Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Initial Investigation of Direct Wind B1pF/B1ApF (with Optimum Integral Dipole Design)

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February 25, 2025

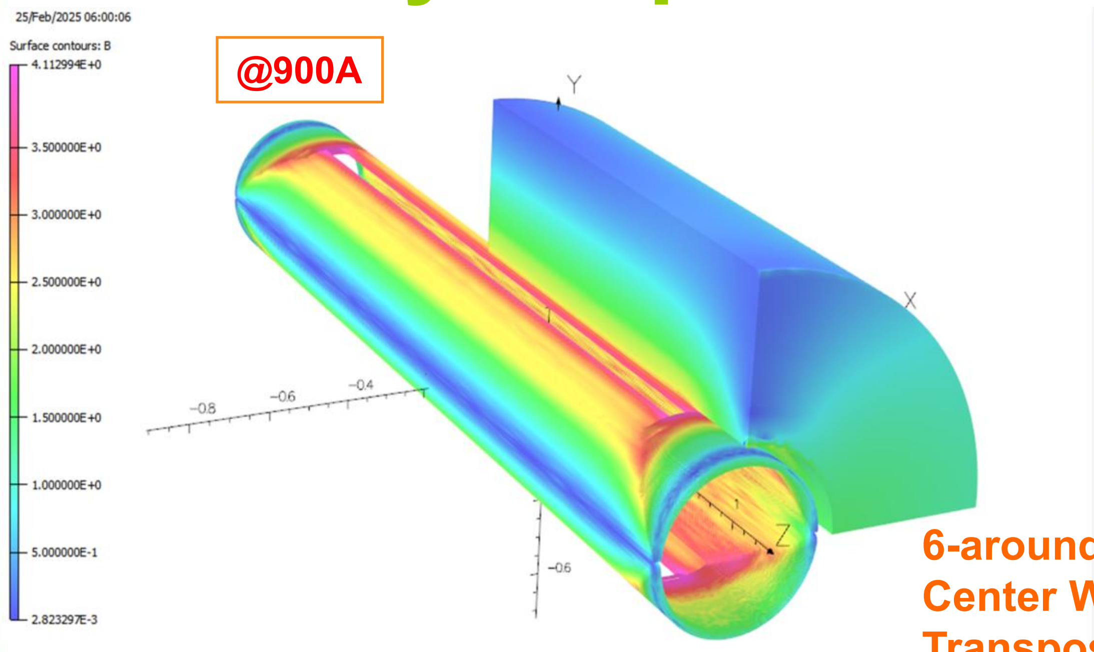
Guidelines for the Initial design of Direct Wind Design

- Inner radius of the additional tube in the Direct Wind B1pF/B1ApF coil is made the same as the inner radius of the coil in the NEW cable magnet (183 mm)
- Optimum Integral design for higher integral field for the given coil length
- Two B1pF must generate the integral field of previous B1pF+B1ApF (14.4 T.meter).
- Field at the center and conductor is significantly lower (Bo <3.2 T, Bpeak < 4T).
- Design must meet the field quality (harmonics).

- Quench protection: Attempt to make them as primarily self-protecting magnets with energy dumped inside the magnet (energy extraction for added margin).
- Significantly higher copper to super ratio (a factor of 2 as compared to the original, initially by replacing SC by Cu wire) to keep hot-spot temperature under control.

Note: This is a preliminary design work done in a short period. Can be pursued more.

6-Layer Optimum Integral Dipole B1pF/B1ApF

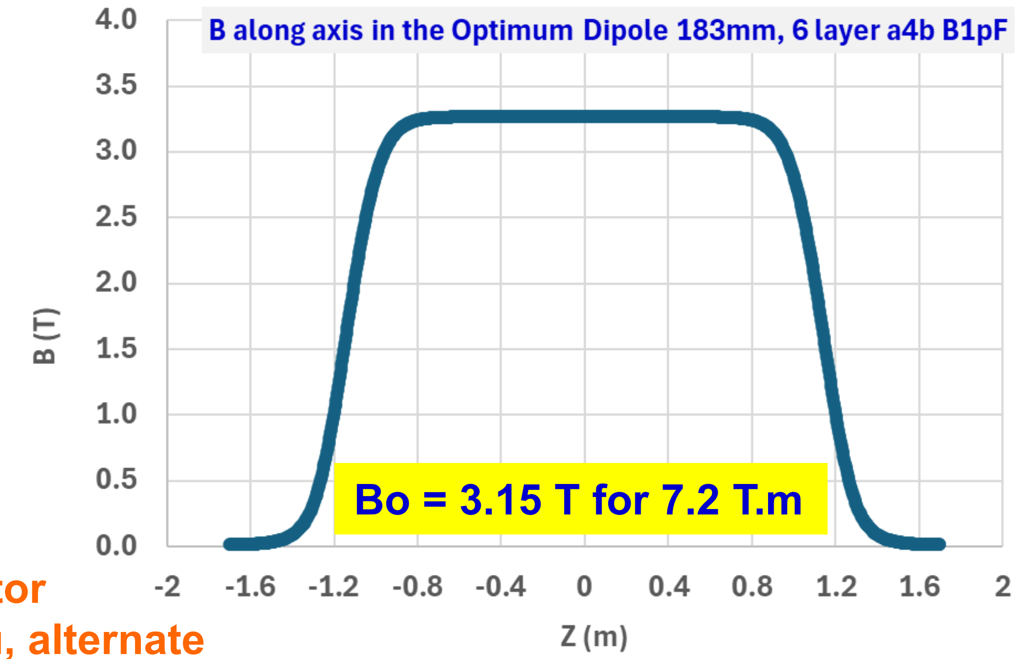


UNITS
Length m
Magn Flux Density T
Magnetic Field A/m
Magn Scalar Pot A
Current Density A/m²
Power W
Force N

MODEL DATA
B1pF-183mm-6lyr-RFe228-a4b.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 3 of 10
817284 elements
370692 nodes
2004 conductors
Nodally interpolated fields
Activated in global coordinates
Reflection in XY plane (Z field=0)
Reflection in YZ plane (X field=0)
Reflection in ZX plane (Z+X fields=0)

Field Point Local Coordinates
Local = Global

FIELD EVALUATIONS
Line LINE (nodal) 1401 Cartesian
x=0.0 y=0.0 z=-1.7 to 1.7



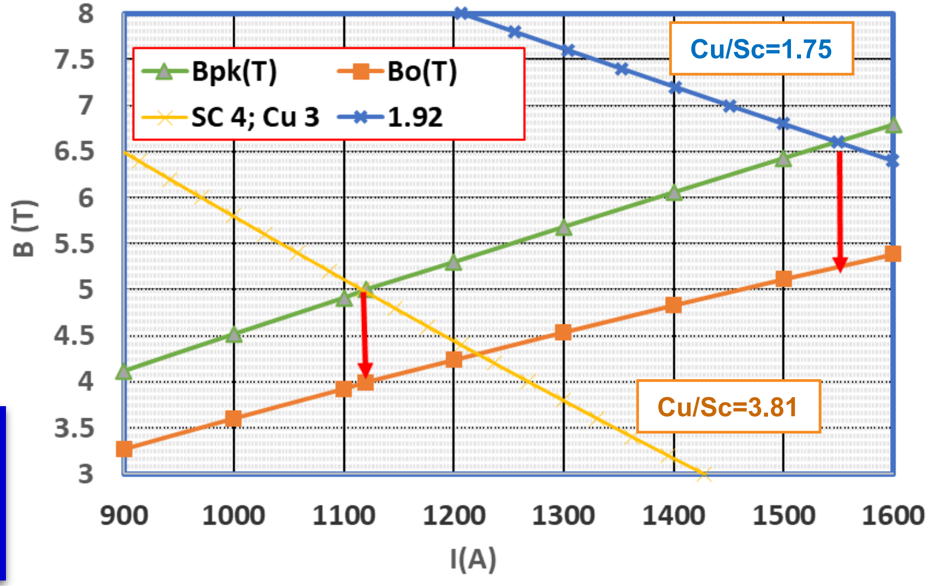
6-around-1 cable
Center Wire Superconductor
Transposed 3 SC and 3 Cu, alternate

Bint(T.m)	Iwire(A)	Bo(T)	Bpk(T)	B/I*1000	Bpk/Bo	Leff(m)
0	0	0	0			
4.169	500	1.829	2.335	3.658	1.277	2.279
6.650	800	2.917	3.694	3.646	1.266	2.280
7.199	870	3.144	3.958	3.614	1.259	2.290
7.447	900	3.267	4.113	3.630	1.259	2.279
8.215	1000	3.602	4.516	3.602	1.254	2.281
8.955	1100	3.925	4.910	3.568	1.251	2.282
9.118	1120	3.996	4.999	3.568	1.251	2.282
9.670	1200	4.237	5.298	3.531	1.250	2.282
10.361	1300	4.539	5.680	3.492	1.251	2.283
11.028	1400	4.832	6.056	3.451	1.253	2.282
11.672	1500	5.115	6.427	3.410	1.257	2.282
12.287	1600	5.387	6.791	3.367	1.261	2.281

Margin: 78% (7 SC)
4 SC and 3 Cu=> 28%

Iquench	**1120**	Amp
Cab Cu Area	**2.623**	mm^2
Jcu@Qnch	**427**	A/mm^2
Idesign	**870**	Amp
Jcu@design	**332**	A/mm^2

Current density in Cu is significantly lower to keep hot spot temperature low



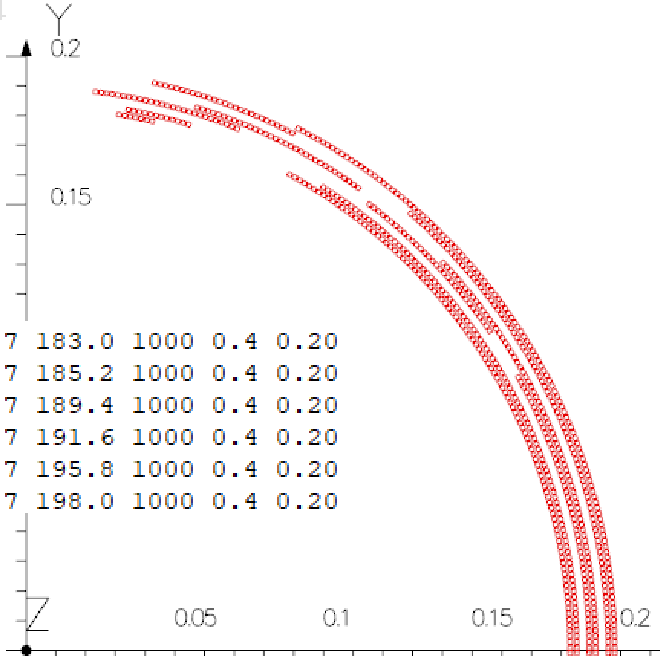
More on the Design

Original	Cu/Sc	1.75		Cu wires	3			
Effective	Cu/Sc	3.8125		SC Wires	4			
						Wire dia	0.473	mm
6-around-1, effective Cu/Sc 2.033						Wire area	0.176	mm^2
						Iquench	**1120**	Amp
Acu	0.301		Acable-cu	2.623		Cab Cu Area	**2.62**	mm^2
Asc	0.172		Acable-sc	0.688		Jcu@Qnch	**427**	A/mm^2
Awire	0.473					Idesign	**870**	Amp
Acable	3.311		Cu/Sc	3.8125		Jcu@design	**332**	A/mm^2

			Current	900	A	**B/I(T/kA)**	**3.629**
			Stored Energy	1.27E+06	J		
Bo(z=0)	**3.267**	**Tesla**	Inductance	3.136	H	**Leff(m)**	**2.280**
			Bpeak	4.113	T	**Bpk/Bo**	**1.26**
Bintegral	**7.447**	**T.m**					

B1pF-183mm-6lyr-a4b.X11

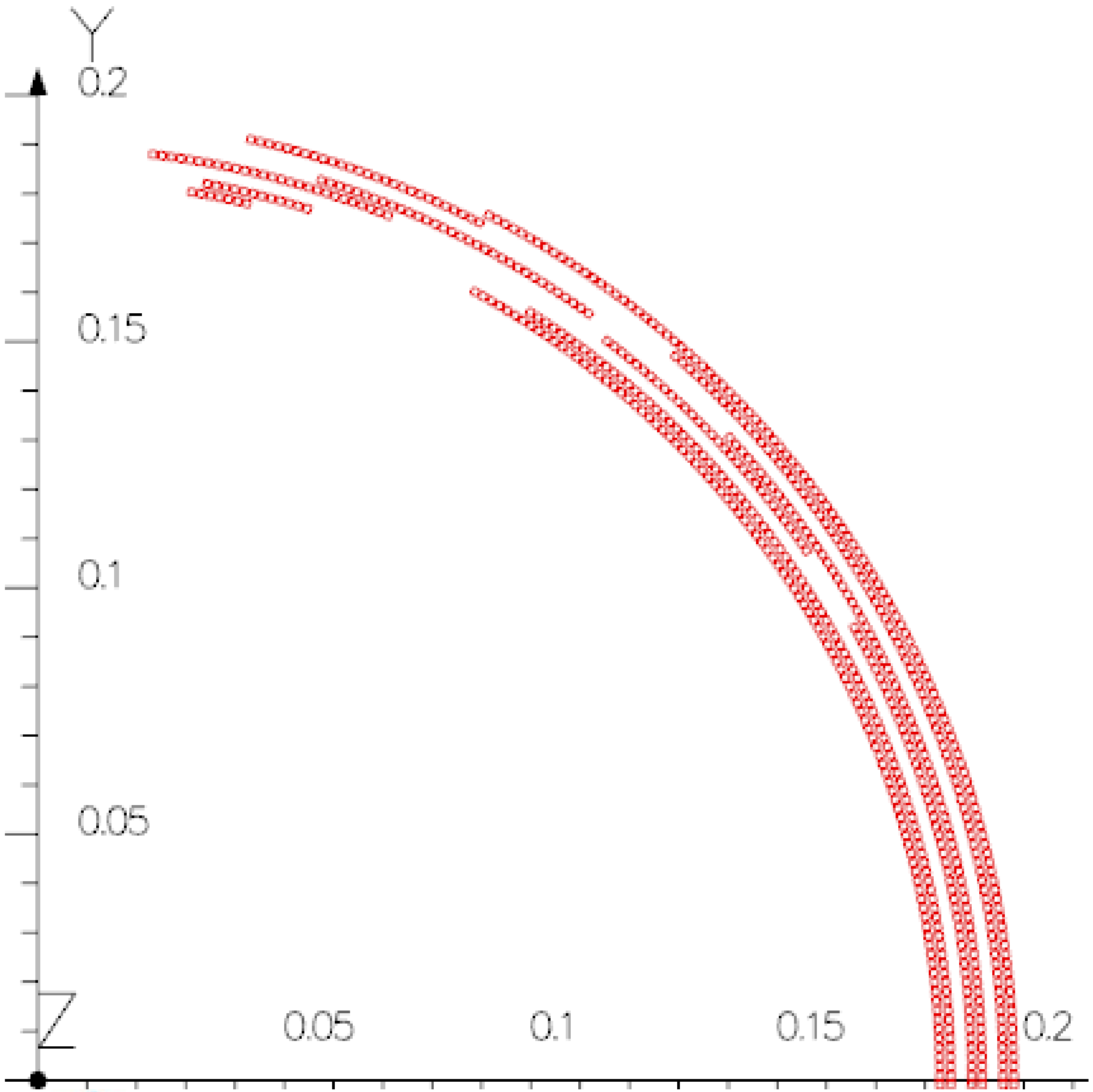
No.	Bn(T.m)	bn*10^4(units)
0	0.84357E+01	10000.0000
2	-0.15430E-05	-0.0018
4	-0.12892E-04	-0.0153
6	-0.12460E-03	-0.1477
8	0.17861E-04	0.0212
10	-0.10068E-05	-0.0012
12	-0.25376E-07	-0.0000
14	0.55324E-08	0.0000
16	-0.49962E-09	-0.0000
18	0.75377E-10	0.0000
20	-0.47206E-11	-0.0000
22	0.12114E-14	0.0000
24	-0.66403E-14	-0.0000
26	0.13715E-14	0.0000
28	-0.18343E-16	-0.0000
30	0.15374E-17	0.0000

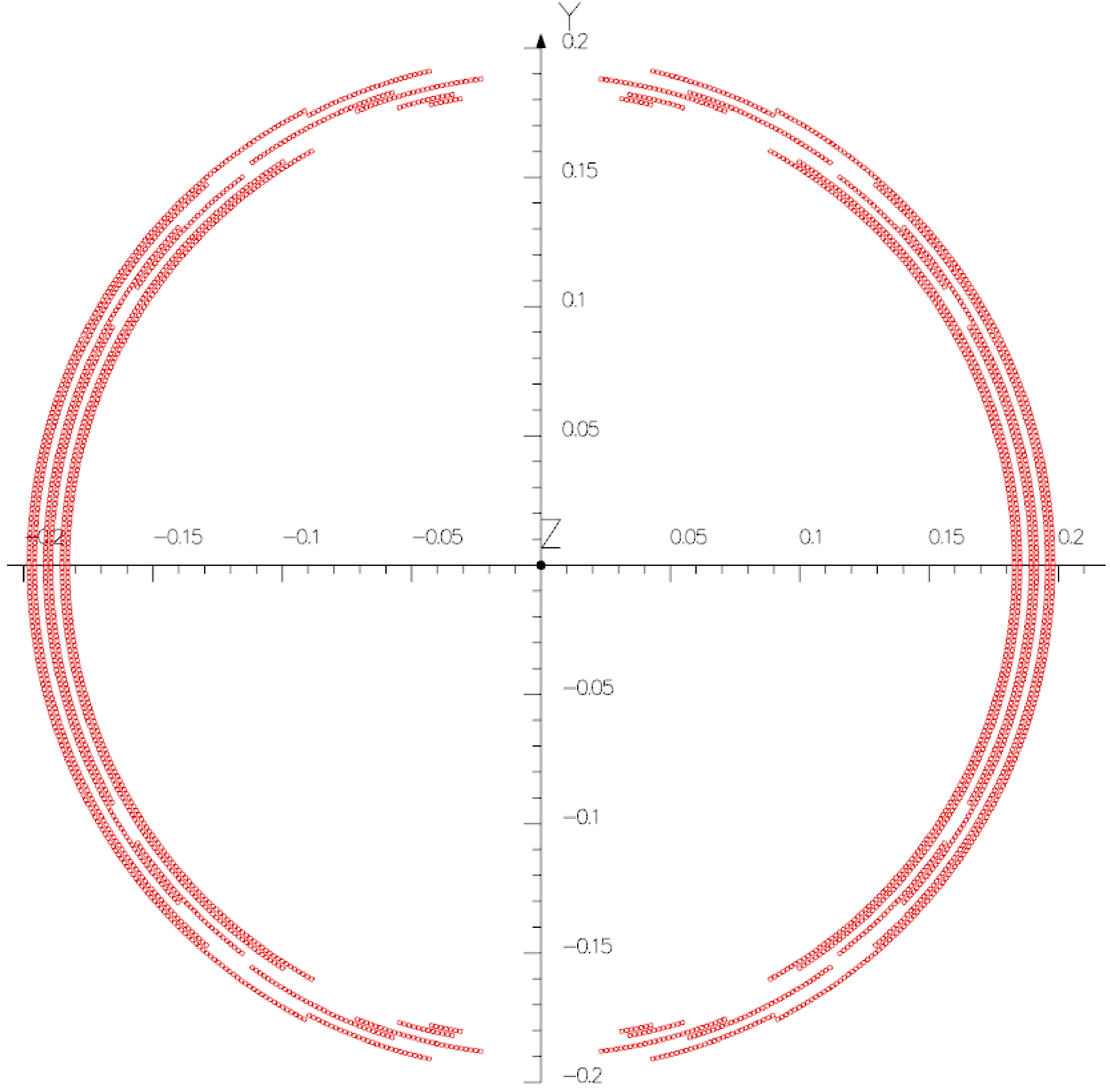


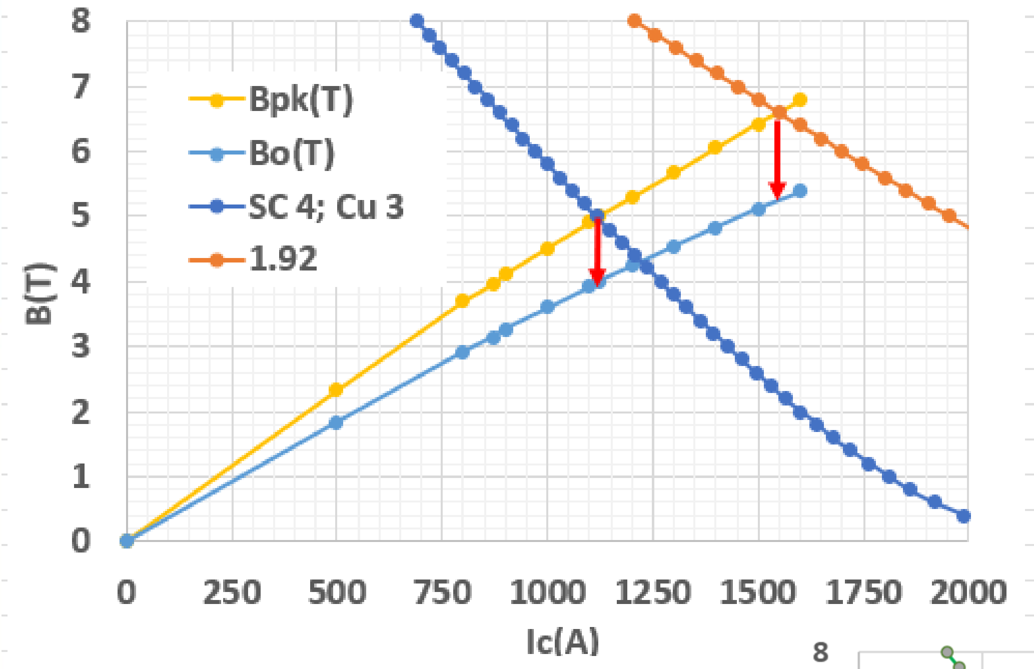
3	3	2.48	1.7	183.0	1000	0.4	0.20
3	3	2.48	1.7	185.2	1000	0.4	0.20
3	3	2.48	1.7	189.4	1000	0.4	0.20
3	3	2.48	1.7	191.6	1000	0.4	0.20
3	3	2.48	1.7	195.8	1000	0.4	0.20
3	3	2.48	1.7	198.0	1000	0.4	0.20

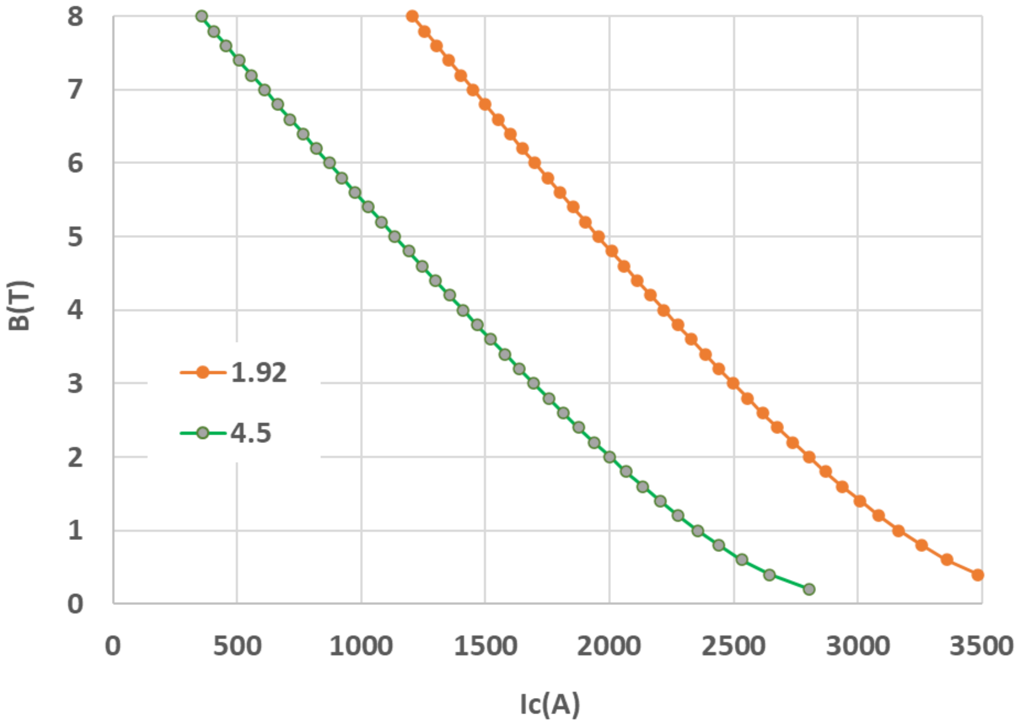
LAYER	TURN	RADIUS(MM)	ANGLE(DEG)	TURN-LENGTH(M)	X(MM)	Y(MM)
1	1	182.247	0.29744	2.480000	182.998	0.950
6	668	197.247	62.48222	1.962081	91.481	175.600

LAYER NO.	BLOCK NO.	TURN NO.	WEDGE(DEGREE)	C2C-BODY(DEG)
1	1	37	0.00000	0.00000
1	2	66	0.04351	0.00000
1	3	7	14.99444	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**END-SPACER(MM)**	**C2C-END(MM)**
1	1	50	0.00000	0.00000
1	2	53	42.61774	0.00000
1	3	7	3.20477	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**WEDGE(DEGREE)**	**C2C-BODY(DEG)**
2	1	59	0.00000	0.00000
2	2	39	0.03188	0.00000
2	3	12	14.91120	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**END-SPACER(MM)**	**C2C-END(MM)**
2	1	31	0.00000	0.00000
2	2	68	1.51393	0.00000
2	3	11	5.16720	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**WEDGE(DEGREE)**	**C2C-BODY(DEG)**
3	1	51	0.00000	0.00000
3	2	32	4.99679	0.00000
3	3	27	14.99218	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**END-SPACER(MM)**	**C2C-END(MM)**
3	1	54	0.00000	0.00000
3	2	36	5.36306	0.00000
3	3	20	0.23650	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**WEDGE(DEGREE)**	**C2C-BODY(DEG)**
4	1	43	0.00000	0.00000
4	2	33	0.01612	0.00000
4	3	33	10.85757	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**END-SPACER(MM)**	**C2C-END(MM)**
4	1	44	0.00000	0.00000
4	2	52	10.82973	0.00000
4	3	13	10.82973	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**WEDGE(DEGREE)**	**C2C-BODY(DEG)**
5	1	56	0.00000	0.00000
5	2	32	0.00008	0.00000
5	3	27	13.57935	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**END-SPACER(MM)**	**C2C-END(MM)**
5	1	59	0.00000	0.00000
5	2	36	5.36306	0.00000
5	3	20	0.23650	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**WEDGE(DEGREE)**	**C2C-BODY(DEG)**
6	1	48	0.00000	0.00000
6	2	33	0.07112	0.00000
6	3	33	0.00789	0.00000
LAYER NO.	**BLOCK NO.**	**TURN NO.**	**END-SPACER(MM)**	**C2C-END(MM)**
6	1	49	0.00000	0.00000
6	2	52	10.82973	0.00000
6	3	13	10.82973	0.00000


Y
0.2
0.15
0.1
0.05
Z
0.05
0.1
0.15
0.2


Y
0.2
0.15
0.1
0.05
Z
−0.15
−0.1
−0.05
0.05
0.1
0.15
0.2
−0.05
−0.1
−0.15
−0.2





		Bc2(T)	Bc2(T)	
SC 4; Cu 3		13.298	13.1719	9.41341
Ic		Ic	Ic	Ic
1.92	B(T)	1.8	1.92	4.5
2095.941	0.2	3695.877	3667.897	2803.12
1990.57	0.4	3510.6	3483.497	2645.19
1918.519	0.6	3384.056	3357.408	2532.532
1859.965	0.8	3281.3	3254.938	2438.312
1808.786	1	3191.542	3165.376	2354.219
1762.279	1.2	3110.013	3083.987	2276.57
1719.004	1.4	3034.18	3008.256	2203.401
1678.106	1.6	2962.535	2936.685	2133.542
1639.033	1.8	2894.104	2868.308	2066.236
1601.409	2	2828.226	2802.466	2000.964
1564.965	2.2	2764.425	2738.689	1937.357
1529.502	2.4	2702.352	2676.629	1875.138
1494.869	2.6	2641.74	2616.021	1814.098
1460.948	2.8	2582.382	2556.659	1754.075
1427.646	3	2524.112	2498.38	1694.937
1394.886	3.2	2466.798	2441.05	1636.58
1362.607	3.4	2410.331	2384.563	1578.915
1330.758	3.6	2354.618	2328.826	1521.872
1299.294	3.8	2299.585	2273.764	1465.389
1268.179	4	2245.166	2219.314	1409.415
1237.382	4.2	2191.306	2165.419	1353.904
1206.876	4.4	2137.957	2112.032	1298.819
1176.636	4.6	2085.077	2059.112	1244.126
1146.642	4.8	2032.63	2006.623	1189.796
1116.876	5	1980.583	1954.532	1135.803
1087.321	5.2	1928.909	1902.812	1082.123
1057.964	5.4	1877.581	1851.437	1028.737
1028.791	5.6	1826.578	1800.384	975.6249
999.7908	5.8	1775.878	1749.634	922.7715
970.9531	6	1725.465	1699.168	870.1614
942.2683	6.2	1675.32	1648.97	817.7811
913.728	6.4	1625.429	1599.024	765.6181
885.3242	6.6	1575.778	1549.317	713.6612
857.0498	6.8	1526.354	1499.837	661.9002
828.8983	7	1477.147	1450.572	610.3255
800.8637	7.2	1428.145	1401.511	558.9284
772.9404	7.4	1379.338	1352.646	507.7008
745.1233	7.6	1330.718	1303.966	456.6353
717.4077	7.8	1282.277	1255.463	405.725
689.7891	8	1234.006	1207.131	354.9634