

# Summary of Field Quality Data in D2L103

Animesh Jain

*Superconducting Magnet Division*

Brookhaven National Laboratory, Upton, NY 11973

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# Warm Measurements

- Warm measurements have been completed in all the nine D2 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.

# D2L103 Vs. Mean and Standard Deviation

## Integral Normal Harmonics (Warm) at 25 mm

	Left Aperture				Right Aperture			
	D2L/D4L Mean	D2L/D4L Std.Dev.	2103(L)	No. of Sigma	D2L/D4L Mean	D2L Std.Dev.	2103(R)	No. of Sigma
I.T.F. (T.m/kA)	5.9569	0.043%	5.9516	-2.0	5.9569	0.043%	5.9520	-1.9
Quadrupole*	-5.34	0.61	-5.57	-0.4	5.13	0.61	4.77	-0.6
Sextupole	-3.22	1.31	-4.25	-0.8	-3.22	1.31	-4.75	-1.2
Octupole	0.10	0.16	0.09	0.0	0.10	0.16	-0.28	-2.4
Decapole	0.62	0.39	0.52	-0.3	0.62	0.39	0.27	-0.9
12-pole	-0.01	0.06	-0.03	-0.3	-0.01	0.06	-0.14	-2.0
14-pole	0.06	0.09	0.08	0.3	0.06	0.09	0.09	0.4
16-pole	0.00	0.02	0.00	-0.2	0.00	0.02	-0.02	-1.0
18-pole	-0.14	0.03	-0.07	2.2	-0.14	0.03	-0.10	1.1
20-pole	0.00	0.01	0.01	1.2	0.00	0.01	0.00	0.0
22-pole	-0.64	0.02	-0.63	0.3	-0.64	0.02	-0.63	0.2
24-pole	0.00	0.01	0.00	0.9	0.00	0.01	0.00	0.3
26-pole	-0.26	0.01	-0.25	0.7	-0.26	0.01	-0.26	-0.2

\* Mean values of the normal quadrupole term are treated as aperture dependent.

All other terms are considered aperture independent.

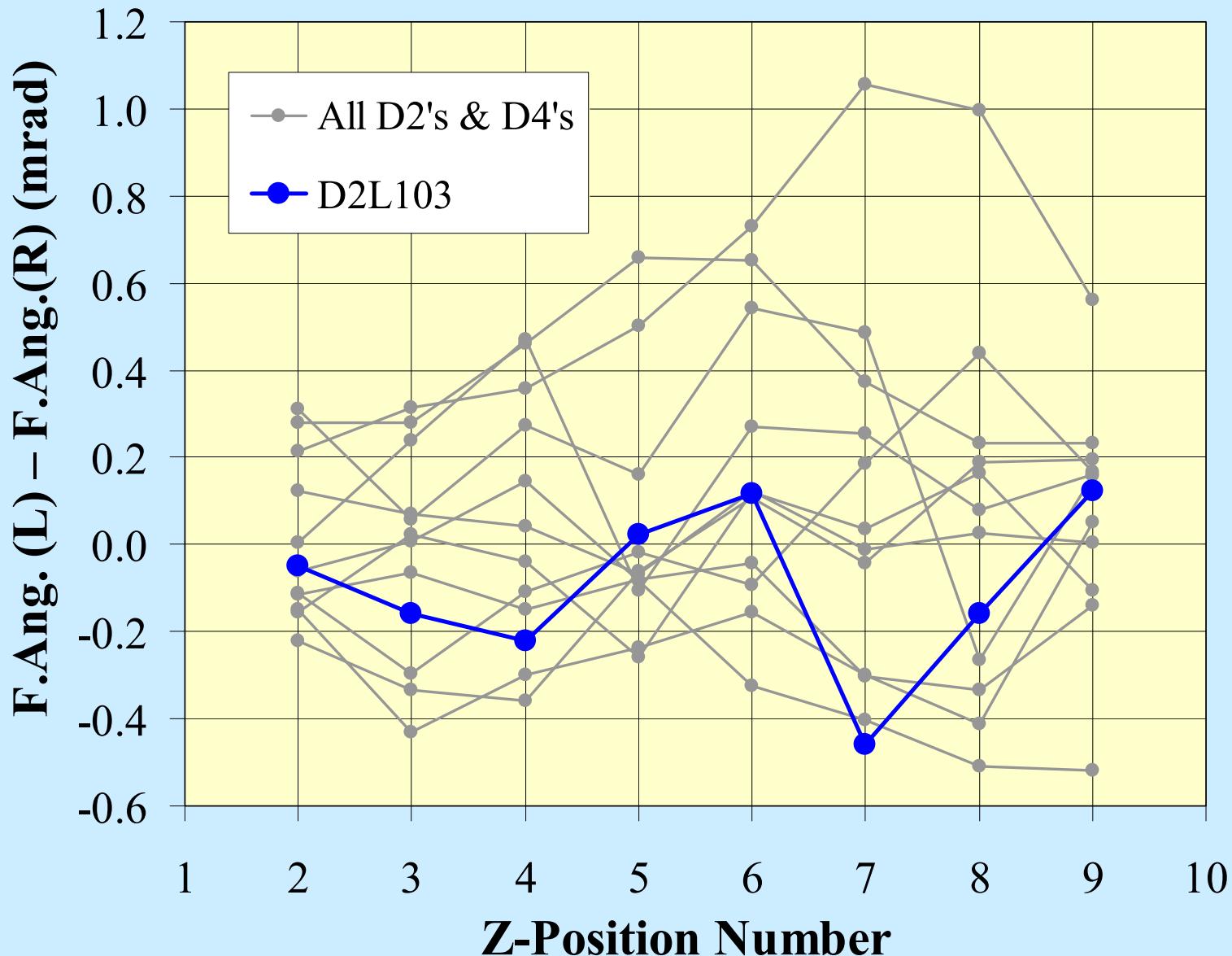
# D2L103 Vs. Mean and Standard Deviation

## Integral Skew Harmonics (Warm) at 25 mm

	D2L/D4L Mean	D2L/D4L Std.Dev.	2103(L)	No. of Sigma	2103(R)	No. of Sigma
<b>Fld. Angle (mrad)</b>	-0.60	0.22	<b>-0.47</b>	<b>0.6</b>	<b>-0.41</b>	<b>0.8</b>
<b>Quadrupole</b>	0.05	1.90	<b>0.41</b>	<b>0.2</b>	<b>4.55</b>	<b>2.4</b>
<b>Sextupole</b>	-0.98	0.38	<b>-0.94</b>	<b>0.1</b>	<b>-0.88</b>	<b>0.3</b>
<b>Octupole</b>	0.16	0.61	<b>-0.59</b>	<b>-1.2</b>	<b>0.78</b>	<b>1.0</b>
<b>Decapole</b>	0.18	0.12	<b>0.01</b>	<b>-1.5</b>	<b>0.34</b>	<b>1.3</b>
<b>12-pole</b>	0.03	0.17	<b>-0.22</b>	<b>-1.5</b>	<b>0.00</b>	<b>-0.2</b>
<b>14-pole</b>	-0.09	0.03	<b>-0.09</b>	<b>-0.2</b>	<b>-0.03</b>	<b>1.6</b>
<b>16-pole</b>	0.01	0.04	<b>-0.01</b>	<b>-0.6</b>	<b>-0.05</b>	<b>-1.4</b>
<b>18-pole</b>	0.03	0.02	<b>0.02</b>	<b>-0.7</b>	<b>0.04</b>	<b>1.1</b>
<b>20-pole</b>	0.02	0.02	<b>0.01</b>	<b>-0.3</b>	<b>0.02</b>	<b>0.2</b>
<b>22-pole</b>	0.00	0.01	<b>0.00</b>	<b>1.0</b>	<b>0.01</b>	<b>1.9</b>
<b>24-pole</b>	0.01	0.01	<b>0.02</b>	<b>1.1</b>	<b>0.02</b>	<b>1.3</b>
<b>26-pole</b>	0.00	0.01	<b>0.01</b>	<b>0.8</b>	<b>0.01</b>	<b>0.8</b>

Field angles are as measured on test stand wrt gravity.

# Field Angle Alignment in D2/D4 Dipoles



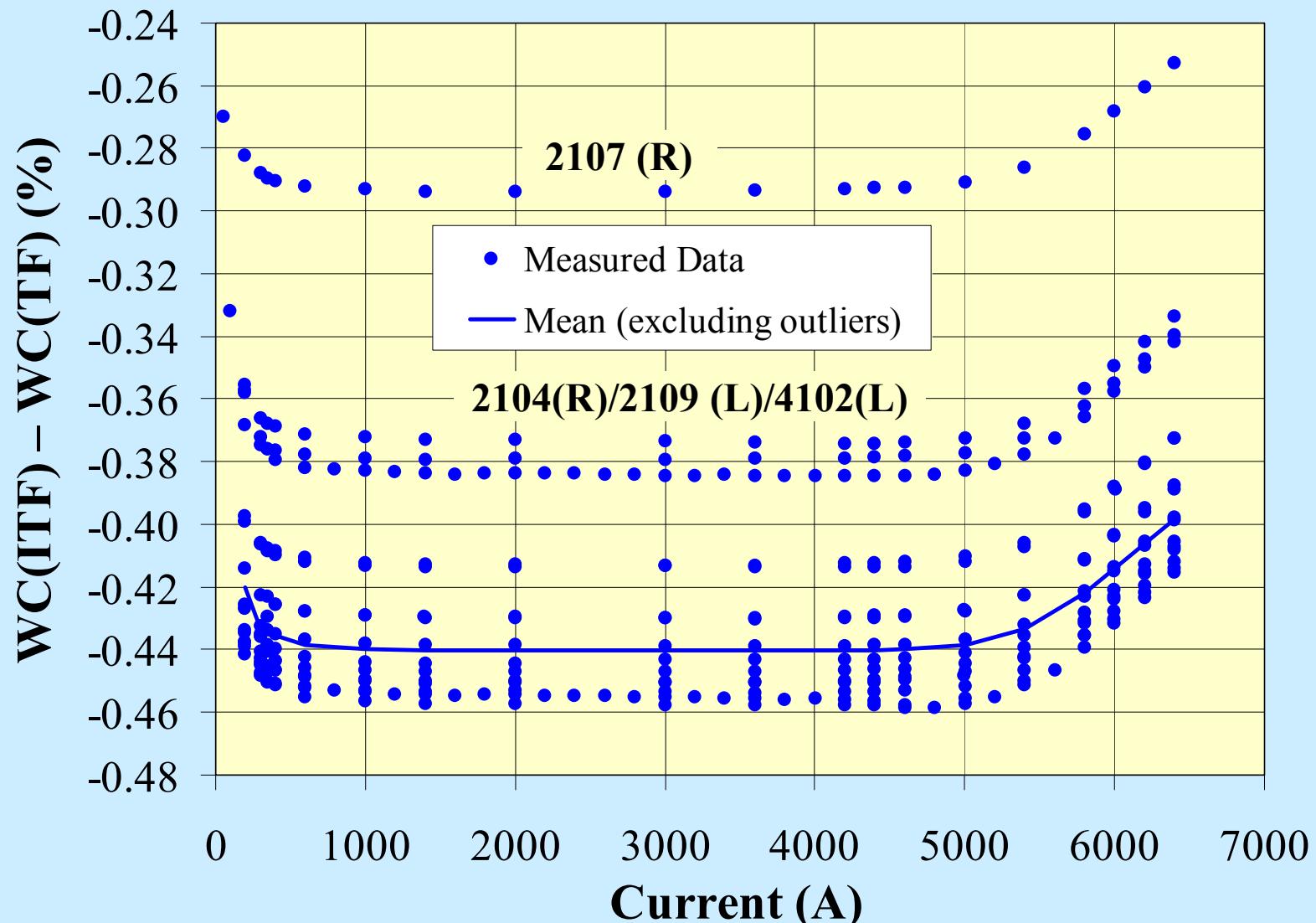
# Cold Measurements

- D2L103 was not measured cold.
- Cold field quality is estimated from the warm data using warm-cold correlations derived from cold measurements in D2L104-109 and D4L101-102.
- Warm-cold correlations are based on data in 16 apertures for harmonics that are aperture independent, and for 8 apertures each where they are aperture dependent.
- Correlations for integral transfer function are obtained after excluding certain “outlier” data (4 apertures), likely arising due to uncertainty in mole positioning.

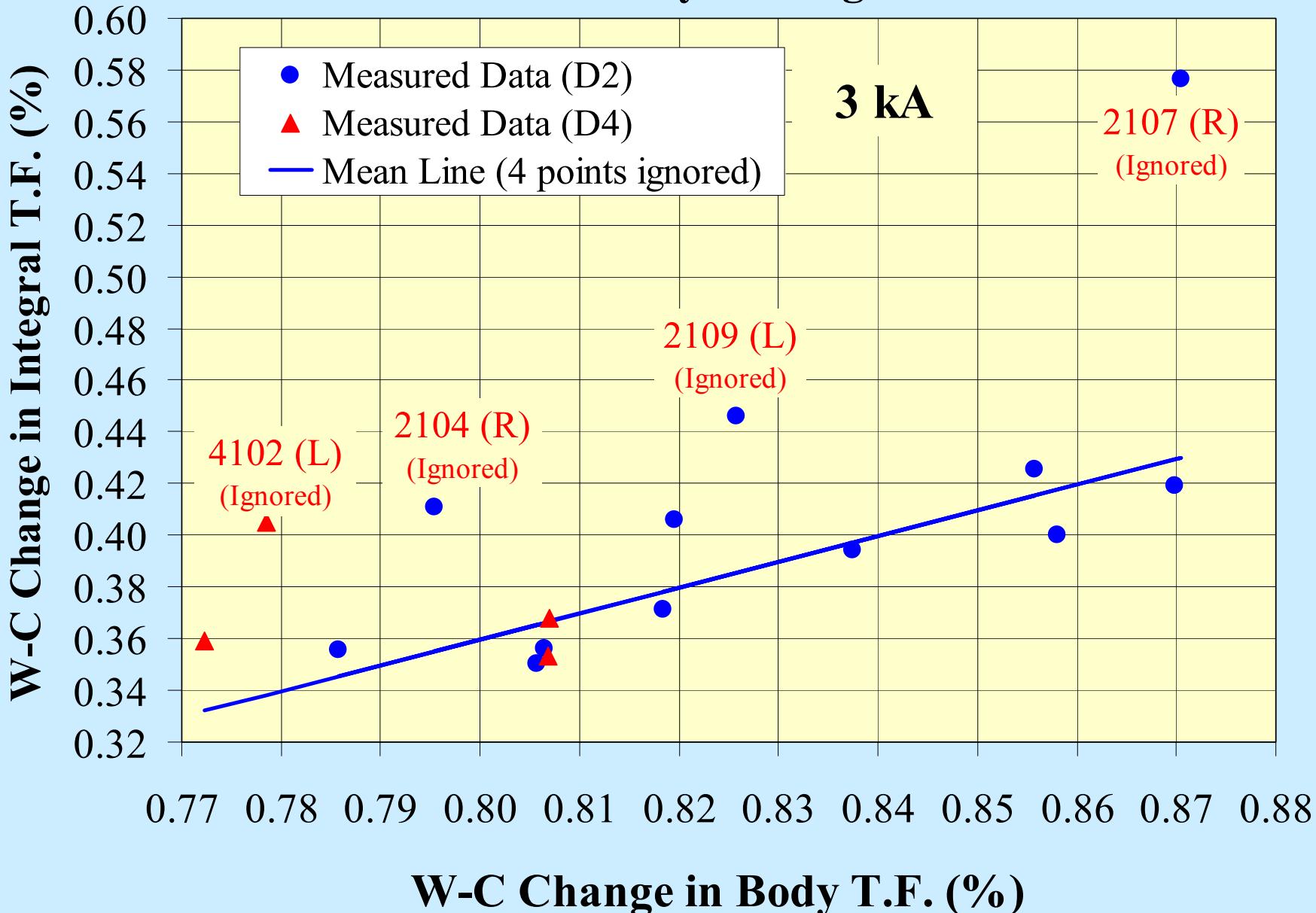
# Warm-Cold Correlations

- Body and Integral transfer functions are evaluated as percentage changes from the warm values.
- All harmonic changes are evaluated as offsets from the warm values.
- The warm-cold correlations are evaluated separately for each aperture, and also for both apertures together.
- Left-right differences are statistically significant only for the normal quadrupole, octupole, 12-pole and 16-pole terms.

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



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



# Comparison of Field Quality in D2L103 with the Expected Ver 1.0 Tables

## Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 315A (0.2 Tesla)

n	$\langle bn \rangle$	$\Delta (bn)$	$\sigma (bn)$	$\langle an \rangle$	$\Delta (an)$	$\sigma (an)$
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

## Estimated Data in D2L103 & Ver 1.0 Comparison

Integral; 0.2 Tesla (interpolated) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	5.34	-6.26	0.46	4.60
3	-16.06	-16.56	-0.98	-0.92
4	0.57	-0.83	-0.77	0.61
5	0.72	0.47	0.03	0.36
6	0.04	-0.19	-0.21	0.02
7	-0.27	-0.26	-0.10	-0.04
8	-0.01	-0.04	-0.02	-0.06
9	0.10	0.07	0.02	0.05
10	0.02	0.00	0.05	0.06
11	-0.78	-0.78	0.01	0.02

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	??	??	OK	OK
3	OK	OK	OK	OK
4	??	??	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	??	??	??	??

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	$\langle bn \rangle$	$\Delta (bn)$	$\sigma (bn)$	$\langle an \rangle$	$\Delta (an)$	$\sigma (an)$
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

## Estimated Data in D2L103 & Ver 1.0 Comparison

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

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	-0.27	-0.60	0.37	4.51
3	-1.95	-2.46	-0.90	-0.84
4	0.41	-0.71	-0.66	0.71
5	0.05	-0.21	0.04	0.37
6	0.09	-0.24	-0.19	0.03
7	0.23	0.24	-0.09	-0.03
8	0.01	-0.05	-0.01	-0.05
9	-0.08	-0.11	0.02	0.05
10	0.01	0.00	0.04	0.05
11	-0.63	-0.63	0.01	0.01

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	OK	OK	OK	OK
3	OK	OK	OK	OK
4	??	??	OK	OK
5	OK	OK	OK	OK
6	??	??	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=Value between (mean- $\Delta$ - $\sigma$ ) & (mean+ $\Delta$ + $\sigma$ )

# Comparison of Field Quality in D2L103 with the Expected Ver 2.0 Tables

## Expected Ver 2.0 Table (at 25 mm radius)

Integral Harmonics at 315A (0.2 Tesla)

n	$\langle bn \rangle(L)$	$\langle bn \rangle(R)$	$\Delta(bn)$	$\sigma(bn)$	$\langle an \rangle$	$\Delta(an)$	$\sigma(an)$
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

## Estimated Data in D2L103 & Ver 2.0 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	5.34	-6.26	0.46	4.60	2	OK	OK	OK	OK
3	-16.06	-16.56	-0.98	-0.92	3	??	??	OK	OK
4	0.57	-0.83	-0.77	0.61	4	??	OK	OK	??
5	0.72	0.47	0.03	0.36	5	OK	OK	OK	OK
6	0.04	-0.19	-0.21	0.02	6	OK	OK	OK	OK
7	-0.27	-0.26	-0.10	-0.04	7	OK	OK	OK	OK
8	-0.01	-0.04	-0.02	-0.06	8	OK	OK	OK	OK
9	0.10	0.07	0.02	0.05	9	OK	OK	OK	OK
10	0.02	0.00	0.05	0.06	10	OK	OK	OK	OK
11	-0.78	-0.78	0.01	0.02	11	OK	OK	OK	OK

## Expected Ver 2.0 Table (at 25 mm radius)

Integral Harmonics at 3.8 Tesla (6000 A)

n	$\langle bn \rangle(L)$	$\langle bn \rangle(R)$	$\Delta(bn)$	$\sigma(bn)$	$\langle an \rangle$	$\Delta(an)$	$\sigma(an)$
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

## Estimated Data in D2L103 & Ver 2.0 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	-0.27	-0.60	0.37	4.51	2	OK	OK	OK	OK
3	-1.95	-2.46	-0.90	-0.84	3	OK	OK	OK	OK
4	0.41	-0.71	-0.66	0.71	4	OK	OK	OK	??
5	0.05	-0.21	0.04	0.37	5	OK	OK	OK	OK
6	0.09	-0.24	-0.19	0.03	6	OK	??	OK	OK
7	0.23	0.24	-0.09	-0.03	7	OK	OK	OK	OK
8	0.01	-0.05	-0.01	-0.05	8	OK	OK	OK	OK
9	-0.08	-0.11	0.02	0.05	9	OK	OK	OK	OK
10	0.01	0.00	0.04	0.05	10	OK	OK	OK	OK
11	-0.63	-0.63	0.01	0.01	11	OK	OK	OK	OK

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