Optimization of X-ray event screening using ground and in-orbit data for the *Resolve* instrument onboard the XRISM satellite

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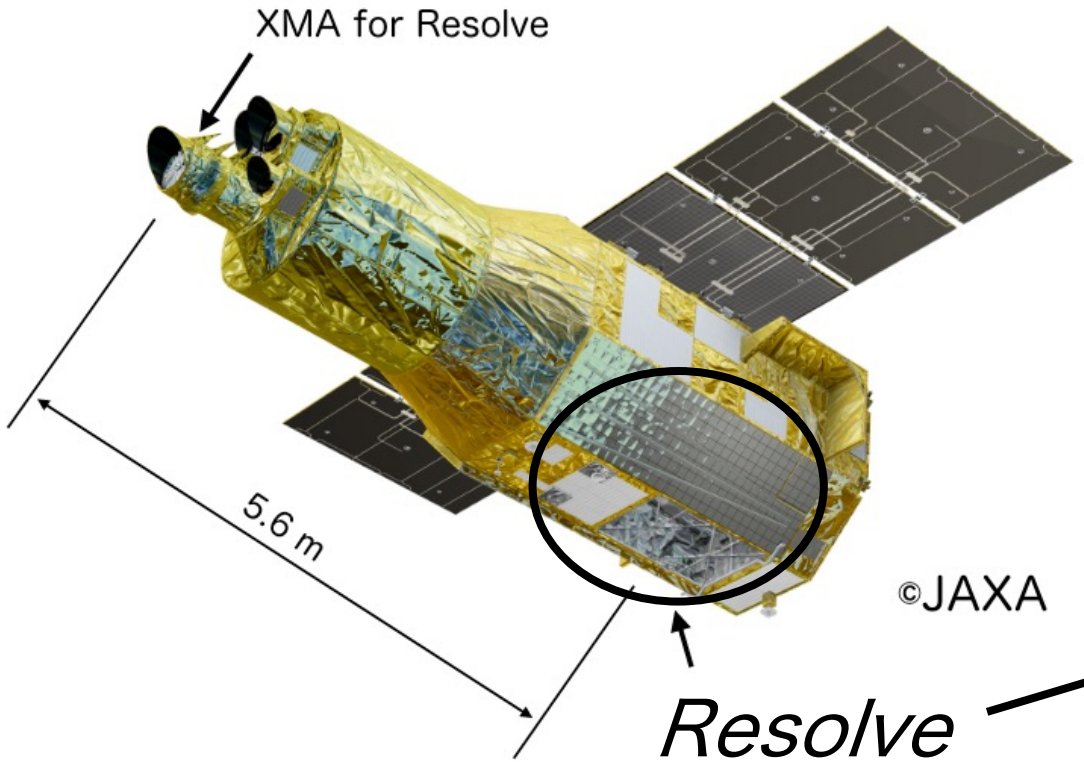
Overview

- Resolve event screening: 3 categories (18 items)
- Automatic screening (prev. talk) meets the background requirement and this methods have been established based on the heritage of the SXS
- The detector team continues to consider more effective screening methods, and three of the most important ones will be presented in this presentation.
- This work based on (a) ground testing data and (b) in-orbit data.
- These results are planned to be incorporated into automated or additional processing before PV or GO data are distributed to users.

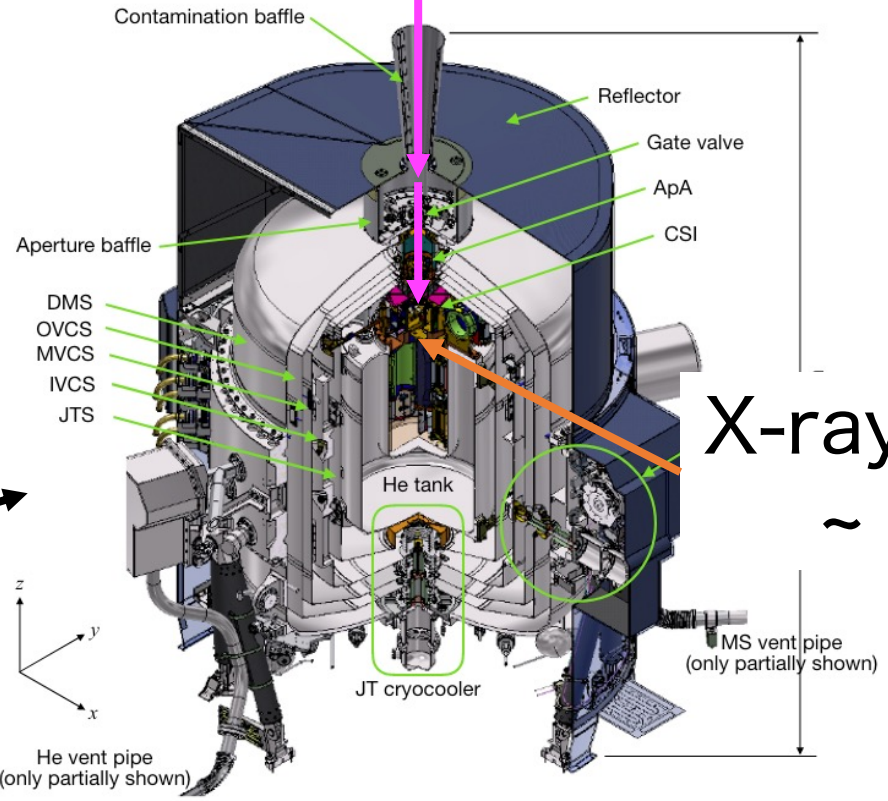
Outline

Outline

1-a XRISM/Resolve



X-ray (0.3—12 keV)

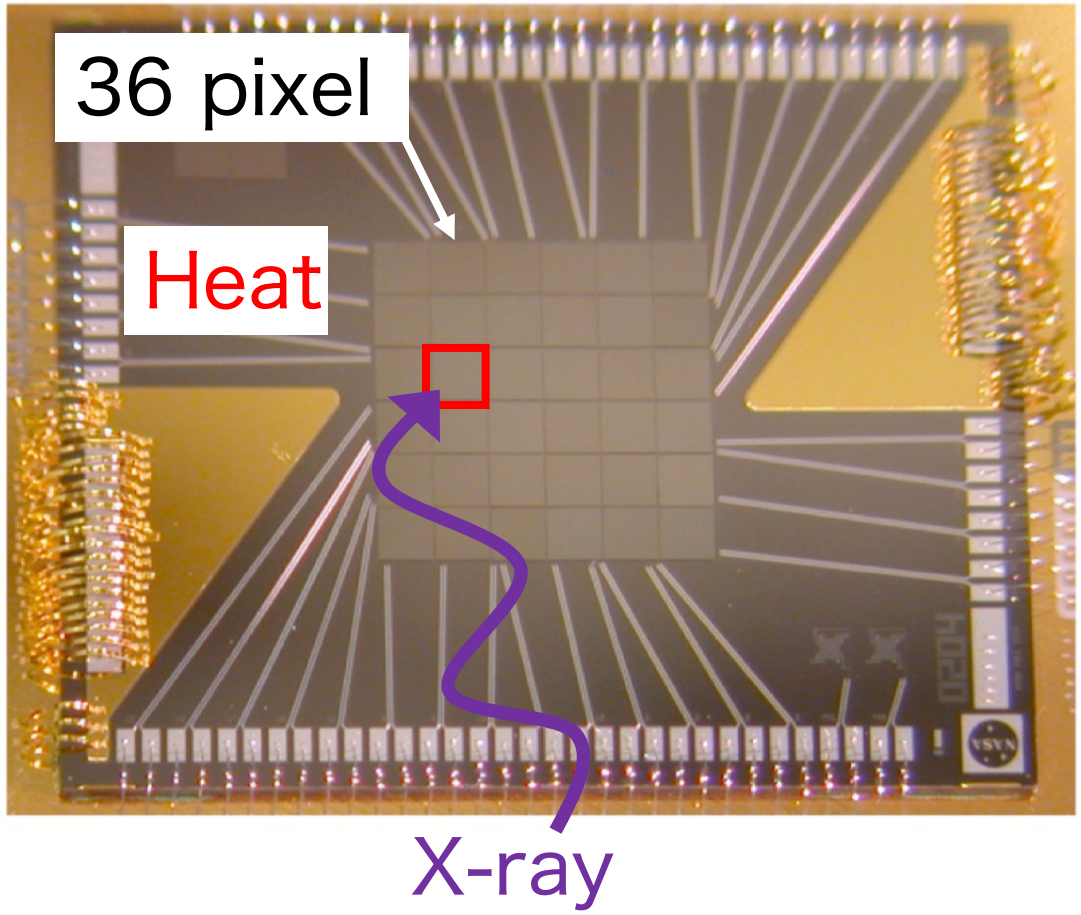


X-ray detector
~ 50 mK

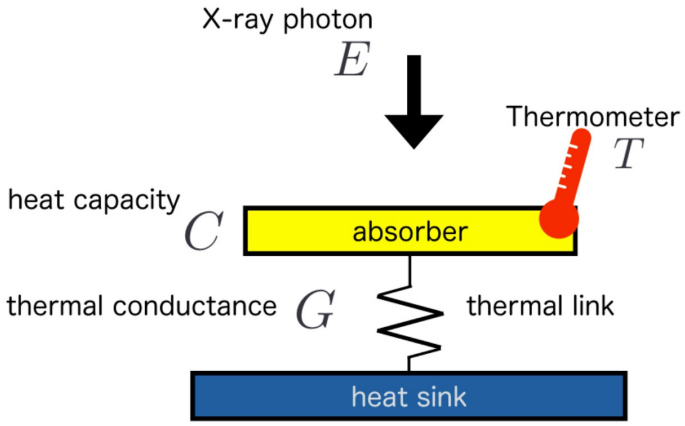
Ishisaki +2022

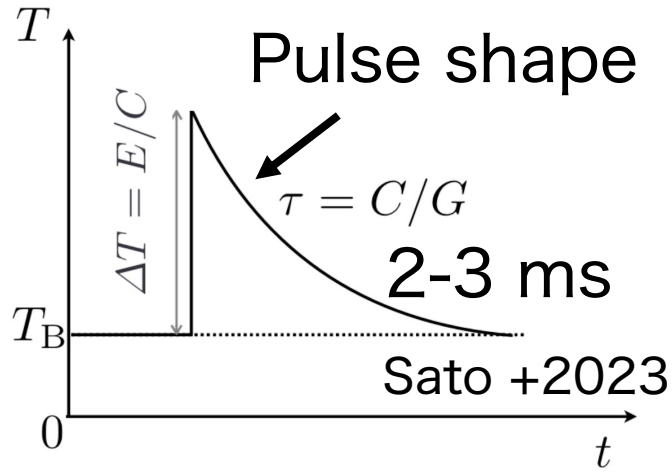
1-b Detector - X-ray microcalorimeter

X-ray microcalorimeter



Kilbourne +2018





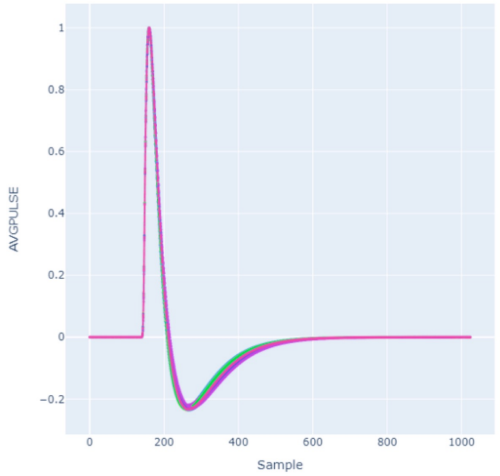
- Detection
  - T increase by energy deposit by r.
  - Decrease in thermometer resistance.
  - Voltage readout for phase shape.
  - Sampled at 12.5 kHz.
  - X-correlated with template shape.

1-c In-orbit processing of pixel events

How do we process the X-ray pulse in-orbit?

Observed pulse | Pulse Height | Average Pulse | Noise

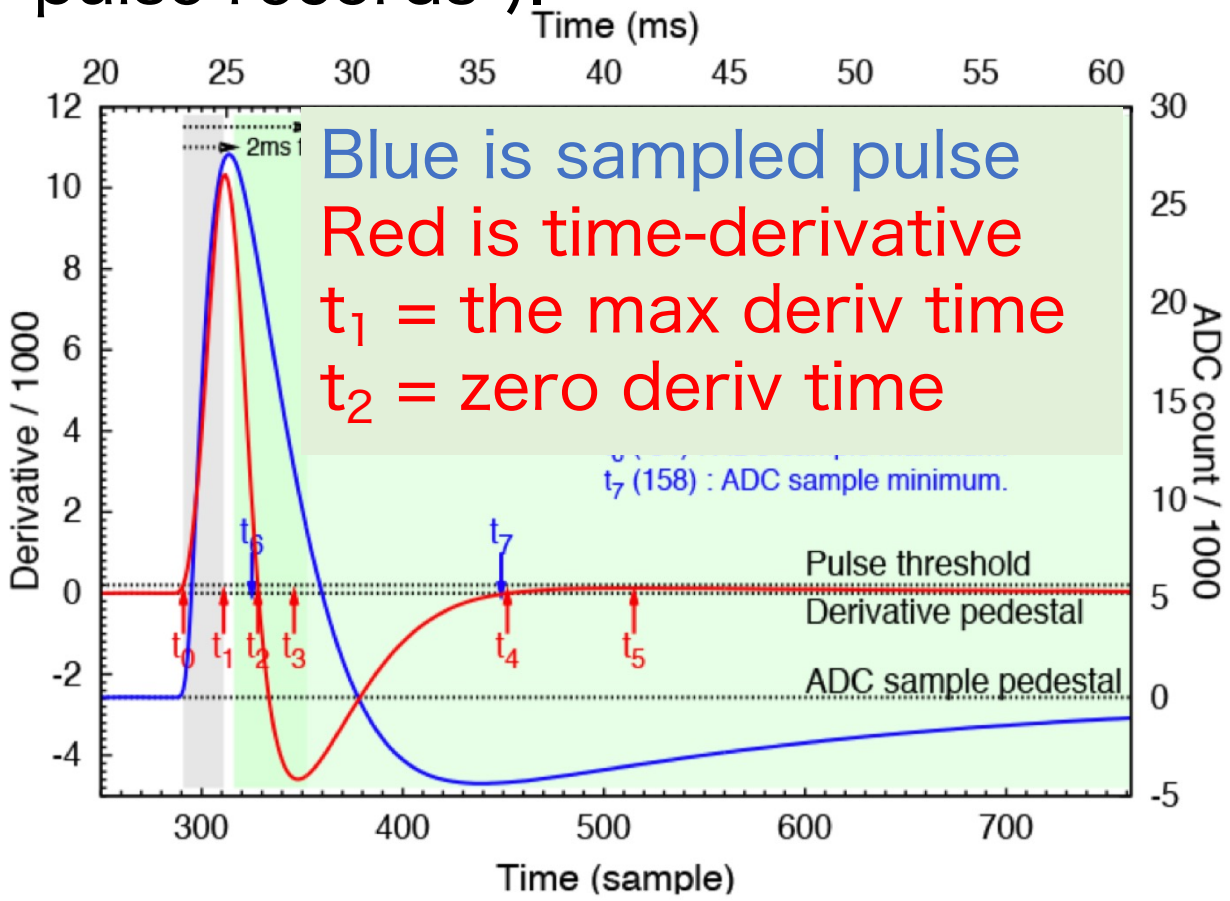
$$D = H \times \text{AVGPULSE} + N$$



- Prepare the using frequency dependence of average pulse and average noise in advance.
- Estimate the most likely H from observed pulse D

1-c In-orbit processing of pixel events

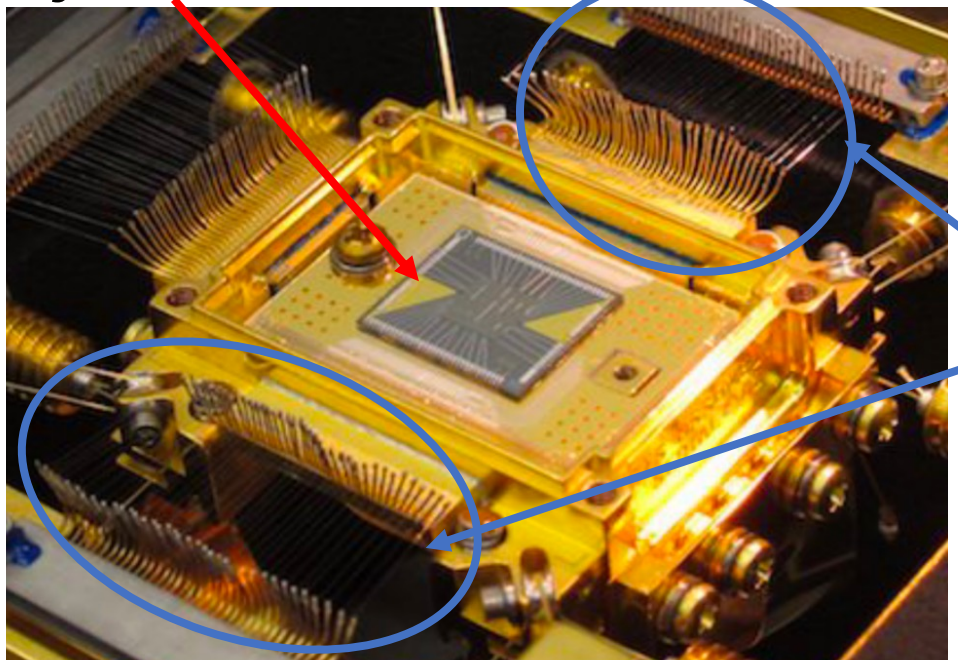
Pulse shape resolved by sampling, but only characteristic values are downlinked due to telemetry limit (except for some pulses for diagnosis: “pulse records”).



- Some characteristic values:
  - Max value of time-deriv of pulse
  - Rising time ~ t_2 — t_1
  - Time shift against template.
  - Pulse height by X-correlation.

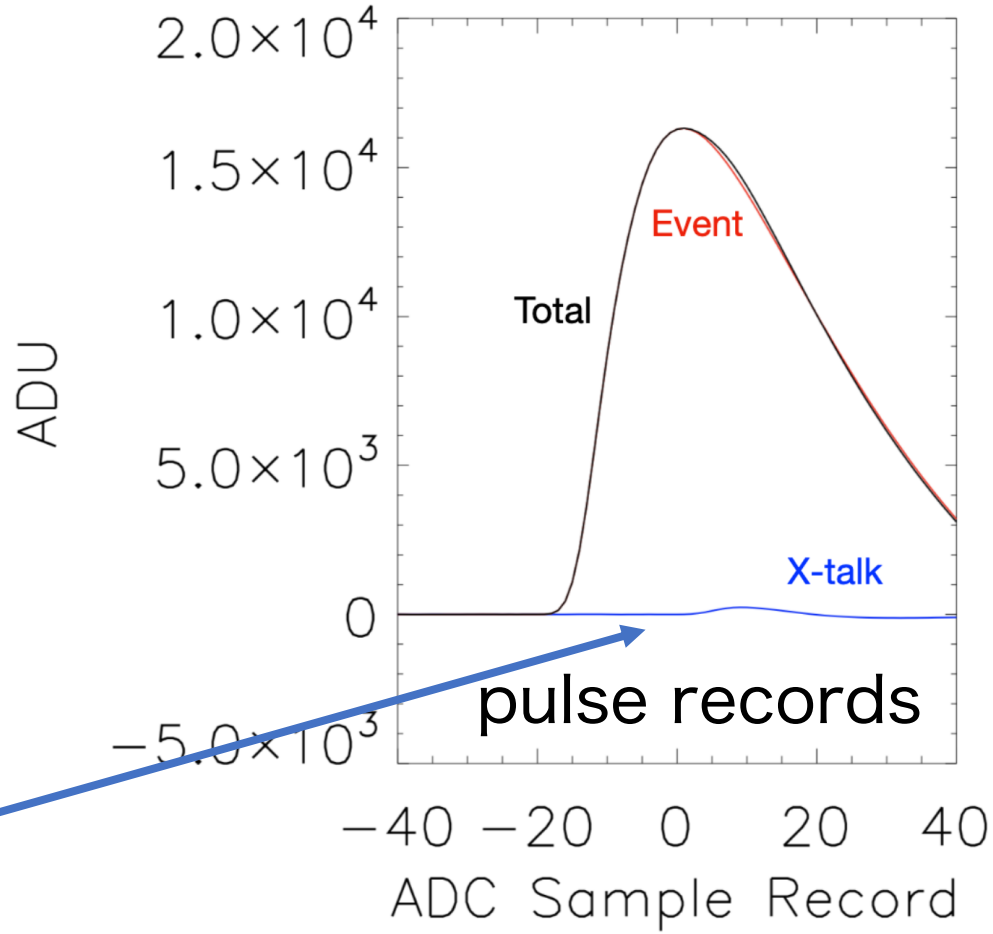
1-b Detector - X-ray microcalorimeter

X-ray microcalorimeter



Chiao +2016

Wire



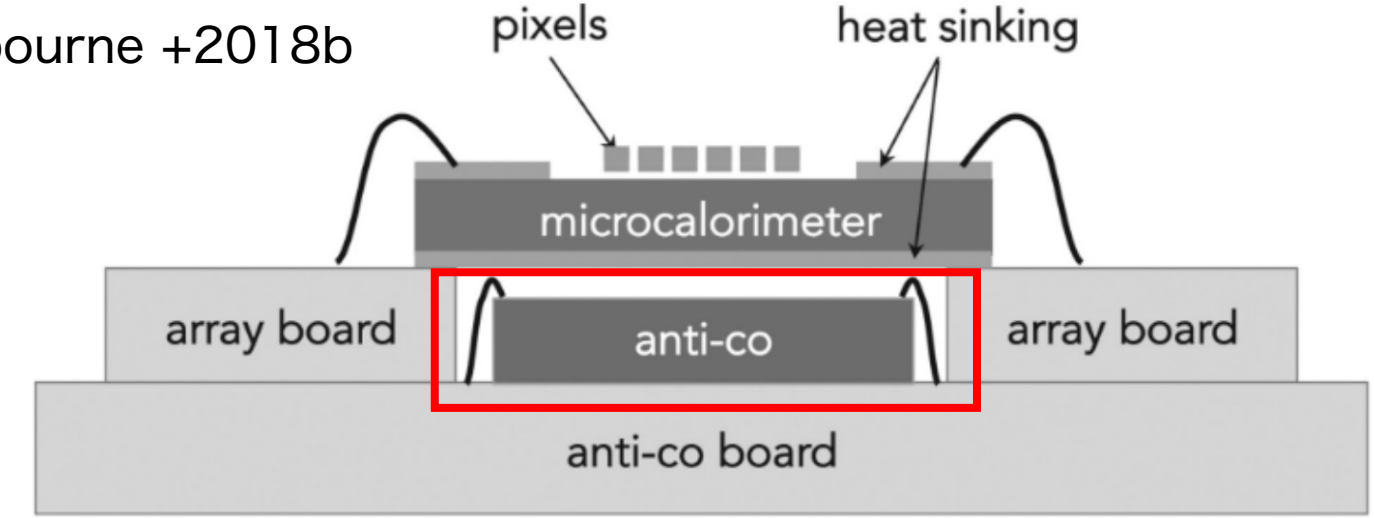
pulse records

□ Electrical crosstalk

Noise events in neighboring wires by capacitive coupling.

1-b Detector - Anti-co

Kilbourne +2018b



- Anti-coincidence detector
- Located beneath the X-ray microcalorimeter
- Anti-co screening of cosmic ray events.

1-d Event screening

- Resolve event screening:
3 categories (18 items)

- Pulse shape (7 items)

- Relative timing of event arrival times (5 items)

- Good time intervals (6 items)

Slide num	Items	SXS	Resolve (in this study)
1-a	Pulse shape (7/7 items)		
	RISE_TIME	Yes	Revised screening conditions
	TICK_SHIFT	No	New screening conditions
	DERIV_MAX	No	New screening conditions
	QUICK_DOUBLE	Yes	Same as SXS
	SLOPE_DIFFER	Yes	Same as SXS
	FLAG_CLIPPED	No	New screening conditions
	SLOW_PULSE	Yes	Same as SXS
1-b	Relative event timing (4/5 items)		
	Anti-coincidence veto	Yes	Revised anti-co window
	Electrical crosstalk (short)	Yes	New CTELDT and pharatio
	Frame events (CR)	No	Proposed change to the number of events in the time window
	Frame events (X-ray)	Yes	
	Electron recoil	Yes	Same as SXS
	Electrical crosstalk (long)	Yes	leave it to Caroline-san et al.
1-c	Good time intervals (4/6 items)		
	ADR recycling	No	Confirm GTI calculated by rsladrgti
	South Atlantic Anomaly	Yes	Revised SAA region
	Earth elevation (ELV)	Yes	Same as SXS for observational data New threthold for NXB
	Cut off Rigidity (COR)	No	Same as SXS
	MXS	Yes	leave it to Sawada-san et al.
	pixel	Yes	leave it to Mizumoto-san et al.

1-d Event screening

- Automatic screening:
3 categories (11 items)

- Pulse shape (4 items)

- Relative timing of event arrival times (2 items)

- Good time intervals (5 items)

Slide num	Items	SXS	Resolve (in this study)
1-a	Pulse shape (7/7 items)		
	RISE_TIME	Yes	Revised screening conditions
	TICK_SHIFT	No	New screening conditions
	DERIV_MAX	No	New screening conditions
	QUICK_DOUBLE	Yes	Same as SXS
	SLOPE_DIFFER	Yes	Same as SXS
	FLAG_CLIPPED	No	New screening conditions
	SLOW_PULSE	Yes	Same as SXS
1-b	Relative event timing (4/5 items)		
	Anti-coincidence veto	Yes	Revised anti-co window
	Electrical crosstalk (short)	Yes	New CTELDT and pharatio
	Frame events (CR)	No	Proposed change to the number of events in the time window
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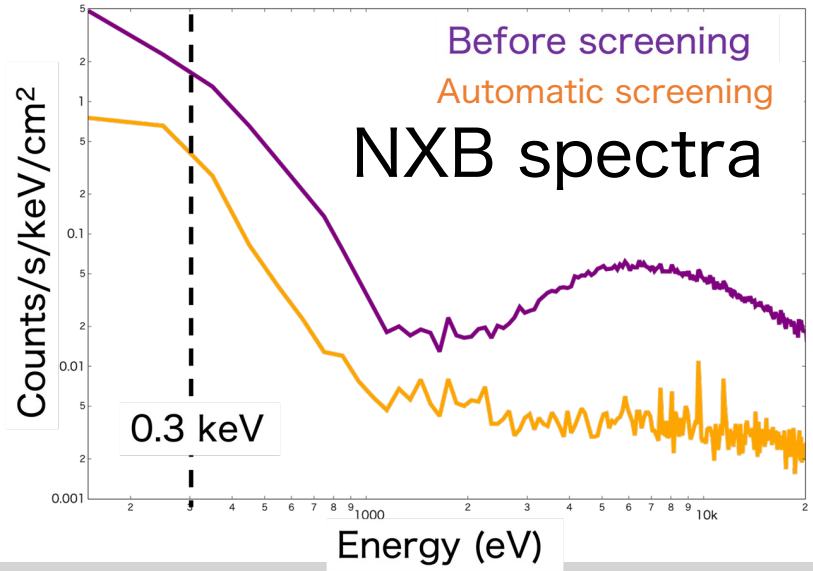
	pixel	Yes	leave it to Mizumoto-san et al.

1-d Event screening

- Requirement Non Xray Background (NXB) counts rate is

$\leq 2 \times 10^{-3}$ counts/s/keV/array (0.3 – 12 keV)

Screening way	Background counts rate $(0.3\text{–}12\ \mathrm{keV})$
Before screening	1.5×10^{-2} counts/s/keV/array
Automatic screening	1.8×10^{-3} counts/s/keV/array



Automatic screening (by pipeline) satisfies the requirement.

Outline

2 Scope

- Event screening: 18 items
  - We studied 15/18 items (YM master's thesis, 2023, UoT).

- Today's talk:
4/15 items (3 topics).

Slide num	Items	SXS	Resolve (in this study)
1-a	Pulse shape (7/7 items)		
	RISE_TIME	Yes	Revised screening conditions
	TICK_SHIFT	No	New screening conditions
	DERIV_MAX	No	New screening conditions
	QUICK_DOUBLE	Yes	Same as SXS
	SLOPE_DIFFER	Yes	Same as SXS
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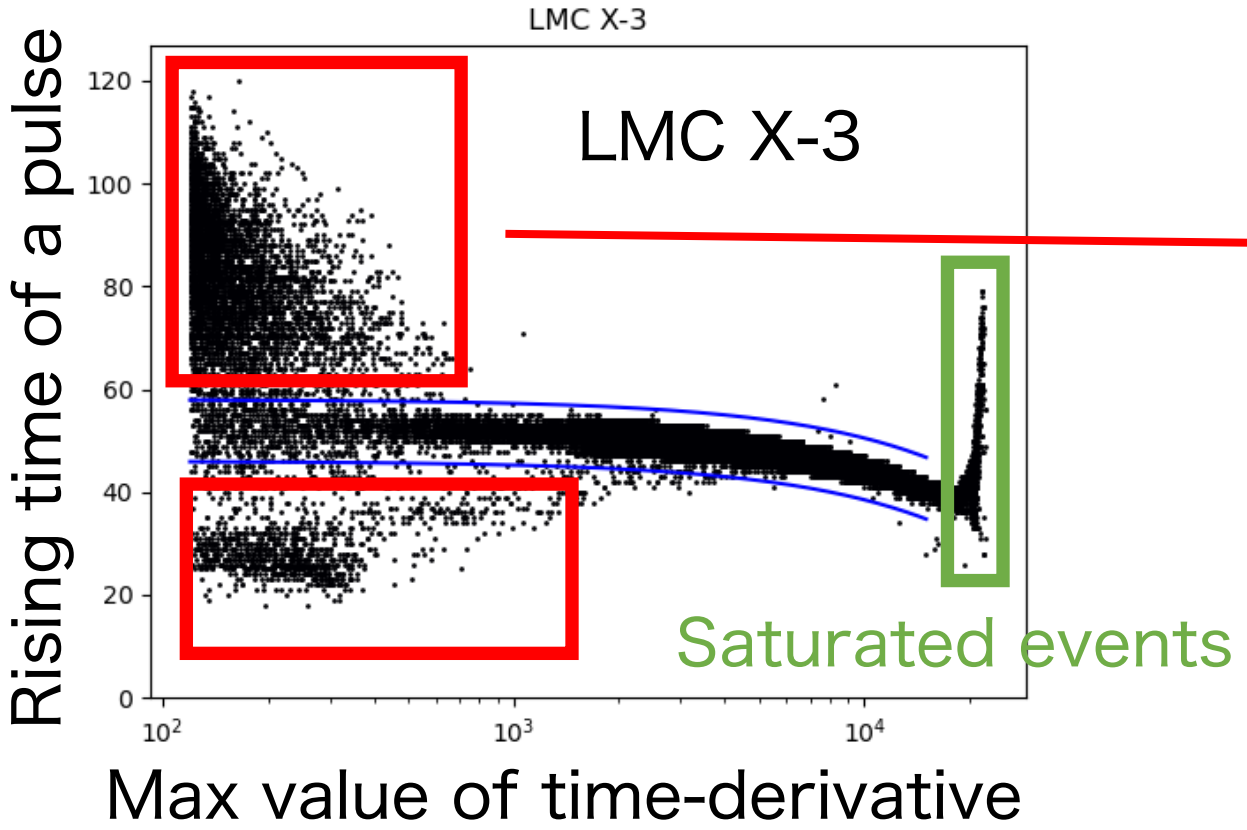
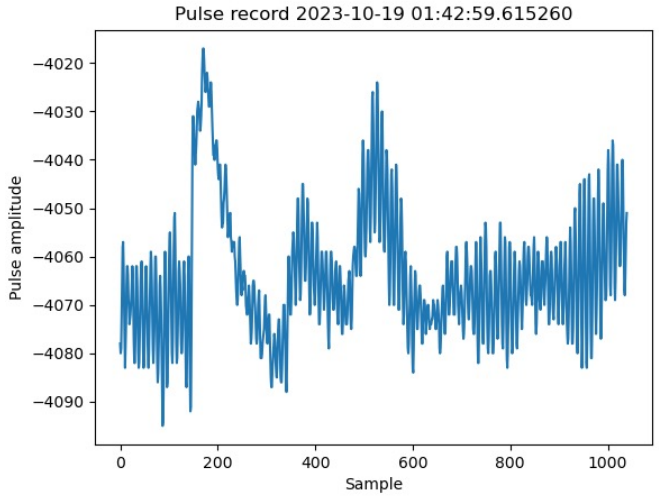
	Cut off Rigidity (COR)	No	Same as SXS
	MXS	Yes	leave it to Sawada-san et al.
	pixel	Yes	leave it to Mizumoto-san et al.

2-a 2D screening – Rising time

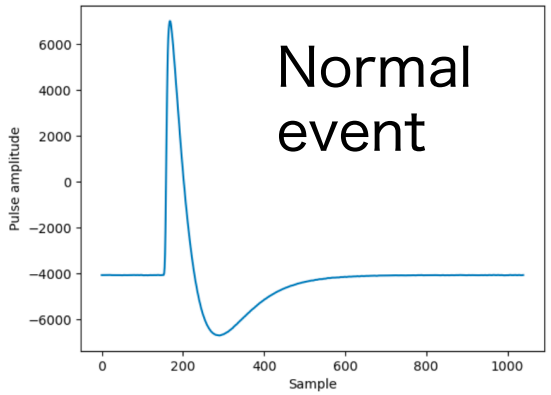
2D screening using 2 characteristic values of pulses.

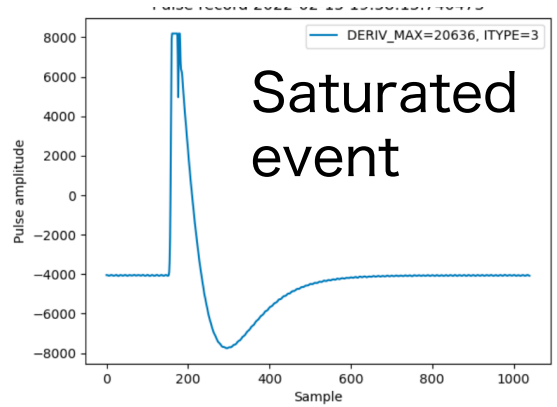


Example of pulse records.



Spurious events





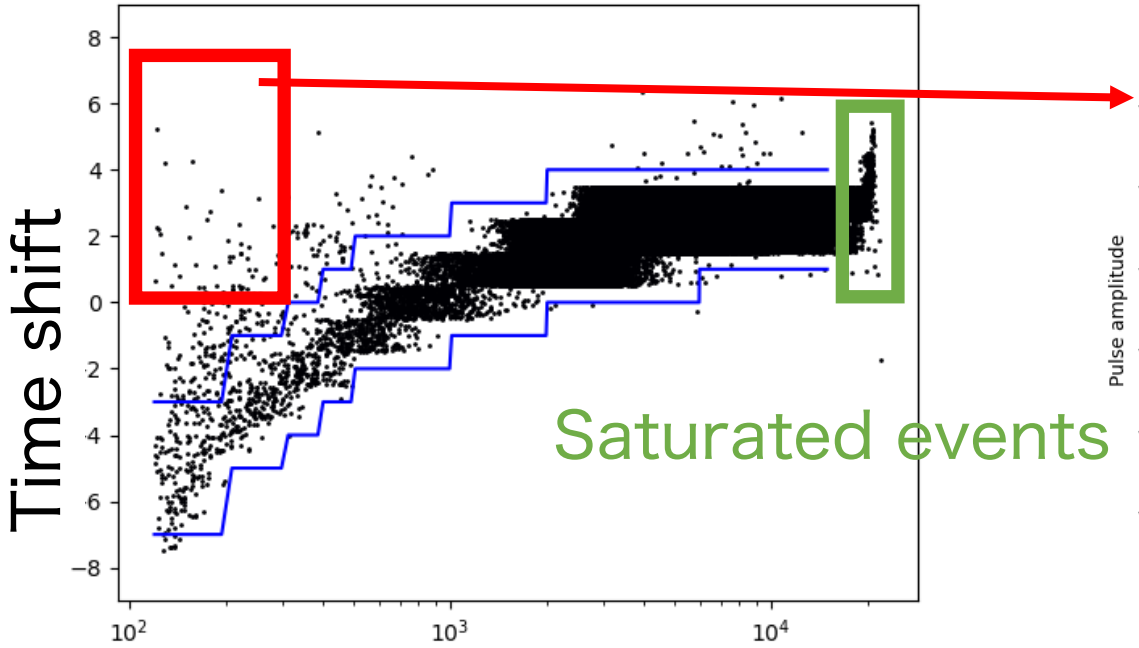
Black dot: Events

Blue line: Screening criteria (proposed).

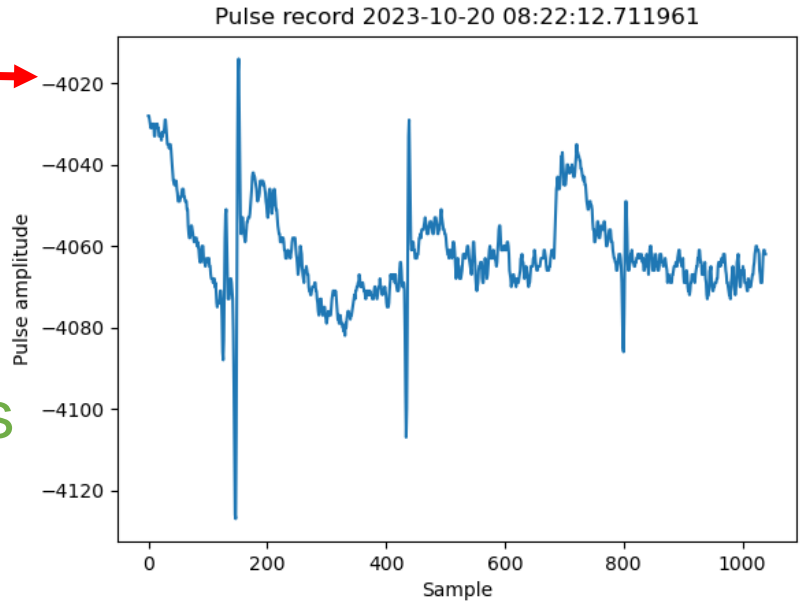
2-a 2D screening – Time shift

Another pair:

LMC X-3



Example of pulse records.

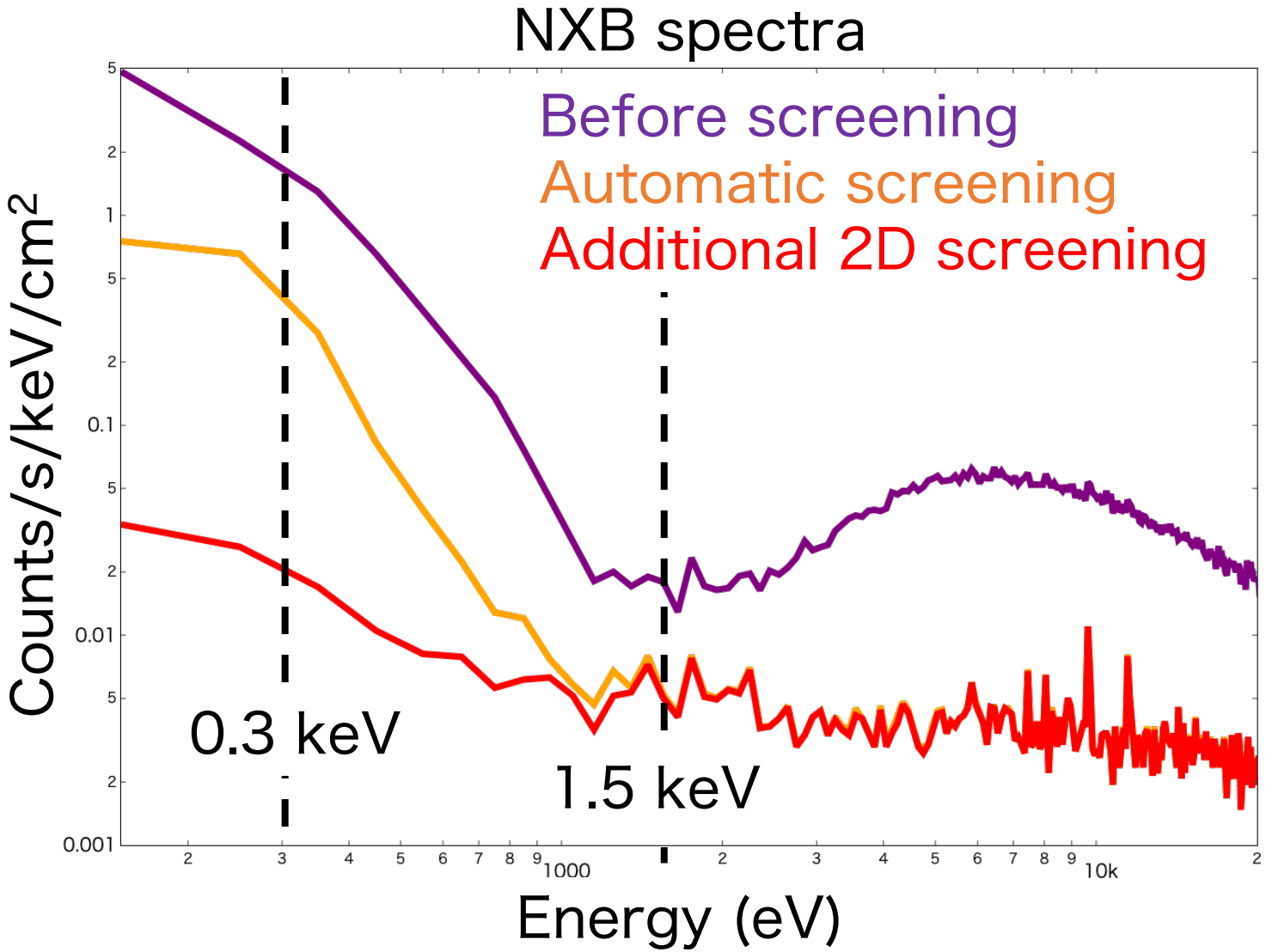


Spurious events remain.

Black dot: Events

Blue line: Screening criteria (proposed)

2-a 2D screening - Evaluation



After Additional 2D screening,

- Background level does not big change beyond 1.5 keV
- Background level decreases below 1.5 keV

NXB decreases by a half with a small loss of signals (0.3-12 keV). This should be considered an optional screening.

2-b Electrical crosstalk

- Effective screening in soft X-ray band when GV opens.
- Need to know the relation between the parent & child events (= electrical crosstalk noise events).
- Monochromatic line data in ground-test used.

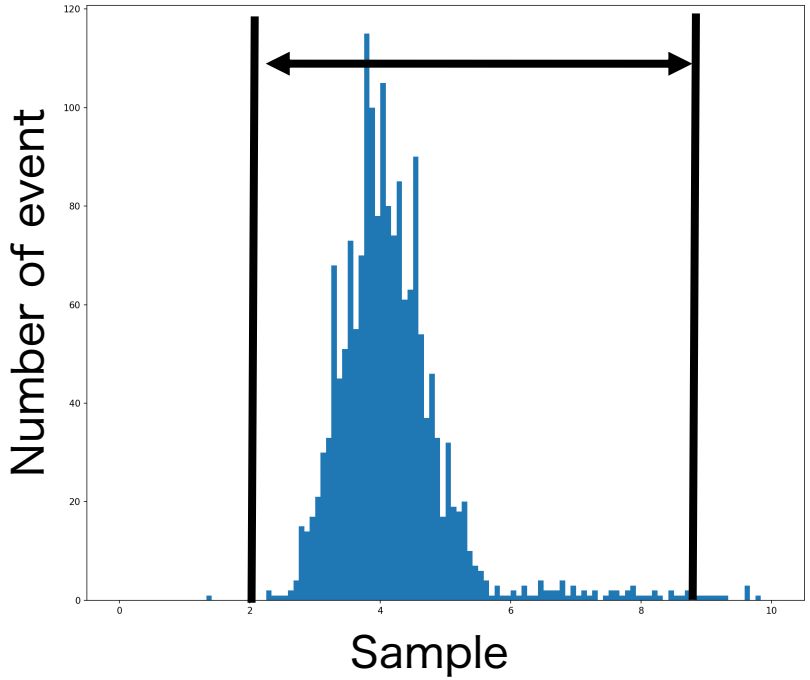
	OBSID	Period	Line	Energy (keV)
1	097091610	2022/02/01 04:00 – 2022/02/01 08:00	Fe Kα	6.4
2	097091650	2022/02/01 20:00 – 2022/02/02 00:00	Au Lα	9.7
3	097091750	2022/02/02 20:00 – 2022/02/03 00:00	Au Lβ	11.4

2-b Electrical crosstalk

Fe Kα 6.4 keV

- Time window

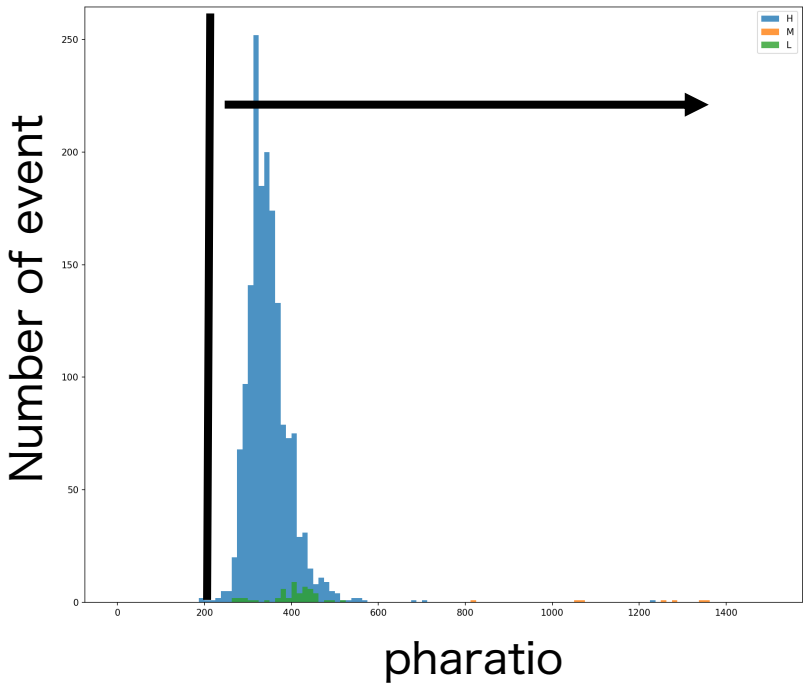
Sample time of parent event – Sample time of child event (in neighbor wire).



Time window : 2-9 samples (1 sample = 80 us)

- PHA window

Parent pulse height over child pulse height (= pharatio)



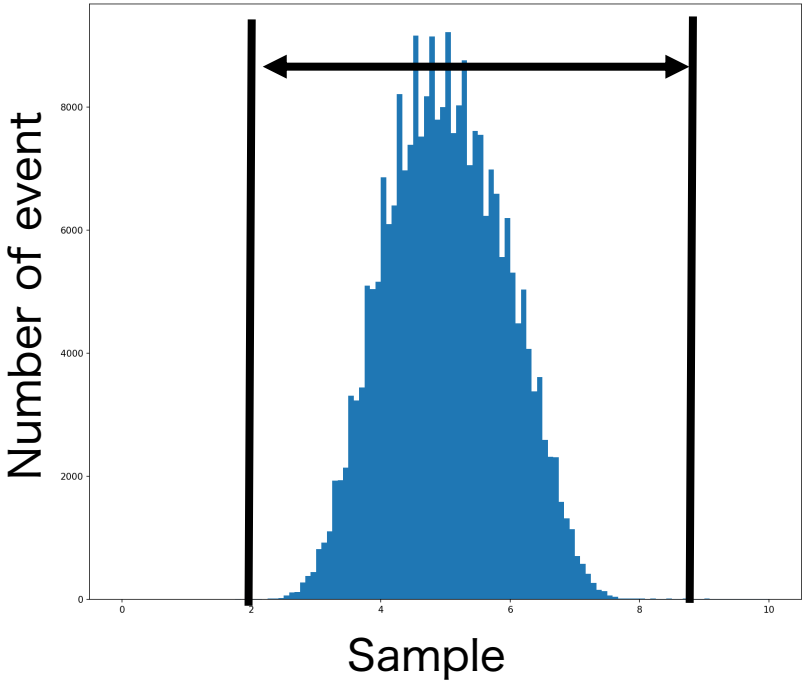
Pharatio > 200

2-b Electrical crosstalk

Au Lα 9.7 keV

- Time window

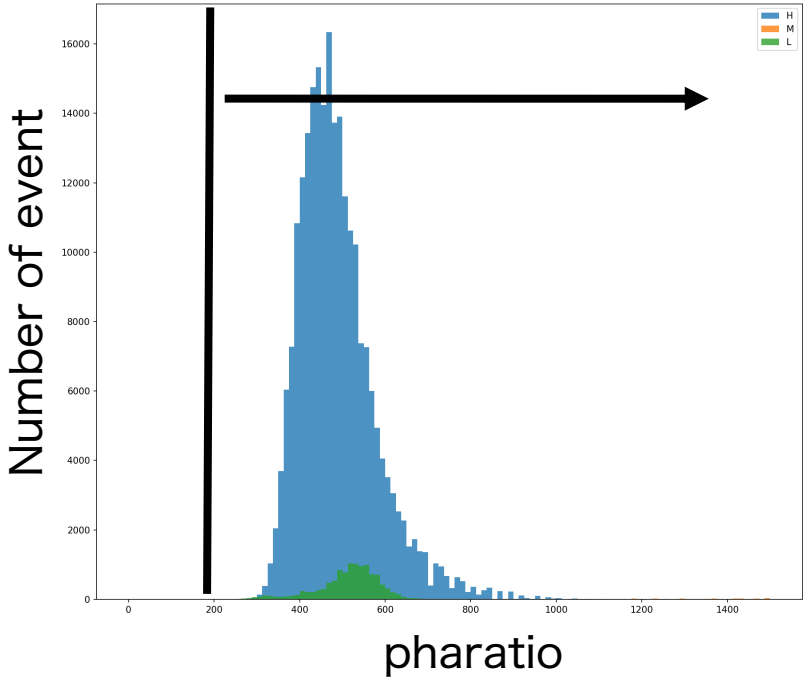
Sample time of parent event – Sample time of child event (parent pixel number ± 1)



Time window : 2-9 samples (1 sample = 80 us)

- PHA window

Parent pulse height over child pulse height (= pharatio)



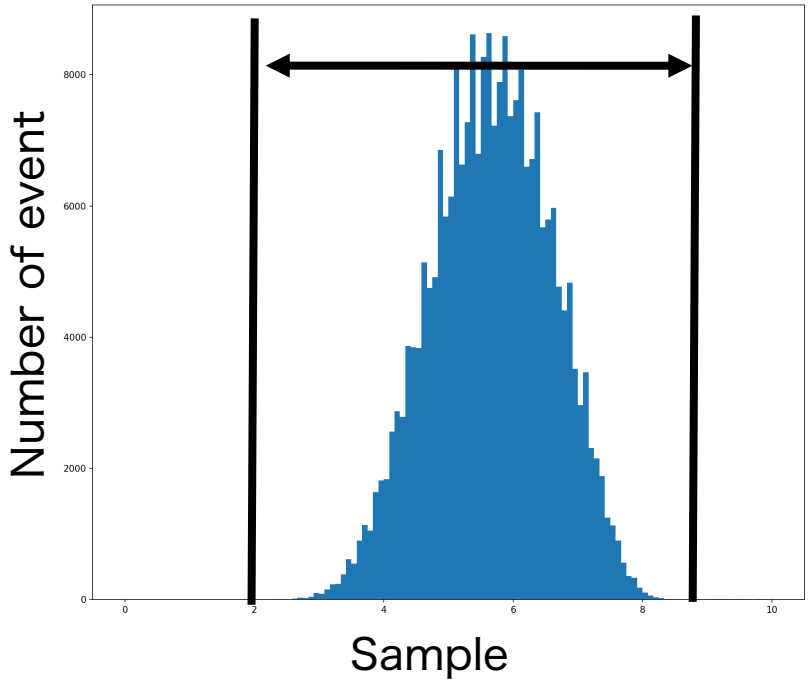
Pharatio > 200

2-b Electrical crosstalk

Au Lβ 11.4 keV

- Time window

Sample time of parent event – Sample time of child event (parent pixel number ± 1)



Time window : 2-9 samples (1 sample = 80 us)

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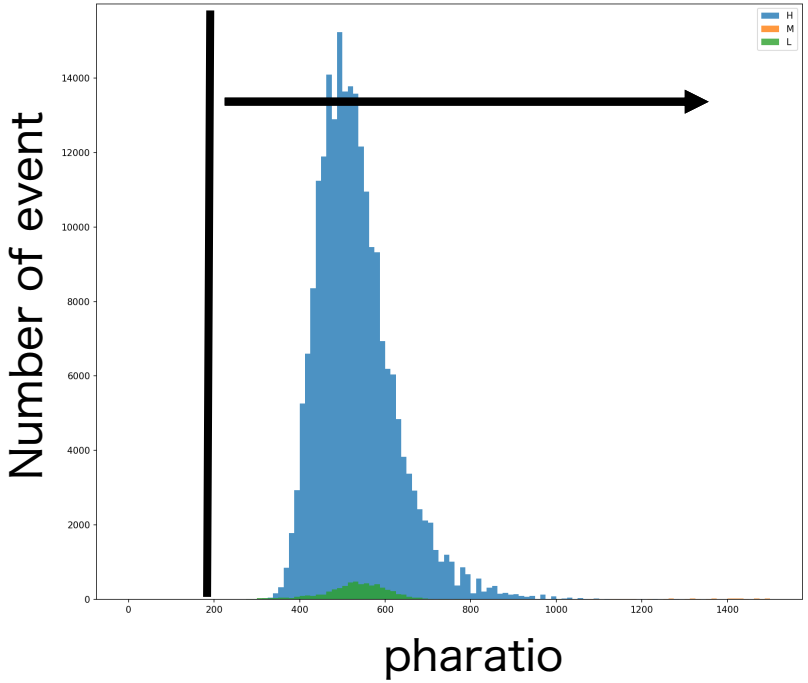
Parent pulse height over child pulse height (= pharatio)



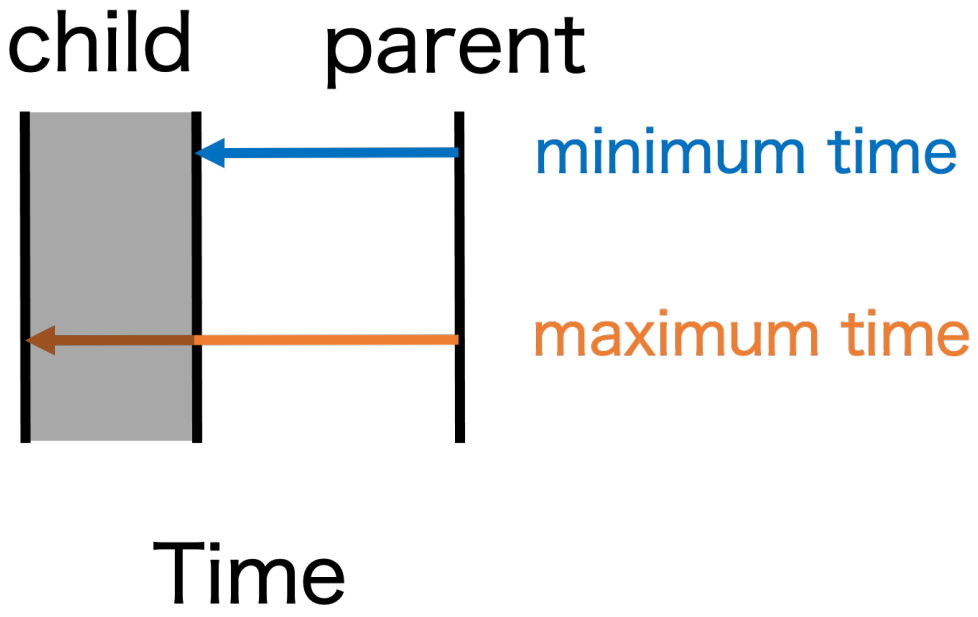
Pharatio > 200

2-b Electrical crosstalk

- Proposed cross-talk window.

1. Time window
- minimum time = 2 sample (0.16 ms)
- maximum time = 9 sample (0.72 ms)

2. PHA window
- Pharatio > 200

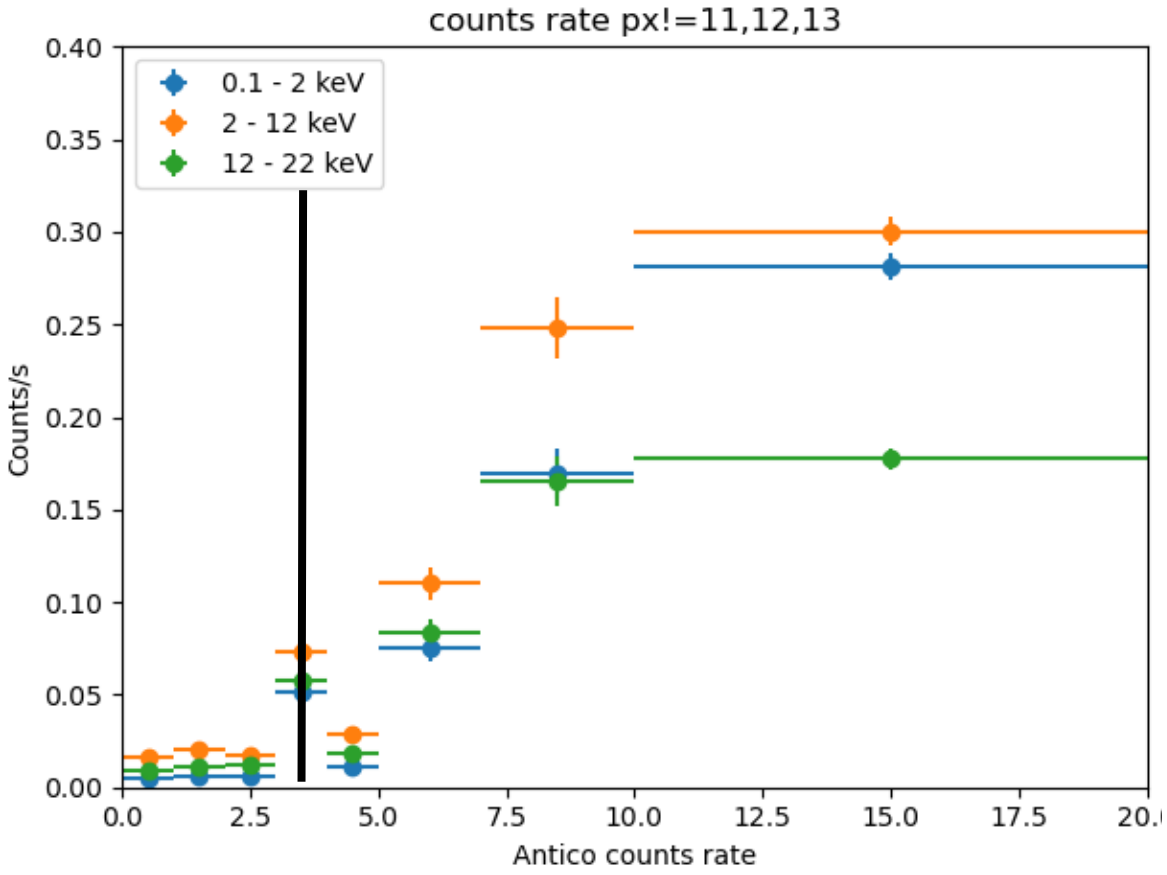


2-c SAA region

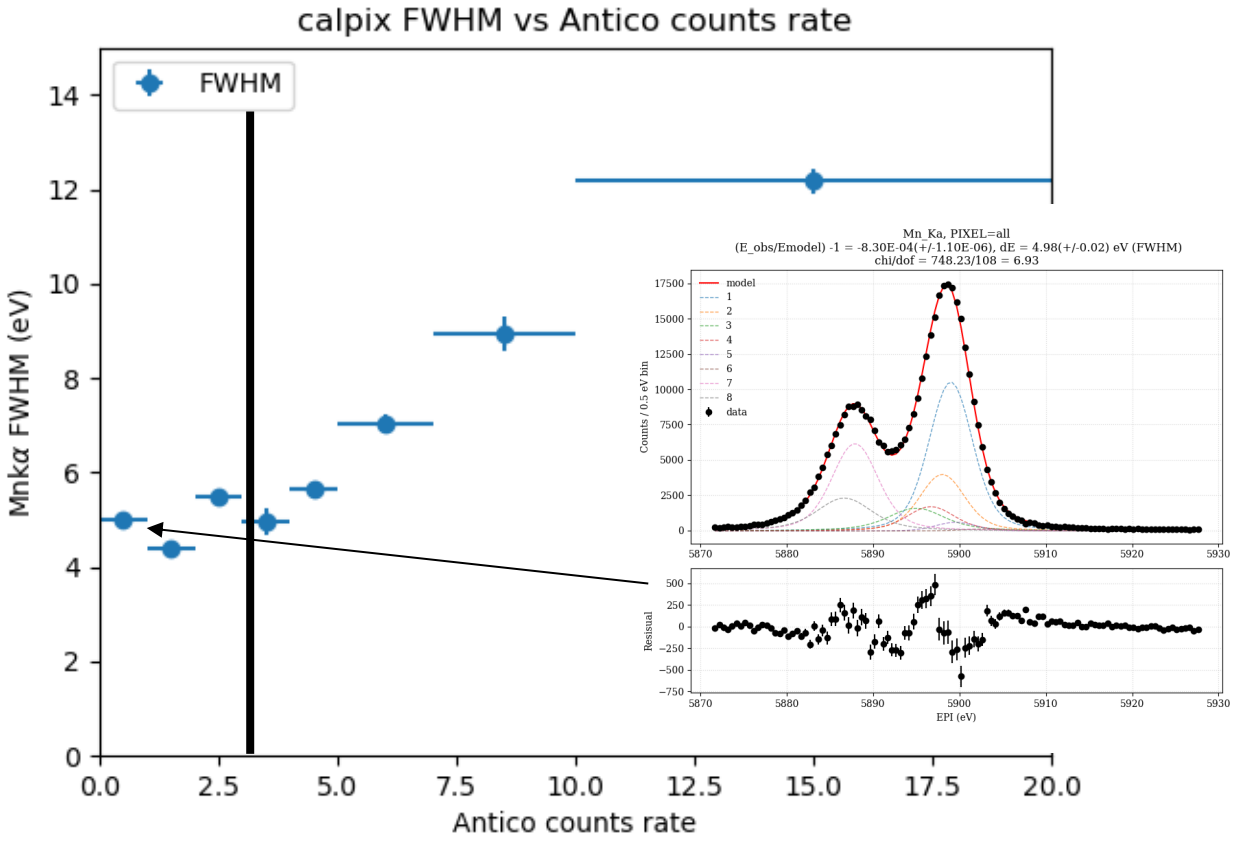
- Define SAA region based on anti-co count rate.
- Pixel and anti-co event dataset during night-earth eclipses from 11/10/2023 to 21/02/2024 used.
- Examine relation between anti-co count rate and
  - NXB pixel counts rate
  - FWHM of calibration source (Mn Kα line)

2-c SAA region

NXB count rate vs anti-co count rate



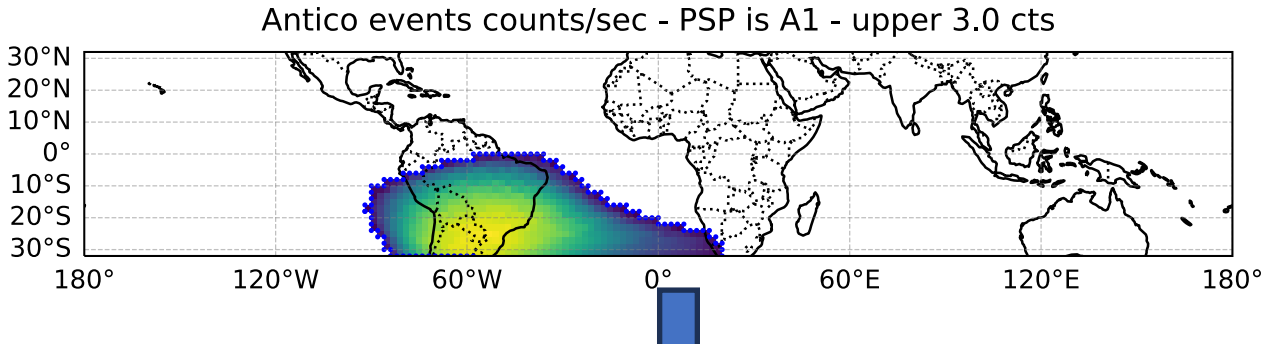
FWHM vs anti-co count rate



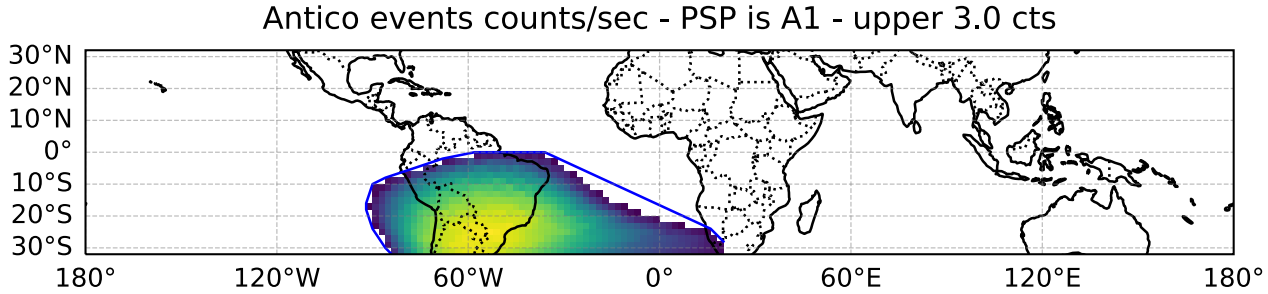
Anti-co count rate < 3 (1/s) is a good threshold.

2-c SAA region

SAA region based on anti-co count rate > 3 (1/s)



Using a scipy module,
find the smallest convex-only region.



- How to plot
  Anti-co counts made to 1s bin and averaged over a 2°x2° mesh of projected longitude and latitude.
- Color map
  Anti-co count rate
- Blue line
  Derived SAA region

Outline

3 Conclusion

- Investigated three of the most important screening of *Resolve*.

- 3 topics:

• **Pulse shape (2D screening)**; user selected screening

Useful for optional additional screening. NXB decreases by a half at a small loss of signals.

• **Relative event timing (Electrical crosstalk)**; user selected screening

Useful after GVO. Screening criteria (asymmetric time window and pharatio) proposed.

• **Good time intervals (SAA region)**; general screening

SAA region based on anti-co count rate. the smallest convex-only region. Fully automated and can be updated easily when SAA moves.