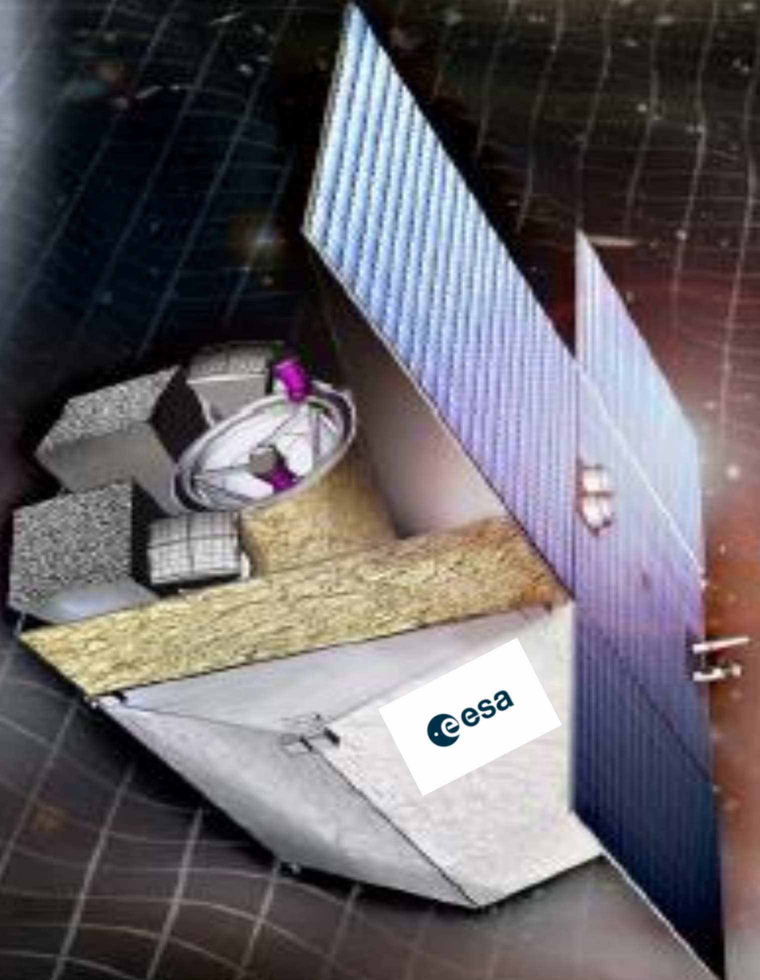
XGIS

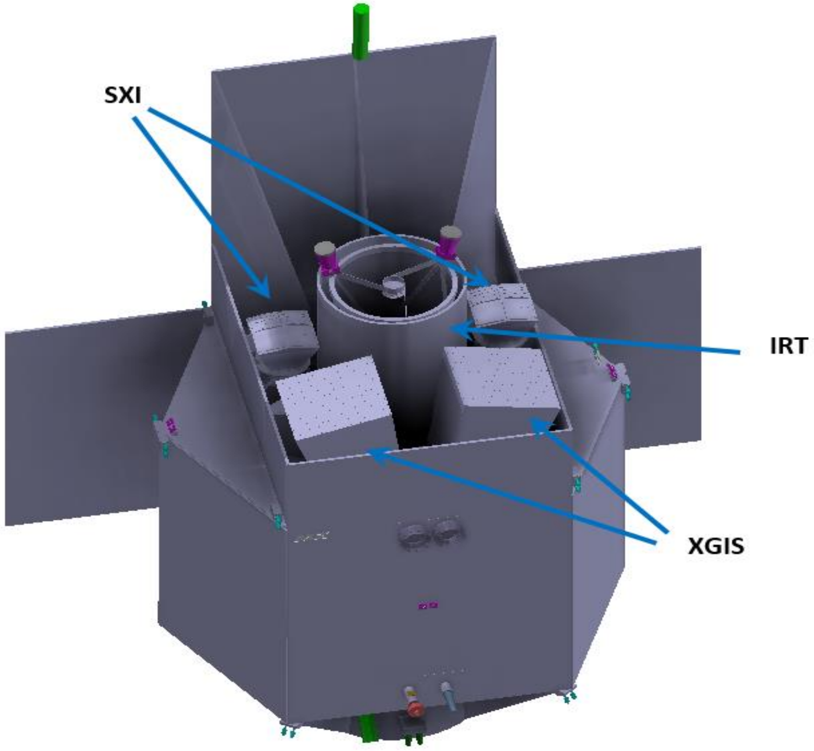
X/Gamma Imaging Spectrometer on-board THESEUS

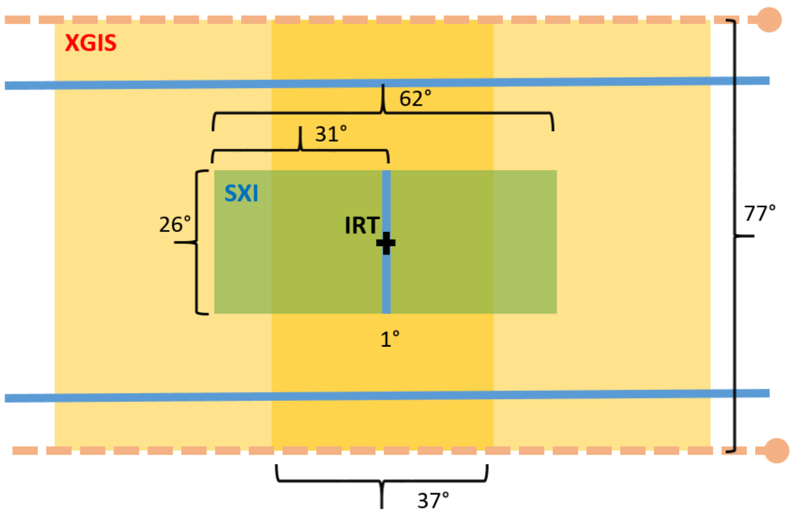
Claudio Labanti

in behalf of XGIS team



Theseus payload and concept of operation





FoV of the three systems
Blue lines contains the allowed pointing area

Thesues after Mission Consolidation Review

2 Monitors system: SXI (.2-5 keV) and
XGIS (2keV -10 MeV)

Infrared telescope: IRT

OPERATIONS

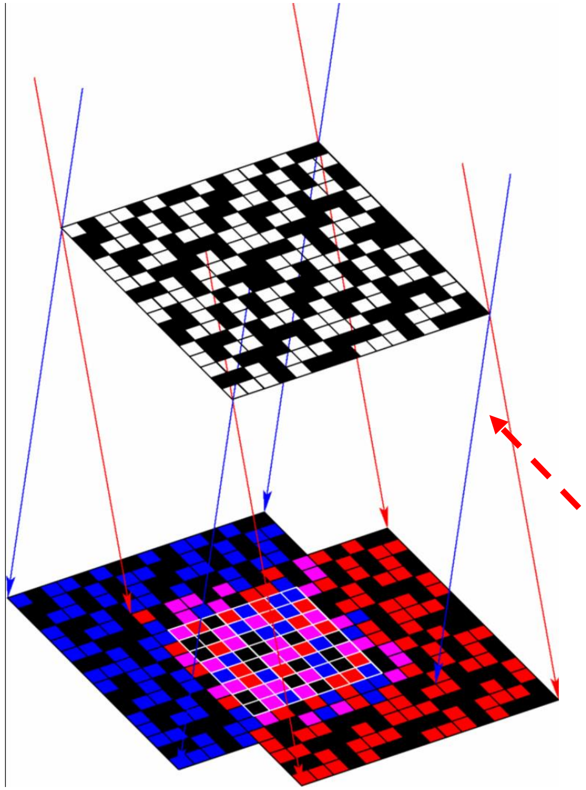
Survey Mode: XGIS monitor and look, with different methods for GRBs within the FoV.

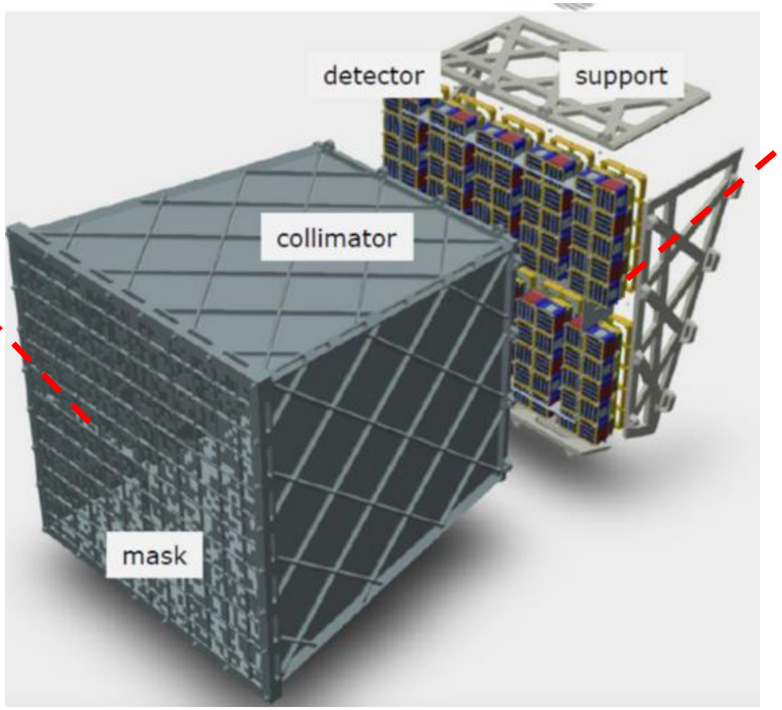
Burst Mode: in case a detected GRB, XGIS switch to the photon-by-photon

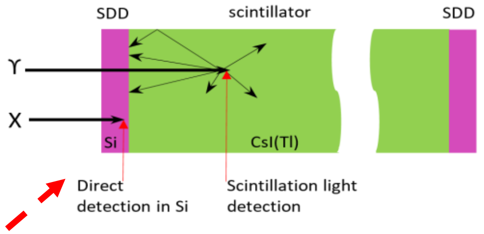
IRT Follow-up and External Trigger Mode: photon-by-photon

XGIS instrument concept

Targets: long (hi-z) and short (black-hole mergers/GW counterparts) GRBs



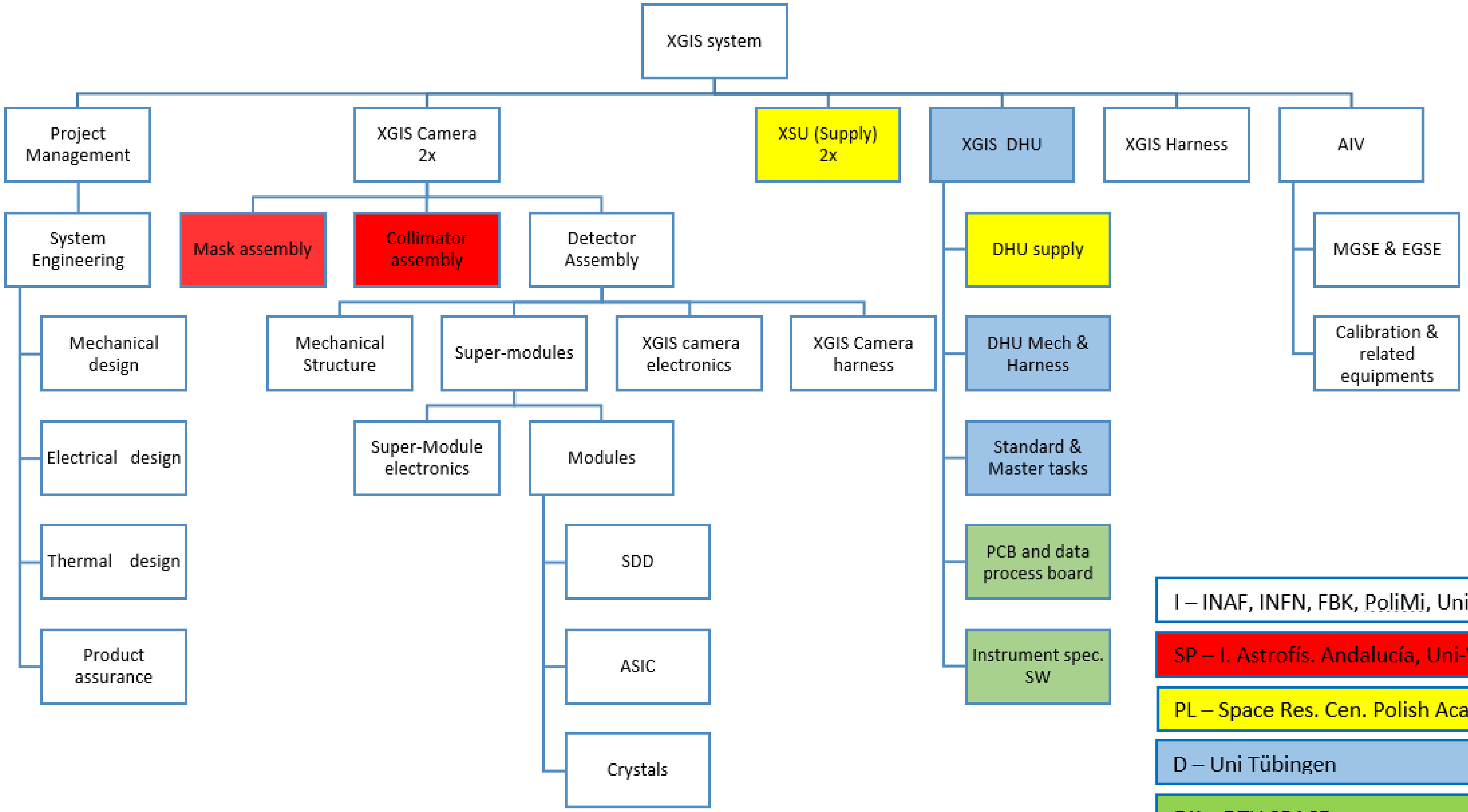




Coded mask telescope with scintillator crystal and Silicon Drift Detectors

Lead:	INAF-Bo IT	2x units
Energy range	2 keV - 10 MeV	
Low en. detector	Silicon Drift Detector SDD	
High en detector	CsI(Tl) scintillators	
Imaging capab	< 150 keV	

XGIS consortium



I – INAF, INFN, FBK, PoliMi, Uni-Pv-Fe-Ud-Bo

SP – I. Astrofís. Andalucía, Uni-Valencia

PL – Space Res. Cen. Polish Acad. of Science

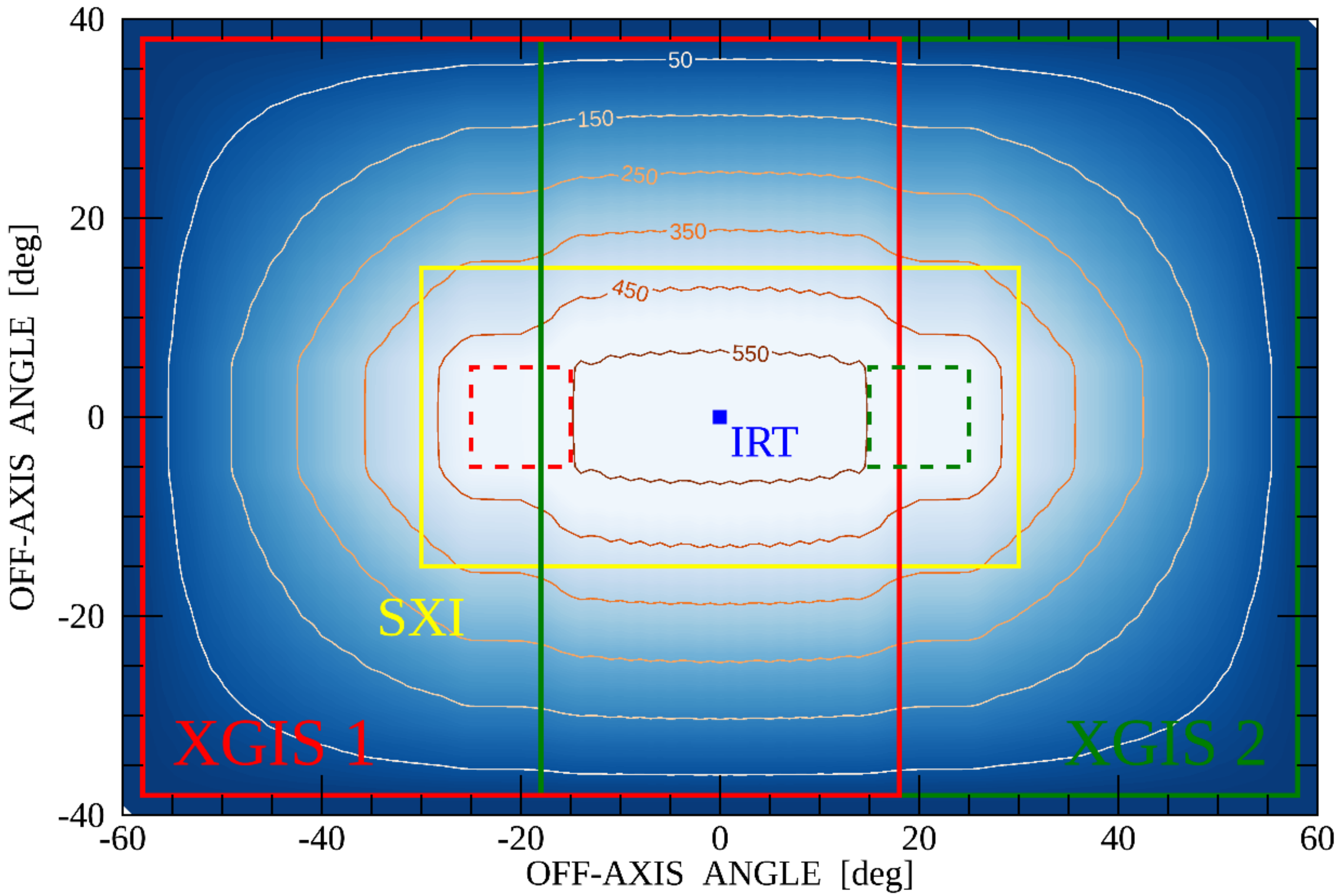
D – Uni Tübingen

DK – DTU SPACE

XGIS camera main parameters

Energy range	2 ÷ 150 keV imaging	> 150 keV (up to 10 MeV) Non imaging
Fully coded FOV (FCFOV)	10.5 x 10.5 deg^2	
Partially coded FOV (PCFOV)	77 x 77 deg^2	
FOV		2π sr
XGIS sensitivity in 1 sec (two combined camera @ EOL) cgs = $erg/cm^2/sec$	> 10^{-8} cgs for 2–30 keV > 3×10^{-8} cgs for the 30–150 keV	> 3×10^{-7} cgs
Angular resolution	< 1 deg	
Source location accuracy	≤ 15 arcmin 90% confidence level for a source with SNR > 7	
Energy resolution	≤ 1200 eV FWHM @ 6 keV	6 % FWHM @ 500 keV
Relative timing accuracy	7 µs	
Physical dimensions	L x W x H = ~ 60 x 60 x 92 cm ~ 66 kg Weight ~ 50 W Power	

XGIS Field of view of combined units



Imaging FoV (<150 keV)

117x77 deg^2

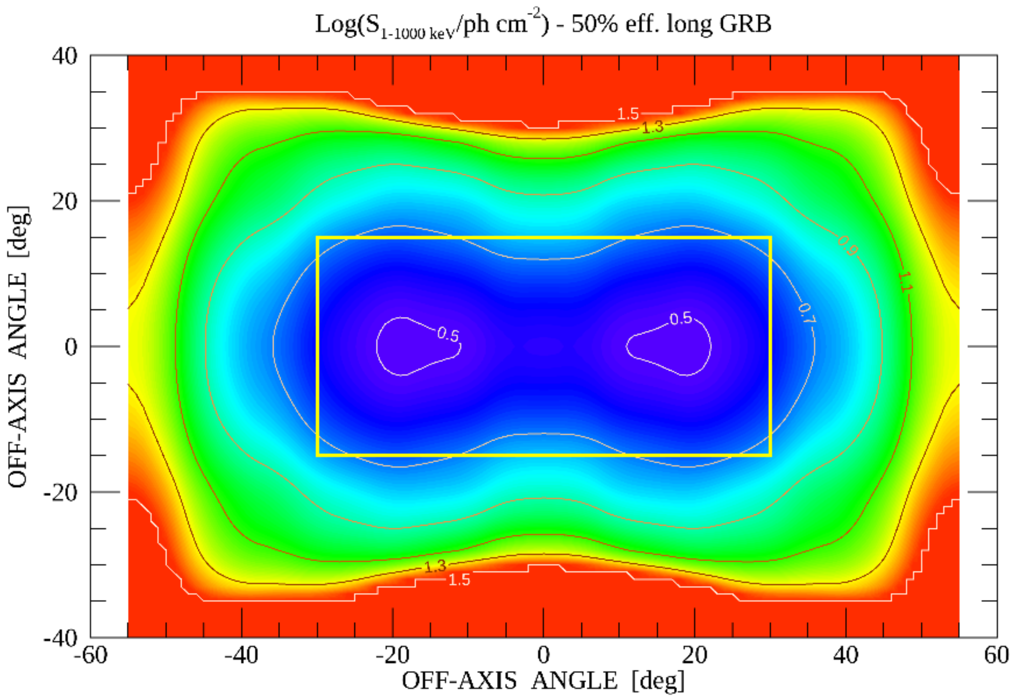
Non-imaging FoV (>150 keV)

~2π sterad

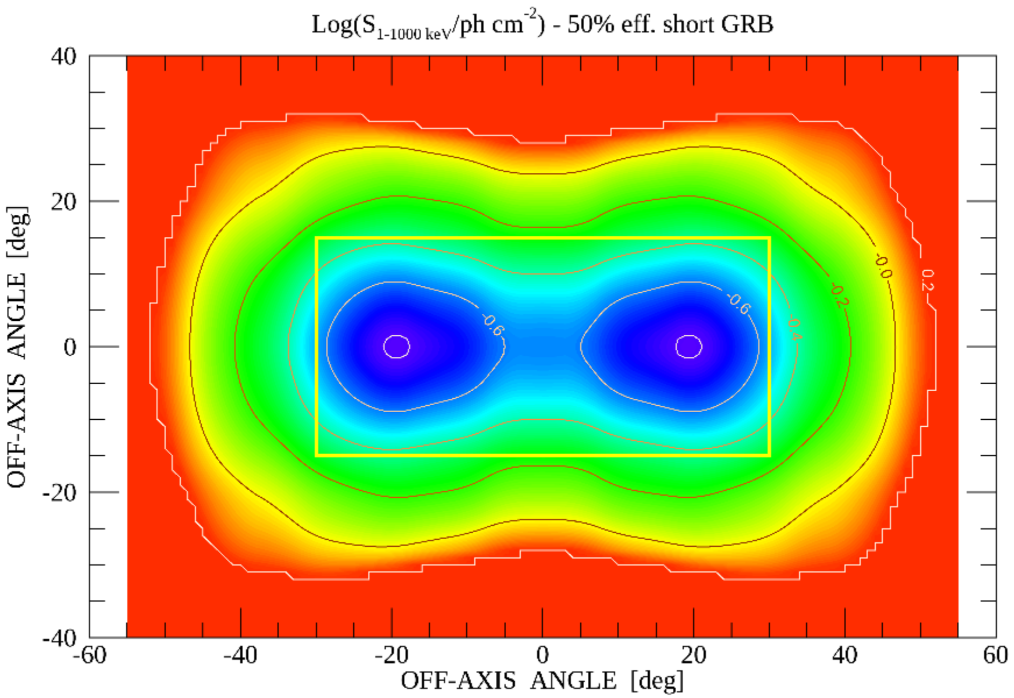
Courtesy S. Mereghetti (INAF-Mi)

XGIS Sensitivity for GRB population

Long GRB



Short GRB

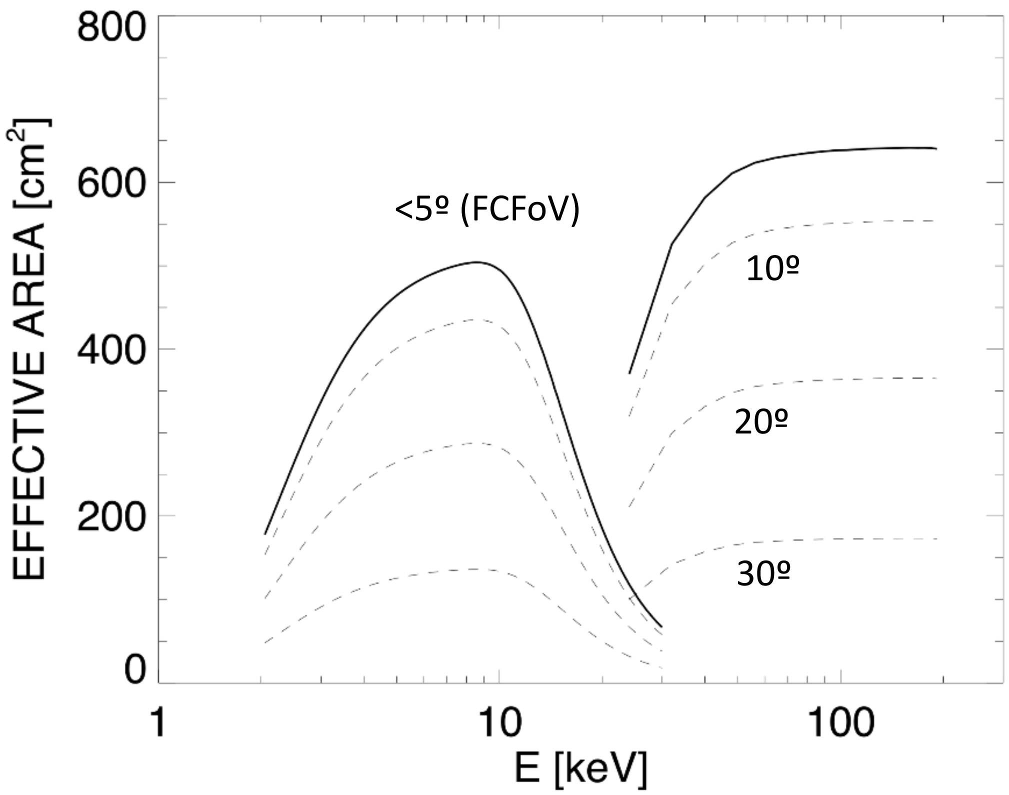


Log (Fluence $_{1\text{-}1000\ keV}$ / ph cm^{-2}) with 50% probability of detection
(average on GRB population used in MOS)

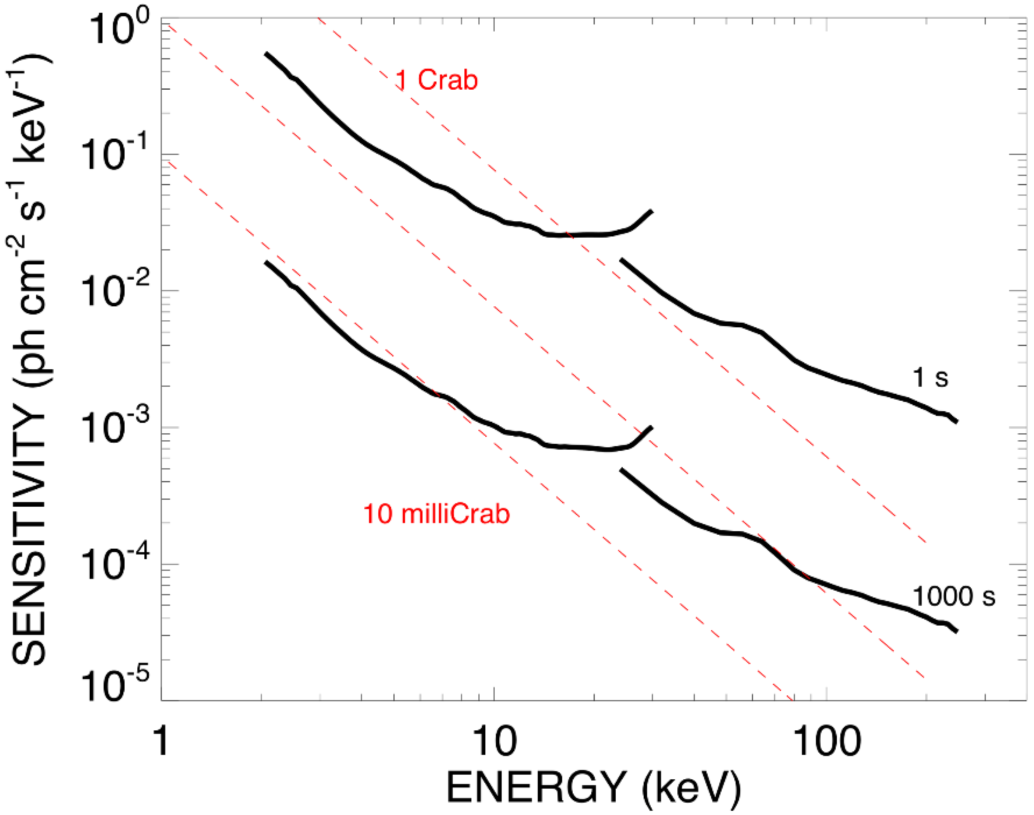
Courtesy S. Mereghetti (INAF-Mi)

XGIS Sensitivity (one unit)

Effective area (for imaging)

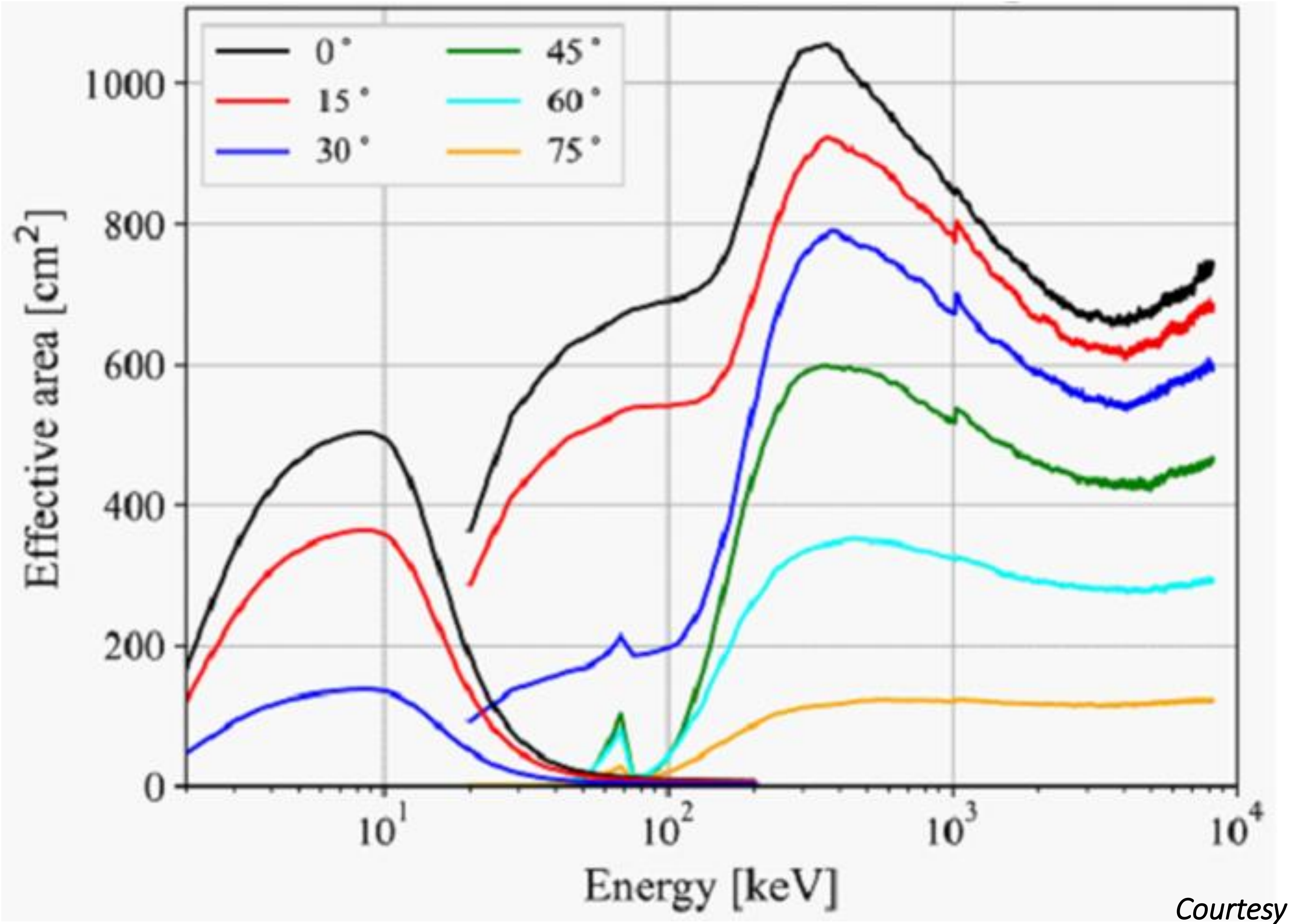


Sensitivity (in FC FoV)



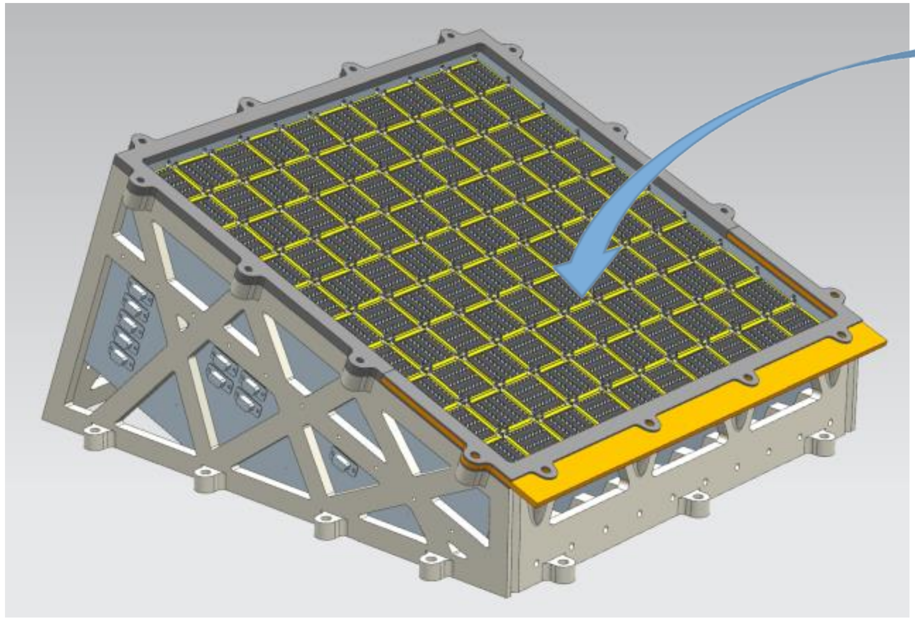
Courtesy S. Mereghetti (INAF-Mi)

XGIS camera effective area vs area and off-axis angle

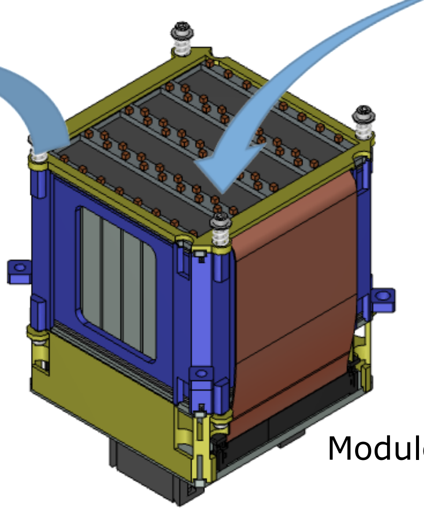


Courtesy R. Campana (INAF-Bo)

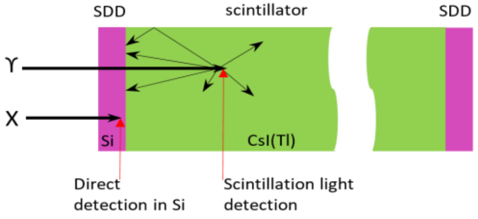
XGIS detector plane



•XGIS detector plane: array of 10x10 detector modules

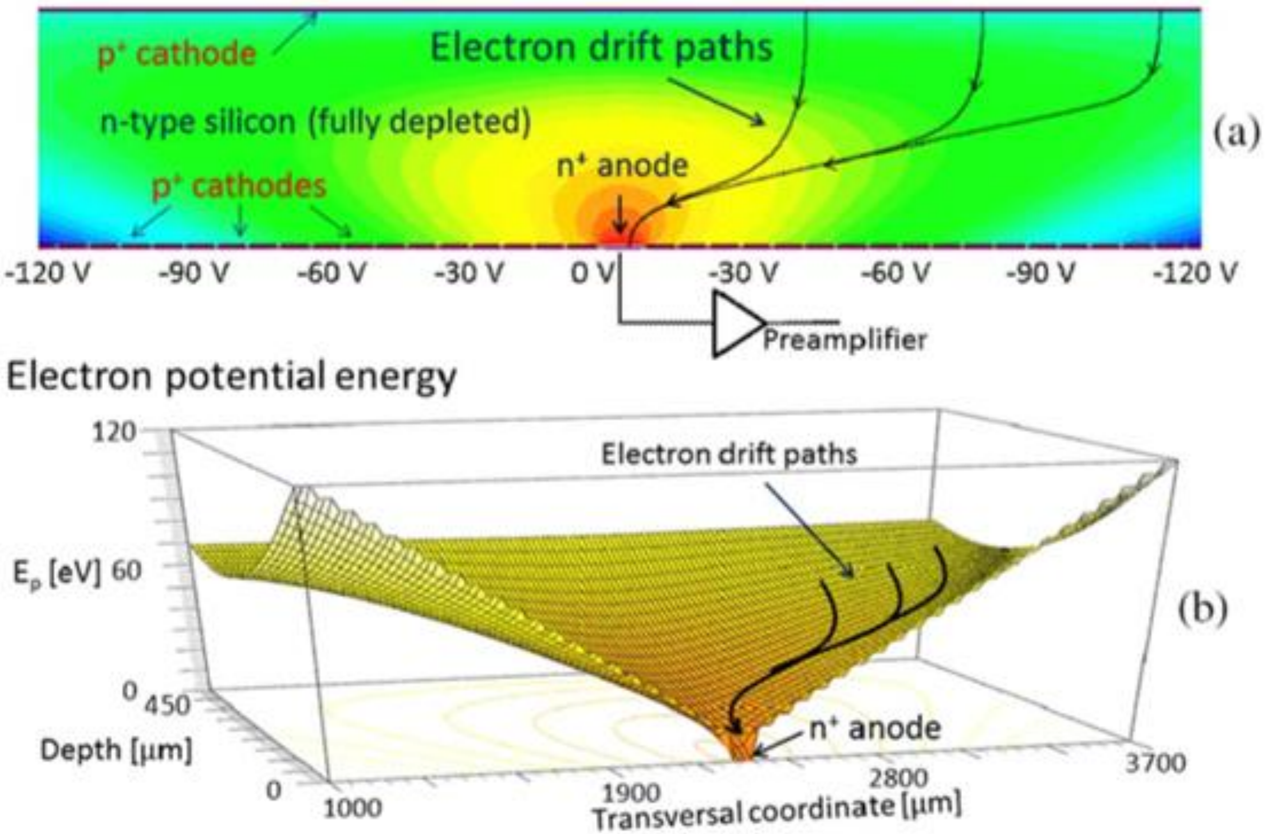


Module: Array of 8x8 pixel



- XGIS plane:
  - **100 Modules**
  - **6400 pixel**
  - **12800 SDD detectors**
- SDD organized in array od 8x8 elements pitch 5 mm
- Signal readout via dedicated ASIC:
  - **12800 ORION-FE ASIC and**
  - **80 ORION-BE ASIC**
    - Discriminating betwee X/γ events and delivering digital data

Operating principle of a Silicon Drift Detector

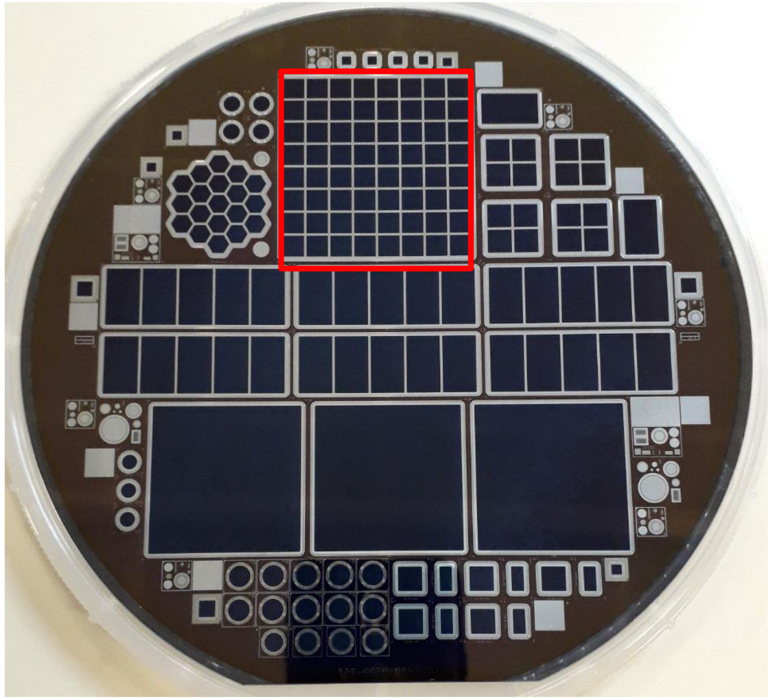


Very low noise device suitable for direct X-ray detection and for light detection

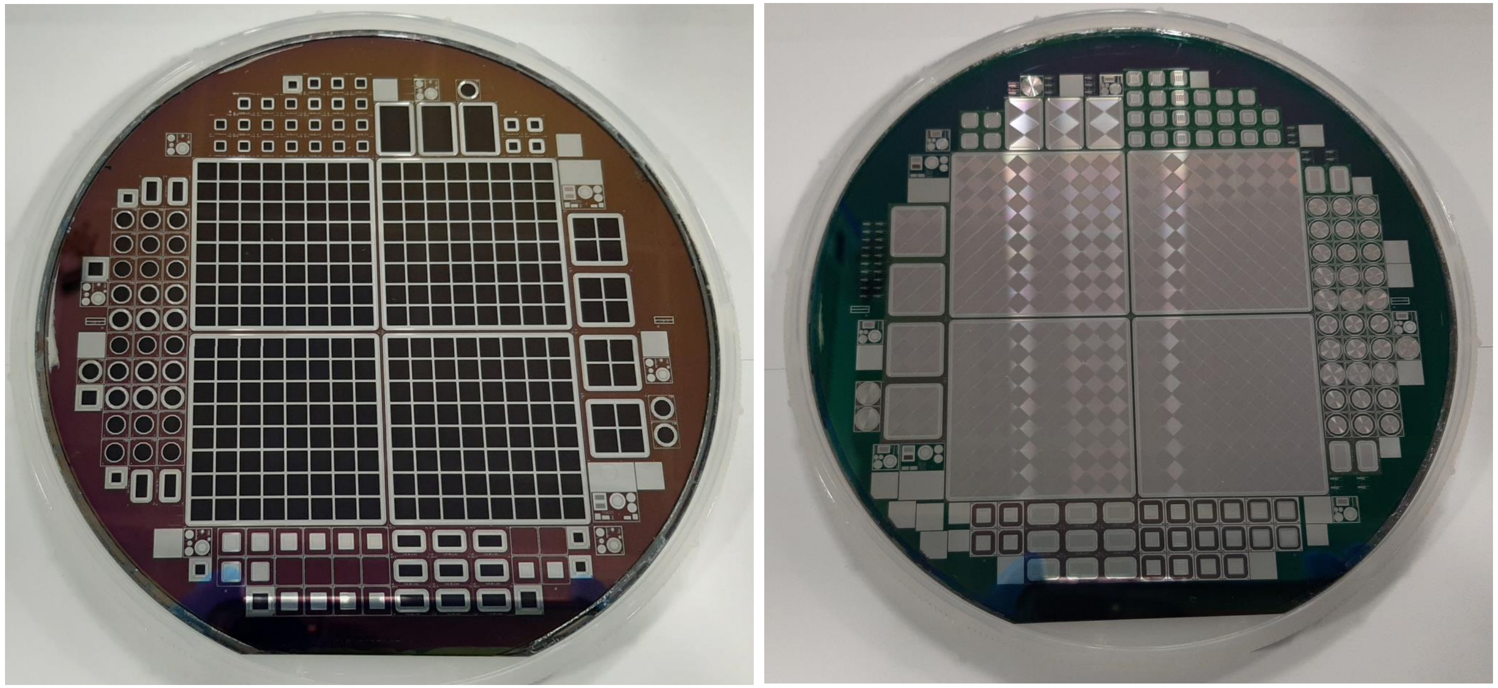
Connections needed for each pixel (power, return, anode)

In XGIS side n (anode side) will be exposed to the incoming radiation

SDD for XGIS



ReDSoX-4 program 2019

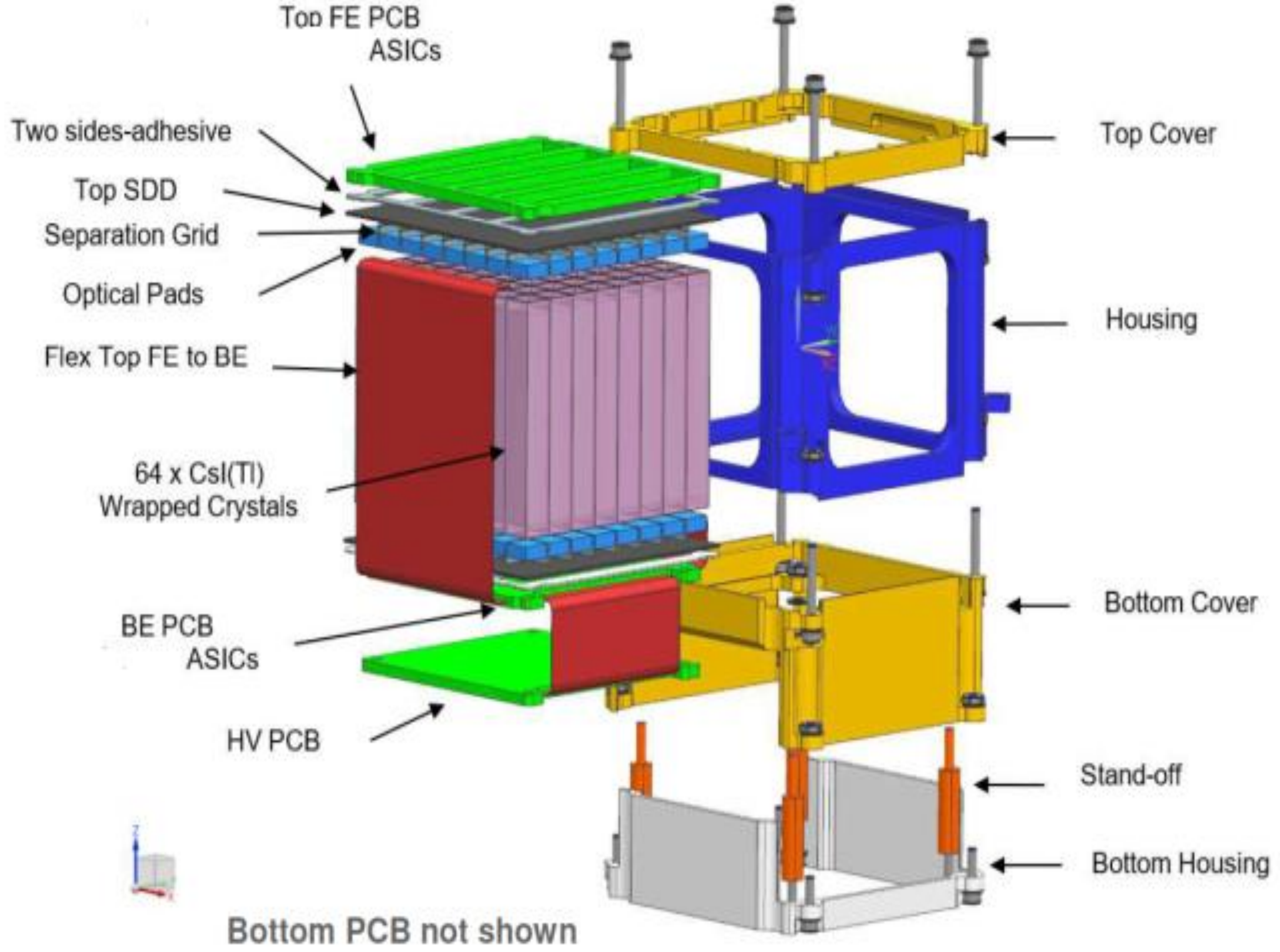


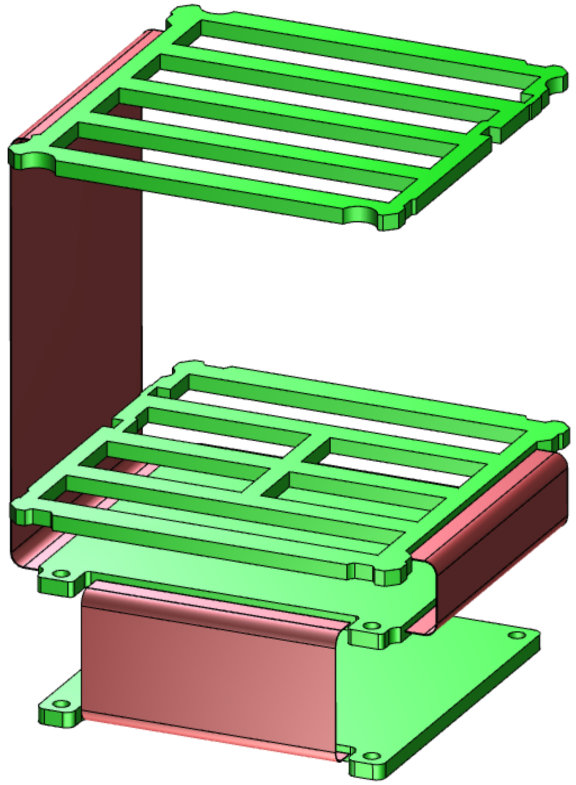
Thesues run 2020

- **64 element matrix (8x8) pitch 5mm;**
- **dimensions 42,4mm x 42,4mm;**
- **Al grid (width 0,5mm) on the light input side (effective area 4,5mm x 4,5mm);**
- **One side polarisation common to the whole structure**

Courtesy Fondazione Bruno Kessler (Trento , I)

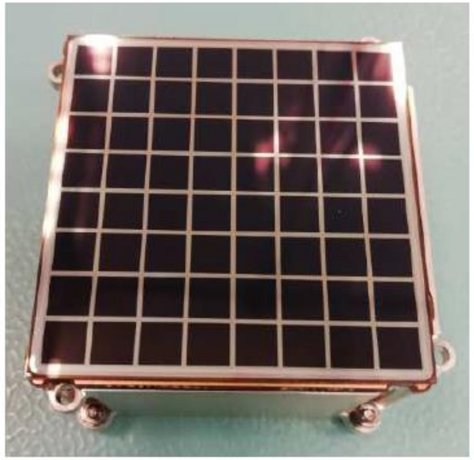
Detector module design

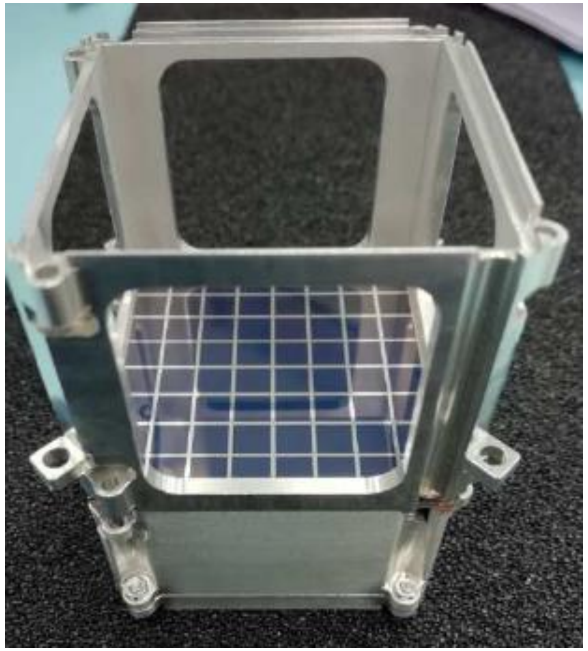


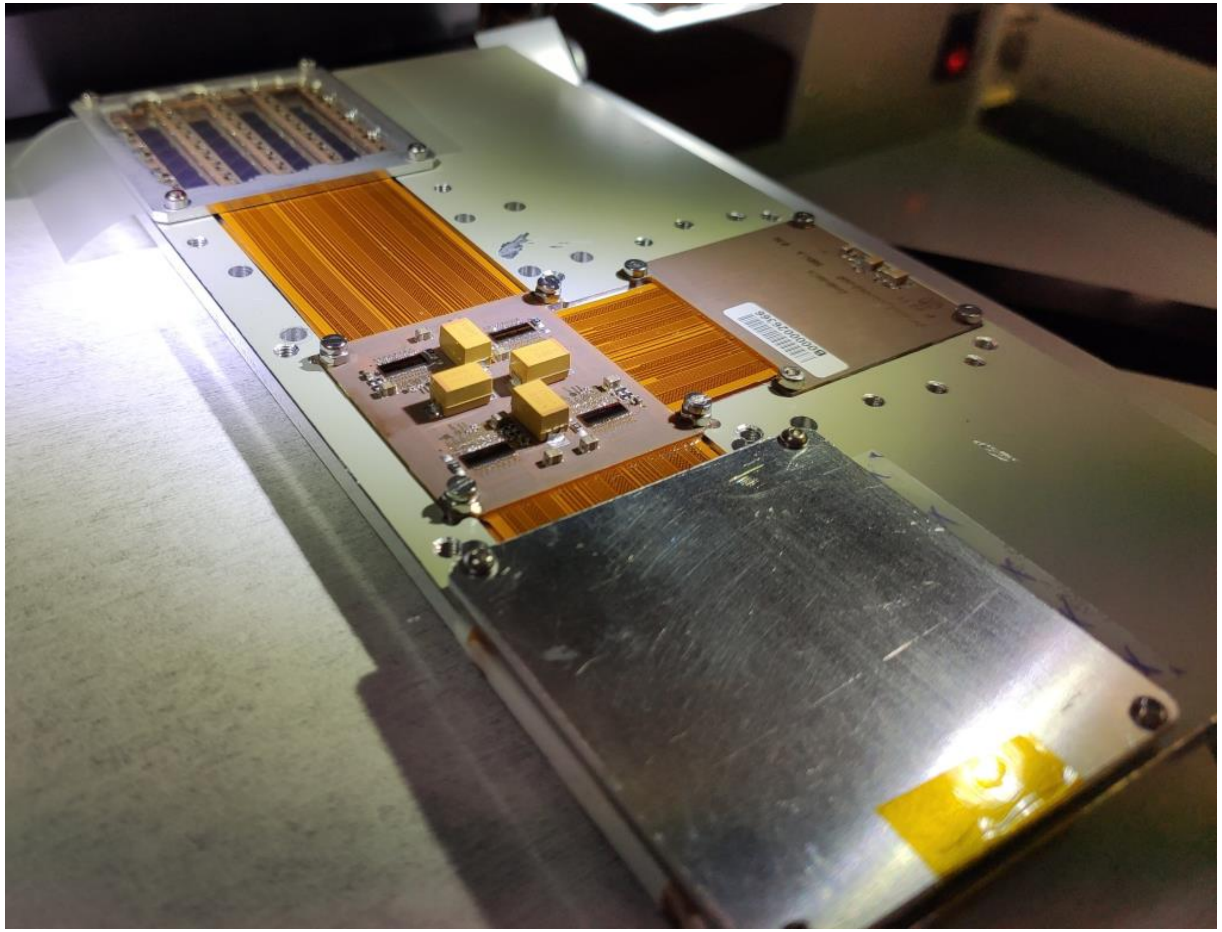


Courtesy OHB-Italia (Milano)

Bottom SDD array on the module prototype

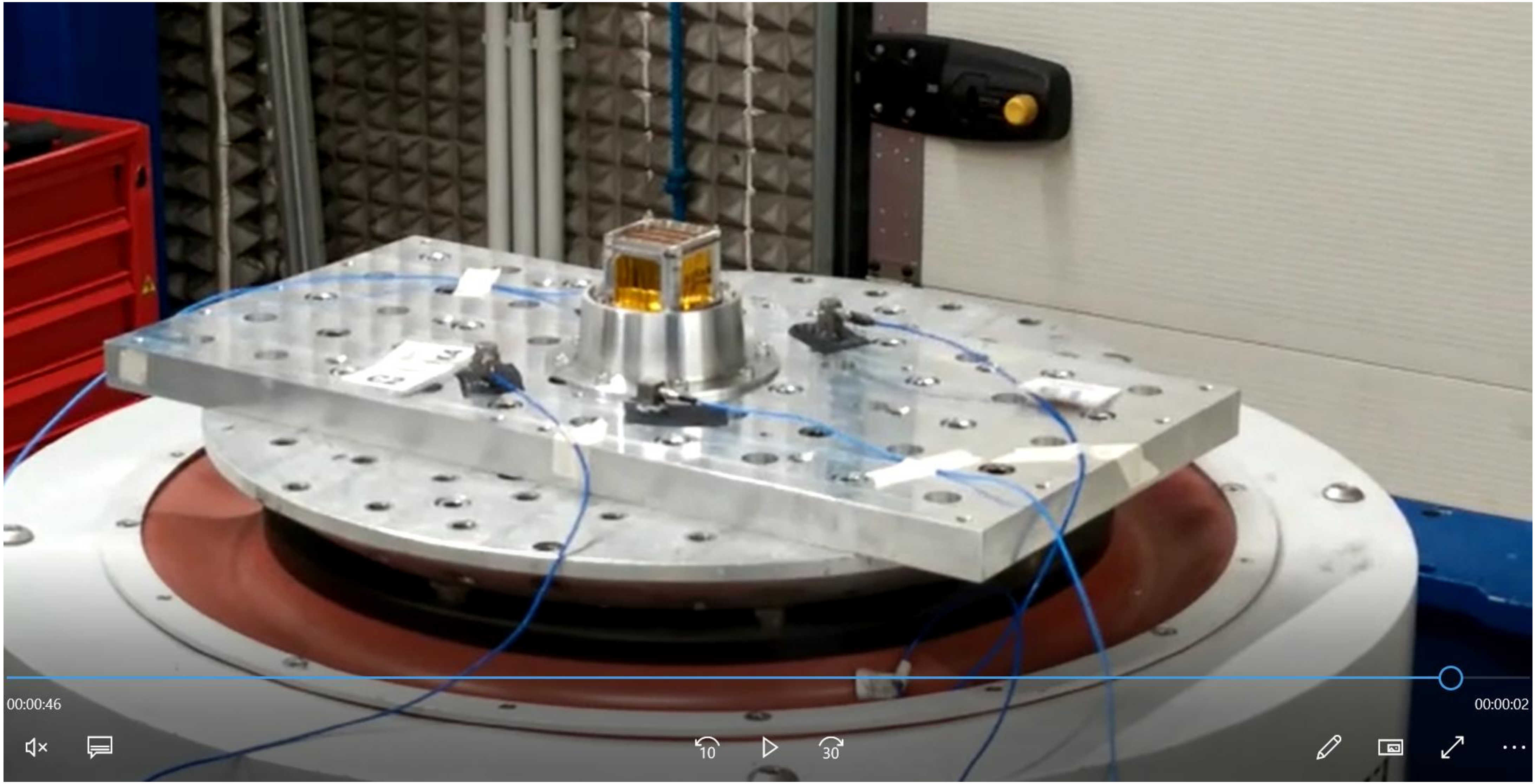






Courtesy OHB-Italia (Milano)

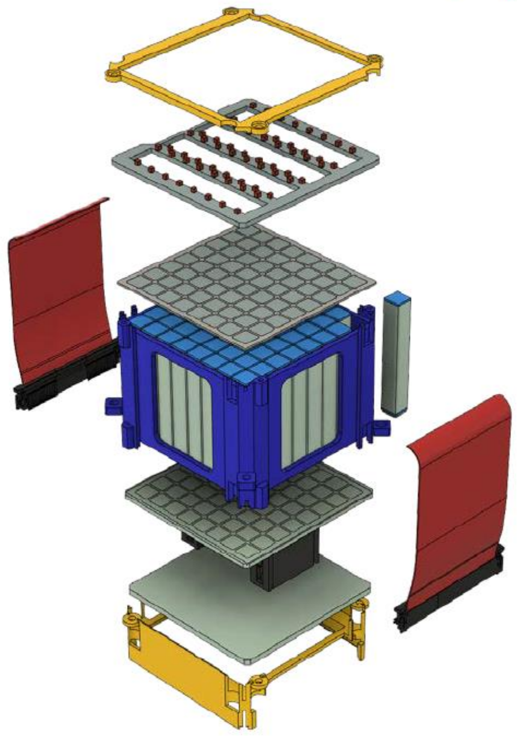
XGIS module mechanical prototype during vibration test

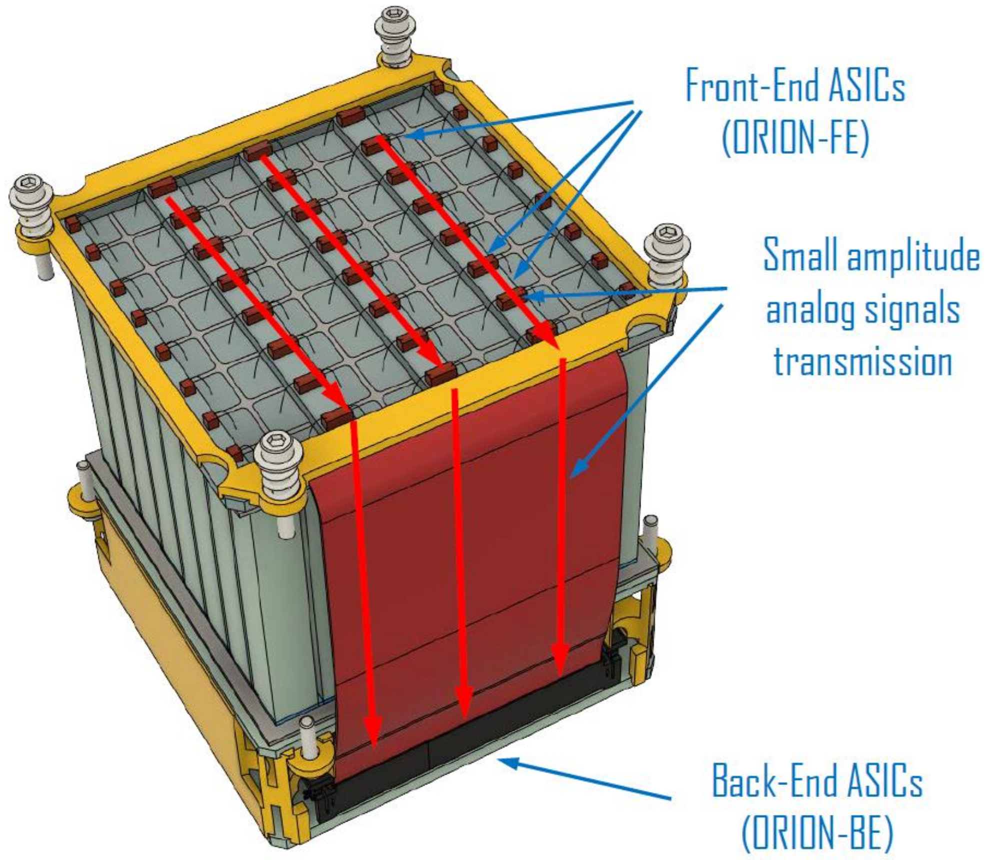


Courtesy OHB-Italia (Milano)

Concept of the module electronics

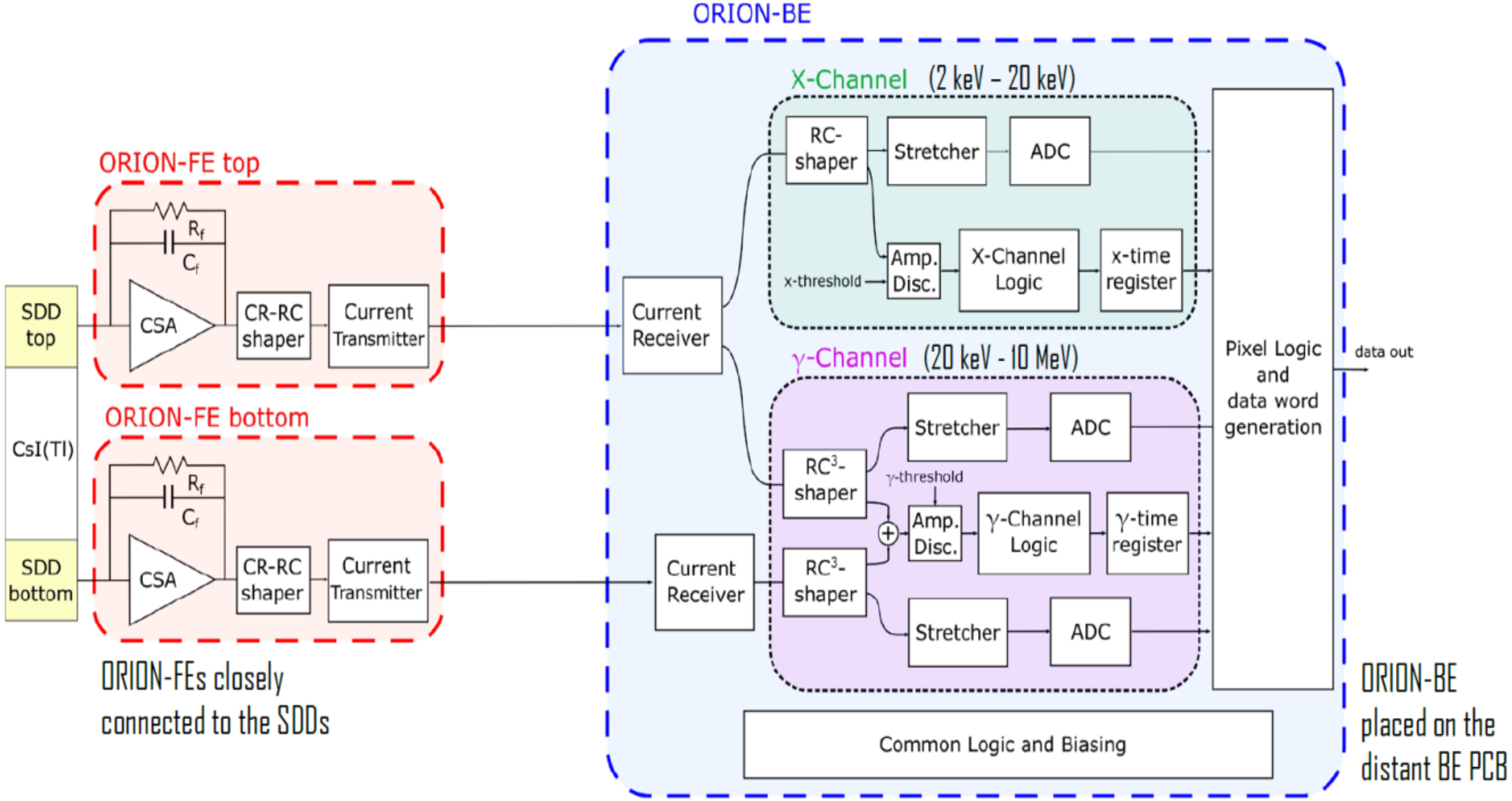
➢ **SDD array peculiarity**
- Central small anode (Ø≈100 μm)
- Large size (≈ 4 cm × 4 cm)

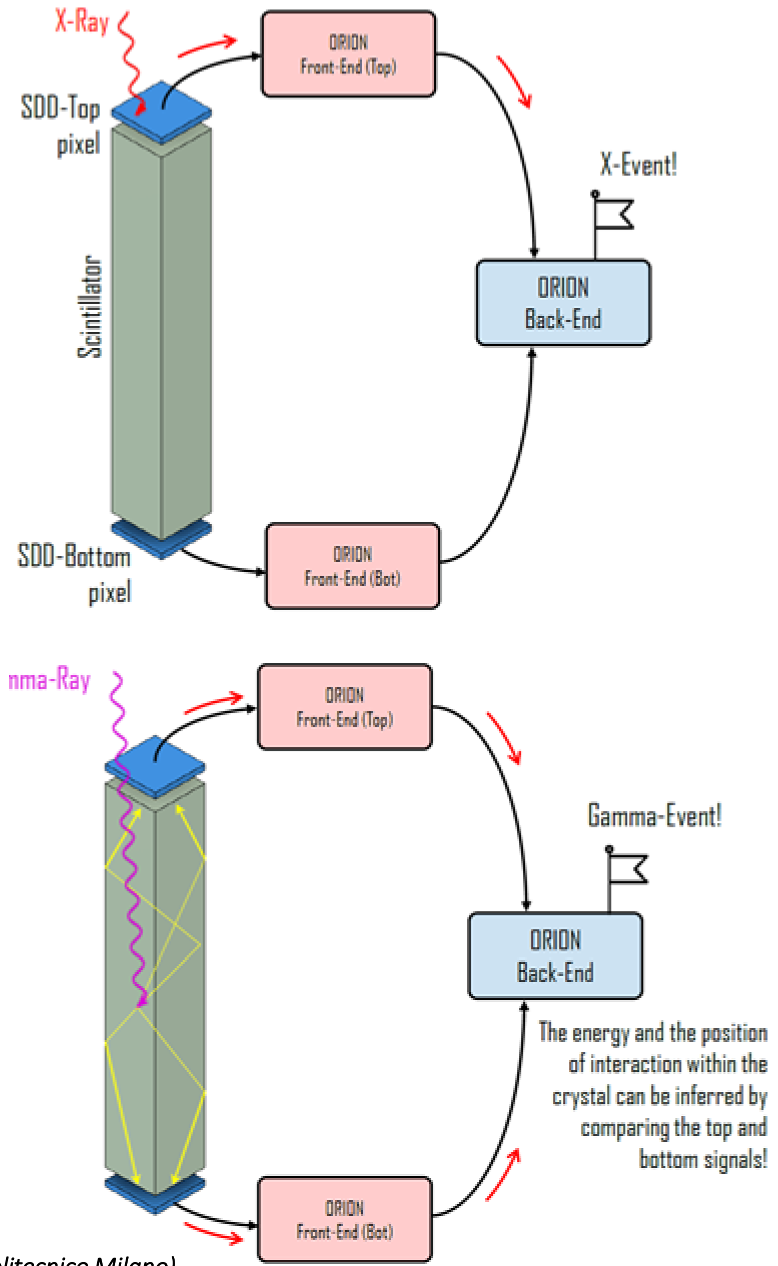




Courtesy G. Bertuccio (Politecnico Milano)
P. Malcovati (Uni Pavia)

The ORION-FE & ORION-BE ASICs





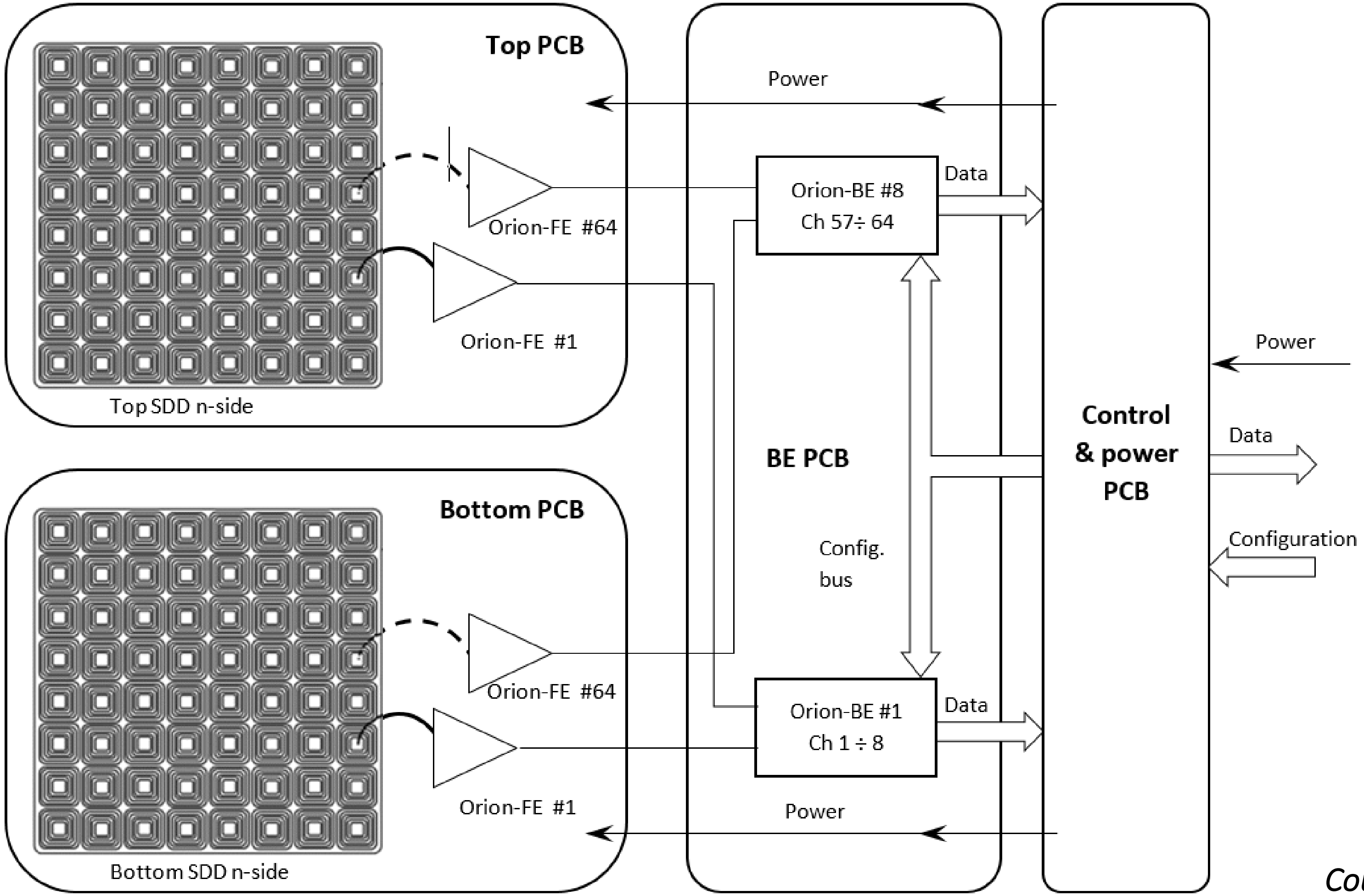
- Output data format → 64 bits (62 bits used)

Time (24)	Address (3)	X-γ	D_{bottom} (16)	D_{top} (16)	TRG_X	TRG_γ	NU (2)

- Output interface (bidirectional SPI) → Five wires
  - LaM (Look at Me) → Valid data available (one per ORION-BE ASIC)
  - CS → Chip select (one per ORION-BE ASIC)
  - CLK (Clock) → Synchronization signal (common to all ORION-BE ASICs)
  - Data (MISO, MOSI) → Bidirectional data transmission (common to all ORION-BE ASICs)

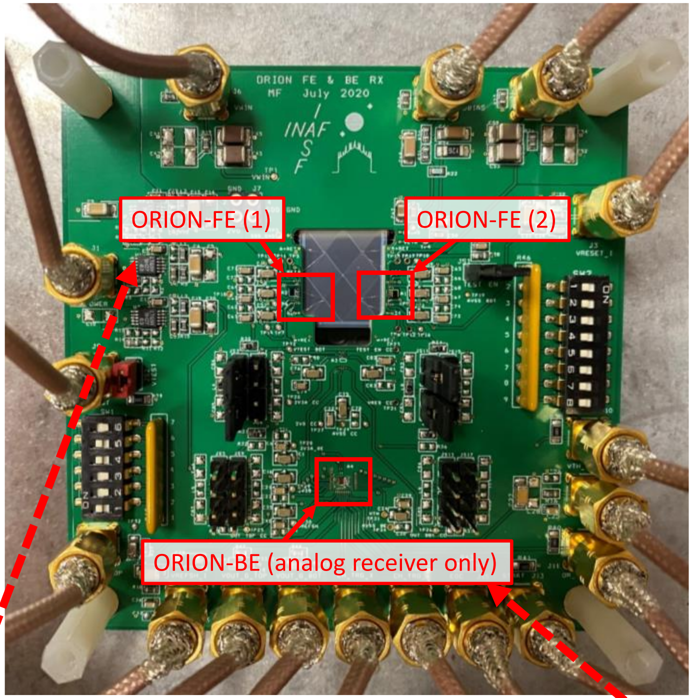
Courtesy G. Bertuccio (Politecnico Milano)
P. Malcovati (Uni Pavia)

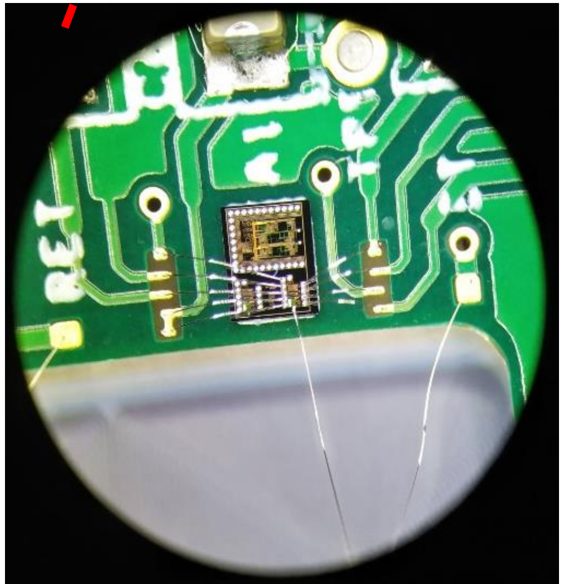
Structure of the module electronics

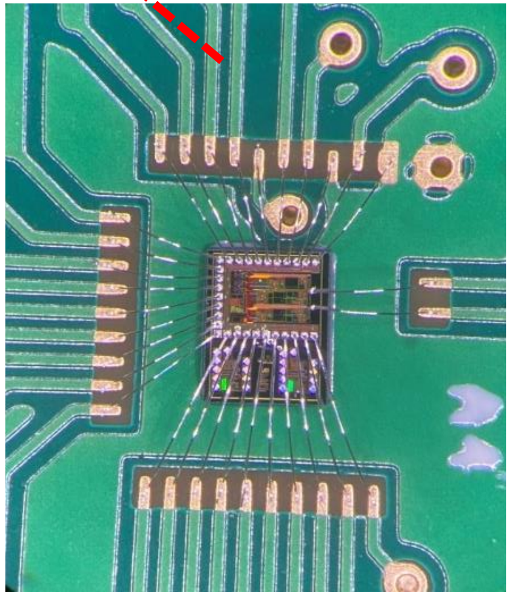


Courtesy F. Fuschino (INAF-Bo)

X and γ signals ORION-v1





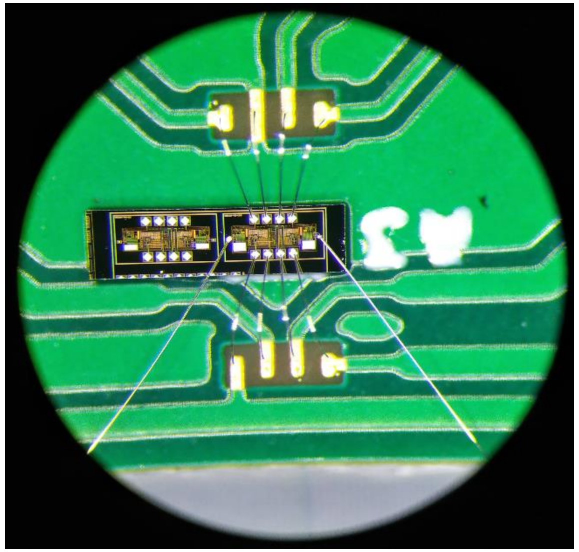


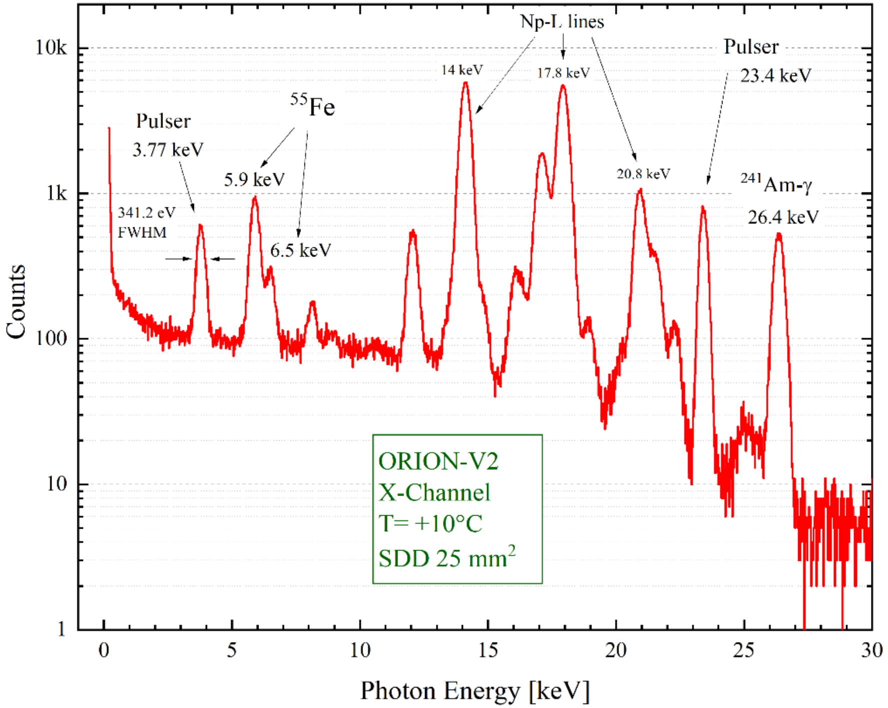
ORION-FE v1 dec 2020

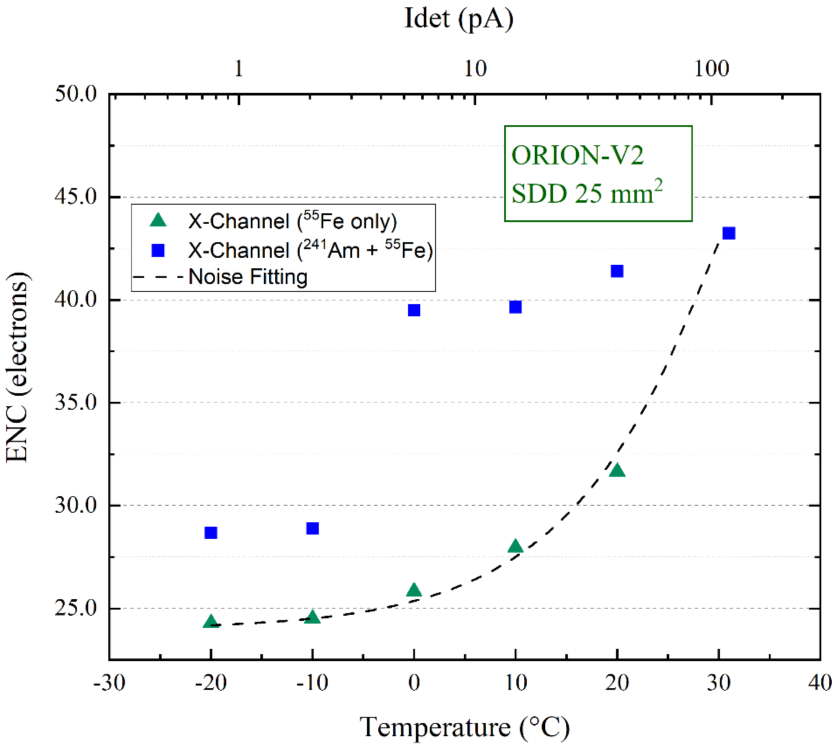
Courtesy I. Dedolli, F Mele (Politecnico Milano)

M. Grassi (Uni Pavia)

ORION-FE v2 preliminary test: X branch







- 2 channl/chip
- Reduced size
- Reduced gain

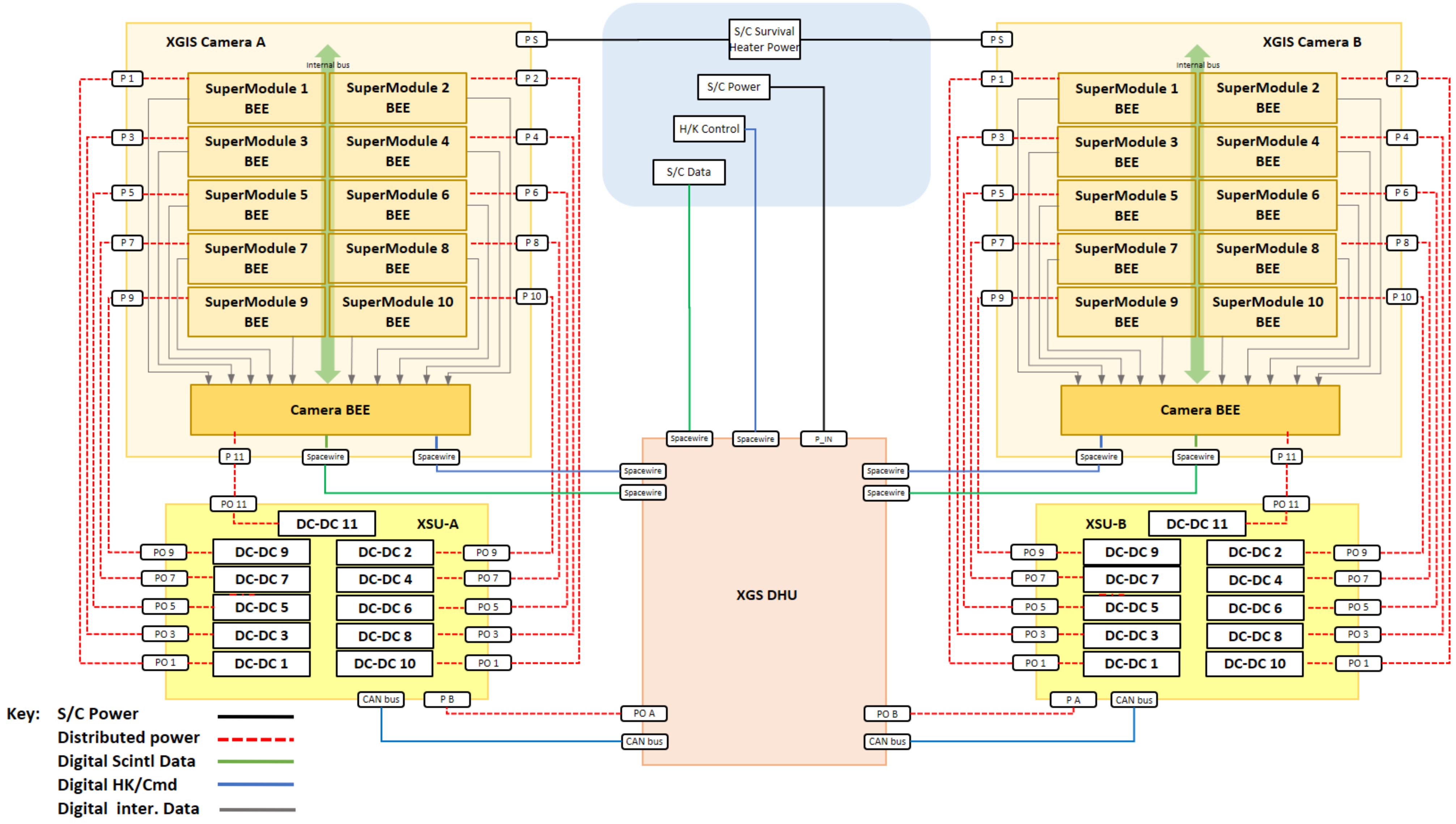
SDD 25 mm^2, ^{55}Fe and ^{241}Am sources

ORION-FE v2 March 2021

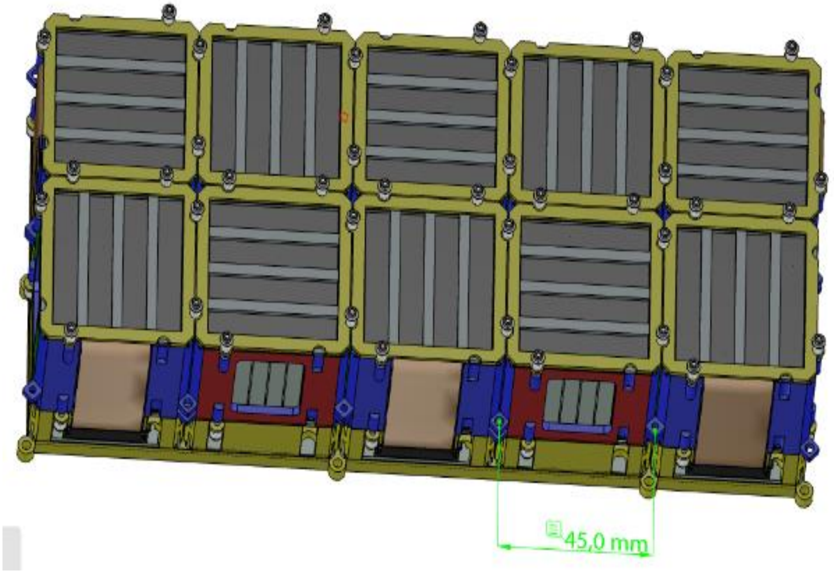
Courtesy I. Dedolli, F Mele (Politecnico Milano)

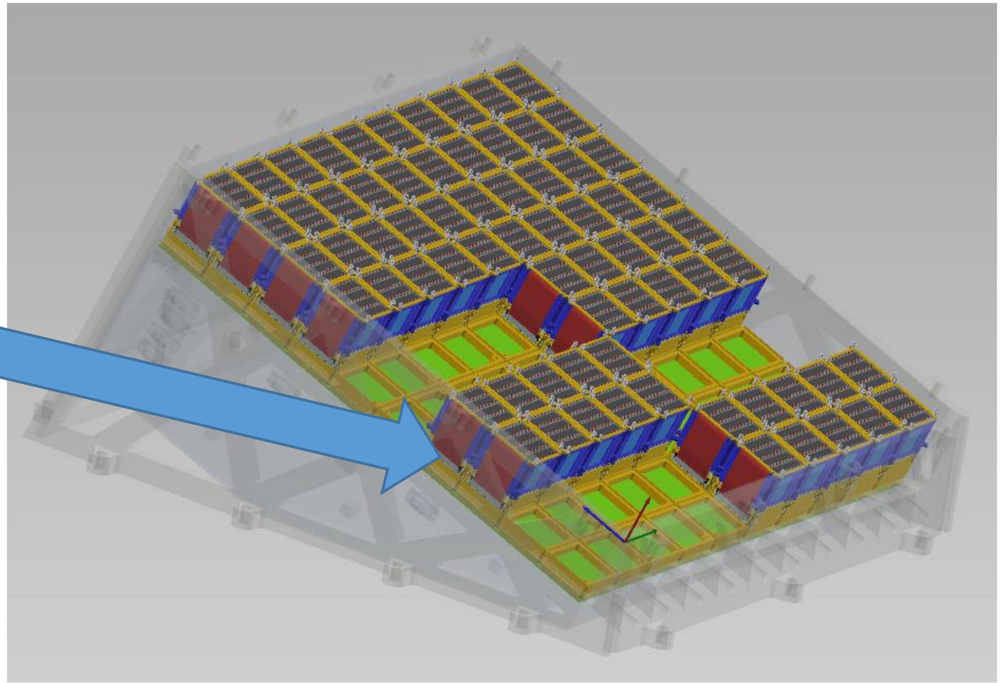
M. Grassi (Uni Pavia)

XGIS connection concept



The SuperModule



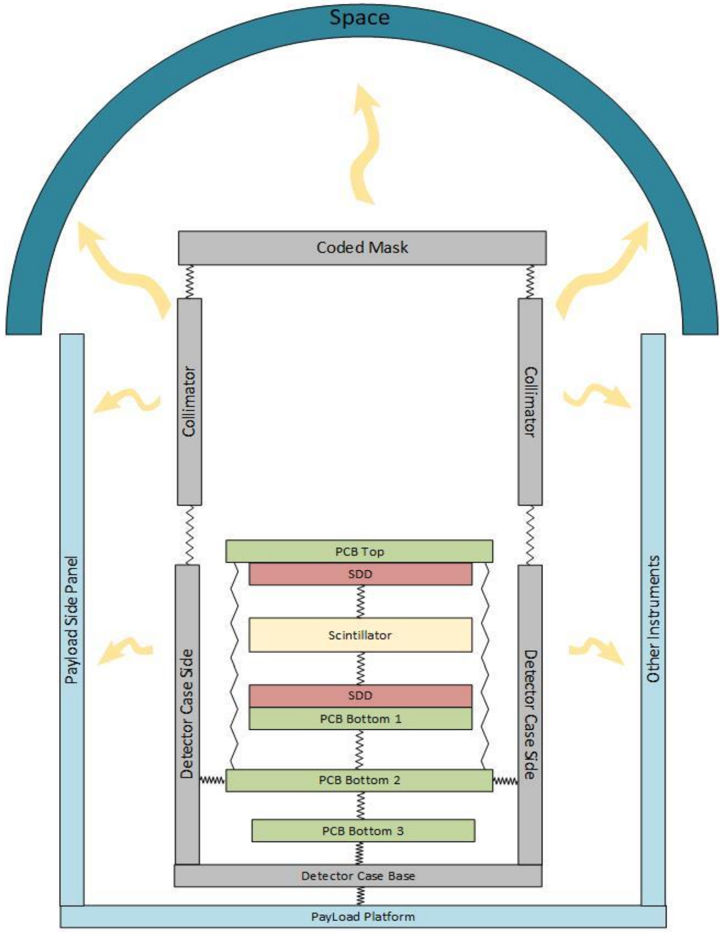


Detector plane with 3 SuperModules removed

- **10 Modules will be assembled mechanically and electrically together to form a SuperModule (SM)**
- **A Super-Module Back End Electronics board (SM-BEE) operates the common services for the modules, logics, memory ..**
- **A Camera Back End Electronics board (C-BEE) operates the common services for the SuperModules and Interfaces Power Supply and Data Handling units**

Courtesy F. Evangelisti, S. Squerzanti, M. Melchiorri (INFN-Fe)

Thermal aspects

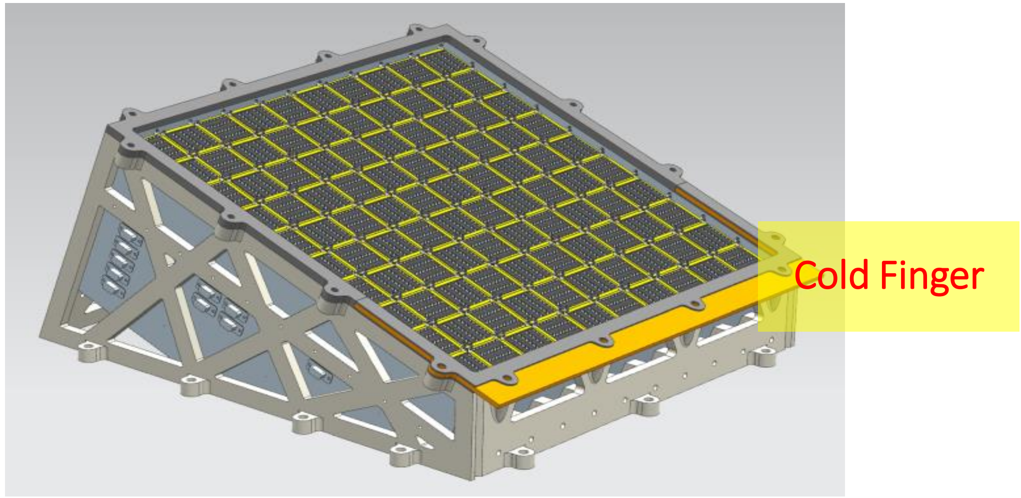


XGIS Camera thermal model

The baseline of the thermal control strategy is fully passive

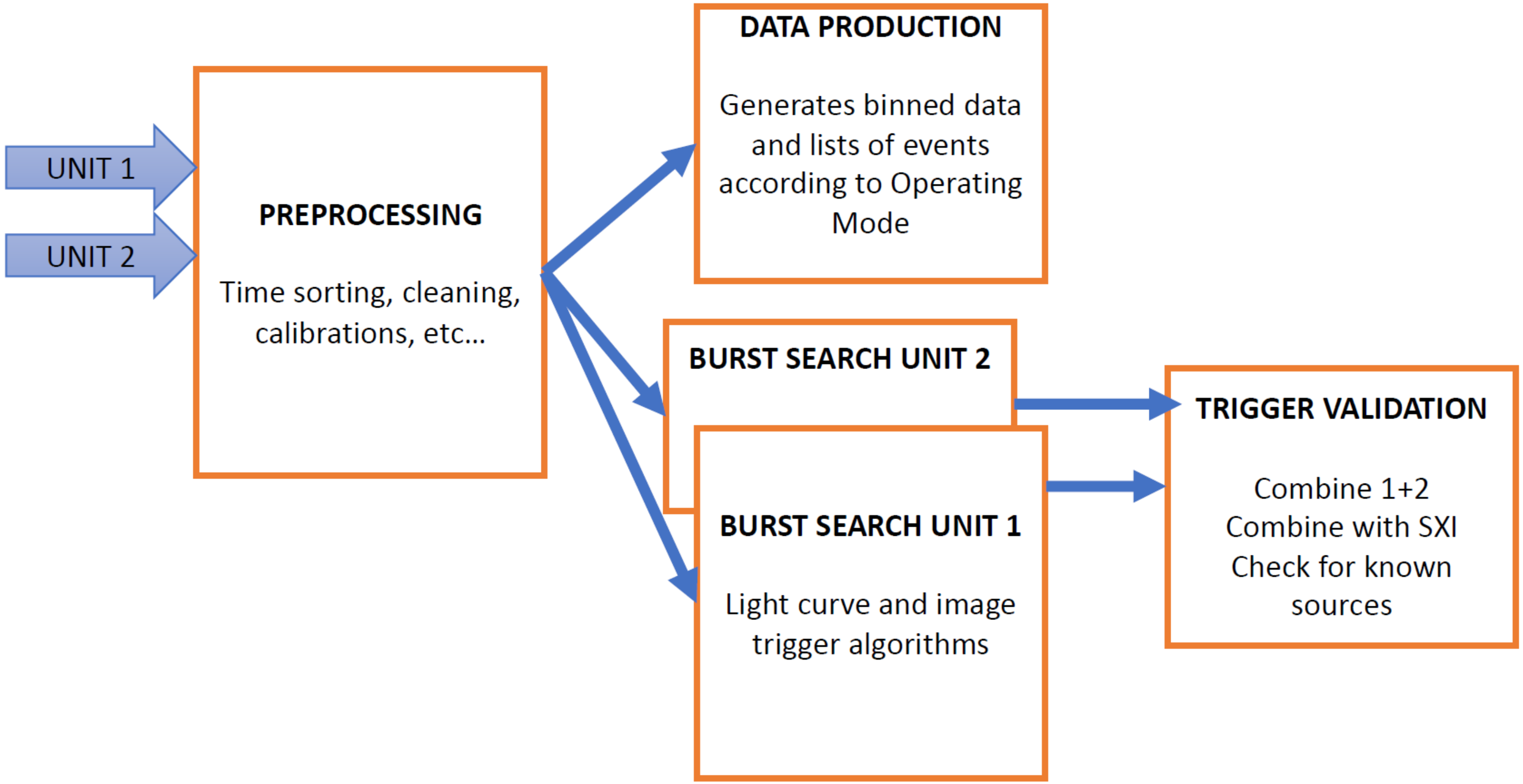
The relevant interface the Cold Finger (CF) operative range is:

-25 ÷ +5 °C



Courtesy L. Terenzi (INAF-Bo)

XGIS observation data processing flow



XGIS main DHU task during observation

DATA PRODUCTION

- **Input**
  - cleaned XGIS events
  - good triggers
- **Output**
  - standard data [event lists, histograms] produced always
  - GRB data produced in case of valid trigger
- **Function**
  - produces binned data, i.e. light curves, images, spectra in fixed (but programmable)
  - keeps a cyclic buffer of events and in case of triggers transmits pre- and post- burst data

BURST SEARCH (duplicated for the two units)

- **Input**
  - cleaned events from one XGIS unit
- **Output**
  - trigger packets containing: time, significance, E range, timescale, instrumental coordinates, etc…
  - the content of the trigger packets depends on case by case
- **Function**
  - searches for GRBs using two main methods:
    a) rate trigger
    b) image trigger

	Average	Maximum
Survey mode	40.5	40.5
Burst mode	3.5	10.5
Follow up mode	0.5	1.5
Total	44.5	52.5

Telemetry budget Gbit/day with no data compression   Average: 1 GRB/day   Max: 3 GRB/day


Thank you
esa