XRISM/Resolve data (a whirlwind tour)

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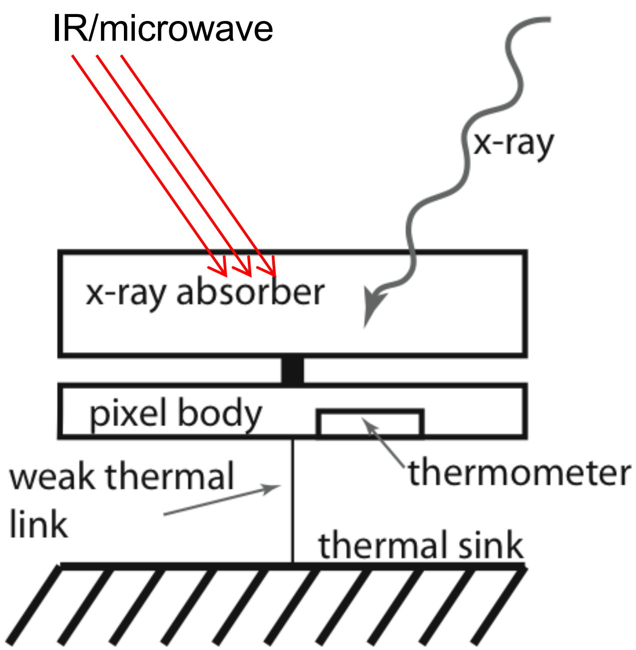
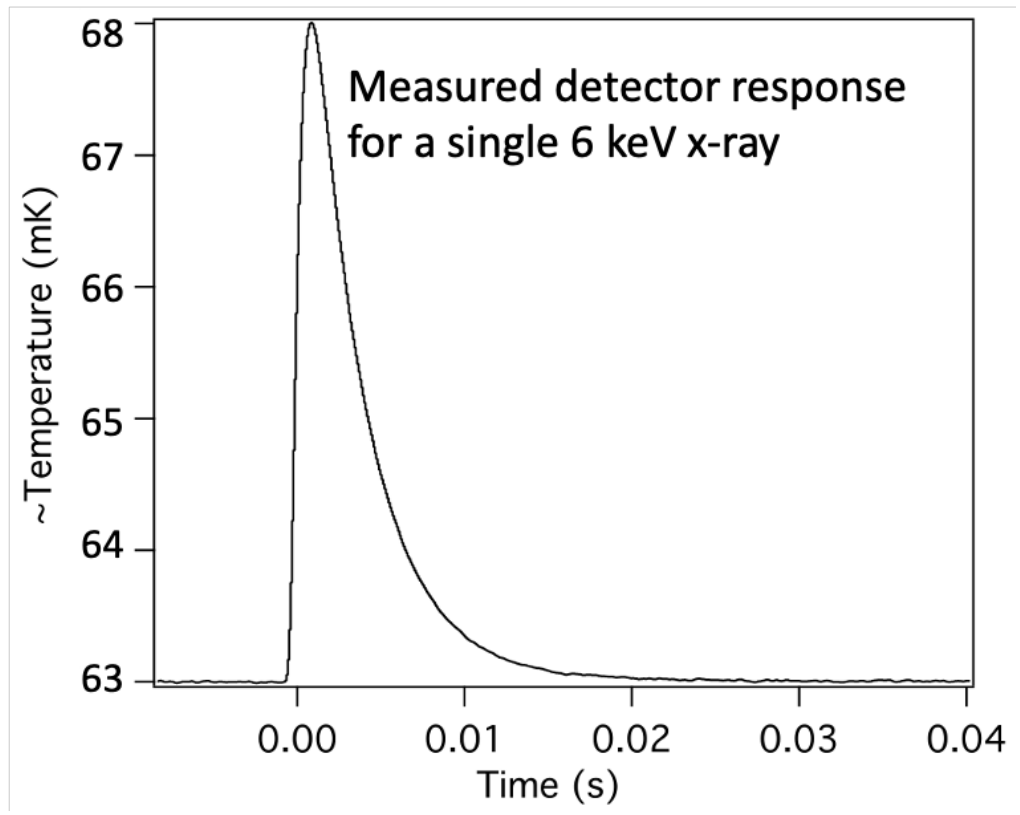
An x-ray calorimeter is a thermal measurement of the photon energy



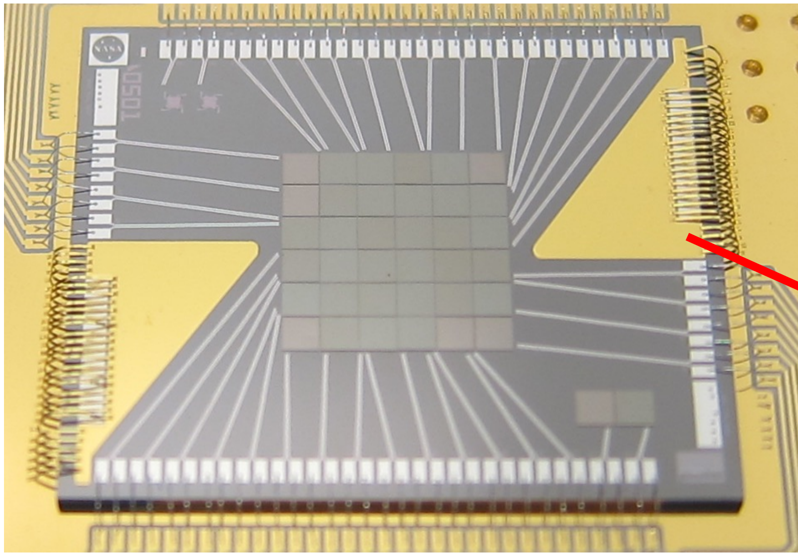
- High resolution ***non-dispersive*** spectrometer
- linear detectors: large bandpass
- Must operate at **low temperatures** for high resolution

$$E_{photon} = \int C(T)\, dT \approx C \cdot \Delta T$$

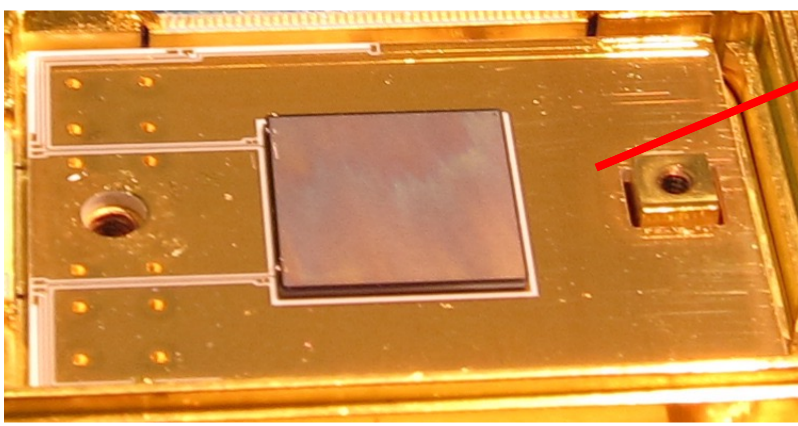


Resolve detector system

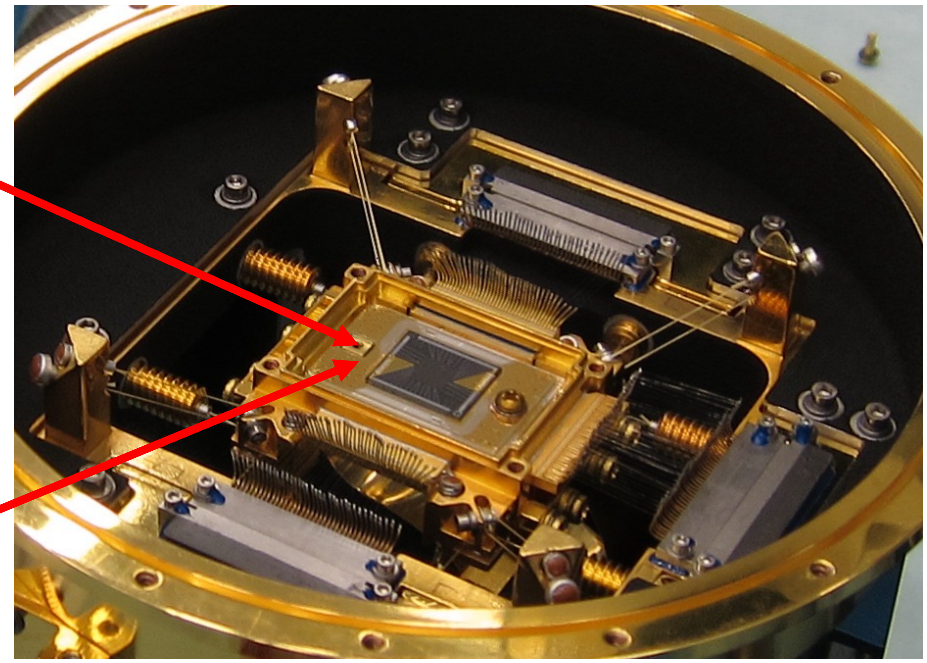
Detector Array



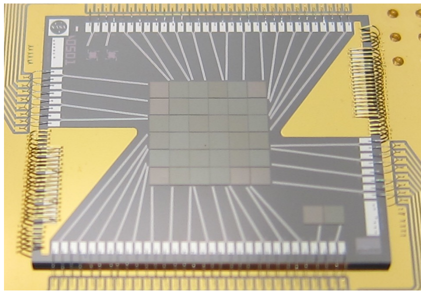
Anti-coincidence detector



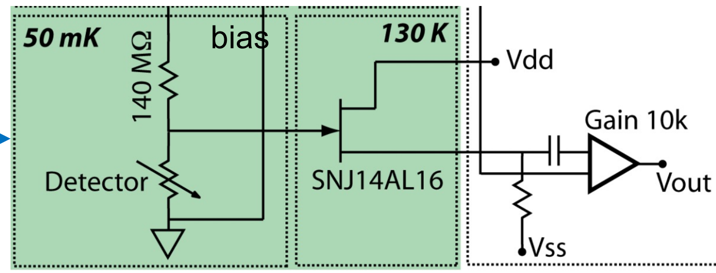
Focal Plane Assembly

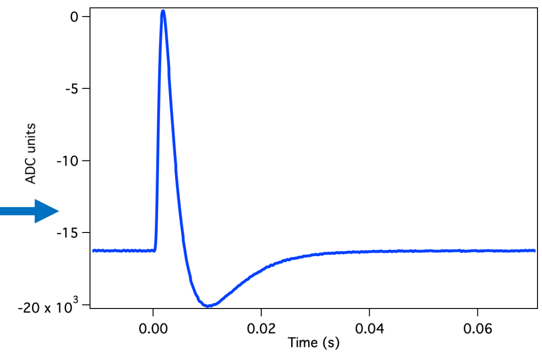


X-ray signal path

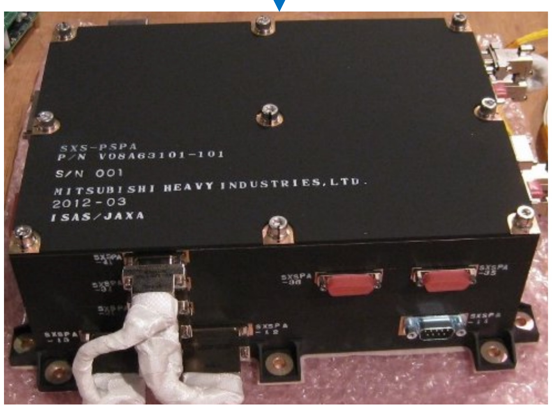


XBOX





8 Mb/s



Pulse Shape Processor

Event list:

- **PH (det units)**
- **Event time**
- **Risetime**
- **Grading**
- **Pile-up**
- **etc**

20 kb/s

Ground station

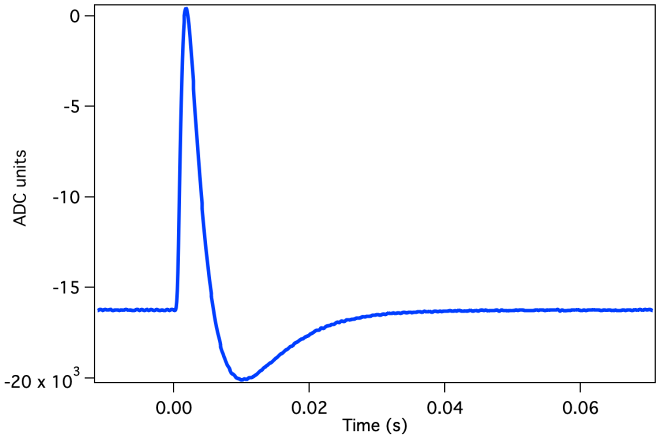
Pre-pipeline (fff)

Quick look

Pipeline

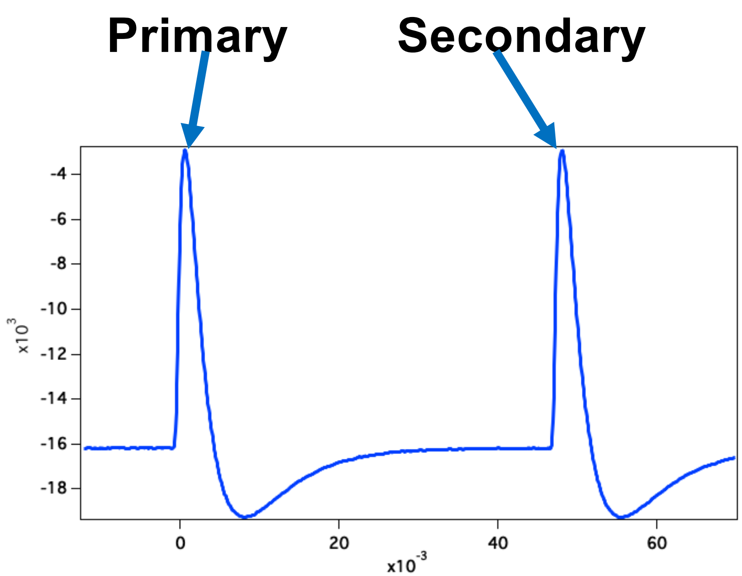
Observer data

Pulse height processing and event grading



Want to measure x-ray energy

- **Use all available information**
  - **Optimal estimator**
    - **Signal/noise in all freq bins**
- **What do you do with pile-up?**



Two kinds of pileup

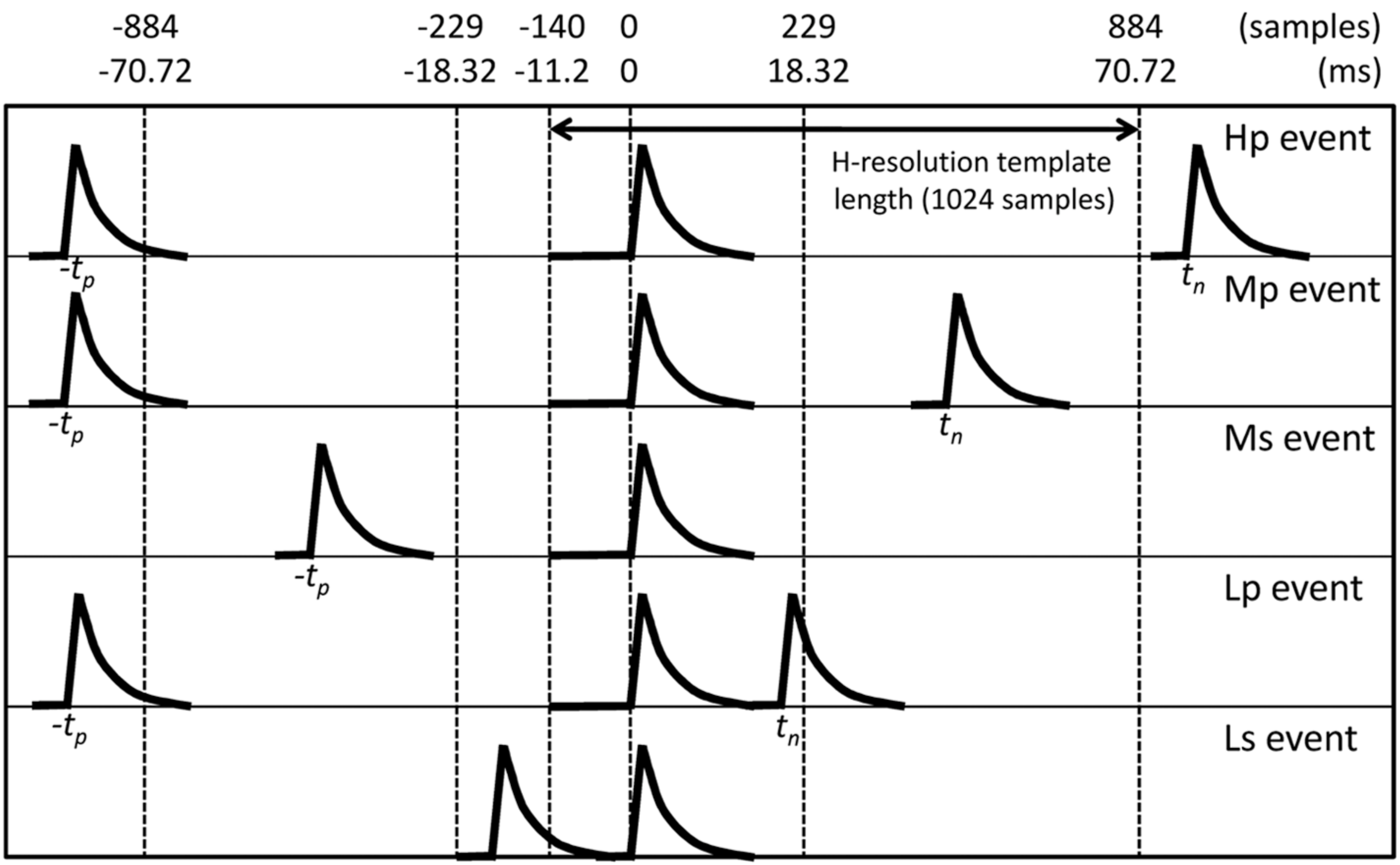
- **Only effects the pulse processing**
- **Effects the pulse thermally**

Event grades:

- **High Resolution → full record**
- **Mid Resolution → ¼ record**
- **Low Resolution → Simple PH**
- **Secondaries (only mid and low)**

Event grades

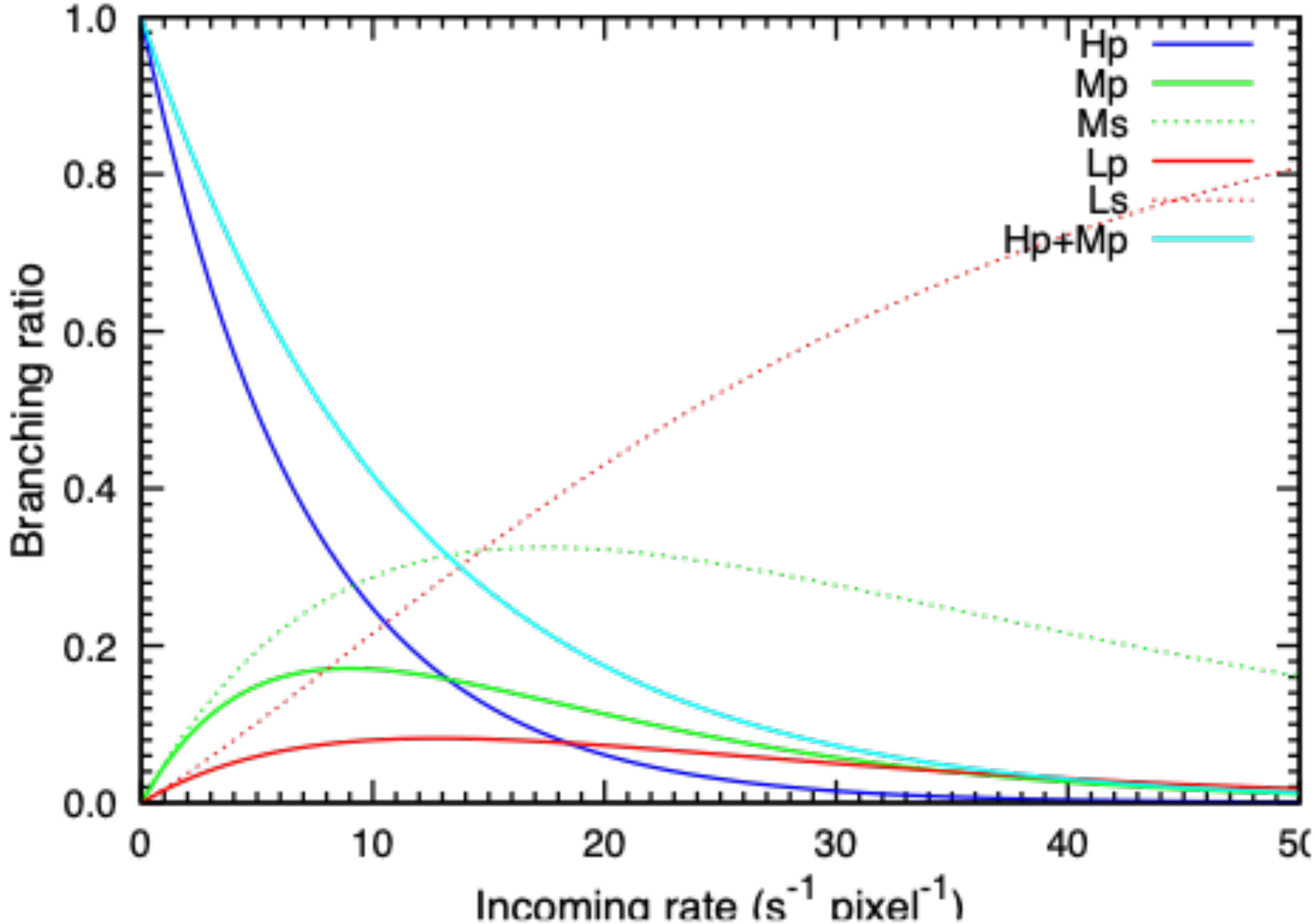
Full event grading matrix for Resolve



Ishisaki et al. (2018)

Branching ratio

Note: Most celestial sources are < 1 cps/pixel
i.e. Almost entirely hires

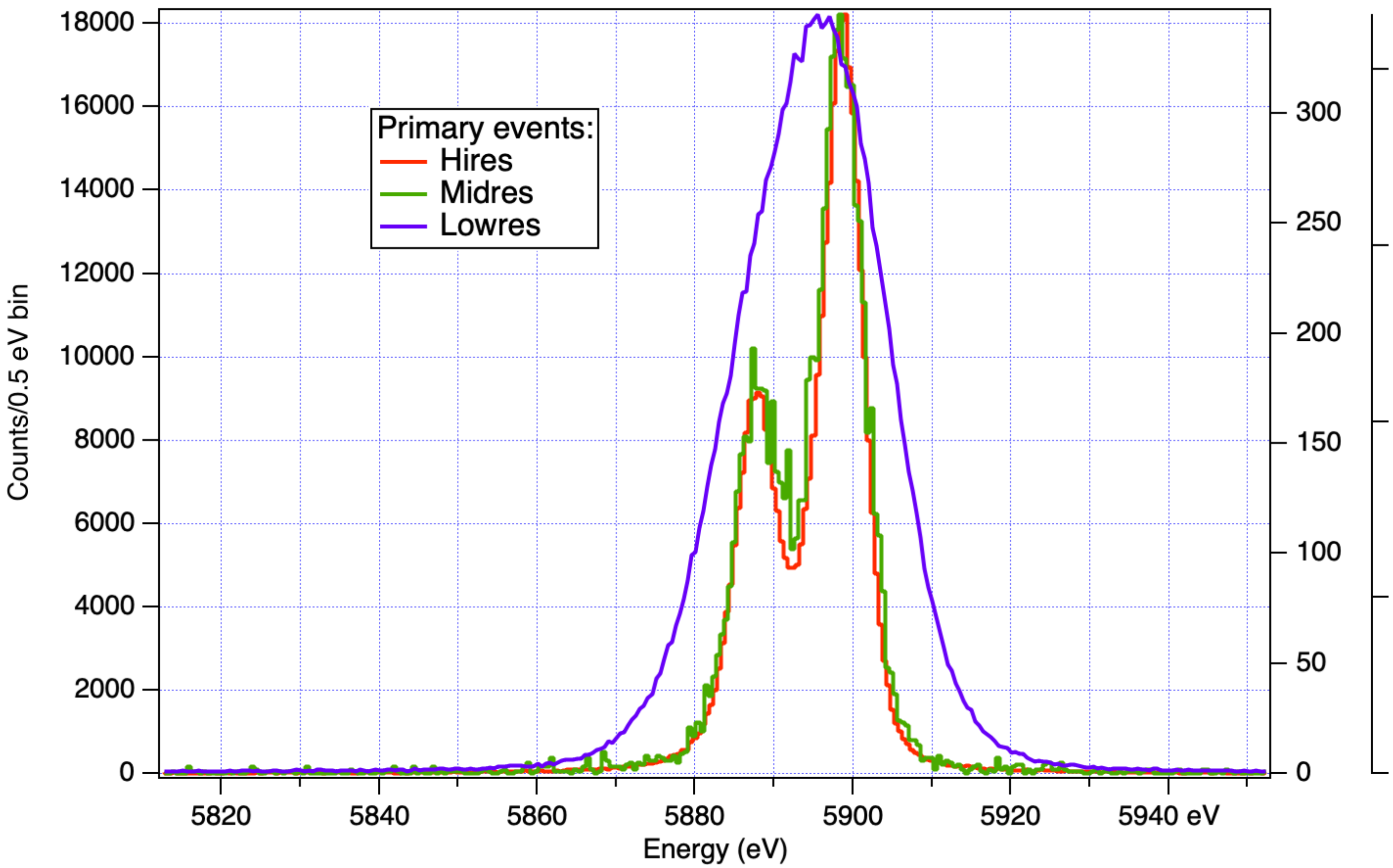


Performance for different grades

XRISM
Resolve - High Resolution Soft X-Ray Spectrometer

- **Both Hp and Mp must meet energy resolution requirement of 7eV**
- **Low res and secondaries are degraded**

Example from in-flight data:



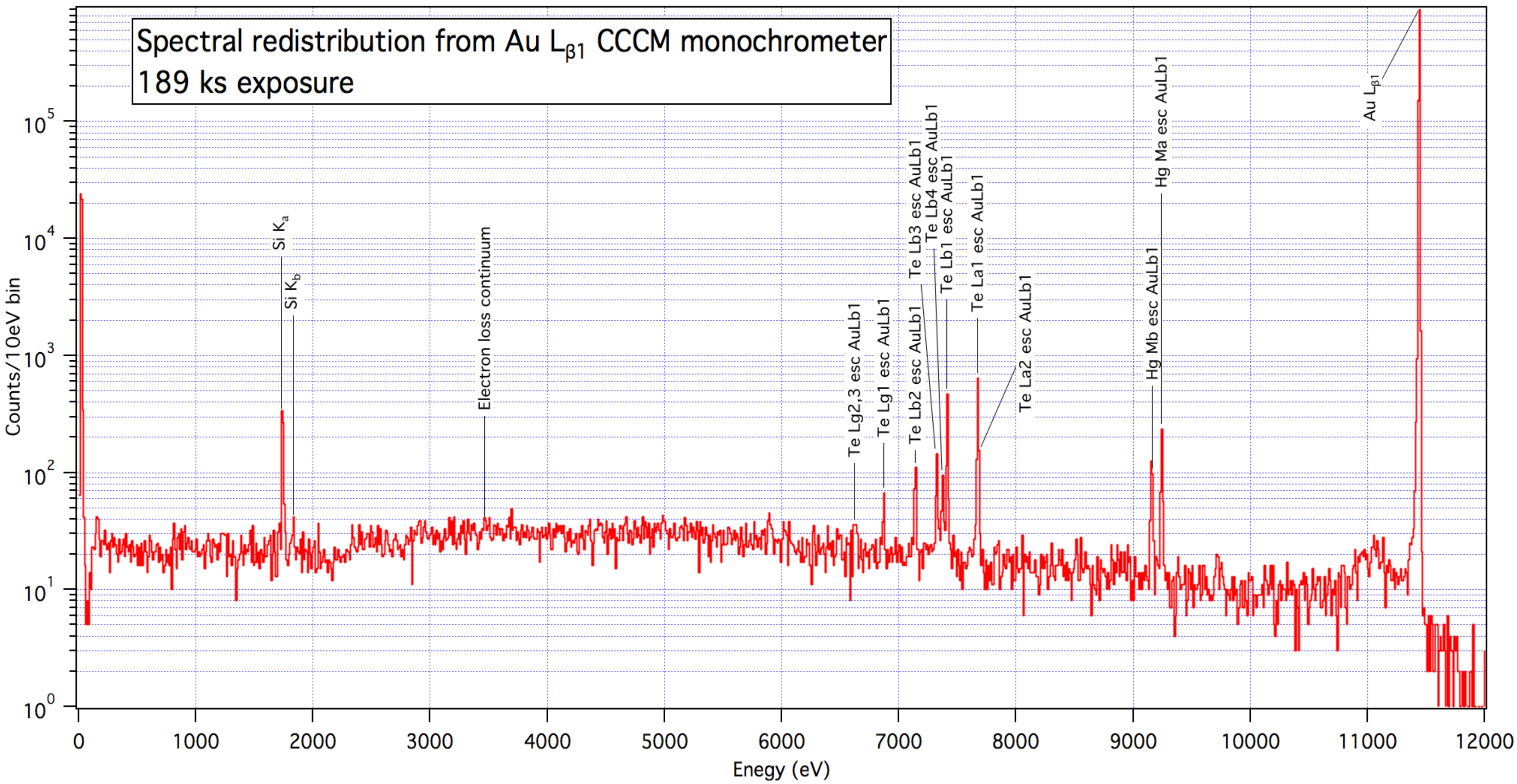
At 6 keV:
Hires: 4.5 eV
Midres: 4.8 eV
Lowres: 15.8 eV

Calibration

- Put physical units on instrument data
- Parameterize model of the instrument response
- Correct instrument non-linearities
- Examples:
  - Line spread function and redistribution (inputs to rmf)
  - Spectrometer Energy Scale and reconstruction
  - Throughput (i.e. effective area)

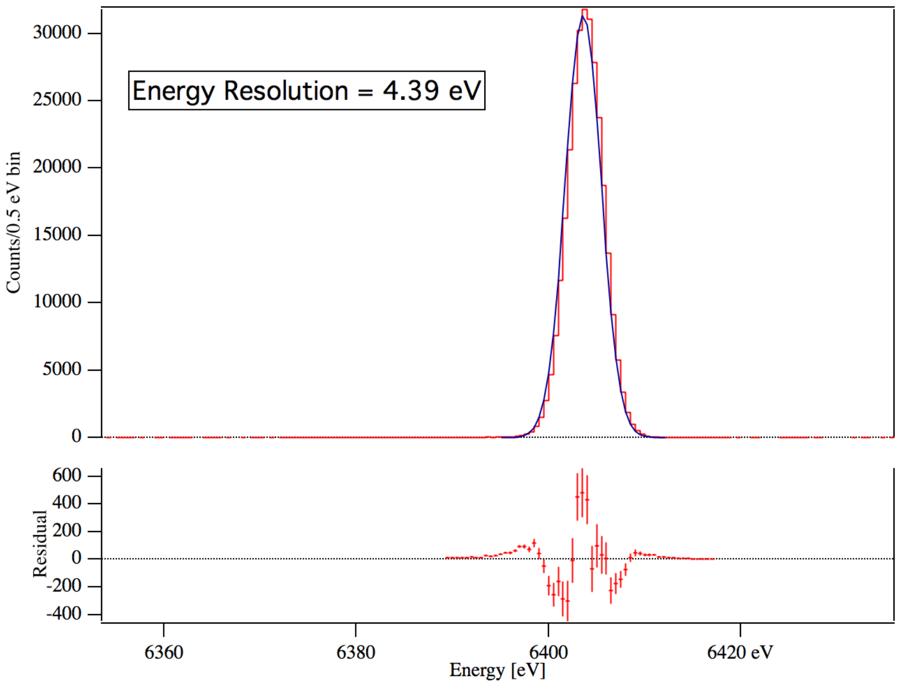
Spectral redistribution

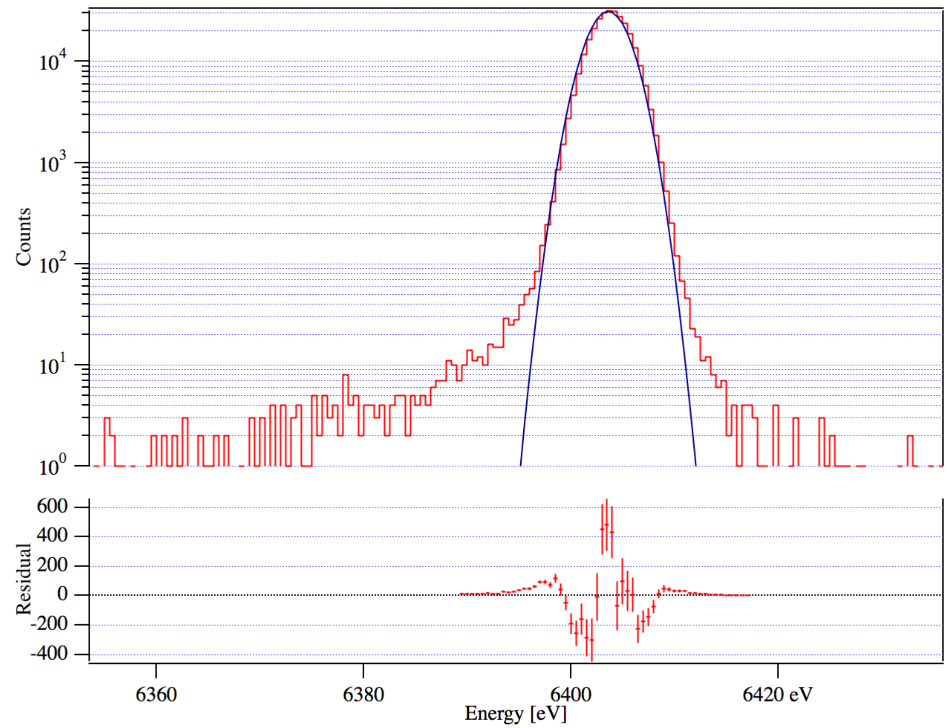
- Core line shape: dominated by detector intrinsic noise and system noise
- Broadband redistribution: dominated by detector material properties.
- To measure: Monochrometers, modeled fluorescent lines, EBIT measurements
- Different RMFs containing different amounts of this detail



Core line shape

Deviates from a gaussian instrumental function at the 1% level

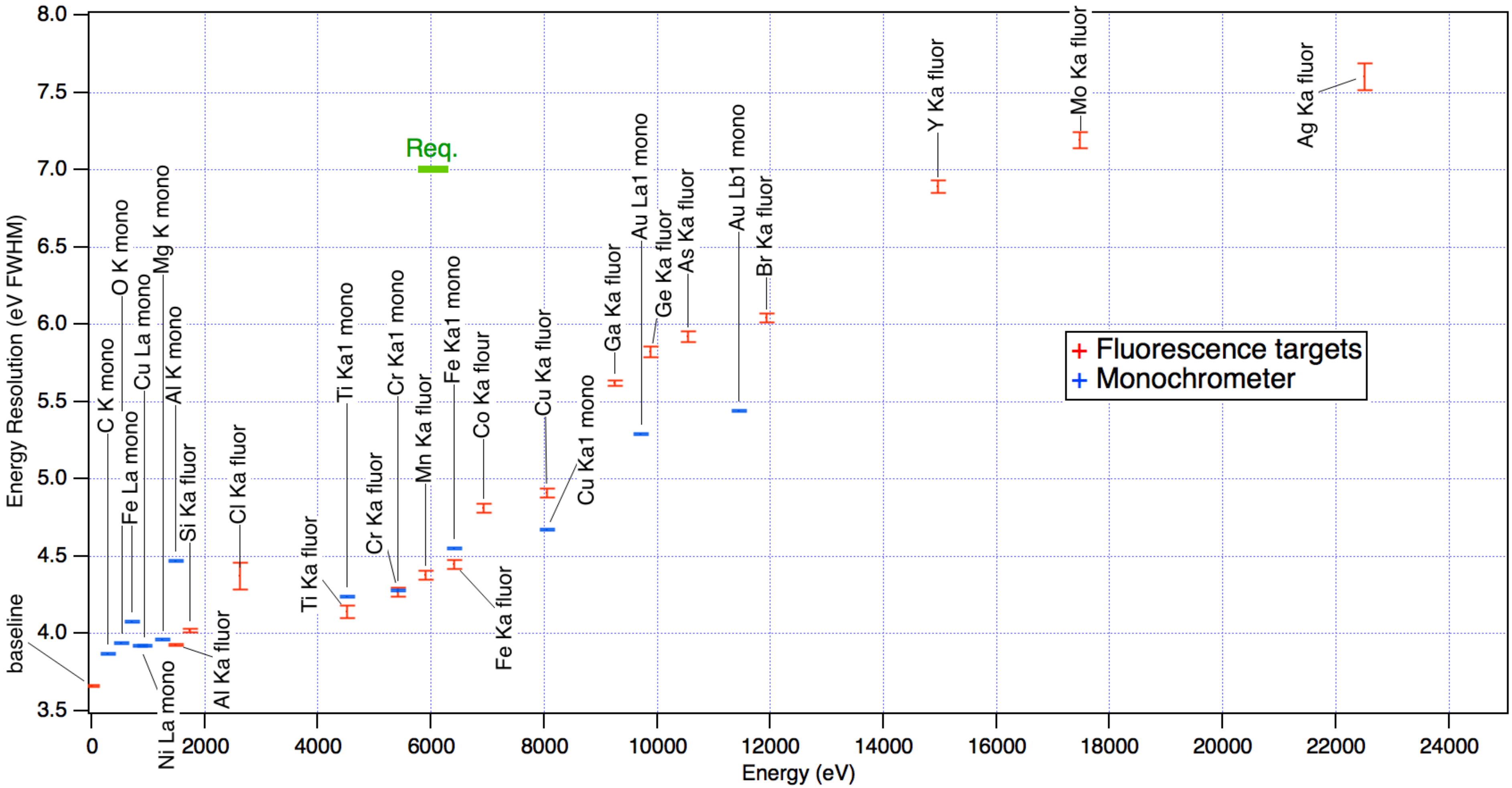




Core line shape across the band pass

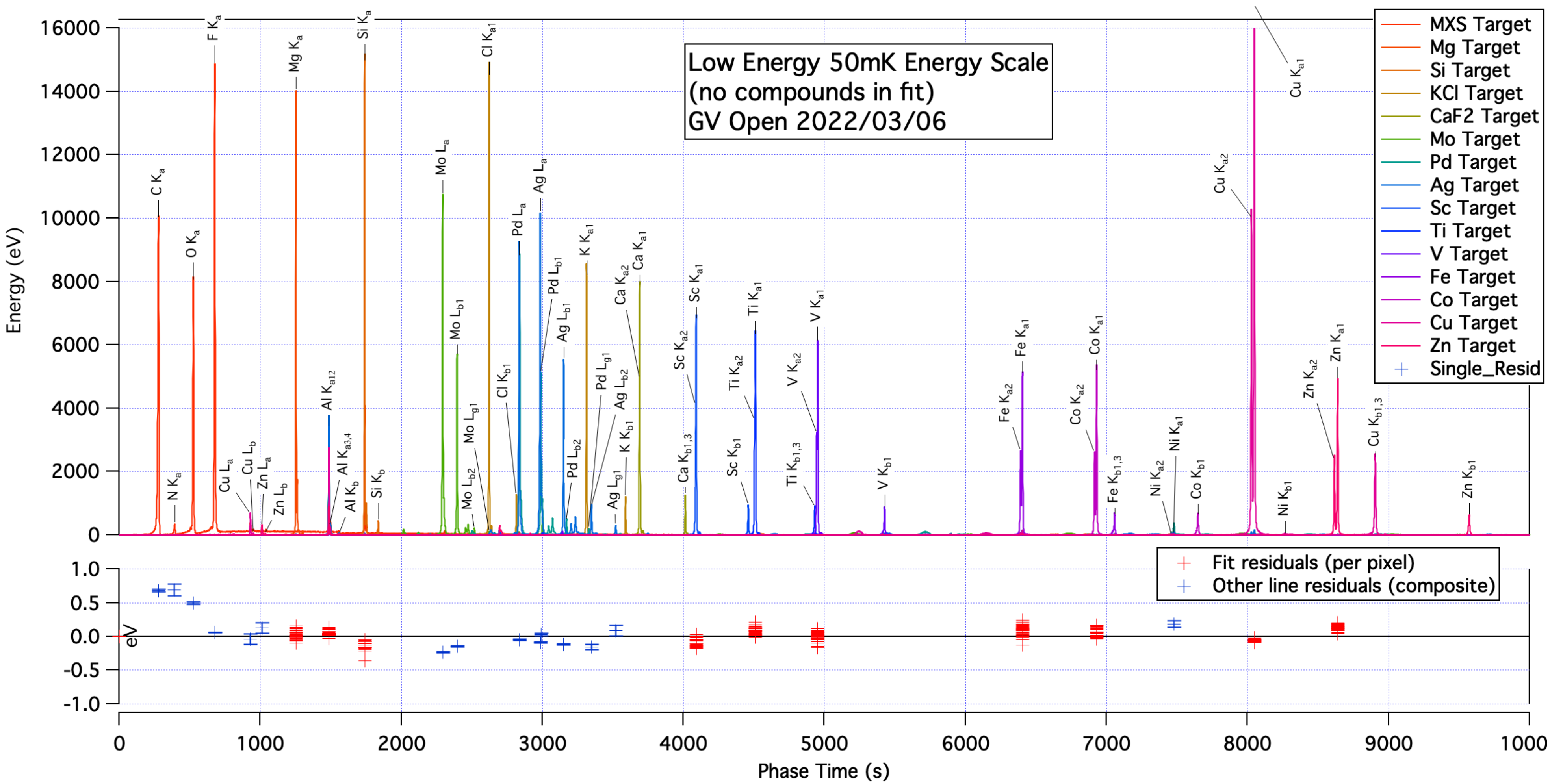
XRISM Resolve - High Resolution Soft X-Ray Spectrometer

- Energy resolution scales with Energy
- Some systematic differences between monochrometer and fluorescent measurements: incomplete line shape knowledge



Energy Scale measurement

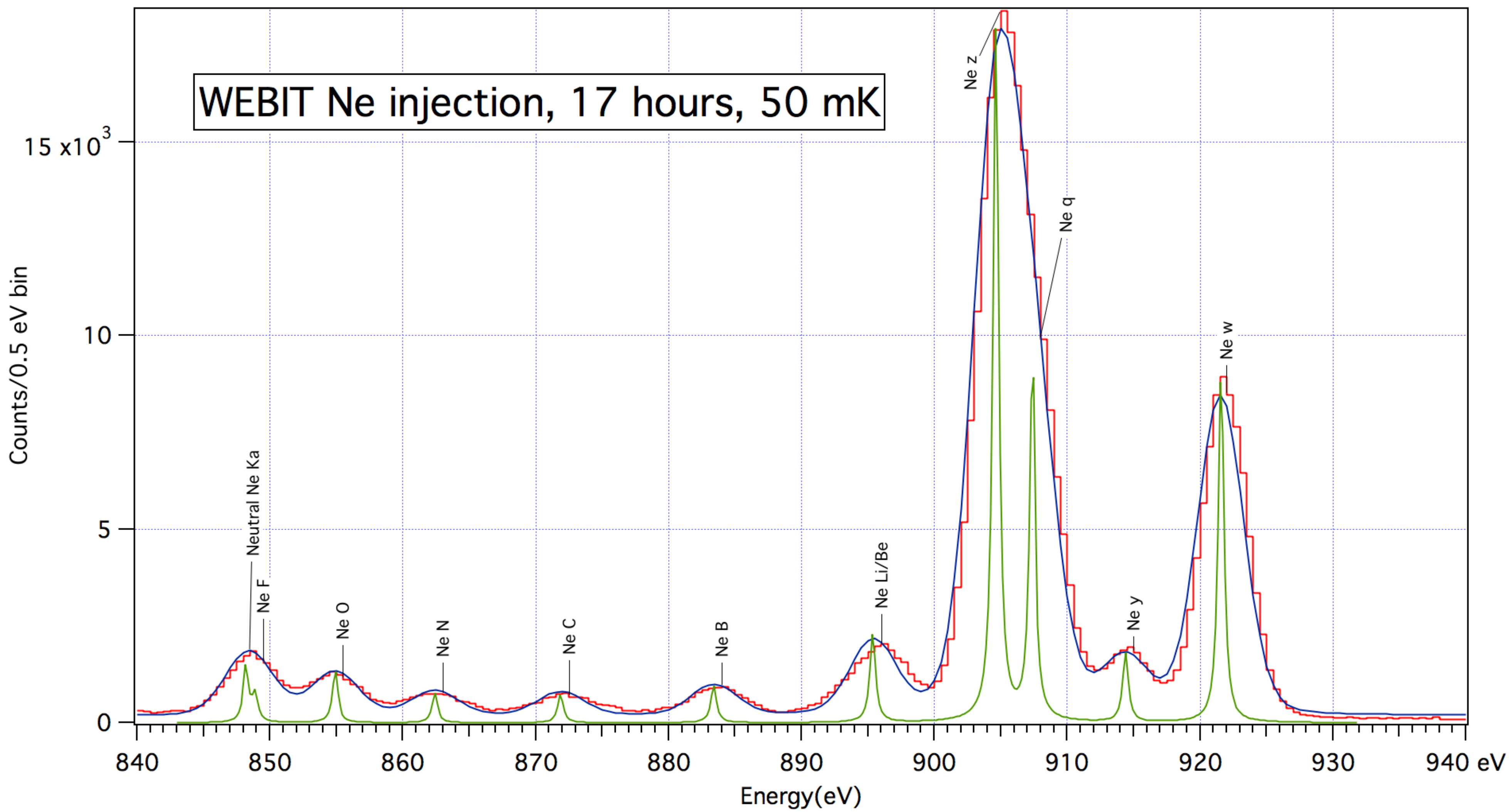
- **One of 3 sets of measurements to span bandpass**
- **Precision dominated by fluorescent line models**



Low energy measurements with EBIT

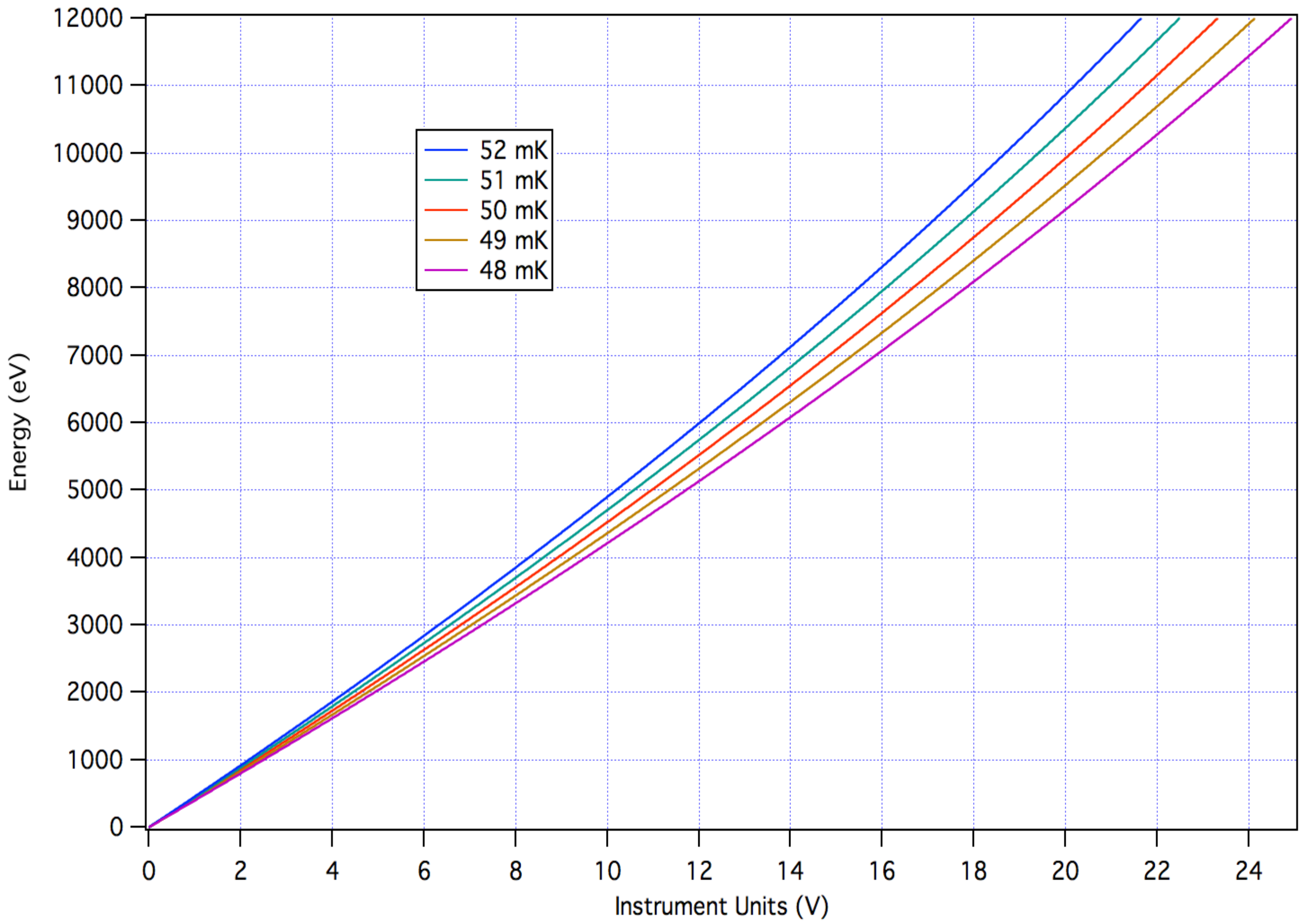
EBIT results for Neon

Energy scale error = +0.41 eV, Energy resolution = 3.83 eV (composite 35 pixels)



Energy scales (cont'd)

- **Energy Scale is non-linear and varies with temperature**
- **Need to reconstruct vs time on-orbit using a fiducial**

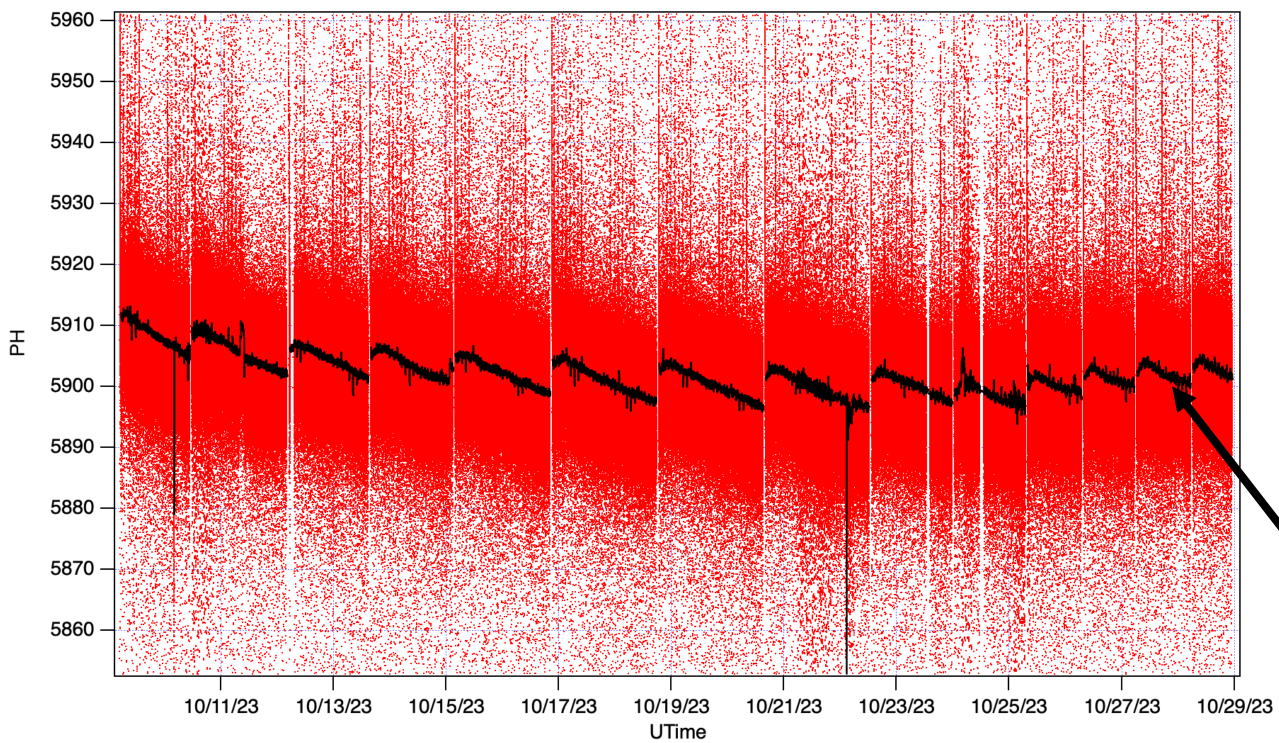


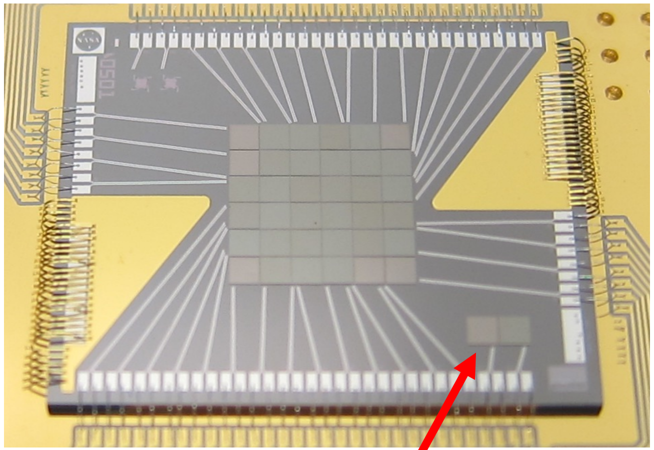
Energy scale reconstruction

XRISM has three fiducials to track detector gain vs time:

- **Calibration pixel with internal 55-Fe source (5.9 keV), always on**
- **Modulated x-ray source: flood source for all pixels, but well defined time**
- **55-Fe source on the filter wheel which can be rotated into the FOV**

XRISM on orbit





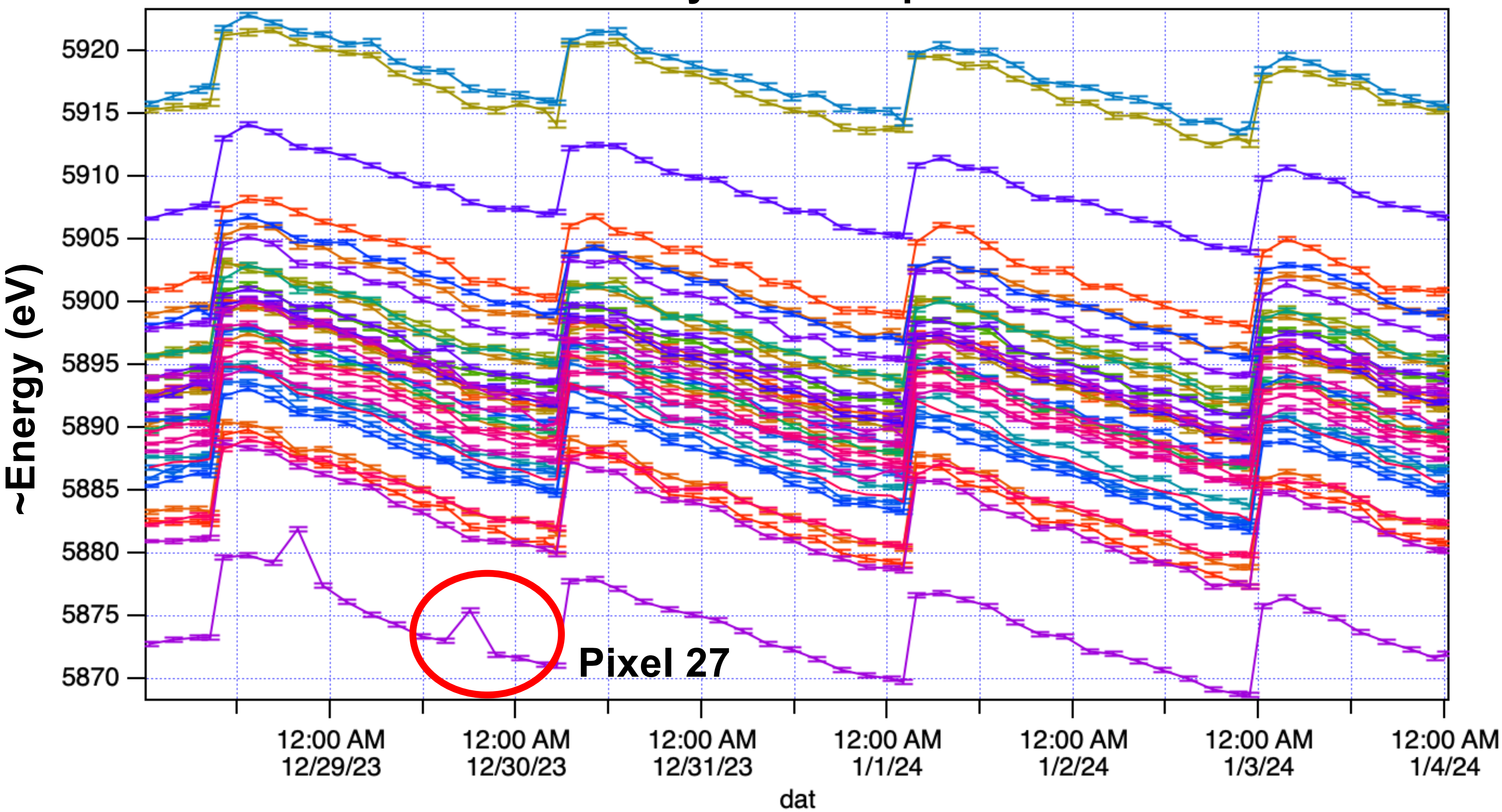
Cal pixel

Gain tracking function

During Gate valve closed observations → FW 55-Fe

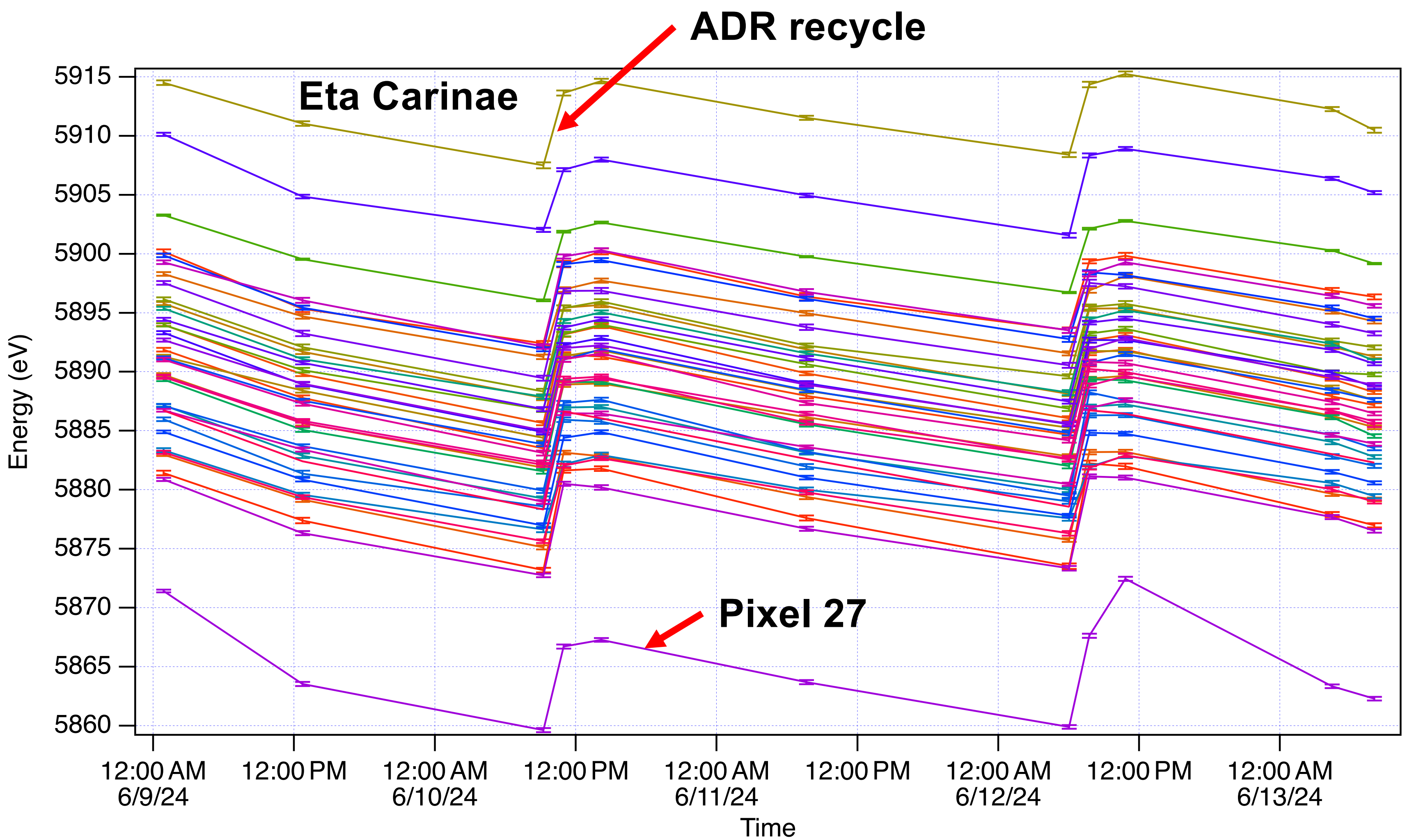
With the Gate Valve closed, each modulated x-ray source only illuminates ½ the array → gain tracking using the FW 55-Fe source during eclipse

Gain tracking during 7 day trial observation of the Centaurus Cluster
FW rotated to fiducials every earth eclipse for ~30 minutes



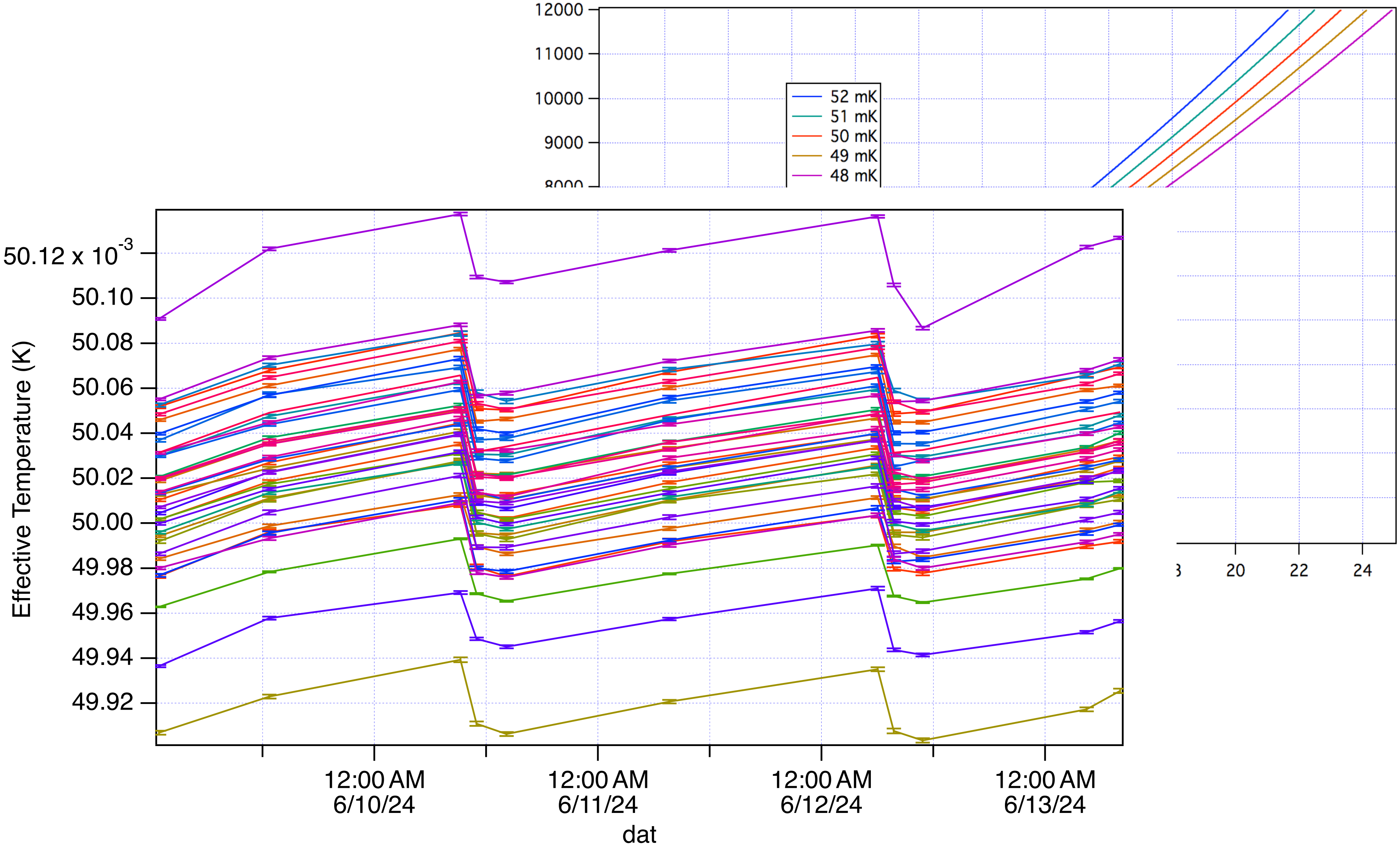
Optimized fiducials

- **Sufficient to reconstruct the gain**
- **Minimizes filter wheel motion**



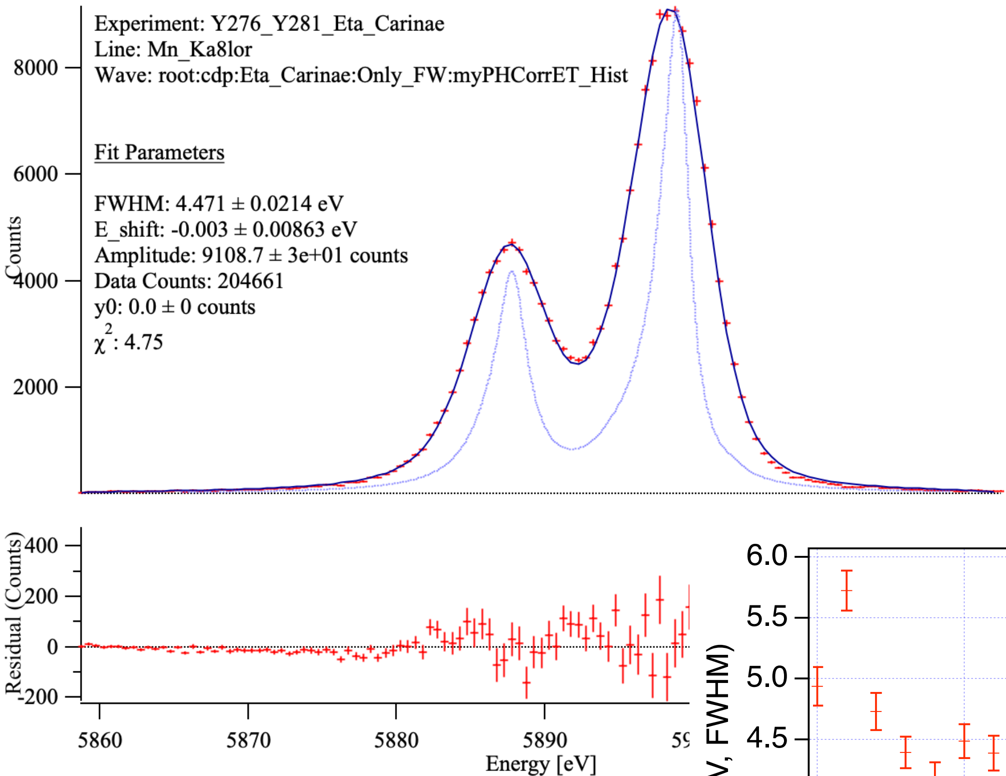
Non-linear gain reconstruction

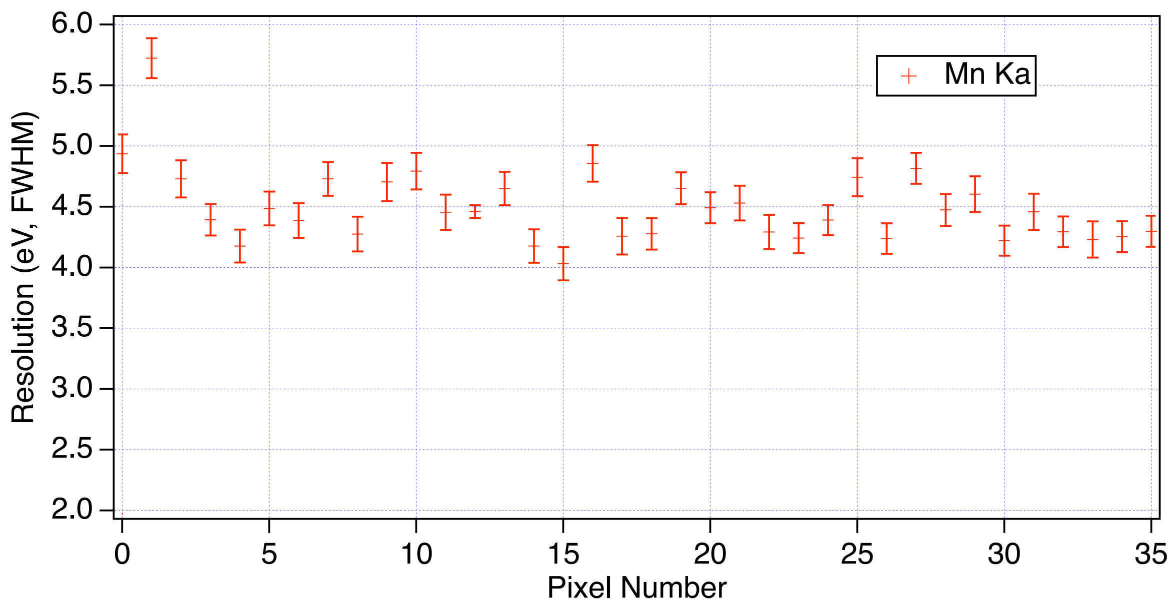
- **Assume all gain errors can be parameterized as temperature**
- **Synthesize new gain curve for each event**



Reconstructed energy scale

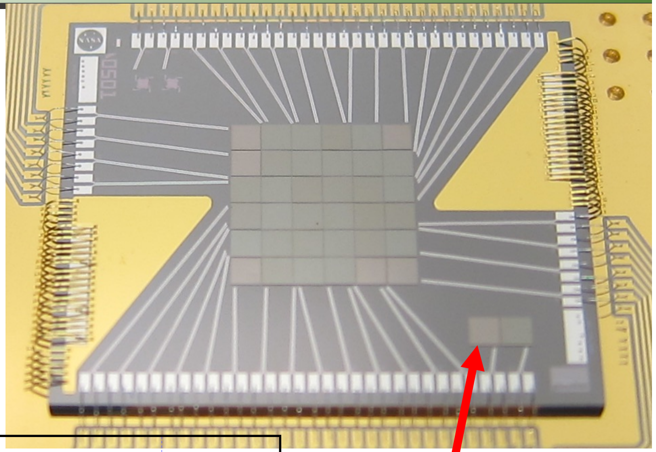
Reconstructed 55-Fe spectrum during fiducials
Composite resolution of 35 pixels: 4.47 eV. Energy scale error = 0.00 eV at 6 keV



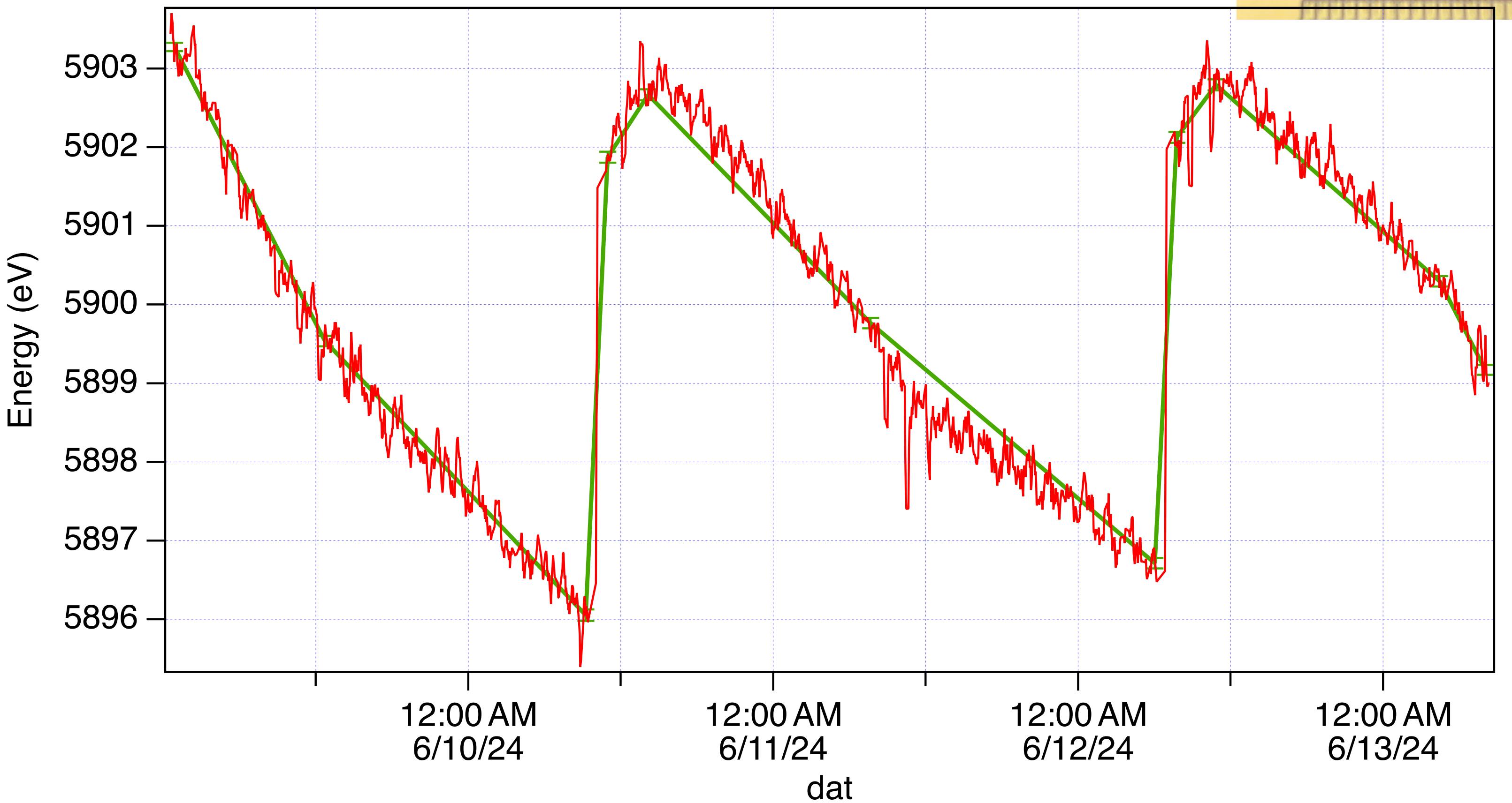


Check using calibration pixel

- **Calibration pixel is constantly illuminated**
- **Measure gain both during fiducials and in-between fiducials**



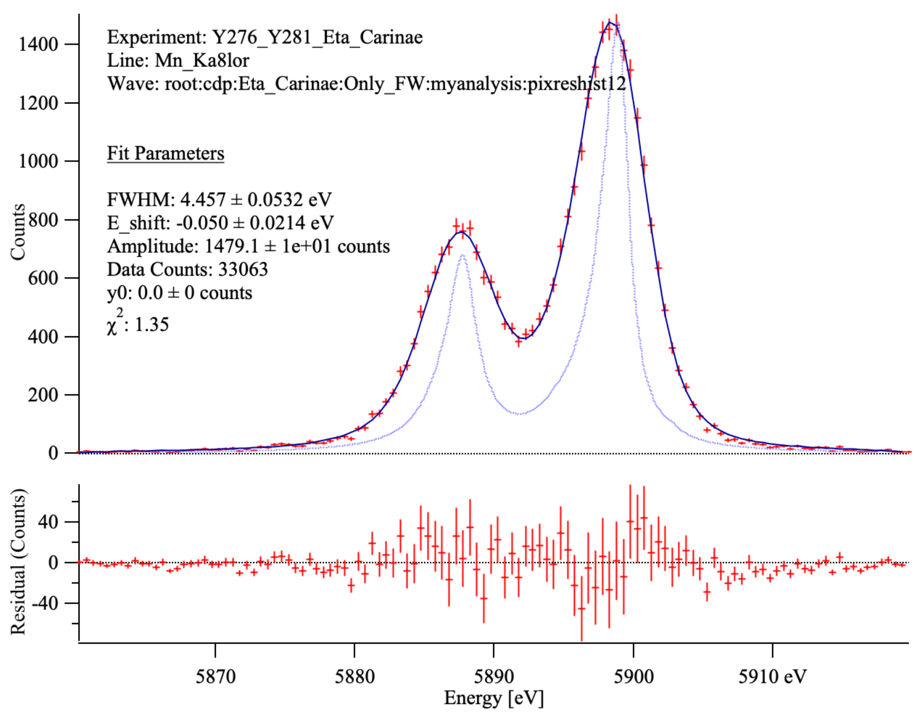
Cal pixel



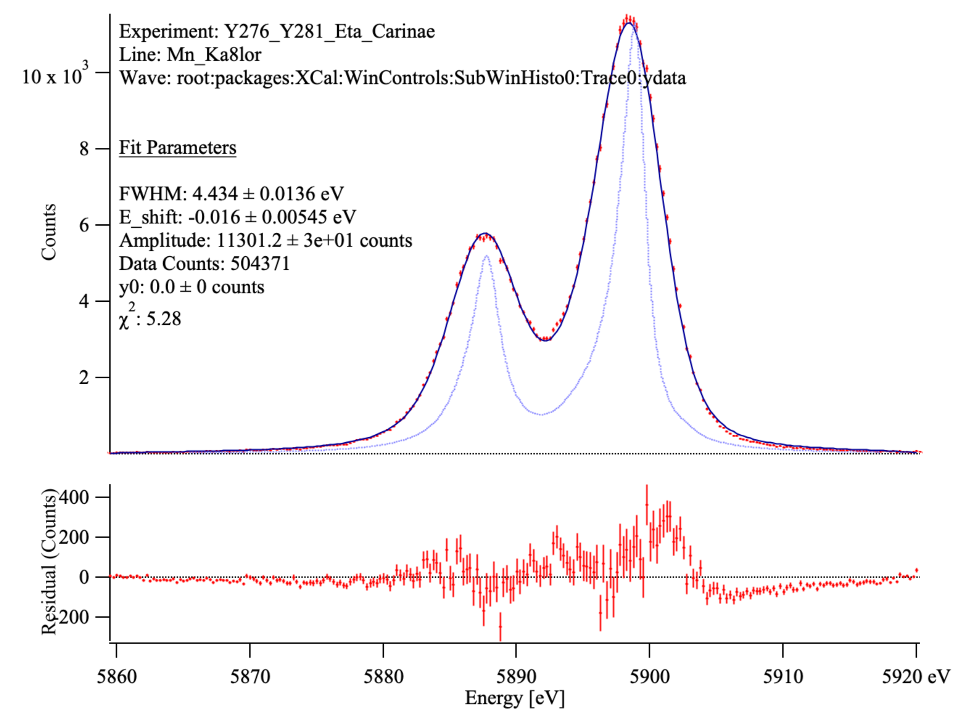
Reconstructed cal pixel gain

- **Reconstruct cal pixel gain only using same sparse sampling as main array**
- **Compare during fiducials to between fiducials**

Events from just the fiducial intervals:
Resolution = 4.46 eV, line shift: -0.05 eV



Events from observation but not the fiducial intervals:
Resolution = 4.43 eV, line shift: -0.02 eV



Gain reconstruction reports

- SDC provides energy scale (gain) reconstruction reports
  - Contains the products we just discussed
- Reviewed by the instrument team for every observation
- Will be discussed by Isabella later this morning

Gain Recovery Report, OBSID 201107010 (WR140)

Generated 12/05/2024

Date observed: 2024-11-22T20:21:02

Pre-processing version: 005_003.20Jun2024_Build8.014

Processing version: 03.00.013.010

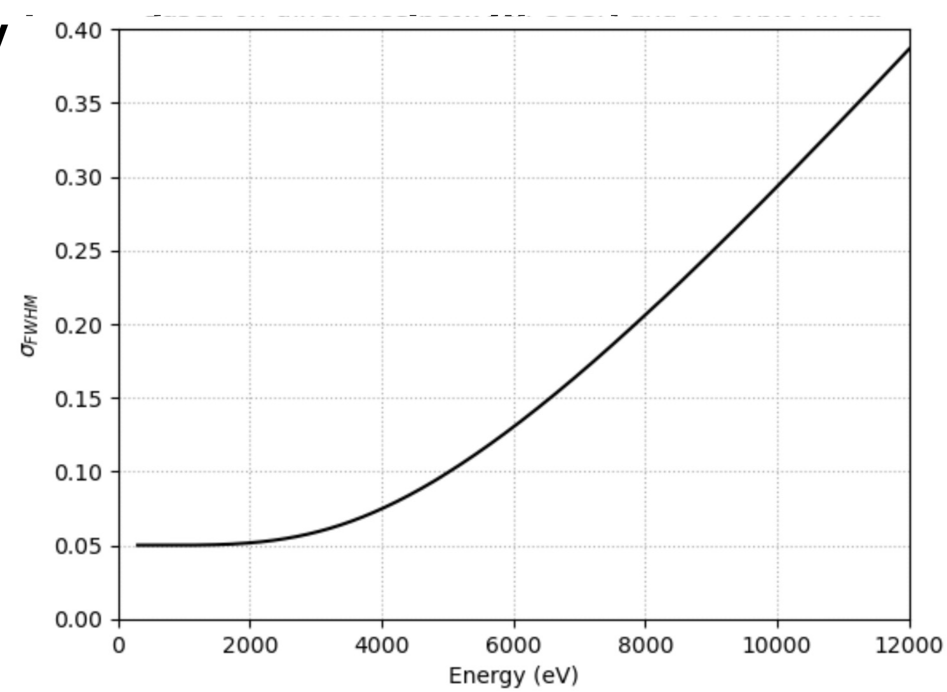
Using report generator gain_report_generator_v8.py

Recommended uncertainties

- Calibration team working hard to reduce systematics
- Right now we have very good energy scale fiducials from 5.4-9.0 keV
- Pinning the low energies is difficult with the GV closed
- There are no simple energy scale fiducials at high energies

- Recommended energy scale uncertainties (1 sigma):
  - 5.4-9.0 keV: 0.3 eV
    - Add cal pixel reconstruction error for each observation in quadrature
  - < 5.4 keV: 1 eV, constrained by Si Ka instrumental line
  - Above 9.0 keV: 2 eV, conservatively

- Recommended core LSF uncertainty
  - Energy dependent
  - 0.13 eV FWHM at 6 keV



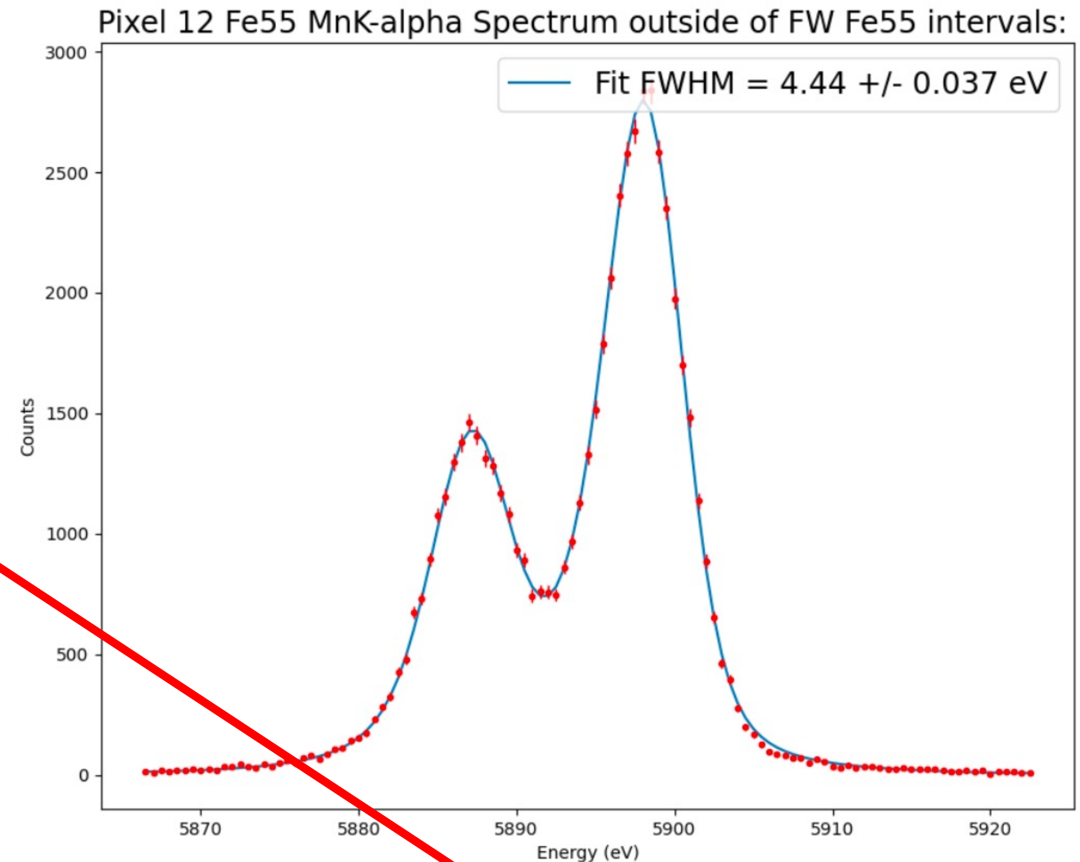
Energy scale uncertainty

From the calibration report for each observation

In this case:

Sqrt (0.3^2 + 0.143^2)

= 0.33 eV (1 sigma)



Event grade: Hp
Fit FWHM: 4.441 +/- 0.0367 eV

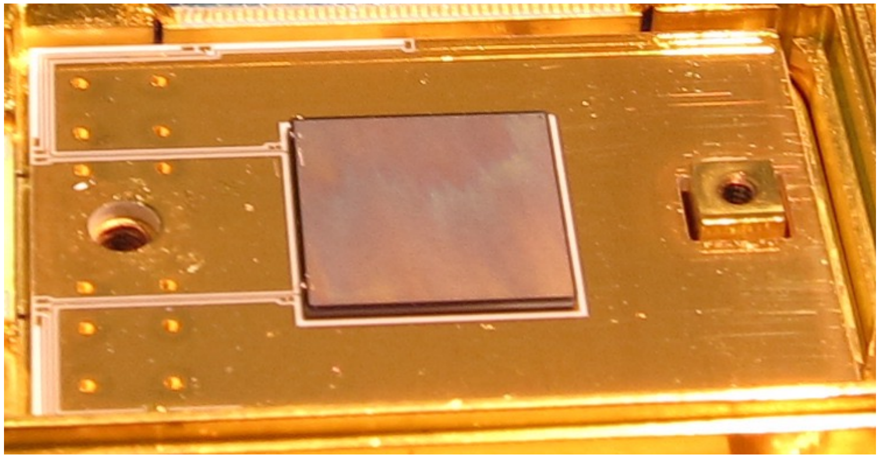
Event rate: 1.576 cts/sec
Fit Shift: -0.1429 +/- 0.0154 eV

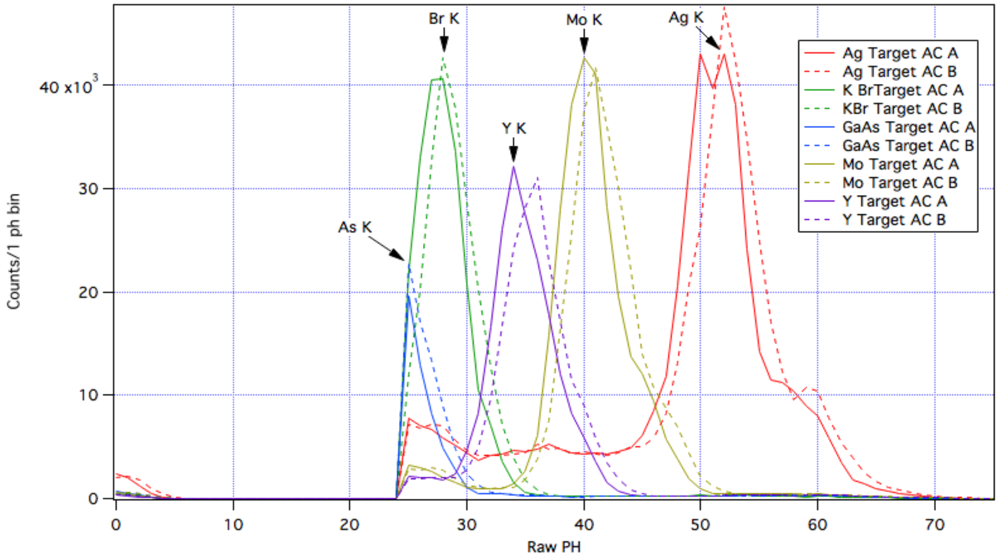
Figure 2 Spectrum of pixel 12 outside of the Fe55 filter wheel intervals.

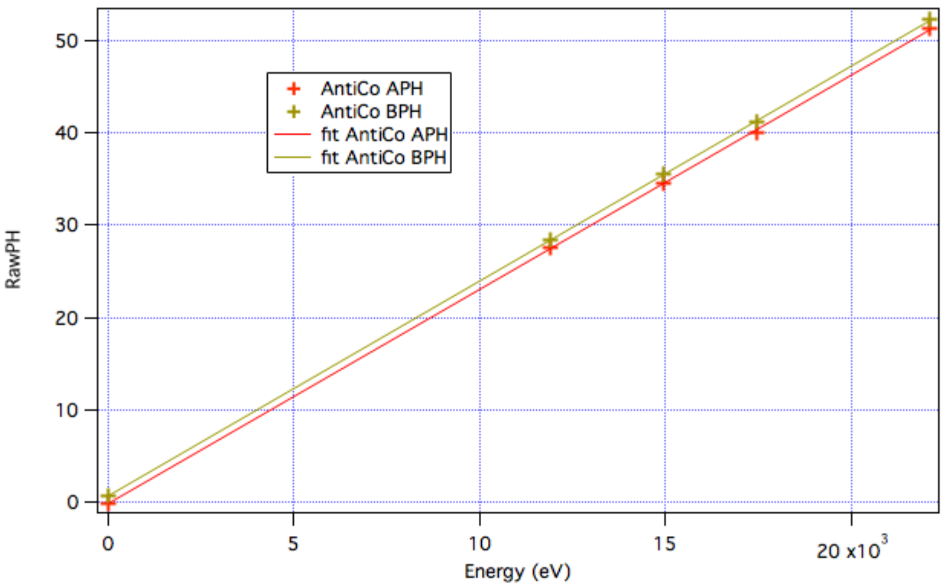
Anti-coincidence detector

- Low voltage ionization detector behind the main detector array
- Dual independent readouts for redundancy
- Energy scale is very linear
- Vetos minimum ionizing charged particles

Anti-coincidence detector

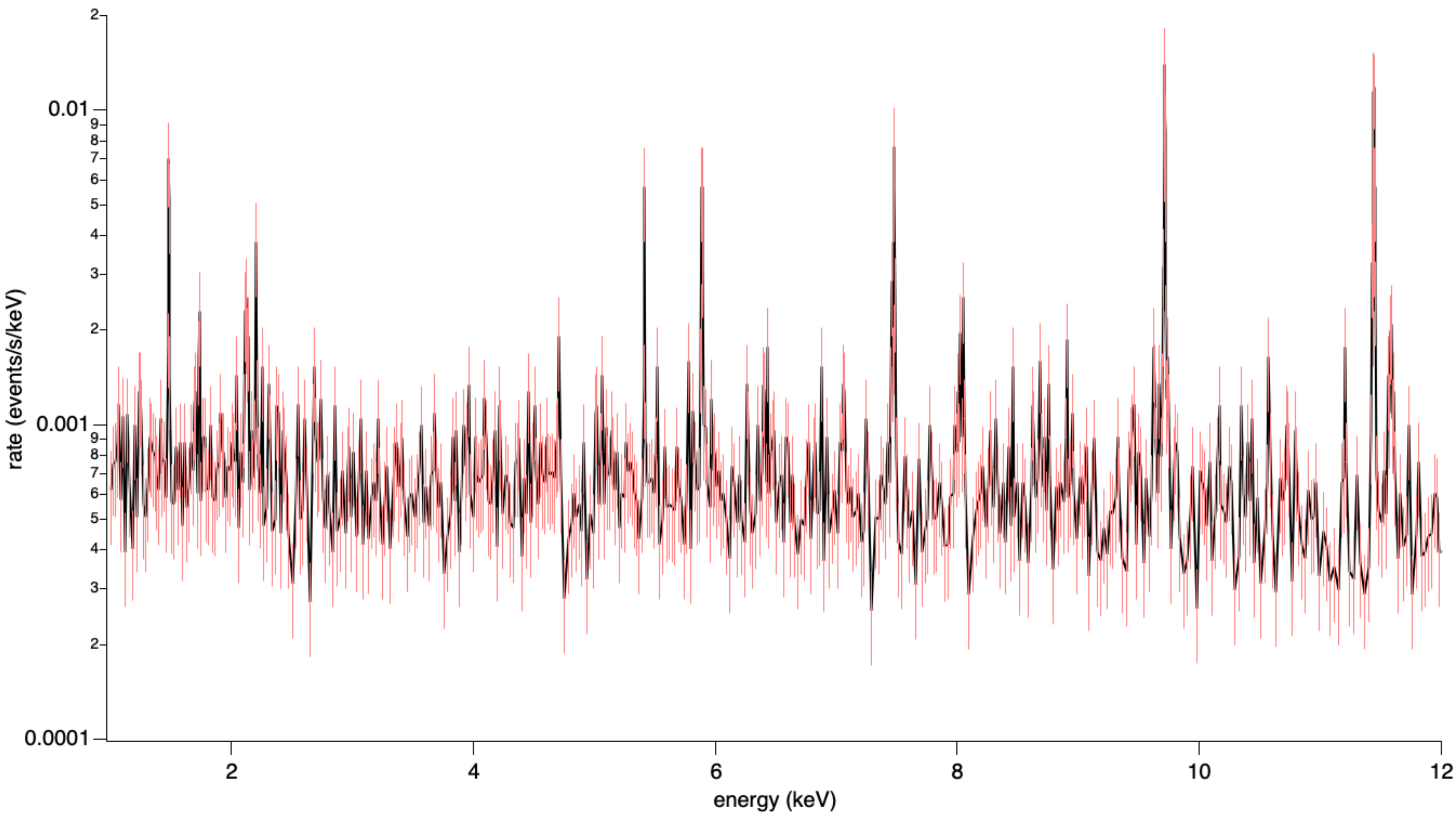






Resolve non-xray background

- **Non x-ray background (NXB) is very low**
- **Becoming better characterized with time**
- **Caroline will discuss extensively tomorrow**



Summary

- Resolve is working very well on-orbit
- Tracking two pixels (24,31) with a small increase in excess noise
  - Likely due to expected radiation damage to cryogenic amplifiers
  - No effect on performance
- Tracking gain shifts on some pixels
  - Pixel 27, not currently useable
  - Observed on a handful of others
    - Almost always during ADR recycle → well sampled reconstruction
    - Handful of cases observed at other times
      - Instrument team is monitoring
      - PI is notified
- Inflight calibration is on-going
  - Midres calibration
  - Improved energy scale systematics
  - NXB