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# ILC Superconducting Quadrupole Characterization

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SLAC NAL

LCWS08 Chicago, IL. USA

November 19, 2008



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November 19, 2008

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# ILC Superconducting Quadrupole

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et al. from March-June 2008 includes:

M. Racine

A. Angelov , R. Badger, M. Berndt

S. St. Lorant, T. Weber

S. Anderson, D. Jensen, L. Juarez, Z. Wolf



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# ILC Superconducting Quadrupole



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# Cryostat containing quad in research lab at SLAC.

Not in the temperature controlled room we wished.

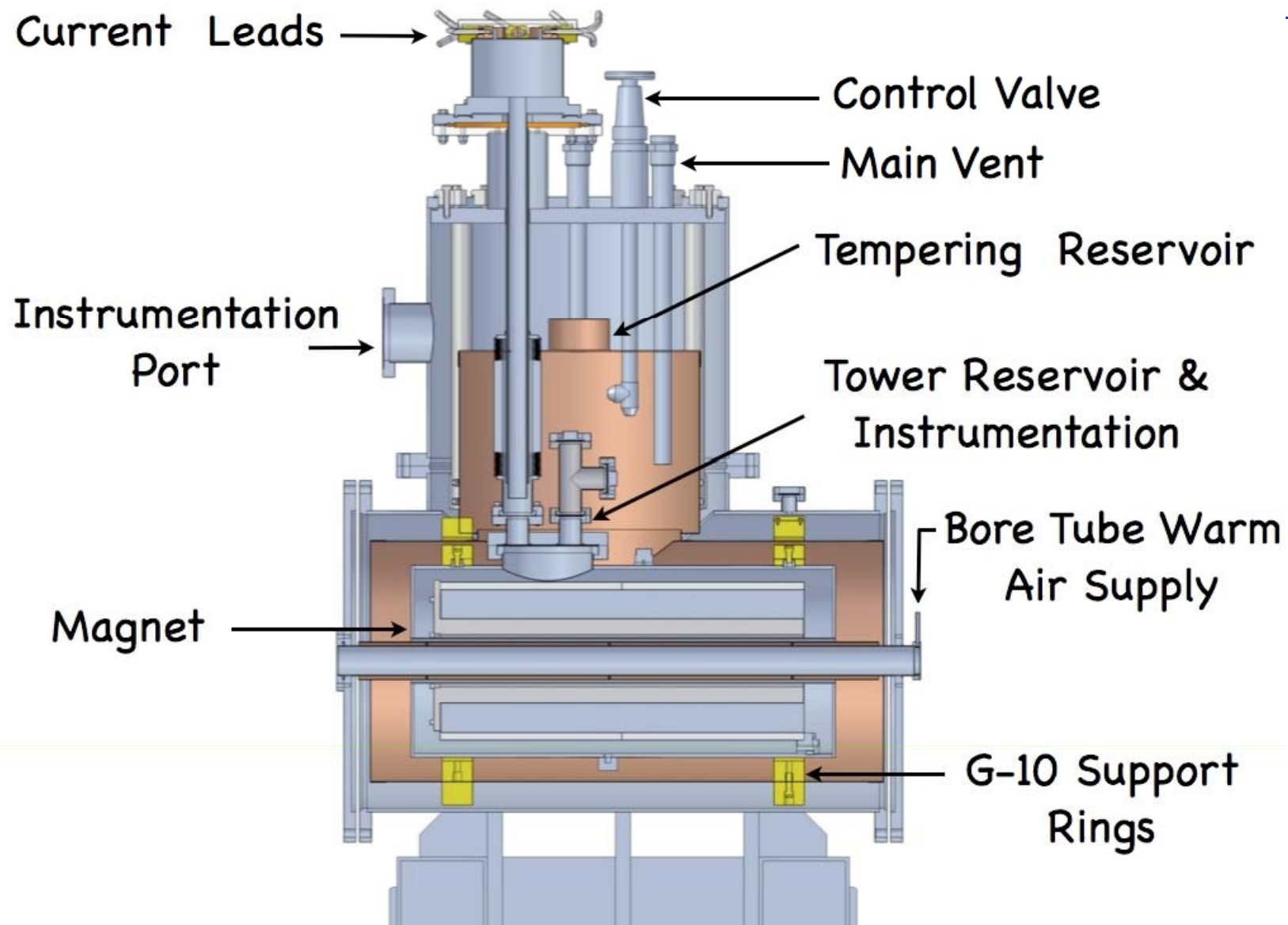


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# ILC Superconducting Quadrupole Cryostat



# Magnet Measurement Goals

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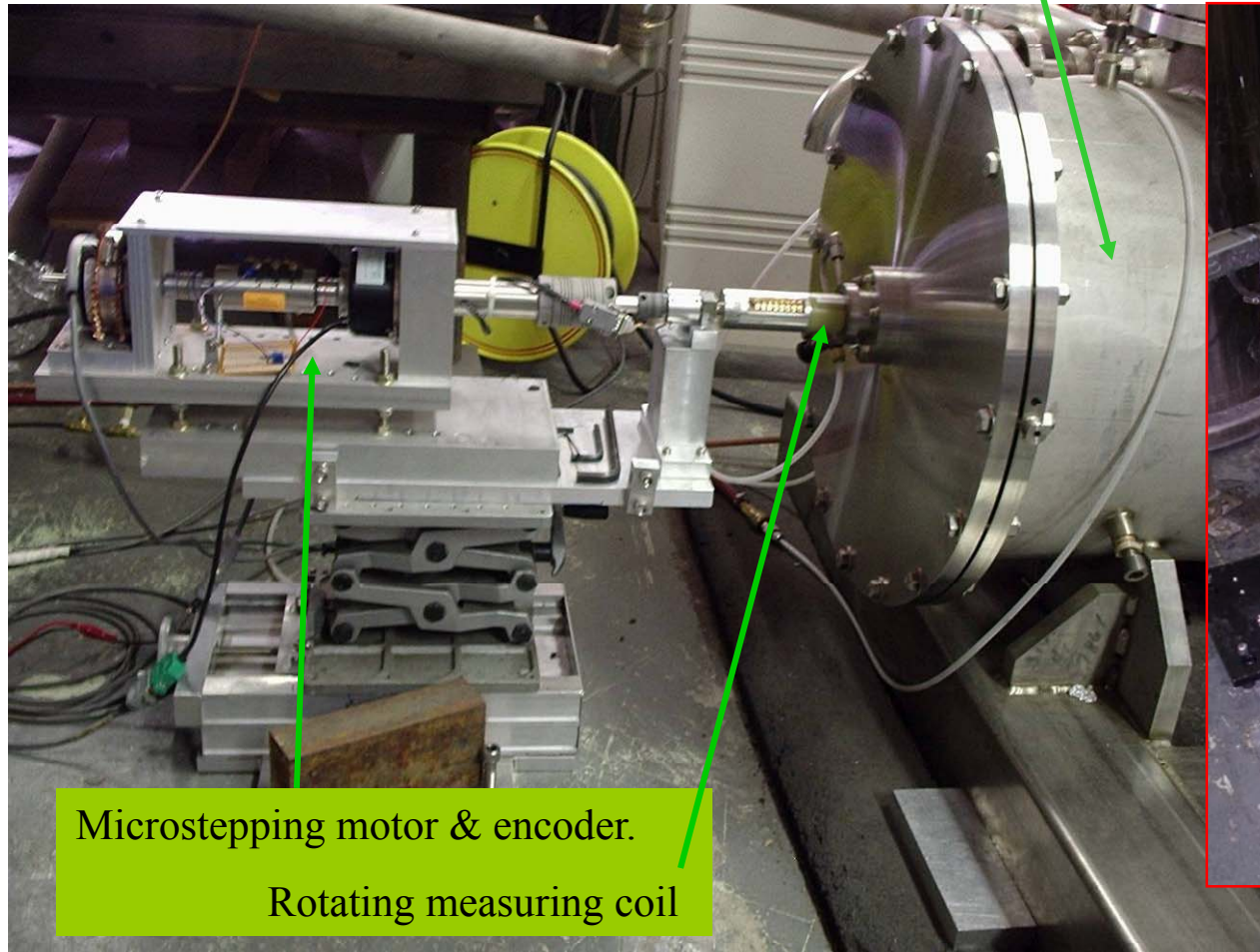
Three basic question to be answered:

What is full useful range of the magnet?

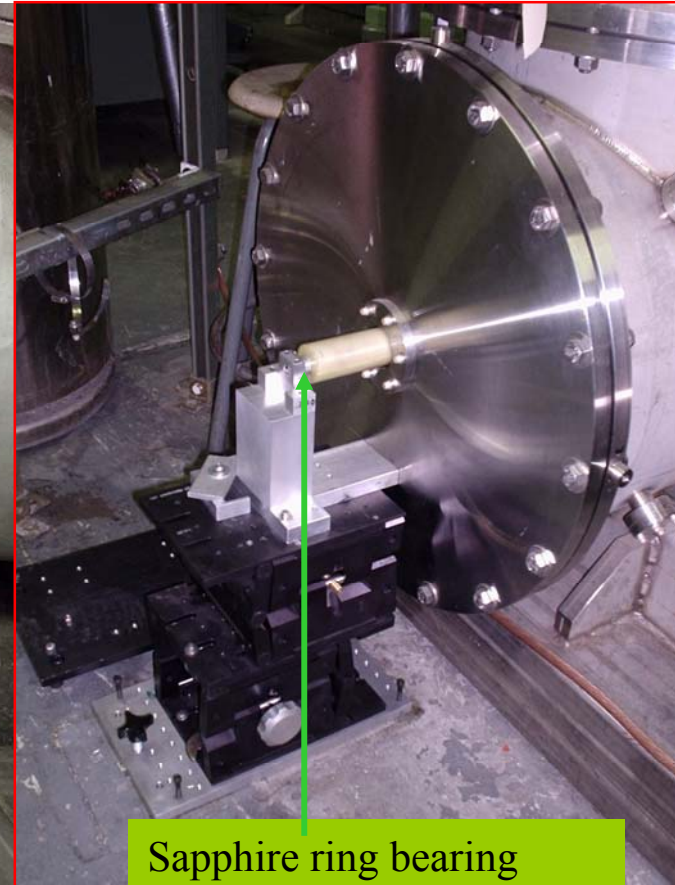
What is going on with the harmonics when the dipoles are energized (an artifact of the DESY measurements?)?

What is the centroid motion when doing a 20% Beam Based Alignment (BBA) procedure?

Photos of both ends of the rotating coil which passes through the warm bore of the superconducting quad, QSC990L626.



Microstepping motor & encoder.  
Rotating measuring coil



Sapphire ring bearing  
allows shaft of rotating  
coil to rotate without any  
wobble or vibration

# Magnet Measurement References

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F. Toral. et al: V:\NLC\Drop-Boxes\Adolphsen\SRF\SC Quad\Talks, Papers and Posters\mt19\_MOA07PO12.pdf: DEC2005

Kashikin Specifications: V:\NLC\Drop-Boxes\Adolphsen\SRF\SC Quad\FNAL Apr 07 Magnet Review\  
MLQuad\_Review\_Part1\_Kashikhin\_040407.ppt: APR2007

C. Spencer, et al. Magnetic Measurements: SLAC-PUB-11473, DEC2006

JCS, et al: Note of these measurements, in prep: NOV2008

A number of technical notes, see C.A.

T. Weber, et al, Warm bore cryostat, SLAC-PUB-12007, SEP2006; also a 2008 pub in prep

V-drive data and matlab files and various pix

# Magnet Specifications

Item	Nominal <sup>1</sup>	Measured	Units	Comments
Integrated Strength	0.36	0.35	T/A	1A-100A
Bore	90/79	/79	mm	Coil/tube i.d.
Effective Length	<b>0.588-0.666</b>	n/a	m	Not measured
Field non-linearity at 5 mm radius	0.05	<0.03	% of quad	1A-100A
Magnetic center stability for 20% BBA <sup>2</sup>	+/-5	<1.2, rms	μm	5A-100A
Dipole coil integrated strength	0.00188 <sup>3</sup>	0.00125 <sup>4</sup>	T-m/A	-25A-to-25A
OD/ID Strength	1.027	1.035	-	<b>114/111 turns ratio</b>
Liquid He Temperature	2	4.5	°K	

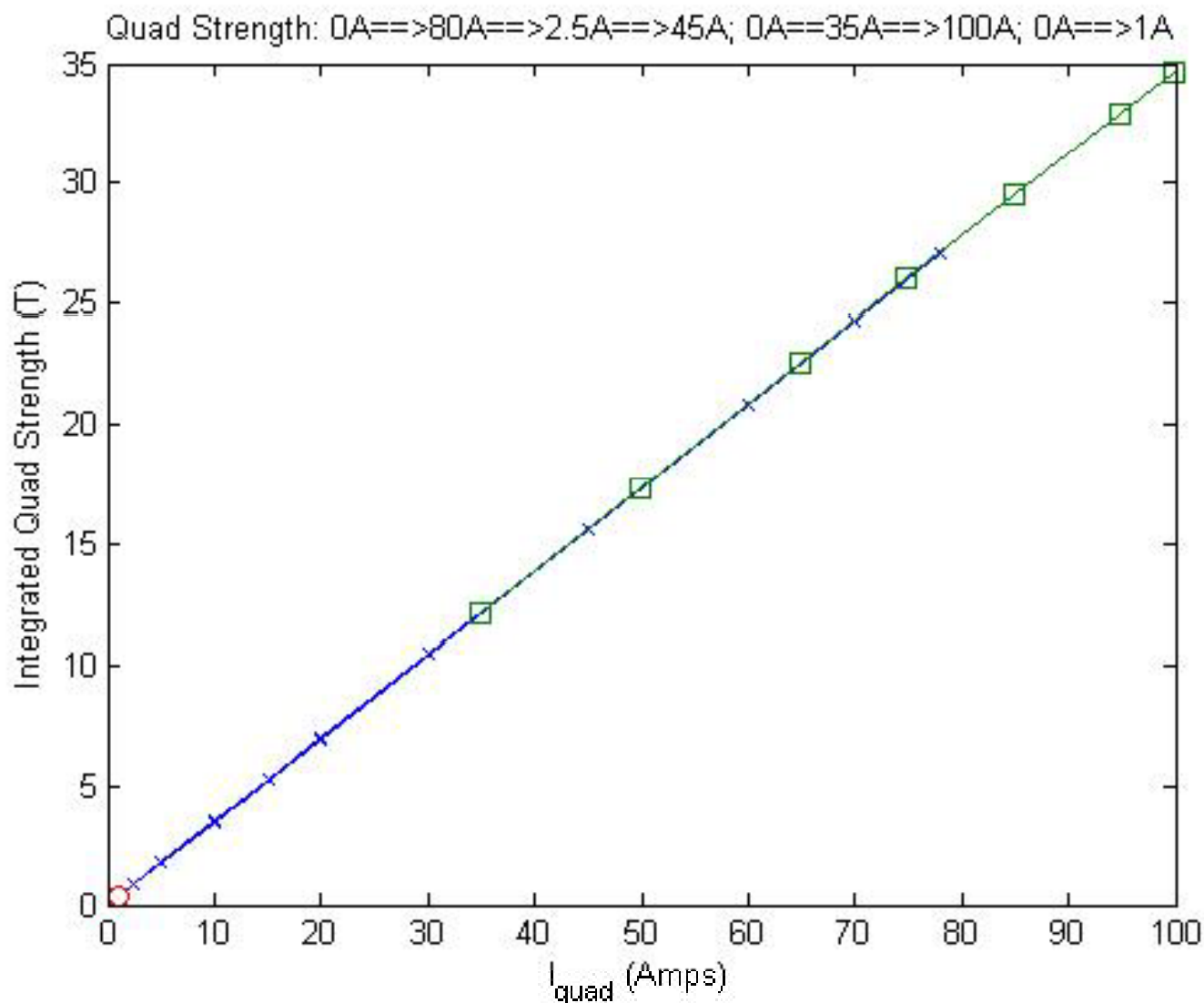
1. Taken from V. Kashikhin talk and F. Toral, et al. paper

2. -20% BBA cycle: 100%, -22%, -20%, -10%, 100%

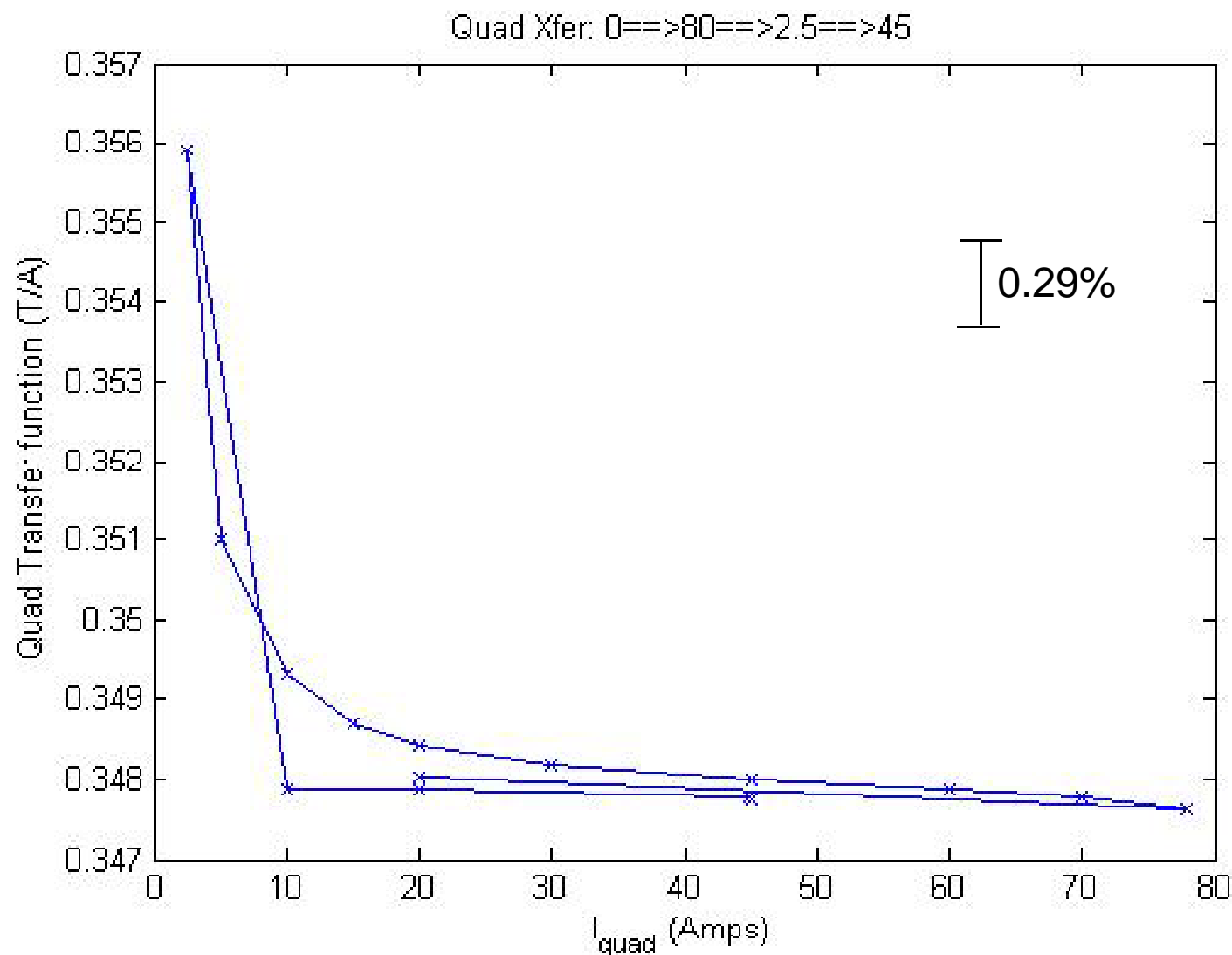
3. Taken to be 0.075T/40A

4. Agrees with figure 11, right of F. Toral, et al. paper

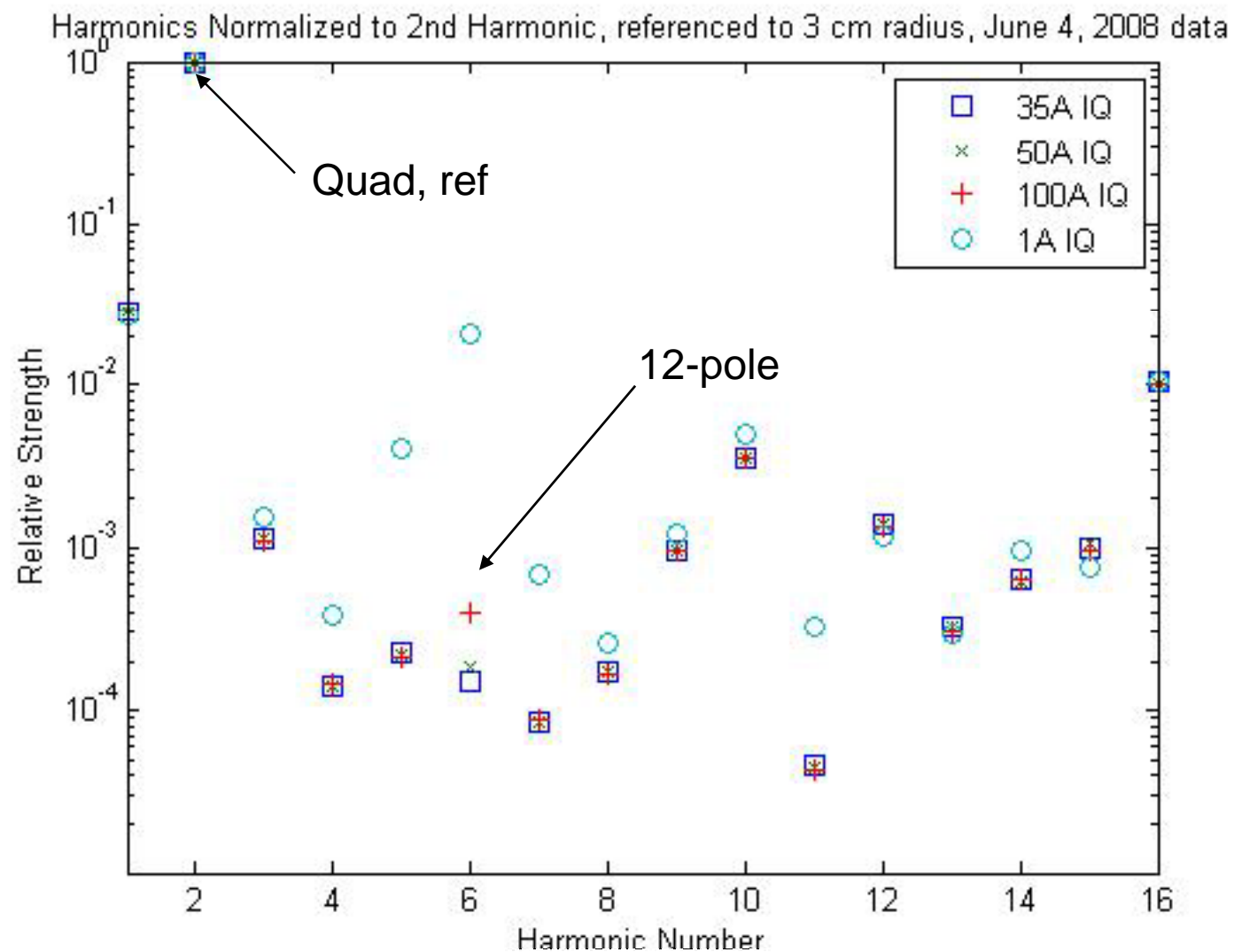
# Quadrupole Strength



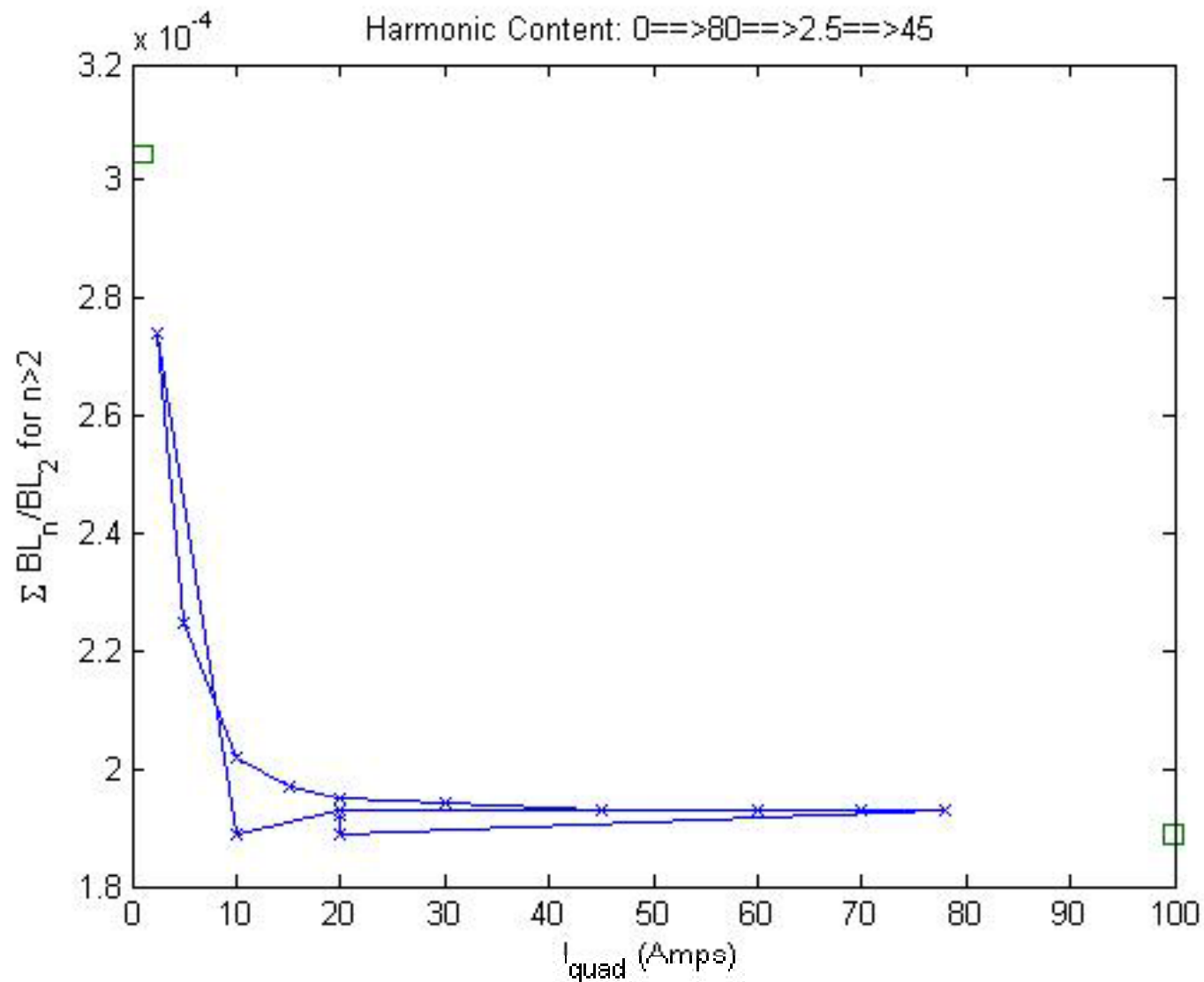
# Quadrupole Strength



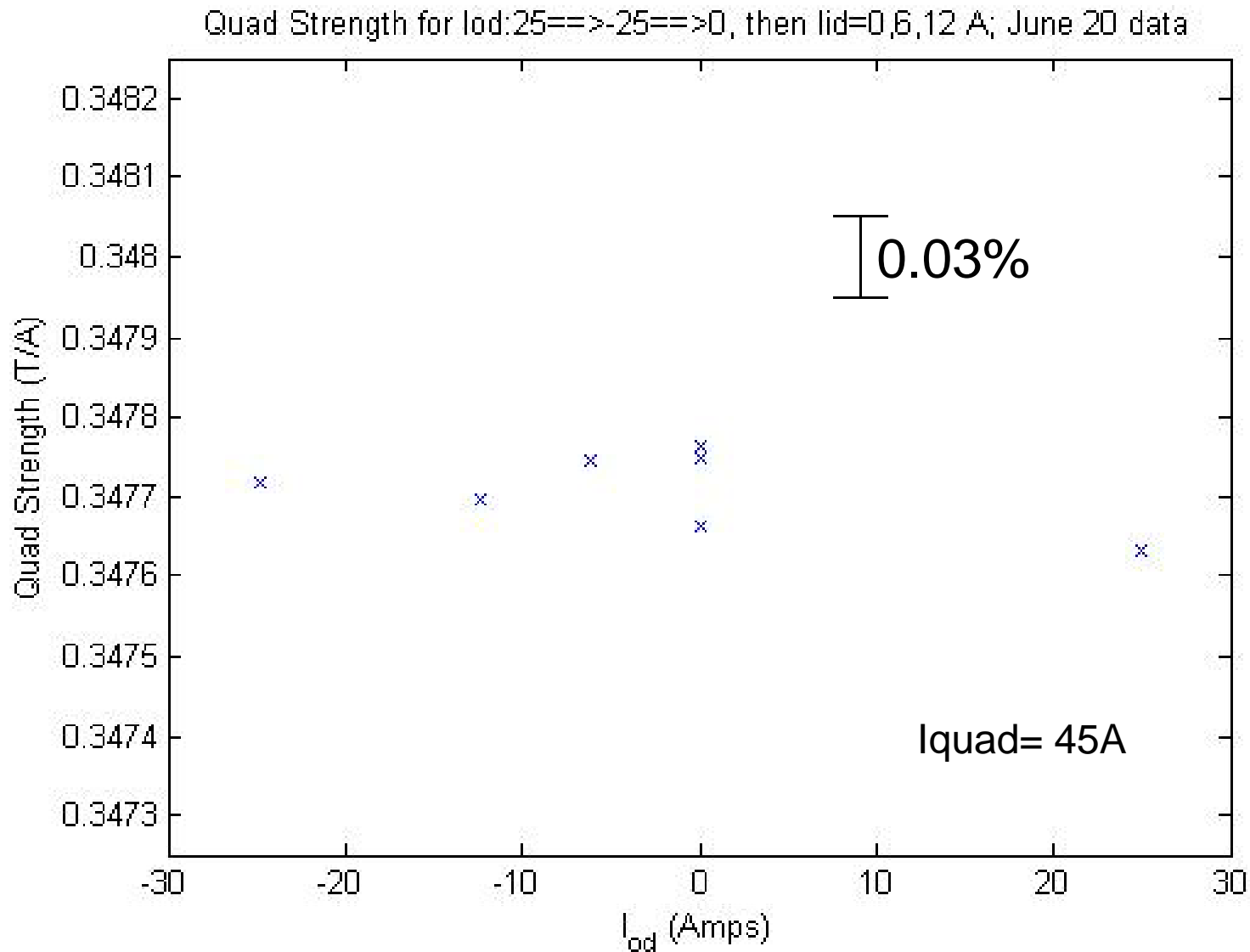
# Magnetic Field Harmonics, 3 cm radius



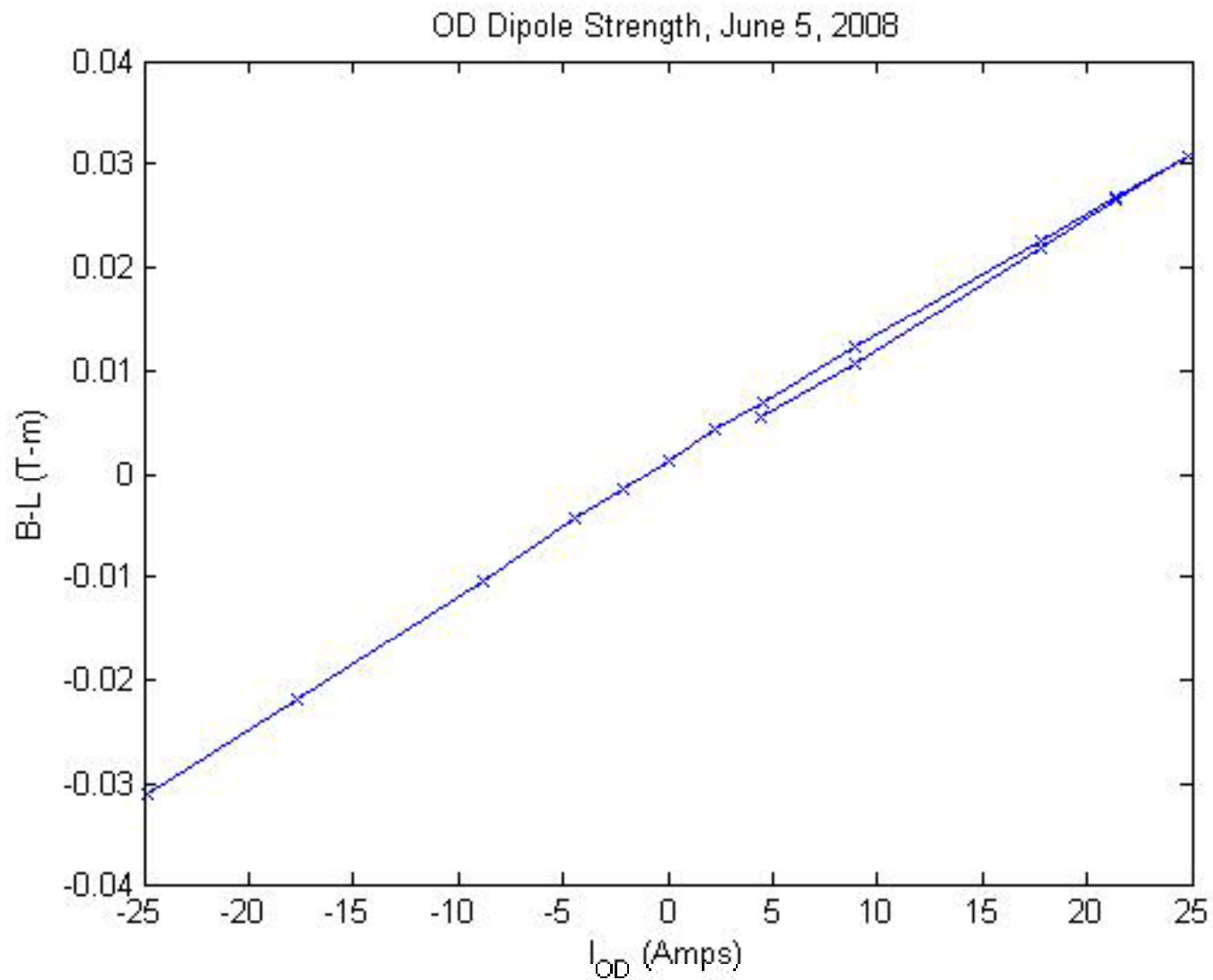
# Field Non-Linearity, 5 mm radius reference



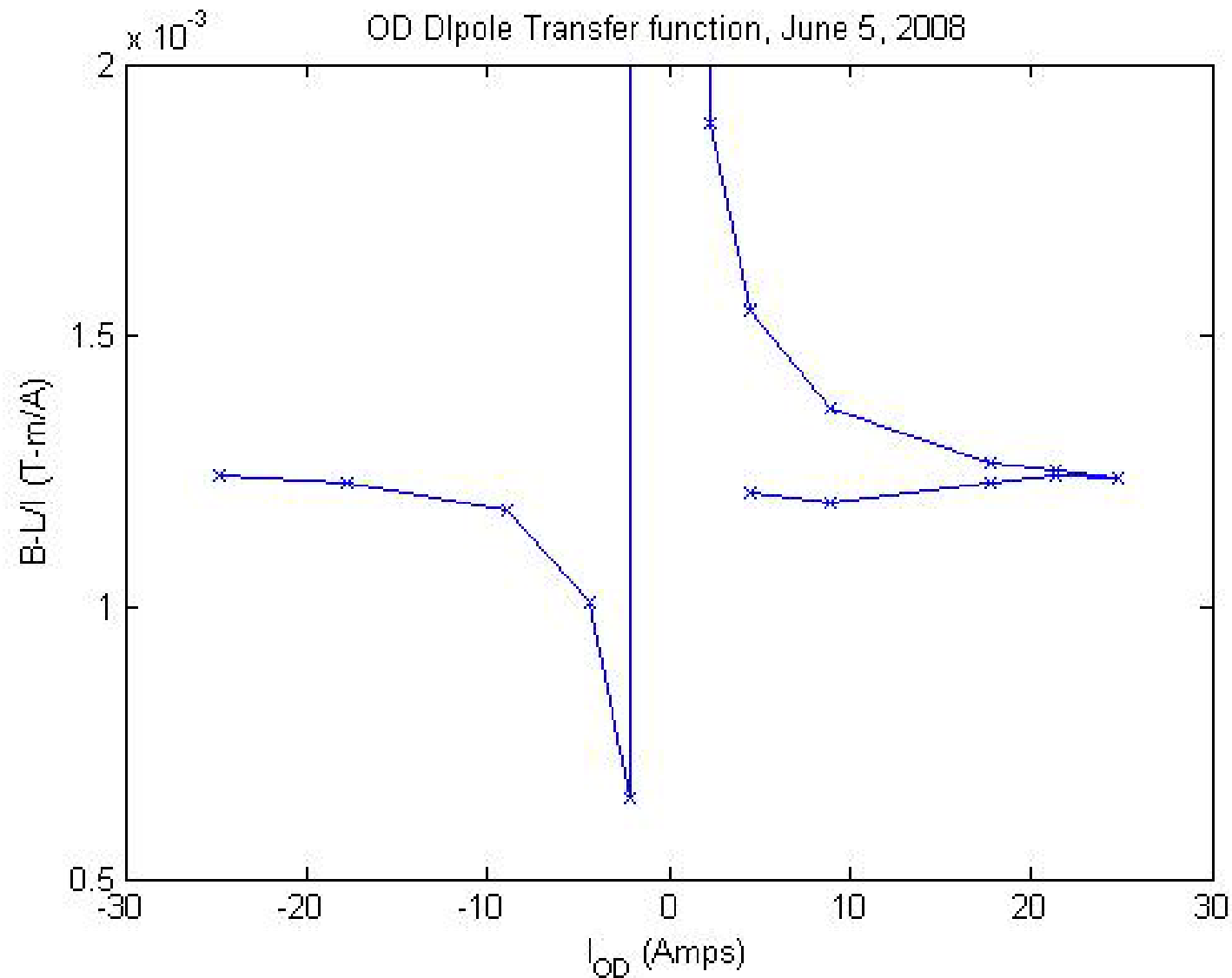
# Quad Strength vs. Dipole Excitation



# Outer Dipole Strength (B-L)



# Outer Dipole Transfer Function (B-L/I)



# Beam Based Alignment Procedure

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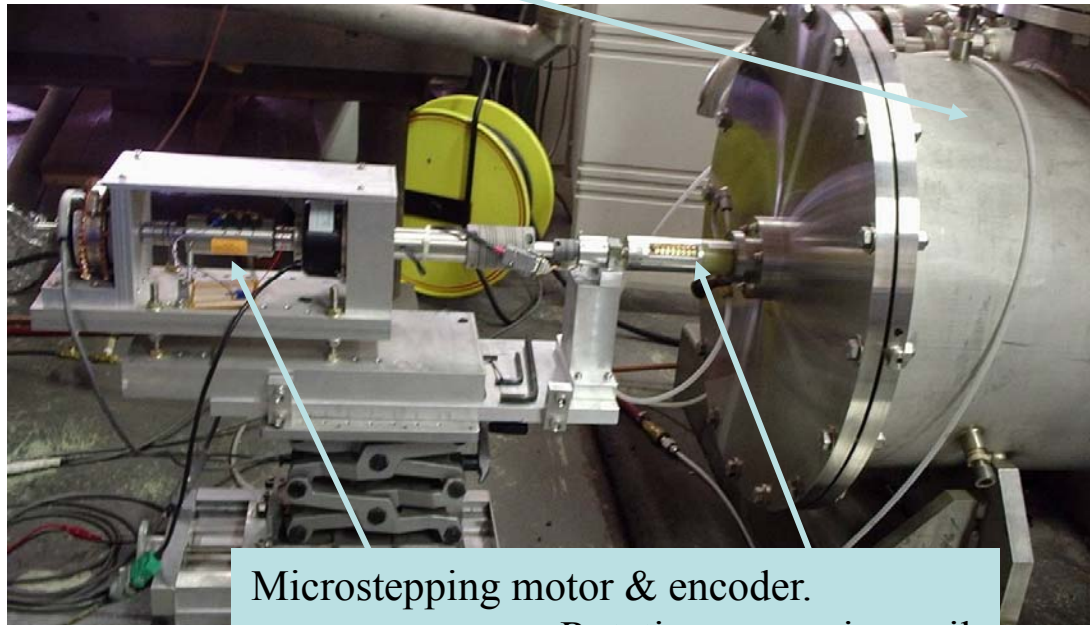
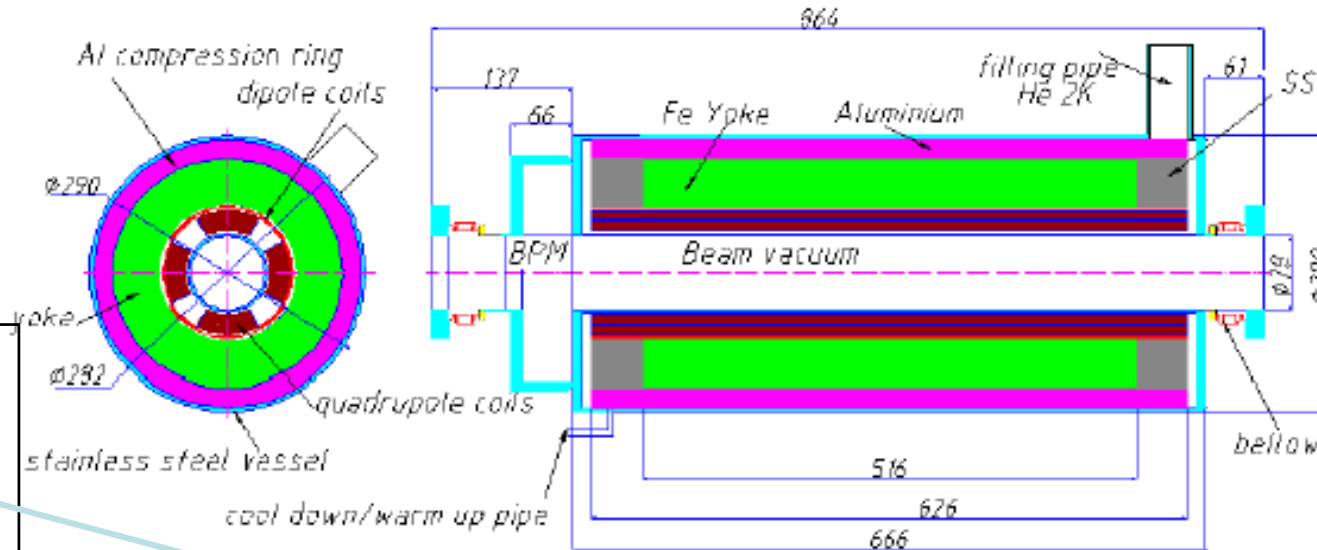
BBA: 100%-78%-80%-90%-100% quad excitation

With no change in excitation current, it is seen that the vertical centroid position is temperature sensitive; horizontal is significantly less sensitive

Do not expect vertical centroid to move differently than horizontal with excitation current; attribute oddities in vertical position to  $\Delta T$

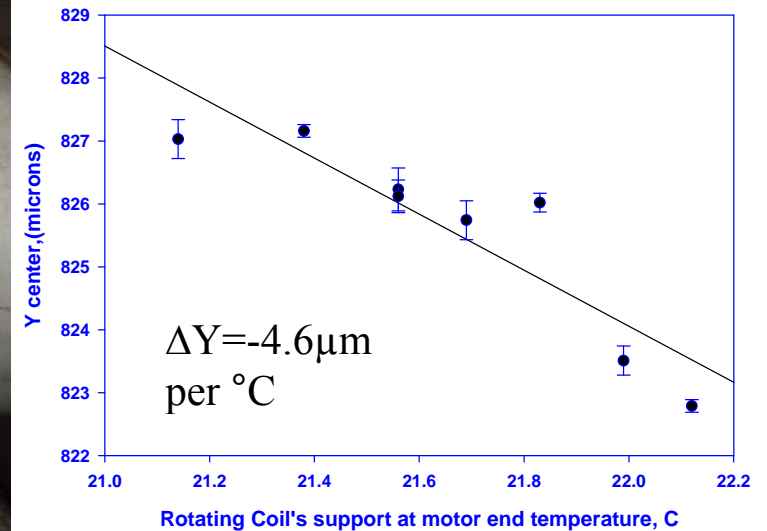
Units in mm

Prototype S-C  
quad, made by  
CIEMAT for  
TESLA.



Microstepping motor & encoder.  
Rotating measuring coil

ILC Prototype SuperCon Quad, 22 May 2008



Small changes in Y value at 8 amps  
correlated with measuring apparatus

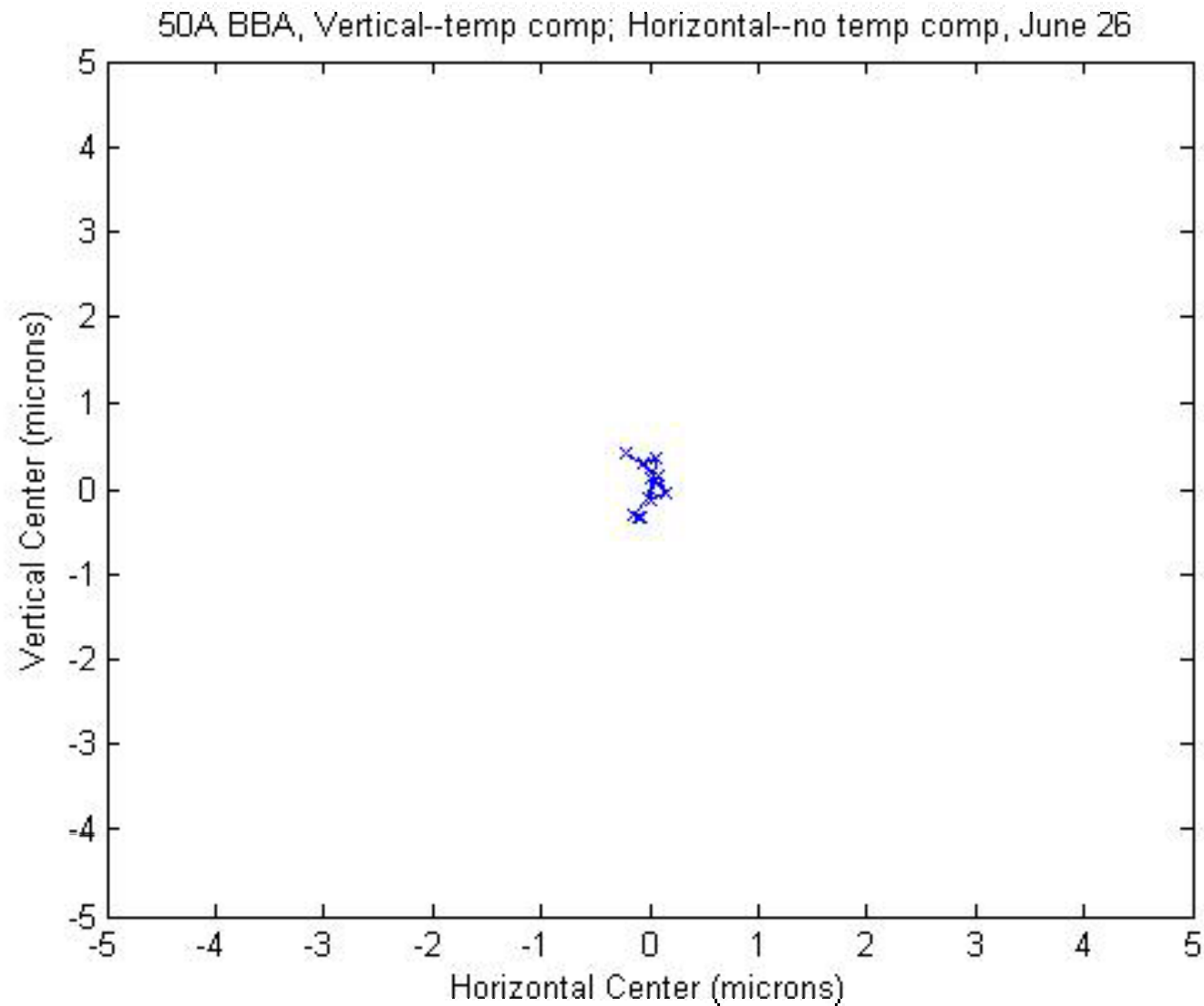
temperature, such as support under one  
end of rotating coil

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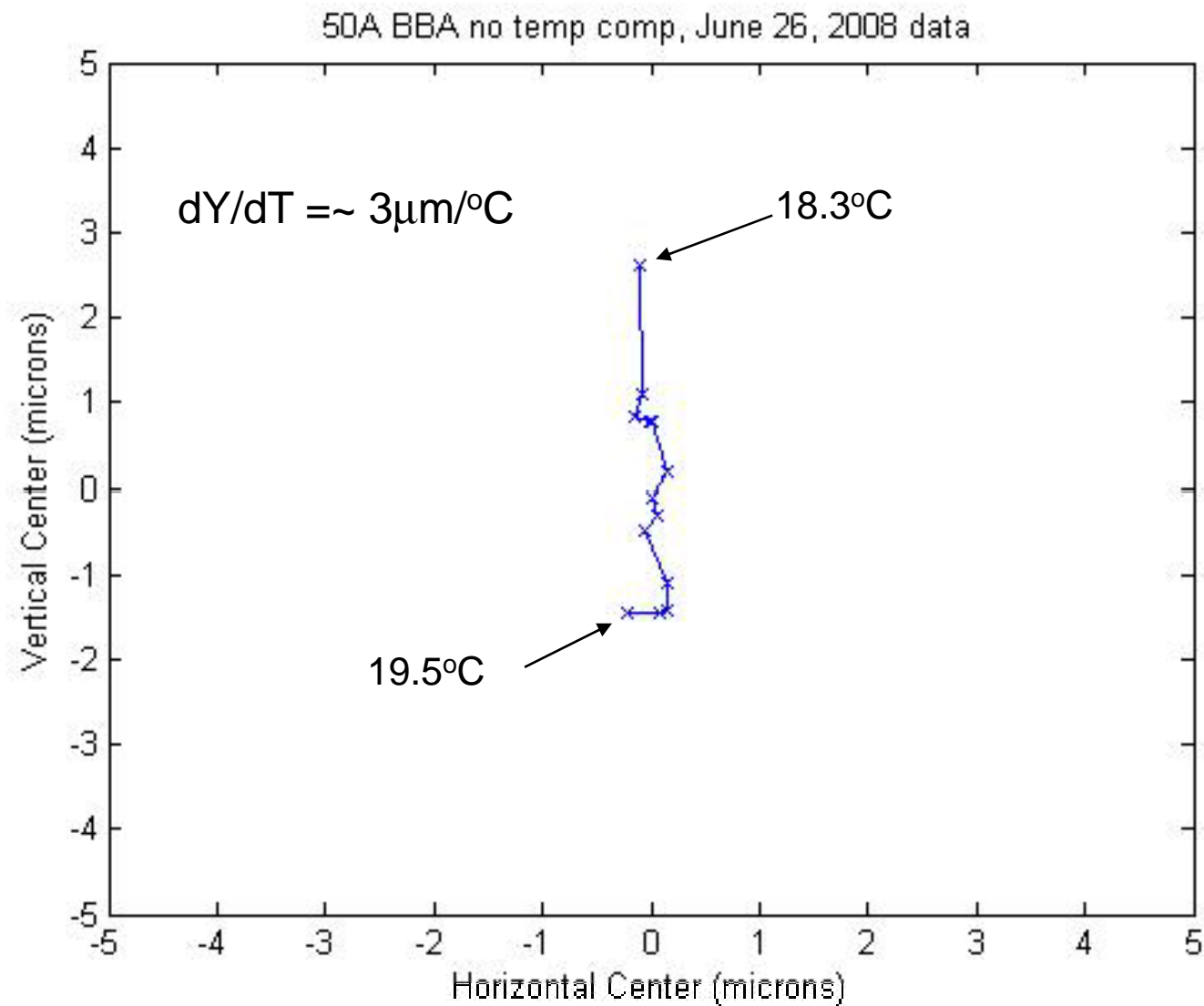
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# 50 Amp BBA: June 26, 2008

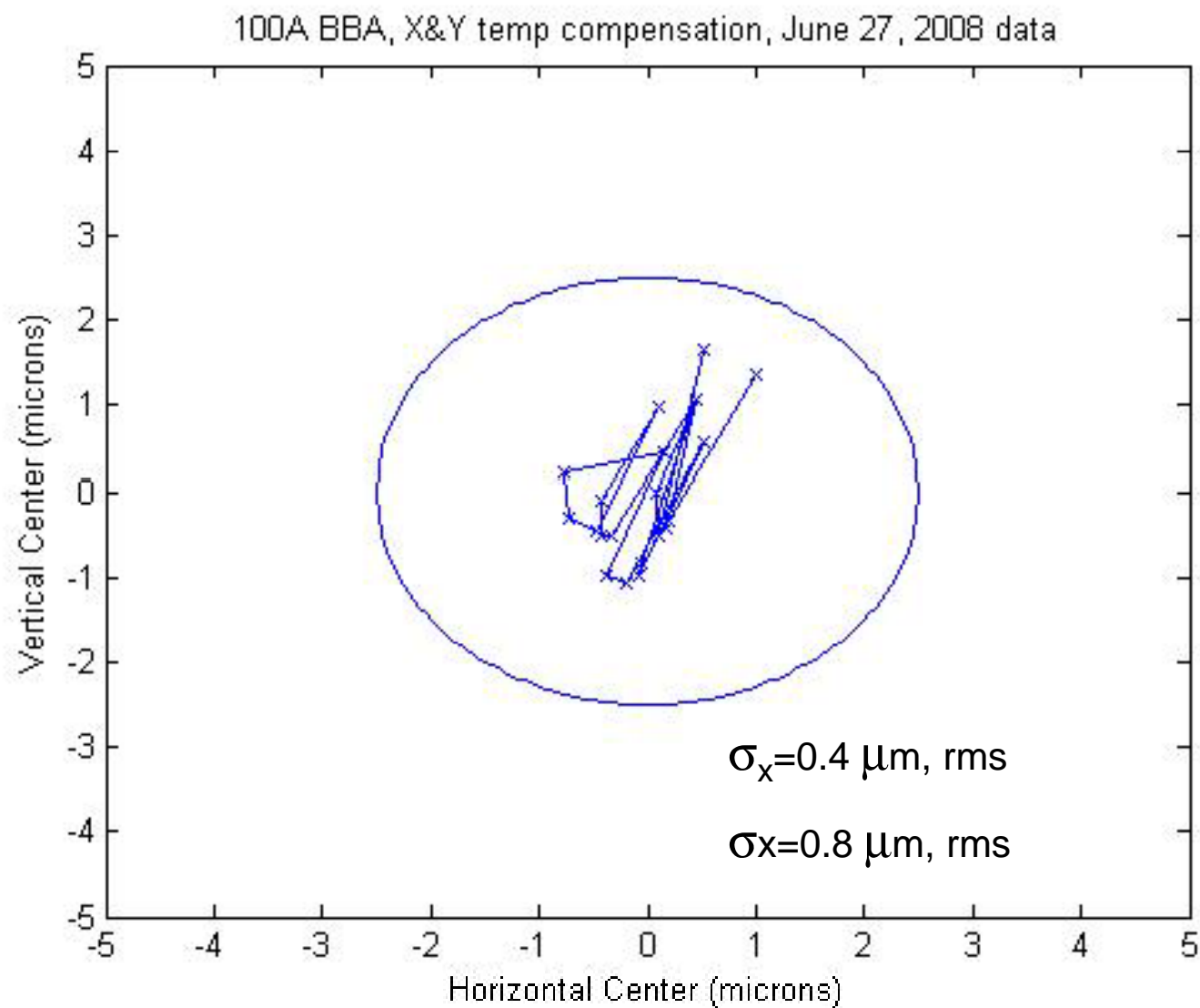


# 50 Amp BBA: June 26, 2008

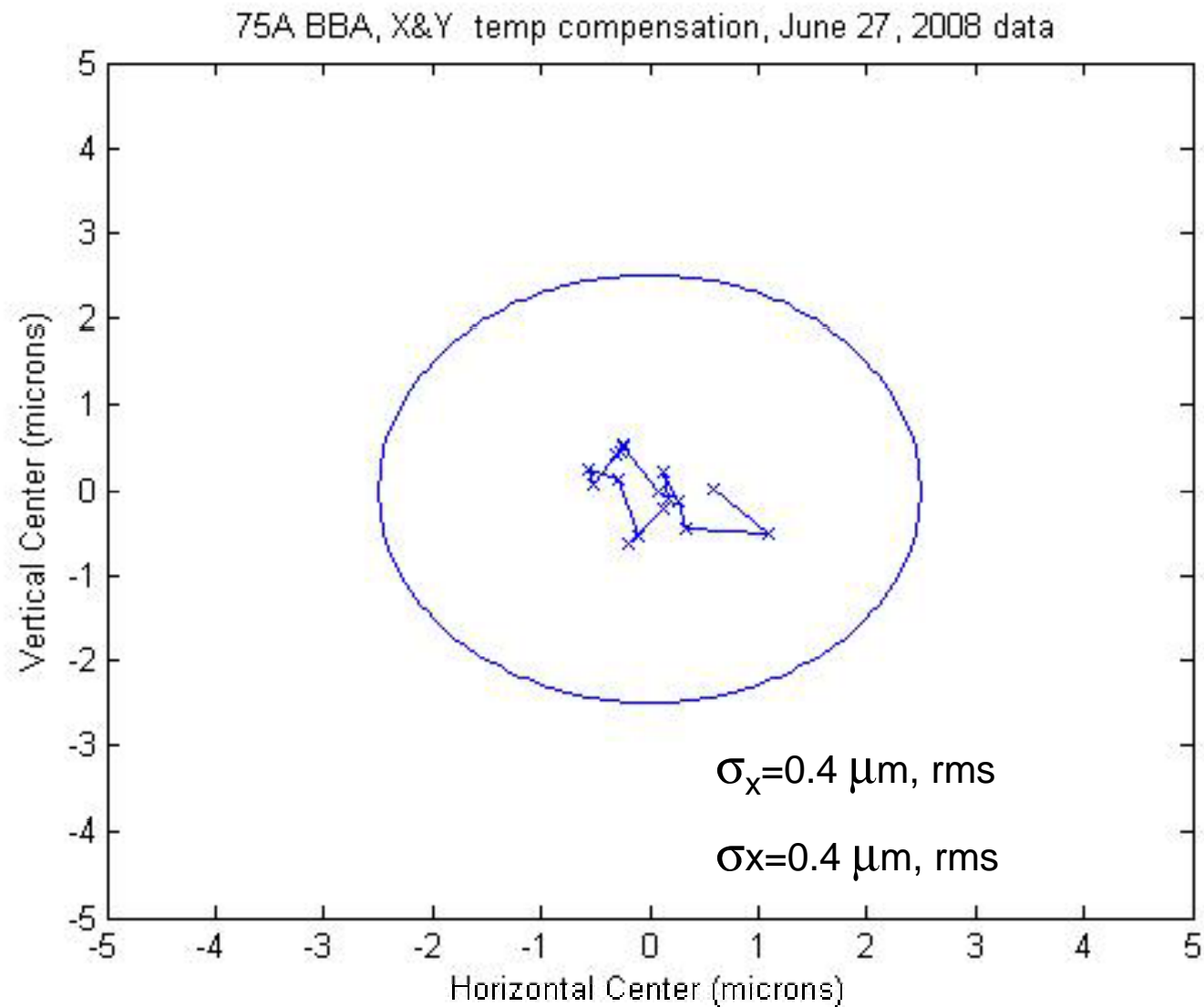


# 100 Amp BBA: June 27, 2008

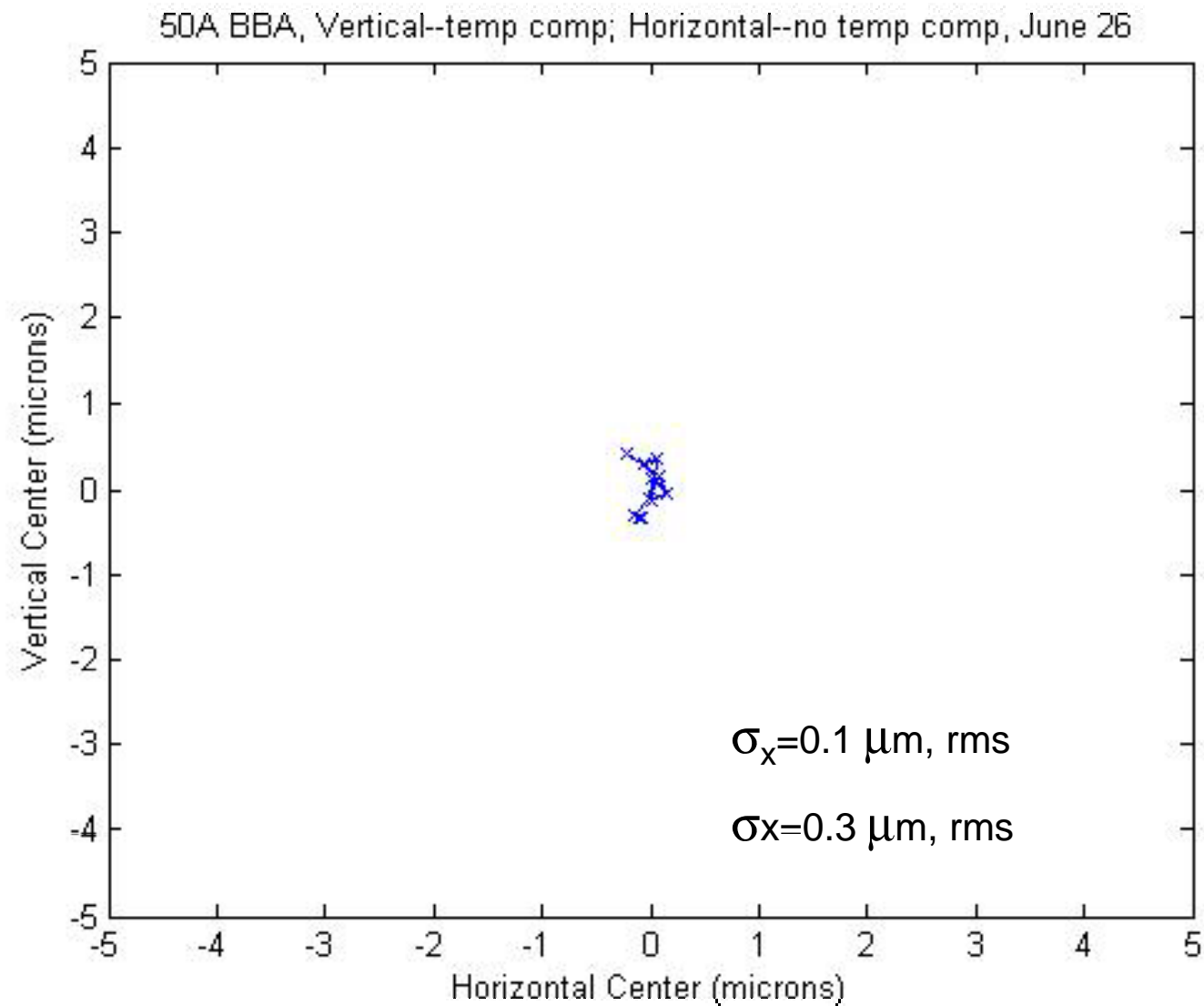
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# 75 Amp BBA: June 27, 2008

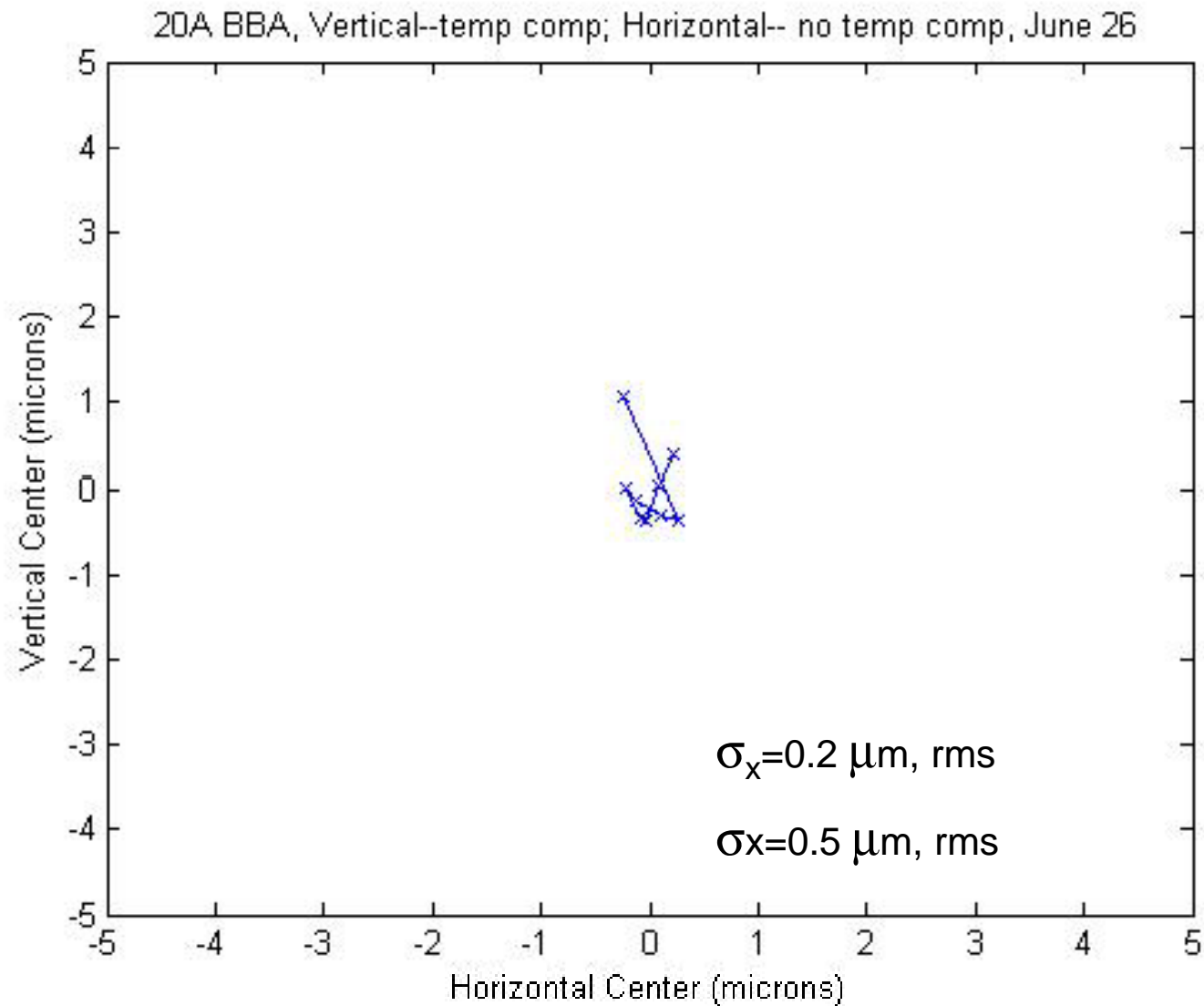


# 50 Amp BBA: June 26, 2008



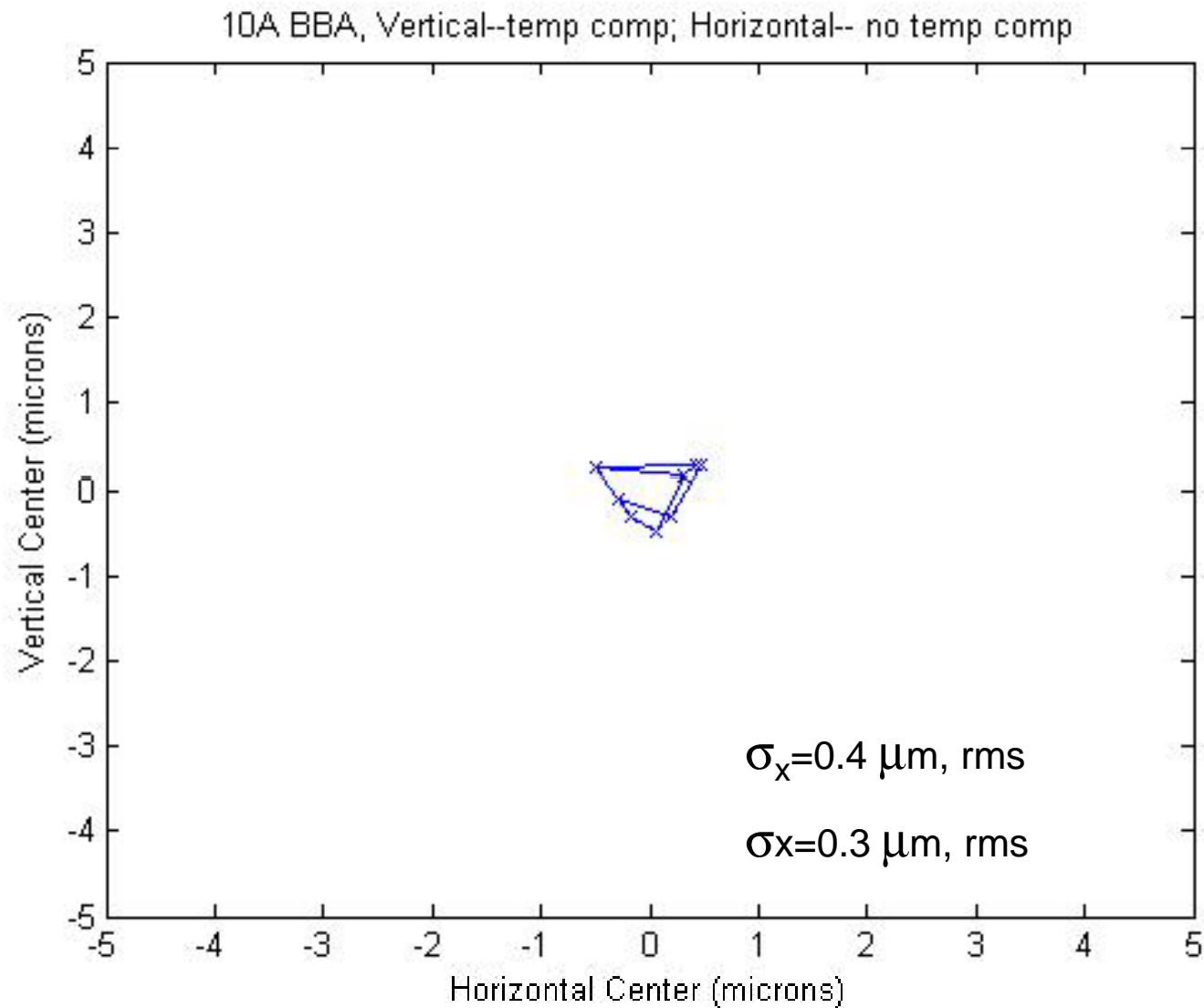
# 20 Amp BBA: June 26, 2008

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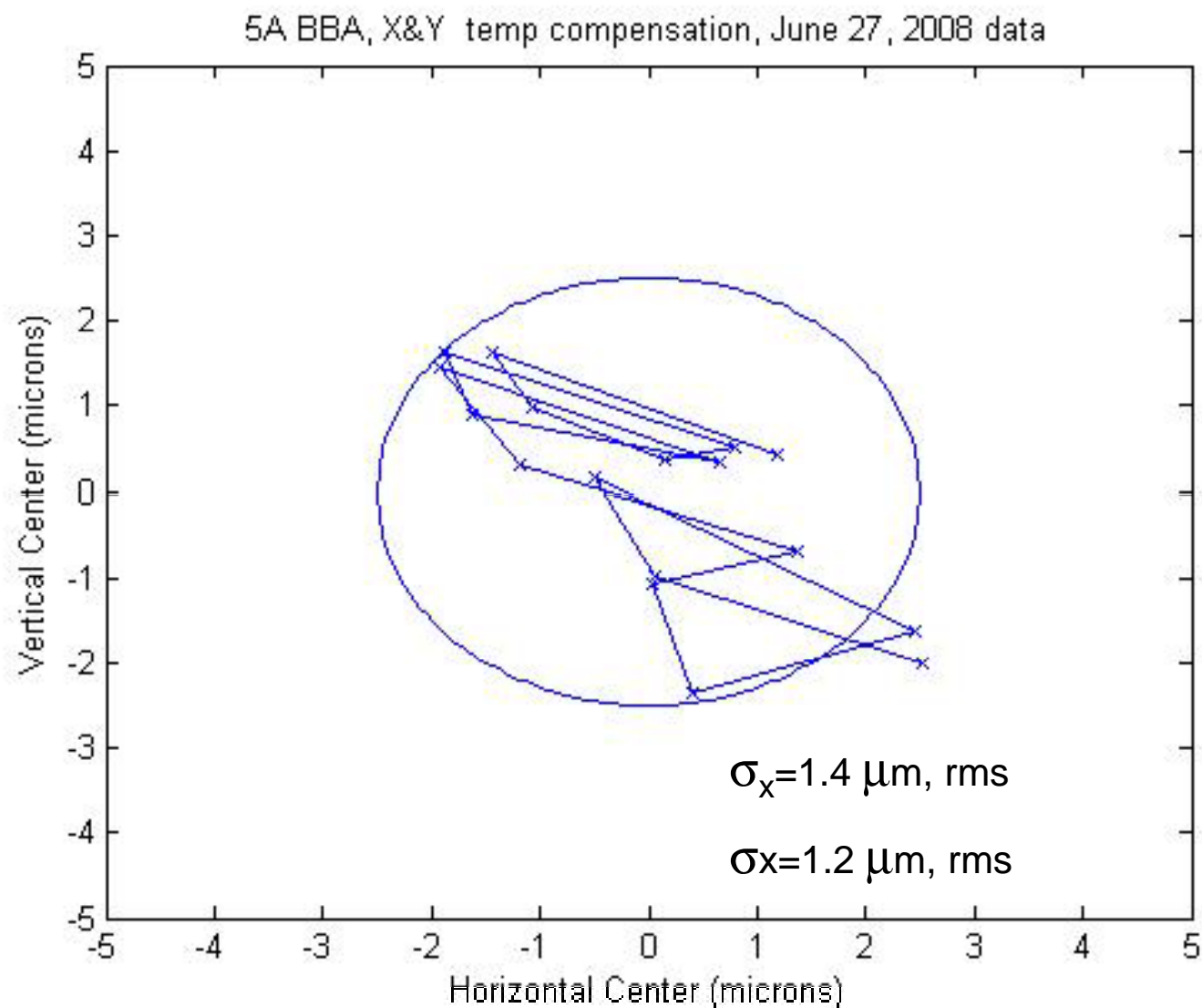


# 10 Amp BBA: June 26, 2008

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# 5 Amp BBA: June 27, 2008



# Beam Based Alignment Procedure

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BBA: 100%-78%-80%-90%-100% quad excitation

Vertical centroid position is temperature sensitive;  
horizontal is significantly less sensitive

Do not expect vertical centroid to move differently than  
horizontal with excitation current; attribute oddities in  
vertical position to  $\Delta T$

In process of collecting results into a Note; all files (data,  
figures, fotos, m-files are available (V-drive?))



Integrated gradient, T	36
Aperture, mm	78
Effective length, mm	666
Peak gradient, T/m	54
Field non-linearity at 5 mm radius, %	0.05
Dipole trim coils	Vertical+Horizontal
Trim coils integrated strength, T-m	0.075
Quadrupole strength adjustment for BBA, %	-20
Magnetic center stability at BBA, $\mu\text{m}$	5
Liquid Helium temperature, K	2
Quantity required	560

# Fabrication and Testing of a Combined Superconducting Magnet for the TESLA Test Facility

*F. Toral, P. Abramian, H. Brueck, J. Calero, L. García-Tabarés, J.L. Gutierrez, W. Maschmann, E. Rodriguez, S. Sanz, M. Stolper, C. Vazquez*

**Abstract**—An international collaboration at DESY is currently studying the possibilities of a new type of particle accelerator: the superconducting linear collider, developed under the project name TESLA. The TESLA Test Facility is trying to establish a well-developed collider design, which will also be helpful for the design of a superconducting X-Ray Free Electron Laser facility (XFEL), a project approved by the German Government and now in its initial stage. Besides, XFEL will be the ideal workbench to improve the necessary components for the next International Linear Collider (ILC). This paper is about the fabrication and testing of the first prototype of a combined superconducting magnet for focusing and steering purposes, in the framework of

TABLE I  
MAGNET SPECIFICATIONS

Parameter	Quadrupole	Dipoles	Units
Nominal current	100	40	A
Bore diameter	90	--	mm
Main field @ nom. current	>60	0.074	T/m – T
Magnetic length	520	520	mm
Multipoles @ 30 mm	<10	<10	units

project. It consists of a quadrupole coil for beam focusing and two additional concentric dipole coils, horizontal and vertical, for steering the particles. Table I shows the main required magnet parameters. The prototype fabrication and tests will be

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Effective Length	<b>0.588-0.666</b>	n/a	m	Not measured
Field non-linearity at 5 mm radius	0.05	<0.03	% of quad	1A-100A
Magnetic center stability for 20% BBA <sup>2</sup>	+/-5	<1.2, rms	μm	5A-100A
Dipole coil integrated strength	0.00188 <sup>3</sup>	0.00125 <sup>4</sup>	T-m/A	-25A-to-25A
OD/ID Strength	1.027	1.035	-	114/111 turns ratio
Liquid He Temperature	2	4.5	°K	

1. Taken from V. Kashikhin talk and F. Toral, et al. paper

2. -20% BBA cycle: 100%, -22%, -20%, -10%, 100%

3. Taken to be 0.075T/40A

4. Agrees with figure 11, right of F. Toral, et al. paper

# Everything Working, May 21, 2008

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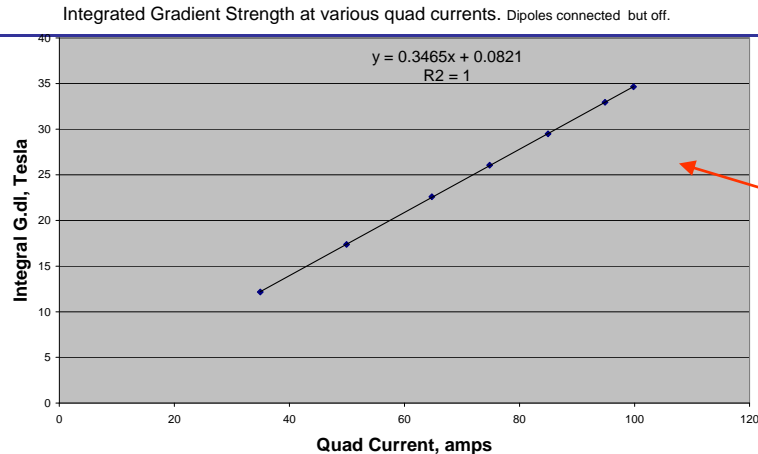


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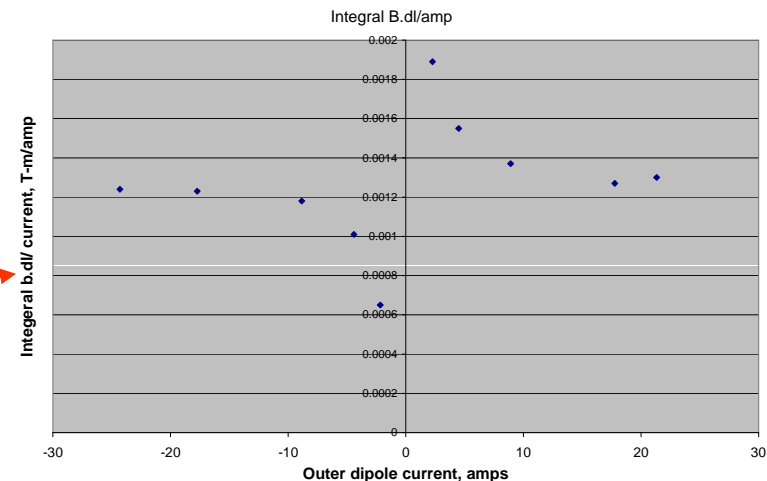


Quad windings been operated up to 100 amps from custom built power supply. Integrated field increases linearly with current. No sign of any saturation in the steel core.

X & Y coords of the magnetic center are measured at each current. Y coord decreases by 1.9 microns, temperatures of various parts of the rotating coil apparatus increased by  $\sim 1^\circ\text{C}$ .

Quad's center coords measured through a "Beam Based Alignment" sequence of currents: 100, 78, 80, 85, 90, 95, 100 A. Largest Y change occurred from 100 to 80 A: -3 microns. Temperature change during measurement period was  $+0.4^\circ\text{C}$ , accounting for  $\sim -1.8$  microns of the -3.

Outer dipole windings been operated with quad windings off, from +21.33 to -24.83 amps. Integral B.dl per amp is NOT constant. It is larger at smaller currents- we believe this is caused by persistent currents. Nor is the Integral B.dl/amp symmetric. See graph. One measurement with both quad (40A) and outer dipole (-24.83A) done- produces shifts in both x and y : to be investigated further.



# Quadrupole Strength, 2

