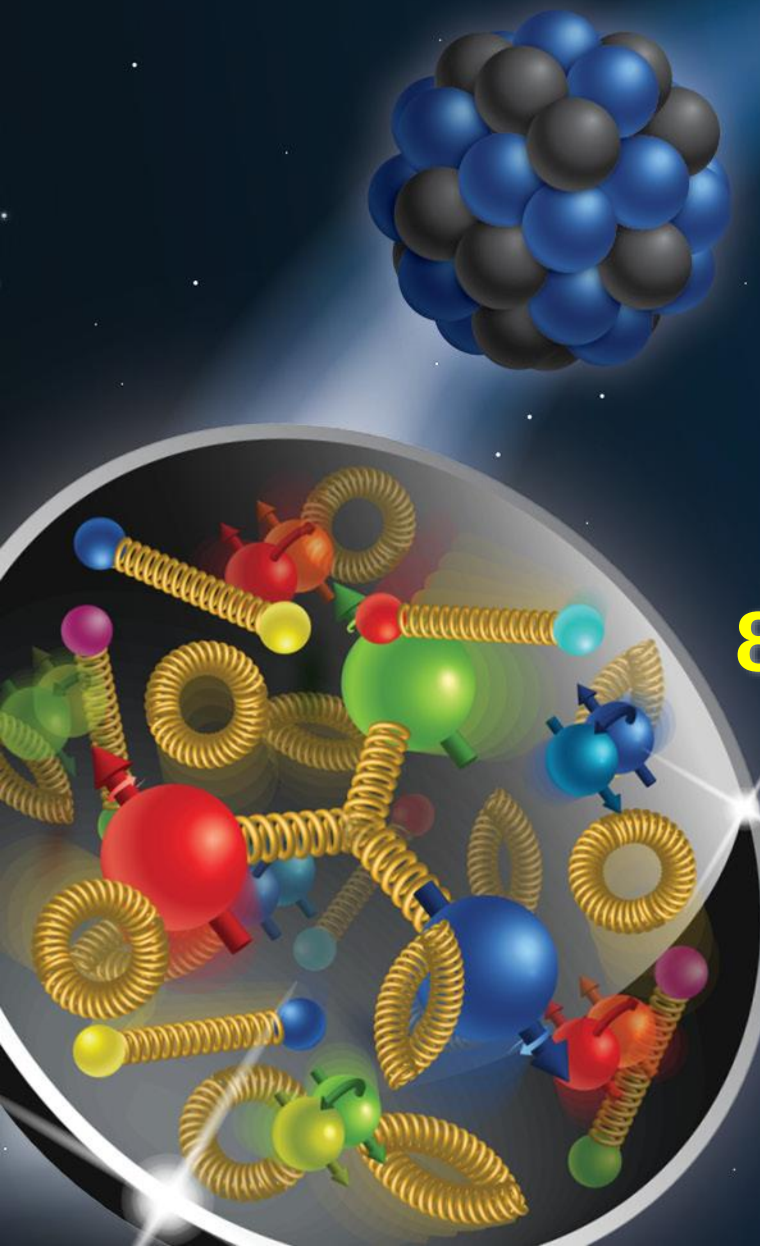

Evaluation of RHIC Magnets for EIC (higher energy and higher temperature)

80 mm and 100 mm Dipoles

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September 28, 2020

Electron Ion Collider – eRHIC

BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

Evaluation of 80 mm & 100 mm Dipoles for EIC
(to operate at higher field and higher temperature)

Questions to be addressed:

Can RHIC magnets operate safely at 275 GeV at elevated temperatures?

What are the temperature margins for 80 mm and 100 mm aperture RHIC dipoles (based on the actual superconducting cable used)?

This is a broader evaluation on the best possible performance of the superconducting coils (no defects, tec.) at higher temperatures

9/17 presentation was at specific operating points for 80 mm dipole

Use of RHIC magnets for EIC parameters requires them to have a sufficient mechanical margin (both by design and by construction) to deal against larger Lorentz forces at higher fields, sufficient thermal margin in superconducting coils at higher temperature, in addition to the sufficient operational margin to prevent quenching during operation

RHIC 80 mm and 100 mm dipoles

Measured values for I(A) & B(T); computed values for peak fields on conductor B_{pk}(T) [up to ~7 kA , ~4.5 T]

RHIC 80 mm dipoles

DRG107		Bpk/Bo
RHIC 80 mm Dipole		1.151
I(A)	Bo(T)	Bpk(T)
49.96	0.04	0.04
100.02	0.07	0.08
199.97	0.14	0.16
300.07	0.21	0.24
400.10	0.28	0.33
600.16	0.42	0.49
660.07	0.47	0.54
800.00	0.57	0.65
1000.13	0.71	0.82
1200.19	0.85	0.98
1400.02	0.99	1.14
1450.06	1.03	1.18
1600.16	1.13	1.30
1800.20	1.28	1.47
2000.20	1.42	1.63
2200.18	1.56	1.79
2400.24	1.70	1.96
2600.30	1.84	2.12
2800.20	1.98	2.28
3000.33	2.12	2.44
3200.32	2.26	2.60
3400.22	2.39	2.76
3600.40	2.53	2.91
3800.32	2.66	3.06
4000.40	2.79	3.21
4200.38	2.92	3.36
4400.38	3.04	3.50
4600.43	3.16	3.64
4800.41	3.28	3.78
5000.45	3.40	3.92
5200.53	3.52	4.05
5400.51	3.63	4.18
5600.57	3.74	4.31
5800.61	3.85	4.43
6000.73	3.96	4.56
6200.63	4.06	4.68
6400.60	4.17	4.80
6600.76	4.27	4.92
6800.61	4.37	5.03
7000.96	4.47	5.15

RHIC 100 mm dipoles

DRZ102	body	Bpk/Bo	
RHIC 100 mm Dipole		1.129	
I(A)	Bo(T)	Bpk(T)	TF(T/kA)
51.08	0.04	0.04	0.749
201.11	0.15	0.17	0.744
401.22	0.30	0.34	0.745
661.69	0.49	0.56	0.746
1001.60	0.75	0.84	0.746
1451.25	1.08	1.22	0.746
2001.11	1.49	1.69	0.746
2600.96	1.94	2.19	0.745
3000.74	2.23	2.52	0.743
3600.41	2.65	2.99	0.736
4000.38	2.91	3.29	0.728
4600.12	3.28	3.71	0.714
5000.08	3.52	3.97	0.703
5599.99	3.85	4.35	0.687
5999.93	4.06	4.59	0.677
6399.87	4.27	4.82	0.668
6599.91	4.38	4.94	0.663
6999.58	4.58	5.17	0.654

Superconducting Cables in 80 mm and 100 mm Dipoles

Specifications

Table 2-2 . 30-Strand Cable Requirements

Requirement	Value
DIMENSIONAL AND MECHANICAL	
Number of Wires in Cable	30
Cable Mid-Thickness	(0.04590±0.00025 in.) 1.166±0.006 mm
Cable Width	(0.383±0.001 in.) 9.73±0.03 mm
Cable Keystone Angle	1.2±0.1 deg
Cable Lay Direction	Left
Cable Lay Pitch	(2.9±0.2 in.) 74±5 mm
Wire Twist Pitch in Cable	(1.9±0.2 twists/in.) 0.75±0.08 twists/cm
ELECTRICAL	
Cable Minimum Critical Current at 5.0 T, 4.2 K	7524 A
Cable Maximum R (295 K)	0.00268 Ω/m
Cable Minimum RRR	38

Delivered

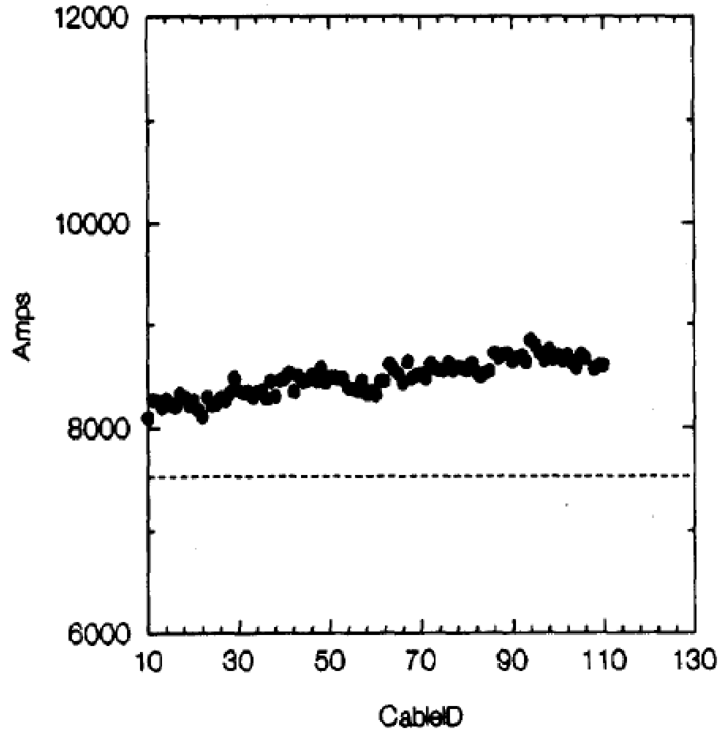
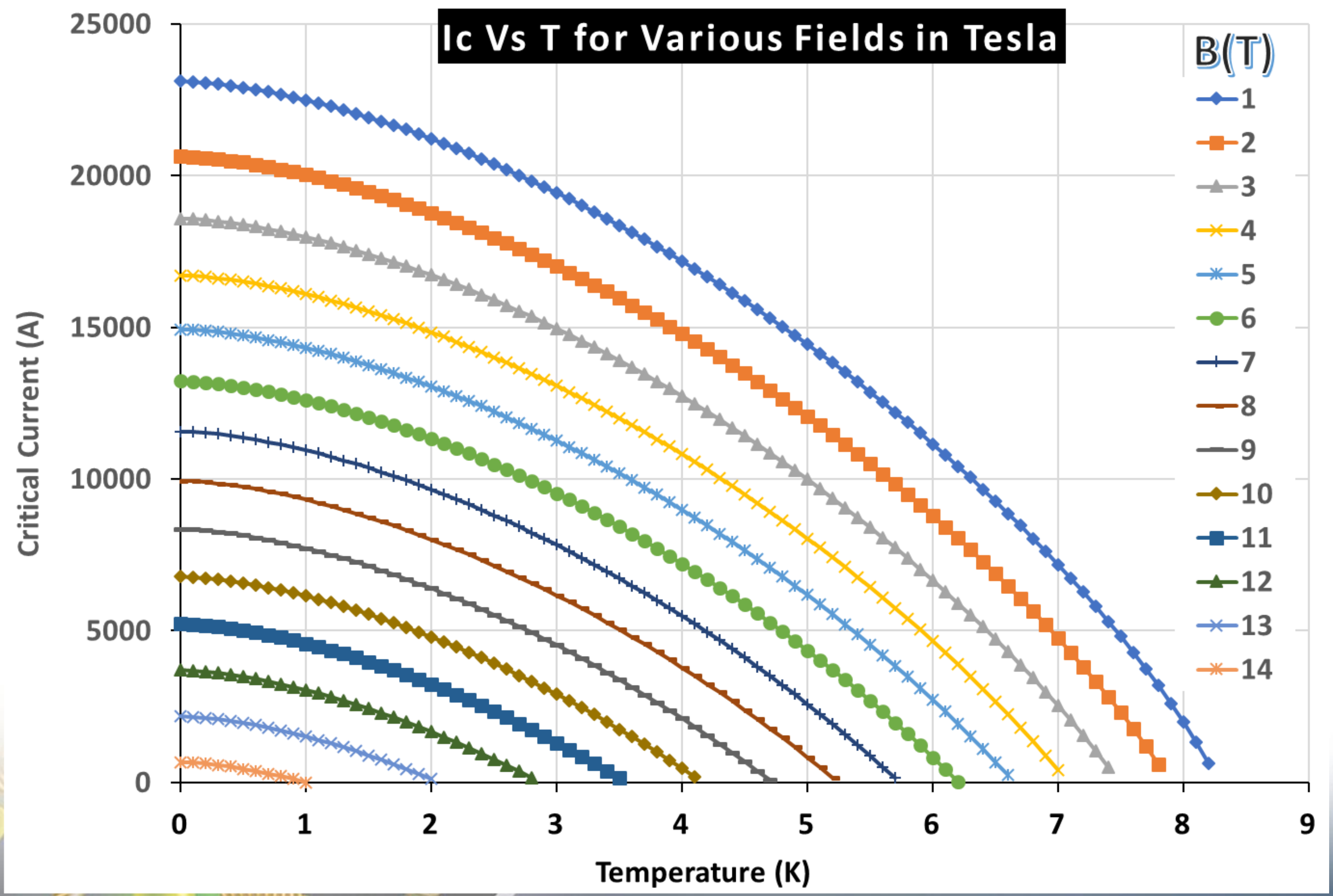


Figure 6. Cable short sample I_c (5T, 4.2 K) results. The mean value is 8475 A, std. dev. = ±163 A (1.9%). The dashed line is the specification minimum.

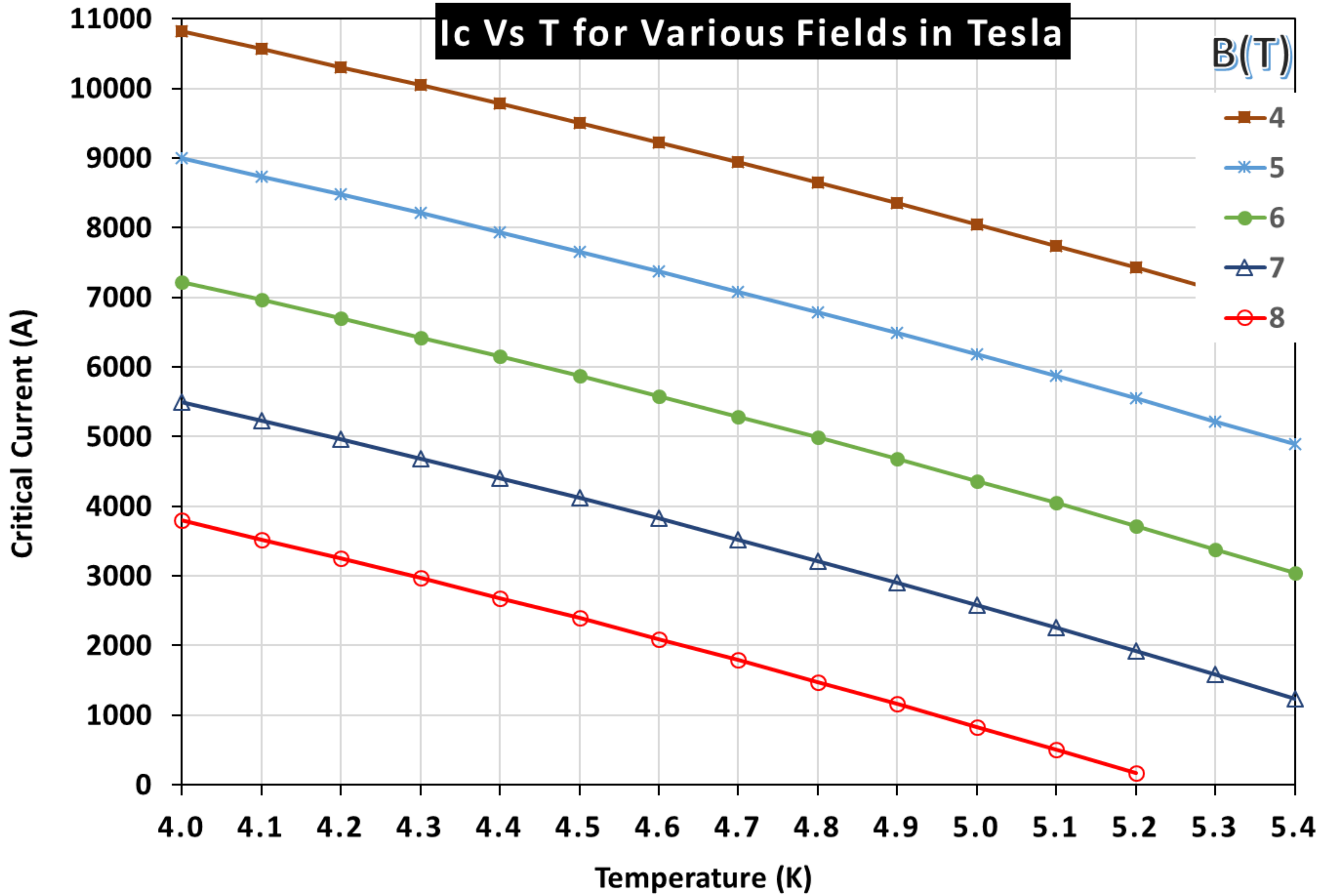
Cable used (8475 A on average) was ~10% better than specified (7524 A) – important for EIC

Critical currents of the 80 mm and 100 mm cable at various fields and temperatures (1)



For 8475 A (5T, 4.2K), Average cable
Note: Weak link limits the performance

Critical currents of the 80 mm and 100 mm cable at various fields and temperatures (2)



Raw fitted numerical values in backup slides

RHIC 80 mm Arc Dipoles

RHIC 80 mm ARC Dipole
(performance computed, field quality measured)

Table I
Basic design parameters of RHIC arc dipoles

Coil inner, outer radius	40 mm, 50 mm
Yoke inner, outer radius	59.7 mm, 133.4 mm
Field, current at injection	0.40 T, 0.57 kA
Maximum design field, current	3.46 T, 5.09 kA
Computed quench at 4.5° K	8.25 kA
Magnetic length at 3.46 Tesla	9.44 m

EIC: 275 GeV @3.8 T, 5.6 kA

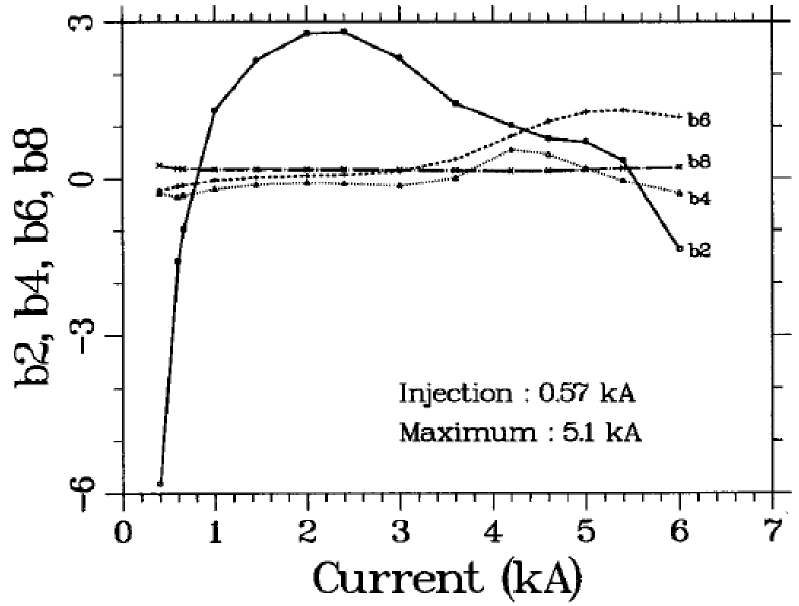
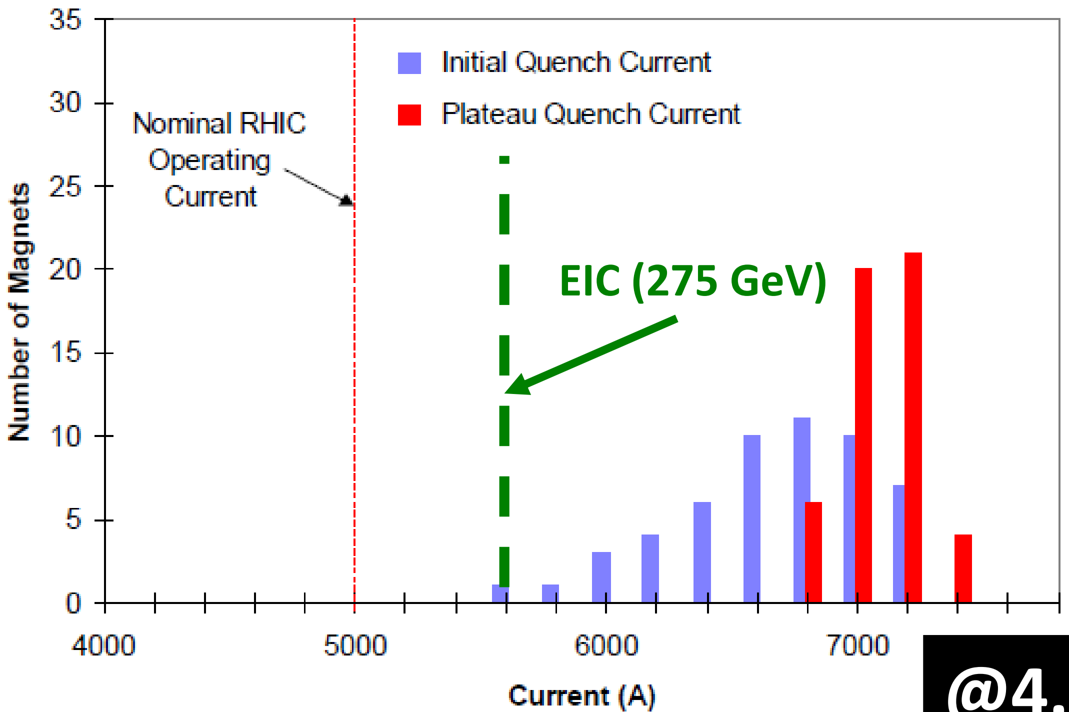


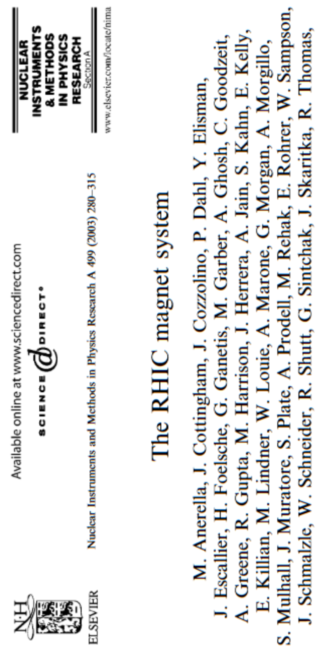
Figure 2. The measured current dependence of harmonics during up ramp (and 20 second wait) in RHIC arc dipoles.

R. Gupta, et al., Field Quality Control Through the Production Phase of RHIC Arc Dipoles, Proceedings of the 1995 International Particle Accelerator Conference, Dallas, Texas (1995).

Quench Performance of RHIC 80 mm Dipoles (as measured)

Measurements show that RHIC 80 mm dipoles have sufficient “*mechanical*” margin for EIC operation at 275 GeV




Nuclear Instruments and Methods in Physics Research A 499 (2003) 280–315

The RHIC magnet system

M. Anerella, J. Cottingham, J. Cozzolino, P. Dahl, Y. Elisman, J. Escallier, H. Foelsche, G. Ganetis, M. Garber, A. Ghosh, C. Goodzeit, A. Greene, R. Gupta, M. Harrison, J. Herrera, A. Jain, S. Kahn, E. Kelly, E. Killian, M. Lindner, W. Louie, A. Marone, G. Morgan, A. Morgillo, S. Mulhall, J. Muratore, S. Plate, A. Prodell, M. Rehak, E. Rohrer, W. Sampson, J. Schmalzle, W. Schneider, R. Shutt, G. Sintchak, J. Skaritka, R. Thomas, P. Thompson, P. Wanderer*, E. Willen

Brookhaven National Laboratory, Upton, NY 11973, USA

@4.5K

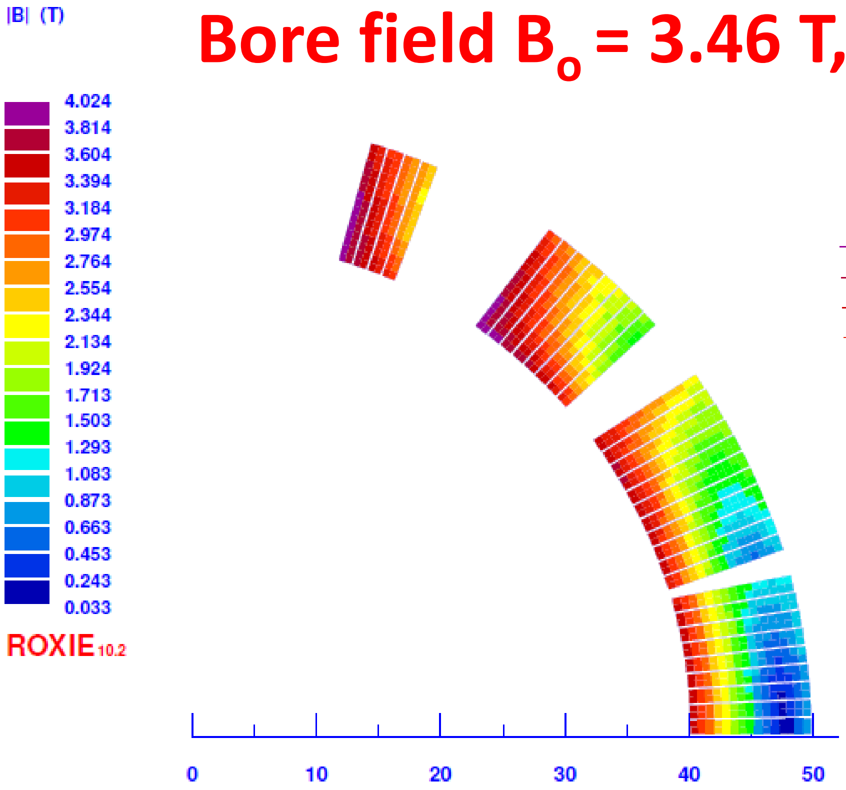
Figure 3 Quench performance of 51 arc dipoles, tested at 4.5 K. The average plateau quench current of these 51 magnets was 7101 A; the field at this average quench current is 4.52 T.

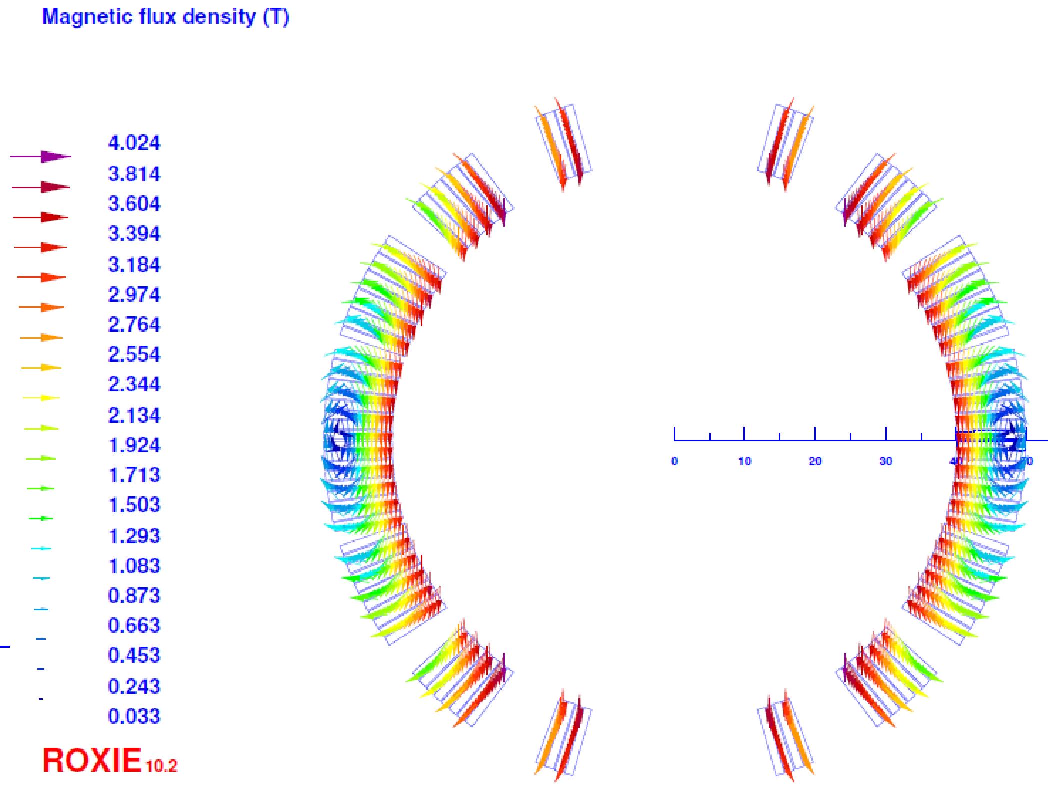
Computed quench field and margins at various temperatures for 80 mm dipoles

(not computed: off-axis field errors)

Field on the superconductor at the design field of RHIC 80 mm dipole (with ROXIE model)

Bore field B_o = 3.46 T, Peak Field B_{pk}= 4.02 T





Validation of the ROXIE Model

Values from the reference paper:

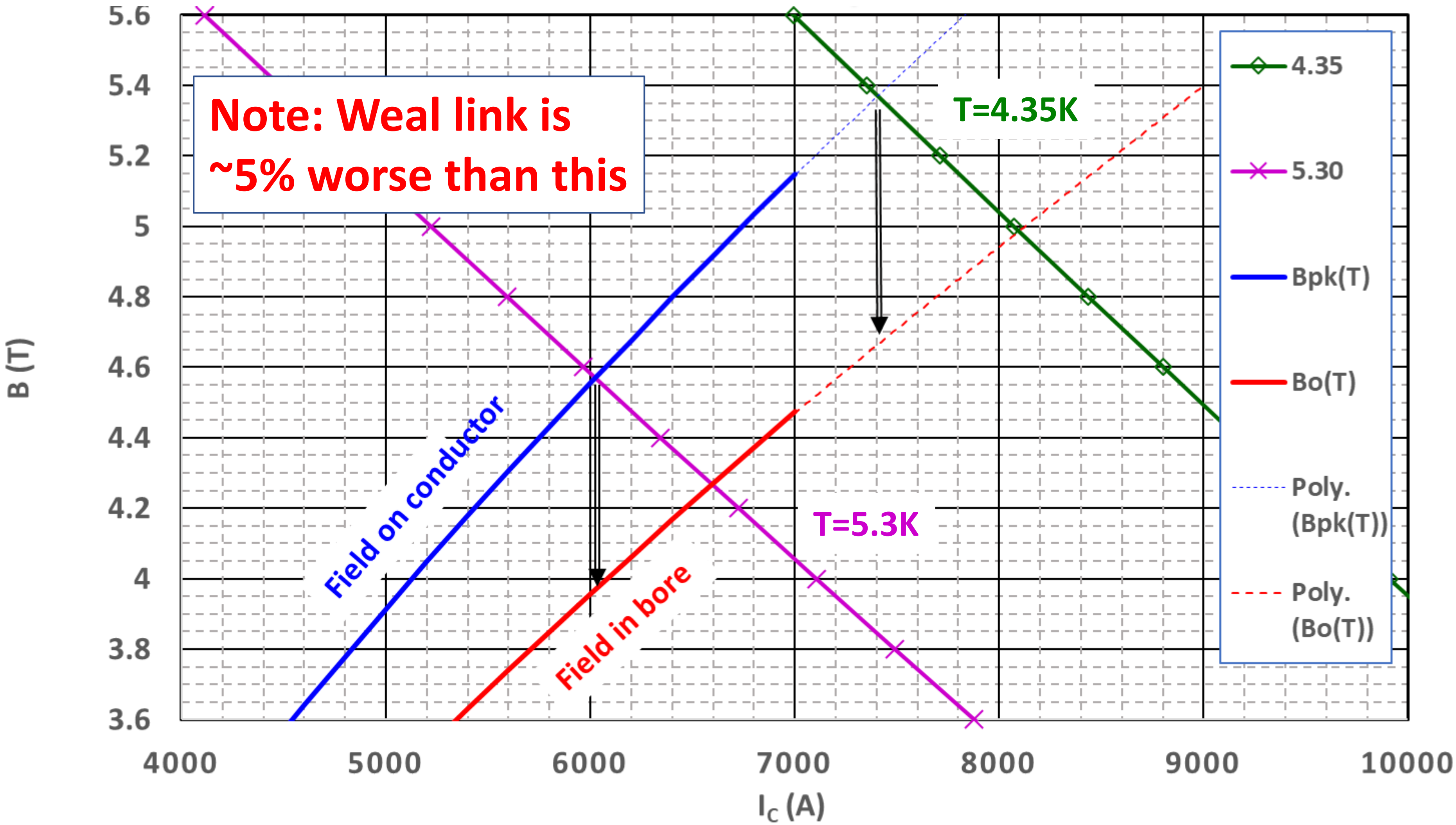
Maximum design field, current	3.46 T, 5.09 kA
Computed quench at 4.5° K	8.25 kA

```
MAIN FIELD (T):3.46
PEAK FIELD IN CONDUCTOR (T): 4.03
CURRENT IN CONDUCTOR (A): 5090
PERCENTAGE ON THE LOAD LINE :76.17
QUENCHFIELD (T): 5.28
TEMPERATURE MARGIN TO QUENCH(K):1.12
PERCENTAGE OF SHORT SAMPLE CURRENT: 61.5
```

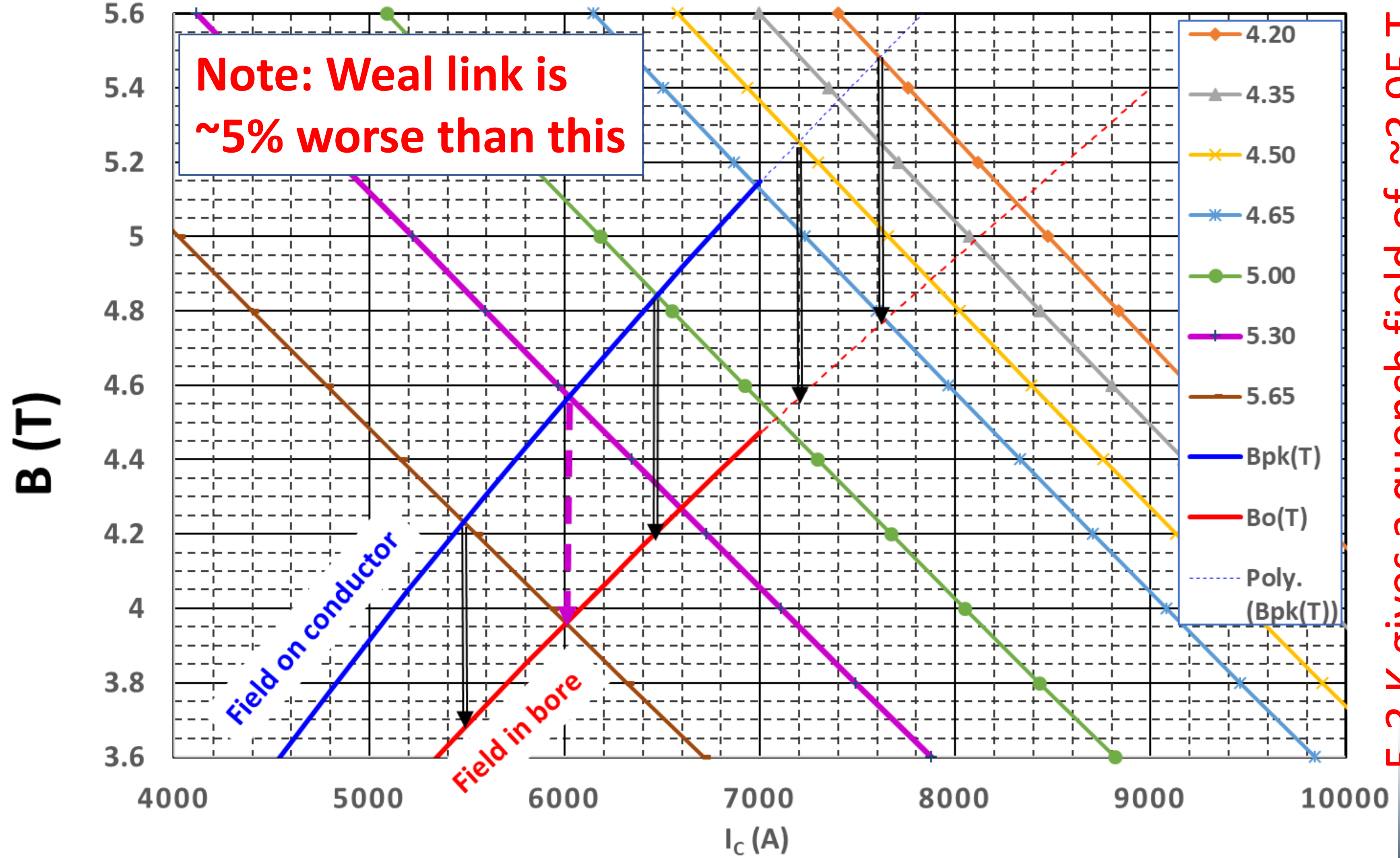
Good Agreement

8.27 kA

Expanded Analytical Calculations of Margins in RHIC 80 mm Dipoles (1)

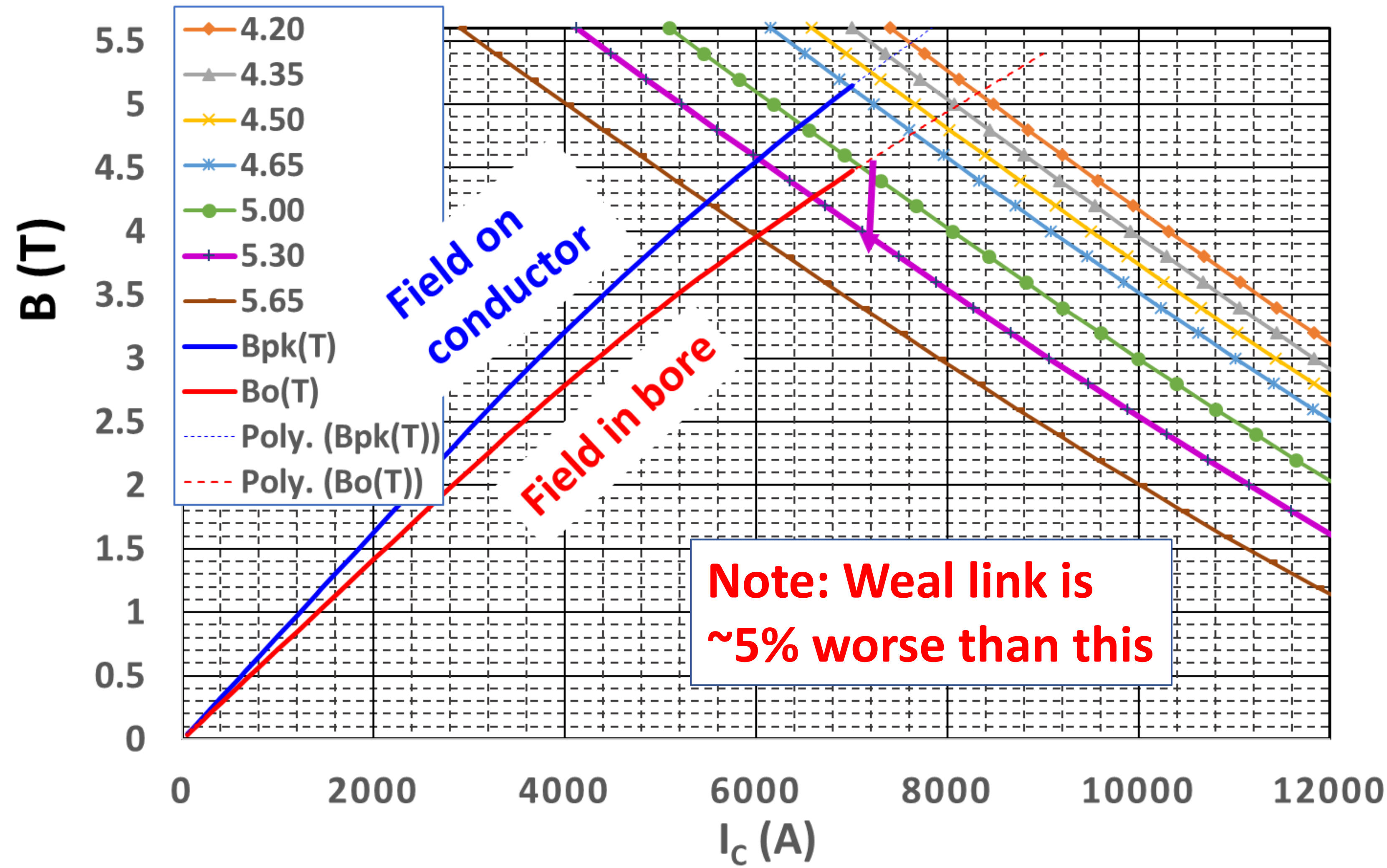


Expanded Analytical Calculations of Margins in RHIC 80 mm Dipoles (2)



5.3 K gives a quench field of ~3.95 T (5% for weak link means 3.75 T)

Expanded Analytical Calculations of Margins in RHIC 80 mm Dipoles (3)



Such curves can be used to compute margin at any place

Computed Quench Temperature Margin at a specific point with computer model (ROXIE)

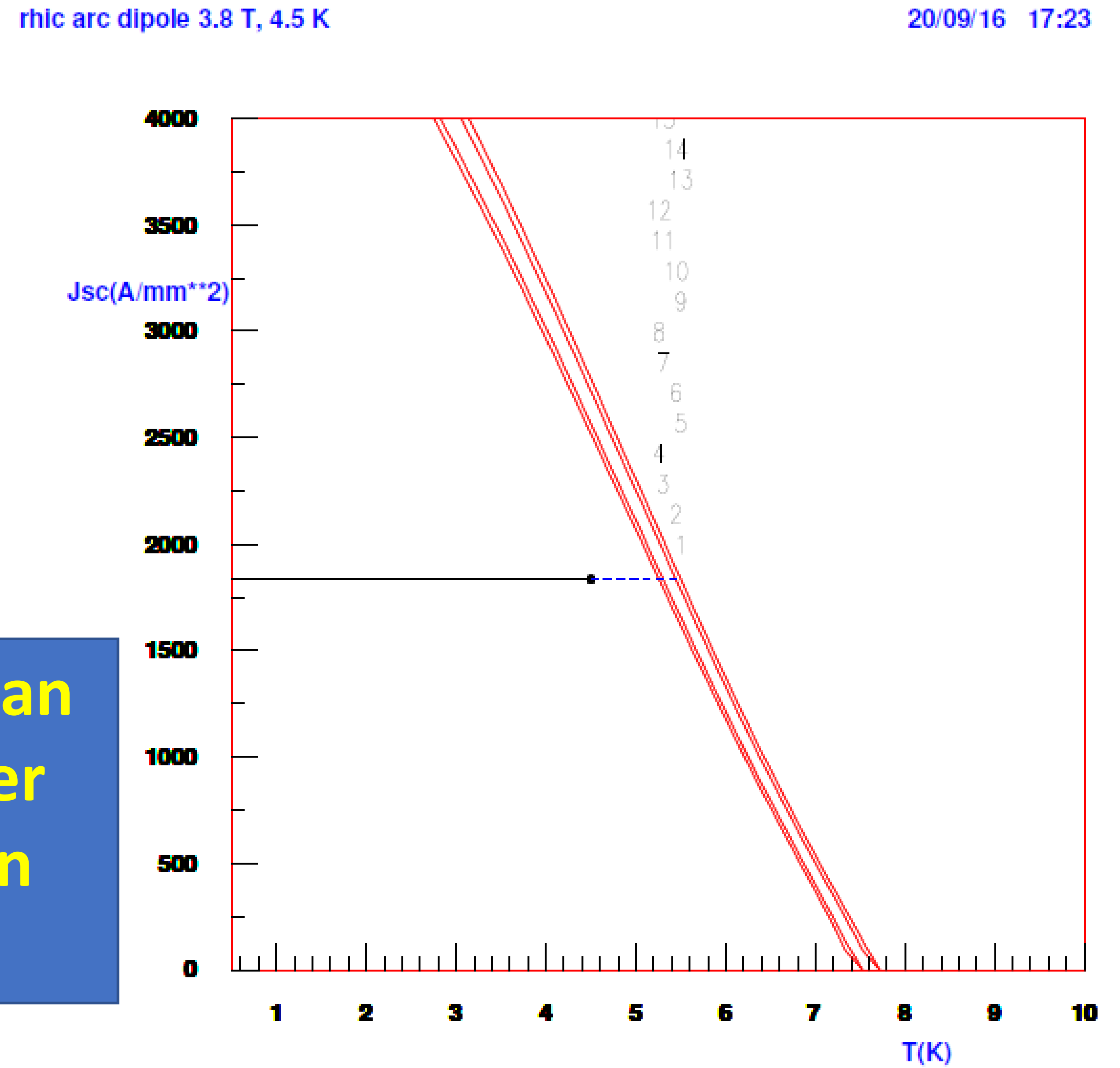
@B_o=3.8 T

I = 5.6 kA

T = 4.5 K

Temp Margin ~0.7

Similar calculations can be performed at other fields (as requested in the table provided)



My take on use of RHIC 80 mm for 275 GeV operation

- RHIC 80 mm dipole magnets have proven mechanical margin for 275 GeV operation (proven by the 51 tested magnets)
- RHIC 80 mm dipole also retain good field quality to 275 GeV
- The electrical/thermal margin may be sufficient at ~5 K in standalone situation. However, with the operating conditions of EIC (load coming from various places, plus the need for some margin), we will be entering in a risky area.
- Also 80 mm dipoles may be the best developed magnet (RHIC 80 mm quad have an even larger margin), situation may be more limited by other magnets

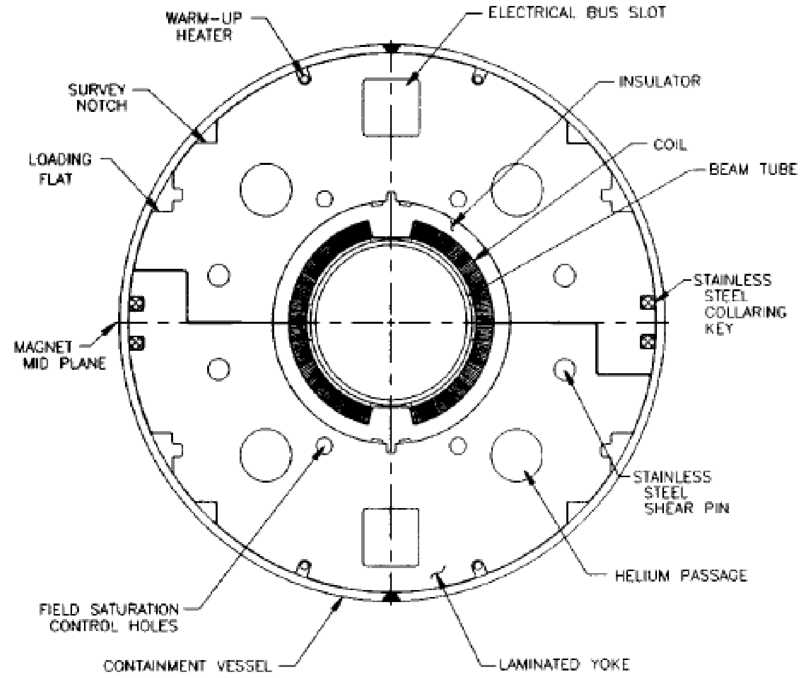
RHIC 100 mm Insertion Dipoles

RHIC 100 mm dipole design

- For the purpose of this meeting, the design of RHIC 100 mm insertion dipole is like the RHIC 80 mm dipoles.
- 100 mm dipole has a bit higher transfer function and lower peak field (both good), giving a bit higher quench field (a few percent) at about the same quench current.
- The 100 mm dipoles, however, did not go through a large numbers of iterations. In fact, the first prototype became the spare and rest went into machine.
- ROXIE model is yet to be made. We have many models but with the VAX codes that are yet to be converted for PC (about one month of work).
- However, we can use analytic curves, as used in the case of 80 mm dipoles, to make some estimates.

RHIC 100 mm dipole

Coil ID	100 mm
Coil OD	120 mm
Number of turns per pole	40
Magnetic length	3.6 m
Iron inner diameter	139.4 mm
Iron outer diameter	310 mm
Shell thickness	6.35 mm
Operating temperature	4.6 K
Design current	5.0 kA
Design field	3.5 T
Quench current	7.4 kA



Measured Quench Performance of 100 mm Dipoles

Measurements show that RHIC 100 mm dipoles have sufficient "*mechanical*" margin for EIC operation at 275 GeV (even though they required several quenches)

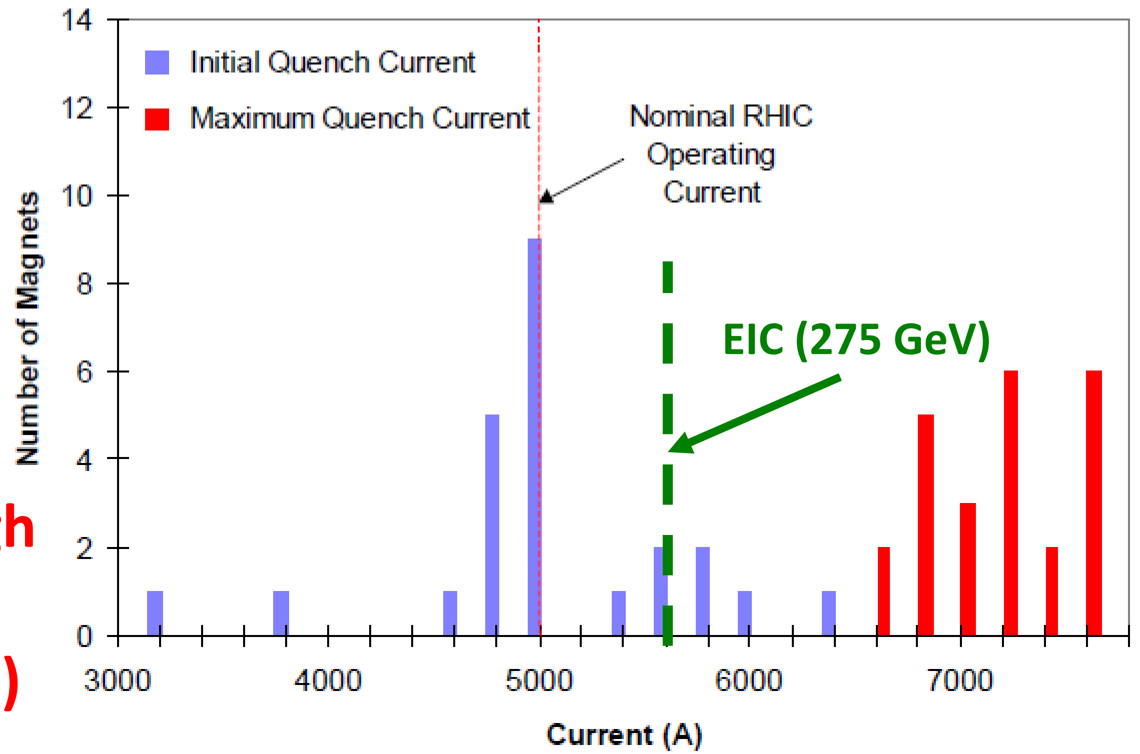


Figure 42 Quench performance of 24 large aperture (100 mm) dipoles, tested at 4.5 K

Comparison of 80 mm Vs 100 mm Dipoles

100 mm

Measurements show that RHIC 100 mm dipoles have sufficient "*mechanical*" margin for EIC operation at 275 GeV (even though they required several quenches)

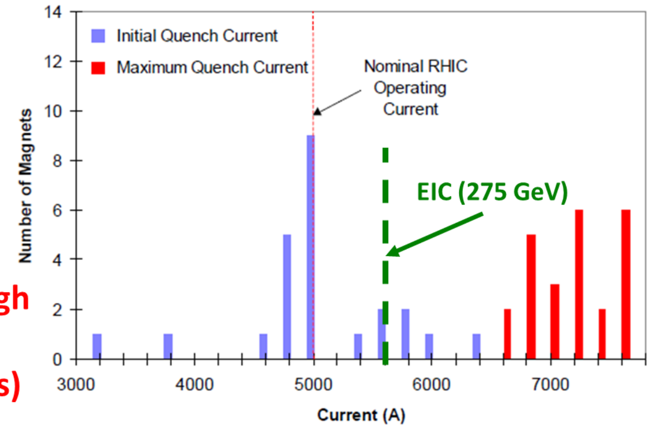
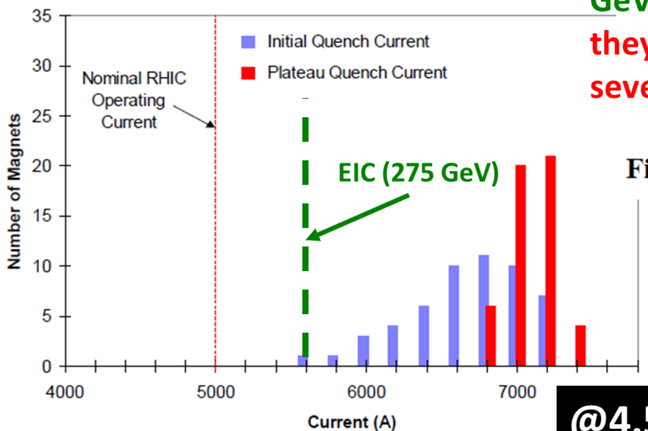


Figure 42 Quench performance of 24 large aperture (100 mm) dipoles, tested at 4.5 K

80 mm



@4.5K

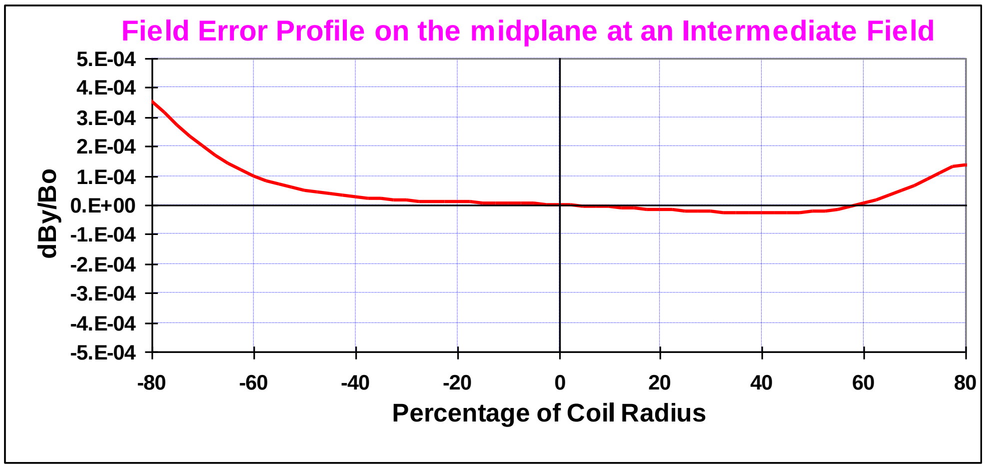
Figure 3 Quench performance of 51 arc dipoles, tested at 4.5 K. The average plateau quench current of these 51 magnets was 7101 A; the field at this average quench current is 4.52 T.

RHIC 100 mm Aperture Insertion Dipole:
The first magnet gets the body harmonics right

Geometric Field Errors on the X-axis of DRZ101 Body

First magnet and first attempt in RHIC 100 mm aperture insertion dipole

A number of things were done in the test assembly to get pre-stress & harmonics right



Note: Field errors are within 10^{-4} at 60% of coil radius and $\sim 4*10^{-4}$ at 80% radius.

Harmonics at 2 kA (mostly geometric).

Measured in 0.23 m long straigth section.

Reference radius = 31 mm

b1	-0.39	a2	-1.06
b2	-0.39	a3	-0.19
b3	-0.07	a4	0.21
b4	0.78	a5	0.05
b5	-0.05	a6	-0.20
b6	0.13	a7	0.02
b7	-0.03	a8	-0.16
b8	0.14	a9	-0.01
b9	0.02	a10	0.01
b10	-0.04	a11	-0.06
b11	0.03	a12	-0.01
b12	0.16	a13	0.06
b13	-0.03	a14	0.03
[illegible]	[illegible]	[illegible]	[illegible]

Later magnets had adjustments for integral field and saturation control.
The coil cross-section never changed.

All harmonics are within or close to one sigma of RHIC arc dipoles.

Average Field errors ~10^{-4} (up to 80% of the coil radius)

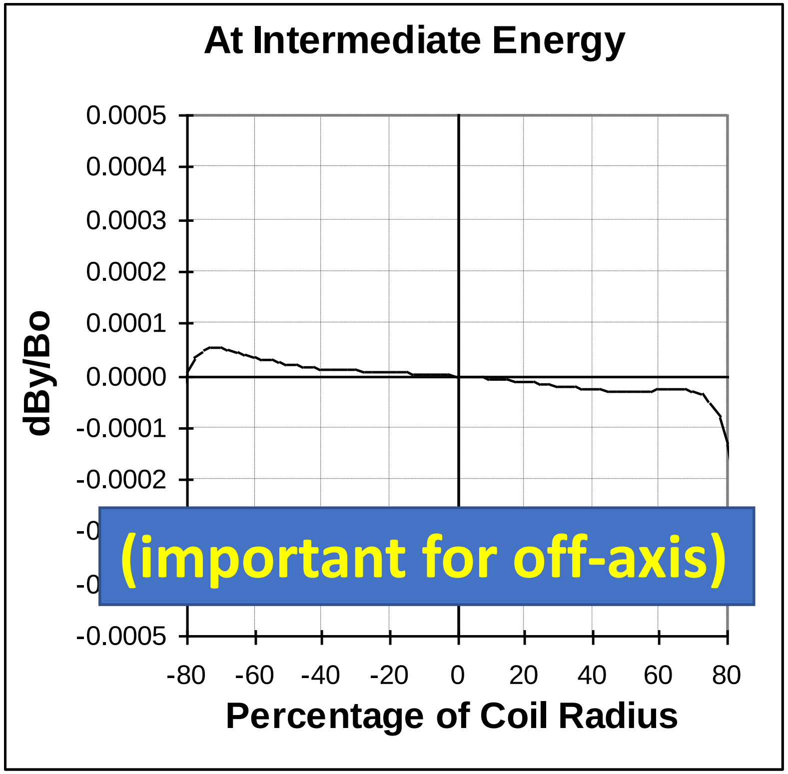
Note:
80% of coil radius, not just 2/3.

At 80%, you are close to inner radius of beam tube. This means that almost entire physical aperture has become a good field aperture.

Geometric Field Errors on the X-axis of RHIC DRZ magnets (108-125)

Coil X-section was not changed between 1st prototype and final production magnet

A Flexible & Experimental Design Approach Allowed Right Pre-stress & Right Harmonics



Estimated Integral Mean in Final Set
(Warm-cold correlation used in estimating)
Harmonics at 3kA (mostly geometric)
Reference radius is 31 mm (Coil 50 mm)

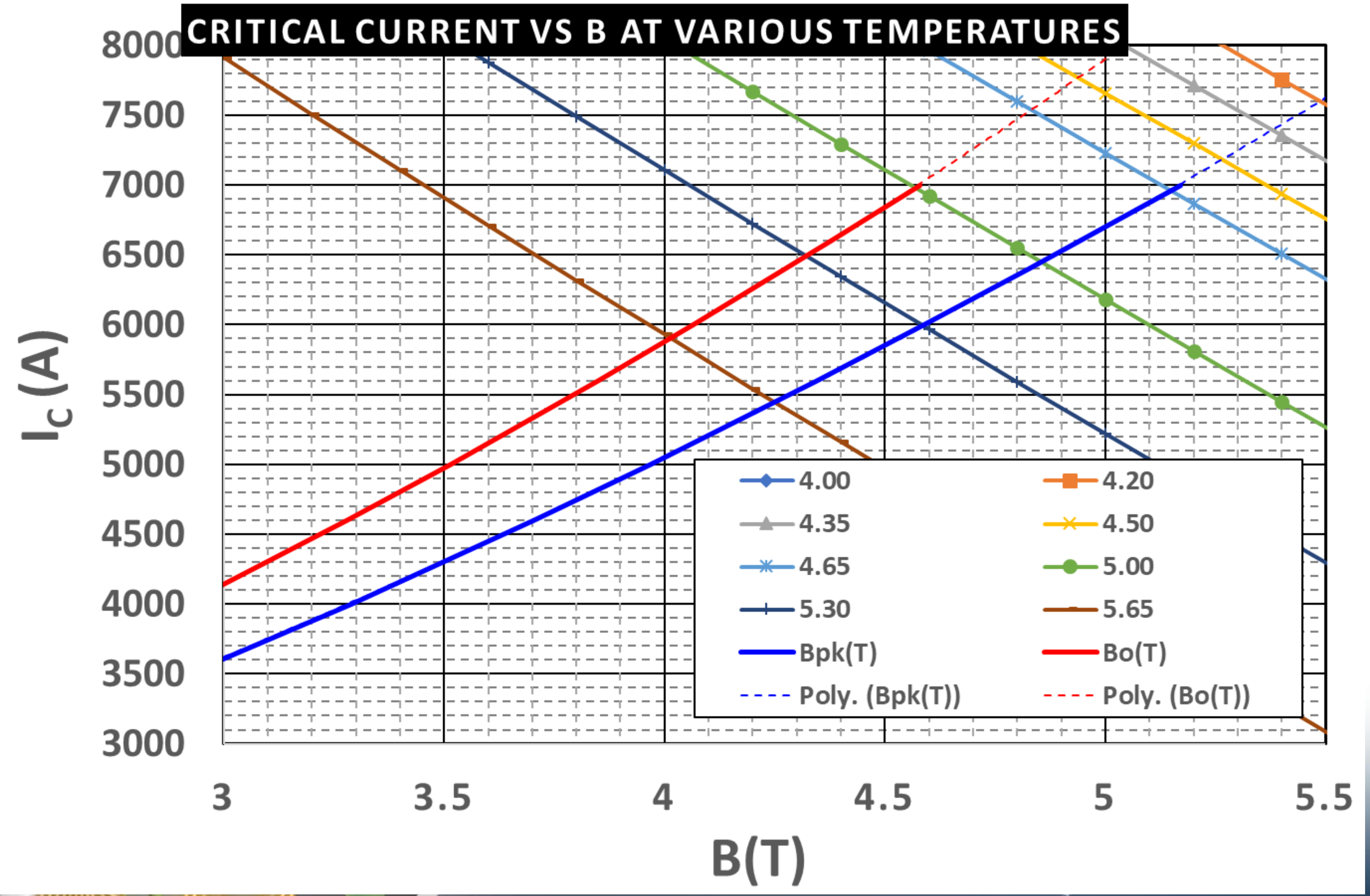
b1	-0.28	a1	-0.03
b2	-0.26	a2	-3.36
b3	-0.07	a3	0.03
b4	0.15	a4	0.48
b5	0.00	a5	0.04
b6	0.32	a6	-0.24
b7	0.00	a7	0.01
b8	-0.08	a8	0.05
b9	0.00	a9	0.00
b10	-0.12	a10	-0.02
b11	0.03	a11	-0.01
b12	0.16	a12	0.06
b13	-0.03	a13	0.03
b14	-0.10	a14	0.02

**Raw Data Provided by Animesh Jain at BNL*

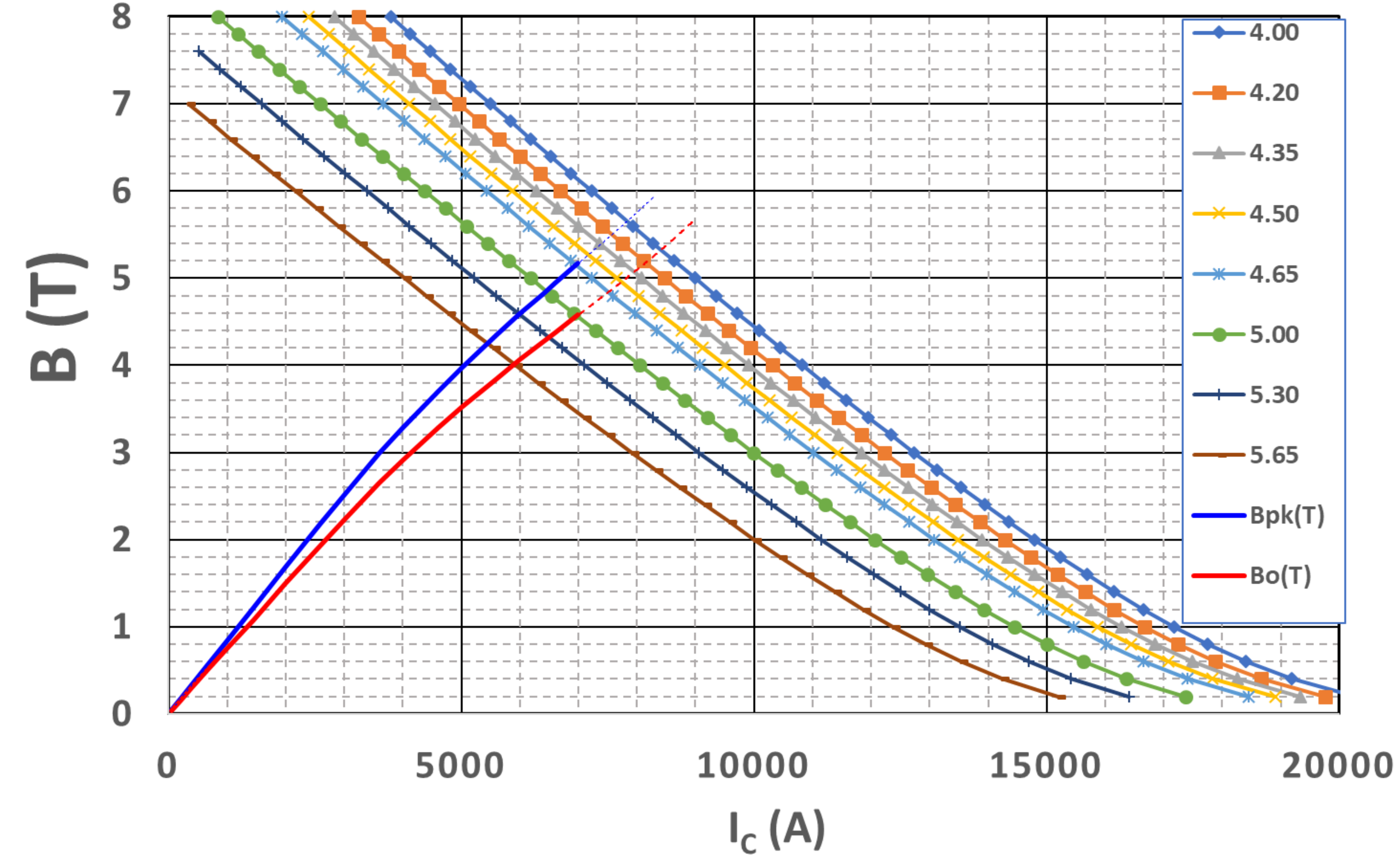
Field errors are 10^{-4} to 80% of the aperture at midplane.

(Extrapolation used in going from 34 mm to 40 mm; reliability decreases)

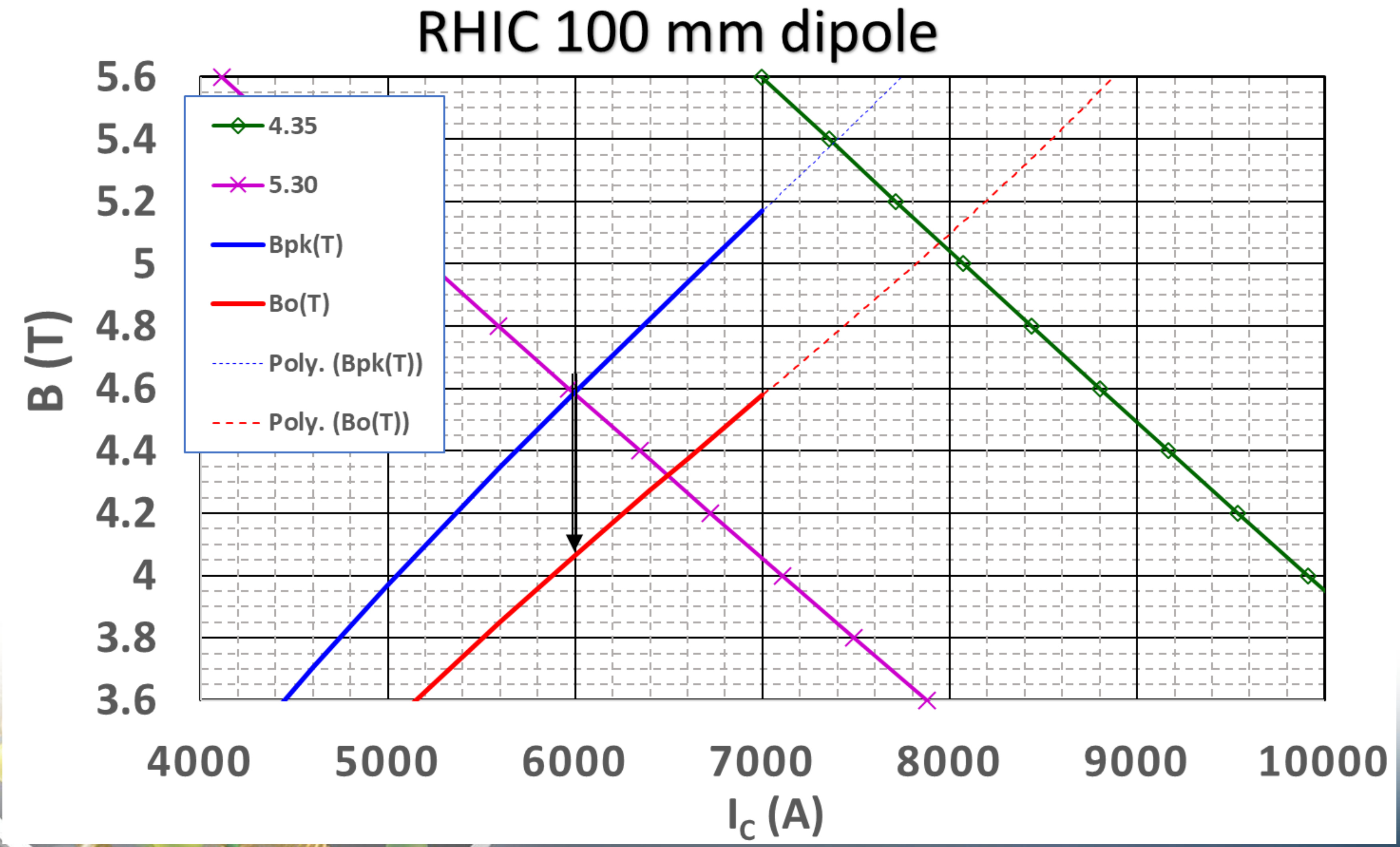
RHIC 100 mm Dipole Performance at Various Temperatures (1)



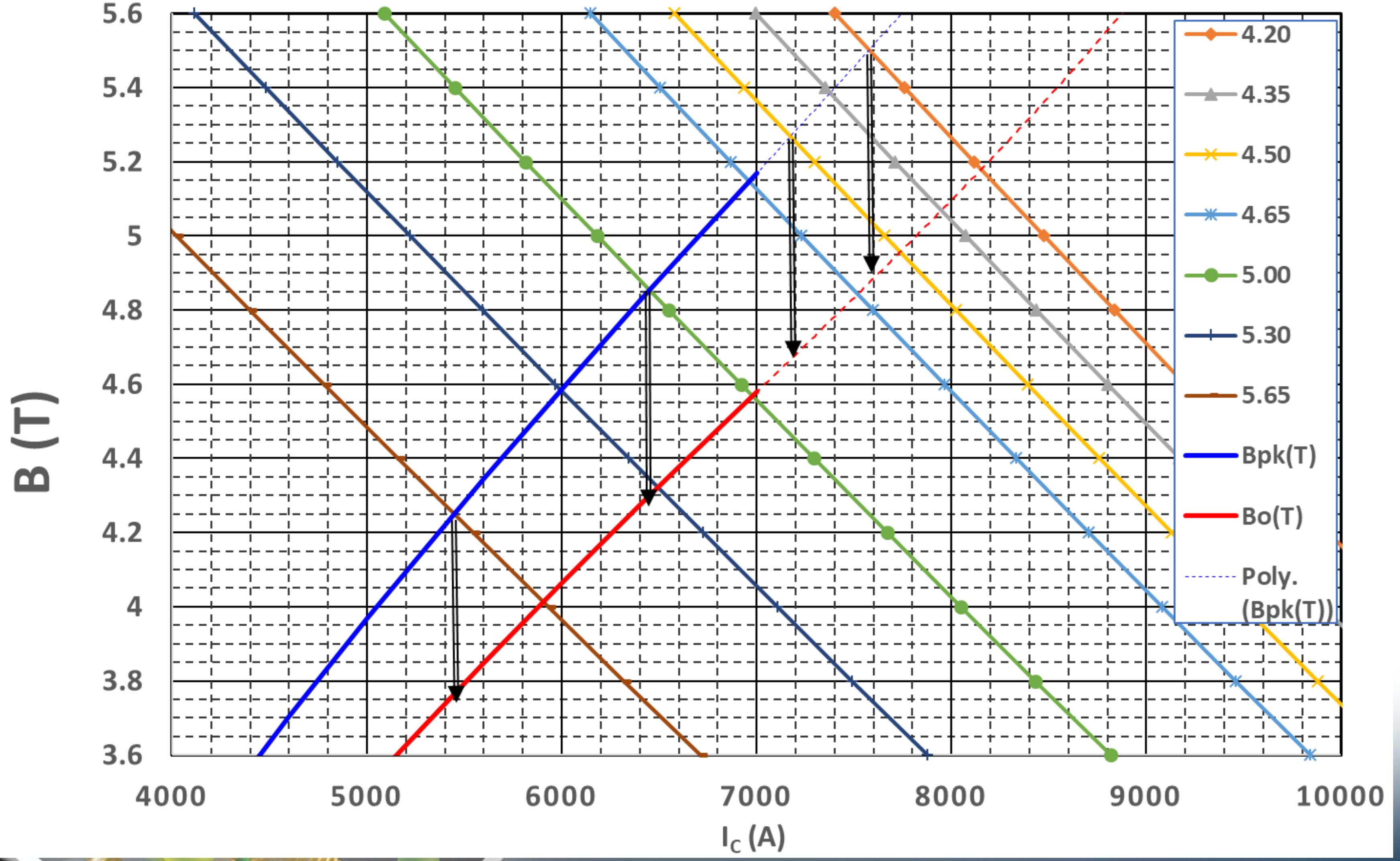
RHIC 100 mm Dipole Performance at Various Temperatures (2)



RHIC 100 mm Dipole Performance at Various Temperatures (3)



RHIC 100 mm Dipole Performance at Various Temperatures (4)



Summary

- **Initial evaluation of RHIC 3.5 T (250 GeV for proton) of 80 mm and 100 mm dipoles made for using in EIC 3.8 T (275 GeV) at various temperatures.**
- **Magnetic and mechanical design margin may be ok but very limited temperature margin at ~ 5 K.**
- **Not yet evaluated – impact of off-axis beam on field quality.**
- **Beside arc quadrupole, arc dipole is the most reliable magnet in the RHIC lattice.**
- **Situation may be worse for other magnets (yet to be evaluated) for the same lattice .**

Backup Slides

Magnet stability (from Silvia Verdú Andrés)

- Which is the preferred margin for stable operation (no quench)?
- Does the margin depend on the magnet topology?
- What is the maximum current (or field) for which the RHIC magnets were trained?
- Do we need to train the RHIC magnets to provide the field values required for EIC?
- How close can training bring the magnets to the simulated quench temperature?
- Training involves making the magnet quench. There are two pathways to quench: increase temperature (e.g. by applying dynamic heat load) or increasing current through coils. Which method can be used to train the magnets and is there any limitation? (Note magnets will remain in the RHIC tunnel.)

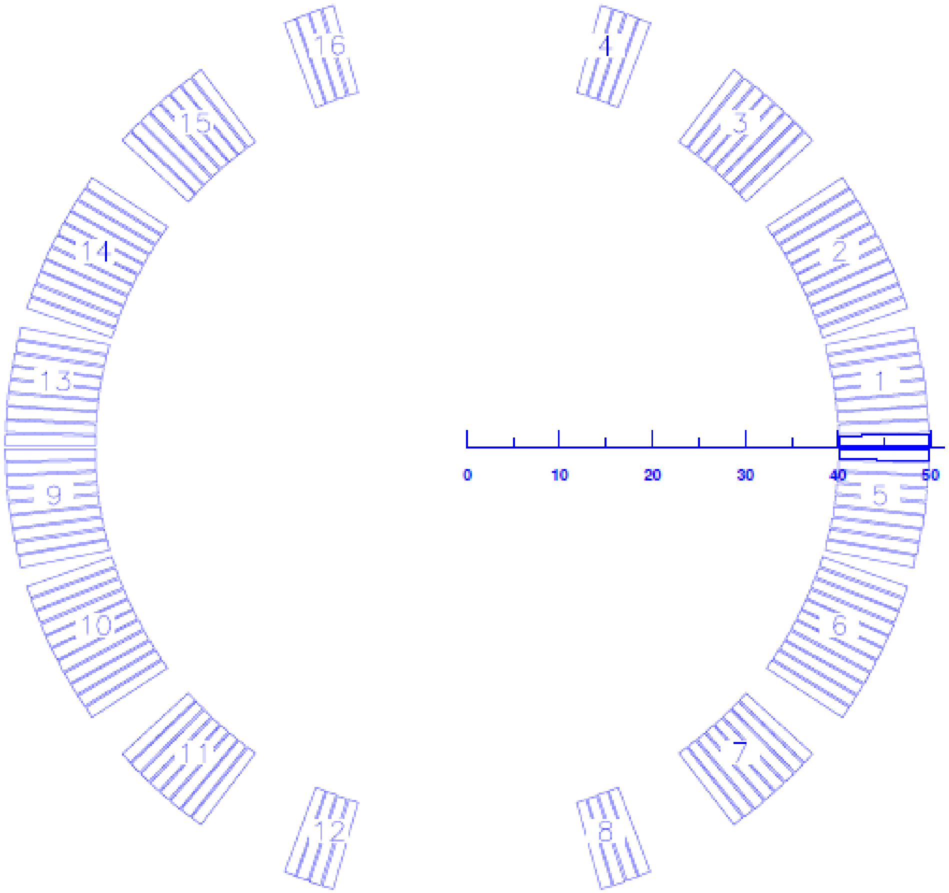
Temperature Margin at different fields

- Specific evaluation with ROXIE models (today)
- A broader evaluation with the basic properties of the superconductor used in various RHIC magnets (next presentations)
- These calculations assume perfect magnets and ignore training quenches, etc. (this could be a significant issue for insertion magnets unless field or field gradient reduced)
- Desired higher requirements for sextupole

Critical currents of the 80 mm and 100 mm cable at various fields and temperatures Fine Prints (the Raw Fitted Data)

	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	Ic(B,T)	
T(K)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	<=B(T)
0	23111	20636	18582	16708	14934	13228	11570	9947	8354	6784	5233	3700	2180	674	
0.1	23096	20621	18568	16693	14920	13213	11554	9932	8338	6768	5217	3684	2164	658	
0.2	23066	20591	18537	16662	14889	13182	11523	9901	8307	6736	5185	3651	2131	624	
0.3	23023	20549	18496	16621	14847	13140	11481	9858	8263	6692	5141	3606	2086	578	
0.4	22971	20498	18445	16570	14796	13088	11428	9805	8210	6638	5086	3551	2030	522	
0.5	22911	20438	18385	16510	14736	13028	11367	9743	8147	6575	5022	3486	1965	456	
0.6	22842	20371	18318	16442	14668	12959	11298	9673	8077	6504	4950	3413	1891	381	
0.7	22766	20296	18243	16368	14592	12883	11221	9596	7998	6424	4870	3332	1809	298	
0.8	22683	20214	18162	16286	14510	12800	11138	9511	7913	6338	4782	3244	1719	207	
0.9	22593	20126	18074	16197	14421	12710	11047	9419	7820	6244	4688	3148	1622	109	
1	22497	20031	17979	16103	14326	12614	10950	9321	7721	6144	4586	3045	1518	4	
1.1	22394	19931	17879	16002	14224	12512	10846	9217	7615	6037	4478	2936	1408		
1.2	22286	19824	17773	15895	14117	12403	10737	9106	7504	5924	4364	2820	1290		
1.3	22172	19712	17660	15782	14003	12289	10621	8989	7386	5805	4243	2698	1167		
1.4	22052	19594	17543	15664	13884	12169	10500	8867	7262	5679	4116	2569	1037		
1.5	21926	19470	17419	15541	13760	12043	10373	8739	7132	5548	3983	2435	901		
1.6	21796	19342	17291	15411	13630	11912	10241	8605	6996	5411	3844	2294	759		
1.7	21660	19208	17157	15277	13494	11775	10103	8465	6855	5268	3700	2148	610		
1.8	21518	19069	17018	15137	13354	11634	9959	8320	6708	5119	3550	1996	456		
1.9	21372	18924	16874	14993	13208	11486	9811	8170	6556	4965	3394	1838	296		
2	21220	18775	16725	14843	13057	11334	9656	8014	6398	4806	3232	1674	131		
2.1	21063	18621	16571	14688	12901	11176	9497	7853	6235	4641	3065	1505			
2.2	20902	18462	16412	14528	12740	11014	9333	7686	6067	4470	2892	1330			
2.3	20736	18298	16248	14363	12573	10846	9163	7514	5893	4294	2714	1149			
2.4	20564	18129	16079	14194	12402	10673	8988	7338	5714	4113	2530	963			
2.5	20388	17955	15906	14019	12226	10495	8808	7155	5530	3926	2341	772			
2.6	20207	17777	15727	13840	12045	10312	8623	6968	5340	3734	2146	574			
2.7	20021	17594	15544	13656	11859	10124	8433	6776	5145	3536	1946	371			
2.8	19831	17406	15356	13467	11669	9931	8238	6578	4945	3333	1740	163			
2.9	19636	17214	15164	13273	11473	9733	8038	6375	4739	3125	1529				
3	19436	17017	14966	13074	11272	9531	7832	6167	4528	2911	1312				
3.1	19232	16815	14764	12870	11067	9323	7622	5954	4312	2692	1090				
3.2	19022	16608	14557	12662	10856	9110	7406	5735	4090	2467	862				
3.3	18809	16397	14346	12449	10641	8892	7185	5511	3863	2237	628				
3.4	18590	16181	14129	12231	10421	8669	6959	5282	3631	2001	389				
3.5	18367	15961	13908	12008	10195	8441	6728	5048	3393	1759	144				
3.6	18139	15735	13682	11780	9965	8207	6491	4808	3149	1512					
3.7	17906	15505	13452	11547	9729	7969	6250	4562	2900	1259					
3.8	17669	15270	13216	11310	9489	7725	6002	4311	2646	1001					
3.9	17427	15031	12976	11067	9243	7476	5750	4055	2385	736					
4	17180	14787	12730	10819	8992	7222	5491	3793	2119	465					
4.1	16928	14537	12480	10566	8736	6962	5228	3525	1846	189					
4.2	16672	14283	12224	10308	8475	6697	4958	3251	1568						
4.3	16410	14024	11964	10045	8208	6426	4683	2971	1284						
4.4	16144	13760	11698	9777	7936	6149	4402	2685	993						
4.5	15873	13491	11428	9503	7658	5867	4115	2393	696						
4.6	15596	13217	11152	9223	7374	5579	3822	2095	392						
4.7	15315	12937	10870	8938	7085	5284	3522	1790	82						
4.8	15029	12653	10583	8648	6790	4984	3217	1479							
4.9	14737	12363	10291	8351	6488	4678	2904	1161							
5	14440	12067	9993	8049	6181	4364	2585	835							
5.1	14138	11767	9689	7741	5867	4045	2260	503							
5.2	13830	11460	9379	7426	5547	3718	1927	163							
5.3	13517	11148	9064	7105	5220	3385	1586								
5.4	13198	10830	8742	6778	4886	3044	1238								
5.5	12874	10505	8413	6444	4546	2696	883								
5.6	12543	10175	8079	6102	4197	2340	519								
5.7	12207	9838	7737	5754	3842	1977	147								
5.8	11864	9495	7388	5399	3478	1604									
5.9	11515	9145	7033	5035	3106	1223									
6	11159	8788	6669	4664	2726	833									
6.1	10797	8423	6298	4284	2336	433									
6.2	10427	8052	5919	3895	1937	24									
6.3	10051	7672	5531	3498	1528										
6.4	9667	7284	5134	3090	1109										
6.5	9275	6888	4728	2672	678										
6.6	8874	6482	4312	2243	236										
6.7	8466	6067	3885	1803											
6.8	8048	5642	3447	1350											
6.9	7621	5206	2997	883											
7	7183	4758	2533	402											
7.1	6735	4298	2055												
7.2	6275	3824	1562												
7.3	5802	3335	1051												
7.4	5315	2830	521												
7.5	4814	2306													
7.6	4295	1761													
7.7	3757	1193													
7.8	3198	596													
7.9	2612														
8	1996														
8.1	1341														
8.2	635														

ROXIE Model



16
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13
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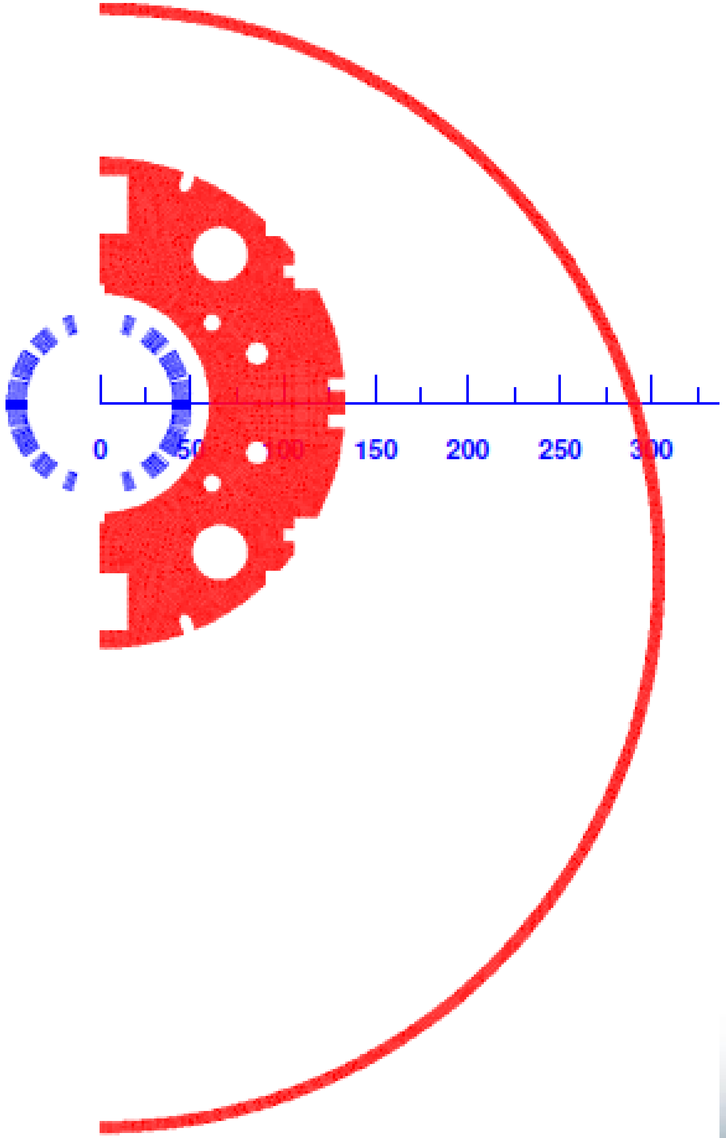
8



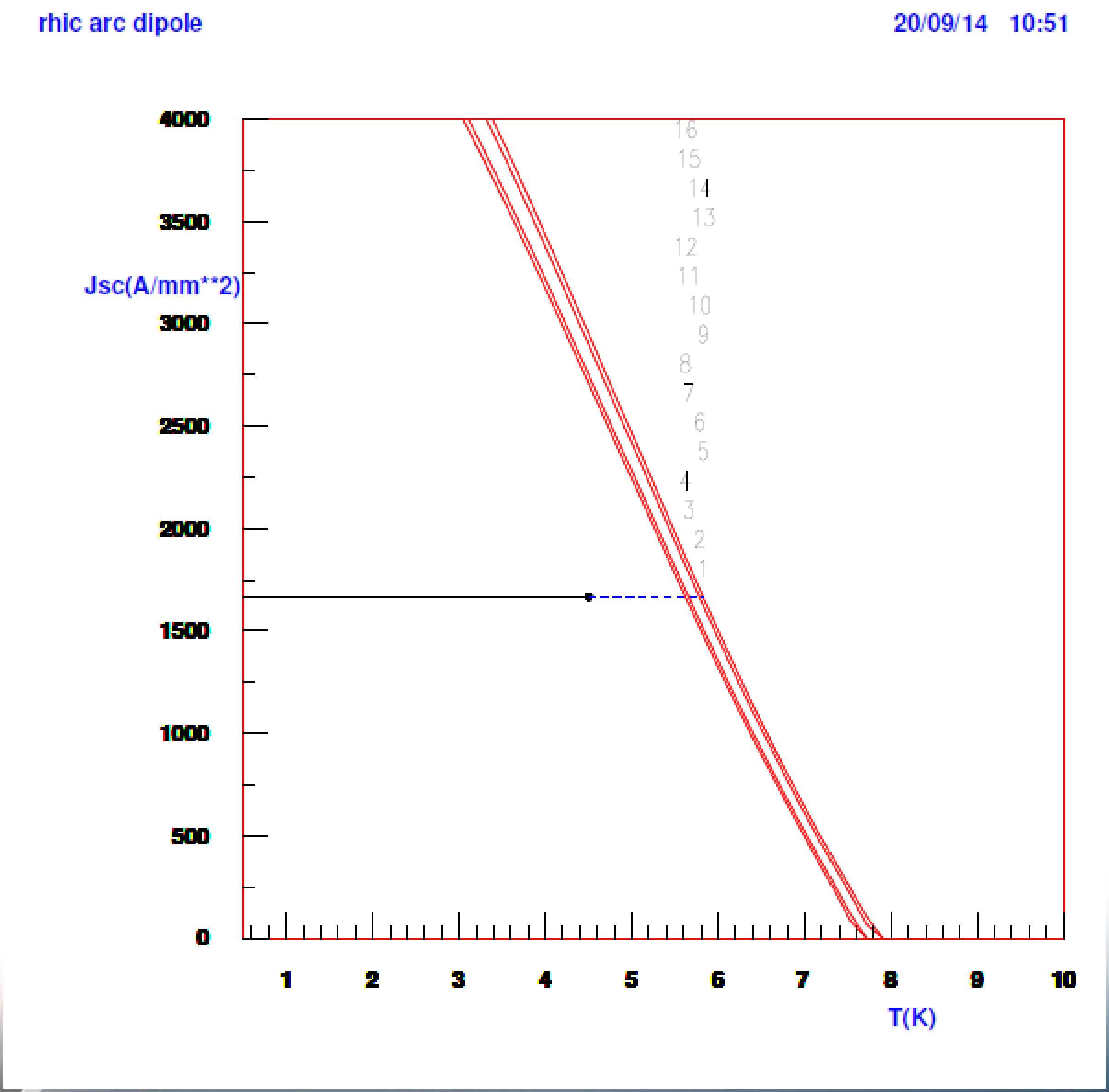
0
50
100
150
200
250
300

Computed Quench Temperature Margin

@B_o=3.46 T

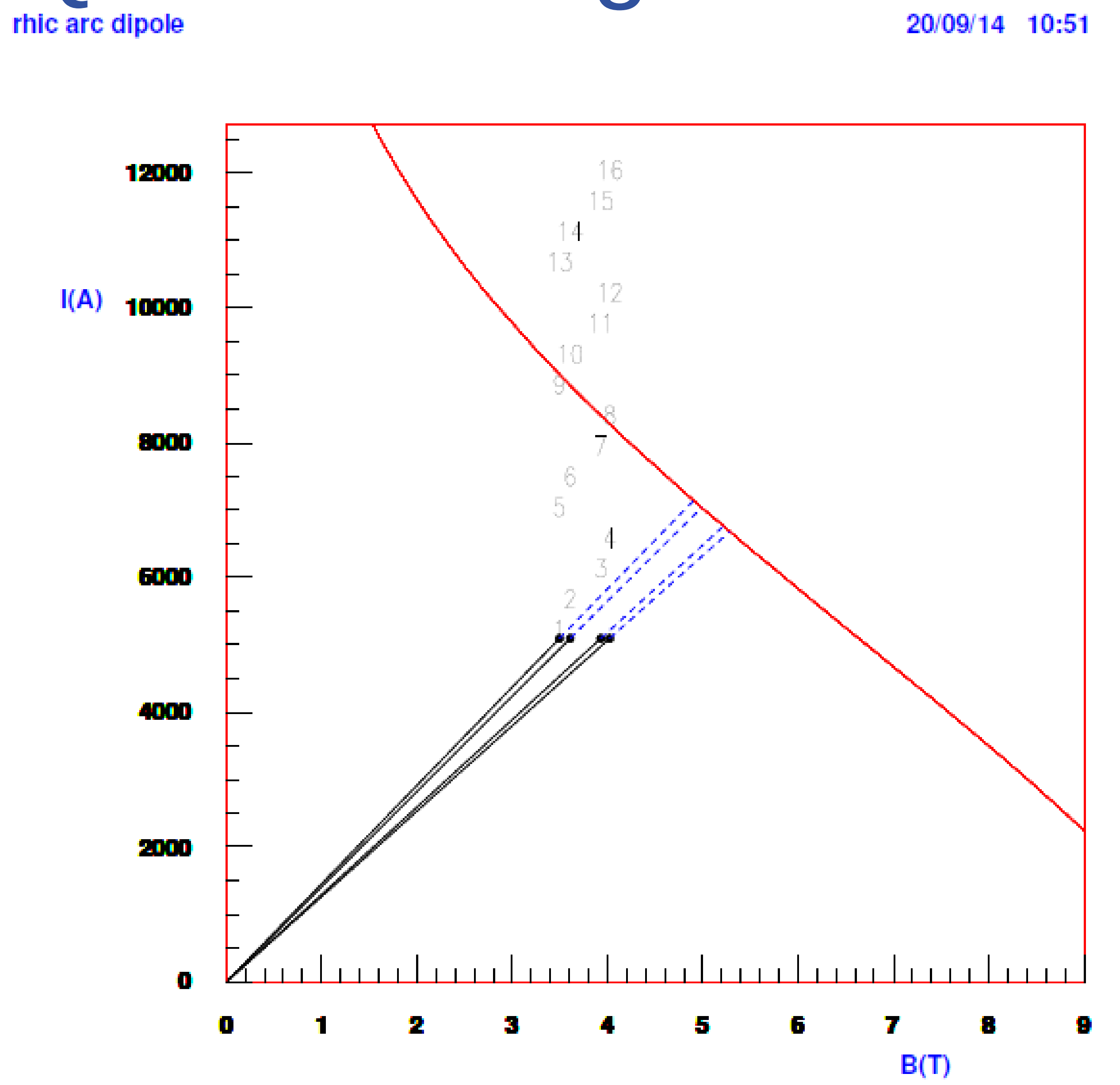
I = 5.09 kA

T = 4.5 K



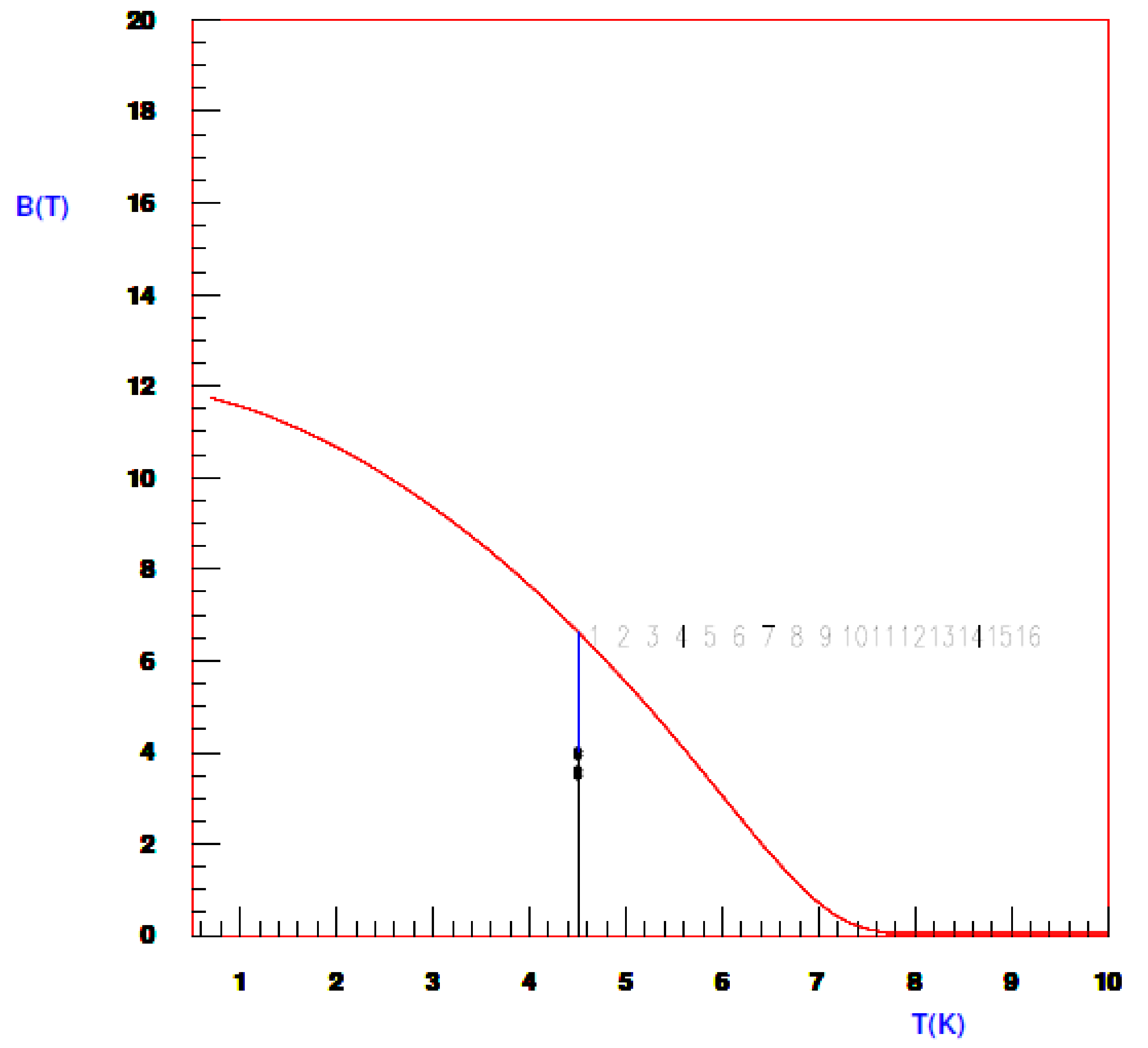
Computed Quench Margin

@B_o=3.46 T
I = 5.09 kA
T = 4.5 K



Computed Quench Field Margin

@B_o=3.46 T
I = 5.09 kA
T = 4.5 K



Model Calculations at EIC Design Field (275 GeV@3.81 T)

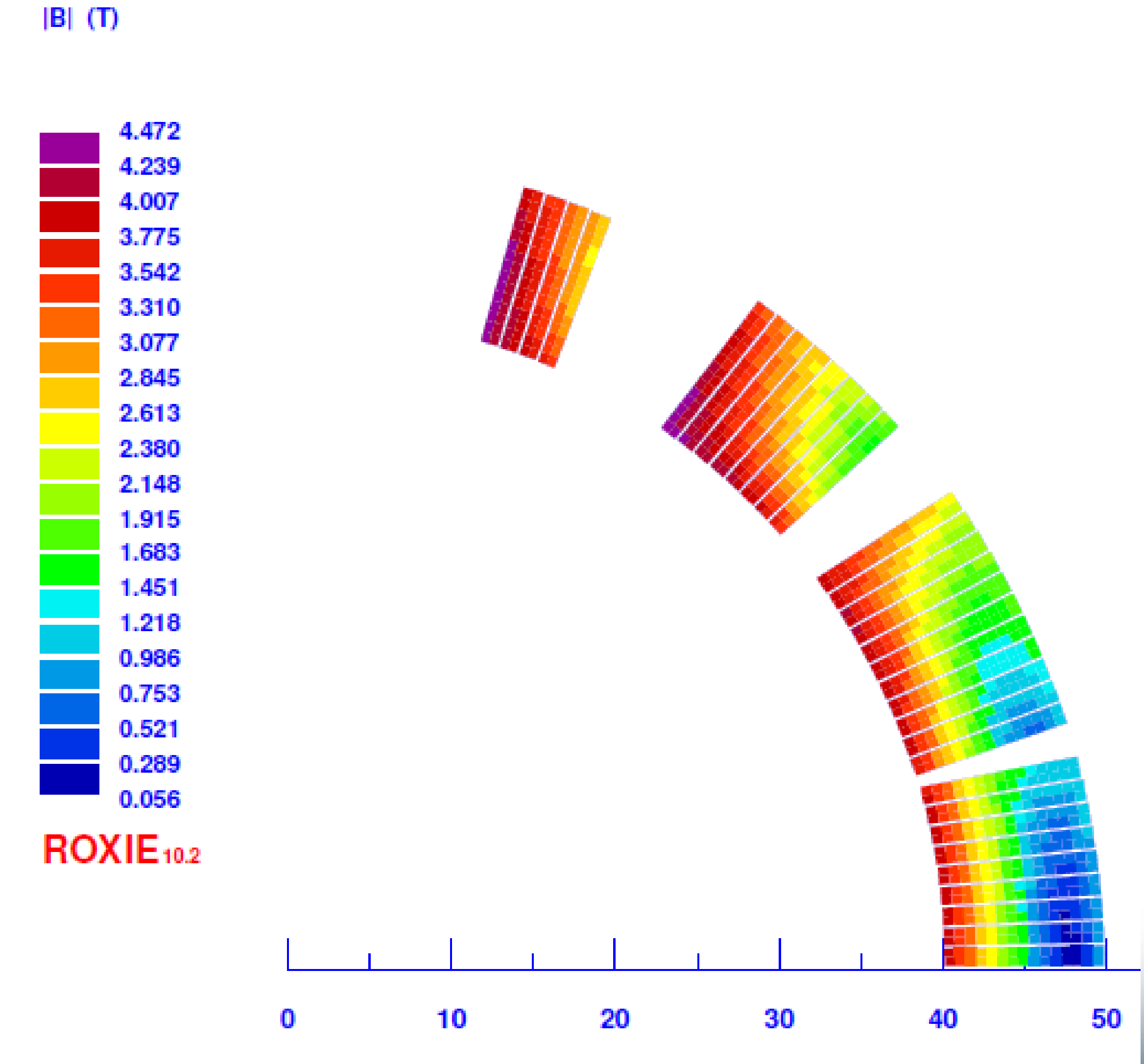
Temperature: 4.5 K

Summary of Calculations for 275 GeV @4.5 K

MAIN FIELD (T)	-3.841283
BLOCK NUMBER	16
PEAK FIELD IN CONDUCTOR 128 (T)	4.4723
CURRENT IN CONDUCTOR 128 (A)	-5600.0000
LOWEST FIELD IN CONDUCTOR 125 (T)	2.6075
SUPERCONDUCTOR CURRENT DENSITY (A/MM2)	-1833.8841
COPPER CURRENT DENSITY (A/MM2)	-818.6983
PERCENTAGE ON THE LOAD LINE	84.2163
QUENCHFIELD (T)	5.3105
TEMPERATURE MARGIN TO QUENCH (K)	0.7574
PERCENTAGE OF SHORT SAMPLE CURRENT	72.8420

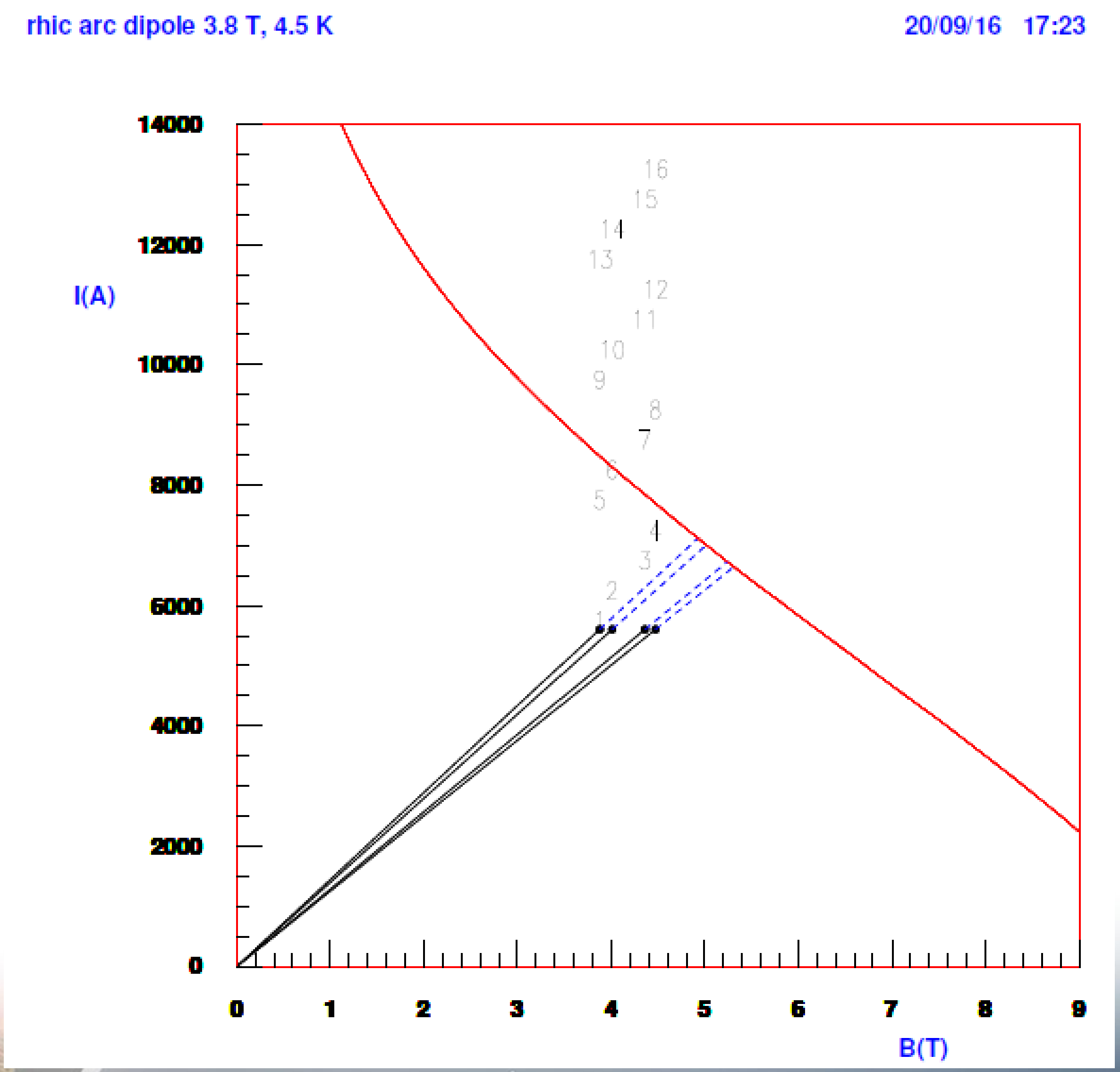
Field in conductor at EIC design field

@B_o = 3.8 T



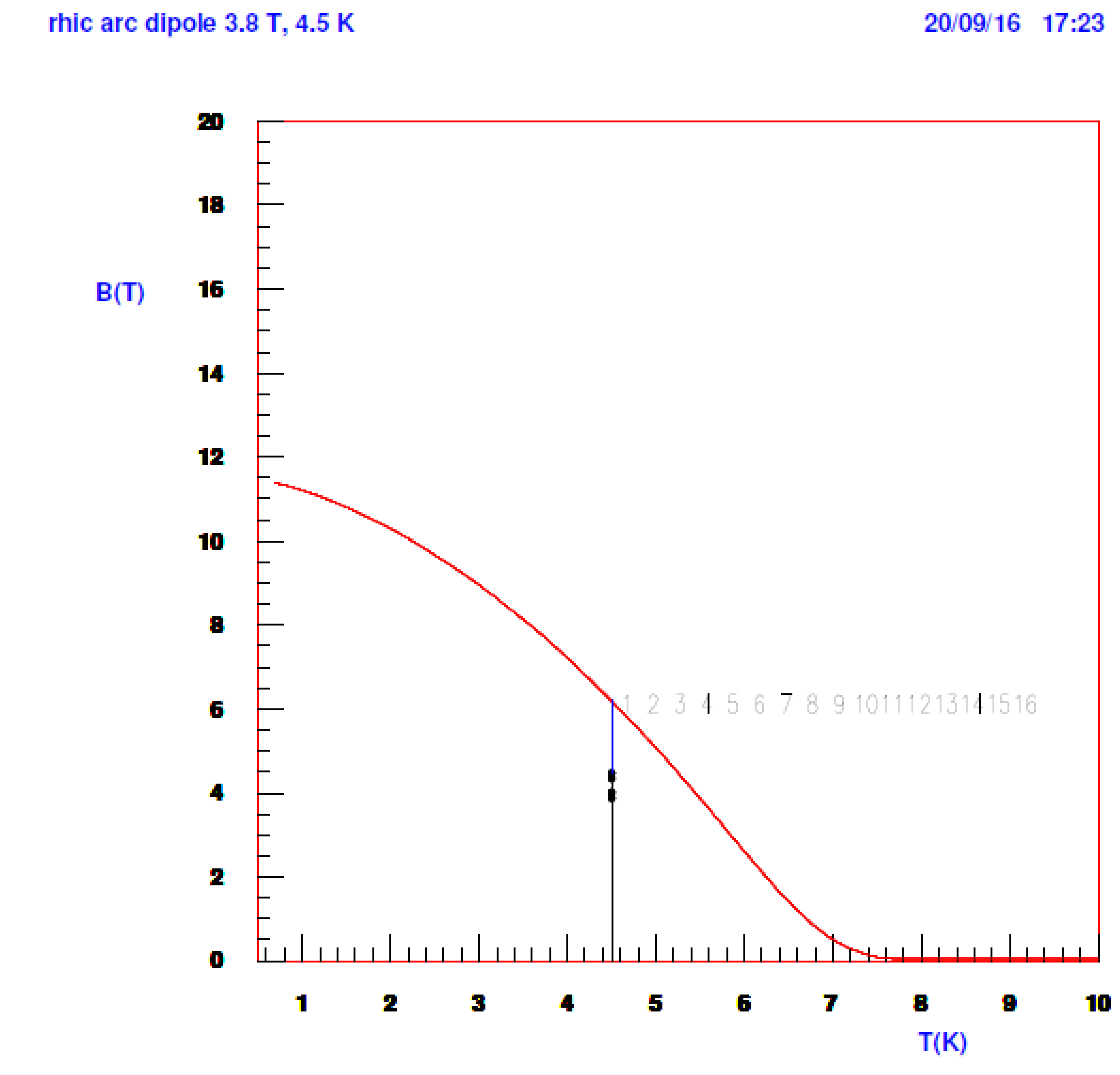
Computed Quench Margin

@B_o=3.8 T
I = 5.6 kA
T = 4.5 K



Computed Quench Field Margin

@B_o=3.8 T
I = 5.6 kA
T = 4.5 K



Model Calculations at EIC Design Field (275 GeV@3.81 T)

Temperature: 5 K

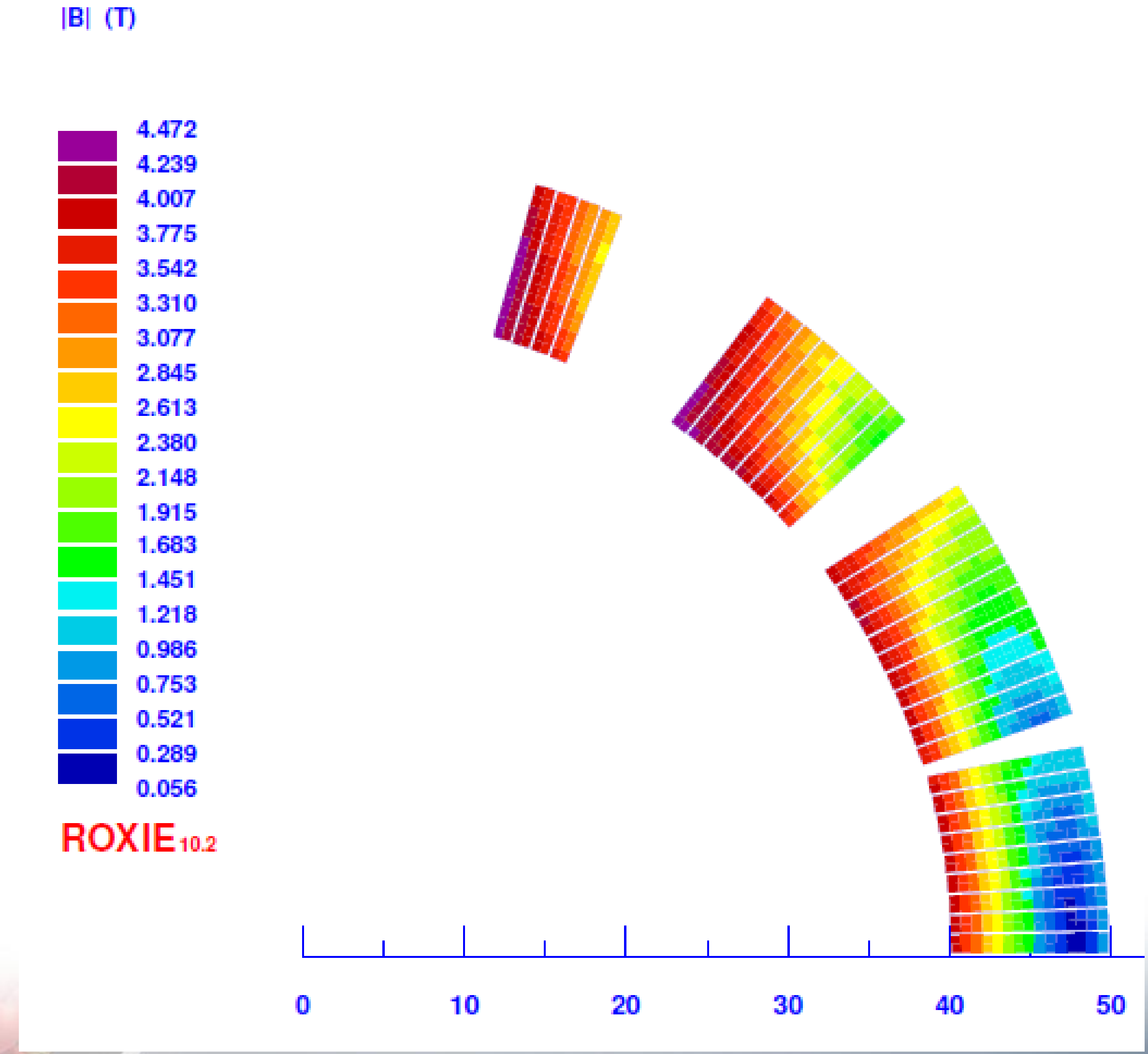
Summary of Calculations for 275 GeV @5 K

```
MAIN FIELD (T) ...................................   -3.841283

BLOCK NUMBER ....................................          16
PEAK FIELD IN CONDUCTOR  128 (T) ..................    4.4723
CURRENT IN CONDUCTOR 128 (A) ......................-5600.0000
LOWEST FIELD IN CONDUCTOR  125 (T) ................    2.6075
SUPERCONDUCTOR CURRENT DENSITY (A/MM2) ............-1833.8841
COPPER CURRENT DENSITY (A/MM2) ....................-818.6983
PERCENTAGE ON THE LOAD LINE .......................   93.8675
QUENCHFIELD (T) ...................................    4.7645
TEMPERATURE MARGIN TO QUENCH (K) ..................    0.2574
PERCENTAGE OF SHORT SAMPLE CURRENT ................   88.7707
```

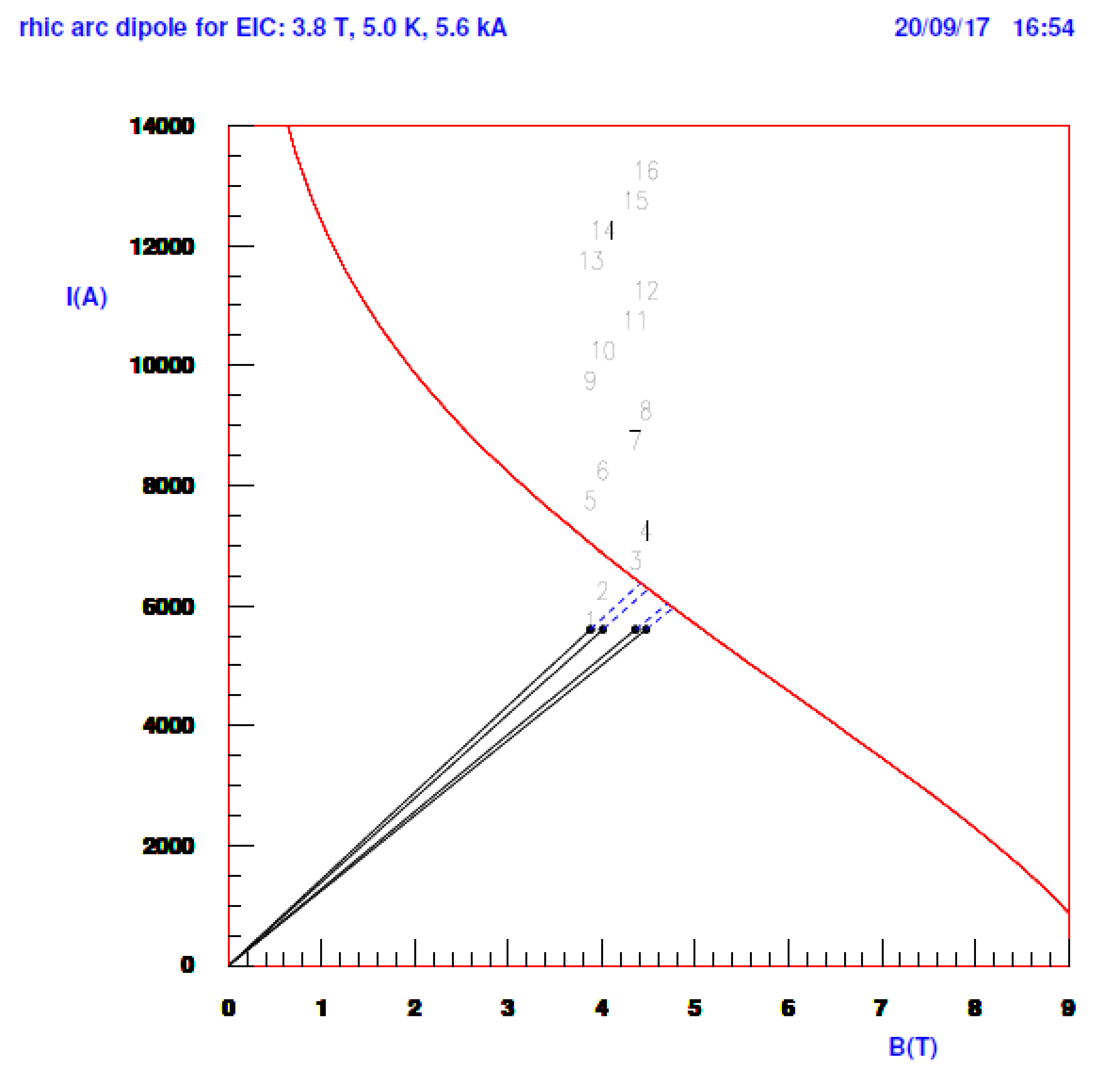
Field in conductor at EIC design field

@B_o = 3.8 T



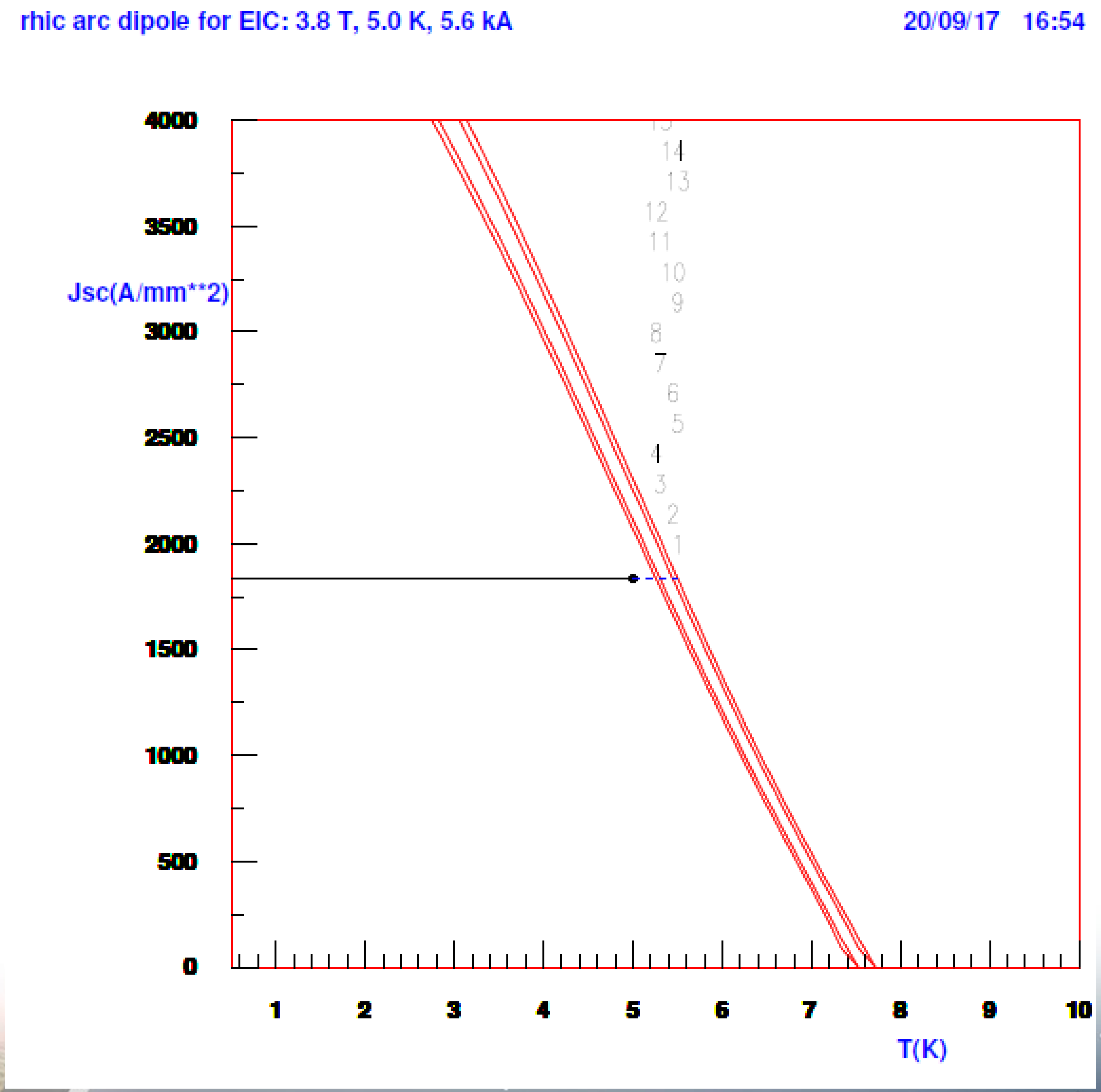
Computed Quench Margin

@B_o=3.8 T
I = 5.6 kA
T = 5 K



Computed Quench Temperature Margin

@B_o=3.8 T
I = 5.6 kA
T = 5 K



Computed Quench Field Margin

@B_o=3.8 T
I = 5.6 kA
T = 5 K