

Summary of the Effects of the Magnet Support Steel on a BMA Magnet

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Summary

This test demonstrated that the presence of the magnet support structure moved the center of the quadrupole field by less than 0.1mm.

Background

The Booster Multipole Magnet project¹ is part of the overall Proton Plan. The motivation for this test was to address a concern that the steel around the magnet, particularly from the support structure and the girder from which the magnet hangs, would cause enough of a shift in the quadrupole center that the alignment would adversely affected. The magnets are aligned to the center of the quadrupole field which is measured by a single stretched wire (SSW) system.

Test Method

The basis of our test was repeating SSW measurements on the same magnet, while altering the environment by moving steel in and out of the area immediately next to the magnet. In order to do this the SSW script needed to be modified to eliminate the iterative feedback normally present in the production measurement methodology.

The plan was to perform the SSW tests in three “steps”:

1. First without any steel near the magnet,
2. Second with the steel in as close to the as-installed position as possible,
3. Without any steel near the magnet.

The goal of the third step was to see if the measured center went back to its original location.

Test Configuration

In order to closely replicate the as-installed environment, we borrowed the prototype support structure (AD assemblies MD-394523 and MD-394537). We did not want to move the SSW stages, and there was not enough room under the magnet to allow us to fit the support structure in its as-installed position. Since we were interested only in the magnitude of the effect, we chose to put the support structure on its side adjacent to the magnet. We used steel bar stock 1” x ¾” to simulate the end of the girder. The support structure was placed in a position that matched closely the sketches provided by AD. See figures 1 – 4 for visuals.

¹ <http://fnalpubs.fnal.gov/archive/2005/conf/fermilab-conf-05-164-ad-td.pdf>

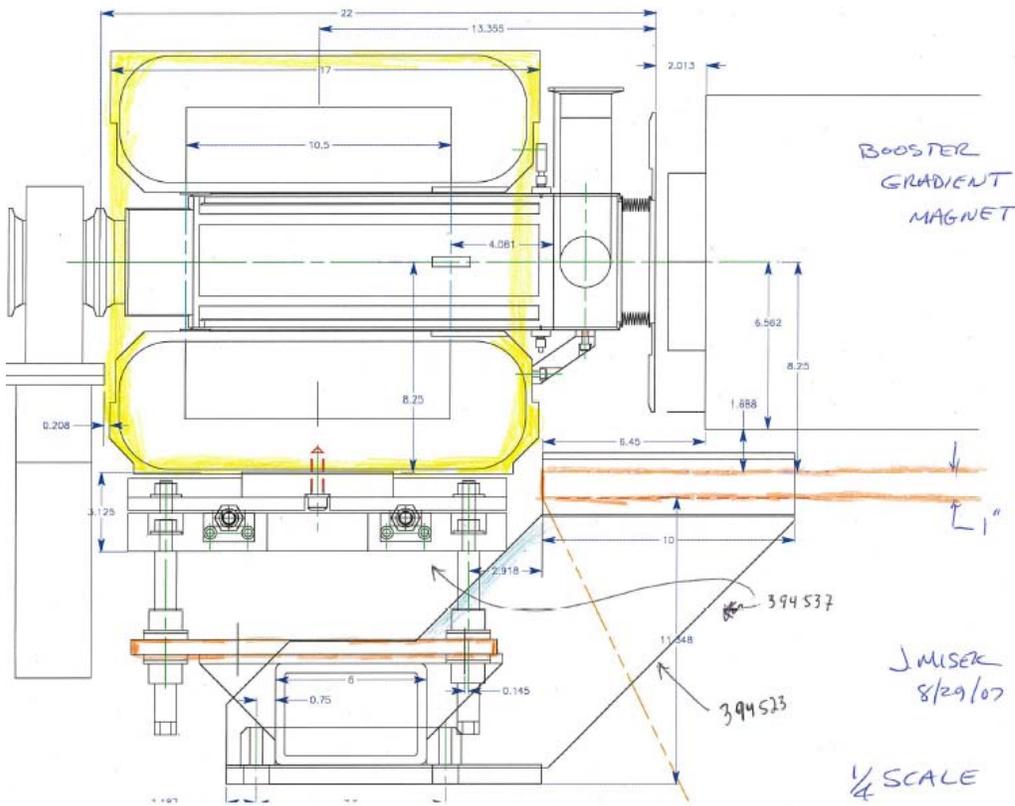


Figure 1 – Sketch of installed BMA magnet



Figure 2 – Test Setup



Figure 3 – Test Setup



Figure 4 – Test Setup

Test Results

Table 1 shows the data and descriptions of the environment for each measurement. Figure 5 is a plot of the results. Since the flux would be pulled towards the side of the magnet in our test configuration, we would expect to see a shift in the x plane. In comparing the appropriate sections, we see that the shift in the x plane is less than 0.1mm.

First comparison (blue lines):

Points 1 – 5 (no steel) with points 6 – 10 (steel present) is ~ 0.09mm

Second comparison (purple lines):

Points 11 – 20 (steel present) with points 21 – 29 (no steel) is ~ 0.06mm.

The large shift between points 10 and 11 is very apparent. It is possible that the unknown cause of this also resulted in the shift in average between points 8 – 10 and points 12 – 20. As a result, at least in part, the magnetic center at the end of the test was not the same as it was at the start of the test. It's possible that the power cycling of the motor contributed to this. Also, the measurement errors greatly decreased after we changed the voltage mode switch to the "off" position at point 15.

One interesting outcome from this test is the visible drift in the y coordinate. Since we are interested in the x plane, the drift in y is not a concern for this steel test. However, it did raise a question over the main use of the SSW system, which is for establishing the quadrupole center for purposes of alignment in the tunnel. It is believed that the drift is a consequence of cycling the power off on the motors. Extra counts are sent and the positioning gets shifted (measurements indicate this shift is ~ 3 microns for each y coordinate measurement). The standard alignment test does not repeatedly cycle the motor this many times, so it is believed that this is not a concern for the regular alignment measurements.

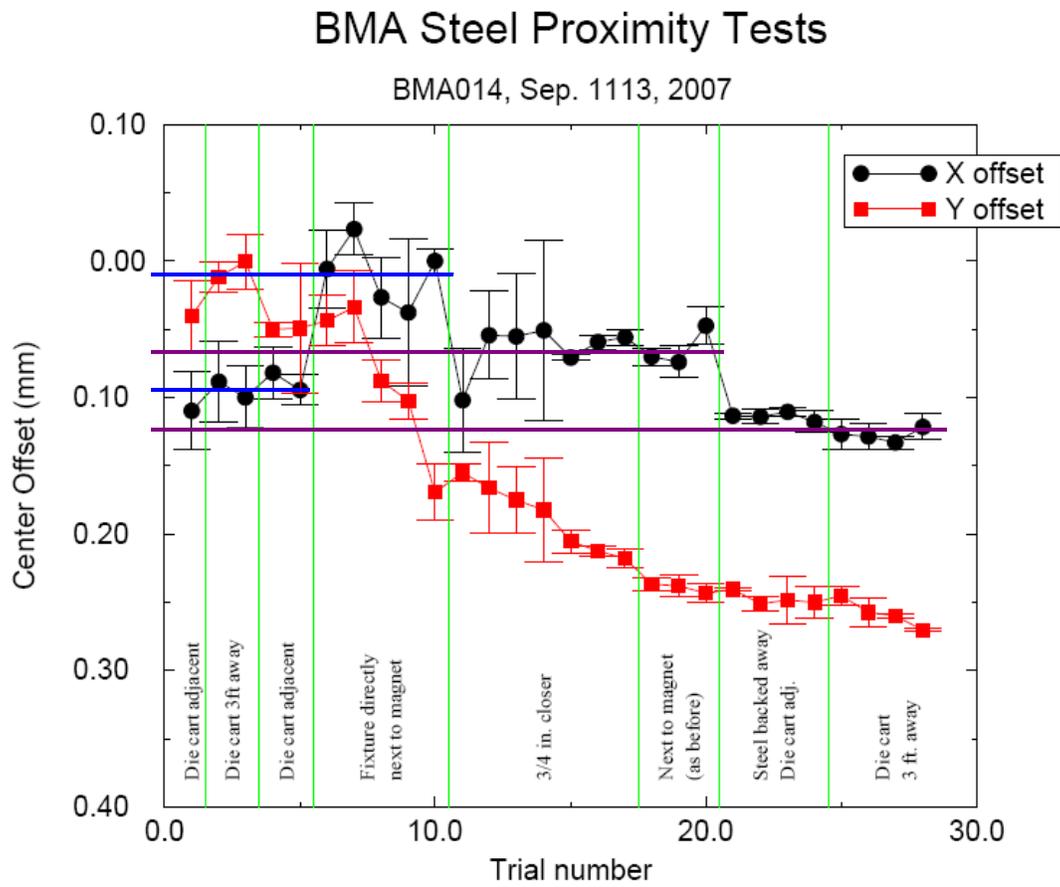


Figure 5 – Plot of Quadrupole Field Center with Error Bars

Number	Date	Time	X (mm)	Y (mm)	Comment
1	9/11/2007	9:30am	-0.1097	-0.0402	Die cart adjacent to granite table; fixture on cart.
2	9/11/2007	10:30am	-0.0885	-0.0117	Die cart 3 feet away from granite table; fixture on cart.
3	9/11/2007	12:00pm	-0.0998	-0.0004	Die cart 3 feet away from granite table; fixture on cart.
4	9/11/2007	12:30pm	-0.0819	-0.0501	Die cart adjacent to granite table; fixture on cart.
5	9/11/2007	1:05pm	-0.0945	-0.0493	Die cart adjacent to granite table; fixture on cart.
6	9/11/2007	1:30pm	-0.0059	-0.0438	Fixture placed directly next to magnet (pics taken).
7	9/11/2007	3:00pm	0.0234	-0.0337	Fixture placed directly next to magnet.
8	9/11/2007	4:40pm	-0.0267	-0.088	Fixture placed directly next to magnet.
9	9/11/2007	5:15pm	-0.0377	-0.1023	Fixture placed directly next to magnet.
10	9/12/2007	7:30am	-0.0001	-0.1696	Fixture placed directly next to magnet.
11	9/12/2007	8:30am	-0.1022	-0.155	Fixture moved about 3/4" closer to magnet.
12	9/12/2007	10:00am	-0.0544	-0.1664	Configuration 12
13	9/12/2007	10:45am	-0.055	-0.1752	Configuration 12
14	9/12/2007	11:30am	-0.0509	-0.1822	Configuration 12
15	9/12/2007	1:00 PM	-0.0708	-0.2054	Configuration 12; flipped red switch "down" before test
16	9/12/2007	2:20 PM	-0.0596	-0.2125	Configuration 12
17	9/12/2007	3:15 PM	-0.0557	-0.218	Configuration 12
18	9/12/2007	4:20 PM	-0.0702	-0.2368	Shifted fixture back to configuration 7
19	9/12/2007	5:30 PM	-0.074	-0.2381	Configuration 7
20	9/13/2007	9:45 AM	-0.0472	-0.2434	Configuration 7
21	9/13/2007	10:00 AM	-0.1135	-0.2407	Configuration 5 (moved fixture back; cart adjacent)
22	9/13/2007	10:30 AM	-0.114	-0.2512	Configuration 5
23	9/13/2007	11:15 AM	-0.1105	-0.2485	Configuration 5
24	9/13/2007	1:00 PM	-0.1179	-0.2501	Configuration 5
25	9/13/2007	1:40 PM	-0.1269	-0.2452	Configuration 3 (moved cart away from granite table about 3 feet).
26	9/13/2007	2:20 PM	-0.1286	-0.2574	Configuration 3
27	9/13/2007	3:40 PM	-0.133	-0.2602	Configuration 3
28	9/13/2007	4:30 PM	-0.1216	-0.2704	Configuration 3
29	9/14/2007	12:30 PM	-0.1095	-0.305	Configuration 3

Table 1