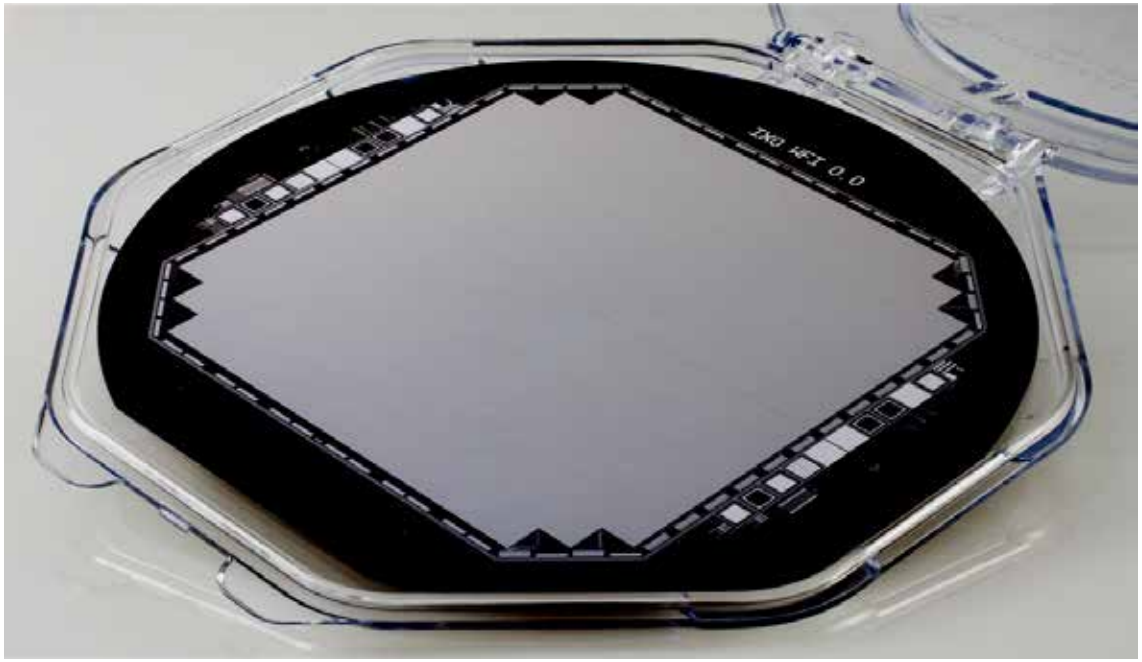
Non-BELLE applications

The Wide Field Imager for the ATHENA+ mission

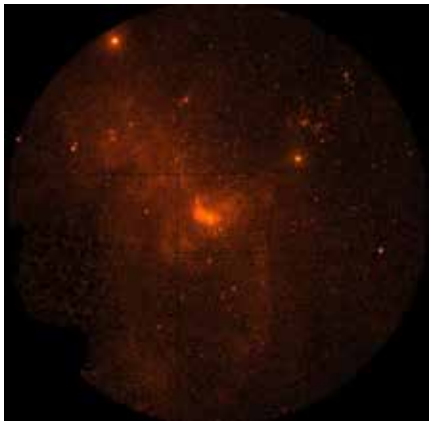
19th international workshop on DEPFET Detectors

Seeon monastery

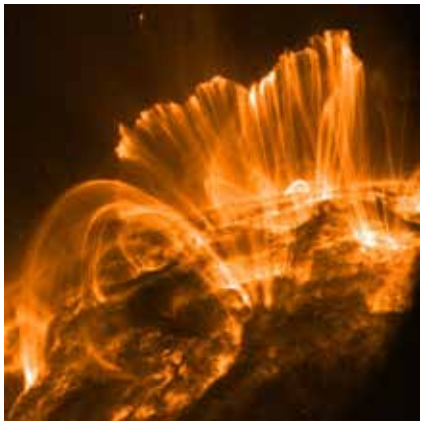
11.5.2015

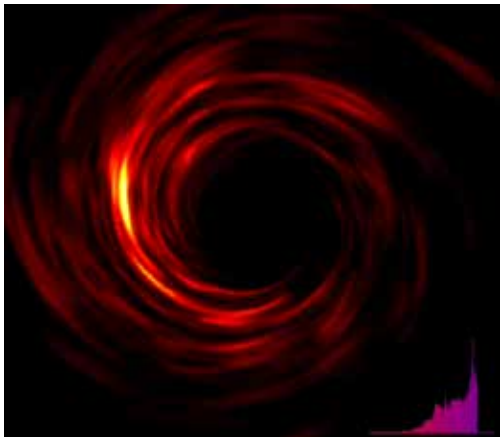


Contents



- The application
- History
- ATHENA+
- The WFI
- Fast timing detector
- Prototype designs
- Summary and outlook

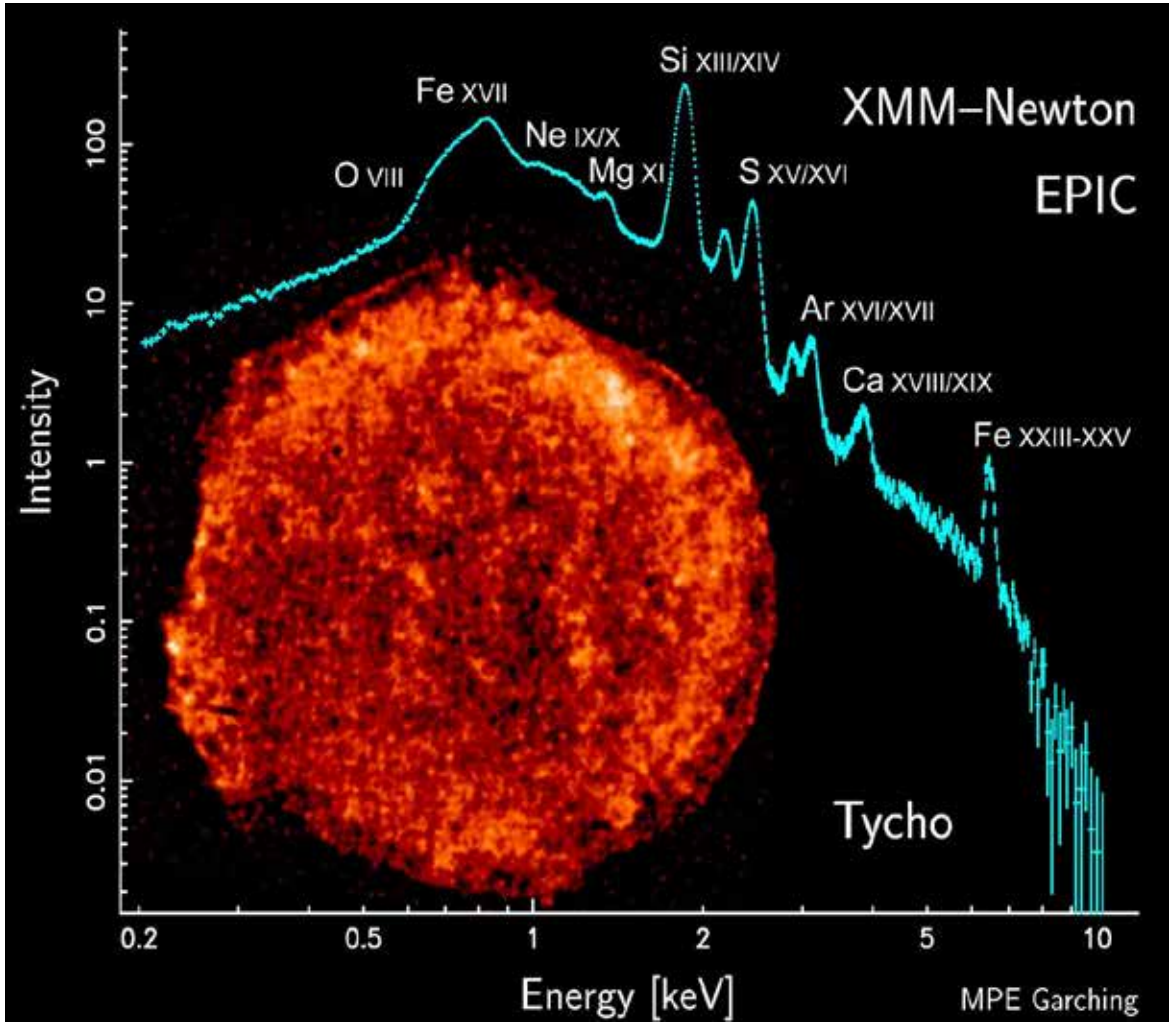




XMM-Newton

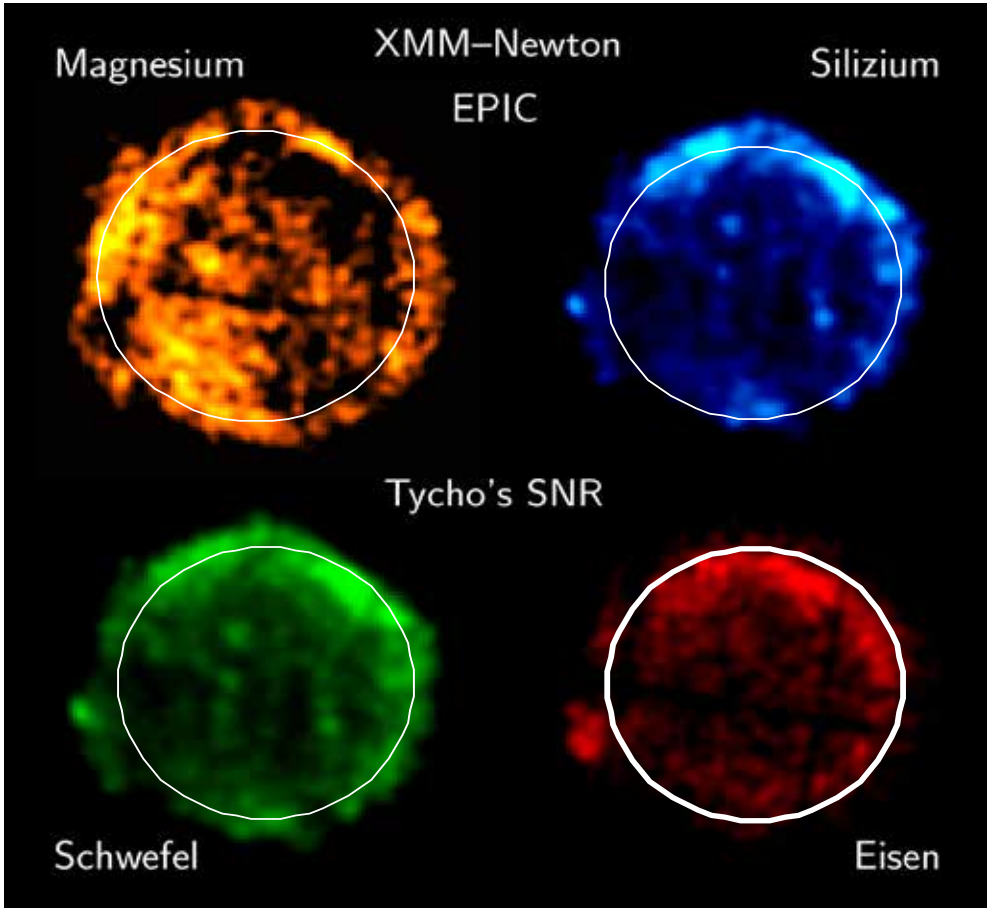
- Launch in 1999
- Still operational
- One of three main focal plane instruments is EPIC pnCCD

Imaging spectroscopy

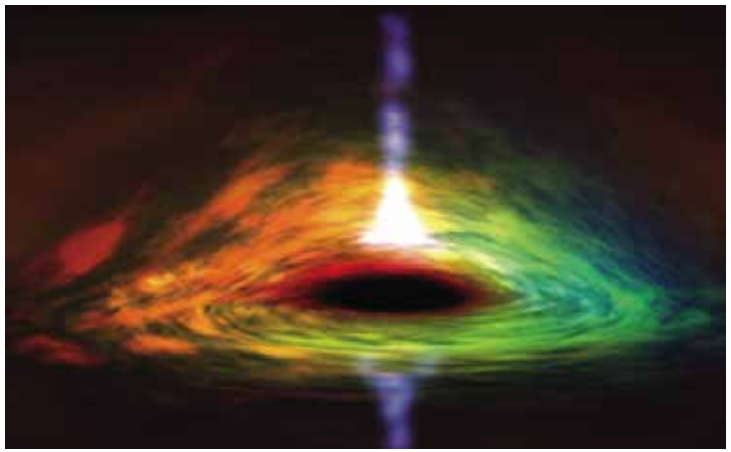


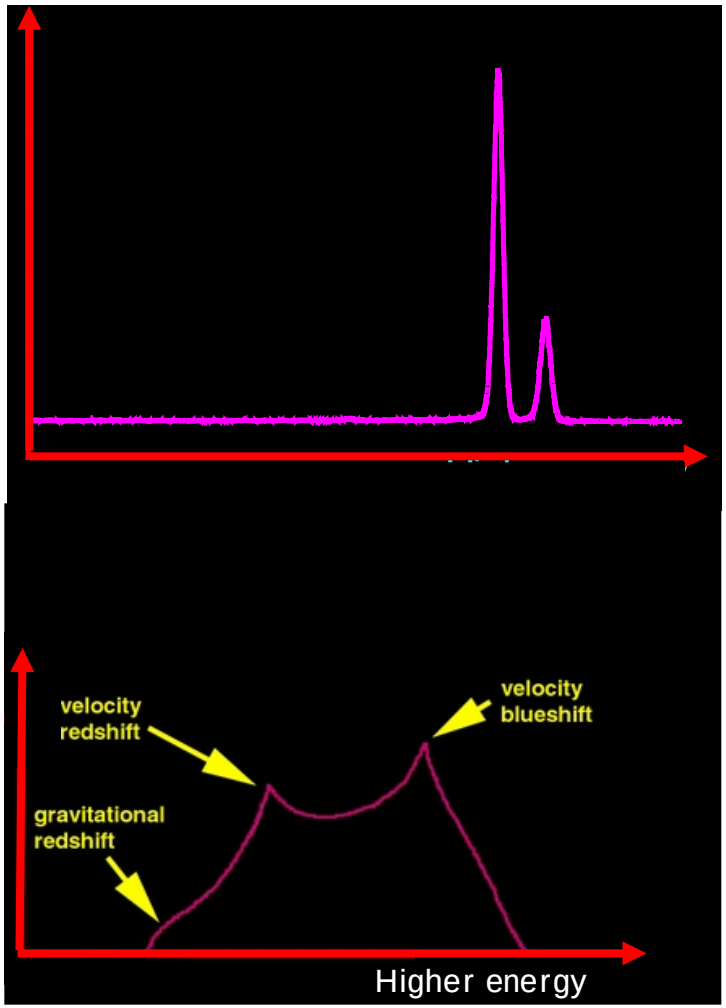
X-ray imaging spectroscopy

- Simultaneous acquisition of location and energy of celestial X-ray emission
- Fluorescence line and continuous spectra
- Silicon as detector material
  - 0.1 kev < E < 20 keV
- Higher energies require different detector materials
- Single-photon resolution forces tradeoff:
  - Source Brightness
  - Mirror efficiency
  - Readout speed
  - Time resolution



X-ray imaging spectroscopy

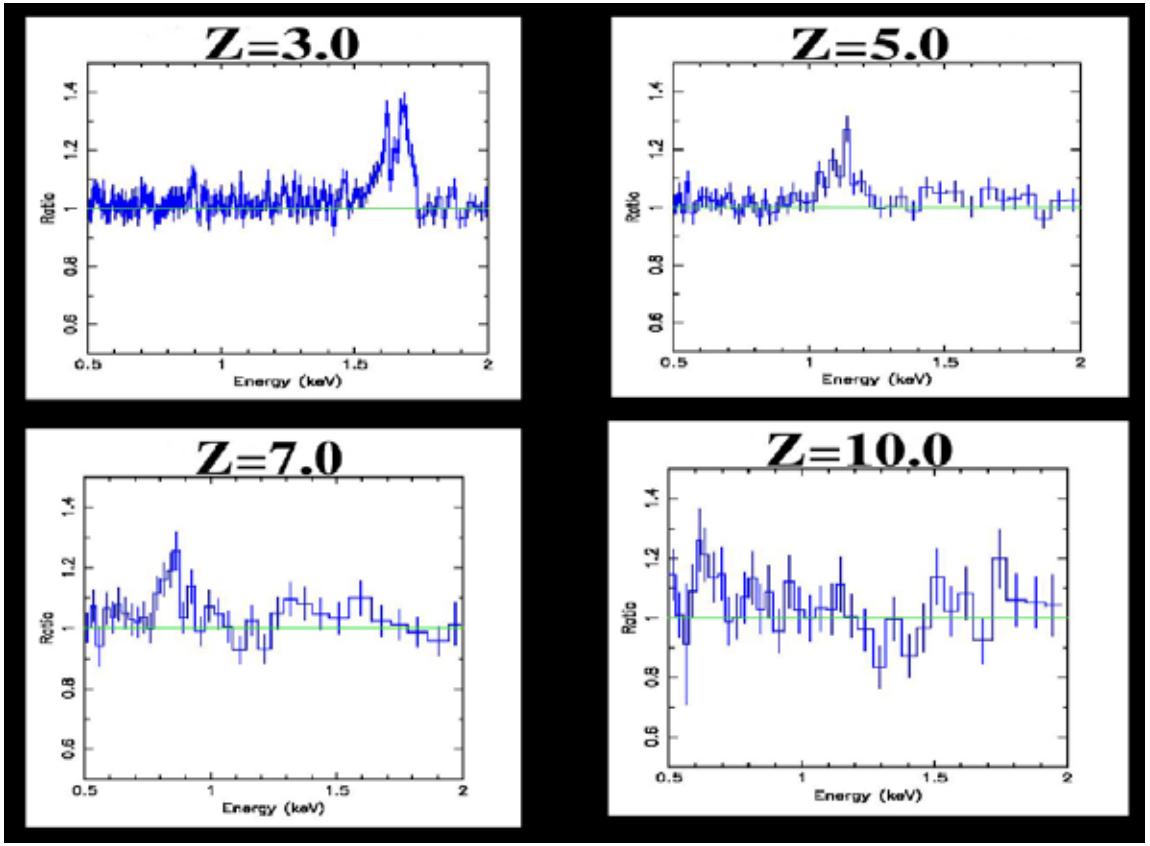




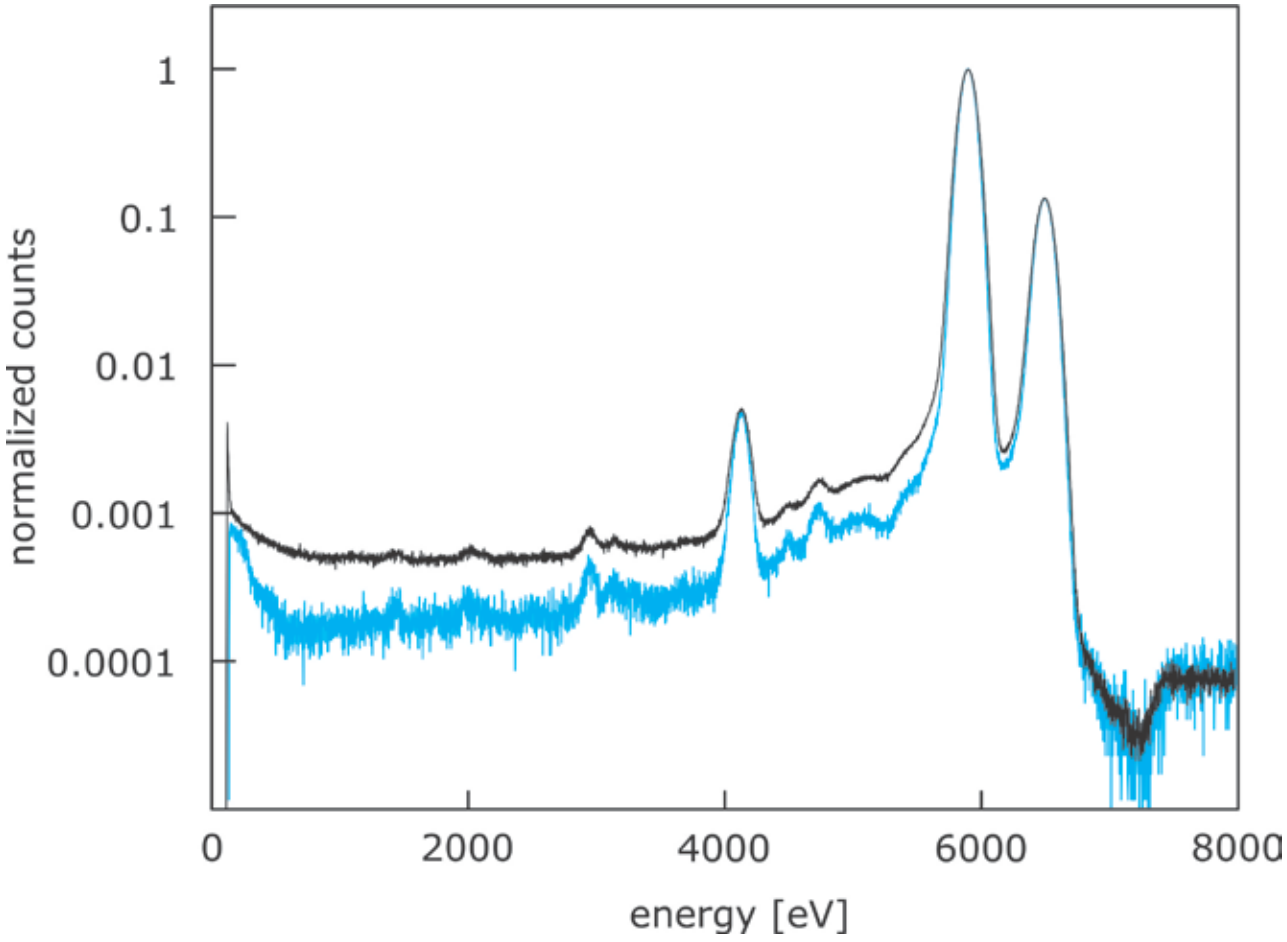
- *Relativistic Iron lines*
  - Iron important tracer element
  - Iron K-a (6.4 keV) and K-b lines (7 keV)
  - Present in accretion disk of black hole
  - Distortion due to:
    - Velocity blueshift
    - Velocity redshift
    - Gravitational redshift

X-ray imaging spectroscopy

- *Relativistic Iron lines*
  - Near Fano-limited resolution
  - Single photon detection
  - Low low energy cutoff mandatory
  - Low peak / background mandatory

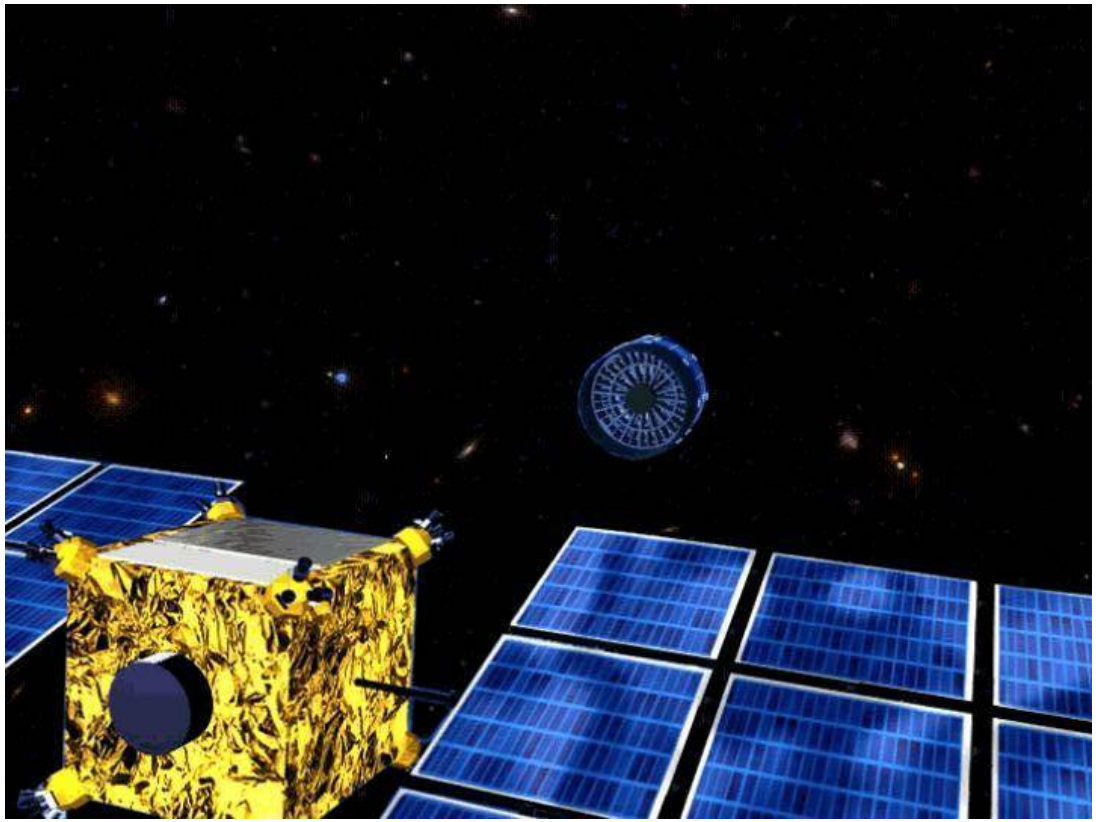


Spectral quality

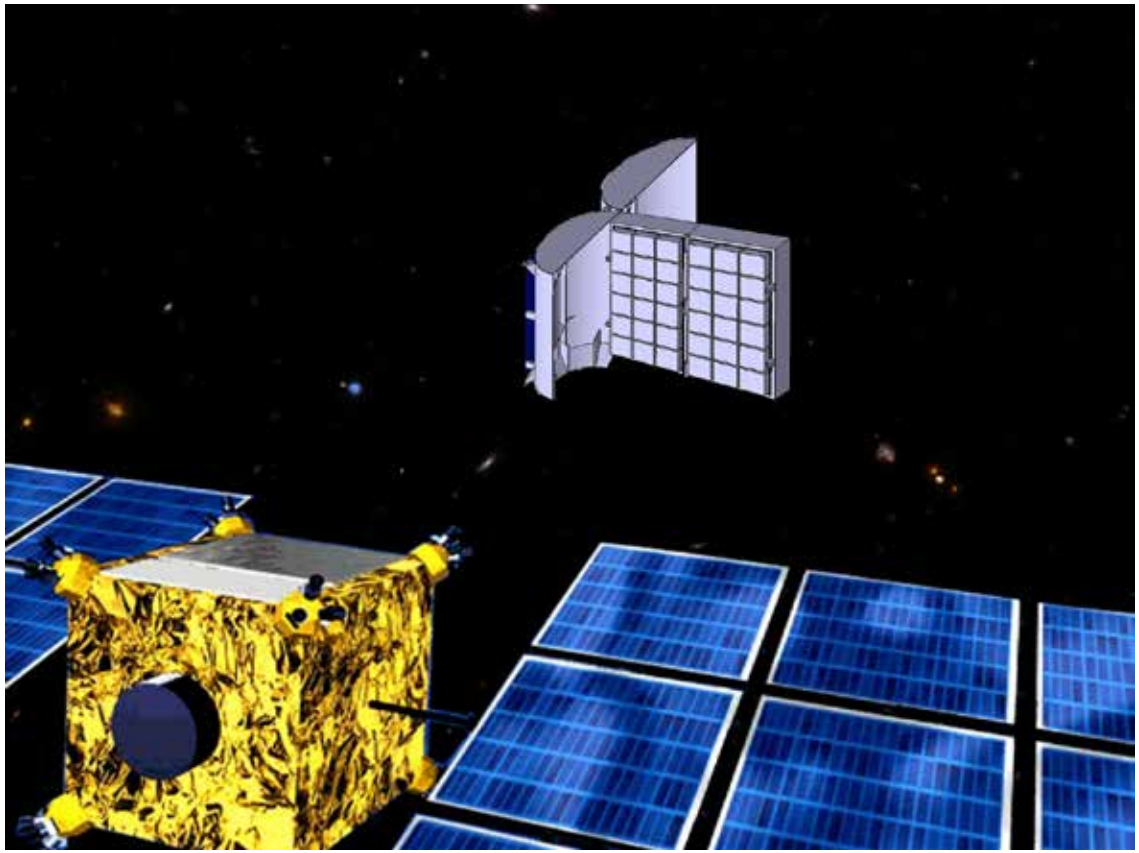


XEUS I (2000)

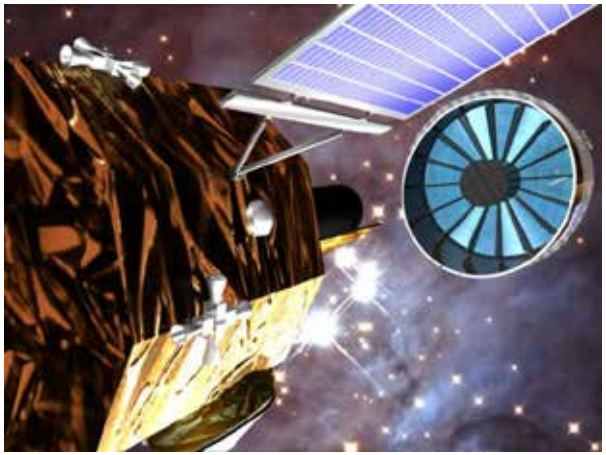
XEUS II (2003)

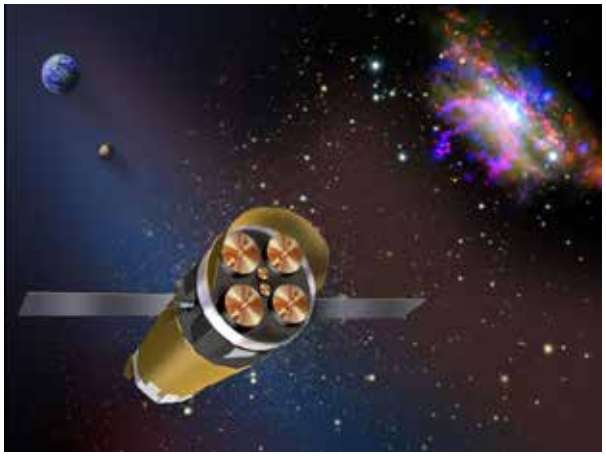


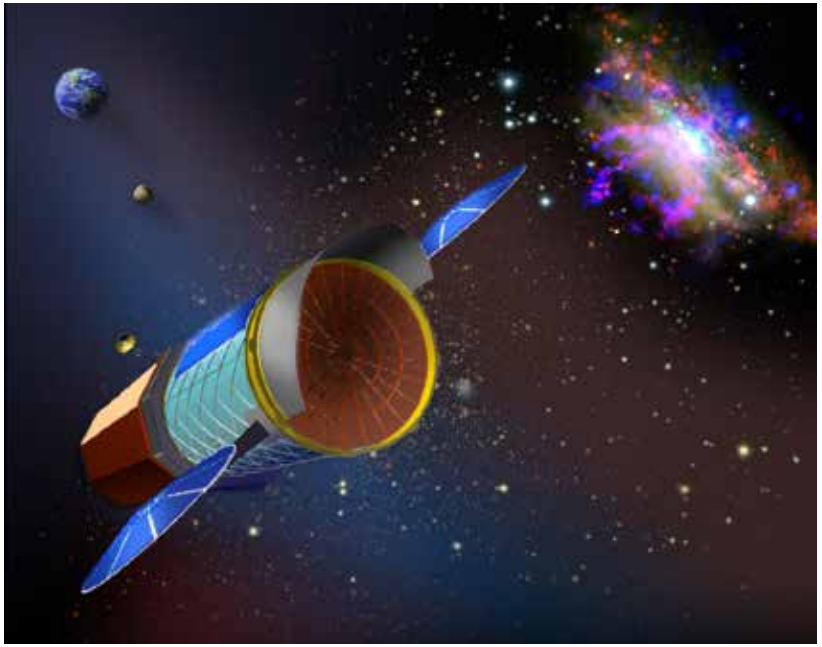
XEUS III (2005)



IXO (2008)

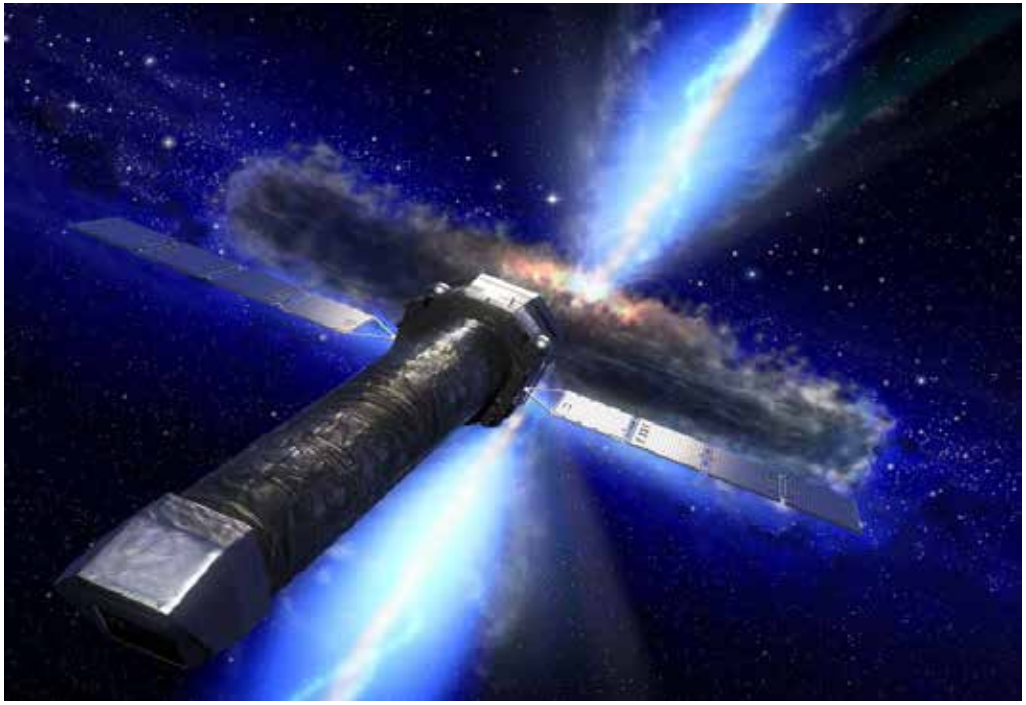






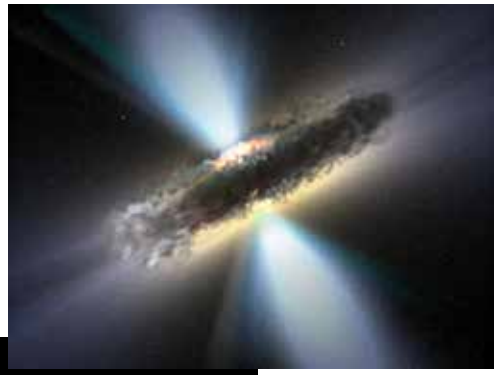
ATHENA (2011)

ATHENA+ (2013)

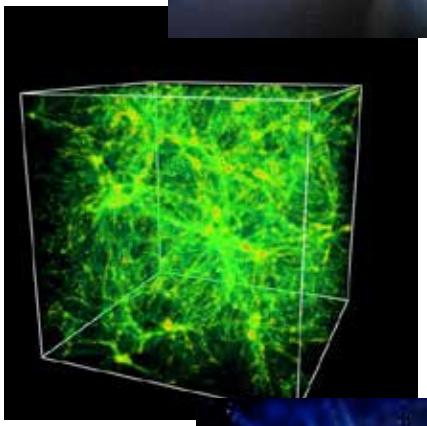


ATHENA+ science objectives

- *Black holes and matter under extreme condition*
  - How do supermassive black holes grow and evolve?
  - Does matter close to the event horiont follow general relativity?
  - Understand physics of accretion onto compact objects



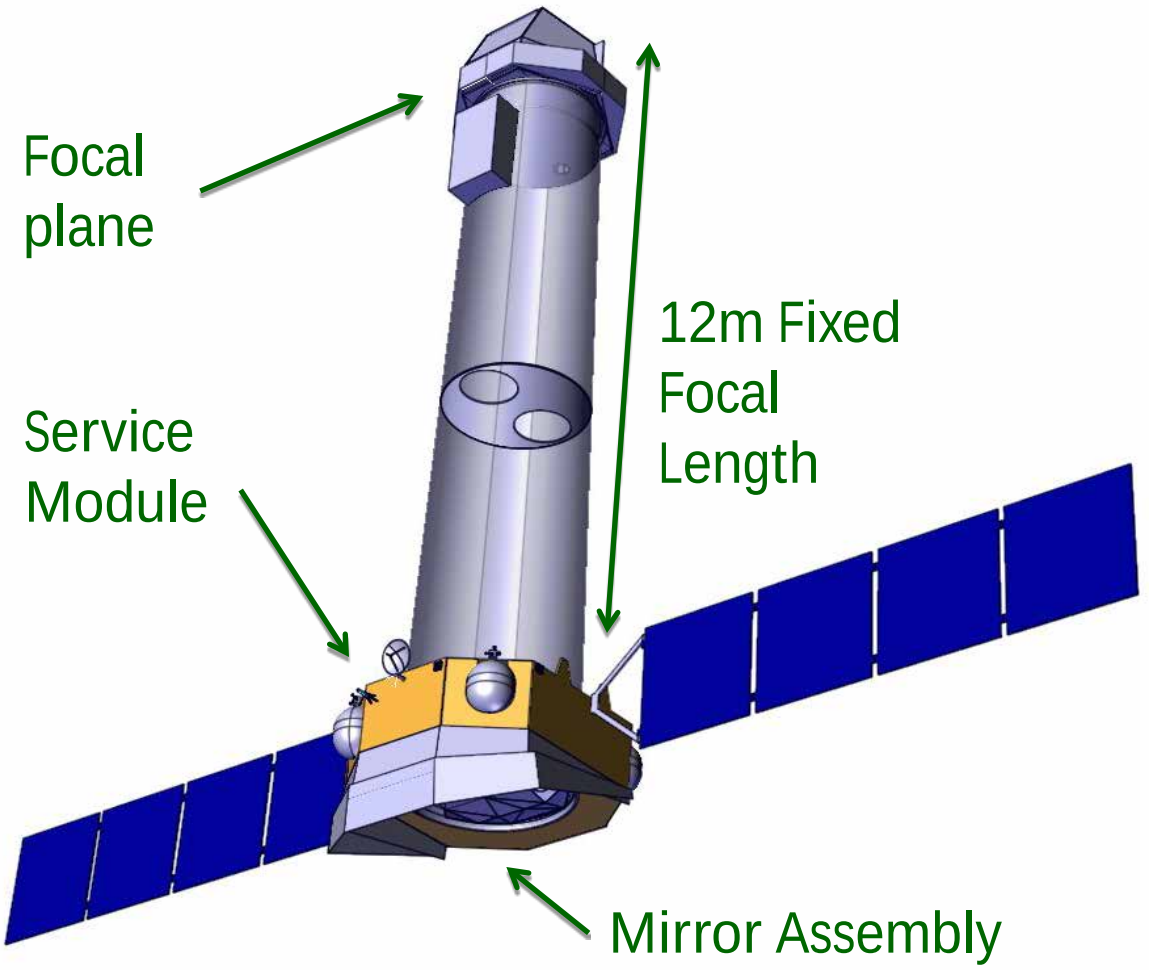
- *Where are the hot baryons and how do they evolve?*
  - How does cosmic feeback work and influence galaxy formation?
  - How does galaxy cluster evolution constrain the nature of dark matter and dark energy?
  - Where are the missing Baryons in the universe?



- *Physics of the hot and energetic universe*
  - Compact objects: *X-ray binaries, neutron star and pulsars, white dwarfs*
  - Stellar evolution: *Young stars, stellar winds, stellar activity, supernovae, GRBs*
  - The Milky Way: *Galactic centre, interstellar dust and gas, hot gas halo*
  - Planets and the solar system: *Planets, exoplanets, comets, solar wind*

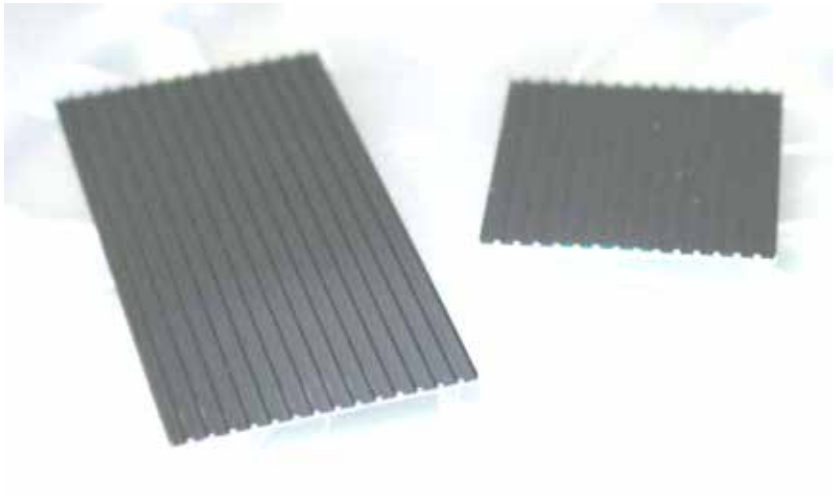
Athena+ Mission

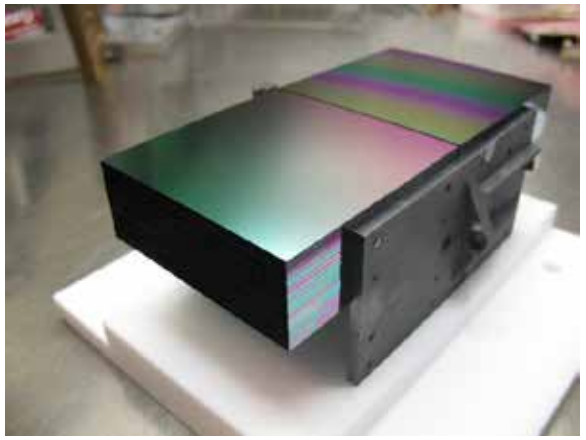
- Ariane V launch to L2,
- 5yr nominal mission

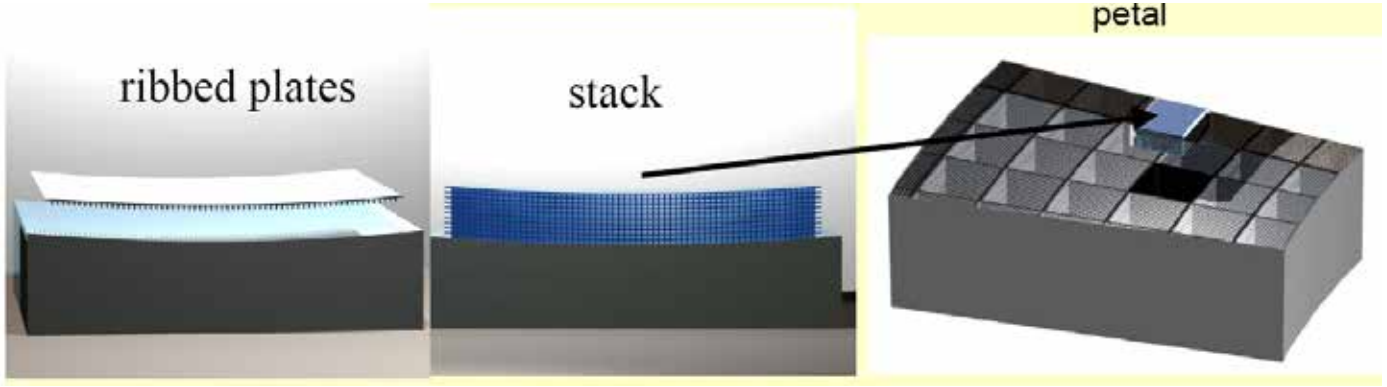


Mirror system

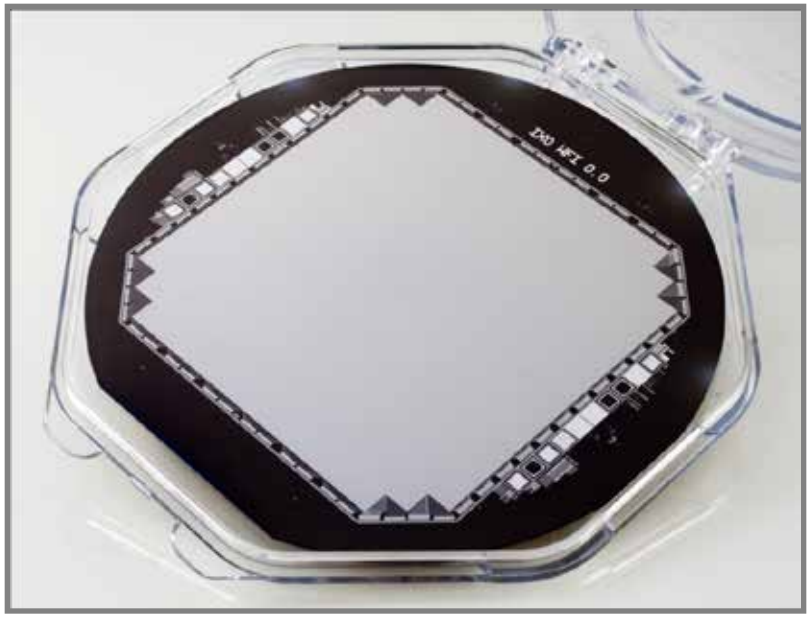
ESA Silicon Pore Optics
5” (3”) resolution



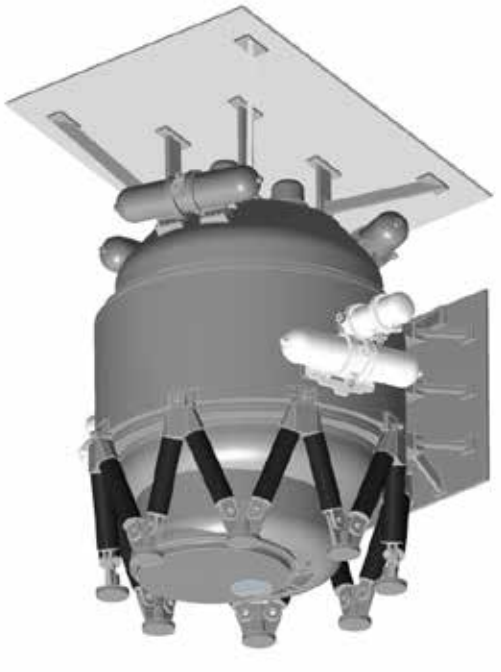




Instrumentational payload



Wide Field Imager
(Si-based DEPFET)



X-ray Integral Field Unit
(TES calorimeter)

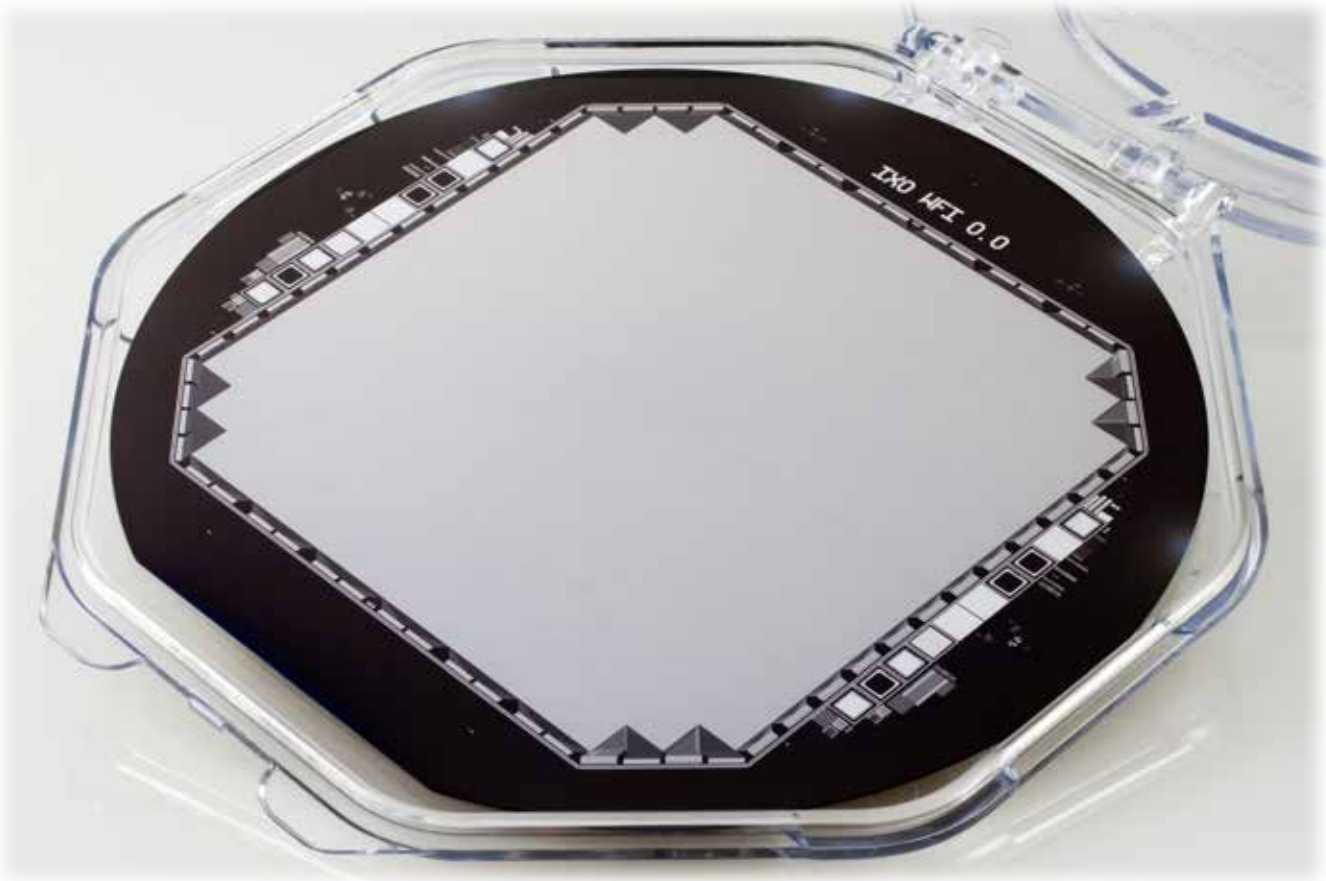
WFI design and key parameters

parameter	characteristic
energy range	0.1 – 15keV
energy resolution	**<150 eV (FWHM) @ 6keV**
Field of View	40‘x40‘
angular resolution	<5 arcsec
array format	4 x 512 x 512
pixel size	130x130µm²
detector area	4 x 66.56 x 66.56 mm²
fast timing and high count rate capability	**window mode: 20µs (baseline)** **10µs (goal)** **1 Crab > 80% throughput < 5% pile up**

Surpassing all existing x-ray facilities by at least a factor of 2 in field of view, timing and count rate capability

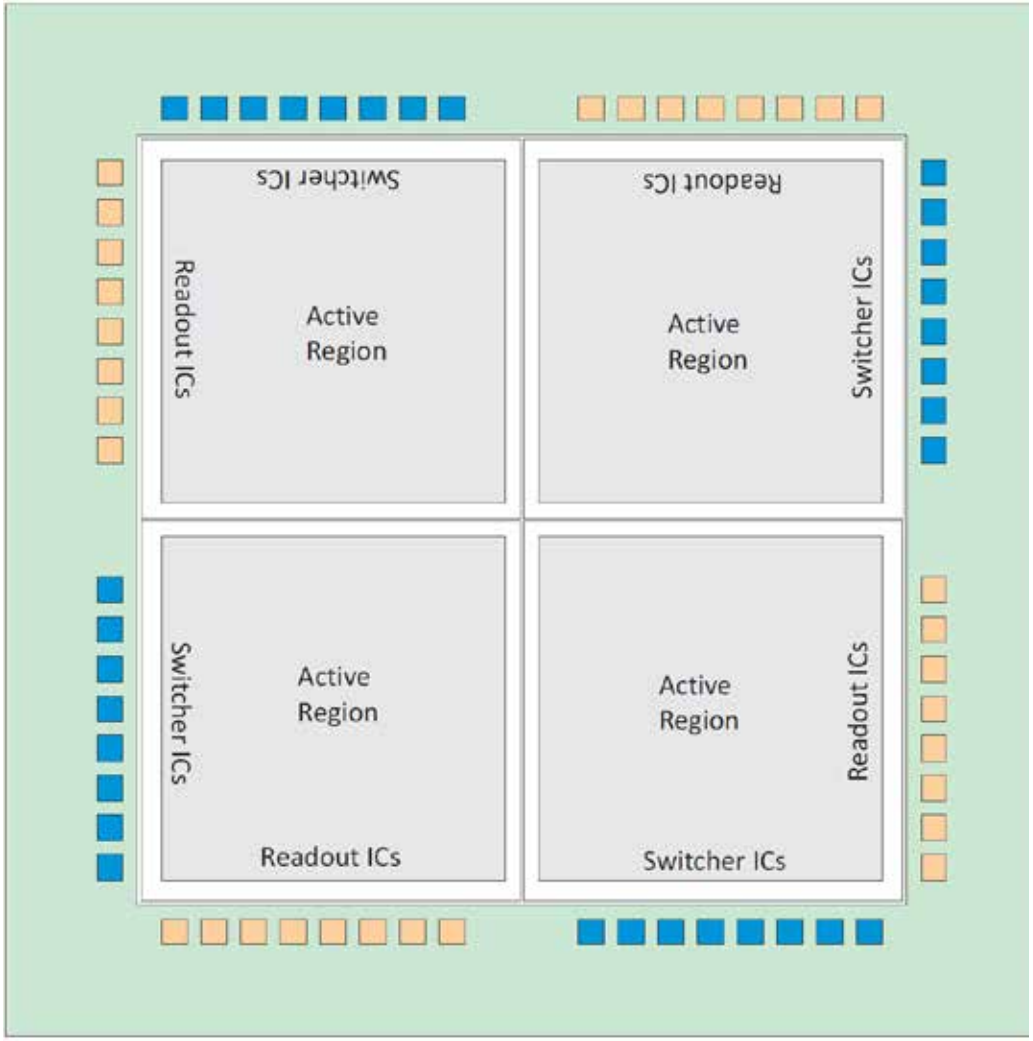
Fast timing requires separate detector unit (Fast timing detector)

WFI

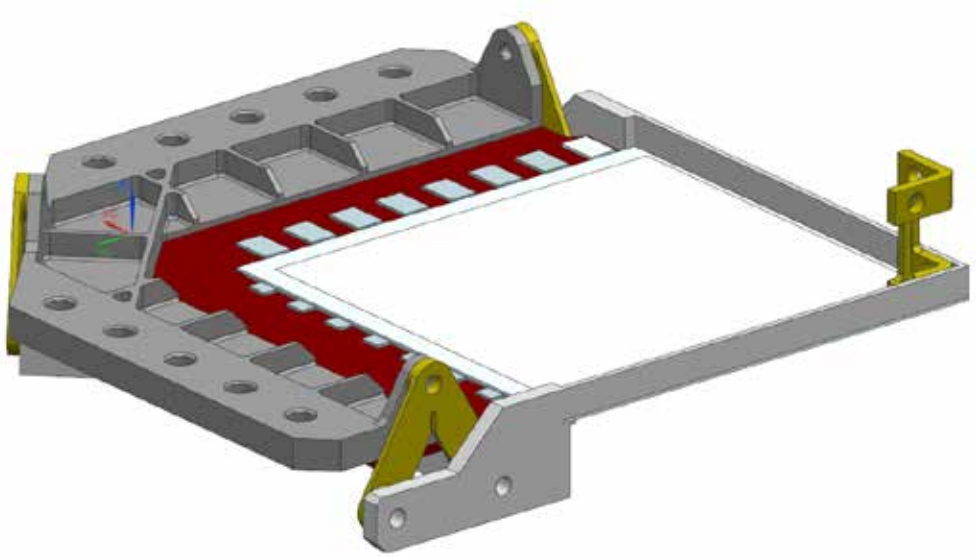


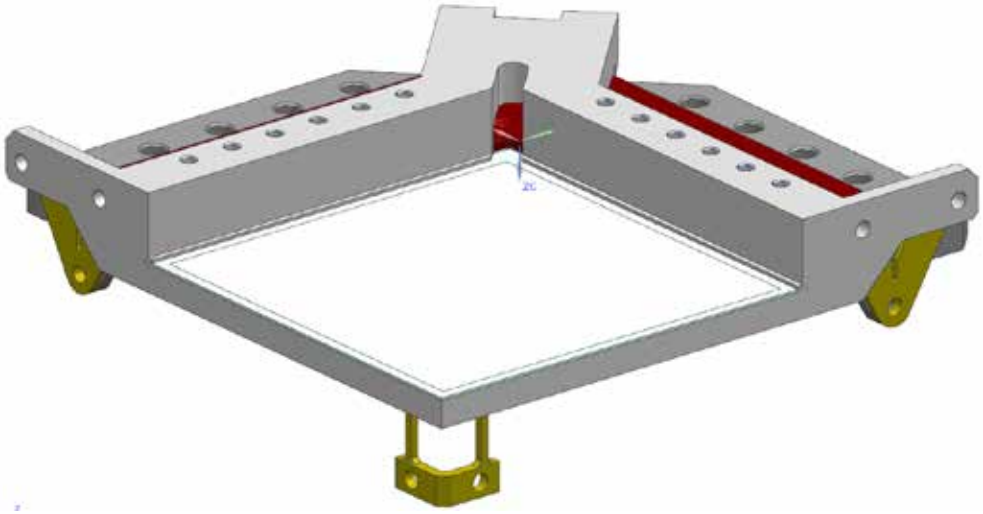
WFI layout

- 4 Quadrants with 512 x 512 pixels each
- Pixel size 130 x 130 mm^2
- 2 side buttalble mounting
- Sensor and readout hybrids are thermally decoupled
- Sensitivity gap between Quadrants is to be minimized
- Readout at frame rate of ~800 Hz with 2.5 μs / row
- Drain based current readout favoured

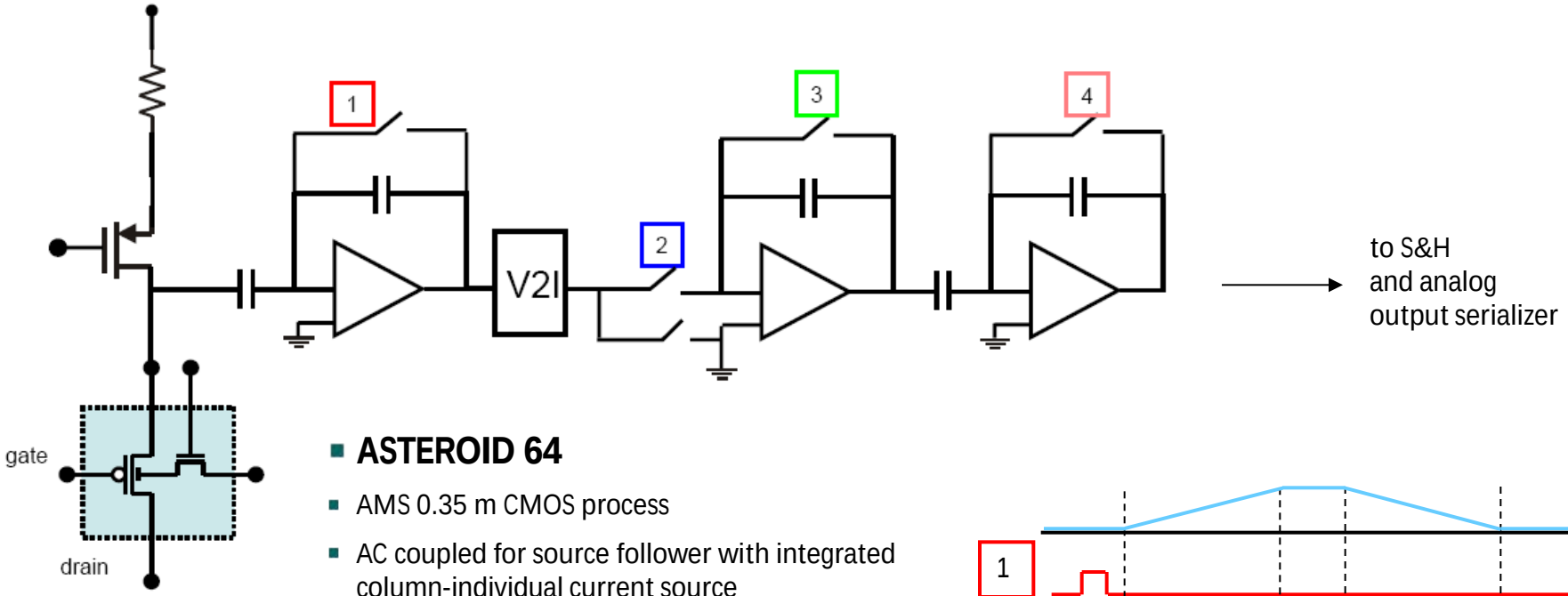


WFI support

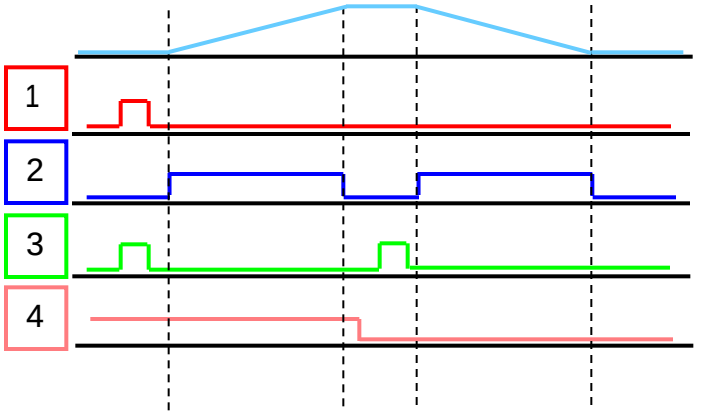




Signal conversion

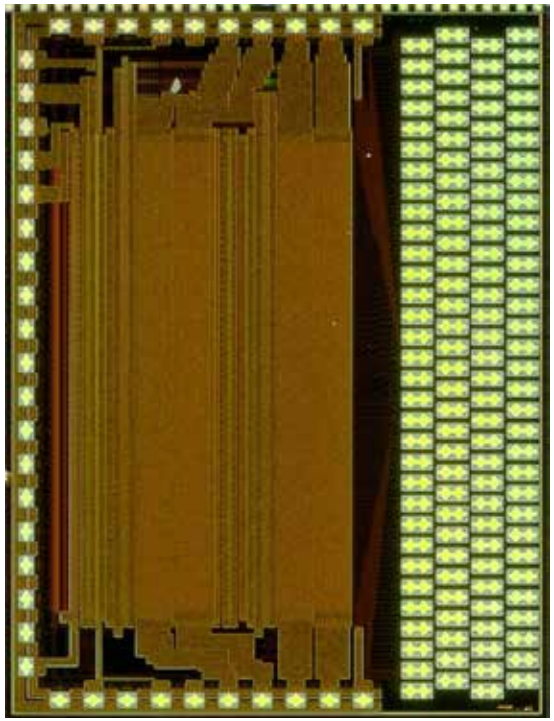


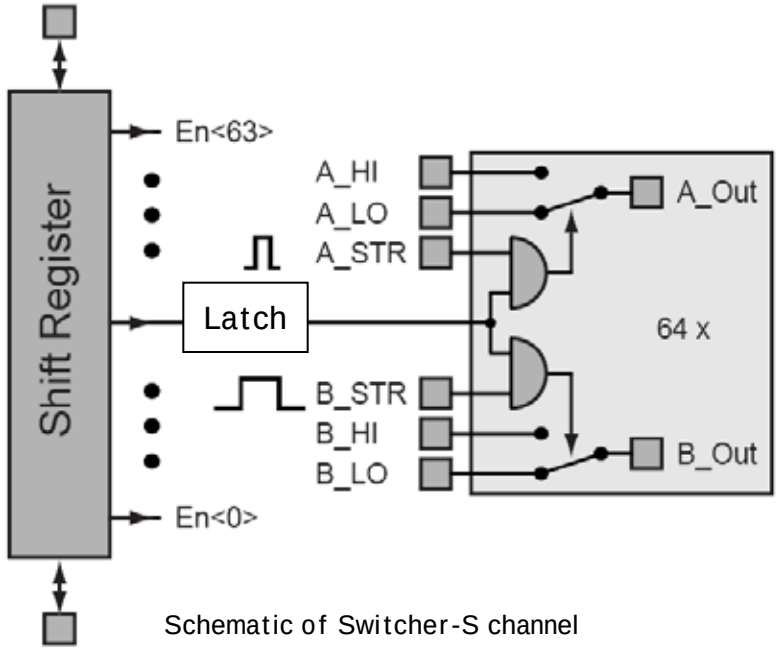
- **ASTEROID 64**
- AMS 0.35 m CMOS process
- AC coupled for source follower with integrated column-individual current source
- Amplifier/Filter circuit implementing a trapezoidal weighting function with integrated S/H and serial analog readout
- Integrated timing sequencer for shaper control
- PRO: AC coupled
- CON: Slow (~4.5 ms)
- **VERITAS 2 -> Current R/O at 2.5 ms / Row**



SWITCHER IC

- **New SWITCHER IC:**
  - (Conceptual) flight heritage from MIXS
  - 35 V Amplitude and higher
  - 3 ports / channel -> new development!
  - 64 channels
  - Jump / widowing functions due to integrated latch

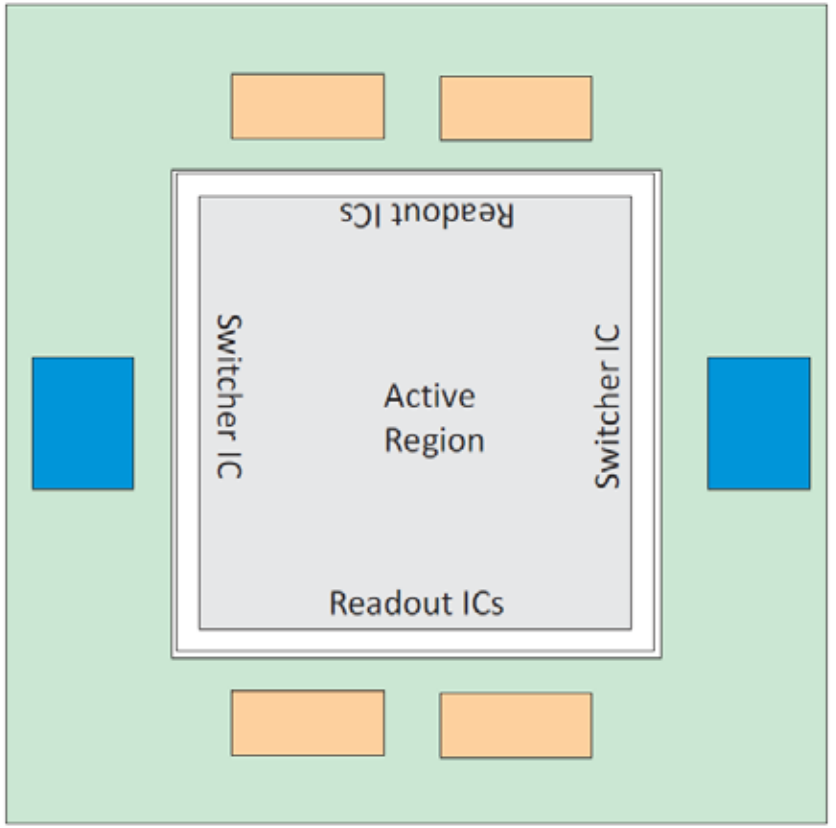




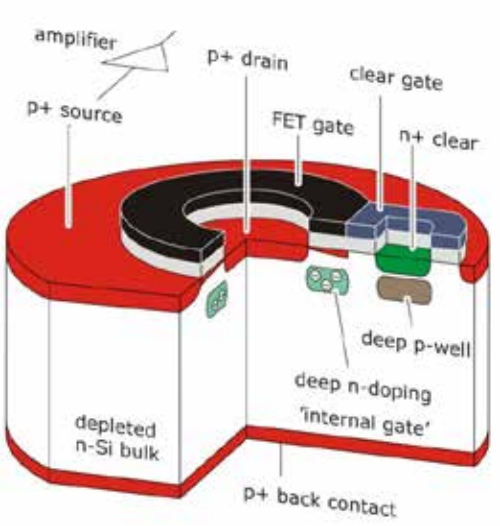
Schematic of Switcher-S channel

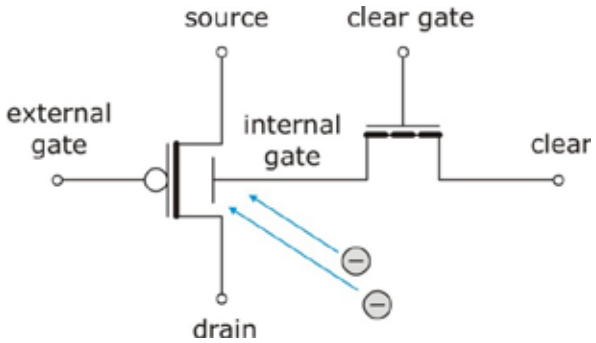
Fast Timing detector

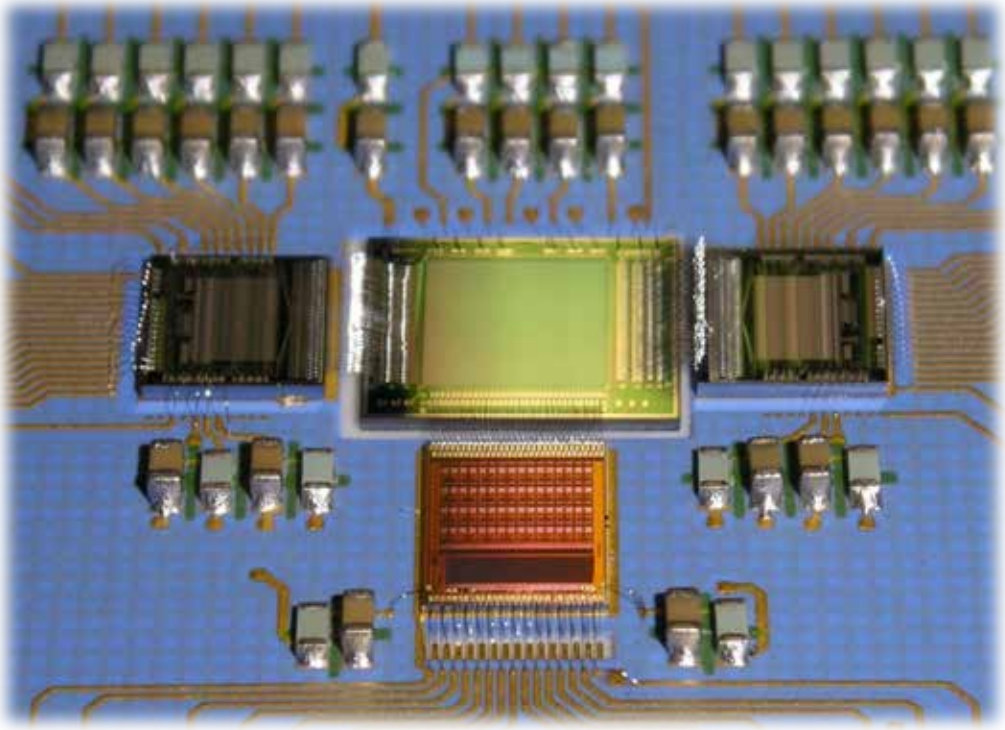
- **Current concept:**
  - Located at different location
  - Defocusing possible to distribute count rate
  - Some imaging capability is desired
  - 64 x 64 pixels
  - 2 hemispheres
  - 2 fold readout (maybe more)
  - 2.5 µs / row
  - Fastest timing requirement demands 16 pixels wide window
  - MISFIT and broken pattern problems require use of an alternative DEPFET concept
  - Infinipix devices - > see talk about multigate DEPFETs



Prototypes (2003)

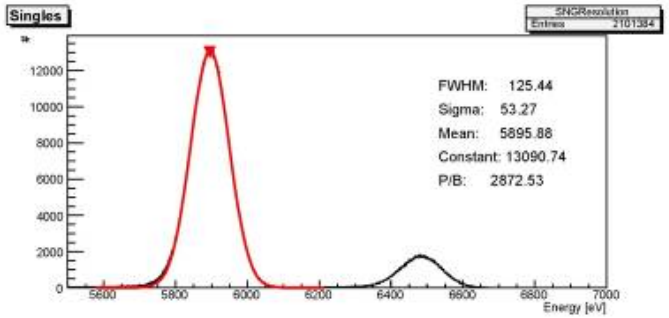


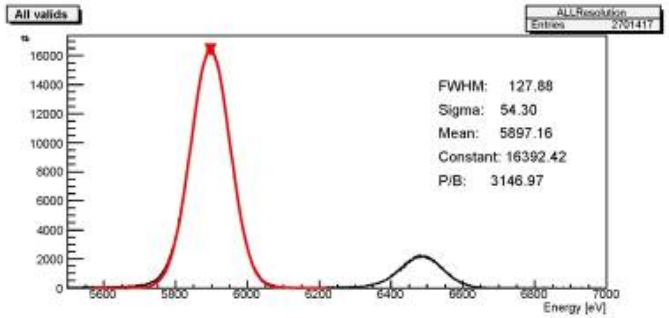


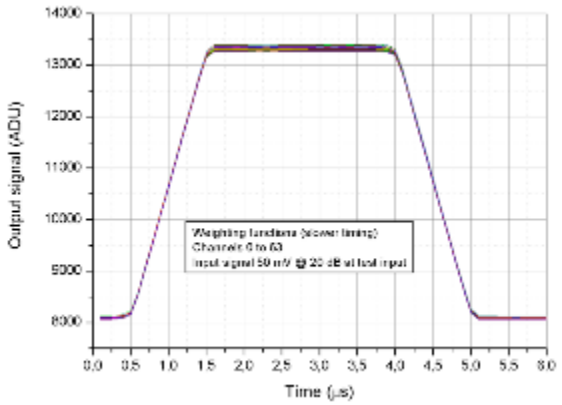


- XS (XEUS small) device
- 64 x 64 pixels
- 75 x 75 mm^2

Prototypes

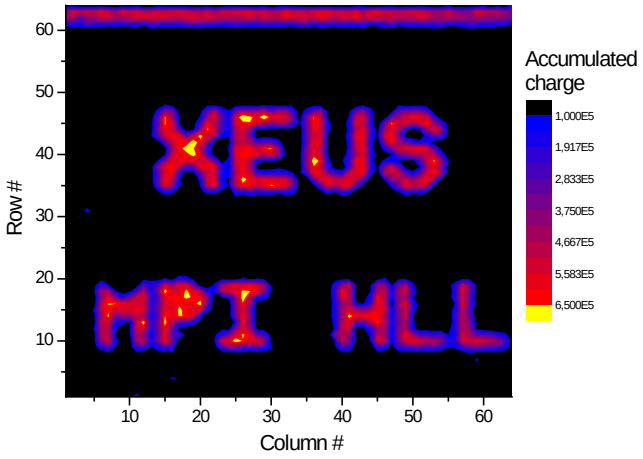




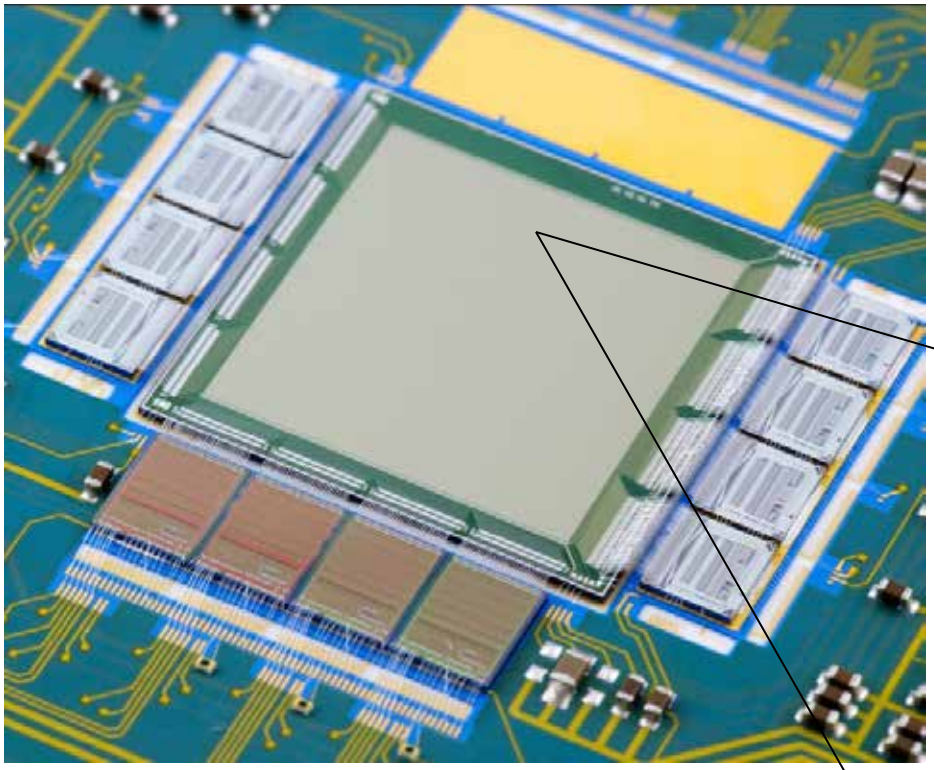


1.0µs integration

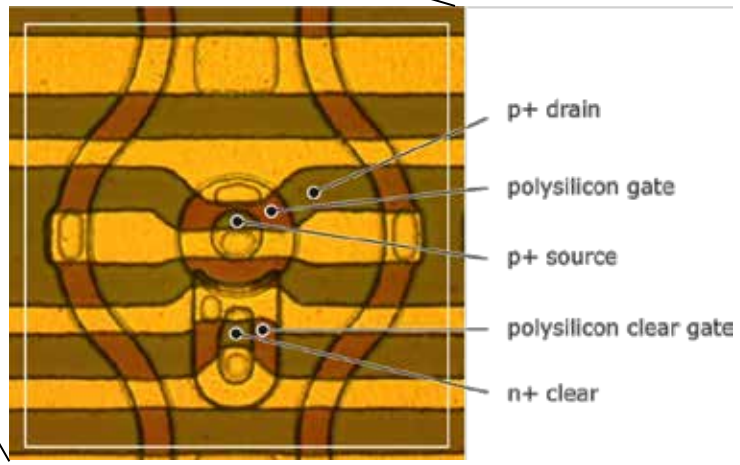
- flat field illumination
- energy esolution (FWHM @ 5.9 keV)
  - **125.4 eV** (singles)
  - **127.9 eV** (all events)
- Readout noise: 3.5 – 4 e^- ENC



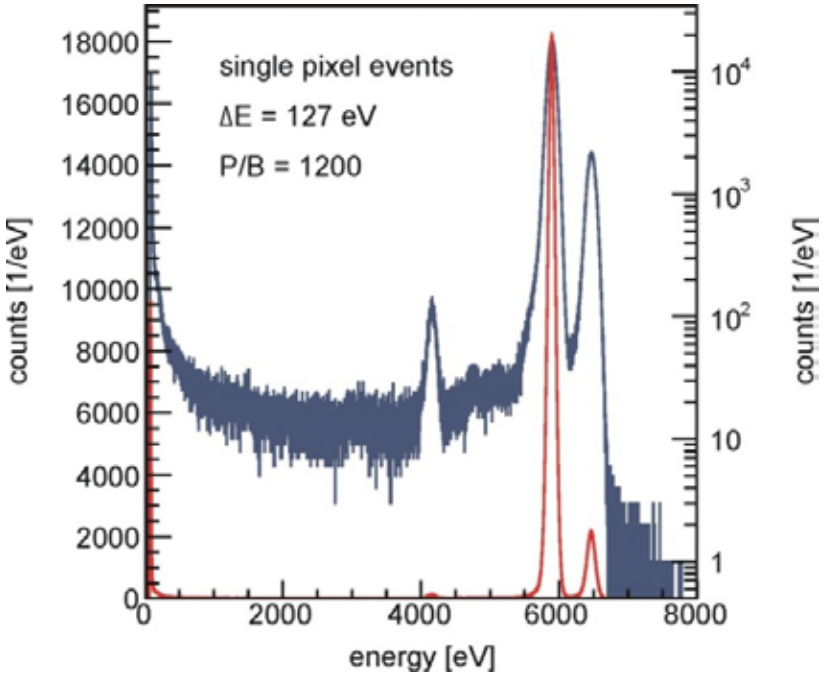
Prototypes (2009)

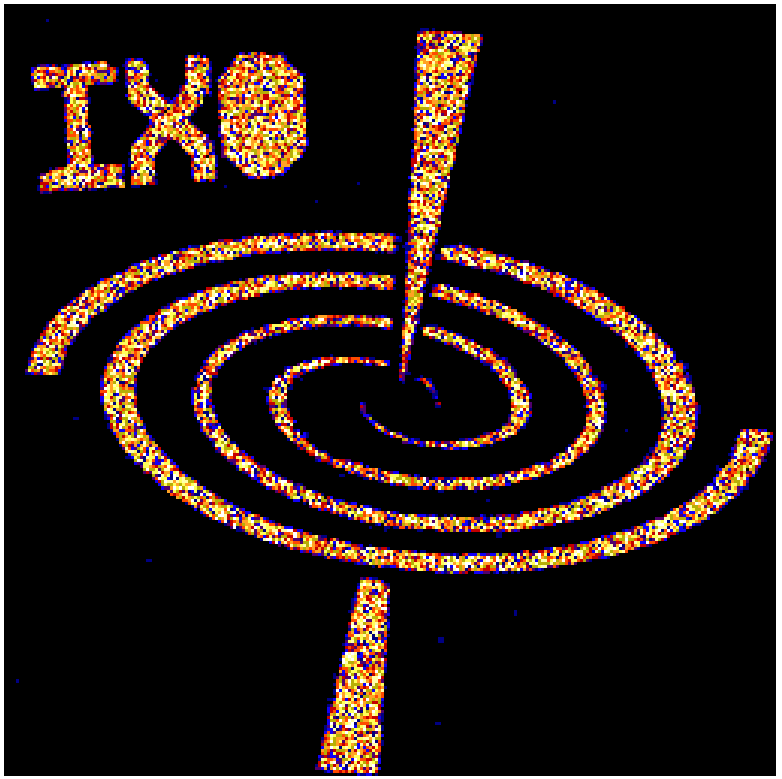


- XL (XEUS large) device
- 256 x 256 pixels
- 75 x 75 mm^2



Prototypes





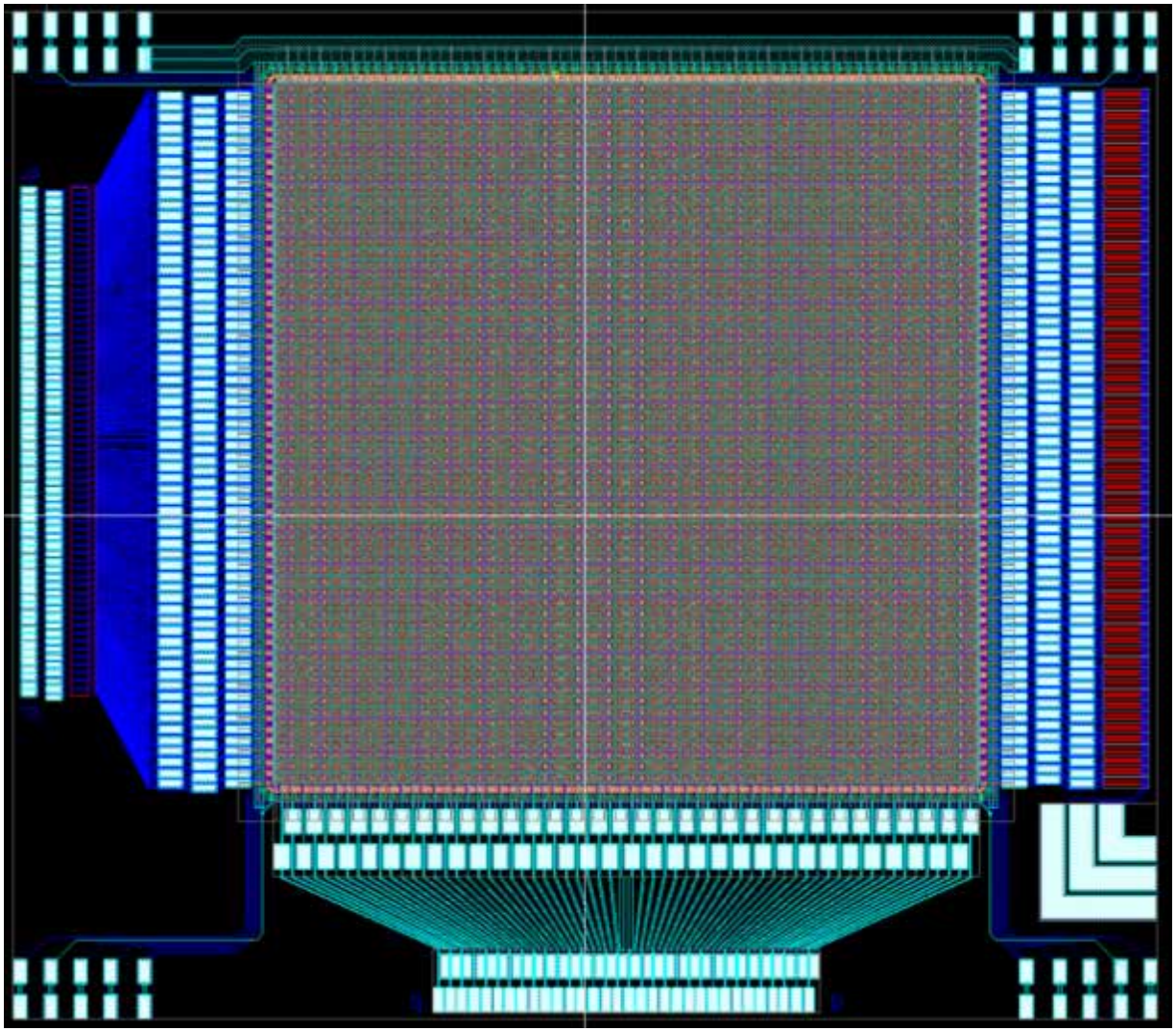
- For ATHENA WFI, we would like to be twice as fast and four time as large at even noise
- Improved pixel structures and technology
- Improved readout electronics

Prototypes in preparation

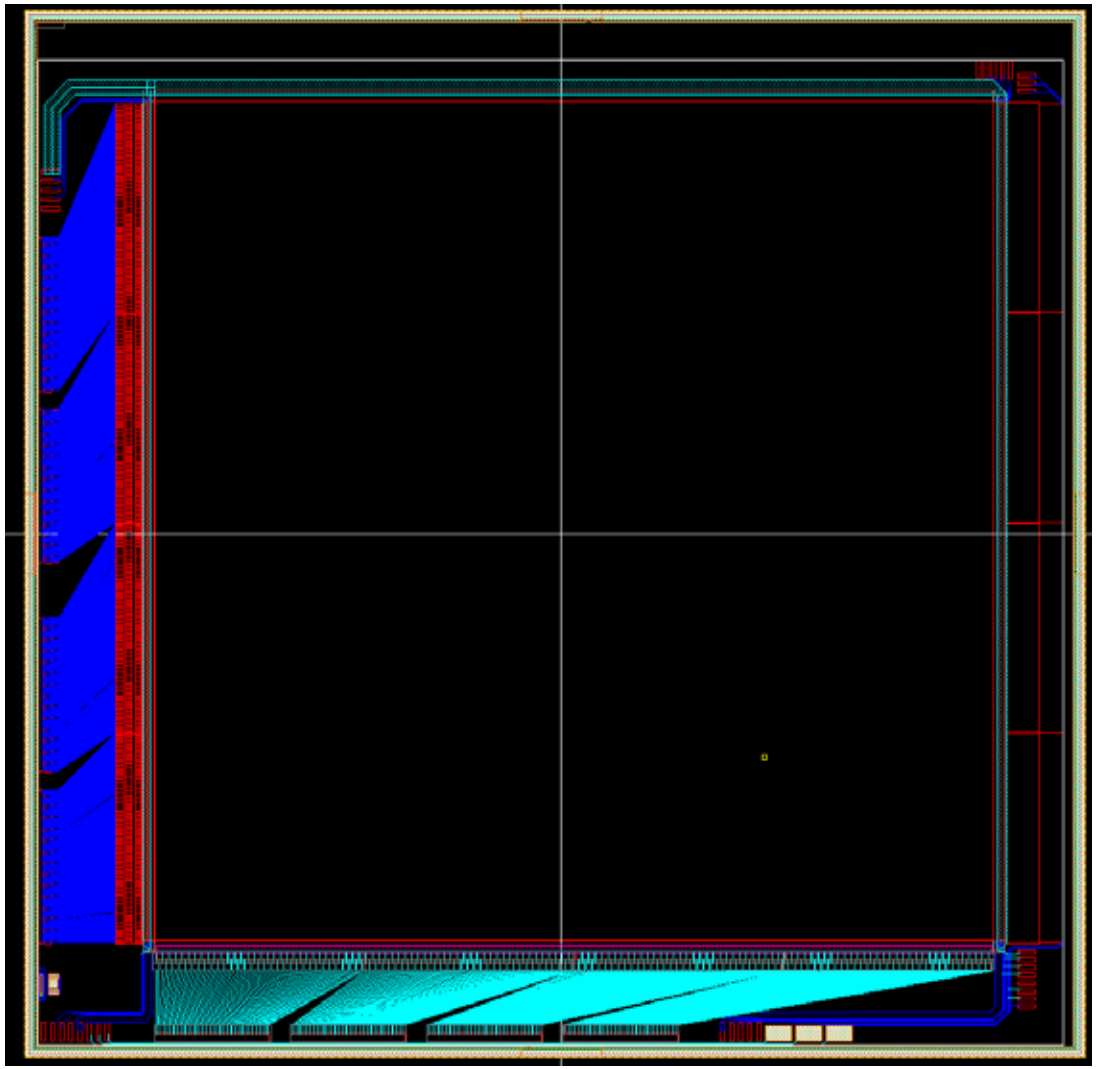
- PXD 11 production started in February
- Finished spring '16
- Various chip formats and pixel types

Name	Abbr.	Format		Size		Comment
		Rows	Cols	Height	Width	
Proto	PC	64	64	13	14,6	Workhorse / test of different variants
Full Width	FW	64	512	13	73	Full width of quadrant for Switcher test
Quarter	QT	256	256	41,2	41,2	Prototype device with wide glueing edges
Full Height	FH	512	128	71,3	23	Full column length for Readout test

Proto-Devices



Quarter devices



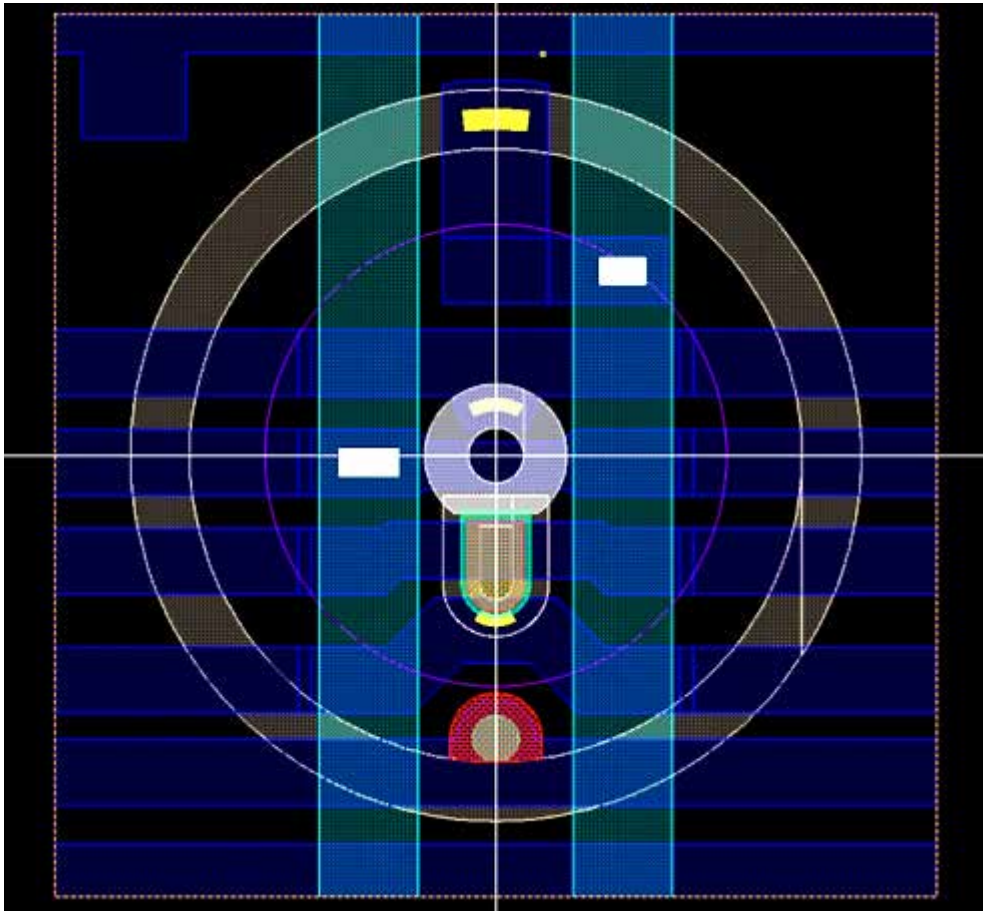
Pixel variants

Cut gate (CG):

- Gate and Cleargate interfere along flat line
- Standard variant, used for e.g. MIXS
- Well known performance

Con:

- W/L fixed
- Not scalable
- Long clear times
- Improvement of performance only via transistor parameters



Baseline for Quarter / Full Width / Full Height - > All large devices

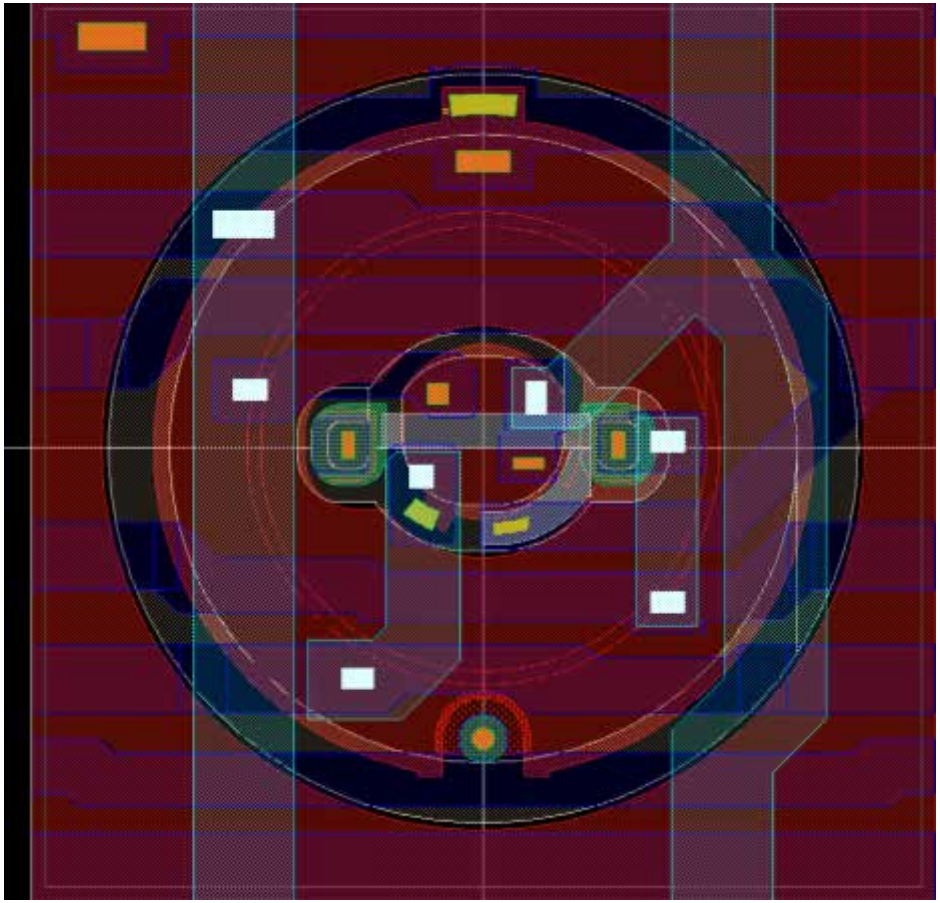
Pixel variants

Linear gate Little Clear (LGLC):

- True linear gate structure
- W/L not fixed
- Performance improvement due to short channel length
- Scalable to some degree
- Much smaller Clear area compared to LG
- Short clear times
- Studied in 3D
- Requires psh gap
- Always wedged

Con:

- Large Polysilicon areas
- Two clear regions
- New structure
- Larger dispersion due to narrow gate geometry



Summary and outlook

- ATHENA+ will be the next generation x-ray observatory
- AO scheduled for early 2016, launch in 2028
- WFI detectors developed by HLL and MPE
- 2 prototype productions at HLL: one dedicated to WFI LAD devices (started in February) and one dedicated to Infinipix devices (starting late 2015)
- Challenge in area, noise and readout speed
- Tackled by technology, topology and readout electronics
- Flight production to start in 2018

- **But: Not the first DEPFET in space!**

DEPFET in space