MEDIPIX DETECTORS

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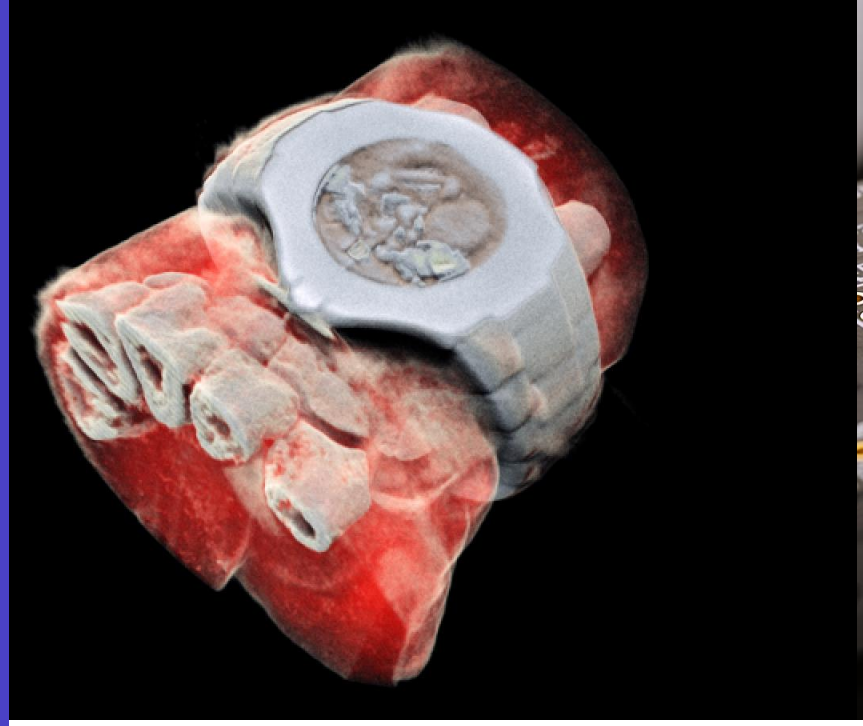
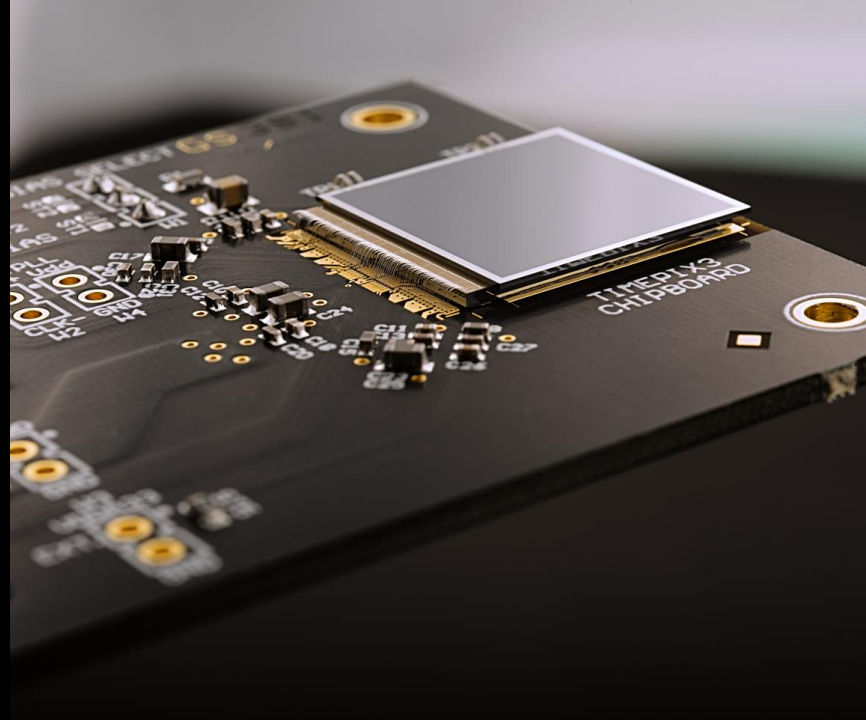
Outline



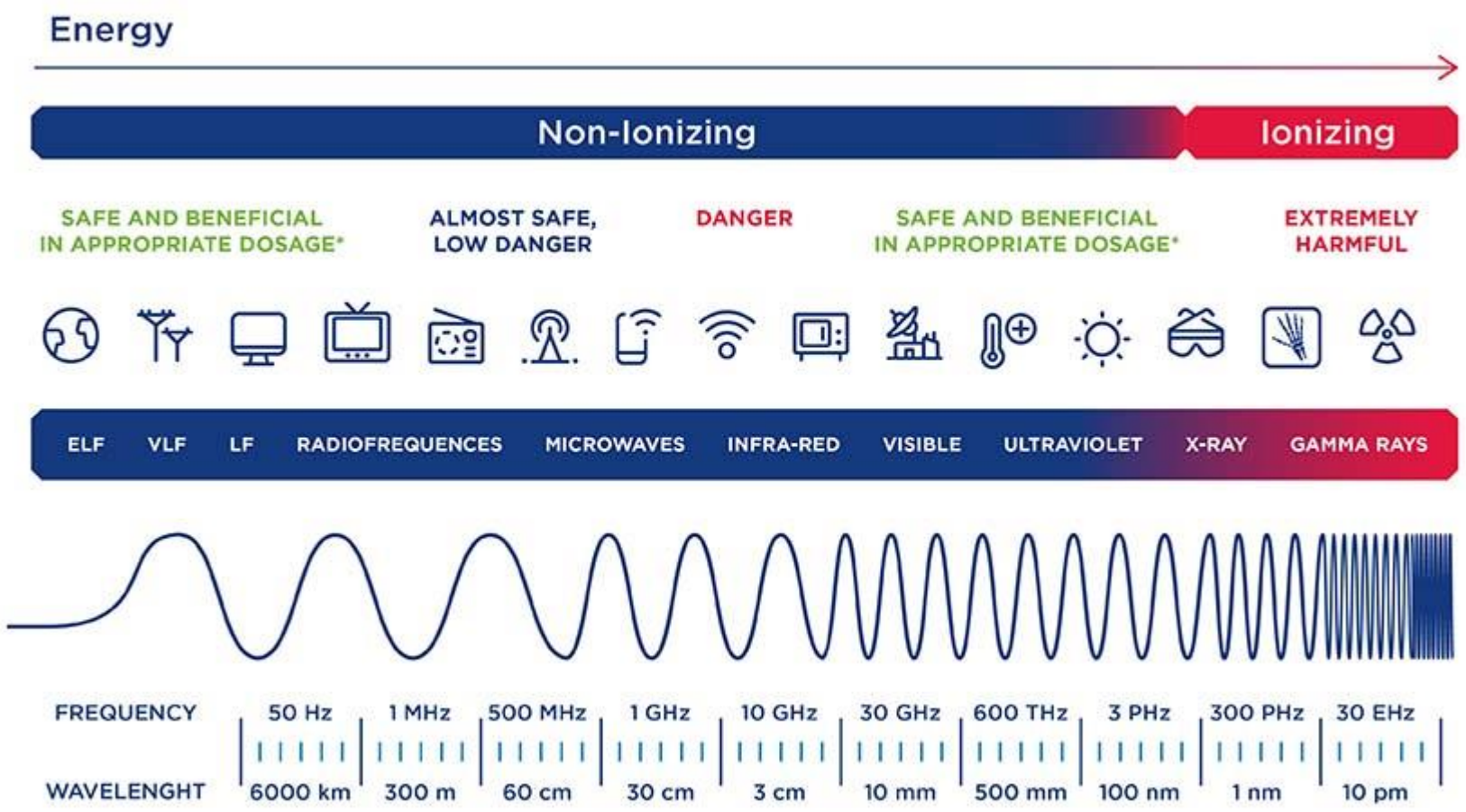


- Interaction of radiation with matter
- Photon counting detectors
- COOL applications of the detectors
- Hands on experience with Minipix-EDU

Introduction about Radiation

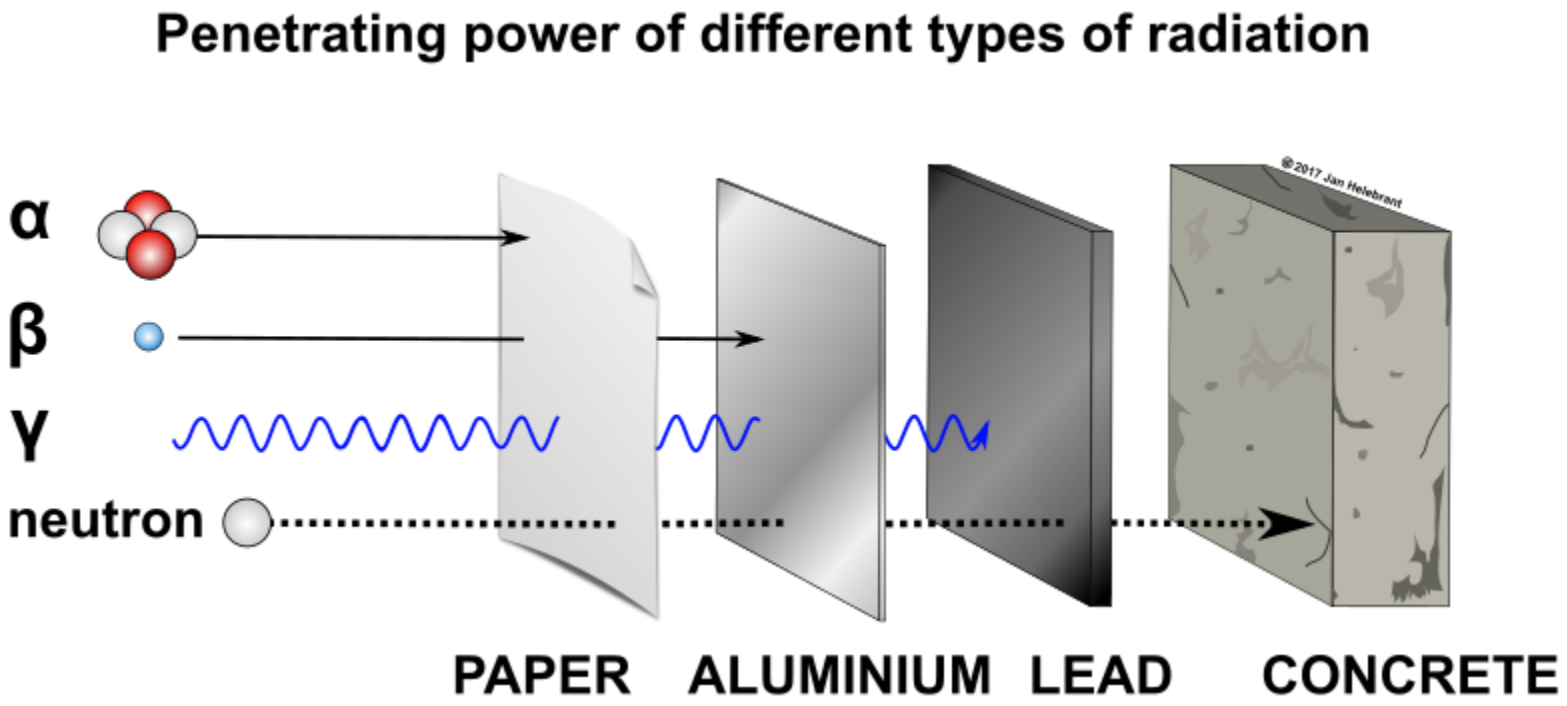
- **Radiation** is the emission or transmission of energy in the form of waves or particles through space or through a material medium.

- Radiation is often categorized as either **ionizing** or **non-ionizing**



https://www.safework.nsw.gov.au/hazards-a-z/ionising-and-non-ionising-radiation

Ionizing irradiation: alpha, beta, gamma particles



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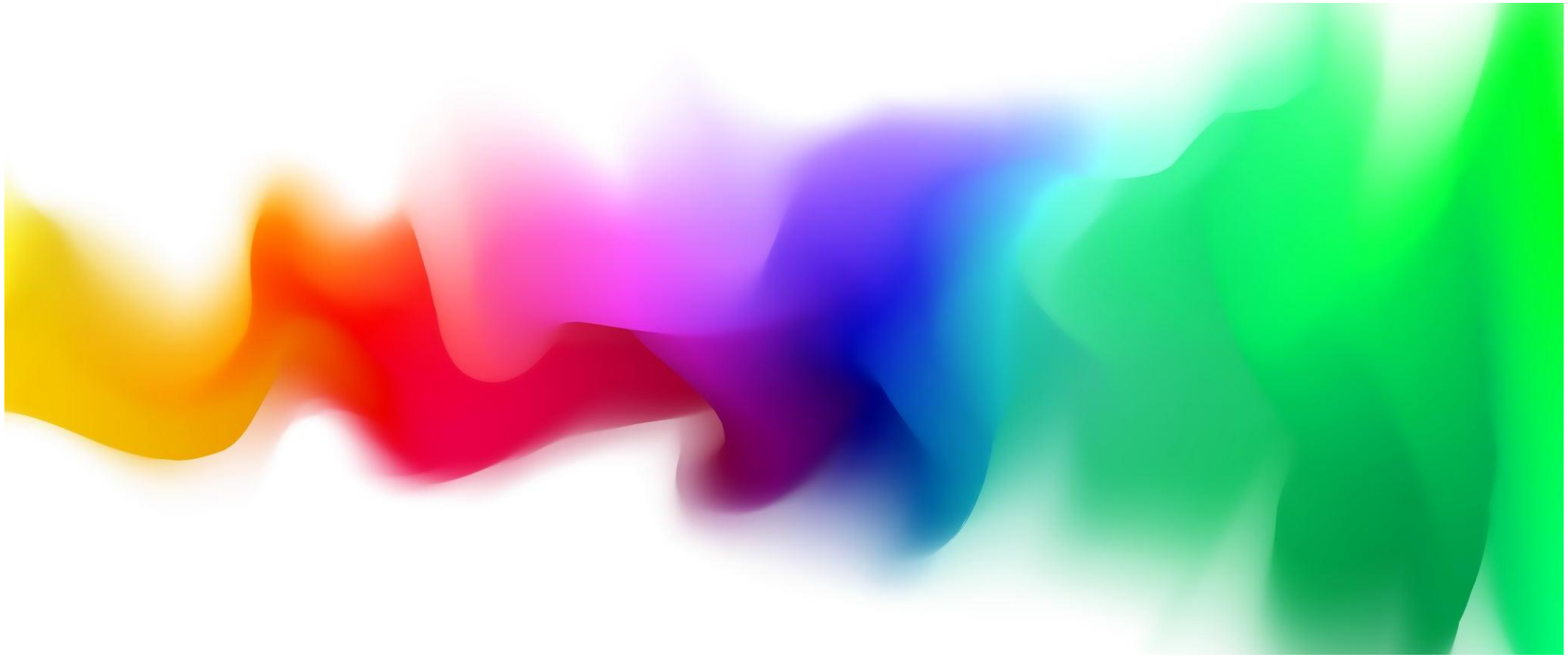
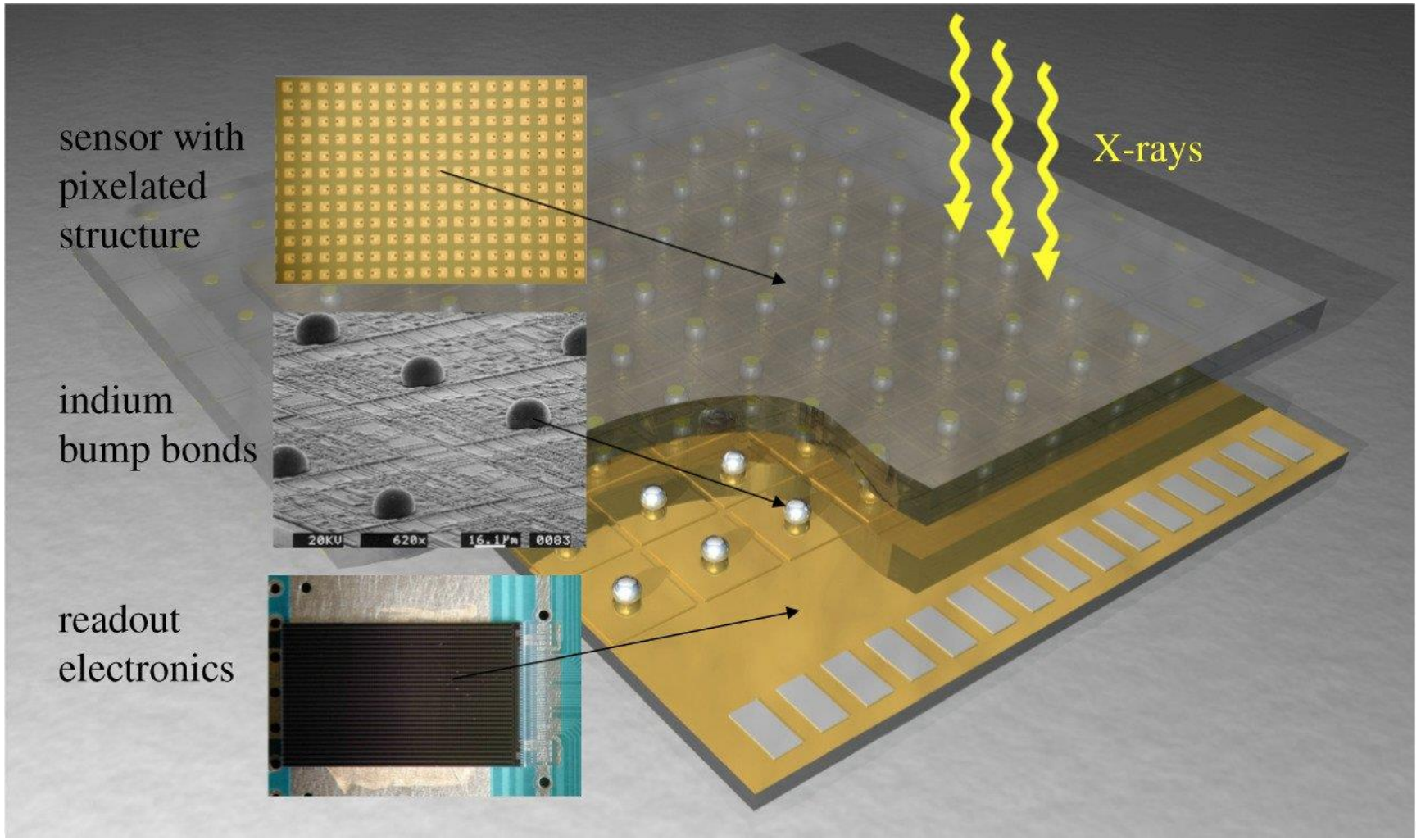
Photon counting detectors

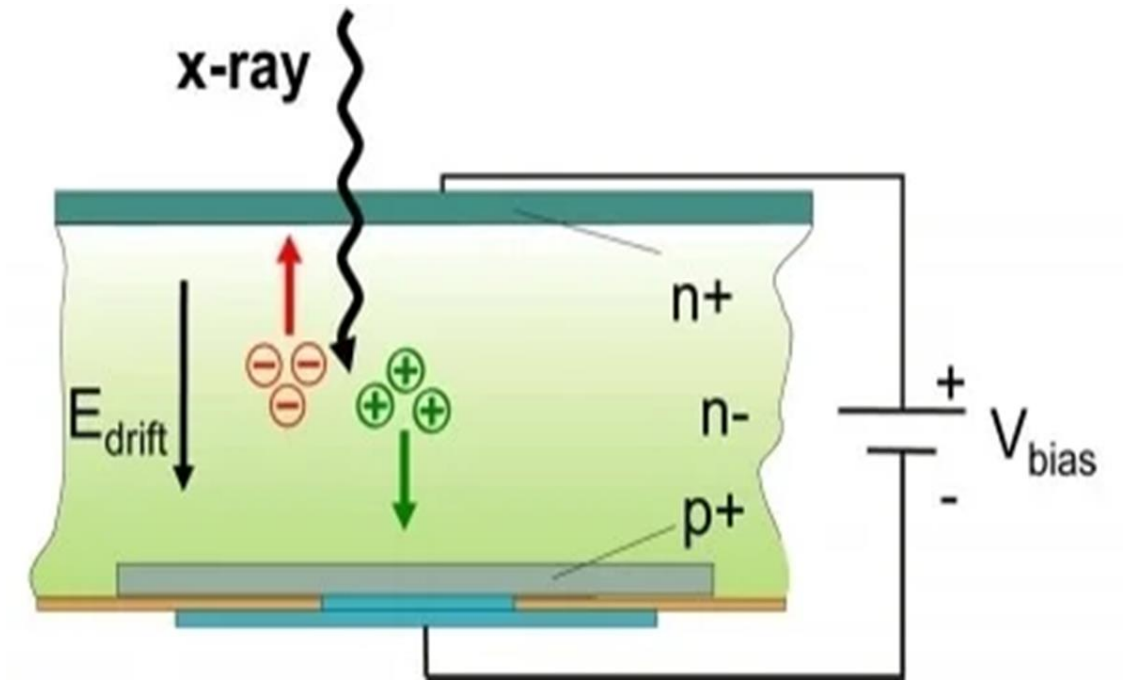


Pixel Detectors



https://www.dectris.com/en/landing-pages/transforming-x-ray-detection/

Interaction of radiation with sensor



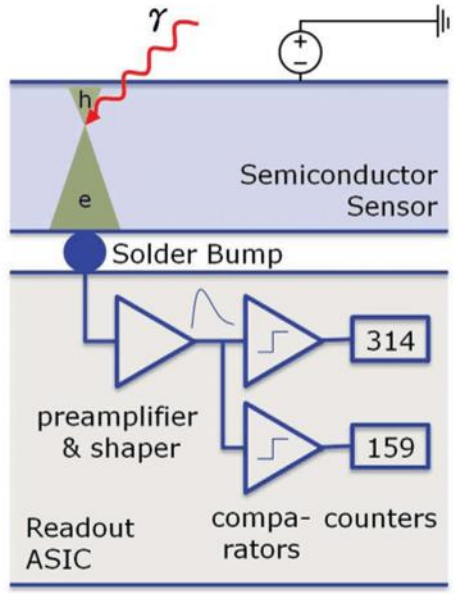
The mechanisms of interaction for ionizing radiation in the form of x-rays and gamma-rays include the:

- Photoelectric effect,
- Compton scattering and at high enough energies,
- Electron positron pair production.

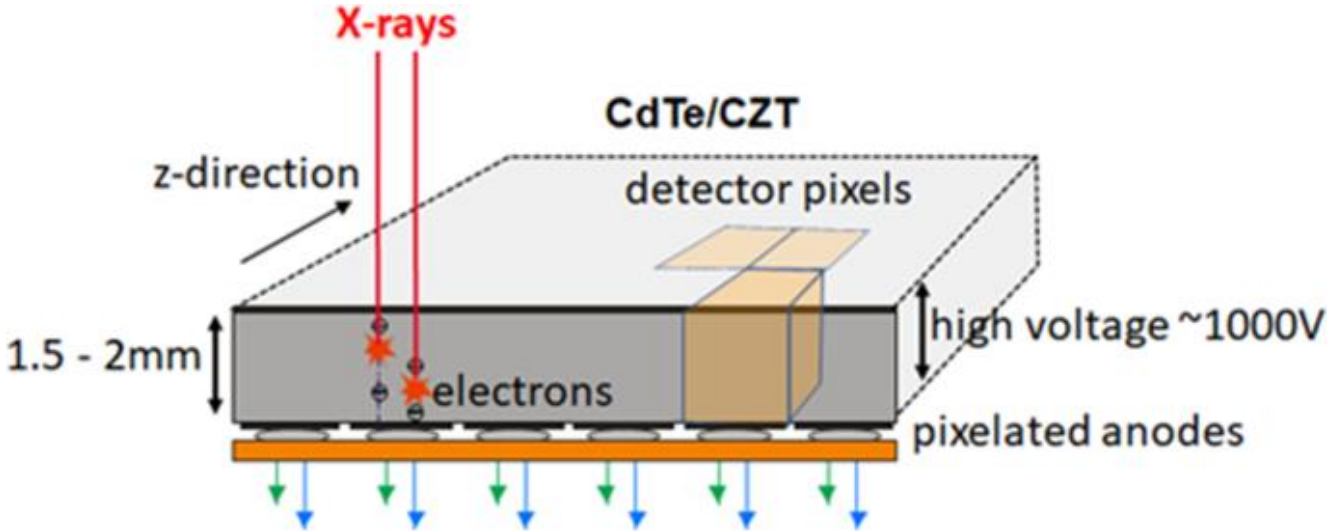
Sensor in pixel detectors

When ionising radiation strikes the detector its energy is deposited in the sensor material (Silicon or Cadmium (Zinc) Telluride).

This is then converted into an electrical signal and amplified.



https://ebrary.net/135261/engineering/introduction



https://link.springer.com/article/10.1007/s00330-023-09545-9

Comparison between indirect and direct detection

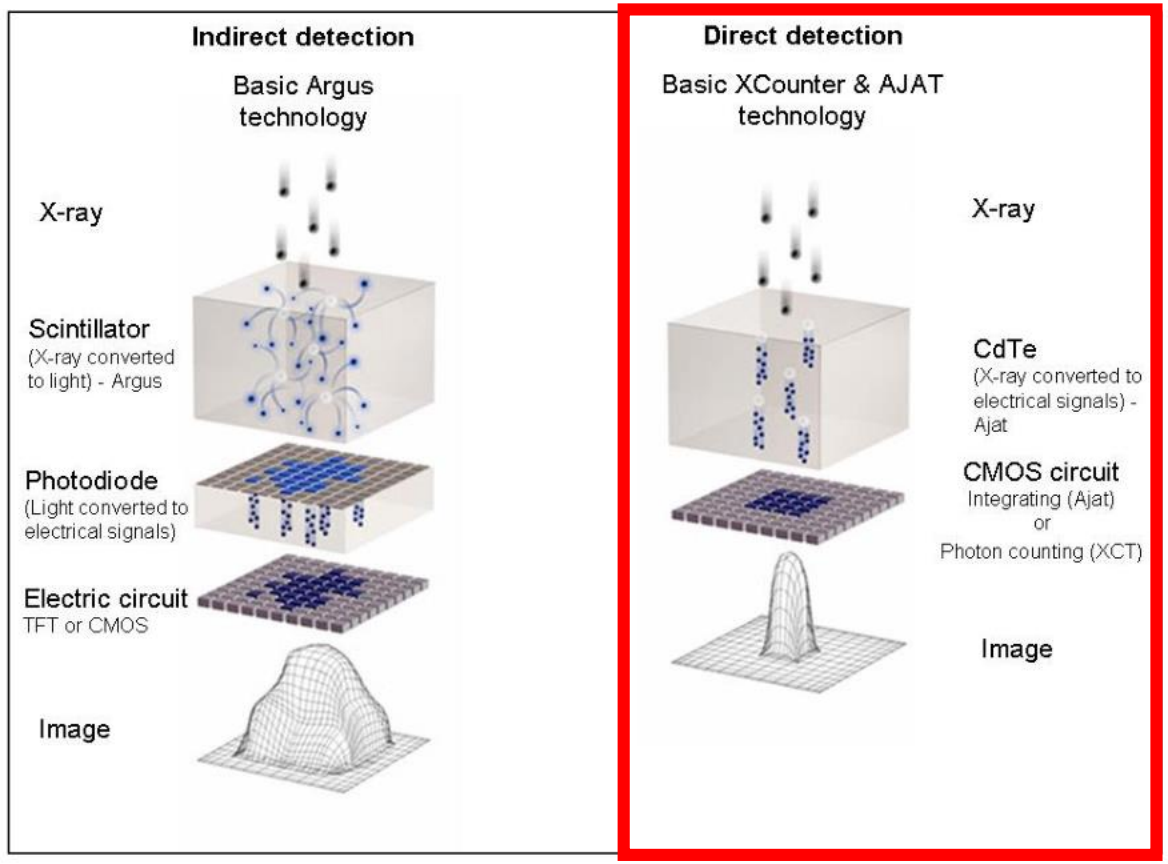
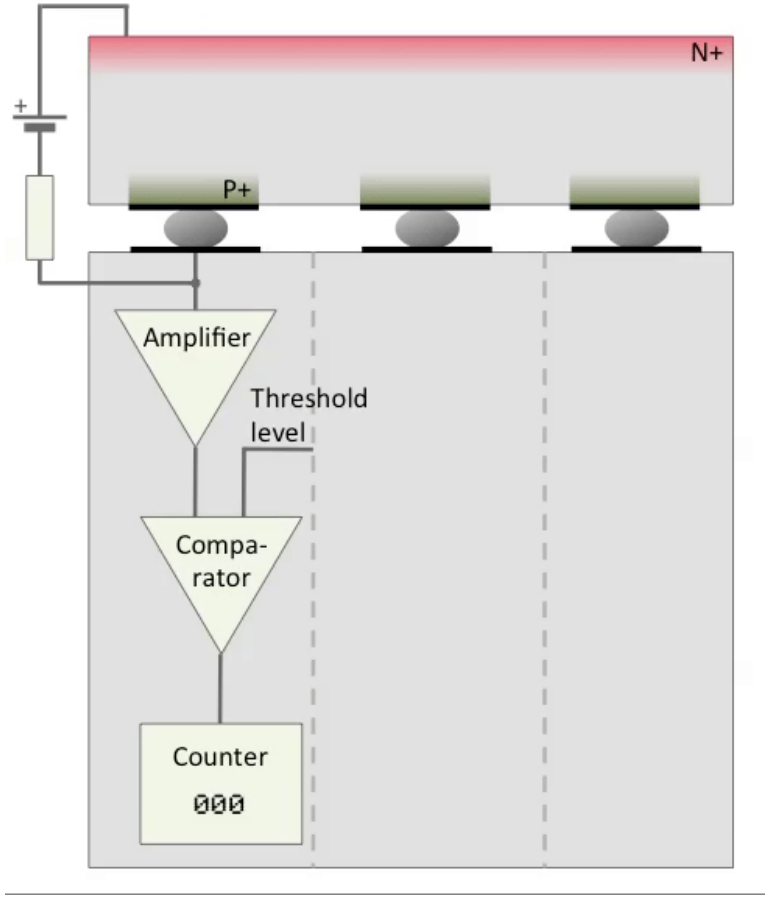


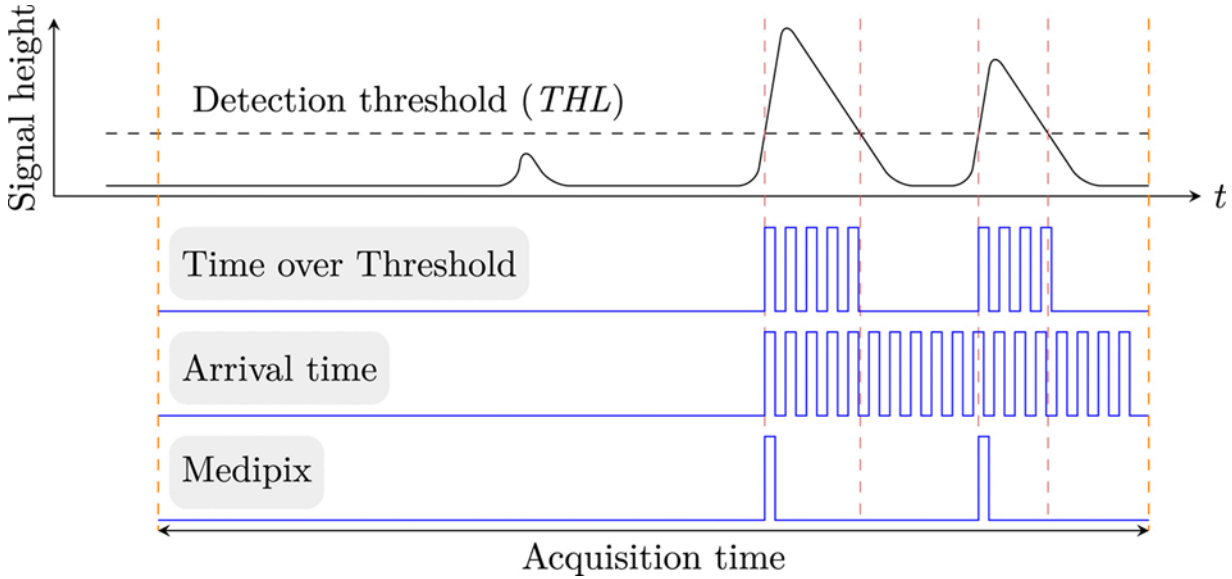
Figure 1: Comparison between indirect (left) and direct (right) detection of X-rays [1]

Better spatial resolution!

https://www.semanticscholar.org/paper/Photon-counting-and-energy-discriminating-x-ray-and-Schumacher-Zscherpel/7c7035c31b1f6fb3cdbddd6b01e945e6f5dc4e9c

Electronic circuit

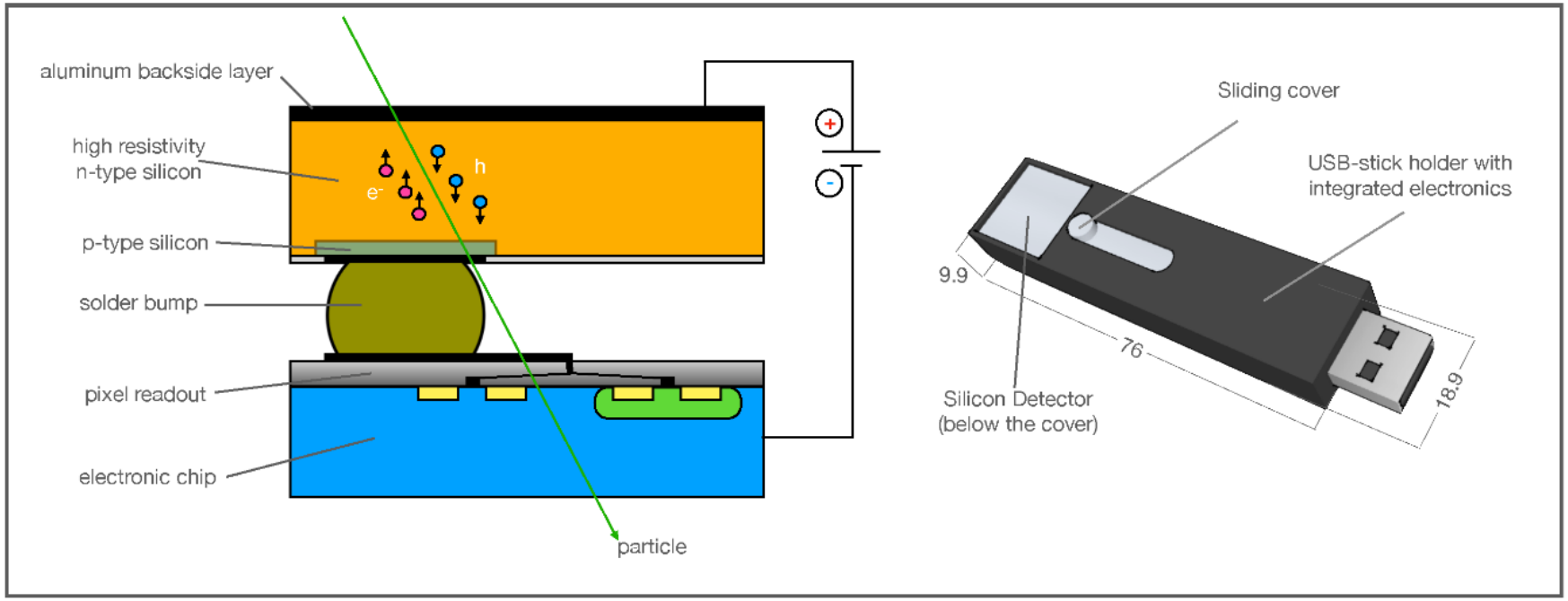




Each pixel has its own electronic circuit!

https://www.technos.in/hybrid-pixel-detectors.php

Minipix-EDU: a photon counting detector
How does it work?

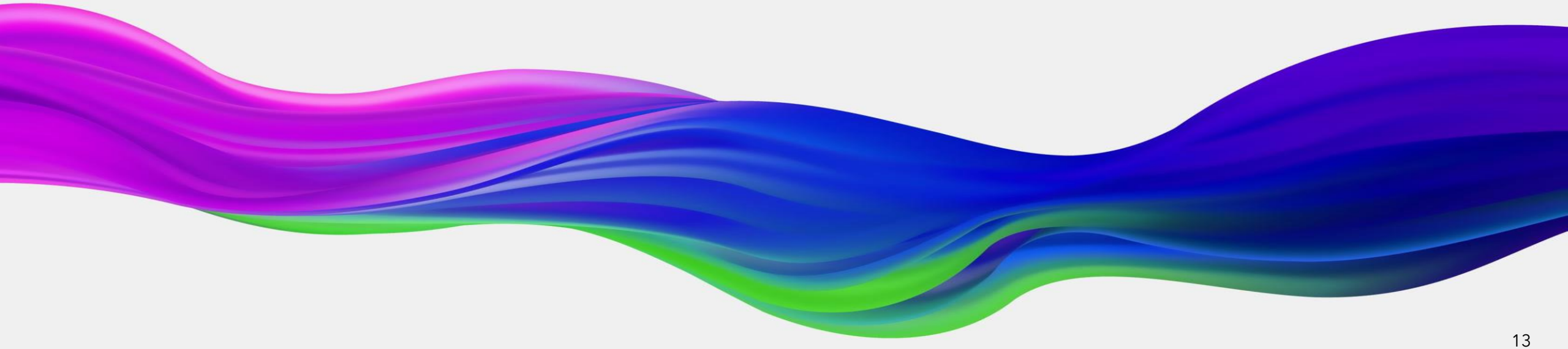


Cross section view of the Minipix Edu chip.

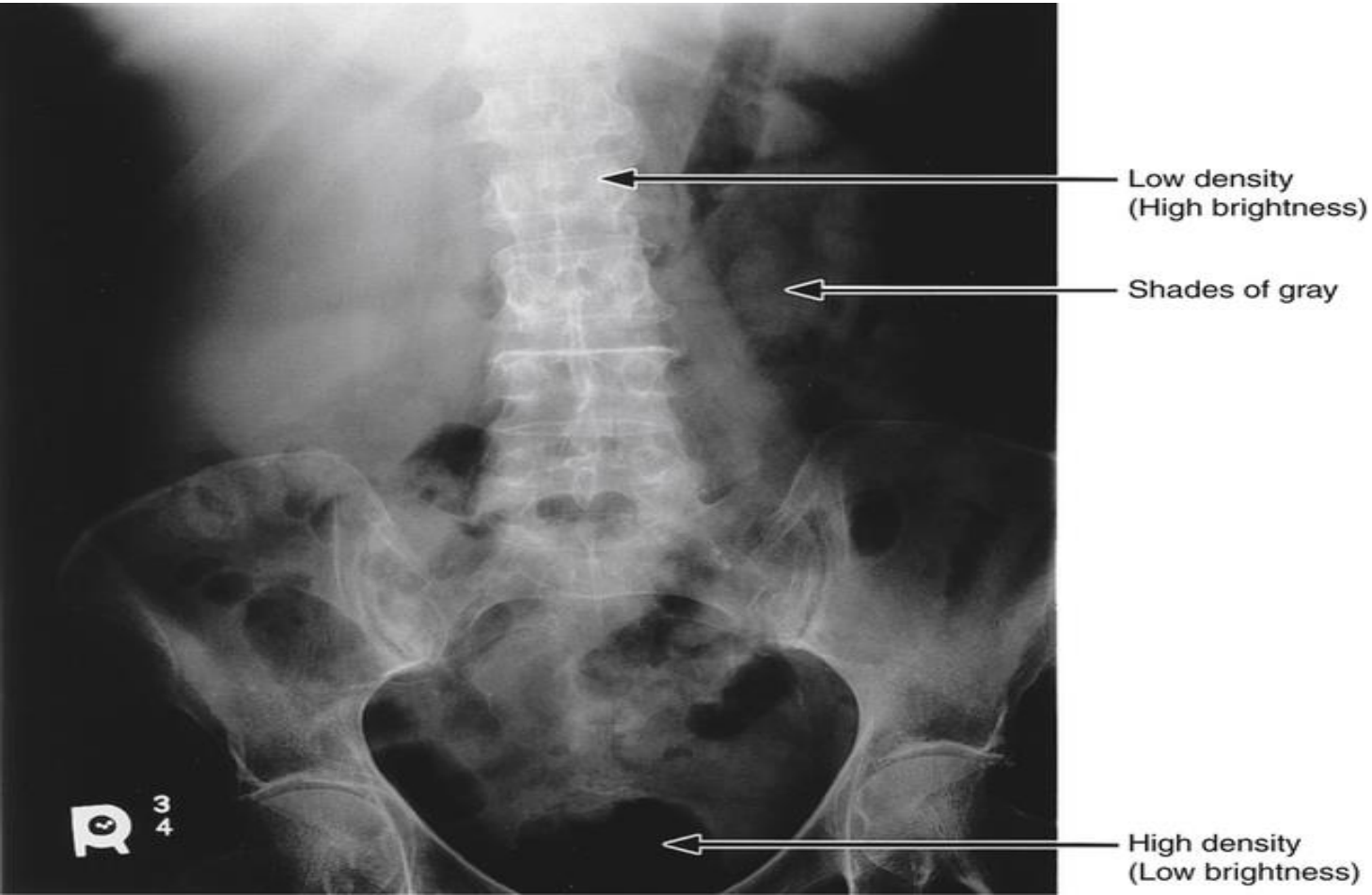
Rizzo, A.; Cardellini, F.; Poggi, C.; Borra, E.; Ciciani, L.; Narici, L.; Sperandio, L.; Vilardi, I. Novel Algorithm for Radon Real-Time Measurements with a Pixelated Detector. Sensors 2022, 22, 516. https://doi.org/10.3390/s22020516

1. Hybrid pixelated (256 x 256 pixels of 55um pitch) semiconductor detector.
2. Information about the **position**, deposited **energy** and **time stamp** of **each** particle interacting in the sensor.

Some of the many applications of photon counting detectors



“Conventional” X-ray CT scan



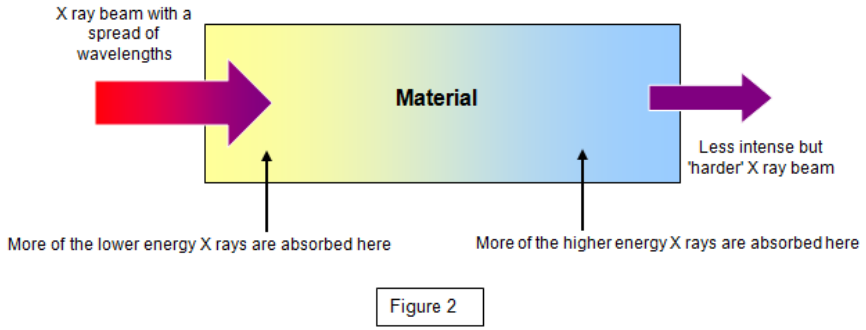
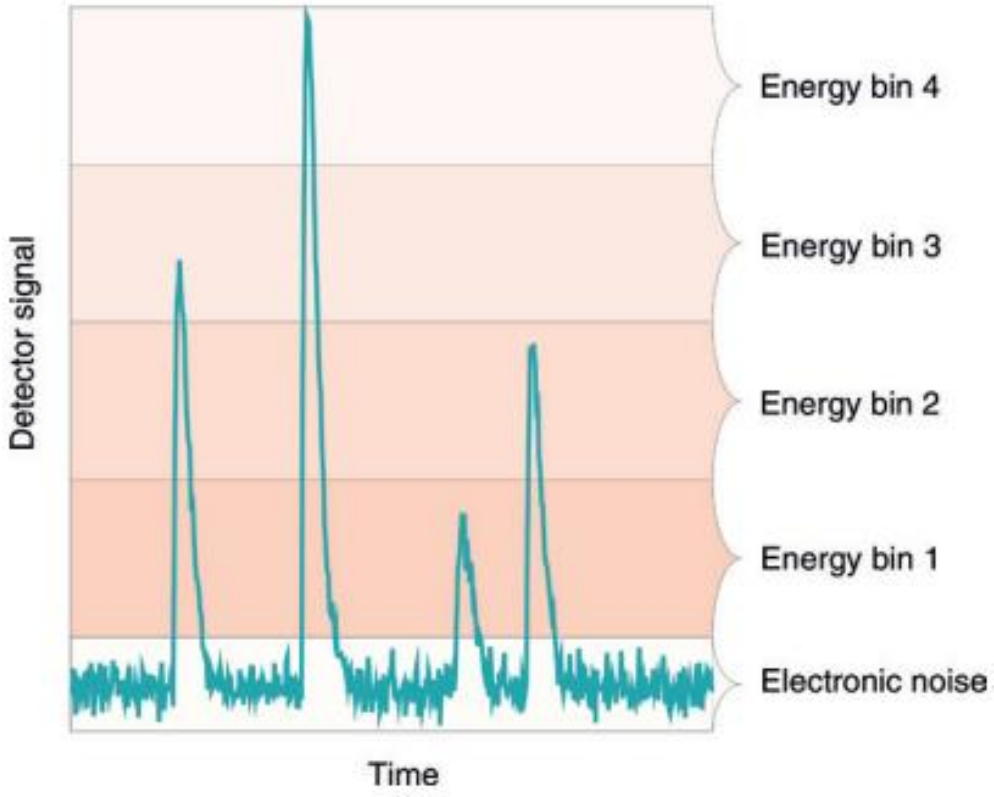


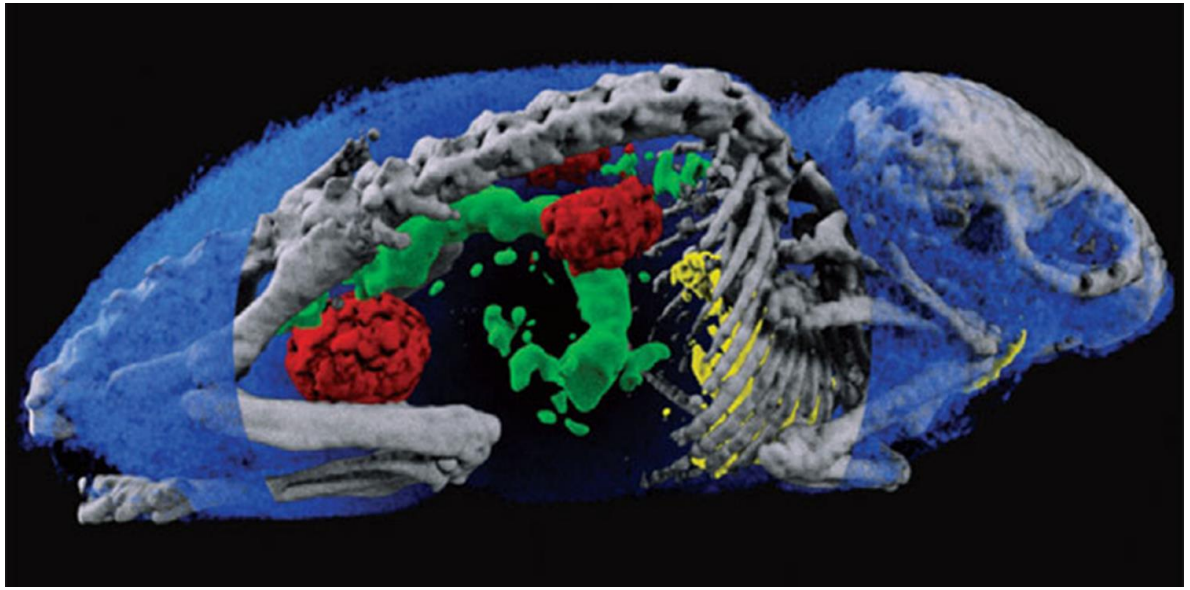
Figure 2

https://www.schoolphysics.co.uk/age16-19/Atomic%20physics/X%20rays/text/X_ray_absorption/index.html

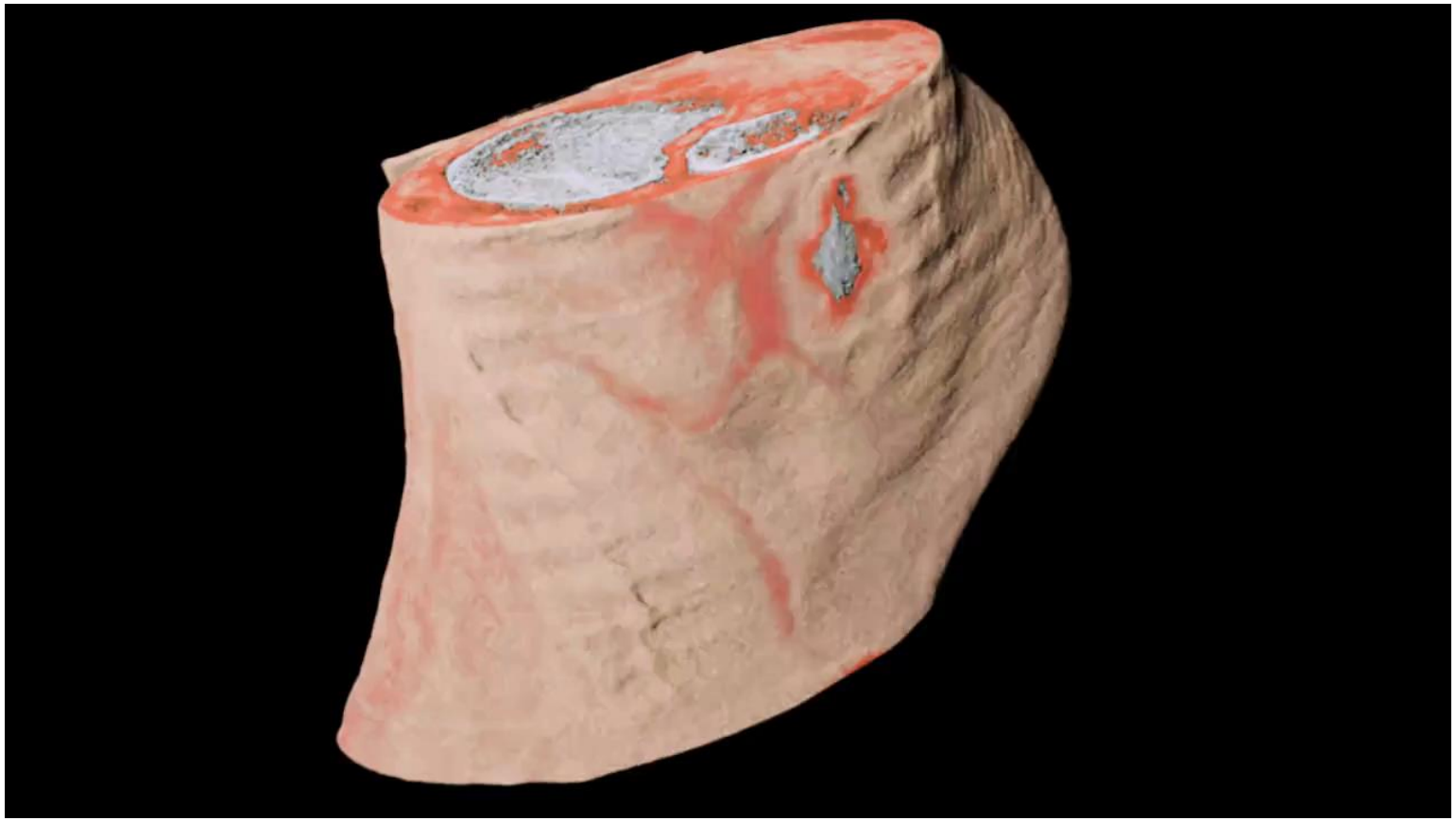
1. Spectroscopic X-ray imaging



- able to discriminate the energy of each incident x-ray photon.



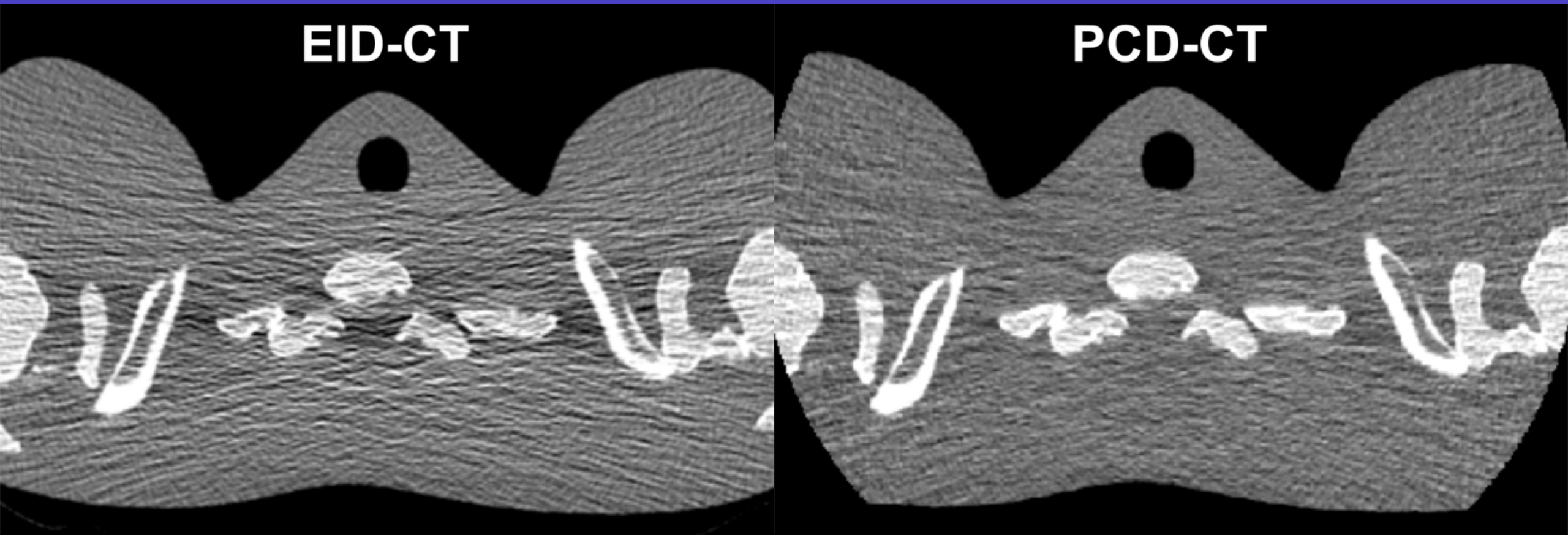
1. Spectroscopic (Color) X-ray imaging



Medical applications: Computed tomography

"Conventional" Energy Integrating Detectors (EID)

Photon Counting Detectors (PCD) Give less noisy image!



The shoulder section of a thorax phantom reconstructed from data acquired with EID CT **(a)** and with PCD CT **(b)** using the same x-ray tube potential and radiation dose

2. Application: school projects Particle identification

The pattern of the energy deposited across numerous pixels allows for identification of alpha, beta, gamma, muon, etc.

Type	Description	Track	Comment
Alpha, α	Helium nucleus: high energy, low speed and high mass	Appears as a spot 	On entering the silicon alphas are stopped very quickly, with energy spread uniformly
Beta, β	Electrons or positrons: high energy, high velocity	Wiggly line 	Wiggle is produced as beta moves further through the chip. Energy spread over a larger number of pixels than alpha
Gamma, γ	High frequency electromagnetic radiation	Dot 	Gamma continues to pass through the detector only interacting with a small number of pixels

Data analysis with Pixet Basic software

Let's compare two datasets using the PIXET BASIC SOFTWARE!

https://satram.utef.cvut.cz/

3. The detector in SPACE!

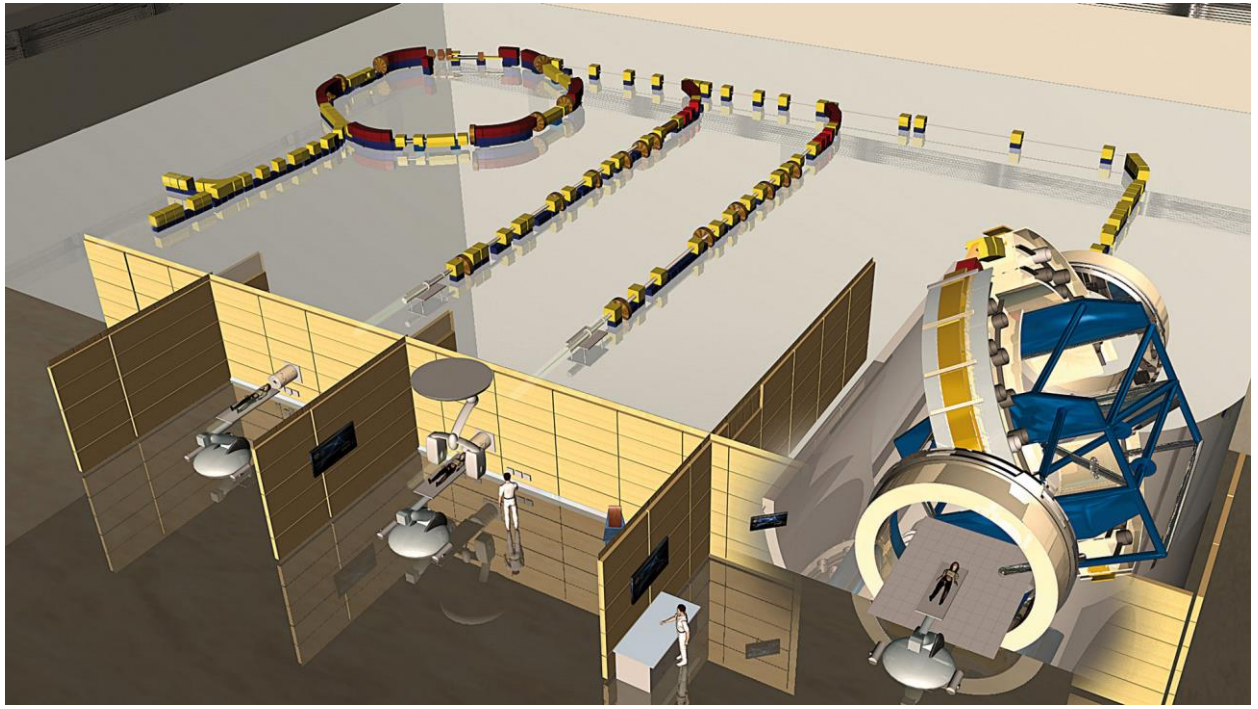
Total Radiation Dose Monitoring

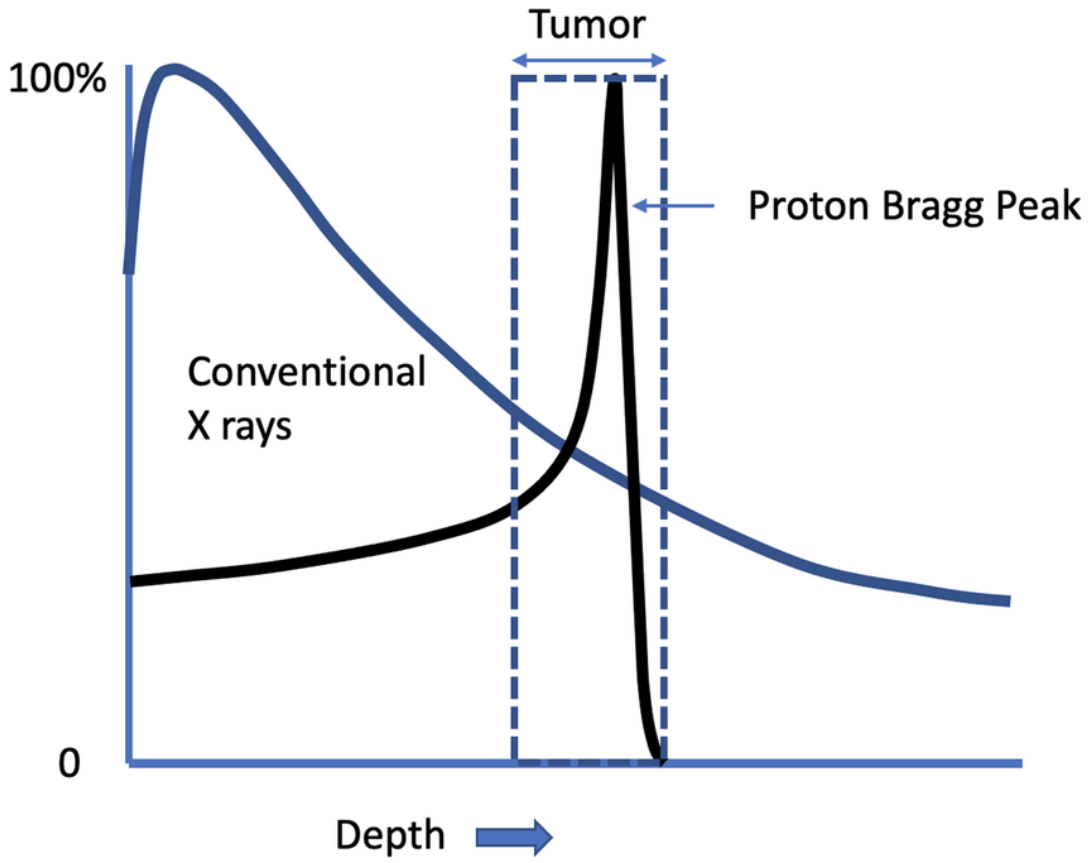
Adaptive Protective Measures

Space Weather Forecasting

Data for the detector on the One Web – JoeySat satellite – launched last year/May 2023. orbit - 600 km LEO. With ADV's MiniPIX Space with TPX3 500 um Si sensor

4. Treatment planning for hadron therapy





Let's check two more datasets!

5. Material reconstruction for art

CERN technology helps rediscover lost painting by Raphael: The Madonna and Child

https://medipix.web.cern.ch/news/news/timepix/cern-technology-helps-rediscover-lost-painting-raphael

SUMMARY

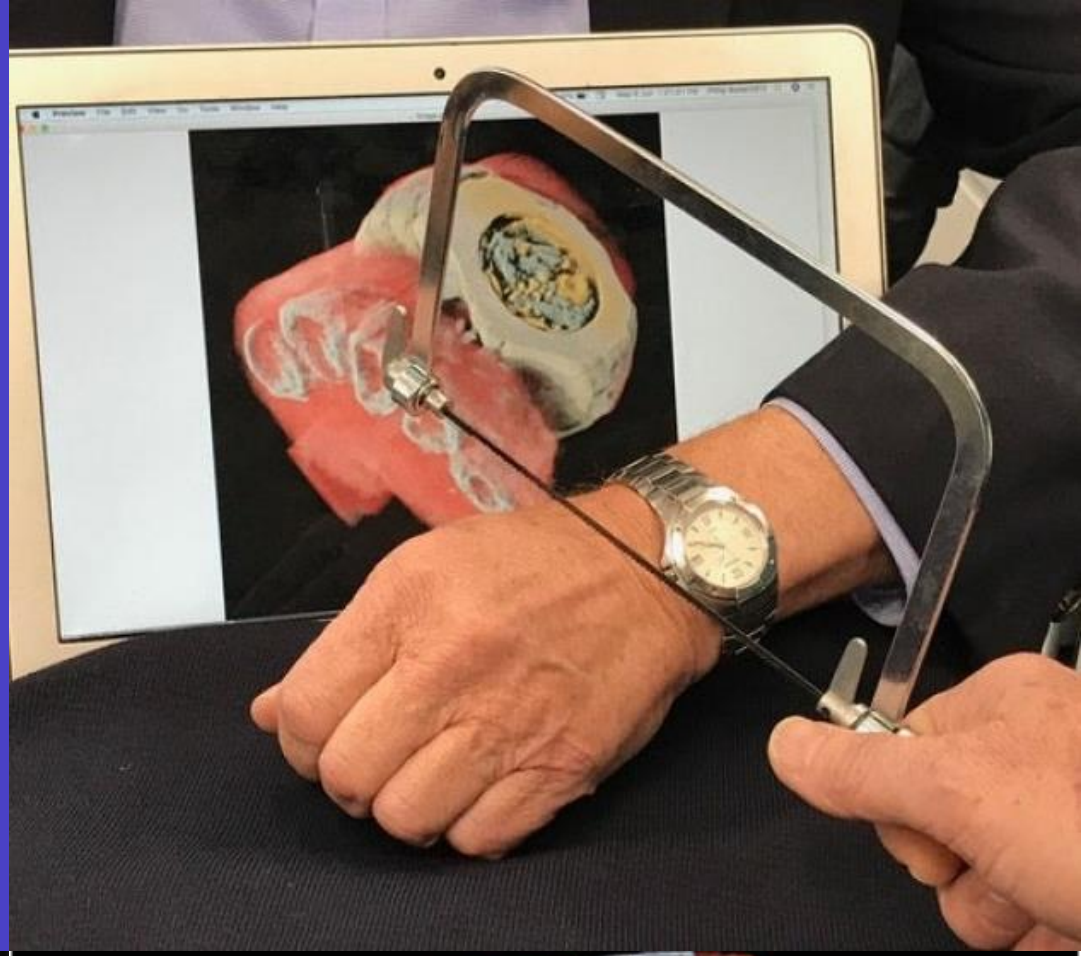
- Ionization is necessary to have signal in our detectors!
- We are dealing with Photon Processing Detectors (we have information for the energy and the time of individual photons interacting with our sensor)

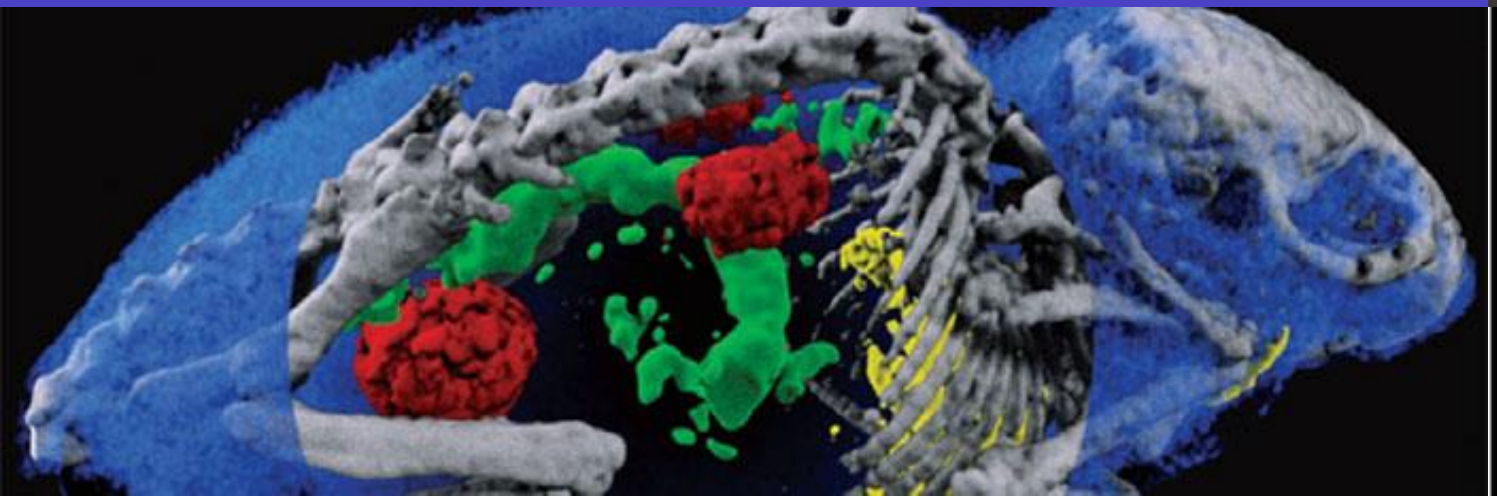
- The spatial and energy resolution improve significantly in photon counting pixelated semiconductor detectors!

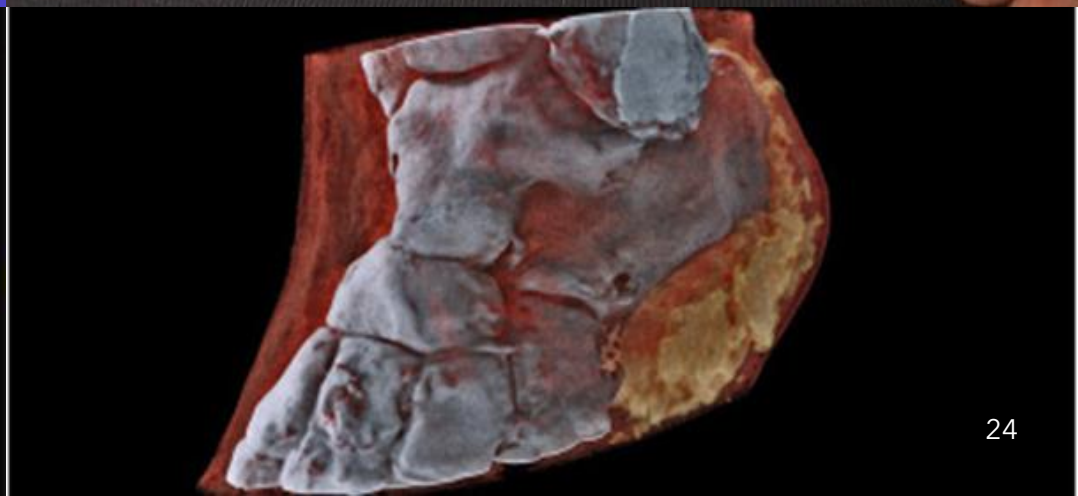
- Particle identification is possible!

- There are many applications in a variety of fields!

So lets connect the Minipix-Edu to the laptops!





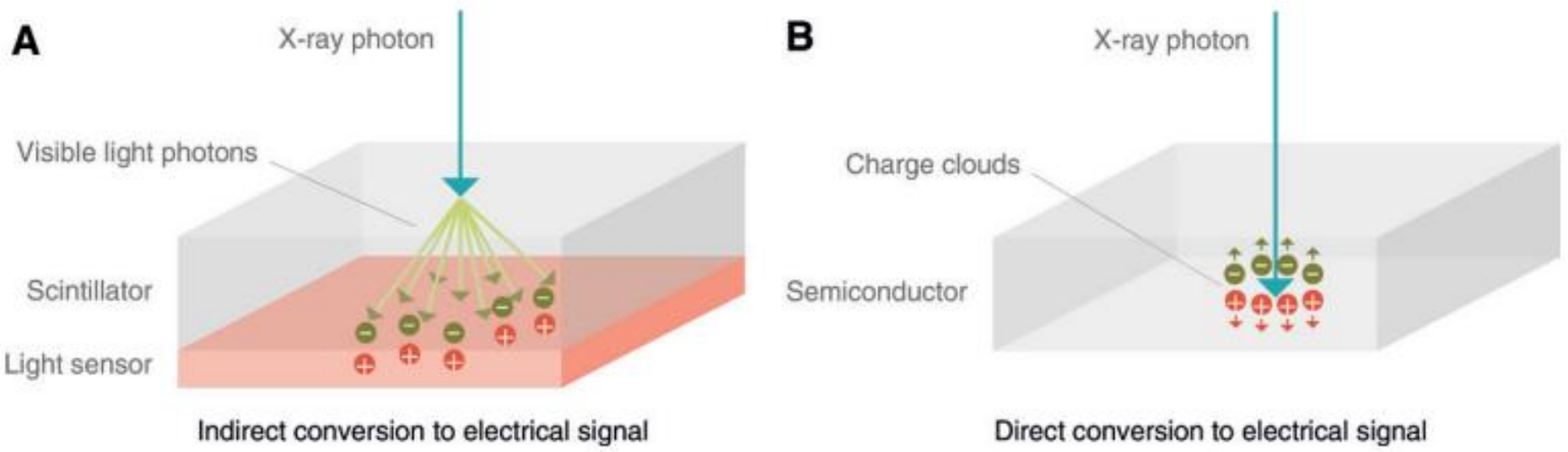


EXTRA SLIDES

USEFUL LINKS

- https://medipix.web.cern.ch/home
- ADMIRA PROJECT: https://serviparticules.ub.edu/en/projects/admira-project
- Really interesting article about educational use of Timepix detectors: https://cds.cern.ch/record/2801427/files/document.pdf
- Knowledge transfer success story: https://knowledgetransfer.web.cern.ch/success-stories/medipix-chips-and-collaborations-medical-imaging-space-dosimetry
- Minipix edu from ADVACAM: https://advacam.com/camera/minipix-edu/
- SESTRA KIT and book with experiments: http://www.utef.cvut.cz/cms_files/original/cms_data/00099/SESTRA_flyer_-_2022-06-02_-_EPS_forum_Paris.docx_compressed.pdf

Photon counting detectors
1. Direct conversion

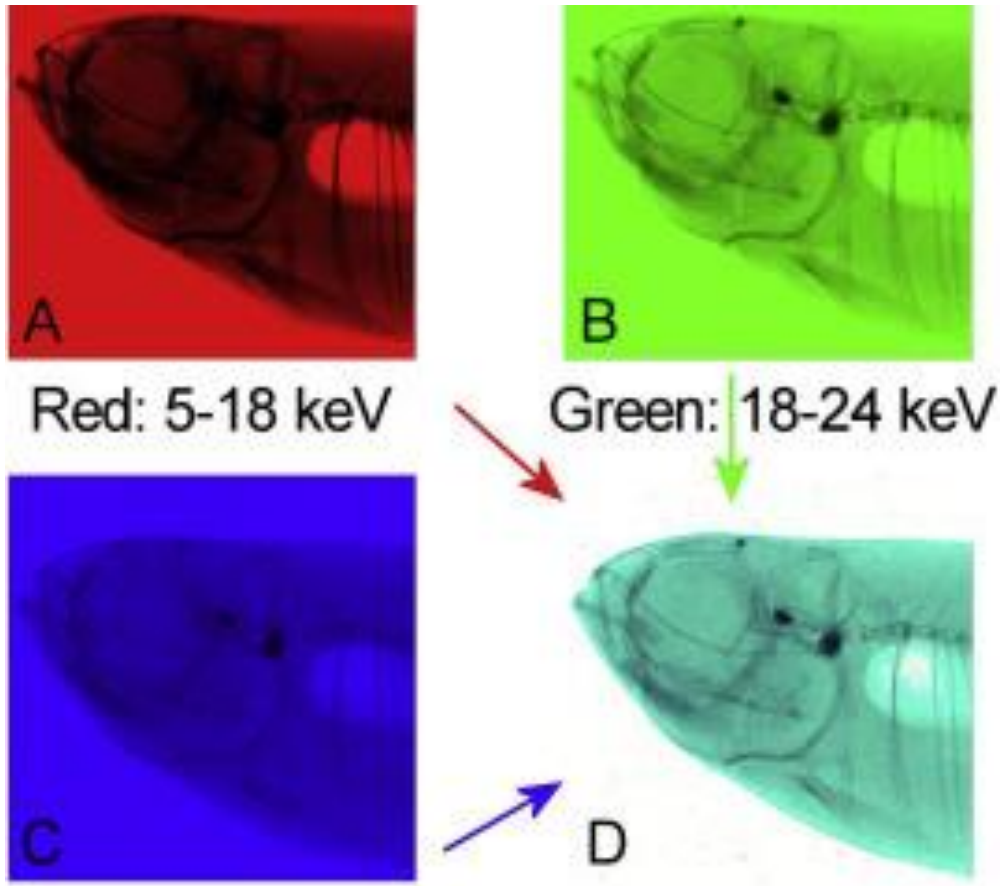


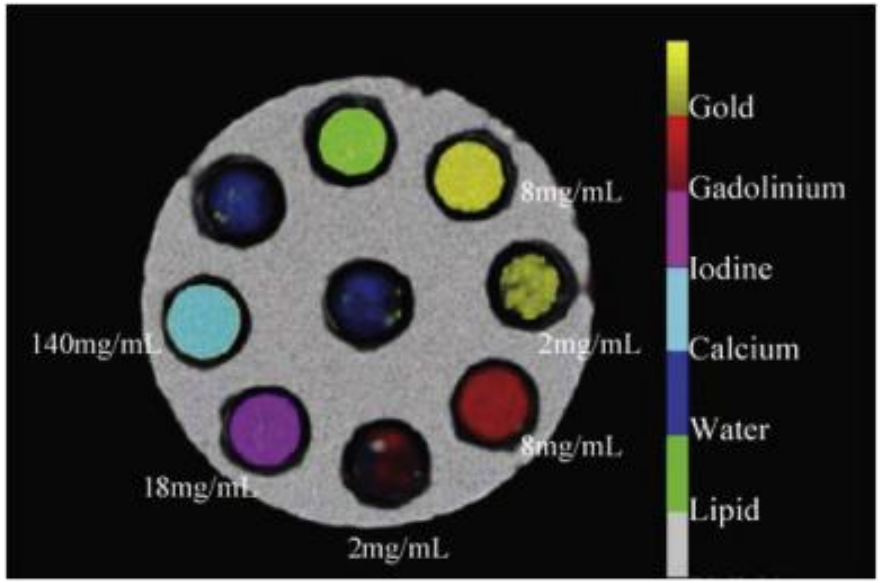
Conventional energy-integrating detector

Photon-counting detector

https://doi.org/10.1148/radiol.2018172656

1. Coloured X-ray imaging using the head of a small fish

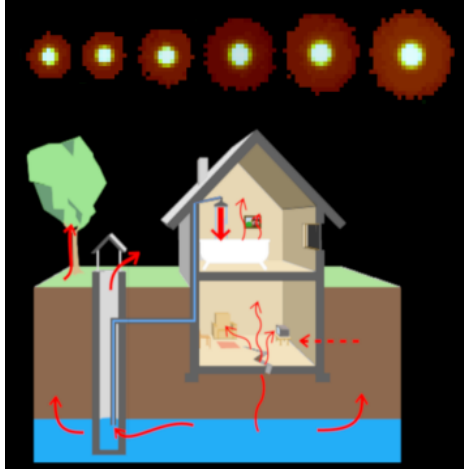




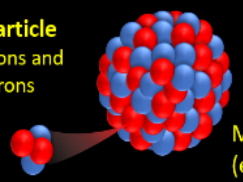
https://www.sciencedirect.com/science/article/pii/S1350448719300599

Different types of particles!

Alpha α



Alpha particle
Two protons and two neutrons

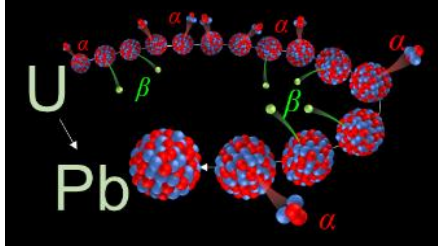


Mother nucleus (e.g. Radon)

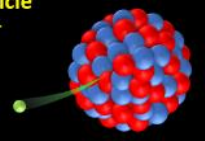
Radon decay

^{222}Rn	**Radon**	α	3.8 days
^{218}Po	Radium A	α	3.1 min
^{214}Pb	Radium B	β⁻	26.8 min
^{214}Bi	Radium C	β⁻	19.9 min
^{214}Po	Radium C'	α	164.3 µs
^{210}Pb	Radium D	β⁻	22.20 years

Beta β



Beta particle
Electron or positron



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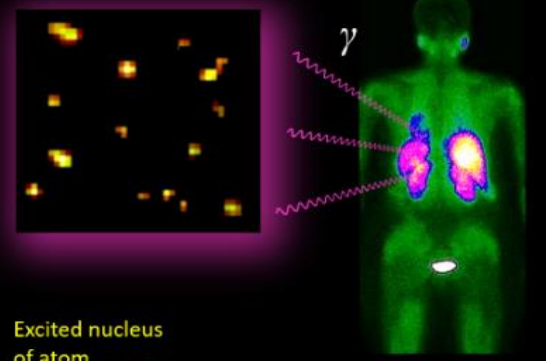
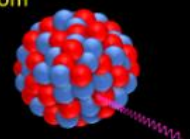
^{210}Pb	Radium D	β-	22.20 years

Gamma γ

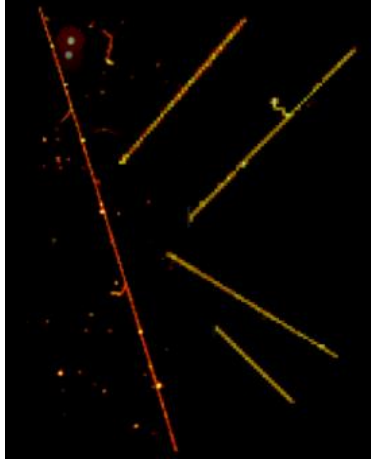


Excited nucleus of atom

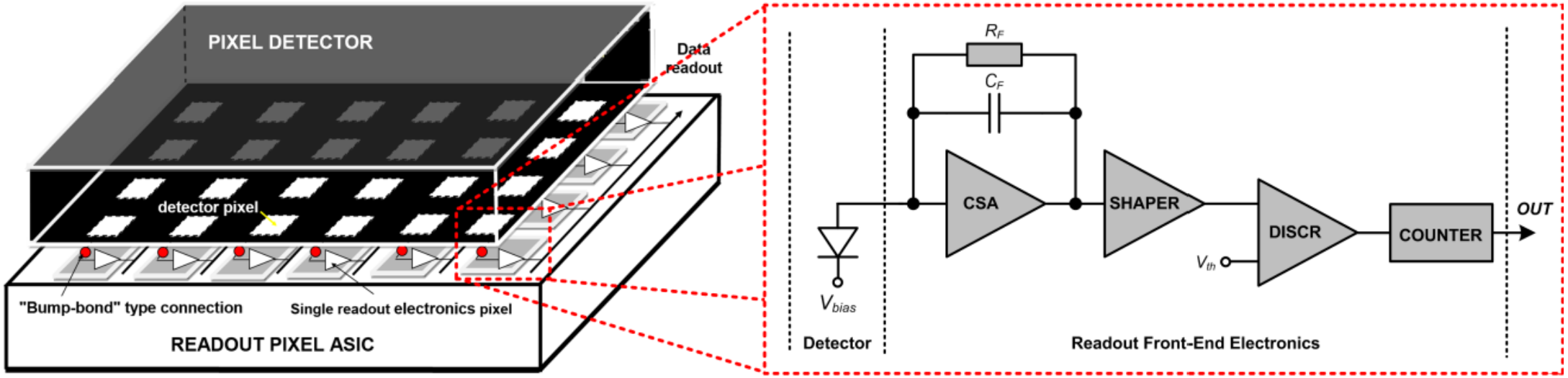


Gamma photon
Electromagnetic radiation of short wavelength

Muon µ



Electronic circuit



https://www.semanticscholar.org/paper/Ultrafast-signal-processing-readout-front-end-in-40-Kleczek-Grybos/02c65115cf5c79d68de222a020b06aeede47736a

Nice video

https://advacam.com/camera/minipix-sprinter/?gad_source=2&gclid=CjwKCAjwzN-vBhAkEiwAYiO7oLRNOM4hJPwT0M0nZts0g35LEOn74Dd9U9Hp7DSS1WYXUk_GezV8sBoC_vgQAvD_BwE