

Summary of Field Quality Data in D4L102

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Warm Measurements

- Warm measurements have been completed in all the nine D2 and the three D4 dipoles.
- Harmonics are measured with 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. The survey data are used to express field angles in the magnet frame.
- Integral transfer function is measured with a non-rotating, 10-meter long coil.
- All warm measurements are done before cold test.

D4L102 Vs. Mean and Standard Deviation Integral Normal Harmonics (Warm) at 25 mm

	Left Aperture				Right Aperture			
	D2L/D4L Mean	D2L/D4L Std.Dev.	4102(L)	No. of Sigma	D2L/D4L Mean	D2L Std.Dev	4102(R)	No. of Sigma
I.T.F. (T.m/kA)	5.9569	0.043%	5.9587	0.7	5.9569	0.043%	5.9606	1.4
Quadrupole*	-5.34	0.61	-4.33	1.7	5.13	0.61	4.95	-0.3
Sextupole	-3.22	1.31	-3.20	0.0	-3.22	1.31	-2.81	0.3
Octupole	0.10	0.16	0.14	0.2	0.10	0.16	0.19	0.6
Decapole	0.62	0.39	0.76	0.4	0.62	0.39	0.93	0.8
12-pole	-0.01	0.06	0.09	1.5	-0.01	0.06	-0.03	-0.3
14-pole	0.06	0.09	0.14	0.9	0.06	0.09	0.10	0.5
16-pole	0.00	0.02	0.03	1.0	0.00	0.02	-0.02	-0.8
18-pole	-0.14	0.03	-0.16	-0.6	-0.14	0.03	-0.14	-0.1
20-pole	0.00	0.01	0.01	1.1	0.00	0.01	-0.01	-0.5
22-pole	-0.64	0.02	-0.63	0.2	-0.64	0.02	-0.61	1.9
24-pole	0.00	0.01	0.00	0.1	0.00	0.01	-0.01	-2.0
26-pole	-0.26	0.01	-0.25	0.9	-0.26	0.01	-0.24	1.0

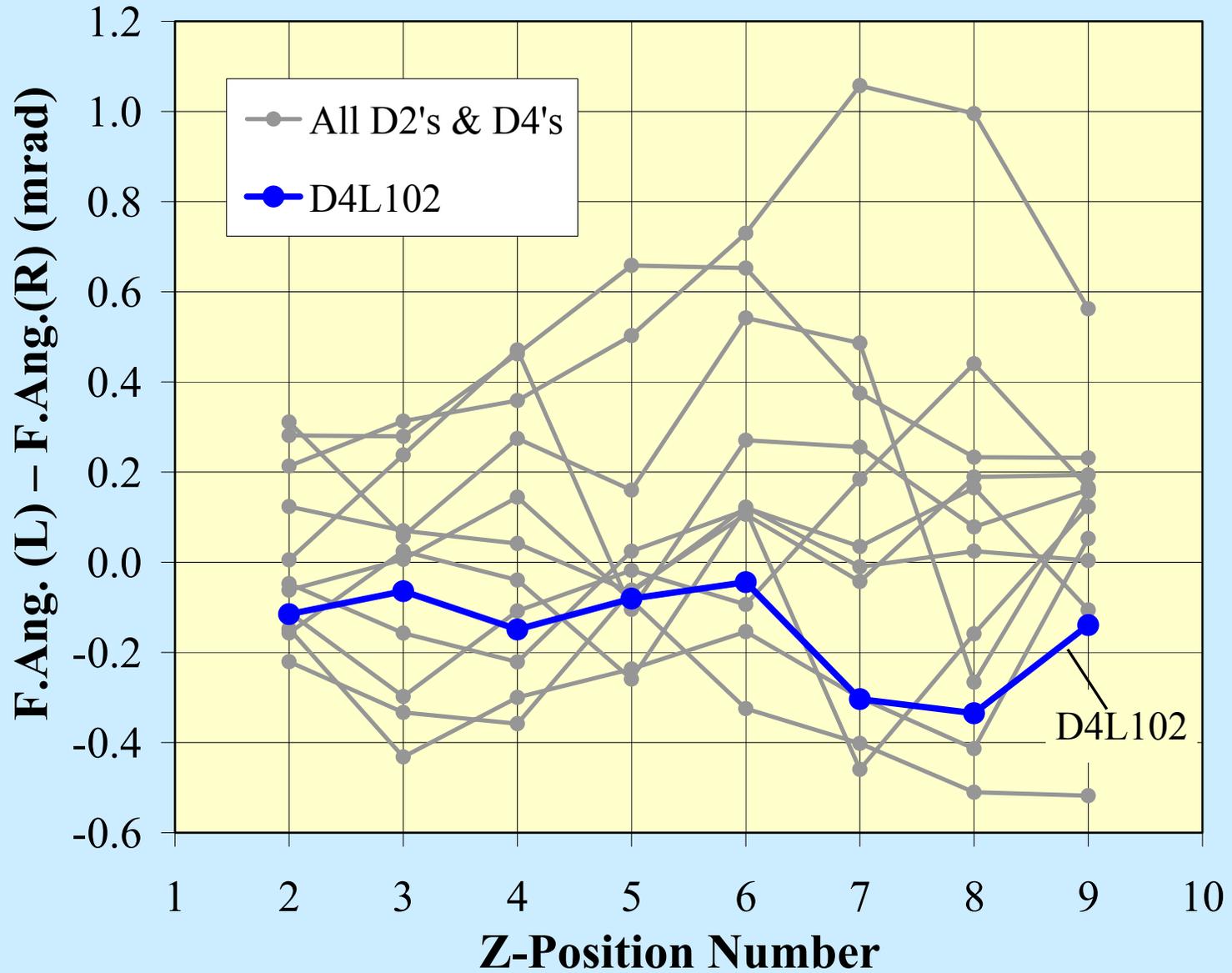
* Mean values of the normal quadrupole term are treated as aperture dependent.
All other terms are considered aperture independent.

D4L102 Vs. Mean and Standard Deviation Integral Skew Harmonics (Warm) at 25 mm

	D2L/D4L Mean	D2L/D4L Std.Dev.	4102(L)	No. of Sigma	4102(R)	No. of Sigma
Fld. Angle (mrad)	-0.60	0.22	-0.54	0.3	-0.40	0.9
Quadrupole	0.05	1.90	0.51	0.2	-2.18	-1.2
Sextupole	-0.98	0.38	-0.34	1.7	-0.59	1.1
Octupole	0.16	0.61	0.74	0.9	-0.40	-0.9
Decapole	0.18	0.12	0.39	1.7	0.19	0.1
12-pole	0.03	0.17	0.19	0.9	-0.12	-0.9
14-pole	-0.09	0.03	-0.06	0.8	-0.06	0.8
16-pole	0.01	0.04	0.00	-0.4	0.05	0.8
18-pole	0.03	0.02	0.03	0.1	0.05	1.8
20-pole	0.02	0.02	-0.01	-1.9	0.02	0.4
22-pole	0.00	0.01	0.00	0.5	-0.01	-1.6
24-pole	0.01	0.01	0.00	-0.8	0.00	-0.5
26-pole	0.00	0.01	0.01	0.2	-0.01	-1.2

Field angles are as measured on test stand wrt gravity.

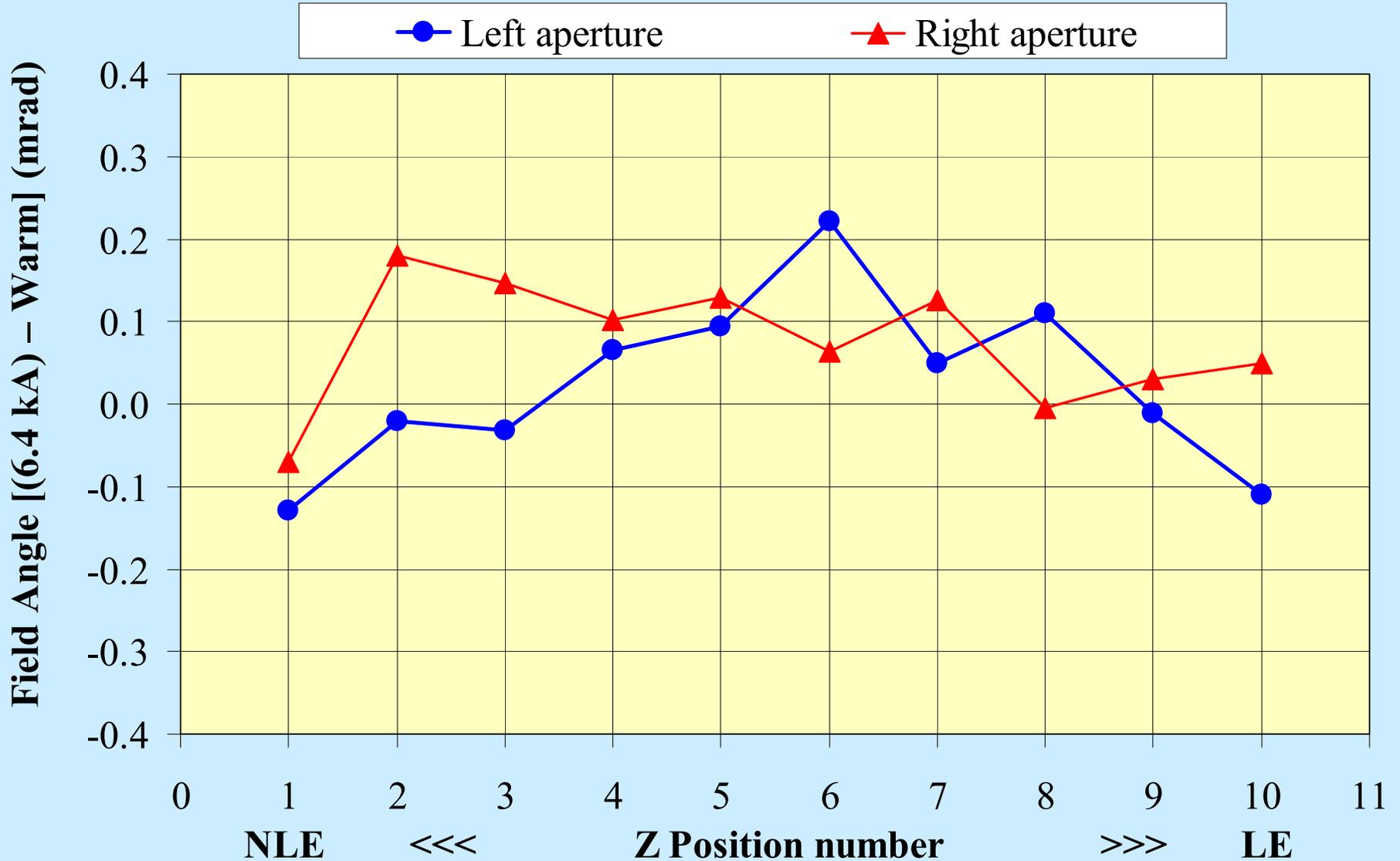
Field Angle Alignment in D2/D4 Dipoles



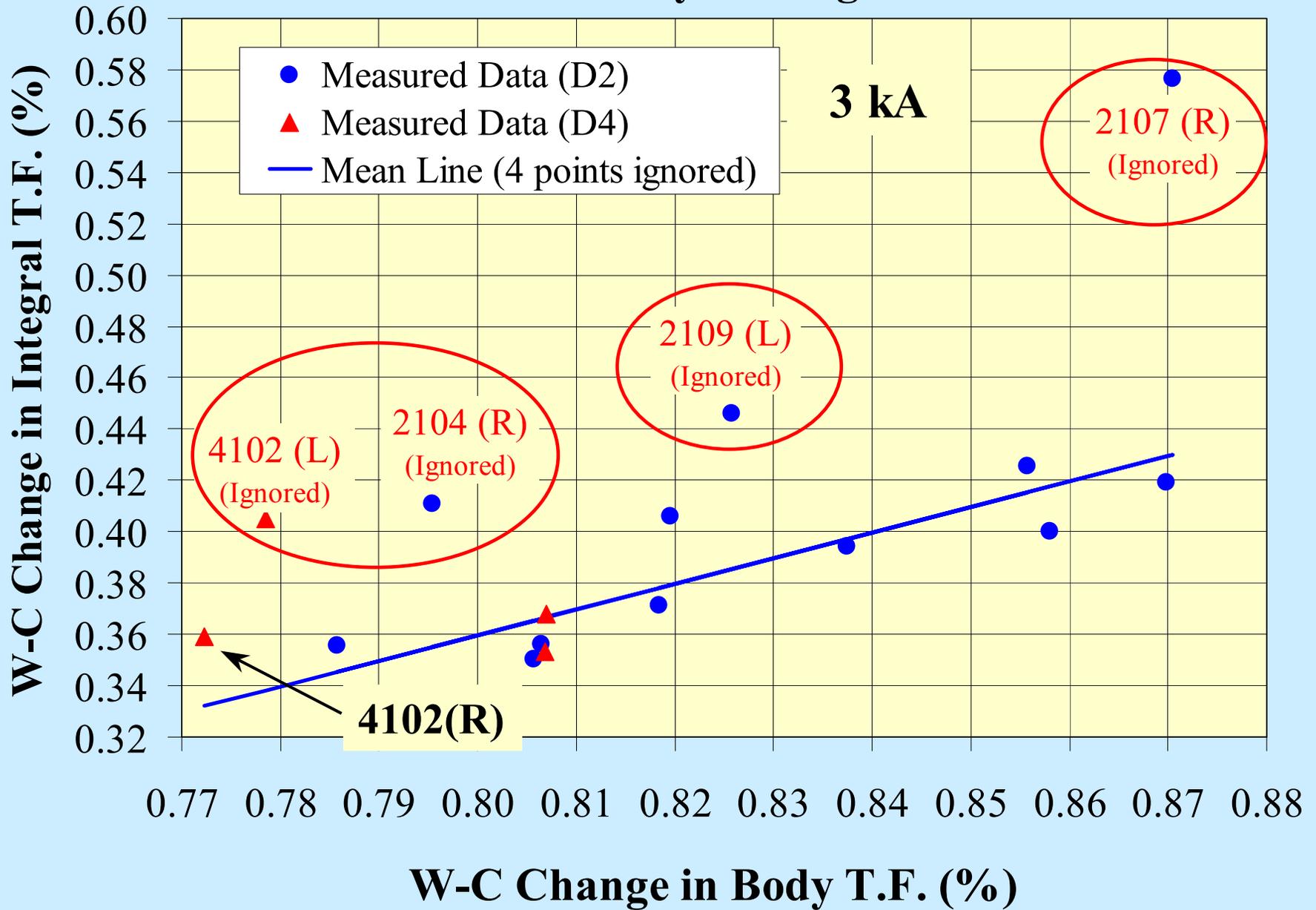
Cold Measurements

- Only a minimal set of measurements was done in D4L102.
- 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 6400A, and are carefully chosen to catch all the “features” of a full excitation curve.
- The integral T.F. is obtained from Z-scan, and can have random errors of up to $\sim 0.1\%$.
- D4L102(Left) I.T.F. was adjusted based on warm-cold.
- Down ramp measurements are done at only one position in each aperture.

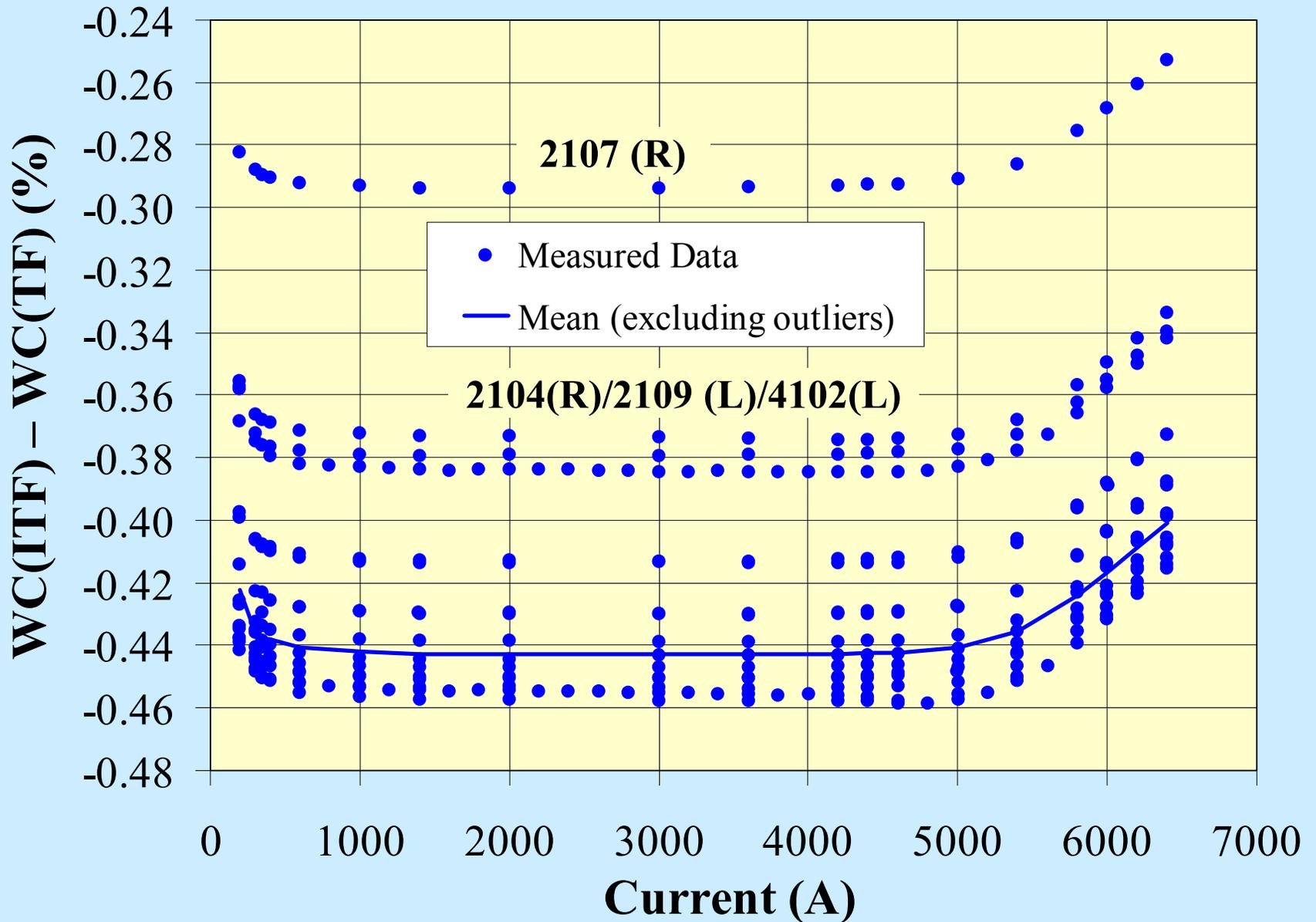
Field Angle Changes on Cool Down in D4L102



Correlation between Body & Integ. T.F. Warm-Cold



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



Comparison of Field Quality in D4L102 with the Expected Ver 1.0 Tables

Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 315A (0.2 Tesla)

n	<bn>	Δ (bn)	σ (bn)	<an>	Δ (an)	σ (an)
2	0.08	0.77	0.28	-0.12	3.68	1.53
3	-9.92	5.52	1.95	-1.10	0.49	0.17
4	-0.05	0.20	0.08	0.13	1.15	0.42
5	0.64	0.83	0.40	0.18	0.16	0.06
6	-0.01	0.08	0.03	-0.03	0.54	0.15
7	-0.26	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 D4L102 & Ver 1.0 Comparison

Integral; 0.2 Tesla (interpolated) at 25 mm radius

n	bn(L)	bn(R)	an(L)	an(R)	n	bn(L)	bn(R)	an(L)	an(R)
2	6.10	-5.50	-0.39	-1.29	2	??	??	OK	OK
3	-15.00	-14.48	-0.44	-0.58	3	OK	OK	OK	OK
4	0.50	-0.37	0.68	-0.94	4	??	??	OK	OK
5	0.88	0.89	0.34	0.31	5	OK	OK	OK	OK
6	0.01	-0.01	0.06	-0.09	6	OK	OK	OK	OK
7	-0.25	-0.19	-0.04	-0.06	7	OK	OK	OK	OK
8	-0.01	-0.01	0.01	-0.01	8	OK	OK	OK	OK
9	-0.02	0.00	0.04	0.05	9	OK	OK	OK	OK
10	0.06	-0.02	0.07	0.12	10	OK	OK	OK	??
11	-0.77	-0.71	-0.01	0.03	11	??	OK	OK	??

Note: Large b2 at low fields was not foreseen in Ver 1.0 tables

Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 3.8 Tesla (6000 A)

n	<bn>	Δ (bn)	σ (bn)	<an>	Δ (an)	σ (an)
2	-0.07	0.79	0.28	0.53	3.71	1.51
3	1.99	3.57	1.70	-1.07	0.55	0.18
4	-0.21	0.21	0.08	0.05	1.08	0.41
5	0.04	0.80	0.39	0.19	0.17	0.06
6	-0.05	0.10	0.04	0.00	0.55	0.16
7	0.06	0.19	0.10	-0.10	0.06	0.02
8	-0.01	0.03	0.01	-0.01	0.15	0.05
9	0.00	0.12	0.04	0.01	0.03	0.01
10	0.03	0.05	0.02	0.03	0.04	0.02
11	-0.56	0.04	0.02	-0.01	0.01	0.01

Measured Data in D4L102 & Ver 1.0 Comparison

Integral; 3.8 Tesla (6000 A) at 25 mm radius

n	bn(L)	bn(R)	an(L)	an(R)	n	bn(L)	bn(R)	an(L)	an(R)
2	0.22	0.16	0.30	-2.00	2	OK	OK	OK	OK
3	-1.54	-0.94	-0.37	-0.45	3	OK	OK	OK	OK
4	0.42	-0.21	0.55	-0.44	4	??	OK	OK	OK
5	0.21	0.46	0.34	0.32	5	OK	OK	OK	OK
6	0.09	-0.10	0.19	-0.11	6	??	OK	OK	OK
7	0.21	0.26	-0.04	-0.06	7	OK	OK	OK	OK
8	0.02	-0.04	0.02	0.02	8	OK	OK	OK	OK
9	-0.18	-0.16	0.05	0.06	9	??	OK	OK	??
10	0.06	-0.03	0.05	0.08	10	OK	OK	OK	OK
11	-0.64	-0.60	0.00	0.00	11	??	OK	OK	OK

OK=Value between (mean- Δ - σ) & (mean+ Δ + σ)

Comparison of Field Quality in D4L102 with the Expected Ver 2.0 Tables

Expected Ver 2.0 Table (at 25 mm radius)

Integral Harmonics at 315A (0.2 Tesla)

n	<bn>(L)	<bn>(R)	Δ (bn)	σ (bn)	<an>	Δ (an)	σ (an)
2	4.08	-5.07	1.97	0.63	-0.03	5.99	1.56
3	-22.28	-22.28	1.87	1.50	-0.72	0.74	0.44
4	-0.08	-0.56	0.36	0.20	-0.84	0.65	0.41
5	1.17	1.17	1.20	0.85	0.21	0.25	0.18
6	0.04	-0.16	0.20	0.12	0.10	0.67	0.39
7	-0.40	-0.40	0.16	0.11	-0.13	0.08	0.05
8	-0.03	-0.03	0.04	0.03	-0.01	0.27	0.17
9	0.16	0.16	0.15	0.10	0.03	0.03	0.02
10	-0.03	-0.03	0.08	0.04	0.02	0.08	0.05
11	-0.77	-0.77	0.03	0.02	0.02	0.02	0.01

Measured Data in D4L102

Integral; 0.2 Tesla (interpolated) at 25 mm radius

n	bn(L)	bn(R)	an(L)	an(R)	n	bn(L)	bn(R)	an(L)	an(R)
2	6.10	-5.50	-0.39	-1.29	2	OK	OK	OK	OK
3	-15.00	-14.48	-0.44	-0.58	3	??	??	OK	OK
4	0.50	-0.37	0.68	-0.94	4	??	OK	??	OK
5	0.88	0.89	0.34	0.31	5	OK	OK	OK	OK
6	0.01	-0.01	0.06	-0.09	6	OK	OK	OK	OK
7	-0.25	-0.19	-0.04	-0.06	7	OK	OK	OK	OK
8	-0.01	-0.01	0.01	-0.01	8	OK	OK	OK	OK
9	-0.02	0.00	0.04	0.05	9	OK	OK	OK	OK
10	0.06	-0.02	0.07	0.12	10	OK	OK	OK	OK
11	-0.77	-0.71	-0.01	0.03	11	OK	??	OK	OK

Expected Ver 2.0 Table (at 25 mm radius)

Integral Harmonics at 3.8 Tesla (6000 A)

n	<bn>(L)	<bn>(R)	Δ (bn)	σ (bn)	<an>	Δ (an)	σ (an)
2	-0.50	-0.77	1.02	0.32	-0.67	5.94	1.55
3	-4.17	-4.17	1.63	1.47	-0.84	0.69	0.43
4	-0.01	-0.63	0.29	0.18	-0.38	0.56	0.40
5	-0.13	-0.13	1.14	0.85	0.21	0.24	0.18
6	0.04	-0.17	0.05	0.03	-0.02	0.58	0.38
7	0.15	0.15	0.12	0.10	-0.11	0.06	0.05
8	0.00	-0.04	0.03	0.03	0.01	0.25	0.17
9	-0.09	-0.09	0.13	0.10	0.05	0.02	0.01
10	-0.01	-0.01	0.05	0.03	0.00	0.05	0.03
11	-0.62	-0.62	0.02	0.01	0.00	0.03	0.02

Measured Data in D4L102

Integral; 3.8 Tesla (6000 A) at 25 mm radius

n	bn(L)	bn(R)	an(L)	an(R)	n	bn(L)	bn(R)	an(L)	an(R)
2	0.22	0.16	0.30	-2.00	2	OK	OK	OK	OK
3	-1.54	-0.94	-0.37	-0.45	3	OK	??	OK	OK
4	0.42	-0.21	0.55	-0.44	4	OK	OK	OK	OK
5	0.21	0.46	0.34	0.32	5	OK	OK	OK	OK
6	0.09	-0.10	0.19	-0.11	6	OK	OK	OK	OK
7	0.21	0.26	-0.04	-0.06	7	OK	OK	OK	OK
8	0.02	-0.04	0.02	0.02	8	OK	OK	OK	OK
9	-0.18	-0.16	0.05	0.06	9	OK	OK	OK	OK
10	0.06	-0.03	0.05	0.08	10	OK	OK	OK	OK
11	-0.64	-0.60	0.00	0.00	11	OK	OK	OK	OK

OK=Value between (mean- Δ - σ) & (mean+ Δ + σ)