Analysis of PACS Chopper Characteristics by closed loop full range FOV Scan at He-II stage during FM-IST TV/TB

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1 Document History

Version	Date	Author(s)	Change description
1.0	14th January 2009	M. Nielbock, U. Klaas, J. Bouwman, H. Dannerbauer, J. Schreiber (all MPIA)	initial version

2 Data Reference Sheet

Reference document	**Date**	**Archive filename**
PACS Calibration Document (Draft 11) req. 2.3.1	**16-Jun-2008**	**PACS-MA-GS-001 (RD1)**
Angular Calibration of PACS FM 1 Chopper for FM ILT cold tests	**16-Jul-2007**	**PICC-MA-TR-021 (RD2) Issue 2.4**
Basic Drive Parameters of PACS FM 1 Chopper for FM ILT cold tests	**30-Jul-2007**	**PICC-MA-TR-023 (RD3) Issue 1.2**
FM 1 Chopper Cold Short Functional Tests He-II at Integrated System level	**03-Dec-2008**	**PICC-MA-TR-049 (RD5) Issue 1.1**
PACS Chopper Position Measuring Device Description	**29-Aug-2003**	**PACS-MA-TN-464 (RD6)**
PACS Chopper Flight Model (FM1) User Manual and Handling Procedure	**07-Jun-2005**	**PACS-MA-HM-655 (RD7)**
Electrical Interface Control Document for PACS chopper FM1	**30-Jan-2006**	**PACS-MA-TN-678 (RD8)**
DEC/MEC User Manual	**13-Oct-2008**	**PACS-CL-SR-002 (RD9) Issue 4.7**

Telemetry file	**Date**
FIST_FFT_ChopperFullFovScanSpec_409_20081204.tm	**04-Dec-2008**

3 Summary

After integrating the three Herschel Space Observatory (HSO) instruments HIFI, PACS, and SPIRE into the telescope's cryostat, the satellite was put inside the Large Space Simulator (LSS) chamber for extensive thermal testing during FM-IST TV/TB at ESTEC. The satellite was tilted by 20° during the entire test. The telemetry files were made accessible for immediate analysis of the performance. The spectrometer FOV scan across the entire valid angular range using the nominal set-up is used to derive the drive properties of the PACS chopper with a closed control loop. As a result, open-loop oscillation characteristics could not be addressed during this measurement.

An angular calibration of the chopper based on a closed loop FOV scan could be established and was applied during the analysis of this measurement. We found a slight but measurable deviation in the current consumption of the chopper. The current needed to attain a certain angle within the PACS sky range amounts to about 94% of what was measured at module level, and deviated even more for higher deflections. This behaviour can be explained by (i) an uncertainty in the amplification factors of the field-plate voltages, (ii) the different electronic set-ups, i.e. open loop vs. closed loop, (iii) a known deviation between the current commanded by the PID controller (DMC_CHOP_OUTPUT) and the actual drive current applied to the chopper coils (DMC_CHOP_IA), and (iv) the implementation of the chopper field plate voltage linearisation into the DECMEC for controlled operation (RD9, Sect. 4.2.1.4).

As a result, the specific torque shows a slight offset of approximately +0.002 Nm/A. However, despite a minor asymmetry, the shape of the plot vs. the chopper angle is very similar to what was measured during module level tests. This demonstrates for the first time during FM-IST that the chopper shows a nominal behaviour across the entire valid angular range that is similar to what has been found before.

4 Document Outline

A series of open loop chopper measurements have been done with a variety of ambient conditions and have been analysed to determine its drive properties (cf. RD2, RD3, RD5). However, only the angular range of the sky window has been probed with these tests, and a full range examination was last done during FM-ILT. In order to overcome this situation, the closed loop FOV scan was used as a diagnostic to extend the angular range beyond this limit up to the range that covers the internal calibration sources (CS). The subsequent analysis can therefore be seen as an extension to the previous open-loop investigations during various SFTs (Short Functional Tests).

5 Mechanical Zero Point

The mechanical zero-point is the position of the chopper without a commanded drive current. It is chosen to be the origin of the angular calibration curve determined to translate the digital read-out units into angles. The appropriate default chopper control parameters have been used for this measurement, including the mechanical zero point offset correction. Therefore, the mechanical zero point was set to be zero throughout this test, as was confirmed during the subsequent analysis. Note that the calibration is based on the offsets measured for a switched-on but disabled chopper controller. This means that in reality a small offset current for the nominal commanded zero current is applied.

6 Angular Calibration

The shape of the angular calibration curve is determined by the module level measurements at ZEISS. Selecting the mechanical zero-point as the origin of this relationship between digital read-out units and the chopper angle defines the actual angular calibration. Since the appropriate control parameters were uploaded prior to the test execution, the mechanical zero point was already set to zero.

The relation between the angle and the read-out units can be expressed by polynomials. Following the results of the investigations on the original ZEISS calibration curve (RD2), the polynomial fits are applied in the three ranges $-4.1^\circ < \Phi < +4.1^\circ$ (sky range), $-10.1^\circ < \Phi < -4.1^\circ$ (negative calibration source range), and $+4.1^\circ < \Phi < +10.0^\circ$ (positive calibration source range). For the sky range, a 6th order polynomial is necessary, for the calibration source ranges a 4th order polynomial. The relation is expressed as:

$$\Phi(^\circ) = a_0 + a_1 \cdot \frac{ROU}{10000} + a_2 \cdot \left(\frac{ROU}{10000}\right)^2 + a_3 \cdot \left(\frac{ROU}{10000}\right)^3 + a_4 \cdot \left(\frac{ROU}{10000}\right)^4 + a_5 \cdot \left(\frac{ROU}{10000}\right)^5 + a_6 \cdot \left(\frac{ROU}{10000}\right)^6$$

Reversely, the ROU can be determined with 6th and 4th order polynomials of the angle Φ, respectively. Φ has to be specified in degrees.

$$ROU = 10000 \cdot (b_0 + b_1 \cdot \Phi + b_2 \cdot \Phi^2 + b_3 \cdot \Phi^3 + b_4 \cdot \Phi^4 + b_5 \cdot \Phi^5 + b_6 \cdot \Phi^6)$$

In case, the rotation angle should be specified as the throw on the sky θ (in $''$), the scale factor of 80.69 has to be applied and a conversion into degrees be performed:

$$\Phi(^\circ) = 80.69 \cdot \frac{\Theta('')}{3600}$$

6.1 FP1 calibration with DECMEC FM

Table 1: Coefficients for polynomial fits describing the relation of rotation angle Φ with the DECMEC FM readout output for field-plate FP1 depending on the selected angle range.

	FP1 with DECMEC FM		
	$-4.1° < \Phi < +4.1°$	$-10.5° < \Phi < -4.1°$	$+4.1° < \Phi < 9.9°$
a_0	0*	-1.4915484448	1.6790957971
a_1	3.2423487441	-0.5643814384	-0.8734625564
a_2	0.0204956859	-3.5850380561	3.6815215958
a_3	0.0505123005	-1.4352347717	-1.3532788724
a_4	-0.0184288411	-0.2434324278	0.2122140755
a_5	0.0149878734	–	–
a_6	0.0080222955	–	–

*formally the value of $a_0 = -1.647028e - 013$

Table 2: Coefficients for polynomial fits describing the relation of the DECMEC FM readout output for field-plate FP1 with rotation angle Φ depending on the selected angle range.

	FP1 with DECMEC FM		
	$-4.1° < \Phi < +4.1°$	$-10.5° < \Phi < -4.1°$	$+4.1° < \Phi < 9.9°$
b_0	0*	0.0179130104	-0.1222423179
b_1	0.3085128809	0.3249523556	0.3982078889
b_2	-0.0005741951	0.0044512676	-0.0230727083
b_3	-0.0004999232	-0.0001403531	0.0016587421
b_4	0.0000462606	0.0000072787	-0.0000648448
b_5	-0.0000060616	–	–
b_6	-0.0000016583	–	–

*formally the value of $a_0 = 4.170592e - 014$

6.2 Look-up table for FP1

Table 3: ROU values for selected chopper angles.

Φ	Θ	ROU
−9.50°	CS1	−24878
−8.11°	CS1	−22183
−5.27°	CS1	−15448
−4.10°	−183″	−12279
−2.69°	−120″	−8217
−1.34°	−60″	−4131
−1.01°	−45″	−3116
0.00°	0″	0
1.01°	45″	3105
1.34°	60″	4113
2.69°	120″	8170
4.10°	183″	12190
5.27°	CS2	15283
8.11°	CS2	21940
9.50°	CS2	24724

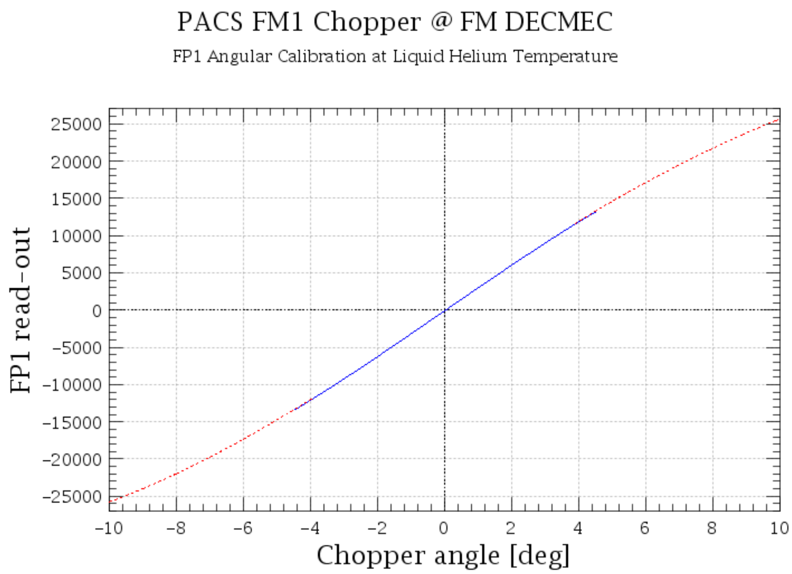

Figure 1: Angular calibration curve of the controlled PACS chopper attached to the nominal FM DECMEC. It is separated into three individual ranges with some overlap covering the two CS parts and the sky range.

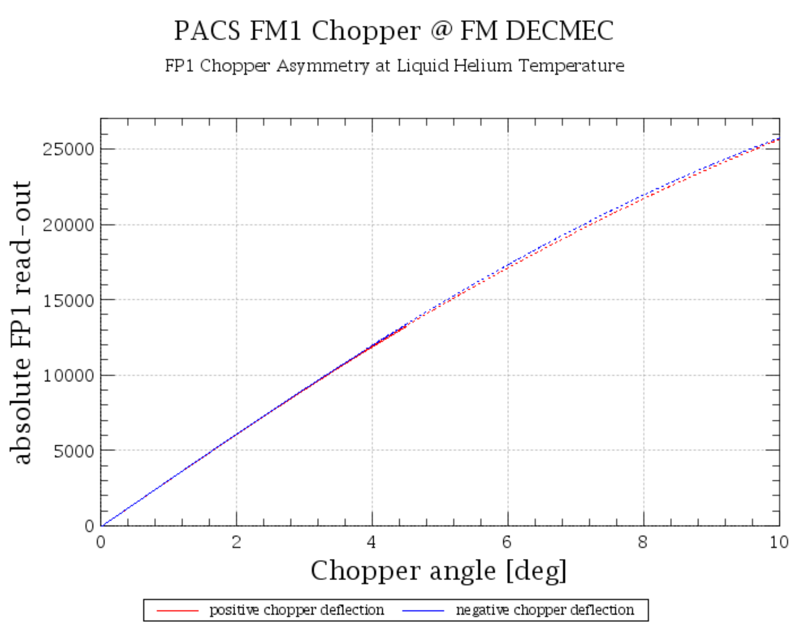

Figure 2: FP1 DECMEC FM read-out vs. angle calibration asymmetry for positive and negative chopper deflections. For a better visibility of the difference, the negative branch has been mirrored. The solid line represents the sky range fit, the dashed line the positive and negative CS range fit, respectively. There is an overlap between the fits for the $-4.5° < \Phi < -3.9°$ and $3.9° < \Phi < 4.5°$, respectively. Note that for closed loop measurements, the DECMEC provides a correction for the non-linearity of the field plate voltage vs. chopper angle relation that leads to a compensation of the intrinsic asymmetry (RD9, Sect. 4.2.1.4).

7 FM-IST TV/TB FOV Scan Measurement

Fig. 3 displays the read-out of the nominal field-plate signal (DM_CHOP_CUR_POS) acquired on 4th December 2008 and contained in the telemetry (TM) file FIST_FFT_ChopperFullFovScanSpec_409_20081204.tm. The mechanical zero point offset was artificially set to zero via the appropriate PID control parameter table upload. The chopper was operated with a closed control loop for the FOV scan with the FM DECMEC configured to the nominal setup. The measurement comprised two identical bidirectional full range FOV scans with the chopper returning to the zero position between the two scans and at the end of the entire measurement.

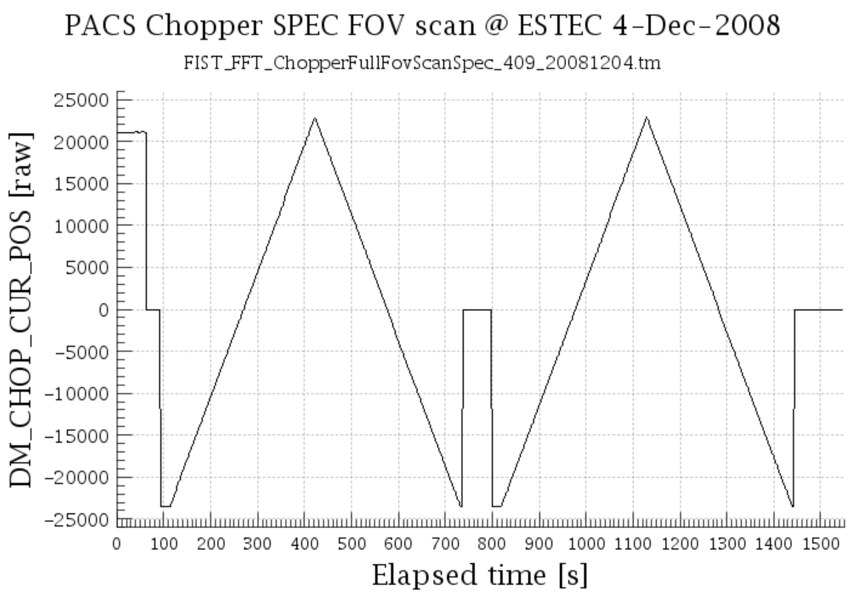

Figure 3: Measurement sequence of FIST_FFT_ChopperFullFovScanSpec_409_20081204.tm. The test execution consists of two identical bidirectional full range FOV scans.

The control loop monitors the DECMEC housekeeping parameter DM_CHOP_CUR_POS and applies the necessary drive currents to maintain a linear increase and decrease of the chopper position. Fig. 4 depicts the drive current as determined and commanded by the PID control loop (DMC_CHOP_OUTPUT). Note the non-linear behaviour of the current during the measurement. The movement of the chopper in real angular units is shown in Fig. 5 after applying the angular calibration.

Fig. 6 shows the angle vs. current relations for the FM-IST TV/TB closed loop FOV scan and the module level tests at ZEISS. For this comparison, the ZEISS relation has been corrected for the angular offset of the mechanical zero point found for the module level tests. There is a minor difference between the two relations that becomes increasingly larger with rising deflections. The drive current needed for a certain angular deflection in the sky range is smaller under FM-IST conditions than under module level test conditions. The differences are most probably a consequence of the different electrical configurations used during the two measurements. Furthermore, the current monitored by the HK parameter DMC_CHOP_OUTPUT is not identical with the current that actually is applied to the chopper coils (DMC_CHOP_IA) leading to an uncertainty that might explain the difference to some extent.

In order to quantify this difference, Fig. 7 shows the ratio of the drive currents for the angle range $-9° < \Phi < +9°$ after fitting both measured relations with 6th order polynomials. The drive current needed for a certain angular deflection in the sky range under FM-IST conditions with a closed control loop amounts to $\sim 94\%$ of the current needed during the ZEISS module level tests. Stronger deviations are found for large deflections beyond the range of the PACS sky window of $-4.1° < \Phi < +4.1°$. However, this discrepancy can be explained by the uncertainty of the amplification factor of the position sensor voltage and the implementation of the chopper

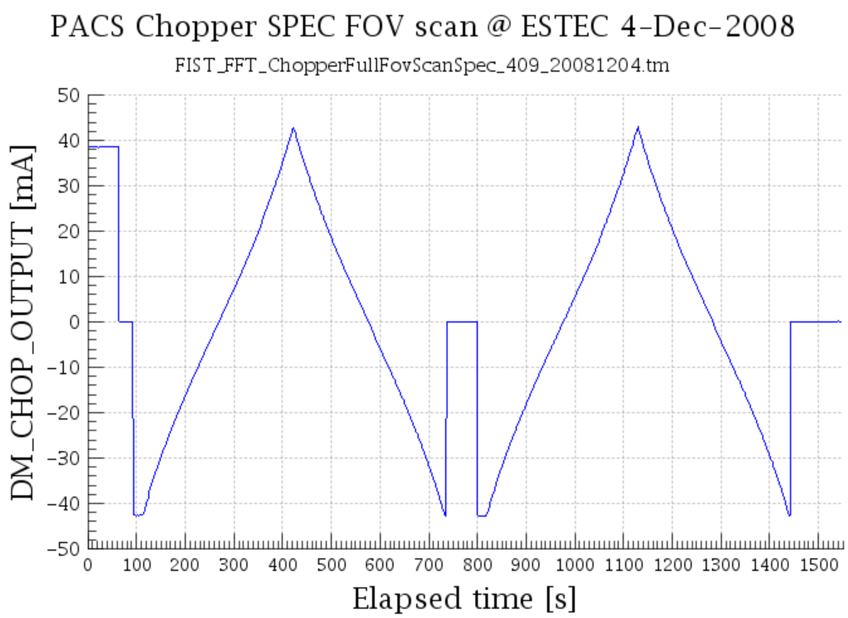

Figure 4: Chopper drive currents of the measurement sequence of FIST_FFT_ChopperFullFovScanSpec_409_20081204.tm as determined by the control loop. The test execution consists of two identical bidirectional full range FOV scans.

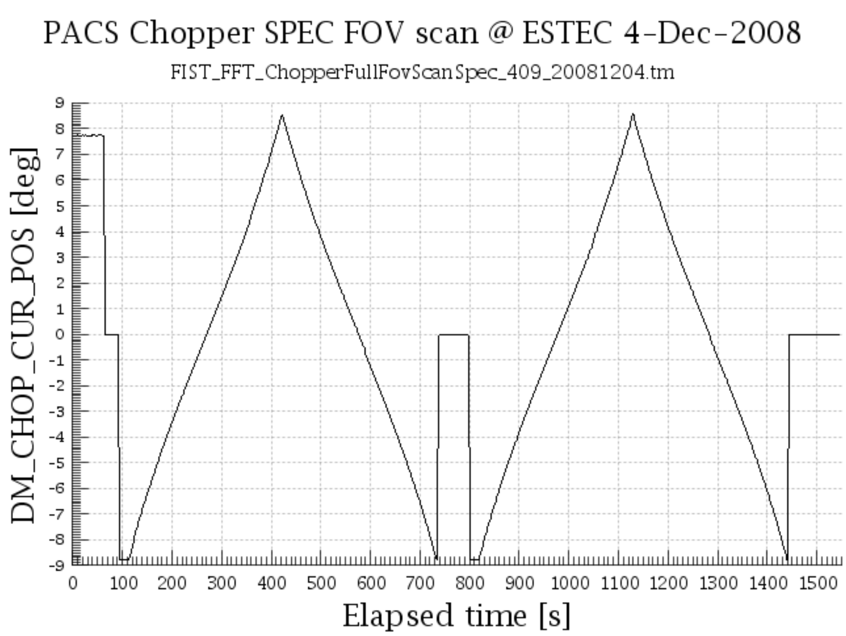

Figure 5: Measurement sequence of FIST_FFT_ChopperFullFovScanSpec_409_20081204.tm in angular units after the angular calibration. The test execution consists of two identical bidirectional full range FOV scans.

field plate voltage vs. angle linearisation into the DECMEC (RD9, Sect. 4.2.1.4).

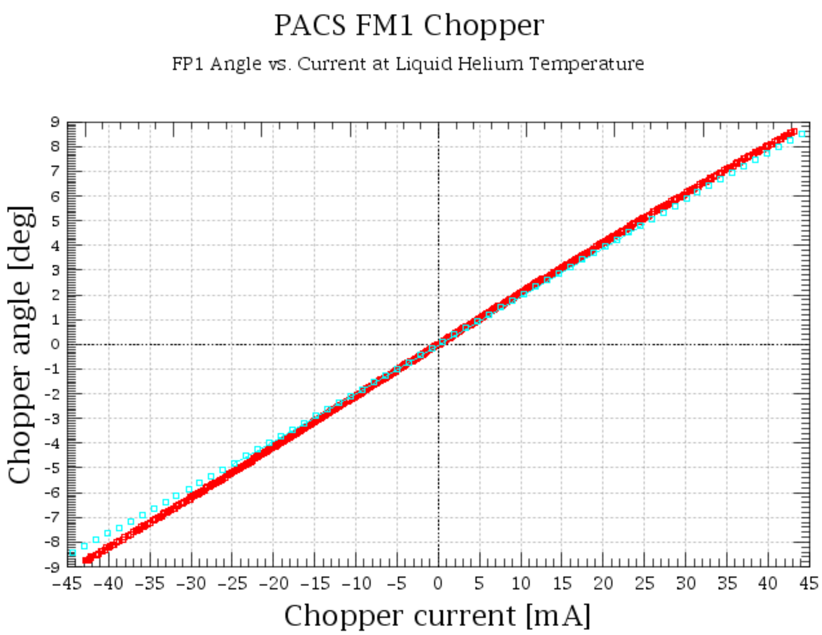

Figure 6: Resulting static chopper deflection angle when applying a drive current under open loop conditions and after damping of the swing-in oscillation. For comparison, the angle-current relation determined on module level at ZEISS is shown. The ZEISS relation has been corrected for the angular offset of the mechanical zero point.

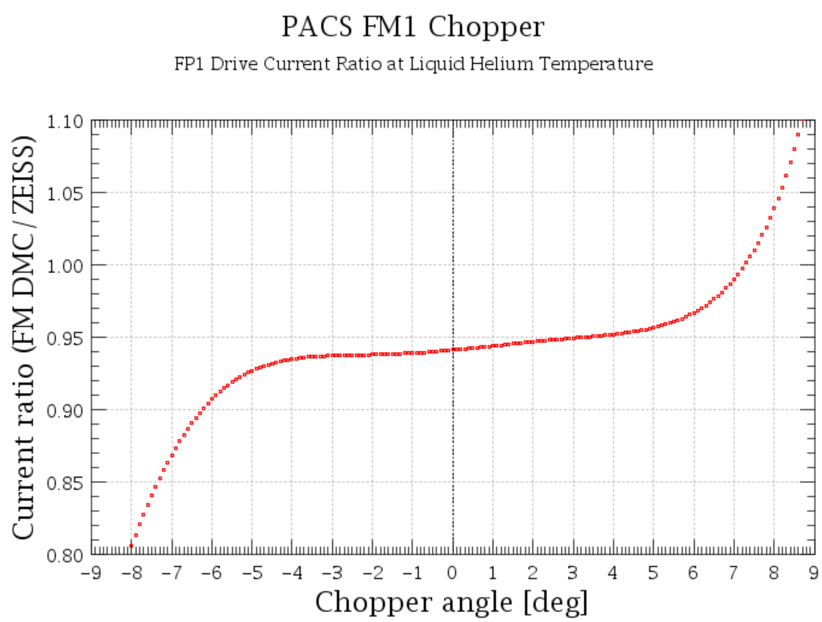

Figure 7: Ratio of chopper drive currents between the configuration used for the closed loop FOV scan during FM-IST TV/TB and module level tests (MLT) at ZEISS for the angle range $-9^\circ < \Phi < +9^\circ$.

Fig. 8 shows the behaviour of the specific torque

$$S = \frac{c \cdot \Phi}{I} = \frac{T}{I}$$

with changing angles both for the module level tests and the FOV scan during FM-IST TV/TB. The shapes are very similar, but the specific torque is generally higher during FM-IST than during module level tests at ZEISS. This is a consequence of the smaller current needed to attain a certain elongation. This behaviour is almost similar to what has been found during FM-ILT and FM-IST.

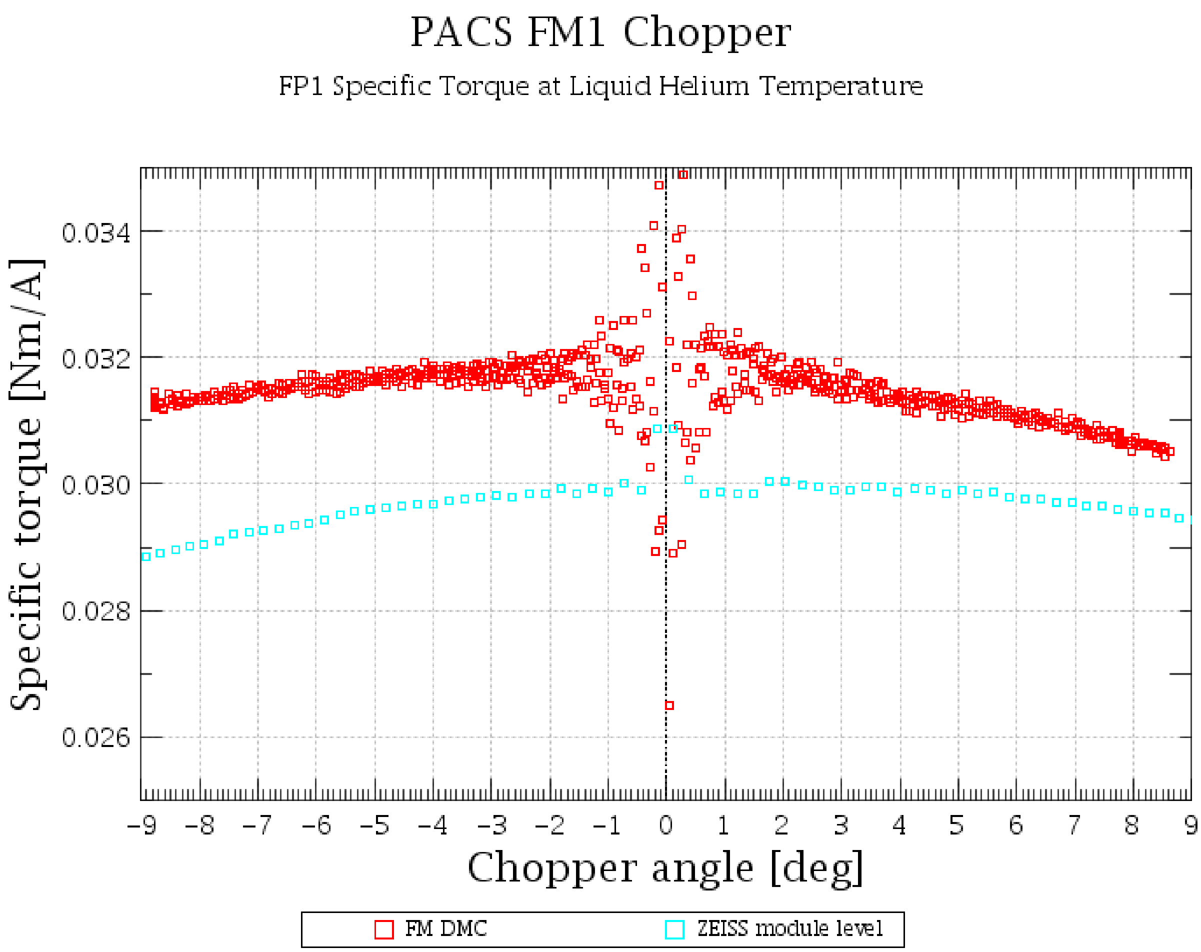

Figure 8: Specific torque of the chopper drive as measured on module level at ZEISS (cf. RD8, section 3.4.3) and during FM-IST TV/TB.

8 Conclusions

Altogether, the closed loop chopper FOV scan carried out on 4th December 2008 during FM-IST TV/TB at He-II conditions at ESTEC yielded the following results.

- An angular calibration was established that is consistent with the one determined from previous FM-ILT and FM-IST measurements.
- The current consumption during the FOV scan appears to generally lower that what was seen at module level. Only about 94% of the current that was needed during module level tests to drive the chopper within the PACS sky range is consumed during the closed loop FOV scan. The deviations become increasingly larger for higher deflections. This behaviour can be explained by:
  1. inaccurate knowledge of the field plate voltage amplification factor
  2. electrical feedback with closed loop conditions during the FOV scan opposed to the open loop test at module level
  3. known shift between DMC_CHOP_OUTPUT and DMC_CHOP_IA
  4. implementation of chopper field plate voltage linearisation in DECMEC (RD9, Sect. 4.2.1.4)
- The specific torque is shifted by approx. +0.002 Nm/A which can be attributed to the current ratio between module level and the FOV scan. Nevertheless, the general shape of the plot representing the specific torque vs. chopper angle relation is very symmetric and similar to the plot of the specific torque of the module level test.
- Altogether, the static and dynamical drive parameters derived from the closed loop FOV scan are well reproducible for the measurements done during IST and are very similar to what was established during FM-ILT.