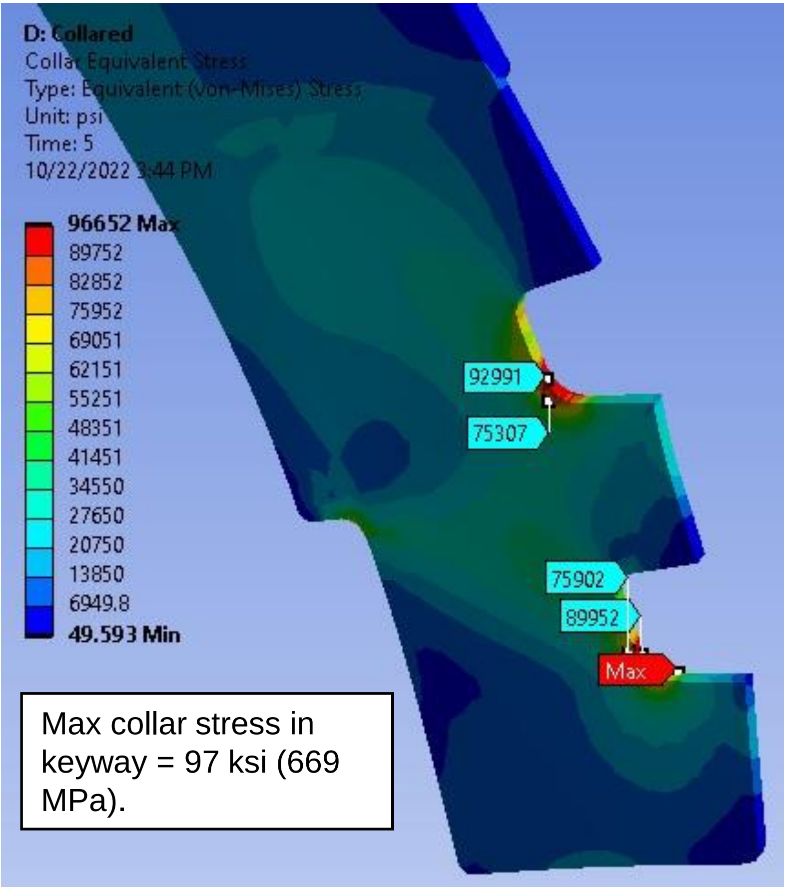
Q2pF Straight Section

- 403 mm collar O.D.
- 30.6 mm collar radial thickness
- 1200 mm yoke O.D.
- Block current density: 253 A/mm^2
- 40 T/m flux gradient (approx.)
- 8700 A operating current



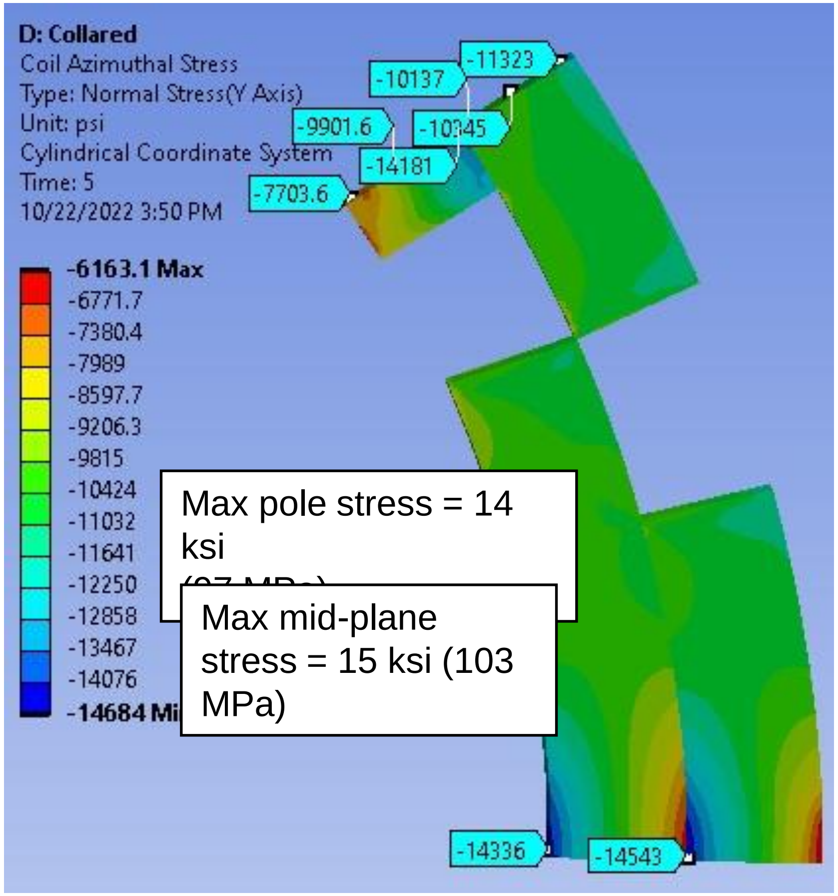
Physicist’s design files:
Q2pF-15mm2K30mmcol-h379-8500A.dxfxy
Q2pF-15mm2K30mmcol-h379-8500A.dxfiron

Q2pF - Warm Collared



D: Collared
Collar Equivalent Stress
Type: Equivalent (Von-Mises) Stress
Unit: psi
Time: 5
10/22/2022 3:44 PM

Max collar stress in keyway = 97 ksi (669 MPa).

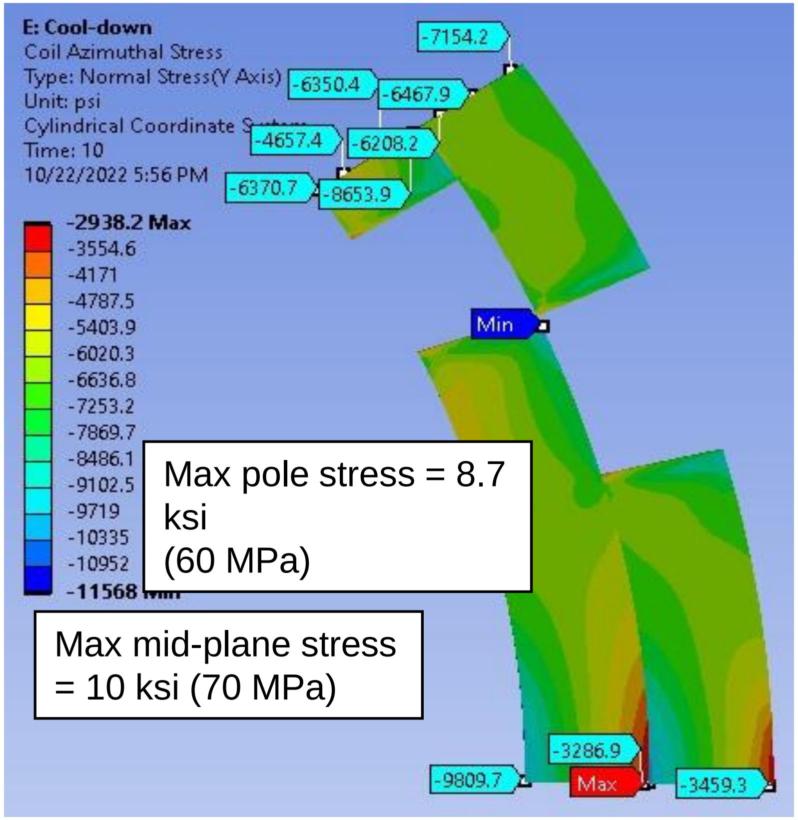


D: Collared
Coil Azimuthal Stress
Type: Normal Stress(Y Axis)
Unit: psi
Cylindrical Coordinate System
Time: 5
10/22/2022 3:50 PM

Max pole stress = 14 ksi (97 MPa)

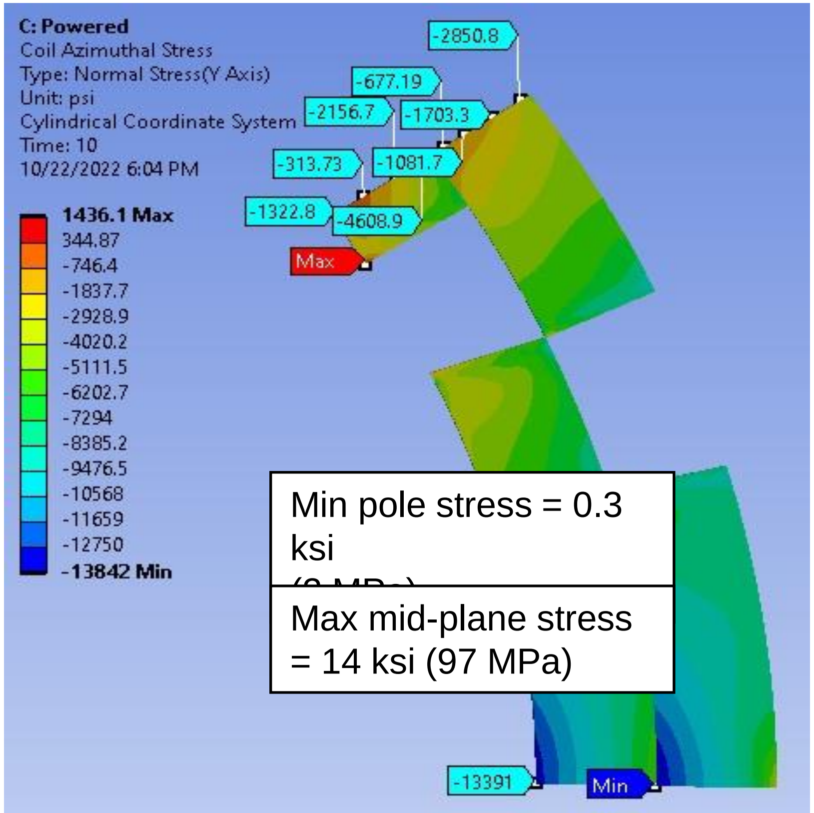
Max mid-plane stress = 15 ksi (103 MPa)

Q2pF - Cold vs. Powered



Max pole stress = 8.7 ksi
(60 MPa)

Max mid-plane stress = 10 ksi (70 MPa)



Min pole stress = 0.3 ksi
(2 MPa)

Max mid-plane stress = 14 ksi (97 MPa)

Radial coil movement at mid-plane from cold to powered = 79 microns.

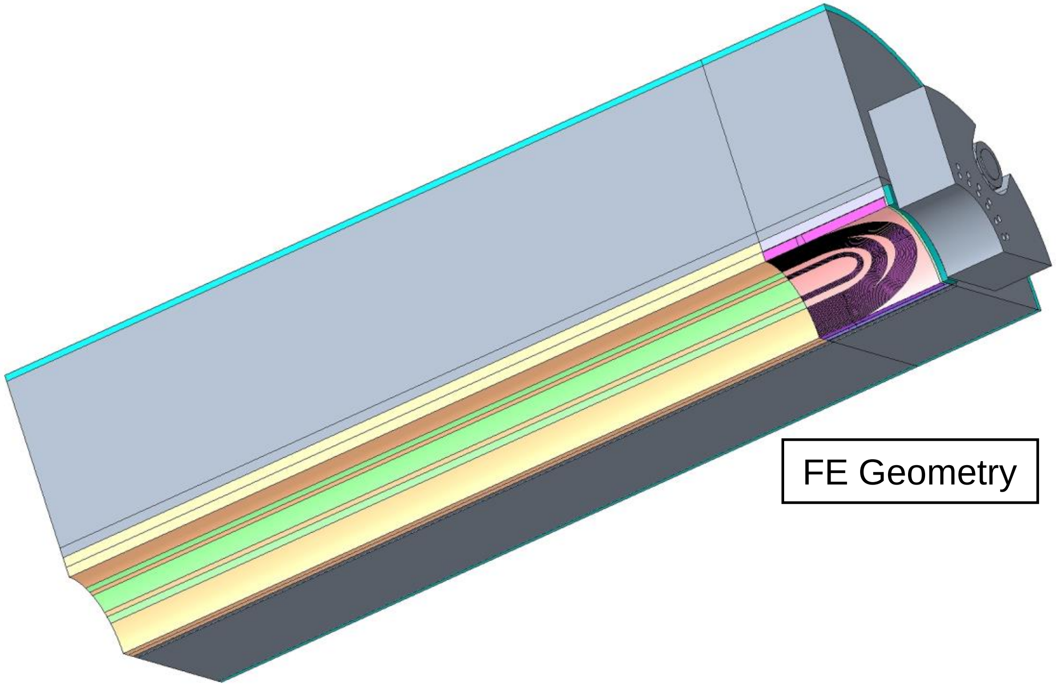
EIC Q2pF
3D FE Coil FEA
Non-Lead End (preliminary)

John Cozzolino

May 14, 2021

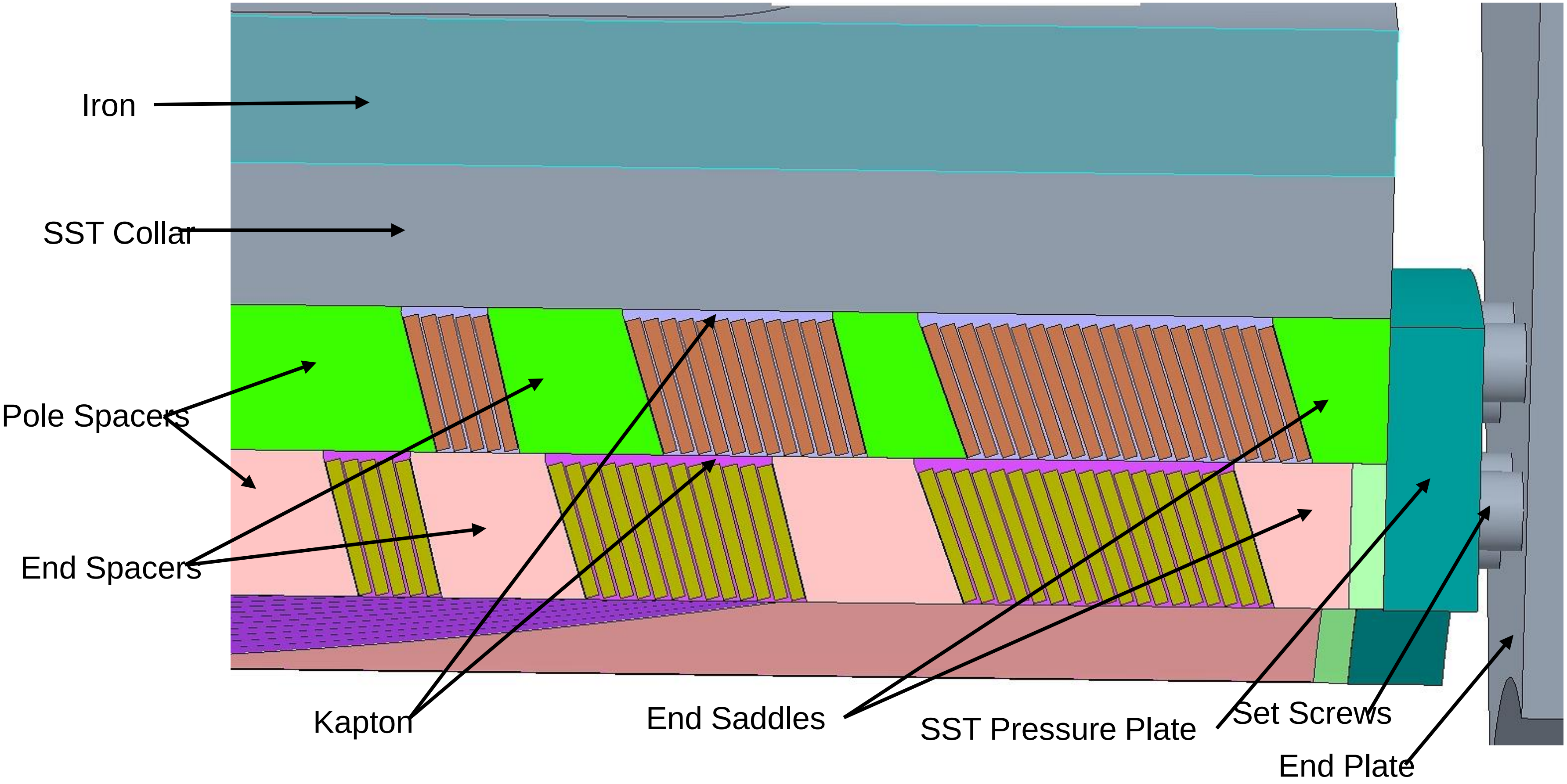
Q2pF Non-Lead End (3-D)

- 262 mm collar O.D.
- 1100 mm yoke O.D.
- 20 mm collar radial thickness
- 127 mm thick end plate
- Current = 7510 A
- 6.7 T peak field
- 39 T/m Flux Gradient



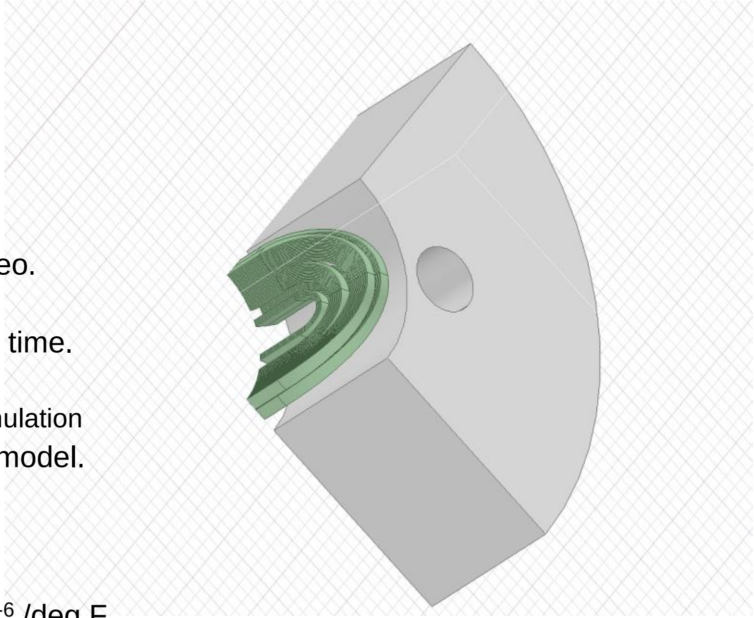
FE Geometry

Q2pF Non-Lead End (3-D)



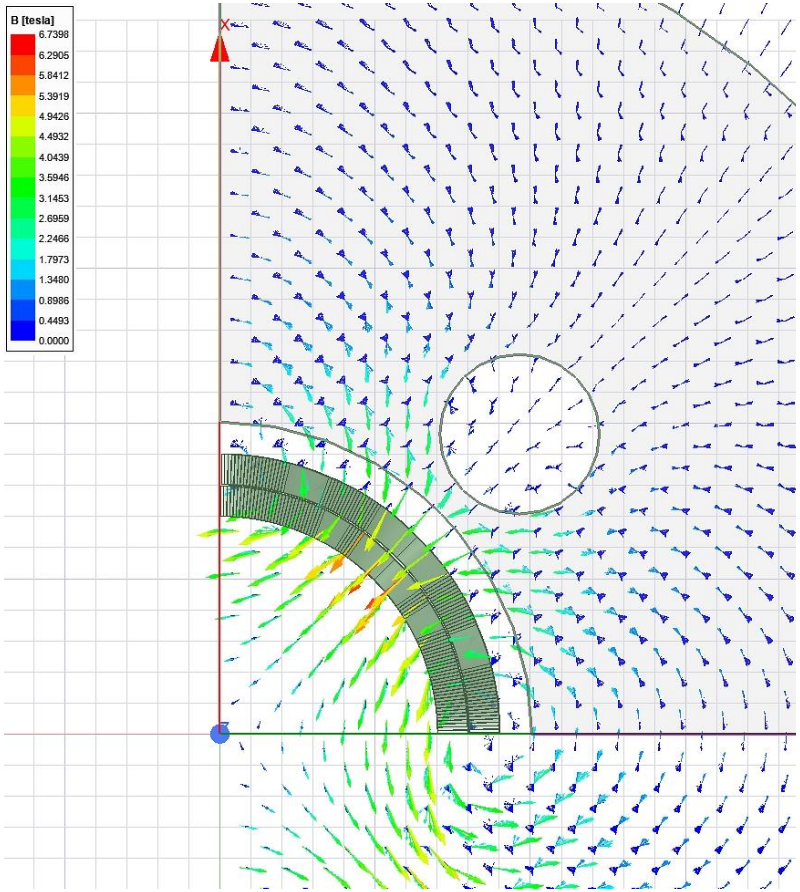
Q2pF Non-Lead End (3-D)

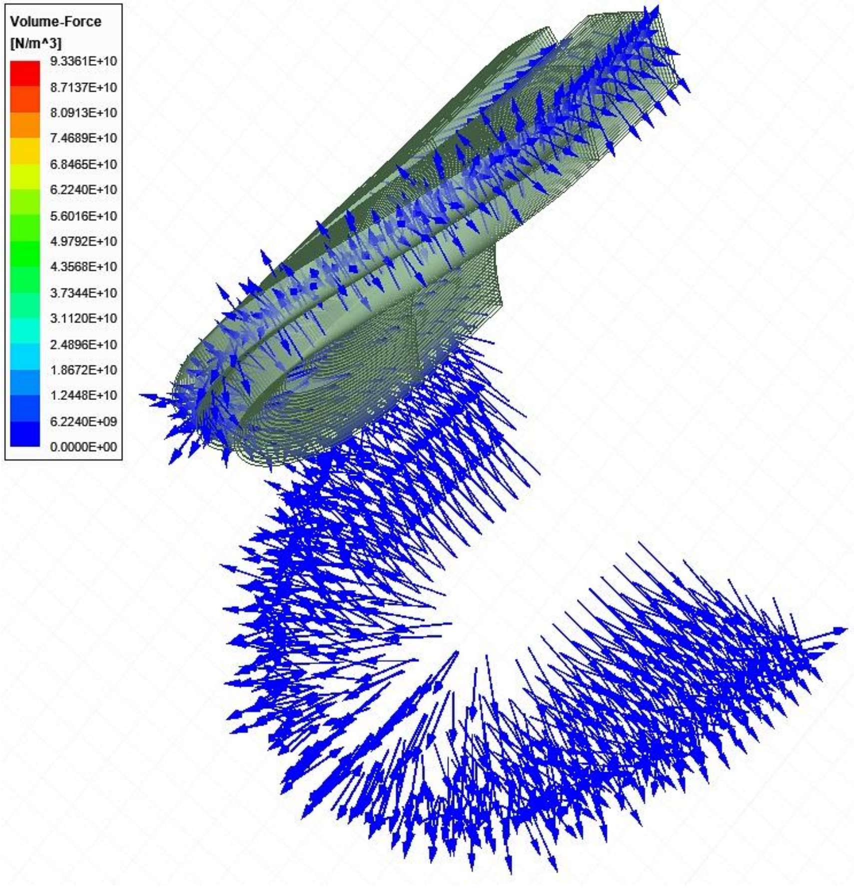
- Model Features
  - 3-D conductor geometry and path imported from Roxio directly into Creo.
    - Kapton insulation, wedges, spacers, and saddles added separately
  - Only the coil end is modeled in Maxwell as individual turns to save run time.
    - Straight section introduced in the mechanical model.
    - Straight section coil forces and collar stresses studied in separate FE simulation
  - Lorentz forces calculated in Maxwell are mapped into the mechanical model.
  - Coil axial support structure modeled accurately
  - Coil azimuthal and axial preload included
    - Both are iterated and optimized in this simulation
  - NbTi conductor: E = $1.45e^{6}$ psi, Isotropic instantaneous CTE = 5.58 e^{-6} /deg F.
  - Frictional contact between shell-yoke, yoke-collar, and collar-coil.



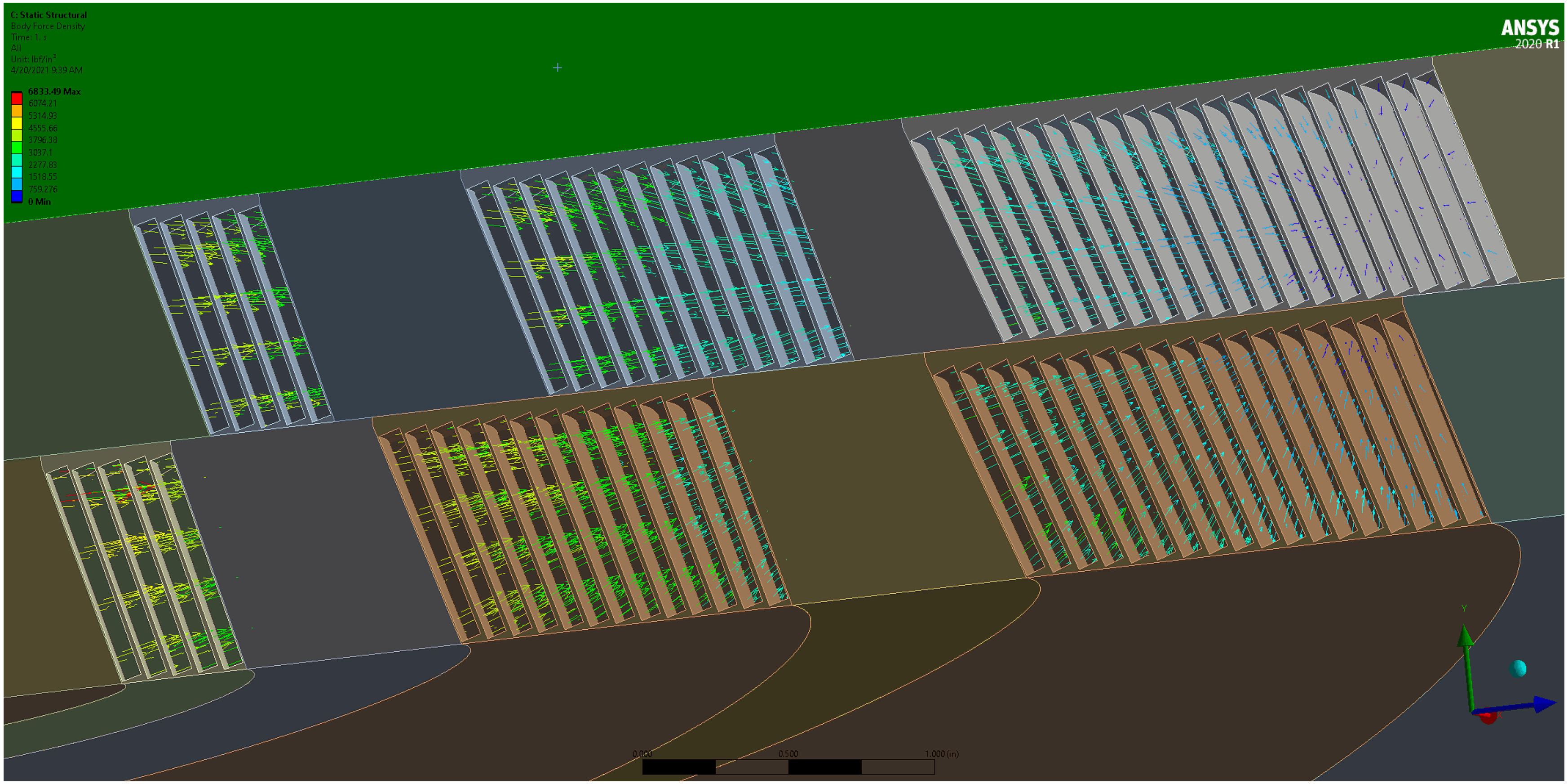
Maxwell Geometry

Q2pF Non-Lead End Field Vectors and Lorentz Forces

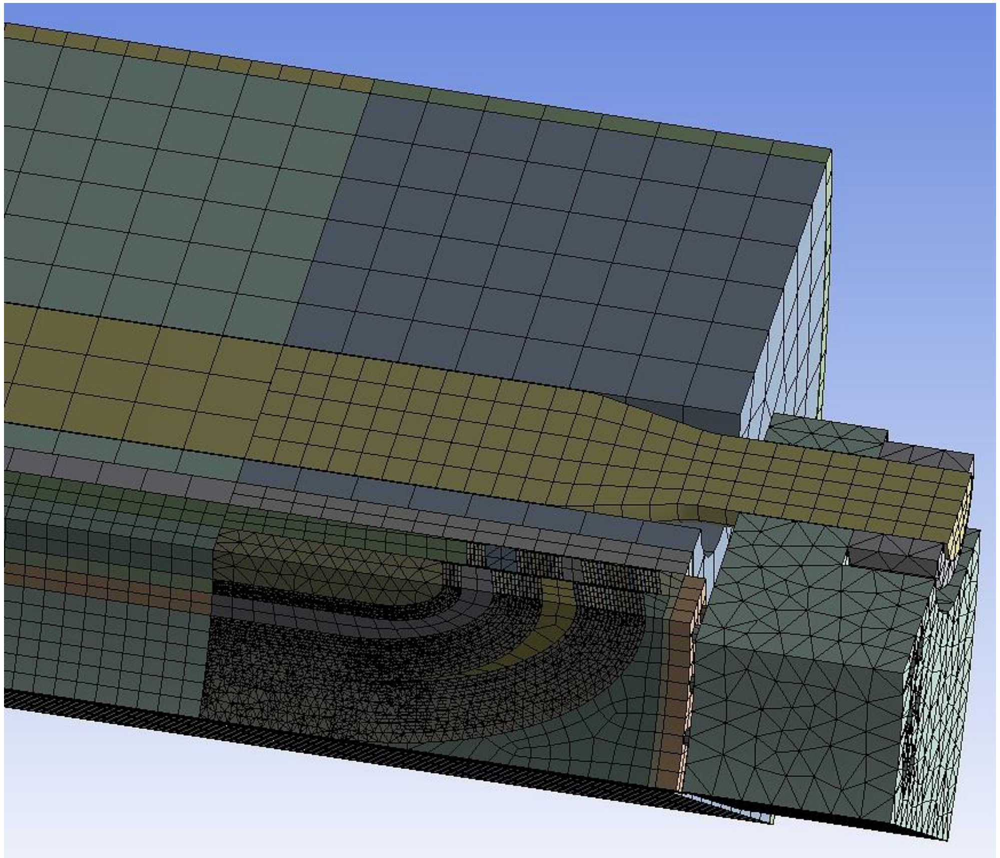




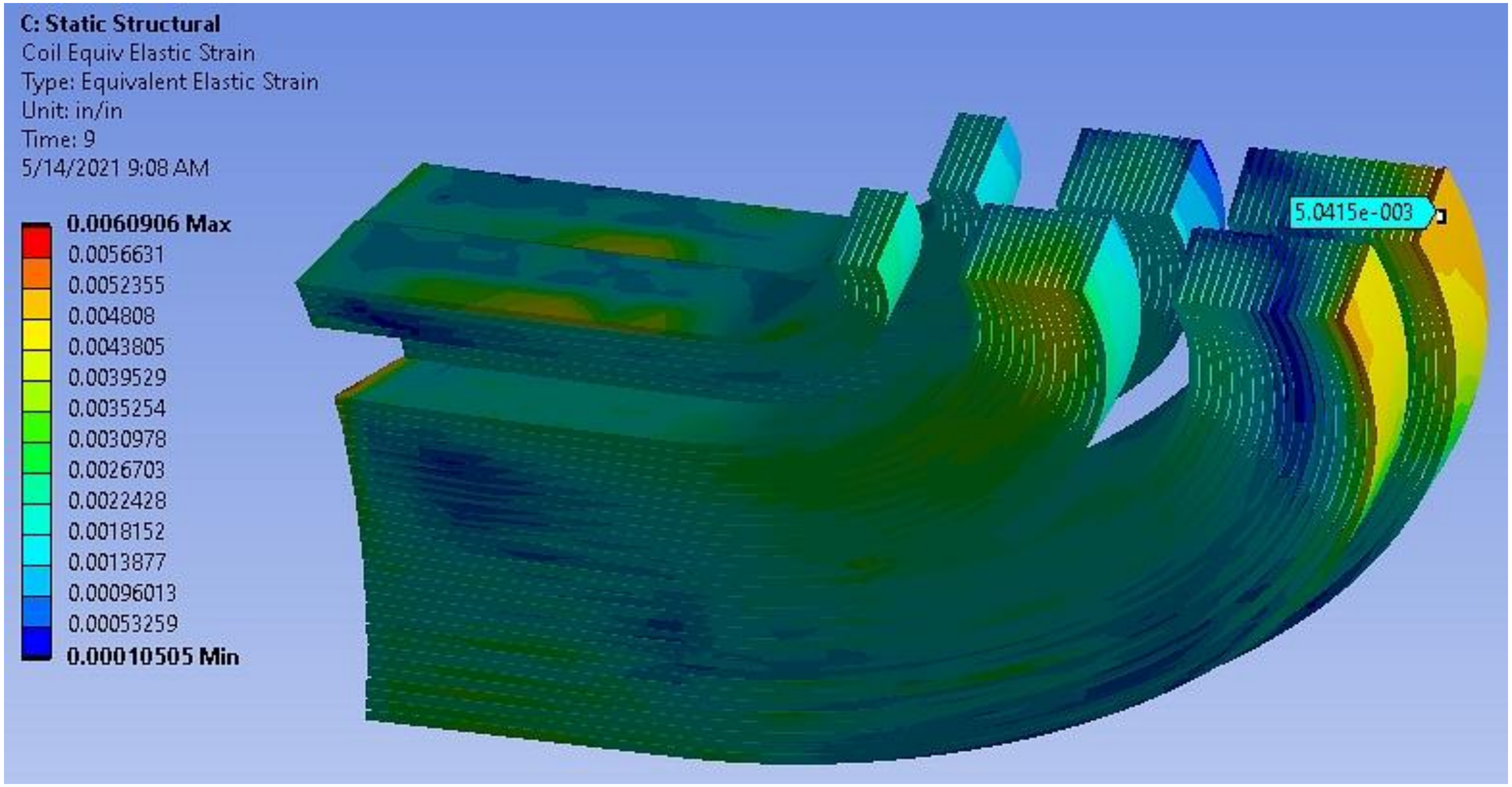
Q2pF Lorentz Forces Mapped into Mechanical Model



Q2pF Mesh – mechanical model



Q2pF End – Equivalent Axial Strain



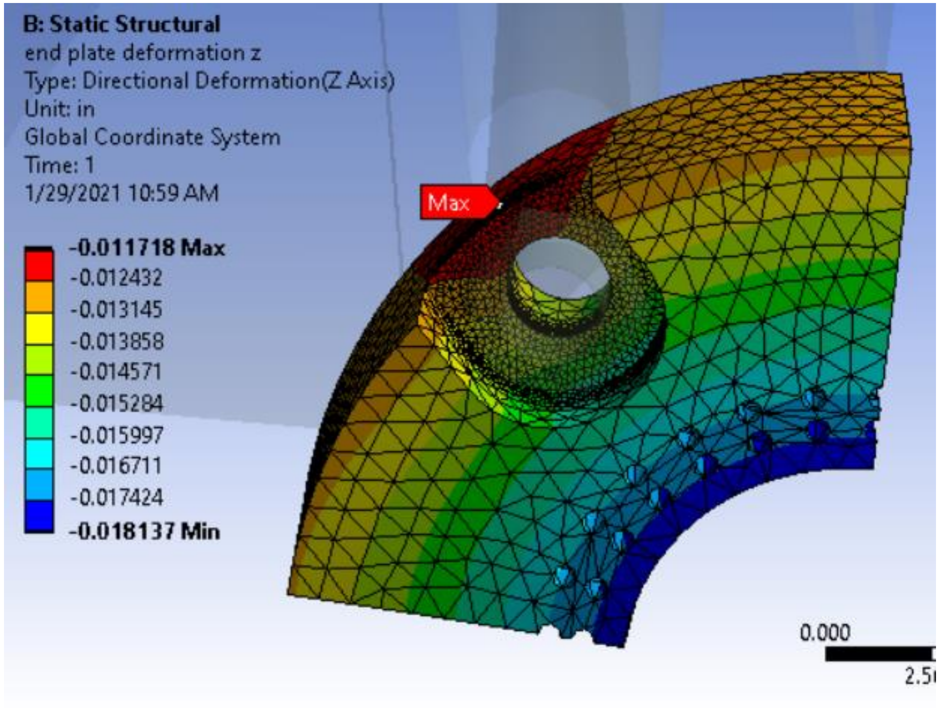
C: Static Structural
Coil Equiv Elastic Strain
Type: Equivalent Elastic Strain
Unit: in/in
Time: 9
5/14/2021 9:08 AM

0.0060906 Max
0.0056631
0.0052355
0.004808
0.0043805
0.0039529
0.0035254
0.0030978
0.0026703
0.0022428
0.0018152
0.0013877
0.00096013
0.00053259
0.00010505 Min

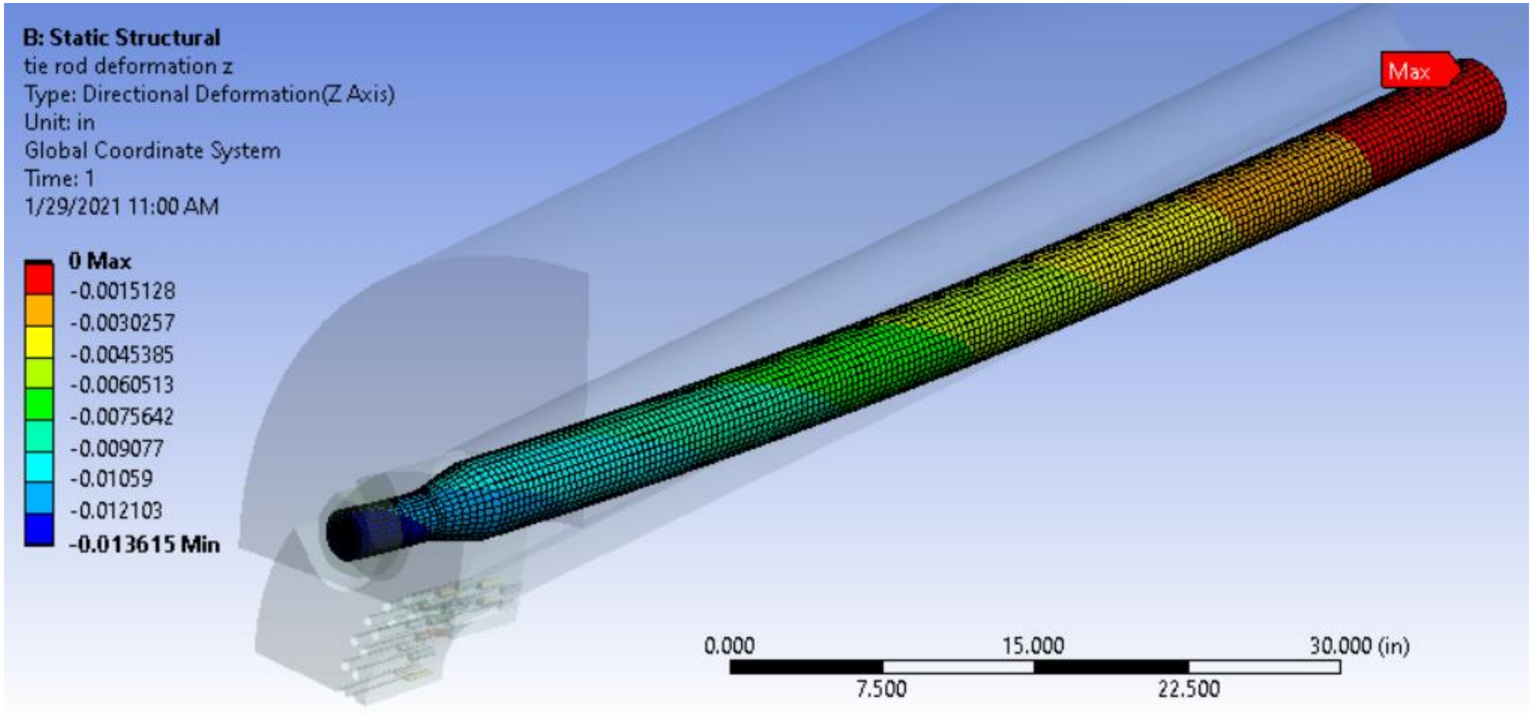
EIC Endplate Analyses

Chris Runyan
ANSYS 2020 R1
Updated 01/29/21

Q2pF NLE
Endplate Z deformation



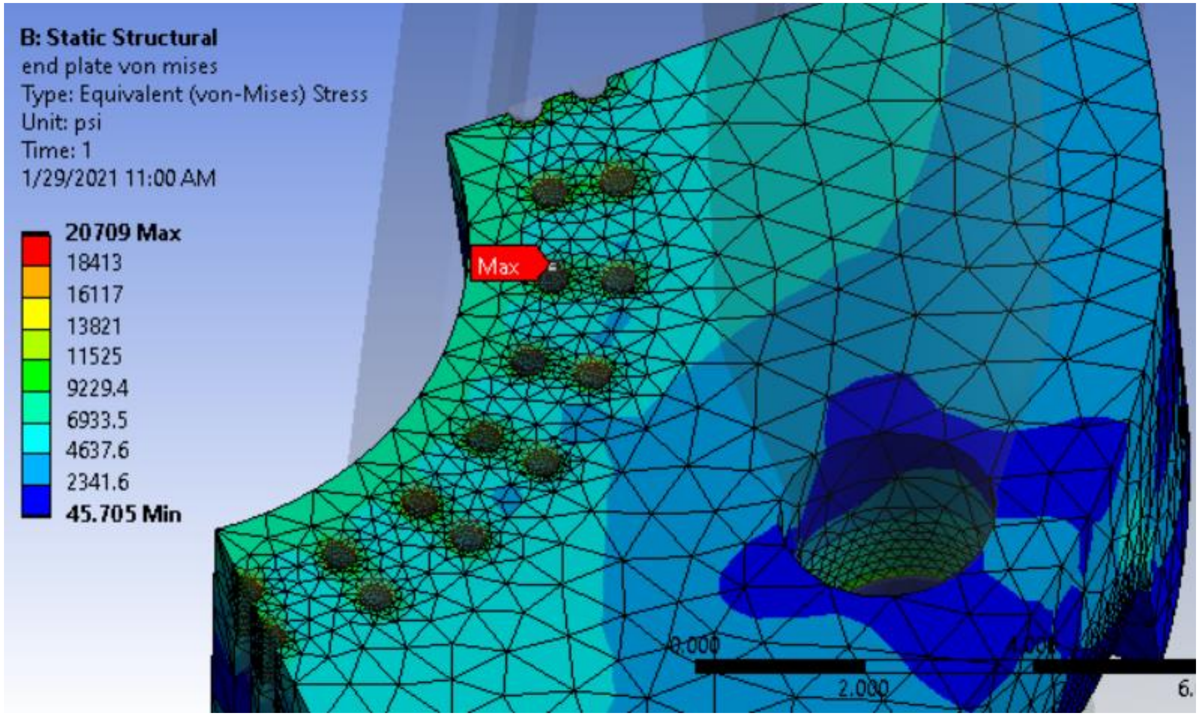
Q2pF NLE
Tie Rod Z deformation



B: Static Structural
tie rod deformation z
Type: Directional Deformation(Z Axis)
Unit: in
Global Coordinate System
Time: 1
1/29/2021 11:00 AM

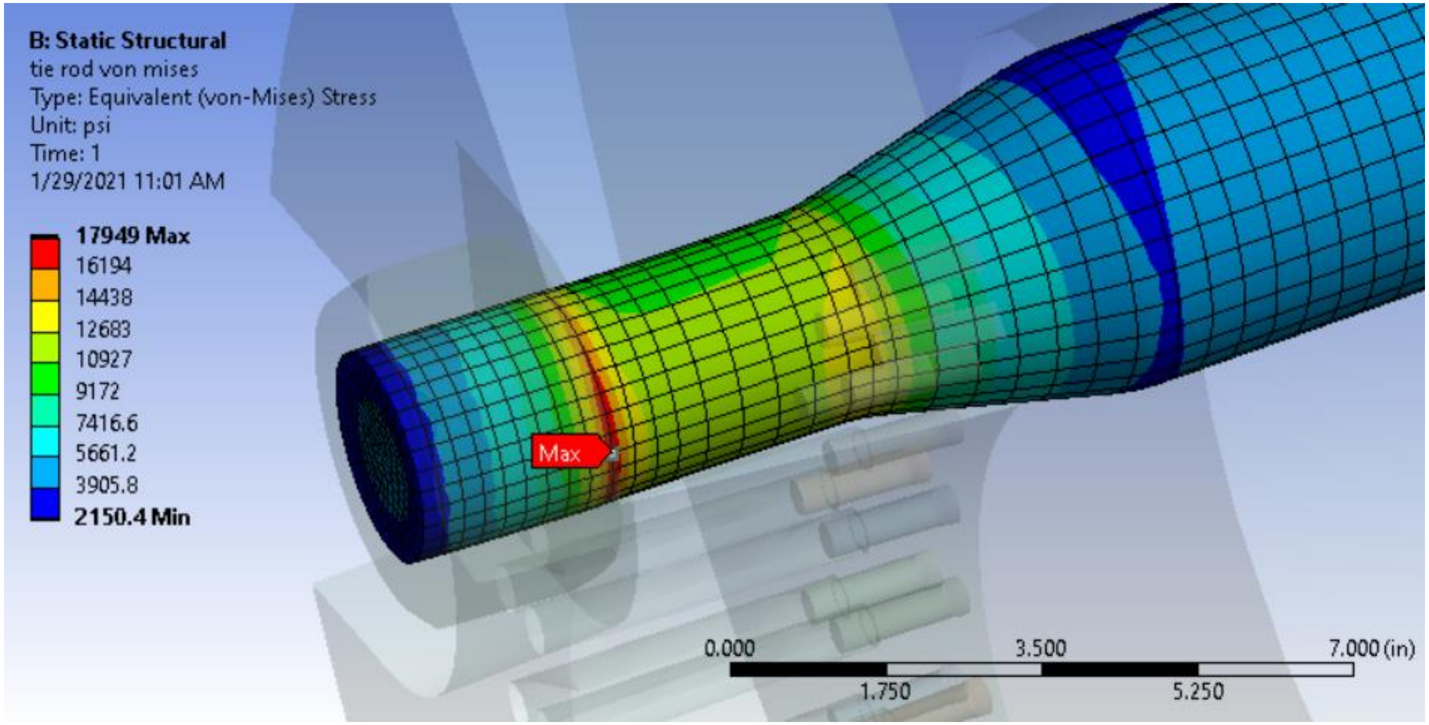
	0 Max
🟥	-0.0015128
🟧	-0.0030257
🟨	-0.0045385
	-0.0060513
🟩	-0.0075642
	-0.009077
	-0.01059
	-0.012103
🟦	**-0.013615 Min**

Q2pF NLE
Endplate Stress

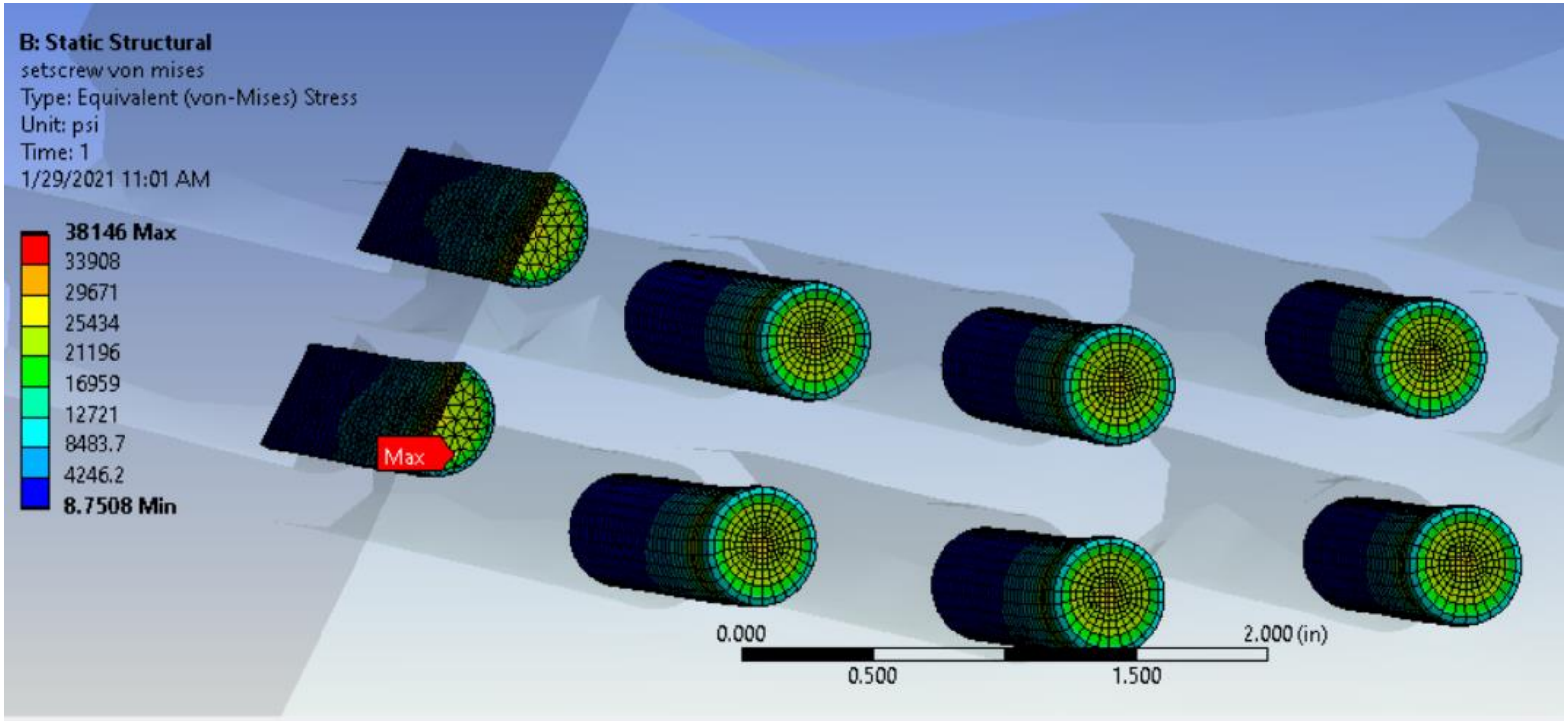


B: Static Structural
end plate von mises
Type: Equivalent (von-Mises) Stress
Unit: psi
Time: 1
1/29/2021 11:00 AM

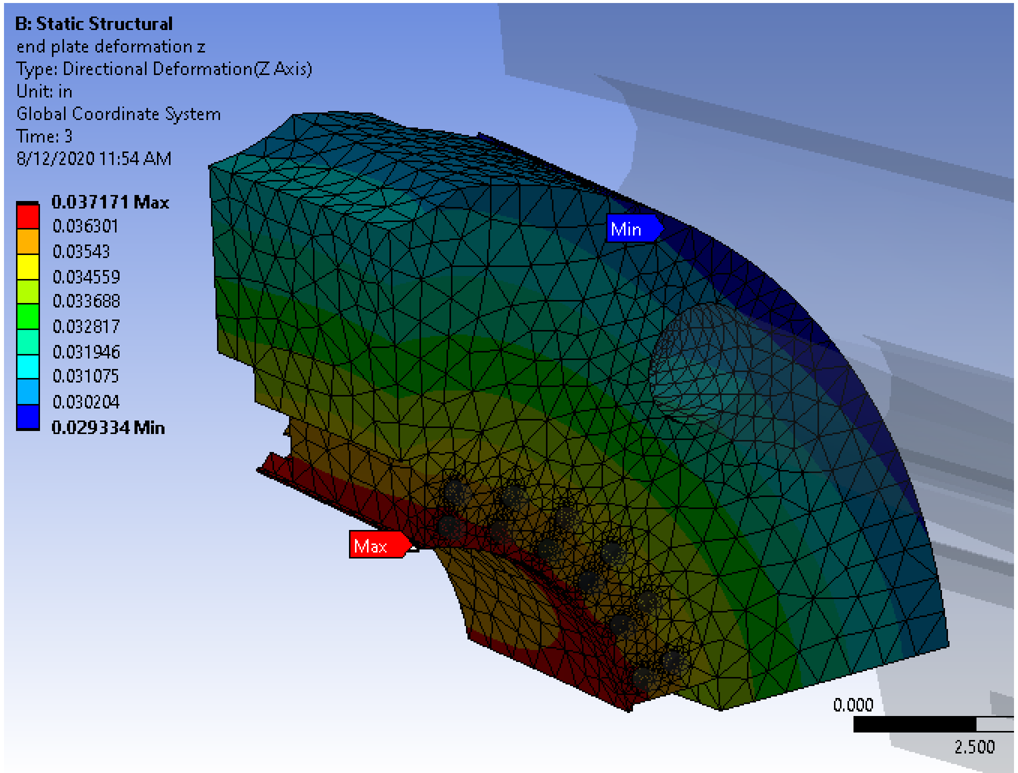
Q2pF NLE
Tie Rod Stress



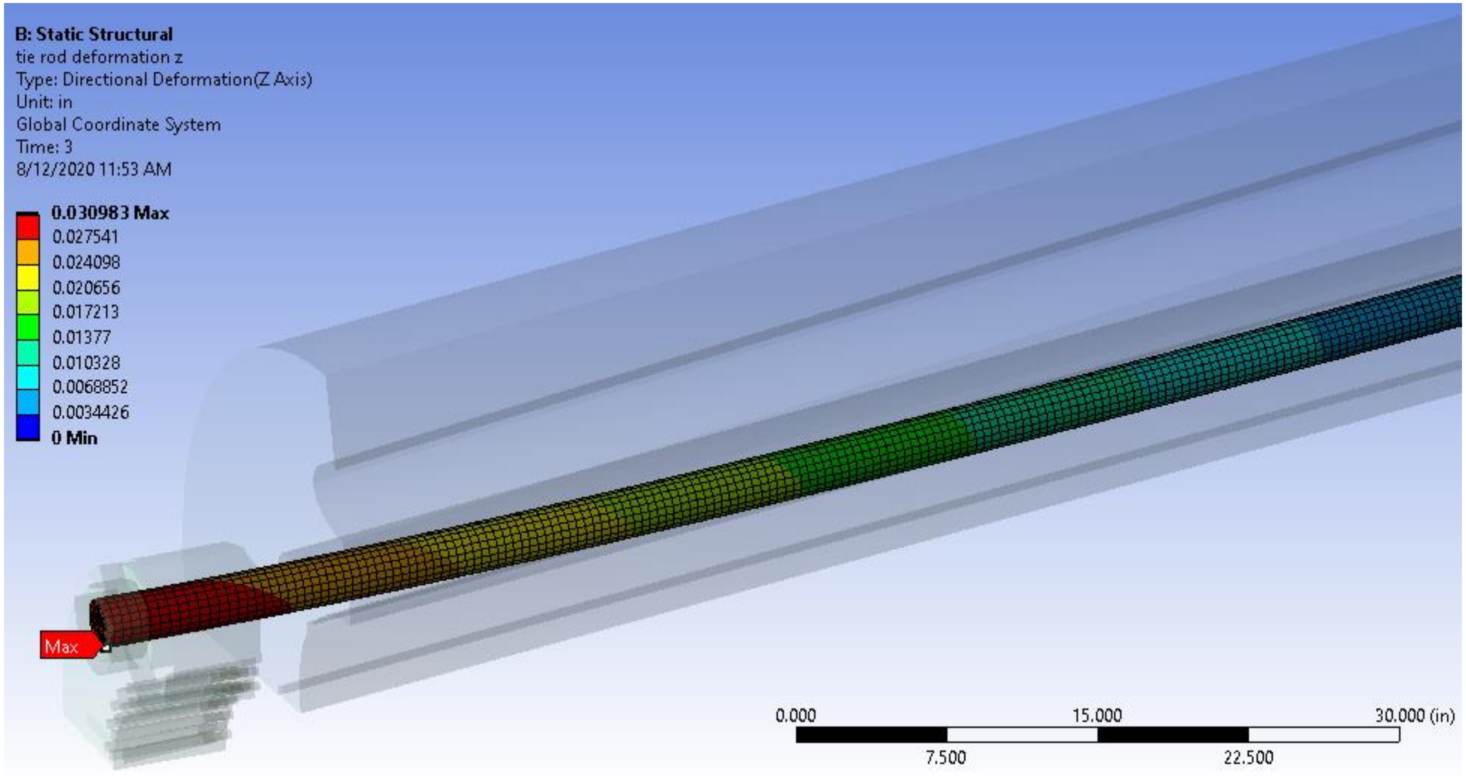
Q2pF NLE
Setscrew Stress



Q2pF LE
Endplate Z deformation



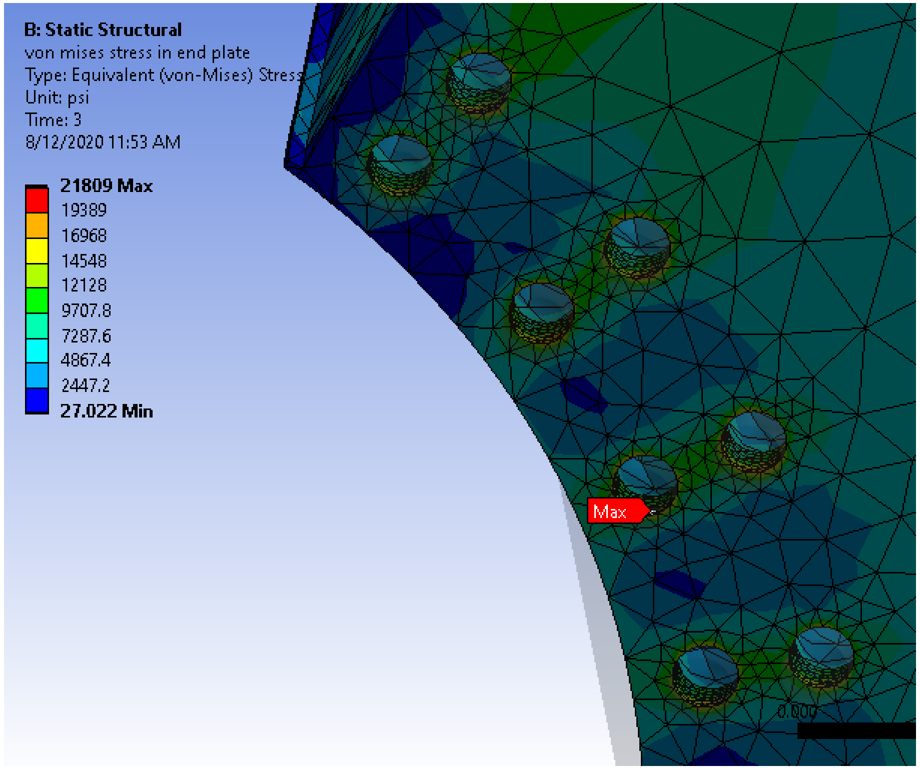
Q2pF LE
Tie Rod Z deformation



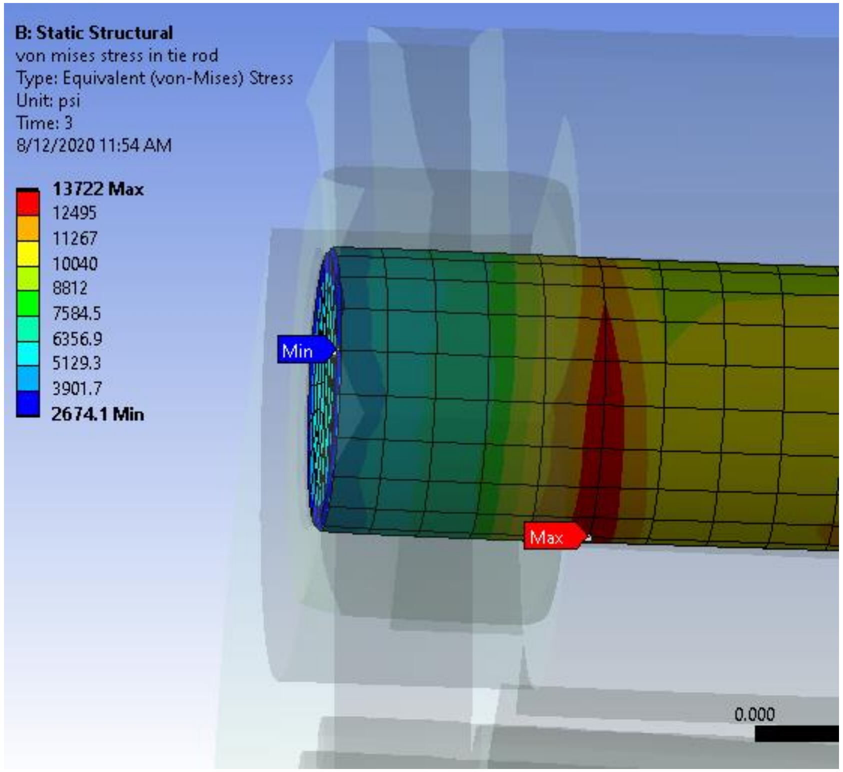
B: Static Structural
tie rod deformation z
Type: Directional Deformation(Z Axis)
Unit: in
Global Coordinate System
Time: 3
8/12/2020 11:53 AM

🟥	**0.030983 Max**
🟥	0.027541
🟧	0.024098
🟨	0.020656
🟩	0.017213
🟩	0.01377
🟩	0.010328
🟦	0.0068852
🟦	0.0034426
🟦	**0 Min**

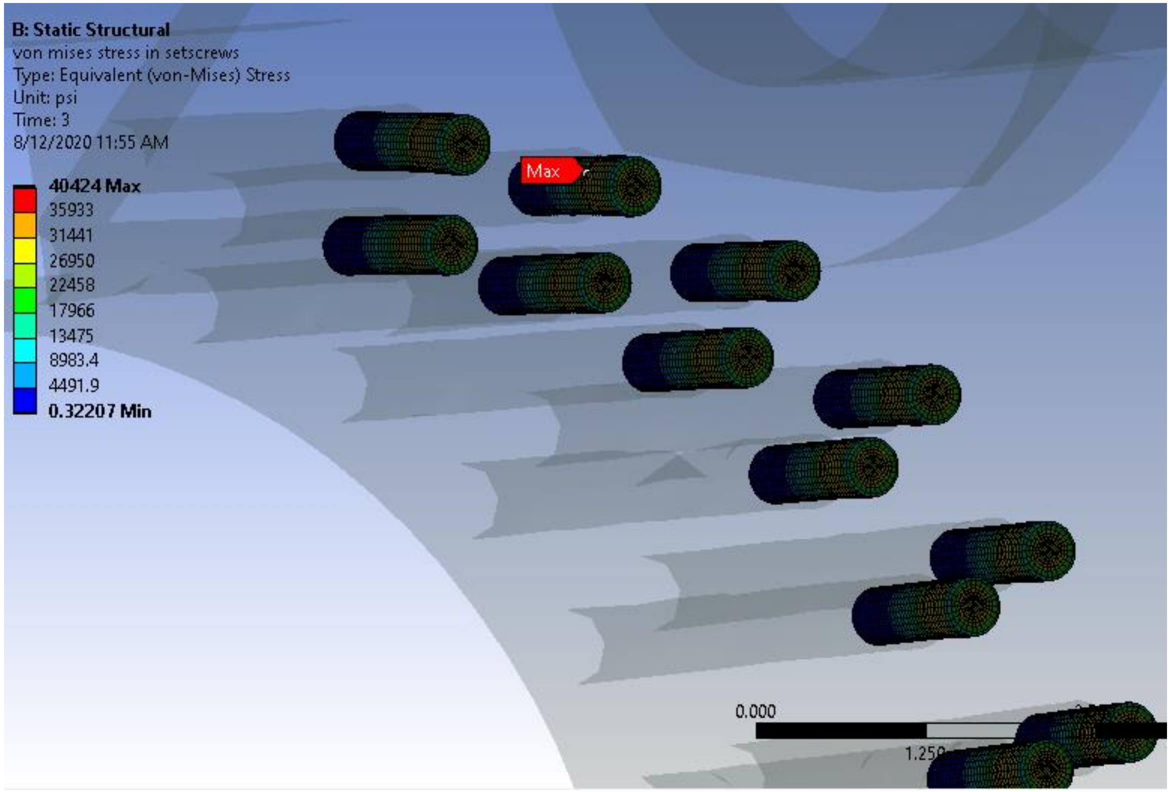
Q2pF LE
Endplate Stress


B: Static Structural
von mises stress in end plate
Type: Equivalent (von-Mises) Stress
Unit: psi
Time: 3
8/12/2020 11:53 AM

Q2pF LE
Tie Rod Stress



Q2pF LE
Setscrew Stress



B: Static Structural
von mises stress in setscrews
Type: Equivalent (von-Mises) Stress
Unit: psi
Time: 3
8/12/2020 11:55 AM

EM\Mech\Thermal analysis Section

EM\Thermal\Mechanical model check list	Y/N/?
Have mechanical models to understand the stress distributions in the windings been understood.	
Are full cycle stress analysis from winding, prestressing, cool down and powering (if needed) been carried out.	
Are the effects of mechanical tolerances on the EM design analyzed and understood	
Does the design need shimming	
Has provisions for shimming been included in the design	
Is the shinning capacity of the design known.	
Has the effect of material variability in the Iron been analyzed and understood.	
Is it understood if eddy currents an issue in any of the magnet components	
Has the any updated magnet design information an a result of this analysis been recorded in the requirements folder .	
Have persistent current effects on field quality been analyzed.	
For combined magnets has the inductance coupling matrix been calculated.	
Has a protection strategy been defined?	

EM\Mechanical analysis details 3

Combined magnet coupled Induction table

For combined magnets add Induction coupling matrix here

EM\Mech design analysis Summary

Magnet design information	Func 1		`
The magnet design info from	Hyperlink		
The magnet design intent is	New		
The magnet model name is	Q2PF		
The number of magnets required is	1		
General Magnet Spec			
Bagnetic length =	TBD	(m)	
Bore tube outer-dia =	TBD	(mm)	
Bore field (B or G) =	TBD	(T),(T/m),(T/m2)	
Field integral =	TBD	(T.m),(T),(T/m)	
Coil aperture IR or pole gap =	TBD	(mm)	
Ramp rate =	TBD	(T/s)	
Operating temperature =	TBD	(K)	
Total ampere turns =	TBD	(Aturns)	
Total number of num Layers =	TBD		
Layer function =	TBD		
This layer index =	TBD		
Number of turns per pole =	TBD		
Current =	TBD	(A)	
Inductance =	TBD	(H)	
Stored energy =	TBD	(MJ)	
Resistance =	TBD	(mOhm)	
Engineering current density =	TBD	(A/mm2)	
Power dissipation =	TBD	(W)	
Peak field in winding =	TBD	(T)	
Magnet bore Harmonics			
Analysis radius R_A Analysis current I_A =	TBD	(mm) (A)	
Field at I_A and R_A=	TBD	(T)	
Design harmonics allowed multipoles =	TBD	(10-4)	
Design harmonics nonallowed multipoles =	TBD	(10-4)	
Xtalk and fringe fields			
Xtalk Location (x,y,z) =	TBD	(mm,mm,mm)	
Xtalk analysis radius R_A, Analysis current I_A =	TBD	(mm) (A)	
Xtalk Field at I_A and R_A=	TBD	(T)	
Xtalk harmonics multipoles =	TBD	(10-4)	
Location of Fringe filed R or Location (x,y,z) =	TBD	(mm)	
Value of fringe field at target location =	TBD	(T)	
SC Cables, Strand's =			
Superconductor type used =	TBD		
Conductor\cable used =	TBD		
Cu:Sc ratio =	TBD		
Critical field of wire =	TBD	(T)	
Xsectional area of wire =	TBD	(mm2)	
Critical current of wire =	TBD	(A)	
Critical temperature =	TBD	(K)	
Operating margin =	TBD	%	

Issues & outstanding work needed

Add here as needed

Inductance – for combined magnets this is a matrix. Need coupling coefficients

Magnet heat load\Cooling			
Operational temp of magnet =	TBD	(K)	
Max operational temp of magnet =	TBD	(K)	
Nominal operating heat loads =	TBD	(W)	
Peak quench heat loads =	TBD	(W)	
Peak quench heat load duration =	TBD	(s)	
Coils			
Coil width in X (od or dx) =	TBD	(m)	
Coil height (od or dy) =	TBD	(m)	
Coil length dz =	TBD	(m)	
Mass of coils =	TBD	(Kg)	
Iron collar\Yoke			
Iron temp=	Cold	(Cold,Warm)	
Iron extent (od or dx) =	TBD	(m)	
Iron extent (od or dy) =	TBD	(m)	
Iron length dz =	TBD	(m)	
Yoke mass =	TBD	(Kg)	
Cold Mass			
Cold mass extent (od or dx) =	TBD	(m)	
Cold mass extent (od or dy) =	TBD	(m)	
Cold mass length dz =	TBD	(m)	
Coldmass mass =	TBD	(Kg)	
Fully Assembled insertion			
Complete magnet width dx =	TBD	(m)	
Complete magnet height =	TBD	(m)	
Complete magnet length dz =	TBD	(m)	
Full assembly mass =	TBD	(Kg)	

Quench Analysis

Quench protection of EIC collared magnets

V. Marinozzi 11/17/2023

Quench Analysis Section

Conceptual EM model check list	Y/N/?
Has a preliminary quench analysis like XQuench been carried out	
Is the production conductor, insulation, resin captured in the model	
Are the peak temperatures and stresses likely to damage the coil	
Is a more complex quench analysis needed	
Is a quench protection resistor needed.	
Are Quench heaters needed.	
Are diodes needed.	
Are there significant effects due to the interaction of this coil with surrounding coils when it quenches.	
Has the any updated magnet design information an a result of the quench analysis been recorded in the requirements folder	
Should be filled by Vittorio Marinozzi (FNAL)	

Quench Analysis

Conductor

Parameter	Value
Strand diameter [mm]	1.065
Number of strands	28
Cable bare width [mm]	15.1
Cable average height [mm]	1.9
Insulation thickness [mm]	0.15
RRR	(40) 70 – 100
Cu/NCu	1.5
Ic @ 4T, 1.9 K [A]	69000

Changed after Q2pF study (JUNE) to 40

Dump resistor assumptions

- 37.5 mΩ is the preference
- 1 kV between magnet leads is the max limit

Courtesy Vittorio Marinozzi (FNAL)

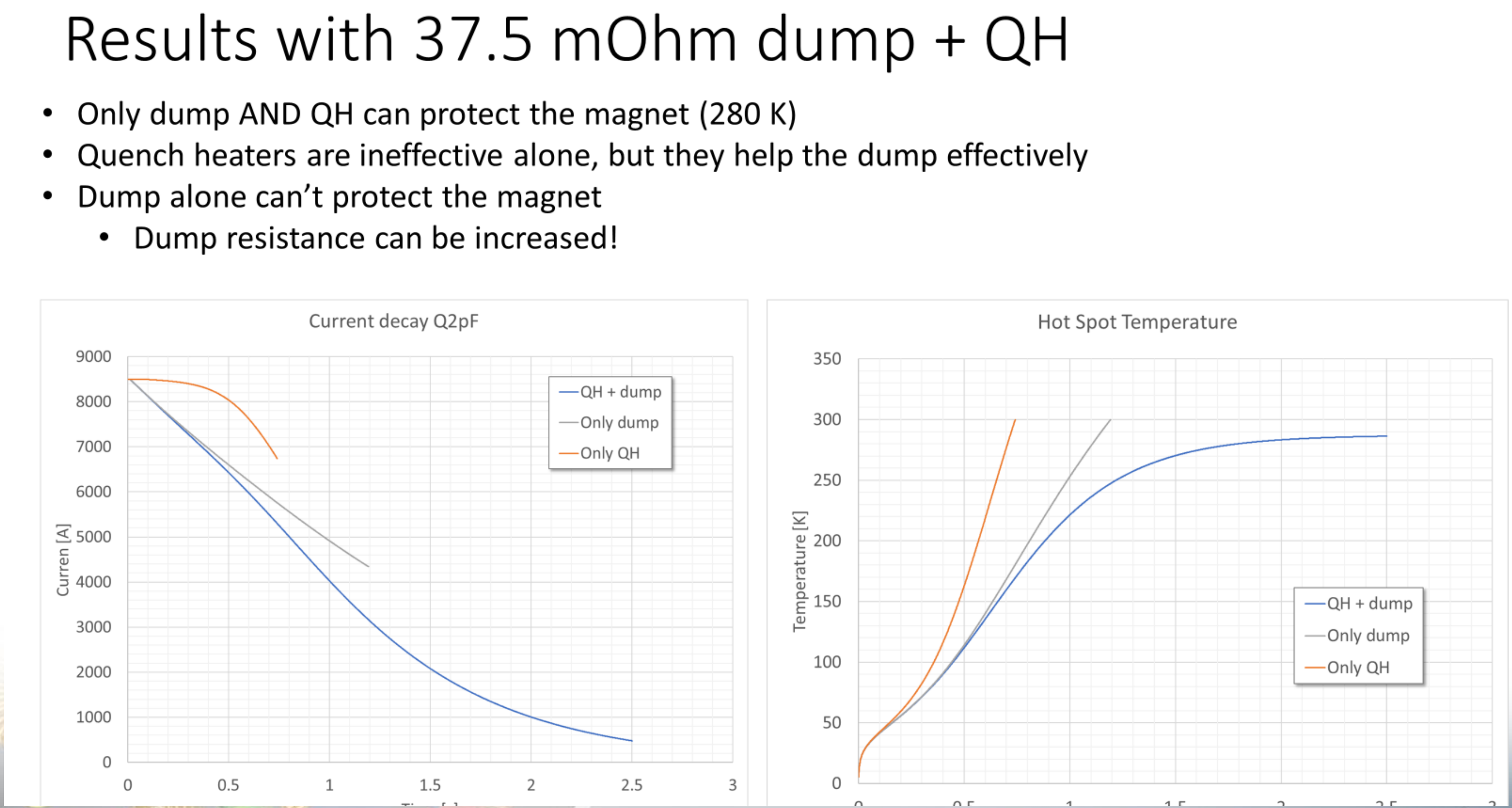
Quench simulation software: QLASA

- Simulations made with QLASA
  - Faster feedback, easier to implement cold diodes to separate the coils
  - No AC losses, no dynamic effect on inductance
  - QH delay time is an input (from quench detection)
  - It’s 3D (quench propagates in 3 dimensions after being induced by QH)
  - Fully adiabatic (no helium cooling effect)

Courtesy Vittorio Marinozzi (FNAL)

Q2pF quench protection

- Current: 8500 A; Inductance: 75 mH



Results with 37.5 mOhm dump + QH

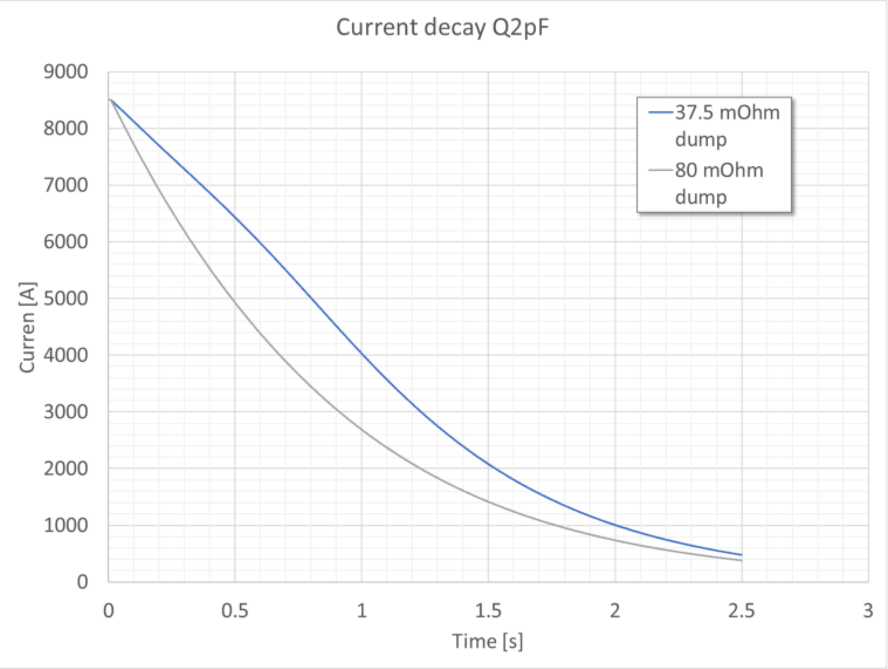
- Only dump AND QH can protect the magnet (280 K)
- Quench heaters are ineffective alone, but they help the dump effectively
- Dump alone can’t protect the magnet
  - Dump resistance can be increased!

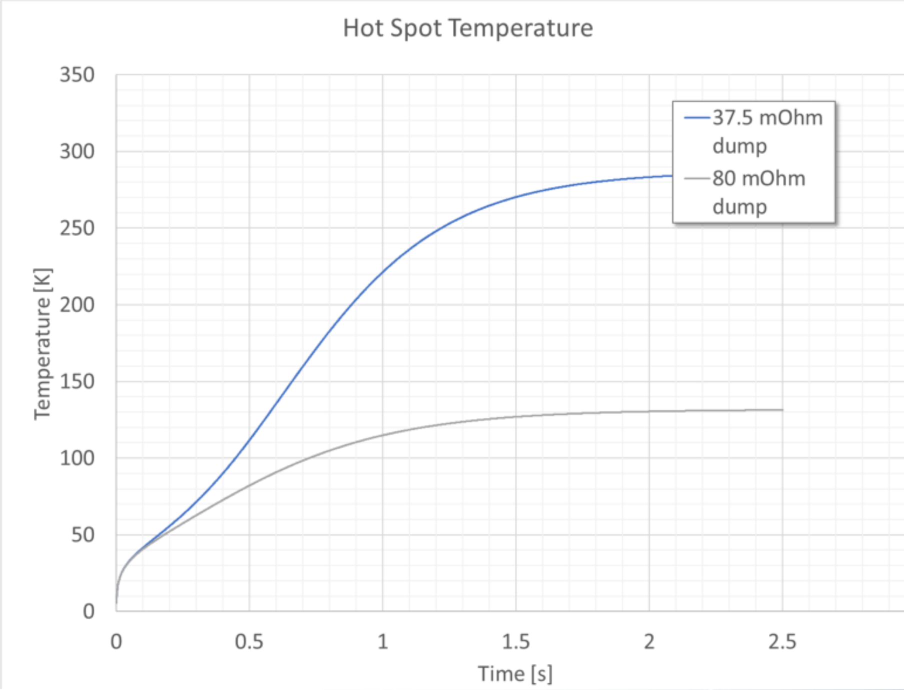
Courtesy Vittorio Marinozzi (FNAL)

Q2pF quench protection (contd.)

Results with 80 mOhm dump + QH

- Higher dump much more effective
- Voltage: 680 V between leads





Courtesy Vittorio Marinozzi (FNAL)

Q2pF analysis with LEDET

- 2D lumped loop
- Real cos-theta geometry
- Focus on coupling currents (CLIQ)
- Can simulate QH with insulation
- Computes inductance independently
- Magnetic field from ROXIE
- Material properties up to 1000 K and beyond (reliable up to 500 K)

Courtesy Vittorio Marinozzi (FNAL)

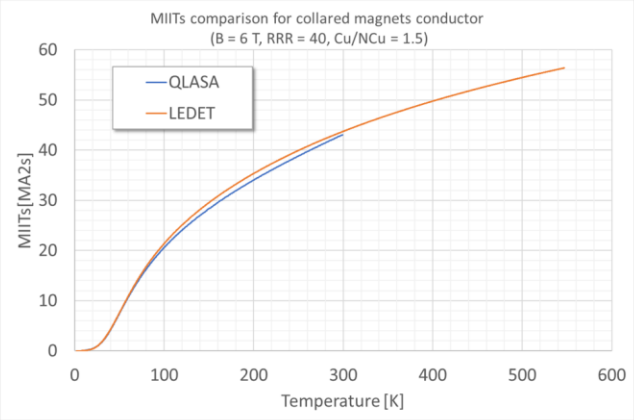
Assumptions for fair comparison

- I made simulations so that they are as similar as possible
- Fixed QH delay: 60 ms
- QH cover 75% of the turns of the outer layer
- No coupling currents
- Inductance rescaled to match 75 mH (LEDET computes 68 mH)

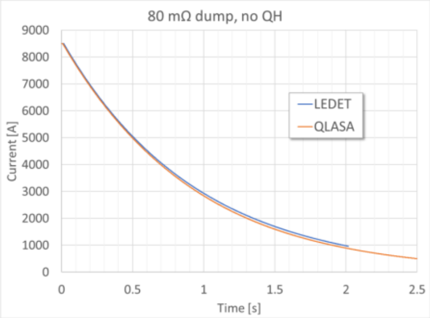
Courtesy Vittorio Marinozzi (FNAL)

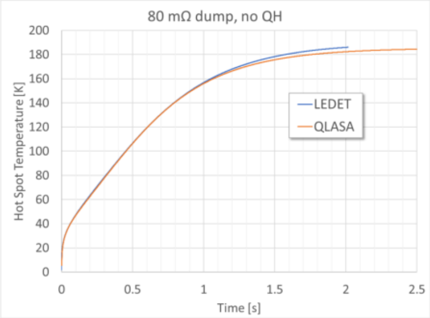
Q2pF quench protection (contd.)

MIITs comparison

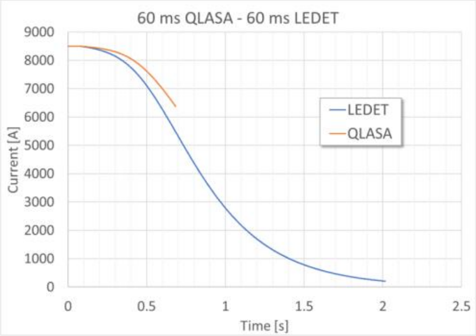


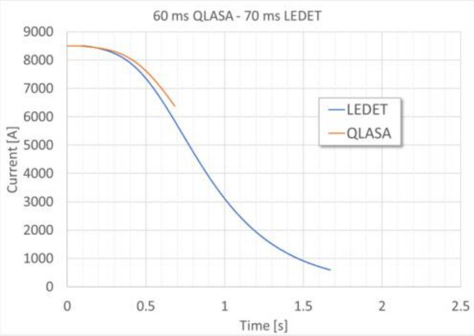
Current decay and Hot Spot comparison



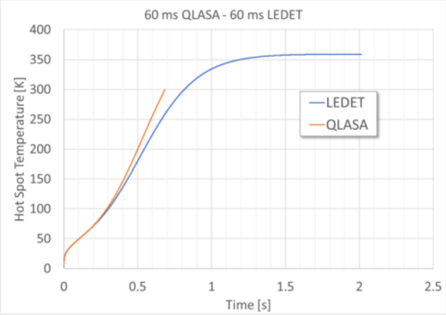


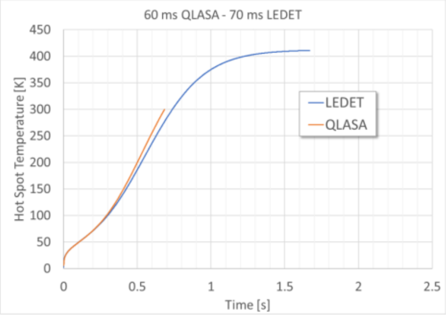
No dump comparison





No dump comparison





Courtesy Vittorio Marinozzi (FNAL)

Quench analysis Summary

Magnet design information	Func 1		`
The magnet design info from	Hyperlink		
The magnet design intent is	New		
The magnet model name is	Q2PF		
The number of magnets required is	1		
General Magnet Spec			
Bagnetic length =	TBD	(m)	
Bore tube outer-dia =	TBD	(mm)	
Bore field (B or G) =	TBD	(T),(T/m),(T/m2)	
Field integral =	TBD	(T.m),(T),(T/m)	
Coil aperture IR or pole gap =	TBD	(mm)	
Ramp rate =	TBD	(T/s)	
Operating temperature =	TBD	(K)	
Total ampere turns =	TBD	(Aturns)	
Total number of num Layers =	TBD		
Layer function =	TBD		
This layer index =	TBD		
Number of turns per pole =	TBD		
Current =	TBD	(A)	
Inductance =	TBD	(H)	
Stored energy =	TBD	(MJ)	
Resistance =	TBD	(mOhm)	
Engineering current density =	TBD	(A/mm2)	
Power dissipation =	TBD	(W)	
Peak field in winding =	TBD	(T)	
Magnet bore Harmonics			
Analysis radius R_A Analysis current I_A =	TBD	(mm) (A)	
Field at I_A and R_A=	TBD	(T)	
Design harmonics allowed multipoles =	TBD	(10-4)	
Design harmonics nonallowed multipoles =	TBD	(10-4)	
Xtalk and fringe fields			
Xtalk Location (x,y,z) =	TBD	(mm,mm,mm)	
Xtalk analysis radius R_A, Analysis current I_A =	TBD	(mm) (A)	
Xtalk Field at I_A and R_A=	TBD	(T)	
Xtalk harmonics multipoles =	TBD	(10-4)	
Location of Fringe filed R or Location (x,y,z) =	TBD	(mm)	
Value of fringe field at target location =	TBD	(T)	
SC Cables, Strand's =			
Superconductor type used =	TBD		
Conductor\cable used =	TBD		
Cu:Sc ratio =	TBD		
Critical field of wire =	TBD	(T)	
Xsectional area of wire =	TBD	(mm2)	
Critical current of wire =	TBD	(A)	
Critical temperature =	TBD	(K)	
Operating margin =	TBD	%	

Issues & outstanding work needed

Will request the person at FNAL who did the quench analysis to update this table (Vittorio Marinozzi)

Magnet heat load\Cooling			
Operational temp of magnet =	TBD	(K)	
Max operational temp of magnet =	TBD	(K)	
Nominal operating heat loads =	TBD	(W)	
Peak quench heat loads =	TBD	(W)	
Peak quench heat load duration =	TBD	(s)	
Coils			
Coil width in X (od or dx) =	TBD	(m)	
Coil height (od or dy) =	TBD	(m)	
Coil length dz =	TBD	(m)	
Mass of coils =	TBD	(Kg)	
Iron collar\Yoke			
Iron temp=	Cold	(Cold,Warm)	
Iron extent (od or dx) =	TBD	(m)	
Iron extent (od or dy) =	TBD	(m)	
Iron length dz =	TBD	(m)	
Yoke mass =	TBD	(Kg)	
Cold Mass			
Cold mass extent (od or dx) =	TBD	(m)	
Cold mass extent (od or dy) =	TBD	(m)	
Cold mass length dz =	TBD	(m)	
Coldmass mass =	TBD	(Kg)	
Fully Assembled insertion			
Complete magnet width dx =	TBD	(m)	
Complete magnet height =	TBD	(m)	
Complete magnet length dz =	TBD	(m)	
Full assembly mass =	TBD	(Kg)	

Courtesy Vittorio Marinozzi (FNAL)

Design wrap up (Add current date here)

Current Design Summary

Magnet design information	Func 1		`
The magnet design info from	Hyperlink		
The magnet design intent is	New		
The magnet model name is	Q2PF		
The number of magnets required is	1		
General Magnet Spec			
Bagnetic length =	TBD	(m)	
Bore tube outer-dia =	TBD	(mm)	
Bore field (B or G) =	TBD	(T),(T/m),(T/m2)	
Field integral =	TBD	(T.m),(T),(T/m)	
Coil aperture IR or pole gap =	TBD	(mm)	
Ramp rate =	TBD	(T/s)	
Operating temperature =	TBD	(K)	
Total ampere turns =	TBD	(Aturns)	
Total number of num Layers =	TBD		
Layer function =	TBD		
This layer index =	TBD		
Number of turns per pole =	TBD		
Current =	TBD	(A)	
Inductance =	TBD	(H)	
Stored energy =	TBD	(MJ)	
Resistance =	TBD	(mOhm)	
Engineering current density =	TBD	(A/mm2)	
Power dissipation =	TBD	(W)	
Peak field in winding =	TBD	(T)	
Magnet bore Harmonics			
Analysis radius R_A Analysis current I_A =	TBD	(mm) (A)	
Field at I_A and R_A=	TBD	(T)	
Design harmonics allowed multipoles =	TBD	(10-4)	
Design harmonics nonallowed multipoles =	TBD	(10-4)	
Xtalk and fringe fields			
Xtalk Location (x,y,z) =	TBD	(mm,mm,mm)	
Xtalk analysis radius R_A, Analysis current I_A =	TBD	(mm) (A)	
Xtalk Field at I_A and R_A=	TBD	(T)	
Xtalk harmonics multipoles =	TBD	(10-4)	
Location of Fringe filed R or Location (x,y,z) =	TBD	(mm)	
Value of fringe field at target location =	TBD	(T)	
SC Cables, Strand's =			
Superconductor type used =	TBD		
Conductor\cable used =	TBD		
Cu:Sc ratio =	TBD		
Critical field of wire =	TBD	(T)	
Xsectional area of wire =	TBD	(mm2)	
Critical current of wire =	TBD	(A)	
Critical temperature =	TBD	(K)	
Operating margin =	TBD	%	

Magnet summary table

Add any notes here as needed

Magnet heat load\Cooling			
Operational temp of magnet =	TBD	(K)	
Max operational temp of magnet =	TBD	(K)	
Nominal operating heat loads =	TBD	(W)	
Peak quench heat loads =	TBD	(W)	
Peak quench heat load duration =	TBD	(s)	
Coils			
Coil width in X (od or dx) =	TBD	(m)	
Coil height (od or dy) =	TBD	(m)	
Coil length dz =	TBD	(m)	
Mass of coils =	TBD	(Kg)	
Iron collar\Yoke			
Iron temp=	Cold	(Cold,Warm)	
Iron extent (od or dx) =	TBD	(m)	
Iron extent (od or dy) =	TBD	(m)	
Iron length dz =	TBD	(m)	
Yoke mass =	TBD	(Kg)	
Cold Mass			
Cold mass extent (od or dx) =	TBD	(m)	
Cold mass extent (od or dy) =	TBD	(m)	
Cold mass length dz =	TBD	(m)	
Coldmass mass =	TBD	(Kg)	
Fully Assembled insertion			
Complete magnet width dx =	TBD	(m)	
Complete magnet height =	TBD	(m)	
Complete magnet length dz =	TBD	(m)	
Full assembly mass =	TBD	(Kg)	

Current Design Summary

Issues & outstanding work needed

Add here as needed

Appendices

Scope

The purpose of this review is to status the IR magnet designs.

Identify the baseline design and its parameters.

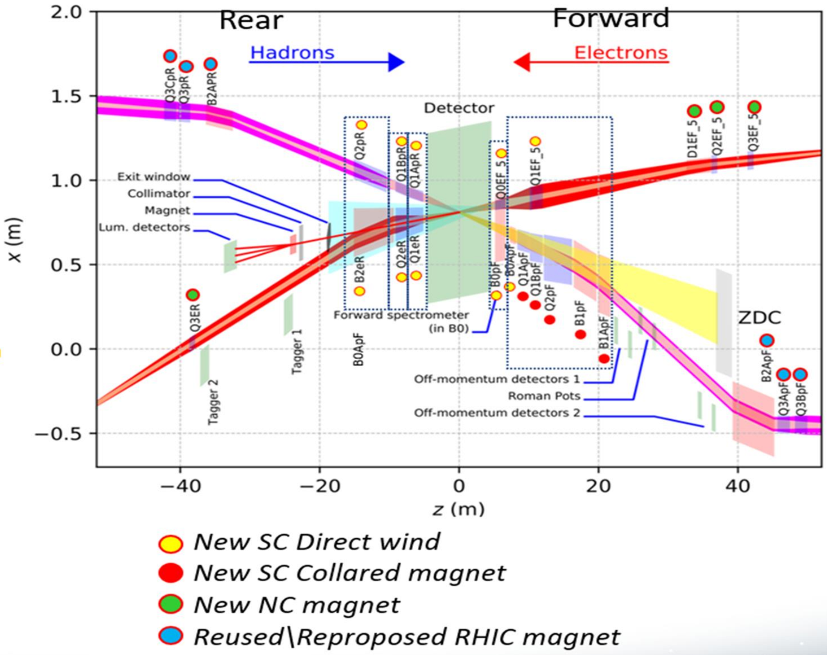
Align requirements with magnet design.

Inform the team of Progress made and work outstanding.

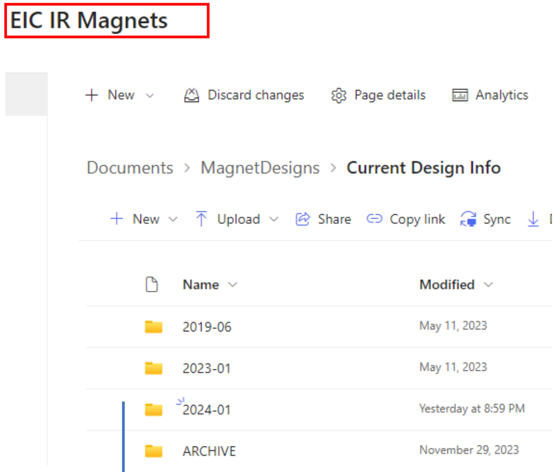
Utilize the knowledge and experience of your colleague to inform your designs

Formally commit the most design to the design archive.

PowerPoint Notes have some instructions also see design folder content in appendices .



Design Archive Info

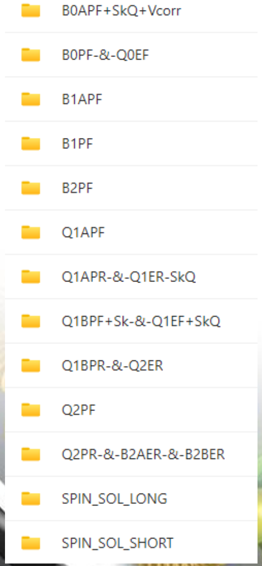

EIC IR Magnets

Documents > MagnetDesigns > Current Design Info

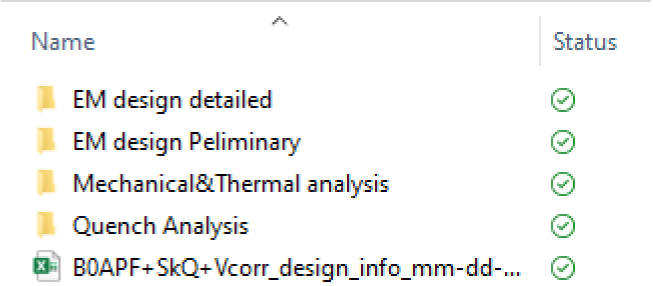
Name	Modified
2019-06	May 11, 2023
2023-01	May 11, 2023
2024-01	Yesterday at 8:59 PM
ARCHIVE	November 29, 2023

2024

Magnet folders

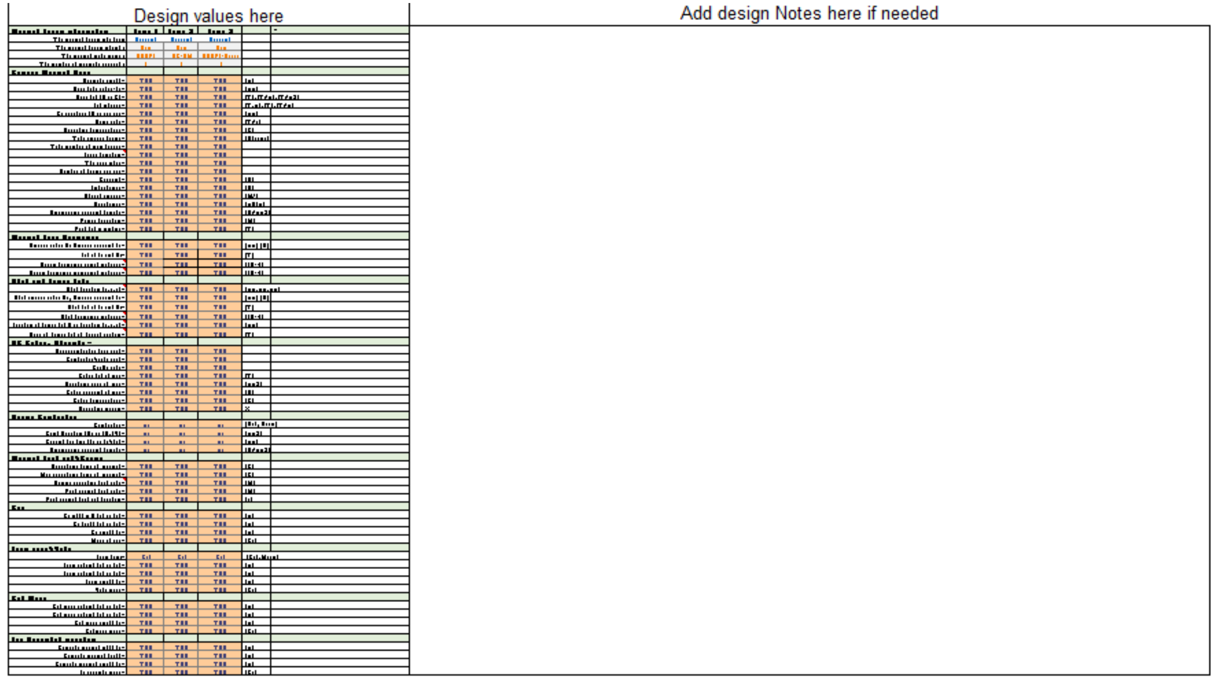

- B0APF+SkQ+Vcorr
- B0PF-&-Q0EF
- B1APF
- B1PF
- B2PF
- Q1APF
- Q1APR-&-Q1ER-SkQ
- Q1BPF+Sk-&-Q1EF+SkQ
- Q1BPR-&-Q2ER
- Q2PF
- Q2PR-&-B2AER-&-B2BER
- SPIN_SOL_LONG
- SPIN_SOL_SHORT

Populate folders and XLSX design book



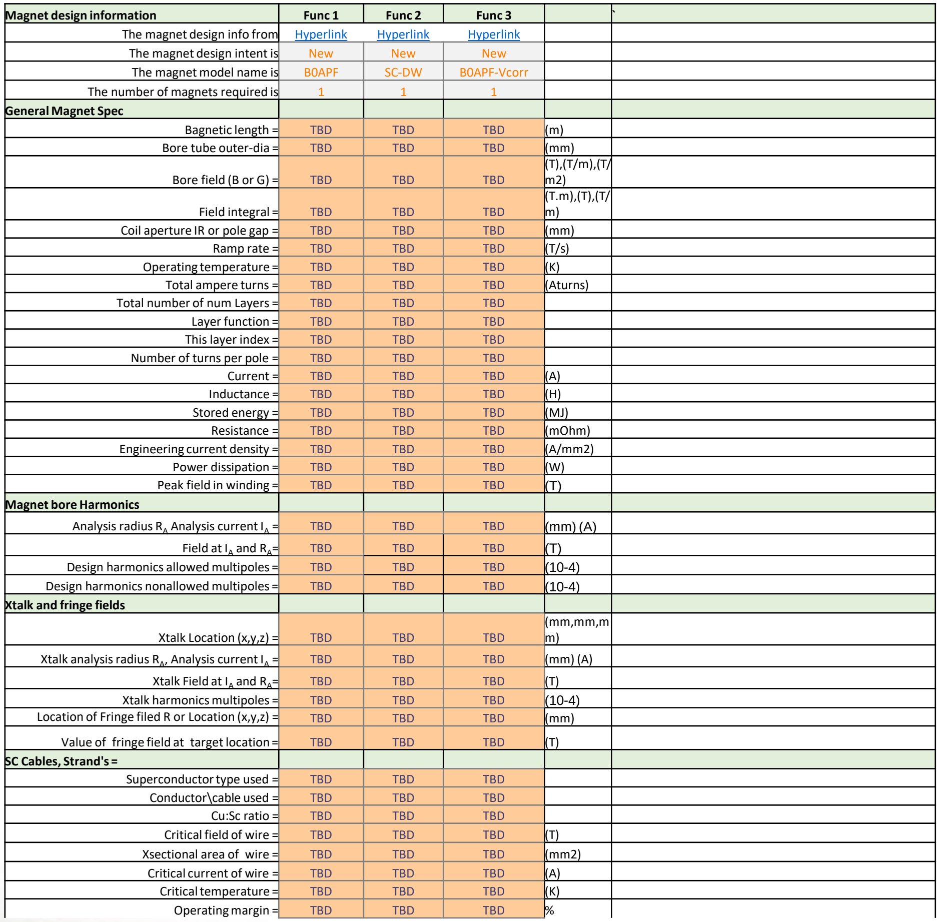
Name	Status
EM design detailed	✓
EM design Peliminary	✓
Mechanical&Thermal analysis	✓
Quench Analysis	✓
B0APF+SkQ+Vcorr_design_info_mm-dd-...	✓

XLSX design book


Design values here

Add design Notes here if needed

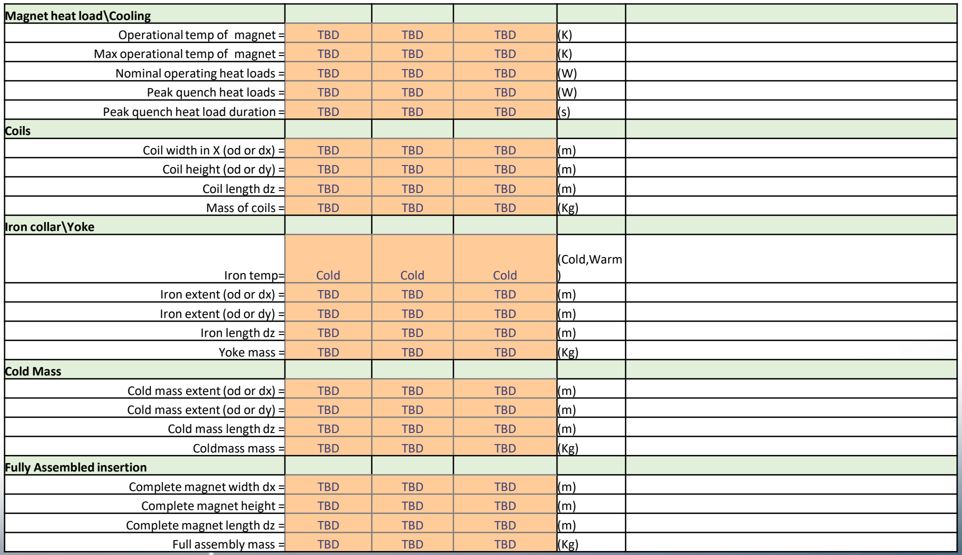
Design archive content



Magnet design information	Func 1	Func 2	Func 3		`
The magnet design info from	Hyperlink	Hyperlink	Hyperlink		
The magnet design intent is	New	New	New		
The magnet model name is	B0APF	SC-DW	B0APF-Vcorr		
The number of magnets required is	1	1	1		
General Magnet Spec					
Bagnetic length =	TBD	TBD	TBD	(m)	
Bore tube outer-dia =	TBD	TBD	TBD	(mm)	
Bore field (B or G) =	TBD	TBD	TBD	(T),(T/m),(T/m2)	
Field integral =	TBD	TBD	TBD	(T.m),(T),(T/m)	
Coil aperture IR or pole gap =	TBD	TBD	TBD	(mm)	
Ramp rate =	TBD	TBD	TBD	(T/s)	
Operating temperature =	TBD	TBD	TBD	(K)	
Total ampere turns =	TBD	TBD	TBD	(Aturns)	
Total number of num Layers =	TBD	TBD	TBD		
Layer function =	TBD	TBD	TBD		
This layer index =	TBD	TBD	TBD		
Number of turns per pole =	TBD	TBD	TBD		
Current =	TBD	TBD	TBD	(A)	
Inductance =	TBD	TBD	TBD	(H)	
Stored energy =	TBD	TBD	TBD	(MJ)	
Resistance =	TBD	TBD	TBD	(mOhm)	
Engineering current density =	TBD	TBD	TBD	(A/mm2)	
Power dissipation =	TBD	TBD	TBD	(W)	
Peak field in winding =	TBD	TBD	TBD	(T)	
Magnet bore Harmonics					
Analysis radius R_A Analysis current I_A =	TBD	TBD	TBD	(mm) (A)	
Field at I_A and R_A=	TBD	TBD	TBD	(T)	
Design harmonics allowed multipoles =	TBD	TBD	TBD	(10-4)	
Design harmonics nonallowed multipoles =	TBD	TBD	TBD	(10-4)	
Xtalk and fringe fields					
Xtalk Location (x,y,z) =	TBD	TBD	TBD	(mm,mm,mm)	
Xtalk analysis radius R_A, Analysis current I_A =	TBD	TBD	TBD	(mm) (A)	
Xtalk Field at I_A and R_A=	TBD	TBD	TBD	(T)	
Xtalk harmonics multipoles =	TBD	TBD	TBD	(10-4)	
Location of Fringe filed R or Location (x,y,z) =	TBD	TBD	TBD	(mm)	
Value of fringe field at target location =	TBD	TBD	TBD	(T)	
SC Cables, Strand's =					
Superconductor type used =	TBD	TBD	TBD		
Conductor\cable used =	TBD	TBD	TBD		
Cu:Sc ratio =	TBD	TBD	TBD		
Critical field of wire =	TBD	TBD	TBD	(T)	
Xsectional area of wire =	TBD	TBD	TBD	(mm2)	
Critical current of wire =	TBD	TBD	TBD	(A)	
Critical temperature =	TBD	TBD	TBD	(K)	
Operating margin =	TBD	TBD	TBD	%	

Magnet summary table

Add any notes here as needed



Magnet heat load\Cooling					
Operational temp of magnet =	TBD	TBD	TBD	(K)	
Max operational temp of magnet =	TBD	TBD	TBD	(K)	
Nominal operating heat loads =	TBD	TBD	TBD	(W)	
Peak quench heat loads =	TBD	TBD	TBD	(W)	
Peak quench heat load duration =	TBD	TBD	TBD	(s)	
Coils					
Coil width in X (od or dx) =	TBD	TBD	TBD	(m)	
Coil height (od or dy) =	TBD	TBD	TBD	(m)	
Coil length dz =	TBD	TBD	TBD	(m)	
Mass of coils =	TBD	TBD	TBD	(Kg)	
Iron collar\Yoke					
Iron temp=	Cold	Cold	Cold	(Cold,Warm)	
Iron extent (od or dx) =	TBD	TBD	TBD	(m)	
Iron extent (od or dy) =	TBD	TBD	TBD	(m)	
Iron length dz =	TBD	TBD	TBD	(m)	
Yoke mass =	TBD	TBD	TBD	(Kg)	
Cold Mass					
Cold mass extent (od or dx) =	TBD	TBD	TBD	(m)	
Cold mass extent (od or dy) =	TBD	TBD	TBD	(m)	
Cold mass length dz =	TBD	TBD	TBD	(m)	
Coldmass mass =	TBD	TBD	TBD	(Kg)	
Fully Assembled insertion					
Complete magnet width dx =	TBD	TBD	TBD	(m)	
Complete magnet height =	TBD	TBD	TBD	(m)	
Complete magnet length dz =	TBD	TBD	TBD	(m)	
Full assembly mass =	TBD	TBD	TBD	(Kg)	

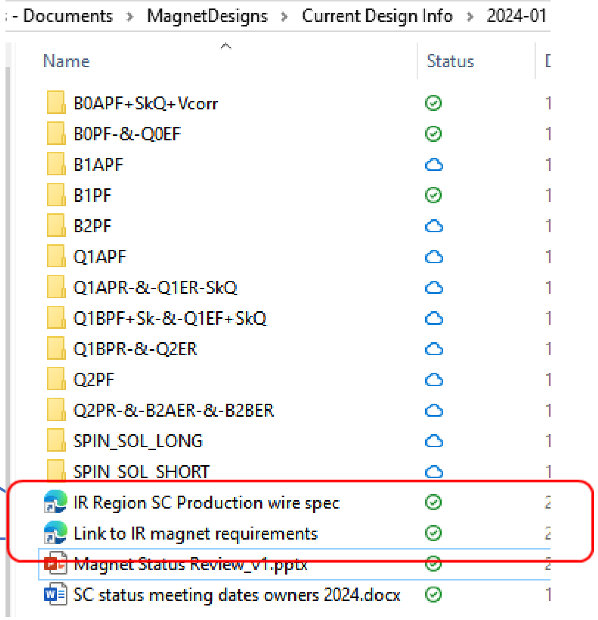
Useful Links

Location of shortcuts in 2024 SharePoint folder

Link to IR prod wire spec can be found in the 2024 folder

Link to IR Requirements can be found in the 2024 folder

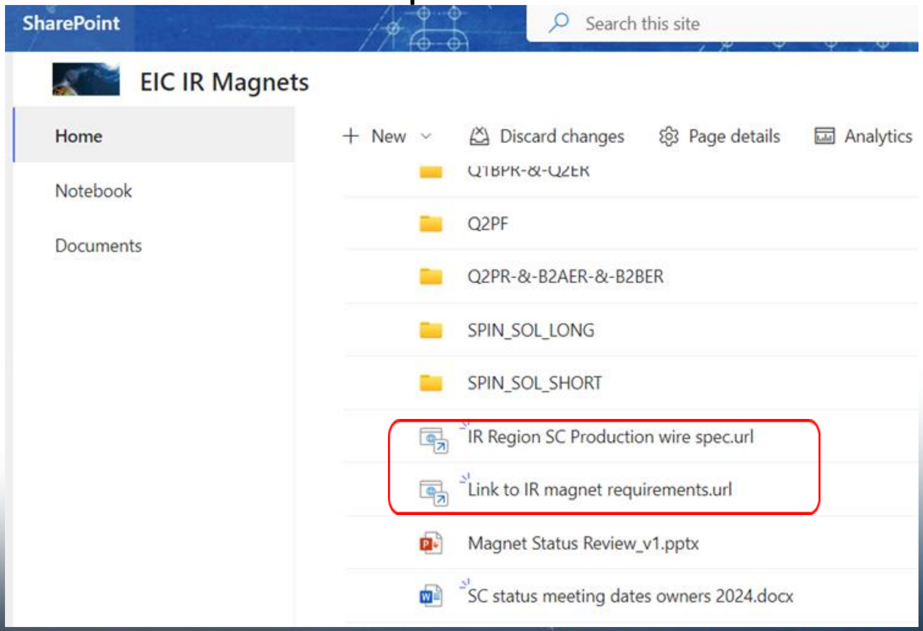
Windows view



- Documents › MagnetDesigns › Current Design Info › 2024-01

Name	Status
B0APF+SkQ+Vcorr	✓
B0PF-&-Q0EF	✓
B1APF	☁
B1PF	✓
B2PF	☁
Q1APF	☁
Q1APR-&-Q1ER-SkQ	☁
Q1BPF+Sk-&-Q1EF+SkQ	☁
Q1BPR-&-Q2ER	☁
Q2PF	☁
Q2PR-&-B2AER-&-B2BER	☁
SPIN_SOL_LONG	☁
SPIN_SOL_SHORT	☁
IR Region SC Production wire spec	✓
Link to IR magnet requirements	✓
Magnet Status Review_v1.pptx	✓
SC status meeting dates owners 2024.docx	✓

Sharepoint view



Q1BPR-&-Q2ER

Q2PF

Q2PR-&-B2AER-&-B2BER

SPIN_SOL_LONG

SPIN_SOL_SHORT

IR Region SC Production wire spec.url

Link to IR magnet requirements.url

Magnet Status Review_v1.pptx

SC status meeting dates owners 2024.docx