Silicon drift detectors and their application on XGIS instrument for the Theseus mission

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in behalf of
Theseus-XGIS team
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Theseus (Transient High Energy Sky Early Universe Surveyor)

- ESA M5 Candidate mission
- Probing the physical properties of the early universe with high-redshift GRBs
- Multimessenger time domain astrophysics with deep monitoring of X-ray transient sky
- Broadband simultaneous NIR and X/γ-ray observations for thousands of faint X-ray sources
- Flexible follow-up observatory (ToO, guest observer program)

The X/Gamma-ray Imaging Spectrometer (XGIS) on-board THESEUS

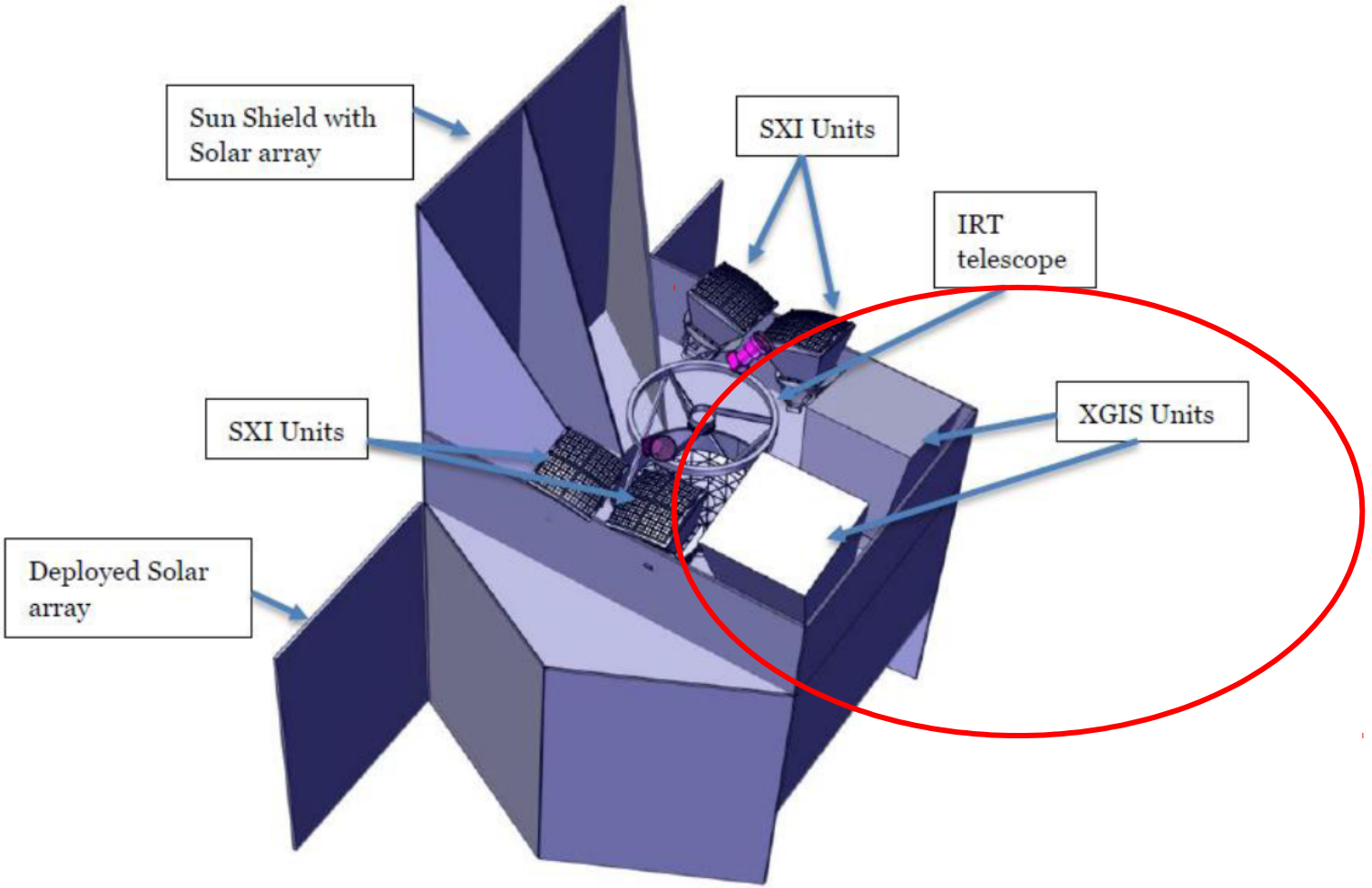
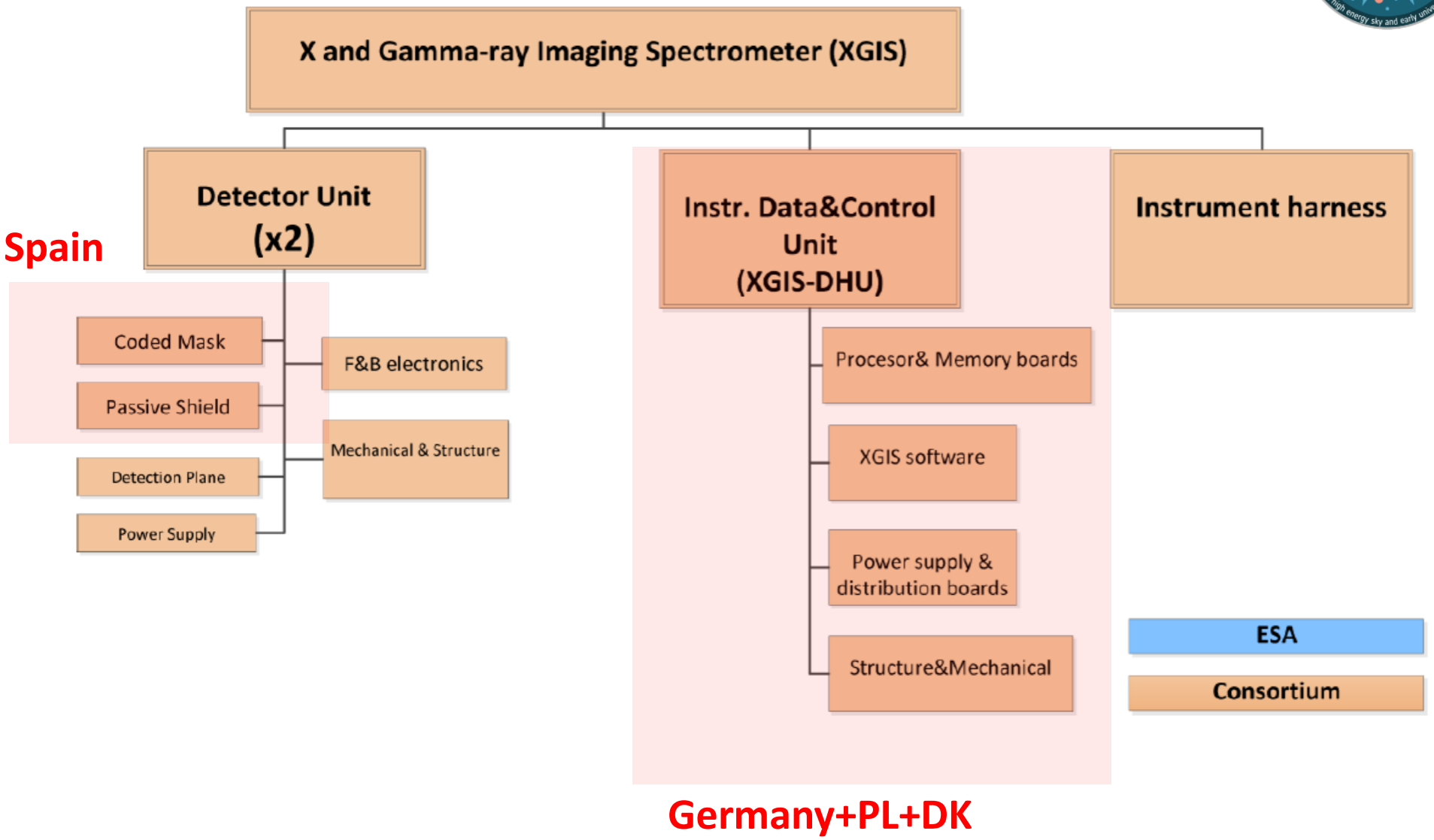


Figure 2: THESEUS spacecraft current design and payload accommodation

International XGIS collaboration



XGIS: need, role and concept

- The SXI grants the required combination of sensitivity, FOV and location accuracy in the soft X-rays for high-z GRBs and many classes of soft X-ray transients (including e.m. counterparts of some GW signals)

- Main limitation of SXI is the soft energy band (< 5 keV) -> a broad band spectral coverage (up to several MeVs) **is needed, in order to:**

✓ improve the efficiency in classifying and filtering the SXI triggers

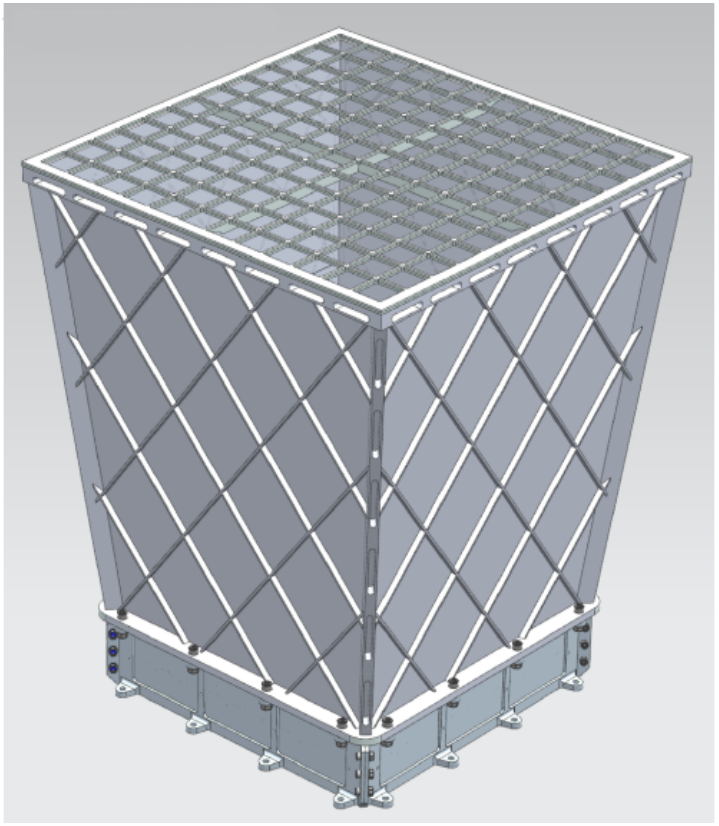
✓ **detect and localize any kind of GRBs including short ones (fundamental for multi-messenger astrophysics)**

✓ getting clues to the emission physics and progenitors of GRBs and other transients

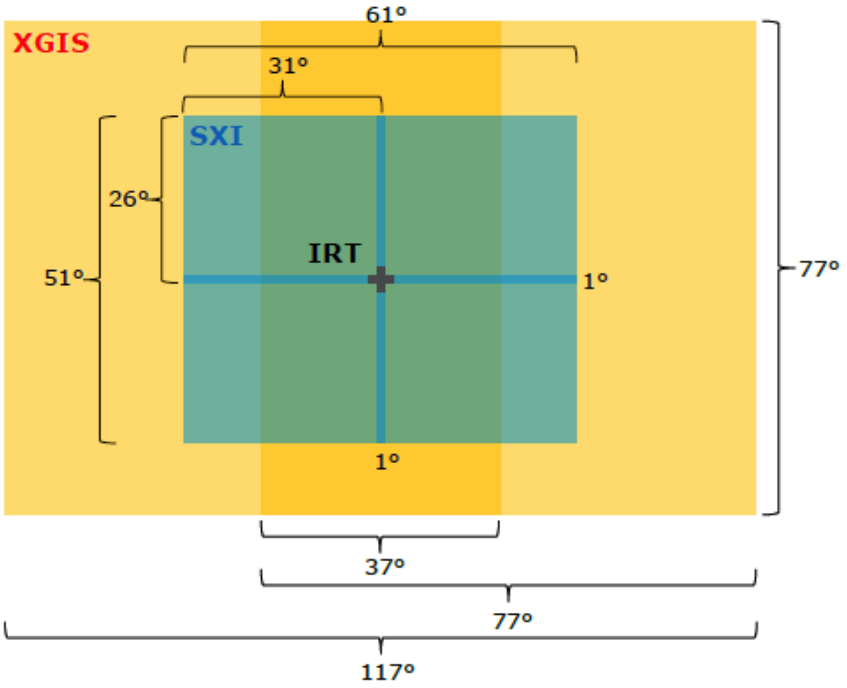
Theseus Payload

- Soft X-ray Imager (SXI) – a set of four Lobster-Eye telescopes
  - 0.3–5 keV band (CMOS detector), $\sim 2 \cdot 10^{-10}$ erg cm^{-2} s^{-1} sensitivity
  - 1 sr FoV
  - Source Localisation Accuracy of $\sim$1'.
- X-Gamma Imaging Spectrometer (XGIS) – a set of two X-γ cameras
  - 2 keV – 10 MeV band (imaging up to 150keV)
  - 2.5 sr FoV (overlapping SXI)
  - Source Localisation Accuracy of $\sim$5'.
- InfraRed Telescope (IRT) – 70 cm IR Korsch telescope
  - 0.7–1.8 μm
  - 10'x10' FoV
  - Imaging and (moderate) spectroscopy (low res. default, high res. for bright sources).

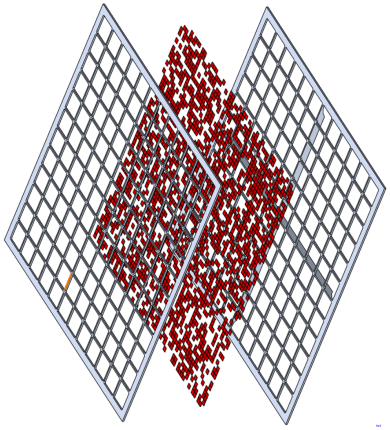
XGIS X-Gamma ray Imaging Spectrometer

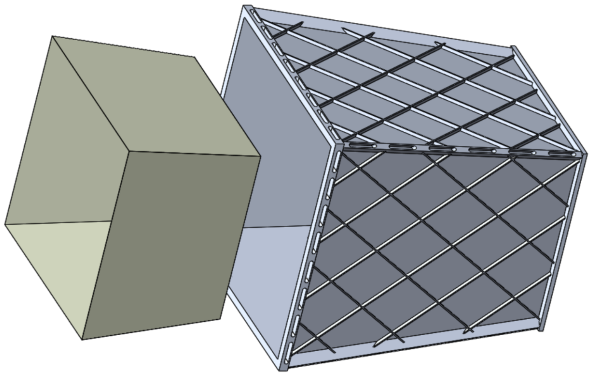


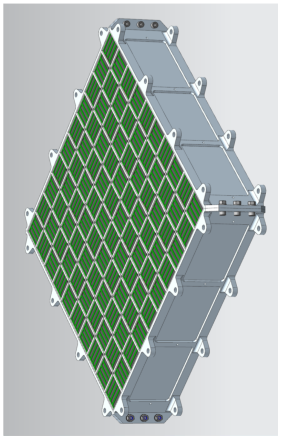
- 2 units
- imaging in 2-150 keV
- detection up to ca. 10MeV
- FoV 77ºx77º per unit
- Total FoV 77ºx117º (37º overlap)



XGIS structure







Mask assembly

Mask: 1mm thick tungsten

Collimator assembly

Collimator: 0.25 mm thick tungsten

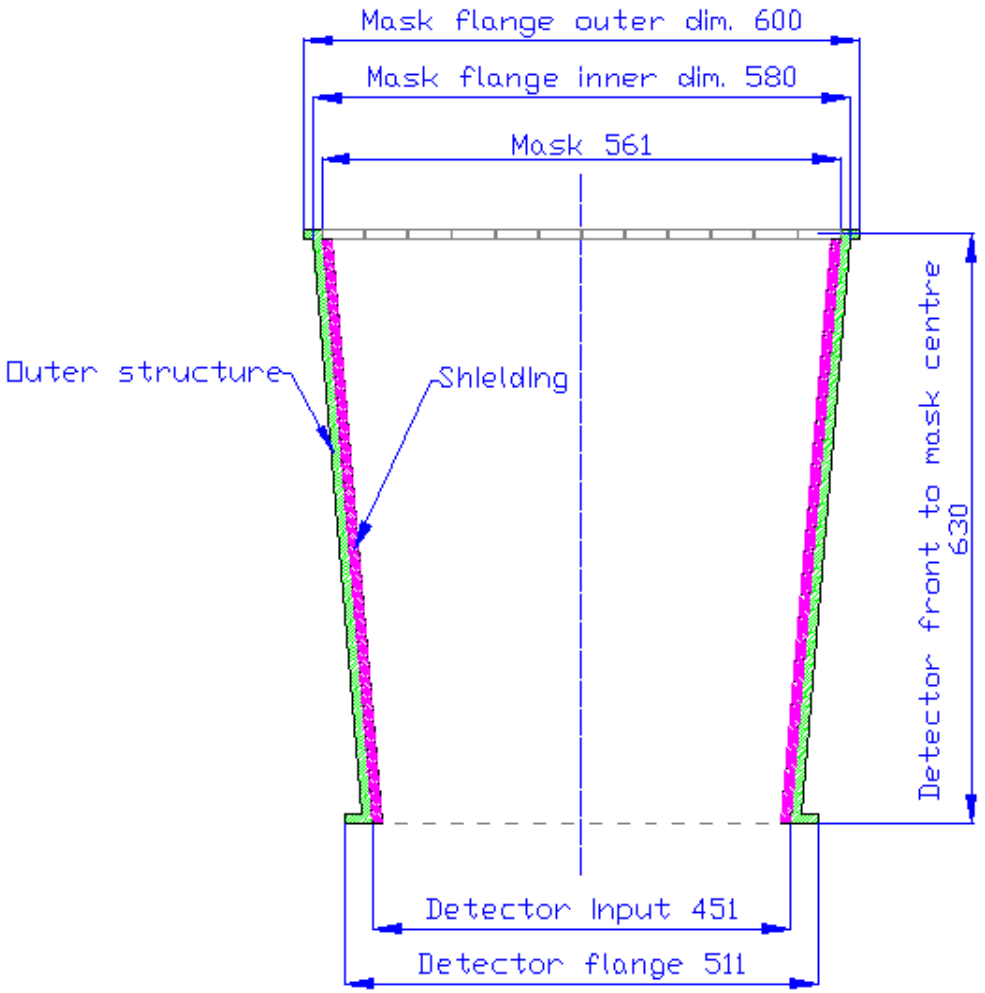
Detector assembly

+ Data handling unit (DHU)

+ Power supply unit (PSU)

Overall dimension of the mask an collimator

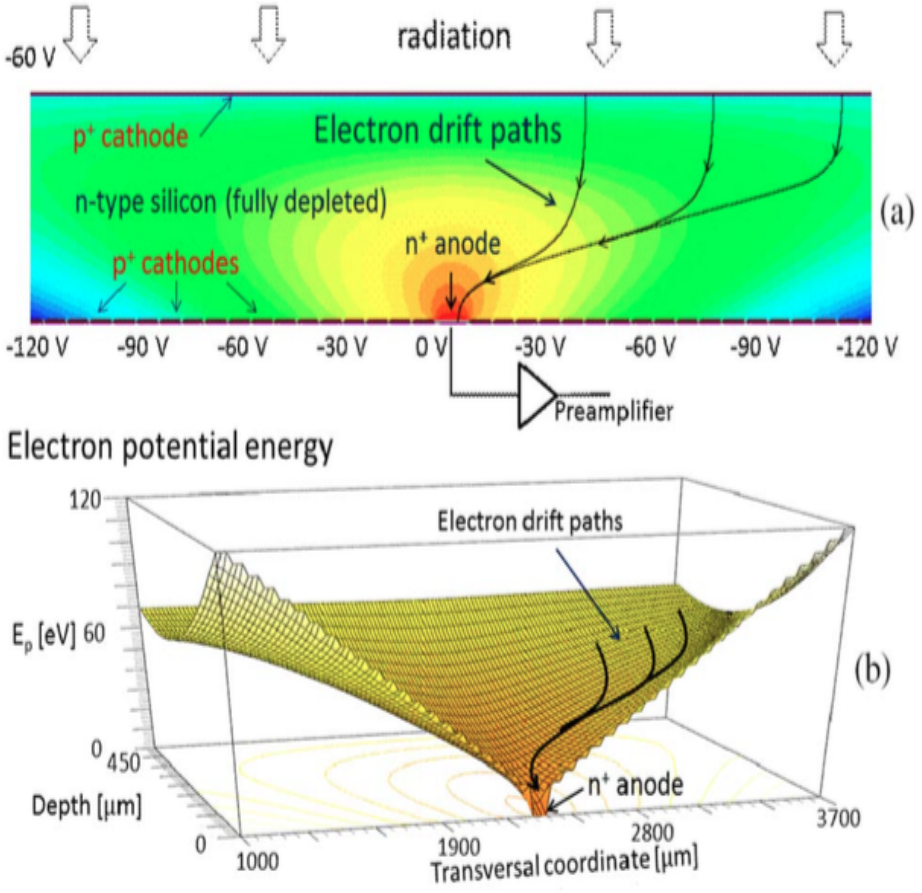
External dimension of the mask plane 600x600 mm to give room for a flange connecting the plane to the collimator



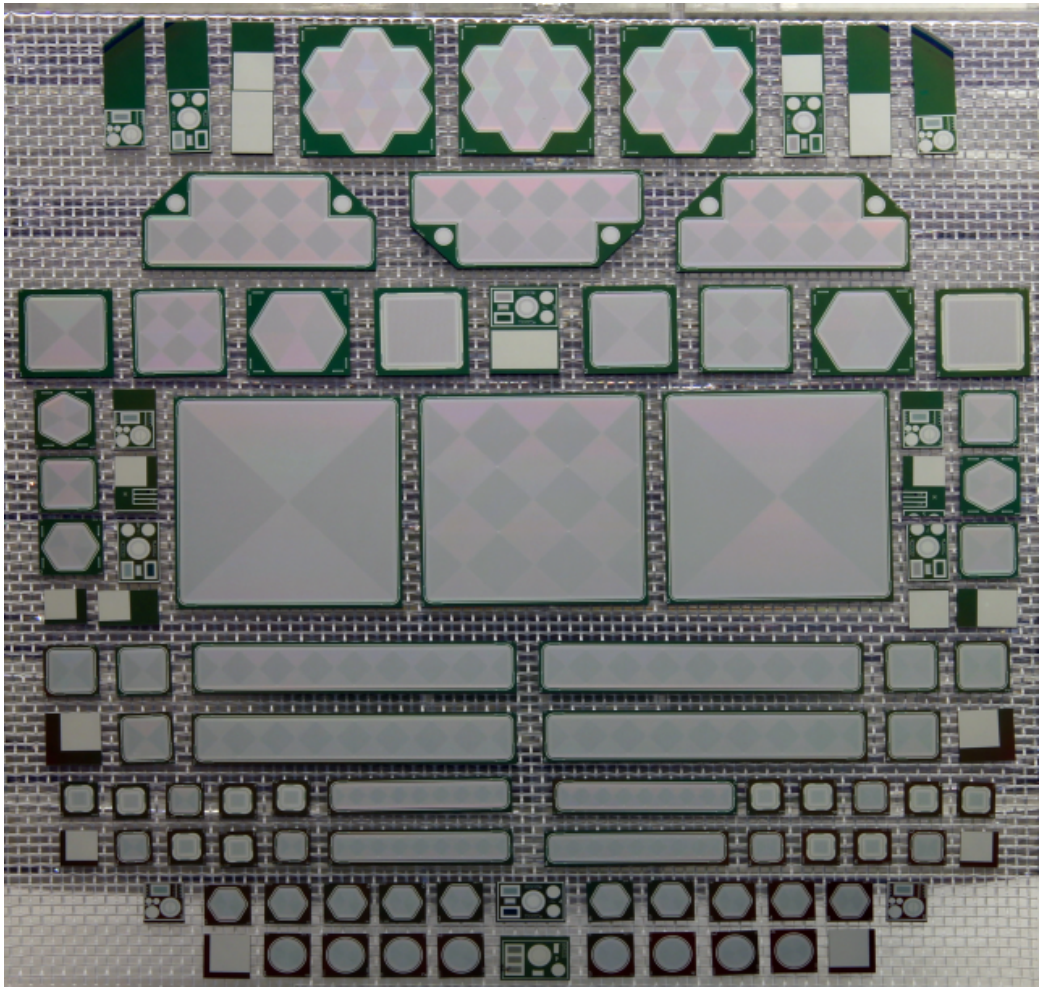
Why to use silicon drift detectors (SDD)

- low noise
- good energy resolution
- well proved technology
- can be made of defferent sizes and areas including a big volume
- can be used for detection of wide spectrum of EM radiation
- can be used with a scintillator

Operating principle of a Silicon Drift Detector

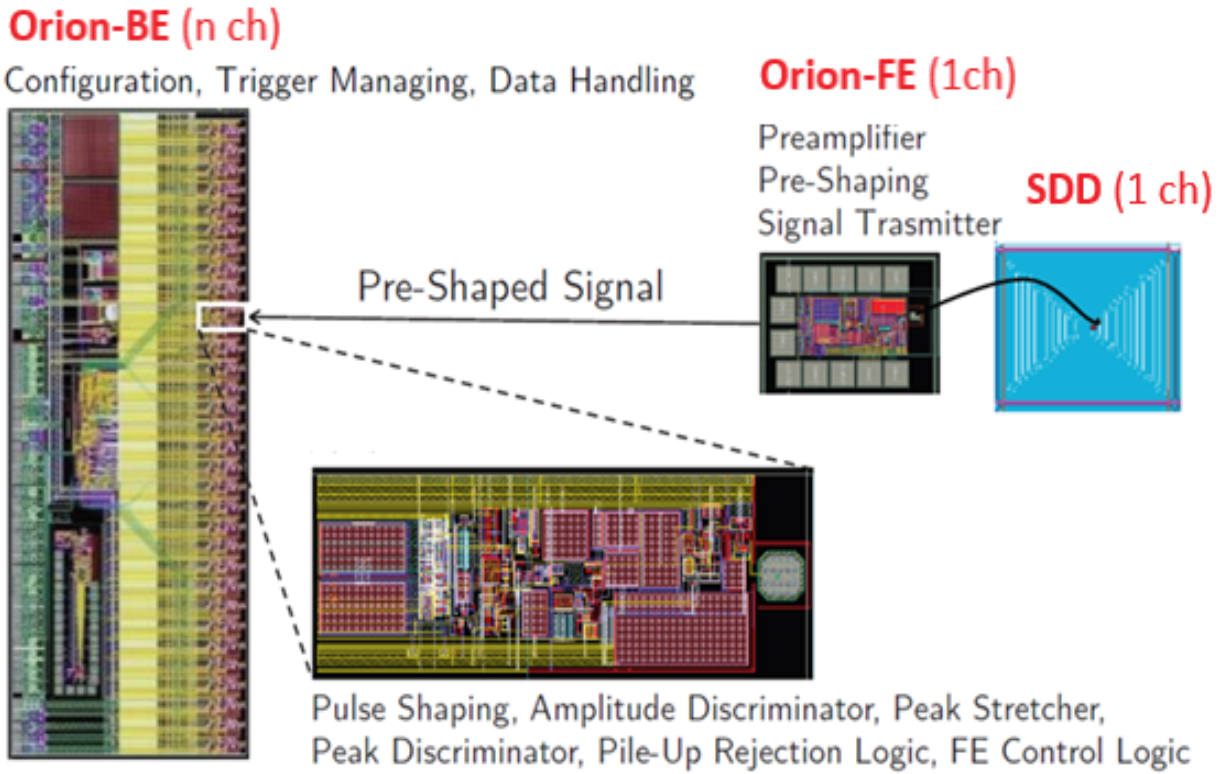


Silicon Drift Detectors at FBK-Tn



Silicon Drift Detectors (SDD) from REDSOX project (INFN) realized at Fondazione Bruno Kessler (FBK Trento)

Orion ASIC readout



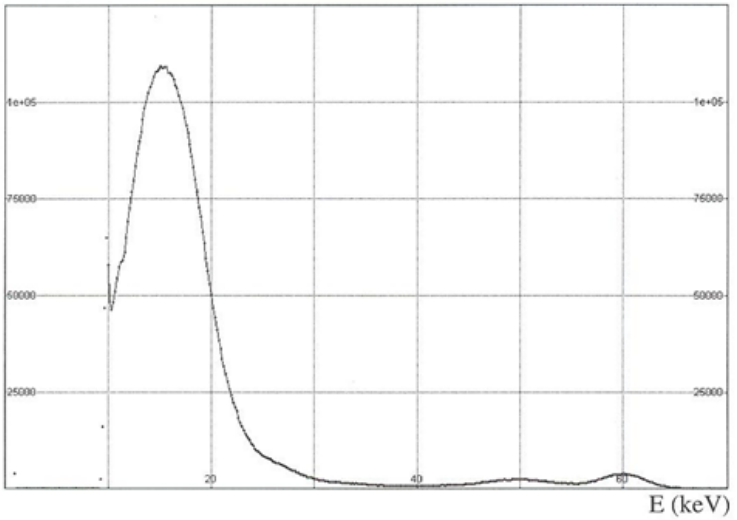
Si PIN vs SDD

1998 – 2003

Noise performance of the
Si PIN PD
used in INTEGRAL PICsIT (area PD 1 cm^2)
and AGILE MCAL (area PD 3.5 cm^2)

Si directly illuminated with an ^{241}**Am**
source (X lines @ 14.0, 17.7, 59.6 keV)

Noise ~ 1000 e^- rms @ 20 ºC
Power ~ 10 mW



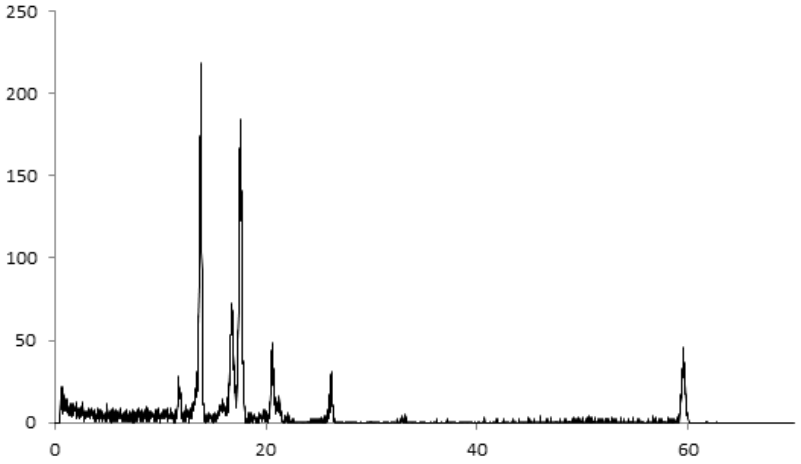
2016

Noise performance of the
SDD PD
Produced in FBK (area PD 1 cm^2)

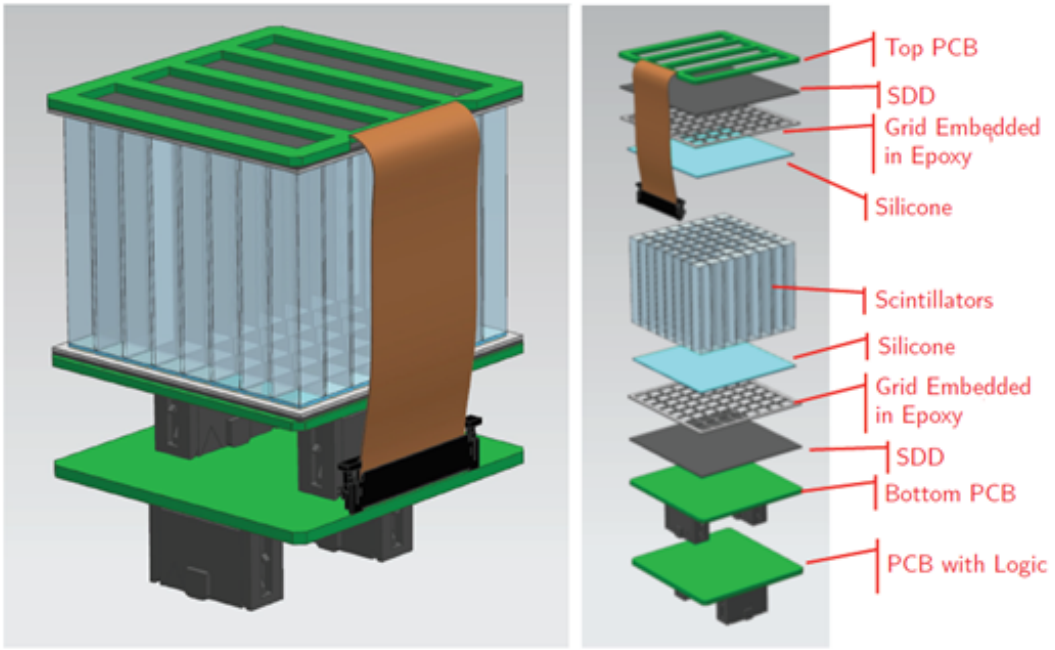
Si directly illuminated with an ^{241}**Am**
source (X lines @ 14.0, 17.7, 59.6 keV)

VEGA ASIC
Noise ~ 15 e^- rms @ 20 ºC
Power ~ 0.5 mW

SIRIO ASIC
Noise ~ 8 e^- rms @ 20 ºC
Power ~ 8 mW

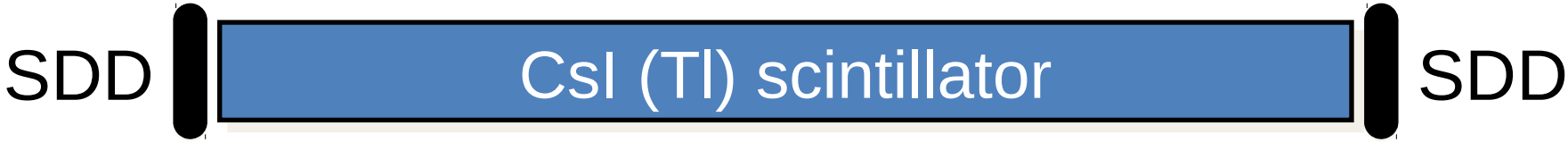


Module structure



- Detection band 2keV-20MeV
- Top and bottom PCB contain preamplifiers
- CsI(Tl) scintillator 4.5x4.5x30 mm
- PCB with Logic distinguish between X-ray and gamma

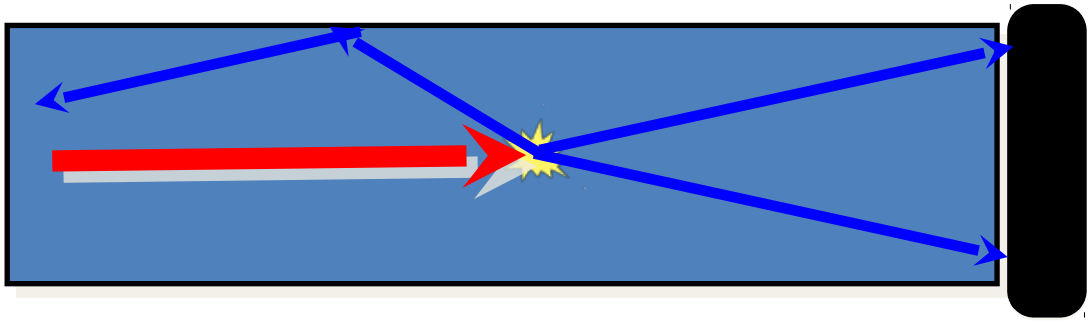
Ancora un altro design



Scintillator bar with double-SDD readout

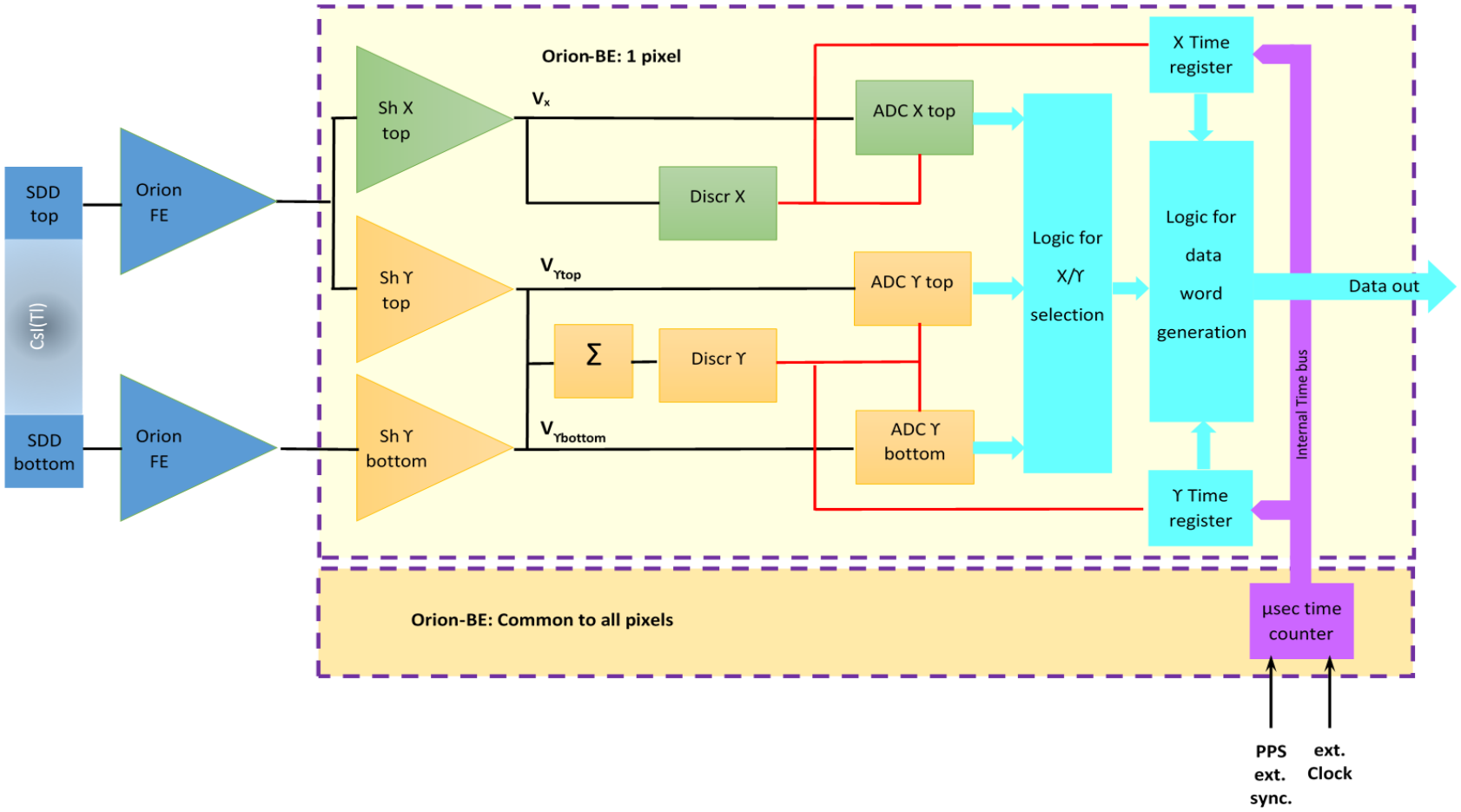
Dual architecture

X-ray events: direct absorption and readout by SDD-A (Theseus only)



y-ray events: scintillation light readout by both SDDs Position reconstruction possible using the two signals

Orion FE & BE Proposed architecture for pixel readout



- 2 shaping times, faster for X and slower for Υ events (3 amps total)
- 2 discriminators for X and Υ events
- Individual ADC for each amp line (3 ADC total)
- Event data formation inside the channel with logic for selection between X and Υ event
- Timing of the event loaded from an external 'Time bus' at the occurence of the event

Detector assembly structure

1 detector assembly contains

10 supermodules of

10 modules of

8x8 pixels