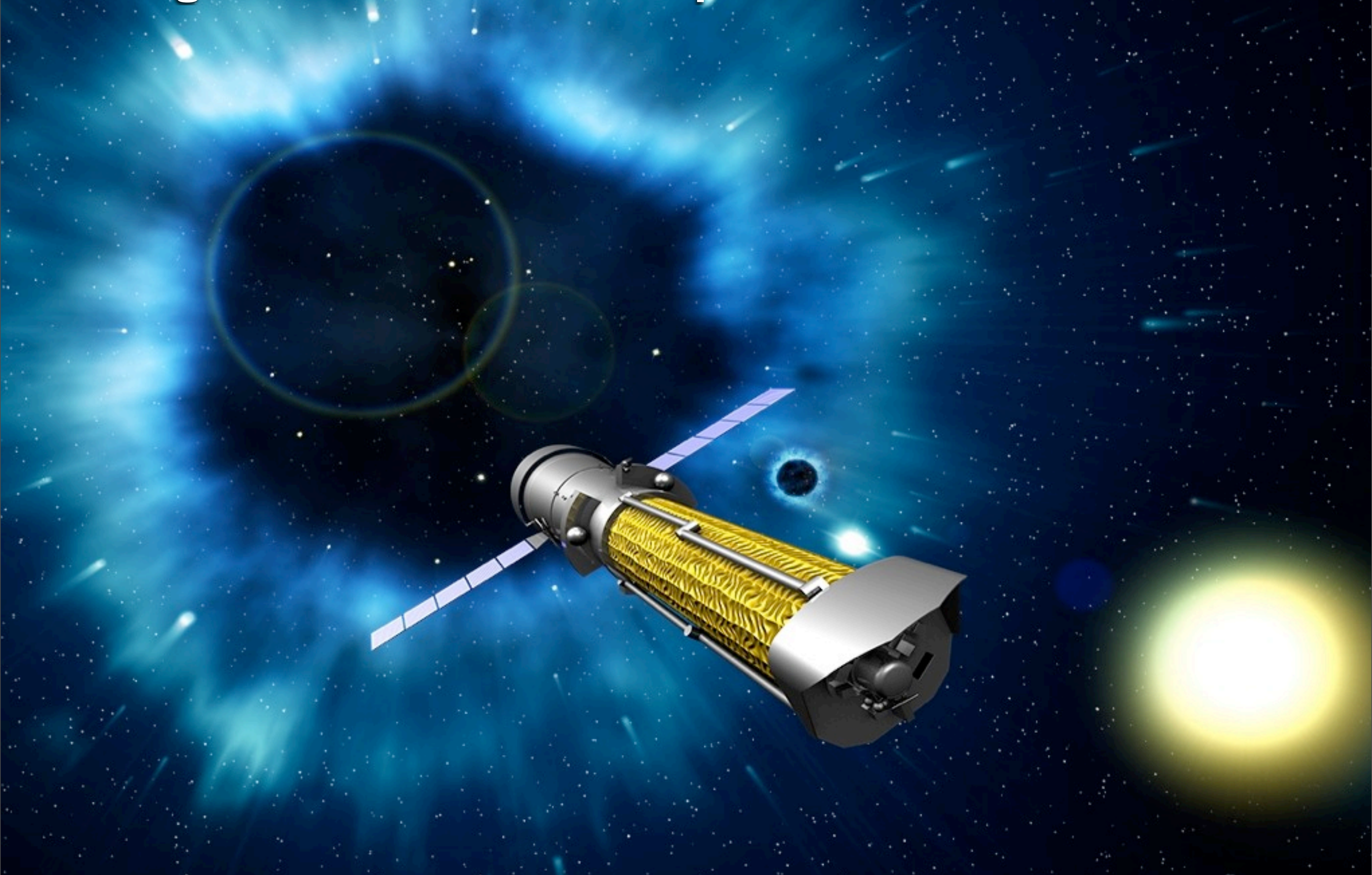
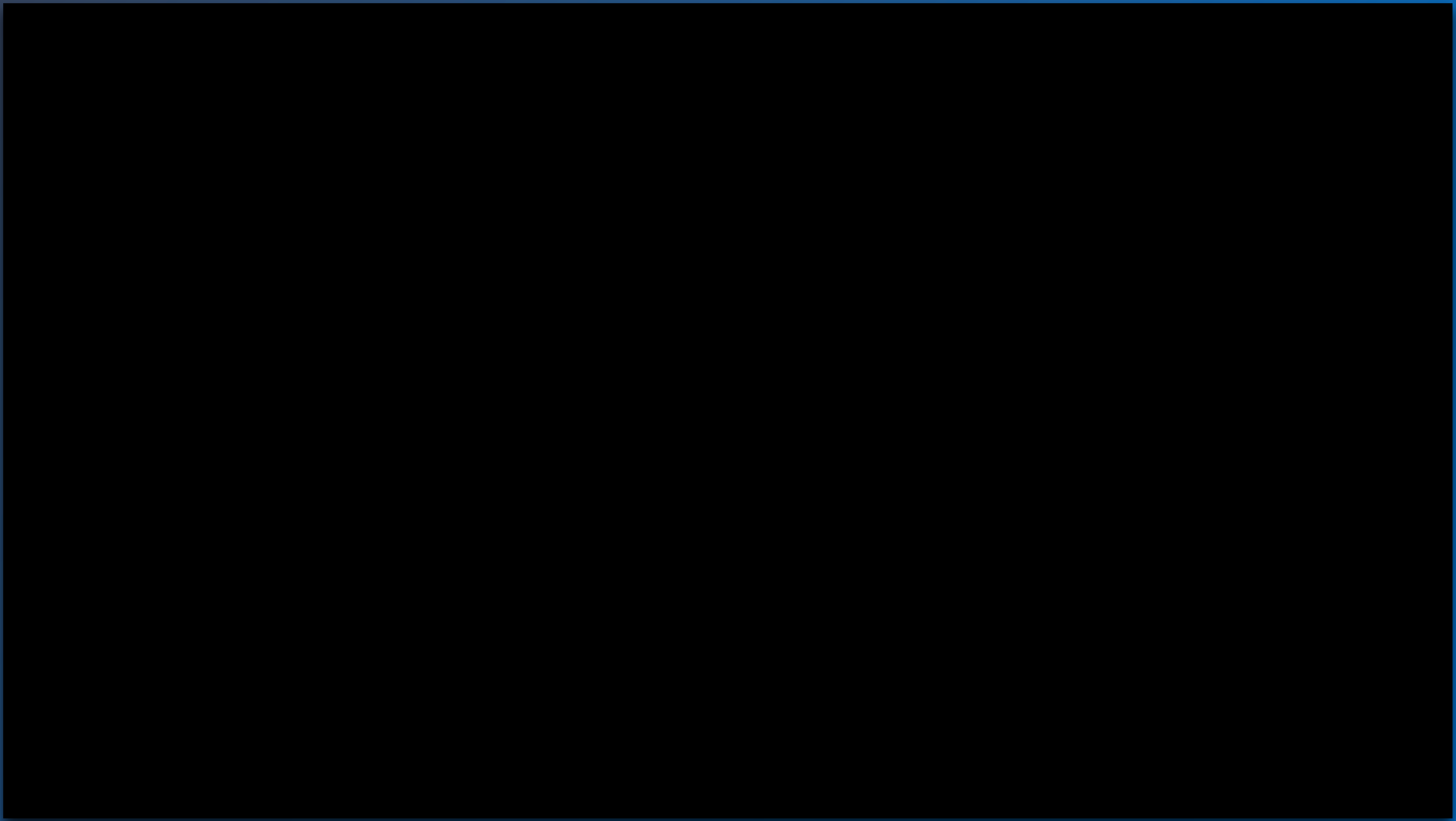
The High Time Resolution Spectrometer onboard IXO



The HTRS team

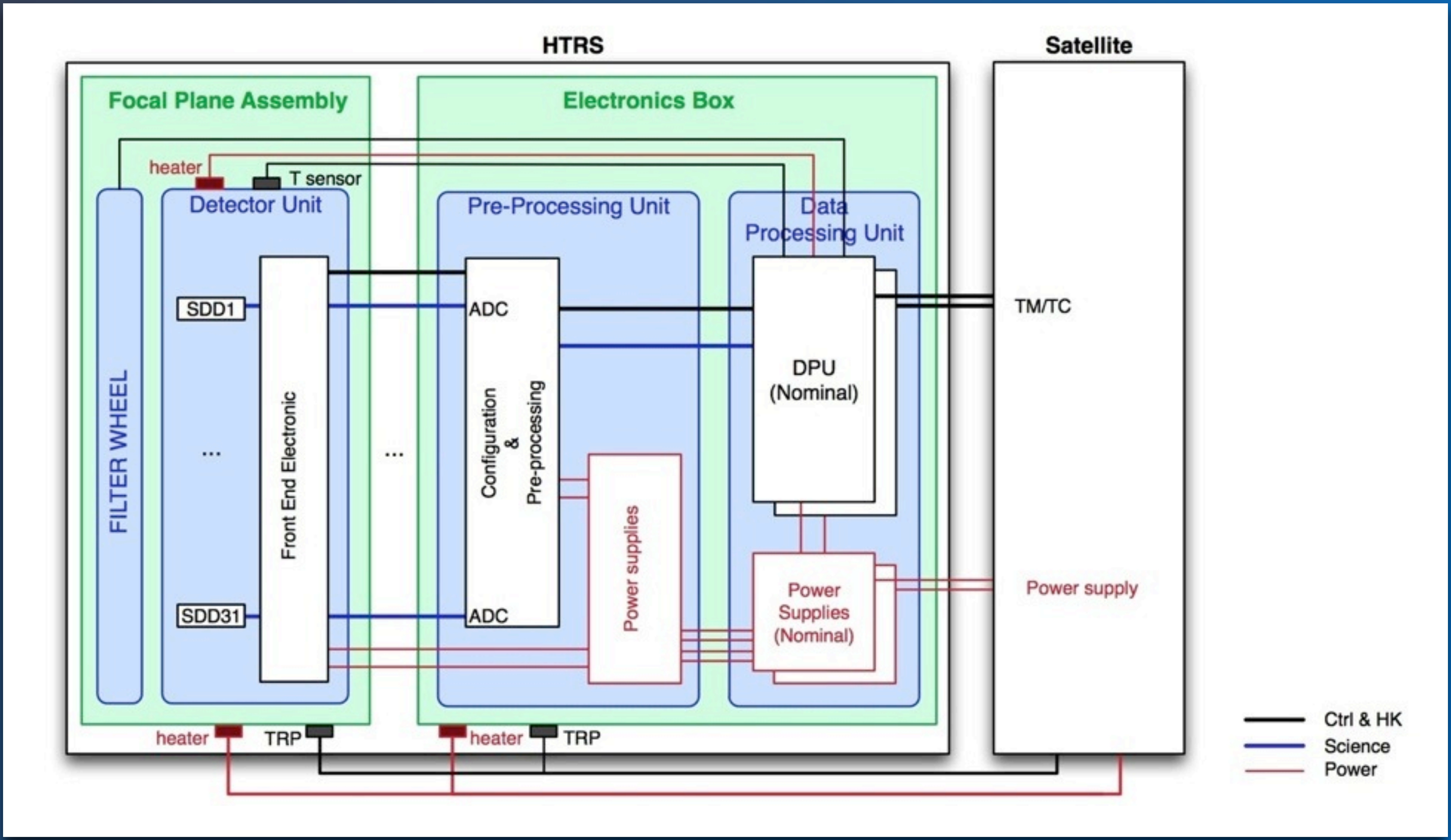
The International X-ray Observatory



Main requirements

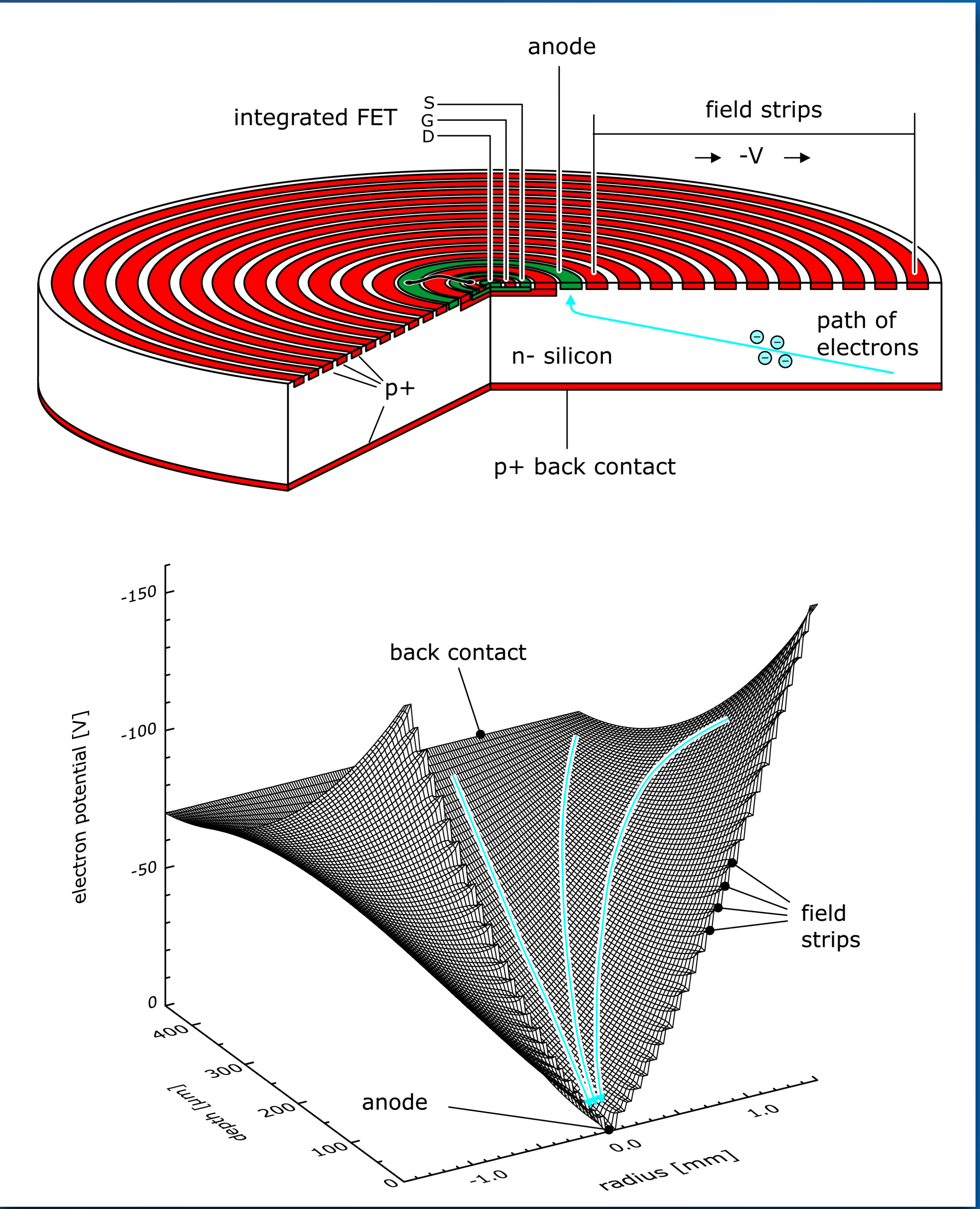
Parameter	Value	Remark
Max count rate	2 Mcounts/s	(about 12 Crab)
Energy range	0.3 to 15 keV	
Energy resolution (FWHM @ 5.9 keV)	150 eV	Goal (BOL)
	200 eV	Requirement (BOL)
	300 eV	Requirement (EOL)
Time resolution	10 µs	
Absolute Timing Accuracy	100 µs	Easily compliant
Dead time @ 1 Crab	< 2 %	Top level IXO requirement = 1 Crab with > 90% throughput
Pile up @ 1 Crab	< 2 %	

Functional diagram



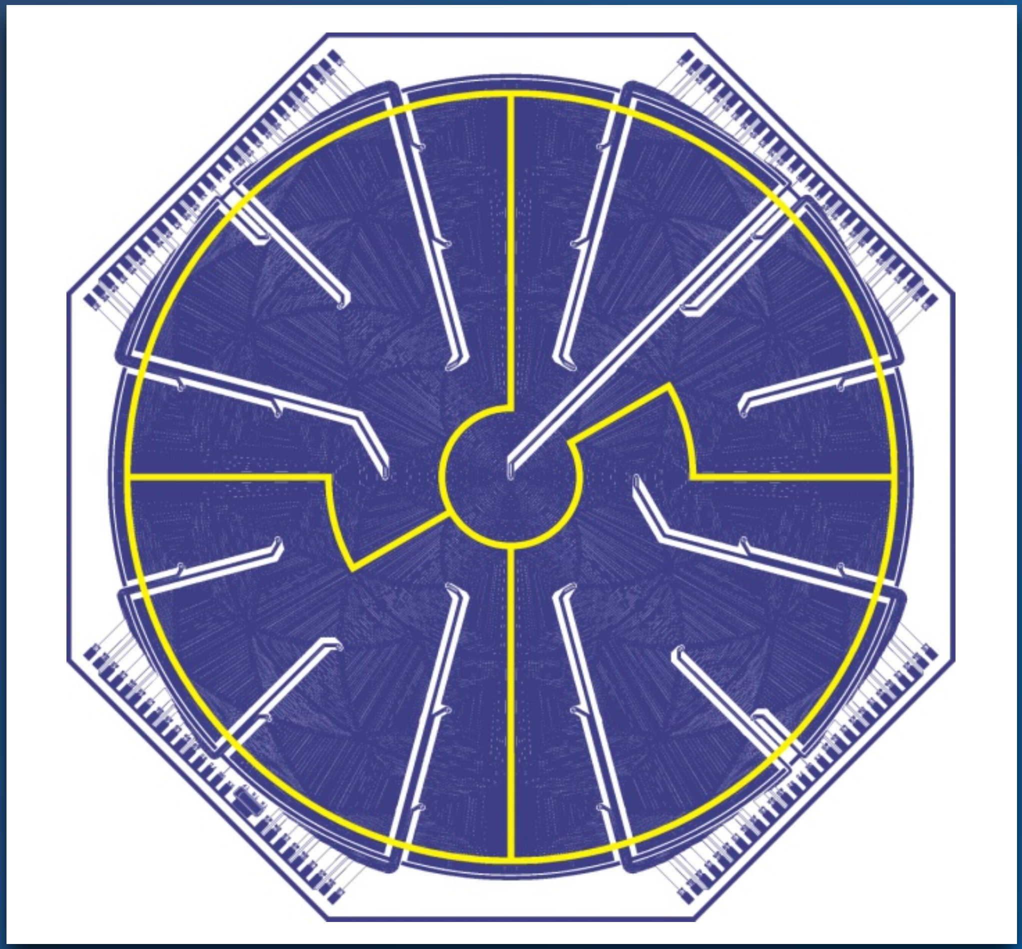
The SDD detectors

- Large sensitive area
- Small capacitance + integrated FET
  - ✓ Low electronics noise
  - ✓ Insensitive to pickup
  - ✓ High count rate capabilities
- Low leakage current level
  - ✓ Operation at room temperature or at moderate cooling
- Homogeneous entrance window
  - ✓ Backside illumination
- Flexible in shape and size

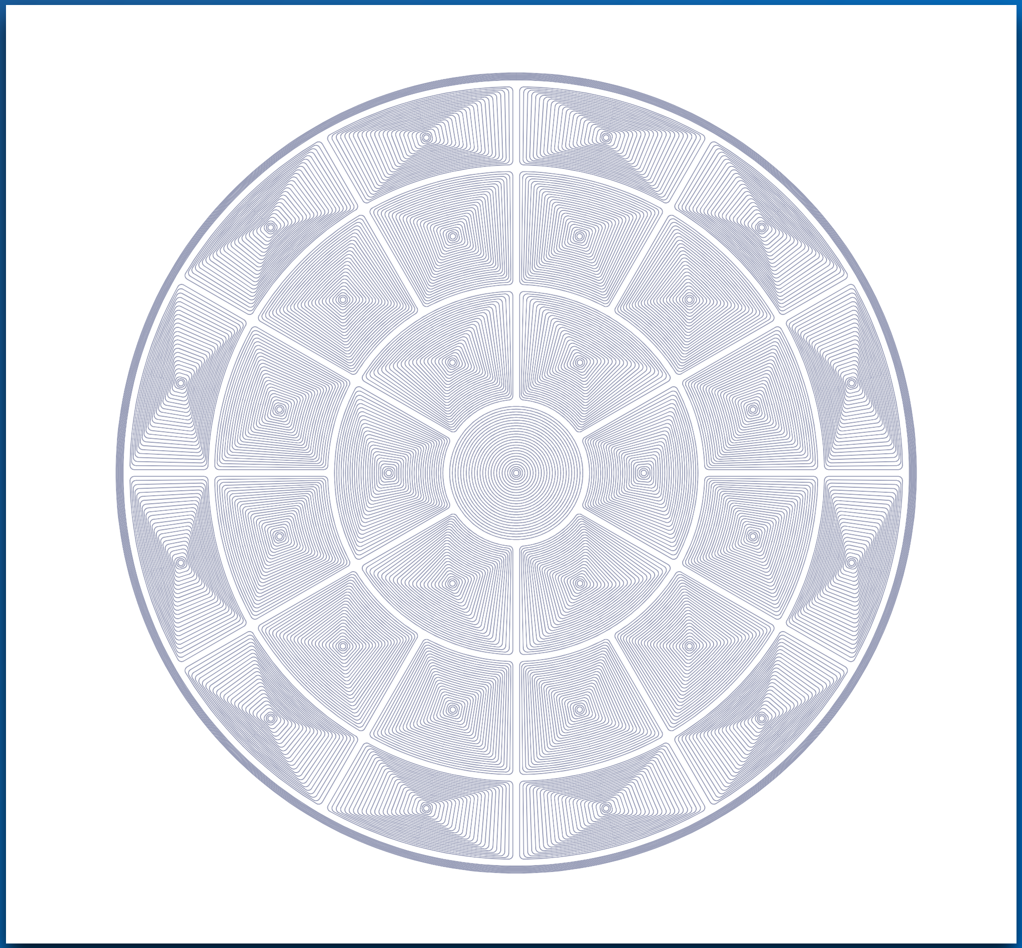


The detector array

- 31 pixels with same area
- Flux spread almost homogeneously on the array (HTRS is not an imaging device)
- Shape and size has to handle tilt and misalignment
- Cooled at -40°C
- Split in 4 quadrants to limit failure impacts

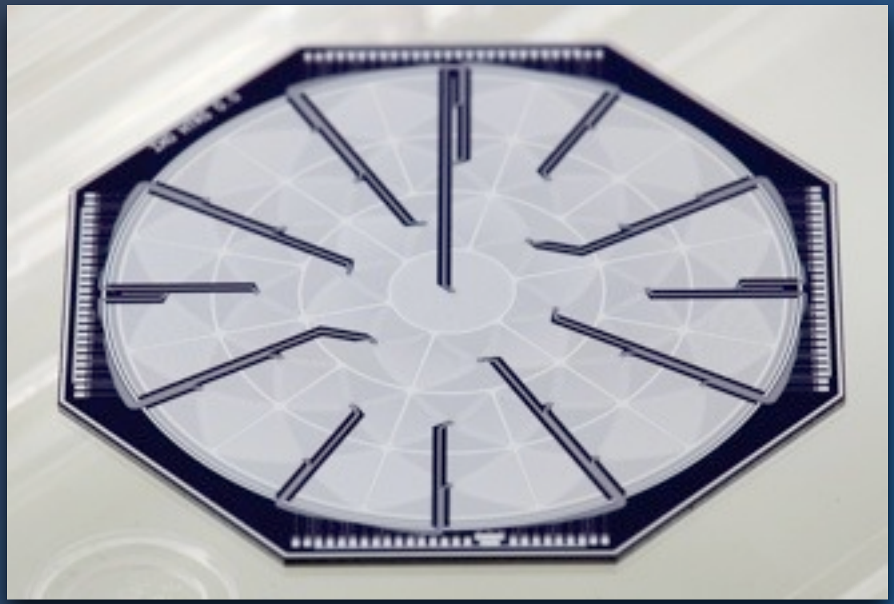


(top metal layer)

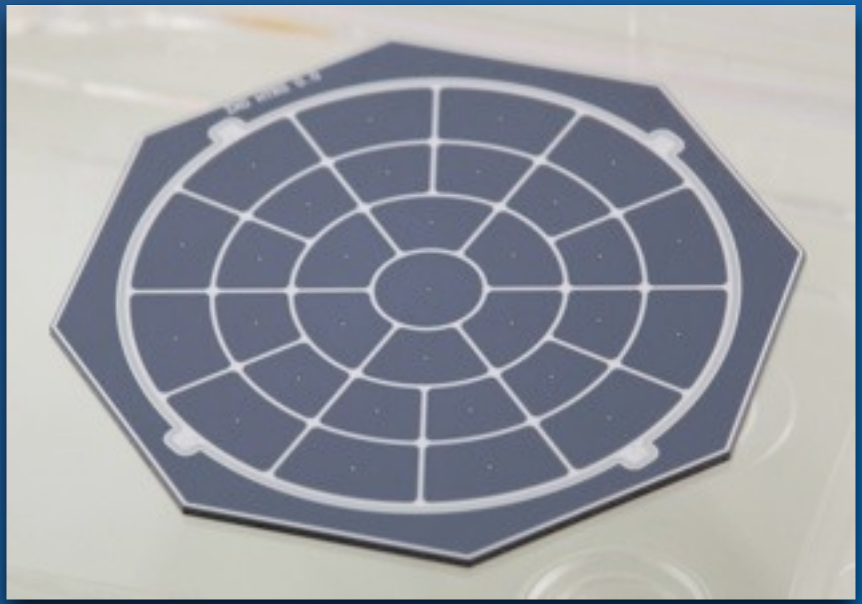


(drift ring structure)

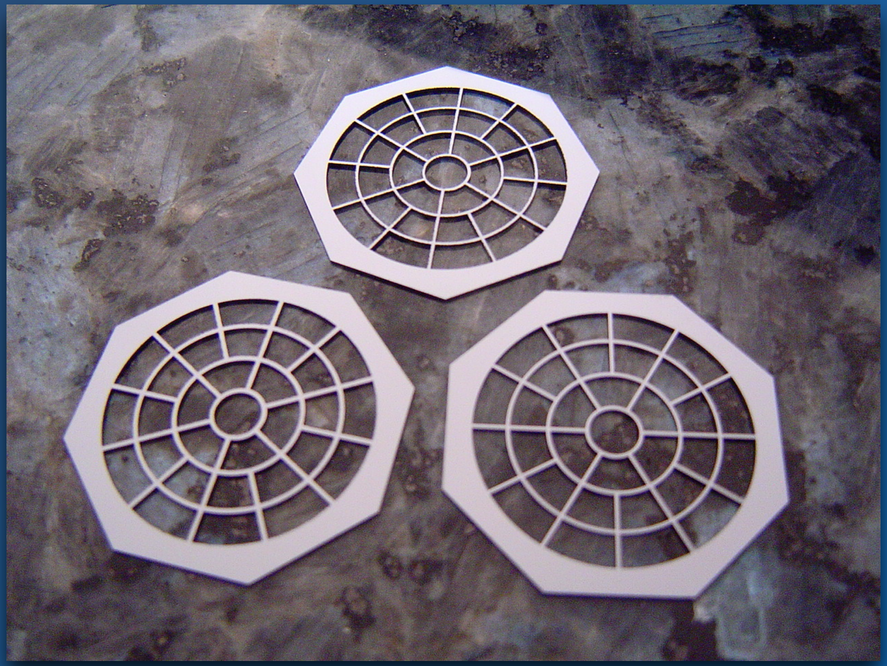
The detector array

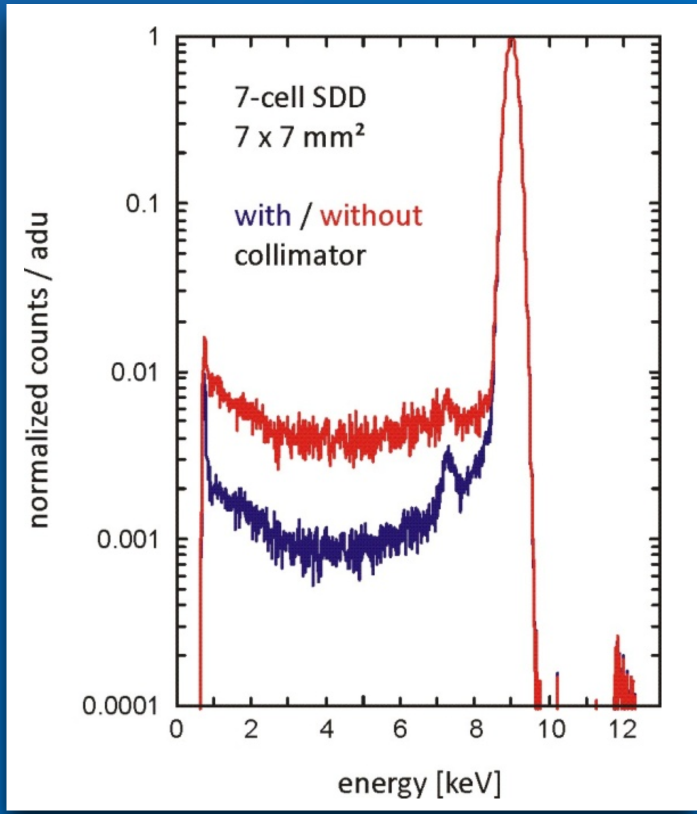


(Dummy array - readout side)


(Dummy array - entrance window)

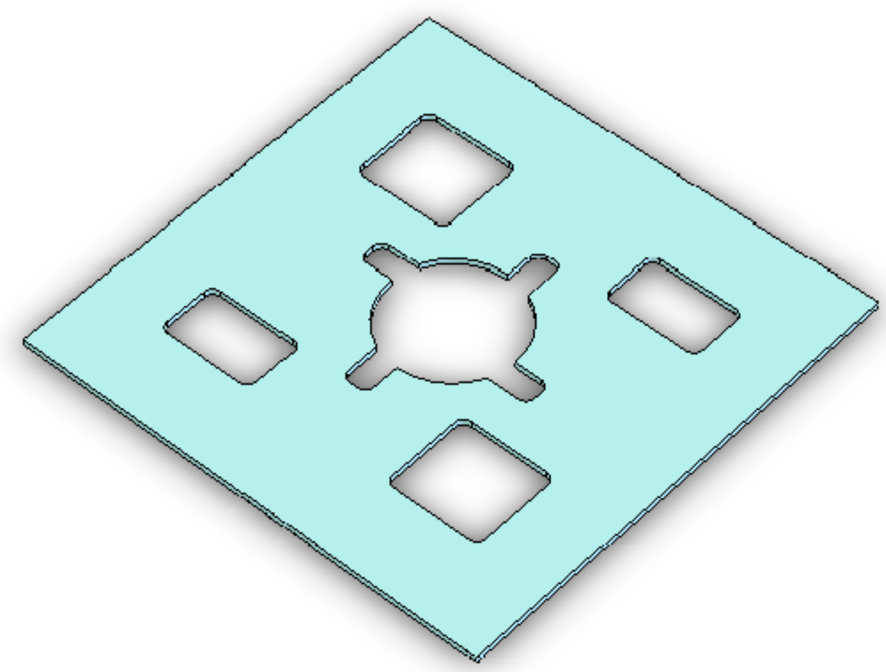
- A 200 µm width collimator is placed on top the array to avoid split events


(200 µm, 300 µm and 400 µm width masks)



The Detector Unit (DU)

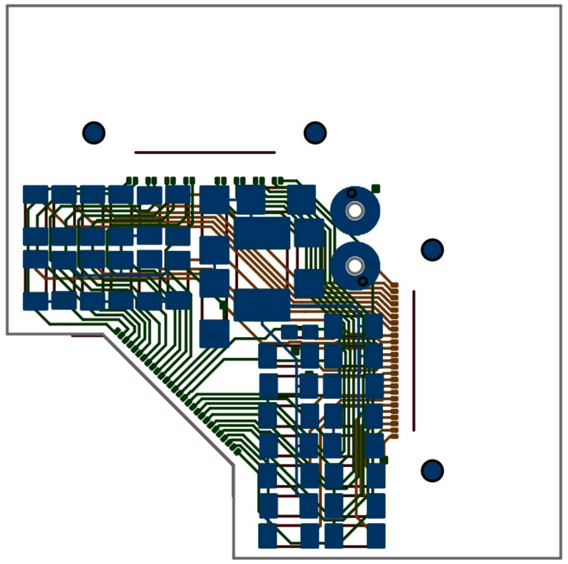
Base ceramic

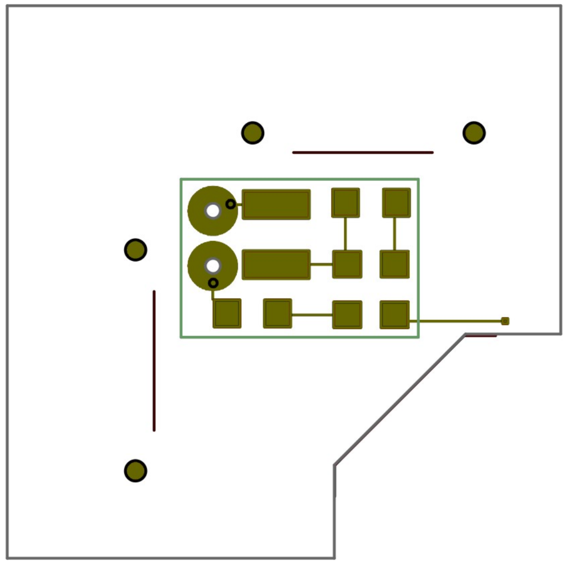


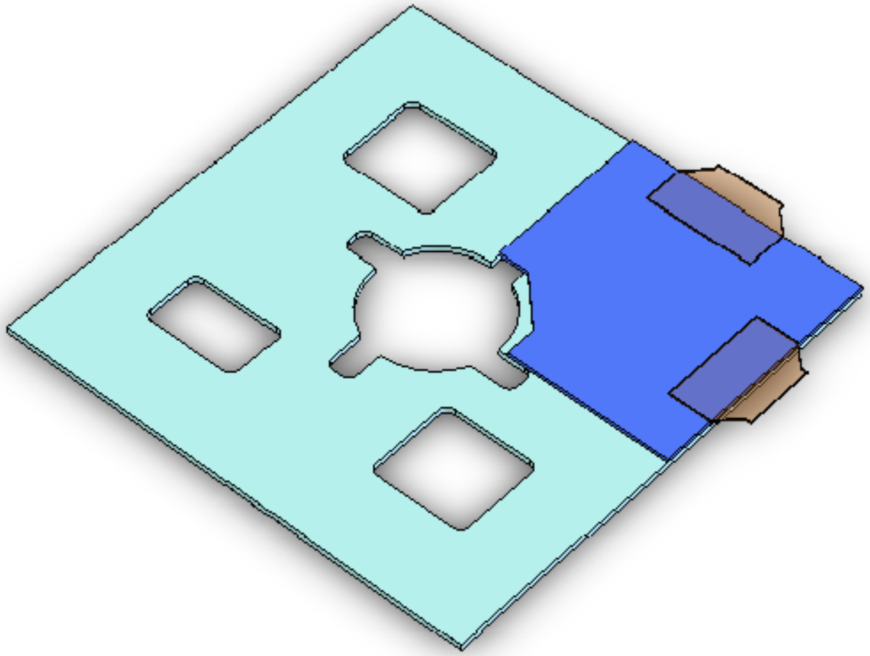
The Detector Unit (DU)

Base ceramic

Sensor hybrid



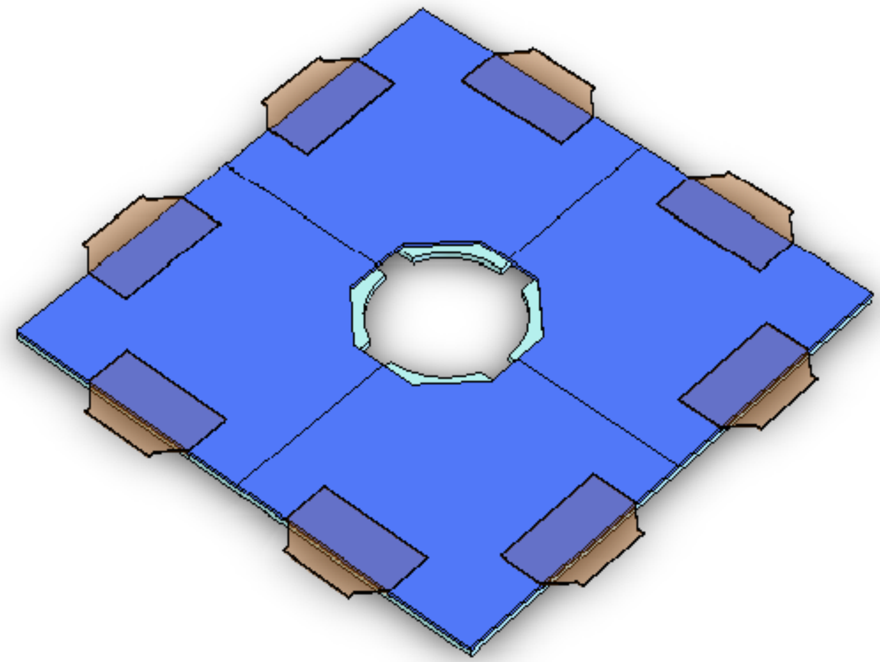




The Detector Unit (DU)

Base ceramic

Sensor hybrid

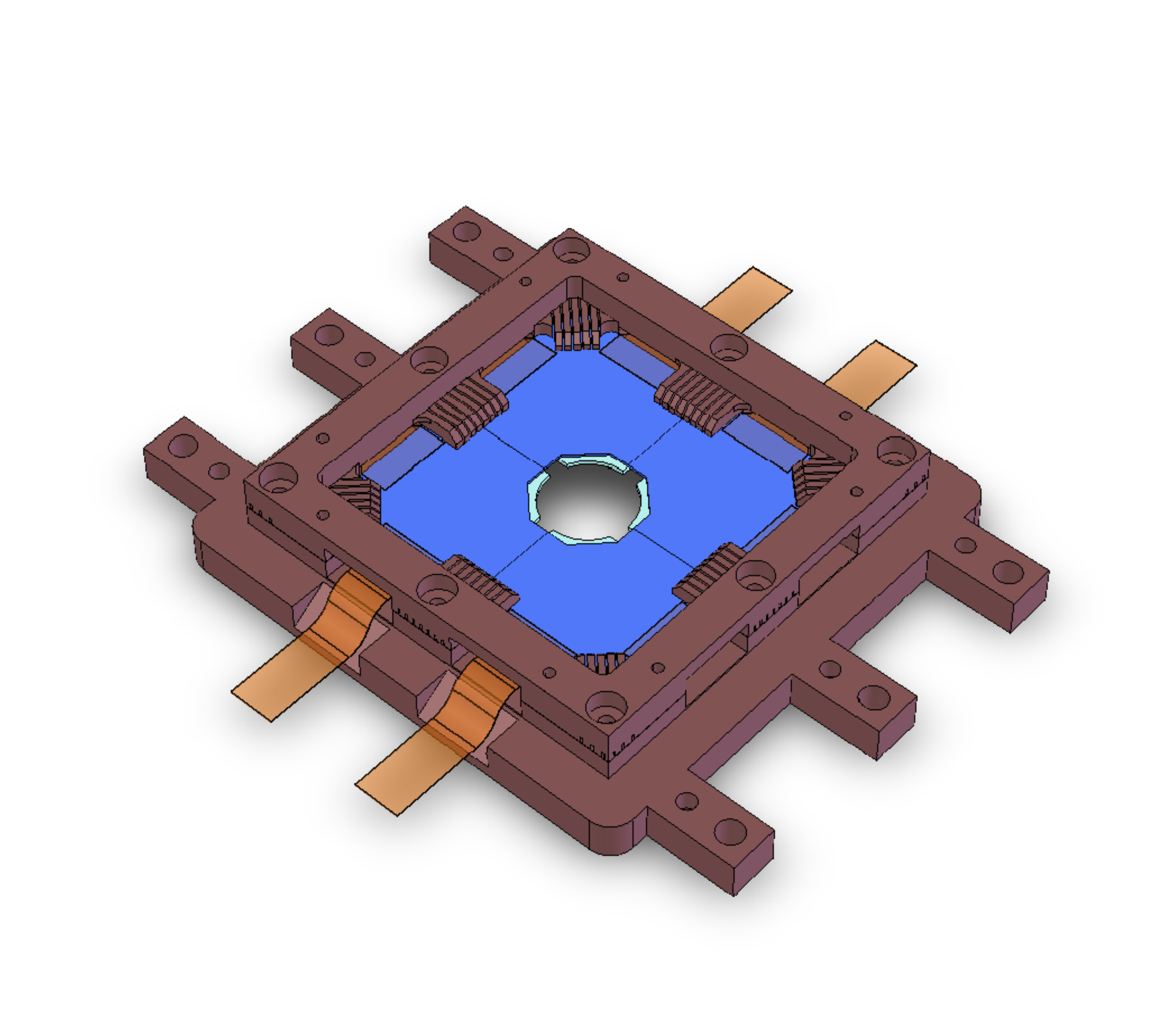


The Detector Unit (DU)

Base ceramic

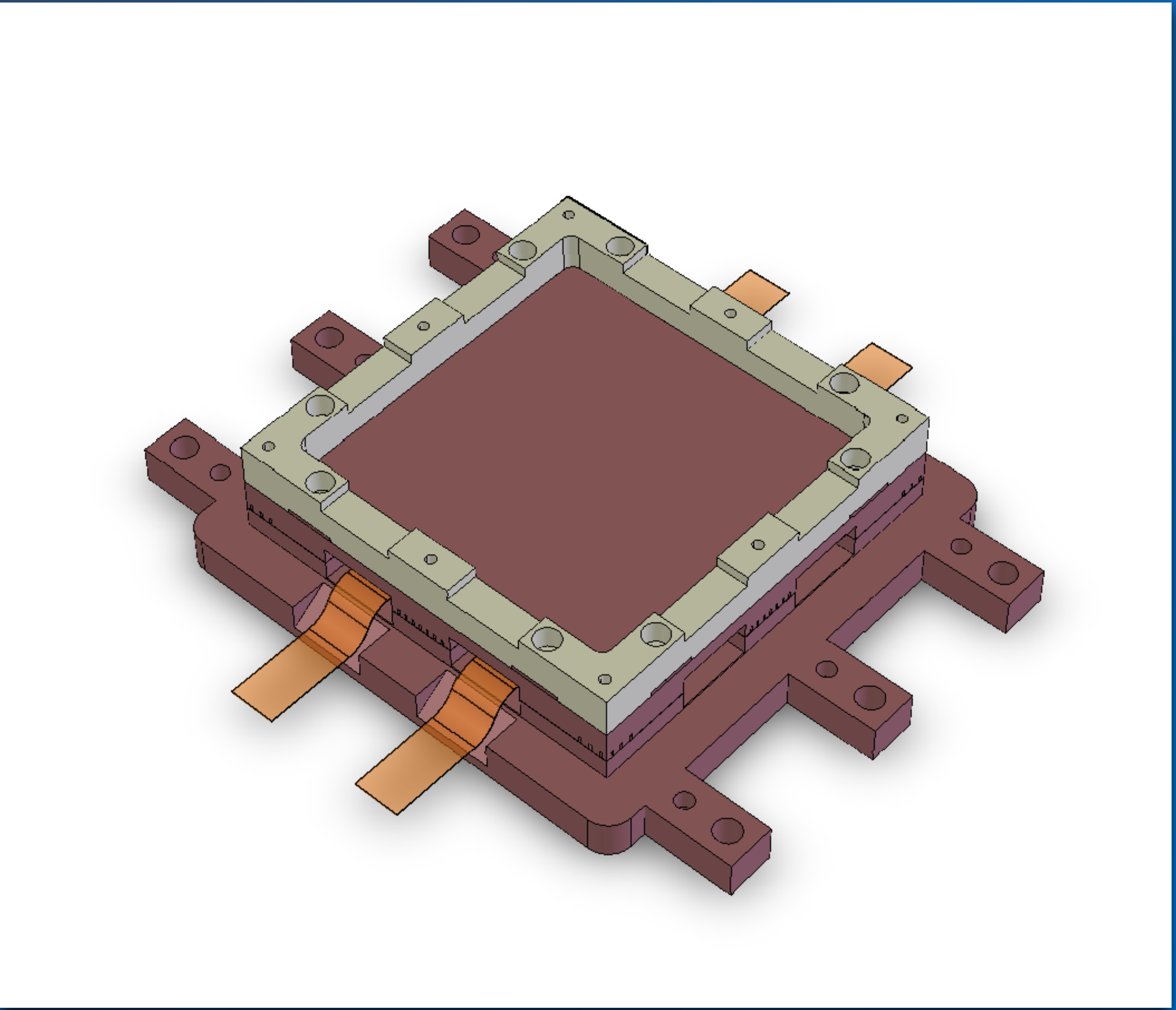
Sensor hybrid

Carrier frame



The Detector Unit (DU)

- Base ceramic
- Sensor hybrid
- Carrier frame
- **Graded shield**
- **Thermal insulator**



The Detector Unit (DU)

Base ceramic

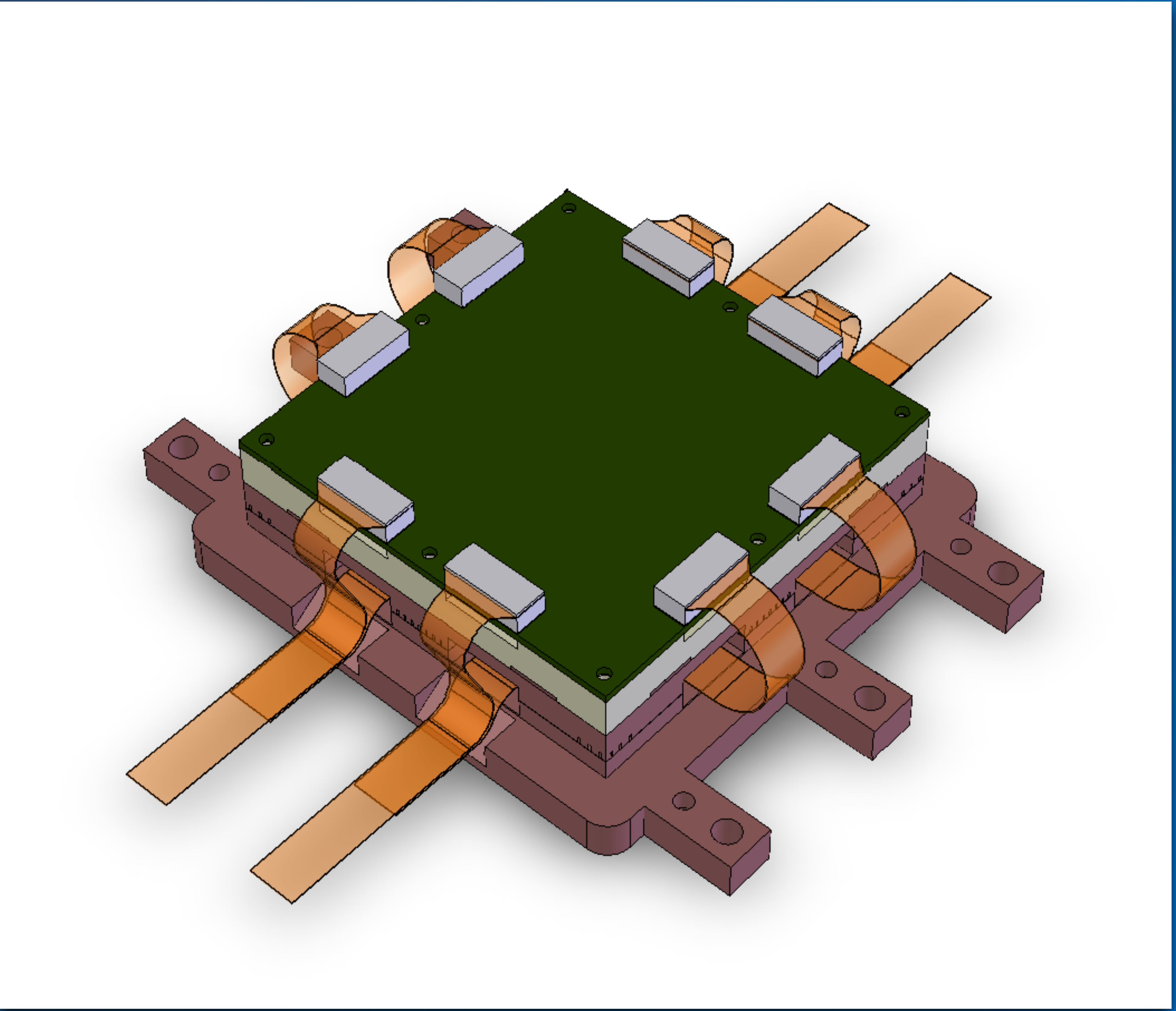
Sensor hybrid

Carrier frame

Graded shield

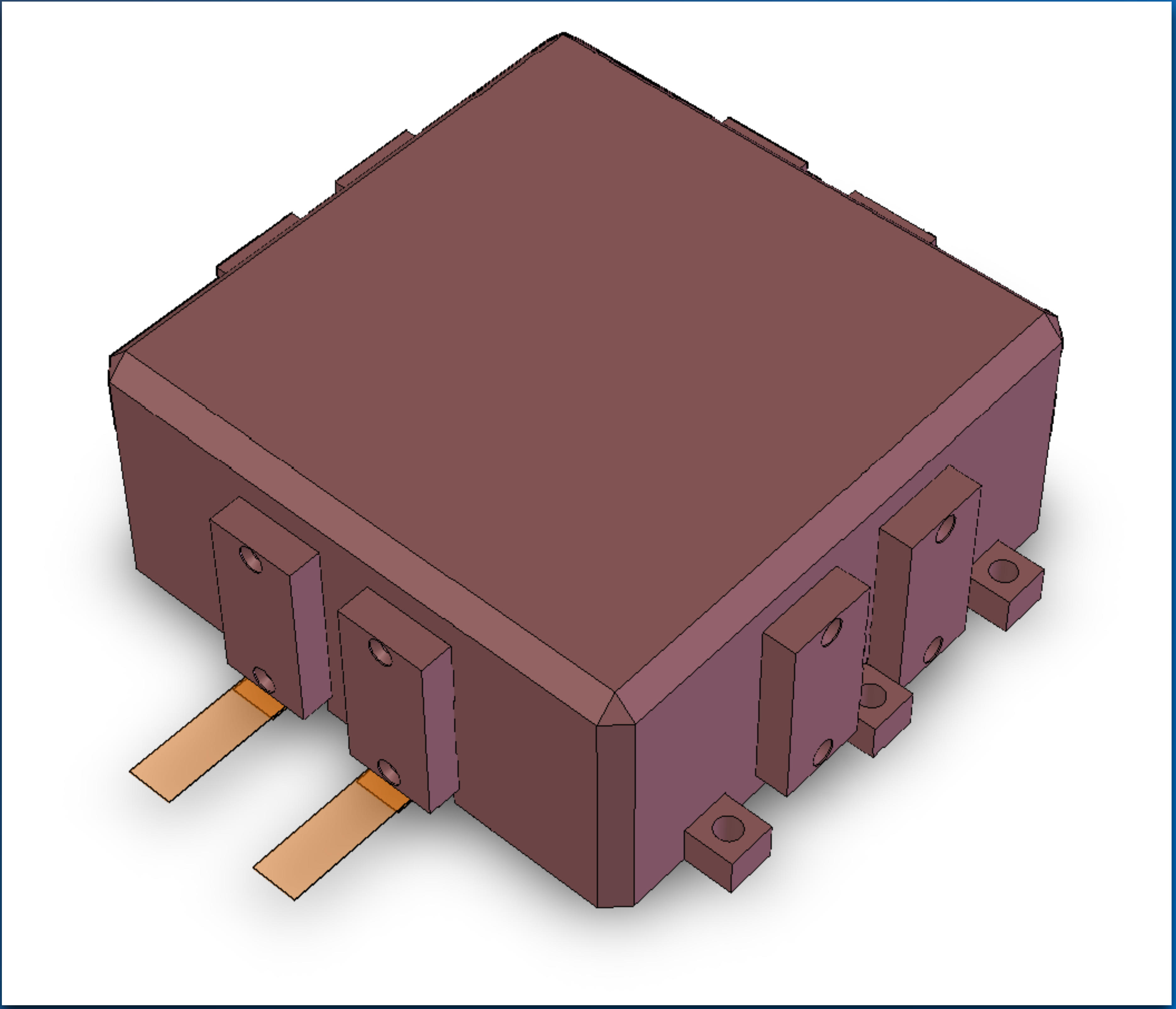
Thermal insulator

ASIC board



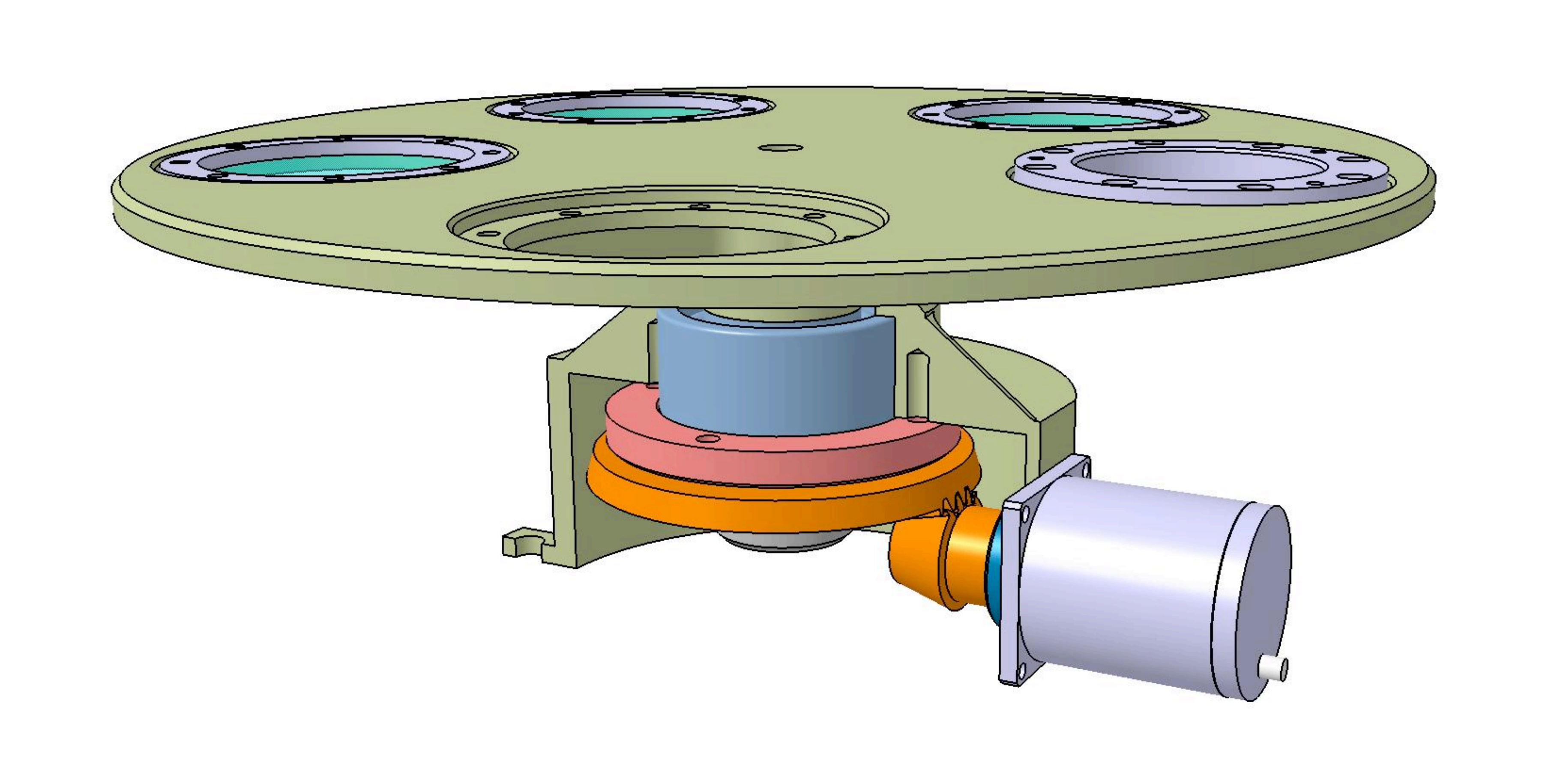
The Detector Unit (DU)

- Base ceramic
- Sensor hybrid
- Carrier frame
- Graded shield
- Thermal insulator
- ASIC board
- **15 mm Al Shield**

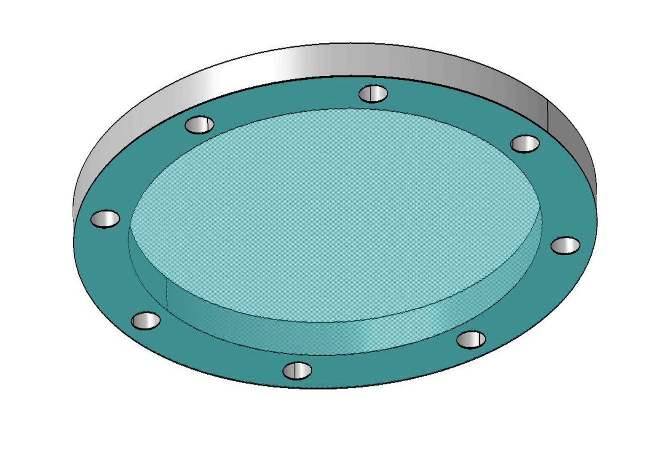


The Filter Wheel (FW)

- 5 positions:
  - ✓ Closed
  - ✓ Open
  - ✓ Thin filter
  - ✓ Thick filter
  - ✓ Calibration source

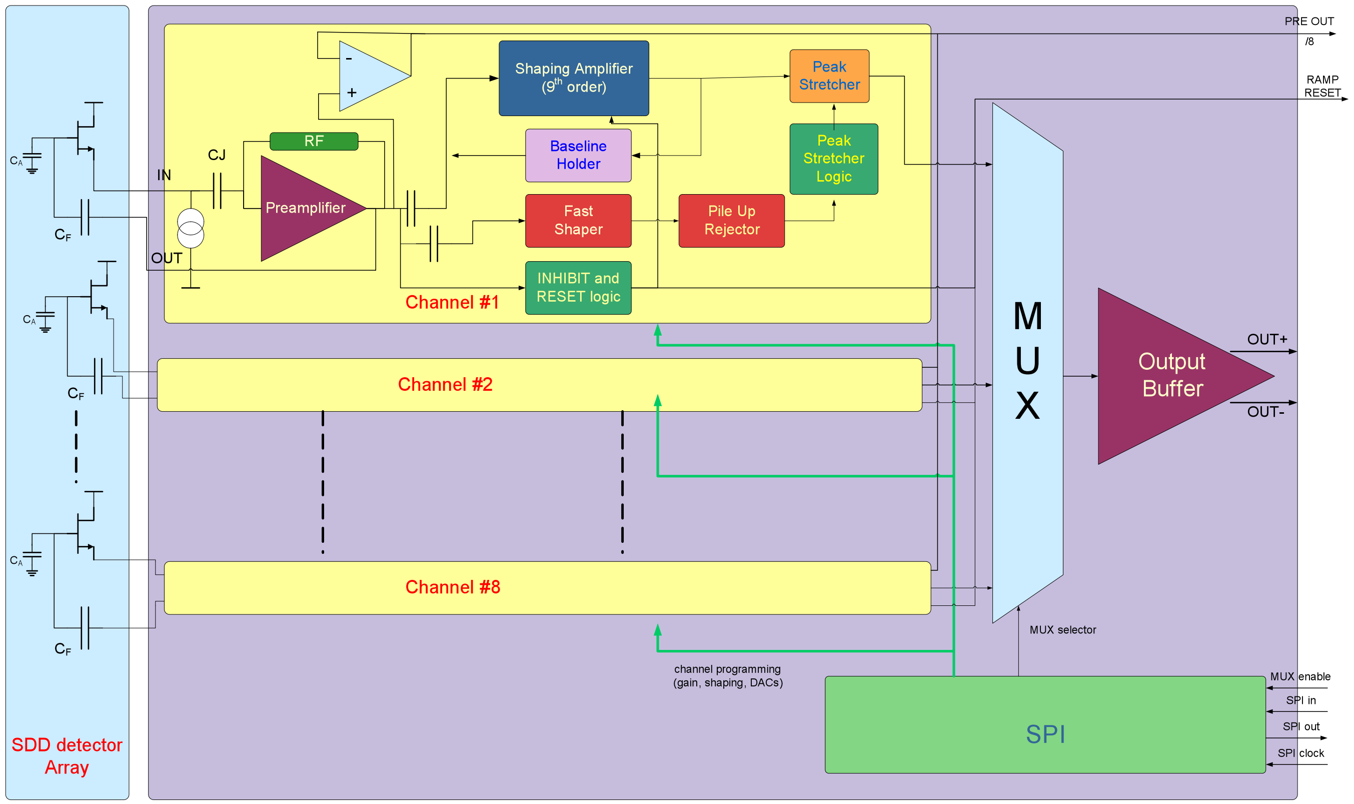


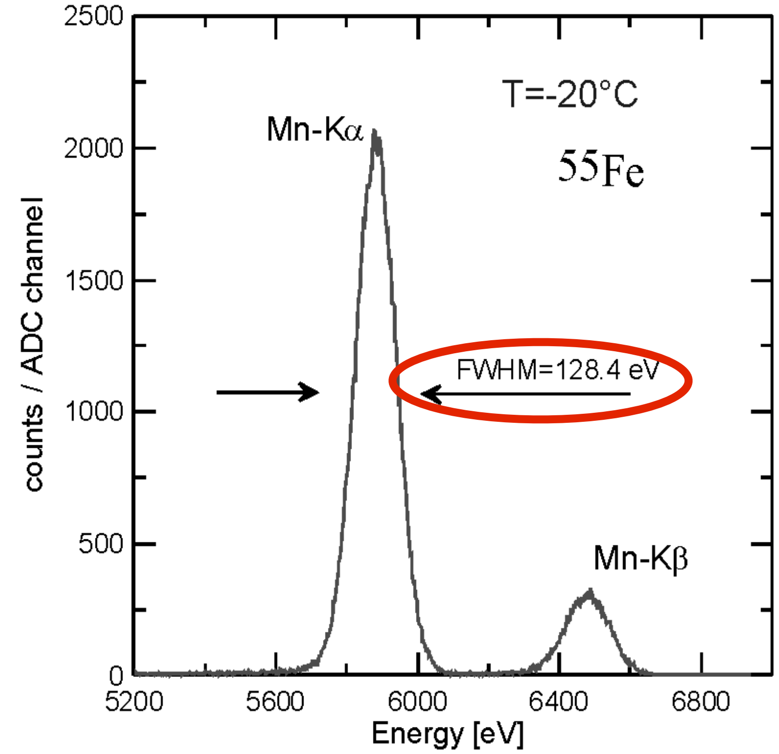
- Space qualified motor (Phytron VSS 25.200.1.2)
- Motor and gears enclosed for limited contamination

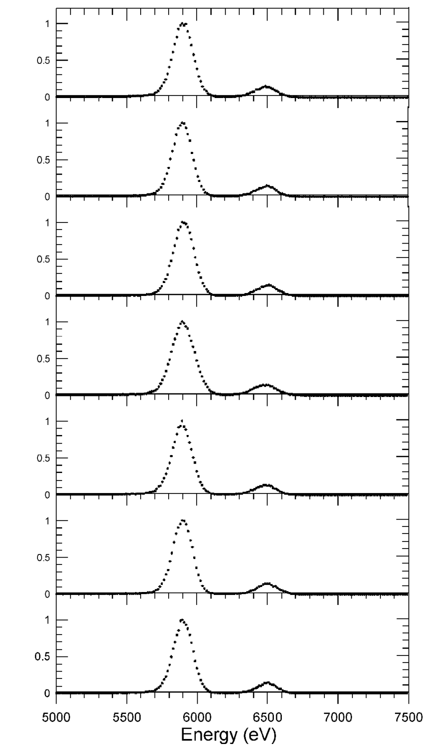


(Filter in its support)

The Front End Electronic (FEE)



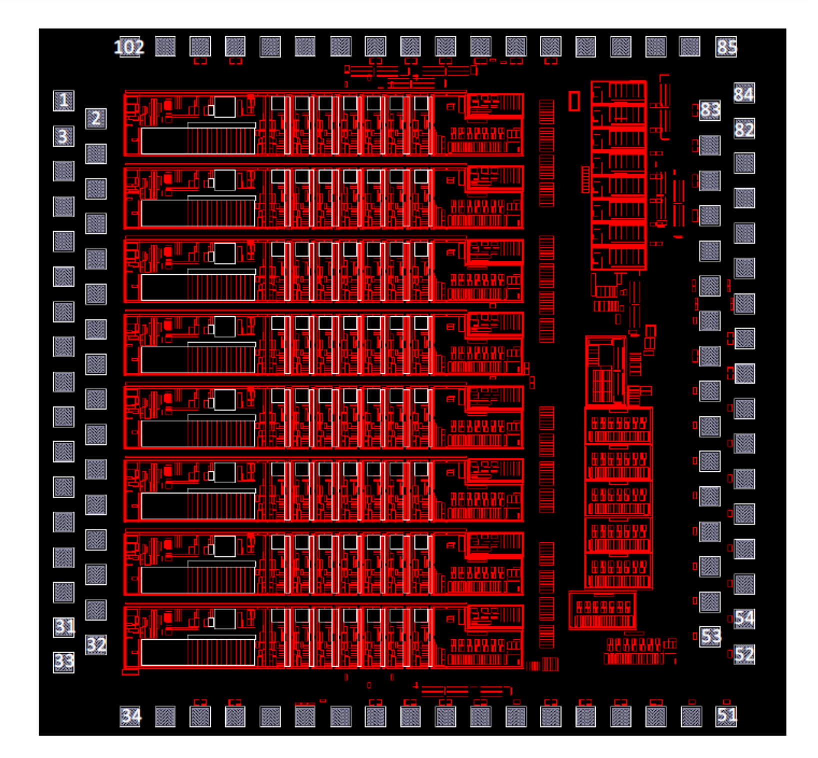




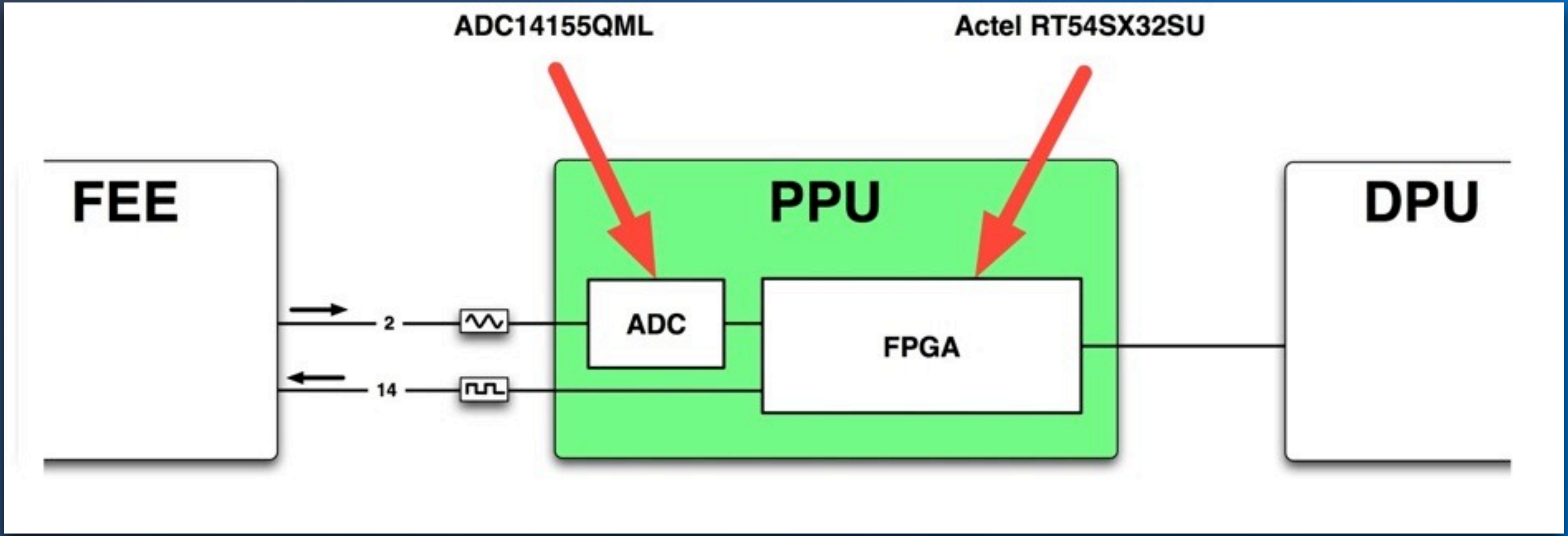
- Similar ASICs have already been developed by Politecnico di Milano

- New design ready, submission in July 2010

- Will be tested with the 7 pixel prototype Q1/Q2 2011

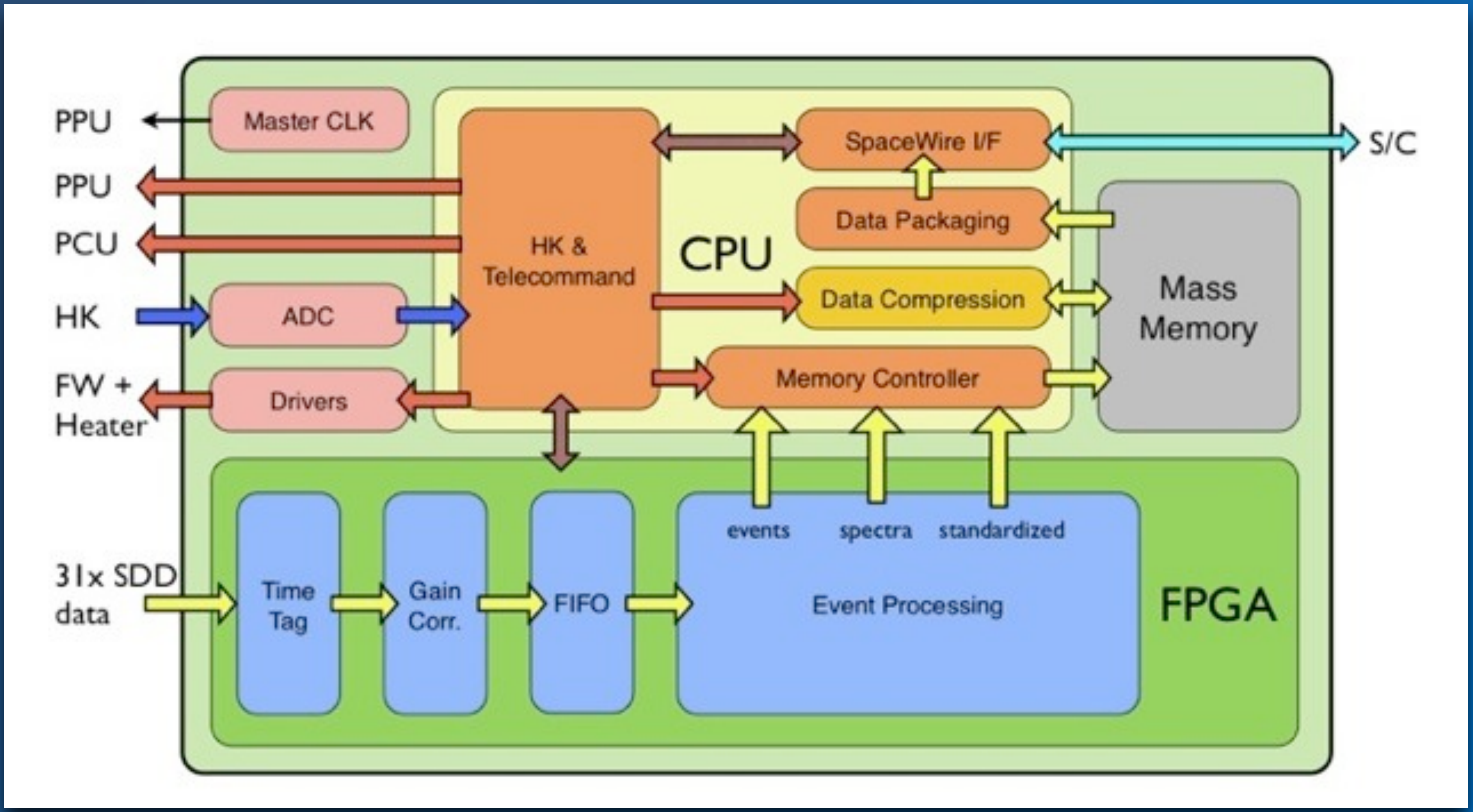


The Pre-Processing Unit (PPU)



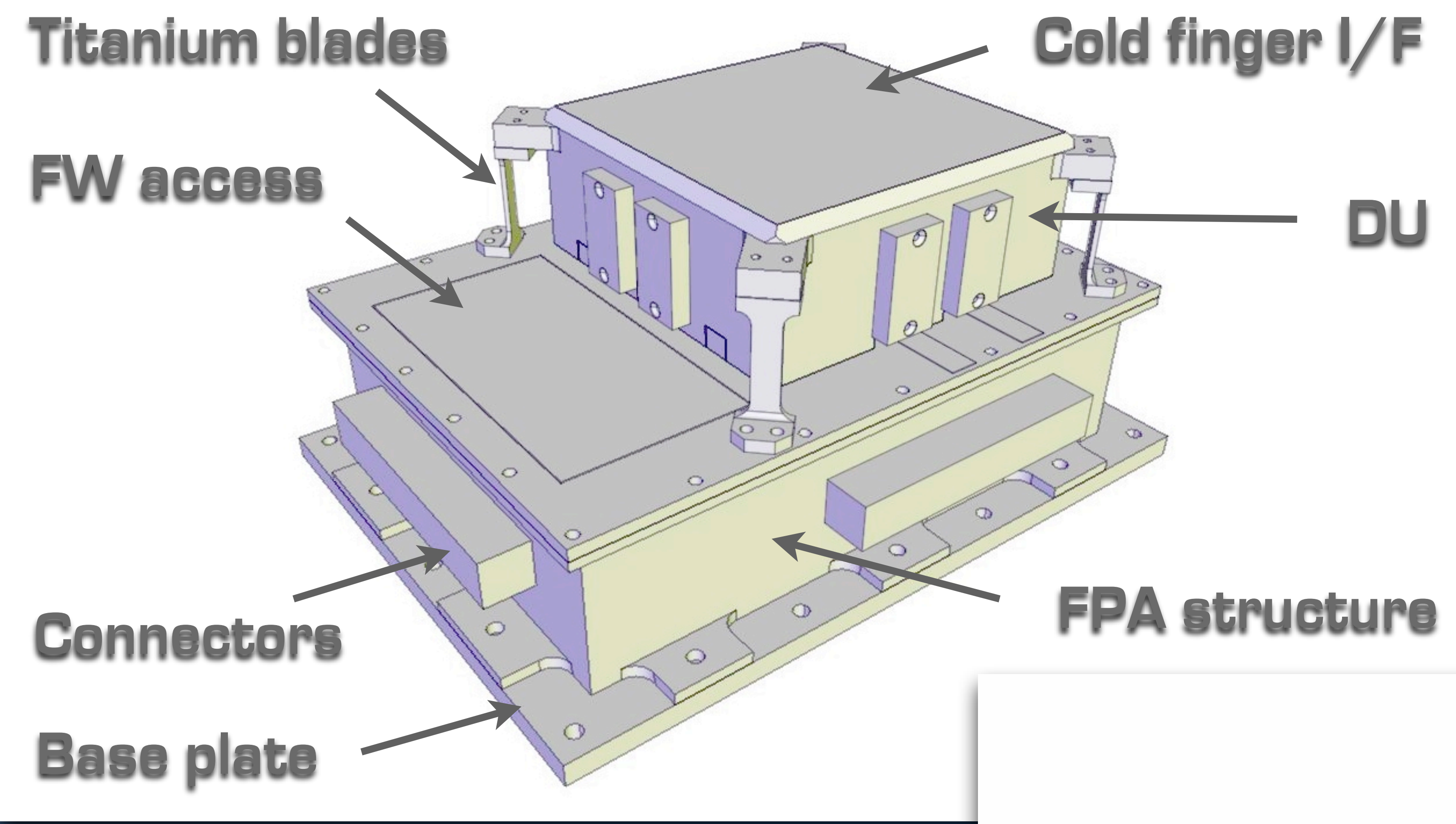
- Digitisation of FEE signals
- Transmission of the events to the DPU
- Based on space qualified products (ADC and FPGA)

The Data Processing Unit (DPU)

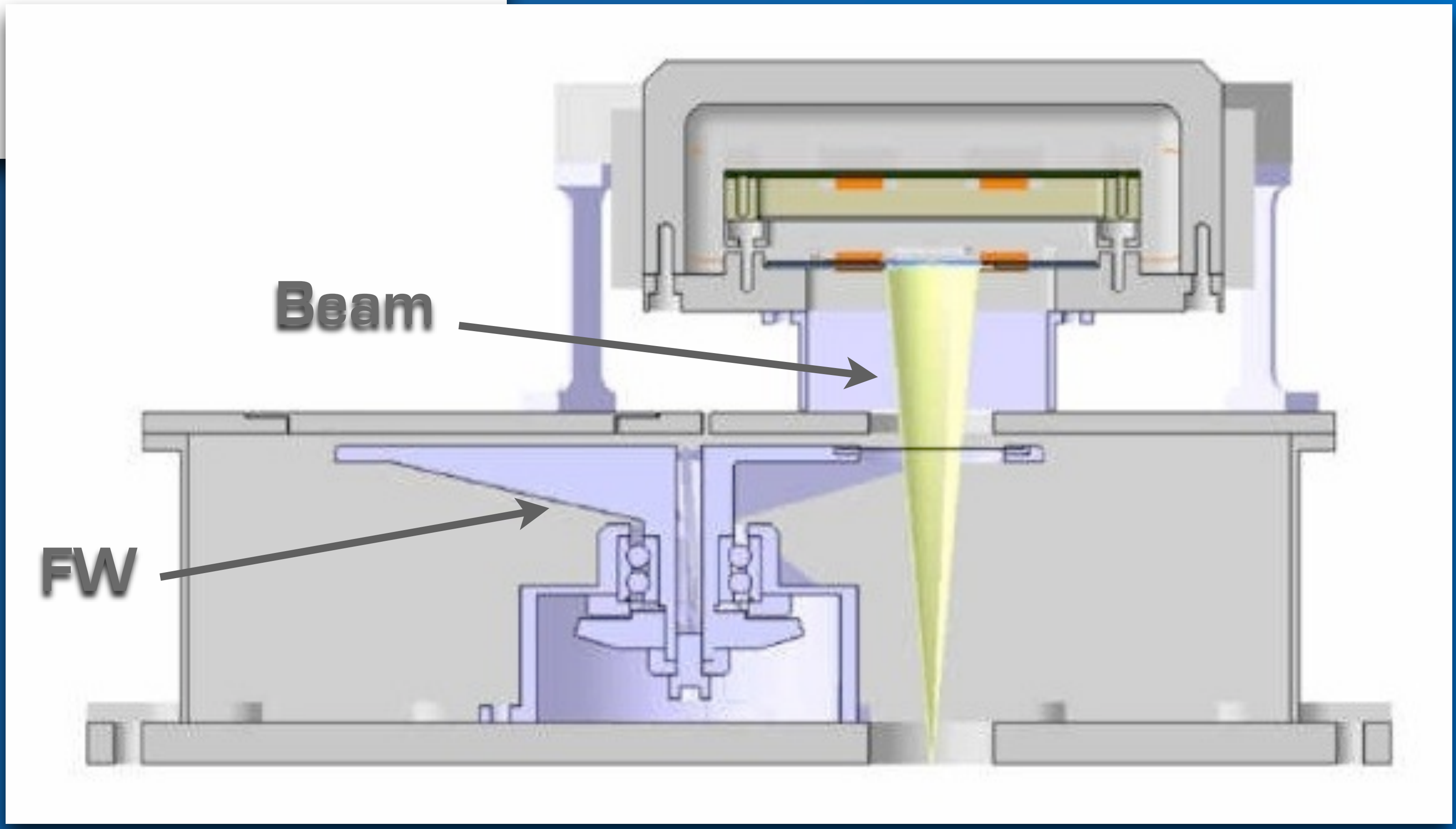


- Processing of science data (gain correction, spectra management, data compression, ...)
- Management of the HTRS (configuration, monitoring of HK, ...)
- Cold redundancy
- Internal mass memory (64 Gbits)
- SpaceWire interface with S/C

The mechanical architecture

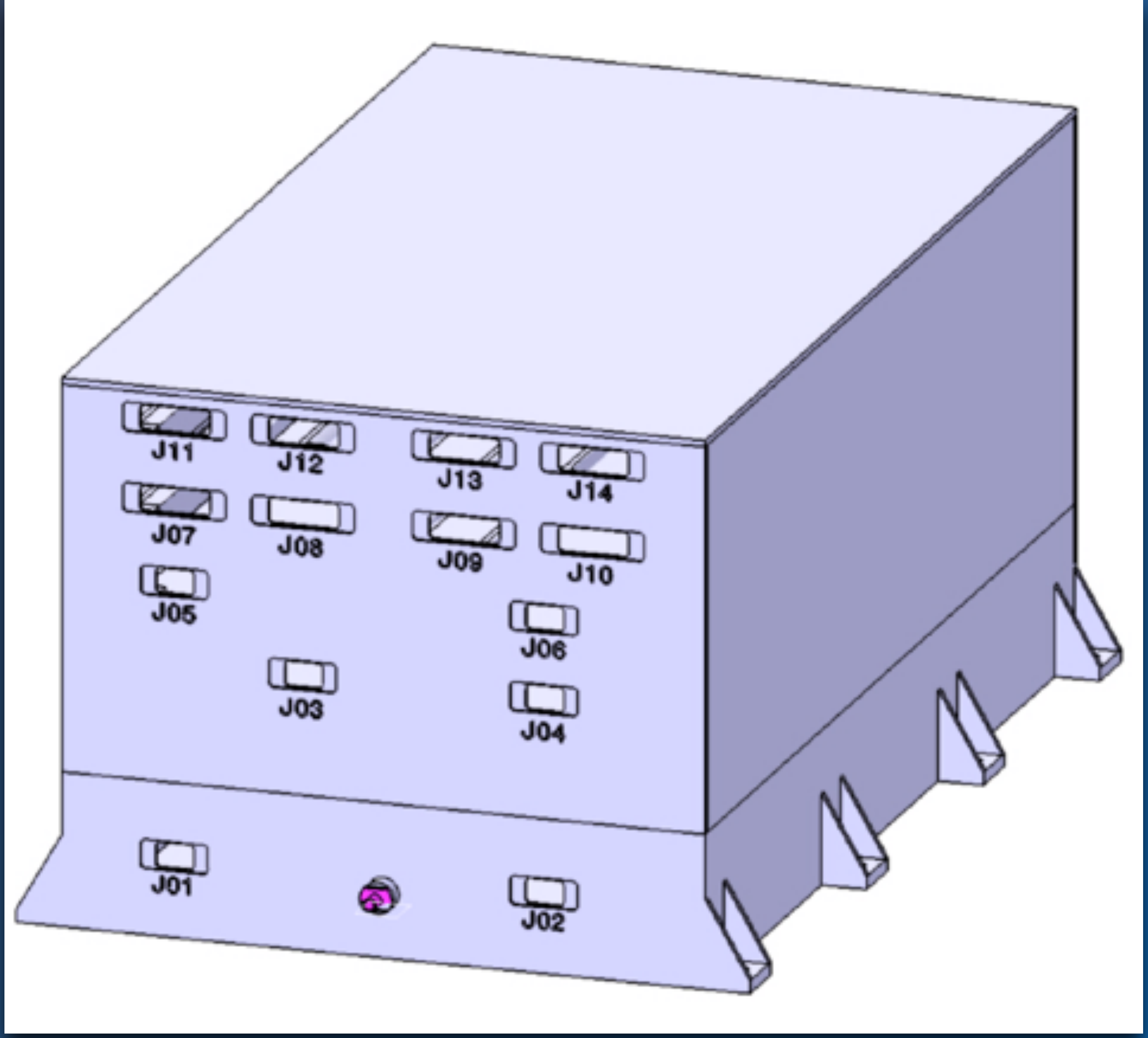


The HTRS-FPA



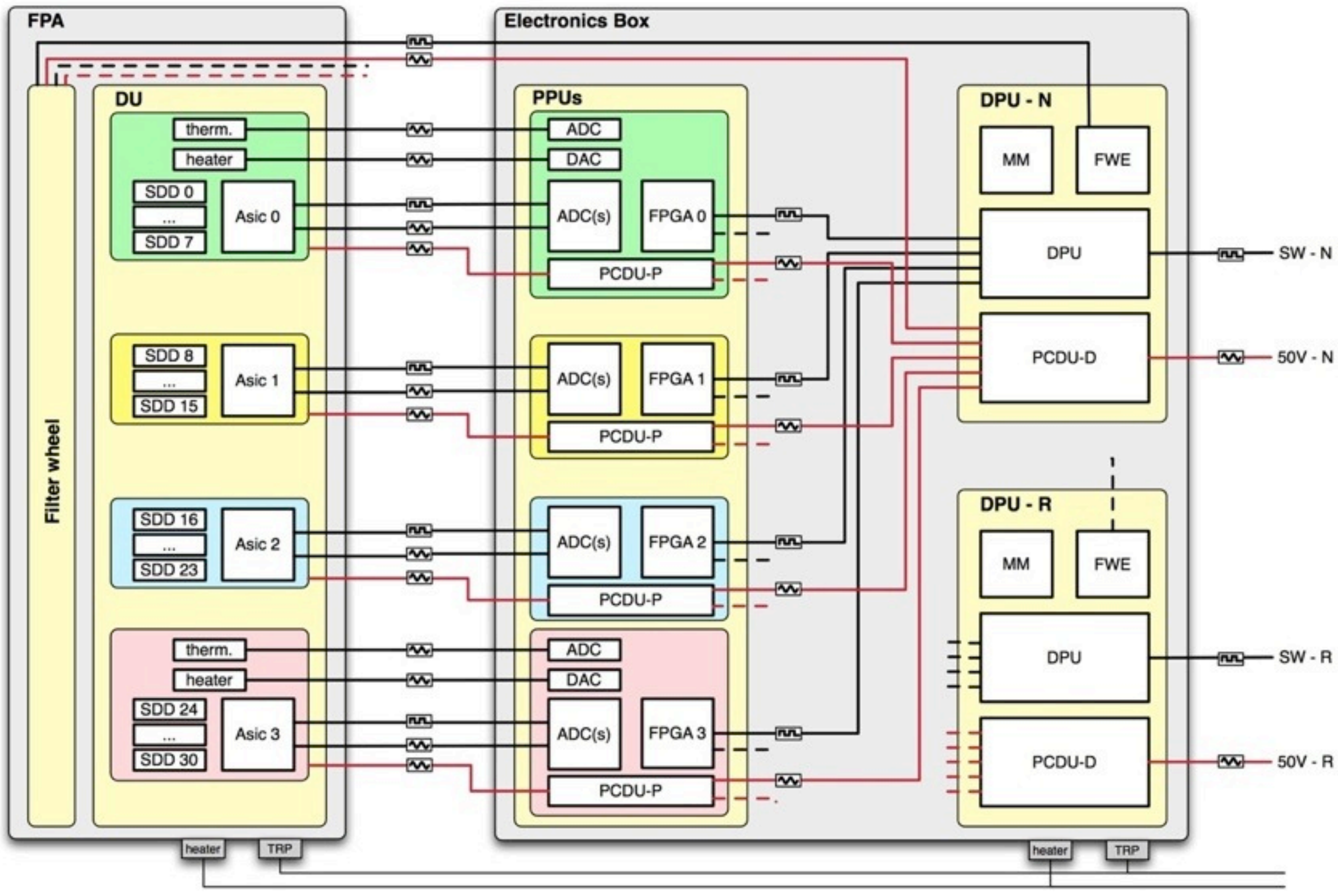
The mechanical architecture

The HTRS-EB

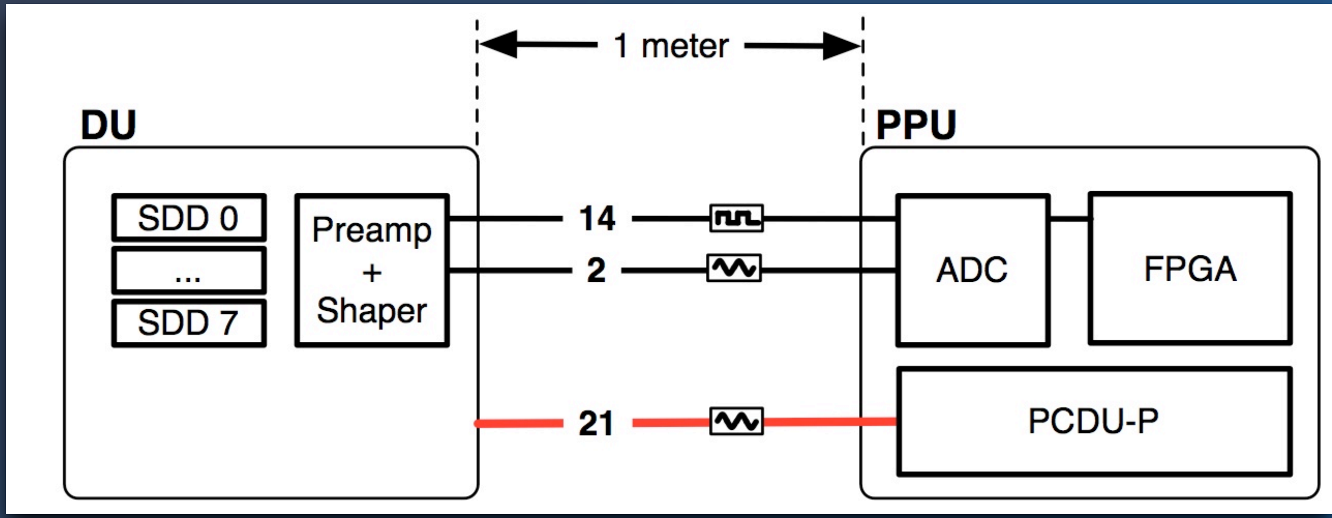


- Interfaces on a single face of the box for easier mounting

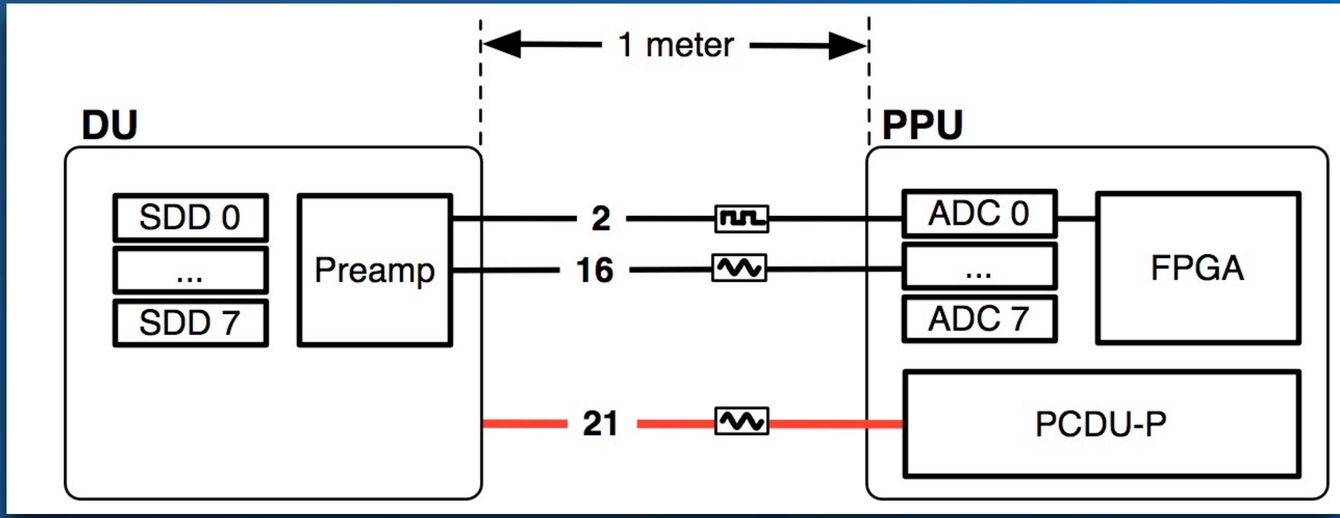
The electrical architecture



Digital shaping vs. Analogue shaping



«Analogue» option



«Digital» option

- The two options require approximately the same number of connections

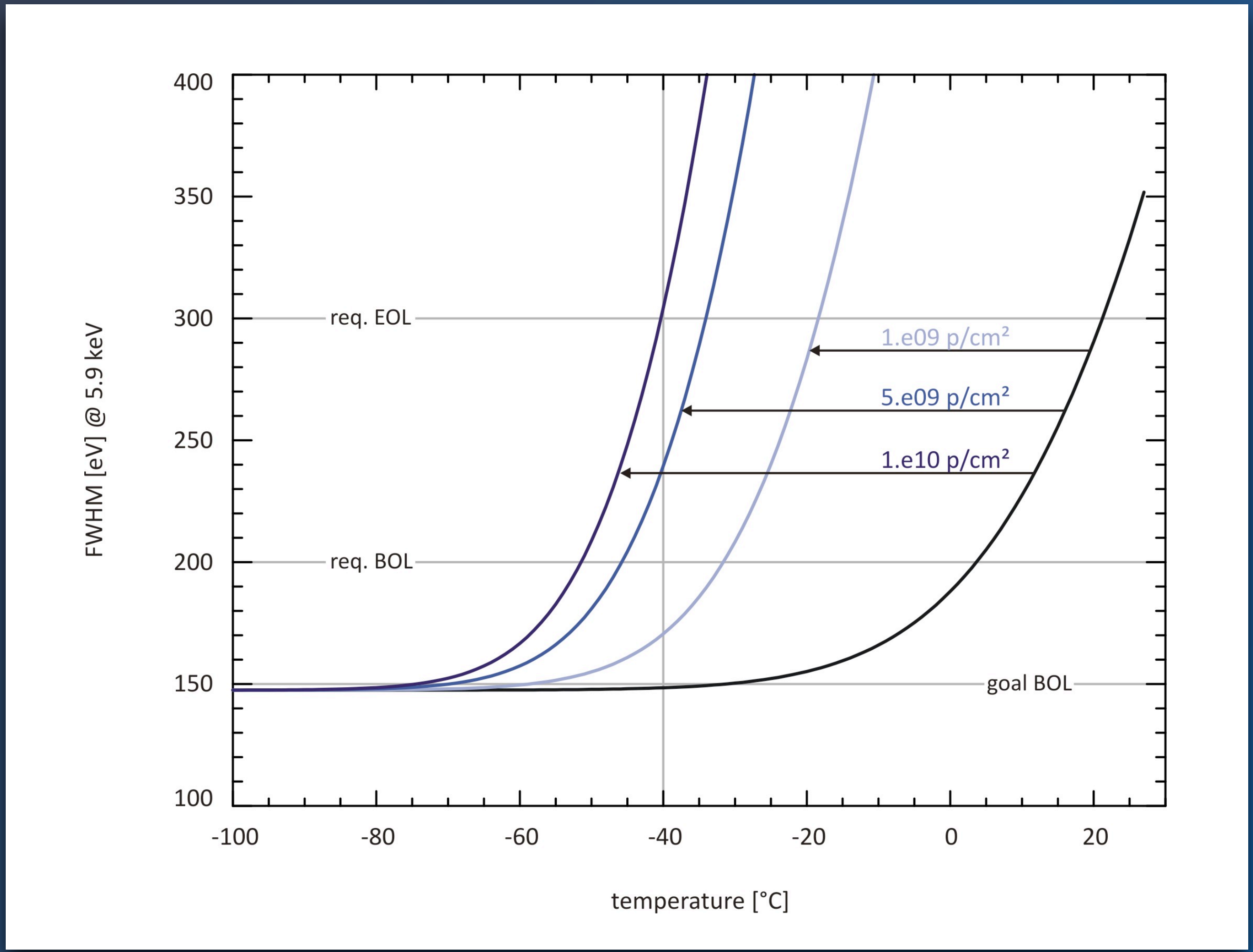
- Achieves the requested performance

- Requires more power consumption (+30W)
- Allow better performance (less pile-up)

- This trade-off will be studied further during phase B

Radiation hardness

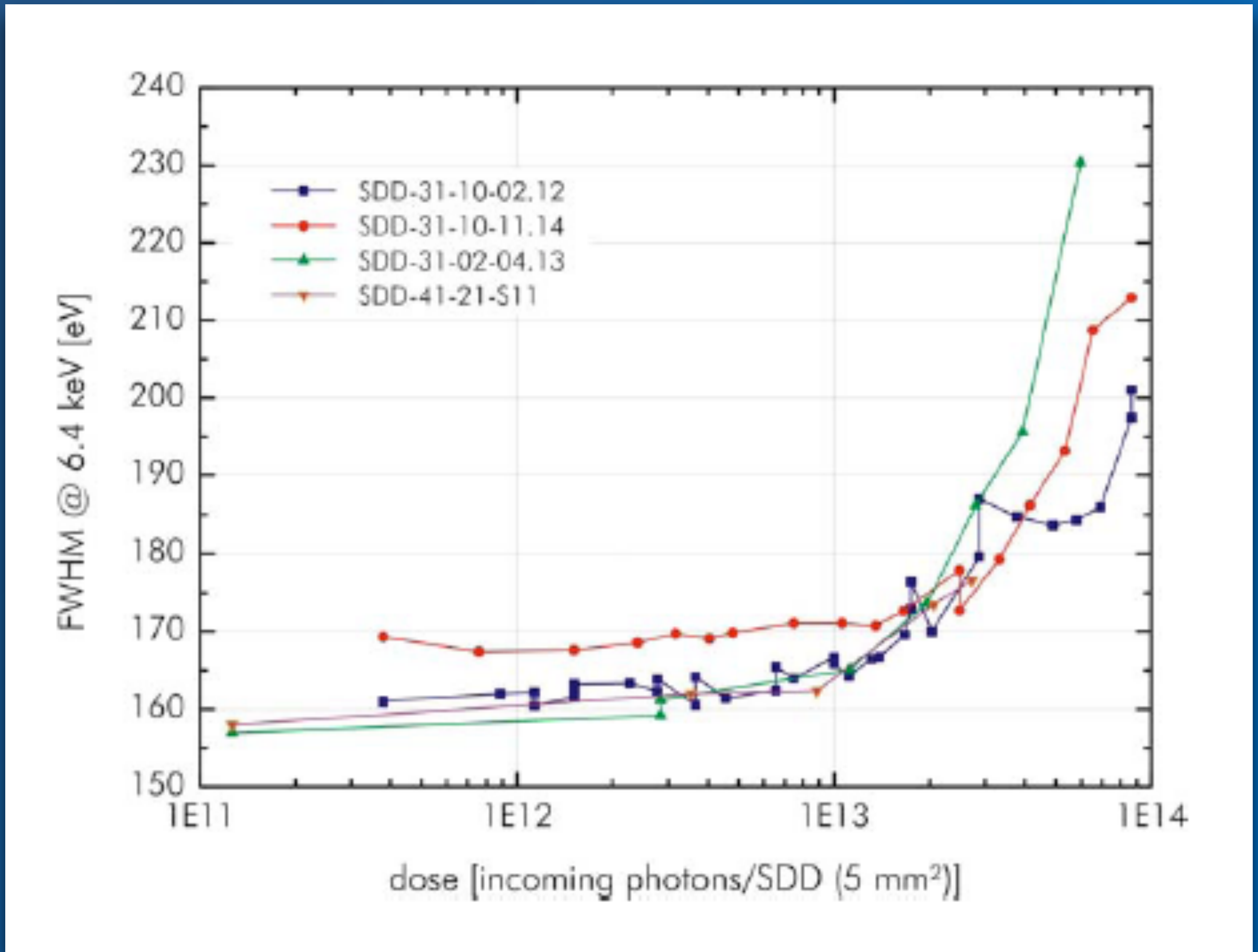
Proton irradiations



Degradation of energy resolution against the operating temperature and proton irradiation

The 1.5 cm thick Al shield of the DU guaranties less than 5.10^9 eq. 10 MeV protons / cm^2 after 10 years (compatible with the requirement EOL).

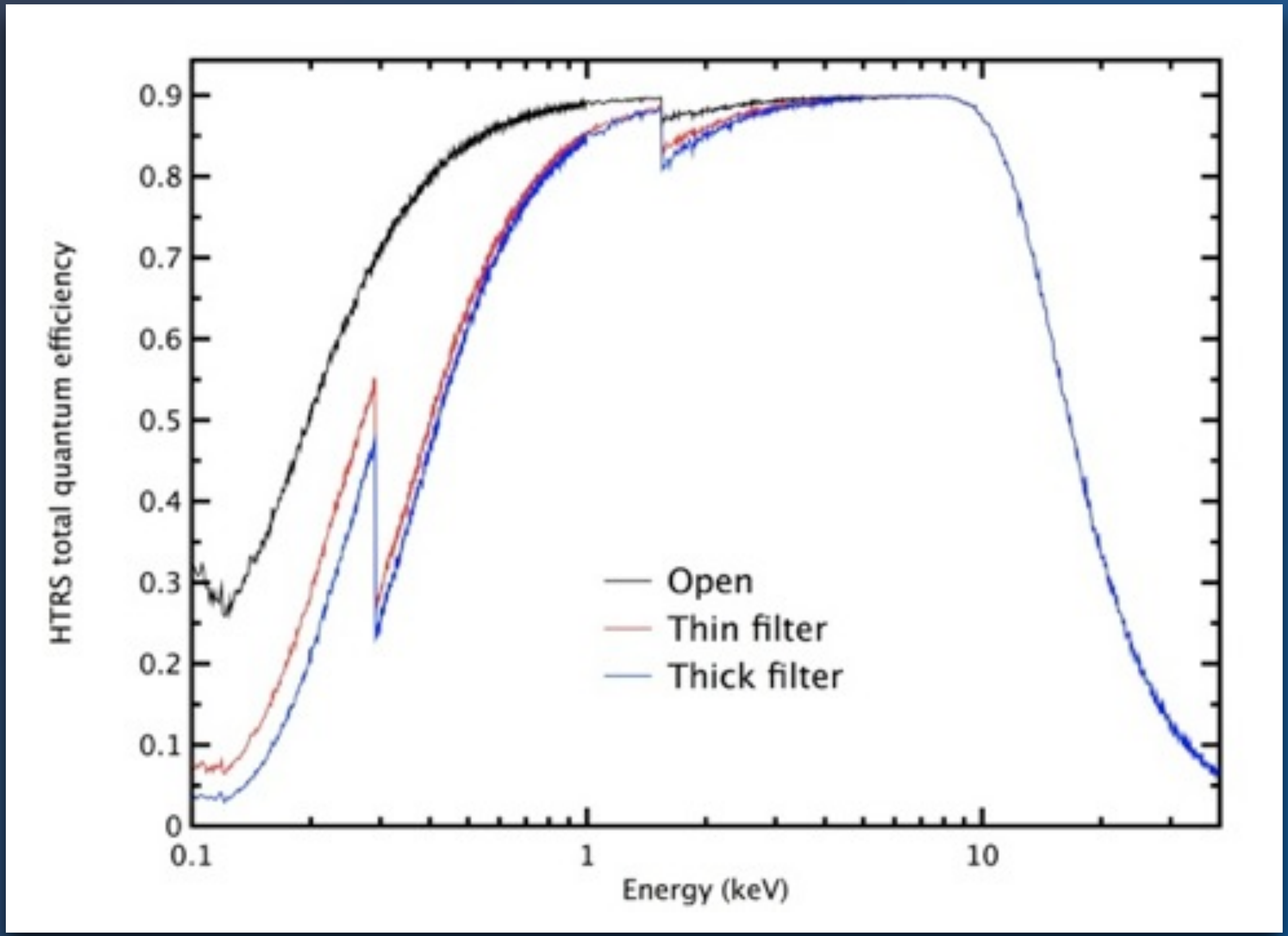
Photon irradiations



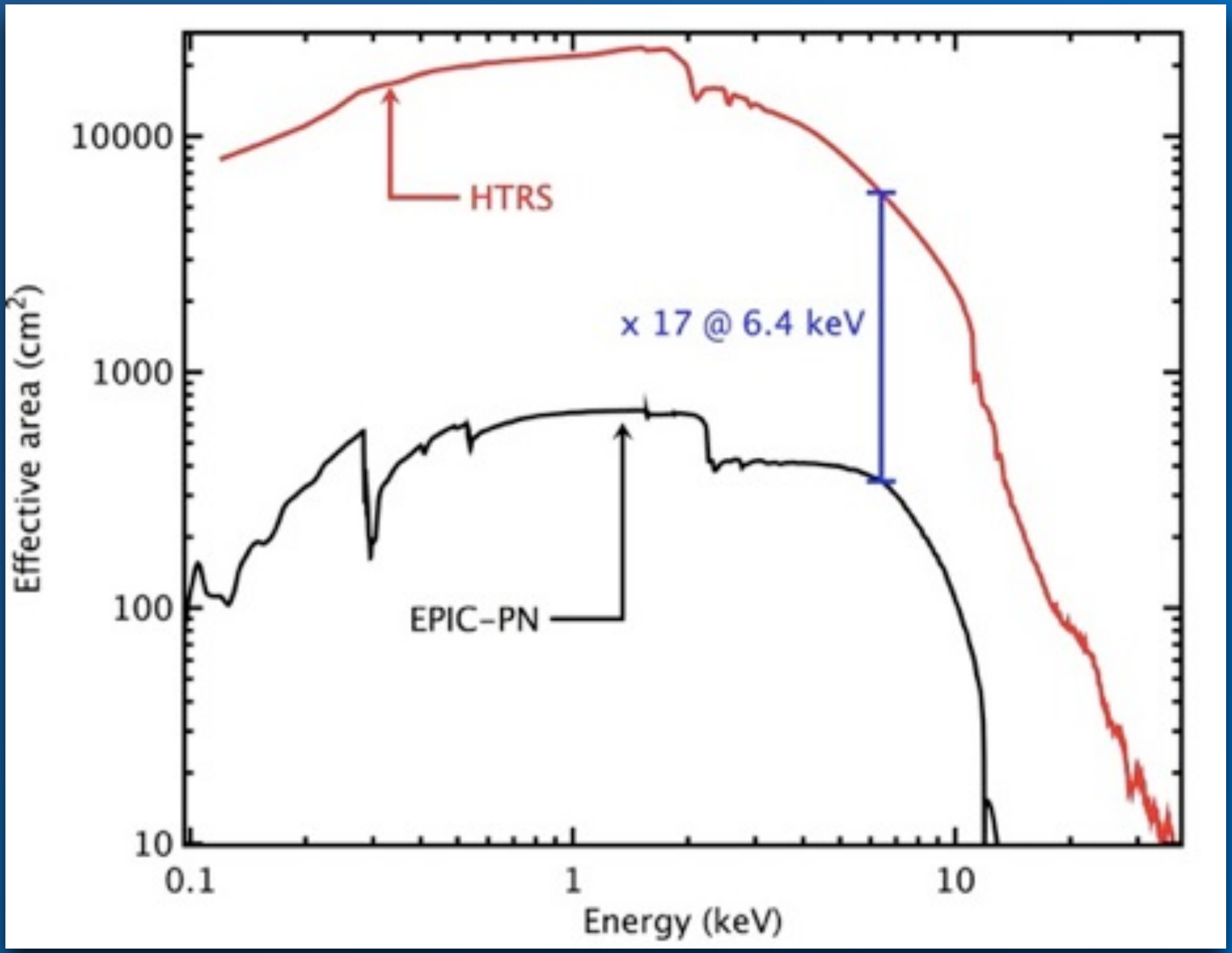
Degradation of the energy resolution against dose of incoming photons

Laboratory measurements have shown that SDDs survive 10^{13} photons without degradation of the energy resolution (eq. to a 10-year continuous observation of a moderately bright source).

Quantum efficiency & effective area

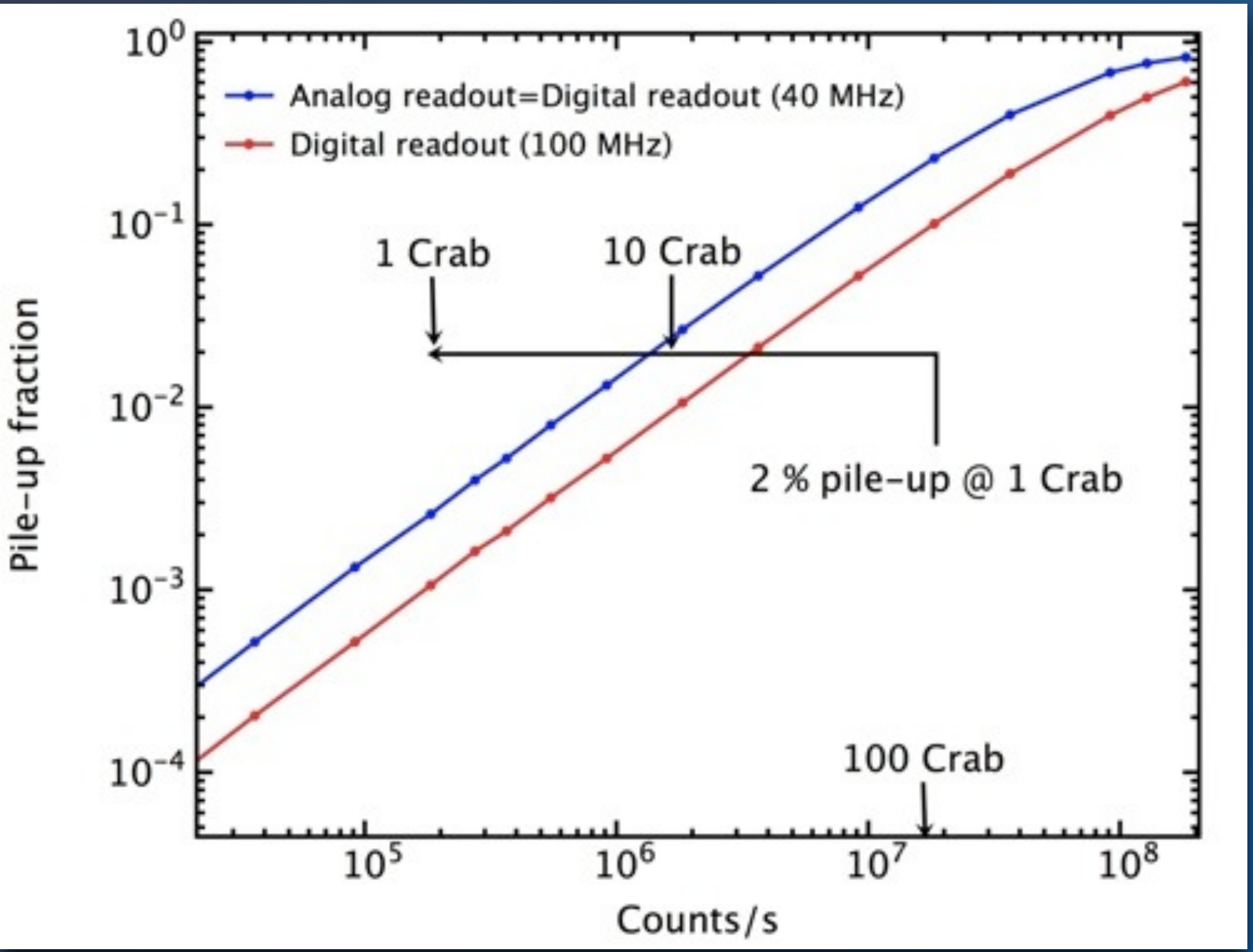


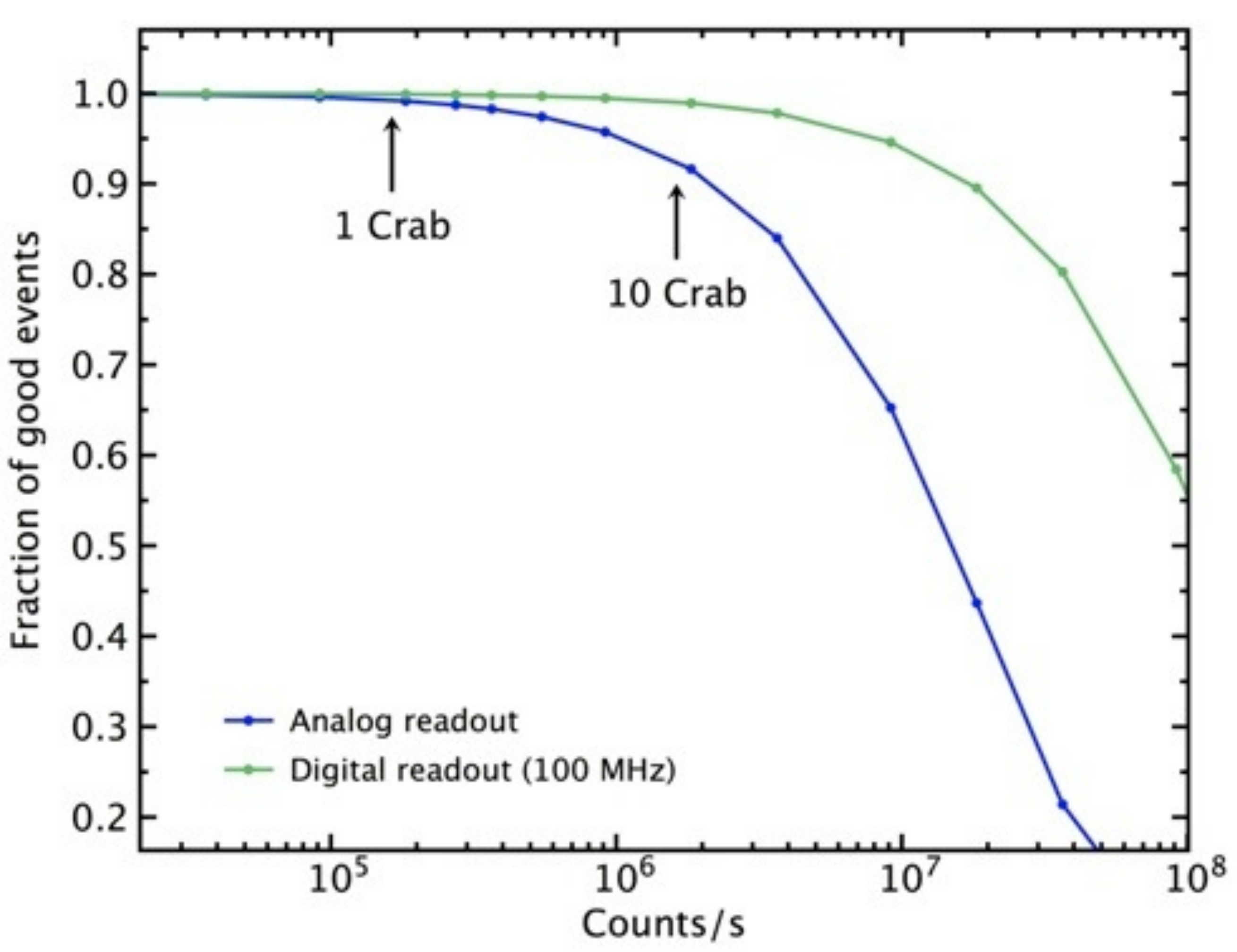
HTRS quantum efficiency



Based on the latest mirror design (ESA provided) assuming the HTRS quantum efficiency (thin filter)

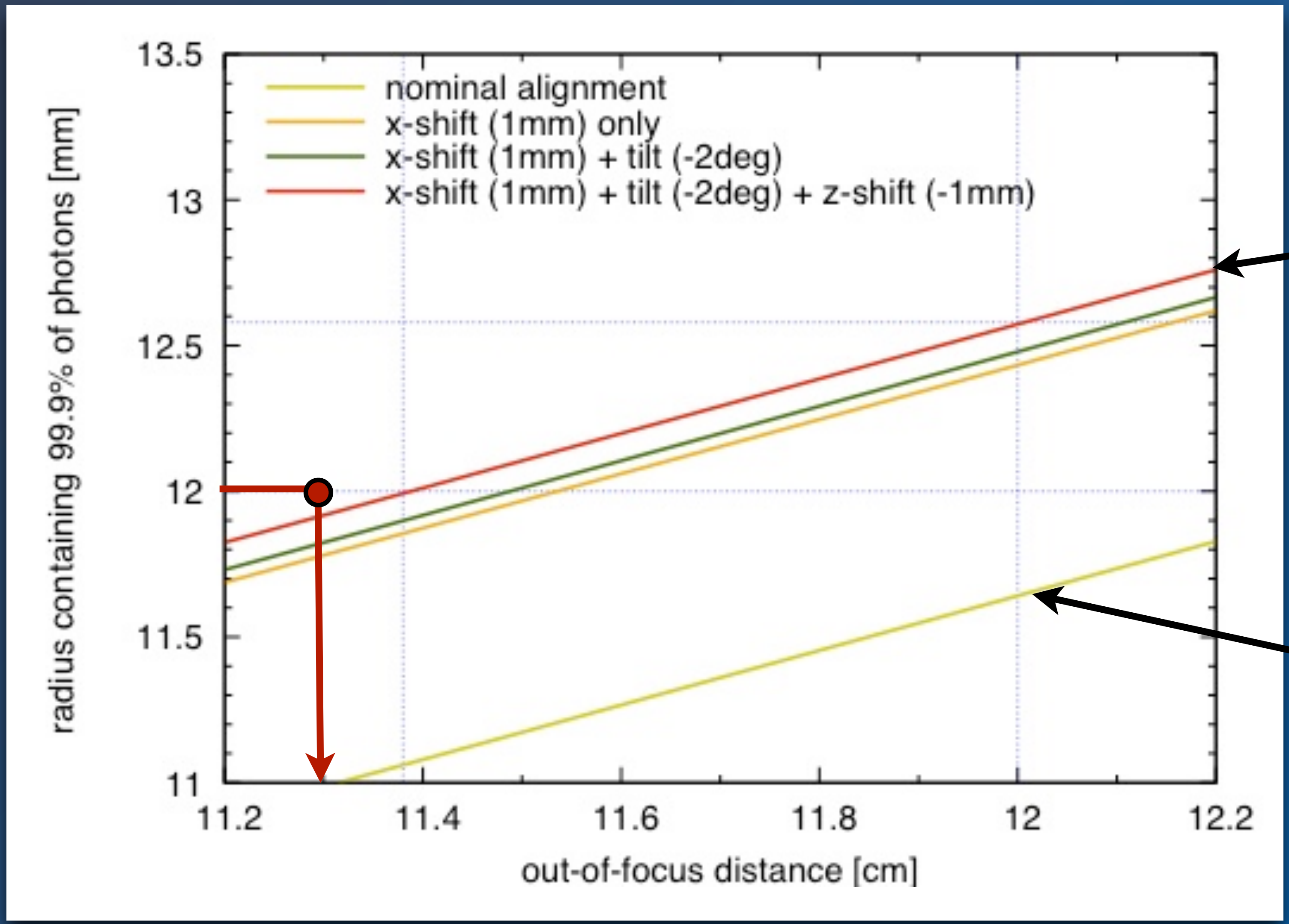
Detection efficiency

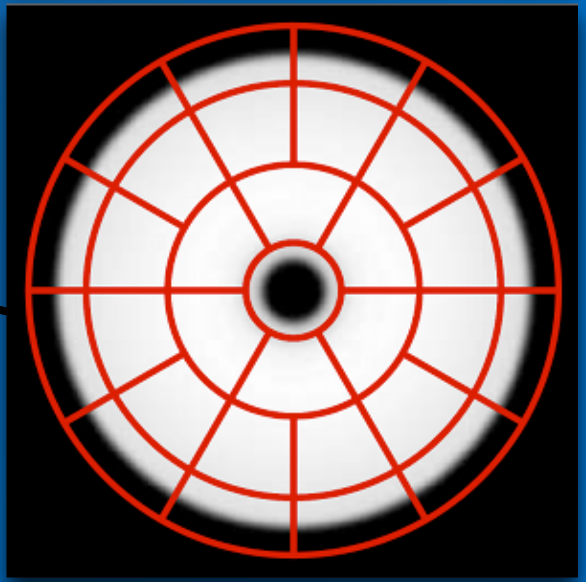




- Pile-up: Two events are measured as a single «wrong» event
- «Good events»: Events for which the time and energy are accurately measured (e.g. exclude pile-up events, ...)

Alignment requirement





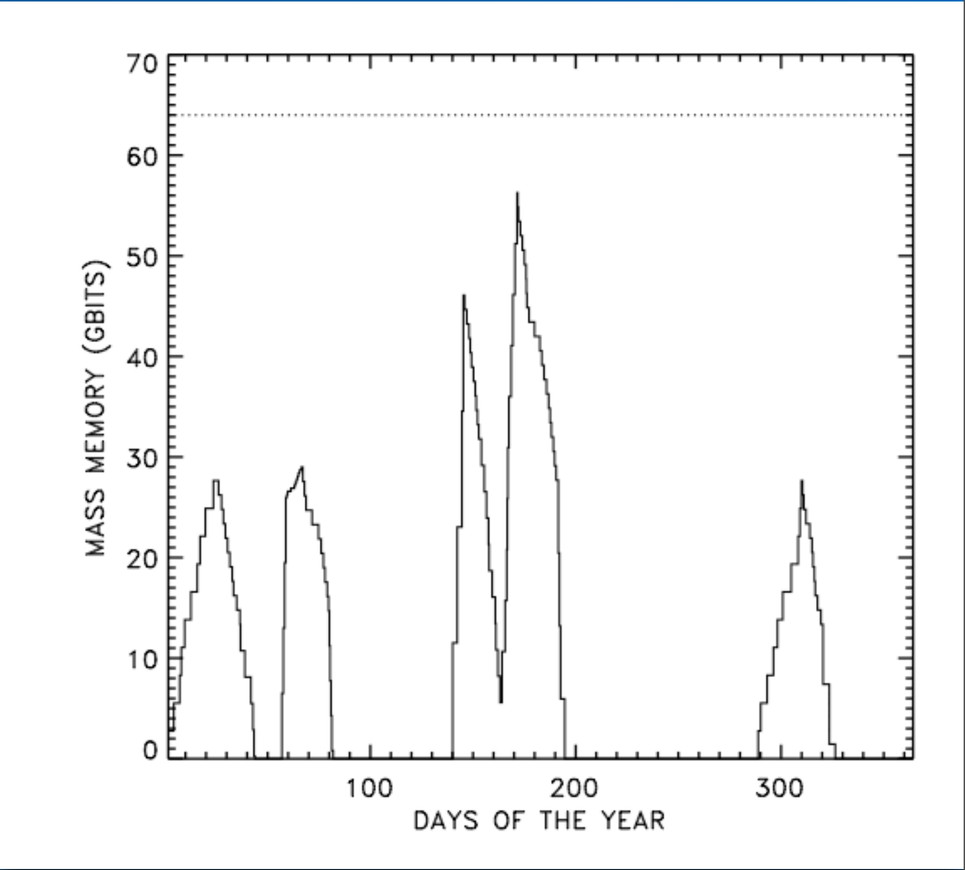
With a detector radius of 12 mm and a defocus of 11.3 cm, any misalignments within the requirements lead to a loss of less than 0.1% of the photons

Mass memory optimisation

- **Assumptions:**
  - ✓ The HTRS TM data rate is 0.84 Mbits/s
  - ✓ The HTRS is used 15% of the time
  - ✓ The HTRS DPU compresses the data in real time
  - ✓ The DPU stores the compressed data in the HTRS mass memory
  - ✓ The processor is a Leon III in a FPGA clocked @ 125 MHz (compression by 3)

- **Simulations results:**
  - ✓ An internal mass memory of 64 Gbits is needed

  (based on a typical one year observation program)



Amount of data in the HTRS mass memory along one year

The HTRS in a nutshell

Parameter	Value
Detector	31 SDDs, 450 µm width, circular, 150 V high voltage, out of focus by 11.3 cm, cooled at -40 ±1°C
Energy range	0.3 to 15 keV
Energy resolution (FWHM @ 5.9 keV)	150 eV Goal (BOL) 200 eV Requirement (BOL) 300 eV Requirement (EOL)
Time resolution	10 µs
Dead time @ 1 Crab	2 %
Pile-up @ 1 Crab	2 %
Size FPA: EB:	310 x 230 x 165 mm^3 (L x W x H) 360 x 233 x 175 mm^3 (L x W x H)
Mass	31.26 kg with harness & 20% margins
Power	145 / 132 / 60 / 51 W (Peak / On / Standby / Idle)
Internal mass memory	64 Gbits

Vielen Dank Eckhard !

The HTRS has benefited from the unique expertise of Eckhard, who hopefully will remain a key member of the project for the years to come.

Eckhard has not only brought in his infinite knowledge in X-ray instrumentation, but he also came with his very friendly, cooperative spirit and more importantly his never diminishing enthusiasm.

He has also been a relatively good student for learning about French wines from south of Toulouse, although for his current skills to develop and improve he will have to keep visiting us on a regular basis.

Didier, Pierre & Laurent on behalf of HTRS instrument team