

Summary of Field Quality Data in D3L101

Animesh Jain

Superconducting Magnet Division

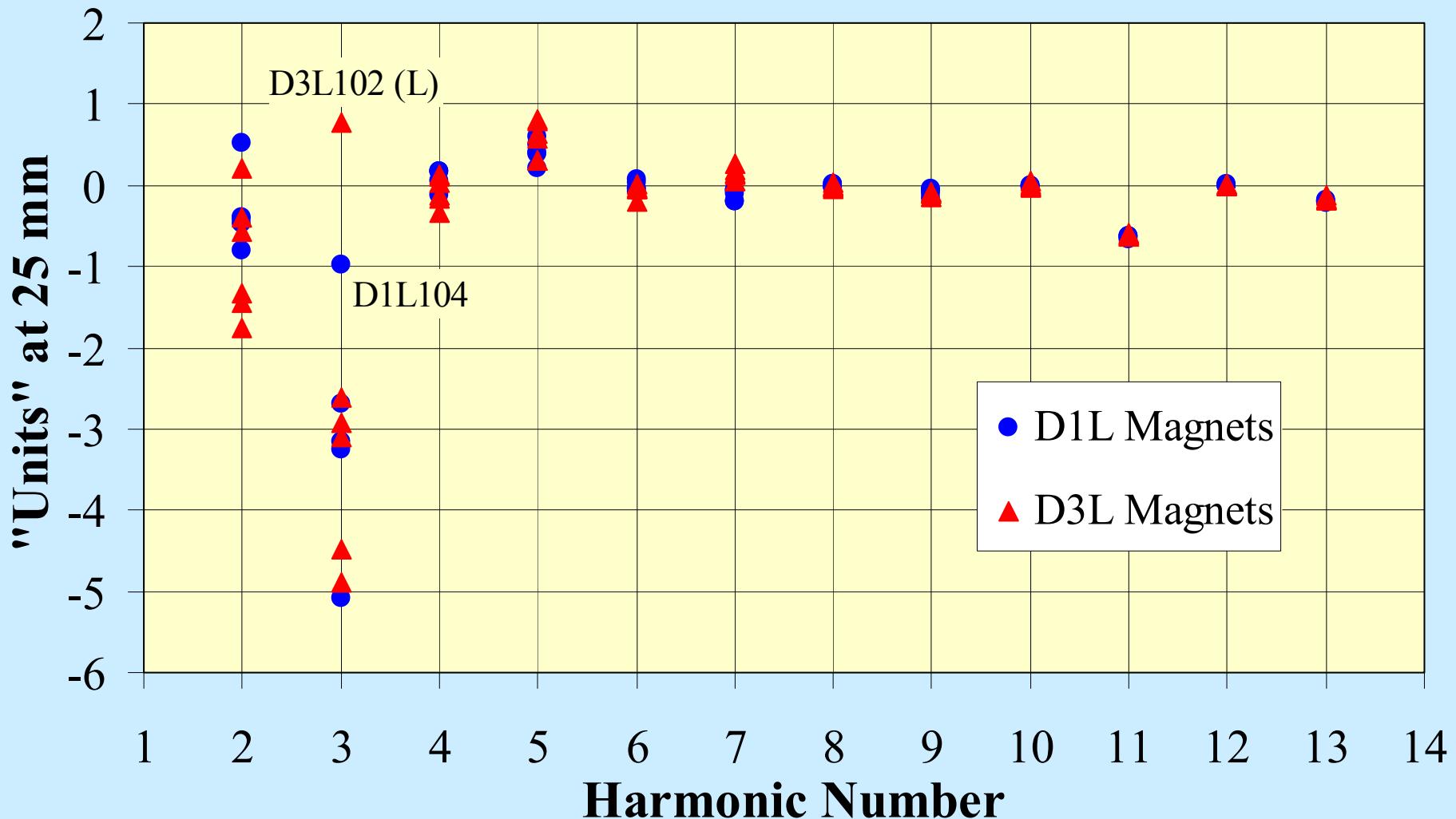
Brookhaven National Laboratory, Upton, NY 11973

D3L101 Acceptance, BNL, May 5, 2005

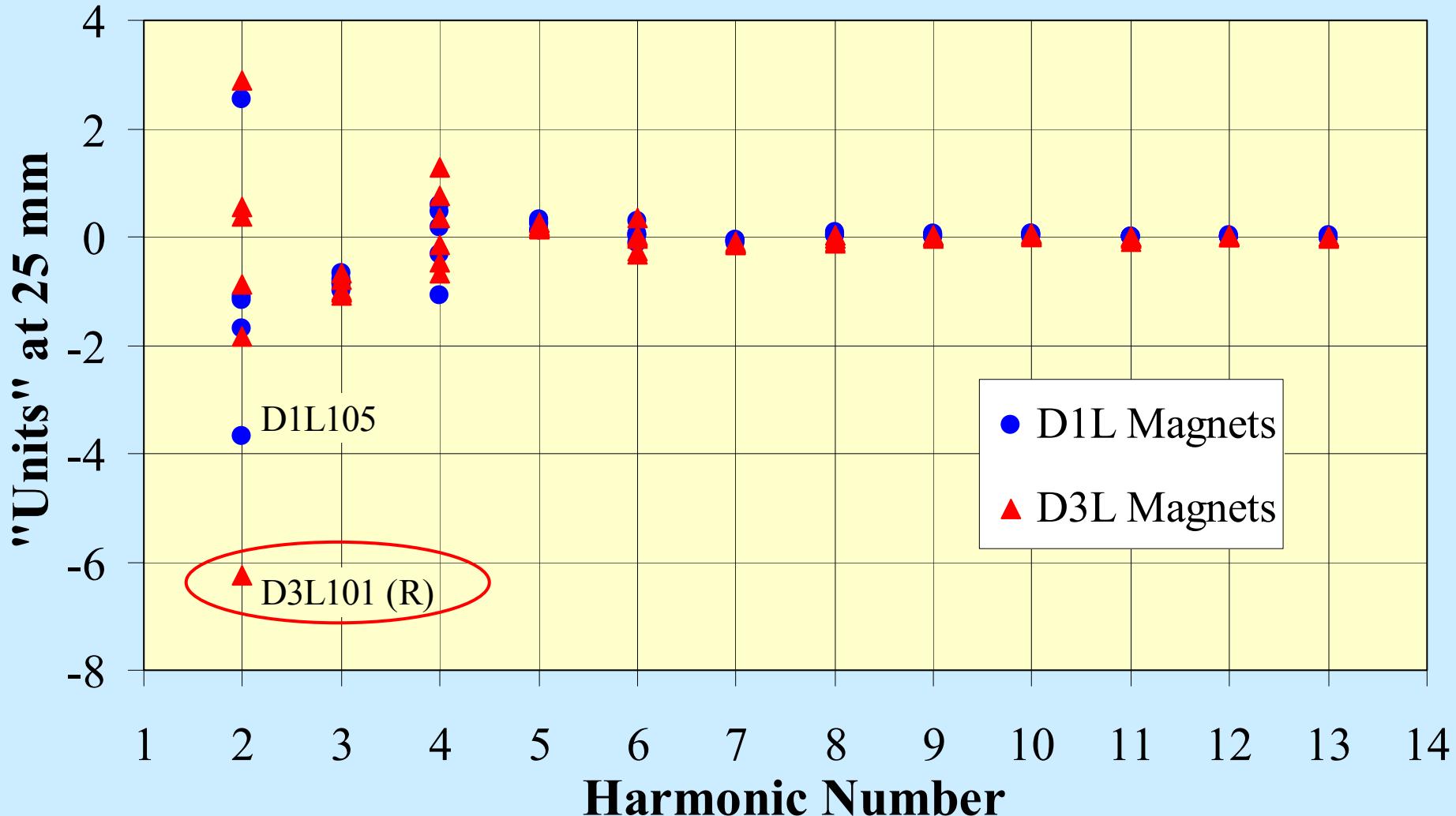
Warm Measurements

- Warm measurements have been completed in all the three D3 dipoles, using a 1 meter long mole at 10 axial locations in each aperture.
- Field angle is measured relative to gravity. Systematic error in calibration is removed by measuring field angles from both ends.
- Fiducials are surveyed on the test stand. Survey and field angle data are combined as per agreement with CERN regarding coordinate transformations.
- Integral transfer function is measured with a non-rotating, 10-meter long coil.
- All warm measurements are done *before* cold test.
(All the D1's were measured *after* cold test— T.F. diff.)
- The *warm harmonics* in D3 are consistent with the D1 dipoles. (The cold harmonics differ due to cross-talk.)

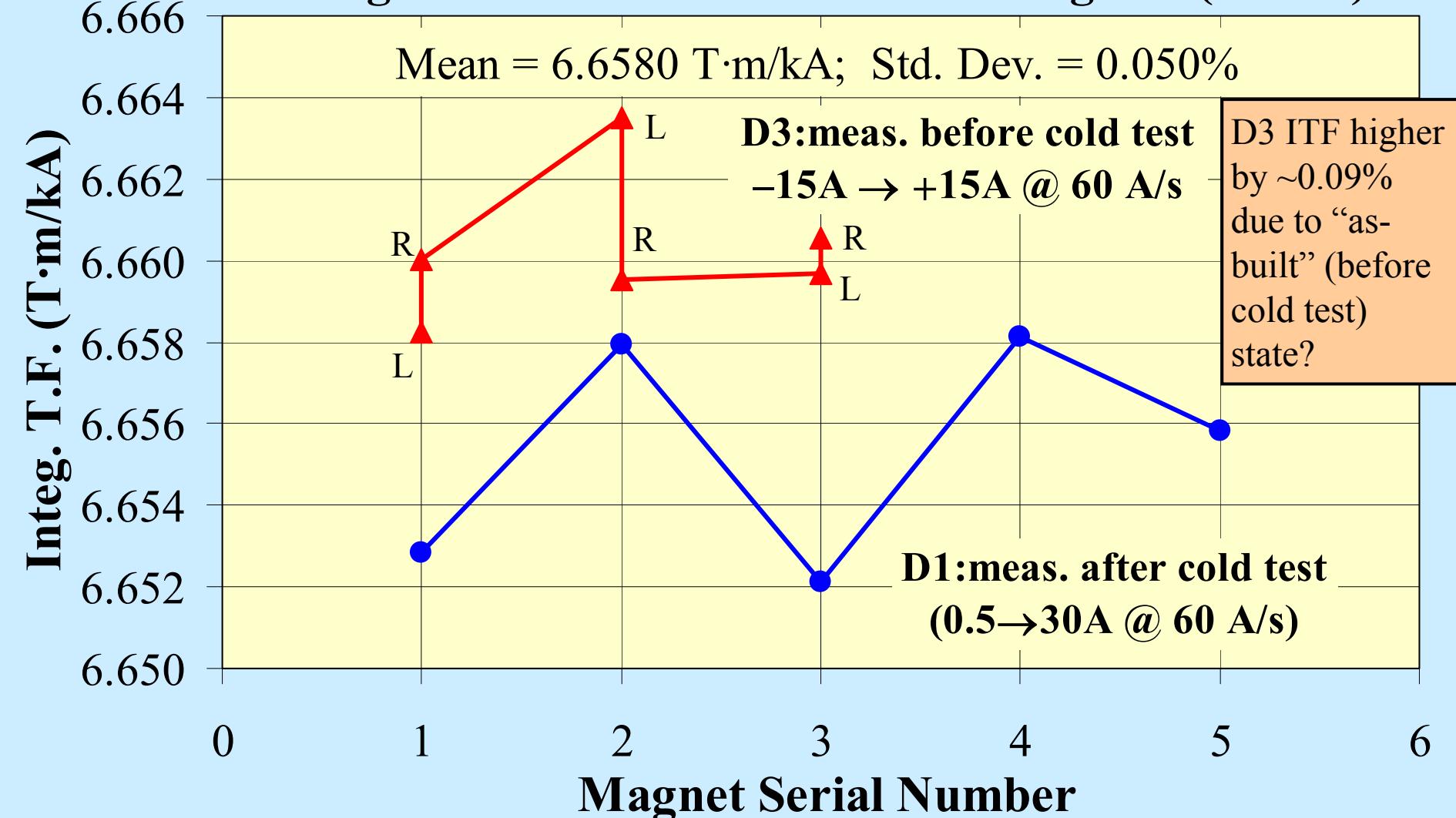
Int. Normal Harmonics in D1/D3 Magnets (Warm)



Int. Skew Harmonics in D1/D3 Magnets (Warm)



Integral Trans. Func. in D1/D3L Magnets (Warm)



Individual cold masses of D3L101 measured as D1 gave same results.

Body Transfer Func. in D1/D3L Magnets (Warm)

Body T.F. (T/kA)

0.7040
0.7039
0.7038
0.7037
0.7036
0.7035
0.7034
0.7033
0.7032

0 1 2 3 4 5 6

Magnet Serial Number

Mean = 0.7036 T/kA; Std. Dev. = 0.029%

D3

L

L/R

R

D1

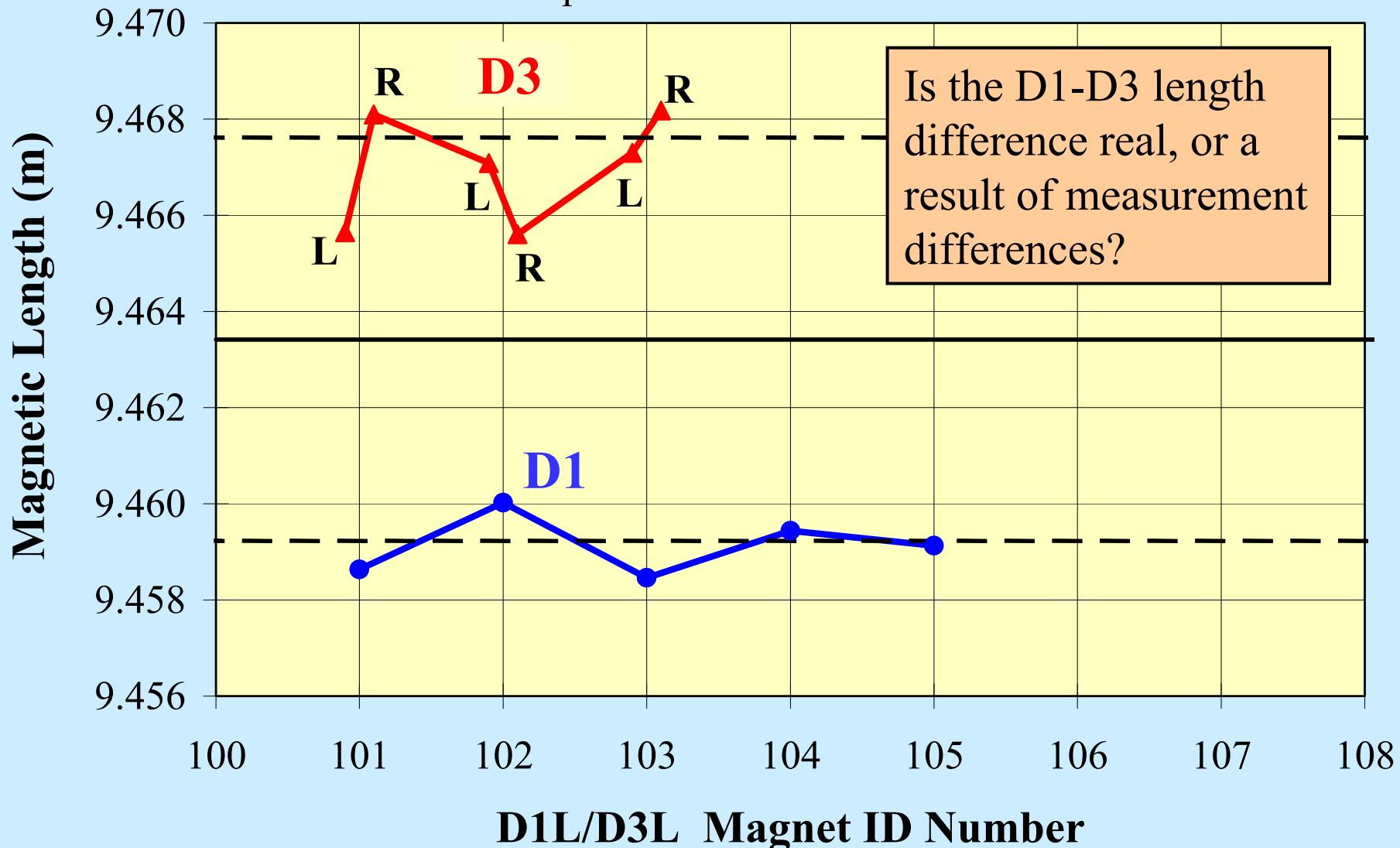
Why is D3
Body T.F. not
higher than
D1?

D3: $\pm 15\text{A}$; before cold test
D1: $\pm 20\text{A}$; after cold test

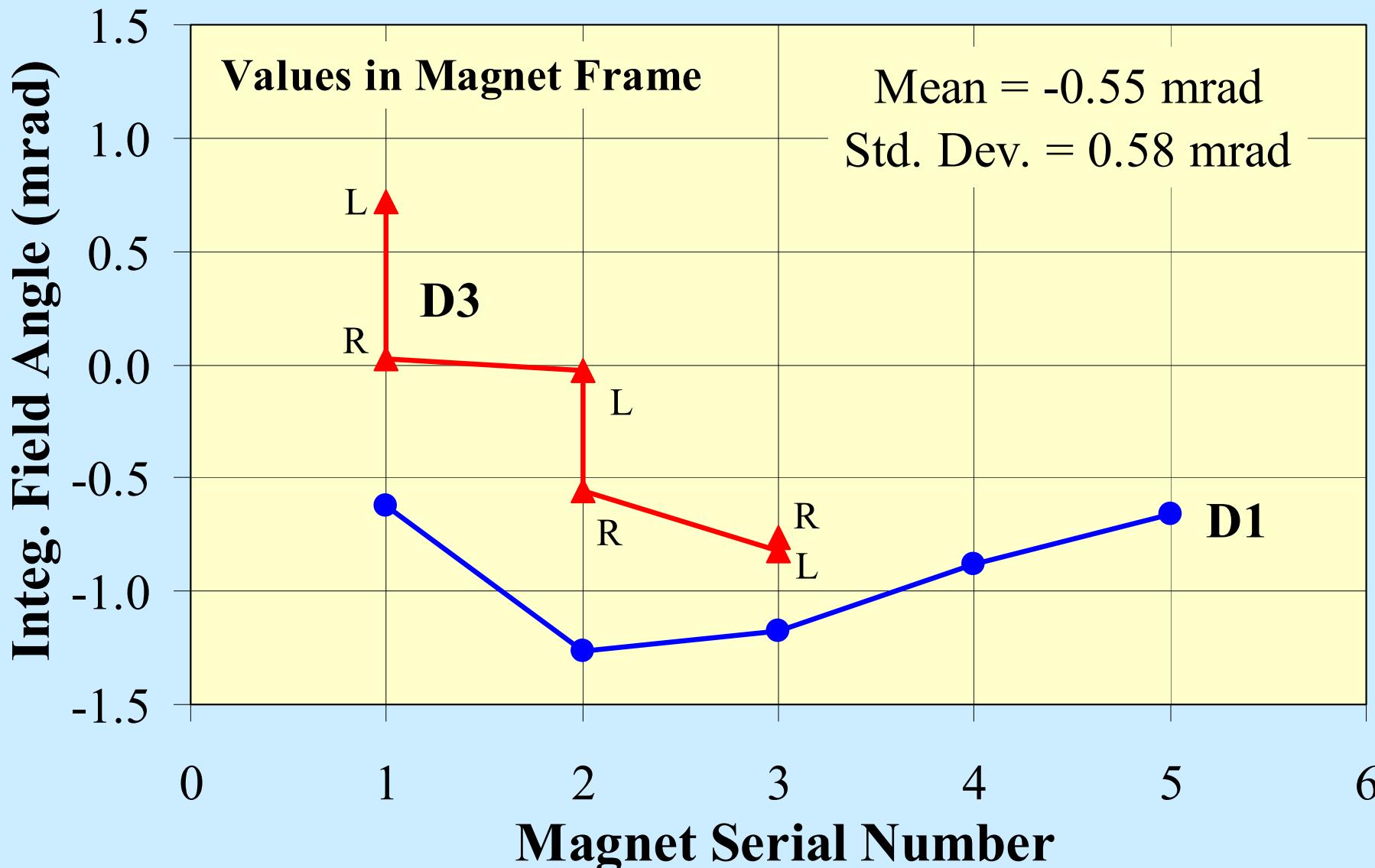
Body T.F. was not measured for individual cold mass in any D3L.

D1L/D3L Dipoles -- Magnetic Length (Warm)

11 Apertures : Mean = 9.463 STD Dev. = 0.004



Integ. Field Angle in D1/D3 Magnets (Warm)



D3L101 Vs. Mean and Standard Deviation

Integral Normal Harmonics (Warm) in units at 25 mm

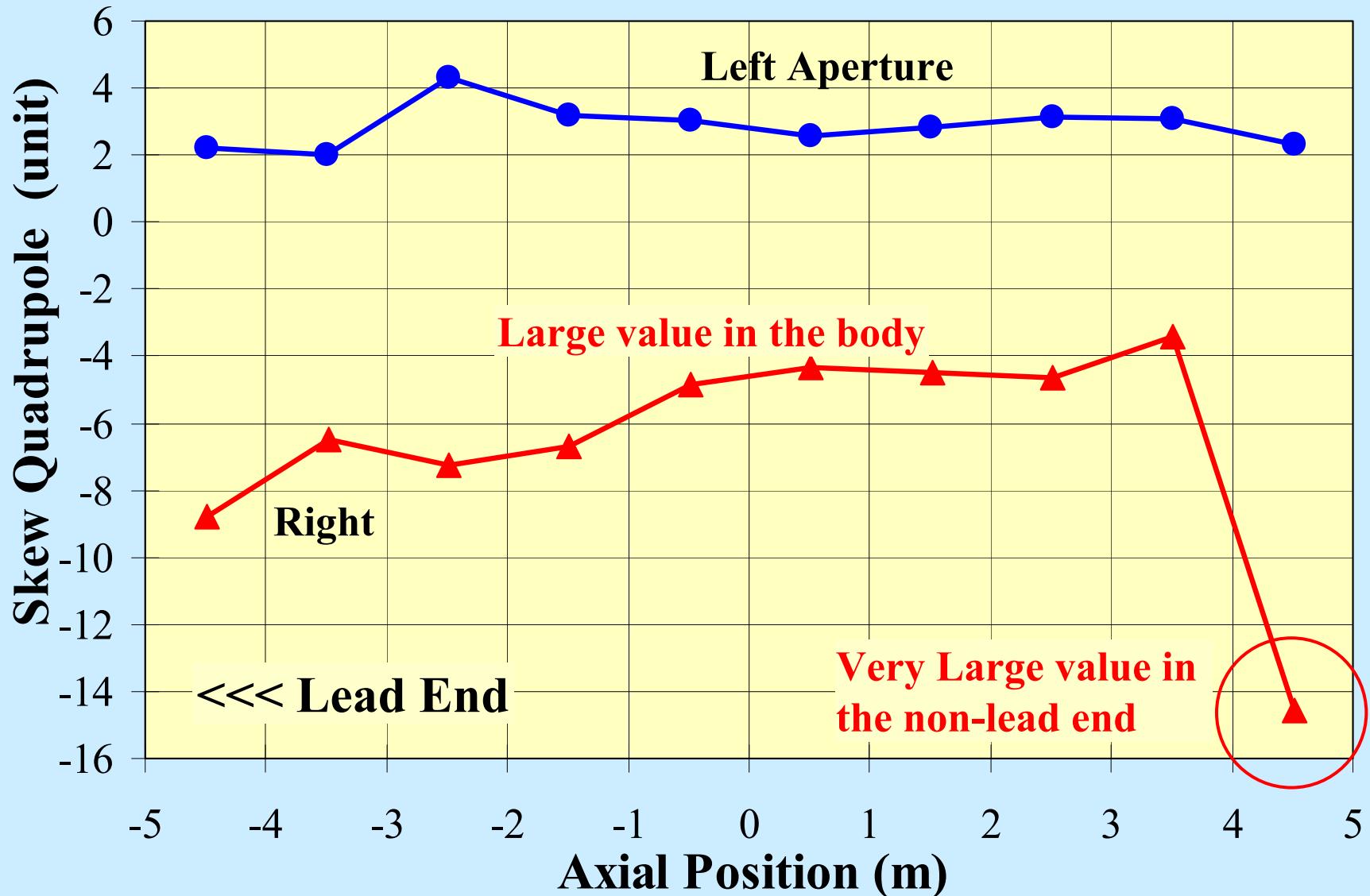
	D1L/D3L Mean	D1L/D3L Std.Dev.	D3L101(L)	No. of Sigma	D3L101(R)	No. of Sigma
I.T.F. (T.m/kA)	6.6580	0.050%	6.6583	0.1	6.6600	0.6
Quadrupole	-0.62	0.68	-1.44	-1.2	-1.33	-1.0
Sextupole	-2.94	1.70	-2.62	0.2	-3.10	-0.1
Octupole	0.01	0.17	-0.12	-0.7	-0.16	-1.0
Decapole	0.50	0.20	0.58	0.4	0.63	0.6
12-pole	-0.04	0.07	-0.02	0.2	-0.04	0.0
14-pole	0.03	0.16	0.14	0.7	0.16	0.8
16-pole	-0.01	0.02	-0.01	0.0	-0.01	0.0
18-pole	-0.10	0.03	-0.14	-1.2	-0.09	0.4
20-pole	0.00	0.02	0.00	0.2	0.01	0.6
22-pole	-0.62	0.02	-0.64	-0.7	-0.60	1.0
24-pole	0.00	0.01	0.00	0.2	0.00	-0.8
26-pole	-0.18	0.03	-0.18	0.1	-0.18	0.2

D3L101 Vs. Mean and Standard Deviation

Integral Skew Harmonics (Warm) in units at 25 mm

	D1L/D3L Mean	D1L/D3L Std.Dev.	D3L101(L)	No. of Sigma	D3L101(R)	No. of Sigma
Field Angle (mrad)	-0.49	0.63	0.72	1.9	0.02	0.8
Quadrupole	-0.93	2.61	2.90	1.5	-6.24	-2.0
Sextupole	-0.89	0.14	-0.79	0.7	-1.03	-1.0
Octupole	0.08	0.69	0.77	1.0	-0.66	-1.1
Decapole	0.20	0.07	0.18	-0.3	0.28	1.2
12-pole	0.01	0.20	-0.02	-0.1	-0.33	-1.7
14-pole	-0.11	0.03	-0.16	-1.6	-0.12	-0.4
16-pole	0.00	0.06	-0.02	-0.4	-0.10	-1.7
18-pole	0.01	0.02	-0.01	-1.1	0.01	-0.4
20-pole	0.03	0.02	0.02	-0.3	0.06	1.1
22-pole	-0.01	0.02	-0.02	-0.5	-0.02	-0.2
24-pole	0.00	0.01	0.00	-0.8	0.01	0.6
26-pole	0.00	0.01	-0.01	-0.4	0.01	1.1

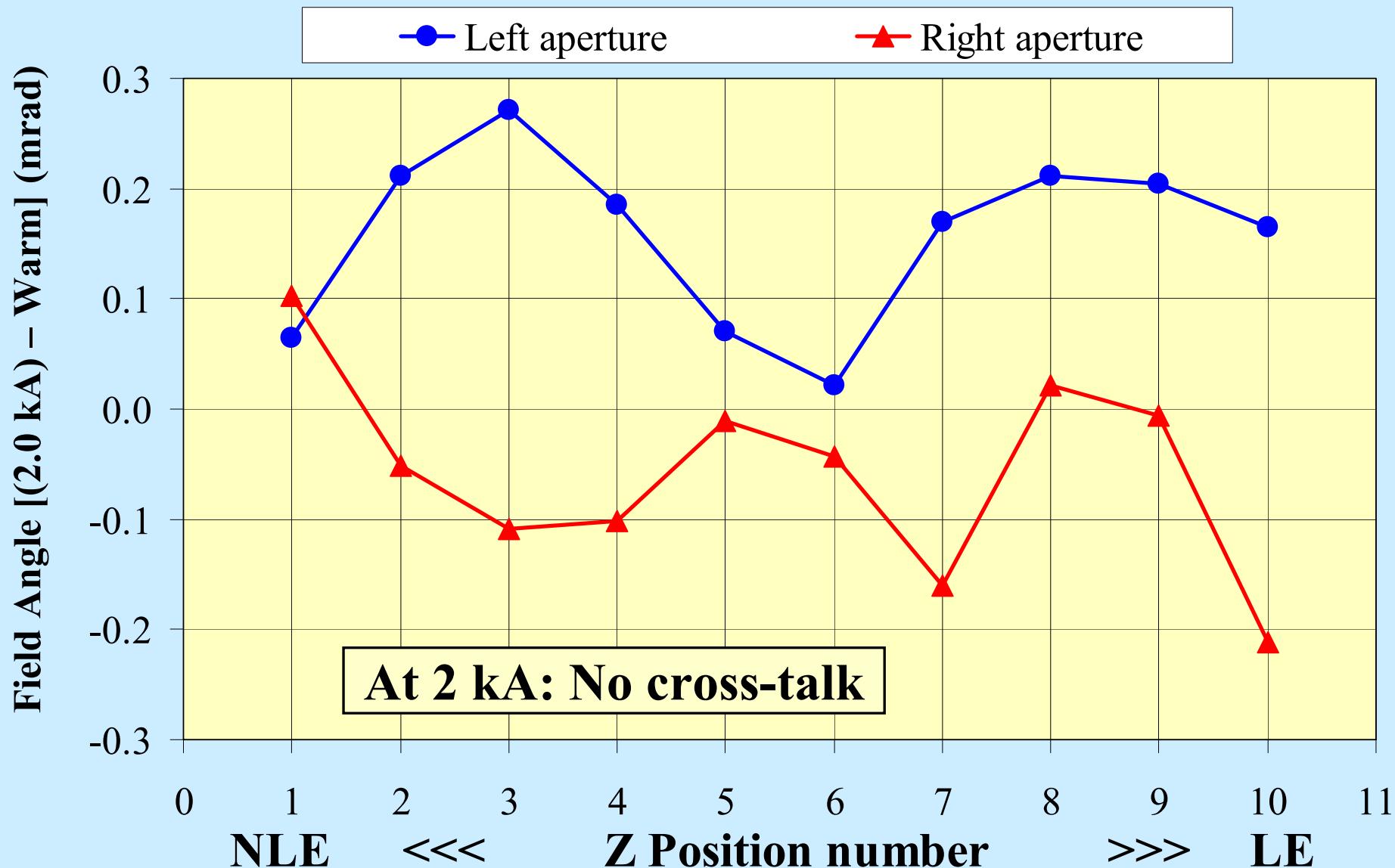
Skew Quadrupole (Warm) in D3L101



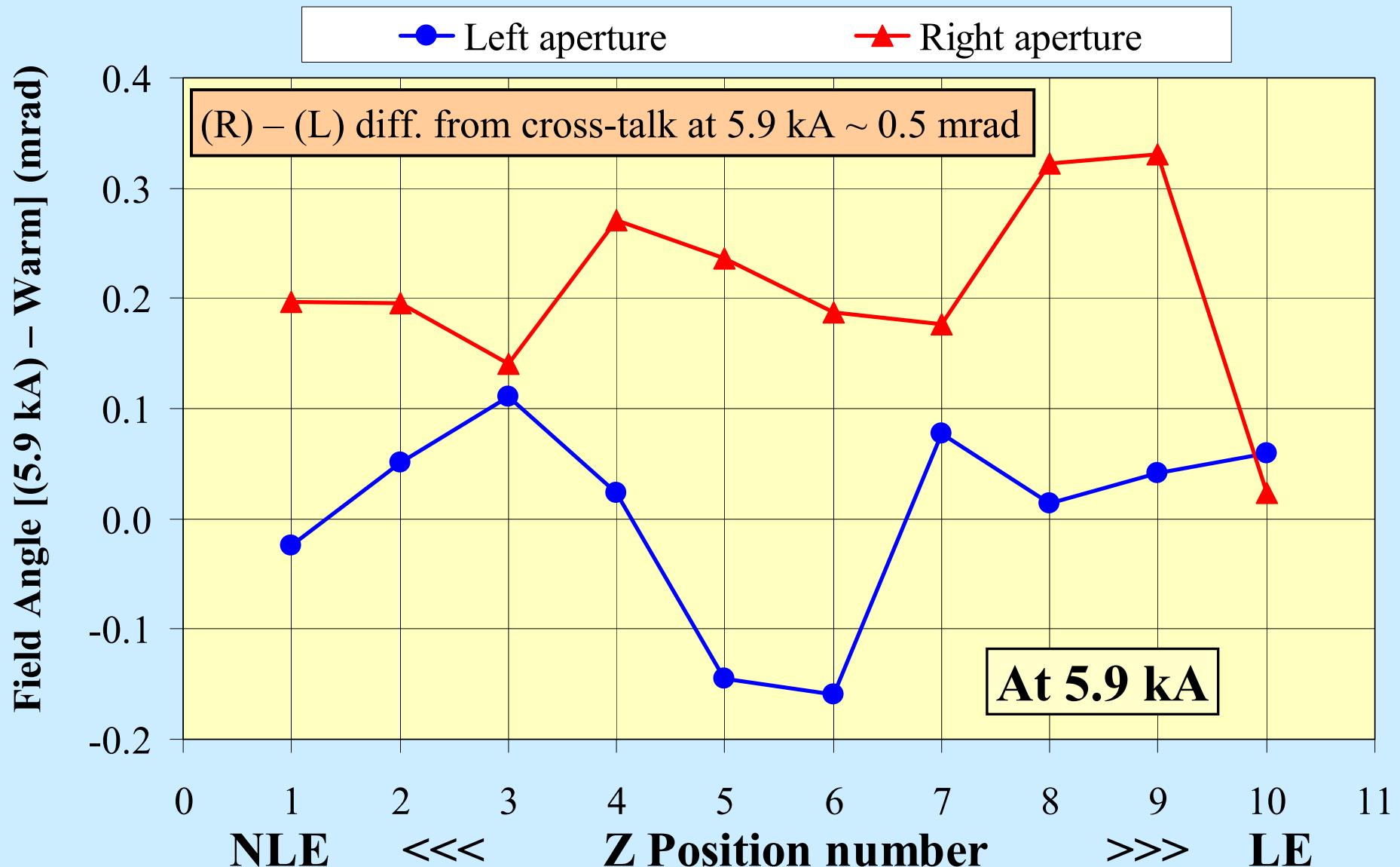
Cold Measurements

- Only a minimal set of cold measurements was done in D3L101.
- Minimal set consists of a sparse excitation curve at each of the 10 axial positions, in each aperture.
- The 19 currents in the sparse loop cover 200A to 5900A.
- The integral T.F. is obtained from Z-scan only, and can have errors of up to ~0.1%. (**Warm-cold correlations *may* help in identifying “outliers”.**)
- Down ramp measurements are done at only one position in each aperture.
- No dynamic measurements were made in D3L101.

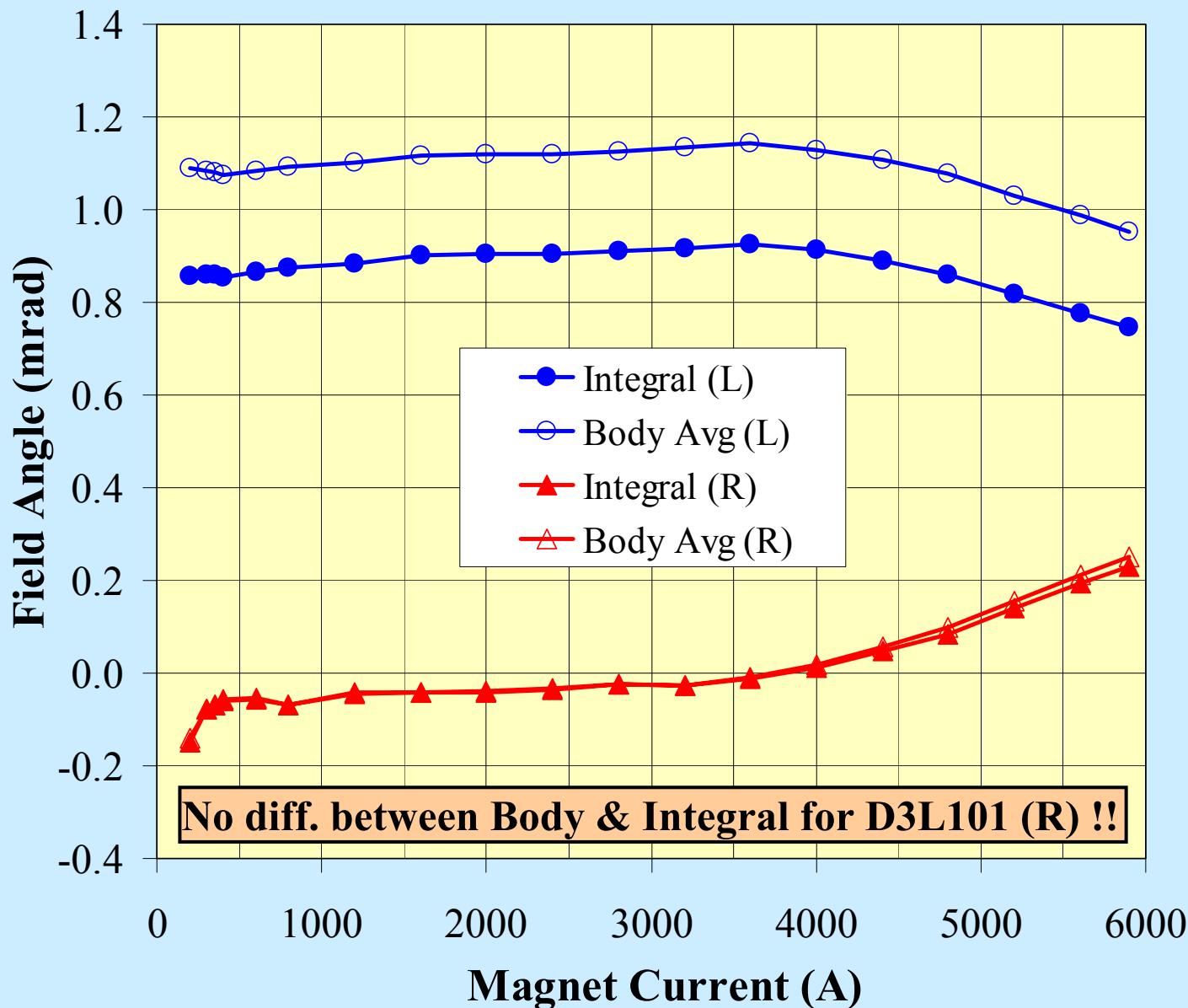
Field Angle Changes on Cool Down in D3L101



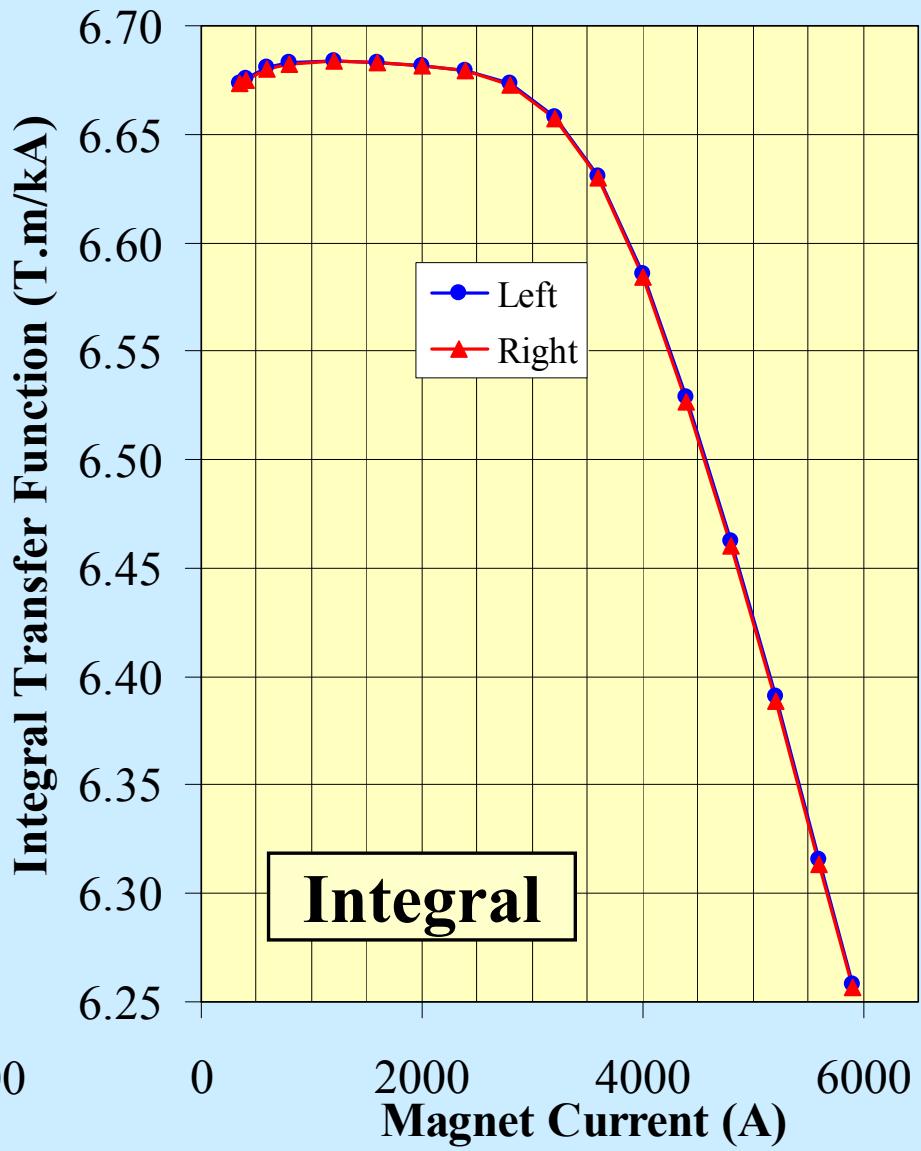
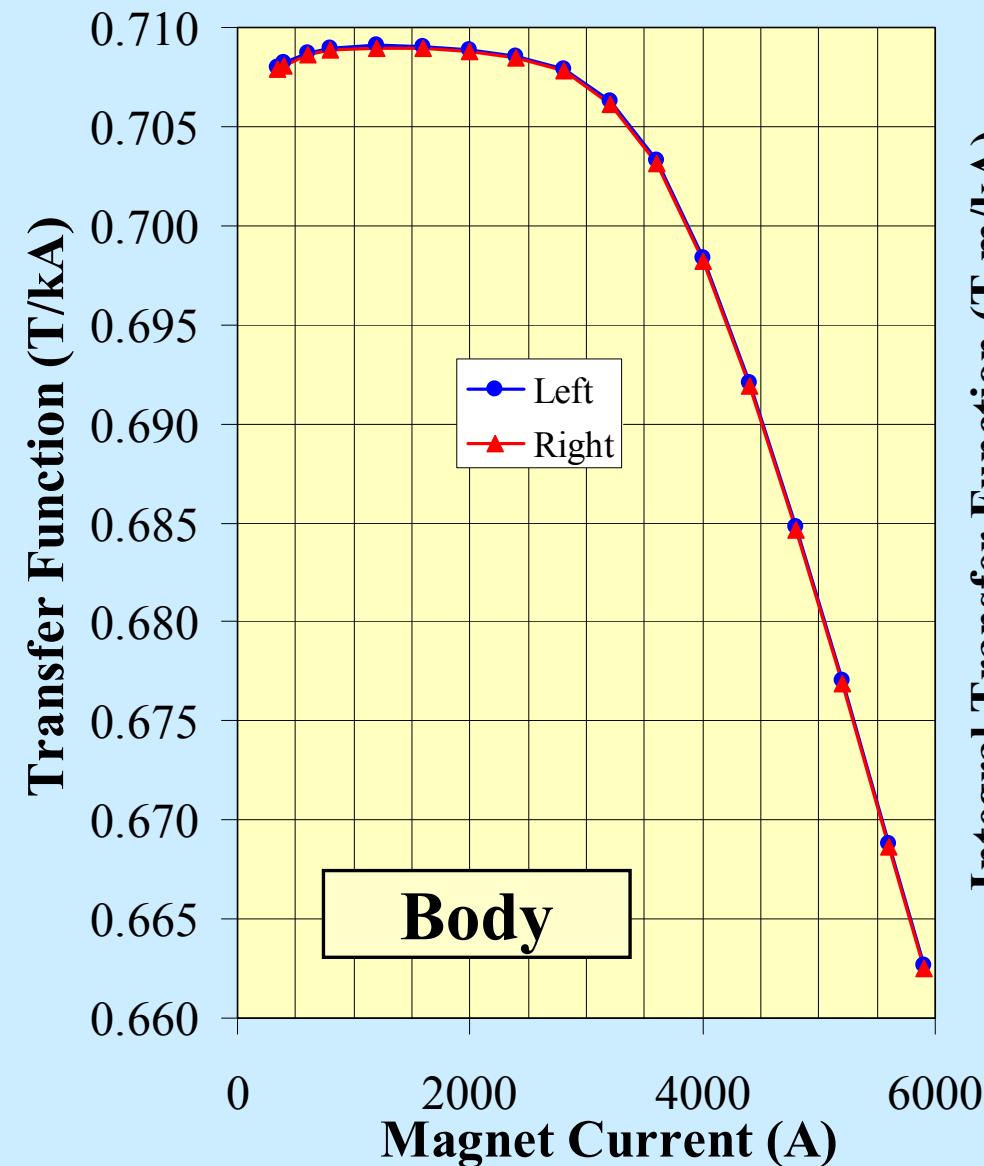
Field Angle Changes on Cool Down in D3L101



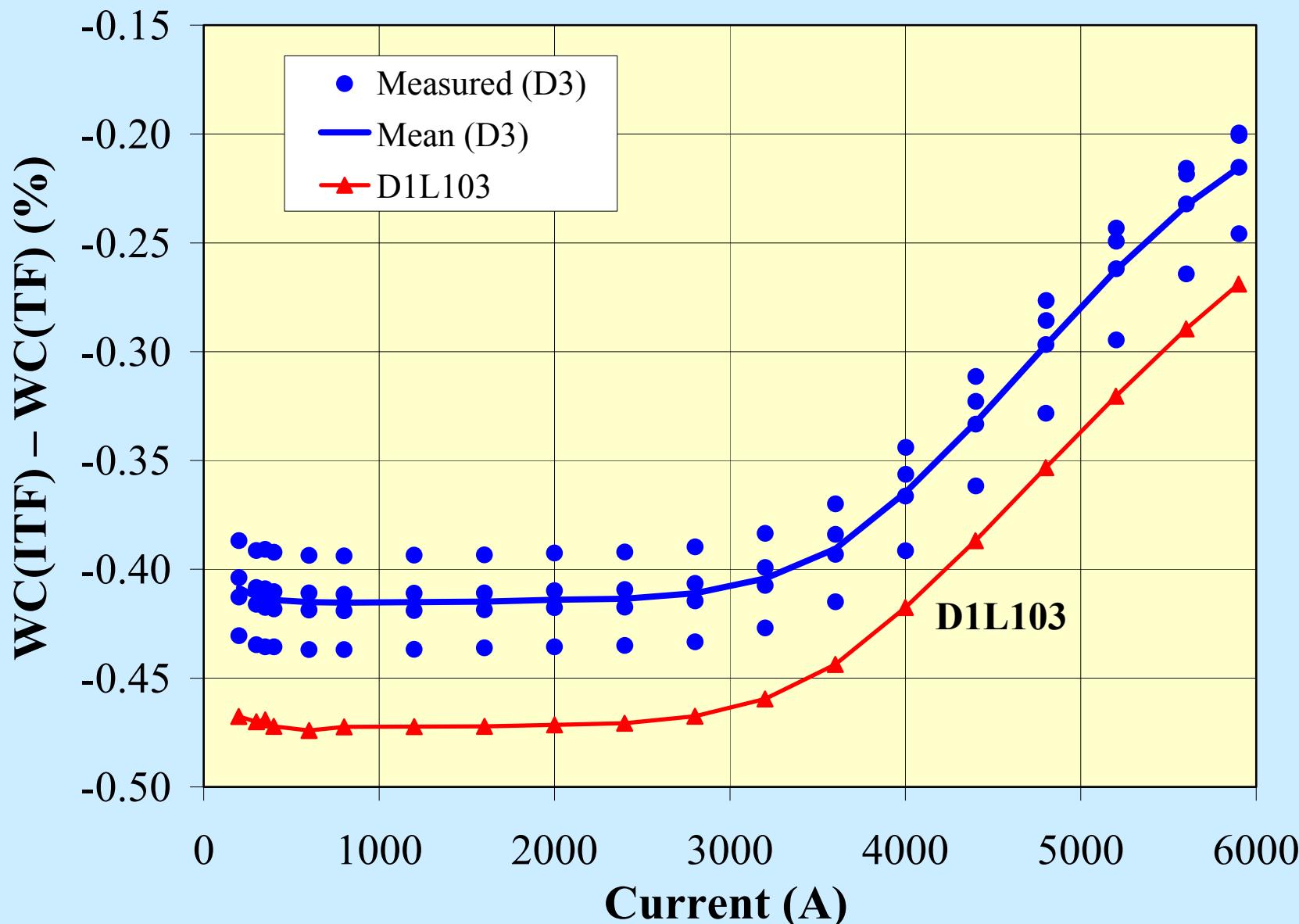
St. Section and Integral Field Angles in D3L101



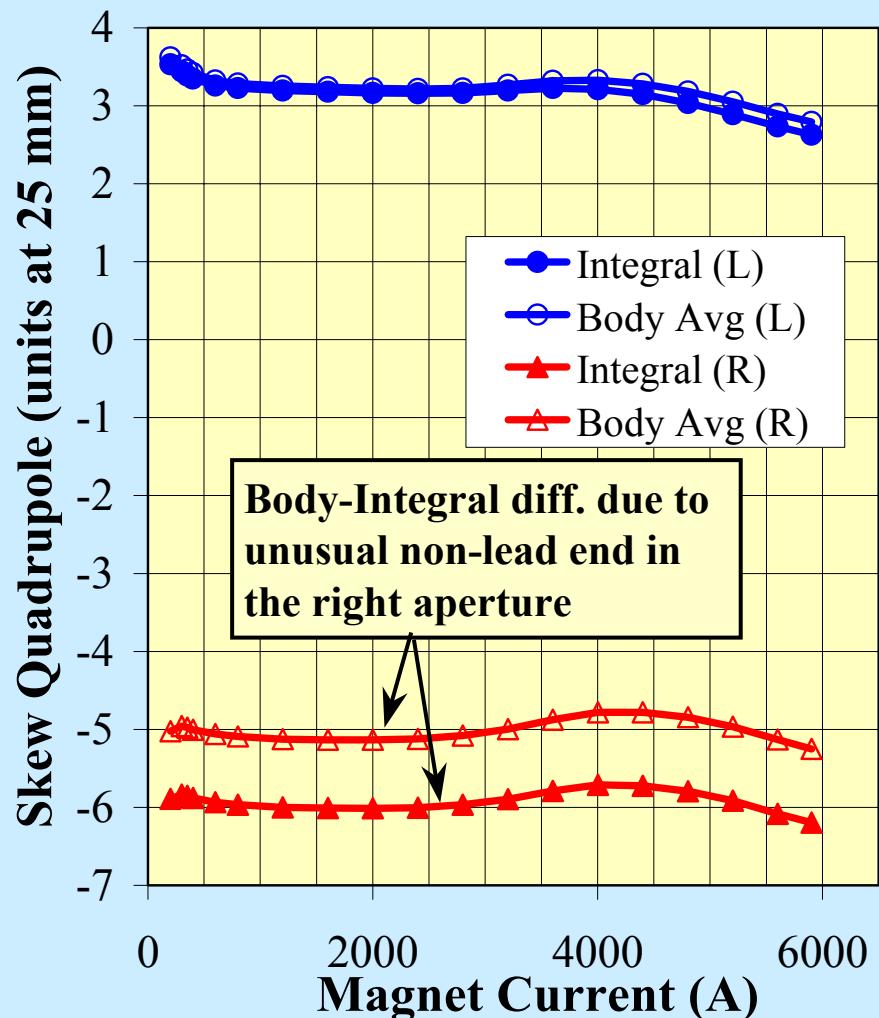
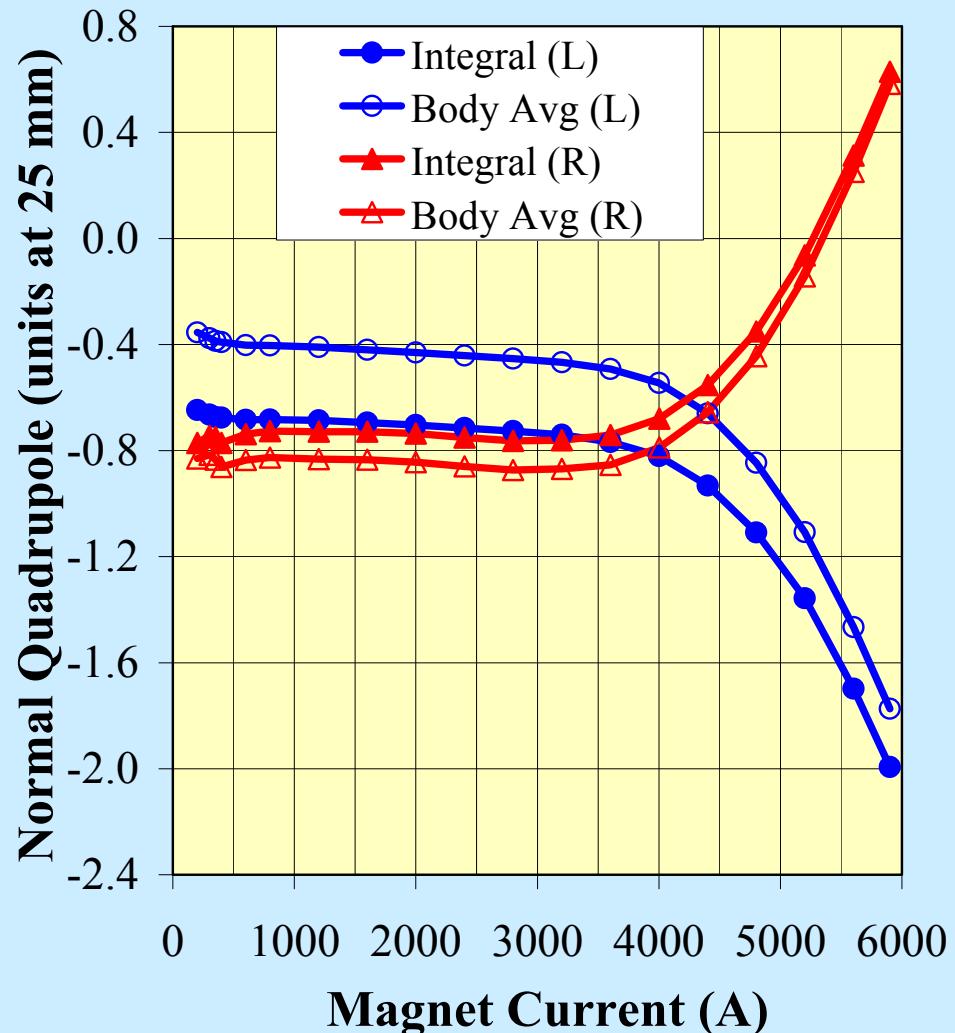
St. Section and Integral T.F. in D3L101



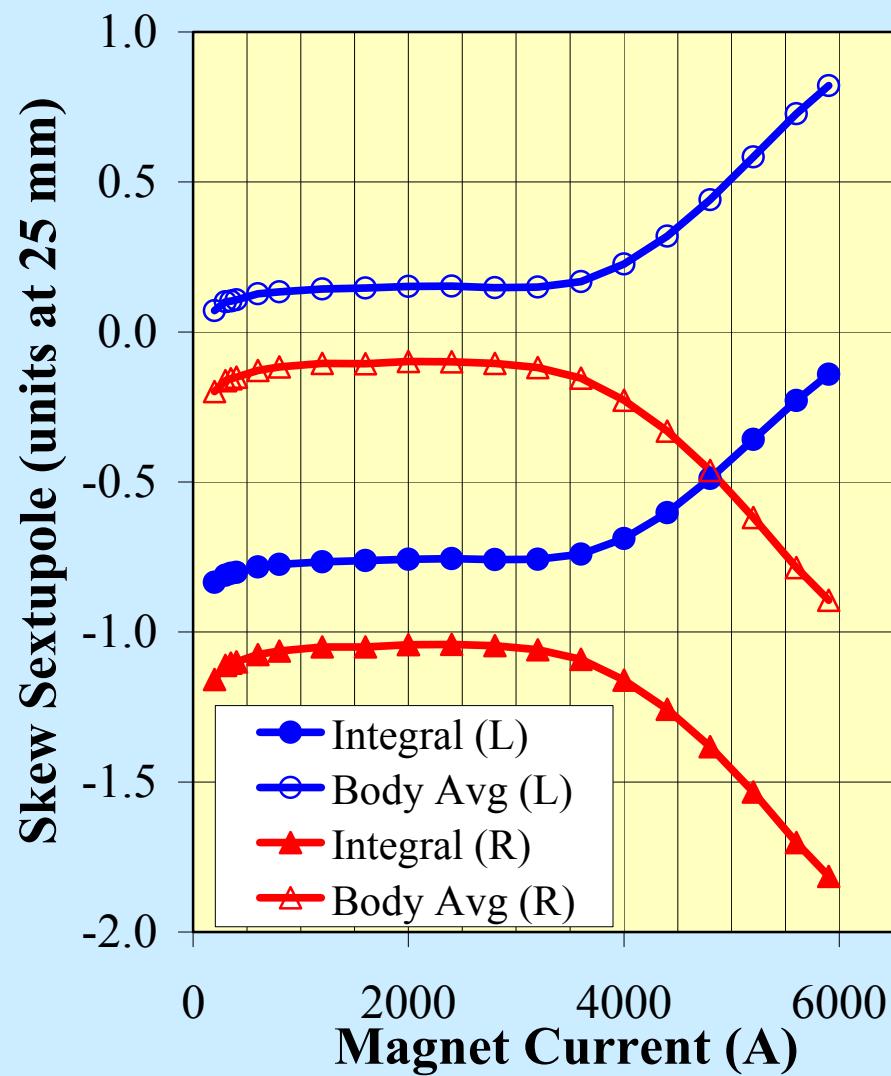
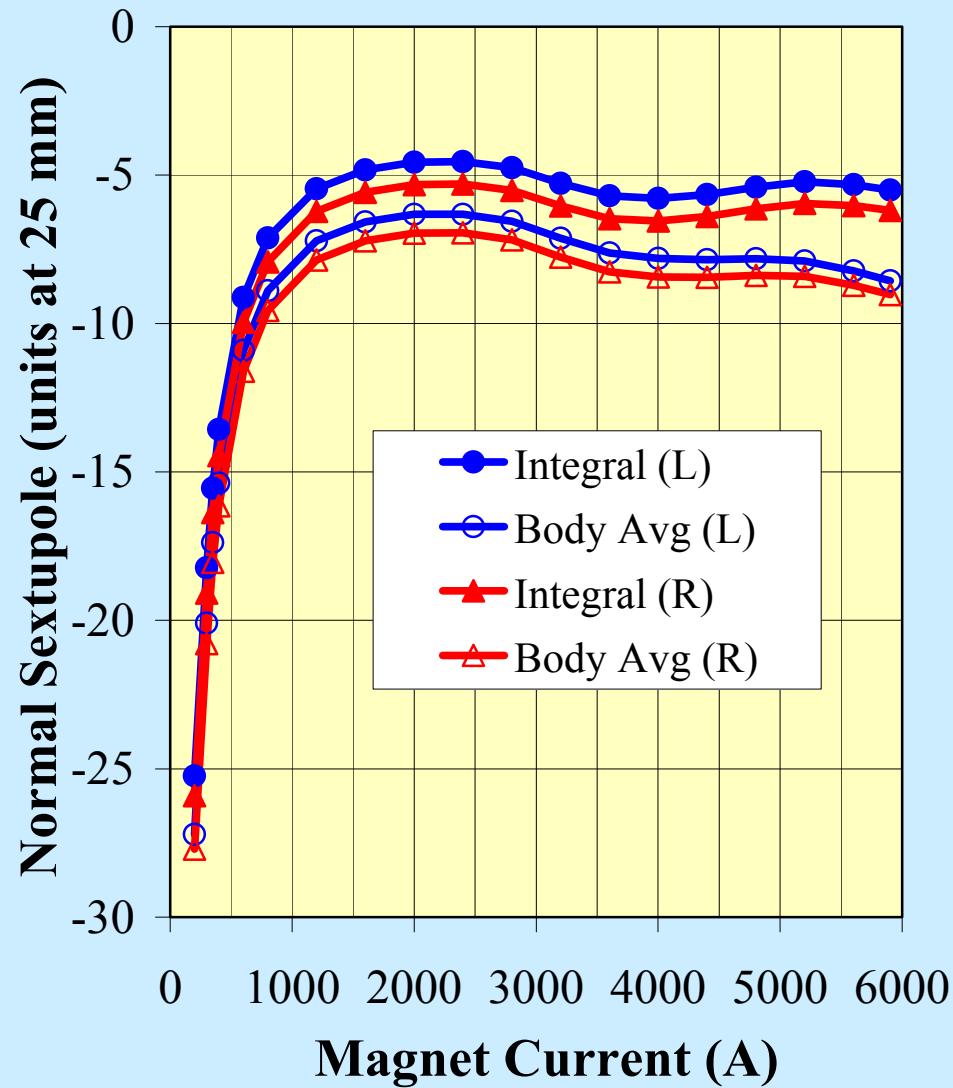
Body TF and ITF W-C Offset differences as a function of Current



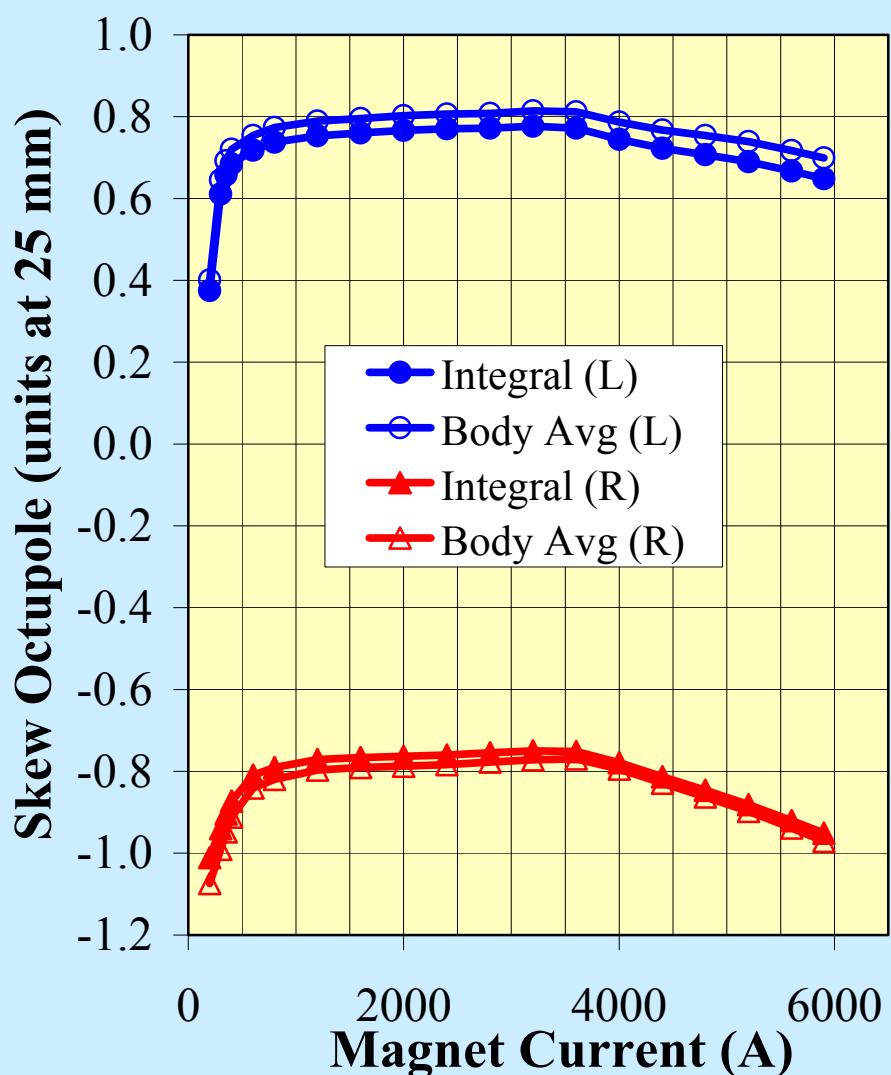
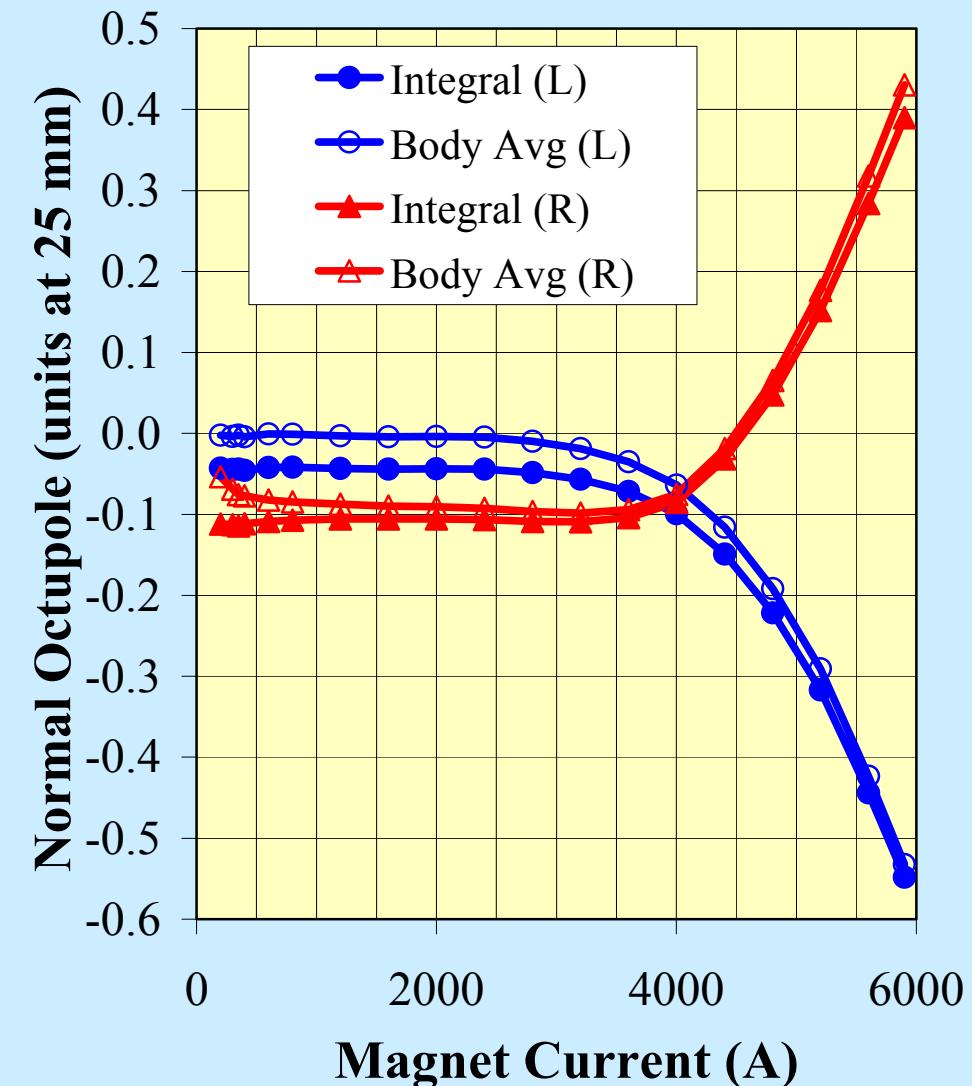
Quadrupole Terms in D3L101



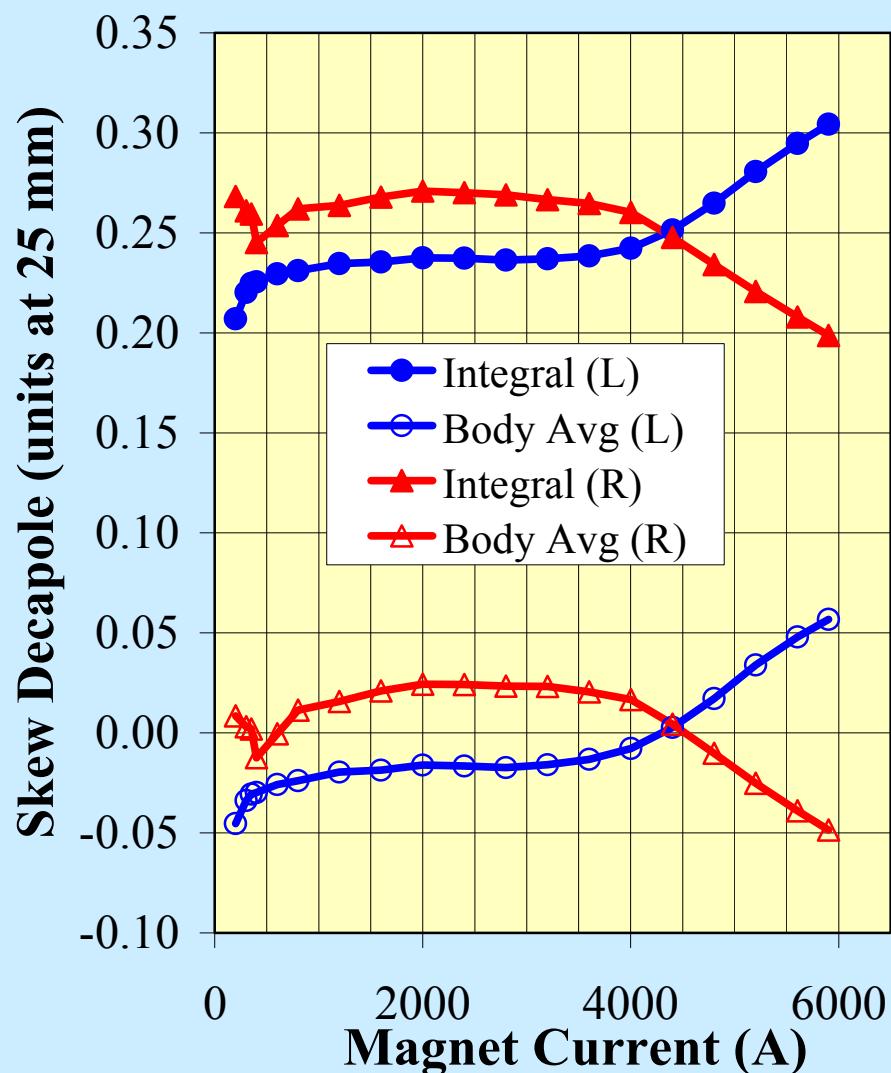
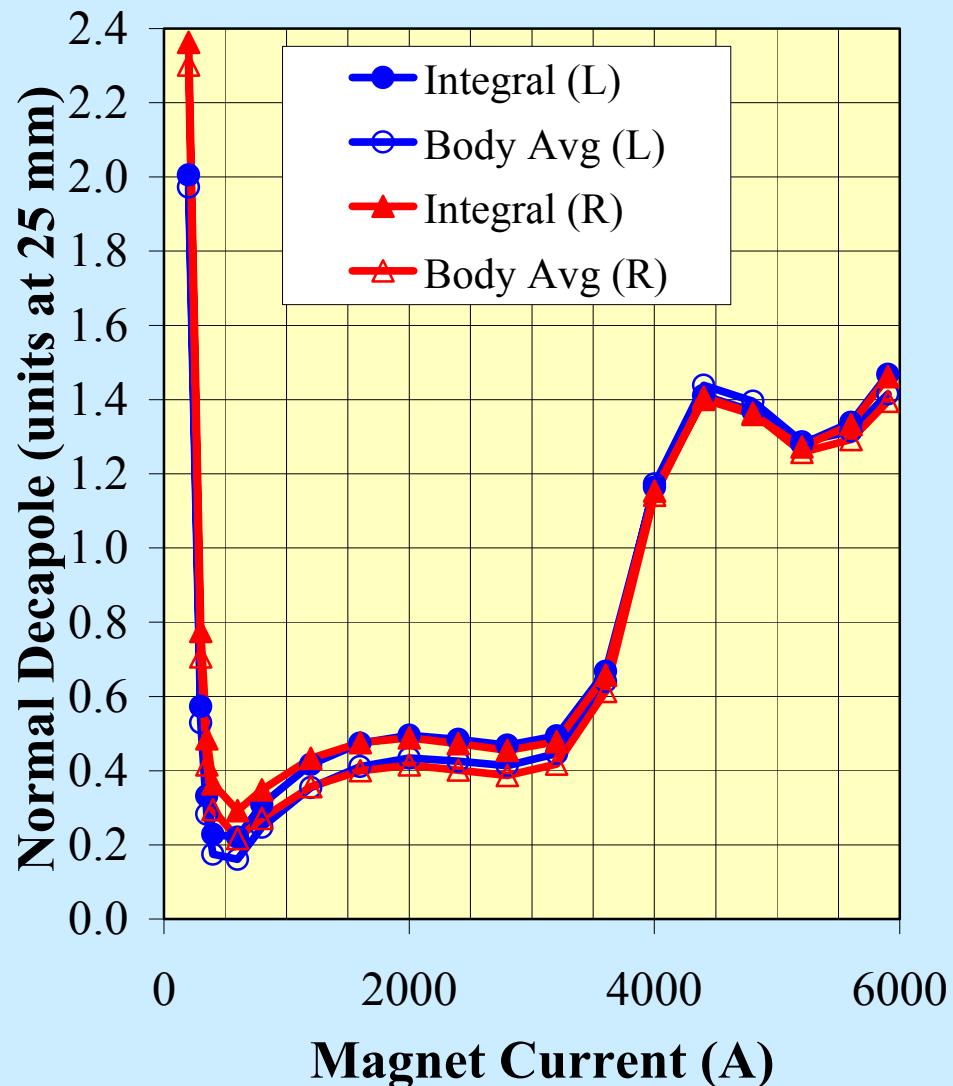
Sextupole Terms in D3L101



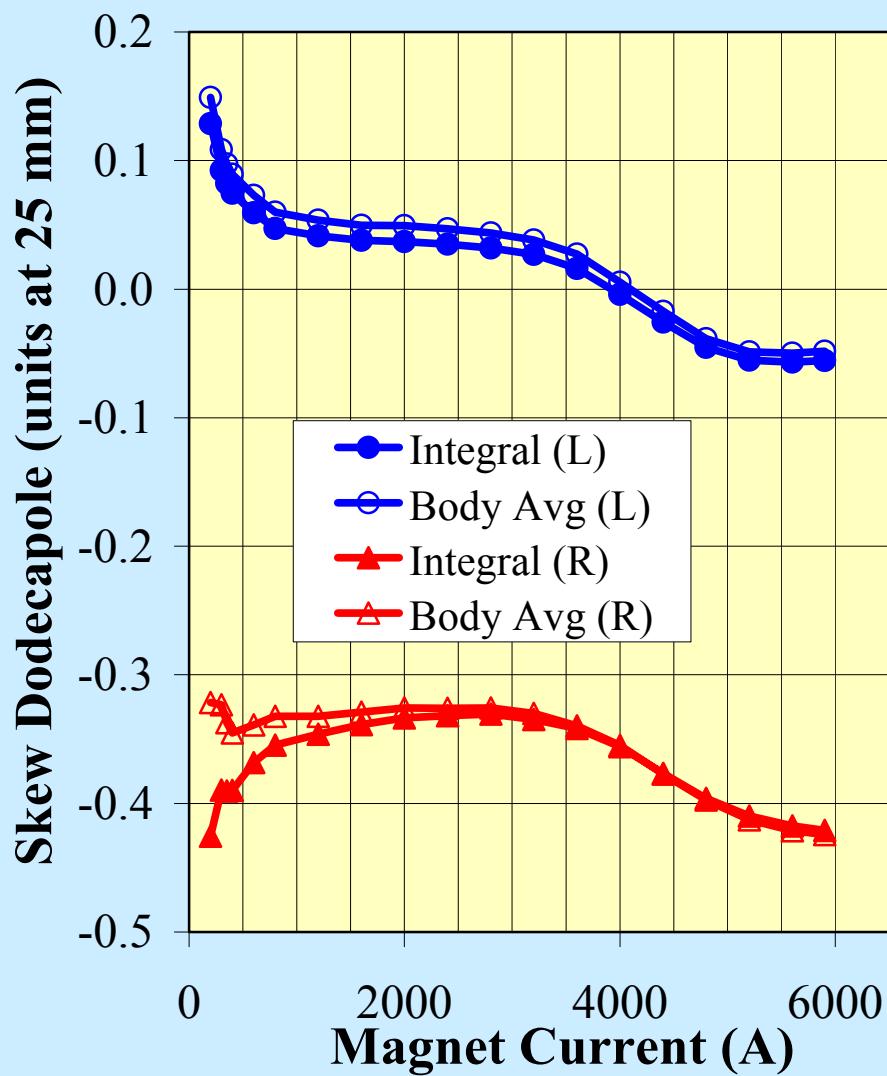
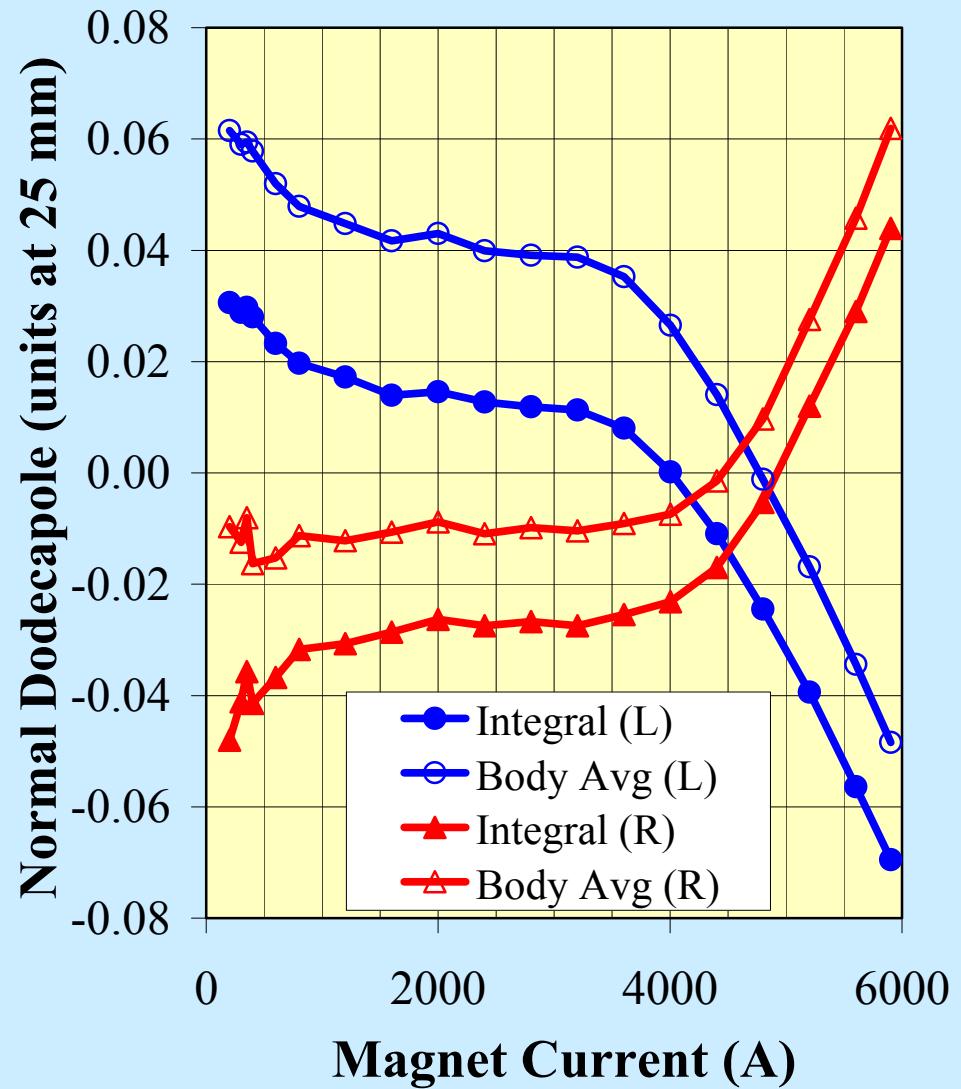
Octupole Terms in D3L101



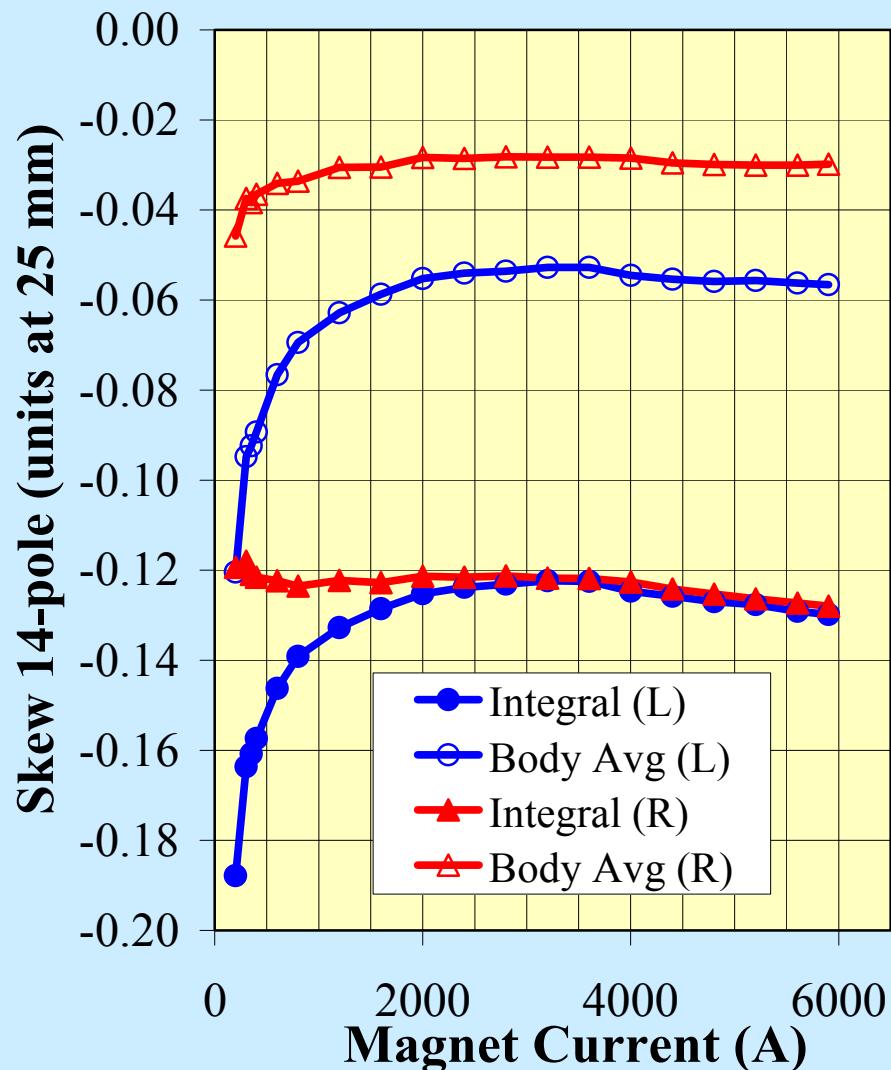
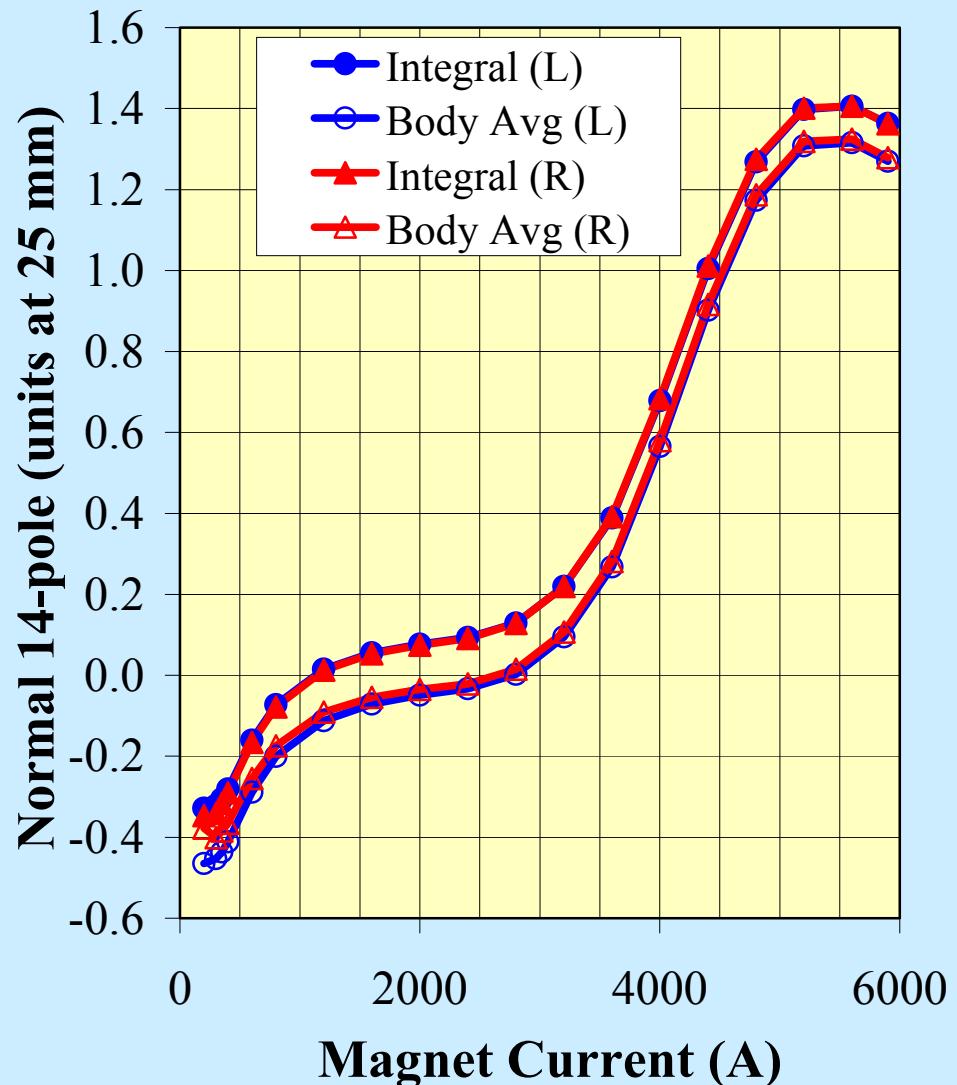
Decapole Terms in D3L101



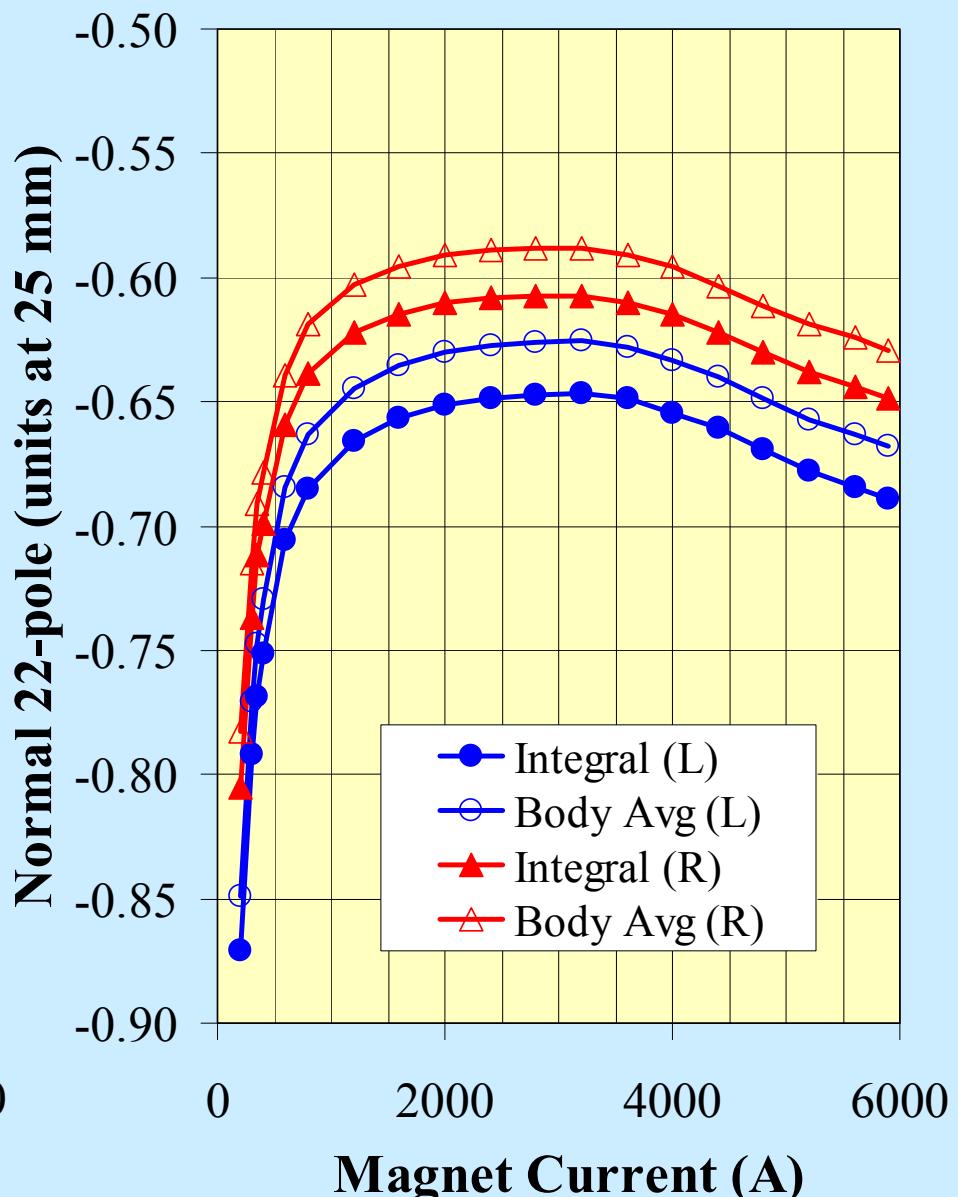
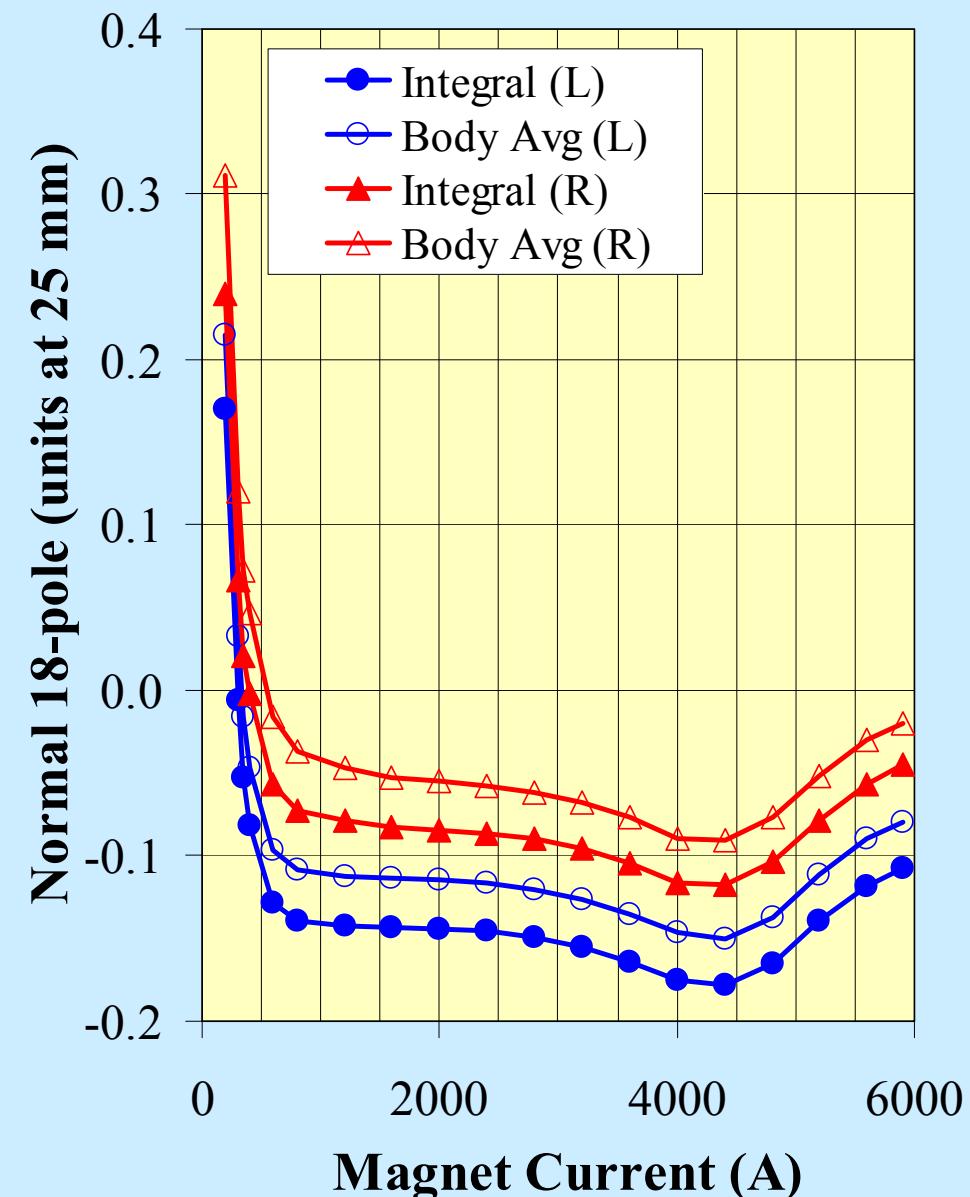
Dodecapole Terms in D3L101



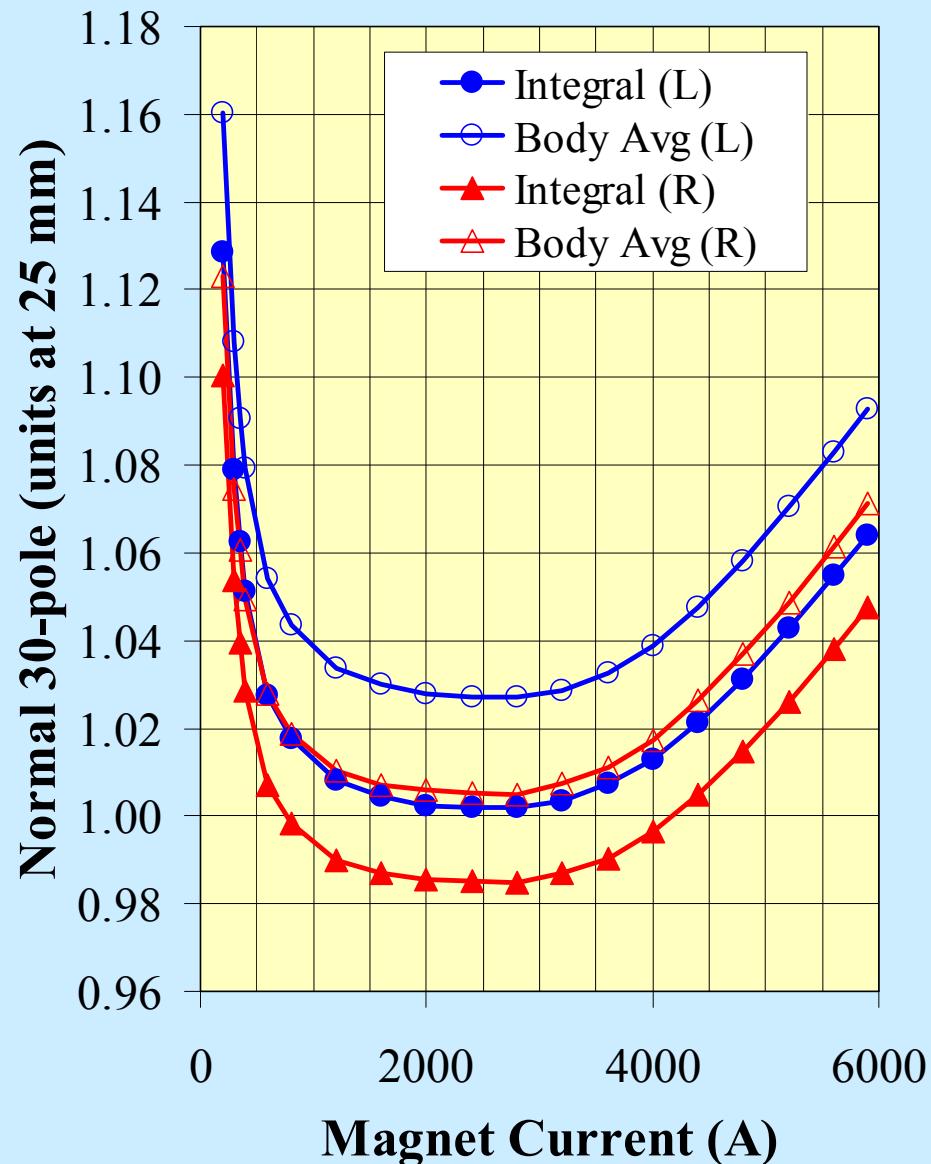
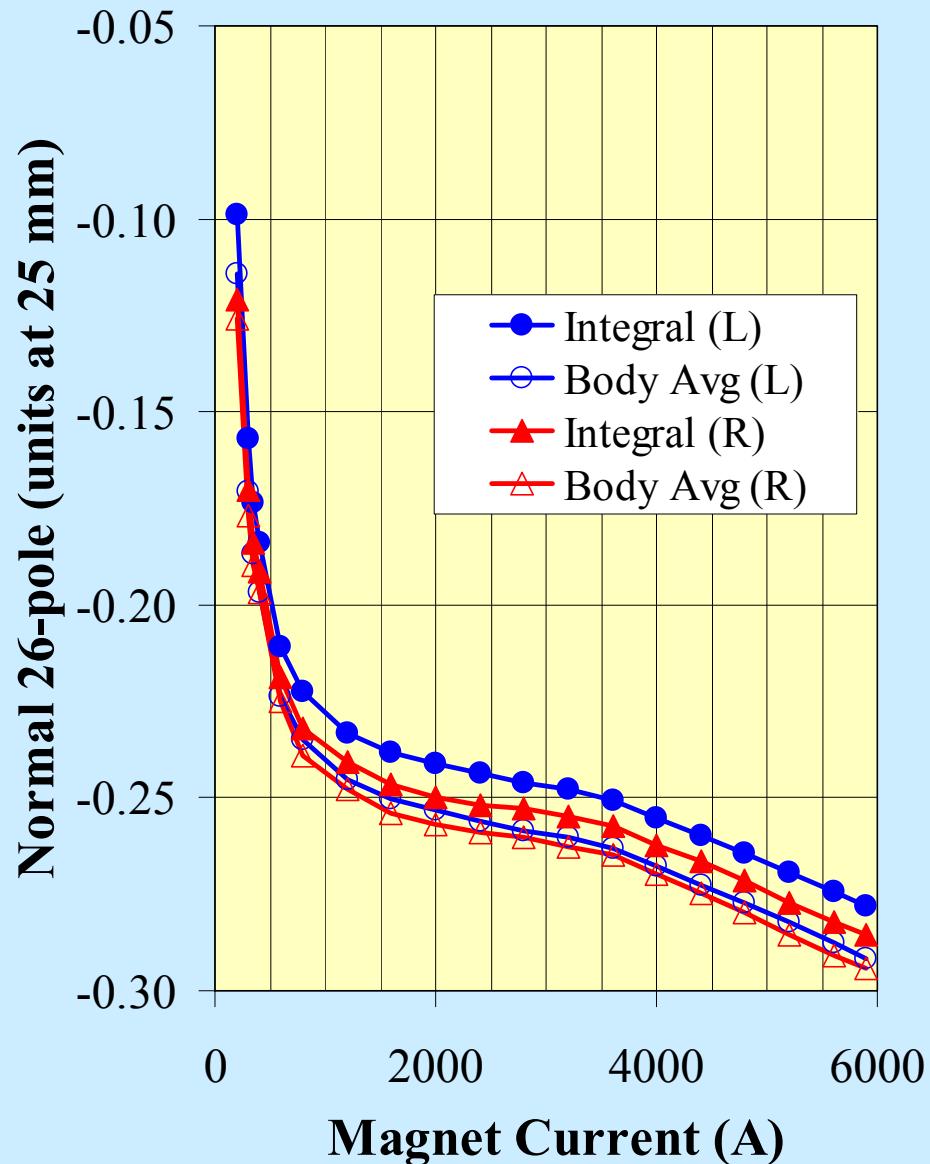
14-pole Terms in D3L101



Normal 18-pole and 22-pole Terms in D3L101



Normal 26-pole and 30-pole Terms in D3L101



Comparison of Field Quality in D3L101 with the Expected Ver 1.0 Tables

Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 300A (0.2 Tesla)

n	$\langle bn \rangle$	$\Delta(bn)$	$\sigma(bn)$	$\langle an \rangle$	$\Delta(an)$	$\sigma(an)$
2	0.11	0.77	0.28	-0.09	3.68	1.53
3	-11.26	5.52	1.95	-1.10	0.49	0.17
4	-0.05	0.20	0.08	0.12	1.15	0.42
5	0.62	0.83	0.40	0.18	0.16	0.06
6	-0.01	0.08	0.03	-0.03	0.54	0.15
7	-0.27	0.21	0.10	-0.09	0.07	0.02
8	-0.03	0.03	0.01	-0.01	0.15	0.05
9	0.14	0.13	0.04	0.02	0.03	0.01
10	0.03	0.05	0.02	0.02	0.05	0.02
11	-0.66	0.04	0.02	-0.01	0.02	0.01

Measured Data in D3L101 & Ver 1.0 Comparison

Integral; 0.2 Tesla (interpolated) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	-0.66	-0.75	3.46	-5.85
3	-19.44	-20.26	-0.82	-1.12
4	-0.04	-0.11	0.57	-0.95
5	0.82	1.05	0.22	0.26
6	0.03	-0.04	0.10	-0.40
7	-0.32	-0.34	-0.17	-0.12
8	-0.03	-0.01	0.01	-0.11
9	0.02	0.10	0.04	0.02
10	0.00	0.02	0.10	0.12
11	-0.81	-0.75	0.00	-0.01

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	OK	OK	OK	??
3	??	??	OK	OK
4	OK	OK	OK	OK
5	OK	OK	OK	OK
6	OK	OK	OK	OK
7	OK	OK	OK	OK
8	OK	OK	OK	OK
9	OK	OK	OK	OK
10	OK	OK	??	??
11	??	??	OK	OK

Ver.1.0 known issues: Systematic b3 difference from RHIC production; No cross-talk at high field included for D3.

Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 3.8 Tesla (5700 A)

n	$\langle bn \rangle$	$\Delta(bn)$	$\sigma(bn)$	$\langle an \rangle$	$\Delta(an)$	$\sigma(an)$
2	0.25	0.79	0.28	0.54	3.71	1.51
3	-1.71	3.57	1.70	-1.31	0.55	0.18
4	0.07	0.21	0.08	0.06	1.08	0.41
5	0.24	0.80	0.39	0.16	0.17	0.06
6	-0.12	0.10	0.04	-0.05	0.55	0.16
7	1.17	0.19	0.10	-0.11	0.06	0.02
8	-0.02	0.03	0.01	-0.01	0.15	0.05
9	0.01	0.12	0.04	0.01	0.03	0.01
10	0.04	0.05	0.02	0.04	0.04	0.02
11	-0.60	0.04	0.02	-0.01	0.01	0.01

Measured Data in D3L101 & Ver 1.0 Comparison

Integral; 3.8 Tesla (interpolated) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	-1.80	0.42	2.70	-6.12
3	-5.38	-6.09	-0.20	-1.74
4	-0.48	0.32	0.66	-0.93
5	1.38	1.38	0.30	0.20
6	-0.06	0.03	-0.06	-0.42
7	1.39	1.39	-0.13	-0.13
8	-0.01	-0.01	0.01	-0.11
9	-0.11	-0.05	0.01	0.02
10	0.01	0.01	0.09	0.09
11	-0.69	-0.65	-0.02	-0.01

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	??	OK	OK	??
3	OK	OK	??	OK
4	??	OK	OK	OK
5	OK	OK	OK	OK
6	OK	??	OK	OK
7	OK	OK	OK	OK
8	OK	OK	OK	OK
9	OK	OK	OK	OK
10	OK	OK	OK	OK
11	??	OK	OK	OK

OK=Value between ($\text{mean} - \Delta - \sigma$) & ($\text{mean} + \Delta + \sigma$)