Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

3-d Optimization of the Magnetic Design of Q2pF

Ramesh Gupta

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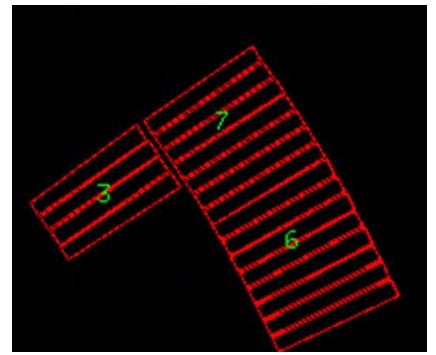
@BrookhavenLab

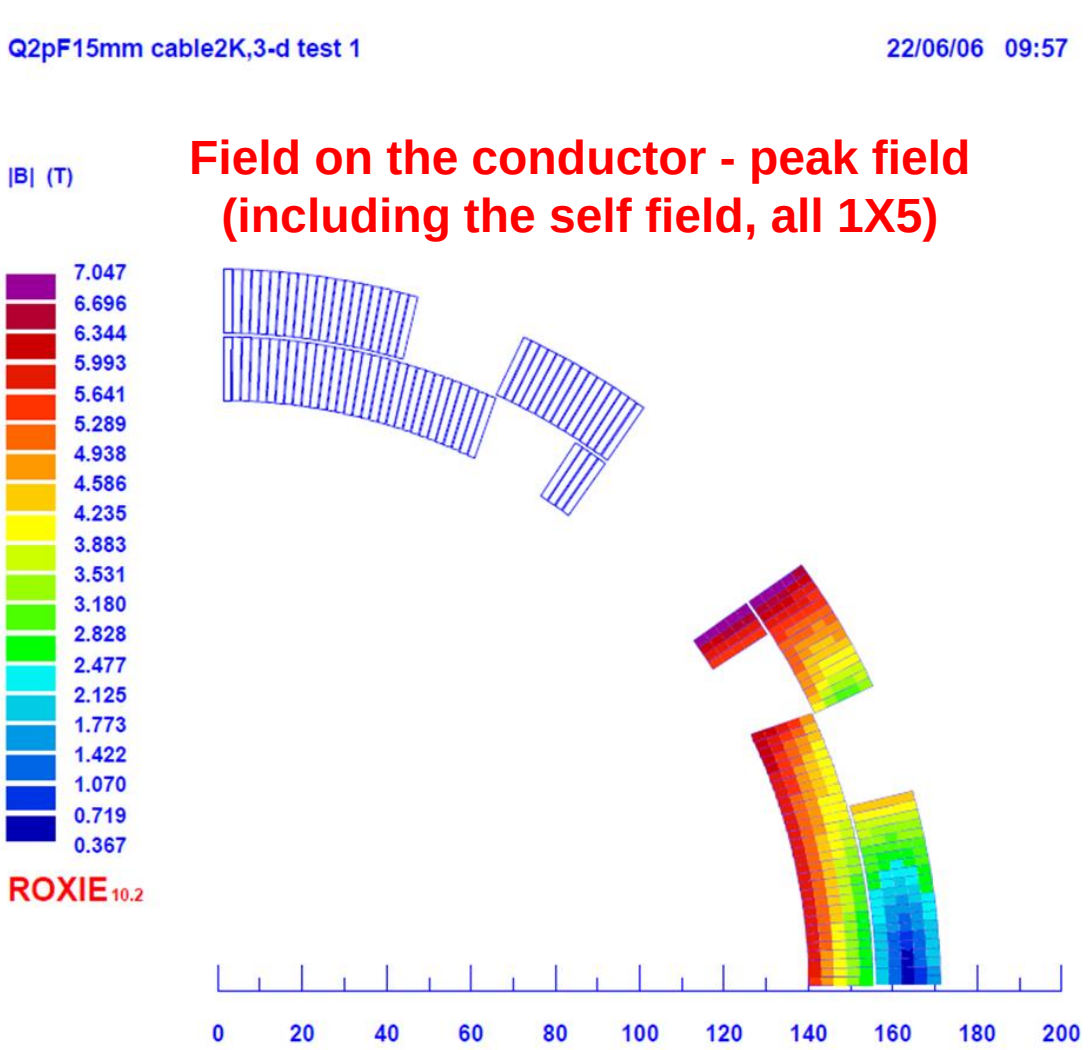
Overview

- First optimization of the End Design of Q2pF
  - ➢ Attempt to make peak field in the Ends within a few percentage of the 2-d peak
  - ➢ A higher peak field reduces the margin
- Ends also have small integrated harmonics so that the straight section (body) and Ends of the magnet can be optimized independently
- End turns should also be easy to wind with minimum strain on the conductor.
- Initial results are encouraging and provides a good basis for the next iteration.

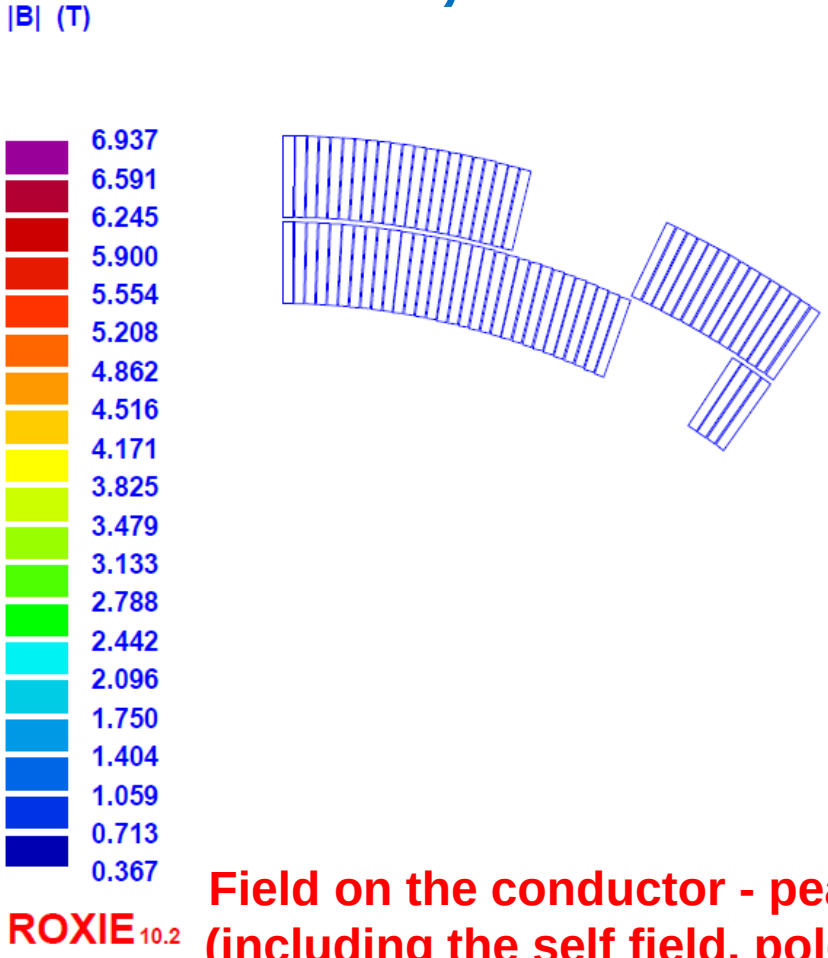
Peak Field in the Body of the Magnet (must have sufficient subdivision and must include self field, both in 2-d and 3-d)

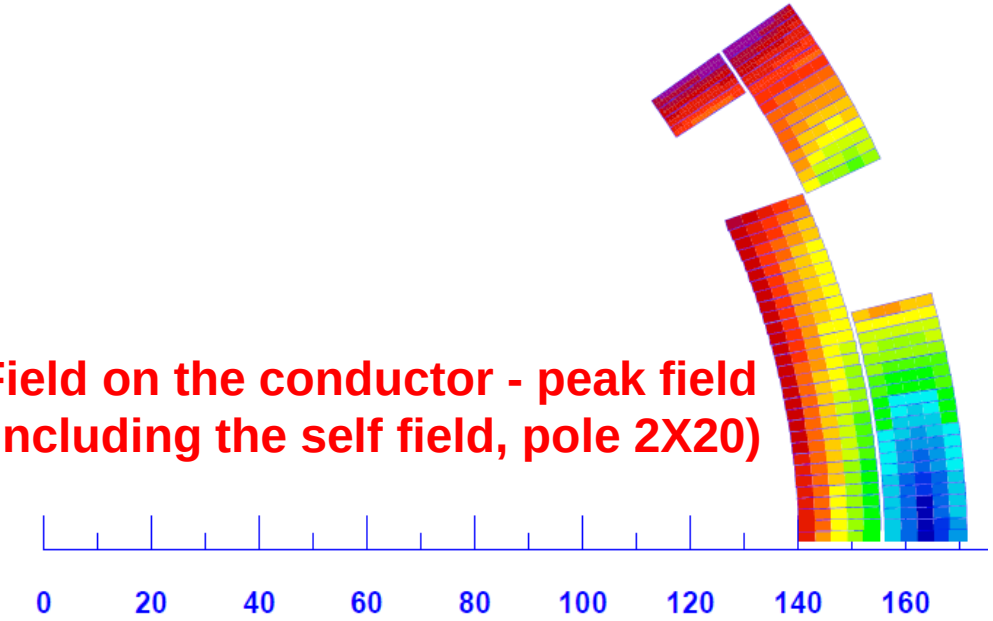
(#3 & #7)





Field on the conductor - peak field (including the self field, all 1X5)

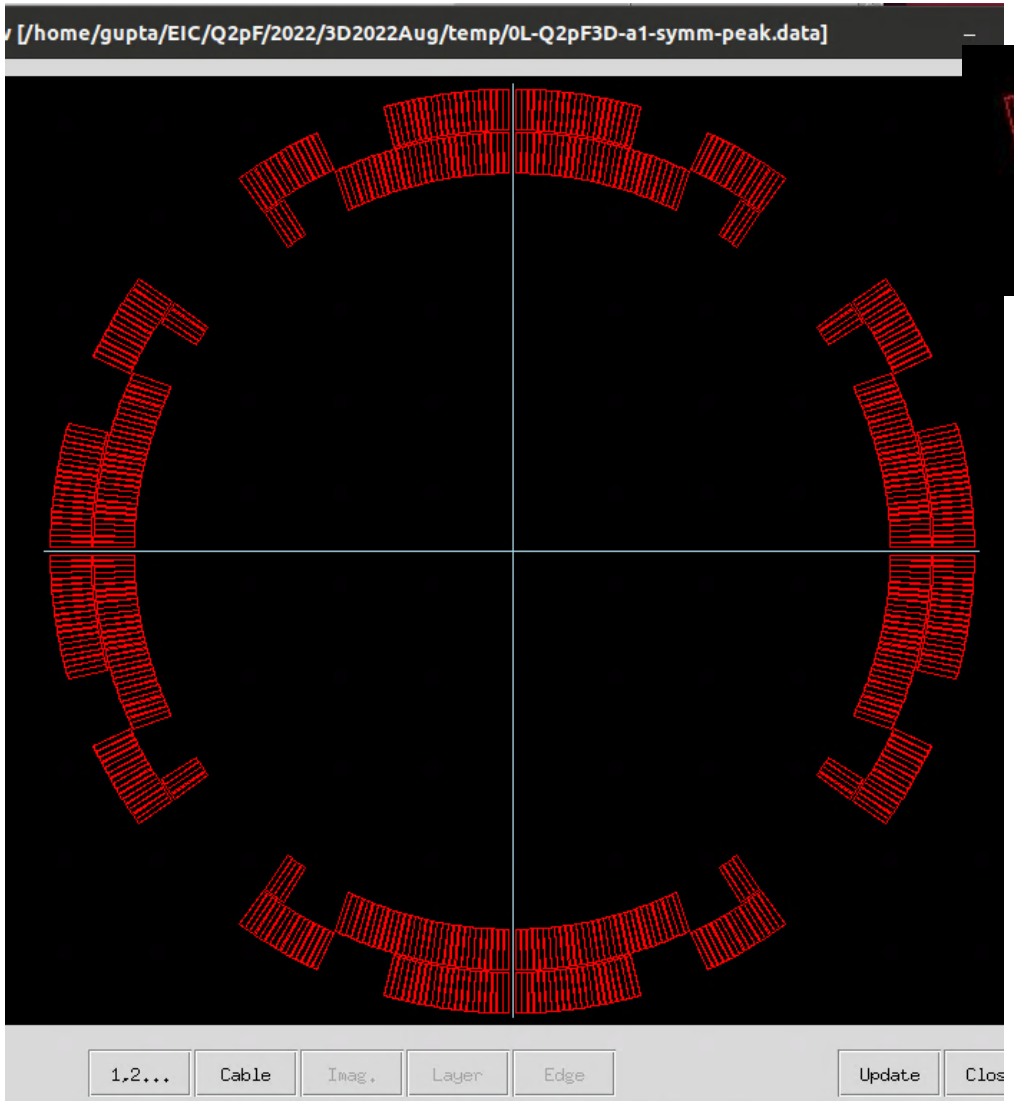


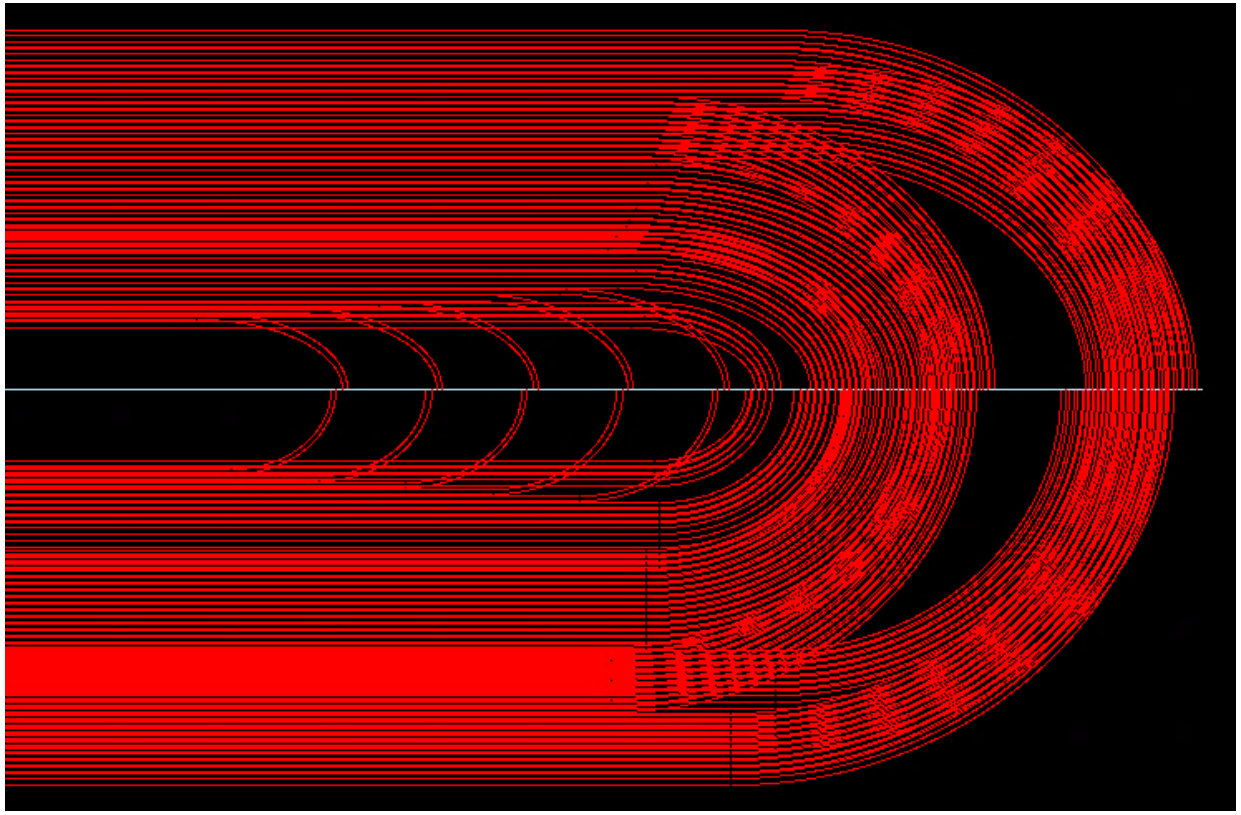


Field on the conductor - peak field (including the self field, pole 2X20)

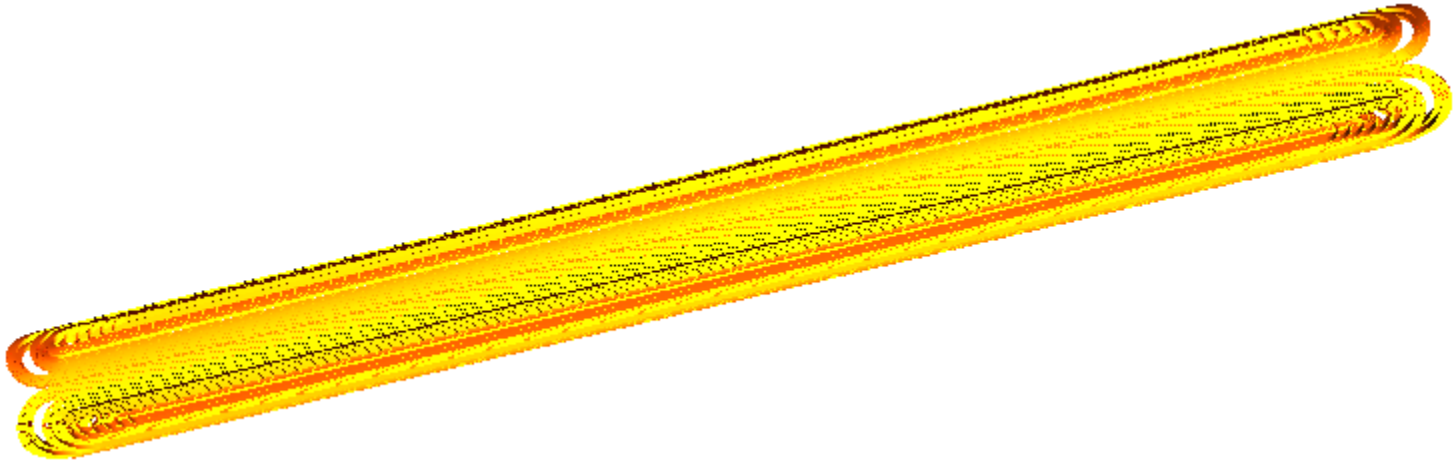
Due to the required computational time in 3-d, perhaps ~0.1 T is the uncertainty in the results

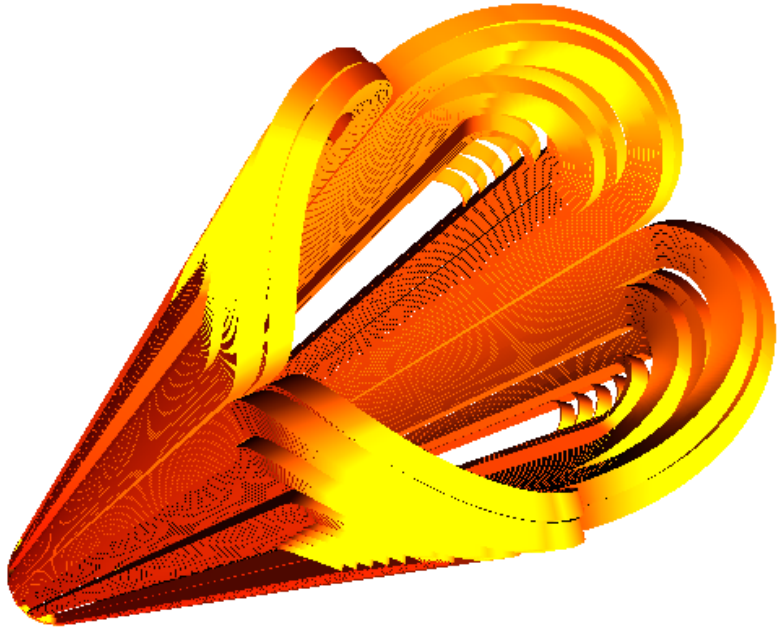
End Geometry (1)

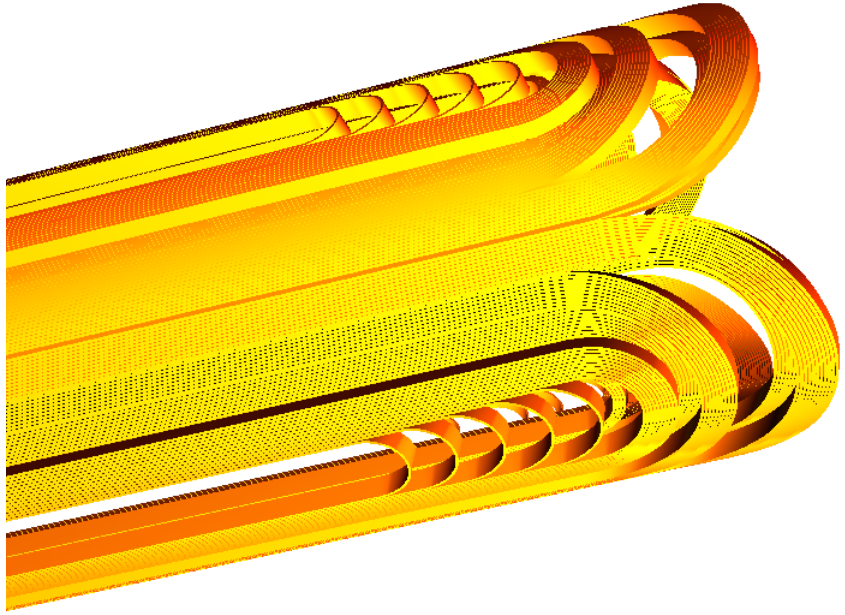


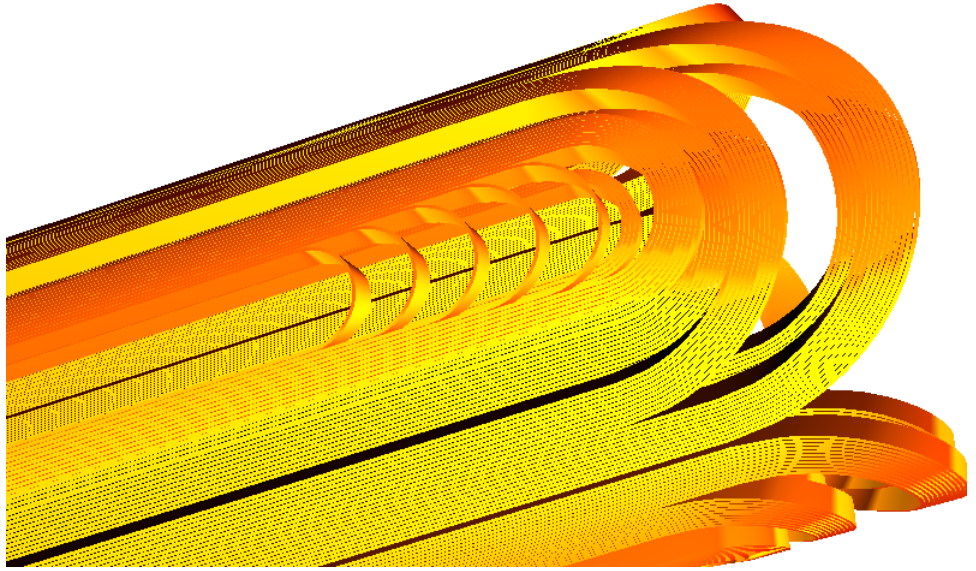


End Geometry (2)









Peak Field in the Ends

- Peak field in the body (including self field) : 6.94 T (7.05 T, without fine sub-division)
- **Peak field in the ends (including self field): 7.03 T**
  - **This is very close to the field in cross-section**

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MARGIN CALC (USING JC-FIT):
BLOCK NUMBER ..........................................          11
PEAK FIELD IN CONDUCTOR   70 (T) ......................      7.0305
CURRENT IN CONDUCTOR  70 (A) ..........................   -8500.0000
SUPERCONDUCTOR CURRENT DENSITY (A/MM2) ................    -886.0233
PERCENTAGE ON THE LOAD LINE ...........................      66.6742
QUENCHFIELD (T) .......................................      10.5446
TEMPERATURE MARGIN TO QUENCH (K) ......................       3.0966
PERCENTAGE OF SHORT SAMPLE CURRENT ....................      27.2859
```

These results to be checked with other codes (OPERA3d, COMSOL?)

Field Harmonics in the Ends

Tip to tip coil length : ~3.65 meter

Integrated Harmonics:

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NORMAL 3D INTEGRAL RELATIVE MULTIPOLES (1.D-4):
b 1:       0.00000  b 2:   10000.00000  b 3:      -0.00000
b 4:       0.00000  b 5:       0.00000  b 6:      -0.32226
b 7:      -0.00000  b 8:      -0.00000  b 9:      -0.00000
b10:      -0.82137  b11:       0.00000  b12:       0.00000
b13:      -0.00000  b14:      -0.49446  b15:      -0.00000
b16:      -0.00000  b17:       0.00000  b18:       0.00319
b19:      -0.00000  b20:      -0.00000  b
```

Summary

- The results presented were optimized by hand via a systematic investigation
- There is no large increase in the peak fields in the ends over the body (important part of the exercise). This helps in not degrading the 2-d margin.
- Field harmonics looks ok as a good starting point (within one unit).
- Peak field and harmonics will be further optimized together with the turn layout.

Block Data 2D

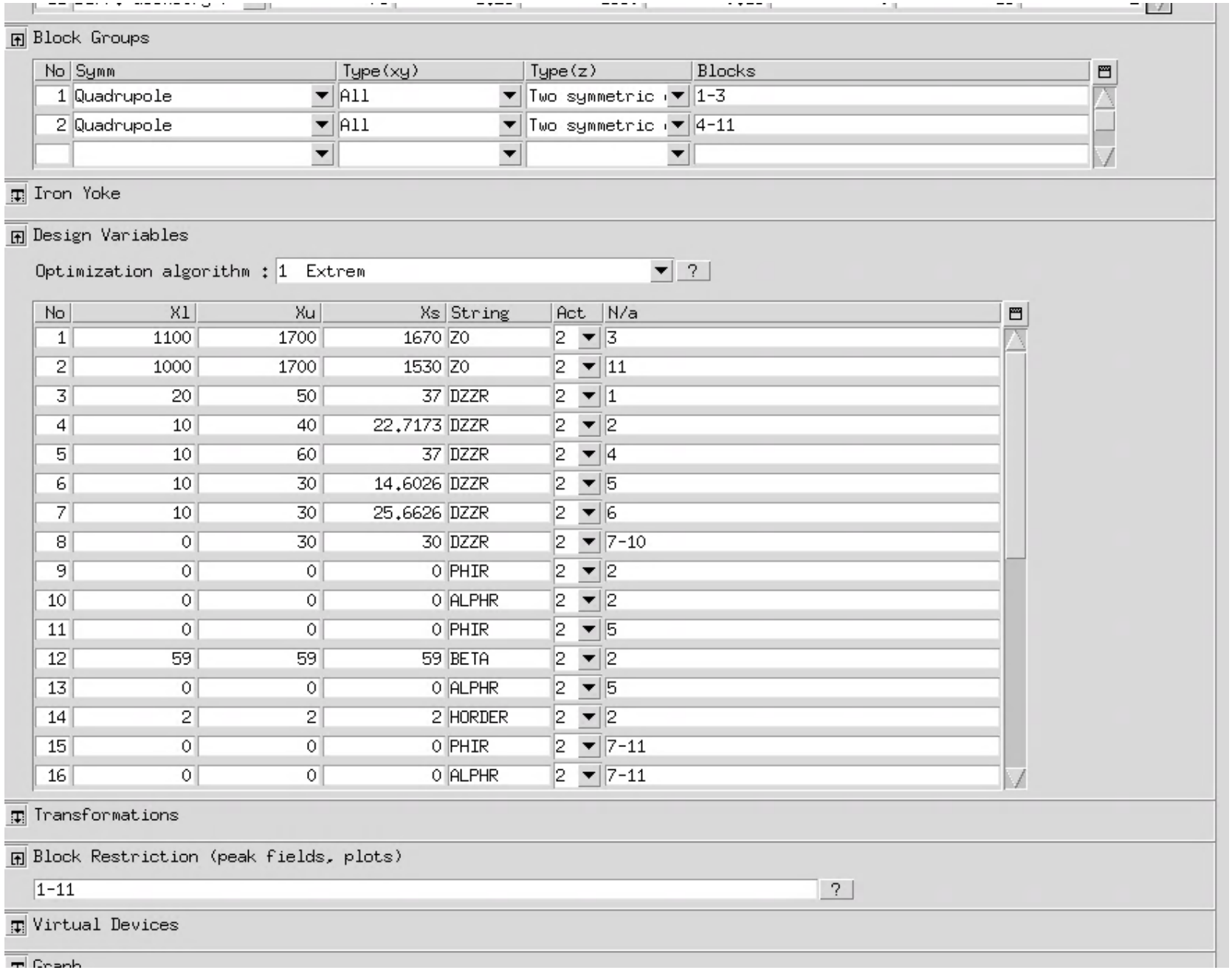
No	Type	NCab	X	Y	α	Current	Cable name	N1	N2	Imag	Turn	Ne
1	Cos	15	140	0.5	0	-8500	EICLHCB2K	1	5	0	0	1
2	Cos	15	140	0.5	0	-8500	EICLHCB2K	1	5	0	0	2
3	Cos	4	140	33.0446	32.8991	-8500	EICLHCB2K	2	10	0	0	3
4	Cos	11	156	0.5	0	-8500	EICLHCB2K	1	5	0	0	4
5	Cos	10	156	0.5	0	-8500	EICLHCB2K	1	5	0	0	5
6	Cos	10	156	24.9744	25.2508	-8500	EICLHCB2K	1	5	0	0	6
7	Cos	1	156	24.9744	25.2508	-8500	EICLHCB2K	1	5	0	0	7
8	Cos	1	156	24.9744	25.2508	-8500	EICLHCB2K	1	5	0	0	8
9	Cos	1	156	24.9744	25.2508	-8500	EICLHCB2K	1	5	0	0	9
10	Cos	1	156	24.9744	25.2508	-8500	EICLHCB2K	2	10	0	0	10
11	Cos	1	156	24.9744	25.2508	-8500	EICLHCB2K	2	20	0	0	11

More options :

No	String	N/a	N/a
1	CONTR	0	0

Block Data 3D

Ne	Type	ß	Bo	zo	Wi	Wo	Hwed	Horder
1	Diff. Geometry f	58	1.1	1140	0.15	0	15	2.2
2	Diff. Geometry f	60	1.2	1100	0.15	0	15	2.2
3	Diff. Geometry f	78	1.3	1670	0.1	0	15	2.3
4	Diff. Geometry f	60	1.1	1100	0.15	0	15	2
5	Diff. Geometry f	65	1.15	1150	0.15	0	15	2
6	Diff. Geometry f	70	1.2	1100	0.1	0	15	2
7	Diff. Geometry f	75	1.25	1530	0.15	0	15	2
8	Diff. Geometry f	75	1.25	1530	0.15	0	15	2
9	Diff. Geometry f	75	1.25	1530	0.15	0	15	2
10	Diff. Geometry f	75	1.25	1530	0.15	0	15	2
11	Diff. Geometry f	75	1.25	1530	0.15	0	15	2



Block Groups

No	Symm	Type(xy)	Type(z)	Blocks
1	Quadrupole	All	Two symmetric	1-3
2	Quadrupole	All	Two symmetric	4-11

Iron Yoke

Design Variables

Optimization algorithm : 1 Extrem ?

No	Xl	Xu	Xs	String	Act	N/a
1	1100	1700	1670	Z0	2	3
2	1000	1700	1530	Z0	2	11
3	20	50	37	DZZR	2	1
4	10	40	22.7173	DZZR	2	2
5	10	60	37	DZZR	2	4
6	10	30	14.6026	DZZR	2	5
7	10	30	25.6626	DZZR	2	6
8	0	30	30	DZZR	2	7-10
9	0	0	0	PHIR	2	2
10	0	0	0	ALPHR	2	2
11	0	0	0	PHIR	2	5
12	59	59	59	BETA	2	2
13	0	0	0	ALPHR	2	5
14	2	2	2	HORDER	2	2
15	0	0	0	PHIR	2	7-11
16	0	0	0	ALPHR	2	7-11

Transformations

Block Restriction (peak fields, plots)

1-11 ?

Virtual Devices

Graph