Magnetic field mapping on a translation table

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I. Introduction

We conducted a magnetic field measurement on a translation table with a 3-axis magnetic field probe (TYPE: 3R 100-3, Serial N.O.: 151 GMW Associates), to test the accuracy of TOSCA model for Hall-A experiment E08-027 target field. First, we took the measurement of each point on the translation table with a square of 22 cm long, 64 cm wide and step size 2 cm. Then we employed Tminuit program to fit the matrix from the translation table coordinates to magnetic coil coordinates by minimizing chisquare of measured field data and that predicted from TOSCA model. We found that our result had 15% off a TOSCA model used in SANE experiment, but was in excellent agreement with the theoretical prediction from new TOSCA model.

II. Field Measurement

We did the magnetic field measurement on a translation table which was about 6 cm away from the target can and tested to be horizontal by a level tube bubble. We chose a certain orientation and height for the 3-axis probe to make its 3-axis parallel to the coil coordinate system and make it as close possible to Y=0 plane. Then we moved the probe to do measurement at this chosen orientation and height relative to the table. See Fig.1.

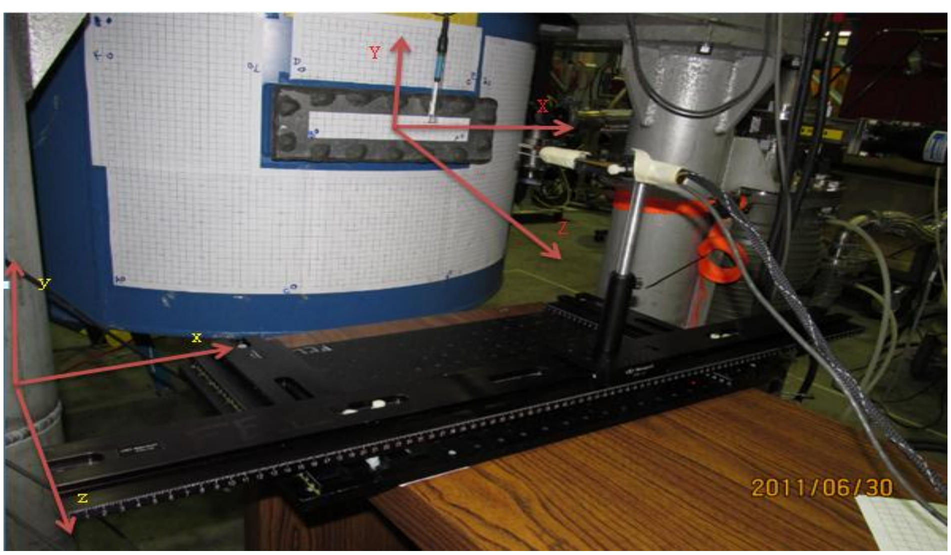

Fig.1. Field map measurement on target can surface.

We set up the table coordinate system (left) and magnetic coil coordinate system (right) here. Now the translation table was in the z-x plane in the table coordinate system with $\vec{z}$ the main target field direction. Meanwhile, the 3-axis of the probe was corresponding to 3-axis of our table coordinate system. In this experiment, we did the magnetic field measurement of 396 points by moving the probe along 2 cm steps in a square with x from 14 to 78 cm and z form 0 to 22 cm in our table coordinates.

Another field measurement was done on the can surface by a single-axis along a grid laser aligned to the surface of the can, see Fig.2. This measurement was more sensitive to y direction since it had a much larger range of y values. You can find this data analysis in the report of Toby Badman.

Fig.2. Field map measurement on target can surface.

III. Calibration

The survey group measured 4 points on the translation table and 3 points on the 3-axis probe relative to coil origin in survey coordinate system, see Table 1 for details. For the 4 points, 2 points were along x direction while the other 2 were along z direction, so we could calculate the vector of the plane in survey coordinate system. The 3 points measured on probe were actually for determining the position of probe, since the probe was not just a point. Survey group measured the left side, right side and center of the probe, so we could get the probe sensitivity point more accurately. With these 7 points, we could get all measured points with respect to the coil origin in survey coordinates.

Table 1. Survey Points Data: The first three measurements were for probe point at (45.5, 0, 22) in table coordinate system, the following two measurements were for two points (14, 0, 22) and (78, 0, 22) along x direction, the last two measurements were for two points (45.5, 0, 0) and (45.5, 0, 22) along z direction.

Survey point	z/mm	x/mm	y/mm
M_POINT_TX45Z22R	755.8526	25.7673	4.0574
M_POINT_TX45Z22L	752.708	30.1726	4.2191
M_POINT_TX45Z22C	728.4528	29.2061	4.9334
M_CIRCLE_TX14Z22R	905.0754	-274.9607	-125.5332
M_CIRCLE_TX78Z22L	894.0685	365.9864	-122.7858
M_CIRCLE_TX45Z00U	684.0247	33.2987	-124.4857
M_CIRCLE_TX45Z22D	904.5429	41.7796	-124.1416

From the first 3 survey points in Table 1, we could get probe position:

table coordinates: survey coordinates:

(45.5, 0, 22) cm ⟷ (2.796995, 0.49334, 72.84528) cm.

Also, we could obtain table plane vectors from the last 4 survey points, in survey coordinates:

$$\vec{x} = (1.001480, 0.004293, -0.017198)\ cm$$

$$\vec{z} = (0.0385450, 0.001564, 1.002355)\ cm$$

Now we plotted part of the raw data directly against the Tosca Model with 2 kinds of calibration as in Fig.3 ~ Fig.6. Both plots showed a large variance. So there are several additional cases we should consider when we tried to find a more accurate matrix between two coordinate systems: 1) Magnetic coil origin might not be the same as the survey coordinate origin. 2) Survey coordinates, table coordinates, 3-axis coordinates might not be parallel to magnetic coil coordinates. 3) Current ratio. Note that probe point (45.5, 0, 22) was close to two measured points (44, 0 , 22) and (46, 0, 22), so we could calculate a rough average current ratio 0.973 as in Table 2. We would use Tminuit program to fit for these parameters with 2 methods in the following pages. Restricting current ratio 0.973 +/- 1% in these two fittings gave current ratio 0.983. Also, consider the field map analysis on can surface, we restricted the current ratio 0.982 ~ 0.983 during following fittings.

Table 2. Current ratio calculated against new TOSCA model.

x/cm	y/cm	z/cm	Btot meas. /T	Btot calc. /T	Current ratio
46	0	22	0.160175	0.164261	0.9751
44	0	22	0.159858	0.16475	0.9703

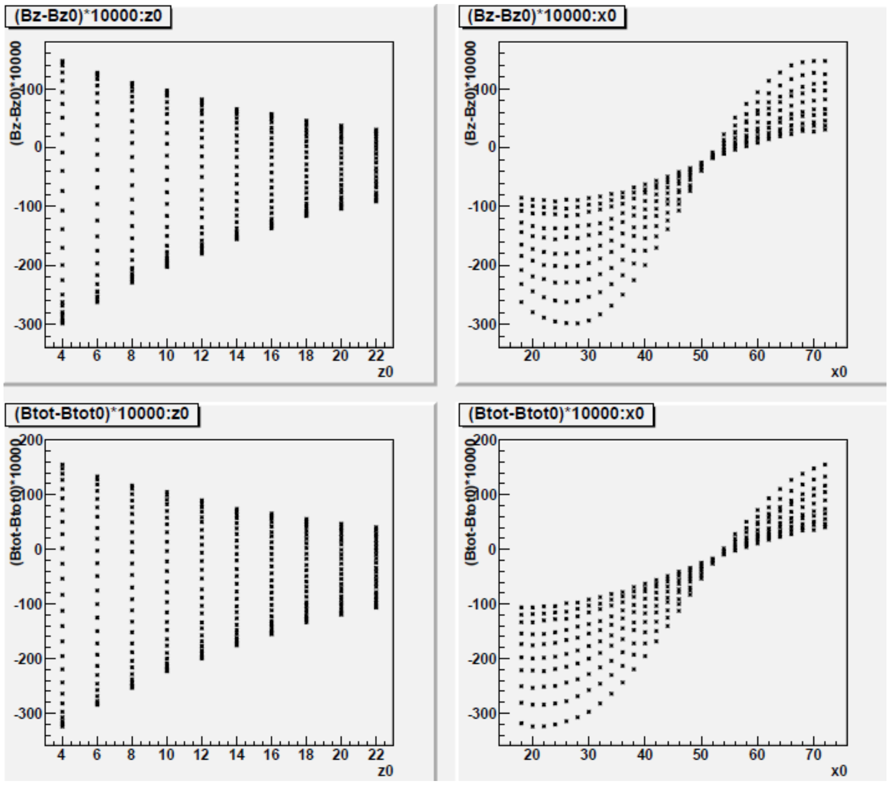

Fig.3. Field map comparison calibrated by just probe point (horizontal axis unit is cm)

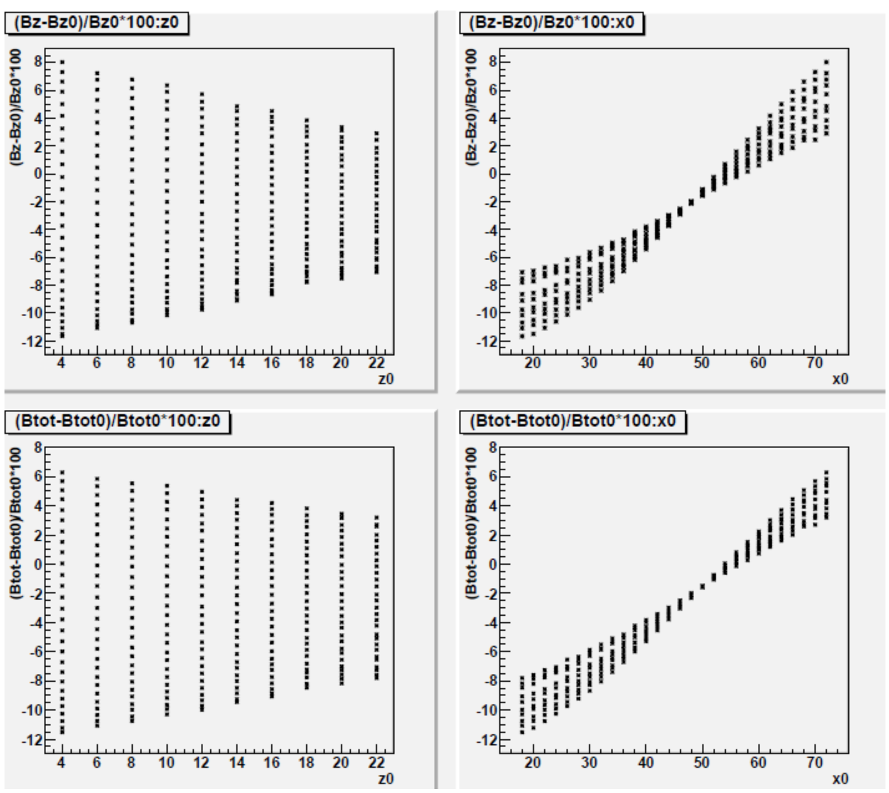

Fig.4. Field map comparison calibrated by just probe point (horizontal axis unit is cm, vertical is Gauss)

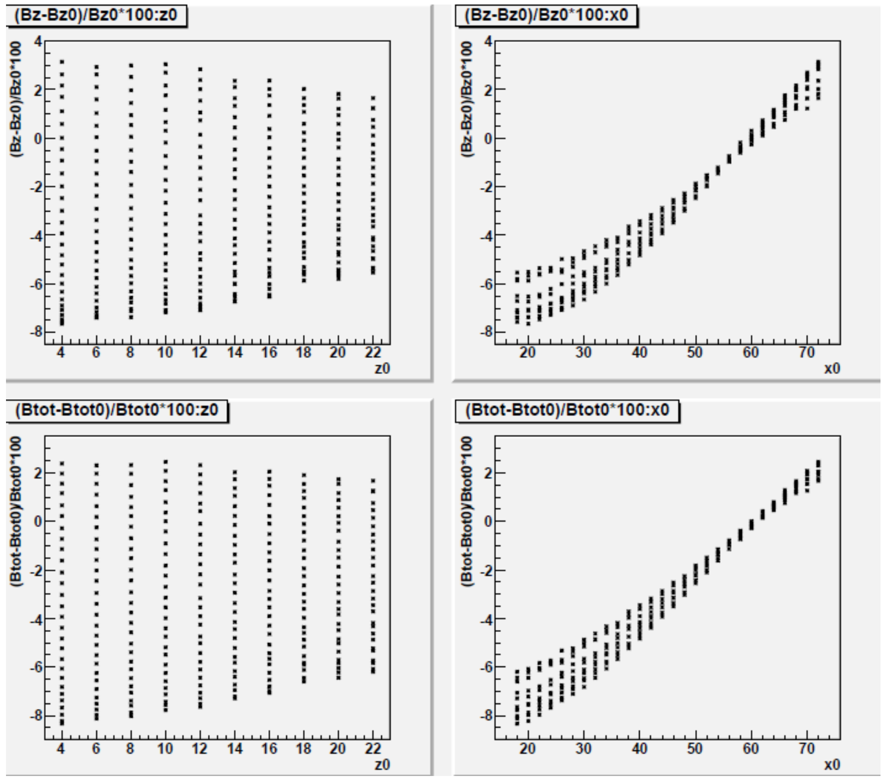

Fig.5. Field map comparison calibrated by all survey points (horizontal axis unit is cm)

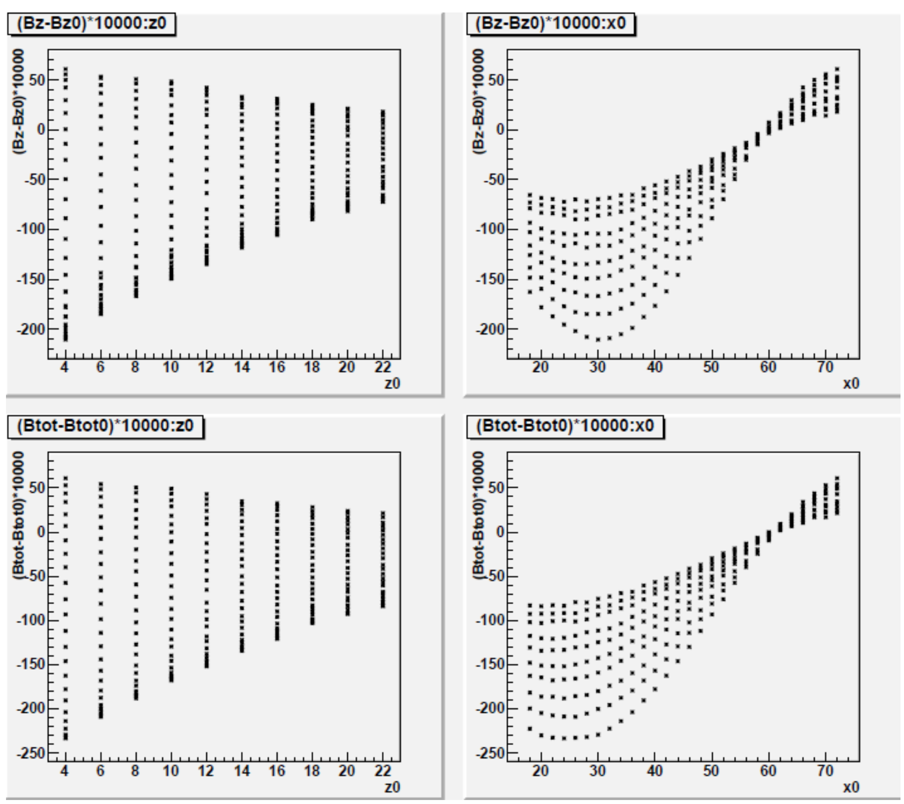

Fig.6. Field map comparison calibrated by all survey points (horizontal axis unit is cm, vertical is Gauss)

IV. Data Analysis

Method 1: One probe point to do first calibration

We employed the Tminuit program to fit for two matrix: one matrix was from table coordinates (x_0, y_0, z_0) to the magnetic coil coordinates (x, y, z) due to coil origin offset (xOffset, yOffset, zOffset) and table not horizontal (θ_{1X}, θ_{1Y}, θ_{1Z}); the other matrix from magnetic field in table coordinates (B_{x1}, B_{y1}, B_{z1}) to that in the magnetic coil coordinates (B_x, B_y, B_z) due to probe angle (θ_{2X}, θ_{2Y}, θ_{2Z}). See matrix relationship as follows:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \cos\theta_{1z} & -\sin\theta_{1z} & 0 \\ \sin\theta_{1z} & \cos\theta_{1z} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{1X} & -\sin\theta_{1X} \\ 0 & \sin\theta_{1X} & \cos\theta_{1X} \end{pmatrix} \begin{pmatrix} \cos\theta_{1Y} & 0 & \sin\theta_{1Y} \\ 0 & 1 & 0 \\ -\sin\theta_{1Y} & 0 & \cos\theta_{1Y} \end{pmatrix} \begin{pmatrix} x_0 - 45.5 \\ y_0 \\ z_0 - 22 \end{pmatrix} + \begin{pmatrix} 2.796995 \\ 0.49334 \\ 72.84528 \end{pmatrix} + \begin{pmatrix} xOffset \\ yOffset \\ zOffset \end{pmatrix}$$

$$\begin{pmatrix} B_{x0} \\ B_{y0} \\ B_{z0} \end{pmatrix} \xleftrightarrow[\text{currentratio}]{\text{TOSCA model}} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

$$\begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} = \begin{pmatrix} \cos\theta_{2z} & -\sin\theta_{2z} & 0 \\ \sin\theta_{2z} & \cos\theta_{2z} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{2X} & -\sin\theta_{2X} \\ 0 & \sin\theta_{2X} & \cos\theta_{2X} \end{pmatrix} \begin{pmatrix} \cos\theta_{2Y} & 0 & \sin\theta_{2Y} \\ 0 & 1 & 0 \\ -\sin\theta_{2Y} & 0 & \cos\theta_{2Y} \end{pmatrix} \begin{pmatrix} B_{x1} \\ B_{y1} \\ B_{z1} \end{pmatrix}$$

Then we minimized the chisquare by comparing magnetic field (B_x, B_y, B_z) and magnetic field (B_{x0}, B_{y0}, B_{z0}) predicted from TOSCA model and obtained parameters as in Table 3. Data N.O. 3 was more sensitive to x values. Used this matrix results to plot Data N.O.2 in Fig.7 and Fig.8.

Table 3. Fit results.

Data N.0.	xOffset /cm	yOffset /cm	zOffset /cm	Probe θ_x /rad	Probe θ_y /rad	Probe θ_z /rad	Table θ_x /rad	Table θ_y /rad	Table θ_z /rad	Ratio k
1	-0.37243	-0.10908	0.323409	-0.002430	-0.011614	-0.001275	-0.007423	0.052684	0.002534	0.983
2	-0.68850	-0.11888	0.333181	-0.002435	-0.016578	-0.002247	-0.007650	0.048385	0.001593	0.983
3	-0.58653	-0.12458	0.331062	-0.002647	-0.012823	-0.002642	-0.007963	0.050219	0.001304	0.983

Note: Data N.O. to fit : X rang (x low, x high) × Z range(z low , z high)

NO.1 X(32, 58)× Z(4, 22): 140 points

NO.2 X(18, 72)× Z(4, 22): 280 points ;

NO.3 X(18, 30)× Z(4, 72) + X(60, 72)× Z(0, 22): 140 points ;

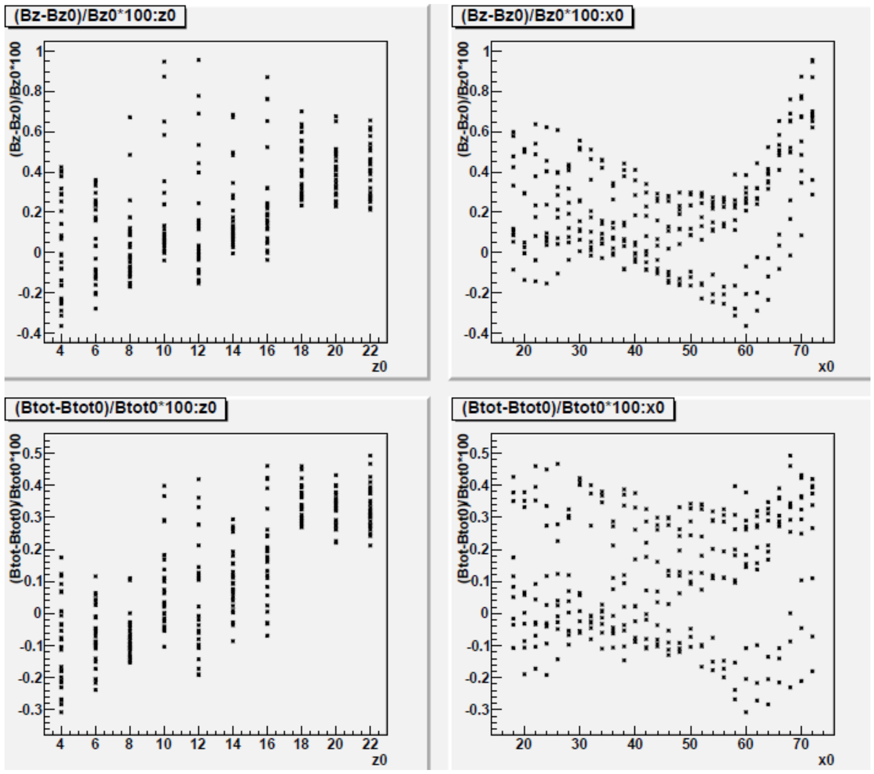

Fig.7. Field map comparison calibrated by just probe point (horizontal axis unit is cm)

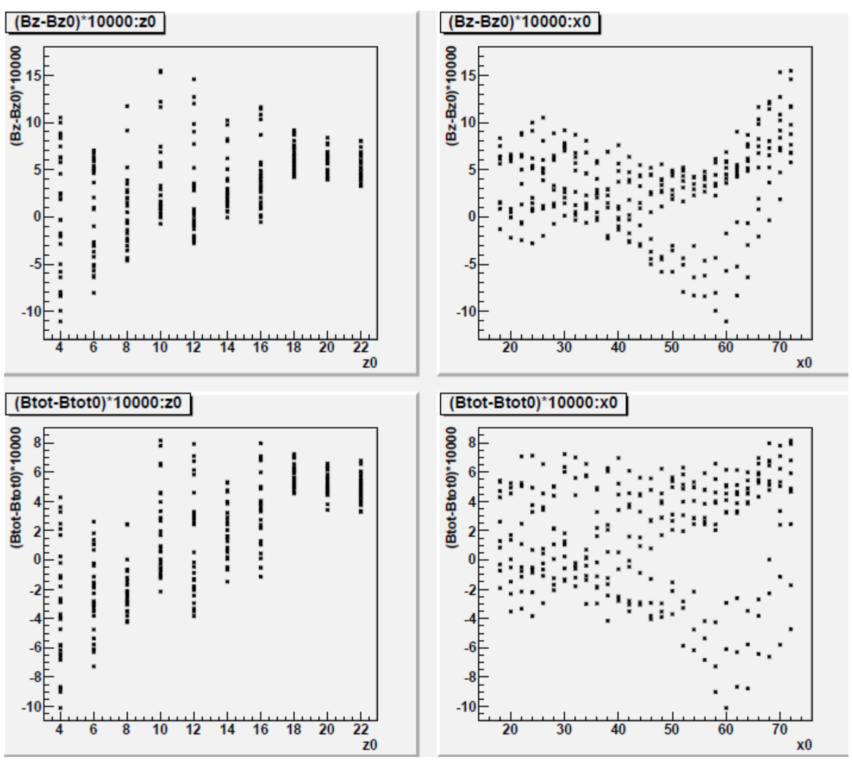

Fig.8. Field map comparison calibrated by just probe point (horizontal axis unit is cm, vertical is Gauss)

Method 2: All survey points to do first calibration

We employed the Tminuit program to fit for two matrix: one matrix was from table coordinates (x_0, y_0, z_0) to the magnetic coil coordinates (x, y, z) due to coil origin offset (xOffset, yOffset, zOffset) and coil angle (θ_{1X}, θ_{1Y}, θ_{1Z}); the other matrix from magnetic field in table coordinates (B_{x1}, B_{y1}, B_{z1}) to that in the magnetic coil coordinates (B_x, B_y, B_z) due to probe angle (θ_{2X}, θ_{2Y}, θ_{2Z}). The matrix relationship was as follows:

$$\begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix} = \begin{pmatrix} 1.001480 & 0 & 0.038545 \\ 0.004293 & 0 & 0.001564 \\ -0.017198 & 0 & 1.002355 \end{pmatrix} \begin{pmatrix} x_0 - 45.5 \\ y_0 \\ z_0 - 22 \end{pmatrix} + \begin{pmatrix} \text{xOffset} \\ \text{yOffset} \\ \text{zOffset} \end{pmatrix} + \begin{pmatrix} 2.796995 \\ 0.49334 \\ 72.84528 \end{pmatrix}$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \cos\theta_{1z} & -\sin\theta_{1z} & 0 \\ \sin\theta_{1z} & \cos\theta_{1z} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{1X} & -\sin\theta_{1X} \\ 0 & \sin\theta_{1X} & \cos\theta_{1X} \end{pmatrix} \begin{pmatrix} \cos\theta_{1Y} & 0 & \sin\theta_{1Y} \\ 0 & 1 & 0 \\ -\sin\theta_{1Y} & 0 & \sin\theta_{1Y} \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix}$$

$$\begin{pmatrix} B_{x0} \\ B_{y0} \\ B_{z0} \end{pmatrix} \xleftrightarrow[\text{currentratio}]{\text{TOSCA model}} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

$$\begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} = \begin{pmatrix} \cos\theta_{2z} & -\sin\theta_{2z} & 0 \\ \sin\theta_{2z} & \cos\theta_{2z} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{2X} & -\sin\theta_{2X} \\ 0 & \sin\theta_{2X} & \cos\theta_{2X} \end{pmatrix} \begin{pmatrix} \cos\theta_{2Y} & 0 & \sin\theta_{2Y} \\ 0 & 1 & 0 \\ -\sin\theta_{2Y} & 0 & \cos\theta_{2Y} \end{pmatrix} \begin{pmatrix} B_{x1} \\ B_{y1} \\ B_{z1} \end{pmatrix}$$

Then we minimized the chisquare by comparing magnetic field (B_x, B_y, B_z) and magnetic field (B_{x0}, B_{y0}, B_{z0}) predicted from TOSCA model and obtained parameters as in Table 4 for Data N.O. 2. See plot in Fig.9 and Fig.10. From the results, we found it gave a much larger origin offset for x than the first method. This might be due to the movement of the table after the raw data measurement and before survey group measurement.

Table 4. Fit results.

xOffset /cm	yOffset /cm	zOffset /cm	Probe θ_x /rad	Probe θ_y /rad	Probe θ_z /rad	Coil θ_x /rad	Coil θ_y /rad	Coil θ_z /rad	Ratio K
-2.36278	-0.866455	0.438227	0.007769	-0.051711	-0.0110489	-0.000410	0.002622	-0.011494	0.983

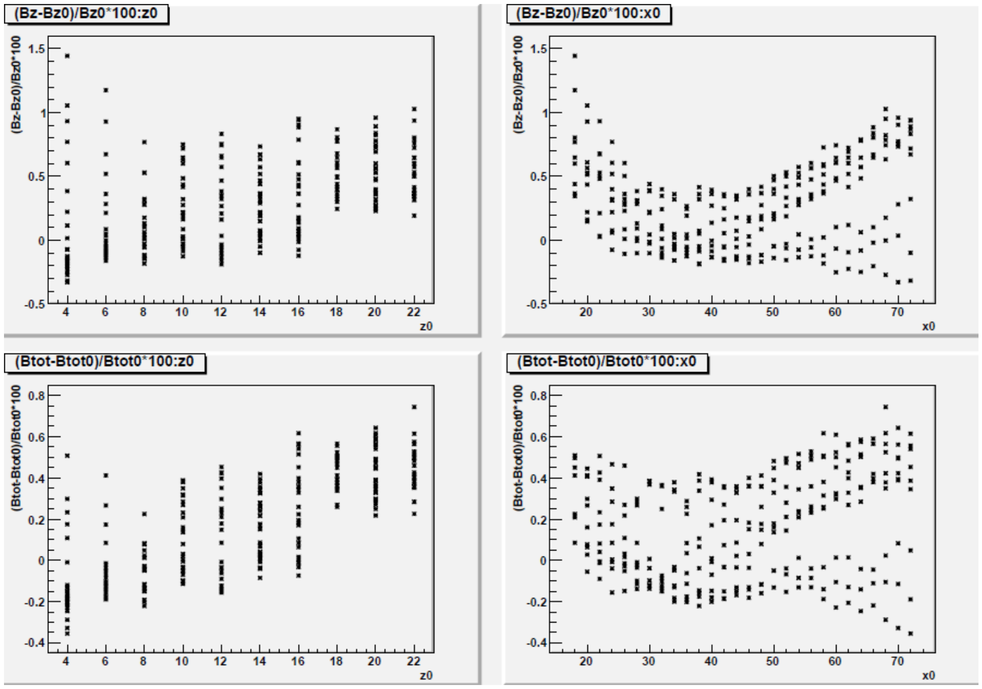

Fig.9. Field map comparison calibrated by all survey points (horizontal axis unit is cm)

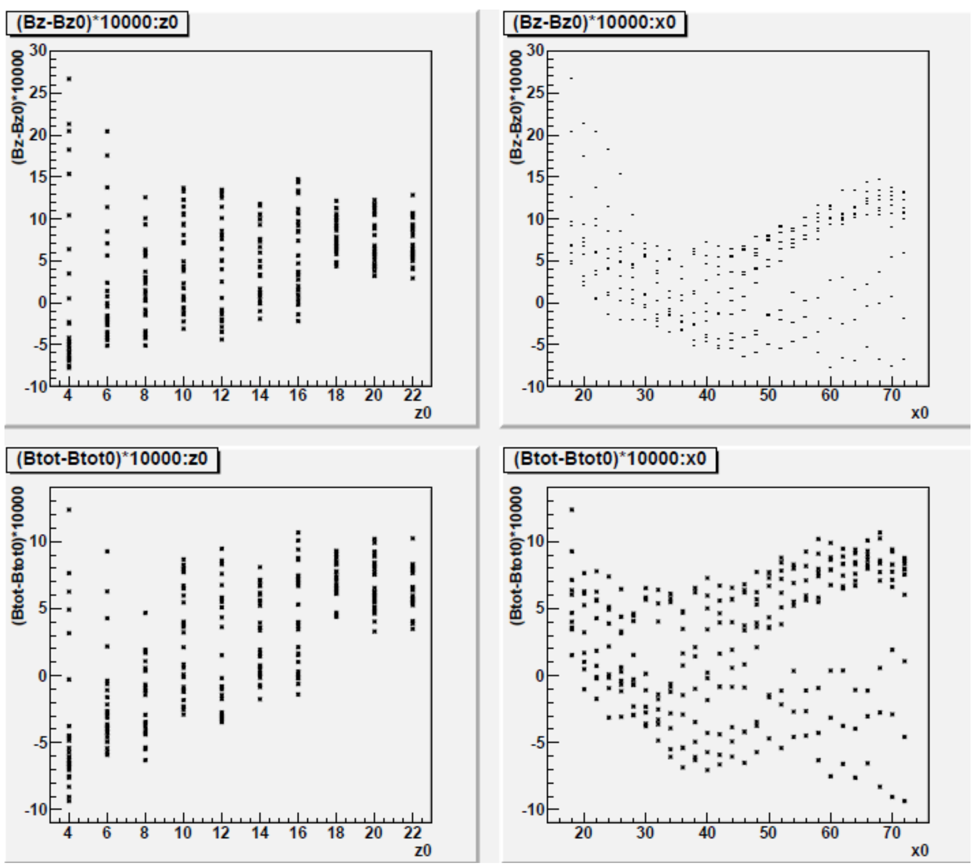

Fig.10. Field map comparison calibrated by all survey points (horizontal axis unit is cm, vertical is Gauss)

During above fittings, we just used the new TOSCA Model since fitting the old TOSCA model gave a current ratio 1.15, while the new TOSCA model gave a more reasonable result as showed above. Here we made a comparison of new TOSCA model and old TOSCA model, see Fig. 11. The new TOSCA model was at current of 77.245A, while the original model was at current of 78.75A.

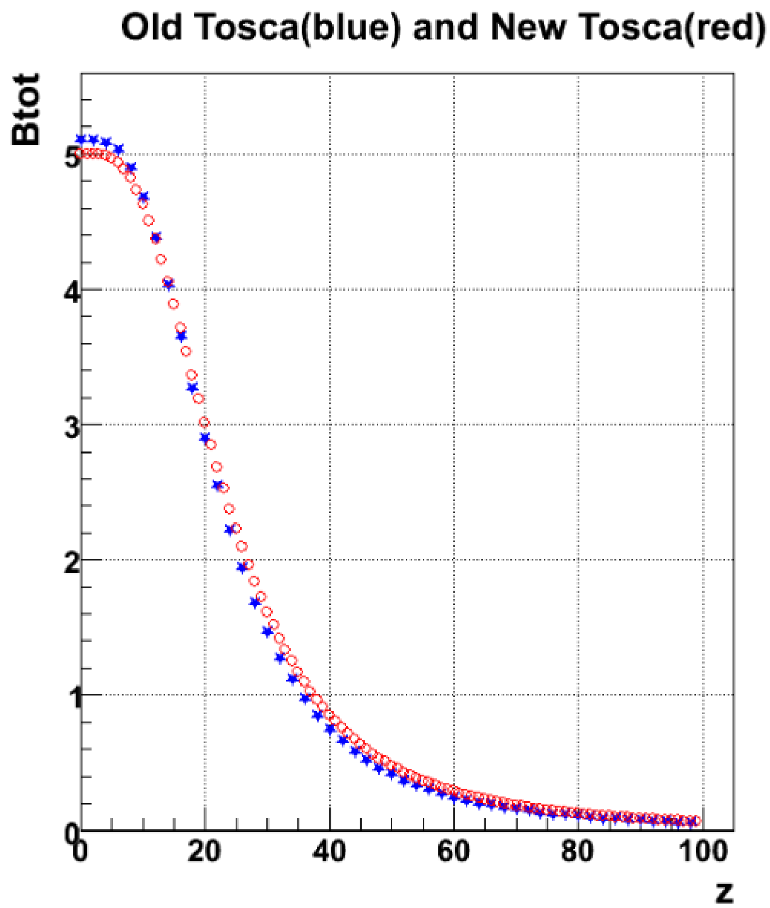

Fig.11. Comparison of new Tosca Model and old Tosca Model (SANE)

V. Conclusions

In summary, the measured field map on the translation table is in excellent agreement with that predicted from new TOSCA model, especially for B_z, B_{tot} almost within 2% tolerance after fitting, in the range of z from 50 ~72cm and x from -30 ~ 33cm respect to target coil origin. The new TOSCA map can be a reasonable model to use for Hall-A E08-027 experiment.

Appendix A

Table 5. Raw Data: CH1, CH2, CH3 are relative to measured magnetic field along z, y, x axis with 1mv = 2 Gauss. CH1, CH2, CH3 have offsets -0.1mV, -0.7mV, -0.3mV respectively.

x/cm	y/cm	z/cm	CH1/mV	CH2/mV	CH3/mV
78	0	0	-820	4	1032
76	0	0	-922	5	1051
74	0	0	-1030	5	1062
72	0	0	-1144	5	1064
70	0	0	-1259	6	1056
68	0	0	-1374	6	1036
66	0	0	-1490	6	1004
64	0	0	-1603	6	961
62	0	0	-1710	6	905
60	0	0	-1812	6	838
58	0	0	-1905	6	758
56	0	0	-1987	6	670
54	0	0	-2056	6	574
52	0	0	-2112	5	470
50	0	0	-2154	5	361
48	0	0	-2180	5	247
46	0	0	-2191	4	132
44	0	0	-2187	4	16.8
42	0	0	-2167	4	-98.1
40	0	0	-2131	3	-210.1
38	0	0	-2083	2	-315.6
36	0	0	-2021	2	-416
34	0	0	-1947	1	-508
32	0	0	-1862	1	-593
30	0	0	-1770	0	-667
28	0	0	-1669	0	-732
26	0	0	-1564	-1	-785
24	0	0	-1455	-1	-828
22	0	0	-1345	-1	-860
20	0	0	-1235	-2	-881
18	0	0	-1128	-2	-892
16	0	0	-1025	-2	-894

14	0	0	-924	-2	-888
78	0	2	-781	4	934
76	0	2	-872	4	948
74	0	2	-967	5	954
72	0	2	-1067	6	953
70	0	2	-1169	6	942
68	0	2	-1269	6	922
66	0	2	-1370	6	892
64	0	2	-1466	6	852
62	0	2	-1561	7	801
60	0	2	-1647	7	741
58	0	2	-1727	7	671
56	0	2	-1798	7	592
54	0	2	-1856	6	508
52	0	2	-1905	6	417
50	0	2	-1940	6	321
48	0	2	-1964	6	222
46	0	2	-1973	6	124
44	0	2	-1970	5	19.3
42	0	2	-1953	5	-81.6
40	0	2	-1923	4	-178.9
38	0	2	-1882	4	-273
36	0	2	-1828	3	-361
34	0	2	-1765	3	-444
32	0	2	-1694	2	-518
30	0	2	-1613	2	-585
28	0	2	-1527	1	-644
26	0	2	-1435	1	-693
24	0	2	-1341	0	-732
22	0	2	-1246	0	-762
20	0	2	-1150	0	-784
18	0	2	-1055	-1	-797
16	0	2	-964	-1	-801
14	0	2	-875	-2	-800
78	0	4	-740	4	848
76	0	4	-821	4	857
74	0	4	-906	5	861
72	0	4	-994	6	857
70	0	4	-1082	6	846

68	0	4	-1171	6	826
66	0	4	-1259	6	798
64	0	4	-1343	7	761
62	0	4	-1424	7	716
60	0	4	-1499	7	662
58	0	4	-1569	7	599
56	0	4	-1631	7	530
54	0	4	-1683	7	455
52	0	4	-1725	7	374
50	0	4	-1757	7	290
48	0	4	-1777	6	204
46	0	4	-1786	6	114
44	0	4	-1784	6	24.3
42	0	4	-1770	5	-65
40	0	4	-1745	5	-150.6
38	0	4	-1710	5	-233.9
36	0	4	-1664	4	-313.5
34	0	4	-1610	4	-386
32	0	4	-1548	3	-453
30	0	4	-1479	3	-513
28	0	4	-1405	2	-567
26	0	4	-1327	2	-612
24	0	4	-1245	1	-649
22	0	4	-1161	1	-678
20	0	4	-1076	0	-700
18	0	4	-994	0	-714
16	0	4	-911	0	-722
14	0	4	-835	-1	-722
78	0	6	-703	4	769
76	0	6	-776	5	775
74	0	6	-851	5	776
72	0	6	-928	6	771
70	0	6	-1007	6	758
68	0	6	-1084	6	739
66	0	6	-1160	6	712
64	0	6	-1233	7	678
62	0	6	-1303	7	637
60	0	6	-1369	7	588
58	0	6	-1428	7	533

56	0	6	-1482	7	471
54	0	6	-1527	7	405
52	0	6	-1564	7	334
50	0	6	-1592	6	259
48	0	6	-1609	7	182
46	0	6	-1617	6	104
44	0	6	-1615	6	25.9
42	0	6	-1603	5	-53.3
40	0	6	-1582	5	-129.2
38	0	6	-1552	5	-203.3
36	0	6	-1513	4	-272
34	0	6	-1467	4	-337
32	0	6	-1413	3	-398
30	0	6	-1354	3	-453
28	0	6	-1289	2	-501
26	0	6	-1220	2	-542
24	0	6	-1149	1	-577
22	0	6	-1076	1	-605
20	0	6	-1003	1	-625
18	0	6	-930	0	-640
16	0	6	-858	0	-649
14	0	6	-787	0	-652
78	0	8	-669	4	700
76	0	8	-733	4	703
74	0	8	-801	5	701
72	0	8	-869	5	694
70	0	8	-937	6	682
68	0	8	-1004	6	663
66	0	8	-1070	6	637
64	0	8	-1134	6	606
62	0	8	-1196	7	568
60	0	8	-1253	7	524
58	0	8	-1304	7	475
56	0	8	-1350	7	420
54	0	8	-1390	7	361
52	0	8	-1421	7	299
50	0	8	-1445	7	233
48	0	8	-1460	7	164
46	0	8	-1467	6	95.2

44	0	8	-1466	6	25.4
42	0	8	-1456	6	-45.1
40	0	8	-1438	5	-112.5
38	0	8	-1411	5	-177.3
36	0	8	-1378	5	-239.2
34	0	8	-1338	4	-295.4
32	0	8	-1292	4	-351
30	0	8	-1240	3	-400
28	0	8	-1184	3	-443
26	0	8	-1125	2	-481
24	0	8	-1062	2	-513
22	0	8	-999	1	-539
20	0	8	-933	1	-560
18	0	8	-869	1	-575
16	0	8	-806	0	-585
14	0	8	-743	0	-589
78	0	10	-636	4	638
76	0	10	-694	4	639
74	0	10	-753	5	636
72	0	10	-814	5	628
70	0	10	-875	5	614
68	0	10	-934	6	596
66	0	10	-993	6	572
64	0	10	-1048	6	543
62	0	10	-1101	6	509
60	0	10	-1152	6	468
58	0	10	-1197	6	424
56	0	10	-1236	6	375
54	0	10	-1270	6	322
52	0	10	-1297	6	266
50	0	10	-1318	6	207
48	0	10	-1331	6	147.6
46	0	10	-1337	6	85.2
44	0	10	-1336	6	22.9
42	0	10	-1327	5	-38.5
40	0	10	-1311	5	-98.6
38	0	10	-1289	5	-156.6
36	0	10	-1259	4	-212.5
34	0	10	-1225	4	-264

32	0	10	-1184	3	-312.1
30	0	10	-1139	3	-356
28	0	10	-1090	2	-395
26	0	10	-1038	2	-430
24	0	10	-984	2	-459
22	0	10	-927	1	-484
20	0	10	-871	1	-504
18	0	10	-814	0	-518
16	0	10	-757	0	-528
14	0	10	-701	0	-534
78	0	12	-602	4	581
76	0	12	-655	4	581
74	0	12	-707	4	576
72	0	12	-761	4	568
70	0	12	-814	5	555
68	0	12	-867	5	537
66	0	12	-918	5	515
64	0	12	-967	5	488
62	0	12	-1015	6	456
60	0	12	-1057	6	420
58	0	12	-1096	6	380
56	0	12	-1131	6	336
54	0	12	-1161	6	288
52	0	12	-1185	6	238.6
50	0	12	-1203	6	186.8
48	0	12	-1215	5	132.1
46	0	12	-1218	5	86
44	0	12	-1218	5	22.1
42	0	12	-1211	5	-31.5
40	0	12	-1198	4	-85.6
38	0	12	-1177	4	-137.6
36	0	12	-1153	4	-187
34	0	12	-1122	3	-233.8
32	0	12	-1087	3	-276
30	0	12	-1048	2	-316
28	0	12	-1005	2	-352
26	0	12	-959	2	-384
24	0	12	-911	1	-411
22	0	12	-862	1	-434

20	0	12	-812	1	-452
18	0	12	-762	1	-467
16	0	12	-712	0	-478
14	0	12	-662	0	-484
78	0	14	-569	3	531
76	0	14	-616	3	529
74	0	14	-663	4	524
72	0	14	-710	4	515
70	0	14	-758	5	502
68	0	14	-804	5	486
66	0	14	-850	5	465
64	0	14	-893	5	440
62	0	14	-934	5	411
60	0	14	-972	5	379
58	0	14	-1006	5	343
56	0	14	-1037	5	303
54	0	14	-1063	5	261
52	0	14	-1085	5	216
50	0	14	-1100	5	169
48	0	14	-1111	5	121.5
46	0	14	-1116	5	73.3
44	0	14	-1115	5	24.2
42	0	14	-1109	4	-24.4
40	0	14	-1097	4	-71.6
38	0	14	-1081	4	-118.3
36	0	14	-1059	3	-163.3
34	0	14	-1032	3	-205.1
32	0	14	-1001	3	-244.8
30	0	14	-968	2	-280.2
28	0	14	-930	2	-313.5
26	0	14	-892	2	-339
24	0	14	-848	1	-368
22	0	14	-805	1	-389
20	0	14	-760	1	-407
18	0	14	-716	0	-422
16	0	14	-672	0	-432
14	0	14	-628	0	-440
78	0	16	-541	3	486
76	0	16	-582	3	483

74	0	16	-624	3	477
72	0	16	-666	4	468
70	0	16	-708	4	456
68	0	16	-750	4	440
66	0	16	-790	4	420
64	0	16	-828	5	397
62	0	16	-863	5	371
60	0	16	-897	5	342
58	0	16	-927	5	309
56	0	16	-954	5	273
54	0	16	-977	5	235
52	0	16	-996	5	195
50	0	16	-1010	5	153.8
48	0	16	-1019	4	110.5
46	0	16	-1023	4	66.9
44	0	16	-1023	4	23.4
42	0	16	-1018	4	-20.4
40	0	16	-1008	4	-62.7
38	0	16	-993	4	-104
36	0	16	-974	3	-144.2
34	0	16	-950	3	-182.2
32	0	16	-923	3	-217.9
30	0	16	-894	2	-250.4
28	0	16	-862	2	-280.2
26	0	16	-826	2	-307.4
24	0	16	-789	1	-330
22	0	16	-750	1	-351
20	0	16	-711	1	-368
18	0	16	-672	0	-382
16	0	16	-631	0	-392
14	0	16	-591	0	-400
78	0	18	-509	2	445
76	0	18	-547	2	442
74	0	18	-584	3	436
72	0	18	-623	3	427
70	0	18	-660	3	415
68	0	18	-697	4	400
66	0	18	-733	4	382
64	0	18	-766	4	362

62	0	18	-798	4	338
60	0	18	-828	4	311.1
58	0	18	-855	4	282
56	0	18	-879	4	250
54	0	18	-899	4	215.8
52	0	18	-916	4	180
50	0	18	-928	4	143
48	0	18	-937	4	104
46	0	18	-941	4	64.7
44	0	18	-941	4	26.4
42	0	18	-937	4	-12.5
40	0	18	-929	4	-51.3
38	0	18	-916	3	-90.1
36	0	18	-899	3	-126.1
34	0	18	-880	3	-159.7
32	0	18	-857	3	-192.1
30	0	18	-831	2	-222
28	0	18	-801	2	-250.2
26	0	18	-770	2	-275
24	0	18	-739	1	-296.6
22	0	18	-705	1	-315.9
20	0	18	-669	1	-332
18	0	18	-634	1	-345
16	0	18	-598	0	-356
14	0	18	-562	0	-365
78	0	20	-479	2	411
76	0	20	-516	3	404
74	0	20	-550	3	398
72	0	20	-584	3	389
70	0	20	-618	3	378
68	0	20	-650	4	364
66	0	20	-682	4	347
64	0	20	-712	4	328
62	0	20	-740	4	306.6
60	0	20	-767	4	281.7
58	0	20	-791	4	254.9
56	0	20	-811	4	226.2
54	0	20	-829	4	195.4
52	0	20	-844	4	163.3

50	0	20	-855	4	129.7
48	0	20	-862	4	95.1
46	0	20	-866	4	60.2
44	0	20	-866	4	24.8
42	0	20	-862	4	-10.9
40	0	20	-855	3	-45.3
38	0	20	-845	2.9	-79.1
36	0	20	-830	2.7	-111.4
34	0	20	-813	2.5	-142.5
32	0	20	-792	2.2	-171.7
30	0	20	-770	2	-199
28	0	20	-744	1.7	-224.5
26	0	20	-716	1.5	-247.3
24	0	20	-688	1.3	-267.7
22	0	20	-658	1.1	-285.5
20	0	20	-627	0.8	-301
18	0	20	-595	0.7	-313.9
16	0	20	-563	0.4	-324.5
14	0	20	-531	0.2	-332
78	0	22	-451	1.9	378
76	0	22	-487	2.1	371
74	0	22	-518	2.4	364
72	0	22	-548	2.8	356
70	0	22	-577	3	345
68	0	22	-608	3.2	332
66	0	22	-635	3.4	316
64	0	22	-662	3.4	298
62	0	22	-687	3.5	278.3
60	0	22	-710	3.6	256.2
58	0	22	-731	3.6	232
56	0	22	-750	3.6	205.8
54	0	22	-766	3.6	178
52	0	22	-779	3.6	149
50	0	22	-789	3.5	118.9
48	0	22	-795	3.5	87.4
46	0	22	-799	3.3	55.8
44	0	22	-799	3.2	24.4
42	0	22	-796	3	-6.6
40	0	22	-790	2.8	-38.2

38	0	22	-781	2.6	-68.1
36	0	22	-767	2.4	-98.8
34	0	22	-753	2.2	-126.7
32	0	22	-735	2	-153.4
30	0	22	-715	1.8	-178.2
28	0	22	-692	1.6	-200.9
26	0	22	-669	1.4	-222.4
24	0	22	-642	1.2	-241.3
22	0	22	-616	0.9	-258.2
20	0	22	-588	0.7	-272.6
18	0	22	-560	0.6	-285.2
16	0	22	-531	0.4	-295.5
14	0	22	-502	0.1	-303.7

Appendix B

Table 6. Calibrated Data: used the matrix for Data N.O. 3 in fitting Method 1.

x/cm	y/cm	z/cm	Bx/T	By/T	Bz/T
33.5654	0.221696	49.5734	0.204343	0.00084121	0.166611
31.5679	0.219891	49.6738	0.207882	0.00108599	0.187057
29.5704	0.218085	49.7742	0.209805	0.00113816	0.208684
27.5729	0.21628	49.8746	0.209913	0.00119824	0.231487
25.5754	0.214475	49.975	0.208019	0.00146407	0.254464
23.578	0.212669	50.0754	0.203724	0.00153617	0.277411
21.5805	0.210864	50.1758	0.197027	0.00161506	0.300527
19.583	0.209059	50.2761	0.188139	0.00169807	0.323014
17.5855	0.207254	50.3765	0.176665	0.00178465	0.344269
15.5881	0.205448	50.4769	0.163005	0.00187429	0.364495
13.5906	0.203643	50.5773	0.146768	0.00196588	0.382889
11.5931	0.201838	50.6777	0.128959	0.00205575	0.399061
9.59563	0.200032	50.7781	0.109584	0.00214281	0.412614
7.59815	0.198227	50.8785	0.0886417	0.00202708	0.423547
5.60067	0.196422	50.9789	0.0667359	0.00210645	0.431667
3.60319	0.194617	51.0793	0.0438713	0.00217985	0.436574
1.60571	0.192811	51.1797	0.0208445	0.00204573	0.438479
-0.391764	0.191006	51.2801	-0.0021833	0.00210367	0.437384
-2.38924	0.189201	51.3805	-0.02511	0.00215288	0.43309
-4.38672	0.187396	51.4809	-0.0474164	0.00199199	0.425603
-6.3842	0.18559	51.5812	-0.0683921	0.00182128	0.415734
-8.38168	0.183785	51.6816	-0.0883114	0.0018404	0.403078
-10.3792	0.18198	51.782	-0.106521	0.00164871	0.388044
-12.3766	0.180174	51.8824	-0.123301	0.00164746	0.370827
-14.3741	0.178369	51.9828	-0.137865	0.00143673	0.352239
-16.3716	0.176564	52.0832	-0.150605	0.00141648	0.331874
-18.3691	0.174759	52.1836	-0.160935	0.00118782	0.310741
-20.3665	0.172953	52.284	-0.169255	0.0011518	0.288832
-22.364	0.171148	52.3844	-0.175373	0.00110951	0.266752
-24.3615	0.169343	52.4848	-0.179291	0.00086149	0.244701
-26.359	0.167537	52.5852	-0.181216	0.00080985	0.223274
-28.3565	0.165732	52.6856	-0.181352	0.00075567	0.202671
-30.3539	0.163927	52.786	-0.179894	0.00069838	0.182488

33.6657	0.237732	51.5708	0.184845	0.00087141	0.15856
31.6683	0.235927	51.6712	0.187411	0.0009129	0.176795
29.6708	0.234121	51.7716	0.188368	0.00116071	0.195808
27.6733	0.232316	51.872	0.187913	0.00141485	0.215803
25.6758	0.230511	51.9724	0.185451	0.00147527	0.236173
23.6783	0.228705	52.0728	0.181195	0.00153933	0.25612
21.6809	0.2269	52.1732	0.174937	0.00160913	0.276241
19.6834	0.225095	52.2736	0.166692	0.00168146	0.295337
17.6859	0.22329	52.374	0.156249	0.001959	0.314204
15.6884	0.221484	52.4743	0.14403	0.00203641	0.331249
13.691	0.219679	52.5747	0.129826	0.00211581	0.347068
11.6935	0.217874	52.6751	0.113846	0.00219509	0.361064
9.696	0.216068	52.7755	0.0968978	0.00207	0.372448
7.69852	0.214263	52.8759	0.0785738	0.00214373	0.382014
5.70104	0.212458	52.9763	0.0592857	0.00221257	0.388767
3.70357	0.210653	53.0767	0.0394259	0.00227707	0.393313
1.70609	0.208847	53.1771	0.0198045	0.00233301	0.394861
-0.291389	0.207042	53.2775	-0.0011266	0.00218601	0.393993
-2.28887	0.205237	53.3779	-0.0212613	0.00222952	0.390335
-4.28634	0.203432	53.4783	-0.0406432	0.00206419	0.384087
-6.28382	0.201626	53.5787	-0.0593565	0.00209128	0.375646
-8.2813	0.199821	53.6791	-0.0768171	0.00190823	0.364622
-10.2788	0.198016	53.7794	-0.0932542	0.00191774	0.35181
-12.2763	0.19621	53.8798	-0.107872	0.00171827	0.337422
-14.2737	0.194405	53.9802	-0.121063	0.00170978	0.321051
-16.2712	0.1926	54.0806	-0.132642	0.00149444	0.303702
-18.2687	0.190795	54.181	-0.142205	0.00147067	0.285178
-20.2662	0.188989	54.2814	-0.149764	0.00124061	0.26628
-22.2636	0.187184	54.3818	-0.15552	0.00120532	0.247205
-24.2611	0.185379	54.4822	-0.159674	0.00116532	0.22795
-26.2586	0.183573	54.5826	-0.16203	0.00092116	0.208919
-28.2561	0.181768	54.683	-0.162597	0.00087445	0.19071
-30.2536	0.179963	54.7834	-0.16217	0.00062621	0.172915
33.7661	0.253768	53.5682	0.167751	0.00089428	0.15014
31.7686	0.251963	53.6686	0.169344	0.00093302	0.166362
29.7712	0.250157	53.769	0.169926	0.0011765	0.18337
27.7737	0.248352	53.8694	0.168901	0.00142577	0.200958
25.7762	0.246547	53.9698	0.166476	0.0014787	0.218528
23.7787	0.244741	54.0702	0.162248	0.00153685	0.236276

21.7812	0.242936	54.1706	0.156423	0.00159864	0.253802
19.7838	0.241131	54.271	0.148809	0.00186297	0.270505
17.7863	0.239326	54.3714	0.139602	0.00192988	0.286589
15.7888	0.23752	54.4718	0.128611	0.00199825	0.301449
13.7913	0.235715	54.5722	0.115832	0.00206865	0.315286
11.7939	0.23391	54.6725	0.101875	0.00213788	0.327508
9.79638	0.232104	54.7729	0.0867427	0.00220488	0.337715
7.7989	0.230299	54.8733	0.0704364	0.00226964	0.345906
5.80142	0.228494	54.9737	0.0535558	0.00233061	0.35209
3.80394	0.226689	55.0741	0.0363055	0.00218619	0.35587
1.80646	0.224883	55.1745	0.018284	0.00223796	0.357439
-0.191014	0.223078	55.2749	0.00035062	0.00228367	0.356809
-2.18849	0.221273	55.3753	-0.0174725	0.00212274	0.353781
-4.18597	0.219468	55.4757	-0.0345269	0.00215398	0.348562
-6.18345	0.217662	55.5761	-0.0510958	0.00217866	0.341349
-8.18093	0.215857	55.6765	-0.0668971	0.00199552	0.331946
-10.1784	0.214052	55.7769	-0.0812574	0.00200438	0.320961
-12.1759	0.212246	55.8773	-0.0944979	0.00180608	0.308391
-14.1734	0.210441	55.9776	-0.10632	0.00180037	0.294438
-16.1708	0.208636	56.078	-0.11693	0.00158886	0.279501
-18.1683	0.206831	56.1784	-0.125729	0.00157051	0.263787
-20.1658	0.205025	56.2788	-0.132919	0.00134584	0.247294
-22.1633	0.20322	56.3792	-0.138503	0.00131593	0.230421
-24.1607	0.201415	56.4796	-0.142685	0.00108183	0.213367
-26.1582	0.199609	56.58	-0.145275	0.00104516	0.196932
-28.1557	0.197804	56.6804	-0.146662	0.00100483	0.180313
-30.1532	0.195999	56.7808	-0.146468	0.00076408	0.165115
33.8665	0.269804	55.5656	0.152048	0.00091564	0.142538
31.869	0.267999	55.666	0.153061	0.00115165	0.157152
29.8715	0.266193	55.7664	0.153069	0.00119135	0.172153
27.8741	0.264388	55.8668	0.151872	0.00143524	0.187539
25.8766	0.262583	55.9672	0.14907	0.00148438	0.203304
23.8791	0.260777	56.0676	0.145073	0.00153558	0.218654
21.8816	0.258972	56.168	0.139478	0.00159041	0.233783
19.8841	0.257167	56.2684	0.132492	0.00184728	0.248294
17.8867	0.255362	56.3688	0.124114	0.0019062	0.262188
15.8892	0.253556	56.4692	0.114145	0.00196715	0.275261
13.8917	0.251751	56.5696	0.102995	0.00202747	0.286919
11.8942	0.249946	56.67	0.0904576	0.00208876	0.297559

9.89675	0.24814	56.7704	0.0771434	0.00214731	0.306389
7.89927	0.246335	56.8707	0.0628498	0.00220418	0.313606
5.90179	0.24453	56.9711	0.0477787	0.00205831	0.319014
3.90432	0.242725	57.0715	0.032337	0.00230759	0.322216
1.90684	0.240919	57.1719	0.0167173	0.00215256	0.323616
-0.09064	0.239114	57.2723	0.00110378	0.00219222	0.323016
-2.08812	0.237309	57.3727	-0.0147046	0.0020271	0.320414
-4.0856	0.235504	57.4731	-0.0298295	0.00205542	0.316019
-6.08307	0.233698	57.5735	-0.0445713	0.00207799	0.30983
-8.08055	0.231893	57.6739	-0.0582107	0.00189291	0.301855
-10.078	0.230088	57.7743	-0.0710917	0.00190214	0.292489
-12.0755	0.228282	57.8747	-0.0831528	0.00170501	0.281534
-14.073	0.226477	57.9751	-0.0940006	0.00170206	0.269594
-16.0705	0.224672	58.0755	-0.103434	0.00149224	0.256472
-18.0679	0.222867	58.1758	-0.111456	0.00147663	0.242568
-20.0654	0.221061	58.2762	-0.118274	0.00125681	0.22828
-22.0629	0.219256	58.3766	-0.123686	0.00123228	0.21361
-24.0604	0.217451	58.477	-0.127499	0.00120357	0.19896
-26.0579	0.215645	58.5774	-0.130312	0.00097225	0.184323
-28.0553	0.21384	58.6778	-0.131927	0.00093834	0.169901
-30.0528	0.212035	58.7782	-0.132345	0.00090183	0.155695
33.9669	0.28584	57.5631	0.138336	0.0009334	0.135562
31.9694	0.284035	57.6635	0.138772	0.00096615	0.148369
29.9719	0.282229	57.7638	0.138198	0.00120365	0.161962
27.9744	0.280424	57.8642	0.136624	0.00124377	0.175543
25.9769	0.278619	57.9646	0.13405	0.00148649	0.18911
23.9795	0.276813	58.065	0.130079	0.00153232	0.20246
21.982	0.275008	58.1654	0.12471	0.00158127	0.215593
19.9845	0.273203	58.2658	0.118347	0.00163175	0.228312
17.987	0.271398	58.3662	0.110589	0.00188482	0.240613
15.9896	0.269592	58.4666	0.101644	0.00193833	0.251899
13.9921	0.267787	58.567	0.0917138	0.00199123	0.261973
11.9946	0.265982	58.6674	0.0805968	0.00204458	0.271031
9.99712	0.264176	58.7678	0.0686953	0.0020968	0.278879
7.99965	0.262371	58.8682	0.0562169	0.00214576	0.284919
6.00217	0.260566	58.9686	0.0429565	0.00219305	0.289549
4.00469	0.258761	59.0689	0.0291192	0.00223708	0.292372
2.00721	0.256955	59.1693	0.0153419	0.00207672	0.293596
0.0097352	0.25515	59.2697	0.0013857	0.00211259	0.293217

-1.98774	0.253345	59.3701	-0.0126875	0.002144	0.291037
-3.98522	0.251539	59.4705	-0.0261207	0.0019695	0.287265
-5.9827	0.249734	59.5709	-0.0390104	0.00198882	0.281699
-7.98018	0.247929	59.6713	-0.0513047	0.00200341	0.274941
-9.97765	0.246124	59.7717	-0.0624418	0.00181128	0.266798
-11.9751	0.244318	59.8721	-0.0734429	0.00181561	0.257456
-13.9726	0.242513	59.9725	-0.0831093	0.00161329	0.246932
-15.9701	0.240708	60.0729	-0.091565	0.00160569	0.235622
-17.9676	0.238903	60.1733	-0.0990137	0.00139387	0.223726
-19.965	0.237097	60.2737	-0.105252	0.00137678	0.211045
-21.9625	0.235292	60.374	-0.11029	0.00115657	0.19838
-23.96	0.233487	60.4744	-0.114321	0.00113213	0.185128
-25.9575	0.231681	60.5748	-0.117156	0.00110564	0.17229
-27.955	0.229876	60.6752	-0.118995	0.00087708	0.159666
-29.9524	0.228071	60.7756	-0.119634	0.00084538	0.147057
34.0672	0.301876	59.5605	0.126022	0.00094804	0.128804
32.0698	0.300071	59.6609	0.126073	0.00097862	0.140405
30.0723	0.298265	59.7613	0.125322	0.00121182	0.152196
28.0748	0.29646	59.8617	0.123566	0.0012487	0.164374
26.0773	0.294655	59.962	0.12061	0.00128871	0.176537
24.0798	0.292849	60.0624	0.11686	0.00152973	0.18829
22.0824	0.291044	60.1628	0.111909	0.00157388	0.200027
20.0849	0.289239	60.2632	0.105968	0.0016185	0.210952
18.0874	0.287434	60.3636	0.099033	0.00166465	0.221464
16.0899	0.285628	60.464	0.090703	0.00171338	0.231558
14.0925	0.283823	60.5644	0.0817884	0.00176046	0.240444
12.095	0.282018	60.6648	0.0718893	0.00180693	0.248118
10.0975	0.280212	60.7652	0.061203	0.0018528	0.254781
8.10002	0.278407	60.8656	0.0499348	0.00189648	0.260037
6.10254	0.276602	60.966	0.0380819	0.00193852	0.264085
4.10507	0.274797	61.0664	0.0261696	0.00197647	0.266533
2.10759	0.272991	61.1668	0.0136753	0.00201223	0.267573
0.11011	0.271186	61.2671	0.00121896	0.00204419	0.267213
-1.88737	0.269381	61.3675	-0.0110374	0.00187139	0.265256
-3.88485	0.267575	61.4679	-0.0230154	0.00189416	0.261902
-5.88232	0.26577	61.5683	-0.034558	0.00191261	0.257354
-7.8798	0.263965	61.6687	-0.0456607	0.00172568	0.251212
-9.87728	0.26216	61.7691	-0.0558727	0.00173431	0.24428
-11.8748	0.260354	61.8695	-0.0653873	0.00153742	0.235958

-13.8722	0.258549	61.9699	-0.0740512	0.00153618	0.226846
-15.8697	0.256744	62.0703	-0.0817254	0.00133025	0.216948
-17.8672	0.254939	62.1707	-0.0885916	0.00132063	0.206459
-19.8647	0.253133	62.2711	-0.0942527	0.0013068	0.195585
-21.8621	0.251328	62.3715	-0.0991067	0.00108927	0.184123
-23.8596	0.249523	62.4719	-0.102963	0.00106968	0.172872
-25.8571	0.247717	62.5722	-0.105617	0.00084642	0.161438
-27.8546	0.245912	62.6726	-0.107471	0.00082107	0.150013
-29.8521	0.244107	62.773	-0.108527	0.00079418	0.138799
34.1676	0.317912	61.5579	0.11471	0.00095954	0.121858
32.1701	0.316107	61.6583	0.114574	0.00098796	0.132457
30.1727	0.314301	61.7587	0.113441	0.00101845	0.142843
28.1752	0.312496	61.8591	0.111702	0.00105158	0.153622
26.1777	0.310691	61.9595	0.108967	0.00128677	0.164187
24.1802	0.308885	62.0599	0.105232	0.00132458	0.17474
22.1827	0.30708	62.1602	0.100701	0.0013634	0.184883
20.1853	0.305275	62.2606	0.0951763	0.00140376	0.194613
18.1878	0.30347	62.361	0.0886543	0.00164618	0.204129
16.1903	0.301664	62.4614	0.0813473	0.00168748	0.212436
14.1928	0.299859	62.5618	0.073248	0.00172925	0.220133
12.1954	0.298054	62.6622	0.0643591	0.00177097	0.22702
10.1979	0.296248	62.7626	0.054683	0.00181209	0.232896
8.2004	0.294443	62.863	0.0447423	0.00185072	0.237569
6.20292	0.292638	62.9634	0.0343371	0.00188739	0.241036
4.20544	0.290833	63.0638	0.0233667	0.00172236	0.243296
2.20796	0.289027	63.1642	0.0141398	0.00174801	0.243777
0.210485	0.287222	63.2646	0.0013609	0.00178134	0.243614
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-7.77943	0.280001	63.6661	-0.0402894	0.00165554	0.230079
-9.7769	0.278196	63.7665	-0.0495697	0.00146333	0.22376
-11.7744	0.27639	63.8669	-0.0579193	0.00146658	0.216652
-13.7719	0.274585	63.9673	-0.0658191	0.00126653	0.208751
-15.7693	0.27278	64.0677	-0.0729083	0.00126225	0.200059
-17.7668	0.270975	64.1681	-0.0791899	0.00125427	0.190778
-19.7643	0.269169	64.2685	-0.0844669	0.00104262	0.18111
-21.7618	0.267364	64.3689	-0.0889409	0.00102834	0.171252
-23.7593	0.265559	64.4693	-0.0924124	0.00101092	0.161207

-25.7567	0.263753	64.5697	-0.095284	0.00099194	0.151169
-27.7542	0.261948	64.6701	-0.0973562	0.00077087	0.141142
-29.7517	0.260143	64.7704	-0.0984279	0.00074719	0.131128
34.268	0.333948	63.5553	0.104795	0.00076793	0.115131
32.2705	0.332143	63.6557	0.104274	0.00079417	0.124525
30.273	0.330337	63.7561	0.103154	0.00102198	0.133911
28.2756	0.328532	63.8565	0.101234	0.00105187	0.143287
26.2781	0.326727	63.9569	0.0985118	0.00128439	0.152852
24.2806	0.324921	64.0573	0.0951941	0.0013174	0.16201
22.2831	0.323116	64.1577	0.0908766	0.00135302	0.171156
20.2856	0.321311	64.2581	0.0857668	0.00138911	0.179691
18.2882	0.319506	64.3584	0.0798622	0.00142622	0.187816
16.2907	0.3177	64.4588	0.0733653	0.00146329	0.195333
14.2932	0.315895	64.5592	0.0660788	0.00150029	0.20204
12.2957	0.31409	64.6596	0.058	0.00153778	0.208137
10.2982	0.312284	64.76	0.0495341	0.00157363	0.213229
8.30077	0.310479	64.8604	0.0404785	0.00160889	0.217513
6.30329	0.308674	64.9608	0.0310408	0.00164145	0.220392
4.30582	0.306869	65.0612	0.0215135	0.00167212	0.22247
2.30834	0.305063	65.1616	0.0118615	0.00169994	0.223347
0.310859	0.303258	65.262	0.00204488	0.00172501	0.223021
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-5.68157	0.297842	65.5632	-0.0263661	0.00158111	0.215856
-7.67905	0.296037	65.6635	-0.0353094	0.00139278	0.211342
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-15.669	0.288816	66.0651	-0.0650167	0.00120195	0.185159
-17.6664	0.287011	66.1655	-0.0700189	0.00119488	0.177495
-19.6639	0.285205	66.2659	-0.0757061	0.00098641	0.168622
-21.6614	0.2834	66.3663	-0.0797956	0.00097431	0.159968
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34.3684	0.349984	65.5527	0.0958672	0.00077638	0.109416
32.3709	0.348179	65.6531	0.0951622	0.00079993	0.117608
30.3734	0.346373	65.7535	0.0938546	0.00082558	0.125991

28.3759	0.344568	65.8539	0.0919476	0.00105279	0.134367
26.3784	0.342763	65.9543	0.0894402	0.00108157	0.142736
24.381	0.340957	66.0547	0.0861328	0.00111244	0.151094
22.3835	0.339152	66.1551	0.0820306	0.00114432	0.159042
20.386	0.337347	66.2555	0.0773341	0.00137669	0.166582
18.3885	0.335542	66.3559	0.0720449	0.00140901	0.173514
16.3911	0.333736	66.4563	0.0661582	0.00144237	0.180239
14.3936	0.331931	66.5566	0.0594819	0.00147567	0.186154
12.3961	0.330126	66.657	0.0522133	0.00150892	0.191462
10.3986	0.32832	66.7574	0.044555	0.00154107	0.195964
8.40115	0.326515	66.8578	0.036507	0.00157212	0.199661
6.40367	0.32471	66.9582	0.0282318	0.00160112	0.202355
4.40619	0.322905	67.0586	0.0195489	0.00142853	0.204044
2.40871	0.321099	67.159	0.0108194	0.00145341	0.204732
0.411234	0.319294	67.2594	0.00212018	0.0014761	0.204621
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-19.5635	0.301241	68.2633	-0.0679556	0.00093496	0.15692
-21.561	0.299436	68.3637	-0.0720552	0.000925	0.149067
-23.5585	0.297631	68.4641	-0.075355	0.00091296	0.141224
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-27.5535	0.29402	68.6649	-0.07995	0.00068258	0.125164
-29.5509	0.292215	68.7653	-0.0814474	0.0006653	0.117144
34.4687	0.36602	67.5501	0.0877494	0.00058061	0.102912
32.4713	0.364215	67.6505	0.087052	0.00060255	0.110504
30.4738	0.362409	67.7509	0.0857578	0.00082552	0.117887
28.4763	0.360604	67.8513	0.083858	0.00085112	0.125663
26.4788	0.358799	67.9517	0.0813634	0.00087722	0.133032
24.4813	0.356993	68.0521	0.0782693	0.00110488	0.140392
22.4839	0.355188	68.1525	0.0745774	0.00113357	0.147545
20.4864	0.353383	68.2529	0.0704931	0.0011617	0.154094
18.4889	0.351578	68.3533	0.0656115	0.00119138	0.160431

16.4914	0.349772	68.4537	0.0601551	0.00122149	0.166362
14.494	0.347967	68.5541	0.0542664	0.00125115	0.171687
12.4965	0.346162	68.6545	0.0478054	0.0012807	0.176404
10.499	0.344356	68.7548	0.0409147	0.00130927	0.180316
8.50152	0.342551	68.8552	0.0337118	0.00133705	0.183624
6.50404	0.340746	68.9556	0.0262816	0.00136279	0.185929
4.50656	0.338941	69.056	0.0184592	0.00138795	0.187629
2.50909	0.337135	69.1564	0.0105897	0.00141059	0.188328
0.511609	0.33533	69.2568	0.00293031	0.00143057	0.18823
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-5.48082	0.329914	69.558	-0.0203041	0.00127793	0.182932
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-17.4657	0.319082	70.1603	-0.0569073	0.00109608	0.153261
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-21.4606	0.315472	70.3611	-0.0649205	0.00088257	0.140158
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-27.4531	0.310056	70.6623	-0.0726661	0.00064611	0.118657
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34.5691	0.382056	69.5476	0.0810269	0.00058226	0.0968252
32.5716	0.380251	69.6479	0.0795327	0.00080575	0.104206
30.5742	0.378445	69.7483	0.0782456	0.00082711	0.11099
28.5767	0.37664	69.8487	0.0763586	0.00085003	0.117766
26.5792	0.374835	69.9491	0.0740717	0.000874	0.124538
24.5817	0.373029	70.0495	0.0711904	0.00109846	0.130901
22.5842	0.371224	70.1499	0.0677087	0.00112448	0.137257
20.5868	0.369419	70.2503	0.0638321	0.00115048	0.143207
18.5893	0.367614	70.3507	0.0594807	0.00117665	0.148752
16.5918	0.365808	70.4511	0.0544319	0.00120412	0.154088
14.5943	0.364003	70.5515	0.0490109	0.00123096	0.158818
12.5969	0.362198	70.6519	0.0432201	0.00125666	0.162744
10.5994	0.360392	70.7523	0.0370145	0.00128237	0.166265
8.6019	0.358587	70.8527	0.0305566	0.00130716	0.169183
6.60442	0.356782	70.953	0.023809	0.00133058	0.171296

4.60694	0.354977	71.0534	0.0168716	0.00135238	0.172607
2.60946	0.353171	71.1538	0.00988197	0.00137273	0.173318
0.611984	0.351366	71.2542	0.00280258	0.00139119	0.173227
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-15.3678	0.336924	72.0574	-0.0467417	0.0009958	0.148191
-17.3653	0.335118	72.1578	-0.0512296	0.00095268	0.142533
-19.3628	0.333313	72.2581	-0.0552376	0.00090831	0.136881
-21.3603	0.331508	72.3585	-0.0587205	0.00086151	0.130836
-23.3578	0.329703	72.4589	-0.0617409	0.00079297	0.124597
-25.3552	0.327897	72.5593	-0.0642387	0.00076254	0.118165
-27.3527	0.326092	72.6597	-0.0662767	0.00069091	0.111738
-29.3502	0.324287	72.7601	-0.0676946	0.00063767	0.10532
34.6695	0.398092	71.545	0.0744991	0.00056446	0.0911411
32.672	0.396287	71.6454	0.0730071	0.00062741	0.0983224
30.6745	0.394481	71.7458	0.0715279	0.00070768	0.104504
28.677	0.392676	71.8461	0.0698514	0.00080794	0.110483
26.6796	0.390871	71.9465	0.0675773	0.00086923	0.116254
24.6821	0.389065	72.0469	0.0648982	0.00093263	0.12242
22.6846	0.38726	72.1473	0.0616294	0.00099545	0.127778
20.6871	0.385455	72.2477	0.0579605	0.00101932	0.133132
18.6897	0.38365	72.3481	0.0539568	0.001063	0.13808
16.6922	0.381844	72.4485	0.0494783	0.00110686	0.142623
14.6947	0.380039	72.5489	0.0445848	0.00113074	0.146761
12.6972	0.378234	72.6493	0.0392966	0.00115459	0.150493
10.6997	0.376428	72.7497	0.0336961	0.00117767	0.153622
8.70227	0.374623	72.8501	0.0278632	0.00119976	0.156147
6.70479	0.372818	72.9505	0.0218181	0.00120083	0.15807
4.70731	0.371013	73.0509	0.0155032	0.00122047	0.159189
2.70984	0.369207	73.1512	0.00917341	0.0011991	0.159908
0.712359	0.367402	73.2516	0.0028939	0.00119548	0.159828
-1.28512	0.365597	73.352	-0.003298	0.00117004	0.159148
-3.2826	0.363791	73.4524	-0.0096022	0.0011433	0.157867
-5.28008	0.361986	73.5528	-0.0155587	0.00111407	0.155991

-7.27755	0.360181	73.6532	-0.0216624	0.00108258	0.153113
-9.27503	0.358376	73.7536	-0.0272061	0.00104962	0.150241
-11.2725	0.35657	73.854	-0.0324996	0.0010139	0.146573
-13.27	0.354765	73.9544	-0.0374081	0.00097611	0.14251
-15.2675	0.35296	74.0548	-0.0418888	0.00093561	0.137852
-17.2649	0.351154	74.1552	-0.0461296	0.0008945	0.133198
-19.2624	0.349349	74.2556	-0.0498402	0.00084988	0.12775
-21.2599	0.347544	74.356	-0.0531534	0.00078475	0.122507
-23.2574	0.345739	74.4563	-0.0559615	0.00073725	0.116871
-25.2549	0.343933	74.5567	-0.0584096	0.00070881	0.111239
-27.2523	0.342128	74.6571	-0.0603952	0.00065863	0.105413
-29.2498	0.340323	74.7575	-0.0619609	0.00058736	0.0995929

Appendix C

Table 7. Survey Points Data.

Survey point	z/mm	x/mm	y/mm
M_POINT_TX45Z22R	755.8526	25.7673	4.0574
M_POINT_TX45Z22L	752.708	30.1726	4.2191
M_POINT_TX45Z22C	728.4528	29.2061	4.9334
M_CIRCLE_TX14Z22R	905.0754	-274.9607	-125.5332
M_CIRCLE_TX78Z22L	894.0685	365.9864	-122.7858
M_CIRCLE_TX45Z00U	684.0247	33.2987	-124.4857
M_CIRCLE_TX45Z22D	904.5429	41.7796	-124.1416