Cycle 28 COS FUV Detector Gain Maps

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\textbf{ABSTRACT}

Exposures were taken with the onboard deuterium lamp in order to illuminate the regions of the COS FUV detector used during normal operations in two programs during Cycle 28. Visits 3E and 4E of program 15772 provided an initial measure of the gain for new High Voltage (HV) levels for LP3 and LP4, and Program 16323 was executed to collect data two times during the year at all Lifetime Positions. The pulse height information obtained was used to create gain maps in order to monitor the detector gain sag, and thus to determine when to adjust the commanded high voltage on the detector.

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1. Introduction

Monitoring the gain (the number of electrons generated by the microchannel plate stack for each incident photon) of the COS FUV detector is crucial to ensure its optimal performance. When the modal gain (the peak of the pulse height distribution) at a particular location on the detector drops below a value of about 3, approximately 5% of the counts there fall below the lower pulse height threshold, which leads to an apparent local loss of sensitivity (Sahnow et al. 2011). The amount of gain sag is a function of the number of photon events incident on the detector, the high voltage (HV), and other factors. The largest gain drops are seen in the regions of the detector where Lyman-α airglow lines fall, since they have collected the most counts.

Cumulative Counts Image files (CCIs; Sahnow 2018) are created at each commanded HV approximately weekly by combining all of the TIME-TAG exposures obtained during that time. Gain map files are made by binning these (by 8 in X and 2 in Y) to collect the counts in a 48 µm square superpixel. A Pulse Height Distribution (PHD) is then constructed for each superpixel, and the modal gain is determined by fitting a gaussian to identify the peak of the distribution. These gain maps can be used to track the change of modal gain as a function of time at the locations where photons are detected.

However, since at least ~25 counts in a superpixel are necessary to reliably measure the peak of the PHD, the regions of the detector where the modal gain can be measured varies from week to week, depending on the grating, central wavelength, and Lifetime Position (LP) of the data collected. Even for the most commonly used cenwaves, it may be rare to ever collect enough counts for a valid measurement in any one week period in the the wings of the cross dispersion profiles, and this effect has been exacerbated as more LPs have been used during recent cycles.

In order to ensure more complete coverage at each LP and HV, exposures of the internal deuterium lamp (D1) are also regularly collected. The lamp illuminated a wider area in the cross-dispersion direction (y axis) of the detector than an external target so that modal gain measurements can be made everywhere that photons from science targets can fall. These gain map exposures are taken both before and after any change to the nominal detector high voltage at any Lifetime Position, and at approximately six month intervals when the voltage is not changed. Because of the strongly varying intensity of the lamp as a function of wavelength, data is collected using both G130M/1309 and G160M/1600. The former is the best choice for obtaining approximately uniform coverage on Segment A, while the latter does the same for Segment B. In order to maximize the number of counts in the PHD, data from both central wavelengths is combined when creating the gain maps.

2. Observations

The primary program used for gain maps in Cycle 28 was Program 16323 (PI Sahnow). This program was originally written to include eight one-orbit visits as in previous cycles, with visits 2A, 3A, 4A and 4B planned for April, and visits 2C, 3C, 4C and 4D
planned for October. Since the nominal HV levels for G130M/1222 and the G130M Standard Modes can differ, two visits for LP4 were allocated at each epoch. However, since the HV values for these two modes were the same in Cycle 28, it was not necessary to execute visits 4B and 4D. In addition, two contingency visits, 3E and 4E were added to the Cycle 27 gain map monitoring program (15772, PI Sahnow) to obtain deuterium spectra after the HV changes at the beginning of Cycle 28. These changes were implemented for LP3 (FUVA HV increased from 167 to 173) and LP4 (FUVA/B HV increased from 163/163 and 163/167 to 167/169).

The visits were labeled such that the first character denoted the Lifetime Position (2 for LP2, etc.). The second character in the visit label was A for the first visit at that LP in the spring, and C for the first visit in the fall. For LP4, where multiple HV values were possible in each case, B was used for the second visit in the spring, and D for the fall.

Cycle 28 also includes a contingency gain map program (16333, PI Sahnow) to obtain gain maps if HV changes were made during the cycle. One visit (4C) was executed after the LP4 FUVA HV was increased from 167 to 173 on October 4, 2021. Since this was after the start of Cycle 29, it will be discussed in a future ISR.

All visits executed successfully, although visit 2A of Program 16323 did not execute until more than a month after visits 3A and 4A. Since the exact timing of the visits is not critical, however, this had no effect on the success of the program. The reason for the delay of 2A was that the initial design of each visit did not include a command to return the aperture to the PSA LP4 position. For LP3 and LP4 exposures the default time padding at the end of the visit was long enough to allow the aperture to return to its home position, but for the move from LP2, it was not, and the visit could not be scheduled. Once the problem was identified, an aperture move was added to all of the unexecuted visits.

Table 1 shows the details of all of these visits. The LP, mode, HV, and aperture positions listed refer to the four primary exposures in each visit; the shorter initial exposures (see below) used values appropriate for LP1.
Table 1. Deuterium visits executed during Cycle 28

<table>
<thead>
<tr>
<th>PID</th>
<th>Root Name</th>
<th>Vis</th>
<th>Date</th>
<th>LP</th>
<th>Mode</th>
<th>HV (A/B)</th>
<th>LAPXSTP (G130M)</th>
<th>LAPXSTP (G160M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15772</td>
<td>le5d3e*</td>
<td>3E</td>
<td>10/5/20</td>
<td>3</td>
<td>Standard</td>
<td>173/175</td>
<td>-72,-128</td>
<td>-84,-140</td>
</tr>
<tr>
<td>15772</td>
<td>le5d4e*</td>
<td>4E</td>
<td>10/5/20</td>
<td>4</td>
<td>Standard &amp; 1222</td>
<td>167/169</td>
<td>-32,-86</td>
<td>-41,-95</td>
</tr>
<tr>
<td>16323</td>
<td>leeg2a*</td>
<td>2A</td>
<td>5/25/21</td>
<td>2</td>
<td>Blue</td>
<td>173/175</td>
<td>-213,-267†</td>
<td>-225,-267†</td>
</tr>
<tr>
<td>16323</td>
<td>leeg3a*</td>
<td>3A</td>
<td>4/15/21</td>
<td>3</td>
<td>Standard</td>
<td>173/175</td>
<td>-72,-128</td>
<td>-84,-140</td>
</tr>
<tr>
<td>16323</td>
<td>leeg4a*</td>
<td>4A</td>
<td>4/16/21</td>
<td>4</td>
<td>Standard &amp; 1222</td>
<td>167/169</td>
<td>-32,-86</td>
<td>-41,-95</td>
</tr>
<tr>
<td>16323</td>
<td>leeg2c*</td>
<td>2C</td>
<td>10/1/21</td>
<td>2</td>
<td>Blue</td>
<td>173/175</td>
<td>-213,-267†</td>
<td>-225,-267†</td>
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<td>10/2/21</td>
<td>3</td>
<td>Standard</td>
<td>173/175</td>
<td>-72,-128</td>
<td>-84,-140</td>
</tr>
<tr>
<td>16323</td>
<td>leeg4c*</td>
<td>4C</td>
<td>10/3/21</td>
<td>4</td>
<td>Standard &amp; 1222</td>
<td>167/169</td>
<td>-32,-86</td>
<td>-41,-95</td>
</tr>
</tbody>
</table>

† The commanded value of LAPXSTP for these positions was set to -267 in order to avoid the soft stop at -275

The two visits from program 15772 were laid out as described in Sahnow & Johnson (2023), and had exposure times of 440 seconds. The program 16323 visits were laid out slightly differently in order to add a short exposure at LP1 at the beginning of the visit. This extra exposure had two advantages: (1) it collected data on the LP1 region of the detector, which had not been regularly used since 2012; and (2) it provided a common, known reference point for the aperture position and HV for all other exposures. The procedure was:

- Take a 125 second deuterium exposure with the aperture at the default LP1 FCA location, using G130M/1309 and the default LP1 HV values of 178/175
- Adjust the HV for the selected LP (1 – 4)
- Adjust the aperture block in the cross-dispersion direction so that the deuterium lamp projected through the FCA illuminates the appropriate region on Segment A when using G130M/1309
- Take a 440 second deuterium lamp exposure at FP-POS=1 using both detector segments
- Adjust the aperture block to a second cross-dispersion location to obtain additional coverage on Segment A and take a 440 second deuterium lamp exposure at FP-POS=4 using both detector segments
- Adjust the aperture block in the cross-dispersion direction so that the deuterium lamp will illuminate the appropriate region on Segment B when using G160M/1600
• Take a 440 second deuterium lamp exposure using both detector segments
• Adjust the aperture block to a second cross-dispersion location to obtain additional coverage on Segment B and take another 440 second deuterium lamp exposure
• Return the aperture block to the nominal location. As noted above, this step was not included in visits 3A and 4A, but was added for the other visits to allow enough time for the move back to the aperture home position.

The two offset positions for each grating were chosen so that when the data from the exposures are combined, the count rate is roughly uniform in the cross-dispersion direction and they overlap with the science spectra at the same LP. The aperture offset values used (LAPXSTP) are shown in Table 1; these were determined by measuring the position of spectra as a function of aperture position during previous deuterium lamp observations. In several cases, the calculated value of LAPXSTP would have moved the aperture block beyond its soft stop at -275. In those cases, a value of -267 was used.

3. Analysis and Results

Standard gain map creation routines were used to calculate the modal gain; they fit a gaussian to the pulse height distribution for each $8 \times 2$ binned pixel, and the value of the peak of that fit is taken as the modal gain. Figure 1 shows the modal gain as a function of X pixel (XCORR) near the center of the LP4 detector location for both the spring and fall visits of program 16323 for both segments, along with the data obtained as part of Program 15772, both before and after the HV change.

Figure 2 shows an expanded view for each segment. The top panel shows a region with relatively low gain on FUVA, and the bottom panel shows the region around the most heavily gain sagged region on FUVB.
Figure 1. Modal gain as a function of unbinned X pixel at the center of the LP4 region for FUVA (top) and FUVB (bottom) at the end of Cycle 27 (green) and immediately after the HV was increased on both segments at the beginning of Cycle 28 (blue) from Program 15772; and at two later times during Cycle 28 from Program 16323 (orange and black). As expected, there is an increase in gain at the time of the HV increase, followed by a decrease during Cycle 28, with a variation as a function of position due to varying exposure levels.
Figure 2. Zoomed in view of the data shown in Figure 1. On Segment B at the positions corresponding to the Lyman-α lines from G130M/1291, FP-POS 3 and 4, the modal gain has dropped below 3, which is allowed under the COS2025 rules. Note that the y scale is different than in the previous figure.

The figures in this ISR show the modal gain at a constant Y superpixel for each LP, with the Y value chosen to be along the most sagged region. Although the most sagged Y superpixel can vary slightly as a function of X, this effect is not included here.

The modal gain is comfortably above 3 at all locations on both segments, except at the two locations of the Lyman-α airglow lines on FUVB. These two “gain sag holes” have been allowed since the adoption of the COS2025 rules (Oliveira et al. 2018), which were implemented to extend the life of the detector.

The modal gain measured at the LP3 region on the detector at the same times as in the previous figures is displayed in Figure 3, and Figure 4 shows an expanded view highlighting the deepest gain sag holes on each segment. In this case, the holes have dropped to a modal gain of 3 or below at four locations on FUVB, which is operating at the maximum currently allowable HV value of 175. On FUVA, the modal gain at the most sagged locations just reached a value of 3 at the end of the previous cycle, but the HV had not reached its maximum allowed value; as a result, the HV on that segment was increased at the beginning of Cycle 28, increasing the modal gain to well above 3.
Figure 3. Modal gain as a function of X pixel at the center of the LP3 region of the detector for the same times as in Figure 1. The FUVA HV was increased from 167 to 173 at the beginning of the cycle to keep the gain sagged regions near the left edge above a modal gain of 3. The low gain feature near the center of FUV has been present since launch.

Figure 5 shows the modal gain at the center of the LP2 region for the same times as the other LPs. Very little change has occurred during Cycle 27 since the number of counts that fell on this region of the detector is much smaller than at LP3 or LP4.

As noted above, LP1 gain map data is again being collected, and the results are shown in Figure 6 and Figure 7. The shorter time for these exposures does not provide enough counts to measure the modal gain at all X locations, but the extremely sagged regions on FUVB due to Lyman-α are clearly visible.

The primary purpose of Program 16323 was to obtain gain maps which are used to determine the slope of the modal gain vs. extracted charge curve over the entire illuminated area of the detector at all of the nominal high voltage values used during the cycle. Making regular measurements allows a more accurate determination of these slopes, which leads to better predictions of when the gain is likely to drop to 3, and thus when a high voltage change or Lifetime Position change is needed. Examples of gain vs. extracted charge curves are shown in Sahnow et al. (2011).
Figure 4. An expanded view of a portion of the modal gain plot shown in Figure 3. All four Lyman-α lines due to G130M/1291 at LP3 on FUVB had previously dropped to a modal gain below 3 at HV=175, and show little change during Cycle 28. On FUV, the four Lyman-α impacted regions from G140L/1105 had dropped to 3 at the end of Cycle 27, so the HV was increased at the beginning of Cycle 28. Note that the y scale is different than in the previous figure.

Data from this program, along with data from the weekly gain measurements, is also used in the construction of the gain sag reference table (GSAGTAB), which flags the regions where the modal gain has dropped to a level which adversely affect the data.

The results described above are consistent with those from previous cycles, e.g. Sahnow & Johnson (2023) for Cycle 27. Regular gain map measurements will continue in Cycle 29 in Program 16829.

Change History for COS ISR 2023-13

Version 1: 1 June 2023
Figure 5. Modal gain as a function of X pixel at the center of the LP2 (Blue Mode) region of the detector using the Blue Modes HV values of 173/175. There was very little change during this cycle since these modes are not used extensively.

References

Oliveira, C., et al., 2018, “COS2025: A New Strategy to Prolong the Lifetime of the COS/FUV Detector to 2025”


Sahnow, D. 2018, COS TIR 2018-02, “Requirements for COS Cumulative Images”

Sahnow, D. and Johnson, C., COS ISR 2023-12, “Cycle 27 COS FUV Detector Gain Maps”
Figure 6. Modal gain as a function of X pixel at the center of the LP1 region of the detector at three times during Cycle 28. Data is no longer being taken at this location, so very little change is seen. Not enough counts were obtained on the left side of FUVB to measure the gain accurately.
Figure 7. An expanded view around the most gain sagged regions of the data shown in Figure 6. The deepest holes are well below a modal gain of 3.