B2 Tunnel Magnetic Field

Thomas Zuiderveen

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Introduction

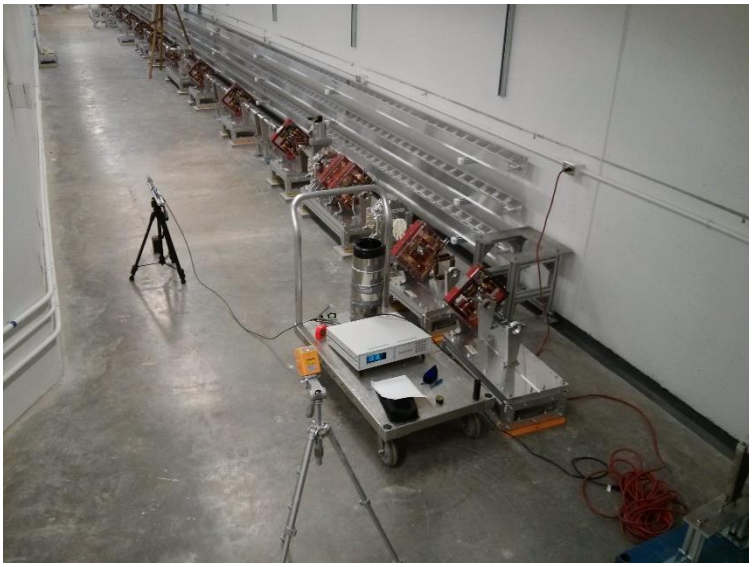
The B2 tunnel connects the Cyclotron and E-Hall to the Ariel Target Hall. It is three stories below ground at the same height as the cyclotron. Because of this, it makes the perfect location to test the magnetic far field strength over a distance. This gives enough room for a good data set for finding a model to use elsewhere. Furthermore, the amount the concrete's rebar has become magnetized can be observed. A measurement set was taken with the main magnets on and then after the main magnet was turn on. Also, the doghouse was measured with the main magnet on.

Methodology

A zeroing device was constructed of layering copper, high permeability metal, and electrical tape as seen in Figure 1. This creates a high magnetic permeability shielding and allows the probe to be tarred. Rotating this device resulted in a peak of 0.04 Gauss magnitude. To reduce this error, the device was inserted in the same orientation every time.

For the measurements, the probe was maintained at 61cm from ground level, although the electron beamline is 50 cm. To have a clear path and be free from any magnetic interference from the beamlines metal, the measurements were taken 1.5m towards the cyclotron, down the middle of the hallway. Tarring took place every 2m or whenever the error exceeded 0.02 Gauss. To ensure accuracy, two lasers where set up, one plumb laser shoot up and down to align the probe with a spot on the ground and a second line laser to maintain the probe along the Z axis. A level was used to align the probe with the X and Y axes. Figure 4 shows which directions the axes are in.

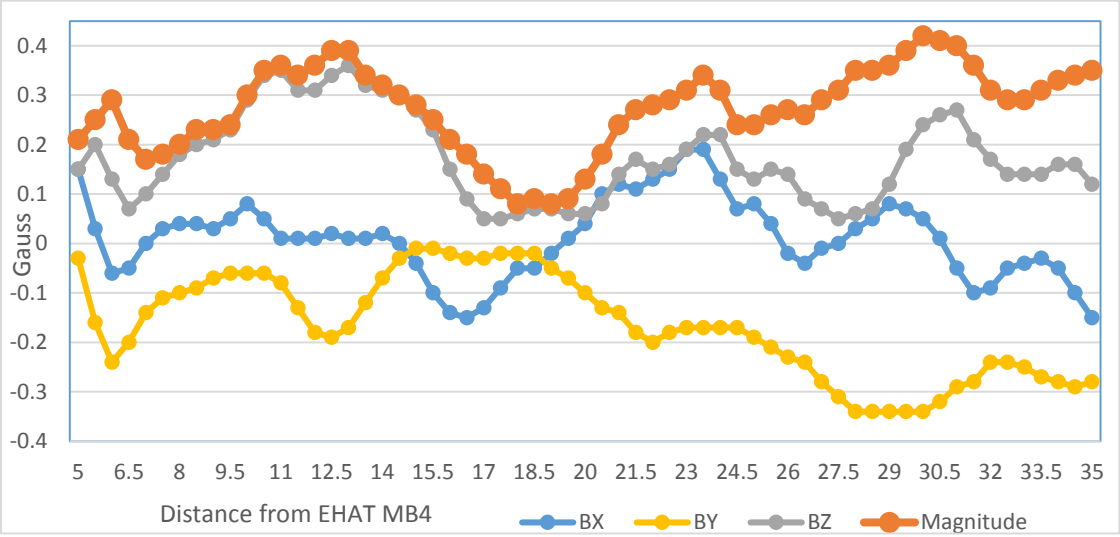
Figure 1: Tarring device being constructed and measurement setup



B2 Tunnel - Main Magnet Off

The first data set is down the B2 tunnel with the main magnet off. Although Figure 2 seems to show a large variance, there is only a small difference in the field of 0.3 Gauss.

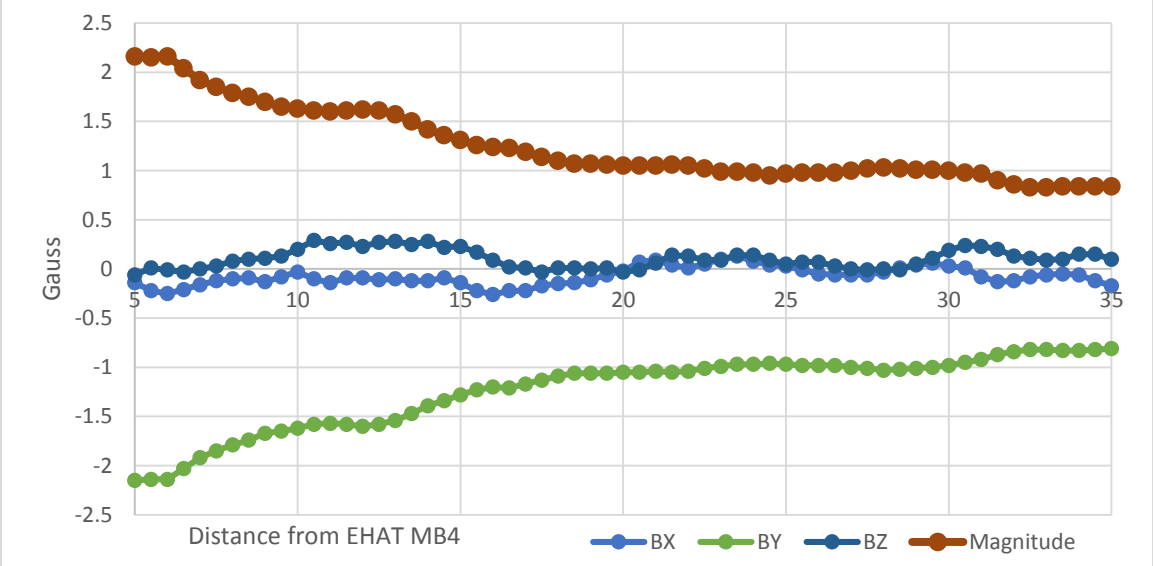
Figure 2: B2 Tunnel - Main Magnet Off graph



B2 Tunnel - Main Magnet On

When the main magnet was turned on the same measurements were taken in the identical way to provide an accurate comparison. Thus the changes caused by the cyclotron can be seen and the effects on the surrounding concrete. Most of the noise from when the magnet was off has now been overpowered by the magnitude of magnetic field. The majority of the field is in the vertical direction as it is at the same level as the cyclotron.

Figure 3: B2 Tunnel - Main Magnet On Graph



Calculations

Far-field strength of a dipole magnetic field is

$$B = \frac{\mu_0 * I * A}{4\pi x^3}\sqrt{1 + 3\sin^2\lambda}$$

μ_0 is the permeability of free space = $(4\pi)10^{-7}$

I is coil current = 500000 Amp turns

A is coil area = π(9m)^2

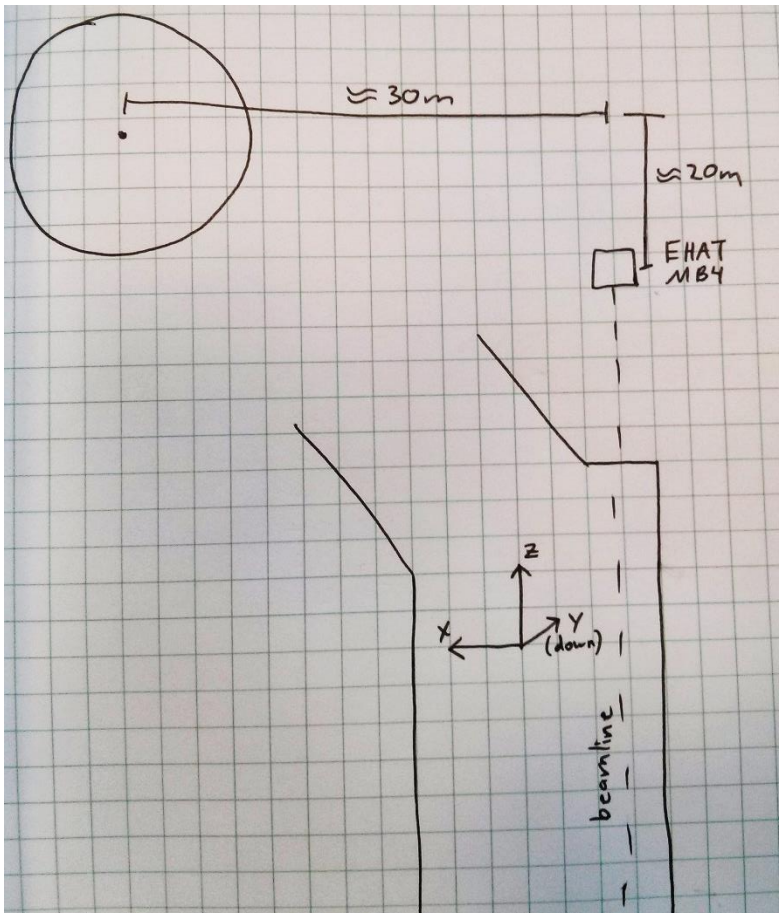
λ is the magnetic latitude = 0

$$B = \frac{4\pi * 10^{-7} * 500000\ Amp\ turns * \pi\ (9m)^2}{4\pi x^3}$$

$$B = \frac{12.7}{x^3} Tesla\ m^3$$

$$x = \sqrt{(z+a)^2 + b^2}$$

Figure 4: Layout of the measurements and cyclotron



a is approximately 20m

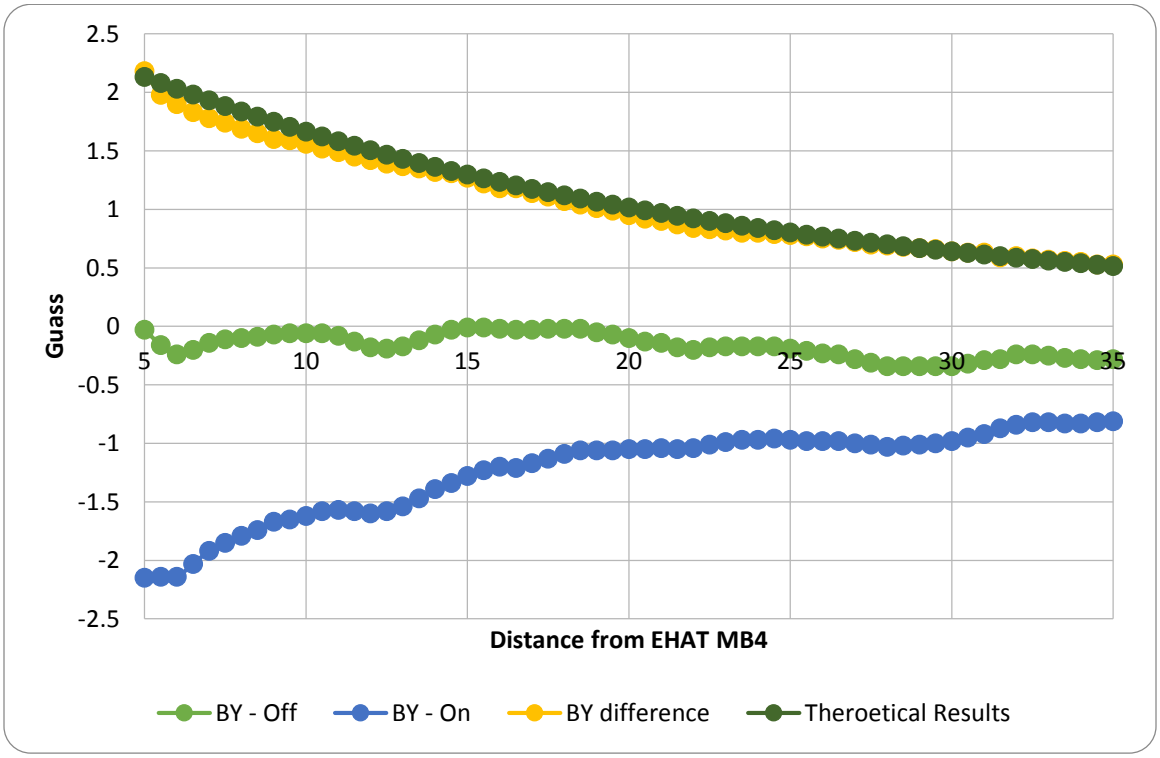
b is approximately 30m

z is distance from EHAT MB4

$$B = \frac{12.7 * 10000}{\sqrt{(z+20)^2 + 30^2}}\ Gauss$$

The difference in the y-axis can now be plotted with the theoretical far field strength. Figure 5 shows that there is very little magnetization of the rebar as the yellow line is smooth and it fits the theoretical results of a $1/R^3$ magnetic propagation.

Figure 5: Compare theoretical with difference graph



Doghouse

A slightly different setup was used for this data set. The measurements were now taken on the beamline path, although still at 61cm from the ground. Because of the higher speculated noise, data was collected every 0.25m rather than 0.5m. The distance from EHAT MB4 was estimated and should only be used as a reference. Z-axis points down the beamline toward the E-Hall, Y-axis points down. X-axis point left. The cored section is from 3.3m to 4.75m. The x and z axis shift at 2.95m to follow the beamline path. Magnitude and the y axis remain the same.

Figure 6: Diagram of beamline path

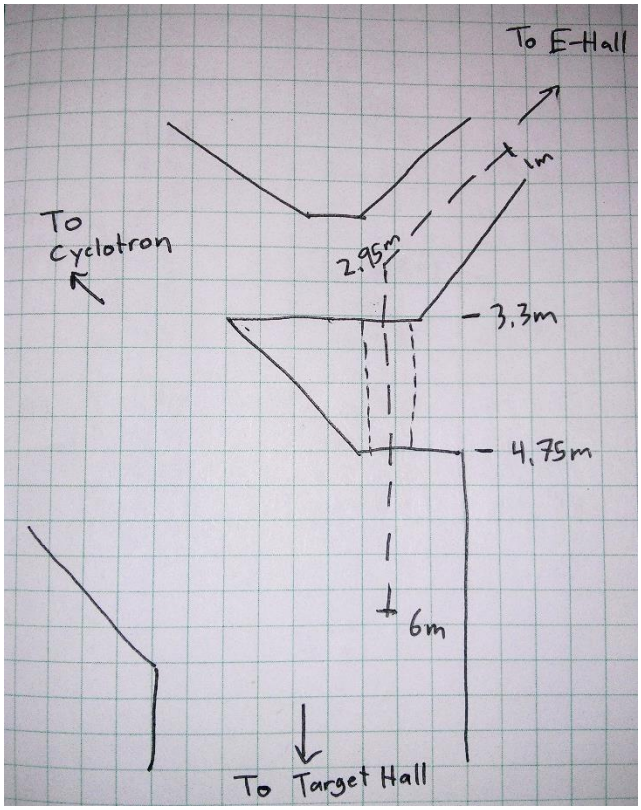
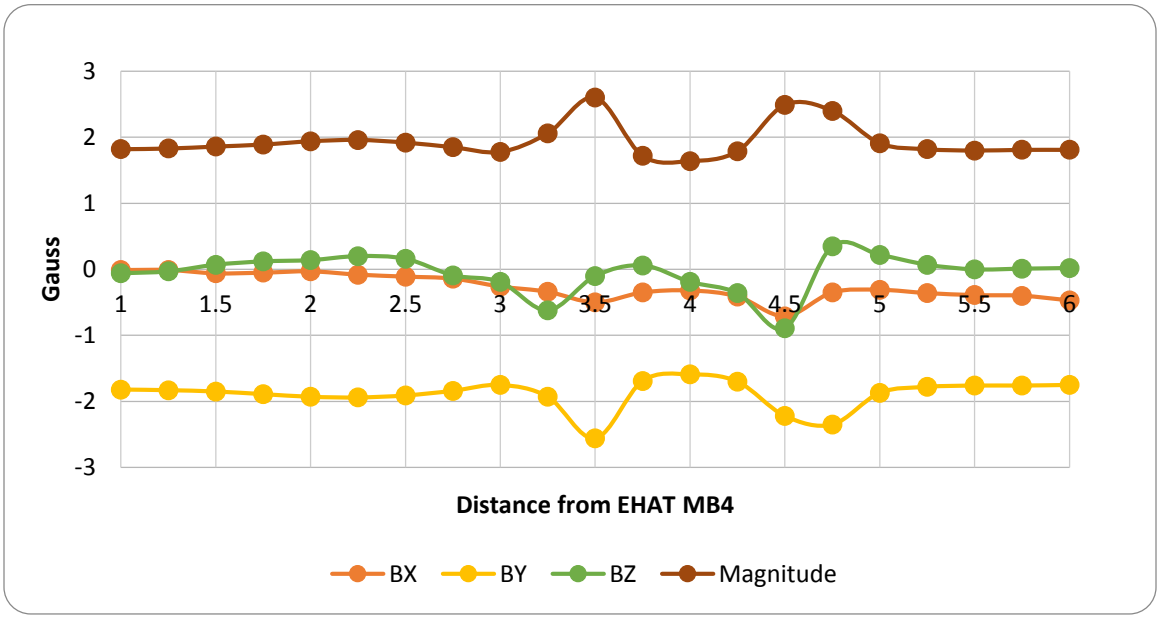


Figure 7: Doghouse Magnetism Graph



As can be seen in Figure 7, the magnetic field as stable except in the cored section, 3.3m to 4.75m. This can be mitigated by putting high permeability shielding around the concrete in the cored section.

Appendix

Table 1: B2 Tunnel magnetic field data

	Main Magnet OFF				Main Magnet ON			
Distance (m)	BX	BY	BZ	Mag	BX	BY	BZ	Mag
5	0.15	-0.03	0.15	0.21	-0.14	-2.15	-0.06	2.16
5.5	0.03	-0.16	0.2	0.25	-0.22	-2.14	0.01	2.15
6	-0.06	-0.24	0.13	0.29	-0.25	-2.14	-0.01	2.16
6.5	-0.05	-0.2	0.07	0.21	-0.21	-2.03	-0.03	2.04
7	0	-0.14	0.1	0.17	-0.16	-1.92	0	1.92
7.5	0.03	-0.11	0.14	0.18	-0.12	-1.85	0.03	1.85
8	0.04	-0.1	0.18	0.2	-0.1	-1.79	0.08	1.79
8.5	0.04	-0.09	0.2	0.23	-0.09	-1.74	0.1	1.75
9	0.03	-0.07	0.21	0.23	-0.13	-1.67	0.11	1.7
9.5	0.05	-0.06	0.23	0.24	-0.08	-1.65	0.13	1.65
10	0.08	-0.06	0.29	0.3	-0.03	-1.62	0.2	1.63
10.5	0.05	-0.06	0.34	0.35	-0.1	-1.58	0.29	1.61
11	0.01	-0.08	0.35	0.36	-0.14	-1.57	0.26	1.6
11.5	0.01	-0.13	0.31	0.34	-0.09	-1.58	0.27	1.61
12	0.01	-0.18	0.31	0.36	-0.09	-1.6	0.23	1.62
12.5	0.02	-0.19	0.34	0.39	-0.11	-1.58	0.27	1.61
13	0.01	-0.17	0.36	0.39	-0.1	-1.54	0.28	1.57
13.5	0.01	-0.12	0.32	0.34	-0.12	-1.47	0.25	1.5
14	0.02	-0.07	0.31	0.32	-0.12	-1.39	0.28	1.42
14.5	0	-0.03	0.3	0.3	-0.09	-1.34	0.22	1.36
15	-0.04	-0.01	0.27	0.28	-0.14	-1.28	0.23	1.31
15.5	-0.1	-0.01	0.23	0.25	-0.22	-1.23	0.17	1.26
16	-0.14	-0.02	0.15	0.21	-0.26	-1.2	0.09	1.24
16.5	-0.15	-0.03	0.09	0.18	-0.22	-1.21	0.02	1.23
17	-0.13	-0.03	0.05	0.14	-0.22	-1.17	0.01	1.19
17.5	-0.09	-0.02	0.05	0.11	-0.17	-1.13	-0.03	1.14
18	-0.05	-0.02	0.06	0.08	-0.15	-1.09	0.01	1.1
18.5	-0.05	-0.02	0.07	0.09	-0.14	-1.06	0.01	1.07
19	-0.02	-0.05	0.07	0.08	-0.11	-1.06	0	1.07
19.5	0.01	-0.07	0.06	0.09	-0.06	-1.06	0.01	1.06
20	0.04	-0.1	0.06	0.13	-0.02	-1.05	-0.03	1.05
20.5	0.1	-0.13	0.08	0.18	0.07	-1.05	-0.01	1.05
21	0.12	-0.14	0.14	0.24	0.09	-1.04	0.06	1.05
21.5	0.11	-0.18	0.17	0.27	0.04	-1.05	0.14	1.06

22	0.13	-0.2	0.15	0.28	0.01	-1.04	0.13	1.05
22.5	0.15	-0.18	0.16	0.29	0.05	-1.01	0.09	1.02
23	0.19	-0.17	0.19	0.31	0.1	-0.99	0.09	0.99
23.5	0.19	-0.17	0.22	0.34	0.13	-0.97	0.14	0.99
24	0.13	-0.17	0.22	0.31	0.08	-0.97	0.14	0.98
24.5	0.07	-0.17	0.15	0.24	0.04	-0.96	0.09	0.95
25	0.08	-0.19	0.13	0.24	0.03	-0.97	0.05	0.97
25.5	0.04	-0.21	0.15	0.26	-0.01	-0.98	0.07	0.98
26	-0.02	-0.23	0.14	0.27	-0.05	-0.98	0.07	0.98
26.5	-0.04	-0.24	0.09	0.26	-0.06	-0.98	0.03	0.98
27	-0.01	-0.28	0.07	0.29	-0.06	-1	0	1
27.5	0	-0.31	0.05	0.31	-0.06	-1.01	-0.01	1.02
28	0.03	-0.34	0.06	0.35	-0.03	-1.03	0	1.03
28.5	0.05	-0.34	0.07	0.35	0.01	-1.02	-0.01	1.02
29	0.08	-0.34	0.12	0.36	0.04	-1.01	0.05	1.01
29.5	0.07	-0.34	0.19	0.39	0.06	-1	0.11	1.01
30	0.05	-0.34	0.24	0.42	0.03	-0.98	0.19	1
30.5	0.01	-0.32	0.26	0.41	0.01	-0.95	0.24	0.98
31	-0.05	-0.29	0.27	0.4	-0.08	-0.92	0.23	0.97
31.5	-0.1	-0.28	0.21	0.36	-0.13	-0.87	0.2	0.9
32	-0.09	-0.24	0.17	0.31	-0.12	-0.84	0.13	0.86
32.5	-0.05	-0.24	0.14	0.29	-0.08	-0.82	0.11	0.83
33	-0.04	-0.25	0.14	0.29	-0.06	-0.82	0.09	0.83
33.5	-0.03	-0.27	0.14	0.31	-0.05	-0.83	0.1	0.84
34	-0.05	-0.28	0.16	0.33	-0.06	-0.83	0.15	0.84
34.5	-0.1	-0.29	0.16	0.34	-0.12	-0.82	0.15	0.84
35	-0.15	-0.28	0.12	0.35	-0.17	-0.81	0.1	0.84

Table 2: Doghouse magnetic field data

Distance	BX	BY	BZ	Magnitude
1	-0.01	-1.82	-0.06	1.82
1.25	-0.01	-1.83	-0.03	1.83
1.5	-0.06	-1.85	0.07	1.86
1.75	-0.05	-1.89	0.12	1.89
2	-0.03	-1.93	0.14	1.94
2.25	-0.08	-1.94	0.2	1.96
2.5	-0.11	-1.91	0.16	1.92
2.75 Axis Shift	-0.14	-1.84	-0.09	1.85
3	-0.26	-1.75	-0.19	1.78
3.25	-0.34	-1.93	-0.62	2.06
3.5	-0.5	-2.56	-0.1	2.6
3.75	-0.35	-1.69	0.06	1.72
4	-0.32	-1.59	-0.19	1.64
4.25	-0.41	-1.7	-0.36	1.79
4.5	-0.71	-2.22	-0.89	2.49
4.75	-0.35	-2.35	0.35	2.4
5	-0.31	-1.87	0.22	1.91
5.25	-0.36	-1.78	0.07	1.82
5.5	-0.39	-1.76	0	1.8
5.75	-0.4	-1.76	0.01	1.81
6	-0.47	-1.75	0.02	1.81