XMM-Newton CCF Release Note

XMM-CCF-REL-124

EPIC MOS Energy Scale

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October 18, 2002

1 CCF components

Name of CCF	VALDATE (start of val. period)	EVALDATE (end of validity period)	List of Blocks changed	CAL VERSION	XSCS flag
EMOS1_CTI_0008	1999-12-10T00:00:00	2000-07-15T12:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS1_CTI_0009	2000-07-15T12:00:01	2000-11-09T12:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS1_CTI_0010	2000-11-09T12:00:01	2001-04-18T00:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS1_CTI_0011	2001-04-18T00:00:01	2001-08-18T00:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS1_CTI_0012	2001-08-18T00:00:01	2001-09-26T22:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS1_CTI_0013	2001-09-26T22:00:01	2001-11-25T12:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS1_CTI_0014	2001-11-25T12:00:01		CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0008	1999-12-10T00:00:00	2000-07-15T12:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0009	2000-07-15T12:00:01	2000-11-09T12:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0010	2000-11-09T12:00:01	2001-04-18T00:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0011	2001-04-18T00:00:01	2001-08-18T00:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0012	2001-08-18T00:00:01	2001-09-26T22:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0013	2001-09-26T22:00:01	2001-11-25T12:00:00	CTI_EXTENDED	cal 3.147+	NO
EMOS2_CTI_0014	2001-11-25T12:00:01		CTI_EXTENDED	cal 3.147+	NO

2 Changes

The correction for Charge Transfer Inefficiency (CTI) of the MOSs has been further improved by taking into account the variations of the degradation rate since the launch, mostly of the parallel CTI. The previous modeling was based on a single linear degradation rate since launch. Using the emission lines from the calibration source, the CTI was fitted in seven periods, where the degradation was linear with time. The periods are delimited by the strongest solar flares, where the CTI experienced step increases.

For this purpose the CTI algorithm had to be further refined. It is available in cal 3.147 onwards of the CAL (Calibration Access Layer), under ALGOID = 2.

The CTI loss for an event in position (RAWX,RAWY) on the CCD is the sum of serial losses and parallel losses : $CTI = CTIX.RAWX + CTIY.RAWY$

The previous CTI was modeled in SAS v5.3 as :

- $CTIX_i = (a_{1Xi} + b_{1Xi}E)$
- $CTIY_i = \delta T.rate_{yi}.E^{\alpha i} + (a_{1Yi} + b_{1Yi}E)$

for CCDi (i = 1 to 7), where $(a, b)_{1X,Yi}$ (CTI at launch) are extrapolated from in-flight measurements (see figure 1) and α_i is a CCD dependent power index.

The new CTI algorithm is modeled as :

- $CTIX_i = (Kx_i + \delta T.rateX_i).E^{\alpha i}$
- $CTIY_i = (Ky_i + \delta T.rateY_i).E^{\alpha i}$

for CCDi (i = 1 to 7), with Kx_i and Ky_i constants per CCDi, $rateX_i$, $rateY_i$ the serial and parallel degradation rates, and α_i is a CCD dependent power index.

This new algorithm allows an energy-scaling of the CTI that fits very well the Mn and Al lines of the internal calibration source, see figure 1.

3 Scientific Impact of this Update

The performance of the new CTI correction is compared to the old one in figure 2 for MOS1 and figure 3 for MOS2 for both Mn and Al line positions.

The new CTI algorithm reduce by a about factor two the under-correction in the energy scale at Mn energies after revolution 350, where a series of strong solar flare developed. The new CTI correction algorithm gives rather good results for MOS1, but still shows some under-correction trend with time for MOS2, where an under-correction up to 10 eV can be observed. Some over-correction is also seen for both MOSs before revolution 100 (Cal/PV phase), although lacking data in this period.

The negative trend for under-correction with time could be due to a gain drift and shall be corrected into the ADUGAIN CCF later on. This trend is better seen for the Al line, but account for a few eV only.

4 Estimated Scientific Quality

During eclipse season, when the cameras are switched off at perigee passage, some serious over-correction can be observed for MOS2. (see figure 4) It is not clear at the moment if this due to change in temperature of the CCD (the telecommanded set-point after switch-on (-97.74 C) is 2.3 degrees cooler than on-board set point (-100 C) used in standard operations for more than 90% of the observations) or if this due to a change of the temperature of the EMAE warm electronic box, which is cooler by a few degrees at the start of eclipse revolution before stabilizing. In the latter case the impact on science observation is probably small, as the EMAE temperature has settled almost to a stable temperature by the time the first science observation of the revolution has started.

The MOS CTI correction is derived, as shown above, based on the data from the internal calibration source, which provides a rather smooth and extended illumination over the field-of-view, but which might not be representative of scientific pointings with (strong) point sources. The simple MOS CTI correction algorithm presented above is count rate (flux) independent, while a count rate dependence is expected, and implemented in SAS for the pn in much more sophisticated way. In a local high count rate, precursor events fill the charge traps and reduce the CTI. As a consequence CTI for these observations will be over-corrected. This is what has been observed on the extreme case of the Cas A SNR observation (bright eand extended emission), where an over-correction of up to 40-50 eV was seen at Mn energies (6keV), but much less at lower energies

The complex issue of the flux dependence of the MOS CTI has not been addressed yet, as no model exists to our knowledge that could take into account the time-dependent degradation together. Note that the worse CTI correction for MOS2 internal calibration data could be due to a count rate effect (the MOS2 calibration source is twice brighter than the one from MOS1), although their energy scale is corrected based on parameters derived from the same observations. Note that this over-correction effect is balanced by the (not-yet corrected gain) under-correction trend, especially after revolution 350.

However for more common (representative) examples (e.g. bright AGNs), no significant over-correction has been measured, but more investigations are needed to quantify this. **Therefore we estimate that for the vast majority of the sources, the MOS energy scale with this new correction shall be correct within 5eV at about 2 keV and within 10 eV at 6keV.**

The same CTI correction is applied to all MOS window modes. While it is believed to be a good description of the large and small window modes, it is expected to yield to an **over-correction in the Timing mode**, because column pixels are binned and charges transferred at a faster rate, filling more the charges traps on average, and hence reducing the CTI. An negative **gain offset of 13 eV** has been reported by S. Sembay to minimize residuals around edges. A proper model for the MOS CTI in timing mode is still to be developed.

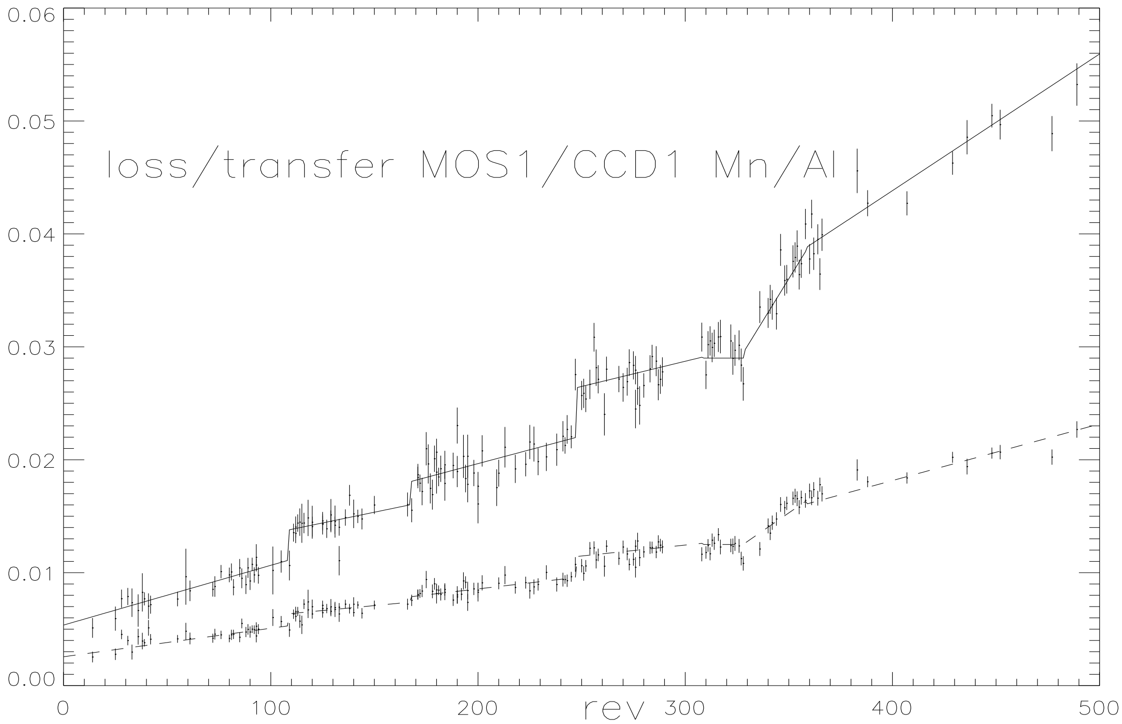
Note finally that, while ground software corrections for CTI manage to restore reasonnably well most of the energy loss, inevitably the detector energy FWHM has widened due to imperfect correction and the statistical noise of charge trapping. This is illustarted in figure 5. The degradation of the MOS energy resolution is about 20% by revolution 500, and is the main rational for cooling the MOS CCDs to -120 C.

5 Test procedures & results

The new CTI CCFs have been tested with the Development Track (DT) version of the SAS at VilSpa that includes the new CTI algorithm, called by the FITS header keyword ALGOID = 2. The results have be shown in the previous section.

6 Expected Updates

A major update of the MOS CTI CCF is expected once the operational temperature of the MOS CCDs will lowered from the current temperature of -100 C down to -120 C, in NOvember 2002. An initial test in revolution 448, shows that the CTI is reduced by 2.5.



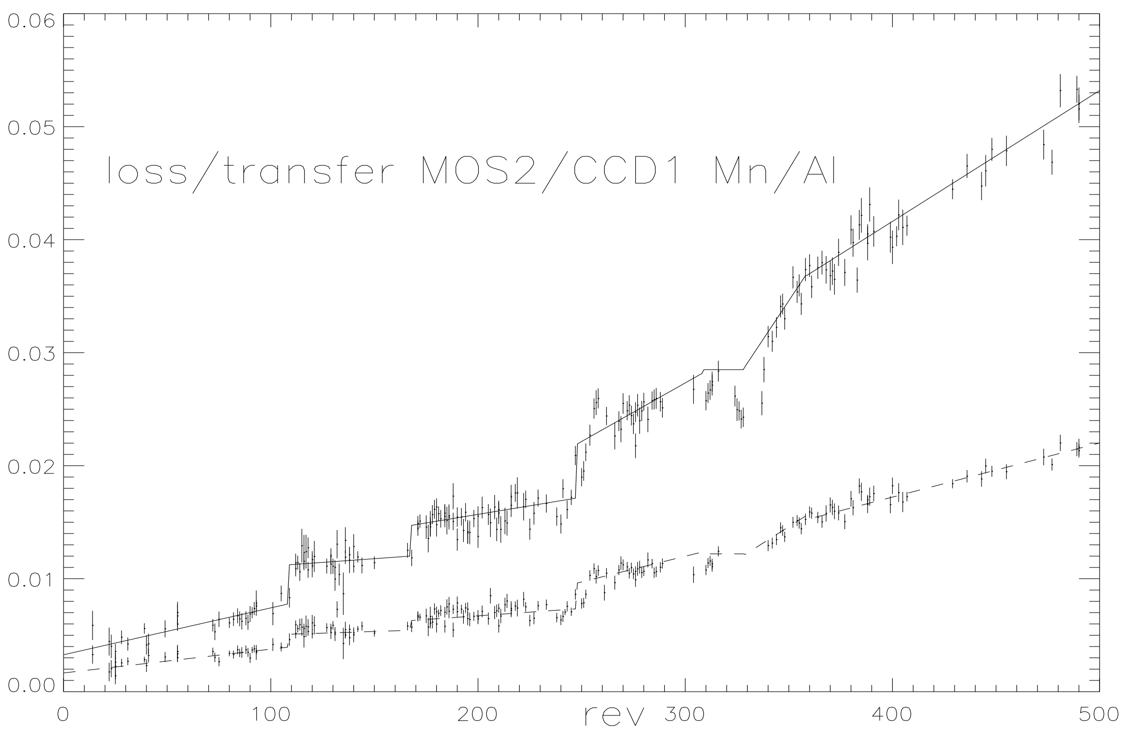


Figure 1: MOSs transfer losses since launch at Mn and Al energies, for the central CCD, overlayed with the CTI model as parametrized in the new set of CCFs

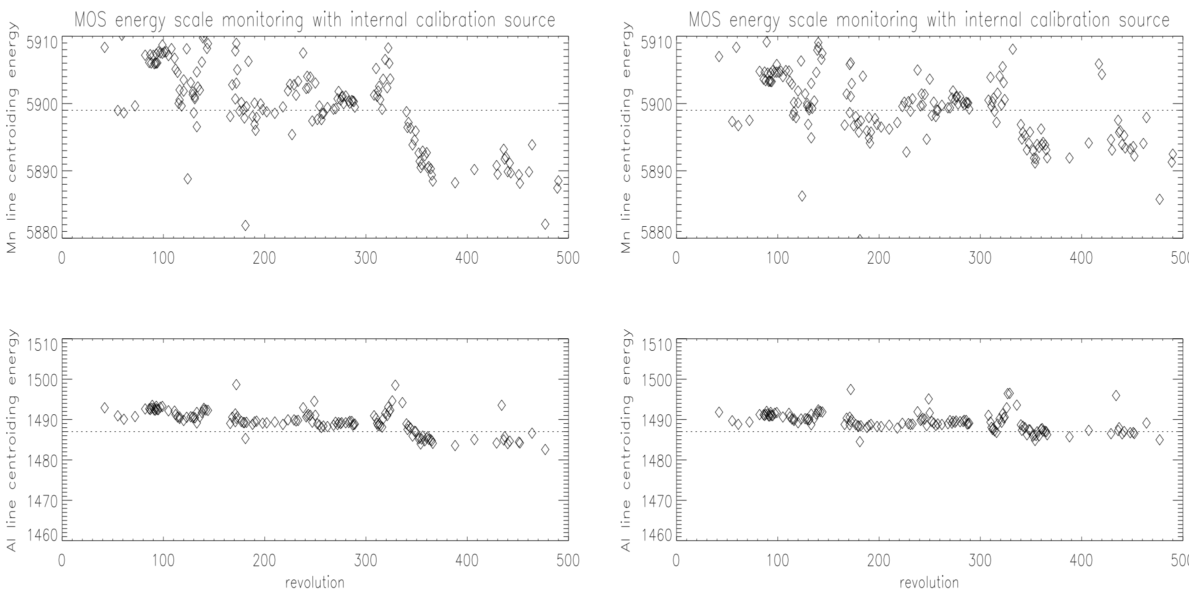


Figure 2: Mn and Al reconstructed line positions for MOS1 CCD1 with the old CCF (left), and with the new set of CCFs on the right since launch

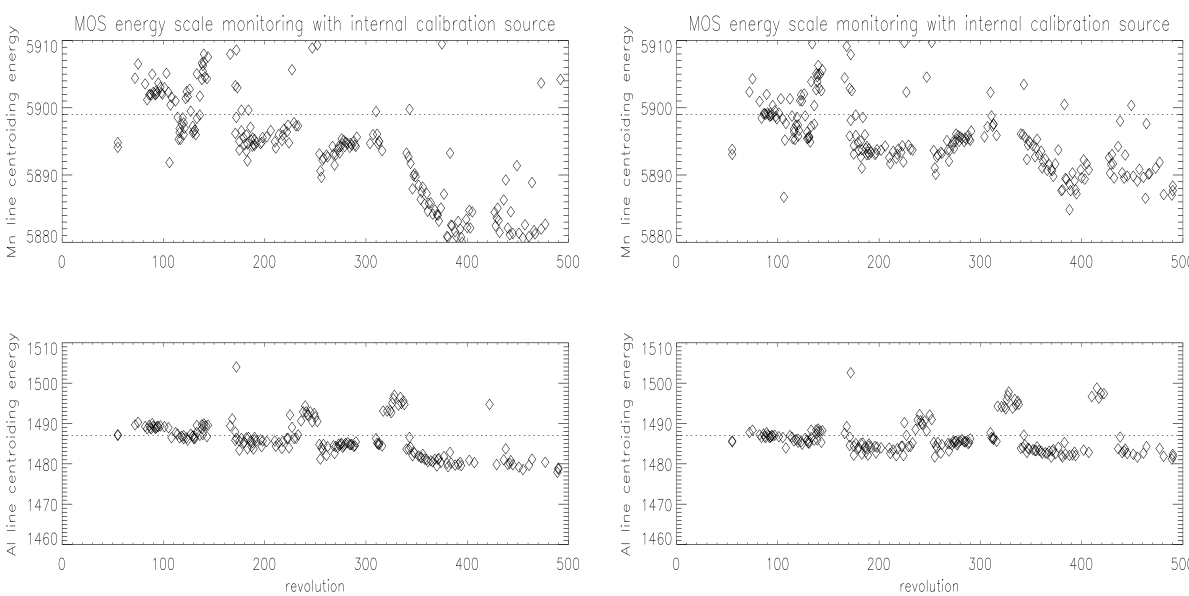


Figure 3: Mn and Al reconstructed line positions for MOS2 CCD1 with the old CCF (left), and with the new set of CCFs (right), since launch

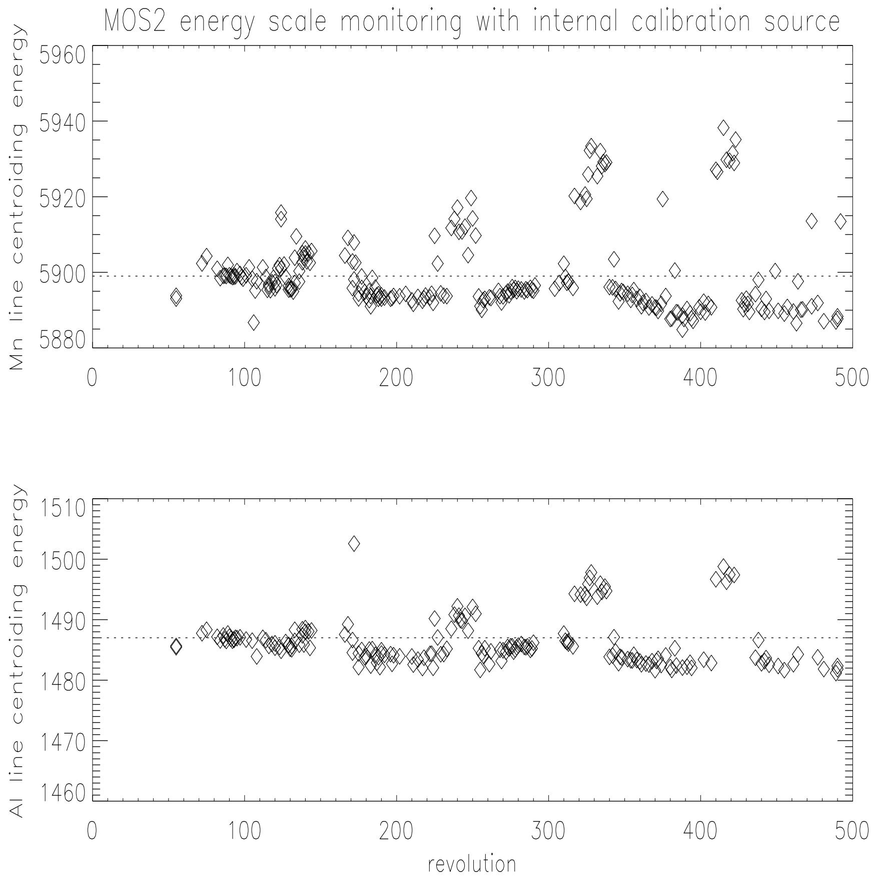


Figure 4: Mn and Al reconstructed line positions for MOS2 CCD1 since launch at a wider scale

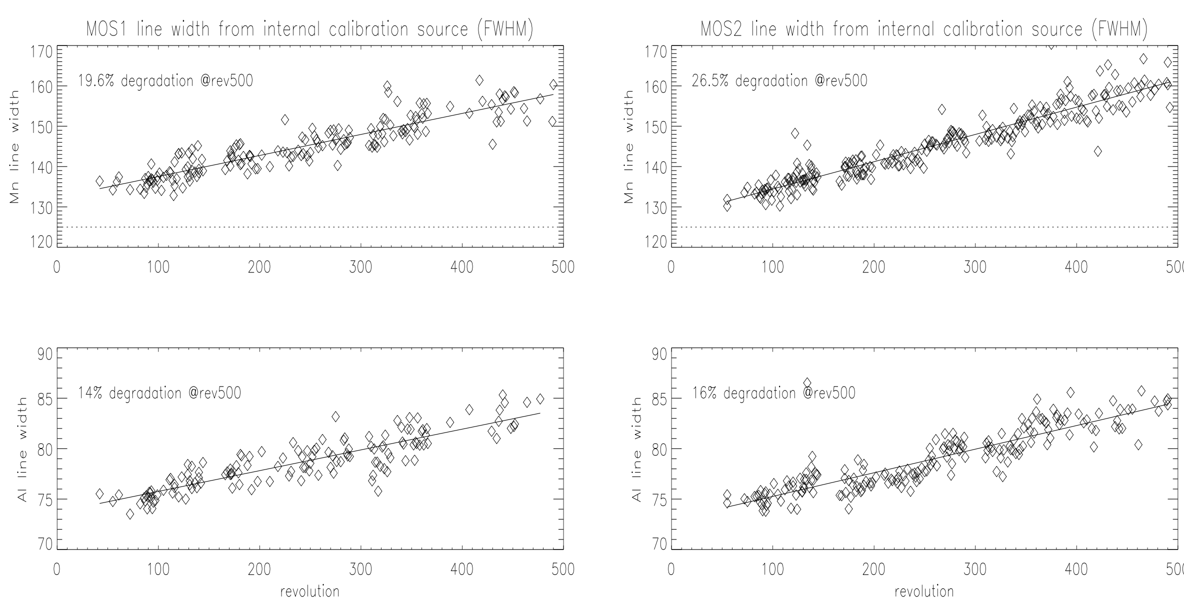


Figure 5: Monitoring of the MOS energy resolution with the emission lines of the internal calibration source