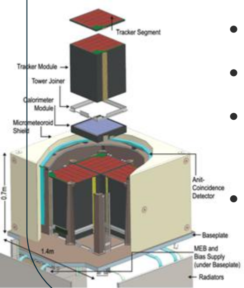
# Development of the AstroPix HV-CMOS active pixel sensor for AMEGO-X

Yasushi Fukazawa, Yusuke Suda, Norito Nakano, Abhradeep Roy (Hiroshima University) Regina Caputo, Daniel Violette, Adrien Laviron (NASA/GSFC), Nicolas Striebig (Karlsruhe Institute of Technology), Manoj Jadhav, Carolyn Kierans (NASA¥GSFC), Richard Leys (Karlsruhe Institute of Technology ), Bobae Kim, Manoj Jadhav, Jessica Metcalfe (Argonne National Laboratory),Ivan Peric (Karlsruhe Institute of Technology), Jeremy Perkins (NASA/GSFC), Hiroyasu Tajima (Nagoya University), and the AstroPix team

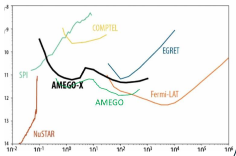
## AMEGO-X

AMEGO-X (PI: R.Caputo GSFC/NASA) is a proposed explorer to study extreme astrophysical phenomena in MeV regime





- Shed light on not-well-studied energy regime (25 keV - 1 GeV)
- Huge impact on multi-messenger astronomy thanks to its wide FoV (2π @ E < 10 MeV)
- Require a lot of low-noise pixelated silicon sensors (~2.4×10$^5$ cm$^2$) with a wide depletion layer to efficiently preform Compton reconstruction
- Power consumption of silicon sensors must be < 1 mW/cm$^2$




→ AstroPix

R. Caputo+ 2022

## AstroPix

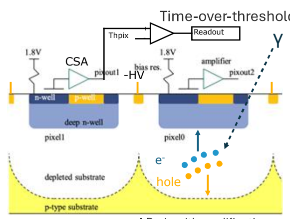
AstroPix is a new monolithic HV-CMOS active pixel sensor

Full depletion could be achieved by applying HV

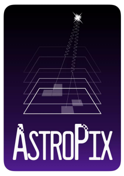
Signal processing (CSA → Comparator for Time-over-threshold) is performed on pixel and digitization is done on chip

Development based on experience from ATLASPix and MuPix

I.Peric&N.Berger 2018

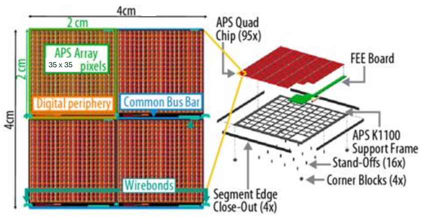



I.Peric with modifications




- AstroPix Team
  - PI: R. Caputo (GSFC/NASA)
  - GSFC, ANL, KIT, UCSC, Hiroshima U, Nagoya U

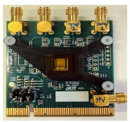
**Quad Chip** = 4 identical AstroPix array



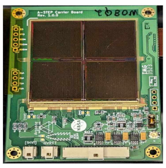

Requirements

| | | | |
|---|---|---|---|
| Pixel pitch | 500 × 500 $\mu m^2$ | Dynamic range | 25 keV - 700 keV |
| Thichness | 500 $\mu m$ | Energy resolution | < 10% (FWHM) at 60 keV |
| Power consumption | < 1 mW/cm$^2$ | | |

## AstroPix Series

| V1 2021 | V2 2022 | V3 2023 | V4 2024 |
|---|---|---|---|
|  |  |  |  |

Quad Chip 2023

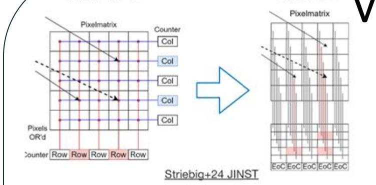


AstroPix5 will be delivered. 2025

| V1 | V2 | V3 | V4 |
|---|---|---|---|
| 0.5 x 0.5 cm$^2$ chip | 1 x 1 cm$^2$ chip | 2 x 2 cm$^2$ chip | 1 x 1 cm$^2$ chip |
| 175 x 175 μm$^2$ pitch | 250 x 250 μm$^2$ pitch | 500 x 500 μm$^2$ pitch | 500 x 500 μm$^2$ pitch |
| 18 x 18 pixels | 35 x 35 pixels | 35 x 35 pixels | 16 x 13 pixels |
| *14.7 mW/cm$^2$ | *3.4 mW/cm$^2$ | *1.04 mW/cm$^2$ 4.12 mW/cm$^2$ (incl. digital) | *1.04 mW/cm$^2$ 1.5 mW/cm$^2$ (Target) |

*CSA+comparator only.

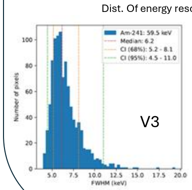
## V4 Evaluation

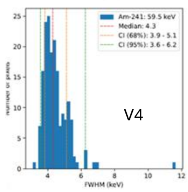



Striebig+24 JINST

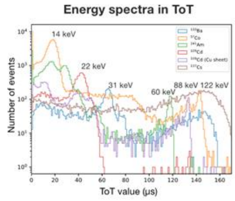
Reduce input-capacitanve by optimizing the routing and minimizing the metal-to-n-well capacitance → Better energy resolution

Dist. Of energy resolution for 59.5 keV (241-Am)

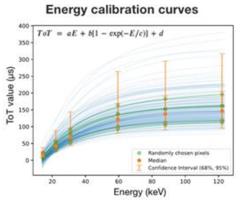


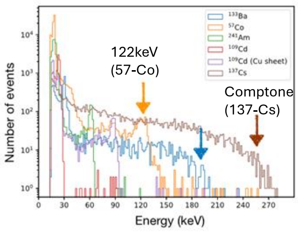

Energy spectra in ToT



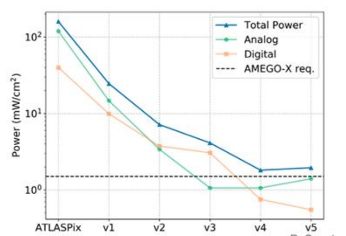

Energy calibration curves




After correcting TOT linearity, dynamic range is found to be up to 270 keV.



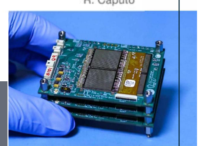

Power Comsumption History

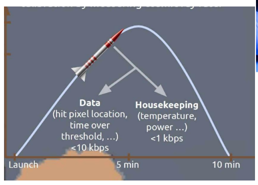


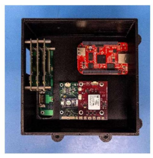

R. Caputo

**A-STEP**

Sounding rocket (2026)
Validating the performance in the orbit altitude
Three layers of Quadchip



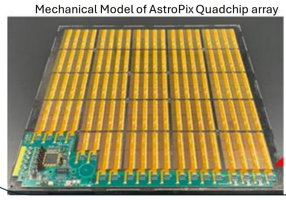


Compair-2

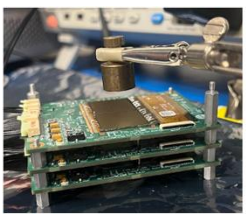
Validating the integration, environmental tests of AstroPix Tower

Mechanical Model of AstroPix Quadchip array

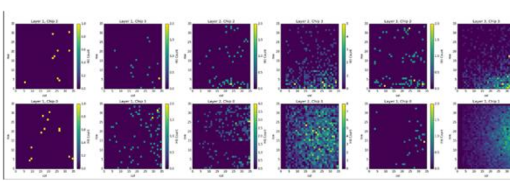


## V3 Evaluation

3-layers of Quadchip



Daisy-chain readout of Quadchip arrays @ ANL



X-ray beam scanning to obtain the depletion layer geometry