22 years of Cd/Te detector: Challenges of ISGRI calibration

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Overview

Evolution of ISGRI

- Presentation of the detector
- Detector evolution and consequences

ISGRI Calibration

- Method
- Challenges in calibration
- Illustration of recent results

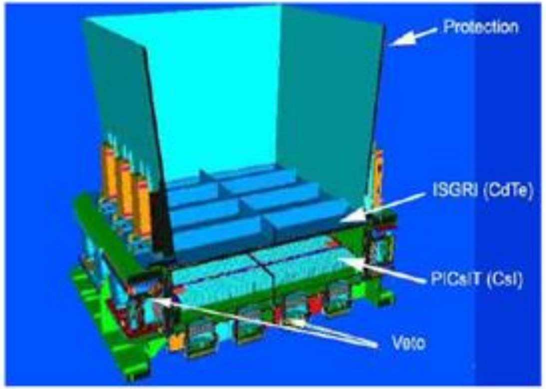
ISGRI Detector Model

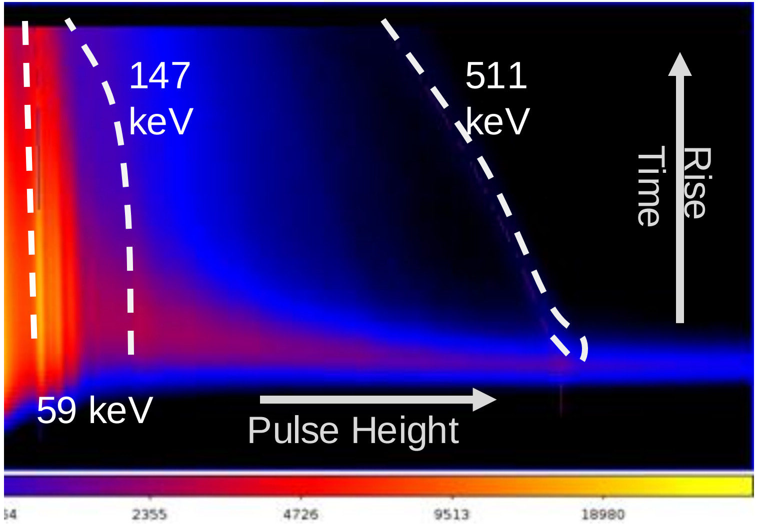
For each incident photon, ISGRI measures Pulse Height (PH) and Rise Time (RT).

A **single incident energy occupies a 2D region in the PH-RT space**. This region has complex properties

- Non-linear effective gain in the whole energy range
- Response at 20 keV extrapolated from the ~60–511 keV region

The IBIS coded mask, placed at 3.2m from detector. Built using 16mm thick W blocks, min.size 11.2mm





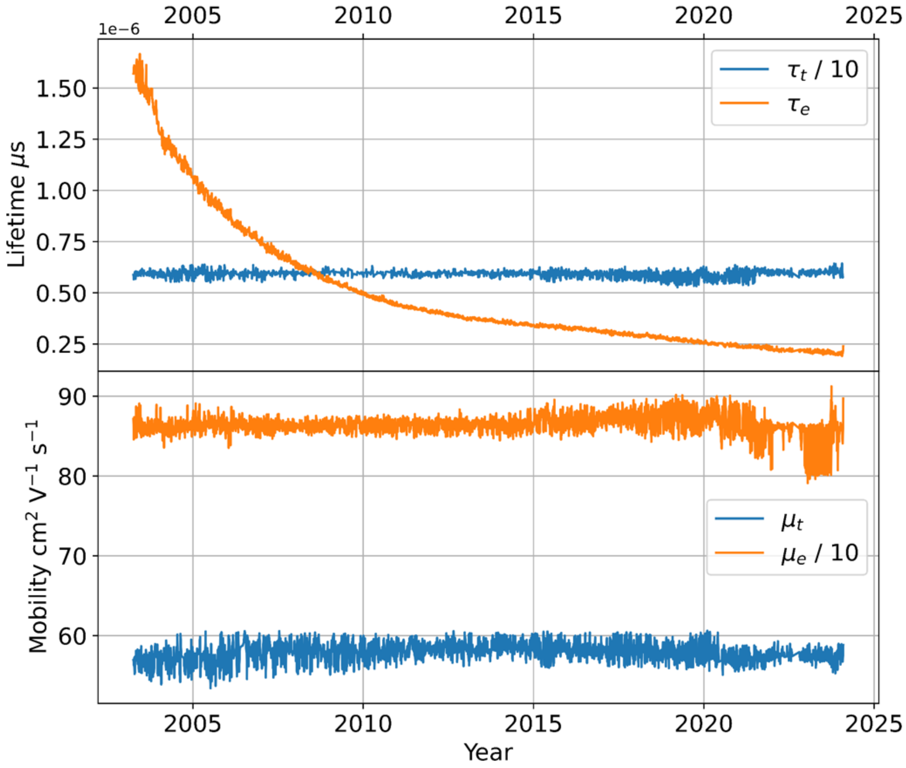
Count rate in PH-RT bins

Detector Evolution

Calibration process involves fitting 6 detector parameters:

- Detector gain
- Offset
- Electron lifetime & mobility
- Hole lifetime & mobility

Significant reduction of electron lifetime over the course of the mission has an impact on ISGRI spectral response



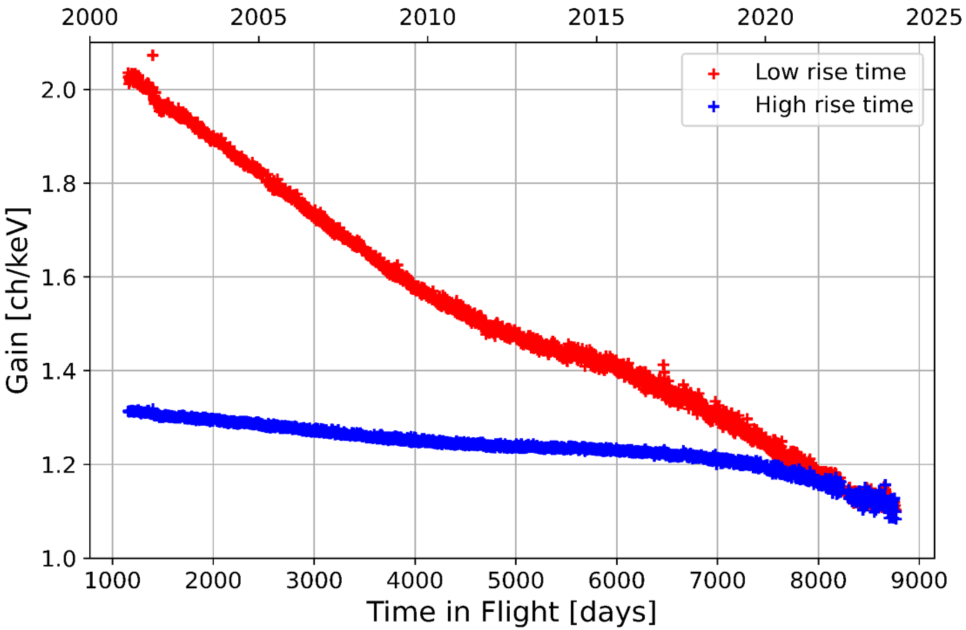
Detector Evolution

Short rise time pulses strongly dependent on electron carrier properties

In more than 20 years the gain of ISGRI has decreased by factor ~2

- Driven by the loss of electron lifetime in CdTe with irradiation

Gain variations are not significant on timescales of a single orbit (0.006%)

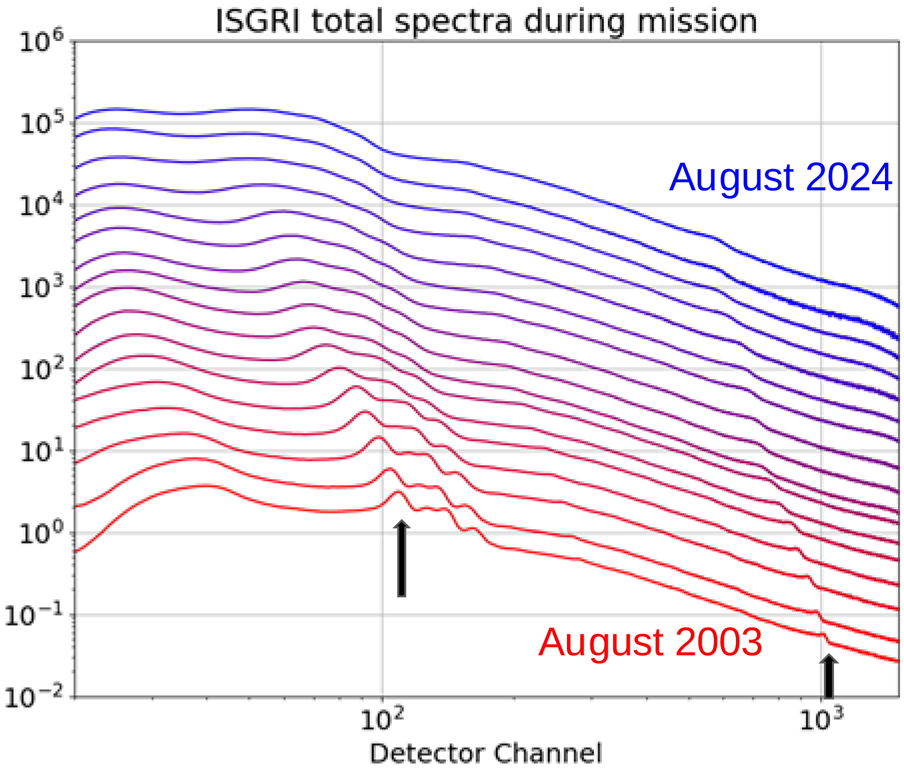


Calibration Lines

Calibration lines visible in ISGRI total spectra

Energy resolution to first approximation degraded due to gain drift.

Challenge fitting calibration lines due to detector evolution

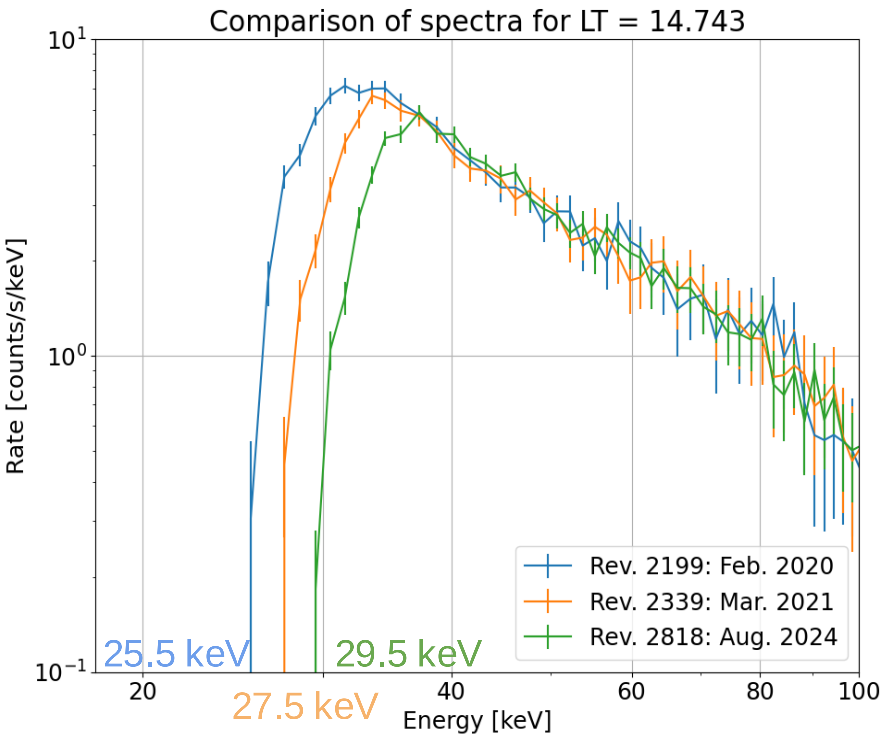


Low Threshold Evolution

Low Threshold (LT) defined for each pixel in the detector

- Every revolution
- Threshold below which events are ignored
- Avoids contribution from noisy pixels

LT is fixed in the Pulse Height, therefore gain drop implies **rise of the Low Threshold in keV.**



Calibration

Summary of key stages

- Reconstruct deposited photon energies
- Reconstruct equivalent count rates
  Fitting of ISGRI efficiency using Crab calibration spectra
- Adjustment of energy resolution in ISGRI response
  (optional, work in progress)
- Validation of calibration
  Fitting of spectra from bright sources

Challenges

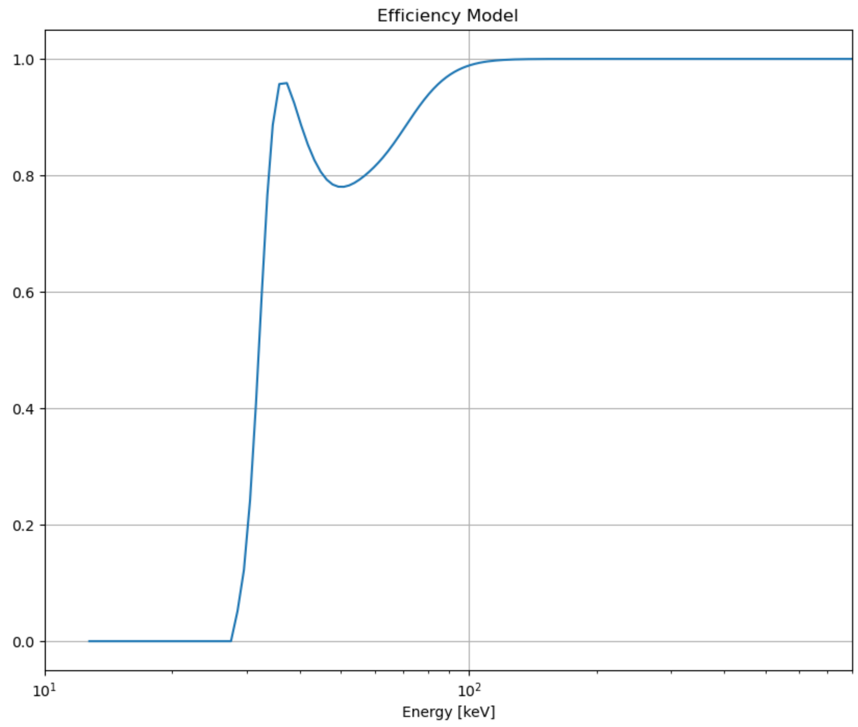
- Above ~60 keV, we can mostly rely on detector model for calibration.
- Challenging to derive the low-energy efficiency
- Fundamental as the LTs vary over time with detector evolution and influence the spectra at low energies.

Efficiency Fitting

Efficiency is fitted empirically with skewed Gaussian

- Minimal number of fitting parameters for long-term consistency
- Optimisation problem through loss function
- Separate fitting for each LT setting based on data from one revolution

Assumptions during event selection updated for computing calibration spectra.



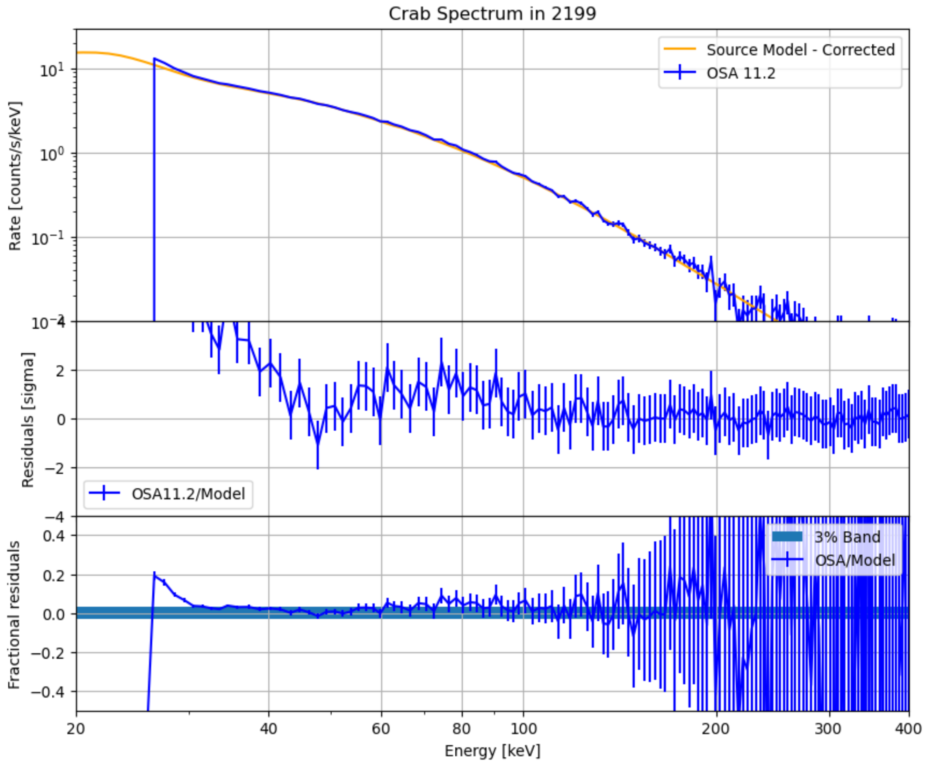
Efficiency Fitting

Verification of fitted efficiency:

- Reconstruction of Crab spectrum in OSA 11.2
- Comparison with flux model

Criterion for quality of fit:

- Fractional residuals within 3%
- Unstable below 30 keV



Calibration Validation

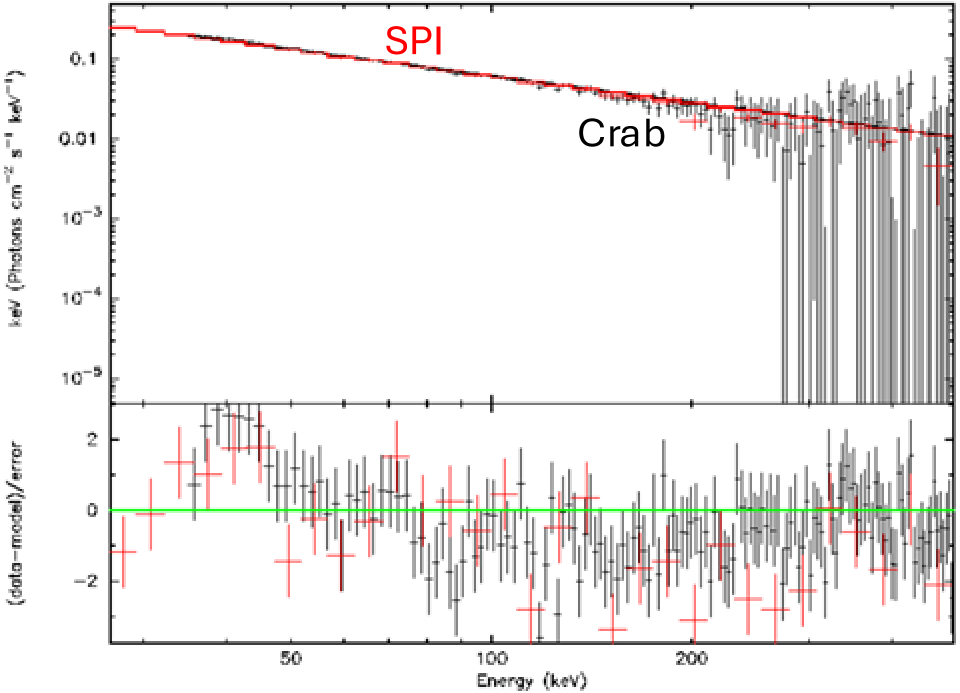
Reproducible workflows

- Appropriate model fitted to source spectra

- Spectral properties compared with SPI / NuSTAR

Capable of achieving reasonable calibration results for recent revolutions

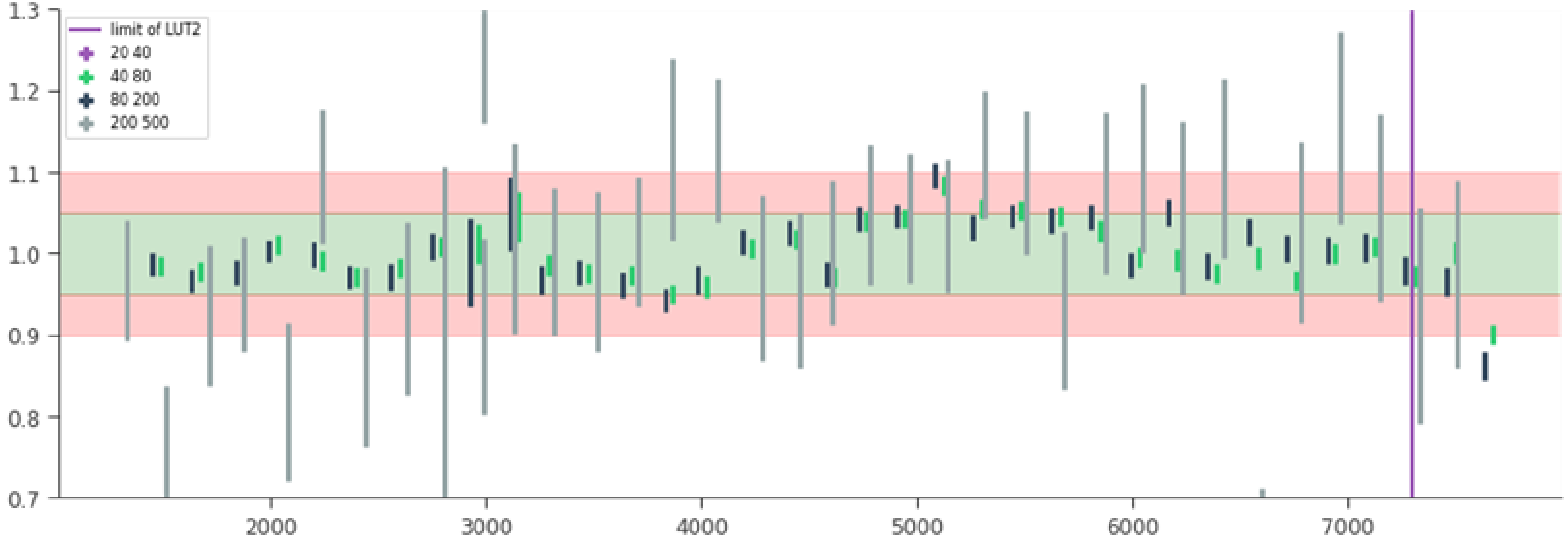
Rev. 2536 - January 2023



Long-term count rate: Crab

Crab flux relative to mean value

- Stability within 3 sigma



Current Status

Calibration validity update	Currently only valid until 2020
	Update starting from rev. 2200
Detector model	Fit complete from 2200 to 2744
	Full calibration every 6 months
Efficiency fitting	Currently in validation stage
	RMF adjustments mainly for overall normalisation

Release expected for end of operations

Thank you

Oliver Dürfeldt Pedros

ISGRI Energy Reconstruction Challenges

Compression of the 2D distribution of events leads to difficulties in fitting calibration lines around 60 keV. Line at 511 keV remains clearly identifiable.