

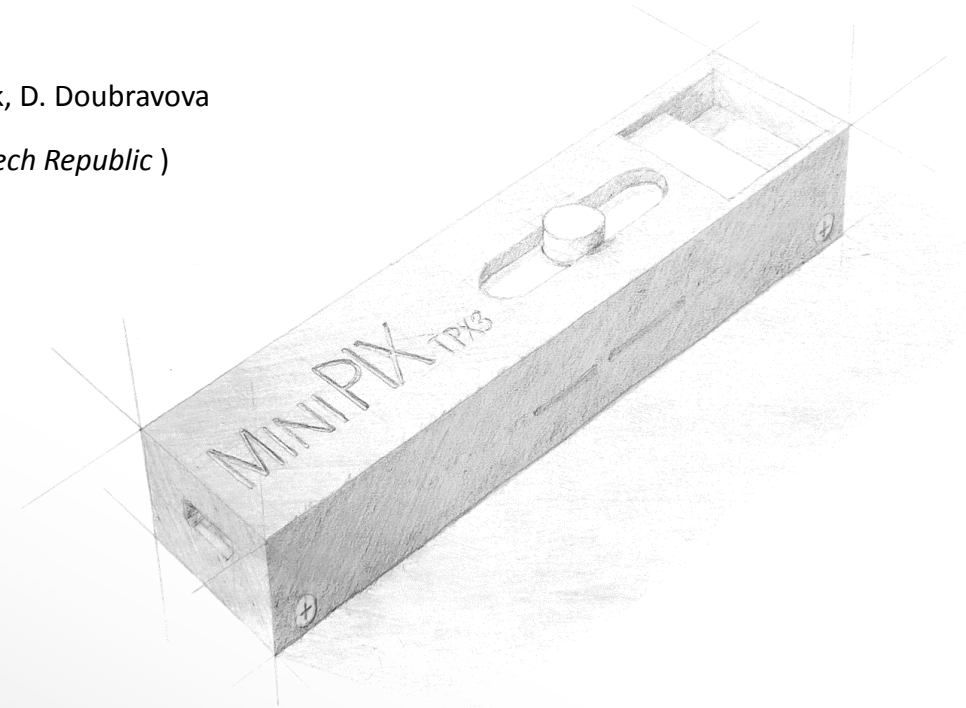


# Miniaturized fully spectroscopic radiation camera based on Timepix3 chip

for tracking of radioactive sources and monitoring of space weather

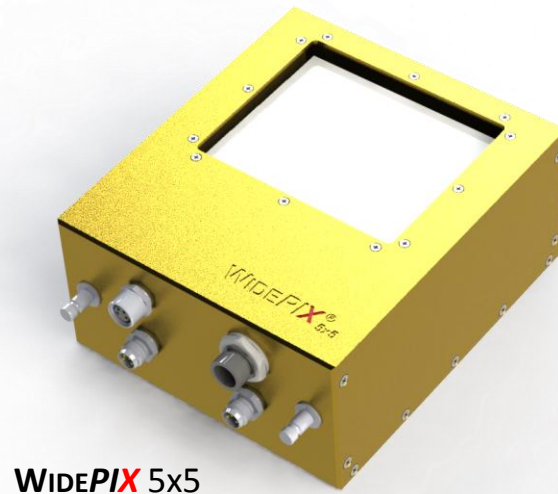
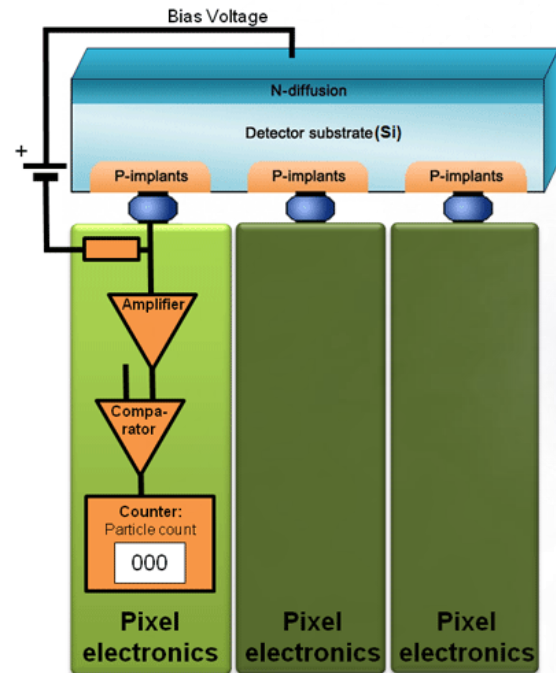
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# Photon counting pixel detectors

- Registration of individual ionizing particles
- Readout and sensor chips (Si, CZT, CdTe, ...) → connected using bump-bonding
- Each pixel is connected to its own electronics
  - preamplifier
  - energy discriminator
  - digital counter
- Pixel array – 256 x 256 pixels, pixel size 55 μm
- Sensitive area 1.4 x 1.4 cm<sup>2</sup> (creating of larger area)



## Particles detection

- Particle hits the sensitive area → generation of pair electron/hole → charge generation → charge collected to pixel electrodes and via bump-bond connected to the CMOS electronics
- The electronics amplifies the signal → compares with preselected discrimination level (threshold)
- The signal post-processing depends on measuring mode
- **Frame based readout or event based readout**



# Spectral detectors

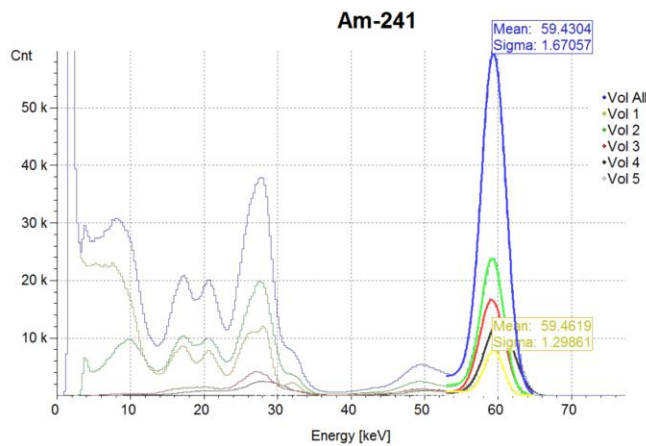
## Timepix3:

- Successor of Timepix: 256x256 pixels, 55  $\mu\text{m}$  pitch
- **Event based readout** (Not frame based as Timepix): Each hit pixel transmits the event information immediately
- ⇒ No dead-time for readout of complete frame
- Ability to measure Energy (ToT) and Time of Arrival (ToA) concurrently
- Time is measured with precision of **1.56 ns**

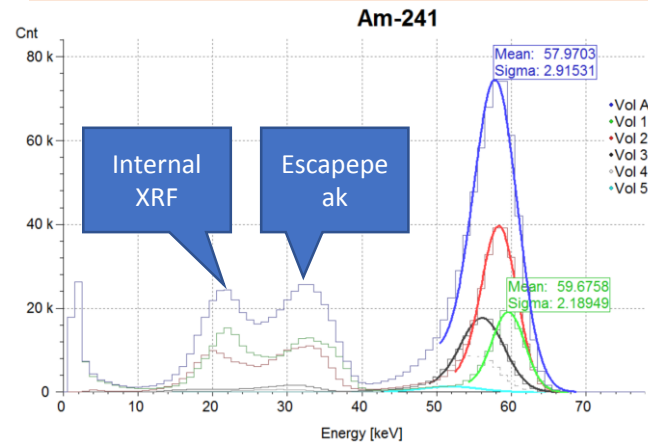


ADVAPIX TPX 3

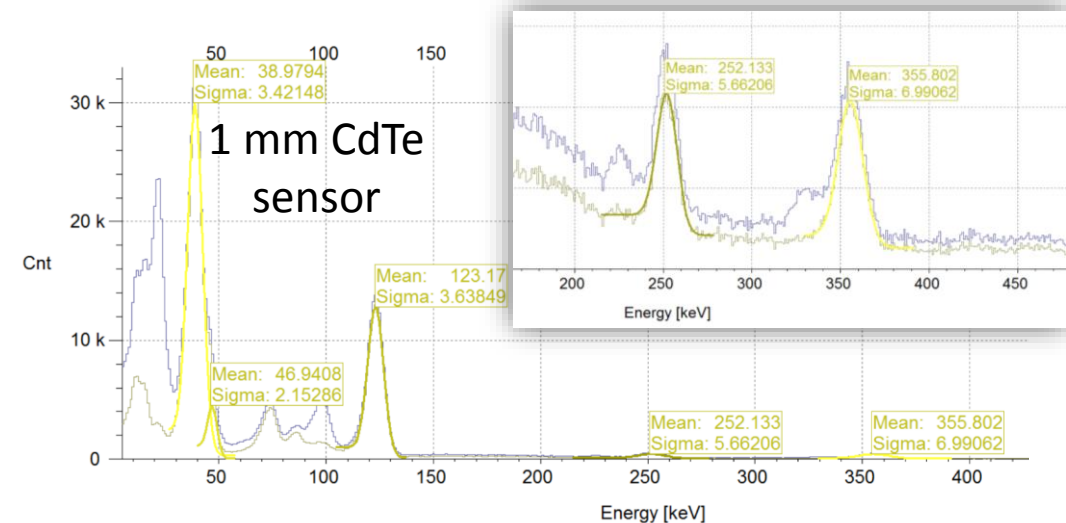
1 mm Si



1 mm CdTe



Eu-152 (Bias=500 V)



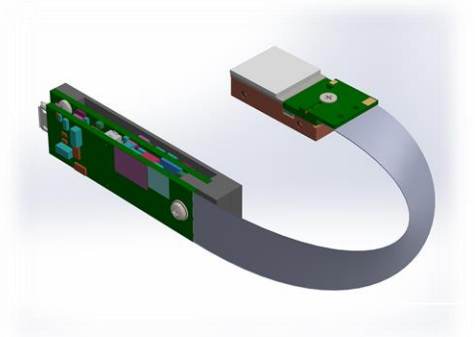


# MINIPIX Timepix3

- Miniaturized and low power radiation camera with particle tracking and imaging detector **Timepix3**
- **Fast sparse data readout**
- Each detected particle or photon is either read-out immediately (pixel mode) at maximal rate of **2.35 million hit pixels per second**
- Frame mode – **16 fps**
- The device is controlled via **USB2.0** interface with standard **µUSB** connector
- Dimension of the detector is **80 mm x 21 mm x 14 mm** and its weight is **30 g**
- Possibility to create a complex configuration via extension unit - **flex cable**
- **Supported sensor types:** Silicon 100 - 1000 µm thick, CdTe 1000 and 2000 µm thick

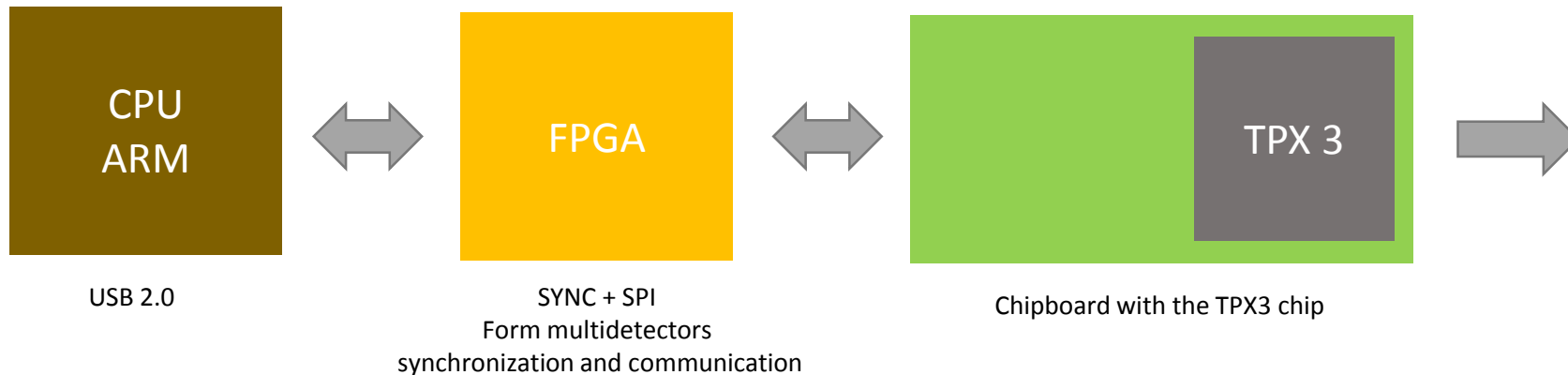


Palmtop device



MINIPIX Timepix3 flex

RAM – 0.5 MB + 2 MB flash  
 Clk 160 MHz  
 STM 32 F777  
 ARM Cortex M7



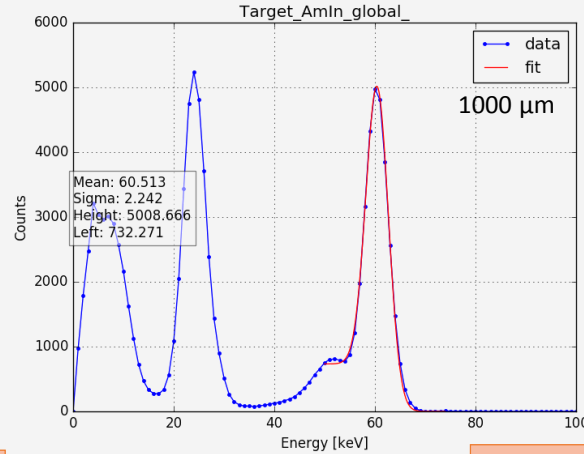
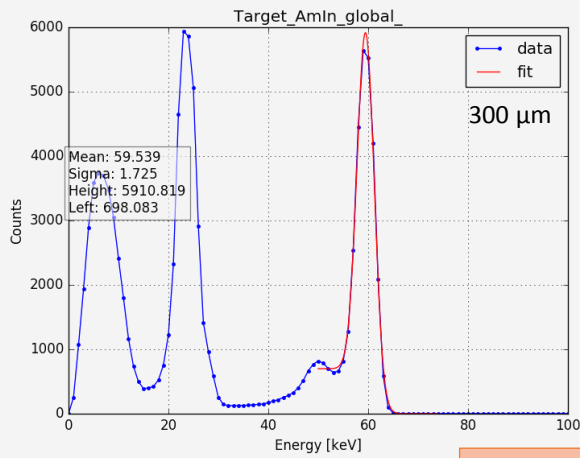




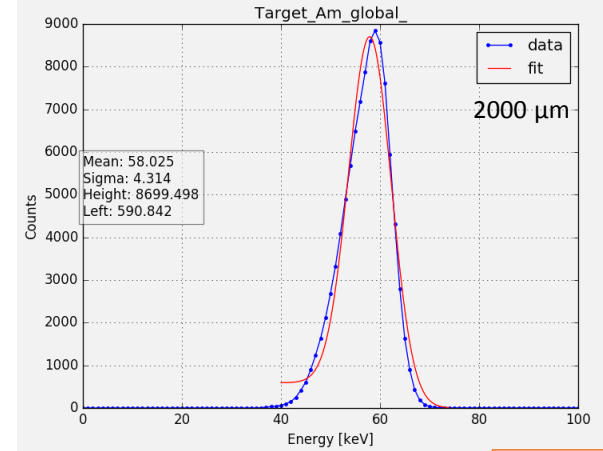
# Spectral properties

- Evaluation and comparison of spectral performance of **MINIPIX** TPX3 and **ADVAPIX** TPX3
- Used source  $^{241}\text{Am}$
- **Si** (300, 1000  $\mu\text{m}$ ) and **CdTe** (2000  $\mu\text{m}$ )

**ADVAPIX TPX 3**

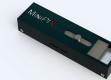
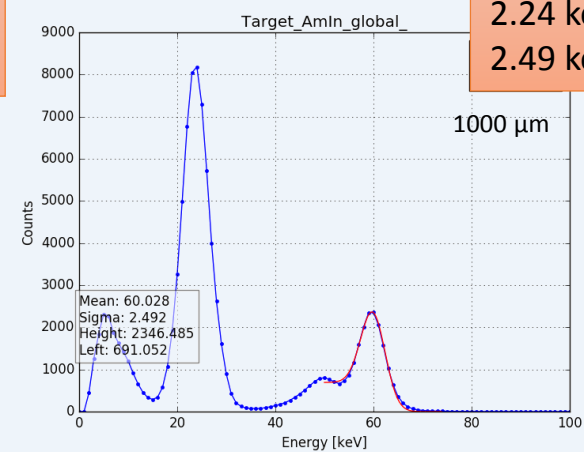
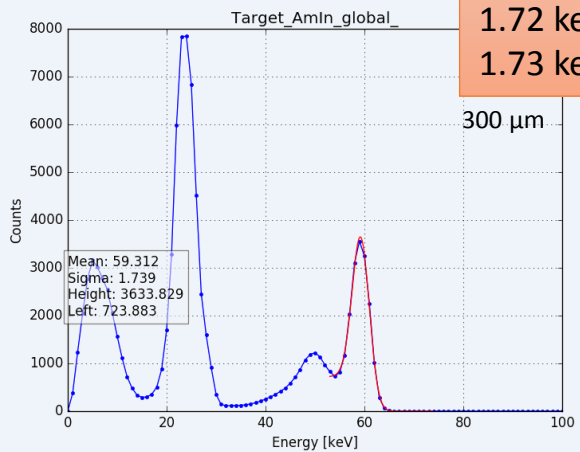


positive  
**Silicon**

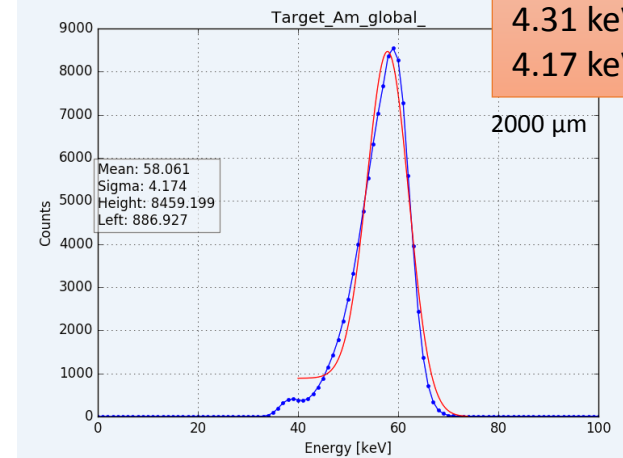


negative  
**CdTe**

**MINIPIX TPX 3**



positive  
**Silicon**



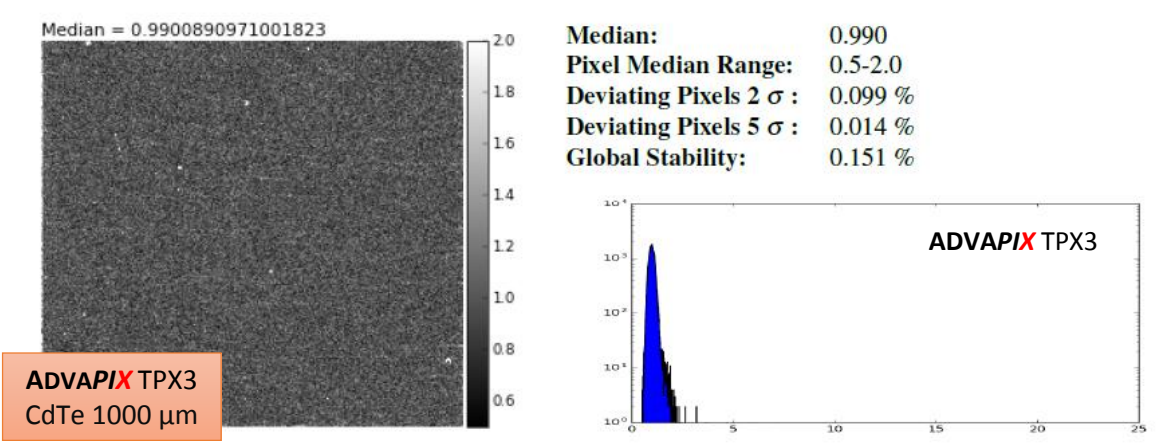
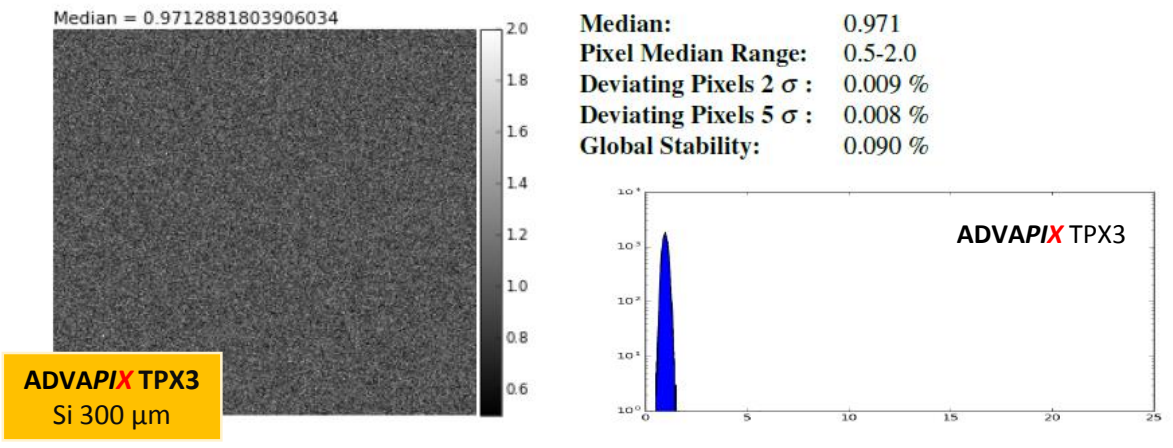
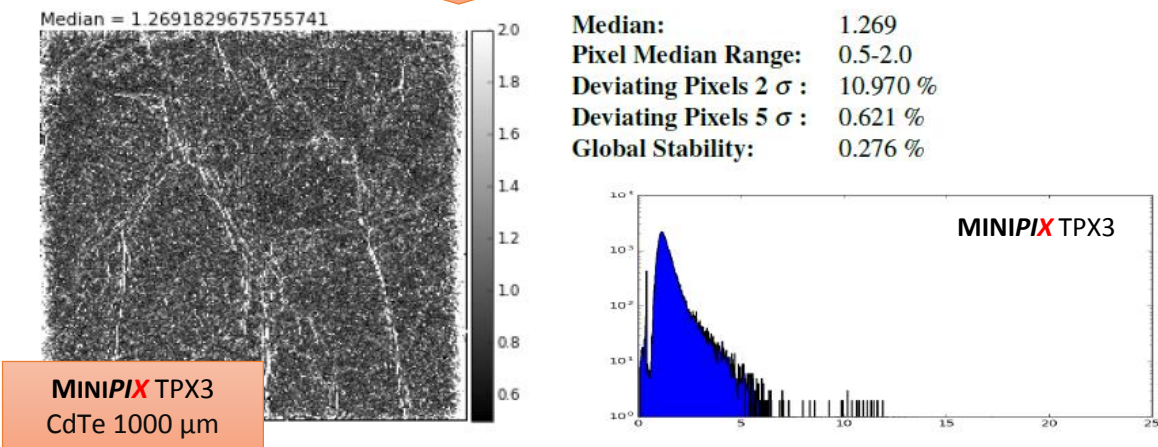
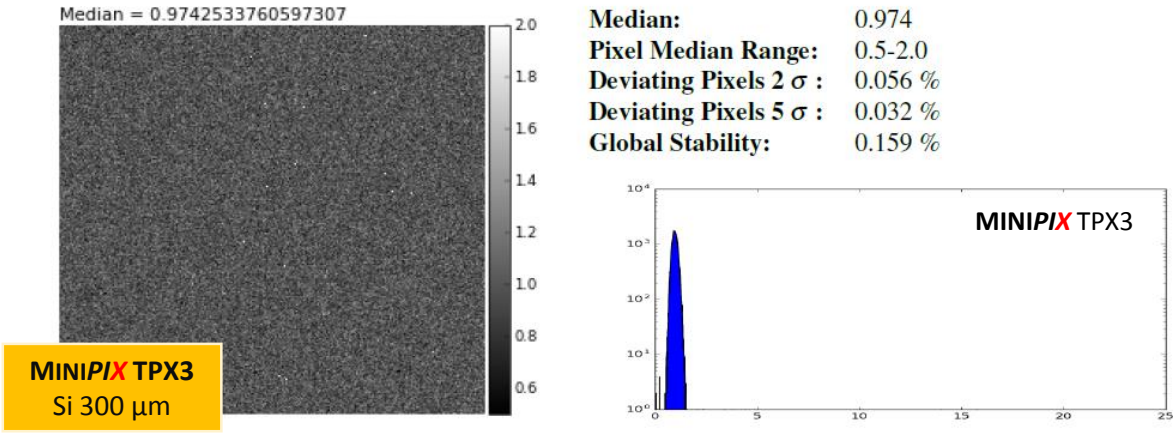
negative  
**CdTe**



# Longterm stability Si vs. CdTe

- The stability test takes 10 minutes (temperature stabilized detector)
- Median of relative noise is calculated
- Poisson distribution
- The ideal distribution is equal to 1

First testing device with lower quality  
Inhomogenities were expected





# MiniPIX TPX3 count rate in event mode

Maximal speed is limited to reduce power consumption

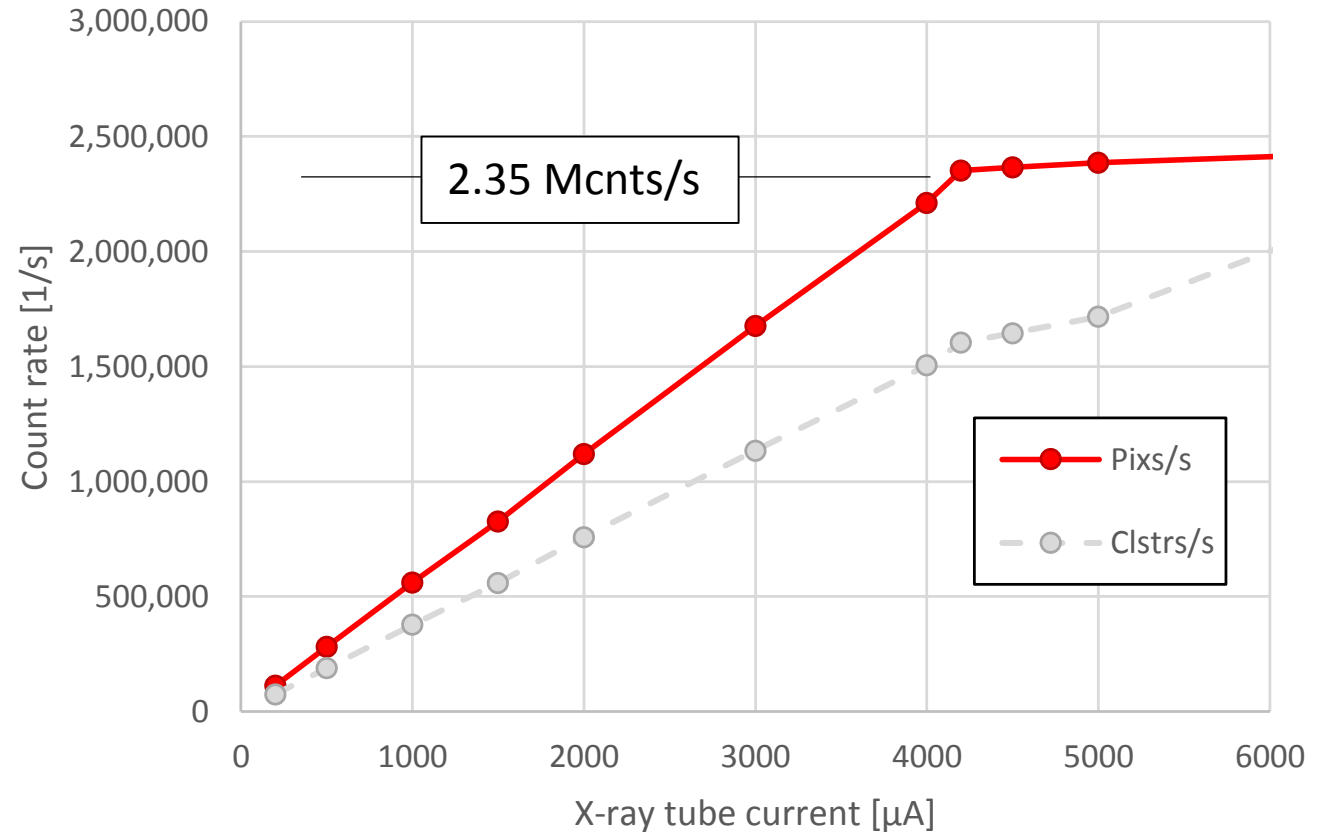
Max count rate measured with

- 300  $\mu\text{m}$  Si sensor at threshold of 3 keV
- 17 keV semi-monochromatic X-rays

More than sufficient for imaging with isotopes.



## Maximal pixel rate of MiniPIX TPX3



# MINIPIX TPX3 vs. ADVAPIX TPX3



Readout chip type

Pixel size

Sensor resolution

Interface

Maximum readout speed

Dimensions

Weight

CPU ARM

Timepix3

55 x 55  $\mu\text{m}$

256 x 256 pixels

**USB 2.0 (High Speed)**

**2.35 milion pixels/s**

**80 x 21 x14 mm**

**30 g**

yes

Timepix3

55 x 55  $\mu\text{m}$

256 x 256 pixels

**USB 3.0 (Super-Speed)**

**40 milion pixels/s**

**125 x 79 x 25.5 mm**

**503 g**

no





# ...ongoing projects and applications

Observation of migration of the radioactive sources in the soil (RADEMET)

Particle tracker for the monitoring of the space weather (ESA – SR, MIRAM)

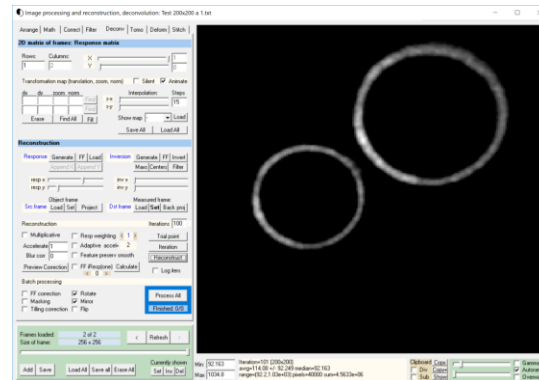
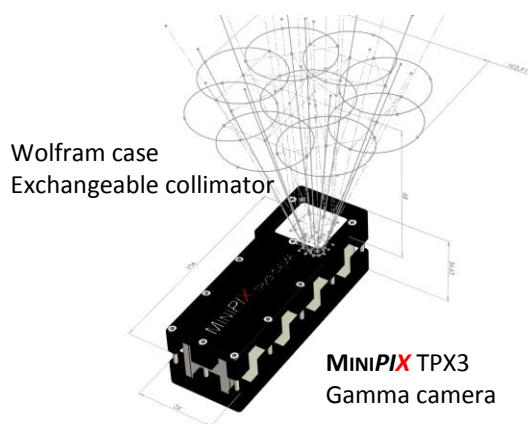


# Observation of migration of the radioactive sources in the soil

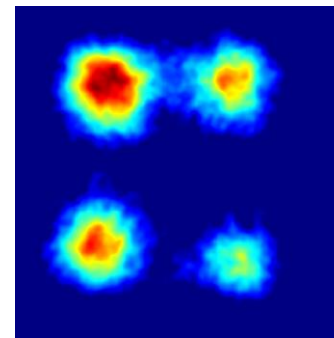
- Detection of radioactive sources in the soil or rock
- Observation of their transport
- Long-term and short-term radioisotopes
- **Two approaches**
  1. Compton camera (two-layer or single-layer)
  2. Gamma camera with suitable collimator

## Use in praxis

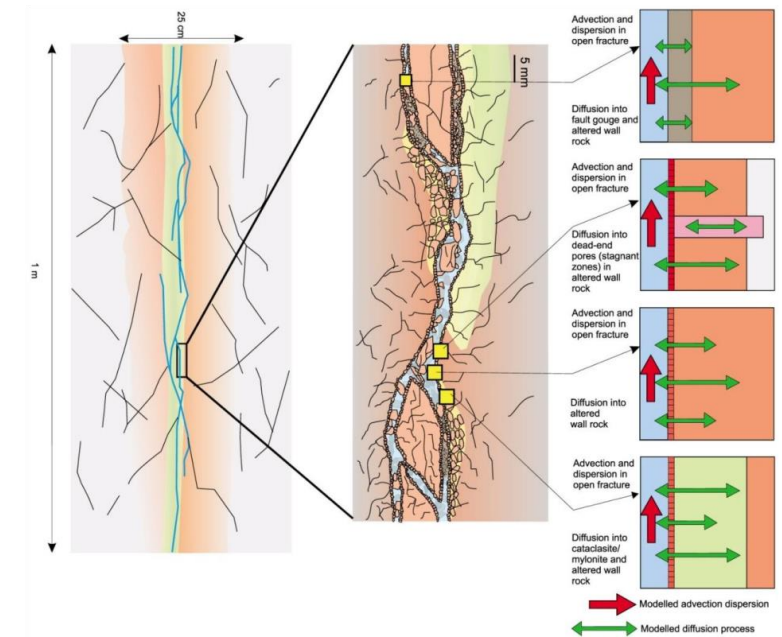
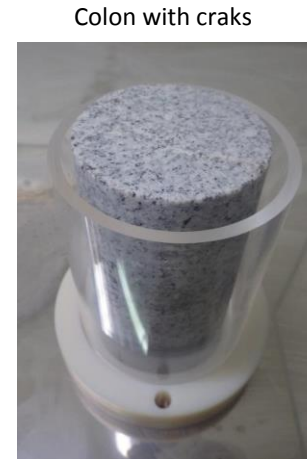
- **Exploration of radioactive repositories and storing of radioactive and toxic waste**
- The detector (small size) is put into the drilled cavities in the rock and monitors the transport of the radionuclides



Use of gamma camera with the collimator  
Reconstructed image of the circle radioactive source



Use of Compton camera  
Reconstructed image of four point sources



## Laboratory setup

- Colon with the naturally created cracks
- Several detectors are placed around this colon to monitor the transport of the radioactive sources

## Project status

- Devices are prepared and experiments will begin in the second half of 2019



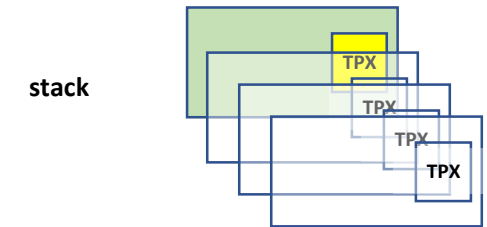
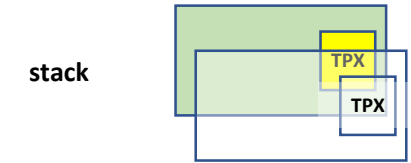
# Particle tracker for the monitoring of the space weather

- MiniPIX TPX3 modified for space application

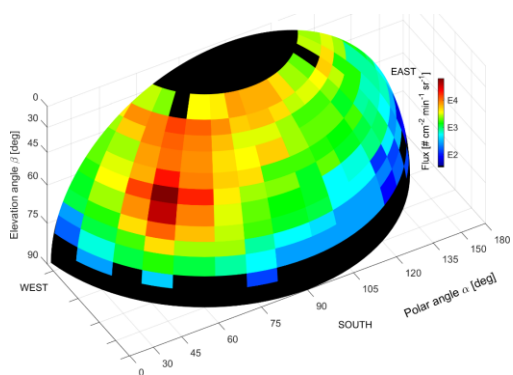
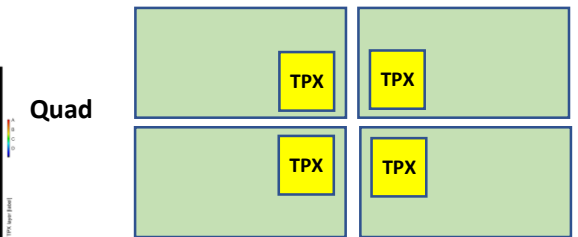
The specially modified detector can be used in different architectures:

1. **Single:** Radiation monitor for telecommunication satellites in GEO
2. **Quad:** Large area X-ray imager
3. **Stack:** Directional and spectral particle tracker

- Ability to detect the wide range of particles LCPs, HCPs, X rays, g rays, n's
- **Low power consumption** – down to 0.5 W
- **On-board data processing possibility thanks to CPU ARM**
- Low weight

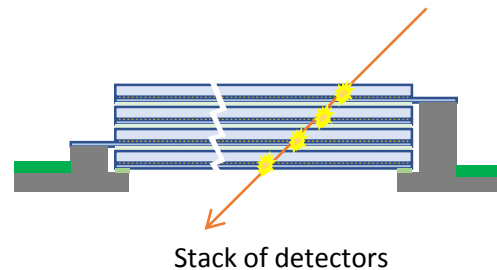


*Tracker/stack architectures*

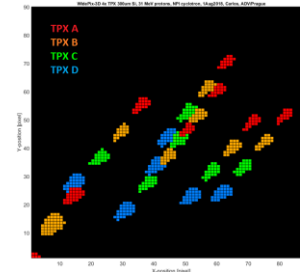


## Fields/applications

- Radiation environment
- Radiation effects
- Space weather
- Astrophysics



Stack of detectors



Data measured in diff. layers



# Summary

- **Development of MiniPIX Timepix3 was finished**
- **Small size** device like a bigger flash disk
- **The data quality of Timepix3 is not affected**
- Special OEM version with flex cable can be used in various configuration (row, quad, stack...)
- The power consumption can be decreased down **to 0.5 W** – suitable for application in space
  
- The presence of **CPU ARM** for basic data processing → use as a stand alone device in future



**Thank you for your  
attention**