Particle Camera
Experiment guidelines

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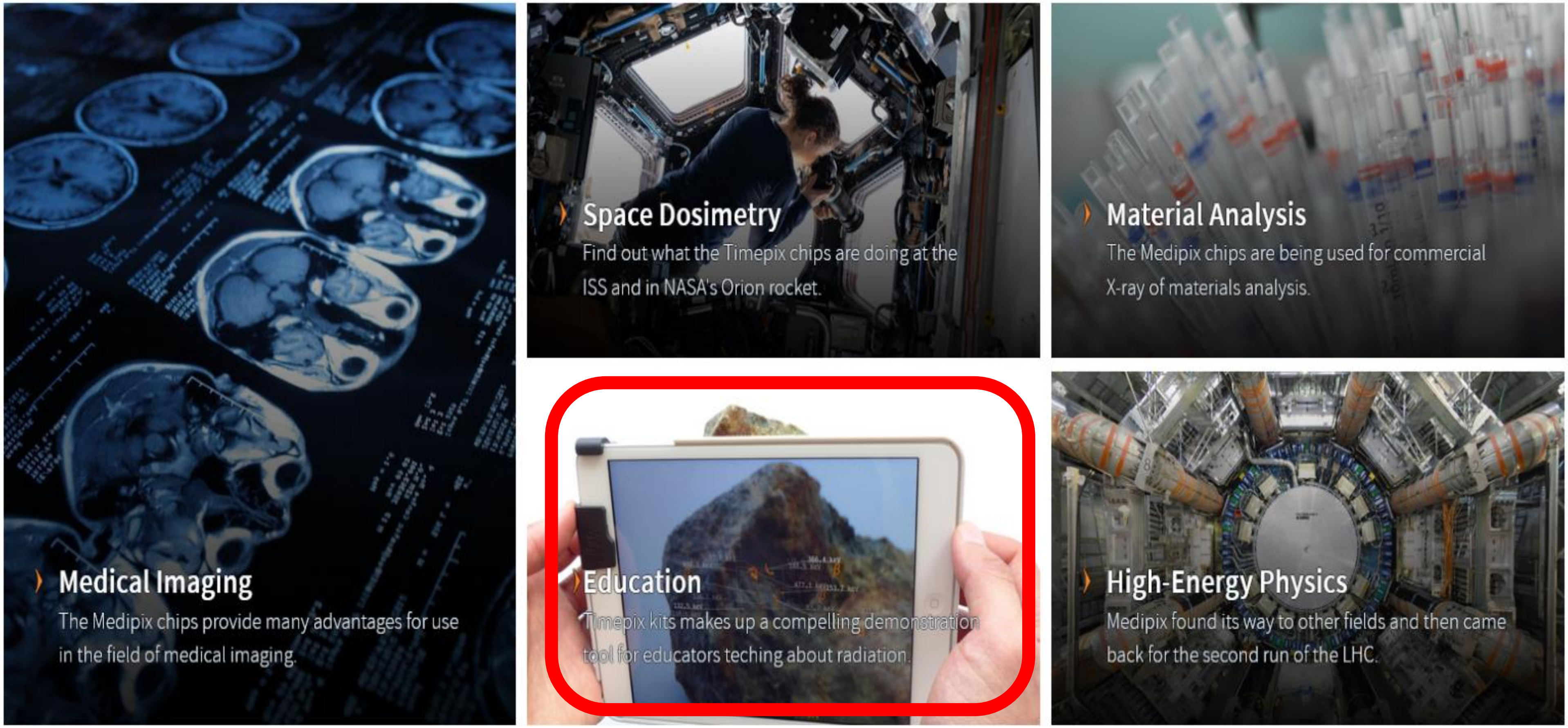
CERN Medipix Collaboration

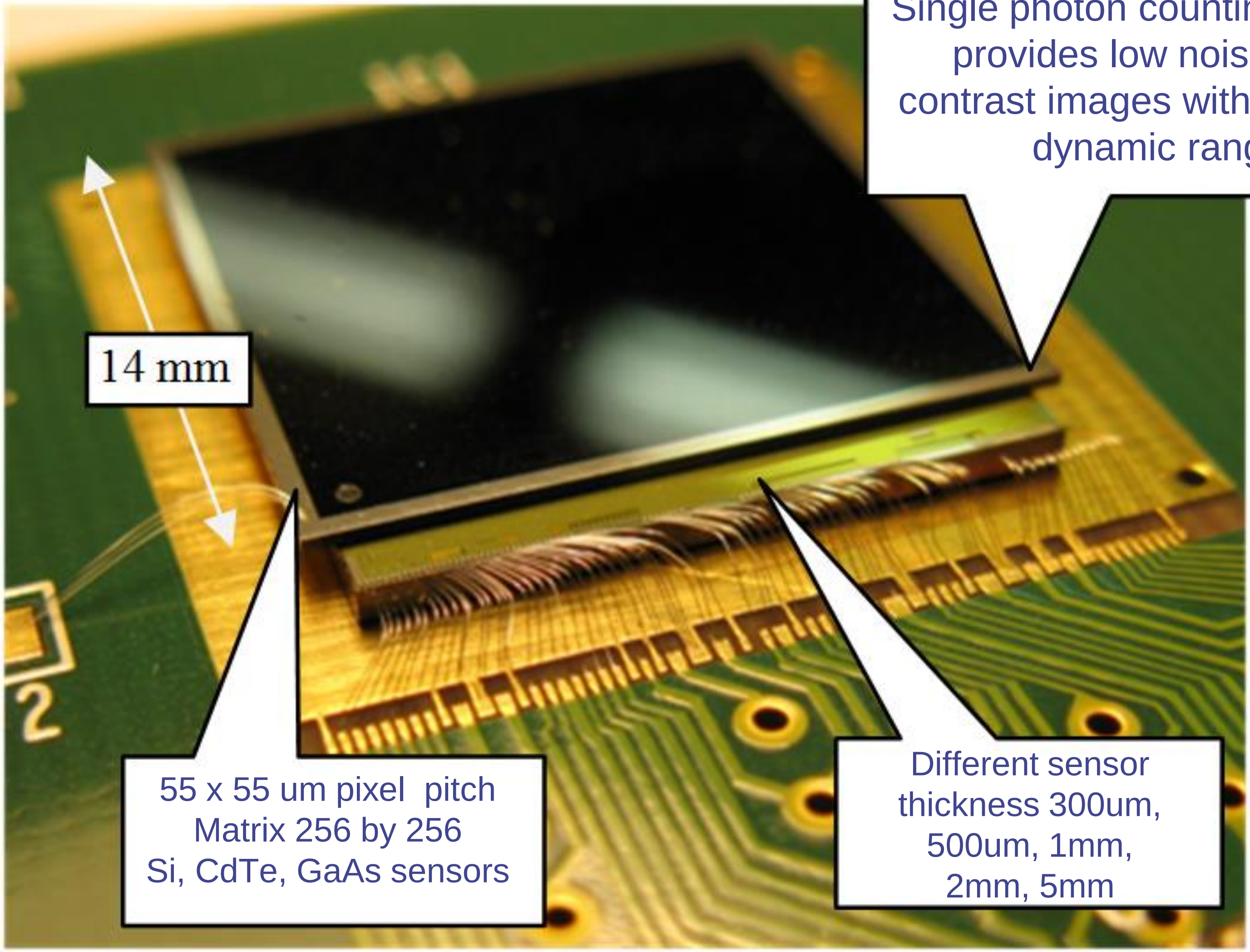
- Development of pixel detectors
- Technology transfer initiative
- **Application of pixel detectors in the field of education**



Particle Camera = Modern Instrument for Teaching of Physics

- Geiger-Muller counter vs Timepix based Particle camera

Timepix - Hybrid Pixel Detector with Single Particle Detecting Capability



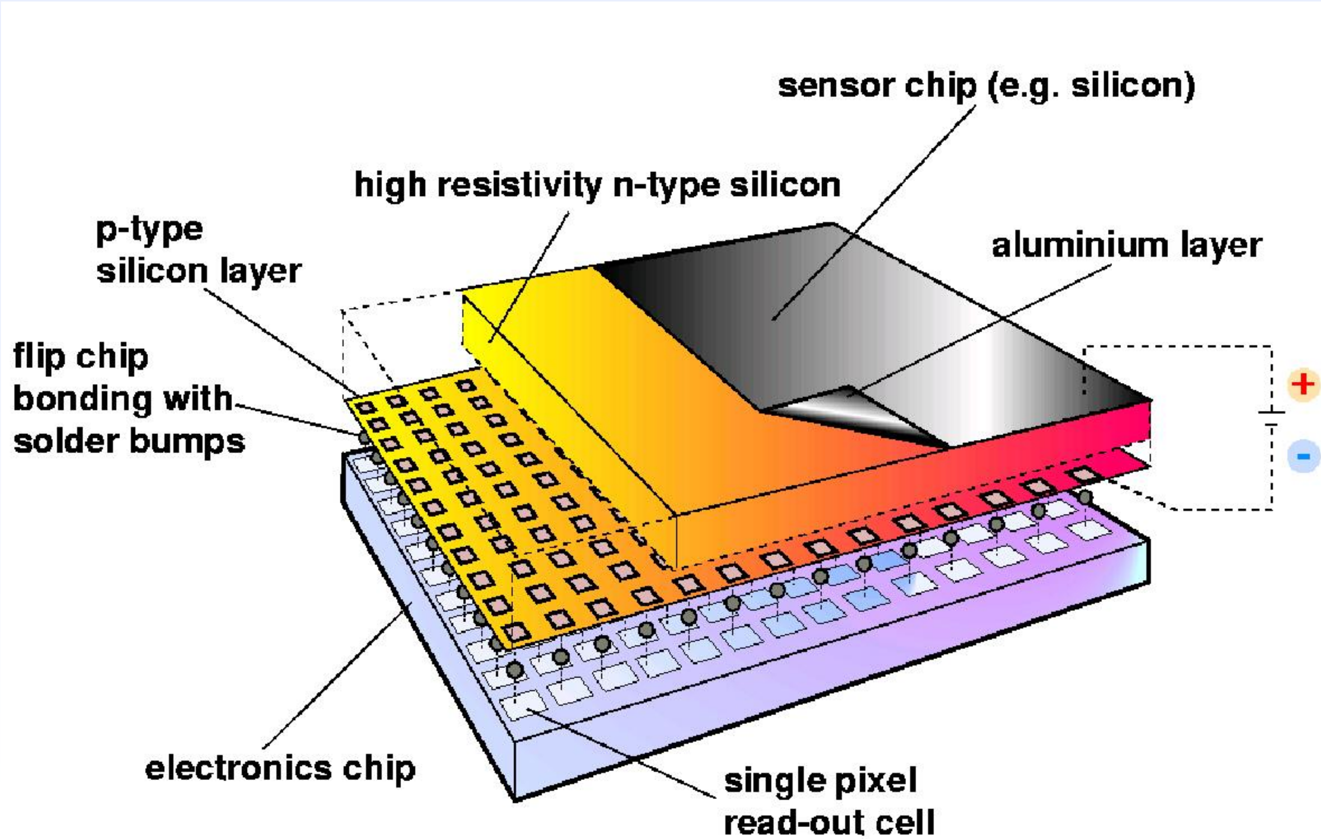
Single photon counting readout provides low noise, high contrast images with very high dynamic range

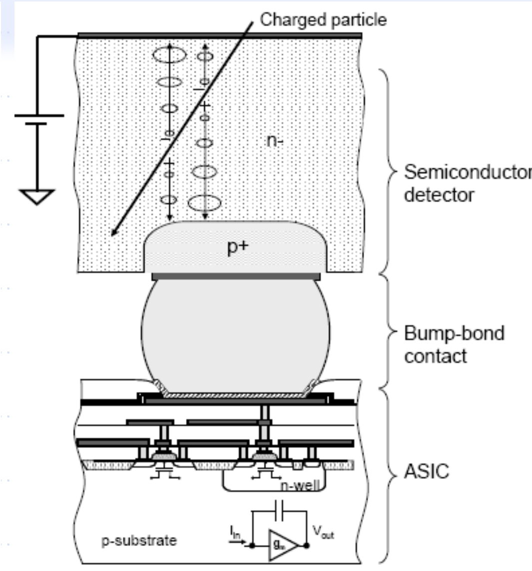
55 x 55 um pixel pitch
Matrix 256 by 256
Si, CdTe, GaAs sensors

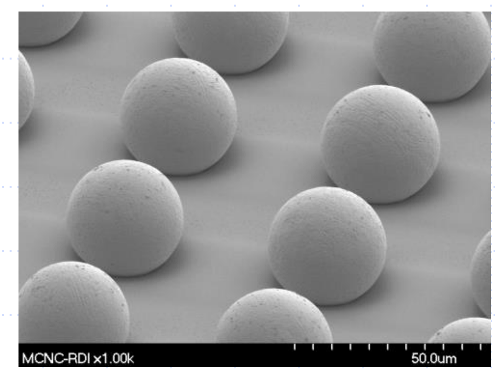
Different sensor thickness 300um, 500um, 1mm, 2mm, 5mm

Timepix

Timepix - Hybrid Pixel Detector with Single Particle Detection Capability



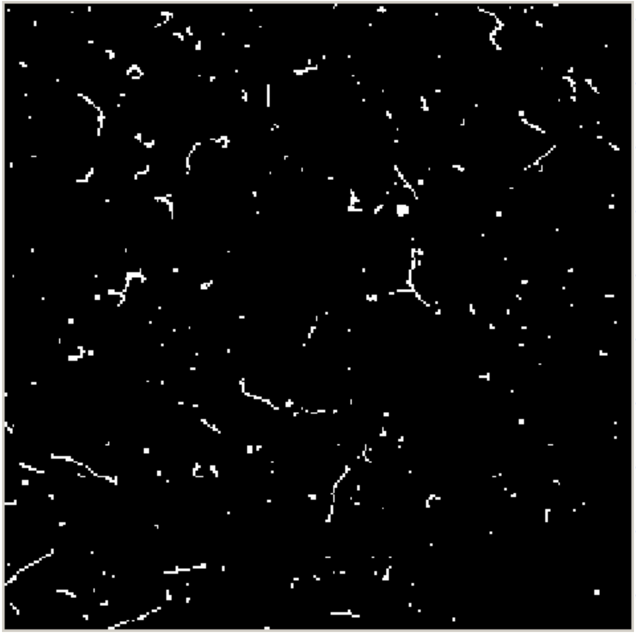


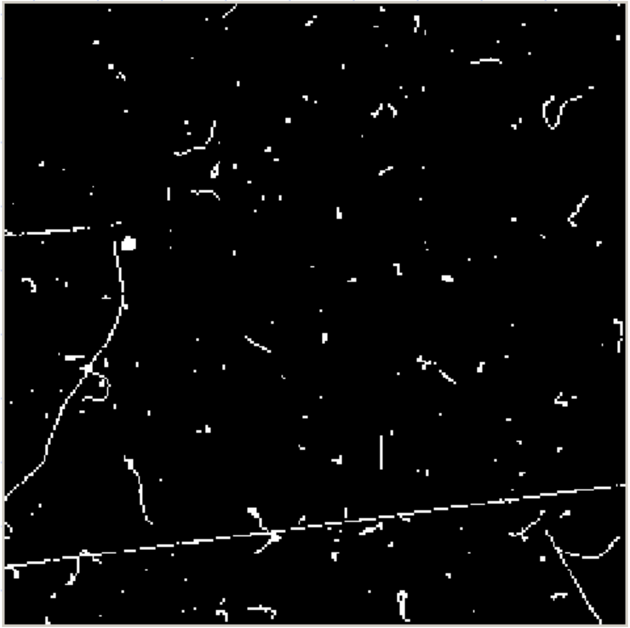


Sensor part and readout electronics part are optimized separately
(sensor materials – Si, CdTe, GaAS)

Pixel detector as "Active emulsion"

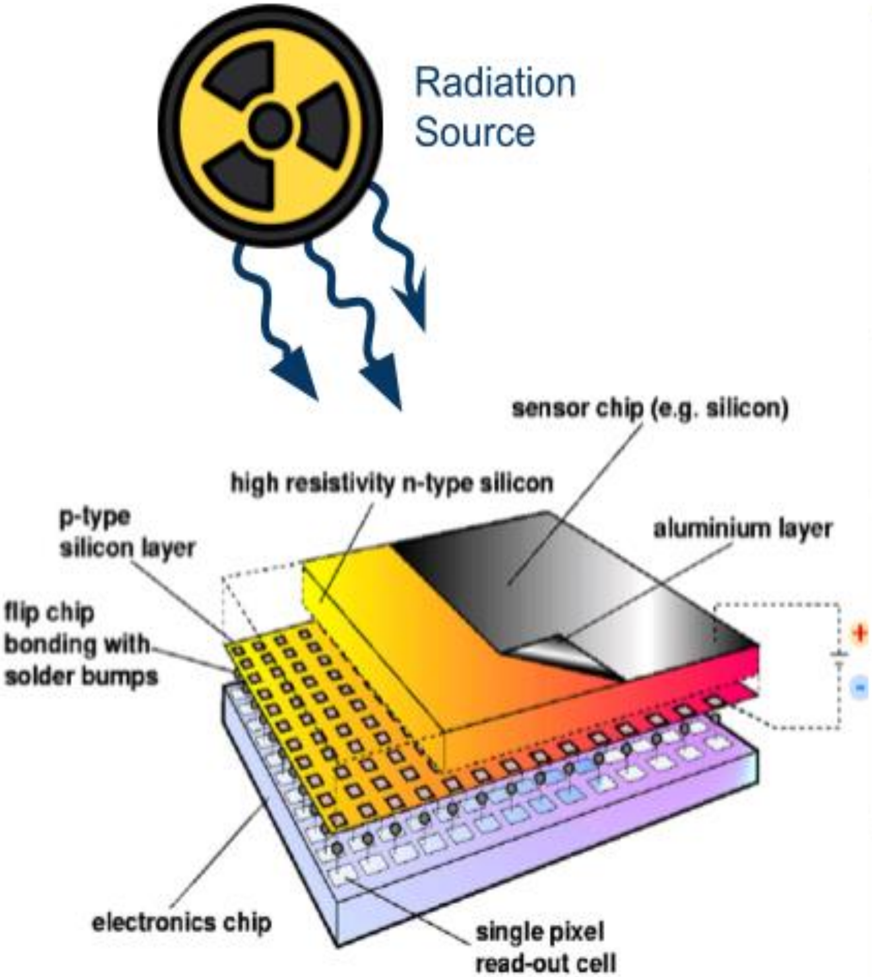
- Some particles can be identified from shape of their tracks as in formerly used nuclear emulsions.
- Example: Cosmic rays and natural background

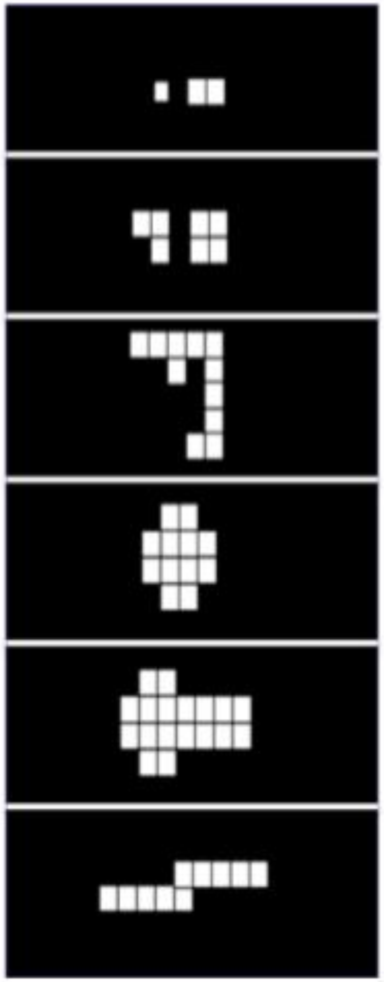




Are particles photogenic?
Yes of course, they are when observing them with Timepix detector.

Particle Camera Working Principle





(1) Dot
Photons and electrons (10keV)

(2) Small blob
Photons and electrons

(3) Curly track
Electrons (MeV range)

(4) Heavy blob
Heavy ionizing particles with low range (alpha particles,…)

(5) Heavy track
Heavy ionizing particles (protons,…)

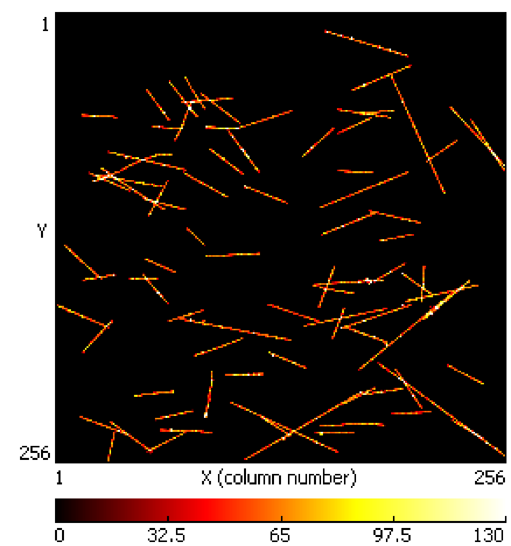
(6) Straight track
Energetic light charged particles (MIP, Muons,…)

….Different kind of radiation produces tracks of different shape

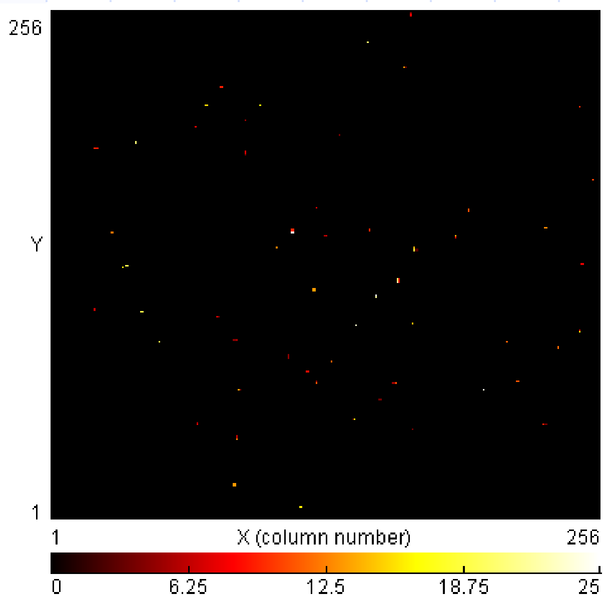
Particle Tracking and Recognition

- **Type of interacting particle can be recognized by its specific track left in the pixel matrix**
  - ***Track shape depends on interacting particle energy, mass, sensor material, bias voltage, angle,…***

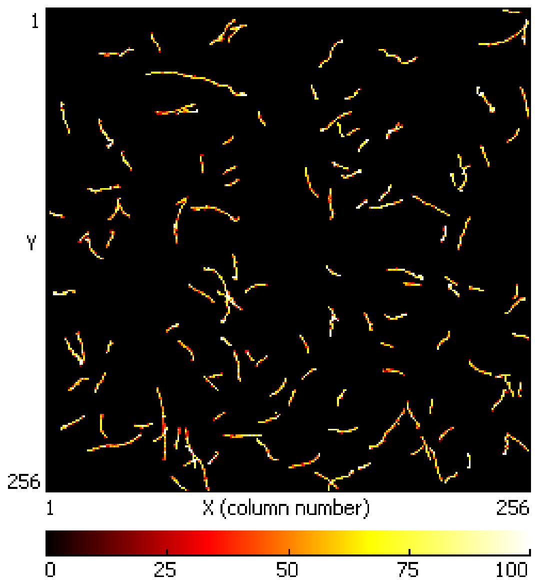
Muons



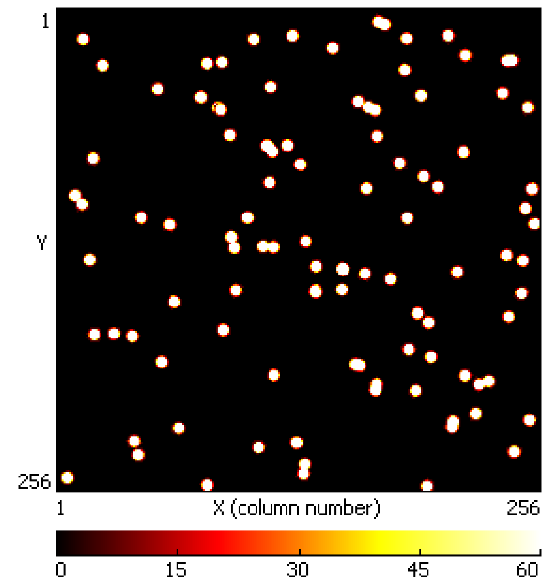
Gammas/X-Rays



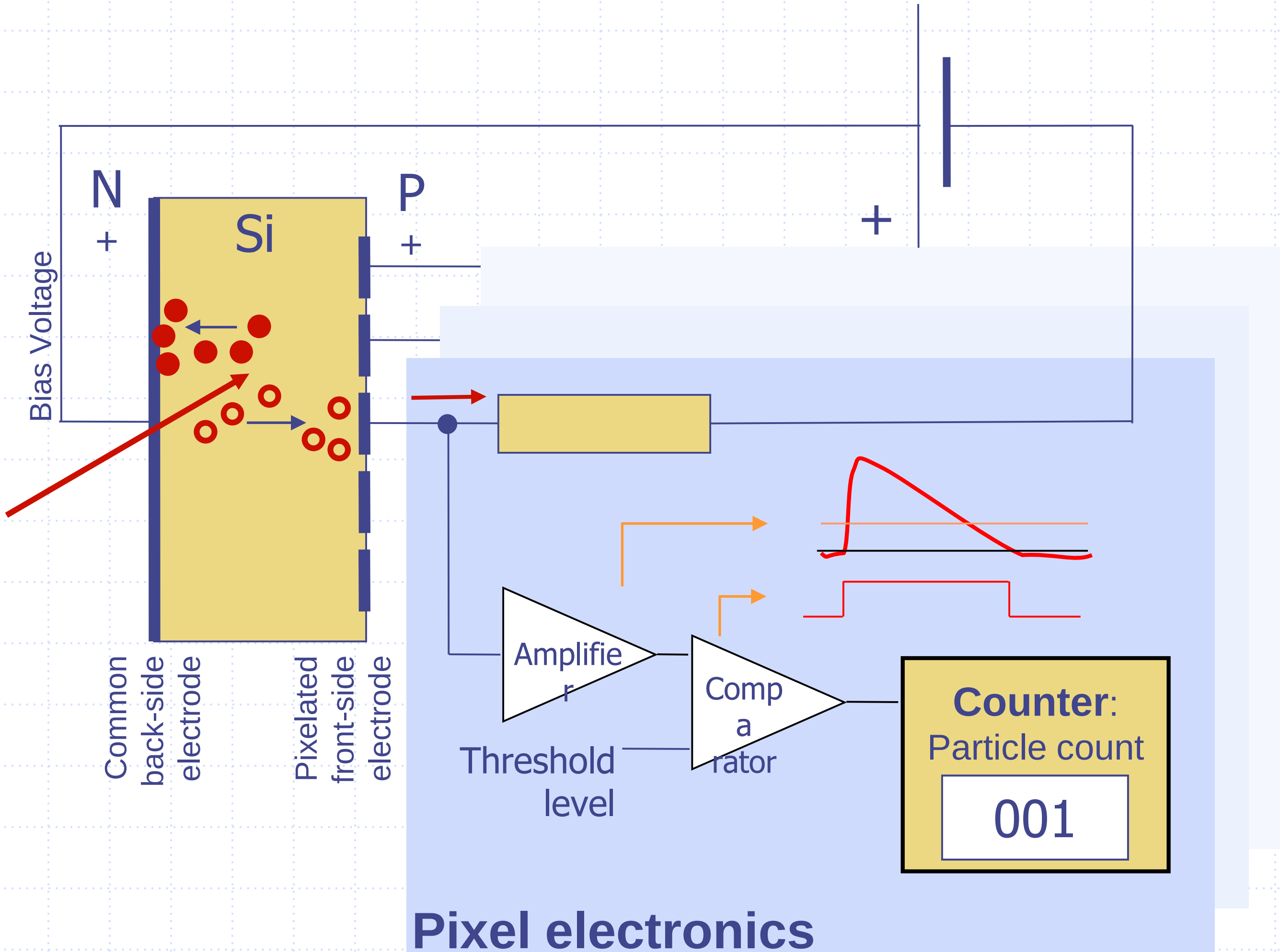
Electrons



Alphas



Principle of semiconductor single particle counting pixel detector



Threshold level above electronic noise
⇒No false counting.

Digital integration (counting)
⇒ No dark current.

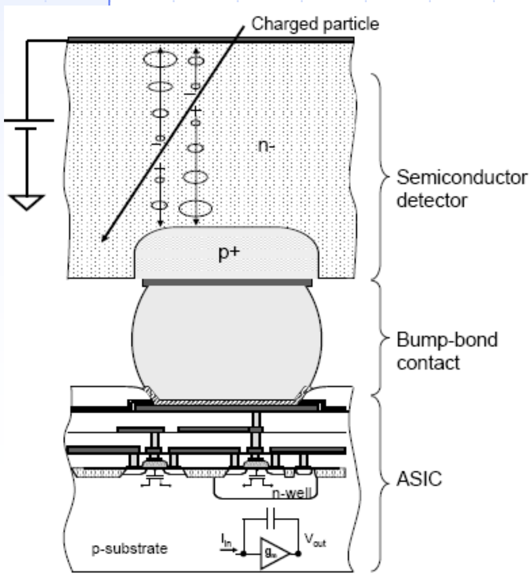
Unlimited dynamic range and exposure time.

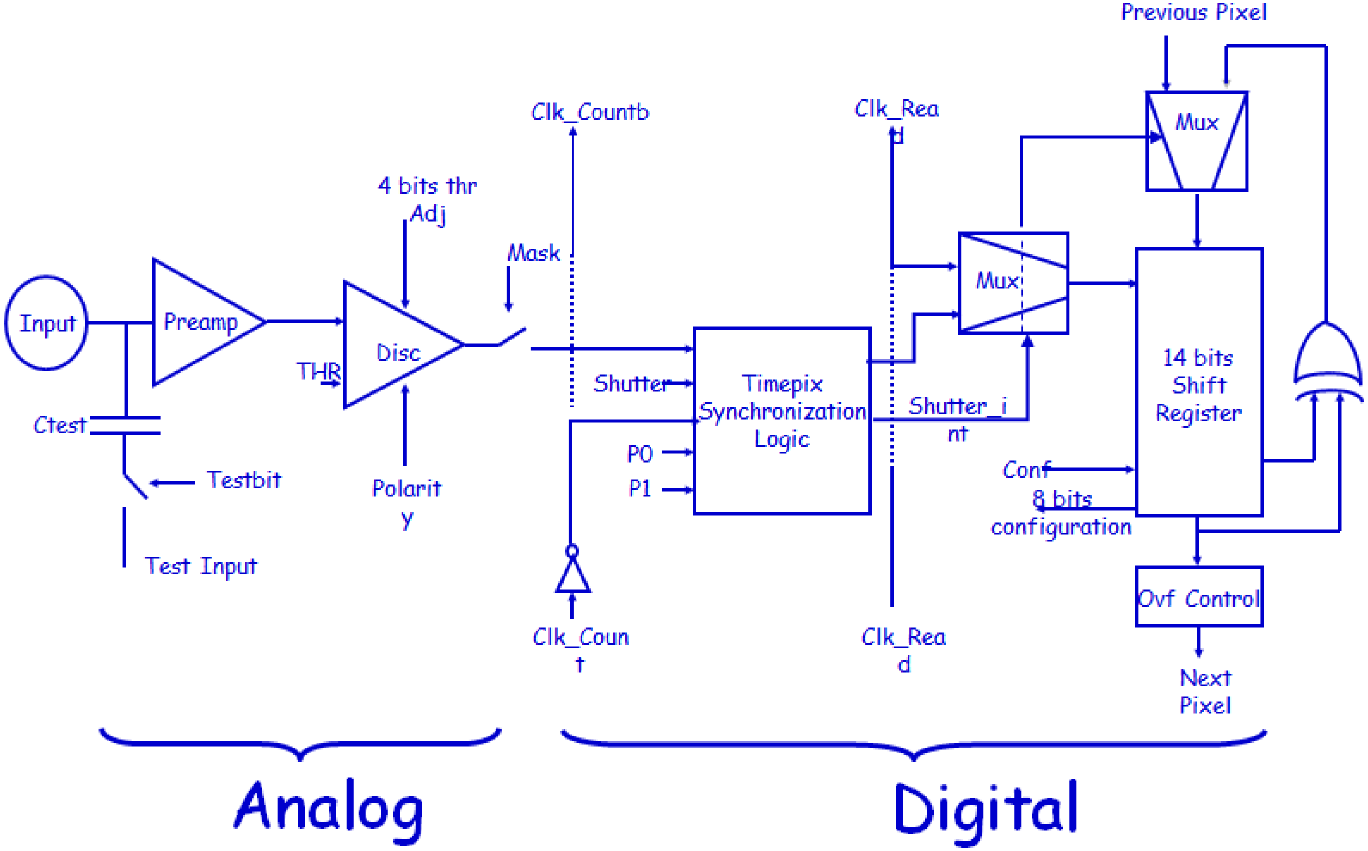
Detected count obeys poissonian distribution

Timepix read-out chip

Single pixel schematics

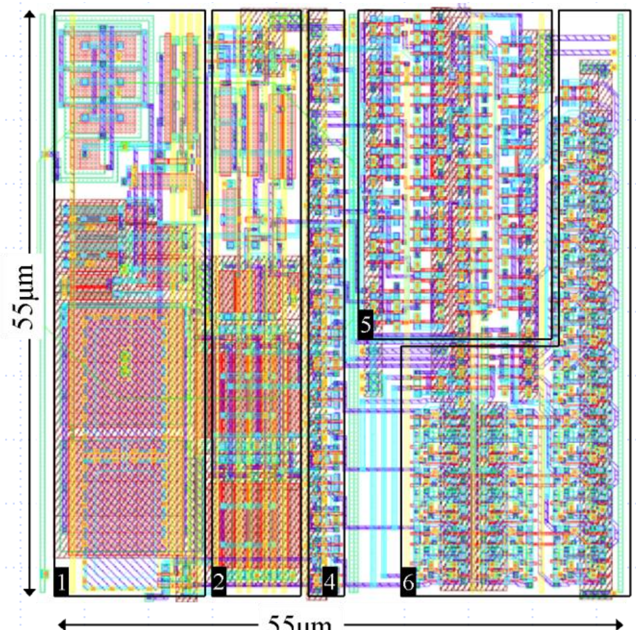
- Independent signal processing is performed in each individual pixel
- Very high level of miniaturization and functionality implementation
- All 65 536 detector channels (pixels) are running in parallel



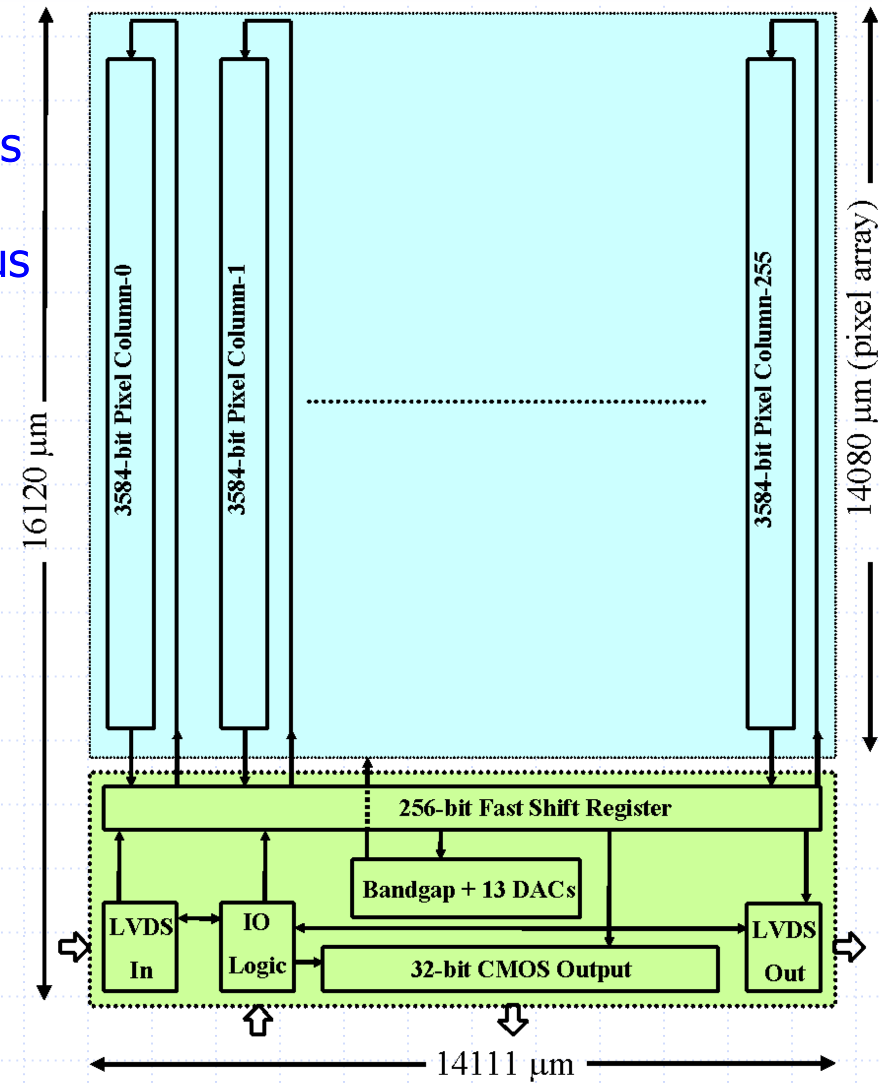


Timepix readout chip layout

- 256x256 55µm square pixels
- 36M Transistors
- Serial readout (@100MHz) -> 9.17 ms
  (~100 frames per second)
- Parallel readout (@100MHz) -> 287 µs
  (~3000 frames per second)



Single pixel floor plan



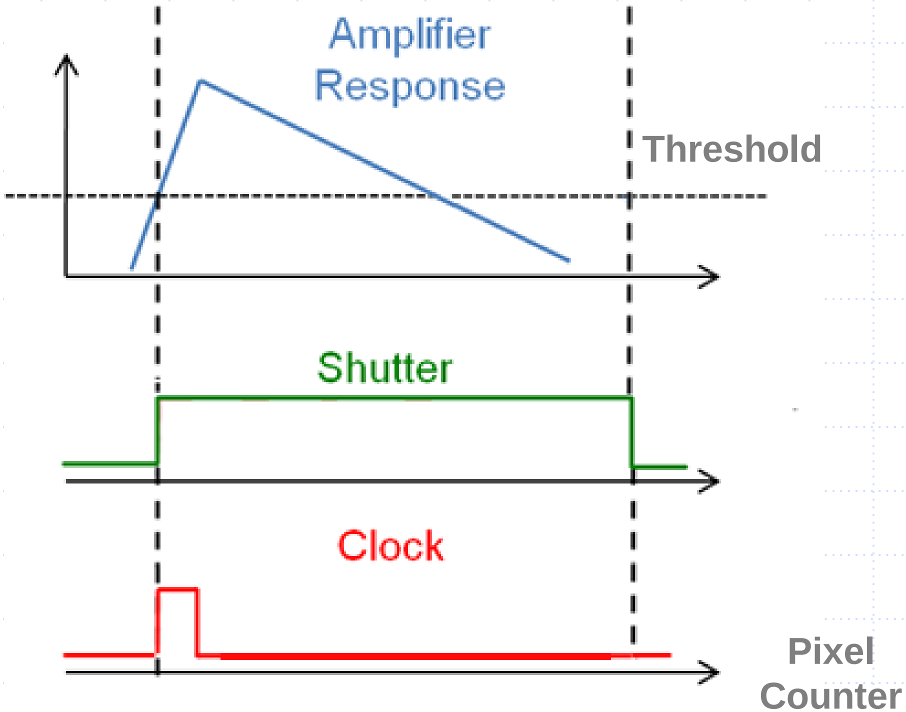
Pixel Operation Modes

- Each pixel can be configured to operate in different mode independently to other pixels

- **Medipix mode**
  Counter is incremented if incoming particle is registered
- **Time of Arival mode**
  Counter is continuously incremented from the time when first particle is registered
- **Time Over Threshold mode**
  Counter is incremented as long as a signal is over threshold
- **Masked mode**
  pixel is disabled

Medipix / Event Counting Mode

- **Each event registered is counted as 1**
- **Counter value equals to a number of interacted particles**
- **Event rate is limited by run up time and time of integration**



High contrast imaging:

Unlimited dynamic range

Example 1:

X-ray transmission

Image of mouse head

(dose 0.9 mGy)

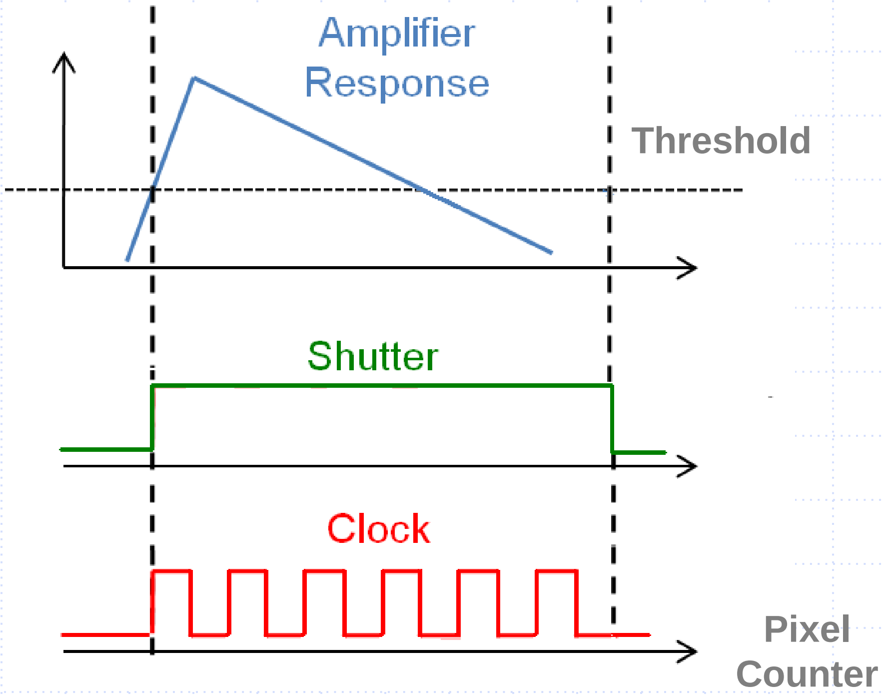
Single photon counting device can count unlimited number of photons, noise in images is given just by poissonian statistics:

=> Unlimited number of gray levels in images depending just on the beam intensity and exposure time.

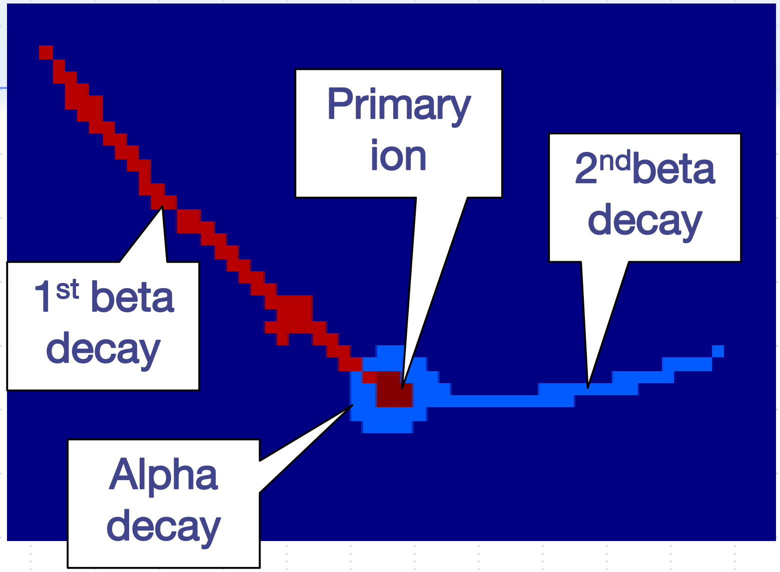
=> Almost unlimited contrast

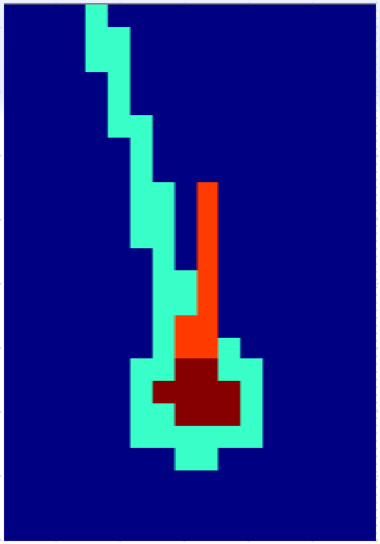
Timepix / Time Of Arrival Mode

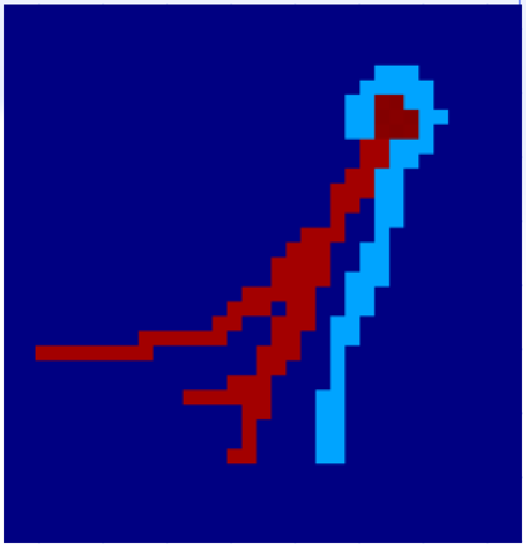
- Counts from passing threshold to closing shutter
- Allows accurate timing of hits in individual pixels

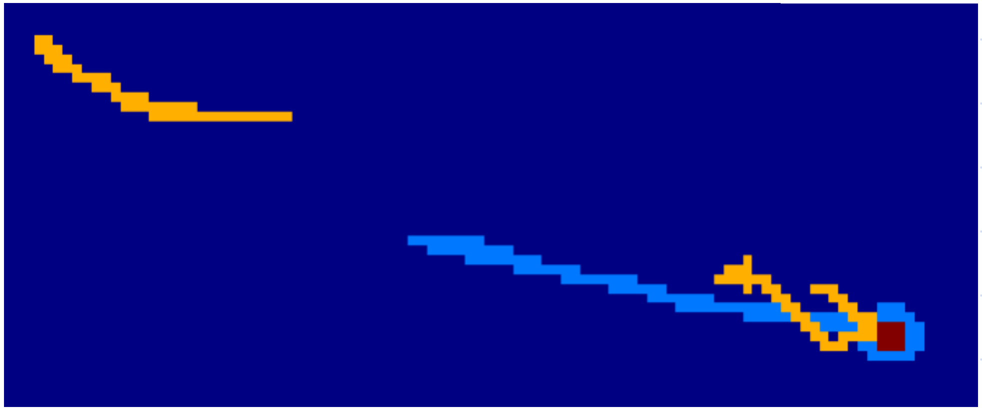


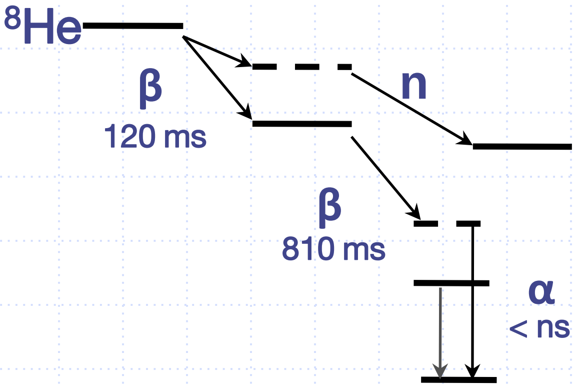
Measured events: ^{8}He decays (TOA Mode)





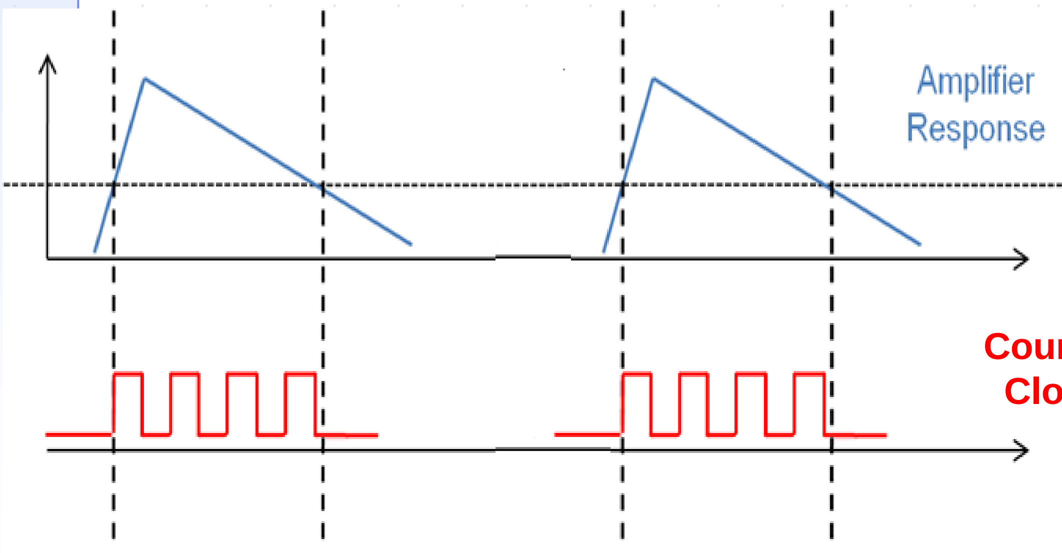


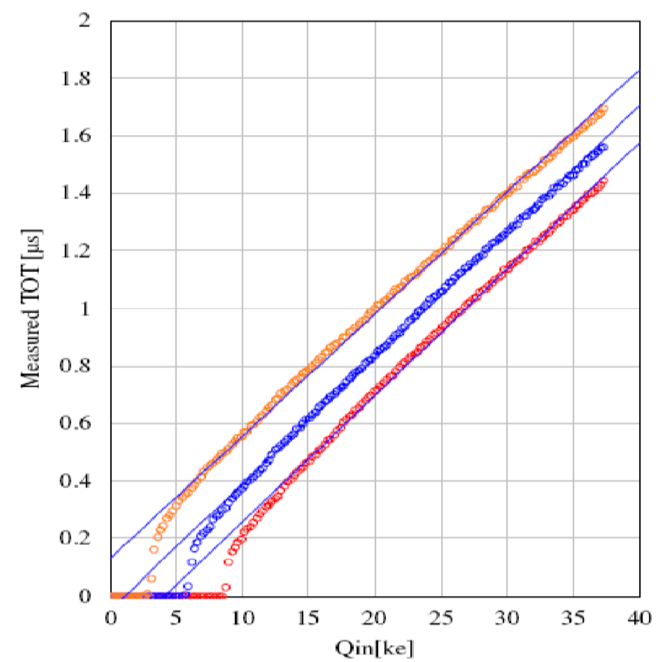




Time Over Threshold Mode
Energy measurement

Counter is incremented as long as a signal is over threshold





Linearity of one pixel measured at three different threshold values

E.g. 20ke- ~1us = 40 x 25ns (i.e. base clock 40 MHz)

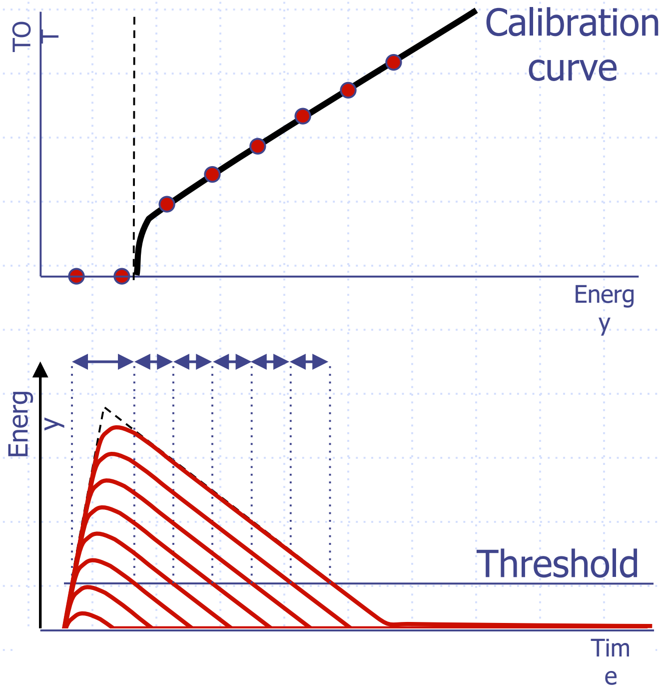
Residual errors come from non linearity with small charge signals and a slow return to baseline

Preamp has fast rise (90ns) but slow (500ns -2500ns) constant current return to zero

per pixel energy measurement:
Time Over Threshold mode

Counter in each pixel can be used as

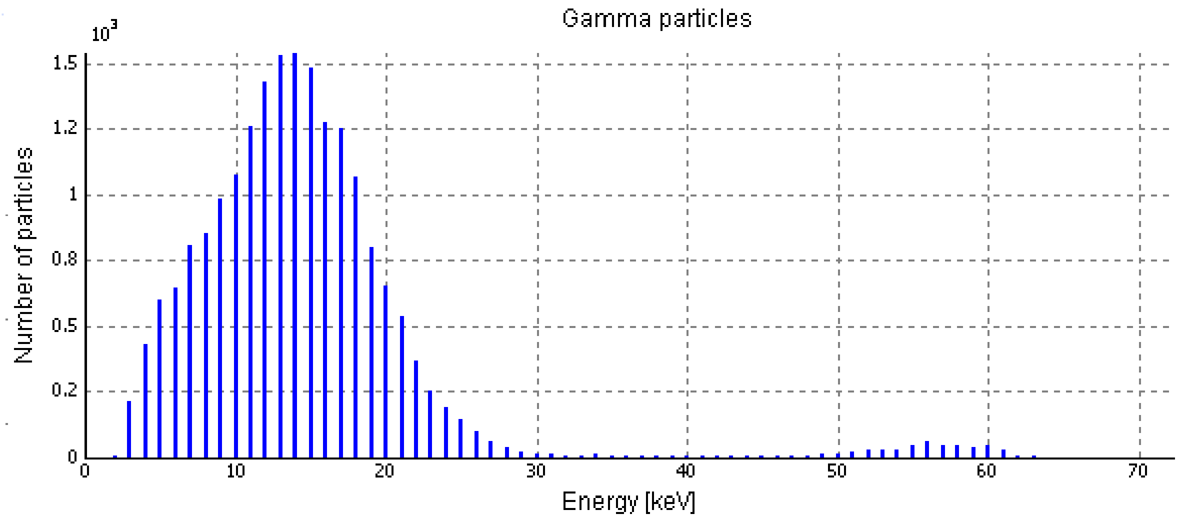
- Wilkinson type **ADC** to measure energy of each particle detected.

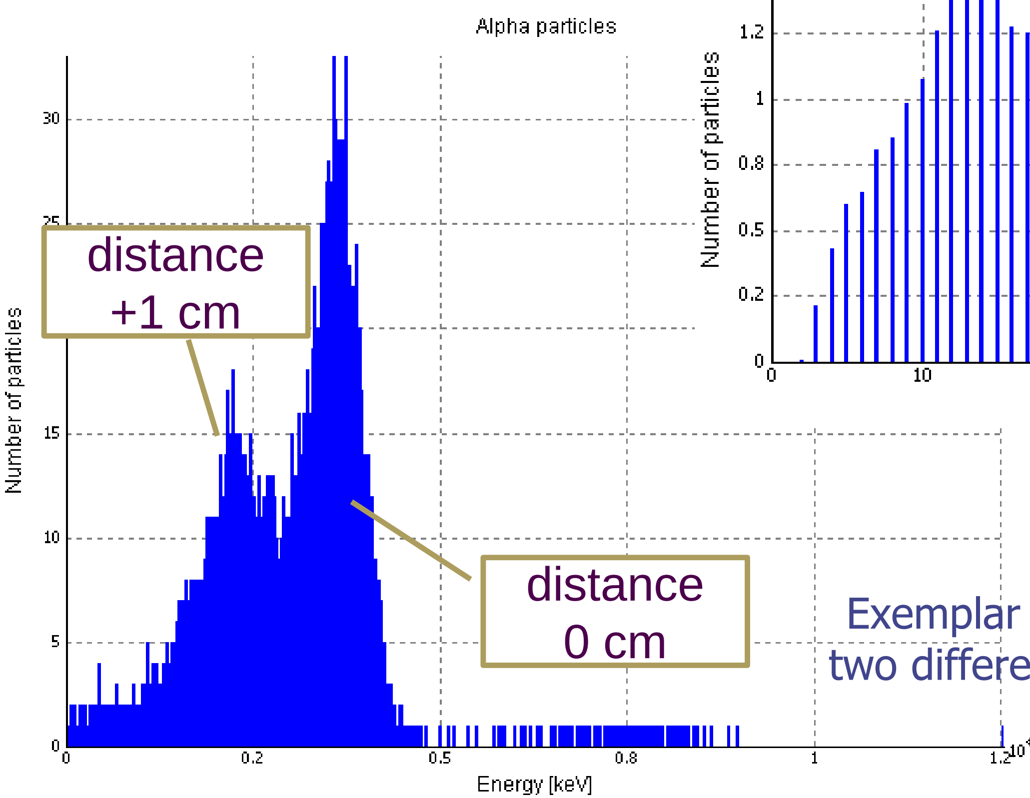


- If the pulse shape is triangular then Time over Threshold is proportional to collected charge i.e. to energy.
- Due to limited bandwidth the pulse can be NEVER perfectly triangular.
- Non-linear TOT to energy dependence

And when per-pixel calibration is applied on measured TOT values…

Exemplar ^{241}Am spectra





Exemplar ^{241}Am alpha spectrum measured in air at two different distances between the radiation source and the Timepix detector

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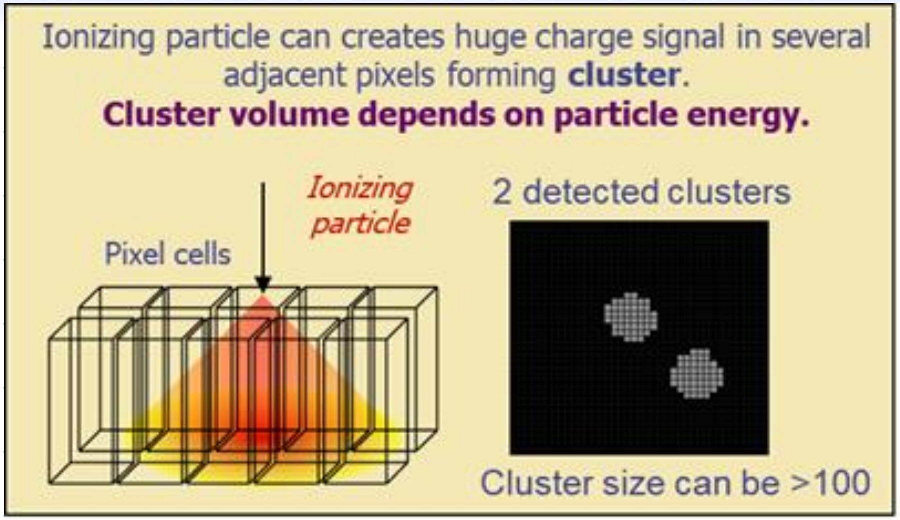
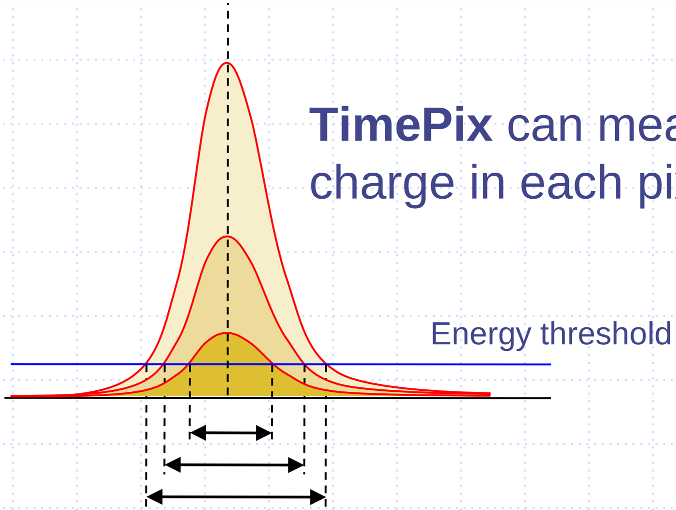
Charge Sharing Effect
creation of clusters

- Ionizing particle creates a charge in the sensor.
- The charge is collected by external electric field => the process takes some time
- Due to charge diffusion the charge cloud expands
- The charge cloud can overlap several adjacent pixels => **CLUSTER**
- Pixels in a cluster will detect the charge if it is higher than certain threshold

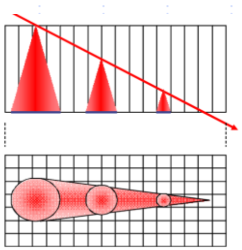
The Cluster size depends on:

- Particle energy and range
- Depth of interaction
- Detector Bias Voltage
- Local CCE (e.g. due to a material inhomogeneities and radiation damage)





TimePix can measure charge in each pixel



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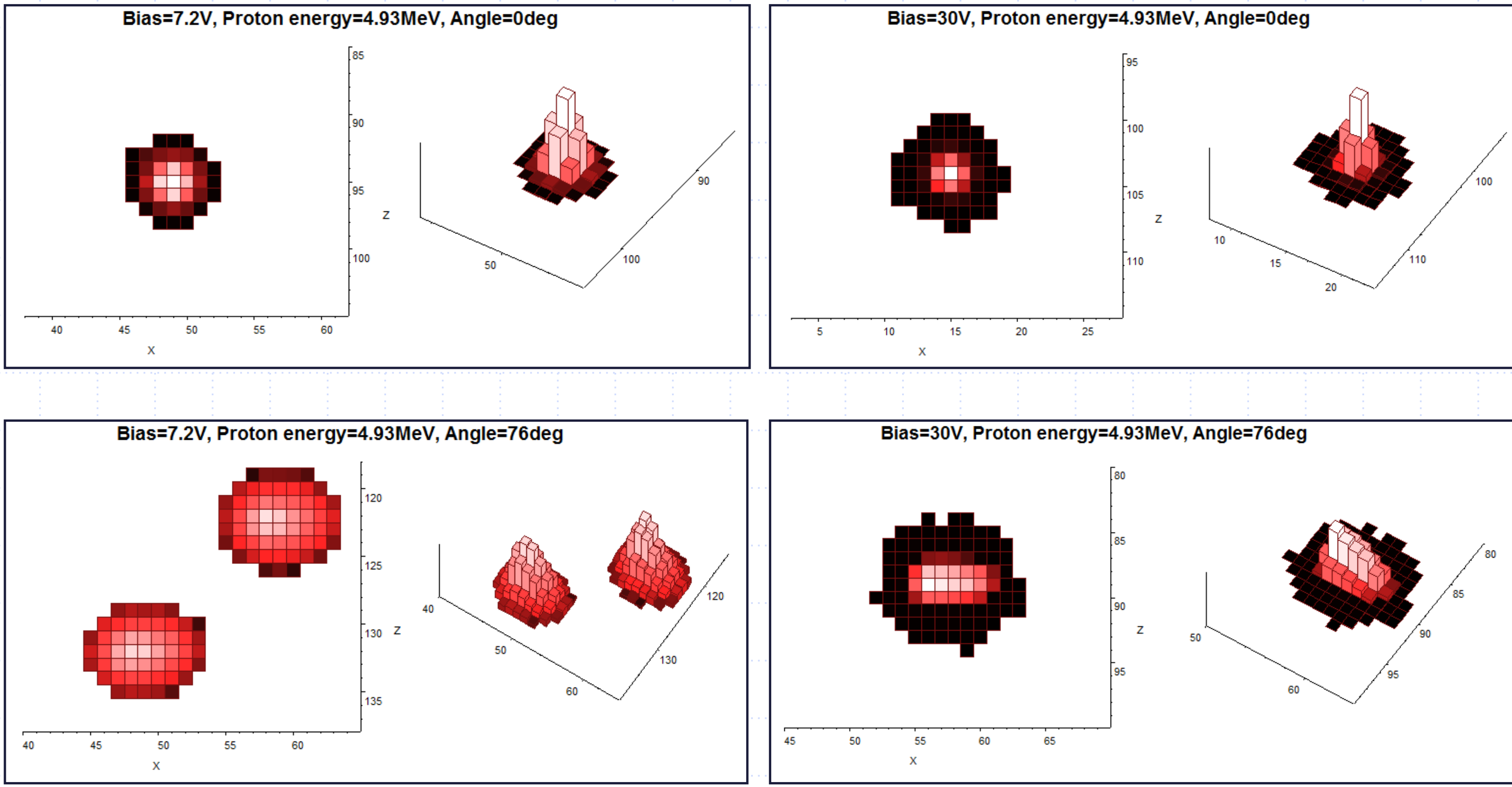
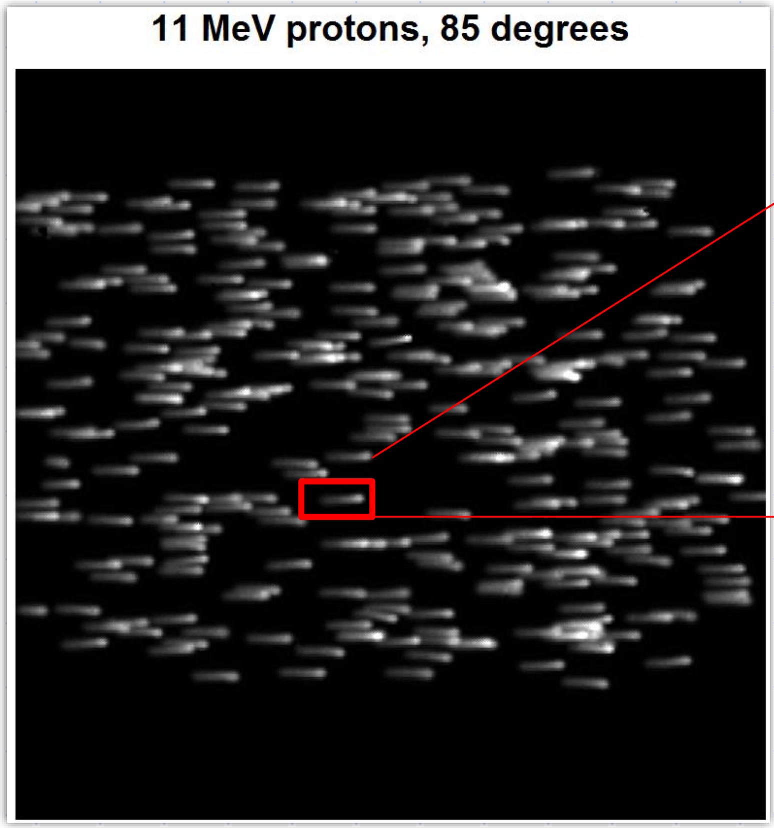
4.93 MeV proton tracks in silicon pixel detector recorded by Timepix device. Exposition under different angles and different applied detector biases.

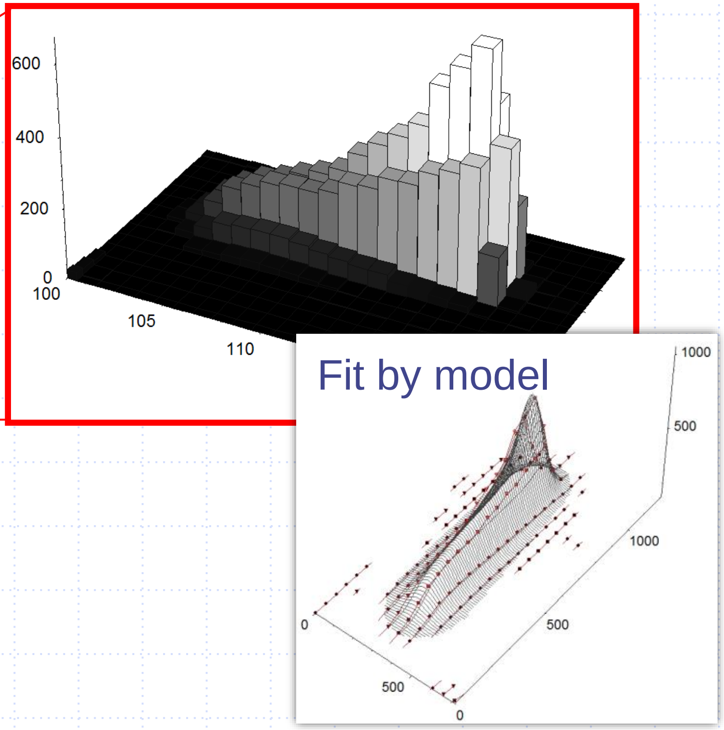


What is the spatial resolution? X- and Y-coordinates are determined with a precision of about 500nm. Determination of angle is with a precision of about 1º. It needs additional experiments.

Flock of 11 MeV protons entering the silicon sensor under 85°



ΔE/Δx Bragg profile nicely pronounced, proton range about 960 μm

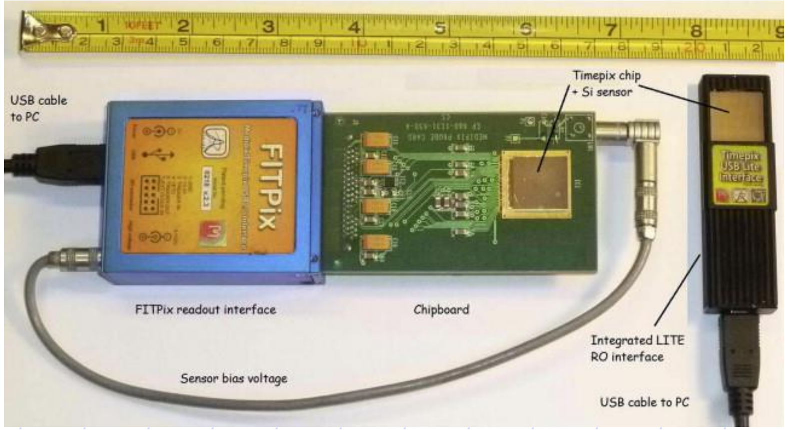


Readout interface and its role in data the acquisition process

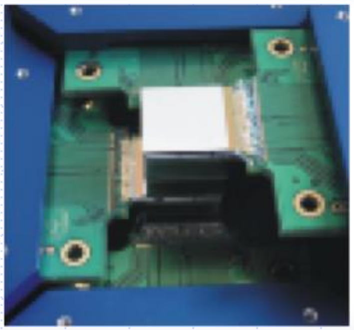
Detector supporting electronics

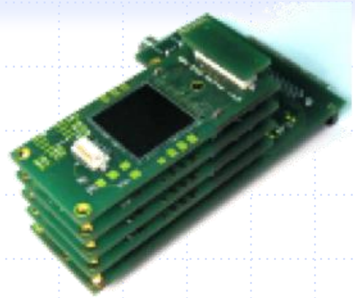
- Acquisition control
- Detector powering
- Data transfer (USB, Ethernet, …)

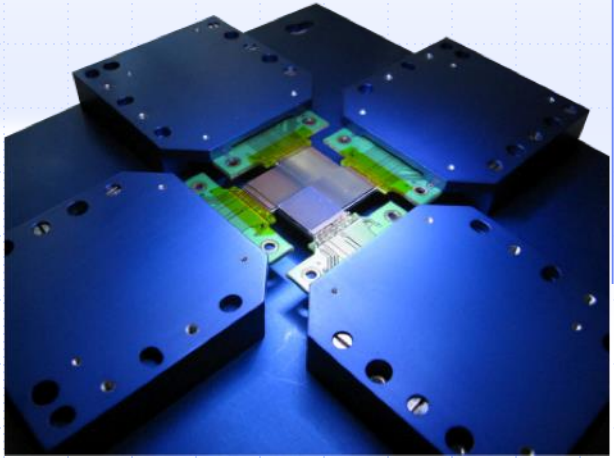
Never ending need for a development of application specific variants of readout interfaces (vacuum operation, space environment, multi-detector arrays,…)



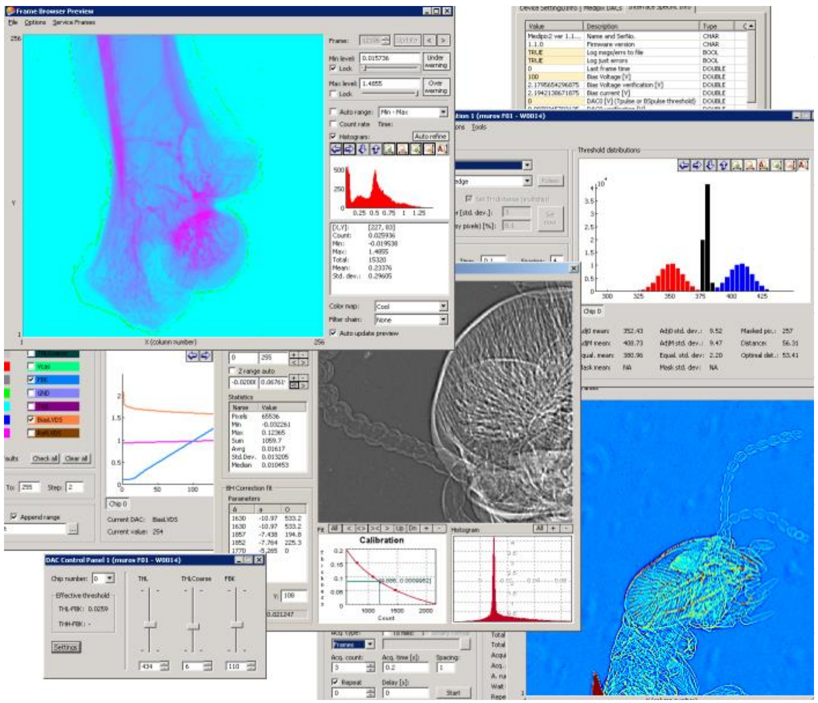
Timepix based devices developed and tested in IEAP CTU







Data Acquisition Control Software



Finally, it makes Timepix detector a powerful tool.

Otherwise it is useful as a car without the steering wheel.

PIXELMAN – *IEAP CTU*

Acquisition and control tool for Medipix & Timepix Detectors

SESTRA - School Education Set with Timepix for Radiation Analysis

SESTRA Kit Components

- Particle Camera MiniPixEDU
  (Timepix detector, calibrated)
- Control Software
  Pixelman Simple preview & Pixet basic (acquisition, online visualisation, etc.,)
- SZZ Alfa
  (241Am, α and γ source, 9.5 kBq)
- DZZ Gamma
  (241Am, γ source, 300 kBq, optional)
- Potassium Salt
  (β and γ source)
- Thoriated Tungsten Electrode
  (α, β and γ source)
- Uranium Glass
  (α, β and γ source)
- Mounting Rails
- Source Holder
- Camera Holder
- Aluminium, Stainless, Copper, Brass and Lead Shielding Plates
- Radiography Adapter Head
  +*Samples with Hidden Patterns*
- Vacuum Cleaner Grate Adapter
- USB Cable
- Book of detailed guidelines
  "Experiments Using Pixel Detector in Teaching Nuclear and Particle Physics"

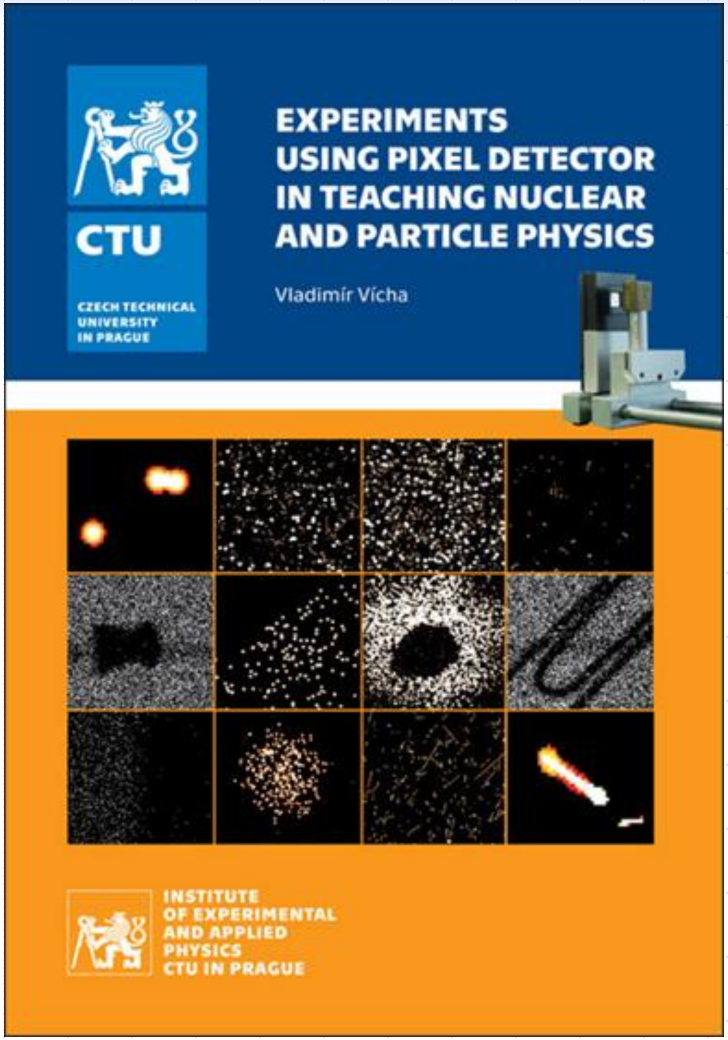
Set of kit accessories was designed according to practical experiences gained while using the Timepix for teaching of students...

Detailed guidelines to experiments practicable with Timepix based particle camera

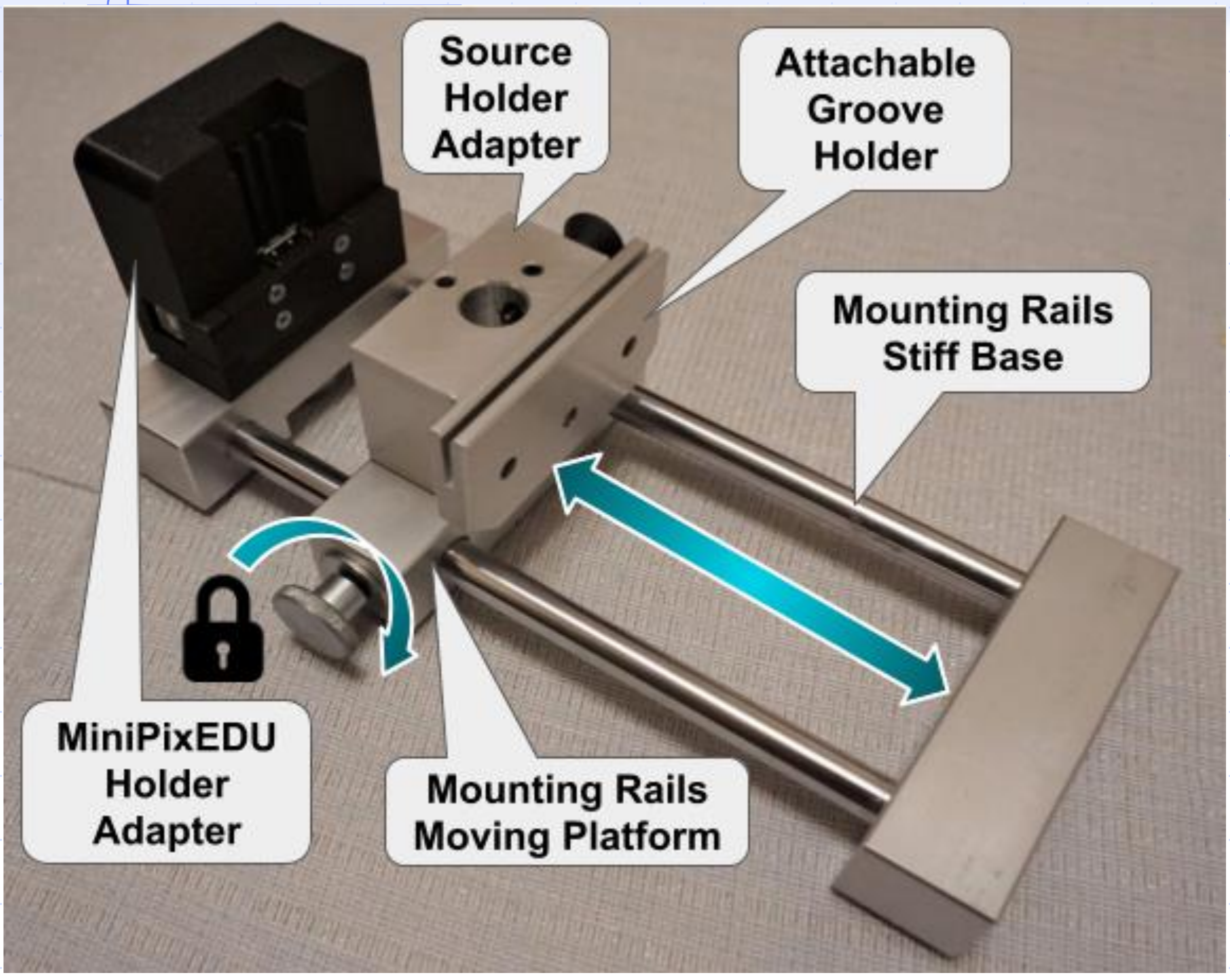
Wide set of 50 experiments

...involving detection and recognition of different kinds of ionising radiation in pixel detector, observation of natural background radiation, space originating radiation, basics of radiography....

Focused on high school students and university students by means of practical exercises to help them to understand physics and motivate them in further learning



Mechanics of the SESTRA educational kit



- Fast (re)arrangement of various experimental set-up(s)
- *Prepared for performing of real time demonstrations within a time span of the standard classes*

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Set of Radiation Sources in the SESTRA kit

- **Thoriated Tungsten Electrode** ***(α, β and γ source)***
- **Uranium Glass** ***(α, β and γ source)***
- **Potassium Salt** ***(β and γ source)***
- ***241Am α and γ source 9.5 kBq (optional)***
- ***241Am γ source 300 kBq (optional)***

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URANIUM Glass Radioactivity

Sample included in the kit

- Uranium serving as a yellowish-green glass colorant
- Freely available on the market in the form of various decorative items

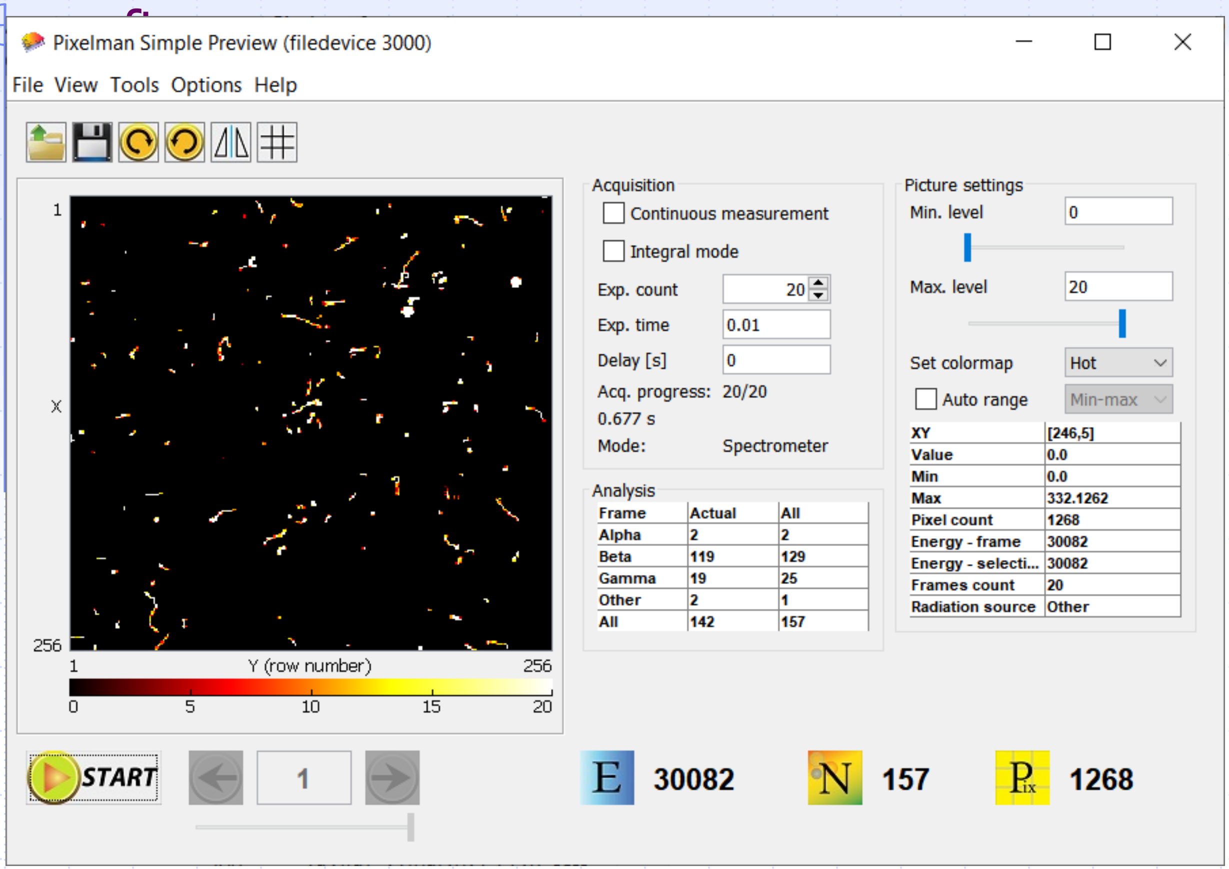
Uranium

^{235}U, 0.72%, $T_{1/2}$ = 7,0.10^8 years

^{238}U, 99.274%, $T_{1/2}$ = 4,5.10^9 years

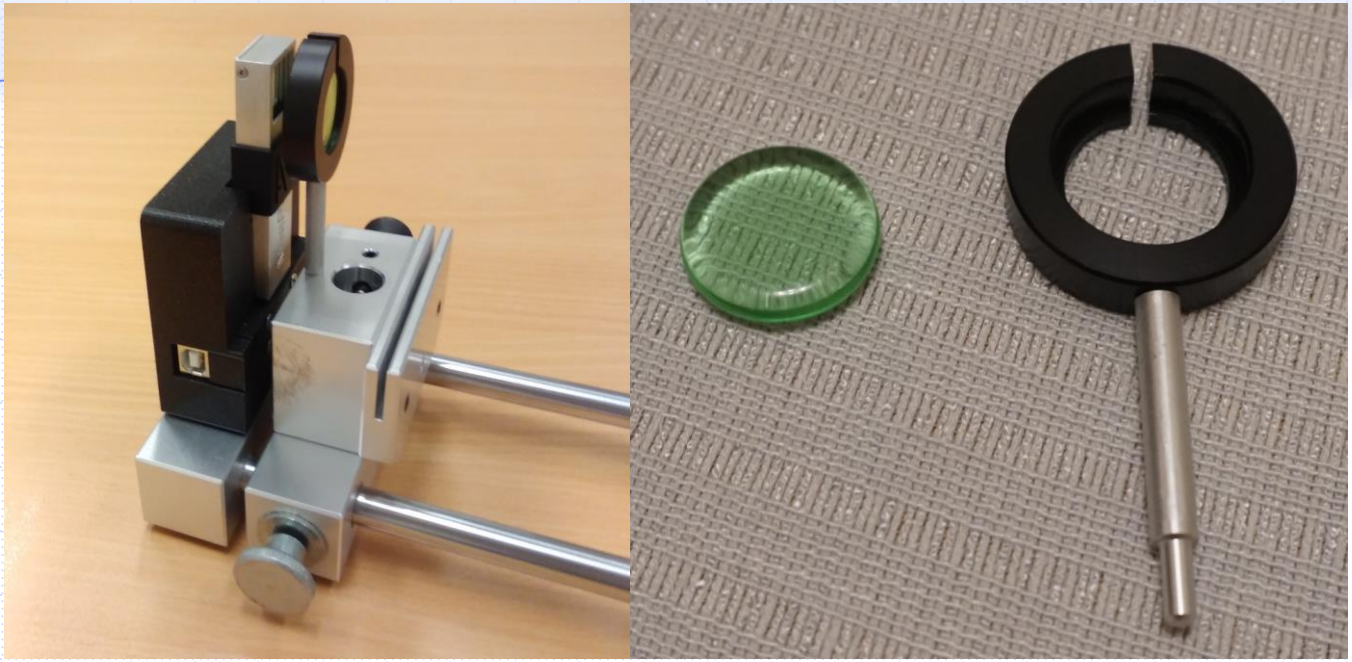
Pixelman - Simple Preview

Measurement control, data acquisition and visualisation



- The main control window appears after starting application “Pixelman.exe”
- One window instance for the real Particle camera and one instance for a virtual (file reader) device will appear on the screen.

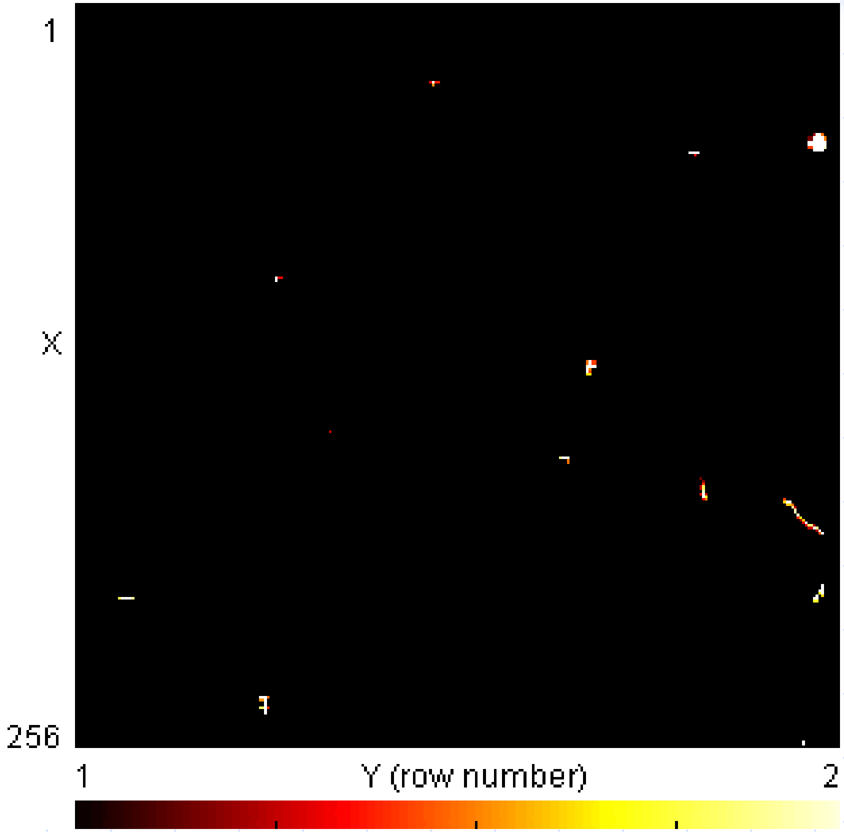
Uranium Glass
preparation of measurement



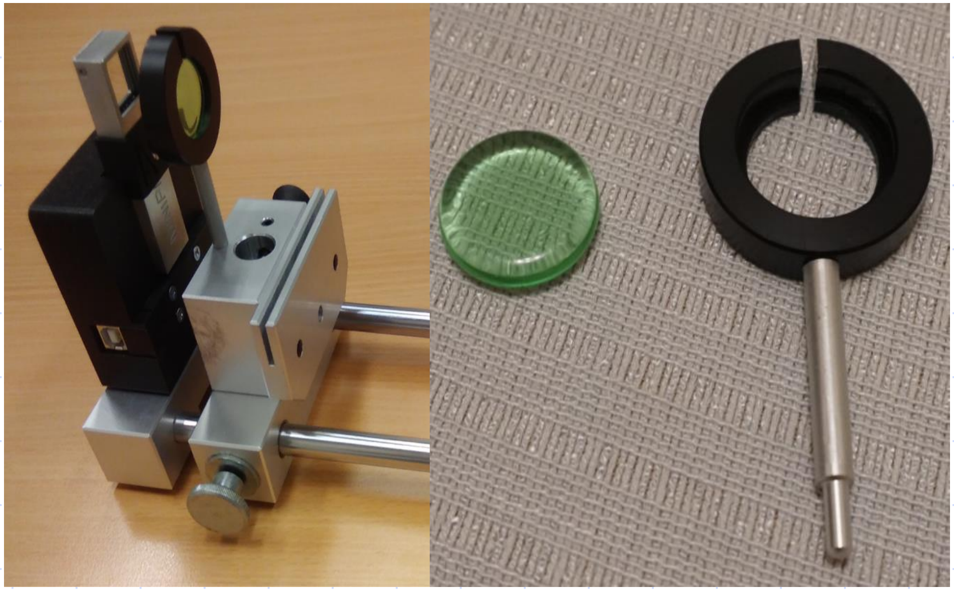
Experiment set-up:
Particle camera and computer, mounting rails, uranium glass sample placed in the source holder close to the detector

Settings:
Exp. count: 60
Mode: Spectrometer
Analysis type: Basic
Bias voltage: 20V
Integral mode: No
Continuous measurement: No
Exp. time: 1 s
Min. level: 0
Max. level: 20
Colormap: Hot

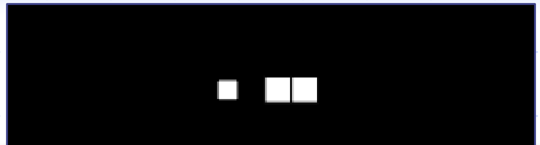
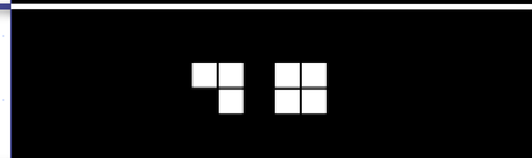
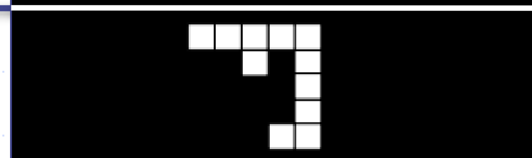
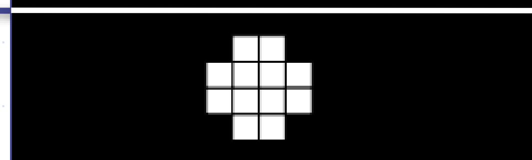
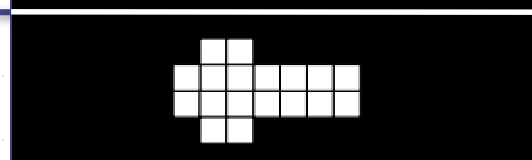
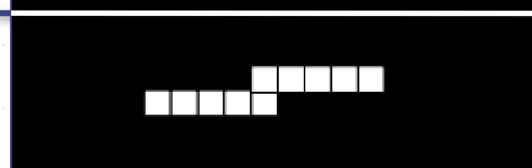
URANIUM Glass Radioactivity Observation



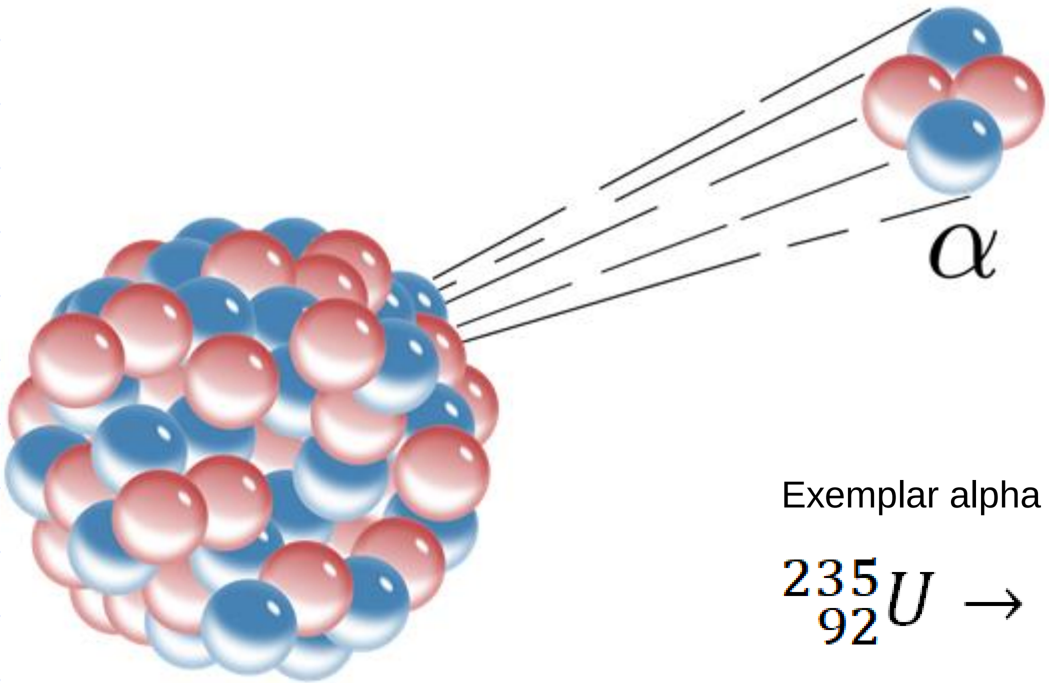
- Uranium glass as a weak source of mixed radiation field
- Evidence of alpha, beta, gamma particle detection



Review of the characteristic patterns

1) Dot		Photons and electrons (10keV)
2) Small blob		Photons and electrons
3) Curly track		Electrons (MeV range)
4) Heavy blob		Heavy ionizing particles with low range (alpha particles,…)
5) Heavy track		Heavy ionizing particles (protons,…)
6) Straight track		Energetic light charged particles (MIP, Muons,…)

Radiation Origin Overview
Alpha Particles

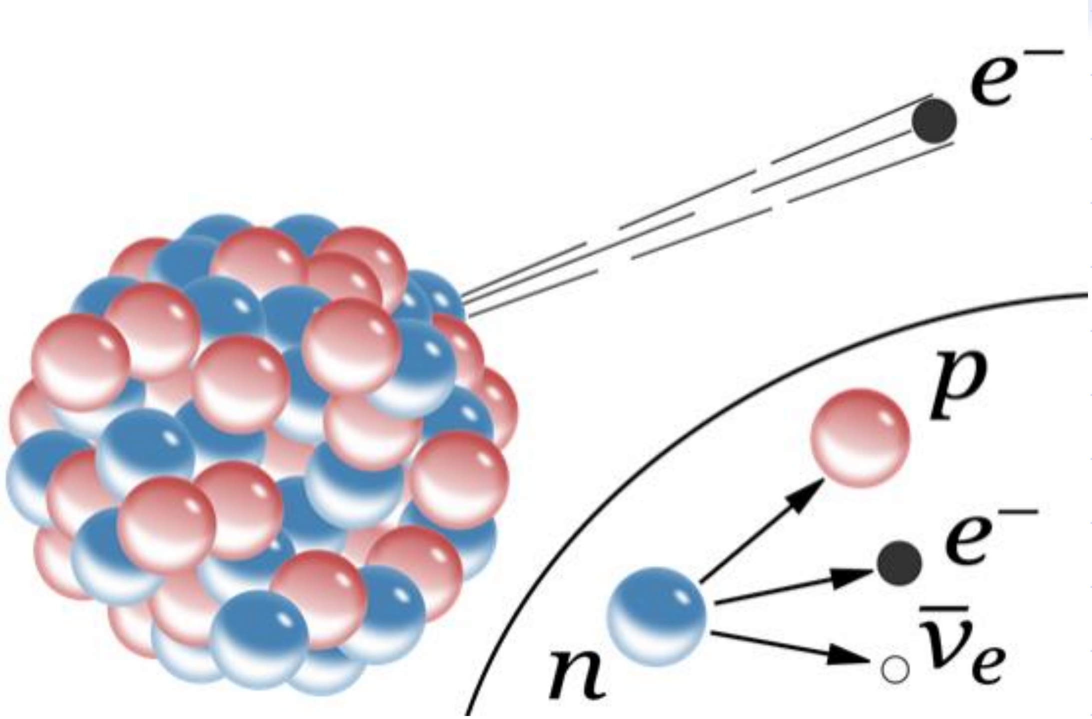


Exemplar alpha decay

$$^{235}_{92}U \rightarrow \, ^{232}_{90}Th + \, ^{4}_{2}He$$

https://en.wikipedia.org/wiki/Alpha_particle

Radiation Origin Overview
Beta Particles

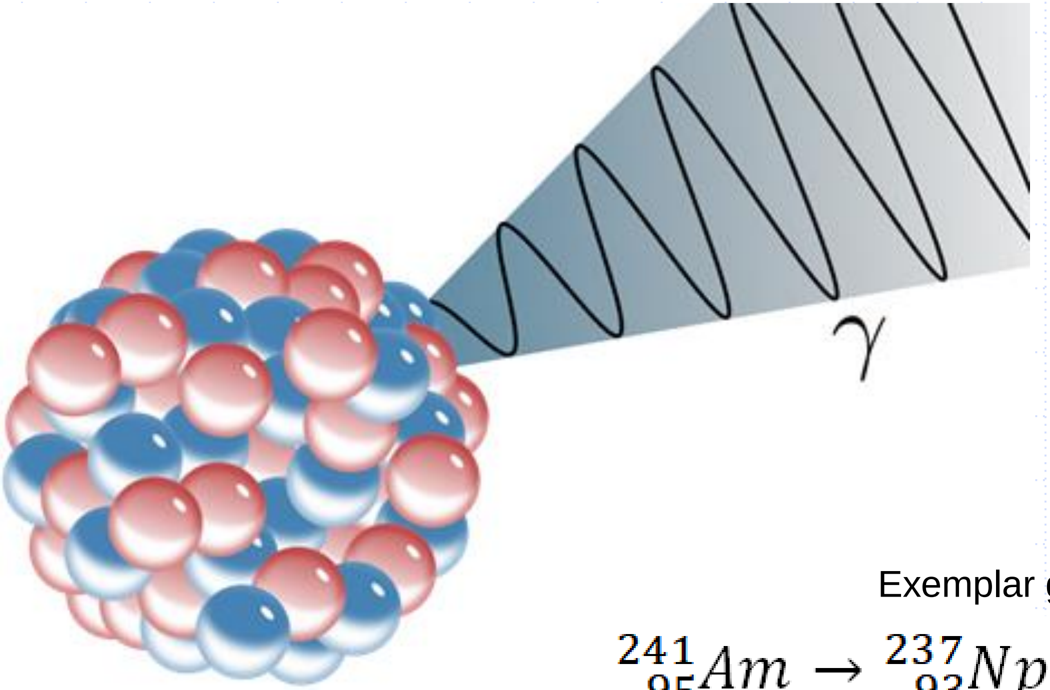


Exemplar beta- decay

$$^{231}_{91}Th \rightarrow\, ^{231}_{91}\mathrm{Pa} + \,^{0}_{-1}e + \tilde{\nu}$$

https://en.wikipedia.org/wiki/Beta_particle

Radiation Origin Overview
Gamma Photons



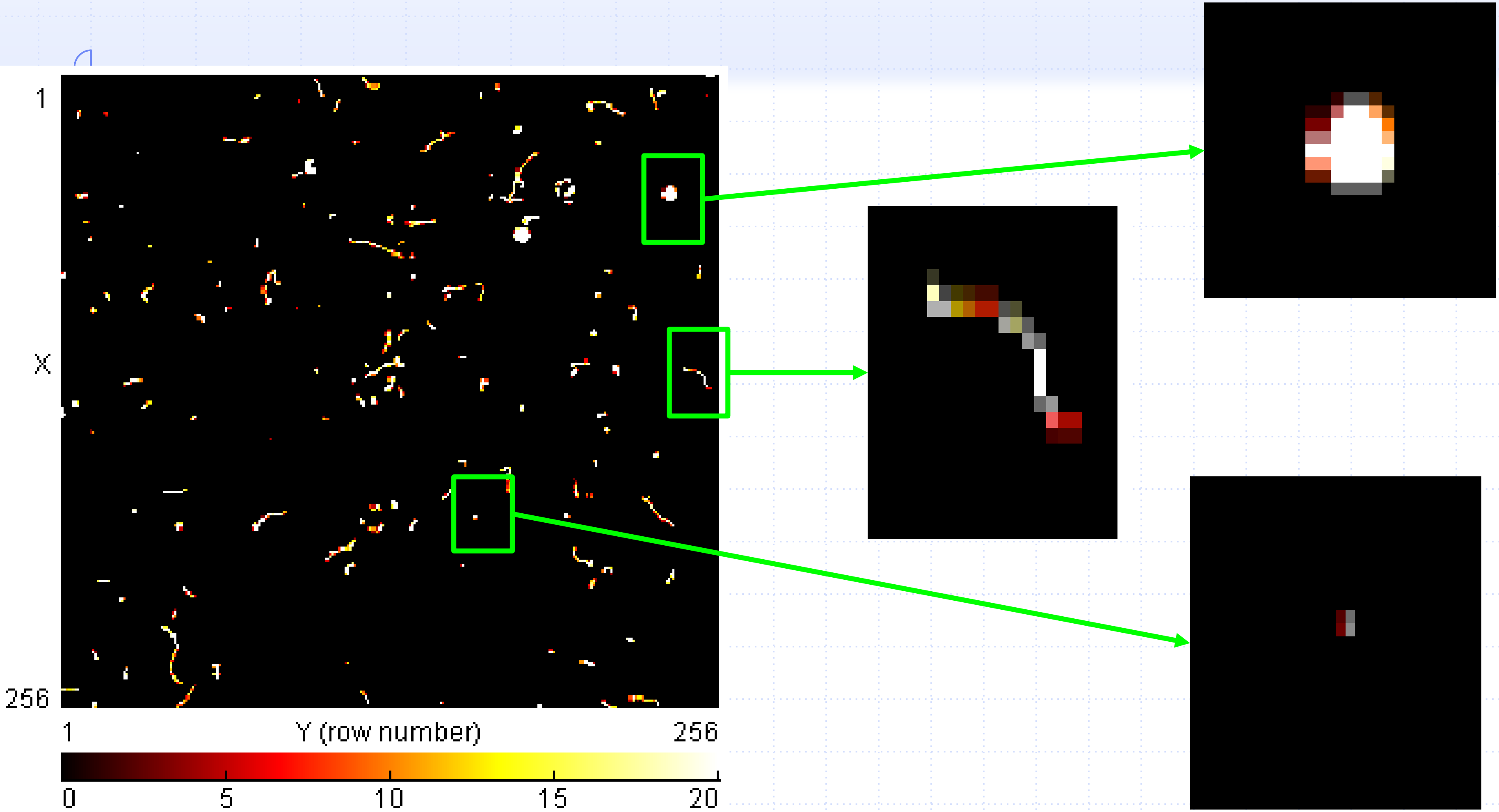
Exemplar gamma photon emission

$$^{241}_{95}Am \rightarrow {}^{237}_{93}Np^{*} + {}^{4}_{2}He$$

**The nucleus in an excited state returns to the ground state by emitting a photon.*

https://en.wikipedia.org/wiki/Gamma_ray

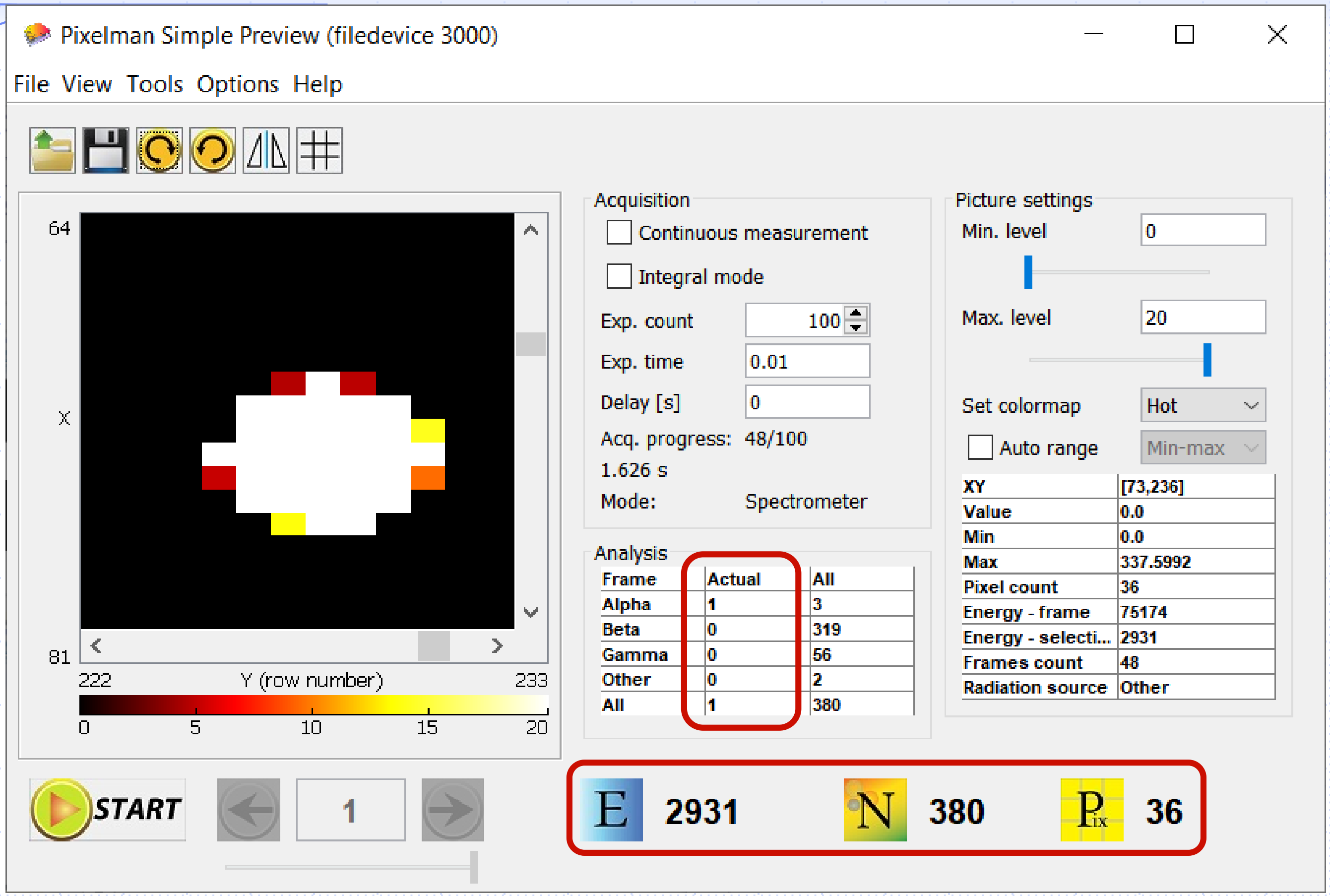
Uranium Glass Radioactivity Close Look Observation



- Evidence of alpha, beta, gamma particle detection

Uranium Glass Radioactivity

Close look on a single particle



When zoomed-in, properties of single particle track can be obtained (deposited energy in keV, cluster area, track type classification)

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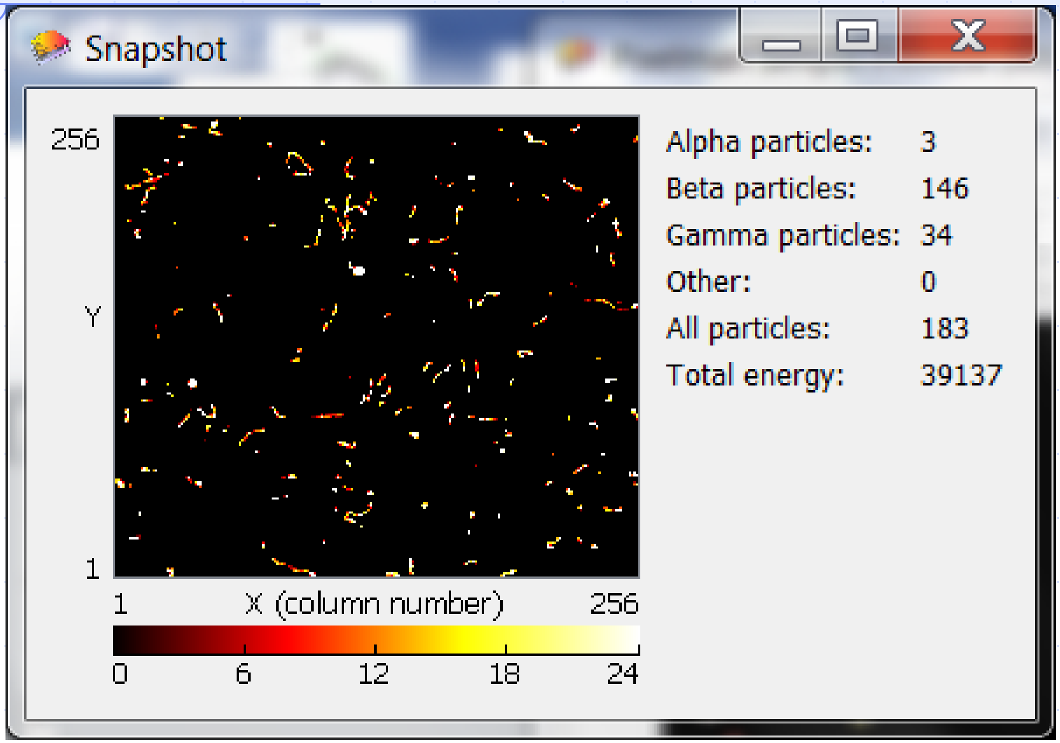
Uranium Glass Radioactivity
as seen by the Timepix pixel detector



Several useful hints on software functionality

Getting a snapshot (Menu: Tools -> Snapshot)

Displaying of integral frame composed of separate frames (Menu: Tools -> Integral frame)

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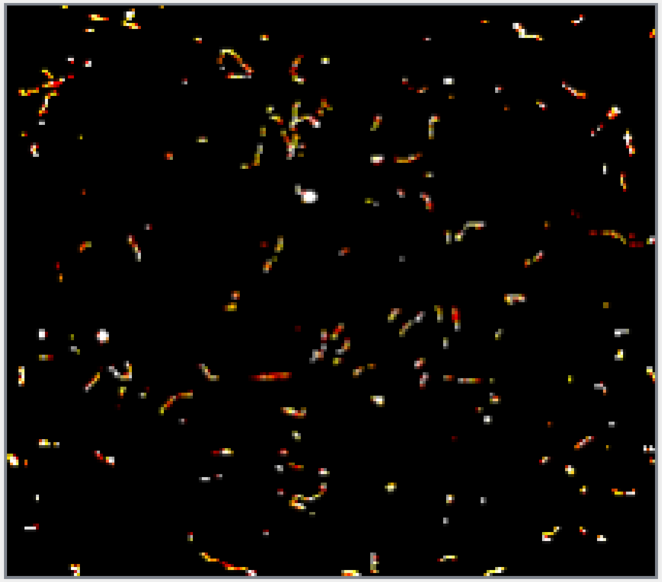
Kinetic Energy Absorbed in the Sensor, How to find-out speed of hitting particle

The Einstein relation

$$E = E_0 + E_k$$

$$v = c\sqrt{1 - \frac{1}{\left(1 + \frac{E_k}{E_0}\right)^2}}$$



Speed of alphas?

Speed of betas?

Rest mass energy:

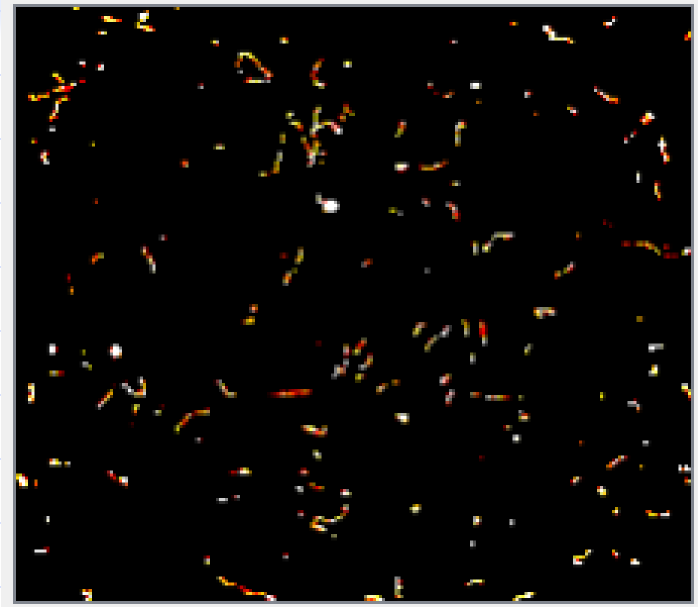
Alpha: E_0 =3,735,000 keV ,

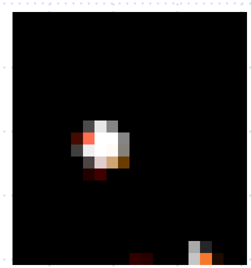
Beta: E_0 = 511 keV

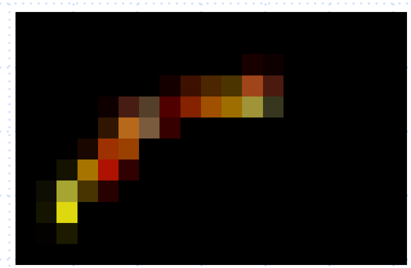
Hint:
Use the excel table "Speeds of particles i lambda.xlsx" to compute speed of observed particles

Kinetic Energy Absorbed in the Sensor, How to find-out speed of hitting particle

- What are the highest energies of detected alphas, bettas and gammas?
- Speed of alphas
  VS
  speed of bettas?
- Can speeds of alphas or betas be comparable to speed of light?







E_{max} ?

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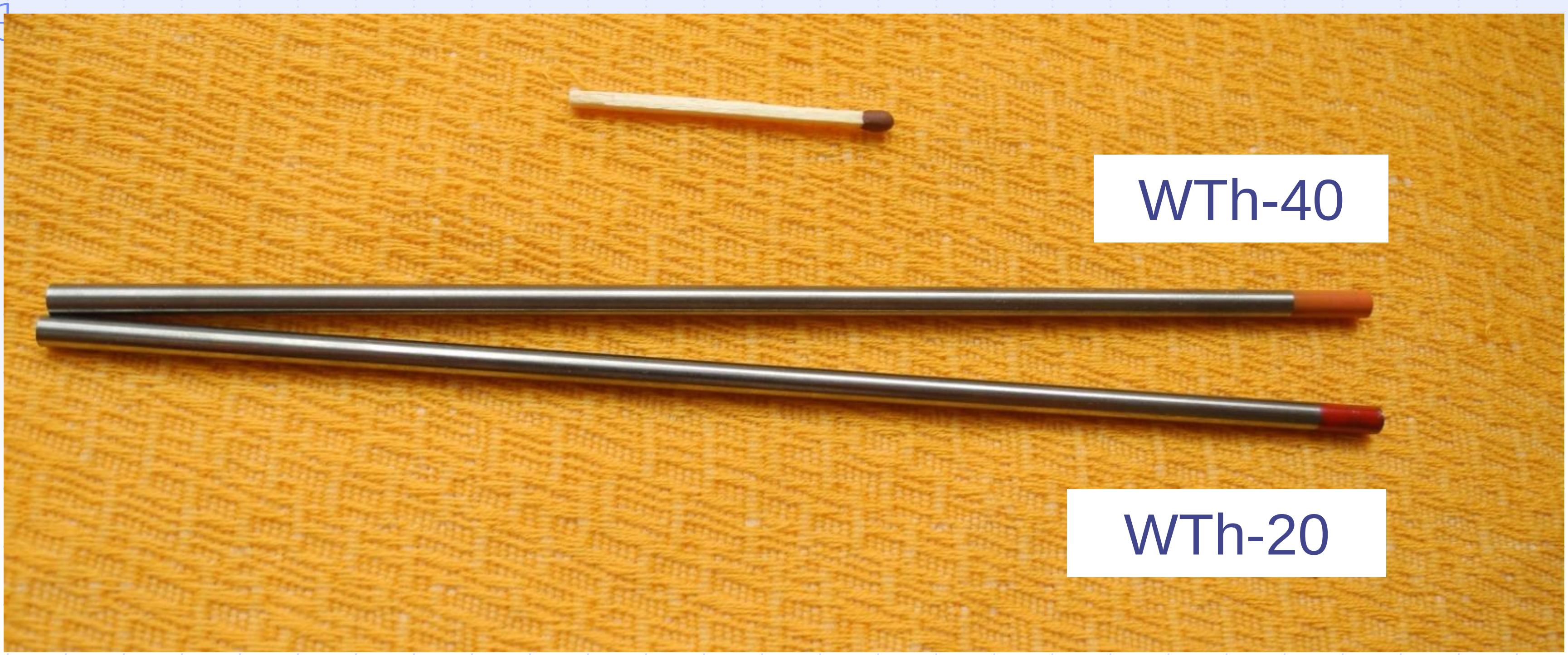
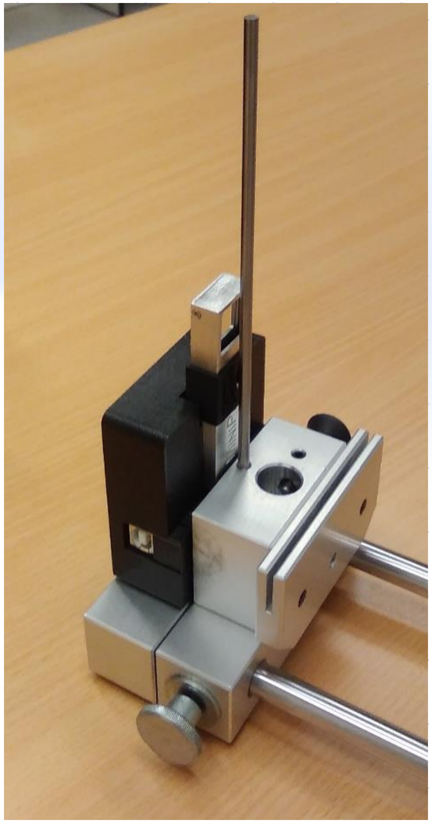
Tungsten Welding Electrode with THORIUM



Thorium ^{232}Th, $T_{1/2} = 1{,}4.10^{10}$ years

Age of the Earth: $4{,}5.10^{9}$ years

Thoriated Welding Rod
preparation of measurement

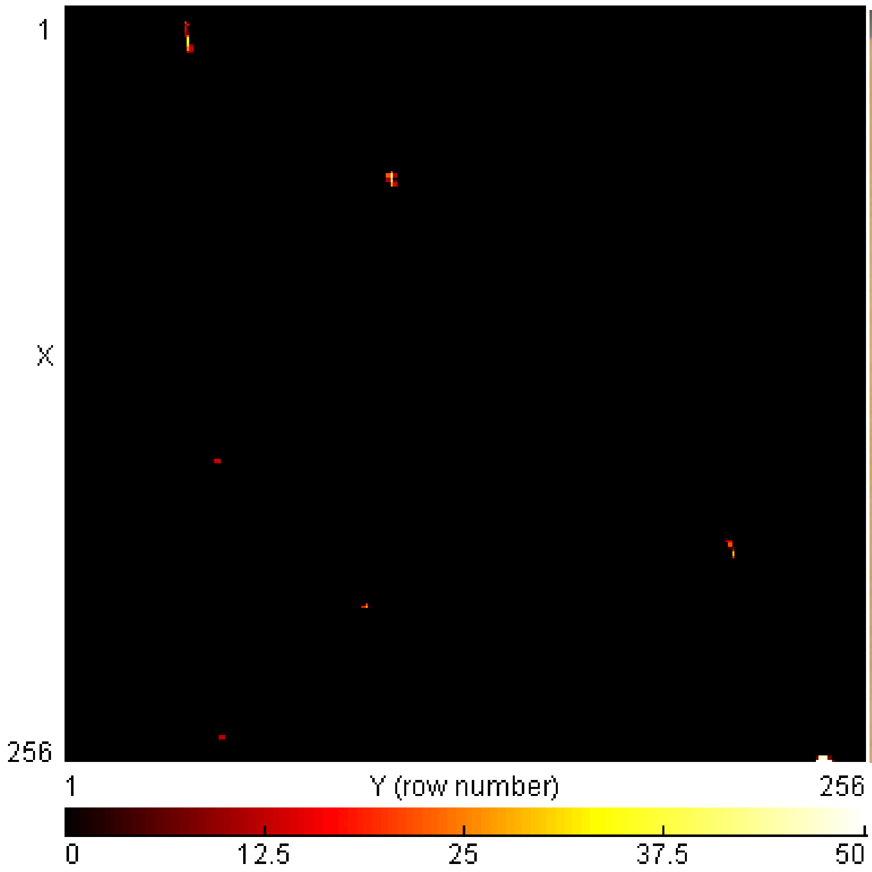


Experiment set-up:
Particle camera, computer, mounting rails, thorium welding rod in a holder.
Settings:

Exp. count: 60
Mode: Spectrometer
Analysis type: Basic
Bias voltage: 20V
Integral mode: No

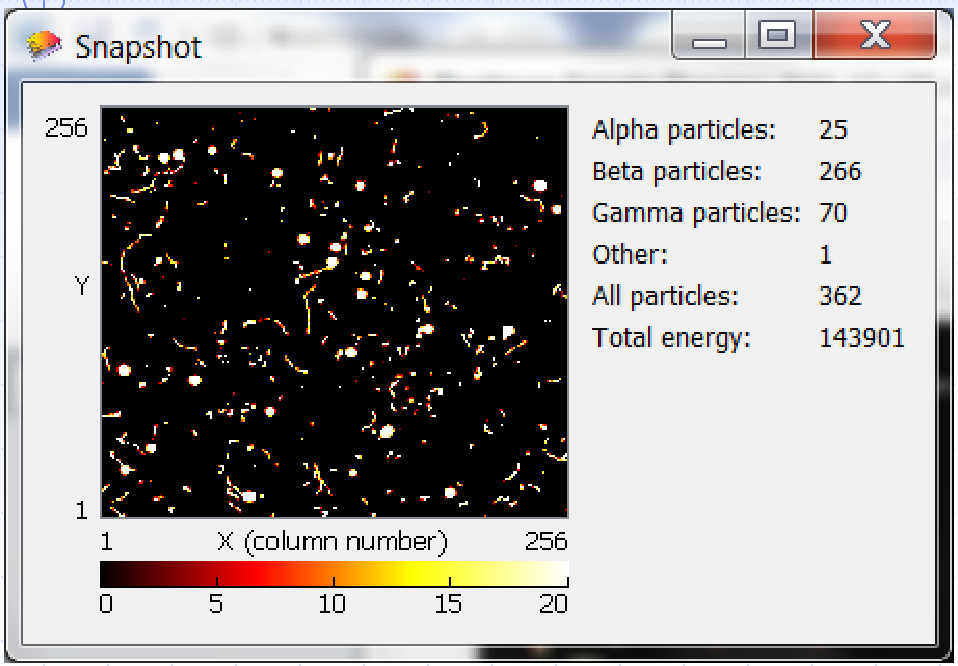
Continuous measurement: No
Exposition time: 1 s
Min. level: 0
Max. level: 20
Colormap: Hot

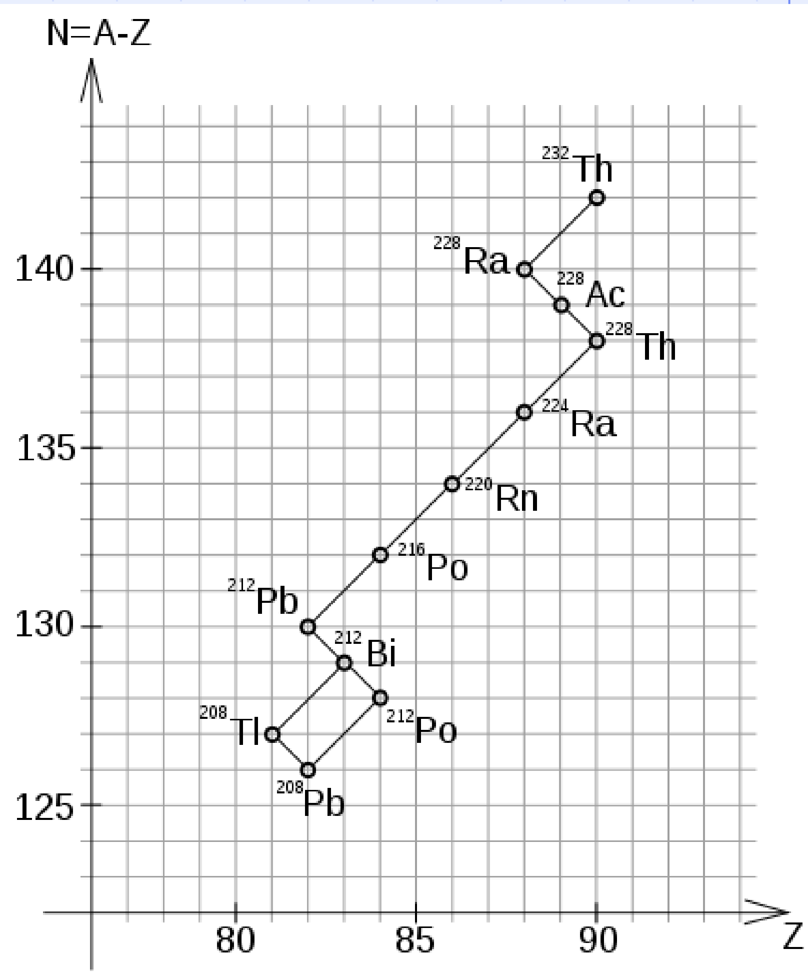
Thoriated Welding Rod Radioactivity Observation



- Thoriated electrode as a weak source of mixed radiation field
- again, evidence of alpha, beta, gamma detection
- Higher portion of alpha radiation is apparent

Thorium Radioactivity
as seen by Timepix pixel detector





Are there more energetic alpha and beta tracks in comparison to uranium glass observation?

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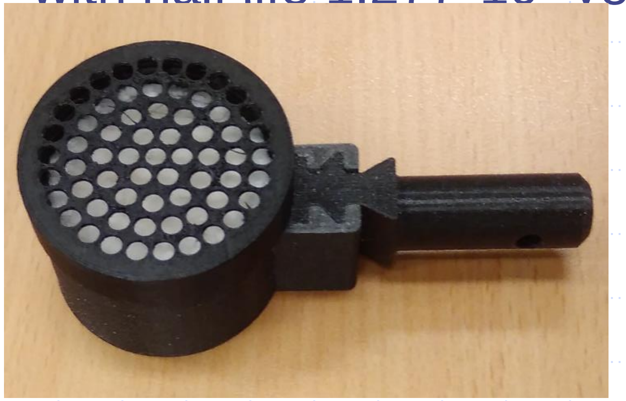
POTASSIUM Chloride Salt

- KCl - Potassium Chloride
- Natural abundance 0.0117% of radioactive isotope ^{40}K with half life $1.277*10^9$ years



Decay modes

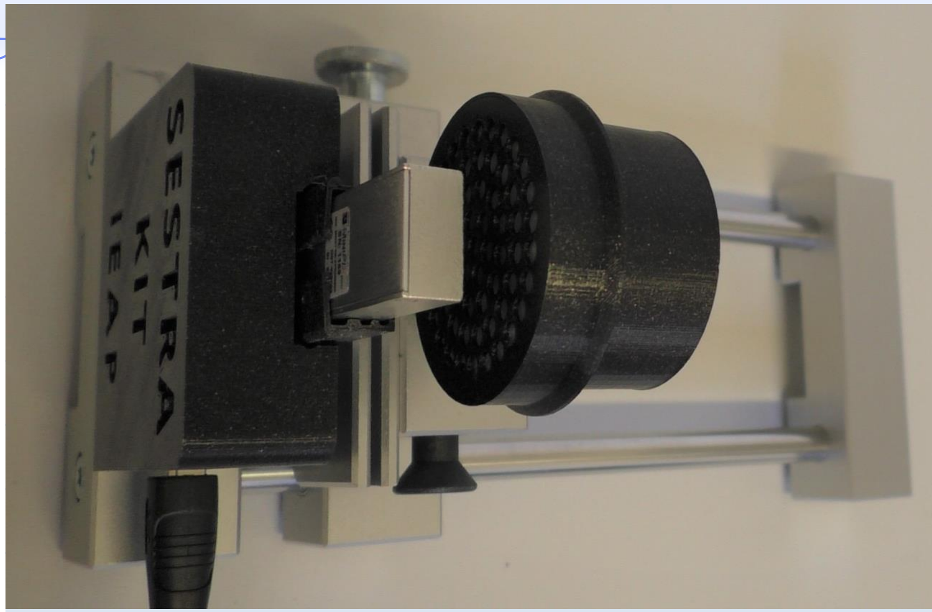
$$^{40}_{19}K \rightarrow \, ^{40}_{20}Ca + \, ^{0}_{-1}e + \bar{\nu}_e$$

89.28 %, emission of β^- with energy 1.311 MeV

$$^{40}_{19}K + \, ^{0}_{-1}e \rightarrow \, ^{40}_{18}Ar^* + \nu_e$$

20.72 %, emission of gamma with energy 1.5049 MeV

Potassium Chloride Salt
preparation of measurement



Experiment set-up:

Particle camera and computer, container with potassium salt inserted into the holder at close position to the detecto.

Settings:

Exp. count: 60
Mode: Spectrometer
Analysis type: Basic
Bias voltage: 20V
Integral mode: No
Continuous measurement: No
Exp. time: 1 s
Min. level: 0
Max. level: 20
Colormap: Hot

…Few facts about potassium

How much potassium does a human body contain?

A human body of 70 kg weigh contains about 140 g of potassium while just (0.0117%) a small portion of 0.0164 g is the radioactive isotope ^{40}K

Aren't we living radiation sources???

Corresponding activity of such amount is 4300 Bq (decays/sec)

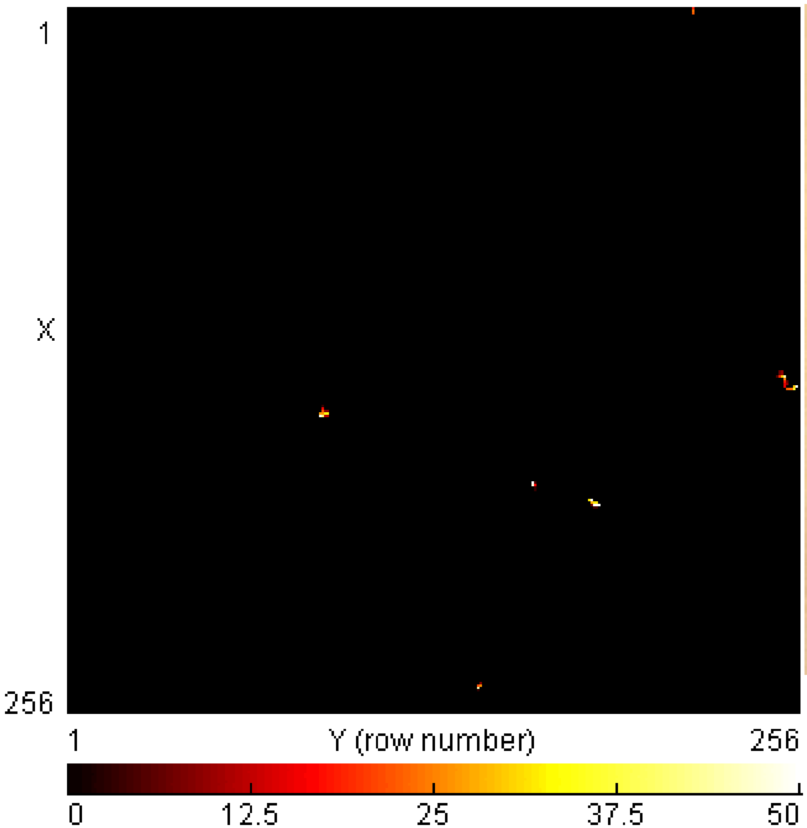
Are bananas save to eat???

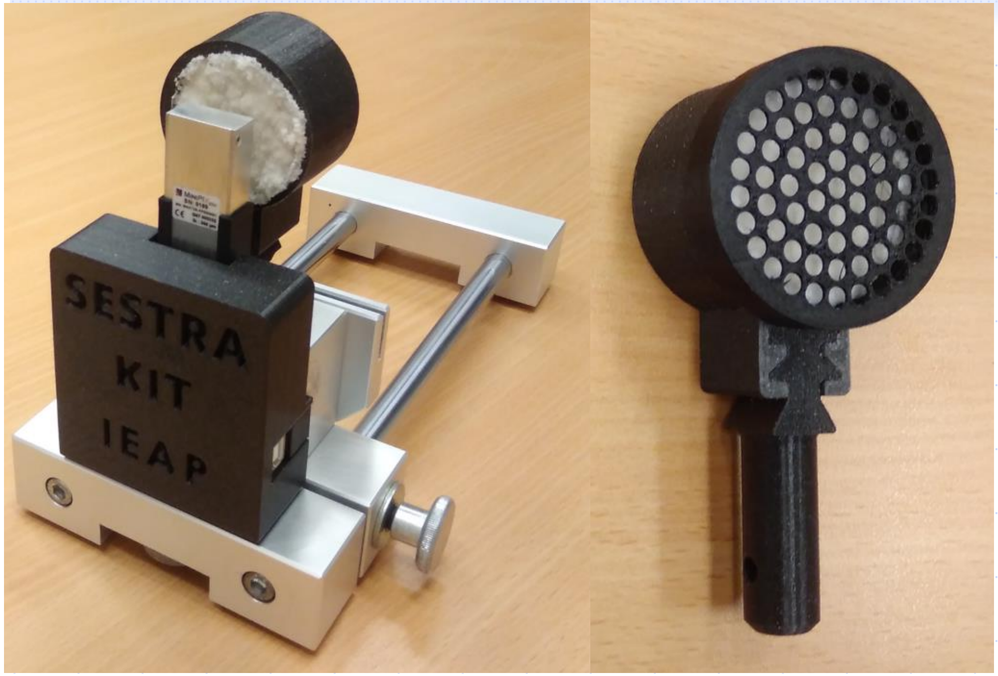
1kg of banana contains 0.390 g of potassium

…where 0.00004563 g is a portion of the radioactive isotope ^{40}K

…with activity of 12 Bq (decays/sec)

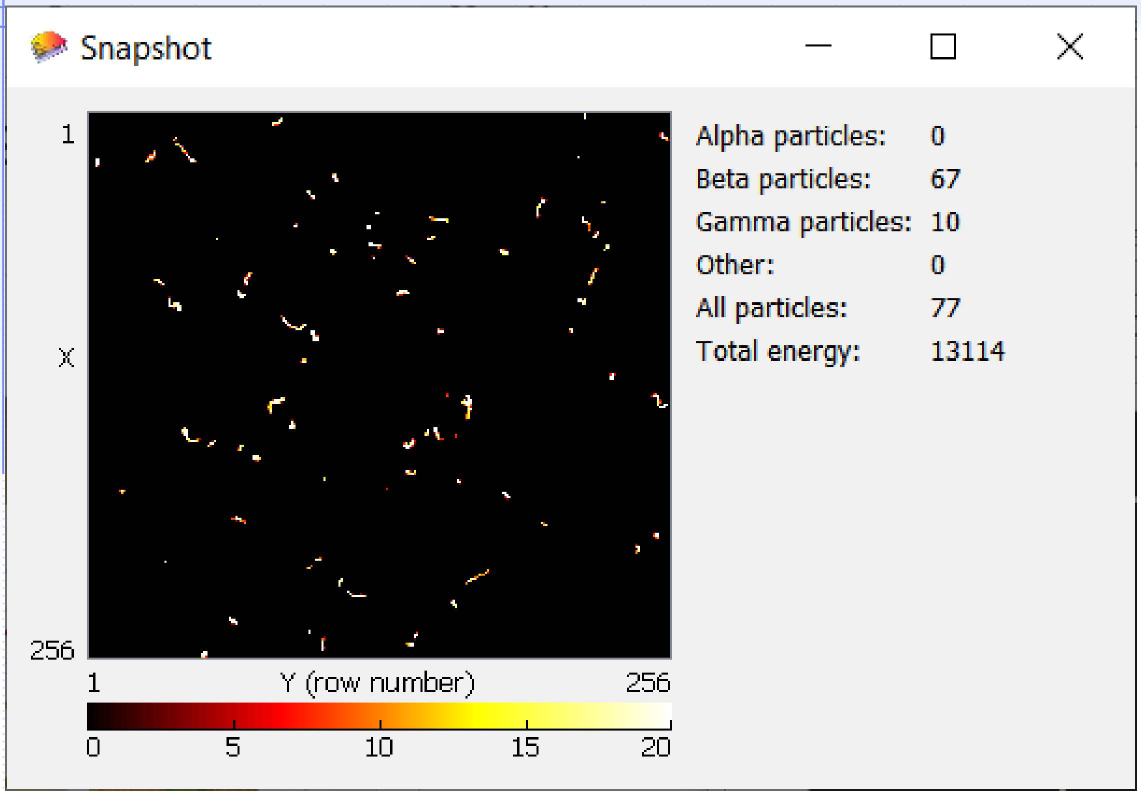
Potassium radioactivity observation





- Container filled with the potassium chloride (KCl) salt
- Weak source of gamma and beta radiation

Potassium Radioactivity
as seen by Timepix pixel detector



Obvious difference to Uranium glass and Thoriated electrode experiment
- no alpha particle tracks present

SZZ Alfa

^{241}Am isotope radiation source

- Activity 9.5 kBq
- Adapted for educational purposes
- Source of alpha and gamma radiation

Alfa decay - Americium:

$$^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}He$$

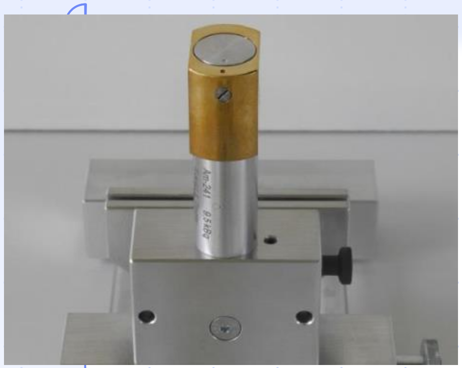
$E(\alpha)$ = 5 500 keV

$E(\gamma)$ = 59.5keV

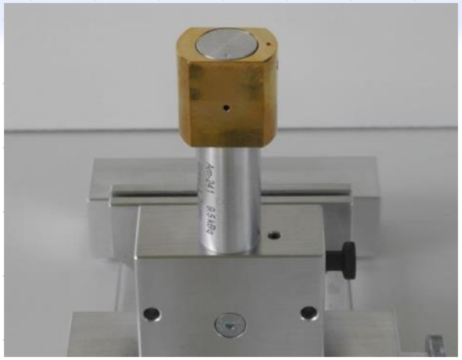
Half-life of ^{241}Am is 432 years.

SZZ Alfa Radiation Source

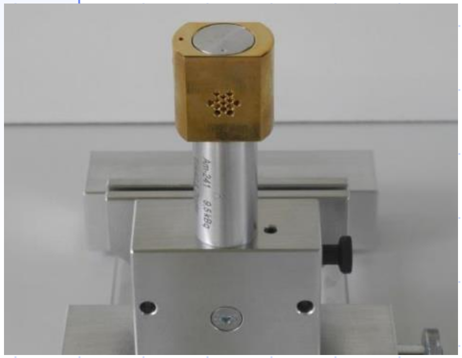
4 selectable output configurations



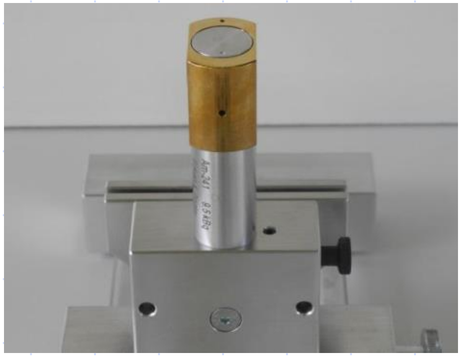
1 - Closed



3 –“Short collimated“



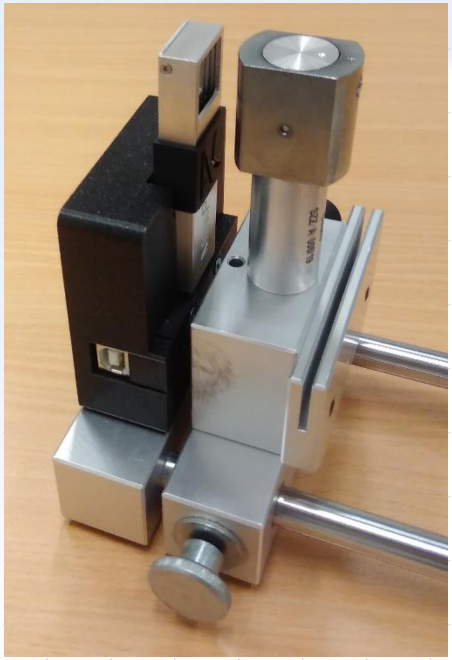
2 - „Sieve“ (multihole)



4 –“Long Collimated“

Note: Radiation in other directions is shielded out by a brass body

9. ENERGY OF ALPHA PARTICLES EMITTED FROM SZZ Alfa 241Am radiation source



Experiment set-up:

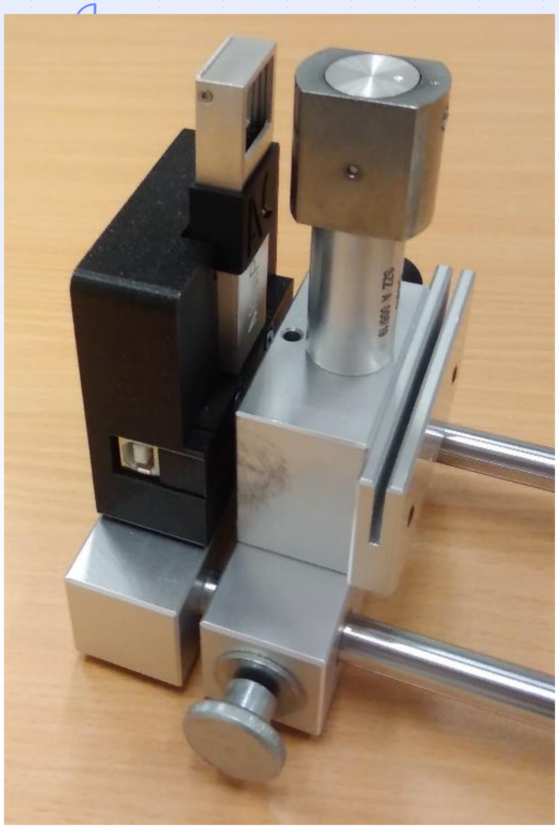
Particle camera, computer, mounting rails, SZZ Alfa placed in a holder.

Settings:

Exp. count: 60
Mode: Spectrometer
Analysis type: Basic
Bias voltage: 20V
Continuous measurement: Yes
Integral mode: No
Exposition time: 0.05 s
Min. level: 0
Max. level: 20
Colormap: Hot

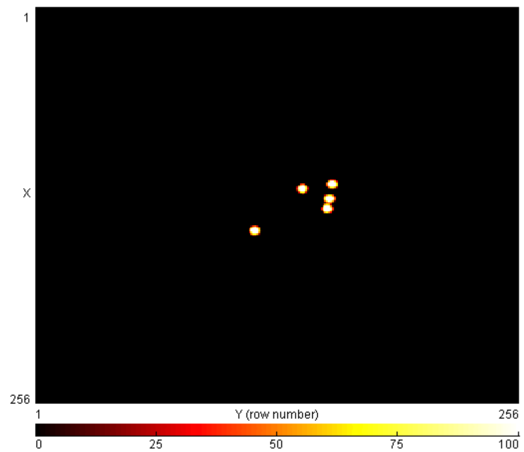
Visual Tools: Histograms of particle properties - Energy all frames (tab Alpha)

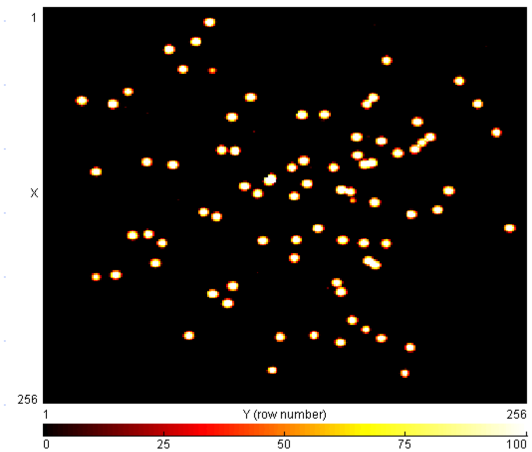
SZZ Alpha Radiation Source Americium 241 source observation



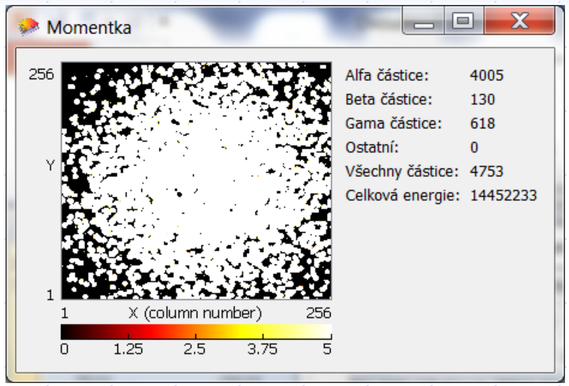
- Source of alpha and gamma radiation
  low activity, 9.6 kBq
- Suitable for demonstration of properties of heavy charged particles

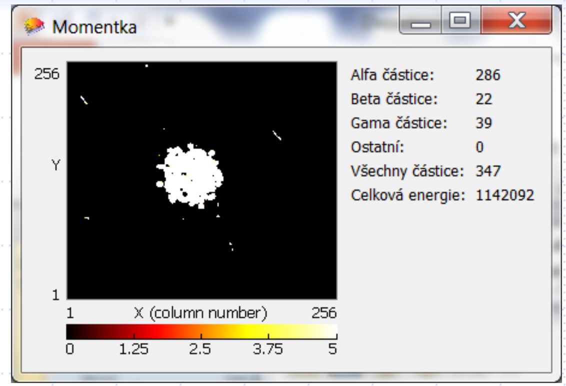
Collimated vs Non-collimated Beam

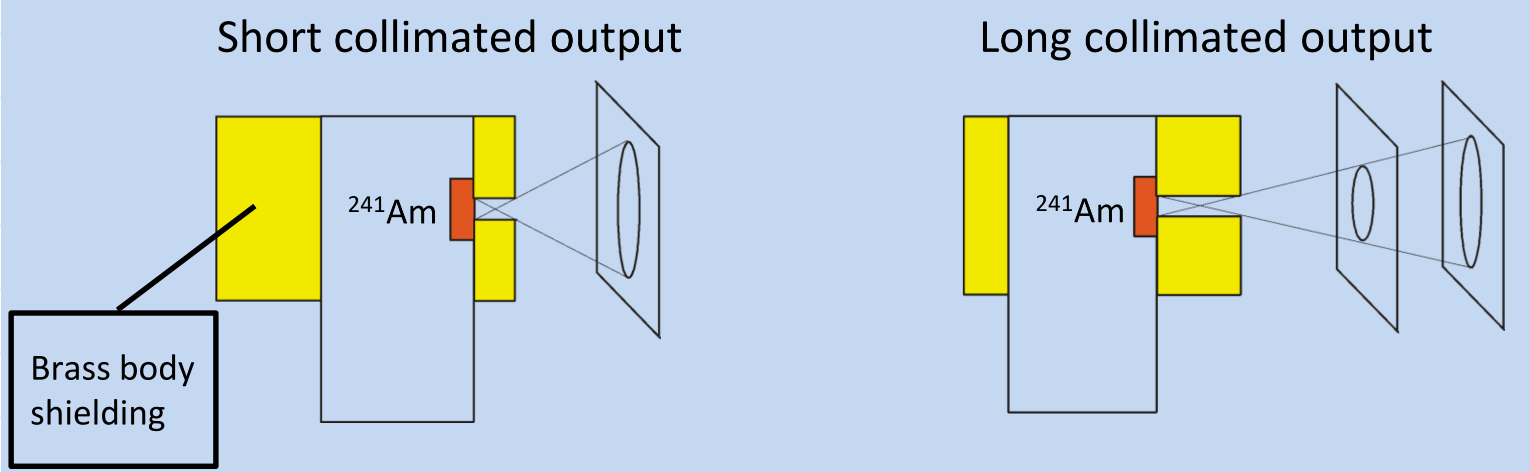




Beam Collimation







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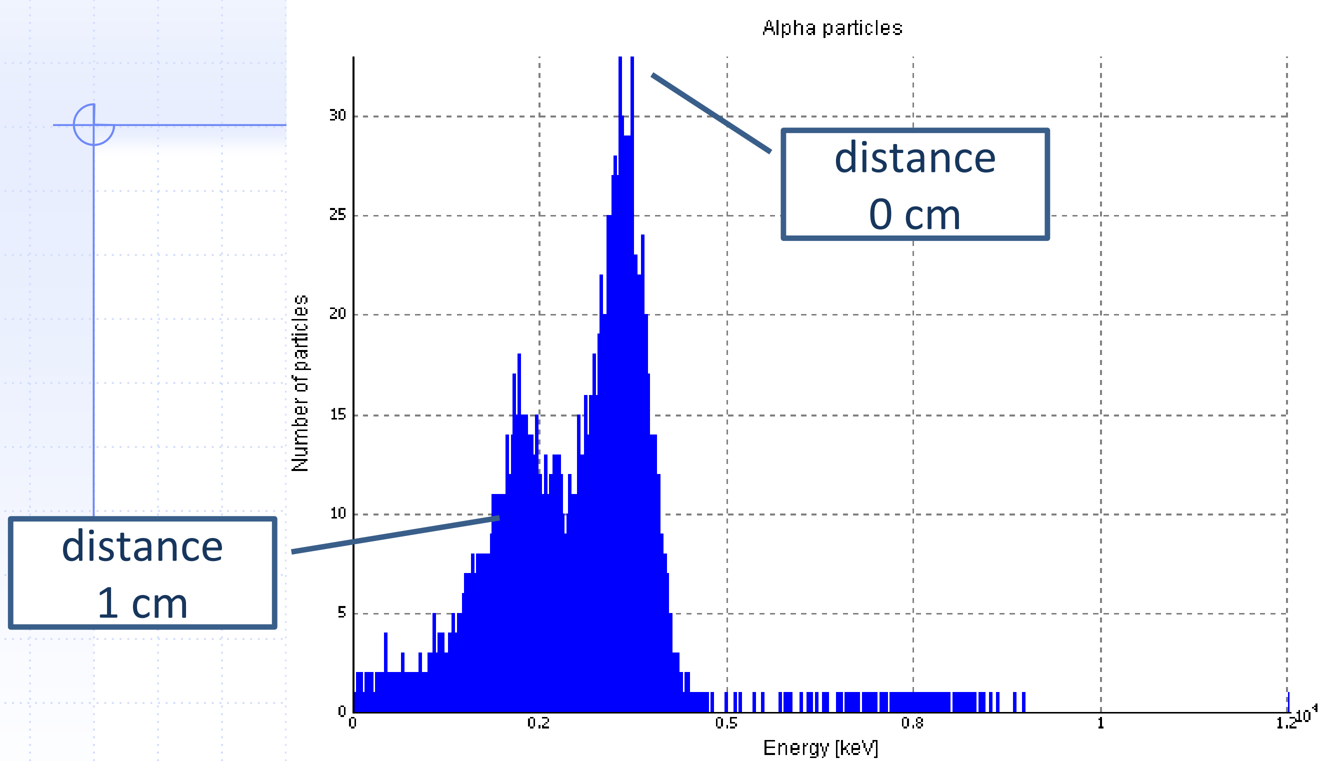
Loss of Alpha Particle Energy in the air



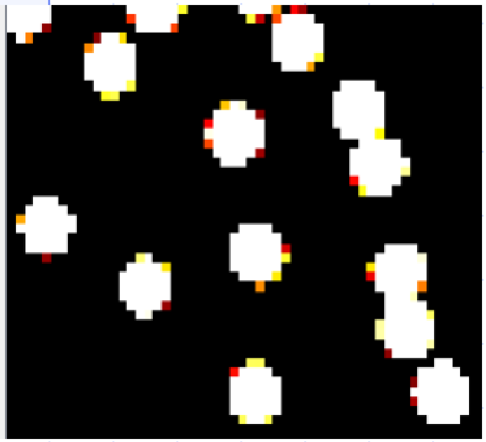
LET=1590 keV/cm
for 3.5 MeV alpha

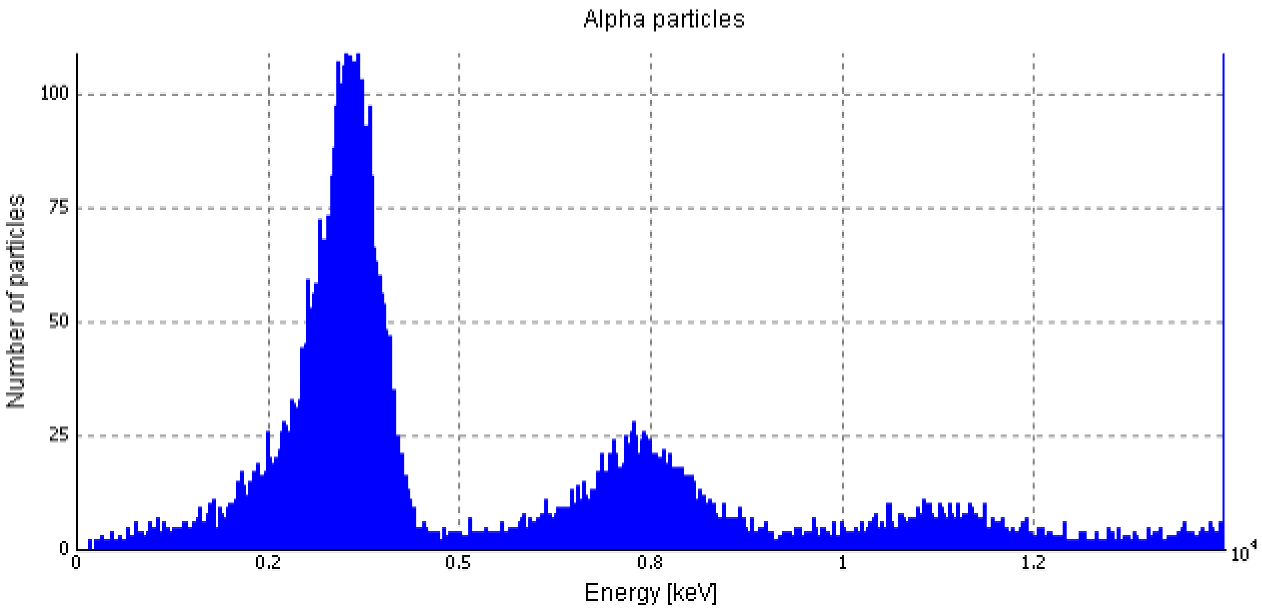
a~10^{15} m/s^2

Experiment set-up:
Particle camera and computer, SZZ alfa placed in the holder, distance in between the detector and radiation source is changed
Settings:
Exp. count: 60
Continuous measurement: YES
Mode: Spectrometer
Exp. time: 0.05 s
Analysis type: Basic
Min. level: 0
Bias voltage: 20V
Max. level: 20
Integral mode: No
Colormap: Hot
Visual Tools: Histograms of particle properties - Energy all frames (tab Alpha)

What happens if frame exposition time is significantly prolonged???

- Americium 241 represents a source of monoenergetic alpha particles but there are displayed several peaks in the spectrum
- Energy of higher peaks exceeds energy of americium alphas





- **Effect of particle track overlapping**

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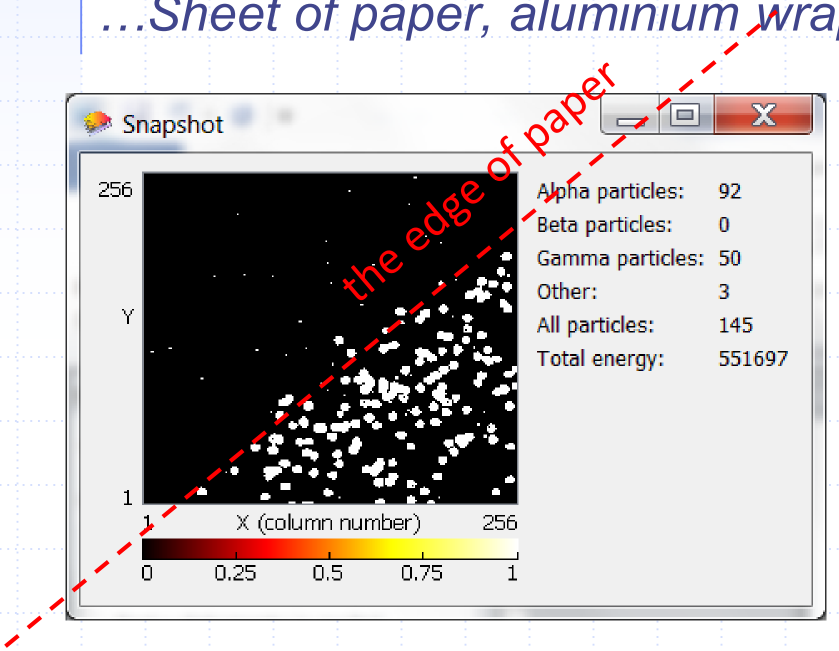
Loss of Alpha Particle Energy in other materials

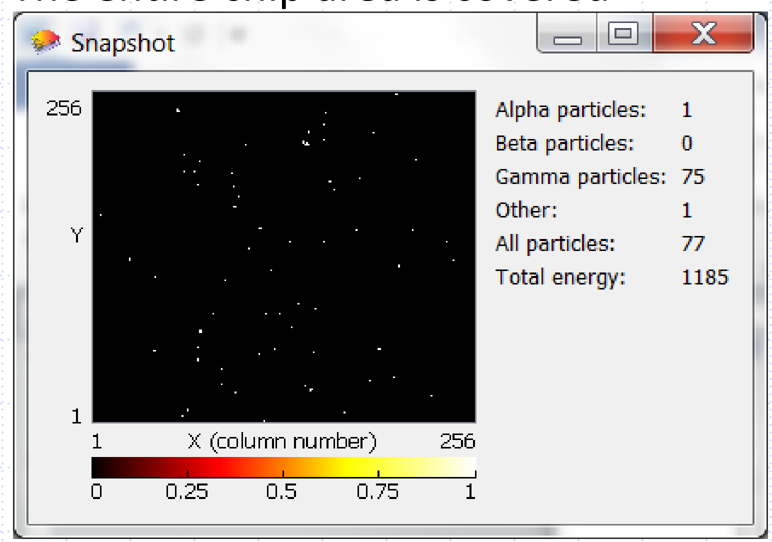
Experiment set-up:
Particle camera and computer, SZZ alfa placed in the holder, various materials are placed in between the detector and radiation source
Visual Tools:
Histograms of particle properties - Energy all frames (tab Alpha)
Histograms of particle properties - Histogram of rate (tab Alpha and Gamma)

What happens if some material is placed in between the alpha source and the detector???

…Sheet of paper, aluminium wrapping foil, thin plastic foil, …..

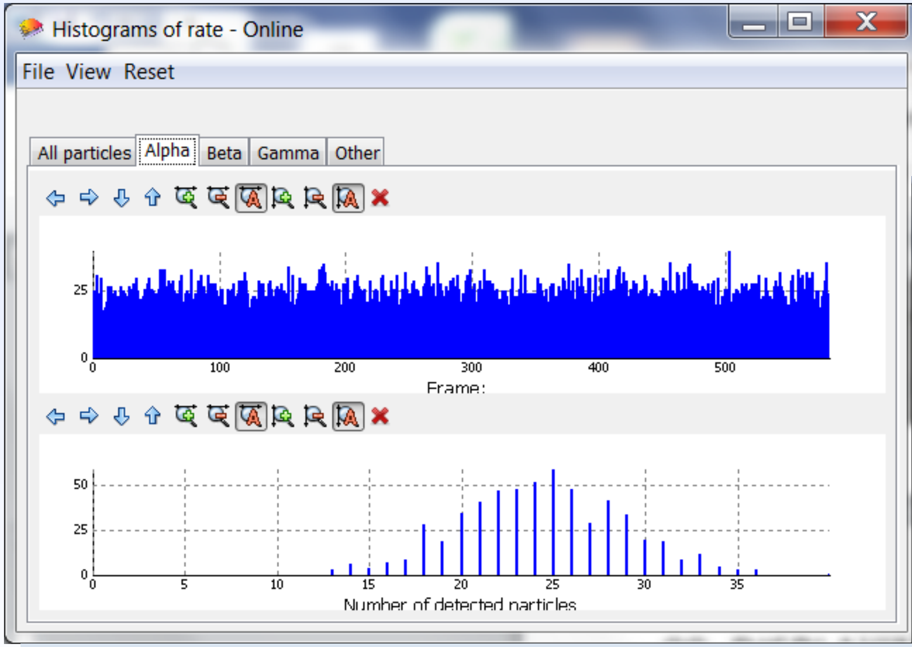


The entire chip area is covered



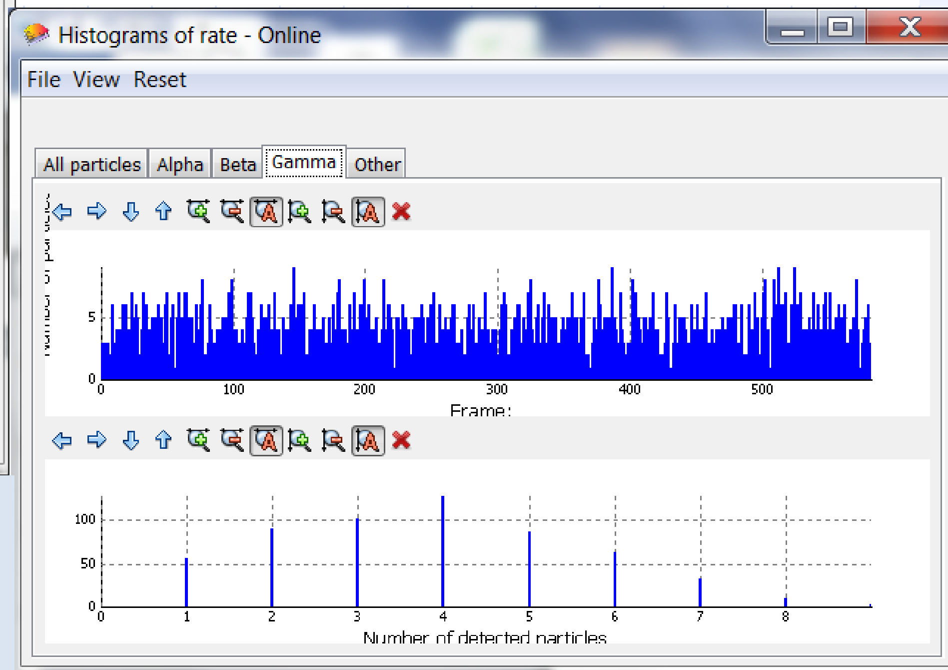
Is the covered area really empty without any tracks?

Statistical Nature of Radioactivity Decay *n* - Random Variable



Alpha particle flux in time

Flux histogram



Experiment set-up:
Particle camera and computer, SZZ alfa placed in the holder, multihole output is selected, radiation source close to the detector

Settings:

Exp. count: 200

Continuous m.: YES

Mode: Spectrometer | *Exp. time:* 0.05 s

Analysis type: Basic | *Min. level:* 0

Bias voltage: 20V | *Max. level:* 20

Integral mode: No | *Colormap:* Hot

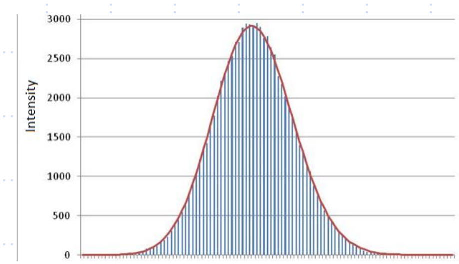
Visual Tools: Histograms of particle properties -

Gama particle flux in time

Flux histogram

$$p_k = \frac{\lambda^k}{k!} e^{-\lambda}$$

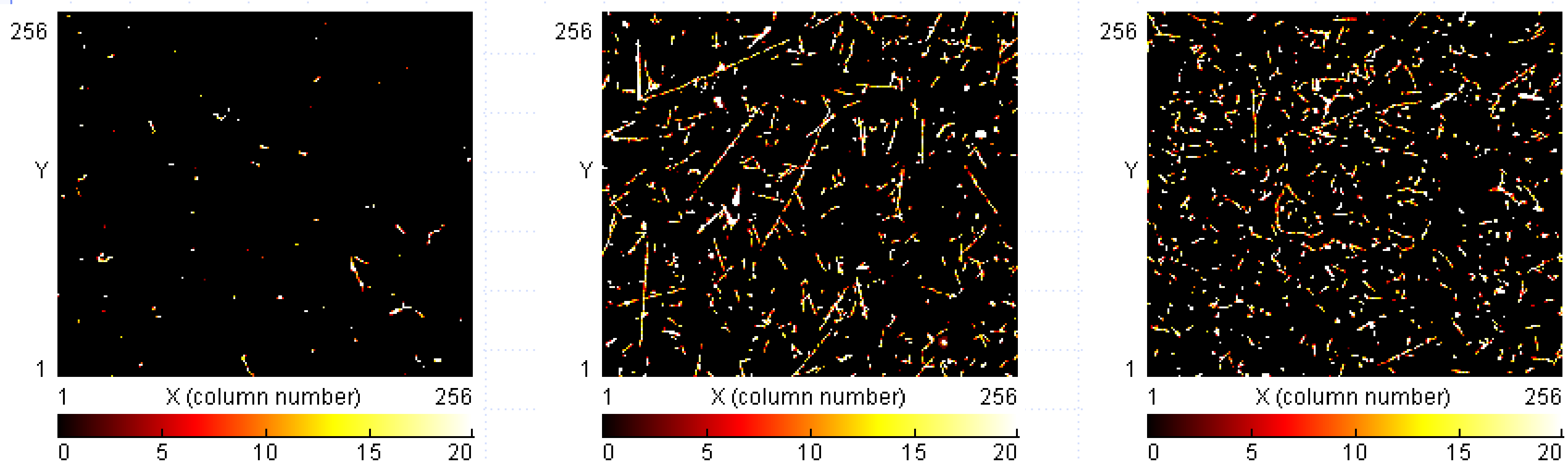
Poisson Distribution



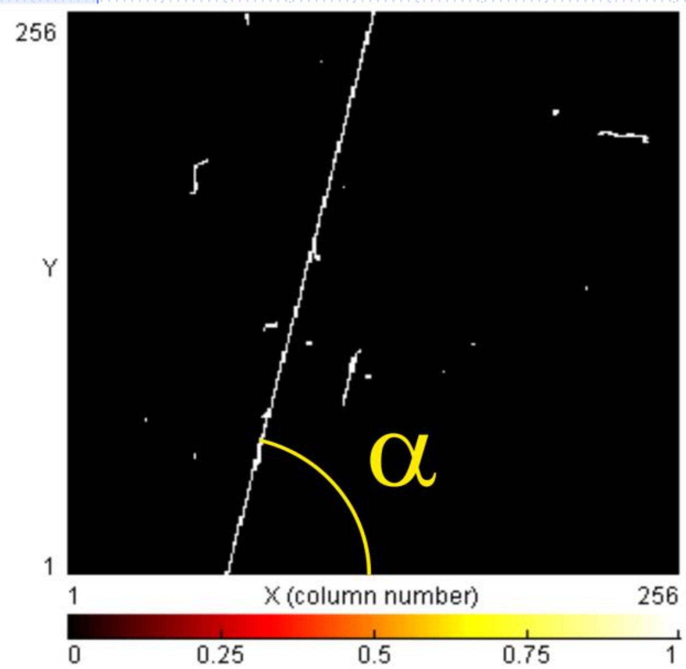
Background Radiation with Origin in Space

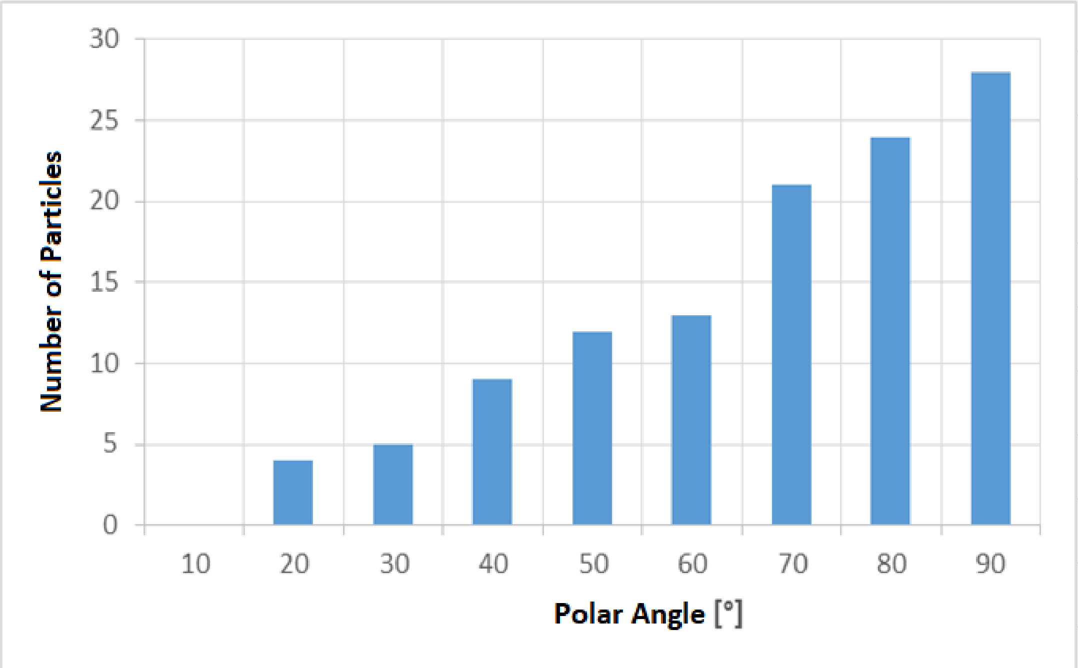
Detection of cosmic muons and their contribution to background radiation on the ground.

Exemplar frames measured at different conditions: one frame represents response acquired at the vertically oriented sensor at the airport. The next one was acquired on board of the airplane on the standard flight level at the vertical sensor orientation and the last one at the horizontal sensor orientation.



Linear Tracks of Interacting Particles at the Polar Angle





- Significantly different results of muon observation are obtained in dependence on the detector orientation
- Note the typical dimensions of Timepix sensor 14 x 14 x 0.3 mm (w x l x h)

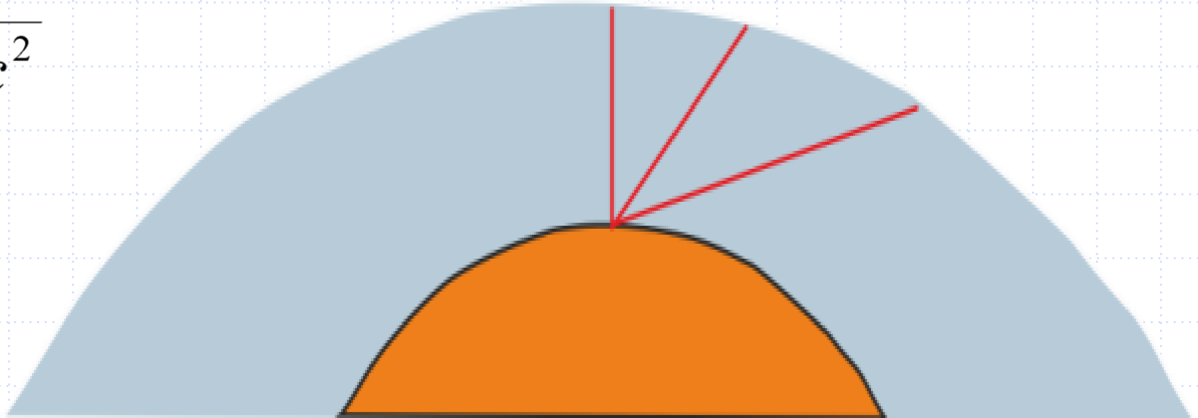
WHY MUONS OF LOW INCLINATION DO NOT REACH TO GROUND?

Half-life of muons is: 2,2 μs.
How long distance can be reached until it decays?

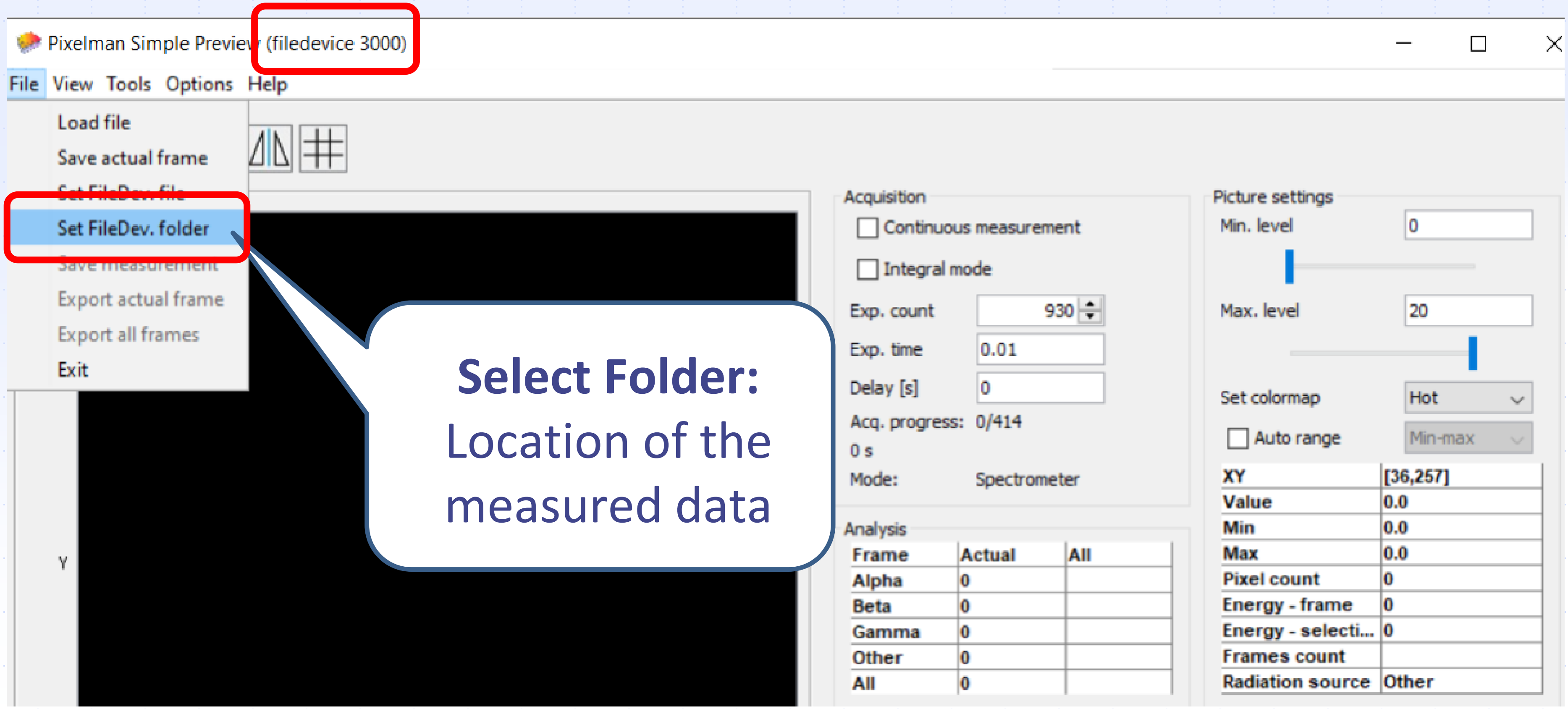
Presumption, muon was created at altitude of 10 km, its velocity is 0,999*c*.
Can it reach the ground?

Classical physics: $s = v \cdot \tau_0 = 659\ \mathrm{m}$ It can not reach the ground

STR: $s = v \cdot \dfrac{\tau_0}{\sqrt{1 - \dfrac{v^2}{c^2}}} = 14\,750\ \mathrm{m}$ It can reach the ground (in dependence inclination on angle)



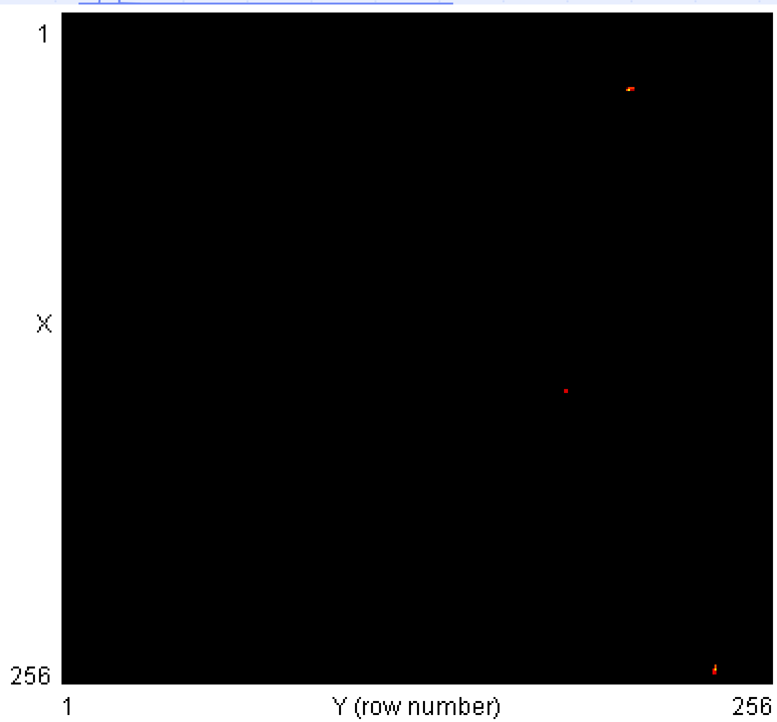
Working with Pre-measured Data Using the Virtual (filedevice 3000) Paraticle Camera

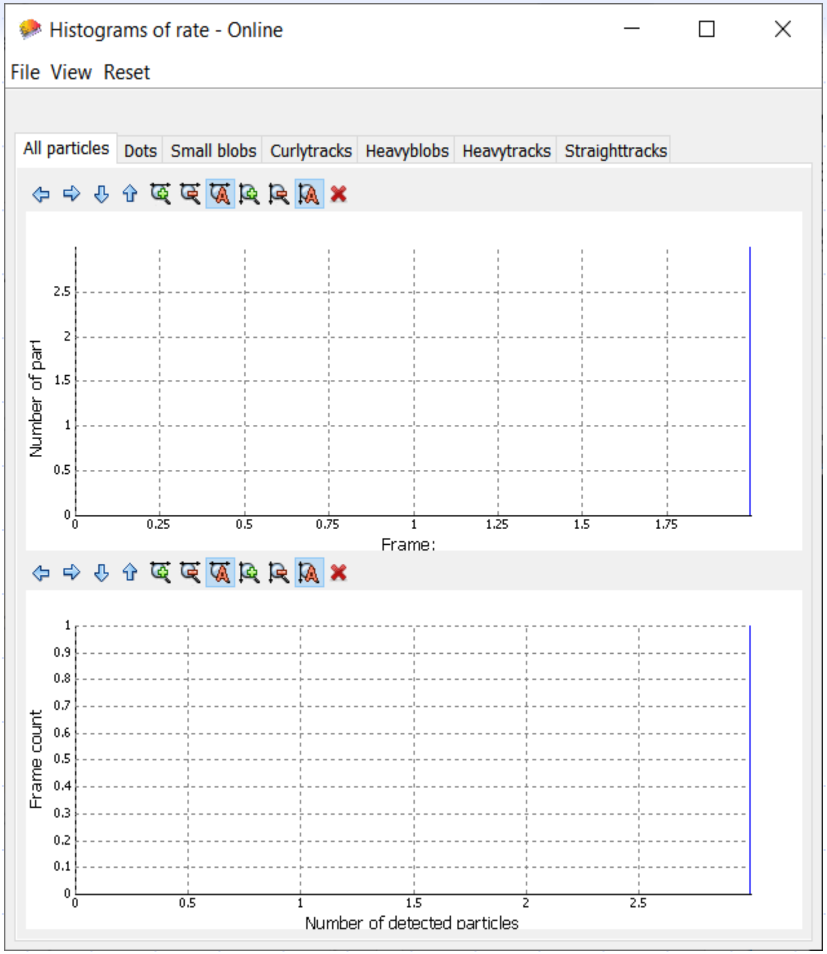


- The virtual particle camera allows to replay experimental data measured in the past

  same visualisation and processing functionalities are available as if a real particle camera would be connected to a computer

Radiation field observation on board of the airplane as seen by the particle camera

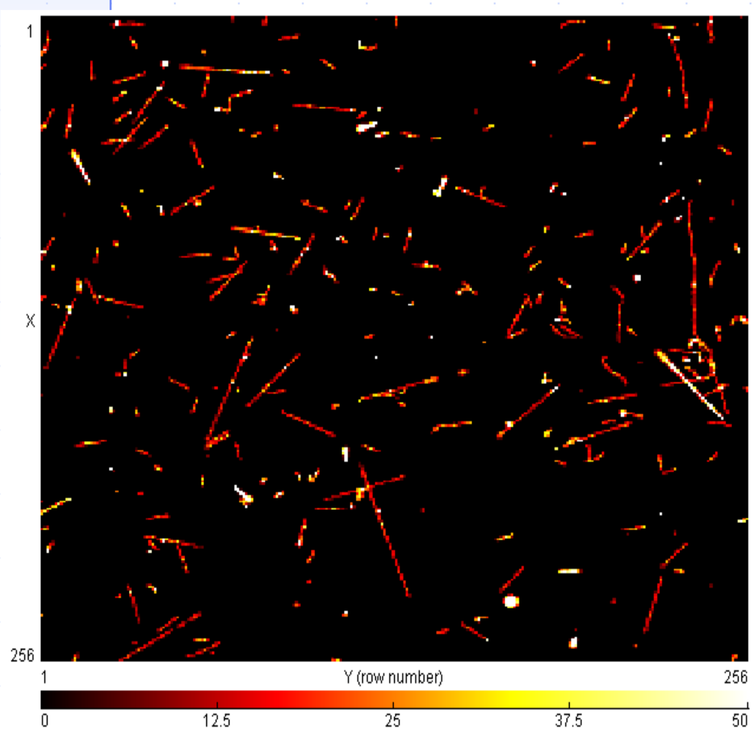


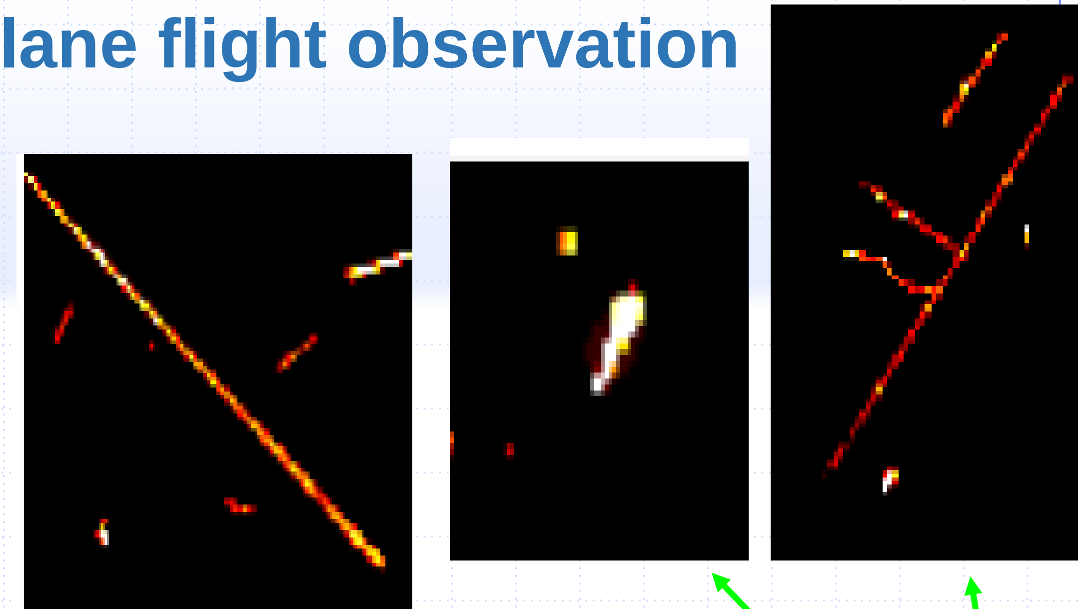


- Recording from the flight from London to Prague
- Significant difference in field composition and intensity when flying or when landed…

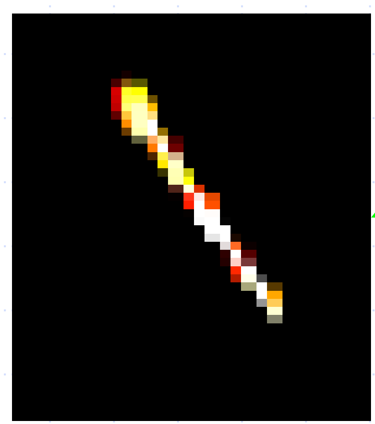
Close look on airplane flight observation recorded by the particle camera

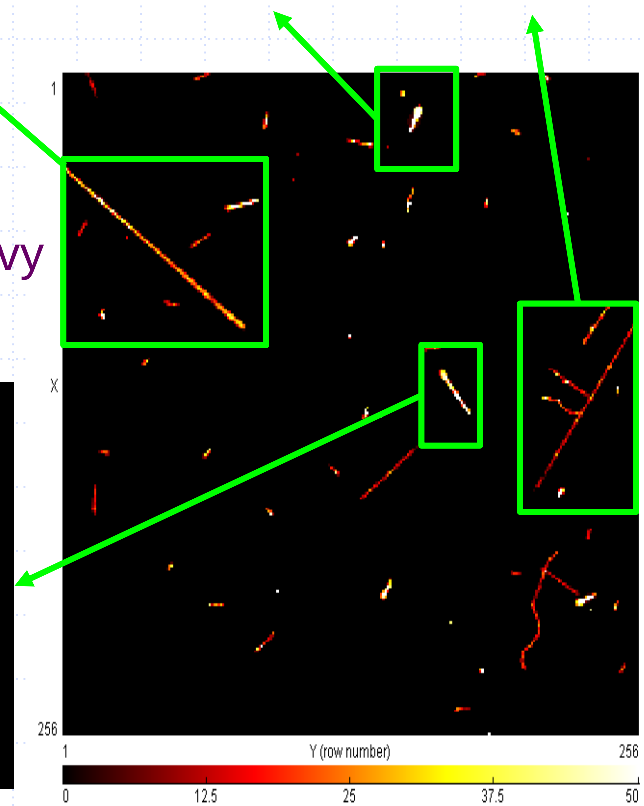
- Typical composition of radiation field at flight level *(high count of muons)*



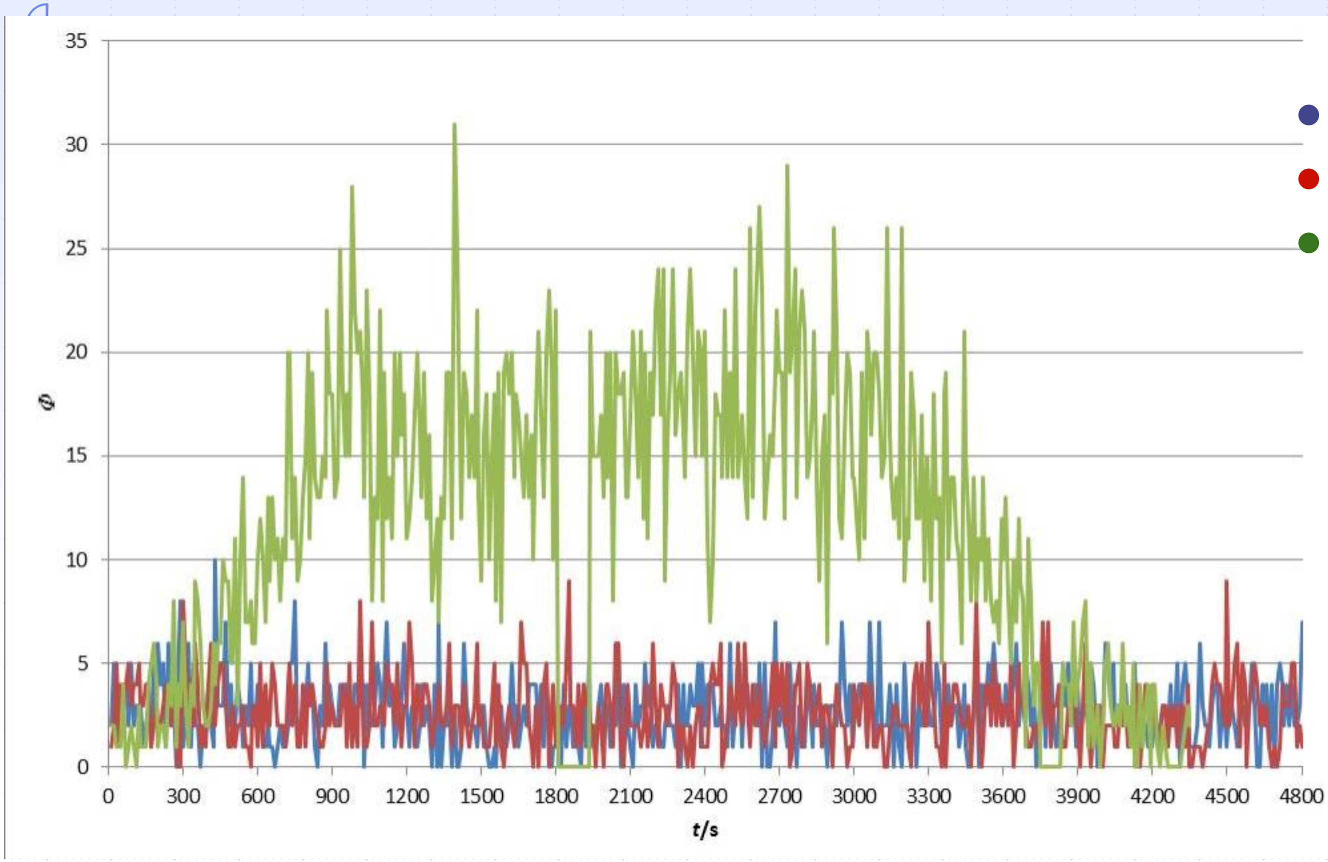


- Occasional detection of heavy energetic ions





Radiation intensity observed on Earth vs on board of the airplane



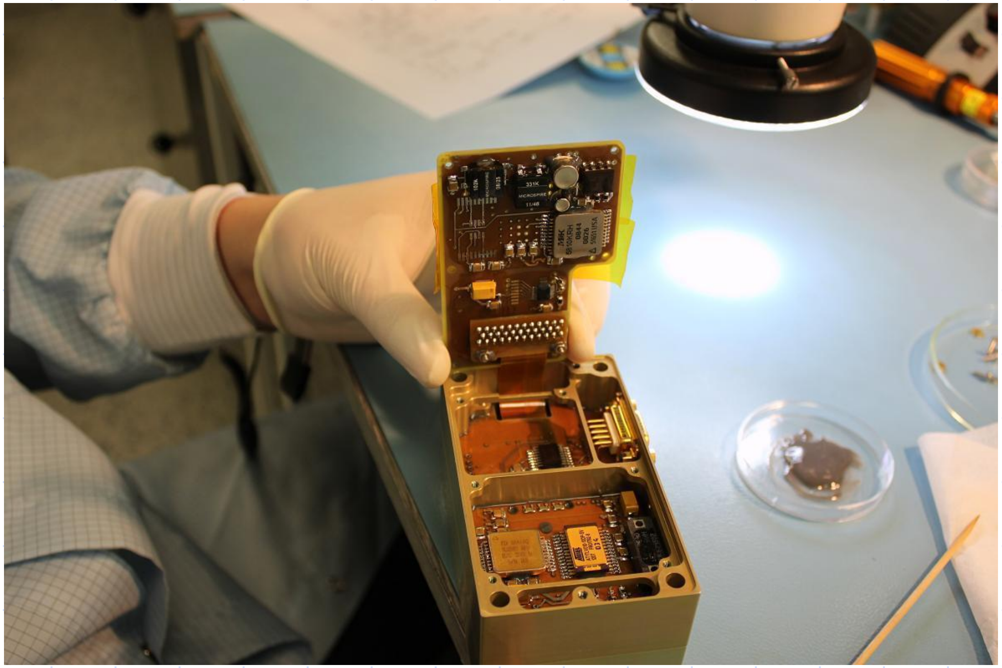
- On Earth 1
- On Earth 2
- On board of the airplane

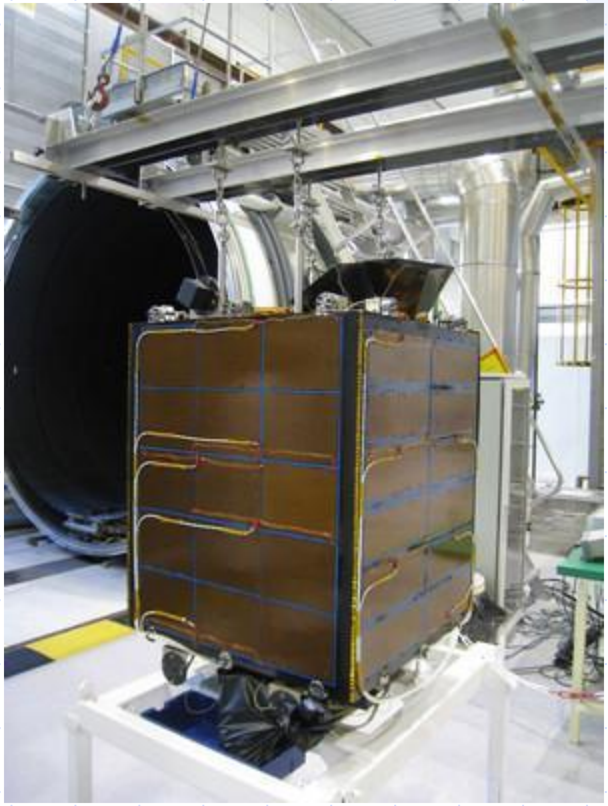
Particle flux Φ in dependence on time (with 10 s step)

Dosimetry in space:
SATRAM – ESA Proba-V satellite

Characterization of mixed radiation field on low orbit of PROBA-V satellite

- Altitude ~ 800 km
- Timepix for the first time outside in the space
- Launched in May 2013

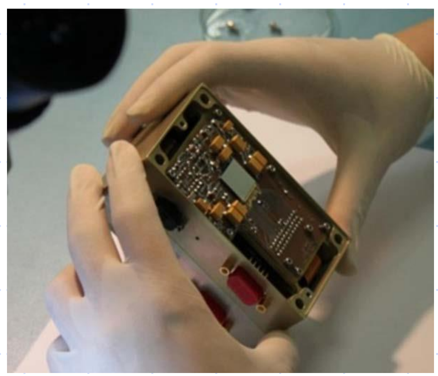




proba VEGETATION

SATRAM
(**S**pace **A**pplication of **T**imepix **R**adiation **M**onitor)

on board of Proba-V ESA satellite

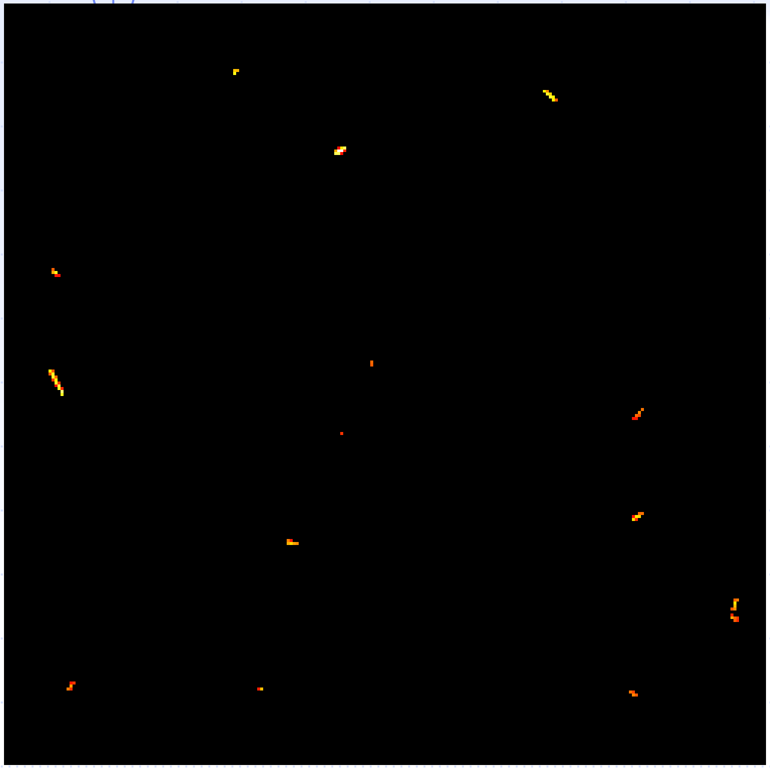


- The same kind of pixel detector Timepix as one embedded in the particle camera MiniPixEDU of the SESTRA educational kit

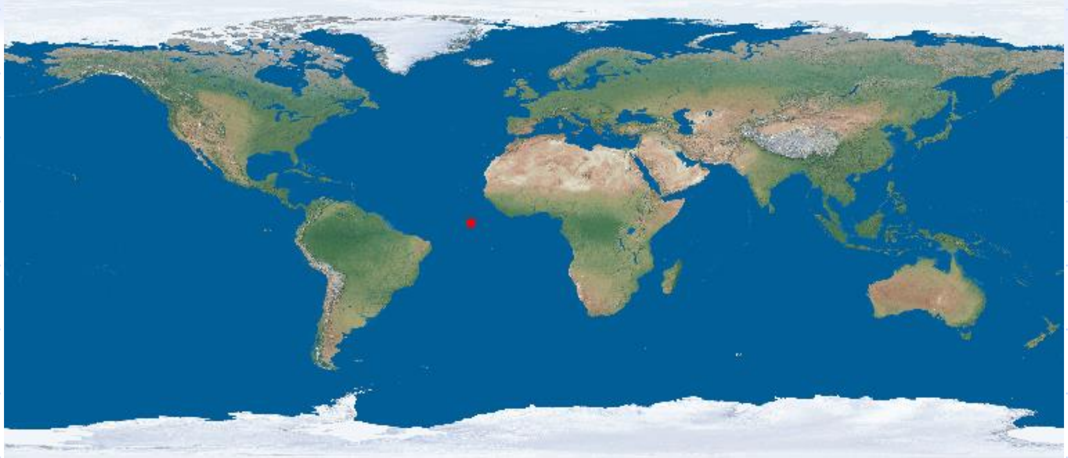
- mission on LEO - altitude 820 km
- Timepix for the first time outside in the space
- Launched in May 2013

- Radiation field recordings available for research and also for educational purposes

SATRAM Radiation Observation on the Earth Orbit



- Radiation field as seen by Timepix detector



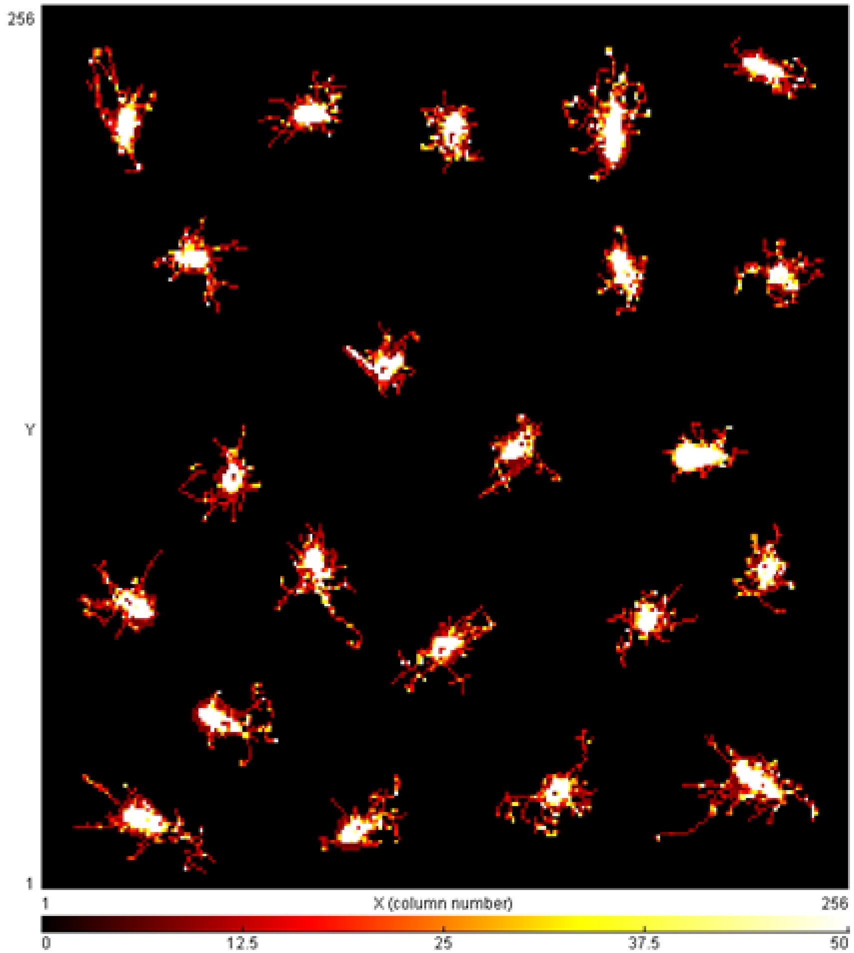
- Variation of radiation field composition in depence on the earth orbit position
  - *Notable difference in field composition when compared to observations performed with natural radiation sources in the SESTRA educational kit*

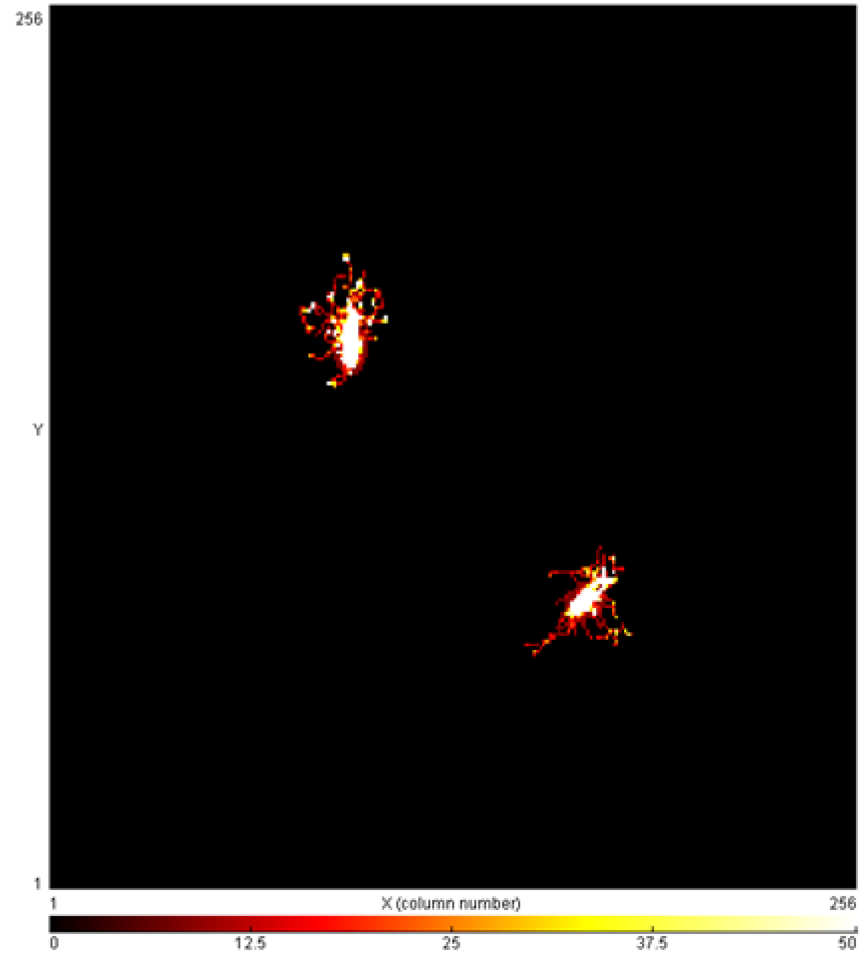
Mission data available online at the web portal:
https://satram.utef.cvut.cz/

Timepix/ESA Proba-V:

LEO space radiation @ 820 km

HETPs: Highly energetic heavy charged particles (ions) HZE’s

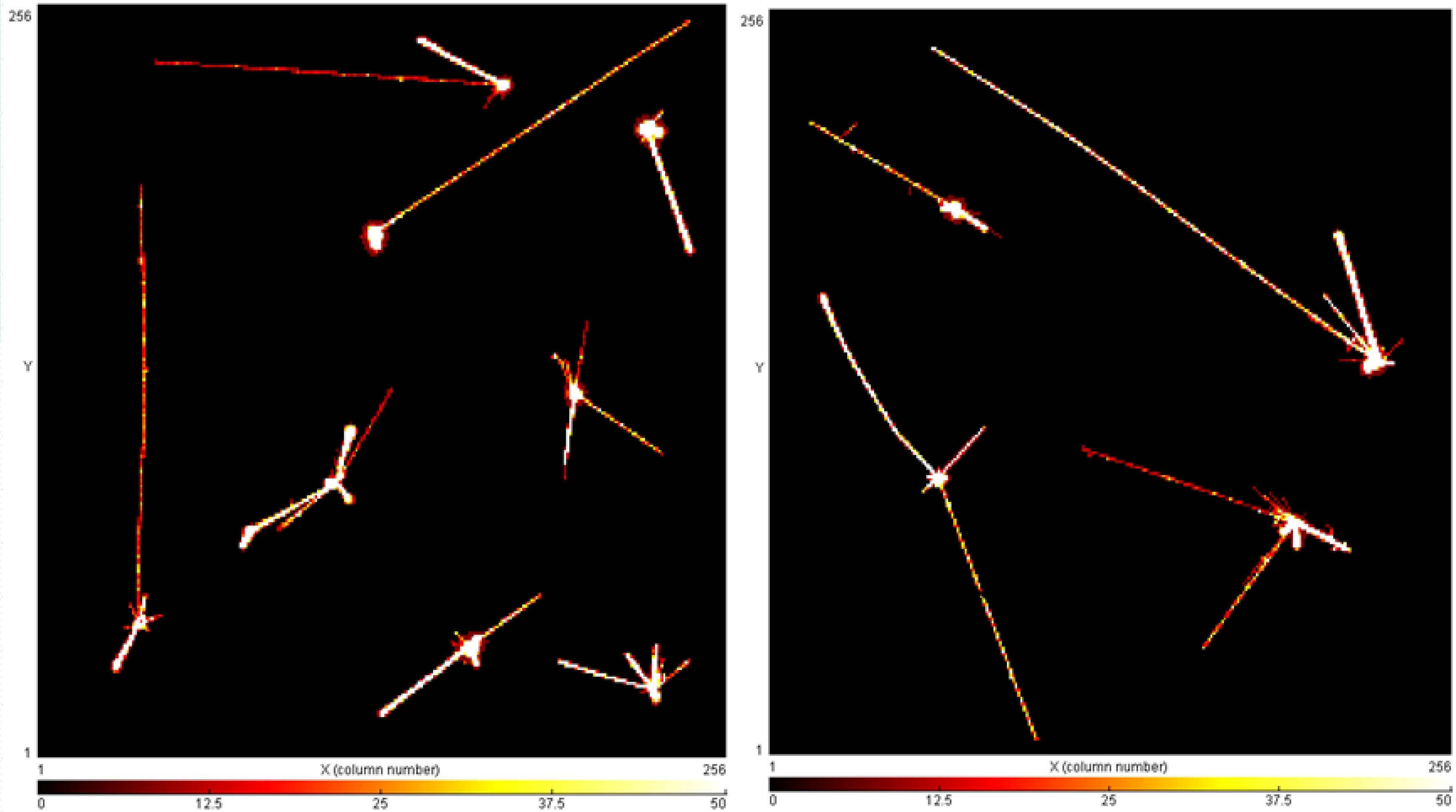




Timepix/ESA Proba-V:

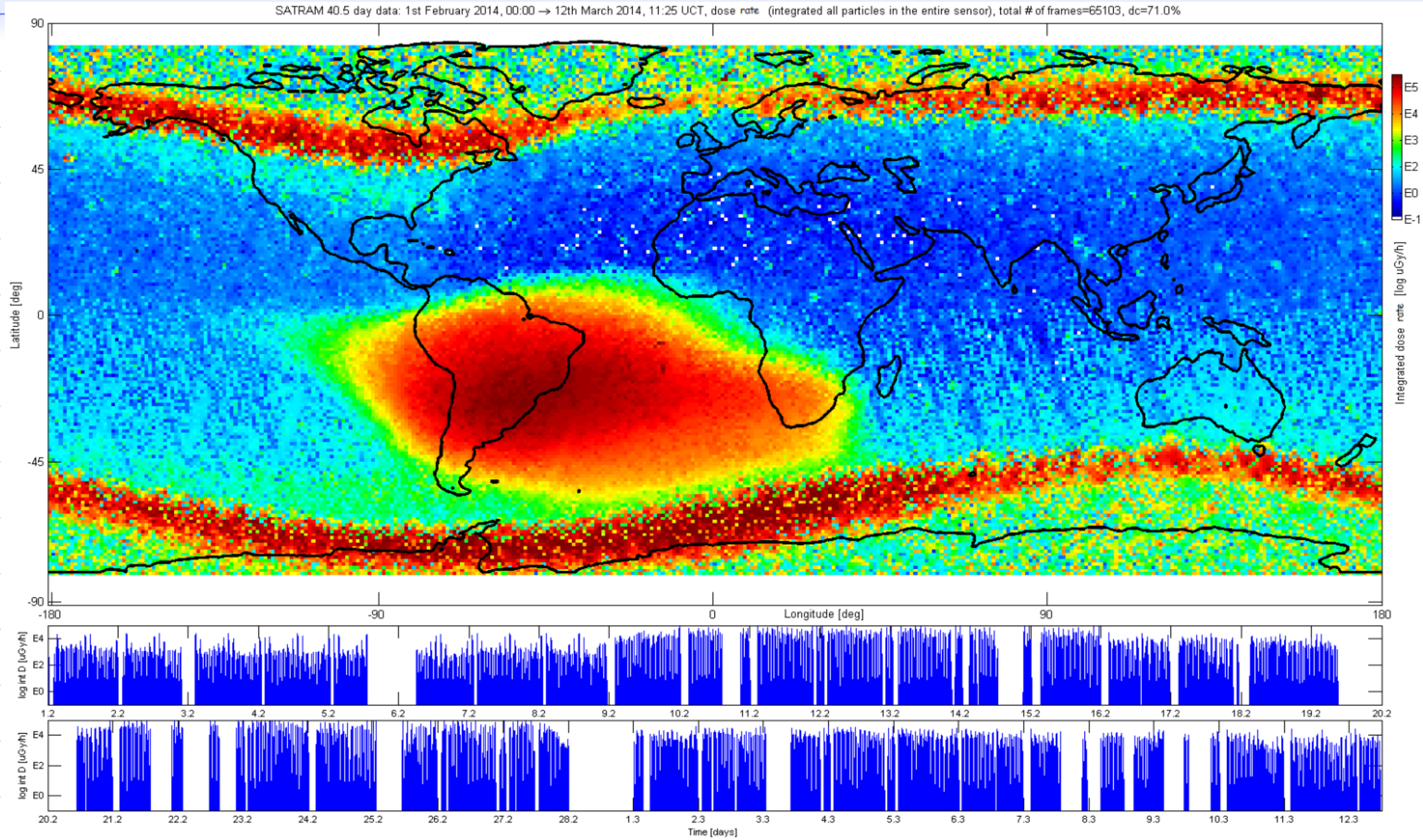
LEO space radiation @ 820 km

LETPs: Energetic light charged particles (I) + nuclear interactions



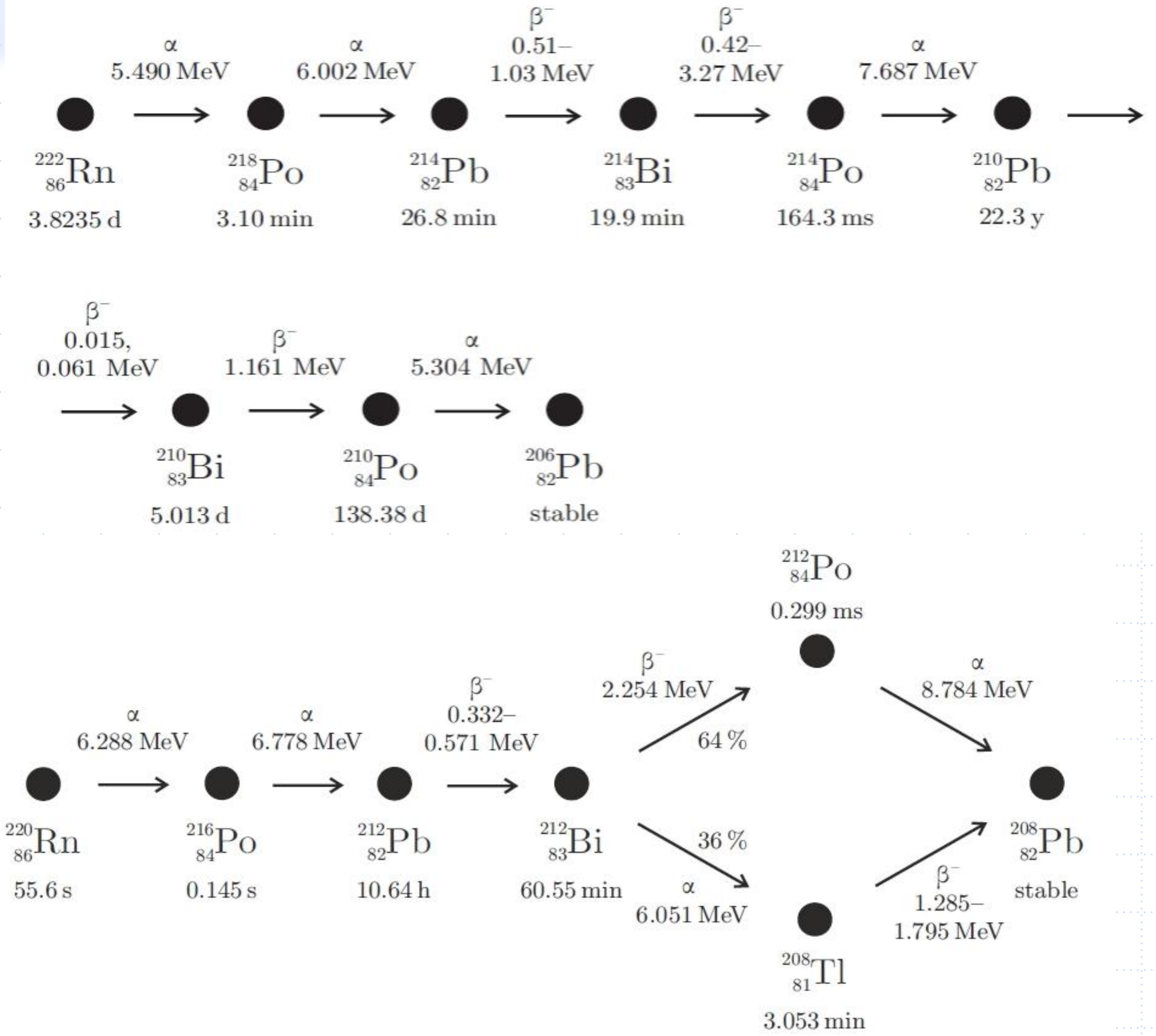
Measured radiation map by Satram device in orbit

around the Earth at an altitude of 820 km from the earth's surface obtained within 36 days from January 1, 2014 to February 7, 2014 logarithmic scale in μG/hr.

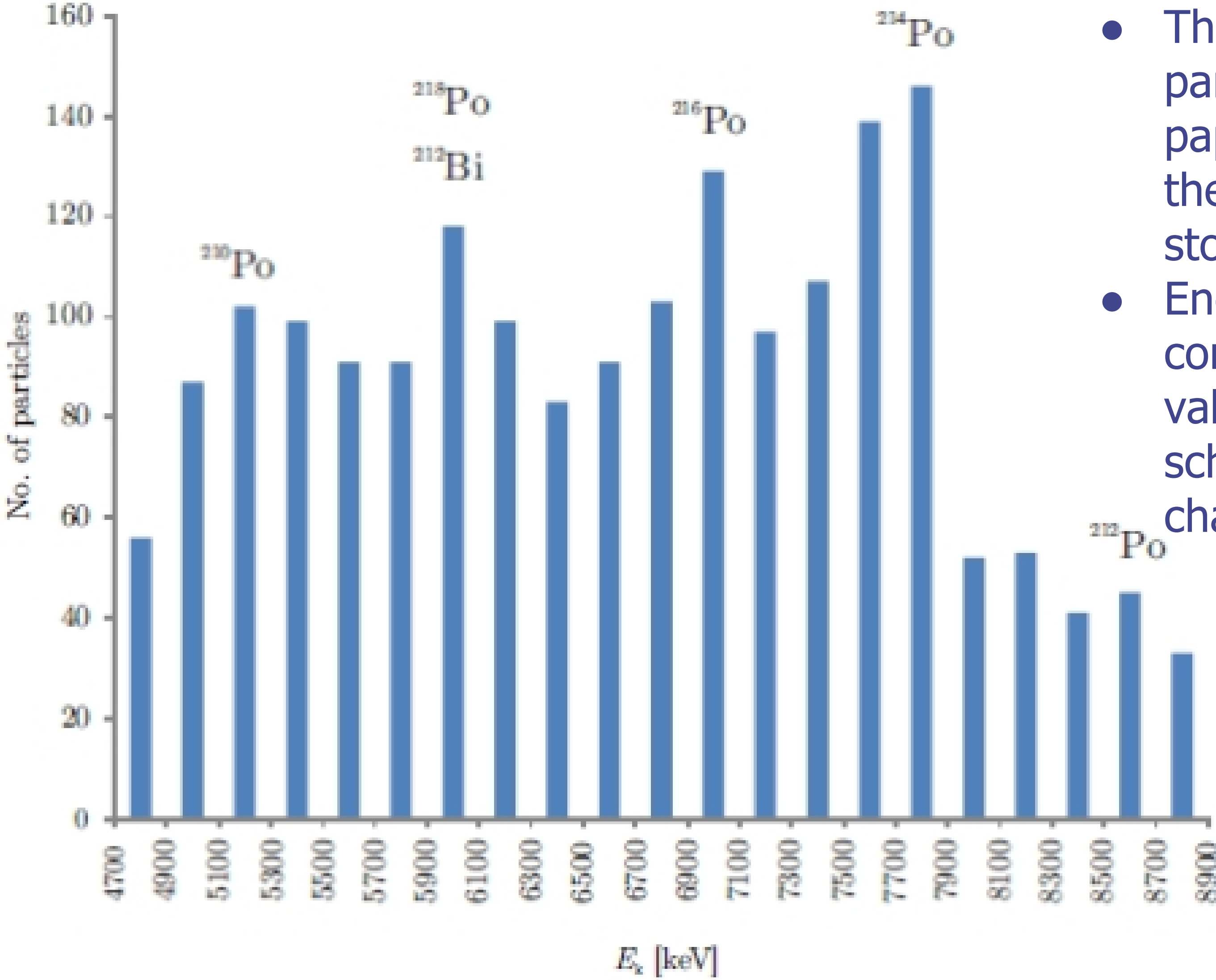


Radon as a common source of background radioactivity

- Noble gas originating from decay of radium
- It further decay through the serie of daughter products



Radon as a common source of background radioactivity



- The histogram of alpha particles emitted from a paper tissue right after the air filtering was stopped.
- Energy peaks correspond to the values presented in the scheme of the decay chain.

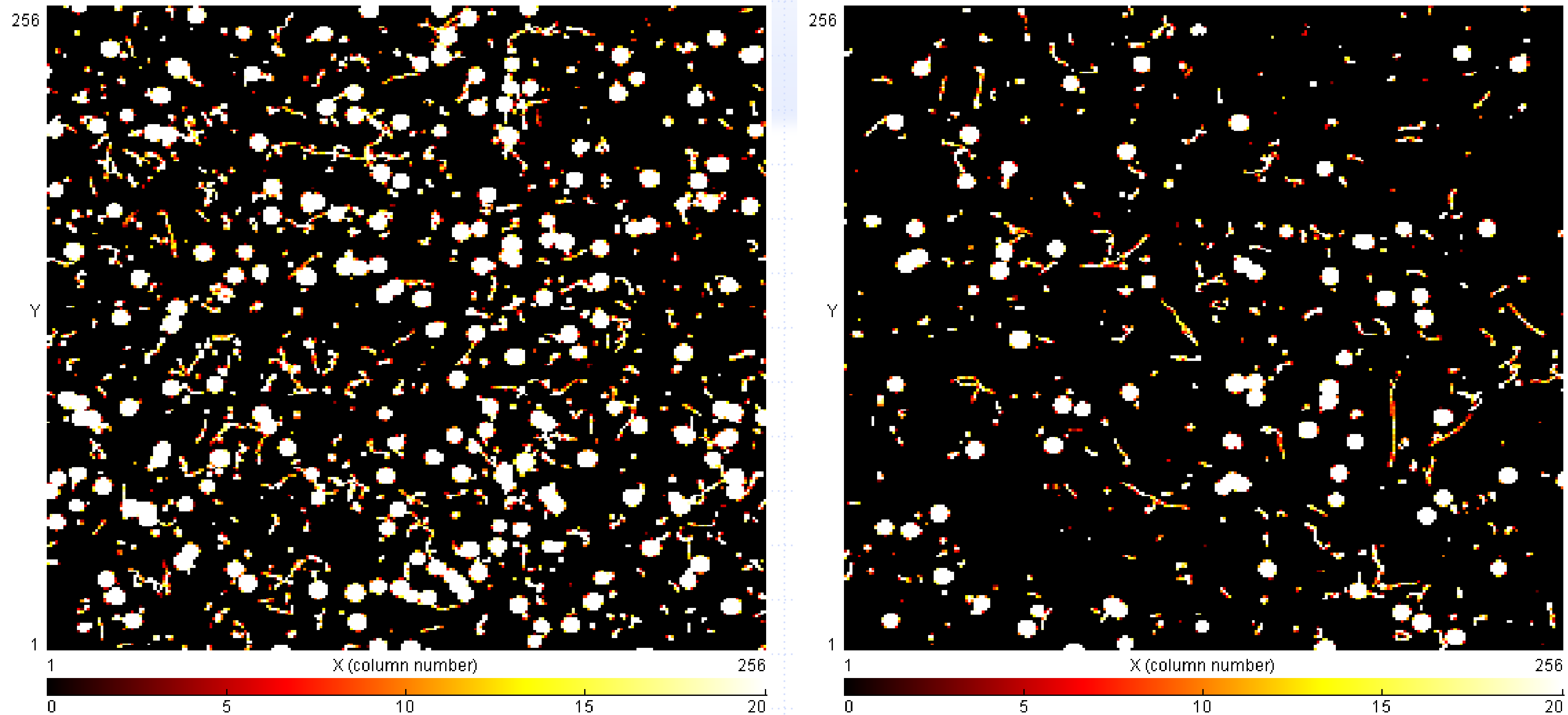
Radon - Easy way how to prepare own radiation source

- Preparation requires just usage of a vacuum cleaner + grate adapter + paper tissue (or head mask)
  (ideal location - non-ventilated basement of an old building)

- After several minutes letting air pass through the filter, radon daughter products get captured in the filter

- Then the paper tissue is placed on the top of the particle camera and radiation measurement is started

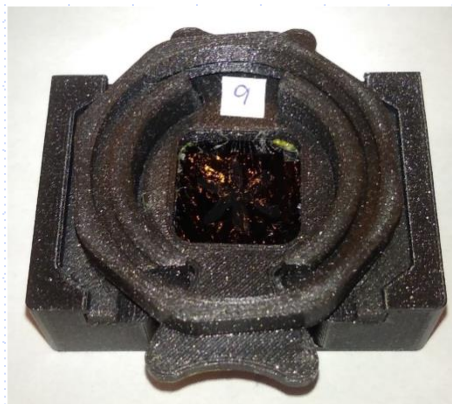
Comparison of Radioactivity observed in the Non-ventilated (left) and ventilated (right) room

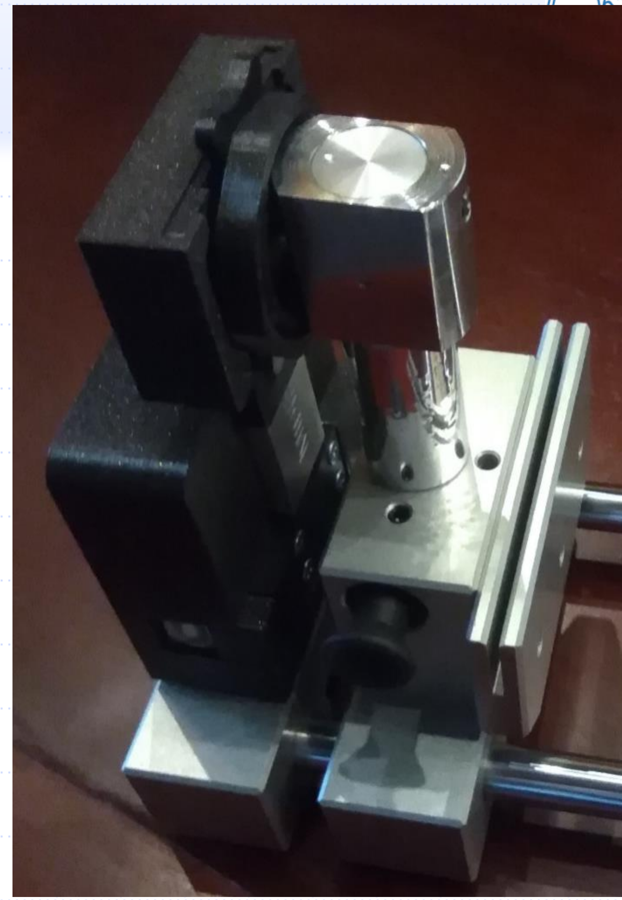


- *Demonstration of the radioactivity of the paper tissue that was used as an air filter in one house in Pardubice – Czech Republic*
- *The filtering took 5 minutes and exposure time was 10 minutes in both cases*

(Alpha) Radiography

Samples with hidden patterns



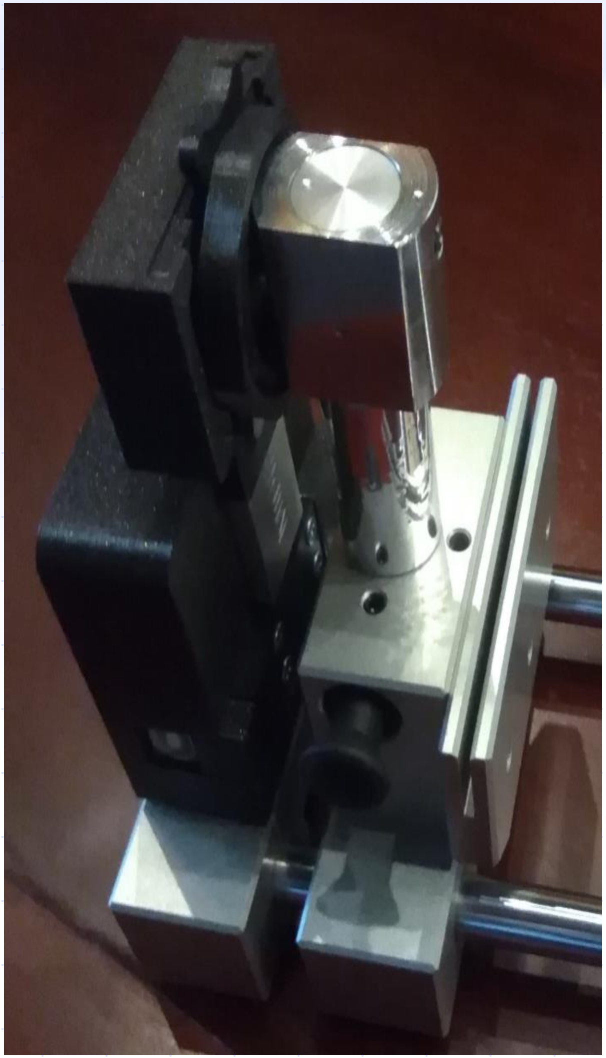


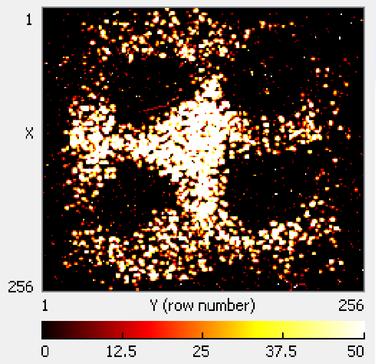
What is Hidden Inside?

Settings of Particle camera: Radiation source other, analysis type OFF, continuous YES, integral YES, exposure count 60, exposure time 1 s, max. level 1, colormap GRAY.

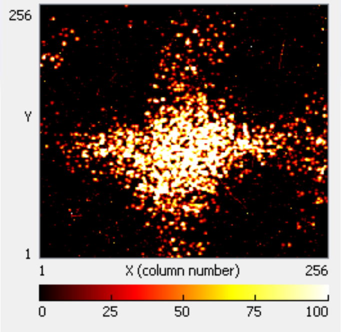
Settings of Filedevice: Radiation source other, analysis type OFF, continuous YES, integral YES, exposure count 60, exposure time 0.01 s, max. level 1, colormap GRAY.

(Alfa) Radiography Demonstration



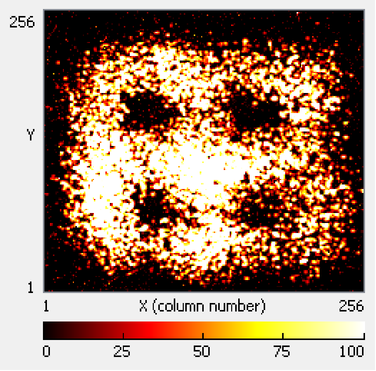


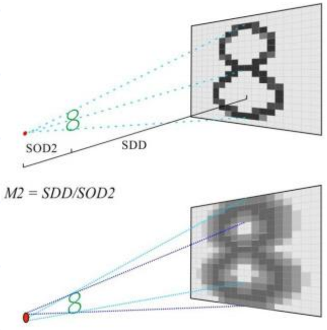
Impact of Sample position (magnification)

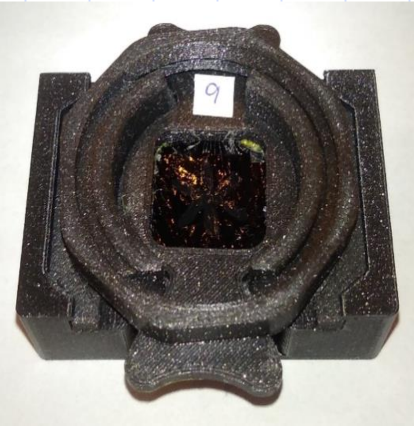


Impact of Beam collimation

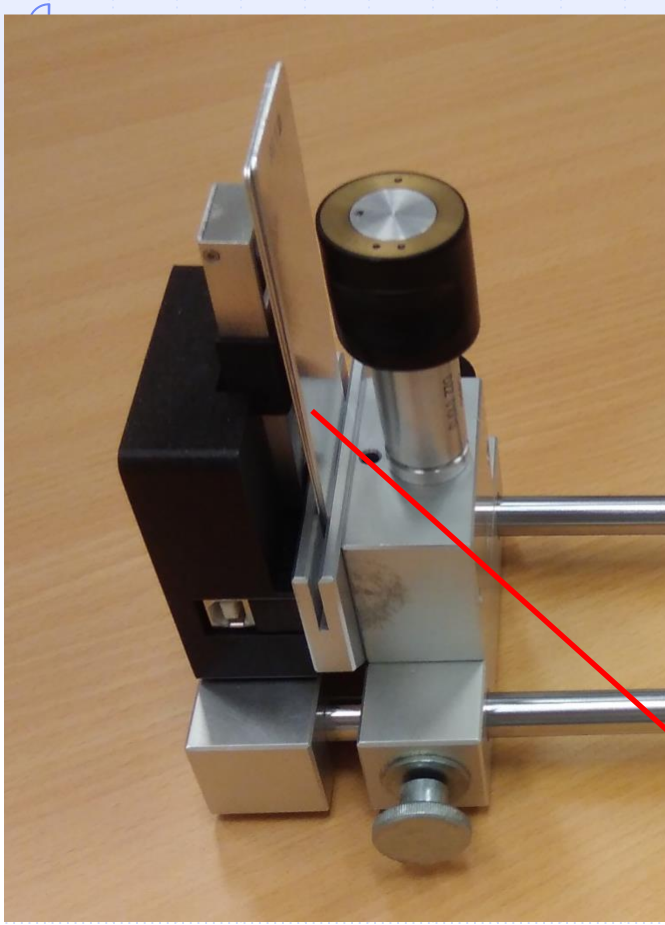
- even μm material thickness matter

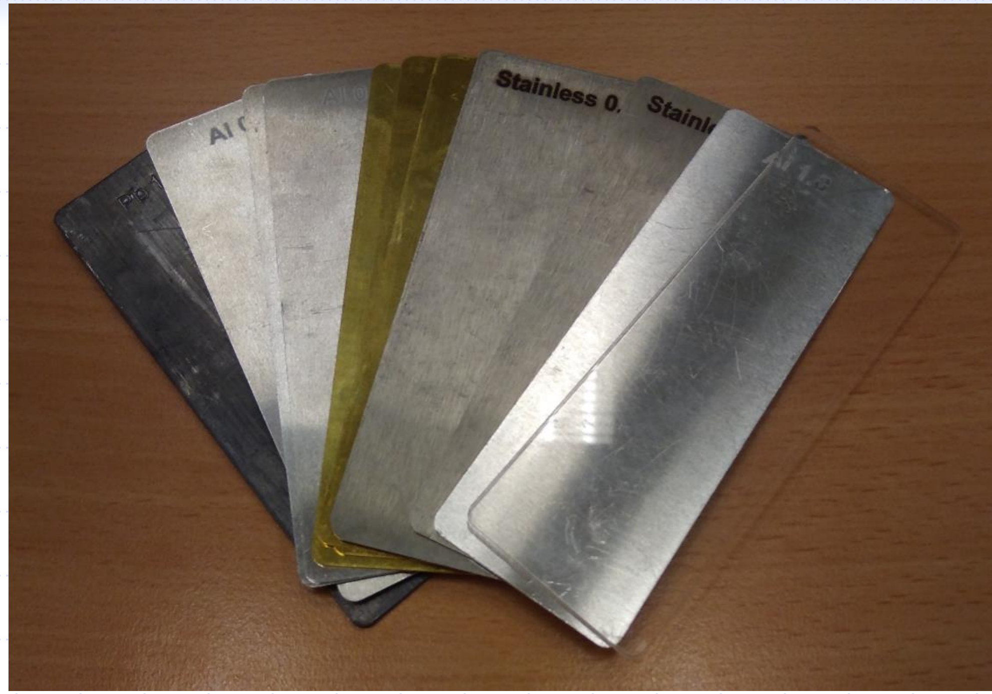






ABSORPTION of gamma particles in metals

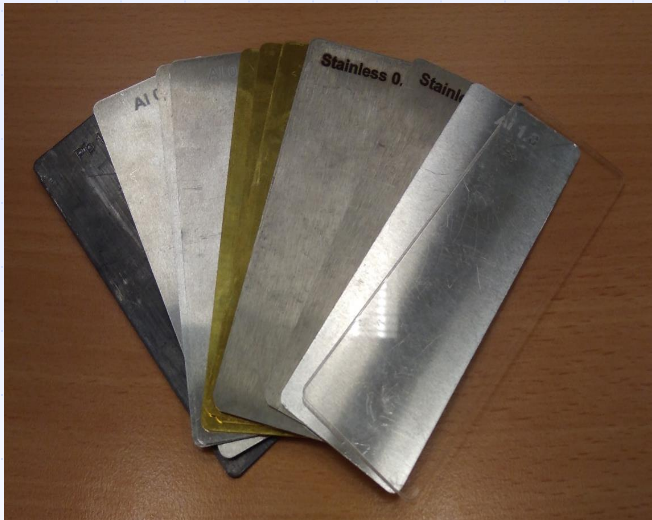


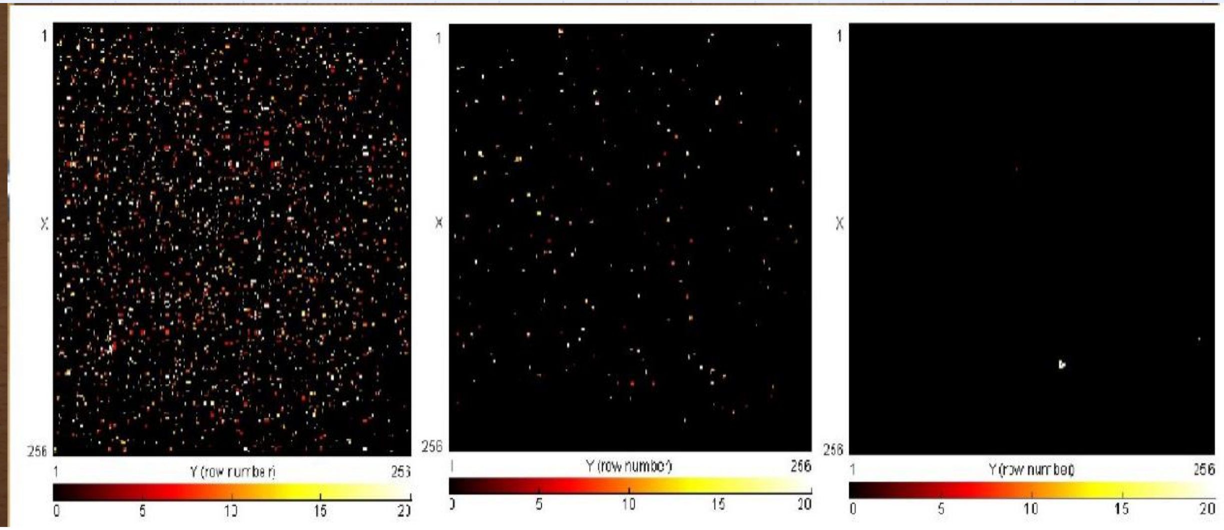


Metallic plate

Settings of Simple preview: *Radiation source americium, bias voltage 50 V, continuous NO, integral NO, exposure count 300, exposure time 0.5 s, max. level 1, colormap GRAY.*

Absorption of Gamma/X-Ray in shielding plates of various materials





Aluminum vs **Brass** vs **Lead**

vs **OTHER materials** vs **Background?**

- **DZZ Gamma**
  Americium 241 source
  300 kBq activity

Settings of Filedevice: *Radiation source other, analysis type OFF, continuous YES, integral YES, exposure count 60, exposure time 0.1 s, max. level 1, colormap GRAY.*

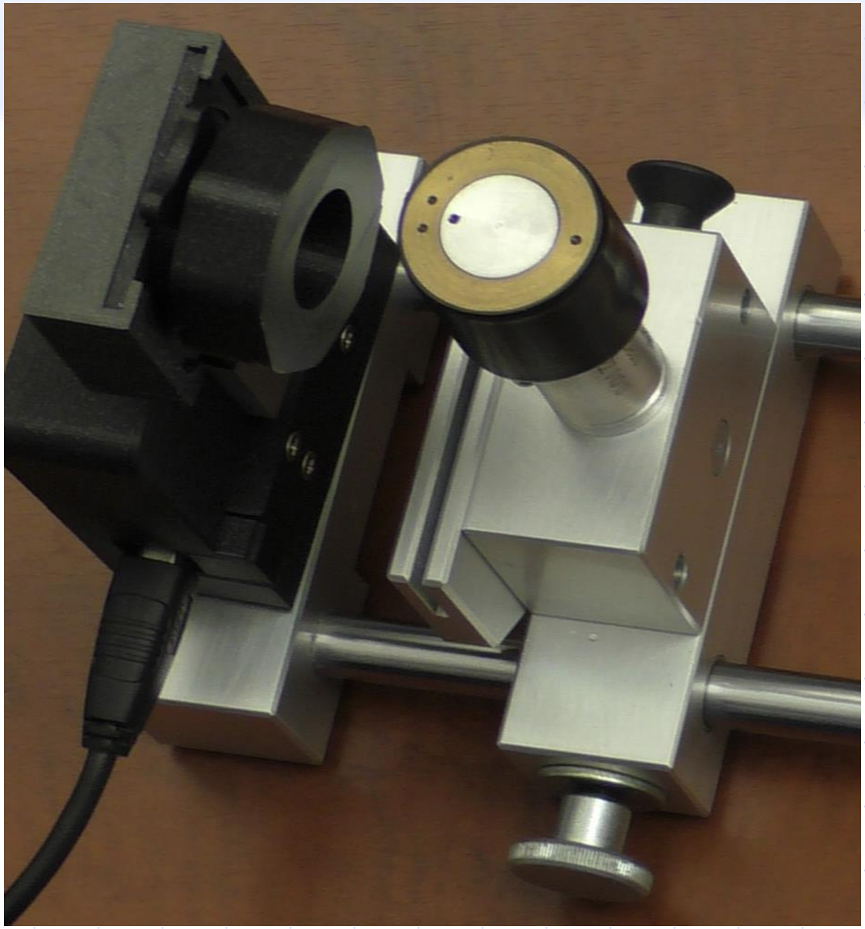
- **SZZ Alpha**
  Americium 241 source
  9.5 kBq activity

Settings of Filedevice: *Radiation source other, analysis type OFF, continuous YES, integral YES, exposure count 60, exposure time 1 s, max. level 1, colormap GRAY.*

Radiography (Gamma)

Samples with hidden patterns

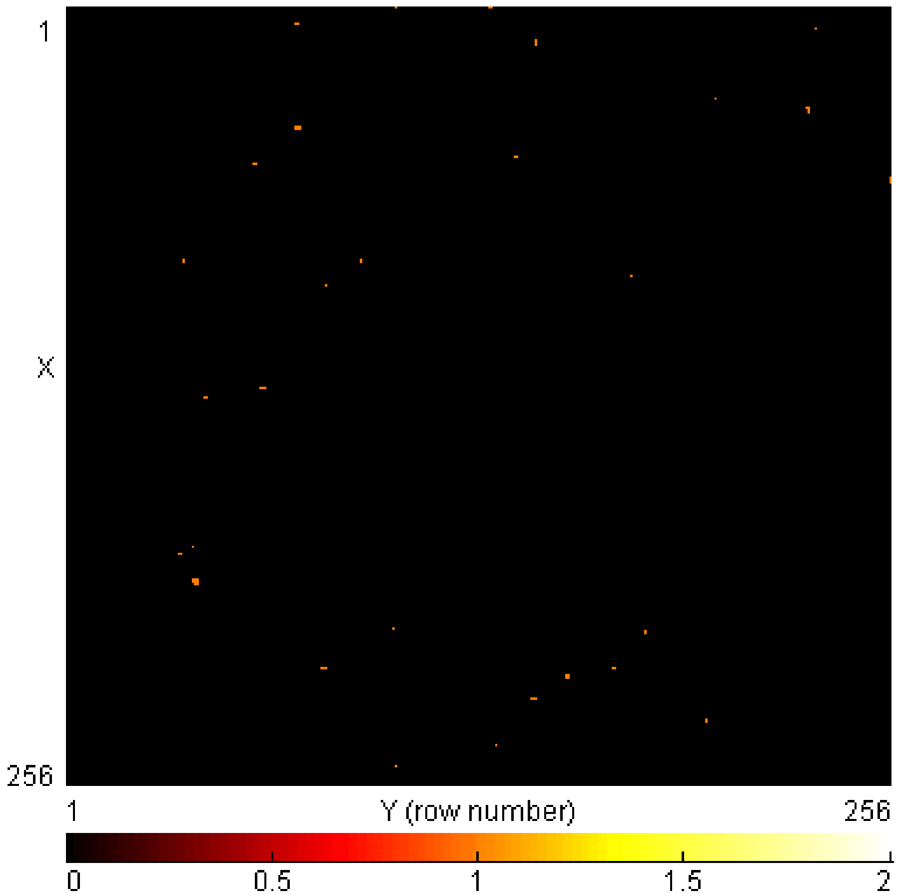
What is hidden inside?

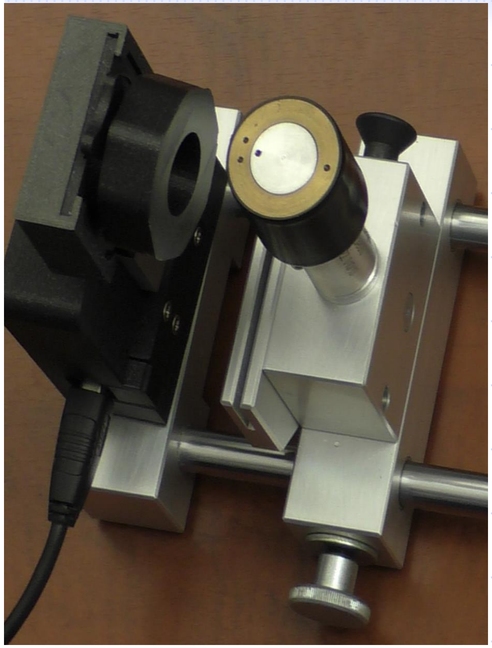


Settings of Particle camera: *Radiation source other, analysis type OFF, continuous YES, integral YES, exposure count 60, exposure time 1 s, max. level 1, colormap GRAY.*

Settings of Filedevice: *Radiation source other, analysis type OFF, continuous YES, integral YES, exposure count 60, exposure time 0.01 s, max. level 1, colormap GRAY.*

(Xray) Radiography Demonstration



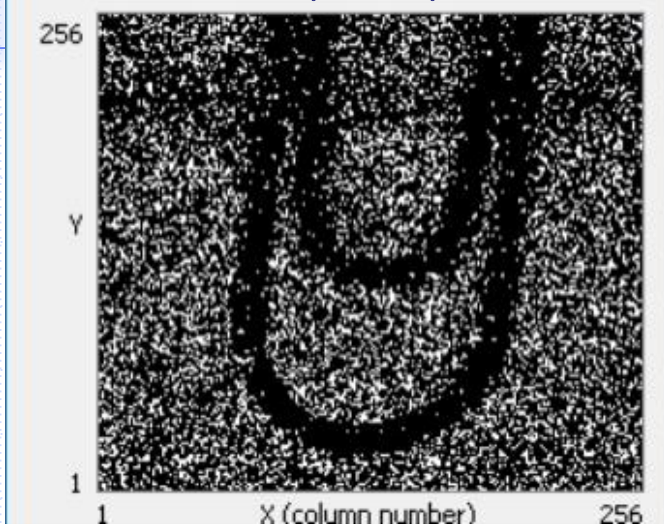


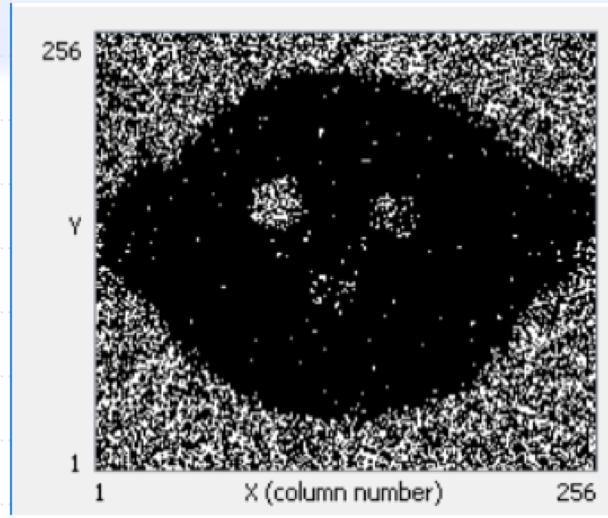
- In contrary to more advanced imaging

- Prove of basic working principle

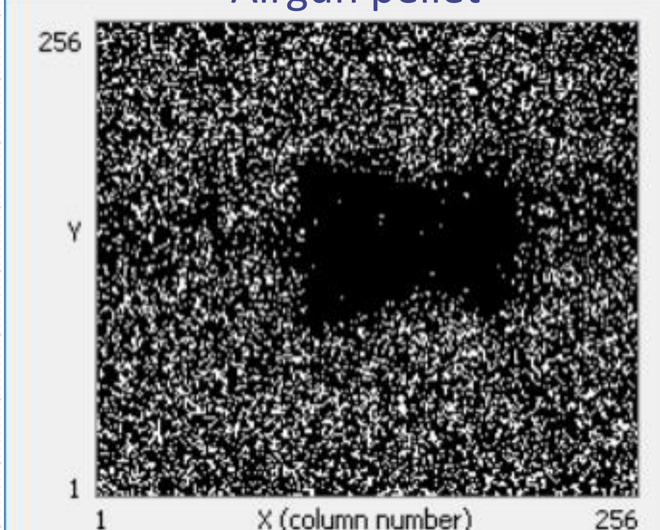
Hidden pattern examples….

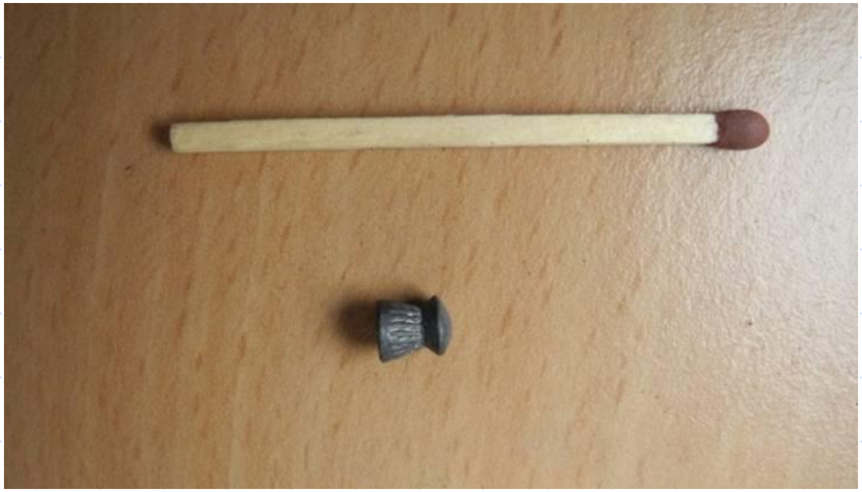
Paper clip





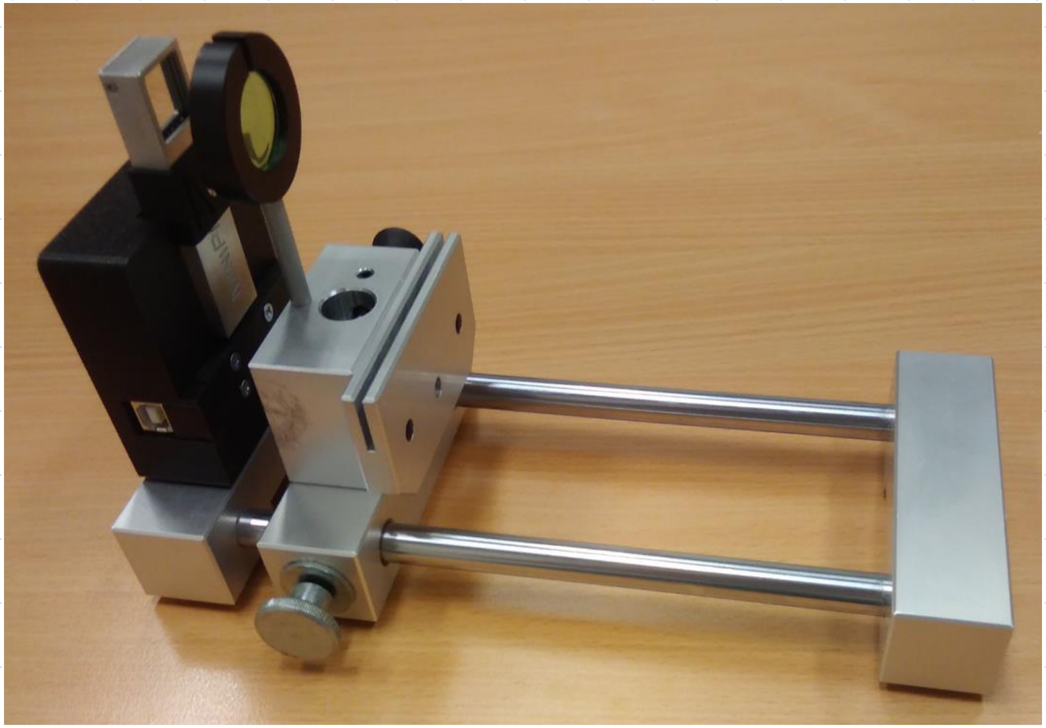
Airgun pellet





Thank you for your participation

Any initiative in a way to further cooperation is welcome!!!



outreach.and.education@utef.cvut.cz

Course Outline

- **Part 1**
  Introduction into Timepix detector, particle camera working principle, content of SESTRA kit, Pixelman simple preview software and its functionality
- **Part 2**
  Uranium glass experiment, Potassium experiment, Thoriated electrode experiment, Study of particle properties, Using of online visualisation tools, americium isotope radiation source, beam collimation, study of alpha radiation properties, start of long term background measurement
- **Part 3**
  Evaluation of long term background measurement, Radiation at on Earth ground vs orbit, observation of radon decay, Cosmic radiation, utilization of virtual particle camera, utilization of advanced particle type analysis
- **Part 4**
  alpha radiography, absorption of gammas in metals, gamma radiography, Own radiation sample study
- **Discussion**

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