SIXTE Implementation of the *Athena* WFI

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on behalf of the SIXTE team

End-to-end simulations with SIXTE: An online workshop, March 2022

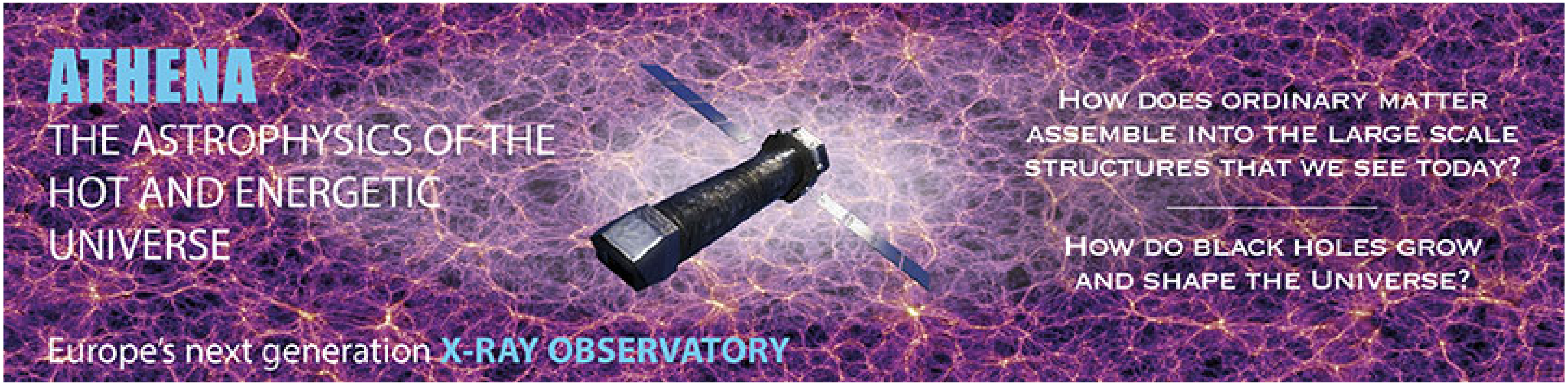
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

WFI ATHENA

IFU ATHENA X-ray Integral Field Unit

The *Athena* X-ray observatory

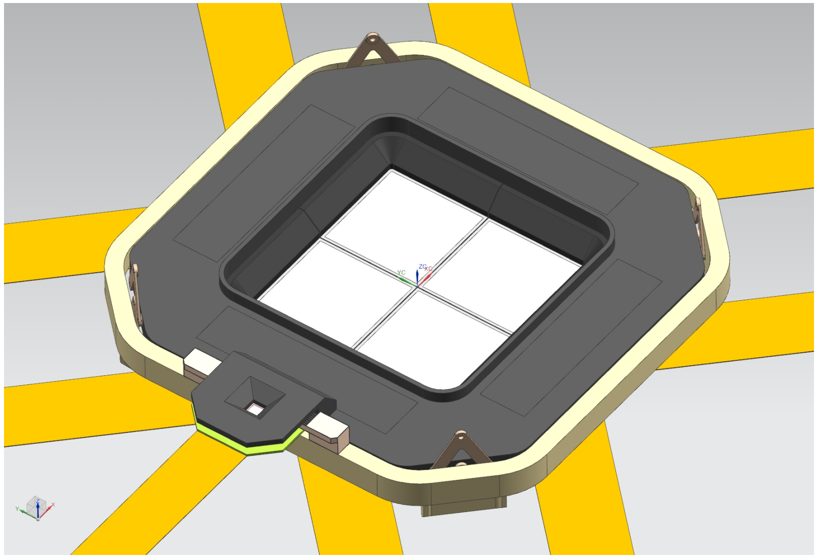


- To be **launched to L1 in early 2030s** as the second ESA L-class mission
- **12 m focal length**, mirror based on Silicon Pore Optics technology
- **Two instruments** on board:
  - Wide Field Imager (WFI)
  - X-ray Integral Field Unit (X-IFU)

The *Athena* Instruments

WFI (Imager)

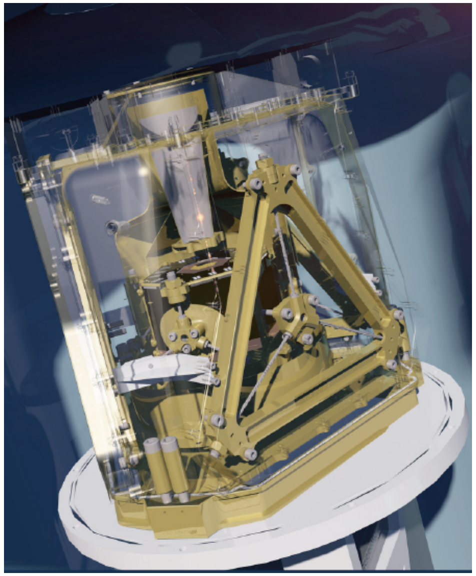
- For **imaging and spectroscopy over large field of view** ($40' \times 40'$ FoV, 170 eV @ 7 keV)
- High count-rate capabilities



Credit: MPE

X-IFU (Calorimeter)

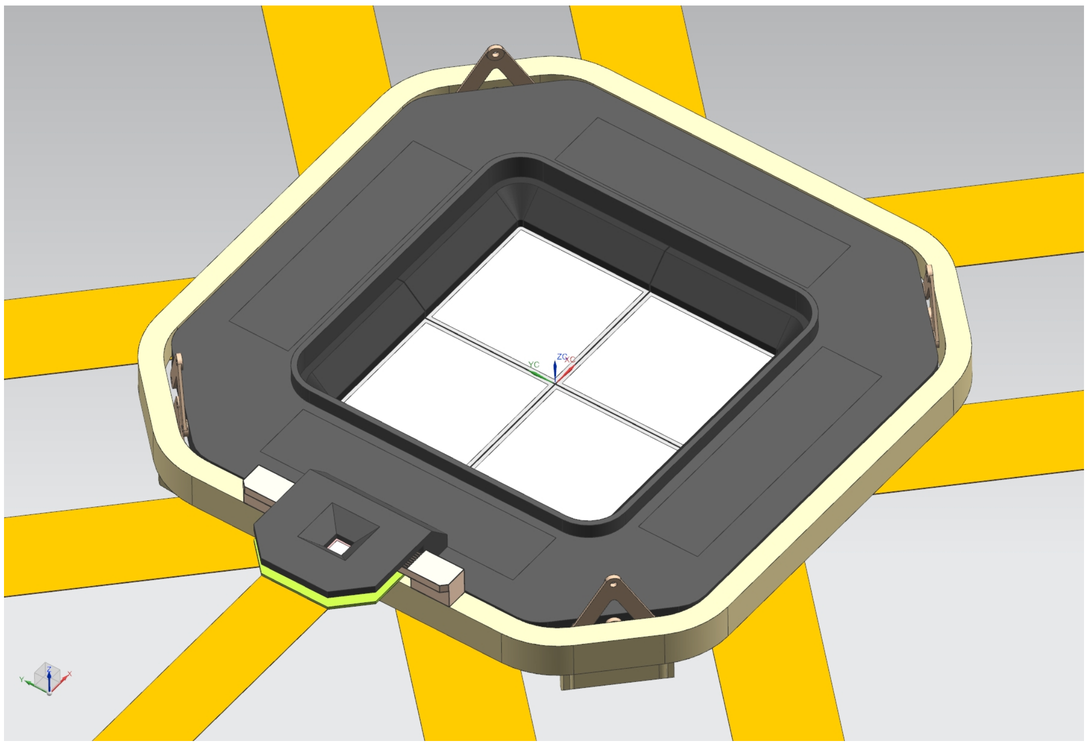
- For **high spectral resolution imaging** ($5'$ FoV, 2.5 eV up to 7 keV)
- Calorimeter operating at 50 mKelvin



Credit: X-IFU Consortium

The Wide Field Imager (WFI)

Large Detector Array (LDA) and **Fast Detector** (FD, 35 mm defocused)

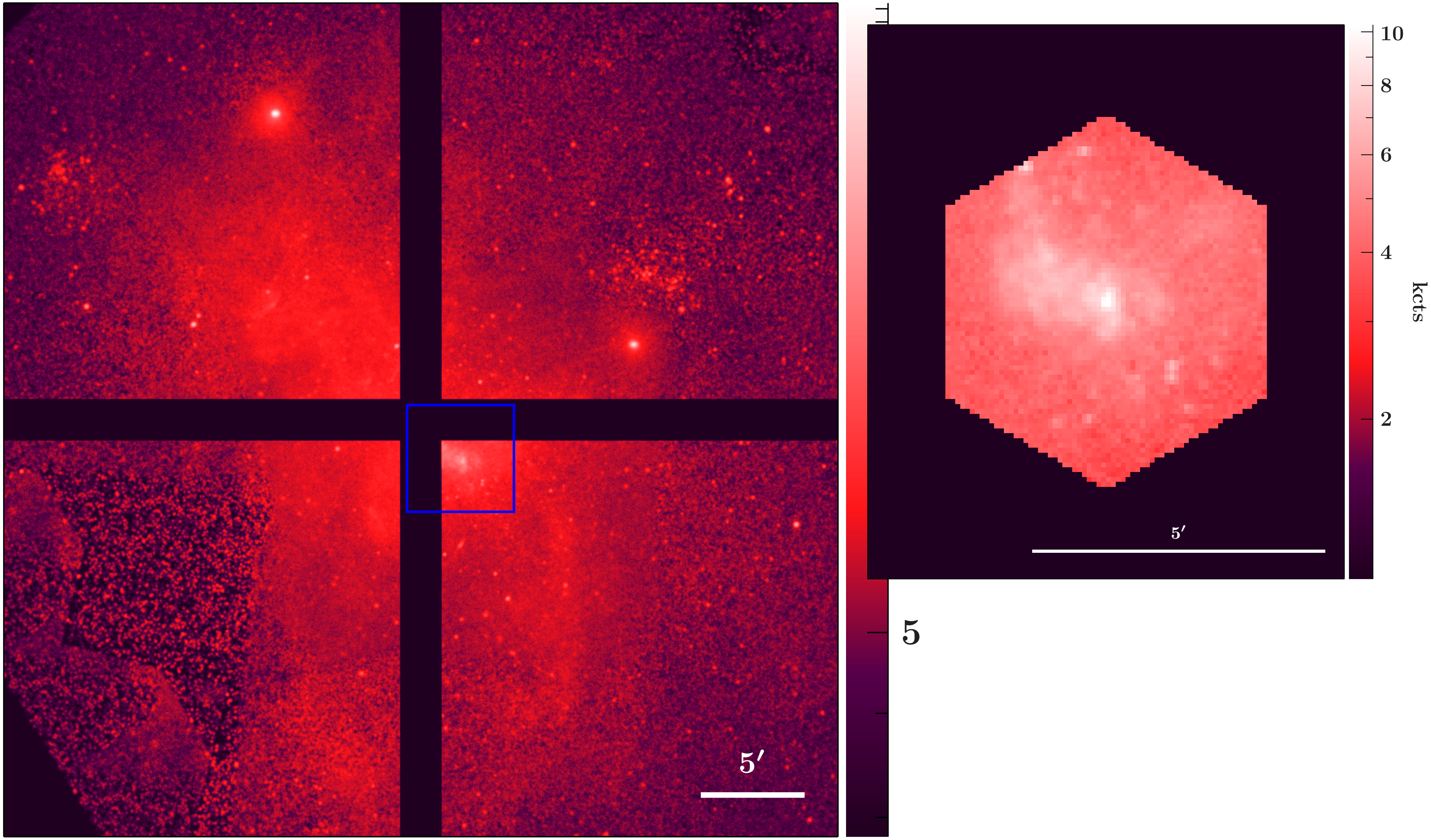


Credit: MPE

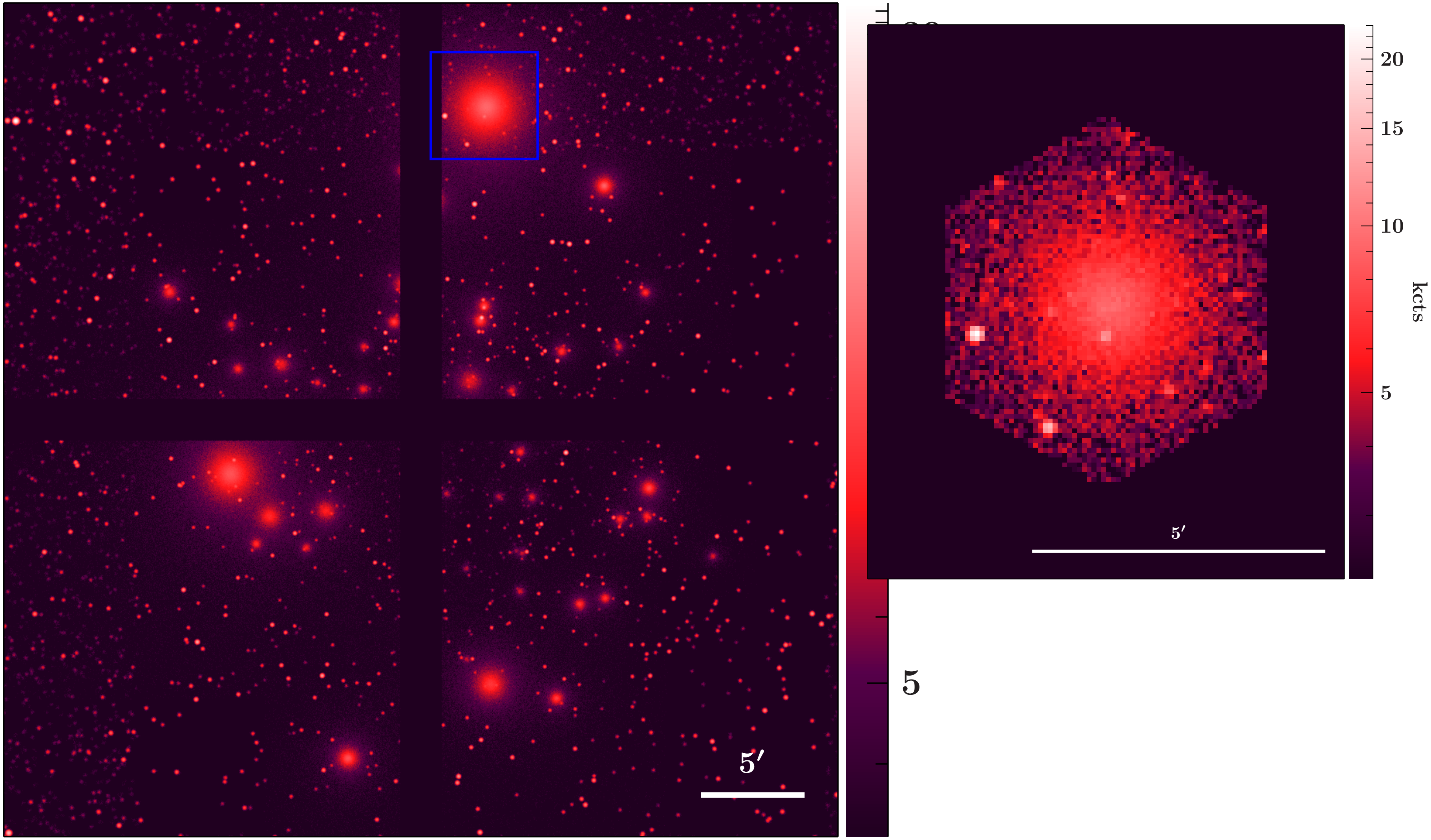
- DePFET active pixel technology (similar to CCD with line-by-line readout)
- Energy resolution: $\leq$ 170 eV @ 7 keV
- Large FOV: $40' \times 40'$
- High count-rate capabilities (10 Crab)

Meidinger et al. (2020)

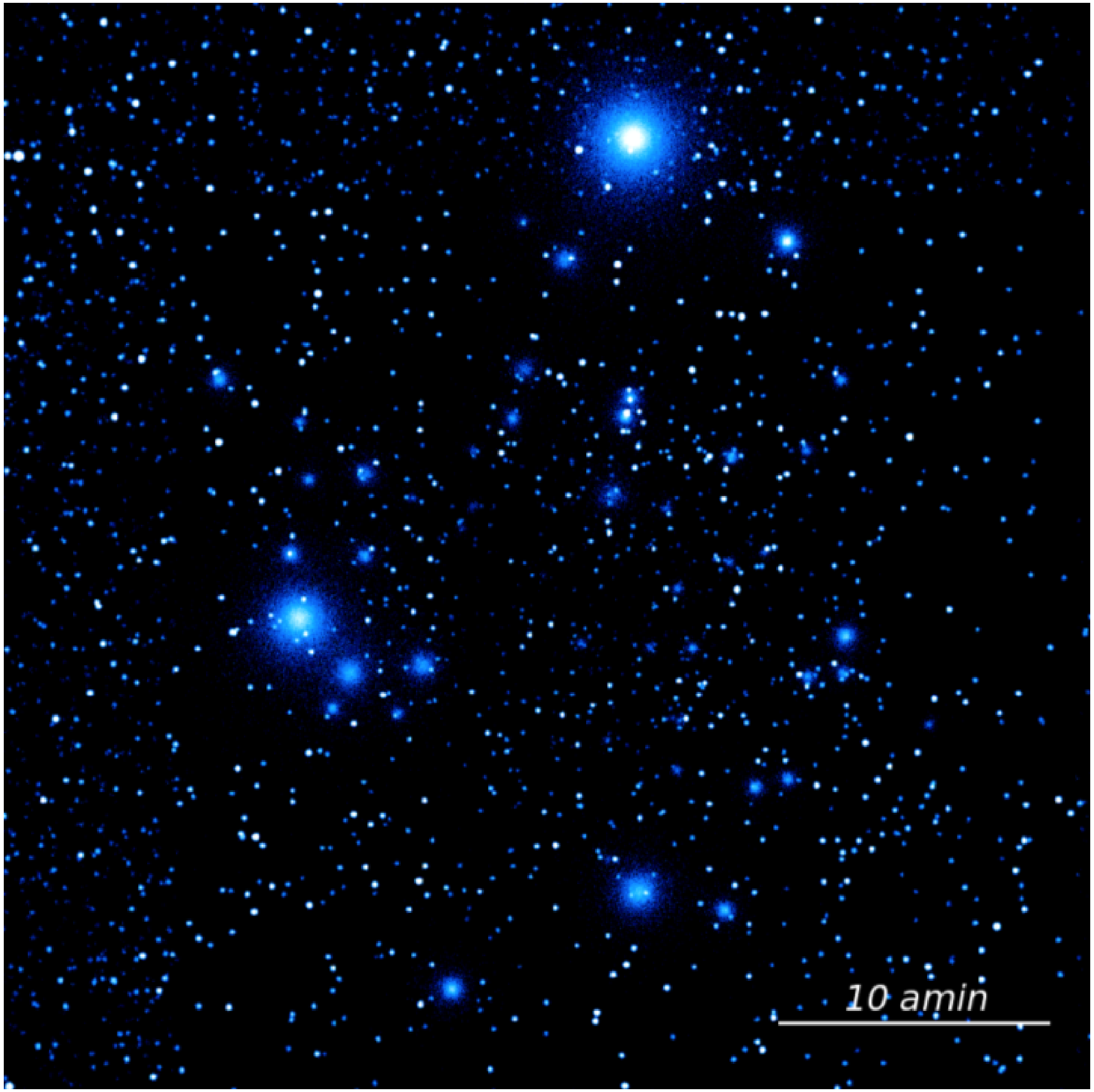
Example: The Galactic Center with *Athena*

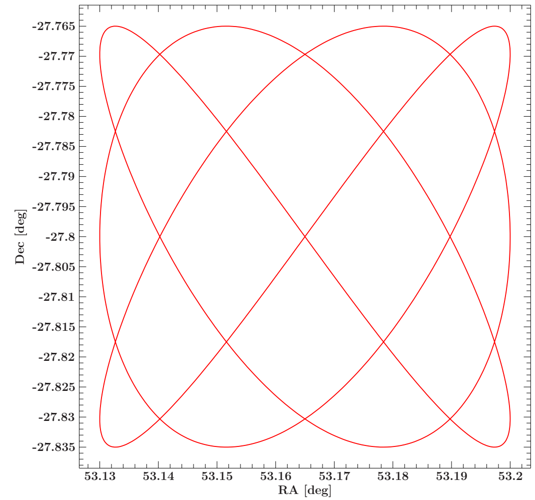


Example: The Chandra Deep Field South with *Athena*



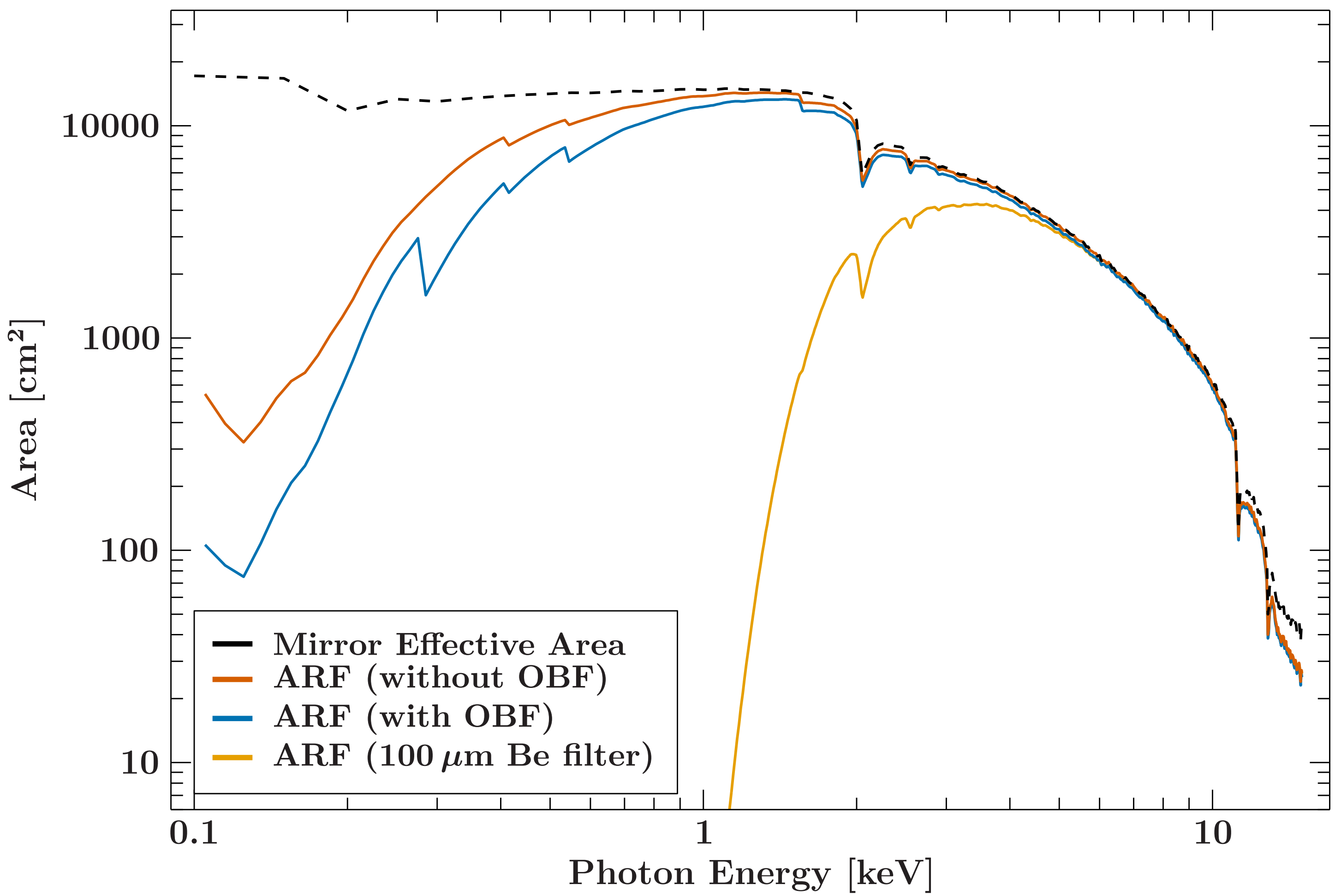
Example: The Chandra Deep Field South with *Athena*





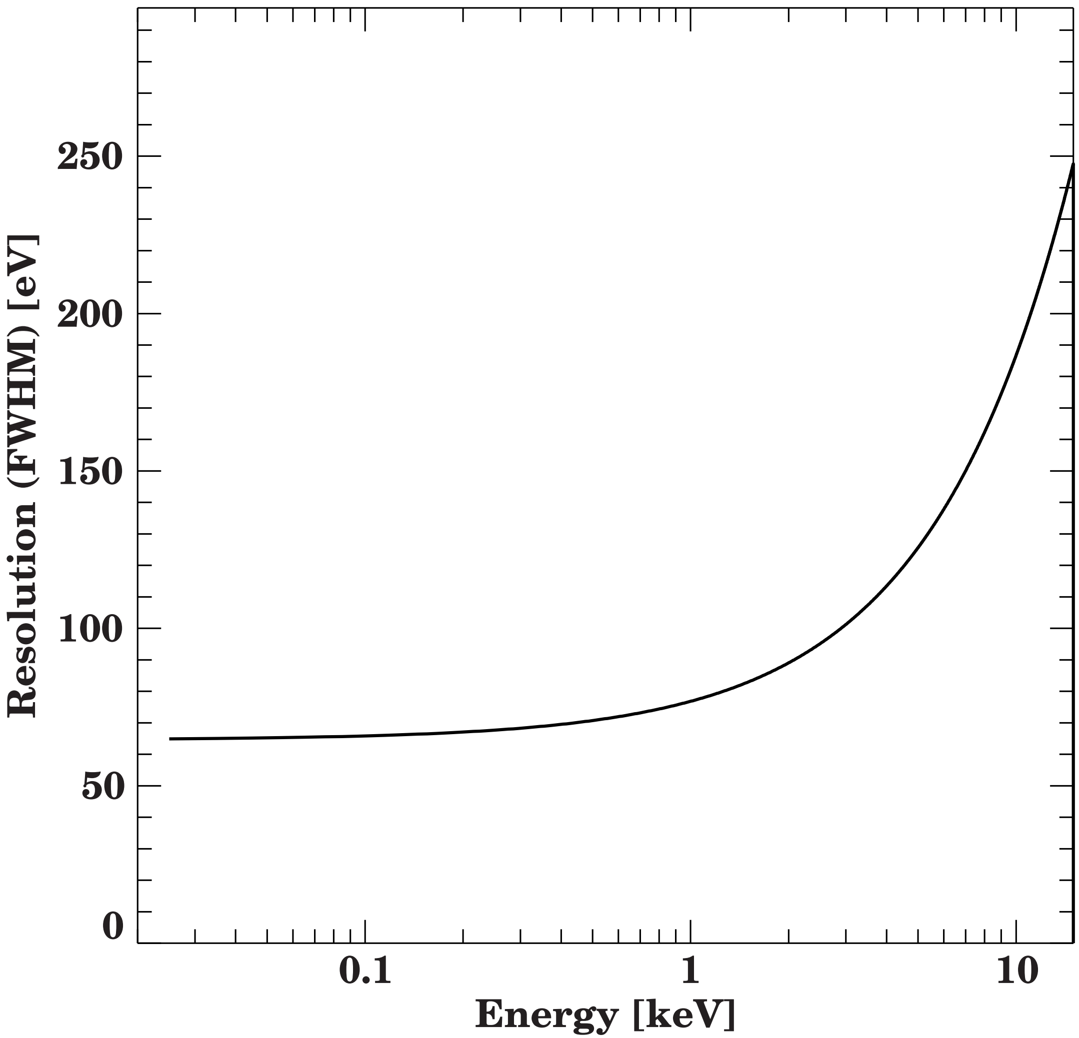
Dithering efficiently removes gaps between the chips.

WFI Mirror Area and Ancillary Response File (ARF)



Be filter $\Rightarrow$ removes photons below 2 keV

WFI Redistribution Matrix File (RMF)

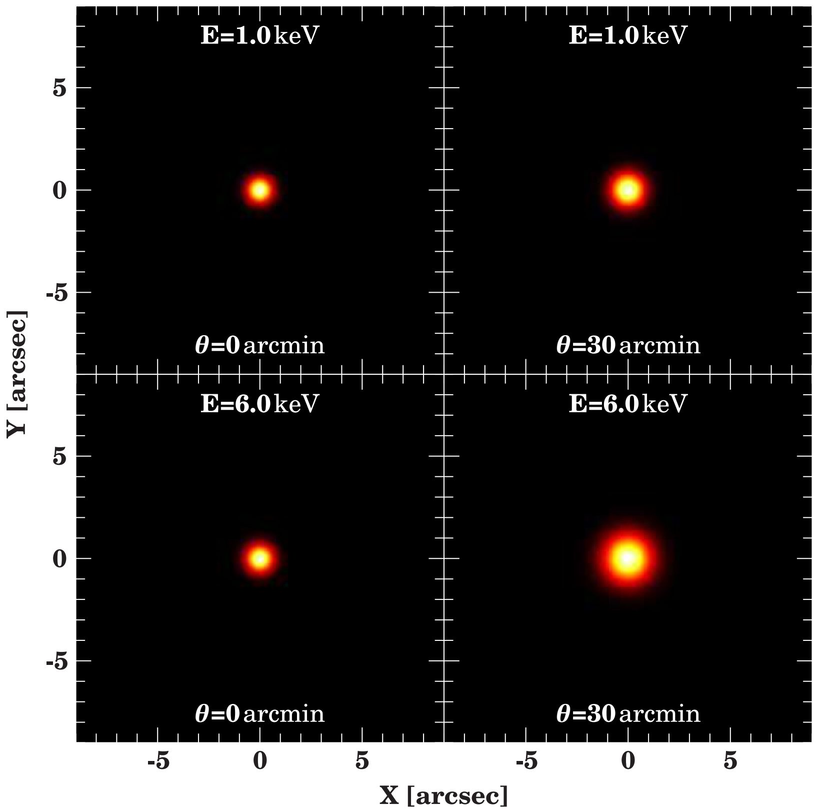


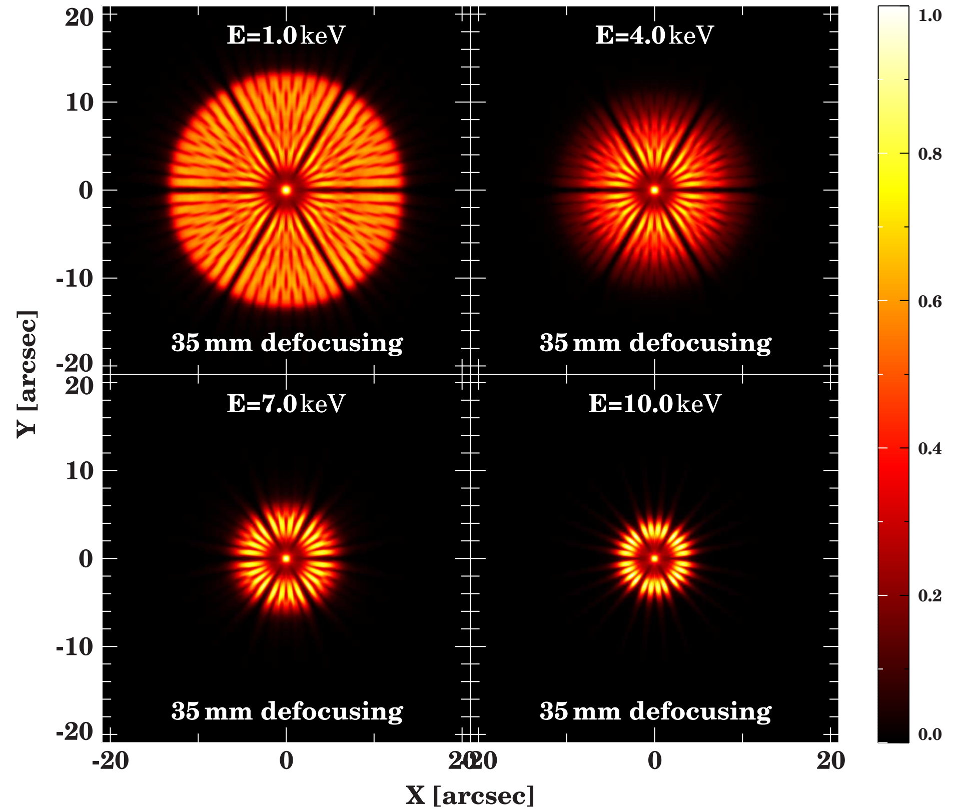
RMF composed of Gaussian with a width fit to lab measurements.

WFI Point Spread Function (PSF)

PSF at different energies and off-axis angles

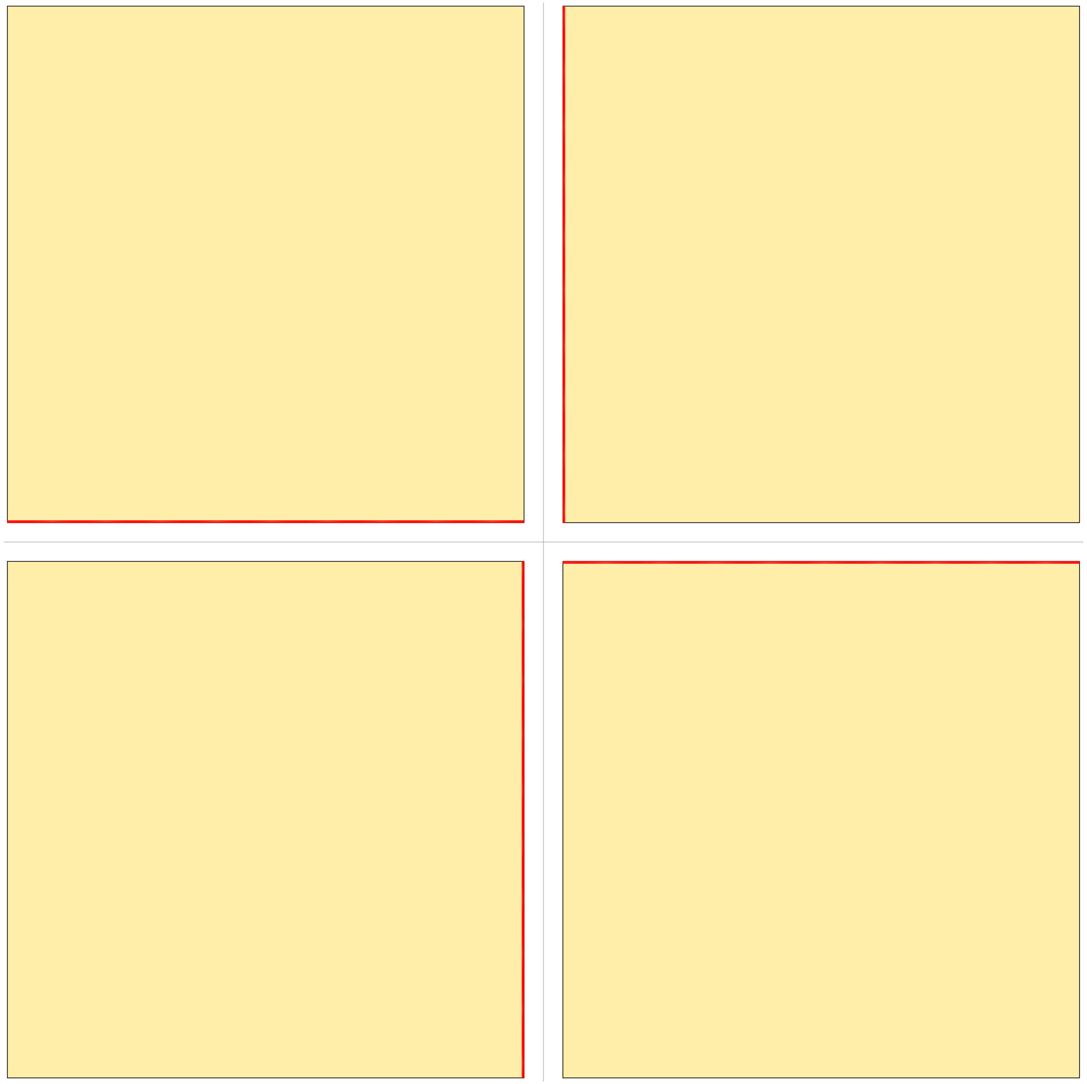
Defocused PSF (35 mm)





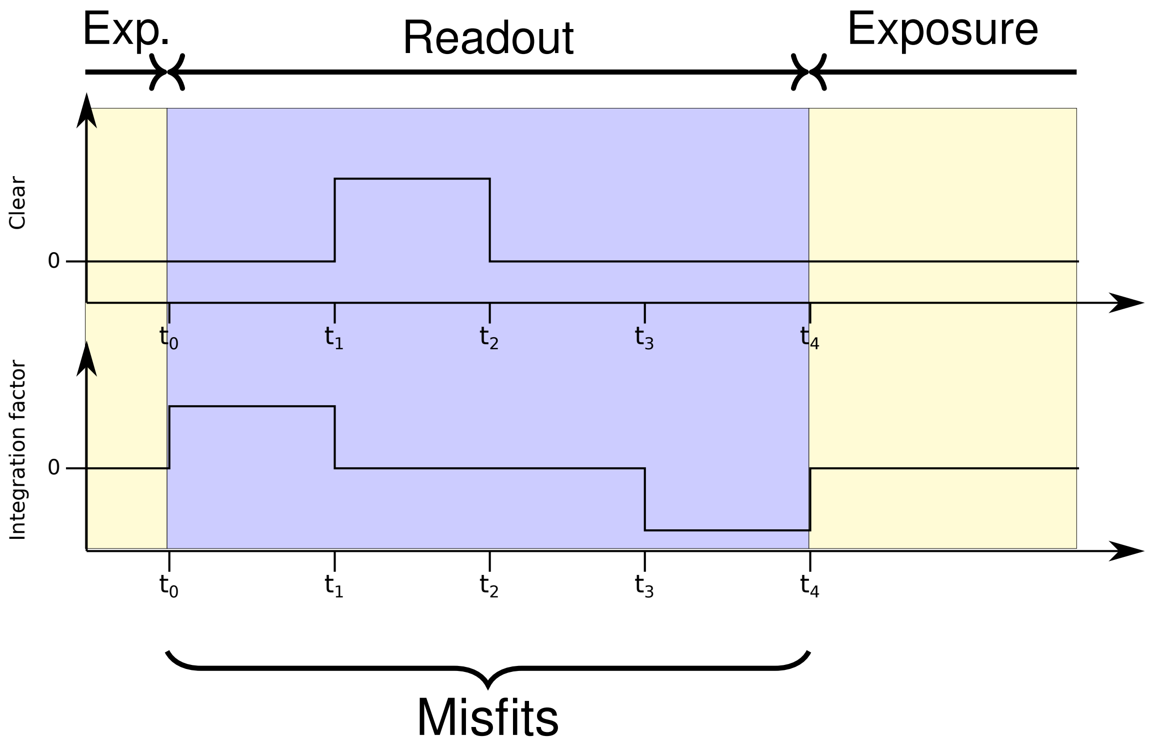
⇒ Defocusing distributes photons over larger area

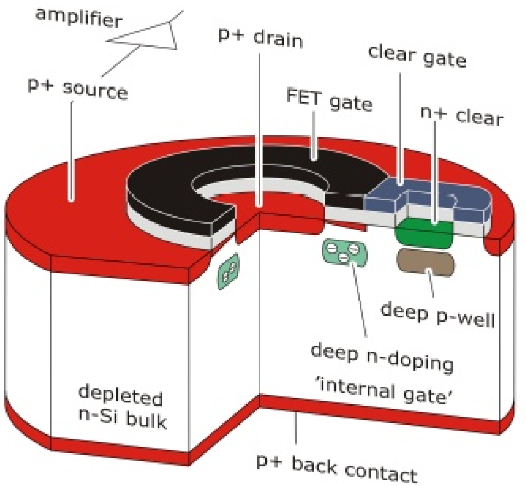
LDA Chip Geometry



- Aim point at LDA center.
- 5 mm gap between chips.

WFI DePFET read-out implementation in SIXTE





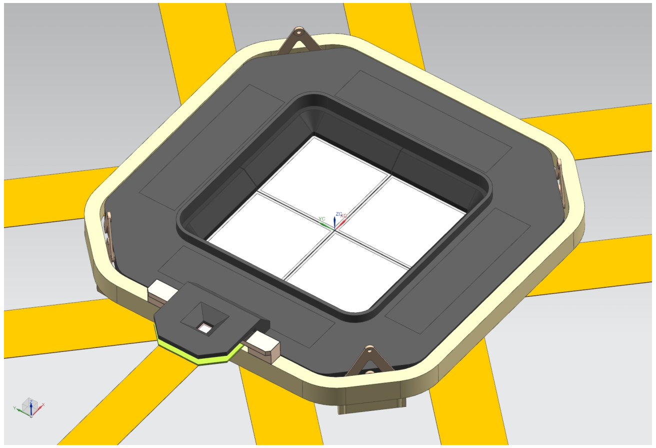
If photon hits during the read-out: measured charge is affected
⇒ Wrong energy ("Misfit")

this is most relevant for window modes or the fast detector

Different modes of the WFI (in SIXTE)

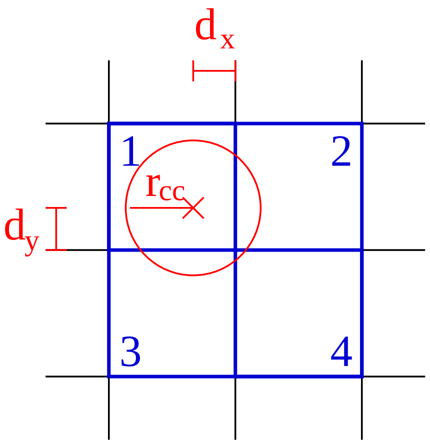
Name	Filename	Size (rows $\times$ columns)	Time Resolution	Defocusing	Filter
full	ld_wfi_ff_chip[0,1,2,3].xml	$(4\times)$ 512×512	5018 μs	—	wo/w
large	ld_wfi_ff_large.xml	512×512	5018 μs	—	wo/w
w128	ld_wfi_w128.xml	128×512	1254 μs	—	wo/w
w256	ld_wfi_w256.xml	256×512	2509 μs	—	wo/w
fast	fd_wfi_df35mm.xml	64×64	80 μs	35 mm	w
fastBe	fd_wfi_df35mm_Be100.xml	64×64	80 μs	35 mm	w

- Large Detector Array configurations available w/wo optical blocking filter.
- Fast Detector defocused by default.
- Option for a 100 μm Be filter.

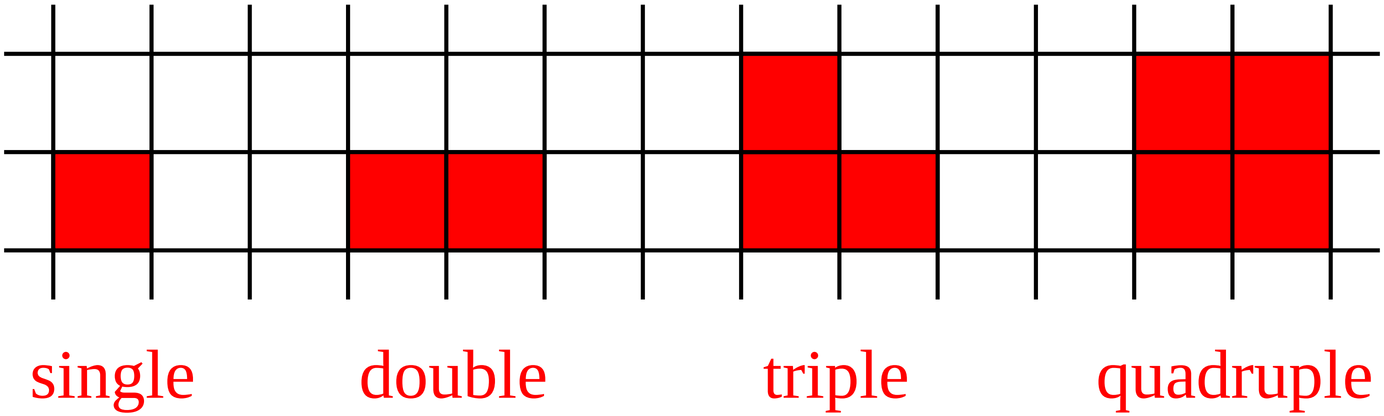


Charge Cloud and Split Patterns

Charge cloud has finite extension and may be distributed among several neighboring pixels.



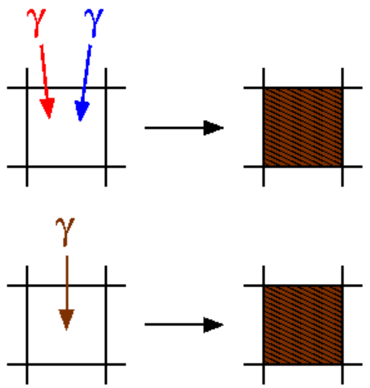
$\Rightarrow$ Four possible types of **valid split patterns** (properly handled by pattern recombination step in SIXTE):



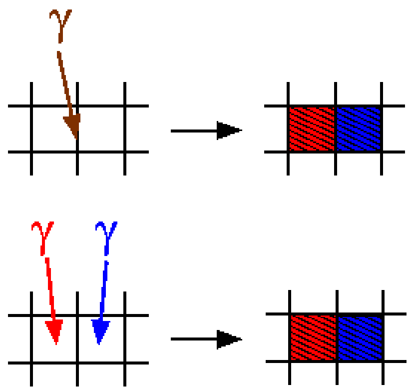
Performance Degradation due to Pile-Up

Main problems when dealing with high count rates:
Emergence of **invalid patterns** and **pile-up**.

Energy pile-up:



Pattern pile-up:



⇒ Pile-up events **distort spectral shape** (hardening)

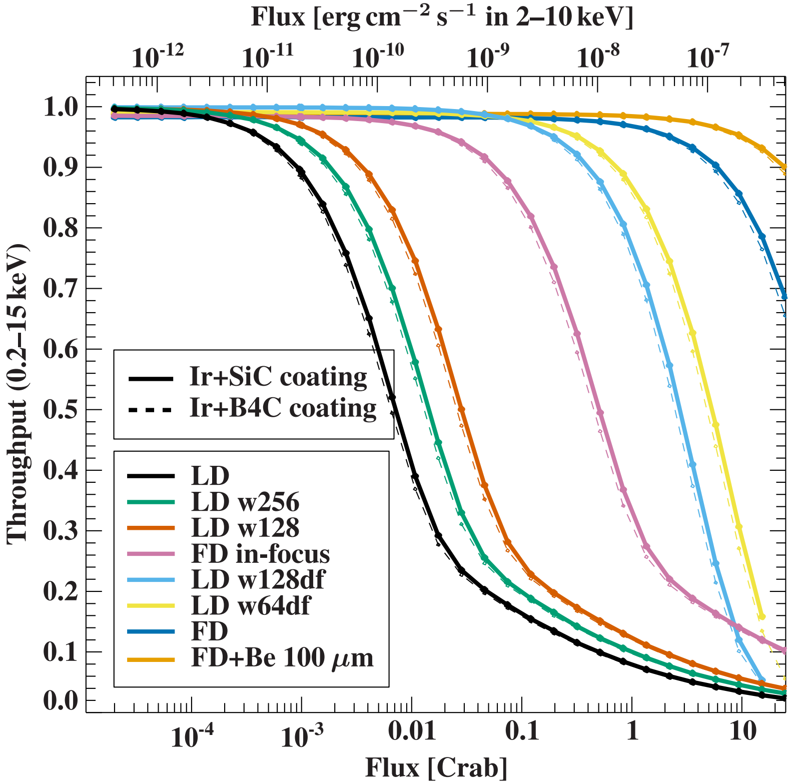
Example: Bright Source Performance of the WFI

Goal: Determine **pile-up limit** (maximum pile-up fraction such that there are no significant changes in the spectrum).

- Simulate **point source (on-axis)** with **Crab-like spectrum**.
- **Simulation procedure:** Vary flux to see how the throughput, pile-up fraction, and spectral shape changes.

Example: Bright Source Performance of the WFI

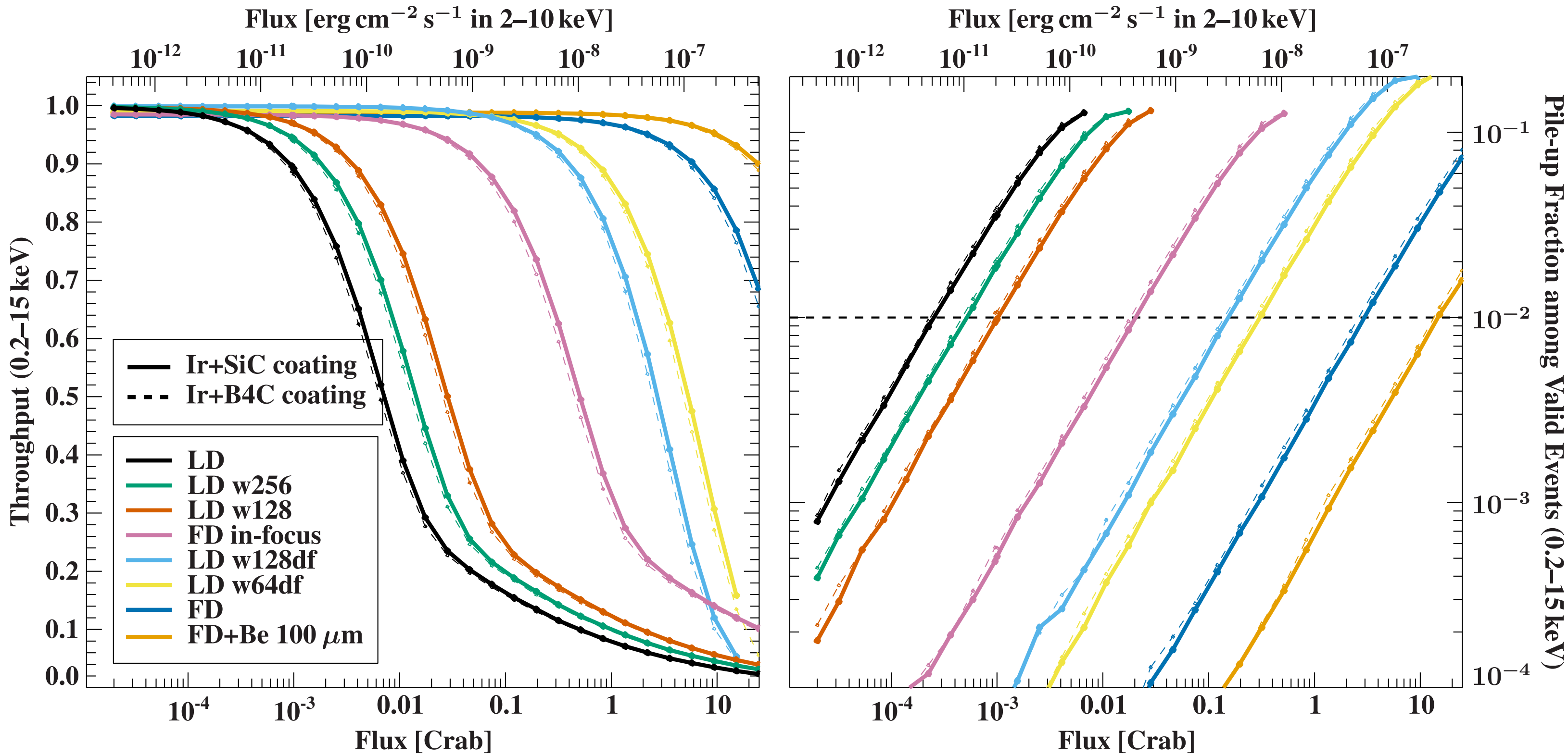
Taking into account **all valid event patterns**:



- **Throughput:** Ratio of the number of valid split patterns and the total number of simulated photons.

Example: Bright Source Performance of the WFI

Taking into account **all valid event patterns**:



- **Throughput:** Ratio of the number of valid split patterns and the total number of simulated photons.
- **Pile-up Fraction:** Fraction of events affected by energy or pattern pile-up among all valid event patterns.

Summary: The WFI with SIXTE

- **DePFET** technology: active pixels, no line shifts $\rightarrow$ **misfits** if pixel is hit during read-out
- Observations possible up to a few Crab, plus a thick filter for even brighter sources.
- large 40' FoV made of 4 chips $\rightarrow$ requires **dithering**
- Simulations possible for the full 4 chip LDA with `athenawfisim`, or only a single chip (LD, or the 35 mm defocused FD) with `runsixt`.

References

- N. Meidinger, et al., "Development status of the wide field imager instrument for Athena," Proc. SPIE 11444, Space Telescopes and Instrumentation 2020: Ultraviolet to Gamma Ray, 114440T (13 December 2020); https://doi.org/10.1117/12.2560507