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XRISM/ Resolve
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03/18/2024
RELEASED

# INSTRUMENT CALIBRATION REPORT

# RESOLVE PULSE CLIPPING THRESHOLD

RESOLVE-SCI-RPT-0175

REVISION (-)

XRISM-RESOLVE-CALDB-CLIPTHR-219

X-ray Imaging and Spectroscopy Mission (XRISM) Project

NASA/GSFC Code 461

**Goddard Space Flight Center**
**Greenbelt, Maryland**

National Aeronautics and
Space Administration

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# Resolve Pulse Clipping Threshold

## Signature/Approval Page

**Prepared by:**
M.E. Eckart and the Resolve Instrument Team

**Reviewers/Approvers:**

Masahiro Tsujimoto
Megan Eckart
Maurice Leutenegger
Caroline Kilbourne
Scott Porter
Michael Loewenstein
Tahir Yaqoob

**Approved by:**

Megan Eckart

***** Electronic signatures are available on-line at: https://ipdtdms.gsfc.nasa.gov*****

# Preface

This document is an XRISM Project signature-controlled document. Changes to this document require prior approval of the applicable Product Design Lead (PDL) or designee. Proposed changes shall be submitted in the Technical Data Management System (TDMS) via a Signature Control Request (SCoRe) along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

All of the requirements in this document assume the use of the word "shall" unless otherwise stated.

Questions or comments concerning this document should be addressed to:
XRISM Configuration Management Office
Mail Stop: 461
Goddard Space Flight Center
Greenbelt, Maryland 20771

# Change History Log

| Revision | Effective Date | Description of Changes (Reference the SCoRe Approval Date) |
|---|---|---|
| - | 03/18/2024 | First version. Based on ground calibration data. Released per RESOLVE-SCoRe-0570 |
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*NOTE to editors: The document name will be XRISM-CAL-RPT-XXXX, where XXXX is assigned by the TDMS system. The document will be cross-referenced in TDMS to the filename in the format XRISM-XXX-CALDB-FILEDESC-NN where XXX is the instrument or component (e.g. RESOLVE), FILEDESC refers to a specific calibration report (e.g., rmfparams) and NN the corresponding number assigned to that report by the SDC. For example the calibration report addressing the Resolve LSF calibration may be assigned XRISM-RESOLVE-CALDB-RMFPARAMS-01, that addressing the Resolve gain calibration XRISM-RESOLVE-GAINPIX-CALDB-02, etc. (where the numbers are to be provided by the SDC).*

*These documents are updated as needed, e.g. when the relevant CALDB files, or the relevant calibration data analysis, is revised. The document version will be assigned by the TDMS system. The tracking tool should be used to record changes.*

*This document must include the CalDB file name, an explanation of how the data were collected and the analysis conducted and, if using standard Ftools, the software version number. All revisions are consolidated into the same document to maintain a full record of all changes.*

# Table of Contents

# 1 Introduction

## 1.1 Purpose

This document describes the Resolve detector clipping thresholds ("clipthr") CalDB file. The file contains a value for each pixel at which pulses begin to clip in the Resolve detector electronics readout chain. The XRISM pipeline software compares each event's lo-res pulse height to the clipping threshold and flags accordingly.

## 1.2 Scientific Impact

Clipping occurs for some x-ray events outside of the Resolve science waveband (at >20 keV for nominal operating conditions) and thus is only relevant for observations using data from the extended high-energy waveband.

For events that are clipped, lo-res pulse heights saturate at the energy corresponding to the clipping threshold. The clipping energy depends on gain scale [1] and thus pixel number and operating heatsink temperature. For 50 mK operation the clipping energy is above 20 keV for all pixels and above 25 keV for half of the pixels.

Hi-res and mid-res pulse heights don't saturate in the same way the lo-res pulse heights do for clipped events, but the gain curves take on different shapes. The energy assignment for clipped events has systematic errors that have not been thoroughly quantified.

At x-ray energies significantly above the clipping threshold (e.g., above 30 keV on many pixels) pulse shapes become sufficiently mismatched from the optimal filter templates that the PSP registers individual x-ray events as multiple lo-res events. In these cases, the PSP does not calculate optimally filtered (hi-res or mid-res) pulse heights.

# 2 First Delivery – 20220510

| CalDB Filename | Validity date | File as delivered | Delivery date | Comment |
|---|---|---|---|---|
| xa_rsl_clipthr_20190101v002.fits | 20190101 00:00 UT | clipped_pulses_v1.txt | 20220510 | All pixels = 12235 |

## 2.1 Data Description

The measurements used to investigate the pulse clipping threshold were acquired for energy scale parameterization during ground calibration of the Resolve microcalorimeter detector array at Goddard Space Flight Center (GSFC) in 2019 and at Tsukuba Space Center (TKSC) in 2021.

The instrument recorded spectra of fluorescent x-ray emission lines generated by external calibration devices (rotating target sources (RTSs)), with exposures at multiple calorimeter thermal sink (CTS) temperatures ranging from 48 mK to 52 mK. The energy scale instrument calibration report (Ref [1]) provides a thorough description of these datasets.

This clipping investigation relies on the high-energy x-ray emission lines, primarily Ag Kα (22.1 keV) and Ag Kβ (24.9 keV), to create events above the clipping threshold.

## 2.2 Data Analysis

During analysis of the energy scale data, in particular the 48 mK dataset from the calorimeter spectrometer insert (CSI)-level calibration at GSFC, we noticed features that led to our incorporating this clipping thresholds CalDB file. First, we found that the hi-res gain scales changed shape on some pixels at high energies causing large residuals when creating polynomial gain scales or poor local energy scale calibration at 22 keV (Ag Kα). Other pixels appeared well behaved. See

Figure 1. Then, when using the lo-res pulse height of hi-res events (LO_RES_PH, also called LowResRawPH) to create lo-res gain scales we found that the Ag Ka lines were missing on some pixels (Figure 2). These observations were caused by the same effect: pulse clipping (Figure 3) in the readout electronics.

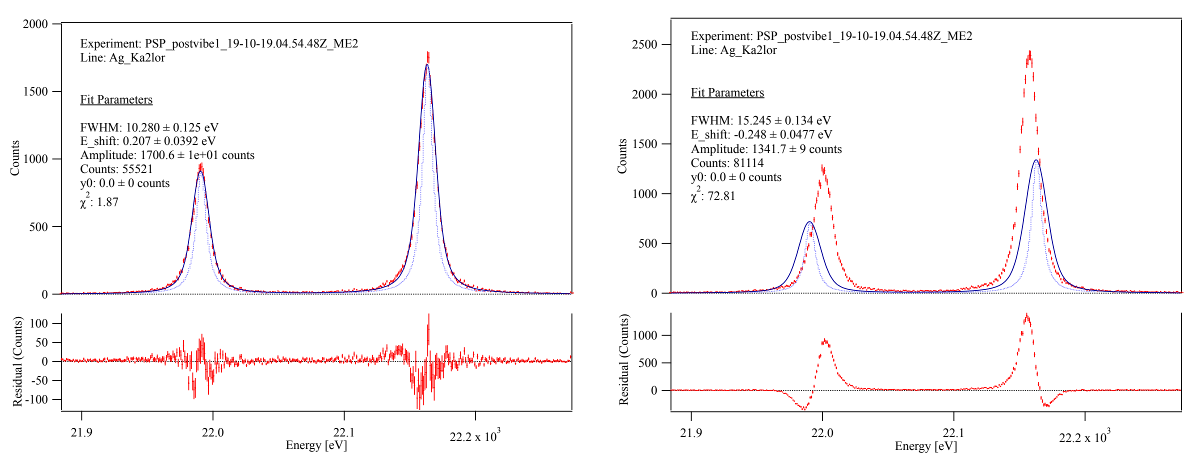

*Figure 1 Ag Ka complex from 48 mK gain scale data taken at GSFC in 2019. The left panel shows a spectrum from the set of 14 pixels that do not have clipped pulses at these operating conditions. The right panel shows data from the set of 21 pixels that have clipped pulses after creating a gain scale that includes the Ag Ka complex. This procedure forces the central energy to be approximately correct but the local slope to be incorrect, causing the large residuals.*

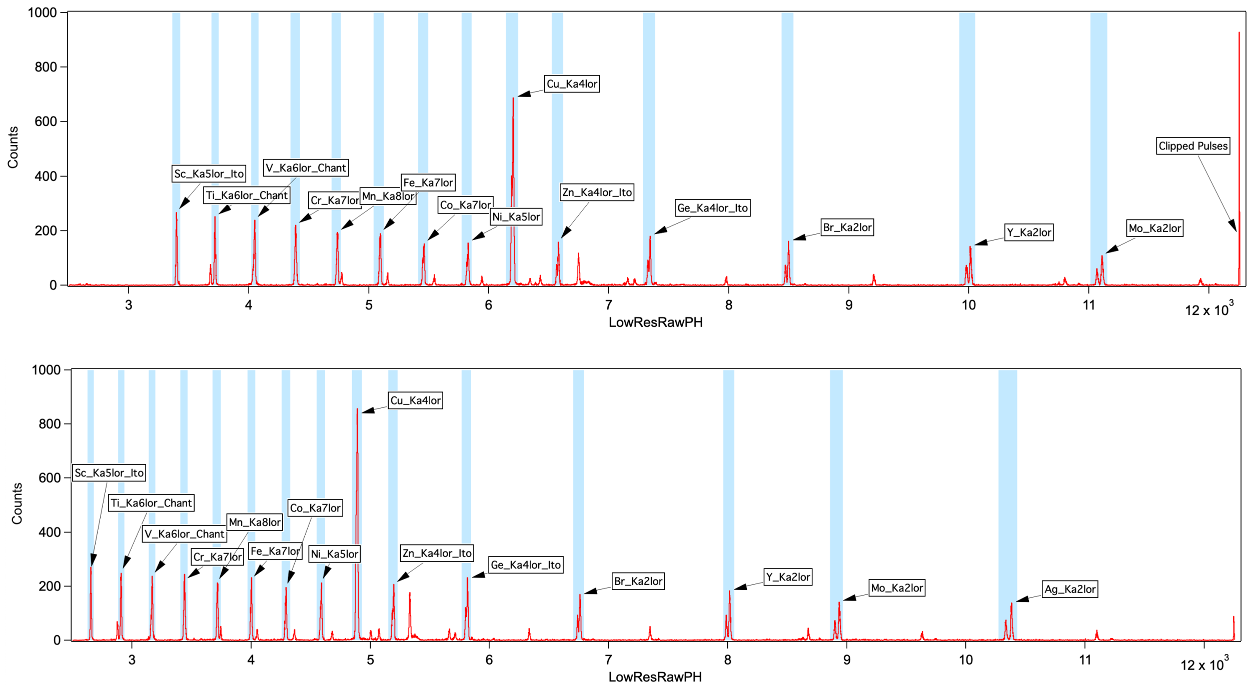


*Figure 2 Spectra not yet gain calibrated, using the lo-res pulse height (LowResRawPH) of hi-res events. The top panel shows pixel 30 and the bottom panel shows pixel 16. On pixel 30 and others with relatively high responsivity the Ag Ka complex is above the clipping threshold, whereas on pixel 16 and others with lower responsivity the Ag Ka complex falls below the clipping threshold. These data are from the 49 mK gain scale exposure at TKSC in December 2021.*

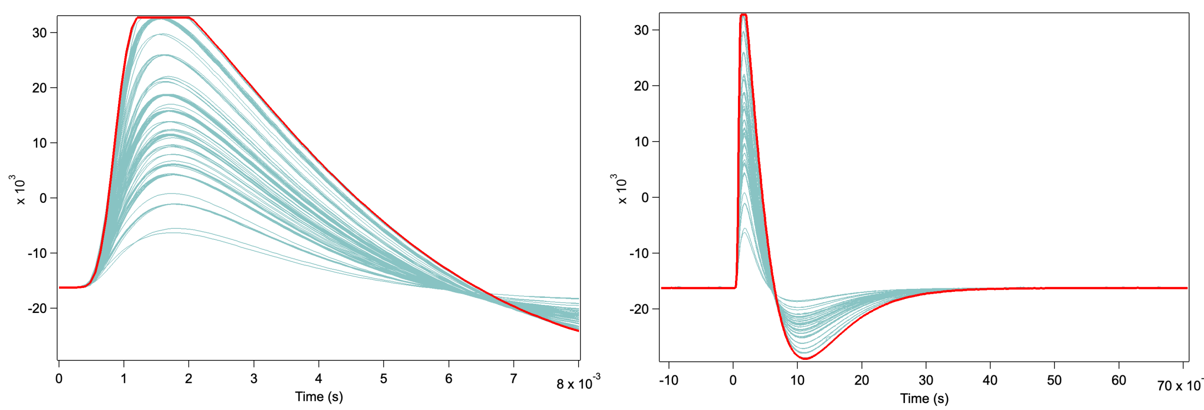


*Figure 3 Example of pulse clipping on pixel 17 (red curve). Lower energy photons do not cause clipping (green curves). These plots show 200 pulse records each. (Left) Zoomed to 8 ms around the pulse peak. (Right) Full range of 81.92 ms pulse record.*

## 2.3 Results

We used the energy gain scale datasets to determine the clipping thresholds. We found that the results were consistent among datasets acquired at CSI level and at instrument level. Figure 4 through
Figure 8 show the analysis to determine the clipping thresholds and Figure 9 presents the x-ray energy at the onset of clipping for each pixel in the Resolve array.

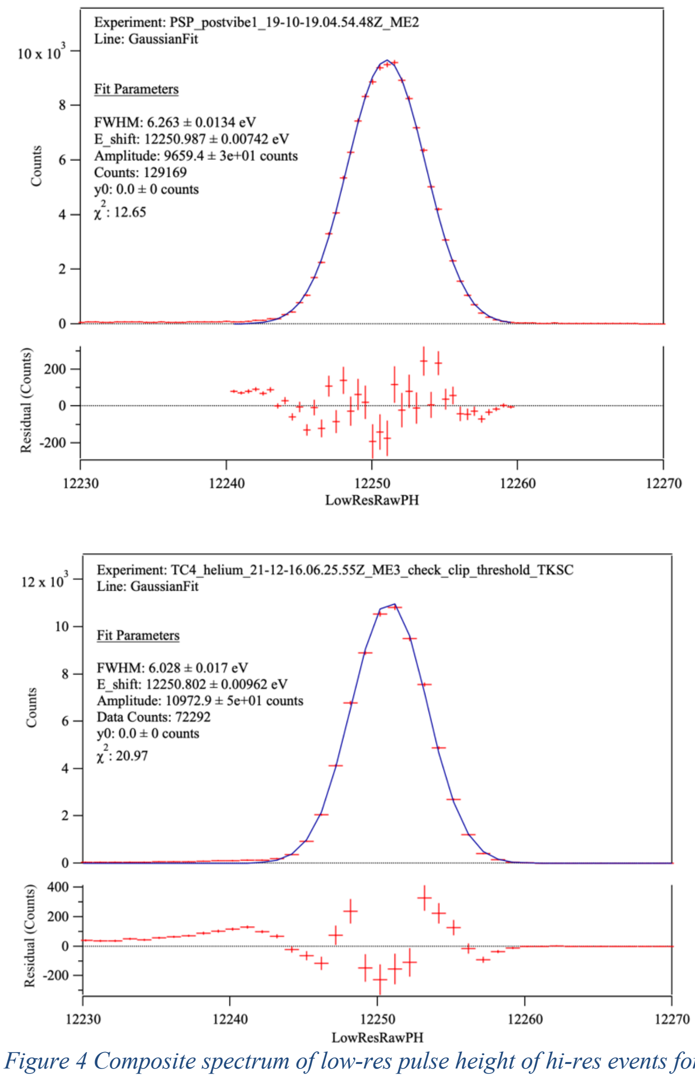


*Figure 4 Composite spectrum of low-res pulse height of hi-res events for Resolve's 35 main array pixels prior to gain calibration, zoomed in on the peak at the clipping threshold. The top panel shows data from a 48 mK exposure at GSFC in 2019 and the bottom panel presents data from a 49 mK exposure at TKSC in 2021. We show datasets with the lowest heatsink temperature available to maximize the number of counts above the clipping threshold (due to the high sensor responsivity). Gaussian fit parameters indicate a centroid of LowResRawPH = 12251 with a FWHM of 6 in both cases. The centroid varies slightly per pixel—see Figure 5 and Figure 6.*

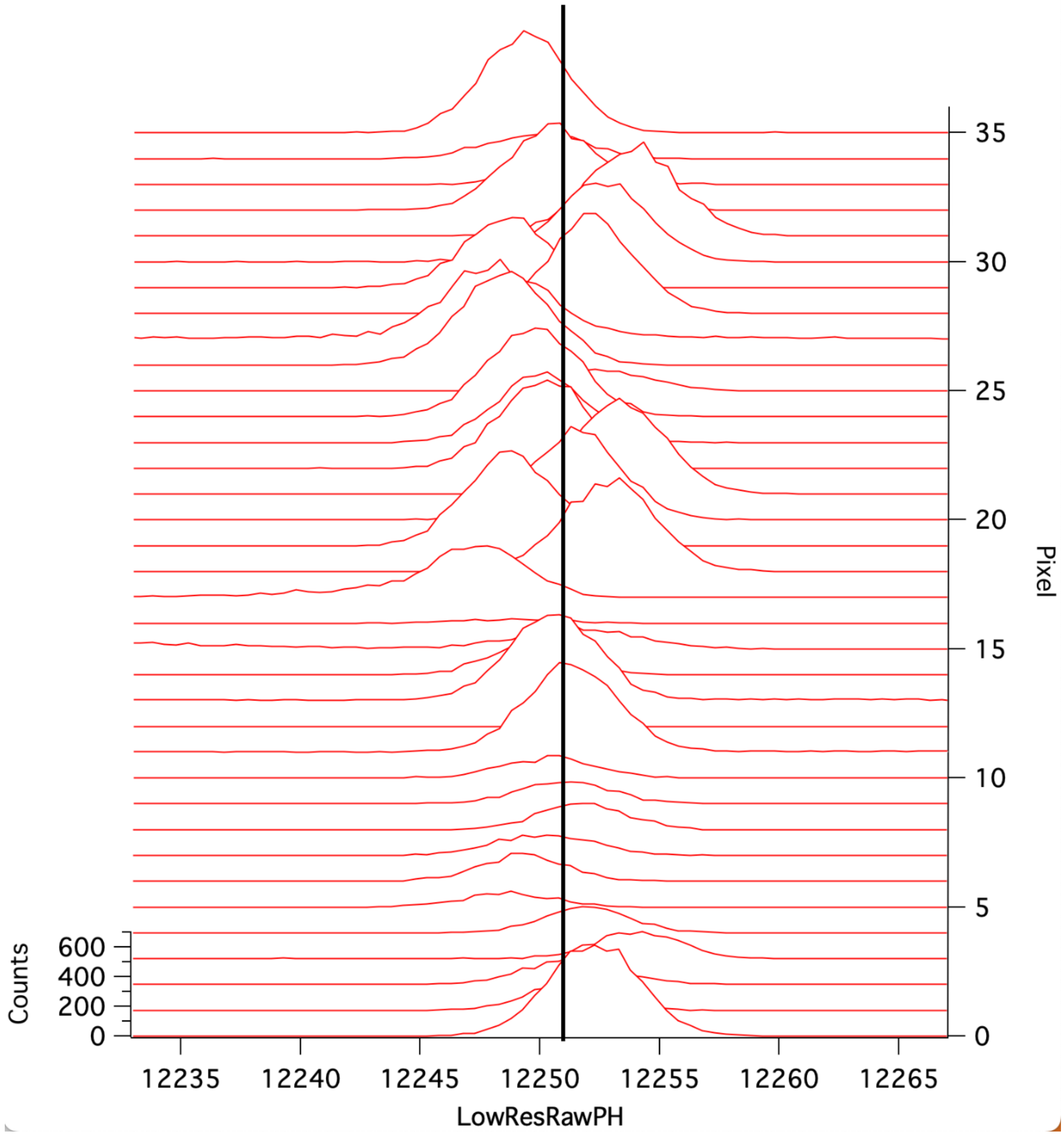


*Figure 5 Individual spectra of Resolve pixels using the lo-res pulse height of hi-res events, highlighting the peak at the clipping threshold. The central peak varies slightly among pixels, for example, pixel 17 has one of the lowest centroids at 12248.0 (FWHM=4.2) and pixel 3 has one of the highest centroids at 12254.4 (FWHM=4.1). The black vertical line at 12251 represents the center of the composite spectrum from Figure 4. The number of events in each peak varies based on where the Ag K counts fall for each pixel with respect to the clipping threshold. This data was acquired at 48mK at GSFC in 2019.*

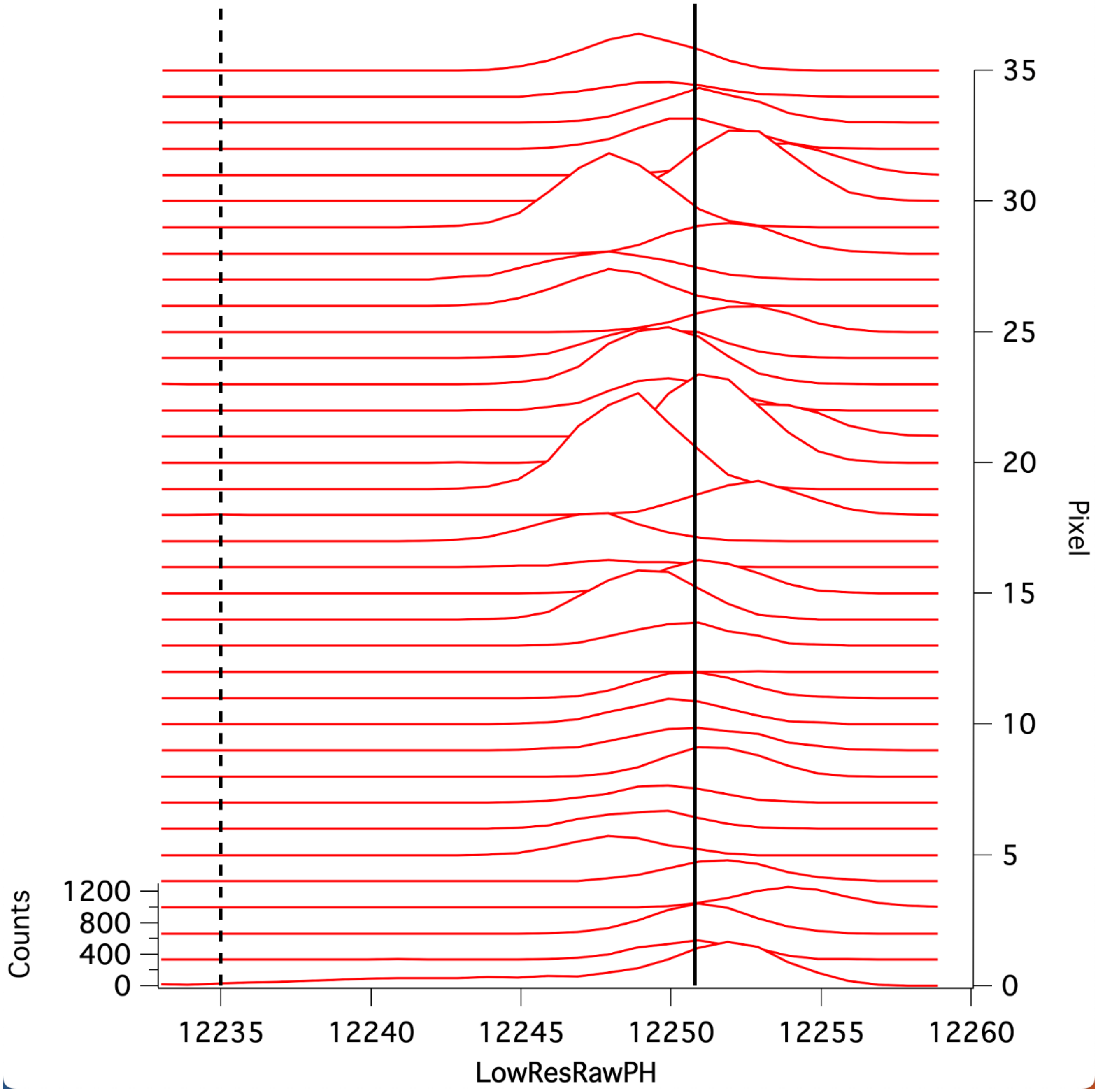


*Figure 6 Similar plot as in Figure 5, but with data taken at TKSC in December 2021 at 49 mK. The black vertical line at 12251 represents the center of the composite spectrum from Figure 4. The dashed vertical line at 12235 indicates the threshold provided in the 20220510 delivery of the clipping threshold CalDB file.*

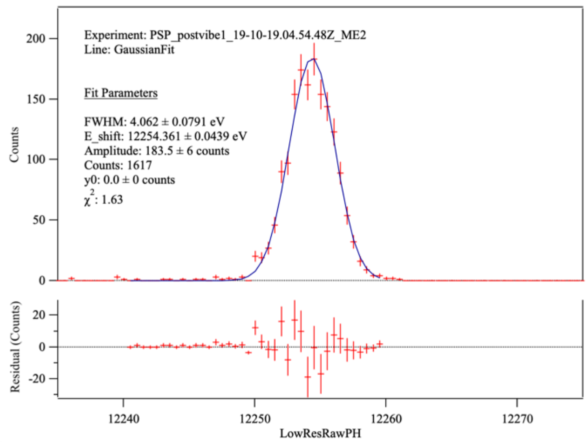


*Figure 7  Event distribution near the clipping threshold on pixel 3. Same data as in the waterfall plot in Figure 5.*

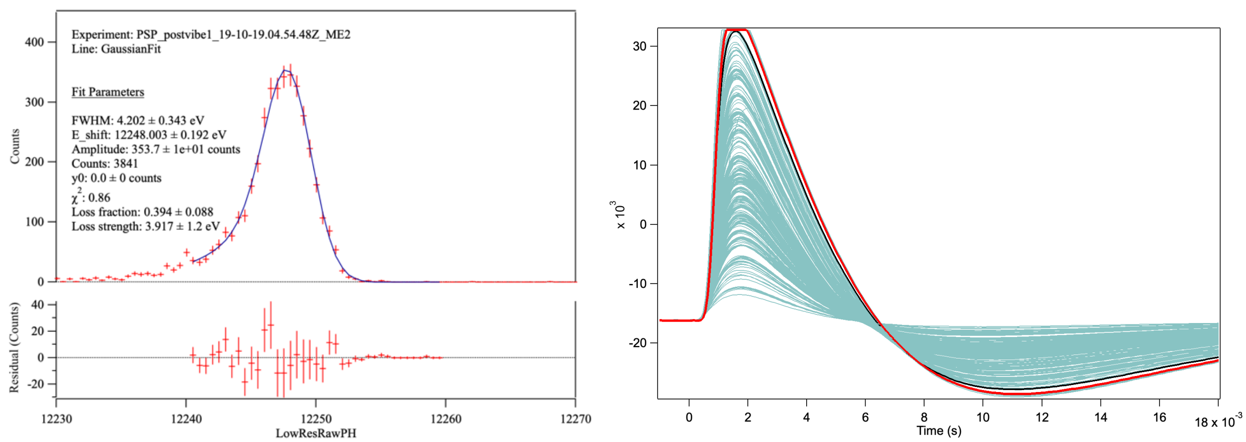


*Figure 8  (Left) Event distribution near the clipping threshold on pixel 17. Same data as in the waterfall plot in Figure 5. An x-ray emission line was present just below the clipping threshold, leading to the appearance of the tail on the low-energy side of the distribution at the clipping threshold. (Right) Pulse records show a set of pulses just missing the onset of clipping, for example, the pulse highlighted in black that peaks close to the peak of clipped pulses (red).*

**Data files as delivered to SDC:**
For this initial delivery of the CalDB data we decided to adopt a constant value of 12235 for all pixels, rather than specify per-pixel thresholds. See dashed line in Figure 6. This value will ensure all clipped pulses are flagged. We delivered a file with 36 rows, one per pixel excluding anti-co channels, and two columns (pixel number and clipping threshold). In this delivery all rows have thresholds set to 12235.

**File in XRISM CalDB:**
The FITS file prepared by the SDC has one extension in addition to the primary extension. The extension name is CLIPTHRES and it contains two columns, PIXELID and THRESHOLD.

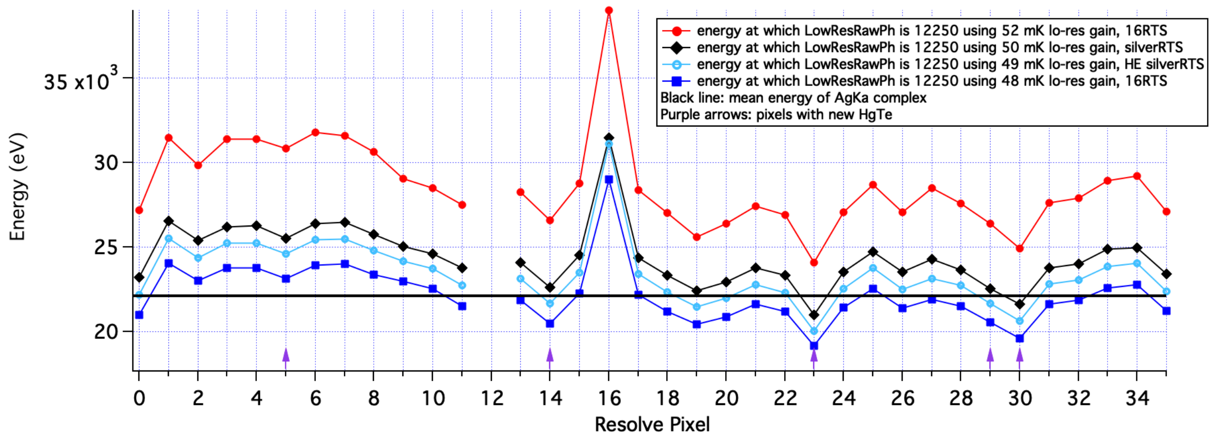

*Figure 9 X-ray energy at which clipping begins on each array pixel for four different heatsink temperatures. The black curve is closest to the case of nominal operation at 50 mK. The black horizontal line indicates the mean energy of the Ag Ka complex used during ground calibration. The purple arrows highlight the five pixels with HgTe absorbers from a different lot of material than then rest of the array. These pixels tend to have lower heat capacity and thus larger detector sensitivity (larger pulses for a given energy), contributing to lower-than-average clipping energies. Pixel 16 has a lower detector sensitivity (smaller pulses for a given energy), causing its higher-than-average clipping energy. The reduced sensitivity is probably due to excess epoxy that was applied on pixel 16 during the absorber assembly process. Note: in this plot we adopt a rough value of clipping threshold of 12250. The value in the CalDB file is 12235, so corresponding thresholds in energy would be ~0.02% lower than indicated in this plot.*

These clipping thresholds can be converted from LowResRawPH to energy using the lo-res gain scales (Figure 9) to estimate the waveband over which the Resolve spectrometer has a well-behaved energy gain scale. At x-ray energies above the black curve in Figure 9, for example, there will be errors in energy assignment using standard XRISM pipeline procedures, and these errors are not well characterized.

### 2.4 Final remarks

This is the first release of this CalDB file based on ground calibration data. The thresholds were consistent between CSI-level testing at GSFC in 2019 and instrument-level testing at TKSC in 2021. These values do not depend on the optimal filter template (SHPTEMPL) or the pixel trigger thresholds. We do not expect to require further updates.

## 3 References

[2] M.E. Eckart, et al. *Instrument Calibration Report, Resolve Detector Gain, XRISM-RESOLVE-CALDB-GAINPIX-214,* in prep. (2024).