



LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia



iAstro – Space Instrumentation for Astrophysics: Summary of the group activities, 2018/19

J M Maia, R M Curado da Silva, J Escada, F P dos Santos, T H V T Dias, M Moita, A Trindade



Outline:

- POLCA
- AMEGO
- COMCUBE
- ProtonRadCdTe
- IXPE

The group goal:

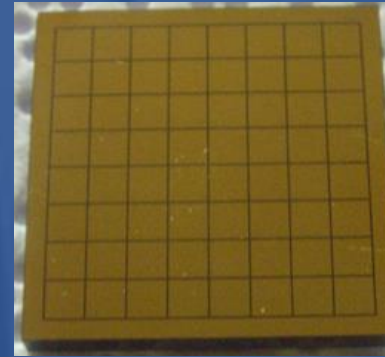
Development of
instrumentation for detection
planes of X and γ rays
telescopes

- Semiconductor detectors:
CdTe, CZT, Si
- Scintillation detectors: CsI(Tl)
- Micropattern Gas Detectors:
GEM

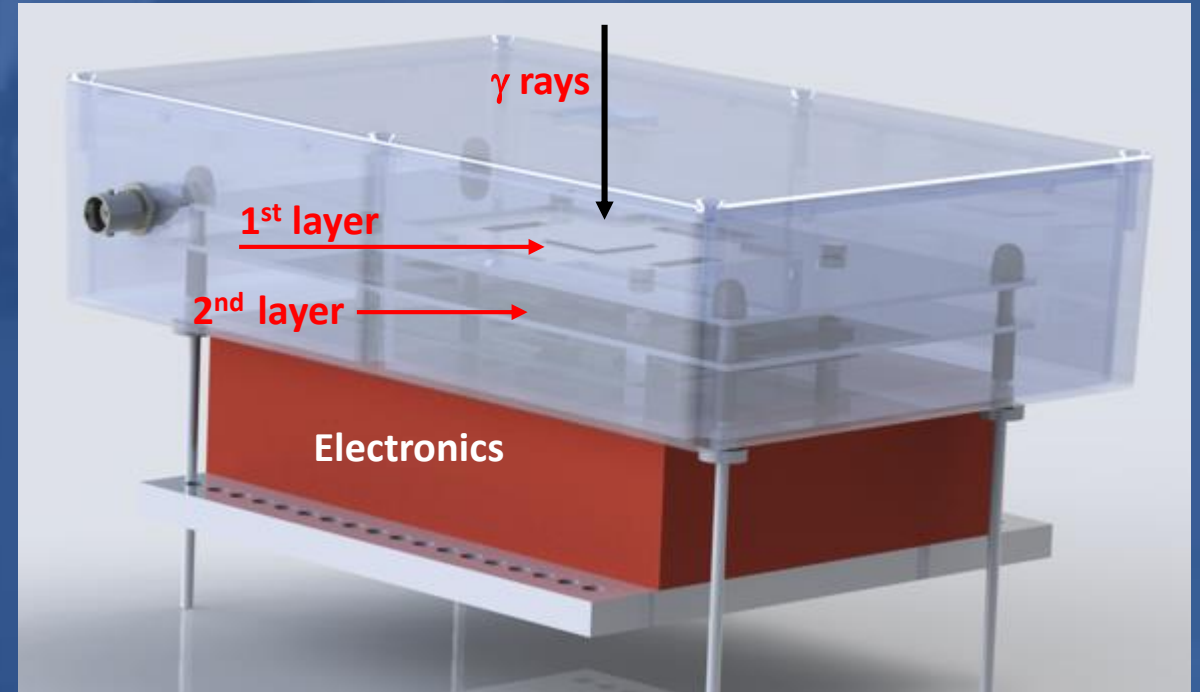
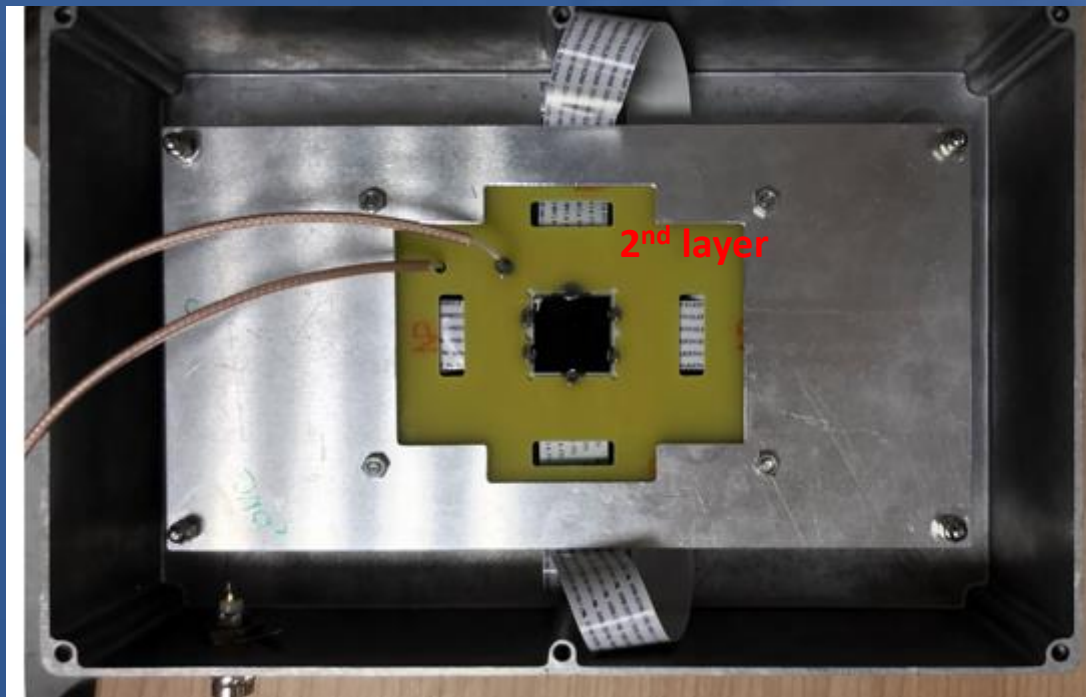
- Imaging
- Spectrometry
- Polarimetry

POLCA: POLarimetry with Cadmium Telluride Arrays

- The two layer CdTe Array – the Compton-POLCA detector
- Two pixelated CdTe arrays in cascade

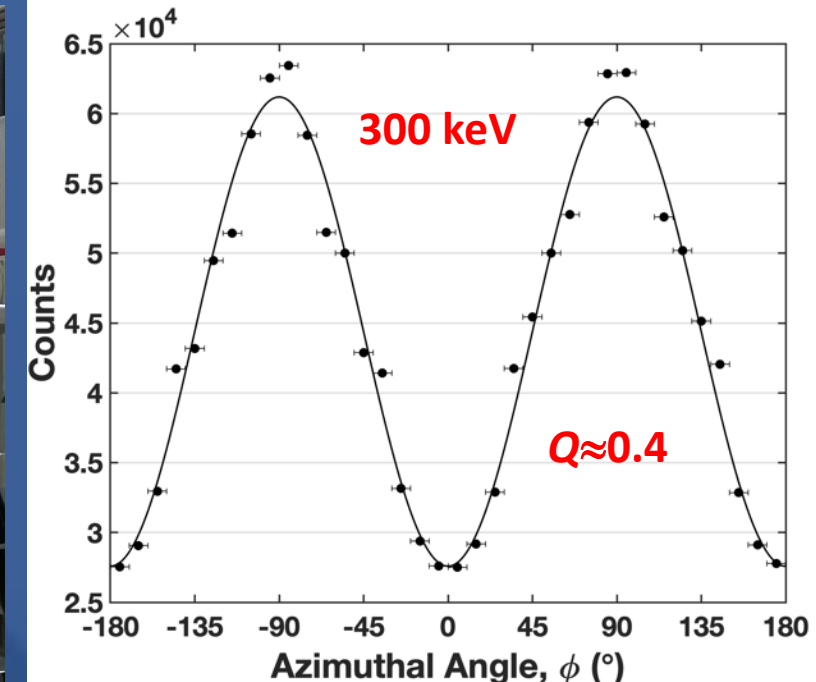
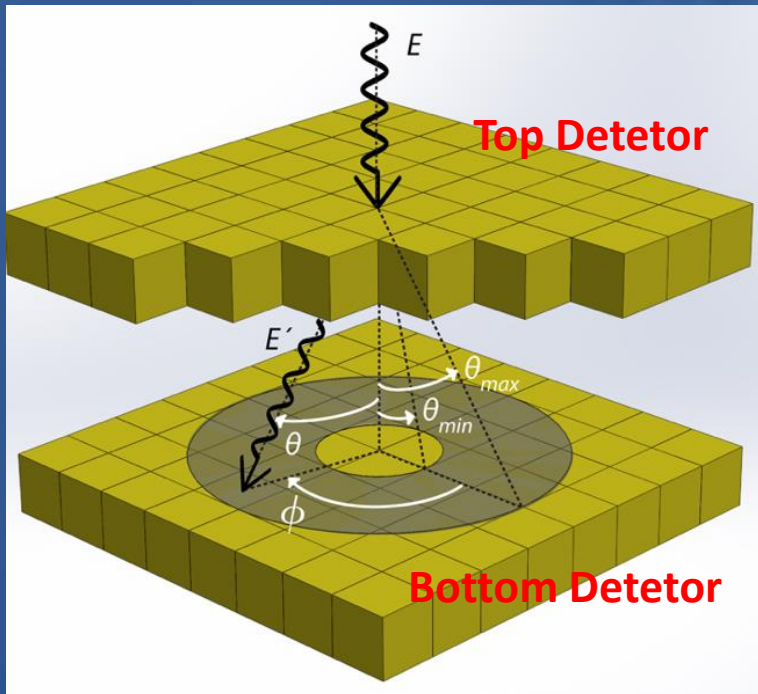


- 2.0 mm thick
- 8×8 pixels
- Pixel: 1.9×1.9 mm²
- Area: 2.56 cm²



POLCA:

- Scattering polarimetric capabilities of the Compton-POLCA detector
- Monte Carlo simulations (MEGAlib), non-polarized/polarized γ -rays 100–900 keV;
- Experimental tests, polarized γ -rays 200–500 keV (ESRF) and non-polarized 100–300 keV (LARIX);



Nucl. Instrum. Methods Phys. Res. A, vol. 918, pp. 93-98, 2019.

AMEGO: All-sky Medium Energy Gamma-ray Observatory, NASA

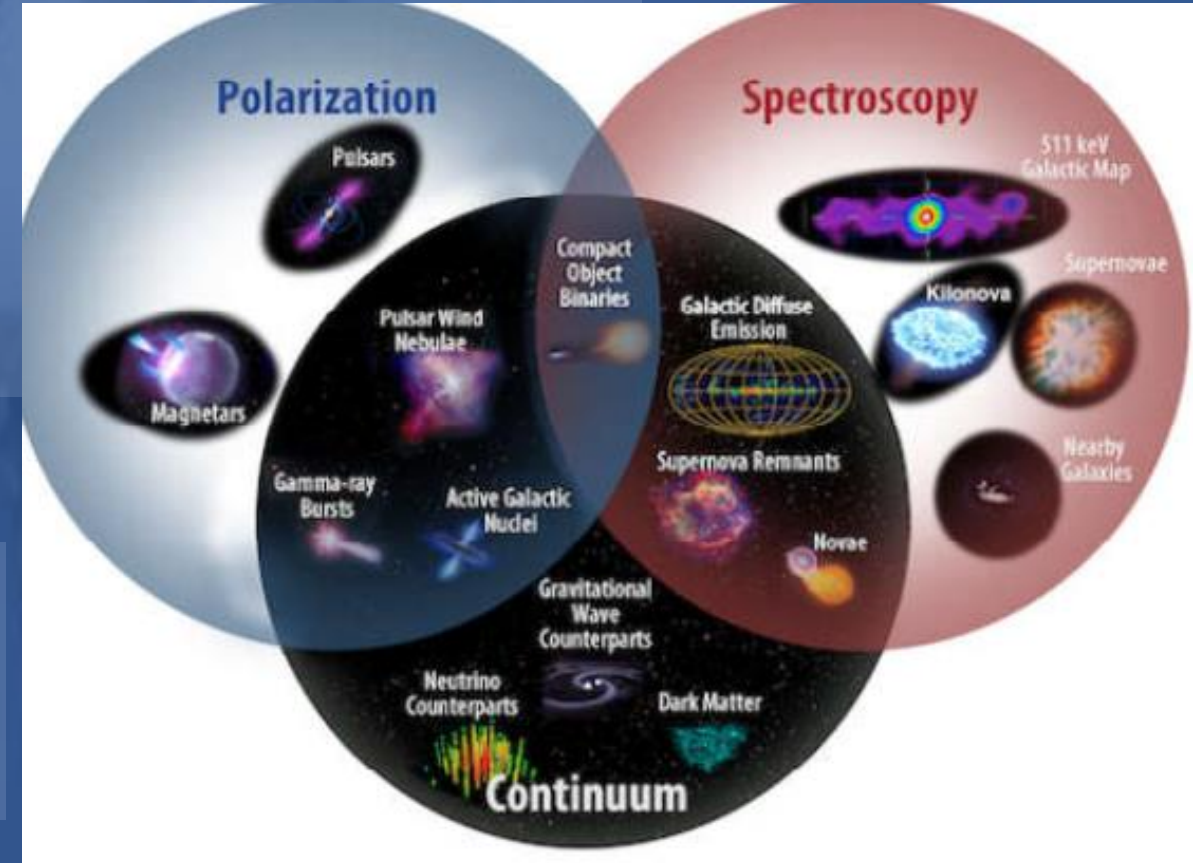
- An MeV γ -ray surveyor probe mission: MeV astrophysics

→ Continuum sensitivity within a broad energy range;

→ Polarimetric capability;

→ Nuclear line spectroscopic capability.

- Sensitivity in Compton regime: 0.2–10 MeV;
- Sensitivity in pair conversion regime: 10 MeV–10 GeV.

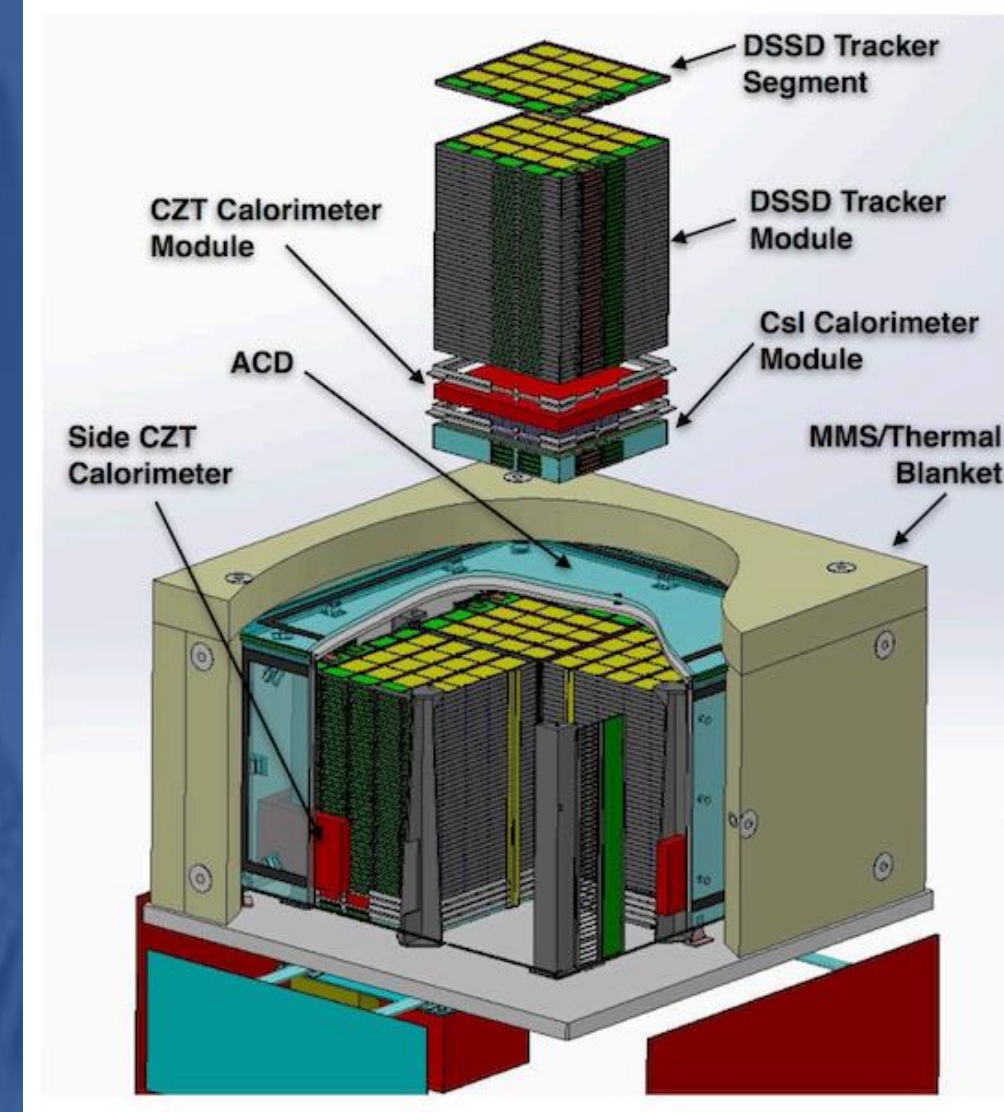


AMEGO:

- The Instrument is composed by four subsystems:
 - A Tracker: double-sided silicon detector (DSSD)
 - A 3D position-sensitive virtual Frisch-grid Imaging CZT calorimeter
 - A segmented CsI(Tl) calorimeter
 - A plastic scintillator Anti-Coincidence Detector (ACD)

Energy Range	200 keV – >10 GeV
Angular Resolution	2.5° (1 MeV), 1.5° (5 MeV), 2° (100 MeV)
Energy Resolution (σ/E)	<1% (<2 MeV), ~ 10% (1 GeV)
Field of View	2.5 sr (20% of the sky)
Line Sensitivity	1×10^{-6} ph cm ⁻² s ⁻¹ for the 1.8 MeV ²⁶ Al line in 5 years
Polarization Sensitivity	<20% MDP for a source 1% the Crab flux, observed for 10 ⁶ s
Sensitivity (MeV s ⁻¹ cm ⁻²)	2×10^{-6} (1 MeV), 1×10^{-6} (100 MeV) in 5 years

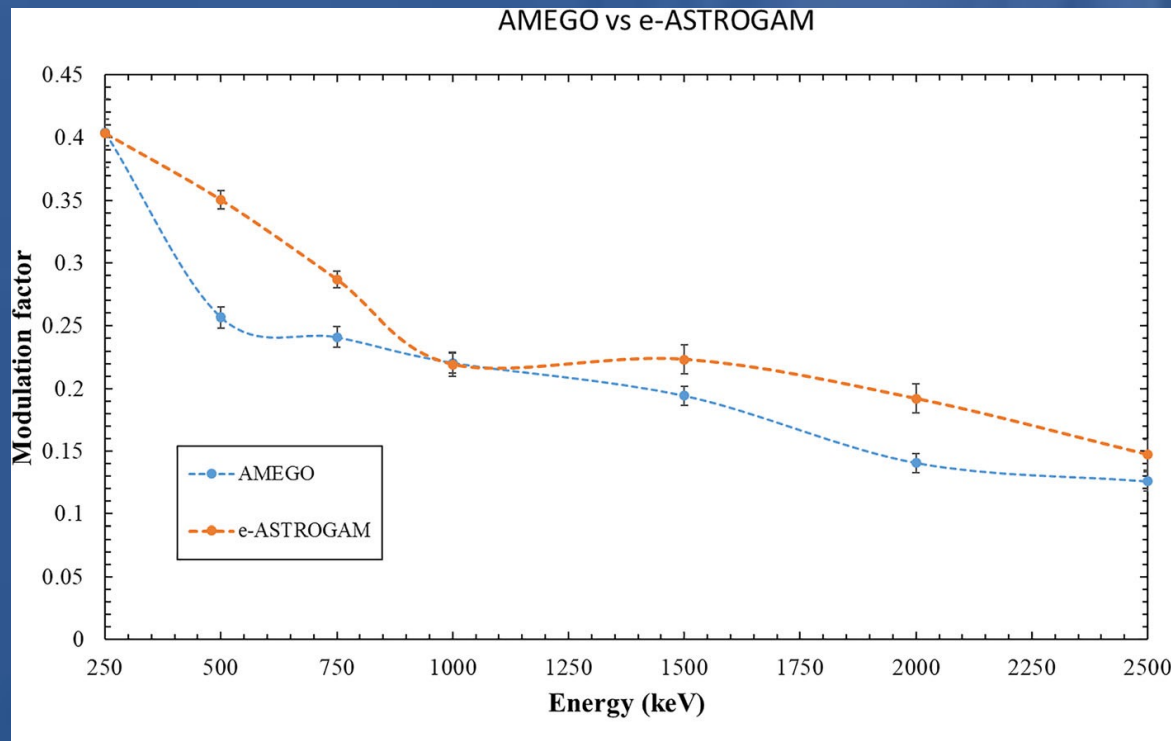
Simulations
results



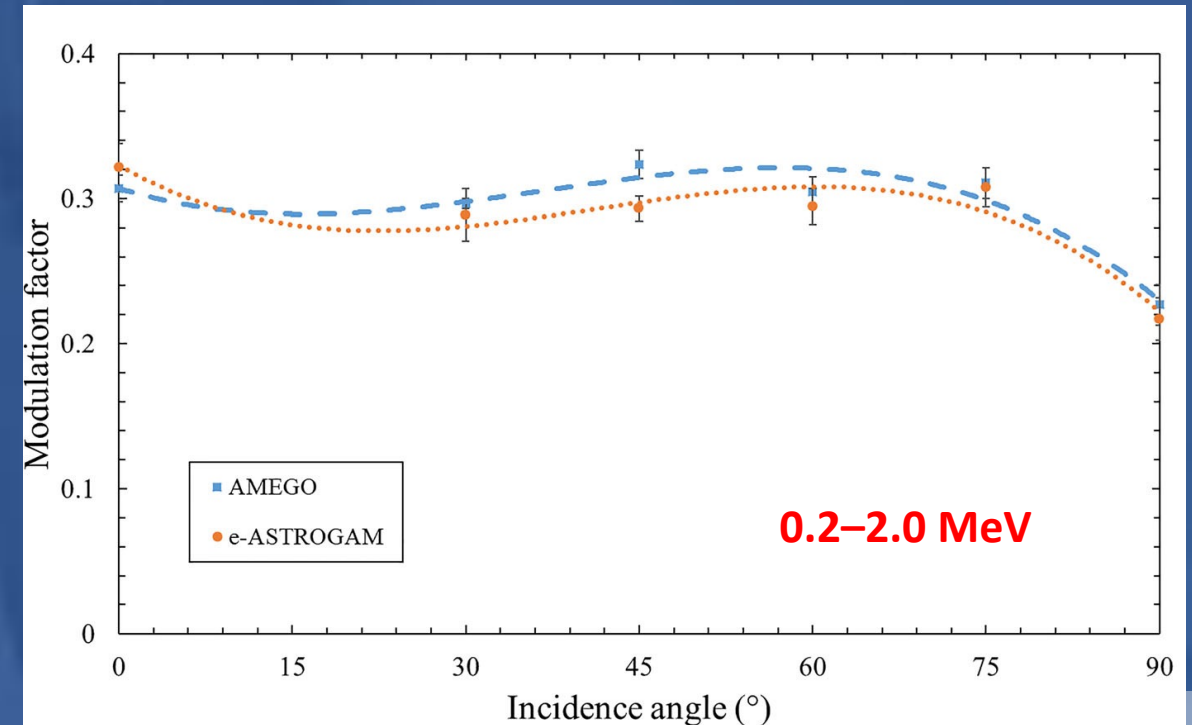
AMEGO: our contribution

- Polarimetric capabilities of AMEGO instrument by Monte Carlo simulations (MEGAlib).

100% polarized, monochromatic , far-field point sources



Exp. Astron., vol. 48, no. 1, pp. 65–76, 2019.



AMEGO: Future work

- Experimental test of a small size AMEGO prototype, in this summer, at the Duke University, NC, USA, with polarized γ -rays, 1–20 MeV range;
 - Previously, prototype calibration and prototype simulation model validation with MEGAlib.
 - Study of the polarimetric capabilities, either in Compton scattering polarimetric regime, either in pair conversion polarimetric regime.



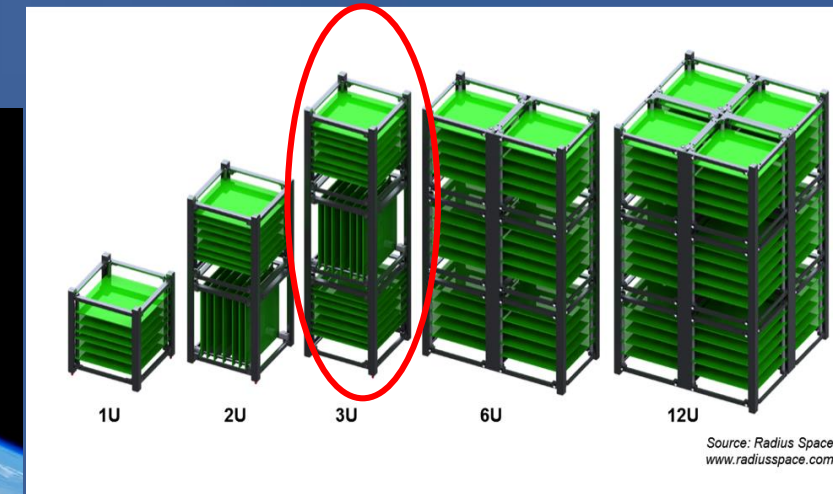
- Si Tracker: Compton scattering & Pair conversion
- CZT Calorimeter: Compton scattering & Pair conversion (If 3D)
- CSI (TI) Calorimeter: Compton scattering

COMCUBE: Compact Compton Telescope, CubeSat-compatible

- Development of a compact Compton Telescope prototype
 - Gamma Ray Bursts (GRBs) polarimetric capability, within few hundred keV;
 - Our contribution:
 - Design and mass model simulation of a prototype based on a double-sided silicon detector (DSSD) and scintillator calorimeter.



- CubeSat missions: low-cost platforms for space science missions
- Nanosatellites constellations

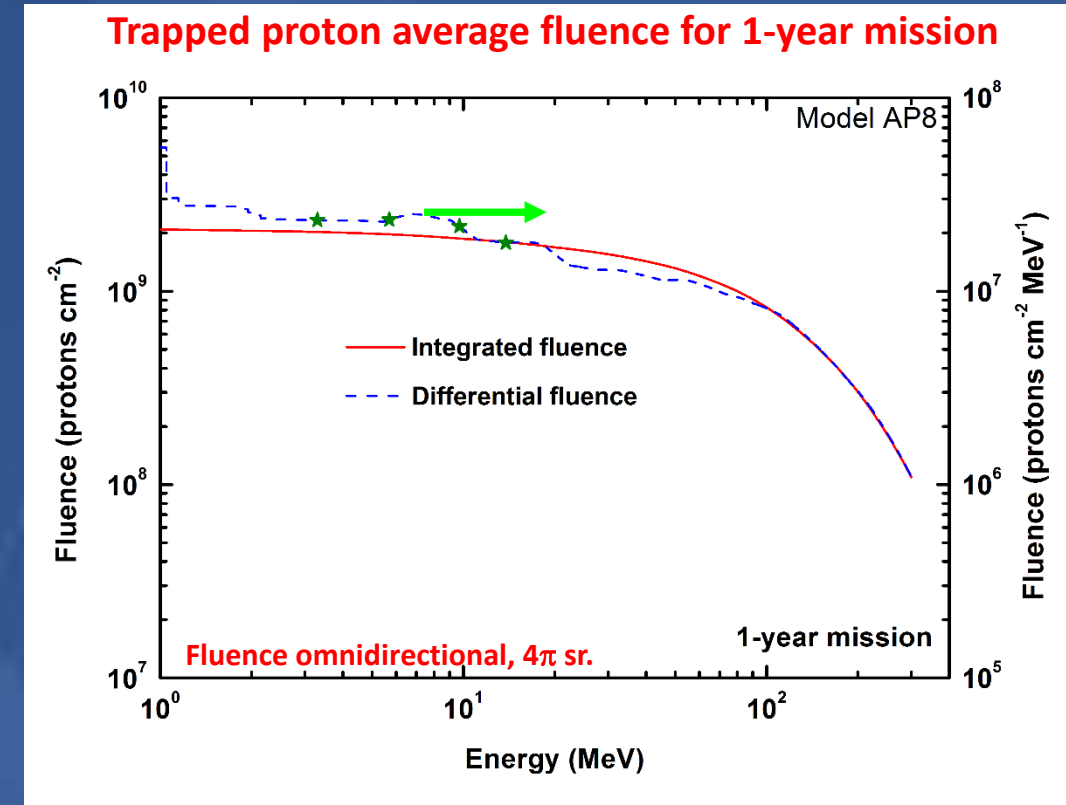
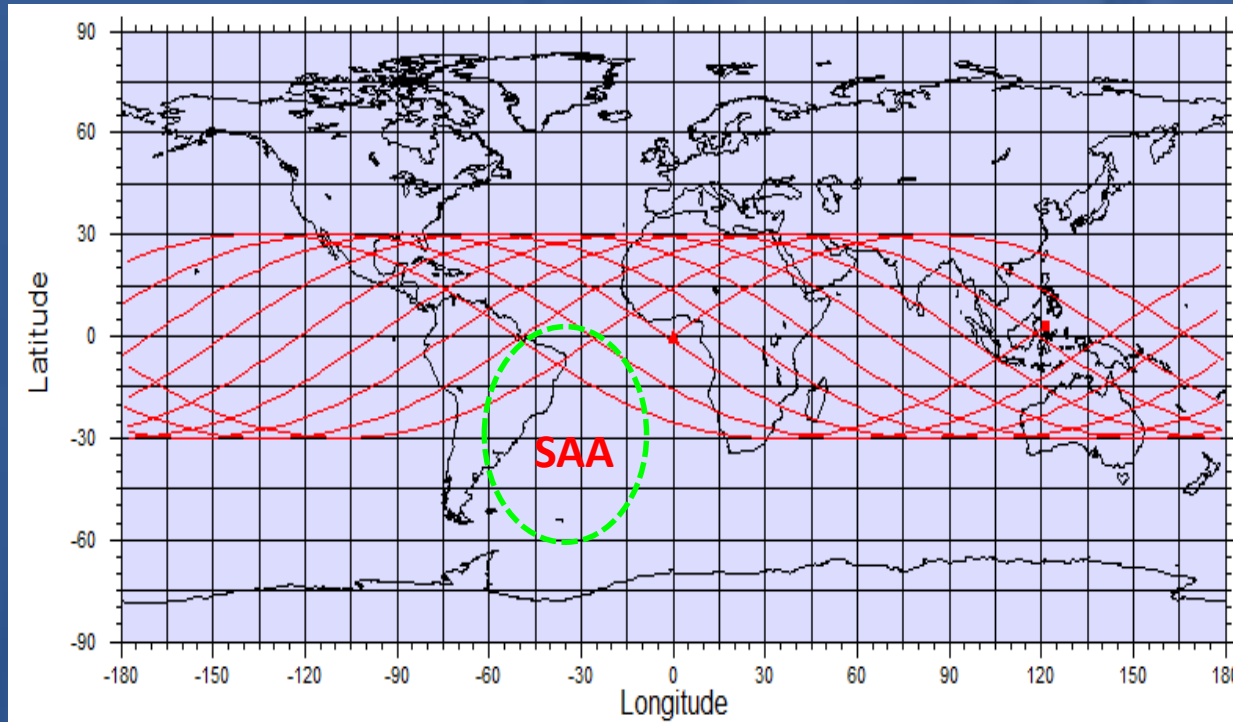


- CubeSat : standard unit $\Rightarrow$ 1U
- Size : $10 \times 10 \times 10 \text{ cm}^3$
- Weight : 1kg
- Power : $\sim 1.3 \text{ W}$

ProtonRadCdTe—Protons Radiation Hardness in CdTe Detectors for Space Instrumentation

- Characterize the effects of Low-Earth Orbit (LEO) proton radiation environment on CdTe based instrument:
 - The damage effects on the CdTe crystals $\Rightarrow$ deterioration of the detectors performance;
 - The nuclear activation in CdTe material $\Rightarrow$ γ -ray background noise in detectors.

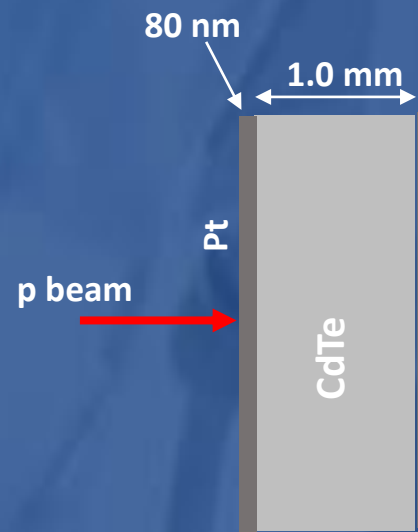
LEO: 550-km altitude , 30° inclination, $\approx$ 96-min period.



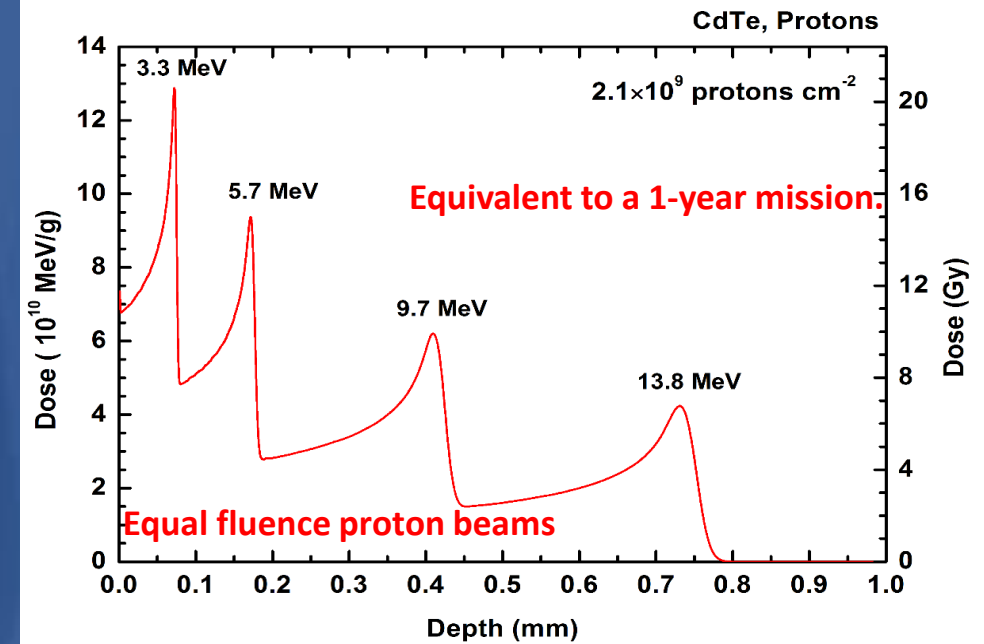
SAA: South Atlantic Anomaly

ProtonRadCdTe

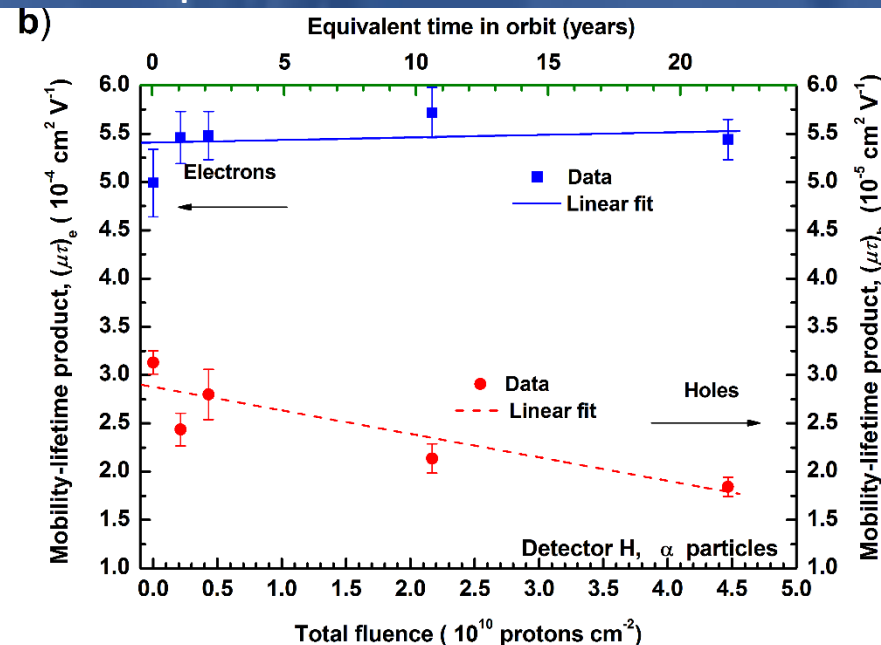
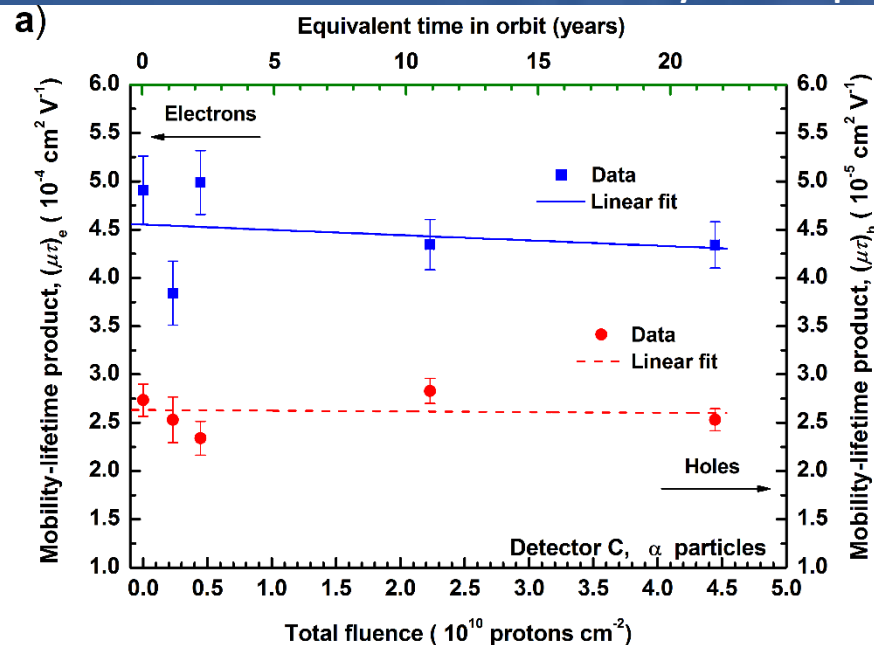
- Dose deposited in CdTe by low MeV range proton radiation field:
 - 3.3, 5.7, 9.7, 13.8 MeV
- Results for $(\mu\tau)_e$ and $(\mu\tau)_h$ proton fluence sensitivity



Total dose deposited along with the CdTe crystal's depth



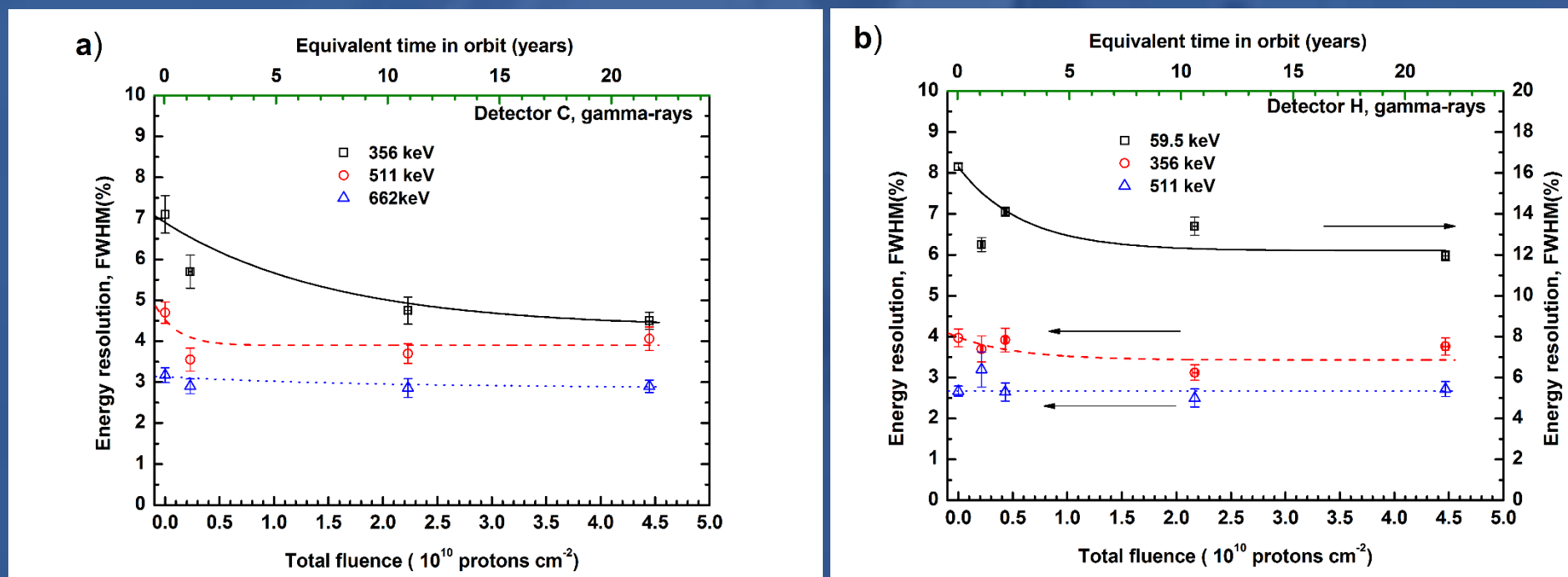
Estimated values for electron and hole mobility-lifetime products versus the proton total fluence



- Detector C: 5.0×3.0×1.0 mm³;
- Detector H: 5.0×2.0×1.0 mm³;
- Overall variation <10%, except for holes in detector H, ≈40%.

- Results for energy resolution proton fluence sensitivity

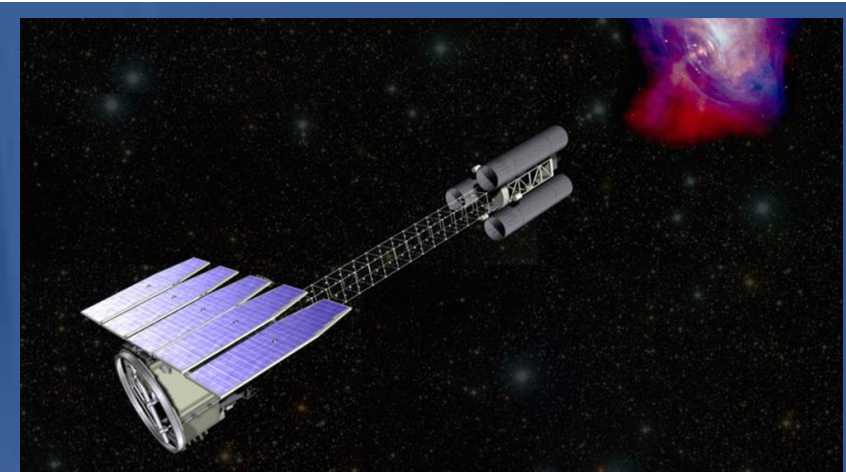
Energy resolution versus the total proton fluence for several γ -ray lines with the CdTe detectors



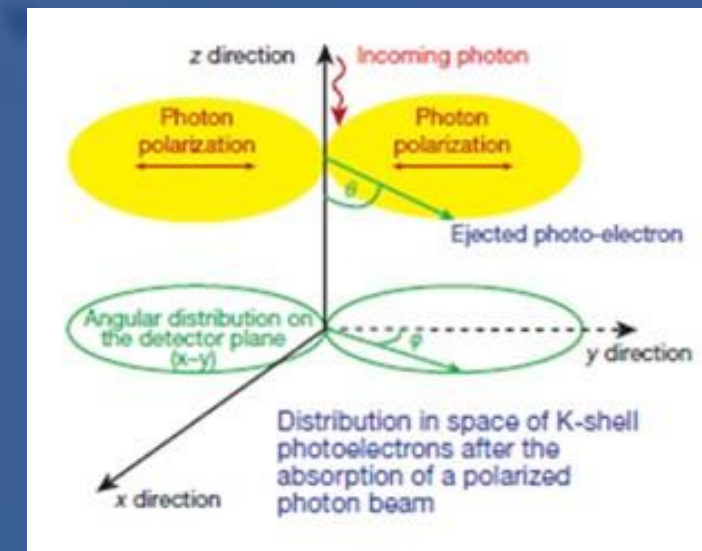
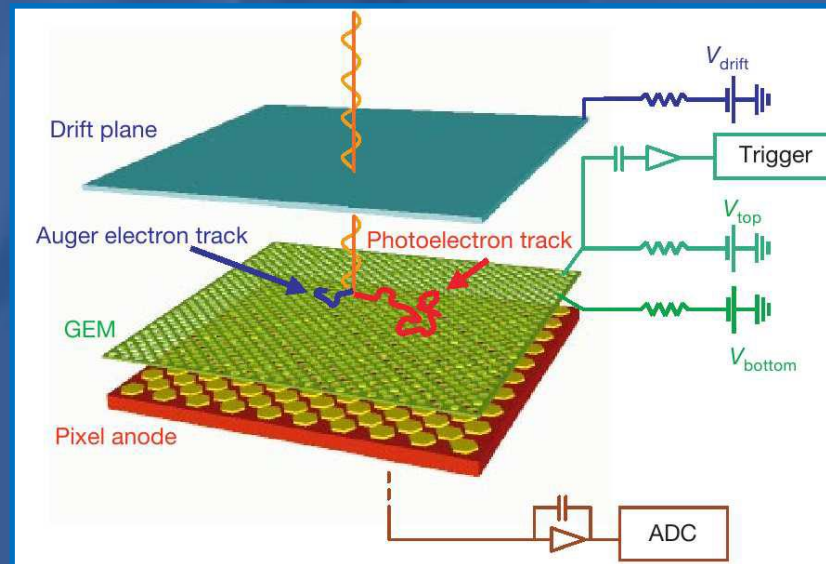
IEEE Trans. Nucl. Sci., vol. 66, no. 9, pp. 2063–2071, 2019.

IXPE—Imaging X-ray Polarimetry Explorer

- A NASA Mission to explore the hidden details of some of the most extreme and exotic astronomical objects:
 - Polarimetric capability for X-rays within 2–8 keV range.
- 1st space polarimeter in photoelectric regime



- The main instrument is composed by two subsystems:
 - Focusing optics
 - Gas pixel detector: GEM + multi-anode readout



IXPE: Some results

- Study the sensitivity of several gaseous media to the X-rays polarization

→ By custom-made Monte-Carlo simulation model

- Incidence $\perp$ XY plane
- Polarization $\parallel$ X-axis

