# STIX data calibration: update and future work

**Paolo Massa (FHNW)**

Joint work with: Anna Volpara, Muriel Stiefel, Olivier Limousin, Gordon Hurford, Nicky Hochmuth, Shane Maloney, Säm Krucker and the STIX team

STIX meeting – Dublin, July 22-24 2026

Credit: ESA website

# New release of STIX-GSW IDL!

## Release of v0.6.2 Latest

Compare

ennosigaeus released this last week v0.6.2 73f3a3f

This release delivers a major update to the calibration pipeline: a new ELUT correction based on daily calibration FITS files with livetime-uncertainty propagation, a new amplitude calibration, and updated subcollimator transmission data (now covering detectors 1a/b/c and 2a/b/c).

**What's new?**

- New ELUT correction based on daily calibration fits files
- Updated sub-collimator transmission
- Corrected visibility amplitude calibration

# New ELUT correction – daily calibration files

# Problem

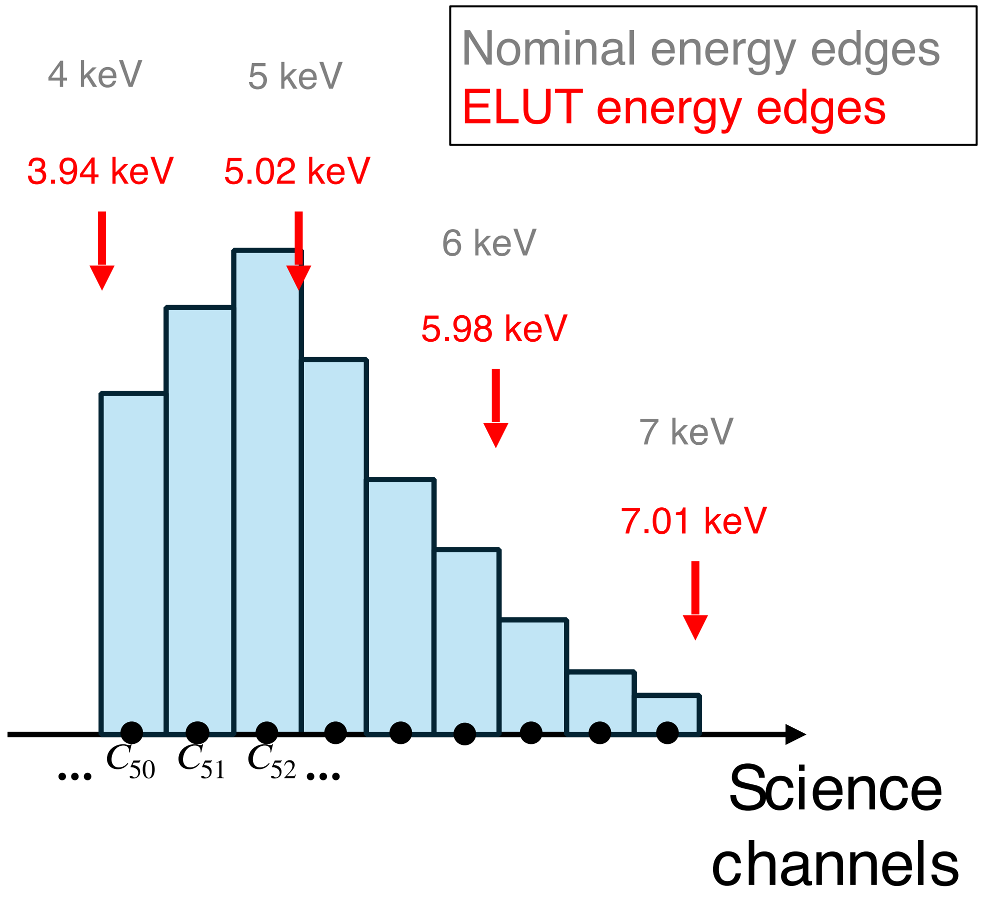
- STIX pixel data are binned onboard into 32 energy channels, referred to as **science energy channels** (e.g., 5–6 keV, 6–7 keV, etc.)

- Each pixel uses slightly different energy bin edges for data binning

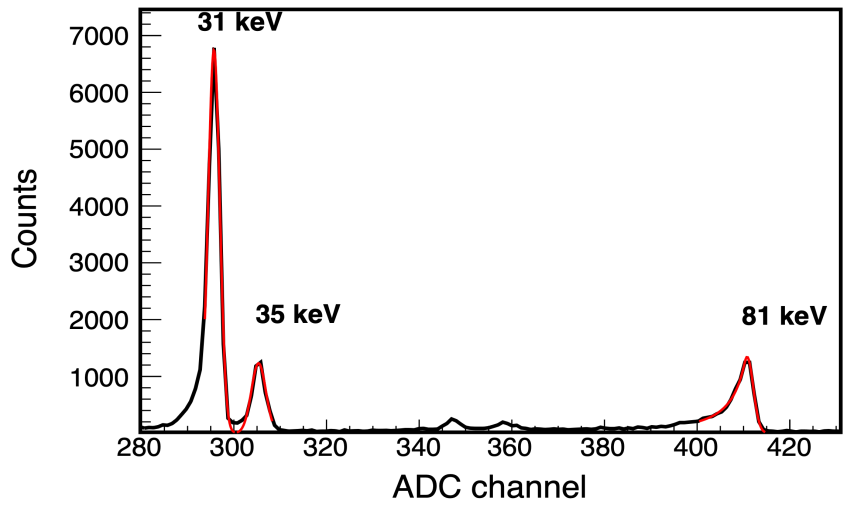
- Knowledge of the energy bin edges (in keV) is necessary to account for pixel-to-pixel discrepancies

- The energy bin edge values are stored in the **Energy Look-Up Table (ELUT)**

# Energy LookUp Table (ELUT)




The values of the actual energy edges in keV are derived by fitting calibration spectra




Xiao et al., The data center for the Spectrometer/Telescope for Imaging X-rays (STIX) on board Solar Orbiter, A&A (2023)

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- A routine for automatic download of the most appropriate calibration file is implemented in IDL

```
;************************************* DOWNLOAD CALIBRATION FITS FILE *********************************

; This file is used for creating a structure containing daily calibration data to be used for ELUT
; correction (see next section)
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- To apply ELUT correction, it is necessary to read the calibration file, create a calibration data structure and pass it as input to, e.g., stx_construct_visibilities **(*elut_corr* keyword has been removed)**

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;;********************************** CONSTRUCT CALIBRATION DATA STRUCTURE *****************************

; Create a structure containing daily calibration data to use for ELUT correction:
; - TIME_START: start time of the calibration file which is used to derive gain/offset values
; - TIME_END: end time of the calibration file which is used to derive gain/offset values
; - T_MEAN: mid point of the time range of the calibration file which is used to derive gain/offset values
; - ENERGY_BIN_LOW: actual lower energy edges (in keV) of the science channels for each pixel
; - ENERGY_BIN_HIGH: actual higher energy edges (in keV) of the science channels for each pixel
; - GAIN: gain value for each pixel
; - OFFSET: offset value for each pixel
; - LIVE_TIME: live time of the calibration file
; - ELUT_NAME: name of the ELUT that was utilized onboard when the calibration file was recorded

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vis=stx_construct_calibrated_visibility(path_sci_file, time_range, energy_range, $
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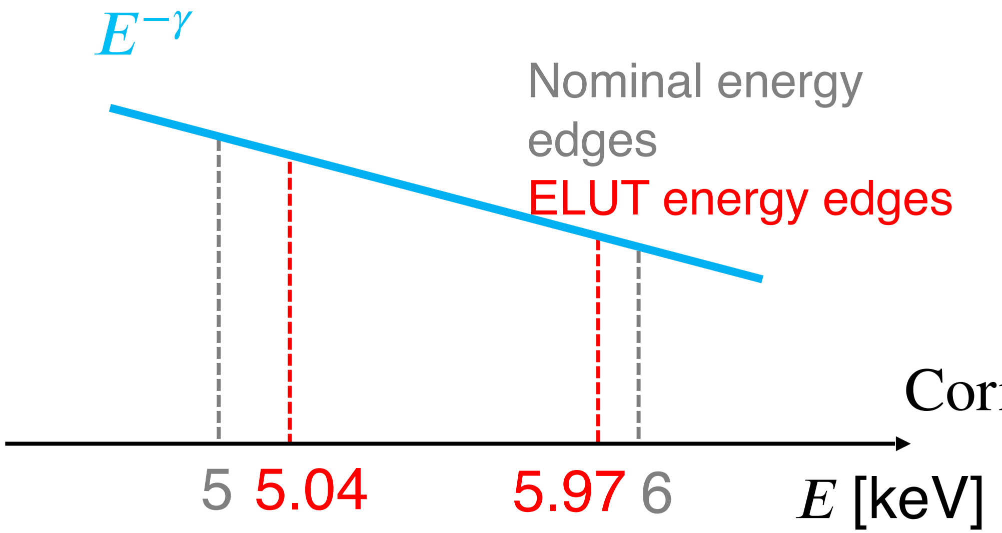
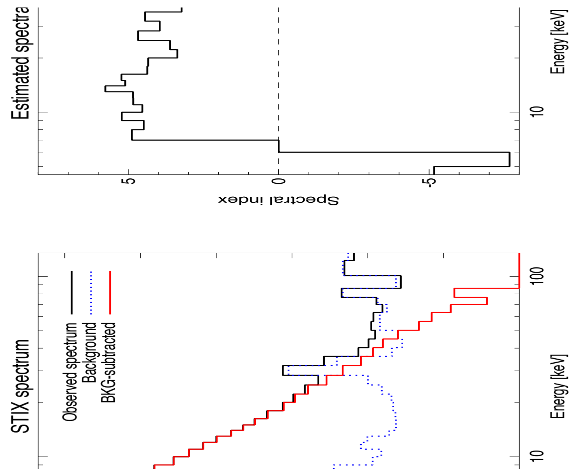
- Examples showing how to use the new calibration files for imaging and spectroscopy are contained in /stix/idl/demo:
  stx_imaging_demo.pro   stx_ospex_spectroscopy_demo.pro

# New ELUT correction

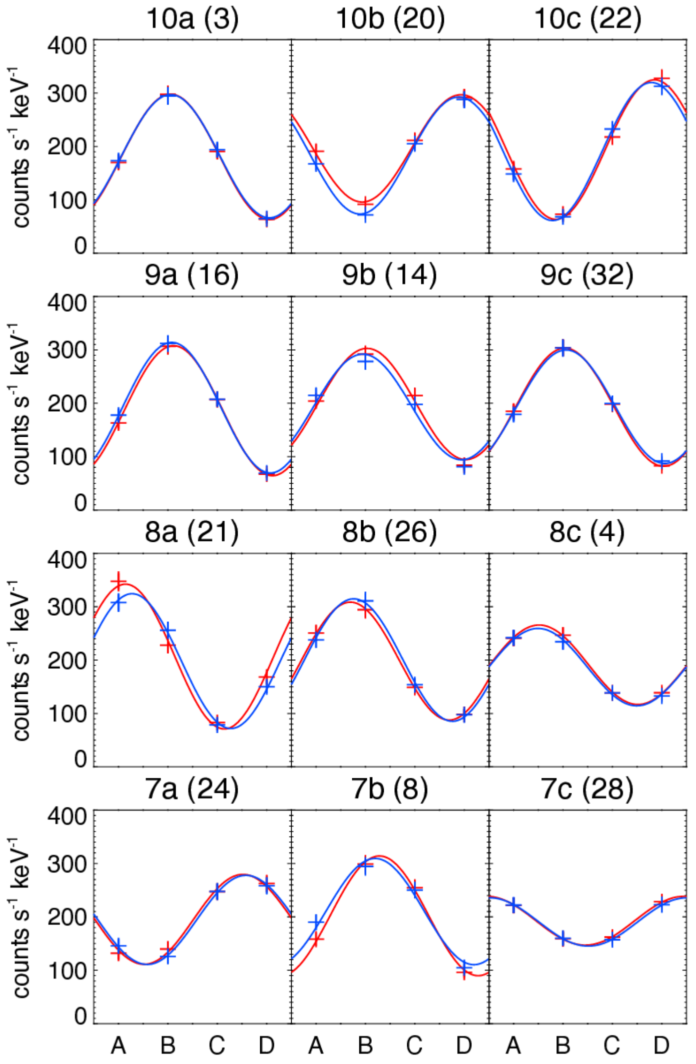



$$\mathrm{Corr} = \frac{\int_{5}^{6} E^{-\gamma}\, \mathrm{d}E}{\int_{5.04}^{5.97} E^{-\gamma}\, \mathrm{d}E}$$

The spectral index of is fitted from the observed spectrum




NO ELUT CORRECTION




TOP ROW PIXELS

BOTTOM ROW PIXELS

# Open issues

- Tests are currently performed to assess impact of high-voltage turnoff on calibration
- Investigate if smoothing of daily gain/offest values improves accuracy of ELUT correction

# Calibration of the sub-collimator transmission at low energies (~8-20 keV)

Massa et al., *In-flight self-calibration of the STIX grid transmission*, under revision in Solar Physics

# Transmission calibration at low energies

- Consider a dataset of ~100 events with at least one fully-illuminated CFL pixels and very large statistics (>200K counts)

# Transmission calibration at low energies

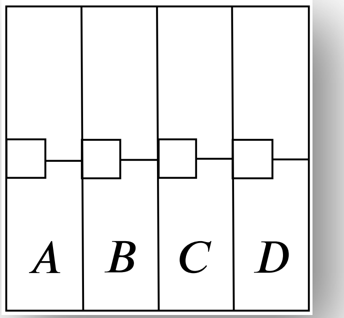
- Consider a dataset of ~100 events with at least one fully-illuminated CFL pixels and very large statistics (>200K counts)

- Integrate pixel data between ***10 and15 keV***: transmission inhomogeneities are negligible

- Estimate total flux $f\ \left[\mathrm{counts\ s^{-1}\ keV^{-1}\ cm^{-2}}\right]$ using CFL data

- Compare with A+B+C+D measured by imaging detectors:

$$t = \frac{\mathrm{A + B + C + D}}{f}$$



# Transmission calibration at low energies

Offset angle $\theta$

- Transmission derived from on-ground optical measurememts ***assuming ideal grids***
- Transmission estimated from flare data
- Linear fit → implemented transmission

# Results

SOL2024-12-08 GOES X2 flare

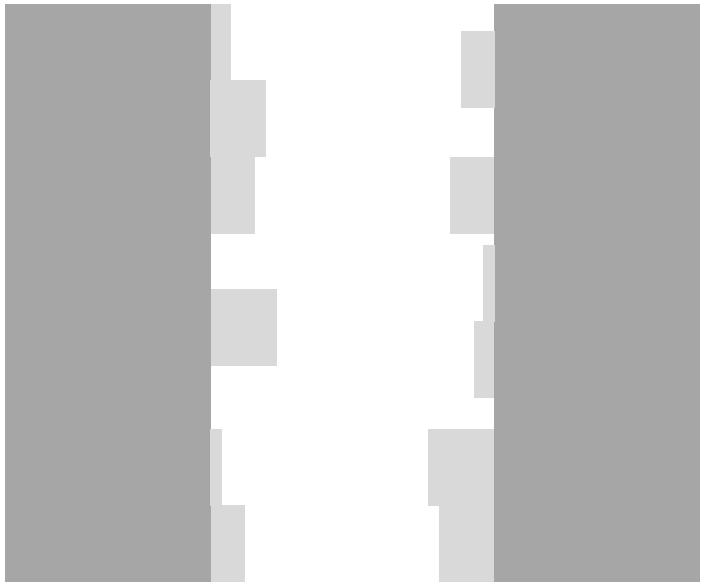
# Calibration of the sub-collimator transmission at high energies

# Problem

- Small-scale imperfections of the grid slats become transparent at high energies → the same transmission calibration can not be applied for every energy range
- CFL-based calibration cannot be performed at high energies
- The amount of slit width increase is comparable for the different subcollimators, but **is relatively more relevant for finer subcollimators**
- We can infer the slidth width increase by modelling the grid geometry and comparing the total flux at high energies of the different subcollimators

# Wedge model

Grid imperfections
(stacking errors, etc.)



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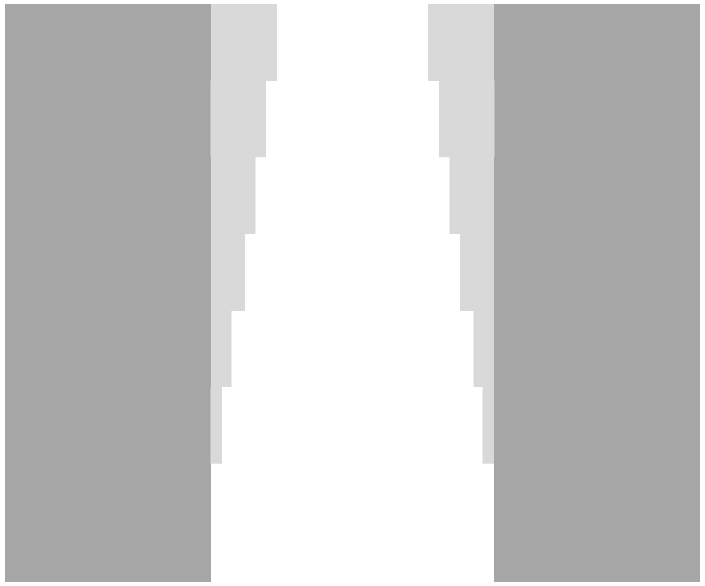

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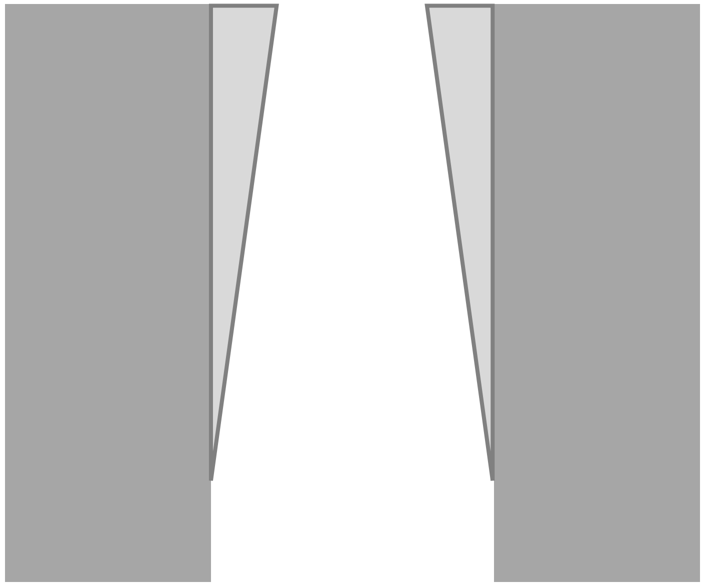

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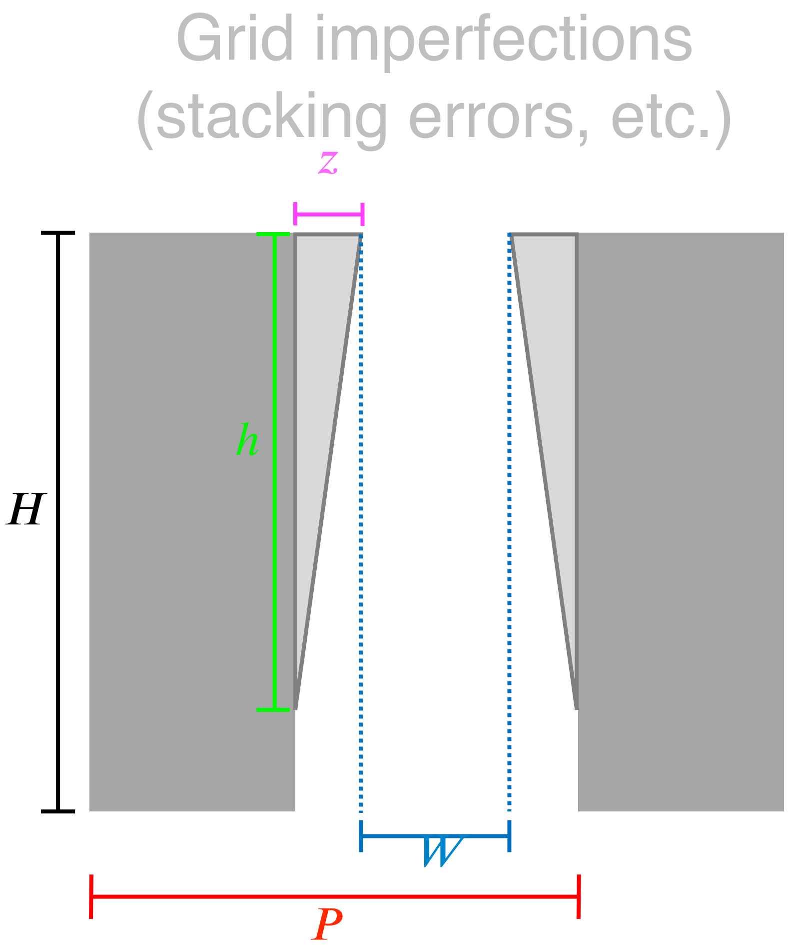
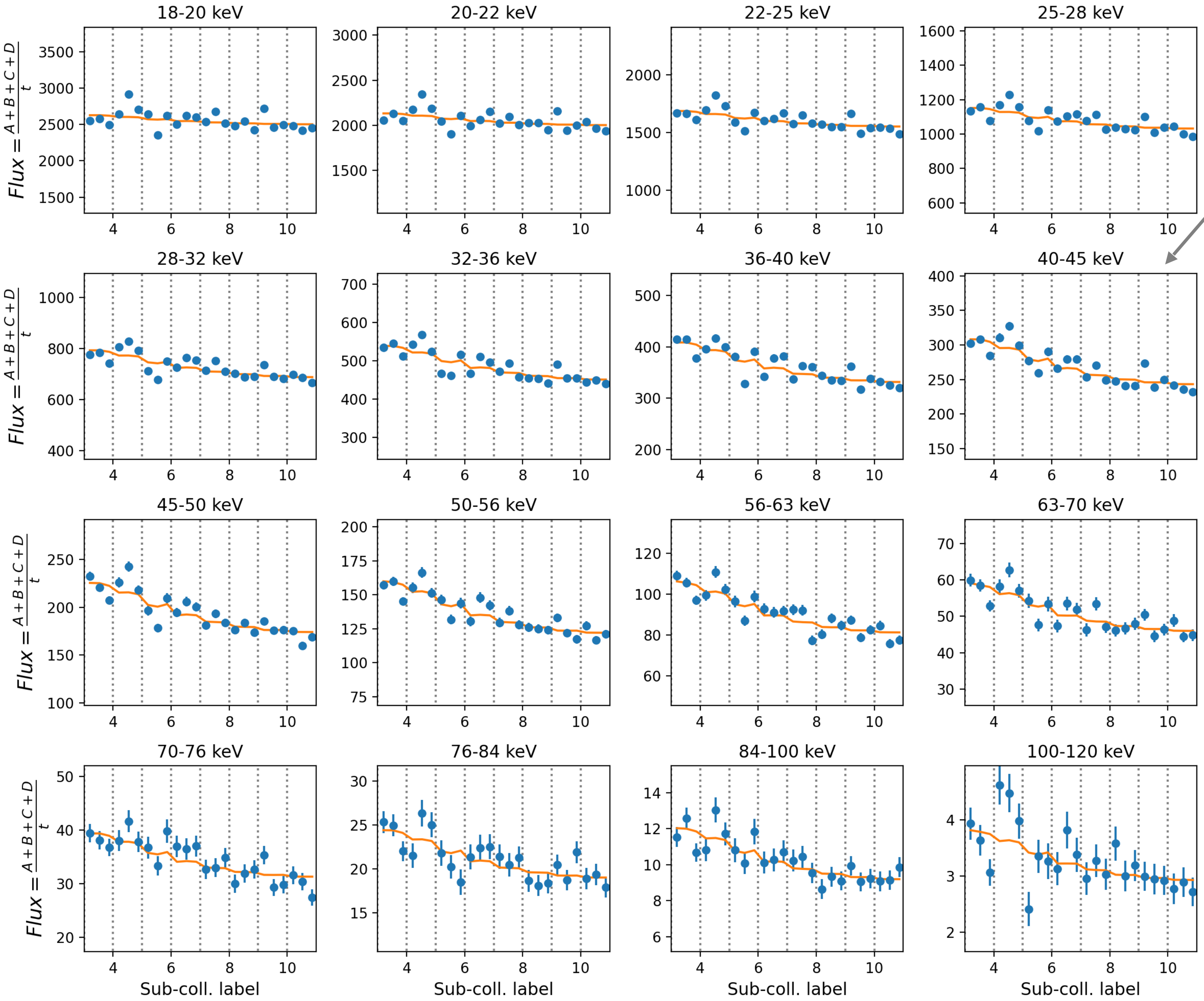



- The grid profile is modelled considering a wedge shape, which is parameterized by $h$ and $z$

- We assume that the shape of the wedge is the same for all sub-collimators

- Consider data from all subcollimators and all energy ranges simultaneously, and perform a (non-linear) fit for $h$ and $z$

# Wedge model

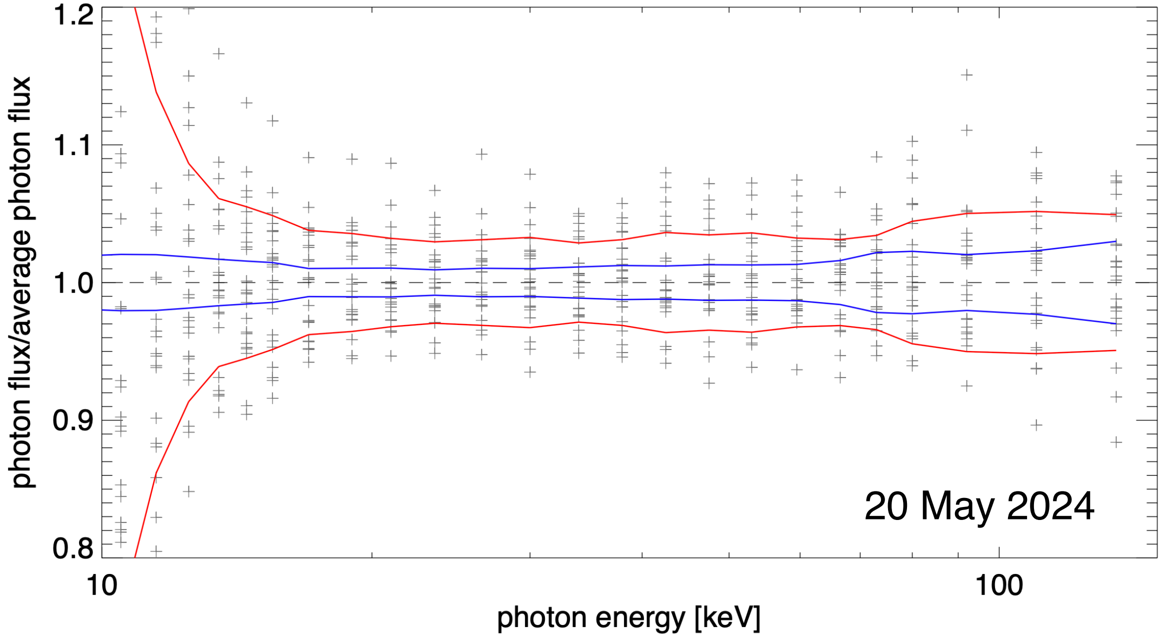



Fit of $h$ and $z$ considering all subcollimators and all energy ranges simultaneously

Fitting 4 different events, we obtain
$h$ : 48.7 - 62.1 μm
$z$ : 4.6 - 5.1 μm

In the IDL software, we implement a wedge model with $h = 50$ μm and $z = 5$ μm

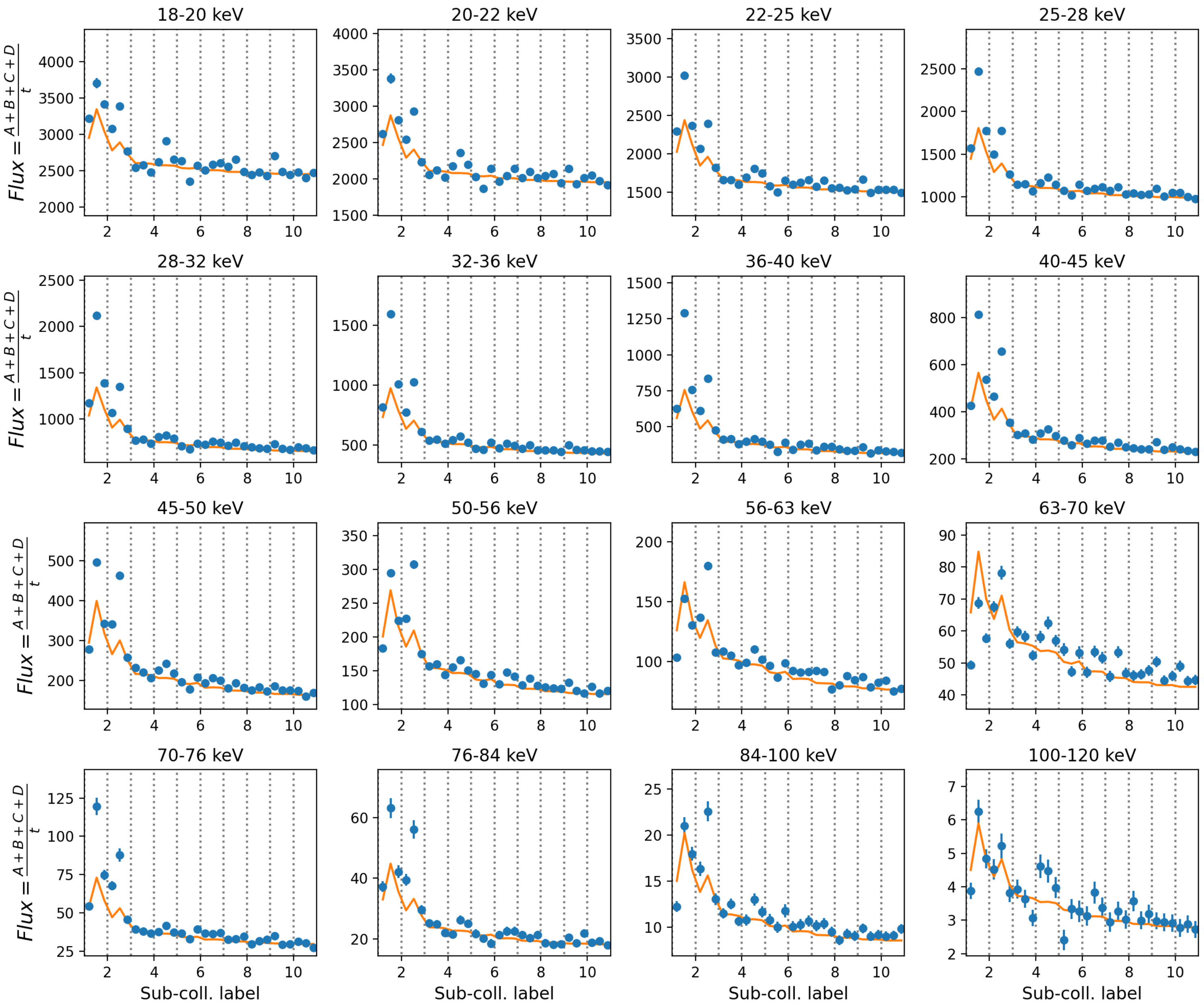
# Self-consistency check




- Independent fit of each subcollimator with two thermals, a thick target and albedo
- Crosses indicate the derived photon spectra of the different subcollimators <u>relative to the averaged photon spectrum</u>
- Blue line: relative error from counting statistics and compression errors in a single detector (**below ~2%**)
- Red line: standard deviation of the observed scatter between the detectors (**3 to 5%**)

Courtesy of Säm Krucker

# Wedge model – sub-collimators 1 and 2



# Open issue: energy dependent visibility amplitude calibration

# Visibility amplitude calibration

- The visibility amplitudes are currently computed as

$$\mathscr{A} = \beta \cdot \sqrt{(C - A)^2 + (D - B)^2}$$

where, the calibration factor is

$$\beta = \frac{\pi^3}{8\sqrt{2} \cdot \mathscr{P}} \cdot \frac{1}{\sin\left(\pi \frac{s_f}{p_f}\right) \cdot \sin\left(\pi \frac{s_r}{p_r}\right)}$$

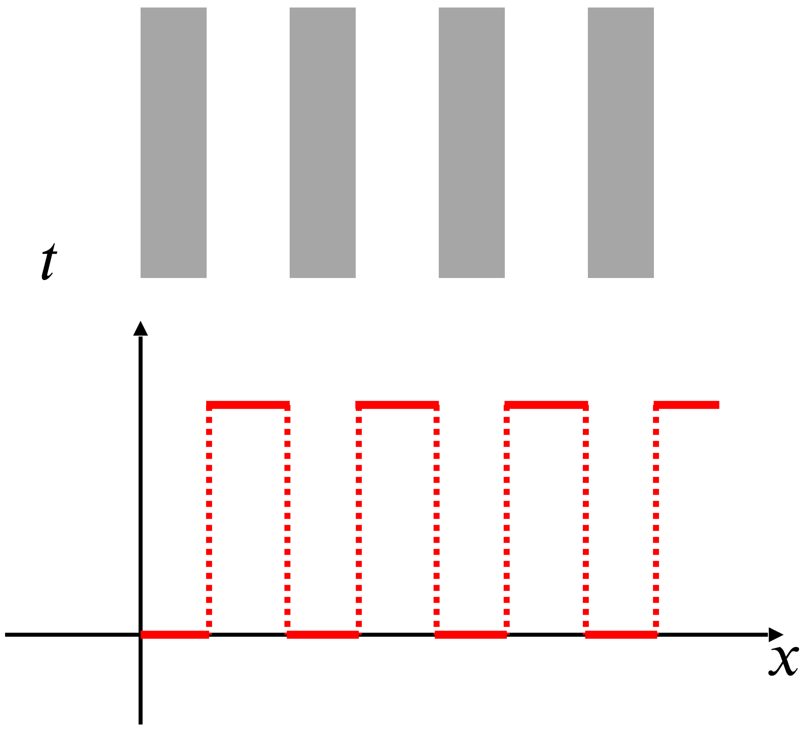
with

  - $\mathscr{P}$: pixel area
  - $s_f$, $s_r$: slit width of the front and rear grid, respectively
  - $p_f$, $p_r$: pitch of the front and rear grid, respectively

- In the current version of the software, we set

$$\frac{s_f}{p_f} = \frac{s_f}{p_f} = \sqrt{t}$$

In *The STIX Imaging Concept* paper, this visibility amplitude calculation is derived assuming perfectly opaque grids



# Visibility amplitude calibration

Simulated
grid profile

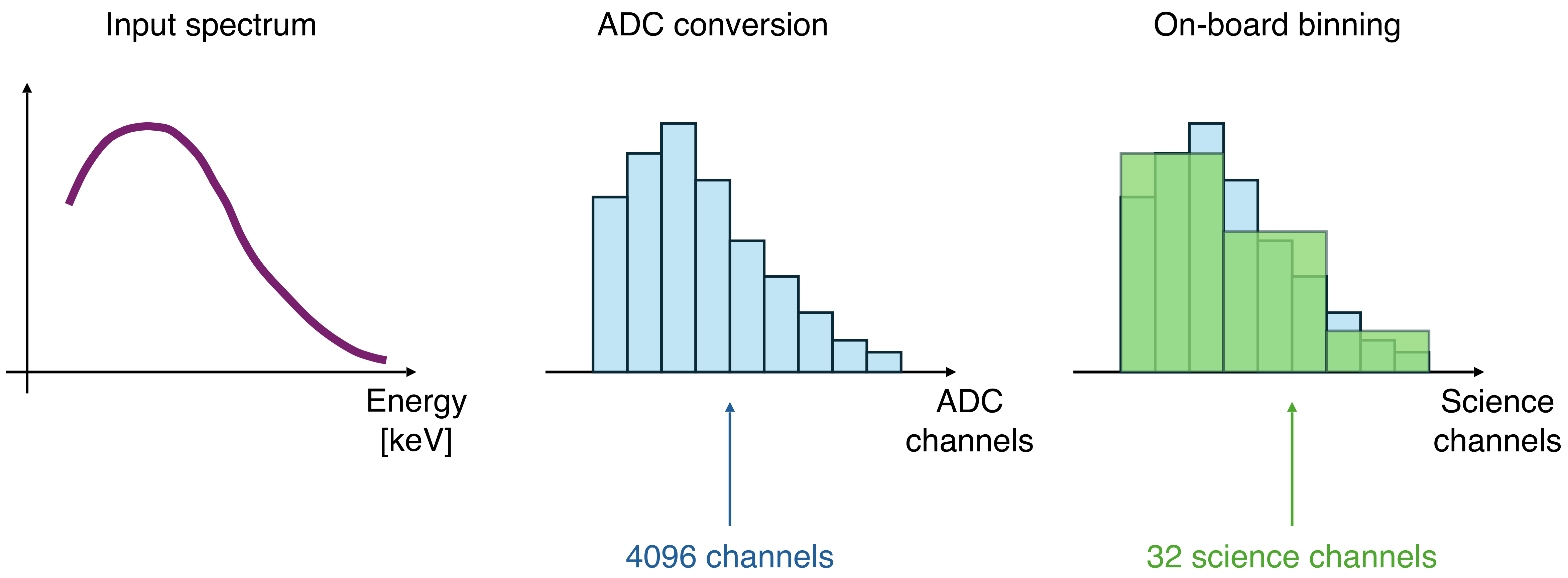
Ideal grid transmission
Simulated grid transmission

10 keV

60 keV

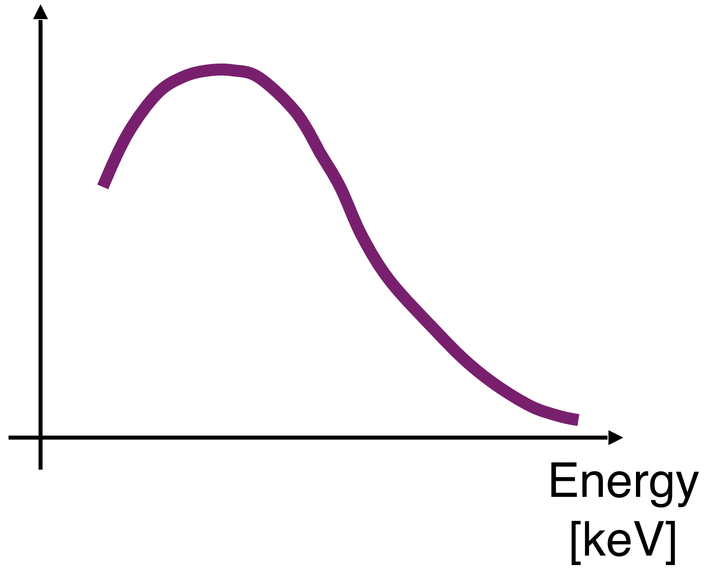
Thank you for the attention!

# Energy LookUp Table (ELUT)



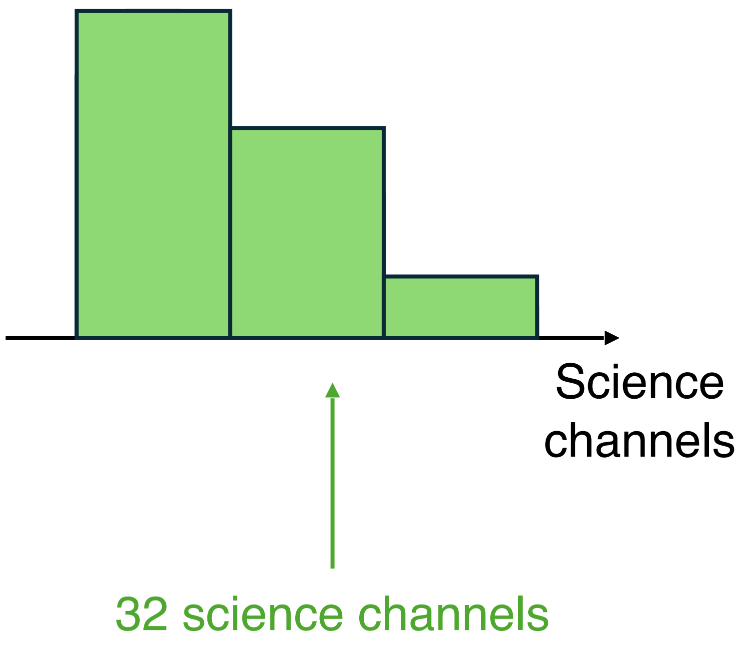
# Energy LookUp Table (ELUT)

Input spectrum




The edges (in keV) of the science energy bins are slighlty different from pixel to pixel

On-board binning



# Results

- Gray lines: $\dfrac{A+B+C+D}{t}$ normalized by the average across all sub-collimators
- Each of the 25 gray lines corresponds to a flaring event recorded between March and December 2025

- SOL2024-12-08 GOES X2 flare
- Each line represents the normalized photon spectra fitted from each individual sub-collimator

# Results

Grid imperfections reduce on axis transmission and impact of  internal shadowing