WPOL

Wide field camera with POLarimetry

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Scientific objectives

The WPOL wide field camera is aimed to monitor the X-ray/γ-ray sources and measure their polarimetric properties. This camera could be used to:

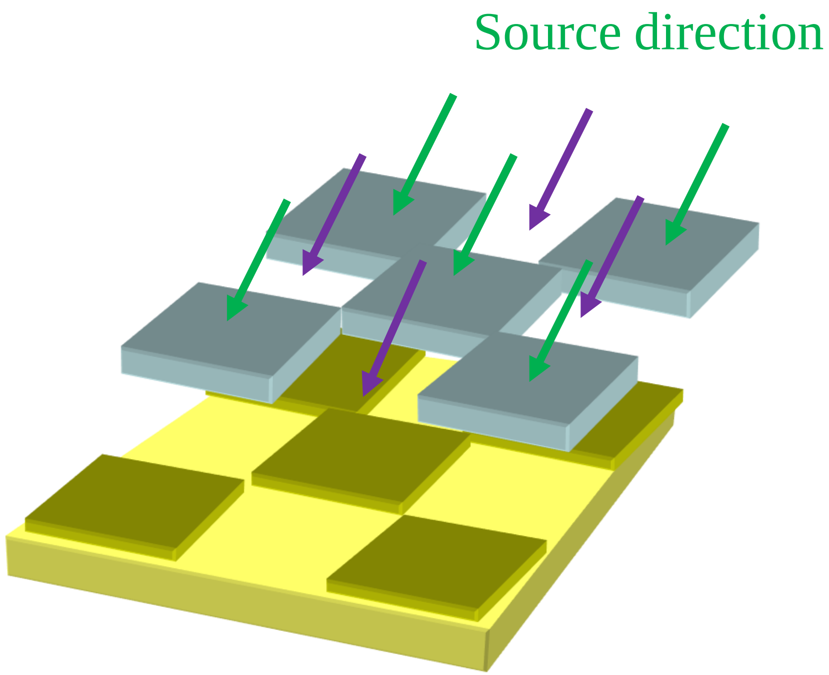
1.alert a main instrument in case of transient events (γ-ray bursts, black hole binaries state transition, supernovae, …).

2. map the X–ray/ γ-ray polarized sources in our Galaxy, which has never been done up to now.

WPOL, a coded mask Compton telescope

Imaging

In the WPOL concept, mapping and alert are done on the first plane through coded mask imaging, a technique widely used by Integral and Swift.



Shadow ⇔ source direction

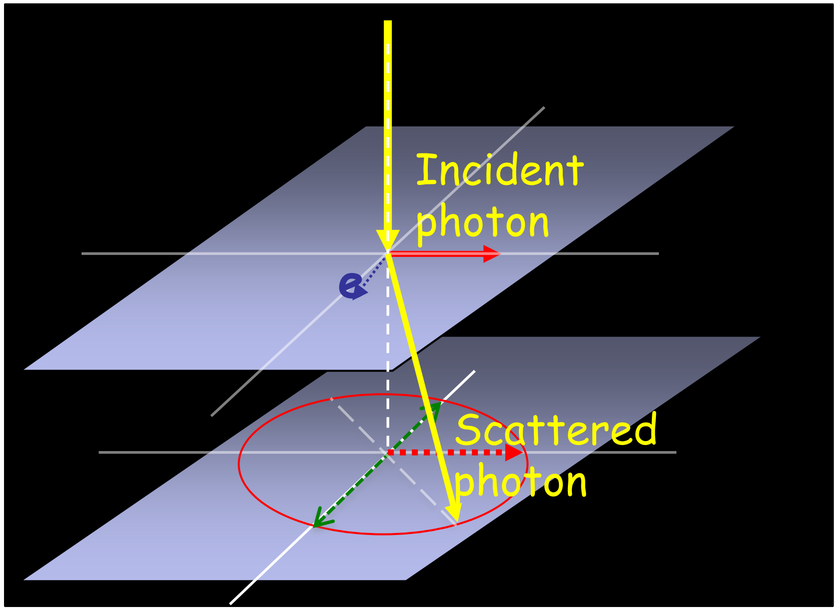
WPOL, a coded mask Compton telescope

Polarization and Spectra

Polarization is measured by studying the azimuthal distribution of Compton scattering events on the 2nd plane, and inside the mask pattern corresponding to the observed source. Also,

1. The source direction is known through the mask pattern.
2. The scattered photon direction is measured between the two planes

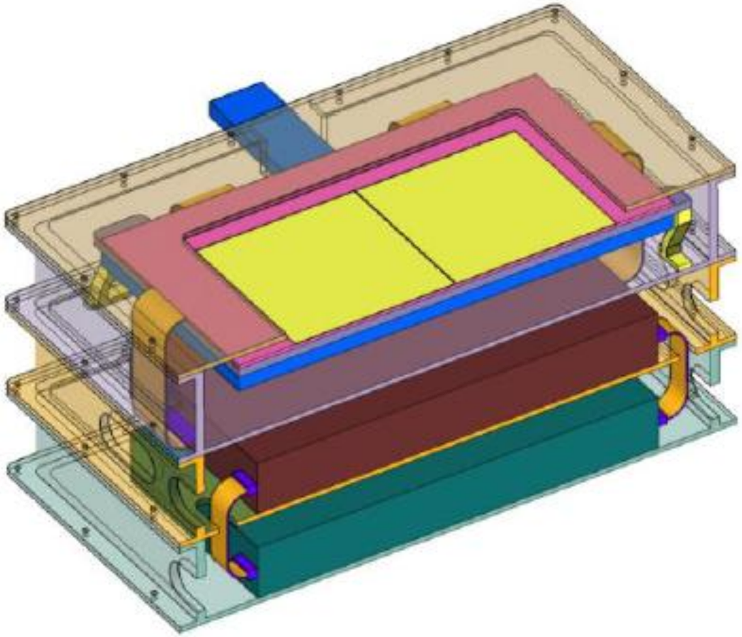
$\Rightarrow$ So, only the determination of the first energy deposit E_1 is needed to compute the whole Compton scattering kinetics and determine the source photon energy E_0.



$$\cos\theta = 1 - \frac{m_e c^2 E_1}{E_0(E_0 - E_1)}$$

WPOL Detection Unit

2 Detection layers composed of 2x2 DSSD :

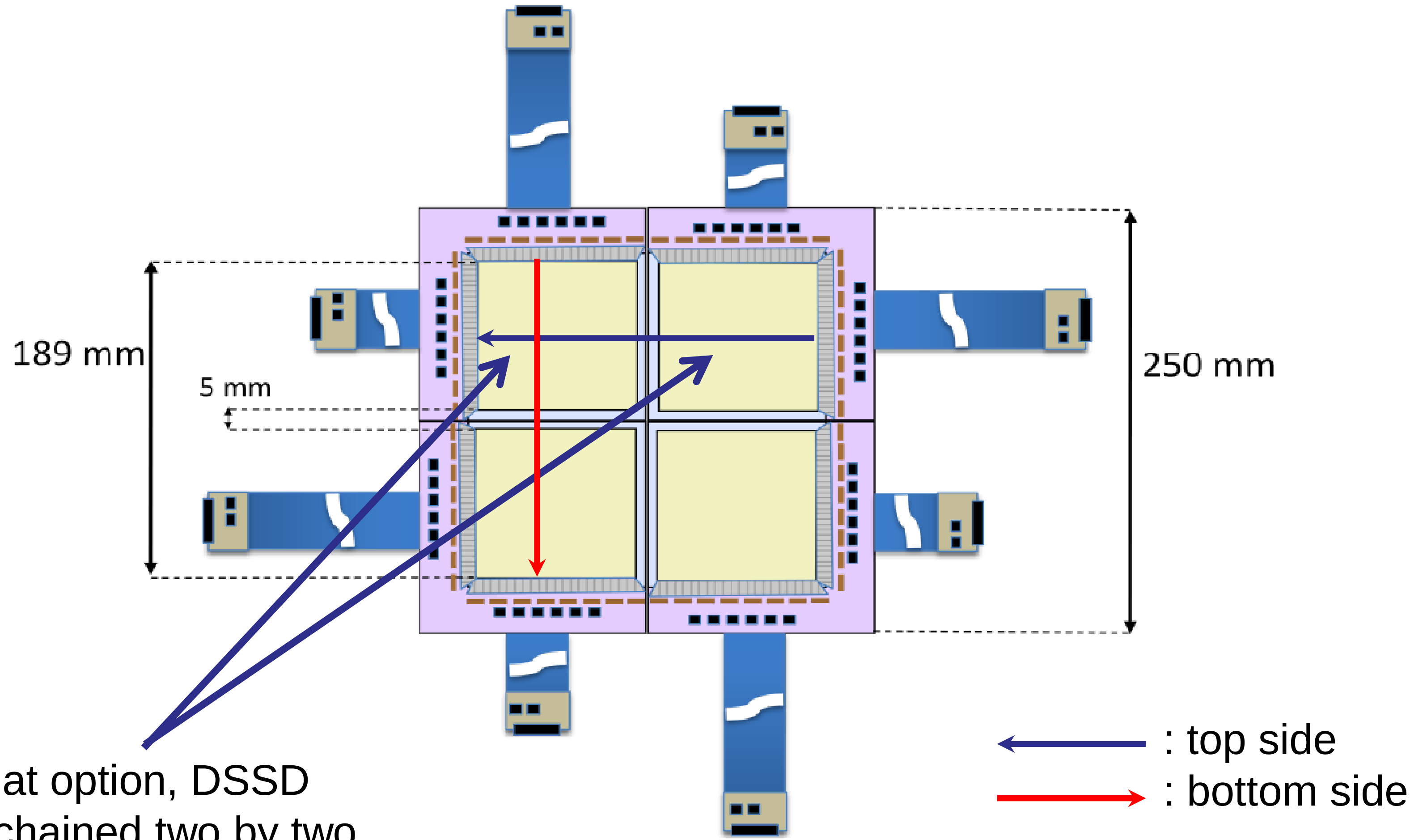


Geometric area : 357 cm2

Effective area : 82 cm2 at 10 keV

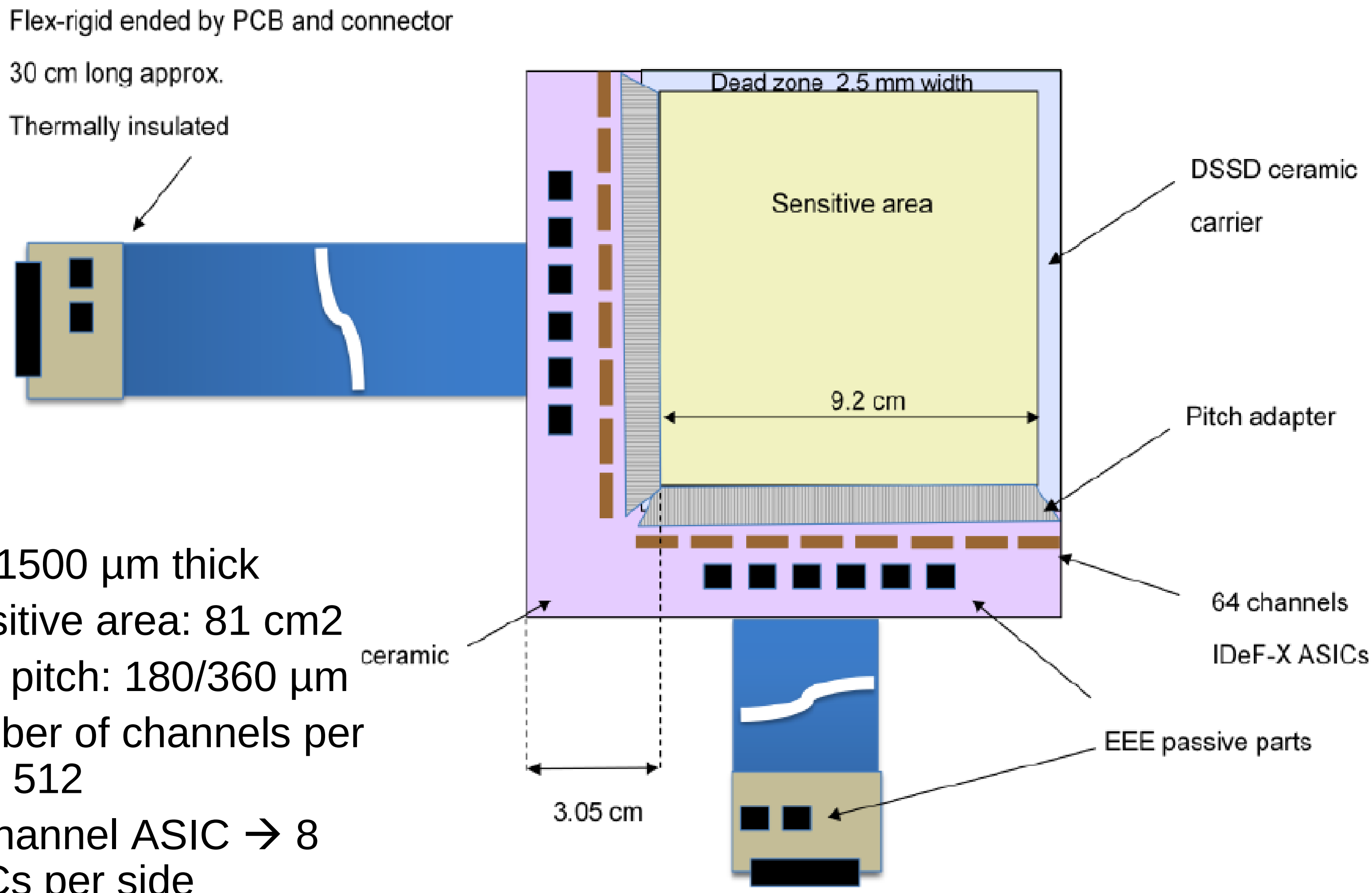
- 1st layer DSSDs :
  - 500 µm thick
  - strip pitch : 180 µm
- 2nd layer DSSDs :
  - 1500 µm thick
  - strip pitch : 360 µm

WPOL detection unit : one layer = 4 DSSD



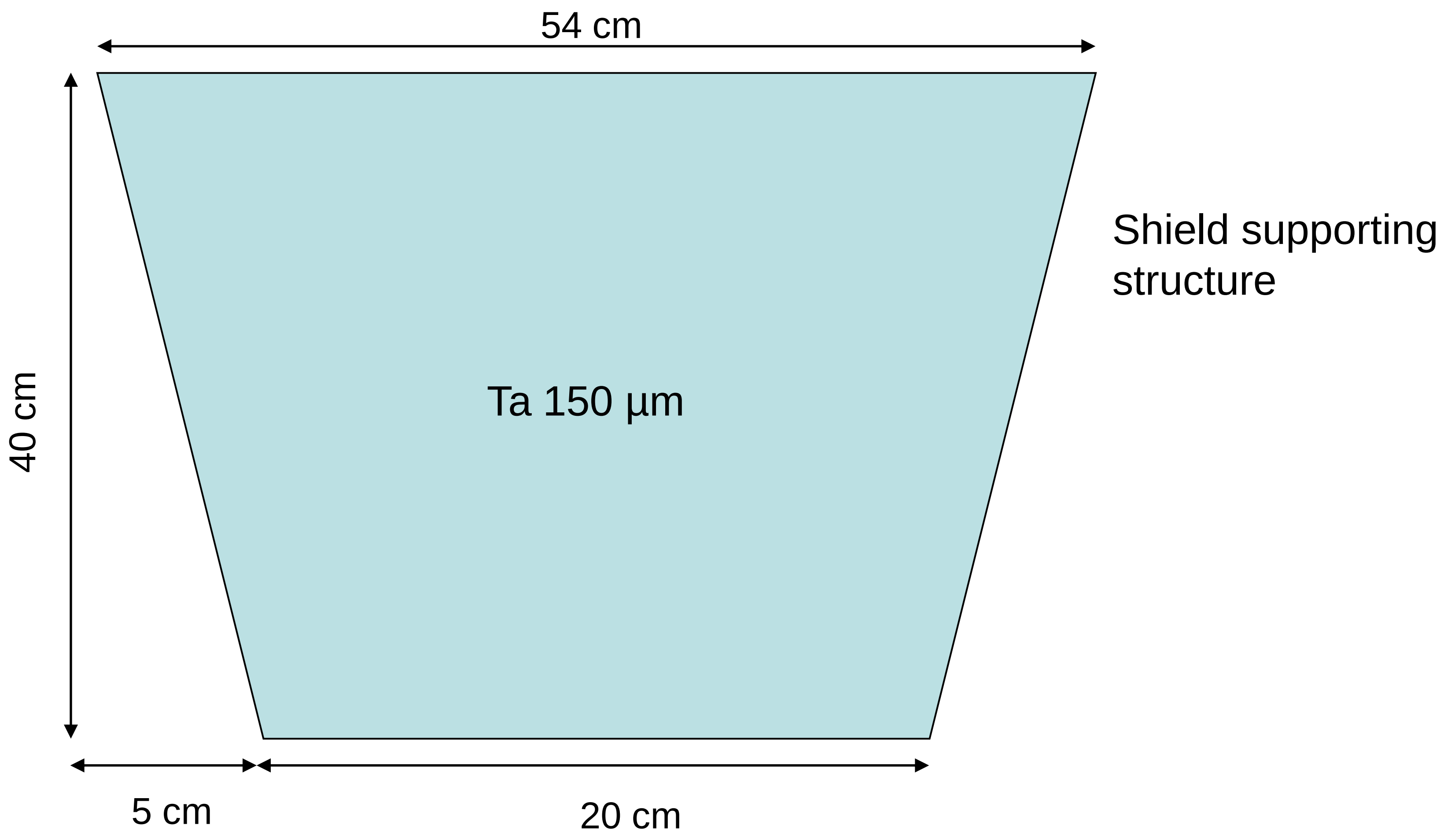
In that option, DSSD are chained two by two.

WPOL Silicon microstrip detector

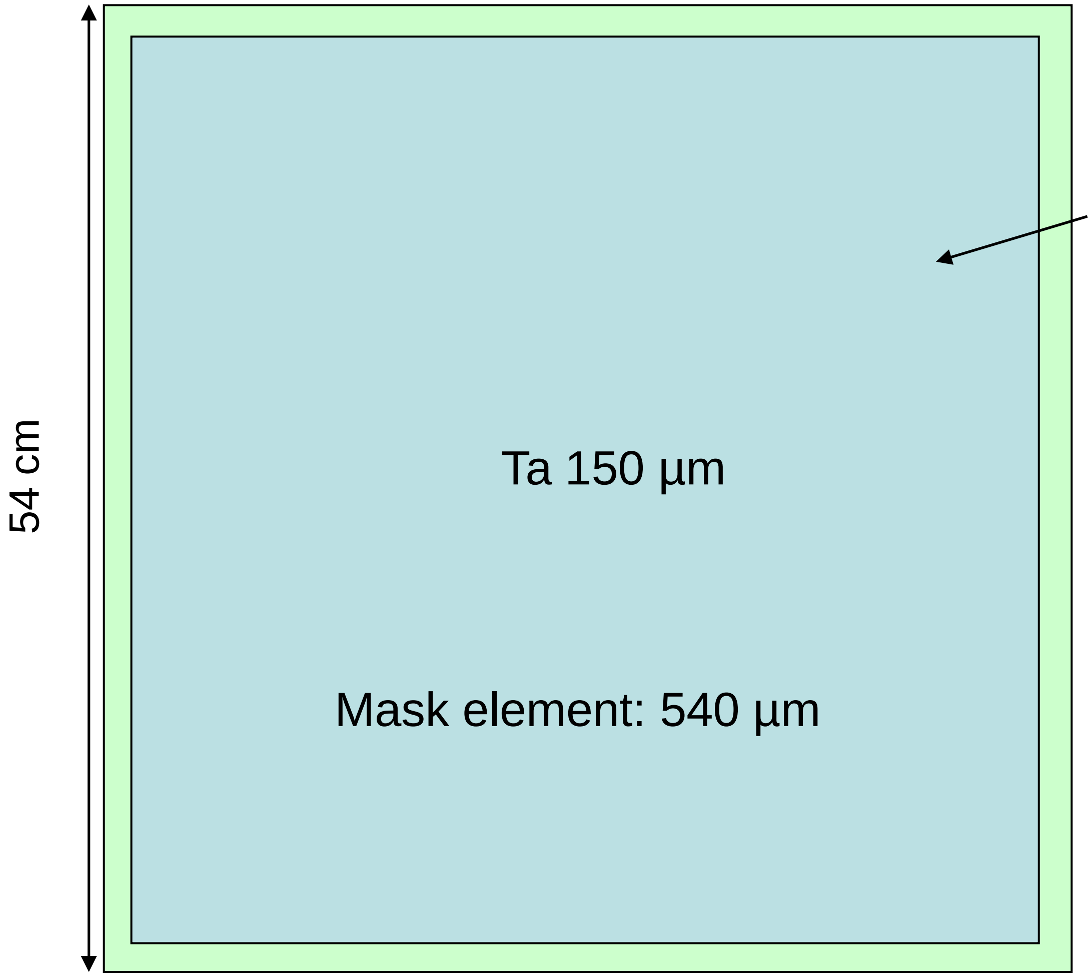


- 500/1500 µm thick
- Sensitive area: 81 cm2
- Strip pitch: 180/360 µm
- Number of channels per side: 512
- 64 channel ASIC → 8 ASICs per side

Ta Shield



WPOL mask



mask composed of Tantalum
540 x 540 x 0.150 mm
placed 400 mm above the detector unit.

Flat mask properties :

- 30% transparent
- FOV : π steradian
- angular resolution: 4'

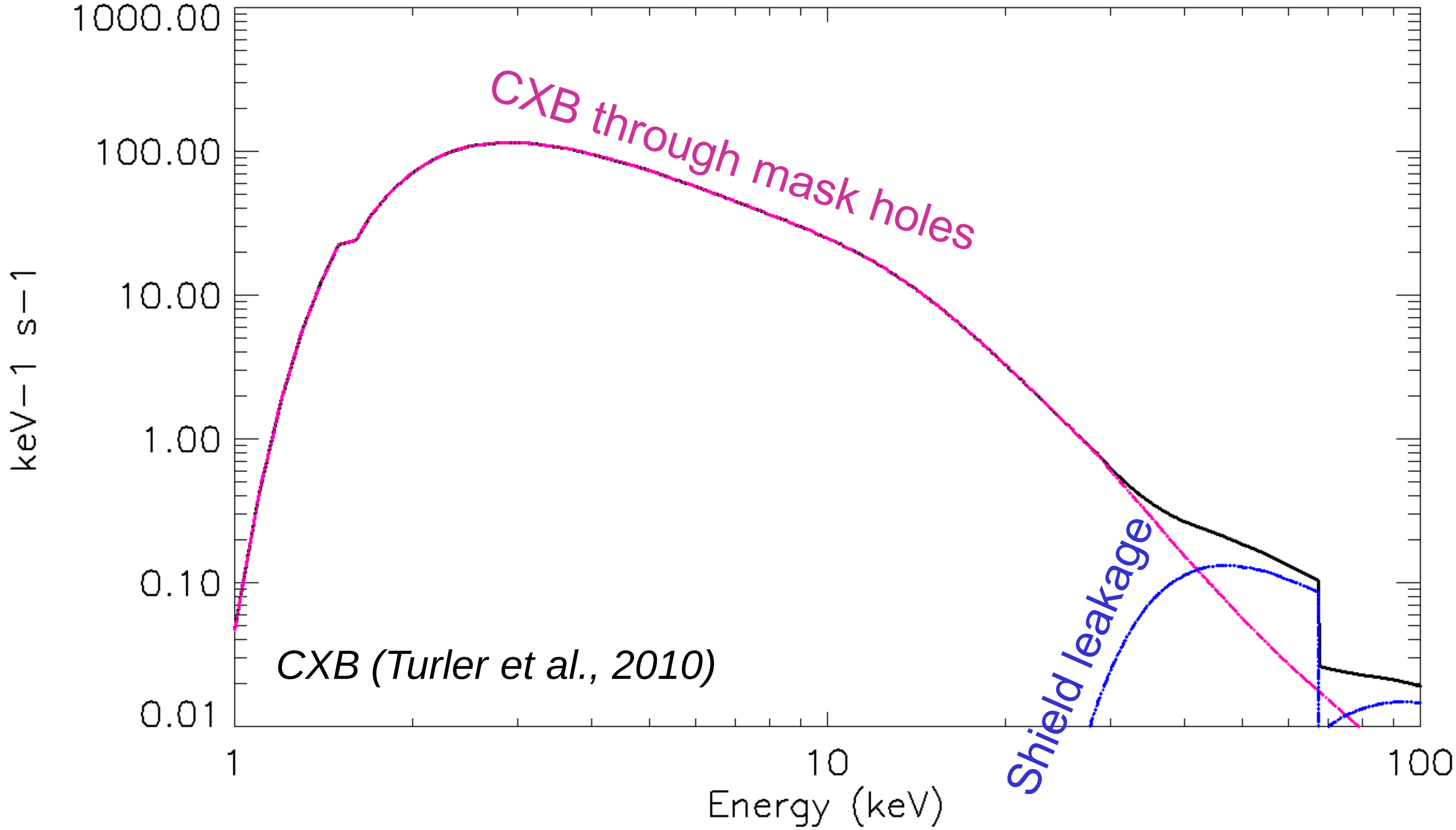
Performances

camera performances (5-200 keV)

• Energy range	:	0.005– 0.2 MeV
• Energy resolution	:	300 eV at 6 keV FWHM
• Field of view	:	60° x 60° deg. HWHM
• Angular resolution	:	0.067 (4’) deg. FWHM
• Polarization MDP	:	10 %
• (3σ, Crablike source in 10^6 s)		
• Timing resolution	:	1 ms

Background

- FOV (1 camera, 50%) ≅ π sr
- BKG ~ CXB + leakage = 650 s^{-1}



camera sensitivity (5-200 keV)

- BKG (5-200 keV) : 650 s^{-1}
- On-axis Crab (5-200 keV) : 500 s^{-1}
- Continuum sensitivity : 0.7 mCrab (0.005 – 0.05 MeV)

  (3σ in 10^6 s, $\Delta E = E/2$) 5 mCrab (0.05 – 0.2 MeV)

- Transient (GRB):
  - Sensitivity (5σ, 1 s): 98 mCrab
- 50 ks observation:
  - Sensitivity (5σ, 50 ks): 1.1 mCrab

System budgets

Camera weight (g)

Mask	650
Frame	3200
Shield	2200
Shield support	2600
DSSD	100
FEE (ASICs + PCB)	200
Detector Frame	1600
Total	**10550**
Total + 30% margin	**14000**

Power budget (W)

Front end electronics	3,5 (based on IdefiX chain)
FPGA + ADC + regulators	8,7 (based on IdefiX chain)
High Voltage	0,8
Thermal control	4
Total (one layer)	17,1
Total camera	**34,2**
Total + 30% margin	**44**

Telemetry rates

TM and on-board memory needed for one 15-Crab source in addition to background		
Mode	TM need (in kbit/s)	On-board storage need (in Gbits)
Detector Images	30	1,1
Detector Spectra	1	0,001
Detector Ratemeter	4	0,04
Event by event	160	0.8

1. “Detector Images” (2 x 1024 × 1024 pixels), taken each 256 seconds on 4 energy channels.
2. “Detector Spectra” taken each 30 s on 256 energy channels.
3. “Detector Ratemeter” giving the overall detectors count rate each 16 ms in 4 energy bands.
4. “Event by event” giving, for each event, its energy E, position (X, Y) and timing Δt.

Temperature, attitude, …

Attitude restitution	: ~ 1 arcmin
Operating temperature	: typically -20°
Alert capability (GRBs, transients)	: Yes

Higher energy range

- This is one possibility of this camera concept, based on the LOFT/WFM 2D proposal, the parameters having to be optimized according to the mission profile and allocations.

- In particular, a third calorimeter layer, possibly in CdTe, $LaBr_3$, or in SrI_2 may be added to enlarge the energy range.

- It will have the drawback to ask for more power, for ~4kg extra mass for the detector unit and possibly a new mask design.

Technology readiness

- This detector plane concept is based upon well-known technologies (DSSD, IdefX ASIC, …), and is studied in a R&D program lead by APC, AIM, IRAP, IPNO and CSNSM.
- Prototypes of these detector planes should be tested in the lab in 2014 – 2015 and also during a balloon flight in 2017 – 2018.
- The coded mask may be implemented in the same way as the SVOM/ÉCLAIR ones.

WPOL spherical mask ?

Flat mask properties :

- 30% transparent
- FOV : π steradian
- angular resolution: 4’

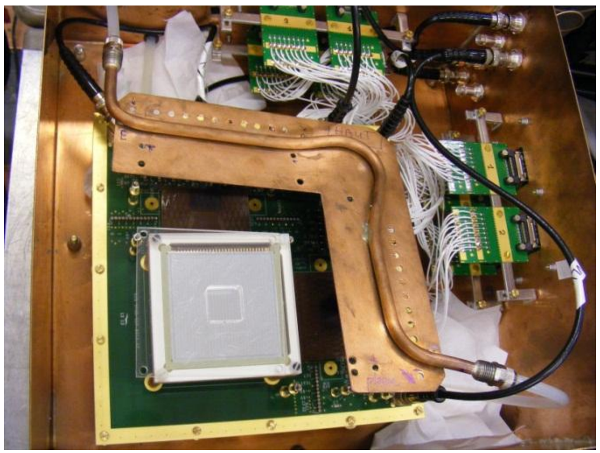
Spherical mask properties :

- 30% transparent
- FOV : 1,3π steradian
- angular resolution: 4’ but depend on off-axis angle
- mechanical support ?

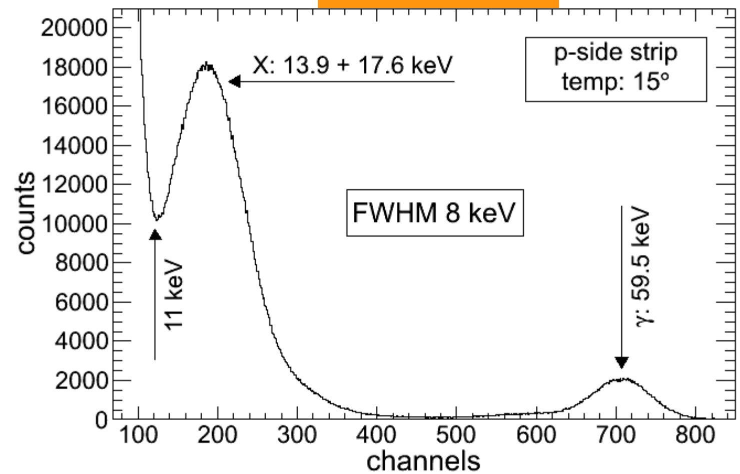
DSSSDs @ IPNO

BB7 detector (Micron Semiconductor):
- 1.5 mm thickness
- 64 x 64 mm^2
- 32 + 32 channels
- Pitch 2mm

Test bench with standard electronic



^{241}Am source



Energy resolution @ 60 keV → 8 keV (FWHM)
Energy threshold: ~ 11 keV

Ongoing: charge sharing study, temperature study,

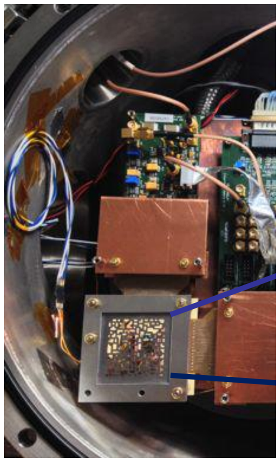
ASIC based solution: → VA32TA7 from IDEAS
- DNR = +/- 72 fC (= 1.6 MeV)
- ENC: 160 e- + 16 e-/pF → ~ 5 keV

Ongoing:
- FEE board design almost finished
- New BB7 detector ordered

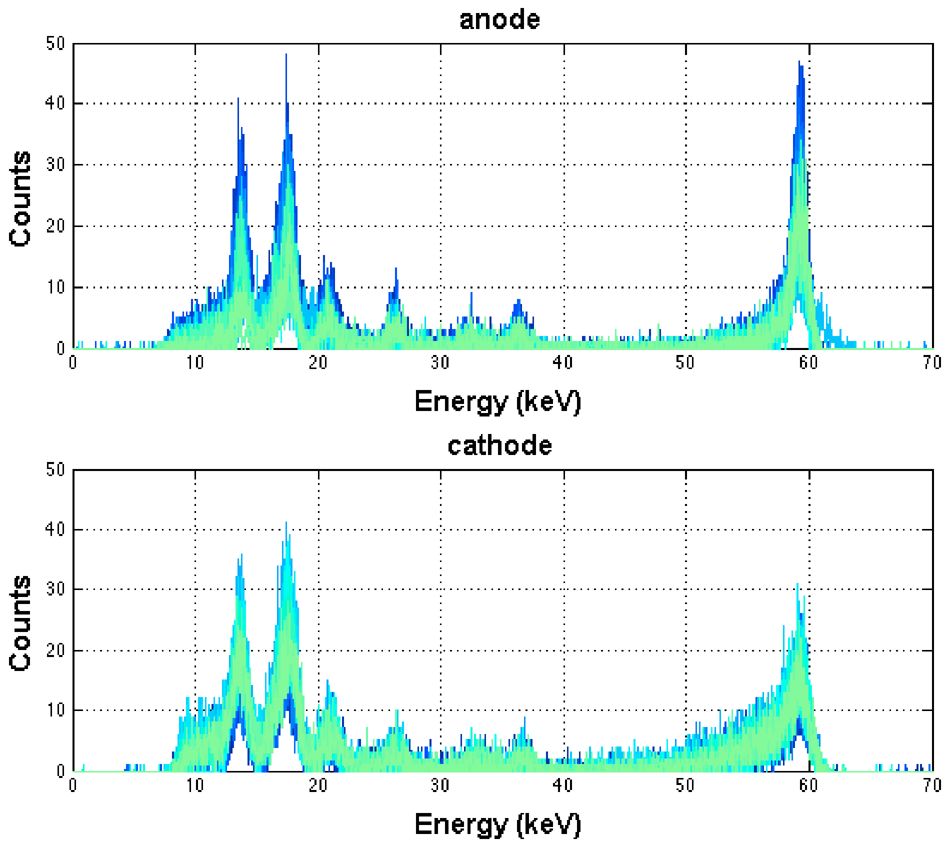
First tests with BB7 beginning of 2014

DS-CdTe development at AIM

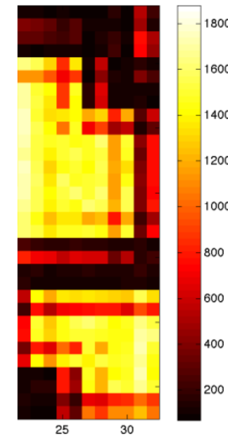
DS-CdTe development in the framework of the Astro-H project, funded by ESA. Front-end electronics may be identical to the ones foreseen for WPOL.



DS-CdTe t



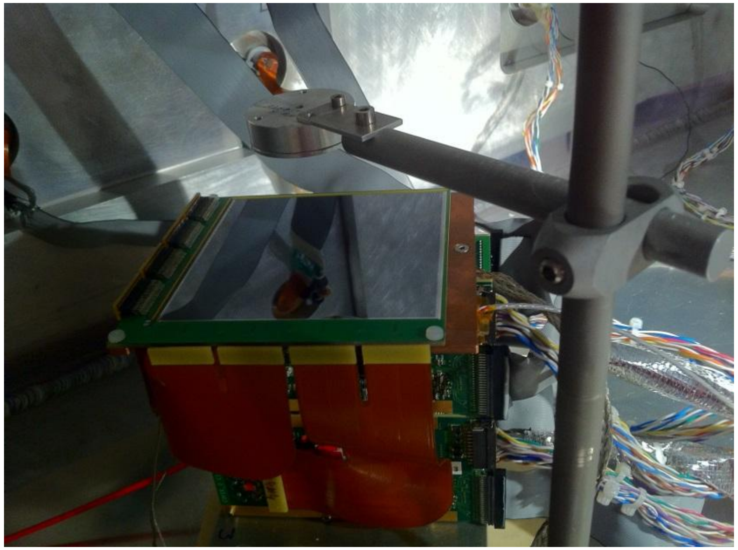
32 Ds-CdTe spectra



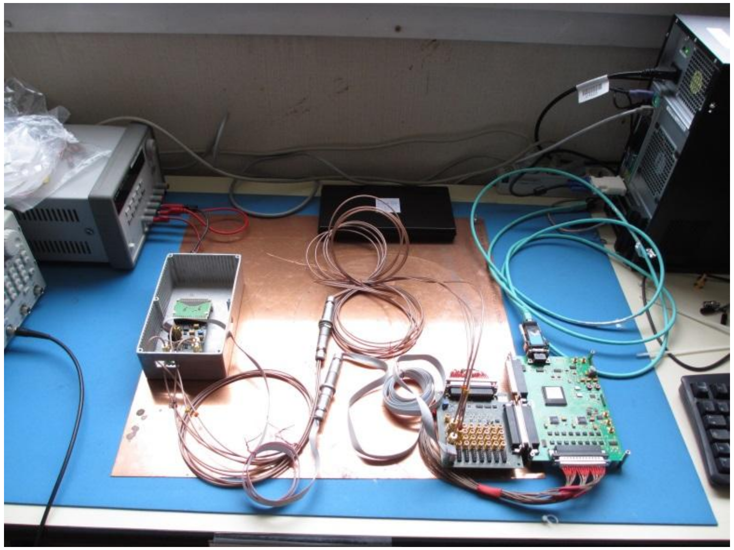
Te image

DSSD development at CEA and APC

DSSD development funded by CNES and LabeX UnivEarth. First light with IdefX chain + MUSETT DSSD (from nuclear physics): beginning of 2014. Image with the optimized DSSD from the “MIcron SemiConductor” company : end of 2014.



MUSETT DSSD



IdefX electronic chain

Thank you !