



# FPG report

Version 1.0 of 2009-09-11, by Michael Olberg

## Abstract

This document summarizes the results of the focal plane geometry observations (FPG-1 and FPG-2) carried out during the commissioning phase of HIFI.

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### Reference Documents

<b>Doc. ref</b>		<b>Title</b>
HERSCHEL-HSC-DOC-1139 ICC/2008-130	RD01	Herschel Pointing Calibration Plan (Sec.4.2.2)
	RD02	HIFI Spacecraft-Instrument Alignment Matrix (SIAM)

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## 1 Introduction

The FPG determination for HIFI was performed in two sets of observations that were meant to allow a coarse measurements of the HIFI apertures (in four groups), followed by measurement of all apertures for all HIFI mixer bands. At the end of these activities a SIAM update was performed.

## 2 Observations

Table 1 lists the observational data on which the analysis presented in this report is based. Note that the observations reported on ODs 21 and 39 were pre-validations of the observing modes with the cryo-cover closed and opened, respectively.

Table 1: List of FPG activities during the Commissioning Phase

OD	ObsId	Title	Source	Date and time	secs
21	1342177771	Aot0_M.FPG2-4b-HalfThrow	Saturn	2009-06-03 17:27:49	1352
21	1342177774	Aot0_M.FPG2-6b-HalfThrow	Saturn	2009-06-03 18:36:36	1377
39	1342178893	Aot1_M.FPG2-6b-HalfThrow	Saturn	2009-06-21 22:39:46	490
39	1342178896	Aot1_M.FPG2-4b-HalfThrow	Saturn	2009-06-21 23:19:59	1353
46	1342179301	FPG1_FastDBSRaster_6b_1625	Saturn	2009-06-29 04:47:42	12046
46	1342179302	FPG1_HalfThrowDBSRaster_6b_1625	Saturn	2009-06-29 08:23:00	12038
46	1342179304	FPG1_FastDBSRaster_1a_491	Saturn	2009-06-29 11:50:44	3840
46	1342179306	FPG1_FastDBSRaster_2b_770	Saturn	2009-06-29 13:01:26	5753
46	1342179308	FPG1_FastDBSRaster_4b_1112	Saturn	2009-06-29 15:09:16	9349
53	1342179565	FPG1_HalfThrowDBSRaster_7b_1893	Saturn	2009-07-06 09:25:50	11154
55	1342179610	FPG2_FastDBSRaster_2b_770	Saturn	2009-07-07 17:22:52	4919
55	1342179611	FPG2_HalfThrowDBSRaster_2b_770	Saturn	2009-07-07 18:49:44	4899
55	1342179613	FPG2_FastDBSRaster_4b_1112	Saturn	2009-07-07 20:43:14	4870
55	1342179614	FPG2_HalfThrowDBSRaster_4b_1112	Saturn	2009-07-07 22:05:49	4850
55	1342179616	FPG2_FastDBSRaster_5a_1127	Saturn	2009-07-07 23:31:47	4870
55	1342179617	FPG2_HalfThrowDBSRaster_5a_1127	Saturn	2009-07-08 00:54:48	4845
55	1342179619	FPG2_HalfThrowDBSRaster_1a_491	Saturn	2009-07-08 02:53:59	4948
55	1342179620	FPG2_FastDBSRaster_1a_491	Saturn	2009-07-08 04:17:31	4963
55	1342179623	FPG2_FastDBSRaster_3a_828	Saturn	2009-07-08 06:53:33	4914
55	1342179624	FPG2_HalfThrowDBSRaster_3a_828	Saturn	2009-07-08 08:16:55	4894
55	1342179626	FPG1_FastDBSRaster_6b_1625_repeat	Saturn	2009-07-08 10:31:00	12046

## 3 Results

### 3.1 FPG-1

The observations performed on OD 46 resulted in a SIAM update (0055\_0001.SIAM) which simply applied a common shift to all HIFI apertures, in order to ensure that the raster maps planned for the FPG-2 campaign were large enough to cover the source sufficiently

for this purpose. However, the map in band 6 failed and this was repeated on OD 55. Also, an additional FPG-1 type of raster map in band 7 was scheduled for OD 53.

A proper SIAM was not delivered in time for the FPG-2 measurements of OD 55 due to lack of time, however such a SIAM was subsequently produced for test purposes and was HIFI internally referred to as 0063\_0001.SIAM. In this SIAM, updates for all individual apertures were based on:

- Actual updates for the apertures directly measured, i.e. the H and V beams for M3 right, synthesized entries correctly represent the average H/V pointing
- For the remaining apertures for M3 right that had not yet been measured, updates were made based on the ground-based knowledge of relative offsets within the clusters of beams. Synthesized entries were calculated on the H-V offsets measured during ILT-3
- The M3 centre position were then calculated on the basis of a ray-trace model including all Offner distortions and the offset-pivot rotation of the chopper mirror. The actual chopper rotation angles are derived from the CoP chopper calibration and chopper angle vs. chopper voltage characteristic.

Final (additional) experimental confirmation of this update was expected through the OD 53/OD 55 FPG-1 measurements in 7b/6b.

The intention with this SIAM was given in an email by Willem: *This SIAM should in principle re-center all individual FPG-1 maps measured so far, provided one calculates synthesized intensity maps when using synthesized SIAM entries. It can furthermore be used to understand where we have been looking during the AOT blocks, in specific for the cases where we have been using M3 center.*

## 3.2 FPG-2

The analysis of the FPG-2 data were carried out in two steps:

1. Running the data through the HIFI pipeline.
  - Retrieving commanded raster map parameters from uplink data.
  - Averaging spectra on each position of the commanded grid, typically 2 spectra were taken per position.
  - Subtracting the position of Saturn (interpolated from a downloaded JPL Horizons ephemeris onto the time of the observation) from the recorded RA, Dec of the individual spectra, in order to work with relative offsets in a co-moving frame of reference.
  - Calculating integrated intensities and saving results to ASCII tables. An example of such ASCII data is given in table 2 below.
2. Offline analysis of ASCII data files from step 1 using MatLab.
  - Fitting two dimensional, circular Gaussian intensity distributions to the observed intensity maps.
  - Calculating residuals.

Table 2: Example of an ASCII data table used as input for the MatLab fitting routines. Only the first 15 lines of the result from a  $15 \times 15$  raster map are given. The columns dThetaZ and dThetaY are the corresponding offsets in the focal plane, resulting from the observed offsets in RA and Dec via a rotation around the X-axis the actual POS-angle of the observation.

ix	iy	dRA.cmd	dDec.cmd	dRA.act	dDec.act	dThetaZ	dThetaY	intensity
0	0	-51.408	-51.408	-52.204	-51.650	-67.338	29.302	0.6550
0	1	-51.408	-44.064	-52.288	-44.929	-61.128	31.875	-0.2893
0	2	-51.408	-36.720	-52.582	-37.544	-54.379	34.890	-0.3345
0	3	-51.408	-29.376	-52.453	-30.283	-47.589	37.465	0.3323
0	4	-51.408	-22.032	-52.757	-22.611	-40.579	40.594	-0.2222
0	5	-51.408	-14.688	-52.290	-15.255	-33.575	42.892	-0.0792
0	6	-51.408	-7.344	-52.574	-7.664	-26.632	45.973	-0.1182
0	7	-51.408	0.000	-52.623	-0.166	-19.688	48.801	0.2094
0	8	-51.408	7.344	-52.439	7.406	-12.588	51.441	-0.7094
0	9	-51.408	14.688	-52.318	14.922	-5.565	54.119	-0.9910
0	10	-51.408	22.032	-52.766	22.507	1.312	57.351	-0.3434
0	11	-51.408	29.376	-52.426	29.756	8.170	59.726	-0.4068
0	12	-51.408	36.720	-53.007	37.003	14.683	62.955	0.2842
0	13	-51.408	44.064	-52.490	45.028	22.327	65.454	-0.8745
0	14	-51.408	51.408	-52.427	52.584	29.367	68.200	0.2207

- Evaluating the fitted profiles on a finer grid.

The items listed for step 1 are available as individual functions in jython script `rasterlib.py` written and maintained by Michael Olberg. The MatLab code used for step 2 was written by Willem Jellema, who also performed this part of the analysis.

A number of issues had to be solved in the course of the data reduction:

- At the time HCSS didn't support pointing products that were capable of supporting the large number of pointing requests associated with the observing program of OD 55 and had to be split in two pointing products covering one half day each.
- Chop phases in fast-chop measurements were assigned incorrectly, leading to a sign error for the intensities reported by the WBS.
- At the time the HIFI pipeline applied the SIAM correction with the wrong sign, this had to be corrected in an extra processing step.
- The pipeline had to be modified in order to preserve the individual ON and OFF maps of the dual beam switch scheme. Both maps had to be fitted in order to retrieve actual chopper throws. For results see appendix C.
- Different developers supported the analysis by running the pipeline, but applied the `DoPointing` task parameter differently. It turned out that the task had a bug in the sense that for `useIntegration = false` the POS angle of the observation was

returned in degrees, whereas for `useIntegration = true` it was returned in radians, leading to inconsistent calculations of the focal plane offsets.

The following transformation was used to make the coordinate transformation from RA, Dec offsets to  $\Delta\theta_Z$ ,  $\Delta\theta_Y$  offsets in the focal plane.

$$\begin{pmatrix} \Delta\theta_Z \\ \Delta\theta_Y \end{pmatrix} = \begin{pmatrix} \cos \Phi & -\sin \Phi \\ \sin \Phi & \cos \Phi \end{pmatrix} \begin{pmatrix} \Delta\alpha \\ \Delta\delta \end{pmatrix}$$

where  $\alpha$ ,  $\delta$  and  $\Phi$  are RA, Dec and POS-angle of the observation, respectively. Note also that  $\Delta\theta_Z$  and  $\Delta\theta_Y$  correspond to `delta_Y` and `-delta_Z` listed in appendix A, the latter being the notation preferred by the HSC.

## 4 Summary

As a result of all HIFI FPG activities, HIFI delivered SIAM file `0068_0002.SIAM` to the HSC, which was merged with the entries for the PACS and SPIRE apertures, accepted in a fast-track CCB and made available as `0068_0003.SIAM`.

This SIAM was based on:

- OD 53: FPG-1 7b half-throw with SIAM `0032_0003` on-board.
- OD 55: FPG-1 6b full-throw plus full- and half-throw FPG-2 for bands 1–5, all with SIAM `0055_0001` on-board.
- Missing data on full-throw band 2, half-throw band 6 and full-throw band 7 was interpolated from observed trend and ray-trace model of chopper movement at the sky.
- All applicable OD 53 and OD 55 data was re-processed with this SIAM and beams were found centered with zero offsets in RA, Dec. For the analysis in spacecraft coordinates zero offsets were found for the ON maps, but offsets of order of the telescope slew in the OFF maps indicating a data analysis problem somewhere at pipeline or IA level.
- Results from ON and OFF maps were used to retrieve actual chopper throws, leading to an update of the corresponding uplink calibration file (see appendix C).
- Visual inspection of the updated SIAM, by plotting them relative to earlier SIAM versions (Fig 1), showed that the theoretical/hybrid SIAM `0063_0001` nicely predicted the actually observed positions, except for band 7. In band 7 a large offset was observed of about 8" in Y and 17" in Z. Note that this suspicious deviation was detected for the map taken on OD 53, where PACS reported similar behaviour (offset of 5.6" in Y and 13" in Z, see email Bruno Altieri, 2009-07-07 18:59).
- Since moving on with the retrieved offsets from the OD 53 measurements could seriously impact the band 7 pointing, it was decided to use a best-guess for a potential band 7 offset, i.e. an update of band 7 on the basis of band 6 with relative position correction for band 7 based on ILT3 measurement and measured co-alignment and chopper throws on OD 53 (which are not affected by a gross pointing error).



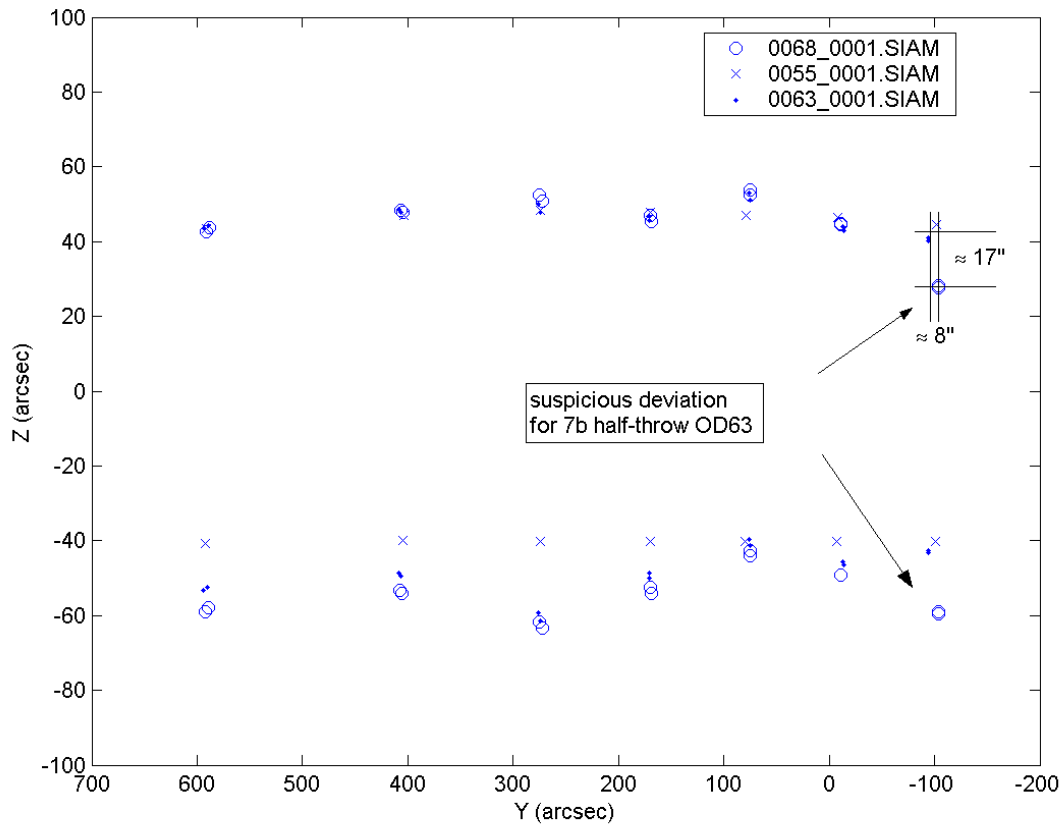


Figure 1: HIFI aperture shifts corresponding to 0068\_0003.SIAM.

- o The resulting SIAM is expected to give better than 2–3" pointing in band 1 to 6, and (hopefully) within 4–5" in band 7. Additional FPG-2 for band 6 and 7 seem crucial to complete pointing calibration of band 7 and confirm the picture for the HEB bands as soon as Mars becomes available.

Fig 1 shows the observed shift of HIFI apertures. Appendix A lists the ancillary data delivered with the new SIAM and in appendix B we list the resulting HIFI aperture entries from 0068\_0003.SIAM.

## A Ancillary data

aperture identifier	chopper position	subband A/B	polarization <u>S</u> ynth./ <u>H</u> oriz.	delta_Y arcsec	delta_Z arcsec	tilt arcsec
H11_0	center	A	S	589.38	-58.00	0.0
H12_0	center	A	H	592.47	-59.11	0.0
H13_0	center	B	S	589.38	-58.00	0.0
H14_0	center	B	H	592.47	-59.11	0.0
H15_0	chopped	A	S	588.00	43.82	0.0
H16_0	chopped	A	H	591.10	42.71	0.0
H17_0	chopped	B	S	588.00	43.82	0.0
H18_0	chopped	B	H	591.10	42.71	0.0
H21_0	center	A	S	405.40	-54.03	0.0
H22_0	center	A	H	407.58	-53.36	0.0
H23_0	center	B	S	405.40	-54.03	0.0
H24_0	center	B	H	407.58	-53.36	0.0
H25_0	chopped	A	S	404.59	47.73	0.0
H26_0	chopped	A	H	406.77	48.39	0.0
H27_0	chopped	B	S	404.59	47.73	0.0
H28_0	chopped	B	H	406.77	48.39	0.0
H31_0	center	A	S	272.70	-63.44	0.0
H32_0	center	A	H	275.30	-61.68	0.0
H33_0	center	B	S	272.70	-63.44	0.0
H34_0	center	B	H	275.30	-61.68	0.0
H35_0	chopped	A	S	272.24	50.82	0.0
H36_0	chopped	A	H	274.83	52.59	0.0
H37_0	chopped	B	S	272.24	50.82	0.0
H38_0	chopped	B	H	274.83	52.59	0.0
H41_0	center	A	S	169.04	-54.20	0.0
H42_0	center	A	H	169.62	-52.54	0.0
H43_0	center	B	S	169.04	-54.20	0.0
H44_0	center	B	H	169.62	-52.54	0.0
H45_0	chopped	A	S	169.27	45.32	0.0
H46_0	chopped	A	H	169.85	46.97	0.0
H47_0	chopped	B	S	169.27	45.32	0.0
H48_0	chopped	B	H	169.85	46.97	0.0
H51_0	center	A	S	75.11	-42.61	0.0
H52_0	center	A	H	75.12	-43.99	0.0
H53_0	center	B	S	75.11	-42.61	0.0
H54_0	center	B	H	75.12	-43.99	0.0
H55_0	chopped	A	S	74.82	53.84	0.0
H56_0	chopped	A	H	74.83	52.46	0.0

*Continued on next page*

aperture identifier	chopper position	subband A/B	polarization <u>S</u> ynth./ <u>H</u> oriz.	delta_Y arcsec	delta_Z arcsec	tilt arcsec
H57_0	chopped	B	S	74.82	53.84	0.0
H58_0	chopped	B	H	74.83	52.46	0.0
H61_0	center	A	S	-10.81	-49.16	0.0
H62_0	center	A	H	-11.16	-49.30	0.0
H63_0	center	B	S	-10.81	-49.16	0.0
H64_0	center	B	H	-11.16	-49.30	0.0
H65_0	chopped	A	S	-11.06	44.82	0.0
H66_0	chopped	A	H	-11.41	44.68	0.0
H67_0	chopped	B	S	-11.06	44.82	0.0
H68_0	chopped	B	H	-11.41	44.68	0.0
H71_0	center	A	S	-104.81	-45.37	0.0
H72_0	center	A	H	-104.80	-44.86	0.0
H73_0	center	B	S	-104.81	-45.37	0.0
H74_0	center	B	H	-104.80	-44.86	0.0
H75_0	chopped	A	S	-104.79	41.92	0.0
H76_0	chopped	A	H	-104.78	42.44	0.0
H77_0	chopped	B	S	-104.79	41.92	0.0
H78_0	chopped	B	H	-104.78	42.44	0.0

## B Delivered SIAM

The following HIFI aperture entries were delivered, on which SIAM file 0068\_0003.SIAM was based.

H11\_0 2009-07-13T16:30:21Z

+9.9999587816327484D-01 +2.8573736388841486D-03 -2.8119805930911461D-04  
-2.8573735259136020D-03 +9.9999591769961127D-01 +8.0349120206769198D-07  
+2.8119920724874767D-04 +0.0000000000000000D+00 +9.999996046350215D-01

H12\_0 2009-07-13T16:30:21Z

+9.9999583358761346D-01 +2.8723988228845396D-03 -2.8658753705945283D-04  
-2.8723987049250358D-03 +9.9999587465399187D-01 +8.2319710007582245D-07  
+2.8658871933708214D-04 +0.0000000000000000D+00 +9.999995893345217D-01

H13\_0 2009-07-13T16:30:21Z

+9.9999587816327484D-01 +2.8573736388841486D-03 -2.8119805930911461D-04  
-2.8573735259136020D-03 +9.9999591769961127D-01 +8.0349120206769198D-07  
+2.8119920724874767D-04 +0.0000000000000000D+00 +9.999996046350215D-01

H14\_0 2009-07-13T16:30:21Z

+9.9999583358761346D-01 +2.8723988228845396D-03 -2.8658753705945283D-04  
-2.8723987049250358D-03 +9.9999587465399187D-01 +8.2319710007582245D-07  
+2.8658871933708214D-04 +0.0000000000000000D+00 +9.999995893345217D-01

H15\_0 2009-07-13T16:30:21Z

+9.9999591413563071D-01 +2.8507155309969103D-03 +2.1244529985297867D-04  
-2.8507154666657067D-03 +9.9999593670222542D-01 -6.0562357660711292D-07  
-2.1244616308500034D-04 +0.0000000000000000D+00 +9.999997743331359D-01

H16\_0 2009-07-13T16:30:21Z

+9.9999587232050602D-01 +2.8657407149973030D-03 +2.0705580077166948D-04  
-2.8657406535666299D-03 +9.9999589375664655D-01 -5.9337067507213379D-07  
-2.0705665099666641D-04 +0.0000000000000000D+00 +9.999997856377143D-01

H17\_0 2009-07-13T16:30:21Z

+9.9999591413563071D-01 +2.8507155309969103D-03 +2.1244529985297867D-04  
-2.8507154666657067D-03 +9.9999593670222542D-01 -6.0562357660711292D-07  
-2.1244616308500034D-04 +0.0000000000000000D+00 +9.999997743331359D-01

H18\_0 2009-07-13T16:30:21Z

+9.9999587232050602D-01 +2.8657407149973030D-03 +2.0705580077166948D-04  
-2.8657406535666299D-03 +9.9999589375664655D-01 -5.9337067507213379D-07  
-2.0705665099666641D-04 +0.0000000000000000D+00 +9.999997856377143D-01

H21\_0 2009-07-13T16:30:21Z

+9.9999803424375600D-01 +1.9654231246524472D-03 -2.6195527304298782D-04  
-1.9654230572179630D-03 +9.9999806855410533D-01 +5.1485394567587379D-07  
+2.6195577899640175D-04 +0.0000000000000000D+00 +9.999996568958438D-01

H22\_0 2009-07-13T16:30:21Z

+9.9999801428343216D-01 +1.9759799425586085D-03 -2.5871308243030991D-04  
-1.9759798764297509D-03 +9.9999804774972767D-01 +5.1121285977524895D-07

+2.5871358750398154D-04 +0.0000000000000000D+00 +9.9999996653363921D-01  
H23\_0 2009-07-13T16:30:21Z  
+9.9999803424375600D-01 +1.9654231246524472D-03 -2.6195527304298782D-04  
-1.9654230572179630D-03 +9.9999806855410533D-01 +5.1485394567587379D-07  
+2.6195577899640175D-04 +0.0000000000000000D+00 +9.9999996568958438D-01  
H24\_0 2009-07-13T16:30:21Z  
+9.9999801428343216D-01 +1.9759799425586085D-03 -2.5871308243030991D-04  
-1.9759798764297509D-03 +9.9999804774972767D-01 +5.1121285977524895D-07  
+2.5871358750398154D-04 +0.0000000000000000D+00 +9.9999996653363921D-01  
H25\_0 2009-07-13T16:30:21Z  
+9.9999804948476656D-01 +1.9615021940064797D-03 +2.3137805744486957D-04  
-1.9615021415009771D-03 +9.9999807625272108D-01 -4.5384944041469498D-07  
-2.3137850255863427D-04 +0.0000000000000000D+00 +9.9999997323199397D-01  
H26\_0 2009-07-13T16:30:21Z  
+9.9999802796635429D-01 +1.9720590119126327D-03 +2.3462023782870679D-04  
-1.9720589576347940D-03 +9.9999805548973619D-01 -4.6268585408457859D-07  
-2.3462069405105448D-04 +0.0000000000000000D+00 +9.9999997247656458D-01  
H27\_0 2009-07-13T16:30:21Z  
+9.9999804948476656D-01 +1.9615021940064797D-03 +2.3137805744486957D-04  
-1.9615021415009771D-03 +9.9999807625272108D-01 -4.5384944041469498D-07  
-2.3137850255863427D-04 +0.0000000000000000D+00 +9.9999997323199397D-01  
H28\_0 2009-07-13T16:30:21Z  
+9.9999802796635429D-01 +1.9720590119126327D-03 +2.3462023782870679D-04  
-1.9720589576347940D-03 +9.9999805548973619D-01 -4.6268585408457859D-07  
-2.3462069405105448D-04 +0.0000000000000000D+00 +9.9999997247656458D-01  
H31\_0 2009-07-13T16:30:21Z  
+9.9999907872114513D-01 +1.3221008548592679D-03 -3.0758119319115174D-04  
-1.3221007923196945D-03 +9.9999912602428287D-01 +4.0665371386212652D-07  
+3.0758146200988057D-04 +0.0000000000000000D+00 +9.9999995269682096D-01  
H32\_0 2009-07-13T16:30:21Z  
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-1.3346776700978965D-03 +9.9999910931728220D-01 +3.9910673377427227D-07  
+2.9902854065230711D-04 +0.0000000000000000D+00 +9.999999529096497D-01  
H33\_0 2009-07-13T16:30:21Z  
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+3.0758146200988057D-04 +0.0000000000000000D+00 +9.9999995269682096D-01  
H34\_0 2009-07-13T16:30:21Z  
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-1.3346776700978965D-03 +9.9999910931728220D-01 +3.9910673377427227D-07  
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H35\_0 2009-07-13T16:30:21Z  
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-1.3198545114069440D-03 +9.9999912899160215D-01 -3.2520013854427886D-07  
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-1.3324313830793211D-03 +9.9999911231285299D-01 -3.3969514716009206D-07  
-2.5494381206750486D-04 +0.0000000000000000D+00 +9.9999996750182585D-01  
H37\_0 2009-07-13T16:30:21Z  
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-1.3198545114069440D-03 +9.9999912899160215D-01 -3.2520013854427886D-07  
-2.4639089070993054D-04 +0.0000000000000000D+00 +9.9999996964576399D-01  
H38\_0 2009-07-13T16:30:21Z  
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-1.3324313830793211D-03 +9.9999911231285299D-01 -3.3969514716009206D-07  
-2.5494381206750486D-04 +0.0000000000000000D+00 +9.9999996750182585D-01  
H41\_0 2009-07-13T16:30:21Z  
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-8.1950504422042560D-04 +9.9999966420566166D-01 +2.1533365946153689D-07  
+2.6276061818841144D-04 +0.0000000000000000D+00 +9.9999996547842818D-01  
H42\_0 2009-07-13T16:30:21Z  
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-8.2235029612241209D-04 +9.9999966186991618D-01 +2.0947553913903377D-07  
+2.5472786150952789D-04 +0.0000000000000000D+00 +9.9999996755685772D-01  
H43\_0 2009-07-13T16:30:21Z  
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+2.6276061818841144D-04 +0.0000000000000000D+00 +9.9999996547842818D-01  
H44\_0 2009-07-13T16:30:21Z  
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+2.5472786150952789D-04 +0.0000000000000000D+00 +9.9999996755685772D-01  
H45\_0 2009-07-13T16:30:21Z  
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-8.2347749325548027D-04 +9.9999966094233395D-01 -1.8753920843485537D-07  
-2.2774053341764034D-04 +0.0000000000000000D+00 +9.9999997406712438D-01  
H47\_0 2009-07-13T16:30:21Z  
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-8.2063224451302990D-04 +9.9999966328128664D-01 -1.8029929031375287D-07  
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H48\_0 2009-07-13T16:30:21Z

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-2.2774053341764034D-04 +0.0000000000000000D+00 +9.999997406712438D-01  
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-3.6417560832735599D-04 +9.9999993368805795D-01 +7.7670777199542651D-08  
+2.1327835708094382D-04 +0.0000000000000000D+00 +9.9999997725617096D-01  
H53\_0 2009-07-13T16:30:21Z  
+9.9999991235587127D-01 +3.6415440601155543D-04 -2.0659094466928777D-04  
-3.6415439824053234D-04 +9.9999993369578211D-01 +7.5231007731543730D-08  
+2.0659095836713967D-04 +0.0000000000000000D+00 +9.9999997866008772D-01  
H54\_0 2009-07-13T16:30:21Z  
+9.9999991094423046D-01 +3.6417561661010396D-04 -2.1327834293804177D-04  
-3.6417560832735599D-04 +9.9999993368805795D-01 +7.7670777199542651D-08  
+2.1327835708094382D-04 +0.0000000000000000D+00 +9.9999997725617096D-01  
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-3.6274843398039744D-04 +9.9999993420678013D-01 -9.4679440052379569D-08  
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-3.6276964520330776D-04 +9.9999993419908584D-01 -9.2258990803938488D-08  
-2.5431837817818946D-04 +0.0000000000000000D+00 +9.9999996766108079D-01  
H57\_0 2009-07-13T16:30:21Z  
+9.9999990014477402D-01 +3.6274844633633804D-04 +2.6100575971958317D-04  
-3.6274843398039744D-04 +9.9999993420678013D-01 -9.4679440052379569D-08  
-2.6100577689199363D-04 +0.0000000000000000D+00 +9.9999996593799167D-01  
H58\_0 2009-07-13T16:30:21Z  
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-3.6276964520330776D-04 +9.9999993419908584D-01 -9.2258990803938488D-08  
-2.5431837817818946D-04 +0.0000000000000000D+00 +9.9999996766108079D-01  
H61\_0 2009-07-13T16:30:21Z  
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+5.2384439477308202D-05 +9.999999862793520D-01 -1.2486242331755925D-08  
+2.3835784255103320D-04 +0.0000000000000000D+00 +9.9999997159276910D-01  
H62\_0 2009-07-13T16:30:21Z  
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+5.4081287304749205D-05 +9.999999853760713D-01 -1.2925221474985068D-08  
+2.3899618056449318D-04 +0.0000000000000000D+00 +9.9999997144041242D-01

H63\_0 2009-07-13T16:30:21Z  
+9.9999997022070430D-01 -5.2384440965405113D-05 -2.3835784222399079D-04  
+5.2384439477308202D-05 +9.9999999862793520D-01 -1.2486242331755925D-08  
+2.3835784255103320D-04 +0.0000000000000000D+00 +9.9999997159276910D-01  
H64\_0 2009-07-13T16:30:21Z  
+9.9999996997801954D-01 -5.4081288849288508D-05 -2.3899618021498687D-04  
+5.4081287304749205D-05 +9.9999999853760713D-01 -1.2925221474985068D-08  
+2.3899618056449318D-04 +0.0000000000000000D+00 +9.9999997144041242D-01  
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-2.1727073471910255D-04 +0.0000000000000000D+00 +9.9999997639671367D-01  
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-2.1663239670564218D-04 +0.0000000000000000D+00 +9.9999997653520212D-01  
H67\_0 2009-07-13T16:30:21Z  
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+5.3628404703824844D-05 +9.9999999856199706D-01 +1.1651883166836132D-08  
-2.1727073471910255D-04 +0.0000000000000000D+00 +9.9999997639671367D-01  
H68\_0 2009-07-13T16:30:21Z  
+9.9999997500476023D-01 -5.5325253853514872D-05 +2.1663239637409888D-04  
+5.5325252555318973D-05 +9.9999999846955812D-01 +1.1985242340634992D-08  
-2.1663239670564218D-04 +0.0000000000000000D+00 +9.9999997653520212D-01  
H71\_0 2009-07-13T16:30:21Z  
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+5.0811937027838686D-04 +9.9999987090733822D-01 -1.1177734968080910D-07  
+2.1998245592367083D-04 +0.0000000000000000D+00 +9.9999997580385924D-01  
H72\_0 2009-07-13T16:30:21Z  
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+5.0807896941764406D-04 +9.9999987092786602D-01 -1.1049578999216126D-07  
+2.1747758523793753D-04 +0.0000000000000000D+00 +9.9999997635174964D-01  
H73\_0 2009-07-13T16:30:21Z  
+9.9999984671120057D-01 -5.0811938257291499D-04 -2.1998242752555006D-04  
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+2.1998245592367083D-04 +0.0000000000000000D+00 +9.9999997580385924D-01  
H74\_0 2009-07-13T16:30:21Z  
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+5.0807896941764406D-04 +9.9999987092786602D-01 -1.1049578999216126D-07  
+2.1747758523793753D-04 +0.0000000000000000D+00 +9.9999997635174964D-01  
H75\_0 2009-07-13T16:30:21Z  
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+5.0801432911697824D-04 +9.9999987096070708D-01 +1.0324662299610364D-07



-2.0323564700089911D-04 +0.0000000000000000D+00 +9.9999997934763563D-01  
H76\_0 2009-07-13T16:30:21Z  
+9.9999984981665280D-01 -5.0797393846858236D-04 +2.0574049114224300D-04  
+5.0797392771752704D-04 +9.9999987098123055D-01 +1.0451082107184318D-07  
-2.0574051768663140D-04 +0.0000000000000000D+00 +9.9999997883541947D-01  
H77\_0 2009-07-13T16:30:21Z  
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-2.0323564700089911D-04 +0.0000000000000000D+00 +9.9999997934763563D-01  
H78\_0 2009-07-13T16:30:21Z  
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+5.0797392771752704D-04 +9.9999987098123055D-01 +1.0451082107184318D-07  
-2.0574051768663140D-04 +0.0000000000000000D+00 +9.9999997883541947D-01

## C Chopper throws

Resulting new CUS file skychopthrow:

```
# Calibration file giving the calibrated chopper throw at the sky
# This config file is to be used together with SIAM version 0068_0001
# The throw is calibrated based on full- and half-throw FPG-1 and FPG-2 maps
# Given the very small and scattered Y-components of the measured throw (< 1.5"),
# and because of limited statistics the angle and halfangle have been kept to zero
# WJ - 2009/07/11
string double    double double    double    string
band  length    angle    halflength halfangle measurement
1a    0.04809    0.0    0.02828    0.0    FPG-2
1b    0.04809    0.0    0.02828    0.0    FPG-2
2a    0.05007    0.0    0.02827    0.0    FPG-2
2b    0.05007    0.0    0.02827    0.0    FPG-2
3a    0.05043    0.0    0.03174    0.0    FPG-2
3b    0.05043    0.0    0.03174    0.0    FPG-2
4a    0.05037    0.0    0.02764    0.0    FPG-2
4b    0.05037    0.0    0.02764    0.0    FPG-2
5a    0.05010    0.0    0.02679    0.0    FPG-2
5b    0.05010    0.0    0.02679    0.0    FPG-2
6a    0.04949    0.0    0.02611    0.0    FPG-1
6b    0.04949    0.0    0.02611    0.0    FPG-1
7a    0.04824    0.0    0.02425    0.0    FPG-1
7b    0.04824    0.0    0.02425    0.0    FPG-1
```