Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

3-d Optimization of Q2pF

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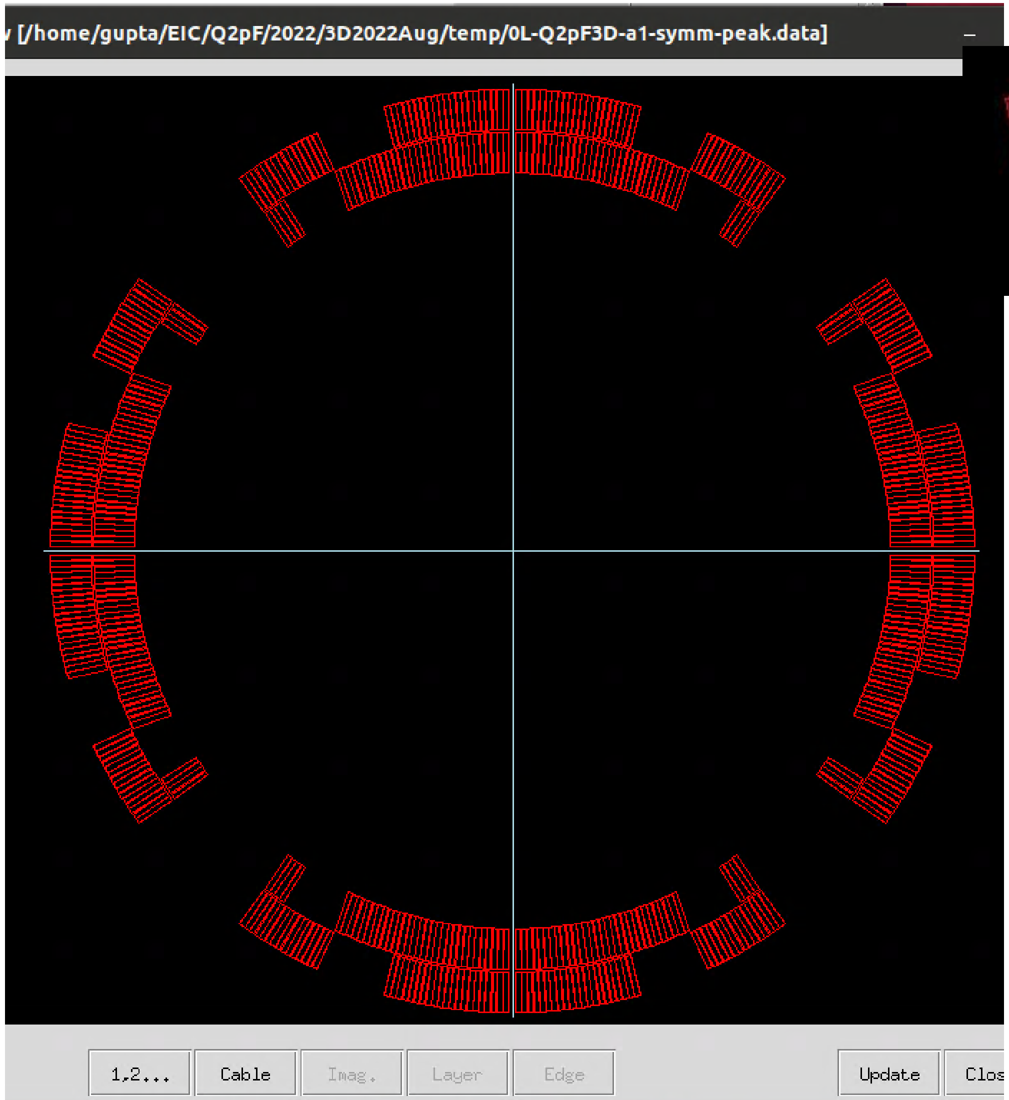
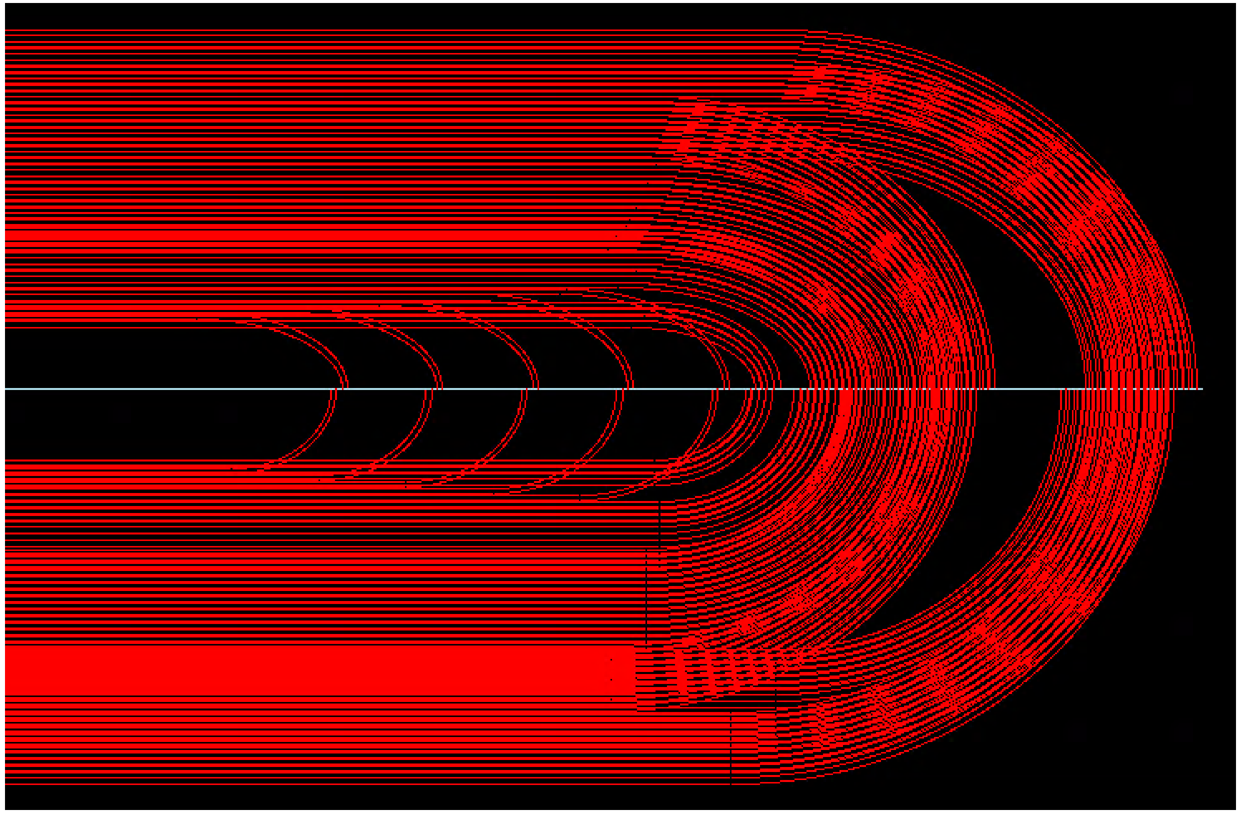
Overview

Results presented last week further analyzed and iterated

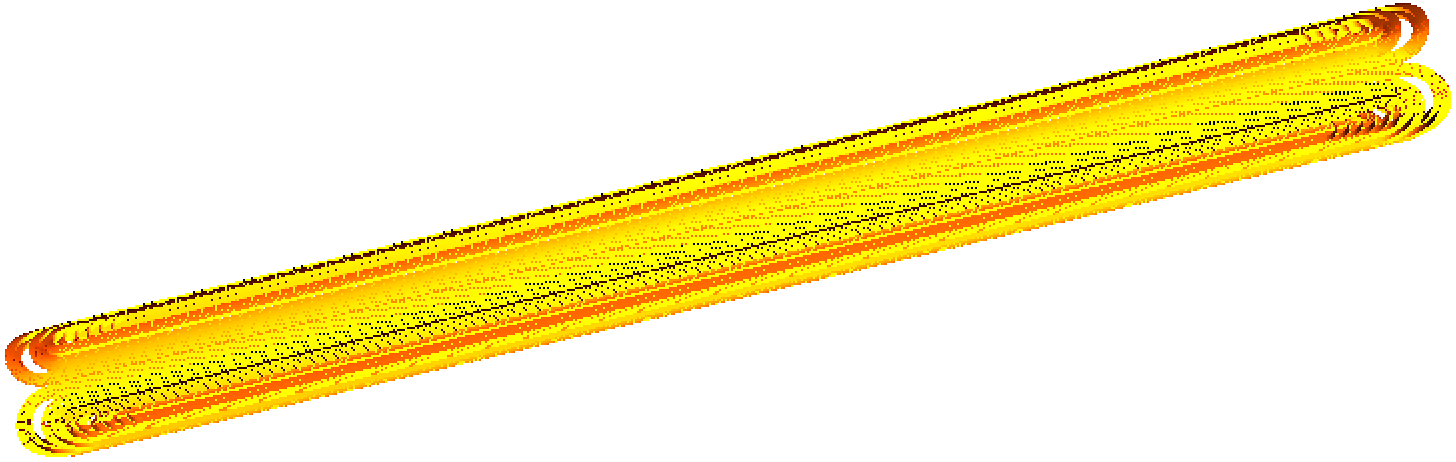
- More detailed harmonic and magnet length examination
- Peak field

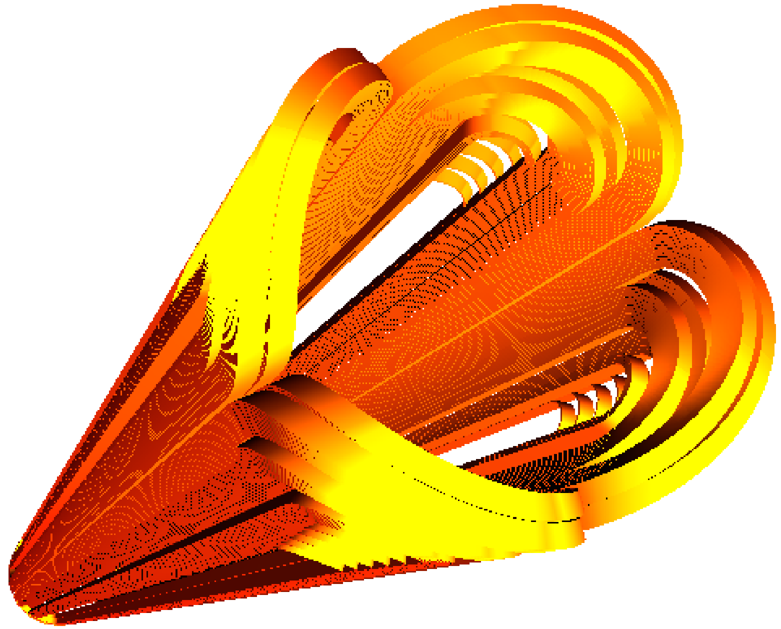
End Geometry (1)

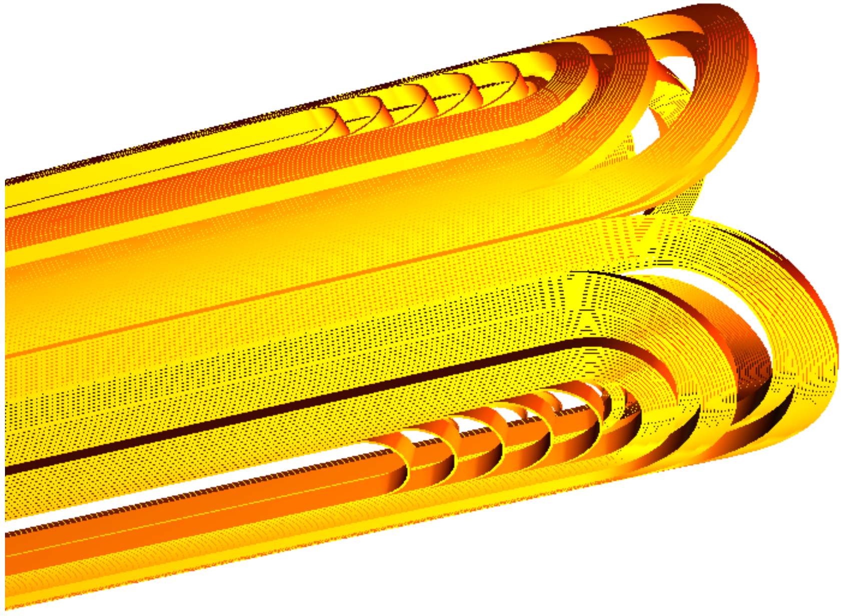


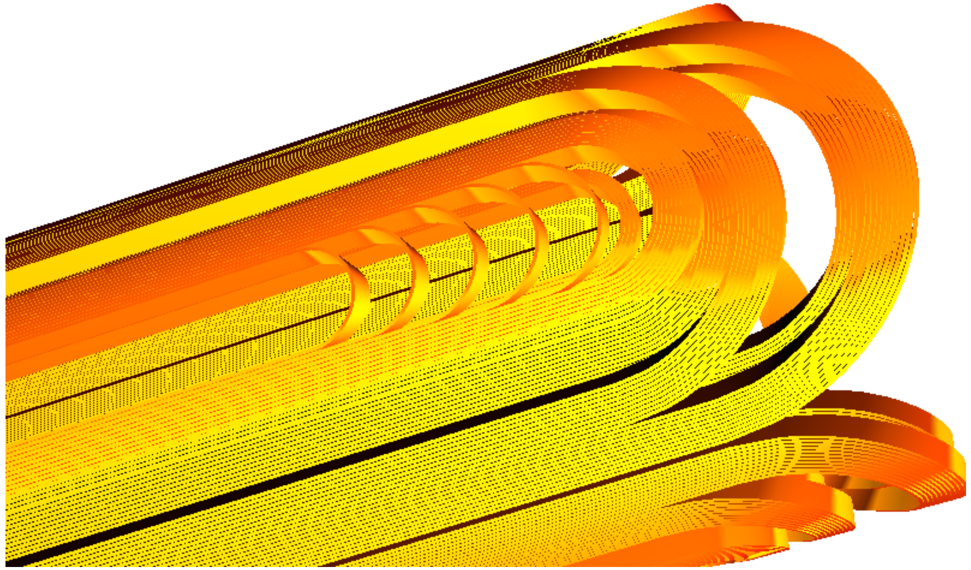


End Geometry (2)









Integrated Harmonics (low enough)

```
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
NUMBER OF ANALYSES ALONG Z ......................        300
LENGTH OF VIRTUAL COIL (mm) .....................  3000.0000
REFERENCE POSITION NUMBER .......................         10
MEASUREMENT TYPE ........................ ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ................ 0.5637E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

3D REFERENCE MAIN FIELD (T) .....................     3.4693
REFERENCE MAGNET STRENGTH (T/(m^(n-1)) ..........    41.7992
MAGNETIC LENGTH (mm) ............................  1740.6647

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:    -0.08941
b 7:     -0.00000   b 8:     -0.00000   b 9:    -0.00000
b10:     -0.20212   b11:      0.00000   b12:     0.00000
b13:     -0.00000   b14:     -0.52143   b15:    -0.00000
b16:     -0.00000   b17:     -0.00000   b18:     0.01153
```

Reference field at 8500 A (mirror iron)

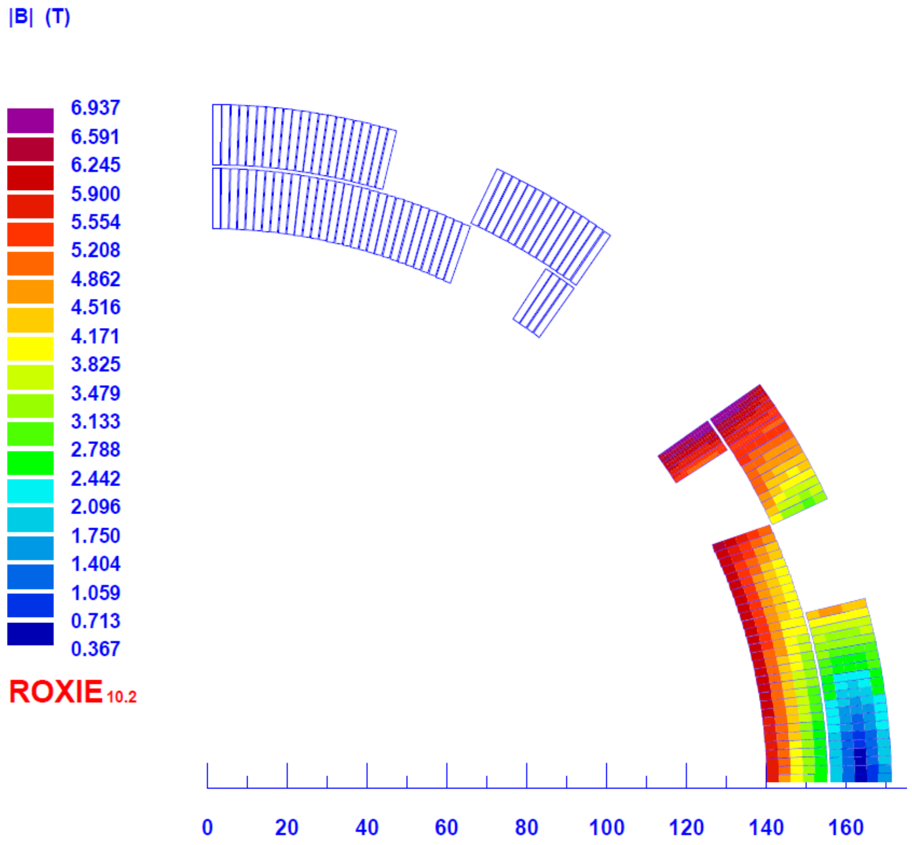
Magnetic length (mirror iron): 2X1.74 = 3.58 meter

Tip to tip coil length: ~3.65 meter

For reference: Magnet length in pCDR: 3.8 m

Comparing 3-d Field Gradient at Center with 2-d Field

- 3-d mirror gradient at the center of the magnet is almost the same as in 2-d
- In 2-d: ~8% drop in gradient due to iron saturation (3-d calculation to follow)



3-d mirror iron

```
3D REFERENCE MAIN FIELD (T) ........................     3.4693
REFERENCE MAGNET STRENGTH (T/(m^(n-1)) ............     41.7992
```

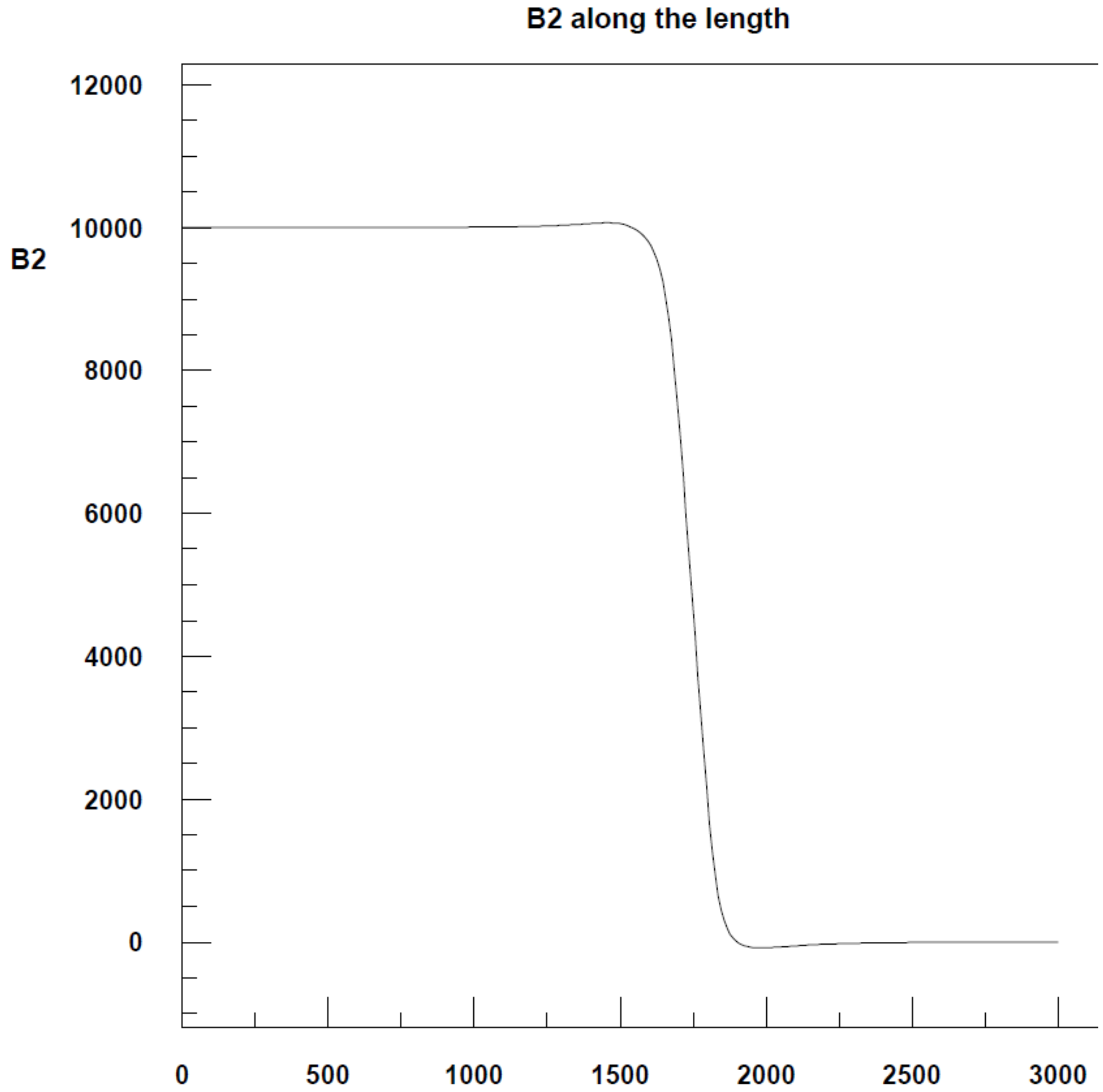
2-d mirror iron

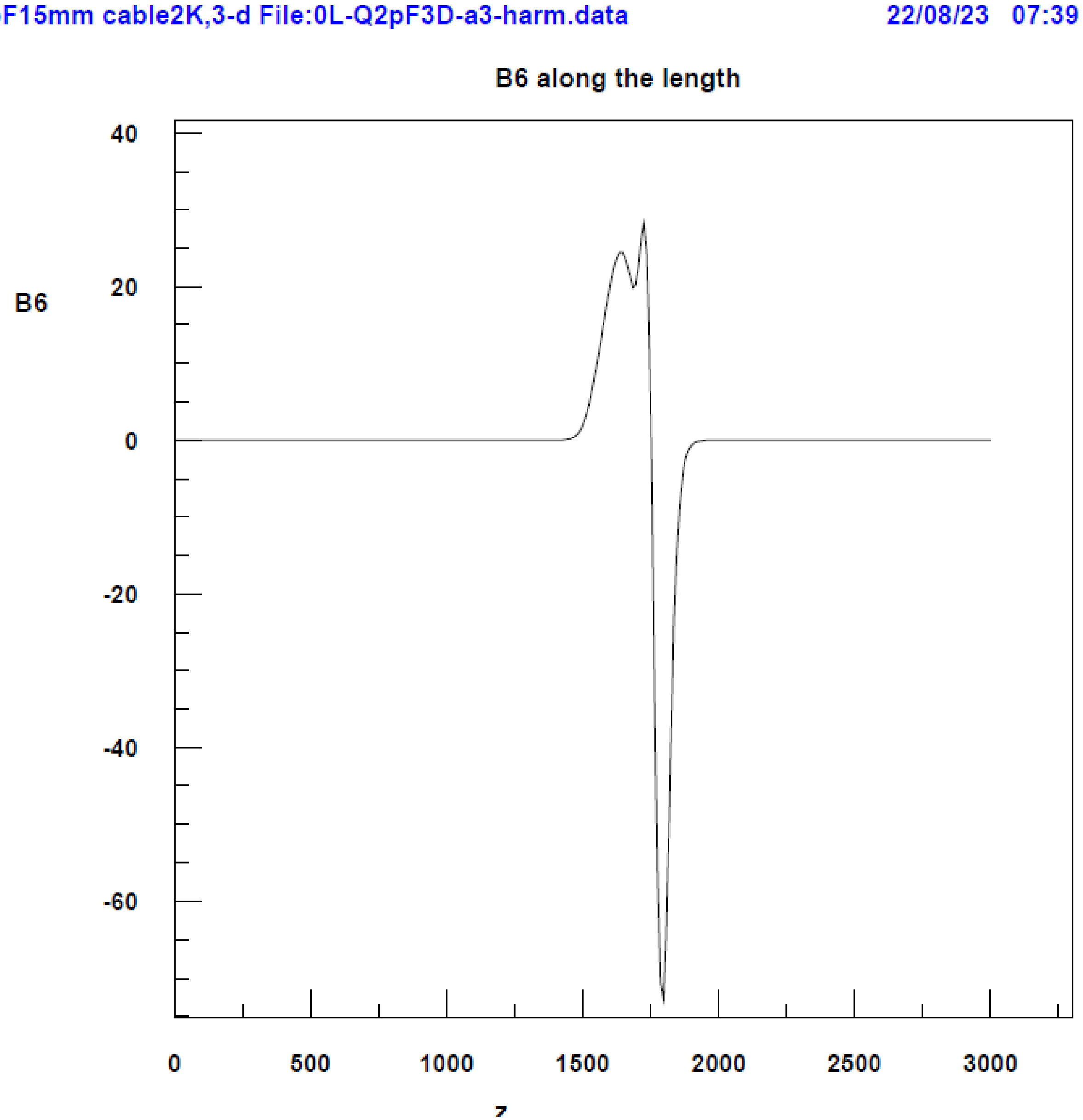
```
MAIN HARMONIC .......................................          2
REFERENCE RADIUS (mm) ...............................    83.0000
X-POSITION OF THE HARMONIC COIL (mm) ...............     0.0000
Y-POSITION OF THE HARMONIC COIL (mm) ...............     0.0000
MEASUREMENT TYPE ........................ ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ...................  0.9032E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) .....................................    3.469052
MAGNET STRENGTH (T/(m^(n-1)) .......................     41.7958
```

2-d saturating iron

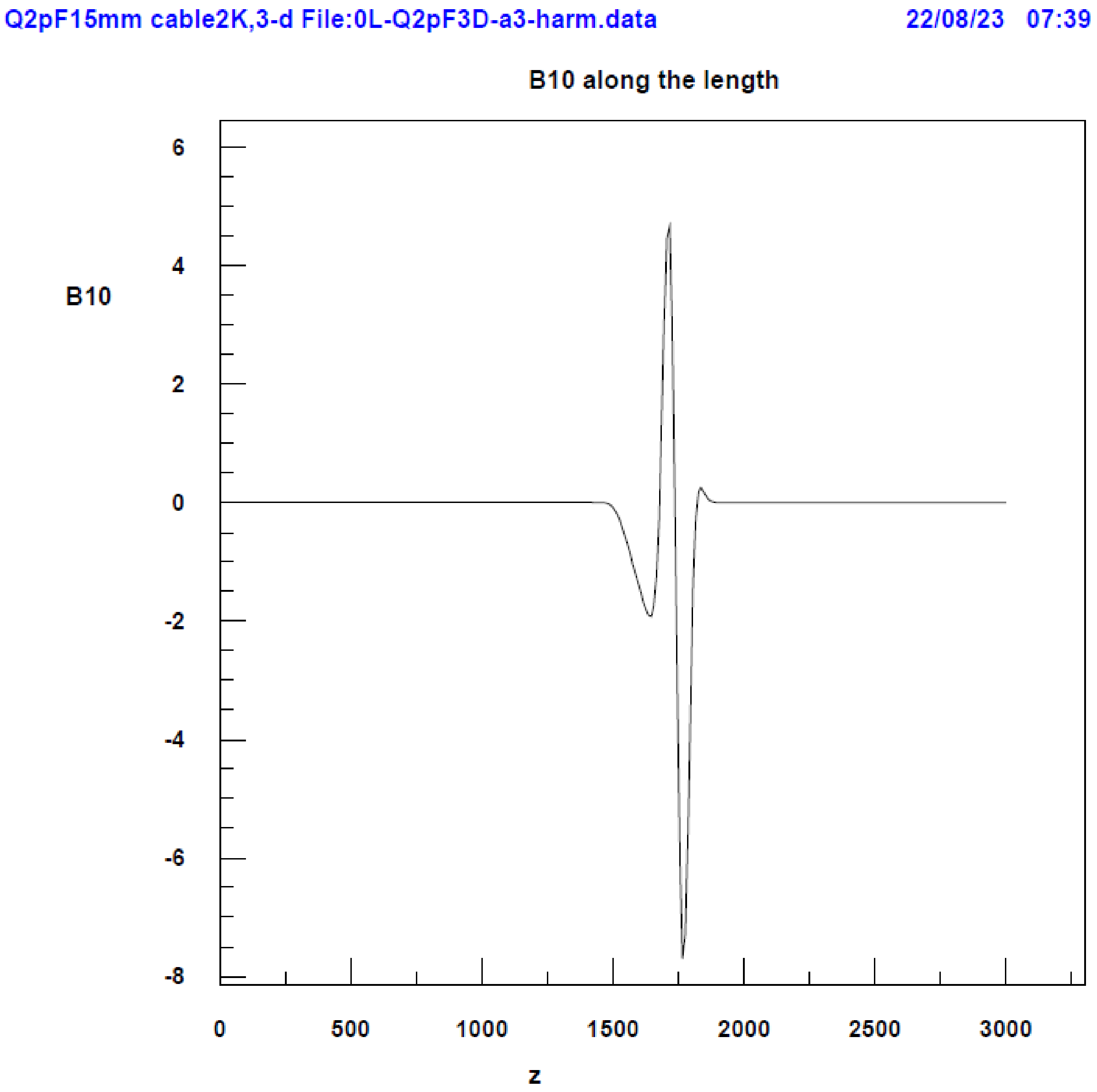
```
MAIN HARMONIC .......................................          2
REFERENCE RADIUS (mm) ...............................    83.0000
X-POSITION OF THE HARMONIC COIL (mm) ...............     0.0000
Y-POSITION OF THE HARMONIC COIL (mm) ...............     0.0000
MEASUREMENT TYPE ........................ ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ...................  0.9037E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) .....................................    3.190771
MAGNET STRENGTH (T/(m^(n-1)) .......................     38.4430
```

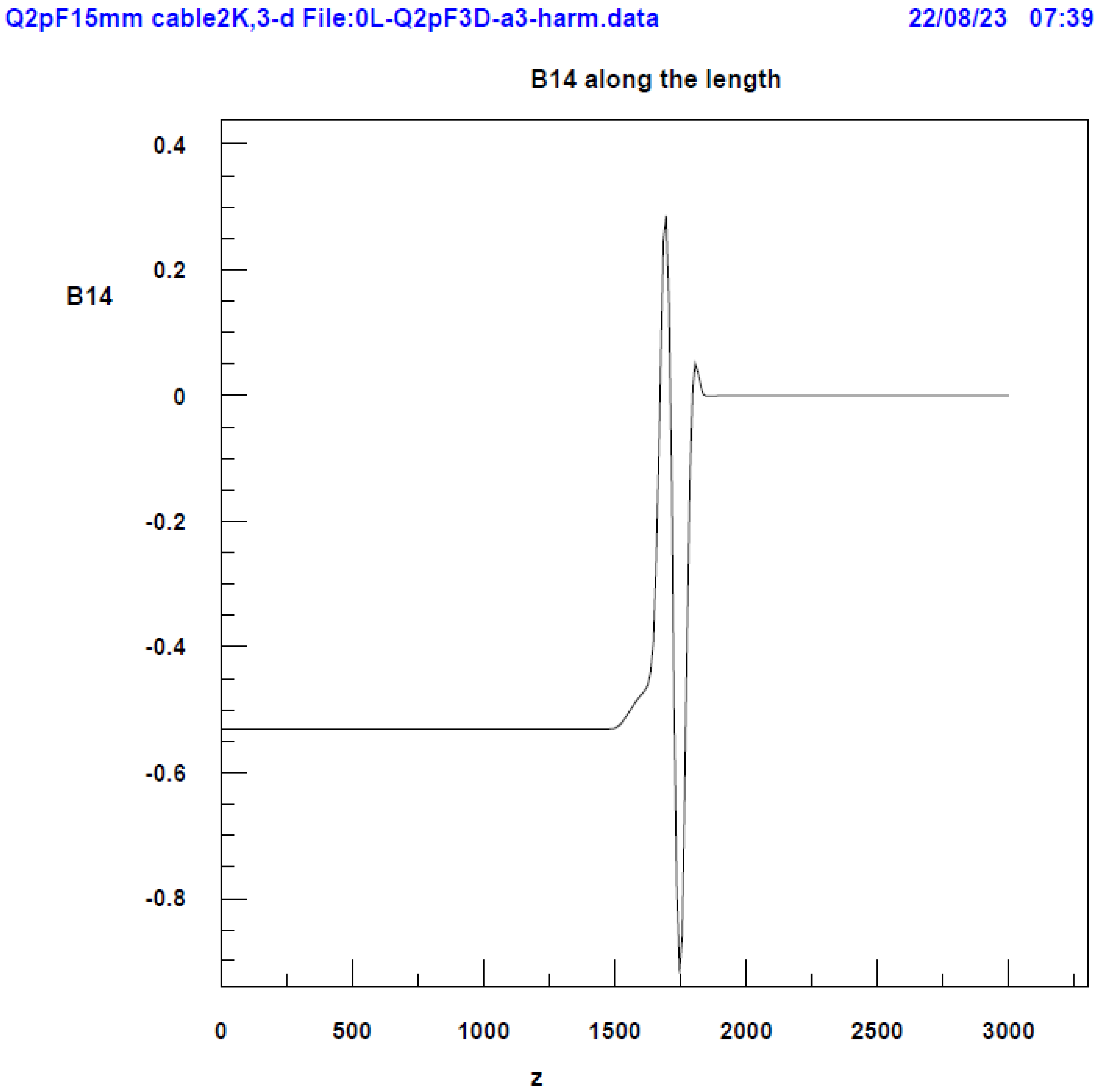
Field Harmonics along the Axis



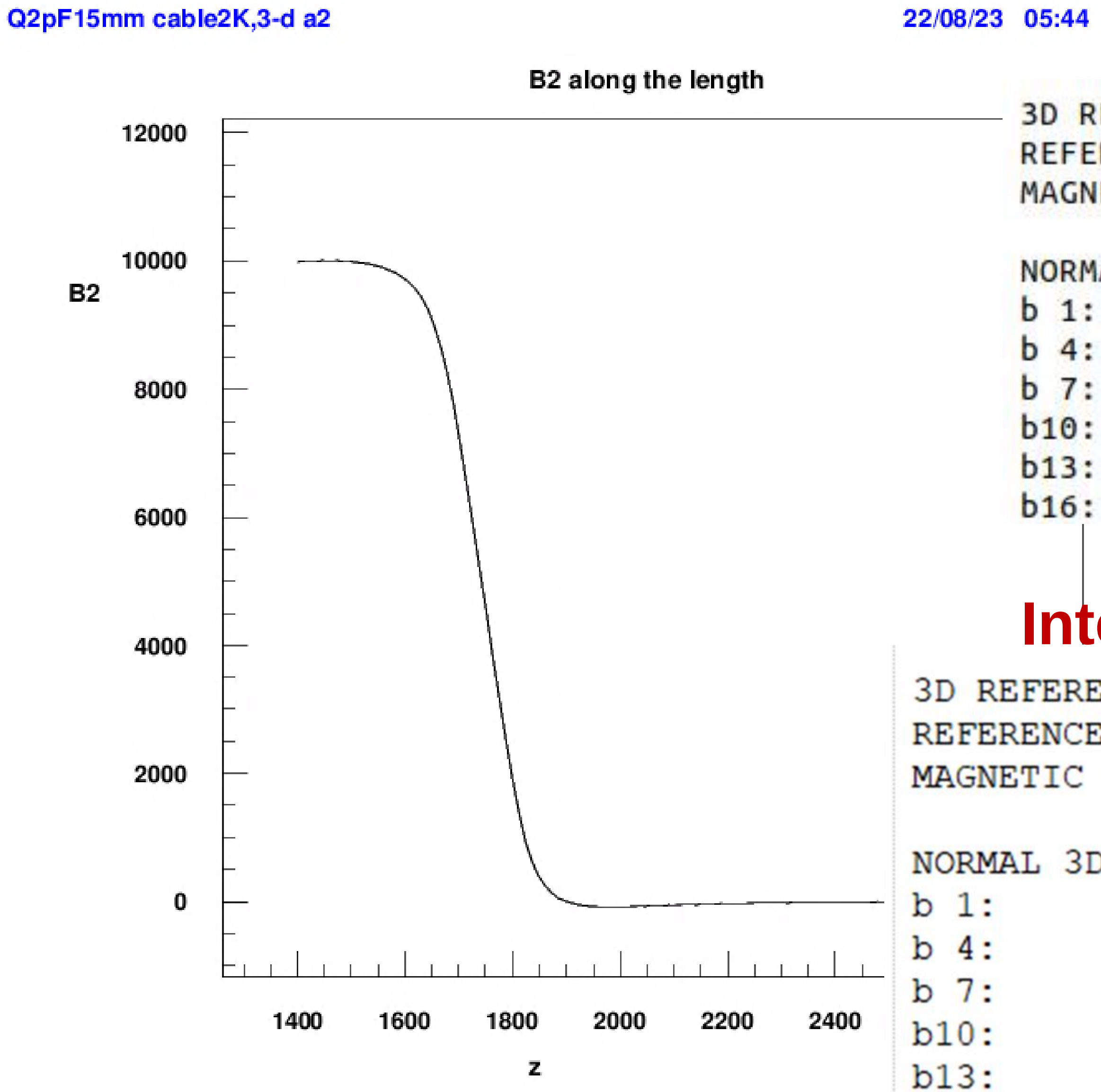


Field Harmonics along the Axis





Harmonics in the Ends



Field Harmonics due to the Ends

3D REFERENCE MAIN FIELD (T) 3.4927
REFERENCE MAGNET STRENGTH (T/(m^(n-1)) 42.0806
MAGNETIC LENGTH (mm) 337.3861

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:	-0.41519
b 7:	-0.00000	b 8:	-0.00000	b 9:	0.00000
b10:	-1.06884	b11:	0.00000	b12:	0.00000
b13:	-0.00000	b14:	-0.48584	b15:	-0.00000
b16:	-0.00000	b17:	0.00000	b18:	-0.00008

Integrated Field Harmonics in the Magnet

3D REFERENCE MAIN FIELD (T) 3.4693
REFERENCE MAGNET STRENGTH (T/(m^(n-1)) 41.7992
MAGNETIC LENGTH (mm) 1740.6647

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:	-0.08941
b 7:	-0.00000	b 8:	-0.00000	b 9:	-0.00000
b10:	-0.20212	b11:	0.00000	b12:	0.00000
b13:	-0.00000	b14:	-0.52143	b15:	-0.00000
b16:	-0.00000	b17:	-0.00000	b18:	0.01153

Peak Field in the Ends

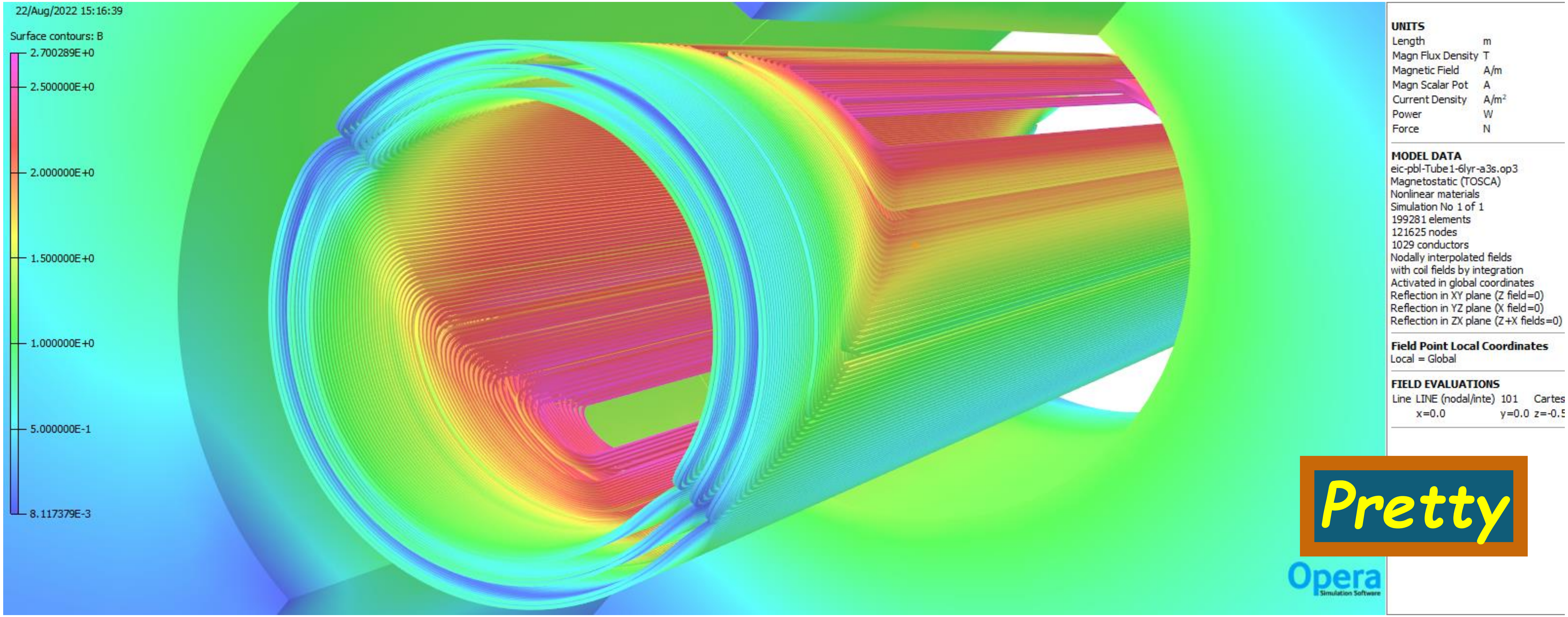
- Peak field in the body (including self field) : 6.94 T (7.05 T, without fine sub-division)
- **Peak field in the ends (including self field): 7.03 T**
  - **This is very close to the field in cross-section**

```
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
```

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

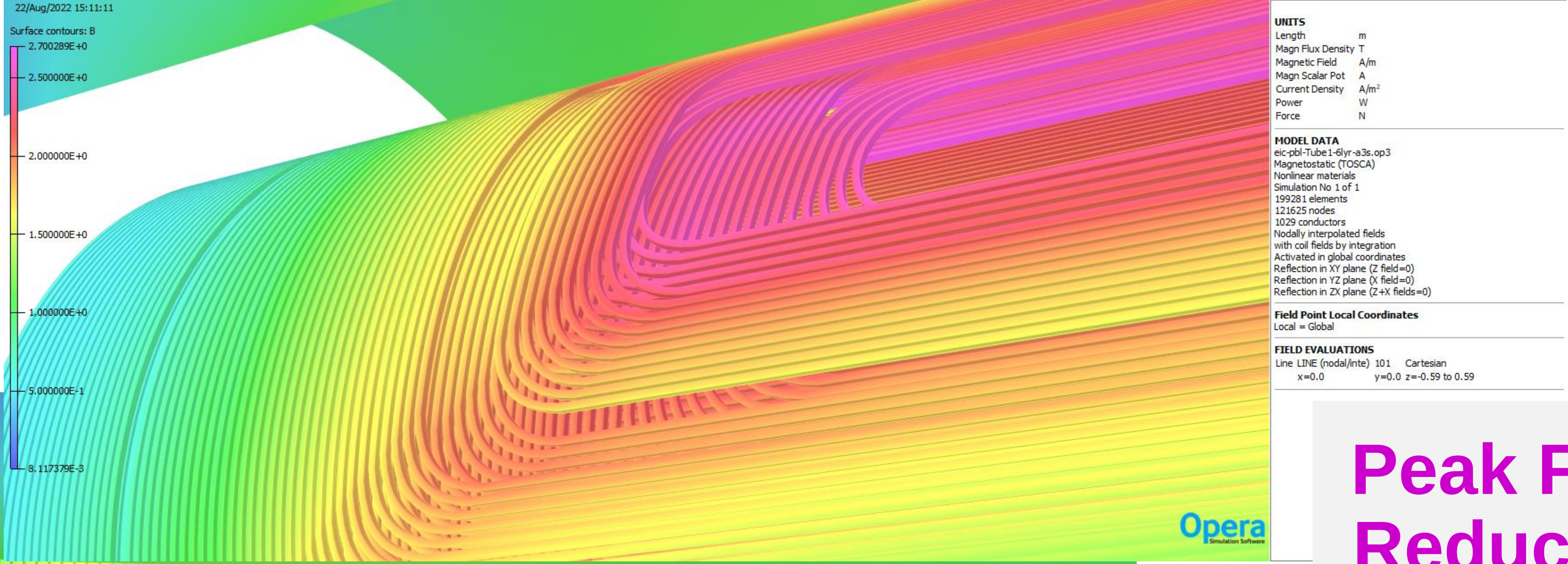
Peak Field Reduction Strategies in the Ends

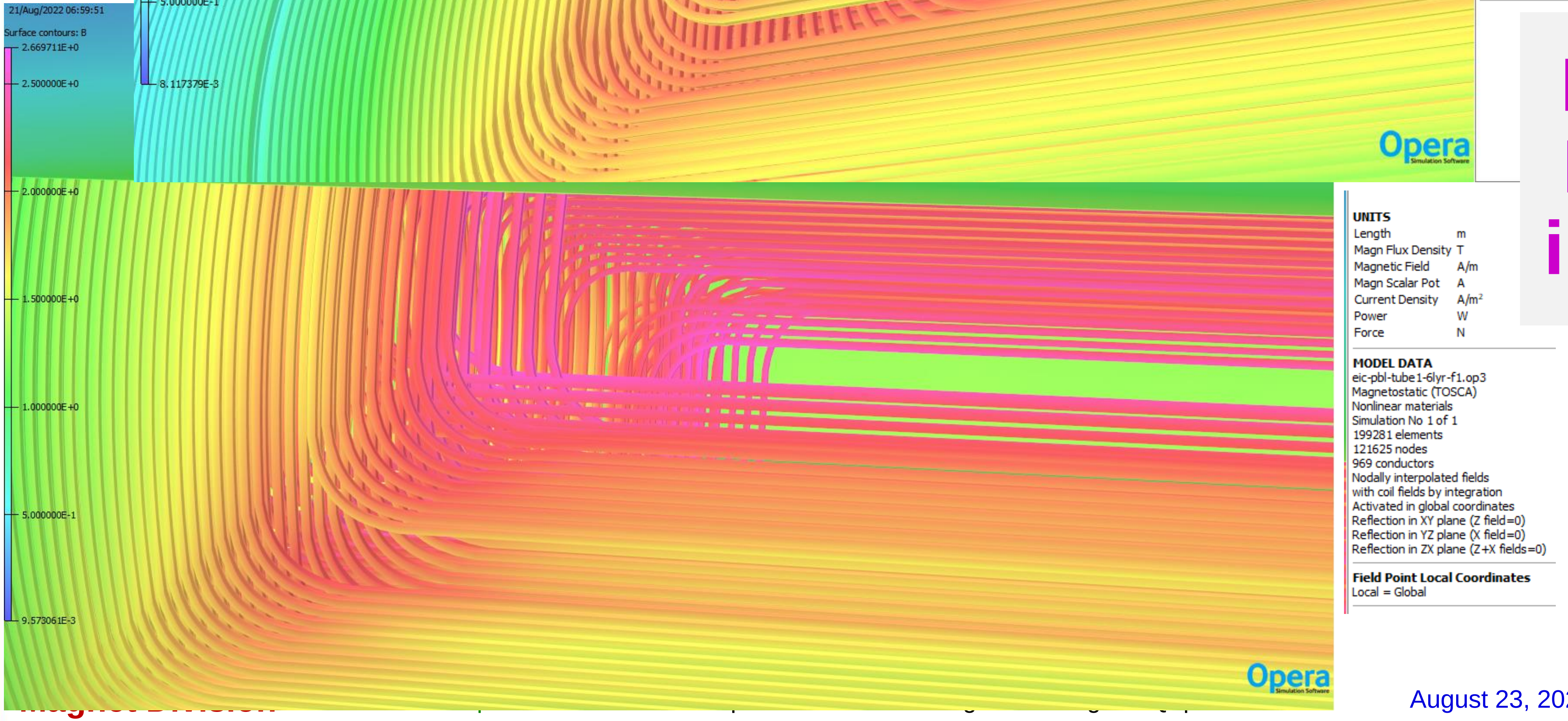
The fundamental peak field reduction strategies are similar in all designs such as in the *Optimum Integral Design* (shown below)



Midplane turns extend full length in the *Optimum Integral Design*

Peak Field Reduction in the Ends





Summary

- The solution presented last time was optimized by hand via a systematic investigation. It still looks good after a more through examination. Other solutions were also examined but the one presented last time looks good in overall sense.
- Coil length is within the guideline specified by engineers (Mike).
- There appears to be no increase in the peak field in the ends over the body (within the calculation errors). This helps in maintaining the margin as computed in 2-d.
- Integral field harmonics are low (about ½ unit). Good for now.
- Next task OPERA model and computation of 3-d harmonics as a function of field, along with the field errors in the hole where electron beam will traverse.

Xroxie [/home/gupta/EIC/Q2pF/2022/3D2022Aug/temp/0L-Q2pF3D-a4-harm.da

File Edit Display Run

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	β	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

Design Variables

Optimization algorithm : 1 Extrem

No	Xl	Xu	Xs	String	Act	N/a
1	1100	1700	1670	ZO	2	3
2	1000	1700	1530	ZO	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