

Radiation detection and particle tracking with pixel semiconductor Timepix detectors

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Advacam: Advanced Radiation Cameras



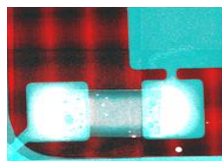
- Design and produce cameras based on the semiconductor chips developed within Medipix Collaboration
- Innovative imaging technology, application in NDT, biomedical, material analysis
- Detection and tracking of various particles, particle identification
- Radiation payloads for satellites and space missions



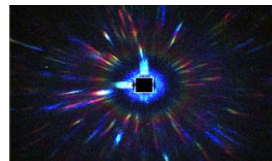
Over 30 customers & contractors



Color XRT



Color XRD



Custom devices



○ ADVACAM CZ, Prague: imaging cameras and solutions (since 2013)

- Spin-off from IEAP Czech TU Prague & CERN Medipix collaboration
- 40+ staff (engineers, researchers/scientists, technicians, students)



○ ADVACAM FIN, Espoo: semiconductor sensors & modules (since 2012)

- Spin-off from VTT Technical Research Centre of Finland, 15+ staff



Timepix, Timepix2, Timepix3, Medipix3 detectors for industry and science

Single chip
USB2 interface, miniaturized



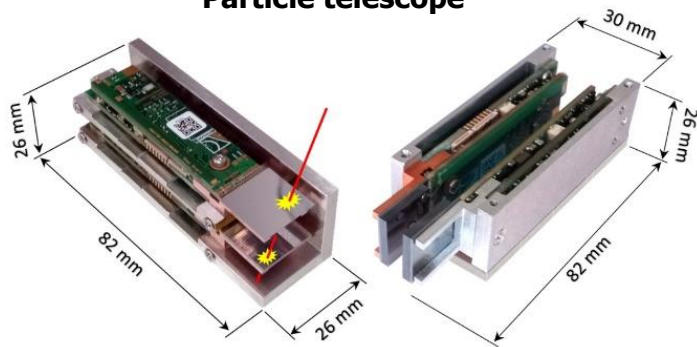
USB3 interface, fast, various sensors
(Si, CdTe)



Product & deployments:

- Space: ISS, satellites, Moon ...
- Electron microscopy
- XRD, X-ray μ CT/radiography
- Gamma & Compton cameras
- Radiation monitors
- Medical: Thyroid gamma imaging
- Education, environment

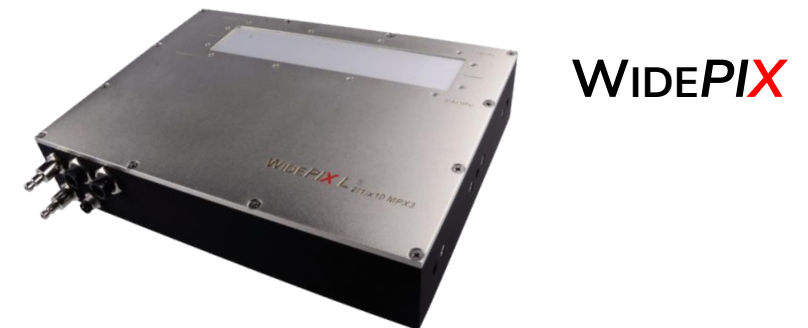
Stacked telescope
Particle telescope



Space version

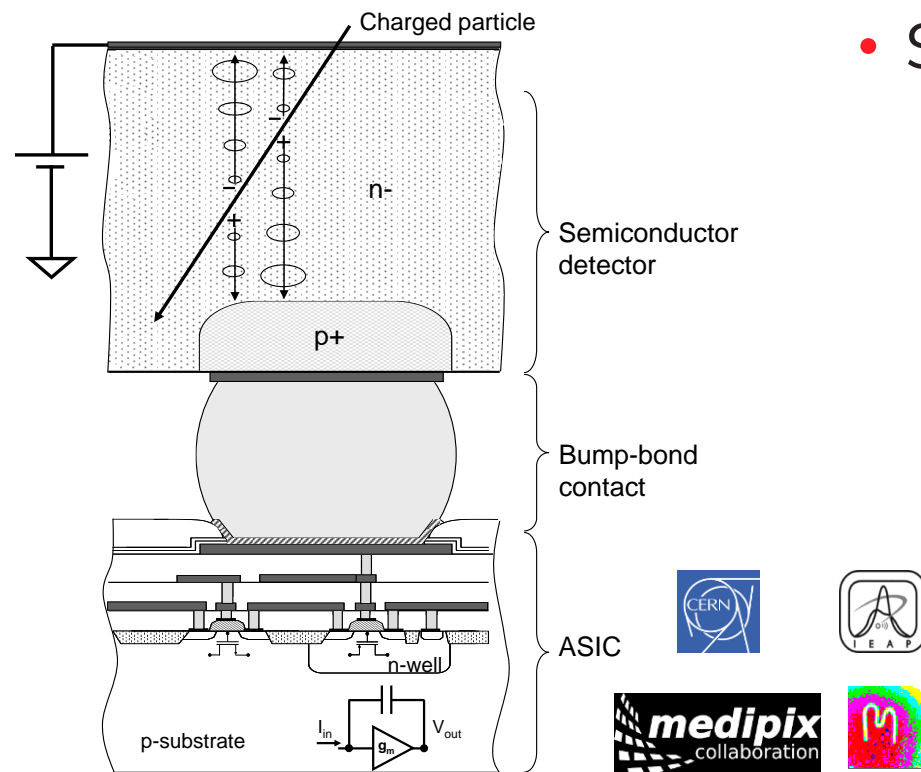


Large area detectors
Composed of multiple units

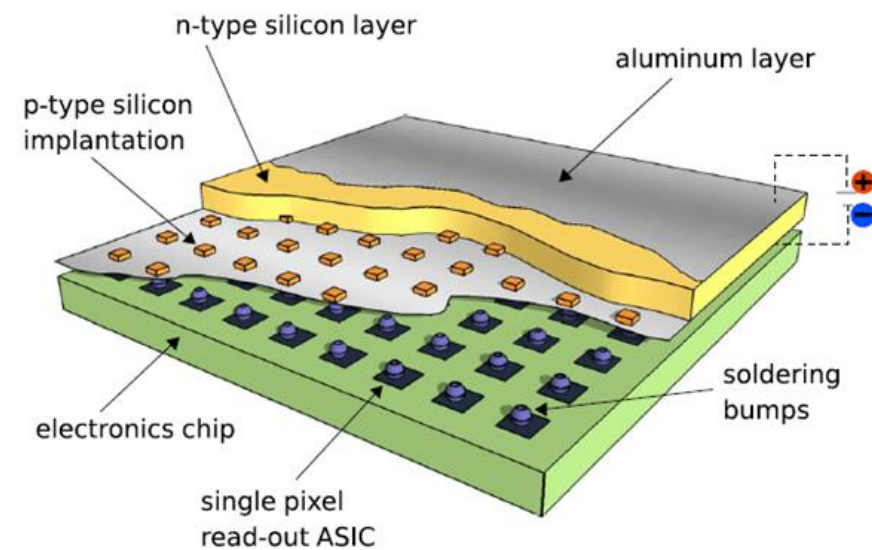


Semiconductor pixel detector Timepix

- Per-pixel readout electronics



- Material: Si, CdTe, ...; Thickness: 100-1500 μm
- Sensitive volume of a chip: $14 \times 14 \text{ mm} = 2 \text{ cm}^2$
 - 256 x 256 pixels, 55 μm pixel pitch



Semiconductor pixel detector Timepix

- Pixelated detector: superb space resolution 55 μm
- Energy measurement: $\sim O(1 \text{ keV})$ energy resolution, $E > 5 \text{ keV}$
- Interacting particles create clusters

Degress of freedom:

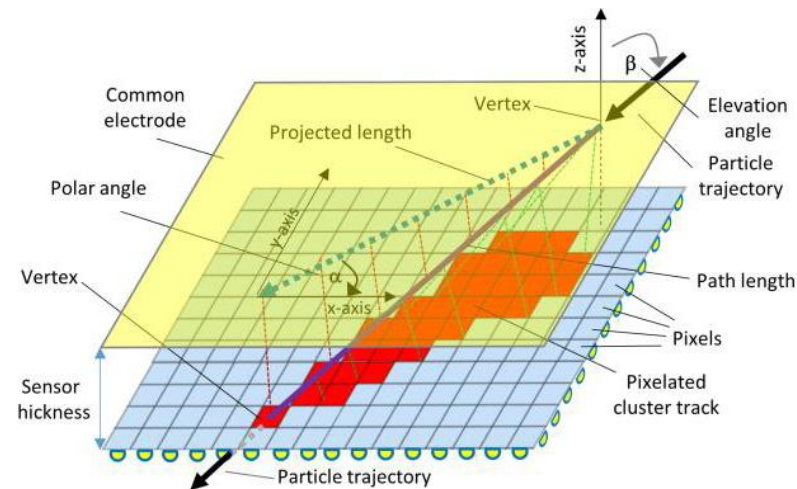
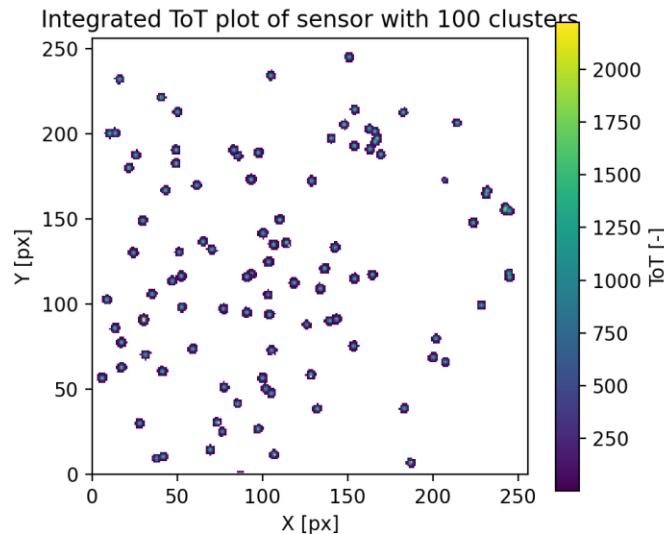
Position

Deposited energy

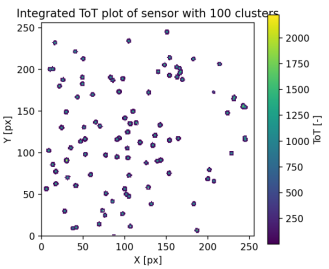
Time of arrival

Particle type/species

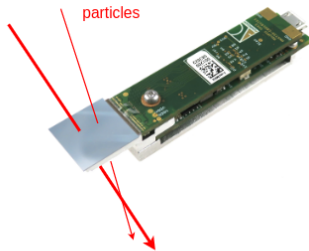
(Direction – elevation angle)



Data processing engine



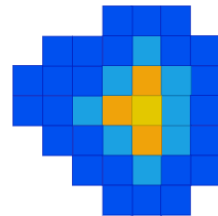
Data acquisition with Timepix detectors and DAQ software
[X, Y, ToT, ToA]



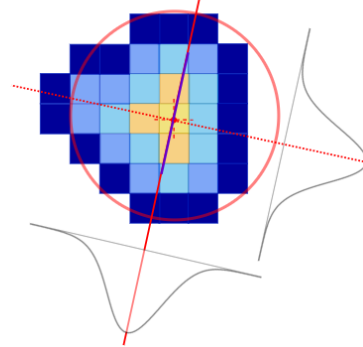
Calibrations, masking and corrections
[X, Y, E, T]



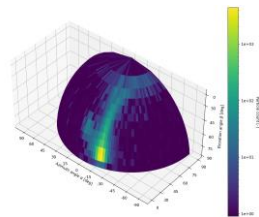
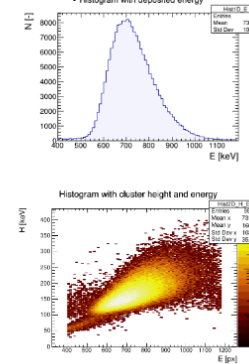
Clusterisation



Cluster analysis and filtering
{E, S, H, Roundness, Linearity, ...}



Distributions of cluster parameters

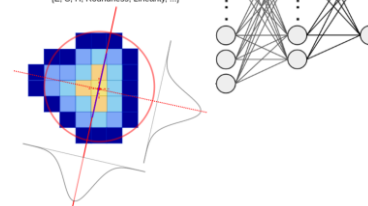


Particle identification

Fully connected neural network

Output is probability to belong to given class

Input are cluster parameters
E, H, Linearity, Roundness, ...
{E, S, H, Roundness, Linearity, ...}



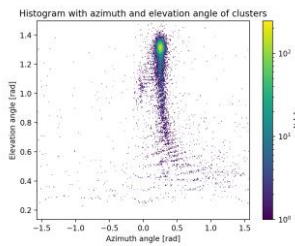
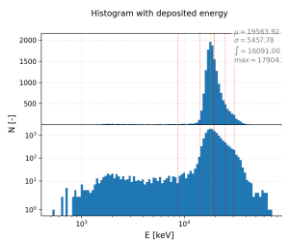
Confusion matrix

	electron & positron	neutron	gamma
electron & positron	98.77%	1.16%	0.07%
neutron	2.12%	97.88%	0.00%
gamma	0.69%	1.48%	97.83%

Confusion matrix (efficiencies)

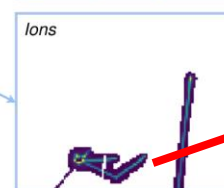
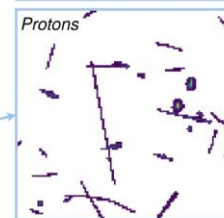
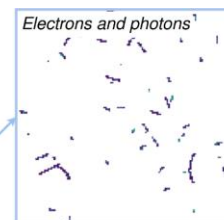
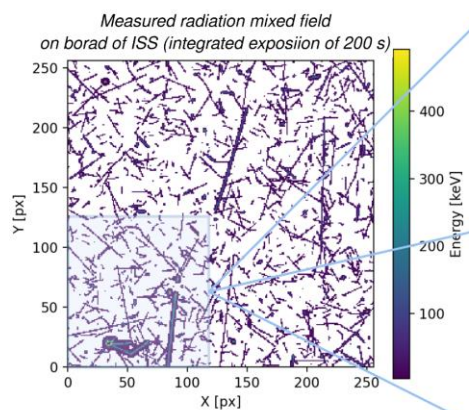
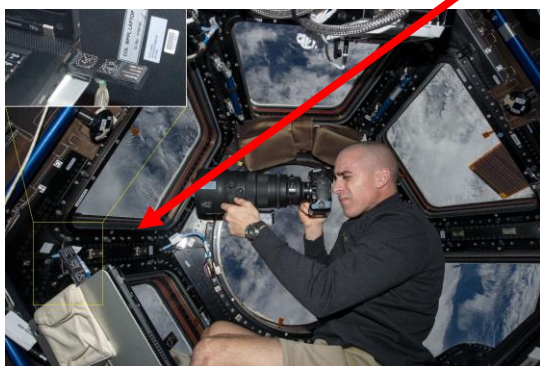
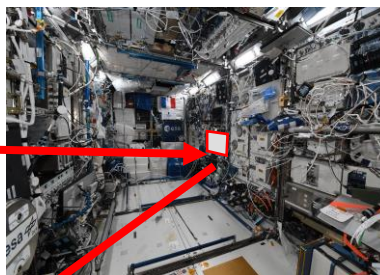
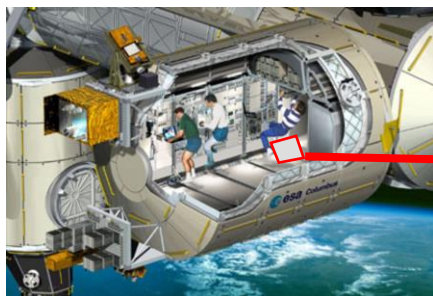
Physical output

- Count, flux, dose, dose rate, etc.
- Frame analysis
- Coincidence analysis
- Directional analysis
- Compton camera

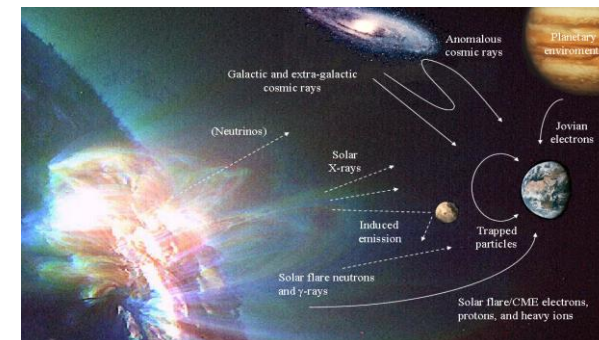
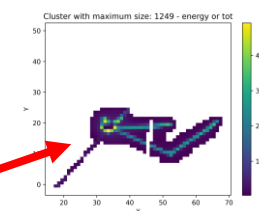


Minipix Timepix 3 in LEO orbit/ISS

- **ICE Cube facility:** commercial service of research technology and education applications in space, launched Dec 2021



High energy particle causing nuclear interaction with several secondaries



Space weather

- Solar wind, plasma
- Ionizing radiation
- Magnetic field/magnetosphere

- C. Granja et al 2022 *JINST* **17** C03019 (MiniPIX Timepix3 — a miniaturized radiation camera with onboard data processing for online characterization of wide-intensity mixed-radiation fields)
- C. Granja et al *Universe* **2022**, 8, 241 (Directional-Sensitive X-ray/Gamma-ray Imager on Board the VZLUSAT-2 CubeSat for Wide Field-of-View Observation of GRBs in Low Earth)
- St. Gohl et al 2022 *JINST* **17** C01066 (A miniaturized radiation monitor for continuous dosimetry and particle identification in space)
- D Parcerisas et al 2022 *Phys. Educ.* **57** 025018 (ADMIRA project: teaching particle physics at high school with Timepix detectors)
- C. Granja et al 2022 *JINST* **17** C11014 (Spectral and directional sensitive composition characterization of mixed-radiation fields with the miniaturized radiation camera MiniPIX Timepix2)
- C. Granja et al 2022 *JINST* **17** C03028 (Spectral tracking of energetic charged particles in wide field-of-view with miniaturized telescope MiniPIX Timepix3 1 × 2 stack)
- C. Granja et al 2022 *JINST* **17** C03019 (MiniPIX Timepix3 — a miniaturized radiation camera with onboard data processing for online characterization of wide-intensity mixed-radiation fields)

Thank you for your attention