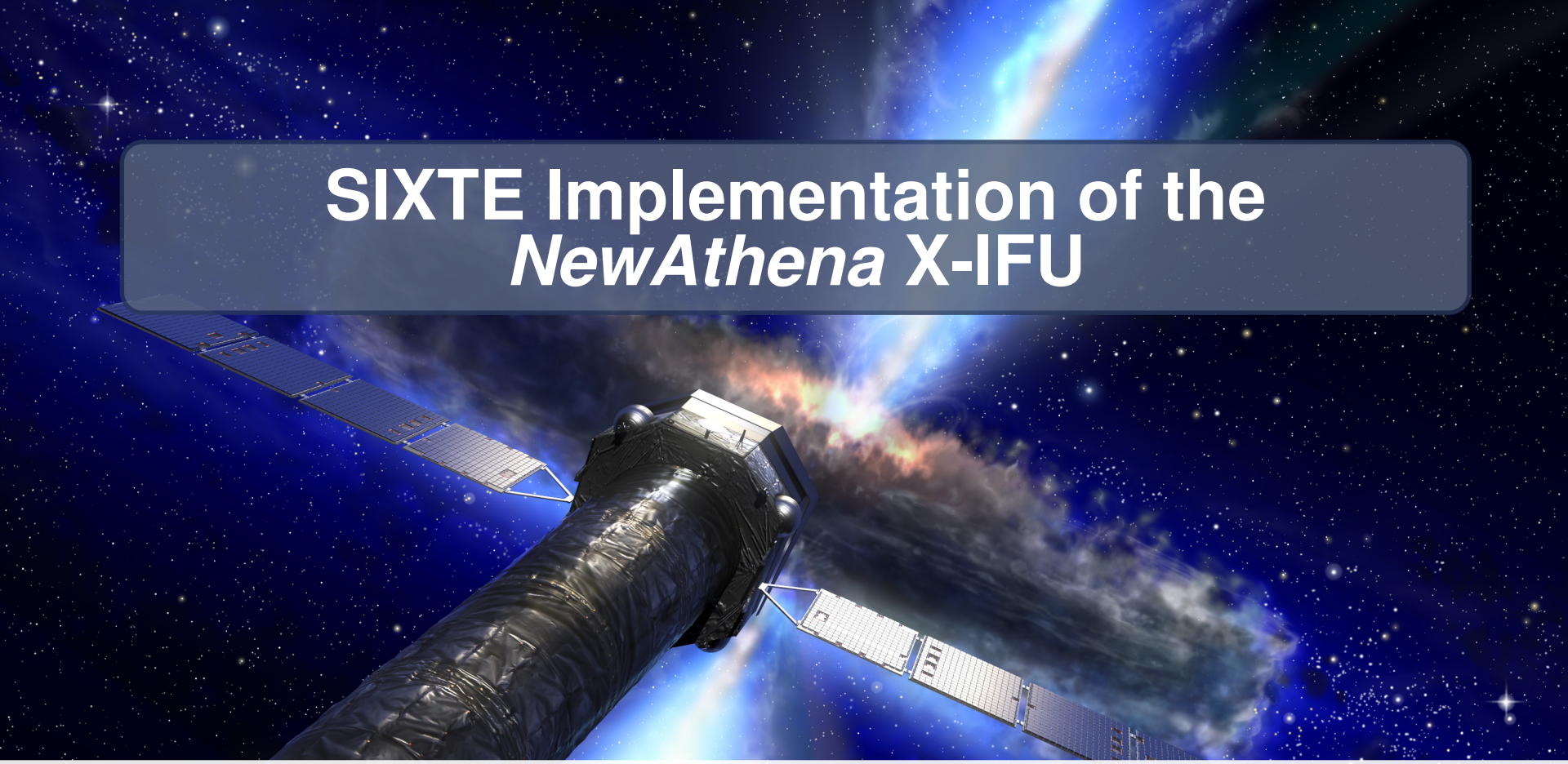
SIXTE Implementation of the *NewAthena* X-IFU



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Remeis Observatory & ECAP

SIXTE Workshop — November 2024

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

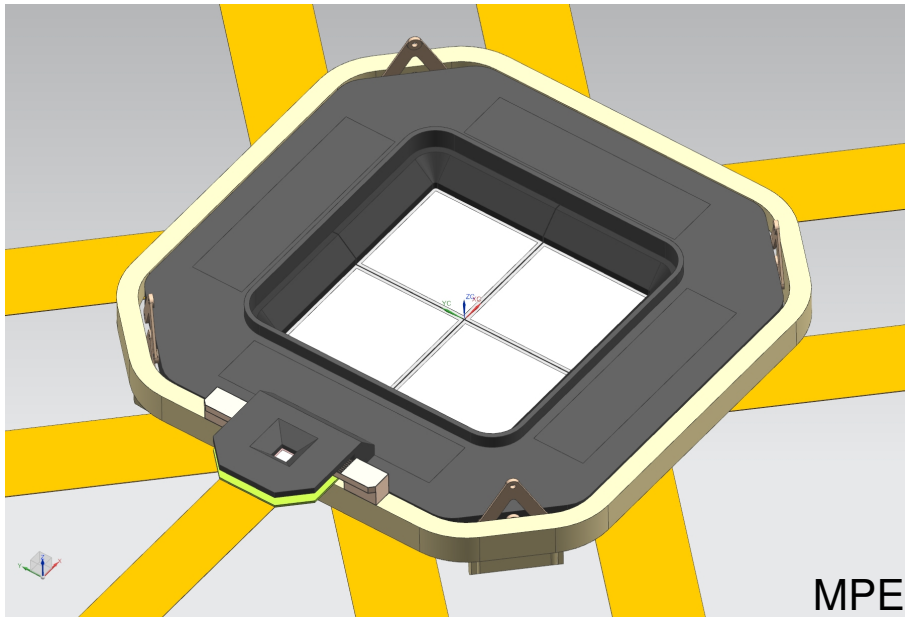
WFI ATHENA

IFU ATHENA X-ray Integral Field Unit

The *NewAthena* Instruments

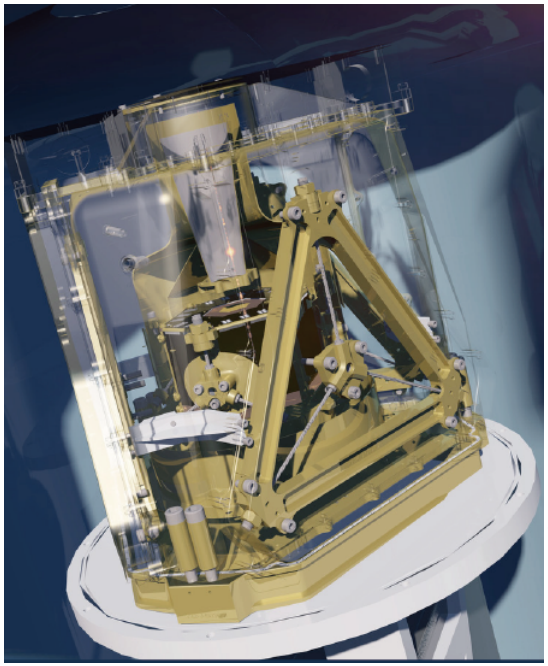
WFI (Imager)

- high count-rate, moderate spectral resolution
- **large field of view**



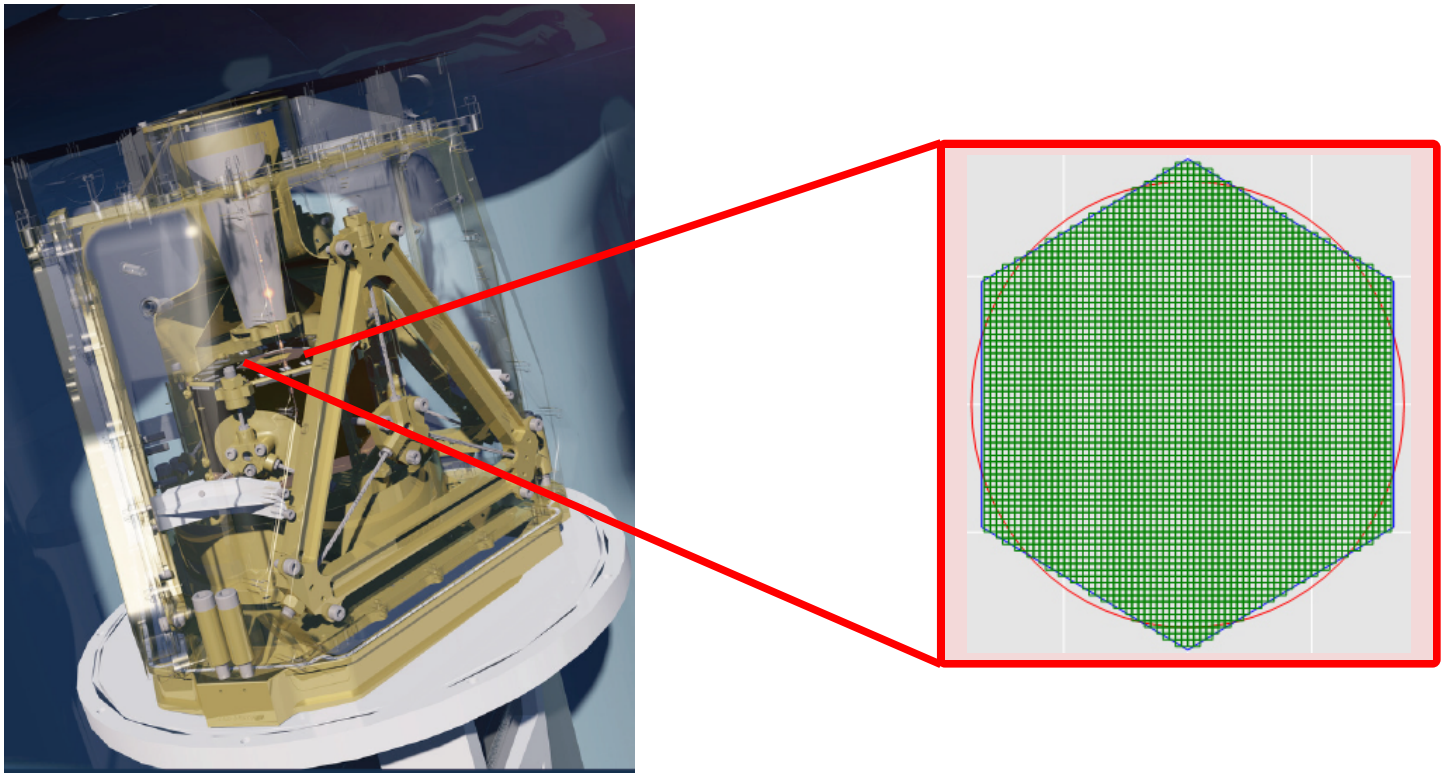
X-IFU (Calorimeter)

- for **high-spectral resolution imaging**
- calorimeter operating at 50 mK



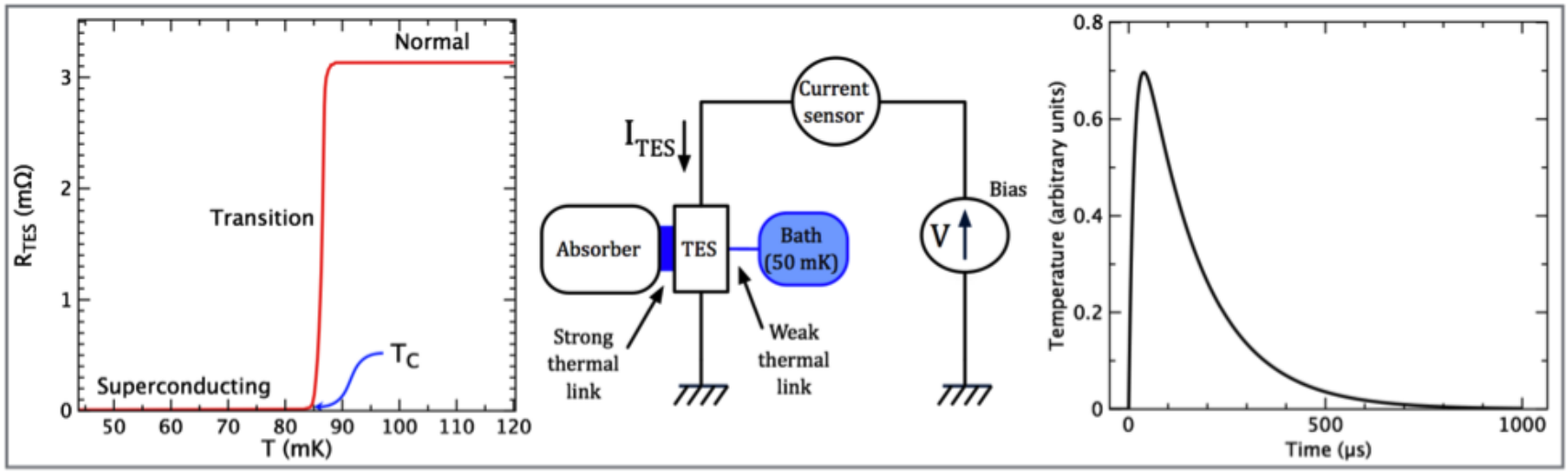
The X-ray Integral Field Unit (X-IFU)

- very high spectral resolution imaging (4 eV FWHM and a 4’ FoV)
- 1504 TES (Transition Edge Sensor) pixels



The X-ray Integral Field Unit (X-IFU)

Pixels are single *Transition Edge Sensors*, operated at 50 mK
$\Rightarrow$ **measure temperature increase** of photon hitting the pixel



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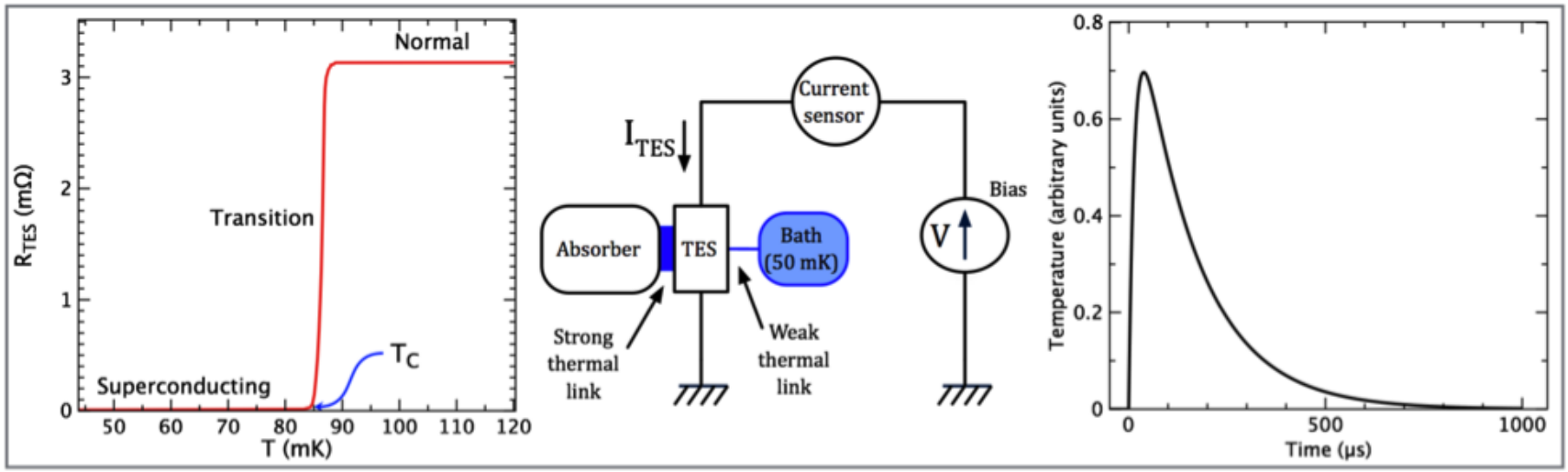

- numerical solution of differential equations for $T(t)$, $I(t)$ (Irwin & Hilton, 2005),

$$C\frac{dT}{dt} = -P_{\rm b} + P_{\rm J} + P + \text{Noise} \quad \text{and} \quad L\frac{dI}{dt} = V - IR_{\rm L} - IR(T, I) + \text{Noise}$$

- linear resistance, $R(T, I; \alpha, \beta)$; noise: Johnson of circuit, bath, excess noise
- input parameters: C, $G_{\rm b}$, n, α, β, m, R_0, T_0, $T_{\rm b}$, $L_{\rm crit}$

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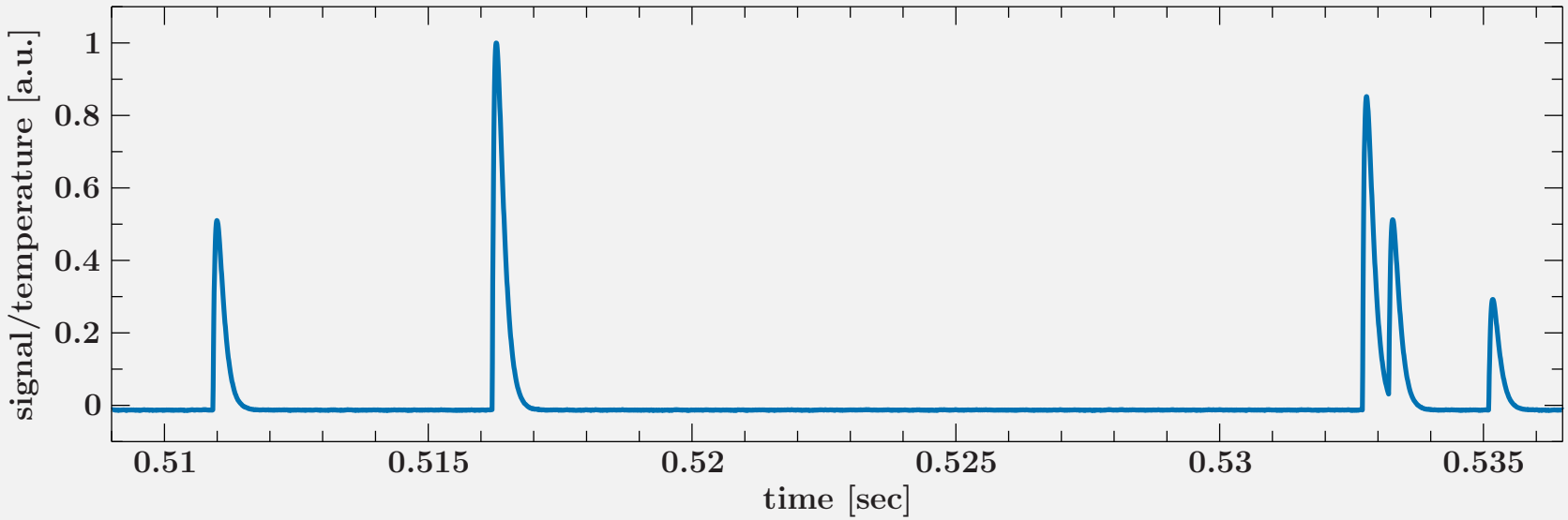


pulses with smaller separation yield lower energy resolution
$\Rightarrow$ **Event Grading** depending on the source flux

X-IFU Implementation in the end-to-end simulator SIXTE

`sixtesim`:

- full detector array
- full imaging implemented
- fast detection simulation using response matrices (works similar to CCD-type simulations)

⇒ **science simulations**

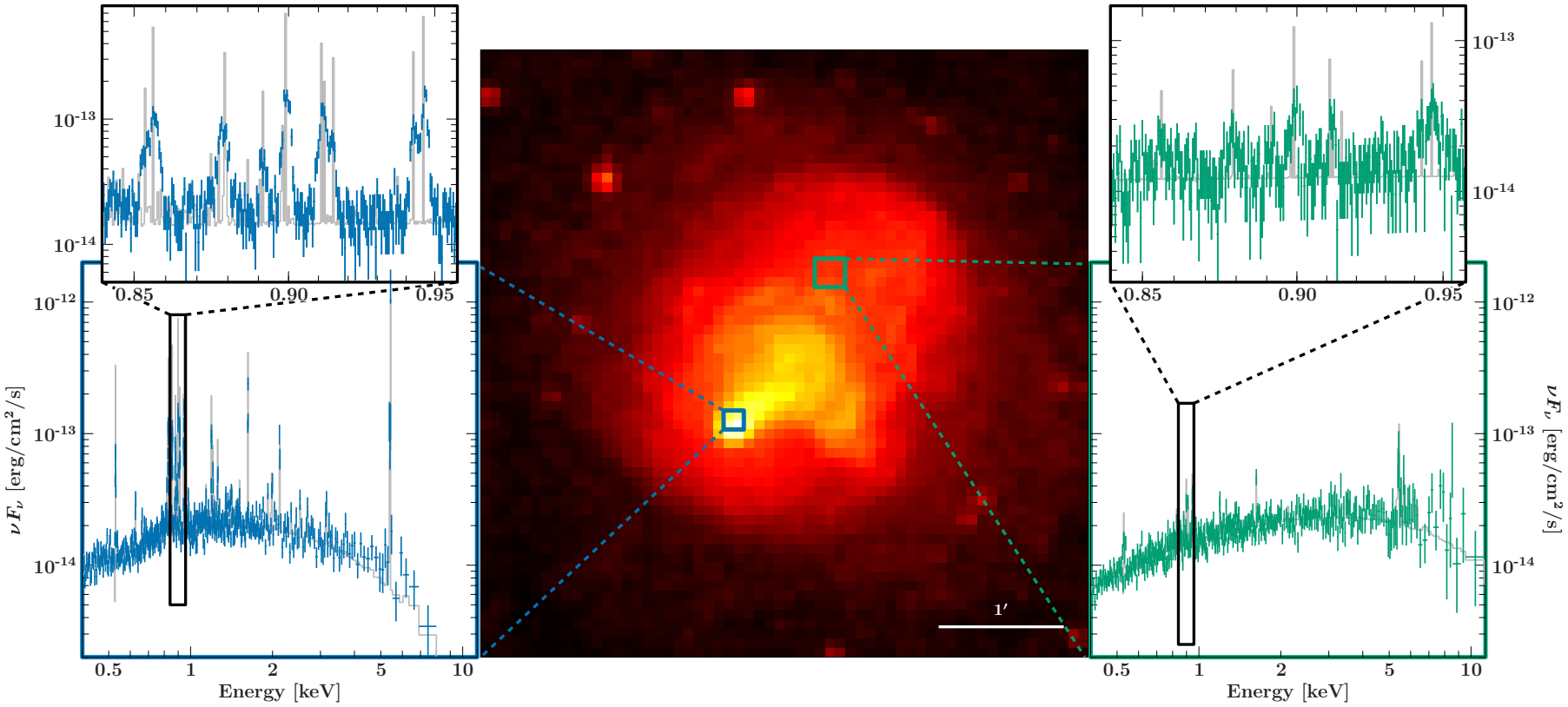
`tessim/xifusim + SIRENA`

- Simulation of TES physics and pulse reconstruction
- Slower than `sixtesim`, but much better physics
- pixel interaction (crosstalk)

⇒ **Input for** `sixtesim`

⇒ **physics-based** `tessim/xifusim` **results converted to be used in the fast and general** `sixtesim` **simulation (event grading, crosstalk, . . .)**

Example: SIXTE X-IFU simulation of a Galaxy Cluster

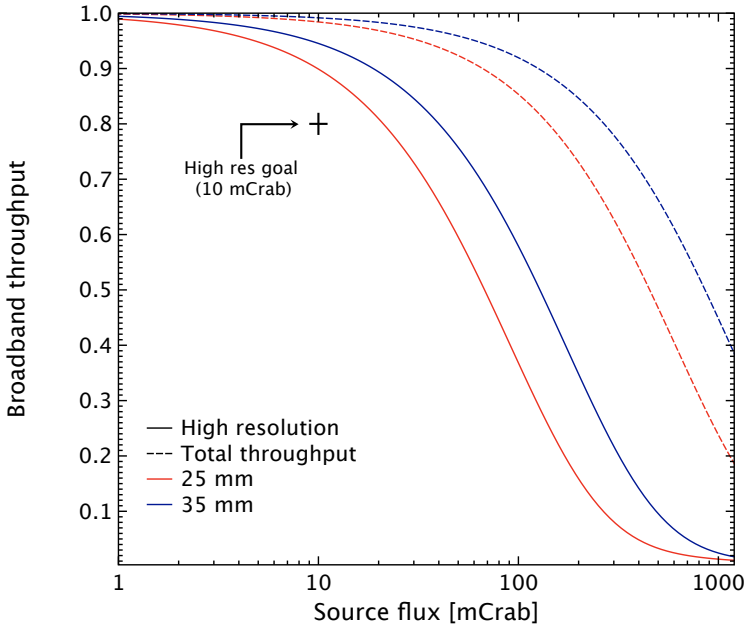


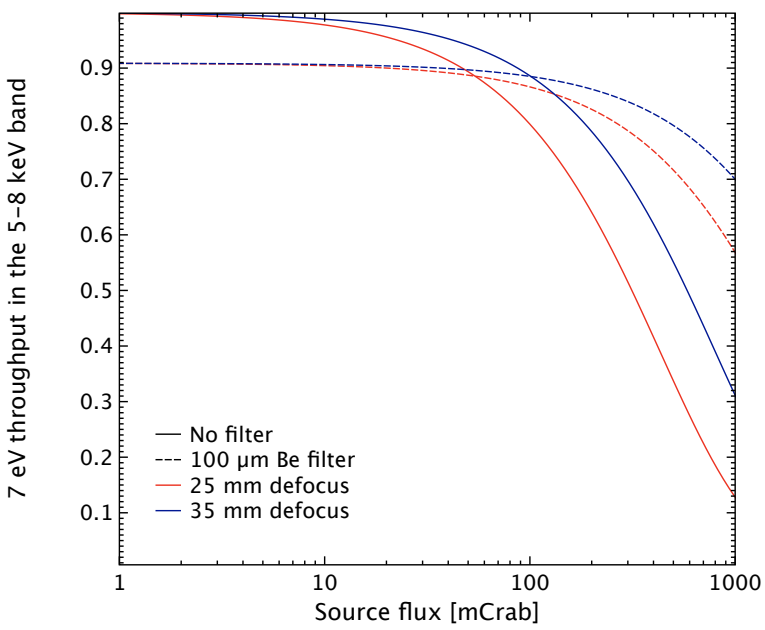
SIXTE describing, simulating, and analyzing complicated sources

X-IFU spatially resolved high-resolution spectroscopy

Performance at High Countrates (grading effect only)

defocusing of the NewAthena optics allows observations up to 1 Crab





Grade	Δt since previous pulse	Δt until next pulse	Energy res.
(1) Very High res.	$\geqslant$ 24.0 ms	$\geqslant$ 55.2 ms	4 eV
(2) High res.	$\geqslant$ 24.0 ms	$\geqslant$ 26.8 ms	$\sim$ 4 eV
(3) Intermediate res.	$\geqslant$ 12.0 ms	$\geqslant$ 11.1 ms	4.2 eV
(3) Medium res.	$\geqslant$ 12.0 ms	$\geqslant$ 3.16 ms	5 eV
(3) Limited res.	$\geqslant$ 12.0 ms	$\geqslant$ 1.20 ms	7 eV
(3) Low res.	$\geqslant$ 12.0 ms	$\geqslant$ 0.05 ms	30 eV

Crosstalk in SIXTE

unintended transmission of information between signal channels

Different types of crosstalk:

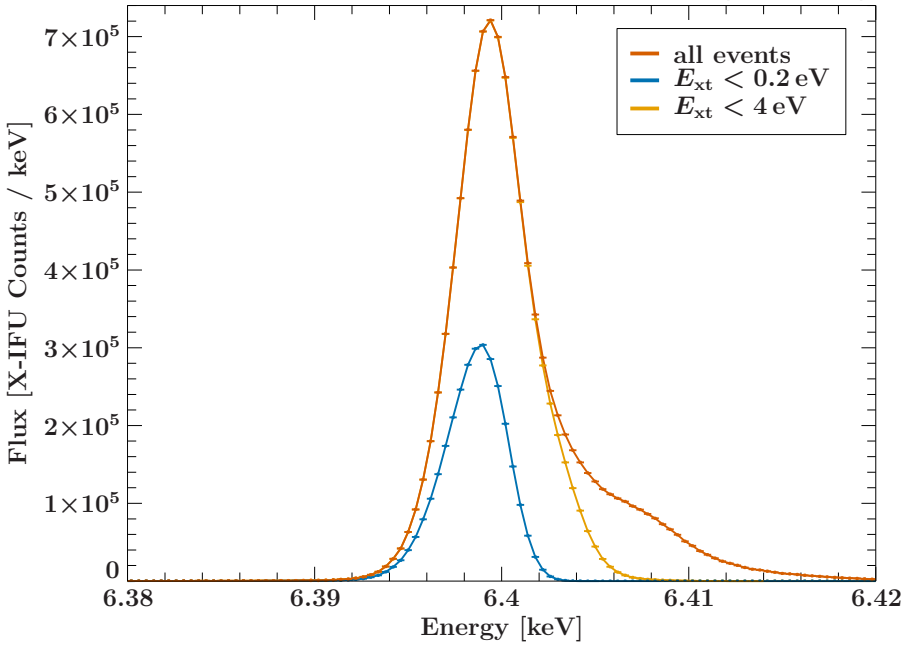
- thermal coupling of two pixels (physical neighbors)
- electrical coupling due to e.g. mutual inductance
- coupling due to multiplexed readout (TDM)

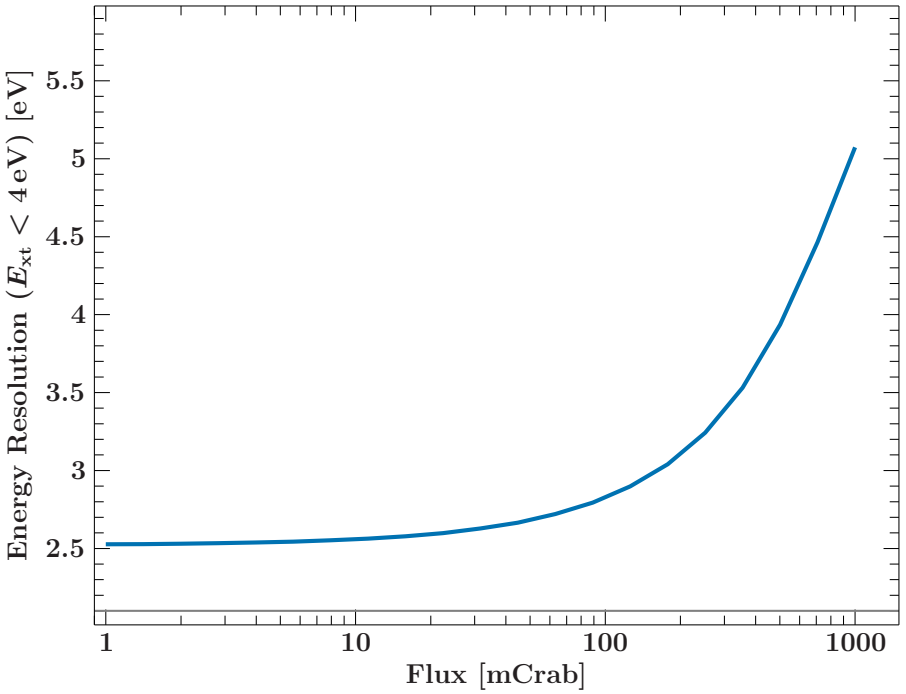
$\rightarrow$ implemented in SIXTE

crosstalk effect on events is predictable

How does Crosstalk affect X-IFU Events?

simulation of a narrow emission line (1 Crab)





$\Rightarrow$ remove events which are *strongly* effected by crosstalk

trade-off between energy resolution and throughput $\Rightarrow$ 10 eV resolution with 50% throughput @ 1 Crab

XML files

Microcalorimeters require some extra XML tags:

Grading

- Define grades via distance in time to previous and next pulse
- Per grade, use a different RMF to calculate measured energy

Crosstalk

- Readout channel specification
- Lookup tables for Crosstalk Mechanisms

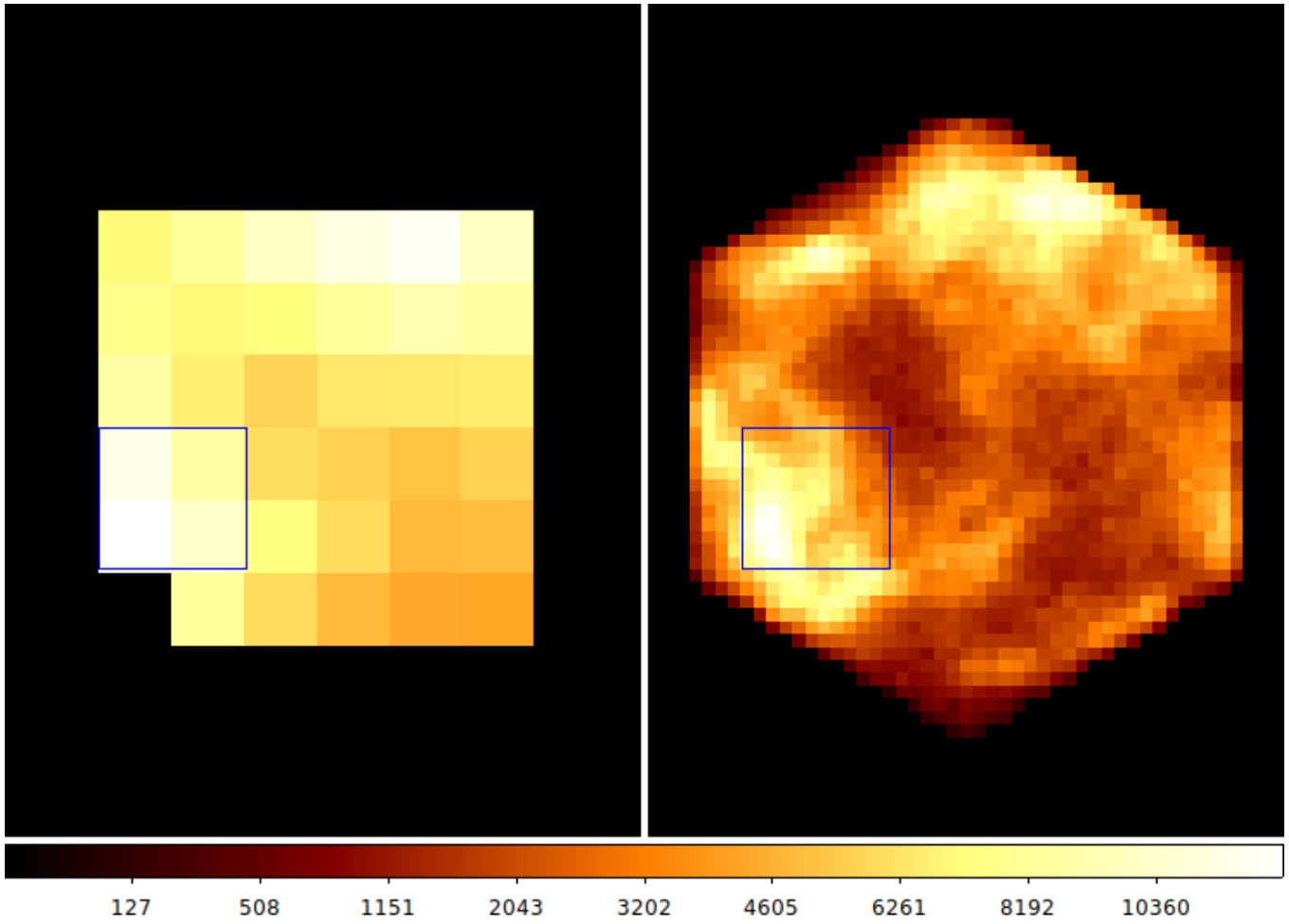
XRISM Resolve

How do we simulate XRISM Resolve with SIXTE?

Simply use `sixtesim` with a different XML!

This simulates the Grading effect as well. Crosstalk is not yet implemented, due to lack of data.

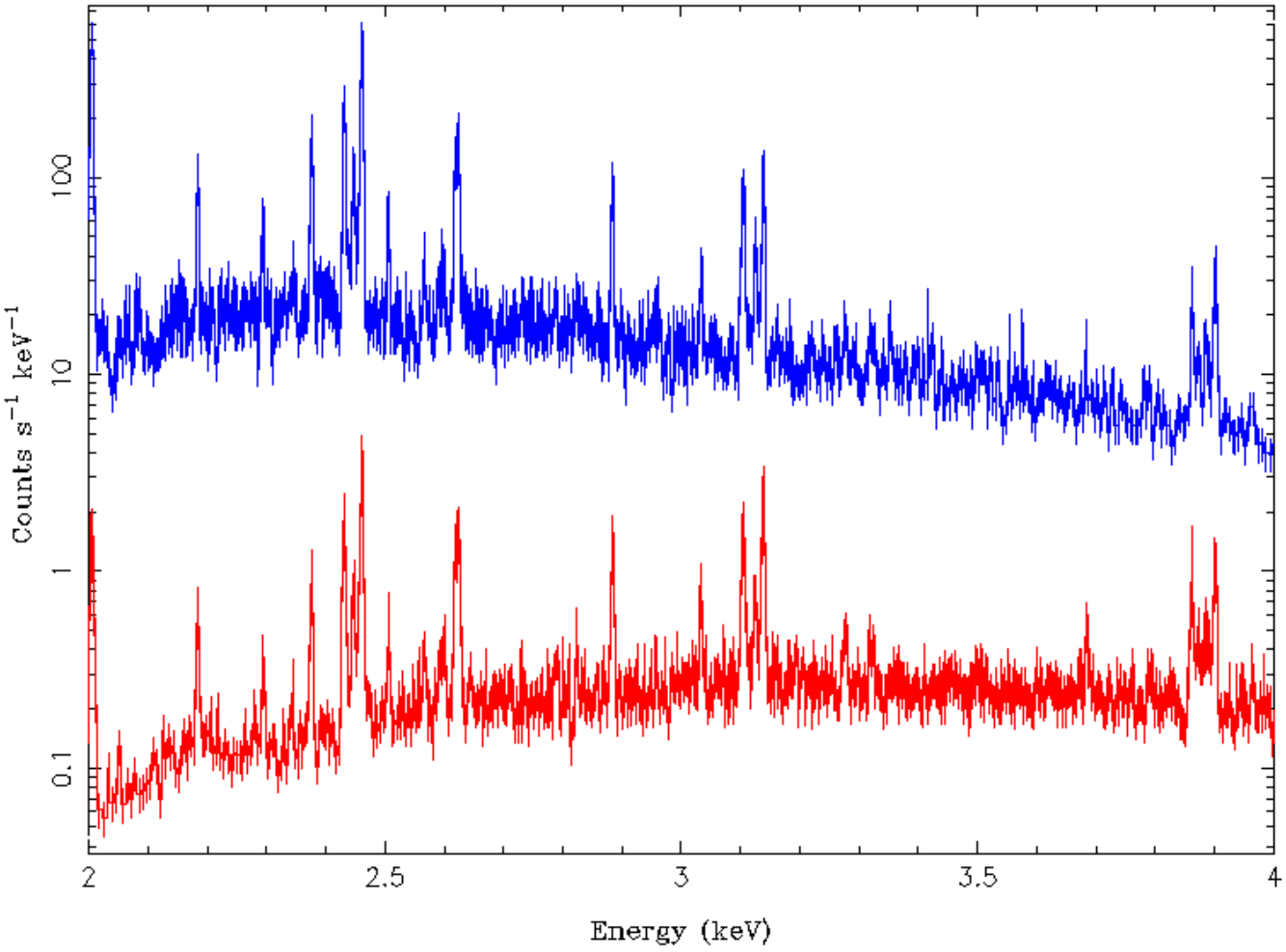
Example Cas A, center



50 ks Resolve with Gate Valve

1 ks X-IFU with Thick Be Filter

Example Cas A, center



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Summary: The X-IFU with SIXTE

- 1504 TES pixels in a hexagonal array
- 4’ FoV
- higher flux ($>$ 10mCrab) reduces energy resolution and throughput
- science simulations with `sixtesim`, taking the most important TES physics effects into account
- physics input to the simulation pipeline by `tessim`/`xifusim`