Study of the residual background events in ground data from the Astro–H/SXS microcalorimeter

C.A. KILBOURNE, K.R. BOYCE, M.P. CHIAO, M.E. ECKART, R.L. KELLEY, M.A. LEUTENEGGER, F.S. PORTER, T. WATANABE – NASA GODDARD SPACE FLIGHT CENTER
Y. ISHISAKI, S. YAMADA – TOKYO MET. UNIV. * M. TSUJIMOTO, K. MITSUDA – ISAS/JAXA * M. TASHIRO – SAITAMA UNIV.

The measured instrumental background of the XRS calorimeter spectrometer of Suzaku had several sources, including primary cosmic rays and secondary particles interacting with the pixels and with the silicon structure of the array. Prior to the launch of Suzaku, several data sets were taken without x-ray illumination to study the characteristics and timing of background signals produced in the array and anti-coincidence detector. Even though the source of the background in the laboratory was different from that in low-earth orbit (muons and environmental gamma-rays on the ground versus Galactic cosmic-ray (GCR) protons and alpha particles in space), the study of correlations and properties of populations of rare events was useful for establishing the preliminary screening parameters needed for selection of good science data. Sea-level muons are singly charged minimum-ionizing particles, like the GCR protons, and thus were good probes of the effectiveness of screening via the signals from the anti-coincidence detector.

Here we present the first analysis of the on-ground background of the SXS calorimeter of Astro-H. On XRS, the background prior to screening was completely dominated by coincident events on many pixels resulting from the temperature pulse arising from each large energy deposition (>200 keV) into the silicon frame around the array. The improved heat-sinking of the SXS array compared with XRS eliminated these thermal disturbances, greatly reducing the measured count rate in the absence of illumination. The removal of these events has made it easier to study the nature of the residual background and to look for additional event populations. We compare the SXS residual background to that measured in equivalent ground data for XRS and discuss these preliminary results.

THE ASTRO–H SOFT X–RAY SPECTROMETER (SXS)

The SXS instrument of Astro-H incorporates a 36-channel microcalorimeter array of Si thermistors with HgTe x-ray absorbers. Paired with nested-foil x-ray optics, each 0.83 mm pixel covers 0.5 arc minutes on the sky. The SXS has been integrated onto the Astro-H spacecraft, where it has demonstrated better than 5 eV FWHM across the array; the required spectral resolution in orbit is 7 eV. SXS will provide unprecedented high-resolution spectroscopy of extended cosmic x-ray sources (e.g. supernova remnants and galaxy clusters) and of all cosmic x-ray sources in the Fe–K band (around 6 keV), which will enable essential plasma diagnostics.
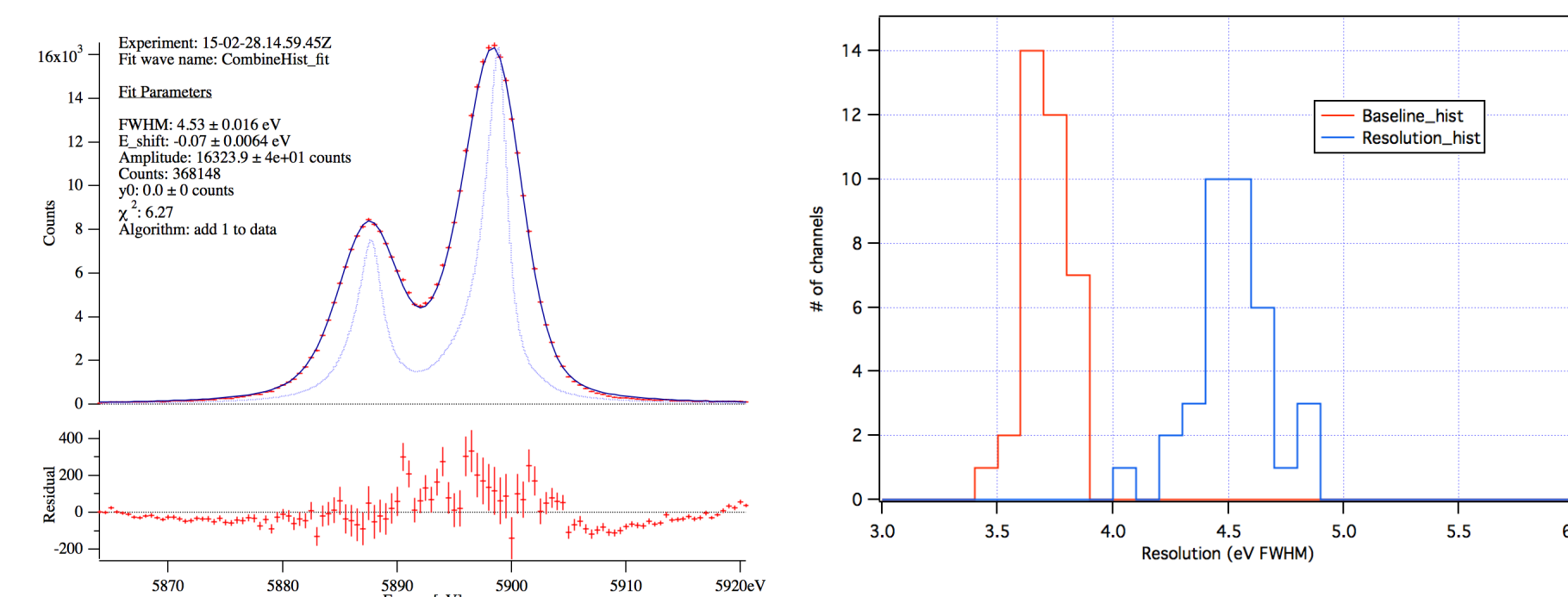
BACKGROUND ANALYSIS ON SUZAKU/XRS vs. ASTRO–H/SXS

Background event energy vs. time, color coded by pixel number
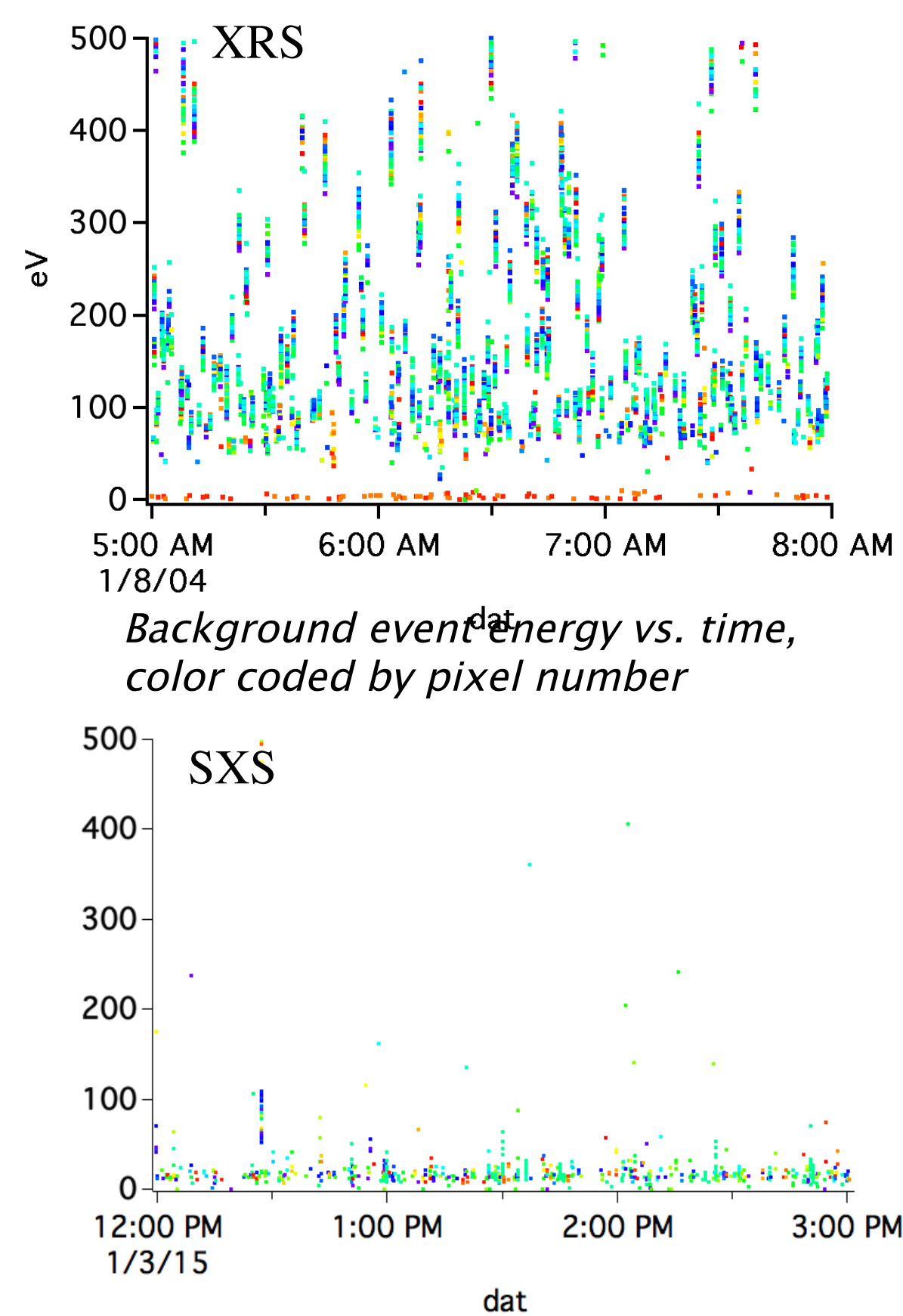
On Suzaku/XRS, the unprocessed instrument background was dominated by clusters of events in which every pixel had triggered; testing with alpha particles had revealed that energy deposited into the frame of the array resulted in pulses on the pixels of a scale comparable to direct deposition of energy a factor of 3000 less. Thus the primary screening task was to correctly identify and remove the groups of correlated events.

On Astro-H/SXS, improved heat-sinking of the array eliminated these events. Clusters of multiple coincident triggers are now so rare that is has not been possible to consider them as a population. They are not all the same, in terms of energy span or rise-time range, thus they are likely the result of transient disturbances.

On XRS, event data from the anti-coincidence detector was not available. The threshold and coincidence window were selected as input parameters, and the on-board processing set a flag on calorimeter events that were determined coincident with an event on the anti-coincidence detector. On SXS, anti-coincidence detector events are included in the telemetry, and coincidence and event flagging is done on the ground.

A ~12-hour (43375.1 s) background file from instrument testing in January 2015 was analyzed. Algorithms to refine the event time tags are under development; in order to study event correlation in the interim, a coincidence window of 1.5 ms was used.

standard groupings in the SXS background
- 1 calorimeter + both anti-co channels (primary and redundant)
- 1 calorimeter + 1–2 small xtalk + with or without anti-co
- 1 calorimeter + 2 small xtalk + both anti-co + anti-co xtalk on 17 and 35
- Close pairing of random pixel with off-line event on calibration pixel (Seen on XRS. Electron lost from cal pixel scattered and absorbed by another pixel.)
- Event pair, usually on adjacent channels, 40% also paired with anti-co. THESE ARE NOT YET UNDERSTOOD.

The last two show that even SXS needs screening by pixel-to-pixel coincidence. But we need rise-time or pulse-height discriminators so that a pulse is not vetoed by its own electrical crosstalk.
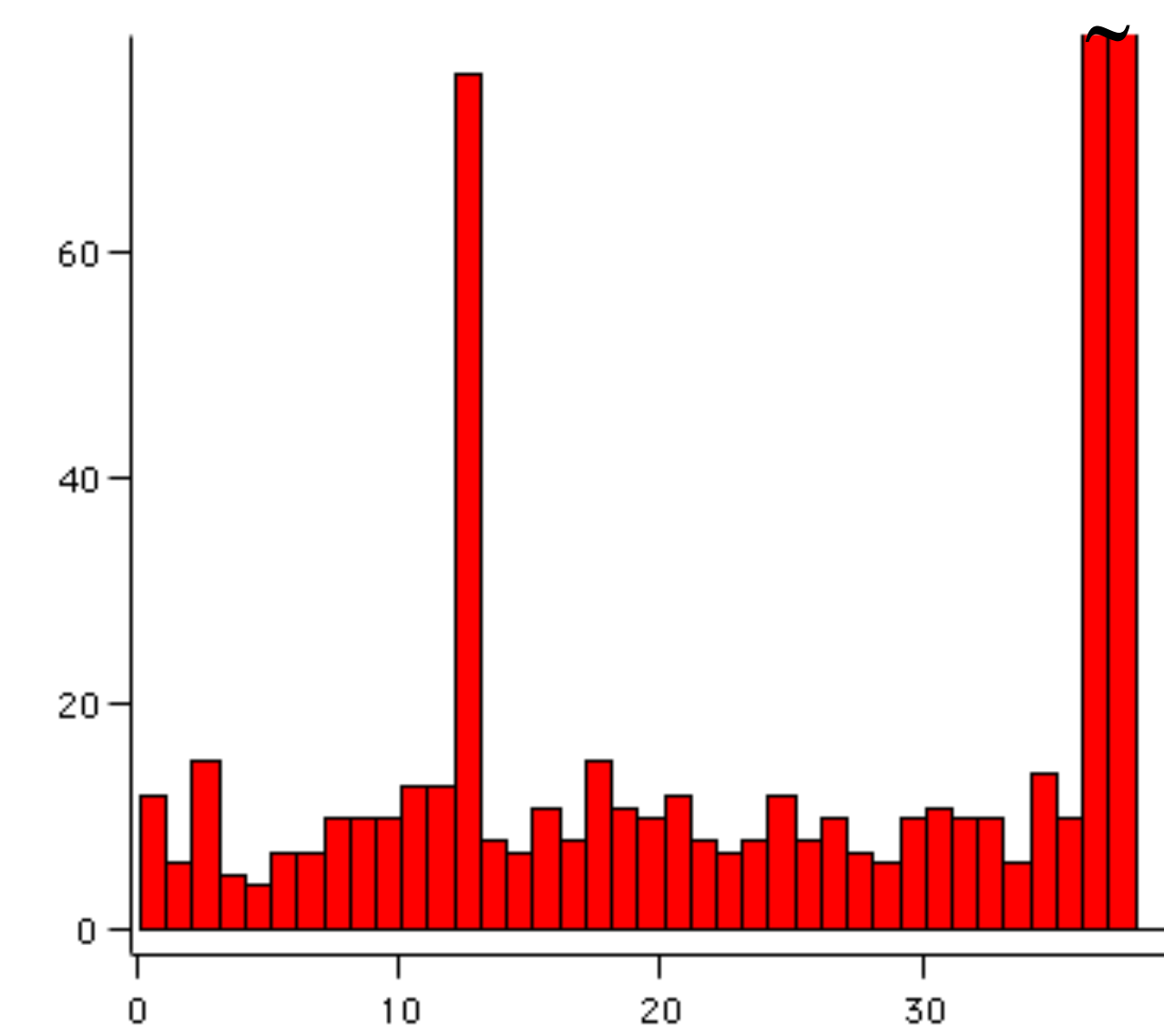
Calibration pixel

12 x 14 mm Astro–H/SXS chip
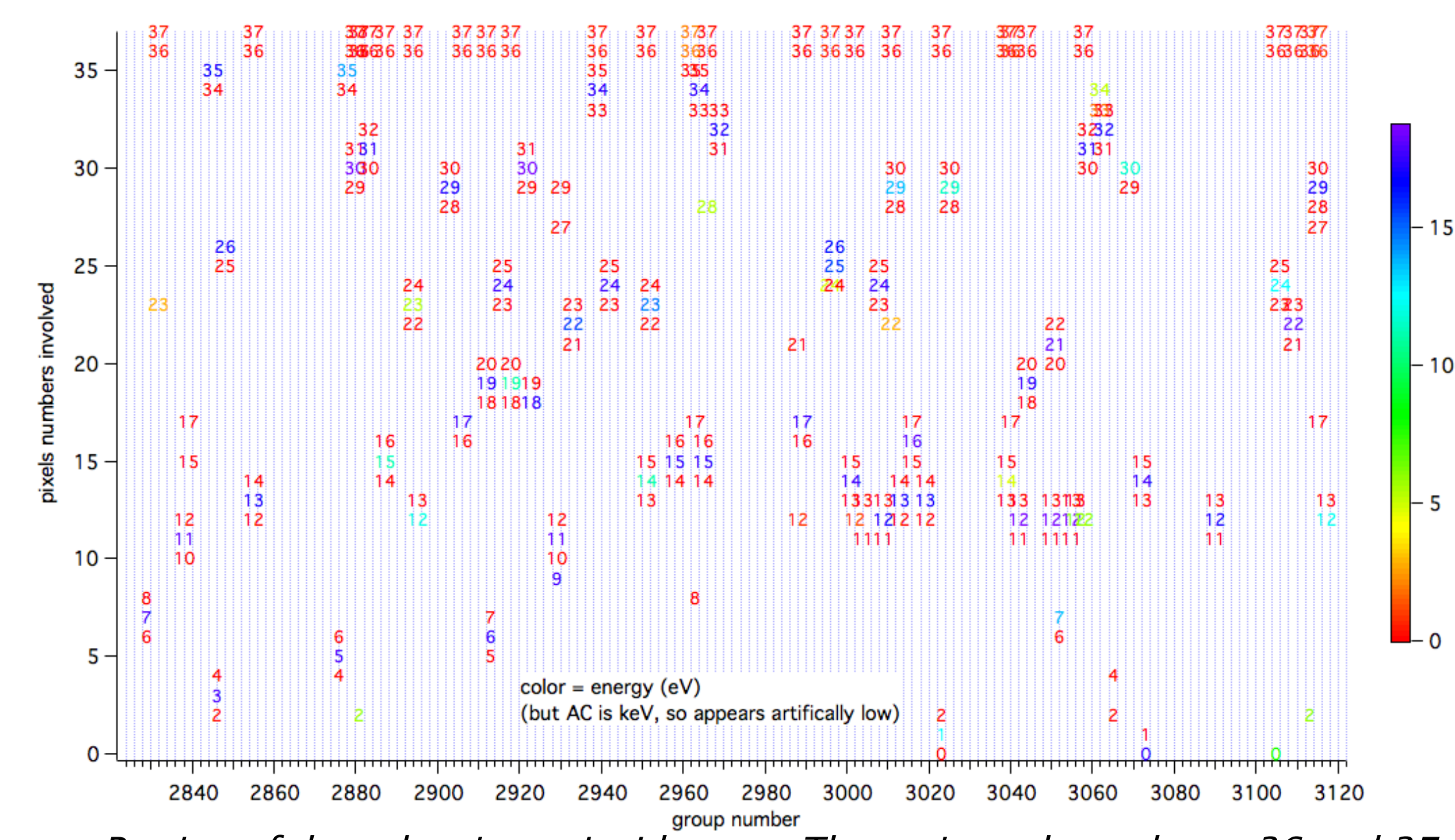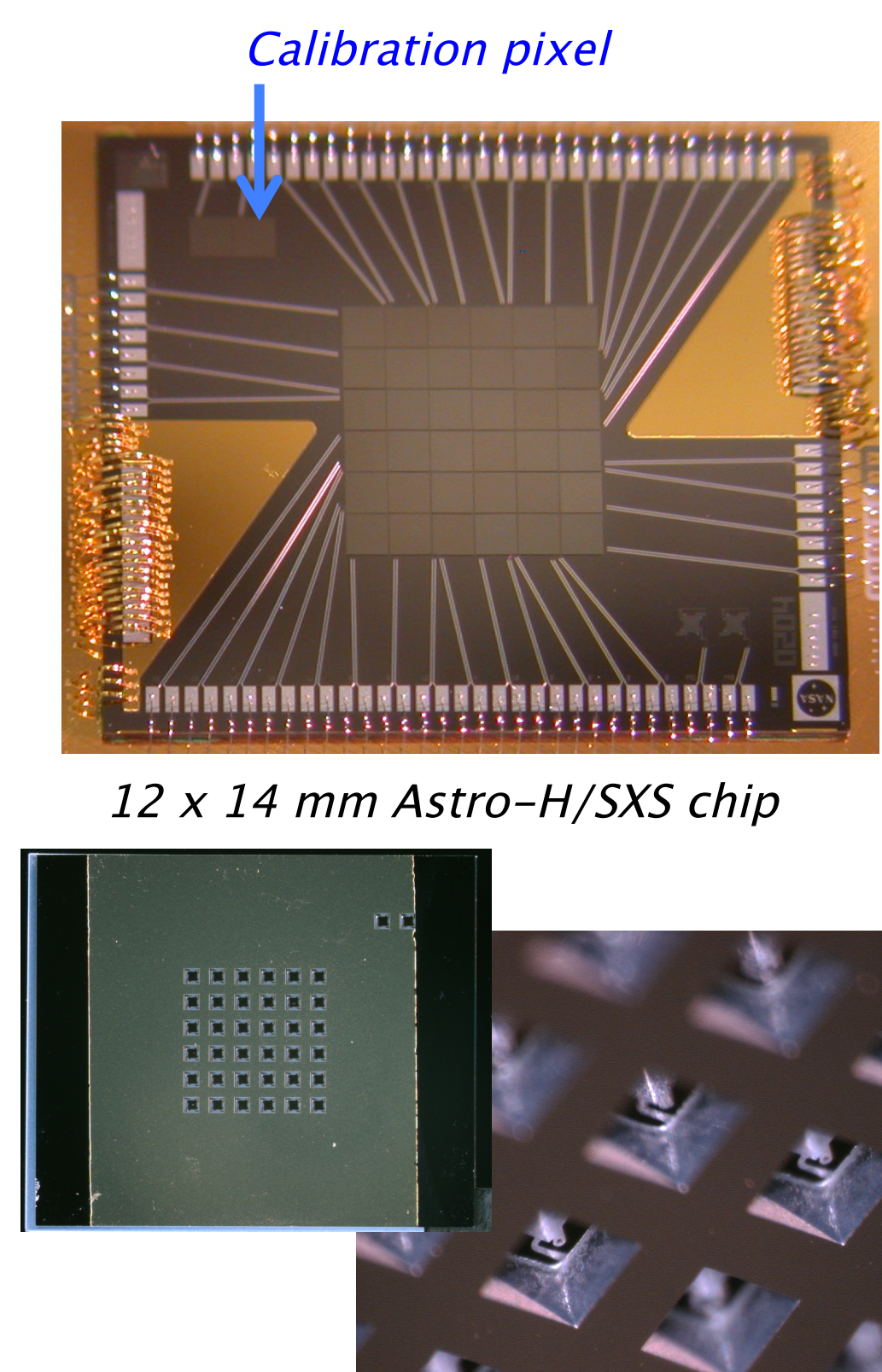
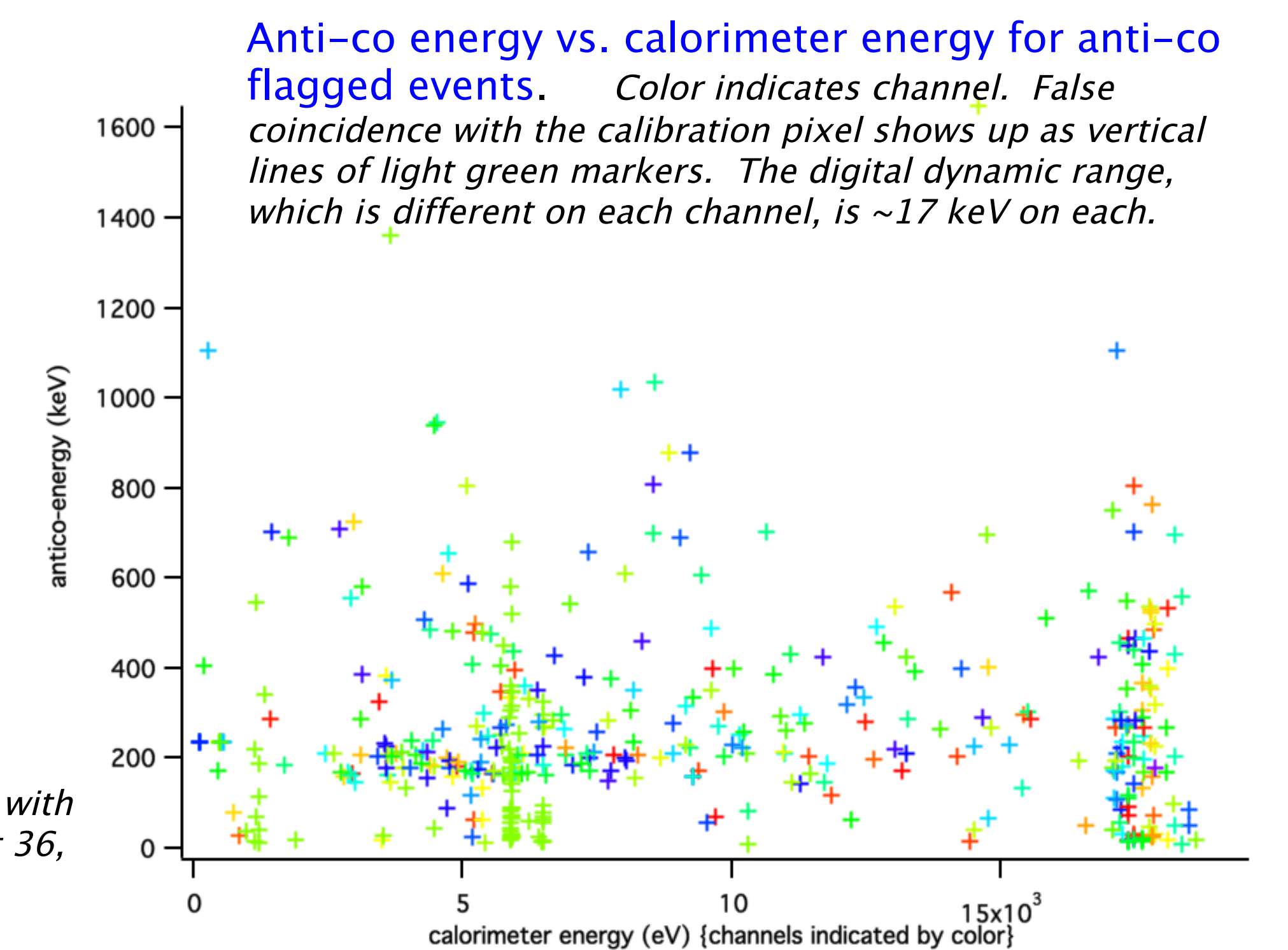*Portion of data showing coincidences. The anti-co channels are 36 and 37.*

ANTI–COINCIDENCE DETECTOR STATISTICS

The rate of events on the 1-cm² anti-co was 6 counts/minute, thus it was dominated by environmental radiation and not minimum-ionizing muons. The rate of events on the calorimeter array in coincidence with the anti-co was 2/min/cm². (Electrical crosstalk events are not included in this sum.)

The anti-coincidence detector is made of silicon and is 0.5 mm thick. A minimum ionizing particle will deposit ~ 200 kev going through 0.5 mm of Si. Indeed, most of the anti-co events are clustered near 200 keV. The lack of strong correlation with the calorimeter signals is unexpected, since track length in both the anti-co and the pixel absorber was expected to scale with incident angle, but more careful modeling is needed.

Anti-co energy vs. calorimeter energy for anti-co flagged events. Color indicates channel. False coincidence with the calibration pixel shows up as vertical lines of light green markers. The digital dynamic range, which is different on each channel, is ~17 keV on each.

Number of events on each channel in coincidence with an anti-co event. The two anti-co channels are at 36, 37, and their data are cut off. Channel 12, the calibration pixel, is illuminated by an internal collimated source; it exhibits false coincidence.
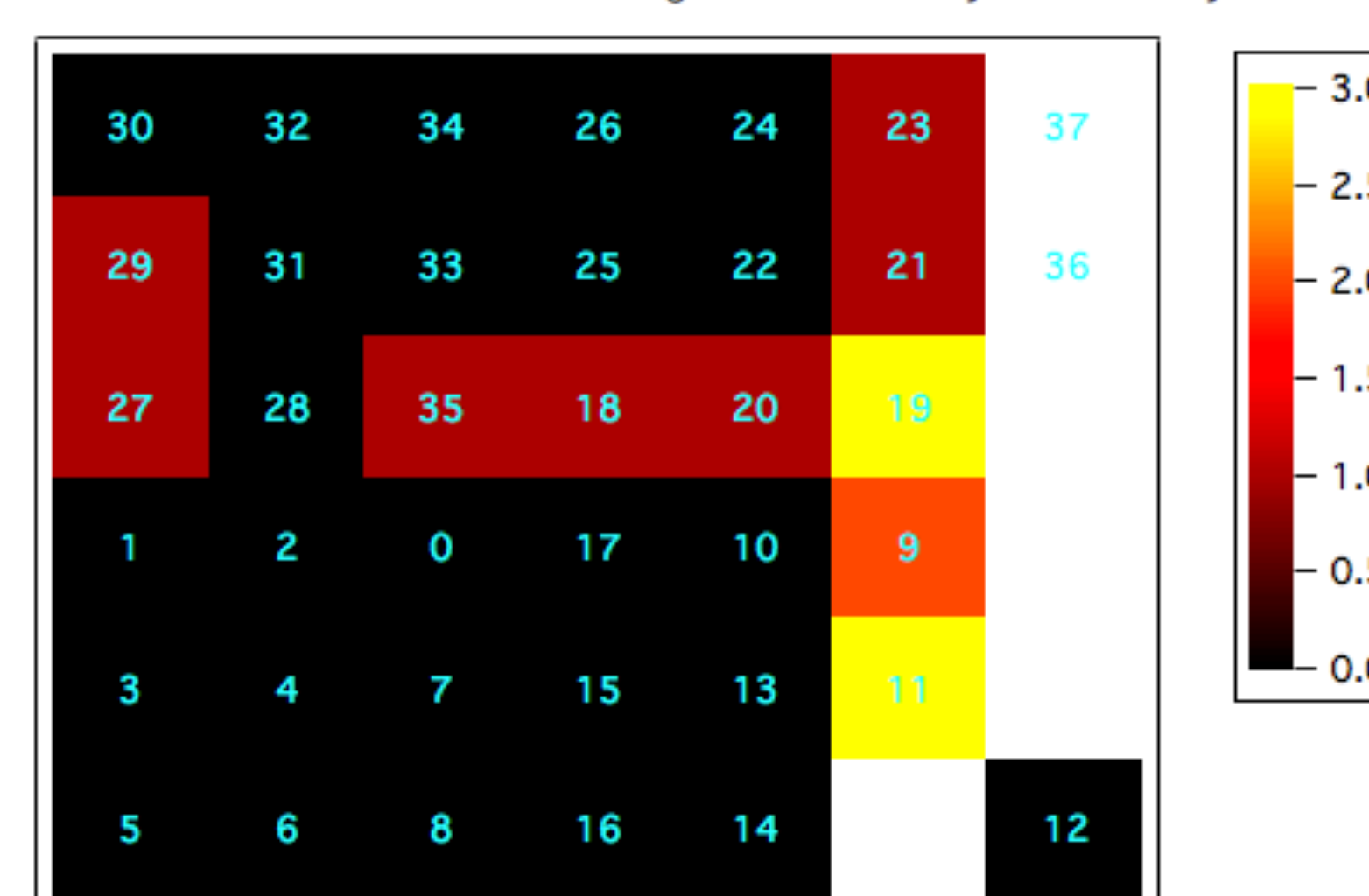
RESIDUAL BACKGROUND

Data above 100 eV were analyzed for correlation (1.5 ms), without any other exclusions. The calibration pixel was included. The remaining isolated events were then screened as follows:
- E < 12 keV (or 15 keV)
- 0.8 ms < risetime < 1.2 ms
- The calibration pixel (12) and the anti-co channels were removed.

A total of 146 from 0.1 – 12keV, 176 events if upper limit is instead 15 keV, remained. (Rate to 12 keV is thus 3.4 x 10⁻³/s). Mn K and Au L lines are clear in the full-array data. The Mn Ka events were detected primarily in pixels near the calibration source. No lines had been observed in the XRS background. The overall rate is about a factor of 2 higher than the XRS ground background, but the environment was not the same as for those measurements.

Next, background data taken after integration on the spacecraft and on the detector system alone before delivery will be analyzed. Only after the impact of environmental radiation is determined can the results be extrapolated to the in-orbit performance.

distribution of background MnKa x-rays on the array

residual background in 15-01-03.11.00.12
1.5 ms coincidence tolerance
risetime 0.8 - 1.2 ms
(all >0.1 keV used in coincidence screening)

scattered cal-source photons?

Au L x-rays