NICST_MEMO_11_006

NICST Internal Memo

Date: June 10, 2011
From: Jeff McIntire
To: Bruce Guenther, Jim Butler, and Jack Xiong
Subject: Spacecraft Level Testing of Thermal Band Radiometric Calibration using the On-board Blackbody

---

References:

[1] NICST_MEMO_11_001, 'Analysis of the Radiometric Calibration from VIIRS F1 RC-05 Part 1 Test (Nominal Plateau, Electronic Side B),' Jeff McIntire and Sanxiong Xiong, January 3, 2011.
[2] NICST_MEMO_11_002, 'Analysis of the Radiometric Calibration from VIIRS F1 RC-05 Part 2 Test (Nominal Plateau),' Jeff McIntire and Sanxiong Xiong, January 31, 2011.
[3] NICST_MEMO_11_003, 'Plateau and Electronics Side Comparison of Thermal Band Radiometric Calibration from VIIRS F1 RC-05 Testing,' Jeff McIntire, February 25, 2011.
[4] 'Performance Specification Sensor Specification,' ps154640-101c.
[5] 'VIIRS F1 BCS/OBC Temperature Offset Study Using RC-5 part 1 and Part 2 Data Updated,' David Moyer and Frank De Luccia, April 1, 2011.

1. Introduction

Spacecraft level testing was conducted during March and April of 2011 at BATC in Boulder CO. During this phase of testing, the OBC blackbody temperature was transitioned through its warm-up / cool-down cycle four times. The cycle was performed on electronics side B for Cold 1 and Hot 4 plateaus as well as on electronics side A for Hot 1 and Cold 4 plateaus. The data used in this work is listed in Tables 1 – 4. Note that although the data was a mixture of operational mode in auto gain and diagnostic mode in fixed high gain (due to FPI testing considerations and time constraints), this did not affect the present calibration.

This memo will compare the results of the OBC warm-up / cool-down testing to instrument level thermal vacuum results [1-3], with an emphasis on radiometric coefficients, NEdT at T_{TYP}, and linearity. The procedure for the analysis was described in [2] and will not be repeated here. The BCS results shown in this work have been determined using a truncated temperature range designed to approximate the OBC warm-up range (262 K – 321 K) and matched to the same electronics side and nearest instrument temperature plateau.

2. Results

The OBC operability was investigated in terms of range and uniformity. The OBC was transitioned through a series of temperature plateaus from about 272 K to 312 K for Cold 1 and Cold 4 plateaus and from about 272 K to 315 K for Hot 1 and Hot 4 plateaus (the OBC was not transitioned to 315 K at either Cold plateau due to time constraints); this satisfied the sensor OBC temperature range requirement [4]. The measured OBC range for all four tests is shown in Figures 1 – 4, where the temperature is plotted versus minutes starting from the beginning of the first day for a particular data set in GMT. Figures 5 – 8 show the standard deviation of the OBC temperature over the six thermistors for each scan used in the calibration. The standard deviations are all below about 18 mK for all scans used in this work (the sensor specification requires that the standard deviation be lower than 30 mK during temperature controlled conditions).

Comparisons of the c_0 coefficient for warm-up are shown in Figures 9 – 12 and for cool-down in Figures 13 – 16 as a function of detector with 1-sigma error bars (black for BCS and red for OBC). The warm-up offsets generally agree for all bands (there are some small discrepancies in the LWIR); the values for the MWIR bands are close, while the LWIR bands seem to be slightly higher (although still largely within the error bars). For the cool-down, the offsets agree less well but with much larger uncertainties. Note that the cool-down fitting range only reached 292 K, and so the offsets are not as tightly constrained.

The c_1 coefficient comparisons are shown in Figures 17 – 20 (warm-up) and Figures 21 – 24 (cool-down) for all bands. The coefficients are plotted versus detector for each band along with the 1-sigma uncertainty estimates from the least squares fitting. Both BCS (black) and OBC (red) results are shown. The band averaged gains are given in Tables 5 – 8. In general, the warm-up c_1 coefficients agree with the BCS results to within 1.9 % for all high gain cases and to less than 1.0 % for all cases except for M14 at both Cold plateaus and I5 at Cold 4 plateau. This difference is within the uncertainties for most bands (exceptions are M12 for most cases as well as M13 high gain and M14 for the Cold plateaus). The warm-up OBC c_1 seem to be slightly higher for the MWIR and slightly lower for the LWIR than the BCS c_1. The cool-down gains for Hot 1 and 4 plateaus agree with the BCS results to 1.3 % while the Cold 1 and 4 plateaus agree to within 5.2 %. Note that the amount of data available for the Cold plateaus is smaller as the OBC cools more rapidly (see Tables 1 – 4). Also, the cool-down begins at 312 K instead of 315 K for the Hot plateaus. In general, the linear coefficient is consistent with the BCS results in that their error bars overlap; however, the uncertainties on the cool-sown c_1 are much larger than the BCS uncertainties.

Figures 25 – 28 (warm-up) and Figures 29 – 32 (cool-down) show the c_2 coefficient comparison between the BCS (black) and OBC (red) for all detectors with 1-sigma uncertainties. The warm-up and cool-down OBC coefficients generally agree to within uncertainties with the BCS results; however, the OBC results have much larger error bars. The nonlinear terms derived from the cool-down data are less stable (due to a smaller OBC temperature range).

Note that recent work on the OBC / BCS differences has uncovered a possible bias between the two sources [5]. As such, the above comparison is expected to improve with the correction of any source biases. Work is ongoing to understand this error source.

The M13 low gain linear coefficients (listed in Tables 7 and 8) were determined using operational mode data from the highest OBC temperature level available (either 312 K or 315 K). As the data is well below the specified dynamic range for M13 low gain, the coefficient was calculated using $c_1=\Delta L_{OBC}/dn_{OBC}$ and is considered only a rough estimate. Nonetheless, the M13 low gain gains are within 7.0 % of previous results. The instrument level thermal vacuum results were determined using the TMC blackbody.

The linearity was investigated in terms of the RRNL (as in previous work [1-3]). The maximum RRNL over detectors are listed in Tables 9 and 10 for all plateaus as well as comparable BCS results from instrument thermal vacuum testing. In general, the results from instrument and spacecraft level thermal vacuums are in good agreement. The spacecraft level results show more nonlinearity in I5 than instrument level; this is due to I5 detector 31 exhibiting a higher nonlinearity (detector 31 is a known noisy detector).

The NEdT at T_{TYP} was determined in the same manner as in [2]. The results for all four plateaus are plotted versus detector in Figures 33 – 36 (red) along with the results from instrument level testing using the BCS (black). The OBC and BCS results are in good agreement for all instrument conditions (the M14 BCS results are slightly larger). In addition, all detectors are well below the specified upper limit on the NEdT at T_{TYP} [4]. Note that due to lack of data, M13 low gain NEdT at T_{TYP} was not calculated.

5. Summary

- OBC is operating normally in terms of range and uniformity.
- Warm-up c_1 coefficients agree with BCS results to within 1.9 % for all high gain cases (and within 1.0 % for all cases except M14 at both Cold plateaus and I5 at cold 4 plateau). Cool-down c_1 coefficients agree with BCS results to with 1.3 % for Hot plateaus and 5.2 % for Cold plateaus.
- Offset and nonlinear terms generally agree to within 1-sigma uncertainties (OBC and BCS).
- The warm-up nonlinearity is in good agreement with instrument level testing, except for band I5 detector 31.
- NEdT at T_{TYP} is comparable to BCS results from instrument level testing and is well within specified limits.

Acknowledgement

The sensor test data used in this document was provided by the Ball Aerospace testing team. Approaches for data acquisition and data reductions, as well as data extraction tools were provided by the Raytheon El Segundo team. We would like to thank the Ball Aerospace and Raytheon El Segundo teams for their support. The data analysis tools were developed by the NICST team.

Table 1: Cold 1 plateau OBC data

Collect	Warm-up / Cool-down	T_{OBC} [K]	Data dump	File #	Mode	Scans
1	Warm-up	272	110322_034453	4	Op	100-200
2	Warm-up	282	110322_034453	12	Op	400-500
3	Warm-up	292	110322_055951	5	Diag	0-100
4	Warm-up	297	110322_080730	5	Diag	50-150
5	Warm-up	302	110322_080730	17	Diag	50-150
6	Warm-up	307	110322_100300	13	Diag	0-100
7	Warm-up	312	110322_145829	1	Op	200-300
8	Cool-down	310	110322_145829	2	Op	200-300
9	Cool-down	305	110322_145829	3	Op	200-300
10	Cool-down	301	110322_145829	4	Op	200-300
11	Cool-down	297	110322_145829	5	Op	200-300
12	Cool-down	293	110322_145829	6	Op	200-300

Table 2: Hot 1 plateau OBC data

Collect	Warm-up / Cool-down	T_{OBC} [K]	Data dump	File #	Mode	Scans
1	Warm-up	272	110401_010710	5	Op	300-400
2	Warm-up	282	110401_030525	5	Op	100-200
3	Warm-up	292	110401_045158	6	Diag	0-100
4	Warm-up	297	110401_045158	12	Diag	0-100
5	Warm-up	302	110401_070928	5	Diag	50-150
6	Warm-up	307	110401_070928	13	Diag	0-100
7	Warm-up	312	110401_090903	3	Diag	50-150
8	Warm-up	315	110401_103553	5	Op	100-200
9	Cool-down	312	110401_103553	6	Op	100-200
10	Cool-down	309	110401_121134	1	Op	100-200
11	Cool-down	306	110401_121134	2	Op	100-200
12	Cool-down	304	110401_121134	3	Op	100-200
13	Cool-down	301	110401_121134	4	Op	100-200
14	Cool-down	299	110401_121134	5	Op	100-200
15	Cool-down	297	110401_121134	6	Op	100-200
16	Cool-down	296	110401_121134	7	Op	100-200

Table 3: Cold 4 plateau OBC data

Collect	Warm-up / Cool-down	T_{OBC} [K]	Data dump	File #	Mode	Scans
1	Warm-up	272	110414_202048	3	Op	400-500
2	Warm-up	282	110414_214015	3	Op	400-500
3	Warm-up	292	110414_234302	7	Diag	10-110
4	Warm-up	297	110414_234302	16	Diag	50-150
5	Warm-up	302	110415_010614	12	Diag	10-110
6	Warm-up	307	110415_023842	13	Diag	50-150
7	Warm-up	312	110415_053240	10	Op	100-200
9	Cool-down	308	110415_053240	11	Op	200-300
10	Cool-down	304	110415_073323	1	Op	200-300
11	Cool-down	300	110415_073323	2	Op	200-300
12	Cool-down	296	110415_073323	3	Op	200-300
13	Cool-down	293	110415_073323	4	Op	200-300

Table 4: Hot 4 plateau OBC data

Collect	Warm-up / Cool-down	T_{OBC} [K]	Data dump	File #	Mode	Scans
1	Warm-up	272	110421_162705	5	Op	200-300
2	Warm-up	282	110421_183339	1	Op	300-400
3	Warm-up	292	110421_183339	6	Op	20-120
4	Warm-up	297	110421_183339	8	Op	300-400
5	Warm-up	302	110421_203037	6	Diag	50-150
6	Warm-up	307	110421_203037	15	Diag	50-150
7	Warm-up	312	110421_231608	10	Diag	20-120
8	Warm-up	315	110422_010633	5	Op	300-400
9	Cool-down	309	110422_022746	1	Op	100-200
10	Cool-down	305	110422_022746	2	Op	100-200
11	Cool-down	303	110422_022746	3	Op	100-200
12	Cool-down	301	110422_022746	4	Op	100-200
13	Cool-down	299	110422_022746	5	Op	100-200
14	Cool-down	297	110422_022746	6	Op	100-200
15	Cool-down	296	110422_051121	1	Op	100-200
16	Cool-down	294	110422_051121	2	Op	100-200
17	Cool-down	293	110422_051121	3	Op	100-200

Table 5: Band averaged warm-up gains ($1/c_1$) for Cold 1 and 4 plateaus along with BCS results

Band	Cold 1 (SC)	Cold B (Instrument)	Cold 4 (SC)	Cold A (Instrument)
I4	1122	1131	1128	1135
I5	176.0	174.4	177.4	175.1
M12	1176	1183	1156	1160
M13 HG	599.6	602.7	589.4	591.4
M14	200.2	196.9	201.3	197.7
M15	178.9	178.2	178.6	178.0
M16A	207.5	205.7	207.9	206.3
M16B	207.6	205.5	207.4	206.0

Table 6: Band averaged warm-up gains ($1/c_1$) for Hot 1 and 4 plateaus along with BCS results

Band	Hot 1 (SC)	Hot A (Instrument)	Hot 4 (SC)	Hot B (Instrument)
I4	1126	1134	1123	1129
I5	174.0	173.2	173.9	172.3
M12	1146	1156	1169	1177
M13 HG	592.2	593.7	603.2	604.2
M14	196.3	195.3	196.0	194.1
M15	175.8	176.8	176.2	176.6
M16A	203.3	203.4	202.7	202.6
M16B	202.6	203.0	202.2	202.1

Table 7: Band averaged cool-down gains ($1/c_1$) for Cold 1 and 4 plateaus along with BCS results

Band	Cold 1 (SC)	Cold B (Instrument)	Cold 4 (SC)	Cold A (Instrument)
I4	1117	1131	1103	1135
I5	172.5	174.4	166.7	175.1
M12	1166	1183	1128	1160
M13 HG	594.7	602.7	568.1	591.4
M13 LG	7.4	7.1	7.4	6.9
M14	195.8	196.9	191.6	197.7
M15	174.2	178.2	168.7	178.0
M16A	199.7	205.7	197.0	206.3
M16B	200.7	205.5	195.9	206.0

Table 8: Band averaged cool-down gains ($1/c_1$) for Hot 1 and 4 plateaus along with BCS results

Band	Hot 1 (SC)	Hot A (Instrument)	Hot 4 (SC)	Hot B (Instrument)
I4	1131	1134	1130	1129
I5	173.3	173.2	173.6	172.3
M12	1140	1156	1168	1177
M13 HG	593.7	593.7	604.9	604.2
M13 LG	7.0	6.9	7.3	7.0
M14	195.5	195.3	194.7	194.1
M15	176.5	176.8	176.1	176.6
M16A	202.0	203.4	202.4	202.6
M16B	202.0	203.0	201.6	202.1

Table 9: Maximum warm-up nonlinearity (RRNL) for Cold 1 and 4 plateaus along with BCS results [%]

Band	Cold 1 (SC)	Cold B (Instrument)	Cold 4 (SC)	Cold A (Instrument)
I4	0.05	0.03	0.03	0.03
I5	0.18	0.03	0.18	0.03
M12	0.02	0.02	0.01	0.01
M13 HG	0.03	0.04	0.03	0.04
M14	0.10	0.16	0.09	0.14
M15	0.02	0.03	0.02	0.03
M16A	0.06	0.04	0.06	0.04
M16B	0.04	0.05	0.03	0.04

Table 10: Maximum warm-up nonlinearity (RRNL) for Hot 1 and 4 plateaus along with BCS results [%]

Band	Hot 1 (SC)	Hot A (Instrument)	Hot 4 (SC)	Hot B (Instrument)
I4	0.03	0.02	0.03	0.02
I5	0.18	0.04	0.06	0.03
M12	0.02	0.01	0.00	0.01
M13 HG	0.02	0.03	0.02	0.03
M14	0.12	0.15	0.07	0.15
M15	0.03	0.03	0.02	0.03
M16A	0.07	0.04	0.02	0.04
M16B	0.05	0.04	0.02	0.04

Figure 1: OBC temperatures for Cold 1 plateau warm-up

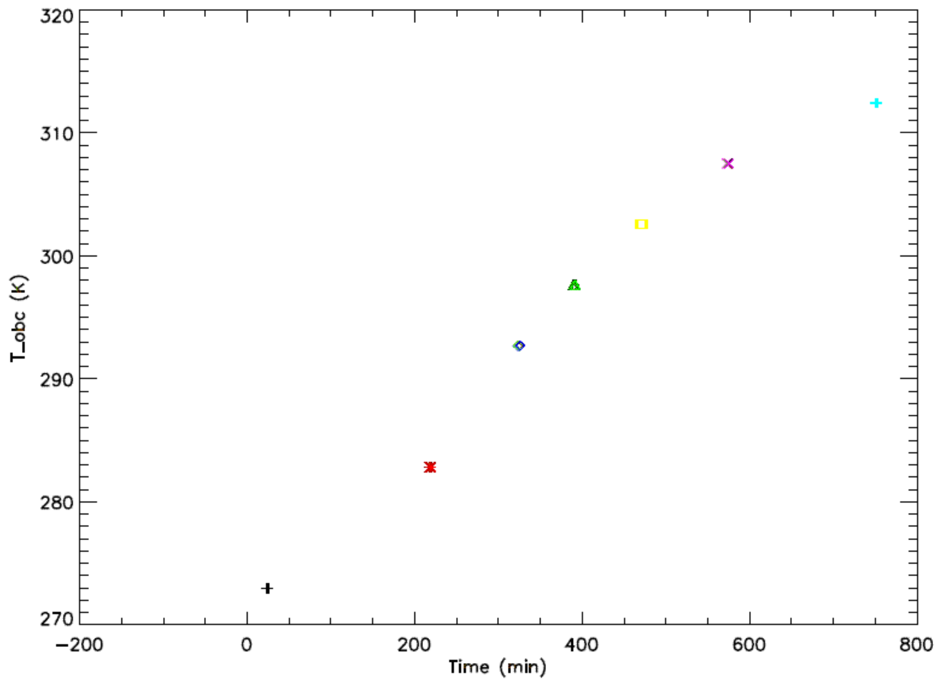

Figure 2: OBC temperatures for Hot 1 plateau warm-up

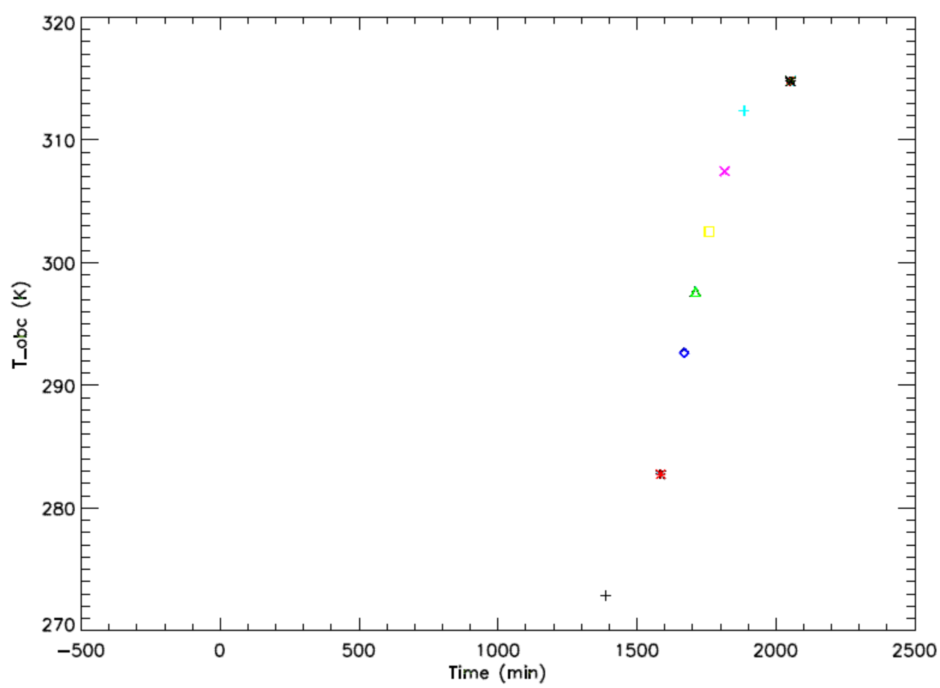

Figure 3: OBC temperatures for Cold 4 plateau warm-up

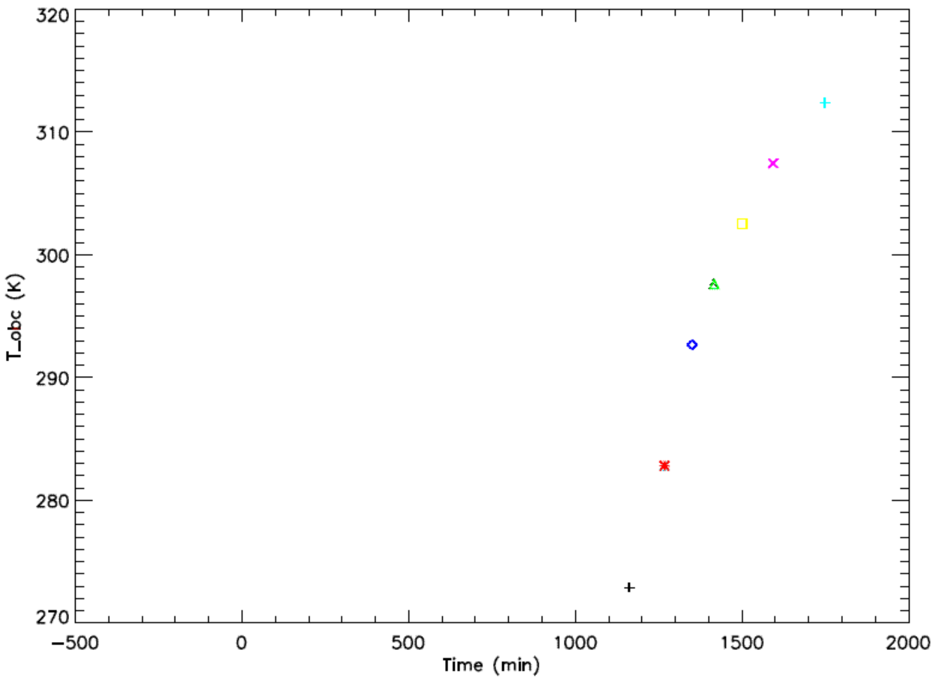

Figure 4: OBC temperatures for Hot 4 plateau warm-up

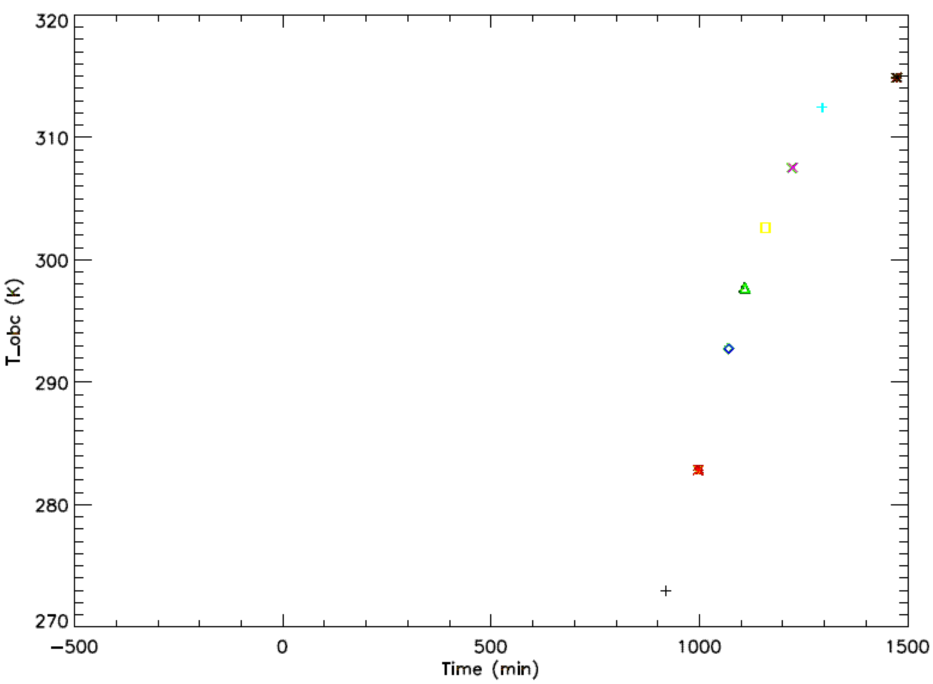

Figure 5: OBC temperature uniformity for Cold 1 plateau warm-up

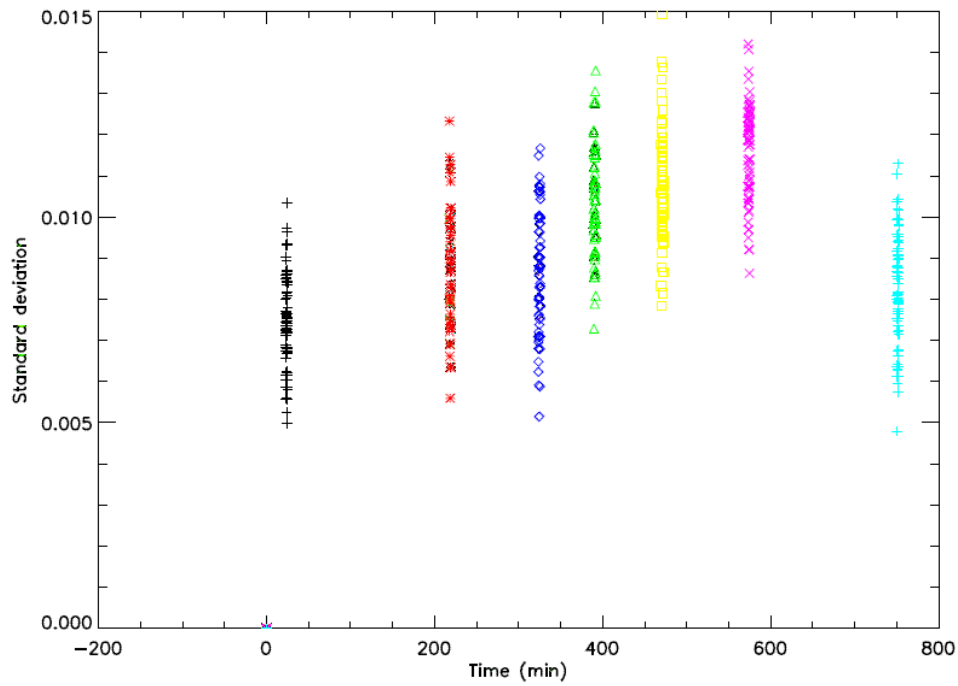

Figure 6: OBC temperature uniformity for Hot 1 plateau warm-up

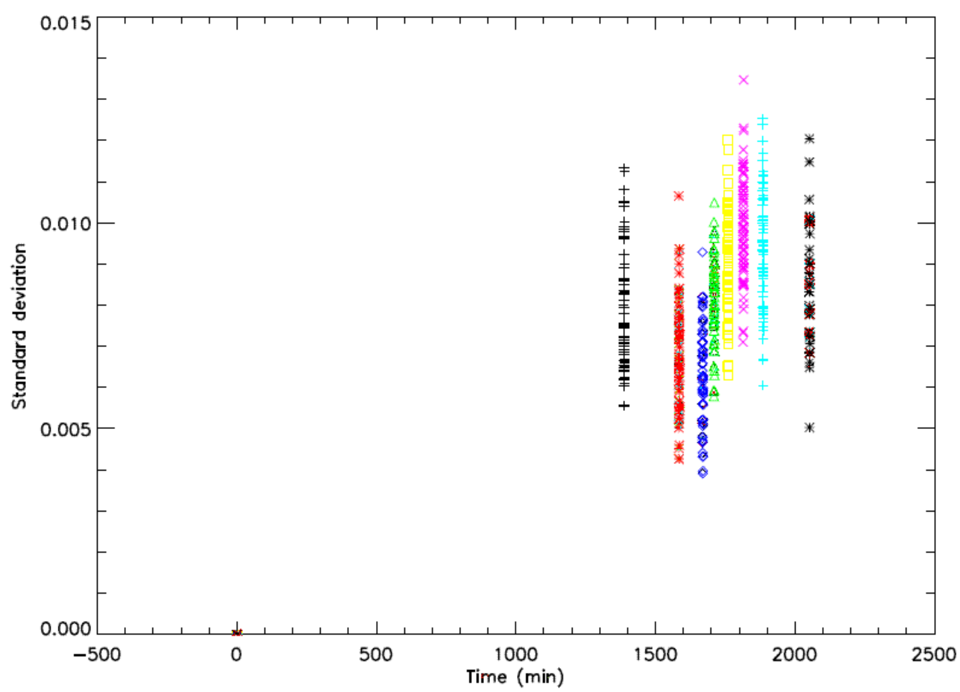

Figure 7: OBC temperature uniformity for Cold 4 plateau warm-up

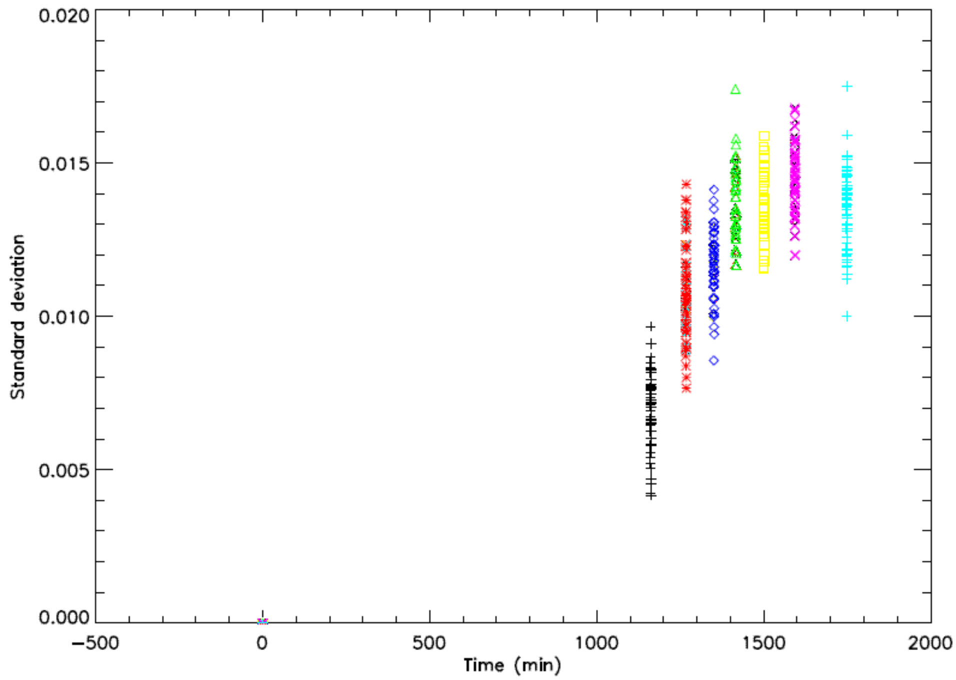

Figure 8: OBC temperature uniformity for Hot 4 plateau warm-up

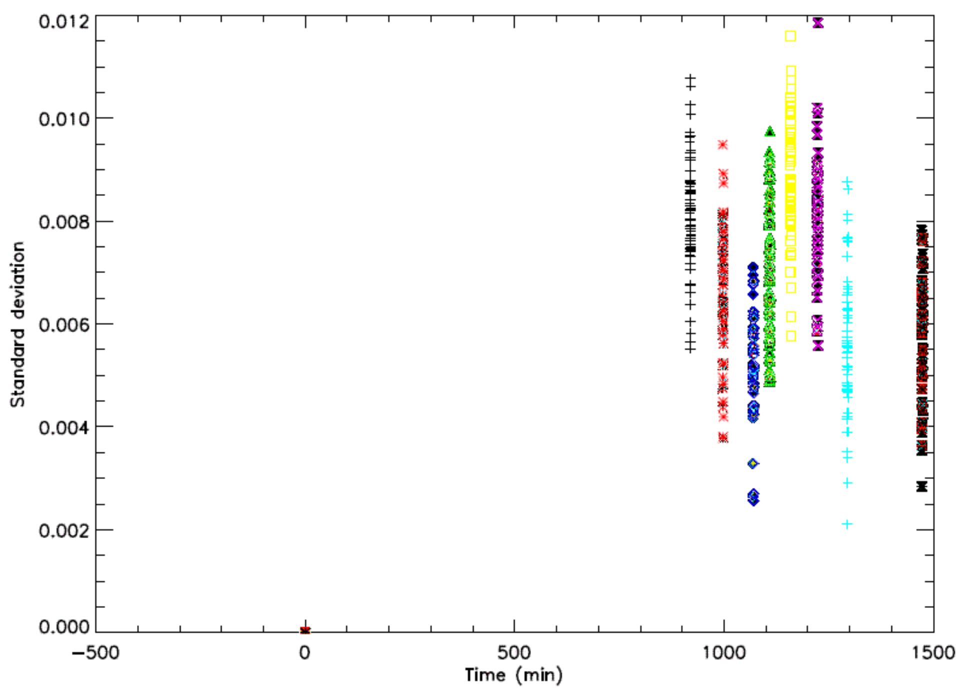

Figure 9: BCS / OBC warm-up c_0 comparison (Cold 1 plateau)

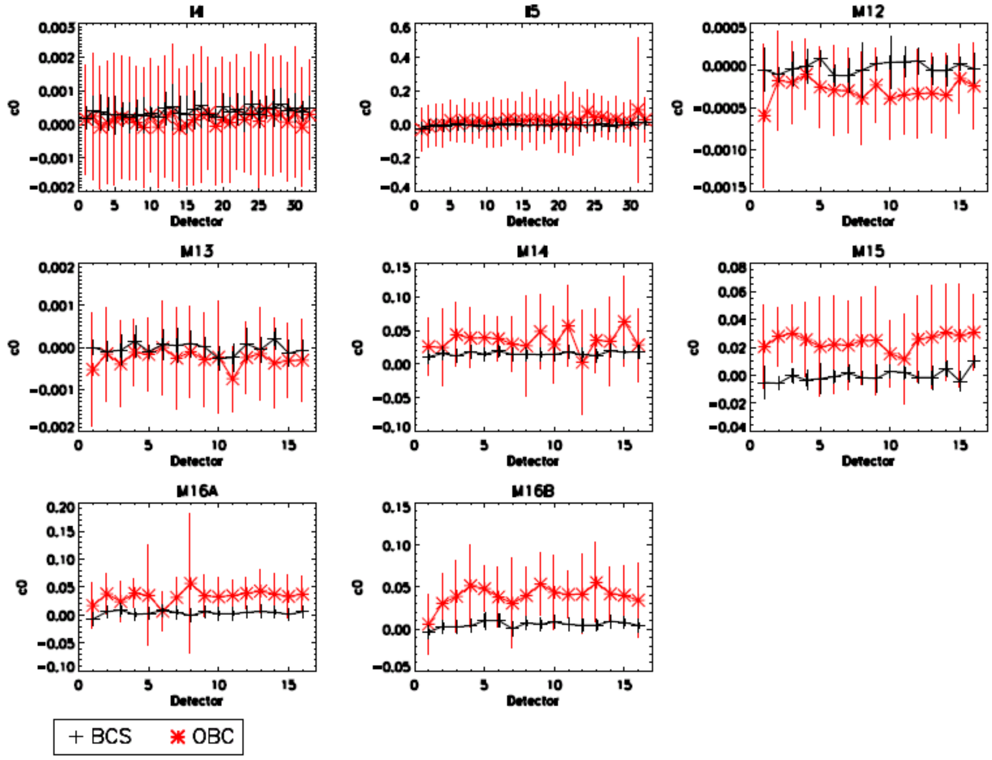

Figure 10: BCS / OBC warm-up c_0 comparison (Hot 1 plateau)

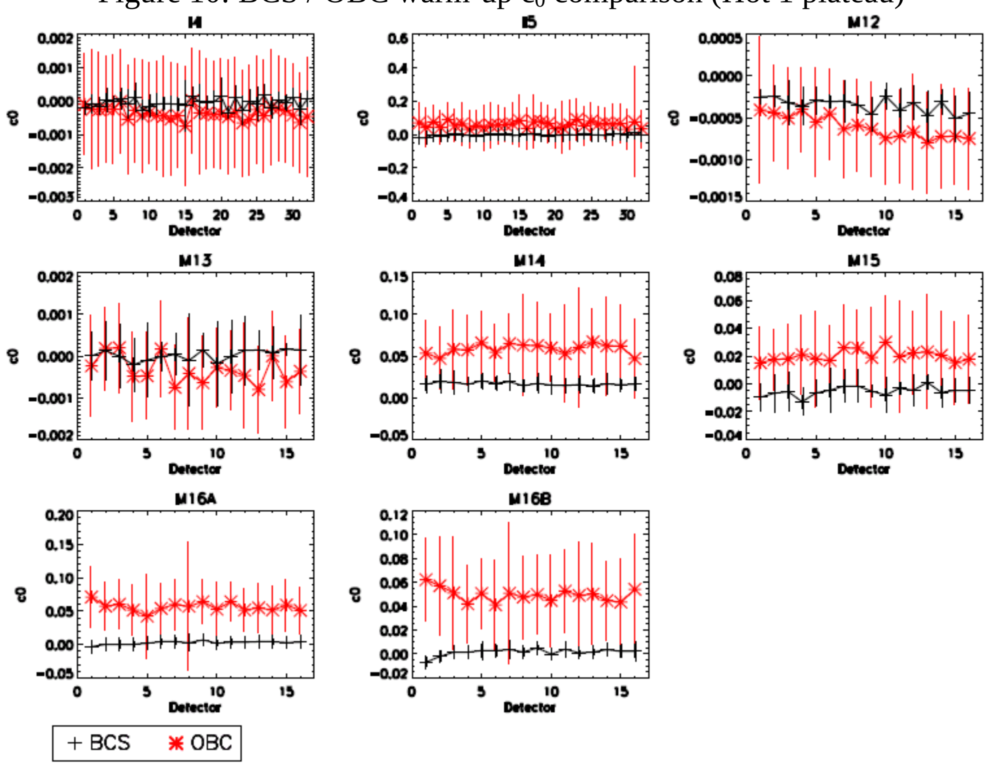

Figure 11: BCS / OBC warm-up c_0 comparison (Cold 4 plateau)

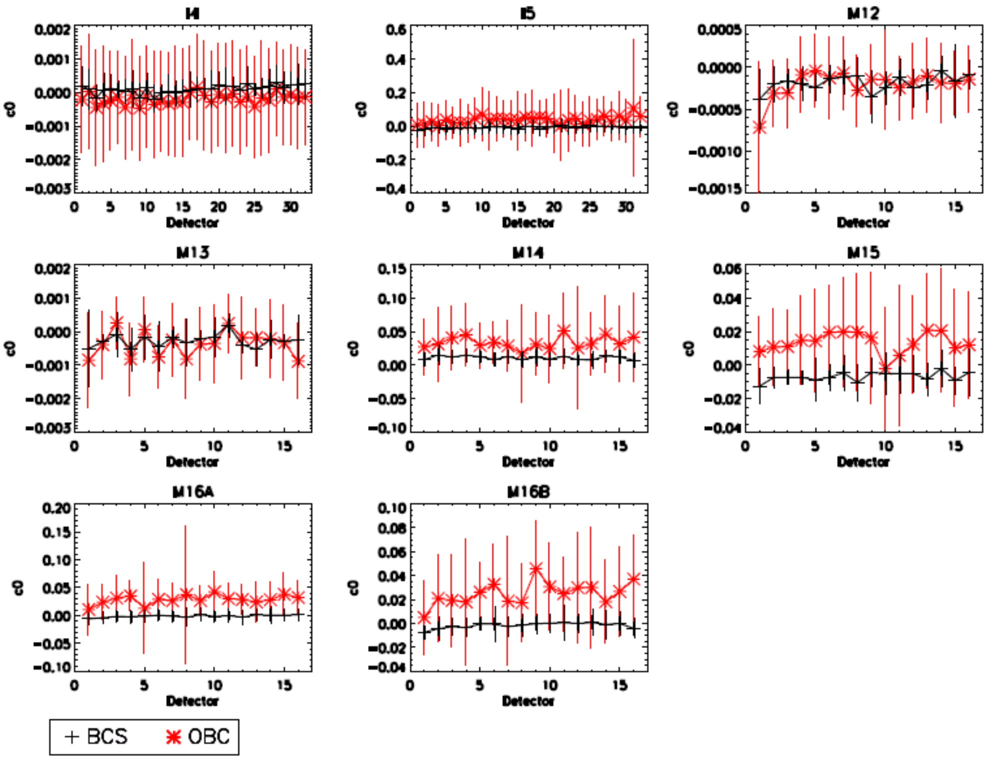

Figure 12: BCS / OBC warm-up c_0 comparison (Hot 4 plateau)

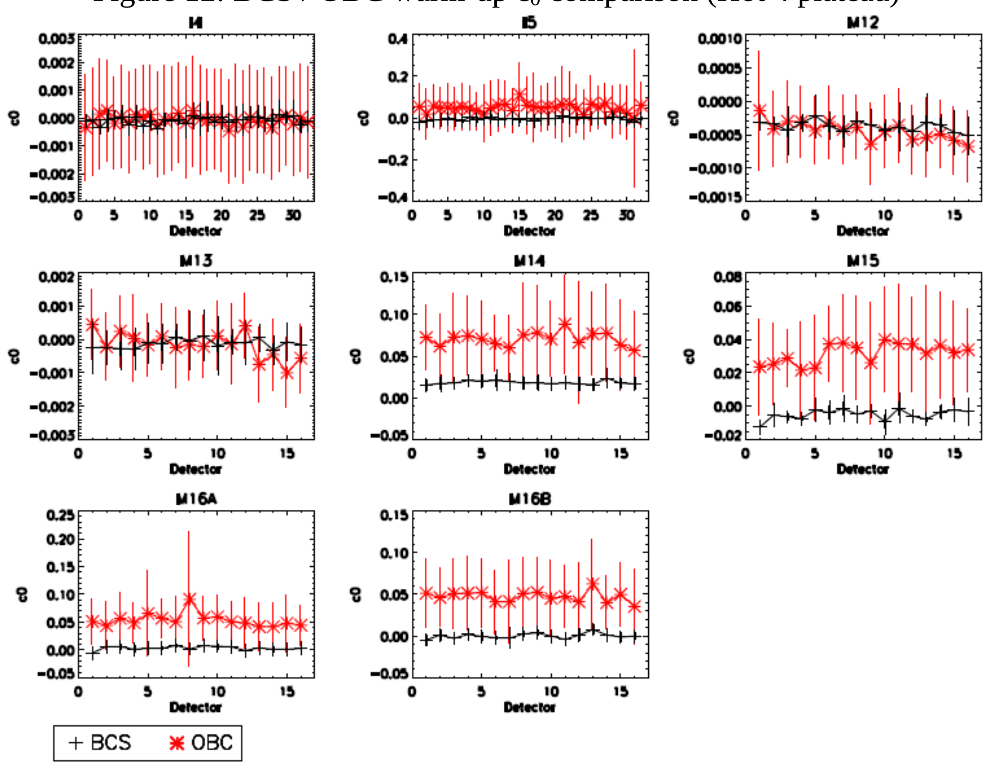

Figure 13: BCS / OBC cool-down c_0 comparison (Cold 1 plateau)

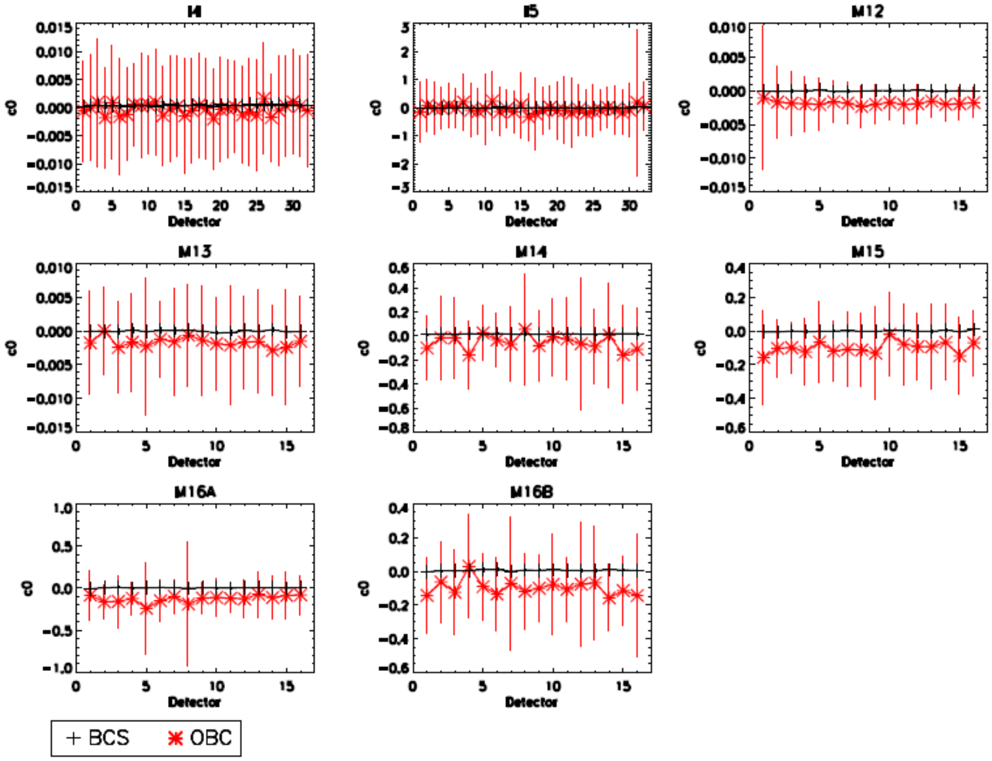

Figure 14: BCS / OBC cool-down c_0 comparison (Hot 1 plateau)

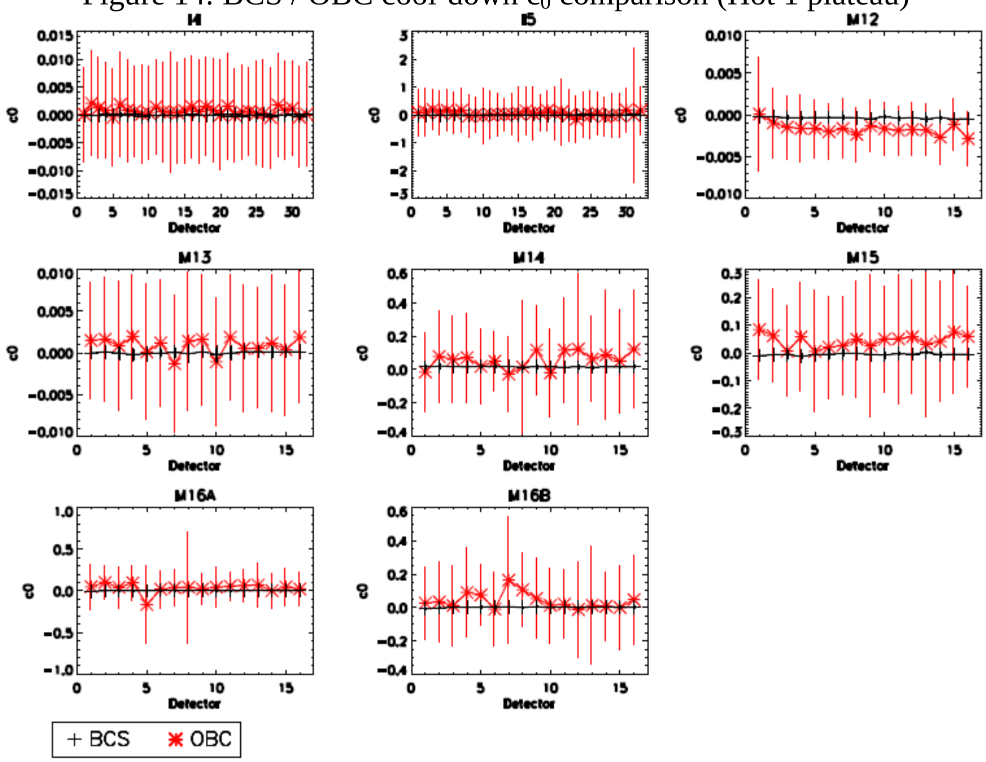

Figure 15: BCS / OBC cool-down c_0 comparison (Cold 4 plateau)

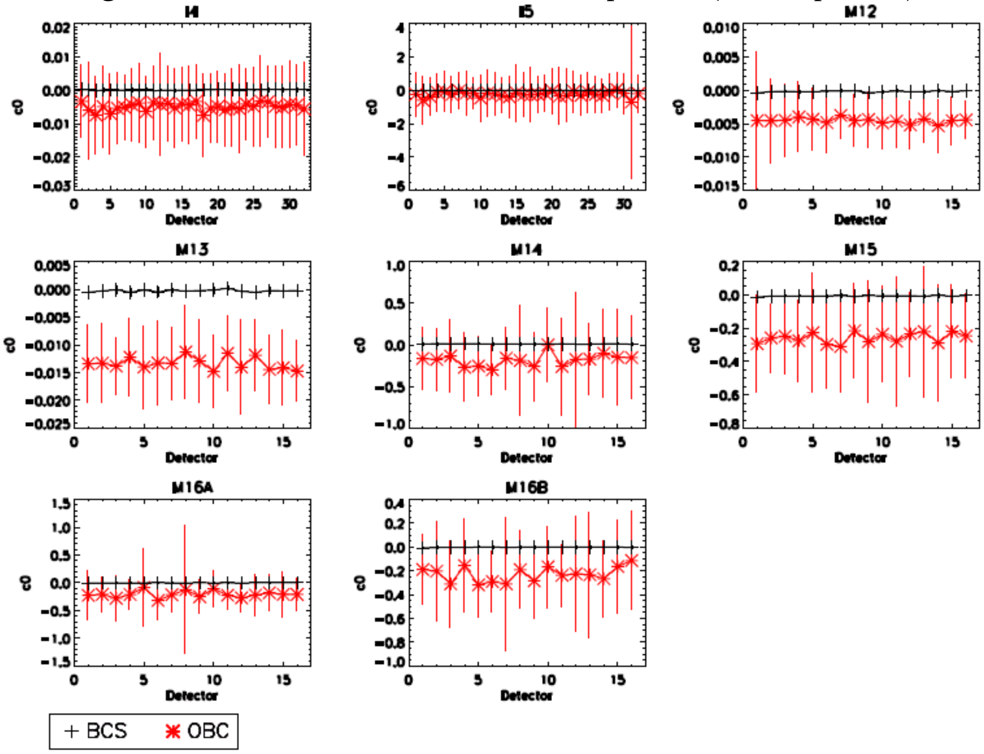

Figure 16: BCS / OBC cool-down c_0 comparison (Hot 4 plateau)

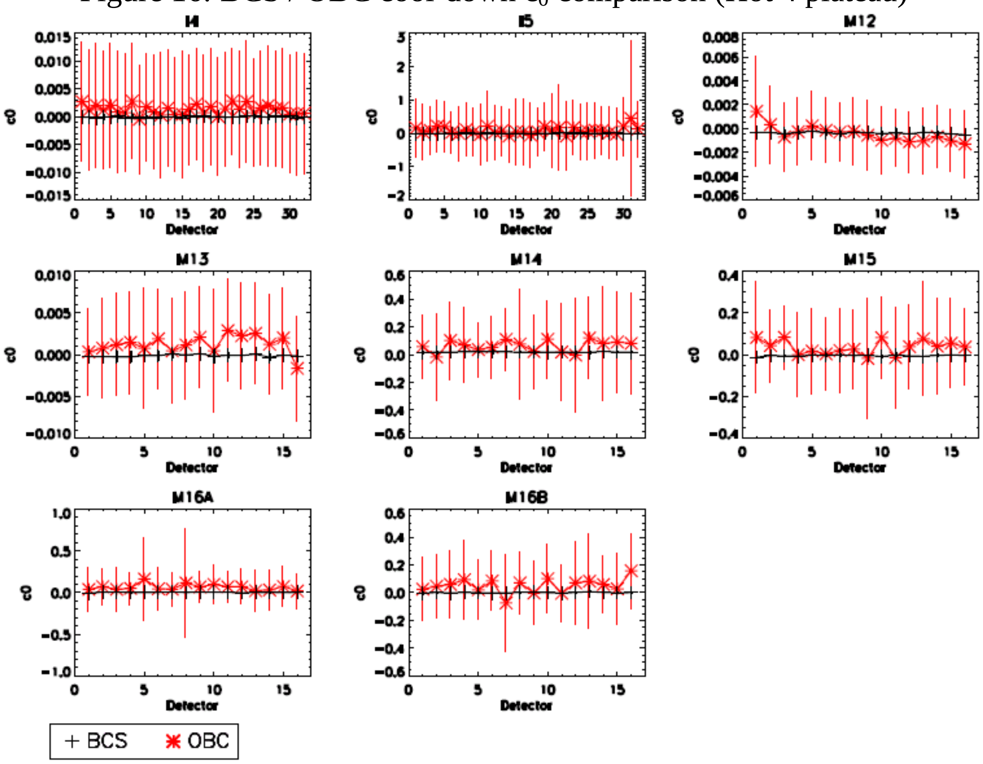

Figure 17: BCS / OBC warm-up c_1 comparison (Cold 1 plateau)

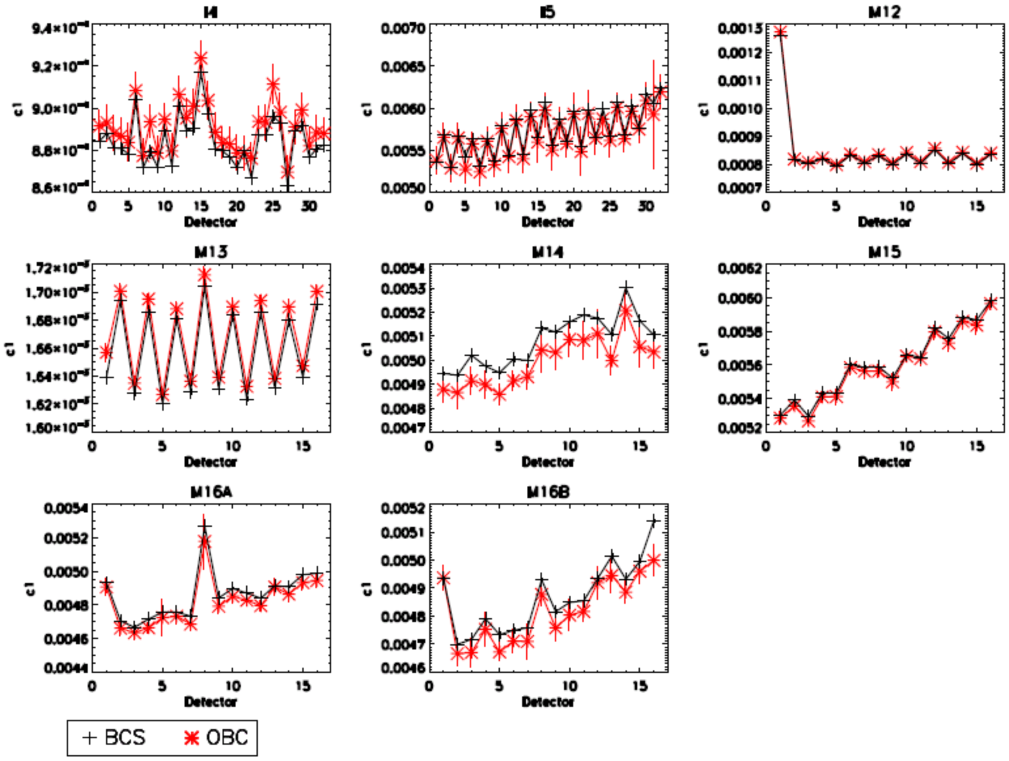

Figure 18: BCS / OBC warm-up c_1 comparison (Hot 1 plateau)

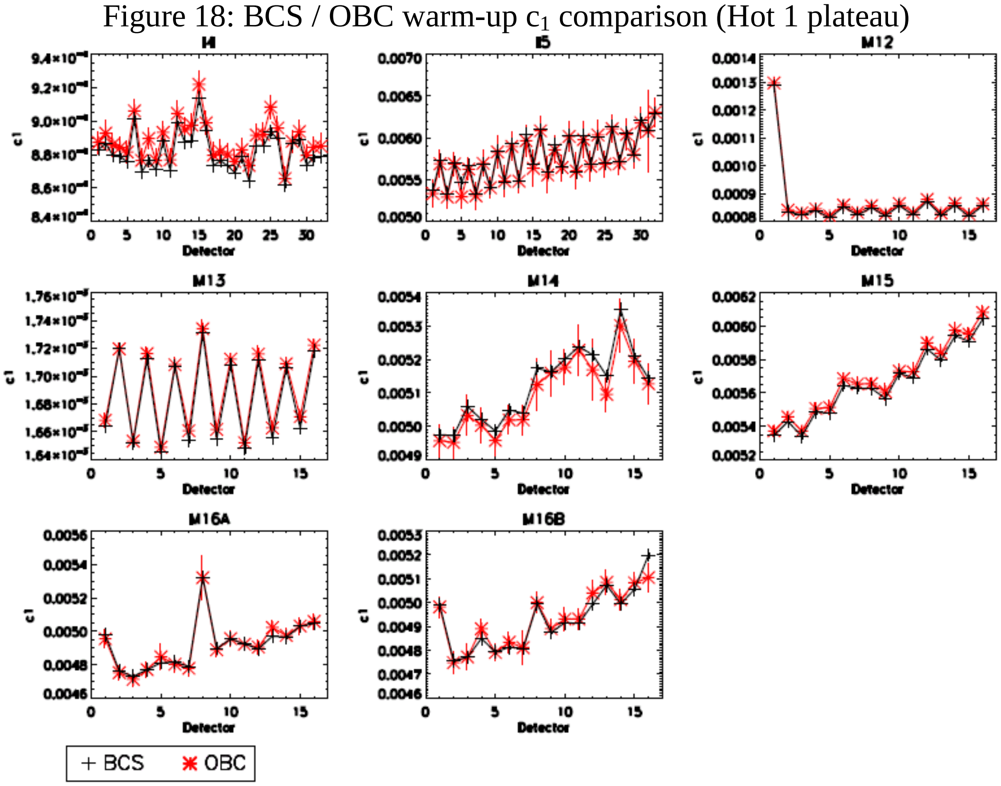

Figure 19: BCS / OBC warm-up c_1 comparison (Cold 4 plateau)

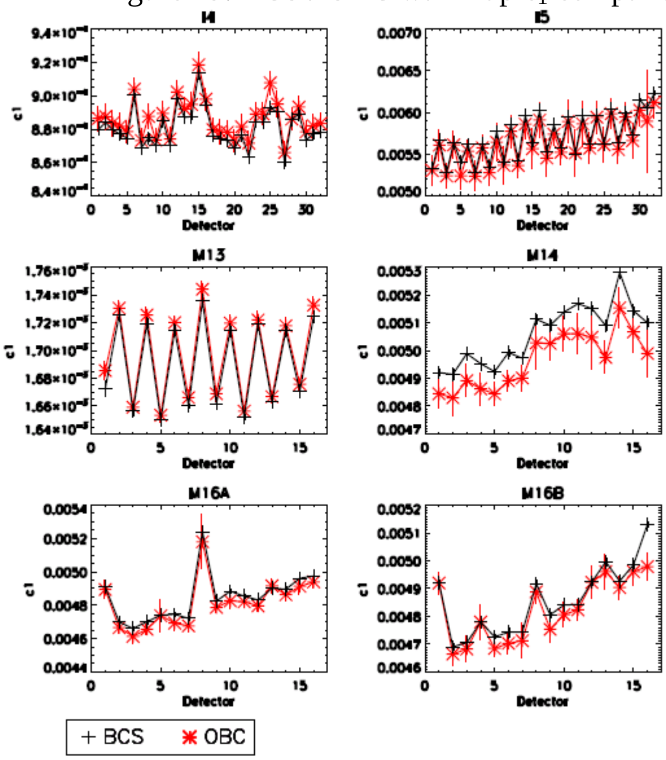

Figure 20: BCS / OBC warm-up c_1 comparison (Hot 4 plateau)

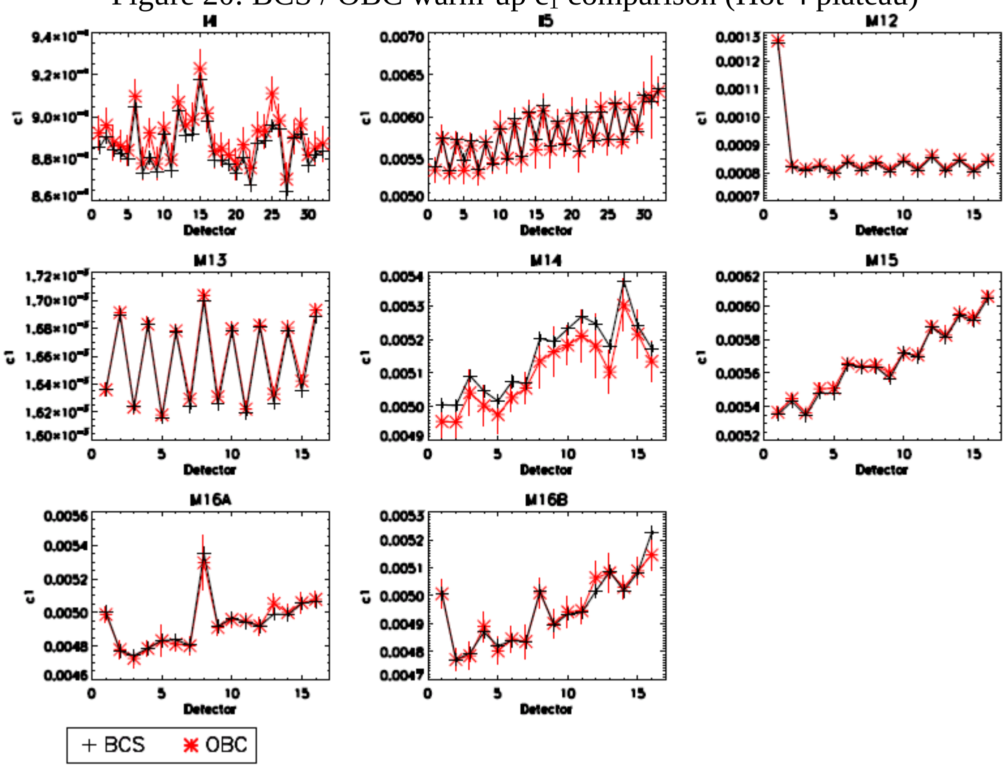

Figure 21: BCS / OBC cool-down c_1 comparison (Cold 1 plateau)

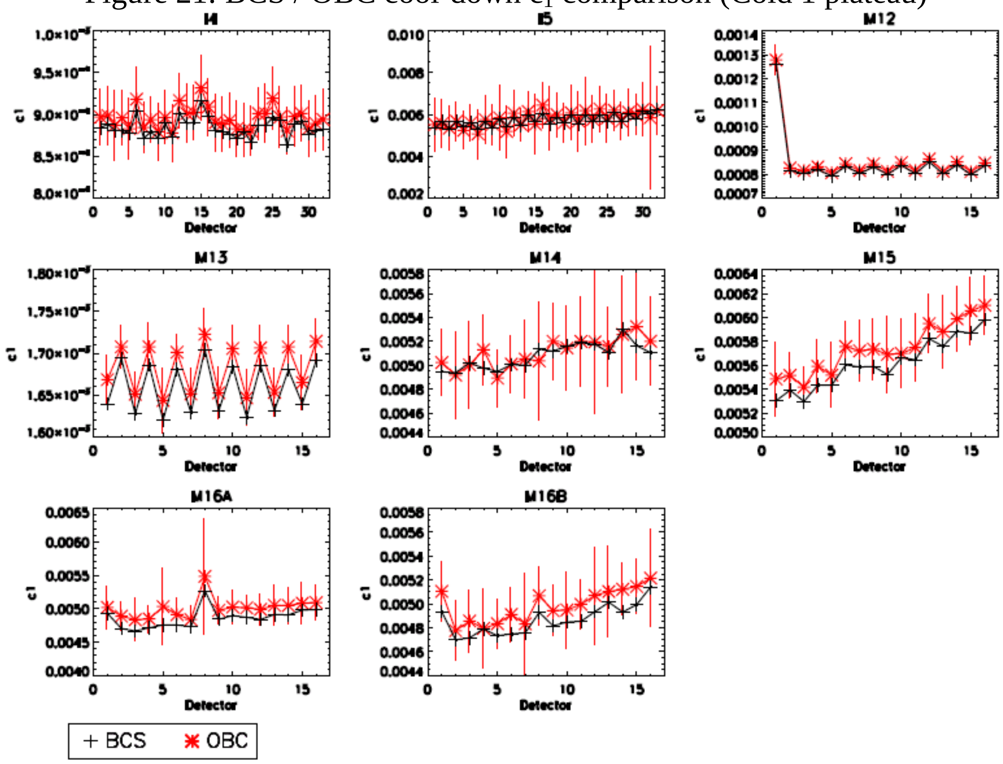

Figure 22: BCS / OBC cool-down c_1 comparison (Hot 1 plateau)

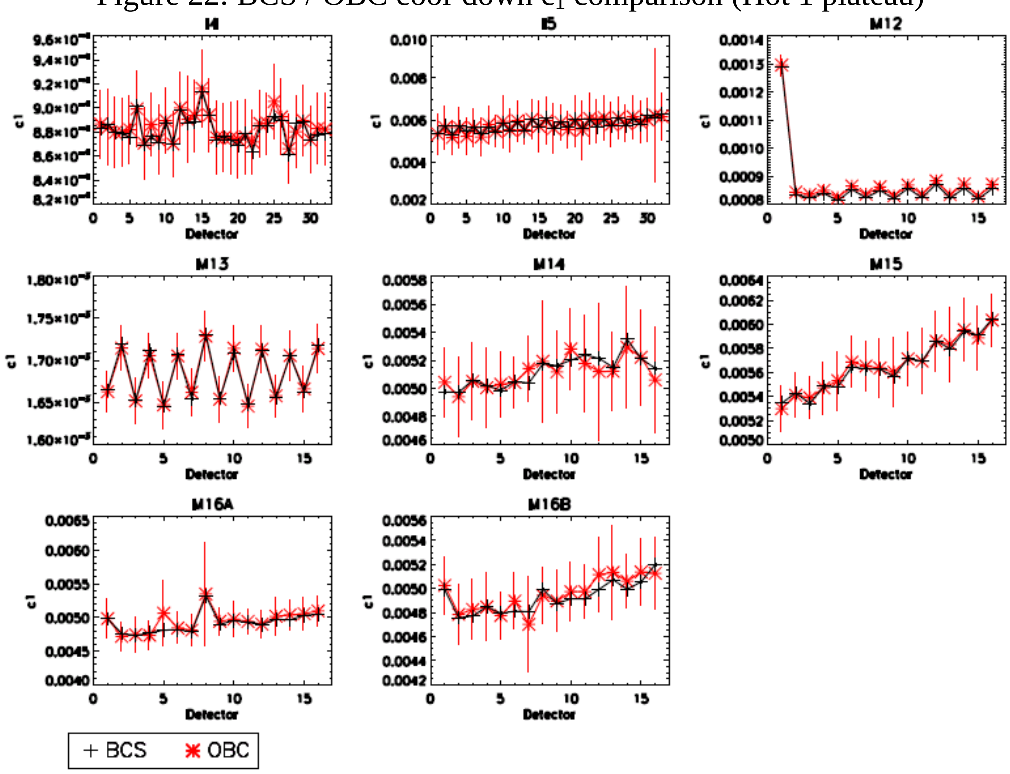

Figure 23: BCS / OBC cool-down c_1 comparison (Cold 4 plateau)

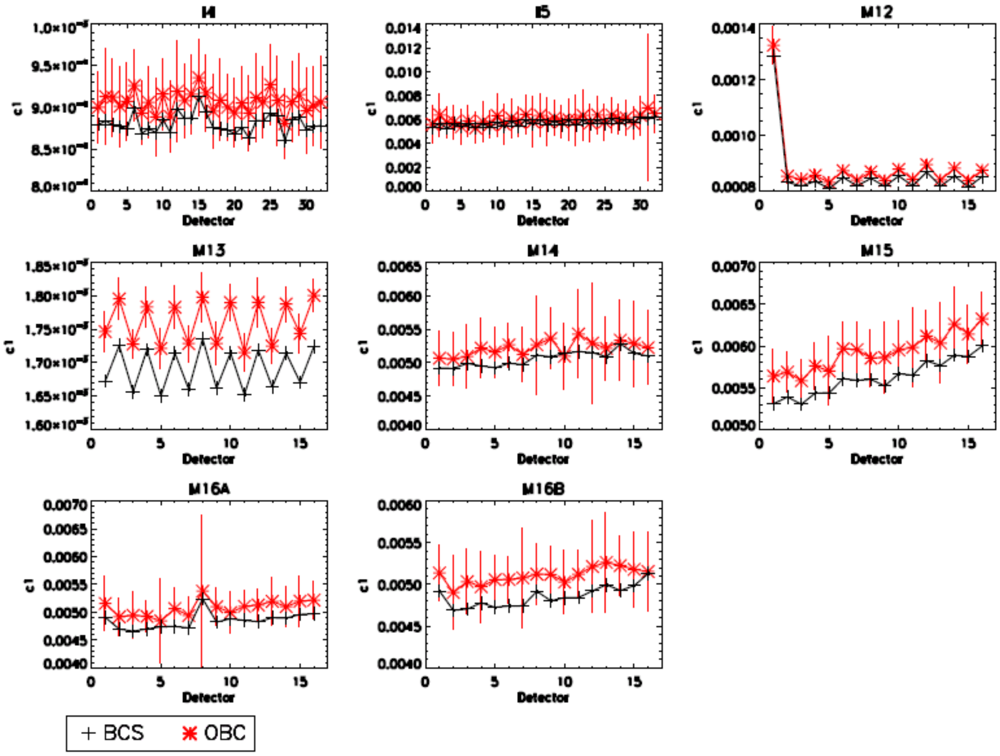

Figure 24: BCS / OBC cool-down c_1 comparison (Hot 4 plateau)

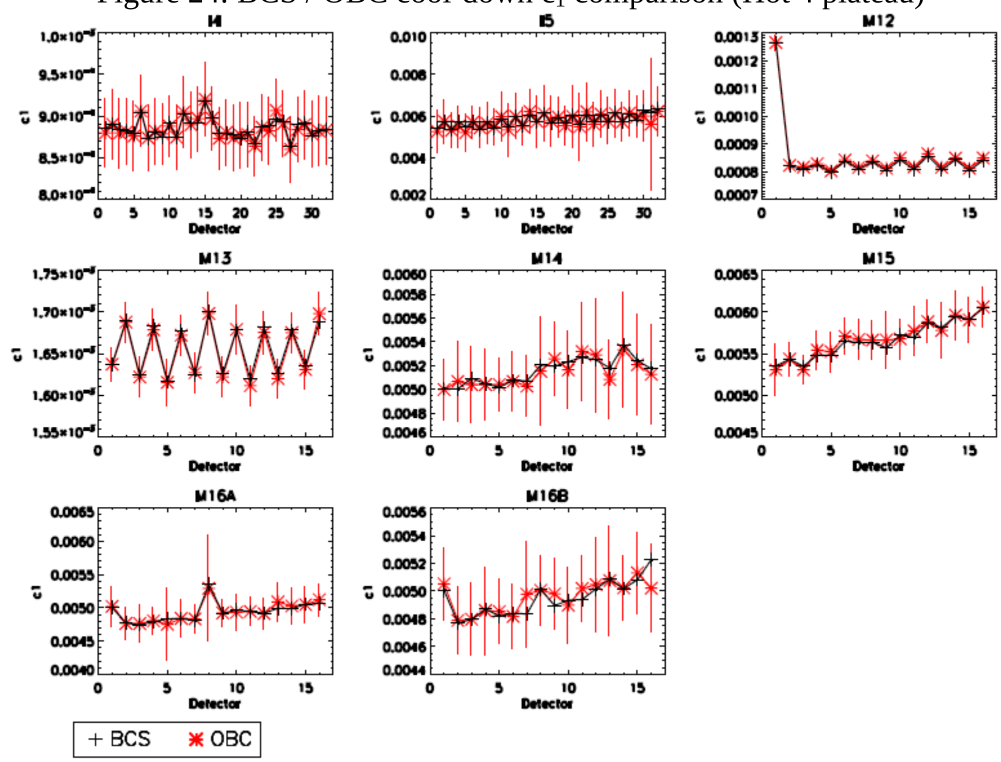

Figure 25: BCS / OBC warm-up c_2 comparison (Cold 1 plateau)

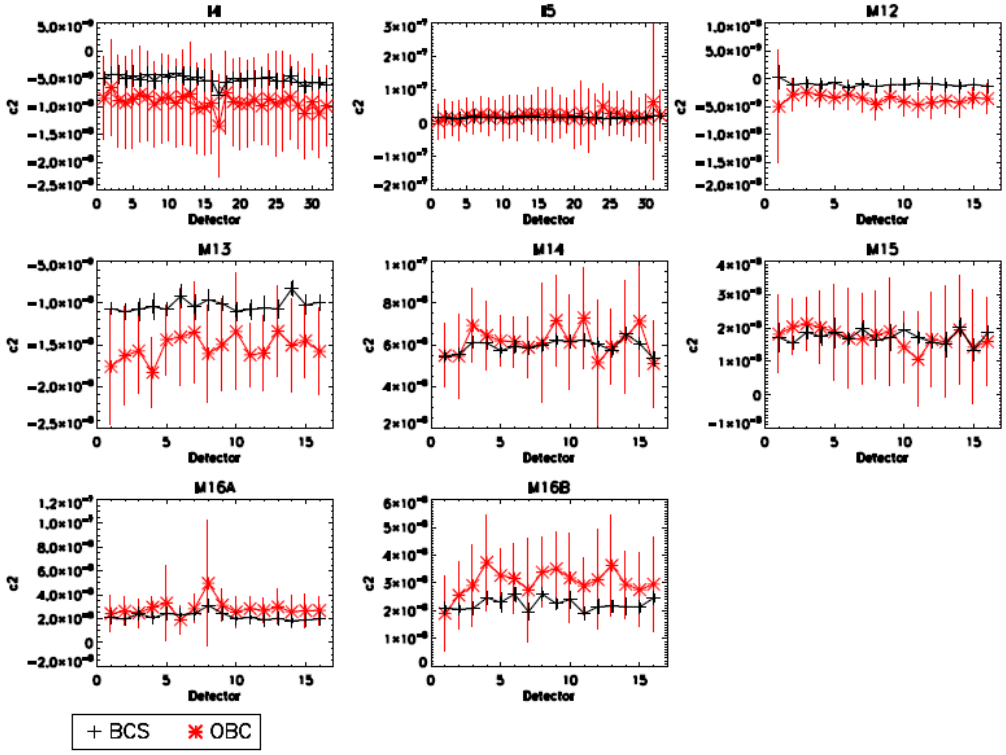

Figure 26: BCS / OBC warm-up c_2 comparison (Hot 1 plateau)

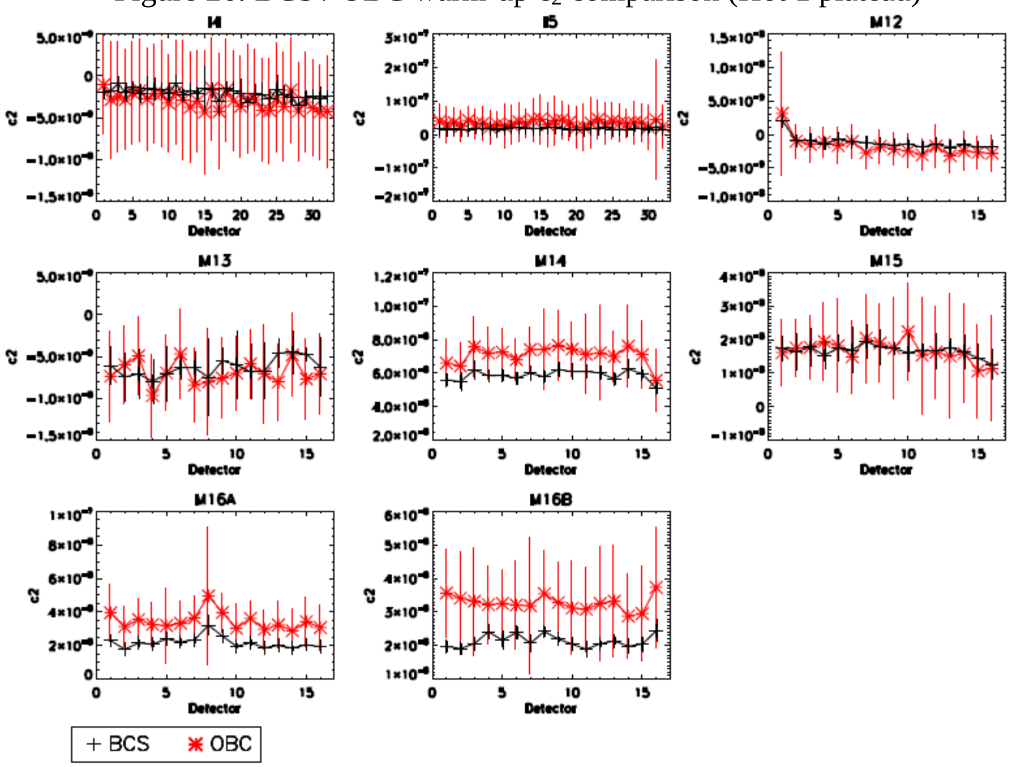

Figure 27: BCS / OBC warm-up c_2 comparison (Cold 4 plateau)

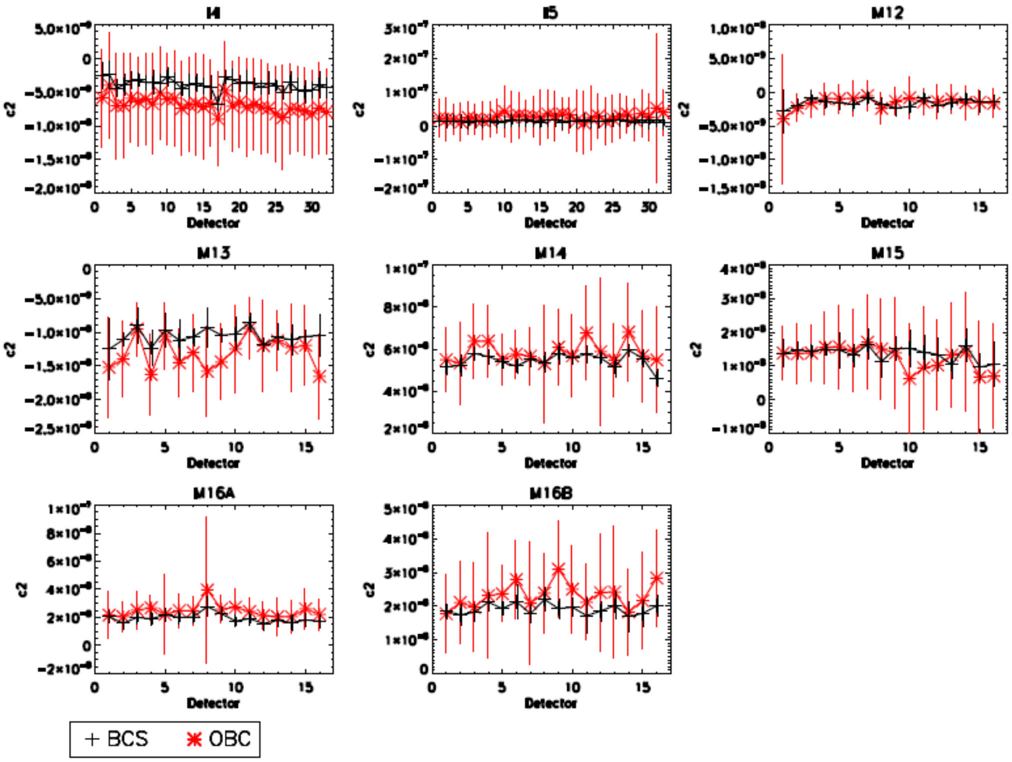

Figure 28: BCS / OBC warm-up c_2 comparison (Hot 4 plateau)

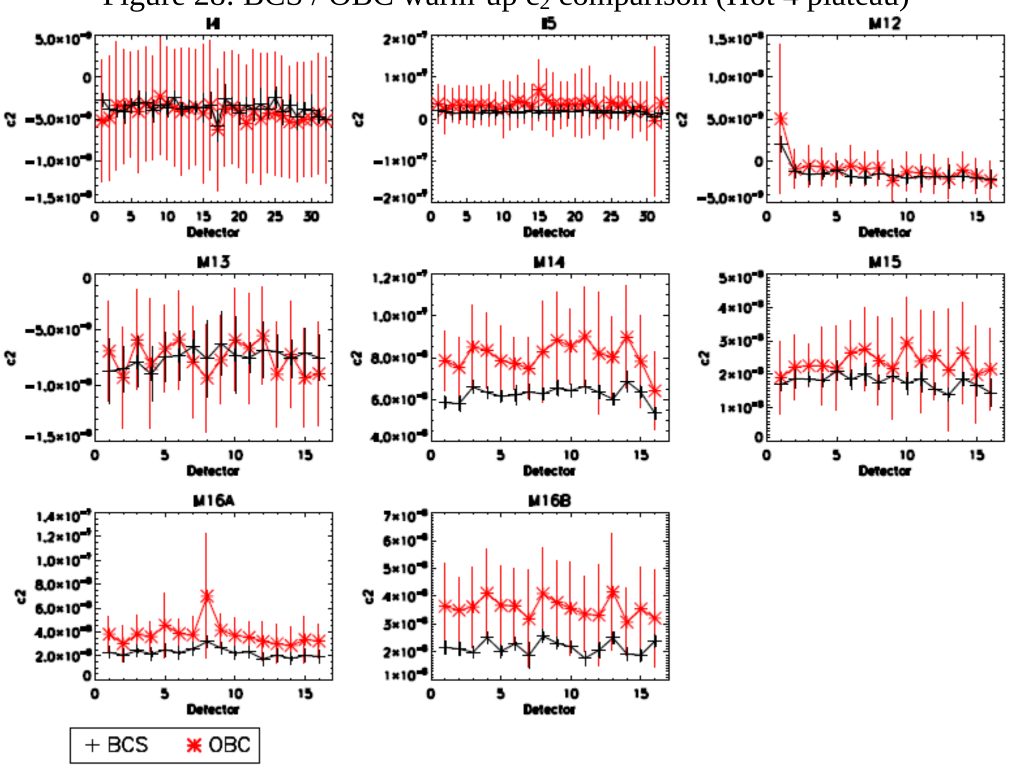

Figure 29: BCS / OBC cool-down c_2 comparison (Cold 1 plateau)

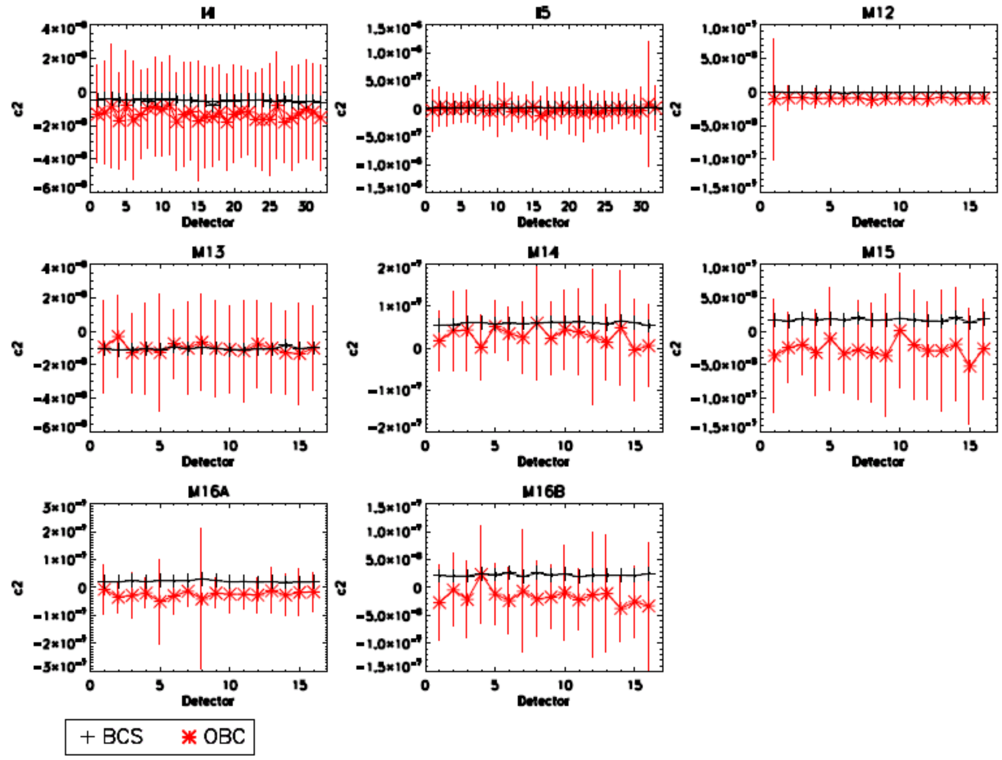

Figure 30: BCS / OBC cool-down c_2 comparison (Hot 1 plateau)

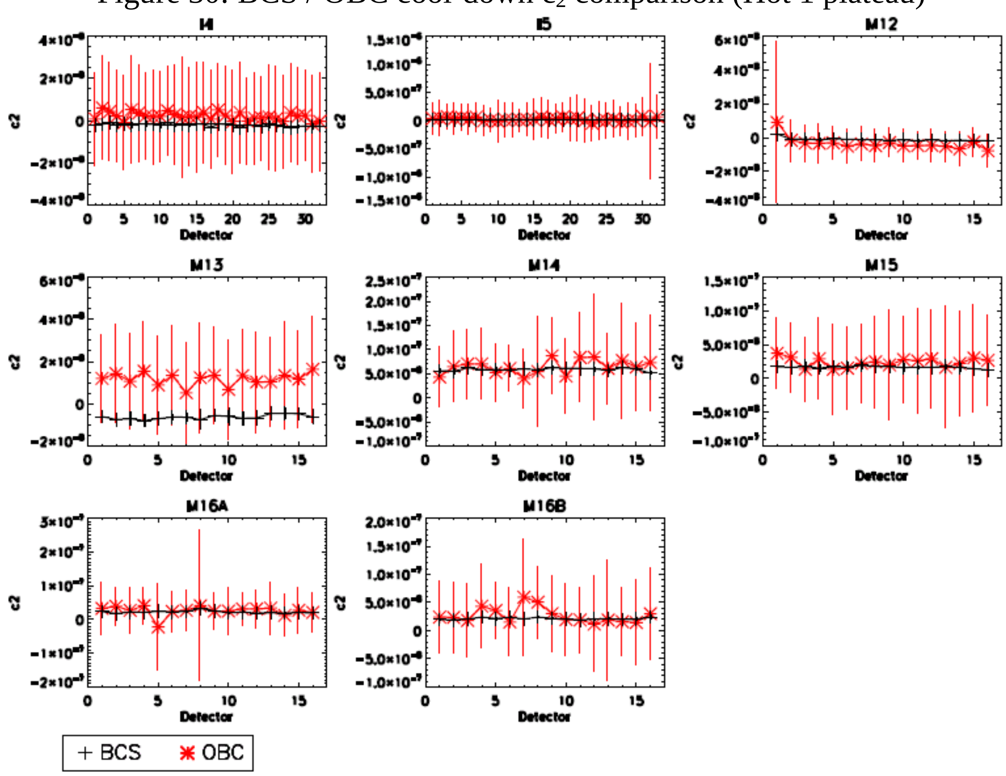

Figure 31: BCS / OBC cool-down c_2 comparison (Cold 4 plateau)

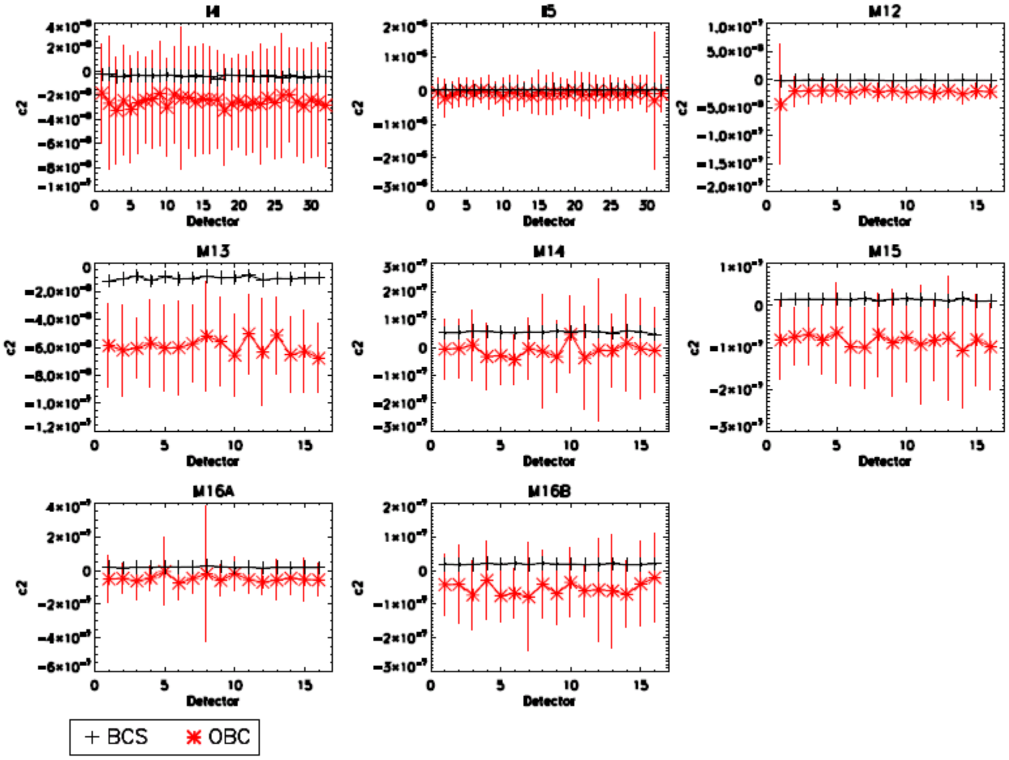

Figure 32: BCS / OBC cool-down c_2 comparison (Hot 4 plateau)

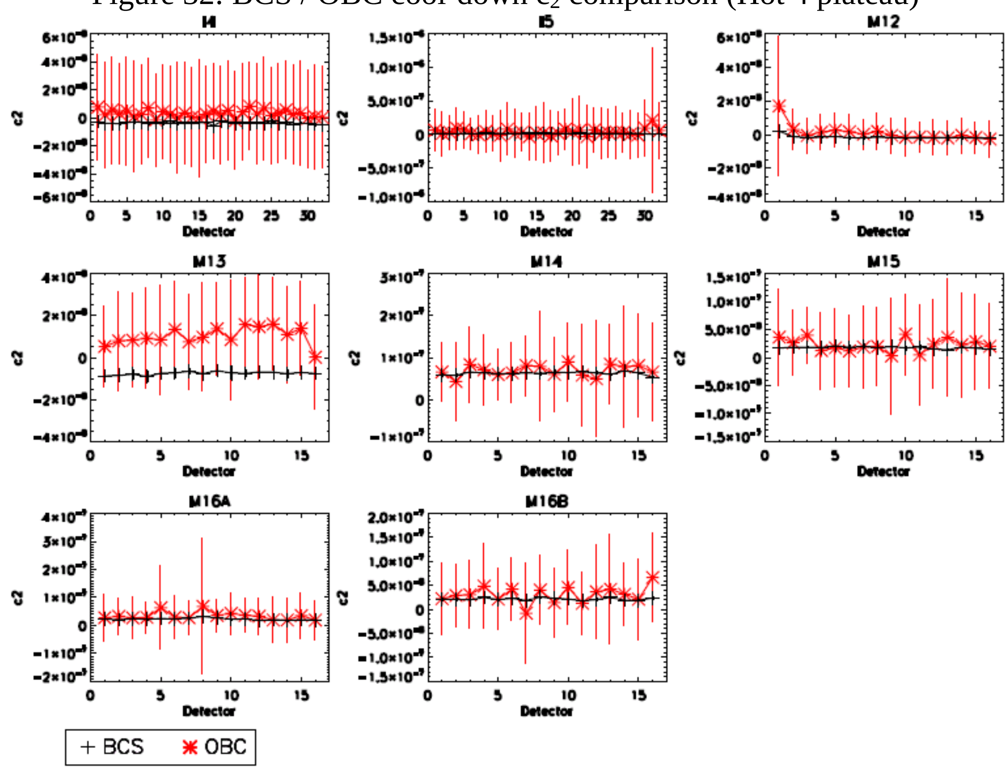

Figure 33: OBC warm-up versus BCS NEdT at T_{TYP} (Cold 1 plateau)

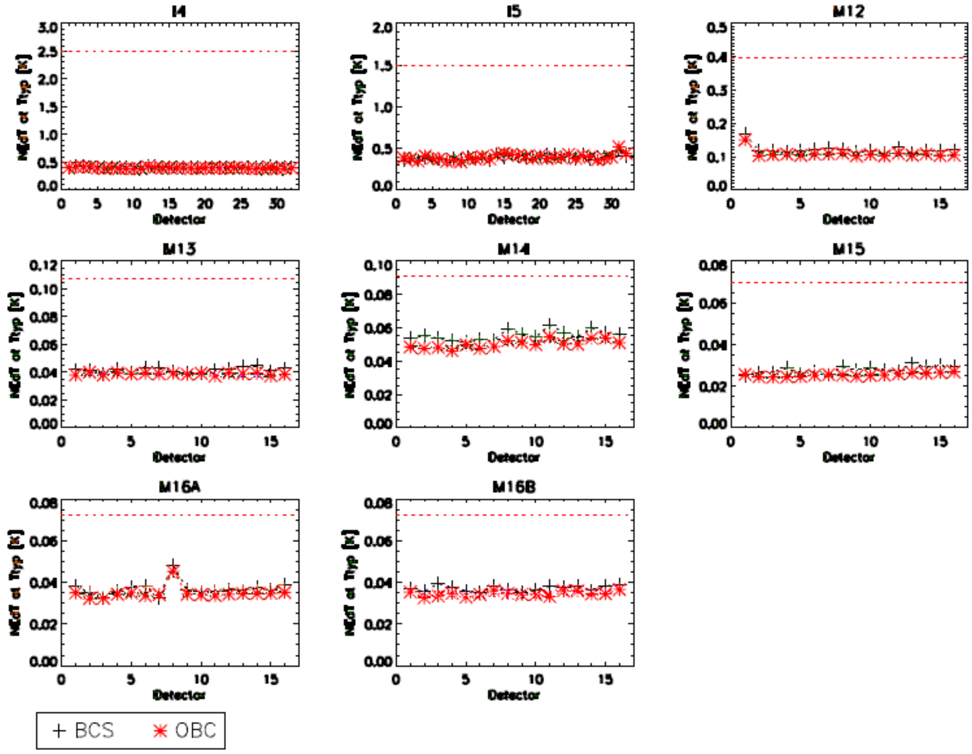

Figure 34: OBC warm-up versus BCS NEdT at T_{TYP} (Hot 1 plateau)

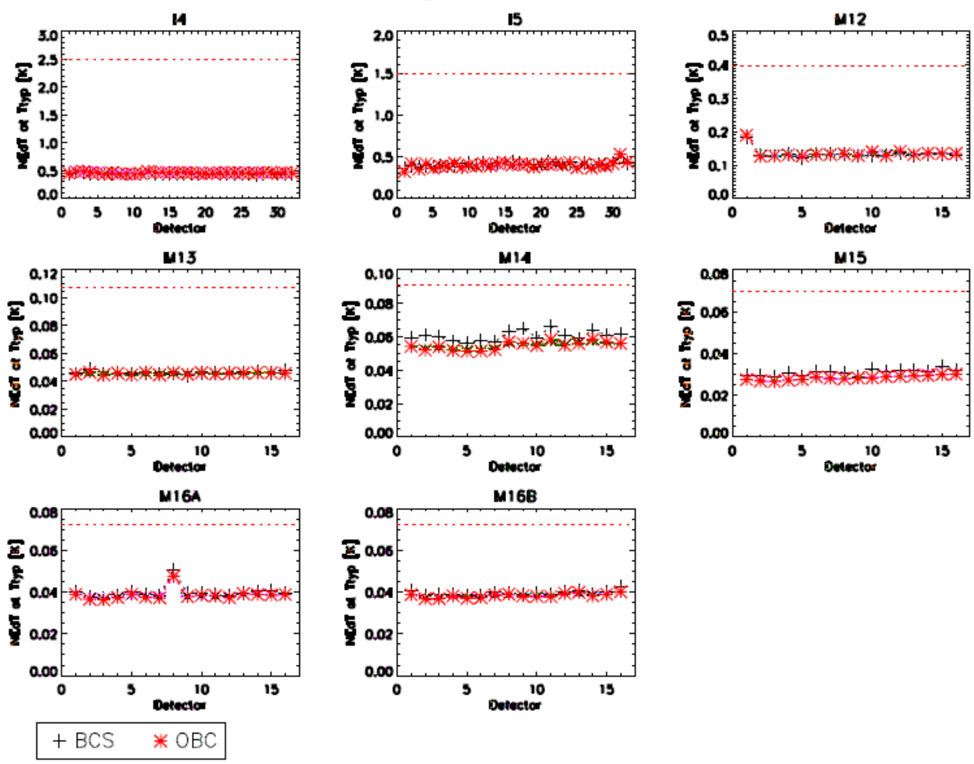

Figure 35: OBC warm-up versus BCS NEdT at T_{TYP} (Cold 4 plateau)

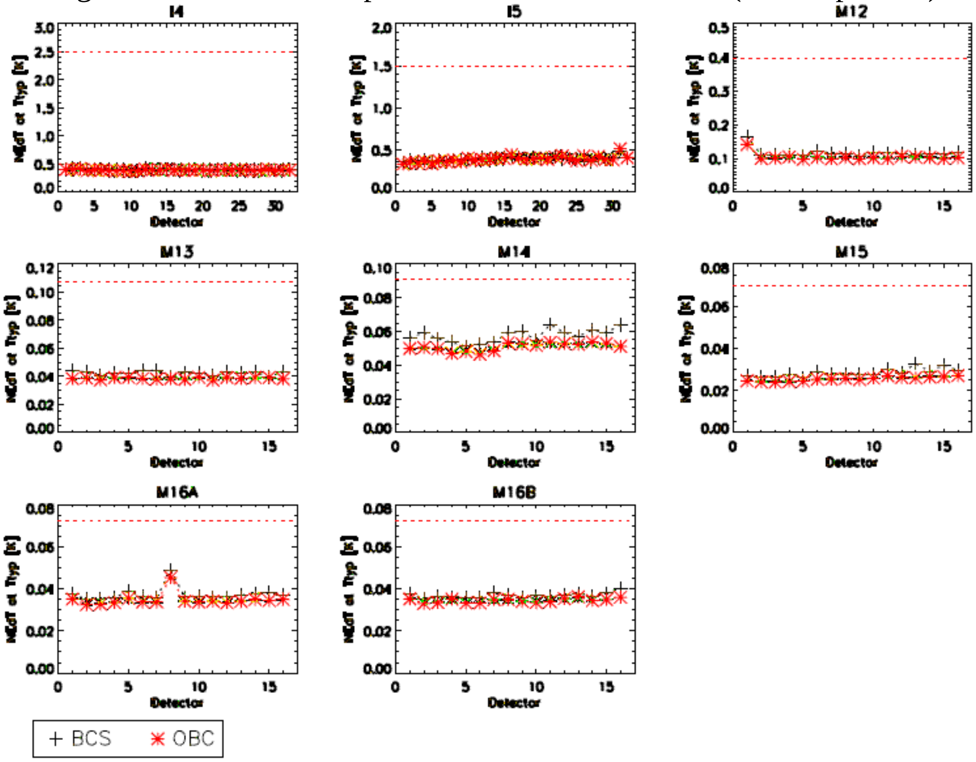

Figure 36: OBC warm-up versus BCS NEdT at T_{TYP} (Hot 4 plateau)

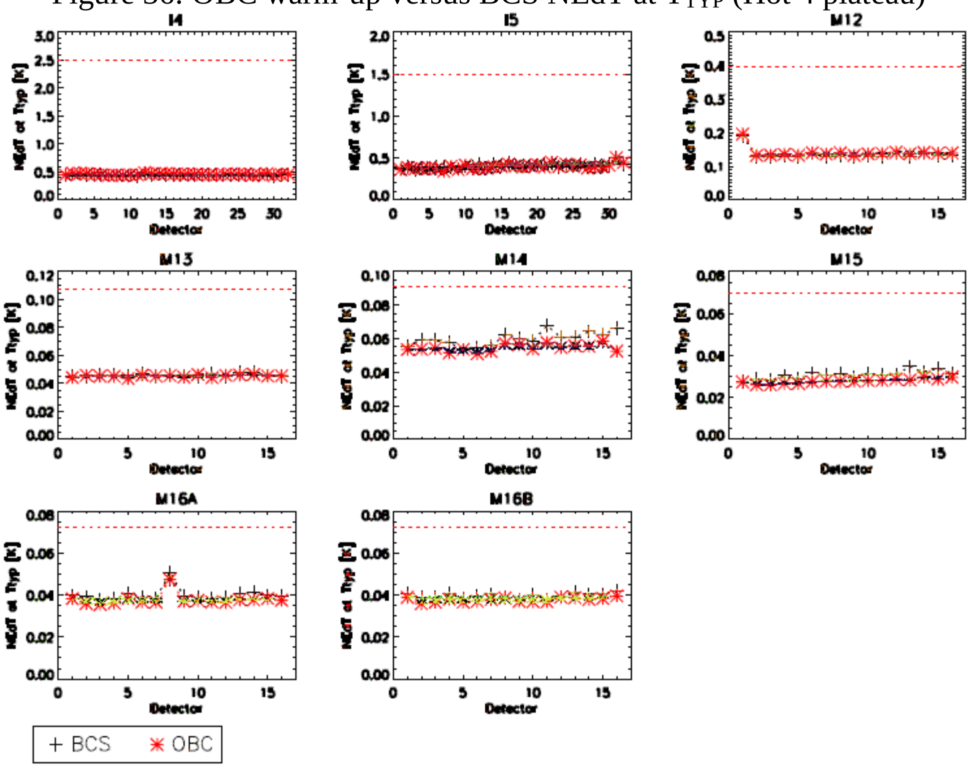

Figure 37: OBC cool-down versus BCS NEdT at T_{TYP} (Cold 1 plateau)

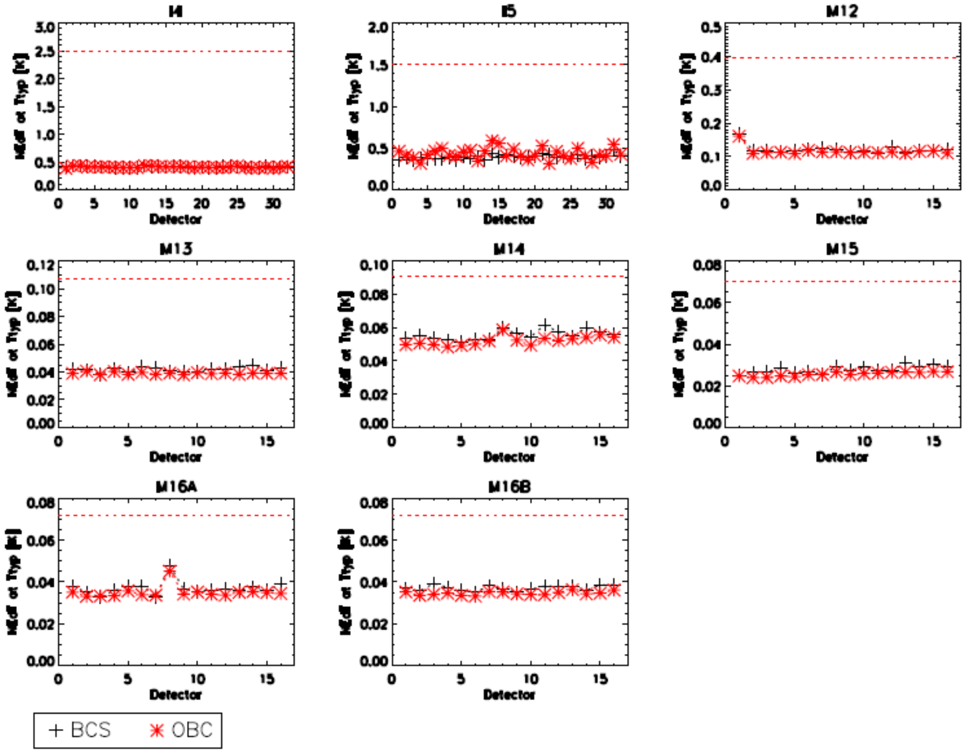

Figure 38: OBC cool-down versus BCS NEdT at T_{TYP} (Hot 1 plateau)

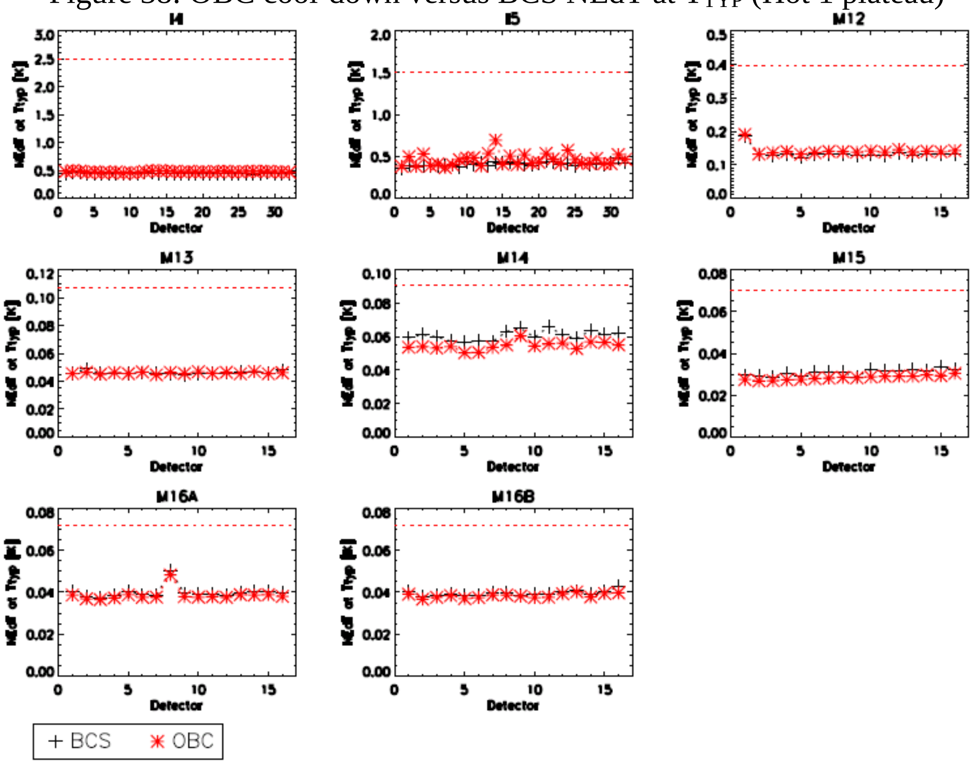

Figure 39: OBC cool-down versus BCS NEdT at T_{TYP} (Cold 4 plateau)

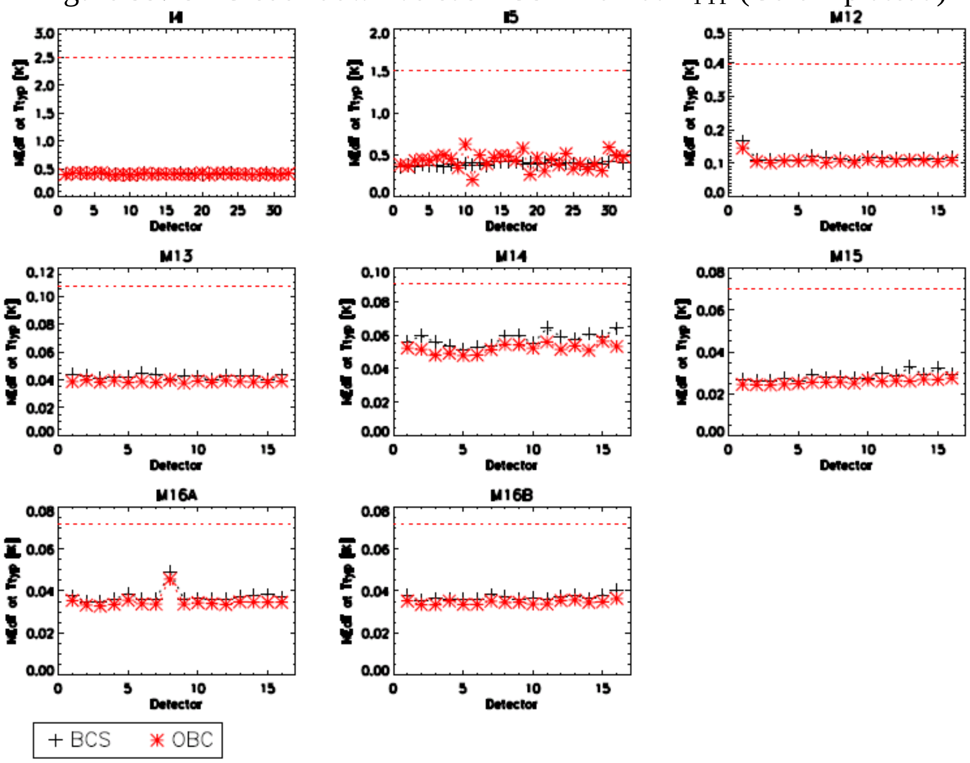

Figure 40: OBC cool-down versus BCS NEdT at T_{TYP} (Hot 4 plateau)