Progress in Q2pF Design (Symmetric Wedges)

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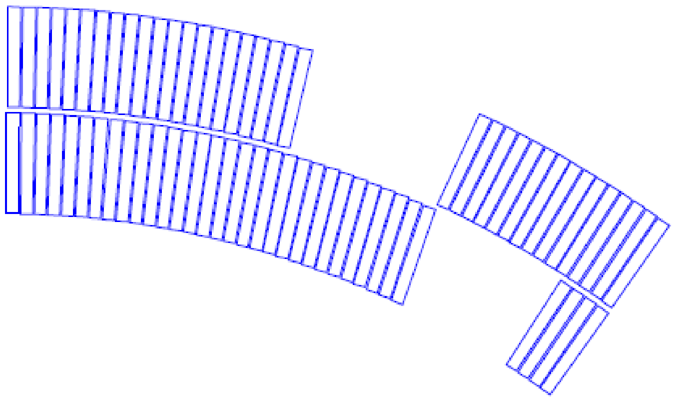
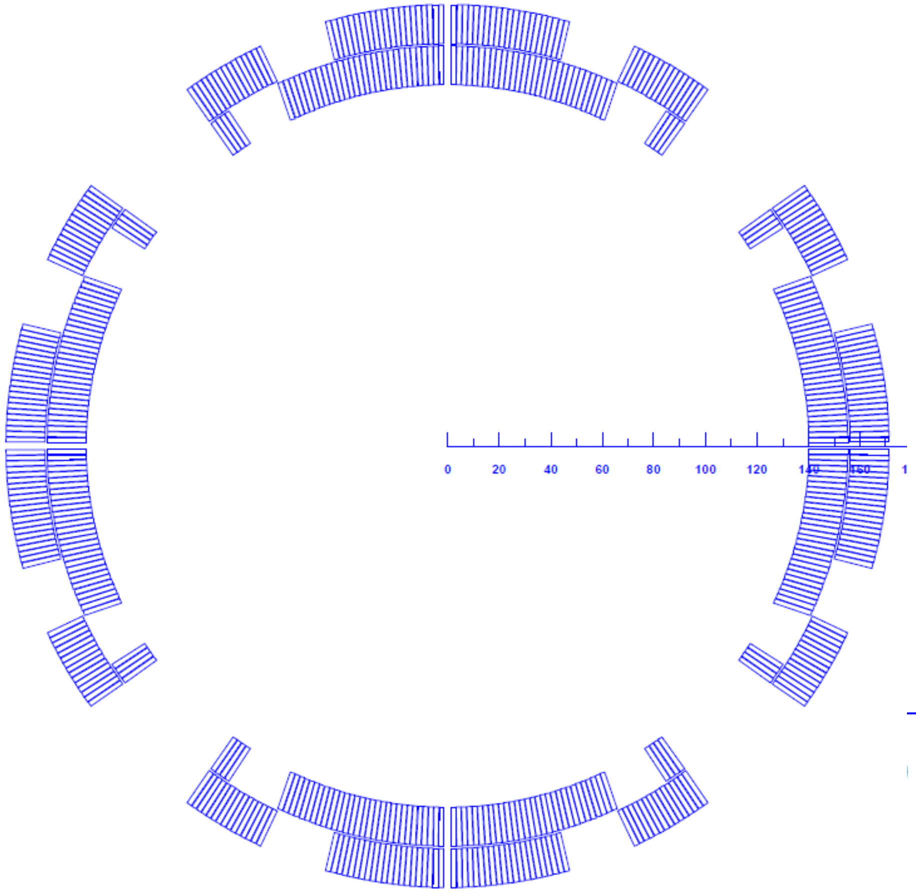
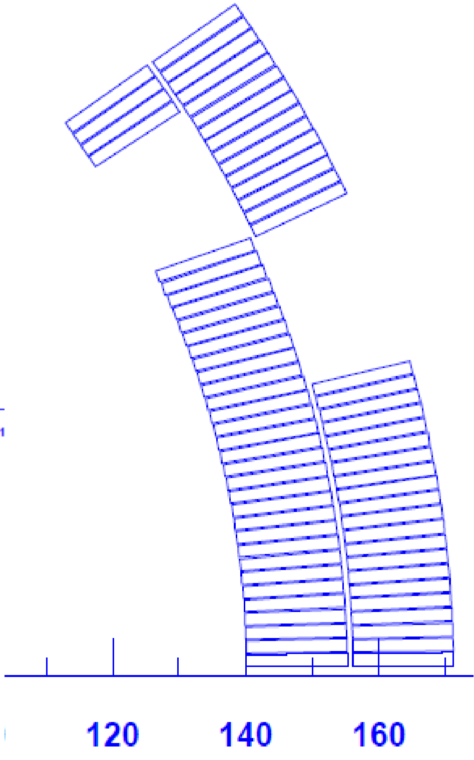
Review of the Current Design

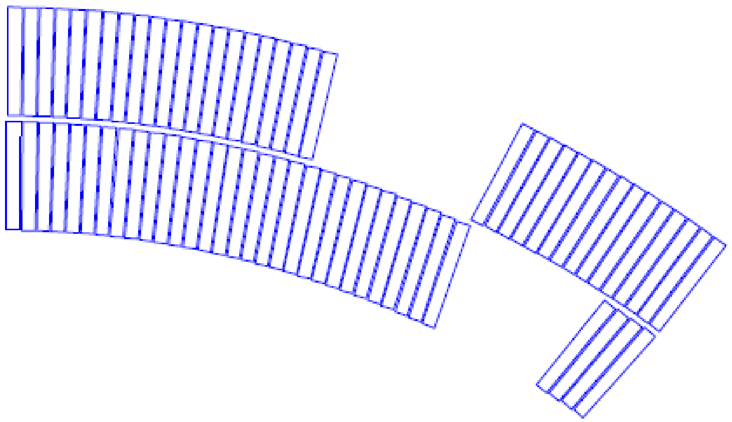


- Field Quality Optimized
- Peak field Optimized
- One wedge per layer only
- Poles of Outer and Inner layers well aligned
- Collaring process will provide pre-stress
- However, the wedges are not exactly symmetric

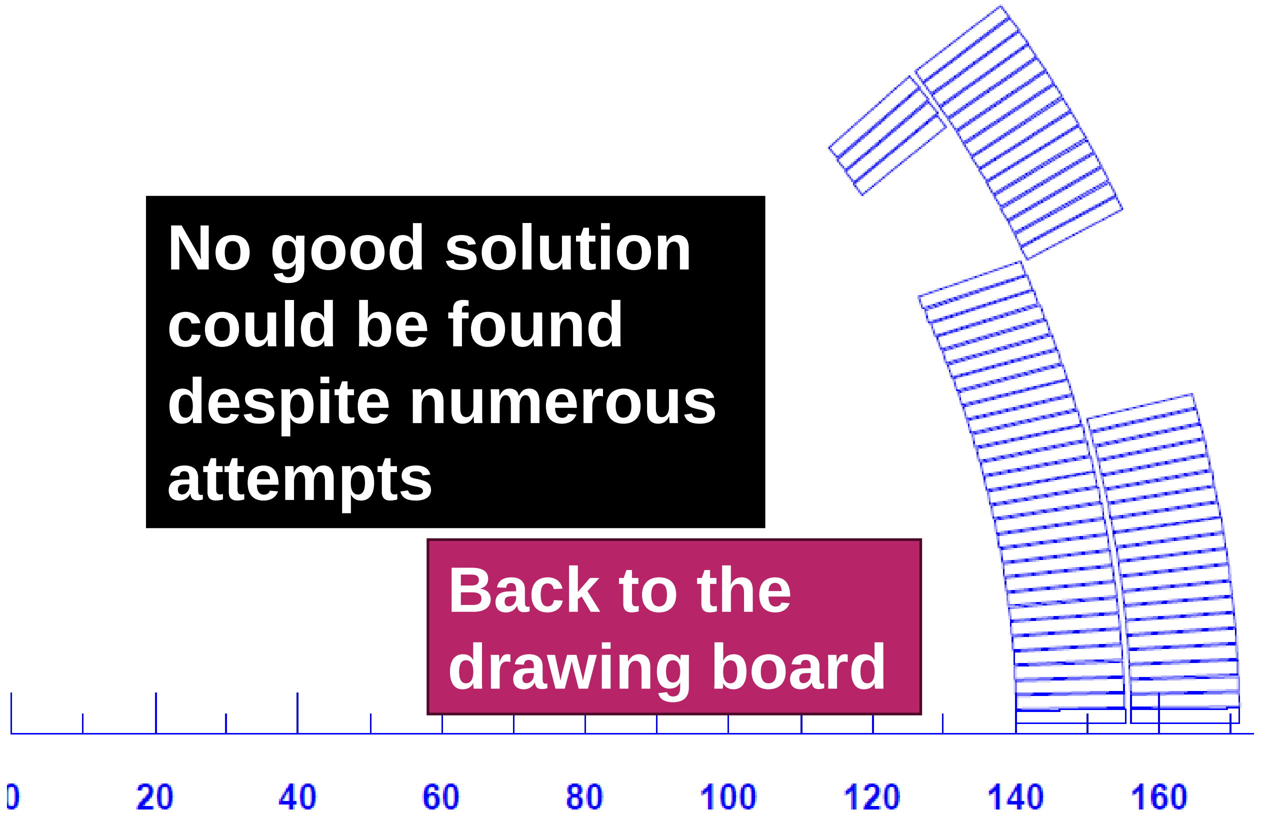




Design with Wedges Forced Symmetric (using ROXIE feature)



- Field Quality Optimized
- Peak field Optimized
- Poles of Outer and Inner aligned and together
- wedges are now exactly symmetric
- However, collaring process will not provide good pre-stress (note: parallel poles)



No good solution could be found despite numerous attempts

Back to the drawing board

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

Cable Geometry

EIC

LHC

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 @4.2K
3	EIC3618	19.4	1.773	2.027	36	115	3	EIC 36 STRAND @1.8K
4	EIC3642A	19.4	1.788	2.012	36	115	3	EIC 36 STRAND @4.2K 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

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

Cable Definition

EIC

LHC

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 @2K
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 @4.2K
	YELLONIN	CABLE01	STR01	NBTII	ALLPOLYIL	TRANS1	NONE	1.9	V6-1 DESIGN DIPOLE INNER
	YELLONOU	CABLE02	STR02	NBTIO	ALLPOLYOL	TRANS1	NONE	1.9	V6-1 DESIGN DIPOLE OUTER

Note: Keystones are reduced for EIC

Cales considered for EIC: "EICLHCB2K" and "EICLHCQ2K" (EICLHCB and EICLHCQ)
Similar to LHC inner: "YELLONIN" (CABLE01)

Brookhaven National Laboratory
Magnet Division
Ramesh Gupta
Cable Parameters of the EIC IR Cable Magnets
March 22, 2022
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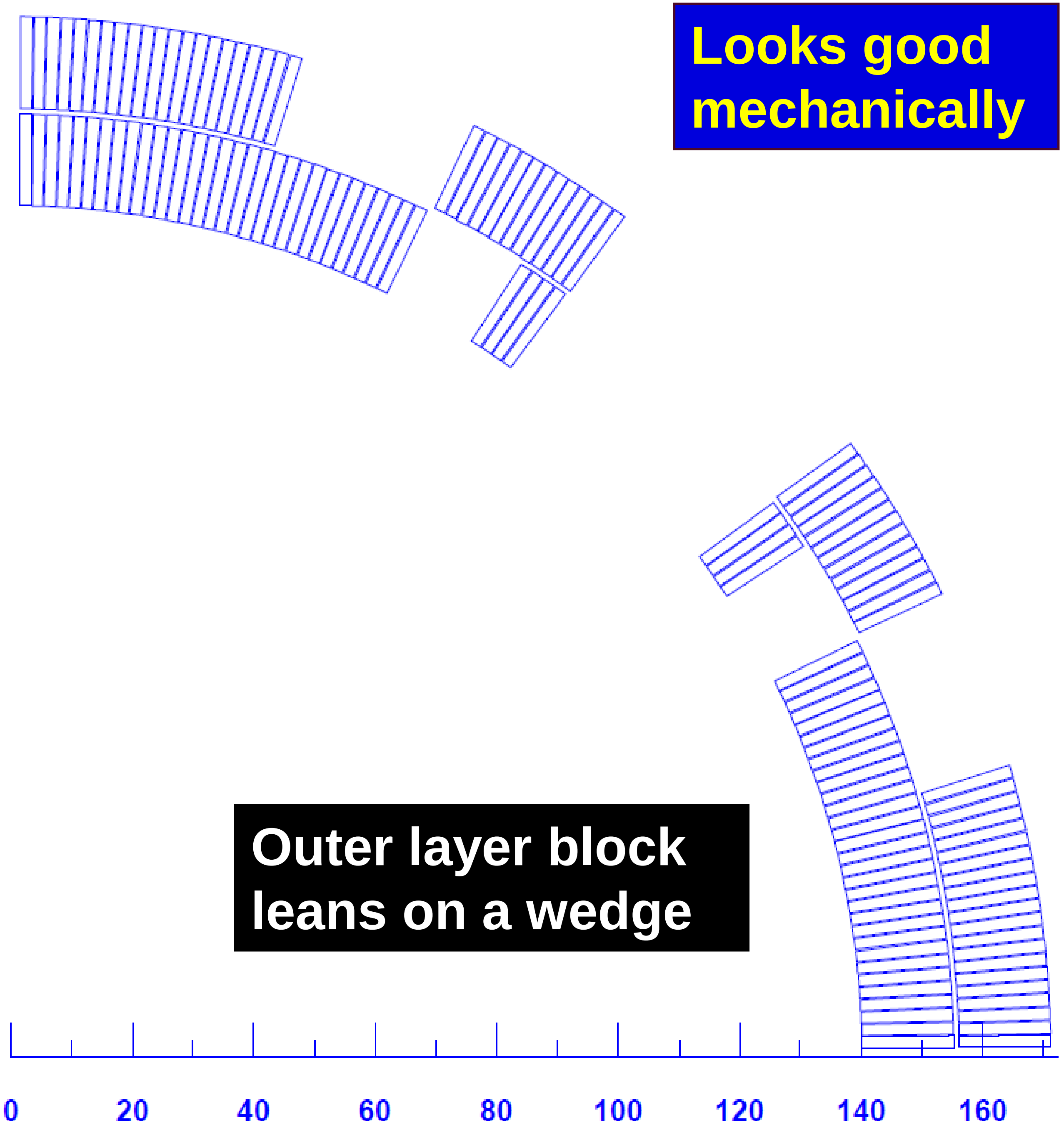
Try cable with different keystone ("Q" cable, instead of "B" cable)

Design with Wedges Forced Symmetric (with EIC "Q" cable)

Looks good mechanically

- **Field Quality Optimized**
- **Peak field Optimized**
- **Poles of Outer and Inner aligned and together**
- **wedges made exactly symmetric with ROXIE feature**
- **Collaring process should provide a good pre-stress**
  (note: wedge shape at poles)



Comparison with the Previous Design

Previous Design

Block Data 2D

No	Type	NCab	R	φ	α	Current	Cable name	N1	N2	I
1	Cos	30	140	0.5	0	-8500	EICLHCB2K	2	20	[illegible]
2	Cos	4	140	31.179	25.196	-8500	EICLHCB2K	2	20	[illegible]
3	Cos	21	156	0.5	0	-8500	EICLHCB2K	2	20	[illegible]
4	Cos	15	156	17	30	-8500	EICLHCB2K	2	20	[illegible]

No	Xl	Xu	Xs	String	Act	Block
1	3	9	7.2697	PHIR	2	2
2	25	33	32.8991	ALPHA	2	2
3	6	10	8.6236	PHIR	2	4
4	18	28	25.2508	ALPHA	2	4

New Design

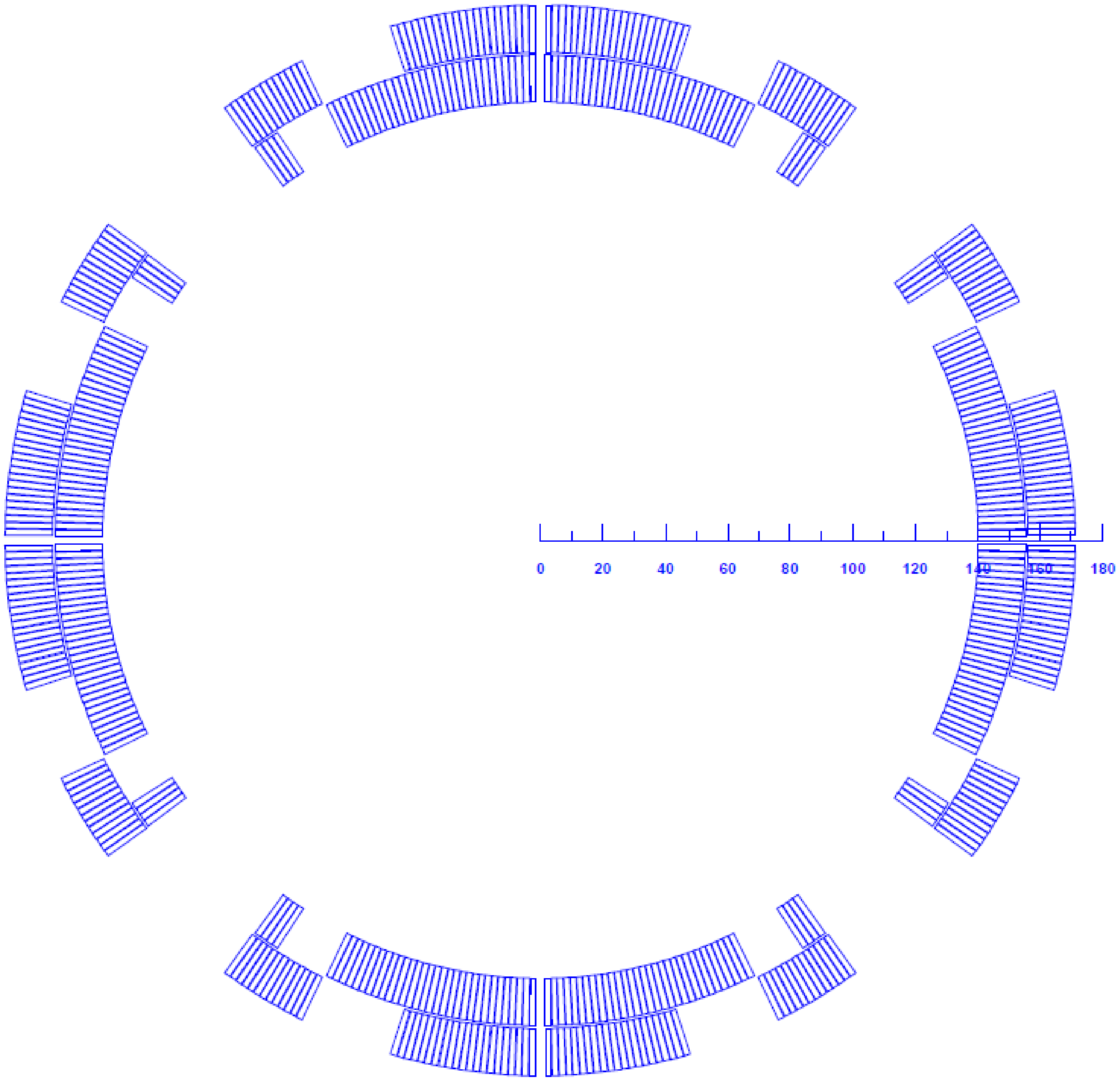
Block Data 2D

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

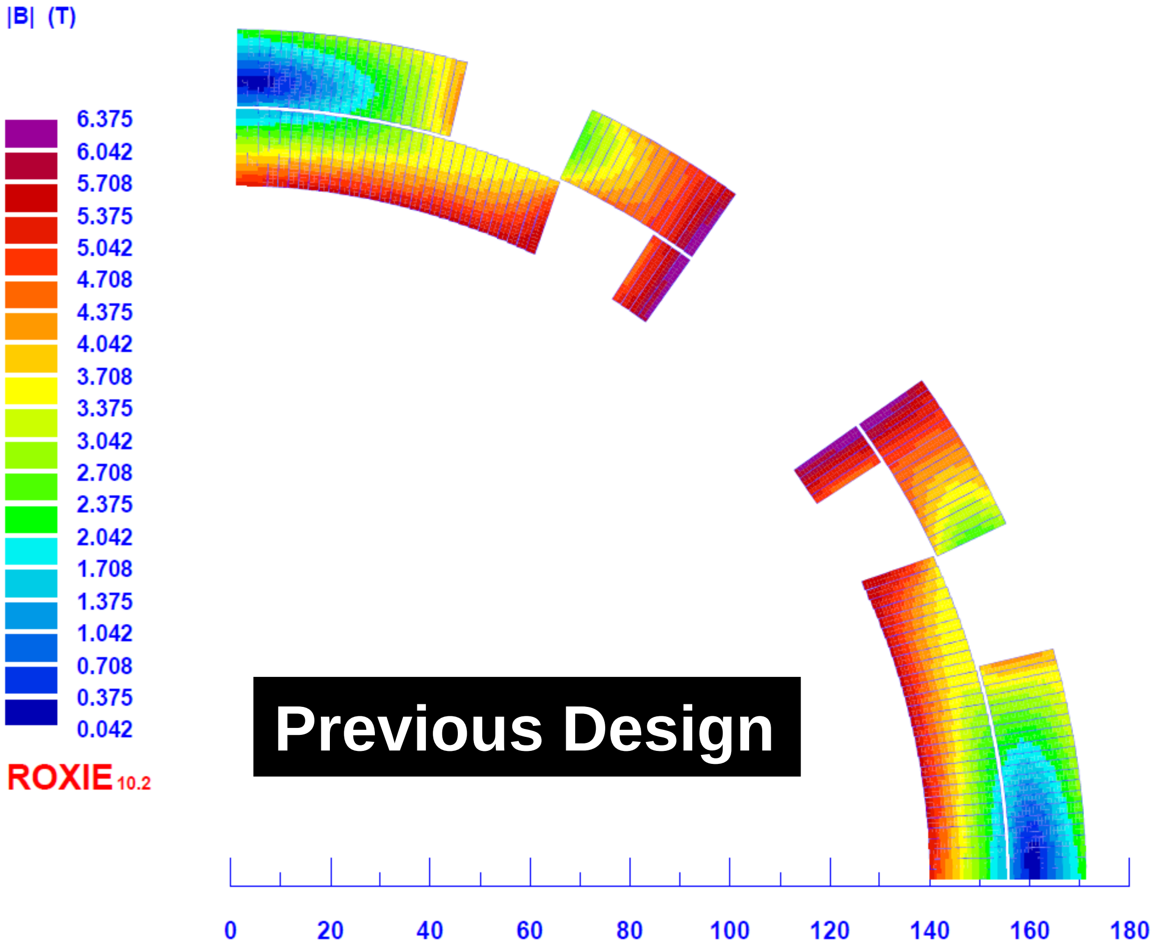
No	Xl	Xu	Xs	String	Act	Block
1	3	9	6.44	PHIRS	2	2
2	6	12	10.34	PHIRS	2	4
3	0	0	0	ALPHRS	2	2
4	0	0	0	ALPHRS	2	4

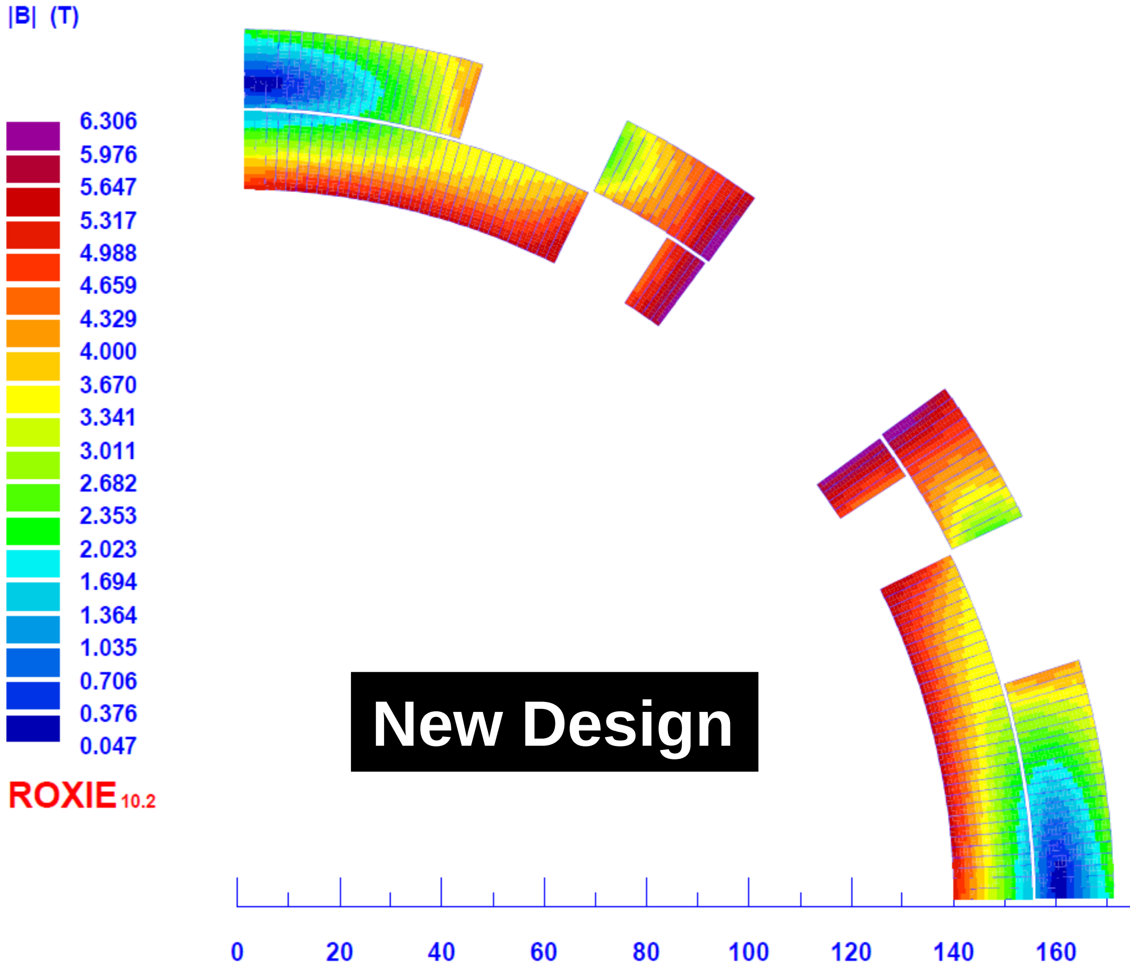
One turn less in total (69 instead of 70)
Inner layer has one more, outer two less

Full View of the Coil Design

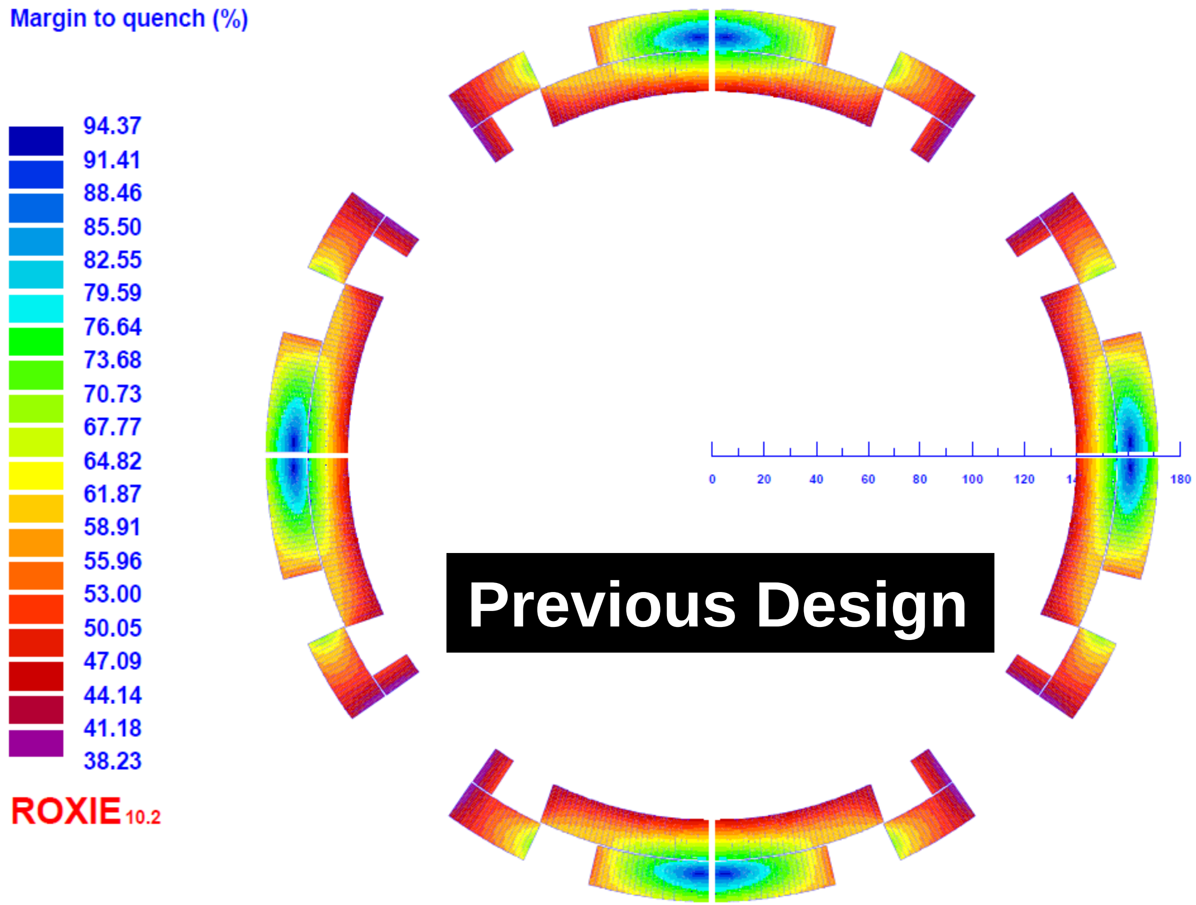


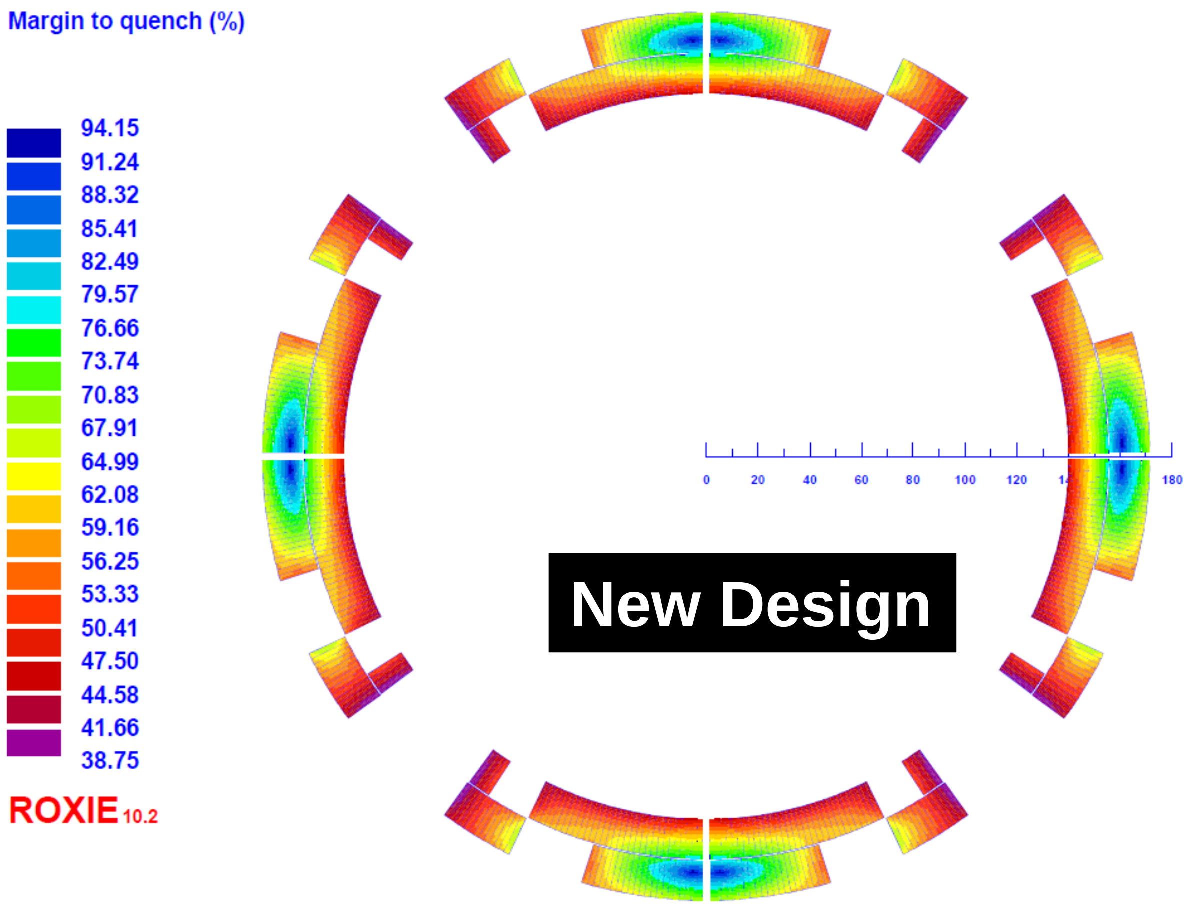
Comparison with the Previous Design (Peak Fields)





Comparison with the Previous Design (Quench Margin)





Comparison with the Previous Design (Field Harmonics)

Previous Design

```
HARMONIC ANALYSIS NUMBER ............................                1
MAIN HARMONIC .......................................                2
REFERENCE RADIUS (mm) ...............................          83.0000
X-POSITION OF THE HARMONIC COIL (mm) ...............            0.0000
Y-POSITION OF THE HARMONIC COIL (mm) ...............            0.0000
MEASUREMENT TYPE .......................... ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ...................       0.8991E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) .....................................         3.167908
MAGNET STRENGTH (T/(m^(n-1)) .......................          38.1676

NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:      -0.16188   b 2:  10000.00000   b 3:      0.00620
b 4:      -0.01232   b 5:      0.02472   b 6:      0.26673
b 7:      -0.00233   b 8:     -0.00086   b 9:      0.00075
b10:       0.04287   b11:     -0.00012   b12:     -0.00000
b13:      -0.00002   b14:     -0.57513   b15:     -0.00000
b16:      -0.00000   b17:     -0.00000   b18:      0.01593
```

New Design

```
HARMONIC ANALYSIS NUMBER ............................                1
MAIN HARMONIC .......................................                2
REFERENCE RADIUS (mm) ...............................          83.0000
X-POSITION OF THE HARMONIC COIL (mm) ...............            0.0000
Y-POSITION OF THE HARMONIC COIL (mm) ...............            0.0000
MEASUREMENT TYPE .......................... ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ...................       0.6776E-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
```

A good 2-d solution with symmetric wedges found.
We are now good to resume with the 3-d optimization.