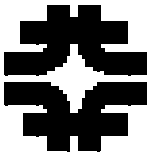

LARP

09/21/2007
TD-07-026

LARP TQC01b Test Summary

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Content:

1. Introduction

TQC01b magnet is a continuation of the TQC short model series assembled at Fermilab. Two coils (7 and 8) of this quadrupole were tested previously as a part of TQS model built at LBNL, while remaining 2 coils (10 and 12) were part of the TQC01 test – these were coils that had not limited the performance of those earlier magnets. The main goal of this test was to check the mechanical model developed at Fermilab before the next (2^{nd}) generation of TQC magnet with new coils is assembled.

The magnet was delivered to the Fermilab magnet test facility on July 6 and electrical checkout was finished by July 17. Magnet test in the Vertical Magnet Test Facility (VMTF) started in the afternoon of July 20. Due to the contamination in the refrigeration system TQC01b test was interrupted for about 4 weeks and was completed on August 24. As a consequence, the full run plan was not completed and the magnetic measurements were done only at room temperature. Also, no quench antenna was installed for this test, so only voltage taps are available for voltage spike and quench analysis. As these coils had all been measured in previous tests, no RRR measurements were made. Analysis of strain gauge data from this test will be reported separately.

2. Quench History

The magnet test program started with quench training at 20 A/s ramp rate at 4.5 K temperature. The quench detection threshold was set to 750 mV. Strip heater on coil 8 was shorted to ground in preparation to this test. Therefore strip heaters on coils 10 and 12 were connected to the same heater firing unit (HFU1) and were set in a protection mode. Strip heater on coil 7 was not used in the protection system (since the coils 7 and 8 are placed in magnet opposite each other).

Quench training start at 4.5K was very smooth and quench current was increased from 8.3kA to 10.3kA. Coils 7 and 8 had most of the quenches at the beginning.

After the quench #22 we found inconsistency in the configurable voltage tap (CVT) connections on the panel. All voltage taps after channel 65 were shifted on the panel, therefore CVT segments on coil 12 and special voltage tap segments were incorrectly assigned.

In the morning on July 25^{th} the refrigeration system performance degraded significantly indicating possible contamination in the system. Since the magnet almost reached quench current plateau at 4.5K we made only few additional quenches for the ramp rate study.

The refrigeration system recovery took almost 4 weeks. The magnet was idle all this time in dewar, with temperature slowly rising, and reached a peak temperature of 150K by noon of August 10; at this time, the temperature was restored to 80K by putting LN_2 though the clamshell heat exchanger.

While awaiting the refrigeration system recovery, a few problematic CVT segments were diagnosed and fixed: A missing jumper was found on the panel for CVT segment in coil 8 (V1_VoTap08a08_08b07M_1), DAQ channel was reassigned for the

segment V1_VoTap08b07_08b05M_1 in configuration files. We also modified isolation amplifier gain for segment a06_a07 in coils 7 and 8 (which showed saturation).

Isolation amplifiers were calibrated during this downtime. In order to check the gains we captured voltage data with +/- 5A current through the magnet before and after the calibration, at the same magnet temperature of about 80K. Gains for the CVT segments are shown in Table 1. The observed small change in gains is acceptable. Only two segments show significant gain change. Gain on V1_VoTap07a06_07a07M_1 segment was intentionally reduced due to the signal saturation we observed during the test. Segment V1_VoTap08b07_08b05M_1 had wrong DAQ channel assigned and it was fixed after the calibration was done.

Magnet testing at 4.5K resumed on August 22 and quench current plateau was reached at around 10.5kA. For completeness of the ramp rate study we made additional quenches at a number of intermediate ramp rates. Note that on August 22 one of the strain gauges (SG) on coil 7 (V1_VoSgPole07BrzLeLM_1) was damaged, most likely after the quench #54 in coil 7, and the SG current chain continuity was broken at around 1:00pm on next day, August 23. In order to fix the problem this channel and adjacent SG segments (V1_VoSgPole07BrzMidLM_1 and V1_VoSgPole07BrzMidAM_1) were bypassed from the readout.

The magnet training at 1.9 K showed generally increasing quench current, from 10.6kA to 11.9 kA. Quenches 60 to 65 showed a plateau with current between 11824 A and 11959 A. The magnet was then warmed up to 4.5K, we made one quench at intermediate temperature (4.0K). Quench currents at 4.5K are consistent with the measurements done at the beginning of test. Further testing was not possible, unfortunately, due to competition for cryogenic resources in the test department, and the scheduling pressure to warm up TQC01b for re-use of parts in building the next TQ magnet.

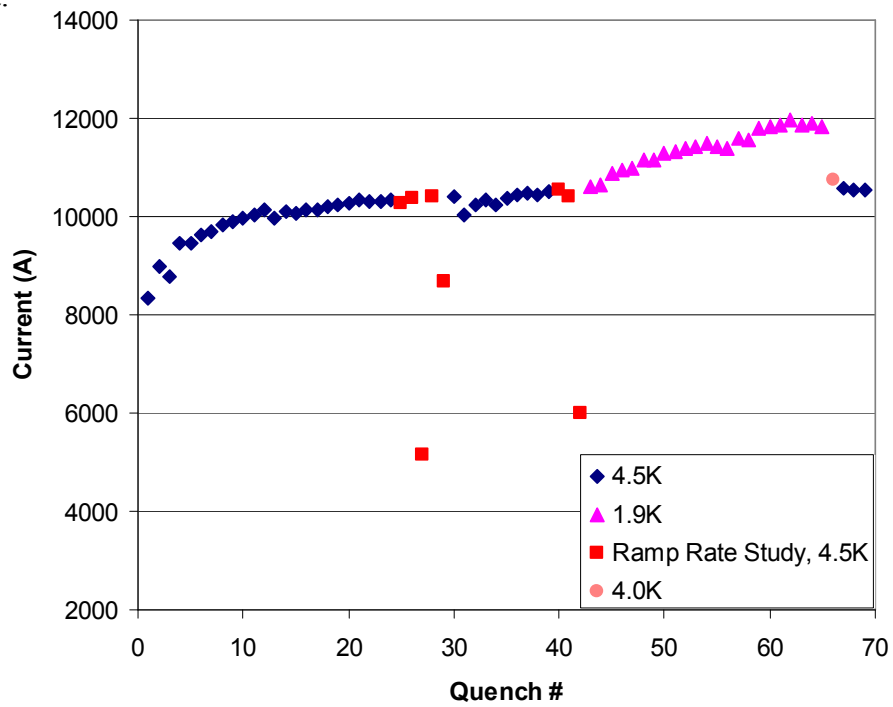

Figure 1. TQC01b Quench History: test at 4.5K and 1.9K; ramp rate study

The quench history is presented in Fig. 1, Fig. 2, and in the following tables 2 and 3. These tables have been generated by processing the quench files. TQC01b magnet successfully survived 61 training quenches and 8 quenches at ramp rate study (69 in total) during this test. Distribution of the training quenches among the coils is shown in Fig.3: coils 7 and 8 had most quenches. More details about the quench locations will be presented in the following section.

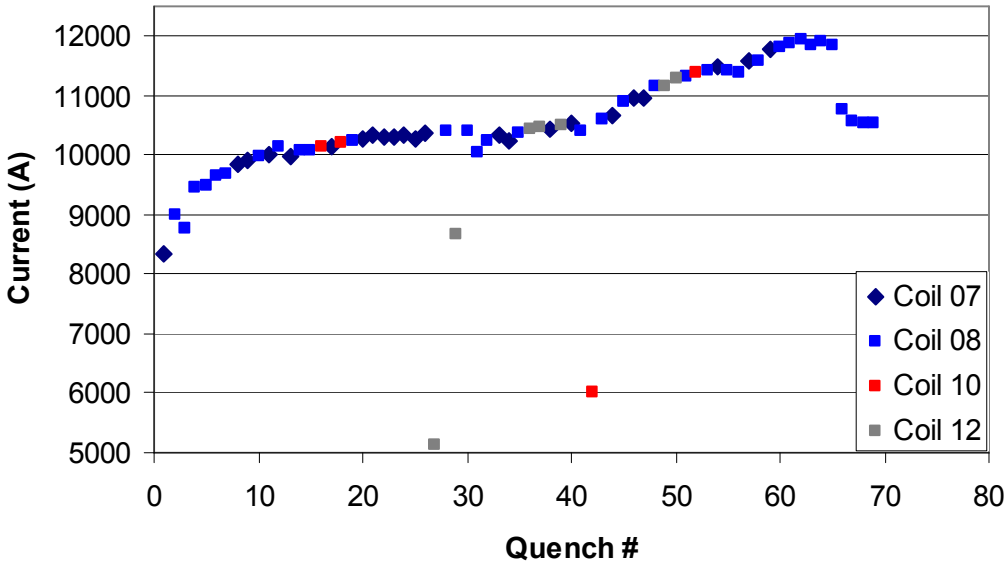

Figure 2. TQC01b Quench History: the marker of each quench shows the coil where it started.

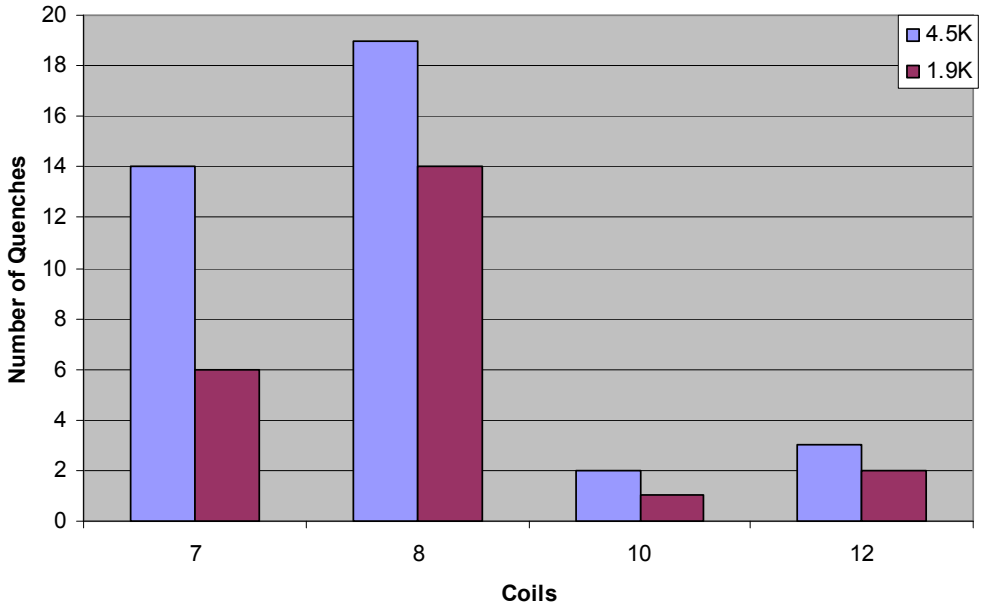

Figure 3. Quench (training only) distribution among the participating coils

Table 1: Measured isoamplifier gain for the CVT segments before and after the calibration

	31-Jul-07			16-Aug-07			
CVT segments	raw	reduced	gain	raw	reduced	gain	difference
V1_VoTap07a01_07a02M_1	0.000494	0.495501	1004.022	0.000541	0.542854	1003.943	-0.0079%
V1_VoTap07a02_07a03M_1	0.085742	0.577907	6.740085	0.095414	0.64308	6.739913	-0.0026%
V1_VoTap07a03_07a05M_1	0.009255	0.602429	65.0927	0.010288	0.669691	65.09375	0.0016%
V1_VoTap07a05_07a06M_1	0.025277	0.582448	23.04243	0.028128	0.648144	23.04274	0.0014%
V1_VoTap07a06_07a07M_1	0.003166	2.55122	805.7748	0.003527	1.77638	503.6147	-37.4993%
V1_VoTap07a07_07a08M_1	0.002157	0.54386	252.1244	0.00241	0.607527	252.1256	0.0005%
V1_VoTap07a08_07b06M_1	0.001511	0.225783	149.449	0.001671	0.249693	149.4505	0.0011%
V1_VoTap07b01_10b01M_1	0.002288	0.653767	285.7785	0.002398	0.685221	285.7433	-0.0123%
V1_VoTap07b02_07b01M_1	0.000509	0.513663	1008.505	0.000558	0.562592	1008.486	-0.0019%
V1_VoTap07b03_07b02M_1	0.095525	0.579777	6.069349	0.106347	0.645451	6.069292	-0.0009%
V1_VoTap07b04_07b03M_1	0.002549	0.60685	238.0616	0.002837	0.675329	238.061	-0.0003%
V1_VoTap07b05_07b04M_1	0.000682	0.688449	1009.049	0.000762	0.769069	1008.995	-0.0054%
V1_VoTap07b06_07b05M_1	0.002433	0.577139	237.2022	0.002706	0.641745	237.1966	-0.0023%
V1_VoTap08a01_08a02M_1	0.000493	0.496685	1007.769	0.00054	0.544652	1007.734	-0.0035%
V1_VoTap08a02_08a03M_1	0.086136	0.581179	6.747217	0.095371	0.643436	6.746691	-0.0078%
V1_VoTap08a03_08a04M_1	0.002656	0.629769	237.1029	0.002939	0.696869	237.0996	-0.0014%
V1_VoTap08a04_08a05M_1	0.006637	0.594691	89.59779	0.007338	0.657544	89.60465	0.0077%
V1_VoTap08a05_08a06M_1	0.025336	0.586368	23.14403	0.028039	0.648844	23.14077	-0.0141%
V1_VoTap08a06_08a07M_1	0.003193	1.61001	504.3101	0.003523	1.77699	504.3367	0.0053%
V1_VoTap08a07_08a08M_1	0.00217	0.546501	251.896	0.00241	0.607124	251.881	-0.0059%
V1_VoTap08a08_08b07M_1	0.002702	0.402679	149.014	0.001673	0.249369	149.03	0.0108%
V1_VoTap08b01_07a01M_1	0.002217	0.686698	309.7364	0.002319	0.718433	309.7442	0.0025%
V1_VoTap08b02_08b01M_1	0.000514	0.516272	1004.565	0.000561	0.56349	1004.537	-0.0028%
V1_VoTap08b03_08b02M_1	0.095807	0.581451	6.069001	0.106109	0.643928	6.068552	-0.0074%
V1_VoTap08b04_08b03M_1	0.001602	0.403107	251.5739	0.001858	0.467335	251.5841	0.0040%
V1_VoTap08b05_08b04M_1	0.000227	0.227477	1001.819	0.000939	0.940292	1001.906	0.0087%
V1_VoTap08b07_08b05M_1	0	0		0.002703	0.641405	237.2771	
V1_VoTap10a01_12b01M_1	0.002206	0.683595	309.8995	0.002294	0.710977	309.9033	0.0012%

V1_VoTap10a02_10a01M_1	0.000515	0.515681	1000.879	0.000561	0.561114	1000.922	0.0043%
V1_VoTap10a03_10a02M_1	0.08705	0.587081	6.744151	0.096832	0.653068	6.744313	0.0024%
V1_VoTap10a04_10a03M_1	0.002711	0.643836	237.4639	0.002992	0.710479	237.4842	0.0085%
V1_VoTap10a05_10a04M_1	0.006746	0.603755	89.49942	0.007488	0.670245	89.50563	0.0069%
V1_VoTap10a06_10a05M_1	0.025711	0.591944	23.02281	0.028557	0.657373	23.02	-0.0122%
V1_VoTap10a07_10a06M_1	0.000828	0.667838	806.3135	0.000908	0.732139	806.2344	-0.0098%
V1_VoTap10a09_10a07M_1	0.003199	0.586179	183.2325	0.003539	0.648397	183.2153	-0.0094%
V1_VoTap10a10_10a09M_1	0.002961	1.08376	366.014	0.003258	1.19235	365.9839	-0.0082%
V1_VoTap10b01_10b02M_1	0.000503	0.505907	1005.733	0.00055	0.552699	1005.604	-0.0129%
V1_VoTap10b02_10b04M_1	0.097149	0.575284	5.921648	0.107623	0.637232	5.920965	-0.0115%
V1_VoTap10b04_10b06M_1	0.00575	1.10043	191.3845	0.006384	1.22168	191.3584	-0.0136%
V1_VoTap10b06_10a10M_1	0.00083	0.334505	402.8332	0.000185	0.074701	402.7855	-0.0118%
V1_VoTap12a02_12a01M_1	0.000478	0.481925	1007.217	0.000518	0.522079	1007.26	0.0043%
V1_VoTap12a03_12a02M_1	0.085712	0.578405	6.748246	0.095185	0.642382	6.748745	0.0074%
V1_VoTap12a04_12a03M_1	0.002586	0.612723	236.9798	0.00287	0.680073	236.998	0.0077%
V1_VoTap12a05_12a04M_1	0.006708	0.600163	89.46747	0.000866	0.077498	89.47389	0.0072%
V1_VoTap12a06_12a05M_1	0.025028	0.57626	23.02461	0.027799	0.6401	23.02617	0.0068%
V1_VoTap12a08_12a06M_1	0.003169	0.606614	191.4297	0.003502	0.670443	191.4359	0.0032%
V1_VoTap12a09_12a08M_1	0.000887	0.59546	671.5803	0.000999	0.671151	671.599	0.0028%
V1_VoTap12a10_12a09M_1	0.028703	9.64401	335.9943	0.028702	9.64401	336.0013	0.0021%
V1_VoTap12a1b_12a2bM_1	0.000278	0.280373	1008.783	0.000287	0.289882	1008.783	0.0001%
V1_VoTap12b01_12b02M_1	0.000556	0.560155	1008.22	0.000606	0.610598	1007.962	-0.0256%
V1_VoTap12b02_12b03M_1	0.095537	0.580289	6.073959	0.106831	0.647951	6.065196	-0.1443%
V1_VoTap12b03_12b04M_1	0.002644	0.665176	251.6042	0.002939	0.739565	251.6212	0.0068%
V1_VoTap12b04_12b05M_1	0.000599	0.602649	1005.404	0.000659	0.662486	1005.377	-0.0027%
V1_VoTap12b05_12b06M_1	0.002434	0.610687	250.8521	0.002699	0.676951	250.8545	0.0009%
V1_VoTap12b06_12a10M_1	0.001202	0.482898	401.8859	5.70E-05	0.022889	401.8903	0.0011%

Table2: TQC01b Quench History with comments

File		Iq (A)	dI/dt (A/s)	t_{quench}	MIITs	QDC	Mag Temp Bot L (K)	Mag Temp Top L (K)	Comments
tqc01b.Quench.070720130131.266		963	0	0.0008	0.09	SlWcoil	4.453	4.447	Manual trip at 1000A to look at signals. Ramp rate 50A/s, T=4.43K
tqc01b.Quench.070720135150.776		5013	0	-0.0364	2.81	HcoilHcoil	4.490	4.487	5000A heater induced quench, fired strip heater 2 at 300V (only one strip) with heater 1 in protection mode also at 300V. Dump delayed 25ms. VSDS file "ramp_to_5000"
tqc01b.Quench.070720144623.003	1	8353	20	-0.0244	4.68	HcoilHcoil	4.500	4.498	Iq= 8338A, ramp = 20 A/s, T = 4.5K
tqc01b.Quench.070720151223.177	2	8997	20	-0.0196	4.79	HcoilHcoil	4.508	4.506	Iq = 8984 A, ramp = 20 A/s, T = 4.5K
tqc01b.Quench.070720153850.612	3	8788	20	-0.0193	4.63	HcoilHcoil	4.538	4.537	Iq = 8779 A, rate = 20 A/s, T = 4.5 K
tqc01b.Quench.070720161229.045	4	9476	20	-0.0161	4.82	HcoilHcoil	4.508	4.514	quench at 9462.8 A, ramp 20A/s, 4.5K
tqc01b.Quench.070720165012.237	5	9490	20	-0.0167	4.86	HcoilHcoil	4.507	4.502	quench at 9474.3A, ramp 20A/s, 4.5K
tqc01b.Quench.070721122846.872	6	9654	20	-0.0139	4.80	HcoilHcoil	4.473	4.475	quench at 9642A, ramp rate 20A/s, T=4.46K
tqc01b.Quench.070721130344.887	7	9692	20	-0.0122	4.57	HcoilHcoil	4.475	4.471	quench at 9681A, ramp 20A/s, 4.48K.
tqc01b.Quench.070721142840.375	8	9856	20	-0.0139	4.82	HcoilHcoil	4.466	4.465	Iq= 9846 A, Ramp = 20 A/s, T = 4.45K
tqc01b.Quench.070721145805.387	9	9909	20	-0.0134	4.80	HcoilHcoil	4.483	4.479	Iq = 9897 A, Ramp = 20 A/s, T = 4.49K
tqc01b.Quench.070721152629.447	10	9993	20	-0.0126	4.77	HcoilHcoil	4.484	4.480	Iq = 9981 A, Ramp = 20 A/s, 4.49K
tqc01b.Quench.070721154654.266	11	1003	20	-0.0133	4.86	HcoilHcoil	4.501	4.502	Iq = 10022 A, Ramp = 20 A/s, 4.5K
tqc01b.Quench.070721162813.427	12	10154	20	-0.0123	4.84	HcoilHcoil	4.487	4.489	Iq = 10142 A, Ramp = 20 A/s, 4.49 K
tqc01b.Quench.070721170705.582	13	9993	20	-0.0133	4.83	HcoilHcoil	4.484	4.477	Iq = 9983 A, Ramp = 20 A/s, T = 4.49K
tqc01b.Quench.070721173152.753	14	10104	20	-0.0123	4.80	HcoilHcoil	4.495	4.497	Iq ~ 10000, Ramp = 20 A/s, T = 4.5 K
tqc01b.Quench.070721175620.983	15	10081	20	-0.0115	4.70	HcoilHcoil	4.505	4.504	Iq = 10066A, RAmp = 20 A/s, 4.5 K
tqc01b.Quench.070721182149.526	16	10151	20	-0.0078	4.34	HcoilHcoil	4.505	4.503	Iq = 10138 A, Ramp = 20 A/s, 4.5 K
tqc01b.Quench.070721185512.247	17	10141	20	-0.0125	4.84	HcoilHcoil	4.486	4.484	Iq =10130 A, Ramp = 20 A/s, T=4.5 K
tqc01b.Quench.070724123318.607	18	10209	20	-0.0410	7.92	HcoilHcoil	4.501	4.499	quench at 10197.6K, T=4.5K, ramp 20A/s.

tqc01b.Quench.070724132844.773	19	10249	10	-0.0056	4.14	HcoilHcoil	4.500	4.496	quench at 10236.7A, T=4.5K, ramp rate was 20A/s upto 9300A and then 10A/s till the quench.
tqc01b.Quench.070724141441.436	20	10276	20	-0.0123	4.88	HcoilHcoil	4.502	4.502	continuing to train up slowly
tqc01b.Quench.070724145235.698	21	10332	20	-0.0113	4.80	HcoilHcoil	4.505	4.502	20A/s 4.5K VSDS ramp 21
tqc01b.Quench.070724154710.592	22	10325	20	-0.0125	4.91	HcoilHcoil	4.499	4.491	20 A/s 4.5K, ramp 22
tqc01b.Quench.070724181936.744	23	10330	20	-0.0108	4.77	HcoilHcoil	4.468	4.467	CVT configuration was changed in both software and hardware for the coil 12 and special taps sections.
tqc01b.Quench.070725111916.204	24	10355	20	-0.0120	4.95	HcoilHcoil	4.507	4.505	quench at 10343.6, ramp rate 20A/s, T=4.5K
tqc01b.Quench.070725120333.915	25	10283	10	-0.0111	4.76	HcoilHcoil	4.488	4.483	quench at 10275A., ramp rate was 10A/s. T=4.51K4724409
tqc01b.Quench.070725124511.190	26	10395	5	-0.0106	4.74	HcoilHcoil	4.484	4.483	quench at 10383.2A ramp rate 5A/s. (was 20A/s upto 5000A). T=4.49K
tqc01b.Quench.070725130457.681	27	5145	300	-0.0102	1.67	HcoilHcoil	4.507	4.501	quench at 5142.6A, ramp rate 300A/s. T=4.5K
tqc01b.Quench.070725132510.651	28	10407	100	-0.0105	4.73	HcoilHcoil	4.485	4.489	quench at 10399.3A, ramp rate 100A/s. T=4.5K934
tqc01b.Quench.070725134542.414	29	8673	200	-0.0048	3.35	HcoilHcoil	4.508	4.508	quench at 8666.4A, ramp rate 200A/s. T=4.5K
tqc01b.Quench.070725141601.609	30	10408	20	-0.0109	4.78	HcoilHcoil	4.486	4.484	quench at 10397.5A, ramp rate 20A/s. T=4.5K.
tqc01b.Quench.070821130806.487		5007	20	-0.0342	2.75	HcoilHcoil	4.436	4.434	HFU2 induced trip at 5000A to verify quench protection and data saving
tqc01b.Quench.070821142336.864	31	10032	20	-0.0120	4.72	HcoilHcoil	4.434	4.432	quench 31 at 10030A, T=4.5K, ramp rate 20A/s.
tqc01b.Quench.070821145801.088	32	10244	20	-0.0095	4.56	HcoilHcoil	4.436	4.431	Ramp to quench #32 A20A/sec and 4.5K
tqc01b.Quench.070821155018.928	33	10345	20	-0.0111	4.76	HcoilHcoil	4.429	4.427	Quench #33 @4.5K, 20A/sec.
tqc01b.Quench.070821163425.357	34	10243	20	-0.0115	4.77	HcoilHcoil	4.428	4.424	quench 34, I=10240A, ramp rate 20A/s, T=4.4K.
tqc01b.Quench.070821170850.131	35	10375	20	-0.0085	4.51	HcoilHcoil	4.435	4.435	quench at 10368A, ramp rate 20A/s, T=4.4K
tqc01b.Quench.070821174426.630	36	10431	20	-0.0102	4.71	HcoilHcoil	4.430	4.426	quench at 10428A, ramp rate 20A/s, T=4.43K

tqc01b.Quench.070821181628.658	37	10471	20	-0.0101	4.70	HcoilHcoil	4.435	4.433	quench at 10400 amps or abouts 4.4 k 20 a/s
tqc01b.Quench.070821190555.269	38	10446	20	-0.0104	4.75	HcoilHcoil	4.426	4.424	Quench at 10445.9 A. Ramp rate 20A/s, T=4.43K.
tqc01b.Quench.070821194458.306	39	10511	20	-0.0101	4.73	HcoilHcoil	4.433	4.430	quench at 10508Am ramp rate 20A/s, T=4.43K
tqc01b.Quench.070821200556.259	40	10523	50	-0.1949	25.21	HcoilHcoil	4.447	4.450	Ramp rate study cont'd, 50A/s. Quench at 10528.9A. T=4.45K.
tqc01b.Quench.070821202524.036	41	10390	150	-0.0101	4.61	HcoilHcoil	4.449	4.453	ramp rate 150A/s, quenched at 10389.8A. T=4.44K.
tqc01b.Quench.070821204809.522	42	6007	250	-0.0076	2.09	HcoilHcoil	4.449	4.448	ramp rate 250A/s, quench at 6004.8A.
tqc01b.Quench.070822115117.665	43	10616	20	-0.0147	5.49	HcoilHcoil	1.848	1.855	quench at 10614A, ramp rate 20A/s, T=1.87K.
tqc01b.Quench.070822122300.793	44	10657	20	-0.0099	4.92	HcoilHcoil	1.897	1.894	Iq= 10656 A, Ramp = 20 A/s, Temp = 1.9K
tqc01b.Quench.070822125218.826	45	10894	20	-0.0069	4.67	HcoilHcoil	1.895	1.897	Iq = 10895 A, Ramp = 20 A/s, Temp = 1.9K
tqc01b.Quench.070822132540.007	46	10953	20	-0.0098	5.04	HcoilHcoil	1.884	1.881	Iq = 10945 A, Ramp = 20 A/s, Temp = 1.9K
tqc01b.Quench.070822135424.799	47	10970	20	-0.0081	4.87	HcoilHcoil	1.912	1.902	quench at 10967.3A, ramp rate 20A/s, T=1.9K.
tqc01b.Quench.070822143540.790	48	11146	20	-0.0041	4.40	HcoilHcoil	1.834	1.835	quench at 11145.2A, ramp rate 20A/s, T=1.88K
tqc01b.Quench.070822150933.176	49	11145	20	-0.0099	5.13	HcoilHcoil	1.862	1.857	quench at ~11140A (see more exact number in elog or logbook), T=1.88K, ramp rate 20A/s
tqc01b.Quench.070822155458.605	50	11309	20	-0.0078	4.93	HcoilHcoil	1.841	1.853	quench at 11303.8A, ramp rate 20A/s. T=1.88K
tqc01b.Quench.070822163015.951	51	11313	20	-0.0080	4.96	WcoilIdot	1.883	1.873	quench at 11309.5A, T=1.9K, ramp rate 20A/s
tqc01b.Quench.070822173137.292	52	11389	20	-0.0109	5.37	HcoilHcoil	1.920	1.910	quench at 11384.2A, ramp rate 20A/s, T=1.9K.
tqc01b.Quench.070822181152.418	53	11416	20	-0.0073	4.93	HcoilHcoil	1.851	1.848	quench at 11415A, ramp rate 20A/s, T=1.88K
tqc01b.Quench.070822184616.424	54	11479	20	-0.0083	5.05	HcoilHcoil	1.861	1.857	quench at 11476.8A, T=1.9K, ramp rate 20A/s□m-2.85997284E-03

tqc01b.Quench.070822192139.539	55	11435	20	-0.0078	4.99	HcoilHcoil	1.857	1.857	quench at 11431.5A, 20A/s ramp rate, 1.9K.
tqc01b.Quench.070822195504.872	56	11401	20	-0.0071	4.89	HcoilHcoil	1.869	1.869	quench at 11397.8A, T=1.9K, 20A/s.
tqc01b.Quench.070822203629.243	57	11593	20	-0.0104	5.38	HcoilHcoil	1.869	1.870	quench at 11588A, ramp rate 20A/s, 1.9K.
tqc01b.Quench.070823092030.318	58	11582	20	-0.0055	4.81	HcoilHcoil	1.850	1.857	
tqc01b.Quench.070823115539.885	59	11800	20	-0.0099	5.39	HcoilHcoil	1.877	1.888	quench at 11794.9A, ramp rate 20A/s, 1.89K.
tqc01b.Quench.070823124320.382	60	11824	20	-0.0060	4.87	HcoilHcoil	1.855	1.870	quench at 11822.7A, ramp rate 20A/s, 1.89K.
tqc01b.Quench.070823132658.418	61	11877	20	-0.0053	4.80	HcoilHcoil	1.876	1.877	Iq = 11876A, Ramp = 20 A/s, T = 1.88K
tqc01b.Quench.070823142911.951	62	11959	20	-0.0059	4.87	HcoilHcoil	1.895	1.889	quench at 11957A, ramp rate 20A/s, 1.89K.
tqc01b.Quench.070823203924.269	63	11864	20	-0.0056	4.85	HcoilHcoil	2.029	2.034	I = 10861 A, Ramp = 20 A/s, Temp = 2.04 K
tqc01b.Quench.070823212731.566	64	11915	20	-0.0122	5.77	HcoilHcoil	1.859	1.857	Iq = 11911 A, Ramp = 20 A/s, Temp = 1.88K
tqc01b.Quench.070823220747.375	65	11850	20	-0.0057	4.84	HcoilHcoil	1.859	1.859	Iq= 11847A, Ramp = 20 A/s, Temp = 1.88K
tqc01b.Quench.070824185902.608	66	10763	20	-0.0088	4.87	HcoilHcoil	3.992	4.026	quench at 10758.5A, ramp rate 20A/s, T=4.00K. We did this quench to speed up warming of the magnet.
tqc01b.Quench.070824200552.605	67	10562	20	-0.0087	4.62	HcoilHcoil	4.529	4.548	quench at 10560A, T=4.54K, ramp 20A/s
tqc01b.Quench.070824204005.776	68	10537	20	-0.0095	4.68	HcoilHcoil	4.575	4.585	quench at 10533A, 4.54K, 20A/s.
tqc01b.Quench.070824220509.075	69	10543	20	-0.0088	4.64	HcoilHcoil	4.577	4.578	quench at 10544A, T=4.58K, ramp 20A/s.

Table 3: TQC01b Quench History with first quenching segments

File		Iq (A)	dI/dt (A/)	t_{quench}	QDC	1st VTseg	t_{rise}	2nd VTseg	t_{rise}	Mag Temp Bot L	Mag Temp Top L
tqc01b.Quench.070720130131.266		963	0	0.0008	SlWcoil	V1_TrigCvtB1	-0.0003	08a07_08a08	-0.0003	4.453	4.447
tqc01b.Quench.070720135150.776		5013	20	-0.0364	HcoilHcoil	07b04_07b03	-0.0339	07b05_07b04	-0.0339	4.490	4.487
tqc01b.Quench.070720144623.003	1	8353	20	-0.0244	HcoilHcoil	07a07_07a08	-0.0259	08a1b_08a2b	-0.0224	4.500	4.498
tqc01b.Quench.070720151223.177	2	8997	20	-0.0196	HcoilHcoil	08a07_08a08	-0.0202	07b1b_07b2b	-0.0183	4.508	4.506
tqc01b.Quench.070720153850.612	3	8788	20	-0.0193	HcoilHcoil	08a07_08a08	-0.0216	08a06_08a07	-0.0195	4.538	4.537
tqc01b.Quench.070720161229.045	4	9476	20	-0.0161	HcoilHcoil	08a07_08a08	-0.0174	10b1b_10b2b	-0.0153	4.508	4.514
tqc01b.Quench.070720165012.237	5	9490	20	-0.0167	HcoilHcoil	08a07_08a08	-0.0172	10b1b_10b2b	-0.0150	4.507	4.502
tqc01b.Quench.070721122846.872	6	9654	20	-0.0139	HcoilHcoil	08a07_08a08	-0.0155	10b1b_10b2b	-0.0137	4.473	4.475
tqc01b.Quench.070721130344.887	7	9692	20	-0.0122	HcoilHcoil	08a06_08a07	-0.0139	08a05_08a06	-0.0127	4.475	4.471
tqc01b.Quench.070721142840.375	8	9856	20	-0.0139	HcoilHcoil	07a07_07a08	-0.0150	07b1b_07b2b	-0.0136	4.466	4.465
tqc01b.Quench.070721145805.387	9	9909	20	-0.0134	HcoilHcoil	07a07_07a08	-0.0154	10b1b_10b2b	-0.0132	4.483	4.479
tqc01b.Quench.070721152629.447	10	9993	20	-0.0126	HcoilHcoil	08a06_08a07	-0.0137	10b1b_10b2b	-0.0129	4.77	4.484
tqc01b.Quench.070721154654.266	11	1003	20	-0.0133	HcoilHcoil	07a07_07a08	-0.0147	10b1b_10b2b	-0.0132	4.86	4.501
tqc01b.Quench.070721162813.427	12	10154	20	-0.0123	HcoilHcoil	08a06_08a07	-0.0125	10b1b_10b2b	-0.0123	4.487	4.489
tqc01b.Quench.070721170705.582	13	9993	20	-0.0133	HcoilHcoil	07a08_07b06	-0.0144	10b1b_10b2b	-0.0130	4.484	4.477
tqc01b.Quench.070721173152.753	14	10104	20	-0.0123	HcoilHcoil	08a07_08a08	-0.0137	10b1b_10b2b	-0.0119	4.495	4.497
tqc01b.Quench.070721175620.983	15	10081	20	-0.0115	HcoilHcoil	08a07_08a08	-0.0123	10b1b_10b2b	-0.0116	4.505	4.504
tqc01b.Quench.070721182149.526	16	10151	20	-0.0078	HcoilHcoil	10b1b_10b2b	-0.0076	07b1b_07b2b	-0.0073	4.505	4.503
tqc01b.Quench.070721185512.247	17	10141	20	-0.0125	HcoilHcoil	07a07_07a08	-0.0134	07b1b_07b2b	-0.0132	4.486	4.484
tqc01b.Quench.070724123318.607	18	10209	20	-0.0410	HcoilHcoil	07b1b_07b2b	-0.0167	08a1b_08a2b	-0.0165	4.501	4.499
tqc01b.Quench.070724132844.773	19	10249	10	-0.0056	HcoilHcoil	08a07_08a08	-0.0053	10b1b_10b2b	-0.0050	4.500	4.496
tqc01b.Quench.070724141441.436	20	10276	20	-0.0123	HcoilHcoil	07a07_07a08	-0.0134	07a08_07b06	-0.0129	4.502	4.502
tqc01b.Quench.070724145235.698	21	10332	20	-0.0113	HcoilHcoil	07a06_07a07	-0.0122	10b1b_10b2b	-0.0115	4.505	4.502
tqc01b.Quench.070724154710.592	22	10325	20	-0.0125	HcoilHcoil	07a07_07a08	-0.0127	10b1b_10b2b	-0.0119	4.499	4.491
tqc01b.Quench.070724181936.744	23	10330	20	-0.0108	HcoilHcoil	07a07_07a08	-0.0132	07a1b_07a2b	-0.0122	4.468	4.467
tqc01b.Quench.070725111916.204	24	10355	20	-0.0120	HcoilHcoil	07a06_07a07	-0.0120	q24p_q24n	-0.0113	4.507	4.505
tqc01b.Quench.070725120333.915	25	10283	10	-0.0111	HcoilHcoil	07a07_07a08	-0.0125	q24p_q24n	-0.0119	4.488	4.483

tqc01b.Quench.070725124511.190	26	10395	5	-0.0106	HcoilHcoil	07a07_07a08	-0.0119	q24p_q24n	-0.0108	4.484	4.483
tqc01b.Quench.070725130457.681	27	5145	300	-0.0102	HcoilHcoil	07a1b_07a2b	-0.0099	q24p_q24n	-0.0099	4.507	4.501
tqc01b.Quench.070725132510.651	28	10407	100	-0.0105	HcoilHcoil	08a06_08a07	-0.0120	07a1b_07a2b	-0.0119	4.485	4.489
tqc01b.Quench.070725134542.414	29	8673	200	-0.0048	HcoilHcoil	07a1b_07a2b	-0.0049	q24p_q24n	-0.0048	4.508	4.508
tqc01b.Quench.070725141601.609	30	10408	20	-0.0109	HcoilHcoil	08a07_08a08	-0.0123	q24p_q24n	-0.0115	4.486	4.484
tqc01b.Quench.070821130806.487		5007	20	-0.0342	HcoilHcoil	07b05_07b04	-0.0344	10b02_10b04	-0.0339	4.436	4.434
tqc01b.Quench.070821142336.864	31	10032	20	-0.0120	HcoilHcoil	08a06_08a07	-0.0123	08a07_08a08	-0.0095	4.434	4.432
tqc01b.Quench.070821145801.088	32	10244	20	-0.0095	HcoilHcoil	08a07_08a08	-0.0108	08a08_08b07	-0.0087	4.436	4.431
tqc01b.Quench.070821155018.928	33	10345	20	-0.0111	HcoilHcoil	07a07_07a08	-0.0119	10a10_10a09	-0.0088	4.429	4.427
tqc01b.Quench.070821163425.357	34	10243	20	-0.0115	HcoilHcoil	07a07_07a08	-0.0129	07a05_07a06	-0.0059	4.428	4.424
tqc01b.Quench.070821170850.131	35	10375	20	-0.0085	HcoilHcoil	08a07_08a08	-0.0102	08a05_08a06	-0.0080	4.435	4.435
tqc01b.Quench.070821174426.630	36	10431	20	-0.0102	HcoilHcoil	12a10_12a09	-0.0091	10b06_10a10	-0.0071	4.430	4.426
tqc01b.Quench.070821181628.658	37	10471	20	-0.0101	HcoilHcoil	12a08_12a06	-0.0092	10b06_10a10	-0.0074	4.435	4.433
tqc01b.Quench.070821190555.269	38	10446	20	-0.0104	HcoilHcoil	07a07_07a08	-0.0116	10a10_10a09	-0.0085	4.426	4.424
tqc01b.Quench.070821194458.306	39	10511	20	-0.0101	HcoilHcoil	12a10_12a09	-0.0088	10b06_10a10	-0.0076	4.433	4.430
tqc01b.Quench.070821200556.259	40	10523	50	-0.1949	HcoilHcoil	07a06_07a07	-0.0118	07a07_07a08	-0.0109	4.447	4.450
tqc01b.Quench.070821202524.036	41	10390	150	-0.0101	HcoilHcoil	08a06_08a07	-0.0112	10b06_10a10	-0.0092	4.449	4.453
tqc01b.Quench.070821204809.522	42	6007	250	-0.0076	HcoilHcoil	10a04_10a03	-0.0064	10a02_10a01	-0.0060	4.449	4.448
tqc01b.Quench.070822115117.665	43	10616	20	-0.0147	HcoilHcoil	08b04_08b03	-0.0109	10a10_10a09	-0.0104	1.848	1.855
tqc01b.Quench.070822122300.793	44	10657	20	-0.0099	HcoilHcoil	07a06_07a07	-0.0102	07a05_07a06	-0.0055	1.897	1.894
tqc01b.Quench.070822125218.826	45	10894	20	-0.0069	HcoilHcoil	08b07_08b05	-0.0088	08a06_08a07	-0.0081	1.895	1.897
tqc01b.Quench.070822132540.007	46	10953	20	-0.0098	HcoilHcoil	07a07_07a08	-0.0106	10a09_10a07	-0.0073	1.884	1.881
tqc01b.Quench.070822135424.799	47	10970	20	-0.0081	HcoilHcoil	07a06_07a07	-0.0087	07a07_07a08	-0.0062	1.912	1.902
tqc01b.Quench.070822143540.790	48	11146	20	-0.0041	HcoilHcoil	08a07_08a08	-0.0053	12b03_12b04	-0.0034	1.834	1.835
tqc01b.Quench.070822150933.176	49	11145	20	-0.0099	HcoilHcoil	12a10_12a09	-0.0087	10a09_10a07	-0.0085	1.862	1.857
tqc01b.Quench.070822155458.605	50	11309	20	-0.0078	HcoilHcoil	10a09_10a07	-0.0056	10a10_10a09	-0.0056	1.841	1.853
tqc01b.Quench.070822163015.951	51	11313	20	-0.0080	WcoilIdot	08a06_08a07	-0.0092	08a07_08a08	-0.0083	1.883	1.873
tqc01b.Quench.070822173137.292	52	11389	20	-0.0109	HcoilHcoil	10b04_10b06	-0.0111	10b06_10a10	-0.0078	1.920	1.910
tqc01b.Quench.070822181152.418	53	11416	20	-0.0073	HcoilHcoil	08a06_08a07	-0.0078	08a07_08a08	-0.0073	1.851	1.848
tqc01b.Quench.070822184616.424	54	11479	20	-0.0083	HcoilHcoil	07b04_07b03	-0.0083	07b05_07b04	-0.0077	1.861	1.857
tqc01b.Quench.070822192139.539	55	11435	20	-0.0078	HcoilHcoil	08a06_08a07	-0.0084	08a07_08a08	-0.0078	1.857	1.857
tqc01b.Quench.070822195504.872	56	11401	20	-0.0071	HcoilHcoil	08a08_08b07	-0.0081	08a07_08a08	-0.0067	1.869	1.869

tqc01b.Quench.070822203629.243	57	11593	20	-0.0104	HcoilHcoil	07b06_07b05	-0.0119	07a08_07b06	-0.0097	1.869	1.870
tqc01b.Quench.070823092030.318	58	11582	20	-0.0055	HcoilHcoil	08a06_08a07	-0.0073	08a05_08a06	-0.0063	1.850	1.857
tqc01b.Quench.070823115539.885	59	11800	20	-0.0099	HcoilHcoil	07b04_07b03	-0.0102	07b05_07b04	-0.0081	1.877	1.888
tqc01b.Quench.070823124320.382	60	11824	20	-0.0060	HcoilHcoil	08a08_08b07	-0.0071	08a05_08a06	-0.0053	1.855	1.870
tqc01b.Quench.070823132658.418	61	11877	20	-0.0053	HcoilHcoil	08a08_08b07	-0.0067	08a05_08a06	-0.0049	1.876	1.877
tqc01b.Quench.070823142911.951	62	11959	20	-0.0059	HcoilHcoil	08a08_08b07	-0.0056	08b07_08b05	-0.0049	1.895	1.889
tqc01b.Quench.070823203924.269	63	11864	20	-0.0056	HcoilHcoil	08a08_08b07	-0.0064	08a07_08a08	-0.0059	2.029	2.034
tqc01b.Quench.070823212731.566	64	11915	20	-0.0122	HcoilHcoil	08a08_08b07	-0.0066	08a05_08a06	-0.0045	1.859	1.857
tqc01b.Quench.070823220747.375	65	11850	20	-0.0057	HcoilHcoil	08a08_08b07	-0.0070	08a05_08a06	-0.0053	1.859	1.859
tqc01b.Quench.070824185902.608	66	10763	20	-0.0088	HcoilHcoil	08a06_08a07	-0.0097	08b04_08b03	-0.0073	3.992	4.026
tqc01b.Quench.070824200552.605	67	10562	20	-0.0087	HcoilHcoil	08a06_08a07	-0.0104	08b04_08b03	-0.0067	4.529	4.548
tqc01b.Quench.070824204005.776	68	10537	20	-0.0095	HcoilHcoil	08a06_08a07	-0.0097	08b04_08b03	-0.0069	4.575	4.585
tqc01b.Quench.070824220509.075	69	10543	20	-0.0088	HcoilHcoil	08a06_08a07	-0.0102	08b04_08b03	-0.0067	4.577	4.578

3. Ramp Rate Dependence

Ramp rate dependence study was performed at 4.5 K. Results are shown in Fig.4. The test was interrupted on July 25th due to the problem with the refrigeration system and almost one month later we completed it. Two data points at the baseline ramp rate of 20A/s represent the highest quench current at 4.5K reached before and after this long downtime. Data points for the ramp rate 50, 150 and 250 A/s were obtained after the long downtime.

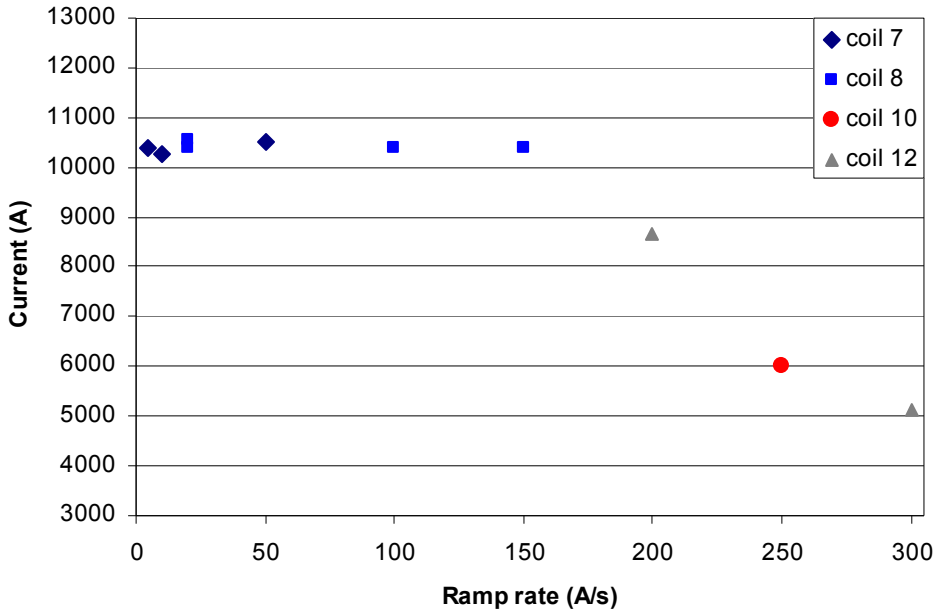

Figure 4. Ramp rate dependence of quench current. The marker of each quench shows the coil where it started

4. Quench Locations

Time-of-flight based quench-origins were calculated from resistive signal growth in voltage tap segments for several quenches during the TQC01b magnet training, using the following three times: quench-onset, 1st exit and 2nd exit (when available). The time-of-flight distance assumed the known voltage-tap locations and equal quench-propagation speeds for both quench-fronts. In our estimations we use the voltage tap locations and segment length presented in LARP TQS02a test summary (see Table 4). Estimated quench origins for the quenches at 1.9K and 4.5K are shown in Fig.5 and Fig.6.

Figure 5. Quench origin location for the quenches at 1.9K

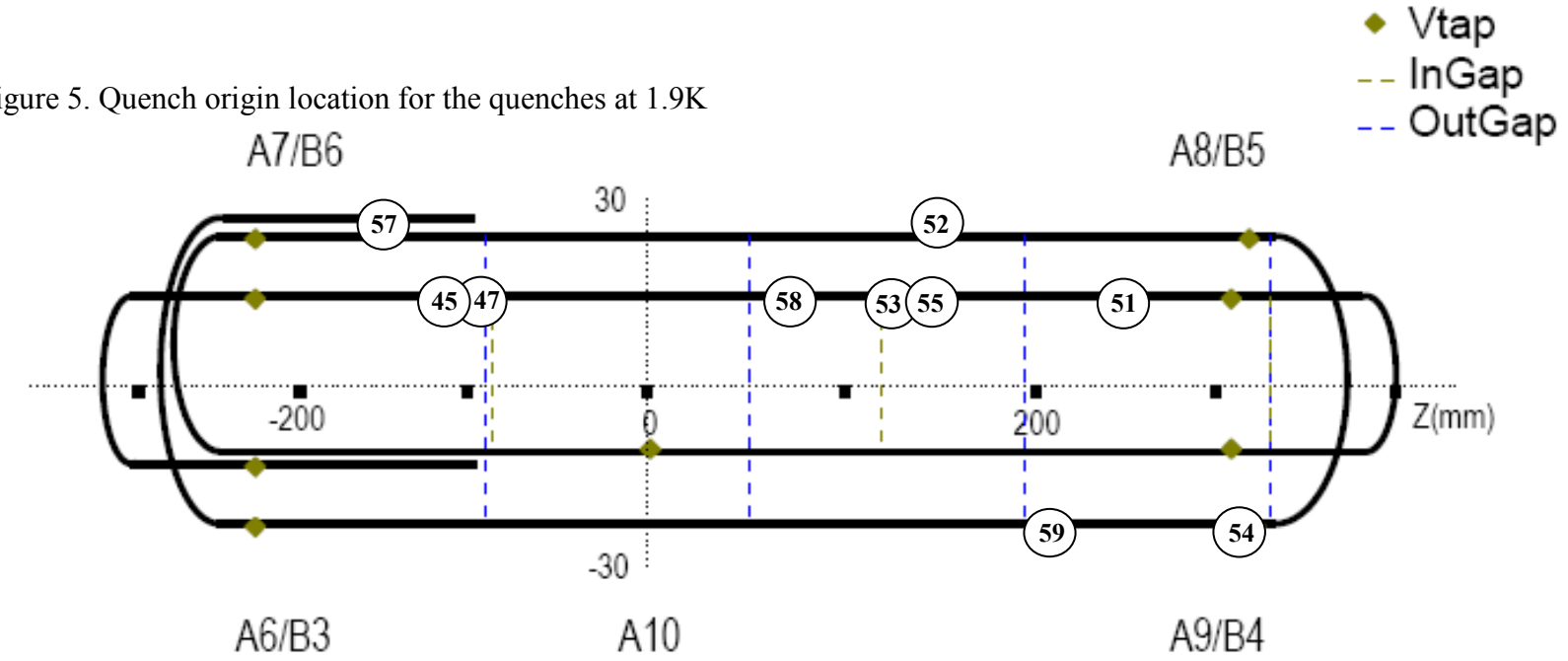

Figure 6. Quench origin location for the quenches at 4.5K

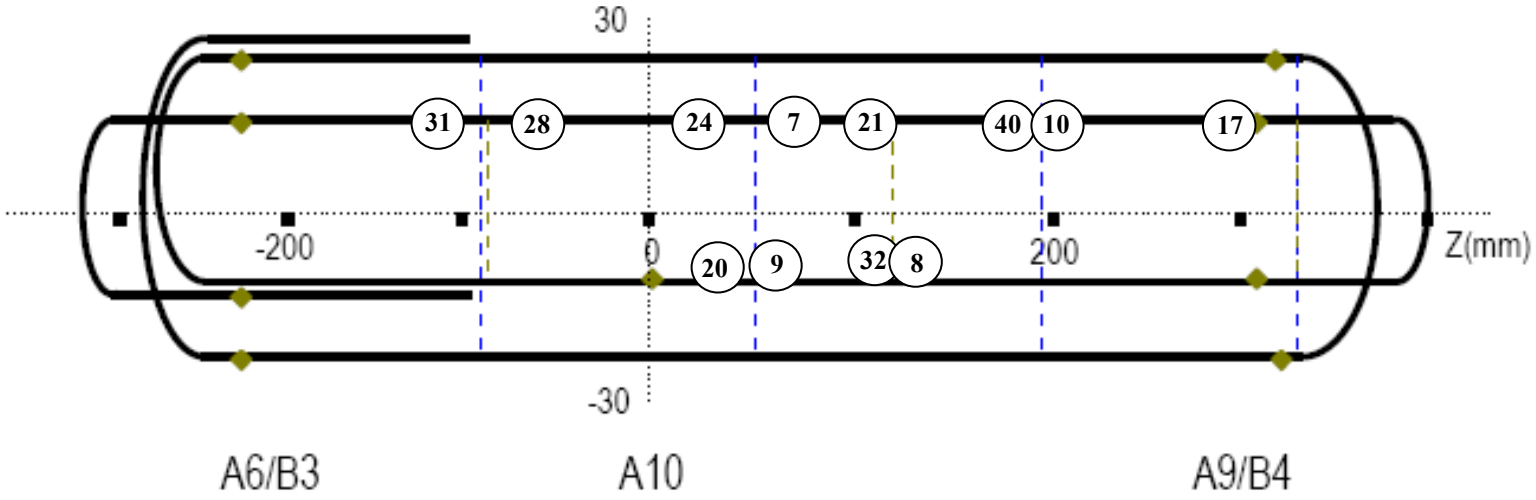

Table 4. Voltage tap locations and calculated segment length

Vtap (ID)	Y (mm)	Z (mm)			L.calc (mm)
A6	-11.08	-230.04	**Wdg7Rs**	A3A4	564
A7	9.08	-230.04	**ILE**	A6A7	168
A8	9.08	314.58	**ILS+LE**	A6A8	713
			ILS+LE+RE	A6A9	900
			IRS+RE	A8A10	499
A9	-9.08	314.58	**IRE**	A8A9	184
A10	-9.08	0.00	**IRS**	A9A10	
B6	26.51	-230.00	**Ramp**	A10B6	352
B5	26.51	326.58	**Ors**	B6B5	557
B4	-26.51	326.58	**Ore**	B5B4	135
B3	-26.51	-230.00	**OLs**	B4B3	557

We estimated quench propagation velocity in the outer layer of coil 7 for the quench #54 as 16m/sec. For quenches in the inner layer of coils we were not able to estimate quench propagation speed due to lack of consecutive single-turn voltage-tap segments.

Schematic view of the inner and outer layers of the coils with voltage taps are shown in Fig.7-10. Quench locations for selected quenches at 4.5K and 1.9K are also shown on these plots. Due to open taps in coils some quench location is uncertain. Following voltage taps were found open: A4 in coil 7, A8, B3 and B5 in coil 10, and A7 in coil 12 (A- and B- indicate voltage taps in inner and outer layers respectively).

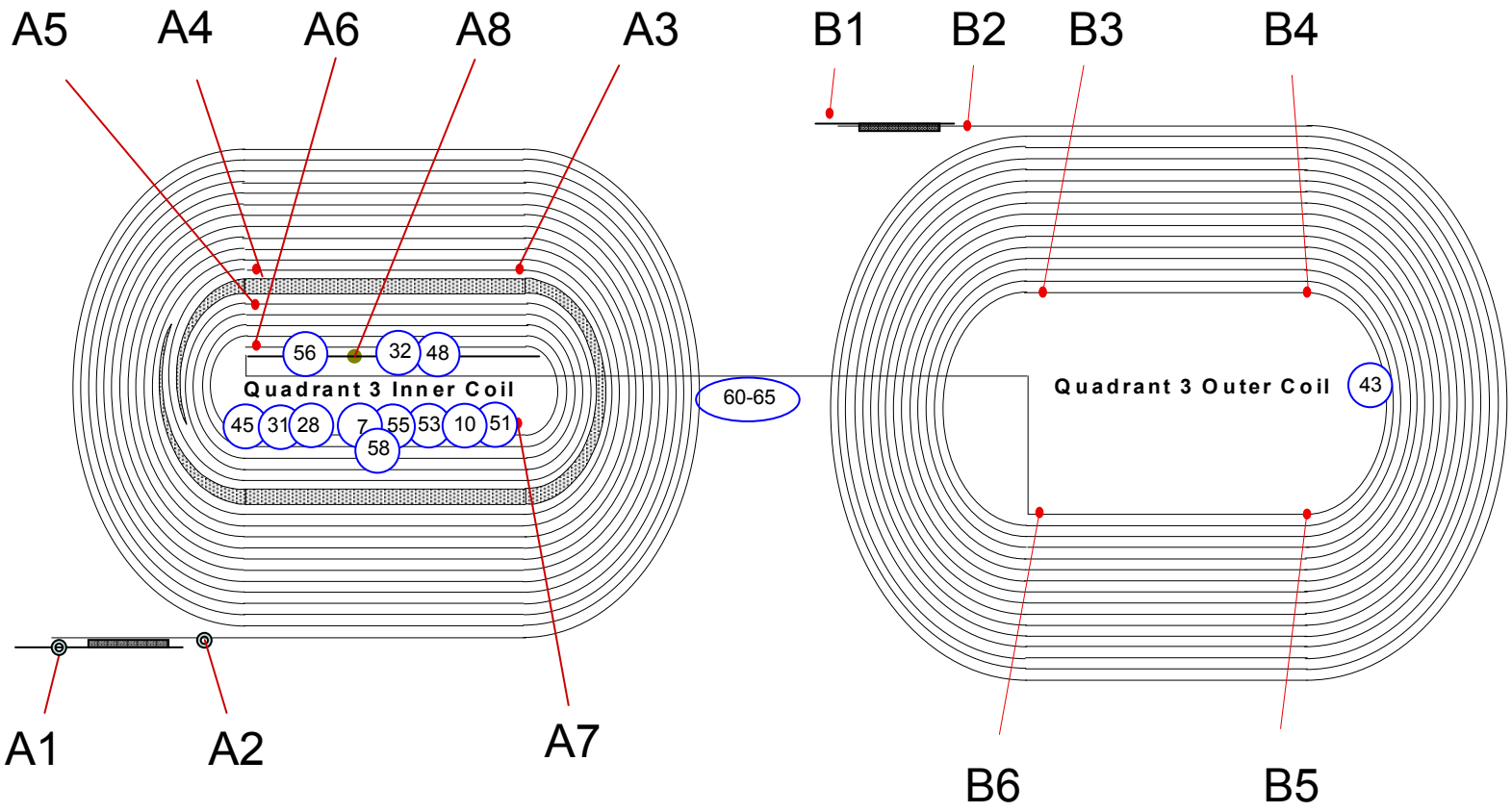

Figure 7. Schematic view of Coil 8 with selected quench locations

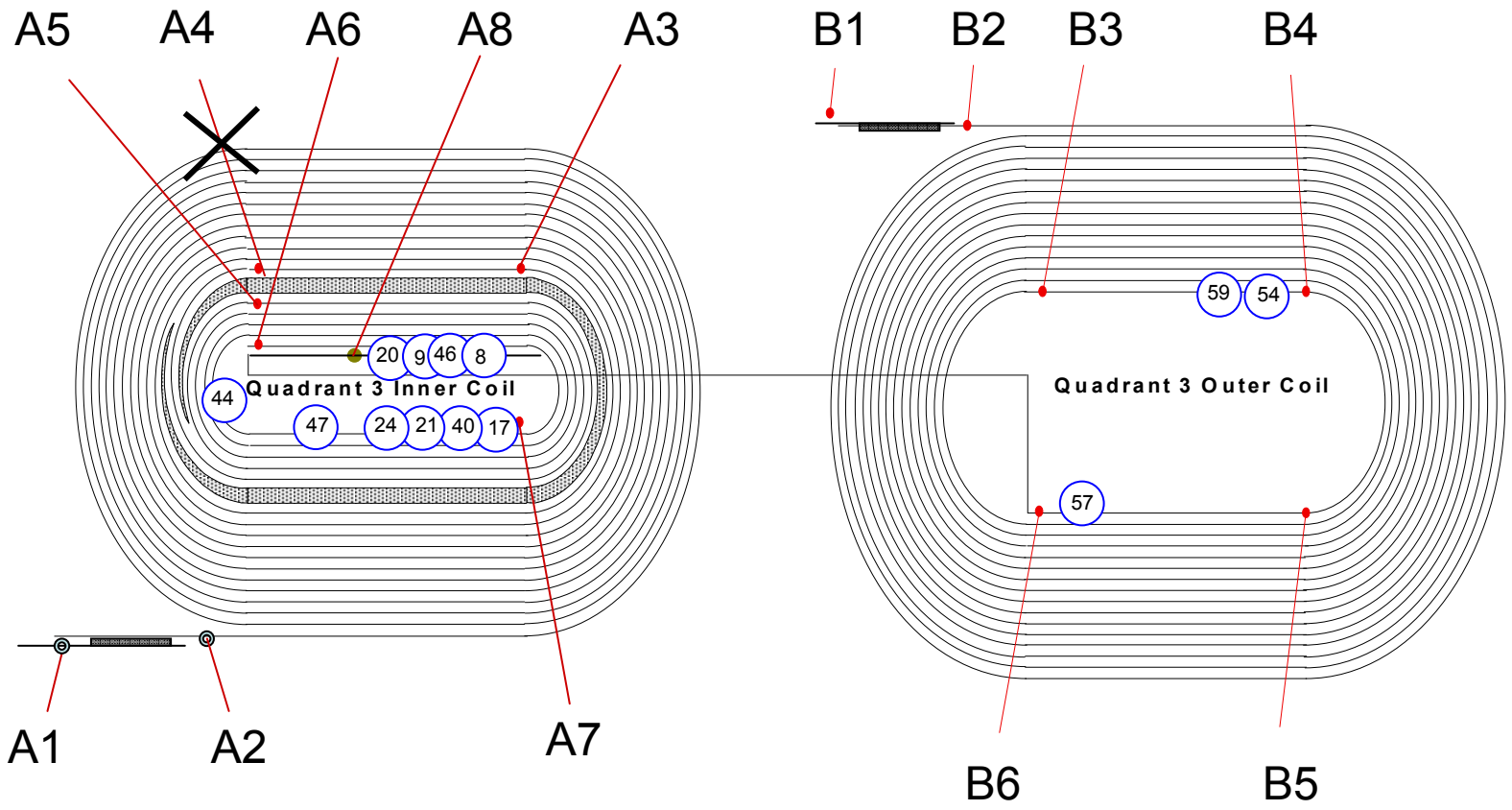

Figure 8. Schematic view of Coil 7 with selected quench locations

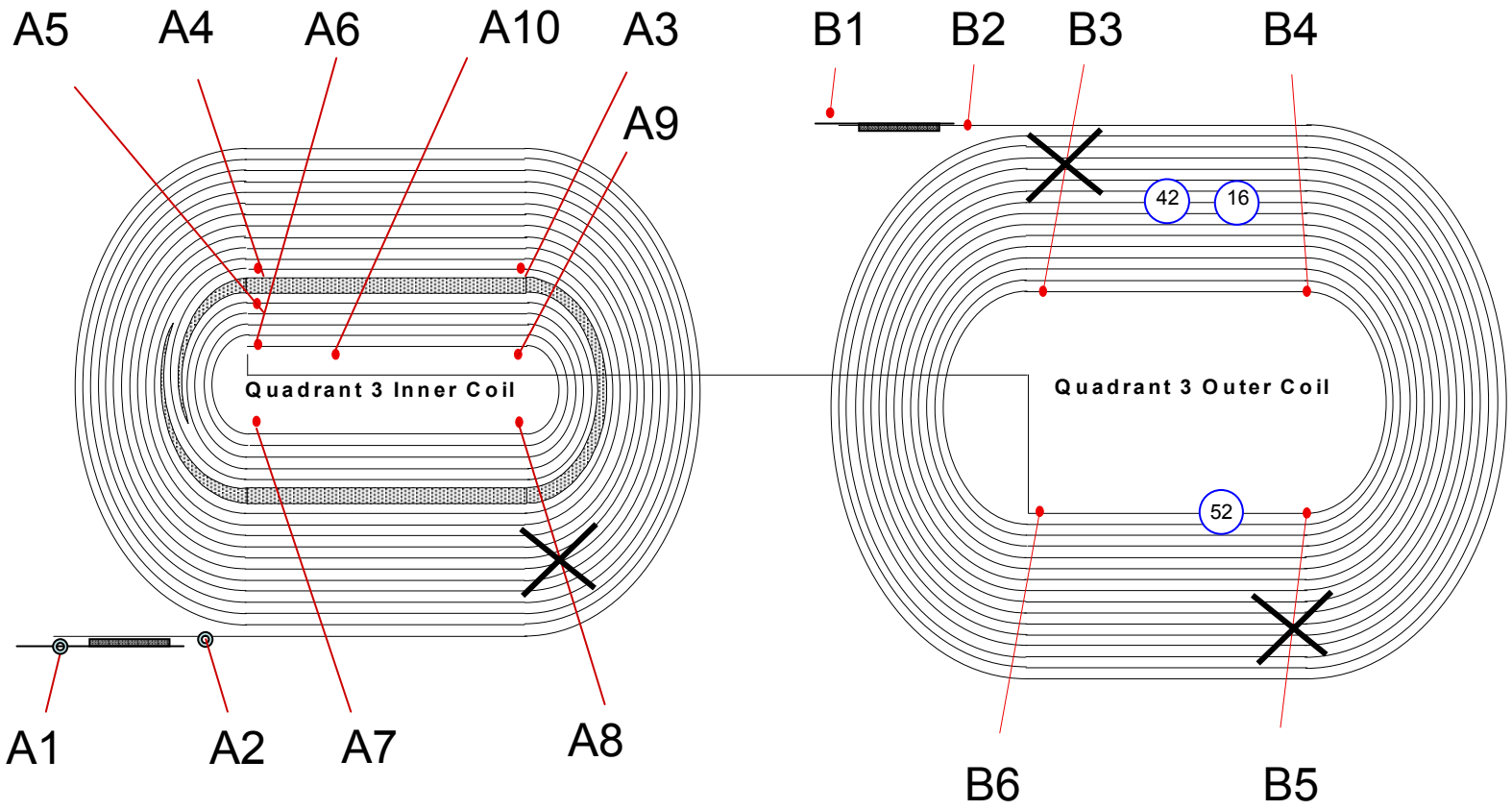

Figure 9. Schematic view of Coil 10 with quench locations

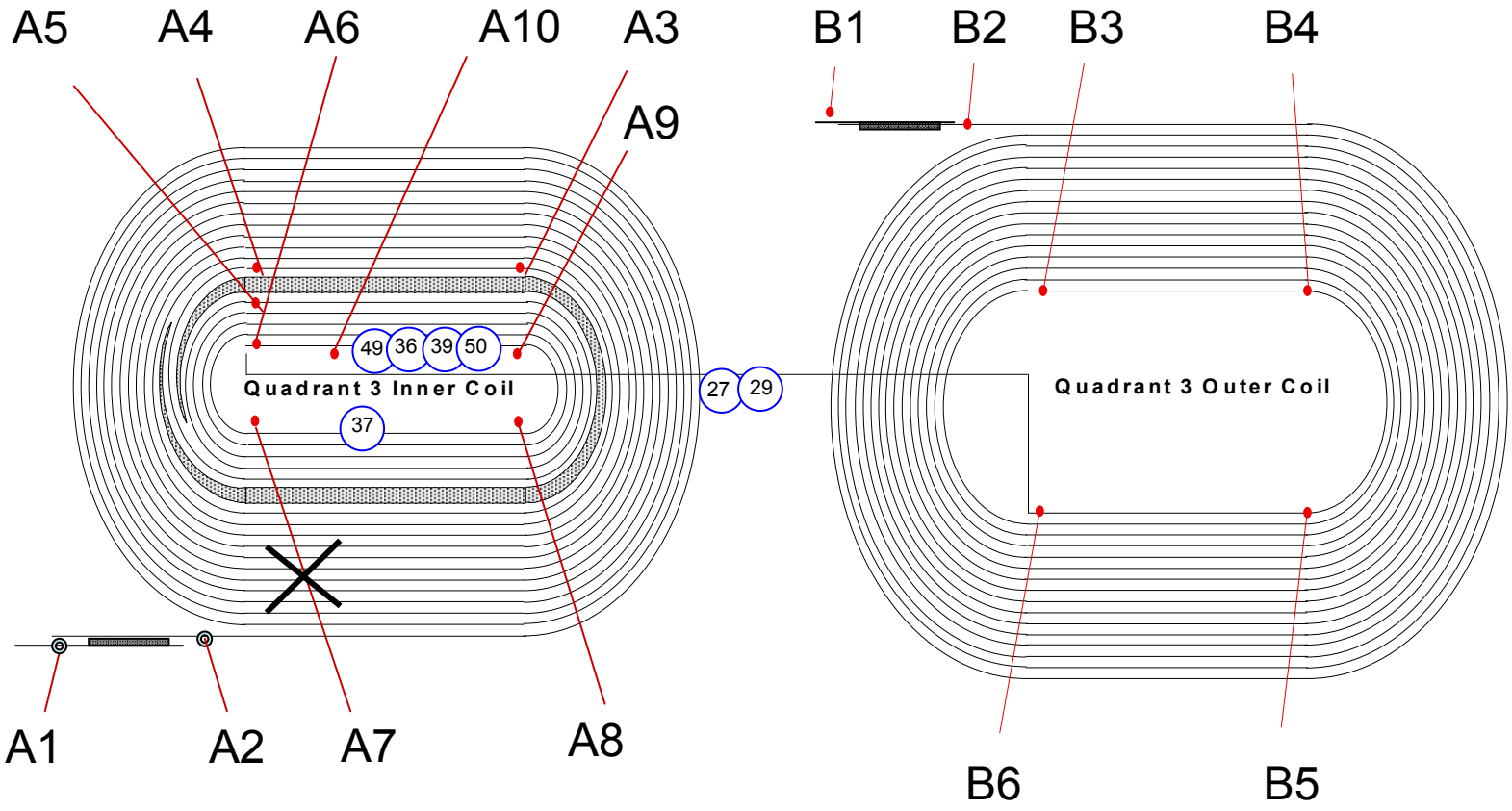

Figure 10. Schematic view of Coil 12 with quench locations